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New Technology Research & Development Program
Grant Contract 582-5-65591-0003

Tasks 1, 2, 3, & 4 Deliverable Report
Final Report

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Texas Commission on Environmental Quality
New Technology Research and Development Grant

Contract No. 582-5-65591-0003

RURAL MONITORING FOR ASSESSING OZONE TRANSPORT INTO TEXAS

Project Period
December 30, 2004 through December 31, 2006

FINAL REPORT

Submitted to

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Air Quality Division
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Summary

The goal of this project was to begin the process of characterizing ozone transport in the eastern half of Texas, by characterizing the ozone entering the State through its eastern boundary. A set of air quality monitoring stations, equipped with ozone monitors, meteorological measurement equipment, data loggers and communication devices, were deployed along the Texas- Louisiana border.

The goal of the monitoring network was to:

1. *Task 1: Quantitatively characterize ozone concentration and ozone fluxes at the State's eastern border at ground level.*
2. *Task 2: Characterize the magnitude of ozone transport as a function of meteorological condition*
3. *Task 3: Perform selected comparisons between measured and modeled ozone concentrations and fluxes*

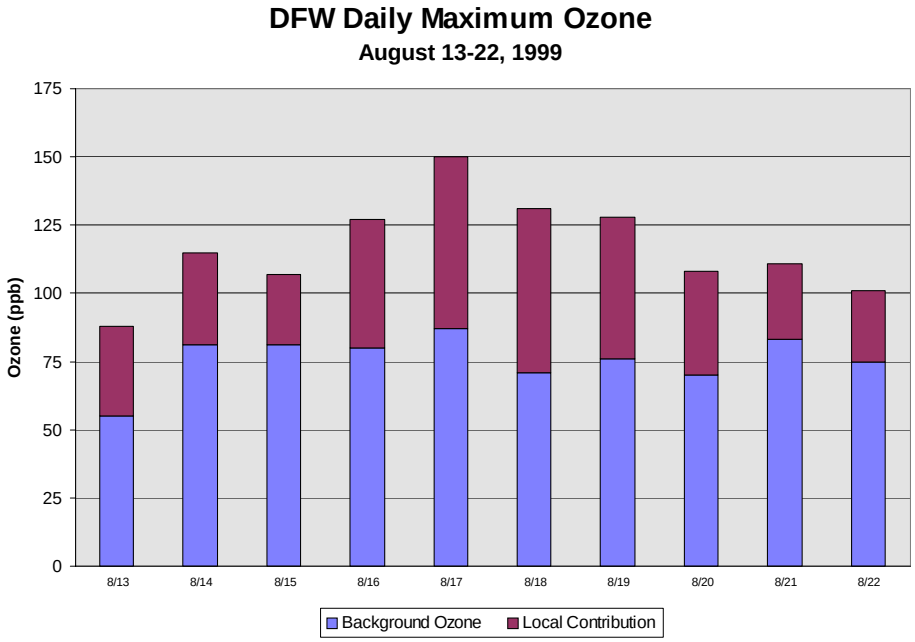
The results from each of these tasks are described in this report.

Introduction

Decades of air quality research, in Texas and elsewhere, have dramatically improved understanding of the local factors that control air quality in urban areas. Increasingly, however, air quality is influenced by more than just local emissions. Regional, continental and even global factors now have a significant influence on air quality in Texas. Identifying the most effective and efficient balance between local, regional and national air quality improvement actions, especially for meeting the new National Ambient Air Quality Standard (NAAQS) for ozone, with concentrations averaged over 8 hours, requires a new body of scientific information. Among the most pressing information needs is a characterization of the regional transport of ozone and its precursors.

Previous air quality studies and analyses of monitoring data have revealed that transport of ozone is substantial in the eastern half of Texas. For example, the Texas Commission on Environmental Quality (TCEQ) estimated the regional, or background, contribution to ozone concentrations in Dallas-Fort Worth by identifying the monitor that had the lowest peak ozone concentration during ozone episodes days. A typical calculation is shown in Figure 1. For each day of this multi-day episode in Dallas-Fort Worth, the lowest peak ozone concentration observed at any of the region's monitors is labeled as background ozone. The difference between the highest peak concentration at any of the region's monitors and the background concentration is labeled as a local contribution.

Figure 1. Contribution of regional background concentrations to ozone concentrations observed during an ozone episode in Dallas-Fort Worth (Breitenbach, 2003)



The results of a different type of analysis, from which similar conclusions can be drawn, is shown in Table 1. Table 1 shows the results of 3-D photochemical modeling simulations in which all of the anthropogenic (man-made) emissions in Texas were "zeroed out" (set equal to zero). The data presented in the Table, show the decrease in 8-hour averaged ozone concentrations for Houston, if all anthropogenic sources of ozone precursor emissions in the State were eliminated. The important point to note in Table 1 is that while significant reductions in ozone concentrations can be achieved on most days by reducing emissions within Texas, there will be some days (for example, 7/9/95) when sources outside the state cause ozone monitors within the state to exceed the NAAQS based on 8-hour averaged concentrations.

Table 1. Results of simulations in which all anthropogenic emissions in Texas were "zeroed out". (Webb, et al., 2002)

Date simulated	Base case maximum 8-hour average ozone concentration in the Houston-Galveston area	All Texas "zero-out" maximum 8 hour average ozone concentration in the HGA	Maximum difference between base case and all Texas "zero-out" in the HGA
7/9/95	124	**88**	67
7/10/95	96	59	53
7/11/95	105	62	64
7/12/95	126	78	79

The analysis shown in Figure 1 and Table 1 demonstrate that regional transport can play an important role in determining 8-hour averaged ozone concentrations in Texas cities, however, additional analyses are required in order to identify the sources of elevated regional ozone concentrations.

A first issue to be addressed in improving our understanding of elevated regional concentrations of ozone is the relative importance of different source regions. Are the source regions in the eastern United States? Are the source regions within Texas? Are they rural? Are they urban? Semi-quantitative answers to these questions can be obtained by using back trajectory calculations. In a back trajectory calculation, meteorological data and models are used to identify the path that an air parcel followed in arriving at a site. The results of a back trajectory calculation indicate where an air parcel came from, but not whether the air parcel has high concentrations of ozone. Nevertheless, knowing where air parcels originate is an important first step in identifying source regions for high regional ozone concentrations.

A representative back trajectory calculation, for the Dallas-Fort Worth region, is shown in Figure 2. The colors represent back trajectories at different elevations. All back trajectories are for 48 hours, so longer lines represent higher average wind speeds.

Figure 2. A representative 48-hour back trajectory calculation, for the Dallas-Fort Worth region (Breitenbach, 2003)

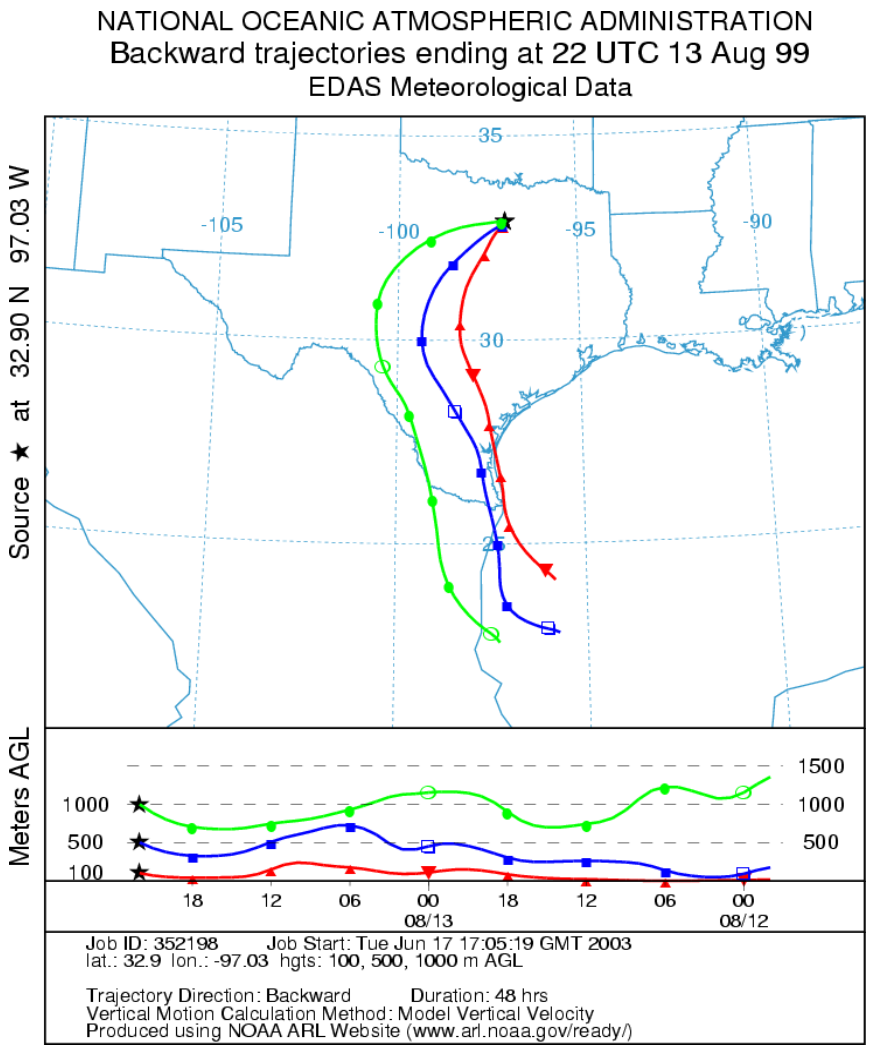


Figure 3 shows back trajectories for all days that experienced high ozone concentrations in the Dallas-Fort Worth area, over a 6 year period (1993-1998). These trajectories show that regional transport is not likely to be confined to a single source region. A similar analysis, performed for Austin, is shown in Figure 4. Again, the back trajectories suggest that regional transport is not likely to be confined to a single source region.

Figure 3. Back trajectories (48 hour) at two altitudes (100m and 500m) for high ozone days in Dallas-Fort Worth (1993-1998) (Breitenbach, 2003)

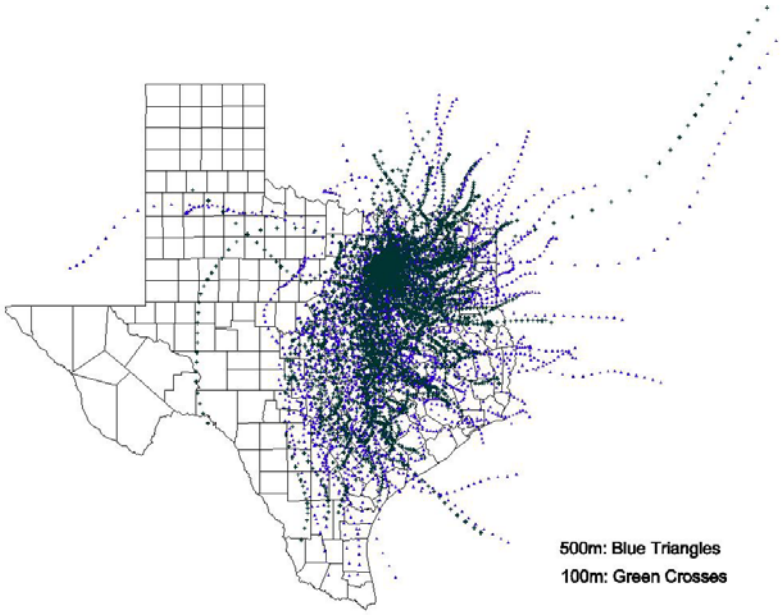
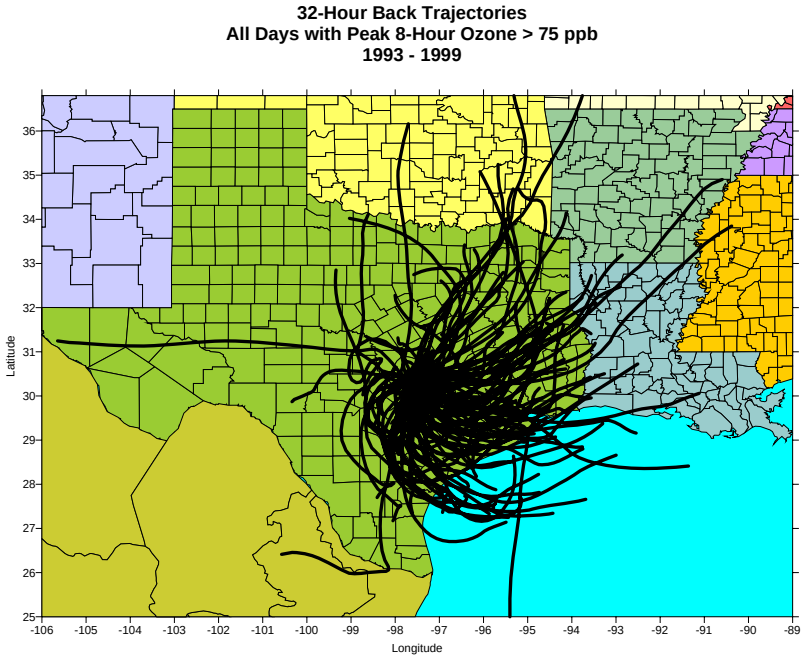


Figure 4. Back trajectories (32 hour) for high ozone days in Austin (1993-1999) (McGaughey, et al., 2002)



Back trajectories, while suggestive, are not quantitative indicators of ozone transport. Air quality models can be used to quantify this phenomenon, however. Shown in Figures 5-7 are the results of a series of air quality modeling analyses. In these analyses, ozone concentrations were predicted for two scenarios – a base case representing best estimates of actual conditions and a case where all of the man-made (anthropogenic) emissions in a selected city were eliminated ("zeroed out"). Figure 5 shows the difference in ozone concentrations between a base case simulation and a simulation, for the same day, where all anthropogenic emissions in the 8-county Houston-Galveston non-attainment area were "zeroed out". Figure 6 shows the analysis for additional days. The differences in ozone concentrations between the base case and the simulation where the Houston-Galveston area was "zeroed out" are substantial. Depending on the particular day that is examined, in Austin, differences in ozone concentration due to "zeroing out" Houston-Galveston emissions can be up to 20 ppb (8-hour average). In San Antonio, the differences can be up to 28 ppb. In Victoria and Beaumont-Port Arthur, the differences can be up to 33 ppb and 71 ppb, respectively.

Figure 5. Difference in 8-hour averaged ozone concentrations between a base case simulation and a simulation, for the same day, where all anthropogenic emissions in the 8-county Houston-Galveston non-attainment area were "zeroed out" (McDonald-Buller, et al., 2000)

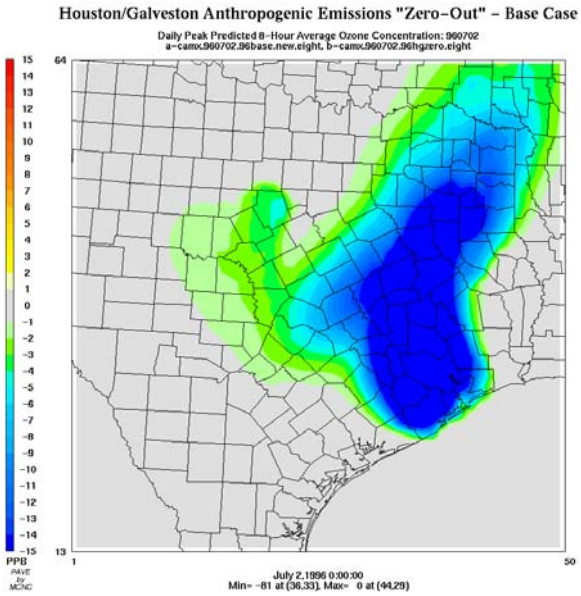
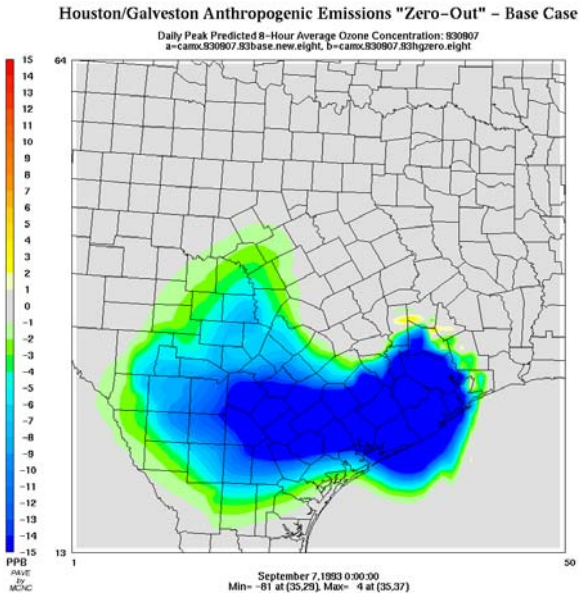
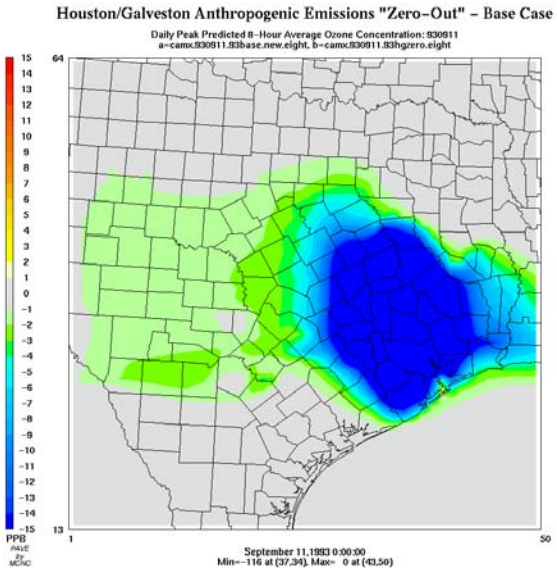


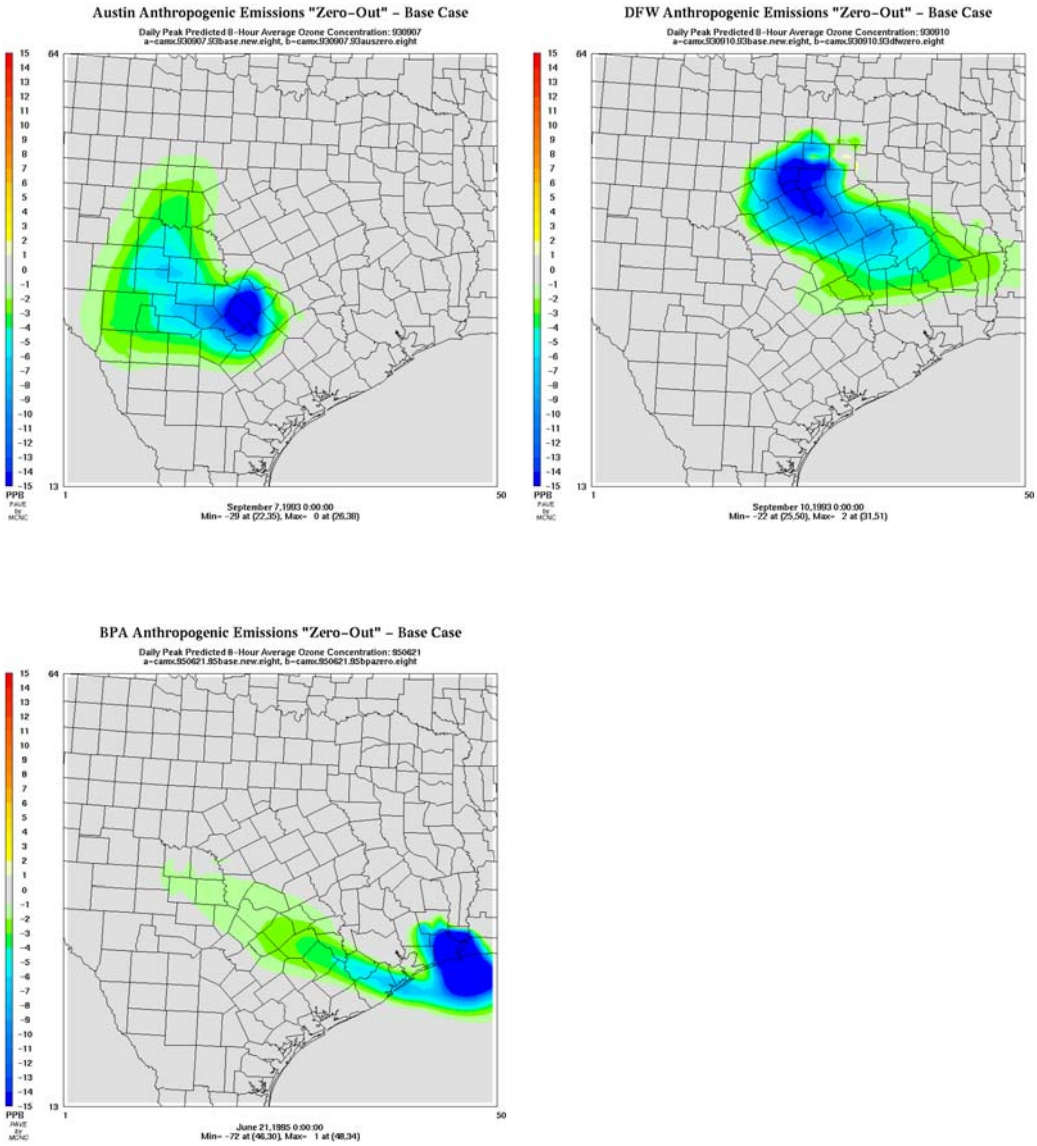
Figure 6. Differences in 8-hour averaged ozone concentrations between base case simulations and simulations, for the same days, where all anthropogenic emissions in the 8-county Houston-Galveston non-attainment area were "zeroed out" (McDonald-Buller, et al., 2000)





The Houston-Galveston area is not the only source region for transport of ozone in eastern Texas. Figure 7 shows the results of "zero-out" analyses for Austin, Dallas-Fort Worth and Beaumont-Port Arthur. Similar analyses done for all the major urban areas in eastern Texas indicate that every urban area contributes to regional ozone concentration and impacts 8-hour averaged ozone concentrations in at least one other urban area.

Figure 7. Differences in 8-hour averaged ozone concentrations between base case simulations and simulations, for the same days, where all anthropogenic emissions in the Austin, Dallas-Fort Worth and Beaumont-Port Arthur areas were "zeroed out" (McDonald-Buller, et al., 2000)



Figures 5-7 provide further evidence indicating that transport of ozone is important in eastern Texas. Ozone formation due to emissions in the rural regions of eastern Texas is also likely to be important in determining regional ozone concentrations. Figure 8 shows the difference in ozone concentrations between a base case simulation and a simulation, for the same day, where all NOx emissions from electricity generating units in eastern Texas were "zeroed-out". The differences in ozone concentrations between the base case and the simulation where the largely rural electricity-generating-unit emissions were "zero-ed out" can be more than 60 ppb in isolated areas and more than 30 ppb over large regions.

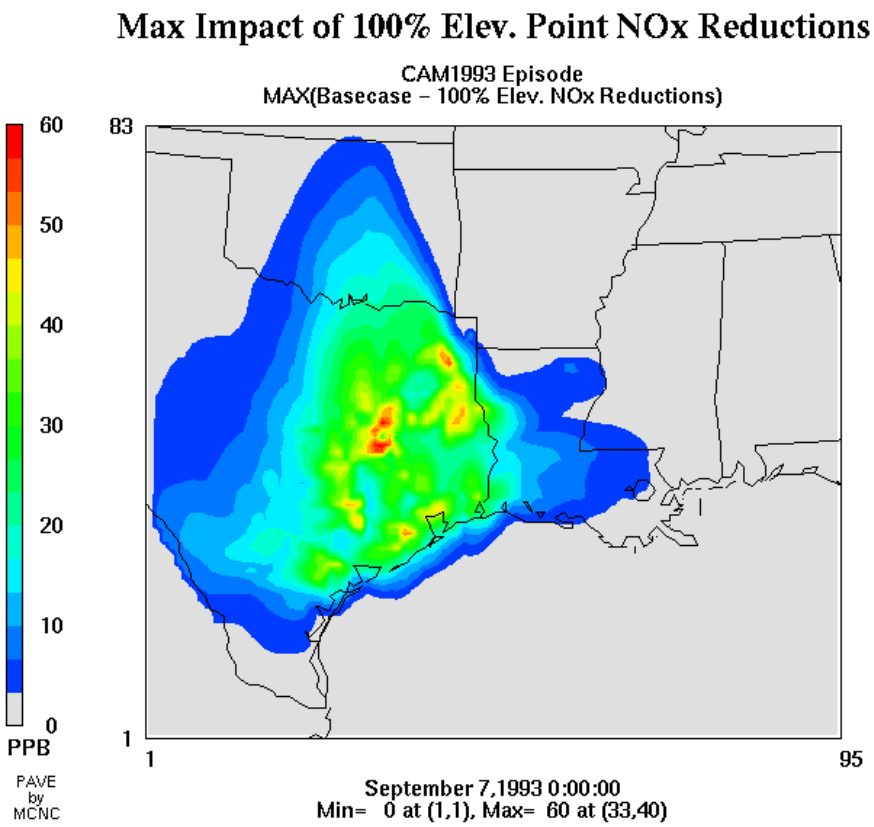


Figure 8. Differences in ozone concentrations between base case simulations and simulations, for the same days, where all NOx emissions from electricity generating units were "zeroed-out". (Nobel, et al., 2001)

Thus, air quality monitoring and modeling indicate that regional ozone concentrations play a major role in determining whether the state's urban areas meet the new National Ambient Air Quality Standard (NAAQS) for ozone (with concentrations averaged over 8-hours). The sources of emissions leading to elevated regional ozone concentrations include the state's urban areas, rural emission sources and sources outside of the state. Preliminary analyses indicate that all of these sources are significant and none can be ignored in developing a strategy for reducing regional ozone concentrations.

Therefore, in designing strategies to meet the new NAAQS for ozone (with concentrations averaged over 8-hours), the State of Texas will need to develop an integrated and comprehensive approach for reducing regional ozone concentrations. The development of this strategy requires information about the relative importance of ozone formed due to emissions in urban areas, ozone due to emissions in rural areas and ozone due to emissions outside of the state.

Project Tasks

The goal of this project was to begin the process of characterizing ozone transport in the eastern half of Texas, by characterizing the ozone entering the State through its eastern boundary. As described below, a set of air quality monitoring stations, equipped with ozone monitors, meteorological measurement equipment, data loggers and communication devices, were deployed along the Texas- Louisiana border to establish a "flux line", as shown in Figure 9.

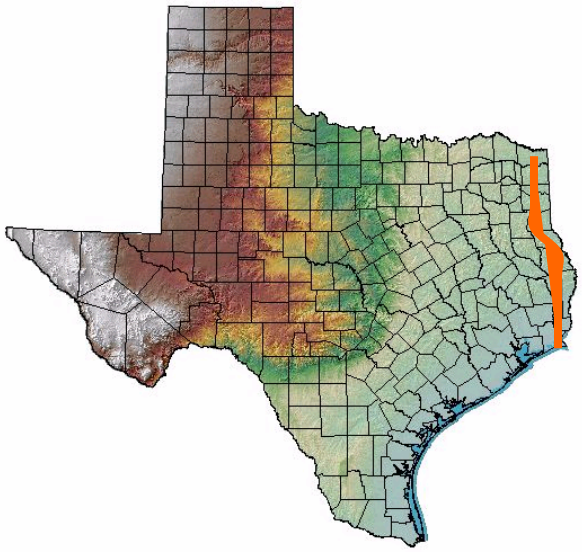


Figure 9. "Flux line" which defines the locations of the monitoring sites deployed in this work

The specific sites that were deployed, along with their site reference number and a link to the portion of the Texas Commission on Environmental Quality web site that describes each site, are listed below.

Wamba NTRD C645
http://www.tceq.state.tx.us/cgi-bin/compliance/monops/site_photo?645
Newton NTRD C639
http://www.tceq.state.tx.us/cgi-bin/compliance/monops/site_photo?639
Clarksville NTRD C648
http://www.tceq.state.tx.us/cgi-bin/compliance/monops/site_photo?648
San Augustine Airport NTRD C646
http://www.tceq.state.tx.us/cgi-bin/compliance/monops/site_photo?646
Smith Point C638
http://www.tceq.state.tx.us/cgi-bin/compliance/monops/site_photo?639
Mauriceville C665
http://www.tceq.state.tx.us/cgi-bin/compliance/monops/site_photo?665

The goal of the monitoring network was to:

1 .*Task 1: Quantitatively characterize ozone concentration and ozone fluxes at the State's eastern border at ground level.* The total amount of ozone entering Texas, through its eastern border, is the ozone concentration along the border (units of mass/m^3), multiplied by the component of wind speed perpendicular to the border (m/s), multiplied by the area that the air mass passes through (the length of the eastern Texas border multiplied by the mixing height, m^2). The ozone flux is defined as the mass of ozone entering the state per unit time, divided by the area for ozone transport, and therefore is the product of the component of the wind speed perpendicular to the border and the ozone concentration. In this project ozone concentrations and wind speeds and directions along the State's eastern border were measured for two ozone seasons. The measurements began in the summer of 2005, and continued until the end of the ozone season in 2006.
2. .*Task 2: Characterize the magnitude of ozone transport as a function of meteorological condition* The measurement program yielded almost two years of data on ozone transport into the State, under a variety of meteorological conditions. The resulting data were compared to the historical data on the wind directions associated with high ozone concentrations in the State's urban areas.
3 *Task 3: Perform selected comparisons between measured and modeled ozone concentrations and fluxes* While modeling of new ozone episodes is beyond the scope of the work proposed here, the data collected by the network can be compared to previously modeled, historical episodes. Ozone episodes documented by the monitoring network were compared to modeled ozone concentrations for the 2002 ozone season.

The details of the work under each of these tasks are described below.

Task 1. Quantitatively characterize ozone entering the state by estimating the ozone flux at ground level.

Six monitoring sites were deployed along the flux line shown in Figure 9. These continuous air quality monitoring stations (CAMS) were equipped with a shelter, an ozone monitor, wind speed and direction measurement, a data logger and communications equipment allowing transmission of data to the Texas Commission on Environmental Quality. The sites were designed to meet all CAMS quality assurance standards established by the TCEQ. All of the data collected at the sites have been uploaded and archived at the TCEQ web sites listed below.

Wamba NTRD C645
http://www.tceq.state.tx.us/cgi-bin/compliance/monops/site_photo?645
Newton NTRD C639
http://www.tceq.state.tx.us/cgi-bin/compliance/monops/site_photo?639
Clarksville NTRD C648
http://www.tceq.state.tx.us/cgi-bin/compliance/monops/site_photo?648
San Augustine Airport NTRD C646
http://www.tceq.state.tx.us/cgi-bin/compliance/monops/site_photo?646
Smith Point C638
http://www.tceq.state.tx.us/cgi-bin/compliance/monops/site_photo?639
Mauriceville C665
http://www.tceq.state.tx.us/cgi-bin/compliance/monops/site_photo?665

Task 2: Characterize the magnitude of ozone transport as a function of meteorological condition

To compare data collected in 2005 and 2006 to meteorological conditions in other years, back trajectory analyses were assembled. These analyses are described in the report attached as Appendix 1, titled "Back-Trajectory Analyses on High and Low Ozone Days for the Dallas/Fort Worth and Houston/Galveston/Brazoria Ozone Nonattainment Areas for the Years 2001 through 2005".

Task 3: Task 3: Perform selected comparisons between measured and modeled ozone concentrations and fluxes

While modeling of new ozone episodes was beyond the scope of the project, the data collected by the network can be compared to previously modeled, historical episodes. Modeling of the ozone season from 2002, using both 2002 and 2009 anthropogenic emissions is described in Appendix 2, titled "Assessing the Predicted Ozone Concentrations Averaged over 8 Hours with a June through September 2002 Seasonal Photochemical Grid Modeling Episode using 2002 and 2009 Anthropogenic Emissions"

References

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G. McGaughey, E. McDonald-Buller, and D.T. Allen (2002) "Development of an Ozone Conceptual Model for the Austin Area", Report submitted to the Capital Area Planning Council, and the Texas Natural Resource Conservation Commission, September, 2002.

C.E. Nobel, E. C. McDonald-Buller, Y. Kimura, and D. T. Allen (2001). "Accounting for Spatial Variation of Ozone Productivity in NOx Emission Trading," *Environmental Science and Technology*, 35, 4397-4407.

A. M. Webb, C. Durrenberger, E.C. McDonald-Buller and D.T. Allen, "Texas Non-Attainment and Near Non-Attainment Zero-Out Modeling Runs for the July 7-12, 1995 episode", Report submitted to the Capital Area Planning Council, and the Texas Natural Resource Conservation Commission, August, 2002.