CONCEPTUAL MODEL OF OZONE FORMATION IN THE TYLER/LONGVIEW/MARSHALL NEAR NONATTAINMENT AREA

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1.0 INTRODUCTION

This report presents a conceptual model of ozone formation in Northeast Texas and incorporates results of a review and analysis of air quality, meteorological, and ozone precursor emissions data and trends as well as ozone modeling results. This document updates the previous conceptual model development and data analysis work of Yarwood et al. (2000), Stoeckenius and Yarwood (2004), and Kemball-Cook and Yarwood (2008a) with data that have become available since August 2008. The previous conceptual models are included in this report as Appendices A, B, and C.

1.1 OZONE ATTAINMENT STATUS HISTORY OF THE TLM AREA

The Northeast Texas Near Non-Attainment Area (NNA) consists of Gregg, Upshur, Rusk, Smith, and Harrison Counties. The NNA has seen large reductions in ozone during the last two decades, achieving the 1-hour National Ambient Air Quality Standard (NAAQS) for ozone and successfully concluding its Early Action Compact (EAC) in 2007 with attainment of the 1997 0.08 ppm 8-hour ozone standard. In March, 2008, the U.S. Environmental Protection Agency (EPA) promulgated a new, more stringent 8-hour ozone standard of 0.075 ppm. On January 6, 2010, EPA proposed reducing the ozone standard even further to a level within the range of 0.060-0.070 ppm. EPA will issue a final standard by August 31, 2010. In this section, we review the definition of the 1-hour and 8-hour ozone standards and give a brief history of the attainment status of the NNA and the measures taken by the NNA to bring the area into attainment of each of these standards.

The 1979 1-hour NAAQS for ozone (no longer in effect) limited the frequency with which the daily maximum 1-hour average concentration can exceed 0.12 ppm to once per year (averaged over three years), while the 8-hour standard sets a maximum level (0.08 ppm) for the annual fourth highest daily maximum 8-hour average concentration. The 1-hour standard was violated if the fourth highest concentration in a period of three consecutive years exceeded 0.12 ppm. Although a single year of data was not considered sufficient to demonstrate attainment, the value of the second highest daily maximum 1-hour concentration in a year was frequently used as an informal indicator of attainment/nonattainment status. This is referred to as the *annual 1-hour design value*. The 8-hour standard is violated if the annual fourth highest daily maximum 8-hour average concentration averaged over three consecutive years exceeds a threshold value, which was 0.08 ppm for the 1997 standard. A single year of data is not considered sufficient to demonstrate attainment; instead, the fourth highest value in a given year is used as an indicator of attainment status. Consequently, we refer to this statistic as the *annual 8-hour design value*.

The Northeast Texas ozone monitoring data are used to calculate the design values that determine whether the area is in compliance with the National Ambient Air Quality Standard for ozone. The Texas Commission on Environmental Quality (TCEQ) operates three Continuous Air Monitoring Stations (CAMS) in the Tyler/Longview/Marshall (TLM) area of Northeast Texas. These stations are shown in Figure 1-1. In recent years, ozone levels measured at the Gregg County Airport in Longview have exceeded both the 1-hour and 8-hour National Ambient Air Quality Standards (NAAQS) for ozone. In 1996, the TLM area became a Flexible Attainment Region (FAR) and a mechanism for developing strategies to attain the 1-hour ozone standard was implemented under a Memorandum of Agreement (Flexible Attainment Region Memorandum of Agreement, September 16, 1996).

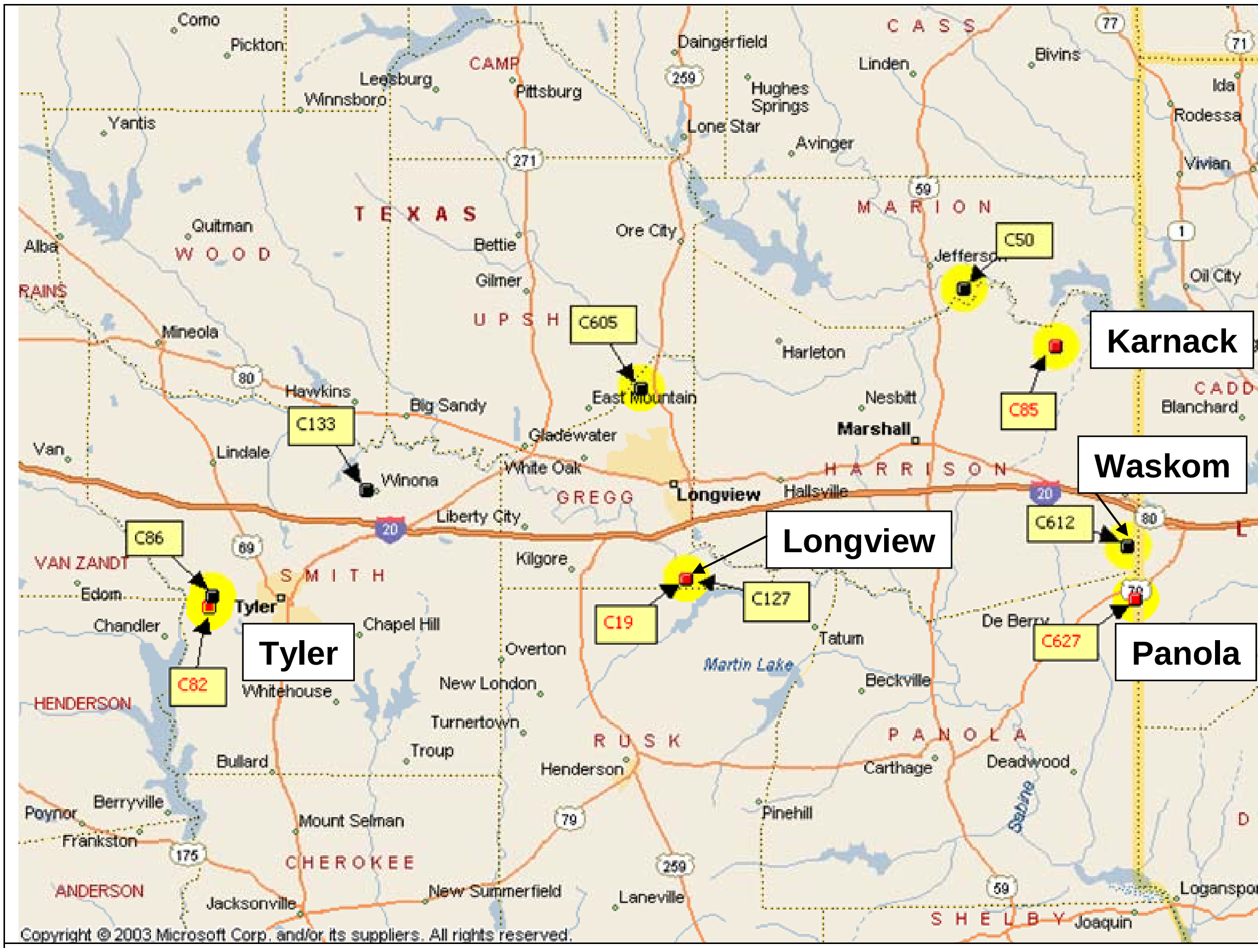

Figure 1-1. TCEQ CAMS monitors in Northeast Texas. Labels bearing monitor location names indicate monitors that were operational during the period 2005-2010. Map downloaded from TCEQ website: http://www.tceq.state.tx.us/assets/public/compliance/monops/graphics/clickable/region05.gif

The TLM area receives funding from the Texas legislature to address ozone air quality issues. These resources have funded studies through the East Texas Council of Governments (ETCOG) under the technical and policy direction of the North East Texas Air Care (NETAC) organization. In 1999, ENVIRON completed an ozone modeling study for two 1-hour ozone episodes that included future year modeling for 2007 and the evaluation of future year emission reduction strategies (Yarwood et al., 1999). In May 2002, the Texas Natural Resource Conservation Commission (now the Texas Commission on Environmental Quality) submitted a State Implementation Plan (SIP) for Northeast Texas that demonstrated attainment of the 1-hour ozone standard by 2007.

In 1997, the U.S. Environmental Protection Agency (EPA) promulgated a new 8-hour NAAQS for ozone that superseded the 1-hour standard. The 8-hour ozone NAAQS was challenged in court and was eventually upheld in 2002 by the U.S. Supreme Court. However, the Court required that the EPA revise its implementation policy. EPA issued a draft revised implementation policy on June 2, 2003. EPA designated all five NETAC counties as 8-hour ozone attainment areas on April 15, 2004 (69 FR 23858).

On December 20, 2002, local governments in a five county area of Northeast Texas (Gregg, Harrison, Rusk, Smith, and Upshur counties) entered into an Early Action Compact (EAC) with the U.S. Environmental Protection Agency (EPA) and the Texas Commission on Environmental Quality (TCEQ). The purpose of the EAC was to develop and implement a Clean Air Action Plan (CAAP) that would reduce ground level ozone concentrations throughout the 5-County area to comply with the 8-hour ozone standard by December 31, 2007 and maintain the standard beyond that date. The EAC included a series of milestones to guide progress toward the development of the CAAP as shown in Table 1-1.

Table 1-1. Key milestone dates for the Northeast Texas Early Action Compact (EAC).

Date	Item
December 31, 2002	Signed EAC agreement
June 16, 2003	Identified/described potential local emission reduction strategies
November 30, 2003	Initial modeling emission inventory completed Conceptual model completed Base case (1999) modeling completed
December 31, 2003	Future year (2007) emission inventory completed Emission inventory comparison for 1999 and 2007 Future case modeling completed
January 31, 2004	Schedule for developing further episodes completed Local emission reduction strategies selected One or more control cases modeled for 2007 Attainment maintenance analysis (to 2012) completed Submit preliminary Clean Air Action Plan (CAAP) to TCEQ and EPA
March 31, 2004	Final revisions to 2007 control case modeling completed Final revisions to local emission reduction strategies completed Final attainment maintenance analysis completed Submit final CAAP to TCEQ and EPA
December 31, 2004	State submits SIP incorporating the CAAP to EPA
December 31, 2005	Local emission reduction strategies implemented
December 31, 2007	Attained the 1997 8-hour ozone standard

On December 31, 2007, all three TCEQ CAMS monitors had 8-hour ozone design values less than 85 ppb, indicating that the Tyler-Longview-Marshall area was in compliance with the 1997 8-hour ozone standard, thereby meeting its final milestone under the Early Action Compact.

In March, 2008, the EPA promulgated a new, more stringent 8-hour ozone standard of 0.075 ppm (75 ppb). The TCEQ subsequently analyzed 2006-2008 ozone data to make recommendations to Governor Perry regarding the attainment status of all Texas counties. In March of 2009, the State of Texas recommended attainment designations to the EPA in reference to the new 2008 ozone standard. As of the end of 2008, the Karnack monitor had a 2006-2008 design value of 71 ppb, which is in attainment of the ozone standard promulgated in 2008. The Tyler and Longview monitors had design values of 78 ppb and 77 ppb, respectively, and did not attain the 75 ppb standard. Accordingly, the TCEQ recommended that Gregg, Rusk, and Smith counties be designated as nonattainment (letter from TCEQ Chairman Garcia to Governor Perry, December 11, 2008). In their recommendation letter, TCEQ noted that 2009 data could be considered by EPA in making attainment designations. At the end of 2009, all three Northeast Texas monitors met the 75 ppb ozone standard by achieving a 2007-2009 design value of 75 ppb or less.

Meanwhile, in May 2008, states, environmental groups and industry groups filed petitions with the D.C. Circuit Court of Appeals for review of the 2008 ozone standard. In March 2009, the Court granted EPA's request to stay the litigation so the new administration could review the standard and determine whether it should be reconsidered. On September 16, 2009, the EPA announced it would reconsider the 2008 standard and notified the Court that was hearing the appeal of the 75 ppb ozone standard that it would like a stay of proceedings. EPA has laid out a fairly aggressive timeline for its review of the standard. A new standard was proposed on January 6, 2010 and EPA will make a final ruling on the new standard by August 31, 2010. EPA has asked that the current 75 ppb standard be stayed during its review and that no designations be made based on this standard. Therefore, no attainment designation would be made for Northeast Texas even though attainment is currently being monitored. EPA plans to compress the usual two-year process for designations into one year. Recommendations on designations from the states to EPA would be due by January, 2011 with EPA making final designations by July, 2011. State Implementation Plans would then be due in December, 2013.

The TCEQ is preparing for SIP development in response to the new 2010 standard. The main goal of the Northeast Texas NNA's air quality planning for the short term is to assist the TCEQ in SIP development by demonstrating that the NNA will comply with the ozone standard by the designated attainment date. Updating the conceptual model is an important step in this effort.

1.2 CONCEPTUAL MODEL

EPA guidance on modeled attainment demonstrations and analyses for ozone (EPA, 2007) indicates that one of the first activities to be completed in development of a SIP is formulation of a "conceptual model" that qualitatively describes ozone formation mechanisms and the rationale for selection of episodes to be modeled. EPA guidance (EPA, 2007) specifies that the key components of the conceptual model are analyses of air quality, meteorological and emissions data. Through these analyses, relationships between weather conditions and high ozone events may be established, important emissions sources and trends may be identified, and periods of high ozone suitable for modeling may be selected. Ozone modeling may be used to shed light on the causes of high ozone events as well as the likely effectiveness of proposed control strategies. As Northeast Texas prepares to participate in SIP development, it is appropriate to synthesize the new air quality and emissions data that NETAC has gathered since the last Conceptual Model update in 2008 and form a revised Conceptual Model.

In Section 2 of this report, we will discuss changes in emissions since the last Conceptual Model update as well as projected short-term trends in emissions. In Section 3, we report on ambient data collected in Northeast Texas since the last Conceptual Model update. This Section begins with a discussion of recent ozone data and trends. Then, we describe high ozone events in Northeast Texas that occurred during the years 2008-2009. Finally, Section 3 reports results of NETAC's surface-based fixed and mobile measurement campaigns undertaken since 2007. In Section 4, we discuss NETAC's ozone modeling of the years 2005 and 2012 and well as modeling of plumes of highly reactive VOCs and ozone at the CAMS 19 monitor in Longview. We describe modeling of ozone impacts of future development of the Haynesville Shale natural gas field as well as the effect of the East Texas Combustion Rule on ozone in Northeast Texas. We then discuss modeling of the effects of ozone transport on Northeast Texas and, finally, put the findings of the ozone modeling in the context of the Conceptual Model. Finally, in Section 5, we present a summary of the revised Conceptual Model.

2.0 EMISSIONS CHANGES

In the previous Conceptual Model, Kemball-Cook and Yarwood (2008) reported on NETAC's development of an emission inventory for the year 2005 and discussed trends from previous NETAC emission inventories for the years 1999 and 2002. Since 2008, NETAC has refined the emission inventory for the year 2005 used for modeling of high ozone events at Longview during that year and has developed a future year 2012 inventory for ozone modeling aimed at control strategy development. In this section, we discuss the status of local emissions reduction measures, changes to the Northeast Texas emission inventory since the previous conceptual model report in 2008, and provide a summary of the TLM 5-County area emission inventory that was used for the 2005 and 2012 ozone modeling described in Section 4.

2.1 STATUS OF LOCAL EMISSIONS REDUCTION MEASURES AS OF MARCH, 2010

NETAC has carried out emission inventory development supplemented by local surveys as well as aircraft- and surface-based ambient air quality monitoring which indicated that Northeast Texas ozone levels can be most effectively lowered by reducing emissions of nitrogen oxides (NOx). This finding was confirmed through ozone modeling of the area. NETAC has played a key role in identifying and facilitating important local emission reductions. NETAC has secured agreements for local NOx reductions from key major sources such as the Eastman Chemical Complex in Longview and several facilities operated by American Electric Power (AEP) and Luminant (formerly TXU) in Northeast Texas. For example, NETAC has worked with Luminant to make installation of NOx-reducing selective catalytic reduction (SCR) technology at the Martin Lake Power Plant a priority.

Luminant has made a commitment to reduce NOx emissions from coal-fired power plants in Eastern Texas by 20% below 2005 annual emissions. To implement this commitment, Luminant has filed with TCEQ applications for the installation of selective catalytic reduction (SCR) technology on the three electric generating units at the Martin Lake station. During TCEQ's June 13, 2007, consideration of a Luminant permit application for a new generating unit, TCEQ commissioner Larry Soward asked for clarification concerning the Luminant commitment. Luminant's legal counsel advised Commissioner Soward and the commission that the commitment was evidenced by the applications to install SCR controls on the Martin Lake units and the Sandow-4 unit. Luminant's legal counsel reaffirmed that these emission reductions will occur.

On July 17, 2007, the NETAC Policy Committee adopted a resolution urging TXU (now Luminant), Kohlberg Kravis Roberts, and Texas Pacific Group to cooperate with NETAC and TCEQ in making its proposed emission reductions legally enforceable. NETAC's co-chairs met with Luminant in 2007 to discuss plans for additional controls at the Martin Lake units. At the NETAC Technical Committee meeting held on November 7, 2008, David Duncan of Luminant reported that Luminant had applied to TCEQ for SCR permits for the Martin Lake plant, but that approval of the SCR permits was being contested. In November, 2009, David Duncan reported that the date when the permit may be granted is still unclear, and so Luminant does not have an estimate for when the SCR will be installed at Martin Lake.

Another focus of NETAC's emission reduction efforts has been gas compressor engines associated with natural gas production. Emission inventory and survey data compiled by NETAC showed that total NOx emissions from these compressor engines in the five NETAC counties are comparable to NOx emissions from a large power plant. In 2005, NETAC implemented a pilot project to demonstrate the effectiveness of retrofitting small (< 500 hp), spark-ignited, rich-burn compressor engines used in natural gas production with exhaust catalysts and electronic air/fuel ratio controllers. At the end of a year-long test period, these controls were achieving an estimated emission reduction efficiency of greater than 90%, or 0.1 ton/day NOx per engine. NETAC then vigorously pursued funding for a catalyst retrofit program for compressor engines. As of March 2010, emissions from larger (>240 hp) gas compressor engines are now regulated by the East Texas Combustion Rule.

In June 2007, the TCEQ adopted an East Texas Combustion Rule as part of the Dallas-Fort Worth 8-Hour Ozone SIP Revision. The rulemaking subjects owners or operators of stationary sources of NOx in the Dallas-Fort Worth eight-hour ozone nonattainment area, as well as in specified counties in the northeast Texas area, to more stringent emission control, monitoring, testing, recordkeeping, and reporting requirements. The Rule applies to rich-burn engines with horsepower greater than 240 hp. The preamble to the proposed rule published in December 2006 noted that catalyst technology is expected to be the primary control technology for rich-burn, gas-fired engines. The rule applies in 33 East Texas Counties, and the compliance deadline is March 1, 2010. An analysis performed by the TCEQ suggests that NOx reductions from the East Texas Combustion Rule for the 5-county Tyler-Longview area would be approximately 7 tons per day. A separate assessment by NETAC predicts a reduction of approximately 17 tons of NOx per day for the 5-county area in the year 2012 (Section 2.4.1).

Other emissions reductions supported by NETAC include energy efficiency programs adopted by the cities of Longview, Marshall, and Tyler. Voluntary on-road vehicle emission reductions were made through funding for clean-fueled propane vans for local transit agencies under the DOE "Clean Cities Program". The East Texas Council of Governments runs public awareness programs that are funded by the State of Texas through Rider funding for near-nonattainment areas (NNAs). These programs include:

- ozone watch and warning communications network between local government and industries to communicate ozone action day forecasts issued by TCEQ;
- NETAC website;
- public service announcements; school programs and teacher training workshops; distribution of public information and educational materials;
- Annual Ozone Season kick-off meeting for the NETAC area.

2.2 2005 EMISSION INVENTORY

During 2007-2008, NETAC developed an ozone model for Northeast Texas for the year 2005. As part of the model development, an emission inventory was assembled that represents the most current estimate of emissions in Northeast Texas. During 2009, this emission inventory was refined; updates to the inventory included a new TCEQ inventory for drilling rigs and load factor data for compressor engines in the 5-County area and Panola County. In this section, we provide a brief summary of the emission inventory. The 2005 emission inventory is described in further detail in NETAC's reports on the ozone modeling (Kemball-Cook et al. 2008; Kemball-Cook et al. 2010).

Figure 2-1 shows a breakdown of VOC emissions by source category for a typical summer weekday. Biogenic emissions constitute 84% of the total VOC inventory, and are by far the most important source category. Much of the biogenic contribution comes in the form of isoprene, which is a highly reactive VOC and is very effective in forming ozone in the presence of sunlight and sufficient NOx. Biogenic emissions are not controllable. The remaining 16% of the VOC inventory comes from anthropogenic sources. Area sources (13%) are the dominant anthropogenic source category, with about 66% of the area source contribution coming from oil and gas sources. Point sources (2%) and on-road mobile (1%) and non-road mobile (0.4%) sources are relatively small contributors to the total VOC inventory.

Biogenic sources constitute only 1% of the NOx inventory, which means that 99% of the NOx emissions in the 5-County Area are from human activities. Point sources are the largest contributor to the NOx inventory (35%), with EGU sources accounted for in the Acid Rain Database making up the bulk of the emissions in this category. Area sources (24%) and on-road mobile sources (22%) are the next largest contributors, with non-road mobile sources (18%) accounting for the smallest NOx contribution.

Figure 2-2 shows the composition of the anthropogenic components of the NOx and VOC inventory for the 5-County Area for a typical summer weekday. The total NOx emissions are 241 tons/day, which is comparable in magnitude to the VOC emissions total of 260 tons/day. The two largest emissions source categories are point source NOx and area source VOC, with more than half of the area source VOCs coming from the oil and gas component (note that the quantity of emissions does not necessarily translate into potential to form ozone). The biogenic contribution to the VOC inventory is 1333 tons/day, which is far larger than all other source categories.

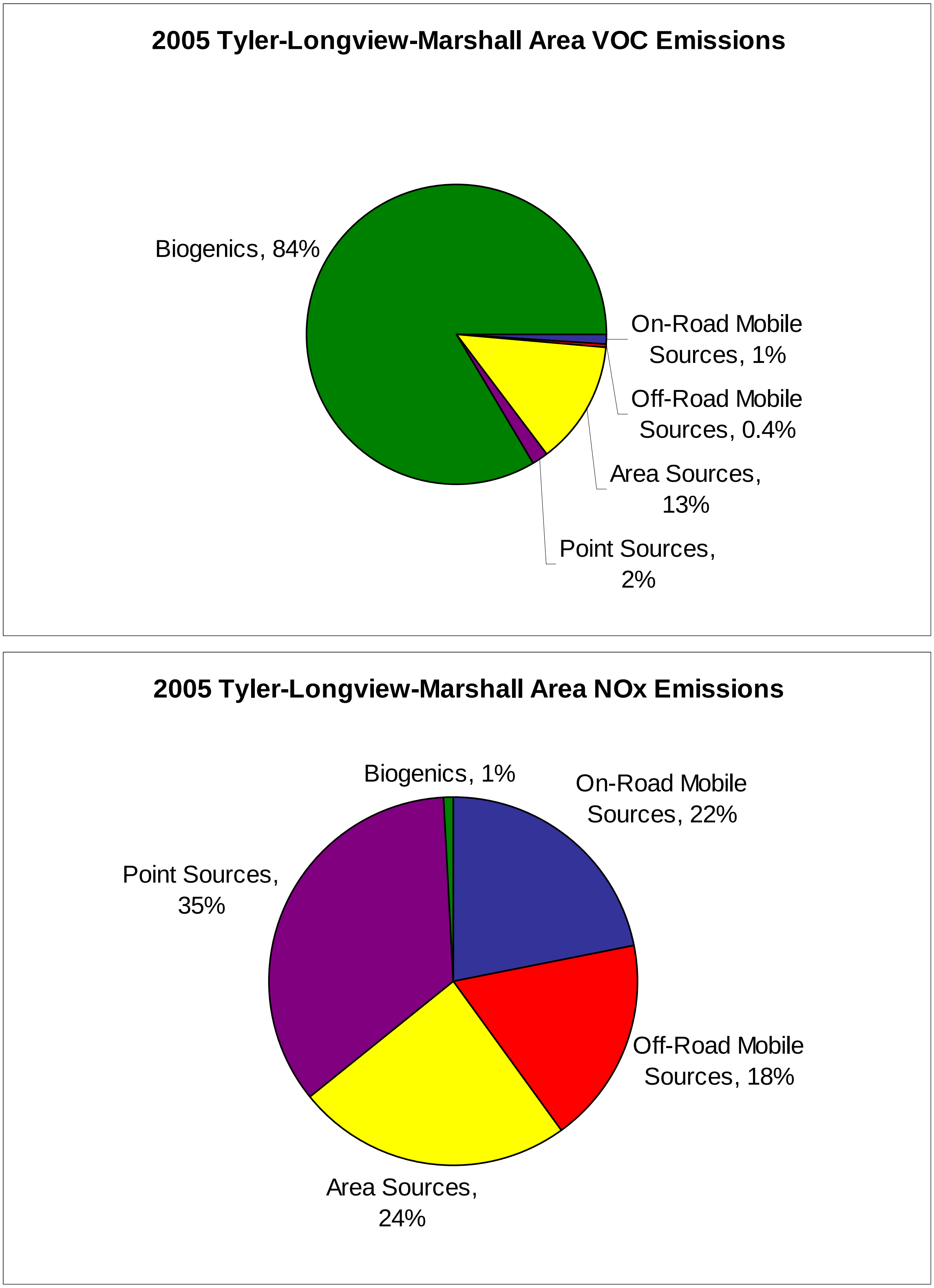

Figure 2-1. Comparison of typical weekday summer VOC (upper panel) and NOx (lower panel) emissions by source category.

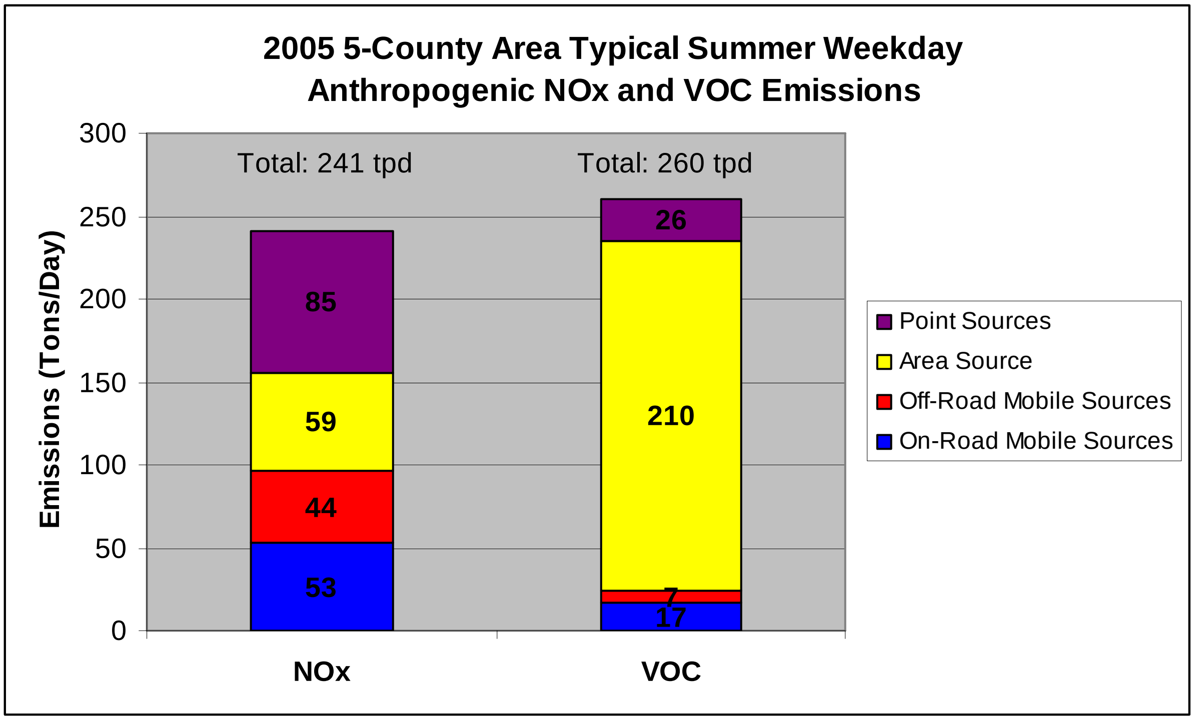

Figure 2-2. Anthropogenic VOC and NOx emissions summaries for a typical summer weekday in the 5-County Area.

2.3 FUTURE YEAR EMISSIONS CHANGES

2.3.1 TERP Program NOx Reductions

The Texas Emissions Reduction Program (TERP) is a TCEQ program aimed at reducing pollution from vehicles and equipment such as drill rigs, compressor engines, buses, fork lifts, etc. Much of this equipment falls into the category of non-road emissions, so non-road is the emissions source category to which TERP reductions were applied. TERP offers grants to individuals, businesses and local governments to retrofit or replace polluting equipment. The TERP program is ongoing, and more information is available at:
http://www.tceq.state.tx.us/implementation/air/terp/.

As of the fall of 2009, the NETAC area had received funding for $30,401,434 for 99 projects totaling 5,322 tons of NOx. Examples of projects funded are: locomotive switcher, forklifts, dump trucks, haul trucks, excavators, tractors, and oil and gas equipment such as drill rigs, rock fracturing units, and gas compressor engines. The TCEQ calculates the NETAC area NOx reduction in 2012 to be 2.9 tons/day NOx.

Table 2-1 and Figure 2-3 provide a summary of emissions reductions in Northeast Texas and other regions that may be expected to occur under TERP. Reductions in Northeast Texas from this program of ~3 tons/day NOx in 2012 are relatively small when compared to the typical summer weekday anthropogenic NOx emission inventory of >200 tons/day NOx.

Table 2-1. Summary of TERP Projects funded as of February, 2010.

AREA	NUMBER OF PROJECTS	NUMBER OF ACTIVITIES	TOTAL NOx (TONS)	GRANT AMOUNT	COST PER TON	TONS PER DAY IN 2010	TONS PER DAY IN 2011	TONS PER DAY IN 2012	TONS PER DAY IN 2013
Dallas/Fort Worth (DFW)	2,767	4,749	56,393.7276	$267,415,540.50	$4,742	21.0528	22.8957	22.1617	21.4336
Houston/Galveston/Brazoria	2,692	5,102	70,640.7789	$328,008,901.59	$4,643	30.1727	29.1498	27.1820	24.8573
San Antonio (SA)	633	930	7,546.6887	$51,741,350.51	$6,856	3.6723	3.8759	3.7854	3.4711
Austin (AUS)	551	854	6,136.9374	$45,011,694.39	$7,335	3.0069	3.2674	3.0405	2.8478
Tyler/Longview (TYL)	163	302	6,656.7958	$39,359,379.42	$5,913	2.8978	3.5743	3.5632	3.4865
El Paso (ELP)	135	170	705.8245	$3,174,307.08	$4,497	0.3302	0.3021	0.2840	0.2205
Beaumont/Port Arthur (BPA)	121	330	8,018.1269	$39,729,066.91	$4,955	3.1923	2.9894	2.9432	2.1819
Corpus Christi (CC)	22	84	1,079.9569	$5,312,696.60	$4,919	0.6621	0.5702	0.3528	0.2563
Victoria (VIC)	9	13	92.5450	$620,288.66	$6,703	0.0553	0.0541	0.0523	0.0034
Unknown (TBD)*	5	5	2,284.3140	$17,132,355.00	$7,500	0.4672	1.3053	1.3053	1.3053
	7,098	**12,539**	**159,555.6956**	**$797,505,580.64**	**$4,998**	**65.5096**	**67.9844**	**64.6704**	**60.0635**

Data from http://www.tceq.state.tx.us/implementation/air/terp/

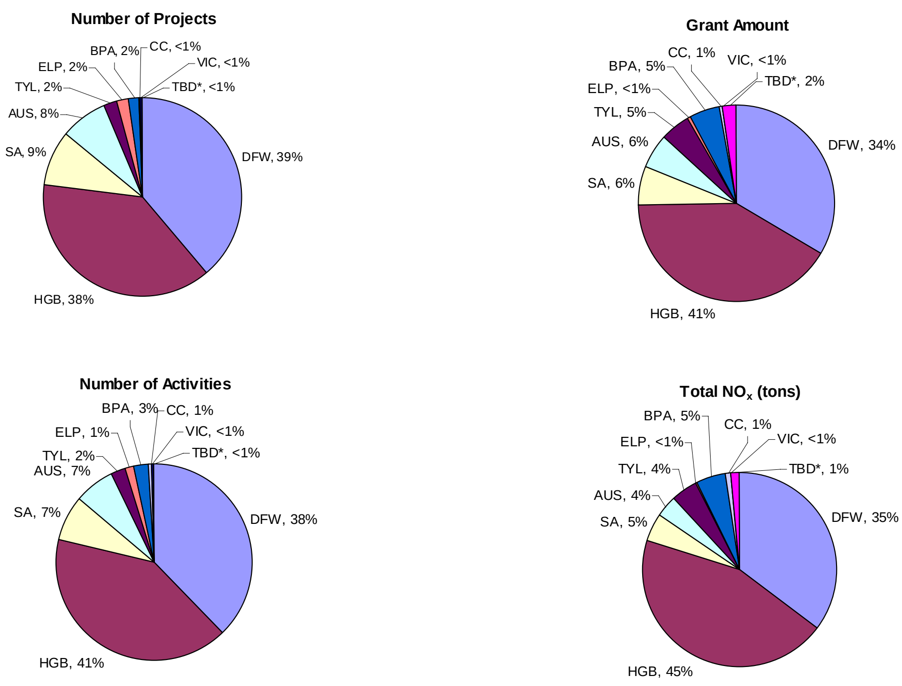

Figure 2-3. Percentage of projects by number and grant amount broken down by region. Data from http://www.tceq.state.tx.us/implementation/air/terp/.

2.3.2 Regional Emissions Reduction Programs

The CAIR program, announced by EPA in March, 2005, was designed to reduce transport of pollution across state lines, and set limits on NOx and SO_2 emissions from power plants in 28 states in the central and eastern U.S. (Figure 2-4). States were required to reduce NOx and SO_2 emissions by either compelling power plants to participate in an EPA-administered interstate cap and trade system that would have capped emissions in two phases, or to meet state-determined emissions targets through the State Implementation Plan (SIP) process. Phase I of CAIR extends from 2010-2014, and Phase II is slated to begin in 2015. The emissions caps for NOx and SO_2 are lower in Phase II than in Phase I, requiring additional emissions reductions after 2015.

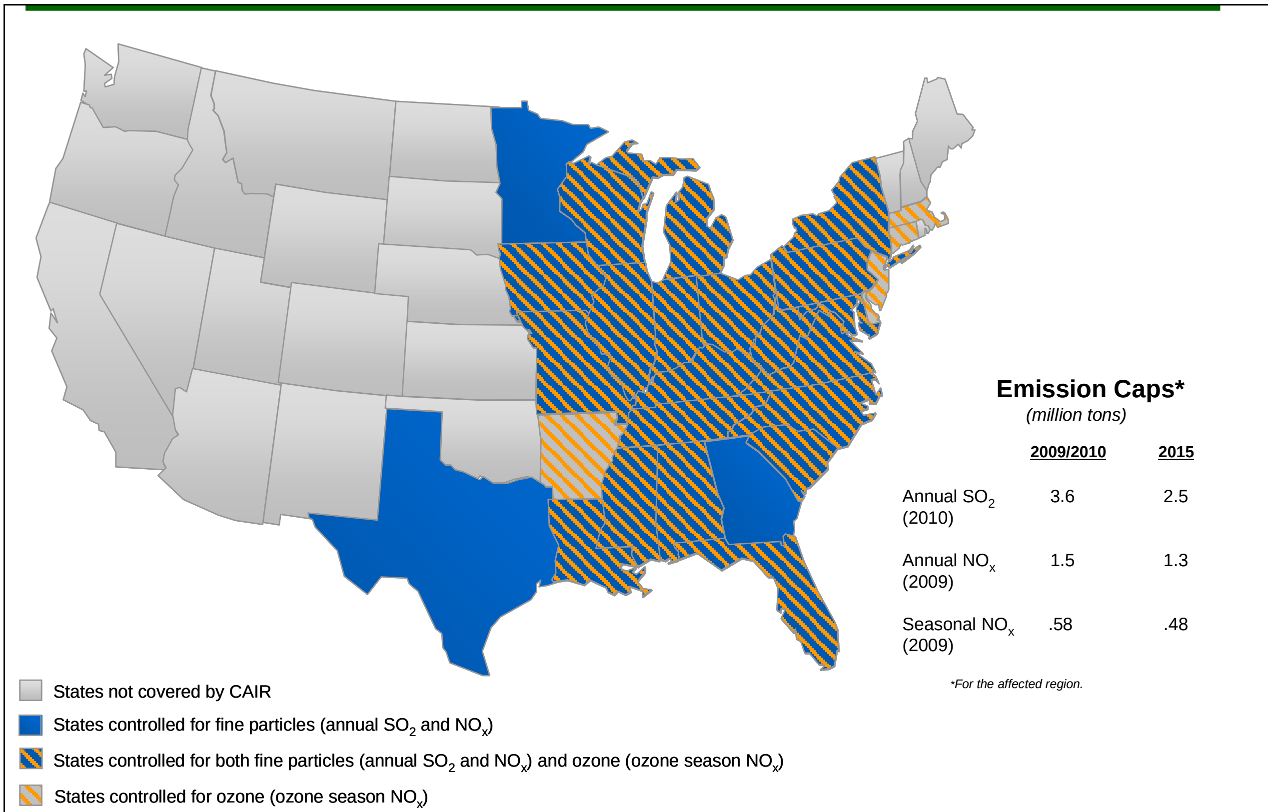

Figure 2-4. States affected by the Clean Air Interstate Rule (CAIR). Figure from presentation by Kim Herndon of the TCEQ, February 23, 2006.

In July, 2008, CAIR was vacated by the D.C. Circuit Court of Appeals, but was remanded back to EPA during a rehearing in December 2008. The December 2008 ruling left CAIR in place until EPA issues a new rule to replace CAIR.

Figure 2-5 shows trends in U.S. EGU NOx emissions and heat input from 1980 through 2008. Although the heat input shows an upward trend with some year-to-year variation, NOx emissions declined steadily from 1997 through 2008. In 1998, the EPA promulgated the NOx SIP Call and began a cap and trade program designed to reduce the regional transport of NOx emissions from power plants and other large combustion sources that contributed to high ozone levels in the eastern United States. Super-regional emission reductions required by the provisions of the NOx SIP call had taken effect in many southeastern states by the end of 2007. The recent NOx emission declines also reflect reductions in EGU NOx emissions due to agreed orders as well as reductions made in anticipation of the first phase of CAIR.

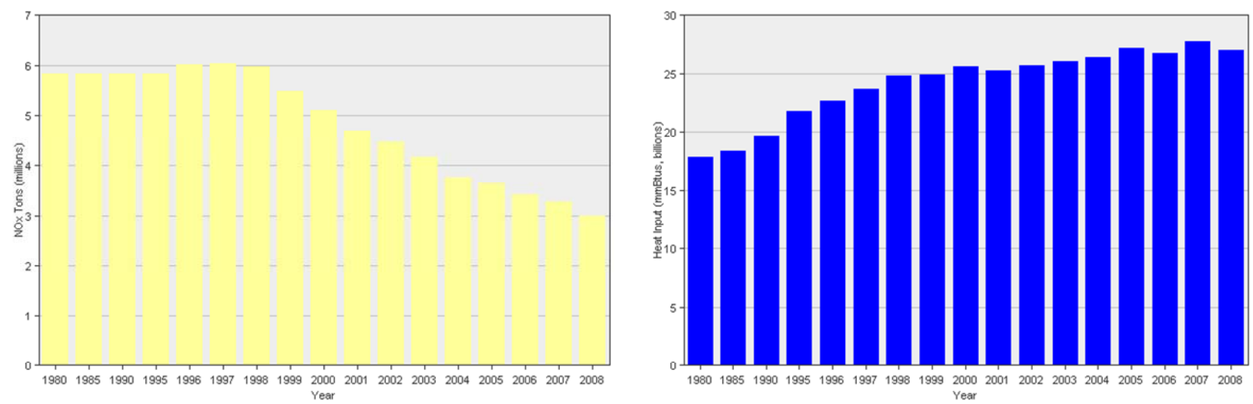

Figure 2-5. Trends in U.S. EGU NOx emissions and heat input. Data downloaded January 14, 2010 from EPA Clean Air Markets web page at http://camddataandmaps.epa.gov/gdm/index.cfm?fuseaction=factstrends.choose. 2009 data were not yet available.

Figure 2-6 shows 2005 to 2008 trends in EGU NOx emissions broken down by state. States that tend to be upwind of Northeast Texas on high ozone days are shown in blue and other states are shown in green. Figure 2-6 indicates that most states that may be expected to influence ozone in Northeast Texas have had reductions in EGU NOx emissions between 2005 and 2008. This is consistent with a reduction of the transport of ozone and precursors into Northeast Texas and a decrease in background ozone levels as shown in the 2012 ozone modeling results in Section 4.

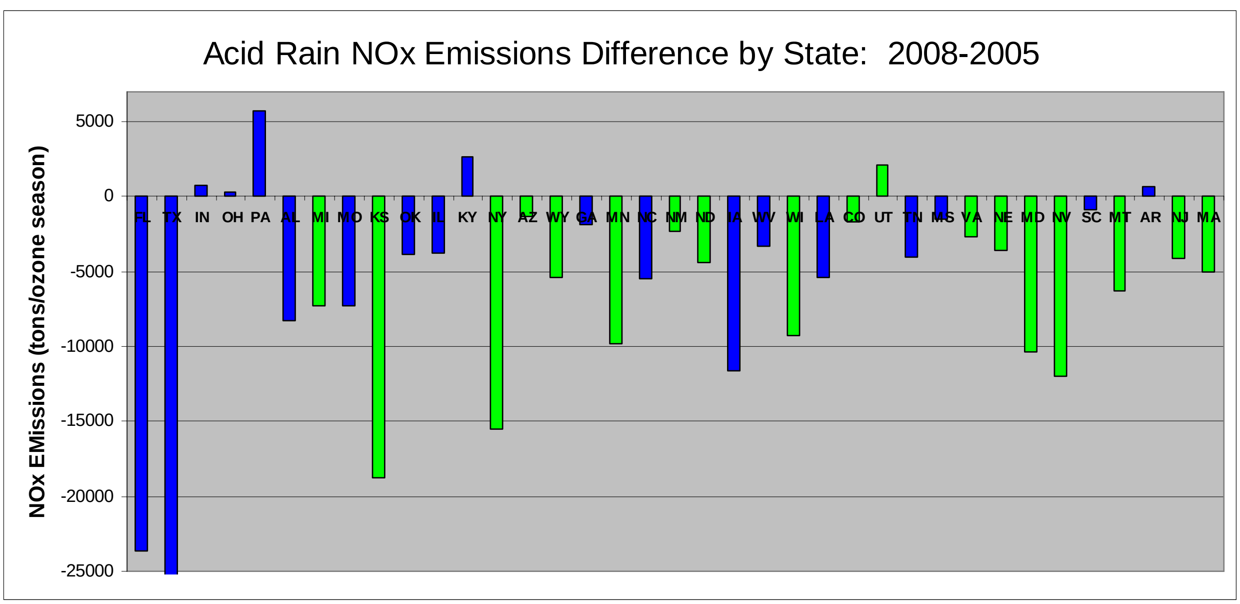

Figure 2-6. Trends in U.S. EGU NOx emissions broken out by state. Data downloaded January 14, 2010 from EPA Clean Air Markets web page at http://camddataandmaps.epa.gov/gdm/index.cfm?fuseaction=factstrends.choose. 2009 data were not yet available.

2.3.3 Trends in Local EGU Emissions

Changes in regional EGU NOx emissions affect transport of ozone and precursors into Northeast Texas, but Northeast Texas ozone levels are also influenced by local sources; EGU NOx emissions an important component of the local NOx emission inventory (included under the point source category in Figures 2-1 and 2-2). Figure 2-7 shows NOx emission trends for Northeast Texas EGUs. These data are ozone season averages of continuous emissions monitoring system (CEMS) data from the EPA CAMD database.

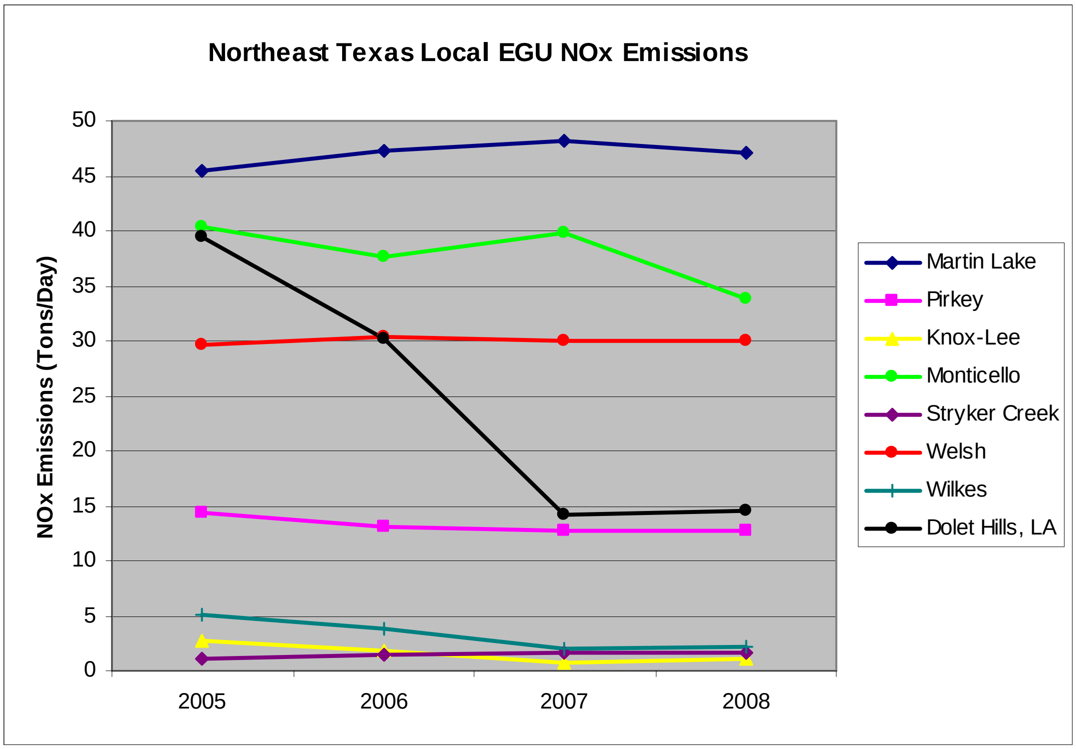

Figure 2-7. Trends in EGU NOx emissions for facilities within and nearby Northeast Texas.

The Northeast Texas EGU NOx emissions generally show little change or a slight decline during the 2005-2008 period. The exceptions are the Monticello facility which has a larger emissions decrease of ~5 tons/day and the Wilkes power plant, which has a NOx emissions reduction of ~3 tons/day. The Dolet Hills Power Plant in Louisiana, however, implemented NOx controls during this period and saw a reduction in NOx emissions from 39 tpd in 2005 to 14 tpd in 2008. Figure 2-8 shows the ozone impacts of this emissions reduction. The Figure shows the 2012-2005 difference in the episode average daily maximum 8-hour ozone. The blue shaded region surrounding the Dolet Hills facility shows local reductions of 6-8 ppb near the facility. Note that these reductions represent an average over the entire May-June modeling episode and that maximum reductions on a particular day range as high as 20 ppb near the facility; these reductions extend well into Northeast Texas. These results highlight the effectiveness of EGU NOx controls in reducing local ozone.

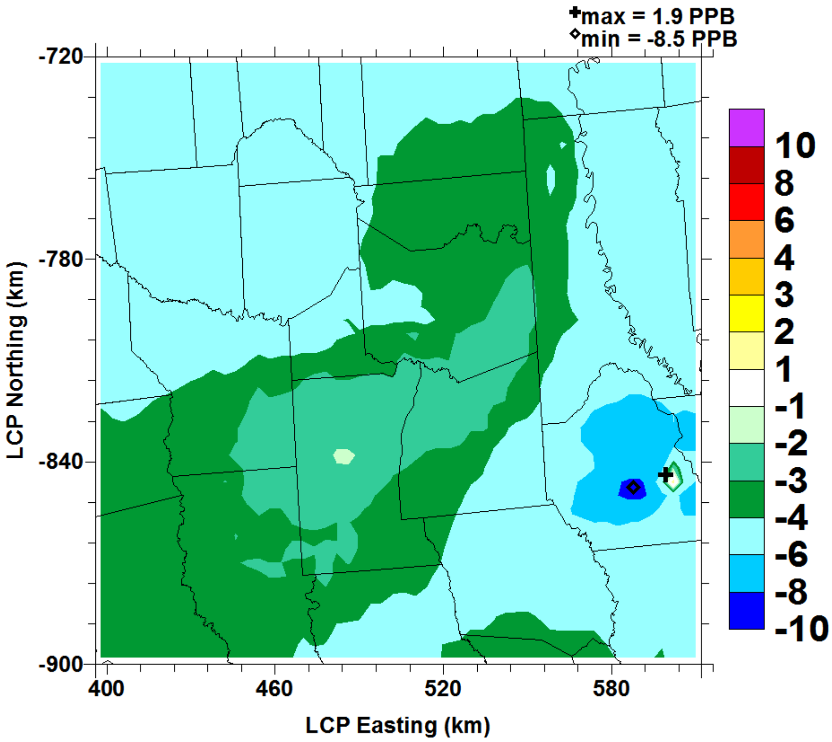

Figure 2-8. Episode average difference in the daily maximum 8-hour ozone in each grid cell of the 4 km grid for 2012 and 2005 baseline CAMx runs. Negative values indicate that ozone is lower in 2012 than in 2005.

2.3.4 Eastman Chemical Complex Emissions

Another large industrial source of NOx and VOC emissions in Northeast Texas is the Eastman Chemical Complex in Longview, which houses facilities owned by the Eastman Chemical Company, Flint Hills Resources, and the Westlake Chemical Corporation. As part of the development of the 2012 emission inventory, Eastman, Flint Hills and Westlake were queried regarding their expected emissions in 2012. Flint Hills and Westlake indicated that leaving emissions fixed at their 2005 levels would be the best estimate of their expected 2012 emissions. Eastman suggested that they expect their emissions to decrease in 2012 relative to 2005 as two of Eastman's three hydrocarbon cracking plants that were operating in 2005 are expected to be shut down in 2010. Eastman recommended using their 2008 emission inventory submittal to the TCEQ as the best approximation to their 2012 emissions; however, the 2008 inventory was not available at the time when the 2012 inventory was being developed, so Eastman's 2005 emission inventory was used in the 2012 inventory as a placeholder. This strategy likely causes an overestimate of Eastman's emissions in the present 2012 emission inventory. As Eastman is an important source of emissions in the 5-County area, these potential changes in the facility should be taken into account in future conceptual model, emission inventory, and ozone model development.

2.4 2012 EMISSION INVENTORY AND PROJECTED 2005-2012 TRENDS

In this section, we use data developed for the 2012 and 2005 ozone modeling to illustrate projected trends in emissions. Figures 2-9 through 2-12 illustrate NOx and VOC trends for the 5-County area broken down by source category. Emissions from 1999 and 2002 NETAC models were presented in the 2004 Conceptual Model of Ozone Formation (Stoeckenius and Yarwood, 2004). The NOx emissions trends show that NOx emissions decreased overall going from 1999 through 2005 and are projected to continue to decrease through 2012. 2005 shows higher emissions than 2002, but this is due in part to the addition of NOx emissions from the TCEQ drill rig inventory to the off-road inventory in 2005; these sources were not well-characterized in earlier inventories and were likely underestimated. During the 1999-2012 period, there is a monotonic decrease in on-road mobile source NOx emissions and point source NOx emissions decrease as well. Area source emissions are the only source category to show an increase, and this increase is largely driven by growth in emissions from oil and gas sources.

For VOC emissions, there is a large increase in area source emissions between 2002 and 2005, followed by a smaller increase 2005 to 2012. Figure 2-11 shows the area source inventory broken out into oil and gas and non-oil and gas sources for 2005 and 2012. (The 1999 and 2002 area source inventory oil and gas/non-oil and gas component breakdown was not readily available). The 2002 oil and gas inventory was derived through extrapolation of the 1999 Pollution Solutions inventory. There was an increase in natural gas development activity between 2002 and 2005, while growth during the period between 1999 and 2002 was relatively flat. The 2005 area source (including oil and gas) inventory is the TCEQ 2005 emission inventory for these sources. Figure 2-11 makes clear that oil and gas sources dominate the 5-County area source VOC inventory during 2005 and 2012 and that there is a small increase in area source VOC emissions from 2005 to 2012.

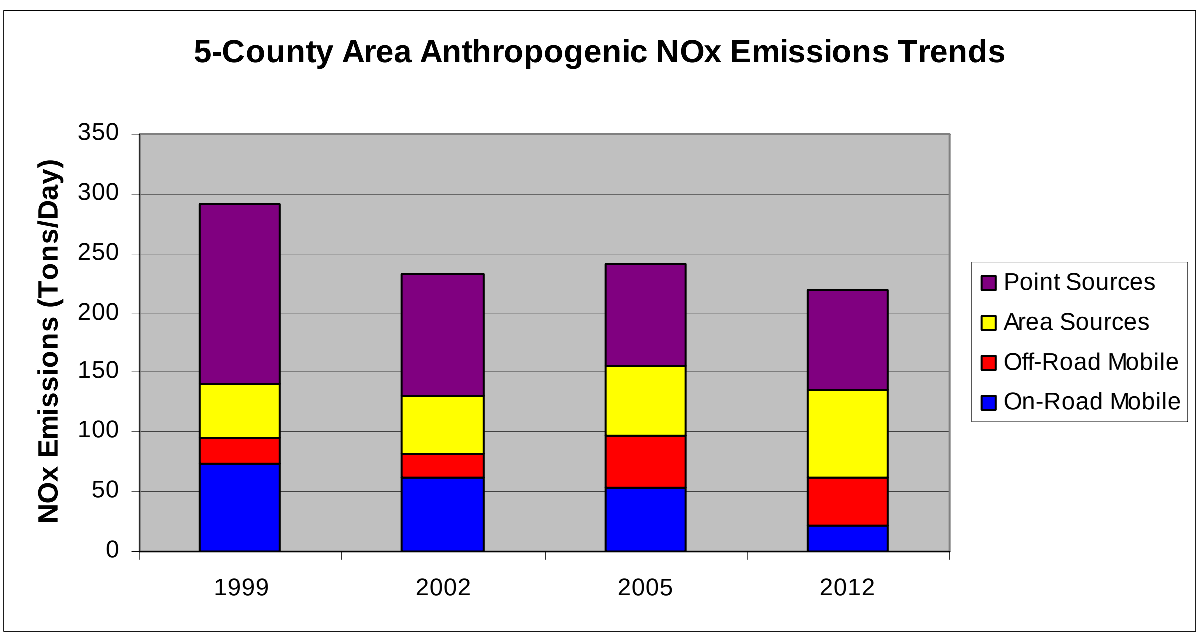

Figure 2-9. 5-County NOx emission trends from 1999-2012 by source category.

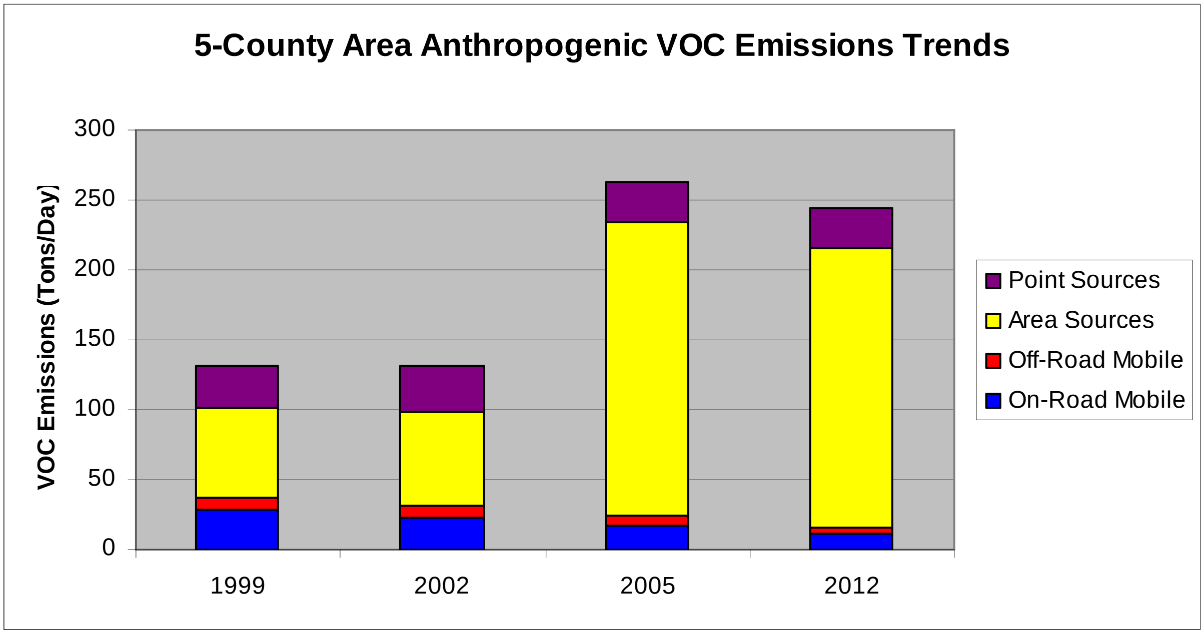

Figure 2-10. 5-County VOC emission trends from 1999-2012 by source category.

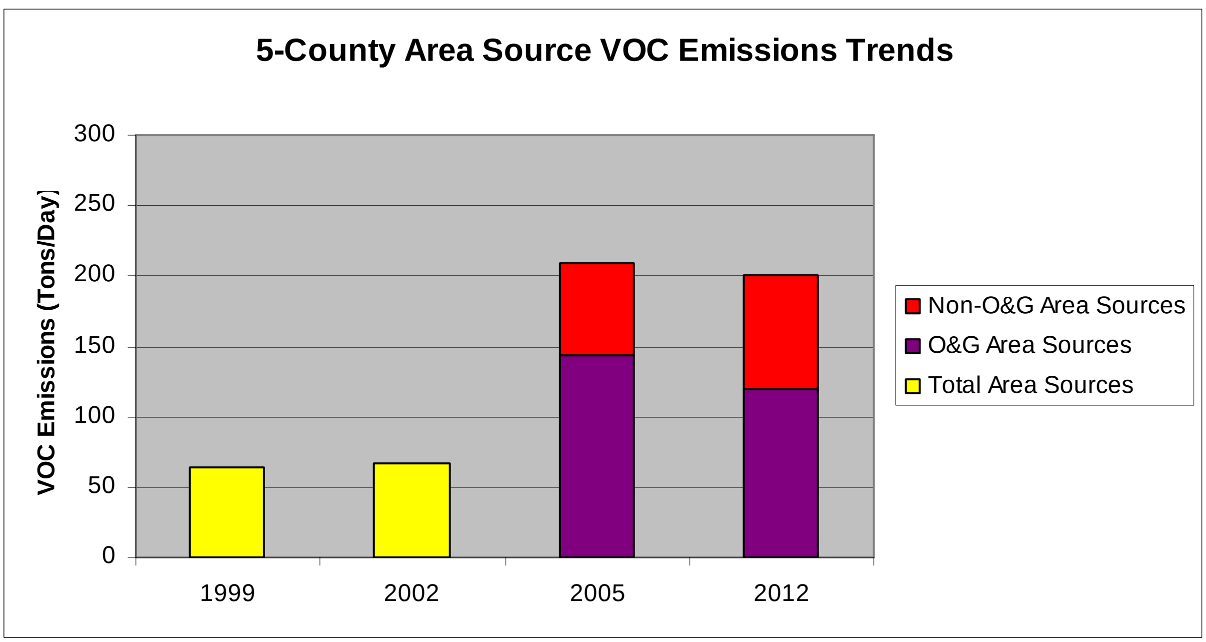

Figure 2-11. 5-County area source VOC emission trends from 1999-2012 with oil and gas source emissions broken out for 2005 and 2012.

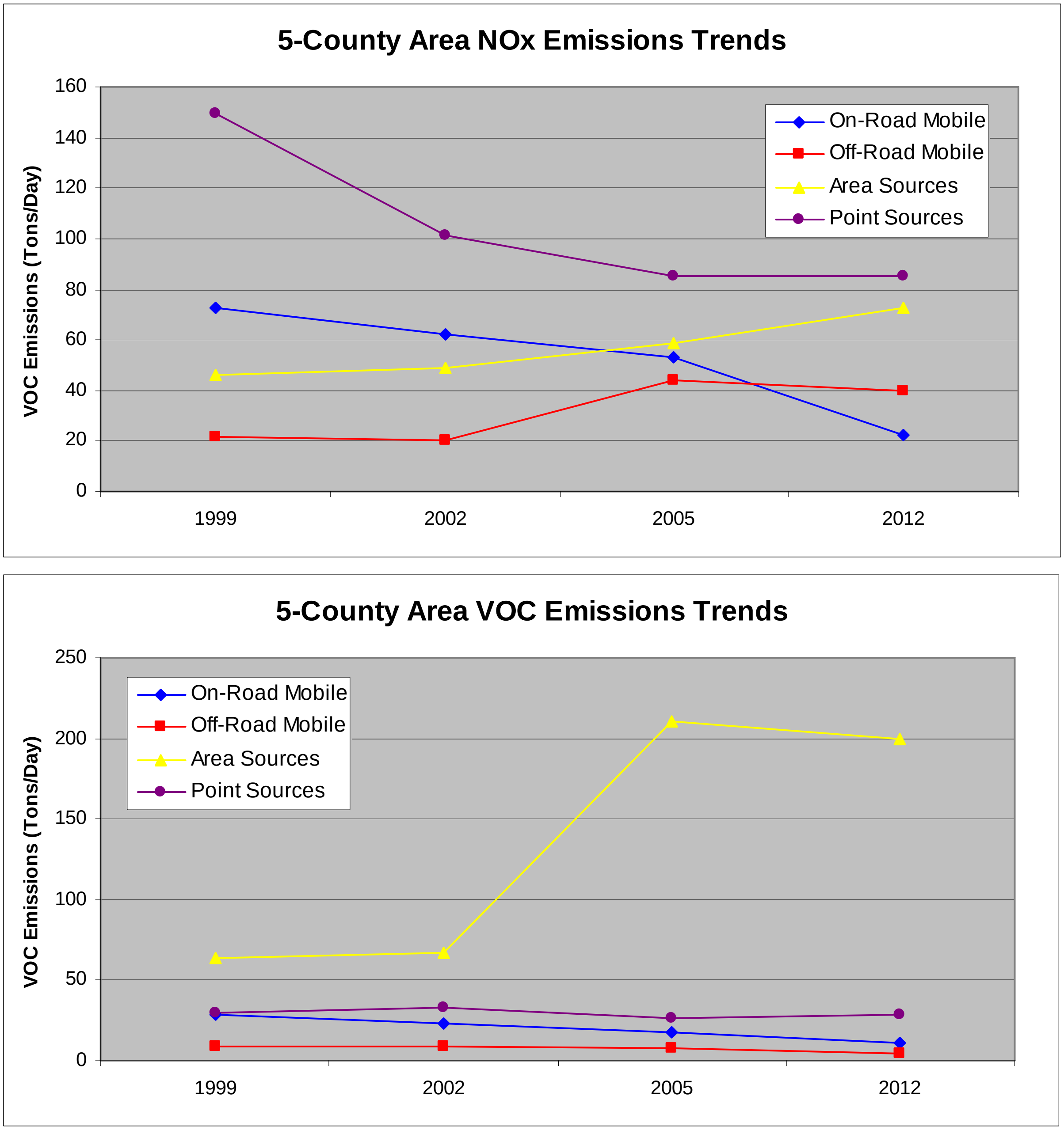

Figure 2-12. 5-County area source NOx (upper panel) and VOC (lower panel) emission trends from 1999-2012 by source category.

2.4.1 Future Natural Gas Exploration and Production in Louisiana and East Texas

As NETAC began work on the development of a future year emission inventory, high priority was placed on the inventory of NOx emissions from compressor engines associated with natural gas production. The future year emission inventory incorporated growth projections and the effects of planned controls on this sector. The effects of growth and controls are shown in Figure 2-13 and 2-14 and Table 2-2. Emissions for 2012 oil and gas sources were developed by scaling 2005 emissions by growth factors calculated by taking the ratio of 2012/2005 production of oil or gas.

Growth factors for oil and gas production for the 5-County area and Panola County were based on data from the Texas Railroad Commission (TRRC). County total gas and oil production data were obtained from the TRRC for each year during the period 1998-2008. (2009 data were not yet complete at the time the projection calculation was performed). These data are shown as filled symbols in the upper (natural gas) and lower (oil) panels of Figure 2-14. Projections for future years 2009-2012 were derived through linear extrapolation of 2005-2008 production through 2012. Projections were performed separately for gas and oil, and projected values are indicated by open symbols in Figure 2-14. The ratio of 2012/2005 production was used to scale 2005 county emissions to 2012 for NOx, VOC, and CO. For NOx only, 2012 emissions for compressor engines associated with natural gas production (identified via source classification code; SCC) were adjusted to account for controls due to the East Texas Combustion Rule described in Section 2.1. The East Texas Combustion Rule went into effect in March, 2010 and therefore will affect 2012 NOx emissions.

In order to calculate the effect of the East Texas Combustion Rule on 2012 NOx emissions in Northeast Texas, the fraction of engines that would be affected was estimated using engine survey data from Pollution Solutions (2006). The fraction of total horsepower in the 5-county area that is due to rich burn engines with horsepower > 240 HP was estimated based on the horsepower distribution of the engine population in the survey. This is the fraction of the total available horsepower that is subject to control under the East Texas Combustion Rule. A rule effectiveness of 80% was assumed consistent with guidelines under EPA's Emissions Inventory Guidance for Implementation of Ozone and Particulate Matter National Ambient Air Quality Standards (NAAQS) and Regional Haze Regulations (EPA, 2005). To apply the East Texas Combustion rule, emissions factors used in the Pollution Solutions (2006) emissions calculations based on survey data were replaced with the required emissions factors for rich burn engines (1.0 g/hp-hr for engines with $240 < HP < 500$ HP and 0.5 g/hp-hr for engines $HP \geq 500$ HP) for the affected fraction of the horsepower.

The resulting NOx emissions are shown in Table 2-2. NOx emissions for a hypothetical scenario without the East Texas Combustion Rule (i.e. uncontrolled growth as forecast based on gas production in Figure 2-14.) are also shown in Table 2-2. The total 5-County area NOx emissions from gas compressor engines are reduced by 17 tons/day over the uncontrolled case. Ozone modeling of the effects of the East Texas Combustion Rule was carried out using the 2012 ozone model, and the results of this emissions sensitivity test are discussed in Section 4.

Table 2-2. NOx emissions from gas compressor engines in the 5-County area with and without the effects of the East Texas Combustion Rule.

County	NOx Emissions (tons/day)			
	2005	2012 Growth + Controls	2012 Growth Only	NOx Reduction from ETxCR
Gregg	5	3	4	1
Upshur	4	2	3	1
Rusk	10	19	27	7
Smith	3	1	1	0
Harrison	8	18	26	8
Total	31	43	60	17

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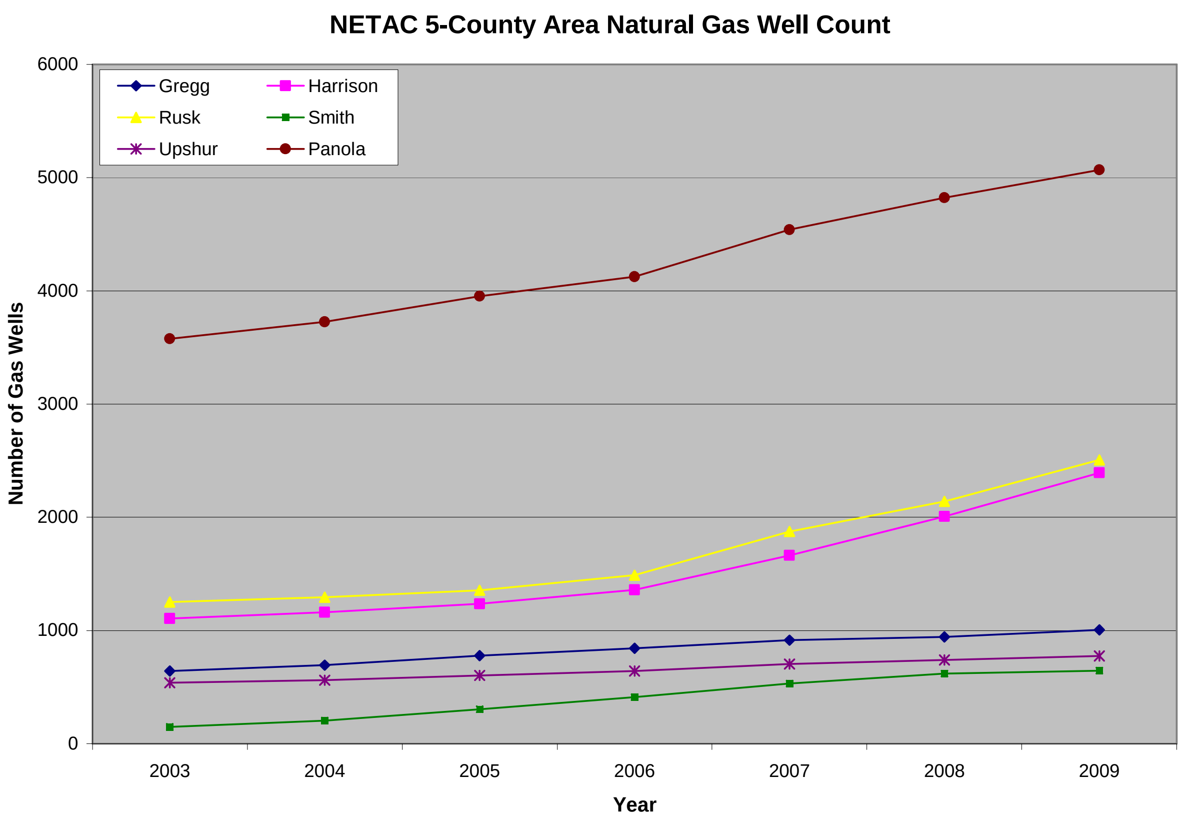
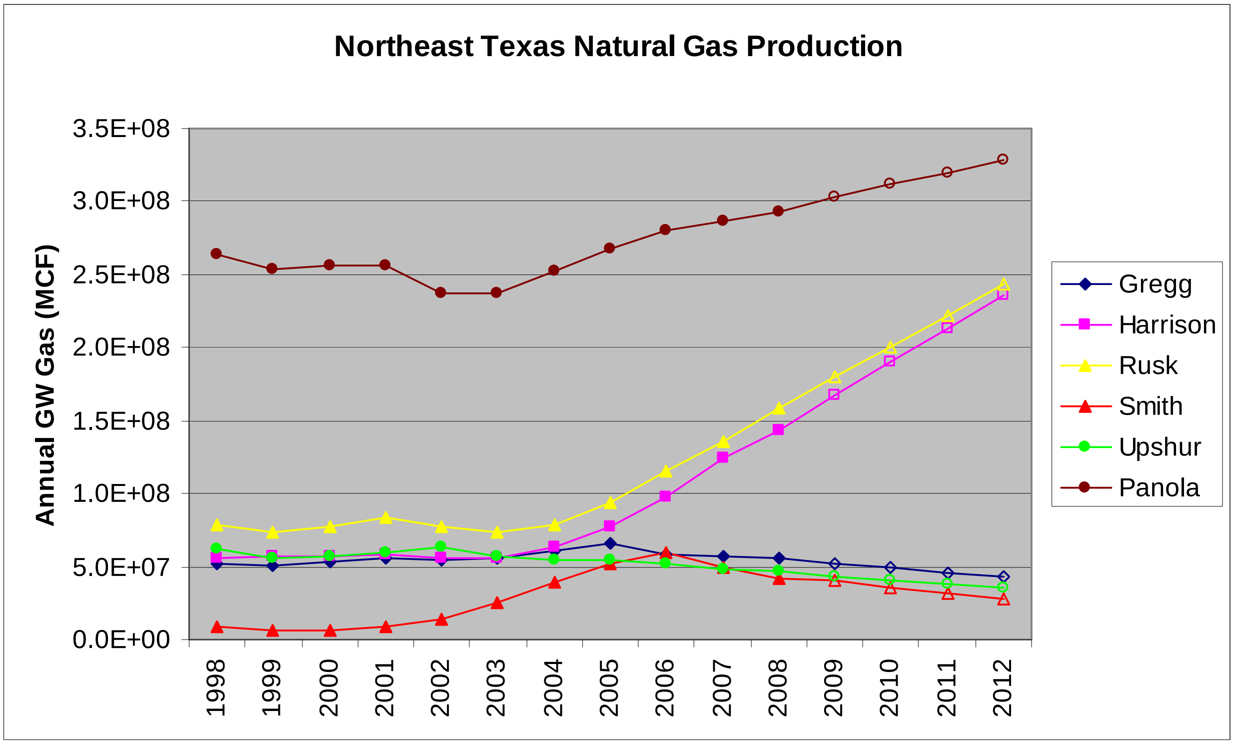


Figure 2-13. Number of natural gas wells for 2003-2009 for the 5-County area.



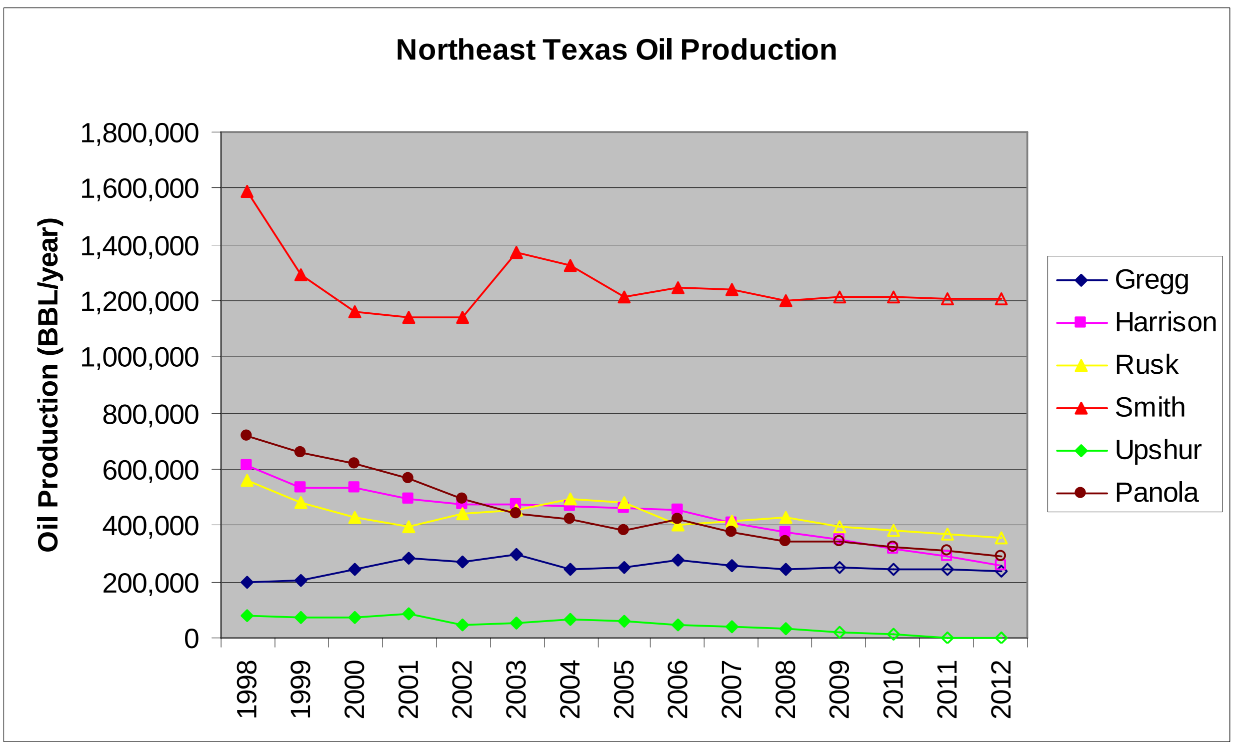


Figure 2-14. Production of natural gas (upper panel) and oil (lower panel) for 1998-2008 for each County in the NETAC 5-County Area and Panola County from Texas Railroad Commission data (filled symbols) and 2009-2012 projections (open symbols) made by performing a linear extrapolation based on the 2005-2008 data.

2.4.2 Projected Development of Gas Resources in the Haynesville Shale

The Haynesville Shale is a rock formation that lies at depths of 10,000 to 13,000 feet below the surface and straddles the border between Northeast Texas and Northwest Louisiana near Shreveport (Figure 2-15). This formation is estimated to contain very large recoverable reserves of natural gas, and during the two years since the drilling of the first highly productive wells in 2008, it has been the focus of intensive exploration and leasing activity. Despite the recent economic downturn and the fall in price of natural gas since 2008, development of the Haynesville Shale has continued.

The development of natural gas resources within the Haynesville Shale is likely to be an important driver of local economic growth, but may also generate significant emissions of ozone precursors. NOx would be emitted during the drilling of wells and the subsequent rock fracturing to stimulate natural gas production and from compressor engines that are used to produce and transmit the gas. VOCs may be emitted from many processes including venting and completion of wells, dehydration of gas and fugitive emissions from well and pipeline components.

Emissions resulting from the development of the Haynesville Shale would be released in a region that is either within or often immediately upwind of the 5-county area of Northeast Texas on high ozone days. Three of these five counties have been recommended to the U.S. Environmental Protection Agency by the state of Texas as potential ozone non-attainment areas. NETAC has therefore undertaken an investigation of how development in the Haynesville Shale may impact future ozone air quality in Northeast Texas. The first step in this investigation was the development of a future year emission inventory for the Haynesville Shale.

Based on well production data from state regulatory agencies and a review of the available literature, projections of future year Haynesville Shale natural gas production for 2009-2020 were derived for three scenarios corresponding to limited, moderate, and aggressive development (Grant et al., 2009). Projections of future year activity were based on the number of new wells drilled each year. All scenarios began with the number of rigs operating in Haynesville as of March 2009. Three emissions scenarios were developed:

Low scenario:	leave March 2009 drill rig count fixed
High scenario:	use 2001-2008 Barnett Shale rig count growth, cap growth at 200 rigs
Moderate:	50% of aggressive scenario

Emissions for the entire Haynesville Shale formation for the 2012 modeling year and the final year of the study, 2020, are shown in Figure 2-16.

Figure 2-15. Spatial extent of the Haynesville Shale in Texas and Louisiana as defined in this study.

Estimates of 2012 NOx emissions in Northeast Texas and Northwest Louisiana due to development in the Haynesville Shale ranged from 61 tons/day in the limited development scenario to 82 tons/day in the moderate scenario to 140 tons/day in the aggressive scenario. Results for the moderate scenario indicate that by 2020, development in the Haynesville Shale results in more than 120 tons/day of additional NOx emitted in Northeast Texas and Northwest Louisiana. The moderate scenario projection of 82 tons/day NOx in 2012 is equal to the total 2005 NOx emissions from all of the Haynesville counties in Texas, and about 30% of the total 5-County 2005 NOx inventory. For the low development scenario, the Haynesville Shale 2012 NOx emissions of 61 tons/day is about 75% of the total 2005 NOx emissions from all of the Haynesville counties in Texas and about 25% of the total NOx emissions from all source categories for the 5-County area. By 2020, NOx emissions from the Haynesville are larger than NOx emissions for the entire 5-County area in 2005. These emissions increases were sufficiently large that it was necessary to evaluate their ozone impacts. The ozone modeling of the Haynesville Shale is discussed in Section 4.

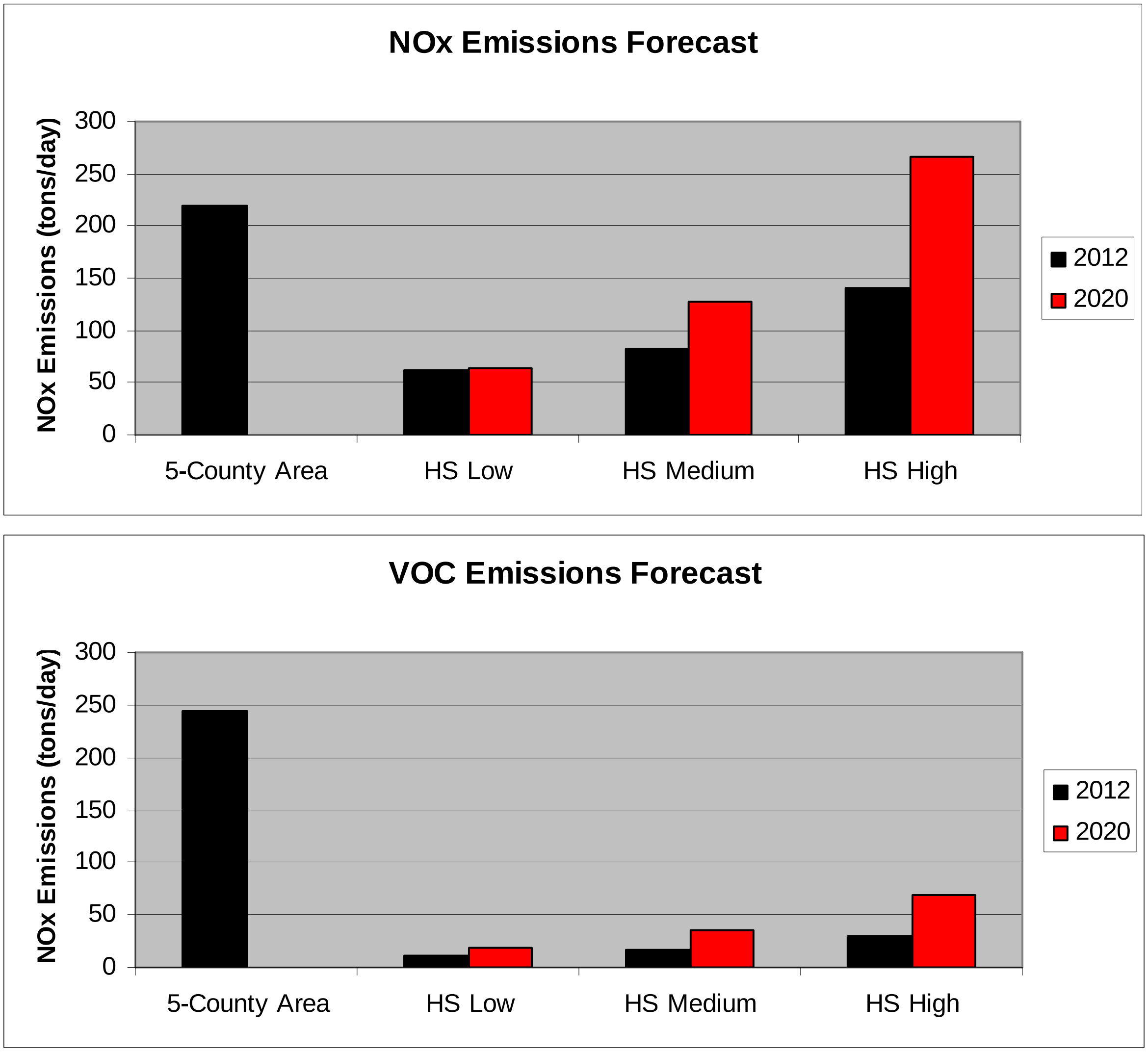


Figure 2-16. NOx (upper panel) and VOC (lower panel) emissions in the Haynesville Shale in 2012 and 2020 for low, medium and high development scenarios and comparison with 5-County area 2012 Baseline emission inventory for NOx and VOC.

3.0 AMBIENT DATA

In this section, we review recent trends in Northeast Texas ozone and results of NETAC's surface-based monitoring and discuss how this new data fits into the Conceptual Model.

3.1 OZONE STATUS AND TRENDS

The Northeast Texas ozone monitoring data determine whether the area is in compliance with the National Ambient Air Quality Standards for ozone. The Texas Commission on Environmental Quality (TCEQ) operates three ozone monitors (Continuous Air Monitoring Stations, CAMS) in Northeast Texas at Longview, Tyler, and Karnack. NETAC has operated a research ozone monitor that was located at Waskom in 2002-2003 and in Panola County in 2004-2006. The Panola research monitor helped to characterize the concentrations of background ozone in air entering the Northeast Texas region on high-ozone days. The locations of these monitors are shown in Figure 1-1.

The annual 4th highest 8-hour ozone values and the resulting design values at monitors in Northeast Texas for recent years are shown in graphical form in Figure 3-1, and are listed in Tables 3-1 and 3-2. Note that all ozone data through December 31, 2009 have been validated by the TCEQ and that the research monitor at Panola was not active after 2006, so a design value cannot be calculated for 2007-2009 for this monitor. Figure 3-1 shows dramatic declines in 4th high ozone levels and design values at all three monitors over the last decade. The ozone data indicate that 2005 was a relatively high ozone year in Northeast Texas; the 2005 data increased the three year averages used to calculate the 2004-2006 design values to the point where the Longview monitor was out of compliance with the 1997 8-hour standard at the end of 2006. The 2007-2008 period, on the other hand, saw the lowest 4th high ozone values in the last decade at the Northeast Texas monitors. The 2005-2007 design values were all 84 ppb or less, which means that all Northeast Texas monitors were in attainment of the 1997 0.08 ppm 8-hour ozone standard at the end of the Early Action Compact in December, 2007. The 2006-2008 design values show a further reduction in ozone levels such that Northeast Texas design values were at their lowest levels in ten years at all three monitors. The 2009 annual 8th high ozone value at Karnack was at its lowest value since the monitor became operational in 2002, while the Longview and Tyler monitors recorded slight increases over 2008. The 2007-2009 design values continued to decline at all three monitors and all three monitors currently attain the 2008 ozone standard of 75 ppb.

Table 3-1. Annual 4th highest 8-hour ozone values (ppb) for Northeast Texas.

Year	Longview	Tyler	Karnack	Panola
2004	83	81	77	75
2005	88	83	84	79
2006	84	82	78	79
2007	81	77	69	N/A
2008	71	72	68	N/A
2009	73	75	67	N/A

Table 3-2. Recent trends in 8-hour ozone design values (ppb) for Northeast Texas.

Design Value for Years	Longview	Tyler	Karnack	Panola
2002-2004	83	81	81	N/A
2003-2005	84	81	80	77
2004-2006	85	82	79	77
2005-2007	84	80	77	N/A
2006-2008	78	77	71	N/A
2007-2009	75	74	68	N/A

Since the 2004-2006 period, design values for all three monitors have declined, although TCEQ data show that NOx levels in the Tyler-Longview-Marshall area have been either flat (Tyler and Karnack monitors) or increasing slightly (Longview) in recent years ("2008 in Review", presentation by Jonathan Steets, TCEQ Air Quality Division, December 16, 2008). NETAC's conceptual model of ozone formation indicates that ozone levels in Northeast Texas are critically dependent on the amount of NOx available. Decreases in local NOx emissions are unlikely to explain the declining ozone design values. One possible explanation is that weather conditions since 2005 have been less conducive to ozone formation than in previous years; another possible explanation is that regional emissions decreases have reduced the amounts of transported ozone and precursors coming into Northeast Texas.

Ozone formation in Northeast Texas peaks on hot, sunny days with winds ranging from northerly to southeasterly. Figure 3-2 shows the relationship between weather conditions favorable for producing high ozone in Northeast Texas and ozone values over the last eight years. At CAMS 19, there was a fairly close correspondence between weather and number of high ozone days from 2002-2006. During 2007-2009, there were fewer high ozone days than days with weather suitable for ozone formation. CAMS 85 also shows a close correspondence between weather and number of high ozone days from 2002-2006 except during 2005, when there were far more days with weather favorable to ozone formation than high ozone days. There were no high ozone days during the 2007-2009, despite the existence of favorable conditions on multiple days. CAMS 82 does not show the same relationship between weather and high ozone days as the CAMS 19 and CAMS 85 monitors during 2002-2006. At the CAMS 82 monitor, there were more high ozone days than days with favorable weather during 2003-2006. This may indicate that CAMS 82 has a different set of weather conditions during its high ozone periods than the other two monitors. During 2007-2009, however, the CAMS 82 monitor shows the same trend as the other two monitors, with a larger number of days favorable to ozone formation than high ozone days.

Considering the flat or increasing NOx levels in Northeast Texas, the data in Figure 3-2 suggest it is possible that declining design values at the Northeast Texas monitors are due in part to weather conditions during the last four years that were less conducive to ozone formation than in previous years (e.g. 2005) and also to decreases in background ozone transported into Northeast Texas resulting from regional NOx emissions reductions measures such as the NOx SIP Call, agreed orders on electric generating units, Federal mobile source controls and the first phase of the Clean Air Interstate Rule.

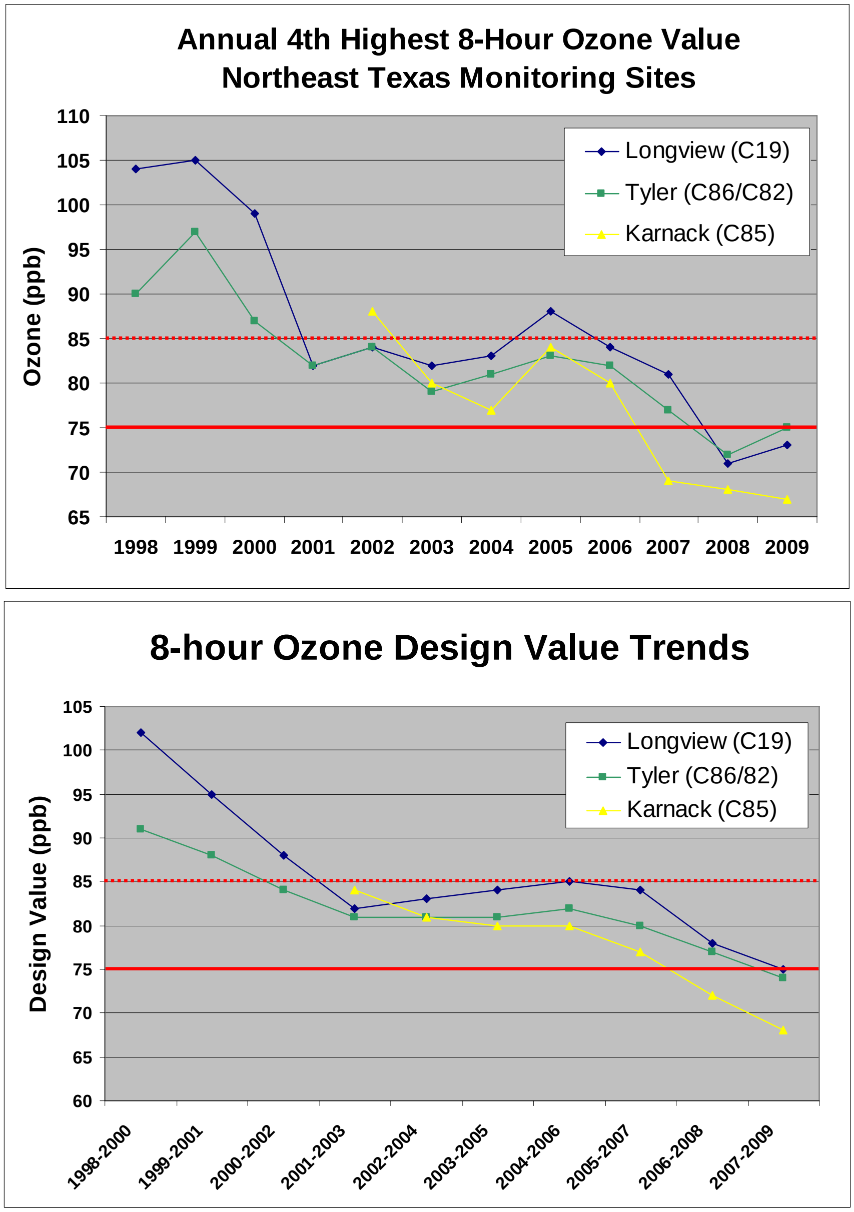


Figure 3-1. Trends in annual 4th highest 8-hour ozone values (upper panel) and design values (lower panel) at the Longview, Tyler, and Karnack monitors in Northeast Texas. The solid red line indicates the 2008 75 ppb ozone standard and the dotted red line shows the 1996 85 ppb standard.

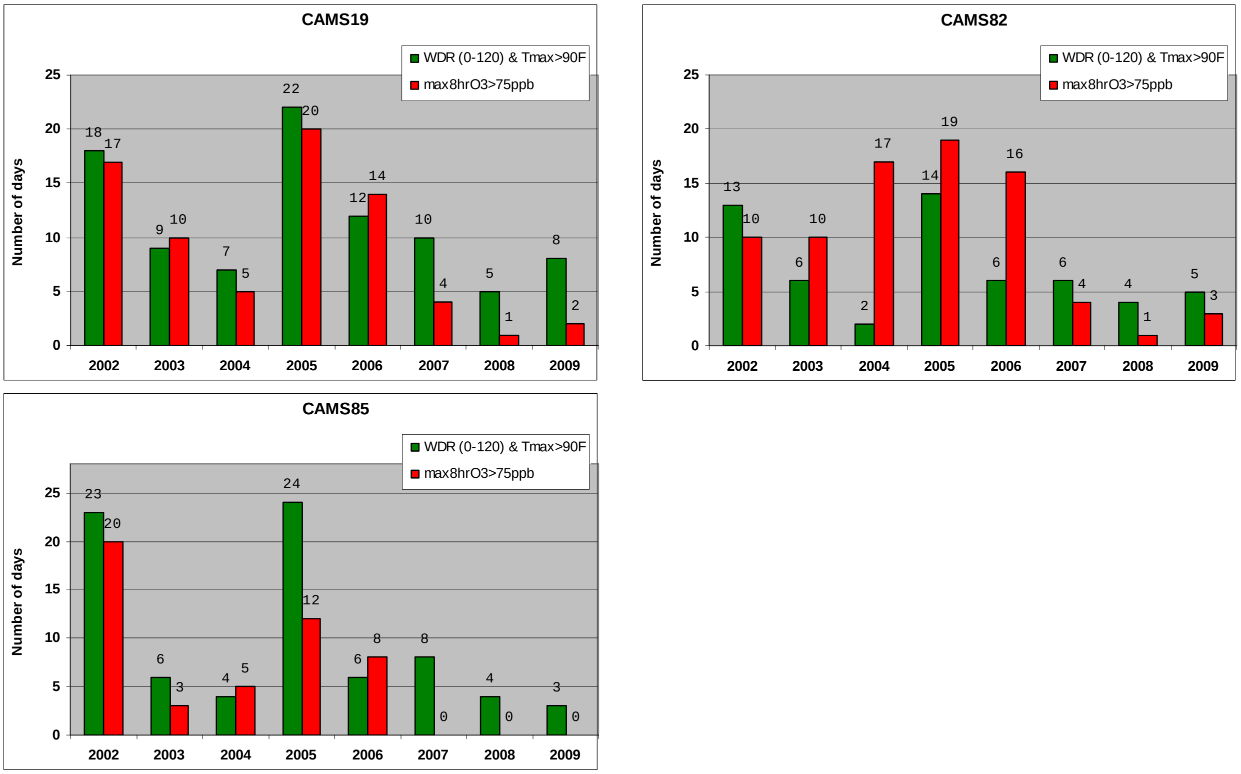


Figure 3-2. Relationship between weather conditions and high ozone in Northeast Texas. Green bars indicate the number of days that had weather conditions typically associated with high ozone in Northeast Texas: daily maximum temperature greater than 90ºF and 10 am-3 pm average wind direction between 0º and 120º (North to Southeast). Red bars in each panel indicate the number of days during each year that the monitor recorded daily maximum 8-hour ozone concentrations greater than 75 ppb. Top left panel: Longview CAMS 19. Top right panel: Tyler CAMS 82. Lower left panel: Karnack CAMS 85.

3.1.1 Trends in Background Ozone in Northeast Texas

At CAMS 19, Figure 3-2 shows that there was a fairly close correspondence between weather and number of high ozone days from 2002-2006. During 2007-2009, there were fewer high ozone days than days with weather suitable for ozone formation. CAMS 85 also shows a close correspondence between weather and number of high ozone days from 2002-2006 except during 2005, when there were far more days with weather favorable to ozone formation than high ozone days. There were no high ozone days during the 2007-2009, despite the existence of favorable conditions on multiple days. CAMS 82 does not show the same relationship between weather and high ozone days as the CAMS 19 and CAMS 85 monitors during 2002-2006. At the CAMS 82 monitor, there were more high ozone days than days with favorable weather during 2003-2006. This may indicate that CAMS 82 has a different set of weather conditions during its high ozone periods than the other two monitors. During 2007-2009, however, the CAMS 82 monitor shows the same trend as the other two monitors, with a larger number of days favorable to ozone formation than high ozone days.

The data shown in Figure 3-2 suggest it is possible that declining design values at the Northeast Texas monitors are due in part to weather conditions during the last four years that were less conducive to ozone formation than in previous years (e.g. 2005), and that the decline in the number of high ozone days may also be related to decreases in background ozone transported into Northeast Texas. Next, we examine trends in diagnosed background ozone in Northeast Texas.

For each of the four highest 8-hour ozone days from each year during the period 2005-2009, we examined time series of ozone for the three Northeast Texas monitors. For each of these days, a value of peak background ozone was determined by inspection of the highest value reached by the monitor with the lowest peak ozone. The peak background ozone value for the four highest ozone days was averaged for the four highest days each year, and the values plotted for each monitor in Figure 3-3. A linear trend was calculated for each monitor and is shown along with the data in Figure 3-3. Although the procedure used to determine the background ozone is subjective, the trend shows background ozone declining at all three monitors with a ~4-7 ppb decrease from 2005-2009.

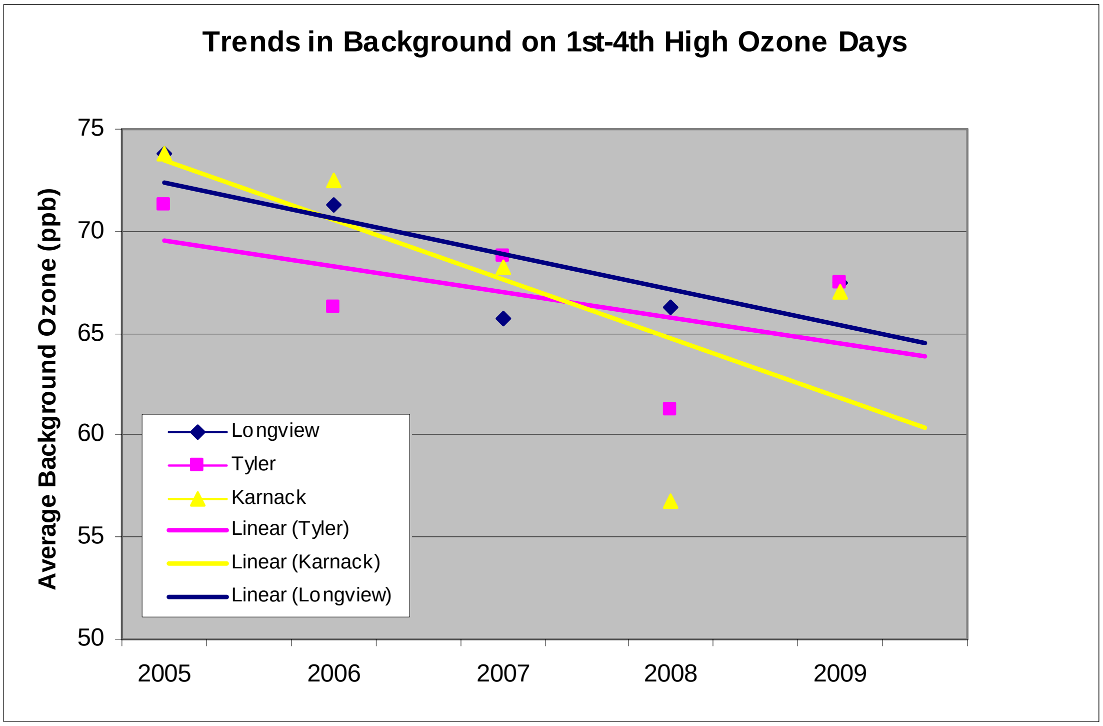


Figure 3-3. Trends in diagnosed background ozone: 2005 to 2009.

<u>3.1.2 2008 High Ozone Days</u>

In this section, we review 2008 ozone concentrations recorded at the Longview, Karnack, and Tyler ozone monitors. For the purposes of the analysis presented below, we define a high ozone day to be one on which the daily maximum 8-hour average ozone concentration was greater than 75 ppb or the daily maximum 1-hour average ozone concentration was greater than 85 ppb at one or more of the three Northeast Texas monitors. There were six such days in 2008.

Each high ozone day was analyzed using data for ozone, sulfur dioxide, NOx, and wind from the TCEQ CAMS ground-level monitors at Longview, Tyler and Karnack. For the period August 1-October 6, 2008, a Reactive Alkene Detector (RAD) instrument was deployed at the CAMS 19 monitor in Longview; this instrument detects highly reactive VOCs (HRVOCs) such as ethylene and isoprene that contribute to rapid, efficient ozone formation. Back trajectories were prepared for air arriving at each monitor that measured high ozone. The back trajectories were calculated using NOAA's HYSPLIT (Hybrid Single-Particle Lagrangian Integrated Trajectory) model and TCEQ's AQplot model. Back trajectories are a qualitative tool subject to theoretical and data limitations and were used only to investigate possible source regions for pollutants transported to the monitor.

Here follows an analysis of the high ozone days in Northeast Texas in 2008 based on the available data described in the previous paragraph:

- Three high ozone days at Longview were associated with calm or northerly winds and a rapid early morning rise in ozone. These sharp ozone increases during times of northerly winds are consistent with the impact of a plume containing highly reactive volatile organic compounds (HRVOCs) from the chemical plant complex owned by Eastman, Westlake, and Flint Hills (formerly Huntsman).

- On two of these three high ozone days at Longview, HRVOC data from the RAD instrument was available and confirmed the presence of HRVOCs during the rapid ozone rise.
- On several high ozone days at Longview, elevated sulfur dioxide was observed at the same time as the ozone peak, indicative of plume impacts from nearby coal-fired power plants. On one of these days, winds were southeasterly, suggesting possible impacts from the Martin Lake power plant in Rusk County. On two of these days, winds were northeasterly, consistent with possible plume impacts from the Pirkey Power Plant.
- Regional 8-hour ozone levels in air entering the region were 70 ppb or higher on August 4, when the Tyler and Longview monitors recorded peak 8-hour ozone values of 101 and 82 ppb, respectively.
- Four high ozone days at Longview and two at Tyler were associated with ozone production from local sources superimposed on a regional 8-hour ozone background of 60 ppb or greater.
- The highest 8-hour ozone measurement during 2008 was 101 ppb at the Tyler on August 4. This was likely due to an impact at the monitor from a source to its southeast and a second, later impact by the City of Tyler urban plume on a day with high (~70 ppb) regional background ozone. The high 8-hour value was due to the sustained high ozone levels caused by two separate plume impacts.

3.1.3 2009 High Ozone Days

Next, we discuss 2009 ozone concentrations recorded at the Longview, Karnack, and Tyler ozone monitors using the same definition of a high ozone day as for 2008 and the same data and method of analysis, except that there was no HRVOC monitoring at CAMS 19 available in 2009. There were nine high ozone days in 2009.

- On two high ozone days at Longview, elevated SO_2 was observed at the same time as the ozone peak, indicative of plume impacts from nearby coal-fired power plants. On both of these days, winds were northerly or northeasterly, consistent with possible plume impacts from the Pirkey Power Plant or power plants in Titus County.
- There was a high ozone event in March at the Longview monitor that was unusual in that it came so early in the year on a day when the peak temperature was 71ºF; this is ~20ºF lower than the typical temperature for a high ozone event in Northeast Texas. The Longview peak was about 40 ppb higher than the regional background of ~45 ppb. On this day, local winds were light and variable at Longview. There was some SO_2 present at the monitor, but there was no peak coincident with ozone peak. There is no clear explanation for this atypical event.
- One high ozone day at Longview occurred with northerly winds and a rapid early morning rise in ozone. This sharp ozone increase during a period of northerly winds and is consistent with the impact of a plume containing highly reactive volatile organic compounds (HRVOCs) from the chemical plant complex owned

by Eastman, Westlake, and Flint Hills. The Longview ozone peak was ~50 ppb higher than the regional background of ~50 ppb. There were two additional high ozone days when back trajectories indicated that emissions from the Eastman Complex may have played a role in elevated ozone at the Longview monitor.

- Three high days at Tyler occurred on days with high regional background, easterly winds and late afternoon impacts from the Tyler urban area. It is possible that power plant impacts also played a role in these Tyler events, but no definitive statement can be made because there is no SO_2 monitor at the Tyler CAMS site.
- The only high ozone day at the Karnack monitor showed a peak ~20 ppb higher than background of ~65 ppb, and was unusual in that ozone at Karnack on this day was higher than at Tyler or Longview. The south/southeasterly winds suggest that this could have been a power plant plume impact.

The surface monitoring data from the 2008 and 2009 ozone seasons are consistent with the conceptual understanding of the factors leading to ozone levels exceeding the 8-hour ozone standard in Northeast Texas. In 2008-2009, high ozone in Northeast Texas was often caused by emissions from sources within Northeast Texas superimposed on a high regional ozone background.

One important difference from previous years is that the Tyler monitor has had more frequent ozone impacts than Longview monitor. This is reflected in Figure 3-1, which shows that the 4th high ozone value for the Tyler monitor was higher than that of the Longview monitor in 2009. In Section 3.1, we noted that the Tyler monitor seems to have a different relationship between weather and high ozone days than the Longview and Karnack monitors during 2002-2006. It is clear that additional analyses should be performed to improve our understanding of high ozone days at Tyler. One important data need is the installation of an SO_2 monitor at the Tyler monitor. This will help determine the role played by impacts from coal-fired power plants in causing high ozone at Tyler and their relative importance compared with impacts from the Tyler urban plume. Other analyses that should be performed are an examination of recent precursor trends in the Tyler area and, subsequently, and evaluation of any modeling needs for accurate representation of ozone impacts at Tyler in future ozone modeling of Northeast Texas.

3.2 HRVOC MONITORING AT CAMS 19

For several years, NETAC has collected canister VOC samples at CAMS 19 to augment the TCEQ's monitoring activities at Longview. NETAC continued to collect VOC data at CAMS 19 in 2008. During August-October of 2008, NETAC carried out a successful monitoring program which confirmed the presence of intermittent plumes containing very high concentrations of highly reactive VOCs (HRVOCs) at CAMS 19 (Jobson and Pressley, 2009). HRVOCs were analyzed using a reactive alkene detector (RAD) which made a measurement once every second, 24 hours a day, providing a nearly continuous record of HRVOCs at CAMS 19 from August 1 through October 6, 2008. The high resolution RAD data confirmed the intermittent character of anthropogenic HRVOC impacts suggested by 2006 VOC monitoring data from CAMS 19 (Air Quality Solutions, 2006; Kemball-Cook et al., 2007), and showed that HRVOCs are present on a significant fraction of days, with 10 of 64 days showing strong RAD signals above 30 ppb.

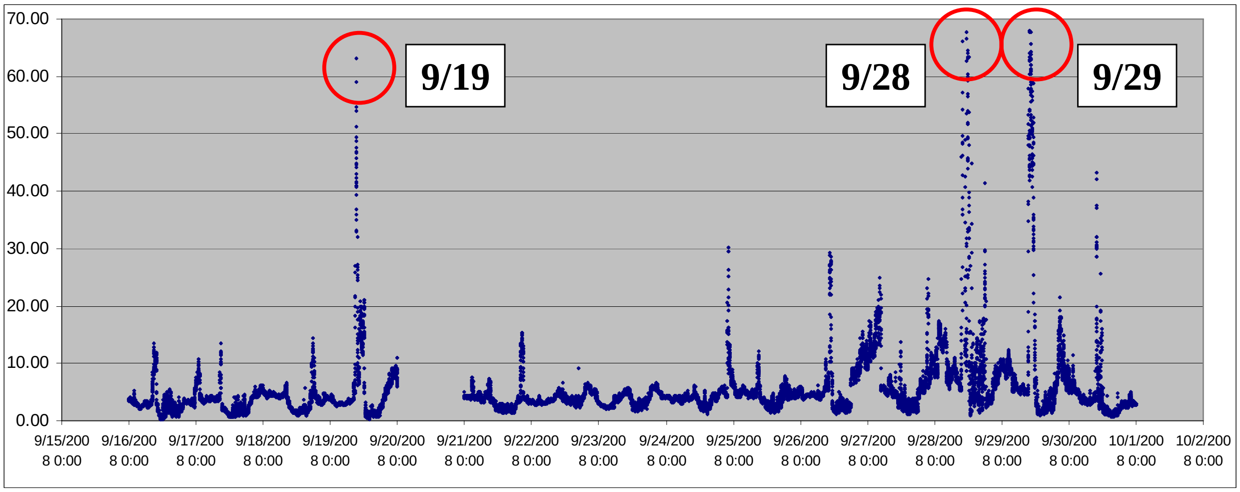


Figure 3-4. RAD time series for September, 2008. Units are ppbV.

The natural background for HRVOCs (i.e. biogenic HRVOCs whose primary constituent is isoprene) may be expected to be approximately 10 ppb at midday. NETAC has investigated the relationship between periods of high ozone and high HRVOC levels at CAMS 19. Many periods of high HRVOC levels were not associated with high ozone at CAMS 19; most of these occurred at night. Some days with strong HRVOC signals may not have been conducive to ozone formation (lower temperatures, clouds). However, high 1-hour ozone values coincided with HRVOC spikes under northerly winds on 3 days in September (Figure 3-4), suggesting Eastman Complex impacts.

As an example of these September high ozone days, Figure 3-5 shows back trajectories showing the path travelled by air that arrived at each of the Northeast Texas monitors at the time of the CAMS 19 ozone peak on September 19. The back trajectories were calculated using TCEQ AQplot tool together with surface winds from the three CAMS monitors. The back trajectory for CAMS 19 shows that air arriving at CAMS 19 at the time of ozone peak traveled over the Eastman Complex just to the north of the monitor. The HRVOC peak precedes the ozone peak, and the SO_2 time series indicates that there was little SO_2 at the time of 10 am ozone peak; this means that the ozone peak at CAMS 19 cannot be attributed to the impact of a plume from a coal-fired power plant such as those in Titus County to the north of CAMS 19.

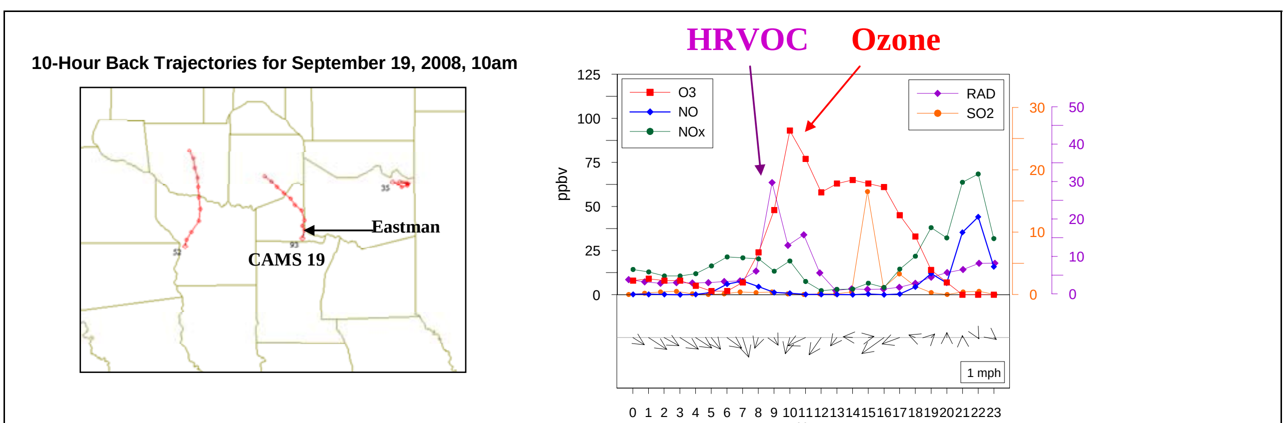


Figure 3-5. Back trajectories from AQplot for the Northeast Texas monitors for September 19 at the time of peak ozone impact at CAMS 19 (left panel).

On March 11, 2009, NETAC sent a request for information to the Eastman Chemical Company, Westlake Chemical Company, and Flint Hills Resources asking whether they had had any upsets or unusual events on the days when HRVOC spikes were observed at CAMS 19. All three companies investigated the 2008 days with HRVOC events and found no unusual activity on those days.

Since the HRVOC measurements suggest that the Eastman Complex can play a role in high ozone events at CAMS 19, a modeling effort was undertaken in 2009 in order to improve our understanding of sources within the Eastman Complex. The main purpose of this modeling, which is described in Section 4, was to determine the magnitude of emissions required to produce HRVOC spikes at CAMS 19, assuming that the HRVOCs originate within the Eastman Complex. The modeling results suggest that the HRVOC emissions needed to produce observed spikes are greater than the typical day emission inventory. Ethene emissions of ~2500 lbs/hr can cause observed morning ozone spikes at CAMS 19 through interaction with readily available NOx. Potential sources of such emissions are not understood. Estimates of Eastman Complex ethene (HRVOC) inventory derived from the 2006 NETAC aircraft flight are consistent with the TCEQ 2005 emission inventory for a typical ozone season day (Kemball-Cook and Yarwood, 2007). The Eastman Complex operators believe that such a large release (about 1 ton per hour) could not have occurred without detection by their control and/or safety instrumentation. Therefore, the origin of these HRVOC spikes remains unclear. NETAC will undertake additional HRVOC monitoring during 2010 using event-triggered canister data sampling. Analysis of canister samples taken during HRVOC spikes will allow chemical fingerprinting of the source(s) of the spikes that can further our understanding of high HRVOC/ozone events at CAMS 19.

3.3 SURFACE MOBILE MONITORING

The monitoring network in Northeast Texas area is relatively sparse compared to that of an urban non-attainment area such as Houston or Dallas-Fort Worth. Surface mobile monitoring is an effective method for collecting air quality data over large geographic regions between fixed surface monitoring stations (e.g., TCEQ's CAMS locations). Instruments are installed in a vehicle that is driven along roads to conduct concentration surveys. Concentration maps can then be used to evaluate the impacts of specific point sources on an area and to assess photochemical model performance.

From September 2009 to November 2009, researchers from the University of Texas Austin (UT) performed surface mobile monitoring in Rusk, Panola, and the southern portions of Gregg and Harrison counties (Durrenberger et al., 2010). The pollutants measured were ozone, CO, $SO_{2,}$ $NO_{y,}$ methane and total non methane hydrocarbon (THMHC). The mobile monitoring study is documented in Durrenberger et al., (2010). The monitoring program was designed and performed by UT and the sampling platform was a General Motors Suburban. UT developed 10 sampling routes that were covered twice on each sampling day. The first cycle was from approximately 11:00 a. m. to 2:00 pm local time and the second cycle was from approximately 2:00 pm to 5:00 p.m. local time. Trips were made when there was no rain. Sampling routes were planned so that they covered approximately 50 to 60 miles. To minimize interference with emissions from mobile sources and to minimize the exposure of the instruments to high levels of dust, it was desired to travel on paved roads that had minimal traffic density. For each sampling cycle, UT developed route concentrations maps for NO_y, ozone, SO_2 and TNMHC. Ten monitoring trips were made from September 2009 to November 2009.

The sampling trips were developed to provide information for photochemical grid model development and performance evaluation, as well as emission inventory assessment. Trip plans were designed to accomplish three specific objectives: (1) collect air quality data in Northeast Texas in the regions between fixed monitoring sites (2) map the potential transport of pollutants into the Northeast Texas, and (3) evaluate emissions from local sources such as drilling rigs. Unfortunately the mobile monitoring study did not coincide with high ozone in Northeast Texas, so the transport assessment was not carried out. Although drill rigs were sampled, it proved difficult interpret the results and the 2 canister samples that were taken were inconclusive. However, the mobile monitoring study did provide data that can be used to evaluate the simulation of NOy in NETAC's 2005 ozone model.

Figure 3-6 shows a composite of the NOy sampling results in which NOy mixing ratios for all sampling trips during a given period are combined onto one plot. Only data for which NO<5ppb are shown on the maps. This is to exclude the passage of trucks, which were more numerous on these farm-to-market roads than was anticipated. The plots show that background levels of NOy on these low ozone days is approximately 2-6 ppb. Superimposed on this background are variations that occur as the vehicle passed plumes emitted from a variety of sources.

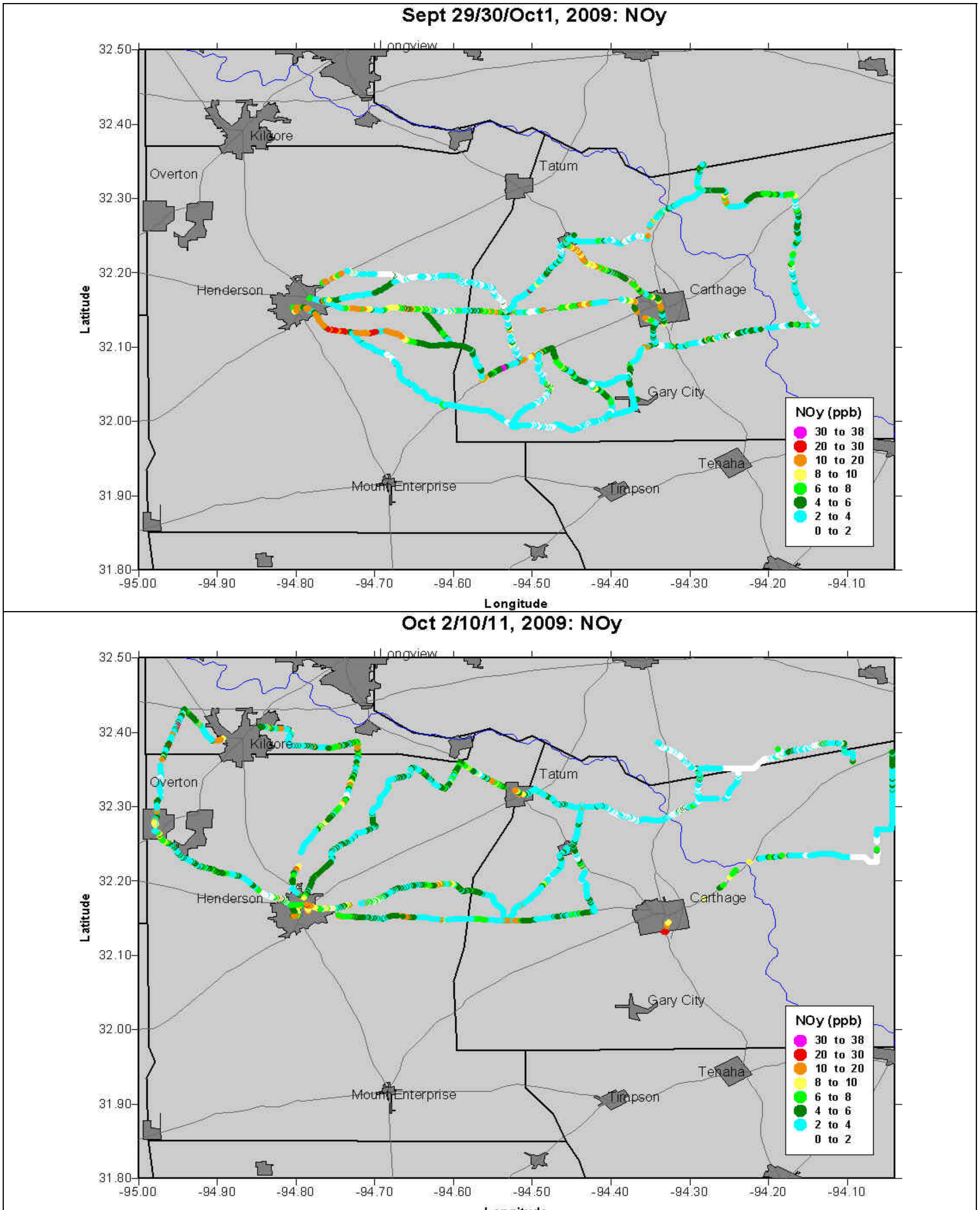


Figure 3-6. Route concentration maps for NOy showing all trips carried out on September 29-October 1, 2009 (upper panel) and October 2, 10 and 11, 2009 (lower panel).

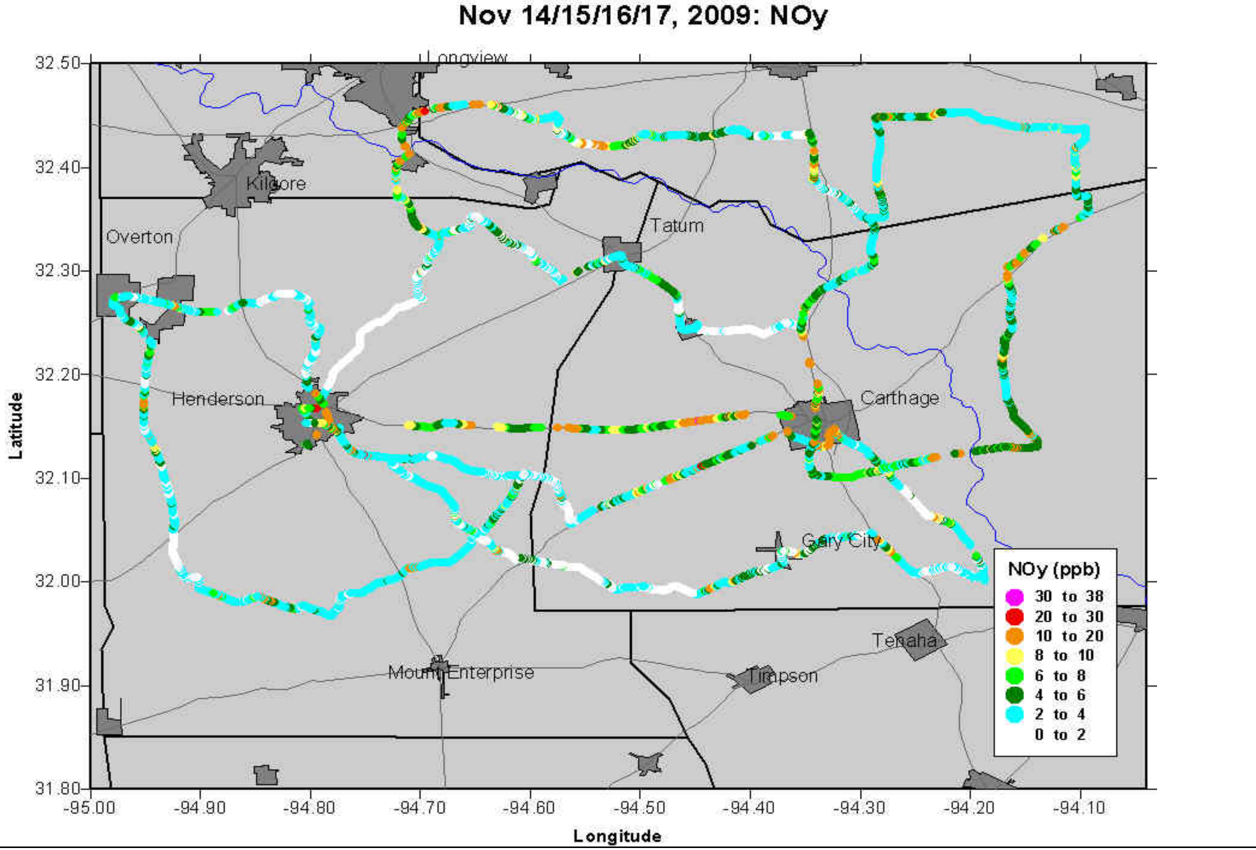


Figure 3-6 (continued). Route concentration maps for NOy showing all trips carried out on November 14-17, 2009.

We now compare the results of the mobile NOy sampling with the NOy predictions from the May-June 2005 ozone model. We select low ozone days to compare the modeled NOy with the mobile monitoring results because the mobile monitoring was conducted on low ozone days. The daily maximum 8-hour ozone is shown for each episode day in Figure 3-7. None of the sampling days had daily maximum 8-hour ozone higher than 56 ppb at any of three Northeast Texas monitors. May 20, May 29, May 30, and June 13 are the days with the lowest average daily maximum 8-hour ozone. The 1 pm NOy field for each of these days is shown in Figure 3-8. 1 pm was chosen because it falls during the middle of the first sampling cycle of the day.

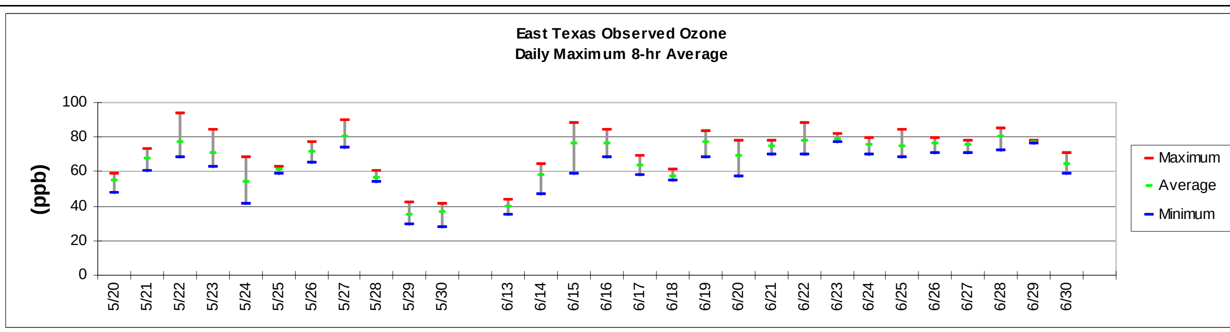


Figure 3-7. Daily maximum 8-hour ozone at Northeast Texas monitors during the May-June 2005 modeling episode.

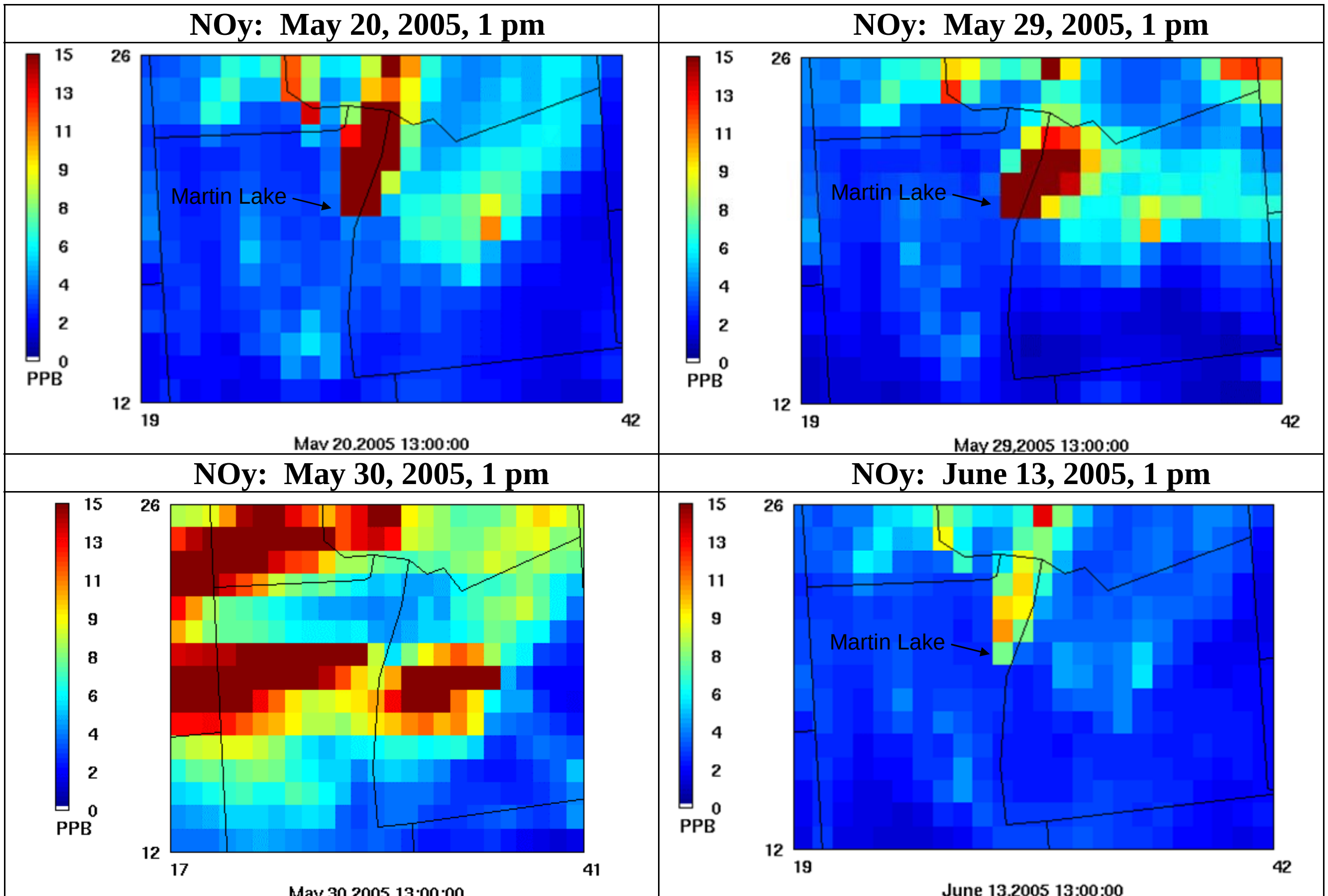


Figure 3-8. 1-hour average NOy within the region of the 4 km domain where the mobile sampling took place. Days shown were low ozone days comparable to the days when the mobile sampling was carried out.

Figure 3-8 shows that NOy varies widely across the region with plumes showing enhancements in NOy against a background of 1-6 ppb. For example, the Martin Lake power plant plume is apparent in all four panels. The background NOy is similar in the model and in the measurements. This can also be seen in the four time series in Figure 3-9. These time series are for grid cells that lie in the southern half of the region shown in Figure 3-8 that are relatively removed from the plumes from Martin Lake and the gas plant at Carthage. These time series show a background of generally less than 10 ppb of NOy with excursions to much higher values when NOy plumes pass over the cell.

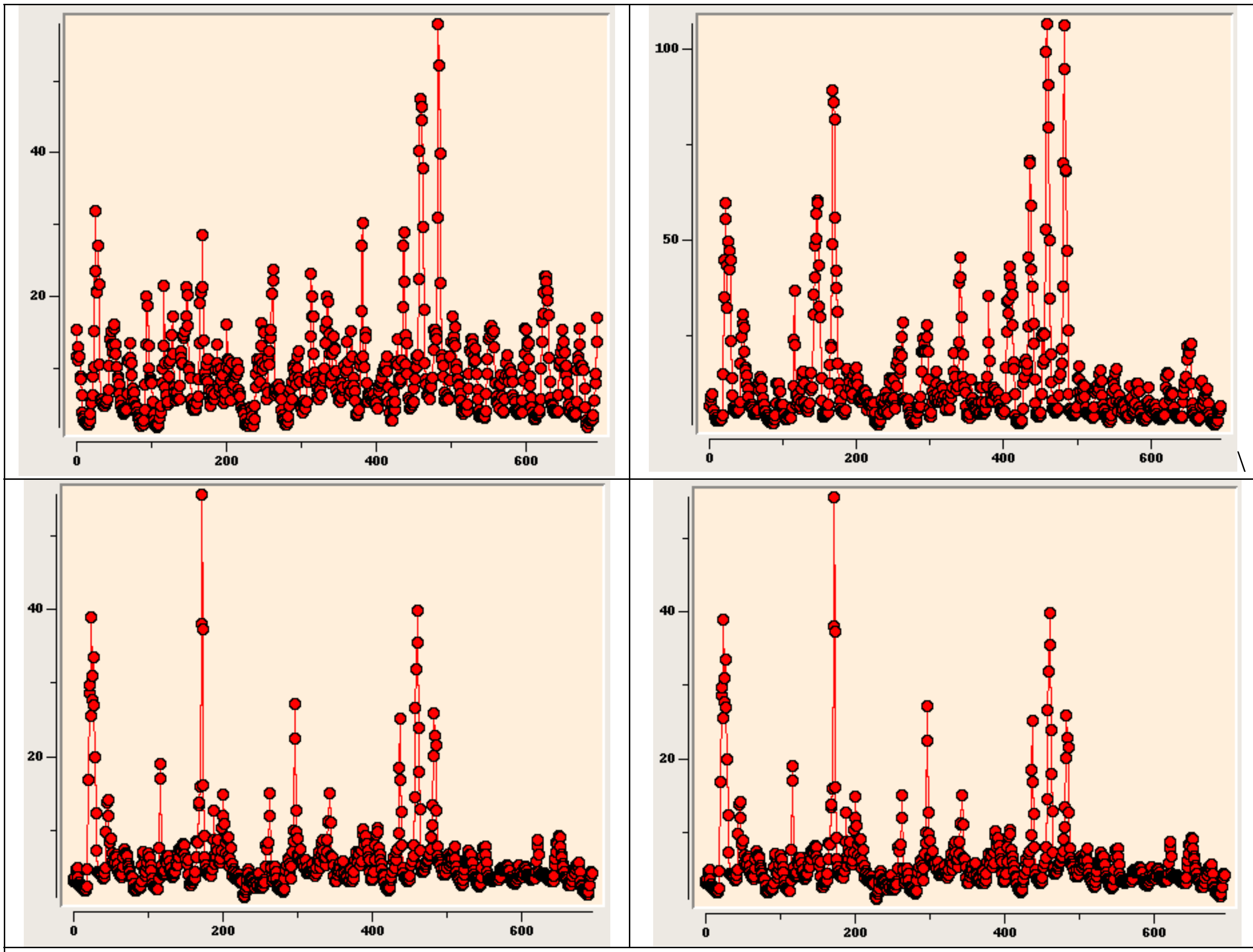


Figure 3-9. 1-hour average NOy time series from grid cells within the region of the 4 km domain where the mobile sampling took place.

4.0 MODELING

In this section, we discuss ozone modeling that NETAC has performed since the last Conceptual Model update. Ozone modeling is used in concert with ambient data and emissions information to form a conceptual picture of the conditions that lead to high ozone days as well as for testing control strategies. The use of source apportionment tools within the framework of an ozone model can shed light on the importance of regional transport relative to the contribution of local sources. Models can also be used to identify components of the emission inventory which require revision.

4.1 MODELING OF MAY-JUNE, 2005

NETAC has developed a SIP-quality seasonal ozone model for the period May-June, 2005 (Kemball-Cook et al., 2008b, Kemball-Cook et al., 2010). This model is being used to understand the conditions leading to elevated 8-hour ozone concentrations in Northeast Texas in 2005, (in particular, at the Longview monitor) through an examination of the influences of regional transport, local sources and meteorological variability on Northeast Texas ozone levels. The purpose of this effort was to extend previous NETAC Northeast Texas modeling work by updating the emissions inventories and meteorological database, incorporating additional ambient monitoring, and bringing all the information together through the development and application of a photochemical ozone modeling system. The model is being used to help evaluate the likelihood of future exceedances of the ozone NAAQS in the area and to develop emissions reduction strategies to ensure that the area does not exceed the ozone NAAQS in the future.

Toward these ends, the following tasks were performed:

- Meteorological modeling for the entire domain was performed using version 3 of the Fifth-Generation Pennsylvania State University/National Center for Atmospheric Research (PSU/NCAR) Mesoscale Model (MM5). As part of this effort, new software was developed to incorporate NOAA Profiler Network tropospheric profiler data for use in observation nudging. TexAQS II boundary layer profiler data supplied by TCEQ was also used for observation nudging.

- A comprehensive 2005 emission inventory was developed with the most recent data available.

- The Comprehensive Air Quality Model with extensions (CAMx) using a nested 36 km/12 km/4 km grid was used to simulate the period May 20-June 30, 2005. The period included five 8-hour ozone exceedance events, four of which occurred at the Longview monitor. Diagnostic tests, a performance evaluation, and sensitivity analyses were performed with the model.

Since the 2008 conceptual model, a series of updates have been made to the emissions and meteorological databases as well as to the CAMx model itself and the model boundary conditions. The MM5 model simulation of winds and the CAMx simulation of peak ozone on two of the highest ozone days were improved through the use of the Grell cumulus parameterization in the MM5 model. Updates to the emission inventory include the new TCEQ 2005 drill rig emission inventory and revised load factor data for gas compressor engines in the 5-County area. A new dry deposition algorithm (Zhang et al. 2003; Zhang et al. 2008) was used in CAMx, as well as a modified treatment of vertical mixing aimed at improving nighttime ozone performance. The sensitivity of the model to each of these changes was tested and a revised model performance evaluation was carried out with the base case 2005 model in its final configuration. The evaluation of the updated base case 2005 ozone model for Northeast Texas showed that the model was able to reproduce observed ozone concentrations at the three Northeast Texas CAMS monitors with good accuracy that is comparable to past regulatory modeling applications. Comparison of the model's performance statistics with those of similar model runs shows that the model performs well enough to be used in SIP modeling and control strategy evaluation. Once the 2005 base case model performance was found to be acceptable, a future year ozone model was developed for the year 2012.

4.2 MODELING OF MAY-JUNE 2012

The selection of the 2012 future year for ozone modeling was made in the fall of 2008 following the promulgation of the 0.075 ppm 2008 ozone standard. At that time, 2012 was a likely date for Northeast Texas to be required to comply with the 2008 ozone standard. Therefore, 2012 was chosen as the future year to be modeled. With a new ozone standard scheduled to be promulgated in 2010, the date designated for Northeast Texas to attain the standard may be pushed further into the future; however, 2012 remains a useful year for examining near-term ozone impacts of expected emissions changes and control strategies on Northeast Texas

Major changes in emissions between 2005 and 2012 are nationwide controls on emissions from on-road vehicles under the Federal Motor Vehicle Control Program (FMVCP) as well as emissions reductions at EGUs due to the CAIR. Locally, the East Texas Combustion Rule affecting certain East Texas engines went into effect on March 1, 2010. These emissions reduction programs are discussed in more detail in Section 2.

The 2012 emission inventory was based on TCEQ's 2018 inventory developed for Houston SIP modeling with revisions to the amount of emissions growth and the implementation of future emission controls in order to adapt the inventory for use in 2012. The TCEQ had developed 2012 emissions data for some source categories (i.e. on-road mobile and area sources), and these were incorporated directly into the 2012 model. Local enhancements were then made to the 2012 emission inventory that were specific to Northeast Texas. Among these were projection of growth and controls for local oil and gas emissions sources, reductions from the Texas Emissions Reduction Program (TERP) and projected 2012 emissions for large local point sources such as EGUs and the Eastman Complex in Longview.

The modeling strategy was to alter the baseline 2012 emission inventory to reflect anthropogenic emissions changes from projected growth or new controls, run the 2012 model with the altered emission inventory, and then compare the ozone results with those of the 2012 baseline model: the difference between the 2012 baseline model results and the results obtained from the 2012 run with the altered emission inventory shows the ozone impacts of the emission changes. First, we present the results of the 2012 baseline modeling and discuss the implications for the 5-County area's attainment status. Then, we discuss the results of two 2012 emissions sensitivity tests in which we examined the ozone impacts of projected development of natural gas resources in the Haynesville Shale and evaluated the 2012 ozone impacts of the East Texas Combustion Rule.

4.2.1 Baseline 2012 Projections

The main question addressed by the 2012 baseline modeling is: How do changes in anthropogenic emissions from 2005 to 2012 as quantified in Section 2 affect Northeast Texas ozone? To answer this question, the CAMx model ozone output for the 2005 and 2012 May-June episode was used to apply EPA's Modeled Attainment Test Software (MATS; Abt, 2009) tool. A detailed description of the procedures used is given in Kemball-Cook et al., (2010). MATS allows the model to be used in a relative sense, scaling observed base year ozone with model results for the base and future years to project future year ozone values. The scaling factors are known as relative reduction factors (RRFs). This technique is designed to reduce the uncertainty in future year projections due to any model bias that may be present. We compare the predictions of the raw CAMx results with the MATS projections and place them in the context of recent observed ozone trends in Northeast Texas. The RRFs, 2005 base year design values and 2012 future year design values for the Longview, Tyler and Karnack monitors are shown in Table 4-1. Note that the current year DVC used in MATS are not true design values but are instead averages of the 2004, 2005, and 2006 design values. This allows 5 years of data to be used rather than three, forming a more stable average that is weighted toward the 2005 year of interest.

Table 4-1. Current (DVC) and future year (DVF) design values and relative reduction factors (RRFs) at monitors in the 4 km domain.

Monitor	DVC: 2005	DVF: 2012	RRF
Longview	84	81	0.9678
Karnack	79	75	0.9617
Tyler	81	76	0.9437
Bossier	78	73	0.9479
Caddo	79	76	0.9662

All of the monitors show RRFs that are less than one, which indicates that ozone is reduced in 2012 relative to 2005 at all monitors. The Karnack, Bossier, and Caddo monitors have DVF<76 ppb, and therefore attain the 2008 ozone standard. The Longview and Tyler monitors have DVF>75 ppb, and do not attain the 2008 ozone standard. None of the monitors has DVF<70 ppb, which means that all monitors in the 4 km domain fail to attain the all potential standards in the range of primary ozone standards proposed by the EPA in 2010 (60-70 ppb).

4.2.2 Unmonitored Area Analysis

The above method of projecting future year design values applies only to grid cells containing monitors, and it is necessary to project future ozone values for areas in the domain that lie between the monitors. An unmonitored area analysis (EPA, 2007) is therefore performed that interpolates the observed DVCs across the modeling domain and performs ozone projections in each grid cell using the procedures given above; one exception is that only the modeling results within each grid cell rather than using the surrounding grid cells in addition to the grid cell itself. DVCs are interpolated from monitoring sites to each grid cell in the modeling domain. The modeled ozone gradients are taken into account in the interpolation in order to reflect modeled higher and lower ozone areas in the interpolated DVC field. Finally, an RRF is calculated for each grid cell and is used together with the DVC for that grid cell to arrive at a DVF for each grid cell. MATS is used to carry out this entire procedure.

The results of the unmonitored area analysis are combined with the results at the monitors and are shown together in Figure 4-1; 2005 DVCs are shown in the left panel and 2012 DVFs are shown in the right panel. The DVF-DVC difference is shown in Figure 4-2.

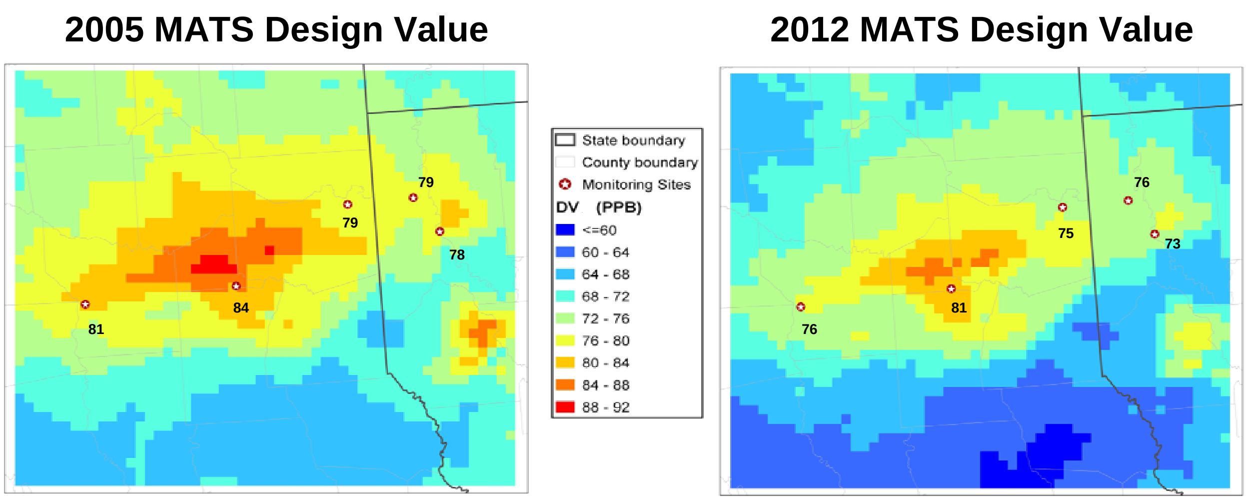


Figure 4-1. MATS Current year design values (DVC) for 2005 (left panel) and future year design values (DVF) for 2012 (right panel). Design values for each monitor are shown adjacent to the monitor.

In Figure 4-1, grid cells colored yellow, orange and red show areas where the design value is greater than 75 ppb, indicating a violation of the 2008 ozone standard. Areas colored green and blue attain the 2008 standard but may violate the proposed 2010 ozone standard. Only a small region in the southern portion of the 4 km domain has DVF<60 ppb, indicating attainment of the full range of values of the proposed 2010 ozone standard. The area of the 4 km domain that violates the 2008 standard is smaller in 2012 than in 2005, consistent with the reductions in ozone precursor emissions discussed in Section 3. Figure 4-2 shows reductions of 5-7 ppb in the northwestern portion of the domain, reductions due to the Dolet Hills power plant in the southeastern portion of the domain, and a band oriented southwest to northeast in which ozone reductions are smaller. The only ozone increase shown anywhere in the domain is in the grid cell containing the Dolet Hills power plant.

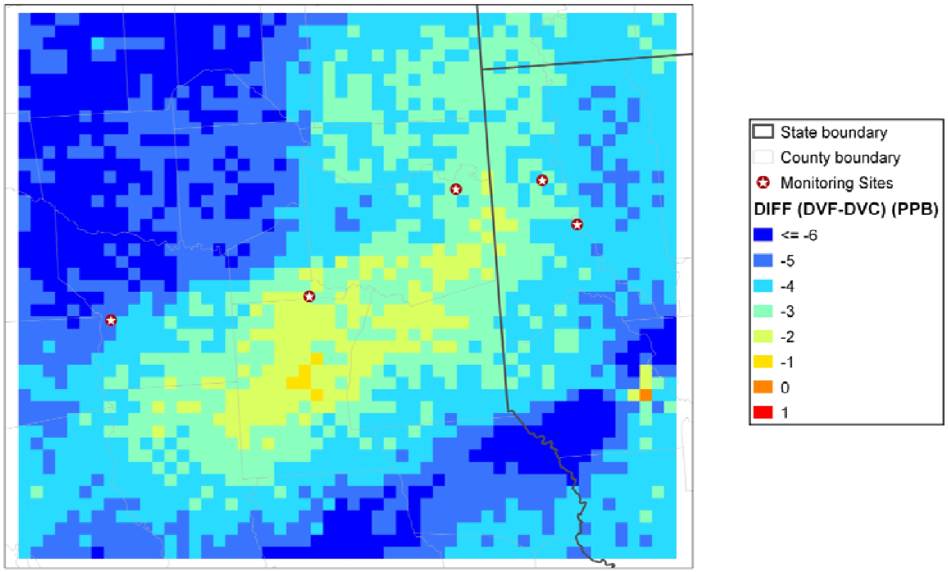


Figure 4-2. Difference between MATS Current year design values (DVC) for 2005 and future year design values (DVF) for 2012.

In summary, the CAMx model was used together with the EPA MATS tool to project future year ozone for a 2012 emissions scenario using 2005 meteorology. The model shows the Karnack monitor in attainment of the 2008 ozone standard of 75 ppb and Longview and Tyler out of attainment of the 2008 standard. All three Northeast Texas monitors had 2012 design values that would cause them to violate the 2010 ozone standard at the entire range of EPA's proposed values of the primary standard (60-70 ppb).

Although the modeled 2005-2012 design value trends show smaller decreases than are observed between 2005 and 2009, the modeled decrease in background ozone is consistent with observed trends, and the modeled ozone changes are consistent with changes in the local and regional emission inventories from 2005 to 2012. Analysis of the emissions data indicates that holding EGU emissions fixed from 2005 to 2012 is not likely to be the source of the difference in observed and modeled design value trends, although uncertainty is introduced by holding the Eastman Chemical Company's 2012 emissions fixed at their 2005 levels. There is however, uncertainty in the future year oil and gas emission inventory.

Examination of the 2012 emission inventory indicates that area sources are the only source category with NOx emissions that increase from 2005 to 2012 and that oil and gas sources are an important component of this inventory. Area source oil and gas emissions in the 5-County area were extrapolated from 2005-2008 TRRC data (Section 2), and therefore do not include effects of the recent economic slowdown. It is possible that the growth projections are too large, given that overall economic activity and natural gas prices fell sharply in 2008; these factors would be expected to make natural gas exploration and production less profitable and therefore to lower emissions associated with these activities. However, the 2012 baseline emission inventory also does not include emissions from development in the Haynesville Shale. Drilling in the Haynesville Shale did not begin in earnest until 2009, so emissions from exploration and production of natural gas resources within the Haynesville Shale are not included in the 2012 projections that are based on 2005-2008 TRRC data. An emission inventory of ozone precursors for the Haynesville Shale for the year 2012 has been developed (Grant et al., 2009), but these projections have a high level of uncertainty associated with them due to the limited amount of data available; therefore, analysis of ozone impacts of the Haynesville Shale emissions was treated as a sensitivity test (see Section 4.3 below) rather than as part of the baseline 2012 modeling.

The 2005 year was selected for the Northeast Texas modeling precisely because 2005 had unfavorable meteorological conditions that resulted in high observed ozone; 2005 ozone values drove the Longview monitor's design value and the area's attainment status through 2006. Although similar weather conditions have not repeated during 2006-2009 period, they could recur, and the modeling suggests that if similar weather conditions were to occur under the 2012 emissions scenario, the area would not meet the ozone standard that is likely to be in place in 2012.

The results of this analysis, taken together with the excellent performance of the 2005 base case model, suggest that the 2012 model results are reasonable given trends in observed ozone and emissions and that the 2012 model can be used to assess effects of emissions growth as well as control strategies.

4.3 OZONE IMPACTS OF DEVELOPMENT OF THE HAYNESVILLE SHALE

As discussed above, the ozone impacts of the Haynesville Shale were evaluated as a sensitivity test using the 2012 ozone model. The Haynesville Shale and the emission inventory for 2012 that was used in the following ozone impact assessment are described in Section 2. The low, medium and high Haynesville Shale scenario emissions were each added in turn to the 2012 baseline emission inventory, and a CAMx simulation for the May-June 2012 period was run for each scenario. These runs were identical to the 2012 baseline CAMx runs except for the addition of the Haynesville Shale emissions. Next, ozone results for each of the three runs were compared with the 2012 baseline ozone model results. Comparison of the differences in the episode average daily maximum 8-hour ozone are shown for the low and high Hayneville Shale scenarios in Figures 4-3 and 4-4 for the 4 km grid and 12 km grid, respectively. The impacts from the medium emissions scenario fall between the low and high cases and are not shown here for the sake of brevity. The average 8-hour ozone impacts in Northeast Texas range from 0-6 ppb with the largest impacts occurring in Louisiana in the high emissions scenario. The episode average impact at the Longview monitor was 3-4 ppb in the high scenario and 1-2 ppb in the low scenario. At the Tyler monitor, impacts were < 1 ppb in the low scenario and 1-2 ppb in the high scenario. The Karnack monitor, which lies within the Haynesville Shale region, has the largest impacts, which are 2-3 ppb in the low scenario and 4-6 ppb in the high scenario. Average impacts greater than 1 ppb were restricted to Northeast Texas, Louisiana, Arkansas and Oklahoma.

Figure 4-5 and 4-6 show the maximum differences in the daily maximum 8-hour ozone across the entire May-June episode. Maximum impacts at the Longview monitor range from 4-6 ppb in the low scenario to 8-10 ppb in the high scenario. Impacts at the Tyler and Karnack monitors are somewhat lower with Tyler ranging from 1-4 ppb. For Karnack, impacts ranged between 3-8 ppb. The 12 km grid shows that the impacts of development in the Haynesville Shale can extend outside Northeast Texas into other regions of Texas in both low and high scenarios.

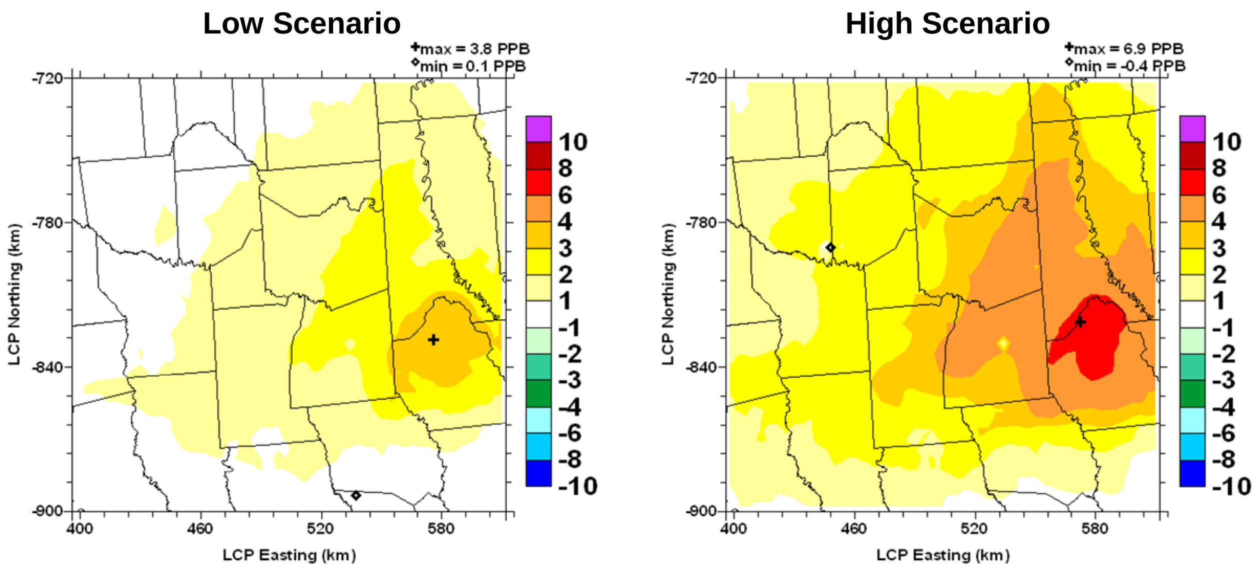


Figure 4-3. Episode average difference in daily maximum 8-hour ozone for the year 2012: Haynesville Run-2012 Baseline Run for the 4 km grid.

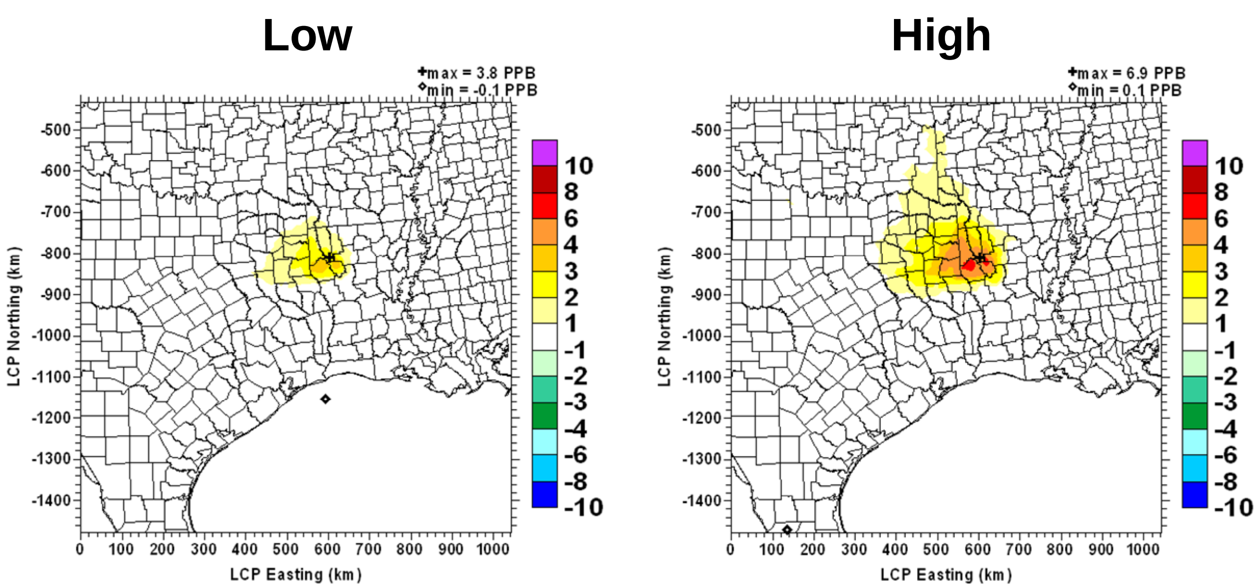


Figure 4-4. Episode average difference in daily maximum 8-hour ozone for the year 2012: Haynesville-Baseline for the 12 km grid.

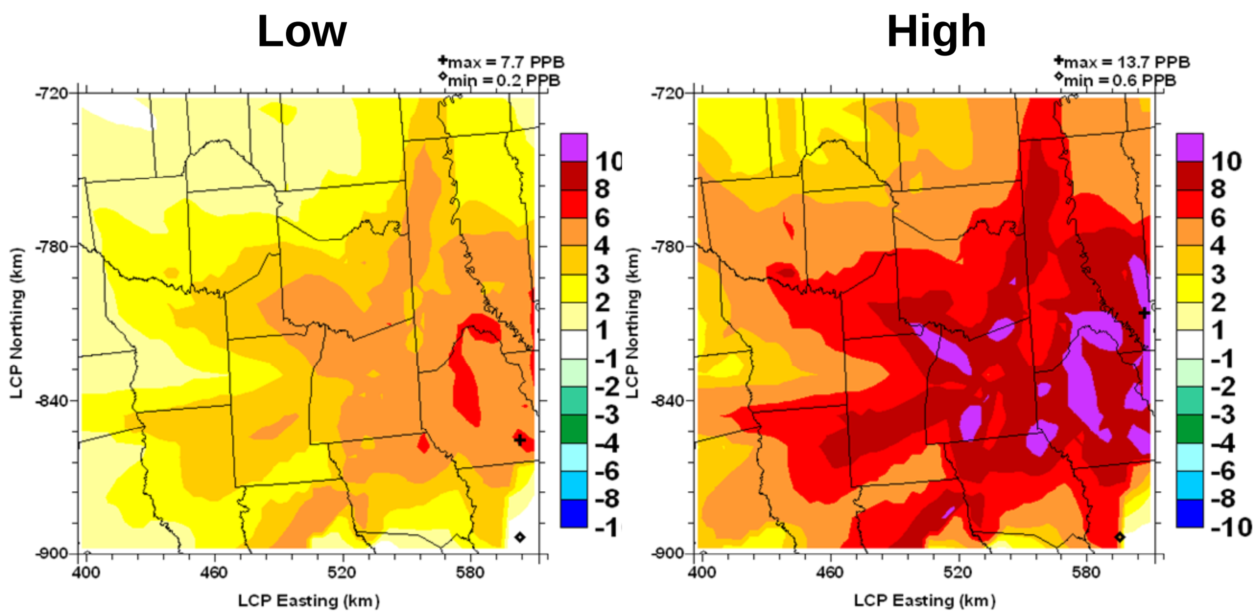


Figure 4-5. Episode maximum difference in daily maximum 8-hour ozone for the year 2012: Haynesville-Baseline for the 4 km grid.

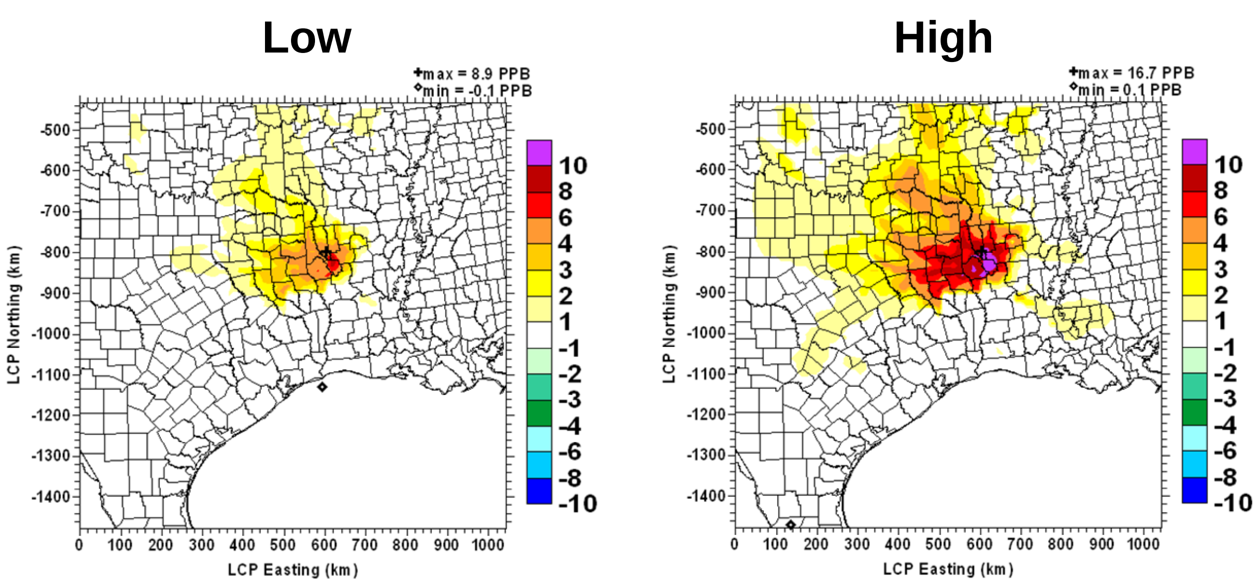


Figure 4-6. Episode maximum difference in daily maximum 8-hour ozone for the year 2012: Haynesville-Baseline for the 12 km grid.

These results show that Haynesville Shale development is an area of concern for future air quality in Northeast Texas. There is significant uncertainty associated with the emissions estimates since development in the Haynesville Shale is still in its early stages. The assumptions used in the development of the inventories – particularly the minimal usage of wellhead compressors –indicate that these inventories could represent a lower bound on the potential emissions from these scenarios. It is also possible that some source categories may be overestimated-for example, improvements in drilling technology could reduce future drilling times and therefore, NOx emissions associated with drilling. Analysis of the emission inventories suggests that if the development of the Haynesville Shale proceeds at even a relatively slow pace, emissions from exploration and production activities will be sufficiently large that their potential impacts on ozone levels in Northeast Texas may affect the area's ozone attainment status. This study only evaluates near-term ozone impacts of development, but the emission inventory indicates that emissions may be expected to increase beyond 2012.

Additional study is required to refine the emission inventories used in this analysis. The inventory would benefit from additional data regarding well site compression, well decline curves, and drill rig use. Input from energy companies would be very useful in constraining the emissions projections.

4.4 OZONE IMPACTS OF THE EAST TEXAS COMBUSTION RULE

The 2012 baseline simulation includes the effects of forecast growth in gas production in the 5-County area as well as the East Texas Combustion Rule (ETxCR). The ETxCR NOx controls on the 5-County area gas compressor engine inventory were removed so that emissions were affected only by growth derived from the TRRC data shown in Figure 2-14.

Figure 4-7 shows that the episode average ozone reductions from the ETxCR were on the order of 1-2 ppb in Northeast Texas, with maximum reductions as high as 5 ppb. Impacts were highest in the vicinity of the region where natural gas wells are concentrated. Maximum reductions ranged from 1-2 ppb at the Longview and Tyler monitors to 2-3 ppb at the Karnack monitor.

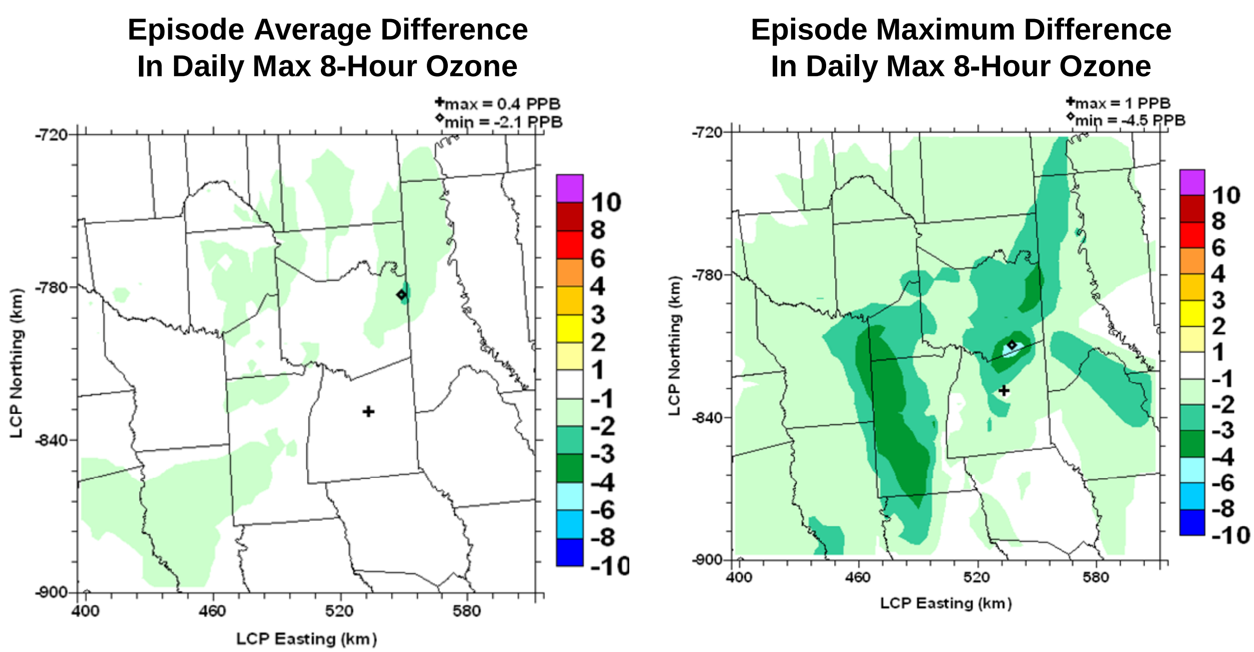


Figure 4-7. Left panel; episode average difference in daily maximum 8-hour ozone for the year 2012: ETxCR-2012 Baseline Run for the 4 km grid. Right panel; episode maximum difference in daily maximum 8-hour ozone for the year 2012: ETxCR-2012 Baseline Run for the 4 km grid.

The ozone modeling results above show that the development in Haynesville Shale may have significant effects on air quality in Northeast Texas, and that the East Texas Combustion Rule can provide significant ozone benefits to Northeast Texas. These results underscore the importance of the accurate characterization of oil and gas emissions and suggest that future emission inventory efforts should be directed toward reducing uncertainty in this source category. Updating the Haynesville Shale emission inventory should be an immediate priority for future work, as should tracking compliance with the East Texas Combustion Rule in order to refine future emission inventory development.

4.5 OZONE TRANSPORT EVALUATION

Previous conceptual models have discussed NETAC's evaluation of the impact of transport on ozone levels monitored locally using both ambient monitoring and photochemical modeling to investigate the contribution of ozone transport to high ozone in Northeast Texas. Ozone measurements collected by aircraft are shown in Figures 4-8 and 4-9 for days from 2002 and 2006 when easterly winds transported high concentrations of ozone (above 70 ppb) across the border and into Northeast Texas (Buhr et al., 2003; Alvarez et al., 2006; Alvarez et al., 2007). On August 29, 2002, Baylor University's aircraft found ozone above 70 ppb at an altitude of 500 to 600 m along the border between Texas and Louisiana. The daily 8-hr ozone recorded at the Karnack surface monitor was 88 ppb on this day. On September 8, 2006, an aircraft from the National Oceanic and Atmospheric Administration equipped with downward looking ozone LIDAR found ozone above 70 ppb through a deep layer along the border between Texas and Louisiana. Winds were easterly on this day and the daily 8-hr ozone at Karnack was 71 ppb. The aircraft data make clear that ozone transport contributed most of the ozone in Northeast Texas on these days.

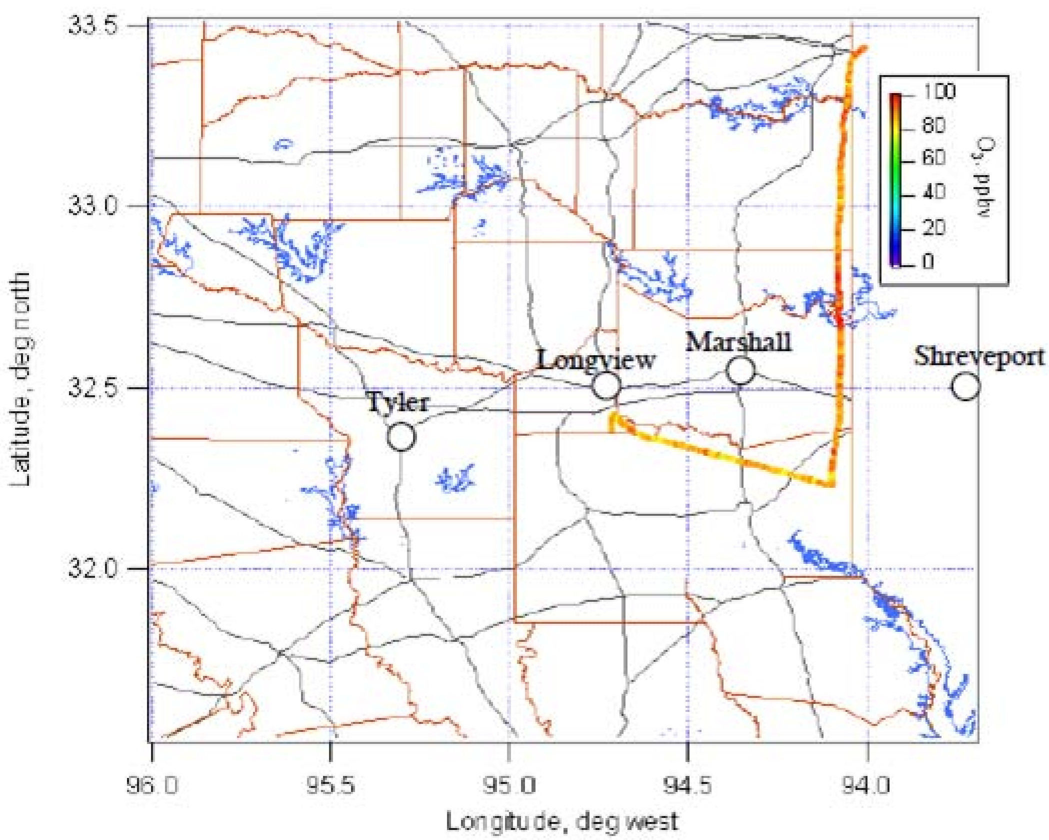


Figure 4-8. Ozone measured upwind of Northeast Texas on August 29, 2002 by the Baylor Aircraft. Under northeasterly winds, ozone was above 70 ppb at an altitude of 500 to 600 m along the border between Texas and Louisiana. The daily 8-hr ozone at Karnack (near Marshall) was 88 ppb on this day.

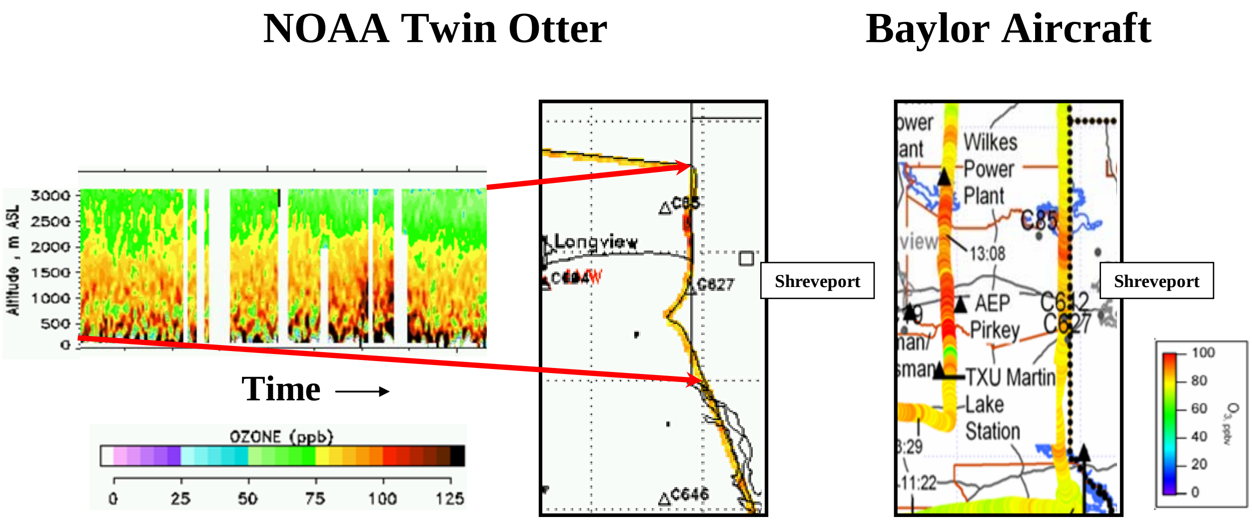


Figure 4-9. Ozone measured upwind of Northeast Texas on September 8, 2006 by the NOAA Twin Otter Aircraft. Under easterly winds, ozone was above 70 ppb through a deep layer along the border between Texas and Louisiana. The daily 8-hr ozone at Karnack (near Marshall) was 71 ppb on this day.

The proposed 2010 ozone standard will enhance the importance of transported background ozone and precursors, and it is important to understand the role of the transported background in ozone exceedance days in Northeast Texas. If the area's high ozone days are exclusively due to transport of ozone into the area, local controls strategies will not be effective. Conversely, if the contribution of local sources generally exceeds that of the transported background, then the benefits of local controls may be substantial. Although the aircraft flights are very useful for looking at ozone transport on a particular day, they are too costly to be undertaken on a routine basis. A photochemical model can be used to determine the relative contributions of source regions both near and distant, and can quantify the importance of transported ozone in causing high ozone days. The following analysis addresses the potential effectiveness of local control strategies in helping Northeast Texas achieve attainment of the ozone standard. We assess the role of the transport of ozone and precursors from regions outside of Northeast Texas on high ozone days and compare previous NETAC 2002 modeling results with new results from the modeling of 2005 and 2012.

NETAC developed a May-September 2002 seasonal model which was run on a 36/12 km grid (Kemball-Cook et al., 2006). The APCA (ENVIRON, 2009) ozone source apportionment tool was used to evaluate ozone contributions from regional transport and local sources across the entire season. Figure 4-10 shows a summary of the results of the source apportionment analysis. In 11 out of 18 high ozone events, source regions outside Texas made the largest contribution to the ozone concentration at the exceeding monitor. In one case, that of September 14 at Tyler, the largest contribution came from Central Texas; intermittent contributions from the Houston area were also noted in the course of the analysis. These results point to the importance of regional transport of ozone in producing 8-hour exceedance days in Northeast Texas. However, the role of ozone production from local sources also plays an equally important role, and the 2002 seasonal modeling may have tended to underestimate local contributions to high 8-hour ozone on some days because the model grid resolution is only 12 km. In the 2005/2012 modeling, a higher resolution 4 km grid was used for Northeast Texas; therefore, the model should be able to more accurately characterize the contribution of local sources of emissions. We will discuss the source apportionment for individual high ozone days during the May-June episode as well as determine average contributions for source regions across the entire episode.

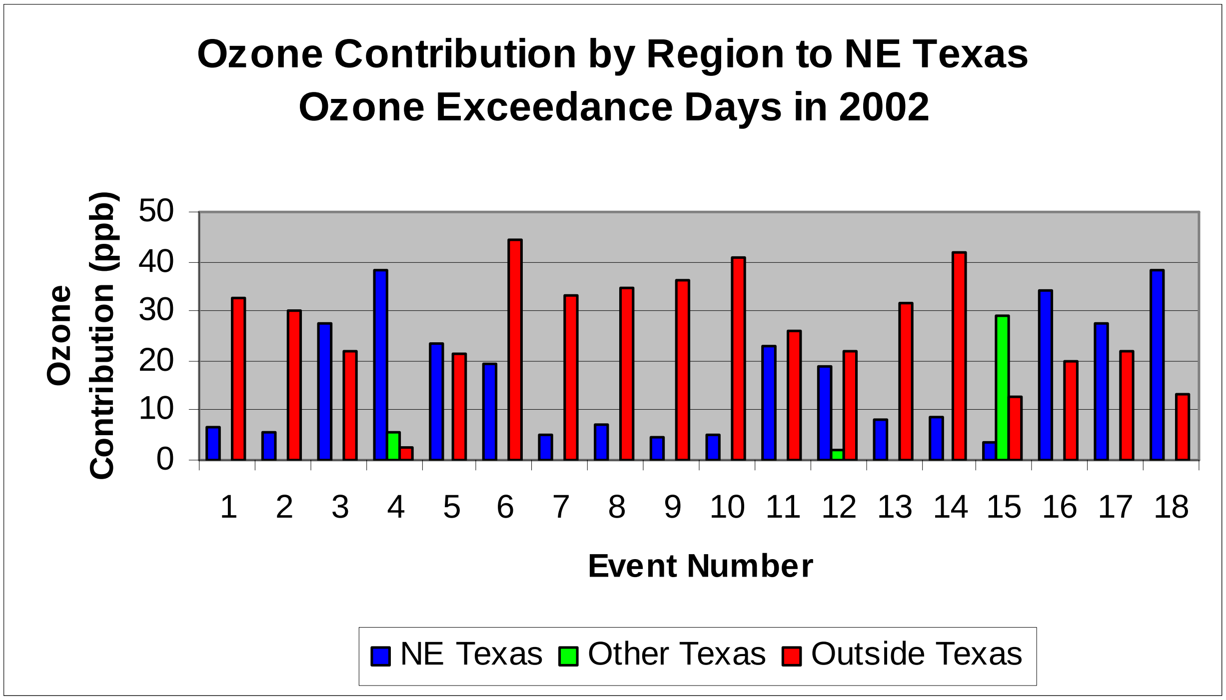


Figure 4-10. Summary of 2002 APCA analysis. Blue bars represent contribution to Northeast Texas monitor concentrations on high ozone days from Northeast Texas sources, green bars show contribution from sources within Texas but outside Northeast Texas, and red bars show total contribution from all sources outside Texas.

We consider the entire May-June episode and examine all days with 8-hour average ozone exceeding 75 ppb and 65 ppb thresholds. These threshold values were chosen because 75 ppb is the 2008 ozone standard and 65 ppb represents the mid-range of the proposed primary 2010 ozone standard. The goal of the following analysis is to determine the relative contributions of local sources and transport over the entire episode and how those contributions change from 2005 to 2012. Because of the current uncertainty in the final level of the 2010 ozone standard, we would like to understand how the change in threshold affects the source apportionment analysis. We use the APCA source apportionment results to determine the relative importance of sources within and outside the 5-County area over the entire May-June high ozone period.

Figure 4-11 shows the APCA results for all hours exceeding the 75 ppb threshold. In this figure, the contribution from the 36 km grid boundary conditions has been grouped with the contributions from all states outside of Texas. Although local sources are important in determining the ozone measured at the three monitors, the contribution from outside Texas is larger for all three monitors in both 2005 and 2012. The contribution from other regions in Texas is smaller than either the 5-County area contribution or the contribution from outside Texas, but is still significant (>10 ppb at Longview in 2005 and 2012). The contribution from transport is largest at Karnack, and the local contribution is largest at Tyler. Tyler tends to be downwind of more of the 5-County area on its high ozone days when winds typically have an easterly component. The modeling indicates that the ozone transported from outside Texas decreases in 2012 relative to 2005 at all three monitors, with the largest decrease seen at Karnack. The contribution from local sources increases slightly for all three monitors in going from 2005 to 2012.

2005 **2012**

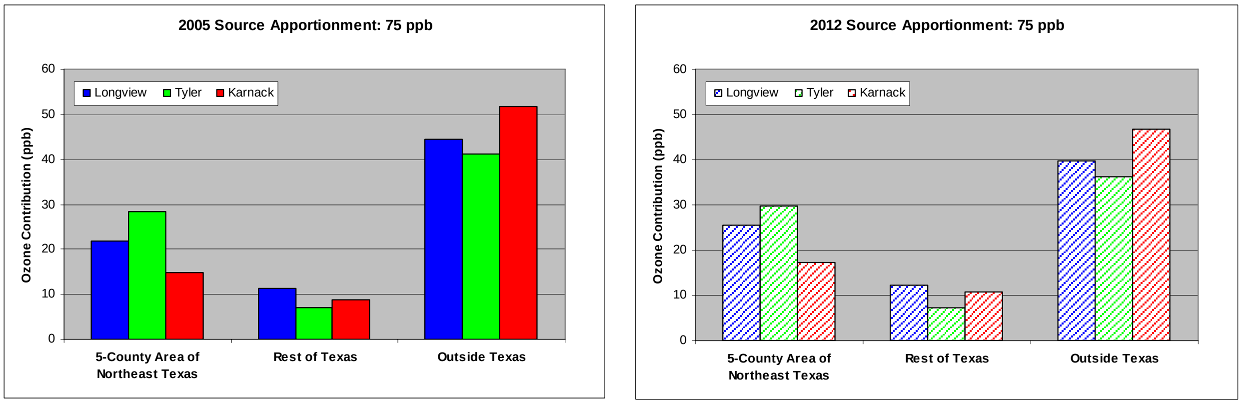


Figure 4-11. Geographic contributions to ozone above 75 ppb in Northeast Texas for the May 20-June 30, 2005 period modeled using CAMx with APCA ozone source apportionment. The contribution from outside Texas includes background ozone from outside the CAMx modeling domain.

The 2005/2012 source apportionment results are consistent with the 2002 results in that both modeling results indicate that transported ozone and local sources are both important in determining high ozone levels in Northeast Texas, although the transported contribution tends to be higher on high ozone days. This indicates that both local controls and regional emissions reduction strategies are required to reduce ozone levels in Northeast Texas. The 2005/2012 analysis indicates that the transported background ozone coming from outside Texas decreases going from 2005 to 2012 on high ozone days and across entire episode. On average, the contribution from the rest of Texas was nearly unchanged, and the local contribution from Northeast Texas sources increased slightly going from 2005 to 2012. This is consistent with the local increase in oil and gas area source emissions.

2005 **2012**

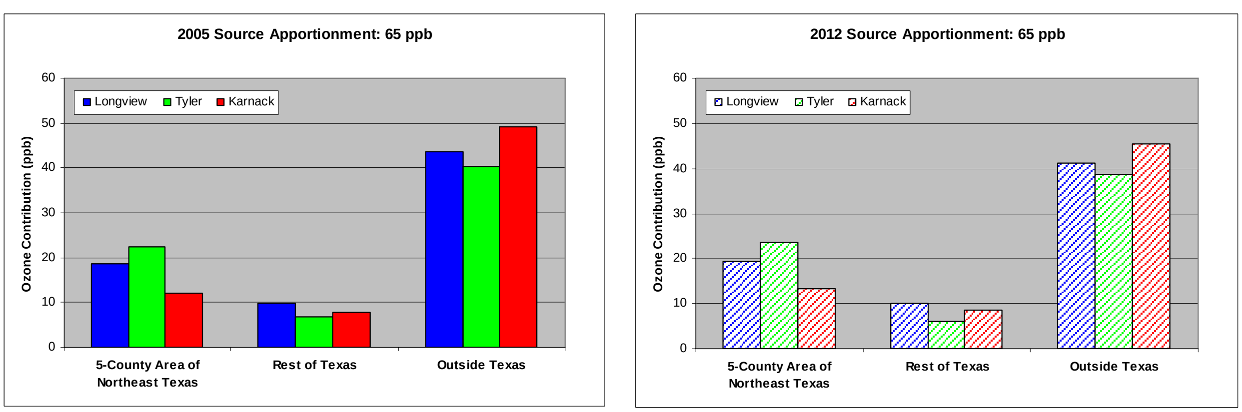


Figure 4-12. Geographic contributions to ozone above 65 ppb in Northeast Texas for the May 20-June 30, 2005 period modeled using CAMx with APCA ozone source apportionment. The contribution from outside Texas includes background ozone from outside the CAMx modeling domain.

Figure 4-12 is similar to Figure 4-11 but shows the APCA results for all hours exceeding the 65 ppb threshold, As in the 75 ppb case, the contribution from outside Texas is larger than that of local sources or other regions in Texas for all three monitors in both 2005 and 2012. The contribution from other regions in Texas is smaller than either the 5-County area contribution or the contribution from outside Texas. Contribution from transport is largest at Karnack, and the local contribution is largest at Tyler. As in the 75 ppb case, the ozone transported from outside Texas decreases in 2012 relative to 2005 at all three monitors, with the largest change at Karnack. The contribution from local sources increases very slightly for all three monitors in going from 2005 to 2012, but the increases are smaller than with the 75 ppb threshold. There is little change for the other Texas sources going from 2005 to 2012. The 65 ppb results are consistent with the 75 ppb results in that local sources make a significant contribution, but their effect is smaller than that of transport from other parts of Texas taken together with regions outside of Texas.

4.6 MODELING HIGH HRVOC/OZONE EVENTS AT LONGVIEW CAMS 19

HRVOC measurements carried out at CAMS 19 during August-September 2008 (Section 3.2) suggest that the Eastman Complex in Longview can play a role in high ozone events at CAMS 19. A modeling effort was undertaken in 2009 in order to improve our understanding of sources within the Eastman Complex. The main purpose of this modeling was to determine the magnitude of emissions required to produce HRVOC spikes at CAMS 19, assuming that the HRVOCs originate within the Eastman Complex. NETAC carried out modeling of September 2008 using two different models: the AERMOD dispersion model and a specific implementation of the CAMx photochemical grid model that is different from the 2005/2012 NETAC ozone model described above.

First, the AERMOD dispersion model was used to model hypothetical emissions from Eastman Complex. AERMOD is EPA's guideline model for assessing local impacts from industrial sources (EPA, 2005). AERMOD treats dispersion and transport of pollutants, but does not model their chemical transformation in the atmosphere. Surface meteorology from CAMS 19 was supplied to AERMOD. Several types of sources known to exist within the Eastman Complex were modeled using AERMOD. There types of sources modeled were: a flare, which is a hot, elevated source; a cooling tower, which is a relatively cool source that is near the ground; and fugitive emissions, which were modeled as and extended, near-surface, relatively cool source.

The AERMOD model was used to determine the quantity of emissions from each type of source that would be required to reproduce observed the observed HRVOC time series at CAMS 19. Note that ozone is a secondary pollutant formed by chemical transformation in the atmosphere and its formation cannot be modeled with AERMOD. We present detailed results for the cooling tower source only for the sake of brevity, and then summarize results for all three source types below.

The AERMOD model was forced with estimated emissions of HRVOC, which was assumed to be ethene based on the results of previous monitoring and emission inventory efforts (e.g. Kemball-Cook et al., 2007; Kemball-Cook and Yarwood, 2008). The estimated emissions were held constant at 4.6 tons per day of ethene, which corresponds to the total reported ethene emissions for the Eastman complex for a typical ozone season day in 2005.

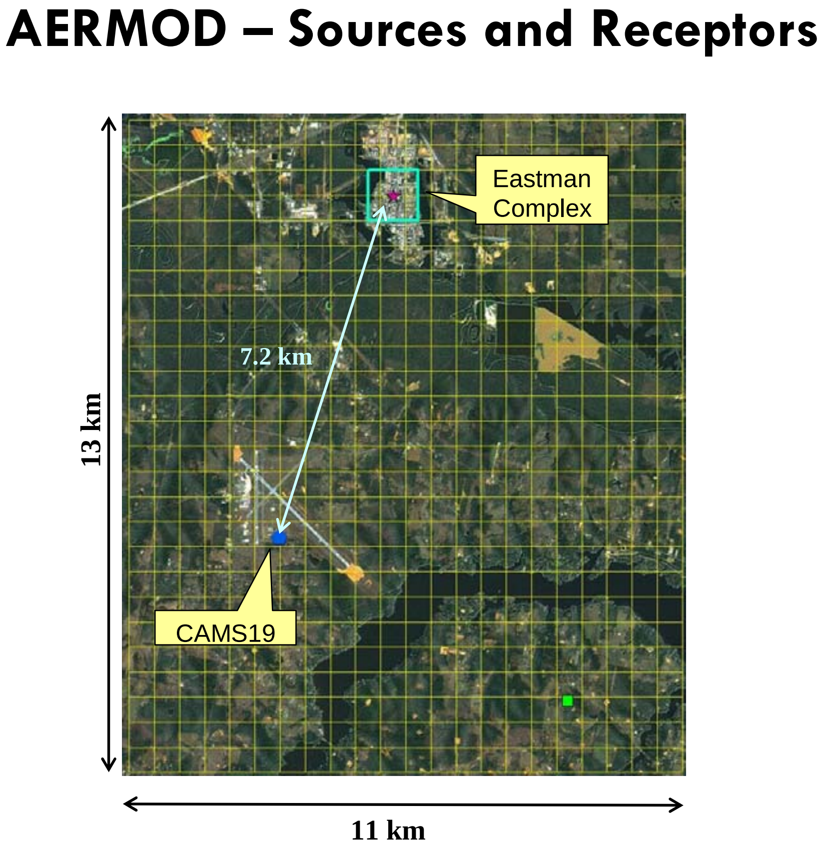


Figure 4-13. Sources and receptor locations for AERMOD modeling of Eastman facility and CAMS 19. The CAMS 19 monitor location at Gregg County Airport in Longview is shown at lower left.

The model was run for the entire period of September 1-30, 2008. The time series of observed and modeled ethene at CAMS 19 for the high HRVOC/ozone day September 19 are shown in Figure 4-14. The model reproduces the timing of the observed peak at 8 am, but underestimates its magnitude. To estimate the amount of emissions that would be required to bring the modeled ethene peak into closer agreement with the observed peak, a quantile-quantile plot was constructed from the observed and modeled CAMS 19 ethene data for September 1-30. The quantile-quantile plot for this run is shown in the left panel of Figure 4-15. Perfect agreement between modeled and measured ethene at CAMS 19 would be indicated if all points fell along the red 1:1 line. Instead, all points fall below the line, which means that the model consistently underestimates the observed ethene at CAMS 19. The right panel of Figure 4-15 shows a quantile-quantile plot where the best fit line has been adjusted to line up with the 1:1 line. The slope of this line is used to calculate the scaling factor for the ethene emissions. The ratio of the slope of the best fit line through the modeled/observed pairs (left panel) from the adjusted best fit line (right panel) indicates that the modeled ethene emissions would need to be increased by approximately a factor of 2 in order to optimize agreement between modeled and measured ethene. This type of simple scaling argument is only possible because the AERMOD model is linear. This analysis suggests that the reported Eastman Complex ethene emission rate of 4.6 tpd is not sufficient to cause the observed HRVOC peaks at CAMS 19.

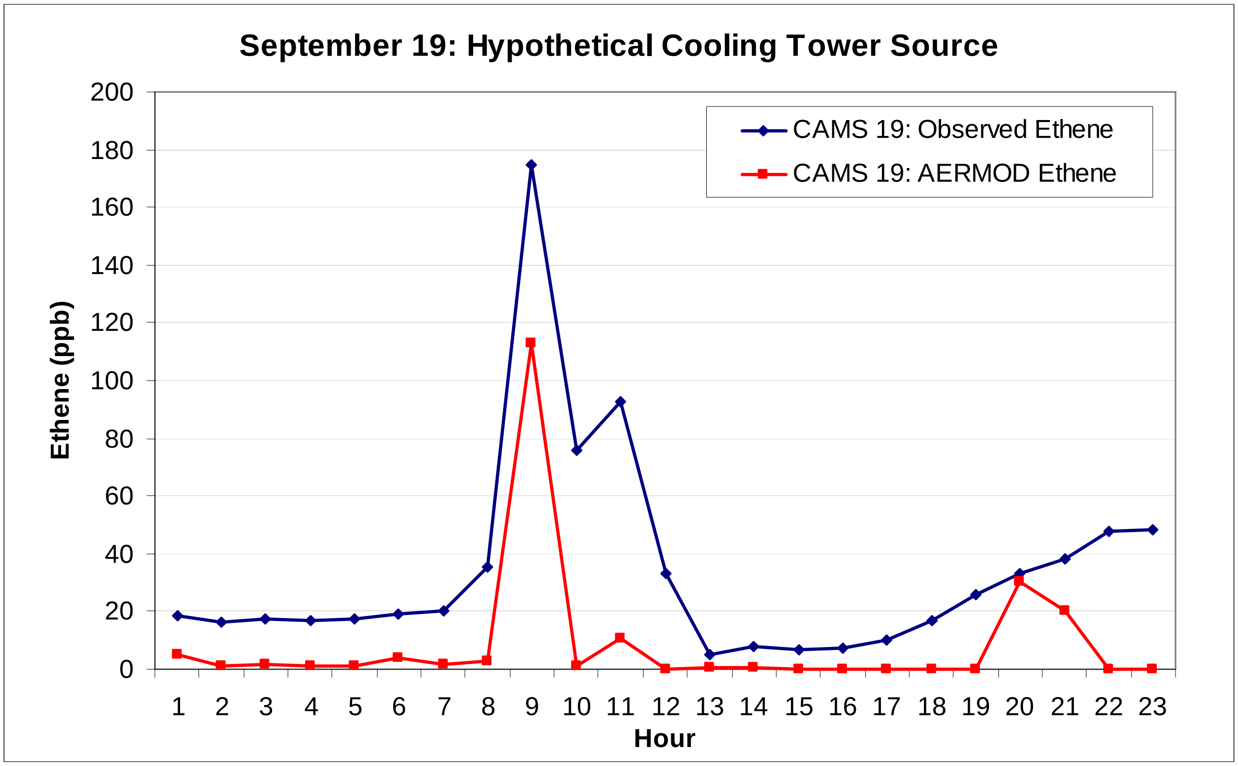


Figure 4-14. Observed and modeled ethene time series for CAMS 19 on September 19, 2008. Modeled time series is for the run in which emissions are set to 4.6 tpd ethene.

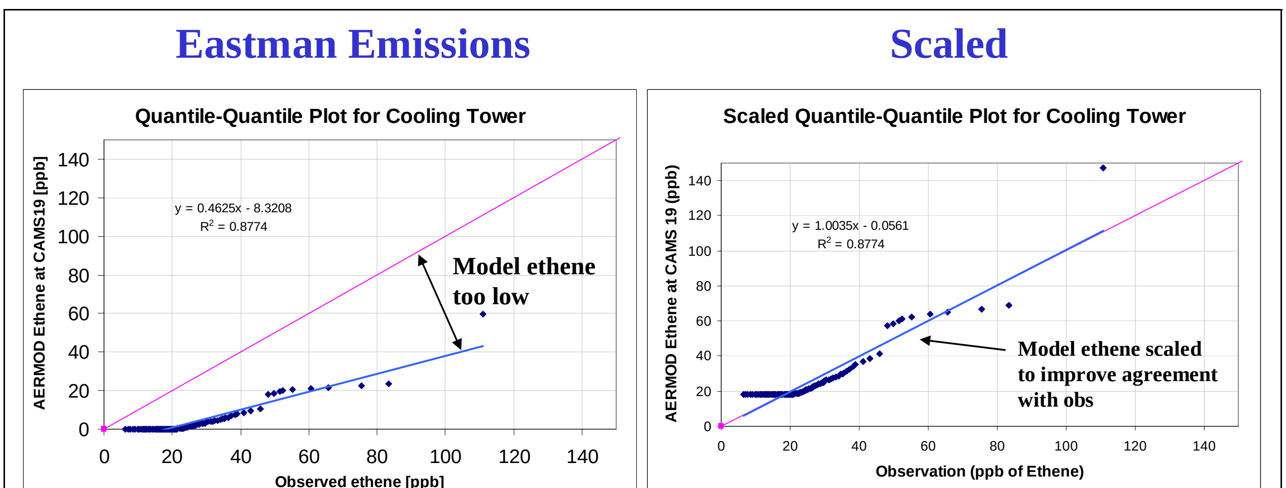


Figure 4-15. Quantile-quantile plots for CAMS19 for September 1-30, 2008. Left panel shows comparison between AERMOD ethene at CAMS 19 and observed ethene atCAMS19 measured by the RAD. Red 1:1 line indicates perfect agreement between modeled and observed values. Right panel shows data adjusted so that the blue best fit line through the data achieves the best possible match with the red 1:1 line.

A similar procedure was followed for the flare and fugitive sources. Table 4-2 shows the ethene emissions rates for each source that produces best agreement between modeled and observed ethene over the entire September 2008 time series. The Eastman operators note that the emissions from the flare shown below are unrealistically large and could not be produced by the Eastman facility even if their entire production stream were routed through the flare.

Table 4-2. Ethene emissions required to optimize agreement Between observed and modeled ethene at CAMS 19 during September, 2008.

Hypothetical Source	Required Emissions (tpd)
Cooling Tower	10
Flare	83
Fugitive Emissions	15

While the AERMOD runs indicate that Eastman ethene emissions were underestimated in 2005, the AERMOD model is a highly simplified representation of the dispersion of pollutants that does not take into account chemical transformation of pollutants in the atmosphere. We turn now to refined modeling using CAMx, which contains a detailed, state-of-the-science treatment of the chemical transformation of emissions of HRVOCs such as ethene into ozone as well as a more accurate treatment of pollutant transport.

High resolution CAMx modeling of Eastman/CAMS 19 local area was carried out with a specially-design version of the model that differs from NETAC's 2005 ozone model. The purpose of the CAMx modeling was to test the source parameters determined through AERMOD modeling and to determine whether it is possible for the model to reproduce observed HRVOC and ozone events at CAMS 19.

A nested 4/1 km grid with a fine-scale 200 meter grid focused on Eastman and CAMS 19 was used in the CAMx modeling. The model was driven with CALMET diagnostic meteorology based on local CAMS observations, and the evolution of the mixed layer height was determined from Longview radar profiler observations. Representative boundary conditions used in the 2005 ozone model were employed at the boundary of the 4 km grid, however, the effects of the boundary conditions are small relative to the Eastman impacts. Boundary condition ozone was set to 40 ppb, ethene to 0.5 ppb, and propene to 0.3 ppb. The CAMx Plume-in-Grid model was not used in this simulation given the fine scale of the 200 meter grid. For all non-Eastman sources including biogenics, the emission inventory for the May-June 2005 episode was used. Because the modeling domain is so closely focused on Eastman, using a 2005 emission inventory to model 2008 events is a reasonable first order approximation.

With Eastman ethene emissions set at their value in the TCEQ 2005 typical day emission inventory, model does not reproduce observed HRVOC or ozone peaks at CAMS 19 (Figure 4-17). With an additional 2500 lbs/hr ethene emitted from a near-surface source, CAMx simulates the timing and magnitude of the ethene peak (Figure 4-18). CAMx requires more HRVOC emissions than AERMOD to reproduce observed ethene peak because of differences in plume dispersion between the models. Most of AERMOD plume lies within 100 meters of the ground, while in CAMx, the plume grows vertically with the morning rise of the mixed layer height.

Figure 4-19 shows the observed and modeled NOx time series at CAMS 19. The left panel shows these time series for a run in which Eastman NOx emissions are set to their values in the TCEQ 2005 typical ozone season day emission inventory. Using this inventory, NOx is well-simulated until the arrival of the Eastman plume at 9 am, then is overestimated. The right panel of Figure 4-19 shows the corresponding results for a run in which the Eastman Complex NOx emissions were scaled down (x 0.23) to be consistent with 2006 Baylor aircraft flight measurements made upwind and downwind of the Eastman Complex. The scaled-down Eastman NOx emissions produce better agreement with observed CAMS 19 NOx and ozone during the 9 am plume impact.

Figure 4-20 shows the observed and modeled ozone time series for the model run with added ethene emissions and the scaled-down NOx emissions. The modeled ozone peak is within 15 ppb of the observed peak, and even though the modeled NOx is lower than the observed NOx at 10 am, the results show that CAMx can reproduce observed ozone on a 200 m grid when precursors are accurately simulated.

Figure 4-21 shows spatial plots of HRVOC and ozone on September 19 at 9 am, which corresponds to the HRVOC peak at CAMS 19. Peak HRVOC values in the modeled plume exceed 2 ppm. There is a corresponding plume of enhanced ozone (right panel) despite the early morning hour.

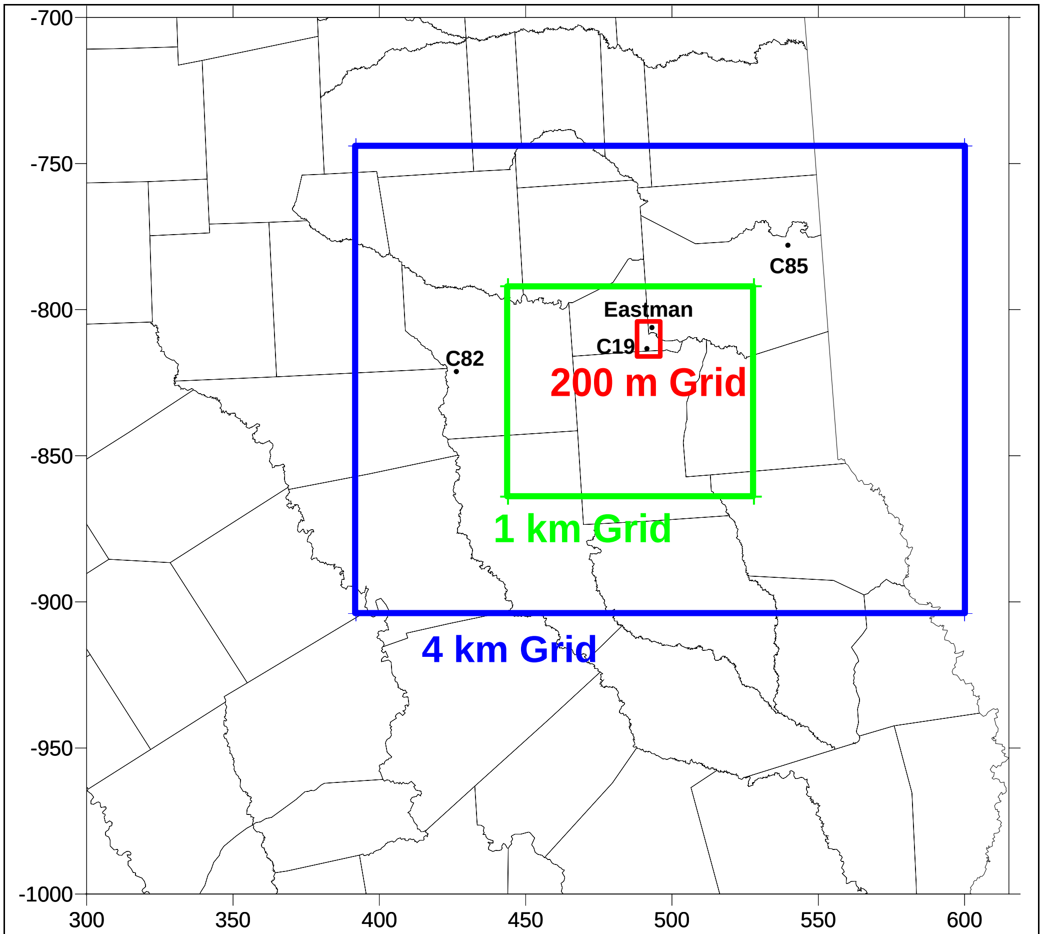


Figure 4-16. Nested 4 km, 1 km, and 200 meter grids for the CAMx modeling of Eastman and CAMS 19.

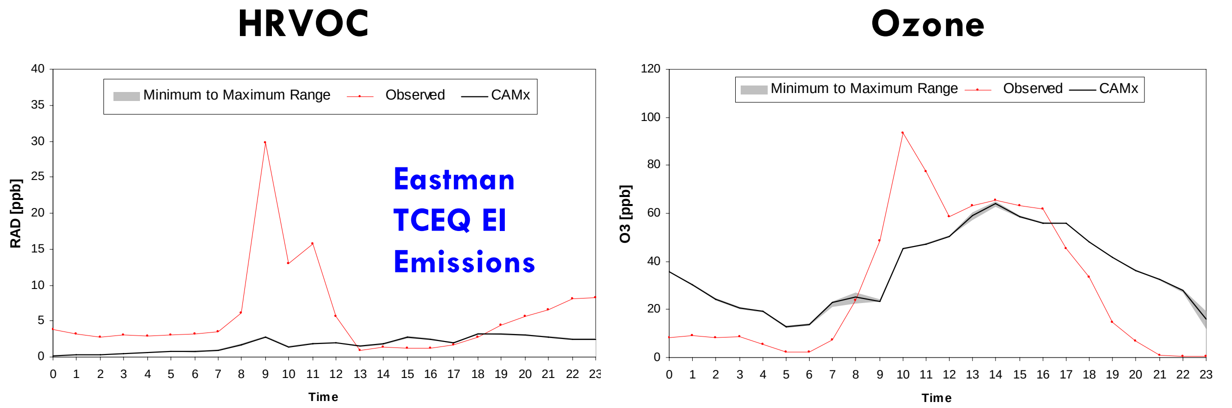


Figure 4-17. Observed and modeled ethene time series for CAMS 19 on September 19, 2008. Modeled time series is for the run in which emissions are set to 4.6 tpd ethene. Left panel: observed and modeled ethene. Right panel: observed and modeled ozone.

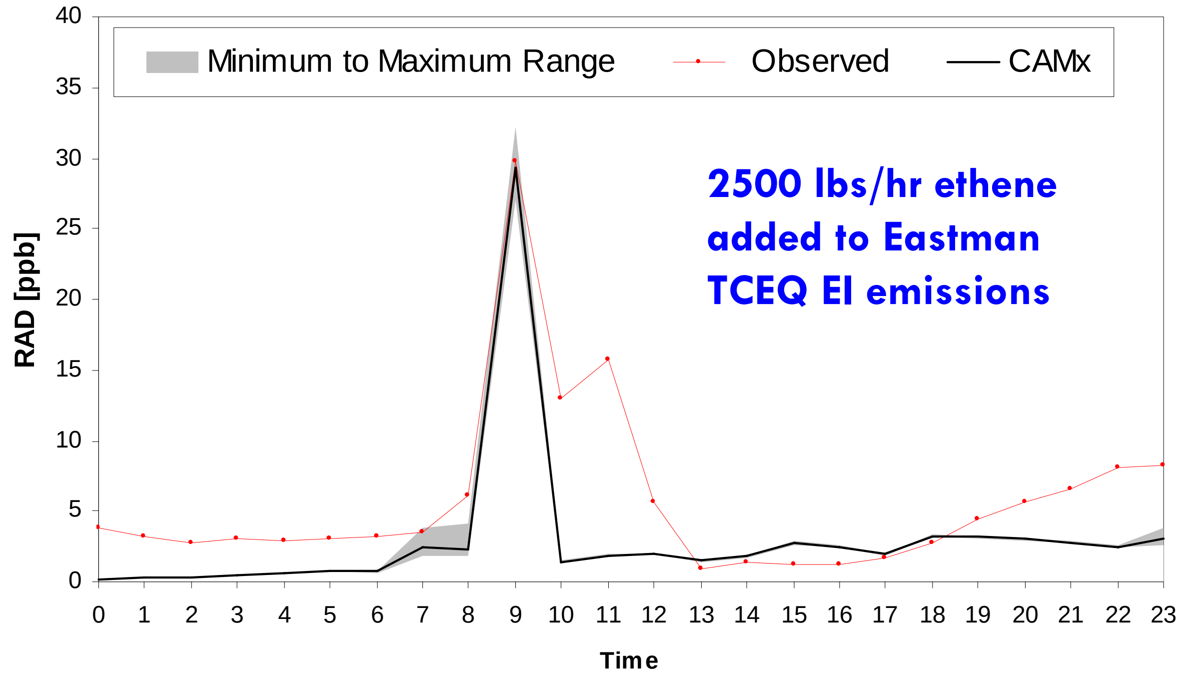


Figure 4-18. Observed and modeled ethene time series for CAMS 19 on September 19, 2008. Modeled time series is for the run in which 2500 lbs/hour ethene have been added to the Eastman emission inventory.

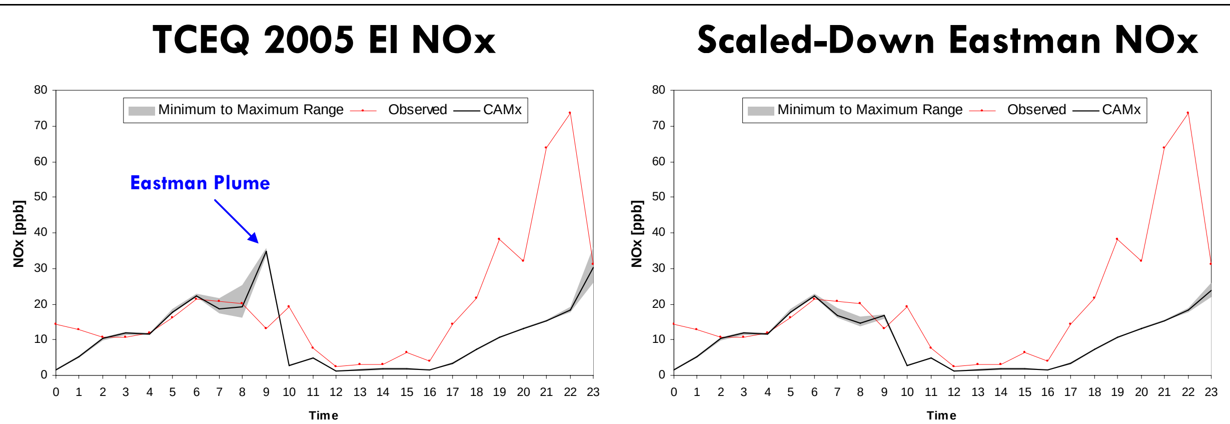


Figure 4-19. Observed and modeled NOx time series for CAMS 19 on September 19, 2008. Left panel: modeled time series is for the run in which emissions are set to their TCEQ 2005 emission inventory values. Right panel: NOx emissions are scaled down based on data from the 2006 Baylor aircraft flight over the Eastman Complex.

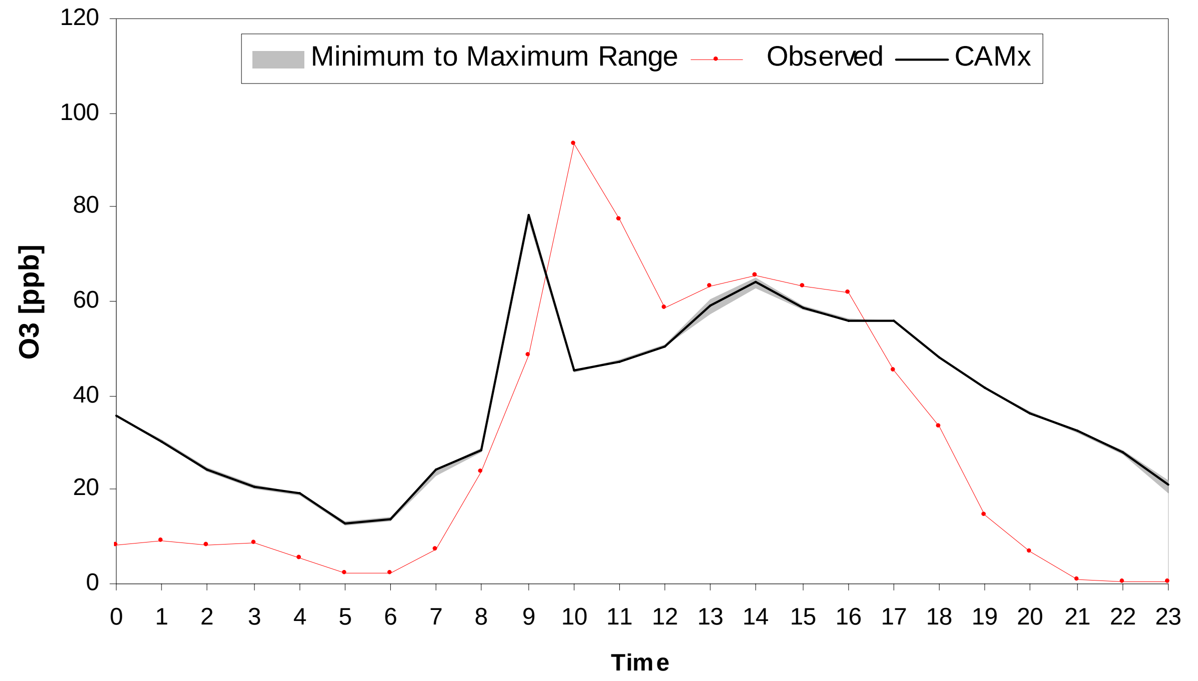


Figure 4-20. Observed and modeled ozone time series for CAMS 19 on September 19, 2008 for run in which 2500 lbs/hour ethene have been added to the Eastman emission inventory and NOx emissions are scaled down based on data from the 2006 Baylor aircraft flight over the Eastman Complex.

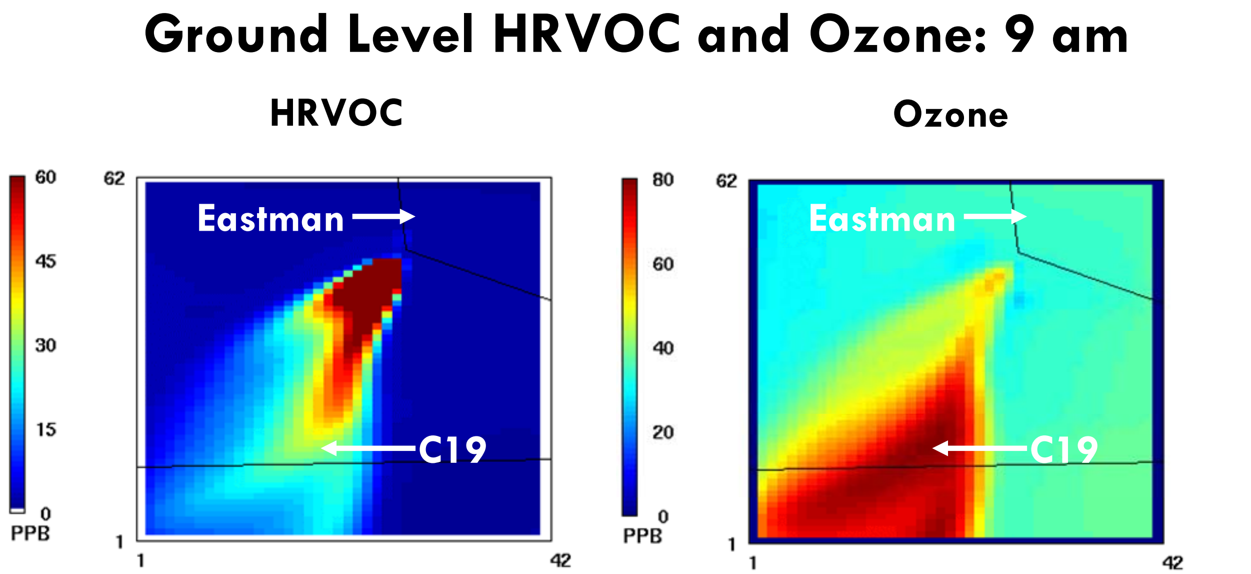


Figure 4-21. Spatial plots of HRVOC (left) and ozone (right panel) on the 200 meter grid at the time of peak HRVOC.

The results shown here indicate that given a good simulation of precursors, CAMx can reproduce the ozone peaks associated with the observed HRVOC spikes at CAMS 19. The AERMOD and CAMx modeling both suggest that the HRVOC emissions needed to produce observed spikes are greater than the typical day emission inventory. Ethene emissions of ~2500 lbs/hr can cause observed morning ozone spikes at CAMS 19 through interaction with readily available NOx. Potential sources of such emissions are not understood. Estimates of Eastman Complex ethene (HRVOC) inventory derived from 2006 NETAC aircraft flight are consistent with the TCEQ 2005 emission inventory for a typical ozone season day. The Eastman Complex operators believe that such a large release (about 1 ton per hour) could not have occurred without detection by their control and/or safety instrumentation. Therefore, the origin of these HRVOC spikes remains unclear. NETAC will undertake additional HRVOC monitoring during 2010 using event-triggered canister data sampling. Analysis of canister samples taken during HRVOC spikes will allow chemical fingerprinting of the source(s) of the spikes that can further our understanding of high HRVOC/ozone events at CAMS 19.

5.0 SUMMARY OF THE CONCEPTUAL MODEL

Since the last Conceptual Model update in 2008, NETAC has carried out surface-based measurements of ozone precursors in Northeast Texas, revised and refined the local and regional emission inventories, and developed ozone models for the years 2005 and 2012. This new information lends additional detail to the Conceptual Model, but does not change the overall picture of the factors leading to high ozone in Northeast Texas. A summary of the Conceptual Model is given below.

5.1 METEOROLOGY

The Tyler-Longview Marshall (TLM) area is located on the plains of Northeast Texas, where the lack of major geographic features means that upper level wind patterns are driven primarily by synoptic-scale meteorological influences. Episodes of high surface ozone concentrations in Northeast Texas occur most often between June and September when the area is under the influence of a semi-permanent subtropical high-pressure system, vertical mixing of pollutants in the atmosphere is restricted, skies are clear to partly cloudy, temperatures are high, and winds are light. Most episodes are associated with near-surface winds from either the east/northeast or south/southwest with the latter direction appearing less consistently on the highest days and with greater variability in direction. Episodes can be classified as either "stagnant", with very little inflow of air from outside of Northeast Texas or "transport", with pollutants usually arriving in Northeast Texas through northwestern Louisiana, southern Arkansas, or southeastern Texas.

Ozone exceedances at the CAMS 19 monitoring site located at the Gregg County airport just south of Longview are often associated with daytime wind shifts that help keep locally-generated emissions within the area and cause plumes from major point sources to cross over the monitoring site. When these plume impacts occur in conjunction with already elevated regional ozone levels, exceedances of the ozone standard can result. Examination of the Longview radar wind profiler data revealed the presence of moderately strong low-level southwesterly winds during the hours between midnight and sunrise on several days. Winds above this low-level flow varied from day to day but ranged from northeasterly to easterly on several of the high ozone days. By mid-day, convective mixing in response to surface heating breaks up the low-level southwest flow and brings the easterly component winds to the surface, causing a rotation of the surface winds from southwest to more easterly. This surface wind pattern is seen not just at Longview, but also at each of the other northeast Texas monitoring sites, consistent with a regional, rather than strictly local, phenomenon. The early morning southwest winds at Longview may represent the northward intrusion of the previous afternoon's sea breeze from the Gulf of Mexico.

5.2 EMISSIONS

On a regional scale, emissions of ozone precursors in Northeast Texas are dominated by highly reactive biogenic VOCs such as isoprene and pinenes; anthropogenic sources account for a much smaller fraction of total daily VOC emissions in the NETAC area. The overall VOC/NOx emission ratios in the five county area is well within the NOx-limited ozone formation regime. As a result, reductions in NOx will be generally more effective in controlling ozone on a regional basis than reductions in anthropogenic VOC. Sensitivity tests using NETAC's 2005 ozone model confirm that NOx reductions are more effective than VOC reductions in controlling ozone in Northeast Texas.

Under the right meteorological conditions, NOx from various sources, including several large electricity generating units located within and upwind of the TLM area in addition to on- and off-road mobile sources and other stationary sources, combine with (mostly biogenic) VOCs to make significant amounts of ozone. Correlations of hourly ozone and SO_2 peaks at Longview are indicative of the influence of large fossil fuel combustion sources. Aircraft data provide corroborating evidence of plumes containing SO_2 and ozone emanating from local power plants. The largest sources of NOx in the TLM area are EGUs and the Eastman Complex Co-Generating Units. The Longview CAMS 19 monitor has large NOx point sources to its north, east, and south.

Although recent modeling and monitoring efforts have focused on the Longview monitor, the Tyler monitor has had more frequent ozone impacts than Longview monitor during 2009. This is reflected in Figure 3-1, which shows that the 4th high ozone value for the Tyler monitor was higher than that of the Longview monitor in 2009. In Section 3.1, we noted that the Tyler monitor seems to have a different relationship between weather and high ozone days than the Longview and Karnack monitors during 2002-2006. It is clear that additional analyses should be performed to improve our understanding of high ozone days at Tyler. One important data need is the installation of an SO_2 monitor at the Tyler monitor. This will help determine the role played by impacts from coal-fired power plants in causing high ozone at Tyler and their relative importance compared with impacts from the Tyler urban plume and other sources. Other analyses that should be performed are an examination of recent precursor trends in the Tyler area and, subsequently, an evaluation of any modeling needs for accurate representation of ozone impacts at Tyler in future ozone modeling of Northeast Texas.

Evidence from both aircraft and surface data indicate that significant ozone formation may also be associated with collocated plumes of NOx and highly reactive VOCs (HRVOCs) from point sources in the area. The Eastman Complex is the largest source of anthropogenic HRVOCs in the TLM area. Reductions in HRVOC emissions from the Eastman Complex were made under the Early Action Compact that ended in 2007, but recent aircraft measurements (Alvarez et al., 2007) as well as the August-September 2008 HRVOC monitoring at CAMS 19 (Jobson and Pressley, 2009) indicate that Eastman is still a significant source of HRVOCs. Several high ozone events during the 2007-2009 period involved rapid, early morning rises in ozone concentrations at the Longview monitor that are consistent with the presence of plume containing both NOx and HRVOC; these events occurred on days with northerly winds and suggest that emissions from the Eastman Complex continue to play a role in ozone formation in the Longview area.

The AERMOD and CAMx modeling results discussed in Section 4 suggest that the HRVOC emissions needed to produce observed spikes are greater than the Eastman typical day emissions in the TCEQ 2005 emission inventory. The CAMx modeling indicated that ethene emissions of ~2500 lbs/hr can cause observed morning ozone spikes at CAMS 19 through interaction with readily available NOx. Potential sources of such emissions are not understood. Estimates of Eastman Complex ethene (HRVOC) inventory derived from the 2006 NETAC aircraft flight are consistent with the TCEQ 2005 emission inventory for a typical ozone season day (Kemball-Cook and Yarwood, 2007). The Eastman Complex operators believe that such a large release (about 1 ton per hour) could not have occurred without detection by their control and/or safety instrumentation. Therefore, the origin of these HRVOC spikes remains unclear. NETAC will undertake additional HRVOC monitoring during 2010 using event-triggered canister data sampling. Analysis of canister samples taken during HRVOC spikes will allow chemical fingerprinting of the source(s) of the spikes that can further our understanding of high HRVOC/ozone events at CAMS 19.

Distributed NOx emissions from gas compressor engines used in natural gas production also make a significant contribution to the TLM emission inventory, comprising over half of the area source NOx inventory. The total NOx emission rate for the 5-county area for gas compressor engines is comparable to the NOx emission rate of a large EGU. Ozone modeling of 2012 showed that NOx controls implemented as part of the East Texas Combustion Rule result in ozone reductions or several ppb within the 5-County area. Projections of future emissions from natural gas exploration and production show they are likely to increase in the TLM area and in areas upwind in coming years, even when the East Texas Combustion Rule is taken into account. Estimates of future year emissions from the development of natural gas resources in the Haynesville Shale show that these emissions may soon be an important component of the regional emission inventory. The ozone modeling results presented in Section 4 show that the development of the Haynesville Shale may have significant effects on air quality in Northeast Texas. The 2012 modeling results underscore the importance of the accurate characterization of oil and gas emissions and suggest that future emission inventory efforts should be directed toward reducing uncertainty in this source category. Updating the Haynesville Shale emission inventory should be an immediate priority for future work, as should tracking compliance with the East Texas Combustion Rule in order to refine future emission inventory development.

Ozone formed within and just upwind of the TLM area is often augmented by transport of elevated ozone concentrations from outside the area, almost always from the east/northeast or south/southwest. As discussed in Section 4, aircraft observations have repeatedly shown large areas with upwards of 70 ppb ozone upwind of the TLM area to the east/northeast. Only a small amount of additional local ozone production is needed under such conditions to produce exceedances of the 8-hour NAAQS of 75 ppb. NETAC aircraft flights have also measured elevated ozone and precursors in plumes emanating from local sources. The 2005/2012 source apportionment results are consistent with the aircraft flight data as well as the 2002 modeling results in that transported ozone from outside Texas, other regions within Texas, and local sources are all important in determining high ozone levels in Northeast Texas, although the transported contribution tends to be higher on high ozone days. This indicates that both local controls and regional emissions reduction strategies are required to reduce ozone levels in Northeast Texas.

As the ozone standard becomes more stringent, the role played by transported ozone from outside Texas and from other regions within Texas becomes more important as the area can more easily be brought to the brink of an ozone exceedance through the effect of transport alone. Although the analysis discussed here focused on U.S. sources of ozone and precursors and their effect on Northeast Texas, sources outside the U.S. (e.g. Asia) may also contribute. Parrish et al. (2009) measured the ozone mixing ratio in the onshore flow of marine air at the North American west coast, and determined that average trend in mean annual ozone is 0.34±0.09 ppbV/yr or ~ 3 ppb per decade. This means that the policy-relevant background ozone may be increasing. The policy-relevant background is defined by the EPA to be "the distribution of ozone concentrations that would be observed in the U.S. in the absence of anthropogenic (man-made) emissions of precursor emissions (e.g., VOC, NOx, and CO) in the U.S., Canada, and Mexico", which is equivalent to the lowest ozone that could possibly be achieved by air quality management efforts within the U.S. An increase in the policy-relevant background ozone would make it more difficult for Northeast Texas to attain the NAAQS.

Further analysis is required to determine the conditions that lead to high ozone days in Northeast Texas when high ozone days are defined in terms of the various possible levels of the new ozone standard. For example, previous analyses have shown that local surface winds are generally from the east/northeast or south/southwest on high ozone days when a high ozone day is defined to mean 8-hour daily maximum ozone of 84 ppb or higher. When the threshold for high ozone is set at 60 ppb, the winds may come from a broader range of directions, and transport from additional regions may become important.

During 2010, NETAC will develop an updated conceptual model of ozone formation that identifies necessary and sufficient conditions for ozone formation at different potential levels of the proposed ozone standard (60, 65, and 70 ppb) and uses data through the end of 2009. The following tasks will be performed:

- Evaluate the wind speeds, directions and time of day associated with high ozone events (for the three proposed levels of the new ozone standard) to determine the local conditions and source alignments most frequently associated with high ozone events.

- Develop 24 hour back trajectories for the three levels of the ozone standard (and for ozone less than 60 ppb) to determine source regions most (and least) likely to affect local area ozone.

- Conduct a weekday/weekend analysis to evaluate the potential effectiveness of reduced levels of local industrial and mobile source activity on their area;

- Evaluate the range and average background ozone concentrations associated with local wind directions. The data should be stratified for the three levels proposed for the new ozone standard to determine which directions are most frequent, and whether different wind directions become relevant at lower levels of the standard and for different seasons;

- Investigate ozone and precursor trends and estimate the annual frequency of high ozone days at varying standard levels.

5.3 USING THE CONCEPTUAL MODEL TO GUIDE OZONE MODELING EPISODE SELECTION

One of the purposes of a conceptual model is to provide guidance for episode selection in ozone modeling. For example, the conceptual model (Stoeckenius and Yarwood, 2004) was used in the selection of the May-June episode simulated in the 2005 ozone model. The analysis of high ozone days in 2009 shows that future ozone modeling should consider high ozone days at Tyler in the episode selection in order to better understand the causes of high ozone days at that monitor. Further analysis is also required to understand the relationship between meteorology and high ozone at Tyler.

As of the writing of this report, the TCEQ is preparing for SIP development in response to the new standard and is planning for increased coordination between the NNAs and the TCEQ. Therefore, the main goal of the Northeast Texas NNA's air quality planning for the near future is to assist the TCEQ in SIP development by demonstrating that the NNA will comply with the 2010 ozone standard by the designated attainment date. Attainment of the standard will provide public health benefits and assure that the region can continue to develop and grow without compromising air quality. The Northeast Texas NNA will carry out air quality planning that is focused on Northeast Texas in collaboration with the TCEQ, whose emphasis will be on state-wide issues.

The TCEQ is planning to develop a statewide master model for a June 2006 episode. Although there were periods of high ozone in Northeast Texas during June 2006, ozone was not as consistently high as it was during the May-June 2005 episode. NETAC will work with the TCEQ on emission inventory development and air quality modeling for this episode, and will also retain the May-June 2005 model, as the Northeast Texas conceptual model indicates that conditions that lead to the highest ozone are more prevalent in the May-June 2005 episode than the June 2006 episode. Modeling both periods should increase our understanding of the causes of high ozone in Northeast Texas under a variety of meteorological conditions and different levels of resulting ozone.

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