TEXAS
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New Research for the Texas SIP: A Science-Policy Synthesis

November 2005

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Key Lessons from Previous Research

Since 2002, the Texas Environmental Research Consortium (TERC) has sponsored over $10 million of research related directly or indirectly to the Texas State Implementation Plan (SIP) for the Houston-Galveston-Brazoria (HGB) and Dallas-Ft. Worth (DFW) ozone non-attainment areas. We have learned much from TERC research and other projects conducted since a previous assessment by Allen and Olaguer in 2004. Key lessons can be organized according to three basic problems: 1) demonstrating local ozone attainment, 2) assessing regional ozone and transport, and 3) deploying effective new control strategies. These lessons are summarized below.

Demonstrating Local Ozone Attainment

Attaining the 8-hour ozone standard will require decreased ozone production from local emissions in Texas non-attainment areas. Various refinements in modeling practice may help more accurately determine the response of ozone to local control strategies to demonstrate attainment. These include:

- Better speciation and quantification of anthropogenic emissions through bottom-up or top-down approaches, especially of Highly Reactive VOC (HRVOC) and Other VOC (OVOC) emissions in HGB, and mobile source NOx emissions in both the HGB and DFW areas;
- Updated land use/land cover data and biogenic emissions inventories, including more detailed tree speciation and tree counts, expanded use of satellite data, and linkage to urban land use planning;
- Improved local meteorological simulation of Planetary Boundary Layer height evolution, Galveston Bay influence in HGB, and stationary fronts in DFW;
- Expanded chemical mechanisms, with greater speciation and more detailed treatment of urban sources and sinks of radicals and NOx; and
- Analysis of supplementary modeling episodes to more thoroughly account for 8-hour design values, including HGB springtime episodes with O_3 exceedances.

Assessing Regional Ozone and Transport

Attaining the 8-hour ozone standard may also require regional strategies in East Texas by targeting intra-State and out-of-State sources for control. Regional ozone is generally similar in concentration to locally produced ozone, except during extreme ozone episodes. To design effective regional strategies, better understanding and improved simulation of the following critical phenomena are needed:

- Apportionment of ozone to precursor emission sources at large distances (i.e., hundreds of kilometers) upwind (Research topics include evaluation of source apportionment techniques through sensitivity and process analysis, modeling inter-comparison, and field study data evaluation.);

- Seasonal evolution of background ozone, including springtime transport and interaction between regional and larger-scale transport at the surface and aloft;
- Transport and chemical transformation of ozone and precursors aloft, both at night and during the day (Research topics include transport by large and small scale circulation systems, such as nocturnal low level jets, the chemistry of less reactive VOCs, lightning and aircraft-generated NOx, long-lived reservoirs of NOx and radicals, and night-time reactions.); and
- Mechanisms of vertical exchange between the surface and layers aloft, including convection, stationary fronts, stalled sea breeze fronts, and turbulent diffusion.

Deploying Effective New Control Strategies
Effective control strategies must be identified to meet the 8-hour ozone standard in view of the delayed impact of controls on federally pre-empted sources. Further study is needed according to the following priorities.

For the HGB and DFW non-attainment areas, greater emphasis should be given to mobile source strategies, such as:

- Improving the effectiveness of voluntary measures for both diesel and gasoline vehicles, such as the Texas Emission Reduction Program (TERP) and the Low Income Vehicle Repair Assistance, Retrofit, and Accelerated Vehicle Retirement (LIRAP) program;
- Considering adoption of the California LEV II program; and
- Further reducing NOx emissions from locomotives, ships, and barges.

Regional NOx emission reduction strategies also deserve priority, for example:

- Controlling NOx emissions from compressor engines used in gas production in East and Central Texas;
- Tightening controls on major point sources of NOx in East Texas outside non-attainment areas to mitigate intra-State transport; and
- Seeking out-of-State NOx reductions beyond those provided by the EPA Clean Air Insterstate Rule (CAIR), especially in nearby States.

In Houston, HRVOC emissions continue to deserve special attention. Potential benefits of increased controls on OVOCs should also be considered. Relevant measures include:

- Expanding the monitoring network for rule violation detection and enforcement;
- Tracking emission events and predicting the impacts of likely future events;
- Incorporating reactivity-based strategies such as trading and/or substitution of HRVOC and OVOC emissions; and
- Controlling VOCs from storage tanks, wastewater, and other sources in Houston.

Other control strategy elements may also contribute to ozone attainment, such as:

- Reducing VOCs in the DFW urban core to address potential NOx disbenefits;
- Coordinating emission reductions for ozone and regional haze; and
- Involving local stakeholders in the identification of potential new strategies.

RECOMMENDED SHORT-TERM RESEARCH

The immediate priority for short-term research is to identify and assess effective new local control strategies for both the HGB and DFW SIPs. An assortment of appropriate projects that are balanced according to geographic area, source category, and ozone precursor species has been proposed for TERC's consideration (see Tables 13 and 14). These control strategy and SIP assessment projects address the fundamental need for additional NOx controls in both Houston and Dallas-Ft. Worth, as well as the need to continue to reduce HRVOCs in the HGB non-attainment area.

A second area of priority for short-term research is the development of a strategy for decreasing regional ozone (the Texas equivalent of CAIR). Sources to the east, southeast, and south of Dallas-Ft. Worth, including major point and other stationary NOx sources in East and Central Texas down to the Gulf of Mexico, should be assessed for potential enhanced controls. The mitigation of pollution transport into East Texas through enhanced controls on major point sources in Louisiana should also be examined.

Given the short-term attainment deadlines faced by the HGB and DFW areas, we cannot rely on TexAQS II-2006 projects to provide information in time for the initial SIP submissions. However, analysis of data from TexAQS 2000 and TexAQS II-2005, especially the Northeast Texas Plume Study (NETPS) and the Southeast Texas Transport Study (SETTS), can be completed largely in time to influence the initial SIP submissions. In addition, short-term modeling projects have been proposed to assess regional transport in East Texas in a manner that goes well beyond previous TERC research in addressing new science issues identified in this report. The projects will provide a deeper analysis of long range transport through inter-comparison of the CMAQ and CAMx models, and sensitivity and process analysis to investigate the underlying physical and chemical mechanisms behind model source apportionment results. The modeling projects will be coordinated with other efforts to interpret data from the NETPS and SETTS campaigns.

Currently, the Houston Eight-Hour Ozone Coalition is sponsoring SIP modeling research using an expanded set of episodes, including at least one with high regional ozone. The transport results of the proposed short-term modeling projects can be used to improve that study. The proposed short-term projects will also facilitate the planning and execution of an extended tetroon (controllable altitude balloon) and aircraft campaign during the intensive portion of TexAQS II, scheduled to occur in the summer of 2006.

Recommended Longer-Term Research

TERC has invested considerable resources in developing infrastructure to support TexAQS II. This includes real-time meteorological and air quality forecast models, the initial application of which has been to provide operational support in the planning and execution of aircraft flights and measurements. The models will also be used in the analysis of forthcoming field study data. This will result not only in thorough evaluation of the models against observations during potential new SIP episodes, but also in increased credibility when the models are deployed to address policy issues. TERC should continue to develop and apply these forecast models and other analysis tools that will enhance the overall capabilities of future SIP models and improve confidence in their assessment of control strategies and demonstration of ozone attainment. To accomplish this goal, the synergies among proposed observational and modeling projects should be fully exploited. Priority observational projects include a tetroon and aircraft campaign and intensive meteorological and chemical measurements at low elevations, both during the day and at night (see Tables 11 and 12). Inter-collaboration and sharing of data and analysis tools among TERC, TCEQ, and other field study investigators will enhance the value of the proposed longer-term research to future SIP revisions.

1. INTRODUCTION

The year 2005 marks a turning point in the quest for clean air in Texas and the nation. The 1-hour ozone standard has been revoked and replaced by an 8-hour standard that promises to be even more challenging than its predecessor. The EPA must still finalize key portions of the Phase II guidance document for demonstrating attainment of the new standard (EPA, 2005a). Meanwhile, the Texas Commission on Environmental Quality (TCEQ) is developing ozone attainment demonstrations for various non-attainment areas simultaneously, along with plans for reducing regional haze (Table 1).

In support of the Texas State Implementation Plan (SIP), a major program of field measurements, monitoring, and modeling known as the Second Texas Air Quality Study (TexAQS II) was launched in the summer of 2005 and will continue until the fall of 2006. This campaign is a follow-up to the highly successful 2000 Texas Air Quality Study (TexAQS 2000). Fulfilling the many SIP requirements, while supporting TexAQS II, will require extensive personnel and fiscal resources. This document provides a framework to allocate scarce resources and to meet both policy and scientific goals needed to bring non-attainment areas in East Texas into attainment of the ozone standard.

Table 1. Key Dates in the Texas SIP Submission Process

Non-Attainment Area SIP Revision	**Proposal Documents Officially Considered**	**Official Adoption of SIP Revision**
Dallas-Ft. Worth	5/17/2006	11/15/2006
Houston-Galveston-Brazoria	11/15/2006	5/16/2007
Regional Haze	5/2007	11/2007

N.B. External input should be submitted about 3 months prior to each official date.

Since 2002, the Texas Environmental Research Consortium (TERC) has sponsored over $10 million of research related directly or indirectly to the Texas SIP for the Houston-Galveston-Brazoria (HGB) and Dallas-Ft.Worth (DFW) ozone non-attainment areas. To guide its research program, TERC produced two major documents: a revised Strategic Research Plan (Hall et al., 2004) geared to the 8-hour federal ozone standard, and a state-of-the-science summary of air quality research in Texas (Allen and Olaguer, 2004). TERC, the TCEQ, and other organizations have already funded a number of projects since the writing of those two documents. Our purpose is to explain what those projects mean in terms of: 1) their policy implications, 2) gaps in knowledge that should be bridged for the SIP, and 3) additional research required to fill those gaps in the context of both TexAQS II and the SIP, including any future SIP revisions.

All TERC project reports, as well as the TERC Strategic Research Plan and the state-of-the-science summary by Allen and Olaguer (2004), are publicly available over the Web at: http://www.harc.edu/harc/Projects/AirQuality/Projects/ReportList.aspx. In addition, TERC has produced Annual Reports for 2003 and 2004 summarizing previous research accomplishments and their impact on the Texas SIP.

2. STATEMENT OF THE PROBLEM

High ozone in Texas frequently occurs along the Gulf Coast, and in parts of Northeast and Central Texas. Along the Gulf Coast, Houston-Galveston-Brazoria (HGB) and Beaumont-Port Arthur (BPA) were both classified as non-attainment areas for 1-hour ozone (Severe-17 and Moderate) and are now in non-attainment of the 8-hour standard (Moderate and Marginal). In Northeast Texas, Dallas-Ft. Worth (DFW) was classified as Serious for 1-hour ozone and Moderate for 8-hour ozone. Tyler-Longview-Marshall is attaining the 8-hour standard and has entered into an Early Action Compact (EAC) to maintain progress. In Central Texas, ozone exceeds the 8-hour standard in Austin and San Antonio. Both areas have entered into Early Action Compacts. BPA and all EAC areas face a 2007 compliance deadline, while Dallas and Houston have a 2010 deadline.

2.1 THE REGIONAL OZONE PROBLEM IN EAST TEXAS

Ozone exists throughout the atmosphere, being most abundant in the stratosphere, starting at the tropopause around 10-12 km above the surface at mid-latitudes. Ozone is produced naturally in the stratosphere, reaching concentrations of 1000-10,000 ppb. Below the tropopause, that is in the troposphere, ozone concentrations are well below 1000 ppb. The largest sources of natural ozone in the troposphere are the mixing of air from the stratosphere and photochemical reactions involving NOx from lightning and soils, natural methane, and VOCs from soil microbes and vegetation.

Attaining the 8-hour ozone standard may require regional control strategies due to the increased significance of both natural and anthropogenic regional O_3 in relation to the new standard. According to global models, natural processes typically contribute 15-25 ppb of O_3 at the surface (19-31% of the 8-hour standard). Occasionally, rapid subsidence of stratospheric air or "tropopause folding" can substantially enhance this contribution during winter and spring, but with much smaller contributions during summer and fall.

Determining the sources of regional ozone requires understanding the dynamics of the troposphere, the lowest layer of which is the Planetary Boundary Layer (PBL). Ozone in the PBL is well mixed during the day, so its height partially determines concentrations of ozone at the surface. PBL height and convective mixing undergo a diurnal (24-hour) cycle (see Figure 1), generally increasing with surface temperature. Deep convection on very hot days produces cumulus towers (see Figure 2), which rapidly vent pollutants and ozone from the PBL to the free troposphere (FT). Deep convection also forces the air around cumulus towers to slowly subside, entraining pollutants and ozone back into the PBL. Lelieveld and Crutzen (1990) have demonstrated the importance of convective venting and subsidence in maintaining the global tropospheric ozone cycle.

Ozone has a longer lifetime aloft in the FT than in the PBL (where surface O_3 deposition occurs) and can be transported long distances by large-scale circulation systems, such as the jet stream and continental-scale centers of high pressure. Some ozone aloft may have been formed within urban plumes far upwind or from anthropogenic NOx emissions and biogenic VOCs on regional scales.

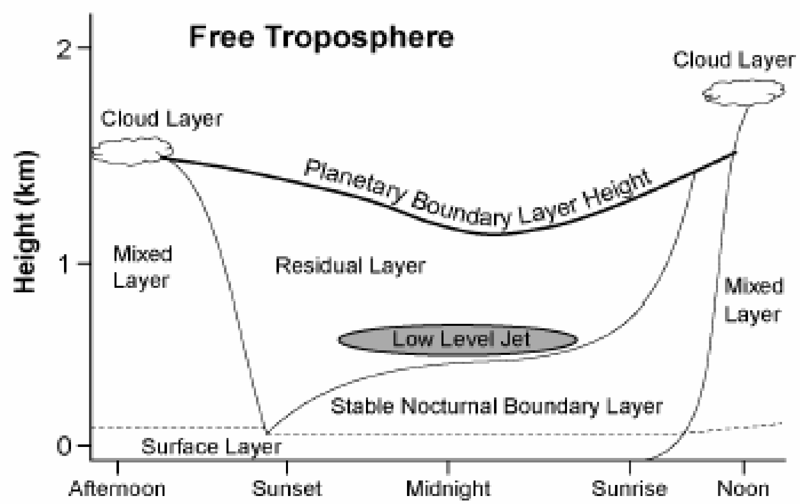


Figure 1. Typical evolution of Planetary Boundary Layer (PBL) and nocturnal jet.

Figure 2. Typical cumulus tower produced by deep convection on a hot day.

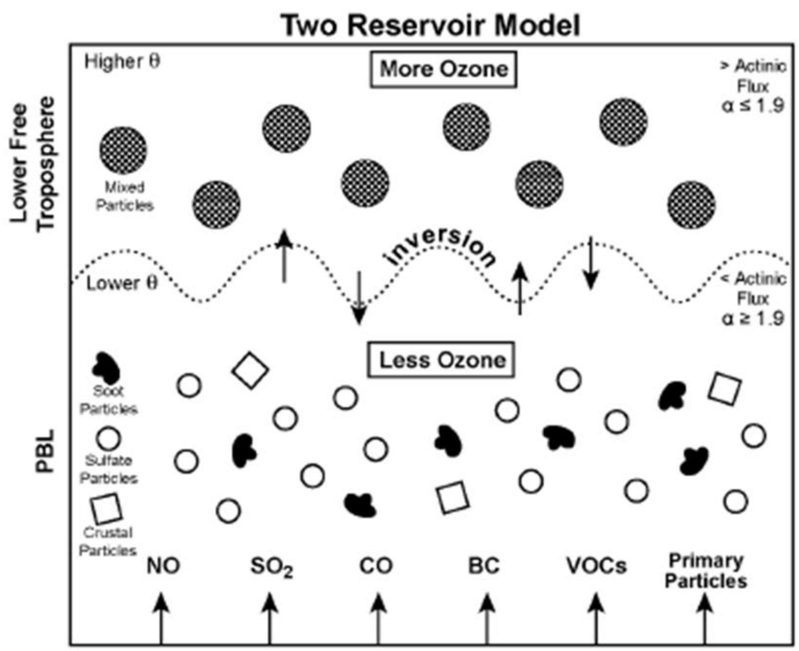


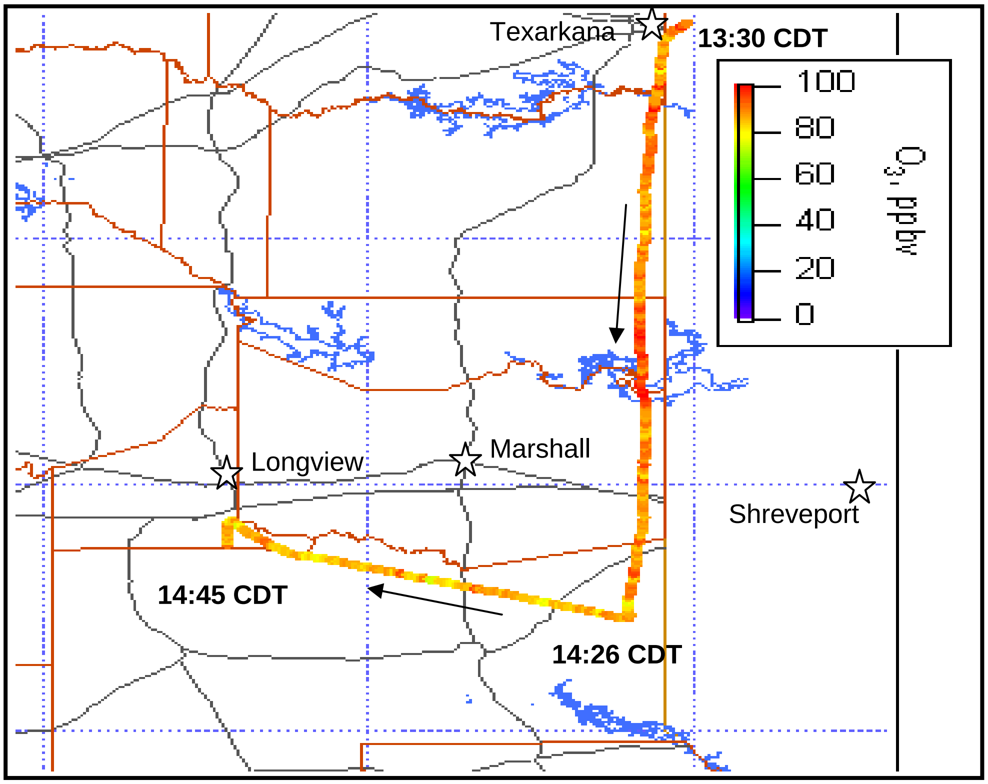
Figure 3. (Left) Conceptual two-level model showing conditions in the PBL and lower free troposphere (LFT) during a multi-day ozone episode (after EPA, 2005b). The dotted line represents top of PBL. Lower arrows indicate ozone and particulate matter precursors emitted into the PBL (BC denotes black carbon). The higher potential temperature (θ) in the LFT than in the PBL indicates protracted stability allowing LFT pollutants to persist. Both larger particles (i.e., lower α) and ozone have higher concentrations in the LFT than in the PBL, thus increasing light scattering and absorption (actinic flux) in the LFT, and intensifying photochemical processing. Upper arrows indicate PBL-LFT air exchange by convection and turbulent diffusion.

Observations in the eastern U. S. show that high surface ozone during the day may be accompanied by high ozone aloft (Taubman et al., 2004, 2005). Figure 3 illustrates a conceptual model that encapsulates the results of airborne observations by Taubman et al. (2004, 2005) from over 500 flights during multi-day haze and ozone episodes over the northeastern and mid-Atlantic States. In this conceptual model, the PBL and lower free troposphere (LFT) are separate reservoirs of pollution, in which greater concentrations of ozone (sometimes in excess of 100 ppb) are found in the LFT compared to the PBL. Prolonged atmospheric stability and drier air aloft allow pollutants in the LFT to persist for multiple days, undiluted by vertical mixing or wet deposition. Together with more efficient light scattering and absorption within the dirty air aloft, these conditions allow rapid photochemical processing ("chemical aging") to occur, converting short-lived NOx into PAN and other longer-lived reactive nitrogen reservoir compounds. The NOx stored in such reservoirs can be recovered when pollution subsides into the PBL. It is not yet known to what extent this conceptual model may apply to pollution episodes in Texas.

Berkowitz et al. (2000) performed airborne observations over several eastern States during a high ozone episode (30 Aug – 5 Sep, 1995). The observations were used to evaluate a coupled meteorology/air quality model. The mass budgets within a column of air on two sets of 2 days were analyzed with the model. The first and second days of both sets started out with comparable morning surface concentrations of ozone. However, the first day of each set had much lower observed 1-hour peak ozone at the surface (40-50 ppb) than the second day, when observed 1-hour peak ozone at the surface reached 90-120 ppb. Surface chemical loss rates produced strong vertical gradients in ozone that the model vertical diffusion reduced by imposing a downward ozone flux of about 20 ppb/hour at the ground. Berkowitz et al. (2000) concluded that the relatively large increases in surface ozone levels were preceded by transport of aged chemical plumes rich in ozone in the upper PBL that were subsequently mixed to the surface.

The processes observed to occur in the eastern U.S. may also be occurring in East Texas. During the TexAQS 2000 campaign in Houston, elevated layers of relatively high ozone concentration compared to those measured at the ground were found by comparing observations at the top of the Williams Tower with observations at Bayland Park, an adjacent surface site. Typical differences of around 20 ppb were commonly observed even when the atmosphere was moderately stable, that is when no capping inversion (temperature increasing with height aloft) was present (Berkowitz et al., 2004).

In the summer of 2002, the Northeast Texas Air Care (NETAC) group of local stake-holders sponsored aircraft flights in the vicinity of the Texas-Louisiana border, which on August 29, 2002 observed ozone concentrations above 85 ppb transported aloft from Louisiana during a period of easterly winds (see Figure 4). Estimated back trajectories for mid-afternoon on August 29, 2002 show that air had traveled 1 to 2 States upwind in the preceding 24 hours. However, the vertical motions associated with these trajectories is unclear. FNL data imply subsidence, whereas EDAS data yield rising trajectories. Nevertheless, on August 29, 2002, peak 8-hour ozone at the surface reached 88 ppb at the Karnack site near Marshall and 94 ppb at Parker County to the west of Fort Worth.



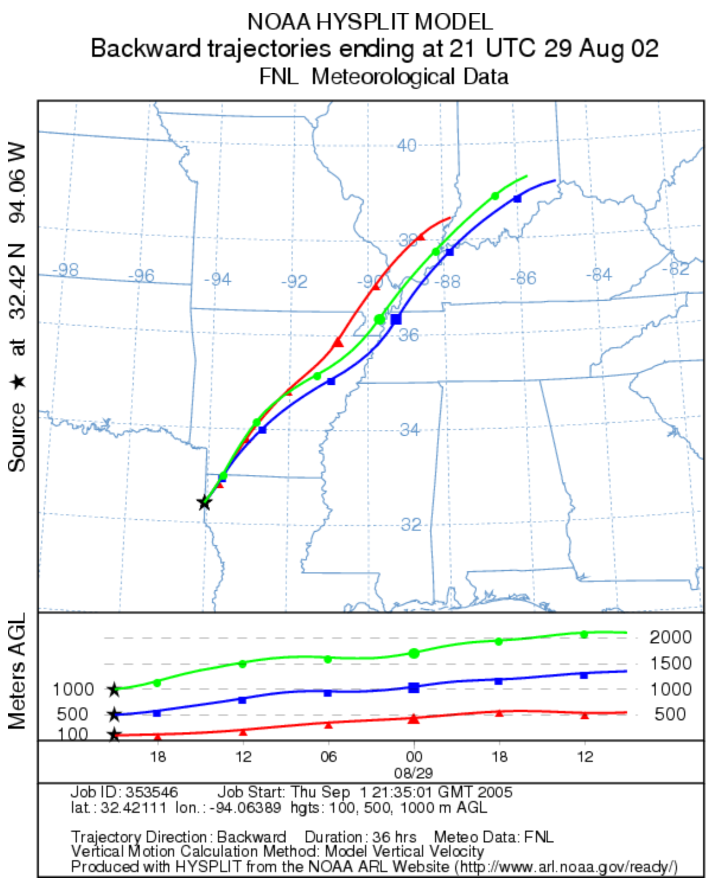


Figure 4. (Top) High ozone aloft entering Texas' eastern border observed by Baylor aircraft on 8/29/02. Variably colored line represents O_3 measurements along aircraft trajectory, with aircraft position times indicated at beginning, middle, and end of trajectory. Flight altitude ranged from 550 to 625 m above mean sea level. Note wide areas of O_3 between 80-90 ppb (after NETAC, 2004). (Bottom) Back trajectories estimated from the FNL data set for mid afternoon of 8/29/02. Note descent of trajectories as they progress towards the Texas-Louisiana border.

Long-range transport of ozone and precursors is not limited to the daytime. Plumes of high ozone far from the original source of precursors are sometimes observed aloft at night when vertical mixing is suppressed and nocturnal low level jets (LLJs) develop a few hundred meters above the ground (see Figure 1), as observed by Verghese et al. (2004) during the NARSTO North East Oxidant and Particle Study (NEOPS).

Nocturnal LLJs are known to occur in East Texas (Bonner, 1968). Banta et al. (2005) concluded that during TexAQS 2000, the lofting of large quantities of pollution to high altitudes in the boundary layer above Houston may have influenced air quality on regional scales through nocturnal transport. Overnight trajectories estimated from radar wind-profiler and rawinsonde data are shown in Figure 5. If the estimated trajectories are accurate, it may be inferred that pollution from Houston was transported by a LLJ toward Beaumont, Texas, and Louisiana; pollution in a second layer of stagnant flow remained over Houston; and pollution in an upper layer was transported toward Austin and San Antonio. Regardless of uncertainties in the inferred trajectories, it is clear that Houston pollution may be transported in complex ways to various areas in East Texas overnight.

Regional reductions in NOx emissions, such as those resulting from the NOx SIP Call and the Clean Air Interstate Rule (CAIR), have been implemented to help States attain the 8-hour standard by decreasing background ozone. "Background" can be taken to mean concentrations observed at relatively remote areas or upwind of a particular location. "Background" can also refer to contributions from uncontrollable (e.g., natural or trans-continental anthropogenic) sources. Lastly, "background" can refer to concentrations not attributable exclusively to local emissions. For the purpose of setting National Ambient Air Quality Standards (NAAQS), the EPA (2005b) defines a Policy Relevant Background (PRB) concentration as that which would result in the United States in the absence of anthropogenic emissions in continental North America (defined as the U.S., Canada, and Mexico). This definition implies that PRB concentrations can only be estimated using 3-D Chemical Transport Models (CTMs). Fiore et al. (2003) used the Harvard GEOS-CHEM CTM to conclude that PRB ozone from 1300 to 1700 local time ranges from 15 to 35 ppb. PRB ozone declines from spring to summer and is generally less than 25 ppb under conditions conducive to high ozone episodes.

For demonstrating ozone attainment in Texas, it is necessary to define background ozone on a smaller scale as compared to the EPA PRB definition. Nielsen-Gammon et al. (2005a) defined background ozone for an urban area as the ozone level that would be attained if there were no local anthropogenic emissions of ozone precursors. They operationally estimated background ozone as the lowest maximum 8-hour ozone concentration observed in a ring of monitors on the outskirts of the urban area, which typically occurs upwind of the metropolis. Applying this method to all days (i.e., not just during high ozone episodes), Nielsen-Gammon et al. (2005a) showed that background ozone in East Texas peaks during the spring and late summer (Figure 6). It should be noted that while the method of Nielsen-Gammon et al. (2005a) may ignore recirculation of local pollution at upwind monitors, their statistical analysis indicates that the dominant cause of variability in upwind background ozone is larger-scale transport.

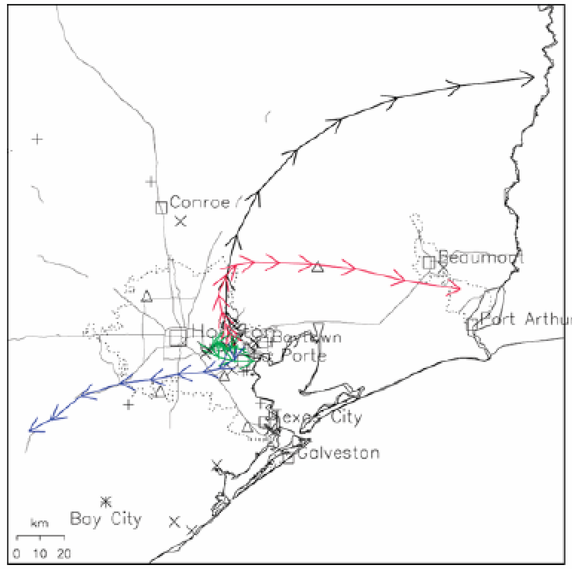


Figure 5. Estimated 12-hr forward trajectories showing overnight transport from Houston starting at 1800 CST on August 30, 2000 and ending at 0600 CST on August 31, 2000. Red is for 200-500 m layer, black is for 500-800m layer, green is for 800-1100m layer, and blue is for 1100-1400m layer (after Banta et al., 2005). Note how Houston pollution is transported in complex ways to various areas in East Texas overnight.

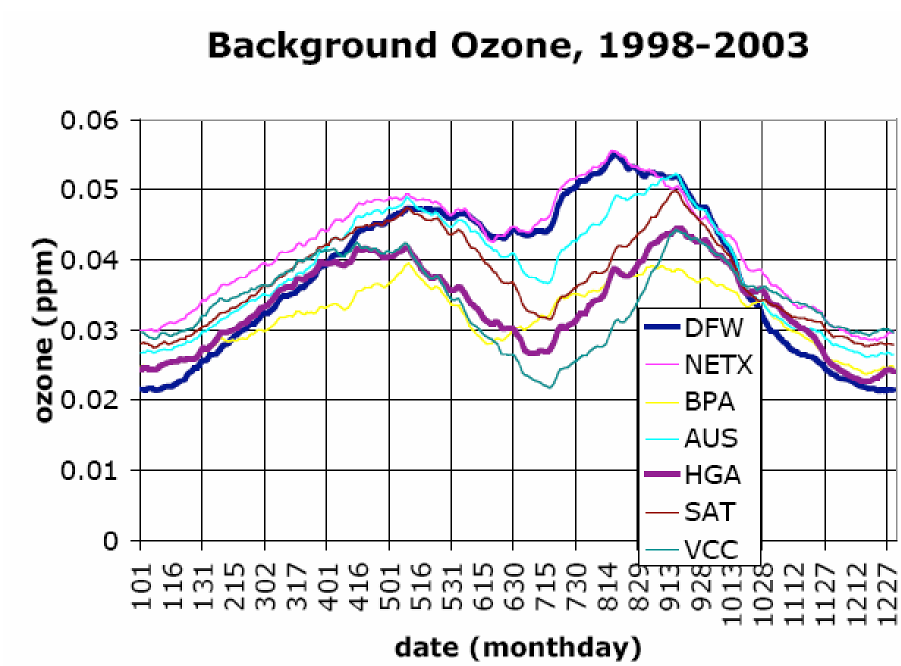


Figure 6. Six year average 8-hour background ozone in in East Texas regions smoothed with a 31-point running mean filter (after Nielsen-Gammon et al., 2005a). DFW denotes Dallas-FT. Worth, NETX denotes Northeast Texas, BPA denotes Beaumont-Port Arthur, HGA denotes Houston-Galveston, SAT denotes San Antonio, and VCC denotes Victoria-Corpus Christi. Note the seasonal peaks in both spring and late summer/early fall.

2.2 THE OZONE PROBLEM IN HOUSTON

While Houston's air quality problem shares many features found in other urban areas in the U.S., it is dramatically influenced by Houston's position as a major international port and the largest producer of petroleum products in the country. Petrochemical production and refining lead to emissions of olefins classified as Highly Reactive VOCs (HRVOCs) by the TCEQ. These emissions are quite variable and are sometimes released in large quantities over a short period of time. Such transient releases or "emission events" are often in close proximity to NOx sources that enhance their ozone formation potential. Furthermore, slow, rotating winds associated with the sea breeze create zones of nearly calm air, trapping these emissions and allowing them to build up to high levels. These factors result in very rapid formation of concentrated ozone plumes, which are seen as intense ozone spikes or Transient High Ozone Events (THOEs) at ground monitors. This is in marked contrast to the more typical situation in many areas in which emissions and ozone are more evenly distributed, and ozone at ground monitors builds up more slowly.

The occurrence of THOEs and their association with HRVOC emissions have been confirmed by many analyses of data from TexAQS 2000 (e.g., Ryerson et al., 2003). This led the TCEQ to adopt a two-pronged control strategy for HRVOCs. First, an annual HRVOC emissions cap was established to ensure that total emissions would remain low enough to attain the 1-hour ozone standard. Second, to control emission events, a "short-term cap" was imposed that limits any emission point with more than 5% HRVOC to less than 1200 lb per hour. The TCEQ also changed reporting requirements so that releases that were 100 lbs over the daily permitted maximum were to be reported in a new on-line database. Analysis of the self-reported emission event data by Allen et al. (2004) showed that over 12% of yearly HRVOC emissions in the HGB area were due to unplanned releases or to planned start-up, shut-down, or maintenance operations. Allen et al. (2004) showed that in 2003, reports of 100-1000 lb releases occurred daily, while 1000-10,000 lb HRVOC emission events were reported 2-3 times a week. Thirty-three times in the same year, there were events of 10,000 to 100,000 lbs. Continuation of such releases would result in frequent severe violations of the TCEQ's short-term cap rule.

One immediate policy implication of THOEs is that an attainment demonstration for Houston needs to have much finer and more accurate representations of industrial emissions, meteorology, and ozone chemistry than for other non-attainment areas. Despite enormous improvements in the TCEQ's modeling practice after TexAQS 2000, a sizeable investment of resources is required to continue progress in this regard. The challenge of treating THOEs accurately makes it difficult to demonstrate that any set of control strategies will result in ozone attainment based on modeling alone. Some 8-hour violations occur in May and June (Figure 7), whereas the TCEQ's current SIP modeling is limited to an ozone episode in August-September, 2000. A wider variety of meteorological episodes may be required to account for HGB 8-hour design values, given the averaging that must be performed to derive these values. This would provide additional confidence that controls would be effective in attaining the 8-hour standard

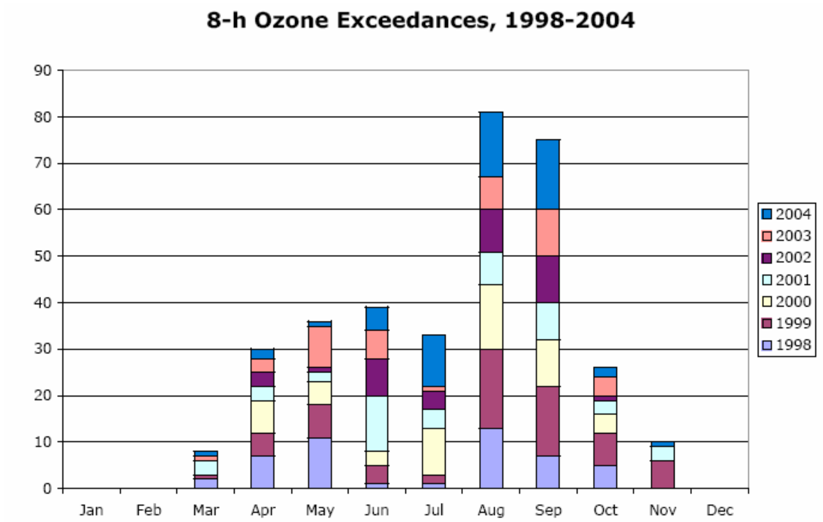


Figure 7. Number of days in which the 8-hour standard was violated at one or more monitors in HGB by month (after Nielsen-Gammon et al., 2005b).

Even if HRVOC emission events were eliminated, Houston's coastal meteorology would not only continue to make local ozone compliance difficult given the remaining precursor emissions; it may also impede progress towards attainment in other areas (see Figure 5). A proper assessment of both the local production and transport of ozone and related pollutants must focus on two distinct features associated with the Houston sea breeze.

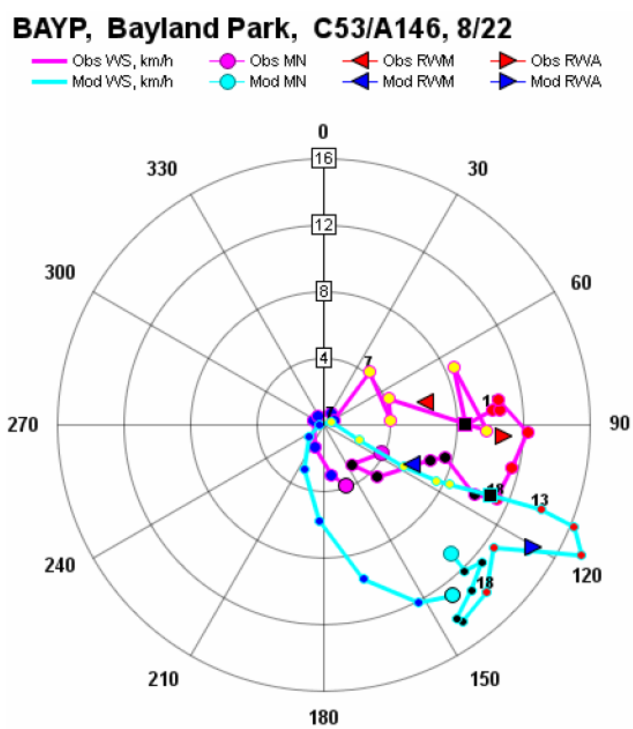


Figure 8. Modeled vs. observed winds after Jeffries et al. (2005). WS is wind speed, MN is midnight, RWM is resultant morning wind, RWA is resultant afternoon wind.

The first feature has already been alluded to, namely the slow wind rotation that traps pollutants locally. Figure 8 compares the observed wind rotation at the Bayland Park monitoring station on the west side of Houston, away from the Ship Channel, to the corresponding wind rotation simulated by the Houston SIP model, as analyzed by Jeffries et al. (2005).

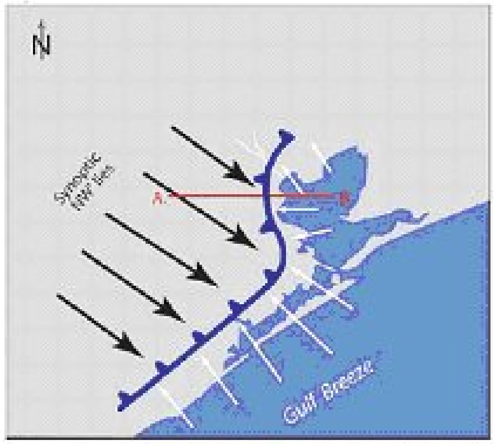


Figure 9. Schematic representation of an incipient sea breeze stalled along the shore of Galveston Bay, as occurred in late afternoon on August 30, 2000. Line AB shows the location of the vertical cross section depicted in Figure 11 (after Banta et al., 2005).

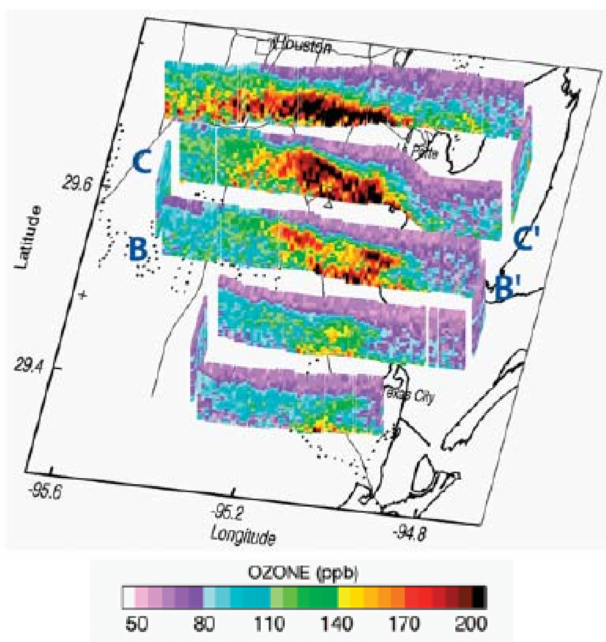


Figure 10. 3-D distribution of O_3 measured by airborne lidar in the Houston-Galveston area in late afternoon (16:53 to 18:11 CST), August 30, 2000. Flight tracks began south and ended north. Measurements extend from 300 to 2000 m. O_3 concentrations of nearly 200 ppb penetrate to almost 2 km. Trajectory analysis indicates that the air in the high-pollution band along the coast passed over the Ship Channel (after Banta et al., 2005).

The second important feature associated with Houston's coastal meteorology is the occurrence of stalled sea breeze fronts, as illustrated in Figure 9. Stalled fronts result in stagnant zones at the boundary of converging air masses, which not only allow ozone and precursors to build up at the surface, but also uplift them to create "walls" of pollution, as observed by airborne lidar during TexAQS 2000 (see Figure 10). This uplift allows transport by daytime winds aloft or by nocturnal jets. Galveston Bay and the Gulf of Mexico play a critical role in creating both slow wind rotation and stalled sea breeze fronts (Figure 11).

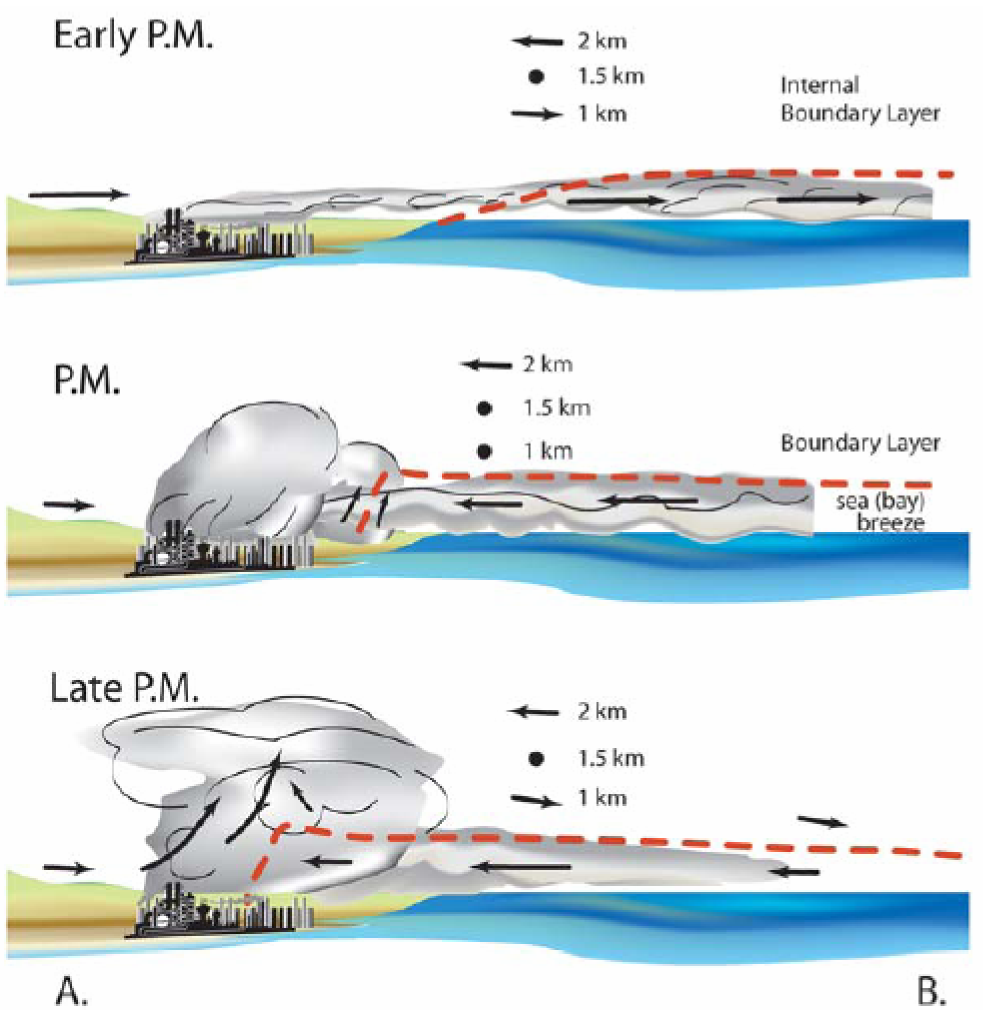


Figure 11. Schematic vertical cross section along line AB in Fig. 9, showing (top) early day offshore flow taking pollutants outward over Galveston Bay, (middle) the incipient bay breeze producing a convergence zone of light and variable surface winds just onshore over the source regions, and (bottom) a more fully developed on-shore flow producing stronger convergence, lofting pollutants high over the coastal zone. Arrows represent direction and relative speed of wind component, and dots represent layers of light flow. Heavy red dashed line indicates top of mixing layer over the bay and of the bay-breeze layer over land (after Banta et al., 2005).

Jeffries et al. (2005) studied the results of TCEQ's modeling extensively and noted several factors which merit further study. These include the difficulty of properly simulating wind and PBL evolution both during the day and at night, uncertainty in characterizing vertical mixing by turbulent diffusion, and uncertain emissions inventories for HRVOCs and possibly NOx. Because these factors have the potential to distort the chemical operating conditions of the Houston SIP model, they need to be addressed to increase confidence that 8-hour SIP control strategies will be effective. Major changes in modeling practice beyond those already implemented by the TCEQ, such as the use of newer emissions models and advanced methods for data assimilation (use of observations to constrain model behavior), may be required to demonstrate 8-hour ozone attainment with increased validity.

The new ozone standard may not only require significant improvements in modeling performance, but also more stringent local controls. Control strategies are particularly difficult to design in Houston because different causes of high ozone predominate in different parts of the airshed. Figure 12 shows the number of different types of ozone exceedances in the HGB non-attainment area. THOEs are low in the west, but dominate in the east both near the Ship Channel and north of the Ship Channel in areas downwind. An analysis of all the 8-hour ozone violations in the last five years suggests that THOEs contribute up to 25-35% of the total 8-hour violations. Thus, to attain the 8-hour ozone standard in Houston, we need strategies that target THOEs (mostly HRVOC controls), as well as the more typical urban emissions (control of Other VOCs and NOx), and perhaps regional emissions. It should be noted that even if all point source NOx emissions were eliminated in Houston (including considerable emissions from ships and barges), the area's NOx emissions would still resemble those of DFW in magnitude, hence the need to focus attention on both mobile sources and Houston Ship Channel industrial facilities.

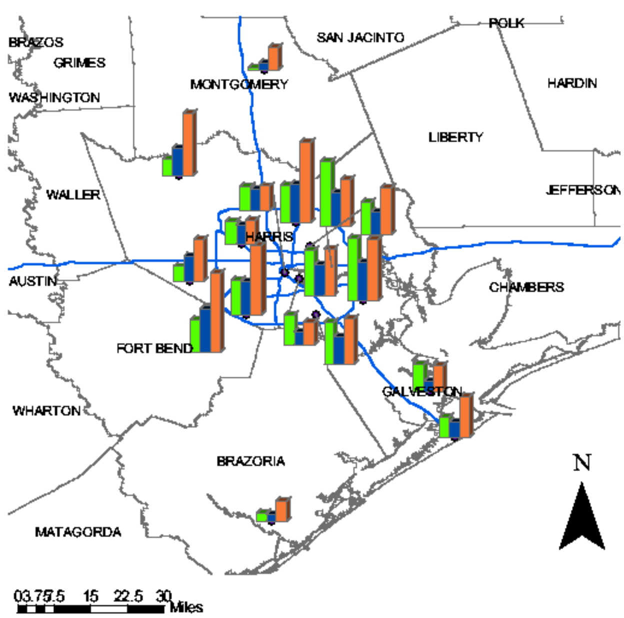


Figure 12. Comparison of the total number of THOEs (green), 1-hr ozone exceedances (blue), and 8-hr ozone exceedances (red) for 1998-2002 in the HGB non-attainment area.

The TCEQ ultimately required a combined 80% NOx emission reduction on industrial sources coupled with annual and hourly caps on HRVOC emissions. In addition, Houston SIP strategies and tightened federal engine standards are expected to result in relative NOx reductions of 49% from on-road mobile sources and 16% from non-road and area sources between 2000 and 2007 (see Table 2). These measures appear to be sufficient for attaining the 1-hour standard. The TCEQ's short-term HRVOC cap rule, in particular, may even be more effective at lowering ozone than the current SIP model predicts due to the apparent inefficiency of ozone production in the model relative to the real world (Jeffries et al., 2005). Nevertheless, preliminary analysis suggests that current Houston SIP measures may not be sufficient for attaining the 8-hour standard. After 2008, the NOx distribution in Houston may be more similar to that of Dallas. Future attainment of the 8-hour standard may require balanced reductions across all source categories.

Table 2. HGB NOx Budget (tpd) from the December 2004 SIP

Source Category	**2000 Base Case**	**2007 Controls**
On-road mobile sources	342 (33%)	175 (33%)
Area and non-road mobile sources	184 (18%)	155 (30%)
Point sources	492 (47%)	174 (33%)
Biogenic sources	21 (2%)	21 (4%)
TOTALS	**1039 (100%)**	**525 (100%)**

2.3 THE OZONE PROBLEM IN DALLAS-FT. WORTH

Past research has indicated that ozone in DFW is largely NOx limited. DFW control strategies in the mid 1990s targeted VOC reductions when the role of biogenics was not understood as well as it is today. A retrospective analysis for DFW from 2000 to 1990 performed by Stoeckenius and Yarwood (2004) in TERC Project H27 showed that VOC emissions declined 32% while NOx emissions remained largely unchanged (Figure 13). Project H27 also showed that there was no obvious trend in 8-hour ozone from 1990 to 2003, based on design values at monitors with substantially complete data records back to at least 1995 (Figure 14). While ozone trends are influenced by other factors in addition to emissions, the findings of Project H27 support the conclusion that NOx reductions are the principal means by which the DFW area can be brought into attainment.

Although control strategies implemented in the DFW 4-county non-attainment area in the mid 1990s targeted VOC reductions, aggressive local point source NOx reductions were implemented in the late 1990s, supported by regional NOx reductions. The shift from VOC to NOx control resulted from studies that increased the simulated amount of biogenic VOC emissions in the area, allowing ozone chemistry to proceed despite reductions in anthropogenic VOCs. The last DFW SIP revision called for a 45% reduction in total NOx emissions to attain the 1-hour standard (Table 3). The latest modeling shows that attaining the 8-hour standard with just local controls may require additional NOx reductions of more than 40 percent from all DFW anthropogenic sources, in addition to reductions resulting from State and federal programs, including cleaner motor vehicles. Modeling also shows that further VOC reductions will have some benefits, particularly in the urban core.

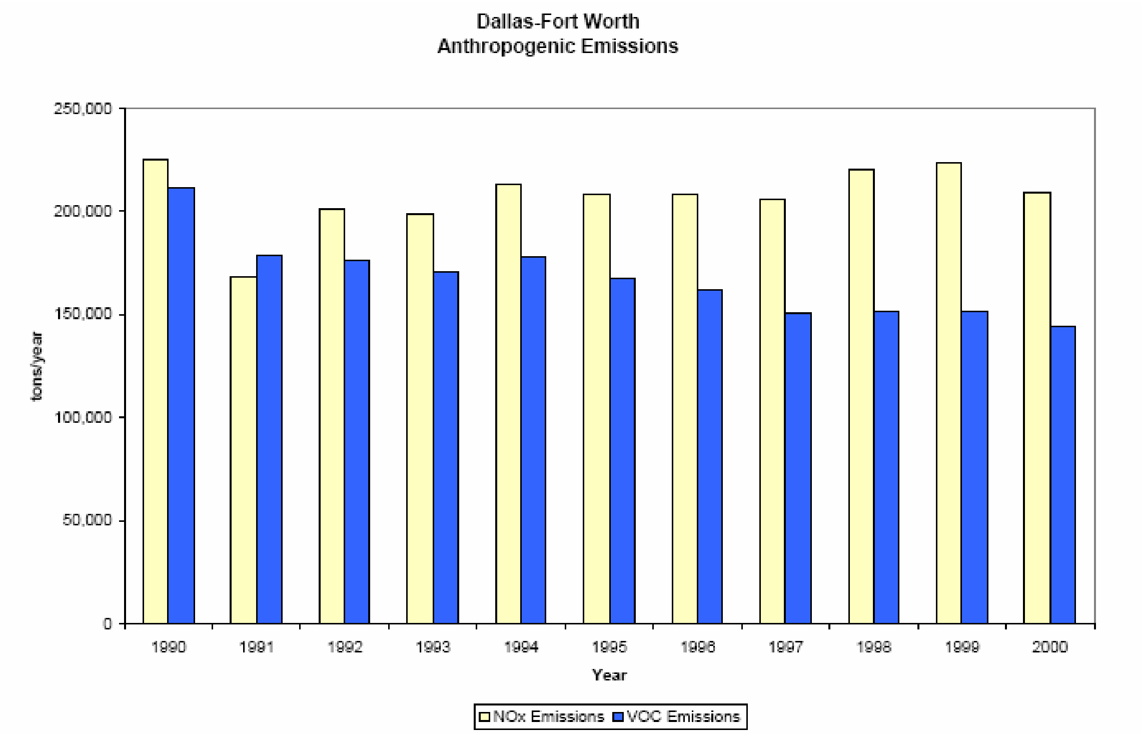


Figure 13. Trends in anthropogenic VOC and NOx emissions in DFW. Note larger VOC reductions relative to NOx reductions.

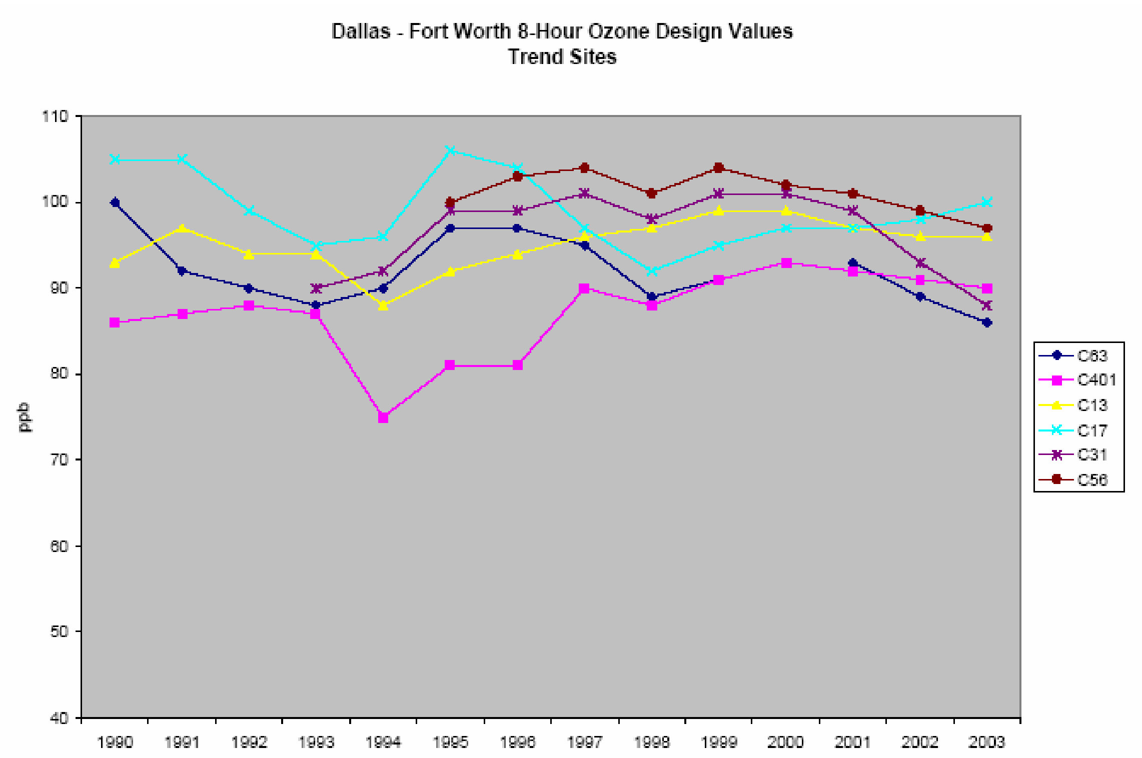


Figure 14. Trends in 8-hour ozone at DFW monitors with long term data. Note relative insensitivity of ozone to major reductions in VOC emissions (see Figure 13).

Table 3. DFW NOx Budget (tpd) from the March 2003 SIP

Source Category	**1996 Base Case**	**2007 Controls**
On-road mobile sources	322 (55%)	164 (51%)
Area and non-road mobile sources	133 (23%)	107 (33%)
Point sources	99 (17%)	23 (7%)
Biogenic sources	27 (5%)	27 (8%)
TOTALS	**581 (100%)**	**321 (100%)**

High ozone events in DFW frequently coincide with high regional ozone levels, creating an expectation that regional strategies will help DFW attain the 8-hour standard. Ozone source apportionment based on the Anthropogenic Precursor Culpability Assessment (APCA) model technique was performed by Stoeckenius and Yarwood (2004) using the August 15-22, 1999 modeling episode developed for the DFW 8-hour ozone SIP. Table 4 summarizes the various contributions to 8-hour exceedances during the SIP episode, including the impacts of intra-State and out-of-State transport and model boundary conditions (i.e., ozone specified at the top and horizontal edges of the modeling domain), as compared to local emissions.

Table 4. APCA Contributions to DFW 8-Hour Ozone Exceedances During August 1999 Episode (from Stoeckenius and Yarwood, 2004)

Source Category	***Ozone Contribution***
9-County DFW Non-Attainment Area	**40 ppb**
Intra-State Transport	12 ppb
Out-of-State Transport	11 ppb
Model Boundary Conditions	31 ppb
Total Non-Local (Background) Contribution	**54 ppb**

N.B. Electric Generating Units (EGUs) in Texas have reduced emissions by over 50% since 1999.

The total non-local contribution to DFW ozone computed by the model of Stoeckenius and Yarwood (2004) agrees well with the peak summertime background ozone computed by Nielsen-Gammon et al. (2005a) for DFW based on (upwind) monitor observations over a six year period (see Figure 6 in Section 2.1), suggesting that background ozone levels during the August 15-22, 1999 ozone episode were typical. The results in Table 4 suggest that controlling in-State and out-of-State emissions would be about equally effective in reducing DFW background ozone. However, the contribution of out-of-State sources may be greater for episodes that have more persistent transport winds, such as the August 29, 2002 event discussed in Section 2.1 (see Figure 4).

Table 4 shows that total background ozone exceeded locally produced ozone during the August 15-22, 1999 episode. This inference is supported by Breitenbach (2003), who analyzed daily upwind/downwind monitor observations during August 1999 (see Figure 15). Note that the upwind values in Figure 15 can sometimes be in the range of 80-100 ppb, although it is possible that these are influenced by re-circulation of polluted air from

DFW. Breitenbach (2003) appears to infer less local ozone production than the APCA modeling possibly because peak downwind ozone can occur away from monitors or because upwind monitors in 1999 may have been too close to the urban area. Moreover, upwind and locally produced ozone are not additive, due to local deposition and non-linear chemistry. Despite these caveats, the upwind/downwind analysis in Figure 15 shows that the relative contributions of local and background ozone vary from day-to-day according to changes in the relative strengths of stagnation and transport winds.

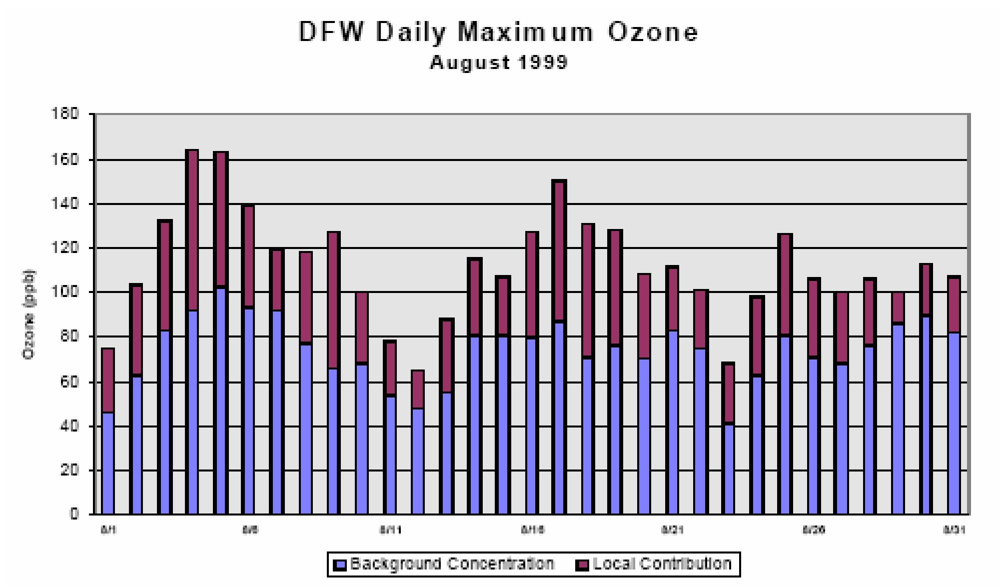


Figure 15. Daily peak hourly ozone in the DFW area: relative contributions of upwind background and local emissions during August 1999 (adapted from Breitenbach, 2003).

Even if background ozone may often exceed locally produced ozone, not all background ozone comes from controllable anthropogenic sources within the influence of the State or federal governments. Nevertheless, if an EPA PRB ozone concentration of 25 ppb is subtracted from the total non-local contribution computed by Stoeckenius and Yarwood (2004), this still leaves 29 ppb for the regional and continental anthropogenic background ozone contribution. This implies that controlling regional and continental sources is important, as well as controlling local sources.

EPA is implementing regional NOx reductions for major point sources under the Clean Air Interstate Rule (CAIR). TERC Project H35 analyzed the benefits of a proposed version of CAIR for current Texas SIP model episodes and found only marginal benefits in the DFW area (Tai et al., 2005). Contributing factors may include meteorological conditions for the episodes studied and specific assumptions about which sources reduce emissions in response to CAIR. Additional study under a wider range of meteorological conditions and different emission reduction assumptions may change the assessment of CAIR benefits to DFW, especially since the final version of CAIR may result in greater

NOx reductions within Texas. Neighboring states may also reduce emissions from eligible major point sources under regional haze SIPs due in 2007 (Table 1). Additional NOx reductions in nearby States beyond CAIR provisions may prove to be beneficial to Texas. Using the CAMx model for the 1999 DFW SIP episode, Yarwood (2003) found that a 50% reduction in Electric Generating Unit (EGU) emissions within Louisiana in 2007 could lead to reductions in peak 8-hour ozone of more than 1.5 ppb within Texas during a majority of episode days. Yarwood (2003) concluded that DFW, along with the other non-attainment and EAC areas of East Texas, would benefit from reducing Louisiana EGU emissions. In comparison, the CAIR modeling in Project H35 assumed only about 20% reductions in Louisiana EGU emissions (from EPA's analysis) and assigned the reductions equally to all EGUs. In reality, CAIR reductions will likely be concentrated at a subset of EGUs that may reduce emissions by greater than 50%.

More aggressive reductions in Texas regional NOx emissions might reduce the significant intra-State transport contribution to DFW ozone non-attainment (Table 4). Figures 16(a) and 16(b) suggest that opportunities for effective additional reductions are likely to be found south and southeast of DFW down to the Gulf Coast, as well as to the east of DFW. The detailed APCA ozone source apportionment modeling results for the DFW episode (summarized in Table 4) confirm these conclusions about which areas in Texas most contribute to DFW ozone exceedances via intra-State transport.

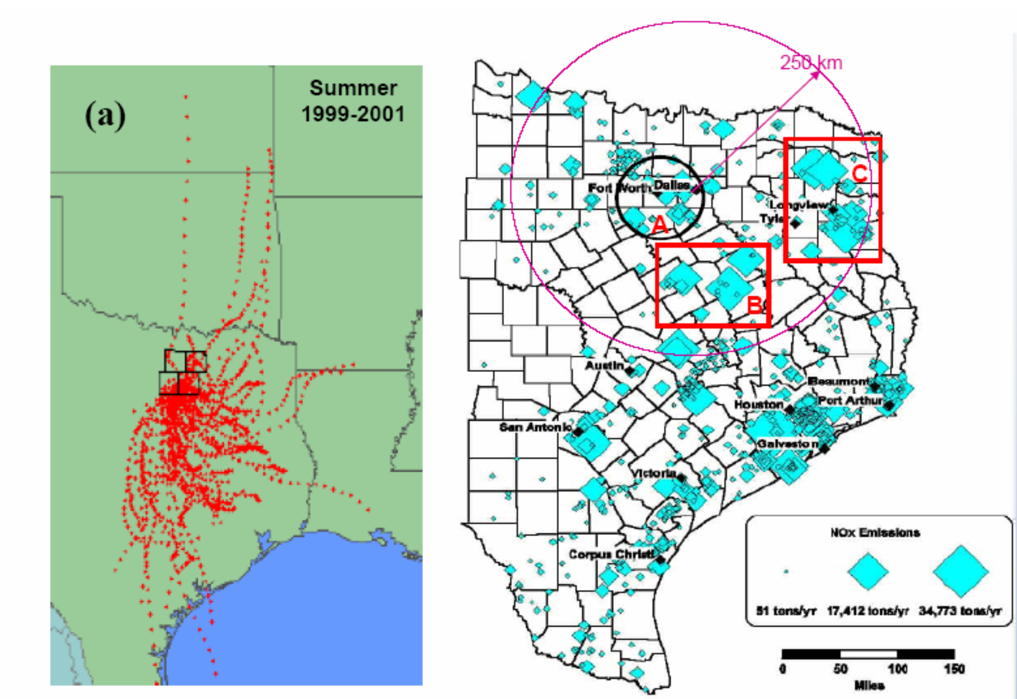


Figure 16. (a) Estimated climatological 24-hour back trajectories from DFW on high ozone days during summers 1999-2001. (b) Major NOx sources in East Texas. Those in Zones A, B, and C are to be investigated during the Northeast Texas Plume Study of 2005. Note that air in East Texas is relatively well mixed horizontally in a period of 24 hours (after Gillani, 2005).

2.4 THE POLICYMAKER’S CHALLENGE

Finding solutions to the ozone problems in East Texas requires monitoring, analysis, and modeling efforts over vastly different areas, ranging from neighborhoods (a few miles) to the entire continent (thousands of miles). Extensively updated modeling assessment of control strategies is likely to take longer than allowed under the current SIP timeline. Moreover, there are significant sources of ozone precursors that may need to be reduced to attain the 8-hour standard, but are beyond the TCEQ’s jurisdiction. These include federally pre-empted sources, such as cars, trucks, ships, and locomotives, and out-of-State point sources that would require a Clean Air Act, Section 126 petition to address.

The difficulty of attaining the 8-hour ozone standard in HGB and DFW by 2010 is exacerbated by the lack of synchronization of federal motor vehicle control measures and the ozone attainment deadline. Table 5 outlines the implementation schedule of federal control measures, while Figure 17 shows anticipated NOx and VOC reductions from these measures. Note that the federal measures apply only to new vehicles, hence their benefits are phased in gradually as older units are retired and replaced by newer ones.

Table 5. Federal Motor Vehicle Control Program Schedule (After Kite, 2005)

Federal Rule	Vehicle Class/ Fuel Type	Pollutants Affected	Model Year Phase-in Begins
National Low Emissions Vehicle (NLEV)	Light Duty Vehicles Light Duty Trucks (Below 6001 lbs)	NOx, VOC, CO, PM (diesel only), Formaldehyde	2001
Tier 2/Low Sulfur Gas (Exhaust/Evaporative)	Light/Medium Duty Vehicles and Trucks	NOx, VOC, CO, PM, Formaldehyde	2004
Heavy Duty (Diesel Exhaust)	Heavy Duty Diesel Vehicles	NOx, VOC	2004 standards with 2002 “pull ahead”
Heavy Duty 2005 (Gasoline Exhaust)	Heavy Duty Gasoline Vehicles	NOx, VOC, CO	2005
Heavy Duty 2007/ Low Sulfur Diesel (Gasoline Exhaust/ Evaporative, Diesel Exhaust)	Heavy Duty Diesel Vehicles	NOx, VOC, PM	2007
	Heavy Duty Gasoline Vehicles	NOx, VOC, PM, Formaldehyde	2008

Figure 17 implies that **federal measures already in place will only yield sufficient benefits in Texas well after the current attainment deadlines for HGB and DFW have expired**. Moreover, the TCEQ must satisfy new EPA guidance, address new science issues posed by the 8-hour standard, improve SIP modeling, and at the same time find and demonstrate the effectiveness of new control strategies within an extremely tight schedule.

Effective research should focus on helping decide the right direction for control strategies despite current uncertainties, to avoid having to reverse course at some future time. Quantitative refinement can occur in an iterative manner, as has been the case with past SIP revisions.

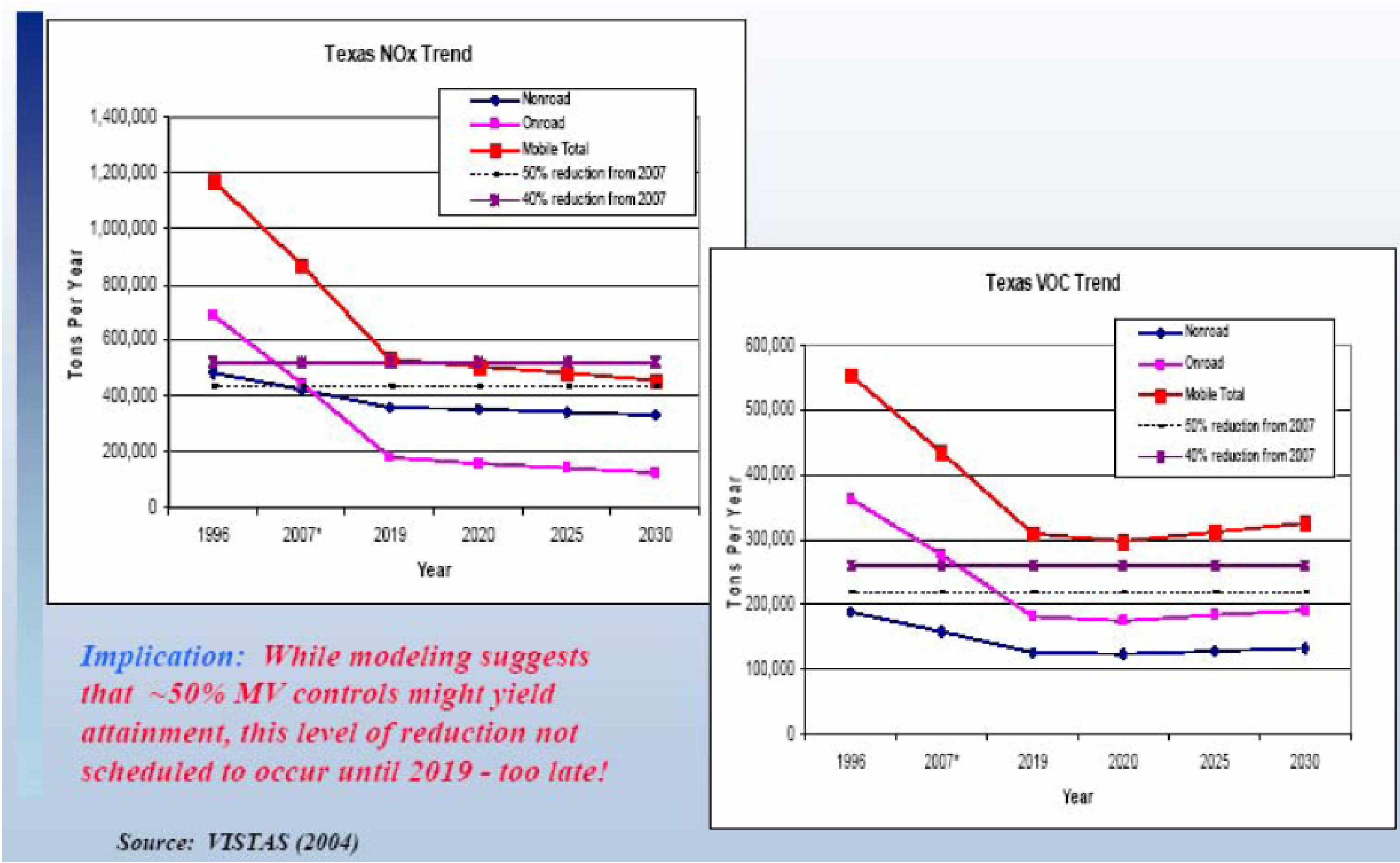


Figure 17. Impact of federally mandated motor vehicle controls in Texas (after Lubertino, 2005)

3. RESEARCH FINDINGS AND KNOWLEDGE GAPS

Tables 6 and 7 summarize the major findings and policy implications of several recently completed TERC projects, whereas Tables 8 and 9 list TERC and TCEQ projects that are either currently underway or planned as part of TexAQS II. Projects listed in Tables 6-9 are classified according to how they address three categories of SIP issues:

- Foundational science issues
- Operational issues related to SIP production
- Strategic issues related to policy endpoints.

Foundational issues concern the basic physical, chemical, engineering and mathematical assumptions upon which SIP modeling is constructed. TERC projects that address foundational issues have been designed to meet a research need previously identified in the Strategic Research Plan. Operational issues concern the manner in which the SIP model is used, such as the selection of episodes used to demonstrate attainment and the State response to the modeling guidance provided by EPA under the 8-hour standard. Operational issues may also involve the collection and processing of input data required for the SIP, such as those pertaining to land use or emissions inventories. Strategic issues concern the development and/or assessment of emission controls required to achieve ozone attainment. All projects listed in Table 7 are classified as strategic.

Several conclusions can be drawn from the various projects recently completed by TERC and other organizations. These conclusions are stated below in terms of the knowledge gaps identified by completed projects, as well as their positive findings. The 2005 field study projects which address the identified knowledge gaps are also indicated below.

3.1 GENERAL CONCLUSIONS FOR EAST TEXAS

3.1.1 Better understanding is needed of the relative importance of transport vs. local O_3 *production, especially under high* O_3 *conditions not captured by current SIP episodes.* Data analysis of ground monitor observations by Nielsen-Gammon et al. (2005a) and APCA modeling by Stoeckenius and Yarwood (2004) agree in their estimate of average regional background ozone in East Texas. However, major uncertainties remain. For example, in Project H35, Tai et al. (2005) changed the convection scheme used in the DFW SIP model and found that Houston's transport contribution to DFW high ozone changed from 3 to 5 ppb. Other uncertainties have yet to be explored. The NETAC study of August 2002 found that easterly flow from Louisiana brought in over 85 ppb of ozone aloft, yet no SIP episode in Texas reflects this situation. Modeling studies that focus more intensively on the causal mechanisms of transport both near the surface and aloft are needed to refine the current conceptual model of background ozone. In addition, if 8-hour ozone design values are to be properly accounted for, it may be necessary to incorporate a larger number of episodes into the SIP modeling, such as a springtime episode with ozone exceedances, to account for the seasonality of background ozone. Whether or not source apportionment performed using such episodes will yield results similar to those of past TERC studies remains to be seen. (Relevant past projects: H12.8HRA, H27, H35; relevant TexAQS II projects: H39, H44.A, H44.B, H44.C)

Table 6. Recently Completed TERC Modeling Projects

Project Number	Project Name/ Methodology	Issue Type	Rationale	Primary Results	Policy Implications
H12.8HRA	*A Conceptual Model for 8-hr Ozone Exceedances in East Texas* Data and modeling analysis, including application of a statistical technique known as Principal Component Analysis, to explain the causal connection between meteorological observations and ozone measured by ground monitors.	Operational Foundational	EPA guidance requires formulation of a conceptual description of an area's non-attainment problem. Explaining the meteorological mechanisms that lead to 8-hr ozone exceedances is a key science issue.	Background ozone is a major contributor to 8-hr ozone exceedances, and peaks in both spring and late summer. Cause of spring maximum is distinctly different from that of summer maximum and may involve very long-range transport as opposed to regional scale transport. Stationary fronts cause stagnation that may result in high local ozone.	Control of background ozone from intra- and out-of State transport may be a key strategy. Episodes during both spring and late summer are necessary to account for 8-hr ozone design values. DFW SIP model may need to better represent a stationary front present in 1999 and future ozone episodes if control strategy impacts are to be accurately assessed.
H12.8HRB	*Role of Modeling Assumptions in the Houston Mid-Course Review and Impacts on the Sensitivity of 1-Hr/ 8-Hr Ozone to Emissions Reductions* Modeling sensitivity studies using both the CAMx and CMAQ air quality models to investigate the impacts of various physical, chemical, numerical, and emissions assumptions on the simulated effectiveness of control strategies in the Houston region.	Strategic Foundational	We need to know how effective current control strategies really are in view of key modeling uncertainties. VOC inventory, land use/land cover, vertical mixing, fine-scale horizontal transport, night-time transport, and chemical mechanisms are key science issues.	There are problems with vertical mixing, horizontal wind, and sub-grid scale transport. SIP model over-predicts ground concentrations of NOx, biogenic and HRVOC precursors. Despite this, model has low ozone productivity. Stronger dilution/vertical mixing or lower emissions are needed. Relative Reduction Factors are sensitive to chemical mechanism details.	It is difficult to assess controls as the model predicts more NOx in future cases after controls are applied than is even currently observed. The short term cap on HRVOC emissions may be more effective than thought. Model simulation of obser-vations and control strategy impacts need improvement. Chemical mechanisms need improvement to better assess control strategies.

Table 6. Recently Completed TERC Modeling Projects (continued)

Project Number	Project Name/ Methodology	Issue Type	Rationale	Primary Results	Policy Implications
H17.A	*Urban Heat Island Modeling* CMAQ model runs to determine the impact of land surface assumptions on urban ozone and temperature.	Operational Foundational	Land use/land cover (LU/LC) data are a critical input in modeling ozone attainment. Surface moisture, isoprene, and energy exchange processes are key issues.	Improved LU/LC methods help to better simulate urban ozone formation. Changes in Houston land cover have increased temperatures and ozone.	Closer attention to LU/LC and biogenic emissions is needed to better assess the impact of control strategies.
H35	*Transport Contributions of Out-of-State Sources to East Texas Ozone* CAMx model sensitivity runs and application of the Anthropogenic Pollution Culpability Assessment (APCA) technique and zero-out modeling to attribute ozone formation in East Texas non-attainment and near non-attainment areas to local sources, intra-State transport, and inter-State transport. This includes analysis of the future impacts of the CAIR rule.	Operational Strategic Foundational	We need to determine if the current 1999 DFW model episode can be used in demonstrating 8-hr ozone attainment. We need to know if measures beyond local and State controls can help bring the DFW area into ozone attainment. We need to know what mix of VOC and NOx controls is best for ozone attainment. PBL and convection physics and NOx recycling are key issues.	The DFW SIP model performance was improved by changing key meteorological and chemical assumptions. Gulf of Mexico, LA, OK, AR, MS, AL, TN, and KY significantly contribute to ozone above 85 ppb in E TX according to CAIR criteria. The CAIR rule may not result in significant ozone reductions in DFW. The DFW urban core may be VOC-sensitive, though biogenics predominate. An uncertainty of 2 ppb in the contributions of Houston and of boundary conditions to DFW ozone is due to convection assumptions.	The 1999 DFW model episode may now be more adequate for demonstrating 8-hr ozone attainment. Local, regional, and out-of-State controls will help reach attainment. Better NOx and biogenic VOC inventories will improve confidence. Closer attention to the details of long range transport may be needed to better assess the role of background ozone in non-attainment.

Table 7. Recently Completed TERC Control Strategy Projects

Project Number	Project Name	Rationale	Primary Results	Policy Implications
H12.EE	Survey of Technological and Other Measures to Control HRVOC Event Emissions	We need to determine ways to reduce HRVOC event emissions. We need to know if HRVOC controls have significant co-benefits, such as reducing Other VOCs (OVOCs).	There are significant OVOC co-benefits to controlling annual, but not event, HRVOC emissions. Concentrated HRVOC hot spots are unlikely as a result of HRVOC emission trading.	Reducing OVOCs together with HRVOCs in routine emissions may result in significant ozone benefits. Emissions trading is a viable option for controlling HRVOC event emissions.
H18.A	Locomotive Emissions – HGB/DFW	Locomotives may be an important source of NOx emissions in urban areas.	NOx emissions may be 32% lower for HGB and 26% lower for DFW, as compared to 2000 SIP estimates.	Controlling railroad emissions may be less effective than previously thought, but still represents a significant control opportunity.
H31	Survey and Demonstration of Monitoring Technology for Houston Industrial Emissions	We need to know how to best design a monitoring strategy to detect rule violations by industrial facilities.	We need about 20 more speciated VOC monitors to detect event emissions in Houston.	The current TCEQ Environmental Monitoring and Response System may need upgrading.
H36	Ozone Precursor Control Strategies in Texas vs. Out-of-State	We need to know if it is feasible to reduce out-of-State pollution transport.	NOx from major sources such as EGUs in some States are subject to less stringent control than in Texas.	Adding better control technologies to NOx sources in neighboring States could reduce ozone in Texas.
H37	Evaluation of the NOx Emission Effects of Adopting CA LEV II Program	We need to know how to better control on-road NOx emissions.	LEV II program showed possible emission reduction benefits.	More detailed analysis and modeling of LEV II program is warranted.
H42	Analysis of 2010 On-Road and Non-Road Emission Reductions	The future effectiveness of the Texas Emission Reduction Program (TERP) needs to be evaluated.	TERP emission reductions could fall short of SIP goals, particularly in the Houston region.	Mobile NOx reduction through voluntary measures in Houston may be difficult.

Table 8. TERC 2005 Field Study (TexAQS II) Projects

Project Number	Project Name	Issue Type	Project Description	Policy Relevance
H39	TexAQS II Tetroon Campaign (Southeast Texas Transport Study)	Foundational	Tetroons are balloons equipped with a Global Positioning System (GPS) meter for location, and meteorological sensors that measure pressure, wind, temperature, and relative humidity. Tetroons with altitude control will be used to study the transport of pollution originating in Houston by serving as air mass trajectory markers. An instrumented chase aircraft will follow the tetroons to measure ozone and its precursors.	Houston air pollution exported to other parts of East Texas may mitigate local control strategies elsewhere in East Texas.
H44.A H44.B H44.C	Meteorological and Science Planning and Support for TexAQS II Aircraft and Instrumentation Support for NETPS	Foundational	This project will provide meteorological and air quality modeling, planning, and implementation support for TexAQS II. This includes services in support of the Northeast Texas Plume Study (NETPS): an airborne experiment in which instrumented aircraft will fly over intense industrial point sources in Northeast Texas to pollution in the DFW non-attainment area. The project will also forecast polluted air mass trajectories and develop modeling tools to improve the use of satellite data in meteorological forecasts. It will also develop advanced modeling methods for interpretation of airborne chemical measurements of industrial pollution plumes and the correction of point source emissions inventories based on these measurements.	Better modeling tools will enhance the accuracy of SIP emission inventories and control strategy assessments. Large point sources in Northeast Texas may affect DFW ozone non-attainment.
H45	Modeling Strategy in Support of TexAQS-II and 8-Hour Ozone Assessment	Operational	This project has already developed an operational system for real-time meteorological and air quality forecasting to support field study planning and operations. The system will also be used to test modeling strategies that can be used in the development of an 8-hour ozone SIP.	A thoroughly validated model will enhance SIP credibility.
		Foundational	Various enhancements to the system will be tested, including the use of an advanced method (Ensemble Kalman Filter) for data assimilation (use of observations to constrain model behavior) and better representations of the physics behind the nocturnal jet.	Better SIP model performance will improve the credibility of control strategy assessments.
		Strategic	Emissions inventories have been prepared that allow the use of an advanced chemical mechanism (SAPRC), with more detailed VOC speciation. A probing tool (DDM) will then be used to correct emissions inventories of underestimated Other VOCs (OVOCs) based on monitoring observations.	Controls on OVOCs may be an important supplement to HRVOC controls in Houston.

Table 8. TERC 2005 Field Study (TexAQS II) Projects (continued)

Project Number	Project Name	Issue Type	Project Description	Policy Relevance
H48	Aircraft Measurements of Highly Reactive VOCs Using Proton Transfer Reaction Mass Spectrometry During TexAQS II	Foundational	This project will equip an aircraft with an advanced PTR-MS monitor for measurement of VOCs in the Houston Ship Channel. The instrument enables fast on-site measurements of chemical concentration to be made. The project supports both the Southeast Texas Transport Study (SETTS) and the Northeast Texas Plume Study (NETPS).	Biogenic VOCs influence DFW and Houston ozone productivity. Houston VOCs may result in pollution export to East Texas.
H53	Reconciliation of Point Source Inventories Using Remote Sensing and SODAR Techniques	Strategic	This project will estimate the total emissions (tons/day) of VOCs emitted from the Houston Ship Channel and/or Sweeney complex using the Solar Occultation Flux (SOF) method. The measurements will be conducted from a pickup, car or a small boat. Wind data will be provided by SODAR equipment.	Correction of uncertain emission estimates for VOCs emitted by petrochemical facilities is an urgent issue for the HGB SIP.
H55	Enhanced Land Surface Characterization	Operational	This project will develop more ground truth data to verify remote sensing-derived land cover data, and use remote sensing and ground-truth data to estimate other land surface characteristics relevant to air quality modeling, especially tree speciation and vegetation distribution. The project will develop a consistent land surface characteristic data set that will improve biogenic emissions estimates and reduce uncertainties in ozone modeling.	Improved biogenic inventories and model performance will enhance assessment of relative and absolute benefits of VOC and NOx controls.
H56	Deployment of Two C-Band Radars to DFW and HGB for the 2005 Ozone Season	Foundational	Two C-Band Doppler radars, overlapping existing National Weather Service NEXRAD radars, will be deployed to provide 3-D wind fields in the boundary layer for the ozone season in 2005. The project will support the NETPS and SETTS studies and provide useful data to evaluate meteorological forecast model performance.	The project may enable additional episodes to be used for ozone attainment demonstrations in DFW and HGB.

Table 9. TCEQ 2005-2006 Field Study (TexAQS II) Projects

Project Name	Issue Type	Project Description	Policy Relevance
Data Assembly and Analysis	Operational	This project will gather, analyze, and evaluate ACARS (Aircraft Communication Addressing and Reporting System) and National Weather Service NEXRAD data for comparison to MM5 model output and use in comprehensive air quality modeling.	The data will be used in SIP model performance assessment of intra-State and out-of-State transport.
Advanced Continuous Atmospheric Chemistry Monitoring	Operational	Collect data for use in assessing current air quality in several locations within Texas and in SIP model performance evaluation. Measurements of both gas and particle phase pollutants will be made at North Padre Island and the Dallas-Fort Worth area.	The data will be used for regional haze source apportionment and to improve haze model performance.
Ozone and Regional Haze Surface Monitoring Sites	Operational	Operation and maintenance of surface monitoring sites throughout the eastern half of Texas, including: five radar wind profilers; twelve rural ozone sites using low-cost ozone monitors plus surface meteorological monitoring equipment; four advanced chemistry sites to monitor ozone and ozone precursors; ten continuous regional haze monitors plus surface meteorological monitors; and four regional haze speciation monitors.	The data will be used for regional haze and ozone source apportionment.
Lower Tropospheric Radar Wind Profilers for TexAQS II Study	Operational	Deploy, operate, and maintain four integrated boundary layer observing systems from April 2005 to October 2006. Each system includes a 915-MHz Doppler wind profiler, a radio acoustic sounding system (RASS) for temperature and moisture profiling, and a 10-m tower for measuring surface pressure, temperature, relative humidity, wind, precipitation, and solar and net radiation. Sites are at the Longview-Gregg County Airport, Huntsville-Madisonville, Sonora, and Victoria-Corpus Christi.	The data will improve assessment of intra-State and out-of-State transport.
A GIS Based Web Interface for TexAQS II Data	Operational	Create a single point-of-access for data pertaining to emissions, meteorological forecasts, trajectories, and aircraft flight based on state-of-the-art, Web-based Geographic Information Systems.	The project will improve access to data relevant to SIP.
HAWK Camera Identification of VOC Emissions	Strategic	Deploy a HAWK camera on a helicopter and on the ground to identify unsuspected and underestimated sources of VOC emissions, especially for HRVOCs.	The project will help identify more VOC sources for control.

3.1.2 Better understand and simulate the physics underlying several key meteorological mechanisms that may lead to 8-hour ozone above 85 ppb.

Some important meteorological mechanisms (see Table 10) leading to high ozone either: 1) are only simulated with difficulty in models (coastal sea breeze, nocturnal jet); 2) are sensitive to physical assumptions (PBL height evolution, convection and lightning, vertical diffusion); or 3) have recently been identified as needing more study (stationary fronts). These key mechanisms may require more rigorous treatment in SIP modeling, particularly since local control strategy evaluation and assessments of long-range transport may be biased by uncertainties in meteorology. For example, a stationary front passed through the DFW area during the August, 1999 ozone episode (Figures 18 and 19). The front's impacts, both at the surface and aloft, are not yet fully understood (McNider et al., 2005a; McNider, 2005b). (Relevant past projects: H12.8HRA, H12.8HRB, H35; relevant TexAQS II projects: H39, H44.A, H44.B, H44.C, H45, H56)

Table 10. Meteorological Mechanisms Influencing High Ozone in East Texas

Meteorological Mechanism	Importance to Air Quality	Relevant Field Study Projects
Coastal Sea Breeze	Slow wind rotation caused by the sea breeze traps pollution over Houston. Stalled sea breeze fronts may cause surface stagnation that builds up pollution and uplift of pollutants leading to transport aloft.	H39, H45, H56
Nocturnal Jet	A fast night-time wind near the surface can transport pollution large distances from its source, causing ozone problems downwind.	H39, H45, H56
PBL Height Evolution	The Planetary Boundary Layer (PBL) height helps determine the concentration of pollutants and the efficiency of ozone formation.	H45, H56
Convection And Lightning	Deep convection leads to tall cumulus towers, which act like chimneys that rapidly vent pollution to the free troposphere (the layer above the PBL), where wind jets can transport it long distances. The slow subsidence around cumulus towers can also entrain pollution from the free troposphere back into the PBL. Convection also breeds lightning, which generates NOx aloft.	H44.A, H44.B, H44.C, H45, H56
Vertical Diffusion	Vertical diffusion turbulently transfers pollution from near the surface to higher levels, which can either raise the efficiency of ozone production near intense NOx sources or dilute ozone.	H45
Stationary Front	Stationary fronts coincide with large areas of stagnation or "dead zones" that trap pollution. Stationary fronts might also bring pollution from aloft down to the surface.	H44.A, H44.B, H44.C, H56

3.1.3 Better quantify the influence of levels aloft on O_3 exceedances at the surface, including the relative importance of natural and anthropogenic sources of O_3 in the free troposphere (FT), and of vertical exchange between the FT and PBL.

Nielsen-Gammon et al. (2005) inferred, based on sophisticated data analysis, that the spring peak in background ozone in East Texas is caused by even longer-range transport than the regional transport leading to the late summer peak. It is known that PBL-FT exchange can be especially intense during spring. Figure 20 shows that current air quality models typically underestimate ozone in the FT. Horizontal transport of ozone and precursors aloft, either in the FT or upper PBL may precede mixing down to the surface. Berkowitz et al. (2000) indicate that descent of ozone from aloft may be critical in explaining large increases in surface ozone during summer high ozone episodes. (Relevant past projects: H12.8HRA; relevant TexAQS II projects: H44.A, H44.B, H44.C)

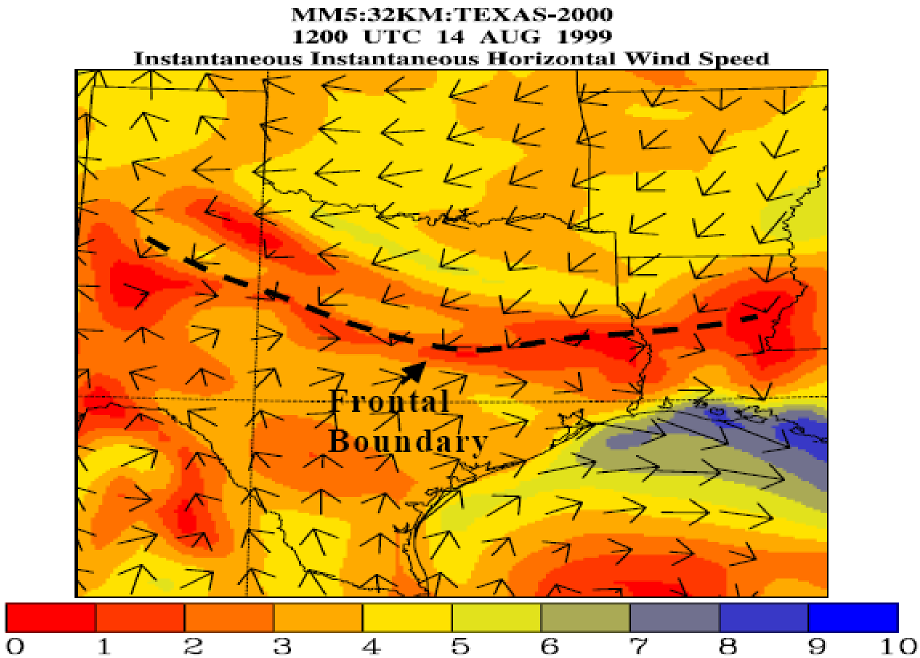


Figure 18. Wind vectors in the vicinity of a stationary front that occurred near DFW on August 14, 1999. Color scale is in meters per second. Note "dead zone" or area of stagnation along the front that may lead to high ozone (after McNider et al., 2005a).

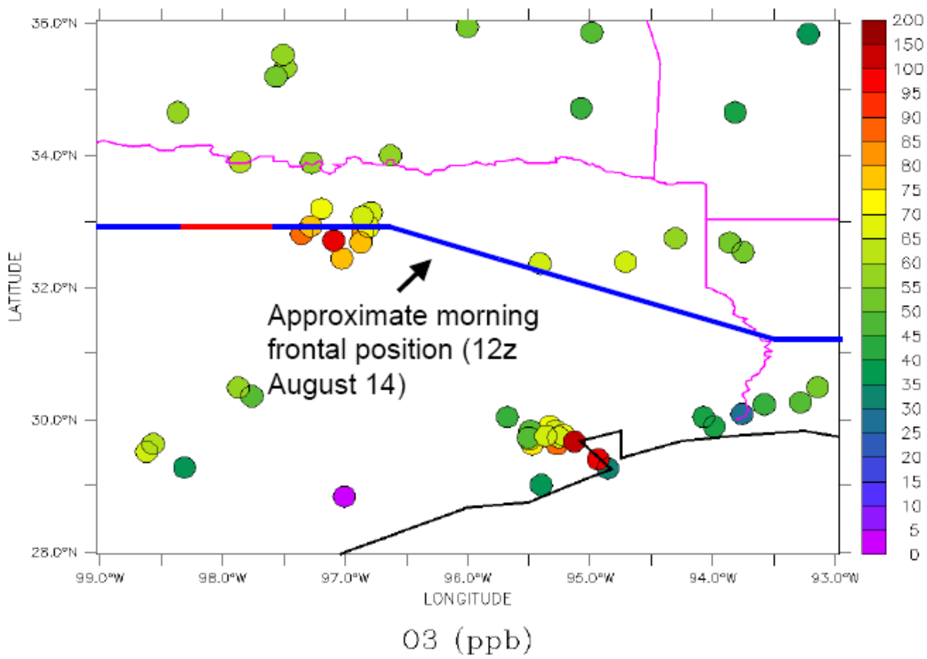


Figure 19. Ozone levels over East Texas at 14:00 August 14, 1999. Note clean conditions at ground monitors upwind and high ozone at the frontal position (after McNider et al., 2005a). While surface transport from upwind sources cannot explain the high ozone at the front, vertical transport has not been ruled out (McNider, 2005b).

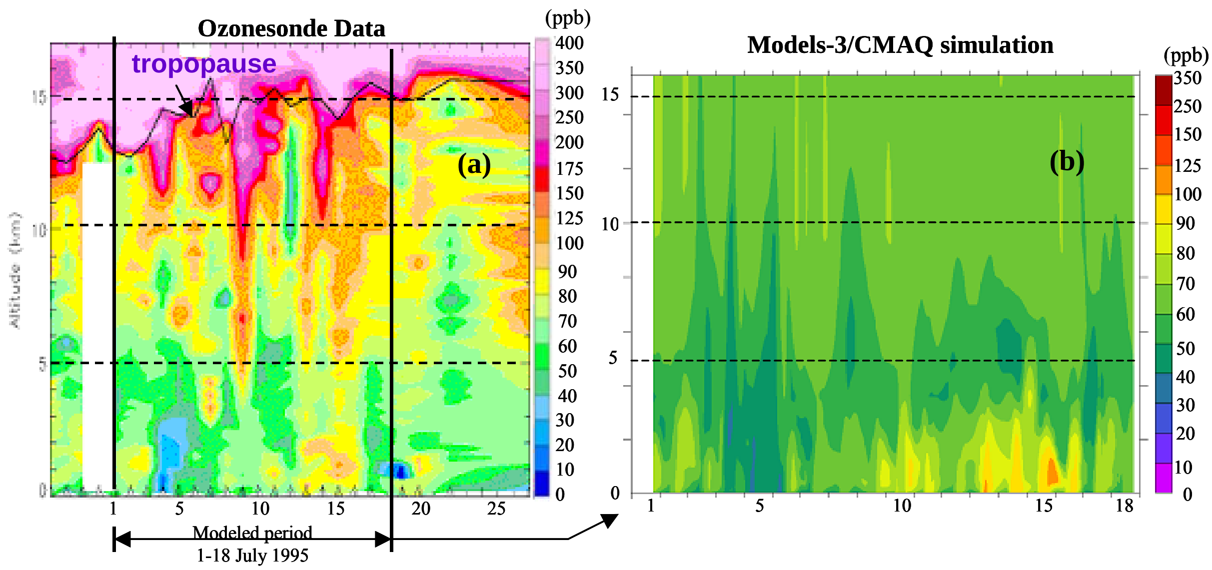


Figure 20. A comparison of a CMAQ simulation of tropospheric ozone over Nashville, TN for the period 1-18 July 1995 with daily local ozonesonde data collected at noon. Observations indicate high O_3 concentrations above 10 km that are missing from the model simulation. Note high surface ozone observed on July 15 (after Gillani, 2005).

3.1.4 Update land use/land cover (LU/LC) data to more accurately simulate the contribution of biogenic emissions to ozone formation.

Biogenic emissions are an important determinant of ozone productivity, and better LU/LC data, such as tree speciation and tree counts, over a much wider area in Texas (and possibly in neighboring States) will be useful in more accurately accounting for biogenic impacts on both regional and local ozone. A more accurate accounting is important for assessing the relative effectiveness of VOC and NOx controls. Biogenic emissions in urban and suburban areas are particularly difficult to classify, because of non-native tree species and mixed land use patterns, and are especially important because they produce VOCs coincident with high NOx emissions. (Relevant past projects: H12.8HRB, H17, H35; relevant TexAQS II projects: H55)

3.1.5 More elaborate chemical mechanisms of ozone formation are needed to support evaluation of control strategy effectiveness.

Chemical mechanism details have a significant impact on both model performance and on the simulated effectiveness of control strategies through Relative Reduction Factors. Important details include NOx recycling through reactive nitrogen reservoirs, sources and sinks of radicals affecting ozone productivity, and the speciation of VOCs and their degradation products. Control strategy assessments may be biased by uncertainties in ozone chemistry. Faraji et al. (2005) found that different chemical mechanisms lead to model ozone predictions that differ by 30-50 ppb in Houston, with differences in relative reductions up to a factor of two due to emission controls. Jeffries et al. (2005) found weak ozone productivity in the Houston SIP model despite overabundant precursors at the surface. Byun et al. (2005a) attribute this to a possible deficit in radical sources. (Relevant past projects: H12.8HRB, H35; relevant TexAQS II projects: H39, H45, H48)

3.1.6 Improve specification of model boundary conditions to more accurately assess the role of transport in ozone exceedances.

Modeling of meteorological and chemical processes over a wider region (more distant horizontal boundaries) and over a deeper vertical extent (higher model top) in the atmosphere is necessary for correct simulation of air quality. Even though this wider coverage explicitly incorporates more source regions, boundary conditions still contribute significantly to simulated East Texas ozone. The level of contribution from the model boundaries depends on both the assumed details of physical processes such as convection and assumed meteorological conditions during the relevant ozone episode. It is likely that very long range transport during spring enhances background ozone in East Texas. Simulating this phenomenon may require greater inflow into the model domain rather than assuming clean default lateral boundary conditions, especially in the FT. Thus, it may be desirable to link regional air quality models with global models. (Relevant past projects: H12.8HRA, H12.8HRB, H35; relevant TexAQS II projects: H45)

3.1.7 Study the feasibility and effectiveness of out-of-State NOx controls to reduce regional ozone transport.

Modeling conducted in Project H35 indicates that CAIR will have little benefit in Texas in 2010, at least for the episodes used in the current SIP, despite significant contributions by other States to high 8-hour ozone in East Texas, as measured by CAIR criteria. Opportunities do exist to reduce NOx emissions in nearby States if commonly implemented control technologies in Texas are also required in those States. Better understanding is needed of how nearby States will respond to CAIR and whether they will reduce emissions at the sources that most influence Texas. The potential for significant reductions from source categories that are under State control, and that CAIR does not regulate, should also be evaluated. (Relevant past projects: H35, H36)

3.1.8 Find new alternatives to supplement proposed control strategies.

The demand for new NOx control strategies will increase if there is a shortfall in meeting the 2010 NOx reduction targets of the Texas Emission Reduction Program (TERP). More comprehensive TERP implementation may require an in-depth survey of all urban diesel equipment types and relevant potential controls. Studies should also be conducted to improve the effectiveness of gasoline vehicle measures, such as the Low Income Vehicle Repair Assistance, Retrofit, and Accelerated Vehicle Retirement (LIRAP) program, and to further assess the benefits of adopting California LEV II standards. Stationary source NOx measures should also be considered, such as controls on compressor engines used in natural gas production. Compressor engines are collectively a large source of NOx in East Texas. Highly effective (> 90% NOx reduction) and cost-effective (< $200/ton of NOx reduced) control technologies are available for many of these engines (Environ, 2005). In addition, an assessment should be conducted of the benefits of controlling OVOCs, which Roberts et al. (2004) suggest are currently underestimated in Houston emissions inventories. There may also be large regional sources of OVOCs, such as emissions associated with the oil and gas industry. Longer-lived OVOCs may undergo long-range transport and influence ozone and reactive nitrogen aloft. (Relevant past projects: H12.EE, H18.A, H37, H42; relevant TexAQS II projects: H53)

3.2 SPECIFIC CONCLUSIONS FOR HOUSTON

3.2.1 Better incorporate HRVOC emissions with high temporal and spatial variability in models to demonstrate the effectiveness of HRVOC control strategies.

There are no procedures or guidance on how to include these extremely important emissions in models. Past work has relied on "after the fact" reporting, on point observations by aircraft, or on "imputing" (i.e., guessing) the mass and location needed to give the observed ozone. These emissions frequently dominate peak ozone in Houston and nearby areas. Byun et al. (2005a) suggest that the problem is not just in the magnitude and timing of HRVOC emissions, but also in their effective release heights as simulated by the SIP model. (Relevant past projects: H12.8HRB; relevant TexAQS II projects: H53)

3.2.2 Update tree species information in LU/LC databases for SIP models.

New high resolution satellite-derived LU/LC databases, combined with updated land surface treatment have led to major improvement in meteorological model predictions, but these improvements do not specify what type of tree covers the land. The biogenic emissions model needs not only LU/LC data, but also detailed tree species information (a live oak emits 1000 times more isoprene than a pecan tree). Previous SIP modeling used older, less resolved LU/LC data, which had more than 600 vegetative species. The newer satellite data lack this species detail. Biogenics are the largest VOC source in the HGB area and contribute over 20 ppb to ozone production in southeast Houston. Eight-hour attainment will be difficult to demonstrate without accurate biogenic VOC predictions. (Relevant past projects: H12.8HRB, H17.A; relevant TexAQS II projects: H55)

3.2.3 Better understand, measure, and simulate the role of Galveston Bay in producing high ozone in the HGB non-attainment area.

Galveston Bay water is cooler in the daytime than the land surface on shore, and so tends to suppress vertical mixing and trap precursors and ozone near the water. However, the present SIP model uses average water surface temperatures that may exaggerate this natural tendency and lead to overly high ozone concentrations that may be blown back on shore by model winds, possibly causing false model ozone exceedances. This pollution over the water may also lead to "over the water transport" of high ozone from Houston to Beaumont in the model. Moreover, the vertical structure of ozone and precursors over Galveston Bay may not be well represented in the SIP model as suggested by aircraft data from TexAQS 2000. (Relevant past projects: H12.8HRB)

3.2.4 Better understand, measure, and simulate the complex behavior of the Planetary Boundary Layer and its impact on vertical mixing and wind speeds over the Ship Channel and nearby bay shore, especially in areas of high emissions.

Much work went into better simulating PBL heights in the present SIP model, yet weak vertical mixing rates over land in the model led to very large over-predictions of the surface concentrations of NOx, CO, and biogenic VOCs (see Table 6). Addressing this issue may improve the Houston SIP model's ability to make reliable predictions of future control strategy impacts. (Relevant past projects: H12.8HRB)

3.2.5 Evaluate and improve mobile source emissions inventories for NOx and CO to enhance the accuracy of SIP modeling.
Jeffries et al. (2005) suggest that meteorological factors may not be sufficient to account for the overabundance of NOx predicted by the Houston SIP model at the surface relative to monitored concentrations. Previous aircraft measurements have noted a discrepancy in NOx/CO ratios observed over Houston compared to the ratios predicted by the EPA MOBILE6 model. High accuracy CO monitors should be installed at TCEQ monitor sites so that the CO and NOx inventories can be further investigated. This will provide a critical test of the accuracy of both emissions inventories and the meteorological model used in the SIP. (Relevant past projects: H12.8HRB)

3.3 Specific Conclusions for DFW

3.3.1 Enhance monitoring of ozone precursors in the DFW area to evaluate emissions inventories and ozone model results, and to track emission trends.
Long-term ozone precursor data are needed for multiple sites throughout the DFW area, although precursor monitoring has recently been enhanced. Fully speciated VOC data are most needed and should include sufficient species resolution to support local source contribution analysis (e.g., receptor modeling). CO and SO_2 measurements with high sensitivity are also valuable to support source contribution analysis by studying pollutant ratios. Measurements should be maintained over several years to track trends. In the short term, field study data may provide useful information for the design of an extended monitoring network. (Relevant past projects: H27; relevant TexAQS II projects: H44.A, H44.B, H44.C, H48)

3.3.2 Analyze potential DFW control strategies for effectiveness, timeliness, and cost per ton in reducing ozone.
Data on local emissions and ozone contributions are available from TCEQ and TERC studies. These data must be rapidly synthesized into a SIP revision by the TCEQ. Local stakeholders should be encouraged to support and participate in an early, broad-based process for identifying and evaluating candidate control measures. Local strategies should focus on NOx reduction. Some consideration should be given to VOC reductions in the DFW urban core since these may accelerate progress by mitigating possible near-term NOx disbenefits. (Relevant past projects: H35 and TCEQ SIP model development)

3.3.3 Refine the biogenic emissions inventory for urban and suburban DFW.
Ozone modeling results and control strategy evaluations for DFW are sensitive to VOC emissions in urban and suburban DFW. Biogenic emissions are difficult to characterize in urban/suburban areas because LU/LC is diverse and because non-native species have been introduced. Improved satellite data sources have become available since the DFW biogenic inventory was last updated. The new data should be combined with field observations of tree species distributions and used with updated biogenic emission models. (Relevant past projects: H27 and H35; relevant TexAQS II projects: H55)

3.3.4 Evaluate projections of future land use and their impact on DFW ozone attainment.
Continued growth will expand the DFW urban area into surrounding rural areas, changing land use and spreading the influence of anthropogenic emissions. NOx emissions form ozone more effectively when they are more widely dispersed. DFW air quality planning studies should be linked to urban land use planning so that future emission inventories account for projected land use changes. Modeling conducted by Byun et al. (2005b) as part of TERC Project H17.A showed that LU/LC changes affect meteorology and ozone levels. Higher temperatures result from the loss of vegetation and an increase in urban land cover types. Higher ozone concentrations are associated with increased temperatures under some conditions. Otherwise, O_3 reductions may result from decreased biogenic emissions due to loss of vegetation. (Relevant past projects: H17.A)

3.4 Regional Haze: Relevance of BRAVO and CENRAP

3.4.1 Investigate the implications of the BRAVO study, which indicates significant impacts of emissions from the eastern U.S. on regional haze in West Texas, and of current CENRAP modeling of regional haze in Texas and surrounding States.
The Big Bend Regional Aerosol and Visibility Observational (BRAVO) Study was an intensive air quality monitoring project measuring fine aerosol mass and its constituents, atmospheric optical properties, gaseous air pollutants, and meteorology from July through October 1999. The BRAVO Study final report (Pitchford et al., 2004) concluded: "SO_2 sources in the eastern U. S. contributed to less than 5 Mm^{-1} on most days during the study period, but during the two haziest episodes of the study period these sources contributed to about 50 Mm^{-1} and about 30 Mm^{-1}, respectively, corresponding to about 50% and 30% of light extinction." The Central Regional Air Planning Association (CENRAP) is performing regional haze modeling for all of 2002 that will determine how Texas and surrounding States comply with regional haze SIPs due in 2007. Better understanding is needed of the relationships between emission reductions for Texas ozone SIPs and regional haze SIPs to gain maximum air quality benefits and provide stable emission control targets for affected sources. The possibility of using CENRAP modeling as the basis for ozone transport assessments in Texas should also be considered.

4. NEW RESEARCH RECOMMENDATIONS

The purpose of this section is to recommend research projects, in addition to those currently funded by TERC, that specifically address the knowledge gaps identified in Section 3, and that can provide timely information to guide the 8-hour ozone SIPs for HGB and DFW either in their initial versions or in subsequent revisions.

The TERC Science Advisory Committee (SAC) was presented with over 60 project proposals on June 1-2, 2005. The SAC, in its subsequent deliberation, ranked these projects within various research categories. Several projects that are recommended for funding by TERC are listed in Tables 11-13 according to the ranking assigned by the SAC. Geographical areas and knowledge gaps addressed by the projects are indicated in Columns 3 and 4 of each table. Highly ranked projects not listed in these tables include: 1) air toxics exposure projects documented in a separate research plan, 2) projects proposed to the TCEQ for separate funding under the Supplementary Environmental Program (SEP), and 3) a project entitled, *Nighttime Chemistry and Transport: a 2-Year Study Using Smart Balloons and Aircraft* (CHM-10). This last project was intended as a follow-up to the SETTS (Project H39 in Table 8). The SAC ranked this project between CHM-3 and CHM-4, but requested further evaluation upon completion of the SETTS. Pertinent information is provided in Appendix A by Berkowitz et al. (2005).

4.1 Short-Term Projects of Relevance to the 2007 SIP

Control strategy and SIP development projects listed in Table 13 should be completed by February 28, 2006, wherever possible. This would enable results to be incorporated into the early versions of the 8-hour SIP (see Table 1). The following additional projects would complement those already considered by the SAC.

4.1.1 Coordinate modeling and other analyses of the results of the recently completed Southeast Texas Transport Study (SETTS) in order to design a follow-up tetroon study.
(Estimated Cost: $75,000)

The SETTS project (H39) was highly successful in deploying tetroons and chase aircraft to track and measure pollution plumes released overnight from the Houston area. The tetroons reached all the way to Northeast Texas by the following morning. The chase aircraft detected plumes of ozone (up to 90 ppb) aloft in some places in the vicinity of the tetroon trajectories (see Appendix A, Figure 5). Model simulations will be performed to explain the evolution of the entire suite of observed species along the tetroon trajectories, and to determine whether the ozone and precursors observed aloft at the tail end of the tetroon trajectories will have a significant impact on surface ozone during the daytime. The project will coordinate, supplement, and interpret the model simulation efforts to be performed in other projects, such as MET-15 and H45, to provide a conceptual plan for a follow-up tetroon campaign (see 4.2.1) that will test how well we understand long-range transport. The project results may also be useful in providing or anticipating weight of evidence arguments in early versions of the DFW SIP, such as quantifying the possible impact of Houston exports of pollution to DFW and Northeast Texas. (Knowledge gaps addressed: 3.1.1, 3.1.2)

Table 11. Recommended 2006 Field Study Chemical Measurement Projects

Proposal Number/ Cost	Project Name	Geographical Coverage	Issue Type/ Knowledge Gaps Addressed	Project Description
CHM-14 $96,000	Use of Aircraft Measurements to Observe Ozone and Aerosol Plume Transport	HGB	Foundational 3.1.1, 3.1.2, 3.1.3	Use airborne ozone/aerosol LIDAR to provide information on plume transport and mixing within, as well as upwind and downwind of, the Houston area. Internal NOAA funds will be available for 4 weeks of flights, 24 flight hours per week; TexAQS II funds would support an additional 2 weeks of data collection. Data would be analyzed the following fiscal year.
CHM-15 $500,000	Aircraft for FY 2006 Flights	DFW East Texas	Foundational 3.1.1, 3.1.2, 3.1.3, 3.1.5, 3.3.1	This project would ensure the availability of aircraft equipped with standard air monitoring instrumentation during TexAQS II.
CHM-3 $400,000	The TexAQS II Radical Measurement Project (TRAMP)	HGB	Foundational 3.1.5	This project will quantify sources and sinks for radicals in the urban atmosphere of Houston using an air quality measurement facility on the roof of the University of Houston North Moody Tower. This facility will include a 35 ft high sampling tower (200 ft above ground level) and will be equipped with instruments to measure key atmospheric primary and secondary species and photolysis rates. The study will include analysis of radical sources and sinks (and production and loss rates) using a steady-state time dependant photochemical box model.
CHM-4 $210,000	Continuation of Aircraft Measure-ments of Highly Reactive VOCs using PTR-MS during TexAQS II – 2006	DFW East Texas	Foundational 3.1.1, 3.1.3, 3.1.5, 3.3.1	The project includes deployment, operation and calibration of a PTR-MS instrument on aircraft and analysis and interpretation of the data during the period of TexAQS II - 2006. The aircraft PTR-MS measurements will allow for *in-situ* investigation of plume transport and chemical transformation, identification of emission sources, improvements of emissions inventories, and evaluation of simulations of ozone and precursors using models.

Table 12. Recommended 2006 Field Study Meteorology and Modeling Projects

Proposal Number/ Cost	Project Name	Geographical Coverage	Issue Type/ Knowledge Gaps Addressed	Project Description
MET-5 $240,000	East Texas Air Quality (ETAQ) Forecasting Project	HGB DFW East Texas	Operational 3.1.1, 3.1.2, 3.1.3, 3.1.4, 3.1.5, 3.1.6, 3.2.3, 3.2.4	The project will improve real-time ozone and haze forecasts for TexAQS II. It will provide: (1) air quality forecasting, (2) Web interface and data archives, (3) real-time trajectory/ particle dispersion modeling, and (4) common real-time emissions input for other air quality forecasting projects.
MET-6 $240,000	Real-Time Meteorological Modeling/Forecasting for TexAQS 2	HGB DFW East Texas	Operational 3.1.1, 3.1.2, 3.1.3, 3.1.6 3.2.3, 3.2.4	This project is a continuation of the existing project for forecasting support and real-time meteorological modeling of the TexAQS II domain in support of field study operations and objectives for the period Sept. 2005-Oct. 2006.
MET-4 $110,000	The Nocturnal Boundary Layer in the Houston Area and its Impact on the Vertical Ozone Distribution	HGB	Foundational 3.1.1, 3.1.2, 3.2.4	The goal of this project is to characterize the ozone residual layers aloft in the nocturnal boundary layer (NBL) over Houston as well as its surrounding urban-rural transition zones. The project will deploy a tethersonde-balloon system for vertical profiles of temperature, relative humidity, winds, and ozone up to 1000 m in altitude at an urban site and at a rural site.
MET-8 $41,000	Doppler Radar Observations of Boundary Layer Winds over Houston and Dallas-Ft. Worth in Support of TexAQS II	HGB DFW	Operational 3.1.2, 3.2.4	The project will provide near real-time 3-D winds in the boundary layer, estimated from the synthesis of dual-Doppler radar observations during high ozone events between May and September 2006. A SMART (Shared Mobile Atmospheric Research and Teaching) radar (mobile, C-band, Doppler) will be deployed in both Houston and Fort Worth within approximately 20 - 25 km of National Weather Service Weather Surveillance Radar (1988 Doppler).
MET-12 $200,000	Frontal Dead Zones	DFW East Texas	Foundational 3.1.1, 3.1.2, 3.1.3, 3.1.6	The goal of this study is to examine ozone and precursor distributions both horizontally and vertically in the vicinity of stationary fronts. The study would: 1. Carry out detailed modeling of high ozone events in DFW during 1999. 2. Compare modeled and observed (from the 2005 pilot study) data on the structure of frontal surfaces and subsidence of mid-tropospheric air. 3. Examine the role of moist convection in producing free troposphere ozone, including possible conjunction with partial tropopause folds. 4. Develop flight plan strategies and other observations for investigating frontal structure under TEXAQS2006.

Table 12. Recommended 2006 Field Study Meteorology and Modeling Projects (continued)

Proposal Number/ Cost	Project Name	Geographical Coverage	Issue Type/ Knowledge Gaps Addressed	Project Description
MET-19 $38,000	Using Satellite-Derived Sea Surface Temperatures in Texas Modeling Simulations	HGB	Foundational 3.2.3, 3.2.4	Satellite measurements from NOAA at very high spatial and temporal resolution over the Gulf of Mexico region will be ingested into MM5 in place of the typical analyzed SSTs. The project will: 1) develop an annual simulation for Houston area to examine the effect of using satellite SST on land-sea breeze circulation, and 2) examine specific episodes to quantify ozone impacts.
MET-15 $180,000	Diagnostic Modeling and Data Analyses of the Summer 2005 Data of the NETPS and SETTS Field Studies	HGB DFW East Texas	Foundational 3.1.1	This project will analyze data from NETPS and SETTS using the LPDM (Lagrangian Plume Dynamics Model) and the LRPM (Lagrangian Reactive Plume Model). The project will simulate ozone and nitric acid production in power plant plumes (PPPs) and their impact on DFW. The project will also simulate the transport and chemistry of pollution plumes from Houston, for nighttime as well as for the subsequent daytime fumigation and transport.
MET-14 $45,000	Satellite Data Assimilation	HGB DFW East Texas	Foundational 3.1.2, 3.2.4	UAH will continue to test and improve the GOES data assimilation system in MM5, and carry out real-time MM5 forecasts in support of TexAQS 2006 in coordination with a TERC project applying chemical data assimilation.
MET-7 $180,000	Implementation, Evaluation and Application of Meteorological and Photochemical Ensemble Forecasts	HGB DFW East Texas	Foundational 3.1.1, 3.1.2, 3.1.3, 3.1.6 3.2.3, 3.2.4	The project will select episodes in HGB and DFW and implement ensemble forecasts for meteorology, including realistic initial/boundary condition uncertainties as well as model errors. The best-performing meteorology ensemble forecast will then drive ensemble forecasts for photochemistry to identify factors that contribute most to ozone exceedances. Adaptive observation planning can also be provided through the Ensemble Kalman Filter.
MET-18 $20,000	Inline Photolysis Rate Calculations in Texas Modeling Simulations	HGB DFW	Foundational 3.1.5	A new fast in-line code for computing photolysis rates will be deployed in the CMAQ model and used to perform sensitivity studies for several modeling episodes in Texas. Process Analysis will be used to show how differences in photolysis rates impact the entire chemical system.
MET-22 $40,000	Continued Creation, Improvement, and Application of Model Evaluation Tools in Collaboration with UH and HARC Data Center	HGB DFW	Operational 3.1.1, 3.1.2, 3.2.4	Graphical model performance evaluation software will be integrated with the University of Houston's CMAQ model. Further work is needed to incorporate aircraft and LIDAR data along with ground monitor data, to refine statistical metrics, and to find ways to present and understand model results. Python-based tools will also be integrated into HARC's Air Research Information Infrastructure to allow Web-based operation of these tools for analyzing a large body of archived model outputs, and to create readily downloadable pdf files of results.

Table 13. Recommended Control Strategy and SIP Development Projects

Proposal Number/ Cost	Project Name	Geographical Coverage	Issue Type/ Knowledge Gaps Addressed	Project Description
SIP-17 $50,000	Role of Biogenic Emissions in Dallas-Ft. Worth SIP Modeling	DFW	Operational 3.1.4, 3.3.3	High-resolution satellite LU/LC data will soon be available from several sources (e.g., University of Texas, National Center for Atmospheric Research, National Land Cover Data, gap analyses). Potential improvements to the DFW biogenic emission inventory using such data as input to the GloBEIS model will be investigated for the next SIP revision.
SIP-23 $100,000	Storage Tank Project	HGB	Strategic 3.1.8	This project will utilize a HAWK camera to identify leaking storage tanks and tank construction blueprints to determine diameters of leaking orifices. The project would also test vents for velocity of plume or make assumptions on the velocity, and bag or otherwise determine volume of plume from non-vent sources. The tanks will be analyzed further with canister samples around the tank. The analytical results will be used to estimate the emissions rate, which would be compared to the emissions rate predicted using AP-42.
SIP-22 $100,000	Wastewater Project	HGB	Strategic 3.1.8	The project will use a HAWK camera or other means to identify VOC emission points in wastewater/ process sewer systems. Traditional testing techniques would also be employed, such as the El Paso Method, VOA samples, VOC hand held analyzers, SUMA canisters, etc.
SIP-21 $100,000	NOx Emission Factors for Compressor Engines	East Texas	Strategic 3.1.8	The project will collect emission rate data from operating engines to be able to statistically evaluate the actual emission rates for East Texas and create estimated inventories on a statistically sound basis.
SIP-7 $35,000	Emissions Inventory Verification Study on Small Electric Power Generating Units in the Houston Region	HGB	Strategic 3.1.8	A previous DFW project surveyed companies that operated small electric power generating units to gain a better measure of activity levels of these units. This project would (1) conduct a survey in the Houston region similar to the one conducted in DFW, (2) compile TCEQ data on small generators into a database, and (3) provide an analysis of the information in the database.
SIP-11 $25,000	Analysis of the Status of Reflashing Heavy Duty Diesel Engines Operating in East Texas Non-Attainment Regions	HGB DFW	Strategic 3.1.8, 3.3.2	A low NOx software upgrade for the electronic control modules in certain heavy-duty diesel engines is being implemented by court order in trucks manufactured by certain companies. The rate of installation of such equipment (called reflashing) should keep pace with Texas SIP projections. This project will analyze the rate at which reflashing is being implemented in Texas and the projected emissions impact on Texas non-attainment regions.

Table 13. Recommended Control Strategy and SIP Development Projects (continued)

Proposal Number/ Cost	Project Name	Geographical Coverage	Issue Type/ Knowledge Gaps Addressed	Project Description
SIP-14 $35,000	Event Emission Tracking	HGB	Operational 3.2.1	The emission event tracking begun in Project H13 will be continued and a TERC web site providing emission event tracking data will be established. The event emission database will be continued until near real time data on releases detected by continuous emission monitors become widely available.
SIP-19 $30,000	Observation-based Ozone Exceedance Forecasting Tool	HGB	Operational 3.2.1	Work at UNC has led to an observation-based model of 1-hour and 8-hour exceedances, and THOE events forecast model. It is capable of making 3-day forecasts of the likelihood of having a 1-hour or 8-hour exceedance and can forecast conditions likely to produce THOEs if large event emissions occur. In addition to refining the formulation of the model, the project will automate the model's operation (e.g., in obtaining weather data) within a GIS system.
SIP-9 $75,000	Reducing Heavy Duty Vehicle Emissions through Non-Engine Technologies and Strategies	HGB DFW	Strategic 3.1.8, 3.3.2	Heavy duty vehicle emissions can be reduced through non-fuel and non-engine changes, some of which are included in EPA's new voluntary SmartWay program. This project would assess these technologies and strategies to determine their potential effect on emission reductions for vehicles operating in and around the Houston and DFW regions.
SIP-12 $40,000	Assessment of Emissions Impacts of LEVII and Tier 2 in the State of Texas	HGB DFW	Strategic 3.1.8, 3.3.2	TERC project (H37) provided an assessment of possible emissions benefits of adopting California Low Emission Vehicle (LEV-II) emission standards, and discussion of the implications of these findings for the potential analysis and adoption of these standards in Texas. The project concluded that there were sufficient potential emission benefits to warrant analyzing this issue in more detail in a second phase of the project.
SIP-26 $55,000	Reactivity Scales	HGB	Strategic 3.2.1, 3.3.2	This project will integrate the new EPA/NARSTO-RRWG national reactivity scales and the new SMOKE/Reactivity Mechanism/ Emissions Processing System (developed at CEP under funding from NARSTO-RRWG) into several of the TERC projects using CMAQ or CAMx and SAPRC or CB4 mechanisms. This would automate the performance of reactivity-based substitutions of OVOCs, HAPs, and cap-and-trade HRVOCs. The project would also determine whether national reactivity scales are appropriate for Houston and contribute to EPA acceptance of reactivity-based control strategies in the SIP.

4.1.2 Use the CMAQ and CAMx models to investigate the sensitivity of regional source apportionment to assumptions involving meteorological mechanisms in Table 10, and to improve the current conceptual model of background ozone in East Texas.
(Estimated Cost: $390,000)
The modeling inter-comparison conducted in Project H12.8HRB was highly fruitful in identifying key areas of uncertainty in the Houston SIP model. An inter-comparison for the DFW SIP model may yield similar benefits. Project H45 is already set up to investigate issues pertaining to regional modeling of East Texas using CMAQ. With additional resources, the project scope and institutional participation could be broadened to enable a deeper analysis of long range transport, including the use of sensitivity and process analysis tools to investigate the underlying physical and chemical mechanisms behind the APCA source apportionment results of H27 and H35. The project could deliver results in time to allow for incorporation into the DFW SIP before its adoption by the State in August, 2006. (Knowledge gaps addressed: 3.1.1, 3.1.2, 3.1.3, 3.4.1)

4.1.3 Conduct an inventory of boilers, process heaters, and stationary engines and gas turbines (including duct burners) at minor sources of NOx.
(Estimated Cost: $200,000)
This project will create a foundation for development of NOx rules for the DFW 8-hour ozone attainment demonstration. The focus of this study is to develop an inventory of gas-fired engines and a survey of available parameter monitoring on engines to increase rule effectiveness, as well as to obtain inventories for process heaters and gas turbines at sources that are minor or have been minor between 1999 and the current emissions inventory reporting year. Emission factor data should be collected for boilers, gas-fired engines, process heaters and gas turbines. This bottom up approach will replace the less accurate EPA default top down approach. (Knowledge gaps addressed: 3.1.8, 3.3.2)

4.1.4 Reevaluate transfer and storage related emissions and control strategy options for selected source categories.
(Estimated Cost: $325,000)
This project would be conducted in two parts. In Part I, a Houston study would measure speciated VOC leak emissions from rail car, barge and ship loading operations, as well as from barges and ships in transit and from barge and ship degassing. Preliminary work with the HAWK camera by the TCEQ has identified leaks from connections during loading and unloading of pressurized rail cars. Emissions from these operations have previously been neglected. Work with the HAWK camera in Texas and Louisiana has also identified VOC emissions coming from barges in transit and from "empty" barges degassing as well as from barge loading. Additional work is needed to determine whether these leaks constitute a significant source of under-reported emissions. In Part II, the study will determine the prevalence of tanks with flash emissions throughout eastern Texas, and characterize, quantify, and speciate VOC emissions from upstream oil and gas operations storage tanks. The project would determine the prevalence of flash using the HAWK camera, gather sufficient information to characterize and quantify emissions, and catalogue the types of existing controls currently used in the field, their control efficiency, and prevalence of use. (Knowledge gaps addressed: 3.1.8)

4.2 LONGER-TERM PROJECTS OF RELEVANCE TO FUTURE SIP REVISIONS

With the possible exception of some aspects of MET-15, the projects listed in Tables 11 and 12 are intended primarily as longer-term research that would not deliver results in time for incorporation into the 2007 version of the 8-hour SIP. However, these projects will still be useful in providing input to future SIP revisions, including a possible Mid Course Review. Additional longer-term projects are listed below.

4.2.1. Conduct a follow-up tetroon study during the 2006 TexAQS II intensive that provides a test of model source apportionment results for DFW and Northeast Texas.
(Estimated Cost: $425,000)
We recommend that tetroons be released along the Gulf Coast, Central and East Texas, and/or Western Louisiana, with accompanying instrumented chase aircraft. Releases should occur when meteorological and air quality forecasts predict transport towards the DFW or Northeast Texas EAC areas during likely ozone exceedances. The recommended project will provide data to test model source apportionment results for sources more distant than those examined in the Northeast Texas Plume Study (NETPS).
(Knowledge gaps addressed: 3.1.1, 3.1.2, 3.1.3, 3.3.1)

4.2.2 Deploy the 4DVar technique for chemical data assimilation to improve regional inventories of anthropogenic and biogenic emissions and perform source apportionment.
(Estimated Cost: $200,000)
This project has already been approved by the SAC. The current project science plan is attached as Appendix B. The plan could be modified to incorporate better LU/LC input data for biogenic emissions estimation and assimilated GOES satellite data for improved meteorological and photolysis inputs. Moreover, the possibility of providing adaptive observation planning (the precise targeting of observations at times and locations identified as optimal by a model) during the 2006 intensive portion of TexAQS II should also be considered. (Knowledge gaps addressed: 3.1.1, 3.1.4)

4.2.3 Assess the role of lightning and aircraft NOx in generating regional ozone.
This is a longer-term project for which alternative sources of funding or co-funding may be appropriate, such as NASA or other agencies whose mission includes research on global pollution. Lightning and aircraft-generated NOx may have a very important influence on ozone aloft. This is a major research topic of interest to the broader atmospheric science community with implications for regional modeling in the SIP.
(Knowledge gaps addressed: 3.1.1, 3.1.2, 3.1.3)

4.2.4 Expand CO and speciated VOC monitoring in Houston to better reconcile mobile and industrial emissions inventories and detect rule violations for enforcement.
4.2.5 Expand the network of speciated VOC monitors in DFW to better evaluate models and emissions inventories and to track emission trends.
These last two recommended projects will require resources beyond those currently available to TERC. However, TERC can use its influence to encourage deployment of resources by the State of Texas to meet these critical longer-term needs.
(Knowledge gaps addressed: 3.2.5, 3.3.1)

5. CONCLUSION

The purpose of this section is to condense the essential lessons from TERC research by:

- summarizing remaining scientific and other gaps in knowledge, and their policy relevance (**policy motivations are bolded in Section 5.1**);
- explaining how recommended short-term research can improve the SIP; and
- advocating longer-term studies to provide material for future SIP revisions.

5.1 What Have We Learned, and How Is It Relevant to Policy?

We have learned much from TERC research and other projects conducted since the last review of the state of air quality science in Texas by Allen and Olaguer (2004). Key lessons can be organized according to three categories of policy issues.

5.1.1 Demonstrating Local Ozone Attainment

Attaining the 8-hour ozone standard will require decreased ozone production from local emissions in Texas non-attainment areas. Various refinements in modeling practice may help more accurately determine the response of ozone to local control strategies to demonstrate attainment. These include:

- Better speciation and quantification of anthropogenic emissions through bottom-up or top-down approaches, especially of HRVOC and OVOC emissions in HGB, and mobile source NOx emissions in both the HGB and DFW areas;
- Updated LU/LC data and biogenic emissions inventories, including more detailed tree speciation and tree counts, expanded use of satellite data, and linkage to urban land use planning;
- Improved local meteorological simulation of Planetary Boundary Layer height evolution, Galveston Bay influence in HGB, and stationary fronts in DFW;
- Expanded chemical mechanisms, with greater speciation and more detailed treatment of urban sources and sinks of radicals and NOx; and
- Analysis of supplementary modeling episodes to more thoroughly account for 8-hour design values, including HGB springtime episodes with O_3 exceedances.

5.1.2 Assessing Regional Ozone and Transport

Attaining the 8-hour ozone standard may also require regional strategies in East Texas by targeting intra-State and out-of-State sources for control. To design effective regional strategies, a better understanding and simulation of the following critical phenomena is needed:

- Apportionment of ozone to precursor emission sources at large distances (i.e., hundreds of kilometers) upwind (Research topics include evaluation of source apportionment techniques through sensitivity and process analysis, modeling inter-comparison, and field study data evaluation.);
- Seasonal evolution of background ozone, including springtime transport and inter-action between regional and larger-scale transport at the surface and aloft;

- Transport and chemical transformation of ozone and precursors aloft, both at night and during the day (Research topics include transport by large and small scale circulation systems, such as nocturnal low level jets, and the chemistry of less reactive VOCs, lightning and aircraft-generated NOx, long-lived reservoirs of NOx and radicals, and night-time reactions.); and
- Mechanisms of vertical exchange between the surface and layers aloft, including convection, stationary fronts, stalled sea breeze fronts, and turbulent diffusion.

5.1.3 Deploying Effective New Control Strategies

Effective control strategies must be identified to meet the 8-hour ozone standard in view of the delayed impact of controls on federally pre-empted sources. Further study is needed according to the following priorities.

For the HGB and DFW non-attainment areas, greater emphasis should be given to mobile source strategies, such as:

- Improving the effectiveness of voluntary measures for both diesel and gasoline vehicles, such as the Texas Emission Reduction Program (TERP) and the Low Income Vehicle Repair Assistance, Retrofit, and Accelerated Vehicle Retirement (LIRAP) program;
- Considering adoption of the California LEV II program; and
- Further reducing NOx emissions from locomotives, ships, and barges.

Regional NOx emission reduction strategies also deserve priority, for example:

- Controlling NOx emissions from compressor engines used in gas production in East and Central Texas;
- Tightening controls on major point sources of NOx in East Texas outside non-attainment areas to mitigate intra-State transport; and
- Seeking out-of-State NOx reductions beyond those provided by CAIR, especially in nearby States.

In Houston, HRVOC emissions continue to deserve special attention. Potential benefits of increased controls on OVOCs should also be considered. Relevant measures include:

- Expanding the monitoring network for rule violation detection and enforcement;
- Tracking emission events and predicting the impacts of likely future events;
- Incorporating reactivity-based strategies such as trading and/or substitution of HRVOC and OVOC emissions; and
- Controlling VOCs from storage tanks, wastewater, and other sources in Houston.

Other control strategy elements may also contribute to ozone attainment, such as:

- Reducing VOCs in the DFW urban core to address potential NOx disbenefits;
- Coordinating emission reductions for ozone and regional haze; and
- Involving local stakeholders in the identification of potential new strategies.

5.2 WHAT CAN RECOMMENDED SHORT-TERM RESEARCH DO FOR THE SIP?

The immediate priority for short-term research is to identify and assess effective new local control strategies for both the HGB and DFW SIPs. Based on the evaluation and ranking of proposed concepts by the TERC SAC, a well-balanced assortment of appropriate projects is presented for TERC's consideration in Table 13, including additional projects in Sections 4.1.3 and 4.1.4. Table 14 summarizes the distribution of these projects according to geographic area, source category, and precursor species.

Table 14. Distribution of Control Strategy and SIP Development Projects

Source Category/ Precursor Species	Houston-Galveston-Brazoria Area	Dallas-Ft. Worth Area
Biogenic VOC		SIP-17
Point Source VOC	SIP-14, SIP-19, SIP-22, SIP-23, SIP-26, Project 4.1.4	
Point Source NOx		Project 4.1.3
On-Road NOx	SIP-9, SIP-11, SIP-12	SIP-9, SIP-11, SIP-12
Non-Road and Area NOx	SIP-7	SIP-21

In addition to the projects listed in Tables 13 and 14, there is an on-going TERC project (H54) that will assess the potential for control of VOC emissions from solvent usage (point and area sources) in both Houston and DFW. Also, the recommended project SIP-17, while not strictly focused on anthropogenic sources, is necessary to evaluate the effectiveness of controls on anthropogenic emissions in the DFW area.

Controls on local sources of ozone precursors alone may not be adequate to demonstrate ozone attainment by 2010. A second area of priority for short-term research is the development of a strategy for decreasing regional background ozone. Sources to the east, southeast, and south of Dallas-Ft. Worth, including major point and other stationary NOx sources in East and Central Texas down to the Gulf of Mexico, should be assessed for potential enhanced controls. The mitigation of pollution transport into East Texas through enhanced controls on major point sources in Louisiana should also be examined.

Given the short-term ozone attainment deadlines faced by the HGB and DFW areas, we cannot rely on TexAQS II projects scheduled to occur in the summer of 2006 to provide information in time for the initial SIP submissions. However, analysis of data from

TexAQS 2000 and TexAQS II-2005, especially the Northeast Texas Plume Study and the Southeast Texas Transport Study, as well as the proposed modeling projects of Sections 4.1.1 and 4.1.2, can be completed largely in time to influence the initial SIP submissions.

The proposed short-term projects to assess the impacts of regional transport in East Texas, its causes, and ultimate sources will especially benefit the DFW SIP. However, there are also potential benefits to the HGB SIP. Currently, the Houston Eight-Hour Ozone Coalition is sponsoring SIP modeling research using an expanded set of episodes (Tesche et al. 2005), including at least one episode with high background ozone. The results of the proposed short-term transport research can be used to improve that study. Likewise, the proposed transport studies will benefit other areas in East Texas.

One last benefit of the proposed short-term transport studies is that they will facilitate the planning and execution of an extended tetroon and aircraft campaign during the 2006 intensive portion of TexAQS II. Data provided by the field study will, after 2006, enable policymakers to make sound decisions in identifying and implementing appropriate controls to reduce regional background ozone (the Texas equivalent of CAIR).

5.3 How Can Longer-Term Studies Facilitate SIP Revisions?

TERC has invested considerable resources in developing infrastructure to support the TexAQS II field study. This includes real-time meteorological and air quality forecast models. Figure 21 shows a sample ozone forecast produced by Byun et al. (2005c) of the University of Houston for July 26, 2005, whereas Figure 22 shows corresponding 1-hour peak ozone observations from EPA's Air Now site. Note the successful prediction of the maxima near Houston and Baton Rouge by the University of Houston forecast model.

The initial application of the TERC-funded meteorology and air quality forecast models has been to provide operational support in the planning and execution of aircraft flights and measurements during TexAQS II. The forecast models will also be used to analyze forthcoming field study data, resulting in thorough evaluation of the models against observations during potential new SIP episodes and increased credibility when the models are deployed to address policy issues. TERC should continue to develop and apply these forecast models and other assessment tools that will enhance the overall capabilities of future SIP models and meet the objectives of Sections 5.1.1 and 5.1.2. To accomplish these objectives and fully support SIP development, synergies among the proposed observational and modeling research projects in Tables 11 and 12 and in Sections 4.2.1 and 4.2.2 should be exploited to the maximum extent possible. This will be done through extensive inter-collaboration and sharing of data and analysis tools among the investigators to be funded by TERC and their counterparts in the TCEQ.

In the final analysis, it may be more difficult for Texas to demonstrate 8-hour ozone attainment in the Houston and Dallas-Ft. Worth regions than to demonstrate 1-hour attainment. Future SIP revisions will benefit from the advanced data collection, monitoring, modeling, and analysis capabilities that TERC, the TCEQ, and other organizations will continue to provide in the coming years.

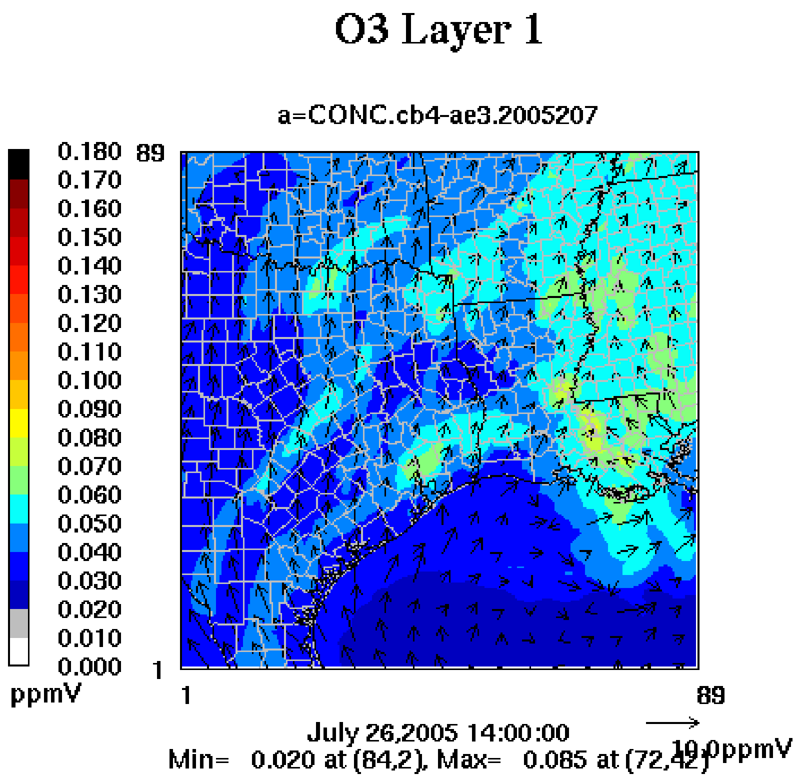


Figure 21. Real-time air quality forecast by Byun et al. (2005c) for July 26, 2005 using MM5 and CMAQ models produced as part of TERC Project H45.

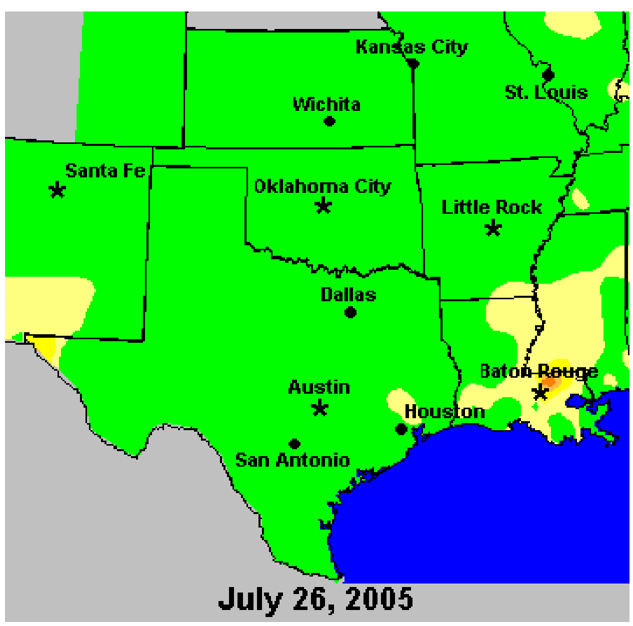


Figure 22. Observed 1-hr peak ozone for July 26, 2005 from EPA's Air Now site. Green is below 60 ppb. Note that the maxima near Houston and Baton Rouge are successfully predicted by Byun et al. (2005c).

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