APPENDIX E

MODELING PROTOCOL FOR THE DFW ATTAINMENT DEMONSTRATION SIP REVISION FOR THE 1997 EIGHT-HOUR OZONE STANDARD

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List of Acronyms

AQP – Air Quality Planning
ARD – Acid Rain Data
Auto-GC – Automated Gas Chromatograph
BCs – Boundary Conditions
BPA – Beaumont-Port Arthur
CAIR2 – Clean Air Interstate Rule, Phase 2
CAMx – Comprehensive Air Model with Extensions
CBIV – Carbon Bond Mechanism, Version 4
CB05 – Carbon Bond Mechanism, Version 05
CENRAP/RPO – Central Region Air Program/Regional Planning Organization
CO – Carbon $MoNO_X$ide
DERC – Discrete Emission Reduction Credit
DFW – Dallas-Fort Worth (nonattainment area)
DV – Design Value
EGAS – Economic Growth Analysis System
EGU – Electrical Generating Unit
EI – Emissions Inventory
EPA – United States Environmental Protection Agency
EPS3 – Emissions Processing System, Version 3
ERG – Eastern Research Group
ESAD – Emission Specific Attainment Demonstration
ETA-PBL – ETA Weather Model Planetary Boundary Layer Numerical Algorithm
FDDA – Four Dimensional Data Assimilation
GEOS-CHEM – Goddard Earth Observing Systems Chemistry Model
GloBEIS – Global Biosphere Emissions and Interactions System
HARC – Houston Advanced Research Center
HECT – HRVOC Emissions Cap and Trade
HC – Hydrocarbon
HGB – Houston-Galveston-Brazoria
H-GAC – Houston-Galveston Area Council
HRVOC – Highly Reactive Volatile Organic Compound
HSC – Houston Ship Channel
IPM – Integrated Planning Model
KM – Kilometer
KVs – Vertical Exchange Coefficient
LU/LC – Land-use Land-cover
MECT – Mass Emissions Cap and Trade
MM5 – Fifth Generation Meteorological Model
NAAQS – National Ambient Air Quality Standard
NASA – National Aeronautics and Space Administration
NCEP – National Centers for Environmental Prediction
NCTCOG – North Central Texas Council of Governments
NEI – National Emissions Inventory
NMIM – National Mobile Inventory Model
NOAA – National Oceanic and Atmospheric Administration
NOAH – NCEP - Oregon State Univ. - Air Force - Hydrological Research Laboratory
NO_X – Nitrogen Oxides
NOY – Nitrogen Species

O3 – Ozone
OSD – Ozone Season Day
PAR – Photosynthetically Active Solar Radiation
PPB – Parts per Billion
PPB-C – Parts per Billion Carbon
PPBV – Parts per Billion by Volume
PSCFv2 – Potential Source Contribution Factor, version 2
REMI – Regional Economic Models, Inc.
RRF – Relative Response Factor
SI – Special (emissions) Inventory
SIP – State Implementation Plan
STARS – State of Texas Air Reporting System
STT – Sea Surface Temperature
TCEQ – Texas Commission on Environmental Quality
TexAER – Texas Air Emissions Repository
TexAQS II – Second (2006) Texas Air Quality Study
TNMHC – Total Non-Methane HydroCarbon
TPD – Tons Per Day
TTI – Texas Transportation Institute
TxDOT – Texas Department of Transportation
UT-CSR – University of Texas Center for Space Research

1 SUMMARY

This protocol presents procedures the Texas Commission on Environmental Quality (TCEQ) is using or plans to use to model ozone in the Dallas-Fort Worth (DFW) area with the Comprehensive Air Quality Model with Extensions (CAMx), an acceptable photochemical model (see Table 13.1; U.S. EPA, 2007). The focus of this modeling is to support attainment demonstration analyses for the eight-hour ozone standard using a future year of 2012. The modeling will use a base case episode encompassing the entire month of June 2006. Modeling this episode, which has an extensive number of days with typical meteorological conditions associated with the formation of unhealthy levels of ozone, will help ensure that control strategies (adopted or proposed) will be effective over the DFW nonattainment area. This modeling analysis will rely heavily upon data and knowledge gained from previous modeling experience and the second Texas Air Quality Study (TexAQS II) air quality study. Recent scientific advancements will be incorporated as appropriate and time allows.

The objective of this modeling protocol is to maintain and enhance the technical credibility of the study by establishing in advance agreed-upon procedures for conducting a successful modeling project. A second but potentially even more important objective of this modeling is to continue advancing the understanding of the many complex processes and interactions that cause ozone standard exceedances in north-central Texas. Section 2 of the protocol describes the study design, including the background, managerial organizational structure, schedule, and modeling episode selection. Section 3 presents the model selection decisions. The remainder of the protocol describes the structure of the modeling system, the development of required model databases, the plans for model performance evaluation, the procedures to determine whether proposed control strategies are sufficient to show attainment of the eight-hour ozone standard, and the procedures for documenting the study results.

This protocol reflects the current plans of the TCEQ modeling staff but may be modified to account for new science, better modeling tools, changes in resources, or other events. This protocol should be considered a living document, which changes as necessary to reflect the current plans of the TCEQ in coordination with EPA Region 6 and stakeholders via the Dallas-Fort Worth Photochemical Modeling Technical Committee (DFW PMTC).

Current plans are to submit a State Implementation Plan (SIP) revision based on this modeling to EPA by December 2011. The purpose of the SIP revision is to satisfy requirements for an eight-hour ozone attainment demonstration.

2 MODELING/ANALYSIS STUDY DESIGN

This modeling protocol describes the procedures that will be used in the development of new ozone modeling for the DFW nonattainment area ozone SIP revision. These procedures generally conform to the recommendations set forth in the EPA "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze" (*EPA*, 2007).

As per the EPA guidance, this protocol includes the following sections:

- background for the study;
- schedule and organizational structure for the study;
- rationale for model selection and description of models to be used;
- methods for developing input data;

- methods for evaluating and interpreting model results;
- procedures for using the model to determine whether proposed control strategies are sufficient to ensure attainment of the National Ambient Air Quality Standard (NAAQS); and
- documentation to be submitted to the regional EPA office for review.

2.1 Background

The 1990 Federal Clean Air Act (FCAA) Amendments established five classifications for ozone nonattainment areas based on the magnitude of the monitored one-hour ozone design values 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 DFW Consolidated Metropolitan Statistical Area (Collin, Dallas, Denton, and Tarrant Counties) was classified moderate, with an attainment date of 1996. On October 16, 2008, the EPA published final notice in the *Federal Register* of one-hour ozone standard attainment in the four-county DFW area, and suspended one-hour SIP requirements so long as the standard is maintained.

With the change in the form of the ozone NAAQS from a one-hour standard to an eight-hour standard in 1997, EPA designated Collin, Dallas, Denton, Tarrant. Ellis, Johnson, Kaufman, Parker, and Rockwall counties as a moderate ozone nonattainment area with an attainment date of June 15, 2010 (Figure 2-1: DFW Nonattainment Area). On May 23, 2007, the commission adopted the DFW Attainment Demonstration (AD) SIP Revision for the 1997 Eight-Hour Ozone Standard showing via photochemical modeling and corroborative analyses that the DFW area would attain the eight-hour standard. EPA conditionally approved the DFW AD SIP Revision on January 14, 2009 (*EPA*, 2009).

Despite showing a reduction of 10 ppb in its eight-hour design value in a three-year period from 2006 to 2009, the DFW area failed to meet the 1997 eight-hour ozone standard by June 15, 2010, missing attainment by two ppb. Because of this failure to attain, the TCEQ expects the EPA to reclassify the DFW area to Serious with an attainment date of June 15, 2013. This protocol details the schedule, methodology, and procedures for photochemical modeling in support of the required new attainment demonstration.

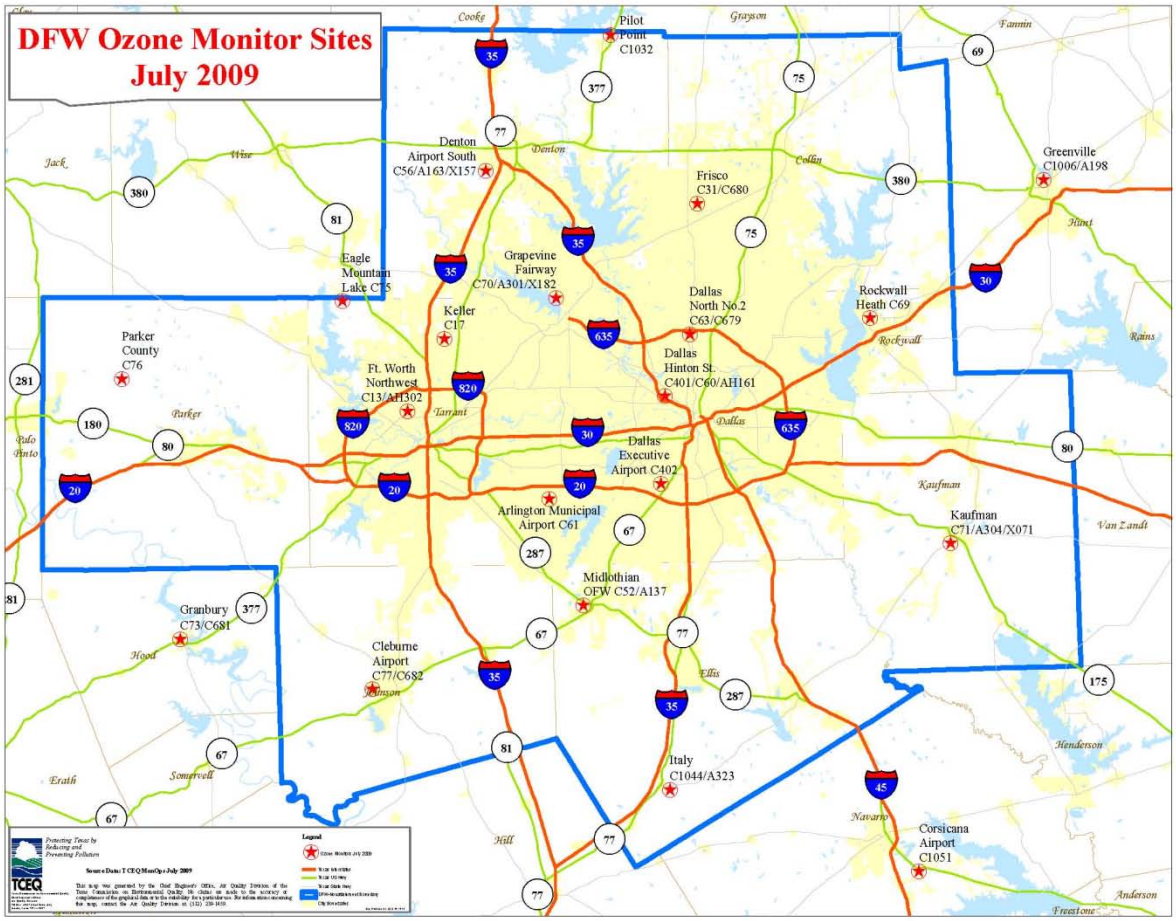

Figure 2-1: DFW Nonattainment Area

2.2 Management Structure

The Air Modeling and Data Analysis (AMDA) section has the responsibility for planning and conducting the eight-hour ozone SIP modeling. AMDA is part of the Air Quality Division of the Chief Engineer's Office (CEO) of the TCEQ. The CEO organization chart is shown in Figure 2-2: Management Organization Chart.

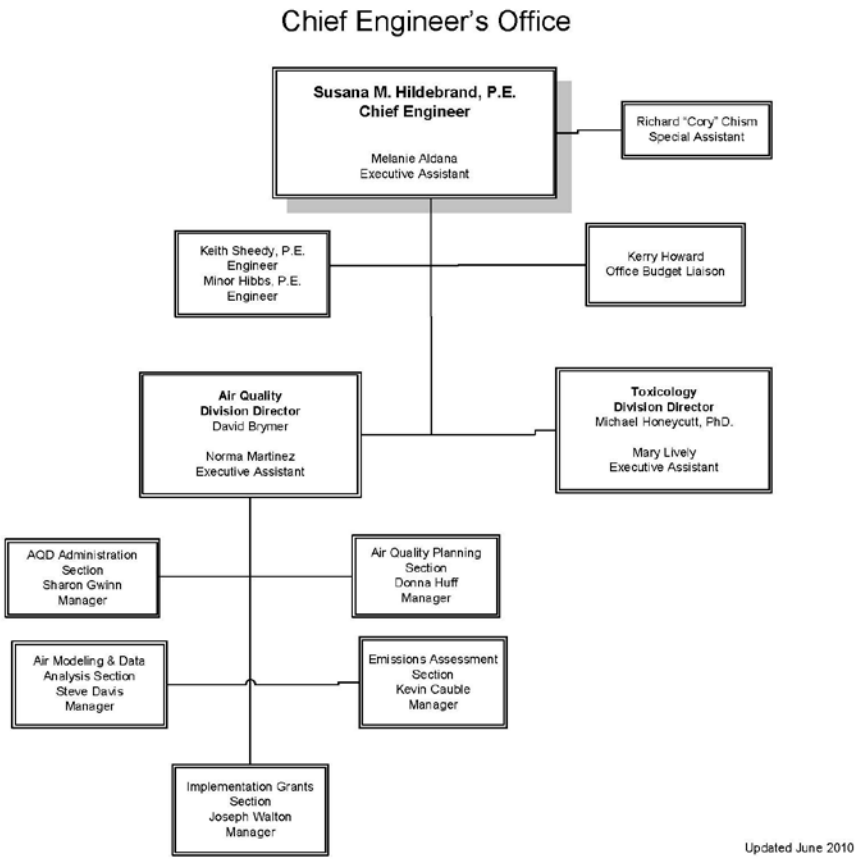

Figure 2-2: Management Organization Chart

2.3 Technical and Policy Organizations

2.3.1 DFW Photochemical Modeling Technical Committee (DFWPMTC)

The DFWPMTC serves in an advisory role for the technical aspects of applying photochemical modeling and improving the science. The TCEQ plans to meet with DFWPMTC members to review modeling progress when updates are available. Meeting materials (e.g., agendas, technical presentations) and the membership of the DFWPMTC are published to the TCEQ's website (*TCEQ, 2010b*).

2.3.2 Schedule of Modeling Activities

The schedule of activities for this eight-hour modeling analysis is shown below in Table 2-1: Schedule of Modeling Activities for DFW. The dates shown are the best current estimates and are likely to change based on problems encountered, emerging research findings, and other requirements. Detailed discussions of most of these activities can be found later in this document.

Table 2-1: Schedule of Modeling Activities for DFW

Modeling Activity	Time Frame

Modeling Activity	Time Frame
Conduct base case and current baseline modeling • Develop base case/baseline emissions • Conduct meteorological modeling • Conduct emissions modeling and processing • Conduct model performance evaluations	January – October 2010
Conduct future baseline modeling with current controls and project future design values • Develop future baseline emissions with applicable growth and current controls • Project future design values • Conduct VOC/NO_X matrix modeling (estimating additional emission reductions) • Conduct attainment modeling with current and proposed controls • Develop emission control modeling files • Conduct modeling sensitivity runs • Conduct attainment modeling with selected controls	May – December 2010

2.4 Conceptual Model of Ozone Formation

The DFW conceptual model of ozone formation is detailed in Appendix D: Conceptual Model for the DFW Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard.

2.5 Episode Selection

The selection of the modeling episode is detailed in Attachment A: Episode Selection for the DFW Attainment Demonstration SIP Revision for the 1997 Eight-Hour Ozone Standard.

3 MODELS AND INPUTS

The modeling system is composed of a gridded photochemical air quality model, a meteorological model, and an emissions processing model. Both the meteorological and emissions models provide input to the air quality model. Therefore, the air quality, meteorological and emissions models selected need to interface effectively.

3.1 Model Selection

3.1.1 Selection of Air Quality Model

To ensure that a modeling study can be successfully used as technical support for an attainment demonstration SIP, the air quality model must be scientifically sound and appropriate for the intended application, and be freely accessible to all stakeholders. In a regulatory environment, it is crucial that oversight groups (e.g., 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 DFW attainment demonstration:

- Must have a reasonably current, peer-reviewed, scientific formulation.

- Must be available at no or low cost to stakeholders.
- 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 plume-in-grid sub-model that 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. In addition, the TCEQ has many years of experience with CAMx. CAMx was used for previous DFW attainment demonstrations, the HGB and BPA nonattainment areas, as well as for modeling being conducted in other areas of Texas (e.g., San Antonio).

The TCEQ plans to use CAMx Version 5.2+, which includes a number of upgrades and new features. Some of the upgrades and features the TCEQ plans to use in this application include:

Parallel Processing - Multi-processor support is now fully included in CAMx.
Piecewise Parabolic Method (PPM) advection solver – The PPM solver may include less numerical diffusion and may be easier to accommodate future improvements to horizontal mixing with than the Smolarkiewicz solver.
CMC fast chemistry solvers for CB05 - The CMC solver provides a ten-fold speedup in the chemistry solution and is compatible with the updated CB05 mechanism.
In addition, the TCEQ plans to use some of the probing tools supported by CAMx 5.2+ for sensitivity analyses, including:
Process Analysis (PA) - PA adds algorithms to the CAMx model that store the integrated rates of species changes due to individual chemical reactions and other sink and source processes. By integrating these rates over time and outputting them at hourly intervals, PA provides diagnostic outputs that can be used to explain model simulation in terms of chemical budgets, conversions of chemical species, and effects of transport and other sink and source terms. Process analysis can also improve model validation and ultimately can assist in the selection of precursor reduction strategies (*Tonnesen*, 2001).
Ozone Source Apportionment Technology (OSAT) - OSAT provides a method for estimating the contributions of multiple source areas, categories, and pollutant types to ozone formation in a single model run. OSAT also includes a methodology for diagnosing the temporal relationships between ozone and emissions from groups of sources.
Anthropogenic Precursor Culpability Assessment (APCA) - APCA differs from OSAT in recognizing that certain emission groups are not controllable (e.g., biogenic emissions) and that apportioning ozone production to these groups does not provide information that is beneficial to control strategies. Where OSAT would attribute ozone production to biogenic emissions, APCA reallocates that ozone production to the controllable portion of precursors that participated in ozone formation with the noncontrollable precursor. APCA would only attribute ozone production to biogenic emissions when ozone formation is due to the interaction of biogenic VOC with biogenic NO_X. When ozone formation is attributable to biogenic VOC and anthropogenic NO_X under VOC-limited conditions, OSAT would attribute ozone production to biogenic VOC while APCA would redirect that attribution to the anthropogenic NO_X precursors present.
Higher-order Direct Decoupled Method (HDDM) - HDDM provides an efficient and accurate methodology for calculating first and second order sensitivities between output concentrations and model input parameters.

3.1.2 Selection of Meteorological Model

Currently the two most commonly used state-of-the-science prognostic meteorological models used to provide input to an air quality model are the Weather Research and Forecasting Model (WRF) and the Penn State University/National Center for Atmospheric Research (PSU/NCAR) Fifth Generation Mesoscale Model (MM5). The WRF model is one of the dominant forecasting models and is increasingly being used for regulatory SIP modeling. Both the WRF and MM5 meteorological models are based on the full set of dynamic equations that govern atmospheric motions and thus are equally suitable for generating inputs to an air quality model. The TCEQ has selected the MM5 model primarily because it is being used for several other air quality modeling projects within Texas (e.g., TexAQS II real-time modeling, Texas universities, Central Regional Air Planning Association (CENRAP), and near-nonattainment areas). Further, the TCEQ has years of experience in applying MM5 to historical ozone episodes and it is publicly available, which allows stakeholders to use and modify the model free of charge.

The TCEQ plans to use the latest version of MM5 (version 3.7.4). This model is supported by a broad user community including the EPA, CENRAP, national laboratories and academia, and is currently being used extensively to develop the meteorological inputs for regulatory air quality modeling analyses throughout the United States. The most recent application of MM5 by the TCEQ was for the 2005 and 2006 episodes for the HGB Attainment Demonstration SIP (*TCEQ*, 2009b). For this application a suitable set of parameterizations was determined to represent the coastal meteorology.

3.1.3 Selection of Emissions Modeling System

Typically, raw emissions inventory databases provide point, area, on- and non-road mobile, and biogenic sources of emission estimates of criteria pollutants, including NO_X and VOC, on an annual, seasonal, daily or, in rare cases, hourly basis. The processing of raw emissions datasets into air quality model-ready inputs is accomplished through the use of emissions models. These emissions models temporally distribute, spatially allocate, and chemically speciate the emissions to the resolution and chemical mechanism used by the air quality model.

The two most common emissions modeling systems used to process anthropogenic emissions into the gridded, hourly resolved, and chemically speciated emissions needed for an air quality model are version 3 of the Emissions Processing System (EPS3 and the Sparse Matrix Operator Kernel Emissions (SMOKE). TCEQ has selected the EPS3 primarily because it is being used for several other air quality modeling projects within Texas, it is easily modified to accommodate the complexity of emissions sources and highly detailed emissions information required, and TCEQ modeling staff have years of experience in using EPS to process emissions in Texas. Additionally, and SMOKE lacks flexibility to accommodate the highly resolved link-based on-road mobile source emissions reflecting the hour of day, day of week, vehicle-type distributed vehicle miles traveled (VMT), diurnal speed distribution and bi-directional traffic.

For biogenic emissions, TCEQ selected version 3.1 of the Global Biosphere Emissions and Interactions System (GloBEIS) biogenics emissions model (Guenther et al., 2002; Yarwood et al., 2001; Yarwood et al., 2000; Guenther et al., 1999) rather than the SMOKE-BEIS, BEIS-3, or MEGAN models, because it can incorporate local land cover data developed specifically for Texas (Feldman et al., 2007), solar radiation data derived from GOES satellite imagery, and temperature data derived from kriged observational data. GloBEIS also has built-in quality assurance functions.

3.2 Modeling Domains

3.2.1 CAMx Modeling Domains

Figure 3-1: CAMx Modeling Domains depicts the modeling domains used in CAMx. The horizontal configuration of the CAMx modeling domains consist of a 4 km grid encompassing the DFW ozone nonattainment counties, nested within a 12 km grid covering the eastern part of Texas, nested within the outer 36 km grid. The 36 km outer domain was selected to minimize the effect of boundary conditions on predicted ozone concentrations.

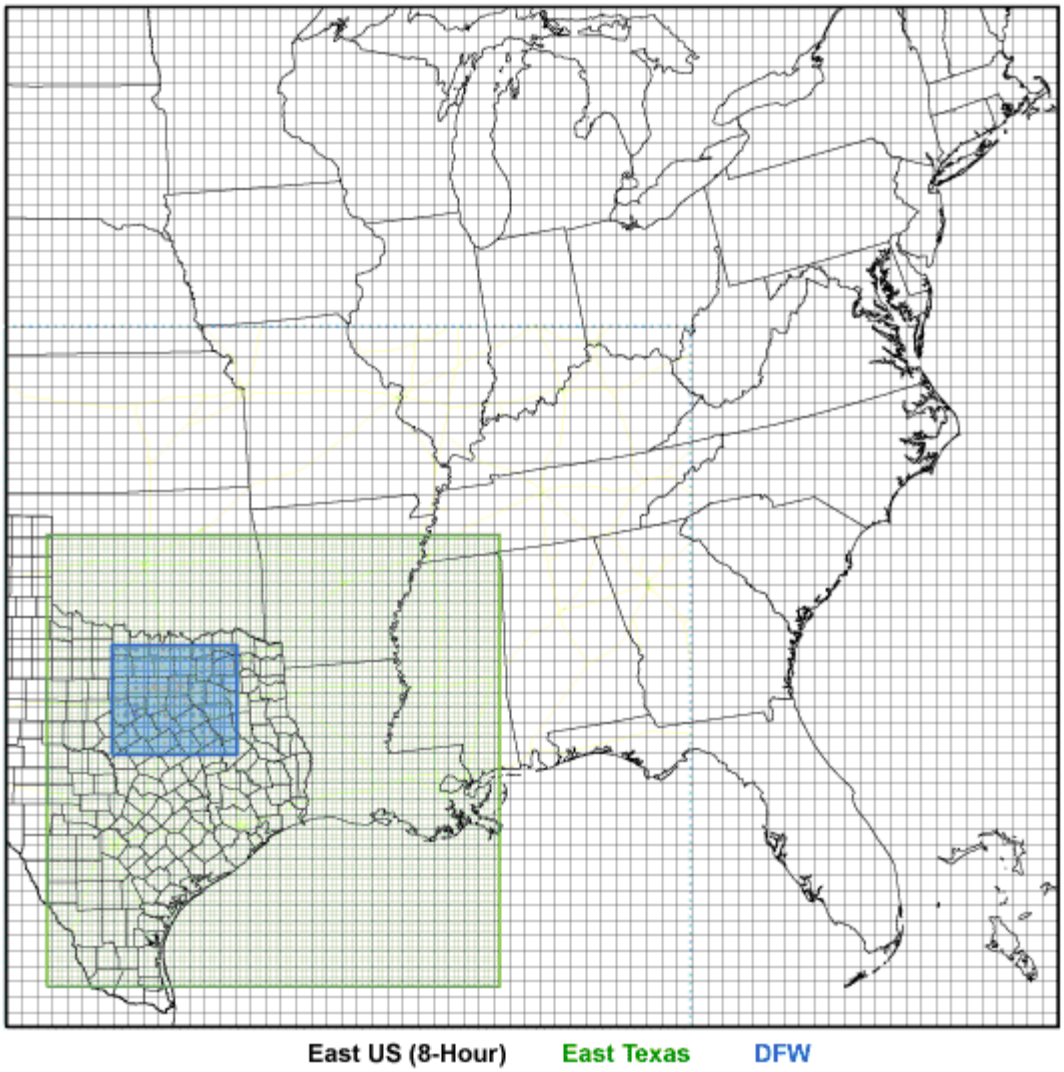

Figure 3-1: CAMx Modeling Domains

All grids are projected in a Lambert Conformal Projection (LCP) with the origin at 100 degrees West and 40 degrees North. The grid configuration is the same as that used in the recent HGB attainment demonstration SIP revision (*TCEQ*, 2010a) except for the placement of the 4 km fine grid. Choosing a grid system compatible with an existing large-scale grid system serves several functions, including ability to use existing modeling data directly, including emissions, spatial surrogates, and boundary conditions, and the ability to compare model results directly with other modeling applications. The grid dimensions for the CAMx domains are listed below in Table 3-1: *CAMx Modeling Domain Definitions*.

Table 3-1: CAMx Modeling Domain Definitions

Grid Name	Grid Cell Size	Dimensions (grid cells)	Lower left-hand corner	Upper right-hand corner
East U.S.	36 × 36 km	69 × 67	(-108, -1584)	(2376, 828)
East Texas	12 × 12 km	89 × 89	(-12, -1488)	(1056, -420)
DFW	4 × 4 km	74 × 65	(140, -940)	(436, -680)

The vertical configuration of the CAMx modeling domains consist of a varying 28-layer structure as shown in Table 3-2: *CAMx Vertical Layer Structure*.

Table 3-2: CAMx Vertical Layer Structure

CAMx Layer	MM5 Layer	Top (m AGL)	Center (m AGL)	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

A feature pertinent to the modeling domains arising from the application of Relative Response Factors (RRFs) is the modeling grid cell array to use near a monitor to calculate the RRF. EPA's guidance suggests that each monitor is normally representative of conditions within about 15 km of the site, hence that a 3 x 3 grid cell array for domains with grid cell sizes of 4 km x 4 km is appropriate. A map of the 4 km fine grid domain depicting the monitors, and the extent of 3 x 3

and 1 x 1 grid cell arrays is shown in Figure 3-2: *Near Monitoring Site Grid Cell Array Size*. The TCEQ initially plans to use the 3 x 3 grid cell array to calculate the RRF for each monitor. If time permits, the TCEQ may conduct an analysis to determine whether a smaller grid cell array may be more appropriate for some monitors.

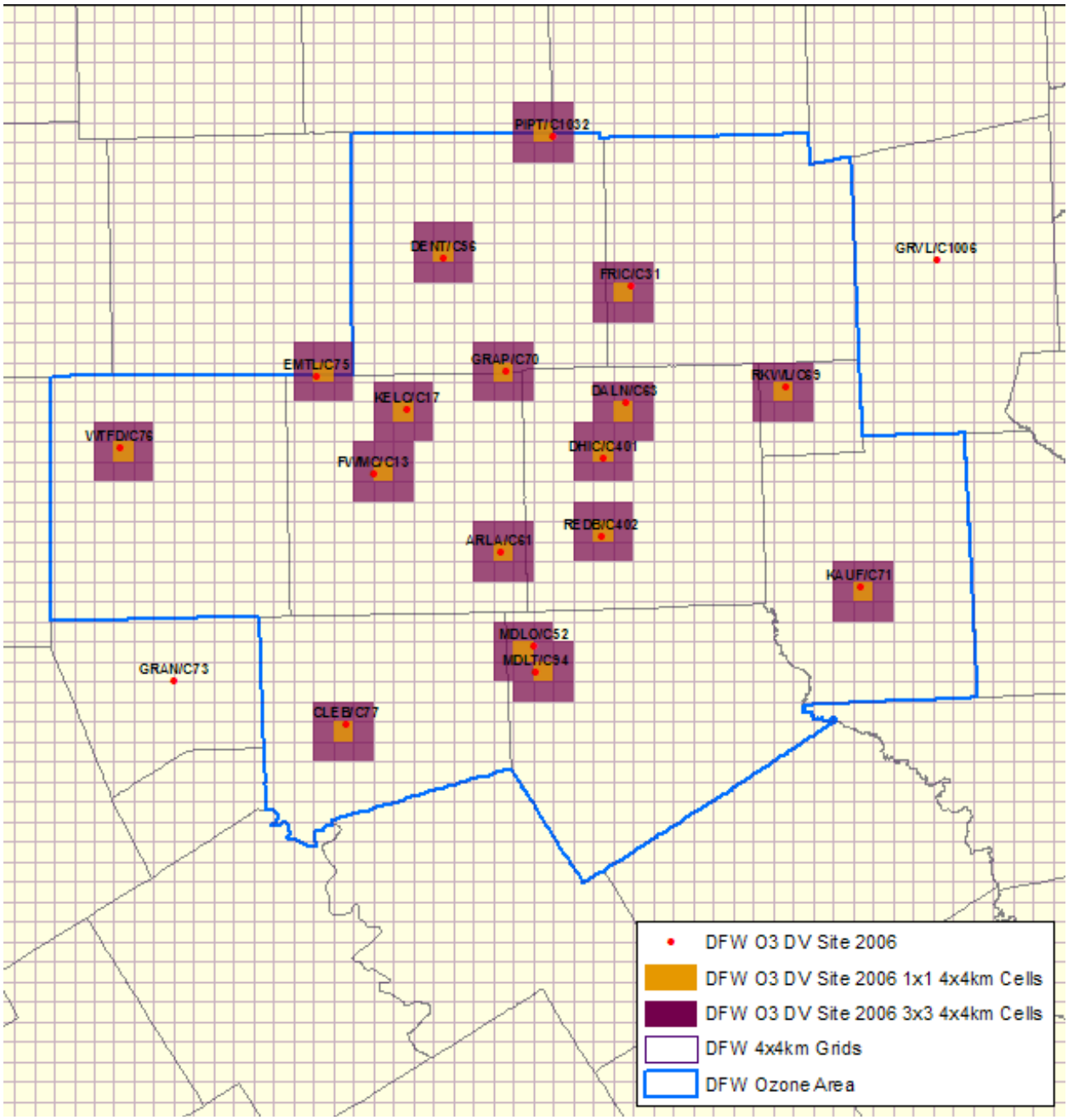

Figure 3-2: Near Monitoring Site Grid Cell Array Size

3.2.2 MM5 Modeling Domains

The horizontal configuration of the MM5 modeling domains consist of a 4 km grid encompassing eastern Texas and western Louisiana (Figure 3-3: *MM5 Modeling Domains*), nested within a 12 km grid covering all of Texas, nested within a 36 km grid covering the eastern

three-fourths of the United States, nested within a 108 km domain covering most of the northern hemisphere. Each of the CAMx domains is inset within the MM5 domain of the same resolution, leaving a buffer of three or more grid cells to avoid boundary effects occurring at the MM5 grid transition, with one notable exception. The MM5 36 km modeling domain does not extend eastward enough to embed the eastern boundary of the 36 km CAMx modeling domain, so the 36 km grid was "padded" with values from the 108 km grid. The padded cells were added to the eastern edge of the MM5 36 km grid to allow the 36 km CAMx grid to fit comfortably within. Since the eastern boundary of the 36 km CAMx modeling domain is distant from the DFW area, this adjustment is expected to have a minimal effect, if any, on predicted ozone concentrations.

Table 3-3: *MM5 Modeling Domain Definitions* lists the horizontal grid configurations for the MM5 modeling domains. Grid corners are in kilometers (easting, northing) relative to the grid origin at 100 degrees West and 40 degrees North. The vertical configuration of the MM5 modeling domains consists of a varying 43-layer structure used with all the horizontal domains (Figure 3-4: *MM5 Vertical Layer Structure*). The first 21 vertical layers are identical to the same layers used with CAMx, while CAMx layers 22-28 each comprise multiple MM5 layers.

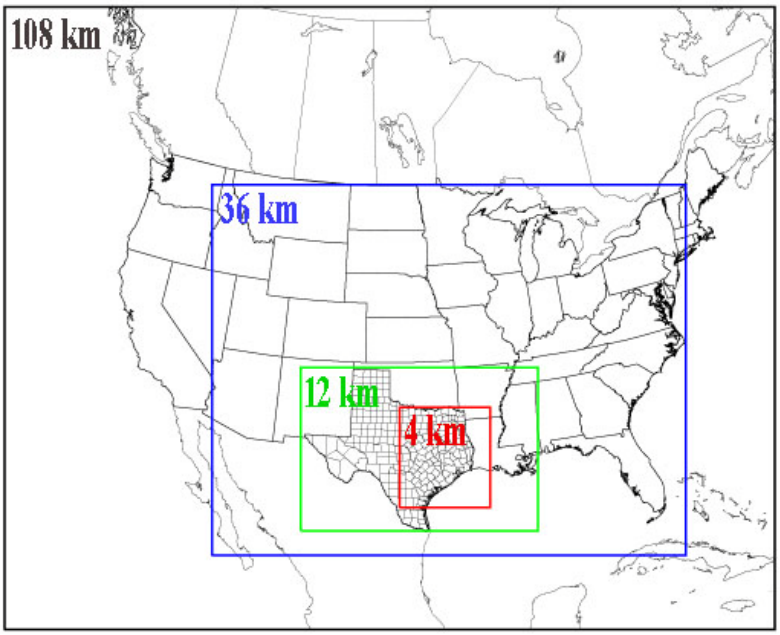

Figure 3-3: MM5 Modeling Domains

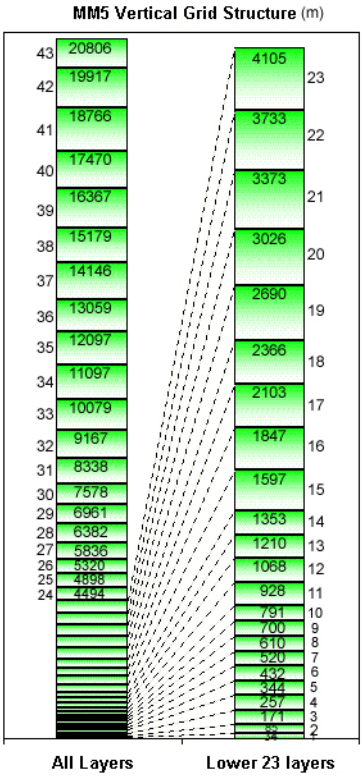

Figure 3-4: MM5 Vertical Layer Structure

Table 3-3: MM5 Modeling Domain Definitions

Domain	Easting Range (km)	Northing Range (km)	East/West Grid Points	North/South Grid Points
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

3.3 Modeling Inputs and Outputs

Since the outputs from the MM5 model and the emissions modeling system are inputs to the CAMx model, the modeling inputs and outputs for the MM5 model and the emissions modeling system are presented before the inputs and outputs for the CAMx model.

3.3.1 Meteorological Model Inputs and Outputs

3.3.1.1 MM5 Model Configuration

The TCEQ developed MM5 modeling of 2005 and 2006 episodes for the coastal HGB area focusing on parameterizations to improve performance of the wind field (*TCEQ*, 2010a). In 2008, the Austin and San Antonio areas optimized the TCEQ meteorological modeling of the June 2006 episode to be more representative for central Texas (*Emery et al.*, 2009a). The TCEQ continued this work on the June 2006 episode by contract with Environ, which resulted in an MM5 configuration that yielded good performance in the DFW and central Texas areas (*Emery et al.*, 2009b). The essential parameters that were specified in that final MM5 run are shown in Table 3-4: *June 2006 Base MM5 Setup*.

Table 3-4: June 2006 Base MM5 Setup

Domain	Nudging Type	PBL	Cumulus	Radiation	Land-Surface	Microphysics
108, 36, 12 km	3-D and Surface Analysis	ETA	Grell	RRTM / Dudhia	5-layer soil model	Simple Ice
4 km	3-D, Surface Analysis, & Obs	MRF	None	RRTM / Dudhia	5-layer soil model	Simple Ice

As time permits, the TCEQ expects to use this configuration as a base to test sensitivities of model options. Some of those sensitivities are expected to include:

- Updated land use/land cover data
- Satellite-based sea surface temperature data
- Observational nudging using radar wind profiler data
- Other physical parameterizations

3.3.1.2 Meteorological Model Inputs

The National Centers for Environmental Prediction (NCEP) North American Model (NAM) (NCEP, 2009) gridded analysis fields are expected to be used for initial, boundary, and analysis nudging conditions as based on experience by the TCEQ, EPA, and the National Center for Atmospheric Research (NCAR). Updated land use and land cover, land/water mask, vegetation fraction, soil type, and sea surface temperature data using satellite based inputs are expected to be used as had been done for the 2010 HGB SIP Revision (TCEQ, 2010a). Base state variables (reference pressures and temperatures) will be set to Texas summertime values to appropriately initialize the model atmosphere. TexAQS II radar profiler data will be used for observational nudging.

3.3.1.3 Meteorological Model Outputs

The meteorological model outputs a variety of meteorological fields of data required by the photochemical model including temperatures, wind components, cloud cover, humidity, and vertical mixing parameters. The meteorological model output will be post-processed using the Environ program MM5CAMx to convert the meteorological fields to the CAMx grid and input format (Environ, 2010). The MM5CAMx post-processor options, including vertical diffusivity schemes, will be evaluated to determine the appropriate CAMx inputs.

Where possible the output parameters from the MM5 model and the post-processed CAMx input are compared to monitored data to evaluate the model's performance. In particular, the TCEQ uses a performance evaluation package designed to interface with MM5 that evaluates four model parameters: wind speed, wind direction, temperature and humidity. This statistical package generates standardized tables and graphics for each of the four meteorological parameters. Other performance evaluation tools are used to evaluate the meteorological model's ability to represent the episode's conditions including cloud fraction plots and trajectory tools.

3.3.2 Emissions Processing System Inputs and Outputs

For stationary sources (i.e., point and area sources), routine emission inventories constitute the major inputs to the emissions modeling system. For mobile sources and biogenic sources

emissions are derived from emission models of their own. For example, link-based, on-road mobile source emissions are derived from a travel demand model coupled with the EPA MOBILE6.2 emission factor model, non-road mobile source emissions are derived from the EPA National Mobile Inventory Model (NMIM) mobile source model, and biogenic emissions are derived from the GloBEIS model. With the exception of the biogenic emissions, for which the GloBEIS model outputs CAMx model-ready emissions, the emissions for the other source categories will be processed using EPS3 to generate CAMx model-ready emissions that are day-specific, gridded, speciated and temporally (hourly) allocated. The TCEQ uses a variety of graphical techniques (e.g., emission density plots) to quality assure (QA) the modeling emissions. Emission density plots (EDPs) used for QA purposes will be developed for each of the major emission source categories (e.g., point, on-road), as well as some sub-categories (e.g., tanks, locomotives). Since emissions for most source categories are ozone season day (OSD) with adjustments for weekend days, EDPs used for QA purposes will focus primarily on weekdays. For those sub-categories with higher temporal resolution (e.g., EGUs, tank landing), EDPs will be developed as needed to compare and contrast differences.

3.3.2.1 Point Source Emissions

Point source modeling emissions are derived from a number of inventories, such as regional inventories (e.g., 2002 Central states Regional Air Planning (CenRAP) organization, national Regional Planning Organizations (RPOs), Acid Rain Database (ARD), Gulf Wide Emissions Inventory (GWEI), Mexico NEI, Canada), state inventories (e.g, the State of Texas Air Reporting System (STARS), adjacent state-provided inventories), and local inventories (e.g., Tank Landing Loss (TLL) special inventory).

For the base case, the same data sources and processing techniques used for the June 2006 episode of the 2010 HGB SIP Revision will be employed for this DFW June 2006 episode. For regions outside of Texas, the TCEQ will use emissions data from the 2002 CENRAP/RPO (adjusted for growth to 2006, with substituted hourly Acid Rain Data (ARD) emissions), the 2005 GWEI, Phase 3 of the 1999 Mexico NEI, and 2000 Canadian emissions as input to EPS3. The TCEQ may locate and process updates to these as available. For the three states bordering Texas (Louisiana, Oklahoma and Arkansas), the TCEQ will use the state-specific point source inventories acquired for the HGB modeling. Louisiana's inventory is from 2004, as they consider it a more representative year (non-Katrina), and the other two are based on 2005. All three were grown to 2006 via EPA's Economic Growth Analysis System (EGAS). For regions inside of Texas, the TCEQ 2006 STARS dataset will be used. Hourly ARD emissions are substituted where appropriate for the power plants. The HGB TLL emissions used in this base case are the 2006 baseline (averaged) TLLs used in the 2010 HGB SIP Revision.

To distinguish between low level and elevated point sources, a plume height cutoff of 30 meters will be used, which essentially matches the 33 meter height of the first CAMx layer. The Plume-in-Grid (PiG) feature of CAMx will also be used for selected point sources (e.g., large power plants) based on a threshold NO_X emission value that varies by distance from DFW from 5 tpd to 25 tpd for the regional states, along with a collocation distance of 200 meters.

For the 2006 baseline non-ARD point sources (including all sources in GWEI, Canada and Mexico), the TCEQ will use the same ozone season day emissions used in the 2006 base case. For the 2006 baseline ARD sources (power plants), the TCEQ will use the average of the 2006 third quarter hourly ARD emissions to provide a typical 2006 summer day.

For the 2012 future year point sources, 2008 emissions will be used as the basis to project. For the states outside of Texas, a 2012 inventory will be interpolated from the 2006 CENRAP/RPO

data and the 2018 CENRAP/RPO data used in the 2010 HGB SIP Revision. If the 2008 NEI is available in a quality-assured format, then this EI may be used instead, and projected to 2012. The EPA CAIR Phase 1 (CAIR) allowances will be used for the ARD units. If a substitute EPA program is proposed to replace CAIR, it will be incorporated as time allows.

Within Texas, the 2008 STARS data will be used as a basis for estimating the 2012 EI. For the attainment areas within Texas, the TCEQ will apply the CAIR allowances to the electric generating units (EGUs) as site-specific caps. The EGU emissions will include consideration of newly-permitted sources that may begin operation after 2008. On-the-books controls will be applied to those 2008 EI units for which existing rule compliance dates have not yet passed. This includes estimated reductions expected from rules such as the East Texas Combustion Rule. For all the other point sources within Texas, growth will be applied via the Texas-specific Regional Economic Models, Inc.- Economic Growth Analysis System (REMI-EGAS), the Texas Industrial Production Index (TIPI), or the banked emissions reduction credits (ERCs and DERCs) within the nonattainment areas as appropriate.

For point sources within the HGB, BPA, and DFW nonattainment areas, emissions consistent with their latest SIP revisions (e.g., MECT and HECT within HGB, refinery expansions within BPA, and cement kiln caps within DFW) will be used. Additionally, the emissions reconciliation for HRVOCs within HGB will be used. Results from the Barnett Shale Special Inventory performed by the TCEQ will be incorporated as resources and time allow (*TCEQ*, 2010d).

3.3.2.2 Area Source Emissions

For regions outside of Texas, the TCEQ plans to use area source emissions data from the 2002 CENRAP, 2005 GWEI and 2008 Canadian inventories. The 2005 NEI area source emissions will be adjusted using EGAS for growth to 2006. Particular to the 2005 GWEI, the non-road emissions are included as area sources.

For regions inside of Texas, the TCEQ will use data from the 2005/2008 Texas Air Emissions Repository (TexAER) data base (*TCEQ*, 2010c), the Northeast Texas 2005 gas compressor inventory, oil and gas production information from the Texas Railroad Commission, and drilling rig information from TexAER and published industry sources . The 2008 TexAER includes the flash emissions associated with the Oil and Gas Production area source category. 2005/2008 TexAER and Northeast Texas 2005 gas compressor emissions will be projected to 2006 using the Texas-specific REMI-EGAS growth factors for the 2006 base case episode. Emissions data from these inventories will be processed with EPS3 to generate CAMx model ready emissions that are day-specific, gridded, speciated and temporally (hourly) allocated.

For the 2006 baseline area sources, the TCEQ plans to use the same emissions as used in the 2006 base case.

For the 2012 future year area source emissions outside of Texas, the TCEQ plans to use the 2005/2008 NEI with the latest EGAS growth factors. For the future year area source emissions within Texas, the TCEQ plans to apply the Texas-specific REMI-EGAS growth factors to the 2005/2008 TexAER emissions data base. The 2012 Haynesville Shale emissions estimates developed for Northeast Texas Air Care by Environ (*Environ*, 2009) will also be included and may be used as a basis for projecting oil and gas emissions from the Barnett Shale. Current industry and Texas Railroad Commission estimates of oil and gas production may also be used as a basis for projecting to 2012.

3.3.2.3 Non-Road Source Emissions

With the exception of marine, aircraft and locomotive emissions, which will be referred to as "off-road" emissions, the initial non-road emissions will be determined using the EPA NMIM mobile source emissions model. The off-road mobile source modeling emissions are derived from a number of inventories, such as the CENRAP, NEI and TexAER inventories.

For regions outside of Texas, the TCEQ will use the non-road emissions data from the EPA NMIM for 2006. As described above, the 2005 GWEI non-road and off-road emissions are included in the area source category. For regions inside of Texas, the TCEQ plans to use the Texas specific non-road emissions model (TexN) developed under contract by ERG for 2006. Drilling rig emissions will be estimated using a state-wide inventory developed under contract by ERG in 2009. The off-road emissions will be developed using data from the 2005 TexAER data base. Emissions data will be processed with EPS3 to generate CAMx model ready emissions that are day-specific, gridded, speciated and temporally (hourly) allocated. In addition, for equipment using heavy-duty diesel engines, EPS3 emissions will be post-processed to adjust for episode-specific temperature and humidity.

Within the 12 km domain, emissions from ships will be modeled as point sources since many have tall stacks and/or sufficient plume rise to exceed the 30 meter plume height cut-off. These sources are modeled by placing pseudo-stacks along shipping lanes, such as the Houston Ship Channel and Intracoastal Waterway. Similarly, emissions from wildfires and controlled burning generate smoke plumes that can rise thousands of feet and will be modeled as pseudo point sources, if data is available.

For the 2006 baseline non-road sources (including the off-road categories), the TCEQ plans to use the same emissions as used in the 2006 base case.

For the 2012 future year non-road mobile source emissions for states outside Texas, the TCEQ plans to use the EPA NMIM model for all applicable categories. For the future year off-road emissions for states outside Texas, the TCEQ plans to use the 2005/2008 NEI with the latest EGAS growth factors and the national locomotive and marine engines controls. For regions within Texas, the TCEQ plans to use the TexN model for non-road emissions, and for the off-road emissions, the TCEQ plans to use the 2008 TexAER with the Texas-specific REMI-EGAS growth factors and locomotive and marine engines national controls. Current industry and Texas Railroad Commission estimates of oil and gas drilling rigs may also be used as a basis for projecting to 2012.

3.3.2.4 On-Road Mobile Source Emissions

On-road mobile source emissions inventories will be developed for the DFW area, the remaining counties within Texas, and the states outside of Texas. For the regions within Texas, NCTCOG and the Texas Transportation Institute (TTI), under contract to the TCEQ, will develop the on-road mobile source emissions. For the region outside of Texas, the TCEQ will use the EPA NMIM to develop emissions for each of the states within the modeling domain. The spatial and temporal resolution of the emissions will decrease with distance from the DFW area.

For the DFW area, NCTCOG conducted link-based travel demand modeling (TDM). The TDM output includes Vehicle Miles Traveled (VMT) and speed parameters estimated by roadway link. NCTCOG used automatic traffic recorder (ATR) data available from TxDOT to adjust the TDM output to create hourly Monday, Weekday, Friday, Saturday, and Sunday "day type" VMT estimates for both school and summer (i.e., non-School) season types. Vehicle classification

data, also available from TxDOT, were used by NCTCOG to allocate the VMT among the 28 available MOBILE6.2 vehicle classes for each roadway link.

NCTCOG estimated average hourly operating speeds on each roadway link for each combination of day and season type. County specific MOBILE6.2 model inputs account for differences in meteorological parameters, local age distribution, and use of Texas Low Emissions Diesel (TxLED), Reformulated Gasoline (RFG), Low Reid Vapor Pressue (RVP) gasoline, and Inspection/Maintenance (I/M) testing. MOBILE6.2 emission rates in grams per mile were estimated for speeds ranging from 2.5 to 65 miles per hour (mph) for the various roadway categories. Link-based VMT and speed-based emission rate are multiplied to develop the link-based hourly emissions for each of the day and season types for the 2006 episode period and a 2012 future year. For the 2006 baseline, the TCEQ plans to use the 2006 summer season type emissions, the same as used for summer days in the 2006 base case. This is consistent with the summer season type emissions used for the 2012 future year. The most current summer fleet age distribution will be used when the 2012 future year inventory is developed.

For the Texas counties outside the DFW region, TTI will use traffic data collected by TxDOT (e.g., ATR) for the Highway Performance Monitoring System (HPMS). This data is used to estimate typical summer season, county-wide, hourly, day-type VMT and speeds on 19 roadway categories for the 28 available MOBILE6.2 vehicle classes. County-specific MOBILE6.2 model inputs will account for differences in meteorological parameters, local age distribution, use of TxLED, RFG, Low RVP and I/M testing. MOBILE6.2 speed-based emission rates are multiplied by the county-wide VMT to develop the hourly emissions for the 2006 episode, and a 2012 future year. For the 2006 baseline, the TCEQ plans to use the same on-road emissions as used in the 2006 base case. No school season adjustment will be used since these county-wide emissions are both relatively small and they are located relatively far from the DFW region.

For the region outside Texas, the TCEQ will use the EPA NMIM to develop emissions for 12 vehicle types on 12 roadway categories. Since the national VMT data provided with NMIM are only for 1999 and 2002, the TCEQ will rely on the Highway Statistics Series of data available from the Federal Highway Administration (FHWA) to project VMT beyond 2002. Ratios from the TTI-developed Texas on-road emissions will be used to adjust the summer weekday emissions output from NMIM to 2006 and 2012. These weekday emissions will then be scaled to create Friday, Saturday, and Sunday emissions using corresponding ratios in the TTI-developed Texas emissions. For the 2006 baseline, the TCEQ plans to use the same on-road emissions as used in the 2006 base case.

The on-road emissions from each of the different regions will be processed with EPS3 to generate day-type specific CAMx model ready emissions that are gridded, temporally allocated by hour, and speciated for the CB05 mechanism. Since the Texas on-road emissions received from TTI are already provided by hour, EPS3 processing will preserve the hourly distribution of the emissions.

For the DFW region, the link-based emissions will be spatially allocated to the appropriate grid cells according to the TDM geographic coordinates defining the links. In accordance with EPA guidance, 3.4 percent of the emissions from vehicle classes Heavy Duty Diesel Vehicle (HDDV) 8a and HDDV8b will be extracted and processed as heavy-duty diesel truck idling emissions. Spatial allocation of these idling emissions will be based on available parking places at known truck stop locations, while temporal allocation will be based on the inverse distribution of hourly HDDV8a and HDDV8b VMT. No heavy-duty diesel truck idling emissions will be developed for the other two regions (i.e., Texas non-DFW counties and states outside Texas). For these

regions, the heavy-duty diesel truck idling emissions are expected to be too small and too distant to warrant development.

For the region consisting of the remaining counties in Texas, the HPMS-based on-road emissions will be spatially allocated by appropriate roadway categories (e.g., interstates, state highways, arterials), while emissions from minor roadways and local streets will be allocated spatially by a human population surrogate.

As indicated previously, after the Texas on-road EPS3 processing is complete, hourly emission profiles for each of the day-types will be created and applied to the non-Texas emissions derived with the EPA NMIM. In addition, a spatial allocation, similar to that used for the Texas non-DFW region (i.e., roadway categories and population) will be used for the non-Texas region.

Table 3-5: *Summary of the Development of On-Road Mobile Sources Emissions* summarizes pertinent features of the planned development of on-road mobile emissions in the different regions of the modeling domain as described above.

Table 3-5: Summary of the Development of On-Road Mobile Sources Emissions

On-Road Inventory Development Parameter	Texas Metropolitan Areas	Texas Rural Areas	Non-Texas States/Counties
VMT Source	Travel Demand Models (TDMs)	HPMS DataSets	NMIM Database
VMT Resolution	Roadway "Links" From TDM	19 Roadway Categories	12 Roadway Categories
Season Types	School and Summer (i.e., non-School)	Summer Only	Summer Only
Day Types	Monday, Weekday, Friday, Saturday, and Sunday	Monday, Weekday, Friday, Saturday, and Sunday	Monday, Weekday, Friday, Saturday, and Sunday
Hourly VMT	Yes	Yes	No
VMT Mix Variation By Day/Time Period	Yes	Yes	No
Roadway Speed Distribution	Varies by Hour and Link	Varies by Hour and Roadway Type	MOBILE6.2 Default
Spatial Resolution	Excellent	Very Good	Good
Temporal Resolution	Excellent	Very Good	Good
MOBILE6.2 Vehicle Classes	28	28	12
Temperature/Humidity Diesel NO_X Correction	Yes	Yes	No
"18-Wheeler" Idling Emissions Separation	Yes	No	No

3.3.2.5 Biogenic Emissions

The TCEQ selected the GloBEIS model because it can incorporate detailed locality specific land-use data and solar radiation data from GOES satellite imagery. The GloBEIS model also has built-in QA reporting functions. The land cover and vegetation data bases used for input to GloBEIS derived from the following sources:

UT-CSR land cover database (*Feldman et al.*, 2007) - This data base was developed from classification of recent Landsat 7 data, Shuttle Radar Topography Mission and National Elevation datasets to identify wetlands, and USDA Common Land Unit (CLU) data to identify agricultural land.
TCEQ Texas vegetation database (*Wiedinmyer et al.*, 2001) - This database was derived from Texas Parks and Wildlife vegetation data, urban land use data from Braden, Collie, and Turner Consulting, agricultural statistics from the National Agricultural Statistics Survey, and field surveys carried out during 1999.
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.
Mexican land use and vegetation database (*Mendoza-Dominguez et al.*, 2000) - The database was created by researchers at the University of Monterrey and Georgia Tech.

For east Texas (i.e., the 4 km domain), the new UT-CSR land cover and vegetation data will be used. For all other regions within Texas, the Wiedinmyer et al. data will be used. The BELD3 database will be used only for the regions outside of Texas, with the exception of Mexico, where the Mexican land use and vegetation database will be used.

Photosynthetically-active solar radiation (PAR) data for the biogenic emissions modeling will be obtained from the website operated by the Global Energy and Water Cycle Experiment (GEWEX) Continental International Project (GCIP) and GEWEX Americas Prediction Project (GAPP) (http://metosrv2.umd.edu/~srb/gcip/cgi-bin/historic.cgi?auth=no). The data can be downloaded at half-degree resolution and will be reprocessed to match the TCEQ modeling grids. These data are derived from hourly GOES satellite imagery of cloud cover, which have been processed with a solar irradiation model (*Pinker and Laszlo*, 1992).

For all regions modeled, the TCEQ plans to prepare the hourly temperature fields using kriging algorithms in the SAS software. Variograms will be fitted for each hour, so that each hour will be interpolated with a variogram that fits its inherent degree of variation. Temperature data will be obtained from weather stations throughout the United States, including data from the National Weather Service, the EPA 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. The data from each of these sources has been quality-assured by the organizations that run the monitoring networks and will be further checked for anomalies by the TCEQ.

After each biogenic emissions modeling file is created, two additional files will be created to assist in quality assurance. An emissions summary file, showing hourly domain-wide total emissions of isoprene, monoterpenes, other VOCs, NO_X, and CO, is created to allow quick comparison of different days. A model configuration file is also created listing the input files used to create the emissions file. The model configuration file shows the GloBEIS model settings. These files will be archived with the emissions files.

Since the biogenic emissions are associated with meteorological features, The TCEQ plans to use the same episode-specific emissions for the 2006 baseline and 2012 future air quality modeling.

3.3.3 CAMx Modeling Inputs and Outputs

3.3.3.1 Modeling Inputs

The outputs from the emissions modeling processors, EPS3 and GloBEIS, and from the MM5 meteorological model serve as the CAMx inputs for emission rates and meteorological

parameters, respectively. Additional CAMx inputs include initial and boundary conditions, spatially resolved surface characteristic parameters, spatially resolved opacity, and photolysis rates.

Initially the TCEQ plans to use the same initial and lateral boundary concentrations prepared by Environ for modeling conducted for the HGB 8-hour SIP (*TCEQ*, 2010a). The TCEQ contracted with Environ (*Environ*, 2008) 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 and each vertical layer for each episode hour. This work also produced initial conditions for the episode. The TCEQ has contracted again with Environ to evaluate updated MOZART modeling data to determine its applicability for initial and boundary condition data (*Emmons et al.*, 2010).

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) Land Use Land Cover (LULC) database. For the 36 km and 12 km domains, the TCEQ used the land-use files developed by Environ for the previous DFW SIP revision approved by the EPA in 2009, which were derived from the most recent USGS LULC database. For the 4 km domain, the TCEQ plans to use 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 will use episode-specific satellite data from the Total Ozone Mapping Spectrometer (TOMS) to prepare the photolysis rates and opacity files.

3.3.3.2 Modeling Outputs

CAMx outputs CB05 species in molar concentration units of parts per million by volume (ppmv). Some of the CB05 species are actual chemical species and include ozone, nitric oxide, nitrogen dioxide, carbon moNO_Xide, ethane, ethene, formaldehyde and acetaldehyde. Typically, CAMx is executed to output hourly average concentrations, which are comparable to hourly monitored aerometric parameters. CAMx also outputs limited diagnostic files, including instantaneous concentration files for the last two simulation hours (typically used for restarts), PiG output files (typically used for restarts, but can be used for diagnostic analyses), and a deposition file (typically used for diagnostic analyses).

CAMx can also be executed to output process analysis and source apportionment results. Process analysis, including chemical process analysis (CPA) and integrated process rate (IPR) analysis, 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. Process analysis modeling output is typically used as a part of the performance evaluation. Source apportionment, such as Ozone Source Apportionment Technology (OSAT) and Anthropogenic Precursor Culpability Assessment (APCA), estimates the culpability of sources from various regions contributing to local ozone concentrations. Source apportionment modeling output can also be used as a part of the performance evaluation, but more typically, it is used with the future year modeling to quantify the region/source type contributions to the projected future design values.

CAMx can also output analysis results of first and higher order sensitivities of modeled concentrations to model input parameters via the Direct Decoupled Method (DDM) and the High-Order Direct Decoupled Method (HDDM), respectively. The DDM or HDDM calculate CAMx's sensitivity to changes in inputs directly as the model is executed and can be used to evaluate base-case performance as well as to assist in control strategy evaluation in the future year modeling.

3.4 Quality Assurance/Quality Control (QA/QC) Plan

The TCEQ's QA/QC plan focuses primarily on the data input to the models and procedures, and post-processing of the output data used for decision making. The TCEQ conducts extensive QA/QC activities when developing modeling inputs, running the models, and analyzing and interpreting the output. The TCEQ has developed a number of innovative and highly effective QA/QC tools that are employed at key steps of the modeling process. Attachment 2 provides a detailed QA/QC plan developed by the TCEQ to be used during modeling, which is consistent with EPA guidance to ensure the scientific soundness and defensibility of the modeling.

4 TEXAS AIR QUALITY STUDY DATA

4.1 The Second Texas Air Quality Study, 2006 (TexAQS II)

TexAQS II was an 18 month project initiated in the latter part of the summer of 2005 concluding with a field intensive monitoring period from August 1 to October 15, 2006. In addition to a wealth of scientific information which has greatly enhanced the understanding of ozone formation, transport, and destruction processes in eastern Texas, TexAQS II products specific to the DFW area include additional rural monitoring of ozone and precursors and additional radar profiler data collection in North Texas, plus several hours of sophisticated aircraft data collected over, upwind of, and downwind of the DFW area.

5 MODEL PERFORMANCE EVALUATION

The performance evaluation of the base case modeling measures the adequacy of the model to correctly replicate the relationship between levels of ozone and the emissions of ozone precursors such as NO_X and VOC. The model's ability to correctly replicate this relationship is necessary to have confidence in the model's prediction of the response of ozone to various control measures.

The TCEQ will conduct two types of performance evaluations, operational (e.g., statistical and graphical evaluations) and diagnostic (e.g., sensitivity evaluations). As recommended by EPA (*EPA*, 2007), these evaluations will be considered as a whole in a weight-of-evidence approach, rather than individually, to gauge the adequacy of the model.

The TCEQ has incorporated the recommended eight-hour performance measures into its routine evaluation procedures, but will continue to focus primarily on one-hour performance analyses, especially in the DFW area. The high-resolution meteorological and emissions features characteristic of the area require model evaluations be performed at the highest resolution possible to determine whether or not the model is getting the right answer for the right reasons.

The TCEQ also plans to evaluate the model performance at some of the more rural monitors within Texas beyond the DFW area, including TexAQS II special-purpose monitors. Since the modeling resolution is more coarse in the rural areas (e.g., 12 km grid), the performance evaluations the TCEQ plans to use will be predominantly based on graphical measures.

5.1 Operational Evaluations

5.1.1 Statistical Measures

Statistical measures provide a quantitative evaluation of model performance. At a minimum, TCEQ plans to use the following recommended statistics (*EPA*, 2007) in evaluating performance of the base case modeling.

Unpaired Peak Accuracy (UPA) - This statistic compares the difference between the maximum modeled ozone concentration and the highest monitored ozone concentration found over all hours and over all monitoring stations for each day simulated. This comparison will be made for both one- and eight-hour peak ozone concentrations.

In the past EPA recommended an acceptable range for the UPA of plus or minus 15-20 percent for one-hour ozone. For eight-hour ozone, EPA has not included the UPA as a recommended statistical measure. However, this statistic will be computed to ensure that the model is generating sufficiently high ozone peaks on each day of the simulation.

Mean Normalized Bias (MNB) - This statistic compares the relative difference between modeled and monitored ozone concentrations, paired in time and space, averaged over all hours and over all monitoring stations. The MNB will be calculated for individual episode days by averaging over all monitoring sites, and individual sites by averaging over all days. The MNB provides a measure of the model's tendency to over- or under-predict monitored ozone concentrations. A positive bias indicates that the model's ozone concentrations are too high, and a negative bias indicates the converse. A bias near zero is desirable, although this does not necessarily mean the model is replicating ozone concentrations well since combining large positive and negative relative differences can result in a near-zero MNB.

For one-hour ozone, EPA has recommended a range of plus or minus 5-15 percent, and calculating the MNB only when the monitored ozone concentration is 60 ppb or greater. For eight-hour ozone, EPA also recommends limiting the calculation of the MNB to monitored ozone concentrations over a minimum threshold of 40 or 60 ppb, but no range is given for consideration of suitable performance. The TCEQ plans to compute the MNB for the one-hour ozone concentrations using a minimum threshold of 60 ppb. However, for the eight-hour ozone concentrations, the TCEQ plans to compute the MNB using the daily maximum eight-hour ozone concentrations.

Mean Normalized Gross Error (MNGE) - This statistic is similar to the MNB, except that the absolute value of the relative differences between modeled and monitored ozone concentrations paired in time and space are averaged over all hours and over all monitoring stations. The MNGE will be calculated for individual episode days by averaging over all monitoring sites and individual sites by averaging over all days. This statistic is representative of the overall deviation between the modeled and monitored concentrations. The MNGE is always greater than or equal to zero.

As for the MNB, the TCEQ will compute the MNGE for the one- and eight-hour ozone concentrations using a minimum threshold of 60 ppb for one-hour and the daily maximum for the eight-hour, respectively. For one-hour ozone concentrations, the recommended range for MNGE is plus or minus 30-35 percent, but no range is specified for eight-hour.

For both the MNB and MNGE, the TCEQ plans to use a modeled value based on a bi-linear interpolation of the ozone concentrations in the grid cells around a monitor.

These statistical measures will be used primarily for ozone concentrations, although they may be applied to some of the ozone precursors. In addition, the TCEQ may use other statistical measures such as mean fractional bias and mean fractional error as deemed necessary in the performance evaluation.

5.1.2 Graphical Measures

Graphical measures provide a qualitative evaluation of model performance. At a minimum, the TCEQ plans to use the following recommended graphics in evaluating performance of the base case modeling (*EPA*, 2007):

Time Series Plots - For monitoring stations in the domain, the hourly monitored and bi-linearly interpolated modeled concentrations can be compared for each hour in an episode. This comparison assesses how well the model predicts diurnal and/or daily variation in the ozone concentrations at specific locations.

The TCEQ plans to develop hourly time series plots for ozone and some ozone precursors (e.g., NO_X, VOC) at appropriate sites. Comparing the modeled versus monitored concentrations of precursors can indicate whether the model is correctly replicating the physico-chemical processes by which ozone was actually generated.

Since averaging over several hours smoothes the modeled and observed concentrations and obscures important features, TCEQ does not plan to develop time series plots for eight-hour concentrations of ozone or ozone precursors.

Scatter Plots - Scatter plots of hourly monitored and bi-linearly interpolated modeled ozone concentrations will be developed for appropriate monitors for all episode days. This should show overall patterns of under- and/or over-prediction for an entire episode. Comparing between selected monitors should show any geographically related differences in prediction patterns. The TCEQ plans to develop hourly scatter plots for some ozone precursors (e.g., NO_X, VOC) at selected monitors and for all episode days, as well. Quantile/Quantile (Q/Q) plots indicating the rank distribution of the monitored versus modeled ozone concentrations will also be developed and included on the scatter plots.

Peak Ozone Tile Plots - Tile plots of one- and eight-hour daily ozone maxima overlaid with monitored maximum values provide a visual means of assessing where the model predicted peak concentrations compared with observations. The TCEQ will develop plots showing the peak daily concentration (one- and eight-hour) simulated in each grid cell.

Ozone Animations - Tile plots of hourly modeled ozone concentrations overlaid with monitored maximum values will be combined into an animated sequence. Animations of ozone precursors (NO_X, VOC) will also be developed as needed. Viewing the sequence of tile plots as an animation provides insight into the model's physico-chemical processes, such as how ozone forms, and how it is transported and dispersed by the model.

Aloft measurements - During the TexAQS II, numerous aircraft flights collected a rich set of aloft ozone, ozone precursor, and reaction product measurements. Additionally, data were collected at the Moody Tower at the University of Houston at an elevation of approximately 70 meters above ground level (AGL). Data from aircraft transects will be compared with model predictions along the flight path. Data collected at the Moody Tower will be compared with model predictions at the appropriate vertical layer using time series plots as described above.

5.2 Diagnostic Evaluations

5.2.1 Sensitivity Analyses

Sensitivity analyses are designed to check the response of the modeled ozone to changes in model inputs including meteorological parameters and precursor emissions. The results of these analyses indicate the sensitivity of the model to various inputs and can identify which inputs must be scrutinized most closely. In addition, sensitivity analyses can also indicate which modeling inputs may be hindering the performance of the model.

The TCEQ plans to perform one or more of the following analyses to determine the model sensitivity to various model input parameters:

Alternative meteorological characterization – The TCEQ will analyze the sensitivity of the predicted ozone and ozone precursors to changes in the meteorological inputs using a variety of parameterizations/characterizations of the meteorological modeling. The use of different parameterizations/characterizations will change various meteorological parameters, such as the wind speed and the vertical mixing coefficients. These analyses may have the added benefit of identifying the best meteorological characterization for use in this modeling application.

Alternative boundary conditions - Because the area of most interest, the fine grid domain about DFW, is far from the lateral boundaries, the sensitivity to boundary conditions has been relatively small in past modeling applications. However, recent modeling conducted for other Texas areas suggests a higher level of sensitivity to the specification of boundary conditions. The TCEQ plans to analyze the sensitivity of the predicted ozone and ozone precursors to changes in the boundary conditions. In particular, the TCEQ plans to work with staff from Environ in evaluating other sources of episode specific boundary conditions.

Alternative emissions inventory assumptions - The TexAQS studies have provided substantial evidence that the reported emissions under-estimate some of the ozone precursors. The TCEQ will analyze the sensitivity of the predicted ozone concentrations to changes in the emissions, particularly the HRVOC, as well as the less highly reactive VOCs. The TCEQ is planning to use the PSCF analysis to reconcile HRVOC emissions with the ambient HRVOC concentrations measured at the auto-GCs. A sensitivity of the predicted ozone concentrations with and without the HRVOC reconciliations will be conducted. Additionally, a sensitivity of the predicted ozone concentrations to changes in the emissions of the less highly reactive VOCs will be conducted.

5.2.2 Diagnostic Analyses

Diagnostic analyses tend to focus more directly on the model's change in predicted ozone to changes in the ozone precursor emissions. At a minimum, the TCEQ plans to conduct the following diagnostic analyses:

Observational Methods - These methods compare changes in modeled ozone associated with changes in emissions input to the model to changes in monitored ozone associated with changes in actual emissions. The primary analysis of this type which the TCEQ plans to conduct is a modeling scenario to compare the weekday versus weekend differences in ozone and emissions to the monitored weekday versus weekend differences for the area. Another analysis of this type that the TCEQ may conduct involves comparing the changes in the modeled versus monitored NO_X- or VOC-limitation both geographically and temporally over the HGB area.

Probing Tools - These tools are embedded procedures in the CAMx model used to discern the contribution to ozone formation from the various inputs. The primary probing tool the TCEQ plans to use is process analysis. The TCEQ may also conduct source apportionment analyses (e.g., OSAT, APCA, HDDM/DDM) on the base case modeling. The TCEQ plans to conduct

source apportionment analyses on the base (and possibly future) case modeling to understand the contribution from various source categories in various source regions to the predicted ozone concentrations.
Retrospective Analyses – A retrospective analysis is intended to examine the ability of the model to respond to emission changes by comparing a recent trend or change in observed ozone concentrations to the model-predicted ozone concentration trend or change over the same period. If time allows, the TCEQ plans to use the model and the attainment test procedure to project year 1999 ozone design values (i.e. back cast from the 2006 baseline to year 1999). The model-projected year 1999 ozone design values will be compared to the actual design values calculated from the ambient measurements

These diagnostic analyses should establish the reliability of the model to adequately predict the response of ozone to changes in the emissions, which is paramount in testing control measures.

6 ATTAINMENT YEAR MODELING AND CORROBORATIVE ANALYSES

The attainment demonstration will consist of the attainment year modeling and the corroborative analyses. The TCEQ plans to conduct attainment year modeling in accordance with the EPA attainment test procedure for eight-hour ozone modeling. Additionally, the TCEQ plans to provide a suite of corroborative analyses providing additional assurance that any control strategy proposed for the DFW area will result in attainment at all monitors.

6.1 Attainment Year Modeling

In accordance with the "serious" eight-hour ozone classification for the DFW area and the EPA modeling guidance, the TCEQ is using 2012 as the future year for attainment modeling. Using the 2012 projected future year emissions, which include growth and current regulatory control measures, the TCEQ will model the future year. As per the EPA guidance, the TCEQ plans to project the 2012 future year design values, DVF, using the relative response factor, RRF, and the 2006 base year design value, DVB, at each of the monitors in the DFW area with a 2006 DVB greater than or equal to 85 ppb.

The TCEQ plans to calculate the RRFs, in accordance with the EPA guidance, using the average of the 2006 baseline modeled daily maximum eight-hour ozone concentrations above 84 ppb within the 3 x 3 grid cell array about the monitor. Also per the EPA guidance, if there are fewer than 10 days with 2006 baseline modeled daily maximum eight-hour ozone concentrations greater than 84 ppb, then the threshold will be reduced on a monitor-by-monitor basis until each monitor has ten days above the threshold, or the threshold reaches 70 ppb. If any monitors have less than five days meeting the 70 ppb threshold, the TCEQ will consult with Region VI modeling staff to determine the appropriate action.

The TCEQ expects that most, if not all, of the DVFs will be below 85 ppb, demonstrating attainment. In the case that not all the DVFs are below 85 ppb, the TCEQ plans to conduct sensitivity testing to determine what additional emission reductions may be necessary to demonstrate attainment. In the case that all the DVFs are notably below 85 ppb, the TCEQ plans to consult with EPA to determine whether mid-year modeling would be needed to address the "as expeditiously as practicable" provision.

Prior to release of the EPA's Modeled Attainment Test Software (MATS), the TCEQ developed its own procedure for calculating RRFs and future design values called the TCEQ Attainment Test for Unmonitored areas (TATU). In addition, TATU performs a spatial interpolation, so like MATS, TATU can also be used to analyze unmonitored areas (i.e., an out-of-network test). While conceptually similar to MATS, TATU was designed specifically to be integrated into the

CAMx modeling process. This facilitates the calculation of RRFs and DVFs and the spatial interpolation. For example, MATS requires input in Latitude/Longitude, while TATU works directly with the Lambert Conformal Projection (LCP) data used in post-processing modeling applications. Also, MATS cannot easily handle multi-year base case data; TATU can. Finally, MATS uses a technique called Voronoi Neighbor Averaging (VNA) for spatial interpolation, while TATU relies on the more familiar kriging technique. The TCEQ staff have conducted an analysis comparing the RRF and DVFs resulting from using MATS and TATU and showed very minimal differences. Since the ozone monitoring network for the DFW area has a relatively large spatial extent, the TCEQ does not anticipate having to conduct an out-of-network test. However, should an out-of-network test be necessary, the TCEQ plans to use TATU.

If needed, to provide directional guidance in identifying control measures that may reduce ozone the most effectively, the TCEQ plans to conduct a number of modeling sensitivities. These sensitivities may include an across-the-board percentage emission reductions matrix, an HDDM analysis and/or an OSAT/APCA culpability assessment. Using these sensitivity modeling results, specific control measures will be evaluated. The emissions reductions associated with selected control measures will be incorporated into the future 2012 modeling and to test their effectiveness, the DVFs will be recalculated.

The control strategy will be incorporated into the future 2012 emissions and modeled for the attainment demonstration.

6.2 Corroborative Analyses

As per EPA guidance, the TCEQ plans to conduct additional analyses to corroborate the attainment modeling. The TCEQ's corroborative analysis for the DFW 8-hour ozone SIP will help demonstrate that the processes of ozone formation, accumulation, and transport in the DFW area are now relatively well understood, and therefore the steps needed to make further progress can be discerned. The corroborative analysis will consist of three main sections:

- Discussion of the implications of the modeling results and model performance evaluation, including findings from TexAQS projects and other advanced air quality research studies that have been conducted for the DFW area, and which have contributed greatly to the understanding of DFW's air quality problems;
- Discussion of the trend analyses for ozone and ozone precursor concentrations, including ozone metrics such as the design value, fourth highest daily maximum, ozone gradients, number of exceedance days, and precursor metrics such as annual average, annual 90th percentile and daily peak hourly ambient NO_X concentrations, monthly geometric mean VOC ambient concentrations and monthly geometric mean TNMHC; and
- Discussion of air quality control measures that are not modeled because they cannot be adequately quantified, but are nonetheless expected to yield tangible air quality benefits, such as marine fuel standards for ocean-going vessels, Smartway Transport Partnerships and Blue Skyways Collaboratives, and energy efficiency measures (e.g. commercial and residential building codes).

The data and analyses presented in the corroborative analysis section will summarize the body of evidence that describes the causes of ozone in DFW.

7 MODELING DOCUMENTATION AND ARCHIVE

7.1 Documentation

EPA recommends that certain types of documentation be provided along with a photochemical modeling attainment demonstration. The TCEQ is committed to supplying the material needed

to ensure that the technical support for any SIP revision is understood by all stakeholders. To that purpose, the TCEQ will document the following items in conjunction with the attainment demonstration:

Modeling Protocol - Establishes the scope of the analysis and encourages stakeholder participation in both the study development and the study itself;
Emissions Modeling Appendix - Summarizes the development of the model-ready emissions estimates. This appendix will contain tabular and graphical summaries of the data for the episodic base cases, and the baseline and future years;
Meteorological Modeling Appendix - Summarizes the development of the meteorological parameters used by the photochemical model. This appendix will contain tabular and graphical summaries of the relevant parameters;
Photochemical Modeling Appendix - As discussed in Section 6, an assessment of the suitability of the model to support emissions control policy will be assessed. The findings of that analysis will be discussed comprehensively in the model performance evaluation section of this appendix. Also, as discussed in Section 6, several diagnostic analyses are planned to determine whether the photochemical modeling results are physically sound;
Description of the Attainment Demonstration Modeling and Weight-of-Evidence (WOE) - This documentation will provide an overall description of the modeling, including the future year modeling with specific control measures, as needed, and WOE arguments based on corroborative analyses, the combination of which suggests attainment will be achieved in a future year; and
External Review - TCEQ will document the review procedures (internal and external) employed in the project. This approach will include instructions provided to interested external parties for accessing the study database, including software utilized as part of the technical analyses.

Note that the above list is not all-inclusive and that additional documentation will likely be developed in the course of fully documenting the modeling activities. Some items may be documented as part of the actual SIP, while others will be provided as Appendices, Attachments, or Supplementary Reports. All relevant documentation will be available electronically, either through the TCEQ web site or by contacting the TCEQ.

7.2 Modeling Archive

The TCEQ plans to archive all documentation and modeling input/output files generated as part of the eight-hour modeling analysis. Interested parties can contact the TCEQ for information regarding data access or project documentation.

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ATTACHMENT 1: EPISODE SELECTION FOR THE DFW ATTAINMENT DEMONSTRATION SIP REVISION FOR THE 1997 EIGHT-HOUR OZONE STANDARD

1 GUIDANCE

The EPA's eight-hour modeling guidance suggests considering the following four main criteria when determining if an ozone episode is appropriate for an attainment demonstration (*EPA*, 2007):

- Meteorological conditions vary and are conducive to eight-hour daily ozone maxima greater than 84 ppb at multiple monitoring sites;
- The observed eight-hour ozone concentrations are similar to the baseline design value;
- Special studies or intensive monitoring are available for data analyses, assimilation, and model performance evaluations; and
- Enough elevated eight-hour ozone days are modeled at each key monitoring site to perform the modeled attainment test.

It is understood that these criteria may be in conflict with each other and tradeoffs will occur. Episode(s) may be chosen considering other factors as well, including previous modeling experience.

2 BACKGROUND

The August 13-22, 1999 episode developed in previous Dallas-Fort Worth (DFW) modeling attainment demonstrations was well suited to the one-hour ozone National Ambient Air Quality Standard (NAAQS) and the initial eight-hour NAAQS analysis. Since 1999, many regulatory, demographic, and emission source changes have occurred. Additional monitors have been installed, including a key design value monitor at Eagle Mountain Lake (see Figure 2-1 A1*: 2006 DFW Monitor* Locations). Also, the 2005 and 2006 Texas Air Quality Study II (TexAQS II) offers a wealth of data sources, analyses, and modeling (*TCEQ*, 2009). Thus, a more recent episode could account for many of those changes and enhance confidence in modeling analyses.

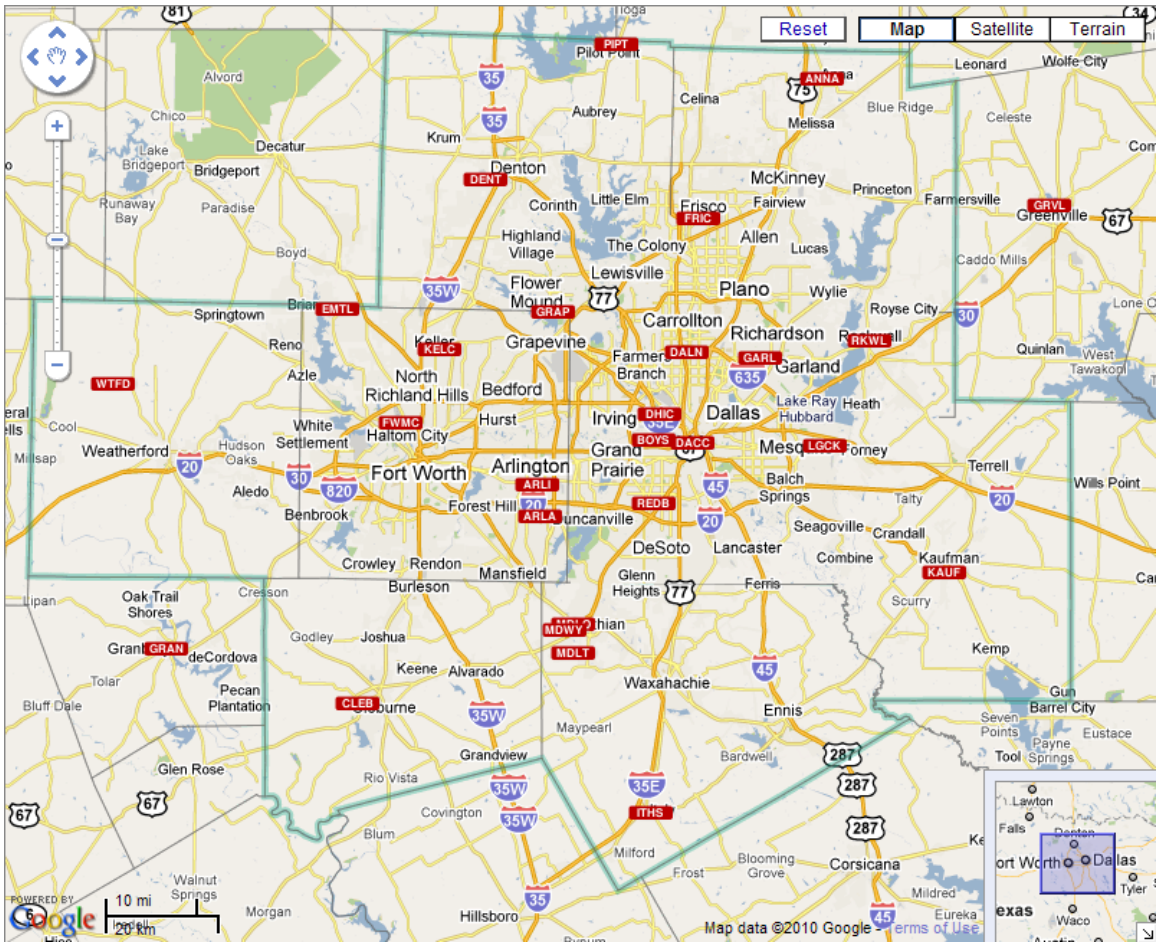

Figure 2-1 A1: 2006 DFW Monitor Locations

3 EVALUATION OF EPISODES

The short time frame available to develop this modeling demonstration necessitates reviewing the applicability of ozone episodes that the TCEQ has recently modeled or analyzed. Six high eight-hour ozone episodes were modeled from TexAQS II for the most recent Houston attainment demonstration (*TCEQ*, 2010a). These periods were investigated first since much of the meteorological and emissions inventory data can be leveraged to the DFW area. The extensive monitoring data collected during TexAQS II, including important radar wind profilers, make these periods even more attractive.

Table 3-1 A1*: DFW Eight-hour Ozone Exceedance Data during TexAQS II* Episodes shows the episodes modeled for the Houston-Galveston-Brazoria attainment demonstration adopted in 2010 by the TCEQ, as well as one additional episode, the extended June 2006 period. The table also shows the magnitude of the highest eight-hour ozone exceedance in the DFW area for each episode. There were more days with more monitors above the eight-hour ozone standard in the June periods in 2005 and 2006 in the DFW nonattainment area than in any of the other episodes. Additional special study monitors were installed just prior to June 2006, along with radar wind profilers, which are important for meteorological modeling performance (*Knoderer and MacDonald*, 2007).

Table 3-1 A1: DFW Eight-hour Ozone Exceedance Data during TexAQS II Episodes

Episode	Dates	Days ≥ 85 ppb	Max 8-hour O3 (ppb)
2005ep0	May 19 - Jun 3, 2005	4	101
2005ep1	Jun 17 - 30, 2005	**9**	**117**
2005ep2	Jul 26 - Aug 8, 2005	6	115
2006ep0	May 31 - Jun 15, 2006	**11**	107
2006ep0ext[1]	May 31 - Jul 2, 2006	**17**	107
2006ep1a	Aug 13 - Sep 15, 2006	6	102
2006ep1b	Sep 16 - Oct 11, 2006	0	81

[1] 2006ep0ext not modeled for Houston

In 2008, the Austin and San Antonio areas optimized the TCEQ meteorological modeling of the June 2006 episode to be more representative of central Texas. The modeling period was also extended to July 2 to include more eight-hour ozone exceedance days (*Emery et al.*, 2009a). For DFW, there were 17 days of the extended June episode (2006ep0ext) with maximum eight-hour ozone concentrations in excess of 85 ppb.

Figure 3-1 A1*: Daily Maximum Eight-hour Ozone in Texas, June* 2006 shows that high eight-hour ozone was observed regionally across Texas during the extended June episode. Because of the regional applicability, the TCEQ has continued developing the meteorological modeling of this episode to improve MM5's performance in non-coastal areas in Texas. Details on the development of MM5 for the episode can be found in (*Emery et al.*, 2009b).

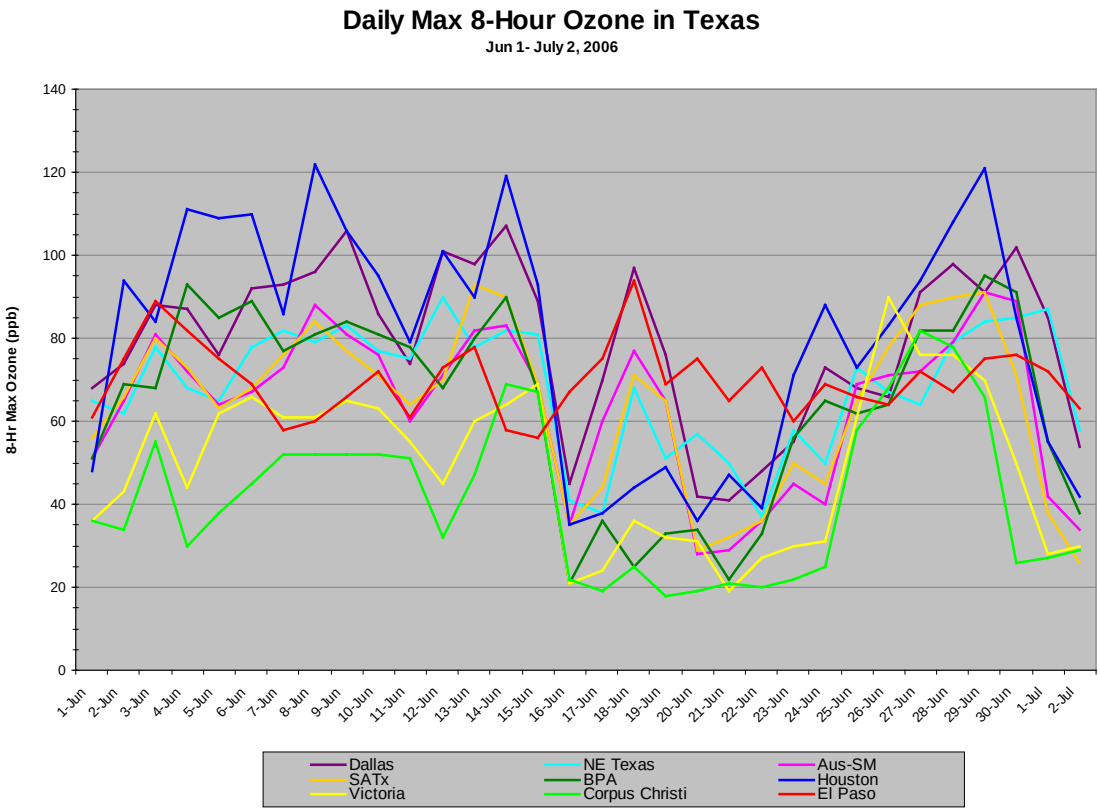

Figure 3-1 A1: Daily Maximum Eight-hour Ozone in Texas, June 2006

The extended June 2006 episode is the focus of episode development because of the number of ozone exceedances, availability of special-study monitoring data, availability of existing high-quality modeling databases, broad regional applicability, and previous TCEQ modeling experience.

4 SUMMARY OF THE EXTENDED JUNE 2006 EPISODE

The DFW monitor with the most eight-hour ozone exceedance days during the extended June 2006 episode was Denton Airport South (C56), with nine over the 33 day episode (see *Table 4-1 A1: DFW Monitor-specific Eight-hour Ozone Data during the Extended June 2006* Episode). Eagle Mountain Lake (C75), Denton Airport South, Keller (C17) and Ft. Worth Northwest (C13) have had the highest design values in the area since 2005 and measured the most ozone exceedance days during the extended June 2006 episode. While these key monitors did not observe ten days with ozone measured in excess of 85 ppb, they did measure almost twenty days of eight-hour concentrations 70 ppb or greater, which can be used for the relative response factor (RRF) calculation. All but the Greenville monitor (C1006) had at least ten days 70 ppb or above, although its northeast location is not in the typical path of high ozone (*TCEQ*, 2010b).

Table 4-1 A1: DFW Monitor-specific Eight-hour Ozone Data during the Extended June 2006 Episode

Monitor	Max 8-hour Ozone (ppb)	**Days ≥ 90 ppb**	Days ≥ 85 ppb	Days ≥ 70 ppb	Site-specific Baseline Design Value (ppb)
Eagle Mountain Lake C75	**107**	**5**	8	18	**93.3**
Denton Airport South C56	106	**5**	**9**	17	**93.3**
Keller C17	103	4	8	**19**	91.0
Grapevine Fairway C70	95	3	5	14	90.7
Ft. Worth Northwest C13	101	**5**	8	17	89.3
Parker County C76	101	3	5	15	87.7
Frisco C31	94	1	7	14	87.7
Cleburne Airport C77	98	2	2	15	85.0
Dallas Exec. Airport C402	91	1	2	17	85.0
Dallas North No.2 C63	86	0	2	12	85.0
Arlington Municipal Airport C61	91	1	3	11	83.3
Granbury C73	92	2	3	12	83.0
Dallas Hinton St. C401	84	0	0	14	81.7
Rockwall Heath C69	78	0	0	11	77.7
Greenville C1006	78	0	0	8	75.0
Kaufman C71	78	0	0	11	74.7
Pilot Point C1032	101	4	**9**	14	NA
Midlothian Tower C94	98	1	2	14	NA
Midlothian OFW C52	96	1	1	11	NA
Italy High School C650	89	0	1	10	NA

Values are sorted in descending order of monitor-specific design values.

The 2010 Dallas-Fort Worth Conceptual Model (*TCEQ*, 2010b) describes the general meteorological conditions that are typically present on days when the 8-hour ozone concentration exceeds the 1997 ozone NAAQS. High ozone is typically formed in the DFW area on days with slower wind speeds out of the east and southeast. These prevailing winds also lead to higher background ozone levels entering into the DFW area. High background ozone concentrations are then amplified as an air mass moves over the urban core of Dallas and Tarrant Counties, which both contain large amounts of NO_X emissions. Those emissions are then transported across the DFW area to the northwest, where the highest eight-hour ozone concentrations are observed.

The 2006 modeling episode showed that these conditions were present on the high ozone days. High pressure developed over the area from June 5th through June 10th which resulted in mostly sunny days with high temperatures above 90 degrees Fahrenheit. High pressure also resulted in winds that calm or light out of the southeast. This resulted in a gradual buildup of ozone and ozone precursors over the Dallas – Fort Worth area. This peaked at an eight-hour ozone concentration of 106 ppb at the Eagle Mountain Lake and Denton Airport monitor sites on June 9th (Figure 4-1 A1*: June 2006 Episode Eight-Hour Ozone by* Monitor).

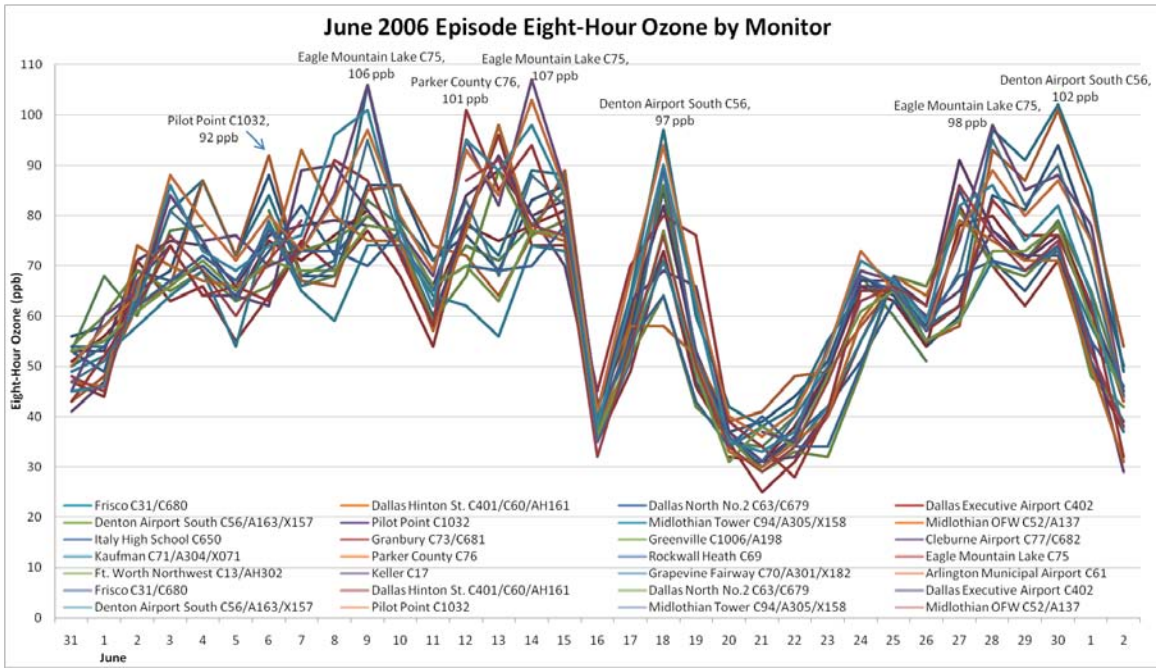

Figure 4-1 A1: June 2006 Episode Eight-Hour Ozone by Monitor

High pressure began to erode away as a weak frontal boundary approached from the north. This resulted in an increase in wind speeds over the area, diluting the ozone and lowering the eight-hour ozone concentrations over the area. As winds switched directions and began blowing from the east-northeast on the backside of the frontal boundary, ozone concentrations again increased. Winds from the east-northeast have the potential for long range transport from the direction of the Ohio River valley. Transport likely contributed to an eight-hour ozone concentration of 107 ppb at the Eagle Mountain Lake monitor site on June 14th. Over the next few days, low pressure moved in to the area from the Gulf of Mexico. This caused an increase in cloudiness and wind speed which reduced the potential for ozone formation. High pressure returned to the area from June 27th through June 30th. This again resulted in the high temperatures and low wind speeds, creating conditions favorable for ozone formation.

Back trajectories from DFW (Eagle Mountain Lake C75) extending backwards in time for 48 hours and terminating at 500 meters above ground level (agl) are shown for every day of the extended June 2006 episode in *Figure 4-2 A1: Daily 48-hour Back Trajectories from DFW (May 31 through June 15, and June 16 through July 2,* 2006). The left panel shows the May 31 – June 15, 2006, period while the right panel shows the June 16 – July 2, 2006, period. The trajectories depict air coming from north, east, and southerly directions. Westerly winds are not common during the summer months in DFW, thus, there are no trajectories coming from the west to northwest (*TCEQ*, 2010b). These trajectories illustrate that the extended June 2006 episode includes periods of synoptic flow from each of the directions commonly associated with high 8-hour ozone concentrations as described in the DFW Conceptual Model.

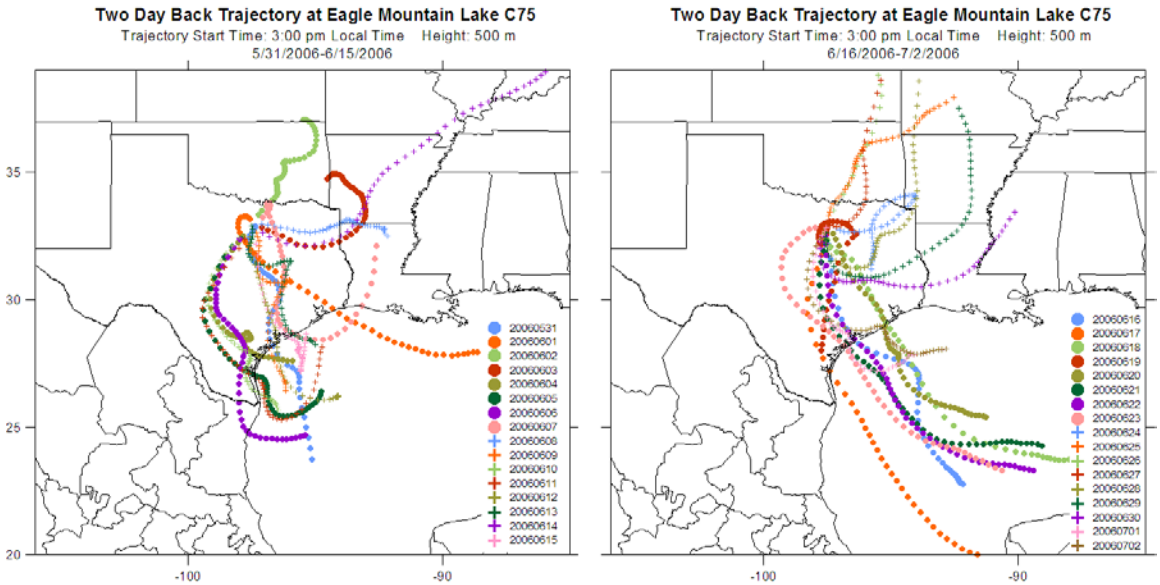

Figure 4-2 A1: Daily 48-hour Back Trajectories from DFW (May 31 through June 15, and June 16 through July 2, 2006)

5 CONCLUSION

The extended June 2006 episode is appropriate for SIP modeling as the period experienced 17 days above the eight-hour ozone standard and monitor-specific concentrations were similar in magnitude to the 2006 baseline design value. While the key design value monitors did not measure 10 or more days above 85 ppb, they all experienced nearly 20 days above 70 ppb, which should ensure the robustness of the modeled attainment test. Meteorological conditions varied throughout the 33 day episode including the passing of three cold/warm fronts. The addition of the TexAQS II monitoring data, previous HGB SIP modeling experience of May 31-June 15, 2006, and existing modeling infrastructure including the extended meteorological modeling optimized for central Texas further demonstrate the suitability of the extended June 2006 episode for the DFW SIP.

6 REFERENCES

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ATTACHMENT 2: QA/QC PLAN

In order to ensure that the inputs to the State Implementation Plan (SIP) modeling are of the highest possible quality, the Texas Commission on Environmental Quality (TCEQ) performs a series of quality assurance procedures on the input files to the various modeling components. All data, whether produced internally or externally by contractors, are examined.

1 EMISSIONS MODELING QA/QC

The modeling emissions, comprised of point sources, on-road mobile sources, non-/off-road mobile sources and area sources, will be developed using the EPS3 emissions processing system, in a manner commensurate with the Comprehensive Air Quality Model with extensions (CAMx) modeling domains configuration. Emissions Processing System version 3 (EPS3) is composed of various modules (e.g., PREPNT) for processing the emissions to generate CAMx-ready inputs. QA/QC of the EPS3 processing modules is automated, and message and error files for each module processed are reported. The message files report the input and output emissions for each EPS3 module, while the error files report any problems encountered during the processing. The biogenic emissions will be developed using the GloBEIS emissions model, for which the TCEQ has developed a number of QA/QC procedures discussed below.

To document quality assurance activities, a log file will be created for the processing sequence of each source category. This log file will contain the name and location of the input and output files, the date the files were processed, and a brief description of the processing results.

1.1 Point Source Emissions

Point source modeling emissions will be developed using data from a number of inventories, such as regional inventories (e.g., 2002 CENRAP, National Emissions Inventory (NEI), Acid Rain Database (ARD), Gulf Wide Emissions Inventory (GWEI), Mexico NEI, Canada), state inventories (e.g., the State of Texas Air Reporting System (STARS), adjacent state inventories) and local inventories (e.g., 2006 TexAQS II Hourly Special Inventory (SI), Tank Landing Loss (TLL) special inventory). In addition, the TCEQ plans to assess the feasibility of using information from the Consolidated Compliance and Enforcement Data System (CCEDS) to identify and quantify significant emission events. The temporal resolution of this data varies greatly from hourly (e.g., EGU emissions from ARD) to annual (e.g., non-EGU emissions from 2002 NEI).

For states outside of Texas in the 36- and 12-km domains, the emissions for EGUs will be obtained from the ARD. Emissions for non-EGUs in states within the 36 km domain, excluding the states of Arkansas, Oklahoma and Louisiana, will be developed using the 2002 NEI with EGAS growth factors. Point source emissions associated with off-shore oil and gas operations in the Gulf of Mexico will be developed using the 2000 GWEI. For the states of Arkansas, Oklahoma and Louisiana, the TCEQ will obtain their latest point source emission inventories. For EGUs in Texas, emissions will also be obtained from the ARD. Non-EGU emissions within Texas will be developed using data from the TCEQ's 2006 STARS, the 2006 TexAQS II Hourly SI, the TLL special inventory, and if feasible from CCEDS.

The point source emissions from each of the different inventories will be compiled into a consistent file format (i.e., AIRS Facility Subsystem (AFS) record format) readable by EPS3. Typically an AFS file is compiled for each original inventory used. For example one AFS file may include only records compiled from the ARD, while another AFS file may include only records compiled the TLL special inventory. Prior to EPS3 processing the emissions in the compiled AFS files are checked against the emissions from the original inventory to ensure that no emissions have been added (e.g., double counted) or lost (e.g., not read). For example, the top 100 NO_X and VOC emitting points from the TCEQ's STARS database are compared to the top 100 NO_X and VOC emitting points in the compiled AFS file. In addition, since an AFS record contains a point source's stack parameters, they can be checked to ensure they are reasonable. If stack parameters are determined to be erroneous (unreasonable), default stack parameters common for the particular source type can be used. Since AFS records include both the county and geographical coordinates where a stack is located, they can be checked to ensure the geographical coordinates are within the county. If a stack's geographical coordinates are located outside of the county, they can be changed to the coordinates of the center of the facility encompassing the stack or in the case where a facility's location cannot be determined, the center of the county.

Point sources are processed sequentially with five EPS3 modules: PREPNT, TMPRL, CHMSPL, PIGEMS and MRGUAM. An important feature of point sources addressed in the PREPNT module (i.e., the first EPS3 module) is the height of the emitted pollutants. The PREPNT module outputs two emission files, one for low level point sources and another for elevated point sources. Point sources with stack parameters characterized by high temperatures and/or high exit velocities typically possess enough plume-rise that the emissions will be elevated. The two point source emission files are processed independently through the remaining EPS3 modules, except that the low level point source files are not processed with the PIGEMS module, which addresses the larger emitting elevated point sources. The MRGUAM module (i.e., the last EPS3 module) is used to combine all the low level point source files into one file, and then used again to combine all the elevated point source files into one file.

EPS3 reports QA/QC message and error files for each module processed. Since, the message files report the input and output emissions for each EPS3 module, emissions can be tracked from the module being processed back to the output from the previous module. Emissions can be tracked all the way back to the AFS files, and, if needed, to the original inventory. Once the CAMx model-ready low level and an elevated file are generated, tile plots and time series of the emissions are made to check for reasonableness. Desirable features of the point source emissions include:

- Emissions spatially allocated according to their geographic coordinates;
- A diurnal profile for elevated point sources peaking in mid afternoon, since ARD sources are the dominant emitters in the elevated file; and
- A diurnal profile for low level point sources, which is fairly constant throughout the day.

1.2 On-road Mobile Emissions

In general, on-road mobile source emissions will be developed combining the emission factors from EPA's MOBILE6.2 model with estimated VMT and speeds for various roadway types. However, the spatial and temporal resolution of the VMT and speed estimates will vary, with less resolution at increasing distance from the nonattainment area of interest. For the states beyond Texas in the 36 km and 12 km domains, the TCEQ will use EPA's NMIM to estimate

state-wide on-road mobile source emissions. For the portion of Texas within the 12 km domain and within the 4 km domain outside the nonattainment area for the current SIP, the on-road mobile source emission estimates will be developed. TxDOT traffic data, collected for the national HPMS program, will be used to estimate VMT and speed at a county-wide spatial resolution and an hourly temporal resolution for day-types: weekdays, Friday, Saturday and Sunday. If data for other day-types exists, it may be used. Link-based travel demand modeling (TDM) output from local areas (e.g. North Central Texas Council of Governments (NCTCOG)) and the TxDOT, will be developed for the nonattainment are of interest. The TDM output includes VMT and speed parameters estimated spatially by roadway link. Using the automatic traffic recorder (ATR) data available from TxDOT, The TDM output will be adjusted to create an hourly temporal resolution for each day-type.

Similar to the point sources, the on-road mobile source emissions from the various inventories will be compiled into a consistent file format, the Area-Mobile Subsystem (AMS) record format, except for the HGB and BPA areas for which a link-based file format will be used. Both of these formats are readable by EPS3. Prior to EPS3 processing the emissions in the compiled AMS and link-based files are check against the emissions from the original inventories to ensure that no emissions have been added (e.g., double counted) or lost (e.g., not read).

The on-road emissions from each of the different regions will be processed with four EPS3 modules: LBase, TMPRL, CHMSPL, and GRDEM. This will generate day-type specific CAMx model-ready emissions that are gridded, temporally allocated by hour, and speciated for the CB05 mechanism. Since the Texas on-road emissions received from TTI are already provided by hour, EPS3 processing will preserve the hourly distribution of the emissions. For the on-road mobile source emission in Texas, TTI provides summary files, which have emissions totals for all pollutants for each individual county. To ensure that no emissions are lost in the EPS3 processing steps, the emissions totals for each pollutant in the message files of LBase, TMPRL, CHMSPL, and GRDEM modules will be compared to the totals in the TTI summary files. Once the CAMx model-ready files are generated, tile plots and time series of the emissions will be made to check for reasonableness. Desirable features of the on-road mobile sources emissions include:

- Emissions located along the major roadways; and
- Differences between emission amounts and diurnal profiles for the day-types.

1.3 Non- and Off-road Mobile Emissions

Non- and off-road mobile source emissions will be developed using data from a number of inventories. For the states beyond Texas in the 36- and 12-km domains, the TCEQ will use EPA's NMIM to estimate state-wide non-road category emissions and the NEI with appropriate EGAS growth to estimate state-wide off-road category emissions. Shipping emissions in the Atlantic Ocean and the Gulf of Mexico will be developed using data from a recent EPA funded study (U.S. EPA, 2007) or more recent local data. For the modeling domains covering Texas, the new non-road TexN model will be used. For the off-road categories within Texas, the latest TexAER database will be used with appropriate REMI-EGAS growth factors.

Similar to the on-road mobile sources, emissions from the various inventories will be compiled into the AMS file format. Prior to EPS3 processing, the emissions in the compiled AMS and link-based files are checked against the emissions from the original inventories to ensure that no emissions have been added (e.g., double counted) or lost (e.g., not read).

The non- and off-road emissions from each of the different regions will be processed with four EPS3 modules: PREAM or LBASE, TMPRL, CHMSPL, and GRDEM. This will generate CAMx model-ready emissions that are temporally allocated by hour for weekday and weekend day-types, speciated for the CB05 mechanism, and spatially allocated by source category specific surrogates. To ensure that no emissions are lost in the EPS3 processing steps, the emissions totals for each pollutant in the message files of PREAM, TMPRL, CHMSPL, and GRDEM modules will be checked for consistency. Once the CAMx model-ready files are generated, tile plots and time series of the emissions will be made to check for reasonableness. Desirable features of the non- and off-road mobile sources emissions include:

- Emissions spatially allocated according to the spatial allocation of their surrogate; and
- Differences between emission amounts and diurnal profiles for the day-types (e.g., the non-road emissions for the recreational marine category should be higher on the weekend day-types).

1.4 Area Source Emissions

Area source emissions will be developed using data from a number of inventories. For the states beyond Texas in the 36- and 12 km domains, the TCEQ will use the NEI with appropriate EGAS growth to estimate state-wide area source category emissions. In addition, for the portion of the Gulf of Mexico in these modeling domains, the TCEQ will use the non-point emissions from the 2000 GWEI. For the modeling domains covering Texas, the TexAER database will be used with appropriate REMI-EGAS growth factors.

Similar to the non-road mobile sources, area source emissions from the various inventories will be compiled into the AMS file format. Prior to EPS3 processing, the emissions in the compiled AMS and link-based files are checked against the emissions from the original inventories to ensure that no emissions have been added (e.g., double counted) or lost (e.g., not read).

The area source emissions from each of the different regions will be processed with four EPS3 modules: PREAM, TMPRL, CHMSPL, and GRDEM. This will generate CAMx model-ready emissions that are temporally allocated by hour for weekday and weekend day-types, speciated for the CB05 mechanism and spatially allocated by source category specific surrogates. To ensure that no emissions are lost in the EPS3 processing steps, the emissions totals for each pollutant in the message files of PREAM, TMPRL, CHMSPL, and GRDEM modules will be checked for consistency. Once the CAMx model-ready files are generated, tile plots and time series of the emissions will be made to check for reasonableness. Desirable features of the area source emissions include:

- Emissions spatially allocated according to the spatial allocation of the respective surrogate (e.g., an area source category associated with population should have more emissions in an urban area than a rural area); and
- Differences between emission amounts and diurnal profiles for the day-types.

1.5 Biogenic Emissions

Biogenic emissions estimates are produced using GloBEIS, which requires land-use/land-cover (LU/LC) data, photo synthetically active radiation (PAR) data, and temperature data as inputs. The TCEQ selected the GloBEIS model because it can incorporate detailed locality specific

LU/LC data and PAR data extracted from GOES satellite imagery. Temperature data acquired from the CAMS network, offshore buoys, an agricultural temperature network, and the National Weather Service are used to prepare the hourly temperature fields applying kriging algorithms in the SAS software.

The LU/LC data used in GloBEIS will be obtained from several sources. For the CAMx 4 km and/or finer resolution domains, the new UT-CSR land cover and vegetation data will be used. For the Texas portion of the 12 km domain, the TCEQ Texas vegetation database (Wiedinmyer et al., 2001) will be used. For the remaining portion of the 12- and 36-km domains, the Biogenic Emissions Landuse Data, version 3 (BELD3; Kinnee et al., 1997) will be used, except for the Mexican portion of the 12- and 36-km domains, for which a Mexican land use and vegetation database (Mendoza-Dominguez et al., 2000) will be used. After processing the LU/LC data into the LU/LC categories used by GloBEIS, tile plots of the LU/LC data will be made to check for reasonableness.

PAR data are derived from hourly GOES satellite imagery of cloud cover, which have been processed with a solar irradiation model (Pinker and Laszlo, 1992). The data will be downloaded at half-degree resolution, and will be reprocessed to match the TCEQ modeling grids. After processing the PAR data used by GloBEIS, tile plots and time series of the PAR data will be made to check for reasonableness. Desirable features of the PAR data include:

- Comparison with total solar radiation measurements at ground-based monitors, showing the relationship between PAR and total solar radiation to be linear with slope of 0.5 and a high correlation coefficient;
- Evaluation of the time variation of the PAR data compared to the total solar radiation measured data shows the two time variations exhibit the same pattern; and
- Evaluation of the effect of clouds on the PAR data, with clouds decreasing overall PAR.

Hourly temperature data will be obtained from the various sources throughout the United States and processed with the SAS kriging software to generate variograms. Variograms will be fitted for each hour, so that each hour will be interpolated with a variogram that fits its inherent degree of variation. After developing the hourly temperature fields used by GloBEIS, contour plots and time series of the temperature data will be made to check for reasonableness. Desirable features of the temperature fields include:

- Small diurnal temperature variations over the Gulf of Mexico;
- Larger diurnal temperature variations over land;
- Differences between temperatures in rural and urban areas, i.e., urban areas should have higher overall temperatures; and
- The effect of rain on the temperature, i.e., any rain storms should decrease overall temperatures.

The output emissions from GloBEIS are checked by creating tile plots and time series. Desirable features include:

- The timing of isoprene emissions, i.e., isoprene emissions should begin at sunrise and end at sunset; and
- Differences between emissions over the bay, in urban areas and riparian areas, i.e., riparian areas should have higher overall emissions.

To document quality assurance activities, a log file will be created for each GloBEIS run. This log file will contain the name and location of the input and output files, the date of the modeling run, and a brief description of the run. Further file traceability will be provided by the tile plots, which are stamped with the name and date of the original file. This provides the opportunity to trace file names from the tile plot back through the log file to the original input files.

Quantitative comparisons of the modeled (CAMx) versus measured isoprene concentrations will be documented by producing time series, and scatter plots with regression statistics. All graphs will be stamped with the file name, date, location, and the date the plot was made.

2 METEOROLOGICAL MODELING QA/QC

The TCEQ plans to use the latest version of MM5 (version 3.7.4). The MM5 modeling system is composed of several modules, including the TERRAIN, PREGRID, GRIDDER, and INTERP modules, which create inputs for the MM5 module. MM5 will be executed in a 2-way nested configuration commensurate with the MM5 modeling domains.

Application of the MM5 modeling system for a given episode requires the specification of initial and boundary conditions, as well as specifying model parameterizations as inputs to the various modules. Some of the inputs to the modules require pre-processing of raw meteorologically related data. The initialization and boundary conditions are derived from global scale modeling performed by the National Center for Environmental Prediction (NCEP). The NCEP modeling staff conducts rigorous QA/QC of the global analysis fields before they are publicly released. The specifications for MM5 include the surface parameters such as soil moisture, a planetary boundary layer (PBL) scheme, and cumulus parameterizations. Due to the importance of the surface parameters and sea surface temperatures (SST) as inputs to MM5 modeling system, the TCEQ has funded the University of Houston (UH) to develop routines for pre-processing newly collected land-use and land-cover (LU/LC) data to generate surface parameter values and satellite imagery data to generate hourly time varying SST. The output from these pre-processing routines is graphically inspected to ensure they are reasonable. Desirable features include:

- Realistic spatial distribution of soil moisture, with less in the urbanized area;
- Realistic spatial distribution of SST with higher values closer to the coastline; and
- Realistic diurnal time-series of SST, with warmer temperatures during the day-time.

In addition, the TCEQ will be using the four dimensional data assimilation (FDDA) capabilities of the MM5 modeling system to conduct both analysis and observational nudging. The analysis and observational nudging data are also derived from pre-processing routines. The analysis nudging uses the NCEP Eta Data Assimilation System (EDAS) reanalysis wind fields on the 108, 36 and 12 km domains. The NCEP modeling staff also conducts rigorous QA/QC on the EDAS reanalysis wind fields prior to public release. The observational nudging uses pre-processed radar profiler wind data on the 4 and 2 km domains. The output from the radar profiler pre-processing routine is graphically inspected to ensure the wind data are reasonable. Desirable features include:

- Realistic vertical profiles of wind speed and wind direction; and
- Realistic diurnal pattern in the change of wind speed and wind direction.

Running the MM5 modeling system requires verification through the job decks (e.g., mm5.deck) that switches and options have been correctly selected. In addition, the surface characteristic parameters (e.g., soil moisture) and SST are graphically inspected after running TERRAIN, PREGRID, and REGRIDDER to ensure they continue to be reasonable. Parameters such as pressure, lapse rate, and stratospheric isothermal temperature, typical for the Texas summertime environment (Nielsen-Gammon, 2001), are used for inputs to the INTERP module.

To document quality assurance activities, a log file will be created for the processing sequence of each of the pre-processors and MM5 modeling system modules. This log file will contain the name and location of the input and output files, the date the files were processed, and a brief description of the processing results.

3 REFERENCES

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