TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

AGENDA ITEM REQUEST

for State Implementation Plan Revision Adoption

AGENDA REQUESTED: March 10, 2010

DATE OF REQUEST: February 19, 2010

NAME & NUMBER OF PERSON TO CONTACT REGARDING CHANGES TO THIS REQUEST, IF NEEDED: Kerry Howard, 239-0556

CAPTION: Docket No. 2009-0802-SIP. Consideration of the adoption of the Houston-Galveston-Brazoria (HGB) Attainment Demonstration State Implementation Plan (SIP) Revision for the 1997 Eight-Hour Ozone Standard.

The adoption will contain Federal Clean Air Act-required SIP elements, including a photochemical modeling analysis, a weight of evidence analysis, a reasonably available control technology analysis, a reasonably available control measures analysis, a motor vehicle emissions budget for 2018, and a contingency plan. In addition, the Houston-Galveston Area Council has committed to emissions reductions through the Voluntary Mobile Emission Reduction Program and implementation of transportation control measures in the eight HGB nonattainment counties (Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller). (Lola Brown, John Minter) (Rule Project No. 2009-017-SIP-NR)

Susana M. Hildebrand
Chief Engineer

Division Director

Joyce Spencer for Kerry Howard
Agenda Coordinator

Copy to CCC Secretary? NO_X_ YES

Texas Commission on Environmental Quality

INTEROFFICE MEMORANDUM

To: Commissioners **Date:** February 19, 2010

Thru: LaDonna Castañuela, Chief Clerk
Mark R. Vickery, P.G., Executive Director

From: Susana M. Hildebrand, P.E., Chief Engineer 1.19.2010

Docket No.: 2009-0802-SIP

Subject: Commission Approval for Adoption
Houston-Galveston-Brazoria (HGB) Attainment Demonstration State Implementation Plan (SIP) Revision for the 1997 Eight-Hour Ozone Standard
Rule Project No. 2009-017-SIP-NR

Background and reasons for the SIP revision:
The United States Environmental Protection Agency (EPA) reclassified the eight-county HGB area (Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller Counties) from a moderate to a severe nonattainment area for the 1997 eight-hour ozone National Ambient Air Quality Standard (NAAQS) effective October 31, 2008. The state is required to submit a SIP revision addressing the severe ozone nonattainment area requirements of the Federal Clean Air Act (FCAA), 42 United States Code (USC), §7410 by April 15, 2010.

Scope of the SIP revision:
A) Summary of what the SIP revision will do:
This SIP revision uses photochemical modeling in combination with a weight of evidence (WoE) evaluation to support a conclusion that the HGB area will attain the 1997 eight-hour ozone NAAQS by June 15, 2019. Demonstration of attainment involves a photochemical modeling analysis that predicts ozone design values in 2018. The photochemical modeling analysis considers federal, state, and local control measures, including the proposed revisions to the Highly Reactive Volatile Organic Compounds Emissions Cap and Trade (HECT) program and the Voluntary Mobile Emission Reduction Program (VMEP) and accounts for population and economic growth. The WoE evaluation includes a corroborative analysis and additional control measures not explicitly accounted for in the photochemical modeling.

B) Scope required by federal regulations or state statutes:
This revision contains the FCAA-required SIP revision elements, including analyses for reasonably available control technology (RACT) and reasonably available control measures (RACM), a motor vehicle emissions budget (MVEB), transportation control measures (TCMs), and a contingency plan.

C) Additional staff recommendations that are not required by federal rule or state statute:
None.

Statutory authority
The authority to propose and adopt this SIP revision is derived from Texas Health and Safety Code, Texas Clean Air Act (TCAA), §382.002, which provides that the policy and purpose of the TCAA is to safeguard the state's air resources from pollution; TCAA, §382.011, which authorizes the commission to control the quality of the state's air; and §382.012, which authorizes the commission to prepare and develop a general, comprehensive plan for the control of the state's air; and Texas Water Code, §5.102, General Powers, and §5.013, General Jurisdiction of Commission.

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The FCAA, 42 USC, §§7401, *et seq.*, requires states to submit SIP revisions that specify the manner in which the NAAQS will be achieved and maintained within each air quality control region of the state. Phase 1 of the EPA's implementation rule for the 1997 eight-hour ozone standard, published in the April 30, 2004, issue of the *Federal Register* (69 FR 23951), outlines classifications, attainment dates, and anti-backsliding principles. Phase 2 of the EPA's implementation rule for the 1997 eight-hour standard, published in the November 29, 2005, issue of the *Federal Register* (70 FR 71612), outlines the requirements for state plans.

Effect on the:

A) Regulated community:

The affected regulated community will be those associated with the rulemakings that are part of this SIP revision. For further information, see the executive summaries for the following rulemakings, which are being adopted concurrently with this SIP revision.

- Rule Project No. 2008-019-115-EN, Volatile Organic Compounds (VOC) Control Technique Guidelines (CTG) Update
- Rule Project No. 2009-006-101-EN, HECT Program Cap Reduction and Allowance Reallocation
- Rule Project No. 2009-019-101-EN, Mass Emissions Cap and Trade (MECT) Program Cap Integrity for the HGB Eight-Hour Ozone Nonattainment Area

Fiscal impact information on the previously referenced rulemakings associated with this SIP revision is included in the executive summaries and preambles for the rulemakings. See the executive summary and preamble for Rule Project No. 2008-019-115-EN, VOC CTG Update, regarding offset lithographic printing operations for information on affected persons who were not affected previously.

This SIP revision also includes local control measures (VMEP measures and TCMs) developed and implemented through the Houston-Galveston Area Council (H-GAC), the regional metropolitan transportation planning agency for the HGB area.

B) Public:

The general public in the HGB and surrounding areas will benefit from reduced ground-level ozone concentrations due to reduced emissions of ozone precursors. There will be no fiscal impact on the public.

C) Agency programs:

The Office of Compliance and Enforcement (OCE) conducts field investigations to verify compliance with the rules addressed in SIP revisions. Enforcement of any revised rules in this SIP revision would not significantly increase the number of facilities investigated by state and local governments. However, the rule revisions may increase the OCE workload when investigating the affected facilities.

Staff solicited comments on whether it is appropriate to perform a mid-course review (MCR) and, if so, what elements should be contained in the analysis. Staff also recommended that the commission seek input on the appropriate date to submit the MCR. An MCR could require additional resources and increase the Air Quality Division workload. In response to comments received, the staff will perform a 1997 eight-hour ozone MCR for commission consideration and approval and submittal to the EPA (see "Significant changes from proposal" section).

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Stakeholder meetings:
The HGB Eight-Hour Ozone SIP Stakeholder Group met March 25 and 26, and November 3, 2008, to discuss development of the SIP revision, review modeling updates, and provide public input on potential control strategies. Meetings were held with the H-GAC and local governments on May 15 and July 22, 2008, to provide background on the SIP revision requirements and discuss the process to identify potential measures that can be implemented at the local level. Staff also participated in meetings held by H-GAC with stakeholder groups representing airports and airlines, railroads, tug boat operators, the construction industry, ports and users of marine equipment, users of non-road mobile industrial equipment, local governments, and the public.

Stakeholders provided comments on a broad range of potential control measures for point, area, and mobile sources of ozone precursors. Stakeholders also commented that evaluation and determination of control strategies should be based on ozone reduction benefits as well as technical and economic feasibilities. Stakeholders' suggested potential control measures were included in the RACM analysis and the H-GAC TCMs and VMEPs.

Public comment:
Public hearings for the proposed SIP revision and associated rulemakings were held on October 28, 2009, at 2:00 p.m. and 6:00 p.m., at the H-GAC offices in Houston; and on October 29, 2009, at 3:00 p.m., at the Texas Commission on Environmental Quality (TCEQ) headquarters in Austin. Question and answer sessions were held 30 minutes prior to the hearings. Neither the October 28, 2009, hearing scheduled for 6:00 p.m. nor the October 29, 2009, hearing was officially opened because no party indicated a desire to provide comment. Five persons presented oral comments concerning this SIP revision at the public hearing held at 2:00 p.m. on October 28, 2009, in Houston.

The public comment period opened on October 9, 2009, and closed on November 9, 2009. Written comments were accepted via mail, fax, and through the eComments system. There were 25 written comments received. Generally, the comments concerned support for or opposition to this attainment demonstration SIP revision, the use of WoE, conducting an MCR, attainment of the 1997 eight-hour ozone standard in the HGB area, and specific control strategies as well as the RACT and RACM analysis. While several comments expressed support for this attainment demonstration SIP revision and its photochemical modeling analysis and weight of evidence determination, a number of commenters contended that this SIP revision does not demonstrate attainment of the 1997 eight-hour ozone standard by the June 15, 2019, deadline. Some of the commenters who opposed this SIP revision also expressed opposition to the use of WoE to augment photochemical modeling.

Comments were received regarding attainment in the HGB area regarding a pending lowered eight-hour ozone standard in 2010. The Environmental Defense Fund (EDF) and the Galveston-Houston Association for Smog Prevention (GHASP) commented that the TCEQ has failed to initiate additional reductions that will be necessary in order to attain the more stringent eight-hour ozone standard, which is under consideration by the EPA. The City of Houston (COH), suggesting that the HGB area is attaining the 1997 eight-hour standard, recommended that the TCEQ develop a redesignation request and maintenance plan for submission to the EPA and to concentrate future efforts on the revised ozone standard.

Several commenters proposed that the TCEQ undertake an MCR and offered suggestions for content and timing of an MCR for the HGB area. There were also numerous comments concerning the general effectiveness of control measures included in this attainment demonstration SIP revision, and statements were submitted about specific control measures, including comments concerning the rules associated with this attainment demonstration SIP revision. For a summary of comments more directly related to the 30

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Texas Administrative Code (TAC) Chapter 101 MECT Program Cap Integrity (Rule Project No. 2009-019-101-EN) and HECT Program Cap Reduction and Allowance Reallocation (2009-006-101-EN) and Chapter 115 Offset Lithographic Printing rule revisions (Rule Project No. 2008-019-115-EN), see the executive summary memos for each of those rules.

Significant changes from proposal:
Significant changes were made to the VOC RACT update element of this SIP revision in response to comments. Staff proposed that RACT for two CTG categories was fulfilled through current state rules and permitting requirements. These categories include: Flexible Packaging Printing; and Paper, Film, and Foil Coatings. However, in response to comments from the EPA, the RACT determinations for these two categories were withdrawn so staff may reevaluate the RACT analyses. The RACT determination for the Fiberglass Boat Manufacturing CTG category was proposed as not representing RACT for the HGB area due to the potential economic impact to small businesses; however, additional staff research indicates that no sources meeting the CTG applicability exist in the HGB area. Therefore, the RACT determination for Fiberglass Boat Manufacturing was changed to a negative declaration.

In preparing the response to the comments, staff reviewed the 2006 baseline, as well as the 2018 projected emissions, including the reduction to the reconciled emissions of highly reactive volatile organic compounds (HRVOC). For the 2006 baseline emissions, updates were made to the point sources and the non-road mobile sources. The updates to the point sources primarily included accounting for annualized emissions from upsets, maintenance, startups, and shutdowns. The revision to the non-road mobile source emissions reflects the use of the updated Texas NONROAD (TexN) model with a more recent database of equipment populations. For the 2018 projected emissions, updates were also made to the point sources and the non-road mobile sources. The updates to the point sources included changes in the application of growth factors to non-MECT sources, a revision to the MECT allocations reflecting more recent emission certifications, and removing the reduction of reconciled emissions of HRVOC in 2018. Similar to the 2006 baseline, the revision to the 2018 non-road mobile source emissions reflects the use of the updated TexN model with a more recent database of equipment populations.

The changes in the 2006 baseline and 2018 future base emissions resulted in slightly smaller 2018 projected eight-hour ozone design values. All regulatory monitors have projected eight-hour ozone design values less than 87 parts per billion (ppb). The projected control strategy 2018 eight-hour ozone design values for the highest two monitors are also slightly lower than originally presented in the proposal (i.e., DRPK: 86.3 ppb and BAYP: 85.3 ppb) due to the emission-related changes in the 2006 baseline and 2018 future base modeling results.

To address comments to the SIP revision and to supplement the corroborative analyses of Chapter 5: *Weight of Evidence*, additional analyses that address the effects of meteorology and economic factors on ozone trends have been included in Appendix I: *Corroborative Analysis for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard* as well as an emissions trend analysis. The discussion of model response to emission changes has been broadened and trends in VOC reactivity have also been analyzed and also added to Appendix I.

In response to comments received, the executive director's staff will perform a 1997 eight-hour ozone MCR for commission approval and submittal to the EPA concurrently with the revised ozone standard SIP revision, which is scheduled to be due to the EPA in December 2013. The MCR will involve a thorough evaluation of all modeling, inventory data, and other tools and assumptions used to develop the attainment demonstration. This effort will include a review of the control measures, WoE, and contingency plan as well as additional analysis that may include photochemical modeling if appropriate. The MCR will contain further evaluation of the potential state and federal measures and new programs or regulations. This MCR will also include the ongoing assessment of new technologies and innovative ideas for possible inclusion into the plan.

The TCEQ executive director will commit to include for commission approval sufficient additional measures to equal 3 percent of the emissions in the adjusted base year inventory to be implemented in the event that the HGB area does not attain the 1997 eight-hour ozone standard by June 15, 2019, at the time of an MCR for this attainment demonstration SIP revision.

In response to comments received applicable to the rules associated with this SIP revision, substantive changes were made to the Chapter 101 and 115 rule revisions, which are addressed in the preambles for those rules.

Potential controversial concerns and legislative interest remaining after proposal and public comment:
In addition to photochemical modeling, this SIP revision relies on WoE, including corroborative analysis and discussion of additional control measures not included in the photochemical modeling, to demonstrate attainment. The commission received comments stating that the attainment demonstration should be based solely on the photochemical modeling and that because the photochemical modeling analysis shows that the proposed control measures will not be sufficient to demonstrate attainment by June 15, 2019, this SIP revision should be disapproved.

RACT determinations were not made for all of the 11 CTGs issued by the EPA between 2006 and 2008. While not stated in formally submitted comments, the EPA has verbally indicated to staff that it may issue notices of failure to submit to states that have not yet addressed all of the CTGs. The EPA's issuance of such a notice would start an 18-month sanctions clock. The TCEQ may need to address the remaining CTGs in a future SIP revision.

Does this SIP revision affect any current policies or require development of new policies?
No.

What are the consequences if this SIP revision does not go forward?
The legal requirement is to submit an attainment demonstration SIP revision for the 1997 eight-hour ozone standard by April 15, 2010. Not submitting a SIP revision to the EPA could result in a Federal Implementation Plan and/or federal sanctions.

Are there alternatives to this revision?
This SIP revision is required by federal statute. There are no alternatives.

Key points in adoption request schedule:

***Texas Register* proposal publication date:** NA
Anticipated *Texas Register* publication date: NA
Anticipated effective date: NA
Six-month *Texas Register* filing deadline: NA

Re: Docket No. 2009-0802-SIP

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REVISION TO THE STATE IMPLEMENTATION PLAN
FOR THE CONTROL OF OZONE AIR POLLUTION

HOUSTON-GALVESTON-BRAZORIA 1997 EIGHT-HOUR OZONE STANDARD
NONATTAINMENT AREA

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY
P.O. BOX 13087
AUSTIN, TEXAS 78711-3087

Houston-Galveston-Brazoria Attainment Demonstration
State Implementation Plan Revision for the 1997 Eight-Hour Ozone Standard

PROJECT NO. 2009-017-SIP-NR

Adopted
March 10, 2010

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EXECUTIVE SUMMARY

The United States Environmental Protection Agency (EPA) reclassified the eight-county Houston-Galveston-Brazoria (HGB) area from a moderate to a severe nonattainment area for the 1997 eight-hour ozone National Ambient Air Quality Standard (NAAQS) effective on October 31, 2008. The HGB eight-county area includes Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller Counties. The EPA set April 15, 2010, as the date for the state to submit a state implementation plan (SIP) revision addressing the severe ozone nonattainment area requirements of the 1990 Federal Clean Air Act Amendments (FCAA). The HGB area must attain the 1997 eight-hour ozone standard of 0.08 parts per million (ppm) as expeditiously as practicable but no later than the attainment date of June 15, 2019. Since emission reductions needed for attainment must be implemented by the beginning of the ozone season immediately preceding the HGB area's attainment date, implementation of controls need to be made by 2018, which is the attainment year for modeling.

This SIP revision addresses ozone formation in the HGB area, the precursor emissions of nitrogen oxides (NO_X) and volatile organic compounds (VOC), the control strategies that are to be implemented, the quantity of emission reductions associated with each strategy, and when these reductions will occur. Based on photochemical modeling and an evaluation of corroborative evidence, ozone measurements in the HGB area are predicted to be compliant with the 1997 eight-hour ozone NAAQS by June 15, 2019.

The existing measures to control ozone formation in the HGB area that have been adopted in previous SIP revisions center on:

- approximately 80 percent NO_X emission reductions from point sources through the Mass Emission Cap and Trade (MECT) program;
- NO_X emission reductions from on-road and non-road sources through the vehicle inspection and maintenance (I/M) program, the Texas Emission Reduction Plan (TERP), and the Texas Low Emission Diesel (TxLED) program;
- highly reactive volatile organic compounds (HRVOC) controls through the associated HRVOC Emission Cap and Trade (HECT) program; and
- VOC controls.

See Chapter 4: *Control Strategies and Required Elements*, Section 4.2: *Existing Control Measures* for a complete list of control measures.

Despite the significant decreases in one-hour and eight-hour ozone design values and in NO_X and VOC emissions in the HGB area, further reductions are needed to assure attainment of the 1997 eight-hour ozone NAAQS. Even as key ozone-targeting regulatory programs have reduced the number and magnitude of ozone exceedances, the area of exceedance, and the population exposed to exceedances, economic and population growth continue to create air quality challenges for the HGB area.

This submittal contains new state and local control measures. The Houston-Galveston Area Council (H-GAC), as the regional metropolitan transportation planning agency for the HGB area, has identified three voluntary programs that will aid in the improvement of the HGB area's air quality. The H-GAC's commitment for NO_X emissions reductions from the Voluntary Mobile Emission Reduction Program (VMEP) is 2.25 tons per day (tpd). The H-GAC has also identified transportation control measures (TCMs) that have been or will be implemented in the nonattainment area. By the start of the 2018 ozone season, these TCMs will reduce NO_X emissions in the HGB area by 0.015 tpd.

Photochemical modeling analysis demonstrates that a 25 percent reduction of the HECT cap on the total Harris County HRVOC allocation will contribute to attainment of the 1997 eight-hour ozone NAAQS by reducing the future 2018 ozone design values at all HGB monitors. Accordingly, this SIP revision contains a 25 percent reduction in the total HRVOC allowance cap and revision to the HRVOC allocation methodology. The HECT program will continue to be applicable only in Harris County.

This plan demonstrates attainment using photochemical modeling that includes the existing control strategies and the control strategies being adopted concurrently with this SIP revision previously discussed. The demonstration also relies on weight of evidence (WoE) corroborative analysis and additional control measures not explicitly accounted for in the photochemical modeling (see Chapter 5: *Weight of Evidence*).

This SIP revision includes base case modeling of representative ozone exceedance episodes that occurred during 2005 and 2006. In general, the model performance evaluation of the base cases for 2005 and 2006 indicates the modeling is suitable for use in conducting the modeling attainment test. The modeling attainment test was applied by modeling a 2006 baseline year and 2018 future year to project 2018 eight-hour ozone design values. Only two regulatory monitors, Deer Park (DRPK) and Bayland Park (BAYP), and one non-regulatory, industry-sponsored monitor, Wallisville (WALV), are projected to have modeled 2018 eight-hour ozone design values greater than the 1997 eight-hour ozone NAAQS.

Modeling analyses of the sensitivity of the 2018 projected eight-hour ozone design values to emission reductions of NO_X and VOC generally indicate that the ozone design values are more sensitive to NO_X reductions than VOC. However, the sensitivity of ozone design values to reductions in HRVOC is much greater than for other VOC.

Table ES-1: *Summary of 2006 Baseline, 2018 Future Year, and 2018 Control Strategy Anthropogenic Modeling Emissions for HGB* lists the anthropogenic modeling emissions in tons per day (tpd) by source category for the 2006 baseline, 2018 future year, and the 2018 control strategies for NO_X and VOC. Carbon monoxide (CO) is listed because it is an ozone precursor. The differences in modeling emissions between the 2006 baseline and the 2018 future year reflect the net of growth and existing controls. The existing controls include both state and federal measures that have already been promulgated. The differences in modeling emissions between the 2018 future year and the 2018 control strategy reflect the controls adopted at the March 10, 2010, commissioner's agenda. These adopted controls include NO_X reductions from both the VMEP measures and TCMs, and the 25 percent reduction in the Harris County total HRVOC cap for the HECT program.

Table ES-1: Summary of 2006 Baseline, 2018 Future Year, and 2018 Control Strategy Anthropogenic Modeling Emissions for HGB

Source Type	2006 Baseline			2018 Baseline			2018 Control Strategy		
	NO_X	VOC	CO	NO_X	VOC	CO	NO_X	VOC	CO
	(tpd)			(tpd)			(tpd)		
Point	172.86	241.00	132.25	154.36	292.05	222.06	154.36	289.35	222.06
On-Road	197.28	99.39	1115.23	50.76	50.39	733.17	49.21	50.39	733.17
Non -Road	79.33	61.41	572.37	33.62	30.18	427.56	32.92	30.18	427.56
Off-Road	73.26	5.75	97.30	85.66	6.68	44.71	85.66	6.68	44.71
Area	36.35	528.99	134.59	42.04	650.09	158.99	42.04	650.09	158.99
Totals	559.08	936.54	2051.74	366.44	1029.39	1586.49	364.19	1026.69	1586.49

Note: VOC is reported as sum of CB05 species

The modeling emissions in Table ES-1: *Summary of 2006 Baseline, 2018 Future Year, and 2018 Control Strategy Anthropogenic Modeling Emissions for HGB* have changed from the September

23, 2009, proposal reflecting updates made in response to comments. Comments were received regarding the projected growth in emissions from 2006 to 2018, and regarding the reduction to the reconciled emissions of HRVOC in 2018.

In preparing the response to the comments, the Texas Commission on Environmental Quality (TCEQ) reviewed the 2006 baseline, as well as the 2018 projected emissions, including the reduction to the reconciled emissions of HRVOC. For the 2006 baseline emissions, updates were made to the point sources and the non-road mobile sources. The updates to the point sources primarily included accounting for annualized emissions from upsets, maintenance, startups, and shutdowns. The revision to the non-road mobile source emissions reflects the use of the updated Texas NONROAD (TexN) model with a more recent database of equipment populations. For the 2018 projected emissions, updates were also made to the point sources and the non-road mobile sources. The updates to the point sources included changes in the application of growth factors to non-MECT sources, a revision to the MECT allocations reflecting more recent emission certifications, and removing the reduction of reconciled emissions of HRVOC in 2018. Similar to the 2006 baseline, the revision to the 2018 non-road mobile source emissions reflects the use of the updated TexN model with a more recent database of equipment populations. Tables ES-2: *Changes to 2006 Baseline and 2018 Future Base Point Source Emissions (tons/day)* and ES-3: *Changes to 2006 Baseline and 2018 Future Base Non-road Mobile Source Emissions (tons/day)* reflect the changes made.

Table ES-2: Changes to 2006 Baseline and 2018 Future Base Point Source Emissions (tons/day)

	2006 Baseline		2018 Future Base	
	NO_X	VOC	NO_X	VOC
Proposal	172.16	208.34	162.75	309.46
Adoption	172.86	241.00	154.36	292.05

Table ES-3: Changes to 2006 Baseline and 2018 Future Base Non-road Mobile Source Emissions (tons/day)

	2006 Baseline		2018 Future Base	
	NO_X	VOC	NO_X	VOC
Proposal	78.85	75.97	35.65	59.56
Adoption	79.33	61.41	33.62	30.18

The changes in the 2006 baseline and 2018 future base emissions resulted in slightly smaller 2018 projected eight-hour ozone design values. All regulatory monitors have projected eight-hour ozone design values less than 87 parts per billion (ppb). Table ES-4: *Summary of Modeled 2006 Baseline, 2018 Future Year, and 2018 Control Strategy Eight-Hour Ozone Design Values for BAYP and DRPK Monitors* lists the eight-hour ozone design values in ppb for the 2006 baseline (DV_B), 2018 baseline future year (DV_F), and 2018 control strategy for the two regulatory monitors with model-projected 2018 eight-hour ozone design values greater than the 1997 eight-hour ozone NAAQS. The projected control strategy 2018 eight-hour ozone design values for both monitors are lower than presented in the proposal (i.e., DRPK: 87.9 ppb and BAYP: 86.8 ppb). In addition, 18 regulatory monitors have model-projected 2018 eight-hour ozone design values less than the 1997 eight-hour ozone NAAQS. Since the modeling cannot provide an absolute prediction of future year ozone design values, additional information from corroborative analyses are used in assessing whether the area will attain the standard in the future year.

Table ES-4: Summary of Modeled 2006 Baseline, 2018 Future Year, and 2018 Control Strategy Eight-Hour Ozone Design Values for BAYP and DRPK Monitors

Monitor Site Code	Monitor Designation	2006 DV_B (ppb)	2018 Baseline DV_F (ppb)	2018 Control Strategy DV (ppb)
DRPK	Deer Park (CAMS 35)	92.0	86.5	86.3
BAYP	Bayland Park (CAMS 53)	96.7	85.5	85.3

Note: The 2006 DV_B is different from the 2006 regulatory design value (DV_R). Figure 3-1: *Baseline Design Value Calculation Illustration* in Chapter 3: *Photochemical Modeling*, illustrates how DV_Bs are calculated using the three DV_Rs containing 2006 data. The 2006 DV_R is the average of the fourth high ozone values from 2004, 2005, and 2006.

This SIP revision provides ozone reduction trends analyses and supplementary data to demonstrate that the HGB eight-county nonattainment area will attain the 1997 eight-hour ozone standard of 0.08 ppm. The EPA's April 2007 "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze" states that a weight of evidence demonstration is allowed when the future control strategy design value is at or below 87.9 ppb. The quantitative and qualitative corroborative analyses in Chapter 5: *Weight of Evidence*, support a conclusion that this SIP revision demonstrates attainment of the 1997 eight-hour ozone NAAQS.

This revision also includes FCAA-required SIP elements, including a reasonably available control measures (RACM) analysis, a reasonably available control technology (RACT) analysis, a motor vehicle emissions budget (MVEB), and a contingency plan. For the MVEB, see Table ES-5: *2018 Attainment Demonstration Motor Vehicle Emissions Budget for the Eight-County HGB Area*.

Table ES-5: 2018 Attainment Demonstration Motor Vehicle Emissions Budget for the Eight-County HGB Area

Eight-County HGB Area	Summer Weekday Emissions (tpd)	
2018 MVEB	NO_X	VOC
	49.22	45.97

The commission solicited comments on whether it is appropriate to perform a 1997 eight-hour ozone mid-course review (MCR) analysis for the HGB area, and, if so, what elements should be contained in the analysis. The commission also requested input on the appropriate date to submit the MCR. In response to the comments received, the executive director's staff will perform a 1997 eight-hour ozone MCR for commission consideration and approval and submittal to the EPA. For further information on the MCR, see Chapter 6: *Ongoing and Future Initiatives*, Section 6.3.1: *Mid-Course Review (MCR)*.

The TCEQ is committed to developing and applying the best science and technology towards addressing and reducing ozone formation in HGB and other nonattainment areas in Texas. This SIP revision also includes a description of how the TCEQ continues to use new technology, such as optical gas imaging cameras, to identify potential unreported or under-reported pollution sources as well as to investigate possible emission reduction strategies and other practical methods to continue making progress in air quality improvement. For more information, see Chapter 6: *Ongoing and Future Initiatives*.

SECTION V: LEGAL AUTHORITY

A. General

The Texas Commission on Environmental Quality (TCEQ) has the legal authority to implement, maintain, and enforce the National Ambient Air Quality Standards (NAAQS) and to control the quality of the state's air, including maintaining adequate visibility.

The first air pollution control act, known as the Clean Air Act of Texas, was passed by the Texas Legislature in 1965. In 1967, the Clean Air Act of Texas was superseded by a more comprehensive statute, the Texas Clean Air Act (TCAA), found in Article 4477-5, Vernon's Texas Civil Statutes. The legislature amended the TCAA in 1969, 1971, 1973, 1979, 1985, 1987, 1989, 1991, 1993, 1995, 1997, 1999, 2001, 2003, 2005, 2007, and 2009. In 1989, the TCAA was codified as Chapter 382 of the Texas Health & Safety Code.

Originally, the TCAA stated that the Texas Air Control Board (TACB) is the state air pollution control agency and is principal authority in the state on matters relating to the quality of air resources. In 1991, the legislature abolished the TACB effective September 1, 1993, and its powers, duties, responsibilities, and functions were transferred to the Texas Natural Resource Conservation Commission (TNRCC). With the creation of the TNRCC, the authority over air quality is found in both the Texas Water Code and the TCAA. Specifically, the authority of the TNRCC is found in Chapters 5 and 7. Chapter 5, Subchapters A - F, H - J, and L, include the general provisions, organization, and general powers and duties of the TNRCC, and the responsibilities and authority of the executive director. This chapter also authorizes the TNRCC to implement action when emergency conditions arise, and to conduct hearings. Chapter 7 gives the TNRCC enforcement authority. In 2001, the 77th Texas Legislature continued the existence of the TNRCC until September 1, 2013, and changed the name of the TNRCC to the Texas Commission on Environmental Quality (TCEQ). In 2009, the 81st Texas Legislature, during a special session, amended § 5.014 of the Texas Water Code, changing the expiration date of the TCEQ to September 1, 2011, unless continued in existence by the Texas Sunset Act.

The TCAA specifically authorizes the TCEQ to establish the level of quality to be maintained in the state's air and to control the quality of the state's air by preparing and developing a general, comprehensive plan. The TCAA, Subchapters A - D, also authorize the TCEQ to collect information to enable the commission to develop an inventory of emissions; to conduct research and investigations; to enter property and examine records; to prescribe monitoring requirements; to institute enforcement proceedings; to enter into contracts and execute instruments; to formulate rules; to issue orders taking into consideration factors bearing upon health, welfare, social and economic factors, and practicability and reasonableness; to conduct hearings; to establish air quality control regions; to encourage cooperation with citizens' groups and other agencies and political subdivisions of the state as well as with industries and the federal government; and to establish and operate a system of permits for construction or modification of facilities.

Local government authority is found in Subchapter E of the TCAA. Local governments have the same power as the TCEQ to enter property and make inspections. They also may make recommendations to the Commission concerning any action of the TCEQ that affects their territorial jurisdiction, may bring enforcement actions, and may execute cooperative agreements with the TCEQ or other local governments. In addition, a city or town may enact and enforce ordinances for the control and abatement of air pollution not inconsistent with the provisions of the TCAA and the rules or orders of the Commission.

Subchapters G and H of the TCAA authorize the TCEQ to establish vehicle inspection and maintenance programs in certain areas of the state, consistent with the requirements of the federal Clean Air Act; coordinate with federal, state, and local transportation planning agencies to develop and implement transportation programs and measures necessary to attain and maintain

the NAAQS; establish gasoline volatility and low emission diesel standards; and fund and authorize participating counties to implement vehicle repair assistance, retrofit, and accelerated vehicle retirement programs.

B. Applicable Law

The following statutes and rules provide necessary authority to adopt and implement the State Implementation Plan (SIP). The rules listed below have previously been submitted as part of the SIP.

Statutes

All sections of each subchapter are included, unless otherwise noted.

TEXAS HEALTH & SAFETY CODE, Chapter 382 September 1, 2009

TEXAS WATER CODE September 1, 2009

Chapter 5: Texas Natural Resource Conservation Commission
Subchapter A: General Provisions
Subchapter B: Organization of the Texas Natural Resource Conservation Commission
Subchapter C: Texas Natural Resource Conservation Commission
Subchapter D: General Powers and Duties of the Commission
Subchapter E: Administrative Provisions for Commission
Subchapter F: Executive Director (except §§ 5.225, 5.226, 5.227, 5.2275, 5.231, 5.232, and 5.236)
Subchapter H: Delegation of Hearings
Subchapter I: Judicial Review
Subchapter J: Consolidated Permit Processing
Subchapter L: Emergency and Temporary Orders (§§ 5.514, 5.5145, and 5.515 only)
Subchapter M: Environmental Permitting Procedures (§ 5.558 only)

Chapter 7: Enforcement
Subchapter A: General Provisions (§§ 7.001, 7.002, 7.00251, 7.0025, 7.004, and 7.005 only)
Subchapter B: Corrective Action and Injunctive Relief (§ 7.032 only)
Subchapter C: Administrative Penalties
Subchapter D: Civil Penalties (except §7.109)
Subchapter E: Criminal Offenses and Penalties: §§ 7.177, 7.179-7.183

Rules

All of the following rules are found in 30, Texas Administrative Code, as of the following effective dates:

Chapter 7: Memoranda of Understanding, § 7.110 and § 7.119 May 2, 2002

Chapter 19: Electronic Reporting March 1, 2007

Chapter 35, Subchapters A-C, K: Emergency and Temporary Orders and Permits; Temporary Suspension or Amendment of Permit Conditions July 20, 2006

Chapter 39: Public Notice, §§ 39.201; 39.401; 39.403(a) and (b)(8)-(10); 39.405(f)(1) and (g); 39.409; 39.411 (a), (b)(1)-(6) and (8)-(10), (c)(1)-(6), and (d); 39.413(9), (11), (12), and (14); 39.418(a) and (b)(3) and (4); 39.419(a), (b), (d), and (e); 39.420(a), (b) and (c)(3) and (4); 39.423 (a) and (b); 39.601-39.605 March 29, 2006

Chapter 55: Requests for Reconsideration and Contested Case Hearings; Public Comment, §§ 55.1; 55.21(a)-(d), (e)(2), (3), and (12), (f), and (g); 55.101(a), (b), and (c)(6)-(8); 55.103; 55.150; 55.152(a)(1), (2), and (6) and (b); 55.154; 55.156; 55.200; 55.201(a)-(h); 55.203; 55.205; 55.209, and 55.211 — March 29, 2006

Chapter 101: General Air Quality Rules — January 1, 2009

Chapter 106: Permits by Rule, Subchapter A — June 30, 2004

Chapter 111: Control of Air Pollution from Visible Emissions and Particulate Matter — July 19, 2006

Chapter 112: Control of Air Pollution from Sulfur Compounds — July 16, 1997

Chapter 113: Standards of Performance for Hazardous Air Pollutants and for Designated Facilities and Pollutants — May 14, 2009

Chapter 114: Control of Air Pollution from Motor Vehicles — June 26, 2008

Chapter 115: Control of Air Pollution from Volatile Organic Compounds — July 19, 2007

Chapter 116: Permits for New Construction or Modification — May 29, 2008

Chapter 117: Control of Air Pollution from Nitrogen Compounds — March 4, 2009

Chapter 118: Control of Air Pollution Episodes — March 5, 2000

Chapter 122: § 122.122: Potential to Emit — December 11, 2002

Chapter 122: § 122.215: Minor Permit Revisions — June 3, 2001

Chapter 122: § 122. 216: Applications for Minor Permit Revisions — June 3, 2001

Chapter 122: § 122.217: Procedures for Minor Permit Revisions — December 11, 2002

Chapter 122: § 122.218 Minor Permit Revision Procedures for Permit Revisions Involving the Use of Economic Incentives, Marketable Permits, and Emissions Trading — June 3, 2001

SECTION VI. CONTROL STRATEGY

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   Chapter 3: Photochemical Modeling
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   Chapter 5: Weight of Evidence
   Chapter 6: Ongoing and Future Initiatives
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4. *El Paso* (No change)
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6. *Northeast Texas* (No change)
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8. *San Antonio Area* (No change)
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C. Particulate Matter (No change)

D. Carbon Monoxide (No change)

E. Lead (No change)

F. Oxides of Nitrogen (No change)

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H. Conformity with the National Ambient Air Quality Standards (No change)

I. Site Specific (No change)

J. Mobile Sources Strategies (No change)

K. Clean Air Interstate Rule (No change)

L. Transport (No change)

M. Regional Haze (No change)

LIST OF ACRONYMS

ACT	Alternative Control Techniques
AERR	Air Emissions Reporting Requirements
AGL	Above Ground Level
AIRS	Aerometric Information Retrieval System
APCA	Anthropogenic Precursor Culpability Assessment
APU	Auxiliary Power Unit
ARD	Acid Rain Database
auto-GC	Automated Gas Chromatograph
AWO	American Waterways Operators
BACT	Best Available Control Technology
BAYP	Houston Bayland Park Monitor (CAMS 53)
BCCA-AG	Business Coalition for Clean Air-Appeal Group
BELD	Biogenic Emissions Landuse Data
BMP	Best Management Practices
BPA	Beaumont-Port Arthur
BYWC	Baytown Wetland Center (CAMS 552)
C35C	Clinton Monitor (CAMS 403/CAMS 113/CAMS 304)
CAIR	Clean Air Interstate Rule
CAMS	Continuous Air Monitoring Station
CAMx	Comprehensive Air Model with Extension
CARB	California Air Resources Board
CARS	Car Allowance Rebate System
CART	Classification and Regression Tree
CEMS	Continuous Emission Monitoring Systems
CENRAP/RPO	Central Regional Air Planning Association/Regional Planning Organization
CFFP	Clean Fuel Fleet Program
CFR	Code of Federal Regulations
CFV	Clean Fuel Vehicles
$ClNO_2$	Nitryl Chloride
CLU	Common Land Unit
CNR2	Conroe Relocated (CAMS 78)
CO	Carbon Monoxide
CTAC	Chemical Transportation Advisory Committee
CTG	Control Technique Guidelines
DERC	Discrete Emissions Reduction Credit
DFW	Dallas-Fort Worth
DIAL	Differential Absorption Lidar
DMA	Marine Distillate Fuel A
DMX	Marine Distillate Fuel X
DOAS	Differential Optical Absorption Spectroscopy
DPS	Department of Public Safety
DRE	Destruction and Removal Efficiency
DRPK	Deer Park Monitor (CAMS 35/139)
DV	Design Value
DV_{18}	2018 Ozone Design Value

DV_B	Baseline Year Ozone Design Value
DV_F	Future Design Value
EBI	Euler Backward Iterative
ECA	Emissions Control Area
ECT-3	Form ECT-3, Level of Activity Certification
EDAS	Ecosystem Dynamics and the Atmosphere Section
EE/RE	Energy Efficiency and Renewable Energy
EGAS	Economic Growth Analysis System
EGUs	Electric Generating Units
EI	Emissions Inventory
EIQ	Emissions Inventory Questionnaires
EPA	United States Environmental Protection Agency
EPS3	Emissions Processing System version 3
ERC	Emissions Reduction Credit
ESL	Energy Systems Laboratory
ETH	Ethylene
FCAA	Federal Clean Air Act
FDDA	Four-Dimensional Data Assimilation
FIP	Federal Implementation Plan
FMVCP	Federal Motor Vehicle Control Program
FORM	Formaldehyde
FTP	File Transfer Protocol
GALC	Galveston Airport Monitor (CAMS 34/CAMS 109/CAMS 154)
GAPP	GEWEX Americas Prediction Project
GCIP	GEWEX Continental International Project
GDP	Gross Domestic Product
GEWEX	Global Energy and Water Cycle Experiment
GloBEIS	Global Biosphere Emissions and Interactions System
GOES	Geostationary Operational Environmental Satellite
g/kW–hr	Grams per Kilowatt Hour
GREASD	Greatly Reduced Execution and Simplified Dynamics
GRVL	Greenville, NW of Dallas
GWEI	Gulf-wide Emissions Inventory
HALC	Aldine Monitor (CAMS 8)
HB	House Bill
HCHV	Channelview Monitor (CAMS 15/CAMS 115)
HCQA	Croquet Monitor (CAMS 409)
HDDV	Heavy-Duty Diesel Vehicle
HECT	Highly Reactive Volatile Organic Compound Emissions Cap and Trade
H-GAC	Houston-Galveston Area Council
HGB	Houston-Galveston-Brazoria
HNWA	Northwest Harris County Monitor (CAMS 26)
HO_2	Hydroperoxy Radical
HOEA	Houston East Monitor (CAMS 1)
HONO	Nitrous Acid
hp	Horsepower
HPMS	Highway Performance Monitoring System

HRM	Haden Road Monitor (CAMS 603)
HROC	TCEQ Houston Regional Office Monitor (CAMS 81)
HRVOC	Highly Reactive Volatile Organic Compounds
HSMA	Swiss and Monroe Monitor (CAMS 406)
HTCA	Houston Texas Avenue Monitor (CAMS 411)
HYSPLIT	Hybrid Single Particle Lagrangian Integrated Trajectory
I/M	Inspection and Maintenance
IAF	Ike Adjustment Factor
I-DOAS	Imaging Differential Optical Absorption Spectroscopy
IMO	International Maritime Organization
IOLE	Internal Olefins
ISOP	Isoprene
JPL	Jet Propulsion Laboratory
km	Kilometer
K_V	Vertical Diffusivity Coefficient
kW	Kilowatts
LACT	Livingston, NW of Houston
lb	Pound
LCP	Lambert Conformal Projection
LDAR	Leak Detection and Repair
LDEQ	Louisiana Department of Environmental Quality
LEADS	Leading Environmental Analysis and Display System
LIRAP	Low Income Vehicle Repair Assistance, Retrofit, and Accelerated Vehicle Retirement Program
LST	Local Standard Time
LULC	Land-Use/Land-Cover
LYNF	Lynchburg Ferry Monitor (CAMS 1015)
m/s	Meters per Second
MACP	Manvel Croix Park Monitor (CAMS 84)
MACT	Maximum Achievable Control Technology
MAPS	Modeling Analysis and Performance Software
MARPOL	Annex VI of the International Convention for the Prevention of Pollution from Ships
MATS	Modeled Attainment Test Software
MAX-DOAS	Multi-Axis Differential Optical Absorption Spectroscopy
MCR	Mid-Course Review
MECT	Mass Emissions Cap and Trade
METDAT	Omnibus Meteorological Database
MGO	Marine Gas Oil
MM5	Fifth Generation Meteorological Model
MMS	Minerals Management Services
MNB	Mean Normalized Bias
MNGE	Mean Normalized Gross Error
MOVES	Motor Vehicle Emission Simulator
MOZART	Model for Ozone and Related Chemical Tracers
mph	Miles per Hour
MVEB	Motor Vehicle Emissions Budget
MW	Megawatt

NAAQS	National Ambient Air Quality Standard
NAM	North American Model
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NCEP	National Center for Environmental Prediction
NEI	National Emissions Inventory
ng/J	Nanogram per Joule
NMIM	National Mobile Inventory Model
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NOAA	National Oceanic and Atmospheric Administration
NOAH	NCEP Oregon State Air Force Hydrological Research Laboratory
NO_X	Nitrogen Oxides
NO_Y	Total Reactive Nitrogen
NPL	National Physical Laboratory
NSR	New Source Review
NTIG	New Technology Implementation Grants
O_3	Ozone
OGV	Oceangoing Vessel
OH	Hydroxyl Radical
OLE	Olefins
OSAT	Ozone Source Apportionment Technology
OSD	Ozone Season Day
P3	The NOAA WP-3D Orion
PADD	Petroleum Administration for Defense District
PAMS	Photochemical Assessment Monitoring Station
PAR	Photosynthetically-Active Solar Radiation
PBL	Planetary Boundary Layer
PEI	Periodic Emissions Inventory
PFC	Portable Fuel Container
PiG	Plume-in-Grid
PM	Particulate Matter
$PM_{2.5}$	Particulate Matter of 2.5 Microns and Less
ppb	Parts per Billion
ppbC	Parts per Billion, Carbon
ppbv	Parts per Billion by Volume
ppm	Parts per Million
ppmv	Part per Million by Volume
PPM	Piecewise Parabolic Method
PSCF	Potential Source Contribution Function
psi	Pounds per Square Inch
PUCT	Public Utility Commission of Texas
QA/QC	Quality Assurance and Quality Control
QQ	Quantile-Quantile
R^2	Correlation Coefficient
RACM	Reasonably Available Control Measures
RACT	Reasonably Available Control Technology

REMI	Regional Economic Models, Inc.
rpm	Revolutions per Minute
RFP	Reasonable Further Progress
ROP	Rate-of-Progress
RRF	Relative Response Factor
RRF_D	Relative Response Factor Denominator
RRF_N	Relative Response Factor Numerator
RV	Research Vessel
RVP	Reid Vapor Pressure
SAGA	San Augustine, Central TX-LA Border
SB	Senate Bill
SBFP	Seabrook Friendship Park Monitor (CAMS 45)
SCCs	Source Category Classifications
SCR	Selective Catalytic Reduction
SECO	State Energy Conservation Office
SEER	Seasonal Energy Efficiency Ratio
SEP	Supplemental Environmental Project
SETPMTC	Southeast Texas Photochemical Modeling Technical Committee
SGIA	Smart Growth Implementation Assistance
SHARP	Study of Houston Atmospheric Radical Precursors
SHWH	Shell Westhollow Monitor (CAMS 410)
SI	Special Inventory
SIC	Standard Industrial Classification
SIP	State Implementation Plan
SO_2	Sulfur Dioxide
SOF	Solar Occultation Flux
SST	Sea Surface Temperature
STARS	State of Texas Air Reporting System
TAC	Texas Administrative Code
TACB	Texas Air Control Board
TAMU	Texas A&M University
TATU	TCEQ Attainment Test for Unmonitored areas
TCAA	Texas Clean Air Act
TCEQ	Texas Commission on Environmental Quality
TCMs	Transportation Control Measures
TDMs	Travel Demand Models
TERP	Texas Emission Reduction Plan
TexAER	Texas Air Emissions Repository
TexAQS 2000	Texas Air Quality Study 2000
TexAQS II	Texas Air Quality Study 2006
TexN	Texas NONROAD
THSC	Texas Health and Safety Code
TKE	Mellor-Yamada Turbulent Kinetic Energy
TNMHC	Total Nonmethane Hydrocarbons
TNRCC	Texas Natural Resource Conservation Commission
TOMS	Total Ozone Mapping Spectrometer
TOPAZ	Tunable Optical Profiler for Aerosol and Ozone

tpd	Tons per Day
tpy	Tons per Year
TSE	Truck Stop Electrification
TTI	Texas Transportation Institute
TXCT	Texas City Monitor (CAMS 620)
TxLED	Texas Low Emission Diesel
UH	University of Houston
UMA	Unmonitored Area
UNC	University of North Carolina
UPA	Unpaired Peak Accuracy
USGS	United States Geological Survey
UT-Austin	University of Texas at Austin
UTC	Coordinated Universal Time
UT-CSR	University of Texas Center for Space Research
VMEP	Voluntary Mobile Emission Reduction Program
VMT	Vehicle Miles Traveled
VNA	Voronoi Neighbor Averaging
VOC	Volatile Organic Compounds
WALV	Wallisville Monitor (CAMS 617)
WDIR	Wind Direction
WoE	Weight of Evidence
WRF	Weather Research and Forecasting
WSPD	Wind Speed

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CHAPTER 1: GENERAL

1.1 BACKGROUND

The "History of the Texas State Implementation Plan (SIP)," a comprehensive overview of the SIP revisions submitted to the United States Environmental Protection Agency (EPA) by the State of Texas, is available at the following Web site:
http://www.tceq.state.tx.us/implementation/air/sip/sipintro.html#History.

1.2 INTRODUCTION

The Houston-Galveston-Brazoria (HGB) area presents a complex air pollution problem because of the nature of the emissions and meteorology of the area. The HGB area's hot, sunny climate, large urban population activities, and extensive, highly concentrated industrial complex provide the ingredients for ozone formation: sunlight, nitrogen oxides (NO_X), and volatile organic compounds (VOC). The Houston area's significant biogenic VOC emissions and complex meteorology, which includes land/sea breeze air parcel recirculation, complicate photochemical modeling. Economic and population growth continue to create air quality challenges for the HGB area. Despite these challenges, key ozone-targeting regulatory programs have reduced the number and magnitude of ozone exceedances, the area of exceedance, and the population exposed to exceedances of the ozone National Ambient Air Quality Standard (NAAQS).

1.2.1 One-Hour Ozone National Ambient Air Quality Standard (NAAQS) History

The EPA established the one-hour ozone NAAQS of 0.08 parts per million (ppm) in the April 30, 1971, issue of the *Federal Register* (36 FR 8186). The EPA revised the one-hour ozone standard to 0.12 ppm in the February 8, 1979, issue of the *Federal Register* (44 FR 4202). The eight-county HGB area, defined as Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller Counties, was first designated as a nonattainment area for the one-hour ozone NAAQS established by the Federal Clean Air Act (FCAA) in the November 6, 1991, issue of the *Federal Register* (56 FR 56694). The HGB area was classified as a Severe-17 nonattainment area, which required it to attain the one-hour ozone NAAQS by November 15, 2007. The one-hour ozone NAAQS was revoked in the June 15, 2005, issue of the *Federal Register* (69 FR 23951).

The following summaries of HGB area one-hour ozone SIP revisions are provided to give context and greater understanding of the complex issues involved in HGB's ozone challenge. For a summary of ozone SIP revisions in the HGB area prior to December 2000, please refer to the "History of the Texas State Implementation Plan (SIP)," mentioned in Section 1.1: *Background* of this chapter.

1.2.1.1 December 2000

The Post-1999 Rate-of-Progress (ROP) and Attainment Demonstration SIP for the Houston/Galveston Ozone Nonattainment Area revision contained rules and photochemical modeling analyses in support of the HGB one-hour ozone attainment demonstration. The majority of the emission reductions identified in this revision resulted from an overall 90 percent reduction in point source NO_X implemented through 30 Texas Administrative Code (TAC) Chapter 117 and the Mass Emissions Cap and Trade (MECT) program in 30 TAC Chapter 101. A modeling analysis, which showed a 141 parts per billion (ppb) peak ozone level, indicated a shortfall of 91 tons per day (tpd) in NO_X emissions reductions that were necessary, but not readily available, for an approvable attainment demonstration. In addition, the revision contained a post-1999 ROP plan for the milestone years 2002 and 2005, as well as the attainment year 2007, and a transportation conformity motor vehicle emissions budget (MVEB) for NO_X and VOC. The SIP revision also contained enforceable commitments to implement further measures (in support of the HGB area's attainment demonstration and to remedy the estimated 91 tpd shortfall), Voluntary Mobile Emission Reduction Program (VMEP) measures, as well as a commitment to perform and submit a mid-course review (MCR) to the EPA.

1.2.1.2 September 2001

The Post-1999 ROP and Attainment Demonstration Follow-Up SIP for the Houston/Galveston Ozone Nonattainment Area revision included the following elements: 1) corrections to the ROP table/budget for the years 2002, 2005, and 2007 due to a mathematical error; 2) incorporation of a change to the idling restriction control strategy, which clarified that the operator of a rented or leased vehicle is responsible for compliance with the requirements in situations where the operator of a leased or rented vehicle is not employed by the owner of the vehicle; 3) incorporation of revisions to the clean diesel fuel rules to provide greater flexibility in complying with the rule requirements while preserving the emission reductions previously represented; 4) incorporation of a stationary diesel engine rule; 5) incorporation of revisions to the point source NO_X rules; 6) incorporation of revisions to the NO_X emissions cap and trade rules; 7) removal of the construction equipment operating restriction and the accelerated purchase requirement for Tier 2/Tier 3 heavy-duty equipment; 8) replacement of the Tier 2/Tier 3 rules with the Texas Emission Reduction Plan (TERP); 9) layout of the MCR process that detailed how the state would fulfill the commitment to obtain the additional emission reductions necessary to demonstrate attainment of the one-hour ozone standard in the HGB area; and 10) replacement of the 2007 ROP MVEB to be consistent with the attainment demonstration MVEB.

Despite the NO_X measures adopted in the December 2000 SIP revision and the stationary diesel engine rules included in the September 2001 SIP revision, an estimated 56 tpd NO_X reduction shortfall remained. The state committed to address the remaining shortfall through the MCR process. The EPA approved the December 2000 and September 2001 submittals in the November 14, 2001, issue of the *Federal Register* (66 FR 57160).

1.2.1.3 December 2002

In January 2001, the Business Coalition for Clean Air-Appeal Group (BCCA-AG) and several regulated companies challenged the December 2000 HGB SIP revision and the 90 percent NO_X reduction requirement from stationary sources. Among other things, BCCA-AG contended that the last 10 percent of the NO_X emissions reductions were not cost effective and that the ozone plan would fail because the Texas Commission on Environmental Quality (TCEQ) did not account for VOC emissions associated with upset conditions. In May 2001, the parties agreed to a stay in the case, and Judge Margaret Cooper, Travis County District Court, signed a Consent Order, effective June 8, 2001. The order required the commission to perform an independent and thorough analysis of the causes of rapid ozone formation events and to identify potential mitigating measures not yet included in the HGB attainment demonstration.

In compliance with the Consent Order, the commission conducted a scientific evaluation based in large part on aircraft data collected by the Texas Air Quality Study 2000 (TexAQS 2000). The TexAQS 2000 was a comprehensive research project, conducted in August and September 2000, involving more than 40 research organizations and over 200 scientists that studied ground-level ozone air pollution in the HGB and east Texas regions. These and other studies suggested that the HGB area's high ozone events can be attributed, in part, to the presence of significant reactivity in the airshed. An analysis of automated gas chromatograph data revealed that four highly reactive volatile organic compounds (HRVOC) were frequently responsible for high reactivity days: ethylene, propylene, 1,3-butadiene, and butenes. As such, these compounds were selected as the best candidates for HRVOC emission controls. Analysis showed that the ozone control strategy involving limits on emissions of ethylene, propylene, 1,3-butadiene, and butenes from industrial sources, in conjunction with an 80 percent reduction in industrial or point source NO_X, was equivalent or better in terms of air quality benefit than the previous ozone control strategy (a 90 percent point source NO_X emissions reduction requirement alone). Therefore, in December 2002, the TCEQ adopted a SIP revision that replaced 10 percent of industrial point source NO_X emissions reductions with industrial source HRVOC controls. HRVOC is defined in 30 TAC Chapter 115 as ethylene, propylene, 1,3-butadiene, and all isomers of butene for Harris County and ethylene and propylene for the other seven counties in the HGB area. The result was an industrial source ozone control strategy that relies on an 80 percent

reduction in NO_X emissions through Chapter 117 and the MECT program, and HRVOC rules in Chapter 115 that better quantify and reduce emissions of HRVOC from four key industrial sources: fugitives, flares, process vents, and cooling tower heat exchange systems. The HRVOC fugitive emission controls are more stringent leak detection and repair requirements for components in HRVOC service such as valves and flanges. The HRVOC rules for flares, process vents, and cooling tower heat exchange systems are performance-based and emphasize monitoring, recordkeeping, reporting, and enforcement, rather than establishing individual unit emission rates. Site-wide HRVOC emission caps were established and adopted in the SIP for sites subject to the HRVOC rules for flares, process vents, and cooling tower heat exchange systems. The December 2002 SIP revision exchanging the two strategies for the one strategy met the FCAA, §110(l) requirement, which allows a revision of the SIP where that revision would not interfere with reasonable further progress toward attainment of the NAAQS.

1.2.1.4 December 2004

As previously noted in Section 1.2.1.1: *December 2000* of this chapter, in December 2000, the TCEQ committed to perform an MCR to ensure attainment of the one-hour ozone standard. The MCR process provided the opportunity to update emissions inventory data, use current modeling tools, and enhance the photochemical grid modeling. The data gathered from the TexAQS 2000 was used to improve the photochemical modeling of the HGB area. These technical improvements provided a more comprehensive understanding of the ozone challenge in the HGB area that is necessary to develop an attainment plan. In early 2003, as the TCEQ was preparing to move forward with the MCR, the EPA announced its plans to begin implementation of the 1997 eight-hour ozone standard. The EPA published its proposed implementation rule for the 1997 eight-hour ozone standard in the June 2, 2003, issue of the *Federal Register* (68 FR 32802). In the same timeframe, the EPA formalized its intentions to designate areas for the 1997 eight-hour ozone standard by April 15, 2004, requiring states to reassess their efforts and control strategies to address this new standard in a revised plan to be submitted to the EPA by June 2007. Recognizing that existing one-hour nonattainment areas would soon be subject to the 1997 eight-hour ozone standard and in an effort to efficiently manage the state's limited resources, the TCEQ developed an approach that addressed the outstanding obligations under the one-hour ozone standard while beginning to analyze eight-hour ozone issues.

The TCEQ's one-hour ozone SIP revision commitments that were addressed in the December 2004 HGB Ozone Nonattainment Area SIP revision include: completion of a one-hour ozone MCR; performance of modeling; adoption of measures sufficient to fill the shortfall of NO_X reductions; adoption of measures sufficient to demonstrate attainment; revision of the MVEB using the EPA's MOBILE6 model; and revision of the VMEP measures.

The December 2004 revision reflected a shift from primarily reducing industrial emissions of NO_X to reducing both industrial emissions of NO_X and industrial point source HRVOC. This revision included measures to ensure compliance with the specific strategies to control HRVOC emissions and replaced the site-wide caps adopted in the SIP with the HRVOC Emissions Cap and Trade (HECT) program in 30 TAC Chapter 101. The HECT program is an annual cap and trade program developed to provide sources compliance flexibility in meeting the control requirements for flares, process vents, and cooling tower heat exchange systems in 30 TAC Chapter 115. Sites subject to the program are required to possess an HRVOC allowance for each ton of HRVOC emissions. Sites have the option to trade excess HRVOC allowances on the open market. The December 2004 SIP revision also reflected the repeal of the motor vehicle idling rules and modified certain recordkeeping requirements of the general VOC fugitive emission rules to make them apply only to sources of HRVOC fugitive emissions.

1.2.1.5 EPA Approval of the One-Hour Ozone Attainment Demonstration

The EPA published its approval of the HGB nonattainment area one-hour ozone attainment demonstration in the September 6, 2006, issue of the *Federal Register* (71 FR 52656). Also in a separate action, the EPA concurrently approved rules for the control of HRVOC, the HECT program, the MECT program, and the emissions reduction credit banking and trading program,

and conditionally approved rules for the discrete emissions reduction credit banking and trading program.

1.2.2 Eight-Hour Ozone NAAQS History

In 1997, the EPA revised the health-based NAAQS for ozone, setting it at 0.08 ppm averaged over an eight-hour time frame. The final 1997 eight-hour ozone NAAQS was published in the *Federal Register* on July 18, 1997 (62 FR 38856), and became effective on September 16, 1997. On April 30, 2004, the EPA finalized its attainment/nonattainment designations and promulgated the first phase of its implementation rule for the 1997 eight-hour ozone standard (69 FR 23951). These actions became effective on June 15, 2004. The EPA classified the HGB area as a moderate nonattainment area for the standard under the 1990 FCAA (42 United States Code, §§ 7401 *et seq*.). The TCEQ was required to submit a SIP revision for the 1997 eight-hour ozone NAAQS to the EPA by June 15, 2007, and demonstrate attainment of the standard by June 15, 2010. In the November 29, 2005, issue of the *Federal Register* (70 FR 71612) the EPA published its second phase of the implementation rule for the 1997 eight-hour ozone NAAQS, which addressed the control obligations that apply to areas designated nonattainment for the standard.

The commission adopted the 1997 eight-hour ozone nonattainment area SIP revision and the reasonable further progress SIP revision for the HGB area on May 23, 2007. These SIP revisions were the first step in addressing the 1997 eight-hour ozone standard in the HGB area. The TCEQ demonstrated reasonable further progress toward attaining the 1997 eight-hour ozone standard and committed to attaining the 1997 standard as expeditiously as practicable and developing an HGB 1997 eight-hour ozone attainment demonstration SIP revision.

On June 15, 2007, these two revisions to the Texas SIP and a letter from the governor of Texas requesting that the HGB ozone nonattainment area be reclassified from a moderate nonattainment area to a severe nonattainment area were submitted to the EPA. The EPA granted the governor's request to voluntarily reclassify the HGB ozone nonattainment area from a moderate to a severe nonattainment area for the 1997 ozone NAAQS in the October 1, 2008, issue of the *Federal Register* (73 FR 56983). The EPA set April 15, 2010, as the date for the state to submit a revised SIP addressing the severe ozone nonattainment area requirements of the FCAA. The area's new attainment date for the 1997 eight-hour ozone standard is as expeditiously as practicable but no later than June 15, 2019.

1.2.2.1 May 23, 2007

On May 23, 2007, the commission adopted the HGB 1997 Eight-Hour Ozone Nonattainment Area SIP revision. This SIP revision contained the reasonably available control technology (RACT) analysis, additional VMEP commitments, and the Texas 2002 Periodic Emissions Inventory for the HGB Ozone Nonattainment Area. This SIP revision also included rule revisions to 30 TAC Chapter 114 to add marine diesel fuels to the definition of diesel fuels that are subject to the Texas Low Emission Diesel Rule and to 30 TAC Chapter 115 to control underestimated, unreported, or underreported VOC emissions from tank landings, flash emissions, and degassing of storage tanks, transport vessels, and marine vessels with liquid heels. In an associated rulemaking project, 30 TAC Chapter 117 was reformatted and the 10 nanogram per Joule (ng/J) heat input NO_X standard for residential water heaters was repealed in accordance with House Bill (HB) 965, 79th Texas Legislature, 2005. The emission standard of 40 ng/J NO_X was retained.

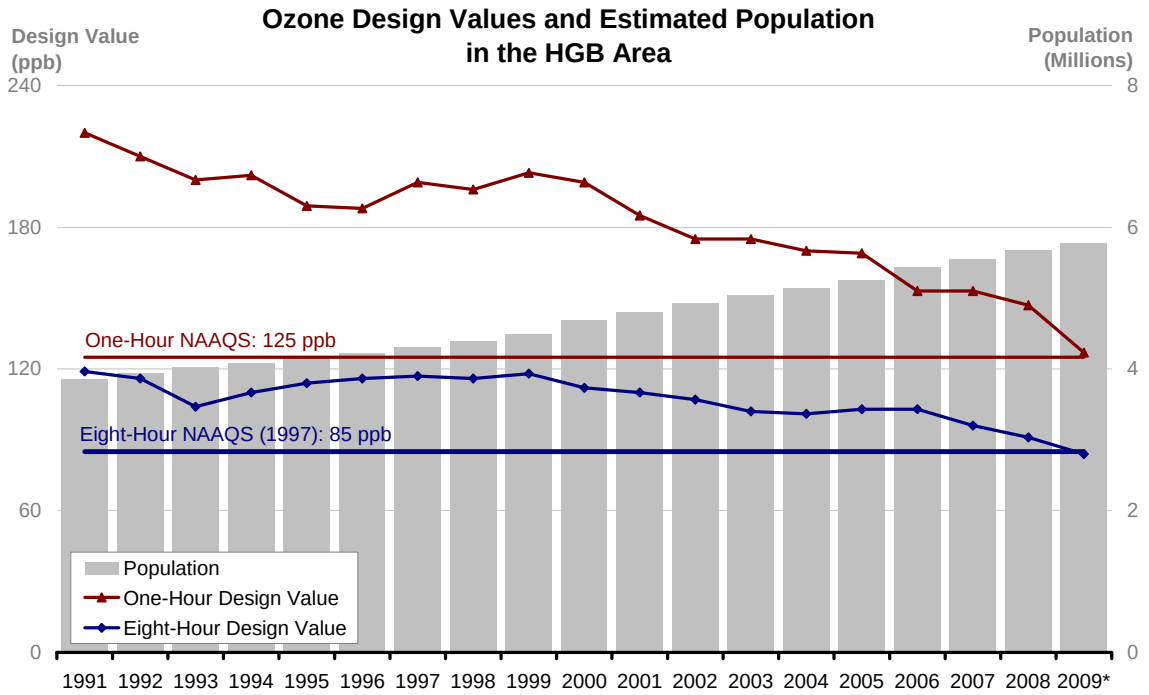
This revision also described ongoing efforts to develop the eight-hour ozone attainment demonstration including a new modeling episode using days from 2005 and 2006, the continued implementation of increasingly lower federal on-road and non-road engine standards, and further research and consideration of additional control strategies.

The HGB 1997 Eight-Hour Ozone Nonattainment Area Reasonable Further Progress SIP revision, also adopted by the commission on May 23, 2007, demonstrates that the reasonable further progress 15 percent reduction requirement would be met for the analysis period of 2002 -

2008. Demonstration of reasonable further progress is based on the guidelines in the second phase of the EPA's 1997 eight-hour ozone implementation rule. On April 22, 2009, the EPA published a direct final approval of the reasonable further progress SIP revision, its associated MVEB, and the 2002 base year emissions inventory (74 FR 18298).

1.2.3 Existing Ozone Control Strategies

Existing ozone control strategies and VMEP measures, discussed in Chapter 4: *Control Strategies and Required Elements*, Section 4.2: *Existing Control Measures* show key control strategies for complying with both the one-hour and eight-hour ozone NAAQS in the HGB nonattainment area. Existing control strategies targeted to the one-hour standard are expected to continue to reduce emissions of ozone precursors in the HGB area and positively impact progress toward attainment of the 1997 eight-hour ozone standard. The one-hour and 1997 eight-hour ozone design values for the HGB area from 1991 to 2009 are illustrated in Figure 1-1: *One-Hour and 1997 Eight-Hour Ozone Design Values and HGB Area Population.* Both design values have decreased over the past 18 years. The 2009 one-hour ozone design value was 127 ppb, representing a 42 percent decrease from the value for 1991 (220 ppb). The 2009 eight-hour ozone design value was 84 ppb, a 29 percent decrease from the 1991 value of 119 ppb. These decreases occurred despite a 50 percent increase in area population, as shown in the Figure 1-1: *One-Hour and 1997 Eight-Hour Ozone Design Values and HGB Area Population*.



*Source: Ozone -- EPA's AQS database.
1991-2008 Population --http://www.census.gov/popest/archives/1990s/MA-99-03b.txt and http://www.census.gov/popest/counties/CO-EST2008-popchg2000_2008.html
2009 Data is current as of December 1, 2009 and is subject to change. 2009 population data is estimated from the Texas Department of State Health Services, http://www.dshs.state.tx.us/CHS/popdat/ST2009.shtm.

Figure 1-1: One-Hour and 1997 Eight-Hour Ozone Design Values and HGB Area Population

1.2.4 Current SIP Revision

The EPA reclassification of the HGB area as a severe nonattainment area for the 1997 eight-hour ozone NAAQS became effective on October 31, 2008. Severe nonattainment areas are required to attain the 1997 eight-hour ozone standard as expeditiously as practicable but no later than June 15, 2019. The state must submit a SIP revision addressing the severe ozone nonattainment area requirements of the FCAA by April 15, 2010.

This SIP revision demonstrates attainment of the 1997 eight-hour ozone NAAQS using a photochemical modeling analysis and a WoE corroborative analysis. This submittal contains new state and local control measures. The Houston-Galveston Area Council (H-GAC), as the regional metropolitan transportation planning agency for the HGB area, has identified VMEP measures and transportation control measures for NO_X emission reductions.

Photochemical modeling analysis demonstrates that a 25 percent reduction of the HECT cap on the total Harris County HRVOC allocation will contribute to attainment of the 1997 eight-hour ozone NAAQS by reducing the future 2018 ozone design values at all HGB monitors. Accordingly, this SIP revision contains a 25 percent reduction in the total HECT allowance cap and revision of the HRVOC allocation methodology. The HECT program continues to be applicable only in Harris County.

This SIP revision also contains the RACT analysis, the reasonably available control measures (RACM) analysis, updates to existing control measures, contingency measures, and the MVEB. The plan also describes ongoing technological research and development as well as future initiatives.

The HGB Reasonable Further Progress SIP Revision for the1997 Eight-Hour Ozone Standard (Project No. 2009-018-SIP-NR), which demonstrates the FCAA requirement of interim reductions of ozone precursors through the 2019 attainment date, is being adopted in a concurrent action.

Table 1-1: *Associated Rule Revisions* contains the project number, title, and description of rule revisions to 30 TAC Chapters 101 and 115 that are associated with this SIP revision. Additional information regarding these rule revisions is included in Chapter 4: *Control Strategies and Required Elements*.

Table 1-1: Associated Rule Revisions

Rule Project Number	Title	Description
2009-019-101-EN	MECT Program Cap Integrity for the HGB Eight-Hour Ozone Nonattainment Area	The revisions to the MECT program will ensure the integrity of the modeled HGB nonattainment area cap by prohibiting the issuance of allowance allocations to major sources that did not submit the required Level of Activity Certification forms by the compliance date in 30 TAC §101.360. This rule change will not reduce the current NO_X cap in the HGB nonattainment area.
2009-006-101-EN	HECT Program Cap Reduction and Allowance Reallocation	The revisions to the HECT program rule will result in a 25 percent reduction in the total HECT allowance cap and revise the HRVOC allocation methodology. The HECT program was adopted by the commission as an ozone control measure for the HGB area on December 1, 2004. The HECT program is applicable only in Harris County.
2008-019-115-EN	VOC Control Technique Guidelines (CTG) Update	The revisions to 30 TAC Chapter 115, Subchapter E, Division 4 will limit the VOC content of solvents used by offset lithographic printing facilities located in the HGB area and will implement the CTG recommendations to reduce the VOC content of the fountain solutions and cleaning materials used by such facilities. Additionally, the revisions will expand the current rule applicability to include smaller sources not currently subject to the rule. The revisions are to satisfy RACT for the 2006 federal CTG document for offset lithographic and letterpress printing operations.

The commission solicited comments on whether it is appropriate to perform a 1997 eight-hour ozone MCR analysis for the HGB area, and, if so, what elements should be contained in the analysis. The commission also requested input on the appropriate date to submit the MCR. In response to the comments received, the executive director's staff will perform a 1997 eight-hour ozone MCR for commission approval and submittal to the EPA. For further information on the MCR, see Chapter 6: *Ongoing and Future Initiatives*, Section 6.3.1: *Mid-Course Review (MCR)*.

1.3 HEALTH EFFECTS

In 1997, the EPA revised the NAAQS for ozone from a one-hour to an eight-hour standard. To support the 1997 eight-hour ozone standard, the EPA provided information indicating that health effects can occur at levels lower than the previous standard and at exposure times longer than one hour. High concentrations of one-hour ozone were not shown to correlate well with mortality. Exposure to ambient ozone can aggravate asthma in some people. Repeated exposures to ozone can make people more susceptible to respiratory infection and lung inflammation and can aggravate preexisting respiratory diseases, such as bronchitis and emphysema.

Children are at a relatively higher risk from exposure to ozone when compared to adults, since they breathe more air per pound of body weight than adults and because children's respiratory systems are still developing. Children also spend a considerable amount of time outdoors during summer and during the start of the school year (August - October) when high ozone levels are typically recorded. Adults most at risk to ozone exposure are people working or exercising outdoors and individuals with preexisting respiratory diseases.

1.4 STAKEHOLDER PARTICIPATION AND PUBLIC HEARINGS

1.4.1 Local Program Control Strategy Development Meetings

The TCEQ contracted with the H-GAC to identify possible local on-road and non-road mobile source control strategies. As part of this process, stakeholder meetings were held in the HGB

area. Table 1-2: *H-GAC Public and Stakeholder Meeting Dates* lists the stakeholder meetings held by H-GAC and its subcontractor, ENVIRON International Corporation, from May 2008 through January 2009. These meetings gave stakeholders and the public in the HGB area the opportunity to hear about and comment on the development of the local mobile source control strategies.

Table 1-2: H-GAC Public and Stakeholder Meeting Dates

Meetings	Dates
Airports/Airlines	5/22/08, 10/1/08, 1/6/09
Railroads	6/12/08, 12/1/08
Tug Boat Operators	12/3/08
Public Meetings	7/10/08, 12/8/08
Construction Industry	6/3/08, 12/15/08
Ports/Marine Equipment	6/12/08, 6/19/08, 12/15/08
Industrial Mobile Sources	8/13/08, 12/16/08, 1/8/09
Local Governments	1/27/09

1.4.2 TCEQ SIP and Control Strategy Development Stakeholder Meetings

The TCEQ held two identical open-participation HGB Eight-Hour Ozone SIP Stakeholder Group meetings to discuss concepts of potential control strategies for the eight-county HGB ozone nonattainment area, to hear the public's ideas on potential rulemaking concepts, and to provide the public an overview of the development of the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard. The meetings were held on March 25 and 26, 2008, at the Houston City Hall Annex. In these meetings, the TCEQ presented attendees with an update on the HGB Attainment Demonstration SIP Revision timeline, an update on modeling efforts, and a draft list of initial potential control strategy concepts for stationary, area, and mobile sources. The TCEQ held an additional stakeholder meeting to discuss the initial 2018 HGB modeling results, provide an update on the development status of the HGB SIP revision, and provide an update from H-GAC regarding potential local mobile source control strategies. This meeting was held on November 3, 2008, at H-GAC. Additional information on the HGB Eight-Hour Ozone SIP Stakeholder Group is available at:
http://www.tceq.state.tx.us/implementation/air/sip/hgb_stakeholder.html.

A meeting was held on May 15, 2008, at H-GAC to discuss the development of the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard and potential local control measures with local governments. Letters were sent to the 15 mayors of cities in the HGB area with populations greater than 20,000, the eight county judges, and the four Harris County commissioners inviting participation. Notification was also sent to state representatives and senators representing the districts in the HGB area. A separate meeting was also held on July 22, 2008, at H-GAC to provide local governments information on the SIP revision, as well as discuss the process to identify potential measures that can be implemented at the local level. For this meeting, 109 letters were sent to mayors of cities in the HGB area with populations of 20,000 or less inviting participation.

1.4.3 Public Hearings and Comment Information

The commission held public hearings for the proposed SIP revisions and associated rulemakings on October 28, 2009, at 2:00 p.m. and 6:00 p.m., at the H-GAC offices in Houston; and on October 29, 2009, at 3:00 p.m., at the TCEQ headquarters in Austin. Question and answer sessions were held 30 minutes prior to the hearings. Neither the October 28, 2009, hearing scheduled for 6:00 p.m. nor the October 29, 2009, hearing was officially opened because no party indicated a desire to provide comment. Five persons presented oral comments at the 2:00 p.m. hearing in Houston regarding this SIP revision.

The public comment period opened on October 9, 2009, and closed on November 9, 2009. Written comments were accepted via mail, fax, and through the e-Comments system. There were 25 written comments received. Summaries of public comments and TCEQ responses are included as part of this SIP revision.

Copies of the proposed SIP revision and all appendices can be obtained from the TCEQ's Web site at http://www.tceq.state.tx.us/implementation/air/sip/hgb.html#.

1.5 SOCIAL AND ECONOMIC CONSIDERATIONS

For a detailed explanation of the social and economic issues involved with any of the measures, please refer to the preambles that precede each rule package accompanying this SIP revision.

1.6 FISCAL AND MANPOWER RESOURCES

The state has determined that its fiscal and manpower resources are adequate and will not be adversely affected through the implementation of this plan.

CHAPTER 2: ANTHROPOGENIC EMISSIONS INVENTORY (EI) DESCRIPTION

2.1 INTRODUCTION

The 1990 Federal Clean Air Act Amendments (FCAA) require that attainment demonstration emissions inventories (EI) be prepared for ozone nonattainment areas. Ozone is photochemically produced in the atmosphere when volatile organic compounds (VOC) are mixed with nitrogen oxides (NO_X) in the presence of sunlight. The Texas Commission on Environmental Quality (TCEQ) maintains an EI of up-to-date information on NO_X and VOC sources. The EI identifies the types of emissions sources present in an area, the amount of each pollutant emitted, and the types of process and control devices employed at each plant or source category. The inventory provides data for a variety of air quality planning tasks, including establishing baseline emission levels, calculating emission reduction targets, control strategy development for reducing emissions, emission inputs into air quality simulation models, and tracking actual emission reductions against the established emissions growth and control budgets. These EIs are critical for the efforts of state, local, and federal agencies to demonstrate attainment of the National Ambient Air Quality Standards.

This chapter discusses general EI development for each of the source categories. Chapter 3: *Photochemical Modeling* details specific emissions inventories and emissions inputs developed for the Houston-Galveston-Brazoria (HGB) ozone photochemical modeling.

2.1.1 EI Improvement

The Texas Commission on Environmental Quality (TCEQ) EI reflects years of continuous emissions data improvement, including extensive point and area source inventory reconciliation with ambient emissions monitoring data. Since the Texas Air Quality Study 2000 (TexAQS 2000), when ambient VOC concentrations were measured to be greater than EI estimates, EI improvements have targeted more accurate speciation and reporting of industrial VOC emissions. The following have significantly improved the HGB point source or area source inventory.

- Implementation of the 30 Texas Administrative Code (TAC) Chapter 115 highly reactive volatile organic compounds (HRVOC) monitoring rules improved the HGB point source VOC inventory with measurements required of vents, cooling towers, and the streams to flares in HRVOC service.

- The Houston Advanced Research Center project H51C (http://www.harc.edu/Projects/AirQuality/Projects/Projects/H051C) identified thousands of tons of VOC flash emissions from upstream oil and gas operations in the HGB area that the TCEQ has added to the area source inventory.

- A special landing loss EI was conducted that required the reporting of landing loss emissions from floating roof tanks. This special inventory also required regulated entities in the HGB area to revise their emissions inventories back to 2002, resulting in a reporting increase of approximately 7,000 to 8,000 tons of VOC per year (2002 through 2004). The episodic nature of these emissions is represented in the 2005 and 2006 ozone modeling based on site-specific activity data.

- A month-long hourly EI of approximately 1,200 emissions sources at 125 industrial sites was conducted during the TexAQS II intensive period. These hourly data are integrated into the 2006 modeling episode, providing highly resolved hourly VOC and NO_X emissions data for sources located in the HGB area. Monitored emissions data were collected for the majority of the VOC hourly emissions and all of the NO_X emissions rates. Because these sources are not included in the United States Environmental Protection Agency's (EPA) Acid Rain database, these hourly data present an opportunity

to model a unique and extensive set of monitoring data that characterizes the time-dependent nature of industrial ozone precursor emissions.

- The TCEQ *Emissions Inventory Guidelines* (RG-360A), a comprehensive guidance document that explains all aspects of the point source EI process, is updated and published annually. The latest version of this document is available on the TCEQ's Point Source Emissions Inventory Web site at: (http://www.tceq.state.tx.us/implementation/air/industei/psei/psei.html). Currently, six technical supplements provide detailed guidance on determining emissions from potentially underreported VOC emissions sources such as cooling towers, flares, and storage tanks.

2.2 POINT SOURCES

Stationary point source emissions data are collected annually from sites that meet the reporting requirements of 30 TAC § 101.10. These sites include, but are not limited to, refineries, chemical plants, bulk terminals, and utilities. To collect the data, the TCEQ mails EI questionnaires (EIQ) to all sites identified as meeting the reporting requirements. Companies are required to report emissions data and to provide sample calculations used to determine the emissions. Information characterizing the process equipment, the abatement units, and the emission points is also required. All data submitted in the EIQ are reviewed for quality assurance purposes and then stored in the State of Texas Air Reporting System (STARS) database. At the end of the annual reporting cycle, point source emissions data are reported each year to the EPA for inclusion in the National Emissions Inventory (NEI).

2.3 AREA SOURCES

Area sources are stationary emission sources that are not included in the point source EI. Similar area sources such as plants, facilities, equipment, and/or processes are grouped into area source categories including, but not limited to, vehicle refueling, architectural coatings, auto refinishing, dry cleaning, municipal solid waste landfills, bakeries, residential fuel combustion, structural fires, wildfires, and open burning.

Area source categories can further be characterized by the mechanism in which their emissions are released into the atmosphere: hydrocarbon evaporative emissions or fuel combustion emissions. Hydrocarbon evaporative emission sources include, but are not limited to, printing operations, industrial coatings, degreasing solvents, house painting, gasoline service station underground tank filling, and vehicle refueling operations. Fuel combustion emission sources include, but are not limited to, stationary source fossil fuel combustion at residences and businesses, outdoor burning, structural fires, and wildfires. Since area source categories represent individual emission sources that are small and numerous and that have not been inventoried as specific point or mobile sources, the EI for an area source category is developed for a specified geographic area by estimating the emissions collectively.

The emissions from these area source categories, with some exceptions, may be calculated by applying an EPA-established emission factor (emissions per unit of activity) to the appropriate activity or activity surrogate responsible for generating emissions. Population is the most commonly used activity surrogate; examples of other activity data are the amount of gasoline sold in an area, employment by industry type, and acres of crop land. Activity data for an area source category is obtained via surveys, research, and/or investigations. Air emissions data from the different area source categories are collected, reviewed for quality assurance purposes, stored in the Texas Air Emissions Repository database system, and compiled to develop the statewide area

source EI. This area source Periodic Emissions Inventory (PEI) is reported every third year (triennially) to the EPA for inclusion in the NEI; the TCEQ submitted the most recent PEI for calendar year 2005.

2.4 NON-ROAD MOBILE SOURCES

Non-road mobile sources include vehicles, engines, and equipment used for construction, agriculture, transportation, recreation, and many other purposes. Non-road vehicles are also referred to as off-road or off-highway vehicles that do not normally operate on roads or highways. This broad category is comprised of a diverse collection of machines, many of which are powered by diesel engines. Examples of non-road mobile sources include, but are not limited to: agricultural equipment, commercial and industrial equipment, construction and mining equipment, lawn and garden equipment, aircraft, locomotives, and commercial marine vessels.

A Texas specific version of the EPA's NONROAD 2005 model, called the Texas NONROAD (TexN) model, is used in calculating emissions from all non-road mobile equipment and recreational vehicles except aircraft, locomotives, and commercial marine vessels. Emissions for these three source categories are estimated using other EPA-approved methods and guidance documents. Airport emissions are calculated using the Federal Aviation Administration's Emissions and Dispersion Modeling System, version 5.1. Locomotive emission estimates for Texas are based on specific fuel usage data derived from railway segment level gross ton mileage activity (line haul locomotives) and hours of operation (yard locomotives) provided directly by the Class I railroad companies operating in Texas. Data captured from the Automatic Identification System program is applied to the latest known emission factors to quantify emissions from commercial marine vessels.

2.5 ON-ROAD MOBILE SOURCES

On-road mobile sources consist of automobiles, trucks, motorcycles, and other motor vehicles traveling on public roadways. Combustion-related emissions are estimated for vehicle engine exhaust, and evaporative hydrocarbon emissions are estimated for the fuel tank and other evaporative leak sources on the vehicle. The information necessary to estimate on-road mobile emissions is emission factors for each vehicle type, the estimated level of vehicle activity, and estimated roadway speed.

Emission factors were developed using the newest version of the EPA's mobile emissions factor model, MOBILE6.2.03. Various inputs are provided to the model to simulate the vehicle fleet in each nonattainment area. Inputs used to develop localized emission factors include vehicle speeds, vehicle age distributions, local meteorological conditions, type of inspection and maintenance program in place, and local fuel properties. Emission factors are developed for all 28 MOBILE6.2.03 vehicle types.

The level of vehicle travel activity is developed using localized travel demand models (TDMs) run by the Texas Transportation Institute, Texas Department of Transportation, or regional metropolitan planning organizations. The TDMs have been validated using a large number of ground counts from traffic counters placed in various locations throughout Texas. Estimates of vehicle miles traveled (VMT) are often calibrated to outputs from the federal Highway Performance Monitoring System, which is a model validated using a different set of traffic counters. VMT is allocated to the appropriate vehicle types using regional specific VMT mixes developed using ground counts and vehicle registration data.

Roadway speeds are needed to select the appropriate MOBILE6.2.03 emission factors. Roadway speeds are calculated by a post-processor to the TDMs. The speed models use roadway capacity information, the estimated volumes from the TDMs, and speed correlations based upon volume to capacity ratios to estimate roadway speeds. To develop on-road mobile emissions estimates, the speed specific MOBILE6.2.03 emission factors are multiplied by the VMT for each roadway link in the TDMs network.

CHAPTER 3: PHOTOCHEMICAL MODELING

3.1 INTRODUCTION

This chapter describes modeling conducted in support of the Houston-Galveston-Brazoria (HGB) Attainment Demonstration State Implementation Plan (SIP) Revision for the 1997 Eight-Hour Ozone Standard. The HGB nonattainment area consists of Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller Counties. The 1990 Federal Clean Air Act (FCAA) amendments require that attainment demonstrations be based on photochemical grid modeling or any other analytical methods determined by the United States Environmental Protection Agency (EPA) to be at least as effective. The EPA's April 2007 "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze" (EPA, 2007; hereafter referred to as "modeling guidance") recommends new procedures for determining whether a control strategy package will lead to attainment of the 1997 eight-hour National Ambient Air Quality Standard (NAAQS) for ozone.

The current modeling guidance recommends several qualitative methods for preparing attainment demonstrations that acknowledge the limitations and uncertainties of photochemical models when used to project ozone concentrations into future years. First, the guidance recommends using model results in a relative sense and applying the model response to the observed ozone data. Second, the guidance recommends using available air quality, meteorology, and emissions data to develop a conceptual model for eight-hour ozone formation and to use that analysis in episode selection. Third, the guidance recommends using other analyses (Weight of Evidence) to supplement and corroborate the model results and support the adequacy of a proposed control strategy package.

The 1990 FCAA amendments established five classifications for ozone nonattainment areas based on the magnitude of the regional one-hour ozone design value and established dates by which each classified area should attain the NAAQS. Based on the monitored one-hour ozone design value at that time, the eight-county HGB Consolidated Metropolitan Statistical Area (Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller Counties) was classified severe-17, with an attainment date of November 15, 2007. Dating back to 1990, there have been six SIP revisions with supporting photochemical modeling addressing the one-hour ozone NAAQS. The most recent one-hour ozone HGB SIP revision, submitted in December 2004, was approved by the EPA on September 6, 2006.

With the change of the ozone NAAQS from a one-hour standard to an eight-hour standard, in April 2004, the EPA classified the HGB area as a moderate ozone nonattainment area with an attainment date of June 15, 2010. Ozone SIP revisions addressing the 1997 eight-hour ozone standard were due June 15, 2007. Ozone modeling and other analyses conducted by the Texas Commission on Environmental Quality (TCEQ) for the SIP revision resulted in a determination that it was not possible to attain the 1997 eight-hour ozone NAAQS in the HGB area by the prescribed attainment date.

Therefore, the ozone SIP revision submitted to EPA on June 15, 2007, included a request to reclassify the area as severe nonattainment for the 1997 eight-hour ozone NAAQS, with an attainment date of June 15, 2019. Because the attainment date is early in the 2019 ozone season, the EPA has prescribed that the modeling attainment test be applied to the previous ozone season. Thus, 2018 is the attainment year used in the ozone modeling.

This attainment demonstration uses photochemical modeling in combination with corroborative analyses primarily associated with the 2000 and 2006 Texas Air Quality Studies (TexAQS 2000 and TexAQS II, respectively) to support a conclusion that the HGB eight-county nonattainment area will attain the 0.08 parts per million (ppm) 1997 eight-hour ozone standard by June 15, 2019. Extensive use is made of the data collected during TexAQS II to evaluate the model's

performance and to improve understanding of the physical and chemical processes leading to ozone formation in the HGB area.

3.1.1 Overview of the Ozone Photochemical Modeling Process

The modeling system is composed of a meteorological model, several emissions processing models, and a photochemical air quality model. The meteorological and emissions models provide the major inputs to the air quality model.

Ozone is a secondary pollutant; it is not generally emitted directly into the atmosphere. Ozone is created in the atmosphere by a complex set of chemical reactions between sunlight and several primary (directly emitted) pollutants. The reactions are photochemical and require ultraviolet energy from sunlight. The majority of primary pollutants directly involved in ozone formation fall into two groups, nitrogen oxides (NO_X) and volatile organic compounds (VOC). In addition, carbon monoxide (CO) is also an ozone precursor, but much less effective than either NO_X or VOC in forming ozone. As a result of these multiple factors, higher concentrations of ozone are most common during the summer with concentrations peaking during the day and falling during the night and early morning hours.

Ozone chemistry is complex, involving hundreds of chemical compounds and chemical reactions. As a result, ozone cannot be evaluated using simple dilution and dispersion algorithms. Due to this chemical complexity, the modeling guidance strongly recommends using photochemical computer models to simulate ozone formation and evaluate the effectiveness of future control strategies. Computer simulations are the most effective tools to address both the chemical complexity and the future case evaluation.

3.1.2 Ozone Modeling

Ozone modeling involves two major phases, the base case modeling phase and the future year modeling phase (with substeps in each phase). The purpose of the base case modeling phase is to evaluate the model's ability to adequately replicate measured ozone and ozone precursor concentrations during recent periods with high ozone concentrations (base case episodes). The purpose of the future year modeling phase is to predict attainment year ozone design values at each monitor, as well as evaluate the effectiveness of controls in reaching attainment. The TCEQ developed a modeling protocol (plan) describing the process to be followed to evaluate the ozone in the urban area and submitted the plan to the EPA as prescribed in the modeling guidance.

3.1.3 Base Case Modeling

Base case modeling involves several steps. First, recent episodes are analyzed to determine what factors were associated with ozone formation in the area and whether those factors were consistent with the conceptual model. In consultation with the Southeast Texas Photochemical Modeling Technical Committee (SETPMTC), which serves in an advisory role for the technical aspects of applying photochemical modeling and improving the science, the TCEQ selected episodes to model.

The next step is to generate and quality-assure the emissions and meteorological data for the selected episodes. Then the meteorological and emissions (NO_X, VOC and CO) data are input to the photochemical model and the ozone photochemistry is simulated, resulting in predicted ozone and ozone precursor concentrations. Base case modeling results are evaluated by comparing them to the observed measurements of ozone and ozone precursors. Typically this step is an iterative process incorporating feedback from successive evaluations to ensure that the model is adequately replicating observations throughout the modeling episode. The adequacy of the model in replicating observations is assessed based on compliance with statistical and graphical measures as recommended in the modeling guidance. In addition to the recommended analyses, the TCEQ used the TexAQS II observations to extend its model performance evaluation to areas and chemical species not typically monitored. This extended analysis included use of monitoring data collected on aircraft and ship-based platforms. Satisfactory performance of the base case

modeling provides a degree of reliability that the model can be used to predict future year ozone concentrations (future year design values), as well as to evaluate the effectiveness of possible control measures.

3.1.4 Future Year Modeling

Future year modeling involves several steps. The procedure for predicting a future year ozone design value (attainment test) involves determining the ratio of the future year to the baseline year modeled ozone concentrations. This ratio is called the relative response factor (RRF). Whereas the emissions data for the base case modeling are episode-specific, the emissions data for the baseline year are based on typical ozone season emissions. Similarly, the emissions data for the future year are developed applying growth and control factors to the baseline year emissions. The growth and control factors are developed based on the projected growth in the demand for goods and services and the reduction in emissions expected from state, local, and federal control programs.

Both the baseline and future years are modeled using their respective ozone season emissions and the base case episode meteorological data as inputs. The same meteorological data are used for modeling both the baseline and future years, and thus, the ratio of future year modeled ozone concentrations to the baseline year concentrations provides a measure of the response of ozone concentrations to the change in emissions from projected growth and controls.

A future year ozone design value is calculated by multiplying the RRF by a baseline year ozone design value (DV_B). The DV_B is the average of the regulatory design values for the three consecutive years containing the baseline year (see Figure 3-1: *2006 Baseline Design Value Calculation Illustration*). When the calculated future year ozone design value is less than or equal to 0.08 ppm (84 parts per billion (ppb)), this signifies modeled attainment. When the calculated future year ozone design value is greater than 84 ppb, then additional controls may be needed and the model can be used to test the effectiveness of various control measures in developing a control strategy.

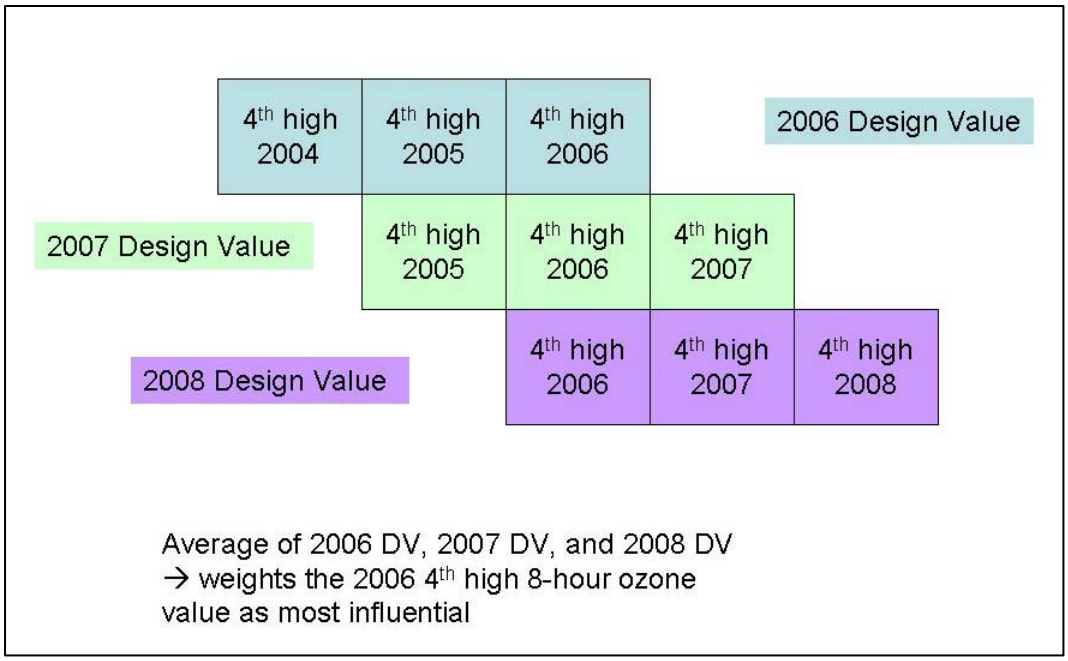


Figure 3-1: 2006 Baseline Design Value Calculation Illustration

3.2 EPISODE SELECTION

3.2.1 EPA Guidance for Episode Selection

The modeling guidance sets forth the primary criteria for selecting ozone episodes for eight-hour ozone attainment demonstration modeling:

- Select a mix of episodes reflecting a variety of meteorological conditions that frequently correspond with observed eight-hour daily maximum ozone concentrations greater than 84 ppb at different monitoring sites;
- Select periods during which observed eight-hour ozone concentrations are close to the eight-hour ozone design values at monitors with a DV_B greater than or equal to 85 ppb;
- Select periods for which extensive air quality/meteorological databases exist; and
- Model a sufficient number of days so that the modeled attainment test can be applied at all of the ozone monitoring sites that are in violation of the NAAQS.

3.2.2 HGB Ozone Episode Selection Process

An episode selection analysis was performed to identify time periods with eight-hour ozone exceedance days that complied with the primary selection criteria. The analysis identified several episodes from 2005 and 2006.

Figure 3-2: *Eight-Hour Ozone Exceedance Days in HGB and Other Areas of Texas* shows the frequency distribution of days with measured daily maximum eight-hour ozone concentrations greater than 84 ppb for the period 1991 through 2008. The distribution for the HGB area is somewhat bi-modal with a notable high frequency, i.e., greater than 40 days, in the late May to late June period and the more prominent period of high frequency occurring from late July through early October.

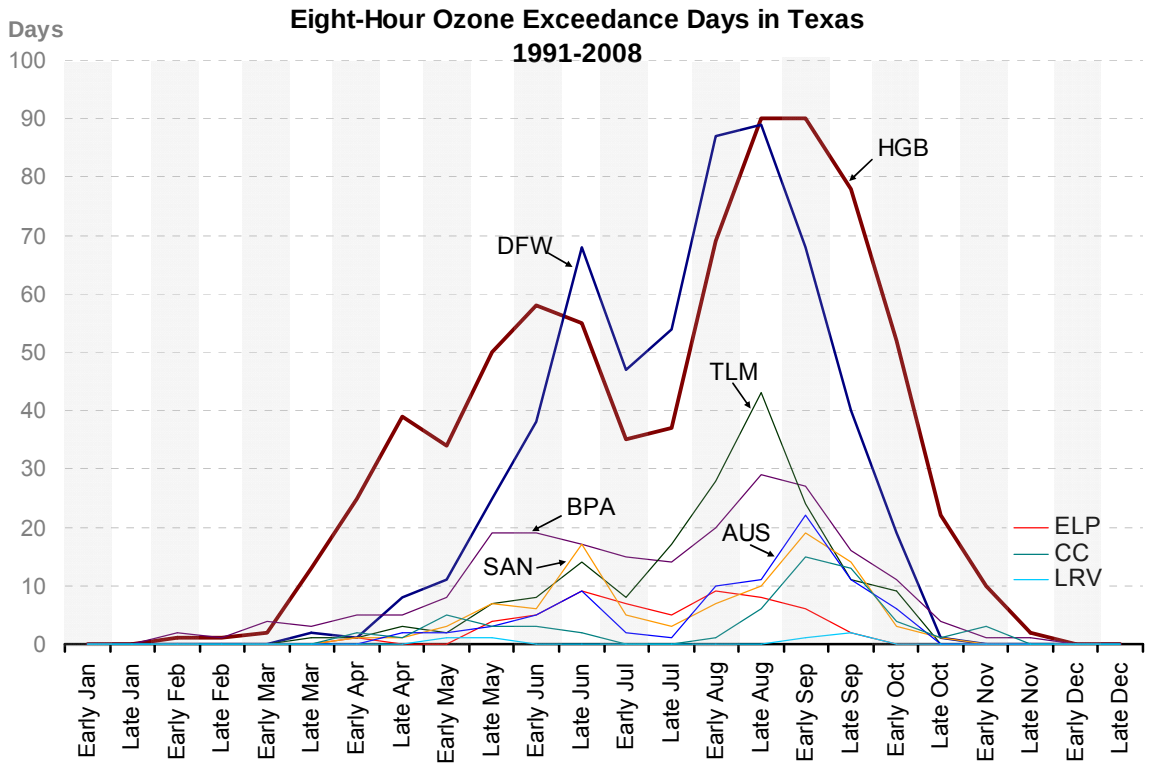


Figure 3-2: Eight-Hour Ozone Exceedance Days in HGB and Other Areas of Texas

Notes: AUS = Austin
BPA = Beaumont-Port Arthur
CC = Corpus Christi
DFW = Dallas-Fort Worth
ELP = El Paso
LRV = Lower Rio Grande Valley
SAN = San Antonio
TLM = Tyler-Longview-Marshall

In consultation with the SETPMTC, the TCEQ selected three episodes from 2005 and three episodes from 2006. Two of these occurred during the TexAQS II field intensive period. Table 3-1: *Selected Episodes* summarizes the dates of the selected episodes.

Table 3-1: Selected Episodes

Period of Episode	Number of Exceedance days
5/19/05 through 6/3/05	8
6/15/05 through 6/30/05	9
7/26/05 through 8/8/05	8
5/31/06 through 6/15/06	12
8/15/06 through 9/14/06*	10
9/19/06 through 11/11/06*	5

*TexAQS II field study intensive period

These episodes contain 52 exceedance days with occurrences from late May to early October, the primary window during which high ozone concentrations have been historically observed, and cover the periods depicted in Figure 3-2: *Eight-Hour Ozone Exceedance Days in HGB and Other Areas of Texas*. In addition, these episodes take advantage of the TexAQS II data and findings, including the August 1 through October 15, 2006, intensive field campaign.

Selecting a large number of days also increases the likelihood that the distribution of days associated with various ozone-conducive wind patterns will be consistent with the conceptual model. The conceptual model of ozone formation in the HGB area (see Appendix C: *Photochemical Modeling for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard)* suggests that the wind pattern characterized by a diurnal clockwise rotational veering as depicted in Figure 3-3: *Hourly Average Resultant Winds; Eight-Hour Exceedance Days, August through September 1998 through 2006* is frequently associated with eight-hour ozone exceedance days.

Hourly average resultant winds are plotted in the figure. The x-axis represents the east-west component of the wind while the y-axis represents the north-south component. Each point on the loop represents an hour of the day. The red data point corresponds to midnight and the aqua point corresponds to noon. Wind vectors have two attributes, wind speed and direction, and these components were averaged across monitors for each hour of the day and then plotted. Each point represents the tail of that hour's averaged resultant wind vector, and although not plotted, all the resultant wind vectors terminate at the origin. In other words, the direction from the point to the origin represents the direction the wind blew. The distance of a point from the origin represents the average wind speed in meters per second. The pink arrow indicates the daily average of all 24 one-hour vectors, and the green halo around each point gives an indication of the variability of the data across monitors.

Of the 52 exceedance days in the selected episodes, 25 days exhibit this clockwise rotational veering wind pattern. The conceptual model identifies a second wind pattern also frequently associated with eight-hour ozone exceedance days, which is characterized by a northerly morning to southerly afternoon flow reversal. Twenty-three of the 52 exceedance days exhibit this wind pattern. Therefore, the selected episodes are consistent with the conceptual model.

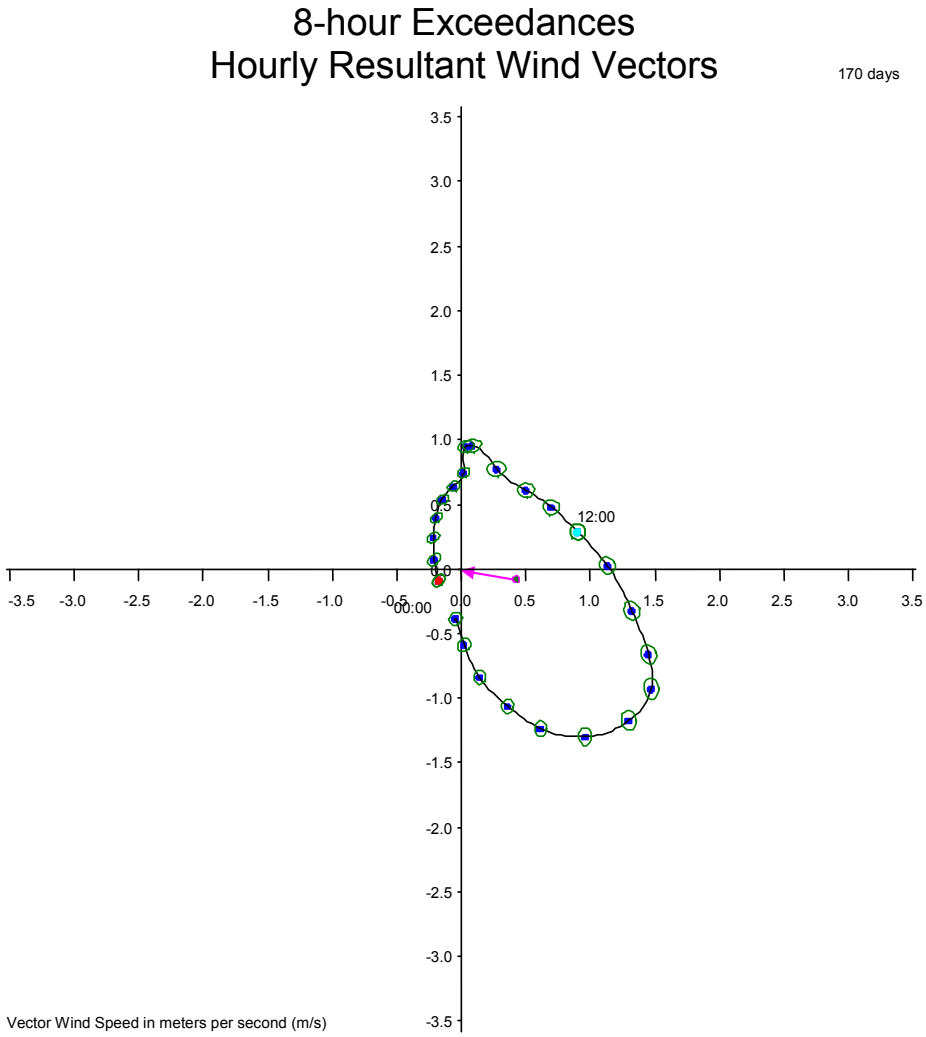


Figure 3-3: Hourly Average Resultant Winds; Eight-Hour Exceedance Days, August through September 1998 through 2006

Figure 3-4: *2005 and 2006 Non-TexAQS II Modeling Episodes* and Figure 3-5: *2006 TexAQS II Modeling Episodes* show the daily maximum eight-hour ozone concentrations observed and the number of regulatory (20) and non-regulatory, industry-sponsored (5) monitors exceeding 84 ppb.

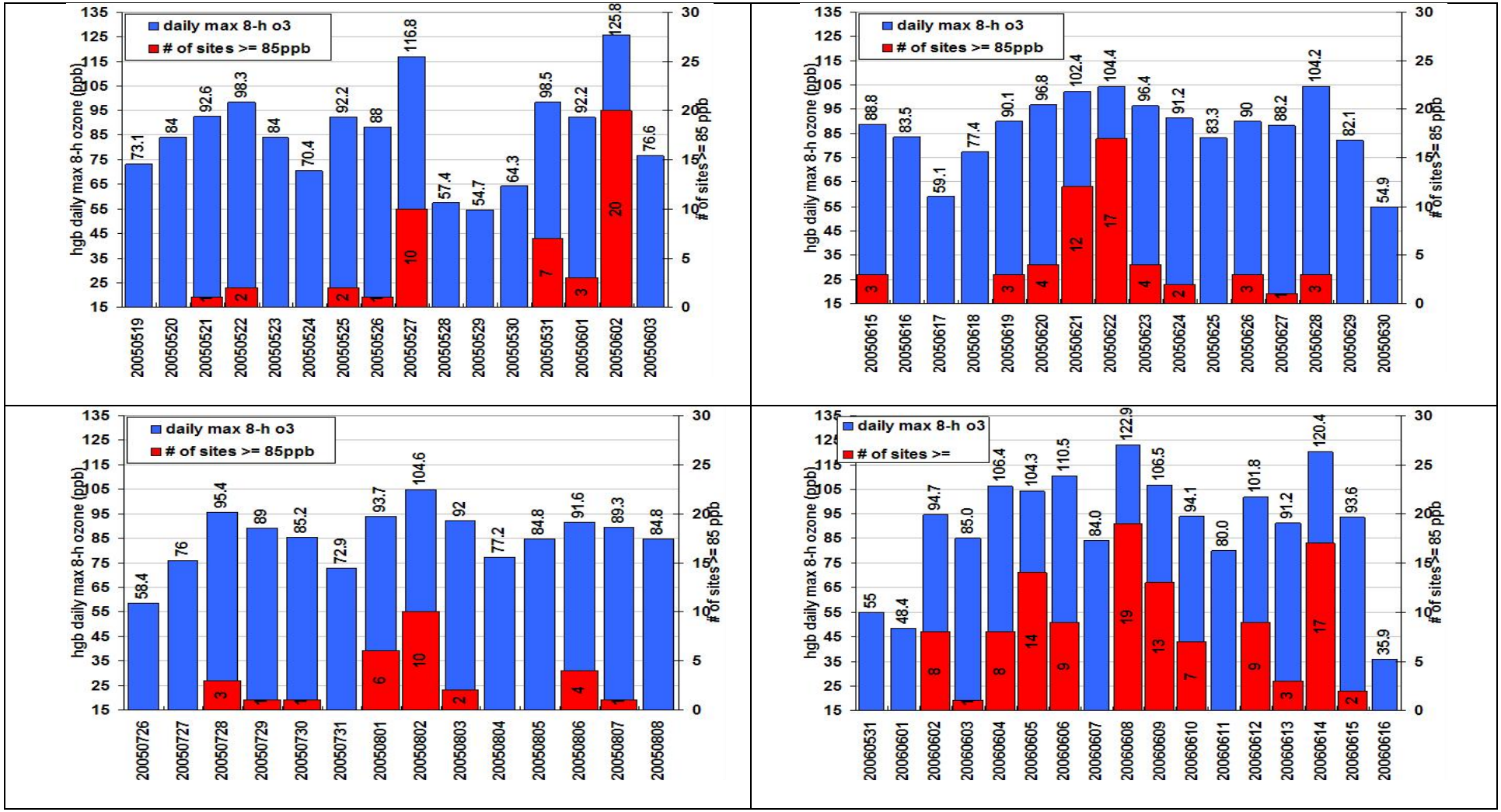


Figure 3-4: 2005 and 2006 Non-TexAQS II Modeling Episodes

Note: 8-h o3= eight-hour ozone

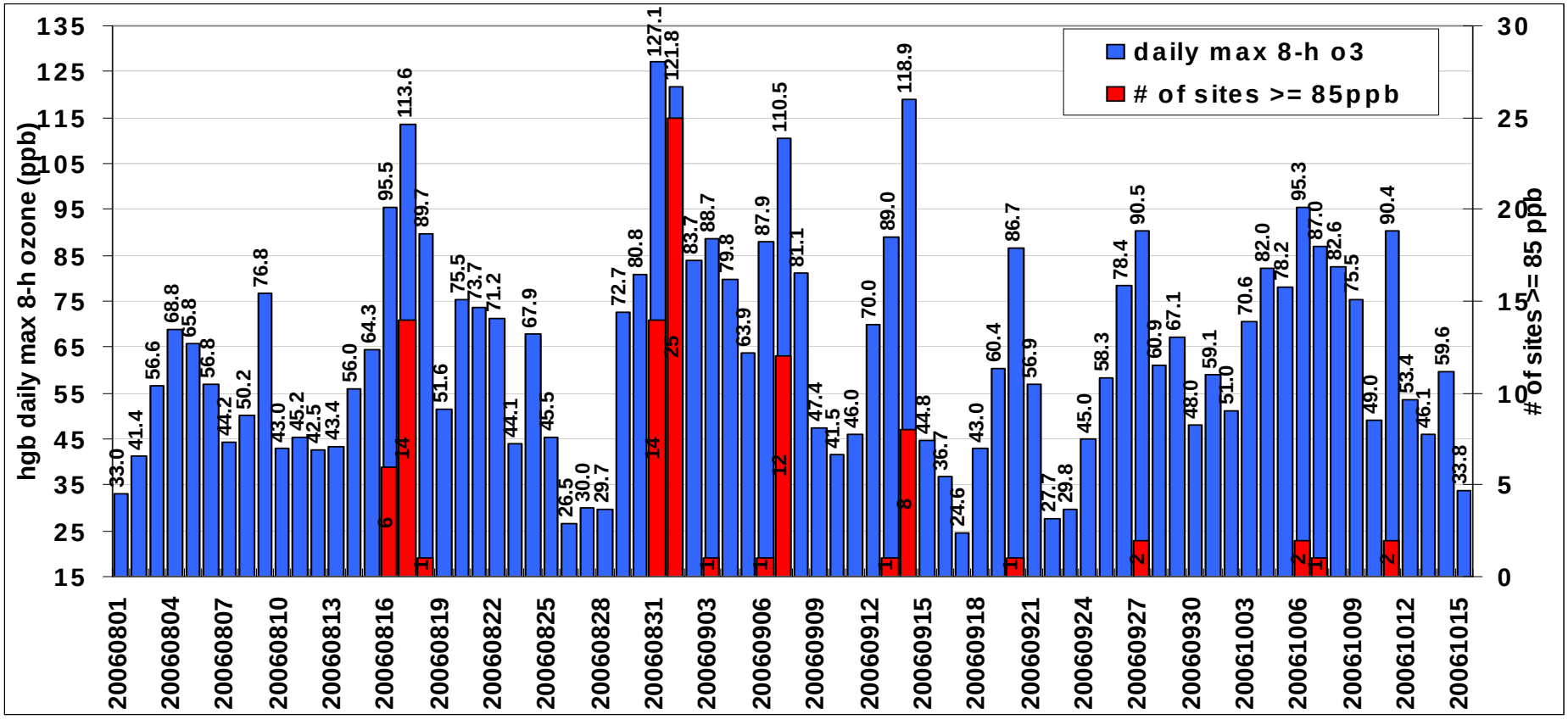


Figure 3-5: 2006 TexAQS II Modeling Episodes

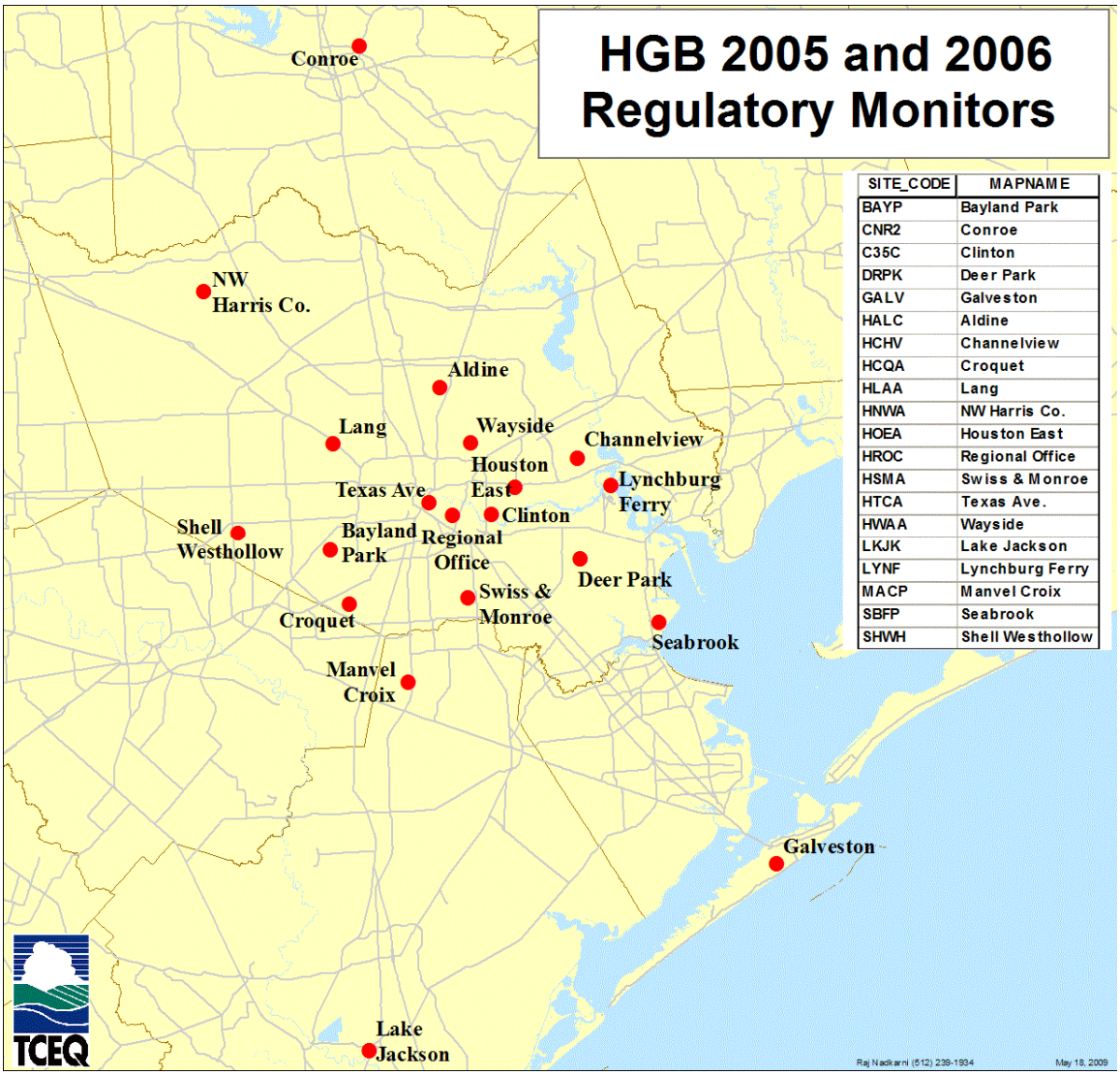
Table 3-2: *Eight-Hour Ozone Design Values and Number of Exceedance Days During Selected Episodes* lists the regulatory monitors in the eight-county HGB area for which 2005 and 2006 eight-hour ozone design values are greater than the NAAQS and the number of days during the episodes selected for modeling that had measured daily maximum eight-hour ozone greater than 84 ppb.

Table 3-2: Eight-Hour Ozone Design Values and Number of Exceedance Days During Selected Episodes

Monitor Designation	Site Code	2005 Design Value (ppb)	2006 Design Value (ppb)	Number of Episode Days > 84ppb
Houston East (CAMS 1)	HOEA	87	83	7
Aldine (CAMS 8)	HALC	92	88	5
Channelview (CAMS 15)	HCHV	89	85	5
Northwest Harris County (CAMS 26)	HNWA	93	91	13
Galveston (CAMS 1034)	GALC	87	83	3
Deer Park (CAMS 35)	DRPK	100	96	10
Seabrook Friendship Park (CAMS 45)	SBFP	92	90	8
Bayland Park (CAMS 53)	BAYP	103	103	14
Conroe Relocated (CAMS 78)	CNR2	86	85	5
Regional Office (CAMS 81)	HROC	88	84	9
Manvel Croix Park (CAMS 84)	MACP	97	96	16
Clinton (CAMS 403)	C35C	95	85	1
Swiss and Monroe (CAMS 406)	HSMA	97	99	10
Croquet (CAMS 409)	HCQA	98	94	8
Shell Westhollow (CAMS 410)	SHWH	89	96	12
Texas Avenue (CAMS 411)	HTCA	88	84	1
Lynchburg Ferry (CAMS 1015)	LYNF	96	89	8

Note: CAMS = Continuous Ambient Monitoring Station

Figure 3-6: *Map Depicting Regulatory Monitors in the HGB Area* shows the location of the regulatory monitors in the eight-county HGB area.



SITE_CODE	MAPNAME
BAYP	Bayland Park
CNR2	Conroe
C35C	Clinton
DRPK	Deer Park
GALV	Galveston
HALC	Aldine
HCHV	Channelview
HCQA	Croquet
HLAA	Lang
HNWA	NW Harris Co.
HOEA	Houston East
HROC	Regional Office
HSMA	Swiss & Monroe
HTCA	Texas Ave.
HWAA	Wayside
LKJK	Lake Jackson
LYNF	Lynchburg Ferry
MACP	Manvel Croix
SBFP	Seabrook
SHWH	Shell Westhollow

Figure 3-6: Map Depicting Regulatory Monitors in the HGB Area

Even though there are 52 exceedance days in the 2005 and 2006 episodes, only a few of the regulatory monitors measured daily maximum eight-hour ozone concentrations of greater than 84 ppb on 10 or more days. This reflects the complexity of ozone formation and distribution in the HGB area. For example, the Houston Texas Avenue (HTCA; CAMS 411) and TCEQ Houston Regional Office (HROC; CAMS 81) monitors are in fairly close proximity to one another, but the Houston Texas Avenue (CAMS 411) monitor measured a daily maximum eight-hour ozone concentration of greater than 84 ppb on only one day, while the TCEQ Houston Regional Office (CAMS 81) monitor measured it on nine days. The attainment test considers the modeled daily maximum eight-hour ozone concentration from an array of grid cells around the cell containing a monitor. By considering an array of grid cells around the monitor, rather than the single grid cell where the monitor is located, the likelihood of modeled concentrations exceeding 84 ppb is increased. This increases the number of days used in the attainment test (i.e., the RRF calculation).

There were a few other ozone episodes during the 2005 and 2006 ozone season that were not developed due to unusual meteorological conditions. For example, exceedance days that occurred in late August and September of 2005 may have been influenced by Hurricanes Katrina and Rita.

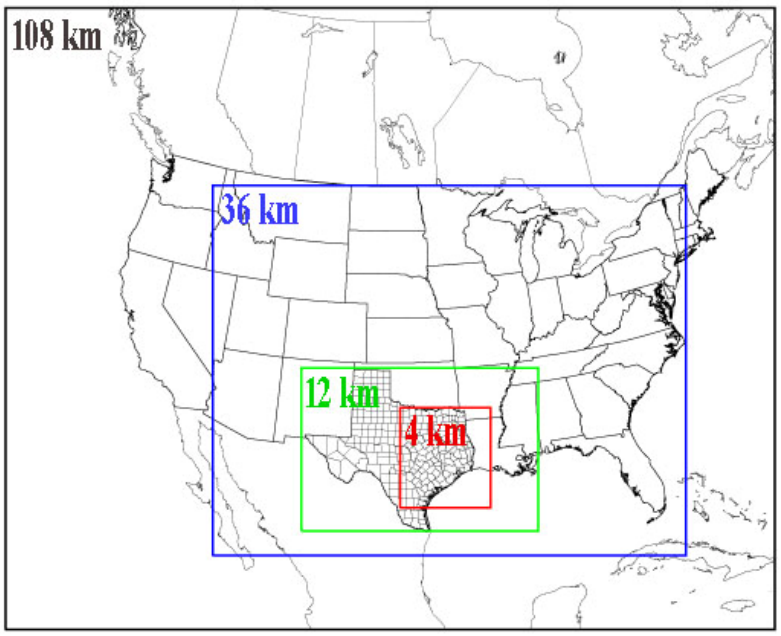
3.3 METEOROLOGICAL MODEL

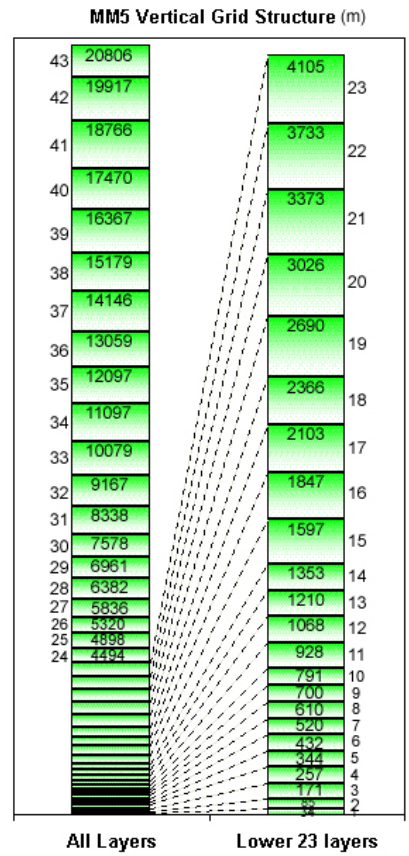
The TCEQ is using the Fifth Generation Meteorological Model (MM5, version 3.7.3) developed jointly by the National Center for Atmospheric Research (NCAR) and Pennsylvania State University (Grell *et al.*, 1994). This model, supported by a broad user community including the Air Force Weather Agency, national laboratories, and academia, is being used extensively for regulatory air quality modeling analyses throughout the United States.

3.3.1 Modeling Domains

MM5 was configured with three two-way nested outer grids (108 kilometer (km), 36 km, and 12 km horizontal resolution) to cover the United States and regional areas of interest. A one-way nested 4 km fine grid covering the eastern half of Texas was used to focus on metropolitan areas with air quality degradation, as shown in Figure 3-7: *MM5 Modeling Domains*. The extent of each of the MM5 modeling domains was selected to accommodate the embedding of the commensurate air quality modeling domains (see Section 3.5: *PHOTOCHEMICAL MODELING*).

Vertically, MM5 is structured with 43 layers from the surface to approximately 20 km. Twenty layers are within the first 3,000 meters in order to resolve boundary layer phenomena. The same MM5 vertical layering structure is used for all of the domains.





Domain	Range Easting (km)	Range Northing (km)	Grid Points Easting	Grid Points Northing
108 km	(-2808, 2808)	(-2268, 2268)	53	43
36 km	(-1296, 2160)	(-1728, 972)	97	76
12 km	(-648, 1080)	(-1548, -360)	145	100
4 km	(72, 372)	(-1380, -648)	166	184

Figure 3-7: MM5 Modeling Domains

3.3.2 Model (MM5) Configuration

Based on past TCEQ modeling efforts, the modeling guidance, contractor experience, and other demonstrations including sensitivity tests and model performance evaluation, the MM5 was configured with parameterizations and improved input data to optimize the performance of the wind field (i.e., wind speed and direction). Wind speed and direction are the most important parameters predicted by the meteorological model for air quality modeling purposes because the wind field determines the transport and dispersion of pollutants. The pre-processing of the MM5

input data followed the standard progression using the TERRAIN, REGRID, and INTERPF (NCAR, 2005) programs. The NESTDOWN program was used to interpolate from the 12 km domain output to the 4 km domain input.

To improve the MM5 simulation of the meteorological parameters, in particular the wind field, the land use characteristics and sea surface temperatures on all domains were updated with high resolution satellite measurements. In addition, observed parameters are assimilated in MM5 during the model run through a process called Four-Dimensional Data Assimilation (FDDA), or nudging (Stauffer and Seaman, 1990; Stauffer *et al.*, 1991; Stauffer and Seaman, 1994). The outer domains (108 km, 36 km, and 12 km) were nudged to the National Center for Environmental Prediction (NCEP) North American Model (NAM) gridded output for winds, temperature, and water vapor. The fine scale 4 km domain was observationally nudged using quality-assured upper air wind profiler data. MM5 default nudging strength parameters were used for both the NAM and profiler nudging. The NCEP NAM gridded output was also used for model initialization (NCEP, 2009).

MM5 parameterization schemes and options typically selected for air quality applications are shown in Table 3-3: *Selected MM5 Modeling Schemes*. The selection of these schemes and options was based on previous modeling experiences, MM5 community use, and features of the ozone exceedance episodes being modeled.

Table 3-3: Selected MM5 Modeling Schemes

Domain	Nudging Type	PBL	Cumulus	Radiation	Land-Surface Model	Microphysics
108, 36, 12 km	Analysis 3-D	Eta	Grell	RRTM	NOAH	Simple Ice
4 km	Observational	Eta	Grell	RRTM	NOAH	Simple Ice

Notes: PBL = Planetary Boundary Layer
RRTM = Rapid Radiative Transfer Model
NOAH = NCEP Oregon State Air Force Hydrological Research Laboratory

MM5 output was post-processed using the MM5CAMX utility to convert the MM5 meteorological fields to the Comprehensive Air Quality Model with Extensions (CAMx) grid and input format (Environ, 2008). The MM5CAMX utility was used with the Mellor-Yamada turbulent kinetic energy (TKE) vertical diffusivity methodology, and a minimum vertical diffusivity coefficient (K_V) of 1.0.

Appendix A: *Meteorological Modeling for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard* provides details on the development of the MM5 configuration, including the satellite-based Land-Use/Land-Cover (LULC) and Sea Surface Temperature (SST) data, the nudging methodology, the TKE methodology and the Grell cumulus scheme.

3.3.3 MM5 Application and Performance

The final MM5 modeling configuration was applied to periods spanning the eight-hour ozone exceedance episodes, as listed in Table 3-4: *2005 and 2006 Meteorological Modeling Episodes*.

Table 3-4: 2005 and 2006 Meteorological Modeling Episodes

Episode	Outer Grids Begin Date/Time (UTC)	Outer Grids End Date/Time (UTC)	Fine Grid End Date/Time (UTC)
2005ep0	May 18, 2005 06:00	June 4, 2005 06:00	June 4, 2005 06:00
2005ep1	June 15, 2005 06:00	July 1, 2005 06:00	July 1, 2005 06:00
2005ep2	July 25, 2005 06:00	August 9, 2005 09:00	August 9, 2005 07:00
2006ep0	May 29, 2006 06:00	June 17, 2006 06:00	June 17, 2006 06:00
2006ep1a	August 13, 2006 06:00	October 13, 2006 09:00	August 23, 2006 07:00
2006ep1b			September 16, 2006 07:00
2006ep1c			October 1, 2006 07:00
2006ep1d			October 13, 2006 07:00

Note: UTC = Universal Time, Coordinated.

A detailed performance evaluation for each of the 2005 and 2006 meteorological modeling episodes is included in Appendix A: *Meteorological Modeling for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard*. In addition, all performance evaluation products are available on the TCEQ FTP site (ftp://ftp.tceq.state.tx.us/pub/OEPAA/TAD/Modeling/HGB8H2/mm5)

As mentioned, the wind speed and direction are deemed to be the most important meteorological parameters input to the air quality model. The MM5 modeled wind field was evaluated by comparing the hourly modeled and measured wind speed and direction for all monitors in the HGB area. Figure 3-8: *Meteorological Modeling Performance* exhibits the percent of hours for which the average absolute difference between the modeled and measured wind speed and direction, for all monitors in the HGB area, was within the specified accuracy benchmarks (e.g., wind speed difference less than or equal to two meters per second: WSPD $\leq$ 2 m/s).

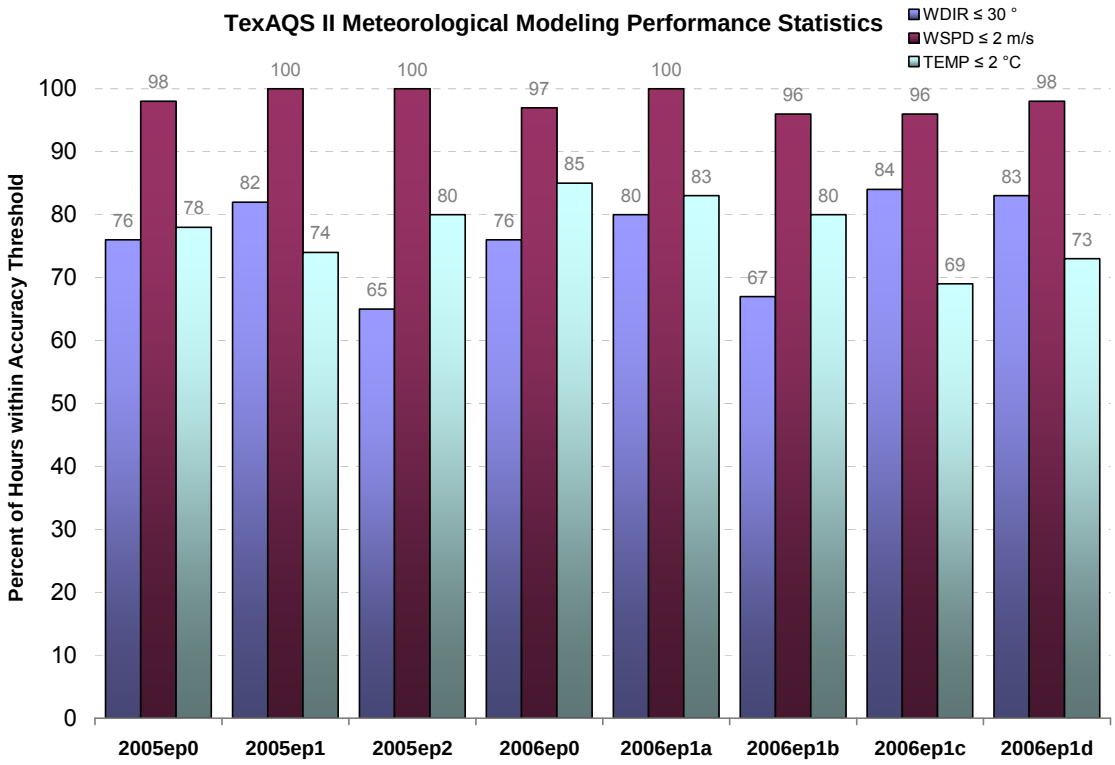


Figure 3-8: Meteorological Modeling Performance
Notes: WDIR = Wind Direction
WSPD = Wind Speed
TEMP = Temperature

Table 3-5: *Average HGB Percent Accuracy for all Meteorological Modeling Episodes* provides an additional evaluation of MM5 predictions to stricter benchmarks (Emery et al., 2001).

Table 3-5: Average HGB Percent Accuracy for all Meteorological Modeling Episodes

Episode	Wind Direction (°) Error ≤ 30 / 20 / 10	Wind Speed (m/s) Error ≤ 2 / 1 / 0.5	Temperature (°C) Error ≤ 2 / 1 / 0.5
2005ep0	76 / 67 / 49	98 / 73 / 40	78 / 49 / 30
2005ep1	82 / 71 / 40	100 / 93 / 60	74 / 50 / 28
2005ep2	65 / 54 / 33	100 / 75 / 43	80 / 57 / 31
2006ep0	76 / 63 / 45	97 / 72 / 38	85 / 57 / 33
2006ep1a	80 / 67 / 43	100 / 83 / 43	83 / 61 / 39
2006ep1b	67 / 54 / 33	96 / 63 / 26	80 / 52 / 25
2006ep1c	84 / 76 / 57	96 / 57 / 29	69 / 33 / 16
2006ep1d	83 / 66 / 33	98 / 75 / 42	73 / 51 / 32

3.4 MODELING EMISSIONS

For the stationary emission source types, which consist of point and area sources, routine emission inventories provided the major inputs for the emissions modeling processing. Emissions from mobile and biogenic sources were derived from relevant emission models. Specifically, link-based on-road mobile source emissions were derived from a travel demand model coupled with the EPA MOBILE6.2 emission factor model, and non-road mobile source emissions were derived from the EPA's National Mobile Inventory Model (NMIM), or the Texas NONROAD (TexN) mobile source models. The on- and non-road emissions were processed to air quality model-ready using version three of the Emissions Processing System (EPS3; Environ, 2007). Biogenic emissions

were derived from the Global Biosphere Emissions and Interactions System (GloBEIS) model, which outputs air quality model-ready emissions.

Appendix B: *Emissions Modeling for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard* provides details on the development and processing of the emissions using the various EPS3 modules. The modules, listed in Table 3-6: *EPS3 Emissions Processing Modules* are used to create the chemically speciated, temporally (hourly) allocated, and spatially distributed emission files needed for the air quality model.

Table 3-6: EPS3 Emissions Processing Modules

EPS3 Module	Description
PREAM	Prepare area and non-link based mobile sources emissions for further processing
LBASE	Spatially allocate link-based mobile source emissions among grid cells
PREPNT	Group point source emissions into elevated and low-level for further processing
CNTLEM	Apply controls to model strategies, apply adjustments, etc.
TMPRL	Apply temporal profiles to hourly allocate emissions
CHMSPL	Chemically speciate emissions into nitrogen oxide (NO), nitrogen dioxide (NO_2), and various CB05-VOC species
GRDEM	Spatially distribute emissions by grid cell using source category surrogates
MRGUAM	Merge and adjust multiple gridded files for model-ready input
PIGEMS	Assigns PiGs and merges elevated point source files

Notes: CB05 = the 2005 version of the Carbon Bond chemical mechanism
PiG = Plume-in-Grid

Model-ready emissions were developed for the episode days listed in Table 3-7: *2005 and 2006 Episode Days for Emissions Modeling*.

Table 3-7: 2005 and 2006 Episode Days for Emissions Modeling

2005 and 2006 Base Case Episodes		
Episode Code	Episode Designation	Episode Days
Bc05ep0	May/June 2005	May 19 through June 3, 2005
Bc05ep1	June 2005	June 17 through 30, 2005
Bc05ep2	July/August 2005	July 26 through August 8, 2005
Bc06ep0	June 2006	May 31 through June 15, 2006
Bc06aqs1	August/September 2006	August 13 through September 15, 2006
Bc06aqs2	September/October 2006	September 16 through October 11, 2006

The following sections give a brief description of the development of each type of emissions.

3.4.1 Biogenic Emissions

The TCEQ used Version 3.1 of the GloBEIS model to develop the biogenic emissions. It incorporates detailed locality-specific land-use data to generate the mix and density of vegetative species. In addition, solar radiation data from Geostationary Operational Environmental Satellite (GOES) imagery, which is used to generate the photosynthetically active solar radiation (PAR), can be input to the GloBEIS model. Further, the GloBEIS model can accept hourly temperature data generated from weather station data.

Biogenic Emissions Landuse Data,Version 3 (BELD3; Kinnee et al., 1997), a vegetation database for the entire North American continent prepared specifically for creating biogenic emissions inventories, was used for the 36 km domain and the portion of the 12 km domain outside Texas. For the land-use data in the 12 km domain within Texas, the TCEQ used the Texas vegetation

database (Wiedinmyer et al., 2001), which was derived from Texas Parks and Wildlife vegetation data and agricultural statistics from the National Agricultural Statistics Survey, and field surveys carried out in 1999. Within the 4 km nested domain, a new land-cover database from the University of Texas Center for Space Research (UT-CSR) was used (Feldman et al., 2007). This database was developed from classification of recent Landsat 7 data, Shuttle Radar Topography Mission and National Elevation datasets to identify wetlands, and United States Department of Agriculture, Common Land Unit CLU data to identify agricultural land.

The episode-specific PAR data input to GloBEIS were obtained from the website operated by the Global Energy and Water Cycle Experiment (GEWEX) Continental-Scale International Project (GCIP) and GEWEX Americas Prediction Project (GAPP) located at http://metosrv2.umd.edu/~srb/gcip/cgi-bin/historic.cgi?auth=no. The episode-specific temperature data were obtained from weather stations throughout the United States, including data from the National Weather Service, the EPA Aerometric Information Retrieval System (AIRS) air quality database, the National Buoy Data Center, the Texas A&M Crop Weather Program, the Louisiana Agricultural Information Service, and the Texas Coastal Oceanographic Observation Network.

GloBEIS3.1 was run for each of the modeling episode days listed in Table 3-7: *2005 and 2006 Episode Days for Emissions Modeling*. Figure 3-9: *An Example of Day-Specific Biogenic Emissions* shows the typical magnitude and distribution of biogenic VOC and NO_X emissions in the 4 km modeling domain.

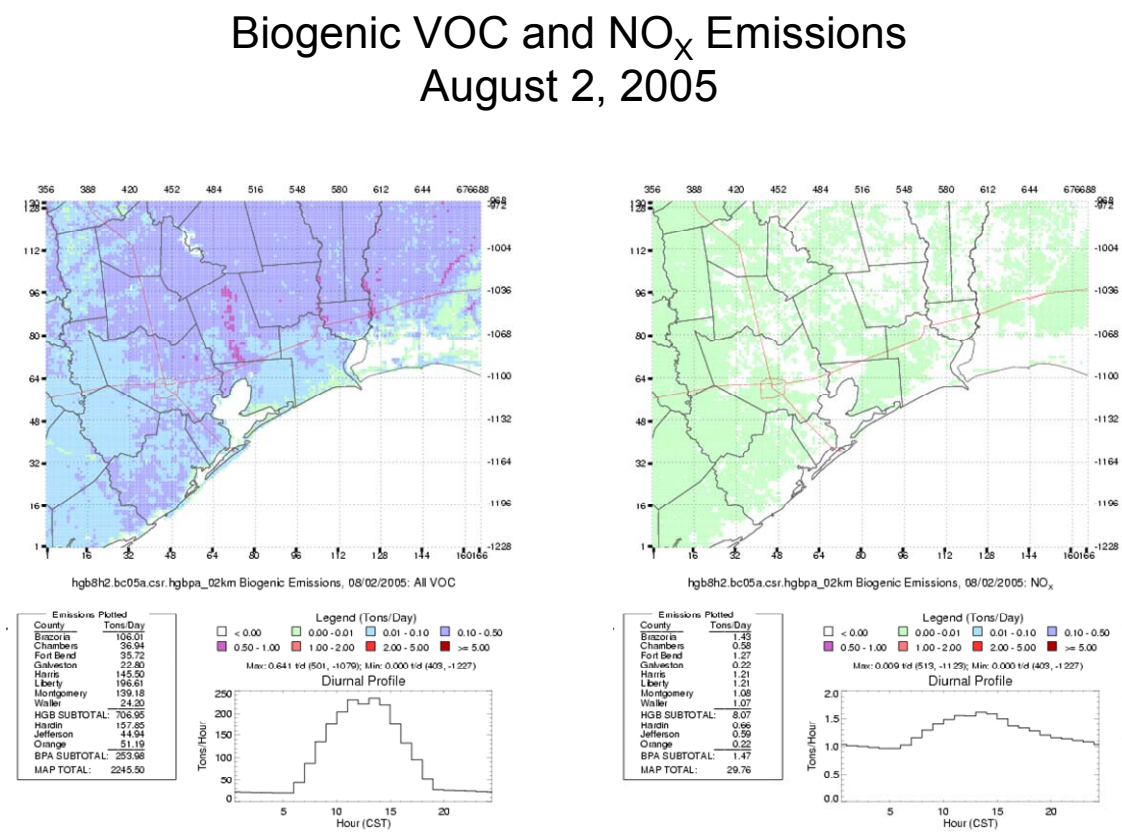


Figure 3-9: An Example of Day-Specific Biogenic Emissions

Since biogenic emissions are associated with meteorological features, the same episode day-specific emissions were used as input for the 2006 baseline and 2018 future air quality modeling.

3.4.2 Base Cases

3.4.2.1 Point Sources

Point source modeling emissions were developed using data from regional inventories such as the Central Regional Air Planning Association/Regional Planning Organization (CENRAP/RPO) emissions database and EPA's Acid Rain Database (ARD), state inventories including the State of Texas Air Reporting System (STARS), and local inventories including the TexAQS II Hourly Special Inventory (SI). Data were processed with EPS3 to generate model-ready emissions, and similar procedures were used to develop each base case episode.

Outside Texas

Point source emissions data for the regions of the modeling domains outside Texas were obtained from a number of different sources. Emissions from point sources in the Gulf of Mexico (e.g., oil and gas production platforms) were obtained from the 2005 Gulf-wide Emissions Inventory (GWEI) provided by the Minerals Management Services (MMS) as monthly totals. The Canadian emissions were obtained from EPA modeling emission files developed for the 2001 Clean Air Interstate Rule (CAIR) base case analysis (EPA, 2005) and the Mexican emissions inventory data were obtained from Phase III of the Mexican National Emissions Inventory (NEI; http://www.epa.gov/ttn/chief/net/mexico.html).

For all states beyond Texas, hourly NO_X emissions for major electric generating units (EGUs) were obtained from the ARD for each hour of each episode day. Emissions for non-ARD sources in states beyond Texas were obtained from the 2002 CENRAP/RPO emissions database, with the exception of Arkansas, Louisiana, and Oklahoma. State-specific 2005 point source annual emissions for non-ARD sources were provided by Arkansas and Oklahoma. Louisiana provided their 2004 annual point source emissions, since the 2005 annual emissions are incomplete due to Hurricane Katrina. The EPA's Economic Growth Analysis System Version 5.0 (EGAS5) was used to grow these emissions to 2005 and 2006 as appropriate for the various episodes.

Within Texas

Hourly NO_X emissions from EGUs within Texas were obtained from the ARD for each episode day. Emissions from non-ARD sources were obtained from the TCEQ 2005 and 2006 STARS emissions inventories. The 2006 TexAQS II hourly special inventory (SI) collected August 15 through September 15, 2006, was used for the August/September 2006 episode (bc06aqs1). In addition, agricultural and forest fire emissions for the 2005 and 2006 episodes were obtained from a TCEQ-funded study (Environ, 2008b), which treated fires as point sources. For the HGB area, 2005 and 2006 event-specific tank landing loss emissions were obtained from an SI revision requested by the TCEQ. Highly Reactive Volatile Organic Compounds (HRVOC) ethylene, propylene, butenes and 1,3-butadiene) emissions were reconciled with ambient measurements by comparing concentrations measured by automated gas chromatographs (auto-GCs) in the area with concentrations expected at those locations based on the reported inventory. Appendix B: *Emissions Modeling for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard* provides more details on the reconciliation of HRVOC emissions.

Table 3-8: *2005 and 2006 Base Case Episode Point Source Modeling Emissions for HGB* summarizes the typical weekday point source emissions for the eight-county HGB area by episode.

Table 3-8: 2005 and 2006 Base Case Episode Point Source Modeling Emissions for HGB

Point Source Type	Bc05ep0			Bc05ep1			Bc05ep2		
	NO_X	VOC	CO	NO_X	VOC	CO	NO_X	VOC	CO
	(tpd)			(tpd)			(tpd)		
ARD[1]	43.89	3.28	29.59	43.03	3.08	38.56	55.26	4.04	48.24
N-ARD[2]	147.52	224.87	95.51	147.52	224.87	95.51	147.52	224.87	95.51
Tank L[3]	NA	49.50	NA	NA	17.80	NA	NA	33.10	NA
Fires[4]	0.04	0.29	3.61	0.10	0.81	10.37	0.92	7.19	92.70
HRVOC[5]	NA	29.92	NA	NA	29.92	NA	NA	29.92	NA
Totals	191.45	307.86	128.71	190.65	276.48	144.44	203.70	299.12	236.45

Point Source Type	Bc06ep0			Bc06aqs1			Bc06aqs2		
	NO_X	VOC	CO	NO_X	VOC	CO	NO_X	VOC	CO
	(tpd)			(tpd)			(tpd)		
ARD[1]	46.65	2.87	39.66	40.41	2.45	29.45	48.42	2.72	36.47
N-ARD[2]	124.13	180.62	89.52	121.95	165.39	88.34	124.13	180.62	89.52
Tank L[3]	NA	17.40	NA	NA	10.40	NA	NA	0.30	NA
Fires[4]	0.04	0.27	3.46	0.13	1.05	13.47	0.04	0.30	3.72
HRVOC[5]	NA	21.17	NA	NA	21.17	NA	NA	21.17	NA
Totals	170.82	222.33	132.64	162.49	200.46	131.26	172.59	205.11	129.71

Notes:
1. ARD emissions listed are for a Wednesday in a specific episode.
2. Non-ARD emissions listed are for OSD weekday, OSD weekend days are slightly less.
3. Tank landing emissions listed are episode-specific average for days with non-zero emissions.
4. Agriculture and forest fire emissions listed are episode-specific average for days with non-zero emissions.
5. HRVOC reconciled emissions listed are the amounts added through the emissions reconciliation procedure to those reported.

3.4.2.2 On-Road Mobile Sources

On-road mobile source modeling emissions were developed using the EPA's NMIM, and Highway Performance Monitoring System (HPMS) data and travel demand modeling (TDM) output coupled with the EPA MOBILE6.2 emissions model. The output from these emission modeling applications were processed through EPS3 to generate the air quality model-ready on-road mobile source emission files.

Outside Texas

For all of the states beyond Texas, the TCEQ used NMIM to generate average summer weekday mobile source emissions by county for 2005 and 2006. Average summer Friday, Saturday, and Sunday mobile source emissions were estimated using the weekday to Friday, Saturday, and Sunday ratios developed for the on-road mobile source emissions within Texas.

Within Texas

For the Texas counties outside of HGB and Beaumont-Port Arthur (BPA: Jefferson, Hardin, and Orange Counties) areas, on-road emissions were developed by the Texas Transportation Institute (TTI) using HPMS data for 2005 and 2006, and the EPA's MOBILE6.2 on-road mobile source emissions model to generate average summer emissions for the four day types of weekday (Monday through Thursday average), Friday, Saturday, and Sunday.

For the eight-county HGB and three-county BPA areas, link-based on-road emission were developed by TTI using the TDM output for 2005 and 2006, and the EPA MOBILE6.2 on-road mobile source emissions model to generate average summer and school season on-road emission

for the four day types. For the 2005 and 2006 base case episodes, both the school and summer season day type emissions were used as appropriate.

Table 3-9: *Summary of the Development of On-Road Mobile Sources Emissions* summarizes features of the on-road mobile emissions in the different regions of the modeling domain.

Table 3-9: Summary of the Development of On-Road Mobile Sources Emissions

On-Road Inventory Development Parameter	HGB and BPA	Non- HGB and BPA	Non-Texas States/Counties
VMT Source and Resolution	TDM Roadway Links	HPMS Data Sets -19 Roadways	NMIM Database - 12 Roadways
Season Types	School and Summer	Summer Only	Summer Only
Day Types	Weekday, Friday, Saturday, and Sunday	Weekday, Friday, Saturday, and Sunday	Weekday, Friday, Saturday, and Sunday
Hourly VMT Mix By Day Type	Yes	Yes	No
Roadway Speed Distribution	Varies by Hour and Link	Varies by Hour and Roadway Type	MOBILE6.2 Default
MOBILE6.2 Classes	28	28	12
Temperature/Humidity Diesel NO_X Correction	Yes	Yes	No
"18-Wheeler" Idling Emissions Separation	Yes	No	No

Note: VMT= Vehicle Miles Traveled

Table 3-10: *2005 and 2006 Base Case Episode On-Road Modeling Emissions for HGB* summarizes the on-road mobile source emissions for each of the 2005 and 2006 base case episodes for the eight-county HGB area.

Table 3-10: 2005 and 2006 Base Case Episode On-Road Modeling Emissions for HGB

On-Road Day Type	Bc05ep0			Bc05ep1			Bc05ep2		
	NO_X	VOC	CO	NO_X	VOC	CO	NO_X	VOC	CO
	(tpd)			(tpd)			(tpd)		
Weekday	233.35	110.29	1307.35	221.67	104.27	1244.93	221.67	104.27	1244.93
Friday	241.06	123.43	1457.80	223.68	113.73	1359.36	223.68	113.73	1359.36
Saturday	192.67	85.51	1099.39	180.72	80.09	1032.63	180.72	80.09	1032.63
Sunday	148.68	70.51	906.86	143.17	67.81	873.70	143.17	67.81	873.70

On-Road Day Type	Bc06ep0			Bc06aqs1			Bc06aqs2		
	NO_X	VOC	CO	NO_X	VOC	CO	NO_X	VOC	CO
	(tpd)			(tpd)			(tpd)		
Weekday	197.28	99.39	1115.23	207.64	105.15	1171.27	207.64	105.15	1171.27
Friday	199.92	108.40	1217.36	215.43	117.70	1305.77	215.43	117.70	1305.77
Saturday	160.76	76.06	920.59	171.37	81.21	980.17	171.37	81.21	980.17
Sunday	127.68	64.42	778.75	132.59	66.99	808.41	132.59	66.99	808.41

Notes: 1. Episodes bc05ep0, bc06aqs1 and bc06aqs2 use school season emissions; episodes bc05ep1, bc05ep2 and bc06ep0 use summer season emissions.
2. VOC is reported as sum of CB05 species.

3.4.2.3 Non- and Off-Road Mobile Sources

Non/Off-road mobile source modeling emissions were developed using the EPA NMIM, the EPA NEI, TexN, and data from the TCEQ's Texas Air Emissions Repository (TexAER). The output from these emission modeling applications and databases were processed through EPS3 to generate the air quality model-ready non- and off-road mobile source emission files.

Outside Texas

For all the states beyond Texas, the TCEQ used the EPA's NMIM. NMIM generates average summer weekday non-road mobile source category emissions by county and was run for 2005 and 2006. For the off-road mobile source categories (aircraft, locomotive, and marine) in the non-Texas states, the TCEQ used the EPA's 2002 NEI with EGAS5 growth factors and national controls for locomotives and marine vessels to generate 2005 and 2006 average summer weekday off-road mobile source category emissions. Summer weekend day emissions for the non- and off-road mobile source categories were developed as part of the EPS3 processing using category specific weekly activity profiles.

Within Texas

The TCEQ used the TexN model to generate average summer weekday non-road mobile source category emissions by county for 2005 and 2006. County-level off-road emissions for 2005 were obtained from the TCEQ's 2005 TexAER, and the 2006 county-level off-road emissions were estimated by adjusting the 2005 TexAER emissions with the Texas-specific Regional Economic Models, Inc. (REMI)-EGAS growth factors, except for the aircraft/airport emissions in the HGB and DFW areas. The 2005 and 2006 aircraft/airport emissions in the HGB and DFW areas were provided through a stakeholder process and these emissions are airport-specific rather than county-level. Summer weekend day emissions for the non- and off-road mobile source categories were developed as part of the EPS3 processing using category specific weekly activity profiles.

Table 3-11: *2005 and 2006 Base Case Episode Non- and Off-Road Modeling Emissions for HGB* summarizes the non- and off-road mobile source weekday emissions for each of the 2005 and 2006 base case episodes for the eight-county HGB area. Since these are average summer weekdays, the 2005 emissions are used for each of the 2005 base case episodes and the 2006 emissions are used for each of the 2006 base case episodes.

Table 3-11: 2005 and 2006 Base Case Episode Non- and Off-Road Modeling Emissions for HGB

Non-Road Type	Bc05ep0			Bc05ep1			Bc05ep2		
	NO_X	VOC	CO	NO_X	VOC	CO	NO_X	VOC	CO
	(tpd)			(tpd)			(tpd)		
Non-Road	84.97	81.01	805.50	84.97	81.01	805.50	84.97	81.01	805.50
Airports	9.53	2.72	38.22	9.53	2.72	38.22	9.53	2.72	38.22
Locomotive	30.34	2.48	8.52	30.34	2.48	8.52	30.34	2.48	8.52
Marine	34.47	0.79	6.30	34.47	0.79	6.30	34.47	0.79	6.30
Totals	159.31	87.00	858.54	159.31	87.00	858.54	159.31	87.00	858.54

Non-Road Type	Bc06ep0			Bc06aqs1			Bc06aqs2		
	NO_X	VOC	CO	NO_X	VOC	CO	NO_X	VOC	CO
	(tpd)			(tpd)			(tpd)		
Non-Road	78.85	75.97	772.94	78.85	75.97	772.94	78.85	75.97	772.94
Airports	9.89	2.80	38.07	9.89	2.80	38.07	9.89	2.80	38.07
Locomotive	28.56	2.45	8.77	28.56	2.45	8.77	28.56	2.45	8.77
Marine	35.10	0.80	6.41	35.10	0.80	6.41	35.10	0.80	6.41
Totals	152.40	82.02	826.19	152.40	82.02	826.19	152.40	82.02	826.19

Note: VOC is reported as sum of CB05 species

3.4.2.4 Area Sources

Area source modeling emissions were developed using the EPA NEI and the TCEQ TexAER. The emissions information in these databases was processed through EPS3 to generate the air quality model-ready area source emission files.

Outside Texas

For all the states beyond Texas, the TCEQ used the EPA's 2002 NEI with EGAS5 growth factors to generate 2005 and 2006 daily area source emissions.

Within Texas

The TCEQ used 2005 TexAER to generate 2005 daily area source emissions and for the 2006 daily area source emissions, applied the Texas-specific REMI-EGAS growth factors.

Since these are daily emissions, the 2005 emissions are used for each of the 2005 base case episodes and the 2006 emissions are used for each of the 2006 base case episodes.

3.4.2.5 Base Case Summary

Table 3-12: *2005 and 2006 Base Case Episode Anthropogenic Modeling Emissions for HGB* summarizes the typical weekday emissions in the eight-county HGB area by source type for each base case episode.

Table 3-12: 2005 and 2006 Base Case Episode Anthropogenic Modeling Emissions for HGB

Source Type	Bc05ep0			Bc05ep1			Bc05ep2		
	NO_X	VOC	CO	NO_X	VOC	CO	NO_X	VOC	CO
	(tpd)			(tpd)			(tpd)		
Point[1]	191.45	307.86	128.71	190.65	276.48	144.44	203.70	299.12	236.45
On-Road[2]	233.35	110.29	1307.35	221.67	104.27	1244.37	221.67	104.27	1244.37
Non –Road[3]	84.97	81.01	805.50	84.97	81.01	805.50	84.97	81.01	805.50
Off-Road[3, 4]	74.35	5.99	53.04	74.35	5.99	53.04	74.35	5.99	53.04
Area[3]	36.18	524.35	131.71	36.18	524.35	131.71	36.18	524.35	131.71
Totals	620.30	1029.50	2426.31	607.82	992.10	2379.06	620.87	1014.74	2471.07

Source Type	Bc06ep0			Bc06aqs1			Bc06aqs2		
	NO_X	VOC	CO	NO_X	VOC	CO	NO_X	VOC	CO
	(tpd)			(tpd)			(tpd)		
Point[1]	170.82	222.33	132.64	162.49	200.46	131.26	172.59	205.11	129.71
On-Road[2]	197.28	99.39	1115.23	207.64	105.15	1171.27	207.64	105.15	1171.27
Non –Road[3]	78.85	75.97	772.94	78.85	75.97	772.94	78.85	75.97	772.94
Off-Road[3, 4]	73.55	6.05	53.25	73.55	6.05	53.25	73.55	6.05	53.25
Area[3]	36.35	528.99	134.59	36.35	528.99	134.59	36.35	528.99	134.59
Totals	556.85	932.73	2208.65	558.88	916.62	2263.31	568.98	921.27	2261.76

Notes:
1. Point source emissions are based on non-startup Wednesday ARD emissions and average non-zero tank landing emissions
2. On-road emissions are season- (school or summer) and year-specific emissions
3. Non-road, off-road and area emissions are year-specific OSD emissions
4. Off-road emissions consist of airport, locomotive, and marine emissions
5. VOC is reported as sum of CB05 species

3.4.3 2006 Baseline

In general, the baseline modeling emissions are based on typical ozone season emissions, whereas the base case modeling emissions are episode day-specific. The biogenic emissions are an exception in that the same episode day-specific emissions are used in the 2006 baseline and base cases. In addition, the 2006 baseline non- and off-road and area source modeling emissions are the same as used for the 2006 base case episodes, since they are based on typical ozone season emissions. No fire emissions were included in the 2006 baseline.

3.4.3.1 Point Sources

For the non-ARD point sources, the 2006 baseline emissions are the same as the modeling emissions used for the June 2006 (bc06ep0) and the bc06aqs2 episodes, with a couple of exceptions. The 2006 baseline includes the addition of annual emissions from point sources that reported upsets, emission events, and scheduled maintenance, startups, or shutdowns. When these additional annual emissions included tank landing losses, an adjustment was made to prevent double counting. The 2006 baseline also uses the pseudo stack parameters for flares as documented in an interoffice memorandum (http://www.tceq.state.tx.us/assets/public/permitting/air/Guidance/NewSourceReview/flareparameters.pdf), which better estimates the actual buoyancy flux of a flare's combustion gases. The 2006 baseline ARD sources EGUs emissions were estimated using the average of the 2006 third quarter hourly ARD emissions. The 2006 baseline tank landing emissions were estimated as the average of the tank landing emissions for those 2006 episode days with non-zero emissions. The HRVOC emissions reconciliation developed for the 2006 base cases was used for the 2006 baseline. For the Gulf of Mexico, Canada, and Mexico, the 2006 baseline uses the same emissions as the base cases.

3.4.3.2 On-Road Mobile Sources

The 2006 baseline on-road mobile source emissions are the same as used for the June 2006 (bc06ep0) base case episode. These are the summer season modeling emissions for each of the day types, weekday, Friday, Saturday, and Sunday.

3.4.4 2018 Future Base and Control Strategy

The biogenic emissions used for the 2018 future base and control strategy modeling are the same episode day-specific emissions used in the base cases. In addition, similar to the 2006 baseline, no fire emissions were included in the 2018 future base and control strategy modeling. Appendix B: *Emissions Modeling for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard* provides extensive details of the 2018 modeling emissions development.

3.4.4.1 Point Sources

Outside Texas

The non-ARD point source emissions data in the regions outside Texas were obtained from the modeling emissions files used for the 2018 CENRAP/RPO regional haze SIP. For the Gulf, Canada, and Mexico, the 2018 emissions are the same as used in the 2006 baseline. The CAIR Phase 2 emission levels were used for the ARD point source (EGU) 2018 emissions, with an adjustment for the ozone season. The ozone season adjustment was developed using the ratio of the average of the 2006 third quarter hourly ARD emissions to the annual average ARD emissions.

Within Texas

Emissions for the non-ARD point sources were projected to 2018 using the larger of the Texas Industrial Production Index (TIPI) or Texas-specific REMI-EGAS growth factors or banked Emissions Reduction Credits (ERCs) and Discrete Emissions Reduction Credits (DERCs) in the DFW and BPA nonattainment areas. For the DFW and BPA nonattainment areas, the total existing bank registry of ERCs and DERCs was assumed to be available for 2018 (worst-case). Controls pertinent to existing HGB, DFW, and BPA SIP revisions were applied to appropriate point source categories (e.g., Mass Emissions Cap and Trade program (MECT), HRVOC Emissions Cap and Trade program (HECT), and East Texas Combustion Rule). The MECT rule allows applicable

sources to use a limited amount of DERCs to compensate for emission events that may occur in a given year that result in an annual emission above their allocation. The 2018 future base emissions for MECT-applicable sources in HGB used their MECT allocations plus 2.74 tpd (1,000 tpy) of DERCs, which is the maximum allowed in any one year for all MECT sources. The addition of the maximum possible DERCs to the MECT emissions in 2018 provides a conservative (worst-case) estimate. The 2018 future base emissions for HECT-applicable point sources in Harris County used their current HECT allocations. The 2018 control strategy includes a reallocation and a 25 percent reduction (2.7 tpd HRVOC) to the HECT cap for applicable point sources in Harris County.

Similar to the 2018 emissions for ARD sources outside Texas, the ARD sources within Texas used the CAIR Phase 2 emissions adjusted to the ozone season, with the exception of ARD sources in the eight-county HGB area, which are subject to the MECT rule. The 2018 emissions for ARD sources within the HGB area used the MECT allocations adjusted to the ozone season, similar to the adjustment for the ARD sources in the non-HGB area. Newly-permitted ARD sources were limited to the CAIR 9.5 percent set-aside for growth. The 2018 tank landing emissions and the HRVOC reconciliation were the same as the 2006 baseline. It is possible that some, but not all, of the 2006 reconciled HRVOC emissions are associated with HECT-applicable sources (e.g., flares). Since all the reconciled HRVOC emissions in Harris County were retained in the 2018 modeling, this potentially represents a double-counting of emissions.

For the eight-county HGB area, the point source NO_X emissions are reduced by about 11 percent from the 2006 baseline (172.86 tpd) to the 2018 future base (154.36 tpd) and the VOC emissions are increased about 21 percent from the 2006 baseline (241.00 tpd) to the 2018 future base (292.05 tpd). The 25 percent HECT control strategy reduces the 2018 control strategy VOC emissions to 289.39 tpd.

3.4.4.2 On-Road Mobile Sources

Outside Texas

The TCEQ used the EPA's NMIM to generate average summer weekday mobile source emissions by county for 2018 for all of the states beyond Texas. Average summer Friday, Saturday, and Sunday mobile source emissions were estimated using the weekday to Friday, Saturday, and Sunday ratios developed for the on-road mobile source emissions within Texas.

Within Texas

For the Texas counties outside of the HGB and BPA areas, summer season, day type, non-link on-road emissions were developed by TTI using 2018 projected traffic data and the EPA's MOBILE6.2. For the eight-county HGB and three-county BPA areas, link-based on-road emissions were developed by TTI using the TDM output projected for 2018, and the EPA's MOBILE6.2 on-road mobile source emissions model to generate average summer season on-road emissions for the four day types. The 2018 control strategy includes a 1.55 tpd Voluntary Mobile Emission Reduction Program (VMEP) NO_X reduction to the on-road mobile sources for alternative commuting, vehicle retrofit and replacement, and traffic flow improvement measures.

For the eight-county HGB area, the on-road mobile source NO_X emissions are reduced by about 74 percent from the 2006 baseline (197.28 tpd) to the 2018 future base (50.76 tpd) and the VOC emissions are decreased about 49 percent from the 2006 baseline (99.39 tpd) to the 2018 future base (50.39 tpd). The VMEP control strategies reduce the 2018 control strategy NO_X emissions to 49.21 tpd.

3.4.4.3 Non- and Off-Road Mobile Sources

Outside Texas

For the states outside of Texas, the TCEQ used the EPA's NMIM to generate average summer weekday non-road mobile source category emissions by county for 2018. For the off-road mobile source categories, aircraft, locomotive, and marine, in the states beyond Texas, the TCEQ used the

EPA's 2002 NEI with EGAS5 growth factors and national controls for locomotives and marine vessels to generate 2018 average summer weekday off-road mobile source category emissions. Summer weekend day emissions for the non- and off-road mobile source categories were developed as part of the EPS3 processing using category specific weekly activity profiles.

Within Texas
The TCEQ used the TexN model to generate average summer weekday non-road mobile source category emissions by county for 2018. 2018 county-level off-road emissions were estimated by adjusting the 2005 TexAER emissions with the Texas-specific REMI-EGAS growth factors, except for the aircraft/airport emissions in the HGB and DFW areas and marine vessels in HGB and BPA. The 2018 aircraft/airport emissions in the HGB and DFW areas were provided through a stakeholder process and these emissions are airport-specific rather than county-level. The 2018 emissions for marine vessels in HGB and BPA were developed using emission trends provided by the HGB and BPA Port Authorities (Starcrest, 2000). Summer weekend day emissions for the non- and off-road mobile source categories were developed as part of the EPS3 processing using category specific weekly activity profiles.

For the eight-county HGB area, the non- and off-road mobile source NO_X emissions are reduced by about 22 percent from the 2006 baseline (152.59 tpd) to the 2018 future base (119.28 tpd) and the VOC emissions are decreased about 45 percent from the 2006 baseline (67.16 tpd) to the 2018 future base (36.86 tpd). The 2018 control strategy includes 0.70 tpd VMEP NO_X reduction for non-road control measures.

3.4.4.4 Area Sources
Outside Texas
The TCEQ obtained area source emissions data used in the 2018 regional haze SIP revision that was created by the CENRAP/RPO for all the states beyond Texas.

Within Texas
The 2018 county-level area source emissions were estimated by adjusting the 2005 TexAER emissions with the Texas-specific REMI-EGAS growth factors, except for the flash emissions category. Flash emissions will be controlled in the future as a result of the Storage Vessel and Degassing rule (30 Texas Administrative Code (TAC) Chapter 115), which is expected to at least off-set growth. Therefore, no growth was applied to flash emissions and the same emissions were used for the 2018 future base and control strategy as the 2006 baseline.

For the eight-county HGB area, the area source NO_X emissions are increased by about 16 percent from the 2006 baseline (36.35 tpd) to the 2018 future base (42.04 tpd) and the VOC emissions are increased about 23 percent from the 2006 baseline (528.99 tpd) to the 2018 future base (650.09 tpd).

3.4.5 2006 and 2018 Modeling Emissions Summary for HGB

Table 3-13: *Summary of 2006 Baseline and 2018 Future Base, and 2018 Control Strategy Anthropogenic Modeling Emissions for HGB* summarizes the typical weekday anthropogenic emissions in the eight-county HGB area by source type for the 2006 and 2018 future base modeling emissions as well as the 2018 control strategy.

Table 3-13: Summary of 2006 Baseline and 2018 Future Base, and 2018 Control Strategy Anthropogenic Modeling Emissions for HGB

Source Type	2006 Baseline			2018 Baseline			2018 Control Strategy		
	NO_X	VOC	CO	NO_X	VOC	CO	NO_X	VOC	CO
	(tpd)			(tpd)			(tpd)		
Point	172.86	241.00	132.25	154.36	292.05	222.06	154.36	289.35	222.06
On-Road	197.28	99.39	1115.23	50.76	50.39	733.17	49.21	50.39	733.17
Non -Road	79.33	61.41	572.37	33.62	30.18	427.56	32.92	30.18	427.56
Off-Road	73.26	5.75	97.30	85.66	6.68	44.71	85.66	6.68	44.71
Area	36.35	528.99	134.59	42.04	650.09	158.99	42.04	650.09	158.99
Totals	559.08	936.54	2051.74	366.44	1029.39	1586.49	364.19	1026.69	1586.49

Figure 3-10: *2006 Baseline and 2018 Future Base, and 2018 Control Strategy Anthropogenic NO_X and VOC Modeling Emissions for HGB* graphically compares the anthropogenic NO_X and VOC modeling emissions for the eight-county HGB area.

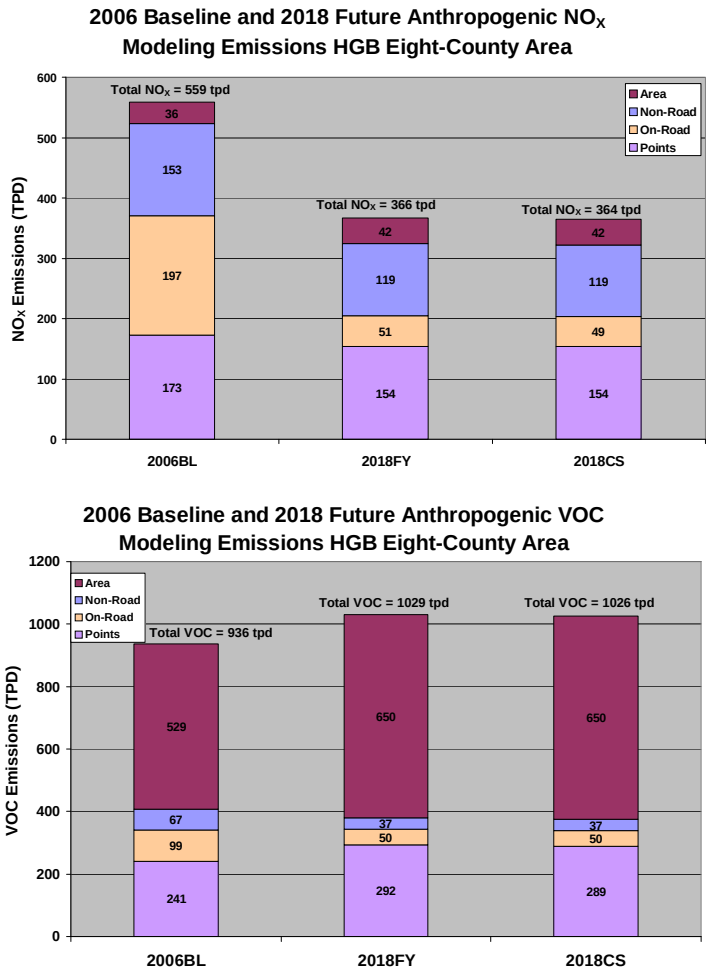


Figure 3-10: 2006 Baseline and 2018 Future Base, and 2018 Control Strategy Anthropogenic NO_X and VOC Modeling Emissions for HGB

Notes: 2006BL = 2006 Baseline
2018FY = 2018 Future Year or Future Base
2018CS = 2018 Control Strategy
In the above figures, Non-Road includes the off-road emissions

3.5 PHOTOCHEMICAL MODELING

To ensure that a modeling study can be successfully used as technical support for an attainment demonstration SIP revision, the air quality model must be scientifically sound and appropriate for the intended application and freely accessible to all stakeholders. In a regulatory environment, it is crucial that oversight groups (e.g., the EPA), the regulated community, and the interested public have access to and also be convinced of the suitability of the model. The following three prerequisites were identified for selecting the air quality model to be used in the HGB attainment demonstration:

- must have a reasonably current, peer-reviewed, scientific formulation;
- must be available at no or low cost to stakeholders; and
- must be consistent with air quality models being used for other Texas nonattainment or near nonattainment areas.

The only model to meet all three of these criteria is CAMx. The model is based on well-established treatments of advection, diffusion, deposition, and chemistry. Another important feature is that NO_X emissions from large point sources can be treated with the PiG submodel, which helps avoid the artificial diffusion that occurs when point source emissions are introduced into a grid volume. The model software and the CAMx user's guide are publicly available at http://www.camx.com (Environ, 2009). In addition, the TCEQ has many years of experience with CAMx. CAMx was used for the modeling conducted in the DFW and BPA nonattainment areas, as well as for modeling being conducted in other areas of Texas (e.g., San Antonio).

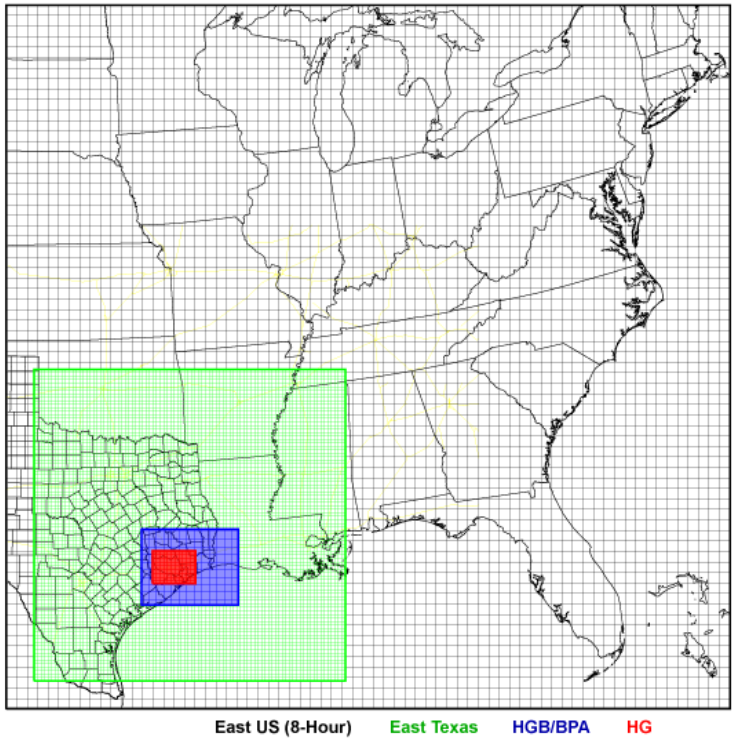
CAMx Version 4.53 was used for this modeling study. Some of the features in this version include the ability to process in parallel on multiple processors and the following probing tools for sensitivity analysis:

- Process Analysis, which provides in depth details of ozone formation, showing the various physical and chemical processes that determine the modeled ozone concentrations at specified locations and times;
- Ozone Source Apportionment Technology (OSAT), which estimates the contribution of emissions from multiple geographical areas and source categories (including biogenic emissions) to ozone formation; and
- Anthropogenic Precursor Culpability Assessment (APCA), which reallocates ozone apportioned to non-controllable biogenic emissions to the controllable portion of precursors that participated in ozone formation.

3.5.1 Modeling Domains and Horizontal Grid Cell Size

Figure 3-11: *CAMx Modeling Domains* depicts the modeling domains used in CAMx. All domains are projected in a Lambert Conformal Projection (LCP) with origin at 100 degrees west and 40 degrees north, and aligned with the grid developed by the EPA for nationwide modeling. Choosing a grid system compatible with an existing large-scale grid system serves several functions, including ability to use ready-made regional inventory data directly, ability to integrate the TCEQ's modeling into regional modeling projects, and promoting consistency among various regional and urban modeling applications in the central United States.

The horizontal configuration of the CAMx modeling domains consist of a grid of 2 km x 2 km cells (2 km) encompassing a major portion of the HGB nonattainment counties (red box), nested within a grid of 4 km x 4 km cells (4 km) encompassing both the HGB and BPA counties (blue box), nested within a grid of 12 km x 12 km cells (12 km) covering the eastern part of Texas (green box), nested within the outer (black box) grid of 36 km x 36 km cells (36km). The size of the 36 km outer domain was selected to minimize the effect of boundary conditions on predicted ozone concentrations at the finer grid resolutions (e.g., 2 km).



Domain Name	Grid Cell Size	Dimensions (grid cells)	Southwest corner	Northeast corner
East US (8-Hour)	36 × 36 km	69 × 67	(-108, -1584)	(2376, 828)
East Texas	12 × 12 km	89 × 89	(-12, -1488)	(1056, -420)
HGB/BPA	4 × 4 km	83 × 65	(356, -1228)	(688, -968)
HG	2 × 2 km	74 × 56	(394, -1154)	(542,-1042)

Figure 3-11: CAMx Modeling Domains

The finer Houston-Galveston 2 km subdomain within the 4 km HGB-BPA domain better replicates the emission gradients in the narrow industrial plumes emanating from the Ship Channel and surrounding areas.

3.5.2 Vertical Layer Structure

The vertical configuration of the CAMx modeling domains consists of 28 layers of varying depth used with the 2 km and 4 km domains, and 17 layers of varying depth used with the 12 km and 36 km horizontal domains. The unique meteorology induced by the land/sea/bay effects and the diverse mixture of industrial source types, which release pollutants across a wide range of elevations, require more vertical layers, particularly below the PBL, in the fine-grid domains. Table 3-14: *CAMx Vertical Layer Structure for 2 km and 4 km Fine Grids* and Table 3-15: *CAMx Vertical Layer Structure for Intermediate and Coarse Grids* show the vertical structuring of the 28-layered and 17-layered configurations, respectively.

Table 3-14: CAMx Vertical Layer Structure for 2 km and 4 km Fine Grids

CAMx Layer	MM5 Layer	Top (m AGL[1])	Center (m AGL[1])	Thickness (m)
28	38	15179.1	13637.9	3082.5
27	36	12096.6	10631.6	2930.0
26	32	9166.6	8063.8	2205.7
25	29	6960.9	6398.4	1125.0
24	27	5835.9	5367	937
23	25	4898	4502.2	791.6
22	23	4106.4	3739.9	733
21	21	3373.5	3199.9	347.2
20	20	3026.3	2858.3	335.9
19	19	2690.4	2528.3	324.3
18	18	2366.1	2234.7	262.8
17	17	2103.3	1975.2	256.2
16	16	1847.2	1722.2	256.3
15	15	1597.3	1475.3	249.9
14	14	1353.4	1281.6	243.9
13	13	1209.8	1139	143.6
12	12	1068.2	998.3	141.6
11	11	928.5	859.5	137.8
10	10	790.6	745.2	90.9
9	9	699.7	654.7	90.1
8	8	609.5	564.9	89.3
7	7	520.2	476.0	88.5
6	6	431.7	387.8	87.8
5	5	343.9	300.4	87.0
4	4	256.9	213.7	86.3
3	3	170.5	127.7	85.6
2	2	84.9	59.4	51.0
1	1	33.9	16.9	33.9

Note: 1. AGL - Above ground level.

Table 3-15: CAMx Vertical Layer Structure for Intermediate and Coarse Grids

CAMx Layer	MM5 Layer	Top (m AGL)	Center (m AGL)	Thickness (m)
17	38	15179.1	12172.9	6012.5
16	32	9166.6	7501.3	3330.7
15	27	5835.9	4970.9	1730
14	23	4105.9	3565.9	1080
13	20	3025.9	2564.5	922.9
12	17	2103	1728.1	749.8
11	14	1353.2	1210.6	285.2
10	12	1068.2	929.3	277.5
9	10	790.6	700.0	181.0
8	8	609.5	564.9	89.3
7	7	520.2	476.0	88.5
6	6	431.7	387.8	87.8
5	5	343.9	300.4	87.0
4	4	256.9	213.7	86.3
3	3	170.5	127.7	85.6
2	2	84.9	59.4	51.0
1	1	33.9	16.9	33.9

3.5.3 Model Configuration

The TCEQ used CAMx version 4.53, which includes a number of upgrades and features from previous versions. The following CAMx 4.53 options were employed:

- Parallel processing of the chemistry and transport algorithms;
- CB05 chemical mechanism with Euler Backward Iterative (EBI) chemistry solver;
- Piecewise Parabolic Method (PPM) advection solver;
- Flexi-nesting to interpolate the 4 km meteorological parameters to the 2 km CAMx domain; and
- PiG treatment of larger point sources of NO_X using the Greatly Reduced Execution and Simplified Dynamics (GREASD) Lagrangian module.

In addition to the CAMx inputs developed from the meteorological and emissions modeling, inputs are needed for initial and boundary conditions, spatially resolved surface characteristic parameters, spatially resolved albedo/haze/ozone (i.e., opacity) and photolysis rates, and a chemistry parameters file.

The TCEQ contracted with Environ (Environ, 2008b) who worked with National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL) to derive episode-specific boundary conditions from the Model for Ozone and Related Chemical Tracers (MOZART) global air quality model. Boundary conditions were developed for each grid cell along all four edges of the 36 km domain (number of horizontal grid cells [69 or 67 for east-west or north-south edges, respectively] times the number of vertical layers [17]) for each episode hour. This work also produced initial conditions for each of the episodes. The TCEQ used these episode-specific initial and boundary conditions for this modeling study. The top-boundary conditions were set at the clean concentration levels as previously derived by Environ and used in the recently approved DFW Ozone Attainment Demonstration SIP revision (TCEQ, 2007).

Surface characteristic parameters, including roughness, vegetative distribution, and water/land boundaries, are input to CAMx via a land-use file. The land-use file provides the fractional contribution (0 to 1) of eleven land-use categories, as defined by the United States Geological Survey (USGS) LULC database. For the 36 km and 12 km domains, the TCEQ used the land-use files developed by Environ for the DFW SIP revision approved by the EPA in 2009, which were

derived from the most recent USGS LULC database. For the 2 km domain and portions of the 4 km domain, in the vicinity of HGB, the TCEQ used updated land-use files developed by Texas A&M University (Popescu et al., 2008), which were derived from more highly resolved LULC data collected by the Texas Forest Service and the UT-CSR.

The spatially-resolved opacity and photolysis rates are input to CAMx via a photolysis rates file and an opacity file, which are specific to the chemistry parameters file for the CB05 mechanism, which is also input to CAMx. The TCEQ used episode-specific satellite data from the Total Ozone Mapping Spectrometer (TOMS) to prepare the photolysis rates and opacity files.

3.5.4 Model Performance Evaluation

The CAMx model configuration was applied to the 2005 and 2006 base cases using the episode-specific meteorological parameters and emissions. The CAMx modeling results were compared to the measured ozone and ozone precursor concentrations, which resulted in a number of modeling iterations involving improvements to the meteorological and emissions modeling and subsequent CAMx modeling. A detailed performance evaluation for each of the 2005 and 2006 base case modeling episodes is included in Appendix C: *Photochemical Modeling for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard*. In addition, all performance evaluation products are available on the TCEQ Web site, http://www.tceq.state.tx.us/implementation/air/airmod/data/hgb8h2/hgb8h2.html.

3.5.4.1 Performance Evaluations Overview

The performance evaluation of the base case modeling demonstrates the adequacy of the model to correctly replicate the relationship between levels of ozone and the emissions of NO_X and VOC. The model's ability to suitably replicate this relationship is necessary to have confidence in the model's prediction of the response of ozone to various control measures. As recommended in the EPA modeling guidance, the TCEQ conducted two types of performance evaluations, operational and diagnostic.

3.5.4.2 Operational Evaluations

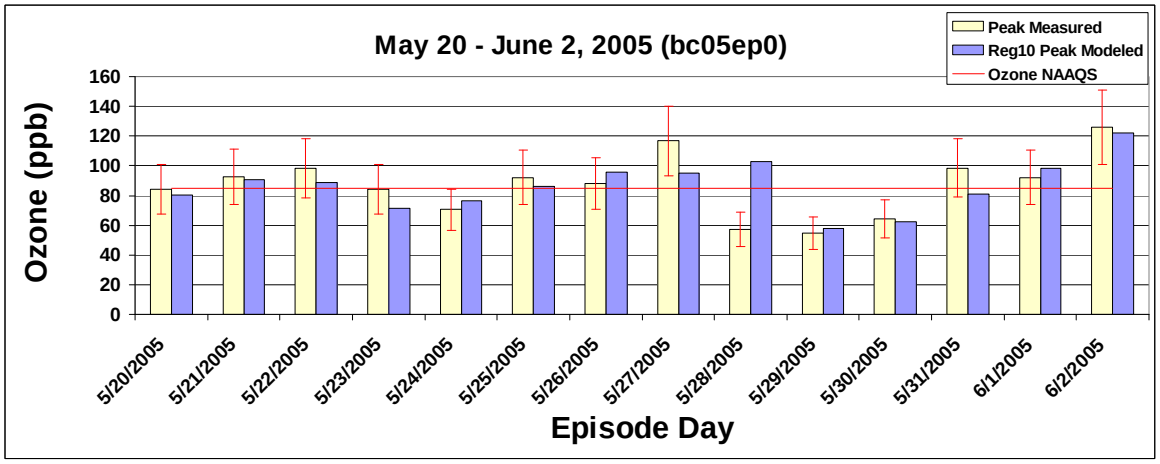
Statistical measures including the Unpaired Peak Accuracy (UPA), the Mean Normalized Bias (MNB), and the Mean Normalized Gross Error (MNGE) were calculated by comparing monitored (measured) and 4-cell bi-linearly interpolated modeled ozone concentrations for all episode days and monitors. Graphical measures including time series and scatter plots of hourly measured and bi-linearly interpolated modeled ozone and where applicable, some ozone precursors (e.g., nitric oxide (NO), nitrogen dioxide (NO_2), ethylene (ETH), and isoprene (ISOP) concentrations were developed for each regulatory monitor. In addition, tile plots of modeled daily maximum eight-hour ozone concentrations were developed and overlaid with the measured daily maximum eight-hour ozone concentrations. Detailed operational evaluations for each of the 2005 and 2006 base case modeling episodes are included in Appendix C: *Photochemical Modeling for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard*.

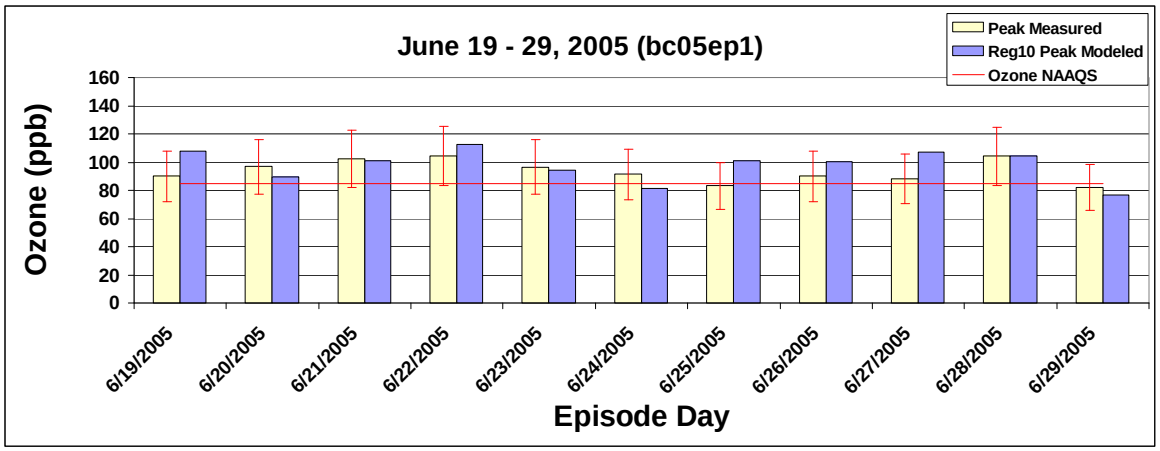
Statistical Evaluations

The statistical evaluations presented focus on the comparison of the measured and modeled eight-hour ozone concentrations. Figure 3-12.a: *Peak Eight-Hour Ozone Concentration, Measured versus Modeled for the 2005 Episode Days* and Figure 3-12.b: *Peak Eight-Hour Ozone Concentration, Measured versus Modeled for the 2006 Episode Days* compare the measured and modeled daily maximum eight-hour ozone concentrations for each episode day of the 2005 and 2006 base cases, respectively. Figure 3-13.a: *Mean Normalized Gross Error (MNGE) and Bias (MNB) for 2005 Episode Days* and Figure 3-13.b: *Mean Normalized Gross Error (MNGE) and Bias (MNB) for 2006 Episode Days* show the MNGE and MNB for monitored eight-hour ozone concentrations greater than 40 ppb for each episode day of the 2005 and 2006 base cases, respectively. Although there are no recommended criteria for the eight-hour UPA, MNGE, and

MNB, the one-hour levels recommended by the EPA (i.e., plus or minus 20 percent, 30 percent, and plus or minus 15 percent, respectively) were used for statistical evaluations.

The error bars on the daily peak measured eight-hour ozone concentrations, in Figures 3-12.a: *Peak Eight-Hour Ozone Concentration, Measured versus Modeled for the 2005 Episode Days* and 3-12.b: *Peak Eight-Hour Ozone Concentration, Measured versus Modeled for the 2006 Episode Days* represent the plus or minus 20 percent UPA range for comparison with the daily maximum modeled eight-hour ozone concentrations. For the 37 episode days in the 2005 base cases, only seven days have daily maximum modeled eight-hour ozone concentrations greater than 20 percent of the daily maximum measured eight-hour ozone concentrations. For the 50 episode days in the 2006 base cases only ten days have daily maximum modeled eight-hour ozone concentrations outside the plus or minus 20 percent UPA range.





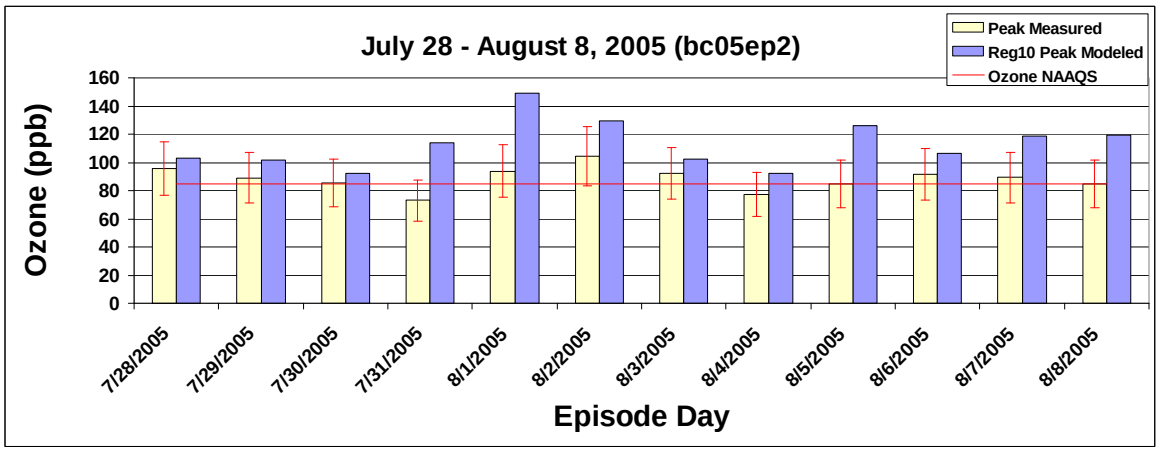
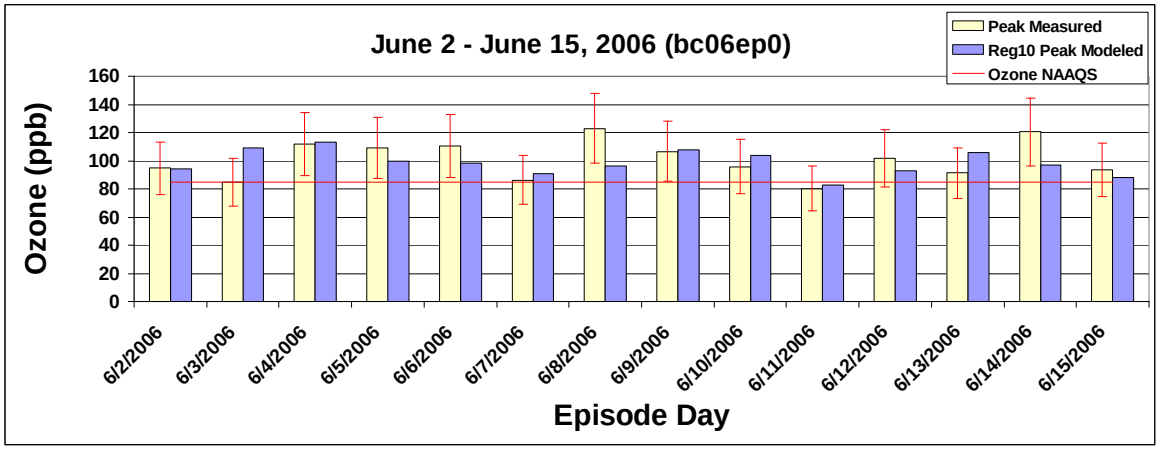
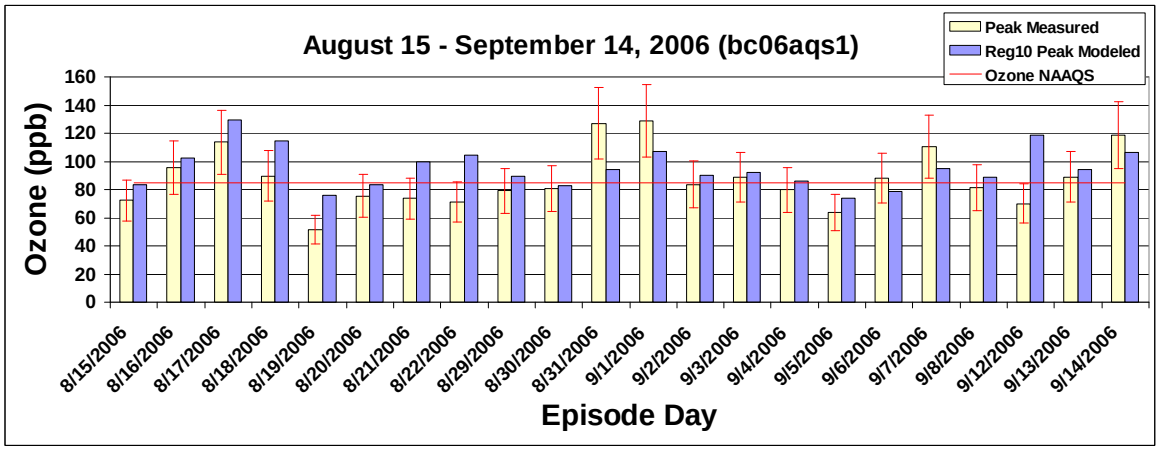


Figure 3-12.a: Peak Eight-Hour Ozone Concentration, Measured versus Modeled for the 2005 Episode Days





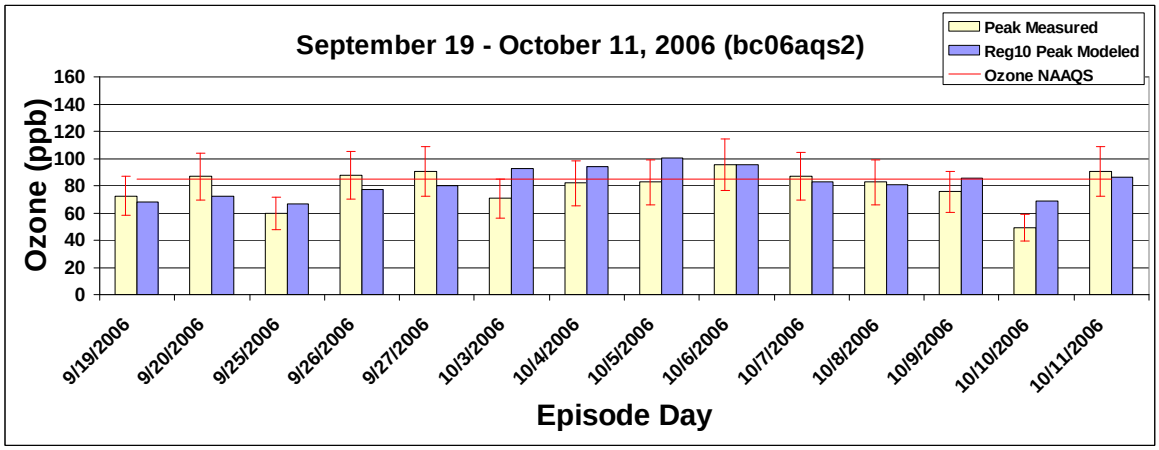


Figure 3-12.b: Peak Eight-Hour Ozone Concentration, Measured versus Modeled for the 2006 Episode Days

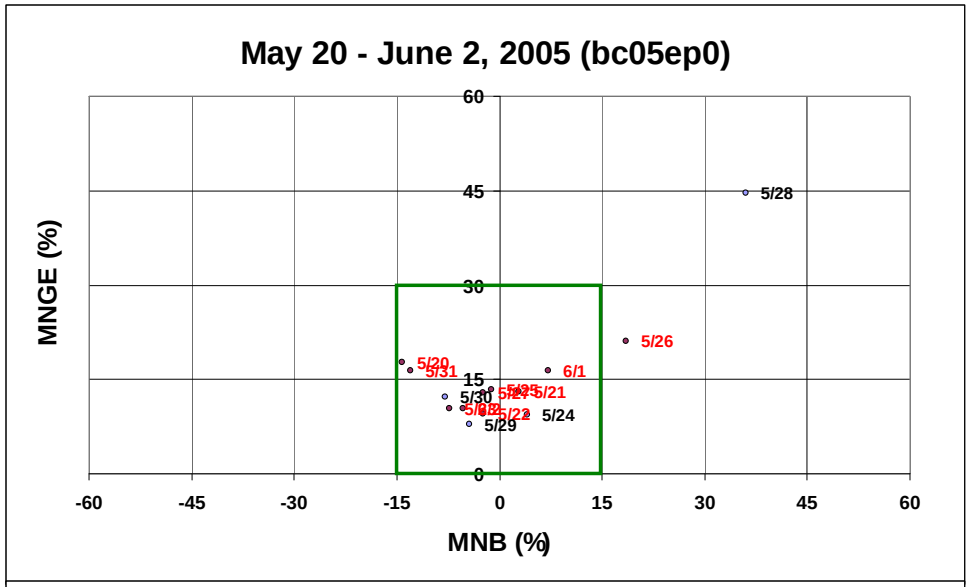
Taking into consideration that only 17 days out of the 87 days modeled in the 2005 and 2006 base case episodes have daily maximum modeled eight-hour ozone concentrations outside the plus or minus 20 percent UPA range, the model suitably predicts the daily maximum eight-hour ozone concentrations.

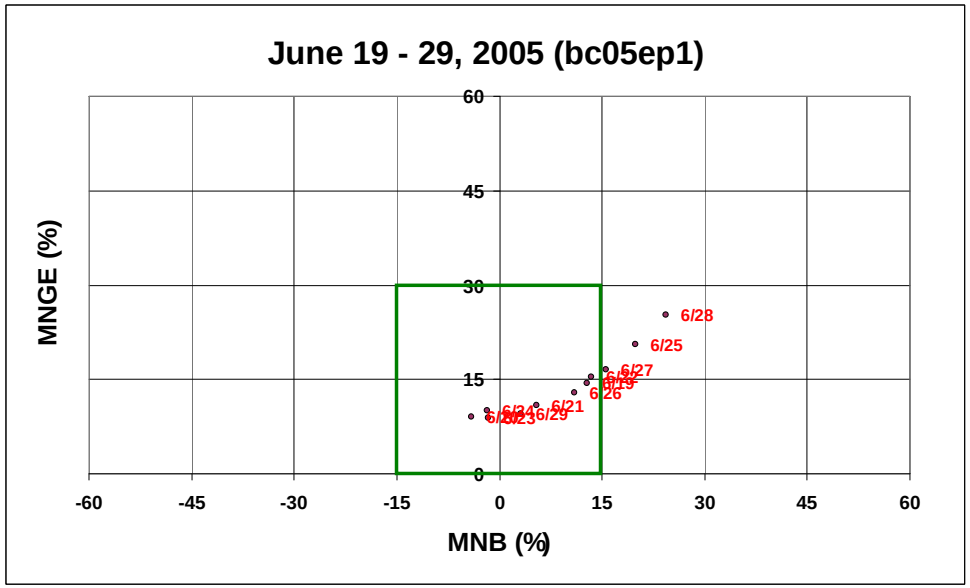
The area depicted in Figures 3-13.a: *Mean Normalized Gross Error (MNGE) and Bias (MNB) for 2005 Episode Days* and 3-13.b: *Mean Normalized Gross Error (MNGE) and Bias (MNB) for 2006 Episode Days* with MNGE $\leq$ 30 percent and minus 15 percent $\leq$ MNB $\leq$ plus 15 percent represents the joint condition for which both the MNGE and MNB are within acceptable ranges. The episode days labeled in red indicate those days for which daily peak measured eight-hour ozone concentrations were greater than or equal to 80 ppb.

For the 31 days of the 2005 base case episodes with daily maximum measured eight-hour ozone concentrations greater than or equal to 80 ppb 19 days meet the joint condition of having both the MNGE $\leq$ 30 percent and minus 15 percent $\leq$ MNB $\leq$ plus 15 percent. The average daily maximum monitored ozone for those 31 days was 93.9 ppb, and the corresponding average daily maximum modeled ozone concentration was 101.1 ppb. The average mean normalized bias and mean normalized gross error were 11.4 and 19.0 percent, respectively.

For the 36 days of the 2006 base case episodes with daily maximum measured eight-hour ozone concentrations greater than or equal to 80 ppb, 24 days meet the joint condition of having both the MNGE $\leq$ 30 percent and minus 15 percent $\leq$ MNB $\leq$ plus 15 percent. The average daily maximum monitored ozone for those 36 days was 96.9 ppb, and the corresponding average daily maximum modeled ozone concentration was 95.1 ppb. The average mean normalized bias and normalized gross error were 8.8 and 16.9 percent, respectively.

Taking into consideration that 43 days out of the 67 episode days in the 2005 and 2006 base cases with daily maximum measured eight-hour ozone concentration greater than or equal to 80 ppb meet the joint condition of having both the MNGE $\leq$ 30 percent and minus 15 percent $\leq$ MNB $\leq$ plus 15 percent, the model suitably simulates the frequency and magnitude of daily maximum eight-hour ozone concentrations at the various monitors.





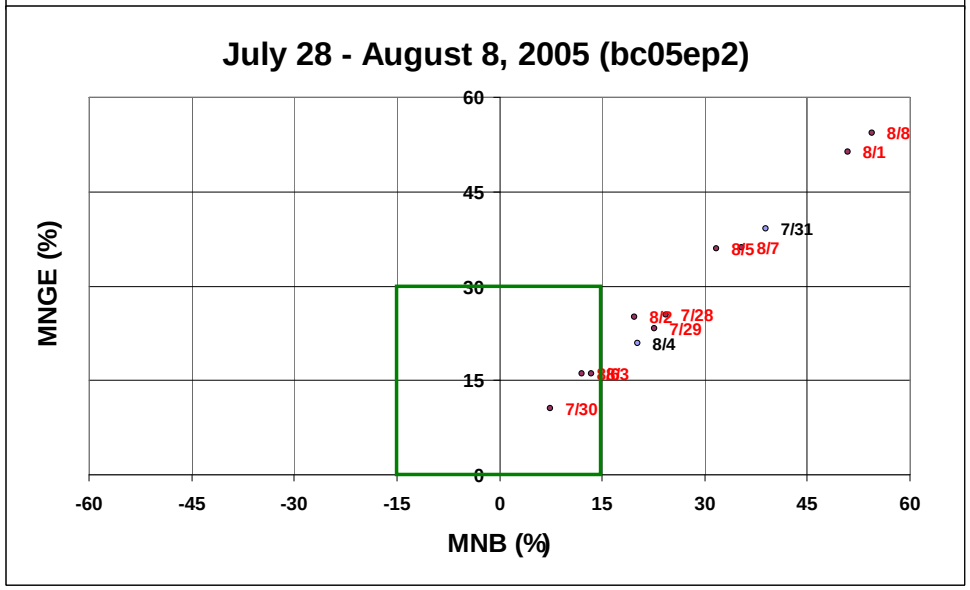
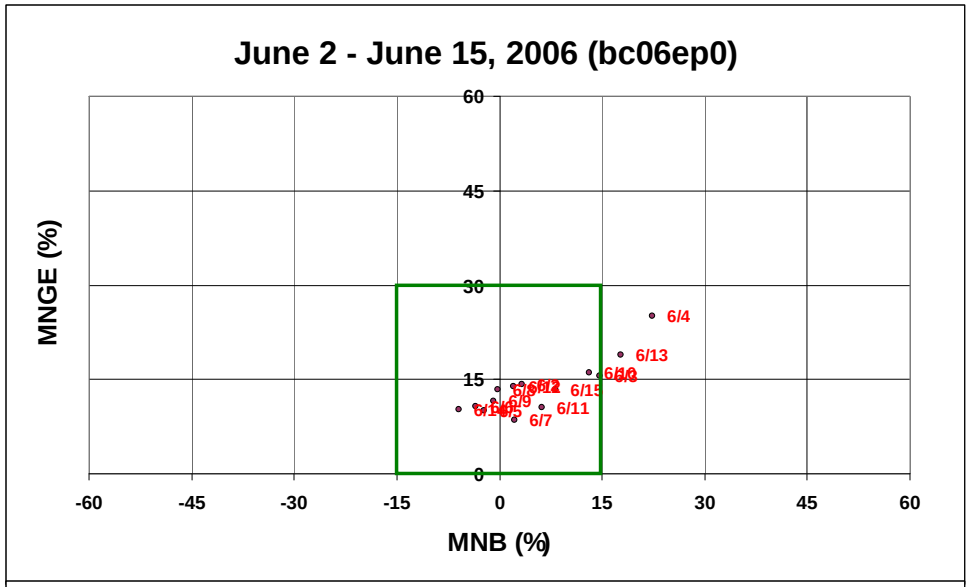
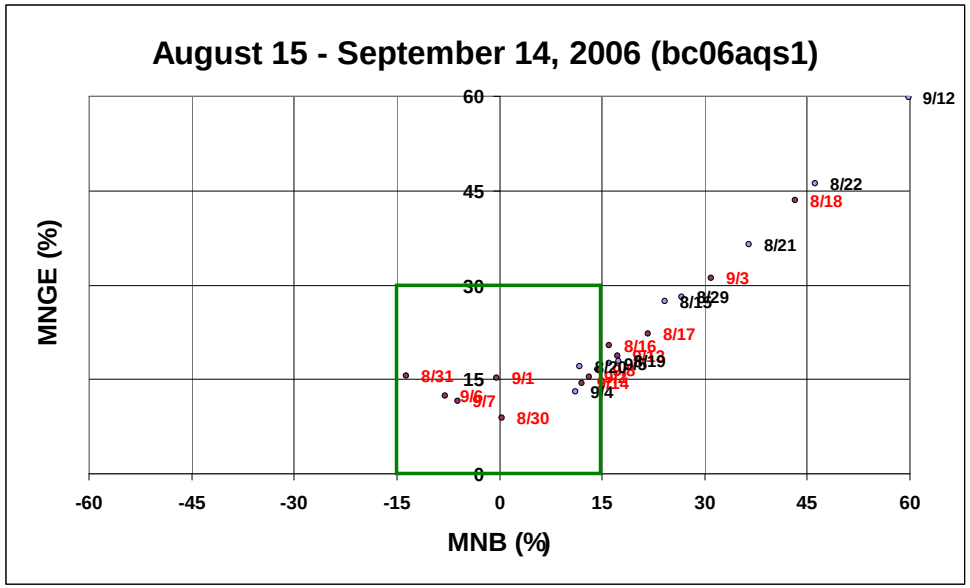


Figure 3-13.a: Mean Normalized Gross Error (MNGE) and Bias (MNB) for 2005 Episode Days





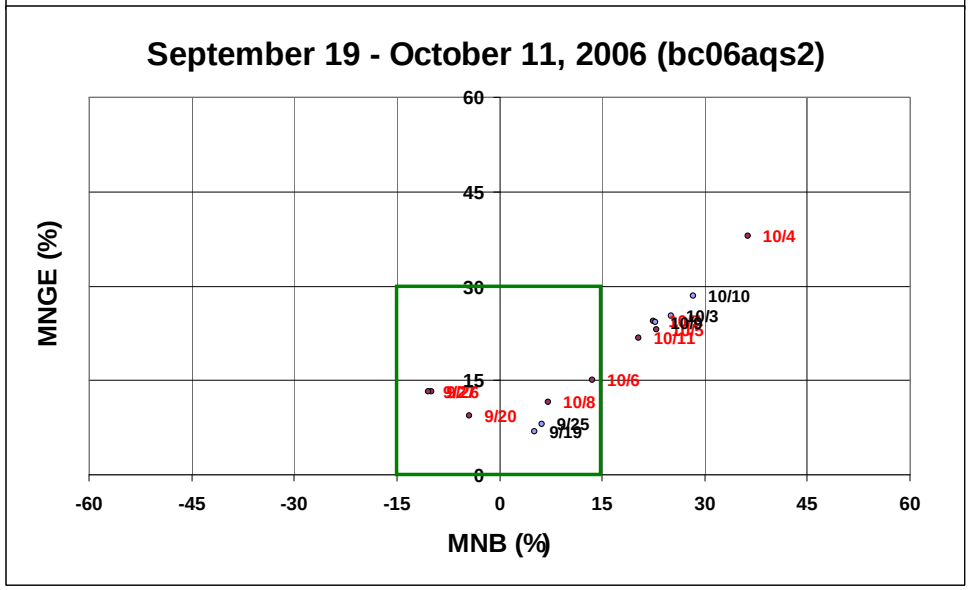
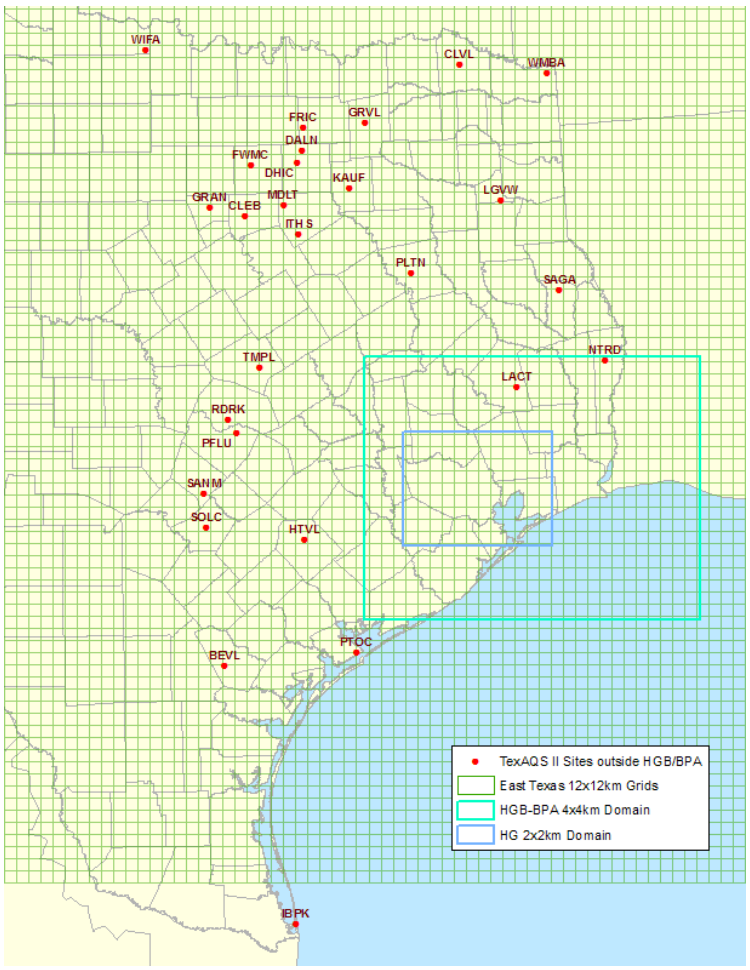


Figure 3-13.b: Mean Normalized Gross Error (MNGE) and Bias (MNB) for 2006 Episode Days

Graphical Evaluations

A detailed graphical evaluation of modeling results is presented in Appendix C: *Photochemical Modeling for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard*. A selection of graphical evaluations, organized by episode modeled, is presented in this section.

For each of the 2005 and 2006 base case episodes, time series comparing hourly measured (red dots) and modeled (blue line) ozone concentrations are shown for three monitors in the eight-county HGB area. The monitors presented vary by episode and were selected on the basis of ozone measured. Included on the time-series graphic is the modeled maximum and minimum hourly ozone concentration within the 7 x 7 grid cell array around the monitor (green shading). Additionally, time series comparing hourly measured and modeled ozone concentrations are shown for two or three rural monitors (GRVL and LACT, and SAGA, which was not in operation during bc05ep0 and bc05ep1). Figure 3-14: *TexAQS II Monitoring Sites Outside HGB/BPA* is a map of rural monitors and a list detailing the selected monitors.



Site Code	Site Name
GRVL	Greenville, NW of Dallas
CLEB	Cleburne, SW of Fort Worth
LACT	Livingston, NW of Houston
BEVL	Beeville, NW of Corpus Christi
CLVL	Clarksville, eastern TX-OK border
NTRD	Newton, South-Central TX-LA Border
PLTN	Palestine, Central East Texas
SAGA	San Augustine, Central TX-LA Border
WMBA	Wamba, Near Texarkana
HTVL	Halletsville, N of Victoria
ITHS	Italy, S of Dallas
PTOC	Port O'Connor, Middle TX Coast
TMPL	Near Temple

Figure 3-14: TexAQS II Monitoring Sites Outside HGB/BPA

Also included for each of the episodes are logarithmically-scaled scatter plots comparing the hourly measured and modeled concentrations of ozone (O_3), NO_X, ETH, and olefins (OLE). Monitor sites included in the graphical representation were the three monitors with the highest daily maximum monitored eight-hour ozone concentrations. If one of the top three sites did not also have an auto-GC, the third highest ozone monitoring site was replaced by the auto-GC site measuring the highest ozone. OLE is a CAMx chemical surrogate representing olefinic VOC,

such as propylene, but excluding ethylene and certain compounds known as internal olefins such as butenes (internal olefins are represented in CB05 by the surrogate species IOLE). Both ethylene and propylene are HRVOC and their emissions were adjusted in the base case modeling by the emissions reconciliation discussed previously in Section 3.4: *Modeling Emissions*. Included on the scatter plots is the measured versus modeled Quantile-Quantile (QQ) plot, which first sorts independently both the measured and modeled concentrations, then plots the sorted values together. QQ plot data, shown as red dots, provide a measure of how close the modeled and measured distributions of values are to each other. If the red dots lie close to the diagonal one-to-one line, the model generates the correct proportions of small, medium, and large concentration values.

Tile plots of the of the daily maximum modeled eight-hour ozone concentrations are shown for selected episode days on which several monitors measured daily maximum eight-hour ozone concentrations greater than 84 ppb. Included on the tile plots are the monitor locations represented by small circles, color coded for the measured ozone concentration. The same scale is used for the measured and modeled maximum daily eight-hour ozone concentrations.

Bc05ep0: May 19 through June 3, 2005

For the bc05ep0 episode, hourly time series are presented for the Conroe Relocated (CNR2; CAMS 78), Northwest Harris County (HNWA; CAMS 26), and Wallisville Road (WALV; CAMS 617)[1] monitors in Figure 3-15: *Time Series of Hourly Ozone Concentrations for Episode bc05ep0 at the CNR2, HNWA, and WALV Monitors*. In general, the modeled ozone concentrations, including the 7 x 7 cell maximum-minimum range, replicate the diurnal pattern of the observations. The lower ozone concentrations measured during the early morning hours, especially at the CNR2 monitor, and the very highest ozone concentrations, for example, HNWA, May 27, 2005, were less well replicated. The unfavorable comparison between the measured and modeled hourly ozone concentrations during the early morning hours at the CNR2 monitor is likely due to local factors, such as nearby NO_X emissions and low wind speed meteorological conditions, which reduces the areal representation of the monitor to much less than the 4 km grid cell size on which the modeled concentration is simulated. Thus, at the CNR2 monitor during the early morning hours the comparison of modeled and measured ozone concentrations may be inappropriate and a disparity is not necessarily an indication of poor model performance.

Figure 3-16: *Time Series of Hourly Ozone Concentrations for Episode bc05ep0 at the GRVL and LACT Rural Monitors* provides a comparison of measured and modeled hourly ozone concentrations at rural monitors. Modeled concentrations generally replicate the diurnal pattern of the observations, except for the latter part of the episode in the rural region represented by the LACT monitor, for which the modeled concentrations are relatively constant throughout the day. The lower ozone concentrations at these monitors measured during the early morning hours on some days are likely due to localized emissions and meteorology, which limits the areal representation of the monitors. Therefore, they may be inappropriate for model performance evaluation, as described previously. Overall, modeled and measured rural concentrations compare favorably, and modeled rural concentrations are unlikely to cause any substantial predictive bias within the HGB area during this episode.

[1] Note that CAMS 617 is a non-regulatory monitor.

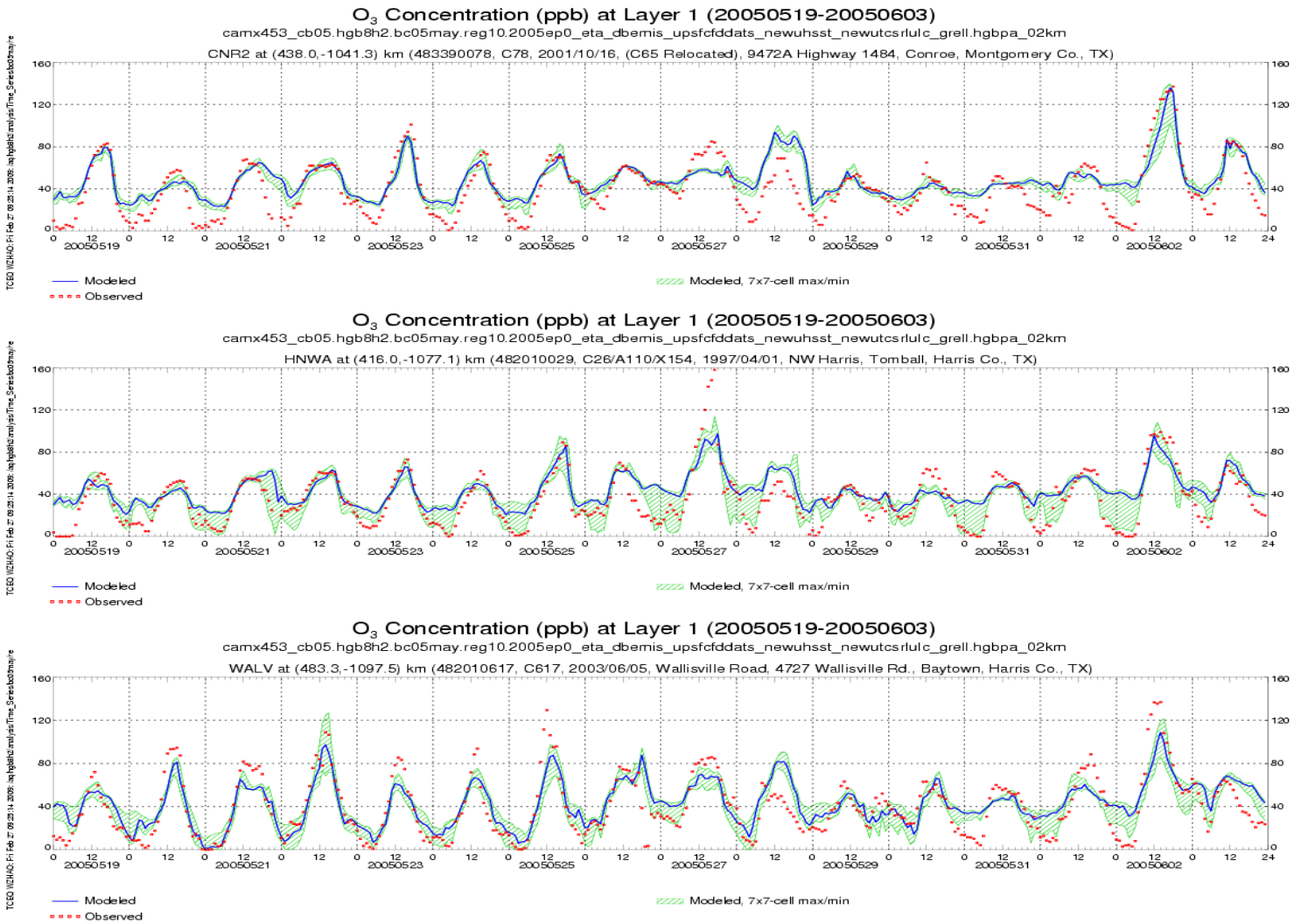


Figure 3-15: Time Series of Hourly Ozone Concentrations for Episode bc05ep0 at the CNR2, HNWA, and WALV Monitors
Note: WALV is a non-regulatory, industry-sponsored monitor.

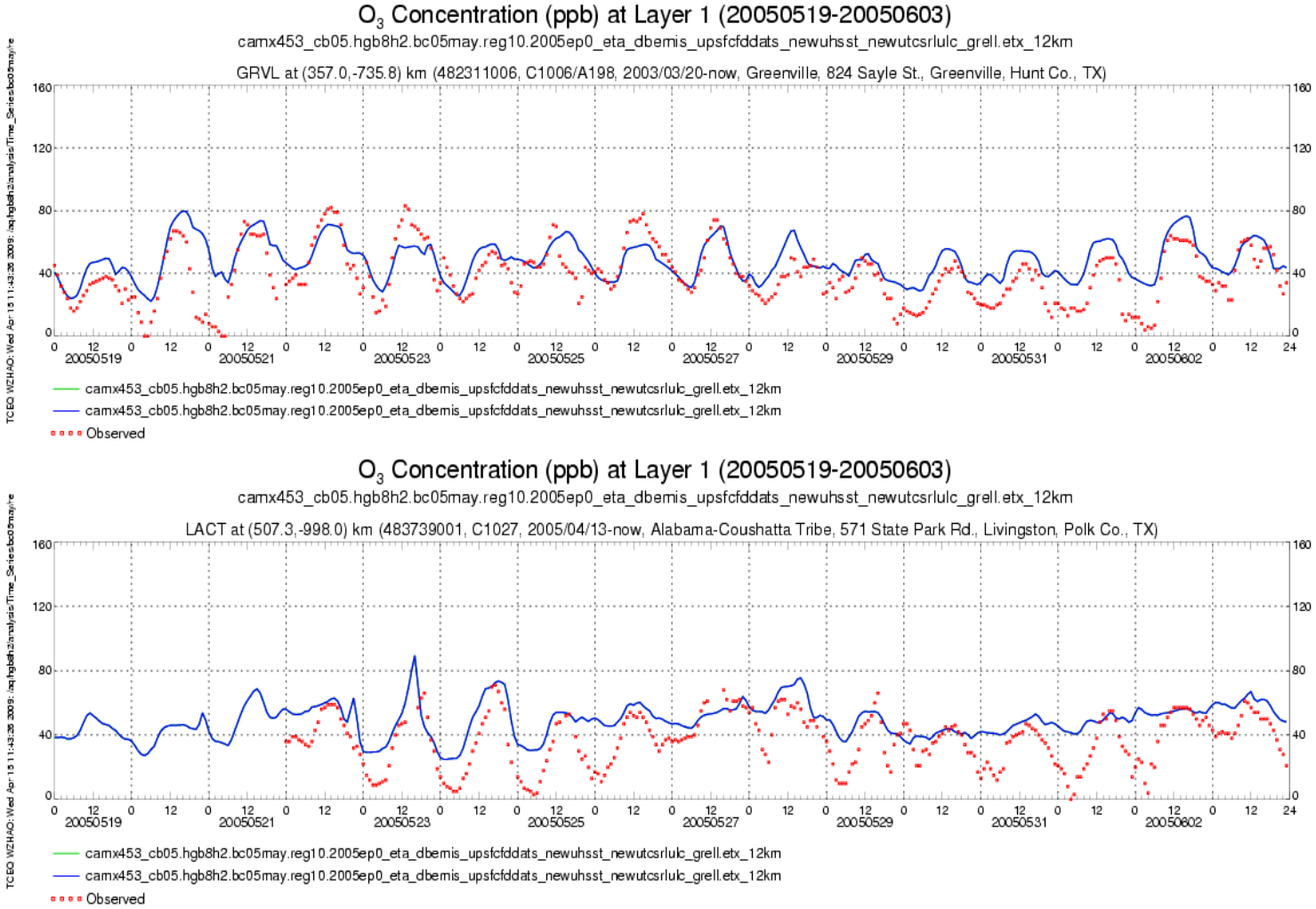


Figure 3-16: Time Series of Hourly Ozone Concentrations for Episode bc05ep0 at the GRVL and LACT Rural Monitors

Scatter plots for the bc05ep0 episode comparing the hourly measured and modeled concentrations at the non-regulatory, industry-sponsored Wallisville Road (WALV; CAMS 617) monitor are shown in Figure 3-17: *Scatter Plots of Hourly Ozone, NO_X, ETH, and OLE at the WALV Monitor for the bc05ep0 Episode.* The model tends to over-predict ozone at the lower measured concentrations (less than 60 ppb), but compares favorably at the higher ozone concentrations. Conversely, the model tends to under-predict the NO_X at the lower measured concentrations, but compares favorably at the higher NO_X concentrations. The quantile-quantile (QQ) plot, which shows the comparison between the measured and modeled distributions of ETH concentrations, is favorable, although there is notable scatter in the individual hourly comparisons. The model tends to under-predict the lower and higher OLE concentrations.

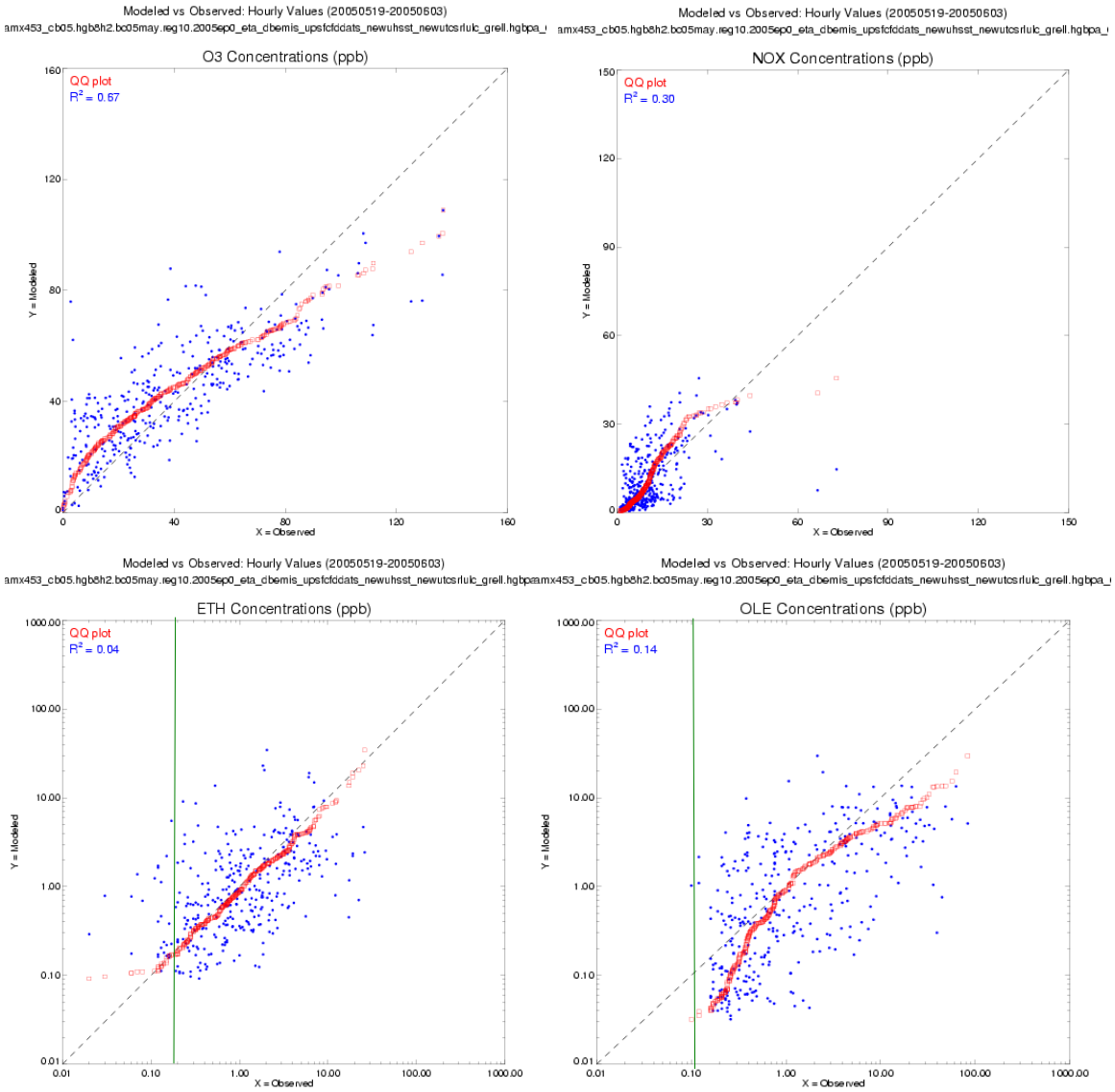


Figure 3-17: Scatter Plots of Hourly Ozone, NO_X, ETH, and OLE at the WALV Monitor for the bc05ep0 Episode

Note: WALV is a non-regulatory, industry-sponsored monitor.

Tile plots of daily maximum eight-hour ozone concentrations for May 27, May 31, June 1, and June 2, 2005, are shown in Figure 3-18: *Tile Plots of Daily Maximum Eight-Hour Ozone Concentrations for May 27 and 31 and June 1 through 2, 2005*. The dots represent the monitored value, whereas the background color represents the modeled results. Where a dot's color matches the surrounding color, the model has accurately replicated the measured ozone at that monitor. The model replicates the areas of highest eight-hour ozone for the selected days, with the exception of May 31, 2005.

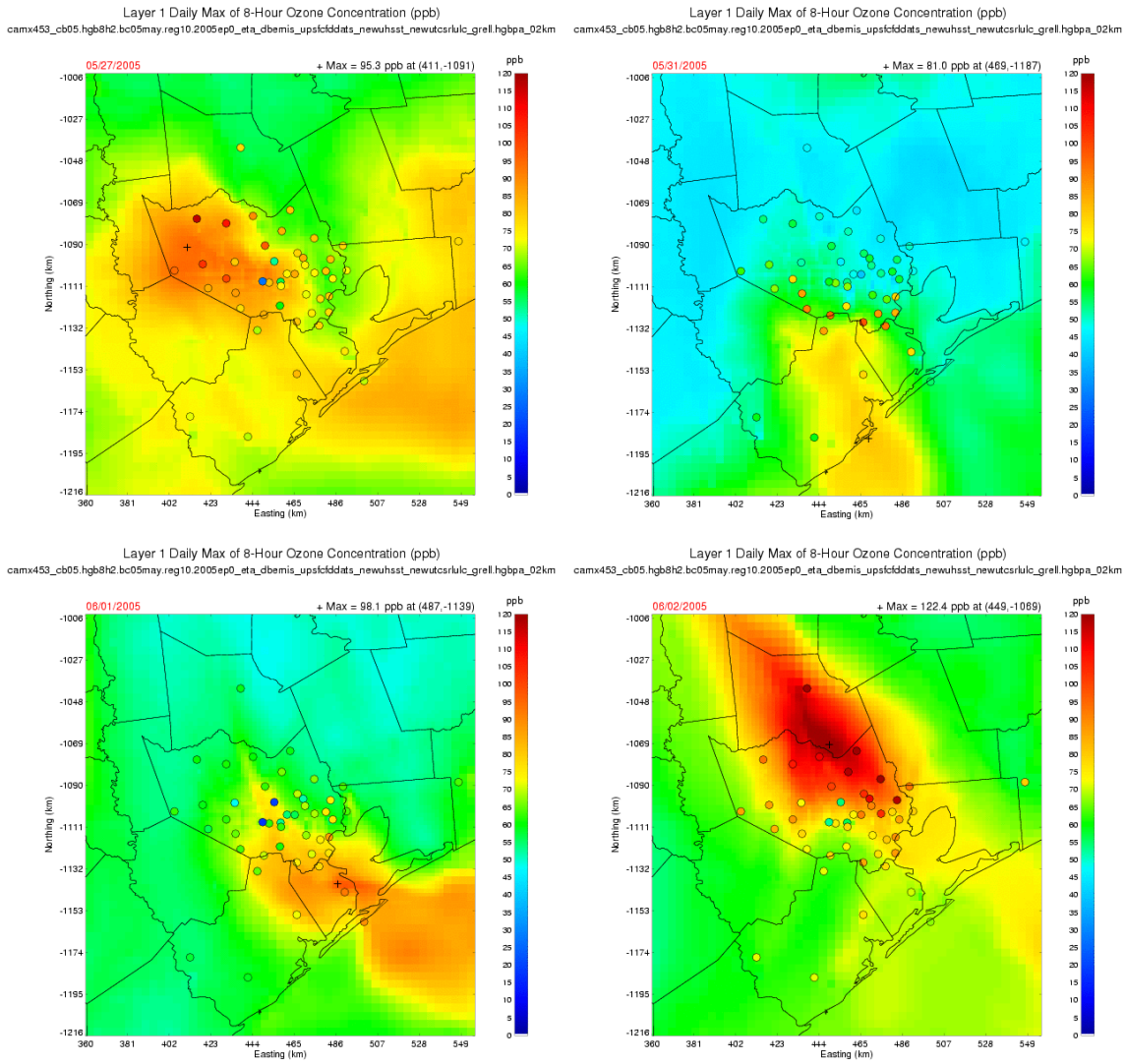


Figure 3-18: Tile Plots of Daily Maximum Eight-Hour Ozone Concentrations for May 27 and 31 and June 1 through 2, 2005

Overall, the graphical evaluation of model performance at key monitors on key episode days indicates the modeling adequately replicates the features that produced high ozone during this episode.

Bc05ep1: June 17 through 30, 2005

For the bc05ep1 episode, hourly time series are presented for the Deer Park (DRPK; CAMS 35), Houston Croquet (HCQA; CAMS 409) and Manvel Croix Park (MACP; CAMS 84) monitors in Figure 3-19: *Time Series of Hourly Ozone Concentrations for Episode bc05ep1 at the DRPK, HCQA, and MACP Monitors*. In general the modeled ozone concentrations, including the 7 x 7 cell maximum-minimum range, replicate the diurnal pattern of the observations, with the exception of the lower ozone concentrations measured during the early morning hours, especially at the MACP monitor. As previously discussed, the over-prediction bias during the early morning hours is not necessarily an indication of poor model performance, since local emissions and meteorological conditions can limit the areal representation of a monitor and thereby make the comparison of modeled and measured ozone concentrations inappropriate.

Figure 3-20: *Time Series of Hourly Ozone Concentrations for Episode bc05ep1 at the GRVL and LACT Rural Monitors* provides a comparison of measured and modeled hourly ozone concentrations at rural monitors. Modeled concentrations generally replicate the diurnal pattern of the observations, with generally favorable comparisons during the daytime. Since the higher ozone concentrations occur during the daytime, this is the more important period when the model predictions need to be the most accurate. The model does not replicate the lower ozone concentrations measured on some days during the early morning hours, likely due to local emissions and meteorological conditions which limit the areal representativeness of the monitor, as previously discussed. Overall, modeled and measured rural concentrations compare favorably, and modeled rural concentrations are unlikely to cause any substantial predictive bias of daily maximum eight-hour ozone concentrations within the HGB area during this episode.

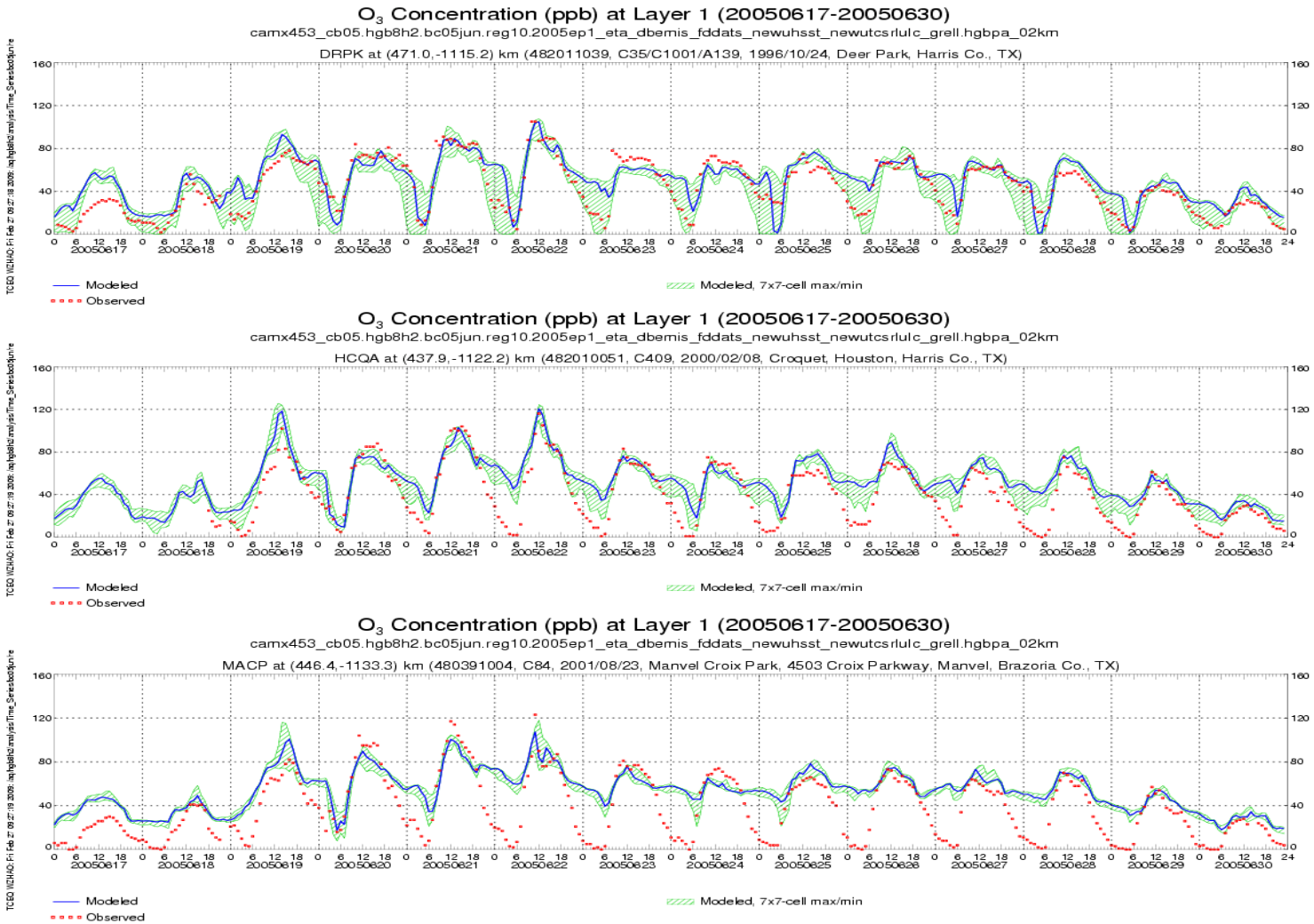


Figure 3-19: Time Series of Hourly Ozone Concentrations for Episode bc05ep1 at the DRPK, HCQA, and MACP Monitors

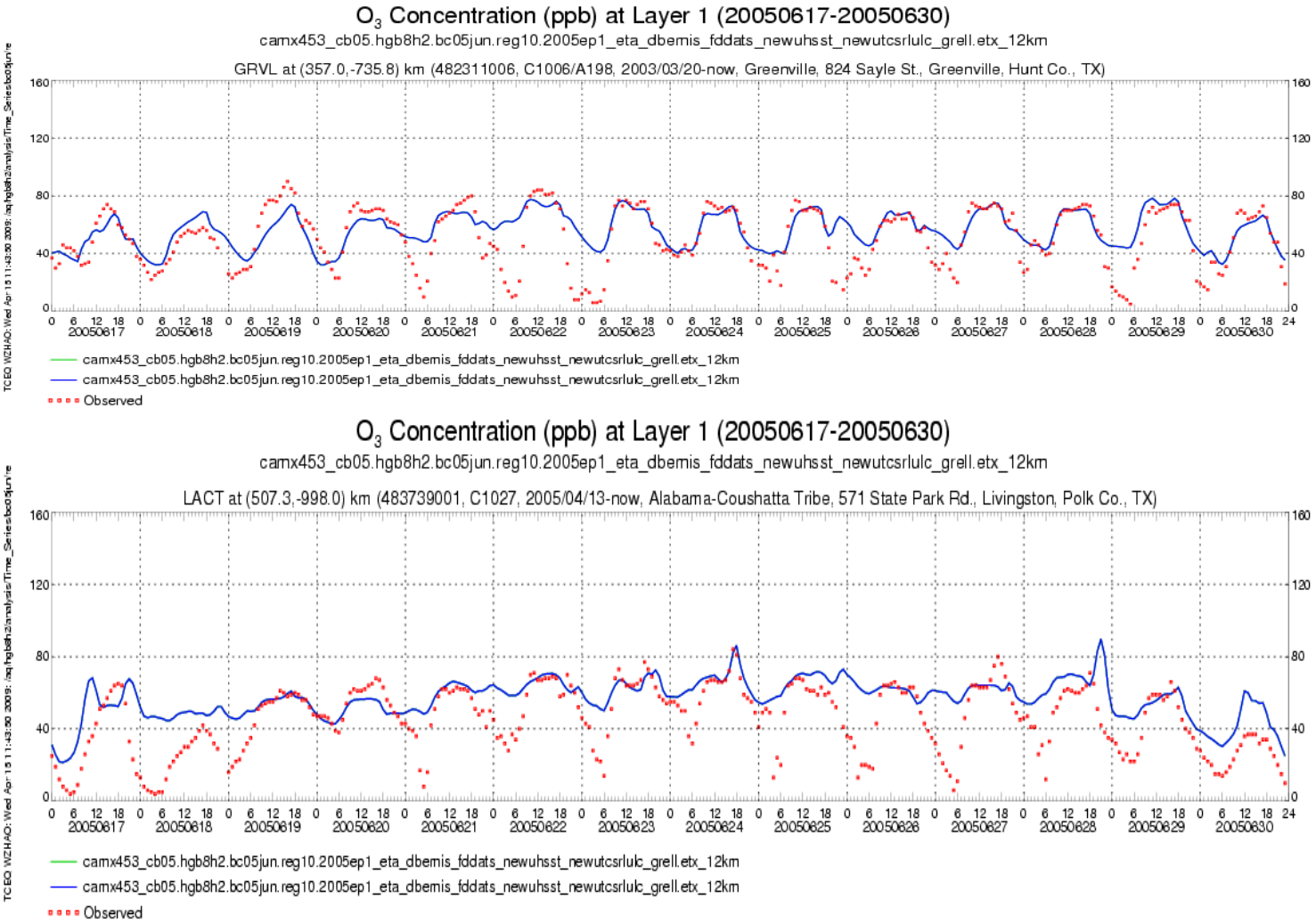


Figure 3-20: Time Series of Hourly Ozone Concentrations for Episode bc05ep1 at the GRVL and LACT Rural Monitors

Scatter plots for the bc05ep1 episode comparing the hourly measured and modeled concentrations at the Deer Park (DRPK; CAMS 35) monitor are shown in Figure 3-21: *Scatter Plots of Hourly Ozone, NO_X, ETH, and OLE at the DRPK Monitor for the bc05ep1 Episode.* The model tends to over-predict ozone at the lower measured concentrations, but compares quite favorably at the higher ozone concentrations. The model tends to generally over-predict the NO_X, especially at the lower measured concentrations. The QQ plot for ETH is quite favorable, although there is some scatter in the individual hourly comparisons. The model tends to under-predict the lower OLE concentrations and while the QQ plot shows a favorable comparison between the measured and modeled distributions of concentrations, there is notable scatter in the individual hourly comparisons.

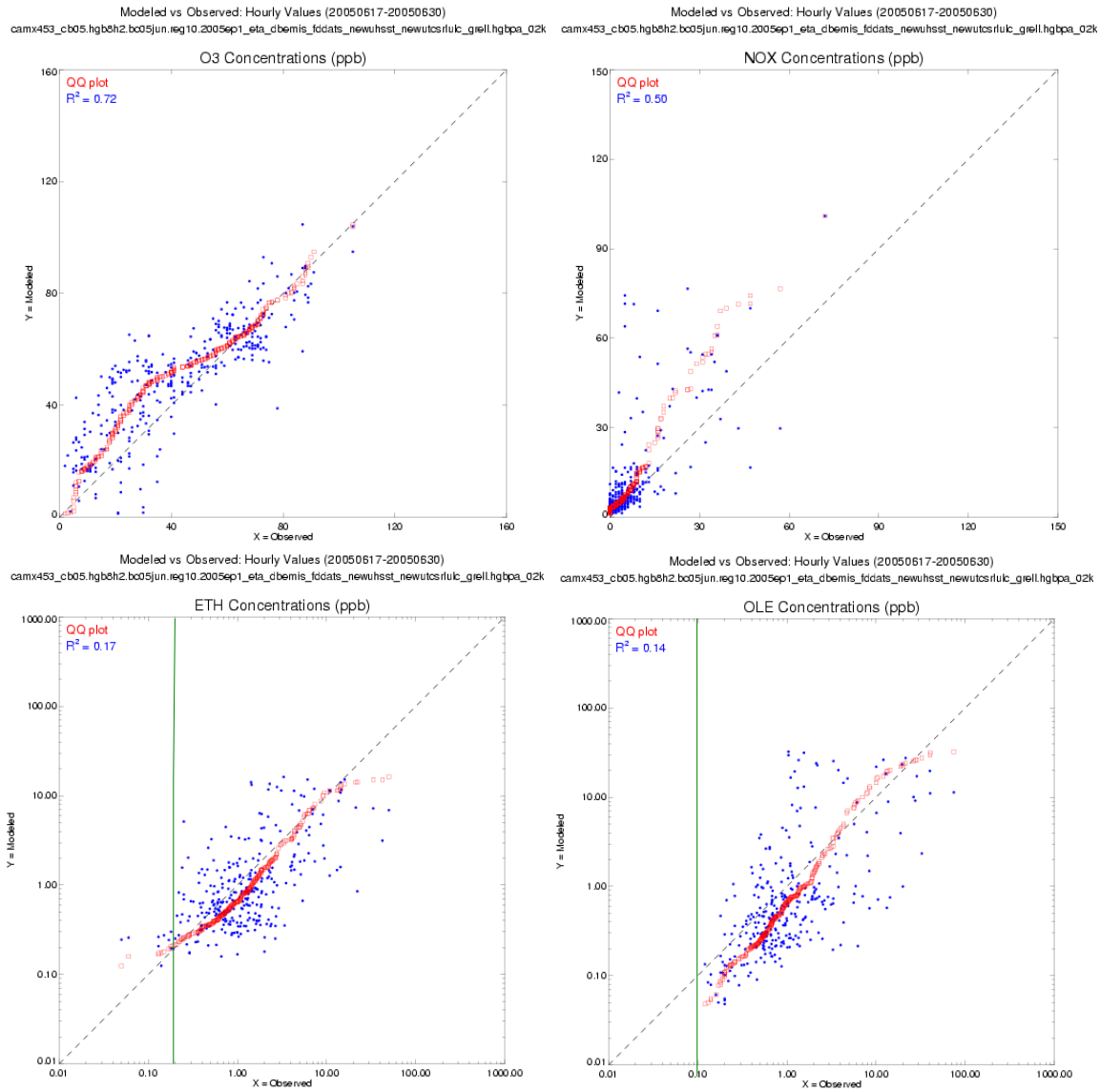


Figure 3-21: Scatter Plots of Hourly Ozone, NO_X, ETH, and OLE at the DRPK Monitor for the bc05ep1 Episode

Tile plots of daily maximum eight-hour ozone concentrations for June 20 through 23, 2005, are shown in Figure 3-22: *Tile Plots of Daily Maximum Eight-Hour Ozone Concentrations for June 20 through 23, 2005*. The model replicates the areas of highest eight-hour ozone for the selected days quite favorably.

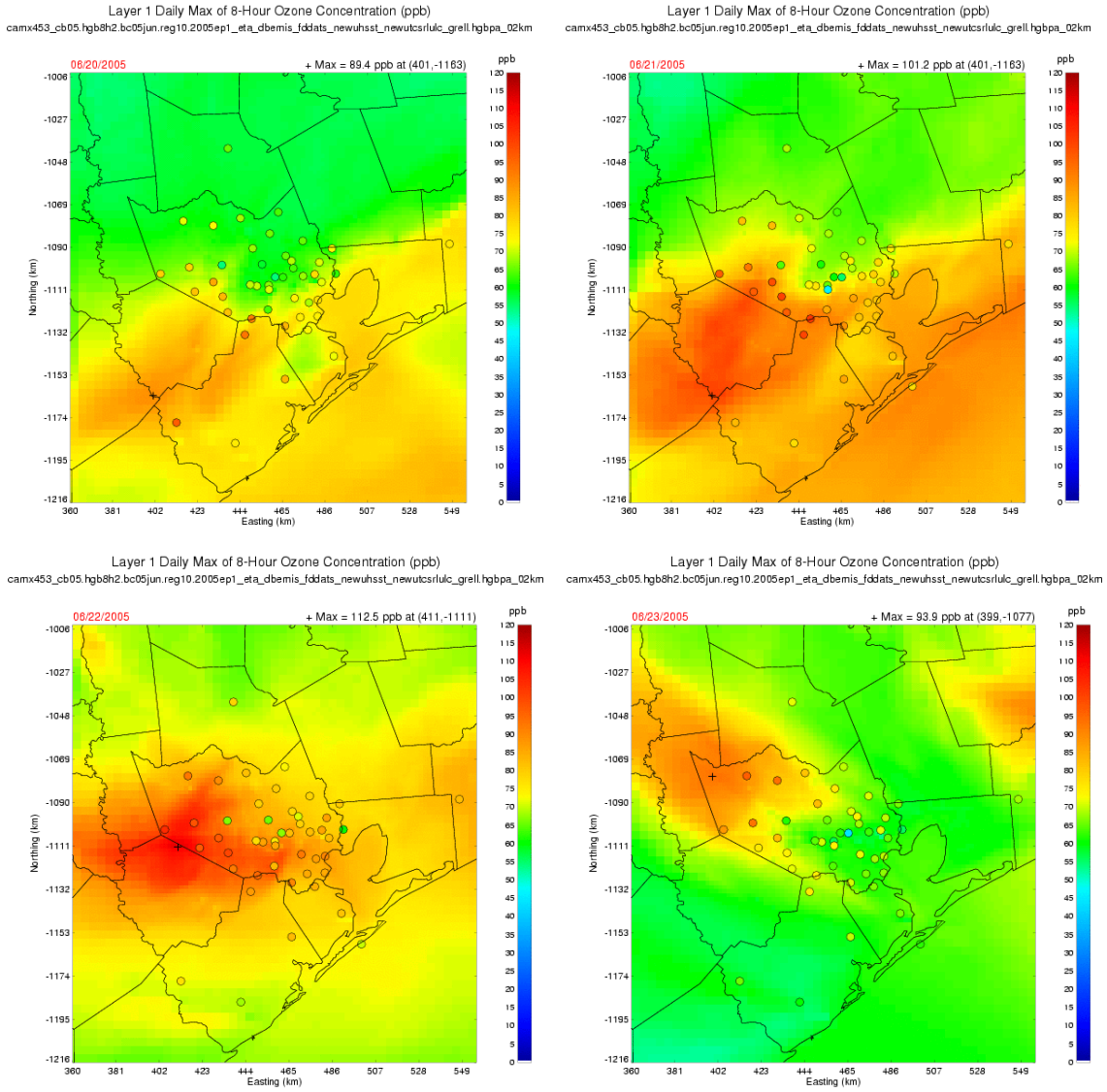


Figure 3-22: Tile Plots of Daily Maximum Eight-Hour Ozone Concentrations for June 20 through 23, 2005

Overall, the graphical evaluation of model performance at key monitors on key episode days indicates the modeling adequately replicates the features that produced high ozone during this episode.

Bc05ep2: July 26 through August 8, 2005

For the bc05ep2 episode, hourly time series are presented for the Houston Bayland Park (BAYP; CAMS 53), TCEQ Houston Regional Office (HROC; CAMS 81), and Texas City (TXCT; CAMS 620) (non-regulatory monitor) monitors in Figure 3-23: *Time Series of Hourly Ozone Concentrations for Episode bc05ep2 at the BAYP, HROC, and TXCT Monitors*. Relatively high ozone concentrations were measured at these monitors on several days during this episode. In general, the modeled ozone concentrations, including the 7 x 7 cell maximum-minimum range, replicate the diurnal pattern of the observations, with the exception of the lower ozone concentrations measured during the early morning hours, especially at the BAYP (CAMS 53) monitor.

Figure 3-24: *Time Series of Hourly Ozone Concentrations for Episode bc05ep2 at the GRVL, LACT, and SAGA Rural Monitors* provides a comparison of measured and modeled hourly ozone concentrations at rural monitors. Modeled concentrations generally replicate the diurnal pattern of the observations, with a tendency to over-predict the peak hourly ozone concentrations during the daytime and do not replicate the generally lower ozone concentrations measured at night and during the early morning hours. The over-prediction at these rural monitors appears to follow the same pattern as the over-prediction of ozone concentrations in the HGB area, especially during the latter part of the episode.

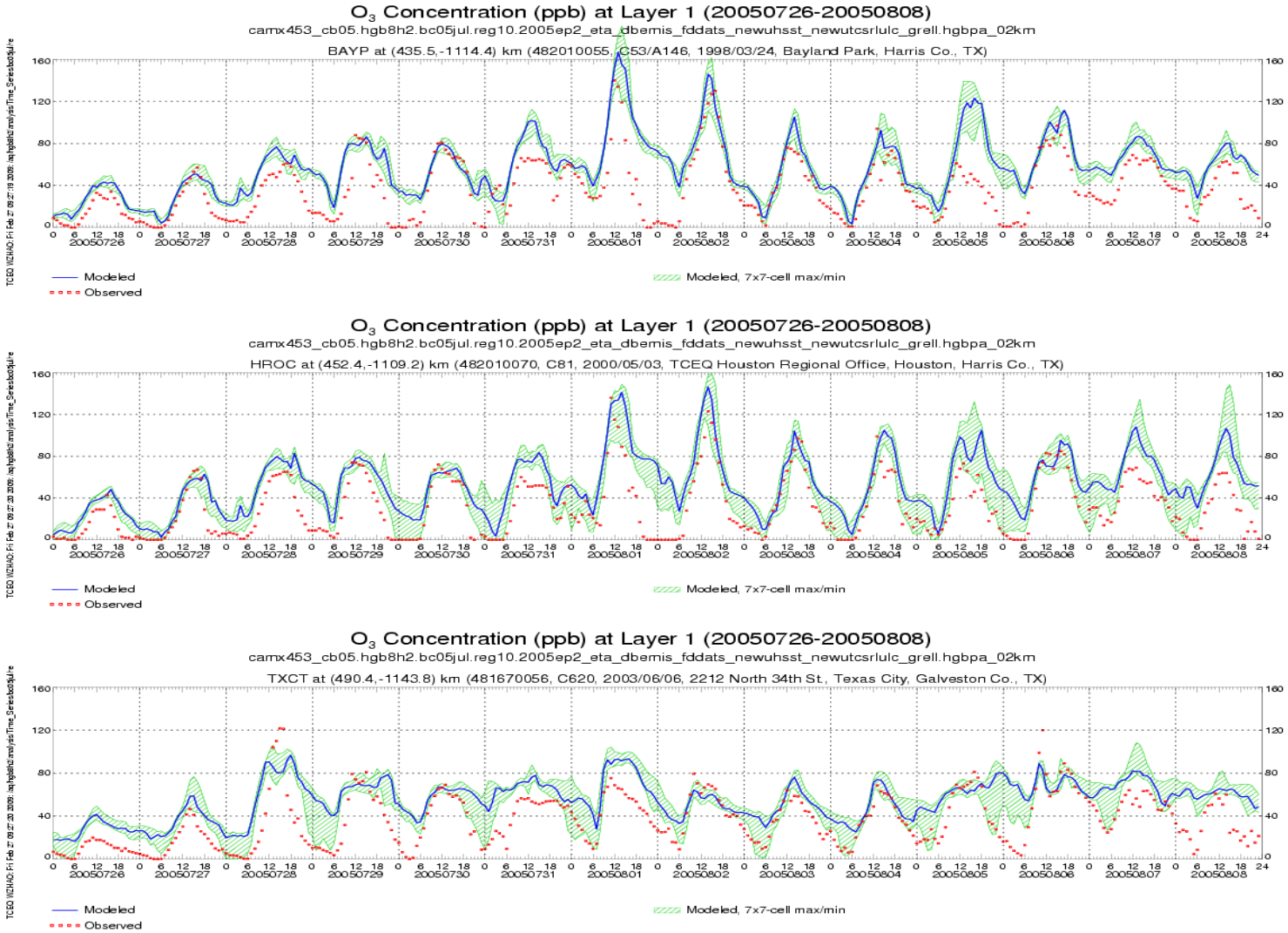


Figure 3-23: Time Series of Hourly Ozone Concentrations for Episode bc05ep2 at the BAYP, HROC, and TXCT Monitors
Note: TXCT is a non-regulatory monitor.

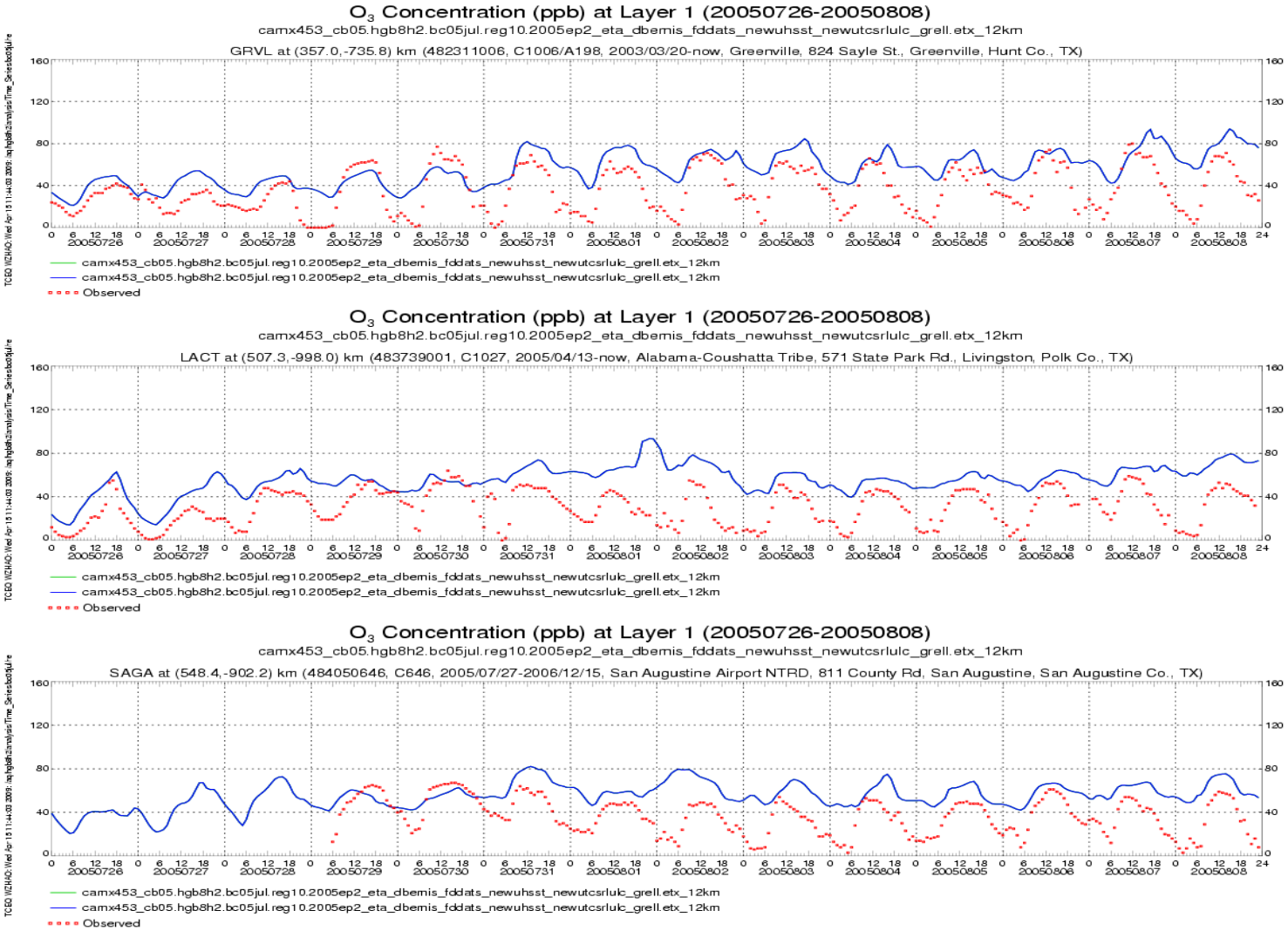


Figure 3-24: Time Series of Hourly Ozone Concentrations for Episode bc05ep2 at the GRVL, LACT, and SAGA Rural Monitors

Scatter plots for the bc05ep2 episode comparing the hourly measured and modeled concentrations at the TXCT monitor (non-regulatory monitor) are shown in Figure 3-25: *Scatter Plots of Hourly Ozone, NO_X, ETH, and OLE at the TXCT Monitor for the bc05ep2 Episode.* The model generally tends to over-predict ozone, especially at the lower measured concentrations. Although the QQ plot indicates a more favorable comparison between the measured and modeled distributions for the NO_X, there is notable scatter in the individual hourly comparisons. The QQ plot for ETH indicates an even more favorable comparison between the measured and modeled distributions, again with notable scatter in the individual hourly comparisons. The model tends to under-predict the lower and higher OLE concentrations, also with considerable scatter in the individual hourly comparisons.

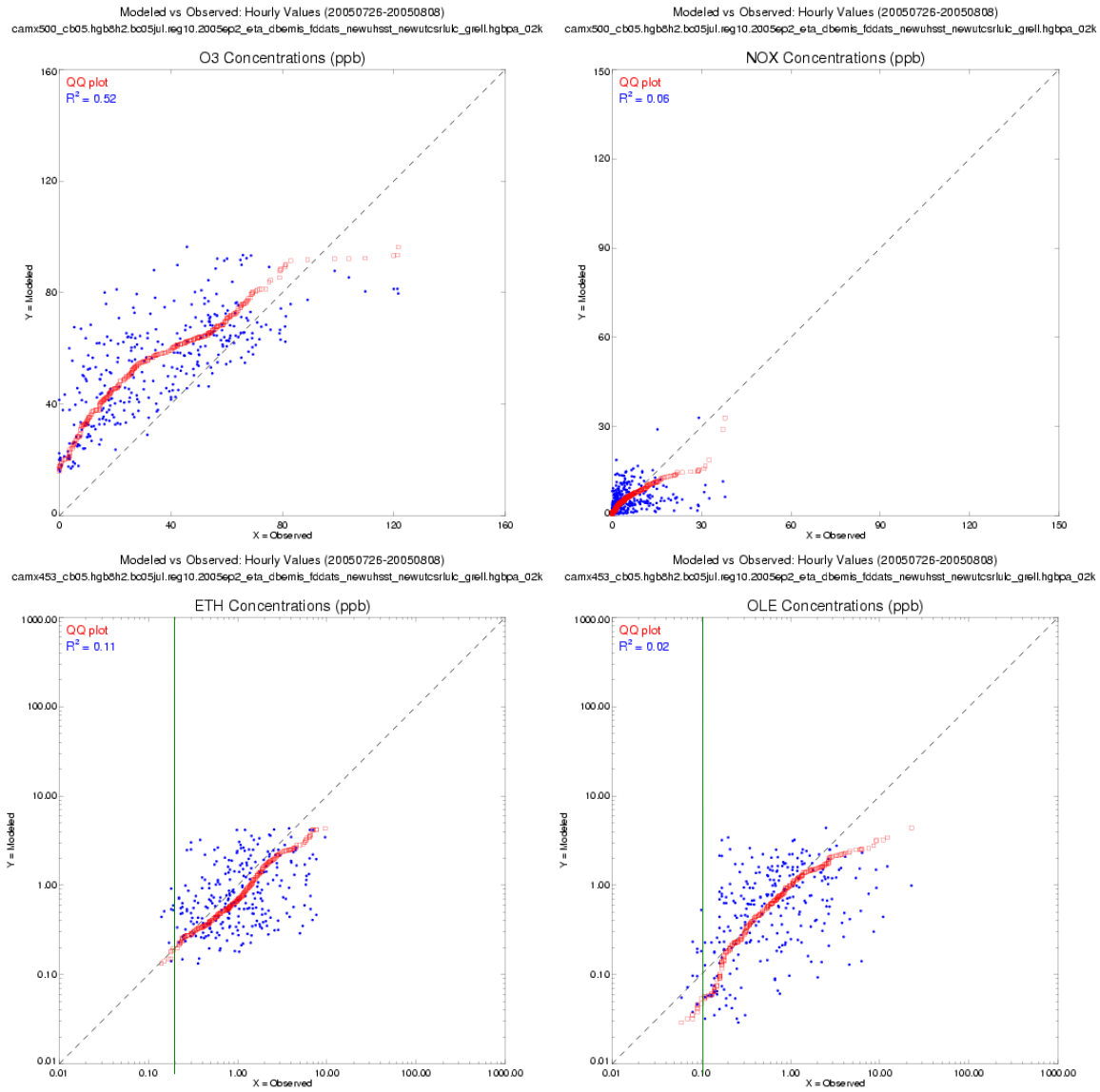


Figure 3-25: Scatter Plots of Hourly Ozone, NO_X, ETH, and OLE at the TXCT Monitor for the bc05ep2 Episode

Note: TXCT is a non-regulatory monitor.

Tile plots of daily maximum eight-hour ozone concentrations for July 28, August 1 through 2, and August 6, 2005, are shown in Figure 3-26: *Tile Plot of Daily Maximum Eight-Hour Ozone Concentrations for July 28, August 1 through 2, and August 6, 2005*. The model replicates the areas of highest eight-hour ozone for the selected days, although it over-predicts the daily maximum eight-hour ozone concentrations, especially on August 1 and 2, 2005.

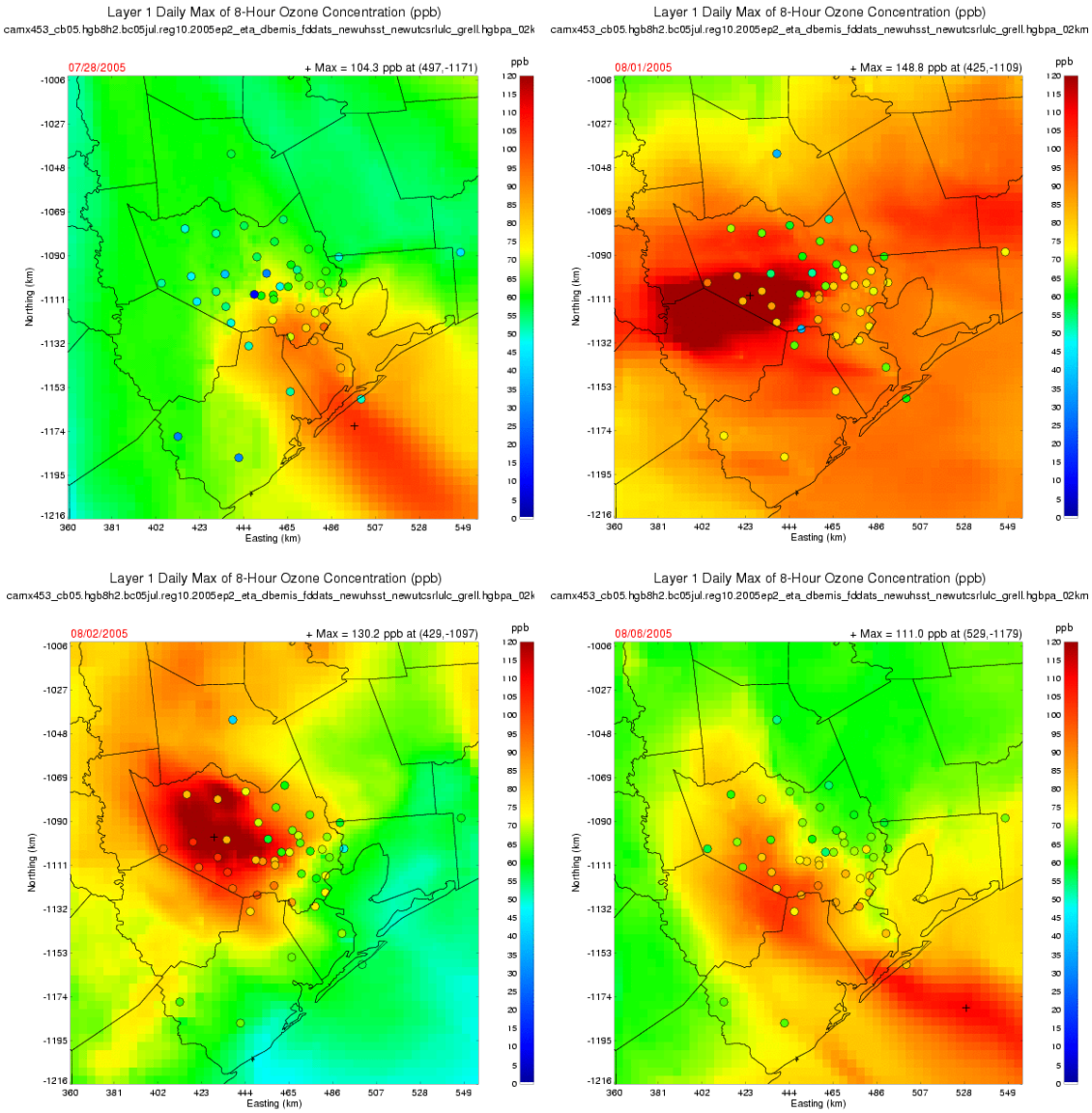


Figure 3-26: Tile Plot of Daily Maximum Eight-Hour Ozone Concentrations for July 28, August 1 through 2, and August 6, 2005

Overall, the graphical evaluation of model performance at key monitors on key episode days indicates the modeling only marginally replicates the features that produced high ozone during this episode.

Bc06ep0: May 31 through June 15, 2006

For the bc06ep0 episode, hourly time series are presented for the TCEQ Houston Regional Office (HROC; CAMS 81), Shell Westhollow (SHWH; CAMS 410), and Wallisville (WALV; CAMS 617) (non-regulatory monitor) monitors in Figure 3-27: *Time Series of Hourly Ozone Concentrations for Episode bc06ep0 at the HROC, SHWH, and WALV Monitors*. Relatively high ozone concentrations were measured at these monitors on several days during this episode. In general, the modeled ozone concentrations, including the 7 x 7 cell maximum-minimum range, replicate the diurnal pattern of the observations, with the exception of the lower ozone concentrations measured during the early morning hours, especially at the SHWH (CAMS 410) monitor. Again, the over-prediction bias during the early morning hours is likely due to localized emissions and meteorology limiting the representativeness of the monitor.

Figure 3-28: *Time Series of Hourly Ozone Concentrations for Episode bc06ep0 at the GRVL, LACT, and SAGA Rural Monitors* provides a comparison of measured and modeled hourly ozone concentrations at rural monitors. Modeled concentrations generally replicate the diurnal pattern of the observations, with generally favorable comparisons during the daytime. The model does not replicate the lower ozone concentrations measured on some days during the early morning hours, most likely due to localized emissions and meteorology limiting the representativeness of the monitors. Overall, modeled and measured rural concentrations compare favorably, and modeled rural concentrations are unlikely to cause any substantial predictive bias within the HGB area during this episode.

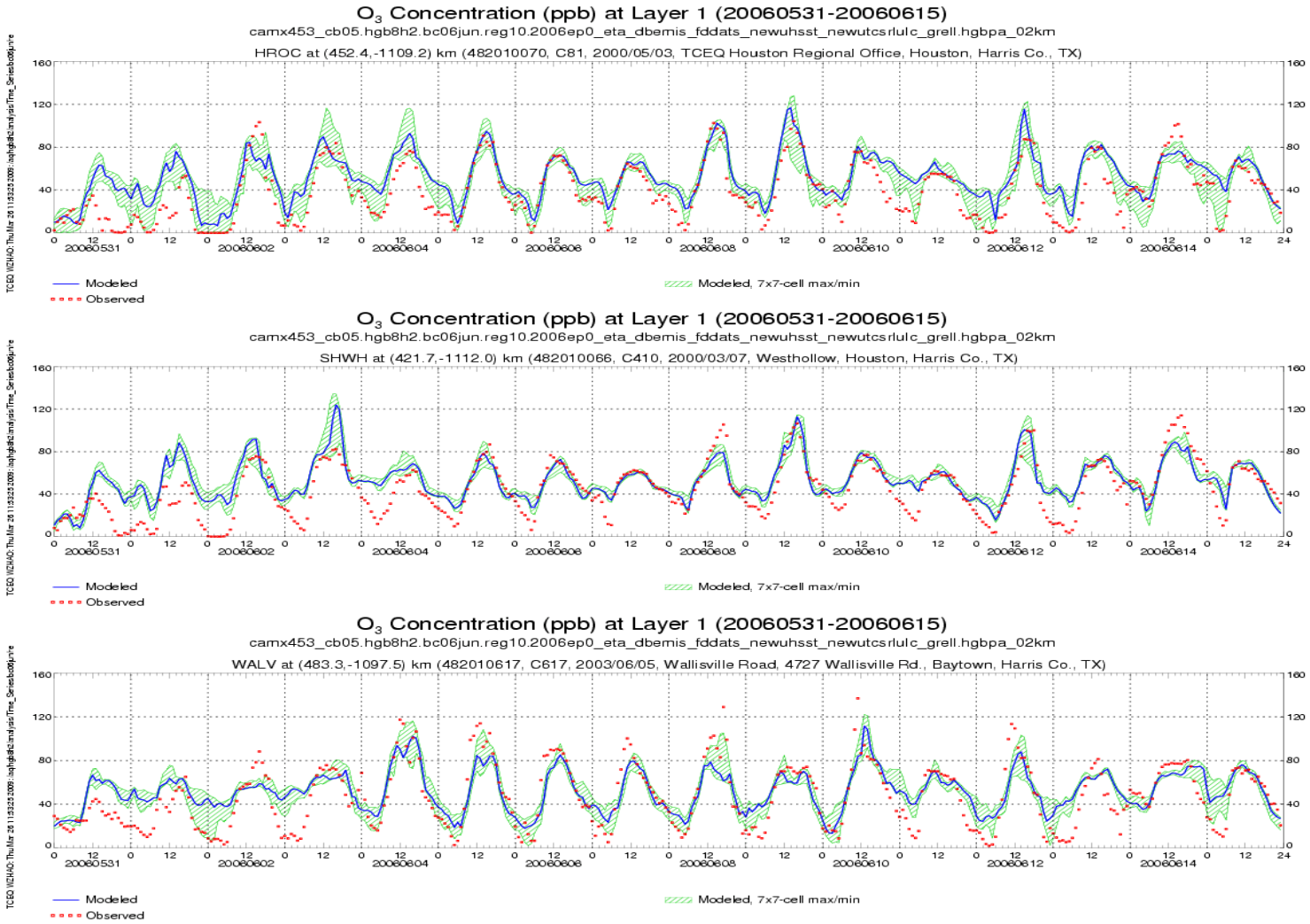


Figure 3-27: Time Series of Hourly Ozone Concentrations for Episode bc06ep0 at the HROC, SHWH, and WALV Monitors
Note: WALV is a non-regulatory monitor.

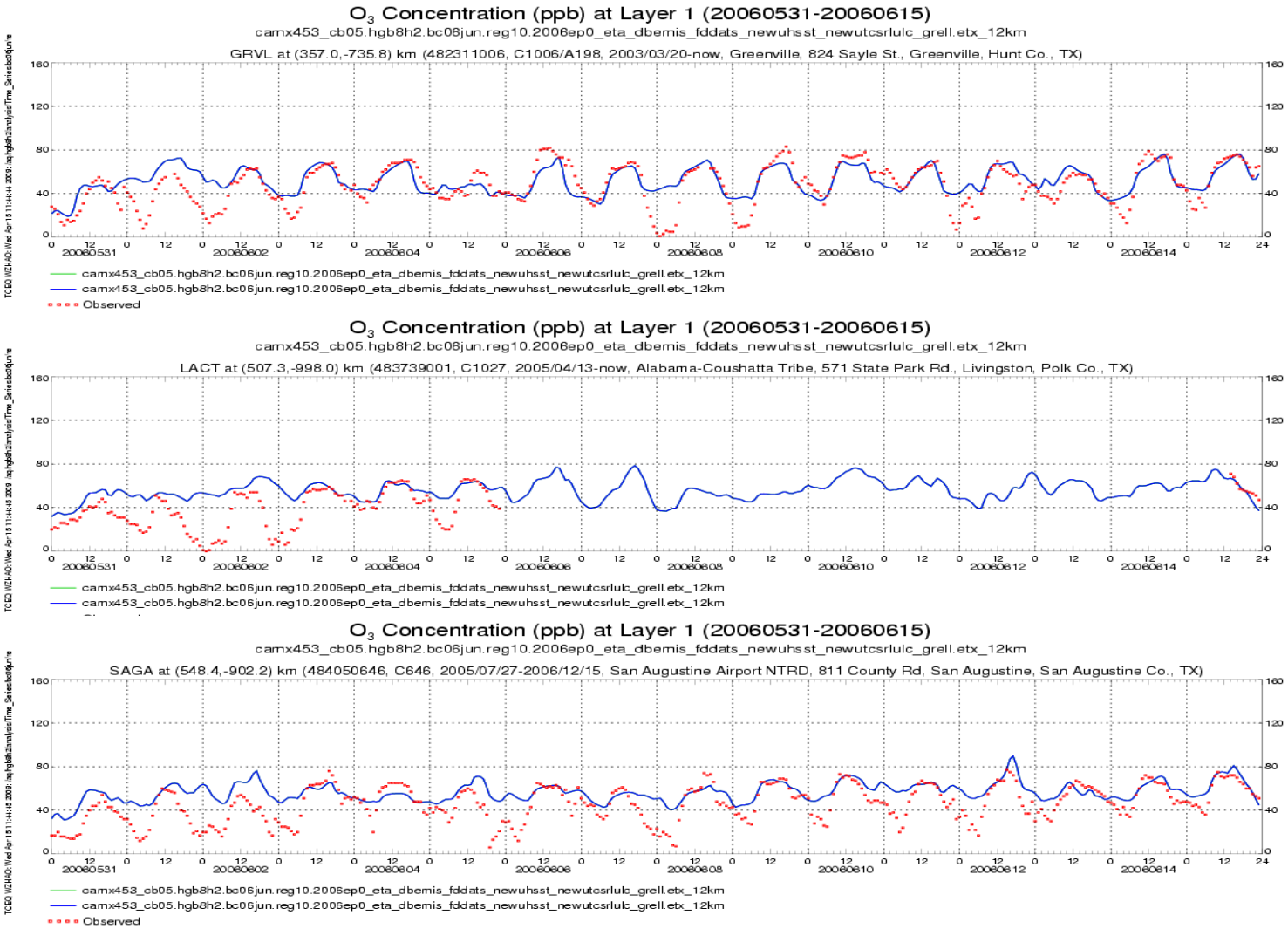


Figure 3-28: Time Series of Hourly Ozone Concentrations for Episode bc06ep0 at the GRVL, LACT, and SAGA Rural Monitors

Scatter plots for the bc06ep0 episode comparing the hourly measured and modeled concentrations at the Wallisville Road (CAMS 617) monitor (non-regulatory monitor) are shown in Figure 3-29: *Scatter Plots of Hourly Ozone, NO_X, ETH, and OLE at the WALV Monitor for the bc06ep0 Episode.* The model tends to over-predict ozone at the lower measured concentrations, but compares more favorably at the higher concentrations. Conversely, the model tends to under-predict NO_X at the lower measured concentrations, and slightly over-predict at the higher NO_X concentrations. The QQ plot for ETH indicates a somewhat favorable comparison between the measured and modeled distributions, although the model generally tends to under-predict the ETH concentrations. The model also tends to under-predict the OLE concentrations.

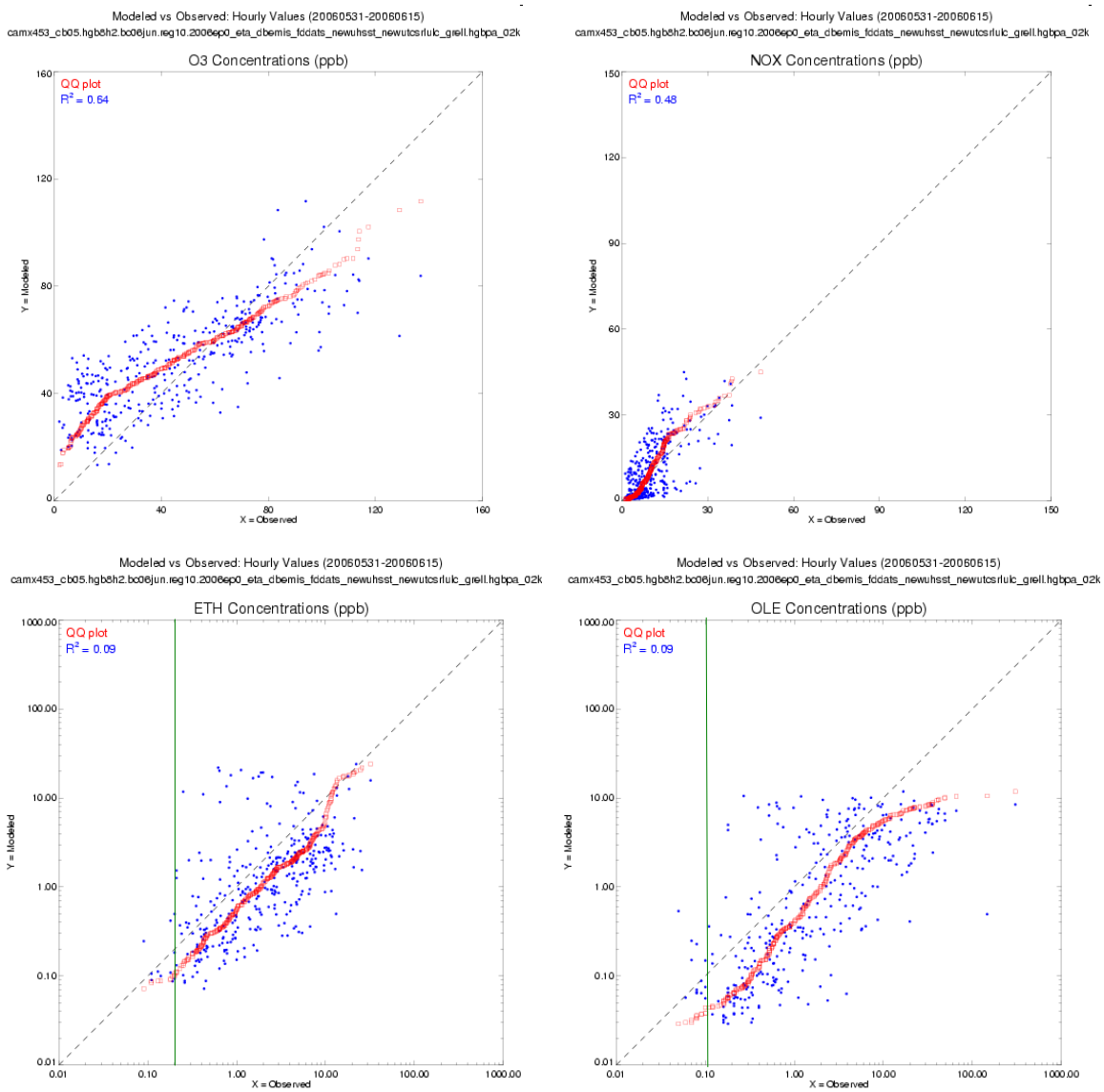


Figure 3-29: Scatter Plots of Hourly Ozone, NO_X, ETH, and OLE at the WALV Monitor for the bc06ep0 Episode

Note: WALV is a non-regulatory monitor.

Tile plots of daily maximum eight-hour ozone concentrations for June 5, June 8 through 9, and June 14, 2006, are shown in Figure 3-30: *Tile Plot of Daily Maximum Eight-Hour Ozone Concentrations for June 5, 8 through 9, and 14, 2006*. The model replicates the areas of highest eight-hour ozone for the selected days, although it somewhat under-predicts the daily maximum eight-hour ozone concentrations.

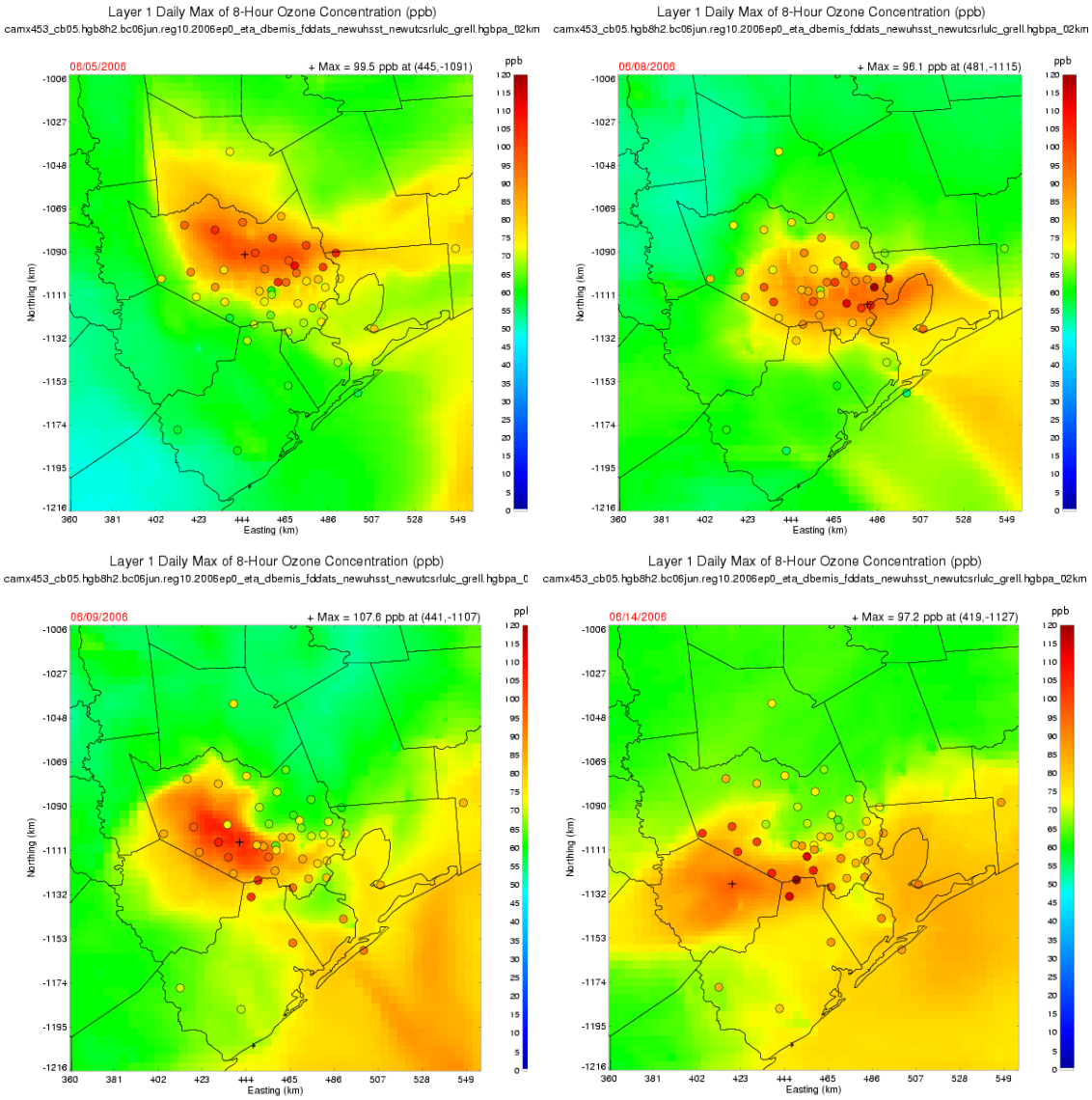


Figure 3-30: Tile Plot of Daily Maximum Eight-Hour Ozone Concentrations for June 5, 8 through 9, and 14, 2006

Overall, the graphical evaluation of model performance at key monitors on key episode days indicates the modeling adequately replicates the features that produced high ozone during this episode.

Bc06aqs1: August 13 through September 15, 2006

For the bc06aqs1 episode, hourly time series are presented for the Houston Bayland Park (BAYP; CAMS 53), Swiss and Monroe (HSMA; CAMS 406), and Deer Park (DRPK; CAMS 35) monitors in Figure 3-31: *Time Series of Hourly Ozone Concentrations for Episode bc06aqs1 at the BAYP, DRPK, and HSMA Monitors*. Relatively high ozone concentrations were measured at these monitors on several days during this episode. In general, the modeled ozone concentrations, including the 7 x 7 cell maximum-minimum range, replicate the diurnal pattern of the observations, with the exception of the very highest measured hourly ozone concentrations.

Figure 3-32: *Time Series of Hourly Ozone Concentrations for Episode bc06aqs1 at the GRVL, LACT, and SAGA Rural Monitors* provides a comparison of measured and modeled hourly ozone concentrations at rural monitors. Modeled concentrations generally replicate the diurnal pattern of the observations, with generally favorable comparisons during the daytime, with the exception of the region represented by the GRVL monitor on August 31 and September 1, 2006, when the higher measured ozone concentrations are notably under-predicted. In addition, the model tends to over-predict the ozone concentrations during the first segment of this episode, August 15 through 22, 2006, in the regions represented by LACT and SAGA monitors. Again, the model does not replicate the lower ozone concentrations measured on some days during the early morning hours, which is most likely due to localized emissions and meteorology limiting the areal representativeness of the monitors. Overall, modeled and measured rural concentrations compare favorably enough that the modeled rural concentrations are unlikely to cause any substantial predictive bias within the HGB area during this episode.

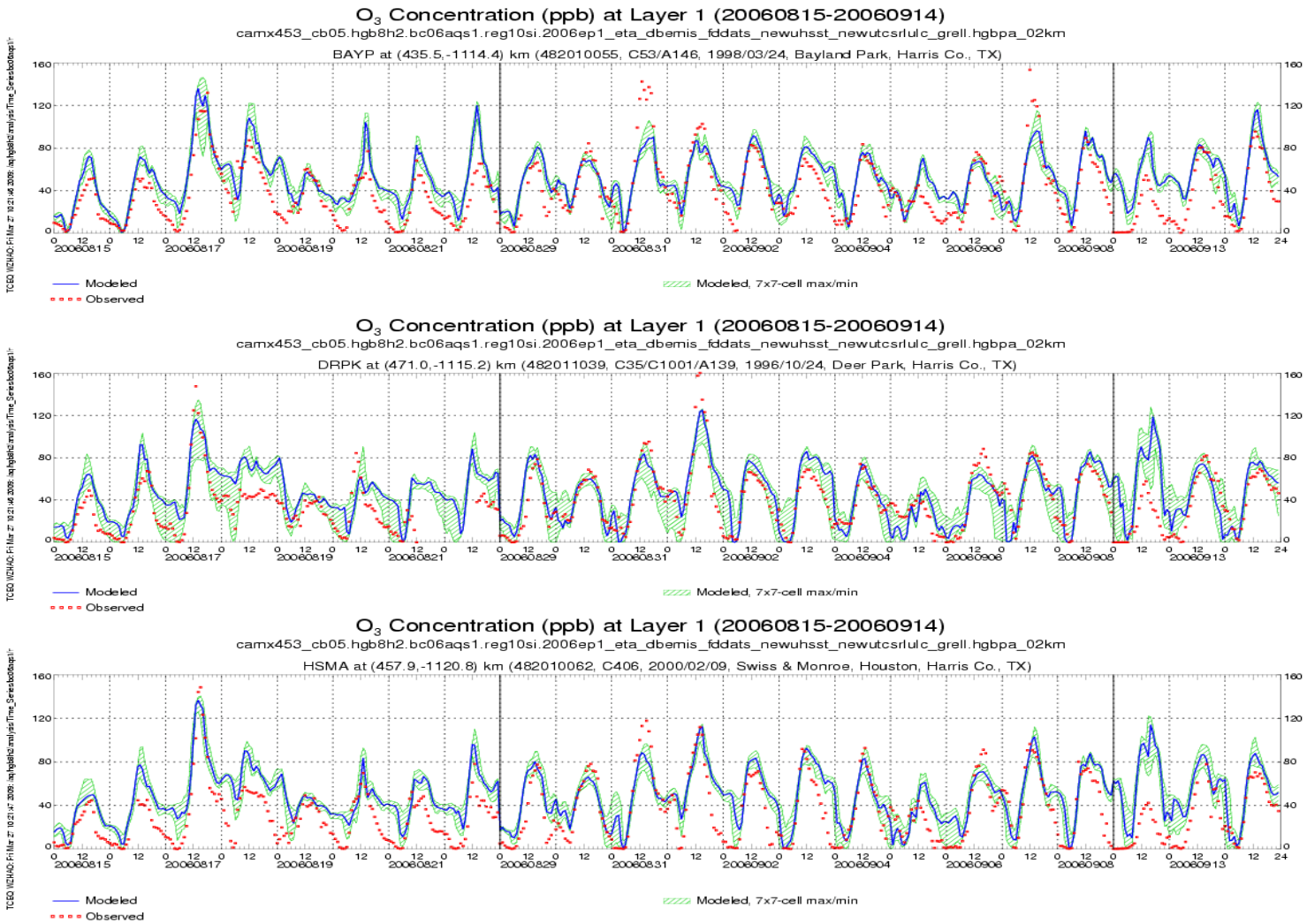


Figure 3-31: Time Series of Hourly Ozone Concentrations for Episode bc06aqs1 at the BAYP, DRPK, and HSMA Monitors

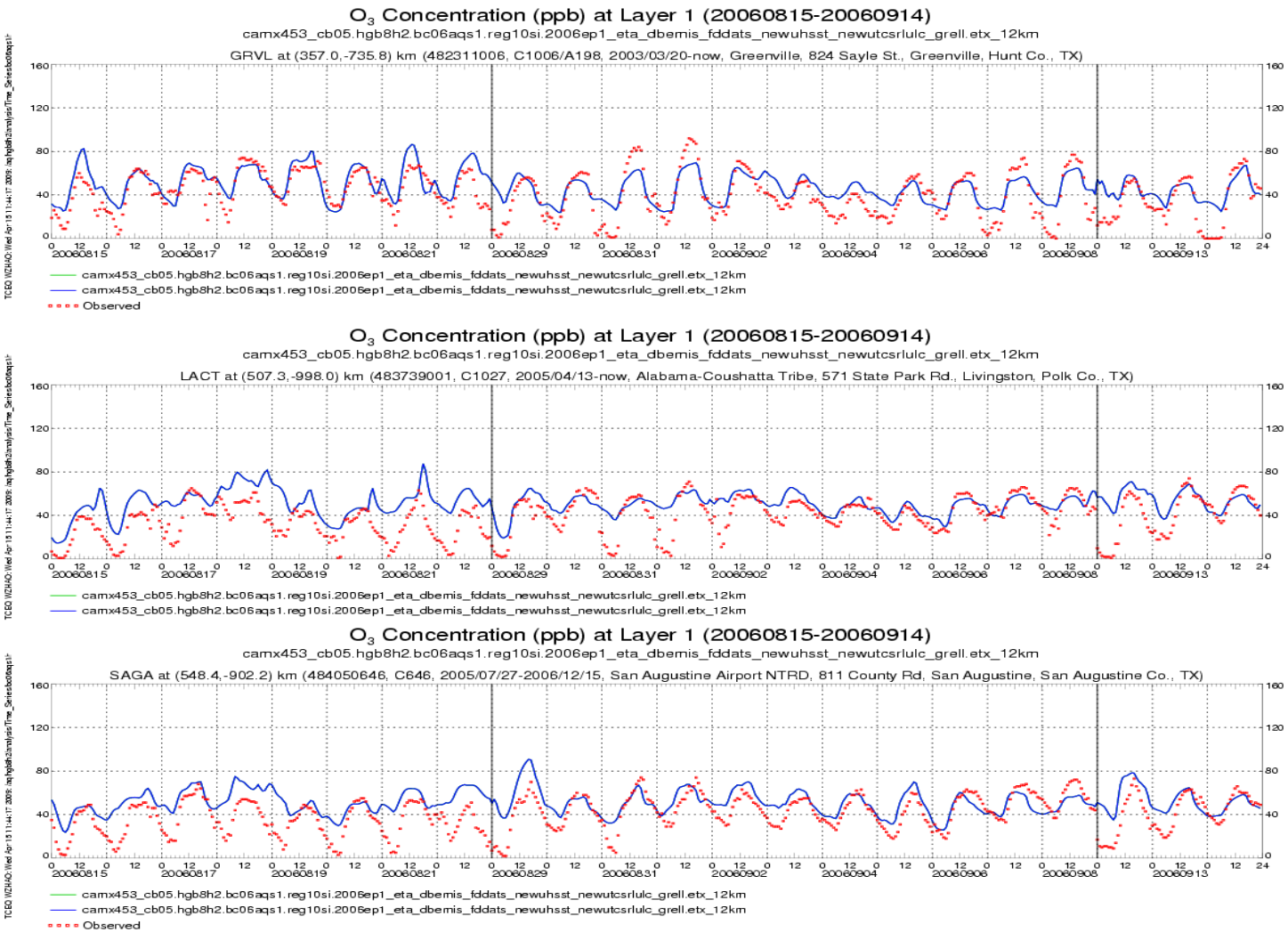


Figure 3-32: Time Series of Hourly Ozone Concentrations for Episode bc06aqs1 at the GRVL, LACT, and SAGA Rural Monitors

Scatter plots for the bc06aqs1 episode comparing the hourly measured and modeled concentrations at the Deer Park (CAMS 35) monitor are shown in Figure 3-33: *Scatter Plots of Hourly Ozone, NO_X, ETH, and OLE at the DRPK Monitor for the bc06aqs1 Episode.* The model tends to over-predict ozone at the lower measured concentrations, but compares more favorably at the higher concentrations. The model tends to generally over-predict NO_X concentrations. The QQ plot for ETH indicates a somewhat favorable comparison between the measured and modeled distributions, although the model tends to under-predict the higher ETH concentrations. The model tends to under-predict the lower range of OLE concentrations and also under-predicts the very highest.

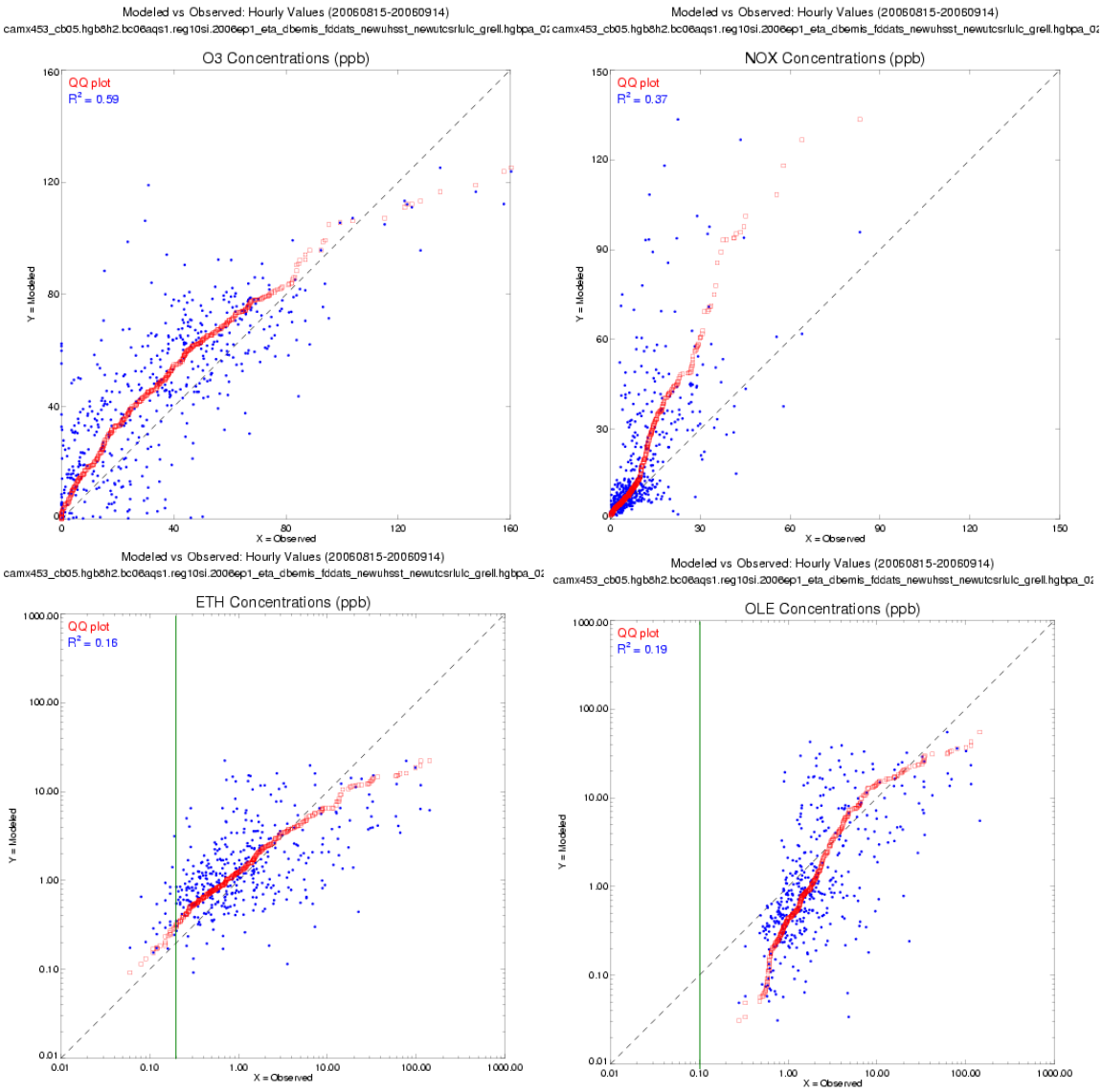


Figure 3-33: Scatter Plots of Hourly Ozone, NO_X, ETH, and OLE at the DRPK Monitor for the bc06aqs1 Episode

Tile plots of daily maximum eight-hour ozone concentrations for August 17, August 31, September 1, and September 7, 2006, are shown in Figure 3-34: *Tile Plot of Daily Maximum Eight-Hour Ozone Concentrations for August 17 and 31, and September 1 and 7, 2006*. The model replicates the areas of highest eight-hour ozone for the selected days, although it somewhat under-predicts the daily maximum eight-hour ozone concentrations, except on August 17, 2006, when the model tends to over-predict the daily maximum eight-hour ozone concentrations.

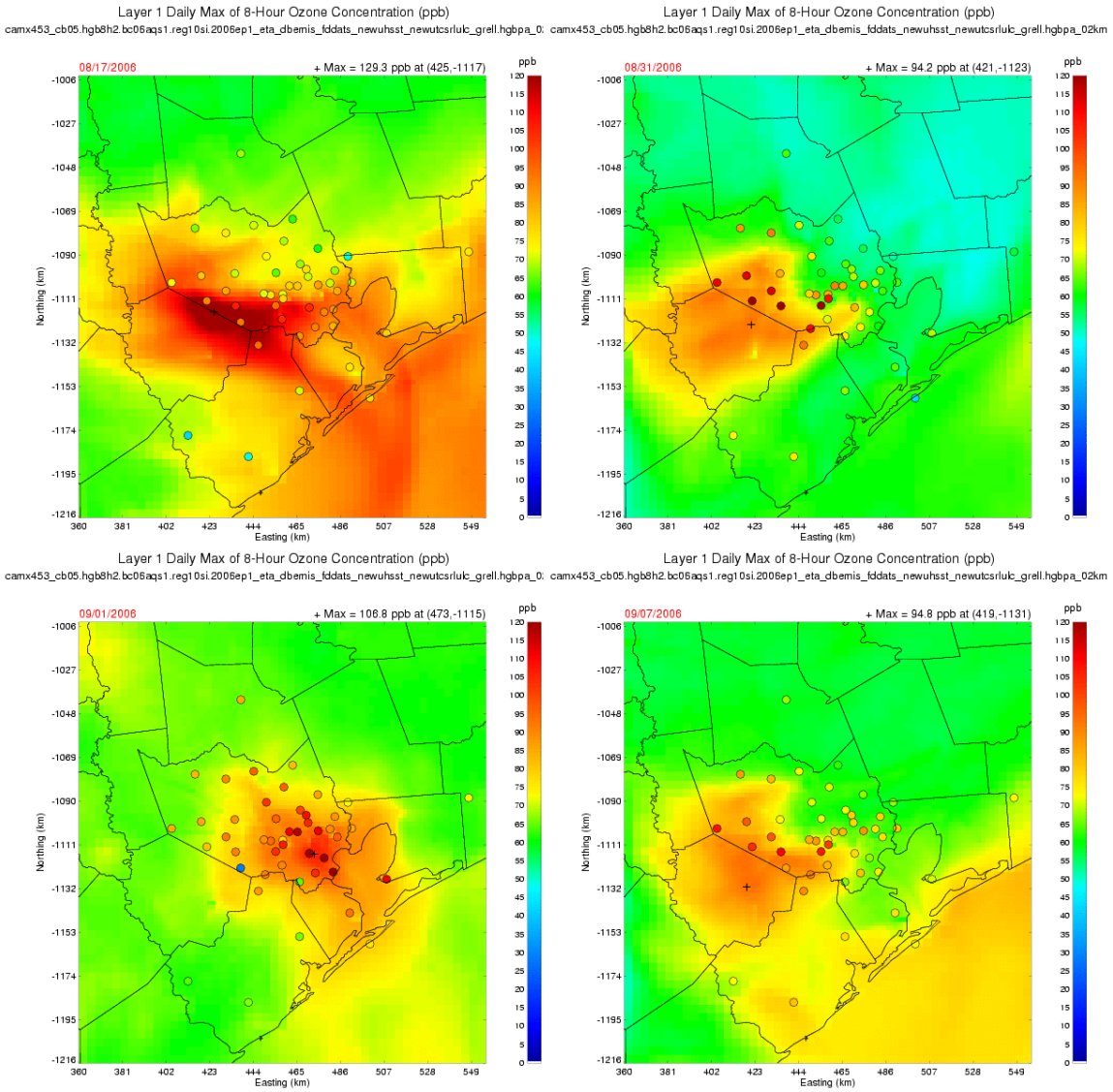


Figure 3-34: Tile Plot of Daily Maximum Eight-Hour Ozone Concentrations for August 17 and 31, and September 1 and 7, 2006

Overall, the graphical evaluation of model performance at key monitors on key episode days indicates the modeling adequately replicates the features that produced high ozone during this episode.

Bc06aqs2: September 16 through October 11, 2006

For the bc06aqs2 episode, hourly time series are presented for the Conroe Relocated (CNR2; CAMS 78), Galveston (GALC; CAMS 34), and Deer Park (DRPK; CAMS 35) monitors in Figure 3-35: *Time Series of Hourly Ozone Concentrations for Episode bc06aqs2 at the CNR2, DRPK, and GALC Monitors*. Relatively high ozone concentrations were measured at these monitors on several days during this episode. In general, the modeled ozone concentrations, including the 7 x 7 cell maximum-minimum range, replicate the diurnal pattern of the observations, with the exception of the lower ozone concentrations measured during the early morning hours, especially at the CNR2 (CAMS 78) monitor, which is most likely due to localized emissions and meteorology limiting the areal representativeness of the monitor.

Figure 3-36: *Time Series of Hourly Ozone Concentrations for Episode bc06aqs2 at the GRVL, LACT, and SAGA Rural Monitors* provides a comparison of measured and modeled hourly ozone concentrations at rural monitors. Modeled concentrations generally replicate the diurnal pattern of the observations. However, the model performance in the rural areas represented by these monitors varies for the different segments of the episode. For example, during the first segment, the model notably under-predicts the peak daytime ozone concentrations at all three monitors but compares more favorably with the peak daytime ozone concentrations measured during the middle portion of the third segment. Again, the model does not replicate the lower ozone concentrations measured on some days during the early morning hours, most likely due to localized emissions and meteorology limiting the representativeness of the monitors. Overall, modeled and measured rural concentrations compare favorably enough that the modeled rural concentrations are unlikely to cause any substantial predictive bias within the HGB area during this episode.

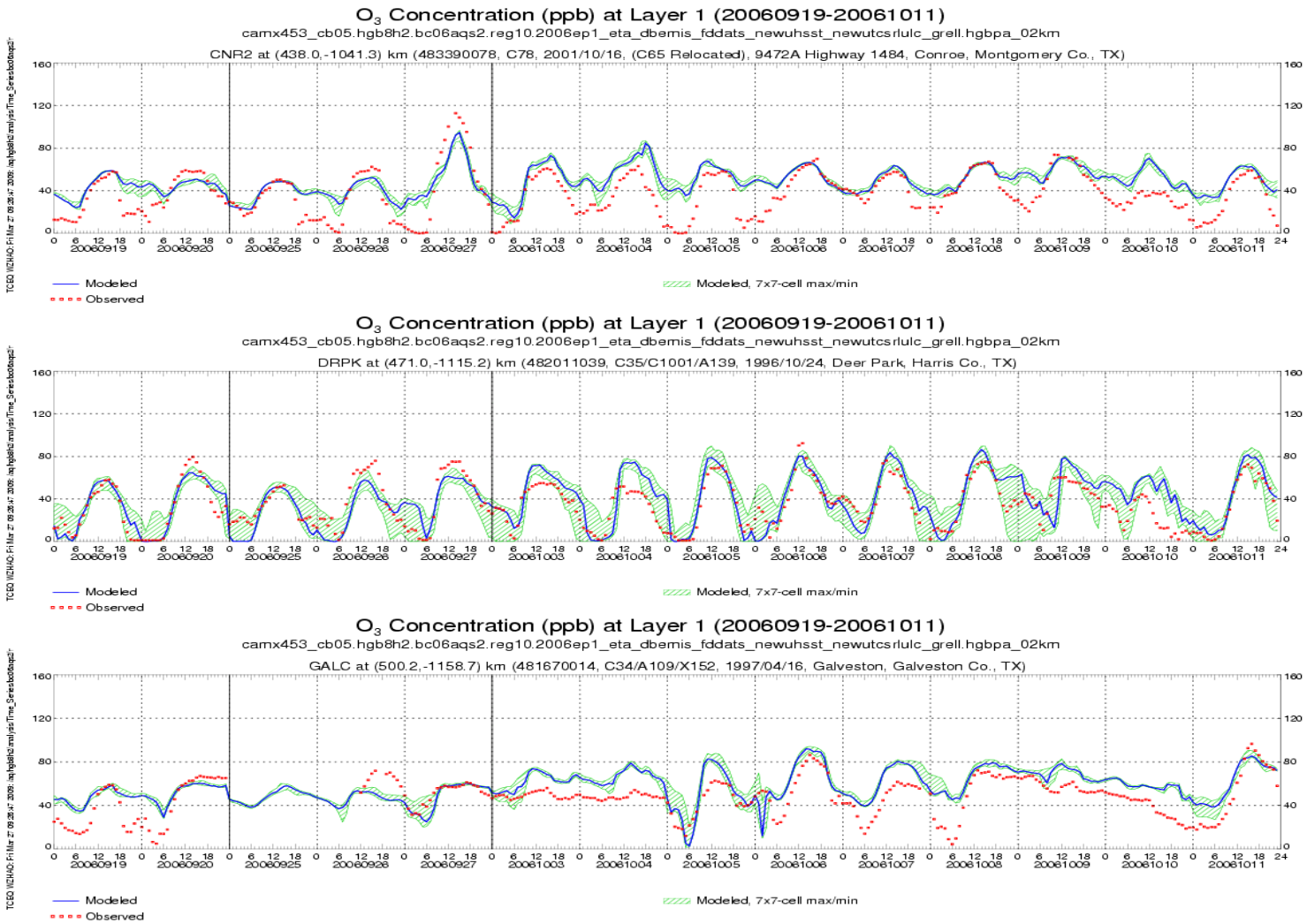


Figure 3-35: Time Series of Hourly Ozone Concentrations for Episode bc06aqs2 at the CNR2, DRPK, and GALC Monitors

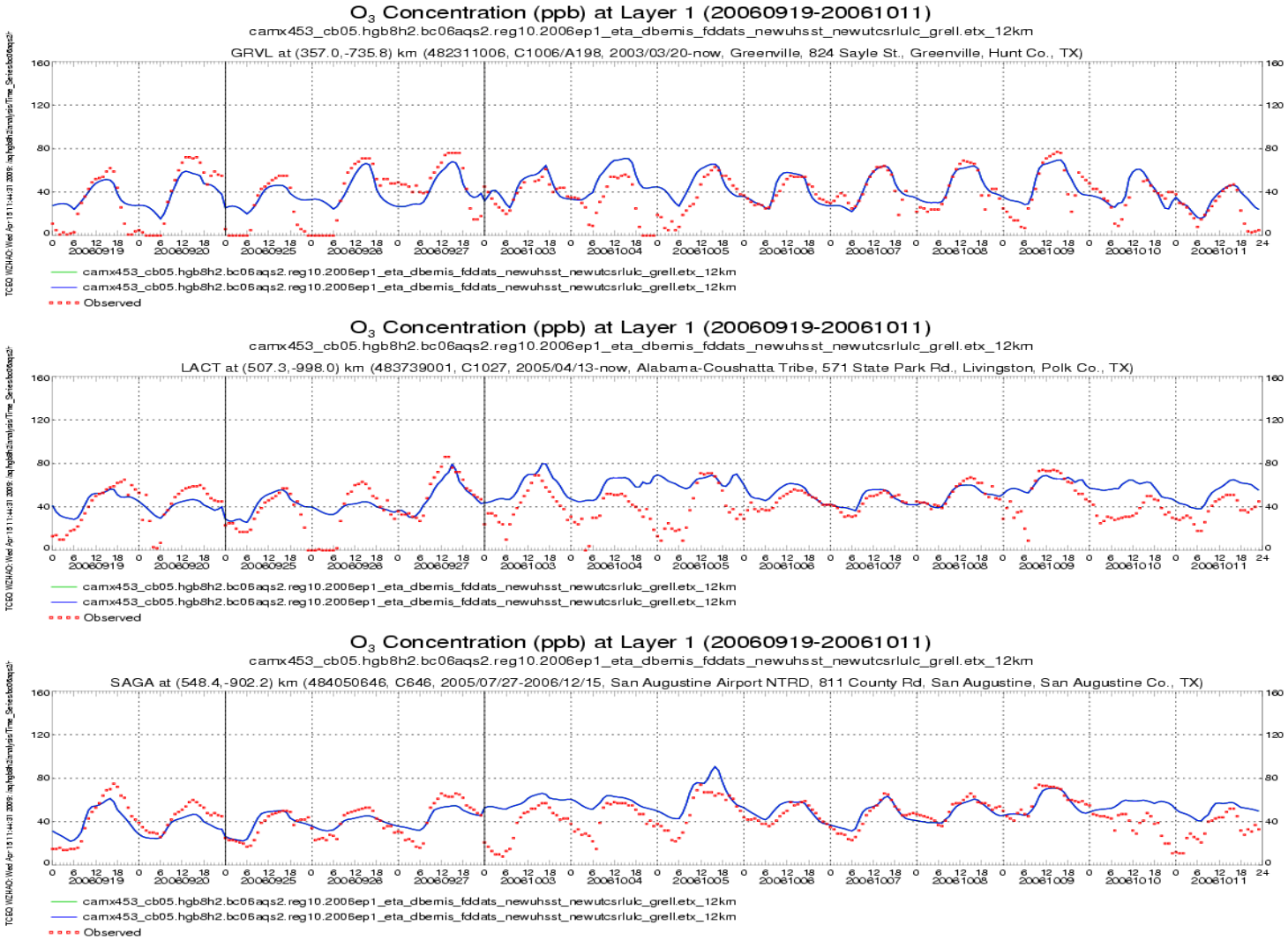


Figure 3-36: Time Series of Hourly Ozone Concentrations for Episode bc06aqs2 at the GRVL, LACT, and SAGA Rural Monitors

Scatter plots for the bc06aqs2 episode comparing the hourly measured and modeled concentrations at the Deer Park (CAMS 35) monitor are shown in Figure 3-37: *Scatter Plots of Hourly Ozone, NO_X, ETH, and OLE at the DRPK Monitor for the bc06aqs2 Episode.* As shown, there is a favorable comparison for the mid-range and higher ozone concentrations, with a slight tendency for the model to over-predict the measured concentrations. The model tends to generally over-predict the NO_X concentrations. The QQ plot for ETH indicates a favorable comparison between the measured and modeled distributions, although the model tends to over-predict the lower concentrations and under-predict the higher ETH concentrations. The model tends to under-predict the lower range of OLE concentrations with considerable scatter in the higher concentrations.

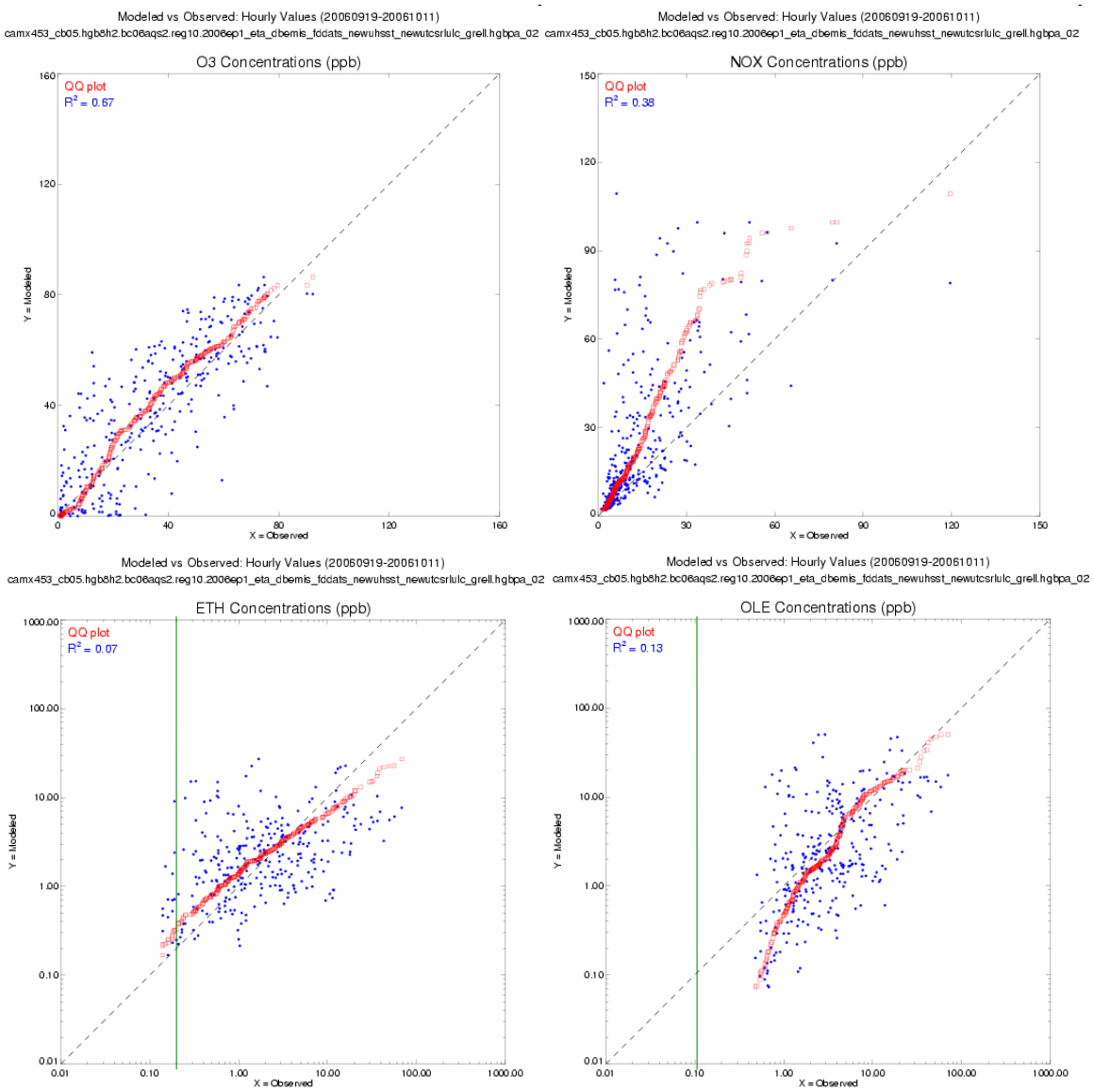


Figure 3-37: Scatter Plots of Hourly Ozone, NO_X, ETH, and OLE at the DRPK Monitor for the bc06aqs2 Episode

Tile plots of daily maximum eight-hour ozone concentrations for September 20, September 27, October 6, and October 11, 2006, are shown in Figure 3-38: *Tile Plot of Daily Maximum Eight-Hour Ozone Concentrations for September 20 and 27, and October 6 and 11, 2006*. The model replicates the areas of highest eight-hour ozone for the selected days, with the exception of September 20, 2006, when the model under-predicts higher levels of daily maximum eight-hour ozone concentrations.

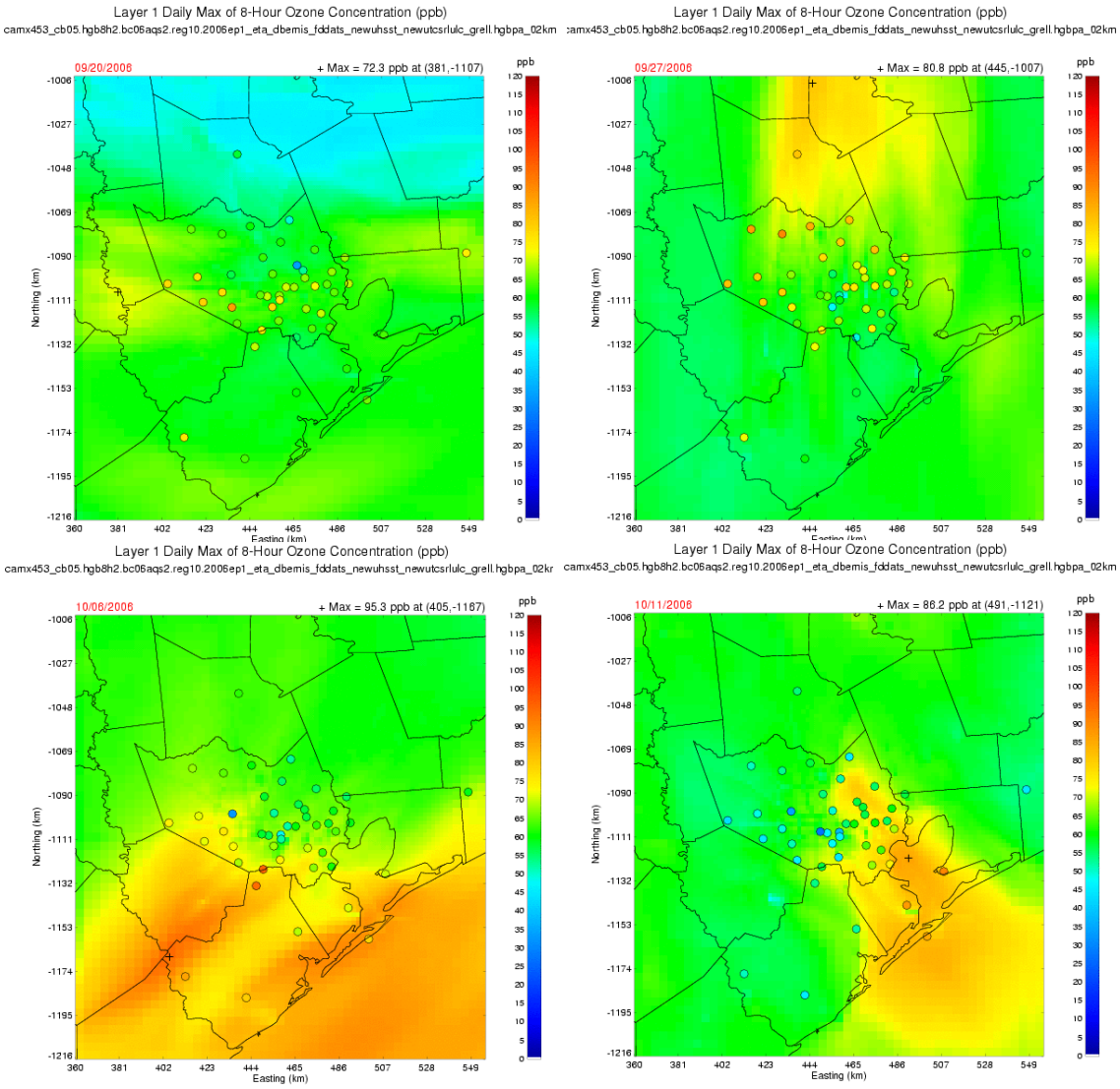


Figure 3-38: Tile Plot of Daily Maximum Eight-Hour Ozone Concentrations for September 20 and 27, and October 6 and 11, 2006

Overall, the graphical evaluation of model performance at key monitors on key episode days indicates the modeling adequately replicates the features that produced high ozone during this episode.

Evaluations Based on TexAQS II Data

Appendix C: *Photochemical Modeling for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard* includes extensive comparisons of model predictions with observations collected by the many platforms employed during TexAQS II. This section provides general descriptions of the major sampling platforms employed and presents highlights of some of the conclusions reached based on these comparisons. In graphics comparing TexAQS II observations with modeled output, observational data are typically labeled as mixing ratios,

which report moles of the pollutant per mole of ambient air. In practical terms, the term mixing ratio is synonymous with concentration in units of parts per billion by volume (ppbv).

Rural Monitoring Network

The TexAQS II study included a number of additional monitoring sites, which began collecting data in the summer of 2005 and continued until late October, 2006. During the TexAQS II intensive period, August 1 through October 15, 2006, a total of nine additional ozone monitors had been deployed in rural areas. Two of these additional monitors, located near the Texas-Oklahoma border, were the SAGA monitor, which collected NO_X in addition to ozone, and the CLVL monitor, which also collected NO_X as well as total reactive nitrogen (NO_Y). A full discussion of model performance at these and other rural monitors is provided in Appendix C: *Photochemical Modeling for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard*.

National Oceanic and Atmospheric Administration (NOAA) WP3-3D Orion

The NOAA WP-3D (P3) flew missions in the area between August 31 and October 13, 2006, and sampled many species not routinely monitored, including formaldehyde, NO_Y, nitric acid, and a suite of reactive hydrocarbons. Figure 3-39: *Comparison of Modeled and P3 Observed Ozone (O_3), August 31, 2006, 14:16 to 15:33 CST*, illustrates the flight of August 31, 2006, as the aircraft first arrived from Florida. The top two panels compare observed and modeled ozone concentrations (referred to on the plots as mixing ratio) along the flight track, while the bottom two compare the observed and modeled concentrations as a time series and a scatter plot superimposed with a QQ plot. The results are consistent with Figure 3-34: *Tile Plot of Daily Maximum Eight-Hour Ozone Concentrations for August 17 and 31, and September 1 and 7, 2006*, which showed that the model correctly placed the highest ozone concentrations geographically, but did not replicate the magnitude of the highest observations at the surface. The P3 flight shows that at the elevation of the aircraft, around 500 meters above ground level (AGL), the model also replicated the position of the highest ozone concentrations, but, as above, the model did not replicate the high concentrations seen in western Harris County.

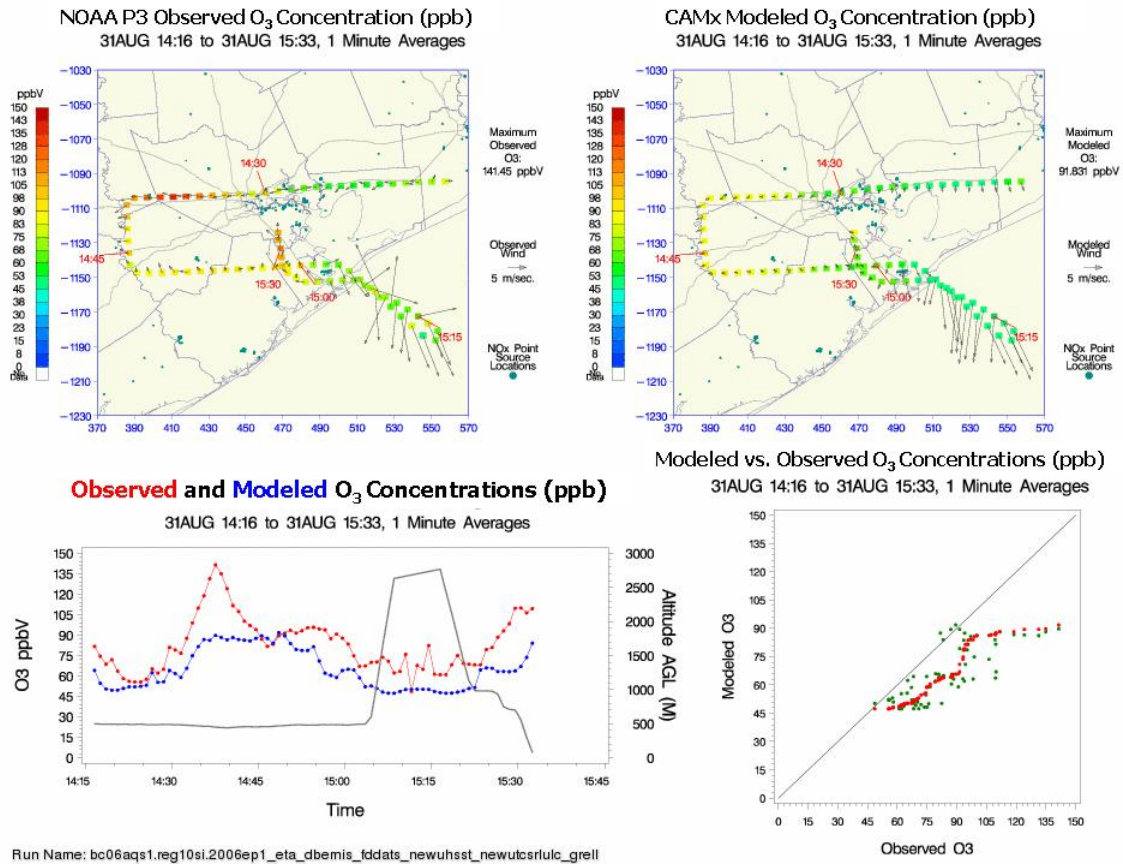


Figure 3-39: Comparison of Modeled and P3 Observed Ozone (O_3), August 31, 2006, 14:16 to 15:33 CST

The model's under-prediction of the highest observed ozone concentrations was common throughout most of the flights. A detailed discussion of model comparisons with P3 data can be found in Appendix C: *Photochemical Modeling for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard*. Some of the conclusions reached are that the model usually replicated the winds observed by the P3 well and even in cases where it showed a directional bias, usually placed the highest ozone concentrations in about the right location. The model reproduced the observed NO_X concentrations well, but over-predicted CO. Most hydrocarbon species were under-predicted by the model, even after the HRVOC reconciliation, as was formaldehyde on most occasions. Isoprene concentrations were generally modeled well, but some high modeled isoprene concentrations did not match the observations.

NOAA Twin Otter Tunable Optical Profiler for Aerosol and oZone (TOPAZ)

A second NOAA aircraft, a Twin Otter, carried a downward-looking lidar tuned to ozone and aerosol loading called TOPAZ. Data from this instrument were valuable because they allowed modeled ozone to be compared with measurements vertically up to 3,000 meters AGL. The instrument was flown on 13 missions between August 15 and September 13, 2006. The top two panels of Figure 3-40: *TOPAZ-Observed and Modeled Ozone Concentrations on August 31, 2006* compare observed and measured ozone concentrations between 255 and 377 meters AGL, which is the fifth vertical modeling layer. The lower plots are ozone curtains, showing ozone concentrations from the surface up to the aircraft elevation along the entire flight path and show that at around 15:00 the under-prediction carried upwards to over 1,500 meters. The TOPAZ concentrations near the surface are highly variable and may include contamination from surface features and thus, may not accurately reflect ozone concentrations within the first 200 meters.

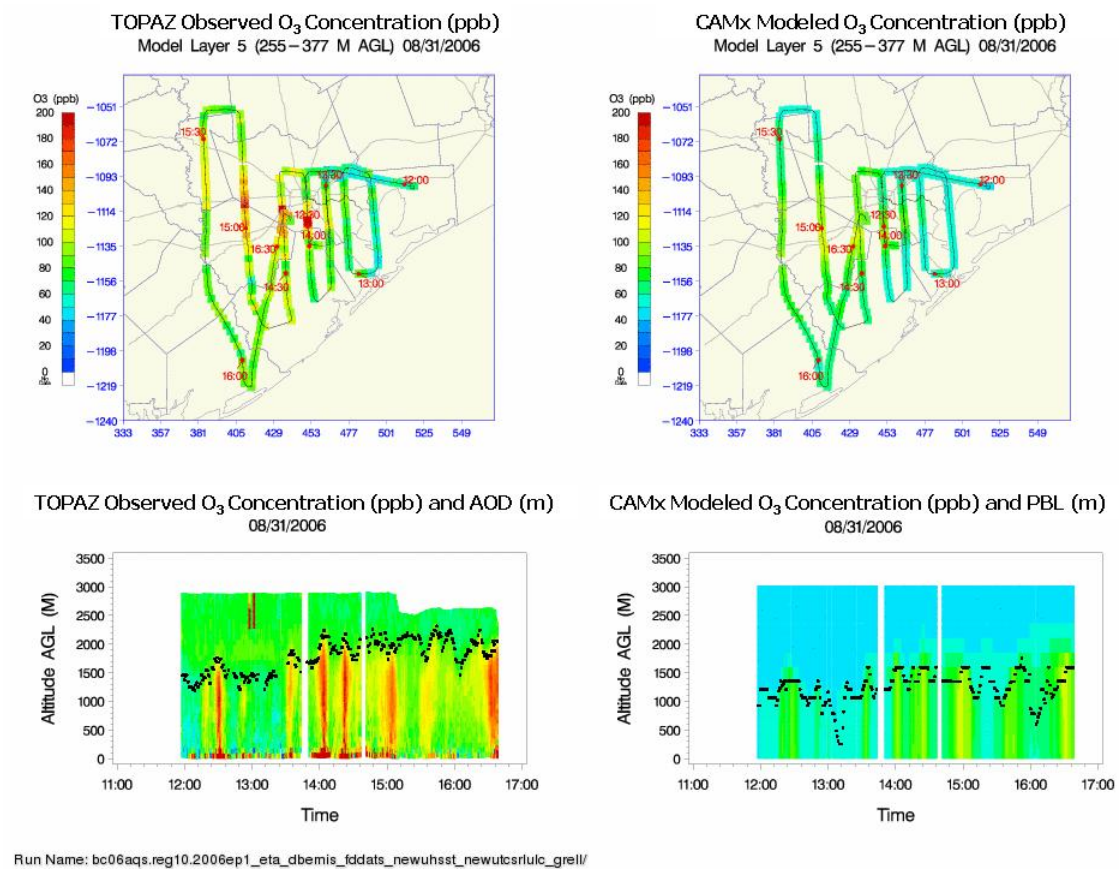


Figure 3-40: TOPAZ-Observed and Modeled Ozone Concentrations on August 31, 2006
Note: The color scales on the lower plots are the same as those on the top row.

Like the P3, the TOPAZ also showed that the model usually placed the highest ozone concentrations in the correct location, but generally under-predicted the observed peak concentrations. A comparison between the TOPAZ measurements of ozone concentration with those made by the P3 (the two flew together on only two days), showed relatively good agreement. The TOPAZ measured ozone concentrations above the mixed layer on most days that were notably higher than the model predicted.

The Research Vessel (RV) Ronald H. Brown

The NOAA RV Ron Brown arrived in the HGB area on August 15, 2006, and collected data until its departure on September 13. The ship carried a wide array of sampling platforms onboard and provided extensive data collected in the Gulf of Mexico, Galveston Bay, and in the Houston Ship Channel. Figure 3-41: *Comparison of Ozone Concentrations Observed by the RV Ron Brown with Modeled Concentrations, August 31, 2006, 08:00 to 16:30*, compares observed and modeled ozone for the period from 8:00 to 16:30 on August 31. The ship sailed from Barbour's Cut into the Gulf of Mexico, and then along the coast to near Freeport. This figure shows that the model predicted the observed concentrations of ozone very well from Barbour's Cut to Galveston and then showed a brief period of over-prediction as the observed concentrations dipped between 11:00 and 12:00. The decrease in measured ozone concentrations coincided with a period of very high NO_X concentrations observed in the channel between Galveston Island and Bolivar Peninsula. The observed NO_X was probably emitted by local ship traffic and likely reduced the ozone concentrations through titration. As the ship sailed into the Gulf of Mexico, it measured unusually high ozone concentrations moving onshore, which the model under-predicted. This under-prediction may be the result of long-range transport or of model boundary conditions that are too low on this day. As an alternative, the under-prediction may have resulted from air advected out into the Gulf of Mexico the previous day from the Houston or Beaumont areas.

More often, the ship encountered low ozone concentrations in the Gulf of Mexico, particularly under southerly wind conditions, which the model often over-predicted.

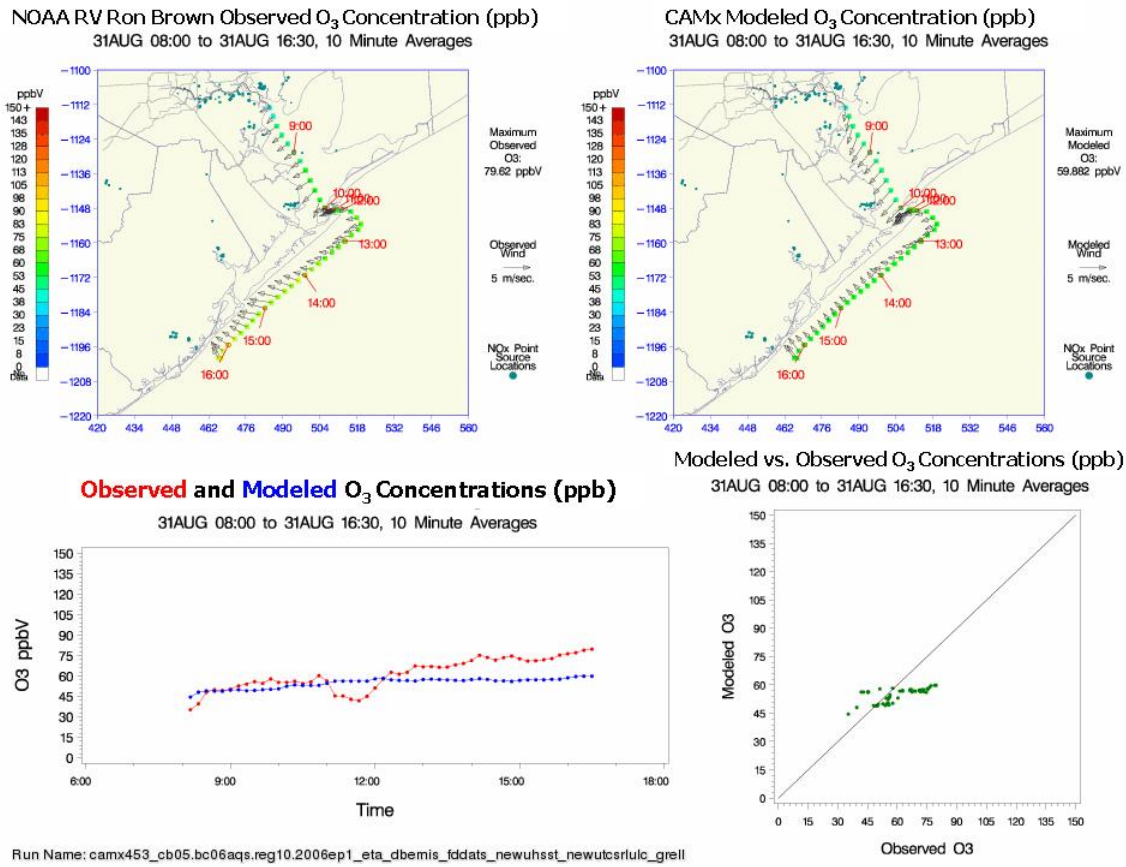


Figure 3-41: Comparison of Ozone Concentrations Observed by the RV Ron Brown with Modeled Concentrations, August 31, 2006, 08:00 to 16:30

Ozone Sondes

A number of ozone sondes, lightweight and compact balloon-borne instruments, were launched from the University of Houston (UH) campus southeast of downtown Houston and also from the deck of the RV Ron Brown in 2006. Ozone monitors attached to these balloons provide an opportunity to evaluate the model's vertical ozone distribution. Figure 3-42: *Comparison of Modeled and Observed Vertical Ozone Profiles from Two Sonde Launches at UH Campus and One Sonde Launch from the RV Ron Brown in the Gulf of Mexico, August 31, 2006,* shows three vertical ozone profiles measured by sondes launched from the UH campus on August 31, 2006, compared with modeled concentrations on that day. The left-hand panel shows that for the morning (6:00 a.m.) launch from the UH campus, ozone concentrations fluctuated with altitude within the first 1,500 meters. This effect may not represent actual variability in concentrations, however, since the measurements made by the sondes launched from UH were susceptible to interference by sulfur dioxide (SO_2); each molecule of SO_2 encountered by the instrument effectively cancels out one molecule of ozone. Because there are numerous SO_2 sources relatively close to the UH campus, it is very likely that the balloon may have encountered one of these plumes during ascent.

Aside from the fluctuations, the model replicated ozone concentrations reasonably well up to around 1,200 meters. The model under-predicted ozone concentrations up to about 5,000 meters, but predicted concentrations fairly well above that altitude. At 12:29 p.m. (center panel), the model slightly over-predicted ozone concentrations near the surface, but observed ozone concentrations increased dramatically within the first 100 meters or so to 30 ppb greater than

modeled concentrations. Unlike the notches seen in the morning launch, this effect is most likely caused by ozone scavenging by nearby NO_X sources, probably vehicular traffic. More significantly, after the first few meters, the model continued to under-predict observed ozone concentrations up to 4,000 meters.

The right-hand panel of Figure 3-42: *Comparison of Modeled and Observed Vertical Ozone Profiles from Two Sonde Launches at UH Campus and one Sonde Launch from the RV Ron Brown in the Gulf of Mexico, August 31, 2006* shows ozone concentrations observed (red line) and modeled (blue line) for a sonde launch from the deck of the RV Ron Brown, coincident with the 12:29 p.m. launch from the UH. In this case, the model initially over-predicted ozone concentrations near the surface by 15 ppb, but within the first 100 meters or so the sonde recorded a drop in ozone concentrations, followed by a rapid rise. This feature is probably due to the balloon encountering sulfate emissions from a ship plume, possibly from a passing ship or from the RV Ron Brown. The modeled and observed profiles crossed at about 1,200 meters, and then the observations exceeded the model by 10 to 20 ppb up to 4,000 meters. Farther above, the observations oscillated around the modeled values.

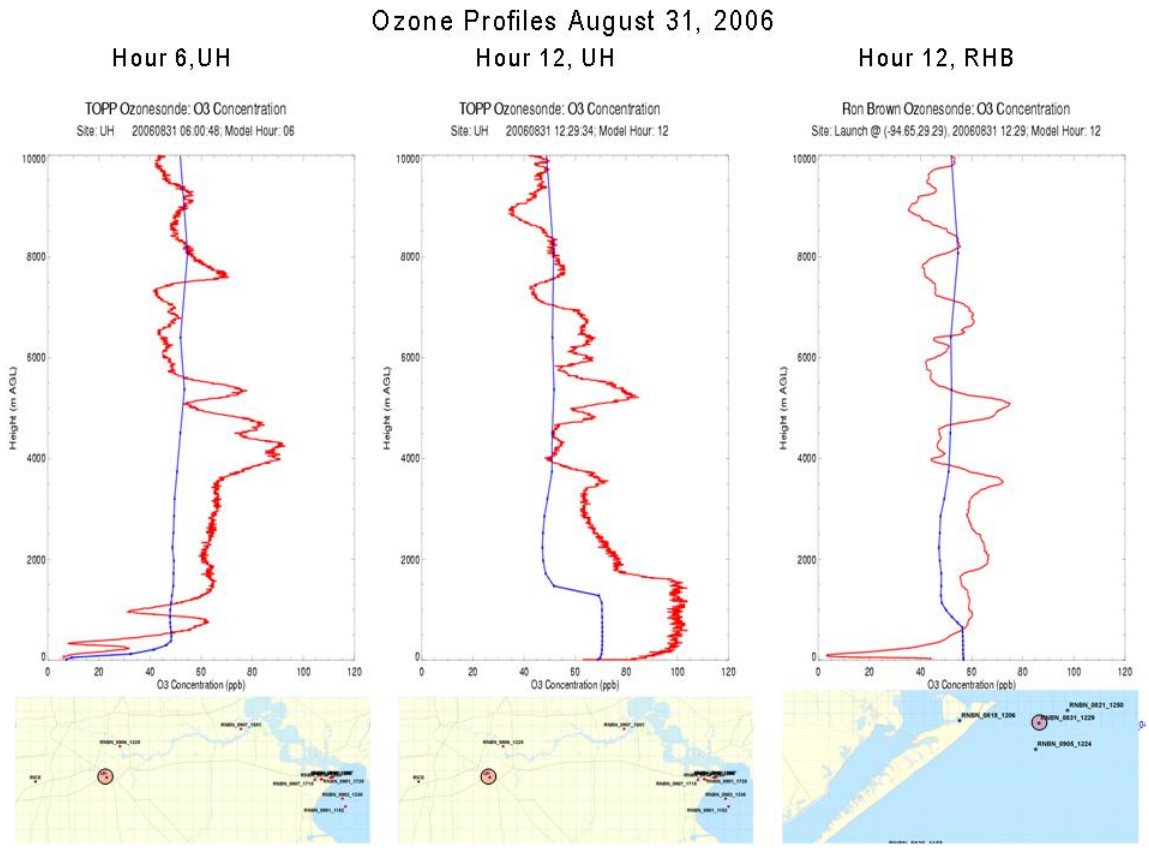


Figure 3-42: Comparison of Modeled (Blue Line) and Observed (Red Line) Vertical Ozone Profiles from Two Sonde Launches at UH Campus and One Sonde Launch from the RV Ron Brown in the Gulf of Mexico, August 31, 2006
Notes: TOPP = Tropospheric Ozone Pollution Project
RHB = Ronald H. Brown

Moody Tower

The Moody Tower site is located atop a dormitory on the UH campus southeast of downtown Houston. The site is useful because it is located 60 meters AGL (in model layer 2), hence is insulated from some of the more localized emission sources. Much of the Moody Tower data has been incorporated into the standard model performance evaluation processing performed at the

TCEQ for surface sites, with special provisions to use modeled concentrations from layer 2 instead of layer 1. Within this framework, the Moody Tower data offers measurements of some atmospheric constituents explicitly tracked in the CB05 mechanism, including nitric acid, nitrous acid, and formaldehyde. In addition, researchers at this site collected a wealth of information on radicals associated with photochemical ozone production. These data are used in conjunction with CAMx Chemical Process Analysis in Section 5.1: *QUANTITATIVE CORROBORATIVE ANALYSIS* of this document.

Other TexAQS II Data

During TexAQS II, formaldehyde data were collected at two sites, Lynchburg Ferry (LYNF; CAMS 603) and Houston Regional Monitor-3 (H03H; CAMS 1015). These data have been incorporated into the TCEQ model performance evaluation database and are being used in routine comparisons between modeled and observed concentrations.

Some additional TexAQS II data have not yet been used for model performance evaluation because they were not yet available in a usable form, but may be useful in the future. These data sources include the Houston Triangle project, the Baylor Aztec flights, the Solar Occultation Flux (SOF) measurements, "smart" balloon data, Differential Optical Absorption Spectroscopy (DOAS) observations, and satellite observations.

3.5.4.3 Diagnostic Evaluations

Since future design values are based on the model's relative response and not on the magnitude of its future case ozone predictions, evaluating the model's response to emission changes becomes at least as important as evaluation of its ability to reproduce historically observed events. The EPA modeling guidance recommends several possible means of assessing model response to emission changes. However, most of these methods are either indirect (probing tools, alternative base cases, most observation-based models) or are difficult to employ in practice (retrospective analyses). In this section the TCEQ employs three tests to evaluate the model's response to emission changes. The first of these is a sensitivity analysis designed to test the model's response to a hypothetical inventory change, specifically, an increase in emissions from flares. The second test is a retrospective analysis that uses an existing 2000 baseline inventory to test the model's ability to predict ozone design values in a previous year. The third, a weekday-weekend analysis, is based on observational modeling designed to assess an area's VOC- or NO_X-sensitivity.

Flare Sensitivity Modeling

The TCEQ has been evaluating flares as a potential source of underreported VOC emissions since TexAQS 2000. Flare monitoring requirements in the HRVOC rules in 30 TAC Chapter 115, Subchapter H, Division 1, were adopted in 2002 and designed to provide more accurate information on HRVOC and total flow rate to the flares. More recently, the TCEQ has been evaluating potential issues with the destruction efficiencies used to calculate emissions from flares. Due to the open combustion nature of flares, direct measurement of flare emissions or verification of flare destruction efficiencies is problematic. Remote sensing technologies such as differential absorption lidar (DIAL) can be used to estimate flare emissions and destruction efficiency. Recent work with DIAL during TexAQS II indicated destruction efficiencies on an actual industrial flare were less than assumed for emissions reporting purposes. However, the use of such remote sensing technology is expensive and currently limited to research activities. Therefore, companies must still use an assumed destruction efficiency to calculate VOC emissions from flares. Most companies assume a flare destruction efficiency of 98 to 99 percent, meaning the VOC emission rate is only 1 or 2 percent of the VOC mass rate sent to the flare. These assumptions are based on a small number of controlled studies conducted in the early 1980s and may not represent flare operations in real-world conditions. Furthermore, the chemistry that occurs within the flare flame is not well-understood in the majority of situations. Products of incomplete combustion may be formed and emitted from flares in addition to uncombusted VOC from the material sent to the flares. Some researchers have speculated that

flares could emit formaldehyde in sufficient quantities to significantly enhance photochemical reactivity in the flare plumes (Castineira and Edgar, 2006; Robinson et al., 2008).

To study the sensitivity of the model to potential unaccounted-for flare emissions, a model run was conducted in which flare emissions were increased ten-fold (10X). This is equivalent to reducing assumed flare destruction efficiency from 99 percent to 90 percent. At the same time, the potential source contribution function (PSCF)-based HRVOC reconciliation was removed. The net effect on emissions was to replace the ground-level HRVOC emissions with 321.6 tpd of elevated flare VOC, of which 87.9 tpd is HRVOC.

Figure 3-43: *Comparison of P3 Measurements (in ppb) with Base Case and Enhanced Flare Emissions; observed ethylene, formaldehyde, and ozone compared to modeled concentrations using the base case inventory, and (right) the base case inventory with 10X flare VOC emissions, minus the HRVOC reconciliation* compares (A) modeled ETH, (B) formaldehyde (FORM), and (C) ozone concentrations with observations made on the NOAA WP-3D Orion aircraft during TexAQS II, inside the 2 km HGB modeling grid. In each row, the left-hand panel shows the comparison using the 2005-2006 base case modeling inventory, while the right-hand panel shows a similar comparison using the inventory with the ten-fold increase in flare VOC emissions (and concurrent removal of the HRVOC reconciliation discussed earlier in Section 3.4.2.1: *Point Sources*). The green dots represent actual data pairs. The red dots are plotted by matching the smallest observed value with the smallest modeled value, then the next smallest of each, and so on. The resulting QQ plot provides a means to compare the two distributions; if it lies close to the diagonal line, then the model is simulating the correct proportions of small, medium, and large concentrations of the pollutant.

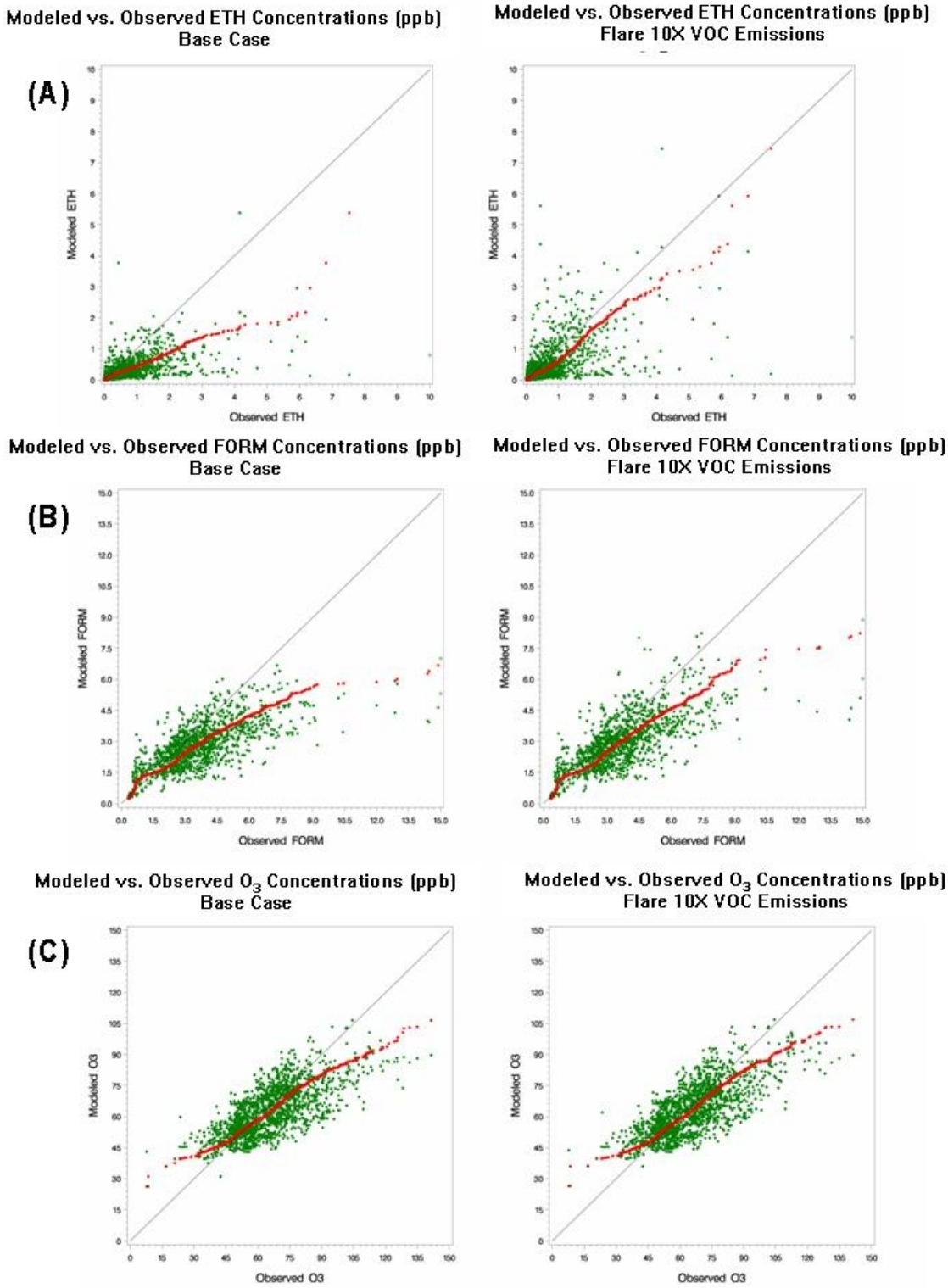


Figure 3-43: Comparison of P3 Measurements (in ppb) with Base Case and Enhanced Flare Emissions; observed ethylene (Panel A), formaldehyde (Panel B), and ozone (Panel C) compared to modeled concentrations using (left) the base case inventory, and (right) the base case inventory with 10X flare VOC emissions, minus the HRVOC reconciliation

The flare sensitivity markedly improves the distribution of modeled ethylene concentrations compared with observations and also improves modeled formaldehyde and ozone concentrations, although the highest modeled ozone concentration remains at about 105 ppb compared with

observations ranging to near 145 ppb. This discrepancy is at least partly due to the incommensurability of the measurements: modeled values represent averages over one hour over a 2 km x 2 km region (also across a vertical depth depending on model layer), while the aircraft measurements are essentially single points in space and time. However, the 10X flare sensitivity modeling degrades performance for some pollutants at the surface, as illustrated in Figure 3-44: *Log-Log Plots of Observed vs. Modeled Ethylene at Deer Park September 19 through October 11, 2006; with base case inventory, and base case inventory with 10X flare emissions minus the HRVOC reconciliation*, which compares modeled and observed ozone concentrations at Deer Park to base case and 10X flare emissions (note that these plots use a log-log scale; blue dots represent observed-modeled pairs, and red dots indicate the QQ plot).

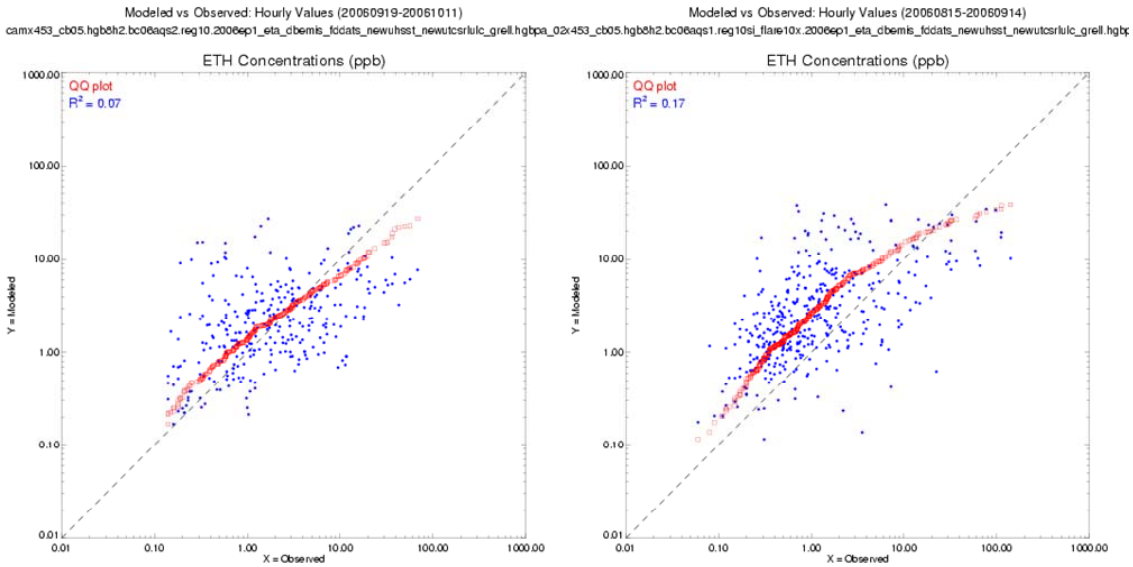


Figure 3-44: Log-Log Plots of Observed vs. Modeled Ethylene at Deer Park September 19 through October 11, 2006; with (Left) base case inventory, and (Right) base case inventory with 10X flare emissions minus the HRVOC reconciliation

Figure 3-45: *Daily Peak Modeled Eight-Hour Ozone Concentrations with Base Case Inventory and 10X Flare Inventory; the difference between the two plots (Flare 10X – Reg 10) is shown at right* shows the effect of the 10X flare VOC increase on eight-hour peak ozone concentrations on October 6, 2006. The ozone plume, while still under-estimated, clearly matches the observed surface concentrations better with the 10X flare inventory (center) than the base case inventory (left). Observed eight-hour peak ozone concentrations are shown as small circles at the monitor locations.

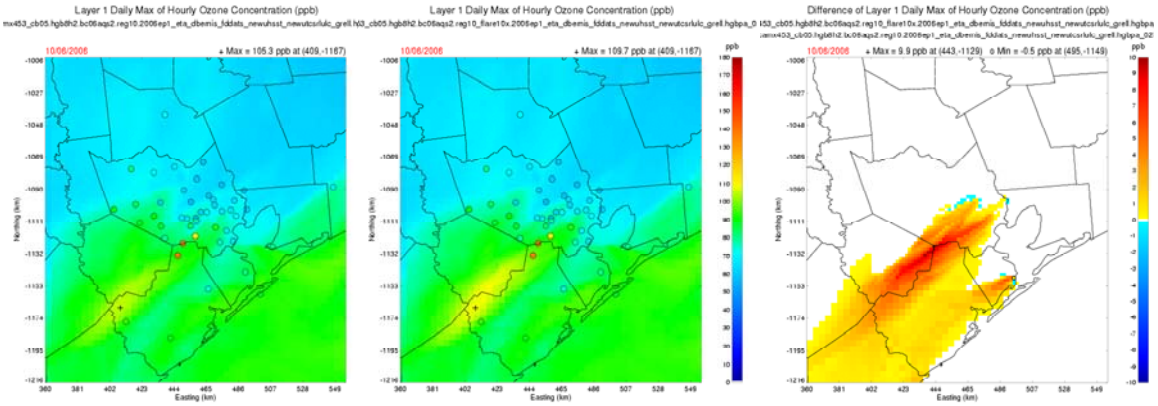


Figure 3-45: Daily Peak Modeled Eight-Hour Ozone Concentrations with Base Case Inventory (Left) and 10X Flare Inventory (Center); the difference between the two plots (Flare 10X – Reg 10) is shown at right

In addition to the 10X VOC sensitivity, the TCEQ ran a sensitivity in which only HRVOC emissions from flares were increased (also 10X). A third sensitivity further modified the 10X HRVOC sensitivity to add a formaldehyde boost equal to 10 percent of the added HRVOC emissions. Results of these sensitivities can be found in Appendix C: *Photochemical Modeling for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard*.

More work is needed to determine whether a flare adjustment is superior to the surface-level reconciliation currently in use. The TCEQ plans to investigate using a PSCF-based technique applied to flare emissions in the near future.

Retrospective Modeling – 2000 Backcast

The purpose of this diagnostic analysis is to test the model in a forecast (in this case, backcast) mode, where the answer is known in advance. Retrospective modeling is usually difficult to implement in practice because of the need to create an inventory, but a 2000 inventory was already available. In this test, most of the 2006 baseline inventory was replaced with a baseline inventory previously developed for the 2000 ozone episode used in prior SIP revisions. However, the episode day-specific biogenic emissions for the 2005 and 2006 episodes were not replaced, as is also the practice when modeling a future base emissions inventory. Similarly, the 2005 and 2006 meteorology was used with the 2000 baseline emissions as is the procedure when modeling with the future emissions.

Since the model predictions of a typical future design value is based on a DV_B, which is the average of three regulatory design values (EPA, 2007), the quantity forecast in this test is not a specific future year's design value but rather the average of three years. Thus, the regulatory design values for 2000, 2001, and 2002 were averaged in the same manner as the 2006 DV_B was calculated as the average of the 2006, 2007, and 2008 regulatory design values. Table 3-16: *2000 Baseline Design Values Calculation for Retrospective Analysis* shows the calculation. Only monitors that had at least one regulatory design value in both the 2000 through 2002 and the 2006 through 2008 periods were used.

Table 3-16: 2000 Baseline Design Values Calculation for Retrospective Analysis

Modeling Site Code	CAMS Number	Eight-Hour DV (ppb)			2000 Baseline DV (ppb)
		2000	2001	2002	
BAYP	53	111	110	100	107.0
C35C	403	101	97	93	97.0
DRPK	35	112	108	103	107.7
GALC	34	108	98	89	98.3
HALC	8	111	108	107	108.7
HCQA	409	110	104	102	105.3
HLAA	408	96	91	83	90.0
HNWA	26	108	105	101	104.7
HOEA	1	102	103	101	102.0
HROC	95	-	-	95	95.0
HSMA	406	106	93	90	96.3
HWAA	405	105	98	89	97.3
SHWH	410	102	104	95	100.3

Once the model was run with the 2000 baseline emissions, RRFs were calculated. In a retrospective analysis, most of the RRFs are expected to be greater than 1 because ozone has decreased since the retrospective year. Table 3-17: *2000 Projected DVs Compared with Calculated DVs (in ppb)* shows the calculated RRFs and the respective projected 2000 design values, compared with those listed in Table 3-16: *2000 Baseline Design Values Calculation for Retrospective Analysis*.

Table 3-17: 2000 Projected DVs Compared with Calculated DVs (in ppb)

Modeling Site Code	CAMS Number	2006 Baseline DV	2006-to-2000 RRF	Projected 2000 DV	Baseline 2000 DV
BAYP	53	96.7	1.11	107.0	107.0
C35C	403	79.0	1.18	93.5	97.0
DRPK	35	92.0	1.18	108.1	107.7
GALC	34	81.7	1.11	90.7	98.3
HALC	8	85.0	1.15	97.9	108.7
HCQA	409	87.0	1.13	98.6	105.3
HLAA	408	77.7	1.11	86.4	90.0
HNWA	26	89.0	1.13	100.4	104.7
HOEA	1	80.3	1.17	94.0	102.0
HROC	95	79.7	1.15	91.6	95.0
HSMA	406	90.3	1.16	104.8	96.3
HWAA	405	76.3	1.14	86.9	97.3
SHWH	410	92.3	1.11	102.9	100.3

For two sites, Houston Bayland Park (CAMS 53) and Deer Park (CAMS 35), the projections were identical, or nearly identical, to the calculated baseline values. For all other sites but one, the model-projected 2000 DVs were lower than the calculated values, indicating that the model

did not respond as well to emission changes as the actual airshed for these sites. In only one case did the model respond notably more strongly than the airshed, Swiss and Monroe (CAMS 406).

In conclusion, the modeled response generally was lower than the actual airshed's response to 2000-2006 emission changes. This conclusion gives confidence going forward that the model's predictions are conservative, and that future ozone concentrations may be even lower than predicted by the model.

Observational Modeling – Weekday/Weekend

Weekend emissions of NO_X in urban areas tend to be lower than weekday emissions because of fewer miles driven. The effect is most pronounced on weekend mornings, especially Sundays, since commuting is much lower than weekdays. In a detailed analysis presented in Appendix C: *Photochemical Modeling for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard* an analysis using episode-specific Wednesdays, Saturdays, and Sundays is described, but the results were rather inconclusive because of small sample sizes (15 Wednesdays and 11 each Saturdays and Sundays). A more comprehensive analysis was undertaken to simulate more of each day type; in three separate runs each episode day's modeled emissions were substituted with, Wednesday, Saturday, and Sunday emissions. These runs provided a total of 88 each Wednesdays, Saturdays, and Sundays.

For comparison, 6:00 a.m. NO_X concentrations were averaged for every Wednesday, Saturday, and Sunday between May 15 through October 15 in the years 2005 through 2008, which gives over 100 of each day (less for some monitors because of missing data). Figure 3-46: *Mean Observed NO_X Concentrations at HGB Monitors as a Percentage of Wednesday Mean Values, May 15 through October 15, 2005 through 2008* shows observed and modeled 6:00 a.m. NO_X concentrations at 15 sites in the HGB area. Except for anomalous behavior at Galveston Airport (CAMS 34), all monitors show observed and modeled NO_X concentrations that decline monotonically from Wednesday through Saturday to Sunday. The observed concentrations (excluding Galveston Airport (CAMS 34)) show similar percentage declines, but the modeled values have much greater variability, with sites in eastern Harris County (near the Ship Channel) showing the slowest declines. This effect could be due to the model mixing down industrial NO_X emissions too rapidly.

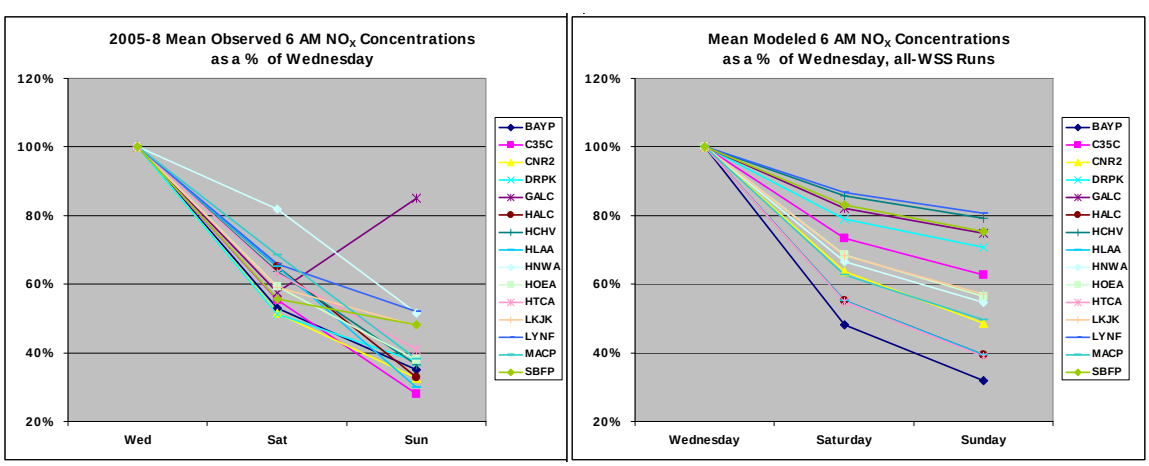


Figure 3-46: Mean Observed NO_X Concentrations at HGB Monitors as a Percentage of Wednesday Mean Values, May 15 through October 15, 2005 through 2008

Figure 3-47: *Observed and Modeled Daily Peak Eight-Hour Ozone Concentrations as a Percentage of Wednesdays* shows observed and modeled daily peak eight-hour ozone concentrations as a percentage of Wednesdays for the same sites. Because the modeled episodes represent periods of higher-than-average ozone concentrations, the observed concentrations were

filtered to remove values less than 40 ppb. The left-hand panel of the figure shows observed concentrations trending downward for nearly all sites, but some seem to rebound on Sunday and exceed the respective Saturday concentrations. This effect is probably due to filtering concentrations below 40 ppb, which removes very low concentrations from the average.

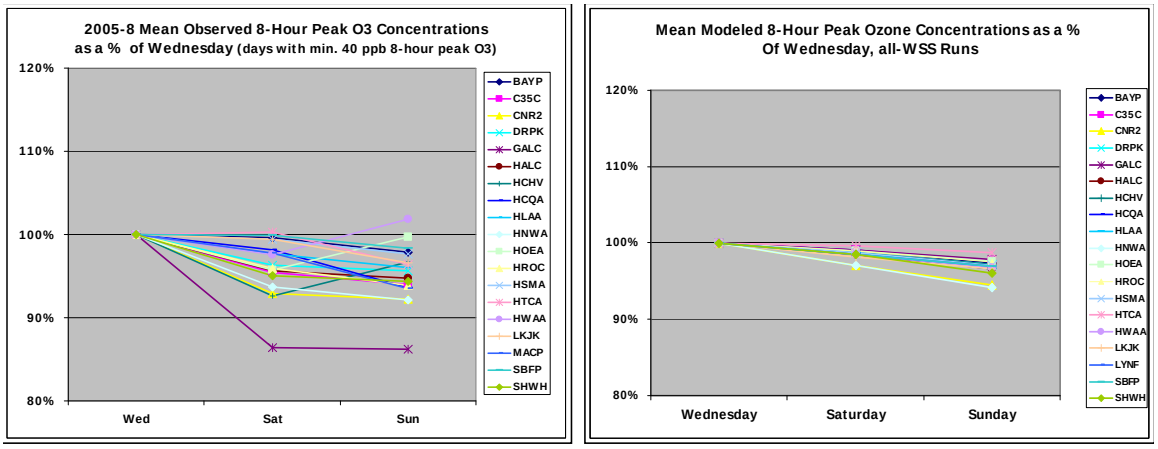


Figure 3-47: Observed and Modeled Daily Peak Eight-Hour Ozone Concentrations as a Percentage of Wednesdays

While the modeled concentrations are very tightly clustered in the figure, they universally decline from Wednesday through Saturday to Sunday, similar to the pattern shown by the observations (ignoring the anomalous rebound effect). The airshed and model both show sensitivity to NO_X reductions, at least for days with some ozone-forming potential. In fact, the airshed seems to show greater sensitivity to NO_X than the model, which suggests that anticipated reductions to motor vehicle emissions over the next several years may be more effective than suggested by the model.

3.6 BASELINE (2006) AND FUTURE CASE (2018) MODELING

3.6.1 2006 Baseline Modeling

The TCEQ selected 2006 as the baseline year for conducting the attainment modeling. Two features of the 2006 baseline year are used in the attainment modeling. First, the 2006 baseline year identifies the three consecutive years (2006, 2007, and 2008) with design values that include the fourth high of the 2006 baseline year. These three DVs are averaged to calculate the baseline design value (DV_B), as previously illustrated in Figure 3-1: *Baseline Design Value Calculation Illustration*. Second, typical 2006 ozone season day (OSD) emissions were developed, as previously summarized in Table 3-13: *Summary of 2006 Baseline and 2018 Future Base, and 2018 Control Strategy Anthropogenic Modeling Emissions for HGB*.

The typical 2006 OSD emissions were modeled for all episode days to calculate the denominator of the RRF for each of the regulatory monitors. The denominator of the RRF is the average of the modeled maximum daily eight-hour ozone concentrations for those days with modeled concentrations greater than or equal to 85 ppb, within a grid cell array about each monitor.

Figure 3-48: *Near Monitoring Site Grid Cell Array Size* shows a map of the 2 km subdomain nested in a portion of the 4 km x 4 km fine grid domain depicting the monitors, and the extent of 7 x 7, 5 x 5, and 3 x 3 grid cell arrays based on the 2 km grid. The TCEQ has calculated RRF values for each of these array sizes, but used a 7 x 7 grid array about each monitor. Non-regulatory, industry-sponsored monitors, Danciger (DNCG; CAMS 618), Haden Road (H03H; CAMS 603), Mustang Bayou (MSTG; CAMS 619), Texas City (TXCT; CAMS 620) and Wallisville Road (WALV; CAMS 617), were included since they reduce the unmonitored area. Including non-regulatory, industry-sponsored monitors that have a DV_B and a RRF denominator

greater than or equal to 85 ppb mitigates the need to conduct an unmonitored area analysis for the area represented by the monitors, as recommended by the EPA's modeling guidance.

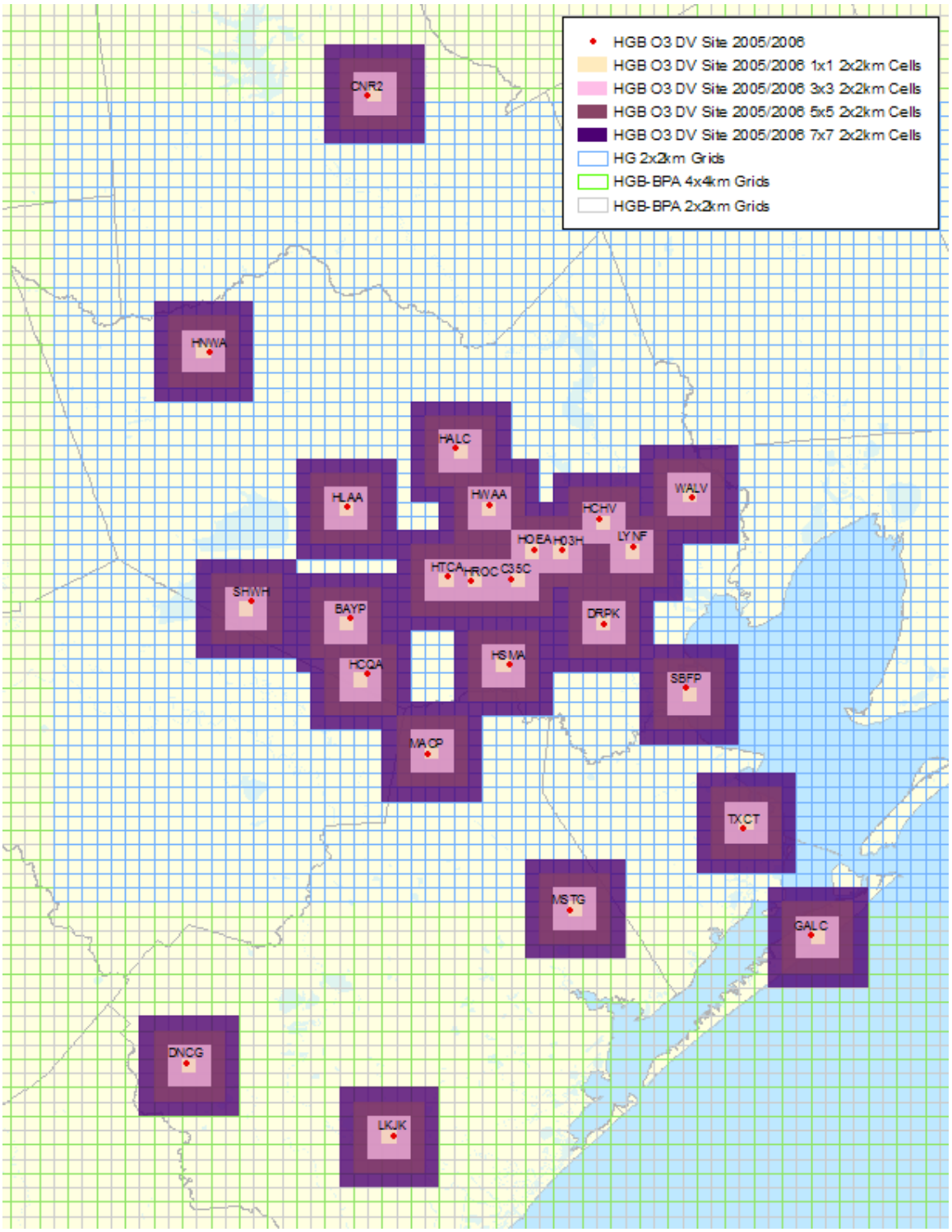


Figure 3-48: Near Monitoring Site Grid Cell Array Size

The monitor-specific denominator of the RRF is calculated as the average of the modeled daily maximum eight-hour ozone concentrations above 84 ppb at that monitor. Per the EPA's modeling guidance, if there are fewer than 10 days with 2006 baseline modeled concentrations greater than 84 ppb, then days with modeled concentrations less than or equal to 84 ppb can be used so the average is based on at least 10 days. Table 3-18: *2006 DV_B, RRF Denominator*

(RRF_D), and Number of 2006 Baseline Modeled Days Averaged summarizes the DV_B and the denominator of the RRF for the HGB regulatory and industry-sponsored monitors.

Table 3-18: 2006 DV_B, RRF Denominator (RRF_D), and Number of 2006 Baseline Modeled Days Averaged

Monitor Designation	Site Code	2006 DV_B (ppb)**	2006 RRF_D (ppb)	Modeled Days Averaged
Houston East (CAMS 1)	HOEA	80.3	96.842	19
Aldine (CAMS 8)	HALC	85.0	96.431	17
Channelview (CAMS 15)	HCHV	82.7	95.976	16
Northwest Harris County (CAMS 26)	HNWA	89.0	93.284	21
Galveston Airport (CAMS 34)	GALC	81.7	94.131	10
Deer Park (CAMS 35)	DRPK	92.0	95.083	19
Seabrook Friendship Park (CAMS 45)	SBFP	85.3	94.299	10
Houston Bayland Park (CAMS 53)	BAYP	96.7	97.626	25
Conroe Relocated (CAMS 78)	CNR2	83.0	90.728	10
TCEQ Houston Regional Office (CAMS 81)	HROC	79.7	95.742	23
Manvel Croix Park (CAMS 84)	MACP	90.7	93.920	24
Clinton (CAMS 403)	C35C	79.0	97.872	20
North Wayside (CAMS 405)	HWAA	76.3	96.149	19
Swiss and Monroe (CAMS 406)	HSMA	90.3	95.432	24
Lang (CAMS 408)	HLAA	77.7	96.908	25
Croquet (CAMS 409)	HCQA	87.0	95.778	26
Shell Westhollow (CAMS 410)	SHWH	92.3	100.694	22
Houston Texas Avenue (CAMS 411)	HTCA	79.3	96.311	24
Haden Road (CAMS 603)*	H03H	84.0	96.699	18
Wallisville Road (CAMS 617)*	WALV	92.0	94.232	13
Danciger (CAMS 618)*	DNCG	80.3	87.537	10
Mustang Bayou (CAMS 619)*	MSTG	84.7	93.761	11
Texas City (CAMS 620)*	TXCT	84.3	91.691	10
Lynchburg Ferry (CAMS 1015)	LYNF	81.7	94.503	17
Lake Jackson (CAMS 1016)	LKJK	77.0	88.239	10

* Non-regulatory, industry-sponsored monitor;
** Values 85 ppb or greater are shown in red.

3.6.2 Future Baseline Modeling

Similar to the 2006 baseline modeling, the 2018 modeling was conducted for each of the episode days using the projected 2018 ozone season day emissions, as previously summarized in Table 3-13: *Summary of 2006 Baseline and 2018 Future Base, and 2018 Control Strategy Anthropogenic Modeling Emissions for HGB*. Using the same days as used in the 2006 baseline modeling to calculate the RRF_D, an RRF numerator (RRF_N) was calculated as the average of the of the 2018 modeled maximum daily eight-hour ozone concentrations within the 7 x 7 grid cell array about each monitor. The RRF at each monitor was calculated as the ratio RRF_N / RRF_D, and the 2018 future design value (DV_F) at each monitor was estimated as per EPA's modeling guidance, by the multiplying the 2006 DV_B by the RRF. Table 3-19: *Summary of 2006 Baseline Modeling, RRF, and Future Design Values* summarizes the 2006 DV_B, RRF and 2018 DV_F at each of the regulatory and industry-sponsored monitors.

Table 3-19: Summary of 2006 Baseline Modeling, RRF, and Future Design Values

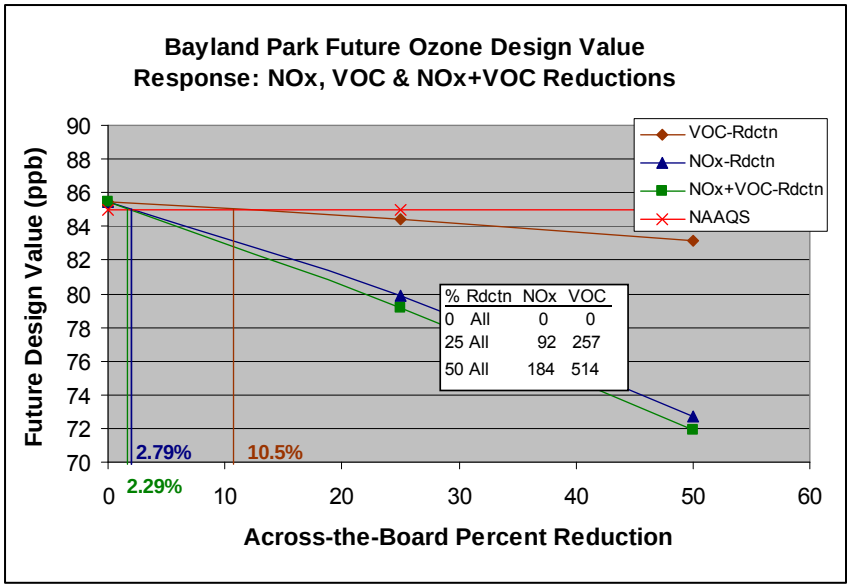
Monitor Designation	Site Code	2006 DV_B (ppb)**	RRF	2018 DV_F (ppb)**
Houston East (CAMS 1)	HOEA	80.3	0.935	75.1
Aldine (CAMS 8)	HALC	85.0	0.907	77.1
Channelview (CAMS 15)	HCHV	82.7	0.937	77.5
Northwest Harris County (CAMS 26)	HNWA	89.0	0.858	76.4
Galveston Airport (CAMS 34)	GALC	81.7	0.939	76.7
Deer Park (CAMS 35)	DRPK	92.0	0.940	86.5
Seabrook Friendship Park (CAMS 45)	SBFP	85.3	0.926	79.0
Bayland Park (CAMS 53)	BAYP	96.7	0.885	85.5
Conroe Relocated (CAMS 78)	CNR2	83.0	0.866	71.9
Houston Regional Office (CAMS 81)	HROC	79.7	0.945	75.3
Manvel Croix Park (CAMS 84)	MACP	90.7	0.882	80.0
Clinton (CAMS 403)	C35C	79.0	0.938	74.1
North Wayside (CAMS 405)	HWAA	76.3	0.917	70.0
Swiss and Monroe (CAMS 406)	HSMA	90.3	0.911	82.3
Lang (CAMS 408)	HLAA	77.7	0.876	68.0
Croquet (CAMS 409)	HCQA	87.0	0.883	76.8
Shell Westhollow (CAMS 410)	SHWH	92.3	0.844	77.9
Houston Texas Avenue (CAMS 411)	HTCA	79.3	0.929	73.7
Haden Road (CAMS 603)*	H03H	84.0	0.939	78.9
Wallisville Road (CAMS 617)*	WALV	92.0	0.940	86.5
Danciger (CAMS 618)*	DNCG	80.3	0.880	70.7
Mustang Bayou (CAMS 619)*	MSTG	84.7	0.892	75.6
Texas City (CAMS 620)*	TXCT	84.3	0.925	78.0
Lynchburg Ferry (CAMS 1015)	LYNF	81.7	0.948	77.5
Lake Jackson (CAMS 1016)	LKJK	77.0	0.891	68.6

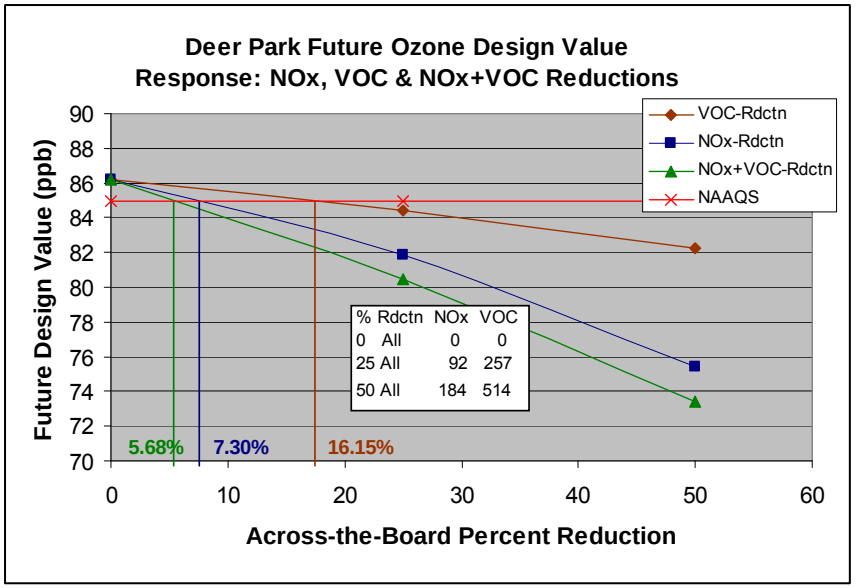
* Non-regulatory, industry-sponsored monitor;
** Values 85 ppb or greater are shown in red.

The 2018 baseline attainment modeling projects two regulatory monitors (BAYP (CAMS 53) and DRPK (CAMS 35)) and one non-regulatory, industry-sponsored monitor (WALV (CAMS 617)) to have DV_Fs greater than 84 ppb.

3.6.2.1 Matrix Modeling

A series of modeling sensitivities using across-the-board percentage reductions to the 2018 baseline modeling emissions from sources in the eight-county HGB area was conducted. The results of the modeling were used to estimate the amount of NO_X and/or VOC emissions reduction needed to reduce the DV_Fs for each of the three monitors to 85 ppb. Figure 3-49: *DV_F versus NO_X and/or VOC Emissions Reduction Response Curves for the BAYP, DRPK, and WALV Monitors* graphically shows the response of the DV_Fs for the BAYP (CAMS 53), DRPK (CAMS 35) monitors, and the WALV (CAMS 617) non-regulatory, industry-sponsored monitor to reductions in emissions of NO_X and/or VOC from sources in the eight-county HGB area.





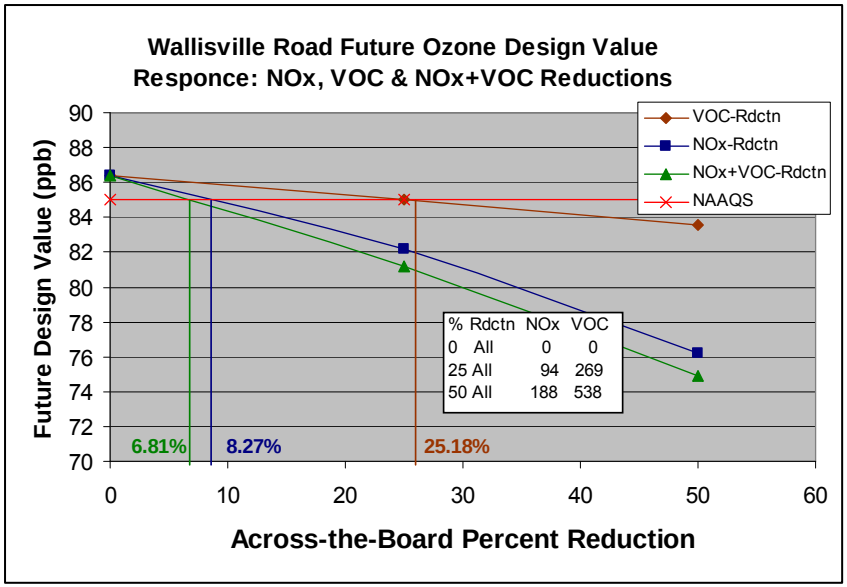


Figure 3-49: DV_F versus NO_X and/or VOC Emissions Reduction Response Curves for the BAYP, DRPK, and WALV Monitors

Table 3-20: *VOC, NO_X, and VOC+NO_X Emissions Reductions Needed to Model Attainment* summarizes the percent and mass emissions reductions projected to be needed to model attainment for the BAYP (CAMS 53), DRPK (CAMS 35) monitors, and the WALV (CAMS 617) non-regulatory, industry-sponsored monitor.

Table 3-20: VOC, NO_X, and VOC+NO_X Emissions Reductions Needed to Model Attainment

Monitor Site Code	VOC Reductions		NO_X Reductions		VOC + NO_X Reductions	
	Percent	Mass (tpd)	Percent	Mass (tpd)	Percent	Mass (tpd)
BAYP	10.5	108	2.79	10.2	2.29	31.9
DRPK	16.2	166	7.30	26.7	5.68	79.1
WALV	25.2	259	8.27	30.2	6.81	94.9

Note: WALV is a non-regulatory, industry-sponsored monitor.

3.6.2.2 Modeling Sensitivities: Emissions Reductions within 100 and 200 km of HGB

Since the EPA allows NO_X and VOC reduction credit for reasonable further progress within 200 km and 100 km of a nonattainment area, respectively, emissions reduction modeling sensitivities were conducted for selected point sources of NO_X and area sources of VOC in the 200 km adjacent to the eight-county HGB area. Figure 3-50: *Map of Counties within 100 km (Red) and 200 km (Orange) of the Eight-County HGB Area* displays a map of the counties within 100 km and 200 km of the HGB area.

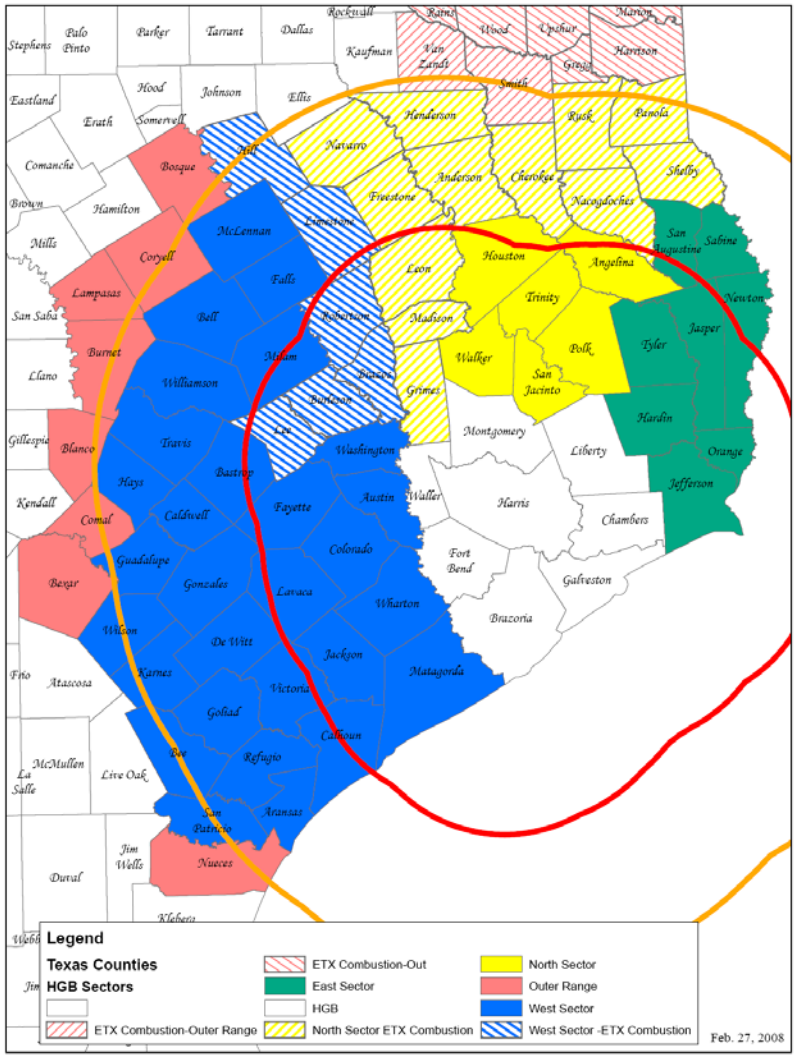


Figure 3-50: Map of Counties within 100 km (Red) and 200 km (Orange) of the Eight-County HGB Area

These modeling sensitivities were conducted on an earlier version of the 2018 modeling emissions inventory. However, the sensitivity of the HGB 2018 future design value at each monitor to reductions of NO_X and VOC emissions from these outer regions is still representative for the final version of the 2018 modeling.

For the counties within 200 km of the eight-county HGB area, point source NO_X emission reductions (i.e., 25 and 50 percent) were made to selected Texas non-ARD sources including compressor engines, boilers, and process heaters. Compressor engines account for approximately 47 tpd of the estimated 124 tpd of NO_X emissions from the selected sources in the 2018 baseline modeling emissions. In addition, in a separate modeling run, a 50 percent NO_X emissions reduction was made to only those counties in the eastern segment of the 200 km region (the green sector in Figure 3-50: *Map of Counties within 100 km (Red) and 200 km (Orange) of the Eight-County HGB Area*). Compressor engines in the eastern segment account for approximately 11 tpd of the estimated 64 tpd of NO_X emissions from the selected sources in the 2018 baseline modeling emissions.

Table 3-21: *200 km NO_X Reduction Modeling Sensitivity* summarizes the sensitivity of the projected DV_Fs for the DRPK (CAMS 35), BAYP (CAMS 53), and WALV (CAMS 617; non-regulatory, industry-sponsored) monitors to NO_X emissions reduction from the selected point

sources in the 200 km region. The columns indicating change rate report the amount by which the DV_F is reduced per 1.0 tpd of NO_X emissions reduction in this region. Of the three monitors, the DRPK (CAMS 35) monitor DV_F shows the largest sensitivity to NO_X emission reductions. However, even the 0.0134 ppb per tpd change rate for 50 percent NO_X emissions reductions from the eastern segment is rather low, indicating that the HGB monitors are not very sensitive to emission reductions from the sources analyzed.

Table 3-21: 200 km NO_X Reduction Modeling Sensitivity

Monitor Site Code	25% NO_X All (31 tpd)		50% NO_X All (62 tpd)		50% NO_X East (32 tpd)	
	DV_F Change (ppb)	Change Rate (ppb/tpd)	DV_F Change (ppb)	Change Rate (ppb/tpd)	DV_F Change (ppb)	Change Rate (ppb/tpd)
DRPK	0.23	0.0074	0.47	0.0076	0.43	0.0134
BAYP	0.14	0.0045	0.27	0.0044	0.23	0.0072
WALV	0.11	0.0035	0.30	0.0048	0.26	0.0081

Note: WALV is a non-regulatory, industry-sponsored monitor.

The TCEQ also tested the sensitivity of DV_Fs to reductions by 50 percent of VOC emissions from area sources in the counties within the 200 km region. The VOC reduction modeled was approximately 273 tpd. Table 3-22: *200 km VOC Reduction Modeling Sensitivity* summarizes the sensitivity of the projected DV_Fs for the DRPK (CAMS 35), BAYP (CAMS 53), and WALV (CAMS 617) monitors to VOC emission reduction from the area sources in the200 km region.

Table 3-22: 200 km VOC Reduction Modeling Sensitivity

Monitor Site Code	50% VOC (273 tpd)	
	DV_F Change (ppb)	Change Rate (ppb/tpd)
DRPK	0.09	0.0003
BAYP	0.06	0.0002
WALV	0.0	0.0

Note: WALV is a non-regulatory, industry-sponsored monitor.

3.6.2.3 Ozone Source Apportionment Tool and Anthropogenic Precursor Culpability Analysis

The TCEQ applied the OSAT and APCA CAMx tools to the 2018 baseline modeling. For both types of analyses, emission source groups, for example, on-road mobile, non- and off-road mobile, and biogenics, and source regions, HGB and non-HGB, are defined. OSAT keeps track of the origin of the NO_X and VOC precursors creating the ozone, and ozone can then be apportioned to specific sources groups and regions. APCA is similar to OSAT, but it recognizes that certain sources groups, such as biogenics, are not controllable. Where OSAT would apportion ozone production to biogenic emissions, APCA reallocates that ozone production to the controllable or anthropogenic emissions that combined with the biogenic emissions to create ozone.

Results are graphed as layered area plots for every rolling eight-hour average for the BAYP (CAMS 53), DRPK (CAMS 35) and WALV (CAMS 617; non-regulatory) monitors and are included in Appendix C: *Photochemical Modeling for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard*. Results of the June 2005 episode are presented here.

Table 3-23: *OSAT/APCA Source Groups and Regions Defined* lists all of the source groups and regions tracked in the OSAT and APCA analyses.

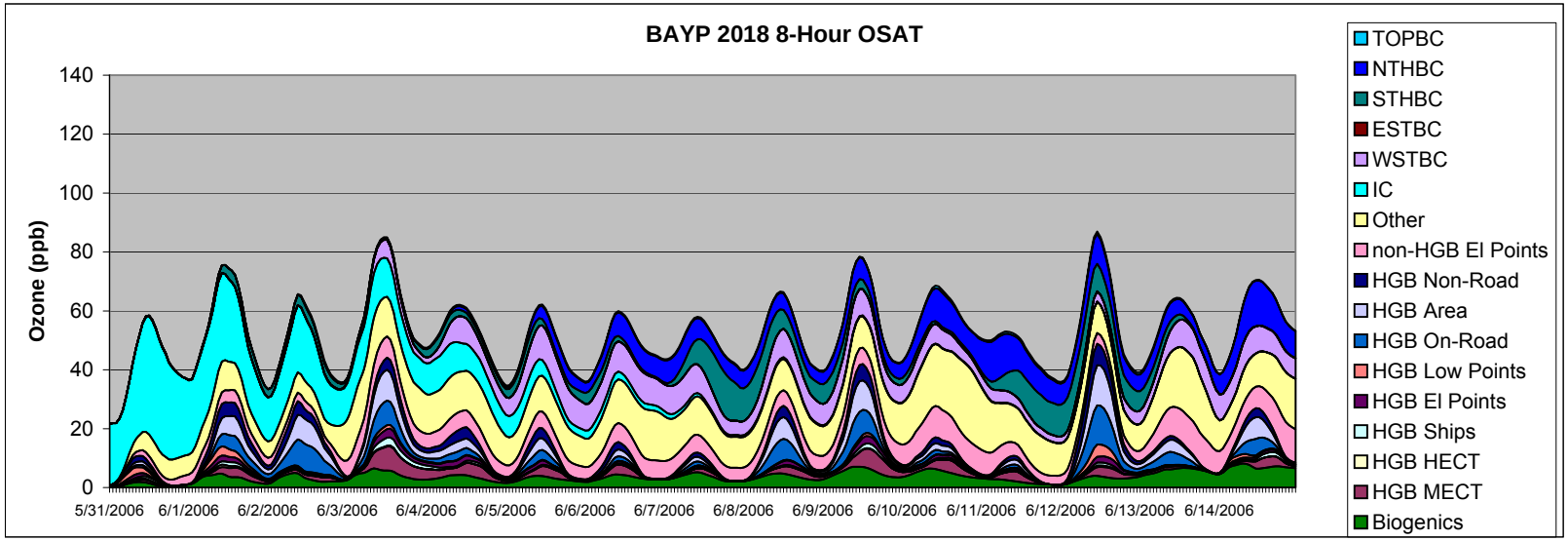
Table 3-23: OSAT/APCA Source Groups and Regions Defined

Figure Legend Abbreviation	Description of Source Group and Region
TOPBC	Top Boundary Condition
NTHBC	North Boundary Condition
STHBC	South Boundary Condition
ESTBC	East Boundary Condition
WSTBC	West Boundary Condition
IC	Initial Condition
Other	All emission source types outside HGB, with the exception of elevated point sources
Non-HGB El Points	Elevated point sources outside HGB
HGB Non-Road	Non-road sources in HGB
HGB Area	Area sources in HGB
HGB On-Road	On-road sources in HGB
HGB Low Points	Low-level point sources in HGB
HGB El Points	Elevated point sources in HGB
HGB Ships	Ship emissions in HGB
HGB HECT	HECT sources in HGB
HGB MECT	MECT sources in HGB
Biogenics	Biogenic emissions from the entire modeling domain

Figures 3-51: *OSAT and APCA Results for BAYP*, 3-52: *OSAT and APCA Results for DRPK,* and 3-53: *OSAT and APCA Results for WALV* show the results of these analyses for BAYP (CAMS 53), DRPK (CAMS 35), and WALV (CAMS 617; non-regulatory, industry-sponsored monitor), respectively. The layer corresponding to the initial model conditions disappears after the first few days of the episode are modeled, as expected. Layers corresponding to boundary conditions give an indication of wind direction on individual episode days and concentrations of ozone attributable to that boundary.

Layers that correspond to HGB emission sources indicate HGB contribution to the total modeled ozone concentration. The other layers, Biogenics, Other, Initial and Boundary Conditions, and Non-HGB Elevated Points, indicate non-HGB contributions to ozone concentration. Differences between the depth of the biogenic layers between the OSAT and APCA plots indicate how ozone of biogenic origin is reallocated to anthropogenic sources in APCA.

Lower-level local emission sources, including non-road mobile, area, on-road mobile, and low-level points, make a greater contribution to ozone at BAYP (CAMS 53) than DRPK (CAMS 35), although Ship Channel sources make a noticeable contribution at BAYP (CAMS 53). Conversely, local elevated sources, including HGB elevated points, ships, HECT, and MECT, make a greater contribution at DRPK (CAMS 35) than BAYP (CAMS 53). WALV (CAMS 617; non-regulatory, industry-sponsored monitor) ozone origins are more like DRPK (CAMS 35) than BAYP (CAMS 53).



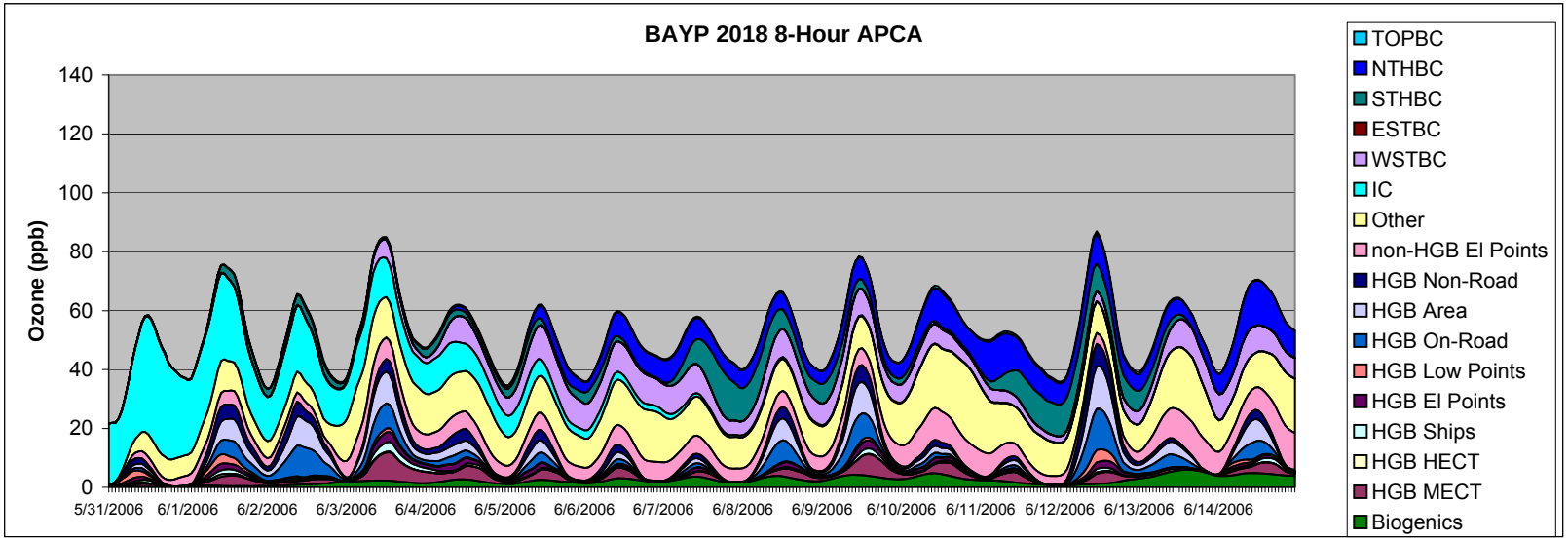


Figure 3-51: OSAT and APCA Results for BAYP

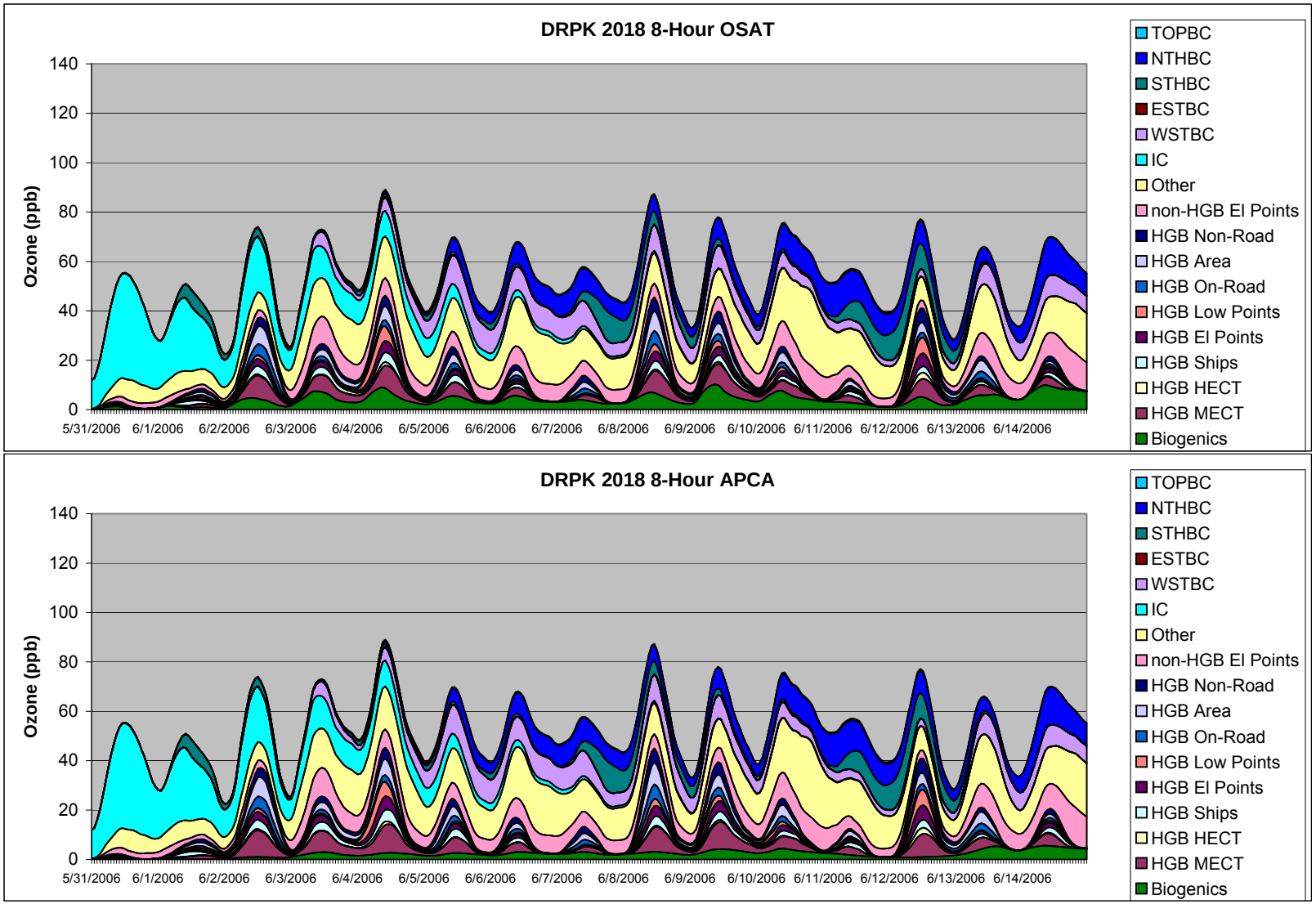
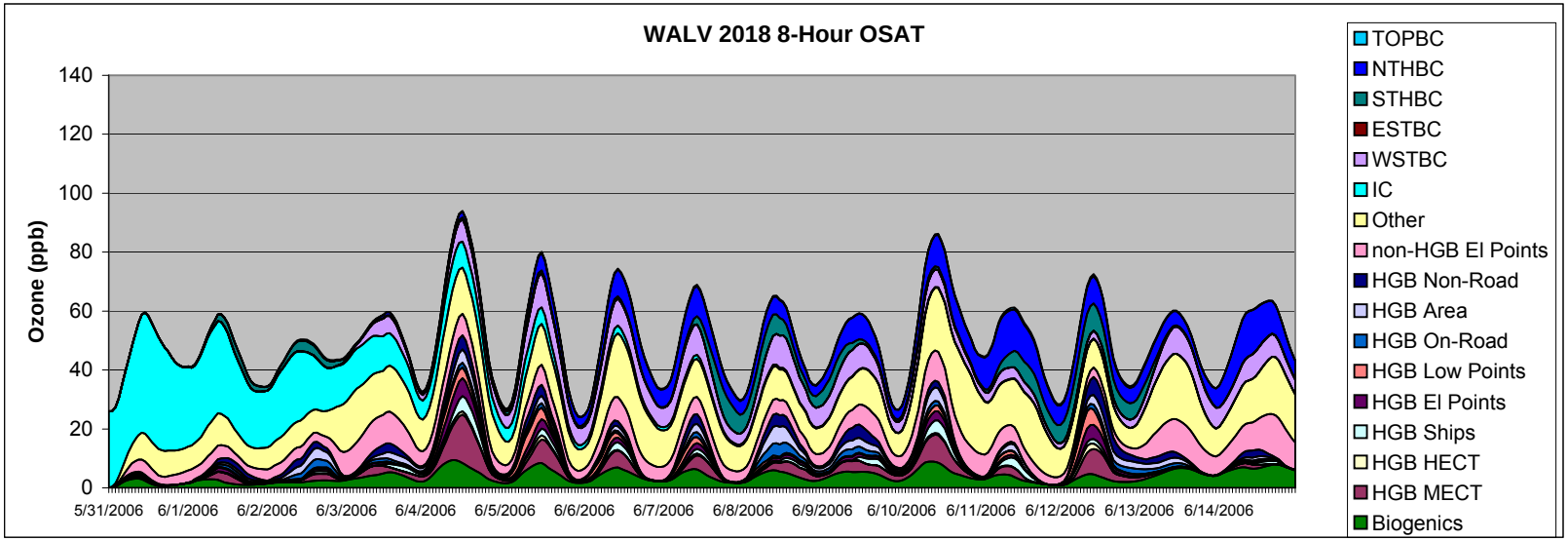


Figure 3-52: OSAT and APCA Results for DRPK



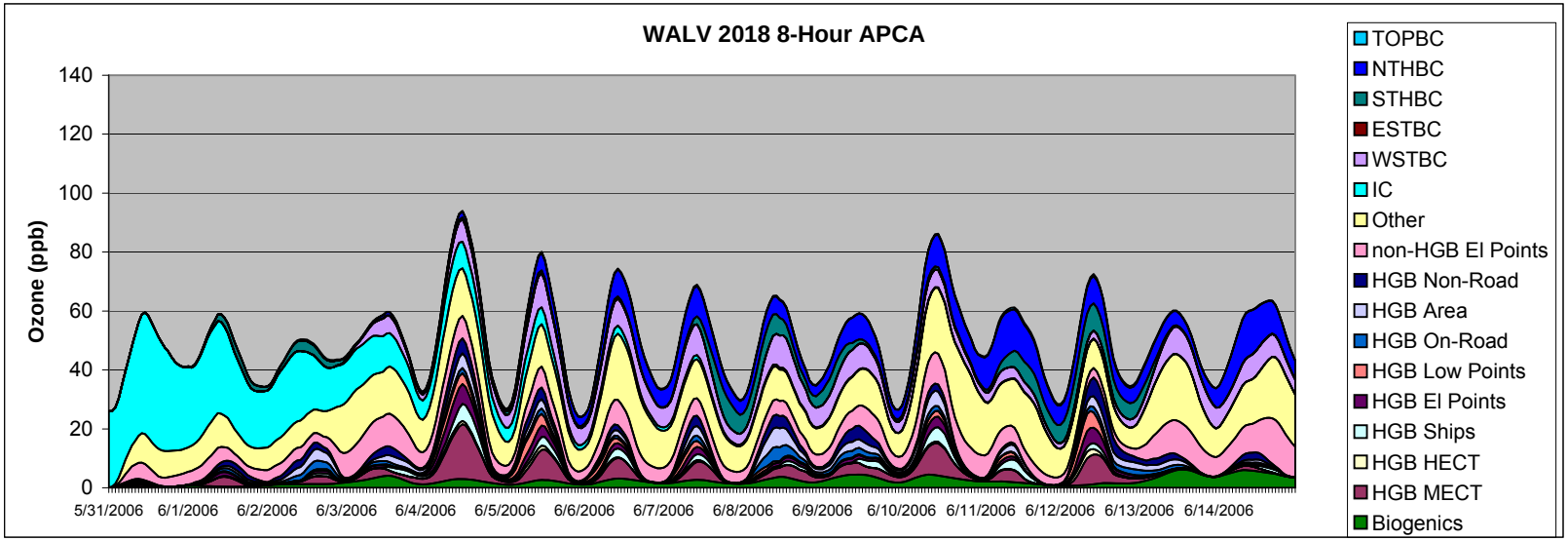


Figure 3-53: OSAT and APCA Results for WALV

3.6.3 Future Case Modeling with Controls

Controls being adopted concurrently with this SIP revision include reallocating and lowering the total point source HRVOC emissions allocated by the HECT rule in Harris County and voluntary emission reductions of NO_X and VOC from on- and non-road mobile sources within the eight-county HGB area.

3.6.3.1 HECT Reallocation and 25 Percent Cap Reduction

The modeling sensitivity for the HECT rule revision redistributes and reduces current total allocated point source HRVOC emissions by 25 percent, 2.69 tpd from HECT applicable sources in Harris County. Table 3-24: *HECT Modeling Sensitivity Results* shows the DV_Fs at the DRPK (CAMS 35), BAYP (CAMS 53), and WALV (CAMS 617) (non-regulatory, industry-sponsored) monitors for the 2018 baseline as well as those resulting from the reallocation and 25 percent reduction in the HRVOC from HECT applicable sources in Harris County.

Table 3-24: HECT Modeling Sensitivity Results

Monitor Site Code	Baseline DV_F (ppb)	HECT DV_F (ppb)
DRPK	86.49	86.36
BAYP	85.53	85.44
WALV	86.50	86.32

Note: WALV is a non-regulatory, industry-sponsored monitor.

3.6.3.2 VMEP Reductions

The Houston-Galveston Area Council (H-GAC; http://www.h-gac.com/taq/) has estimated that approximately 2.25 tpd of NO_X emissions reductions from on-road (1.55 tpd) and non-road (0.70 tpd) mobile sources will result from the application of VMEPs, including alternative commuting, regional traffic flow and vehicle retrofit and replacement, as well as non-road equipment measures. The results of the modeling sensitivity for the HECT reduction and VMEP are shown in Table 3-25: *HECT and VMEP Modeling Sensitivity Results* for the DRPK (CAMS 35), BAYP (CAMS 53), and WALV (CAMS 617; non-regulatory) monitors.

Table 3-25: HECT and VMEP Modeling Sensitivity Results

Monitor Site Code	Baseline DV_F (ppb)	HECT/VMEP DV_F (ppb)
DRPK	86.49	86.30
BAYP	85.53	85.26
WALV	86.50	86.26

Note: WALV is a non-regulatory, industry-sponsored monitor.

Applying the truncating convention for calculating DV_Fs, as per the EPA's modeling guidance, each of these monitors is projected to have a DV_F less than 87 ppb, the recommended limit for weight-of-evidence considerations.

3.6.4 Unmonitored Area Analysis

EPA guidance (EPA, 2007) recommends that areas not near monitoring locations (unmonitored areas) be subjected to an "unmonitored area (UMA) analysis" to demonstrate that these areas are expected to reach attainment by the area's attainment year, in this case 2018. The standard attainment test is applied only at monitor locations, and the UMA analysis is intended to identify any areas not near a monitoring location that are at risk of not meeting the attainment date. Recently, the EPA provided software that can be used to conduct UMA analyses, but has not specifically recommended using its software (called the Modeled Attainment Test Software (MATS)) in EPA guidance, instead stating that "States will be able to use the EPA-provided

software or are free to develop alternative techniques that may be appropriate for their areas or situations."

The TCEQ chose to use its own procedure to conduct the UMA analysis instead of MATS for several reasons. While both procedures incorporate modeled predictions into a spatial interpolation procedure, the TCEQ Attainment Test for Unmonitored areas (TATU) is already integrated into the TCEQ's model post-processing stream, while MATS requires that modeled concentrations be exported to a personal computer-based platform. Additionally, MATS requires input in latitude/longitude, while TATU works directly off the LCP data used in TCEQ modeling applications. MATS cannot easily handle multi-year baseline data (which are used in the HGB attainment modeling), while TATU can. Finally, MATS uses the Voronoi Neighbor Averaging (VNA) technique for spatial interpolation, while TATU relies on the more familiar kriging geospatial interpolation technique. More information about TATU is provided in Appendix C: *Photochemical Modeling for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard*, Attachment 2.

Figure 3-54: *Spatially Interpolated 2006 Baseline (left) and 2018 Future Case (right) Design Values for the HGB Area* shows two color contour maps of ozone concentrations produced by TATU, one for the 2006 baseline (left) and one for the 2018 future case, including proposed controls (right). The figure shows the extent and magnitude of the expected improvements in ozone design values resulting from controls modeled in this attainment demonstration, with only a few grid cells at or above 84 ppb in the future case plot. No areas outside Harris County show nonattainment in 2018.

Figure 3-55: *HGB Grid Cells Within 7×7 Arrays of Monitoring Sites Used in Attainment Analysis (Purple) and Grid Cells With Predicted 2018 Future Design Values ≥ 85 ppb (Pink)* highlights the grid cells with 2018 projected $DV_F \geq 85$ ppb (shown in pink), and the 7x7 grid cell arrays around each of the regulatory and industry-sponsored monitors (shown in purple) as well as the Baytown Wetland Center (BYWC; CAMS 552) non-regulatory monitor (shown in green). This plot verifies that all the grid cells with $DV_F \geq 85$ ppb lie within the 7×7 array around a monitor used in the attainment test with the exception of five cells in eastern Harris County. Since these five cells are not considered to be near any monitor used in the attainment test, additional analysis of these cells is warranted. Fortunately, all five cells in question lie within a 7×7 array around the BYWC monitor.

While the BYWC monitor does not receive the level of quality assurance and quality control (QA/QC) required for regulatory status, it is reasonable to include it in the assessment of nearby grid cells. The BYWC monitor has a DVB equal to 85.3 ppb and an RRF of 0.954, yielding a DV_F equal to 81.4 ppb. This value is far enough below the NAAQS that we can have confidence the monitor will measure levels below the NAAQS in 2018, even allowing for possibly inflated measurement errors arising from the monitor's reduced level of QA/QC.

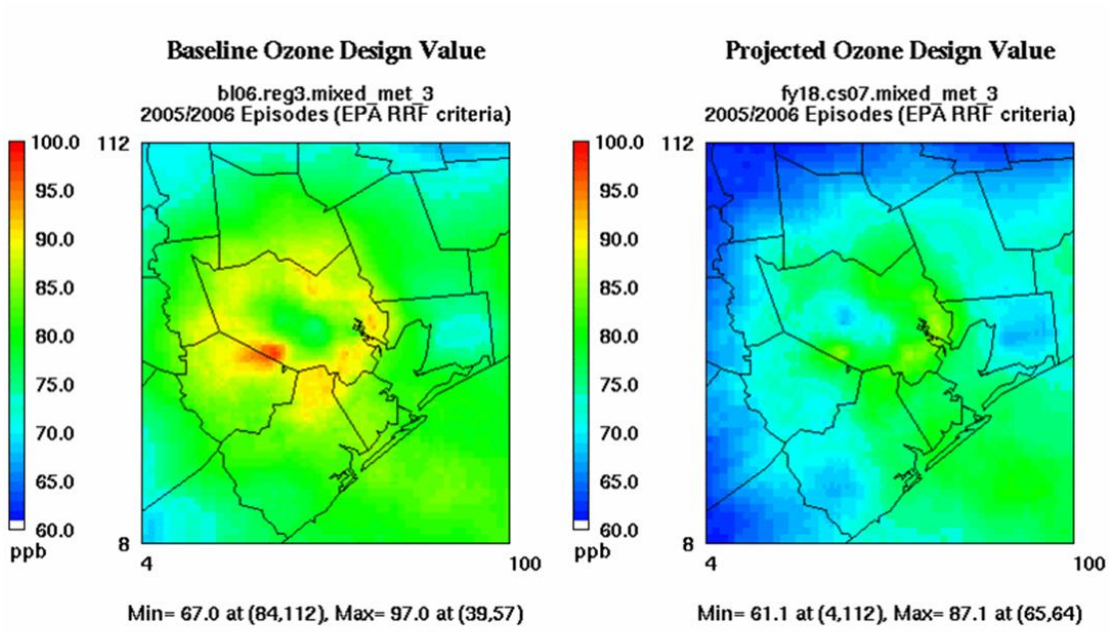


Figure 3-54: Spatially Interpolated 2006 Baseline (left) and 2018 Future Case (right) Design Values for the HGB Area

In conclusion, of the 18 grid cells projected to be ≥ 85 ppb in 2018, all but five lie within a 7×7 array around a monitor used in the attainment test, hence by definition are not part of the unmonitored area. For the five grid cells that can be considered to be part of the unmonitored area, all lie within a 7×7 array surrounding the BYWC non-regulatory monitor. The BYWC monitor has a DV_F enough below the NAAQS to conclude that grid cells within its 7×7 surrounding array will attain the NAAQS in 2018.

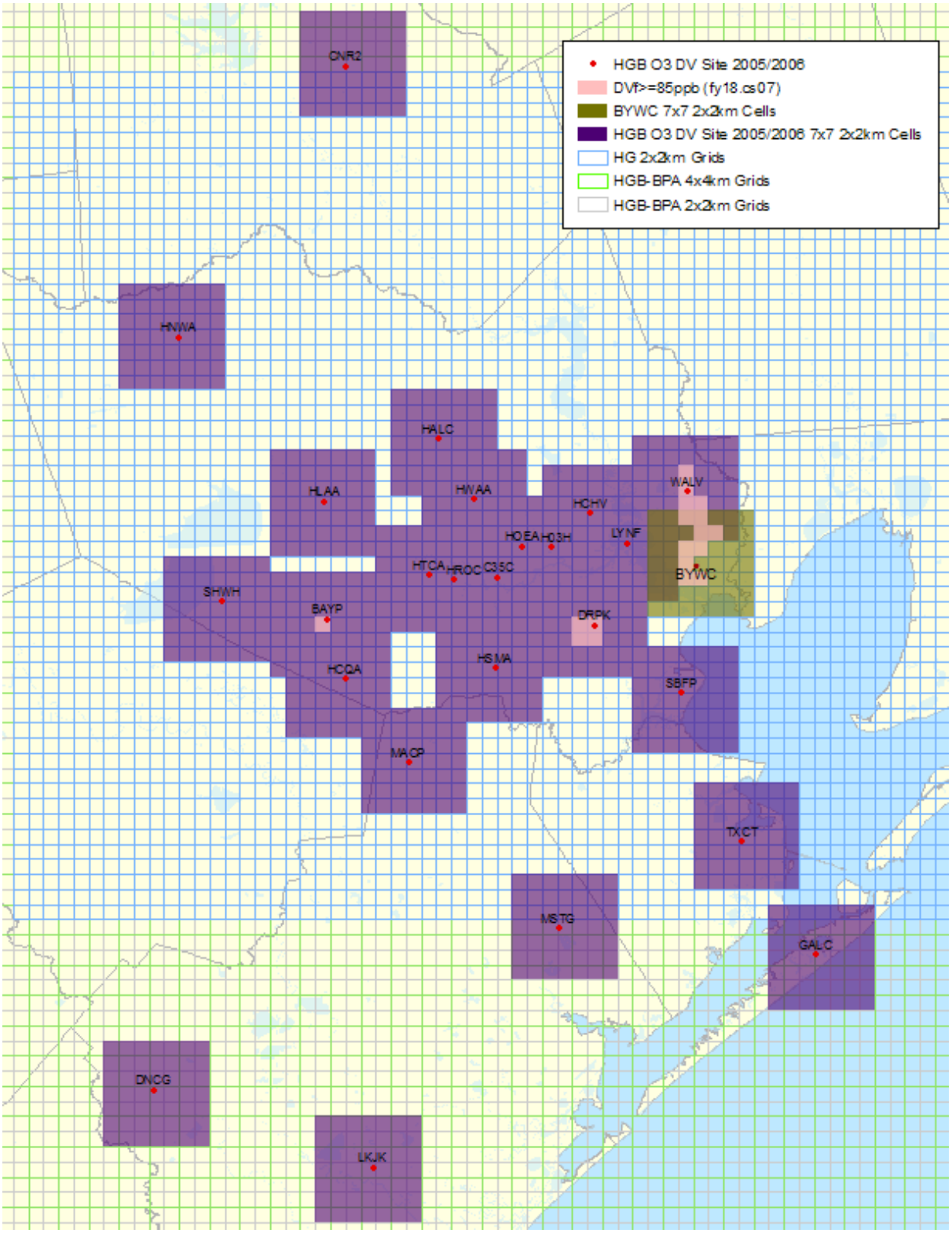


Figure 3-55: HGB Grid Cells Within 7×7 Arrays of Monitoring Sites Used in Attainment Analysis (Purple) and Grid Cells With Predicted 2018 Future Design Values > 85 ppb (Pink).

3.7 MODELING ARCHIVE AND REFERENCES

3.7.1 Modeling Archive

The TCEQ has archived all modeling documentation and modeling input/output files generated as part of the HGB SIP modeling analysis. Interested parties can contact the TCEQ for information regarding data access or project documentation.

3.7.2 Modeling References

Castineira and Edgar, 2006. Computational Fluid Dynamics for Simulation of Steam-Assisted and Air-Assisted Flare Combustion Systems, Energy & Fuels, 20: 1044-1056.

Emery, C., E. Tai, and G. Yarwood, 2001. Enhanced Meteorological Modeling and Performance Evaluation for Two Texas Ozone Episodes, Final Report to the Texas Natural Resource Conservation Commission under TNRCC Umbrella Contract No. 582-0-31984, Environ International Corporation, Novato, CA.

Environ, 2007. User's Guide Emissions Processor, Version 3, Environ International Corporation, Novato, CA.

Environ, 2008. Description from MM5CAMx README file contained in mm5camx.21feb08.tar.gz archive, http://www.camx.com/files/mm5camx.21feb08.tar.gz, Environ Holdings, Inc.

Environ, 2008b. Boundary Conditions and Fire Emissions Modeling, Final Report to the Texas Commission on Environmental Quality (TCEQ), Contract No. 582-7-84005-FY08-06, Environ International Corporation, Novato, CA.

Environ, 2009. User's Guide Comprehensive Air Quality Model with Extensions (CAMx), Version 4.53, Environ International Corporation, Novato, CA.

EPA, 2005. Modeling files obtained via data request from the EPA in support of the Clean Air Interstate Rule Notice of Data Availability Technical Support Document, as documented at http://www.epa.gov/cair/technical.html.

EPA, 2007. Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze, http://www.epa.gov/scram001/guidance/guide/final-03-pm-rh-guidance.pdf.

Feldman, M.S., T. Howard, E. McDonald-Buller, G. Mullins, D.T. Allen, A. Webb, Y. Kimura, 2007. Applications of Satellite Remote Sensing Data for Estimating Dry Deposition in Eastern Texas. Atmospheric Environment, 41(35): 7562-7576.

Grell, G., J. Dudhia, and D. Stauffer, 1994. A Description of the Fifth Generation Penn State/NCAR Mesoscale Model (MM5), Technical Report NCAR/TN-398+STR, National Center of Atmospheric Research (NCAR) Tech Note.

Kinnee et al., 1997. United States Land Use Inventory for Estimating Biogenic Ozone Precursor Emissions. Ecological Applications 7(1): 46-58.

NCAR, 2005. MM5 On-line Tutorial Home Pages, http://www.mmm.ucar.edu/mm5/On-Line-Tutorial/teachyourself.html, NCAR, Colorado.

NCEP, 2009. Global Energy and Water Cycle Experiment (GEWEX) Continental International Project (GCIP) National Centers for Environmental Prediction (NCEP) Eta Model Output,

Computational and Information Systems Laboratory (CISL) Research Data Archive (RDA): ds609.2 Home Page, http://dss.ucar.edu/datasets/ds609.2/, NCEP.

Popescu, Sorin C., Jared Stukey, Mark Karnauch, Jeremiah Bowling, Xuesong Zhang, William Booth, and Nian-Wei Ku, 2008. The New Central Texas Land Use Land Cover Classification Project, Final Report to the TCEQ, Contract No. 582-5-64593-FY08-23, Texas A & M University, College Station, Texas.

Robinson, R., T. Gardiner, and B. Lipscombe, 2008. Measurements of VOC Emissions from Petrochemical Industry Sites in the Houston Area Using Differential Absorption Lidar (DIAL) During Summer 2007, Draft. Submitted to Russell Nettles, TCEQ, by Rod Robinson, Tom Gardiner, and Bob Lipscombe of the National Physical Laboratory, Teddington, Middlesex UK TW11 0LW, February 8, 2008, pp. 86.

Starcrest, 2000. Houston-Galveston Area Vessel Emissions Inventory, Starcrest Consulting Group, Houston, Texas.

Stauffer, D. R. and N. L. Seaman, 1990. Use of Four-Dimensional Data Assimilation in a Limited-Area Mesoscale Model. Part I: Experiments with Synoptic-Scale Data. Monthly Weather Review, 118: 1250-1277.

Stauffer, D.R. and N.L. Seaman, 1994. Multiscale four-dimensional data assimilation. Journal of Applied Meteorology, 33: 416-434.

Stauffer, D. R., N. L. Seaman, and F. S. Binkowski, 1991. Use of Four-Dimensional Data Assimilation in a Limited-Area Mesoscale Model. Part II: Effects of Data Assimilation Within the Planetary Boundary Layer. Monthly Weather Review, 119: 734-754.

TCEQ, 2007. Revisions to the State Implementation Plan (SIP) for the Control of Ozone Air Pollution, Dallas-Fort Worth Eight-Hour Ozone Nonattainment Area Attainment Demonstration, TCEQ, Austin, Texas.

TCEQ, 2009. TCEQ Air Modeling and Data Analysis (AMDA) Section public web site, http://www.tceq.state.tx.us/implementation/air/airmod/data/hgb8h2/hgb8h2.html.

Wiedinmyer , C., A. Guenther, M. Estes, I.W. Strange, G. Yarwood, and D. Allen, 2001. A Land Use Database and Examples of Biogenic Isoprene Emission Estimates for the State of Texas, USA. Atmospheric Environment, 35: 6465-6477.

CHAPTER 4: CONTROL STRATEGIES AND REQUIRED ELEMENTS

4.1 INTRODUCTION

The Houston-Galveston-Brazoria (HGB) nonattainment area for the 1997 eight-hour ozone National Ambient Air Quality Standard (NAAQS), which consists of Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller Counties, includes one of the most comprehensively controlled industrial complexes in the world. The Texas Commission on Environmental Quality (TCEQ) has developed stringent and innovative regulations that address nitrogen oxides (NO_X), volatile organic compounds (VOC), and highly reactive volatile organic compounds (HRVOC). Despite the significant decreases in ozone design values and emissions of ozone precursors in the HGB area, further reductions are necessary to ensure attainment of the 1997 eight-hour ozone standard. This chapter describes existing ozone control measures and ozone control measures being adopted concurrently with this SIP revision for the HGB area, as well as how Texas meets the following severe ozone nonattainment area state implementation plan (SIP) requirements: reasonably available control technology (RACT), reasonably available control measures (RACM), motor vehicle emissions budget (MVEB), and contingency measures.

4.2 EXISTING CONTROL MEASURES

Over several years of ozone planning in the HGB area, a broad range of control measures have been implemented for each emission source category. Table 4-1: *Existing Ozone Control Measures Applicable to the HGB Eight-County Nonattainment Area* lists the existing ozone control strategies that were implemented for the one-hour and 1997 eight-hour ozone standards in the HGB area.

Table 4-1: Existing Ozone Control Measures Applicable to the HGB Eight-County Nonattainment Area

Measure	Description	Start Date(s)
POINT SOURCE MEASURES		
NO_X Mass Emissions Cap and Trade (MECT) Program	Overall 80 percent NO_X reduction from existing industrial sources and utility power plants, implemented through a cap and trade program. Affects utility boilers, gas turbines, heaters and furnaces, stationary internal combustion engines, industrial boilers, and many other industrial sources.	April 1, 2003, and phased in through April 1, 2007
HRVOC Rules and HRVOC Emissions Cap and Trade (HECT) Program	Affects cooling towers, process vents, and flares, and establishes an annual emissions limit with a cap and trade for each site in Harris County. The seven perimeter counties are subject to permit allowable limits and monitoring requirements.	Monitoring requirements began January 31, 2006, and cap and trade program implemented January 1, 2007
HRVOC Fugitive Rules	More stringent leak detection and repair (LDAR) requirements for components in HRVOC service. Additional components included in LDAR program are more stringent repair times, lower leak detection, and third part audit requirements.	March 31, 2004

Measure	Description	Start Date(s)
VOC Rules on Storage and Degassing Operations	Requires controls for slotted guide poles and more stringent controls for other fittings on floating roof tanks, and control requirements or operational limitations on landing floating roof tanks. Eliminates exemption for storage tanks for crude oil or natural gas condensate, and regulates flash emissions from these tanks. Requires vapors from degassing to be vented to a control device for a longer time period, and removes exemption from degassing to control for tanks with capacity of 75,000 to 1,000,000 gallons.	January 1, 2009
NO_X Emission Standards for Nitric Acid and Adipic Acid Manufacturing	NO_X emission standards for nitric acid and adipic acid manufacturing facilities in the HGB area.	November 15, 1999
Utility Electric Generation in East and Central Texas	NO_X control requirements (approximately 55 percent) on utility boilers and stationary gas turbines at utility electric generation sites in East and Central Texas.	May 1, 2003, through May 1, 2005
VOC Control Measures	Additional control technology requirements for batch processes, bakeries, and offset lithographic printers by December 31, 2002. Examples of additional VOC measures adopted earlier for RACT purposes include: storage, general vent gas, industrial wastewater, loading and unloading operations, general VOC LDAR, solvent using process, etc. (see Appendix D: *Reasonably Available Control Technology Analysis* for more details).	December 31, 2002, and earlier
AREA/NON-ROAD MEASURES		
Refueling - Stage I	Stage I vapor recovery captures gasoline vapors that are released when gasoline is delivered to a storage tank. The vapors are returned to the tank truck as the storage tank is being filled with fuel, rather than released into the ambient air.	1990
Refueling - Stage II	Stage II vapor recovery captures gasoline vapors when a vehicle is being fueled at the pump. The vapors are returned through the pump hose to the petroleum storage tank, rather than released into the air.	1992
Federal Area/Non-Road Measures	The United States Environmental Protection Agency (EPA) has implemented a series of emissions limits for area and non-road sources. Examples are diesel and gasoline engine standards for locomotives and leaf-blowers.	Through 2007
Texas Emission Reduction Plan (TERP) (See also on-road TERP reductions)	Provides grant funds for heavy-duty diesel engine replacement/retrofit.	January 2002
California Gasoline Engines	California standards for non-road gasoline engines 25 horsepower and larger.	May 1, 2004
Stationary Diesel Engines	Prohibition on operating stationary diesel and dual-fuel engines for testing and maintenance purposes between 6:00 A.M. and noon.	April 1, 2002

Measure	Description	Start Date(s)
Natural Gas-Fired Small Boilers, Process Heaters, and Water Heaters	NO_X emission limits on small-scale residential and industrial boilers, process heaters, and water heaters equal to or less than 2.0 million British thermal units per hour.	2002
Minor Source NO_X Controls for Non-MECT Sites	NO_X emission limits on boilers, process heaters, and stationary engines and turbines at minor sites not included in the MECT program (uncontrolled design capacity to emit less than 10 tons per year (tpy)).	March 31, 2005
VOC Control Measures	Additional control technology requirements for batch processes, bakeries, and offset lithographic printers by December 31, 2002. Examples of additional VOC measures adopted earlier for RACT purposes include: storage, general vent gas, industrial wastewater, loading and unloading operations, general VOC LDAR, solvent using process, cutback asphalt, etc. (see Appendix D: *Reasonably Available Control Technology Analysis* for more details).	December 31, 2002, and earlier
Texas Low Emission Diesel (TxLED)	Requires all diesel for both on-road and non-road use to have a lower aromatic content and a higher cetane number.	Phase in began October 31, 2005
TxLED for Marine Fuels	Adds marine distillate fuels X and A commonly known as DMX and DMA, or Marine Gas Oil (MGO), into the definition of diesel fuels, requiring them to be TxLED compliant.	June 24, 2007
Texas Low Reid Vapor Pressure (RVP) Gasoline	Requires all gasoline for both on-road and non-road use to have a RVP of 7.8 pounds per square inch (psi) or less from May 1 through October 1 each year.	April 2000
Voluntary Mobile Emissions Reduction Program (VMEP)	Voluntary measures administered by the Houston-Galveston Area Council (H-GAC) (see Appendix F7 of the 2004 HGB Mid-Course Review SIP revision)	Through 2007
ON-ROAD MEASURES		
Federal On-Road Measures	The EPA has implemented a series of emissions limits for on-road vehicles. Some of these include Tier 1 and Tier 2 vehicle standards, low sulfur diesel standards, National Low Emission Vehicle standards, and reformulated gasoline.	Phase in through 2007
TERP (See also area/non-road TERP)	Provides grant funds for heavy-duty diesel engine replacement/retrofit.	January 2002
Vehicle Inspection/ Maintenance (I/M)	Yearly treadmill-type testing for pre-1996 vehicles and computer checks for 1996 and newer vehicles.	May 1, 2002, in Harris County. May 1, 2003, in Brazoria, Fort Bend, Galveston, and Montgomery Counties.
Speed Limit Reduction	On roadways where speeds were 65 mph or higher, speed limits remain at 5 miles per hour (mph) below what was posted before May 1, 2002.	September 2003
TxLED	Requires all diesel for both on-road and non-road use to have a lower aromatic content and a higher cetane number.	Phase in began October 31, 2005
Texas Low RVP Gasoline (see also non-road Low RVP Gasoline)	Requires all gasoline for both on-road and non-road use to have a RVP of 7.8 psi or less from May 1 through October	April 2000

Measure	Description	Start Date(s)
	1 each year.	
VMEP	Voluntary measures administered by the H-GAC (see Appendix F7 of the 2004 HGB Mid-Course Review SIP revision)	Phase in through 2007
Transportation Control Measures	Various measures in H-GAC's long-range transportation plans.	Phase in through 2007
OTHER		
Portable Fuel Containers Rule See section 4.3.2 *Repeal of State Portable Fuel Container Rule* for additional information about this measure.	Establishes new design "no spill" criteria requirements for portable fuel containers sold, offered for sale, manufactured, and/or distributed in Texas.	December 31, 2004
Voluntary Energy Efficiency/Renewable Energy	Senate Bill (SB) 5 and SB 7 from the 80th session of the Texas Legislature have encouraged energy efficiency and renewable energy projects.	December 2000
Automotive Windshield Washer Fluid	VOC content limitation on automotive windshield washer fluid sold, supplied, distributed, or manufactured for use in Texas.	January 1, 1995

4.3 UPDATES TO EXISTING CONTROL MEASURES

4.3.1 Mass Emissions Cap and Trade (MECT) Program

The MECT program in 30 Texas Administrative Code (TAC) Chapter 101 is a market-based component of the SIP that provides flexibility for stationary source compliance with the emission specifications under 30 TAC Chapter 117, while establishing a mandatory cap for total NO_X emissions from affected source categories in the HGB area. The MECT program was adopted as a primary control measure of the HGB attainment demonstration for the one-hour NAAQS for ozone.

The revision to the MECT program being adopted concurrently with this SIP revision (TCEQ Rule Project Number 2009-019-101-EN) will ensure the integrity of the modeled HGB nonattainment area cap by prohibiting the issuance of allowance allocations to major sources that did not submit the required Level of Activity Certification forms by the compliance date in 30 TAC §101.360. This rule change does not reduce the current NO_X cap in the HGB nonattainment area.

The MECT program allocated NO_X emission allowances to applicable existing facilities in the HGB area based on their 1997 to 1999 levels of activity. The program also provided for a system of allocating allowances to facilities that had submitted administratively complete permit applications before January 2, 2001. After January 2, 2001, any applicable new or modified facilities in the HGB area must acquire allowances equal to their annual NO_X emissions (one NO_X ton per year equals one annual allowance) from existing facilities already participating in the program.

The adopted changes to the rule will maintain the integrity of the MECT program NO_X cap for maintenance of the HGB one-hour ozone attainment demonstration. Additionally, maintaining the integrity of the MECT program NO_X cap prevents potential adverse impacts on the attainment and maintenance of the 1997 eight-hour ozone NAAQS. The revised Chapter 101, Subchapter H, Division 3 rules prohibit the future allocation of additional allowances to applicable facilities that failed to previously participate in the MECT program and to previously permitted facilities that failed to submit the required level of activity certification by the applicable deadline. These facilities include:

- facilities that were in operation prior to January 1, 1997;

- new and modified facilities not in operation prior to January 1, 1997, but included in a submitted New Construction or Modification Permit determined to be administratively complete before January 2, 2001; and
- new and modified facilities not in operation prior to January 1, 1997, but qualified for a Permit by Rule and had commenced construction before January 2, 2001.

This rulemaking also revises Chapter 101, Subchapter H, Division 3, to clarify the definition of "uncontrolled design capacity" as it relates to applicability of this division. The TCEQ has received comments from stakeholders requesting clarification of the MECT program applicability, specifically relating to uncontrolled designed capacity and how it differs from a facility's potential to emit. The definition of "uncontrolled design capacity" is also revised to "uncontrolled design capacity to emit" to allow owners or operators of emergency back-up engines at minor sources an alternative to using 8,760 hours to calculate the uncontrolled designed capacity to emit for the engines. Emergency back-up engines at minor sites are typically authorized by Permit by Rule and restricted to 10 percent or less of the normal annual operating schedule. Allowing companies to use this restriction to calculate the uncontrolled designed capacity more accurately reflects the actual restriction on use of the engine while avoiding potentially making many minor sites needlessly subject to the MECT program solely because the engine is no longer exempt under Chapter 117. Because these sites would still be subject to the Chapter 117 minor source rules in Subchapter D, Division 1, this change does not constitute backsliding under the Federal Clean Air Act (FCAA).

4.3.2 Repeal of State Portable Fuel Container Rule

The EPA adopted a federal portable fuel container (PFC) rule in the February 26, 2007, issue of the *Federal Register* (72 FR 8432) that set a national standard for gasoline, diesel, and kerosene PFCs. The rule requires all PFCs manufactured on or after January 1, 2009, to comply with the federal standards. The new federal PFC regulations are consistent with the revised PFC regulations adopted by the California Air Resources Board (CARB) on September 15, 2005. The current Texas PFC regulations are inconsistent with the new federal standards, because they are based on the previous PFC testing methods adopted by CARB in 2001. Therefore, the TCEQ proposed to repeal its PFC regulation at the August 26, 2009, commissioners' agenda (TCEQ Rule Project Number 2008-032-115-EN). The commission is scheduled to consider adoption of the repeal of the PFC regulations at a commissioners' agenda on February 10, 2010. If the repeal is adopted, the state will rely on the implementation of the federal PFC regulations to control VOC emissions from PFCs used within the state. According to an EPA analysis entitled, *Federal Register Rule vs. Texas Register Rule Portable Fuel Containers*, the Federal PFC rule is more stringent than the Texas PFC rule.

The repeal of the current Texas PFC regulations and reliance on the new federal PFC standards will not have a negative impact on the Texas SIP. The estimated emission reductions applicable to the implementation of the federal PFC rule in Texas are expected to be equivalent to the current Texas PFC rule in the early years and to provide greater reductions in the later years.

4.3.3 Clean Fuel Fleet Requirement

Participation in a Clean Fuel Fleet Program (CFFP) is required by §246 of the FCAA for nonattainment areas with 1980 populations greater than 250,000 that are classified as serious or above for ozone. In accordance with this requirement, a CFFP was instituted by rule in the HGB area beginning on September 1, 1998. The CFFP requires that a certain percentage of fleet purchases after model year 1998 be Clean Fuel Vehicles (CFV) that meet the standards set forth in §243 of the FCAA.

The most recent federal standards for both light-duty and heavy-duty vehicles have eclipsed the CFV standards because subsequent to September 1, 2005, any new vehicle purchase ranging from 0-26,000 pounds gross vehicle weight rating would have either equaled or, in most cases, exceeded CFV standards. In a letter to manufacturers (EPA, 2005), the EPA stated that

"subsequent to publishing its CFV regulations, EPA has promulgated new emission standards that are generally more stringent than or equivalent to the CFV emission standards for light-duty vehicles, light-duty trucks, and heavy-duty engines." This EPA letter, dated July 21, 2005, applied to fleet purchases that began with the 2006 model year (September 1, 2005).

During the 79th Texas Legislature Regular Session in 2005, SB 1032 was signed into law, which repealed the Texas Clean Fleet Program in its entirety because the federal standards already in place at that time eclipsed the CFV standards referenced in the FCAA. On April 26, 2006, the TCEQ formally repealed the Texas Clean Fleet Program because no additional benefit could be achieved from new vehicle purchases under CFFP. A revision to the SIP that reflected the repeal of the Texas Clean Fleet Program was submitted to the EPA on May 15, 2006. EPA approval of measures that substitute for the initial requirement to implement CFFP is provided for in §182(c)(4) of the FCAA as long as the EPA determines the substitute will accomplish equal long-term reductions attributable to the CFFP. However, the EPA has not provided guidance on how states are to address the Clean Fuel Fleet substitution requirement in their SIP submittals, in light of the more stringent federal standards. Since new vehicle purchases subsequent to the date of repeal would meet more stringent federal emission standards, cancellation of the Texas Clean Fleet Program does not necessitate action to substitute this program with a separate emission reduction measure containing equivalent benefits. Such a substitution would only be warranted when a net increase in emissions would occur due to repeal or cancellation of an existing program.

4.4 REASONABLY AVAILABLE CONTROL TECHNOLOGY (RACT) ANALYSIS

4.4.1 General Discussion

The HGB area is currently classified as a severe nonattainment area for the 1997 eight-hour ozone NAAQS. Under the eight-hour ozone standard, the HGB area is required to meet the mandates of the FCAA under §§172(c)(1), 182(b)(2), and 182(f). According to the EPA's Final Rule to Implement the 1997 eight-hour ozone NAAQS (40 Code of Federal Regulations (CFR) §51.912, November 29, 2005), states containing areas classified as moderate nonattainment or higher must submit a SIP revision demonstrating that their current rules fulfill the RACT requirements for all control techniques guidelines (CTG) emission source categories and all non-CTG major sources of NO_X and VOC. The major source threshold for severe nonattainment areas is a potential to emit 25 tpy or more of either NO_X or VOC.

In the September 17, 1979, issue of the *Federal Register* (44 FR 53762) RACT is defined as the lowest emissions limitation that a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economic feasibility. RACT requirements for nonattainment areas classified as moderate and higher are included in the FCAA to assure that significant source categories at major sources of ozone precursor emissions are controlled to a reasonable extent, but not necessarily to best available control technology (BACT) levels expected of new sources or to maximum achievable control technology (MACT) levels required for major sources of hazardous air pollutants. While RACT and RACM have similar consideration factors like technological and economic feasibility, there is a significant distinction between RACT and RACM. To be considered RACM, a control measure must advance attainment of the area towards meeting the NAAQS for that measure (see FCAA, §172(c)(1)). Advancing attainment of the area is not a factor of consideration when evaluating RACT because the benefit of implementing RACT is presumed under the FCAA.

Under the current state rules, the HGB area is subject to some of the most stringent NO_X and VOC emission control requirements in the country, and for many source categories, the existing rules are more stringent than recommended RACT standards for those categories. In the final approval notice for the revised HGB one-hour ozone attainment demonstration SIP published in the September 6, 2006, issue of the *Federal Register* (71 FR 52676), the EPA noted that the HGB VOC rules in 30 TAC Chapter 115 and NO_X rules in Chapter 117 were previously determined to meet the FCAA RACT requirements. Under the one-hour ozone NAAQS, the HGB area was

also designated as a severe nonattainment area and the threshold for major stationary sources under the one-hour ozone nonattainment designation was identical to the current threshold under the eight-hour ozone designation. Therefore, controls to satisfy RACT for most major sources under the eight-hour ozone designation were implemented by the TCEQ under the one-hour ozone attainment demonstration and previously approved by the EPA.

Specified information regarding the TCEQ's NO_X and VOC RACT analysis is provided in Appendix D: *Reasonably Available Control Technology Analysis*; Table D-1: *State Rules Addressing RACT Requirements in CTG and ACT Reference Documents* provides additional details on the CTG and Alternative Control Techniques (ACT) source categories; and Table D-2: *State Rules Addressing RACT Requirements for Major Emission Sources in the HGB Area* provides additional detail on the non-CTG/ACT major emission source categories.

4.4.2 NO_X RACT Determination

The TCEQ's analysis demonstrates that the current NO_X rules and controls for the HGB area fulfill the FCAA requirements for NO_X RACT. The MECT program and accompanying Chapter 117 rules represent one of the most comprehensive NO_X control strategies in the nation and encompass both RACT and beyond-RACT levels of control. Except for the EPA's Glass Furnace ACT document, the current EPA-approved Chapter 117 rules fulfill RACT requirements for all CTG and ACT NO_X emission source categories. For non-CTG/ACT major NO_X emission source categories, RACT is fulfilled by the MECT program or by separate source-specific rules in Chapter 117 for sources that NO_X controls are technologically and economically feasible.

The TCEQ identified one major source glass manufacturing facility, Longhorn Glass Corporation (TCEQ Account No. HG-0028-R), in the 2006 point source emissions inventory for the HGB area. TCEQ Permit Number 42623 requires Longhorn's oxy-fired glass furnace to meet a NO_X emission specification of 1.48 pounds per ton of glass produced. As discussed in Appendix D: *Reasonably Available Control Technology Analysis* of this SIP revision, oxy-firing represents the most effective NO_X control technique for glass furnaces. This control requirement is also more stringent than the current Chapter 117 NO_X emissions specification of 4.0 pounds per ton of glass produced for glass furnaces that was approved by the EPA as part of the 2007 Dallas-Fort Worth 1997 eight-hour ozone attainment demonstration SIP revision. Furthermore, no other glass furnaces were identified in the HGB area. Based on these facts, the TCEQ determined that requiring additional NO_X controls was not necessary for the glass furnace category in the HGB area. Therefore, the TCEQ is not implementing any rule amendments or new rules to satisfy RACT for the glass furnaces in the HGB area.

4.4.3 VOC RACT Determination

The TCEQ's analysis demonstrates that the current VOC rules and controls for the HGB area satisfy the FCAA requirements for RACT for all CTG or ACT VOC source categories specific to any CTG or ACT documents issued prior to 2006. For all non-CTG/ACT major VOC emission source categories that controls are technologically and economically feasible, RACT is fulfilled by the EPA-approved Chapter 115 rules or other federally enforceable measures.

The EPA issued 11 CTG documents between 2006 and 2008 with recommendations for VOC controls on a variety of consumer and commercial products. Some of the new CTG recommendations are updates to previously issued CTG documents and some are recommendations for new categories. The TCEQ evaluated these new CTG documents in this RACT analysis to determine if additional VOC controls were necessary to fulfill RACT requirements. The following is a list of the 11 CTG documents:

- *Flat Wood Paneling Coatings, Group II Issued in 2006*
- *Flexible Packaging Printing Materials, Group II Issued in 2006*
- *Industrial Cleaning Solvents, Group II Issued in 2006*
- *Offset Lithographic and Letterpress Printing, Group II Issued in 2006*
- *Large Appliance Coatings, Group III Issued in 2007*
- *Metal Furniture Coatings, Group III Issued in 2007*
- *Paper, Film, and Foil Coatings, Group III Issued in 2007*
- *Auto and Light-Duty Truck Assembly Coatings, Group IV Issued in 2008*
- *Fiberglass Boat Manufacturing Materials, Group IV Issued in 2008*
- *Miscellaneous Industrial Adhesives, Group IV Issued in 2008*
- *Miscellaneous Metal and Plastic Parts Coatings, Group IV Issued in 2008*

The following provides a brief summary of the TCEQ's determinations regarding these 11 CTG documents. Additional details regarding the evaluation of the 11 CTG documents are provided in Appendix D: *Reasonably Available Control Technology Analysis*.

4.4.3.1 CTG Documents That Are Not Applicable to the HGB Area

The TCEQ provides a negative declaration for the Automobile and Light-Duty Truck Assembly Coatings, Flat Wood Paneling Coatings, and the Fiberglass Boat Manufacturing Materials CTG documents. The TCEQ determined that no sources meeting the applicability criteria recommended in these three CTG documents are located in the HGB area.

4.4.3.2 CTG Documents That a RACT Determination Cannot Be Made at This Time

The TCEQ is not making a determination at this time whether the recommendations in the following CTG documents represent RACT for Texas: Industrial Cleaning Solvents; Miscellaneous Industrial Adhesives; Large Appliance Coatings; Metal Furniture Coatings; Miscellaneous Metal and Plastic Parts Coatings; Flexible Packaging Printing Materials; and Paper, Film, and Foil Coatings.

The TCEQ's initial assessment indicates that the EPA substantially underestimated the scope and potential impact of the Industrial Cleaning Solvents and the Miscellaneous Industrial Adhesives CTG recommendations and that implementing the CTG recommendations would have widespread and potentially adverse impacts to small businesses and micro-businesses. The TCEQ will continue to evaluate these CTG documents and plans to conduct research to determine the quantity of sources that would be affected by these CTG recommendations and to provide small business outreach to engage stakeholders that could be potentially impacted by the EPA's suggested control measures. The executive director will proceed with RACT analyses of these CTG documents and initiate a future SIP revision and rulemaking for the commission's consideration, if necessary, in order to submit RACT determinations to the EPA in a timely manner.

By letter dated December 8, 2008, the TCEQ requested clarification from the EPA regarding several issues related to the recommendations in the Large Appliance Coatings, Metal Furniture Coatings, and Miscellaneous Metal and Plastic Parts Coatings CTG documents. A number of the recommended VOC content limits for specific coatings categories in the CTG documents are less stringent than the more general VOC content limits specified in the EPA's original CTG recommendations. The TCEQ requested clarification to assure that implementing the CTG recommendations would not be considered as backsliding and to be certain that the TCEQ has the appropriate information to determine whether the CTG recommendations actually represent RACT for Texas. As of the September 23, 2009, commissioner's agenda for proposal of this SIP revision, the EPA had not formally responded to the TCEQ’s request for clarification on these CTG recommendations. Therefore, the TCEQ did not propose RACT determinations for these three CTG documents. However, in the comments submitted for this SIP revision, the EPA did provide suggestions and guidance regarding the issues raised by the TCEQ in the December 2008 letter. The executive director will proceed with RACT analyses of these three CTG documents

based on the guidance provided in the EPA's comments and initiate a future SIP revision and rulemaking for the commission's consideration, if necessary, in order to submit RACT determinations to the EPA in a timely manner.

At the September 23, 2009, agenda for proposal of this SIP revision, the TCEQ proposed that additional controls were not necessary for the Flexible Packaging Printing Materials and the Paper, Film, and Foil CTG categories. However, in response to the EPA's comments on this SIP revision, the TCEQ has decided to reevaluate the RACT analyses for the Flexible Packaging Printing Materials and the Paper, Film, and Foil CTG recommendations. The executive director will proceed with RACT analyses of these CTG documents and initiate a future SIP revision and rulemaking for the commission's consideration, if necessary, in order to submit RACT determinations to the EPA in a timely manner.

4.4.3.3 CTG Documents That Represent RACT for the HGB Area

The TCEQ has determined that portions of the Offset Lithographic and Letterpress Printing CTG recommendations represent RACT for the HGB area. Concurrent with this SIP revision, the TCEQ is adopting rulemaking to limit the VOC content of solvents used by offset lithographic printing facilities in the HGB area (Rule Project 2008-019-115-EN). The rulemaking being adopted concurrently with this SIP revision implements the CTG recommendations to reduce the VOC content of the fountain solutions and cleaning materials. Additionally, this rulemaking expands the current rule applicability to include smaller sources not currently subject to the rule. The TCEQ is not implementing any rule amendments or new rules associated with the CTG-recommended control requirements for heatset presses or with the letterpress printing portion of this CTG document for the HGB area. Additional discussion concerning the TCEQ's determination regarding the CTG recommendations is provided in Appendix D: *Reasonably Available Control Technology Analysis*.

4.5 REASONABLY AVAILABLE CONTROL MEASURES (RACM) ANALYSIS

4.5.1 General Discussion

States are required by FCAA, §172(c)(1) to "provide for implementation of all reasonably available control measures as expeditiously as practicable" and to include RACM analyses in the SIP. In the General Preamble for implementation of the FCAA Amendments of 1990 published in the April 16, 1992, issue of the *Federal Register* (57 FR 13498), the EPA explains that it interprets §172(c)(1) of the FCAA as a requirement that states incorporate into their SIP all reasonably available control measures that would advance a region's attainment date. However, regions are obligated to adopt only those measures that are reasonably available for implementation in light of local circumstances.

The TCEQ used a two-step process to identify potential control strategies for the HGB area RACM analysis. The TCEQ compiled a list of potential control strategy concepts based on an initial evaluation of the existing control strategies and existing sources of VOC and NO_X in the HGB area. The EPA allows states the option of considering control measures outside the ozone nonattainment area that can be shown to advance attainment; however, consideration of these sources is not a requirement of the FCAA. Sources of VOC within 100 kilometers (km) of the HGB area and sources of NO_X within 200 km of the HGB area were also considered for this initial evaluation. Draft lists of potential control strategy concepts for stationary and mobile sources were developed from this initial evaluation. The draft lists of potential control strategy concepts were presented to stakeholders for comment at stakeholder meetings held in the HGB area on March 25 and 26, 2008. The TCEQ requested comment on the potential control strategies and invited stakeholders to suggest any additional strategies that might help advance attainment of the HGB area. The final lists of potential control strategy concepts for the RACM analyses of stationary and mobile sources include both the strategies presented to stakeholders in March 2008 and the strategies suggested by stakeholders during the informal stakeholder comment process.

Each potential control measure identified through the control strategy development process was evaluated to determine if the measure would meet established criteria to be considered reasonably available. The TCEQ used the general criteria specified by the EPA in the proposed approval of the New Jersey RACM analysis published in the January 16, 2009, issue of the *Federal Register* (74 FR 2945):

> *RACM is defined by the EPA as any potential control measure for application to point, area, on-road and non-road emission source categories that meets the following criteria:*
> - *The control measure is technologically feasible*
> - *The control measure is economically feasible*
> - *The control measure does not cause ''substantial widespread and long-term adverse impacts''*
> - *The control measure is not ''absurd, unenforceable, or impracticable''*
> - *The control measure can advance the attainment date by at least one year.*

The EPA did not provide guidance in the *Federal Register* on how to interpret the criteria "*advance the attainment date by at least one year."* Because modeling all possible year scenarios for potential control measures is not practical, the TCEQ evaluated whether a potential control measure would help the HGB area make progress toward attainment of the NAAQS based on potential eight-hour ozone reduction benefit in terms of parts per billion (ppb) using modeling sensitivity runs.

The TCEQ also considered whether the potential control measure could be implemented before and reduce emissions prior to the beginning of the ozone season immediately before the attainment date. The attainment date for the 1997 eight-hour ozone NAAQS for the HGB area is June 15, 2019, so suggested control measures that could not be implemented by January 1, 2018, were not considered RACM because the measures would not advance attainment. However, the HGB area must make progress toward attainment of 1997 eight-hour ozone NAAQS as expeditiously as practicable. Therefore, if control measures can be implemented earlier than January 1, 2018, and will help the area make progress toward attainment of the NAAQS earlier than the attainment year, the measure should be implemented as early as feasible.

The TCEQ also considered whether the control measure was similar or identical to control measures already in place in the HGB area. If the suggested control measure would not provide substantive and quantifiable benefit over the existing control measure, then the suggested control measure was considered not RACM because reasonable controls were already in place.

4.5.2 Results of RACM Analysis

Based on the RACM analysis, the TCEQ determined that only one potential control measure met the criteria to be considered RACM. A reduction in the HRVOC cap for Harris County under the HECT program was determined to help advance attainment of the HGB area and to meet the other RACM criteria. Reported HRVOC emissions from sources in the HECT program during the first two years of the HECT program, calendar years 2007 and 2008, averaged approximately 56 percent of the total allocated HRVOC allowances for Harris County. Because there is a demonstrated substantial surplus in the HRVOC cap, a 25 percent reduction in the cap for Harris County is technologically feasible and should have minimal economic impact. Modeling demonstrates that a 25 percent reduction in the HRVOC cap for Harris County will help the HGB area make progress toward attainment of the 1997 eight-hour ozone NAAQS. Based on 2007 and 2008 emissions, a 25 percent reduction would leave a buffer of approximately 600 tpy, or more, in the cap that should be sufficient to account for any significant variations in HRVOC emissions in future years due to emission events and scheduled startup, shutdown, and maintenance events as well as allow for future economic growth. Additional discussion regarding the control

measure to reduce the HRVOC cap for Harris County is included in Section 4.6: *New Control Measures*.

All other potential control measures evaluated for both stationary and mobile sources were determined not to be RACM due to technological or economic feasibility, enforceability, adverse impacts, or ability of the measure to advance attainment of the NAAQS. Additional information and specific details regarding the RACM analysis for the HGB area are provided in Appendix E: *Reasonably Available Control Measure Analysis*.

4.6 NEW CONTROL MEASURES

4.6.1 Stationary Sources

4.6.1.1 HECT Cap Reduction and Allowance Reallocation

The revisions to the HECT program rules being adopted concurrently with this SIP revision result in a 25 percent reduction in the total HECT allowance cap and revise the HRVOC allocation methodology. The HECT program was adopted by the commission as an ozone control measure for the HGB area on December 1, 2004. Currently, the HECT program is applicable only in Harris County.

Based on modeling done for proposal, the 25 percent reduction will reduce the 2018 future eight-hour ozone design value by 0.11 ppb on average for all monitors and by 0.24 ppb at the Deer Park monitor. The final modeling done for adoption shows an average ozone decrease of 0.13 ppb for the three monitoring sites with 2018 projected eight-hour ozone design values greater than the 1997 eight-hour ozone NAAQS, Deer Park, Bayland Park, and Wallisville. The Deer Park monitor's design value was the highest in the HECT sensitivity modeling and the HECT sensitivity modeling showed a decrease in the Deer Park monitor design value from 86.49 ppb to 86.36 ppb ozone.

HRVOC data from the first two years indicate that the total reported actual emissions from sources in the HECT program are approximately 50 percent of the total HRVOC cap. Because the HRVOC rules in Chapter 115, Subchapter H, Divisions 1 and 2, require emissions from startup, shutdown, and maintenance activities be included in the HECT program, the total surplus observed in the first two years of the program cannot be removed. A 25 percent reduction leaves a buffer in the cap that is still needed to account for the inherent variability of HRVOC emissions associated with these activities.

Following the initial allocation of allowances, companies participating in the HECT program commented that the allocation was not equitably distributed and that some sites did not receive enough allocations while other sites received allocations greater than necessary. Monitoring data supports the assertion of an inequitable distribution of allowances. Revisions to the rule will result in a more equitable approach while contributing to the area's attainment of the NAAQS as expeditiously as practicable.

The existing allocation methodology was based on the total amount, in pounds, of HRVOC produced as an intermediate, byproduct, or final product, or used by a process unit at each participating site. Analysis of the monitoring data from previous control periods indicate that refineries may have been over-allocated while polymer, plastics, and other chemical producers may have not received a sufficient allocation.

This HECT rule revision includes a new allocation methodology beginning with the 2011 calendar-year control period based on actual monitored emissions data with the goals of fairly and equitably distributing the compliance burden for HECT program participants, applying credit for controlling and reducing HRVOC emissions, and not rewarding or encouraging emissions from emissions events. This revised allocation methodology is based on calculating "uncontrolled" or "precontrolled" emissions for facilities using control efficiencies based on rule specifications and stack performance testing data for combustion devices; applying credit for quantified flare and

vent gas recovery and flare minimization; and dividing the cap into four industry-type sector pools to account for different HRVOC emission rates associated with the various processes of the chemical, petroleum refining, polymer, and storage/loading sectors. The rulemaking does not contain an emissions event set aside and the entire available cap of 3,451.6 tons is available for reallocation. Only emissions from normal, routine, and permitted operations will be used in determining "uncontrolled emissions" and no emissions from emissions events will be applied toward reallocation. All emissions from HECT-applicable facilities, including emissions from emission events, must be reported and accounted for using HRVOC allowances. Qualifying sites that have acquired allowance streams may be permitted to apply a portion or the entire allowance stream toward the site allocation as actual emissions, depending on the site's total uncontrolled emissions during the baseline emissions period.

The HECT rulemaking will also reduce the cap in a gradual step down fashion beginning with a 10 percent cap reduction at the beginning of the 2014 calendar-year control period, and continue to reduce the cap to a total of 25 percent in annual five percent reductions from 2015 to 2017.

4.6.2 Local Programs

The H-GAC worked with HGB area local governments and business stakeholders to develop appropriate control strategies to meet the SIP requirements and to recruit stakeholders who would take legal responsibility for implementing these strategies through the establishment of memoranda of agreement. As a result, six projects were identified as Transportation Control Measures (TCMs), and numerous strategies were agreed upon with local governments as voluntary measures. For more information regarding the development of local control strategies, see Appendix F: *Evaluation of Mobile Source Control Strategies for the Houston-Galveston-Brazoria State Implementation Plan* (prepared by ENVIRON for the H-GAC).

4.6.2.1 Transportation Control Measures

TCMs are transportation projects and related activities that are designed to reduce on-road mobile source emissions and are included as control measures in the SIP. Allowable types of TCMs are listed in §7408 (Air Quality Criteria and Control Techniques) of the FCAA, and defined in the federal transportation conformity rule found in 40 CFR, Part 93 (Determining Conformity of Federal Actions to State or Federal Implementation Plans). The federal transportation conformity rule requires that timely implementation of TCMs be demonstrated. In general, TCMs are transportation related projects that attempt to reduce vehicle use, change traffic flow, or reduce congestion conditions. Projects that add single-occupancy-vehicle roadway capacity or are based on improvements in vehicle technology or fuels are not considered to be TCMs.

The H-GAC has identified TCMs that have been or will be implemented in the nonattainment area. By the start of the 2018 ozone season, these TCMs will reduce NO_X emissions in the HGB area by .015 tons per day (tpd). Appendix G: *Transportation Control Measures for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard* (prepared by ENVIRON for the H-GAC) summarizes the emission reductions by type of TCM. The H-GAC's Technical Advisory Committee approved and identified funding for these local commitments.

4.6.2.2 Voluntary Mobile Emission Reduction Programs (VMEP)

Voluntary mobile source measures have the potential to contribute, in a cost-effective manner, emission reductions needed for progress toward attainment and maintenance of the NAAQS.

Historically, federal mobile source control strategies have focused primarily on reducing emissions per mile through vehicle and fuel technology improvements. Tremendous strides have been made resulting in new light-duty vehicle emission standards that are 70 to 90 percent less than that for the 1970 model year. However, mobile sources continue to constitute a significant portion of ozone precursor emissions in the HGB area due to population and employment growth as well as an increase in daily vehicle miles traveled per person. Therefore, mobile source strategies that attempt to complement existing regulatory programs through voluntary, non-

regulatory changes in local transportation sector activity levels or changes in vehicle and engine fleet composition were explored and developed.

A number of voluntary mobile source and transportation programs have already been initiated at the state and local levels in response to increasing interest by the public and business sectors in creating alternatives to traditional emission reduction strategies. Some examples include economic and market-based incentive programs, trip reduction programs, growth management strategies, ozone action programs, and targeted public outreach. These programs attempt to gain additional emissions reductions beyond mandatory FCAA programs by engaging the public to make changes in activities that will result in reducing mobile source emissions.

The H-GAC identified three voluntary measures that will aid in the improvement of the HGB region's air quality. These measures were identified through a contract between the H-GAC and ENVIRON International Corporation. Nineteen meetings were held with stakeholders from the region to solicit comments and suggestions for voluntary programs. The H-GAC's commitment for NO_X from VMEP is 2.25 tpd. The H-GAC, as the regional metropolitan transportation planning agency for the HGB area, has committed to make a good faith effort to implement the projects and/or programs outlined in this document and will be responsible for monitoring and reporting the emission reductions to the TCEQ. More information on each of the VMEP commitments can be found in Appendix H: *Voluntary Mobile Emission Reduction Programs for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard* (prepared by ENVIRON for the H-GAC).

4.7 Motor Vehicle Emissions Budget (MVEB)

The MVEB refers to the maximum allowable emissions from on-road mobile sources for each applicable criteria pollutant or precursor as defined in the SIP. The budget must be used in transportation conformity analyses. Areas must demonstrate that the estimated emissions from transportation plans, programs, and projects do not exceed the MVEB. The attainment budget represents the on-road mobile source emissions that have been modeled for the attainment demonstration. The budget reflects all of the on-road control measures reflected in that demonstration. The MVEB is shown in Table 4-2: *2018 Attainment Demonstration Motor Vehicle Emissions Budget for the Eight-County HGB Area*. For additional detail, see Appendix B*: Emissions Modeling for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard*.

Table 4-2: 2018 Attainment Demonstration MVEB for the Eight-County HGB Area

Eight-County HGB Area	Summer Weekday Emissions (tpd)	
2018 MVEB	NO_X	VOC
	49.22	45.97

4.8 MONITORING NETWORK

States are required by 40 CFR, Part 58, Subpart B, to submit an annual monitoring network review to the EPA by July 1 of each year. This network review is required to provide the framework for establishment and maintenance of an air quality surveillance system. The annual monitoring network review must be made available for public inspection for at least 30 days prior to submission to the EPA. The review and any comments received during the 30-day inspection period are then forwarded to the EPA for final review and approval. The TCEQ posted this plan from June 1 through June 30, 2009. The document presented the current Texas network of ambient air Photochemical Assessment Monitoring Station (PAMS) monitors as well as proposed changes to the network from July 1, 2009, through December 31, 2010.

This network review includes posting of the TCEQ's EPA-approved PAMS Network Plan which focuses on ozone precursors. The reclassification of the Houston ozone nonattainment area to severe requires one major change in the HGB area PAMS plan. The TCEQ will conduct

intensive carbonyl sampling at the Clinton PAMS Type 2 Site (AQS ID 48-201-1035) each year. As agreed upon with the EPA, Region 6, the TCEQ will collect a total of 240 carbonyl samples at this site at a sampling frequency of eight 3-hour samples per day every three days during July-September. Carbonyl sampling will be terminated at the Houston Channelview site to offset this increased sampling schedule at the Clinton site. The 24-hour sample every sixth day carbonyl sampling at the Deer Park monitor (AQS ID 48-201-1039) will continue January through December.

4.9 CONTINGENCY PLAN

SIP revisions for nonattainment areas are required by §172(c)(9) of the FCAA to provide for specific measures to be implemented should a nonattainment area fail to meet reasonable further progress (RFP) requirements or attain the applicable NAAQS by the attainment date set by the EPA. These contingency measures are to be implemented without further action by the state or the EPA. In the General Preamble for implementation of the FCAA Amendments of 1990 published in the April 16, 1992, issue of the *Federal Register* (57 FR 13498), the EPA interprets the contingency requirement to mean additional emissions reductions that are sufficient to equal up to 3 percent of the emissions in the adjusted base year inventory. These emissions reductions should be realized in the year following the year in which the failure is identified (i.e., an RFP milestone year or attainment year).

The adjusted base year emissions inventory is used in the RFP planning process to calculate required emissions reduction targets and excludes certain on-road mobile source emissions reductions from controls that were promulgated prior to the 1990 amendments to the FCAA. This 1997 eight-hour ozone attainment demonstration SIP revision also uses the adjusted base year inventory as the inventory from which to calculate the required 3 percent reduction for contingency. For further information regarding the adjusted base year inventory for the HGB area and how the area meets RFP requirements, see the Houston-Galveston-Brazoria Reasonable Further Progress State Implementation Plan Revision for the1997 Eight-Hour Ozone Standard (Project No. 2009-018-SIP-NR), which is being adopted concurrently with this attainment demonstration SIP revision.

A summary of the 2019 contingency analysis is provided in Table 4-3: *2019 Contingency Demonstration for the HGB Area*. Consistent with the EPA's NO_X substitution guidance, the 3 percent attainment demonstration contingency analysis for 2019 is based on a 2 percent reduction in NO_X emissions (17.16 tpd) and a 1 percent reduction in VOC emissions (9.36 tpd) to be achieved between 2018 and 2019 (EPA, 1993). Inventory analyses were performed on the fleet turnover effects for the federal emission certification programs for on-road and non-road vehicles. The emission reductions from 2018 to 2019 were estimated for these programs. For a detailed description of the contingency reductions, see Appendix 1: *HGB Reasonable Further Progress Demonstration Calculations Spreadsheet* of the Houston-Galveston-Brazoria Reasonable Further Progress State Implementation Plan Revision for the1997 Eight-Hour Ozone Standard (Project No. 2009-018-SIP-NR).

Table 4-3: 2019 Contingency Demonstration for the HGB Area

Description		
	NO_X	VOC
Adjusted 2018 Base Year Emissions Inventory	**858.18**	**935.57**
Percent for Contingency Calculation (total of 3 percent)	**2.00**	**1.00**
2018 to 2019 Required Contingency Reductions	**17.16**	**9.36**
Federal On-Road Mobile New Vehicle Certification Standards	3.97	2.73
Federal On-Road Reformulated Gasoline (RFG)	5.09	0.70
State I/M and Anti-Tampering Programs (Brazoria, Fort Bend, Galveston, Harris, and Montgomery Counties)	1.23	0.31
Federal Non-Road Mobile New Vehicle Certification Standards	3.56	1.78
Non-Road RFG Gasoline	0.00	0.03
Federal Tier I and II Locomotive Standards	0.68	0.01
Federal Tier 2 Marine Diesel Standard	0.55	0.02
Additional Contingency Measures to be Quantified before 2019	2.08	3.78
Total Contingency Reductions	**17.16**	**9.36**
Contingency Excess (+) or Shortfall (-)	**0.00**	**0.00**

Note: Emissions are represented in tons per day.

To meet the contingency requirement, the TCEQ will evaluate potential control measures to be implemented at the state level that require more study before emissions reductions can be quantified and federal measures that are not yet final or have not yet been implemented. The TCEQ executive director commits to include for commission approval sufficient additional measures to equal 3 percent of the emissions in the adjusted base year inventory to be implemented in the event that the HGB area does not attain the 1997 eight-hour ozone standard by June 15, 2019, at the time of a mid-course review (MCR) for this attainment demonstration SIP revision. For more information on the MCR commitment, see Chapter 6: *Ongoing and Future Initiatives* Section 6.3.1 *Mid-Course Review (MCR)*. Potential measures include but are not limited to the following:

<u>Potential State Measures</u>

- *Gas Imaging "Find and Fix" Rule*
  Contingency measure rule to require the use of gas imaging camera technology for periodic inspection of sources of VOC emissions such as storage tanks, barges, etc., that are not currently subject to leak detection monitoring programs and set reasonable time periods for companies to address possible problems found (e.g., leaking seals).

- *Enhanced LDAR for Difficult-to-Monitor Components*
  Contingency measure rule to require the use of gas imaging camera technology for more frequent monitoring on difficult-to-monitor and unsafe-to-monitor components that would normally have very long monitoring frequencies under traditional LDAR monitoring rules.

<u>Potential Federal Measures</u>

- *International Maritime Engine Emission Standards for Oceangoing Vessels*

If implemented by the EPA, this measure would result in annual emissions reductions from fleet turnover.

- *EPA Proposed Rule to Reduce Air Toxics from Stationary Diesel and Gas-Fired Engines*
  If finalized, this rule would become effective in 2013.

- *EPA Proposed Rule to Reduce Air Toxics Emissions from Area Source Asphalt Refining and Asphalt Roofing Manufacturing Facilities*
  If finalized, this rule would likely go into effect before 2019.

- *EPA Final Rule for National VOC Emission Standards for Aerosol Coatings*
  Final rule amendments to add compounds and reactivity factors go into effect July 2009.

4.10 REFERENCES

EPA, 1993. NO_X Substitution Guidance, http://www.epa.gov/ttncaaa1/t1/memoranda/noxsubst.pdf

EPA, 2005. Clean-Fuel Vehicle Standards, no. CCD-05-12.

CHAPTER 5: WEIGHT OF EVIDENCE

5.1 QUANTITATIVE CORROBORATIVE ANALYSIS

5.1.1 Introduction

The corroborative analysis presented in this chapter demonstrates the progress that the Houston-Galveston-Brazoria (HGB) area is making towards attainment of the 1997 eight-hour ozone National Ambient Air Quality Standard (NAAQS) of 0.08 parts per million (ppm). The United States Environmental Protection Agency's (EPA) April 2007 "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze" (EPA, 2007) states that all model attainment demonstrations should include supplemental evidence that the conclusions derived from the basic attainment modeling are supported by other independent sources of information. This document will present the supplemental evidence, i.e., the corroborative analyses, for the current modeling demonstration. The guidance also states that a weight of evidence demonstration is allowed when the future design value is at or below 87.9 parts per billion (ppb).

The first section of the quantitative corroborative analysis will discuss photochemical grid modeling. Modeling is one of the most important tools available for evaluating progress toward meeting air quality standards, but it is not a perfect tool. The first section will also discuss known issues with photochemical grid modeling and how the Texas Commission on Environmental Quality (TCEQ) has dealt with them. It also discusses overall model performance. Finally, it discusses the diagnostic analyses performed by the TCEQ, and the implications of those analyses on the projected attainment status. The second section of the quantitative corroborative analysis will discuss trends in ozone and ozone precursors observed in the HGB area, and examines the possible causes for those trends. The third section describes air quality control measures that cannot yet be adequately quantified but are nonetheless expected to yield tangible air quality benefits.

5.2 Corroborative Analysis: Modeling

Photochemical grid modeling of the HGB area is challenging, due to complex coastal wind circulation, complex petrochemical point sources of emissions in Brazoria, Chambers, Galveston, and Harris Counties, and the challenges associated with modeling a metropolitan area of over five million inhabitants.

One purpose of the Texas Air Quality Study 2000 (TexAQS 2000) and the Texas Air Quality Study 2006 (TexAQS II) field studies was to address the uncertainties that affect photochemical grid modeling and their regulatory applications. Insights gleaned from the TexAQS 2000 and subsequent studies have helped resolve some of these uncertainties.

Several studies have tried to identify and reduce uncertainties in the HGB photochemical grid modeling. Foremost among these efforts are the studies that have sought to quantify underreported industrial highly reactive volatile organic compounds (HRVOC) emissions (Wert et al., 2003; Xie and Berkowitz, 2007; Yarwood et al., 2004; TCEQ, 2002, 2004, 2006; Smith and Jarvie, 2008) and to assess the sensitivities of ozone simulations to underreporting these emissions (TCEQ, 2002, 2004, 2006; Byun et al., 2007; Jiang and Fast, 2004). Other modeling efforts have tested different chemical mechanisms in the HGB area's photochemical grid modeling, to study the effects of using different mechanisms on ozone model performance and control strategy effectiveness (Byun et al., 2005b; Faraji et al., 2008; Czader et al., 2008). Modeling sensitivity studies have also been performed to guide selection of model parameters such as vertical mixing schemes, number and depth of model layers, and horizontal grid resolution (Kemball-Cook et al., 2005; Byun et al., 2005b; Byun et al., 2007; Bao et al., 2005).

Some of the most important findings of these studies include the following.

- Emissions inventories must be reconciled to some extent with observational data before the model can accurately depict the ozone formation processes in the HGB area, especially for HRVOC.
- Adding HRVOC to modeling emissions inventories generally increases ozone concentrations and alleviates a portion of the ozone and HRVOC under-prediction problems found by every modeling group who has attempted to model the HGB area.
- Reactivities of the TCEQ-defined HRVOC are high regardless of which chemical mechanism is used to evaluate their effects. In addition to the TCEQ list of HRVOC, formaldehyde also displays high reactivity.

Mesoscale meteorological modeling is used to drive photochemical grid models, and many studies have examined and reduced uncertainties in these models as well. One of the most successful efforts improved meteorological simulations of ozone episodes by using radar profiler and other upper level wind data to "nudge" the meteorological modeling (Nielsen-Gammon et al., 2007; Zhang et al. 2007; Stuart et al., 2007; Bao et al., 2005; Fast et al., 2006). Other efforts improved land cover data and land surface modeling (Byun et al., 2005a; Cheng et al., 2008a, 2008b) and studied the sensitivity of ozone simulations to solar irradiance and photolysis rates (Zamora et al., 2005; Fast et al., 2006; Pour-Biazar et al., 2007; Byun et al., 2007; Koo et al., 2008).

Some of the most important findings of these meteorological modeling studies include the following.

- Assimilation of radar profiler and other upper air wind data is essential to good meteorological modeling performance in the HGB area.
- Modeling parameterizations must be chosen carefully to alleviate the common problem of spurious thunderstorms and clouds.
- Accurate simulation of cloud cover is crucial to getting photolysis rates correct in the photochemical grid model, and ozone predictions are very sensitive to photolysis rates.
- An ensemble approach to meteorological and photochemical grid modeling may be warranted, given the sensitivity of ozone modeling to relatively small changes in meteorology. The ensemble approach allows probabilistic attainment demonstrations to be produced.

In the remainder of this section, modeling issues identified by the studies described above are discussed, as well as issues raised by TexAQS 2000 research, by TexAQS II research, and by TCEQ-sponsored investigations. Overall performance of the photochemical grid modeling and the implications of the model's ability to accurately simulate ozone episodes are also discussed. Finally, additional metrics that show the effects of the proposed control strategies on ozone in the HGB area are presented.

5.2.1 Solving Modeling Problems

For the HGB area, there are several aspects of ozone modeling that require special attention, due to their role in current or historical shortcomings in model performance. This section discusses some of these issues, and how TCEQ has attempted to resolve them in this round of modeling.

5.2.1.1 Industrial Point Source Emission Inventory Issues

High concentrations of light alkenes such as propylene, ethylene, 1,3-butadiene, and butenes have been observed in the HGB metropolitan area, and are closely associated with petrochemical industry facilities in eastern Harris, Galveston, Chambers, and Brazoria Counties (Ryerson et al., 2003; Daum et al., 2003; Daum et al., 2004; Berkowitz et al., 2004; Berkowitz et al., 2005; Kleinman et al., 2002; Kleinman et al., 2005; Jobson et al., 2004; Karl et al., 2003; Buzcu and Fraser, 2006; Xie and Berkowitz, 2006, 2007; Kim et al., 2005). These compounds have been identified as highly reactive, and they play a major role in forming the highest concentrations of ozone observed in the HGB area (Ryerson et al., 2003; Daum et al., 2003, 2004; Kleinman et al., 2002, 2005; Wert et al., 2003; Czader et al., 2008). Historical analyses of routinely collected volatile organic compounds (VOC) data indicate that these compounds are present in high concentrations on a routine basis in the HGB area (Hafner Main et al., 2001; Estes et al., 2002;

Brown and Hafner Main, 2002; Brown et al., 2002; Hafner and Brown, 2003; Jolly et al., 2003; Fang and McDowell, 2003; Jolly, 2003; Kim et al., 2005; Buzcu and Fraser, 2006; Xie and Berkowitz, 2006, 2007). Consequently, the high HRVOC concentrations observed during the two field study periods in 2000 and 2006 are not anomalously large, and the conclusions drawn from those data should be generally applicable to the HGB area.

Both field studies sponsored by the TCEQ, TexAQS 2000 and TexAQS II, have indicated that there are discrepancies in reported emissions of VOC, such as ethene and propylene (Ryerson et al., 2003; Daum et al., 2003; Daum et al., 2004; Wert et al., 2003; Gilman et al., 2009; de Gouw et al., 2009). The TCEQ remote sensing studies of flares, storage tanks, cooling towers, and other sources have shown that large quantities of VOC emissions have gone unreported (Robinson et al., 2008; Smylie et al., 2004). In addition, solar occultation flux measurements have shown that 30-minute variations in industrial HRVOC emissions can be an order of magnitude or more (Mellqvist et al., 2007, 2008).

In an attempt to better quantify underreported HRVOC for purposes of photochemical grid modeling, the TCEQ commissioned a study by researchers at the Pacific Northwest National Laboratory (Xie and Berkowitz, 2006, 2007). The researchers used historical HRVOC measurements from the extensive automated gas chromatograph network currently in place in the industrial areas of the HGB area. Most of the sites in this network went into operation during 2003. Using trajectories to link the source areas to the observations, the researchers were able to estimate which areas had the greatest emissions relative to other areas.

For the current round of modeling, TCEQ researchers extended the methods developed by Pacific Northwest National Laboratory to quantitatively estimate underreported HRVOC emissions in the HGB area. The Potential Source Contribution Function method has measurably improved model performance for ozone and its precursors by reconciling the industrial point source emissions inventory with observed HRVOC concentrations during 2005-2006 (Smith and Jarvie, 2008). This method does not attempt to reproduce the temporal variations in emissions, but instead calculates a median rate of emission for each square kilometer of the HGB area. Since two years of data are used to estimate the medians, the metric is statistically robust.

5.2.1.2 Modeling of Emissions Events

Attempts have been made to quantify temporal variations in industrial point source emissions by accessing emission event reports that are delivered by industry to the TCEQ (Murphy and Allen, 2005). Problems with the event report data include the following.

- Emission events were self-reported by industry, and the quantities of emissions reported were not independently observed or verified. Facilities are allowed, by rule, to estimate emissions during emergency releases due to safety concerns.
- Emission events were only reported if estimated emissions were greater than a certain threshold above the permitted emission level. Some facilities have very large permitted emissions levels, and therefore large fluctuations in emissions may occur under an authorized emission rate that are not included in the data set. Consequently, the frequency and magnitude of emission events in this data set does not reflect the actual magnitudes or frequency of episode releases or authorized emissions.
- Emission event data for the Murphy and Allen study were collected before industry was required to monitor HRVOC. Therefore, most of the emission estimates are not based upon measurements of the events.
- The TCEQ infrared camera studies have found instances where emissions were emanating from locations that were not included in any emissions inventory.
- The TCEQ flare investigations have found that flares are typically managed to reduce noise, smoke, and glare. Optimizing the flare to keep destruction efficiency at a maximum is typically a secondary consideration. In particular, flares used as both emergency flares and process flares have been observed to operate with poor combustion efficiency when operating in process flare mode (Robinson et al., 2008).

- In addition, flare monitoring records only the chemicals flowing to the flare, not which species are actually being emitted. Combustion efficiencies are estimates of how much of the original material has been destroyed, and no effort is made to estimate the composition or reactivity of the combustion products. Circumstantial evidence from the TexAQS II and from the Study of Houston Atmospheric Radical Precursors (SHARP) suggests that formaldehyde may be produced during or immediately after flare combustion, though the absolute quantity of emissions may only constitute a small part of the observed ambient formaldehyde (Gilman et al., 2009; De Gouw et al., 2009). The SHARP field campaign in April-May 2009 and TCEQ flare study in 2010 are investigating this hypothesis in greater depth.
- Field studies (Mellqvist et al., 2007, 2008; de Gouw et al., 2009) and recent infrared camera and differential absorption lidar (DIAL) results (Robinson et al., 2008) show that the techniques used by industry to estimate HRVOC emissions from flares and other sources may still be inadequate to quantify them properly, because these experiments measured much higher emission fluxes than were reported.

A number of recent modeling studies have attempted to investigate the frequency, magnitude, and impact of emission events upon ozone in Houston (Webster et al., 2007; Nam et al., 2006, 2008). Since these studies are based upon the emission event reports, they have not properly quantified the frequency or magnitude of the emission events, due to the problems discussed above. Therefore, the modeled impact of emission events described in the Webster et al. and Nam et al. studies are unlikely to accurately reflect the complete impact of emission events in the HGB area. The TCEQ has not attempted to speculate on the exact frequency or magnitude of future sporadic emission events in this modeling exercise.

5.2.1.3 Resolution of Photochemical Modeling Grids

Numerous studies have investigated the effects of grid size on model behavior (Cohan et al., 2006; Esler, 2003; Gego et al., 2005; Valari and Menut, 2008). The main interest in finer grid resolution is that higher resolution can increase concentrations of ozone precursors in narrow plumes, which can affect ozone production rate and sensitivity to VOC or nitrogen oxides (NO_X) within the plumes. In a city such as Houston, using a higher resolution grid is sensible, given the abundance of industrial point sources, which can generate narrow plumes. Researchers during TexAQS 2000 determined that rapid ozone formation occurring within narrow industrial plumes are responsible for the highest observed ozone in the HGB area and for the strong ozone gradients that can form. Strong ozone gradients can cause large increases in ozone concentration at monitoring sites as the plume is carried across town by winds that have shifted direction and are no longer parallel to the plumes. To resolve these atmospheric features, the TCEQ is using smaller-sized grid cells than previous modeling exercises (2 kilometer (km) × 2 km instead of 4 km × 4 km). In general, the TCEQ has found that smaller grid sizes can yield higher ozone production and can alleviate, in part, the commonly observed low bias for ozone within industrial plumes. There are limits to this solution, however; it is inappropriate to decrease grid size indefinitely. Parameterizations in both the meteorological modeling and the photochemical grid modeling are based upon the assumption that turbulence features within the planetary boundary layer (PBL) are much smaller than the grid size. If the grid size is decreased to 1 km × 1km or lower, the assumption probably no longer holds, and more uncertainty can be added to the modeling as a result of the finer resolution. If smaller grid sizes are desired, large eddy simulation modeling should be considered rather than photochemical grid modeling.

Also, note that if the spatial resolution of the photochemical grid modeling is reduced, then the temporal resolution of the meteorological and chemical processes within the model ought to be reduced, to match the shorter residence time of precursors in each grid cell. In other words, as the size of the box shrinks, the amount of time that a mass of air resides in the box also shrinks, affecting how the ozone chemistry plays out. While the Comprehensive Air Model with Extensions (CAMx) automatically adjusts the time step for chemical processes, the meteorological process time step is fixed, based upon the input data from the Fifth Generation Meteorological Model (MM5). While it is possible to extract meteorological output with higher temporal resolution, reduction of the time steps seems likely to cause unusual model behavior. The reduction of time steps in regulatory photochemical grid modeling has not been well studied. For this round of modeling, the TCEQ has reduced the size of the CAMx modeling grid cells from 4 km to 2 km through flexi-nesting, but has kept the size of the MM5 modeling grid cells at 4 km.

5.2.1.4 Incommensurability and Model Performance Evaluation

Swall and Foley (2009) discuss the problems inherent in comparing point measurements to grid cell values. In statistical parlance, this problem is known as incommensurability. A portion of the difference between point measurements and grid cell values is due solely to the fact that measurements made at a monitoring station do not generally represent an average of the conditions for the 2 km × 2 km grid cell in which it resides. The ability of a point measurement to represent the average of the entire grid cell area is related to how much sub-grid variation is observed in the area. If sub-grid variation is small, then the point measurement and the grid cell value are commensurate. If the spatial gradients of the variables of interest are large, the point measurements are less able to reflect the average conditions of the entire grid cell, and therefore they are incommensurate with the grid cell value.

HGB area ozone often has strong spatial gradients due to the rapid ozone formation within industrial source plumes. In the HGB area, the worst ozone model performance is sometimes found in areas with the steepest ozone gradients, and the best ozone model performance is often found in areas further downwind, where the ozone gradients have lessened. Swall and Foley demonstrated that incommensurability alone is capable of degrading model performance in areas of steep gradients. They state in their discussion: "This means that, even if the model is performing perfectly and there is no observational error, we cannot expect that in a scatterplot, points representing paired modeled and observed values will lie on a one-to-one line. Our comparison of Gaussian and exponential correlation structures with the same effective range shows that this concern looms larger for correlation structures in which there is a rapid decrease in correlation for small distances relative to grid cell size (like the exponential)." While there are other causes of poor model performance as well, incommensurability is likely to be responsible for some of the differences between model output and point measurements.

5.2.1.5 Ensemble Modeling

A number of researchers have discussed the benefits of using ensembles of models to create more accurate forecasts (Pinder et al., 2009; Zhang et al., 2007). Pinder et al. and Zhang et al. have noted that probabilistic attainment demonstrations could be made using ensemble modeling and have argued that this approach can be more scientifically sound than a deterministic attainment demonstration. The TCEQ acknowledges the potential soundness of the ensemble approach but notes that the current regulatory framework does not easily allow for a probabilistic attainment demonstration.

5.2.1.6 Vertical Distribution of Ozone

Ozonesonde measurements have been made each summer in the HGB area since 2003 (Morris et al., 2006). Findings from this study indicate that elevated free tropospheric ozone (i.e., above the PBL) in the HGB area is usually underestimated, and it often does not appear to mix down to the ground. Ozone in the lowest layers of the atmosphere often shows much more structure than the model simulates. For example, ozone profiles observed on August 17, 2006, by the ozonesonde released from the Research Vessel (RV) Ronald H. Brown at hour 1300 showed a drop in ozone of about 70 ppb below 500 meters (see Appendix C: *Photochemical Modeling for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard*, Figure 2.9.3-70). Another example was observed at the Moody Tower on August 31, 2006 (see Appendix C: *Photochemical Modeling for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard*, Figure 2.9.3-78). One explanation is that the model is mixing the lowest layers of the atmosphere more efficiently than they are actually mixing. Another, more compelling explanation, however, was identified by ozonesonde experiments on May 30, 2009, at the Moody Tower. In this experiment, Gary Morris of Valparaiso University and his colleagues at the University of Houston showed that the electro-chemical ozone measurement method used in the ozonesondes can lose ozone if sulfur dioxide (SO_2) is present in the air. The experiment on May 30, 2009, used a dual-channel ozone measurement, with one channel filtering out any SO_2 that may be present in the air. This experiment showed that these large, abrupt decreases in ozone are likely due to SO_2 interferences. Since there are large sources of SO_2 in the HGB area, it is likely that the largest mismatches between the observed and modeled vertical ozone profiles can be explained by the measurement artifact.

To improve vertical mixing in the model, the TCEQ has attempted to address two issues. For the free tropospheric ozone, the TCEQ has obtained global model output for the appropriate time periods so that boundary conditions of free tropospheric ozone are more appropriate. Some of the discrepancies still persist; they appear to be related to phenomena that occur between the outermost domain boundaries and the HGB area. For the PBL mixing issue, the TCEQ has improved the land cover data and sea surface temperature data in its latest round of modeling, in an attempt to improve the simulations of surface energy balance. In addition, the TCEQ has chosen the Eta PBL scheme (i.e., the Mellor-Yamada-Janjic scheme), which appears to be more effective at simulating PBL dynamics in the coastal regions than other available schemes (Zhong et al., 2007). The TCEQ continues to investigate potential improvements for vertical mixing in the modeling.

5.2.1.7 Photolysis Discrepancies Due to Improper Placement of Clouds

Researchers at the University of Alabama-Huntsville performed a modeling study that examined the effects of modeled cloud cover on ozone performance in the HGB area, and found that some of the shortcomings in model performance could be corrected with better depiction of clouds (Pour-Biazar et al., 2007). University of Houston researchers also found that their forecasts were occasionally biased due to poor depiction of cloud cover (Byun et al., 2007). TCEQ-funded research found that higher-order decoupled direct method analysis of modeling sensitivities indicated substantial sensitivity to photolysis rates (Koo et al., 2008).

The TCEQ has found similar cloud cover effects in the photochemical modeling for this state implementation plan (SIP). The greatest discrepancies tend to involve the model under-predicting cloud cover, and hence, greatly over-predicting ozone on low ozone days. Modeled episode days for which cloud cover problems exist include: May 28, 2005; June 17, 2005; July 31, 2005; August 5, 2005; May 31-June 1, 2006; August 15, 2006; August 19, 2006; August 22, 2006; September 12, 2006; October 10, 2006. The average mean normalized bias for these days is +34.6 percent, compared to an average mean normalized bias on exceedance days of +9.7 percent. TCEQ process analysis shows that most of the radical initiation, propagation and termination steps are very sensitive to photolysis rates. Hence, improvements in cloud placement could greatly improve ozone and precursor performance, though the greatest improvements will likely occur on low ozone days.

To improve the cloud distribution, the TCEQ has followed the guidance of Texas A&M University (TAMU) researcher and state climatologist John Nielsen-Gammon and has utilized the Grell cumulus parameterization, which reduces the amount of spurious thunderstorm formation in the HGB area.

5.2.1.8 Radical Shortage

A number of researchers studying urban photochemistry in the HGB area and other cities have found that available mechanisms for simulating radical production are unable to replicate the observed radical formation and propagation rates (Mao et al., 2007, 2009; Chen et al., 2009). The process analysis section of Appendix I: *Corroborative Analysis for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard* discusses this issue in detail and compares TCEQ process analyses to the Mao et al. and Chen et al. work. The TCEQ modeling is consistent with the Mao et al. and Chen et al. findings that a radical formation process is apparently missing from the chemical mechanism used in the photochemical grid modeling. The atmospheric chemistry community as a whole has not yet resolved the problem or problems with the current mechanisms. Several hypotheses for the missing radical formation mechanism exist, including daytime nitrous acid (HONO) production from nitric acid-aerosol interactions and photolysis (Ziemba et al., 2009); isoprene production of hydroxyl radical (OH) (Lelieveld et al., 2008; North and Ghosh, 2009); formation and decomposition of electronically excited nitrogen dioxide (NO_2^*) (Li et al., 2008); nitryl chloride ($ClNO_2$) chemistry (Osthoff et al., 2008; Simon et al., 2008); improved aromatic chemistry (Faraji et al., 2008; Hu et al., 2007); primary or rapid secondary formaldehyde emission from petrochemical flares (Rivera et al., in press; Mount, 2009); and molecular chlorine reactions (Chang et al., 2002; Tanaka et al., 2003; Chang and Allen, 2006; Sarwar and Bhave, 2007). Given the manifold hypotheses and the current lack of a definitive explanation, the TCEQ has not incorporated modified chemical mechanisms into its base case modeling at this time. However, the

TCEQ continues to support investigations for improving chemical mechanisms and is prepared to adopt an improved mechanism when it becomes sufficiently mature.

5.2.2 Model Performance Evaluations: Implications of the Model Performance of the Current SIP Modeling

Model performance evaluation is presented in Chapter 3, *Photochemical Modeling* and in its associated appendices. Appendix I: *Corroborative Analysis for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard* includes two discussions of model performance in the Chemical Process Analysis and Intensive Model Performance sections. In addition, Appendix I: *Corroborative Analysis for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard* includes a discussion of using 2005 baseline modeling to estimate future 2018 design values. Based upon these evaluations, the following overall conclusions can be reached.

<u>Ozone performance</u>

- The model simulates the location, spatial extent, and relative intensity of ozone relatively well on most of the high-ozone days.
- The model often underestimates high ozone concentrations observed within specific plumes during the 2005-2006 modeled episodes.
- Simulated ozone depicts rapid morning ozone increases (30-50 ppb) relatively well, but tends to miss afternoon peak concentrations.
- Radical and ozone precursor budgets were calculated directly from observations by Mao et al. (2009) at the Moody Tower during TexAQS II. They observed that ozone formation in the HGB area is both VOC- and NO_X-sensitive, with VOC-sensitive ozone formation usually occurring in the morning and NO_X-sensitive formation occurring in the afternoon. Based upon the TCEQ's process analysis, the TCEQ modeling appears to be simulating the VOC- and NO_X-sensitivity of ozone formation at Moody Tower relatively well, because the relative radical termination rates generally agree with the Mao et al. data.
- Process analysis and modeling sensitivity analyses show that peak eight-hour ozone is primarily NO_X-sensitive in much of the domain, but can be VOC-sensitive downwind of the urban core and the HGB industrial areas.
- According to TCEQ process analyses, VOC-sensitive conditions occur more often and more strongly in the industrial and urban core plumes. When ozone production is VOC-sensitive, usually more ozone is created than in NO_X-sensitive conditions.
- Studies by Mao et al. (2009) and Chen et al. (2009) suggest that the chemical mechanisms used in all photochemical grid modeling applications may underestimate radical production. Consequently, ozone production is being underestimated in urban and industrial plumes. One hypothesis for this observed shortfall in radical production is that nitrous acid (HONO) is being generated by an unknown process. The lack of this HONO formation process is one proposed cause of the shortfall in radical production.
- Decreases in ozone production rates and other reaction rates correlate with decreases in NO_2 photolysis, implying that most of the ozone formation chemistry is highly sensitive to photolysis, and hence, highly sensitive to cloud-cover errors.
- Background ozone concentrations are important in accurately simulating the modeling for the HGB area. For most of the modeled days, the background ozone is unlikely to bias the modeling results in the HGB area, but during the July-August 2005 episode, excessively high background concentrations seem to compromise the model performance.
- In rural areas, the model routinely over-predicts nighttime ozone and under-predicts NO_X. The cause of this issue is unknown, but it could involve unreported NO_X sources or problems with vertical mixing in rural areas.
- Above the planetary boundary layer, the model sometimes underestimated ozone concentrations, especially in the springtime. Usually the high ozone above the PBL was not being mixed downward, so that this error usually did not have much effect upon the ozone concentrations in the HGB area.
- Transport and mixing of urban and industrial emissions within the HGB area can apparently affect the ozone chemistry substantially, especially when the urban core plume and the industrial

plumes mix together. Ozone behavior, including VOC- and NO_X-sensitivity, appears to change when these plumes mix. The implication is that the VOC- and NO_X-sensitivity of ozone formation in the HGB area depend somewhat on the wind direction.

- Since ozone was sometimes overestimated during the evening hours, the model did not display the amount of dynamic range present in the observations.

Ozone precursor performance

- In general, the modeling simulated ozone precursor concentrations relatively well, albeit with a large degree of scatter, and the peak concentrations for some species were underestimated.
- NO_2 was usually simulated in an unbiased manner, but nitric oxide (NO) was often underestimated for the peak concentrations, which were usually observed in the pre-dawn hours, i.e., during morning rush hour.
- The highly reactive Carbon Bond 05 species ETH and OLE, which represent ethylene, propylene, and other alkenes, were well simulated much of the time, but the model tended to underestimate the peak concentrations. Concentrations of these two species were routinely overestimated at the Wallisville Road (CAMS 617) monitoring site.
- The performance of isoprene, represented by the Carbon Bond 05 species ISOP, was mixed, with some areas showing no bias, others showing high bias, and others showing low bias.
- Formaldehyde data were available during the TexAQS II study at three sites.
    - For the Moody Tower site, the concentrations were usually well simulated, but the peak concentrations were underestimated.
    - For the Lynchburg Ferry (CAMS 1015) and HRM-3 Haden Road (CAMS 603) sites, the performance was mediocre.
    - The HRM-3 Haden Road (CAMS 603) observations were consistent with secondary formaldehyde formation as the main source of formaldehyde, but the diurnal patterns of the modeled concentrations were more consistent with a primary source: concentrations peaked in the pre-dawn hours, like NO.
- The aircraft data generally show that the model underestimated formaldehyde peaks, though the location, extent, and relative magnitude were well simulated, much like the ozone data.

Meteorological performance evaluation

- The meteorological modeling was able to successfully replicate the major features of ozone episodes in the HGB area much of the time, including the typical veering pattern of local winds, stagnation and flow reversal, and the coastal oscillations associated with the Galveston Bay breeze and Gulf breeze.
- Trajectory analyses and vertical wind profiles in the HGB area show that much of the time on high ozone days, the model transported ozone and precursors to approximately the correct areas at approximately the correct times.
- The model occasionally did not generate enough cloud cover, resulting in high ozone on days when low ozone was observed. While the addition of the Grell cumulus parameterization and improved land surface characteristics data appeared to reduce the common problem of spurious thunderstorms, the problem has not been completely eliminated.
- Episode days with strong stagnation were more difficult to model precisely than days for which the winds did not stagnate. The model sometimes simulated nighttime winds that were too brisk, resulting in more dilution of emissions than was actually observed.
- Ozonesonde and radar profiler data indicate that for most episode days, the PBL over land appeared to be modeled with good accuracy. Over water, however, planetary boundary layer depth was consistently modeled less accurately.

Model response to emission changes

The base case modeling has been challenged with different emissions inventories in order to evaluate its dynamic response to emission changes (Gilliland et al., 2009).

- Adding more VOC to the flare emissions increases peak ozone concentrations, though the emission changes do not completely correct the ozone underestimations. Addition of formaldehyde emissions to HRVOC flares increases peak ozone concentrations further.
- Substitution of flare emissions for the standard emission reconciliation tends to improve the model performance by increasing ozone production close to the industrial emission sources and by increasing the peak ozone concentrations, without adversely affecting ozone performance at other times and places.
- Modeled ozone appears to decrease slightly in response to NO_X emission decreases typical of the changes that occur on weekends. The observed weekend effect is a slightly stronger response to NO_X emission decreases, implying that the model may be slightly less NO_X-sensitive than actual observations.
- Some of the strongest model responses to emission changes occur outside the boundaries of the current ozone monitoring network, and sometimes outside the current nonattainment area. This finding suggests that the proposed controls may have a greater impact on ozone than the responses registered at the HGB monitoring sites would indicate.
- Modeled ozone increases substantially in response to VOC and NO_X emission increases commensurate with the difference between 2006 emissions and 2000 emissions in the HGB area. When relative response factors are calculated using 2000 as the baseline year and 2006 as the future year, the modeled response to emission reductions is less vigorous than the observed response. This finding implies that the current modeling appears to underestimate the response to emission controls. If the atmosphere responds to the emission reductions from 2006 to 2018 in a manner similar to its response to the emission reductions between 2000 and 2006, the actual decrease in ozone design value will be greater than the model predicts.

5.2.3 Model Response to Proposed Controls: Additional Ways to Measure Progress

Table 5-1: *Changes in the Area and Population Affected by an Eight-Hour Ozone Design Value Greater than or Equal to 85 ppb in Response to Growth and Controls* shows how the area affected by high ozone is expected to shrink dramatically in response to the emission changes projected to occur between 2006 and 2018. Even though peak ozone drops by only 12 percent, the area with an estimated ozone design value greater than the 85 ppb standard shrinks by 64 percent. The population living in those areas and how the changes might reduce the number of people that encounter high ozone were considered. The estimated number of people residing in the high ozone areas decreases by 41 percent. Population data used are from the 2000 Census and have not been grown to reflect changes in population in those areas in 2006 or 2018. Also, the numbers reflect areas where people reside, i.e., their home addresses, not necessarily where they might be during the hours of highest ozone during the ozone season. However, the dramatic decrease in the area with high ozone suggests that ozone decreases arising from the proposed control strategies are likely to benefit many residents of the HGB area.

Table 5-1: Changes in the Area and Population Affected by an Eight-Hour Ozone Design Value Greater than or Equal to 85 ppb in Response to Growth and Controls

Run name	Peak Ozone, ppb	Area with design value > 85 ppb, km^2	2000 population in area with design value > 85	Area × Concentration (km^2 × ppb)	Population × ppb
Ozone design value > 85 ppb					
baseline 2006.reg3	98	23,688	4,662,727	183,915	51,611,840
future year 2018.cs07a	86	8,540	2,728,809	26,422	11,570,880
Percentage decrease from 2006 to 2018	12%	64%	41%	86%	78%

5.2.4 Conclusion

The photochemical grid model performed by the TCEQ for this SIP revision has been rigorously evaluated against observational data. While there are a number of shortcomings that this modeling has in common with other modeling exercises in the HGB area as discussed in Section 5.2.1: *Solving Modeling Problems* and Section 5.2.2: *Model Performance Evaluations: Implications of the Model Performance of the Current SIP Modeling*, modeling for many of the simulated ozone days appears to behave in a manner consistent with most of the atmospheric phenomena of interest. Evaluation of the modeling response to emission changes appears to show that the modeled ozone is slightly less responsive to emission changes than the observed ozone. Thus, modeling of 2018 emissions with the proposed control package in place may overpredict the future ozone concentrations.

5.3 AIR QUALITY TRENDS IN THE HGB AREA

This section describes analyses of air quality observational data in the HGB area. Trends in ozone and its precursors demonstrate not only the substantial progress the HGB area has made in improving air quality but also the magnitude of the future challenge in attaining the ozone NAAQS. Trends are also useful to show how ozone is related to its precursors. Decreases in NO_X and VOC demonstrate the effectiveness of policies to reduce emissions; however, due to its dependence on meteorological variables, ozone may not always exhibit trends identical to its precursors. Separating variations in meteorological factors from trends in ozone and its precursors can highlight whether ozone reductions are due to decreases in precursor emissions or are due to year-to-year variability in local meteorology (Sullivan, 2009; Camalier, et al., 2007).

5.3.1 Ozone Trends

This section examines the frequency at which the NAAQS for ozone are exceeded, with the understanding that the 1997 eight-hour standard of 0.08 ppm (or 85 ppb) is the subject of interest for this SIP revision and that the one-hour standard is no longer in effect, but still a useful benchmark for understanding ozone behavior in the HGB area. While the NAAQS is expressed in units of ppm, this section will use the familiar convention of expressing concentrations in ppb.

The trend in design values for the HGB area is seen clearly in Figure 5-1: *Ozone Design Values for the HGB Area*. While the HGB area continues to exceed the one-hour ozone NAAQS, preliminary 2009 data show that the HGB area is in attainment of the 1997 eight-hour ozone NAAQS. The 2009 ozone data set covers the period from January 1, 2009, to December 1, 2009, so it does not include the entire year of data. The 2009 ozone data set is also preliminary, and as it undergoes further quality assurance, it is subject to change. Nonetheless, it is useful to review in this context, and the data are unlikely to change substantially. The one-hour ozone design value has generally decreased over the past 18 years, and the eight-hour ozone design value has decreased over at least the past ten years. The eight-hour ozone design value in 2009 was 84 ppb, a 29 percent decrease from the 1991 design value of 119 ppb, and below the 1997 eight-hour ozone NAAQS of 0.08 ppm (or 85 ppb). A regression analysis of design value on year estimates that the eight-hour ozone design value decreased at the rate of 1.4 ppb per year, which is statistically significant at the 5 percent level ($\alpha = 0.05$).

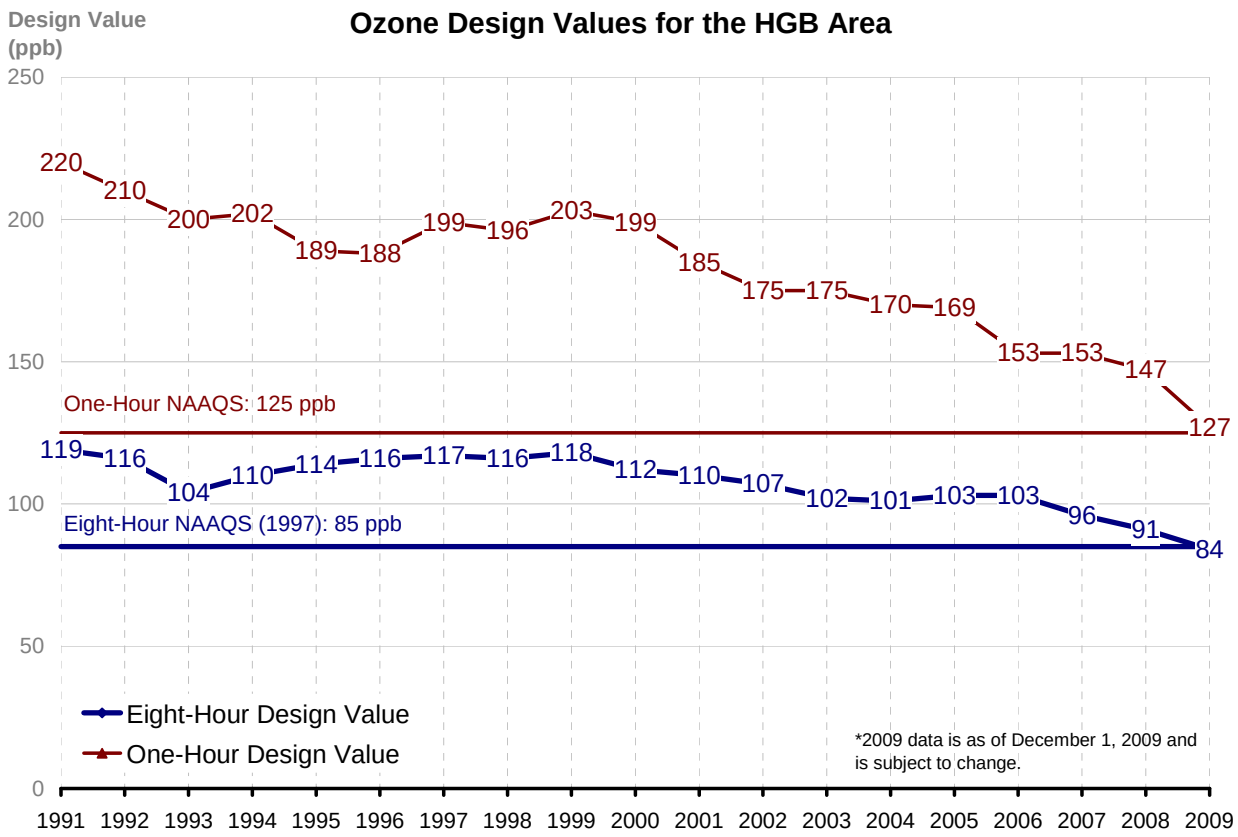


Figure 5-1: Ozone Design Values for the HGB Area

The one-hour ozone design value in 2009 was 127 ppb, a 42 percent decrease from the 1991 design value of 220 ppb. The 2009 one-hour ozone design value is only 3 ppb higher than the one-hour NAAQS of 0.12 ppm (or 125 ppb). Regression of one-hour design value on year shows a decrease at the rate of 4 ppb per year, which is faster than the decrease for the eight-hour ozone design value; the slope is also statistically significant at the 5 percent level.

The design value in a metropolitan area is the highest design value of all of the area's regulatory monitors' individual design values. Because ozone varies spatially, it is also prudent to investigate trends at all monitors in an area. Table 5-2: *Eight-Hour Ozone Design Values (in ppb) for Each Regulatory Monitor in the HGB Area* and Table 5-3: *One-Hour Ozone Design Values (in ppb) for Each Regulatory Monitor in the HGB Area* contain the eight-hour and one-hour ozone design values at all regulatory monitors in the HGB area from 1991 to 2009. More monitors than these operate in the HGB area, but because the data at those monitors do not meet the EPA's quality control standards, the design values at those additional monitors are not displayed here. These non-regulatory monitors are discussed in Section 5.2.2: *Model Performance Evaluations: Implications of the Model Performance of the Current SIP Modeling*.

Table 5-2: Eight-Hour Ozone Design Values (in ppb) for Each Regulatory Monitor in the HGB Area

Monitor/CAMS #	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009*
Houston Bayland Park C53										111	110	100	102	101	103	103	96	91	84
Manvel Croix Park C84													91	97	97	96	91	85	84
Northwest Harris Co. C26/A110/X154	98	101	100	110	113	110	106	106	109	108	105	101	100	94	93	91	91	85	84
Houston Aldine C8/AF108/C150	119	116	104	102	103	114	116	116	108	111	108	107	100	95	92	88	84	83	83
Houston Deer Park 2 C35/139									108	112	108	103	102	101	100	96	93	87	81
Houston Westhollow C410						95	101	95	102	102	104	95	87	87	89	96	92	89	79
Park Place C416																		89	78
Seabrook Friendship Park C45													85	94	92	90	86	80	78
Channelview C15/C115													87	90	89	85	83	80	78
Galveston 99th St. C1034/A320/X183																			77
Houston Croquet C409	117	112	103	96	104	104	117	115	118	110	104	102	99	99	98	94	87	80	76
Houston East C1	104	103	88				86	108	106	102	103	101	100	95	87	83	78	80	76
Houston Texas Avenue C411													88	89	88	84	78	76	75
Lang C408	105	103	93	95	98	99	100	96	96	96	91	83	78	79	79	80	77	76	75
Lake Jackson C1016															79	79	76	76	74
Clinton C403/C113/C304	115	109	100	100	106	106	107	100	103	101	97	93	96	96	95	85	79	73	74
Houston North Wayside C405	114	102	94	91	91	91	96	99	104	105	98	89	86	85	82	78	76	75	72
Houston Regional Office C81												95	94	88	88	84	81	74	72
Houston Monroe C406	105	102	96	93	97	102	109	112	113	106	93	90	90	95	97	99	91	81	71
Conroe Relocated C78													78	85	86	85	84	80	71
Lynchburg C1015															96	89	82	74	69
Galveston Airport C34/C109/C154								90	112	106	98	89	89	91	87	83	71		
Clute C11		96	93	91	96	92	92	84	95	93	91	86	87						
Texas City C10	93	82	90	89	114	102	105	91	100	97	91	83	80	74					
Conroe C65											91								
Houston Manchester C22	103	104	104	103	106	102	103												
Houston Crawford C407	105	98	89	89	95	91	97	96	100	100	81								
Houston Deer Park C18	107	96	85	89	107	116													

Note: Missing values indicate a monitor was not operating during that year or did not produce a valid year of data. Three years of valid data are required to calculate an eight-hour ozone design value.
*2009 design values are current as of December 1, 2009 and are subject to change.

Table 5-3: One-Hour Ozone Design Values (in ppb) for Each Regulatory Monitor in the HGB Area

Monitor/CAMS #	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009*
Houston Bayland Park C53									189	185	173	154	163	148	148	143	142	139	112
Manvel Croix Park C84												143	132	142	134	138	128	128	120
Northwest Harris Co. C26/A110/X154	160	160	166	173	172	172	165	164	163	161	157	154	156	148	131	127	127	126	127
Houston Aldine C8/AF108/C150	220	190	197	197	189	173	189	187	187	180	166	166	143	136	139	125	122	122	120
Houston Deer Park 2 C35/139							147	164	203	185	182	168	161	157	153	150	150	147	120
Houston Westhollow C410					164	155	164	155	165	150	150	141	141	128	126	131	127	126	111
Park Place C416																136	136	136	122
Seabrook Friendship Park C45												132	135	135	153	153	153	119	114
Channelview C15/C115												154	141	140	135	134	128	120	118
Galveston 99th St. C1034/A320/X183																	115	115	104
Houston Croquet C409	200	200	178	152	167	167	168	168	167	167	160	157	150	141	136	131	126	117	112
Houston East C1	210	200	200	202		177	182	182	198	180	180	171	171	165	154	137	119	119	111
Houston Texas Avenue C411												146	172	157	157	127	110	110	107
Lang C408	200	183	158	159	159	159	158	155	155	175	175	149	128	128	127	126	108	108	111
Lake Jackson C1016														113	112	105	99	101	97
Clinton C403/C113/C304	210	210	176	158	173	173	173	161	183	199	176	157	175	158	158	124	121	111	120
Houston North Wayside C405	210	190	173	173	155	143	155	158	189	190	168	153	131	138	138	118	100	102	102
Houston Regional Office C81											185	178	175	170	169	135	131	119	111
Houston Monroe C406	170	170	155	147	154	161	174	196	196	170	143	151	141	141	131	133	131	117	108
Conroe Relocated C78												119	137	128	128	128	124	116	94
Lynchburg C1015														157	156	152	149	117	117
Galveston Airport C34/C109/C154							170	170	176	168	164	133	123	129	129	117	103	96	
Clute C11	150	150	132	129	144	144	148	134	154	161	154	136	133	133	115				
Texas City C10	150	150	163	163	184	182	182	146	175	172	139	121	116	113	113	77			
Conroe C65										145	145	140							
Houston Manchester C22	190	190	180	160	172	170	175	173	176										
Houston Crawford C407	220	190	165	165	165	166	172	172	164	173	173	194							
Houston Deer Park C18	160	160	150	157	188	188	199	163											
San Jacinto Monument C166/C245												143	124	124	94				

Note: Missing values indicate a monitor was not operating during that year or did not produce a valid year of data. Only one year of valid data is required to calculate a one-hour ozone design value; therefore, some monitors that have a one-hour ozone design value may not have an eight-hour ozone design value.
*2009 design values are current as of December 1, 2009 and are subject to change.

Figure 5-2: *Eight-Hour Ozone Design Value Statistics for All Monitors in the HGB Area* and Figure 5-3: *One-Hour Ozone Design Value Statistics for All Monitors in the HGB Area* display three summary statistics for the eight-hour and one-hour design values, respectively: the maximum, median, and minimum design values computed across all monitors in the HGB area. These figures facilitate assessment of the range of design values observed within a year, as well as how these distributions change over time. From these figures, it appears that neither eight-hour nor one-hour design values exhibited a noticeable trend until about 1999, after which both began falling steadily. Before 2002, no monitors in the HGB area met either standard; since then, the area has seen a steady increase in the number of monitors attaining both standards. By 2009, all of the monitors in the HGB area were below the 1997 eight-hour ozone NAAQS and only one monitor, Northwest Harris County, was above the one-hour ozone NAAQS.

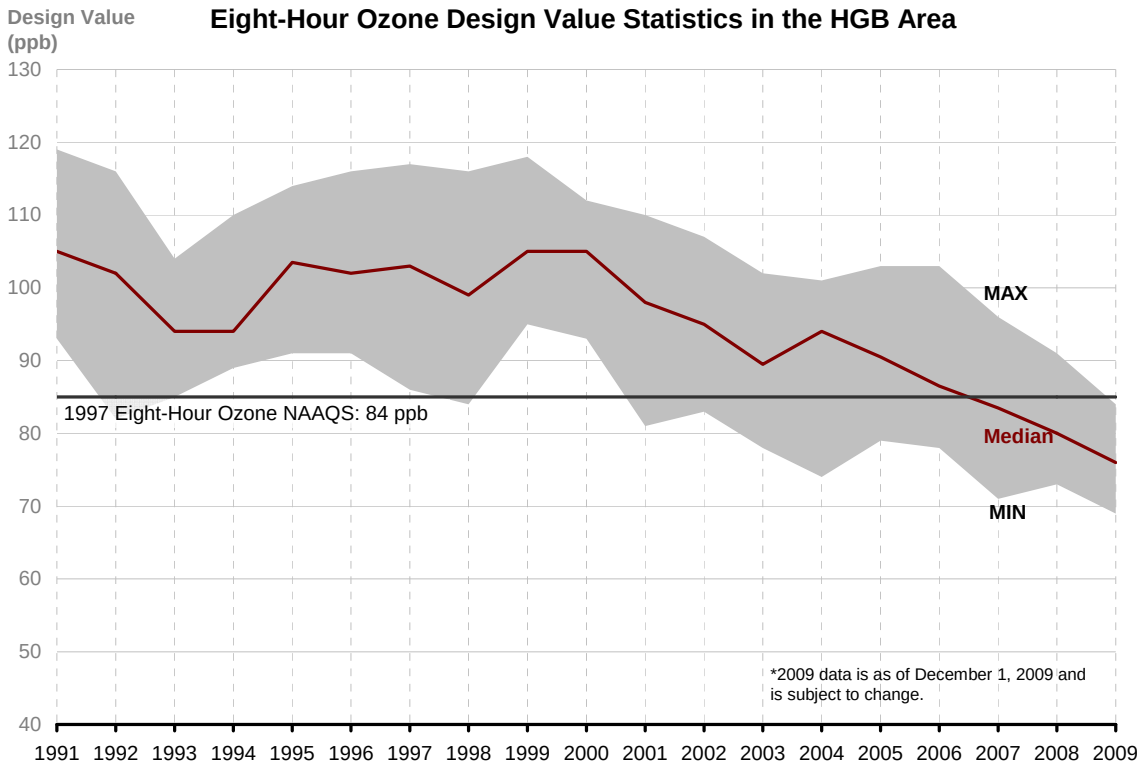


Figure 5-2: Eight-Hour Ozone Design Value Statistics for All Monitors in the HGB Area

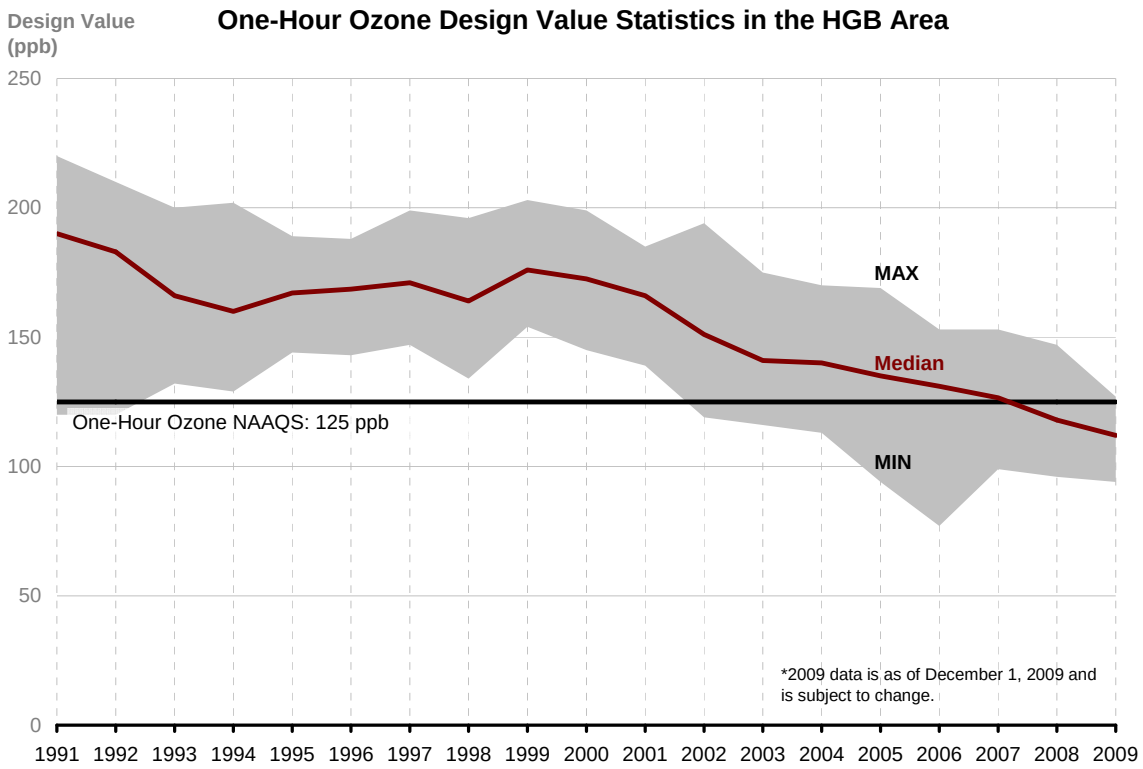


Figure 5-3: One-Hour Ozone Design Value Statistics for All Monitors in the HGB Area

Ozone trends can also be investigated by looking at the number of days an exceedance of the ozone NAAQS was recorded, termed an exceedance day. An exceedance day for the 1997 eight-hour ozone NAAQS is any day that any monitor in the area measures an eight-hour average ozone concentration greater than or equal to 85 ppb over any eight-hour period. An exceedance day for the one-hour ozone NAAQS is any day that any monitor in the area measures a one-hour average ozone concentration greater than or equal to 125 ppb for at least one hour. Previous research (Savanich, unpublished, 2006) by the TCEQ has shown that, until 2006, the number of exceedance days was positively correlated with the number of monitors in a particular area. As the number of monitors increases, so does the number of exceedance days recorded, at least until the area has been saturated with monitors or until ozone concentrations truly decrease. Because of this correlation, when examining exceedance-day trends, the number of monitors must always be considered. Thus, it is especially noteworthy that Figure 5-4: *Number of Monitors and Ozone Exceedance Days in the HGB Area* shows that, despite an increase in the number of monitors, the number of exceedance days for both one-hour and 1997 eight-hour ozone NAAQS has decreased, a decrease that is especially pronounced over the past four years. Since 1999, the number of 1997 eight-hour and one-hour ozone exceedance days occurring in the HGB area has fallen 80 percent and 92 percent, respectively. In just the last three years, the number of 1997 eight-hour and one-hour ozone exceedance days has fallen 71 percent and 85 percent, respectively.

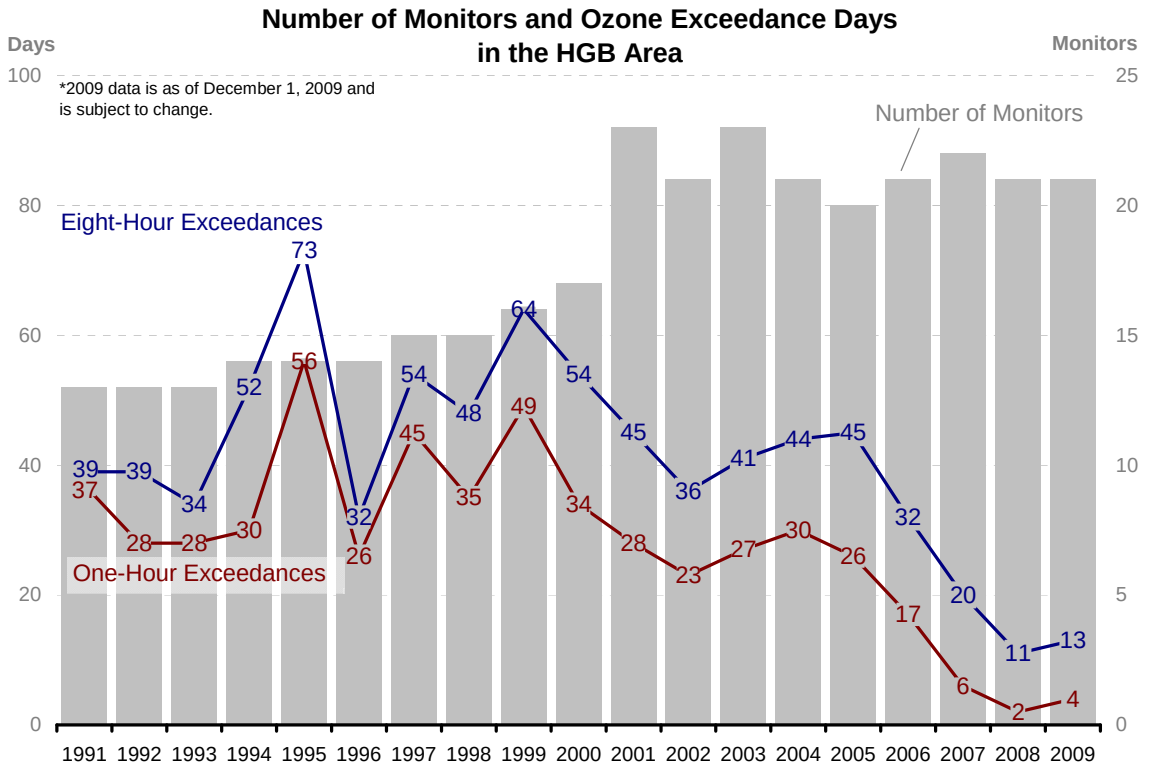


Figure 5-4: Number of Monitors and Ozone Exceedance Days in the HGB Area

Results for individual monitors, displayed in Figure 5-5: *Number of 1997 Eight-Hour Ozone Exceedance Days by Monitor* and Figure 5-6*: Number of One-Hour Ozone Exceedance Days by Monitor* support the conclusion that the number of exceedance days at individual monitors also appears to be decreasing. Figure 5-5: *Number of 1997 Eight-Hour Ozone Exceedance Days by Monitor* highlights two monitors, Houston Aldine (CAMS 8) (red line) and Houston Bayland Park (CAMS 53) (blue line), that recorded the most 1997 eight-hour ozone NAAQS exceedances in the past. Since recent peaks in 1999 (at Houston Bayland Park (CAMS 53)) and in 2000 (Houston Aldine (CAMS 8)), neither monitor, in any year, has come within 60 percent of these peaks; in 2009 both monitors experienced at least an 84 percent reduction from the recent peaks. While results for other monitors are less impressive, overall, the trend in ozone exceedance days at monitors throughout the HGB area is clearly downward. Due to the large number of monitors in the HGB area, data from Figure 5-5: *Number of 1997 Eight-Hour Ozone Exceedance Days by Monitor* and Figure 5-6: *Number of One-Hour Ozone Exceedance Days by Monitor* are presented in Table 5-4: *Number of Days with a 1997 Eight-Hour Ozone Exceedance* and Table 5-5: *Number of Days with a One-Hour Ozone Exceedance* for detailed inspection.

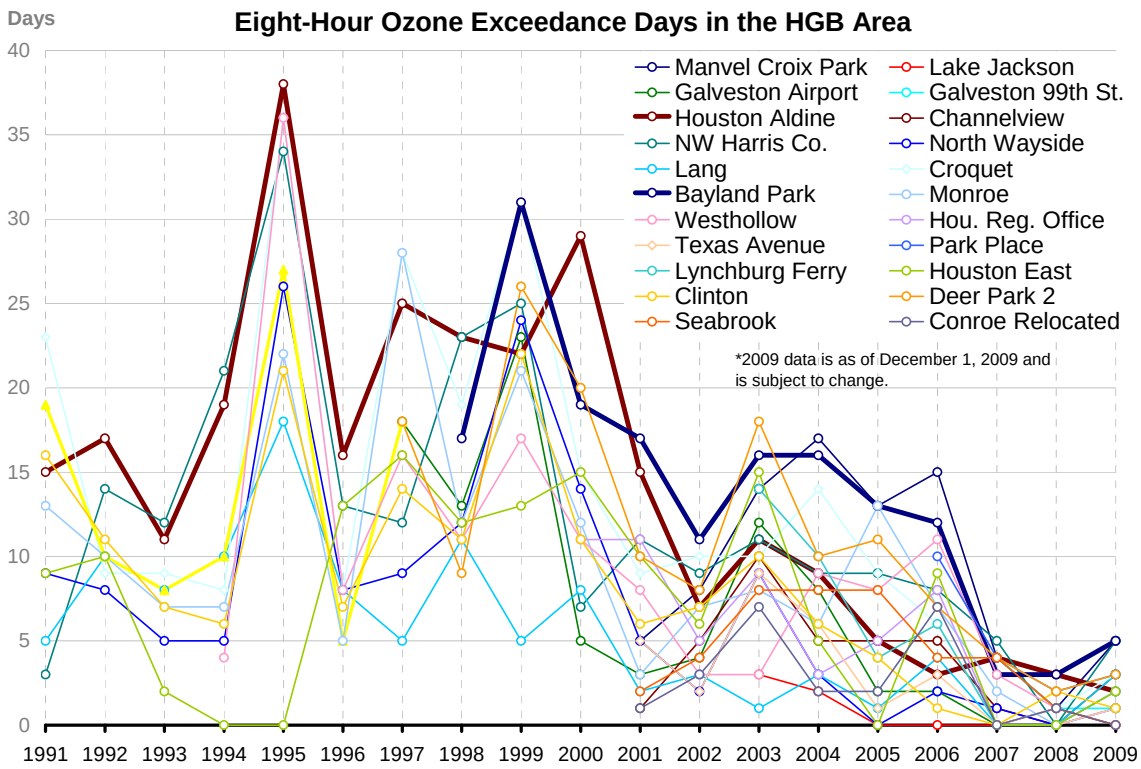


Figure 5-5: Number of 1997 Eight-Hour Ozone Exceedance Days by Monitor

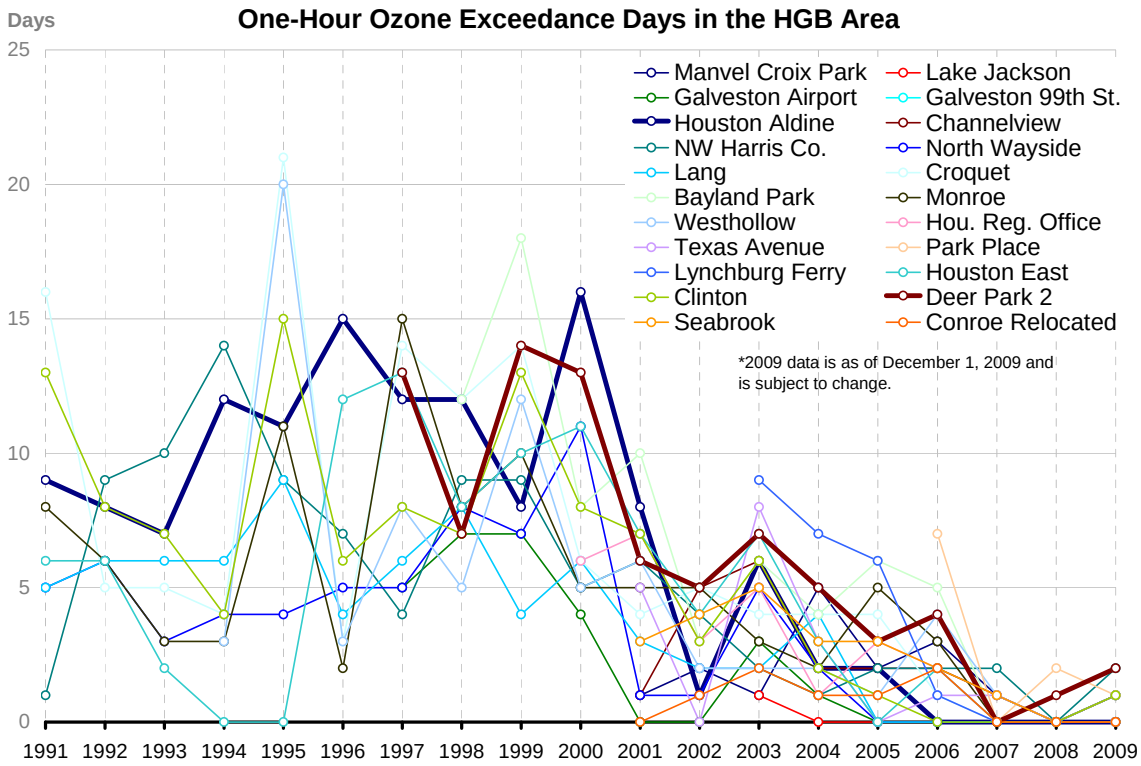


Figure 5-6: Number of One-Hour Ozone Exceedance Days by Monitor

The progress in recent years in reducing eight-hour and one-hour ozone concentrations in the HGB area is evident in Table 5-4: *Number of Days with a 1997 Eight-Hour Ozone Exceedance* and Table 5-5: *Number of Days with a One-Hour Ozone Exceedance*. The number of times the monitors in the HGB area registered daily peak eight-hour ozone ≥ 85 ppb fell from a high of 340 occurrences in 1995, to 39 occurrences in 2007, to 19 occurrences in 2008. Prior to 2007, that number was never below 90. The number of monitors recording at least one exceedance of the 1997 eight-hour ozone standard has fallen by half, from a maximum of 23 monitors in 2003 to only 12 in 2008.

A similar pattern is apparent with the number of exceedances of the one-hour ozone NAAQS presented in Table 5-5: *Number of Days with a One-Hour Ozone Exceedance*. The table shows that the total number of one-hour ozone NAAQS exceedance occurrences fell from a high of 165 in 1995 to just three in 2008. Prior to 2005, the number of one-hour exceedances was never below 50. The three exceedances in 2008 occurred at only two monitors. As recently as 2006, a total of 15 monitors recorded at least one exceedance. This significant progress has occurred in a fairly short amount of time in an area well known for its air quality challenges.

Table 5-4: Number of Days with a 1997 Eight-Hour Ozone Exceedance

Monitor	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009*
Houston Bayland Park C53								17	31	19	17	11	16	16	13	12	3	3	5
Manvel Croix Park C84											5	8	14	17	13	15	4	1	5
Northwest Harris Co. C26/A110/X154	3	14	12	21	34	13	12	23	25	7	11	9	11	9	9	8	5	0	5
Houston Aldine C8/AF108/C150	15	17	11	19	38	16	25	23	22	29	15	7	11	9	5	3	4	3	2
Houston Deer Park 2 C35/139							18	9	26	20	10	8	18	10	11	7	4	2	3
Houston Westhollow C410				4	36	8	16	11	17	11	8	3	3	9	8	11	3	1	
Park Place C416																10	4	2	3
Seabrook Friendship Park C45											2	4	8	8	8	4	4	1	0
Channelview C15/C115											1	5	10	5	5	5	1	0	3
Galveston 99th St. C1034/A320/X183																	4	1	1
Houston Croquet C409	23	9	9	8	36	8	28	19	31	15	9	10	10	14	9	6	0	1	3
Houston East C1	9	10	2	0	0	13	16	12	13	15	10	6	15	5	0	9	0	0	2
Houston Texas Avenue C411											5	2	9	6	1	3	0	0	1
Lang C408	5	10	8	10	18	8	5	11	5	8	2	3	1	3	1	4	0	0	3
Lake Jackson C1016													3	2	0	0	0	1	0
Clinton C403/C113/C304	16	11	7	6	21	7	14	11	22	11	6	7	10	6	4	1	0	2	1
Houston North Wayside C405	9	8	5	5	26	8	9	12	24	14	5	2	9	3	0	2	1	0	1
Houston Regional Office C81										11	11	5	9	3	5	8	0	0	1
Houston Monroe C406	13	10	7	7	22	5	28	12	21	12	3	7	8	6	13	7	2	0	2
Conroe Relocated C78											1	3	7	2	2	7	0	1	0
Lynchburg C1015													14	10	4	6	0	0	2
Galveston Airport C34/C109/C154							18	13	23	5	3	4	12	8	2	2	0		
Clute C11	8	10	6	5	15	3	4	5	9	2	3	6	3						
Texas City C10	6	1	9	7	25	1	10	10	11	6	1	3	3	0					
Conroe C65									4	17	6								
Houston Manchester C22	19	10	8	10	27	5	18												
Houston Crawford C407	5	6	7	4	15	3	16	10	11	8	0								
Houston Deer Park C18	8	4	3	18	27	12													
San Jacinto Monument C166/C245											0	5	1						
Number of Monitors in Operation	13	13	13	14	14	14	15	15	16	17	23	21	23	21	20	21	22	21	21

Note: Monitors with exceedance days do not necessarily have a complete year of ozone data; therefore, there may be years where a monitor has ozone exceedance days but no ozone design value.
*2009 exceedance days are current as of December 1, 2009 and are subject to change.

Table 5-5: Number of Days with a One-Hour Ozone Exceedance

Monitor	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009*
Houston Bayland Park C53								12	18	8	10	3	6	4	6	5	0	0	1
Manvel Croix Park C84											1	2	1	5	2	3	1	0	1
Northwest Harris Co. C26/A110/X154	1	9	10	14	9	7	4	9	9	5	6	4	2	1	2	2	2	0	2
Houston Aldine C8/AF108/C150	9	8	7	12	11	15	12	12	8	16	8	1	6	2	2	0	0	0	0
Houston Deer Park 2 C35/139							13	7	14	13	6	5	7	5	3	4	0	1	2
Houston Westhollow C410				3	20	3	8	5	12	5	6	2	2	2	1	4	1	0	0
Park Place C416																7	0	2	1
Seabrook Friendship Park C45											3	4	5	3	3	2	1	0	0
Channelview C15/C115											1	5	6	2	2	2	1	0	1
Galveston 99th St. C1034/A320/X183																	0	0	0
Houston Croquet C409	16	5	5	4	21	3	14	12	14	6	4	5	4	4	4	1	0	0	1
Houston East C1	6	6	2	0	0	12	13	8	10	11	7	4	7	3	0	2	0	0	0
Houston Texas Avenue C411											5	0	8	3	0	1	1	0	1
Lang C408	5	6	6	6	9	4	6	8	4	6	3	2	2	4	0	0	0	0	1
Lake Jackson C1016													1	0	0	0	0	0	0
Clinton C403/C113/C304	13	8	7	4	15	6	8	7	13	8	7	3	6	2	1	0	0	0	1
Houston North Wayside C405	5	6	3	4	4	5	5	8	7	11	1	1	5	2	0	0	0	0	0
Houston Regional Office C81										6	7	3	5	1	3	2	0	0	0
Houston Monroe C406	8	6	3	3	11	2	15	8	10	5	5	5	3	2	5	3	0	0	1
Conroe Relocated C78											0	1	2	1	1	2	0	0	0
Lynchburg C1015													9	7	6	1	0	0	0
Galveston Airport C34/C109/C154							5	7	7	4	0	0	3	1	0	0	0		
Clute C11	3	3	2	0	6	1	3	1	4	2	0	2	1						
Texas City C10	4	1	7	2	14	0	3	3	7	3	0	0	1	0					
Conroe C65									1	5	2								
Houston Manchester C22	11	7	7	7	18	4	10												
Houston Crawford C407	5	4	5	3	9	4	11	12	5	8	0								
Houston Deer Park C18	6	2	1	6	18	4													
San Jacinto Monument C166/C245											0	2	0						
Number of Monitors in Operation	13	13	13	14	14	14	15	15	16	17	23	21	23	21	20	21	22		21

*2009 exceedance days are current as of December 1, 2009 and are subject to change.

The ozone season spans the entire year in the HGB area; the period of elevated ozone concentrations, however, varies from year to year. Figure 5-7: *1997 Eight-Hour Ozone Exceedance Days in the HGB Area* shows the frequency of, and variation in, the number of 1997 eight-hour ozone NAAQS exceedance days in the HGB area by month and year. While the duration and intensity of the ozone season does vary from year to year, in the past few years the HGB area has experienced fewer ozone exceedance days over fewer months. The darker areas in the figure show that peak ozone season in the HGB area typically occurs from August through September, with a smaller, secondary peak occurring earlier, roughly in June.

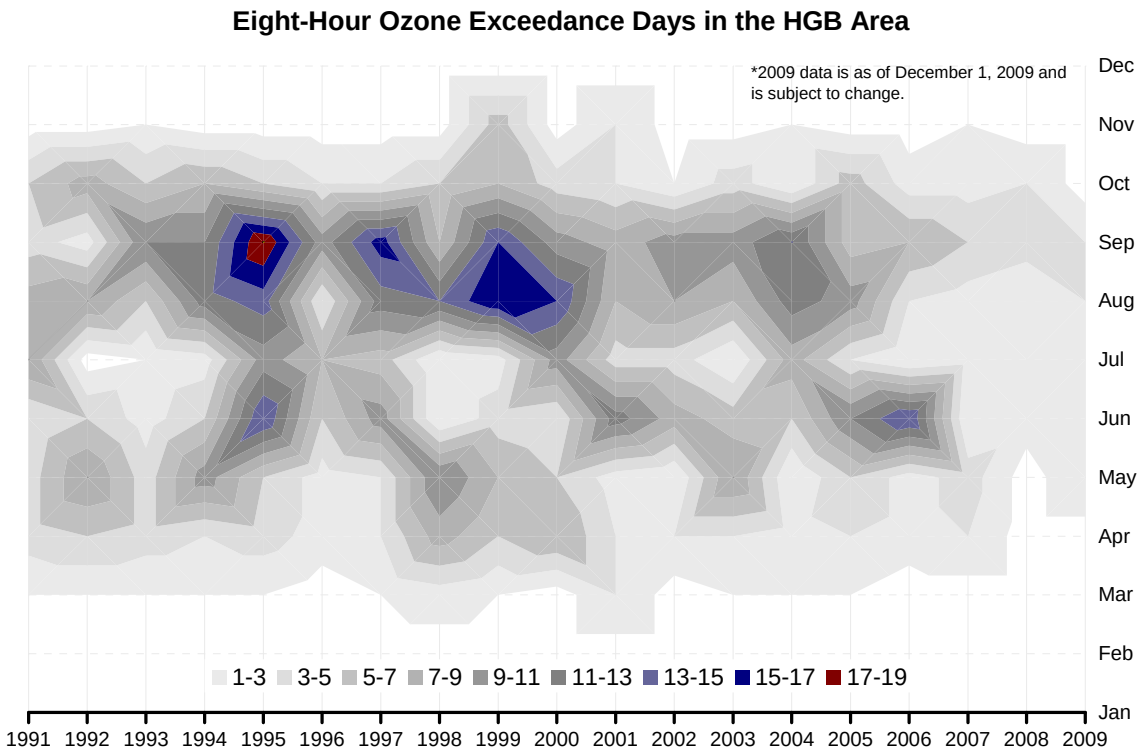


Figure 5-7: 1997 Eight-Hour Ozone Exceedance Days in the HGB Area

In summary, the number and intensity of ozone exceedances in the HGB area has been dropping, especially since 2000, with 2007 and 2008 demonstrating the largest of these decreases.

5.3.2 Ozone Trends at Regulatory and Non-Regulatory Monitors

Twenty-three monitors in the HGB area, listed in Table 5-6: *Eight-Hour Ozone Design Values at Regulatory and Non-Regulatory Monitors* and Table 5-7: *One-Hour Ozone Design Values at Regulatory and Non-Regulatory Monitors* report ozone concentrations following EPA certification protocols and are used for attainment determinations for regulatory purposes. However, since 2003, over 20 additional monitors have become operational in the HGB area that measure ozone concentrations following protocols that have not been certified to EPA standards. Usually, this means fewer quality control checks are performed for these monitors. These non-regulatory monitors are located throughout the HGB area. The locations were chosen with the aim of ensuring that all episodes of elevated ozone and precursors are observed. The additional monitoring sites also help to describe the spatial extent and distribution of high ozone more fully than the regulatory monitors alone. While the non-regulatory monitors are not acceptable for making regulatory determinations, they help describe the spatial patterns of ozone more completely and thus provide a broader perspective on trends in ozone concentrations across the HGB area.

Table 5-6: Eight-Hour Ozone Design Values at Regulatory and Non-Regulatory Monitors

AIRS	Site Name	2003	2004	2005	2006	2007	2008
		ppb	*ppb*	*ppb*	*ppb*	*ppb*	*ppb*
Regulatory Monitors							
482010055	Houston Bayland Park C53	**102**	**101**	**103**	**103**	**96**	**91**
482010066	Houston Westhollow C410	87	87	89	96	92	89
482010416	Park Place C416						89
482011039	Houston Deer Park 2 C35/139	102	101	100	96	93	87
480391004	Manvel Croix Park C84	91	97	97	96	91	85
482010029	Northwest Harris Co. C26/A110/C154	100	94	93	91	91	85
482010024	Houston Aldine C8/AF108/X150	100	95	92	88	84	83
482010062	Houston Monroe C406	90	95	97	99	91	81
482010051	Houston Croquet C409	99	99	98	94	87	80
483390078	Conroe Relocated C78		85	86	85	84	80
482010026	Channelview C15/C115	87	90	89	85	83	80
482011034	Houston East C1	100	95	87	83	78	80
482011050	Seabrook Friendship Park C45	85	94	92	90	86	79
482010075	Houston Texas Avenue C411	88	89	88	84	78	76
482010047	Lang C408	78	79	79	80	77	76
480391016	Lake Jackson C1016			79	79	76	76
482010046	Houston North Wayside C405	86	85	82	78	76	75
482011015	Lynchburg Ferry C1015			96	89	82	74
482010070	Houston Regional Office C81	94	88	88	84	81	74
482011035	Clinton C403/C113/C304	96	96	95	85	79	73
481670014	Galveston Airport C34/C109/C154	89	91	87	83	71	
480391003	Clute C11	87					
481671002	Texas City C10	80					
Non-Regulatory Monitors							
482010554	West Houston C554				102	99	**94**
482010558	Tom Bass C558				**104**	**100**	93
482010559	Katy Park C559				98	96	92
482010562	Bunker Hill Village C652				81	96	91
482010617	Wallisville Road C617			**96**	93	93	90
482010561	Meyer Park C561				90	89	84
482010557	Mercer Arboretum C557				88	88	84
482010560	Atascocita C560				88	86	83
482010556	La Porte Sylvan Beach C556				90	87	82
482010552	Baytown Wetlands Center C552			87	89	86	81
480390619	Mustang Bayou C619			93	89	84	81
482010572	Clear Lake High School C572			83	88	84	81
482010803	HRM-3 Haden Road C603			92	88	84	80
482010553	Crosby Library C553			87	86	84	80
481670056	Texas City 34th St, C620			89	90	84	79
482010570	Clear Brook High School C570			89	92	84	78
480390618	Danciger C618			80	83	80	78
482010555	Kingwood Library C555				82	81	77
482010551	Sheldon C551			92	85	80	76
481670571	Clear Creek High School C571			83	84		

Source: Leading Environmental Analysis and Display System (LEADS).
Monitors are sorted in descending order of 2008 design values, then 2007, 2006, etc. The annual maximum of each series is noted in boldface type. Because of the way design values are computed, some monitors in some years may have a one-hour but not an eight-hour design value.

Table 5-7: One-Hour Ozone Design Values at Regulatory and Non-Regulatory Monitors

AIRS	Site Name	2003	2004	2005	2006	2007	2008
		ppb	*ppb*	*ppb*	*ppb*	*ppb*	*ppb*
Regulatory Monitors							
482010055	Houston Bayland Park C53	**163**	148	148	143	142	139
482010066	Houston Westhollow C410	141	128	126	131	127	126
482010416	Park Place C416				136	136	136
482011039	Houston Deer Park 2 C35/C139	161	**157**	**153**	**150**	**150**	**147**
480391004	Manvel Croix Park C84	132	142	134	138	128	128
482010029	Northwest Harris Co. C26/A110/C154	156	148	131	127	127	126
482010024	Houston Aldine C8/AF108/X150	143	136	139	125	122	122
482010062	Houston Monroe C406	141	141	131	133	131	117
482010051	Houston Croquet C409	150	141	136	131	126	117
483390078	Conroe Relocated C78	137	128	128	128	124	116
482010026	Channelview C15/C115	141	140	135	134	128	120
482011034	Houston East C1	171	165	154	137	119	119
482011050	Seabrook Friendship Park C45	135	135	153	153	153	119
482010075	Houston Texas Avenue C411	172	157	157	127	110	110
482010047	Lang C408	128	128	127	126	108	108
480391016	Lake Jackson C1016		119	113	105	99	101
482010046	Houston North Wayside C405	131	138	138	118	100	102
482011015	Lynchburg Ferry C1015		157	157	152	149	117
482010070	Houston Regional Office C81	175	170	169	135	131	119
482011035	Clinton C403/C113/C304	175	158	158	124	121	111
481670014	Galveston Airport C34/C109/C154	123	129	129	117	104	97
481671034	Galveston 99th St. C1034					115	115
480391003	Clute C11	133	136				
481671002	Texas City C10	116	116	124			
Non-Regulatory Monitors							
482010554	West Houston C554		141	141	146	145	131
482010558	Tom Bass C558		145	145	146	146	**138**
482010559	Katy Park C559		127	143	143	135	129
482010562	Bunker Hill Village C562			135	137	135	132
482010617	Wallisville Road C617		147	145	138	139	134
482010561	Meyer Park C561			139	133	127	111
482010557	Mercer Arboretum C557		108	118	121	121	121
482010560	Atascosita C560			137	137	125	120
482010556	La Porte Sylvan Beach C556			148	**149**	**149**	133
482010552	Baytown Wetlands Center C552		138	138	133	129	129
480390619	Mustang Bayou C619		134	130	127	112	107
482010572	Clear Lake High School C572		145	141	140	119	114
482010803	HRM-3 Haden Road C603	**161**	**161**	144	135	127	122
482010553	Crosby Library C553		141	147	141	126	123
481670056	Texas City 34th St C620		143	139	136	119	114
482010570	Clear Brook High School C570		140	140	135	117	109
480390618	Danciger C618		121	120	111	108	108
482010555	Kingwood Library C555			130	123	122	108
482010551	Sheldon C551	153	153	**150**	130	125	123
481670571	Clear Creek High School C571		138	138	138	119	99
480710013	Smith Point Hawkins Camp C96				143	143	133
482010808	HRM-8 LaPorte C608	149					
482010804	HRM-4 Sheldon Rd. C604	128					

480710900	HRM-10 Mont Belvieu C610	119
482010807	HRM-7 W Baytown C607	113

Source: LEADS (Leading Environmental Analysis and Display System).
The annual maximum of each series is noted in boldface type. Because of the way design values are computed, some monitors in some years may have a one-hour but not an eight-hour design value.

Figure 5-8: *Distributions of Eight-Hour Ozone Design Values at Regulatory and Non-Regulatory Monitors in the HGB Area* compares eight-hour ozone design values at regulatory and non-regulatory monitors in the HGB area from 2003 to 2008. This period was chosen because many non-regulatory monitors only became operational, or had complete data, in 2003 and later years. The distributions of eight-hour ozone design values dropped for both types of monitors over the six-year period, though the interquartile range, a measure of spread between high and low values, did not narrow noticeably for either. The annual median fourth high eight-hour ozone design value fell from 90 ppb in 2003 to 80 ppb in 2008 at regulatory monitors, a drop of 11.1 percent. The median at non-regulatory monitors fell from 89 ppb to 81 ppb over the period, a 9.0 percent drop.

While medians and other moments from the distributions all dropped over the period, the annual maximum eight-hour ozone design value is most relevant, as this value is the current standard used for regulatory attainment determinations. The annual maximum eight-hour ozone design value measured at regulatory monitors fell from 102 ppb in 2003 to 91 ppb in 2008, a drop of 10.4 percent. The annual maximum at non-regulatory monitors fell from 96 ppb in 2005, when three-year design values were first computable, to 94 ppb in 2008, a drop of 2.1 percent. Note, however, that maximum eight-hour design values at non-regulatory monitors in 2006 and 2007 were higher than in 2008, 104 ppb and 100 ppb respectively, presumably because those years are strongly influenced by the fourth high value observed at Wallisville Road (CAMS 617) in 2006 (111 ppb). Even though this 2006 fourth high value continued to influence the 2008 design value, when averaged with the 2008 fourth high value of 85 ppb, the three-year average dropped to 94 ppb, a 6 percent decline in a single year.

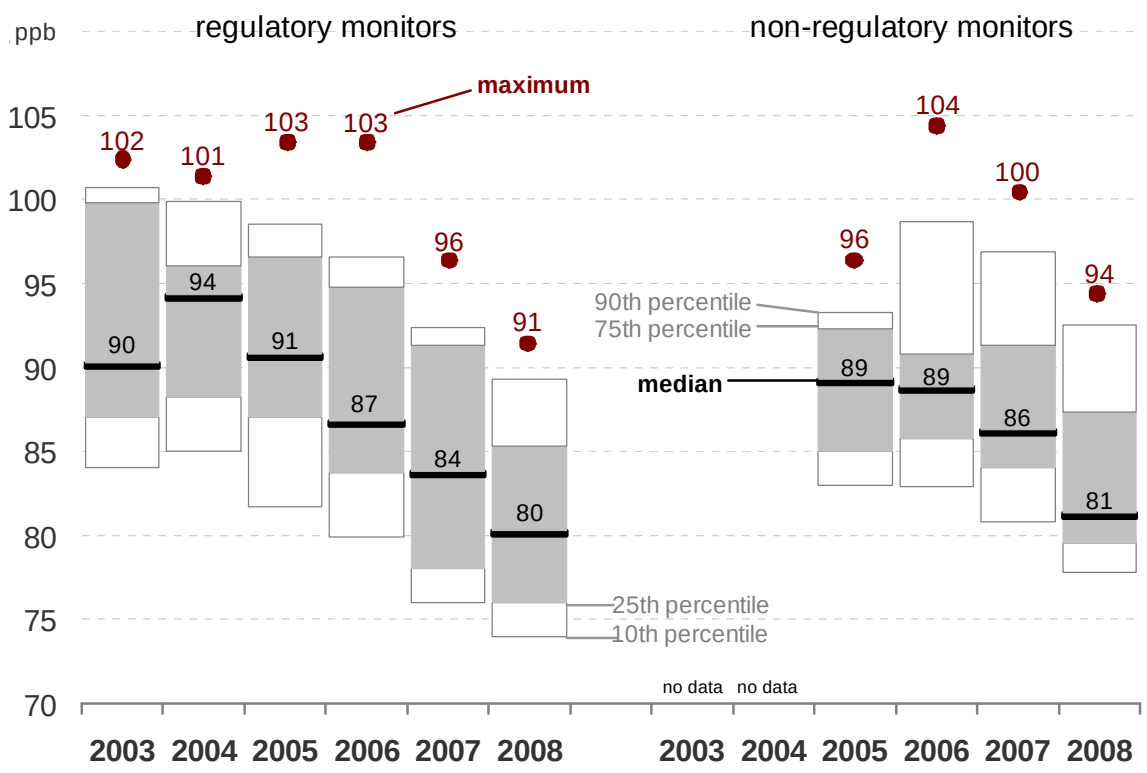


Figure 5-8: Distributions of Eight-Hour Ozone Design Values at Regulatory and Non-Regulatory Monitors in the HGB Area

The ozone design values computed for the non-regulatory monitors are within the range of design values computed for the regulatory monitors. This finding suggests that both sets of monitors observe the same ozone behavior.

Figure 5-9: *Distributions of One-Hour Ozone Design Values at Regulatory and Non-Regulatory Monitors in the HGB Area* compares one-hour ozone design values at regulatory and non-regulatory monitors in the HGB area from 2003 to 2008. This period was chosen because many non-regulatory monitors became operational or had complete data in 2003 and later years. The one-hour design value is computed as the fourth highest one-hour value observed among all values during each rolling three calendar-year period. The distributions of one-hour ozone design values dropped for both types of monitors over the six-year period and the spread between high and low values narrowed for both. The annual median fourth high one-hour ozone design value fell from 141 ppb in 2003 to 118 ppb in 2008 at regulatory monitors, a drop of 16.3 percent. The median at non-regulatory monitors fell from 149 ppb to 122 ppb over the period, an 18.1 percent drop.

While medians and other moments from the distributions all dropped over the period, the annual maximum one-hour ozone design value is most relevant, as this design value would be compared to the one-hour ozone NAAQS to determine attainment, were the one-hour standard still in force. The annual maximum one-hour ozone design value measured at regulatory monitors fell from 175 ppb in 2003 to 147 ppb in 2008, a drop of 16.0 percent. The annual maximum at non-regulatory monitors fell from 161 ppb to 138 ppb over the period, or 14.3 percent. Note that the eight-hour design value does not change when the data from the non-regulatory monitors are added to the calculation.

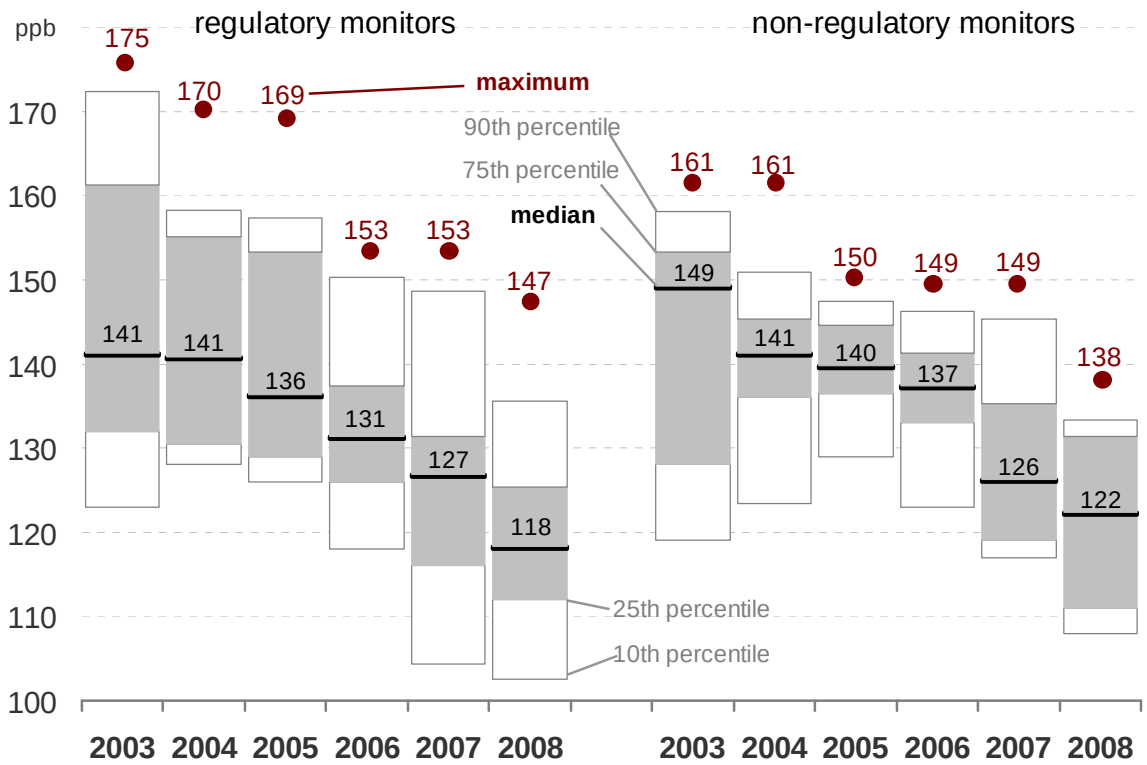
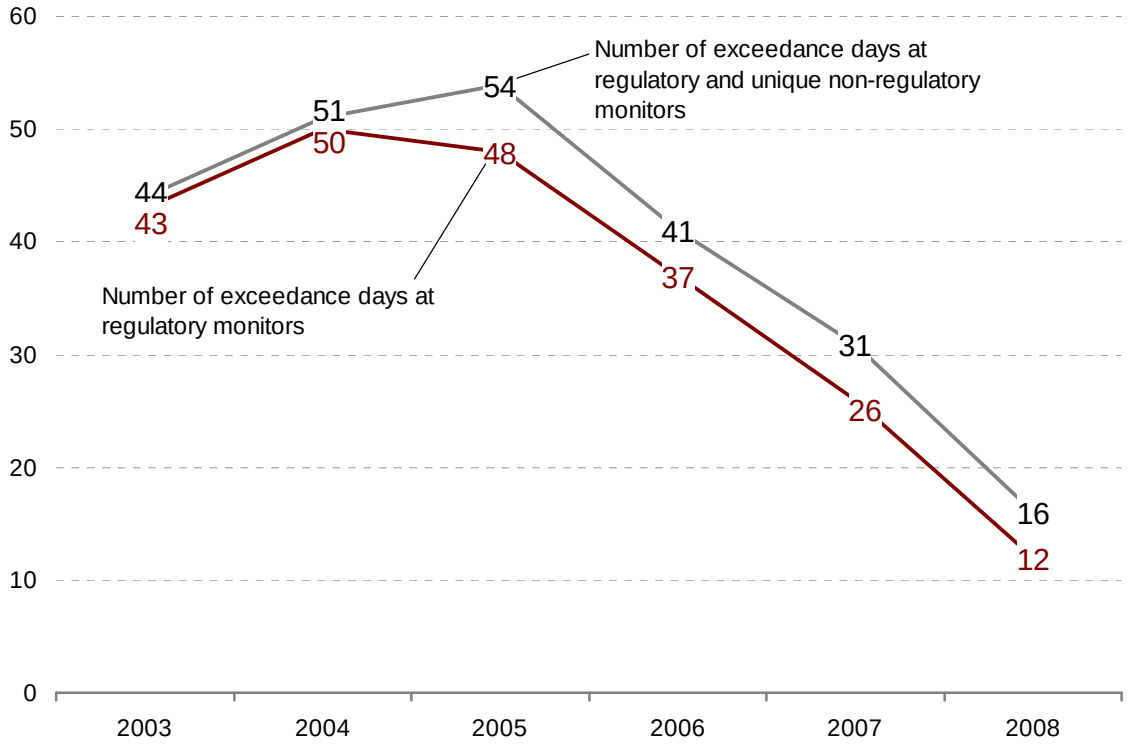


Figure 5-9: Distributions of One-Hour Ozone Design Values at Regulatory and Non-Regulatory Monitors in the HGB Area

Figure 5-10: *1997 Eight-Hour Ozone Exceedance Days at Regulatory and Non-Regulatory Monitors, 2003 through 2008* presents the number of days per year from 2003 through 2008 that the 1997 eight-hour ozone NAAQS was exceeded in the HGB area at regulatory monitors and at all monitors, both regulatory and non-regulatory. Since 2005, the combined network has recorded a total of 19 additional exceedances of the 1997 eight-hour ozone standard that would not have been captured by the regulatory network, i.e., about four to five per year. This result confirms earlier findings that suggest as the monitoring network has expanded, fewer episodes of elevated ozone concentrations are likely to elude detection.



Number of regulatory monitors operating:

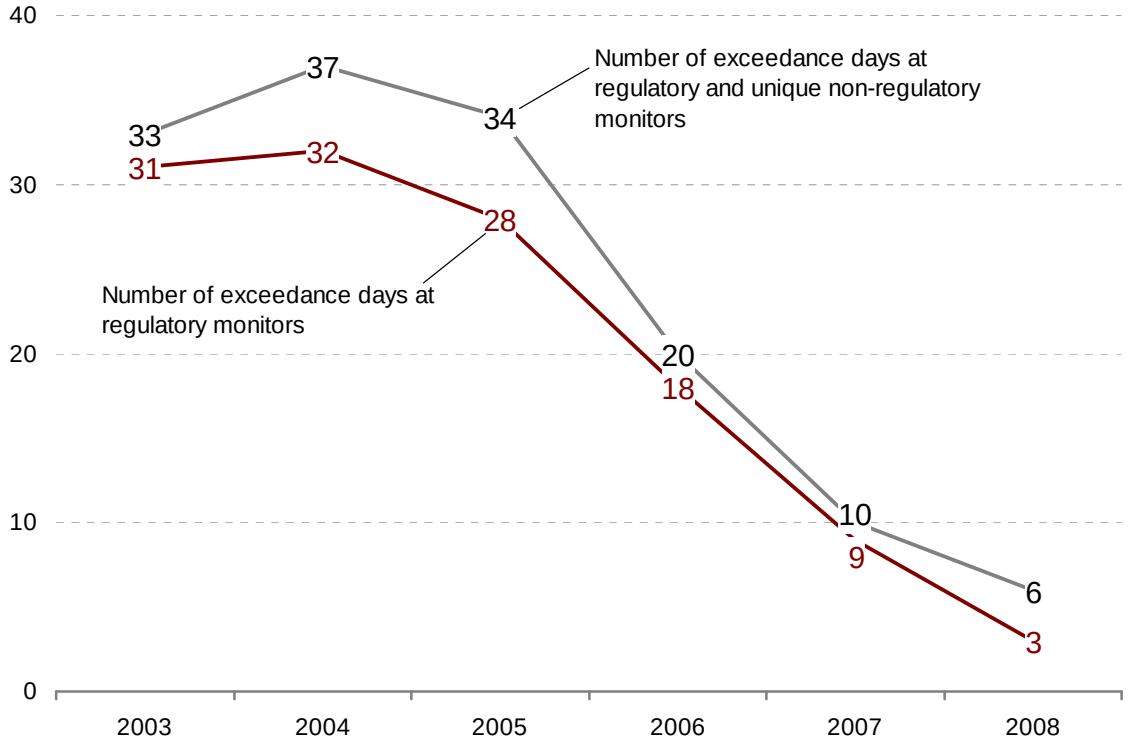
2003	2004	2005	2006	2007	2008
21	22	21	21	22	22

Number of non-regulatory monitors operating:

2003	2004	2005	2006	2007	2008
5	15	20	21	21	21

Figure 5-10: 1997 Eight-Hour Ozone Exceedance Days at Regulatory and Non-Regulatory Monitors, 2003 through 2008

Figure 5-11: *One-Hour Ozone Exceedance Days at Regulatory and Non-Regulatory Monitors, 2003 through 2008* presents the number of days per year from 2003 through 2008 that the one-hour ozone NAAQS was exceeded in the HGB area at regulatory monitors and at all monitors, both regulatory and non-regulatory. The number of exceedance days are also illustrated in Table 5-8: *Exceedance Days at Regulatory and Non-Regulatory Monitors, 2003 through 2008***.** Both series initially increased, then fell at similar rates throughout the period, suggesting that the two sets of monitors measure broadly similar phenomena. During the first half of the period, non-regulatory monitors measured from five to nine additional exceedance days that were not detected by regulatory monitors. However, in the second half of the period, that gap dropped to only two to three additional days, indicating that non-regulatory monitors are detecting fewer and fewer events not detected by regulatory monitors. This result confirms earlier findings that suggest that, as the monitoring network has expanded, fewer episodes of elevated ozone concentrations are likely to elude detection. The monitors that recorded the maximum one-hour ozone design value are examined in Table 5-9: *Monitors Recording the Annual Maximum One-Hour Ozone Design Value*. In most instances, the maximum one-hour ozone design value is recorded by a regulatory monitor.



Number of regulatory monitors operating:

2003	2004	2005	2006	2007	2008
21	22	21	21	22	22

Number of non-regulatory monitors operating:

2003	2004	2005	2006	2007	2008
5	15	20	21	21	21

Figure 5-11: One-Hour Ozone Exceedance Days at Regulatory and Non-Regulatory Monitors, 2003 through 2008

Table 5-8: Exceedance Days at Regulatory and Non-Regulatory Monitors, 2003 through 2008

	One-Hour Ozone Exceedance days			Number of monitors		
Year	regulatory monitors	non-regulatory monitors	total	regulatory monitors	non-regulatory monitors	total
	#	#	#	#	#	#
2003	31	2	33	21	5	35
2004	32	5	37	22	15	37
2005	28	6	34	21	20	41
2006	18	2	20	21	21	42
2007	9	1	10	22	21	43
2008	3	3	6	22	21	43

Source: Leading Environmental Analysis and Display System (LEADS).

Table 5-9: Monitors Recording the Annual Maximum One-Hour Ozone Design Value

	Regulatory monitors		Non-regulatory monitors	
year	site name	value	site name	value
		ppb		*ppb*
2003	Houston Bayland Park C53	163	HRM-3 Haden Road C603	161
2004	Houston Deer Park 2 C35/139	157	HRM-3 Haden Road C603	161
2005	Houston Deer Park 2 C35/139	153	Sheldon C551	150
2006	Houston Deer Park 2 C35/139	150	La Porte Sylvan Beach C556	149
2007	Houston Deer Park 2 C35/139	150	La Porte Sylvan Beach C556	149
2008	Houston Deer Park 2 C35/139	147	Tom Bass C558	138

Source: Leading Environmental Analysis and Display System (LEADS).

Another way to see the ozone trend in the HGB area is to examine how the spatial distributions of ozone have changed over the years. Figure 5-12: *Eight-Hour Ozone Design Values for 2000, 2005, and 2009* shows the spatial distribution of eight-hour ozone design values in the HGB area, for regulatory monitors only, and the changes that have occurred from 2000 to 2005 to 2009. In 2000, local peaks in design value were at Houston Aldine (CAMS 8), Houston Bayland Park (CAMS 53), and Deer Park (CAMS 35/139), and all three peaks were 110 ppb or higher.

By 2005, eight-hour ozone design values had dropped across the region. While the highest concentrations still occurred at Houston Bayland Park (CAMS 53) and Deer Park (CAMS 35/139), they were no longer observed in the Houston Aldine (CAMS 8) area. Further, the 2005 peaks are much lower, between 100 and 103 ppb. The lowest eight-hour ozone concentration is still observed at Lang (CAMS 408), but low ozone also occurs to the northeast at Houston North Wayside (CAMS 405), to the north at Conroe (CAMS 65) or Conroe Relocated (CAMS 78), and to the south at Galveston Airport (CAMS 34/CAMS 109/CAMS 154). The minimum eight-hour ozone concentration in 2005 is below the 1997 NAAQS.

In 2009, eight-hour ozone design values dropped even further. Ozone concentrations are substantially lower across a large part of the HGB area, with the kriging model predicting design values below the 1997 eight-hour ozone NAAQS at all locations. Maximum eight-hour ozone concentrations are now considerably lower, between 81 ppb and 84 ppb. The highest measurements occurred at Houston Bayland Park (CAMS 53), Manvel Croix Park (CAMS 84), and Northwest Harris County (CAMS 26). The eight-hour ozone concentrations in 2009 are lower throughout the HGB area, with a local ozone minimum located in the urban core area surrounding the Lang (CAMS 408), Houston North Wayside (CAMS 405), Houston Texas

Avenue (CAMS 411), Clinton (CAMS 403/CAMS 113/CAMS 304), and the TCEQ Houston Regional Office (CAMS 81) monitors.

Notice that while the overall concentrations of eight-hour ozone are lower, the areas that experience the highest and lowest ozone remain the same. Spatial interpolation shows that high ozone concentrations continue to occur south of downtown Houston, and stretch from the Houston Ship Channel in the east to west Houston, near Houston Bayland Park (CAMS 53). The lowest ozone values are found to the south along the coast, at the northern edge of the nonattainment area towards Conroe (CAMS 65), and to the northwest of downtown Houston, at Lang (CAMS 408).

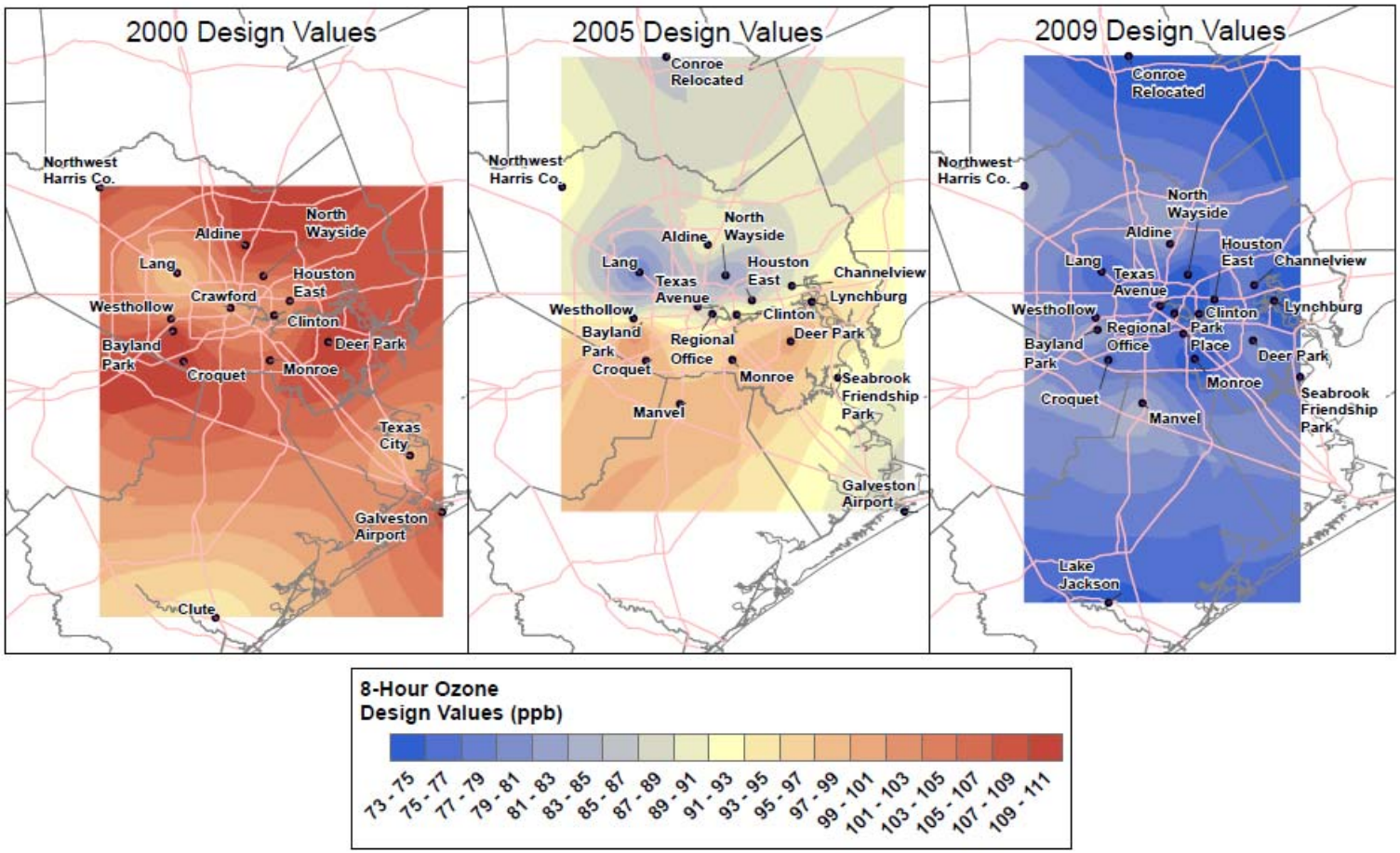


Figure 5-12: Eight-Hour Ozone Design Values for 2000, 2005, and 2009

The kriging method can also be employed to investigate the geographic origins of high ozone concentrations. Studies during the TexAQS 2000 field study reported that the highest ozone in the HGB area occurs in plumes emanating from industrial areas (Daum et al., 2004; Kleinman et al., 2005; Ryerson et al., 2003; Berkowitz et al., 2005; Banta et al., 2005). As these plumes are transported across the region, they can be tracked by the high ozone concentrations recorded at successive downwind monitors as the day progresses. An analysis of the time of day of maximum ozone at each monitoring site can confirm or challenge conclusions of the field study about these origins by revealing spatial patterns of ozone formation and movement.

Yet another way to examine the ozone behavior in the HGB area is to investigate the time of day that ozone peaks, on average, in each part of the monitoring network. Daily maximum ozone concentrations were divided into two groups: days with values exceeding the 1997 eight-hour ozone NAAQS, and days not exceeding the 1997 eight-hour ozone NAAQS. The time of day when peak ozone was recorded at each monitor was determined for each day, then averaged across the two groupings of days. Only monitors that report data to the EPA were included. Days were restricted to March through November to exclude months when few or no exceedance days occur in the HGB area.

Maps of the time of peak ozone in the HGB area, averaged from March through November 1998-2008, are found in Figure 5-13: *Time of Day of Peak Hourly Ozone on Low and High Ozone Days*. The left map shows that on days with low eight-hour ozone values, daily maximum values are recorded in the Galveston area early in the day, between 11:30 a.m. and 11:45 a.m. Inland monitors record their highest daily values at progressively later times of day, as monitors are located farther inland from the Gulf Coast. On low ozone days, the earliest ozone maxima occur near the coast, and the latest occur in the Conroe area between 2:00 p.m. and 2:15 p.m. This pattern of ozone concentrations is consistent with the occurrence of the sea breeze, which often dominates local weather during the summer in the absence of strong synoptic-scale weather influences. After the plume is carried past a monitor, ozone levels often drop, reflecting the cleaner maritime air behind the sea breeze front.

By contrast, the right map of the daily pattern on high eight-hour ozone days looks quite different. Daily maximum ozone concentrations are observed earliest in the industrial areas, and successively later at sites that are progressively farther away from these areas. This pattern indicates that high ozone forms first in the industrial areas, and is transported outward to urban, suburban, and rural sites later in the day. Maximum ozone occurs latest at Lake Jackson (CAMS 1016), Clute (CAMS 11), Northwest Harris Co. (CAMS 26), Conroe (CAMS 65) and Conroe Relocated (CAMS 78), the sites at the greatest distance from the industrial area.

The time of day of maximum ozone on high eight-hour ozone days represents a composite pattern: high ozone formed in industrial areas is carried by winds to Conroe (CAMS 65) and Conroe Relocated (CAMS 78) on some days, to Lake Jackson (CAMS 1016) on other days, and to western Houston on other days. Combined with the earlier spatial analysis of design values, the patterns of peak ozone appear to show that the highest ozone concentrations are formed in the vicinity of the heavily industrialized areas of metropolitan Houston and are then transported throughout the area.

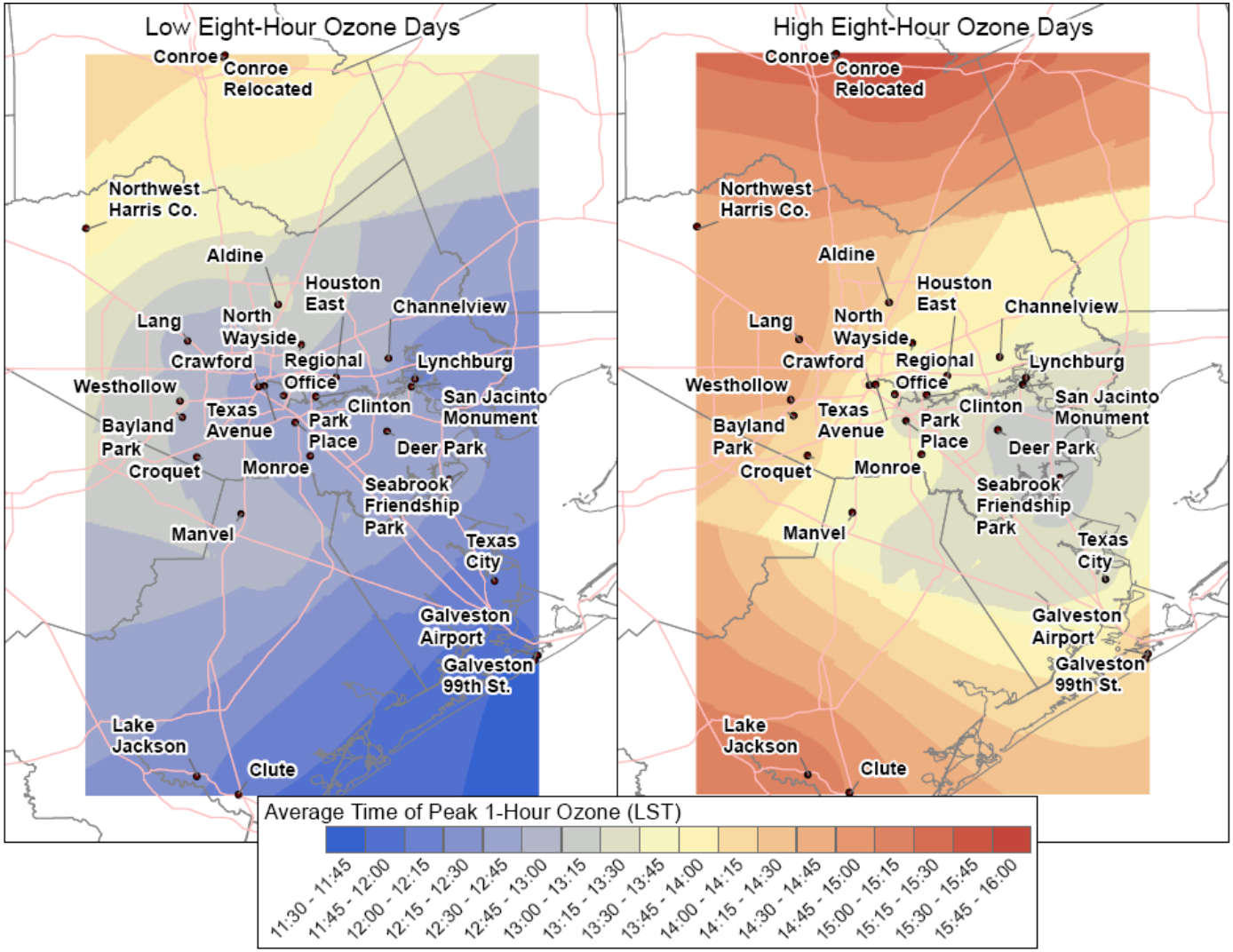


Figure 5-13: Time of Day of Peak Hourly Ozone on Low and High Ozone Days

5.3.3 Trends in the Strength of Observed Ozone Gradients in the HGB Area

Rapid ozone increases have been observed at HGB area monitoring sites for many years, but the phenomenon was not sufficiently explained until the TexAQS 2000 study. Researchers from Brookhaven National Laboratory and National Oceanic and Atmospheric Administration (NOAA) Aeronomy Laboratory were able to establish that the rapid ozone increases were due to strong spatial ozone gradients that arose when ozone formed very rapidly in industrial plumes. The rapid ozone formation observed by Daum et al. (2003, 2004) allowed ozone to build up in the plumes before ozone and its precursors could disperse. Shifting winds due to the coastal oscillation or bay/Gulf breeze phenomena pushed the strong ozone gradients over the monitoring sites, resulting in observations of rapid ozone increases (Banta et al., 2005). The rapid ozone formation occurs when industrial HRVOC reacts with co-emitted NO_X (Ryerson et al., 2003; Wert et al., 2003). The following analysis examines whether the strength of these ozone gradients has lessened, as measured by the magnitude of one-hour changes in ozone observed at monitoring sites.

One-hour changes in ozone concentrations examined for each hour during the ozone season (May through October) at each site for each year. The maximum daily peak change in ozone concentration was chosen for each day, and various statistical measures were calculated from those values. Not all sites were included in this analysis: only those with long operating histories were included.

Figure 5-14: *Trends in the Strength of Ozone Gradients Measured in the HGB Area from 1995 through 2008* shows how the daily maximum one-hour change in ozone has changed since 1995 in the HGB area. While at the mean and median levels the change is slight, the steepest observed ozone gradients have been reduced dramatically since 1995, decreasing by about 40 percent.

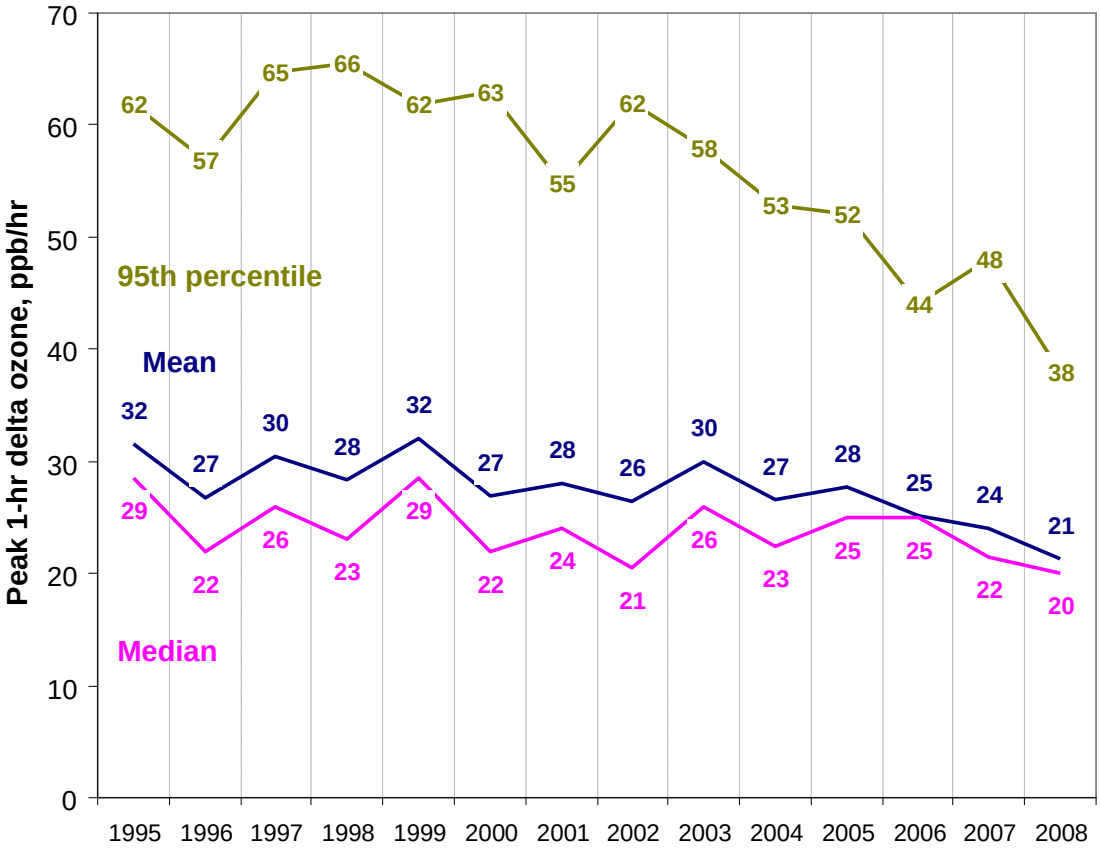


Figure 5-14: Trends in the Strength of Ozone Gradients Measured in the HGB Area from 1995 through 2008

Figure 5-15: *The Number of Occurrences of One-Hour Increases in Ozone Greater Than 40 ppb/hr in the HGB Area for the Subset of Monitors with Long Historical Records* shows that the number of strong ozone gradients observed by monitoring sites in the HGB area has also decreased substantially since the 1990s, matching the general trends in decreasing ozone concentrations. The intensity of ozone gradients has decreased, and the frequency of strong ozone gradient observations has also decreased, which strongly suggests that ozone is forming less rapidly in the HGB area than in previous years. This change in ozone behavior is consistent with decreasing reactivity of VOC emitted in the HGB area. Note that the intensity of ozone gradients can depend upon meteorological factors as well as chemical factors. This analysis has not examined the importance of meteorological factors upon the observed trends. Subsequent sections will discuss trends in HRVOC concentrations.

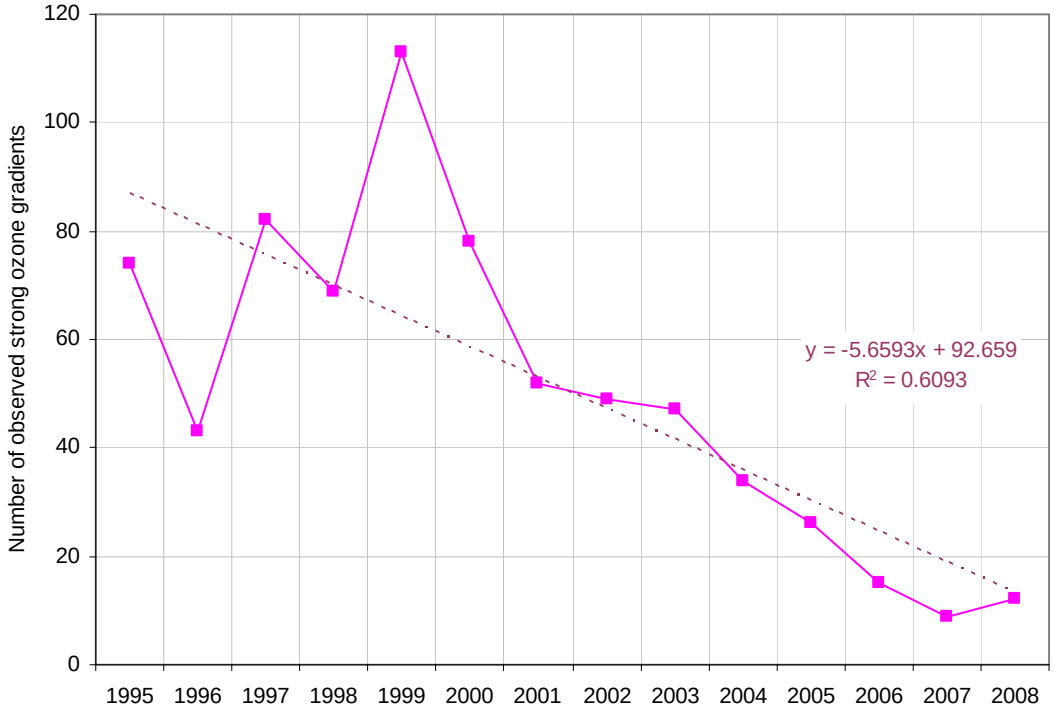


Figure 5-15: The Number of Occurrences of One-Hour Increases in Ozone Greater Than 40 ppb/hr in the HGB Area for the Subset of Monitors with Long Historical Records

5.3.4 The Impact of Hurricane Ike on Ozone Observations in the HGB Area

The HGB area typically records high ozone values each year in September. Sometimes, these values help determine the area-wide design value for that year. The HGB eight-hour ozone design value has been declining recently and was particularly low in 2008 (91 ppb). September 2008 was not typical for the HGB area. Hurricane Ike, a strong Category 2 hurricane, struck the Texas coast near Galveston Bay on September 13, 2008. Most monitors in the area were shut down and emissions patterns were substantially altered. This analysis shows the possible effect of the monitor shutdown on the ozone design value in the HGB area in 2008.

Hurricane Ike struck the Texas coast near Galveston Bay on September 13, 2008. Before the hurricane struck, the evacuation of Galveston Island and the surrounding areas created enormous traffic jams. After the storm passed, there was far less automobile traffic than normal for several weeks. In preparation for the storm, many of the local petrochemical facilities shut down their operations, and after the storm, their operations were atypical for an extended period. Rescue operations, tree cutting and burning, lack of electrical power, unusual traffic patterns, and abnormal industrial operations were among the atypical conditions that occurred before, during, and after the hurricane. The exact effect of the emission changes on ozone concentrations is unknown, due to the number of ozone monitoring sites disabled indirectly or directly by Hurricane Ike. Monitors in the HGB area ceased operations for as little as one day, and as long as 69 days at a site that was severely damaged by storm surge. Key monitors that typically record the area design value were down for as much as 16 days, e.g., Houston Bayland Park (CAMS 53) (see Table 5-10: *List of the Number of Days HGB Ozone Regulatory and Non-Regulatory Monitors were Not Operating Before and After the Landfall of Hurricane Ike*).

Table 5-10: List of the Number of Days HGB Ozone Regulatory and Non-Regulatory Monitors were Not Operating Before and After the Landfall of Hurricane Ike

Monitor	First Date Monitor Did Not Report Data	Restart Date	Days Down
Houston Bayland Park C53/A146	9/13/2008	9/29/2008	16
Houston Westhollow C410	9/12/2008	9/30/2008	18
Park Place C416	9/12/2008	9/15/2008	3
Houston Deer Park 2 C35/C139	9/12/2008	9/22/2008	10
Manvel Croix Park C84	9/12/2008	9/21/2008	9
Northwest Harris Co. C26/A110/X150	9/13/2008	9/14/2008	1
Houston Aldine C8/AF108/X150	9/13/2008	9/15/2008	2
Houston Monroe C406	9/12/2008	9/19/2008	7
Houston Croquet C409	9/12/2008	9/26/2008	14
Conroe Relocated C78/A321	9/13/2008	9/17/2008	4
Channelview C15/AH115	9/13/2008	9/16/2008	3
Houston East C1/G316	9/13/2008	9/29/2008	16
Seabrook Friendship Park C45	9/13/2008	9/16/2008	3
Houston Texas Avenue C411	9/12/2008	9/16/2008	4
Lake Jackson C1016	9/12/2008	9/16/2008	4
Lang C408	9/12/2008	9/18/2008	6
Houston North Wayside C405	9/12/2008	9/15/2008	3
Lynchburg Ferry C1015/A165	9/12/2008	10/16/2008	34
Houston Regional Office C81	9/13/2008	9/20/2008	7
Clinton C403/C304/AH113	9/12/2008	9/30/2008	18
West Houston C554	9/13/2008	9/14/2008	1
Tom Bass C558	9/13/2008	9/18/2008	5
Wallisville Road C617	9/12/2008	9/17/2008	5
Meyer Park C561	9/13/2008	9/15/2008	2
Atascocita C560	9/14/2008	9/23/2008	9
La Porte Sylvan Beach C556	9/12/2008	11/6/2008	55
Baytown Wetlands Center C552	9/12/2008	10/31/2008	48
Mustang Bayou C619	9/12/2008	9/26/2008	14
Clear Lake High School C572	9/13/2008	9/14/2008	1
HRM-3 Haden Road C617	9/12/2008	9/22/2008	10
Crosby Library C553	9/13/2008	9/20/2008	7
Texas City 34th St. C620	9/12/2008	9/18/2008	6
Dacinger C618	9/12/2008	9/19/2008	7
Kingwood Library C555	9/13/2008	9/14/2008	1
Mercer Arboretum C557	9/22/2008	10/8/2008	16
Sheldon C551	9/12/2008	9/22/2008	10
Clear Creek High School C571	9/13/2008	9/15/2008	2
Galveston 99th St. C1034/A320/X183	9/12/2008	11/20/2008	69
Pasadena AAMS C672	9/12/2008	9/22/2008	10

Hurricane Ike's greatest impact occurred during the second half of September and the first half of October. August and September are typically the months when the HGB area records the most number of days that exceed the ozone standard. For 2000 through 2008, 21 percent of the 266 observed 85 ppb exceedance days in the HGB area were recorded in September (Figure 5-16: *Number of Days that Exceeded the 1997 Eight-Hour Ozone NAAQS by Month from 2000 through 2008) in the HGB Area.*

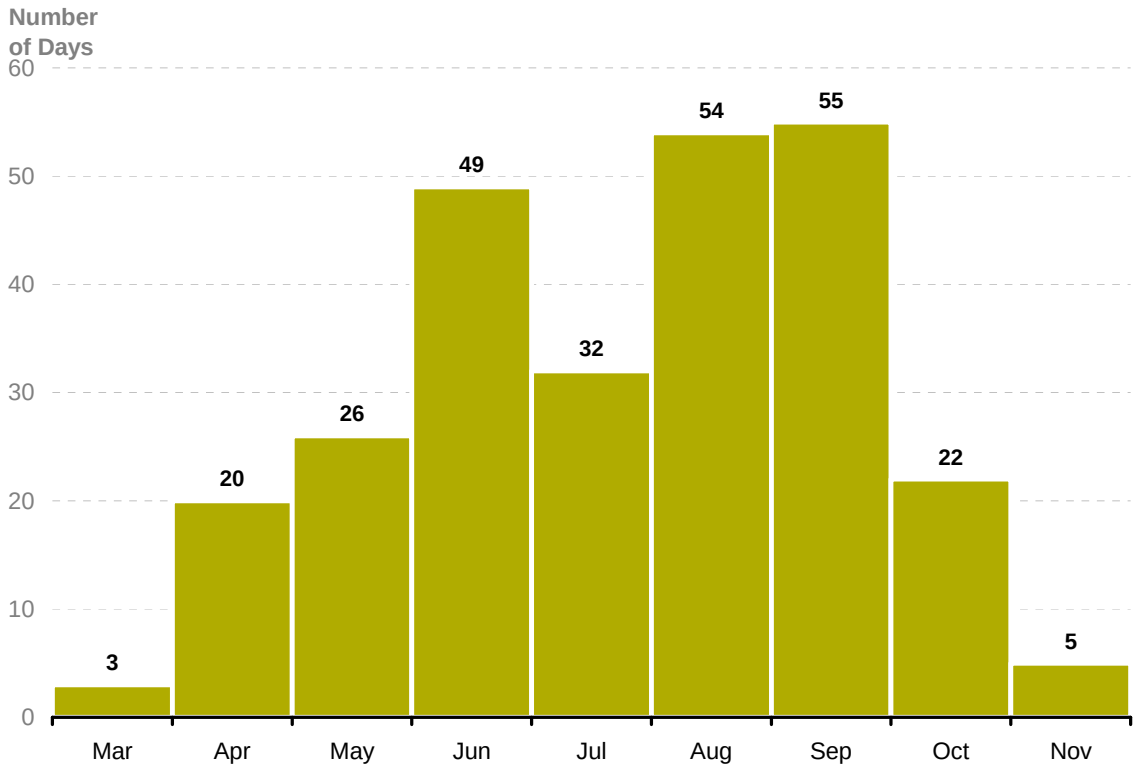


Figure 5-16: Number of Days that Exceeded the 1997 Eight-Hour Ozone NAAQS by Month from 2000 through 2008 in the HGB Area

Figure 5-17: *Frequency of Daily Peak Eight-Hour Ozone Values for All Ozone Monitoring Sites in Texas, September 2006* and Figure 5-18: *Frequency of Daily Peak Eight-Hour Ozone Values for All Ozone Monitoring Sites in Texas, September 2008* show peak eight-hour ozone at all Texas monitoring sites in September 2006, which was unaffected by tropical systems and in September 2008, the month in which Hurricane Ike struck. In 2008, the number of monitors in operation dropped substantially just before the hurricane made landfall, as they were shut down by the TCEQ. The monitors came back on-line gradually, as electrical power was restored, and storm damage was repaired. Ozone concentrations immediately before and after Ike were fairly low.

The purpose of this analysis is to examine how the ozone behavior in September and October 2008 deviated from the 2000 through 2007 average, and thus to ascertain whether the lower design value observed in 2008 was due primarily to the effects of Hurricane Ike.

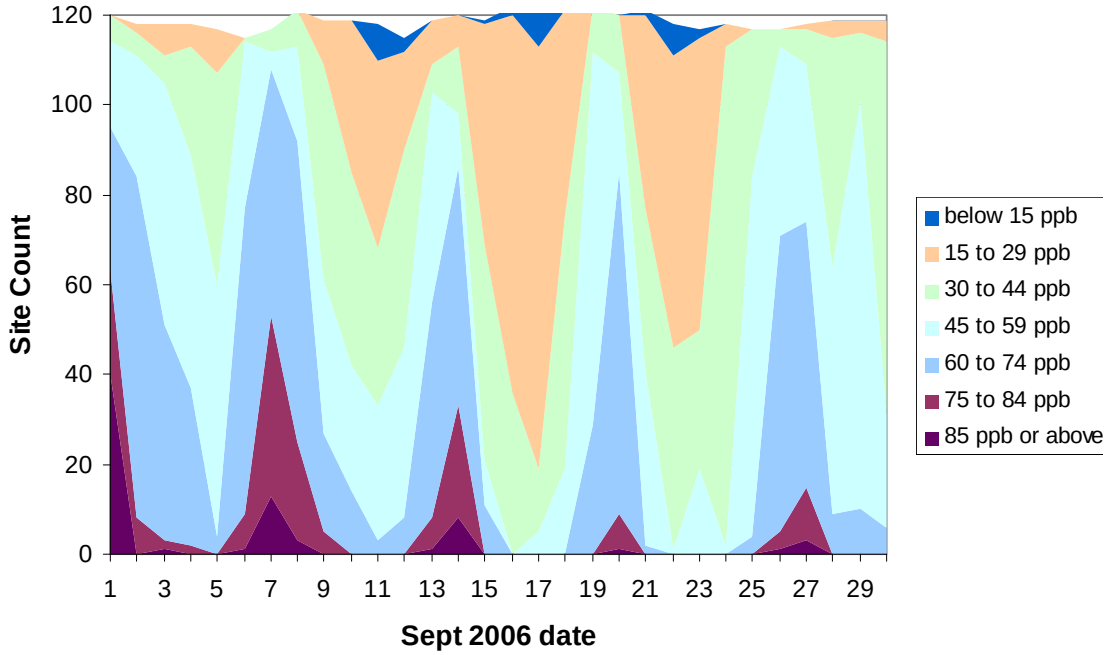


Figure 5-17: Frequency of Daily Peak Eight-Hour Ozone Values for All Ozone Monitoring Sites in Texas, September 2006

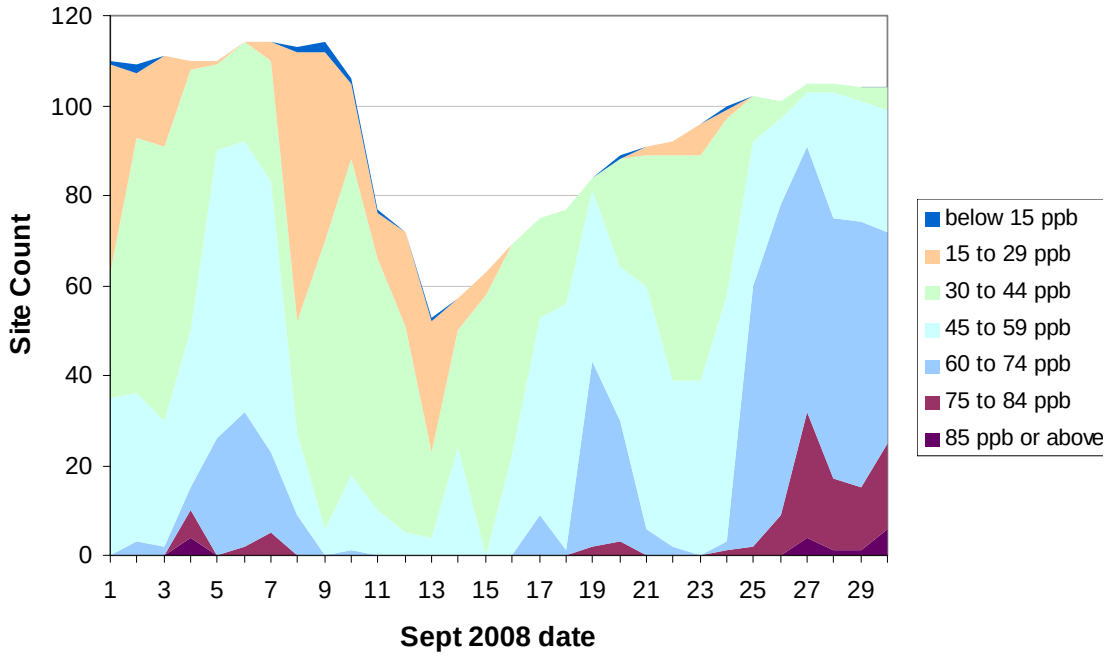


Figure 5-18: Frequency of Daily Peak Eight-Hour Ozone Values for All Ozone Monitoring Sites in Texas, September 2008

5.3.4.1 Approach

One approach to estimate the influence of Hurricane Ike on the HGB area's ozone design value is to estimate what the eight-hour ozone design value might have been in 2008 if Hurricane Ike had not occurred. This estimate is derived from historical data collected during 2000-2007. Removing calendar days affected by Hurricane Ike and replacing them with averages derived from historical data yields a re-calculated fourth-highest eight-hour ozone concentration for each monitor. The actual fourth-high is then divided by the re-calculated fourth-high to obtain an

adjustment ratio or an Ike Adjustment Factor (IAF). This ratio is expected to be greater than one, and can be used to adjust 2008 ozone data to non-hurricane conditions. The IAF can be calculated as an area-wide average IAF or as a monitor-specific IAF. An area-wide average IAF is computed as the average of all IAFs from all monitors in the region, applied to all 2008 data. The monitor-specific IAF was applied only to the monitor in question. After the data were adjusted with IAFs, an IAF-corrected design value was calculated and compared to the current unadjusted ozone design value to determine the influence of Hurricane Ike.

The days affected by Hurricane Ike are not easy to identify. As stated before, many unusual activities occurred in the HGB area before the arrival of Hurricane Ike, and many others occurred in the aftermath. For example, many industrial facilities shut down operations before the storm arrived, releasing emissions that they usually would not release. After the hurricane, electrical power was not available in parts of the HGB area for two or more weeks. Given the difficulties in establishing the exact period of Hurricane Ike's influence, alternative IAFs were calculated by removing three different time periods from the historical ozone data. The first period considered for exclusion was a two-week period from September 11 through September 25, 2008, which includes days immediately before and after the hurricane. Two other periods considered for exclusion were a one-month period from September 6 through October 5, 2008, and a one-month period after the storm (September 13 through October 12, 2008). All data used in this analysis were obtained from the TCEQ-LEADS system, and are eight-hour ozone averages. The HGB area eight-hour ozone design value was obtained from the EPA.

5.3.4.2 Results

Table 5-11: *Alternative Fourth-High Daily Peak Eight-Hour Ozone Concentration Calculations Using Different Ike Adjustment Factors (IAFs)* shows results of the six different methods for estimating the fourth-high daily peak eight-hour ozone concentration for each monitoring site. The table shows that the expected fourth high is greater than the observed at most sites, regardless of which method is used to calculate the expected fourth high. This indicates that the atypical conditions experienced during and after Hurricane Ike during September and October in 2008 did have an effect on the monitored values, but the effect was no greater than 4 ppb on the fourth-high daily maximum ozone concentration.

Table 5-11: Alternative Fourth-High Daily Peak Eight-Hour Ozone Concentration Calculations Using Different Ike Adjustment Factors (IAFs)

Monitoring site	2008 observed fourth high	9/11-9/26 average IAF	9/11-9/26 monitor-specific IAF	9/6-10/5 average IAF	9/6-10/5 monitor-specific IAF	9/13-10/12 average IAF	9/13-10/12 monitor-specific IAF
	ppb	*ppb*	*ppb*	*ppb*	*ppb*	*ppb*	*ppb*
Houston Aldine C8 /AF108/X150	83	85	86	87	86	86	86
Houston Bayland Park C53	83	85	84	87	86	86	85
Channelview C15/C115	76	78	77	79	78	79	78
Houston Croquet C409	76	78	78	79	80	79	79
Houston Deer Park C18	76	78	78	79	79	79	78
Lake Jackson C1016	76	78	77	79	80	79	78
Northwest Harris Co. C26/A110/C154	76	78	78	79	81	79	80
Manvel Croix Park C84	75	77	77	78	81	78	78
Conroe C65	73	75	74	76	75	76	75
Houston East C1	73	75	74	76	76	76	76
Houston Monroe C406	71	73	73	74	75	74	74
Seabrook Friendship Park C45	71	73	75	74	75	74	75
Houston North Wayside C405	70	72	70	73	71	73	71
Houston Texas Avenue C411	70	72	71	73	73	73	73
Lang C408	70	72	73	73	75	73	74
Clinton C403/C113/C304	69	71	70	72	72	71	72
Houston Westhollow C410	69	71	70	72	71	71	71
Houston Regional Office C81	68	70	69	71	71	70	70
Lynchburg Ferry C1015	65	66	65	68	66	67	66

This table compares the observed 2008 fourth-high at each monitor to the expected fourth high, as calculated by six different methods.

The attainment status of an area is not based upon fourth-high ozone concentrations, but upon the design value. Table 5-12: *Observed and Expected Design Values, Recalculated to Account for Hurricane Ike* shows the observed 2008 design value, and the expected design value, as calculated with the six different methods described above. As Table 5-12: *Observed and Expected Design Values, Recalculated to Account for Hurricane Ike* shows, the effect upon the design value for the HGB area is at most 1 ppb, and for two of the alternatives there is no effect. This analysis is robust, because six different methods of estimating the effect of the hurricane on ozone design value have given substantially the same answer: the 2008 eight-hour ozone design value was not different from the expected design value, based upon comparisons with historical data. Therefore, based upon the historical analysis, the effect of Hurricane Ike upon the eight-hour ozone design value for 2008 in the HGB area was apparently minimal.

Table 5-12: Observed and Expected Design Values, Recalculated to Account for Hurricane Ike

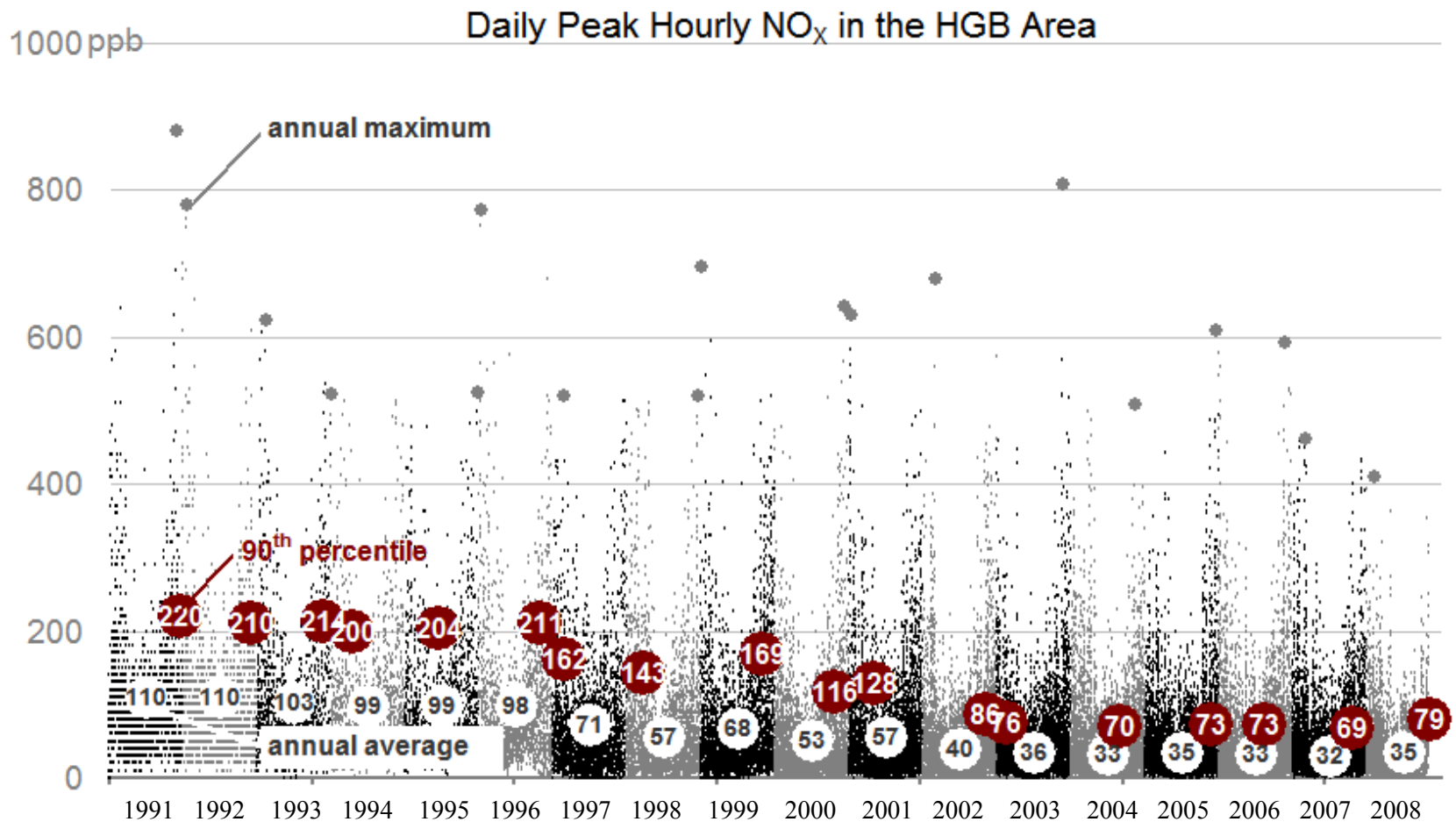
Observed Design Value: 91 ppb	2-weeks 9/11-9/25	1-month 9/13-10/12	1-month 9/6-10/5
Estimated Design Value after applying area-wide average Ike Adjustment Factor	91 ppb	92 ppb	92 ppb
Estimated Design Value after applying monitor-specific Ike Adjustment Factor	92 ppb	91 ppb	92 ppb

5.3.5 NO_X Trends

NO_X are a variable mixture of NO and NO_2 and are critical precursors to ozone formation. As the NO_X emissions decrease, the ambient concentrations of these compounds should also decrease. NO_X are primarily created by fossil fuel combustion, lightning, biomass burning, and microbial action in the soil.

Previous analyses performed using aircraft measurements and emission inventories obtained during TexAQS 2000 and TexAQS II indicate that NO_X emissions in the Houston Ship Channel area have decreased between 2000 and 2006 (Cowling et al., 2007). Furthermore, aircraft data obtained during the two field studies were in agreement with data measured by continuous emission monitoring systems (CEMS) located at the facilities. Analyses done by the Rapid Science Synthesis Team of the 2005-2006 Texas Air Quality Study (TexAQS II) indicate that NO_X emissions at several electric generating units (EGUs) have decreased by factors ranging from two to four between 2000 and 2006 (Cowling et al., 2007). These reductions were seen at EGUs that implemented NO_X control features, such as selective catalytic reduction (SCR), between 2000 and 2006, which suggests these control strategies are working. The two field studies effectively describe the emissions during two short time windows, six years apart. To complement these analyses, the TCEQ has performed a more comprehensive investigation of long-term trends in NO_X concentrations.

Daily peak one-hour NO_X from all monitors in the HGB area from 1991 through 2008 is plotted in Figure 5-19: *Daily Peak Hourly NO_X in the HGB Area*. The increasing density of NO_X data points shows that the number of NO_X monitors in the HGB area has greatly increased since 1991. Annual 90th percentile and annual average NO_X values are also plotted in the figure. Both of these measures have decreased markedly over the 1991 to 2008 period, falling 64 percent and 68 percent, respectively. Even more remarkable may be the 53 percent and 48 percent declines since 1999.



Date of 90th percentile:

Oct 22	Dec 15	Dec 25	Oct 30	Nov 22	Dec 12	Nov 19	Feb 24	Nov 12	Sep 5	Apr 27	Dec 15	Dec 19	Apr 28	Dec 1	Nov 16	Nov 14	Oct 22

Figure 5-19: Daily Peak Hourly NO_X in the HGB Area

Table 5-13: *NO_X Values in the HGB Area by Year* shows the degree of decrease in *NO_X* concentrations from 1991 through 2008 and 1999 through 2008.

Table 5-13: NO_X Values in the HGB Area by Year

year	annual maximum NO_X *ppb*	annual average NO_X *ppb*
1991	880	110
1992	780	110
1993	622	103
1994	523	99
1995	524	99
1996	773	98
1997	521	75
1998	520	67
1999	696	75
2000	641	57
2001	629	66
2002	678	52
2003	809	53
2004	509	49
2005	609	49
2006	593	49
2007	461	48
2008	409	35
overall decrease through 2008 since:		
1991	-53.5%	-67.7%
1999	-41.2%	-53.0%
annual decrease through 2008 since:		
1991	-4.4%	-6.4%
1999	-5.7%	-8.0%

Annual decreases are computed as compound annual rates.

Though highly variable from season to season, daily peak hourly NO_X also shows a general decreasing trend since 1991. Maximum NO_X concentrations have decreased overall by 41 percent since 1999, an average of roughly 32 ppb per year, or nearly 6 percent per year. The drop since the 1991 high of 880 ppb is 54 percent or greater than 4 percent annually.

Average daily peak hourly NO_X has dropped even more precipitously, falling 53 percent, or 8 percent per year, from 75 ppb to 35 ppb, since 1999. Since 1991, average hourly NO_X has dropped 68 percent, or over 6 percent per year, from the series high of 110 ppb. Notice that in 2008, both the NO_2 design value and maximum daily peak NO_X recorded the lowest values of any previous year back to 1991.

While the highest NO_X values occur in the winter, the NO_X values during the summer months, when ozone production is the highest, are of particular interest. Trends in median hourly NO_X concentrations at individual monitors in the HGB area from May through October, 1998 to 2008, are shown in Figure 5-20: *Median NO_X Concentrations in the HGB Area*. Four monitors of particular interest, Houston Texas Avenue (CAMS 411), Lang (CAMS 408), Clinton (CAMS 403/CAMS 113/CAMS 304), and Houston Bayland Park (CAMS 53), are highlighted. Sites with less than 75 percent complete data for a year were not plotted for that year; for example, Clinton (CAMS 403/CAMS 113/CAMS 304) had less than 75 percent complete data in 2008 and therefore was not plotted.

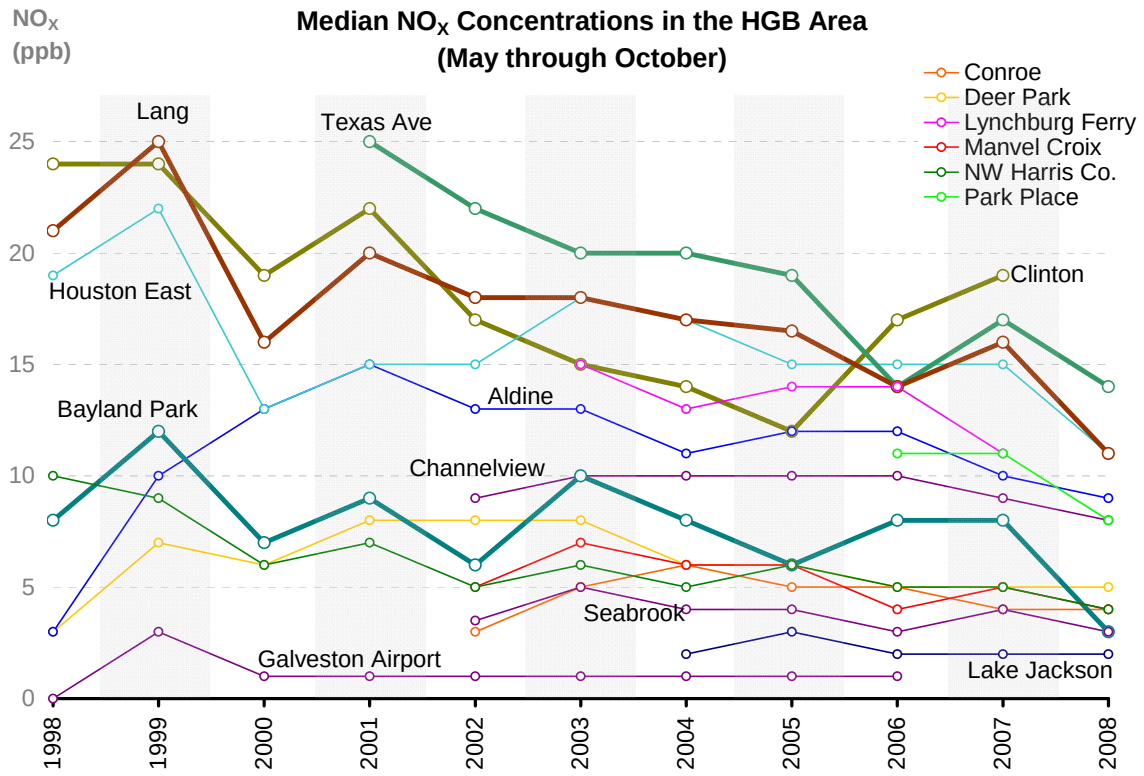


Figure 5-20: Median NO_X Concentrations in the HGB Area

Median NO_X values tend to vary from year to year, but most monitors show overall decreases in median NO_X since 1998. Monitors that show the smallest decreases or show no change are at sites that have traditionally had lower NO_X concentrations. Some of the largest median NO_X concentrations were measured at the Lang (CAMS 408) monitor (in close proximity to Highway 290), and at the Houston Texas Avenue (CAMS 411) monitor (in downtown Houston). These monitors are both near major roadways; their similar trends suggest they may be measuring decreases in NO_X emissions from mobile sources. Monitors at Galveston Airport (CAMS 34/C109/C154), Seabrook Friendship Park (CAMS 45), and Lake Jackson (CAMS 1016) measured the lowest median NO_X concentrations.

Sites recording the highest ozone design values, for example, Houston Bayland Park (CAMS 53) and Park Place (CAMS 416), are not necessarily the sites with the highest median NO_X concentrations. The previous section showed that, in 2008, Houston Bayland Park (CAMS 53) has the highest eight-hour ozone design value in the HGB area of 91 ppb, yet it has a lower median NO_X concentration than many other sites in the area. This observation is consistent with the behavior expected from ozone chemistry; in addition to being an ozone precursor, NO also reacts directly with ozone and in areas with high NO emissions, can destroy more ozone than it

creates. Downwind from the high emission areas, however, ozone destroyed by reaction with NO can re-form.

The largest decreases since 1998 (Table 5-14: *Median and 90th Percentile Hourly NO_X Values*) were observed at monitors primarily influenced by mobile source emissions, rather than industrial sources. Clinton (CAMS 403/CAMS 113/CAMS 304) and Houston East (CAMS 1), which are located near both industrial sources and highways, have seen larger decreases in median NO_X values than in 90th percentile values since 1998. At Houston East (CAMS 1), the 90th percentile value decreased 34 percent, while the median decreased 42 percent between 1998 and 2008. The Clinton (CAMS 403/CAMS 113/CAMS 304) monitor experienced a drop of 16 percent in the 90th percentile, with a 21 percent decrease in the median between 1998 and 2007 (2008 was not used due to incomplete data), though these measures have increased in recent years.

Table 5-14: Median and 90th Percentile Hourly NO_X Values

	median				90th percentile			
monitor	1998	2007	2008	% change 1998-2008*	1998	2007	2008	% change 1998-2008*
	ppb	*ppb*	*ppb*	*%*	*ppb*	*ppb*	*ppb*	*%*
monitors with decreasing trends								
Houston Bayland Park C53	8	8	3	-63	33	30	19	-42
Northwest Harris Co. C26/ A110/C154	10	5	4	-60	21	12	12	-43
Lang C408	21	16	11	-48	65	48	35	-46
Houston East C1	19	15	11	-42	56	46	37	-34
Clinton C403/C113/C304*	24	19	-	-21	56	47	-	-16
monitors with increasing trends								
Houston Aldine C8/AF108/X150	3	10	9	200	30	32	30	0
Houston Deer Park C18	3	5	5	67	25	21	18	-28
monitors with indeterminate trends								
Channelview C15/C115	-	9	8		-	24	20	
Conroe C65	-	4	4		-	10	10	
Galveston Airport C34/C109/C154	0	-	-		1	-	-	
Houston Texas Avenue C411	-	17	14		-	53	37	
Lake Jackson C1016	-	2	2		-	7	6	
Lynchburg Ferry C1015	-	11	-		-	33	-	
Manvel Croix Park C84	-	5	4		-	17	15	
Park Place C416	-	11	8		-	47	32	
Seabrook Friendship Park C45	-	4	3		-	12	12	

* Percentage changes computed from 1998 to 2007 for years missing 2008 data, due to incomplete data.
Monitors are sorted in increasing order by percentage change in median values. Monitors with indeterminate trends began operating after 1998.

While several monitors recorded large decreases from 2007 to 2008, most others observed only minimal changes over that same period. These large disparities in patterns of ambient NO_X concentrations across the region are appropriate for further investigation, suggesting that larger decreases are not due solely to variations in meteorological conditions, which would be expected

to influence all monitors similarly, though not identically. The differences seem to be related to the relative magnitudes of the overall concentrations. Sites with the highest concentrations, which tend to be urban sites, showed the greatest decrease. More rural sites like Lake Jackson (CAMS 1016), Conroe (CAMS 65), and Conroe Relocated (CAMS 78) may reflect slight changes in background values, while more urban sites may reflect actual emission changes.

Similar to ozone, NO_X concentrations in the HGB area appear to be decreasing over time, in large measure the result of the comprehensive suite of NO_X-targeted controls implemented since 2000. Stringent point source NO_X standards have been adopted along with numerous factors affecting mobile source NO_X emissions. Appendix I: *Corroborative Analysis for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard* includes a description of NO_X emission trends, by source type. Strong downward trends in ambient NO_X concentrations are evidence for the effectiveness of the emission controls depicted in the emission-trend data. Decreasing NO_X is a primary cause of decreasing ozone in the HGB area.

5.3.6 Ambient VOC Concentrations

The other major class of compounds that are ozone precursors are VOC. TexAQS 2000 researchers identified a specific subset of VOC that were closely associated with rapid and efficient ozone formation, i.e., light alkenes (Ryerson et al., 2003; Daum et al., 2003, 2004; Jobson et al., 2004). The TCEQ examined the historical data for these compounds, and decided to regulate several light alkenes emitted by industry that were particularly reactive, and that often had particularly high concentrations: ethylene, propylene, 1,3-butadiene, and butenes.

Since the mid-1990s, the TCEQ has collected 40-minute measurements, on an hourly basis, of over 40 VOC compounds using automated gas chromatograph (auto-GC) instruments. Initially, measurements were collected at just one site (Clinton (CAMS 403/CAMS 113/CAMS 304)), but in subsequent years, auto-GC monitors have been added to new sites (see Figure 5-21: *Houston Ship Channel Auto-GC Monitors and 2006 Reported Point Source HRVOC Emissions Points and Plant Boundaries*). Currently, eight sites, listed in Table 5-15: *Auto-GC Monitors in the Houston Ship Channel Area*, along or near the Houston Ship Channel, along with three in Brazoria County and one in Texas City, are collecting VOC measurements with auto-GCs.

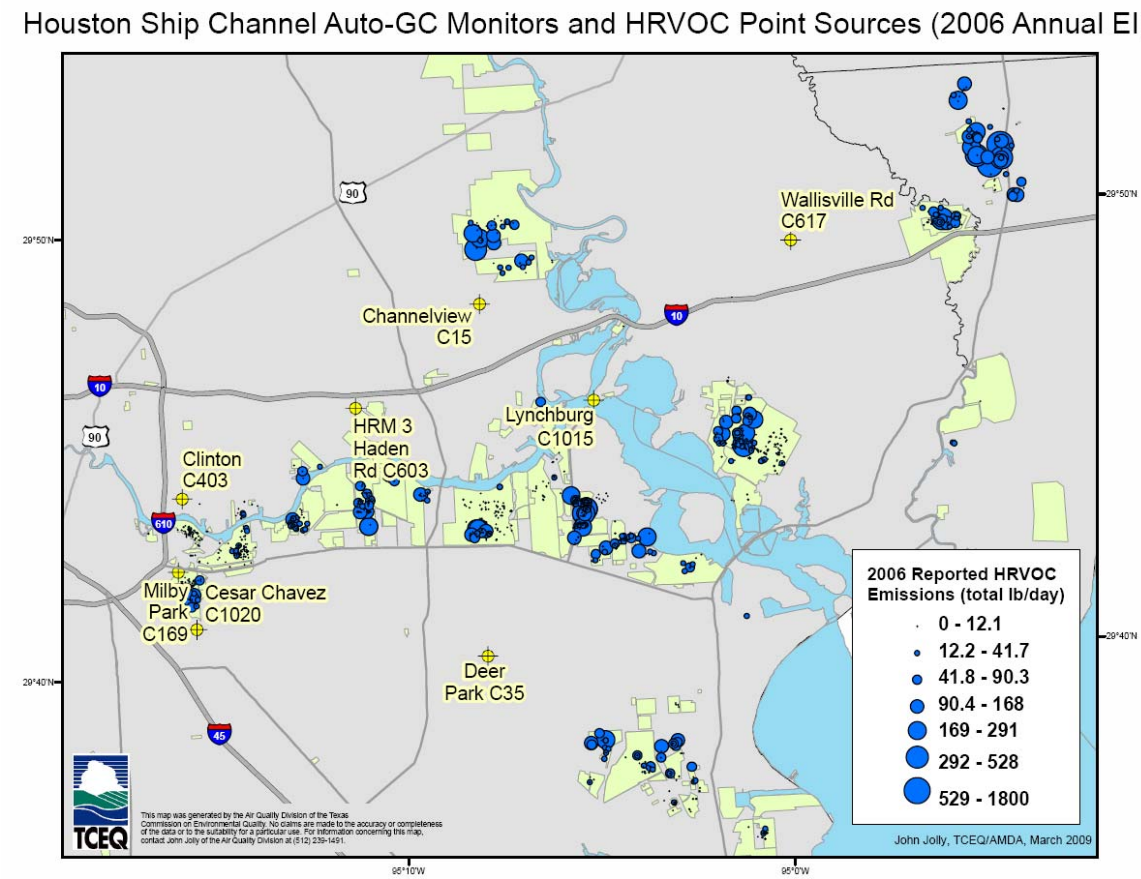


Figure 5-21: Houston Ship Channel Auto-GC Monitors and 2006 Reported Point Source HRVOC Emissions Points and Plant Boundaries

Ambient concentrations of the TCEQ-defined HRVOC (ethylene, propylene, 1,3-butadiene, 1-butene, c-2-butene, and t-2-butene) were analyzed from 1995 to 2008.

Table 5-15: Auto-GC Monitors in the Houston Ship Channel Area

site name	CAMS	AIRS code	latitude	longitude	city	start date
Channelview	C15/C115	482010026	29.8025	-95.1256	Channelview	8/3/2001
Houston Milby Park	A169	482010069	29.7062	-95.2611	Houston	2/19/2005
HRM-3 Haden Road	C603	482010803	29.7483	-95.1811	Houston	8/20/2001
Lynchburg Ferry	C1015	482011015	29.7646	-95.0780	Houston	5/24/2003
Clinton	C403/113/304	482011035	29.7337	-95.2576	Houston	7/1/1995
HousDeerPrk2	C35/139	482011039	29.6700	-95.1285	Deer Park	1/5/1997
Cesar Chavez	C1020/175	482016000	29.6844	-95.2536	Houston	4/13/2004
Wallisville Road	C617	482010617	29.8214	-94.99	Baytown	6/5/2003

Trends at each of the eight Houston Ship Channel monitors were examined. Data from the four other auto-GC monitors were analyzed only for trend slope and possible statistical significance of trends. Daily geometric means were computed from valid ambient hourly measurements for days with at least 18 valid hours of data. A geometric mean was calculated by taking the natural logarithm of each of the measurements, averaging these logs, then calculating the antilog of this mean log value. The geometric mean is a preferable statistic to median or arithmetic (ordinary) mean for evaluating the central tendency of data when the data are skewed, that is, when the data are not symmetrically, or normally, distributed, but clustered around extreme high or low values.

It is more robust than an ordinary average, meaning its value is not greatly influenced by one or a few very high or very low values. Many distributions of pollutant measurements in the HGB area are skewed. Monthly geometric means were also computed with a 75 percent data completeness criterion for valid days in a month.

Figure 5-22: *Monthly Geometric Mean Ethylene Concentrations at the Eight Houston Ship Channel Monitors, July 1995 through December 2008* shows monthly geometric mean ethylene concentrations, ordered according to the monitor location from west to east. Grey bars denote the range of values from the 25th through 75th percentile concentrations, for all monitors. Noteworthy in this figure is the frequency of extremely high values recorded during the 1990s at Clinton (CAMS 403/CAMS 113/CAMS 304), at the western end of the Houston Ship Channel, and Deer Park (CAMS 35/139), in south central Houston Ship Channel. These were the only monitors operating during the early years of this period; this pattern suggests that high ethylene concentrations were not restricted to certain areas of the Houston Ship Channel, but were somewhat geographically widespread.

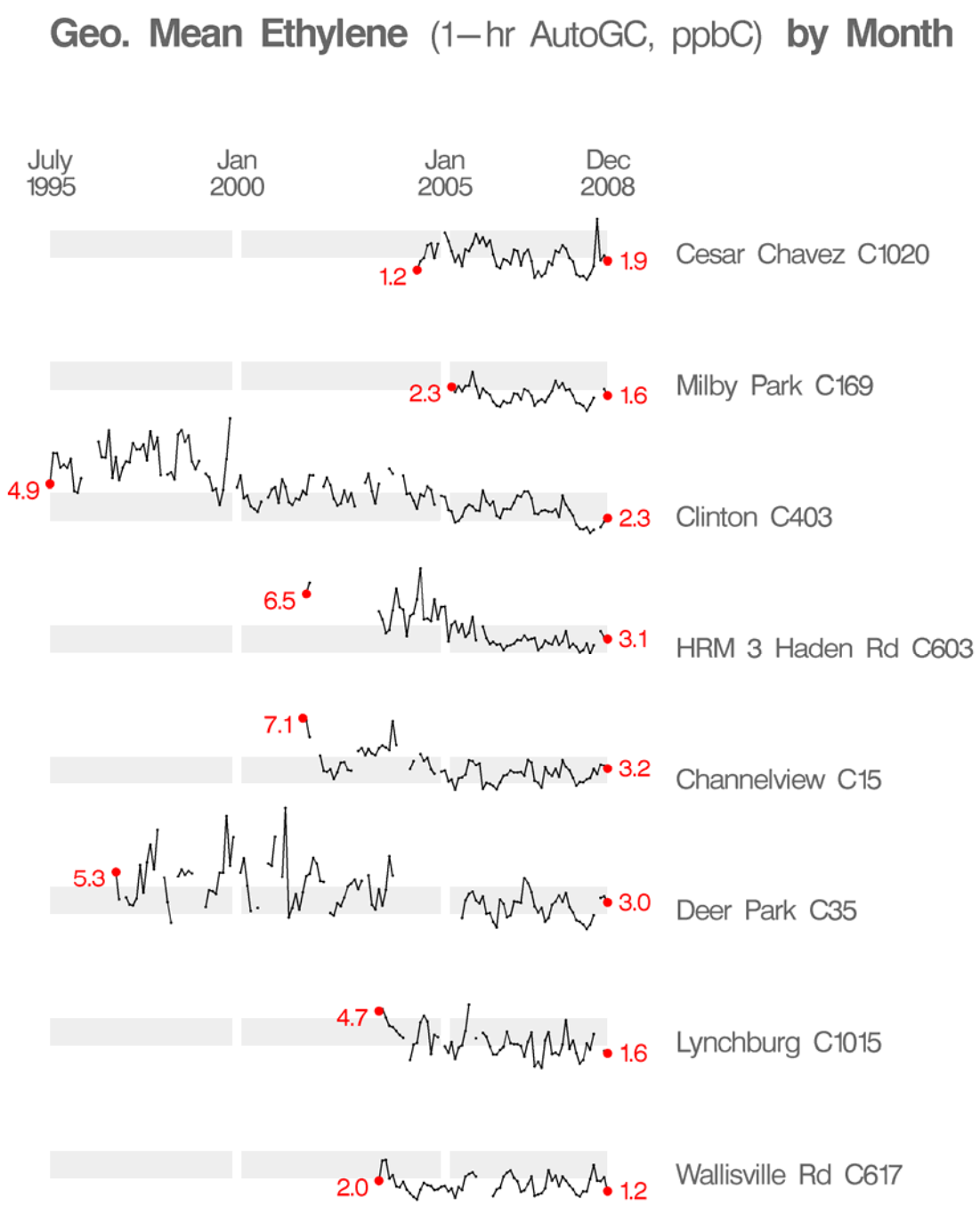


Figure 5-22: Monthly Geometric Mean Ethylene Concentrations at the Eight Houston Ship Channel Monitors, July 1995 through December 2008

For four consecutive years, July 1995 through July 1999, valid monthly geometric mean concentrations at Clinton (CAMS 403/CAMS 113/CAMS 304) exceeded the 75th percentile of the multi-decade series. Deer Park (CAMS 35/139) also exhibited high concentrations in the first several years, including the highest mean value for any complete month, 10.2 parts per billion, carbon (ppbC) in March 2001. By contrast, few monthly mean concentrations exceeded the 75th percentile in the most recent four years, 2005 through 2008.

Though measured ethylene and propylene concentrations show a large degree of variability at all auto-GC monitors, downward trends are apparent at seven of the eight; only Wallisville Road

(CAMS 617) appears to show no decrease. A statistical trend analysis, described below, provides further insight into this.

Peak monthly geometric mean ethylene concentrations at all monitors, 6.9 ppbC and 8.4 ppbC in 2003 and 2004 respectively, decreased to 5.6 ppbC in 2005, 4.9 ppbC in 2006, and 4.5 ppbC in 2007, before climbing to 5.1 ppbC in 2008. This decline in ambient ethylene concentrations suggests that ethylene emissions in the Houston Ship Channel are declining, though meteorology could be responsible for some or all of the decline in geometric mean concentrations.

Similar to Figure 5-22: *Monthly Geometric Mean Ethylene Concentrations at the Eight Houston Ship Channel Monitors, July 1995 through December 2008*, Figure 5-23: *Monthly Geometric Mean Propylene Concentrations at the Eight Houston Ship Channel Monitors, July 1995 through December 2008* displays monthly geometric mean concentrations of propylene for the eight Houston Ship Channel area auto-GC monitors. Again, Clinton (CAMS 403/CAMS 113/CAMS 304) and Deer Park (CAMS 35/139) show higher concentrations in earlier years compared to recent ones; however, the magnitude of concentrations at the two monitors are dissimilar, unlike ethylene, suggesting elevated propylene concentrations are more geographically limited than elevated ethylene concentrations. Two other eastern Houston Ship Channel monitors, Channelview (CAMS 15/CAMS 115) and Lynchburg Ferry (CAMS 1015), report concentrations well above the 75th percentile in 2003, and to a lesser extent in 2004 and subsequent years, suggesting there are greater propylene emissions in the eastern Houston Ship Channel than the western Houston Ship Channel. However, the relatively fast reactivity of propylene, compared to ethylene, may explain part or all of the low concentrations seen in the western Houston Ship Channel.

Similar analyses were performed for 1, 3-butadiene and the isomers of butene; however, trends in these pollutants can be difficult to interpret, as their relatively low concentrations are frequently within accepted measurement uncertainty. Further work is needed before trend estimation for these compounds can be considered accurate.

Though still variable from month to month, pervasive decreases in the ambient concentrations of ethylene and propylene suggest that overall industrial emissions of these compounds have decreased considerably since 1995. This finding agrees with early reports from TexAQS II that ethylene emissions along the Houston Ship Channel have decreased approximately 40 percent from 2000 to 2006.

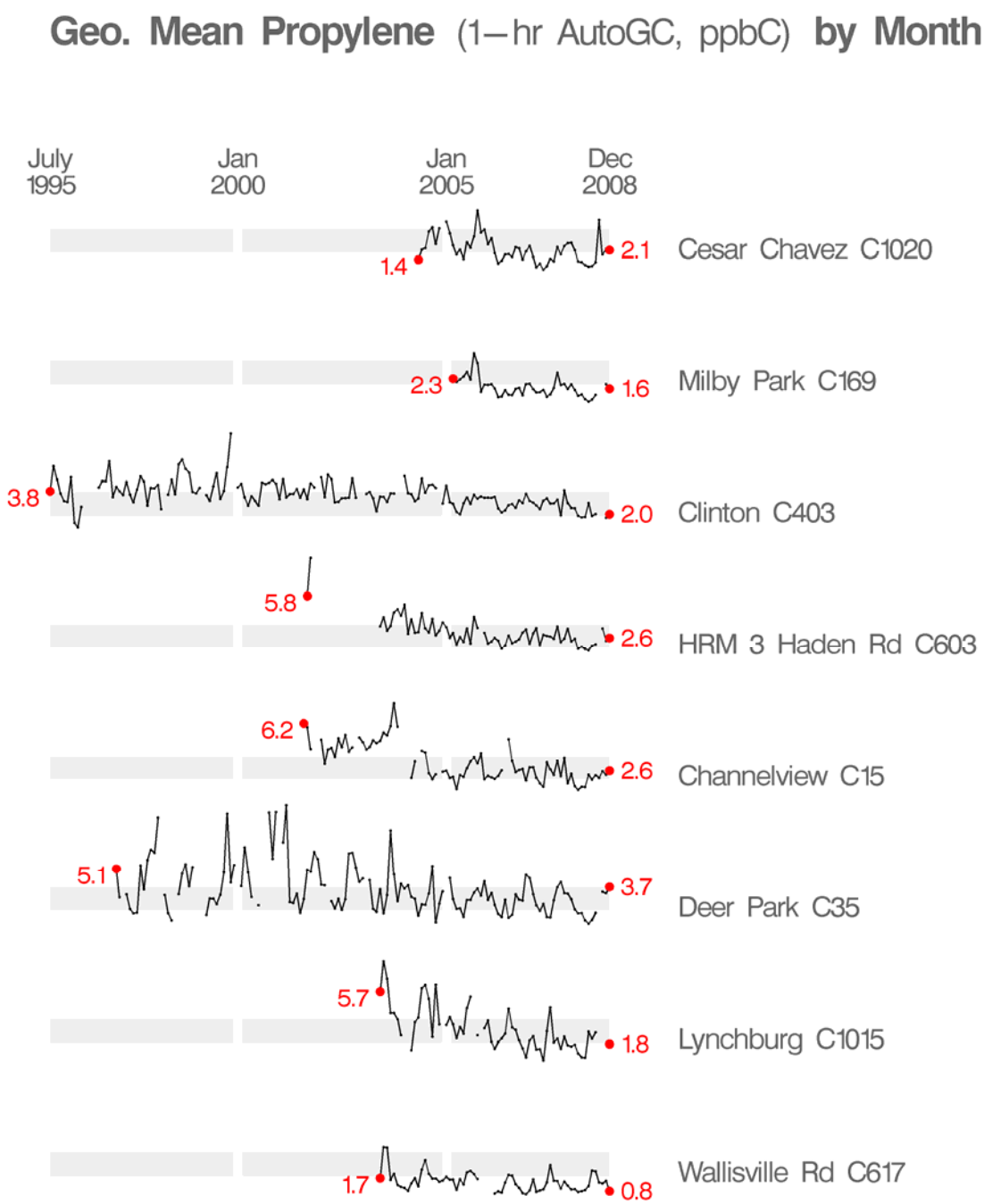


Figure 5-23: Monthly Geometric Mean Propylene Concentrations at the Eight Houston Ship Channel Monitors, July 1995 through December 2008

A preliminary analysis was performed to verify whether decreases observed were statistically significant. Ordinary least squares regression lines were fit to the monthly geometric mean ethylene and propylene concentrations, using an index of month, where the first recorded month was given a value of zero. Results of these fits are reported in Table 5-16: *Parameter Estimates of Monthly Geometric Mean Concentrations Trends*. In 23 of the 24 regressions, concentrations decreased across the respective study periods, with correlation coefficient (r^2) values ranging from 0.045 to 0.549. Eight of 12 monitors recorded statistically significant decreases for ethylene, including six of eight Houston Ship Channel monitors. All 12 monitors recorded statistically significant decreases for propylene. However, caution must be exercised when

interpreting these results. First, some of the computed r^2 values are very low, confirming there is a substantial degree of variation in the measured values, with only a portion of it explained by a simple linear model. Further statistical testing and verification, such as testing for and correcting possible autocorrelation, is necessary to fully validate these models.

Table 5-16: Parameter Estimates of Monthly Geometric Mean Concentrations Trends

	ethylene				propylene			
monitoring site	n	slope	intercept	r^2	n	slope	intercept	r^2
Houston Ship Channel-area auto-GC monitors:								
Cesar Chavez C1020/175	52	-0.019*	2.74	0.09	52	-0.025*	2.86	0.16
Channelview C15/C115	62	-0.017*	3.85	0.22	62	-0.039*	4.64	0.49
Clinton C403/C113/C304	60	-0.032*	4.75	0.44	62	-0.018*	3.85	0.36
Deer Park C35/139	54	-0.033*	4.12	0.25	65	-0.026*	4.09	0.22
HRM-3 Haden Road C603	56	-0.051*	5.37	0.55	55	-0.026*	3.82	0.42
Houston Milby Park A169	39	-0.011	1.88	0.06	39	-0.021*	2.05	0.20
Lynchburg Ferry C1015	56	-0.029*	3.41	0.24	56	-0.059*	4.89	0.42
Wallisville Road C617	55	-0.002	1.79	0.00	55	-0.017*	2.08	0.17
Non-Houston Ship Channel-area auto-GC monitors:								
Mustang Bayou C619	53	-0.008*	0.72	0.20	53	-0.006*	0.83	0.13
Danciger C618	56	-0.003	0.57	0.05	56	-0.006*	0.78	0.16
Lake Jackson C1016	50	-0.006	1.00	0.05	50	-0.007*	0.77	0.18
Texas City 34th St. C620	59	-0.027*	2.43	0.50	59	-0.020*	2.19	0.37

*Significant at the 5 percent (0.05) level. Significance levels for intercepts are not reported.
Parameter estimates from ordinary least squares fits of monthly geometric mean concentrations of ethylene and propylene on an index of month, by monitoring site and compound.

5.3.7 Geographic Patterns in Ambient HRVOC Concentrations Near the Houston Ship Channel

The next analysis showed that, for some HRVOC, geographic patterns are apparent. Wind speed and wind direction measurements, collected in tandem with HRVOC concentrations at the Houston Ship Channel auto-GC monitors, were used not only to identify these patterns, but to track their changes over time. Radar plots of geometric mean concentrations of ethylene and propylene, by wind direction, were plotted, superimposed on maps of the Houston Ship Channel, and displayed in Figure 5-24: *Geometric Mean Ethylene Concentration at Western Houston Ship Channel Monitors* through Figure 5-27: *Geometric Mean Propylene Concentration at Western Houston Ship Channel Monitors*.

These plots consist of jagged rings encircling a monitor. Each ring around a particular monitor represents the geometric mean concentration of the subject HRVOC at each of the 360 degrees surrounding the monitor, for a particular year. The distance from the origin to any point on the ring is proportional to the concentration of HRVOC arriving at the monitor from that direction. For example, Figure 5-25: *Geometric Mean Ethylene Concentrations at Eastern Houston Ship Channel Monitors* shows that in 2003 at Deer Park (CAMS 35/139), the highest mean ethylene concentration, 16 ppbC, occurred when winds were blowing from the northeast, suggesting there may be large ethylene emissions sources upwind of Deer Park (CAMS 35/139) in that direction.

To help interpret these graphs, it is useful to describe a couple of hypothetical scenarios. In the first one, if HRVOC did not vary when winds arrived from different directions, i.e., the same concentrations were observed regardless of the wind direction, the ring would be a smooth circle.

Conversely, in the second scenario, if HRVOC were detected only when winds arrived from a single direction, the ring would simply be an elongated spike pointing in that direction.

In Figures 5-24: *Geometric Mean Ethylene Concentration at Western Houston Ship Channel Monitors* through 5-27: *Geometric Mean Propylene Concentration at Western Houston Ship Channel Monitors*, for the Houston Ship Channel monitors, a strong directional association with mean concentration is typical. The directional spikes seen in these rings are referred to as "lobes" in this section.

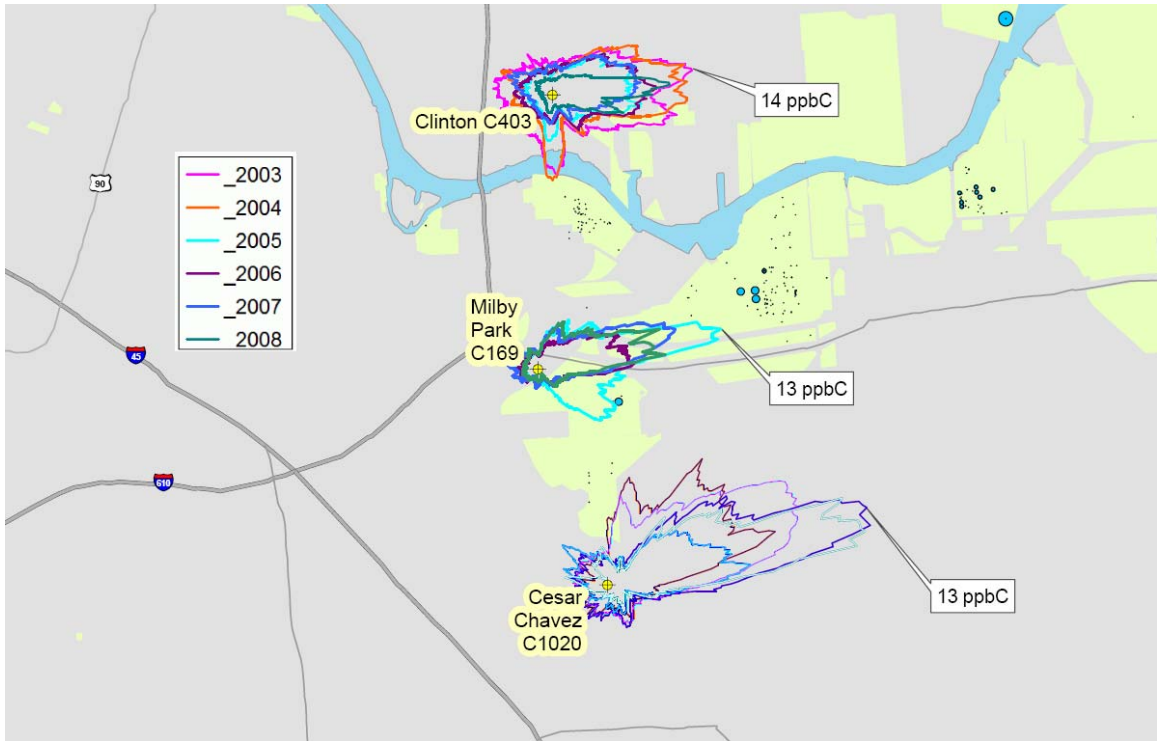


Figure 5-24: Geometric Mean Ethylene Concentration at Western Houston Ship Channel Monitors

Sources of ethylene (blue circles) and propylene (brown circles) are also depicted on the map of the respective compound, with sizes proportional to values reported in the 2006 TCEQ point source emissions inventory. Valid hourly measurements from 2002 through 2008 were used; hours with hourly wind speed measurements less than two miles per hour (mph) were discarded, due to considerable error in wind direction measurements at low wind speeds.

While a compound's concentration for a particular wind direction at a particular monitor is proportional to the distance from the monitor to the ring at that direction, the scale differs across monitors. For example, peak 2003 ethylene concentration (see Figure 5-25: *Geometric Mean Ethylene Concentrations at Eastern Houston Ship Channel Monitors*) at Lynchburg Ferry (CAMS 1015) is 24 ppbC, and 15 ppbC at Wallisville Road (CAMS 617), yet the length from each monitor to its respective peak (tip of sharp "point") is approximately the same. For this reason, peak concentration at each monitor, for each pollutant, is labeled.

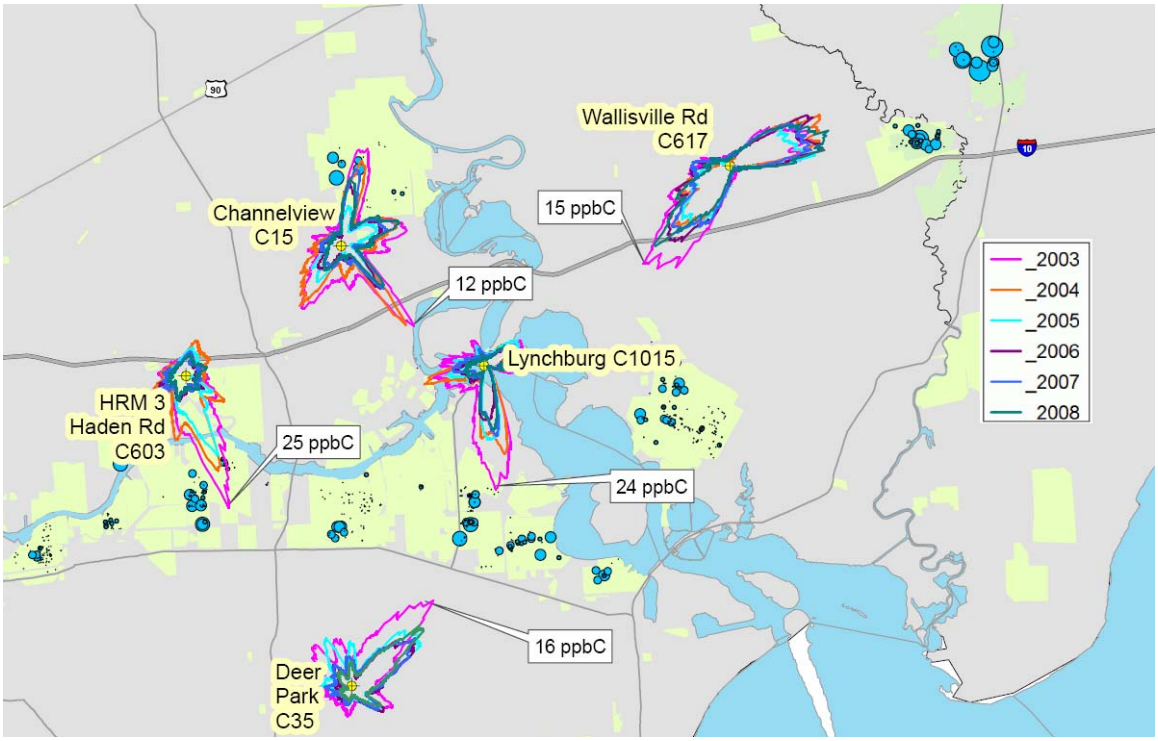


Figure 5-25: Geometric Mean Ethylene Concentrations at Eastern Houston Ship Channel Monitors

Figure 5-24: *Geometric Mean Ethylene Concentration at Western Houston Ship Channel Monitors* shows mean ethylene concentrations at the three western-most Houston Ship Channel auto-GC monitors. Sources of ethylene having the greatest impact on these monitors are all located east of the monitors, because the greatest peaks for each monitor point in this direction for all the years. The plot also shows trends across time at each monitor. At Clinton (CAMS 403/CAMS 113/CAMS 304), peak ethylene occurred in 2003 from almost due east, as seen in the lobe labeled "14 ppbC." Following 2003 and 2004, peak concentrations from that direction have been somewhat lower. Also, the lobes pointing south observed in 2003 and 2004 are markedly smaller in 2005 and subsequent years. An olefins production plant located in the Houston Milby Park (A169) area shut down in 2005; its emissions may have been responsible for those lobes.

The plot shows mean ethylene concentrations for the Cesar Chavez (CAMS 1020/175) and Houston Milby Park (A169) monitors, which started operation in 2004 and 2005, respectively. While these monitors measured peak concentrations in different years, both monitors have peaks pointing in the direction of the Houston Milby Park (A169) olefins plant while it was in operation; Houston Milby Park (A169) observed a large lobe to the southeast in 2005, and Cesar Chavez (CAMS 1020/175) observed a notable lobe to the north in 2004 and 2005. This provides a stronger indication, when combined with the Clinton (CAMS 403/CAMS 113/CAMS 304) peak to the south, of the influence of emissions from that plant on local concentrations.

Figure 5-25: *Geometric Mean Ethylene Concentrations at Eastern Houston Ship Channel Monitors* shows mean ethylene concentrations at the five auto-GC monitors located in the eastern part of the Houston Ship Channel. Variation in mean concentrations by direction is even more pronounced here than in the western portion of the Houston Ship Channel. The pattern in mean concentrations at Lynchburg Ferry (CAMS 1015) suggests there is a large source of ethylene emissions south-southeast of the monitor, near Battleground Road and Highway 225, and that emissions from this area have decreased.

Table 5-17: *Geometric Mean Ethylene for Key Wind Direction Lobes at Eastern Houston Ship Channel Monitors* shows that this lobe's mean 2003 concentration of 24.3 ppbC has halved in recent years.

Table 5-17: Geometric Mean Ethylene for Key Wind Direction Lobes at Eastern Houston Ship Channel Monitors

Monitor	principal direction(s)	2003	2004	2005	2006	2007	2008
		ppbC	*ppbC*	*ppbC*	*ppbC*	*ppbC*	*ppbC*
lobes pointing to the same sources in the central Houston Ship Channel area:							
HRM 3	ESE	**24.8**	**18.0**	**15.6**	5.0	4.7	5.2
Channelview C15/C115	SW	8.9	8.9	5.6	4.3	3.6	4.1
lobes pointing to the same sources in the eastern Houston Ship Channel area:							
Hous.DeerPrk2 C35/139	NE	16.6	missing	12.1	10.7	11.1	**13.0**
Lynchburg Ferry C1015	SSE	24.3	17.7	14.5	10.8	**14.0**	12.6
Channelview C15/C115	SE	12.5	11.9	6.6	6.9	7.1	6.8
Wallisville Road C617	SW	15.0	9.8	8.4	**11.1**	9.9	12.8
lobes pointing in other directions:							
Channelview C15/C115	N	10.5	9.0	3.7	6.3	7.9	6.9
Wallisville Road C617	ENE	9.7	11.5	9.6	10.8	9.2	11.6

Annual maxima are noted in boldface type.

The pattern observed at Deer Park (CAMS 35/139) may provide additional evidence of suspected emission decreases in the same source area. The northeast lobe in Table 5-17: *Geometric Mean Ethylene for Key Wind Direction Lobes at Eastern Houston Ship Channel Monitors* has dropped from a high of 16.6 ppbC in 2003 to a range of about 11 to 13 ppbC in recent years. Similarly, the southeast lobe at Channelview (CAMS 15/CAMS 115), which points yet again to the same source area, peaked at 12.5 ppbC in 2003, dropped to 11.9 ppbC in 2004, and has not exceeded 7.1 ppbC since. While this monitor is farther from this source region than are the other two monitors, and therefore is more likely to be impacted by other emissions sources, consistent decreases observed at these three monitors across the six-year span of available data suggest ethylene emissions have decreased in the subject source region.

HRM-3 Haden Road (CAMS 603) shows a peak of 24.8 ppbC to the southeast in 2003, which fell to 18 ppbC in 2004, then further to 15.6 ppbC in 2005. The mean concentration has dropped since then, not exceeding 5.2 ppbC. The magnitude of the decrease over 2006 to 2008, as compared to 2005 and earlier years, suggests a shut down of one or more major process units, or even entire plants, somewhere southeast of this monitor, or implementation of HRVOC rules.

Peaks at the Wallisville Road (CAMS 617) monitor point southwest, toward the east Houston Ship Channel, and east-northeast, in the direction of the Mont Belvieu industrial area, where there is considerable ethylene and propylene storage in underground salt caverns. Table 5-17: *Geometric Mean Ethylene for Key Wind Direction Lobes at Eastern Houston Ship Channel Monitors* shows that ethylene originating to the southwest decreased from the six-year peak in 2003 (15 ppbC), to a range from 9.9 to 11.1 ppbC, before rising slightly to 12.8 ppbC in 2008. In contrast, the east-northeast lobe at this monitor shows relatively unvarying mean concentrations

across the entire six-year period, ranging from 9.2 to 11.6 ppbC, with the six-year peak occurring in 2008.

These conclusions for five monitors and eight directional lobes show a nearly consistent pattern across these monitors. Seven of eight lobes witnessed their highest mean concentration in 2003. Within one or two years of this peak, concentrations at all seven had dropped, from 27 to 65 percent, and have leveled off since; mean concentrations have not varied appreciably from 2006 to 2008. These findings suggest ethylene emissions from source areas close to these monitors, especially Battleground Road, Highway 225 in La Porte, and the petrochemical complex north of the Channelview (CAMS 15/CAMS 115) monitor, have decreased considerably in recent years. These observations suggest that the new TCEQ regulations specifically targeting HRVOC emissions and requiring full compliance by 2006 are proving effective in controlling point source HRVOC emissions. However, the trends shown here have not been corrected for meteorological variations.

Results for the lobe pointing east-northeast from the Wallisville Road (CAMS 617) monitor disagree with some key findings at other lobes. The Wallisville Road (CAMS 617) east-northeast lobe, unique among the eight, experienced an increase in mean concentration from 2003 (9.7 ppbC) to 2004 (11.5 ppbC). While 2006 to 2008 mean concentrations at Wallisville Road (CAMS 617), like those of other monitors and lobes, changed relatively little, mean concentrations of the east-northeast Wallisville Road (CAMS 617) lobe changed relatively little across the entire six-year period. The absence of recent decreases at this lobe compared to earlier years suggests that meteorology may not have caused high concentrations seen at most other lobes in earlier years.

Figure 5-26: *Geometric Mean Propylene Concentration at Eastern Houston Ship Channel Monitors* displays monthly geometric mean concentrations of propylene in the same area of the eastern Houston Ship Channel. Table 5-18: *Geometric Mean Propylene Concentrations for Key Wind Directions at Eastern Houston Ship Channel Monitors* lists mean propylene concentrations across the study period, for each monitor and lobe. Similarities with ethylene are evident. For propylene, all seven lobes measured their highest concentrations in 2003 or 2004; five of the seven had their two lowest annual concentrations in 2007 and 2008. All seven lobes had concentrations in 2007 and 2008 that were 40 percent or more lower than their respective six-year peaks.

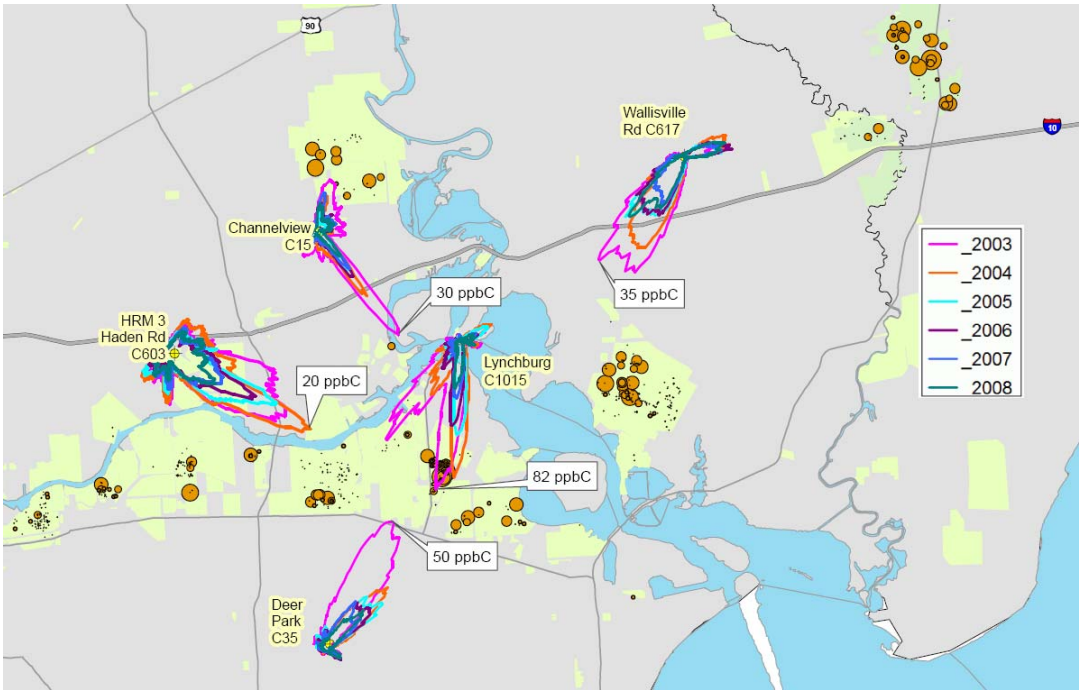


Figure 5-26: Geometric Mean Propylene Concentration at Eastern Houston Ship Channel Monitors

These results suggest that the propylene emissions in the source regions near the monitors have dropped considerably in the six-year study period, and that the HRVOC regulations may be responsible for the decreases. As seen with ethylene, patterns in geometric mean propylene concentrations at the east-northeast Wallisville Road (CAMS 617) lobe differed considerably from the other seven. Propylene concentrations varied relatively little across the six-year period, suggesting that, like ethylene, Mont Belvieu propylene emissions have changed little or not at all, on average, across the study period.

Figure 5-27: *Geometric Mean Propylene Concentration at Western Houston Ship Channel Monitors* shows mean propylene concentrations by wind direction at the three western Houston Ship Channel monitors. Patterns depicted here exhibit strong similarities to those seen with ethylene in this area: the largest propylene source areas are to the east, and judging from the disappearance of strong peaks from 2006 onward, emissions from the now-defunct olefins plant located in the Houston Milby Park (A169) area were probably affecting these monitors.

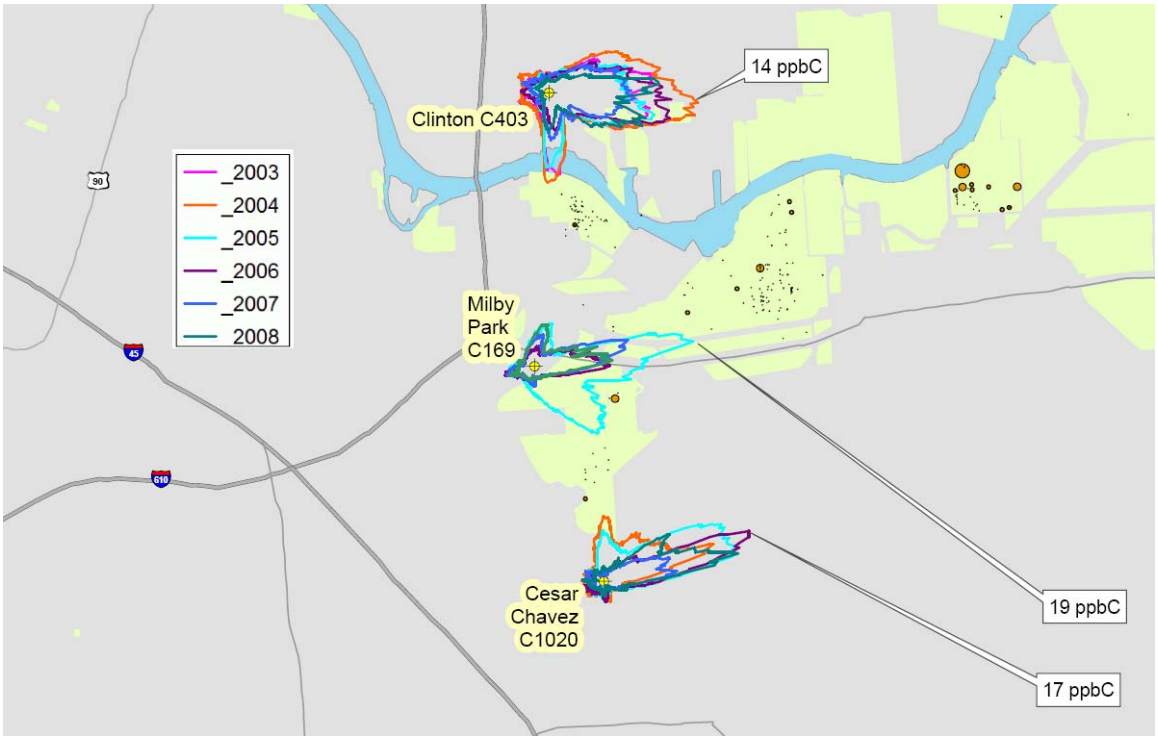


Figure 5-27: Geometric Mean Propylene Concentration at Western Houston Ship Channel Monitors

Table 5-18: *Geometric Mean Propylene Concentrations for Key Wind Directions at Eastern Houston Ship Channel Monitors* lists mean propylene concentrations across the study period, for each monitor and lobe.

Table 5-18: Geometric Mean Propylene Concentrations for Key Wind Directions at Eastern Houston Ship Channel Monitors

Monitor	principal direction(s)	2003	2004	2005	2006	2007	2008
		ppbC	*ppbC*	*ppbC*	*ppbC*	*ppbC*	*ppbC*
lobes pointing to the same source in the eastern Houston Ship Channel area:							
HRM-3 Haden Road C603	SE	17.1	20.5	15.2	12.4	7.8	7.0
Hous.DeerPrk2 C35/139	NE	50.0	30.3	25.4	21.2	19.6	18.6
Lynchburg Ferry C1015	S	**82.8**	**75.4**	**51.5**	**46.2**	**31.5**	**26.3**
Channelview C15/C115	SE	30.1	19.0	11.7	13.8	11.7	8.2
Wallisville Road C617	SW	35.6	27.3	22.3	18.4	14.5	21.3
lobes pointing to other sources:							
Lynchburg Ferry C1015	SW	68.7	33.9	13.7	18.8	9.9	6.8
Channelview C15/C115	N	11.3	7.7	3.0	5.5	8.1	5.2
Wallisville Road C617	ENE	9.0	12.2	9.7	12.3	9.7	11.2

Annual maxima are noted in boldface type.

5.3.8 Ambient Total VOC Concentrations

Considerable research has focused on patterns and trends in HRVOC concentrations in the HGB area (Hafner Main et al. 2001; Brown and Hafner Main, 2002; Jolly et al., 2003; Fang and McDowell, 2003). Less examined are patterns for other, less-reactive VOC. This section presents a detailed examination of patterns in total VOC concentrations in the HGB area, using concentrations of total nonmethane hydrocarbons (TNMHC) as a measure of total VOC. Each TNMHC measurement corresponds to the sum of all chromatogram peaks (identified and unidentified) from the start to the end of sample collection. TNMHC is a useful measure of total VOC because it has been calculated in a consistent manner over the entire study period, unlike other parameters, such as the sum of Photochemical Assessment Monitoring Stations (PAMS) target compounds, whose constituents have changed periodically.

Similar to the first HRVOC analysis presented in this section, geometric mean TNMHC concentrations, by monitor, year, and month, were calculated for valid months for all available data from each of the 12 HGB monitors. Further analysis of the four non-Houston Ship Channel-area monitors has not been completed at this time.

Figure 5-28: *Monthly Geometric Mean TNMHC Concentrations, July 1995 through December 2008* shows, for each of the eight Houston Ship Channel monitors, monthly geometric mean TNMHC concentration for all months with complete data, between the start of monitoring and December 2008. Monitors are sorted according to their location from west (top) to east (bottom); the grey bars denote the 25th through 75th percentile concentrations (85 ppbC and 149 ppbC respectively) of all valid months across all monitors.

As with ethylene and propylene, the two monitors with data before 2001, Clinton (CAMS 403/CAMS 113/CAMS 304) and Deer Park (CAMS 35/139), recorded their highest monthly geometric mean values before 2001. Both monitors exhibited overall decreases across their respective data collection periods. A statistical analysis of possible trends, using ordinary least squares regression, is presented in Table 5-19: *Parameter Estimates of Monthly Geometric Mean TNMHC Concentration Trends Houston Ship Channel Area Auto-GC Monitors*. This statistical model indicates that all 12 monitors had decreasing monthly mean concentrations, from the beginning to the end of each monitor's respective data range. As well, this model indicates that eight of the 12 monitors' decreases were statistically significant at the 95 percent confidence level.

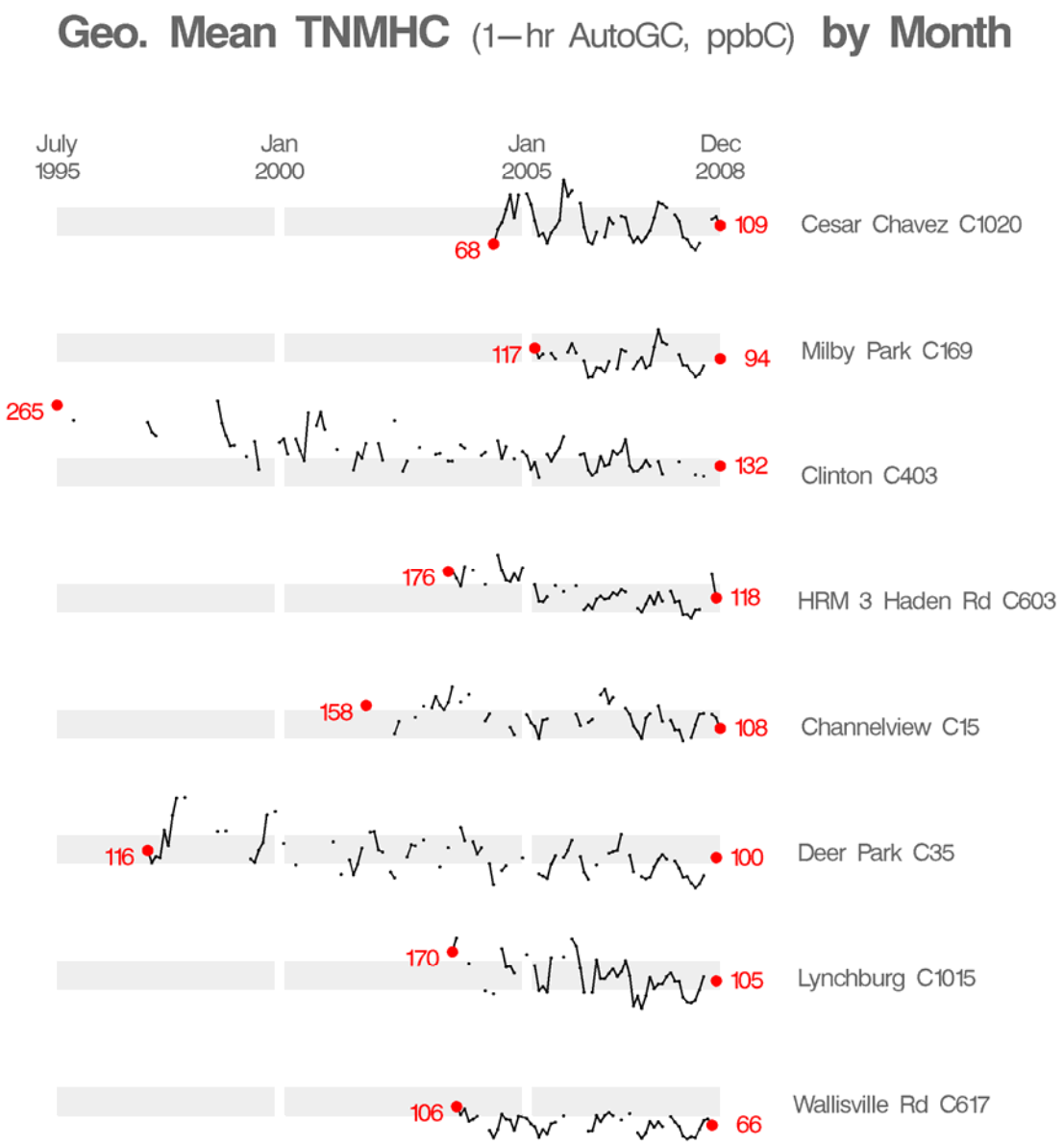


Figure 5-28: Monthly Geometric Mean TNMHC Concentrations, July 1995 through December 2008

Table 5-19: Parameter Estimates of Monthly Geometric Mean TNMHC Concentration Trends Houston Ship Channel Area Auto-GC Monitors

Sitename	Slope of Trend	Intercept	Degrees of Freedom	R squared
Cesar Chavez C1020/175	-0.61	132	47	0.07
Channelview C15/C115	**-0.37***	**153**	**49**	**0.10**
Clinton C403/C113/C304	**-0.63***	**225**	**78**	**0.46**
Hous.DeerPrk2 C35/139	**-0.55***	**148**	**80**	**0.31**
Houston Milby Park A169	-0.33	99	33	0.03
HRM-3 Haden Road C603	**-1.22***	**173**	**47**	**0.52**
Lynchburg Ferry C1015	**-1.14***	**156**	**47**	**0.27**
Wallisville Road C617	**-0.31***	**79**	**49**	**0.11**

Non-Houston Ship Channel-area auto-GC monitors

Sitename	Slope of Trend	Intercept	Degrees of Freedom	R squared
Danciger C618	**-0.22***	**44**	**47**	**0.12**
Lake Jackson C1016	-0.18	34	43	0.04
Mustang Bayou C619	-0.11	61	43	0.01
Texas City 34th St. C620	**-0.95***	**102**	**57**	**0.46**

***Significant at the 5 percent (0.05) level.** Significance levels for intercepts are not reported. Parameter estimates from ordinary least squares fits of monthly geometric mean concentrations of TNMHC on an index of month, by monitoring site.

Figure 5-29: *90th Percentile TNMHC Concentration in the HGB Area* presents 90th percentile TNMHC concentrations at each auto-GC monitor. The area-wide 90th percentile TNMHC concentrations and the 90th percentile TNMHC at most of the individual monitors are decreasing. Smaller decreases are evident at Wallisville Road (CAMS 617), Channelview (CAMS 15/CAMS 115), Lake Jackson (CAMS 1016), Mustang Bayou (CAMS 619), and Danciger (CAMS 618), while larger decreases are observed primarily at monitors closer to the Houston Ship Channel. Monitors in Brazoria County (Danciger (CAMS 618), Lake Jackson (CAMS 1016), and Mustang Bayou (CAMS 619)) and Galveston County (Texas City 34th St. (CAMS 620)) tend to report lower 90th percentile TNMHC than monitors located in Harris County. In the past, Clinton (CAMS 403/CAMS 113/CAMS 304) has recorded the highest TNMHC concentrations, but since 2006 Clinton has decreased at a faster rate and Channelview (CAMS 15/CAMS 115) has recorded the highest concentrations.

Appendix I: *Corroborative Analysis for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard* includes an analysis of the reactivity of VOC in the HGB area. The results of the reactivity analysis are that the official TCEQ HRVOC (ethylene, propylene, butenes, and 1,3-butadiene) have been decreasing, especially since 2000. The total reactivity of all measured VOC in the HGB area is also steadily decreasing. The observed downward trends in ethylene and propylene concentrations (Section 5.3.6: *Ambient VOC Concentrations* and Section 5.3.7: Geographic *Patterns in Ambient HRVOC Concentrations Near the Houston Ship Channel*), total TNMHC concentrations (Section 5.3.8: *Ambient Total VOC Concentrations*), total reactivity (Appendix I: *Corroborative Analysis for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard*), and HRVOC reactivity (Appendix I: *Corroborative Analysis for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard*) strongly suggest that emissions of the most important measurable VOC ozone precursors are steadily decreasing. These steadily decreasing VOC emissions have helped decrease local ozone formation, and hence, ozone concentrations in the HGB area.

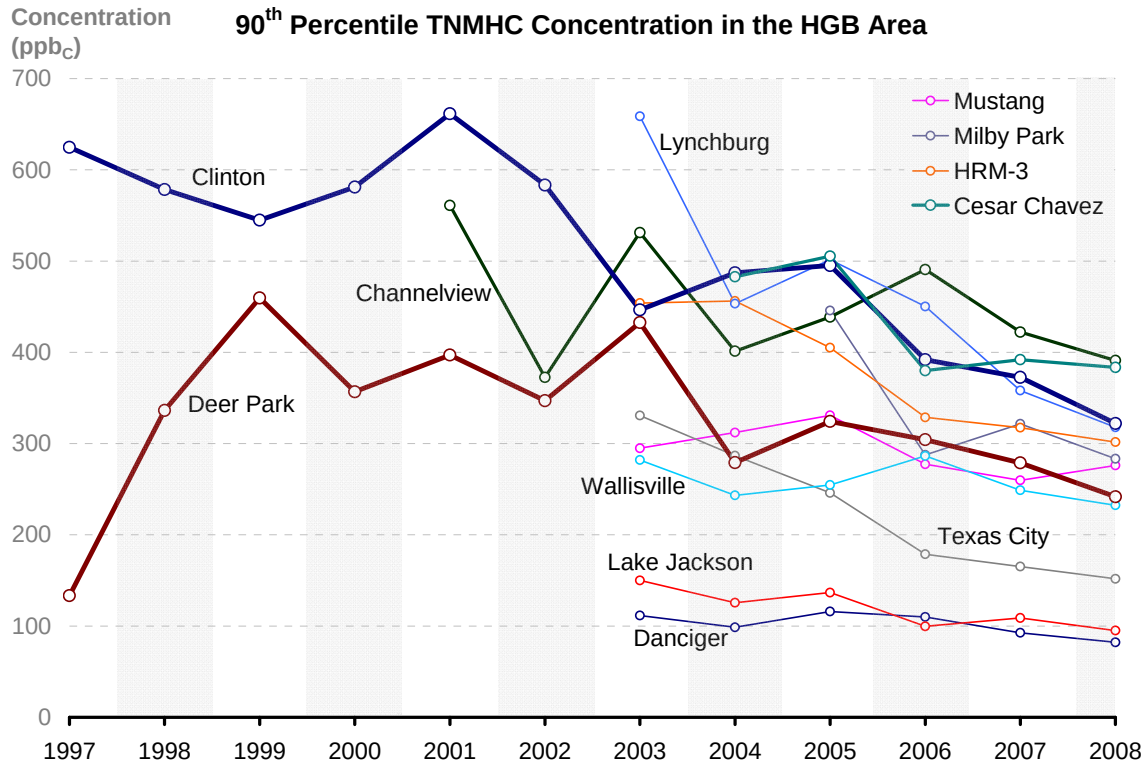


Figure 5-29: 90th Percentile TNMHC Concentration in the HGB Area

5.3.9 Meteorologically Adjusted Ozone Trends

Ozone formation is dependent not only on its precursors (NO_X and VOC), but also on meteorological variables. While trends in ozone design values have been decreasing, design value trends must be examined to determine if the values are decreasing due to emission controls or if they are decreasing simply because of meteorological conditions in the area in the past several years. To determine whether control strategies have been effective, meteorological influences must be removed from ozone trends. Analysis done by Sullivan (2009) used a generalized linear model to account for meteorological influences in ozone trends. The following discussion is based upon Sullivan (2009), who used a modified version of the Camalier et al. (2007) technique for removing the meteorological influences from the ozone trends.

Before meteorological influences can be removed from ozone trends, the meteorological factors that are most important to ozone formation must first be identified. Various correlations and factor analyses were used to identify the most important meteorological variables for ozone formation in the HGB area. Data from the Omnibus Meteorological Database (METDAT) maintained by the EPA was compared to ozone data obtained from surface monitors in the HGB area. Because the set of observed ozone levels can be influenced by the number of monitors in an area, Sullivan (2009) used a consistent set of ozone monitors in the HGB area. These monitors are listed in Table 5-20: *Area Ozone Monitoring Sites with Long-Term Data*. Most contain a consistent set of data from 1990 to 2007. Data from monitors that were moved a short distance during the period from 1990 to 2007 were combined with data from monitors in nearby locations, for example, data at Clute (CAMS 11) were combined with data from Lake Jackson (CAMS 1016).

Table 5-20: Area Ozone Monitoring Sites with Long-Term Data

AQS Number	Site Name
482011039	Hous.DeerPrk2 C35/139
482011035	Clinton C403/C113/C304
482011034	Houston East C1
482010075	Houston Texas Avenue C411
482010062	Houston Monroe C406
482010051	Houston Croquet C409
482010047	Lang C408
482010046	Houston North Wayside C405
482010029	Northwest Harris Co. C26/A110/C154
482010024	Houston Aldine C8/AF108/X150
480391016	Lake Jackson C1016 (and Clute C11)

Source: Sullivan, 2009.

Figure 5-30: *Actual Mean Eight-Hour Ozone Concentrations (Blue Line) and Mean Eight-Hour Predicted Concentrations with the Non-Meteorological Trend Removed (Red Line)*, which was reproduced from Sullivan (2009), displays two time series. The values in blue represent the observed mean daily maximum eight-hour ozone concentrations; values in red represent the daily peak ozone based purely on the meteorological variations, with the non-meteorological factors removed. In other words, the statistical model described above has been used to re-create the ozone time series with only the meteorology taken into account.

For 2006 and 2007, the statistical model predicts that the observed mean daily peak eight-hour ozone should have been higher than observed, based upon the conduciveness of the meteorology toward ozone formation. In other words, based on the weather, ozone concentrations should have been higher in 2006 and 2007. Subtracting the meteorologically-based eight-hour ozone estimates from the actual eight-hour ozone results in a trend with the meteorological effects removed (Figure 5-31: *Residual Meteorologically Adjusted Eight-Hour Ozone Concentrations Trend*). This trend represents how the sum of anthropogenic factors, model error, and undiagnosed meteorological factors have changed from 1996 to 2007. Figure 5-31: *Residual Meteorologically Adjusted Eight-Hour Ozone Concentrations Trend*, which was reproduced from Sullivan et al., 2009, represents the trend in peak daily maximum ozone with the meteorological factors removed. The meteorologically-adjusted ozone trend is clearly downward. Since the meteorological variations have been removed, this downward trend shows the effect of emission reductions in the HGB area. Statistical results of this analysis are listed in Table 5-21: *Summary Statistics for Meteorologically Adjusted Ozone Trends from 1996 to 2007*. The slope of -0.86 shows that eight-hour ozone trends in the HGB area are decreasing and that they are significant (p-value = 0.00).

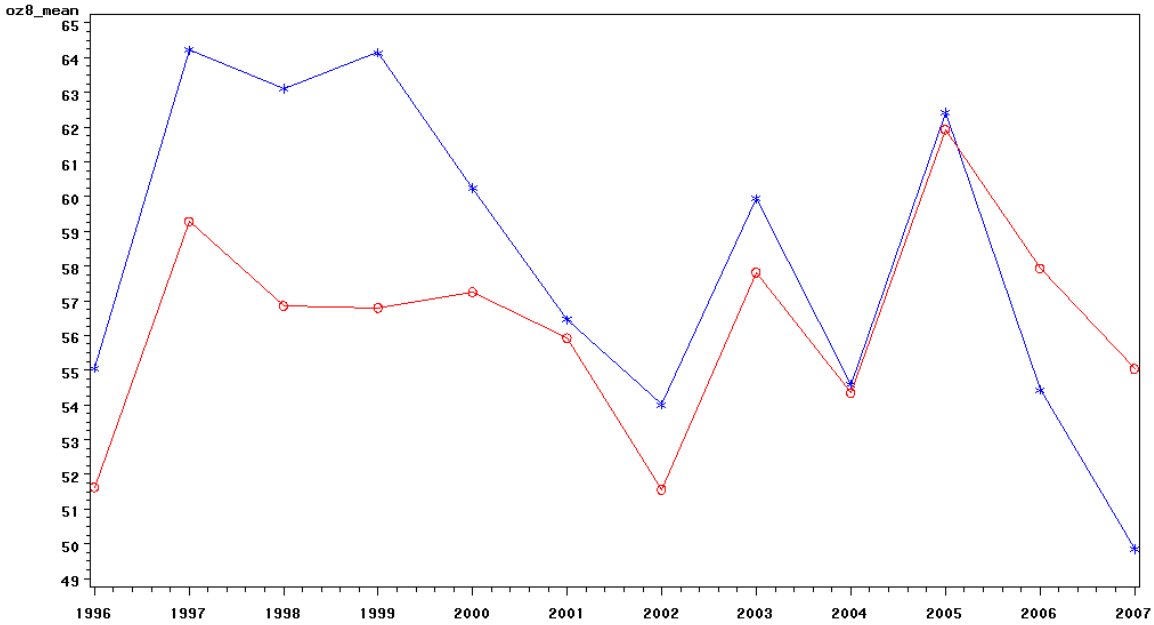


Figure 5-30: Actual Mean Eight-Hour Ozone Concentrations (Blue Line) and Mean Eight-Hour Predicted Concentrations with the Non-Meteorological Trend Removed (Red Line)

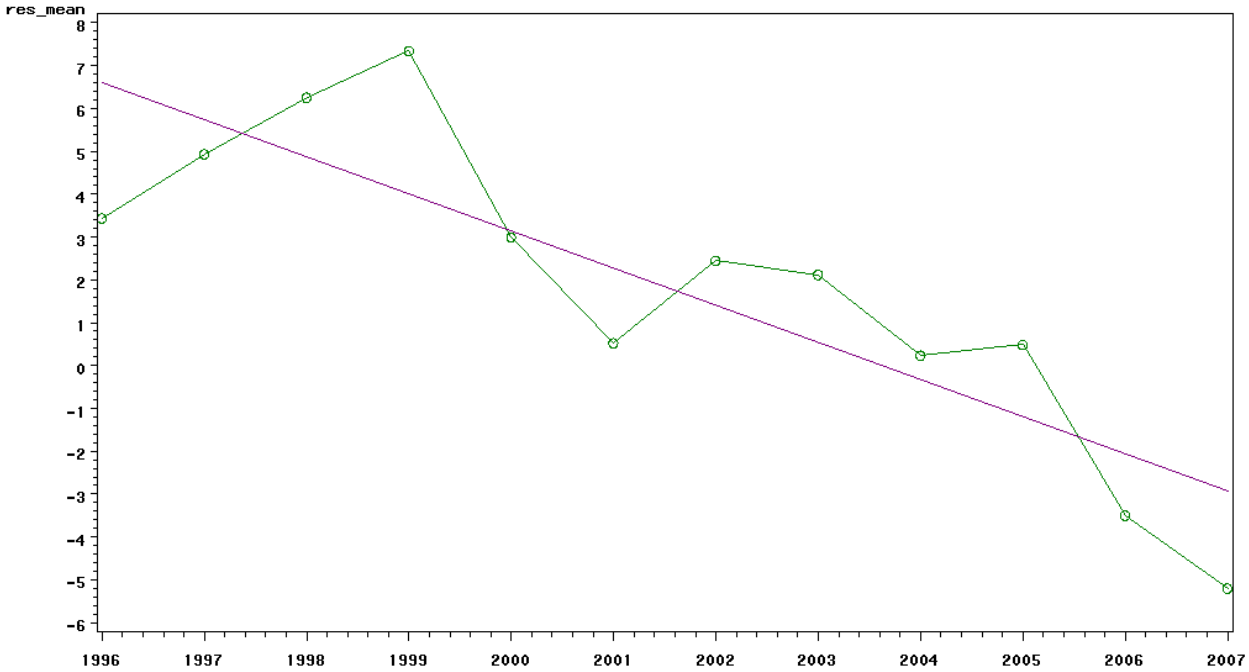


Figure 5-31: Residual Meteorologically Adjusted Eight-Hour Ozone Concentrations Trend

Table 5-21: Summary Statistics for Meteorologically Adjusted Ozone Trends from 1996 to 2007

Parameter	Value
Intercept	6.438
Slope	-0.86*
t-statistic	-4.20
p-value	0.00
Lag 1 Coefficient	-0.20
t-statistic	-0.63

* Value is statistically significant. (Sullivan et al., 2009)

The analysis from Sullivan (2009) shows that, after adjusting for meteorology, concentrations of ozone has declined substantially in the HGB area. All else held equal, daily maximum eight-hour ozone concentrations in the HGB area should be around 9 ppb lower in 2007 compared to 1996.

Appendix I: *Corroborative Analysis for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard* contains additional analyses of the effects of interannual meteorological variations upon ozone concentrations in the HGB area. All of the additional analyses also indicate that the decreasing ozone trend is not due to favorable meteorological conditions, but is due to other factors. Results from ozone precursor trend analyses previously discussed strongly imply that decreasing concentrations of NO_X and VOC are related to the large decreases in ozone concentrations.

5.3.10 Background Ozone Concentrations: Transport of Ozone into the HGB Area

Estimating the levels of ozone transported into the HGB area is important in order to identify the amount of locally produced ozone. Several researchers have previously investigated the background ozone concentrations in Texas and the transport winds that are associated with them. Nielsen-Gammon et al. (2005) investigated background ozone from 1998-2003 in the HGB area and obtained the following insights (paraphrased from Nielsen-Gammon et al., 2005):

- The seasonal variability in eight-hour maximum ozone in eastern Texas is primarily associated with background ozone. Local contributions tend to be highest during the summer when background ozone reaches a minimum.
- The late spring peak in eight-hour maximum ozone in eastern Texas is primarily associated with "tropospheric background" ozone. This ozone maximum has been observed at rural sites elsewhere and is associated with variations in the lifetime of ozone, the concentrations of NOx, and enhanced transport from the stratosphere.
- The midsummer minimum in background ozone in eastern Texas leads to a minimum in eight-hour peak ozone that is strongest in southeastern Texas and barely noticeable in northeastern Texas. The primary cause of the summertime minimum is a decline in the tropospheric background ozone. Although the relatively clean southerly flow is weakening during this period, most air parcel paths remain maritime in nature.
- When easterly and northeasterly winds become more frequent in late summer, background ozone and total ozone in eastern Texas begin rising. Winds are also less steady than in the middle of summer, so continental transport becomes increasingly frequent.

Langford et al. (2009) showed that the techniques used by Nielsen-Gammon et al. (2005) yielded results consistent with a different technique of estimating background, except on some occasions when the Galveston Airport (CAMS 34/CAMS 109/CAMS 154) site was chosen as the background site. Langford et al. showed that the Galveston site is the site most strongly affected by the Gulf breeze, and that on some days, the maritime air from the Gulf does not affect the Houston area, even though this air affects Galveston. Hardesty et al. (2007) have shown that

during the TexAQS II study in August through September 2006, background ozone in southeast Texas averaged about 50 ppb, with background concentrations lower near the coast, and higher in northeast Texas. On one day, September 8, 2006, the background ozone entering Texas from east was 85-90 ppb. The results of these studies have shown that background ozone entering southeast Texas can have a large effect on the total observed eight-hour ozone concentrations. To investigate the role of background ozone for the most recent years, the TCEQ commissioned a study of background ozone and its relationship to larger-scale wind patterns. Below is a description of this work.

Sullivan (2009) used 72-hour back trajectories calculated with the Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) algorithm, using data from the Ecosystem Dynamics and the Atmosphere Section (EDAS) meteorological model to estimate the amount of ozone entering into the HGB area. A total of 1,456 backward trajectories were run starting at 12:00 Central Standard Time in central Houston, at 300 meters above ground level, during the peak of ozone season in the HGB area (May 1 through October 31, 2000 to 2007). Analysis of multiple trajectories can distinguish between source areas, or paths, that lead to higher than average, or lower than average ozone concentrations (Sullivan et al., 2009). A clustering algorithm was used to group multiple trajectories based on trajectory size and shape. Six identified clusters appear in Figure 5-32: *Six Clusters Found Using HYSPLIT Backward Trajectory Clustering Algorithm*, which was reproduced from Sullivan, 2009. Forty backward trajectories that did not end up in any of the six clusters, illustrated in Figure 5-33: *Cluster 0 Backward Trajectories*, reproduced from Sullivan (2009), were grouped and assigned a cluster number of zero. All but one of the back trajectories in cluster zero originate from the south and that these trajectories appear to extend beyond the EDAS modeling domain, which is the only difference between cluster zero and cluster two.

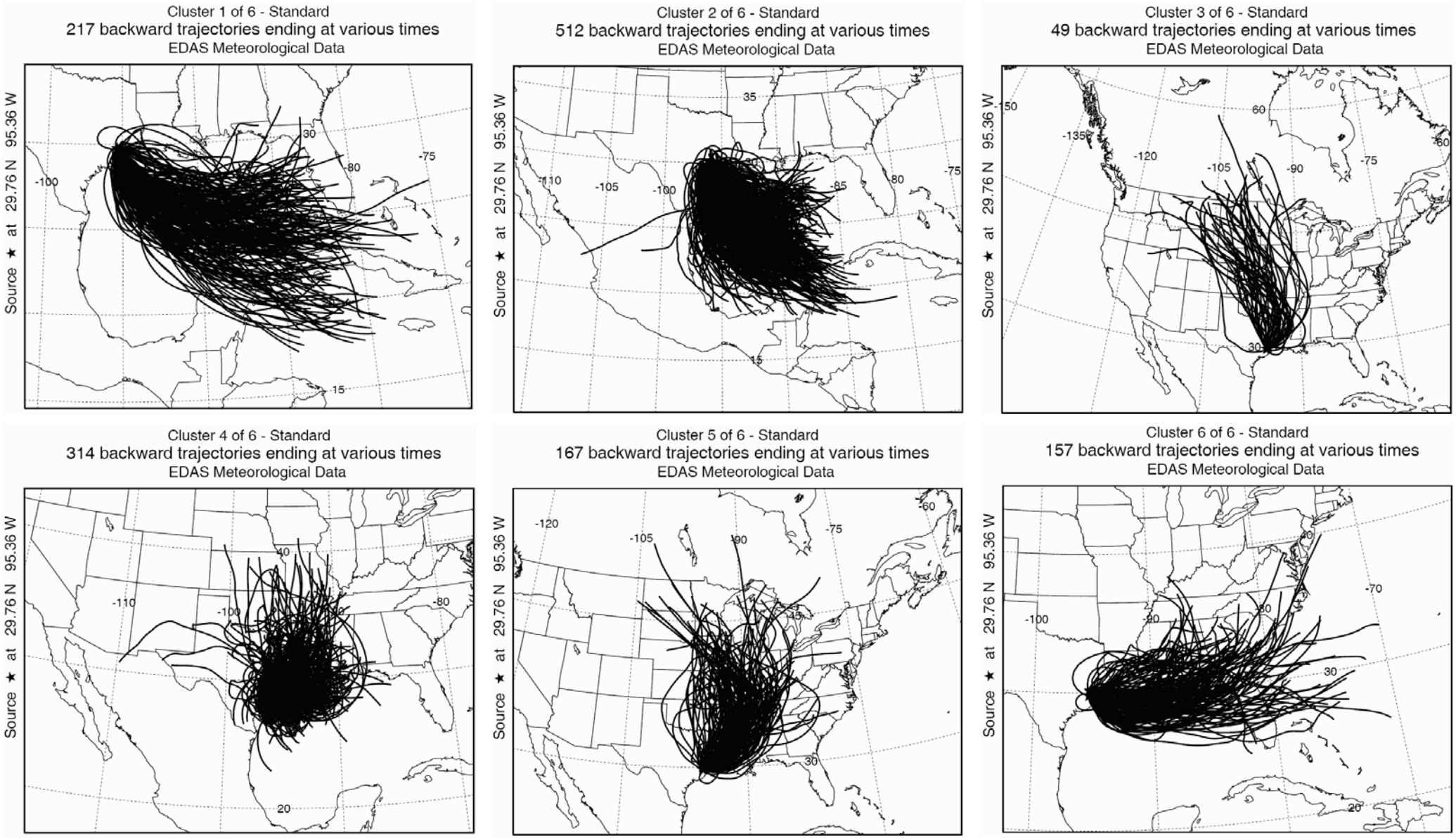


Figure 5-32: Six Clusters Found Using HYSPLIT Backward Trajectory Clustering Algorithm

Figure 5-32*: Six Clusters Found Using HYSPLIT Backward Trajectory Clustering Algorithm* shows that cluster one and cluster two represent days in which winds originated from the Gulf of Mexico; these trajectories typically represent cleaner air coming from the Gulf of Mexico and hence lower observed ozone concentrations in the HGB area. Cluster three represents long trajectories, which come into the HGB area from the north as far away as Canada. This type of trajectory can also bring clean air from northern states and Canada into the HGB area. Cluster four represents stagnant air conditions, a frequent cause of ozone accumulation. Cluster five shows trajectories that originate from the northeast, in the Ohio River Valley, that bring polluted air from more populated areas into the HGB area. Cluster six illustrates trajectories from the east, some of which cross over Louisiana and the Beaumont-Port Arthur (BPA) area and some of which cross over the Gulf of Mexico. The mean centerline from each of the six clusters is shown in Figure 5-34: *Means of Six 60-Hour Backward Trajectory Clusters*. Trajectories were compared to ozone concentrations in the HGB area to quantify how these trajectories are related to ozone in the HGB area.

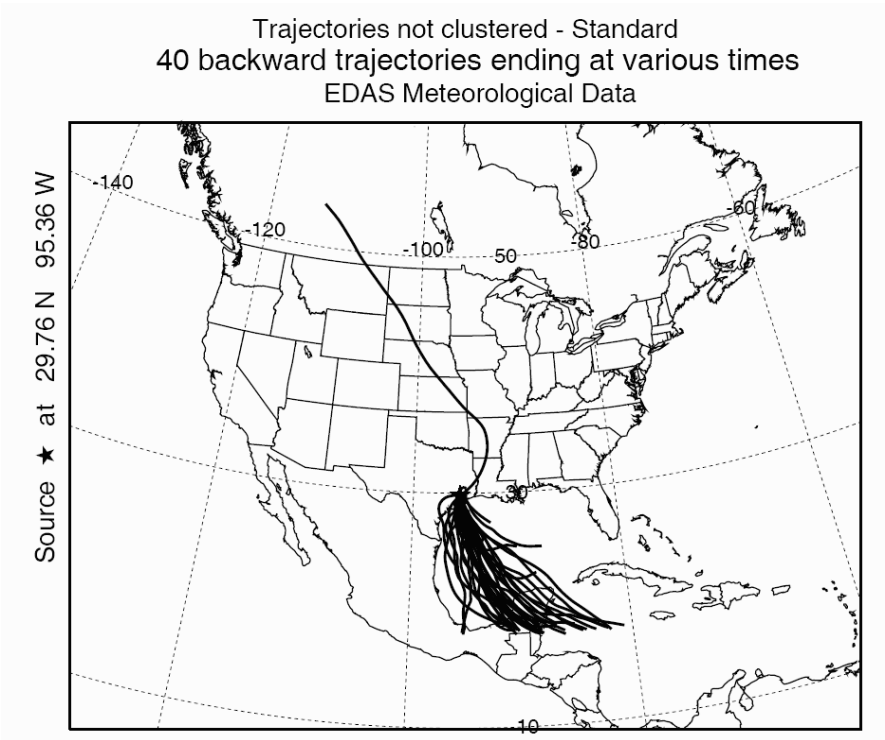


Figure 5-33: Cluster 0 Backward Trajectories

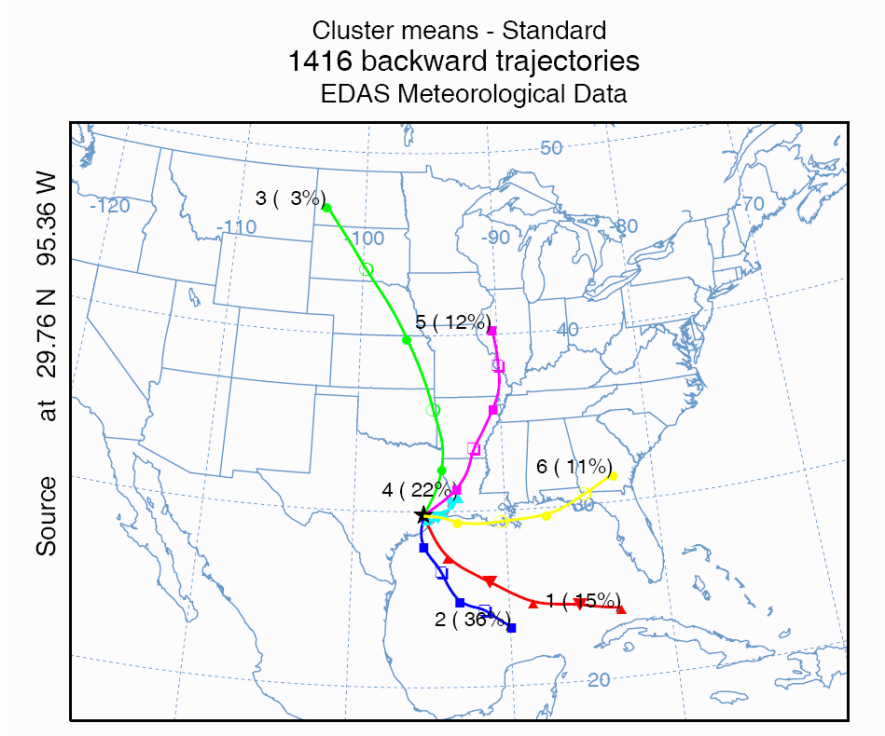


Figure 5-34: Means of Six 60-Hour Backward Trajectory Clusters

Twelve ozone sites, shown in Figure 5-35: *Sites Used in Ozone Area Maximum and Background Determination*, that had near continuous operation from 2000 to 2007 in the HGB area were selected to compare with trajectory clusters. In an effort to use measurements from a consistent, long-term set of monitors, data from sites that were shut down were combined with data from sites that began collecting data near the sites that were taken off-line. Sites where data were combined are Lake Jackson (CAMS 1016) and Clute (CAMS 11), and Galveston Airport (CAMS 34/CAMS 109/CAMS 154) and Galveston Airport 99th St. (CAMS 1034). Sites were selected based on locations as either a site upwind or downwind of the HGB area. Northwest Harris County (CAMS 26), the Lake Jackson (CAMS 1016) / Clute (CAMS 11) combined site pair, and the Galveston Airport (CAMS 34/CAMS 109/CAMS 154)/ Galveston 99th St. (CAMS 1034) combined site pair generally represent sites measuring background ozone concentrations. Sites on the downwind side of downtown Houston and the Houston Ship Channel generally represent sites measuring maximum ozone concentrations in the HGB area. Maximum peak and minimum peak eight-hour ozone concentrations from the twelve monitors were found for each day, then merged with the cluster classification from each day. Following Nielson-Gammon et al. (2005), that minimum peak eight-hour average ozone concentration was used to represent the "background" ozone level in the HGB Area.

Figure 5-35: Sites Used in Ozone Area Maximum and Background Determination

Table 5-22: *Ozone Statistics for HYSPLIT Back Trajectory Clusters* summarizes average maximum and average minimum, or background, ozone concentrations for each cluster. Average maximum peak daily eight-hour ozone among the clusters ranges from 40.6 ppb to 73.3 ppb, while average minimum peak daily eight-hour ozone, considered a proxy for background ozone concentrations, ranges from 21.4 ppb to 45.1 ppb. The difference between these two means can be used as a surrogate for locally produced ozone. Cluster four and cluster five, which represent the short fetch and the northeast fetch, have the highest average maximum ozone concentrations, 71.6 ppb and 73.3 ppb, respectively, and the highest average background, 40.8 ppb and 45.1 ppb. These two clusters also exhibit some of the largest average differences or local contributions. Cluster zero, the far southeast cluster, cluster one, the east southeast cluster, and cluster two, the southeast cluster, exhibited some of the lowest average background and average peak ozone; these clusters are expected to have a lower background ozone due to their origins over the Gulf of Mexico.

Table 5-22: Ozone Statistics for HYSPLIT Back Trajectory Clusters

Cluster	Fetch	Number of back trajec-tories	Average maximum peak daily eight-hour ozone	Average minimum peak daily eight-hour ozone	Average difference, minimum and maximum ozone*
		#	*ppb*	*ppb*	*ppb*
5	NE	166	73.3	45.1	28.1
4	Short	312	71.6	40.8	30.8
6	East	151	61.1	35.6	25.5
3	North	49	59.1	37.2	21.9
2	SE	506	48.5	24.8	23.7
0	far SE	40	45.0	23.8	21.1
1	ESE	217	40.6	21.4	19.1

Note: Data is May through October, 2000 to 2007. Fetch represents the main direction of the cluster, count is the number of back trajectories in each cluster, average minimum peak daily eight-hour ozone is taken as the background ozone concentration. Clusters are sorted in descending order by average maximum peak daily eight-hour ozone.

The 95 percent confidence intervals for the mean eight-hour ozone maximum for each cluster are shown in Table 5-23: *Average Maximum Ozone and 95 Percent Confidence Intervals*. Two standard errors were used for the confidence intervals in each row. The confidence intervals in the table show that differences between means are statistically significant for most of the pair-wise comparison. This is shown graphically in Figure 5-36: *Average Maximum Ozone and 95 Percent Confidence Intervals*. Fetches originating from the northeast and east, as well as the "short" fetch, have the highest average peak daily ozone values, and they are tightly clustered. Clusters originating from the north and far southeast have noticeably wider confidence intervals, indicating more variability, but with lower average peak daily ozone concentrations than the northeast and east clusters.

Table 5-23: Average Maximum Ozone and 95 Percent Confidence Intervals

Cluster ranked by maximum average	Fetch	Count	Average maximum peak daily eight-hour ozone	Average maximum + 2 standard errors	Average maximum - 2 standard errors
		#	*ppb*	*ppb*	*ppb*
5	NE	166	73.3	76.7	69.8
4	Short	312	71.6	74.3	68.9
6	East	151	61.1	64.5	57.8
3	North	49	59.1	65.2	53.0
2	SE	506	48.5	50.3	46.6
0	far SE	40	45.0	51.5	38.4
1	ESE	217	40.6	42.7	38.5

Note: Confidence intervals were constructed using two standard errors. Clusters are sorted in descending order by average maximum peak daily eight-hour ozone. Confidence intervals for differences between the area ozone maximums generally do not overlap beyond one or two rows.

Although many of the selected sites were intended to represent background and maximum ozone in the HGB area, note that on many days true background ozone concentrations may be observed farther away, in more rural areas, and the true maximum ozone concentration may also be underestimated. Despite uncertainty in estimates of true background and maximum ozone

concentrations, the large number of observations used in this analysis, as well as evidence presented earlier, provide clear evidence that ozone in the HGB area is affected by transport of ozone from external sources.

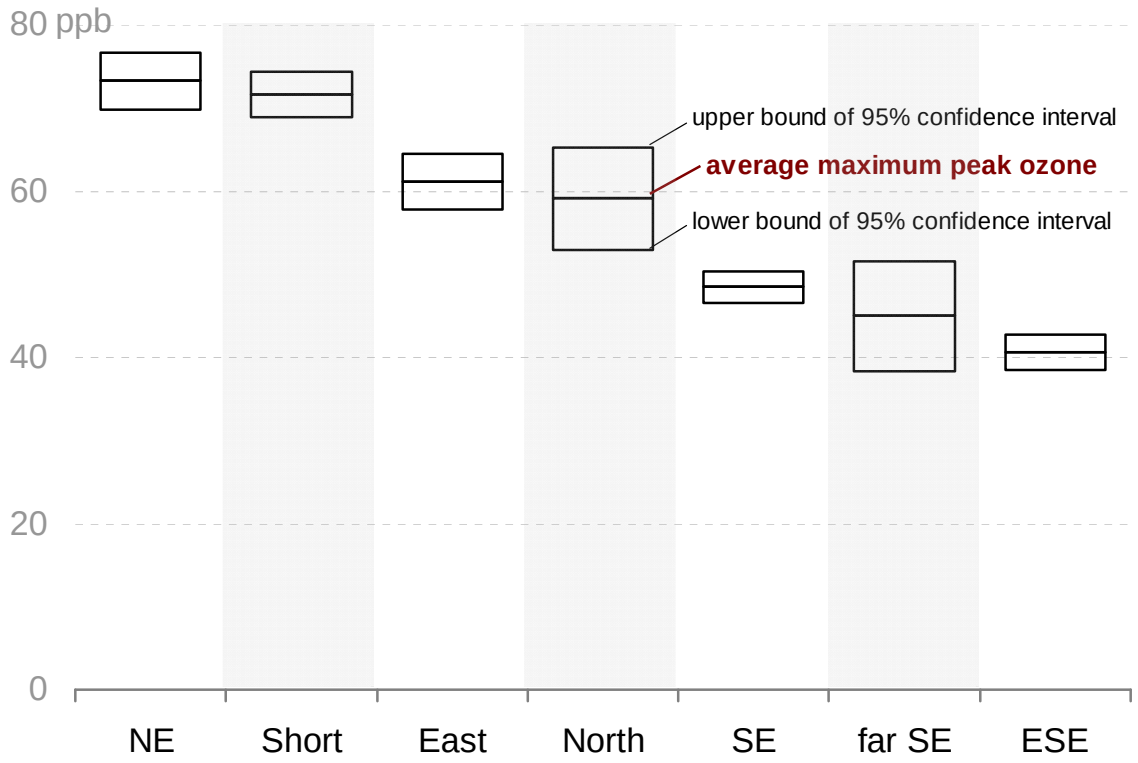


Figure 5-36: Average Maximum Ozone and 95 Percent Confidence Intervals

Figure 5-37*: Relationship Between Minimum and Maximum Ozone Concentrations*, recreated from Sullivan (2009), shows there is a significant linear relationship between mean HGB area minimum and maximum eight-hour average ozone concentrations by trajectory cluster (p-value < 0.01). The dark red points and estimated regression line represent the relationship between mean maximum ozone and mean minimum (background) ozone concentrations by cluster. The olive points and estimated regression line represent the relationship between "local contribution" (difference between maximum and minimum) and mean minimum ozone concentrations by cluster. The relationship between maximum and minimum ozone by cluster suggests that trajectory direction is a factor determining severity of both HGB area maximum and background ozone concentrations (Sullivan, 2009). The estimated slope parameter ($\beta = 1.36$) of the ordinary least squares regression of average minimum ozone concentration against average maximum ozone concentration shows that maximum ozone concentration increases at a greater rate with trajectory direction when compared to minimum ozone.

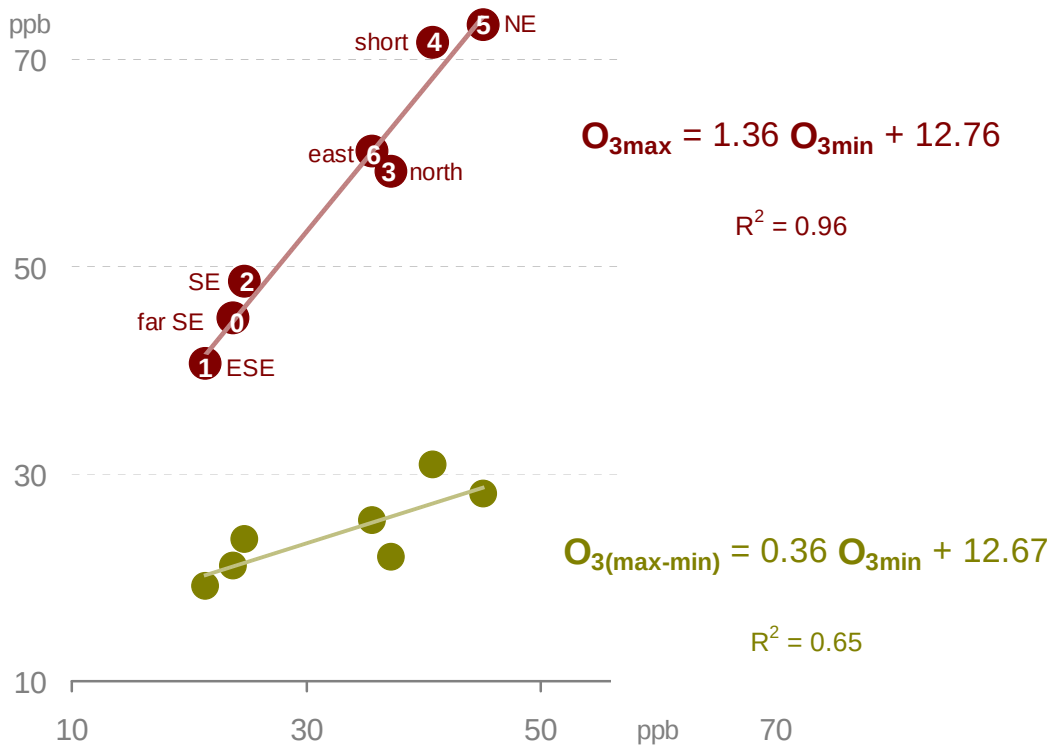


Figure 5-37: Relationship Between Minimum and Maximum Ozone Concentrations

Figure 5-37: *Relationship Between Minimum and Maximum Ozone Concentrations* also shows that the difference between mean HGB area maximum and minimum ozone concentrations is also roughly linear with area minimum, but with a lower slope (β=0.36) and lesser statistical significance (p-value=0.03) (Sullivan, 2009). The linear relationship between the difference and mean HGB area minimum ozone suggests the transport direction also affects local ozone production. The slower air movement of cluster four, which is the "short" cluster, allows greater accumulation in the area under lower local surface wind speeds. Winds originating from the directions of cluster six, the "east" cluster, and cluster five, the "northeast" cluster, help to move surface air along the area around the Houston Ship Channel and across the downtown Houston area, which, as noted, contain large amounts of ozone precursors. Overall, this analysis shows that directions of back trajectories can account for up to 24 ppb of variation in background ozone concentrations, and up to 35 ppb of variation in maximum ozone concentrations.

5.3.11 Transport and Surface Wind Trajectories

While still incomplete, a preliminary analysis of upper level, or transport, wind trajectories was conducted to confirm and extend findings from the previously discussed directional analysis. Additional HYSPLIT modeling of 48-hour back trajectories at 1,500 meters altitude for May through August, 2000 to 2008, was used to detect difference in trajectories across years that may have influenced ozone concentrations in the HGB area.

A simple visual inspection of the densities of distributions of trajectory end points presented in Figure 5-38: *Distributions of End Points from HYSPLIT 48-Hour Back Trajectories* shows that upper level wind patterns for 2008, a year which had relatively low ozone concentrations, do not noticeably differ from patterns in other years. Of the years analyzed, the pattern for 2000, a year with relatively high levels of ozone, is perhaps the most similar to 2008. The spatial distribution is similar among years and wind speeds are also similar. Higher wind speeds are evident in 2004 and 2005, as implied by trajectories with longer fetches. The implication is that the wind patterns

observed during 2008 were not responsible for the lower ozone concentrations observed, since high ozone was observed during other years that had wind patterns similar to 2008.

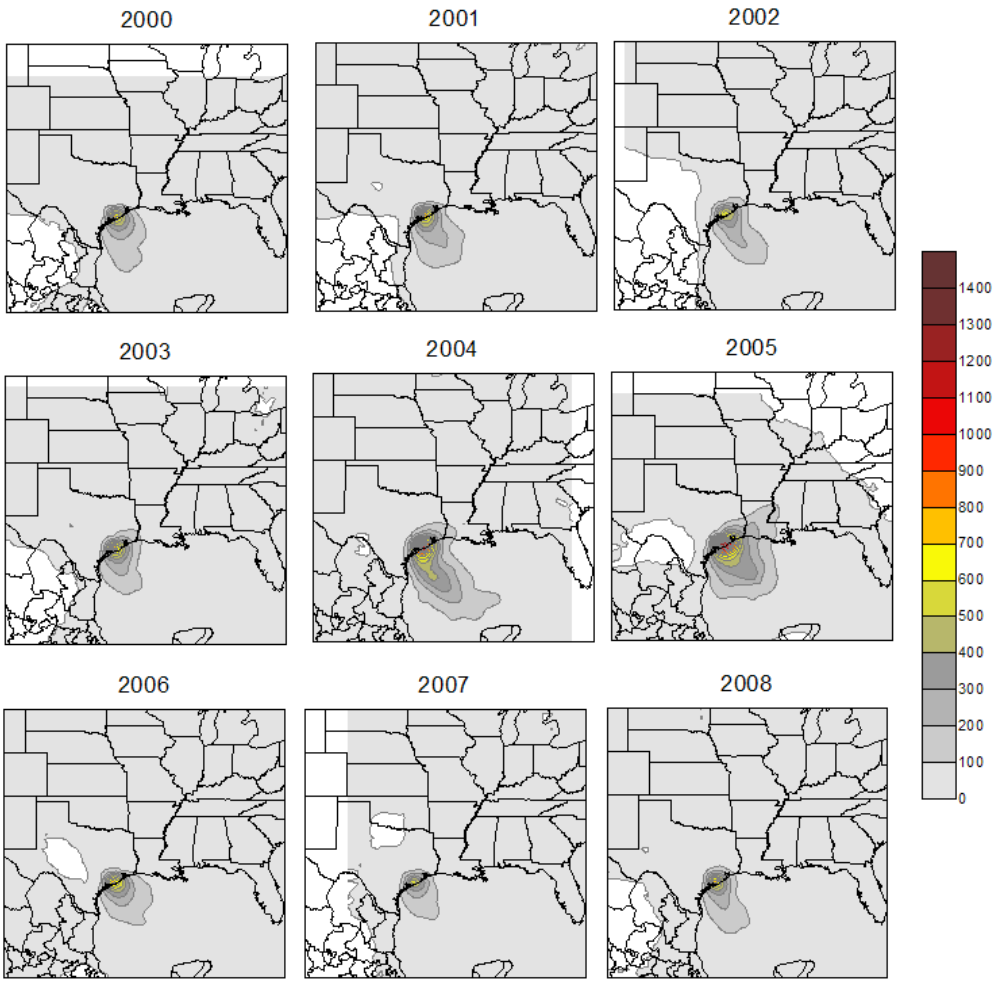


Figure 5-38: Distributions of End Points from HYSPLIT 48-Hour Back Trajectories

5.3.12 Background Ozone in Texas

Research on the meteorology of the HGB area has found that the highest background ozone transported into the HGB area predominately originates from the north and northeast (Nielson-Gammon et al., 2005). In the present analysis, two techniques are used to examine background ozone concentrations in Texas since 2000. The first technique examines the trend in ozone concentrations at four sites that can be considered background sites under certain flow conditions. The second technique examines ozone concentrations associated with different patterns of long-term backward trajectories.

Identifying appropriate background ozone monitoring sites from which to ascertain trends is complicated by local ozone, complex wind patterns, and natural variability in background ozone itself. To estimate background ozone, Nielson-Gammon et al. evaluated all monitors in the region to identify those that could be considered to be recording background ozone values. They proposed a modification of a TCEQ procedure to identify such sites.

The TCEQ procedure involves determining the direction of transport winds, then selecting a rural monitor upwind of the area in that direction. Nielson-Gammon et al. simply select as the background value the lowest of the peak eight-hour ozone values from all monitors. Unlike the

Nielson-Gammon procedure, which used gridded output of a meteorological model, this analysis follows the TCEQ approach using direct measurements of surface winds and tracking background ozone concentrations over time at selected monitors. Modifying the Nielson-Gammon procedure, the approach presented here identifies the 90th percentile values recorded at the selected monitors and examines the distribution of daily maximum ozone concentrations over time to determine whether these supposed background concentrations have increased or decreased. Both the Nielson-Gammon method and the TCEQ method may not strictly estimate background ozone, as defined above, because they do not remove any potential recirculation of pollutants generated via local emissions. Also, background ozone alone may not tell the complete story, since ozone precursors, which can react with each other and with local emissions to produce ozone, may also be present in transported air.

Four candidate monitors were selected for this analysis and are listed in Table 5-24: *Monitors Selected for Background Transport Analysis*. Two monitors, West Orange (CAMS 9) and Mauriceville (CAMS 642/CAMS 311/CAMS 665), are located east of the HGB area, adjacent to the Texas-Louisiana border, east of the BPA area; one, Karnack (CAMS 85), is located in northeast Texas near the Texas-Louisiana-Arkansas border and the Tyler-Longview-Marshall (TLM) area; and one, Hamshire (CAMS 64/CAMS 654), is located east of the HGB area, between the HGB area and the BPA area. Each of these monitors was selected for specific purposes. West Orange (CAMS 9) and Mauriceville (CAMS 642/CAMS 311/CAMS 665) were chosen because they are as close as possible to the Texas border and, thus, are useful for isolating background ozone being transported into the state from the east. Karnack (CAMS 85), in northeast Texas, is also very near the Texas border, and was selected to provide an assessment of background ozone transport from more northerly regions. The final site, Hamshire (CAMS 64/CAMS 654), was selected to aid stratification of background ozone being transported into the HGB area into a component originating outside the state, and a component contributed by the BPA area.

Table 5-24: Monitors Selected for Background Transport Analysis

Monitor	metro area	location	years	CAMS code
West Orange	BPA	TX-LA border	2000-2008	C9/A141
Mauriceville	BPA	TX-LA border	2000-2008	C642/C311/C665
Karnack	TLM	TX-LA-AR border	2001-2008	C85/AFHP303
Hamshire	HGB	between BPA and HGB	2000-2008	C64/C654

Source: TCEQ/LEADS database. Data with wind speeds less than 3 miles per hour were excluded to minimize influences from periods of stagnation which may result in over estimation of background concentrations.

To isolate ozone being transported into the state, measurements at the selected monitors were restricted by wind direction. The West Orange (CAMS 9) monitor is located less than 3 miles from the Louisiana border but is near several industrial sites. Only ozone measurements taken when winds originated from directions ranging from 30° to 90° (Figure 5-39: *Mauriceville C642/C311/C665) and West Orange (C9) Monitors*) were considered, to minimize possible influence from these sources. Thirty degrees corresponds to a north-northeast direction and 90° is due east. The Mauriceville (CAMS 642/CAMS 311/CAMS 665) monitor is located ten miles from the Louisiana border, north of the West Orange (CAMS 9) monitor. This site may have some minor influence from relatively small NO_X and VOC sources. Data from this monitor was restricted to wind directions originating from 30° to 90°, similarly to West Orange (CAMS 9), to minimize any possible influence of nearby point sources.

The Karnack (CAMS 85) monitor in the TLM area is located eight miles from the Texas-Louisiana border, and roughly 20 miles from Arkansas. Measurements from Karnack (CAMS 85) were restricted to wind directions originating from 30° to 135° (Figure 5-40: *Karnack C85Monitor*), that is, from north-northeast clockwise to southeast. Though this site is not near

the HGB area, it records large influxes of continental air transported from the Midwestern United States into Texas, which ultimately may raise background ozone concentrations throughout the state. Also, estimates of background ozone concentrations from Karnack (CAMS 85) can be compared to background estimates from West Orange (CAMS 9) and Mauriceville (CAMS 642/CAMS 311/CAMS 665), which is useful for corroborating estimates at these two sites, and determining the range of background ozone entering the state.

The final site under consideration is Hamshire (CAMS 64/CAMS 654), located between the HGB area and the BPA area. Ozone measurements from this site can be used to estimate background ozone concentrations transported to the HGB area when winds are from the east. These background ozone measurements are a combination of pollution transported into Texas, as well as the contribution of pollution from the BPA area. To avoid undue influence of nearby industrial sites, similar to Karnack (CAMS 85), data from Hamshire (CAMS 64/CAMS 654) are restricted to measurements obtained when winds originate from directions ranging from 30° to 135°. For the four monitors, monthly 10th, 25th, 50th, 75th and 90th percentiles of hourly ozone concentrations were calculated for the spring and summer ozone season, May through September, 2000 through 2008, except Karnack (CAMS 85) which only has data since 2001. These values are plotted in Figure 5-42: *Selected Statistics for the West Orange C9 Monitor*, Figure 5-43: *Selected Statistics for the Mauriceville C642/C311/C665 Monitor*, Figure 5-44: *Selected Statistics for the Karnack C85 Monitor*, and Figure 5-45: *Selected Statistics for the Hamshire C64/C654 Monitor*. Ninetieth percentile values are reported in Table 5-25: *Range of Monthly 90th Percentile Daily Peak Hourly Ozone Concentrations for Subject Wind Directions*.

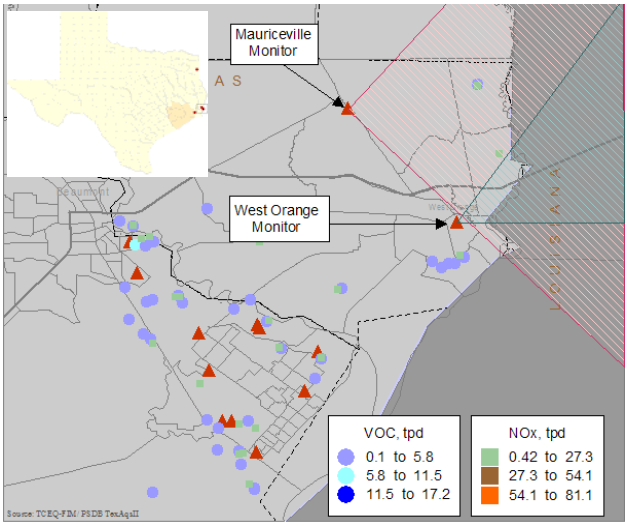


Figure 5-39: Mauriceville C642/C311/C65 and West Orange C9/A141 Monitors

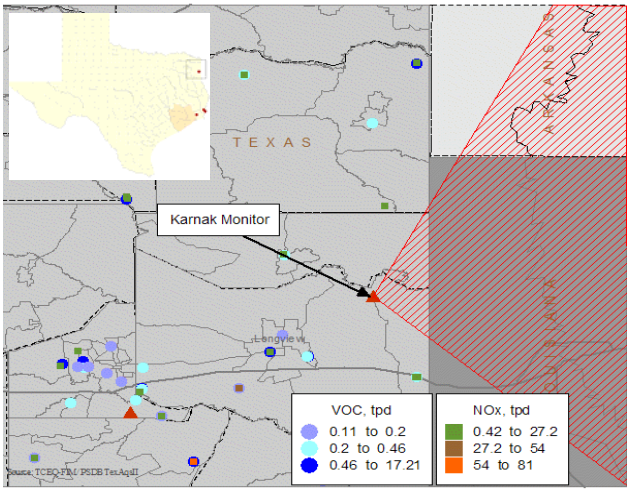


Figure 5-40: Karnack C85 Monitor

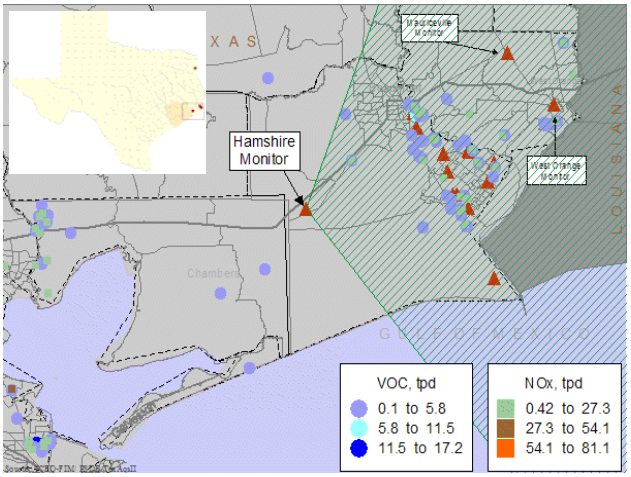


Figure 5-41: Hamshire C64/C654 Monitor

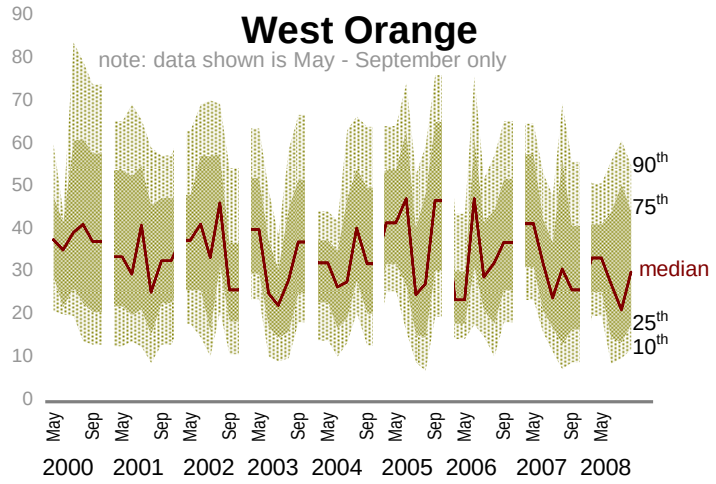


Figure 5-42: Selected Statistics for the West Orange C9 Monitor

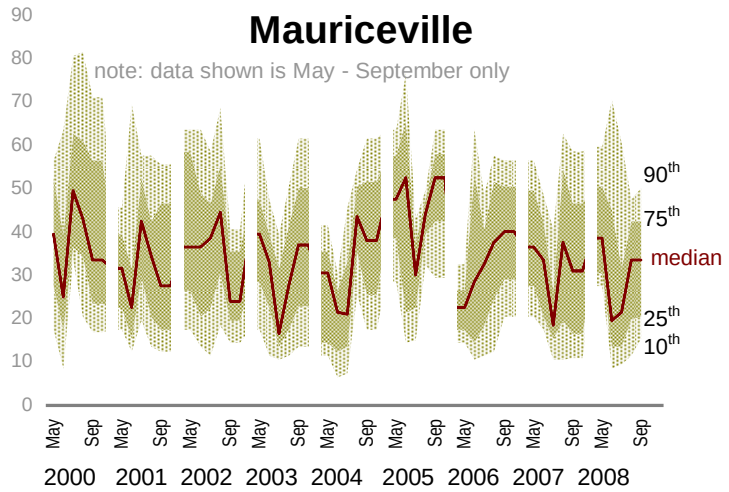


Figure 5-43: Selected Statistics for the Mauriceville C642/C311/C665 Monitor

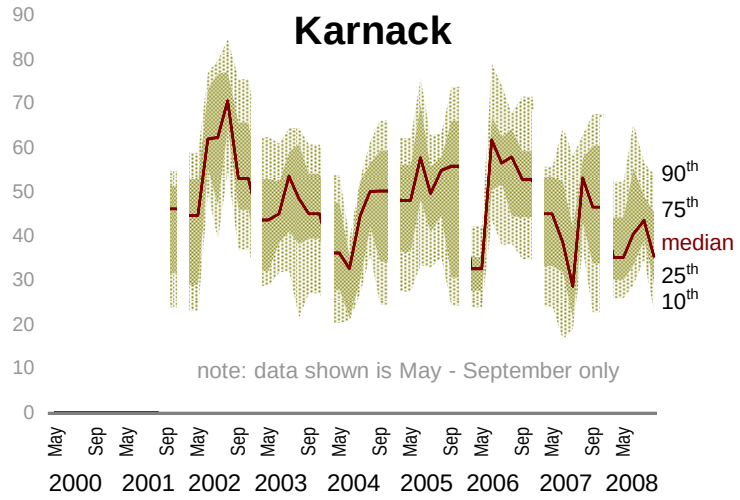


Figure 5-44: Selected Statistics for the Karnack C85 Monitor

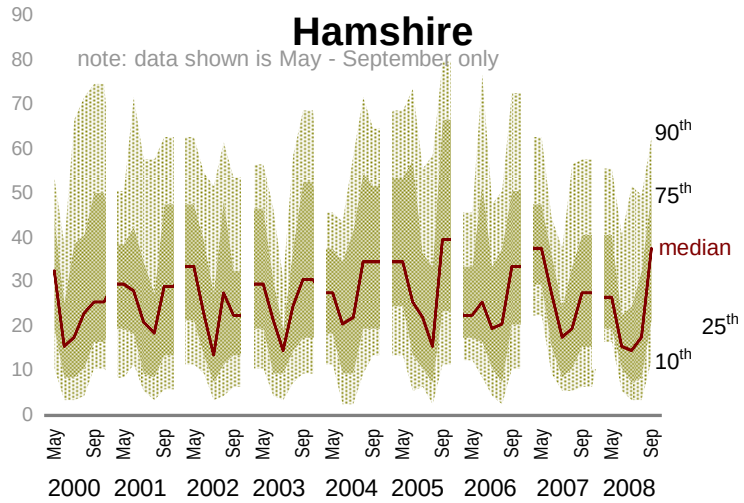


Figure 5-45: Selected Statistics for the Hamshire C64/C654 Monitor

Table 5-25: Range of Monthly 90th Percentile Daily Peak Hourly Ozone Concentrations for Subject Wind Directions

	Hamshire C64/C654		Karnack C85		Mauriceville C642/C311/C665		West Orange C9	
year	min	max	min	max	min	max	min	max
	ppb	*ppb*	*ppb*	*ppb*	*ppb*	*ppb*	*ppb*	*ppb*
2000	38	74	.	.	56	81	43	**83**
2001	50	**71**	.	54	45	69	57	68
2002	51	62	58	**84**	40	68	53	69
2003	30	**68**	60	64	39	61	38	66
2004	43	**71**	39	66	30	61	41	66
2005	55	**79**	62	75	43	76	52	75
2006	45	76	42	**78**	32	63	43	75
2007	37	62	55	67	40	62	47	**69**
2008	40	62	.	65	47	**70**	50	60
9-year period	30	79	39	**84**	30	81	38	83

Note: Though data has been restricted by wind direction to mitigate influences from nearby pollution sources, there may be unknown influences that are unaccounted for. Maximum values for each year are highlighted in boldface type.

To statistically verify whether a trend across time exists in the data, an index of date was fit to the daily peak values using ordinary least squares regression. Additional regressions were performed using an index of month against the selected percentiles of the monthly distributions. The resulting parameter estimates from these models revealed no statistically significant trend at the 5 percent significance level; however, the data likely suffer from autocorrelation, a problem common to time series data. Time series data are often not independent, but correlated with themselves across time, which complicates formal statistical estimation by biasing parameter estimates.

Rather than performing the procedures necessary to detect, measure, and correct for autocorrelation, a careful visual inspection of time series plots, presented in Figure 5-42: *Selected Statistics for the West Orange C9 Monitor* through Figure 5-45: *Selected Statistics for the Hamshire C64/C654 Monitor*, satisfies that no time trend is perceptible. These four figures plot the five selected percentiles of the monthly distributions at each monitor. While no trend is detectable, what is apparent is that ozone concentrations measured at these monitors, which have been restricted in such a way as to proxy background levels, vary substantially. Background ozone at these monitors varies as much as 35 ppb, due to meteorological effects and ozone dynamics occurring in upwind regions.

Notable in Figure 5-45: *Selected Statistics for the Hamshire C64/C654 Monitor*, hourly ozone concentrations at Hamshire (CAMS 64/CAMS 654) behave similarly to West Orange (CAMS 9) and Karnack (CAMS 85), in that there is no observable or statistically significant trend of the median or 90th percentile values. The 90th percentile value at Hamshire (CAMS 64/CAMS 654), considering directionally restricted data for May to September, 2000 through 2008, is 59 ppb.

This value is in the range of values computed by Nielson-Gammon using different procedures; however, the 90th percentile can exceed 80 ppb at any of the sites, and even exceeded 90 ppb at Mauriceville (CAMS 642/CAMS 311/CAMS 665) in 2000. TexAQS II also found background ozone concentrations that exceed the 1997 eight-hour ozone NAAQS (TexAQS II Rapid Science Synthesis Team 2006).

Over the 2000 through 2008 period, the maximum 90th percentile one-hour ozone concentrations at West Orange (CAMS 9) and Mauriceville (CAMS 642/CAMS 311/CAMS 665) are 79 and 92, respectively. The maximum 90th percentile for Karnack (CAMS 85) over the 2001 through 2008 period is 81. Karnack (CAMS 85) appears to consistently measure a higher background than either West Orange (CAMS 9) or Mauriceville (CAMS 642/CAMS 311/CAMS 665). These results are consistent with estimates reported by Nielson-Gammon, et al. (2005), which also found higher background ozone concentrations during the ozone season in northeast Texas than in the HGB area.

Regression analysis was used to determine whether the 90th percentile values at West Orange (CAMS 9) and Mauriceville (CAMS 642/CAMS 311/CAMS 665) track one another, which suggests they are measuring roughly equivalent phenomena. The resulting R^2 of 0.78, which is significant at a probability level less than 0.1 percent (Table 5-26: *Parameter Estimates for Regression of West Orange C9 on Mauriceville C*642/C311/C665, indicates very strong correlation between measurements at the two sites. The scatter plot of the data is illustrated in Figure 5-46: *Scatter-plot of 90th Percentile Hourly Values at West Orange C9 and Mauriceville C642/C311/C665*. The values in the scatter plot are from May through September, 2000 to 2008. The scatter plot supports the contention that these two monitors are measuring roughly the same phenomena, under wind-restricted regimes.

Table 5-26: Parameter Estimates for Regression of West Orange C9 on Mauriceville C642/C311/C665

	intercept	slope
β estimate	4.95706	1.01251
Std. Error	0.55480	0.01421
t-statistic	8.935	71.278
Pr(>|t|)	<2e-16	<2e-16
R^2	0.78	

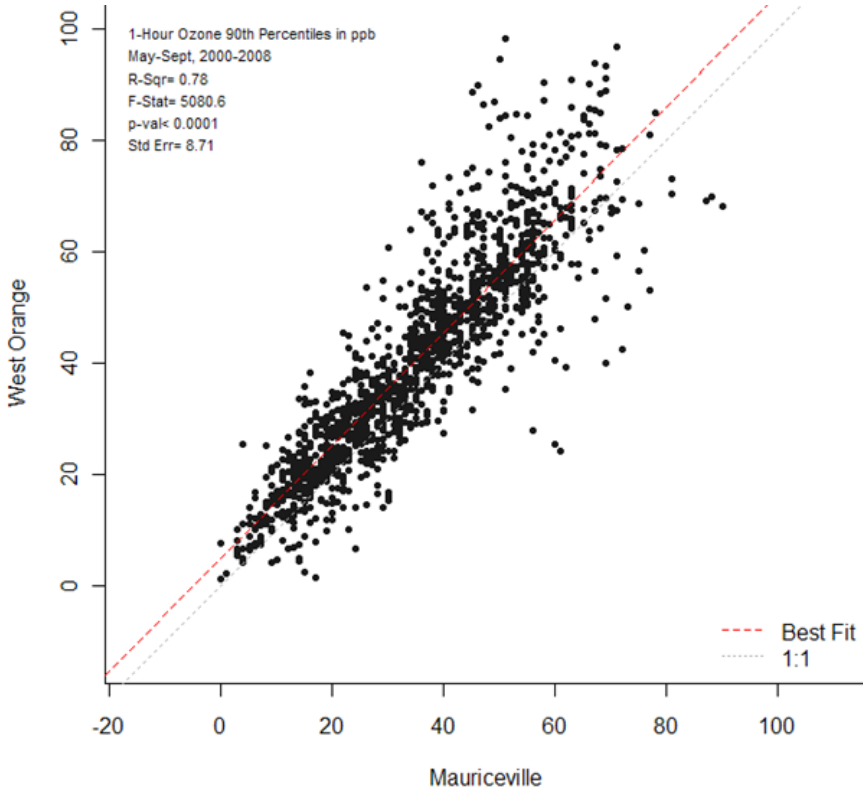


Figure 5-46: Scatter-plot of 90th Percentile Hourly Values at West Orange C9 and Mauriceville C642/C311/C665

In summary, none of the four sites used for estimating background ozone concentrations recorded a statistically significant trend. The Karnack (CAMS 85) monitoring site recorded the highest 90th percentile measurement of the four background sites, with 90th percentile ozone concentrations reaching as high as 63 ppb. Since it is farthest from the HGB area, however, the HGB area may not be strongly affected by the ozone observed at this site, at least not on the same day.

5.3.13 Air Quality Trends Conclusions

Ozone concentrations have decreased dramatically in the HGB area since the 1990s, and in 2009 the preliminary design value dipped below the 1997 eight-hour standard of 0.08 ppm (or 85 ppb). Examination of trends in one-hour ozone, eight-hour ozone, the number of exceedances, the spatial distribution of ozone, the seasonal distribution of ozone, and the strength of ozone gradients all show substantial downward trends. The causes of the trends were investigated by examining the meteorological variations that have occurred over the years, by evaluating the local changes in ozone precursor concentrations, and by examining trends in background ozone. The analyses found that the interannual meteorological variations cannot explain the observed decreases in ozone, and that the ozone precursors are on statistically significant downward trends. In addition, the analyses have found that background ozone in southeast Texas has not dropped substantially since 2000, suggesting that the significant ozone reductions in the HGB area are due to local emission controls, not due to background ozone decreases.

5.4 QUALITATIVE CORROBORATIVE ANALYSIS

5.4.1 Introduction

Because photochemical modeling is an evaluation tool and not an absolute prediction of future ozone concentrations, additional data must be considered in order to draw conclusions about the validity of the final predicted design value and whether the attainment demonstration satisfies the requirements of the Federal Clean Air Act (FCAA). The EPA's "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze," referenced as modeling guidance in Chapter 3, *Photochemical Modeling* acknowledges that many issues cannot be accurately quantified and therefore cannot be properly included in the photochemical modeling demonstration. The qualitative corroborative analysis contains information regarding federal preemption issues and analysis of additional measures that were not included in the modeling.

5.4.2 Federal Preemption Issues

The TCEQ has limited authority to regulate certain components of the emissions inventory. The federal government has jurisdiction over on-road and non-road vehicles, ships, locomotives, and aircraft, among other sources. Since states cannot control sources that are under federal jurisdiction or located in other states, the state is limited in its ability to impose controls on all of the sources that contribute to ozone formation in a nonattainment area.

5.4.2.1 Federal Assignment

While these categories have been addressed through expeditiously implemented state incentive programs such as the Low Income Vehicle Repair Assistance, Retrofit, and Accelerated Vehicle Retirement Program (LIRAP) and the Texas Emissions Reduction Plan (TERP), future reductions are dependent on the prompt implementation of new federal engine and fuel standards for on-road and non-road vehicles, ships, locomotives, and aircraft.

5.4.3 Additional Measures

5.4.3.1 New International Marine Diesel Engine and Marine Fuel Standards for Oceangoing Vessels and Emissions Control Areas

In October 2008, the United States ratified the International Maritime Organization's (IMO) adoption of the amendments to Annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL) for new international marine diesel engine and marine fuel standards for oceangoing vessels (OGV). The new Annex VI Tier II and Tier III emission standards will apply to diesel engines with a power rating above 130 kilowatts (kW) (i.e., 175 horsepower) installed on marine vessels constructed on or after January 1, 2011 (Tier II), and January 1, 2016 (Tier III), or diesel engines above 130 kW that undergo a major conversion on or after those dates. The revised MARPOL Annex VI will become effective on July 1, 2010.

In March 2009, the United States submitted a request to the IMO for the creation of an emissions control area (ECA) around the nation's coastlines. If the ECA is granted, all marine diesel fuels used by OGV in the ECA will be limited to a maximum sulfur content of 1,000 ppm beginning January 1, 2015, and all new engines on OGV operating in these areas must use emission controls that achieve an 80 percent reduction in NO_X emissions beginning January 1, 2016. Table 5-27: *New MARPOL Annex VI Emission Standards for Marine Diesel Engines* lists the new emission standards for marine diesel engines with greater than 30 liter per cylinder displacement.

Table 5-27: New MARPOL Annex VI Emission Standards for Marine Diesel Engines

New MARPOL Annex VI emission standards for marine diesel engines with >30 liter per cylinder displacement			
Engine Speed (n)	NO_X Emission Standards (g/kW–hr)		
	Tier 1	Tier 2	Tier 3
N < 130 revolutions per minute (rpm)	17.0	14.4	3.4
2000 > n ≥ 130 rpm	$45.0 \times n^{-0.20}$	$44.0 \times n^{-0.23}$	$9.0 \times n^{-0.20}$
N ≥ 2000 rpm	9.8	7.7	2.0
Applicable to engines installed in vessels constructed on:	01/01/2000 – 12/31/2010	01/01/2011 - 12/31/2015	01/01/2016 and thereafter

Note: NO_X emission standards presented in grams per kilowatt hour.

In December 2009, the EPA adopted new federal Tier 2 and Tier 3 engine standards for new marine engines above 30 liters per cylinder displacement (i.e., Category 3 marine diesel engines) that are consistent with the new MARPOL Annex VI NO_X emission standards shown in Table 5-27: *New MARPOL Annex VI Emission Standards for Marine Diesel Engines*. The EPA's new Category 3 marine diesel engine standards also include new standards limiting the emissions of hydrocarbons and carbon monoxide from new Tier 2 and later Category 3 engines to 2.0 g/kW-hr and 5.0 g/kW-hr, respectfully.

The EPA regulations for marine diesel fuel and new marine engines less than 30 liters per cylinder displacement and the new MARPOL Annex VI standards for marine residual fuels and new marine diesel engines above 30 liters per cylinder displacement will apply to all OGV flagged and registered in the United States. The EPA's new regulations for new Category 3 marine engines and new sulfur limits for marine diesel fuel will also apply to all OGV flagged and registered in the United States. In addition, the new MARPOL Annex VI standards will apply to all new marine diesel engines and fuels on foreign marine vessels that operate near United States coasts and ports.

The new marine diesel engine and fuel standards will provide a 96 percent reduction in sulfur in marine diesel fuels, as well as an 85 percent reduction in particulate matter emissions and an 80 percent reduction in NO_X emissions, when compared to current standards (EPA, 2009a, http://www.epa.gov/otaq/oceanvessels.htm#emissioncontrol). Cumulatively, these new marine diesel engine and fuels standards will result in a 0.5 to 1.0 ppb reduction of ozone in the ambient air of the HGB ozone nonattainment area by 2020 (EPA, 2009b).

5.4.3.2 SmartWay Transport Partnership and the Blue Skyways Collaborative

Among its various efforts to improve air quality in Texas, the TCEQ is currently promoting two voluntary programs in cooperation with the EPA: the SmartWay Transport Partnership and the Blue Skyways Collaborative.

The SmartWay Transport Partnership is a voluntary EPA program primarily for the freight transport industry that promotes strategies and technologies to help improve fleet efficiency while also reducing air emissions. Fleets participating in the SmartWay Transport Partnership commit to implementing voluntary measures and providing the EPA with annual updates of their progress.

SmartWay carriers typically commit to integrating fuel-saving strategies and technologies into their fleet including: improved aerodynamics, single-wide tires, lighter wheels and rims, idle

reduction, automatic tire inflation systems, driver training, and advanced powertrain technologies. In addition, the SmartWay Transport Partnership is committed to promoting smart transportation choices for individual consumers and companies.

Rolling resistance is estimated by the EPA to account for as much as 13 percent of a heavy-duty vehicle's fuel consumption. SmartWay certifies long-haul tractor and trailer components that significantly lower emissions and fuel consumption. By reducing rolling resistance, as well as vehicle weight, the EPA believes that single-wide tires and aluminum wheels will help to reduce NO_X emissions and improve fuel economy by an average of 4 percent. Aerodynamic drag accounts for most of a long-haul truck's energy losses at highway speeds. As a result, the EPA estimates that improving the aerodynamics of both a long-haul truck and its trailer can help to reduce NO_X emissions and improve fuel economy and by another 5 percent.

The extended periods of idling typically associated with long-haul trucks consume an average of one gallon of fuel per hour, while generating associated emissions. New technologies such as auxiliary power units (APU) and truck stop electrification (TSE) systems reduce vehicle idling by providing power for air conditioning, heating, and onboard electrical accessories, even when the vehicle is not in operation. The EPA estimates that, assuming typical idling levels, idling reduction technologies such as APU and TSE can improve the fuel economy by 8 percent.

The transient nature of freight transportation makes it difficult to isolate emissions reductions to a certain region or even a certain state. As a result, any estimates of the impact of these technologies will largely rely on estimates of accumulated reductions based on estimated levels of overall fleet integration. These estimates are possible through ongoing research, and in conjunction with the more than 2,000 companies nationwide already committed as SmartWay partners, the EPA has identified a variety of technologies and the potential fuel savings and emissions reductions from those technologies. There are approximately 125 Texas companies that are currently SmartWay partners.

The Blue Skyways Collaborative is a related effort, spearheaded by the EPA Region 6 office in Dallas, Texas and the Region 7 office in Kansas City, Missouri.

Partnering with the EPA Region 6 and Region 7 through this effort are the environmental and energy agencies from the 10 states along the Interstate Highway 35 (IH-35) corridor, including Texas, New Mexico, Louisiana, Arkansas, Oklahoma, Kansas, Missouri, Nebraska, Iowa, and Minnesota. In implementing the Blue Skyways Collaborative, the EPA and the participating states recognize that because air quality is often a regional concern, greater reductions are possible through cooperative efforts as opposed to individual efforts initiated independently in each state.

The primary objective of the Blue Skyways Collaborative is to improve air quality in these states by promoting innovative technologies in a variety of sectors. In addition to promoting reduction strategies through the SmartWay Partnership for freight transportation via air, water, and rail, Blue Skyways also focuses on promoting emissions reduction strategies for other on-road sources, non-road sources, and highway fueling and idling reduction infrastructure, while also promoting renewable, efficient, and alternative energy sources.

To achieve these objectives, the collaborative develops partnerships among international, federal, state, and local governments, as well as non-profit organizations, environmental groups, and private industries. These partnerships work together in projects along the key transportation corridors by sharing emission reduction technologies and leveraging financial resources from a variety of sources.

5.4.3.3 Car Allowance Rebate System (CARS)

The Car Allowance Rebate System (CARS), formerly known as Cash-for-Clunkers, was an economic stimulus program implemented by the United States Department of Transportation (DOT) that focused on energizing the economy, boosting auto sales, and putting cleaner and more fuel-efficient vehicles on the road. The program was active from July 27, 2009, through August 25, 2009.

The CARS program provided $3,500 to $4,500 in rebates to buyers who traded in vehicles with mileage ratings of 18 miles per gallon (mpg) or less and purchased new vehicles with improved fuel efficiency. To get the maximum rebate of $4,500, the vehicle's mileage had to improve by 10 mpg for new cars and 5 mpg for new light-duty trucks. Like the TCEQ's AirCheckTexas Drive a Clean Machine program, the CARS program required that trade-in vehicles be destroyed, so they could not be resold or reused in the United States or elsewhere.

The DOT has reported that the CARS program retired and replaced 11,104 vehicles in the eight-county HGB nonattainment area. The majority of vehicles replaced were between the model years of 1993 and 2001. The program achieved an overall 58 percent improvement in fuel efficiency.

5.4.3.4 Control of VOC Emissions from Flash Emissions

When the TCEQ and its research partners began the second Texas air quality study, TexAQS II, in May 2005, one of the study's primary goals was to identify VOC emission sources that have been historically underestimated, unreported, or underreported in the TCEQ emissions inventory and could potentially be contributing to a discrepancy between measured and reported emissions. TexAQS II remote sensing VOC project results indicate that certain types of storage tank emissions, including flash, generally have been underestimated, unreported, or underreported in the emission inventory. Flash emissions occur when a liquid with entrained gases goes from a high pressure to a low pressure. As the pressure on the liquid drops, some of the lighter VOC dissolved in the liquid are released or flashed. Compounds that are liquids at the initial pressure may transform from a liquid into a vapor and are also released from the liquid. As these gases are released, some of the heavier compounds in the liquids may become entrained in these gases and are emitted with the lighter VOC.

In May 2007, the commission adopted rule amendments to 30 Texas Administrative Code (TAC) Chapter 115, Subchapter B, Division 1 that revised the requirements for VOC storage tanks located in the HGB ozone nonattainment area. The revised requirements were developed to reduce VOC emissions that result from uncontrolled flash emissions at upstream oil and gas exploration and production sites and other sources of tank emissions. At the time of the rule proposal, the amount of flash emissions from minor sources was unknown.

A method for quantifying flash emissions became available in October 2006. Houston Advanced Research Center Project 51C, conducted in 2006, quantified emission rates from heater-treaters (separators) and storage tank batteries, including flash and condensate tanks, associated with the upstream oil and gas industry in the Dallas-Fort Worth and HGB ozone nonattainment areas, and Jefferson County. In April 2007, the TCEQ used the results of this study to determine the flash emissions from the oil and gas production industry. However, the flash emissions were not included in the 2005 area source periodic emissions inventory (PEI) because there was not sufficient time to incorporate the emissions before the 2005 area source PEI was submitted to the EPA in May 2007. The updated 2005 area source emissions inventory, which includes flash emissions, is being used for this SIP revision. More information on this study can be found at: http://files.harc.edu/Projects/AirQuality/Projects/H051C/H051CFinalReport.pdf.

The rule amendments adopted in May 2007 resulted in actual reductions to flash emissions but no credit is claimed in this SIP revision. Crude and condensate storage tanks at upstream oil and gas exploration and production sites or midstream pipeline breakout stations with uncontrolled flash emissions greater than 25 tons per year (tpy) are controlled under the rule. Since the method of calculating the emissions was based on county-level production, it is unknown at this time how many sites were over 25 tpy and were required to put on controls. Also unknown is how much flash emissions were already controlled due to economic reasons. Because of the unknown total effect of this rule, the reduction in flash emissions cannot be quantified at this time and is not included in the modeling for this SIP revision. A research study is currently being funded to estimate these reductions for inclusion in a future SIP revision. These amendments to Chapter 115 are described in more detail in the preamble of the adopted rule (Project Number 2006-038-115-EN).

5.4.3.5 Energy Efficiency and Renewable Energy (EE/RE) Measures

Energy efficiency measures are typically programs that reduce the amount of electricity and natural gas consumed by residential, commercial, industrial, and municipal energy consumers. Examples of energy efficiency include increasing insulation in homes, installing compact fluorescent light bulbs, and replacing motors and pumps with high efficiency units. Renewable energy measures include programs that generate energy from resources that are replenished or are otherwise not consumed as with traditional fuel-based energy production. Examples of renewable energy include wind energy and solar energy projects.

The Texas Legislature has enacted a number of EE/RE measures and programs. The following is a summary of Texas EE/RE legislation since 1999.

- 76th Texas Legislature, 1999
    - Senate Bill (SB) 7 (Regular Session)
    - House Bill (HB) 2492 (Regular Session)
    - HB 2960 (Regular Session)
- 77th Texas Legislature, 2001
    - SB 5 (Regular Session)
    - HB 2277 (Regular Session)
    - HB 2278 (Regular Session)
    - HB 2845 (Regular Session)
- 78th Texas Legislature, 2003
    - HB1365 (Regular Session)
- 79th Texas Legislature, 2005
    - SB 20 (First Call Session)
    - HB 2129 (Regular Session)
    - HB 2481 (Regular Session)
- 80th Texas Legislature, 2007
    - HB 66 (Regular Session)
    - HB 3070 (Regular Session)
    - HB 3693 (Regular Session)
    - SB 12 (Regular Session)

SB 5, 77th Texas Legislature, 2001, set goals for political subdivisions in affected counties to implement measures to reduce energy consumption from existing facilities by 5 percent each year for five years from January 1, 2002 through January 1, 2006. In 2007, the 80th Texas Legislature passed SB 12, which extended the timeline set in SB 5 through 2007 and made the 5 percent each year a goal instead of a requirement. The State Energy Conservation Office (SECO) is charged

with tracking the implementation of SB 5 and SB 12. Also during the 77th Texas Legislature, the Energy Systems Laboratory (ESL), part of the Texas Engineering Experiment Station, Texas A&M University System, was mandated to provide an annual report on EE/RE efforts in the state as part of the Texas Emissions Reduction Plan (TERP) under Texas Health and Safety Code (THSC), §388.003(e). HB 2129, 79th Texas Legislature, 2005, directed the ESL to collaborate with the TCEQ to develop a methodology for computing emission reductions attributable to use of renewable energy and for the ESL to quantify annually such emission reductions. HB 2129 directed the Texas Environmental Research Consortium to use the Texas Engineering Experiment Station to develop this methodology. With the TCEQ's guidance, the ESL produces an annual report detailing these efforts (*Statewide Air Emissions Calculations from Energy Efficiency, Wind and Renewables)*. The report:

- analyzes power production from wind and other renewable energy sources;
- quantifies energy savings and NO_X reductions resulting from the installation of wind and other renewable energy sources;
- describes methodologies developed to quantify energy savings and NO_X reductions from energy efficiency, wind and other renewable energy initiatives; and
- provides degradation analysis for future predictions of power production of wind farms.

The ESL documents methods used to develop estimates of energy savings and NO_X emission reductions resulting from reductions in natural gas consumption and displaced power from conventional electric generation facilities. The ESL used the EPA's Emissions and Generation Resource Integrated Database to spatially allocate energy use and emission reductions among electric generation facilities. The THSC, §389.002 and §389.003 contain requirements that the Public Utility Commission of Texas (PUCT), SECO, and the ESL report to the TCEQ all emission reductions resulting from EE/RE projects in Texas. The ESL analyzed the following areas/programs:

Renewable Energy
The 79th Texas Legislature, 2005, amended SB 5 through SB 20, HB 2129, and HB 2481 to add, among other initiatives, the following renewable energy initiatives, which require: 5,880 megawatts of generating capacity from renewable energy by 2015; the TCEQ to develop a methodology for calculating emission reductions from renewable energy initiatives and associated credits; the ESL to assist the TCEQ in quantifying emissions reductions from EE/RE programs; and the PUCT to establish a target of 10,000 megawatts of installed renewable technologies by 2025.

Residential Building Codes and Programs
The THSC, Chapter 388, Texas Building Energy Performance Standards, as adopted in SB 5 of the 77th Texas Legislature, 2001, states in §388.003(a) that single-family residential construction must meet the energy efficiency performance standards established in the energy efficiency chapter of the International Residential Code. The Furnace Pilot Light Program includes energy savings accomplished by retrofitting existing furnaces. Also included is a January 2006 federal mandate raising the minimum Seasonal Energy Efficiency Ratio (SEER) for air conditioners in single-family and multi-family buildings from 10 to 13.

Commercial Building Codes
The THSC, Chapter 388, Texas Building Energy Performance Standards, as adopted in SB 5 of the 77th Texas Legislature, 2001, states in §388.003(b) that non-single-family residential, commercial, and industrial construction must meet the energy efficiency performance standards established in the energy efficiency chapter of the International Energy Conservation Code.

Federal Facilities EE/RE Projects
Federal facilities are required to reduce energy use by Presidential Executive Order 13123 and the Energy Policy Act of 2005 (Public Law 109-58 EPACT20065). The ESL compiled energy reductions data for the federal EE/RE projects in Texas.

Political Subdivisions Projects
SECO funds loans for energy-efficiency projects for state agencies, institutions of higher education, school districts, county hospitals, and local governments. Political subdivisions in nonattainment and affected counties are required by SB 5, 77th Texas Legislature, 2001, to report EE/RE projects to SECO. These projects are typically building systems retrofits, nonbuilding lighting projects, and other mechanical and electrical systems retrofits such as municipal water and waste water treatment systems.

Electric Utility Sponsored Programs
Utilities are required by SB 7, 76th Texas Legislature, 1999, and SB 5, 77th Texas Legislature, 2001, to report demand-reducing energy efficiency projects to the PUCT. See THSC, §386.205 and Texas Utilities Code, §39.905. These projects are typically air conditioner replacements, ventilation duct tightening, and commercial and industrial equipment replacement.

In addition to the programs discussed and analyzed in the ESL report, local governments may have enacted measures beyond what has been reported to SECO and the PUCT. The TCEQ encourages local political subdivisions to promote EE/RE measures in their respective communities and to ensure these measures are fully reported to SECO and the PUCT.

HB 3693, 80th Texas Legislature, 2007, amended the Texas Education Code, Texas Government Code, THSC, and Texas Utilities Code. The bill:

- requires state agencies, universities and local governments to adopt energy efficiency programs;
- provides additional incentives for electric utilities to expand energy conservation and efficiency programs;
- includes municipal-owned utilities and cooperatives in efficiency programs;
- increases incentives and provides consumer education to improve efficiency programs; and
- supports other programs such as revision of building codes and research into alternative technology and renewable energies.

Emission reductions resulting from these programs were not explicitly included in the photochemical modeling because local efficiency efforts may not result in local emissions reductions or may be offset by increased demand in electricity. The complex nature of the electrical grid makes accurately quantifying emission reductions from EE/RE projects difficult. At any given time, it is impossible to determine exactly where a specific user's electricity was produced. The electricity for a user in the HGB area could be generated by a power plant in west Texas, in a nearby attainment county, or within the nonattainment area. If electrical demand is reduced in the HGB area due to these local efficiency measures, then emission reductions from power generation facilities may occur in any number of locations around the state.

5.4.3.6 Clean Air Interstate Rule (CAIR)
The EPA projects that CAIR regional controls will improve air quality in the HGB area, as well as most of Texas, according to EPA's Texas CAIR Web page, http://www.epa.gov/cair/tx.html.

Under CAIR, 28 eastern states (plus the District of Columbia) are required to comply with a cap on SO_2 and NO_X for EGU emissions. The definition of an EGU for the CAIR program is approximately the same definition as that for an FCAA Title IV Acid Rain unit (i.e., larger than 25 megawatt (MW) and more than one-third of its generation going to the public grid for sale). CAIR is a cap and trade program, with each of the CAIR-applicable states given a calculated NO_X budget and a calculated SO_2 budget by the EPA. The EPA modeled all of these states in order to test the effectiveness of controls. A result of EPA's CAIR modeling was that Texas "significantly contributed" to the nonattainment of the particulate matter of 2.5 microns and less ($PM_{2.5}$) standard of two counties in Illinois, therefore, Texas was included in CAIR for the transport of $PM_{2.5}$. Texas is not covered under the CAIR program for 1997 eight-hour ozone standard contribution.

CAIR is implemented in two phases: for NO_X, Phase I covers the years 2009 through 2014 and Phase II is for the years 2015 and later; for SO_2, Phase I covers the years 2010 through 2014 and Phase II is for the years 2015 and later. The Phase I NO_X budget calculated and assigned to Texas was 181,014 tons per year, and the Phase II NO_X budget was 150,845. Because 2018 is the HGB ozone attainment year, this SIP revision incorporates CAIR Phase II (post 2014 step-down of CAIR) which provides for a Texas state-wide NO_X budget of 150,845 tons per year, or 413.3 tons per day.

See Appendix B: *Emissions Modeling for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard*, Section 2.3.1.2.1: *EGUs* for the procedural details that the TCEQ used to simulate CAIR Phase II in Texas and the regional states.

On July 11, 2008, the United States Court of Appeals District of Columbia Circuit (Court) (No. 05-1244) vacated CAIR and the CAIR Federal Implementation Plan (FIP). On December 23, 2008, the Court issued a revised opinion to remand, without vacating, CAIR to the EPA. Therefore, CAIR will remain in effect while the EPA analyzes data and conducts rulemaking to modify the program to comply with the Court's July 2008 opinion. The Court declined to impose a schedule by which the EPA must complete the rulemaking, but reminded the EPA that the Court does ". . . not intend to grant an indefinite stay of the effectiveness of this Court's decision." For more information on the ruling, see EPA's CAIR Web page, http://www.epa.gov/cair/, or the TCEQ CAIR/CAMR Web page, http://www.tceq.state.tx.us/implementation/air/sip/caircamr.html.

Any future EPA revision to the CAIR program to comply with the court's ruling may result in additional reductions.

5.4.3.7 Texas Emission Reduction Plan (TERP)

The TERP program was created in 2001 by the 77th Texas Legislature to provide grants to offset the incremental costs associated with reducing NO_X emissions from high-emitting internal combustion engines. To date the TERP program has funded over $780 million in grants for projects in Texas ozone nonattainment and near-nonattainment areas. Over $323 million of that amount has been awarded to projects in the HGB area since 2001, which will help reduce more than 70,000 tons of NO_X emissions, with an estimated 30 tons per day NO_X emissions reduction during 2009. Of that $323 million, $5 million was awarded to the H-GAC through a third-party grant to administer additional grants in the HGB area.

Additional funds are expected to be awarded to the HGB area in subsequent grant application periods that will result in further NO_X reductions. HB 1796, 81st Texas Legislature, 2009, extended the TERP program beyond its current 2013 date to 2019, which will result in continued reductions in the significant emissions source categories of on-road and non-road engines.

5.4.3.8 Low Income Vehicle Repair Assistance, Retrofit, and Accelerated Vehicle Retirement Program (LIRAP)

SB 12, 80th Texas Legislature, 2007, enhanced LIRAP to expand participation by increasing the income eligibility to 300 percent of the federal poverty rate and increasing the amount of assistance toward the replacement of a retired vehicle. The program, known as AirCheckTexas Drive a Clean Machine, provides $3,500 for hybrids of the current or previous model year; $3,000 for cars of the current or three model years; and, $3,000 for trucks of the current or previous two model years. The retired vehicle must be 10 years or older or have failed an emissions test. In the HGB area, the Drive a Clean Machine program is available to vehicle owners in five counties: Brazoria, Fort Bend, Galveston, Harris, and Montgomery. Between December 2007 and August 31, 2009, the program has retired and replaced 11,151 vehicles at a cost of $33,472,000. An additional 3,850 vehicles have had emissions-related repairs at a cost of $2,085,860. The total repair and retirement/replacement funding for the HGB area between December 12, 2007, and August 31, 2009, is $35,557,860. Senate Bill 1, General Appropriations Act, 81st Texas Legislature, 2009, Regular Session, again appropriated $45 million for Fiscal Years 2010 and 2011 to continue this clean air strategy.

5.4.3.9 Clean School Bus Program

HB 3469, 79th Texas Legislature, 2005, established the Clean School Bus Program. The new program is codified in THSC, Chapter 390 and implemented through 30 TAC §§114.640-114.648.

The program is based on the EPA guidance documents, *Improving Air Quality with Economic Incentive Programs* (EPA-452/R-01-001) and *Diesel Retrofits: Quantifying and Using Their Benefits in SIPs and Conformity* (EPA-420-B-06-005). Under the economic incentive program guidance, the TCEQ is using the financial mechanism option, which is described as subsidies targeted at promoting pollution-reducing activities or products.

The Clean School Bus Program was established to provide monetary incentives for school districts in the state for reducing emissions of diesel exhaust from school buses. Eligible technologies include those approved by the EPA, certified by the California Air Resources Board, or those that the commission finds will bring about significant emissions reductions. Some of the technologies eligible for funding under the program reduce NO_X emissions. However, the technologies mainly reduce particulate matter and reduce only negligible amounts of NO_X. The 80th Texas Legislature, 2007, provided funding for the Clean School Bus Program.

As of October 2009, the TCEQ Clean School Bus grant program has allocated approximately $14 million in grants for over 4,500 school buses in Texas. In addition, through Supplemental Environmental Projects (SEPs), the TCEQ has also allocated over $3.5 million to third-party SEP receivers for the same kind of school bus retrofits.

5.4.3.10 81st Texas Legislature, 2009

HB 432 requires state agencies that purchase passenger vehicles or other ground transportation vehicles for general use to ensure that not less than 25 percent of new vehicles purchased during a biennium meet or exceed EPA's Tier II, Bin 3 emission standards. This bill also limits the purchase of state agency passenger vehicles or other ground transportation vehicles purchased for general use to only those vehicles that use compressed natural gas, liquefied natural gas, liquefied petroleum gas, methanol or methanol/gasoline blends of 85 percent or greater, ethanol or ethanol/gasoline blends of 85 percent or greater, biodiesel or biodiesel/diesel blends of 20 percent or greater, or electricity, including electricity to power a plug-in hybrid motor vehicle.

HB 1796 establishes a New Technology Implementation Grants (NTIG) program for facilities and stationary sources under TERP, requires the current New Technology Research and Development under TERP to be administered by the TCEQ, and extends the TERP to August 31, 2019. See Section 5.4.3.6: *Texas Emission Reduction Plan (TERP)*, for additional information.

SB 1759 establishes a Texas Clean Fleet Program to be administered by the TCEQ, funding it with 5 percent of the 87.5 percent of the Emission Reduction Incentives Grant within TERP. The Texas Clean Fleet Program will provide grants to encourage large fleets to replace diesel-powered fleet vehicles with hybrid vehicles or alternative fuel-powered vehicles.

5.4.3.11 American Waterways Operators Tank Barge Emissions Best Management Practices

Using infrared gas imaging technology in field studies conducted in the summer of 2005, the TCEQ detected inadvertent VOC emissions from tank barges operating in the HGB area. The Louisiana Department of Environmental Quality (LDEQ) also detected inadvertent emissions from tank barges in similar field studies conducted in the same time period. In response to these field studies, the American Waterways Operators (AWO) voluntarily developed industry Best Management Practices (BMP) to reduce VOC emissions from tank barges. The BMP includes procedures to reduce VOC emissions from equipment and operations on tank barges. The recommendations are a combination of inspection, corrective action, preventative maintenance, operational, procedural, and training practices.

The BMP was reviewed by the Chemical Transportation Advisory Committee (CTAC), United States Coast Guard, LDEQ, and TCEQ. The BMP was distributed to AWO members in 2006 for implementation on a voluntary basis. In 2009, AWO reconvened the Tank Barge Emissions Working Group to review the BMP and make further improvements to the document. The improved BMP will be sent to CTAC, the Coast Guard, LDEQ, and TCEQ for review once it has been finalized by industry. While the BMP is a voluntary measure and does not impose an enforceable commitment on AWO members, the implementation of the BMP, where applicable, may contribute to reducing inadvertent VOC emissions from barges during dock operations and during transit, which will help improve the air quality in the HGB area. A copy of the 2006 BMP document is provided in Appendix J: *Recommendations for Best Management Practices to Control and Reduce Inadvertent Cargo Vapor Emissions in the Tank Barge Community*.

5.4.3.12 Local Initiative Projects (LIP)

SB 12, 80th Texas Legislature, 2007, allowed the use of unexpended LIRAP funds to be used for LIP. Funds are provided to LIRAP-participating counties for implementation of air quality improvement strategies through local projects and initiatives. LIP may:

- expand and enhance the repair and replacement program;
- develop and implement programs to remotely determine vehicle emissions and notify the vehicle's operator;
- develop and implement projects for coordinating with local law enforcement officials to reduce the use of counterfeit state inspection stickers;
- develop and implement programs to enhance transportation system improvements; or
- develop and implement new air control strategies designed to assist local areas in complying with state and federal air quality rules and regulations.

In the HGB area, the LIP funding is available to the five counties participating in LIRAP: Brazoria, Fort Bend, Galveston, Harris, and Montgomery. In Fiscal Years 2008 and 2009, the participating counties implemented clean vehicle fleet strategies that retired and replaced 75 light-duty and heavy-duty vehicles. Retired vehicles were required to be destroyed and replaced with cleaner, current model-year vehicles. The participating counties have committed to destroying

and replacing another 160 vehicles by August 31, 2010. Brazoria County has elected not to participate in Fiscal Year 2010.

Additionally, Fort-Bend County will use LIP funds to purchase six buses and initiate a new park-and-ride transit service in early 2010. The transit service will link Fort Bend County residents with the Texas Medical Center area and will create immediate and long-term benefits for reducing emissions and congestion by removing single occupancy vehicle trips from Texas State Highway 59.

5.4.3.13 Other Local Programs

The Houston-Galveston Area Council submitted the following programs, which were not committed to as Transportation Control Measures or Voluntary Mobile Emission Reduction Program (VMEP) measures, but may be implemented locally in the HGB area. For a detailed analysis of these programs, see Appendix F: *Evaluation of Mobile Source Control Strategies for the Houston-Galveston-Brazoria State Implementation Plan* (prepared by ENVIRON for the Houston-Galveston Area Council).

Scrappage and Buy-Back Plan

This measure would build on the existing LIRAP, implemented as part of the AirCheckTexas Vehicle Emissions Testing program, by increasing the number of on-road light-duty gasoline vehicles scrapped. The plan would also make separate funds available to help with the purchase of new on-road heavy-duty diesel vehicles (HDDV) to replace old, highly polluting vehicles.

Pay-As-You-Drive Insurance

Pay-As-You-Drive Vehicle Insurance, also called Distance-Based Vehicle Insurance and Mileage-Based Insurance, is a program that allows a vehicle's insurance premiums to be based directly on how many miles the vehicle is driven during the policy term. Currently, vehicle insurance is structured where high-mileage drivers are, in essence, subsidized by low-mileage drivers since all drivers are charged the same premiums after accounting for driving history related to collisions and traffic violations.

Limitations on Idling of Heavy-Duty Vehicles; Creation of Regional Government Idling Restrictions

Idling of vehicles is inherently an inefficient operation that can produce unwanted air pollutants. Idling also occurs during normal driving and other operations such as when the engine powers necessary accessories, known as power take-off, including man-lifts or concrete tumblers. It is not possible to eliminate all idling, but idle reduction programs are typically low in cost and may result in a net savings to the owner/operator of the vehicle while also reducing air emissions.

Encourage/Mandate Livable Centers

The EPA developed the Smart Growth Implementation Assistance (SGIA) program in response to communities' requests for help achieving their development goals. Through this program, the EPA provides technical assistance from private-sector experts to help communities find the best tools and resources for planning growth in ways that sustain environmental and economic progress and create a high quality of life. The Gulf Coast Institute, Main Street Coalition, and Texas A&M partnered to apply for and received an SGIA grant in 2006. While the City of Houston is not participating in the SGIA program at this time, the area has expressed interest in evaluating the potential effects of these measures on travel activity and emissions.

Enhanced Enforcement of Smoking Vehicles

This measure would encourage local law enforcement officers to enforce existing smoking vehicle laws and enable the emissions inspection status of smoking vehicles to be checked.

Owners of smoking vehicles displaying a valid inspection sticker would be fined. Smoking vehicles not having a valid inspection sticker would be impounded if the sticker were found to be fraudulent.

Limitation on Idling of Heavy-Duty Construction Equipment
Idling is an inefficient use of equipment in general and generates unnecessary emissions. Idling however cannot be avoided in all cases, such as during normal work, when work is performed intermittently, and when the time to restart the engine would be considered a significant delay. This measure would seek to limit excessive idling when equipment is not required immediately. Suggested periods for limiting idling could be as little as 15 minutes maximum. Many on-road trucks have factory-installed engine shutdown systems that automatically shut down the engine after a set period, or devices could be added to existing equipment. To implement this measure, engine shutdown systems could be employed with idle timers set to a period that would not cause typical operational problems. Operator training could provide significant idle reduction perhaps beyond engine shutdown systems.

5.5 CONCLUSIONS

The TCEQ has employed several sophisticated technical tools to evaluate the past and present causes and effects of high ozone in the HGB area in an effort to predict the area's future air quality. Photochemical grid modeling performance has been rigorously evaluated. Historical trends in ozone and ozone precursor concentrations and their causes have been investigated exhaustively. The following conclusions can be reached from these evaluations.

First, the photochemical grid modeling performs relatively well. Problems observed with the modeling are those that are known to exist in all photochemical modeling exercises. In spite of the known shortcomings, the model can be used carefully to predict ozone concentrations. The photochemical grid modeling predicts that the control strategy package chosen by the TCEQ can lower the ozone design value in the HGB area down to a value very near the 0.08 ppm eight-hour ozone standard. The dynamic model evaluations show that the model response to emission decreases is less than the response observed in the atmosphere, suggesting that the proposed emission controls are more likely to yield attainment of the 1997 eight-hour ozone standard than the absolute modeled design values indicate.

Second, the ozone trend analyses show that ozone has decreased significantly since the late 1990s, such that the preliminary 2009 eight-hour ozone design value has dropped below the 1997 eight-hour ozone NAAQS. Meteorological variations alone cannot explain the significant downward trend. Decreases in background ozone cannot explain the downward trend either. Significant decreases in ozone precursors, however, coincide with the decreases in ozone, indicating that the ozone decreases observed in the HGB area are due to local emission controls.

Third, many additional air quality improvement measures are being adopted in the HGB area that cannot be included in the photochemical modeling analysis because they cannot be accurately quantified. These additional measures can provide additional assurance that the HGB area is on the path toward attainment.

Based upon the photochemical grid modeling results, these corroborative analyses, and the fact that the preliminary 2006 HGB area design value is 84 ppb, the weight of evidence indicates that the HGB area will attain the 1997 eight-hour ozone standard by June 15, 2019.

5.6 REFERENCES

Banta R., C. Senff, J. Nielsen-Gammon, L. Darby, T. Ryerson, R. Alvarez, P. Sandberg, E. Williams, and M. Trainer, 2005. A bad air day in Houston. Bull. of the American Meteorological Society, 86(5): 657-669.

Bao, J.-W., S. A. Michelson, S. A. McKeen, and G. A. Grell, 2005. Meteorological evaluation of a weather-chemistry forecasting model using observations from the TEXAS AQS 2000 field experiment. J. Geophys. Res. 110(D21105), doi:10.1029/2004JD005024.

Berkowitz, C. M., T. Jobson, G. Jiang, C. W. Spicer, and P. V. Doskey, 2004. Chemical and meteorological characteristics associated with rapid increases of O_3 in Houston, Texas. J. of Geophysical Research, 109:D10307, doi:10.1029/2004JD004141, 2004.

Berkowitz, C. M., C. W. Spicer, P. V. Doskey, 2005. Hydrocarbon observations and ozone production rates in Western Houston during the Texas 2000 Air Quality Study. Atmos. Environ. 39:3383–3396.

Brown, S. G., P. T. Roberts, and J. A. Roney, 2002. Preliminary characterization of 2001 event-triggered VOC and carbonyl samples. STI-900680-2188-IR. Prepared by Steven G. Brown, Paul T. Roberts, Jason A. Roney of Sonoma Technology, Inc. Prepared for Erik Gribbin, Texas Natural Resources Conservation Commission, July 17.

Brown, S. G., and H. Hafner Main, 2002. Acquisition, review and analysis of auto-GC VOC data in the Houston area, 1998-2001: Final report. STI-900670-2224-FR. Prepared by Steven G. Brown and Hilary Hafner Main, Sonoma Technology, Inc. Prepared for Erik Gribbin, Texas Natural Resource Conservation Commission, July 31. http://www.tceq.state.tx.us/assets/public/implementation/air/am/contracts/reports/da/AutoGC_VOC_Data_Houston_Final_Report.pdf

Buzcu, B., and M. P. Fraser, 2006. Source identification and apportionment of volatile organic compounds in Houston, TX, Atmos. Environ., 40:2385-2400.

Byun, D., S. Kim, B. Czader, D. Nowak, S. Stetson, and M. Estes, 2005a. Estimation of biogenic emissions with satellite-derived land use and land cover data for air quality modeling of Houston-Galveston ozone nonattainment area. J. Environ. Mgmt., 75:285-301.

Byun, D.W., Kim, S.-T., Czader, B., Cheng, F.-Y., Kim, S.-B., Percell, P., In, H.-J., Song, C.-K., Coarfa, V., and F.Ngan, 2005b. Role of modeling assumptions in the Houston midcourse review. Project H12 HRB Final Report by University of Houston for HARC, 25 February, Houston, TX, 90 pp.

Byun, D. W., S.-T. Kim, and S.-B. Kim, 2007. Evaluation of air quality models for the simulation of a high ozone episode in the Houston metropolitan area, Atmospheric Environment, 41(4): 837-853.

Camalier, L., Cox, W., and P. Dolwick, 2007. The effects of meteorology on ozone in urban areas and their use in assessing ozone trends. Atmospheric Environment 41, 7127-7137.

Chang, S., E. McDonald-Buller, Y. Kimura, G. Yarwood, J. Neece, M. Russell, P. Tanaka, and D. Allen, 2002. Sensitivity of urban ozone formation to chlorine emission estimates, Atmos. Environ. 36:4991–5003.

Chang, S., and D. Allen, 2006. Atmospheric chlorine chemistry in southeast Texas: Impacts on ozone formation and control. Environ. Sci. Technol. 40:251-262.

Chen, S., Ren, X., Mao, J., Chen, Z., Brune, W.H., Lefer, B., Rappenglück, B., Flynn, J., Olson, J., Crawford, J.H, 2009. A comparison of chemical mechanisms based on TRAMP-2006 field data, Atmospheric Environment (2009), doi: 10.1016/j.atmosenv.2009.05.027

Cheng, F.-Y. and D. W. Byun, 2008a. Application of high resolution land use and land cover data for atmospheric modeling in the Houston-Galveston metropolitan area, Part I: Meteorological simulation results, Atmos. Environ., 42:7795-7811.

Cheng, F.-Y., S. Kim, and D. W. Byun, 2008b. Application of high resolution land use and land cover data for atmospheric modeling in the Houston-Galveston Metropolitan area: Part II: Air quality simulation results, Atmos. Environ., 42:4853-4869.

Cohan, D., Y. Hu, and A. Russell, 2006. Dependence of ozone sensitivity analysis on grid resolution. Atmos. Environ., 40:126-135.

Cowling, E. and the Rapid Science Synthesis Team, 2007. Final Rapid Science Synthesis Report: Findings from the Second Texas Air Quality Study (TexAQS II). A Report to the TCEQ by the TexAQS II Rapid Science Synthesis Team, Prepared by the Southern Oxidants Study Office of the Director, North Carolina State University, Raleigh, North Carolina, August 31.

Czader, B. H., D. W. Byun, S.-T. Kim, and W. P.L. Carter, 2008. A study of VOC reactivity in the Houston-Galveston air mixture utilizing an extended version of SAPRC-99 chemical mechanism, Atmos. Environ., 42, Issue 23, Selected Papers from the First International Conference on Atmospheric Chemical Mechanisms, July, 5733-5742 pp, doi:10.1016/j.atmosenv.2008.01.039.

Daum, P.H., L. I. Kleinman, S. R. Springston, L. J. Nunnermacker, Y.-N. Lee, J. Weinstein-Lloyd, J. Zheng, and C. M. Berkowitz, 2003. A comparative study of O_3 formation in the Houston urban and industrial plumes during the 2000 Texas Air Quality Study. J. of Geophysical Research, 108:4715, doi:10.1029/2003JD003552.

Daum, P.H., L. I. Kleinman, S. R. Springston, L. J. Nunnermacker, Y.-N. Lee, J. Weinstein-Lloyd, J. Zheng, and C. M. Berkowitz, 2004. Origin and properties of plumes of high ozone observed during the Texas 2000 Air Quality Study (TexAQS 2000). J. of Geophysical Research, 109, D17306, doi:10.1029/2003JD004311.

De Gouw, J., S. Te Lintel Hekkert, J. Mellqvist, C. Warneke, E. Atlas, F. Fehsenfeld, A. Fried, G. Frost, F. Harren, J. Holloway, B. Lefer, R. Lueb, J. Meagher, D. Parrish, M. Patel, L. Pope, D. Richter, C. Rivera, T. Ryerson, J. Samuelsson, J. Walega, R. Washenfelder, P. Weibring, and X. Zhu, 2009. Airborne measurements of ethene from industrial sources using laser photo-acoustic spectroscopy, Environ. Sci. Technol., March 9, 10.1021/es802701a.

EPA, 2007. Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze, http://www.epa.gov/scram001/guidance/guide/final-03-pm-rh-guidance.pdf.

EPA, 2009a. Oceangoing Vessels, Emission Control Area Designation, http://www.epa.gov/otaq/oceanvessels.htm#emissioncontrol, Office of Transportation and Air Quality.

EPA, 2009b. Regulatory Announcement: Proposal of Emission Control Area Designation for Geographic Control of Emissions from Ships, EPA-420-F-09-015, Figure 4: Potential Benefits of U.S. ECA Ozone Reductions in 2020, March 2009.

Esler, J. G., 2003. An integrated approach to mixing sensitivities in tropospheric chemistry: A basis for the parameterization of subgrid-scale emissions for chemistry transport models, J. Geophys. Res., 108(D20), 4632, doi:10.1029/2003JD003627.

Estes, M., S. Wharton, D. Boyer, Z. Fang, J. Smith, S. McDowell, F. Mercado, J. Neece, E. Gribbin, and J. Price, 2002. Analysis of Automated Gas Chromatograph Data from 1996-2001 to determine VOCs with largest ozone formation potential. Houston-Galveston-Brazoria Ozone SIP Revision Technical Support Document, Attachment 6, adopted by the TCEQ on December 12, 2002. 50 pp. http://www.tceq.state.tx.us/assets/public/implementation/air/am/docs/hgb/tsd1/attachment6-agc_voc.pdf .

Fang, Z., and S. McDowell, 2003. Analysis of canister data for the Houston-Galveston and Beaumont-Port Arthur areas. Houston-Galveston-Brazoria Ozone Mid-Course Review SIP Revision, Appendix CC of Chapter 4, 15 pp. http://www.tceq.state.tx.us/assets/public/implementation/air/sip/sipdocs/2004-05-HGB/04042sipapcc.pdf . Figures for Appendix CC: http://www.tceq.state.tx.us/assets/public/implementation/air/sip/sipdocs/2004-05-HGB/04042sipapccfigs.zip .

Faraji, M., Y. Kimura, E. McDonald-Buller, and D. Allen, 2008. Comparison of the carbon bond and SAPRC photochemical mechanisms under conditions relevant to southeast Texas, Atmos. Environ. 42:5821-5836, doi.org/10.1016/j.atmosenv.2007.07.048 .

Fast, J. D., W. I. Gustafson Jr., R. C. Easter, R. A. Zaveri, J. C. Barnard, E. G. Chapman, G. A. Grell, and S. E. Peckham, 2006. Evolution of ozone, particulates, and aerosol direct radiative forcing in the vicinity of Houston using a fully coupled meteorology-chemistry-aerosol model, J. Geophys. Res., 111, D21305, doi:10.1029/2005JD006721.

Gego, E., C. Hogrefe, G. Kallos, A. Voudouri, J. Irwin, and S.T. Rao, 2005. Examination of model predictions at different horizontal grid resolutions, Environmental Fluid Mechanics, 5:63-85.

Gilliland, Alice B., Christian Hogrefe, Robert W. Pinder, James M. Godowitch, Kristen L. Foley, and S.T. Rao, 2008. Dynamic evaluation of regional air quality models: Assessing changes in O3 stemming from changes in emissions and meteorology, Atmospheric Environment, In Press, Accepted Manuscript, Available online February 21.

Gilman, J., W. Kuster, P. Goldan, S. Herndon, M. Zahniser, S. Tucker, A. Brewer, B. Lerner, E. Williams, R. Harley, F. Fehsenfeld, C. Warneke, and J. de Gouw. 2009, Measurements of volatile organic compounds during the 2006 TexAQS/GoMACCS campaign: Industrial influences, regional characteristics, and diurnal dependencies of the OH reactivity, J. Geophys. Res., 114, D00F06, doi:10.1029/2008JD011525.

Hafner Main, H., T. O'Brien, C. Hardy, S. Wharton, and D. Sullivan, 2001. Characterization of auto-GC data in Houston, prepared for Jim Price of the Texas Natural Resource Conservation Commission, August 31, 81 pp.

http://www.tceq.state.tx.us/assets/public/implementation/air/am/contracts/reports/da/CharacterizationAutoGCdata.pdf

Hafner, H. and S. Brown, 2003. Exploratory Source Apportionment of Houston's Clinton Drive Auto-GC 1998-2001 Data. Prepared for Erik Gribbin, Texas Commission on Environmental Quality, May 15, 144 pp. http://www.tceq.state.tx.us/assets/public/implementation/air/am/contracts/reports/da/Source_Apportionment_of_AutoGC_Data.pdf

Hardesty, M., C. Senff, R. Alvarez, R. Banta, S. Sandberg, A. Weickmann, L. Darby, Y. Pichugina, D. Law, R. Marchbanks, W. Brewer, D. Merritt, and J. Machol, 2007. Mixing heights and three-dimensional ozone structure observed by airborne lidar during the 2006 Texas Air Quality Study. AGU Fall Meeting 2007, A51G-02.

Hu D., M. Tolocka, Q. Li, and R. Kamens, 2007. A kinetic mechanism for predicting secondary organic aerosol formation from toluene oxidation in the presence of NO_X and natural sunlight. Atmos. Environ. 41:6478-6496.

Jiang, G. and J. Fast, 2004. Modeling the effects of VOC and NO_X emission sources on ozone formation in Houston during the TexAQS 2000 field campaign. Atmos. Environ. 38:5071-5085.

Jobson, B. T., C. M. Berkowitz, W. C. Kuster, P. D. Goldan, E. J. Williams, F. C. Fesenfeld, E. C. Apel, T. Karl, W. A. Lonneman, and D. Riemer, 2004. Hydrocarbon source signatures in Houston, Texas: Influence of the petrochemical industry, J. Geophys. Res., 109, D24305, doi:10.1029/2004JD004887.

Jolly, J., S. McDowell, B. Kurka, F. Mercado, J. Neece, and G. Cantú, 2003. Analyzing VOC reactivity in Houston. December 13, 2003. Houston-Galveston-Brazoria Ozone Mid-Course Review SIP Revision, Appendix GG of Chapter 4, adopted December 1, 2004, 36 pp. http://www.tceq.state.tx.us/assets/public/implementation/air/sip/sipdocs/2004-05-HGB/04042sipapgg_pro.pdf .

Jolly, J, 2003. Assessing the importance of carbonyl compounds in ozone formation in Houston-Galveston: Relative reactivities of carbonyl and hydrocarbon species. May 2003, updated May 3, 2004. Houston-Galveston-Brazoria Ozone Mid-Course Review SIP Revision, Appendix EE of Chapter 4, 13 pp. http://www.tceq.state.tx.us/assets/public/implementation/air/sip/sipdocs/2004-05-HGB/04042sipapee_pro.pdf .

Karl, T., T. Jobson, W. C. Kuster, E. Williams, J. Stutz, R. Shetter, S. R. Hall, P. Goldan, F. Fehsenfeld, and W. Lindinger, 2003. Use of proton-transfer-reaction mass spectrometry to characterize volatile organic compound sources at the La Porte super site during the Texas Air Quality Study 2000, J. Geophys. Res., 108(D16), 4508, doi:10.1029/2002JD003333, 2003.

Kemball-Cook, S., C. Emery, and G. Yarwood, 2005. Impact and role of air quality modeling assumptions in the development of revisions to the Houston State Implementation Plan for attaining the ozone air quality standard, HARC project H12.8HRB, Final Report, March.

Kim, E., S. G. Brown, H. R. Hafner, and P. K. Hopke, 2005. Characterization of non-methane volatile organic compounds sources in Houston during 2001 using positive matrix factorization, Atmos. Environ., 39:5934-5946.

Kleinman L. I., P. H. Daum, D. Imre, Y.-N. Lee, L. J. Nunnermacker, S. R. Springston, J. Weinstein-Lloyd, and J. Rudolph, 2002. Ozone production rate and hydrocarbon reactivity in 5 urban areas: A cause of high ozone concentration in Houston, Geophys. Res. Lett., 29 (10), doi:10.1029/2001GL014569.

Kleinman, L. I., P. H. Daum, Y.-N. Lee, L. J. Nunnermacker, S. R. Springston, J. Weinstein-Lloyd, and J. Rudolph, 2005. A comparative study of ozone production in five U.S. metropolitan areas, J. Geophys. Res., 110, D02301, doi:10.1029/2004JD005096.

Koo, B., G. Yarwood, and D. Cohan, 2008. Higher-Order Decoupled Direct Method (HDDM) for Ozone Modeling Sensitivity Analyses and Code Refinements, Work order 582-07-84005-FY08-07, August 31.

Langford A., C. Senff, R. Banta, R. Hardesty, R. Alvarez, S. Sandberg, L. Darby, 2009. Regional and local background ozone in Houston during TexAQS 2006, J. Geophys. Res. 114, doi: 10.1029/2008JD011687

Lelieveld, J., T. Butler, J. Crowley, T. Dillon, H. Fischer, L. Ganzeveld, H. Harder, M. Lawrence, M. Martinez, D. Taraborrelli, and J. Williams, 2008. Atmospheric oxidation capacity sustained by a tropical forest, Nature, 452, doi: 10.1038/nature06870, 10 April 2008.

Li, S., J. Matthews, and A. Sinha, 2008. Atmospheric hydroxyl radical production from electronically excited NO2 and H2O, Science, 319: 1657, doi: 10.1126/science.1151443.

Mao, J., Ren, X., Chen, S., Brune, W.H., Chen, Z., Martinez, M., Harder, H., Lefer, B., Rappenglück, B., Flynn, J., and M. Leuchner, 2009. Atmospheric Oxidation Capacity in the Summer of Houston 2006: Comparison with Summer Measurements in Other Metropolitan Studies, Atmospheric Environment, doi: 10.1016/j.atmosenv.2009.01.013

Mellqvist, J., J. Samuelsson, C. Rivera, B. Lefer, and M. Patel, 2007. Measurements of industrial emissions of VOCs, NH_3, NO_2 and SO_2 in Texas using the Solar Occultation Flux method and mobile DOAS, Final Report HARC project H-53, August 20,.http://www.tercairquality.org/AQR/Projects/H053.2005

Mellqvist, J., J. Johansson, J. Samuelsson, C. Rivera, B. Lefer, and S. Alvarez, 2008. Comparison of solar occultation flux measurements to the 2006 TCEQ emission inventory and airborne measurements for the TexAQS II, November 7, Report submitted to the TCEQ.

Morris, G., S. Hersey, A. Thompson, S. Pawson, E. Nielsen, P. Colarco, W. McMillan, A. Stohl, S. Turquety, J. Warner, B. Johnson, T. Kucsera, D. Larko, S. Oltmans, and J. Witte, 2006. Alaskan and Canadian forest fires exacerbate ozone pollution over Houston, Texas, on 19 and 20 July 2004, J. Geophys. Res., 111, D24S03, doi:10.1029/2006JD007090.

Mount, G., 2009. Measurements of Formaldehyde Fluxes in Houston, Texas, Final Report, HARC project H104A, prepared for Texas Environmental Research Consortium and Houston Advanced Research Center, 7 December 2009, pp.35.

Murphy, C. F. and D. T. Allen, 2005. Hydrocarbon emissions from industrial release events in the Houston-Galveston area and their impact on ozone formation, Atmos. Environ. 39:3785–3798.

Nam, J., Y. Kimura, W. Vizuete, C. Murphy, and D. T. Allen, 2006. Modeling the impacts of emission events on ozone formation in Houston, Texas, Atmos. Environ., 40:5329-5341.

Nam, J., M. Webster, Y. Kimura, H. Jeffries, W. Vizuete, and D. T. Allen, 2008. Reductions in ozone concentrations due to controls on variability in industrial flare emissions in Houston, Texas, Atmos. Environ., 42:4198-4211, doi:10.1016/j.atmosenv.2008.01.035 .

Nielsen-Gammon, J., J. Tobin, and A. McNeel, 2005. A Conceptual Model for Eight-Hour Ozone Exceedances in Houston, Texas, Part I: Background Ozone Levels in Eastern Texas. Research report, supported by HARC, TERC, and TCEQ, HARC project H012.2004.8HRA, January 29.

Nielsen-Gammon, J. W., R. T. McNider, W. M. Angevine, A. B. White, and K. Knupp, 2007. Mesoscale model performance with assimilation of wind profiler data: Sensitivity to assimilation parameters and network configuration, J. Geophys. Res., 112, D09119, doi:10.1029/2006JD007633.

North, S. and B. Ghosh, 2009. Refining hydrocarbon oxidation mechanisms via isomeric specific radical initiated chemistry, Final Report. TCEQ tracking number 2008-93, Grant Activity No. 582-5-64593-FY08-22. 16 pp.

Osthoff, H., J. Roberts, A. Ravishankara, E. Williams, B. Lerner, R. Sommariva, T. Bates, D. Coffman, P. Quinn, J. Dibb, H. Stark, J. Burkholder, R. Talukdar, J. Meagher, F. Fehsenfeld, and S. Brown, 2008. High levels of nitryl chloride in the polluted subtropical marine boundary layer. Nature Geoscience doi: 10.1038/ngeo177, published online April 6.

Pinder, R., R. Gilliam, K. W. Appel, S. Napelenok, K. Foley, and A. Gilliland, 2009. Efficient probabilistic estimates of surface ozone concentration using an ensemble of model configurations and direct sensitivity calculations, Environ. Sci. Technol., Article ASAP, March 3, doi: 10.1021/es8025402.

Pour-Biazar, A. R. McNider, S. Roselle, R. Suggs, G. Jedlovec, D. Byun, S. Kim, C. Lin, T. Ho, S. Haines, B. Dornblaser, and R. Cameron, 2007. Correcting photolysis rates on the basis of satellite observed clouds, J. Geophys. Res., 112, D10302, doi:10.1029/2006JD007422.

Rivera, C., J. Mellqvist, J. Samuelsson, B. Lefer, S. Alvarez, and M. R. Patel, 2009. Quantification of NO2 and SO2 emissions from the Houston Ship Channel and Texas City industrial areas during the 2006 Texas Air Quality Study, J. Geophys. Res., doi:10.1029/2009JD012675, in press.

Robinson, R., T. Gardiner, and B. Lipscombe, 2008. Measurements of VOC emissions from petrochemical industry sites in the Houston area using Differential Absorption Lidar (DIAL) during summer 2007, Draft. Submitted to Russell Nettles, TCEQ, by Rod Robinson, Tom Gardiner, and Bob Lipscombe of the National Physical Laboratory, Teddington, Middlesex UK TW11 0LW, February 8, 86 pp.

Ryerson, T. B., M. Trainer, W. M. Angevine, C. A. Brock, R. W. Dissly, F. C. Fehsenfeld, G. J. Frost, P. D. Goldan, J. S. Holloway, G. Huebler, R. O. Jakoubek, W. C. Kuster, J. A. Neuman, D. K. Nicks Jr., D. D. Parrish, J. M. Roberts, and D. T. Sueper, E. L. Atlas, S. G. Donnelly, F. Flocke, A. Fried, W. T. Potter, S. Schauffler, V. Stroud, A. J. Weinheimer, B. P. Wert, and C. Wiedinmyer, R. J. Alvarez, R. M. Banta, L. S. Darby, and C. J. Senff, 2003. Effect of

petrochemical industrial emissions of reactive alkenes and NO_X on tropospheric ozone formation in Houston, Texas. J. of Geophysical Research, 108:4249, doi:10.1029/2002JD003070.

Sarwar, G., and P.V. Bhave, 2007. Modeling the Effect of Chlorine Emissions on Ozone Levels over the Eastern United States. J. Appl. Meteor. Climatol., 46**:**1009–1019.

Savanich, K., 2006. Ozone Exceedance Days as a Function of the Number of Monitors. Unpublished analysis for TCEQ, February.

Simon H., Y. Kimura, G. McGaughey, D. T. Allen, S. S. Brown, H. D. Osthoff, J. M. Roberts, D. Byun, and D. Lee, 2009. Modeling the impact of ClNO 2 on ozone formation in the Houston area, J. Geophys. Res., 114, D00F03, doi:10.1029/2008JD010732.

Smith, J. and J. Jarvie, 2008. Reconciling reported VOC emissions with ambient measurements, continued. Presented at Southeast Texas Photochemical Modeling Technical Committee Meeting, February 12. http://www.tceq.state.tx.us/assets/public/implementation/air/am/committees/pmt_set/20080212/20080212-smith-voc_emissions_ambient_measurements.pdf .

Smylie M., 2004. Further investigation of gas-imaging devices as an alternative to current leak detection and repair methods and the development of correlation equations for the ethylene industry. Prepared for the Texas Council on Environmental Technology, Austin, Texas, by Environ International Corporation, Mountain View, California, June 25, 145 pp.

Stuart, A. L., A. Aksoy, F. Zhang, and J. W. Nielsen-Gammon, 2007. Ensemble-based data assimilation and targeted observation of a chemical tracer in a sea breeze model, Atmos. Environ., 41:3082-3094.

Sullivan, D., 2009. Effects of Meteorology on Pollutant Trends. Final Report to TCEQ. Grant Activities No. 582-5-86245-FY08-01. Prepared by Dave Sullivan, University of Texas at Austin Center for Energy and Environmental Resources, Prepared for Kasey Savanich, for the Texas Commission on Environmental Quality, March 16. http://www.tceq.state.tx.us/assets/public/implementation/air/am/contracts/reports/da/5820586245FY0801-20090316-ut-met_effects_on_pollutant_trends.pdf

Swall, J. and K. Foley, 2009. The impact of spatial correlation and incommensurability on model evaluation. Atmos. Environ. 43:1204-1217, doi:10.1016/j.atmosenv.2008.10.057.

Tanaka, P., D. Allen, and C. Mullins, 2003. Development of a chlorine mechanism for use in the carbon bond IV chemistry model. J. Geophys. Res., 108(D4): 4145, doi:10.1029/2002JD002432.

TCEQ, 2002. Houston-Galveston-Brazoria Attainment SIP Revision for the 1-hour ozone NAAQS, Technical Support Document, and Appendices and Attachments, December 13, 2002, http://www.tceq.state.tx.us/implementation/air/sip/dec2002hgb.html#docs
http://www.tceq.state.tx.us/implementation/air/airmod/docs/hgmcr_tsd.html

TCEQ, 2004. Houston-Galveston-Brazoria Ozone SIP Mid-Course Review Modeling, proposed June 23, 2004, http://www.tceq.state.tx.us/implementation/air/sip/dec2004hgb_mcr.html . Modeling files available at http://www.tceq.state.tx.us/implementation/air/airmod/data/hgb1.html#docs

TCEQ, 2006. Houston-Galveston-Brazoria 8-Hour Ozone SIP Modeling, September 21, 2006, Modeling of August 16 - September 6, 2000
http://www.tceq.state.tx.us/implementation/air/airmod/data/hgb2.html
www.tceq.state.tx.us/assets/public/implementation/air/sip/hgb/hgb_sip_2006/06027SIP_proCh2.pdf
www.tceq.state.tx.us/assets/public/implementation/air/sip/hgb/hgb_sip_2006/06027SIP_proCh3.pdf

Valari, M. and L. Menut, 2008. Does an increase in air quality models' resolution bring surface ozone concentrations closer to reality? J. Atmospheric and Oceanic Technology, 25:1955, doi: 10.1175/2008JTECHA1123.1.

Webster, M., J. Nam, Y. Kimura, H. Jeffries, W. Vizuete, and D. T. Allen, 2007. The effect of variability in industrial emissions on ozone formation in Houston, Texas, Atmos. Environ. 41:9580–9593.

Wert, B. P., M. Trainer, A. Fried, T. B. Ryerson, B. Henry, W. Potter, W. M. Angevine, E. Atlas, S. G. Donnelly, F. C. Fehsenfeld, G. J. Frost, P. D. Goldan, A. Hansel, J. S. Holloway, G. Hubler, W. C. Kuster, D. K. Nicks Jr., J. A. Neuman, D. D. Parrish, S. Schauffler, J. Stutz, D. T. Sueper, C. Wiedinmyer, and A. Wisthaler, 2003. Signatures of terminal alkene oxidation in airborne formaldehyde measurements during TexAQS 2000. J. of Geophysical Research, 108:4104, doi:10.1029/2002JD002502.

Xie, Y., and C. M. Berkowitz, 2006. The use of positive matrix factorization with conditional probability functions in air quality studies: An application to hydrocarbon emissions in Houston, Texas, Atmos. Environ., 40:3070-3091.

Xie, Y., and C. M. Berkowitz, 2007. The use of conditional probability functions and potential source contribution functions to identify source regions and advection pathways of hydrocarbon emissions in Houston, Texas, Atmos. Environ., 41:5831-5847.

Yarwood, G., T. Stoeckenius, and S. Lau, 2004. Top-down evaluation of the Houston emission inventory using inverse modeling. Project H006E.2002, Final Report to the Texas Environmental Research Consortium, available at: http://www.tercairquality.org/AQR/Projects/H006E.2002

Zamora, R. J., E. G. Dutton, M. Trainer, S. A. McKeen, J. M. Wilczak, and Y.-T. Hou, 2005. The accuracy of solar irradiance calculations used in mesoscale numerical weather prediction, Mon. Weather Rev., 133:783–792.

Zhang, F., N. Bei, J. W. Nielsen-Gammon, G. Li, R. Zhang, A. Stuart, and A. Aksoy, 2007. Impacts of meteorological uncertainties on ozone pollution predictability estimated through meteorological and photochemical ensemble forecasts, J. Geophys.Res., 112, D04304, doi:10.1029/2006JD007429.

Ziemba, L.D., Dibb, J.E., Griffin, R.J., Anderson, C.H., Whitlow, S.I., Lefer, B.L., Rappenglück, B., and J. Flynn, 2009. Heterogeneous conversion of nitric acid to nitrous acid on the surface of primary organic aerosol in an urban atmosphere, Atmospheric Environment, doi:10.1016/j.atmosenv.2008.12.024.

Zhong, S., H. In, and C. Clements (2007), Impact of turbulence, land surface, and radiation parameterizations on simulated boundary layer properties in a coastal environment, *J. Geophys. Res.*, 112, D13110, doi:10.1029/2006JD008274.

CHAPTER 6: ONGOING AND FUTURE INITIATIVES

6.1 INTRODUCTION

The Texas Commission on Environmental Quality (TCEQ) is committed to improving the air quality in the Houston-Galveston-Brazoria (HGB) area and continues to work toward identifying and reducing ozone precursors. Texas is investing resources into technological research and development for advancing pollution control technology, improving the science for ozone modeling and analysis, and refining quantification of volatile organic compounds (VOC) emissions. Refining quantification of VOC emissions benefits the state implementation plan (SIP) by improving understanding of ozone formation. Additionally, the TCEQ is working with the United States Environmental Protection Agency (EPA), local area leaders, and the scientific community to identify new measures for reducing ozone precursors. This chapter describes ongoing technical work that will be beneficial to improving air quality in Texas and the HGB area.

6.2 ONGOING WORK

6.2.1 Flare Task Force

In November 2008, the TCEQ formed an agency-wide Flare Task Force to comprehensively evaluate the impact of flare emissions on Texas air quality and assess the adequacy of existing flare regulations. Some of the specific issues under evaluation include: the contribution of flare emissions to air quality issues, with an emphasis on air toxics and ozone; the operational factors affecting flare efficiency, such as waste gas flow rates, turndown ratio, and waste gas to steam assist ratios; the adequacy of existing flare monitoring requirements; and alternatives to flaring non-emergency process streams. A stakeholder group associated with the task force has been formed to promote open communication about flare issues and provide a platform for stakeholder involvement in the evaluation process. Additionally, as discussed in Section 6.2.2.3: *Flare Study*, the TCEQ is planning research to assist in the agency's ongoing evaluation of flares. The Flare Task Force is developing recommendations and options for executive management consideration regarding these issues. The TCEQ may consider additional requirements for flares in a future SIP revision based on this evaluation. Additional information about the Flare Task Force is available at the stakeholder Web site:
http://www.tceq.state.tx.us/implementation/air/rules/flare_stakeholder.html.

6.2.2 Technologies for Detecting VOC

6.2.2.1 Optical Gas Imaging Technology

Optical gas imaging technology offers a unique technological advancement in pollution detection capability and has proved to be highly effective in detecting VOC emissions. Optical gas imaging systems assist the agency in actions such as facility investigations, reconnaissance investigations, mobile monitoring, and special projects. This technology is also useful for identifying sources of VOC emissions that are underestimated, underreported, unreported, or previously unregulated. Examples of how the TCEQ uses this technology include: offsite surveillance to identify potential sources of contaminants in response to ambient or other monitoring results; identification of sites, or areas within a specific site, where a focused investigation may be conducted; identification of potential source control strategies or to assist in assessments of existing strategies; and identification of sources for emissions inventory issues.

Optical gas imaging technology also has the potential to advance leak detection and repair (LDAR) work practices and enable monitoring of components that are difficult to monitor with traditional LDAR methods. Rulemaking was proposed at the December 9, 2009, agenda (TCEQ Rule Project Number 2009-030-115-EN) to allow the optional use of optical gas imaging technology as an alternative work practice for several LDAR rules in 30 Texas Administrative Code (TAC) Chapter 115. This proposed rulemaking would allow an alternative work practice similar to the federal alternative work practice adopted in December 2008 by the EPA in 40 Code of Federal Regulations (CFR) Part 60, §60.18.

The TCEQ has technical and enforcement concerns associated with the regulatory implementation of this technology. The current state of optical gas imaging technology has some technical limitations, e.g., commercially available instruments are not capable of quantifying VOC emissions or speciating contaminants. Additionally, effective use of optical gas imaging technology is highly dependent on the training and experience of the instrument operator. The proposed Chapter 115 rulemaking includes some additional requirements for using optical gas imaging technology for LDAR to address these concerns. However, optical gas imaging technology provides opportunities for more rapid detection and repair of VOC emission leaks. The TCEQ encourages the use of optical gas imaging technology to find sources of VOC emissions in a manner that ensures that the technology is being used effectively.

6.2.2.2 Open Path Sensing Technology

Open path sensing technology generally allows specific pollutants to be rapidly monitored or measured over a given distance (10 meters up to several kilometers). Some of these techniques, such as solar occulation flux (SOF), differential absorption lidar (DIAL), and imaging differential optical absorption spectroscopy (I-DOAS) are able to monitor air pollutants not only at ground level but also along a given path length in the sky, which allows measurements of elevated sources such as flares, vents, and storage tanks. This information coupled with meteorological measurements and modeling tools can potentially provide emission estimates not otherwise available. These data can be helpful in evaluating actual emissions from specific sources. These measurement techniques also have limitations or challenges that include the following.

- These techniques are non-separatory, i.e., they do not physically isolate the chemical or chemicals of interest from other constituents, and as such are more prone to interference.
- These technologies normally measure a path length average concentration or number of molecules and as such do not provide a specific concentration at any given point. Therefore, results can be difficult to compare with standards or guideline concentrations.
- The complex instrumentation necessary for open path measurement can have limited commercial availability and requires both a highly experienced operator and data analyst to obtain quality data. In some cases, such as SOF and DIAL, there may be only a few operational instruments and qualified personnel in the world, which limits the ability of Texas to either acquire and operate the instrumentation or contract operation on anything but an intermittent basis.

DIAL Remote Sensing Technology

The TCEQ continued to advance the science of determining emissions from industrial sources by performing a five-week emissions monitoring study in the Texas City area during the summer of 2007. For the first time, a regulatory agency in the United States used a mobile DIAL remote sensing technology to measure emissions from unique sources at industrial sites. The study, funded by the EPA and the TCEQ, focused on gathering data from industrial sources that are difficult to measure using conventional sampling techniques. The resulting scientific data and future studies will help guide future research efforts and may result in additional control measures and refined emissions models for common sources.

The TCEQ contracted with the National Physical Laboratory (NPL), based in the United Kingdom, to perform DIAL measurements on industrial emissions sources located in a refinery and a storage terminal near Houston during 2007.

Measurements focused on those industrial sources that are difficult to measure using conventional sampling techniques. Specifically, the study involved:

- identifying potentially under-reported industrial emissions source types;
- conducting remote sensing measurements of these sources;
- collecting process and operational data from these sources; and

- comparing emissions determined using conventional EPA-approved determination methods to the remote sensing measurements.

The NPL submitted a draft report in February 2008, which is expected to be finalized in January 2010. An independent third party compared remote sensing measurements to conventionally determined emissions. Although these results are still being analyzed, preliminary total VOC measurements indicate that flare emissions may be underestimated when emissions are determined using conventional material balance calculation methods. Additionally, preliminary results as well as other research indicate flare destruction and removal efficiency (DRE) may be reduced during certain operating conditions, such as combusting small volumes of waste gas and during flare air- or steam-assist operations.

These preliminary results indicate the need to conduct a study that determines the relationship between flare design, operation, and DRE (see section 6.2.2.3: *Flare Study*).

Helicopter-Mounted DIAL Imaging System
The TCEQ completed field work in June 2009 to demonstrate the capabilities of a helicopter-mounted DIAL. The DIAL system used for this study was originally developed to detect methane leaks during flyovers of gas pipelines. The system has been used extensively and successfully to detect pipeline leaks and has achieved detection limits at concentrations lower than 5 parts per million (ppm) for methane. Laboratory trials have shown instrument sensitivity to be approximately 100 ppm for benzene. However, the DIAL instrument was tuned and adjusted during flight measurements to improve its benzene sensitivity.

The study also assessed the DIAL system's ability to locate sources of benzene emissions from industrial facilities in the Houston Ship Channel area. While the primary purpose of this project was to determine the benzene detection capabilities of a helicopter-mounted DIAL, results from this project could also be used to determine potentially unreported or underreported sources of benzene. Successful location of benzene sources in the surveyed areas may show the potential benefit of a full-scale survey of the entire Houston Ship Channel as well as other industrial areas. A final report was submitted to the agency in August 2009 and the agency's final evaluation of the technology is anticipated to be completed by the spring of 2010.

6.2.2.3 Flare Study
The TCEQ is funding a flare research study at a controlled testing facility to examine the impact of various operational conditions on flare combustion efficiency and destruction and removal efficiency. Direct measurement techniques and remote sensing measurement techniques will be used to quantify flare emissions under varying waste gas flow rates, assist gas flow rates, and waste gas stream heat content. Analysis of the process and operational data collected will allow comparisons between traditional flare material balance emissions determinations, process stream measurements, and the emissions rates and concentrations measured by the direct and remote sensing technologies. The TCEQ anticipates that the results of the laboratory tests will be broadly applicable, since these measurements will be conducted under controlled conditions.

The primary study objectives include:

- assessing the potential impact of waste stream flow rate turndown on flare DRE and combustion efficiency;
- assessing the potential impact of steam/air assist on flare DRE and combustion efficiency at various operating conditions, including low flow rate conditions;
- assessing whether flares operating over the range of requirements stated in 40 Code of Federal Regulations §60.18 achieve the assumed hydrocarbon DRE of 98 percent at varying flow-rate turndown and assist ratios as well as variable waste stream heat content; and
- identifying and quantifying the hydrocarbon species in flare plumes.

Field tests should be conducted during the spring of 2010, depending on approval of the final test plan and the availability of a test facility. A draft report is expected during the summer of 2010.

6.2.2.4 Study of Houston Atmospheric Radical Precursors (SHARP)

An extensive field study of ozone precursors and formation was conducted in the HGB area in April, May, and June 2009 using cutting-edge measurement technology. Approximately $2 million of air quality research funds for this project were provided by the state legislature. The goal of the SHARP study is to investigate the:

- contribution of direct emissions of formaldehyde and nitrous acid from flares, stacks, and other point and mobile sources;
- importance of secondary formation of formaldehyde from the ozonolysis of olefins;
- identification of formation pathways of nitrous acid;
- ambient levels of nitryl chloride and potential impact as an ozone precursor; and
- spring and early summer ozone formation mechanisms in the HGB area.

This study included the use of several cutting-edge measurement techniques including SOF, Multi-Axis Differential Optical Absorption Spectroscopy (MAX-DOAS), I-DOAS, quantum cascade laser, and non-dispersive infrared gas analyzer to provide real-time measurement of specific pollutants. The data from this study will be analyzed in 2009 and 2010 and used to better understand the HGB area emissions and chemistry, enhance model inputs and mechanisms, and aid in the evaluation of control strategy development.

6.3 FUTURE INITIATIVES

6.3.1 Mid-Course Review (MCR)

The commission solicited comments on whether it is appropriate to perform a 1997 eight-hour ozone standard MCR analysis for the HGB area, and, if so, what elements should be contained in the analysis. The commission also requested input on the appropriate date to submit the MCR.

Comments regarding MCR were received from the EPA, League of Women Voters of the Houston Area, Houston-Galveston Area Council, Texas Chemical Council, Environmental Defense Fund, and Galveston-Houston Association for Smog Prevention. Summaries of the comments are included in the Response to Comments Received Regarding the HGB 1997 Eight-Hour Ozone Attainment Demonstration SIP Revision.

In response to comments, the executive director will perform a 1997 eight-hour ozone MCR and, with commission approval, submit the results to the EPA concurrently with a SIP revision for the EPA's revised ozone standard, which is scheduled to be submitted to the EPA no later than December 2013. In the event that the schedule for the revised ozone standard is changed by the EPA, the schedule for the MCR submission will change accordingly. For further information on the EPA's ozone standard revision, see Section 6.3.2: *2008 and 2010 Ozone National Ambient Air Quality Standard (NAAQS)* of this chapter.

The MCR will involve a thorough evaluation of all modeling, inventory data, and other tools and assumptions used to develop the attainment demonstration. This effort will include a review of the control measures, weight of evidence, and contingency plan. The MCR will contain further evaluation of the potential state and federal measures listed in Chapter 4: *Control Strategies and Required Elements*, Section 4.9: *Contingency Plan* and any other new programs or regulations. The MCR will also allow the commission to include additional measures adequate to fulfill the 3 percent adjusted base year contingency requirement as shown in Chapter 4: *Control Strategies and Required Elements*, Table 4-3: *2019 Contingency Demonstration for the HGB Area*. This MCR will also include the ongoing assessment of new technologies and innovative ideas for possible inclusion into the plan.

6.3.2 2008 and 2010 Ozone National Ambient Air Quality Standard (NAAQS)

On March 12, 2008, the EPA lowered the primary and secondary NAAQS for ground-level ozone from 0.08 ppm to 0.075 ppm. Governor Rick Perry submitted the state's recommendation regarding boundaries and designations under the federal 2008 eight-hour ozone standard to the EPA on March 10, 2009. The HGB area (Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller Counties) was included in the governor's recommended nonattainment areas for the 2008 eight-hour ozone standard. On September 16, 2009, the EPA announced that it would reconsider the 2008 primary and secondary ozone standards. The EPA stayed the 2008 ozone standards for the purpose of attainment and nonattainment area designations and indicated it would retain the existing 1997 eight-hour ozone standard of 0.08 ppm.

On January 7, 2010, the EPA proposed to lower the eight-hour primary ozone standard to a level within the range of 0.060 to 0.070 ppm. The EPA also proposed a distinct cumulative, seasonal secondary standard within the range of 7 to 15 ppm-hours. The proposed secondary standard is formed by a cumulative peak-weighted index, called W126. The EPA is scheduled to issue the final standards by August 31, 2010.

The EPA proposed an accelerated schedule for designating areas for the primary ozone standard and solicited comment on whether to designate areas for a seasonal secondary standard on an accelerated schedule or a two-year schedule. According to the EPA's accelerated schedule, state recommendations regarding nonattainment areas for the 2010 standard are scheduled to be due to the EPA by January 2011. Final ozone nonattainment area designations are scheduled to be issued by July 2011 and become effective in August 2011. Nonattainment area SIP revisions are scheduled to be due to the EPA in December 2013. Continued efforts to reduce ozone precursors will be necessary to address this new ozone standard.

Appendices are located at:
http://www.tceq.state.tx.us/implementation/air/sip/hgb.html

For persons who do not have access to the Internet, please contact:

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Response to Comments Received Regarding the
Houston-Galveston-Brazoria (HGB)
1997 Eight-Hour Ozone Attainment Demonstration
State Implementation Plan (SIP) Revision

Public hearings for this proposed attainment demonstration SIP revision and associated rulemakings were held on October 28, 2009, at 2:00 p.m. and 6:00 p.m., at the Houston-Galveston Area Council offices in Houston; and on October 29, 2009, at 3:00 p.m., at the Texas Commission on Environmental Quality (TCEQ) headquarters in Austin. Question and answer sessions were held 30 minutes prior to the hearings. Neither the October 28, 2009, hearing scheduled for 6:00 p.m. nor the October 29, 2009, hearing were officially opened because no party indicated a desire to provide comment. Five persons presented oral comments concerning this attainment demonstration SIP revision at the public hearing held at 2:00 p.m. on October 28, 2009, in Houston.

The public comment period opened October 9, 2009, and closed November 9, 2009. The commission received comments from the 8-Hour Ozone SIP Coalition (Coalition), Albemarle Corporation (Albemarle), AmericanAcryl, Arkema Inc. (Arkema), BCCA Appeal Group (BCCA), City of Houston (COH), Clean Air Institute of Texas (CAIT), Environmental Defense Fund (EDF), Galveston-Houston Association for Smog Prevention (GHASP), Houston Sierra Club (HSC), Houston-Galveston Area Council (H-GAC), Kaneka Texas Corporation (Kaneka), KIDS for Clean Air (KIDS), League of Women Voters of the Houston Area (LWV Houston), LyondellBasell Industries (LyondellBasell), PL Propylene LLC (PL Propylene), Printing Industries of the Gulf Coast (PIGC), Sustainable Energy and Economic Development Coalition (SEED), Texas Association of Business (TAB), Texas Chemical Council (TCC), Texas Oil and Gas Association (TxOGA), Texas Petrochemicals, United States Environmental Protection Agency (EPA), and one individual.

Albemarle supported comments made by TCC and the Coalition of Manufacturers for Air Quality (COMAQ). No comments were received from COMAQ concerning this attainment demonstration SIP revision. CAIT, KIDS, SEED, and one individual incorporated by reference any comments submitted by EDF and HSC. EDF and GHASP incorporated by reference as part of their comments and for the administrative record, EDF's January 30, 2008, comments on the EPA's proposed rulemaking for "Clean Air Act Reclassification of the Houston/Galveston/Brazoria Ozone Nonattainment Area; Texas" as published in the December 31, 2007, issue of the *Federal Register* (72 FR 74252) as well as all cited documents and studies included in their comments.

Comments more directly related to the 30 Texas Administrative Code (TAC) Chapter 101 Mass Emissions Cap and Trade (MECT) Program Cap Integrity (Rule Project No. 2009-019-101-EN) and Highly-Reactive Volatile Organic Compounds Emissions Cap and Trade (HECT) Program Cap Reduction and Allowance Reallocation (2009-006-101-EN) and 30 TAC Chapter 115 Offset Lithographic Printing rule revisions (Rule Project No. 2008-019-115-EN), which are incorporated by reference into this attainment demonstration SIP revision, are responded to in the Response to Comments section of the preamble to each of those rulemakings. Those comments are included in this attainment demonstration SIP revision through the adoption of those rules. Some changes were made to the proposed version of this attainment demonstration SIP revision in response to those comments.

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GENERAL COMMENTS

Evaluation of Attainment Demonstration SIP

General Support for Attainment Demonstration SIP Revision

BCCA and the Coalition supported the proposed demonstration that the HGB area will attain the 1997 eight-hour ozone standard by the attainment deadline of 2019.

AmericanAcryl and Arkema appreciated efforts by the Texas Commission on Environmental Quality (TCEQ) to develop programs that contribute to compliance with the National Ambient Air Quality Standards (NAAQS).

COH commented that the TCEQ is making progress in reducing emissions.

LyondellBasell commented that photochemical modeling demonstrates that the proposed Highly Reactive Volatile Organic Compounds (HRVOC) Emissions Cap and Trade (HECT) Program allowance cap reduction, in addition to stationary and mobile source emissions reduction programs, will contribute to attainment of the 1997 eight-hour ozone standard in the HGB area.

The commission appreciates the support and is committed to working with local entities and the EPA to ensure attainment of the 1997 eight-hour ozone standard in the HGB area.

COH commented that the TCEQ should develop a redesignation request to attainment and prepare the required maintenance plan for submission to the EPA as expeditiously as possible. COH also commented that the TCEQ should finalize the proposed attainment demonstration SIP revision and submit it to the EPA in 2010 so that proposed control measures can be implemented to assure continued ozone reductions, and that the proposed attainment demonstration SIP revision may be incorporated into the maintenance plan. COH was also hopeful that ozone levels could be maintained for the necessary length of time to have the nonattainment designation removed for the HGB area.

The commission has developed and adopted this attainment demonstration for the 1997 eight-hour ozone standard in an expeditious manner and will submit this attainment demonstration SIP revision to the governor's office in time to be provided to the EPA by the April 15, 2010, deadline. Although preliminary data for 2007 through 2009 show that the HGB area is monitoring attainment of the 1997 eight-hour ozone standard, on January 7, 2010, the EPA proposed to strengthen the eight-hour primary ozone NAAQS to a level within the range of 0.060 to 0.070 ppm. The EPA has also proposed a distinct cumulative, seasonal secondary standard within the range of 7 to 15 ppm-hours. The EPA is scheduled to issue the final standards by August 31, 2010. According to the EPA's accelerated schedule, states will be required to submit recommendations for the attainment status of areas under the revised primary ozone NAAQS by January 2011 and final area designations are scheduled to be issued by July 2011 and become effective in August 2011. Nonattainment area SIP revisions are scheduled to be due to the EPA in December 2013. At the time of this writing, the EPA has not published guidance on how the 2010 ozone NAAQS should be implemented.

Given the short time frame in which the commission must provide recommendations for nonattainment areas and react to the EPA's implementation guidance to develop SIP revisions for the revised ozone NAAQS, the limited resources available are best utilized in assessing and preparing for the revised ozone NAAQS. The TCEQ will pursue requesting redesignation of the HGB area to attainment for the 1997 eight-hour ozone standard when all elements necessary for redesignation can be considered in the context of the EPA's implementation rule requirements for the 2010 ozone NAAQS. The TCEQ will work with the EPA and the HGB regional stakeholders in this effort.

Mid-Course Review

EDF, the EPA, GHASP, H-GAC, LWV Houston, and TCC supported the TCEQ conducting a mid-course review (MCR). The EPA also suggested that the TCEQ conduct photochemical modeling during the MCR. H-GAC encouraged the TCEQ to include an MCR in the proposed attainment demonstration SIP revision to assure that adequate measures are included to achieve attainment as expeditiously as possible.

The EPA pointed out that the MCR should show whether implemented control measures are sufficient. H-GAC suggested that the MCR include an assessment of the weight of evidence (WoE) to provide an opportunity to adjust the attainment demonstration SIP revision for future technology changes and information and to include additional funding if appropriated or amendments to commitments if funding is reduced. TCC commented that the MCR should evaluate the need to implement a 25 percent HRVOC emissions cap reduction and include additional photochemical modeling to determine the extent to which the HRVOC cap should be reduced in order to attain the 1997 eight-hour ozone standard.

EDF and GHASP suggested that the MCR should occur in the 2012-2013 time frame to allow ample time for the implementation of additional controls, if any, needed to demonstrate attainment by 2019. The EPA noted that the revised eight-hour ozone standard SIP revision will be due to the EPA in 2013, so the MCR could be submitted concurrently with the SIP revision for the revised ozone standard. TCC suggested that the MCR be conducted prior to the first step-down period for the proposed HECT program changes or in the 2011-2013 time frame.

To ensure that the HGB area is in attainment of the 1997 eight-hour ozone standard by June 15, 2019, and that the controls to get there are the most cost-effective, technology-based solutions possible, the executive director commits to performing a 1997 eight-hour ozone standard MCR and submitting it to the commission for consideration. With commission approval, the results of the MCR would be submitted to the EPA concurrently with a SIP revision for the EPA's revised ozone standard, which is scheduled to be due to the EPA no later than December 2013. In the event that the schedule for the revised ozone standard is changed by the EPA, the schedule for the MCR submission will change accordingly. This effort will involve a thorough evaluation of all photochemical modeling, inventory data, and other tools and assumptions used to develop the attainment demonstration. The MCR will include a review of the control measures, WoE, and contingency plan as well as additional analysis that may include photochemical modeling if appropriate. It will also include the ongoing assessment of new technologies and innovative ideas for possible inclusion into the plan. For further information regarding the MCR, see Chapter 6: *Ongoing Future Initiatives,* Section 6.3.1: *Mid-Course Review (MCR)*.

The commission commits to continue working with the EPA and the HGB regional stakeholders in an open, public consultative process to ensure that the MCR is a comprehensive and thorough evaluation.

TCC requested that photochemical modeling scenarios be performed during an MCR to determine if the 84 parts per billion (ppb) standard could be maintained while reducing the 25 percent HECT cap. TCC specifically recommended HECT cap reduction scenarios of 5 percent increments for such an analysis.

When an MCR is developed for the HGB area, the TCEQ will evaluate control strategy scenarios needed for demonstrating attainment of the ozone standard. Since ozone formation is sensitive to anthropogenic HRVOC levels, this specific emission category will continue to receive attention in any future ozone attainment demonstration SIP revision developed by the TCEQ for the HGB area.

Contingency Plan

TCC recommended that the TCEQ, as a potential contingency item during the 2009-2018 period, note emissions reductions of volatile organic compounds (VOC) or nitrogen oxides (NO_X) that are anticipated as a result of consent decrees.

It is not clear from the comments to what specific consent decrees the commenters are referring. The commission does not agree that previously entered EPA consent decrees are an appropriate measure to be included as a contingency measure. Though it is possible that VOC and NO_X emission reductions may occur as a result of consent decrees in the HGB nonattainment area, the timing of the emissions reductions and the quantity of reductions that are surplus to those that are accounted for in the photochemical modeling analysis are extremely difficult to ascertain. Since the emissions reduction for contingency would need to take place during a specific time period and must total to a specific amount (3 percent of the adjusted base-year inventory), the commission has not included consent decrees as a possible contingency measure as part of this attainment demonstration SIP revision. The commission has made no changes in response to this comment.

Reclassification

EDF and GHASP incorporated by reference as part of their comments on the proposed attainment demonstration SIP revision comments submitted by EDF on January 30, 2008, to the EPA proposed rulemaking for reclassifying the HGB nonattainment area, Docket No. R06-OAR-2007-0554, published in the *Federal Register* on December 31, 2007. EDF and GHASP also referenced comments made by the EPA regarding a previous SIP revision.

The commission acknowledges these comments to the EPA as part of the record for this proposed attainment demonstration SIP revision. To the extent those comments are also specifically referenced in other comments made about the current SIP action, responses are made accordingly elsewhere in this response to comments. However, the commission is not responding specifically to the January 30, 2008, comments originally submitted only to the EPA but not submitted to the TCEQ, since the January 30, 2008, comments are relevant only to the EPA's action reclassifying the HGB area and not for this proposed attainment demonstration SIP revision. The commission has made no changes in response to this comment.

COH, EDF, and GHASP commented that they opposed the previous double bump-up request and the prolonged attainment timetable for the HGB area.

The commission acknowledges these comments and the concerns associated with the later attainment date. Because the Federal Clean Air Act (FCAA) requires that the commission implement control strategies as expeditiously as practicable, the TCEQ has set an aggressive schedule to implement the 25 percent reduction in the HRVOC cap. The initial cut in reductions begins in 2014 in advance of the 2019 attainment date. Under the FCAA, §181, the EPA was required to grant the governor's request to reclassify the HGB area and the final rule was effective on October 31, 2008 (73 FR 56983). Thus, the comments are not relevant to this SIP revision and are outside the scope of this attainment demonstration SIP revision. The commission has made no changes in response to these comments.

Attainment of Standard

1997 Eight-Hour Ozone Standard

HSC and LWV Houston commented that the TCEQ has not yet successfully attained the 1997 eight-hour ozone standard in the HGB area. The EPA and LWV Houston expressed concern that the HGB area may still be in nonattainment of the 1997 eight-hour ozone standard in 2018.

LWV Houston rejected this proposed attainment demonstration SIP revision because it does not, on its face, meet the 1997 eight-hour ozone standard. LWV Houston expressed concern about the

TCEQ's credibility in developing a plan that will lead to attainment of the 1997 eight-hour ozone standard by the deadline.

The commission is committed to attaining the 1997 eight-hour ozone standard in the HGB area as expeditiously as practicable. The current preliminary 2009 design value of 84 ppb and this attainment demonstration SIP revision are confirmation that the TCEQ will attain the 1997 eight-hour ozone standard in the HGB area by the June 15, 2019, attainment date. The commission expects that proposed new control measures, along with existing control measures being implemented in the HGB area, will improve the area's air quality by removing ozone precursors from the airshed.

As part of this demonstration, the TCEQ uses photochemical modeling, which is a predictive tool that simulates the changes of ozone precursor concentrations in the atmosphere using a set of mathematical equations characterizing the chemical and physical processes in the atmosphere. In specifying requirements for photochemical modeling, the EPA allows for the use of corroboratory WoE by states to support demonstrations of attainment since there is always uncertainty in numerical forecasts of future events. The TCEQ has analyzed the appropriate reductions necessary for attainment of the 1997 eight-hour ozone standard as described in this attainment demonstration SIP revision. The commission has made no changes in response to these comments.

Revised Eight-Hour Ozone Standard

COH, EDF, and GHASP commented that the EPA is considering lowering the eight-hour ozone standard. COH stated that forward progress must be maintained because the eight-hour ozone standard will be tightening.

EDF and GHASP commented that the modeling contained in the proposed attainment demonstration SIP revision fails to initiate additional reductions to comply with a lowered ozone standard.

The commission is aware of the EPA's recent proposal to reduce the NAAQS for ozone. The commission contends that this SIP revision continues to improve air quality in the HGB area. The commission will prepare SIP revisions to attain and maintain the new eight-hour ozone standard in those areas once nonattainment areas for the revised standard have been designated by the EPA. The commission has made no changes in response to these comments.

One-Hour Ozone Standard

EDF and GHASP commented that, despite recent improvements in ozone levels, the HGB area has failed to reduce emissions of ozone precursors to levels sufficient to ensure attainment of the revoked one-hour ozone standard, the 1997 eight-hour ozone standard, and a revised eight-hour ozone standard currently under consideration by the EPA. Further, EDF and GHASP asserted that the TCEQ must demonstrate why the dramatic increase in overall VOC emissions in the HGB area is not backsliding under the one-hour ozone standard.

In the 2004 HGB MCR SIP revision, 2007 future-year point source VOC emissions were 255 tons per day (tpd) compared to the 2018 future-year emissions of 290 tpd in this attainment demonstration SIP revision. The corresponding NO_X emissions are 512 tpd and 377 tpd, respectively. Since modeling sensitivities for both SIP revisions indicate that, with the exception of HRVOC, ozone formation is much less sensitive to VOC than NO_X reductions, the increase in projected point source VOC emissions should not compromise attainment. As discussed elsewhere in this response to comments, the increase in VOC is due to growth projections, primarily from area and non-major point sources; it is not a result of a relaxation or removal of a SIP requirement. Therefore, the increase is not backsliding under the one-hour ozone standard.

Regarding the one-hour standard, there is no requirement to ensure attainment of this standard because it has been revoked. Phase 1 of the EPA's rules implementing the 1997 eight-hour ozone standard published in the April 30, 2004, issue of the *Federal Register* (69 FR 23951) requires that areas designated nonattainment for the one-hour standard at the time of designation for the eight-hour ozone standard meet certain requirements including having an approved one-hour attainment demonstration. The EPA approved the HGB attainment demonstration for the one-hour standard published in the September 6, 2006, issue of the *Federal Register* (71 FR 52656). The commission has made no changes in response to this comment.

CAIT, KIDS, SEED, and one individual commented that air monitoring data have proven false the assumption that the current eight-hour ozone standard is more protective of human health than the previous one-hour ozone standard. Specific mention was made of exceedances of the one-hour standard during 2007 through 2009 when violations of the eight-hour standard did not occur. CAIT, KIDS, SEED, and one individual claimed that the current form of the eight-hour ozone standard is flawed because it compensates for weather fluctuations providing unusually high design values but does not do so for fluctuations that provide unusually low design values.

As part of the periodic review of the NAAQS required by the FCAA, the structure of the ozone standard is developed by the EPA with substantial input from various scientific and health experts from across the United States. An exceedance of the one-hour ozone standard does not necessarily imply that the current 1997 eight-hour ozone standard is not more protective of human health. Further, the EPA has established through scientific review that there is insufficient evidence to retain the one-hour ozone NAAQS in order to be protective of public health. For more detail about the health impacts of ozone exposure, several documents related to the review of the 84 ppb ozone standard are available at http://www.epa.gov/ttn/naaqs/standards/ozone/s_o3_pr.html.

Air Quality

Emission Reductions

BCCA and the Coalition commented that the majority of ozone precursor emissions reductions have been achieved through programs aimed at the industrial source sector, and they cited that decreases in the ambient concentrations of ethylene and propylene suggest a considerable decrease in overall industrial emissions of these compounds since 1995. Further, BCCA and the Coalition commented that this finding agrees with early reports from the Texas Air Quality Study II (TexAQS II) field program indicating a decrease in ethylene emissions along the Houston Ship Channel.

The commission acknowledges that programs aimed at the industrial source sector have been successful in reducing ozone precursor emissions in the HGB nonattainment area. The commission's goal in the development of this proposed attainment demonstration SIP revision is to advance a plan that will result in the HGB area meeting the 1997 eight-hour ozone standard as soon as practicable and in the most economically feasible manner consistent with continued economic growth in the greater Houston area. The commission's overall strategy for improving air quality in the HGB area is working, as proven by the 26 percent decrease in the one-hour ozone design value and the 19 percent decrease in the eight-hour ozone design value between 2000 and 2008 during a simultaneous increase of 21 percent in population.

Emission reductions from stationary sources have been substantial over the past 10 years in the HGB area. More than 500 tpd of NO_X emissions were reduced from the electric utility, industrial, commercial, and institutional sectors through the 30 TAC Chapter 117: *Control of Air Pollution from Nitrogen Compounds* rules and the NO_X MECT program. In addition, a wide range of VOC control strategies were implemented for stationary sources

in the HGB area, impacting large industrial facilities such as refineries to smaller businesses such as printing operations.

The commission concurs with the comment that the propylene and ethylene trends have shown decreases in their ambient concentrations. This is discussed in greater detail in Chapter 5: *Weight of Evidence*, Sections 5.3.6: *Ambient VOC Concentrations*, 5.3.7: *Geographic Patterns in Ambient HRVOC Concentrations Near the Houston Ship Channel*, and 5.3.8: *Ambient Total VOC Concentrations* of the proposed attainment demonstration SIP revision. The commission has made no changes in response to this comment.

The EPA commented that modeling conducted for the proposed attainment demonstration SIP revision indicates that, even with additional federal measures, the area will not reach attainment by 2018; therefore, further reductions not included in this proposed attainment demonstration SIP revision may be necessary to attain the 1997 eight-hour ozone standard.

The FCAA defines nonattainment based upon the number of expected exceedances at any monitor in a region. As long as monitored data show that the number of expected exceedances is no greater than one, then the area is in attainment. The statistic used in the attainment test is based upon this definition and is defined as the highest design value at any monitor in the region, where each monitor's design value is the fourth-highest one-hour ozone concentration measured at the monitor in the most current three-year period (adjusted for incomplete data, if applicable). Thus, the FCAA allows a region a limited number of exceedances of the standard without causing a violation. The EPA guidance explicitly allows modeled values to exceed the standard in attainment demonstration modeling, provided the exceedance is very limited in time and space, and provided that the state can supply additional compelling evidence that the area will not be in violation in its attainment year. These ancillary arguments are collectively known as WoE.

Conservative photochemical modeling for the 2018 future case, the current preliminary 2009 HGB area design value of 84 ppb, and the WoE analysis demonstrate that the HGB area will attain the 1997 eight-hour ozone standard. The executive director commits to perform a thorough MCR concurrently with the revised ozone standard SIP revision, which is scheduled to be due to the EPA in December 2013, to help the commission identify additional measures or change previously adopted measures to ensure that compliance with the 1997 eight-hour ozone standard is maintained.

Health and Economic Welfare

COH commented that the TCEQ should bring the HGB area into attainment with the ozone standard to protect human health and provide an economic boost for the HGB area. COH further commented that the TCEQ should make the HGB area a priority.

EDF, GHASP, and HSC commented that the TCEQ should bring the HGB area into attainment with the 1997 eight-hour ozone standard to protect human health. EDF and GHASP stated that the SIP is the best opportunity that the state has to require emission control measures to protect human health from air pollution in the HGB nonattainment area. EDF and GHASP went on to state that the TCEQ did not use this proposed attainment demonstration SIP revision to implement control measures to reduce ozone concentrations to a level that is protective of human health.

The commission appreciates the comments related to health effects of ozone and economic welfare. The commission is committed to working with area stakeholders to attain the 1997 eight-hour NAAQS, which is a health-based standard, as expeditiously as practicable to adequately protect public health in accordance with the EPA's 1997 eight-hour implementation rule, EPA guidance, and the FCAA. The primary NAAQS are those that the EPA determines are necessary, with an adequate margin of safety, to protect the public health, including sensitive members of the population such as children, the elderly, and

those with existing lung or cardiovascular conditions. It is well known that some air pollutants, including ozone, can aggravate existing respiratory diseases. The primary health concerns for ozone are effects to the lungs and respiratory system. Health effects from ozone generally can resolve quickly once an individual is no longer exposed to high levels. By demonstrating attainment of the 1997 eight-hour ozone standard in the HGB area, in accordance with the EPA's 1997 eight-hour implementation rule, the EPA's guidance, and the FCAA, the commission is ensuring that public health will be adequately protected.

The commission strives to protect our state's human and natural resources, including those in the HGB area, consistent with sustainable economic development. The commission is committed to attaining the 1997 eight-hour ozone standard as expeditiously as practicable in all of the state's ozone nonattainment areas. The purpose of this plan is to demonstrate attainment of the 1997 eight-hour ozone NAAQS by June 15, 2019, in accordance with the EPA's guidance and FCAA requirements. By improving air quality in the HGB area, this plan will improve the quality of life for many residents of the HGB area.

The rules associated with this attainment demonstration SIP revision include achievable and cost-effective ozone emissions standards for sources in and around the HGB nonattainment area. An achievable and cost-effective level of control for a particular source category depends on the current levels of emissions, available control technologies for the source category, and other technical and economic factors that may be specific to a source or to a region. The commission determined the appropriate level of control for sources in the HGB nonattainment area considering all appropriate factors, including information obtained during the public comment period. Discussion regarding the level of control required on specific source categories is provided in the adopted rules associated with this attainment demonstration SIP revision.

CONTROL STRATEGIES DISCUSSION

HRVOC Emissions Cap and Trade (HECT) Program

BCCA, the Coalition, LyondellBasell, TAB, TCC, Texas Petrochemicals, and TxOGA supported the TCEQ's proposed 25 percent reduction in the HECT program emissions allowance cap. AmericanAcryl and Arkema supported efforts by the TCEQ to reduce the total HECT trading cap.

The commission appreciates the comments and will continue to work with area stakeholders to attain the 1997 eight-hour ozone standard in the HGB area as expeditiously as practicable.

The EPA requested that the commission explain why the reductions cannot be implemented sooner than the proposed 2015-2017 time frame. EDF and GHASP expressed support for reducing the HECT cap for Harris County in stepwise fashion by 10 percent in 2014, followed by annual 5 percent reductions through 2017.

The adopted rule revisions will reallocate the program in 2011 and implement an initial 10 percent reduction of the existing available HECT cap of 3,451.5 tons beginning with the 2014 calendar-year control period. The available cap will then be reduced in 5 percent increments at the start of each calendar-year control period for 2015, 2016, and 2017. The full 25 percent cap reduction will have been in effect for one full calendar-year control period by January 1, 2018. While historical data demonstrate an overall surplus in the HRVOC cap, many sources were operating near their individual cap limits and thus may see a significant change in their HRVOC emissions. The cap reduction and reallocation may require some individual sites to install additional controls or otherwise modify their operations to reduce their HRVOC emissions. The step-down approach allows companies

time to install controls if necessary. The commission has made no changes in response to these comments.

BCCA and the Coalition commented that the reallocation of HRVOC allowances in the HECT program rulemaking included in the proposed attainment demonstration SIP revision is not required for purposes of providing ozone precursor reductions for the 1997 eight-hour ozone HGB SIP package. TAB and TxOGA commented that the proposed attainment demonstration SIP revision does not rely on the reallocation rulemaking. PL Propylene commented that the reallocation of HECT allowances is fair and necessary to protect the integrity of the proposed attainment demonstration SIP revision.

The commission agrees with BCCA, the Coalition, TAB, and TxOGA that the reallocation of HECT allowances is not required to model attainment of the HGB area for the 1997 eight-hour attainment demonstration SIP revision. The reallocation of HRVOC allowances does not in itself include a mandatory reduction in the HRVOC cap in Harris County. However, following the initial allocation of allowances, the TCEQ received comments that the allocation was not equitably distributed. Information from the first two years of monitoring data supports the assertion of an inequitable distribution of allowances. A more equitable allocation of allowances will stimulate the market, creating incentives for further reductions by industry regulated by the program. The commission therefore agrees with PL Propylene that revisions to the rule are anticipated to result in a more equitable approach. Because the change in allowance allocation methodology will create incentives for further reductions, it will contribute to the area's attainment of the NAAQS as expeditiously as practicable. The commission has made no changes in response to these comments.

HSC proposed that the commission should discontinue the HECT program and set command and control emission limits for each emission point.

The commission did not propose discontinuation of the HECT program. This comment is beyond the scope of this attainment demonstration SIP revision. The commission adopted the HECT program having determined it to be the most efficient means by which to achieve cost-effective reductions of HRVOC. The HECT program was approved by the EPA on September 6, 2006, and provides compliance flexibility while maximizing the efficiency of emission reductions through market forces. The commission maintains that the HECT program is the most cost-effective means of achieving emissions reductions of HRVOC. Individual sources of HRVOC emissions also must meet permit limits and any applicable limit is established by rule. The HECT program provides for additional decreases in HRVOC emissions limits above and beyond these basic requirements. The commission has made no changes in response to this comment.

Mass Emissions Cap and Trade (MECT) Program

The EPA requested clarification on the amendment to §101.353(b) and why it does not require minor sources of NO_X submitting late ECT-3 forms to obtain allowances from the market. The EPA commented that these minor sources of NO_X could increase the overall cap and jeopardize the attainment demonstration modeling for the HGB ozone nonattainment area.

The MECT NO_X cap is a product of the emission specifications of Chapter 117 and the submitted levels of activity from applicable existing facilities, about an 80 percent reduction from each existing facility's baseline. A new facility (i.e., a new or modified facility that is part of an administratively complete permit application received on or after January 2, 2001) that is subject to the MECT program cannot receive an allocation of allowances, and the site must obtain allowances to cover the new facility's total emission of NO_X.

Minor sources of NO_X with applicable facilities that are not in the MECT program must meet the emission specifications of Chapter 117 on a unit-by-unit basis. A minor source of

NO_X with facilities subject to the emission specifications of Chapter 117 must comply by installing controls, the use of emission reduction credits (ERCs), or the use of discreet emission reduction credits (DERCs). A minor source of NO_X is subject to the MECT program once the site has a collective uncontrolled design capacity to emit greater than or equal to 10 tons per year (tpy) NO_X. If an existing facility at a minor source of NO_X transitions from being a non-MECT facility to a MECT facility, it may receive allowance allocations based on the emission specifications of Chapter 117. If a minor source of NO_X submits a late Form ECT-3, Level of Activity Certification (ECT-3 form) but installed controls on an existing facility to comply with Chapter 117 prior to entering the MECT program, the site would undergo both the cost of installing the controls and the cost of purchasing the entire amount of allowances needed to comply with the MECT program for each control period if the late ECT-3 form was not accepted. This action would penalize sites that choose to install controls on an existing facility and then become subject to the MECT program. Therefore, the commission is continuing to grant allowances for the portion of an existing facility's emissions at a minor source of NO_X that were previously controlled through compliance with the Chapter 117 emission specifications. If an existing facility required additional allowances for compliance, the allowances would have to be purchased from the market. Although the existing facility's compliance mechanism transitions from direct compliance with the emission specifications to compliance with the MECT program, there is no actual growth in real emissions because the allowance is based on actual level of activity and the emission specification the existing facility was already required to meet.

Although granting these allowances to minor sources does slightly increase the MECT NO_X cap, it does not interfere with the attainment demonstration photochemical modeling for the HGB area. When analyzing future growth in the attainment demonstration model, it is assumed that there is no trading because trading is highly unpredictable from fluctuations in needs and market conditions. Existing facilities subject to the MECT program are modeled at their allowance allocation amount and not allowed any growth. New facilities subject to the MECT program are modeled at zero (i.e., allocated zero allowances), because these facilities are required to obtain allowances from existing facilities through trading. With respect to the model, the sum of the MECT existing facilities and the MECT new facilities is the MECT NO_X cap. With respect to actual emissions, the sum of the MECT existing facilities' and the MECT new facilities' actual NO_X emissions is less than or equal to the MECT NO_X cap.

New and existing facilities not in the MECT program are allowed growth using photochemical modeling values based on EPA-approved growth methodologies. For example, a facility entering late into the MECT program will be recategorized in the model to the allowance allocation amount with zero growth, and the photochemical modeling value based on an EPA-approved growth methodology will be discarded. If the modeled MECT NO_X cap were to increase, then that would result in decreases of the non-MECT modeled NO_X emissions to which this growth was applied. The final result would actually be a net decrease in the total point source NO_X emissions inventory in the model, if the model were to be run with the new numbers.

If an existing facility at a minor source of NO_X is in the area source inventory, the allowances provided to that facility would still be applied to the total point source inventory modeled MECT NO_X cap. However, the commission has decided not to decrease the area source inventory correspondingly at this time because the change would be insignificant. Historically, the increase in the MECT NO_X cap due to approved late ECT-3 forms submitted by minor sources of NO_X has been insignificant. Since January 1, 2004, the commission approved 13 late ECT-3 forms that were due by June 30, 2001. These sites were allocated an average of 3.64 tons of allowances per site, or 0.01 tpd NO_X. The collective total from the 13 sites is about 0.13 tpd. The total 2018 modeled baseline area source inventory and point source inventory NO_X emissions are 42.04 tpd and 154.36 tpd,

respectively. Adjusting the modeled area source inventory for such an inconsequential decrease is an impractical use of resources and provides no benefit. Therefore, the commission has chosen to model such changes conservatively and only include the increase in the point source MECT NO_X cap.

Thus, the continued acceptance of late ECT-3 forms from existing facilities at minor sources of NO_X, while slightly increasing the NO_X cap, will not interfere with attainment demonstration photochemical modeling for the HGB area. The commission has made no changes in response to this comment.

The HSC commented that the commission should discontinue the MECT program and set command and control emission limits for each emission point.

The commission did not propose discontinuation of the MECT program. This comment is beyond the scope of this attainment demonstration SIP revision. The commission adopted the MECT program having determined it to be the most efficient means to achieve cost-effective reductions of NO_X. The MECT program was approved by the EPA and provides compliance flexibility while maximizing the efficiency of emission reductions through market forces. The commission maintains that the MECT program is the most cost-effective means of achieving emissions reductions of NO_X. Individual sources of NO_X emissions also must meet permit limits and any applicable limit as established by rule. The MECT program provides for additional decreases in NO_X emissions limits above and beyond these basic requirements. The commission has made no changes in response to this comment.

Offset Lithographic Printing Rule Revisions

PIGC commented that the health benefit to the public of the proposed Chapter 115 offset lithographic printing rules is negligible because there are relatively few firms in the HGB area that will be affected by the proposed rules in Chapter 115. PIGC further commented that the printing industry is not a major source of emissions in the HGB area.

The commission is aware that printing sources do not constitute a large proportion of the emissions in the HGB area. However, revisions to the 30 TAC Chapter 115: *Control of Air Pollution from Volatile Organic Compounds* offset lithographic printing rules are necessary to fulfill FCAA reasonably available control technology (RACT) requirements.

In accordance with FCAA, §172(c)(1) and §182(b)(2), the state is required to include RACT for VOC emission sources addressed in a control technique guidelines (CTG) document issued between November 15, 1990, and the area's attainment date in the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard. The EPA published a CTG document in lieu of national regulations for VOC emissions from Offset Lithographic Printing and Letterpress Printing in the October 5, 2006, issue of the *Federal Register* (71 FR 58745). The purpose of the offset lithographic printing rule revision is to implement RACT for this CTG emission source category. The commission has made no changes in response to this comment.

Identification of Most Effective Ozone Control Strategies

COH requested a list of the most effective control strategies for reducing regional ozone levels. COH also requested that the ozone reductions associated with each of these key strategies be included.

In general, it is necessary to reduce anthropogenic NO_X and VOC precursors to achieve lower ozone levels in the atmosphere. In VOC-limited arid metropolitan areas with little vegetation and much anthropogenic NO_X, VOC controls tend to be more effective for reducing ozone. In NO_X-limited areas, such as the eastern half of Texas, that have

significant naturally occurring biogenic VOC, it is typically more effective to reduce anthropogenic NO_X instead of VOC for the purposes of lowering ozone concentrations. However, the situation is more complex for industrial areas where HRVOC is common, such as the Houston Ship Channel. In such cases, both NO_X and HRVOC reductions are needed. Numerical quantification of ozone reductions is very difficult because individual areas of the HGB nonattainment area can be either NO_X-limited or VOC-limited on any given day.

The commenter requested the ozone reductgions associated with each strategy. Because ozone formation is a combination of non-linear chemical and photochemical reactions, a simple analysis of the effect of each strategy is not possible. Further, the commission has not conducted an analysis of what each strategy has contributed to ozone reduction because this exercise would be resource intensive while not producing meaningful information upon which to base future plans.

At the March 25 and 26, 2008, stakeholder meetings, the TCEQ provided a list of initial potential control measures that was based on staff's initial evaluation of possible measures to be considered in the RACM analysis. Any control measures suggested by stakeholders during the informal comment period were added to this list. All the measures included on the initial list and those suggested by stakeholders were evaluated in the RACM analysis provided in Appendix E: *Reasonably Available Control Measure Analysis*. However, the TCEQ must also consider other factors in addition to using modeling to estimate the ozone reduction benefits of potential control strategies. Examples of such other factors include technological and economic feasibility, the agency's legal authority, and time required for implementation. The most effective control measures at reducing ozone may not necessarily be cost effective or technologically feasible. The TCEQ must consider all these factors when determining whether a control measure should be implemented as RACM.

The attainment demonstration SIP revision contains sufficient reductions of both NO_X and VOC precursors to demonstrate, in conjunction with the WoE analysis, attainment of the 1997 eight-hour ozone standard by 2018 in HGB. The commission has made no changes in response to this comment.

Mobile Sources

EDF and GHASP stated that the commission should implement more stringent cut-points for use in the I/M program.

In a previous rulemaking, Senate Bill 12: Low Income Repair Assistance, Retrofit, and Accelerated Vehicle Retirement Program (Rule Project No. 2007-026-114-EN), the commission requested public comment to whether a transition to final cut-points should be considered for the acceleration simulation mode (ASM) emissions inspections performed on gasoline-powered model year 1995 and older vehicles. Due to the vehicle inspection failure rate of approximately 9 percent escalating to over 30 percent for this older group of vehicles, and the continuing diminishing fleet of older vehicles, the commission adopted amendments to 30 TAC Chapter 114: *Control of Air Pollution from Motor Vehicles* on December 5, 2007, with no action taken to implement final cut-points for ASM inspections. As the gasoline-powered model year 1995 and older vehicle fleet continues to diminish, down from 23 percent in 2007 to 12 percent in 2009, the reductions diminish from 0.36 tpd NO_X and 0.30 tpd VOC in 2012, to 0.13 tpd NO_X and 0.12 tpd VOC in 2018. Due to the issues identified as part of Rule Project No. 2007-026-114-EN, the commission has opted not to implement final cut-points for ASM inspections. The commission has made no change in response to this comment.

EDF and GHASP recommended that the commission adopt a program to identify high-emitting vehicles.

A remote sensing program that identifies high-emitting vehicles has been part of the Texas Inspection and Maintenance State Implementation Plan since 1996. The program was implemented in the HGB area in 1998. The Texas Department of Public Safety (DPS), the agency that implements the I/M program along with the commission, uses remote sensing technology to identify vehicles operating within the I/M program areas that have a high probability of being high emitters. The remote sensing program focuses on identifying probable high-emitting vehicles that are registered within the subject counties but are not complying with periodic inspection requirements in the I/M program areas and probable high-emitting vehicles commuting from adjacent non-I/M program counties. A motorist whose vehicle meets the high-emitter identification criteria is mailed a notification letter informing him that the vehicle has a high probability of being a high emitter. The notification letter informs the motorist that the vehicle is required to undergo a remote sensing vehicle emissions verification inspection that can be conducted at any DPS-certified safety and emissions inspection station. In addition, the motorist is informed that if the vehicle fails the verification inspection, the vehicle is required to be brought into compliance with the I/M program requirements. If the motorist fails to comply with the request to have the vehicle undergo a verification inspection or bring the vehicle into compliance after failing a verification inspection, the motorist may be issued a citation with progressive penalties that may escalate to a maximum of $1,000 per offense for the continuance of non-compliance and the vehicle may be denied re-registration.

The EPA suggested that the TCEQ include estimated time frames for initiation and completion of the candidate Transportation Control Measures (TCM) listed in Table 1 of Appendix G.

The commission appreciates the comment and has updated Appendix G: Transportation Control Measures for the HGB Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard (Excerpt from Evaluation of Mobile Source Control Strategies for the Houston-Galveston-Brazoria State Implementation Plan), Prepared for Houston-Galveston Area Council, Prepared by ENVIRON International Corporation, Table 1: Projects with Applicable Benefits to show bid acceptance dates and completion dates.

Emissions Inventory

EDF and GHASP commented that the TCEQ should work with the EPA and the United States Coast Guard to better assess barge emissions and adopt appropriate control measures.

Currently, Chapter 115 specifies control measures for barge loading, unloading, and degassing operations while barges are docked. While the TCEQ does not currently have rules specifying control requirements for barges during transit, the TCEQ has worked with the Coast Guard, the American Waterways Operators, and other groups to develop industry Best Management Practices for barge operations to reduce VOC emissions during transit and dock operations, as detailed in Chapter 5: *Weight of Evidence*, Section 5.4.3.10: *American Waterways Operators Tank Barge Emissions Best Management Practices* of this attainment demonstration SIP revision.

The point source inventory accounts for barge emissions while docked. The TCEQ has also initiated mobile source emissions inventory improvement research to account for barge VOC emissions while in transit. Research will build upon the EPA's recently published assessment of barge fugitive emissions entitled *Investigation of Fugitive Emissions from Petrochemical Transport Barges Using Optical Remote Sensing* (EPA/600/R-09/136), available at: http://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryId=213705**.**

REASONABLY AVAILABLE CONTROL TECHNOLOGY (RACT), REASONABLY AVAILABLE CONTROL MEASURES (RACM)

RACT, RACM Adequacy

EDF and GHASP commented that the current attainment demonstration SIP revision fails to adopt all RACM and RACT as expeditiously as practicable. EDF and GHASP commented that the attainment demonstration SIP revision contains no additional RACT requirements for non-CTG major sources of NO_X and VOC emissions and only one additional RACT requirement for a CTG VOC emission source category (offset lithographic printing). EDF and GHASP also commented that the attainment demonstration SIP revision only contains one additional RACM requirement that will not result in actual emission reductions (Harris County HECT cap reduction).

The commission disagrees that the current attainment demonstration SIP revision fails to adopt all RACM and RACT as expeditiously as practicable. As described in the RACT analysis in Appendix D: *Reasonably Available Control Technology Analysis* of this attainment demonstration SIP revision, the commission determined that all technologically and economically feasible controls are implemented. The commission's analysis demonstrates that the RACT requirements are being fulfilled in the HGB area by: (1) identifying all CTG source categories of NO_X and VOC emissions and submitting negative declarations for categories where there are no emission sources of these types within the HGB area; (2) identifying all non-CTG major sources of NO_X and VOC emissions; (3) identifying the state regulation that implements or exceeds RACT for each applicable CTG source category or non-CTG major emission source; and (4) describing the basis for concluding that these regulations fulfill RACT.

As described in the RACM analysis in Appendix E: *Reasonably Available Control Measure Analysis* of this attainment demonstration SIP revision, the commission evaluated all potential RACM identified to determine if all technologically and economically feasible control measures that would advance attainment of the ozone NAAQS were implemented. The commission used a two-step process to identify all potential RACM for stationary sources, including requesting stakeholder suggestions for potential RACM to evaluate during the SIP development process. The commission evaluated all identified potential stationary source RACM and determined that only one potential control measure, reducing the Harris County cap under the HECT program, met the criteria to be considered RACM. All other potential control measures evaluated for both stationary and mobile sources were determined not to be RACM due to technological or economic feasibility, enforceability, adverse impacts, or ability of the measure to advance attainment of the NAAQS. The details of the commission's determinations regarding measures determined not to be RACM are provided in the discussion sections and RACM tables included in Appendix E: *Reasonably Available Control Measure Analysis*. The commission made no changes in response to this comment.

EDF and GHASP commented that the commission did not provide the reasoned justification required by the EPA for rejecting otherwise available RACT measures. EDF and GHASP stated that the commission did not adequately support the conclusion that additional RACT measures for major sources of NO_X and VOC emissions are not economically or technologically feasible. EDF and GHASP also stated that the commission did not adequately explain why the schedule to implement all RACM, including RACT, is the earliest feasible schedule based on the specific circumstances of the area. EDF and GHASP stated the commission must do more than simply assert that additional RACT measures for major sources of NO_X and VOC emissions are unavailable. EDF and GHASP stated that since RACT is a subset of the broader RACM requirements, the commission's obligation to provide a reasoned justification for the rejection of RACM applies equally to the rejection of RACT.

The commission disagrees that the current attainment demonstration SIP revision does not provide a reasoned justification for not adopting all RACT. The commenters are correct that the general discussion portion of the RACT analyses in Appendix D: *Reasonably Available Control Technology Analysis* the attainment demonstration SIP revision only summarizes the commission's conclusion that all RACT measures for major sources of NO_X and VOC emissions are being implemented. However, Appendix D: *Reasonably Available Control Technology Analysis*, Table D-2: *State Rules Addressing RACT Requirements for Major Emission Sources in the HGB Area* of this attainment demonstration SIP revision identifies the state regulation that implements or exceeds RACT for each applicable major emission source category and describes the basis for concluding that these regulations fulfill RACT. The commission made no changes in response to this comment.

RACT

EDF and GHASP expressed support for RACT rules limiting the VOC content of solvents used by offset lithographic printing operations and expanding the rule applicability to include currently unregulated sources.

The commission appreciates the support.

HSC commented on the statement in the preamble to the offset lithographic printing rule revision (Project No. 2008-019-115-EN) that the commission does not agree that applying RACT standards to future equipment installations is necessary to meet the mandates of the FCAA under §§172(c)(1), 182(b)(2), and 182(f). HSC commented that the commission has stated publicly that additional reductions are necessary to achieve the ozone standard. HSC suggested the commission implement RACT to reduce risks to human health and welfare and advance attainment of the ozone standard in the HGB area.

The statement referenced by the commenter was included as part of a discussion about the EPA's 2006 Offset Lithographic and Letterpress Printing CTG recommendations. Specifically, the EPA's CTG recommends requiring control equipment first installed before the effective date of rules implementing the CTG to have an overall control efficiency of 90 percent and control equipment first installed after the effective date of rules implementing the CTG to have an overall control efficiency of 95 percent. The commission disagrees with the EPA's CTG recommendation to correlate control device efficiency requirements with the first installation date of the control device regardless of where the equipment was installed. The commission contends imposing this policy may encourage the installation of older, less efficient equipment and may create potential backsliding issues. This policy could also create significant practical enforceability issues for commission investigators with regard to verifying the first installation date of the control equipment. However, in response to comments received on the offset lithographic printing rule revision, the commission has removed this statement from the rule preamble.

Additionally, as described in the RACT analysis in Appendix D: *Reasonably Available Control Technology Analysis* of this attainment demonstration SIP revision, the commission determined that all technologically and economically feasible RACT controls are implemented. The commission's analysis demonstrates that the RACT requirements are being fulfilled in the HGB area by: (1) identifying all CTG source categories of NO_X and VOC emissions and submitting negative declarations for categories where there are no emission sources within the HGB area; (2) identifying all non-CTG major sources of NO_X and VOC emissions; (3) identifying the state regulation that implements or exceeds RACT for each applicable CTG source category or non-CTG major emission source; and (4) describing the basis for concluding that these regulations fulfill RACT.

The EPA requested confirmation that all NO_X point sources in the HGB area with the potential to emit at least 25 tpy have been included in the list of sources evaluated for RACT purposes.

As discussed in the RACT analysis provided in Appendix D: *Reasonably Available Control Technology Analysis* of this attainment demonstration SIP revision, the commission reviewed the point source emissions inventory and Title V databases to identify all major sources of NO_X emissions. All major NO_X sources in the Title V database were included in the RACT analysis. Since the point source emissions inventory database reports actual emissions rather than potential to emit, the RACT analysis included sources that reported actual NO_X emissions as low as 10 tpy to account for the difference between actual and potential emissions. Sites from the emissions inventory database with emissions of 10 tpy or more of NO_X that were not identified in the Title V database and could not be verified as minor sources by other means are also included in the RACT analysis.

The EPA requested confirmation that the level of NO_X control for affected sources in the HGB area still represents RACT today.

As discussed in the RACT analysis provided in Appendix D: *Reasonably Available Control Technology Analysis* of this attainment demonstration SIP revision, the commission maintains that under the current state rules, the HGB area is subject to some of the most stringent NO_X emission control requirements in the country and for many source categories the existing rules are more stringent than recommended RACT standards for those categories. In the final approval notice for the revised HGB one-hour ozone attainment demonstration SIP published in the September 6, 2006, issue of the *Federal Register* (71 FR 52676), the EPA noted that the HGB NO_X rules in Chapter 117 were previously determined to meet the FCAA RACT requirements. The commission maintains that the level of NO_X control through the Chapter 117 rules and the NO_X MECT program still represent RACT.

The EPA commented that RACT should be federally enforceable and requested additional explanation as to why it is appropriate to use New Source Review (NSR) permit conditions to implement RACT for the glass manufacturing facility identified in the HGB area. The EPA also requested a copy of the NSR permit.

The current NO_X rules in Chapter 117 do not contain a RACT limit for glass furnaces in the HGB area. There were no glass furnaces in the point source emissions inventory year used during the HGB one-hour ozone attainment demonstration SIP revision; therefore, the commission had no reason to establish a RACT limit for this category in the HGB area during that SIP revision. The glass furnace at the Longhorn Glass Corporation facility began operation after the baseline inventory year that was used for the one-hour SIP revision. During the RACT analysis for this attainment demonstration SIP revision for the 1997 eight-hour ozone NAAQS, the glass furnace at this facility was identified in the inventory as an Alternative Control Techniques (ACT) category. However, the glass furnace located at the facility is equipment with oxy-firing and is limited to 1.48 pounds (lb) of NO_X per ton of glass by the site's NSR permit. The level of NO_X control already installed at the facility already meets what the TCEQ considers to be the top end controls for glass furnaces, and additional NO_X control is not possible at this facility. This is consistent with the EPA's ACT document *Alternative Control Techniques Document-NO_X Emissions from Glass Manufacturing*, which describes oxy-firing as the most effective NO_X control technique. Furthermore, there are no other glass furnaces in the HGB area. Therefore, the TCEQ determined that establishing a NO_X RACT rule for the glass furnace source category was not necessary for fulfilling RACT for the HGB 1997 eight-hour ozone standard attainment demonstration because additional controls were not necessary or possible in this specific situation.

This conclusion is supported by the guidance provided by the EPA in the RACT guidance document *RACT Qs & As – Reasonably Available Control Technology (RACT): Questions and*

***Answers*, issued May 18, 2006. The following is the question and response in that guidance document regarding situations where states determine that additional controls are not necessary beyond what was required for the one-hour ozone standard.**

> **Question: "What should a State do if it concludes that for a specific source or source category no additional controls are necessary beyond what was required by the RACT analysis under the 1-hour standard?"**
>
> **EPA's response: "Where a State concludes that the no control is required beyond what was required for purposes of the 1-hour NAAQS, the State should submit its analysis justifying such a conclusion as part of its RACT SIP."**

Additional controls are not required for fulfilling RACT for the glass furnace source category in the HGB area. The NO_X emission rate limit established for this furnace has remained unchanged since the permit was first issued in 2000. If the permit holder (facility) desired to increase their emissions or the emission factor of 1.48 lb of NO_X, the permit holder would be required to modify their permit and demonstrate that best available control technology (BACT) is applied at the higher rate. Because the facility has operated with this emission limit in place since initial startup of the unit, such a modification is unlikely. Therefore, the TCEQ does not expect that this emission limit will be relaxed in the future. The executive director's staff will continue to track the Longhorn Glass Corporation permit. If any changes occur in the permit that interfere with RACT, the executive director will initiate a future SIP revision, if necessary, for the commission's consideration to ensure that that NO_X RACT is maintained for the HGB area. The TCEQ will provide the EPA with a copy of the requested permit information.

EDF and GHASP stated that the commission failed to provide adequate justification for not including the EPA's 2006 Offset Lithographic and Letterpress Printing CTG recommendation to require use of an add-on control device with 95 percent efficiency. EDF and GHASP rejected the commission’s explanation that existing rules are equivalent since the state only requires add-on control devices with 90 percent efficiency.

The commission maintains that the overall VOC control level in the adopted Chapter 115, Subchapter E, Division 4 is equivalent to or more stringent than the EPA's 2006 Offset Lithographic and Letterpress Printing CTG recommendations and sufficient to fulfill RACT for offset lithographic printing operations in the HGB area. The commission must balance arbitrarily implementing the 2006 CTG recommendations with the potential for backsliding, enforceability considerations, and the possible impacts to sources that have already complied with the existing rules.

The commission also notes that in several instances, the adopted Chapter 115 content limits are more stringent than the EPA's 2006 CTG recommendations. The 2006 CTG recommends limiting the VOC content of cleaning solutions used in offset lithographic printing operations to 70 percent VOC by weight in conjunction with work practice standards. The adopted Chapter 115 rules retain the more stringent cleaning solution content limit of 70 percent VOC by volume in conjunction with work practice standards. Assuming the VOC in the cleaning solvent used is kerosene, which is the VOC referenced in the 2006 CTG, the adopted Chapter 115 content limit of 70 percent VOC by volume for cleaning solutions is equivalent to 66 percent VOC by weight. The EPA's 2006 CTG also recommends limiting the fountain solution content to 5 percent alcohol substitutes or less by weight and no alcohol in the fountain solution. To prevent potential backsliding for sources already required to comply with these state regulations, the adopted Chapter 115 rules retain the more stringent fountain solution content limit of 3 percent alcohol substitutes or less by weight and no alcohol in the fountain solution.

The commission maintains that the adopted Chapter 115 rules for heatset offset lithographic presses are at least as stringent as the EPA's 2006 CTG-recommended controls. The EPA's CTG recommends an add-on air pollution control device be required on each individual heatset offset lithographic press with the uncontrolled potential to emit 25 tpy of VOC or more from the dryer. The rules in Chapter 115, Subchapter E, Division 4 require control devices, with a control efficiency of at least 90 percent, to be installed on heatset offset lithographic presses on a property in the HGB area with total uncontrolled VOC emissions of at least 25 tpy, which includes VOC emissions from ink oils evaporated by the press dryer and VOC in fountain and cleaning solutions. In Table 5-1: *Model Plant Product Use and Baseline (Uncontrolled) Volatile Organic Compounds (Average Tons Per Year)* of the 1993 draft Offset Lithographic Printing CTG, the EPA estimates that 26 percent of the total uncontrolled VOC emissions from heatset offset lithographic printing operations are emitted from the press dryer. Based on EPA's assumption, an individual heatset press located on a property with total uncontrolled VOC emissions of 25 tpy would emit less than 7 tpy of VOC from the press dryer. Therefore, the Chapter 115 offset lithographic printing rules are effectively more stringent than the EPA's 2006 CTG RACT recommendations with regard to the applicability threshold for this control requirement. Additionally, the EPA's 2006 CTG recommended exempting heatset presses used for book printing and heatset presses with a maximum web width of 22 inches or less from the add-on control device requirements. The existing Chapter 115 regulations do not exempt these sources from the control requirements, and the commission has not adopted these exemptions into the revised rule.

The EPA's CTG recommends requiring control equipment first installed before the effective date of rules implementing the CTG to have an overall control efficiency of 90 percent and control equipment first installed after the effective date of rules implementing the CTG to have an overall control efficiency of 95 percent. The commission disagrees with the EPA's CTG recommendation to correlate control device efficiency requirements with the first installation date of the control device regardless of where the equipment was installed. The commission contends imposing this policy may encourage the installation of older, less efficient equipment because facilities purchasing used equipment would be held to a less stringent standard and may create potential backsliding issues. This policy could also create significant practical enforceability issues for commission investigators with regard to verifying the first installation date of the control equipment.

Regardless of the first installation date of the device, the EPA recommends providing the alternative option to reduce the control device outlet concentration to 20 parts per million by volume (ppmv) as hexane on a dry basis to accommodate situations where the inlet VOC concentration is too low to demonstrate the 90 or 95 percent control efficiency. The Chapter 115 rules provide affected owners or operators of a heatset offset lithographic printing press the option to operate a control device to reduce VOC emissions from the press dryer exhaust vent by 90 percent by weight or maintain a maximum dryer exhaust outlet VOC concentration of 20 ppmv. The Chapter 115 alternative concentration limit is substantially preferable because it encourages VOC emission reductions without requiring add-on controls and implementing the EPA's recommended approach would penalize operations that were able to achieve the 20 ppmv limit without the installation of expensive and unnecessary add-on control devices.

Based on this analysis, the commission determined that the adopted Chapter 115 rules for offset lithographic printing operations provide an overall VOC control level that is at least equivalent to the 2006 CTG recommendations and are more effective and enforceable. Therefore, the revised Chapter 115, Subchapter E, Division 4 rules are sufficient to fulfill RACT for offset lithographic printing operations. The commission made no change in response to the comment.

EDF and GHASP commented that the commission failed to provide an adequate justification for rejecting all of the EPA's work practice recommendations in the 11 VOC CTG documents issued from 2006 through 2008. EDF and GHASP stated that rejecting the CTG-recommended work practices based on the unverified assumption that facilities are implementing similar practices fails to demonstrate the kind of reasonable explanation required of agencies and is unsupportable given the significant progress needed to restore healthy air to the citizens of the HGB area.

The commission provides a negative declaration for the Flat Wood Paneling Coatings CTG, Fiberglass Boat Manufacturing Materials CTG, and Auto and Light-Duty Truck Assembly Coatings CTG source categories. The commission has determined that no sources meeting the applicability criteria recommended in these CTG documents are located in the HGB area.

The commission is not making a determination at this time whether the recommendations in the following CTG documents represent RACT for Texas: Industrial Cleaning Solvents, Miscellaneous Industrial Adhesives, Large Appliance Coatings, Metal Furniture Coatings, Miscellaneous Metal and Plastic Parts Coatings, Flexible Packaging Printing Materials, and Paper, Film, and Foil Coatings. The executive director will proceed with RACT analyses of these CTG documents and initiate a future SIP revision and rulemaking for the commission's consideration, if necessary, to submit RACT determinations to the EPA in a timely manner.

In response to comments received regarding the offset lithographic printing rule revisions, the commission is revising the rule to include the CTG-recommended work practice requirements for offset lithographic printing operations.

The EPA commented that the commission did not propose a RACT determination for the Industrial Cleaning Solvents CTG or the Miscellaneous Industrial Adhesives CTG. The EPA commented that for the HGB area to meet the requirements for RACT (40 Code of Federal Regulations (CFR) §51.912), the commission will need to complete RACT determinations and take appropriate action for these two CTG categories. The EPA indicated approval of the VOC RACT update would only be considered for those CTG categories that have been thoroughly addressed.

As noted in the EPA's comment, the commission did not make a determination whether the Industrial Cleaning Solvents and Miscellaneous Industrial Adhesives CTG recommendations represent RACT for Texas. The commission maintains the EPA substantially underestimated the scope and potential impact of these CTG recommendations, especially the impacts to small businesses. The commission is conducting research to determine the quantity of affected sources in the HGB area and plans to provide small business outreach to engage stakeholders that could be potentially impacted by the EPA's suggested control measures. The executive director will proceed with RACT analyses of these CTG documents and initiate a future SIP revision and rulemaking for the commission's consideration, if necessary, to submit RACT determinations to the EPA in a timely manner.

The EPA commented that the commission did not propose a RACT determination for the Large Appliance Coatings, Metal Furniture Coatings, and Miscellaneous Metal and Plastic Parts Coatings CTG. The EPA commented that for the HGB area to meet the requirements for RACT (40 CFR §51.912), the commission will need to complete RACT determinations and take appropriate action for these three CTG categories. The EPA indicated approval of the VOC RACT update would only be considered for those CTG categories that have been thoroughly addressed. The EPA acknowledged that it has not yet responded to the commission's request for clarification on potential backsliding issues in the Large Appliance Coatings, Metal Furniture Coatings, and Miscellaneous Metal and Plastic Parts Coatings CTG documents; specifically, the commission requested clarification on implementing CTG recommendations for specialty

coatings that are less stringent than the EPA's general-use coating RACT recommendations from the 1970s. The EPA identified two options for moving forward with the RACT analysis of these CTG recommendations: (1) implement only those CTG-recommended specialty coating content limits that are more stringent than existing state limits; or (2) relax the existing coating content limits consistent with the new CTG recommendations and provide additional analysis to demonstrate compliance with the non-interference provisions under FCAA, §110(l).

As noted by the EPA, the commission did not make a RACT determination for the Large Appliance Coatings, Metal Furniture Coatings, and Miscellaneous Metal and Plastic Parts Coatings CTG recommendations. The EPA's CTG documents for these emission source categories did not contain sufficient information for the commission to determine if the CTG recommendations constitute RACT for Texas. On December 8, 2008, the commission requested written clarification on why the coating content limits in these CTG recommendations were less stringent than the previously issued RACT recommendations for the same source categories. While the EPA has not yet formally responded to the December 2008 letter, the commission appreciates the EPA's suggestions regarding the issues raised by the commission. The executive director will proceed with RACT analyses of these CTG documents based on the guidance provided in the EPA's comments and initiate a future SIP revision and rulemaking for the commission's consideration, if necessary, to submit RACT determinations to the EPA in a timely manner.

The EPA commented that the commission has chosen not to adopt the recommended work practices in the 2006 Flat Wood Paneling Coatings CTG. The EPA added that these work practice requirements provide reasonable, cost-effective controls and are an important way to reduce emissions. The EPA stated that to meet RACT requirements, the commission should either adopt rules implementing the work practice requirements or provide analysis demonstrating that the requirements are satisfied by existing rules.

At the September 23, 2009, agenda for proposal of this attainment demonstration SIP revision, the commission determined that no sources in the HGB area meet the applicability criteria in the 2006 Flat Wood Paneling Coatings CTG. The commission provided a negative declaration for the Flat Wood Paneling Coatings CTG source category in Chapter 4: *Control Strategies and Required Elements*, Section 4.2: *Existing Control Measures*, Section 4.4.3.1: *CTG Documents That Are Not Applicable to the HGB Area* of this attainment demonstration SIP revision; however, some of the language used in the RACT analysis in Appendix D: *Reasonably Available Control Technology Analysis* of this attainment demonstration SIP revision did not clearly reflect this determination. Appendix D: *Reasonably Available Control Technology Analysis* has been revised to clearly indicate that the commission is providing a negative declaration for this emission source category with regard to RACT for the HGB area.

The EPA commented that the commission needs to address the VOC RACT requirements for the Fiberglass Boat Manufacturing Materials CTG source category. The EPA disagreed with the commission's interpretation of the EPA's 1988 guidance for determining alternative applicability thresholds for RACT ("Issues Relating to VOC Regulation Cutpoints, Deficiencies, and Deviations, Clarification to Appendix D of November 24, 1987 *Federal Register*" issued May 25, 1988) since the calculation was not specifically based on emission sources in the HGB area. The EPA commented that the Fiberglass Boat Manufacturing Materials CTG-recommended controls are cost-effective, and RACT for this emission source category should be addressed.

The 2008 Fiberglass Boat Manufacturing Materials CTG document did not identify any sources in Texas that would be subject to the CTG-recommended controls. However, as of the September 23, 2009, agenda for proposal of this attainment demonstration SIP revision, the commission could not make a definitive negative declaration for this source category. Since that time the commission has conducted extensive additional review of sources identified in the point source emissions inventory, Title V permits, and central registry

databases. No sources meeting the applicability criteria recommended in the CTG document were identified in the HGB area. Therefore, the commission provides a negative declaration for this emission source category with regard to RACT for the HGB area.

The EPA commented that the commission has chosen not to adopt the recommended work practices in the 2007 Flexible Package Printing CTG and the 2007 Paper, Film, and Foil Coatings CTG. The EPA added that these work practice requirements provide reasonable, cost-effective controls and are an important way to reduce emissions. The EPA stated that to meet RACT requirements, the commission should either adopt rules implementing the work practice requirements or provide analysis demonstrating that the requirements are satisfied by existing rules.

In response to EPA's comments, the commission has decided to reevaluate the RACT determinations for the Flexible Packaging Printing Materials and the Paper, Film, and Foil Coatings CTG recommendations. The executive director will proceed with RACT analyses of these CTG documents based on the guidance provided in the EPA's comments and initiate a future SIP revision and rulemaking for the commission's consideration, if necessary, to submit RACT determinations to the EPA in a timely manner.

EDF and GHASP disagreed with the statement on Page D-3 of the proposed attainment demonstration SIP revision that the "EPA has issued CTG documents defining RACT for existing facilities and ACT documents that describe available control technologies but do not define presumptive RACT levels." EDF and GHASP stated that the EPA's CTG establish presumptive levels of control that demonstrate RACT.

The commission agrees that the EPA's CTG documents establish presumptive RACT. In the statement referenced by the commenters, the commission generally describes both the EPA's CTG and ACT documents. As quoted in the comment from EDF and GHASP, the commission indicates that the EPA has issued CTG documents defining RACT. In the same sentence, the commission indicates that the EPA has also issued ACT documents that describe available control technologies but do not define presumptive RACT levels. The commission has revised the statement in Appendix D: *Reasonably Available Control Technology Analysis* of this attainment demonstration SIP revision to avoid any future confusion resulting from sentence structure. The revised statement reads, "The EPA has issued CTG documents defining RACT for existing facilities. The EPA has also issued ACT documents that describe available control technologies but do not define presumptive RACT levels."

EDF and GHASP commented that the commission rejected nearly all of the EPA's RACT recommendations in the 11 CTG documents issued from 2006 to 2008 without adequately demonstrating that the alternative strategies relied on to fulfill RACT requirements for these emission source categories will achieve equivalent emission reductions.

The commission disagrees with the commenters' statement that the commission rejected nearly all of the 11 CTG documents. The commission is making a negative declaration for three of the CTG source categories: the Flat Wood Paneling Coatings CTG; Fiberglass Boat Manufacturing Materials CTG; and Auto and Light-Duty Truck Assembly Coatings CTG source categories. The commission has determined that no sources meeting the applicability criteria recommended in these CTG documents are located in the HGB area. States are allowed to provide negative declarations for such situations. Furthermore, the commission did not propose RACT determinations for five of the 11 CTG categories. As discussed elsewhere in this response to comments, the commission determined additional research was needed on two CTG categories (Industrial Cleaning Solvents and Miscellaneous Industrial Adhesives), and the EPA had not yet responded to the commission's request for clarification on three other CTG categories (Large Appliance Coatings, Metal Furniture Coatings, and Miscellaneous Metal and Plastic Parts Coatings).

The commission determined that CTG recommendations for the offset lithographic printing industry do represent RACT, and the commission is adopting rule amendments to implement additional RACT requirements for this category. The commission proposed that additional controls were not necessary for two of the 11 CTG categories (Flexible Packaging Printing Materials and Paper, Film, and Foil Coatings); however, as discussed elsewhere in this response to comments, the commission is withdrawing RACT determinations for these two categories.

The CTG documents for which the commission is not making a RACT determination at this time include: Industrial Cleaning Solvents; Miscellaneous Industrial Adhesives; Large Appliance Coatings; Metal Furniture Coatings; Miscellaneous Metal and Plastic Parts Coatings; Flexible Packaging Printing Materials; and Paper, Film, and Foil Coatings. The executive director will proceed with RACT analyses of these CTG documents and initiate a future SIP revision and rulemaking for the commission's consideration, if necessary, to submit RACT determinations to the EPA in a timely manner.

Regarding the EDF and GHASP comments about equivalent reductions, the commission maintains that the overall VOC control level in the adopted Chapter 115, Subchapter E, Division 4 rules is equivalent to or more stringent than the EPA's 2006 Offset Lithographic and Letterpress Printing CTG recommendations and sufficient to fulfill RACT for offset lithographic printing operations. Additional discussion regarding the overall control level of the adopted rules for the offset lithographic printing industry is provided elsewhere in this response to comments.

RACM

The EPA commented that the proposed reduction and reallocation of the Harris County HRVOC cap does not require HRVOC levels to be reduced below currently reported levels. The EPA stated that the current 25 percent reduction in the HECT cap would still be higher than reported emissions and would allow for growth and allowances for upset conditions. The EPA added that the 25 percent cap reduction would allow HRVOC emission increases at HECT-applicable facilities compared to the highest annual actual HECT emissions. The EPA suggested that the commission consider as part of the RACM analysis whether reductions in actual HRVOC emissions could accelerate attainment.

EDF and GHASP stated that they see no reason to delay additional cap reductions beyond the proposed 25 percent at this time. The commenters stated that to ensure that the area is meeting the FCAA requirement to implement all RACM as expeditiously as practicable, the commission must lower the cap to a meaningful level that will produce actual emissions reductions in the near term, or provide a logical, reasoned explanation as to why doing so is not feasible. EDF and GHASP stated that since this HECT cap reduction is based on the fact that emissions from capped sources during the first two years of the program only averaged approximately 56 percent of the total allocated allowances, the commission should not claim that a 25 percent reduction in the cap would result in any actual emissions reductions. They added that since the reduction is only in allowable emissions there will not be any improvement in actual air quality. EDF and GHASP commented that a HECT cap reduction closer to 50 percent is necessary in order to achieve any actual reductions and air quality improvement.

The commission agrees that the HECT reallocation and cap reduction does not require mandatory reductions of HRVOC emissions from program participants. The purpose of the rulemaking is to reallocate the program for a more equitable distribution of allowances based on actual monitoring data and reduce the HRVOC cap in Harris County by 25 percent. A more equitable allocation of allowances will stimulate the market, creating incentives for further reductions in the industry regulated by the program.

Photochemical modeling analysis demonstrates that the proposed HECT rule revision, which includes a reallocation and 25 percent reduction of the HRVOC emissions in Harris County, would advance attainment of the 1997 eight-hour ozone NAAQS by reducing the future 2018 ozone design values at all HGB area monitors. For the three monitoring sites with 2018 projected eight-hour ozone design values greater than the NAAQS, Deer Park (DRPK; CAMS 35), Bayland Park (BAYP; CAMS 53) and the non-regulatory, industry sponsored Wallisville (WALV; CAMS 617) monitor, the average decrease in the projected DV_{18}s was 0.13 ppb. The DRPK; CAMS 35 monitor's DV_{18} was the highest in the HECT sensitivity modeling. The HECT sensitivity modeling decreased the DRPK; CAMS 35 DV_{18} from 86.49 ppb to 86.36 ppb.

The commission agrees with EDF and GHASP that HRVOC monitoring data reported for 2006 through 2008 indicates that the total actual emissions from sources in the HECT program have been approximately 50 percent of the total current HRVOC cap. Because the HRVOC rules in Chapter 115, Subchapter H, Division 1 and Division 2 require emissions from maintenance, startup, and shutdown activities and emissions events be included in the HECT program, the total surplus observed in the two years that the program has been active cannot be removed. Therefore, a buffer in the cap is still needed to account for the inherent variability of HRVOC emissions associated with these activities. The 25 percent reduction in the Harris County HRVOC cap allows for a sufficient buffer to protect against the inherent variability in HRVOC emissions, and according to photochemical modeling, the average 2018 future cap design value is within EPA's range for WoE discussion.

EDF and GHASP suggested a number of additional general VOC control measures that should be considered sources of additional emission reductions. EDF and GHASP commented that current rules for condensate tanks in §115.112(a)(3) only require a control device capable of a 90 percent reduction. EDF and GHASP suggested additional reductions in flash emissions from hydrocarbon storage tanks, by requiring installation of a control device capable of a 95 percent or 98 percent removal efficiency for tanks with cumulative, uncontrolled emissions equal to or greater than 20 tpy. The commenters cited Colorado and Wyoming requirements as sources for these suggested storage tank control measures. EDF and GHASP suggested a number of other general VOC control measures that should be considered sources of additional emission reductions, including: requiring the use of low-bleed control devices on all new and existing pneumatic devices used in oil and gas operations; requiring all pneumatic pumps to route gas vent lines to a combustion device; requiring VOC controls on glycol dehydrators located at oil and gas exploration and production operations, natural gas compressor stations, drip stations or gas processing plants with actual uncontrolled VOC emissions of 15 tpy or more; requiring natural gas operators to reduce VOC emissions during well completions or work-overs by the use of specified practices generally referred to as green completions; and requiring VOC controls for natural gas-fired reciprocating internal combustion engines rated 100 horsepower or greater.

The commission disagrees that the suggested RACM should be considered as potential sources of additional emission reductions. Based on photochemical modeling sensitivity matrix analyses, the commission determined that reductions in general VOC emissions (i.e., non-HRVOC emissions) would not advance attainment of the HGB area. The 2018 future-year matrix modeling sensitivity runs indicate that even substantial reductions in general VOC emissions will not have a significant enough impact on ozone reduction to be considered as RACM. The two regulatory monitors that still exceed the eight-hour ozone NAAQS in the 2018 future base case, DRPK; CAMS 35 and BAYP; CAMS 53, are insensitive to general VOC reductions. Approximately 130 tpd of general VOC reductions would be needed to reduce ozone at the DRPK; CAMS 35 monitor by 1 ppb. Approximately 230 tpd of general VOC reductions would be needed to reduce ozone at the BAYP; CAMS 53 monitor by 1 ppb. Given the magnitude of VOC reductions needed to affect the ozone concentrations, and the lack of availability of strategies that could accomplish these magnitudes, the commission has concluded that general VOC reduction

control measures would not advance attainment and were not RACM because even large reductions of general VOC emissions would only result in a small ozone reduction benefit in the HGB area. Additional information on the photochemical modeling sensitivity runs is provided in Chapter 3: *Photochemical Modeling* of this attainment demonstration SIP revision. Additionally, the commission notes that the Colorado and Wyoming regulations and permitting requirements referenced by the commenters only apply to new or modified sources. The control requirements in §115.112(a) apply to existing and new sources and result in actual VOC reductions from existing sources.

EDF and GHASP suggested resetting the NO_X cap at a reduced level to account for improvements in NO_X control technology and to reflect the beneficial effects of energy efficiency and renewable energy measures that are increasingly being implemented.

The commission disagrees that the suggested control measure should be implemented. The commission performed a thorough evaluation of additional NO_X control measures as part of the RACM analysis and determined that additional NO_X controls were not RACM due to technological and economic factors. Additional detail regarding the NO_X RACM analysis is provided in Appendix E: *Reasonably Available Control Measures Analysis* of this attainment demonstration SIP revision. In addition, as discussed in Section 5.4.3.5: *Energy Efficiency and Renewable Energy (EE/RE) Measures* of this attainment demonstration SIP revision, the complex nature of the electrical grid makes accurately quantifying emission reductions from EE/RE projects difficult. Any NO_X emission reductions resulting from EE/RE programs cannot be explicitly determined because local efficiency efforts may not result in local emissions reductions or may be offset by increased demand in electricity. Therefore, the commission determined that the suggested measures are not RACM because the emission reduction benefit is not quantifiable.

Kaneka cited a portion of the RACM analysis in Appendix E: *Reasonably Available Control Measure Analysis* of the proposed attainment demonstration SIP revision, describing the practicality issues identified with revising NO_X allowances under the MECT program because allowance streams have been traded and relied upon for compliance with the program. Kaneka concluded that if it is impractical to nullify MECT trades then it is also impractical to nullify HECT trades that have also been relied upon for compliance with the program.

The commission maintains that reallocation associated with reducing the Harris County HECT program cap is RACM. After the initial HECT program allocation, due to stakeholder comments and information from the first two years of monitoring data supporting the assertion that the program was not equitably distributed, the commission committed to reallocating the HECT program as soon as sufficient actual monitored HRVOC emissions data were available. A more equitable allocation of allowances will stimulate the market, creating incentives for further reductions in the industry regulated by the program. The commission acknowledges that practicality is one of the EPA's evaluation criterion considered during the state's RACM analysis. In the portion of the RACM analysis referenced by the commenter, the commission also acknowledges practicality issues associated with revising MECT program NO_X allocations. However, as discussed at length in Appendix E: *Reasonably Available Control Measure Analysis*, Section 4.2.1: *Mass Emission Cap and Trade (MECT) Program and Chapter 117 NO_X Rules RACM* of this proposed attainment demonstration SIP revision, the commission concluded that further NO_X reductions through the MECT program did not constitute RACM on the basis of economic and technological feasibility, not practicality. Therefore, the commission disagrees with the commenter's conclusion that revising the HECT program should not be considered RACM based on the commission's RACM determination regarding revising the MECT program.

The commission agrees that the nullification issue should be addressed. The rules have been revised to allow sites that purchased allowances stream the potential to apply

allowances from the stream to the calculation of uncontrolled emissions as actual emissions. Revised §101.394(a)(1) allows sites holding stream trades to calculate their uncontrolled emissions as the greater of their actual average emissions of their two highest emission years from 2006 through 2009 or the sum of their original existing HECT HRVOC allowance and the amount of the allowance stream in tons. In the event that a site's actual two high year emissions is less than the sum of its original existing HECT HRVOC allowance and the amount of the allowance stream in tons, the difference shall be added to the uncontrolled emissions as actual emissions. The purchase of an allowance stream also allowed some sites to operate with higher emissions during the baseline emissions period. Sites that took advantage of allowance streams would therefore realize the benefit of the higher emissions through the uncontrolled emissions-based reallocation methodology.

Flare Task Force Initiative

The EPA commented that reductions in industrial emissions would be most effective in advancing attainment. The EPA also expressed support for the commission's Flare Task Force initiative and expressed hope that it will result in future reductions of industrial emissions in the southeast quadrant of Houston, including industry around the Houston Ship Channel. The EPA suggested that additional monitoring and requirements for flares would aid in improving the emission inventory and reduce ozone precursor emissions.

As described in the RACM analysis in Appendix E: *Reasonably Available Control Measure Analysis* of this attainment demonstration SIP revision, the commission evaluated all identified potential stationary source control measures, including measures to reduce industrial emissions. The commission appreciates the EPA's support for the Flare Task Force initiative. As noted in Chapter 6: *Ongoing and Future Initiatives*, Section 6.2.1: *Flare Task Force* of this attainment demonstration SIP revision and elsewhere in this response to comments, the agency-wide Flare Task Force is evaluating the impact of flare emissions on Texas air quality and assessing the adequacy of existing flare regulations. The commission may consider additional control measures for flares in a future SIP revision as a result of its ongoing efforts to evaluate flares in Texas.

EDF and GHASP commented that the proposed attainment demonstration SIP revision states that flares represent approximately 45 percent of the total NO_X emissions from unregulated sources, and the commission's justification for not including control measures for these significant emissions was legally insufficient. EDF and GHASP commented that the current attainment demonstration SIP revision acknowledges that flares contribute an unknown amount of HRVOC especially during emissions events but does not contain any additional provisions that would result in more accurate HRVOC emissions data. EDF and GHASP suggested requiring enhanced monitoring and reporting of flare emissions and suggested establishing NO_X and HRVOC emissions limits for flares. Additionally, the commenters requested that the commission undertake a thorough analysis of controls for flares and include flare regulation in the current attainment demonstration SIP revision.

The commission acknowledges that flare NO_X emissions represent a significant percent of the currently exempt sources; however, the actual NO_X emissions from flares was approximately 5.6 tpd based on 2006 emissions inventory data. The external combustion nature of flares makes post-combustion NO_X pollution control technology infeasible, and the commission is unaware of any low-NO_X flare burner designs. The commission considers the lack of available control technology to be a legally sufficient justification for determining a potential control measure is not RACM because a key aspect of the EPA's definition of RACM is that the control measure must be technologically feasible. Any reduction in NO_X emissions from flares could only be made by a reduction in flaring. As noted in Chapter 6: *Ongoing and Future Initiatives*, Section 6.2.1: *Flare Task Force* of this attainment demonstration SIP revision and elsewhere in this response to comments, the agency-wide Flare Task Force is evaluating the impact of flare emissions on Texas air

quality and assessing the adequacy of existing flare regulations. Flare minimization is a part of that evaluation. However, while flare minimization may reduce NO_X emissions at the flare, it could also result in a corresponding increase in NO_X emissions at alternative control equipment. Further evaluation is necessary before the commission can determine whether flare minimization is a viable NO_X control measure.

Regarding the suggestions for enhanced monitoring, reporting, and HRVOC limits for flares, the commission has already established enhanced monitoring through the HRVOC rules in Chapter 115, Subchapter H, Division 1 for all eight counties in the HGB area, and flares are an applicable source category for the HECT program in Harris County. As noted in Section 6.2.1: *Flare Task Force* of this attainment demonstration SIP revision and elsewhere in this response to comments, the agency-wide Flare Task Force is evaluating the impact of flare emissions on Texas air quality and assessing the adequacy of existing flare regulations. The commission may consider additional control measures for flares in a future SIP revision as a result of its ongoing efforts to evaluate flares in Texas.

The EPA commented that since HECT sources were subject to monitoring requirements, any unreported HRVOC emissions could only come from unmonitored sources or incomplete combustion of flares and that because unmonitored sources are small, the most likely source of the emissions was flares. The EPA commented that the TCEQ model sensitivity analyses where increased flare emissions were substituted for the Potential Source Contribution Function (PSCF)-based emission reconciliation yielded improved ozone model performance and that this, along with many other scientific studies, supports the conclusion that flare emissions are underestimated. The EPA noted that the TCEQ is in the process of studying flare operations and is considering the option of requiring more monitoring and oversight of flare operations in the future.

The TCEQ agrees that flares are a potential source of under-reported HRVOC emissions and is currently conducting research to investigate this issue. Additional information concerning the TCEQ's Flare Task Force and upcoming flare studies is contained in Chapter 6: *Ongoing and Future Initiatives*.

PHOTOCHEMICAL MODELING

Support for Attainment Modeling and Weight of Evidence (WoE) Analyses

BCCA and the Coalition submitted similar sets of detailed comments totaling over 50 pages that were strongly supportive of the proposed attainment demonstration SIP revision. BCCA and the Coalition ran independent modeling scenarios that paralleled those presented in the proposed attainment demonstration SIP revision. They stated that "TCEQ adhered to EPA's modeling guidance assiduously," and described the demonstration as "exceeding requirements" and going "well beyond standard EPA methodology."

BCCA and the Coalition were complimentary of the ongoing public participation that the TCEQ facilitated in the modeling process, with specific mention of the monthly technical meetings held in the HGB area, along with the regular data file updates that were made to the TCEQ Web site and file transfer protocol (FTP) sites. BCCA and the Coalition referenced the extensive emissions, meteorological, and air quality datasets that are available from both the Texas Air Quality Study 2000 (TexAQS 2000) and TexAQS II studies, characterizing them as the most extensive and intensive databases ever assembled for regulatory modeling, far exceeding what has typically been used in 1997 eight-hour ozone SIP revisions elsewhere in the United States.

BCCA and the Coalition noted the large number of federal, state, local, academic, research, and private organizations involved in the various measurements and analyses required for the HGB attainment demonstration SIP revision modeling efforts. Supportive comments were made about the refined treatment of the lateral boundary condition inputs for Comprehensive Air Model with Extension (CAM_X), the specialized meteorological inputs for modeling the HGB area with Fifth

Generation Meteorological Model (MM5), and the extensive performance evaluation conducted on the output files from both CAM_X and MM5. The model performance evaluation was independently verified by BCCA and the Coalition using the Modeling Analysis and Performance Software (MAPS) tools, which were originally developed by Alpine/CARA Geophysics, Inc.

BCCA and the Coalition commented that the WoE portion of the proposed attainment demonstration SIP revision is robust and also provided additional corroborative analyses. A URS Corporation analysis was cited that showed the annual number of high ozone days declining from 2003-2009 even when looking solely at those days when weather conditions were conducive to ozone formation. Additional analyses showed a gradual decline from 1990-1998 in the ratio of high-ozone days to ozone-conducive days, followed by a significant drop in that ratio from 2004-2007. BCCA and the Coalition cited considerable decreases in ambient concentrations of ethylene and propylene from industrial sources in the Houston Ship Channel area since 1995.

BCCA and the Coalition cited University of North Carolina (UNC) research indicating that "the TCEQ's 2018 attainment results are, more likely than not, conservative . . ." and that "the standard EPA attainment paradigm followed by TCEQ leads to a significant degree of conservatism" at the BAYP; CAMS 53, DRPK; CAMS 35, WALV; CAMS 617, and Houston Swiss and Monroe (HSMA; CAMS 406), monitors. UNC concluded that if non-typical ozone days are filtered out of the base-case modeling, the 2018 projected future design value (DV_F) for these monitors would all be at 84 ppb or below. BCCA and the Coalition compared the EPA's recommended attainment test with eight alternatives and concluded that more conservative future design values were obtained by using TCEQ's custom approach based on 2007 EPA modeling guidance in lieu of the EPA's Modeled Attainment Test Software (MATS), which yields slightly lower values at most monitors on most episode days. BCCA and the Coalition performed source apportionment modeling on both the base and future-case scenarios and concluded that no single source category or geographic region appears to dominate future ozone formation in the HGB area.

BCCA and the Coalition commented that "TCEQ's weight of evidence determination provides a thorough and up-to-date analysis of ambient ozone and precursor levels and trends, all of which support the conclusion that the region will attain the 1997 ozone standard by the deadline." Additional analyses were provided that showed improving trends in air quality since 2002, with apparent acceleration since 2006. BCCA and the Coalition referenced declines in ambient concentrations of both NO_X and HRVOC precursors, which are attributed to over $2 billion worth of control technologies installed by industries in the HGB area since 2001.

BCCA and the Coalition expressed support for efforts by the TCEQ, described in Chapter 6: *Ongoing and Future Initiatives* to continue improving the scientific basis of the SIP modeling efforts for the HGB area. They recommended that the TCEQ pay specific attention to the following areas for potential improvement: (1) radical sources and atmospheric chemistry; (2) emissions inventory improvements; (3) quantification of emissions control sensitivity; (4) quantification of uncertainty; (5) ensemble modeling; (6) pragmatic two-ozone SIP control paradigm; (7) intercontinental transport of air pollution; (8) forge more scientific methods for attainment modeling; and (9) extended MM5/CAM_X model evaluation across full 36/12/4/2 km grid scales.

The commission concurs with the overall conclusion drawn by BCCA and the Coalition that both the photochemical modeling and WoE analyses are quite robust in demonstrating that the HGB area will attain the 1997 eight-hour ozone standard by 2019. The commission also concurs that ongoing efforts should continue to improve the areas of emissions estimation, meteorological modeling, and chemical processing mechanisms. The commission will continue to work with all interested stakeholders to improve the scientific basis of the photochemical modeling and WoE analyses that will be included in future HGB area SIP revisions.

Weight of Evidence (WoE)

CAIT, EDF, the EPA, GHASP, KIDS, SEED, and one individual commented that the WoE analysis did not account for the effects of favorable meteorological conditions on reducing the 2007-2009 ozone design values to below 85 ppb for HGB area monitors. The EPA stated that favorable meteorological conditions may have played a greater role in reducing the ozone concentrations than the reduced emissions of ozone precursors. The EPA cited 5-10 ppb drops in ozone levels over the past two years from other metropolitan areas within Region 6. The EPA claimed that these decreases are an indication that the meteorological factors affecting the HGB area also affected other Region 6 areas, and that these meteorological factors caused the ozone reductions. The EPA argued that the meteorological conditions during the 2005 and 2006 modeled ozone episodes are more conducive to ozone formation than the 2007-2009 conditions leading to the current design values. The EPA also contended that higher than average wind speeds occurred in both 2007 and 2008, leading to lower ozone concentrations. COH requested a quantification of the impacts of favorable meteorology on monitored ozone levels over the past three years. CAIT, KIDS, SEED, and one individual mention an unusually rainy and cool ozone season during 2007 and an unusually windy ozone season in 2009.

The commission agrees that meteorological factors have played a small role in the recently observed ozone trends but disagrees that the meteorological factors are the primary reason for decreasing ozone. Analyses show that ozone trends are still decreasing in the HGB area, even when the effects of meteorology have been accounted for.

The commission disagrees with the EPA that meteorological conditions in Houston during 2006 through 2009 have been unfavorable for high ozone, and therefore the decline in ozone concentrations is not due to local emission reductions. The EPA bases its position on a finding from an analysis by Sather and Snyder, which shows that higher wind speeds occurred more frequently during 2008 than in 2000 through 2007. Figure 1: *Wind Data from Houston Aldine* shows the graph of interest.

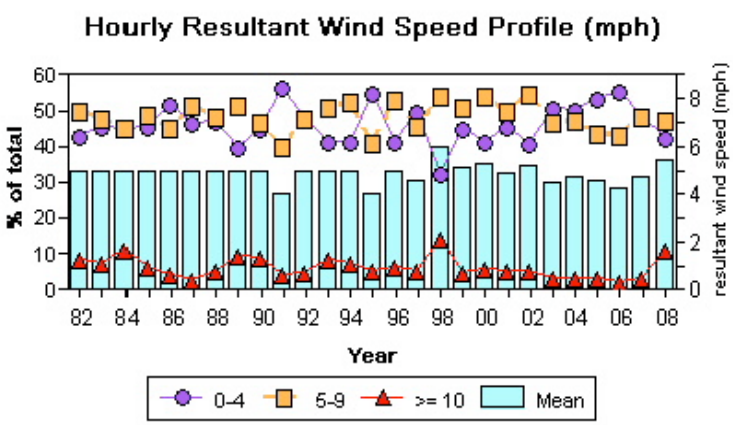


Figure 1: Wind Data from Houston Aldine

(Source: The data are from June through August, 0500 to 1900 local standard time (LST), with 65 percent minimum data capture. Winds of greater than 10 miles per hour (mph) were more frequent during 2008 than any year since 1998. This figure is copied from Sather and Snyder, *Region 6 "State of the Ozone" Report for 2008*, presented at the Southeast Texas Photochemical Modeling Technical Committee (SETPMTC) meeting, April 28, 2009.)

The EPA, and Sather and Snyder, assert that the higher winds in 2008 are the primary cause of lower ozone in 2008. As they have noted, the frequency of high winds in 2008 is

comparable to the frequency observed in 1998. The maximum 4th-high eight-hour ozone concentrations in 1998 ranged from 90 to 117 ppb at regulatory monitors throughout Houston, but the maximum 4th-high eight-hour ozone concentrations in 2008 ranged from 68 to 83 ppb at Houston regulatory monitors. This represents a 29 percent decrease in maximum eight-hour ozone from 1998 to 2008. Since the frequency of high winds is similar in 1998 and 2008, the frequency of high winds cannot explain the difference between ozone concentrations during those two years.

The commission contends that four extensive analyses of meteorological conditions (each of which includes more than just the frequency of high winds) indicate meteorological factors cannot explain the recent decrease in ozone. In addition, an analysis of the frequency of wind speed and direction will show that the period of high winds in 2008 noted by Sather and Snyder occurred at a time of year when high ozone usually does not occur because of the direction of the wind flow at that time of year. It will also show that the wind conditions were more suitable for high ozone formation in August and September of 2008 and 2009 than in 2000 and 2004, but the number of ozone exceedance days was far lower in 2008 and 2009.

Chapter 5: *Weight of Evidence* of this attainment demonstration SIP revision contains an analysis from the University of Texas at Austin (UT-Austin) that shows the ozone trends adjusted for meteorology. Those trends show that ozone levels through 2007 are decreasing even with meteorological influences removed from the trends. Much of the work from UT-Austin was based upon a variation of the analysis technique developed by Camalier, Cox, and Dolwick, which is the technique recommended by the EPA for removing the influences of meteorology from trend data. UT-Austin's analysis shows that when the portion of the ozone variation associated with meteorological factors is removed from the observed ozone trend, the residual trend is still downward. The presence of a strong downward trend after the removal of meteorological effects strongly suggests that the overall downward trend is related to factors other than meteorology.

A second analysis of meteorologically adjusted ozone trends can be found on the EPA's Web site: www.epa.gov/airtrends/weather/region06.pdf**. The EPA trends are shown in Figure 2: *Meteorologically Adjusted Ozone Trends in the HGB Area from 1997 through 2008,* that illustrates the observed seasonal average ozone trend as well as the seasonal average ozone trend adjusted for weather. The ozone trend adjusted for weather represents the expected ozone levels for typical weather conditions. According to the EPA analysis, the downward trend in Houston's ozone is unrelated to meteorological variations, beginning in 2002 and continuing through the end of the analysis period in 2008.**

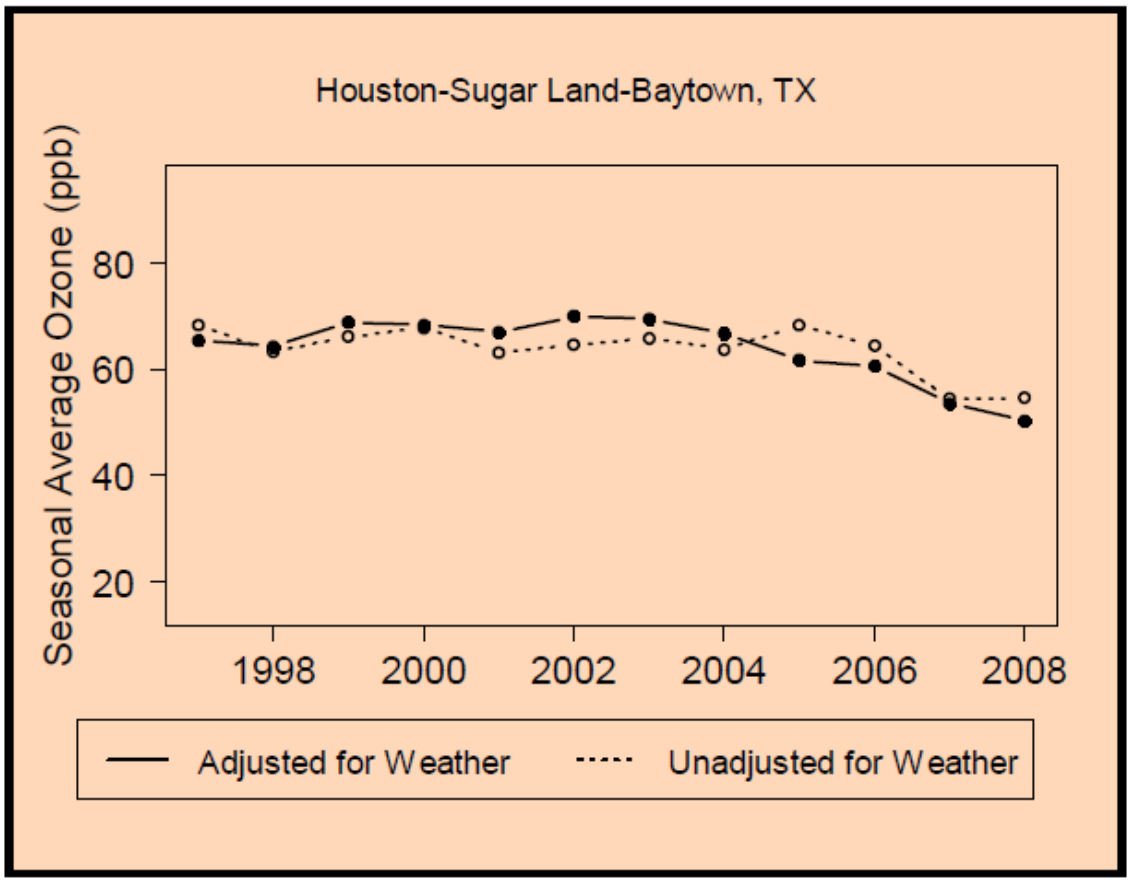


Figure 2: Meteorologically Adjusted Ozone Trends in the HGB Area from 1997 through 2008 (Source: EPA)

URS Corporation performed a third analysis of the effects of meteorology on ozone trends, which is included in comments received from the Coalition. A presentation that discusses URS Corporation's analysis can be found at: http://www.tceq.state.tx.us/assets/public/implementation/air/am/committees/pmt_set/20071212/20071212-setpmtc-hgb_ozone_trend.pdf. In the analysis, the author used the Classification and Regression Tree (CART) method, a multivariate statistical analysis technique, to classify ozone season days according to meteorological conditions, and whether those conditions are conducive to high ozone in Houston. URS Corporation's analysis calculated trends of the number of ozone-conducive days per year. Figure 3: *Number of Ozone Conducive Days and Number of Ozone Conducive Days with Ozone Greater Than 84 ppb* shows that the number of ozone-conducive days in 2007, 2008, and 2009 is similar to or greater than previous years, indicating that the past three ozone seasons have been just as conducive to high ozone formation as previous years. Since 2005, there appear to be more ozone-conducive days than average, but fewer eight-hour ozone exceedance days. Although 2005 had the largest number of ozone-conducive days since 1990, there were fewer exceedance days in 2005 than during previous years with a lower number of ozone-conducive days, such as 1995, 2000, or 2003.

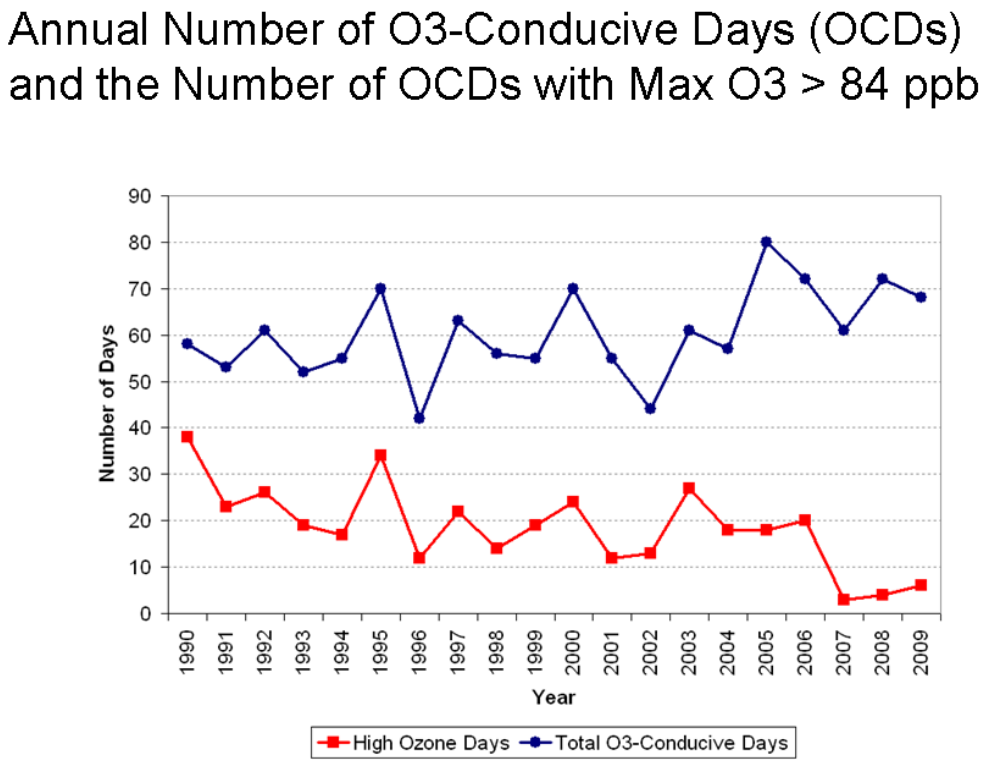


Figure 3: Number of Ozone-Conducive Days and Number of Ozone-Conducive Days with Ozone Greater Than 84 ppb (Source: URS Corporation)

A fourth analysis is presented as a response to the comment by EDF and GHASP about evaluating the trends in forecasted high ozone days. A possible surrogate for the number of ozone-conducive days during each ozone season is the number of TCEQ-forecasted eight-hour ozone exceedance days. Figure 4: *Forecasted and Actual Eight-Hour Ozone Exceedance Days (1997 NAAQS) in the HGB Area* shows that the number of forecasted eight-hour ozone exceedance days is typically greater than the number of actual eight-hour ozone exceedances to avoid missing potentially high ozone days. To adjust the forecasted eight-hour ozone exceedances to compensate for the bias, a bias-adjusted forecast was developed by accounting for the average rates of false positives (predicted exceedances that did not occur) and false negatives (predicted non-exceedances on days with high ozone). The average percent of false negative days was added to the number of forecasted ozone exceedance days, and the average percent of false positive days was subtracted. The bias-adjusted forecasted ozone exceedance days approximately match the actual number of eight-hour ozone exceedance days, with the exception of 2004 and 2008. In 2004, the bias-adjusted ozone exceedance forecast was much lower than the actual number of eight-hour ozone exceedance days. However, in 2008, the bias-adjusted forecast of ozone exceedance days was much higher than the actual number of eight-hour ozone exceedance days, indicating decreases due to factors other than meteorology. There are uncertainties in this analysis because meteorologists at the TCEQ adjust their forecast techniques as they learn more about which conditions are most conducive to ozone formation, accumulation, and transport in Houston. In other words, the criteria used for developing forecasts in 2000 may have differed somewhat from the criteria used in 2008. The results, however, are consistent with the three previous analyses, in that the peak number of ozone-conducive days in recent years appears to be in 2005, with the number decreasing slightly in 2006 to 2007. The number of forecasted ozone days in 2008 approximately matched the number in 2006, but there were about half as many actual exceedance days in 2008 as in 2006.

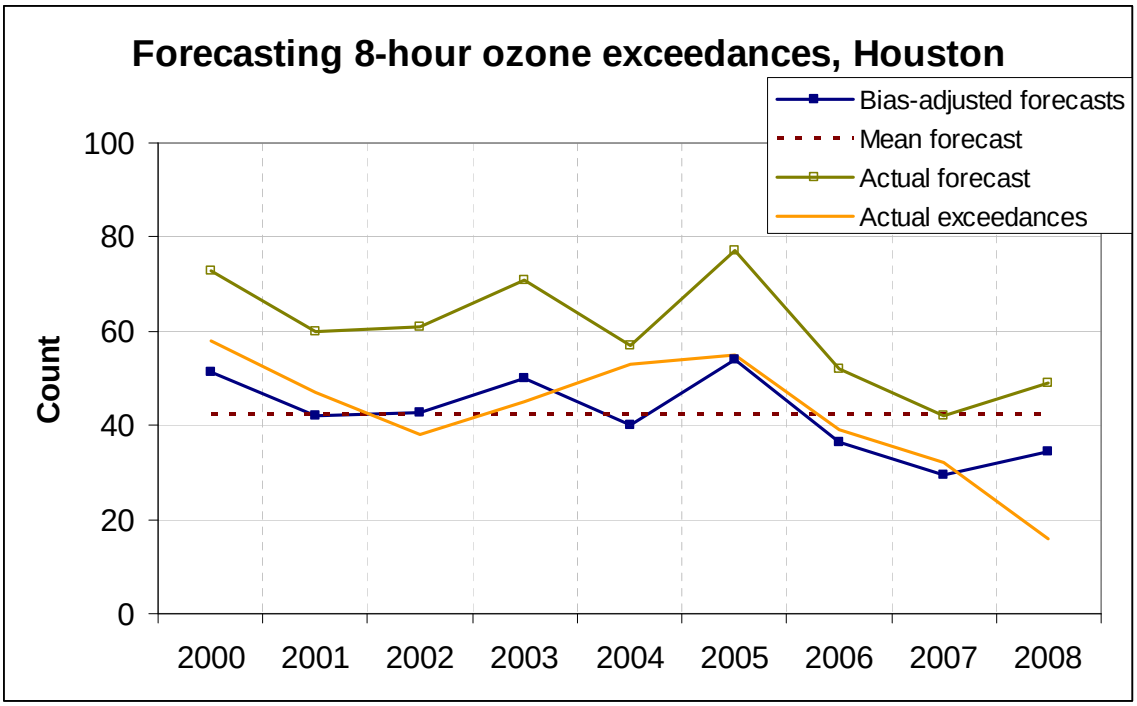


Figure 4: Forecasted and Actual Eight-Hour Ozone Exceedance Days (1997 NAAQS) in the HGB Area

Those four analyses of the effects of inter-annual meteorological variations on ozone trends all imply that meteorological factors alone cannot explain the decrease in ozone concentrations in the Houston area.

The commission has also analyzed the frequency of wind speeds and directions by month and by year to show in greater detail the wind data that the EPA had originally cited in its comment. The winds in the HGB area were examined for each month of the ozone season from 2000 through 2009 to determine if higher wind speeds in 2008 and 2009 caused decreases in ozone concentrations. Daytime wind speeds were grouped into six levels, and the frequencies of those levels were examined by wind direction for each month from May to September, which represents the peak of the ozone season in the HGB area. Figure 5: *Frequency of Morning Wind Direction and Wind Speed by Month in the HGB Area for 2000, 2004, 2008, and 2009* compares years with similar winds and shows the number of eight-hour ozone exceedances that occurred in each month (1997 NAAQS). Winds from 0 to 90 degrees are from the north to east, and, as shown in Chapter 5: *Weight of Evidence* of this attainment demonstration SIP revision, winds from that direction typically represent higher background ozone concentrations, as well as winds that can interact with the bay breeze and Gulf breeze to create stagnant conditions (Darby, 2005; Pakalapati et al., 2008; Sullivan, 2009; Ngan and Byun, 2008; Rappenglueck et al., 2008. For full references of these citations, see Chapter 5: *Weight of Evidence* of this attainment demonstration SIP revision). Winds from 90 to 225 degrees are from the east to southwest and represent cleaner air blowing in from the Gulf of Mexico (Sullivan, 2009; Rappenglueck et al., 2008. For full references of these citations, see Chapter 5: *Weight of Evidence* of this attainment demonstration SIP revision). Those east to southwest winds accentuate the bay and Gulf breezes rather than opposing them (Darby, 2005; Banta et al., 2005. For full references of these citations, see Chapter 5: *Weight of Evidence* of this attainment demonstration SIP revision). Findings from previous studies have indicated that low winds are more favorable for high ozone, whereas high winds are less favorable. Findings also show that northerly winds are more favorable for high ozone in Houston, and that southerly winds are less favorable.

The TCEQ's wind analysis found that:

- **Wind speeds in May 2000 and May 2004 were higher than those observed in May 2008 and May 2009, but the number of eight-hour ozone exceedance days was higher in 2000 compared to 2008 and 2009. May 2000 and 2004 were less conducive to ozone formation based upon wind speeds but had more exceedances than May 2008 and 2009.**

- **May 2009 also had more winds from the north to northeast direction, which typically indicates higher background ozone, but had only three exceedance days. May 2009 was more conducive based upon wind direction yet had fewer exceedances than May 2000 or 2004.**

- **June 2008 and 2009 had higher wind speeds than those observed in June of 2000 and 2004; however, winds in June are mainly out of the south, which brings in clean air from the Gulf of Mexico. There were only three exceedance days in June of 2000, five in June of 2005, and two in both June 2008 and June 2009. For all years, June was dominated by southerly winds, which are not conducive to ozone formation. The low number of exceedances each year reflects how unfavorable southerly winds are to ozone exceedances; therefore, the slightly greater frequency of high winds in June 2008 was unlikely to affect the number of exceedances in that month.**

- **July winds were very similar in 2000 and 2009, but there were only two exceedance days in July 2009 compared to 10 exceedance days in July 2000.**

- **Winds in August 2008 were slower than those observed in August 2000, yet August 2008 had one exceedance day compared to 15 in 2000. August 2008 was more conducive to high ozone than August 2000, based upon wind speeds, but had far fewer exceedances.**

- **September 2009 had slightly lower winds in the northeast direction compared to September 2000 and 2004, but only three exceedance days compared to 10 in September 2000 and 13 in September 2004. September 2009 was more conducive to high ozone, but had far fewer exceedances than September 2000 or 2004.**

In summary, Figure 5: *Frequency of Morning Wind Direction and Wind Speed by Month in the HGB Area for 2000, 2004, 2008, and 2009* shows that the wind speed and direction were actually more conducive to ozone formation during the peak of the ozone season in August and September in 2008 and 2009 than in 2000 and 2004, but 2000 and 2004 had far more exceedances than 2008 and 2009. The greater frequency of high winds in 2008 noted by Sather and Snyder occurred during June, when winds were southerly, and therefore not conducive to high ozone, during all four years.

Evidence provided in the proposed attainment demonstration SIP revision, along with additional analyses presented in this response to comments, show that favorable meteorology is not adequate to explain the decreases in ozone observed in 2007, 2008, and 2009. Because the last stepdown of NO_X emissions in the MECT program occurred in 2007, the commission contends that these substantial reductions are a primary cause of ozone reductions, not weather patterns. Evidence presented in Chapter 5: *Weight of Evidence* of this attainment demonstration SIP revision shows that decreases in ozone precursor emissions played a significant role in the recent decreases in ozone.

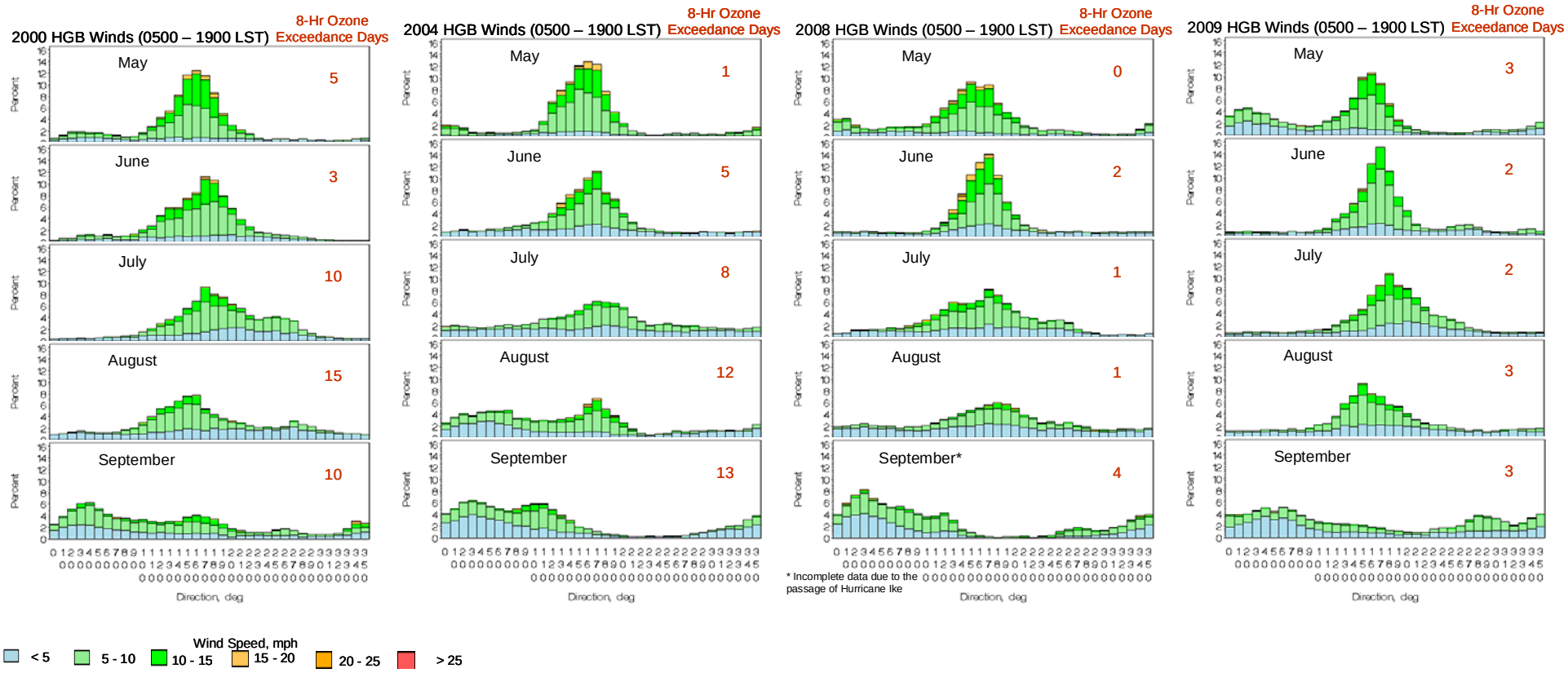


Figure 5: Frequency of Morning Wind Direction and Wind Speed by Month in the HGB Area for 2000, 2004, 2008, and 2009

EDF, the EPA, and GHASP commented that the WoE analysis did not account for the effects of the recent economic downturn on the 2007-2009 ozone design values being at or below 84 ppb for HGB area monitors. Specifically, the EPA noted that "industry representatives have commented . . . that their emissions have been lower in the last few years (starting in 2007) due to economic influences and when demand improves it is likely their emissions will increase over the levels in 2007-2009." The EPA further stated that "after the economy gains strength and emissions likely increase . . . it seems unlikely that the area will continue to monitor attainment." The EPA emphasized that some of the monitors currently at or close to an 84 ppb design value are located within or downwind of industrial areas and would then likely register higher ozone levels when economic demand increases in the future. COH requested a quantification of the emission inventory changes and approximate ozone reductions that have occurred over the past few years due to the economic downturn. COH requested a list of actions necessary to make these emission changes permanent and enforceable.

The commission disagrees with these comments. Detailed analysis of actual economic data from the HGB area, Texas, and the refining industry along the Gulf Coast does not support these conjectures based on anecdotal evidence and speculation. Indeed, there is no evidence of an economic downturn in Texas, the HGB area, or the petrochemical industry specifically, prior to early 2009. None of the commenters provided any specific data to back up the assertions made in their comments.

Though the national economy entered a recession beginning in the fourth quarter of 2007, both Texas and the HGB area continued to experience robust economic expansion during 2007 and 2008. Only in early 2009 did either Texas or the HGB area begin to exhibit flat or slightly reduced economic activity. While Texas Gross Domestic Product (GDP) increased 7.3 percent in nominal terms from 2006 to 2007 (see Figure 6: *Gross Domestic Product of Texas*) and 6.5 percent from 2007 to 2008, the economy of the Houston-Sugarland-Baytown area grew even faster, at 8.4 percent and 7.4 percent over those years, respectively (see Bureau of Economic Analysis, Regional Economic Accounts: www.bea.gov/regional/gsp/ **and GDP by Metropolitan Area:** www.bea.gov/regional/gdpmetro/**). Though these figures are not corrected for inflation, inflation was exceptionally low over this period. Houston-Sugarland-Baytown is the definition of the HGB metropolitan area used by the United States Department of Commerce.**

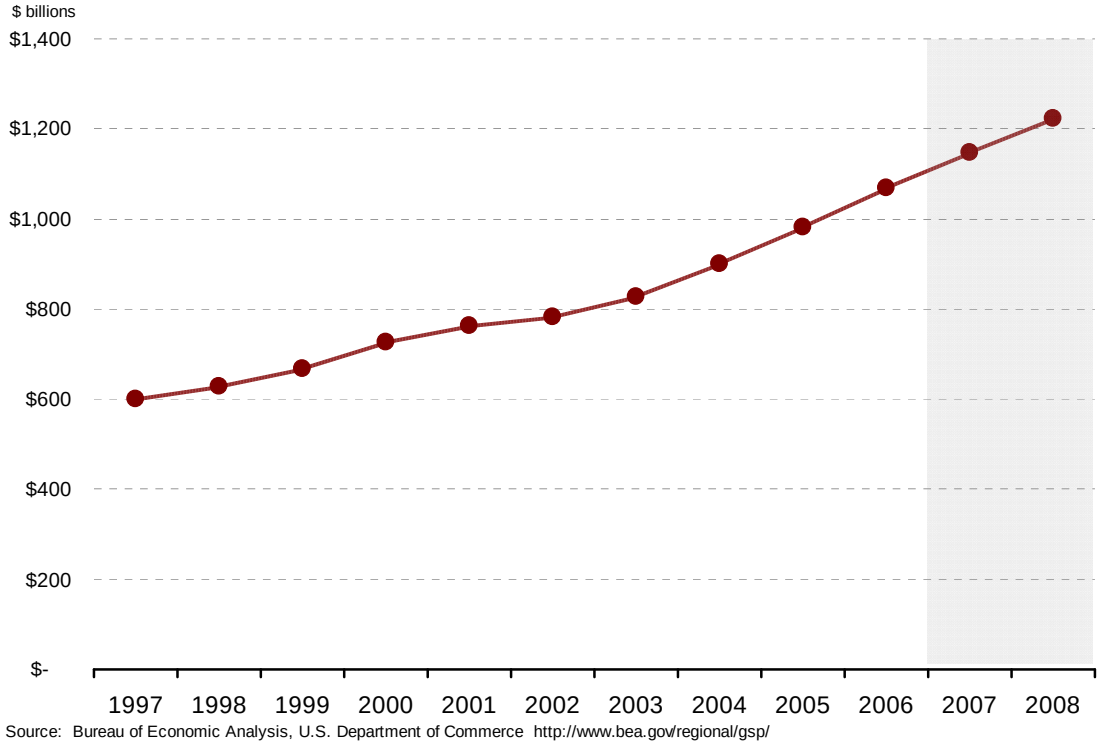


Figure 6: Gross Domestic Product of Texas

Another measure of economic activity for the Houston-Sugarland-Baytown metro area, the business cycle index computed by the Federal Reserve Bank of Dallas (www.dallasfed.org/data/data/houcoini.htm), exhibits a downward trend beginning only in early 2009 (Figure 7: *Metro Area Business Cycle Index, Houston-Sugarland-Baytown*). The index, which incorporates measures of employment, real wages, and retail commerce, grew 5.6 percent from December 2006 to December 2007, and 2.5 percent from December 2007 to December 2008. Through September 2009, the index is down -2.7 percent from the end of 2008. This index, available through the first three quarters of 2009, shows that during each of the years 2007, 2008, and 2009 to date, the HGB area generated greater economic activity than in any previous year on record, exceeding an index value of 245 in every month. Prior to 2007, the index never exceeded that value. Despite this burgeoning economic activity, the HGB area continued to exhibit reductions in both precursor emissions and resultant ozone over those three years.

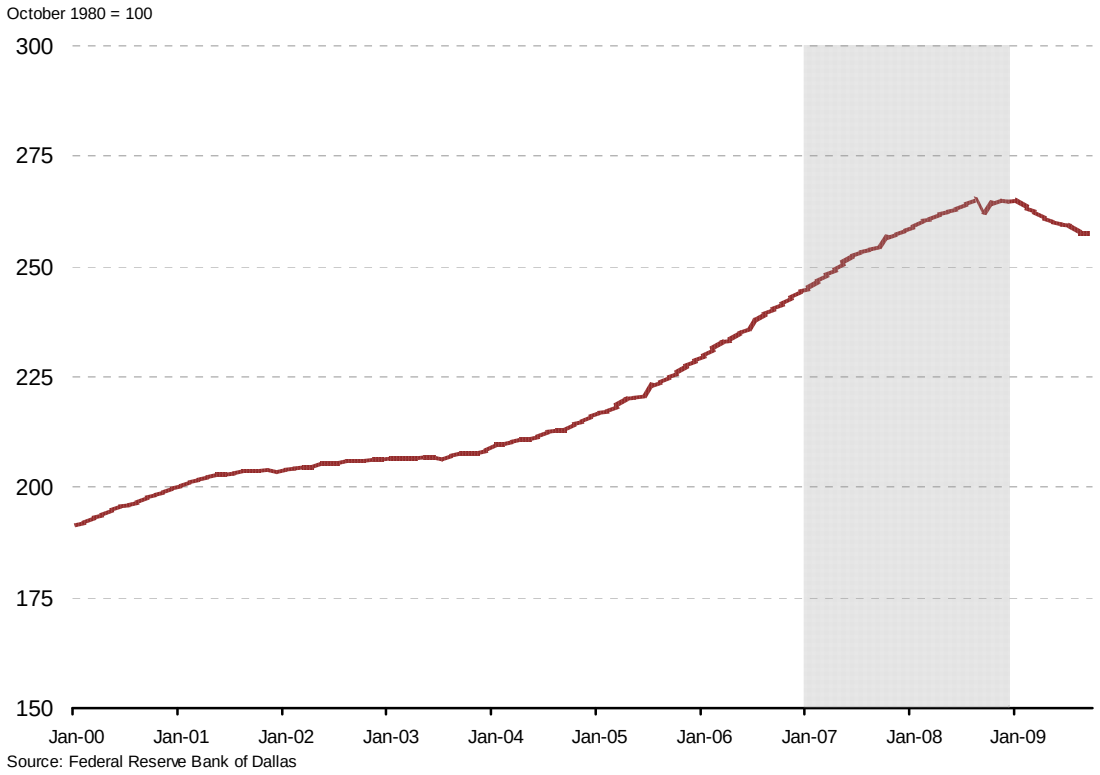


Figure 7: Metro Area Business Cycle Index, Houston-Sugarland-Baytown

While the overall economies of Texas and the HGB area were not impacted by the economic downturn until early 2009, industries linked to petrochemicals and refining, which are key to HGB area air quality, also failed to exhibit the claimed downward trend (see Figure 8: *Gross Domestic Product of Selected Petroleum Related Industries*). From 2006 to 2007, the most recent annual period for which sub-industry GDP data are available, oil and gas extraction increased 7.6 percent. Similar patterns exist for other segments of the petroleum industry over that period. Manufacturing of chemicals grew 9.9 percent, while manufacturing of plastics and rubber products increased 2.7 percent. Only manufacturing of petroleum and coal products declined (at a rate of -1.9 percent) from 2006 to 2007.

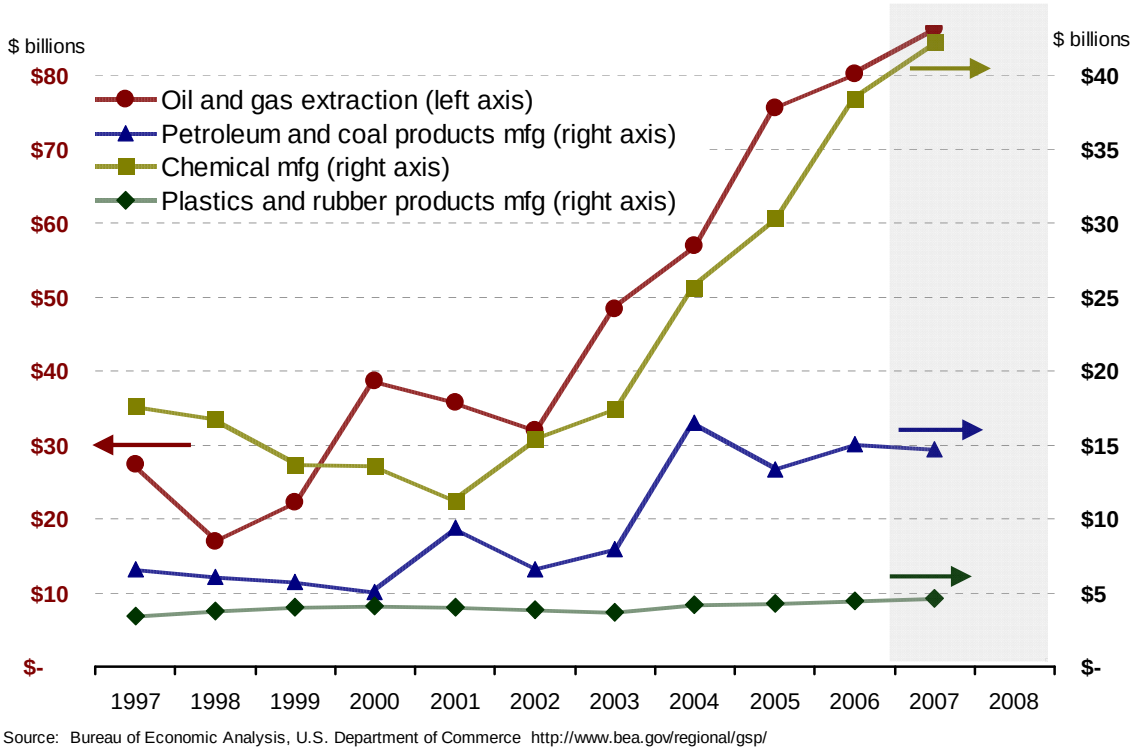


Figure 8: Gross Domestic Product of Selected Petroleum Related Industries

While more recent data on GDP trends in the petrochemical and refining industries are not yet available, other recent information on activity in those industries corroborates these findings. The Energy Information Administration of the United States Department of Energy reports refining activity along the Gulf Coast, termed Petroleum Administration for Defense District (PADD) 3, which includes the HGB area (tonto.eia.doe.gov/dnav/pet/pet_sum_sndw_dcus_r30_w.htm). As evident in Figure 9: *Weekly Gulf Coast (PADD 3) Crude Oil Inputs to Refineries*, reported weekly inputs are highly variable. A 13-week, or roughly quarterly, moving average is superimposed on the weekly data to smooth out some of this variability. That measure reveals the seasonal cycles in the industry, as refineries ramp up production for periods of high product demand. Although inputs to refineries appear to be on a slight downward trend since 2007, they have actually been increasing since early 2009, though this is likely a cyclical phenomenon. In fact, neither high nor low values of the quarterly average since 2007 have strayed beyond the highest or lowest values observed over the previous decade indicating the industry as a whole has neither grown nor shrunk markedly.

A quadratic fit to the weekly data reveals a very slight long-term downward trend in the refining industry, beginning around 2004. Since 2004, PADD 3 inputs to refineries have generally dropped, at a rate of about -0.7 percent per year, even when hurricane-affected periods in 2005 (Katrina, Rita) and 2008 (Ike) are excluded.

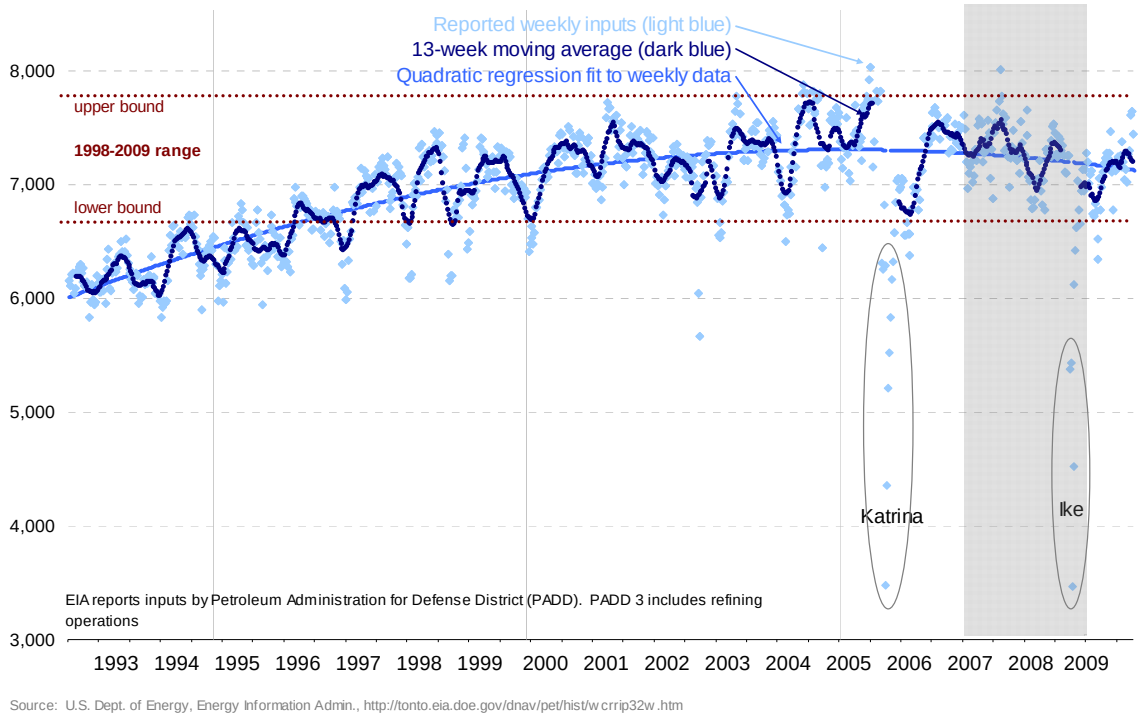
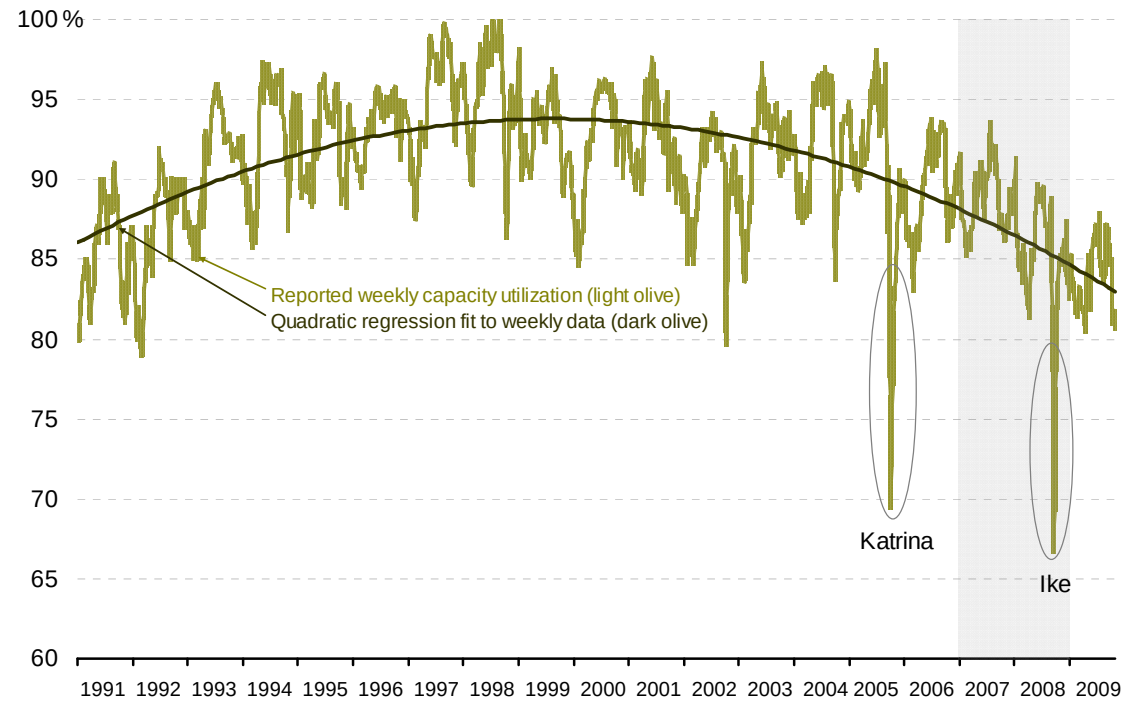


Figure 9: Weekly Gulf Coast (PADD 3) Crude Oil Inputs to Refineries

This may suggest factors other than an economic downturn in 2007 or 2008 were influencing the industry. Average weekly inputs to refineries in 2007 were 7.35 million barrels, 1.4 percent above the average of the previous year and nearly as high as in 2004, when they averaged 7.37 million barrels per week. Although inputs to refineries in 2008 fell about 3 percent after six weeks of hurricane-affected data were removed, they were back on trend again by 2009, dropping -0.6 percent.

An additional perspective on trends in the petrochemical industry is provided in Figure 10: *Weekly Percent Utilization of Refinery Operable Capacity, PADD 3*, which summarizes utilization of available refining capacity, also reported by the Energy Information Administration of the United States Department of Energy (tonto.eia.doe.gov/dnav/pet/hist/wpuleus3w.htm). Capacity utilization, like inputs to refineries, is highly variable from week to week but is clearly on a long-term downward trend, having peaked in 1998 at 100.5 percent of operable capacity. Since then, despite considerable seasonal variation, it has fallen in most years as evident from the quadratic regression fitted to the series. When considered on an annualized basis to smooth out short-term fluctuations, average capacity utilization decreased -0.7 percent from 2006 to 2007, -4.3 percent from 2007 to 2008, and -1.1 percent from 2008 to 2009. The decade-long duration of this downward trend corroborates the earlier conclusion that the petroleum refining industry may likely be experiencing phenomena unrelated to the national recession that began in 2007. That recession, though severe in many areas of the country, is not apparent within the refining industry and was likely not the primary determinant of refining activity in PADD 3.



Source: U.S. Dept. of Energy, Energy Information Admin.

Figure 10: Weekly Percent Utilization of Refinery Operable Capacity, PADD 3

The EPA commented that the WoE analysis excluded a discussion of how recent emission trends correlate with ozone-monitoring trends. The EPA mentioned that the modeling and attainment guidance recommends inclusion of such an analysis for WoE discussions. The EPA stated that future expected emission trends should also be included in this analysis for the area, non-road, on-road, and point major source categories.

As the EPA correctly states on pages 102 and 103 of its modeling guidance, "a simpler (and more uncertain) way to qualitatively assess progress toward attainment is to examine recently observed air quality and emissions trends." Refer to *Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze*, EPA-454/B-07-002, April 2007. An emission trend analysis is less sophisticated, less certain, and less quantitative than other analyses, and for that reason, no emission trend data were included in the original proposal. The commission contends that ambient NO_X and VOC data are a more reliable indicator for historical emission trends than the emissions inventory data, which have more and larger sources of error associated with estimating industrial emissions. Chapter 5: *Weight of Evidence* of this attainment demonstration SIP revision contains extensive historical ozone precursor trend analyses that are based upon monitoring data. Those ozone precursor concentration trends are not subject to the underestimates observed in the industrial emissions inventories.

However, the EPA's request for a trend analysis for past and future emissions by major source category can be satisfied with the emission estimates that are included in Chapter 2: *Emissions Inventories*, Section 2.7: *Emissions Summary* of the Houston-Galveston-Brazoria Reasonable Further Progress (RFP) State Implementation Plan Revision for the 1997 Eight-Hour Ozone Standard (Project No. 2009-018-SIP-NR), which is being adopted concurrently with this attainment demonstration SIP revision. For more detail on the development of those emission inventories, see the RFP SIP revision, along with its accompanying appendices. Figure 11: *RFP NO_X Emission Trends from 2002 to 2018* and Figure 12: *RFP*

VOC Emission Trends from 2002 to 2018 **present bar chart summaries of the controlled NO_X and VOC emissions compared with uncontrolled emission totals.**

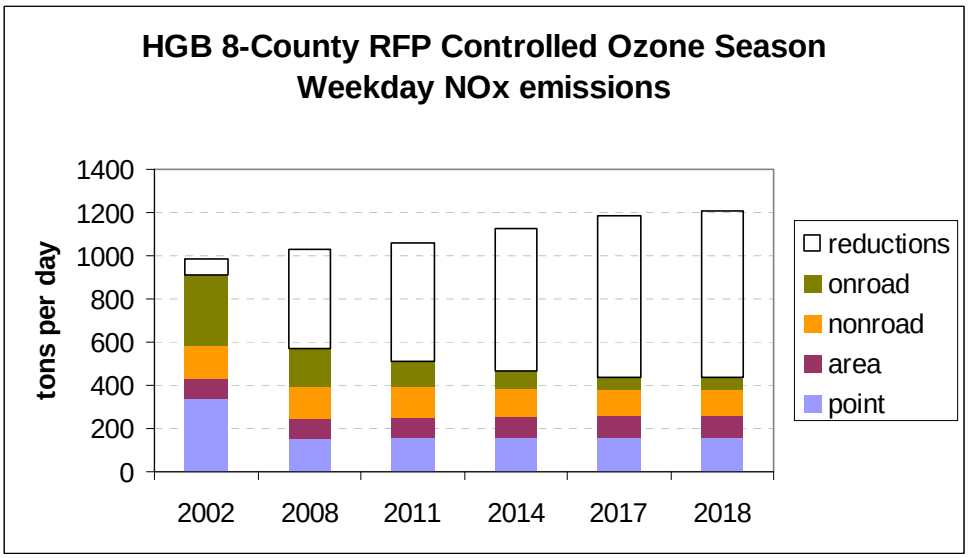


Figure 11: RFP NO_X Emission Trends from 2002 to 2018

Figure 11: ***RFP NO_X Emission Trends from 2002 to -2018*** **includes each source category, based upon weekday emissions within the eight-county HGB area. The reductions shown here represent the mass of weekday NO_X emissions eliminated by controls each year.**

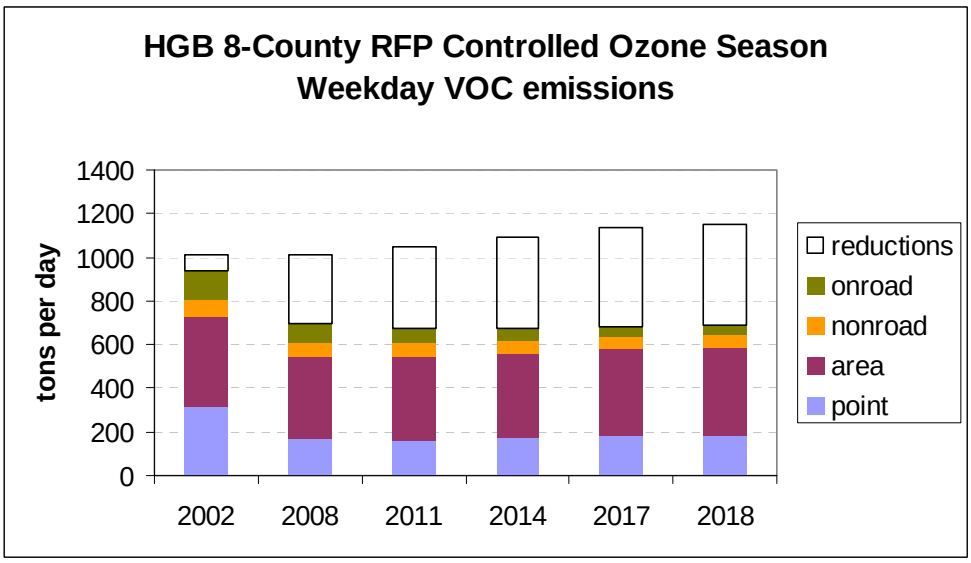


Figure 12: RFP VOC Emission Trends from 2002 to 2018

Figure 12: ***RFP VOC Emission Trends from 2002 to 2018*** **includes each source category, based upon weekday emissions within the eight-county HGB area. The reductions shown here represent the mass of weekday VOC emissions eliminated by controls each year.**

EDF, GHASP, HSC, and LWV Houston opposed reliance on WoE to augment photochemical modeling. EDF and GHASP recommended that additional control measures be included to model below 84 ppb. EDF and GHASP claimed that the following three WoE arguments are insufficient to overcome the absence of modeling lower than 84 ppb: (1) model under-prediction

of reductions; (2) recent trend of decreasing ozone concentrations; and (3) voluntary and other control measures that may not be implemented.

The commission disagrees with this comment. The EPA's modeling and analysis guidance recommends the use of WoE analyses to complement attainment demonstrations. The EPA's *Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze,* Section 2.3: *What Does A Recommended Supplemental Analysis/Weight Of Evidence Determination Consist Of? --An Overview* says that states "should always perform complementary analyses of air quality, emissions and meteorological data, and consider modeling outputs other than the results of the attainment test. Such analyses are instrumental in guiding the conduct of an air quality modeling application. Sometimes, the results of corroboratory analyses may be used in a WoE determination to show that attainment is likely despite modeled results which may be inconclusive." Table 2.1: *Guidelines for Weight of Evidence Determinations* on page 17 states that a WoE demonstration should be conducted when the future ozone design values fall in the range of 82 to 87 ppb. Due to the inevitable uncertainty that exists with respect to emission estimates, meteorological inputs, and chemical mechanisms, Section 7.1: *What Types of Additional Analyses Should Be Completed as Part of the Attainment Demonstration?* on page 105 says "EPA believes that weight of evidence determinations can be used in some cases to demonstrate attainment conclusions that differ from the conclusions of the model attainment test."

TCC commented that it supports the WoE section but recommends that it be further strengthened to include the full range of 2007-2009 ozone monitoring data, which currently shows compliance with the 84 ppb standard. TCC specifically mentioned that the current Deer Park monitor design value is 81 ppb even though the 2018 projected design value is 87.9 ppb. TCC also mentioned the current Bayland Park monitor design value of 84 ppb in contrast to the 2018 projected design value of 86.9 ppb.

The commission has updated Chapter 5: *Weight of Evidence* of this attainment demonstration SIP revision to include the 2009 ozone monitoring data. At the time that the proposal was prepared, the 2009 ozone season was not complete, and these data could not be included. The 2018 ozone design values estimated by the photochemical model are approximate, based upon the expected changes in emissions between the baseline and the future. The various tools used to estimate the emissions levels, meteorological impacts, and chemical mechanisms are inexact and precision cannot be expected.

Emissions Projections

The EPA commented that the attainment section did not include use of the MATS tool. For the monitored attainment test, the EPA stated that MATS should be used to indicate photochemical model predictions for areas outside of each monitor's grid cell array.

The EPA developed MATS to provide regulatory entities conducting SIP revision photochemical modeling with a tool for applying the attainment test. MATS can be used to apply the attainment test for monitored as well as unmonitored areas. Under the EPA's modeling and analyses guidance, an unmonitored area analysis is recommended to identify areas where future-year design values are predicted to be greater than the NAAQS.

The EPA initially released MATS in June 2007 and subsequently updated MATS in 2009. However, to conduct the attainment demonstration modeling for SIP revisions for the 1997 eight-hour ozone standard (e.g., Dallas-Fort Worth; May 2007) with submission dates prior to the initial release of MATS, the TCEQ developed and implemented its own software procedures for both applying the attainment test at monitors and conducting an analysis of unmonitored areas. While conceptually similar to MATS, the TCEQ's procedures offer

advantages, including the advantage that they can be more easily integrated into photochemical modeling output processing streams. For example, MATS requires input in latitude and longitude for monitor coordinates, while the TCEQ's procedures work directly with the Lambert Conformal Projection (LCP) monitoring coordinates used in our photochemical modeling applications. Also, MATS cannot easily handle multi-year baseline photochemical modeling that is for the same month and day, whereas the TCEQ software can. Regarding the unmonitored area analysis, MATS uses a technique called Voronoi Neighbor Averaging (VNA) for spatial interpolation, while the TCEQ's procedures rely upon the more familiar kriging technique. For these reasons, MATS was not used for either the monitored attainment test or the unmonitored area analysis.

On February 18, 2009, at the SETPMTC meeting attended by EPA Region 6 staff, the TCEQ presented a comparison of 2018 future-year eight-hour ozone design values using the EPA's MATS and the TCEQ's software procedures (http://www.tceq.state.tx.us/assets/public/implementation/air/am/committees/pmt_set/20090218/20090218-smith.pdf**). The results of this comparison show the two methods agree closely. Where slight differences in the two methods were found, the error appeared to be with the MATS analysis (e.g., MATS occasionally assigned monitors to the wrong grid cells). In addition, during a conference call on March 10, 2009, with the EPA Region 6 staff, the EPA Office of Air Quality Planning and Standards staff, and the TCEQ photochemical modeling staff, the comparison of the two methods was discussed as well as the planned use of the TCEQ-derived software procedures rather than MATS for photochemical modeling in this attainment demonstration SIP revision. During neither meeting did the EPA indicate that MATS was scientifically superior to the TCEQ-derived software procedure for conducting the monitored attainment test.**

Although the comparison of the two methods focused primarily on the application of the attainment test at monitors and not the unmonitored area analysis, it was not considered necessary to conduct an unmonitored area analysis. The HGB area is well-monitored. As discussed in Chapter 3: *Photochemical Modeling* of the attainment demonstration SIP revision, including non-regulatory, industry-sponsored monitors that have a baseline design value (DV_B) and a relative response factor (RRF) denominator greater than or equal to 85 ppb mitigates the need to conduct an unmonitored area analysis for the area represented by the non-regulatory monitor. The relatively large number of monitors, both regulatory and non-regulatory, industry-sponsored, deployed in the HGB area provides adequate coverage, such that there are no areas outside of a monitor's 7x7 grid cell array for which future-year design values are predicted to be greater than the NAAQS. However, since the EPA, in its comments and subsequent follow-up discussions, expressed strong concerns about the TCEQ's decision to omit the unmonitored area analysis, the issue was re-visited as discussed further in this response to comments. Use of MATS is a part of EPA's guidance, not rule or statute. Since the TCEQ has developed a less resource-intensive yet consistent tool, the commission contends that it is not necessary to conduct a duplicative exercise with the limited resources and time constraints of this SIP revision. Due to these constraints, the re-analysis uses the kriging method and not MATS. If necessary, a MATS analysis could be provided at a later date.

Figure 13: 2 km Modeling Domain Grid Cells Projecting Eight-Hour Ozone DV_F Greater than 84 ppb, and 7x7 Grid Cell Arrays for Regulatory Monitors shows a map of the 2 kilometer (km) modeling domain depicting those grid cells with a projected DV_F greater than the NAAQS (shown in pink), and the 7x7 grid cell arrays around each of the regulatory monitors as well as the WALV; CAMS 617 non-regulatory, industry-sponsored monitor (shown in purple). The grid cells with a projected DV_F greater than the NAAQS were determined using the kriging technique. As shown in the figure, there are eight grid cells with a projected DV_F greater than the NAAQS that fall outside the 7x7 grid cell array around the WALV; CAMS 617 non-regulatory, industry-sponsored monitor. However,

these eight grid cells are within a 7x7 grid cell array around the Baytown Wetland Center (BYWC; CAMS 552) non-regulatory monitor. Although the BYWC; CAMS 552 non-regulatory monitor does not receive the level of quality assurance and quality control (QA/QC) required for regulatory status, the measured ozone concentrations at BYWC; CAMS 552 are more appropriate for testing attainment than a concentration derived from kriging. The BYWC; CAMS 552 non-regulatory monitor has a DV_B equal to 85.3 ppb and a RRF of 0.954 yielding a DV_F less than 85 ppb. Applying the attainment test at the BYWC non-regulatory monitor mitigates the need to conduct a MATS analysis for the eight grid cells with a projected DV_F greater than the NAAQS, derived from kriging. A modified modeling analysis is presented in Chapter 3: Photochemical Modeling and Appendix C: Photochemical Modeling for the HGB Attainment Demonstration SIP that includes the BYWC non-regulatory monitor.

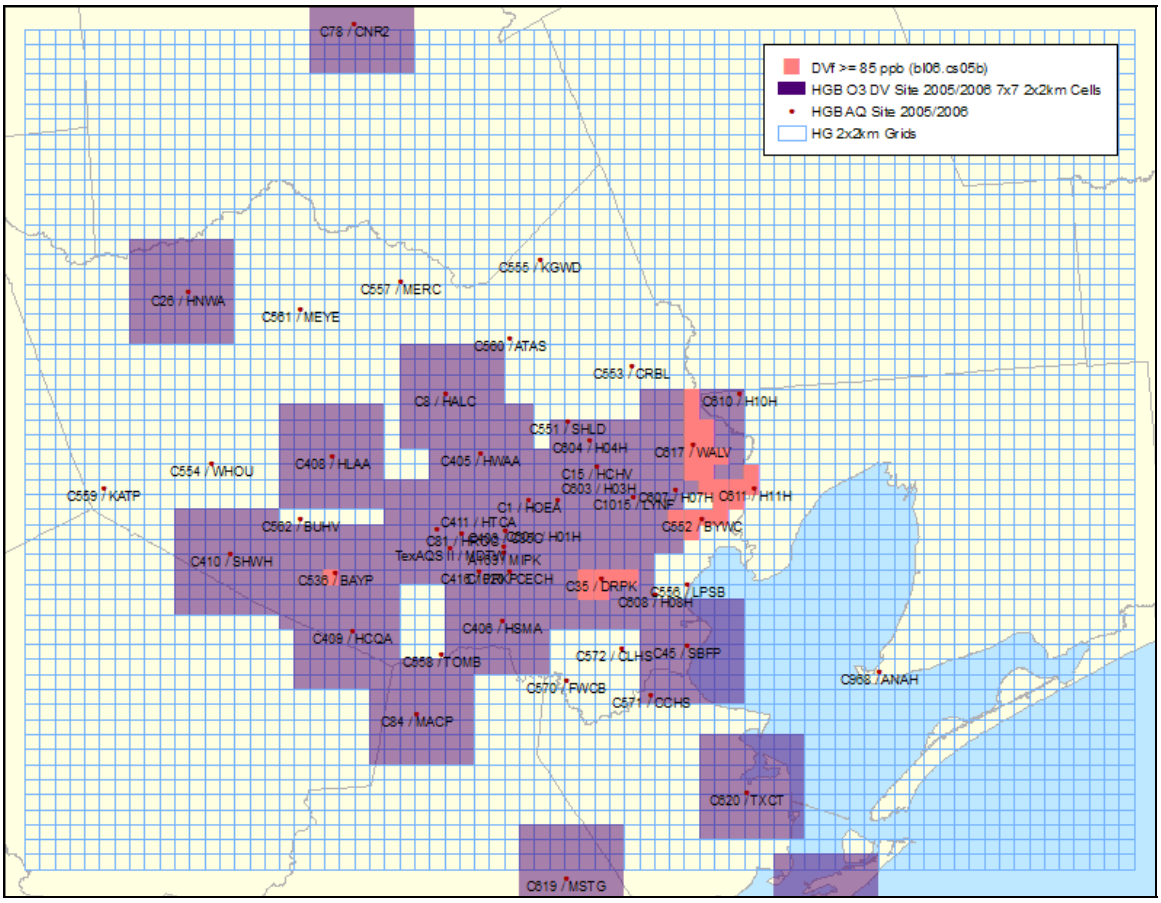


Figure 13: 2 km Modeling Domain Grid Cells Projecting Eight-Hour Ozone DV_F Greater than 84 ppb, and 7x7 Grid Cell Arrays for Regulatory Monitors

EDF and GHASP commented that VOC emissions will steadily rise out to 2018, specifically citing Table 3-13: *Summary of 2006 Baseline and 2018 Future Base, and 2018 Control Strategy Anthropogenic Modeling Emissions for HGB* on page 3-25 of the proposed attainment demonstration SIP revision. EDF and GHASP requested a justification for a roughly 100 tpd increase in VOC emissions from point sources by 2018. TCC requested justification for the projected point source VOC increase in Table ES-1: *Summary of 2006 Baseline, 2018 Future Year, and 2018 Control Strategy Anthropogenic Modeling Emissions for HGB* of the proposed attainment demonstration SIP revision of 208.34 tpd in 2006 to 306.77 tpd in 2018.

Positive VOC emissions growth within the eight-county HGB nonattainment area was projected for the area and point source categories. Area and point source VOC modeling emissions for the 2018 future year were developed using growth factors applied to the 2006 baseline modeling emissions. Emissions growth factors were developed using trends in demographic, economic, and commodity production activity data and the EPA's Economic Growth Analysis System (EGAS) version 5.0, which associates activity data with emissions. Two sets of activity data were used: (1) the Dallas Federal Reserve Bank's Texas Industrial Production Index (TIPI) data, which is specific to an industry's Standard Industrial Classification (SIC) (e.g., petrochemical manufacturing); and (2) a Texas-specific application of the Regional Economic Models, Inc (REMI) model data, which is specific to the source category classifications (SCCs) within an SIC (e.g., product tanks at a petrochemical manufacturing facility).

Both the TIPI and the REMI data sets were used with EGAS version 5.0 to derive two sets of emission growth factors, i.e., TIPI-EGAS and Texas-specific REMI-EGAS. The Texas-specific REMI-EGAS also includes growth factors for area source categories.

As reported in Chapter 3: *Photochemical Modeling* of this attainment demonstration SIP revision, 2018 area source emissions, including VOC emissions, were estimated by applying the Texas-specific REMI-EGAS growth factors to the 2005 TexAER database. However, no growth or control factors were applied to the flash emissions, which are now subject to the storage vessel and degassing rule in Chapter 115 because currently the emission reductions are not quantifiable. Since the net result of the controls and future growth in flash emissions will likely result in emissions reductions, the current modeling likely overestimates the future-year area source VOC emissions.

Also, as reported in Chapter 3: *Photochemical Modeling* of this attainment demonstration SIP revision, 2018 point source emissions, including VOC, were estimated by applying the larger of the TIPI-EGAS, REMI-EGAS growth factors, or banked ERCs and DERCs to the 2006 baseline emissions. This growth was applied to account for emission increases at non-major sources and modifications at major sources that are not significant, neither of which would require offsets. Considering the recent decreasing trend in reported point source VOC emissions (Figure 14: *HGB Point Source VOC and NO_X Emission Trends From 2003 through 2007*), selecting the larger of the growth factors may overestimate the growth in point source emissions by 2018.

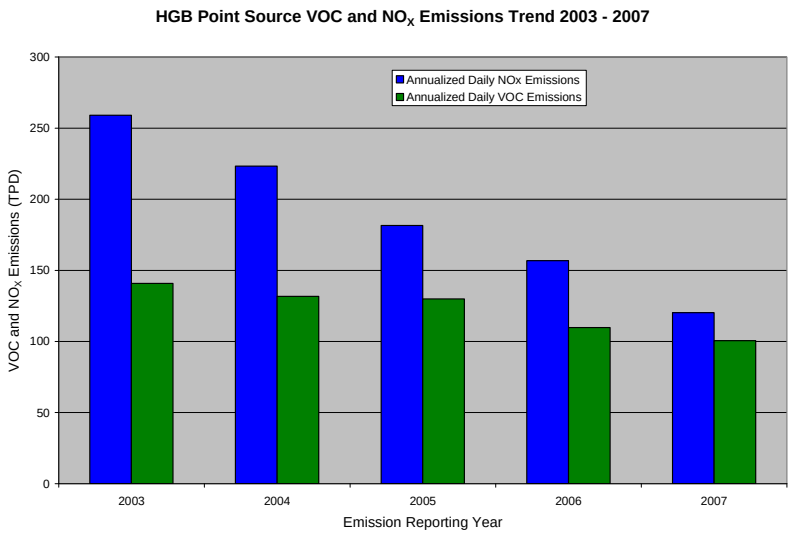


Figure 14: HGB Point Source VOC and NO_X Emission Trends from 2003 through 2007

In the December 2004 HGB MCR SIP revision (Project Number 2004-042-SIP-NR), 2007 future-year VOC emissions were 255 tpd compared to the 2018 future-year emissions of 290 tpd in this proposed attainment demonstration SIP revision. The corresponding NO_X emissions are 512 and 377 tpd, respectively. Since modeling sensitivities for both SIP revisions indicate that, with the exception of HRVOC, ozone formation is much less sensitive to VOC than NO_X reductions, the increase in projected point source VOC emissions should not compromise attainment. As noted, the increase in VOC is due to growth projections, primarily from non-major area and point sources; it is not a result of a relaxation or removal of a SIP requirement. Therefore, the increase is not backsliding under the one-hour ozone standard.

A conservative estimate of emissions growth for future-year attainment modeling was used in this attainment demonstration SIP revision. Subsequently, both the 2006 baseline modeling emissions and the 2018 future-year emissions, including the VOC emissions for point sources, have been reevaluated and revised based on updates to the 2006 State of Texas Air Reporting System (STARS) point source database. The revised 2006 and 2018 point source modeling emissions for the eight-county HGB nonattainment area are 241 tpd and 290 tpd, respectively, representing a growth of 49 tpd, which is approximately 1.6 percent per year.

Because the executive director has committed to a mid-course review, VOC emissions and their growth may be reevaluated at that time, if appropriate, to assess the validity of growth assumptions used within this SIP revision.

Emissions Reconciliation

The EPA commented that the TCEQ's method of reconciling reported emissions of HRVOC with ambient concentrations adds 10 tpd of emissions to Harris County, using a technique derived from the PSCF. The EPA requested confirmation that 6 tpd of the additional 10 tpd originate from HECT sources. The EPA commented that removing these 6 tpd in 2018 is not justified because there are no additional rules or enforceable commitments in the proposed attainment demonstration SIP revision.

The commission partitioned the 10 tpd added through emissions reconciliation into 6 tpd from HECT sources and 4 tons from non-HECT sources, assuming the additional tons were distributed proportionally to 2006 reported emissions. The proposed attainment

demonstration SIP revision narrative was clarified accordingly. The commission disagrees with the EPA's contention that removing the 6 tpd of HRVOC emissions is unjustified. Nevertheless, 2018 control strategy photochemical modeling has been revised so that the additional 6 tpd is not removed.

The EPA commented that the PSCF-based emission reconciliation improves model performance but that even with the added HRVOC emissions, the model underestimates the peak ozone levels. The EPA expressed concern that the reconciliation method did not add sufficient emissions to allow the model to replicate the highest peaks. The EPA suggested two reasons this occurs: (1) incommensurability of modeled and measured concentrations; and (2) using a multi-year annual mean in the reconciliation.

The commission agrees that the emissions reconciliation improves model performance and that, in some cases, the model does not simulate the highest observed one-hour ozone peaks. However, this attainment demonstration SIP revision is for the 1997 eight-hour ozone standard, not the one-hour ozone standard, and the model usually does not underestimate observed peak eight-hour ozone concentrations. The emissions reconciliation method was designed to improve the characterization of routine HRVOC emissions, and neither it nor any other available methodology is capable of a prior prediction of emission events or random emission fluctuations that may cause higher precursor concentrations on specific days. The commission agrees that incommensurability issues may affect the emission reconciliation, but that by using median values in the calculation, this effect should be minimized. Finally, the EPA is mistaken in its claim that the TCEQ used a multi-annual mean in its application of the emissions reconciliation. In fact, the PSCF adjustment was applied separately for 2005 and 2006.

Retrospective Modeling

The EPA commented that the retrospective modeling between 2000 and 2006 is not conclusive in showing responsiveness to emission controls. The EPA stated that ozone design values and meteorology for the time periods are different. The EPA emphasized that conclusions cannot be reached about model responsiveness to controls due to the overall uncertainty in estimated emission levels.

Uncertainty does exist in both the 2000 and 2006 emissions inventories, as it does for any set of emission estimates. Both of the inventories were reconciled with observational data so that the emission inputs used in the retrospective modeling analyses reflect available adjusted inventories. The commission asserts that the retrospective analysis included in this modeling demonstration is appropriate and is in accordance with EPA's modeling and analyses guidance.

The EPA's modeling and analyses guidance does not precisely specify how a retrospective analysis should be done but rather provides flexibility to states in how to carry out this kind of analysis. The commission decided to use the same methodology that the EPA prescribes for an attainment demonstration, which includes modifying the observed design values by the RRF developed from the modeling. In this instance, the relative change between 2000 and 2006 was used in the same way that the relative change between 2006 and 2018 was used in the RRF calculation.

Figure 15: *Modeled and Observed Response to Emission Changes Between 2000 and 2006* shows how the model and observations respond to the emission changes between 2000 and 2006. The model predicts ozone design values 15 percent lower with 2006 emissions compared to 2000 emissions. But the observations show that the ozone design values actually decreased by 28 percent from 2000 to 2006. Figure 16: *Modeled and Observed Response to Weekend Emission Reductions* shows how the model and observations respond

to emission changes that occur between weekdays and weekends. For the weekend effect, the model response is also less than the observed response. Other studies have also found weaker responses by the model than observed. Another example of how photochemical grid models have underestimated the response to emission reductions can be found in a study by EPA scientist Alice Gilliland and colleagues, published in 2008 in *Atmospheric Environment*. In that study, the authors showed that both relative and absolute model response to the NO_X SIP call emission reductions, published on October 27, 1998, in the *Federal Register* (63 FR 57356), are less than the observed responses. For the 2005 version of the Carbon Bond (CB05) chemical mechanism, which is used by the TCEQ, the relative response in modeled ozone concentrations from 2002 to 2005 is about 73 percent of the observed relative response. The retrospective analysis presented in the Chapter 5: *Weight of Evidence*, Section 5.2: *Corroborative Analysis: Modeling* of this attainment demonstration SIP revision is in agreement with other studies showing that modeled ozone response to emission controls is underestimated.

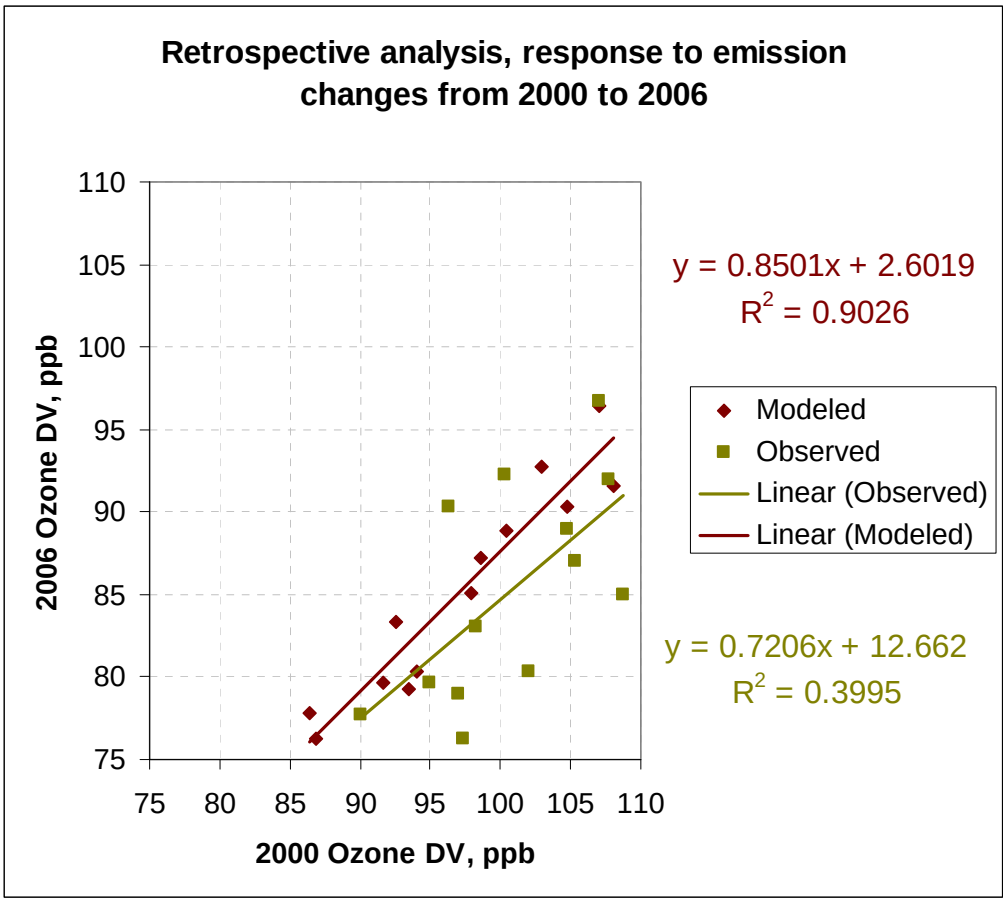


Figure 15: Modeled and Observed Response to Emission Changes between 2000 and 2006

In Figure 15: *Modeled and Observed Response to Emission Changes Between 2000 and 2006*, each point represents the values for a particular monitoring site. The slopes of the response lines show the degree of ozone decrease from 2000 through 2006.

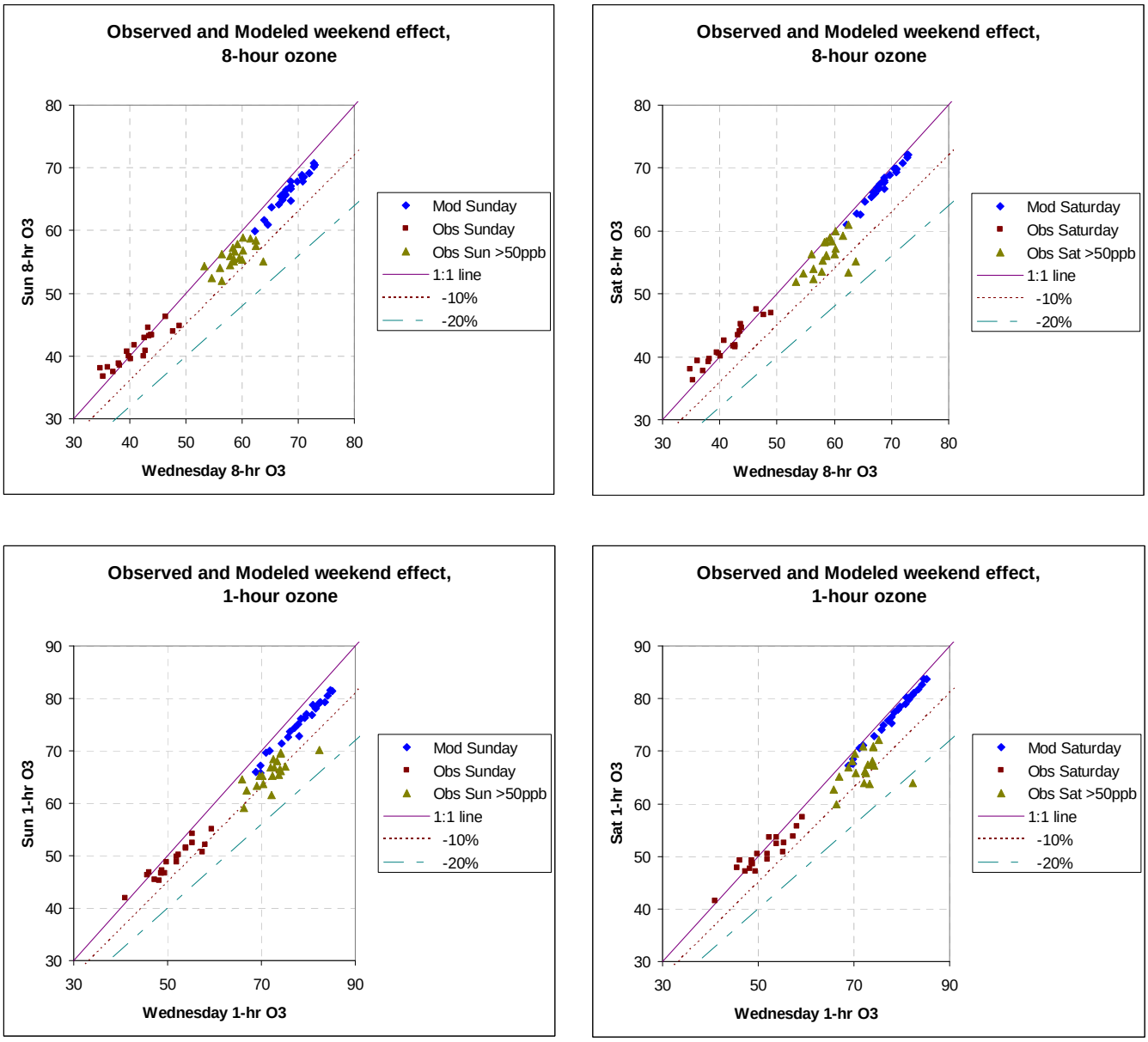


Figure 16: Modeled and Observed Response to Weekend Emission Reductions

In Figure 16: *Modeled and Observed Response to Weekend Emission Reductions*, blue squares show average daily maximum modeled ozone concentrations on Wednesday and Saturday or Sunday; green triangles show the average daily maximum observed ozone concentrations on Wednesday and Saturday or Sunday for days with maximum area-wide peak eight-hour ozone over 50 ppb. The latter values are more comparable to the modeled days, since the modeled days have targeted high ozone days. The green triangles show a greater degree of decrease during the weekends than the blue squares, indicating that the model has less response to emission decreases than the observations. The commission made no changes in response to this comment.

Non-Ozone Emissions Reductions

COH commented that the TCEQ should focus on reductions of air toxic emissions in the ambient atmosphere. COH stated that reducing air toxic levels will help in reducing ozone formation.

The TCEQ has made great strides in driving industrial reductions of air toxics over the past several years and will continue to seek additional reductions. Rules related to HRVOC emissions have already been adopted to reduce the levels of ethylene, propylene, 1,3-butadiene, and butenes in the HGB area. While these four compounds are highly reactive chemicals, only butadiene is of particular toxic concern. Though the rules were put in place primarily to reduce ozone formation, substantial reductions of all four, including 1,3-butadiene have been observed at lower monitored concentrations in the HGB area. Other rules have been in effect for several years in the HGB area to reduce overall VOC emissions. Typically, reduction of overall VOC will also reduce some air toxic emissions. For example, benzene levels from on-road mobile sources have been reduced as both exhaust and evaporative VOC emissions from automobiles have declined over the last several years. Some of these reductions are due to fleet turnover effects from federal standards, and some result from state rules such as the I/M program. Federal and state control programs such as these will continue to provide both air toxic and overall VOC reductions in future years.

Additional work is ongoing at both the state and federal levels to reduce ozone precursors that will also yield lower toxic levels. For example, under the contingency plan description in Chapter 4: *Control Strategies and Required Elements*, Section 4.9: *Contingency Plan* of the proposed attainment demonstration SIP revision, an EPA-proposed rule to reduce air toxic emissions from stationary diesel and gas-fired engines is discussed. If finalized, that rule would become effective in 2013. Also, Chapter 6: *Ongoing and Future Initiatives*, Section 6.2.1: *Flare Task Force* discusses the formation of a Flare Task Force that is charged with "evaluating how flares factor into air quality challenges with an emphasis on air toxics and ozone."

The TCEQ's Toxicology Division analyzes monitoring data for over 100 toxic pollutants in the HGB area and works with other areas of the agency, such as enforcement, field operations, and permitting, to encourage and promote reductions of toxic air pollution.

EDF and GHASP commented that reductions in ozone precursors are also known to reduce particulate matter (PM) levels. EDF and GHASP urged for more ozone precursor controls that would have accompanying PM reductions.

The commission concurs that some of the control strategies designed to reduce NO_X and VOC also reduce particulate emissions of organic carbon, elemental carbon, sulfate, etc. This attainment demonstration SIP revision contains sufficient NO_X and VOC controls to demonstrate, in conjunction with the WoE analysis, attainment of the 1997 eight-hour ozone standard by 2018. In the event that a future SIP revision is required to demonstrate attainment of a PM standard, the commission will consider strategies for necessary PM reductions. The commission made no changes in response to this comment.

Photochemical Modeling Improvements

COH requested a listing of the changes and adjustments that need to be made to local air quality models so that they better reflect actual ozone measurements being taken in the area.

Photochemical air quality modeling tools are constantly being improved as steady incremental progress is made in the areas of emissions estimation, meteorological modeling, and chemical processing mechanisms. The latest available improvements in these areas have always been incorporated into air quality modeling efforts, provided those improvements are scientifically valid and mature enough to be used in a regulatory context. This process will continue in the future as various tools are either updated or replaced. Refer to Chapter 5: *Weight of Evidence*, Section 5.2.1: *Solving Modeling Problems* of this attainment demonstration SIP revision for a discussion of the improvements that have been

made for this modeling exercise and for an explanation about why other improvements were considered too immature for incorporation into regulatory modeling at this time. Future modeling will address the upcoming MCR and new criteria pollutant standards. For example, the Weather Research and Forecasting (WRF) tool that improves on MM5 for meteorological modeling applications is expected to be incorporated. In accordance with EPA guidance, the recently released Motor Vehicle Emission Simulator (MOVES) model (http://www.epa.gov/otaq/models/moves/) will be used instead of the current MOBILE6.2 for estimation of on-road mobile source emissions.

Chapter 6: *Ongoing and Future Initiatives* of this attainment demonstration SIP revision describes a set of ongoing and future initiatives that will result in improved air quality model performance for the HGB area. A Flare Task Force has been working since November 2008 to evaluate "how flares factor into air quality challenges with an emphasis on air toxics and ozone." Ongoing field testing for a flare study should be completed by March 2010, with final results expected by the summer 2010.

Another major effort more fully discussed in Chapter 6: *Ongoing and Future Initiatives* of this attainment demonstration SIP revision is the Study of Houston Atmospheric Radical Precursors (SHARP). That extensive field study of ozone precursors and formation in the HGB area was conducted from April through June 2009 using cutting-edge measurement technology. Specific areas of interest included under SHARP are direct emissions of formaldehyde and nitrous acid, ambient levels of nitryl chloride, and ozone formation mechanisms related to the spring and early summer time periods. As they become available, the results of the flare and SHARP studies will be incorporated into air quality modeling efforts.

Inclusion of Power Plant Emissions Outside of the HGB Area

CAIT, KIDS, SEED, and one individual commented that the attainment demonstration failed to adequately account for new power plants that have either already been permitted or are currently undergoing the permitting process. CAIT, KIDS, SEED, and one individual claimed that the NO_X and VOC emissions from these new power plants in Robertson, Milam, Calhoun, Goliad, and Matagorda Counties will blow into the HGB area and contribute to ozone violations.

The commission disagrees with this comment. The specific sources identified by the commenter were accounted for in the attainment demonstration. Chapter 3: *Photochemical Modeling*, Section 3.4.4.1: *Point Sources* of this attainment demonstration SIP revision states "Newly-permitted ARD [Acid Rain database] sources were limited to the [Texas] Clean Air Interstate Rule (CAIR) 9.5 percent set-aside for growth." Appendix B: *Emissions Modeling for the HGB Attainment Demonstration SIP*, Section 2.3.1.1.1: *EGUs* expands upon that statement, explaining that newly-permitted electric generating units (EGU) are included in the 2018 modeling. The units for which the commission issued air permits as of November 2009 were included in the modeling and are specifically listed in Appendix B: *Emissions Modeling for the HGB Attainment Demonstration SIP*, Section 2.3: *2018 Future Year Point Source Modeling Emissions Development*. The list of EGUs provides the growth in the EGU sector for the entire state. Units that have applied for but have not yet been granted a permit were excluded from the future modeling inventories. Historically, many units have withdrawn permit applications prior to permit issuance due to market speculation and/or market changes. The commission does not speculate which of those permit applications will result in units being built, so only permitted units are included. The commission made no changes in response to this comment.

ORDER ADOPTING
REVISION TO THE STATE IMPLEMENTATION PLAN

Docket No. 2009-0802-SIP

On March 10, 2010, the Texas Commission on Environmental Quality (Commission), during a public meeting, considered adoption of the Houston-Galveston-Brazoria (HGB) Attainment Demonstration State Implementation Plan (SIP) Revision for the 1997 Eight-Hour Ozone Standard. The Commission adopts the SIP revision, which demonstrates the HGB area will attain the 1997 eight-hour ozone National Ambient Air Quality Standard (NAAQS) by June 15, 2019. Under Tex. Health & Safety Code Ann. §§ 382.011, 382.012, and 382.023 (Vernon 2008), the Commission has the authority to control the quality of the state's air and to issue orders consistent with the policies and purposes of the Texas Clean Air Act, Chapter 382 of the Tex. Health & Safety Code. Notice of the proposed attainment demonstration SIP revision was published for comment in the October 9, 2009 issue of the *Texas Register* (34 TexReg 7132).

Pursuant to 40 Code of Federal Regulations § 51.102 and after proper notice, the Commission conducted public hearings to consider the proposed SIP revision. Proper notice included prominent advertisement in the areas affected at least 30 days prior to the dates of the hearings. Public hearings were held in Houston at 2:00 p.m. and 6:00 p.m. on October 28, 2009, and in Austin at 3:00 p.m. on October 29, 2009.

The Commission circulated hearing notices of its intended action to the public, including interested persons, the Regional Administrator of the EPA, and all applicable local air pollution control agencies. The public was invited to submit data, views, and recommendations on the proposed SIP revision, either orally or in writing, at the hearings or during the comment period. Prior to the scheduled hearings, copies of the proposed SIP revision were available for public inspection at the Commission's central office and on the Commission's Web site.

Data, views, and recommendations of interested persons regarding the proposed SIP revision were submitted to the Commission during the comment period, and were considered by the Commission as reflected in the analysis of testimony incorporated by reference to this Order. The Commission finds that the analysis of testimony includes the names of all interested groups or associations offering comment on the proposed SIP revision and their position concerning the same.

IT IS THEREFORE ORDERED BY THE COMMISSION that the revision to the SIP incorporated by reference to this Order is hereby adopted. The adopted revision to the SIP is incorporated by reference in this Order as if set forth at length verbatim in this Order.

IT IS FURTHER ORDERED BY THE COMMISSION that on behalf of the Commission, the Chairman should transmit a copy of this Order, together with the adopted revision to the SIP, to the Regional Administrator of EPA as a proposed revision to the Texas SIP

pursuant to the Federal Clean Air Act, codified at 42 U.S. Code Ann. §§ 7401 - 7671q, as amended.

If any portion of this Order is for any reason held to be invalid by a court of competent jurisdiction, the invalidity of any portion shall not affect the validity of the remaining portions.

Date issued:

TEXAS COMMISSION ON
ENVIRONMENTAL QUALITY

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Bryan W. Shaw, Ph.D., Chairman