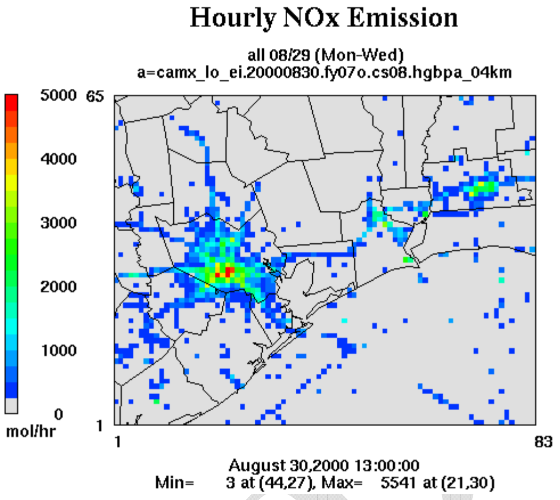
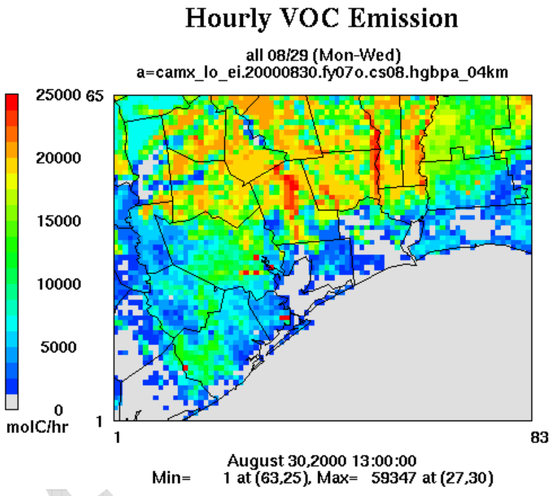
BASE CASE EMISSION INVENTORIES OF OZONE PRECURSORS FOR USE IN THE SECOND TEXAS AIR QUALITY STUDY (TexAQS-II)





Working Committee
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June 21, 2006

Summary

During the data analysis and interpretation phase of the Second Texas Air Quality Study (TexAQS II), the scientific community seeks to have a consistent starting point for developing emission inventories. This report, and associated electronic data files, provides that starting point for ozone precursor emissions. A companion report describes emission inventories for particulate matter and particulate matter precursors.

The most appropriate, existing, comprehensive inventory of ozone precursors that can be used to estimate emissions during the intensive study period (Summer 2006) for the second Texas Air Quality Study (TexAQS II) is the inventory developed by the Texas Commission on Environmental Quality (TCEQ) for use in developing air quality regulations for southeast Texas. This emissions inventory predicts emissions that will occur in 2007, after all of the emission controls necessary to attain the National Ambient Air Quality Standard (NAAQS) for ozone (concentrations averaged over 1 hour) are in place. This inventory includes estimates of both projected growth of emissions (for example, due to increased population and traffic) and the reductions expected from controls. It was used in the development of the State Implementation Plan (SIP) for attaining the ozone NAAQS (1-hour averaged concentrations) that was prepared by the State of Texas in late 2004. It will be referred to in this report as the 2007 attainment demonstration inventory.

Some modifications to the 2007 attainment demonstration inventory will be made, however, for the purposes of the TexAQS II study, and this modified inventory will be referred to as the TexAQS II base case emissions inventory. The primary difference between the 2007 attainment demonstration inventory and version 1.0 of the TexAQS II base case emissions inventory, described in this report, is the emissions inventory for volatile organic compounds from point sources. The inventory used in the TexAQS II base case is as similar as possible in magnitude, composition, spatial distribution and temporal distribution to the 2007 attainment demonstration, but the inventory was created in a more transparent manner than the 2007 attainment demonstration inventory.

In addition, a number of supplementary TexAQS II emission inventory files will be created. This report provides an inventory of anthropogenic chlorine emissions. Future versions of the inventory will contain additional supplementary information. Updates will be posted to www.utexas.edu/research/ceer

The sources of data and procedures used in creating the 2007 attainment demonstration inventory and the TexAQS II base case inventory are summarized in this report. Many of these procedures are described in much greater detail in documents created by the TCEQ and their contractors; these supporting documents are referenced in this report and electronic copies are provided as Appendices.

Contents

Background

Emission inventories for characterizing ozone formation

Photochemical smog is a complex mixture of pollutants that are directly emitted into the atmosphere (primary pollutants) and pollutants that are formed by chemical and physical transformations that occur in the atmosphere (secondary pollutants). Ozone is a secondary pollutant, therefore understanding the formation of ozone in urban atmospheres requires estimates of the emissions of the primary pollutants that lead to its formation. The principal precursor emissions that lead to ozone formation in urban atmospheres are reactive organic compounds and oxides of nitrogen.

Reactive organic compounds include hydrocarbons and partially oxygenated hydrocarbons and are referred to by a variety of similar, but not identical terms, including volatile organic compounds (VOCs), non-methane hydrocarbons (NMHC), and non-methane organic compounds (NMOC). In this report reactive organic compounds will be referred to as NMOC or VOCs. One of the ways in which VOCs are distinguished from NMOC is that compounds that have less than a threshold reactivity are not considered VOCs, while every organic compound except methane is considered to be a NMOC. Allen and Durrenberger (2003) provide a list of compounds that are not considered VOCs, based on their lack of reactivity.

Determining both the magnitude and composition of NMOC emissions is critical because a large number of different NMOCs are emitted in urban areas and because these compounds can have dramatically different reactivities. In addition, many industrial sources in the Houston-Galveston area emit NMOC species which are rarely significant in other urban areas, but are significant in this region.

The oxides of nitrogen that are emitted directly to the atmosphere are mixtures of NO and NO_2, referred to as NO_x. Other oxides of nitrogen (for example, N_2O_5 and NO_3) and groups of oxides of nitrogen (NO_y, NO_z) are important in describing atmospheric chemistry, but are not, in general, emitted directly, and therefore will not be discussed here.

Emissions other than NMOC and NO_x can also lead to ozone formation. Emissions that lead to the formation of free radicals and emissions of particles that may influence heterogeneous reactions in the atmosphere may be of some concern in the Houston Galveston area, and these emissions are described later in this report.

In addition to determining the magnitude and composition of NMOC and NO_x emissions, it is necessary to characterize the spatial and temporal distribution of the emissions. Photochemical grid models, used to describe ozone formation and to evaluate emission reduction strategies, generally use day specific inventories of emissions with a temporal resolution of one hour and a spatial resolution of approximately 2-4 km. Therefore, both spatial and temporal distributions of emissions will be reported.

Inventories of NMOC and NO_x emissions that contribute to ozone formation have generally been categorized into biogenic and anthropogenic emissions, and within the anthropogenic category, emissions are further classified as on-road mobile, non-road mobile, point, and area. Each of these terms is defined below. The definitions are drawn from Texas Commission on Environmental Quality (TCEQ) documentation for the HG State Implementation Plan (SIP) (http://www.tceq.state.tx.us/implementation/air/sip/dec2004hgb_mcr.html)

Biogenic emissions:

Biogenic emissions include NMOC emissions from crops, lawn grass, and forests as well as a small amount of NO_x emissions from soils, which may increase with the application of nitrogen based fertilizers. Plants are sources of NMOCs such as isoprene, monoterpenes, and sesquiterpenes. Tools for estimating emissions include satellite imaging for mapping of vegetative types, field biomass surveys, and modeling of emissions based on emission factors by plant species Biogenic emissions can be highly dependent on temperature and sunlight intensity, so data on these parameters are also necessary for emission estimates.

Anthropogenic emissions:

Point source emissions:

Major point sources are defined for inventory reporting purposes as industrial, commercial, or institutional sources which emit or have the potential to emit criteria pollutants at or above threshold levels. The levels vary depending on the air quality status of the area. For non-attainment areas, typical thresholds are: 10 tons/year (t/y) VOC, 25 t/y NO_x or 100 t/y of any other criteria pollutants that include CO, SO_2, PM_{10} or lead. Any source that generates or has the potential to generate at least 10 t/y of any single hazardous air pollutant (HAP) or 25 t/y aggregate of HAP is also required to report emissions (more detailed definitions of categories of point sources and emission thresholds that trigger reporting can be found in Title 30, Section 101.10 of the Texas Administrative Code).

The TCEQ uses an emission inventory questionnaire (EIQ) to collect emissions and industrial process operating data from plants that have emissions that are above the threshold levels described above. The EIQ is used to report the emissions from each point. Information on the amount of each species of NMOC is requested. Included are the type of emission (stack, fugitive, flare, etc.), process equipment diagrams, operation schedules, emissions control devices, and abatement device control efficiency. Also included are source location, height, stack diameter, gas exhaust temperature and exhaust gas velocity.

On-road Mobile Source emissions

On-road mobile sources consist of automobiles, trucks, motorcycles, and other motor vehicles traveling on public roadways. Combustion related emissions are estimated for vehicle engine exhaust. Evaporative NMOC emissions are estimated for the fuel tank and other evaporative leak sources. Emission factors have been developed using EPA's MOBILE6. Inputs for the mobile model are vehicle speed by roadway type, vehicle registration by vehicle type and age, percentage of vehicles in cold start mode, percentage of miles traveled by vehicle type, type of inspection and maintenance program, and gasoline vapor pressure. Travel activity, represented as vehicle miles traveled (VMT), is developed from travel demand models run by the Texas Department of Transportation or the local council of governments. The travel demand models have been validated with a large number of traffic counters. Estimates of area-wide VMT are calibrated with the federal Highway Performance Monitoring System (HPMS). Roadway speeds used in the MOBILE model are calculated by a post-processor to the travel demand model. On-road mobile emissions are determined for each roadway link and are based on the emission factor from the MOBILE model and the VMT from the travel demand model. Speciation of emissions in the Houston-Galveston area is based on locally collected data.

Non-road Mobile emissions

Non-road mobile emission sources are aircraft operations, marine vessels, recreational boats, railroad locomotives and off-highway equipment. Emission calculations are based on emission factors and activity. Activity data is based on equipment population, engine horsepower, load factor, and annual usage. For southeast Texas, diesel powered construction equipment emissions were based on activity data developed by an extensive survey (TCEQ, 2000), except for equipment less than 50 HP and cranes. An extensive study of commercial marine activity in the HG area was conducted to estimate marine vessel emissions. Aircraft emissions were estimated from landing and takeoff data from airports using the EDMS aircraft emissions model (TCEQ, 2000). Airport ground support equipment emissions were estimated with new methods using local survey data. Locomotive emissions were developed from fuel use and track mileage data obtained from the railroads. Emissions from all other non-road mobile source categories were calculated with EPA's NONROAD (U.S. EPA, 2006a) model.

Area emissions

Area sources include those point sources that fall below the threshold reporting level for point sources, along with sources that are widely dispersed (e.g., personal care products). These are sources that are too numerous or too small to identify individually and emissions are calculated on the basis of a source category or group. Typically area sources are commercial, small scale industrial and residential sources that use materials or operate processes that generate emissions. Area sources can be divided into two groups; those that have hydrocarbon evaporative emissions and those that have fuel combustion emissions. Examples of evaporative losses include: painting (surface coating), industrial coatings, degreasing solvents, leaking underground storage tanks, gasoline service station tank filling and vehicle refueling. Fuel combustion sources include stationary fuel combustion at residences and businesses (small industrial boilers, water heaters), outdoor burning, structural fires and wildfires.

Summary of Current Inventory Data

A number of spatially and temporally resolved emission inventories of ozone precursors have been developed for the Houston-Galveston (HG) area. These inventories include gridded and temporally resolved inventories developed for photochemical modeling applications and county level emission inventories developed for the Environmental Protection Agency's National Emissions Inventory (NEI) data set (U.S. EPA, 2006b).

Inventories developed for photochemical modeling applications

In March 2002, and in continuing updates since 2002, the TCEQ has developed a comprehensive, hourly, speciated emissions inventory for an August-September 2000 episode. The magnitude and speciation for the point source emissions in this inventory were based on special reports covering the period being modeled. These reports detailed, on an hourly basis, the magnitude and species of all emissions. Additional special surveys described in this report were used in developing the inventory. The emission estimates have been assembled into a gridded, temporally resolved inventory for photochemical modeling.

This inventory has also been adapted to predict emissions that will occur in 2007, after all of the emission controls necessary to attain the National Ambient Air Quality Standard (NAAQS) for ozone (concentrations averaged over 1 hour) are in place. This inventory includes estimates of both projected growth of emissions (for example, due to increased population and traffic) and the reductions expected from controls. It was used in the development of the State Implementation Plan (SIP) for attaining the ozone NAAQS (1-hour averaged concentrations) that was prepared by the State of Texas in late 2004. It will be referred to in this report as the 2007 attainment demonstration inventory.

The 2007 attainment demonstration inventory is the most applicable existing, comprehensive inventory of ozone precursors that can be used to estimate emissions during the study period for the second Texas Air Quality Study (TexAQS II). It will serve as the starting point for the base case inventory for the second Texas Air Quality Study (TexAQS II). Some modifications to the 2007 attainment demonstration inventory will be made, however, for the purposes of the TexAQS II study, and this modified inventory will be referred to as the TexAQS II base case emissions inventory.

The sources of data and procedures used in creating the 2007 attainment demonstration inventory and the TexAQS II base case inventory will be summarized in this report. Many of these procedures are described in much greater detail in documents created by the TCEQ and their contractors; these supporting documents are referenced in this report and electronic copies are provided as Appendices.

Whenever possible, summary statistics and spatial and temporal distributions of the emissions will be presented.

2007 Attainment Demonstration Inventory

Table 1 shows a summary of the estimated volatile organic compound (VOC) and NOx emissions in southeast Texas in the 2007 attainment demonstration inventory, and compares these emissions to the emission inventory for 2000. Overall, NOx emissions are projected to be reduced by approximately 50%, compared to 2000, and anthropogenic VOC emissions are projected to decrease by approximately 25%. Individual source categories will have different levels of reduction. For example, point source NOx emissions are projected to decrease by two-thirds between 2000 and 2007, while area and non-road sources decrease by only 15%. The result is a different distribution of emission sources in 2000 and 2007. For example, while point sources accounted for half of all NOx emissions in 2000, that fraction will be reduced to one-third in 2007.

Table 1: Anthropogenic emissions in the 8-county Houston-Galveston Area (TCEQ, 2004)

Emission category	NOx (tpd)		VOC (tpd)	
	2000 base case (Case 5B)	2007 attainment demo. (Case 08)	2000 base case (Case 5B)	2007 attainment demo. (Case 08)
On-road mobile	342	175	151	89
Point sources	492	163	384	245
Area/non-road	184	156	254	234
Total	1018	494	789	568

The control strategies that will be implemented to achieve these reductions are listed in Table 2, which is drawn from the TCEQs December 2004 SIP revisions.

Table 2: Summary of control strategies to be applied in the Houston-Galveston-Brazoria area by 2007 (from the TCEQ December 2004 SIP revision)

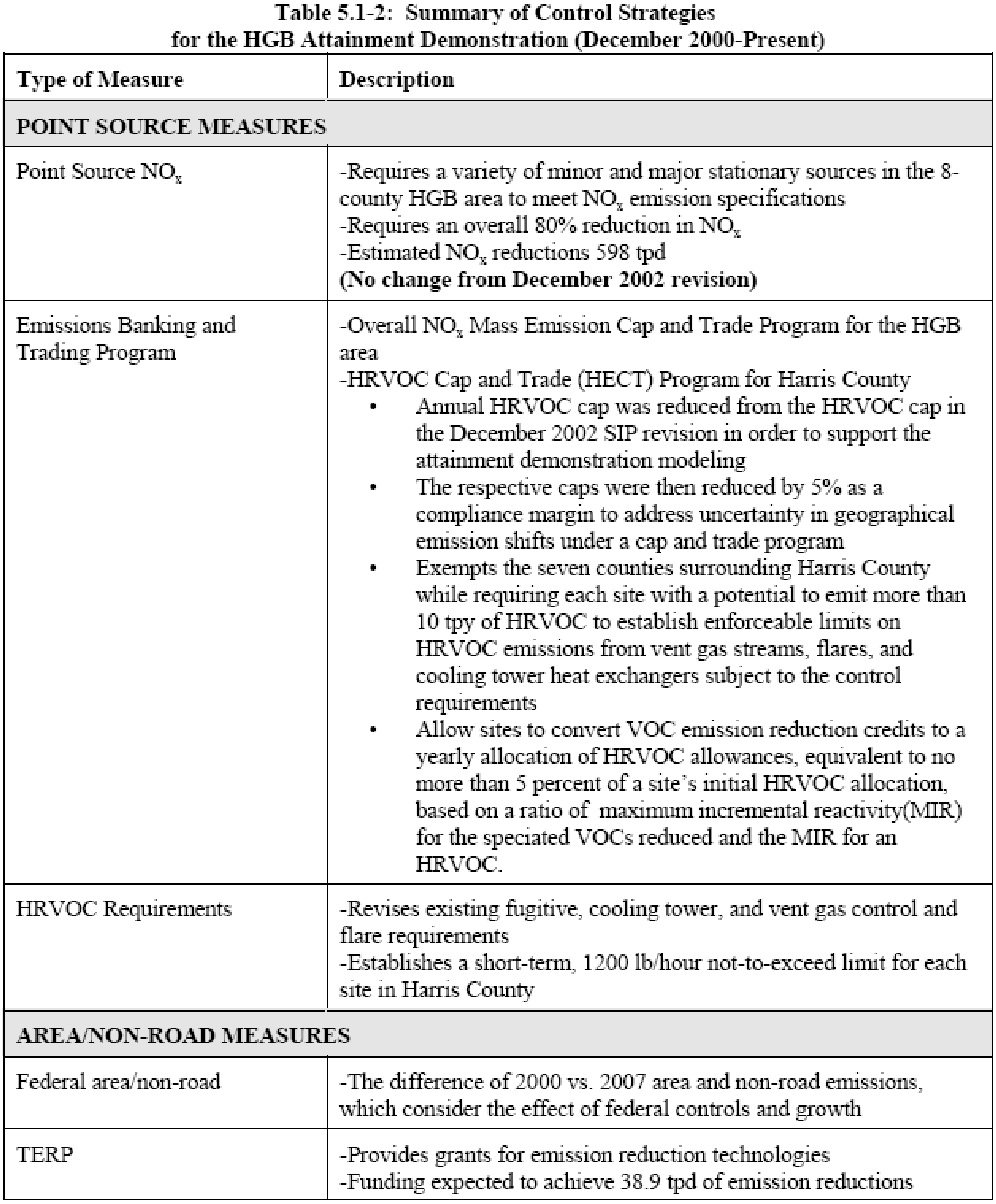


Table 5.1-2: Summary of Control Strategies for the HGB Attainment Demonstration (December 2000-Present)

Type of Measure	**Description**
POINT SOURCE MEASURES	
Point Source NO_x	-Requires a variety of minor and major stationary sources in the 8-county HGB area to meet NO_x emission specifications -Requires an overall 80% reduction in NO_x -Estimated NO_x reductions 598 tpd **(No change from December 2002 revision)**
Emissions Banking and Trading Program	-Overall NO_x Mass Emission Cap and Trade Program for the HGB area -HRVOC Cap and Trade (HECT) Program for Harris County • Annual HRVOC cap was reduced from the HRVOC cap in the December 2002 SIP revision in order to support the attainment demonstration modeling • The respective caps were then reduced by 5% as a compliance margin to address uncertainty in geographical emission shifts under a cap and trade program • Exempts the seven counties surrounding Harris County while requiring each site with a potential to emit more than 10 tpy of HRVOC to establish enforceable limits on HRVOC emissions from vent gas streams, flares, and cooling tower heat exchangers subject to the control requirements • Allow sites to convert VOC emission reduction credits to a yearly allocation of HRVOC allowances, equivalent to no more than 5 percent of a site's initial HRVOC allocation, based on a ratio of maximum incremental reactivity(MIR) for the speciated VOCs reduced and the MIR for an HRVOC.
HRVOC Requirements	-Revises existing fugitive, cooling tower, and vent gas control and flare requirements -Establishes a short-term, 1200 lb/hour not-to-exceed limit for each site in Harris County
AREA/NON-ROAD MEASURES	
Federal area/non-road	-The difference of 2000 vs. 2007 area and non-road emissions, which consider the effect of federal controls and growth
TERP	-Provides grants for emission reduction technologies -Funding expected to achieve 38.9 tpd of emission reductions

Type of Measure	**Description**
Airport Reductions	-Agreements with Continental Airlines, Southwest Airlines, and the City of Houston to make local reductions of NO_x from sources at Houston area airports **(No change from December 2000 revision)**
California Spark-Ignition Engines	-Statewide rule requiring manufacturers to ensure that all affected large spark ignition engines are certified to California LSI standards -Exempts agriculture and construction equipment less than 175 hp, recreational equipment, stationary engines, marine vessels, and equipment on tracks **(No change from December 2000 revision)**
Gas-fired Water Heaters, Small Boilers, And Process Heaters	-Manufacture requirement for state-wide sales of water heaters, small boilers, and process heaters -Delay 10 ng/J compliance date for all Type 0 water heaters by 2 years
Stationary Diesel Engines	-Requires owners and operators of stationary diesel engines or dual-fuel engines in the 8-county HGB area to meet new emission specifications and operation restrictions **(No change from September 2001 revision)**
VOC RACT	-Implements RACT requirements for batch processes, bakeries, and offset lithographic printers in the 8-county HGB area **(No change from December 2000 revision)**
MOBILE SOURCE MEASURES	
Federal on-road	-The difference of 2000 vs. 2007 on-road emissions, which consider the effect of federal controls and growth
Inspection/ Maintenance	-Requires ASM II or equivalent testing as well as OBD testing -Began May 1, 2002 in Harris County -Began May 1, 2003 in Brazoria, Fort Bend, Galveston, and Montgomery Counties -Removes Chambers, Liberty, and Waller Counties
Speed Limit Reduction	-Maintains the speed limits at 5 mph below what was posted before May 1, 2002, where speeds were 65 mph or higher -Removes reinstatement of the 55 mph speed limit on May 1, 2005

Type of Measure	**Description**
Cleaner Diesel Fuel	-Beginning April 1, 2005 (October 1, 2005 *)diesel fuel used in the HGB, BPA, and DFW areas, and in an additional 95 East and Central Texas counties for both onroad and nonroad use does not exceed 500 ppm sulfur, contains less than 10.0% by volume of aromatic hydrocarbons, and has a minimum cetane number of 48. -Alternative diesel fuel formulations that achieve equivalent emission reductions may also be used. -Beginning June 1, 2006, the sulfur will be reduced to 15 ppm in both onroad and nonroad diesel fuel in the HGB, BPA, and DFW areas, and in an additional 95 East and Central Texas counties. **(No change from September 2001 revision)** (*It is anticipated the compliance date will be extended by six months to October 1, 2005. It is anticipated the rule will be revised by Spring 2005 as directed by the commission. See section 5.3.5.)
VMEP	-Numerous projects identified by the HGAC for inclusion in the SIP such as telecommuting, bus fare promotions, alternative fuel programs, and ozone action days -Revised credit taken for this program to 7 tpd
TCMs	-Numerous projects identified by HGAC for inclusion in the SIP, such as traffic signalization and bicycle/pedestrian projects -Updated to show that projects completed prior to the year 2000 have met their commitments and those not captured in the 2000 episode modeling have been incorporated in the appropriate milestone year emissions estimates.
OTHER	
Portable Fuel Containers Rule	-Establishes new design "no spill" criteria requirements for portable fuel containers sold, offered for sale, manufactured, and/or distributed in Texas beginning December 31, 2005

The geographical scope of the TexAQS II base case inventory is shown in Figure 1. The modeling domain is a nested regional/urban scale 36-km/12-km/4-km grid. To the extent that meteorological inputs are required by emission estimation algorithms, they were obtained based on results from the Mesoscale Meteorological Model, version 5, unless otherwise noted. A description of the methods used in generating the meteorological model outputs are given in the Appendix.

Shown in Figures 2-5 are the spatial distribution of NOx and VOC emissions in the attainment demonstration inventory. Figures 2 and 3 show the spatial distributions of NOx emissions in the entire domain and in the portion of the domain with 4-km resolution (the 4-km domain). Figures 4 and 5 show the spatial distributions of VOC emissions in the entire domain and in the 4-km domain. In each Figure, emission inventory data are shown for a typical weekday (Monday-Wednesday), a typical Thursday-Friday, a typical Saturday and a typical Sunday/holiday. In cases where the emissions depend on temperature, the meteorological data were taken from the dates listed on the Figure (August 25=Friday; August 26=Saturday; August 27=Sunday/holiday; August 29=Monday-Wednesday). The emission data are shown for 1300 HR.

In the sections that follow, summary data and Figures will be provided for each of the components of the inventory (point sources, on-road mobile sources, non-road mobile and area sources, and biogenic sources) The methods used in estimating the emissions and references to key documentation will also be provided.

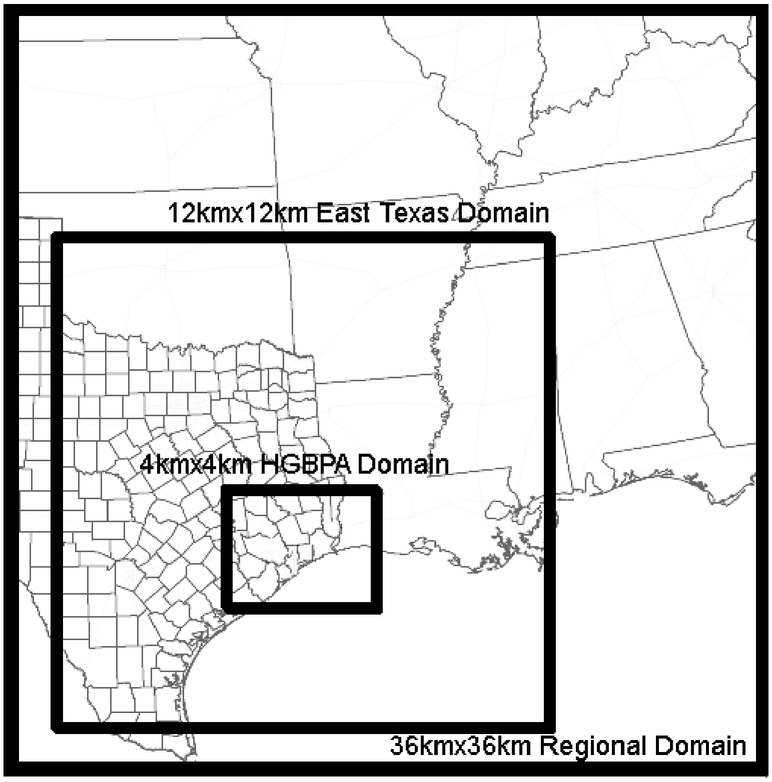
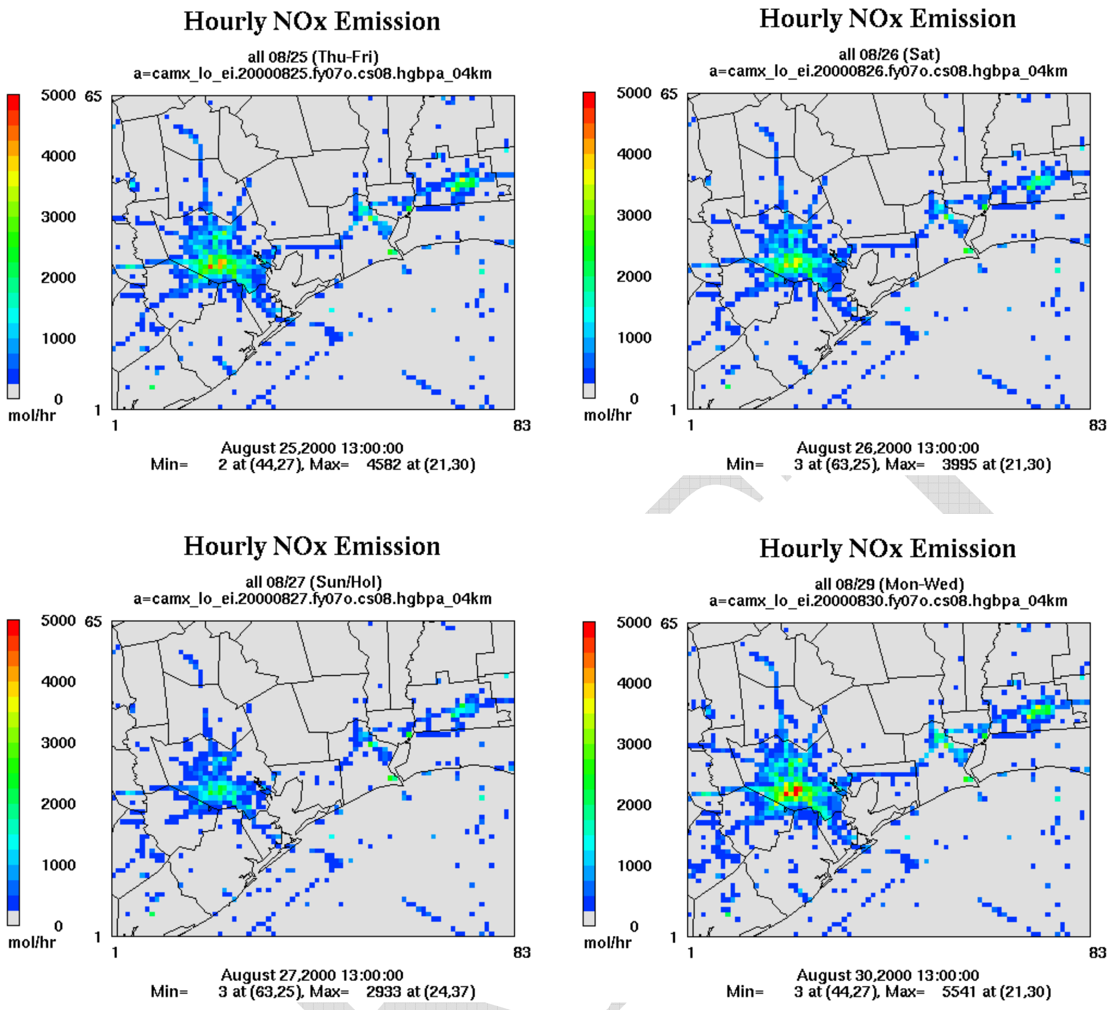


Figure 1. Domain for TexAQS II base case inventory



Hourly NOx Emission

all 08/25 (Thu-Fri)
a=camx_lo_ei.20000825.fy07o.cs08.hgbpa_04km

August 25,2000 13:00:00
Min= 2 at (44,27), Max= 4582 at (21,30)

Hourly NOx Emission

all 08/26 (Sat)
a=camx_lo_ei.20000826.fy07o.cs08.hgbpa_04km

August 26,2000 13:00:00
Min= 3 at (63,25), Max= 3995 at (21,30)

Hourly NOx Emission

all 08/27 (Sun/Hol)
a=camx_lo_ei.20000827.fy07o.cs08.hgbpa_04km

August 27,2000 13:00:00
Min= 3 at (63,25), Max= 2933 at (24,37)

Hourly NOx Emission

all 08/29 (Mon-Wed)
a=camx_lo_ei.20000830.fy07o.cs08.hgbpa_04km

August 30,2000 13:00:00
Min= 3 at (44,27), Max= 5541 at (21,30)

Figure 2. Spatial distributions of NOx emissions in the attainment demonstration inventory on a typical weekday, a Friday, a Saturday and a Sunday, at 1300 HR. Data are for the portion of the domain modeled at 4-km resolution.

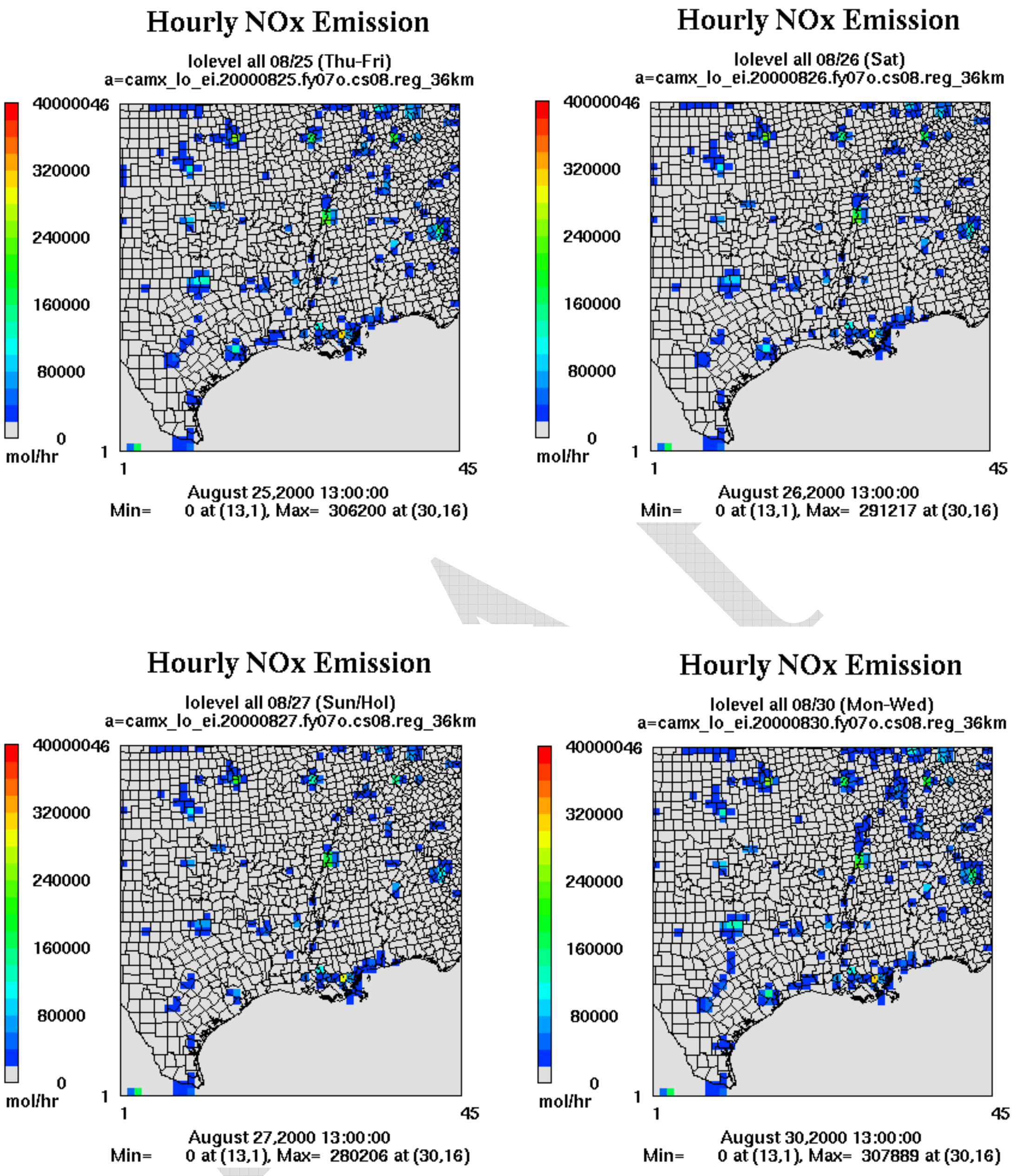


Figure 3. Spatial distributions of NOx emissions in the attainment demonstration inventory on a typical weekday, a Friday, a Saturday and a Sunday, at 1300 HR. Data are for the the entire domain.

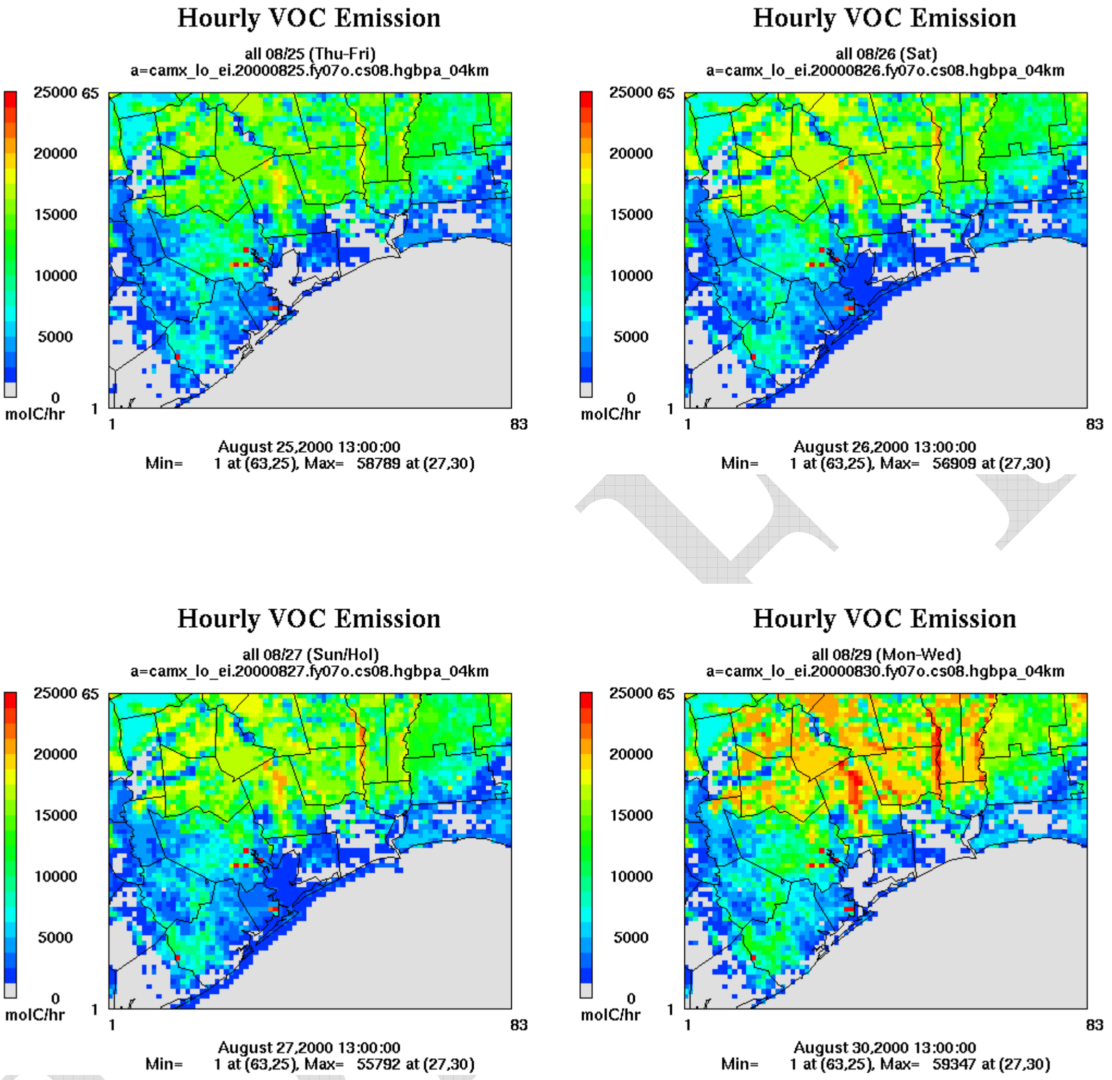


Figure 4. Spatial distributions of VOC emissions in the attainment demonstration inventory on a typical weekday, a Friday, a Saturday and a Sunday, at 1300 HR. Data are for the portion of the domain modeled at 4-km resolution.

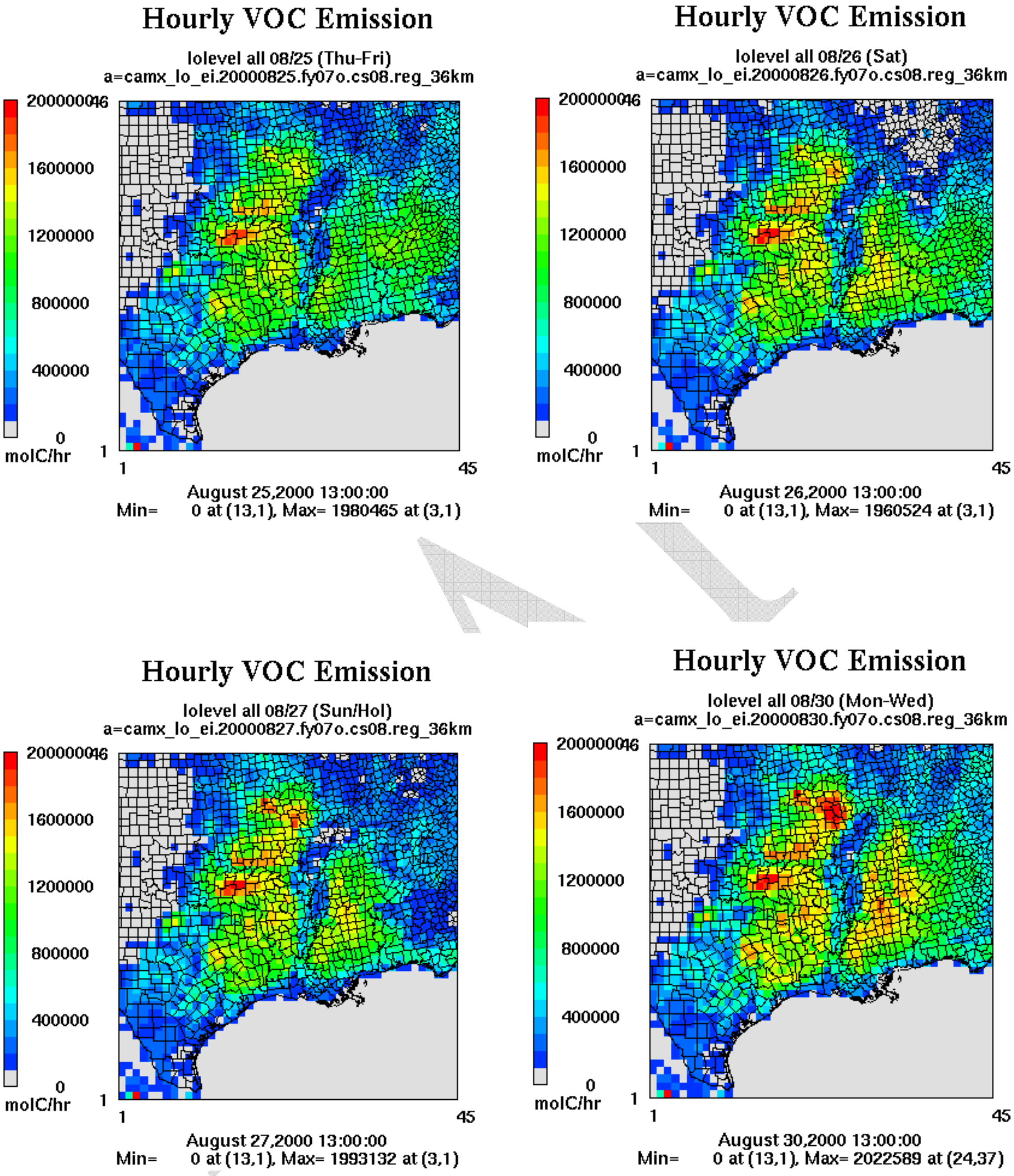


Figure 5. Spatial distributions of VOC emissions in the attainment demonstration inventory on a typical weekday, a Friday, a Saturday and a Sunday, at 1300 HR. Data are for the the entire domain.

POINT SOURCES

NOx Point Sources

Emissions Magnitude

NOx point sources in the 2007 attainment demonstration inventory are estimated to be 175 t/d in the 8-county Houston-Galveston area (Table 1). Only approximately 30 t/d of this total is associated with electricity generating units (EGUs). The remainder is associated with other industrial operations in the 8-county area, primarily refining and petrochemical manufacturing. Emissions in Louisiana are estimated to be approximately 1000 t/d (60%, NEGU, 40% EGU) and emissions in the regional domain are approximately 6700 t/d (30% NEGU, 70% EGU).

The 2007 point source inventories are based on estimated growth of 2000 base year emissions, and estimates of control strategy effectiveness, so the accuracy of the inventory will depend on the accuracy of the base inventory, the growth factors and the estimated control strategy effectiveness. Analyses of prognostic assessments of growth are beyond the scope of this document. These methods are described in the documentation for the SIP. The methods used to develop the 2000 base case inventory and the methods used to assess control strategy effectiveness will be described. Figure 6 shows the methods used in developing the 2000 inventory (Neece, 2002). These methods are described below.

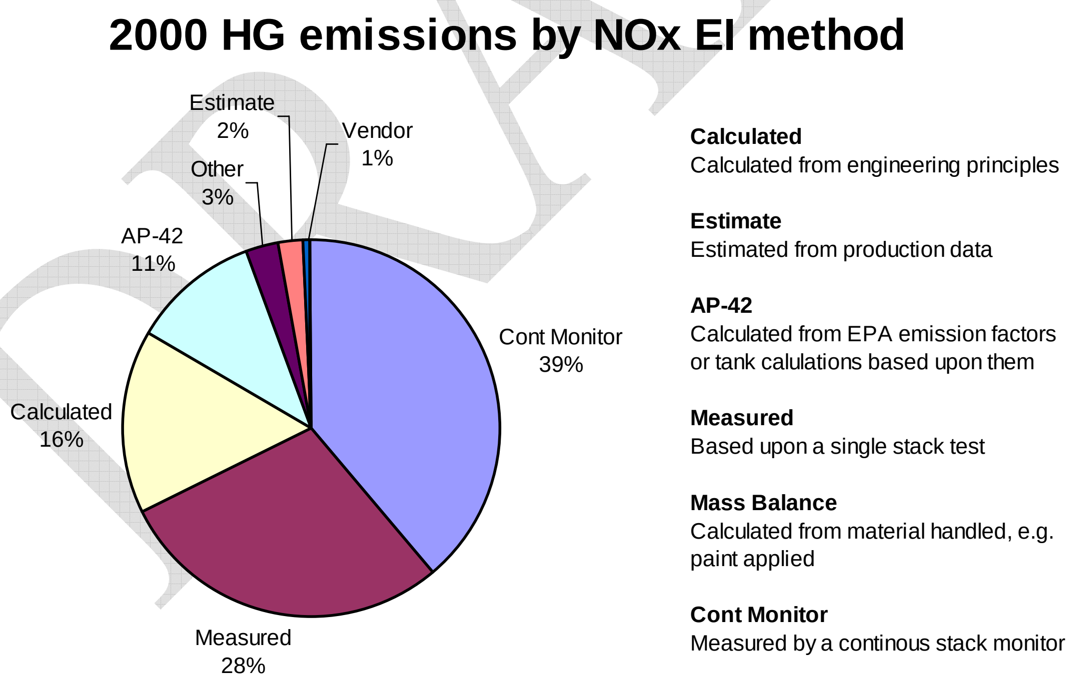


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Figure 2. Methods used to calculate 2000 NOx Point Source emissions in the Houston-Galveston nonattainment area, Neece, 2002.

Continuous monitoring directly or indirectly measures emissions from the stack. Permitted emitters of significant quantities of NO_x from stacks are required to continuously measure NO_x emissions. Direct measurements are performed with continuous emissions monitors (CEM). If it is impractical to use a CEM, continuous NO_x emissions are estimated with a predictive emissions monitor (PEM). The PEM is a mathematical model that predicts NO_x emissions based on continuously measured process data (such as furnace temperatures) that influence NO_x emissions. CEM and PEM have the potential for providing accurate estimates of NO_x emissions and these methods were used for determining 39 percent of the NO_x point source emissions in the 2000 inventory (Neece, 2002).

The term "measured" is used for methods that use stack testing to determine emissions. These methods were used for calculating 28 percent of the NO_x point source emissions in the 2000 inventory (Neece, 2002). Stack testing is normally performed when the plant is well tuned and is running at permitted capacity, so it may not accurately replicate other types of plant operations.

The term "calculated" is used for methods that determine emissions from engineering calculations based on the design of the plant. For example, such methods use specific design characteristics and fuel composition to determine the emissions from a boiler or heater. These calculations are based on source specific information used in permit review or AP-42 factors (EPA, 2001d). These methods were used for 16 percent of the NO_x point source emissions in the 2000 inventory (Neece, 2002)

The term "estimate" was used for methods that calculate emissions based on the actual capacity for which the plant was operated. Emissions based on permit allowable capacity are multiplied by ratios of plant actual operating capacity to permit allowable capacity to estimate actual emissions. This was used for about 2 percent of the NO_x point source emissions in the 2000 inventory (Neece, 2002).

AP-42 emissions factors were used for 11 percent of the NO_x point source emissions (Neece, 2002). This process uses an average emission factor for generic types of sources.

Since half of the point source NO_x emissions documented in the base case (2000) point source inventory are based on estimates, there may be a significant amount of uncertainty in the determination of the quantity of the 2007 NO_x emissions. At this time it is not possible to establish an error bound on these emissions.

An additional uncertainty in the 2007 attainment demonstration inventory is associated with control strategy effectiveness. In regions of eastern Texas outside of the ozone non-attainment areas, Electricity Generating Units (EGUs) are subject to overall emission reductions mandated by Texas Senate Bill 7, but trading among facilities is allowed. In developing the 2007 attainment demonstration inventory, TCEQ assumed uniform reductions at all facilities, and this may or may not actually occur.

Speciation

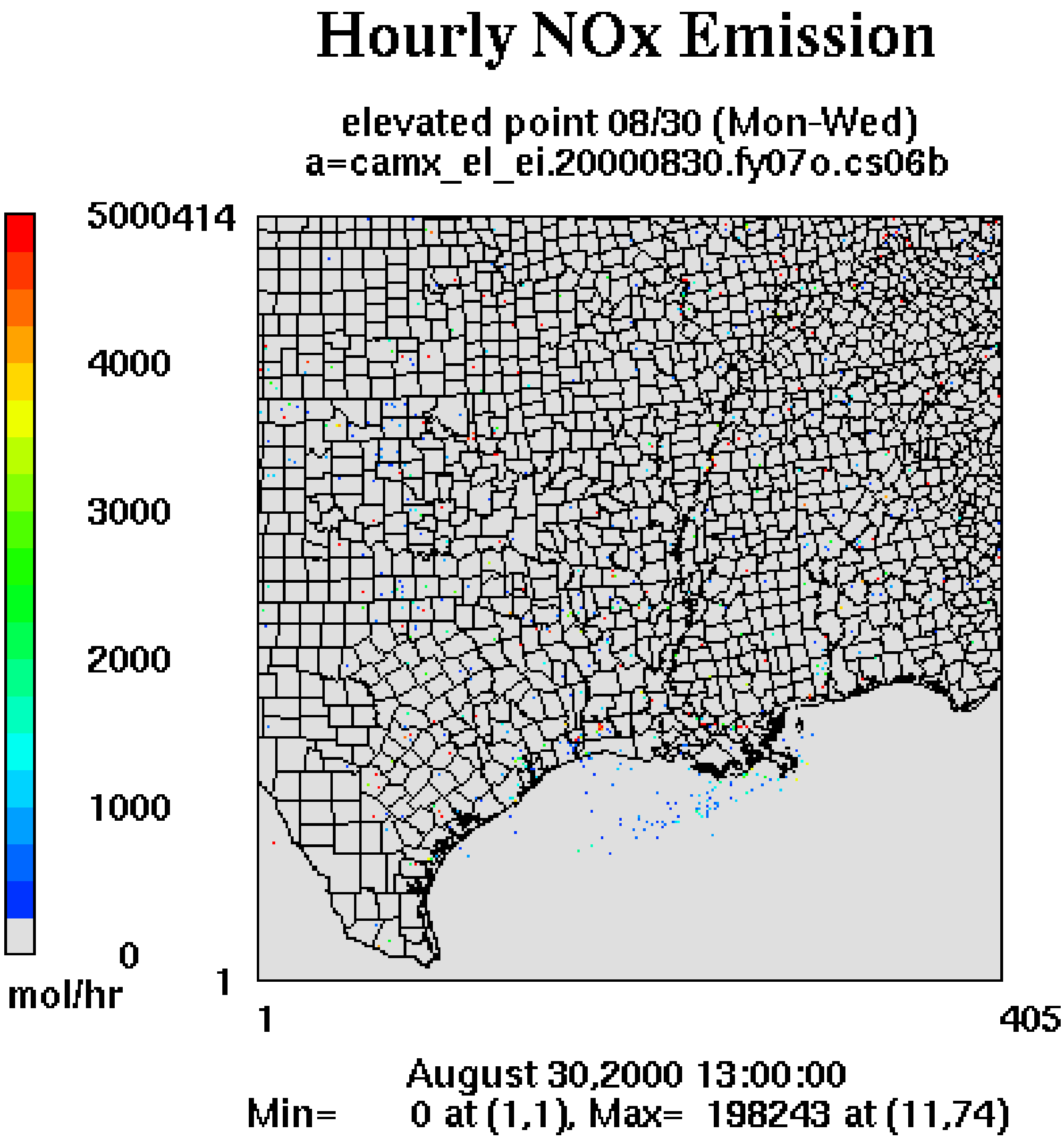
The composition of the NO_x emissions in the HG area is generally believed to be typical of combustion sources nationally. This is accurate except for a few highly specialized processes (e.g., emissions from the manufacture of adipic acid, which can involve significant emissions of N_2O, and individual source profiles for these processes have been developed). These unusual situations have been reviewed by the TCEQ and have been addressed in the inventories. The EPA default speciation of NO_x is 90 percent as NO and 10 percent as NO_2. Some control methods will decrease the total NO_x emissions, but may increase the percentage of NO_2 emitted. (Note for this and all subsequent sections on NO_x speciation that inventories report all NO_x as NO_2; in the photochemical modeling the emissions are speciated)

Spatial resolution

Uncertainty in the spatial resolution of ground position is not an issue for NO_x point source emissions since these emissions come from well defined stacks at specific locations. The spatial distribution of low level and elevated NOx emissions on a typical weekday are shown in Figures 7 and 8. The emission data are shown for 1300 HR.

While ground position is well known, the height at which point source NO_x emissions are effectively released may not be well known. Emissions of NO_x from point sources are often at elevated temperatures, and therefore subject to plume rise.

Figure 7. NOx elevated point source emissions on a typical weekday, 1300 h.



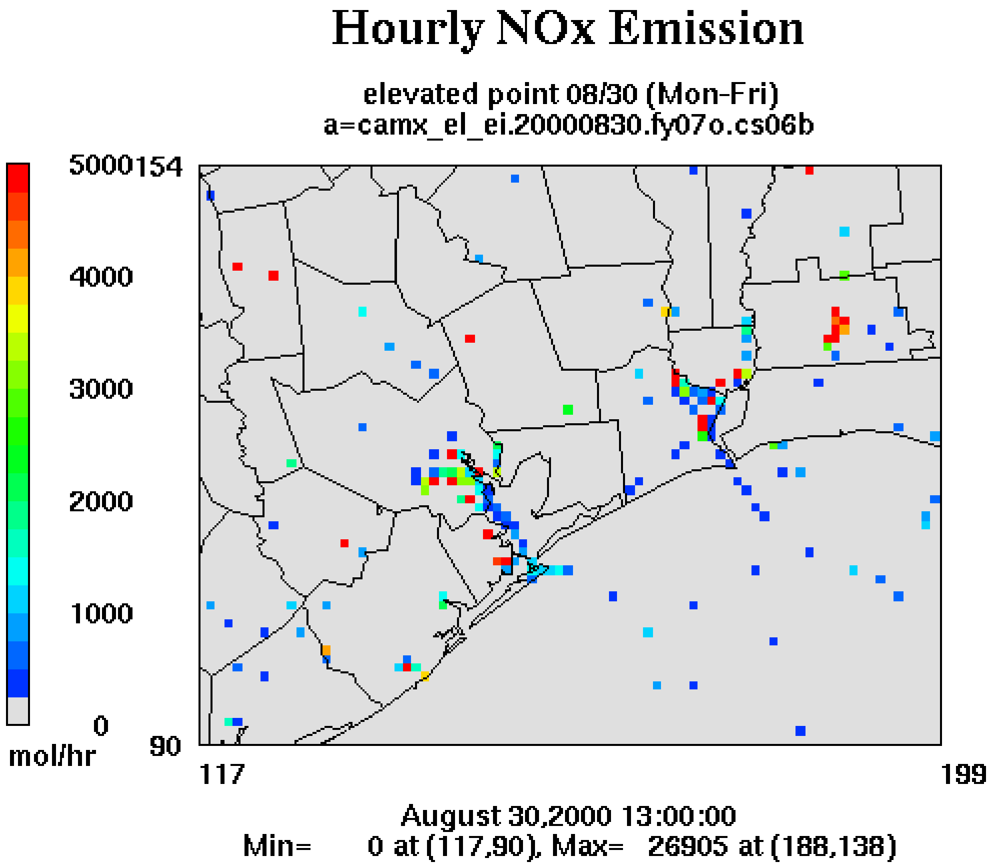
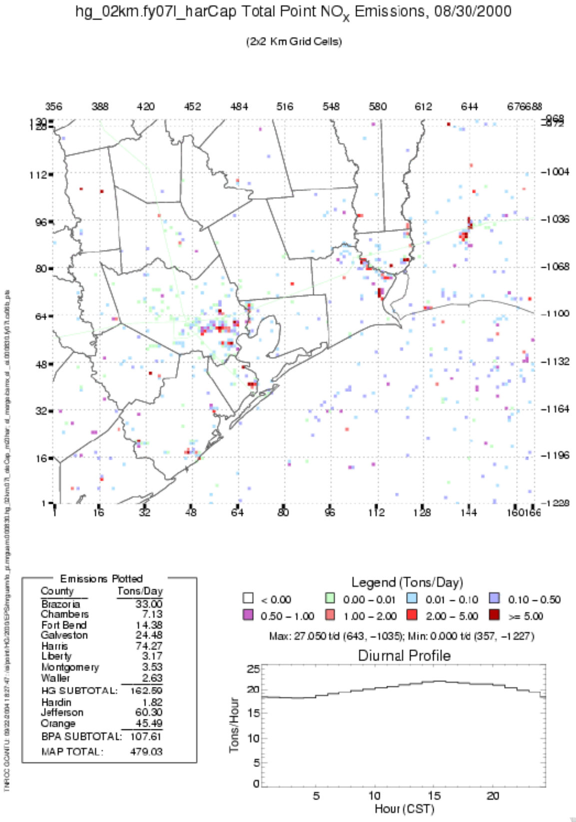


Figure 8. NOx elevated point source emissions on a typical weekday, 1300 h, 4-km domain

Temporal resolution
Because of the use of CEMs and PEMs on most significant point sources of NO_x, continuous data on emission rates are available and are generally believed to be very accurate. This can provide valuable information on the diurnal variation of NO_x point source emissions. Especially useful is the information on power plants that may cycle load and therefore vary their emissions during the day. This is especially true of plants that are run for only a few hours for meeting power demand during peak use periods. TCEQ uses hourly emissions from continuous monitoring at all Acid Rain Program facilities (Large Electric Generating Units) when retrospectively modeling air pollution episodes. For prospective modeling (such as the 2007 attainment demonstration inventory), the TCEQ generally applies a constant percentage reduction (control factor) to sources in the base case inventory and adds new facilities. This can lead to different projected diurnal profiles of NOx emissions in the base case and the projected case, as shown in Figure 9.

Figure 9. Comparison of point source NOx emissions in the 2000 base case and 2007 attainment demonstration inventories. Note the differences in diurnal profiles


hg_02km.fy07l_harCap Total Point NO_x Emissions, 08/30/2000

(2x2 Km Grid Cells)

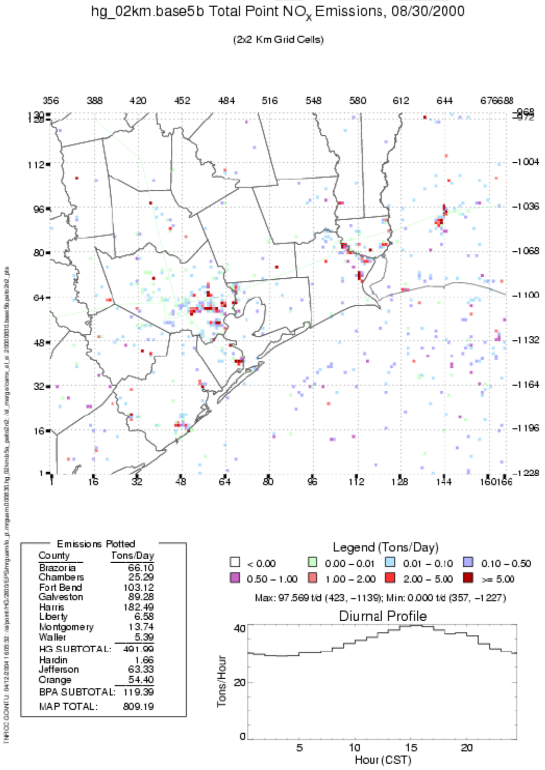
Emissions Plotted

County	Tons/Day
Brazoria	33.00
Chambers	7.13
Fort Bend	14.38
Galveston	24.48
Harris	74.27
Liberty	3.17
Montgomery	3.53
Waller	2.63
HG SUBTOTAL:	162.59
Hardin	1.82
Jefferson	60.30
Orange	45.49
BPA SUBTOTAL:	107.61
MAP TOTAL:	479.03

Legend (Tons/Day)

☐ < 0.00	🟩 0.00 – 0.01	🟦 0.01 – 0.10	🟦 0.10 – 0.50
🟪 0.50 – 1.00	🟥 1.00 – 2.00	🟥 2.00 – 5.00	🟥 >= 5.00

Max: 27.050 t/d (643, –1035); Min: 0.000 t/d (357, –1227)


hg_02km.base5b Total Point NO_x Emissions, 08/30/2000

(2x2 Km Grid Cells)

Emissions Plotted

County	Tons/Day
Brazoria	66.10
Chambers	25.29
Fort Bend	103.12
Galveston	89.28
Harris	182.49
Liberty	6.58
Montgomery	13.74
Waller	5.39
HG SUBTOTAL:	491.99
Hardin	1.66
Jefferson	63.33
Orange	54.40
BPA SUBTOTAL:	119.39
MAP TOTAL:	809.19

Legend (Tons/Day)

☐ < 0.00	🟩 0.00 – 0.01	🟦 0.01 – 0.10	🟦 0.10 – 0.50
🟪 0.50 – 1.00	🟥 1.00 – 2.00	🟥 2.00 – 5.00	🟥 >= 5.00

Max: 97.569 t/d (423, –1139); Min: 0.000 t/d (357, –1227)

NMOC Point Sources

Emissions Magnitude

The daily or hourly magnitude of NMOC emissions from point sources in the Houston-Galveston area is the portion of the emission inventory with the greatest uncertainties. The emission inventory described here represents a best estimate of projected emissions for the TexAQS II period, but, these emission estimates should be viewed with caution, as outlined below.

As was the case in the NOx emission inventory, the 2007 point source NMOC inventories are based on estimated growth of 2000 base year emissions, and estimates of control strategy effectiveness, so the accuracy of the inventory will depend on the accuracy of the base inventory, the growth factors and the estimated control strategy effectiveness. In the case of NMOC emissions, analyses of prognostic assessments of growth factors will be beyond the scope of this document, however, the methods used to develop the 2000 base case inventory and selected control factors will be discussed.

The path from the 2000 base year emissions to the 2007 attainment demonstration inventory is complex; the information flow shown in Figure 10 aids the description of the inventory. The starting point of the emission estimation is the 2000 base year inventory, shown as the first row in Figure 10. This inventory consists of three parts, as shown in the second row in Figure 10. The first two parts are associated with the base inventory and include highly reactive VOCs (HRVOCs, defined as ethylene, propylene, butylenes and 1,3-butadiene) and non-HRVOCs (other VOCs, OVOCs). This base inventory was unable to replicate observations made during the 2000 Texas Air Quality Study field campaign and subsequent measurements, so additional emissions of HRVOCs (but not OVOCs) were added to the inventory. These emissions were imputed based on observational data. Specifically, data from some aircraft flights showed that olefin concentrations, as measured by an instrument designed to detect total olefins, were approximately equal to NOx concentrations in some plumes (for more details, see the Acceletaed Science evaluation document on Emission Inventories at http://www.utexas.edu/research/ceer/texaqsarchive/accelerated.htm). When TCEQ modeled ozone formation, using the assumption that NOx emissions equaled HRVOC emissions at all industrial facilities emitting HRVOCs in the 8-county Houston-Galveston area, acceptable performance in predicting ozone formation resulted. The additional HRVOC emission required so that HRVOC emissions equaled NOx emissions at industrial facilities in the 8-county area is referred to as the “imputed” inventory, since the emissions are imputed based on aircraft data. A summary of the emissions added in the imputed inventory is given in Table 3. The accuracy of this assumption remains a topic of vigorous debate, however, as outlined in the next steps of the emission processing, this assumption does not affect the HRVOC emissions projected for 2007 in Harris County. The assumption may, however, affect the accuracy of HRVOC emissions in the counties other than Harris County and OVOC emissions projected for 2007, as discussed below.

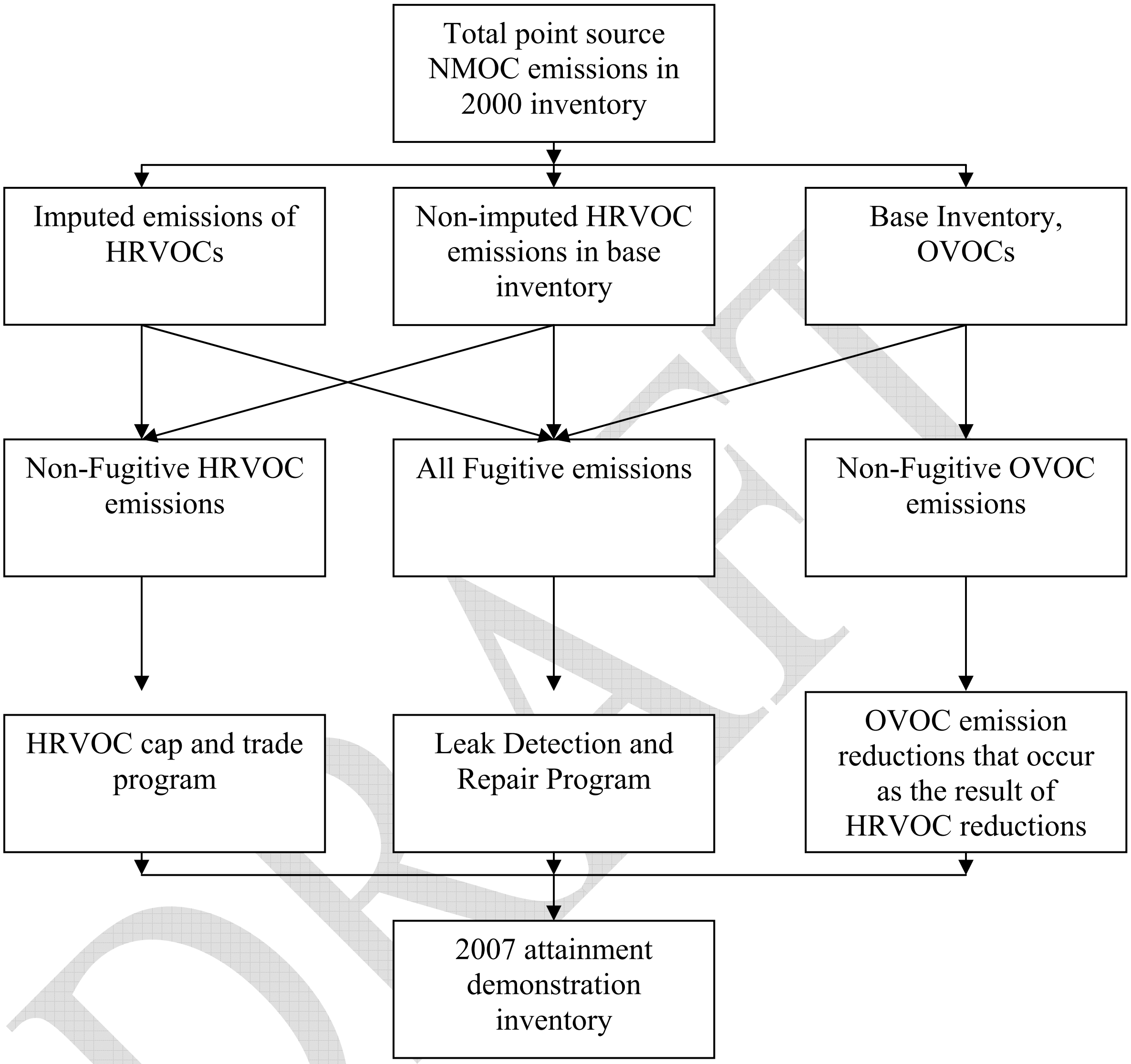
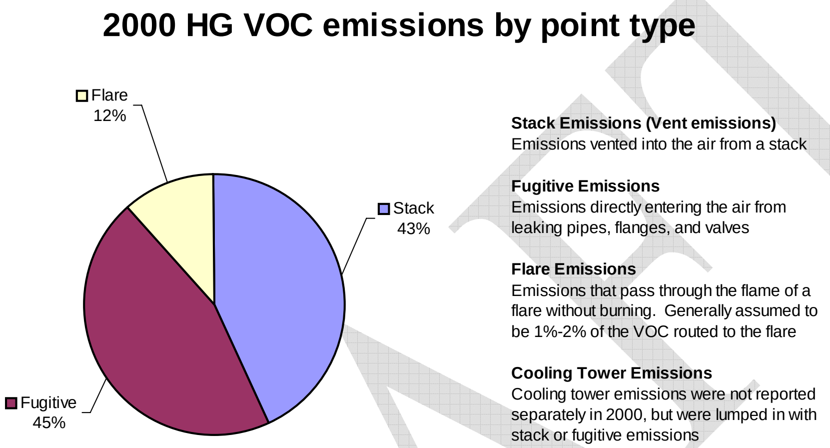


Figure 10. Conceptual diagram of the process used in estimating the 2007 attainment demonstration VOC point source inventory, based on the 2000 base case inventory

Table 3. Effect of imputed inventory on HRVOC emissions

	HRVOC emissions in 2000 base inventory (tpd)	HRVOC emissions in 2000 base+imputed inventory (tpd)	HRVOC emissions in 2007 attainment demonstration inventory (tpd)
Harris County	20.6	115.0	22.6
Seven surrounding counties	10.0	56.3	22.0

The base inventory for 2000, with added (imputed) HRVOC emissions, was subject to controls. The controls are applied to two categories of emissions, each constituting approximately equal fractions of the 2000 base inventory (line 3 in Figure 10). One category is fugitive emissions, which are emissions due to small leaks distributed throughout a complex facility. The other category is stack, flare, cooling tower and vent emissions, emissions which are associated with distinct emission points. As shown in Figure 11, these two categories made roughly equal contributions to the 2000 base case inventory.



Stack Emissions (Vent emissions)
Emissions vented into the air from a stack

Fugitive Emissions
Emissions directly entering the air from leaking pipes, flanges, and valves

Flare Emissions
Emissions that pass through the flame of a flare without burning. Generally assumed to be 1%-2% of the VOC routed to the flare

Cooling Tower Emissions
Cooling tower emissions were not reported separately in 2000, but were lumped in with stack or fugitive emissions

Dateset: oracle.psdb_alloc_2000_v10

Figure 11. Distribution of 2000 VOC Point Source emissions in the Houston/Galveston nonattainment area, Neece, 2002

The controls applied to these 2000 base case emissions, after accounting for economic growth, are different for fugitive and non-fugitive emissions (line 4 in Figure 10). For fugitive emissions, a leak detection and repair program is required and that program was estimated to have a 64% control efficiency (fugitive emissions reduced by 64%). For non-fugitive emissions, an emission cap will be put in place for HRVOCs. The emission inventories include the effect of an emission cap in all 8 counties in the Houston-Galveston area (however current regulations only apply the cap in Harris County).

When controls are applied to HRVOC emissions to meet the cap, it is anticipated that entire process streams will be controlled, rather than just the HRVOCs in the process streams. For example if an emission contains 50% propylene and 50% propane and the entire stream is treated, then equal amounts of propane and propylene will be reduced. This suggests that some OVOC emission reductions will occur as a result of the HRVOC cap. Preliminary estimates suggest that approximately 6 pounds of OVOCs will be reduced for every pound of HRVOCs. If these emissions of OVOCs are weighted by their incremental reactivity, they would account for approximately half as much reactivity as the HRVOC emissions. While these approximations suggest that this may be a relatively large effect, it will be very difficult to assess the precise magnitude of the effect until the controls are actually in place.

So, the estimated magnitude of emissions in the 2007 attainment demonstration includes controls on HRVOC and OVOC fugitive emissions, and the effect of a cap on non-fugitive emissions of HRVOCs. How closely this attainment demonstration inventory will represent emissions during the 2006 TexAQS II study period will depend on a number of factors, including:

- Will facilities have implemented the HRVOC caps by summer 2006, given that they are not required until 2007?
- Will the imputed level of fugitive emissions, coupled with the expected effectiveness of the leak detection and repair program adequately account for the remaining fugitive emissions?
- Was the underestimation of the VOC emissions restricted to the HRVOCs, as suggested by the imputed inventory, or were other VOC emissions also underestimated?

Because of these uncertainties, it is expected that a group of alternative inventories for NMOC emissions from point sources will be developed. These will be documented in future supplements to the TexAQS II emission inventory documentation.

Speciation

Photochemical modeling and a variety of data analysis techniques require that the specific compounds contained within VOC emission streams be identified. Identification occurs either through direct facility reporting or by cross-referencing against typical profiles based on the Source Classification Code (SCC) assigned to a piece of equipment or operating unit. In developing emissions inventories, TCEQ uses Texas-specific profiles when available; EPA default profiles are used in their absence. The resulting VOC profiles are stored in the Texas Point Source Database (PSDB). The profiles are referenced either by a specific emission point or by the SCC code. Emissions inventory data for use in photochemical modeling, including modeling of the attainment demonstration, are managed through Air Facility System (AFS) files. Embedded in the AFS files is information regarding location of the emission point, the type of facility (indicated by Standard Industry Classification (SIC) codes, the type of equipment or operation that produces the emission (SCC), and other data that may be of use to both modelers as well as investigators not actively involved in the modeling process. However, AFS files tend to be very large and make use of codes that are not readily interpretable by the casual user. Furthermore, VOCs emissions are not speciated within the file, but are instead reported as total mass from a given emission point. Separate files containing the profiles are then called upon during the model run.

In 2003, the TCEQ created an AFS file that reports VOC emission mass by compound for the 2000 point source inventory. The resulting file (afs_psdb_voc_2000_v15b.txt), referred to as the 2000 speciated emissions inventory, is available on the TCEQ website (TCEQ, 2003) and represents a data merge of all species reported by individual facilities, all species generated by cross-referencing standard profiles, as well species that are identified as the result of running typical profiles against emissions reported as mixtures (e.g., crude oil, gasoline, etc). For the

TexAQS II base case inventory, the speciated EI was downloaded and imported into an Access database in order to manage and edit the more than 550,000 records (rows of data) contained within this file. Within Access, the data set was modified such that only emissions of greater than one pound per day from non-electric generating units (NEGUs) were considered. In addition, because of the data merge, it was necessary to sum emissions across SAROAD codes (the EPA code used to designate specific compounds). After these modifications, there are approximately 90,000 individual records representing the emission mass of a specific compound from a specific release point. These compound-specific data are then normalized by the total VOCs reported from that point (within this inventory) to give the fraction emitted by compound, as designated by the SAROAD code. There are a total of 364 SAROAD codes used in the speciated EI. The database developed by Carter (Carter, 2005) contains a complete listing of the CAS numbers and compound names for each of code. As there are some differences between states, only those assignments appropriate for Texas are considered. This listing was used to form a lookup table within the database, herein referred to as the TX NEGU VOC Species Database.

Included in the speciated inventory file is a code indicating whether the profile is based on reported compounds or cross-referenced against a profile. According to this information, 16.9% of all Texas non-electric generating (negu) operating units that are designated by facility identification numbers (FINs) have facility-specific compositional profiles associated with them (i.e., VOC compositions reported by the owner). This represents 65.7% of the VOC mass emitted from NEGU point sources across the state. In the Houston Galveston area, 61.5% of FINs, representing 75.2% of the mass, have facility-specific VOC compositional profiles. It should be noted, however, that while the species are directly reported, very few of the measurements themselves are made directly. Less than 8% of the mass is based on stack measurements (7.97% in HG and 7.75% state-wide) (Table 4) and there are virtually no profiles derived from continuous monitors (approximately 0.1%). Most of the VOC mass is speciated using indirect methods based on production estimates or engineering calculations. These methods account for 56% of the VOC speciated mass state-wide, and 62% in the Houston-Galveston area. Roughly 20% of the mass is speciated using "typical" emission factors defined by EPA in AP-42 methodologies. The composition of the remaining approximately 10-15% is determined by mass balance or other methods.

Table 4. Distribution of Speciation Methodologies in Texas and the Houston Galveston Area

Speciation Methodology	Texas	HG
Production Estimate	33.70%	27.00%
Calculated	22.39%	35.01%
AP-42	21.32%	19.20%
Mass Balance	10.10%	5.48%
Stack Measurement	7.75%	7.97%
Other	4.63%	5.20%
Continuous monitor	0.11%	0.14%

The compounds represented by the SAROAD codes were roughly categorized by molecular weight and functional group in order to more easily analyze data trends within the TX NEGU VOC Species Database. The lookup table containing these categories may be easily modified at a later date to include specific categories of interest (e.g., C7-C9 substituted aromatics). The categories currently in use are:

C2-C7 alkane
Other VOC
Aromatic
Alcohol
Ethene (Ethylene)
Propene (Propylene)
>C7 alkane
Butene (Butylene)
>C4 Alkene
Butadiene
Other

Based on the 2000 speciated EI, the following distribution of VOC categories is indicated for the Houston-Galveston area; Harris County is very similar, differing by a maximum of 1%.

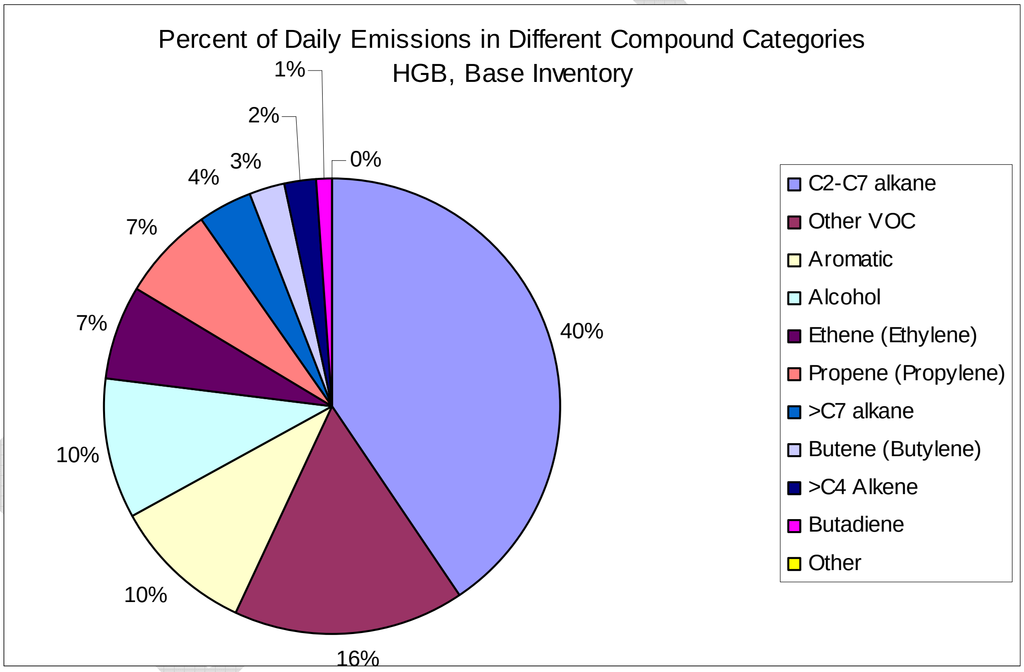


Figure 1. Distribution of percent VOC emissions by category in the 2000 speciated emissions inventory

The speciated emissions inventory described above was developed for an early version of the 2000 point source emissions inventory. Among other changes, a “Special Inventory” developed for the HGA August 2000 episode was included as a daily average into the regular Texas negu point source inventory (afs.tx_negu.agg_re.000818-000906.v15b.3pols.lcp). This and other adjustments to the inventory have resulted in a higher VOC mass in the attainment demonstration 2000 EI than for the speciated VOC 2000 EI. The former contains 199.3 tons per day (TPD) total VOC in HGB and 407.8 TPD in the rest of Texas; in contrast, the speciated EI contains

131.8 VOC TPD in the Houston-Galveston area and 314.2 TPD in the remainder of the state. The assumption is made, however, that the relative amounts of the species are similar; thus fractions determined by normalizing the speciated inventory, are used to define a final speciated 2000 regular inventory. In developing the future year case, all of these emissions are grown using a factor of 1.0662 based on NAA Banks data. This same growth factor is used in the attainment demonstration and to develop a speciated, uncapped 2007 EI for the database.

A second modification was made to the 2000 inventory for the Houston-Galveston area only. This is the inclusion of additional VOC mass in the form of terminal olefins. Unlike other AFS files used in the attainment demonstration, this file (afs.exole.term_v2.2000_v15b.lcp) contains species-specific SAROAD codes. The mass added in tons per day (TPD) is shown in Table 5.

Table 5. Mass added to the inventory through the imputed inventory AFS file

	HRVOC TPD	OVOC TPD	TOTAL TPD
Harris	94.36	9.05	103.41
7-Cty	50.82	1.14	51.95
Total	145.18	10.18	155.36

The particular species added are as follows

Pentadiene (E-1,3)
Decene,1-
Butadiene, 1,3
Butadiene, 1,2-
Butene
Butene (1)
Ethylene
Isoprene
Butene (2-methyl-1)
Butene (3- methyl -1)
Pentene (1)
Propylene
Propadiene
Hexene

These emissions of terminal olefins are not grown for 2007, in part because the majority of them are expected to be significantly capped, as will be discussed below.

The final step in estimating a controlled, grown inventory is to cap the HRVOC emissions. The TexAQS base case VOC speciated emissions database, caps HRVOC emissions in a manner that most closely matches the December, 2004 SIP. That is to reduce only HRVOC emissions from stacks and flares, with no change in OVOCs that might be emitted from the same source. HRVOCs are reduced by 90% in Harris County only for those accounts (sites) slated for HRVOC cap as of June 2004 (Table 6). All VOC fugitive emissions in the regular inventory were reduced by 64% with no preferential reduction of HRVOCs over OVOCs. Table 7 reports the data fileds contained in the TCEQ base case VOC emission inventory.

Table 6. Accounts in Harris County Slated to be Capped for HRVOCs

Account	Owner
HG0017W	Williams Terminals Holdings LP
HG0029P	LBC Houston L P
HG0033B	Equistar Chemicals LP
HG0035U	Mobil Chemical Co
HG0036S	Fina Oil & Chemical Co
HG0037Q	Akzo Nobel Chemicals Inc
HG0048L	Lyondell Citgo Refining L P
HG0052U	Engelhard Corporation
HG0076G	Newpark Shipbuilding Brady Island
HG0126Q	Hoechst Celanese Chemical Group In
HG0130C	Valero Refining Texas LP
HG0131A	PPG Industries Inc
HG0132V	Advanced Aromatics LP
HG0134R	Texmark Chemicals Inc
HG0175D	Crown Central Petroleum Corp
HG0218K	EI duPont Denemours and Company
HG0225N	Albemarle Corp
HG0228H	Exxon Chemical Co
HG0229F	ExxonMobil Chemical Co
HG0232Q	ExxonMobil Corp
HG0234M	Exxon Corporation
HG0235K	Exxon Company USA
HG0261J	Kinder Morgan Liquids
HG0262H	Kinder Morgan Liquids
HG0276T	Georgia Gulfchem & Vinyls LLC
HG0288M	Goodyear Tire & Rubber Co
HG0289K	Goodyear Tire and Rubber Company
HG0310V	Chevron Chemical Co
HG0319D	Haltermann Limited
HG0323M	Montell USA Inc
HG0390U	Zeneca Products
HG0403N	Intercontinental Terminals Co
HG0426B	K M C O Incorporated
HG0457N	lonza Incorporated
HG0459J	Lubrizol Corporation
HG0460B	The Lubrizolcorporation
HG0461W	Atofina Chemicals Inc
HG0467K	Marathon Ashland Pipe Line LLC
HG0486G	Merisol USA LLC
HG0512H	Natural Gas Odorizing Inc
HG0537O	Lyondell Chemical Worldwide Inc
HG0558G	ELF Atochem North America Inc
HG0562P	Texas Petrochemicals LP
HG0564L	Petrolite Corporation
HG0566H	Phillips Chemical Company
HG0629I	Vopak Terminal
HG0632T	Rohm & Haas Texas
HG0657D	Shell Oil Company
HG0659W	Shell Oil Co
HG0660O	Equilon Pipeline Co LLC
HG0665E	BP Solvay PolyEthylene N America
HG0669T	South Coast Terminals
HG0686T	Southwest Shipyard LP
HG0713S	Enron Methanol Co
HG0714Q	Eott Energy Liquids
HG0717K	Akzo Nobel Chemicals Inc
HG0770G	Equistar Chemicals LP
HG0786O	Dynegy Midstream Services LP
HG0813N	BASF Corporation
HG0825G	Sunoco Inc
HG0929Q	Haltermann
HG0941D	Solvay Interox Inc
HG0944U	Rohm and Haas Co-bayport Plant
HG1006U	Odfjell Terminal Inc
HG1045K	Stolthaven Houston Inc
HG1065E	Kaneka Texascorp
HG1249P	Sunoco Incorporated R & M
HG1269J	Amoco Chemicals
HG1310O	Eval Company America
HG1575W	Lyondell Chemical Co
HG1939G	Oxy Vinyls LP
HG1996R	Equistar Chemicals LP
HG2798Q	Universal Urethanes Inc
HG3043A	TM Chemicals LLC
HG3553S	Amoco Chemical Co
HG3585F	Channel Shipyard Company Inc
HG3604D	Global Octanes Corp
HG4662F	Atofina Petrochemicals Inc
HG4807D	Hoyer USA Inc
HG6831P	Ethyl Corporation
HG7255B	Wetmore & Company
HG7698J	Noltex LLC
HX0029W	MEMC Pasadena Inc
HX0055V	Amoco Chemical Company
HX1726J	Millennium Petrochemicals Inc
HX2334A	Linde Gas Inc
HX2786H	Resolution Performance Products

Table 7. List of Fields in Texas NEGU VOC Species Database

Field	Source	Description
ID	Created by Access during import	The record number from the original speciated EI afs file, as imported into Access; used only for referencing in file updates
Subregion	afs file for speciated EI [1]	Subregions (area of state) as defined by TCEQ
Subregion Name	afs format documentation [1]	Name of subregions (area of state) as defined by TCEQ
Subregion Designation	afs format documentation [1]	Designation of subregions (area of state) as defined by TCEQ
FIPS	afs file for speciated EI [1]	State and County Code
County	afs file for speciated EI [1]	County in which site is located
City	afs file for speciated EI [1]	Closest city to which site is located
Account	afs file for speciated EI [1]	The TCEQ air account number that is linked to the site. There is nearly always a one-to-one relationship between this number and the RN number used for upset emissions
RN	TCEQ Central Registry website [2]	Registration Number; unique for each facility operating in the state; each facility typically has a single air account number; included because event emissions are reported by RN rather than account numbers
Owner	afs file for speciated EI [1]	Owner of facility (site)
FacType	afs file for speciated EI [1]	Permit description; G = Grandfathered, P = Permitted, E = Exempted, U = Unknown
SIC	afs file for speciated EI [1]	Standard Industry Classification code; describes the primary activity of the account
SIC Name	OSHA website for SIC codes [3]	Name of SIC category
SCC	afs file for speciated EI [1]	Source Classification Code; describes the primary activity of the FIN or operating unit
SCC L1 Name	EPA CHIEF website for SCC codes [4]	Name of Highest Order Category of SCC Code
SCC L2 Name	EPA CHIEF website for SCC codes [4]	Name of Second Highest Order Category of SCC Code
SCC L3 Name	EPA CHIEF website for SCC codes [4]	Name of Third Highest Order Category of SCC Code
SCC L4 Name	EPA CHIEF website for SCC codes [4]	Name of Lowest Order (most detailed) Category of SCC Code
Plant	afs file for speciated EI [1]	A numeric code used in the EPA NEI; numbers are unique only at the county level, therefore they must be combined with FIPS code if used at the regional or state level
Stack	afs file for speciated EI [1]	A numeric code used in the EPA NEI; numbers are unique within the facility
Point	afs file for speciated EI [1]	A numeric code used in the EPA NEI; numbers are unique within the facility
Height_m	afs file for speciated EI [1]	Stack height in meters
Diameter_m	afs file for speciated EI [1]	Stack diameter in meters
Temp_K	afs file for speciated EI [1]	Stack gas exit temperature in degrees Kelvin
Velocity_mps	afs file for speciated EI [1]	Velocity of emissions at release in meters per second
Winter	afs file for speciated EI [1]	Percent time that plant is operational Dec- Feb
Spring	afs file for speciated EI [1]	Percent time that plant is operational Mar- May
Summer	afs file for speciated EI [1]	Percent time that plant is operational Jun- Aug
Fall	afs file for speciated EI [1]	Percent time that plant is operational Sep- Nov
HrsDay	afs file for speciated EI [1]	Number of hours per day the unit is operational
BegHr	afs file for speciated EI [1]	Starting time for the unit
DaysWk	afs file for speciated EI [1]	Days per week the unit is operational
HrsYr	afs file for speciated EI [1]	Hours per year the unit is operational

FIN	afs file for speciated EI [1]	TCEQ, Facility Identification Number; associated with a particular piece of operating equipment; emissions described by SCC; may be serviced by multiple emission release points (EPNs)
EPN	afs file for speciated EI [1]	TCEQ, Emission Point Number; associated with a specific release point, located by either latitude and longitude or Lambert Conformal Projections; may service multiple pieces of equipment (FINs)
Species_Name	afs file for speciated EI [1]	Compound name as listed in Speciated Inventory afs file; not used
EI_Method	afs file for speciated EI [1]	A = AP-42, B = mass Balance, C = Calculated, D = continuous monitor, E = production Estimate, M = stack Measurement, P = Production estimate, O = Other
Profile_Type	afs file for speciated EI [1]	Pt = Point Specific, EPA = EPA default (nat'l average) or other substituted profile, U = Unknown
Point_Type	afs file for speciated EI [1]	ST = Stack, FL = Flare, FU = Fugitive
Speciation Date	afs file for speciated EI [1]	data entry date
Species_Source	afs file for speciated EI [1]	Origin of speciation data; R = Reported Species, U = Derived from speciation profile
Species_Profile	afs file for speciated EI [1]	Speciation profile used for unspeciated data
Acct_FIN_EPN_SAROAD	Calculated Value, source data = afs file for speciated EI [1]	An alternative form of the unique compound emission point identifier, used in older studies and included for reference only
SOURCE_ID	Calculated Value, source data = afs file for speciated EI [1]	The unique identifier for each emission point; formed by concatenating the TCEQ account number with the EPA stack and point numbers as 4 and 3 character text fields (respectively)
Lat	afs file for speciated EI [1]	Latitude (decimal degrees)
Long	afs file for speciated EI [1]	Longitude (decimal degrees)
XLCP	afs file for Texas 2000 negus [5]	East-West Lambert Conformal Projection, measured in meters
YLCP	afs file for Texas 2000 negus [5]	North-South Lambert Conformal Projection, measured in meters
TPD_SRC_VOC_2000spEI	Calculated Value, source data = afs file for speciated EI [1]	The total mass of VOCs released from this point in tons per day as reported in the speciated EI. This amount is equivalent to what is reported in the TX 2000 negu less the special inventory.
TPD_SRC_VOC_2000negu	afs file for Texas 2000 negus [5]	VOCs released from this point in tons per day as reported in the 2000 TX negu EI. This amount is equivalent to what is reported in the TX 2000 plus the daily average of the special inventory.
TPD_SRC_VOC_2007grown	Calculated Value, source data = afs file for Texas 2000 negus [5] , TIPIEGAS [6], NAA Banks [7]	VOCs released from this point in tons per day as reported in the 2000 TX negu EI grown to 2007 based on the factors in the attainment demonstration. Growth factors are derived from TIPIEGAS (by point) and NAA Banks (by county)
TPD_SRC_VOC_2007EXOLE	EXOLE File [8]	
TPD_SRC_VOC_2007capped		
SRC_ID_SAROAD	Calculated Value, source data = afs file for speciated EI [1]	The unique identifier for each compound from each emission point; formed by concatenation of the TCEQ Account, EPA stack (as 4 character text string), EPA point, (as 3 character text string), and SAROAD code
SAROAD	afs file for speciated EI [1]	EPA compound code
Compound_Name	Carter, 2005, emitdb [10]	Name assigned to the SAROAD code, varies slightly by state; Texas versions used
Compound_CAS#	Carter, 2005, emitdb [10]	CAS numbers assigned to non-mixtures
Compound_Category	Manual assignment	A simple categorization of compounds by molecular weight and functional groups; may also wish to add groups of particular interest at a later date (e.g., terminal olefins)
Compound_Type	Manual assignment	HRVOC (highly reactive VOCs) are those defined by Texas code, LROC (low reactivity organic compounds) taken from VOC exempt list in Carter emitdb, all others are VOCs
Compound_SRC_Fraction	Calculated Value, source data = afs file for speciated EI [1]	Calculated by taking dividing TPD_SRC_Compound_2000spEI by TPD_SRC_VOC_2000spEI; this fraction is then applied to VOC totals from other inventories to obtain the mass of each compound emitted from each emission point for that EI

TPD_SRC_Compound_2000spEI	afs file for speciated EI[1]	Tons per day of a specific compound emitted from a specific point, as reported in the 2000 speciated EI, summed across SAROAD codes and excluding amounts less than one pound per day
TPD_SRC_Compound_2000negu	Calculated Value, source data = afs file for speciated EI 1, afs file for Texas 2000 negus[5]	
TPD_SRC_Compound_2000grown		
TPD_SRC_Compound_2000capped		

1	afs file for speciated EI	ftp://ftp.tnrcc.state.tx.us/pub/OEPAA/TAD/Modeling/HGMCR/EI/
2	TCEQ Central Registry website	http://www.tceq.state.tx.us/permitting/central_registry/
3	OSHA website for SIC codes	http://www.osha.gov/pls/imis/sicsearch.html
4	EPA CHIEF website for SCC codes	http://www.epa.gov/ttn/chief/codes/index.html#scc
5	afs file for Texas 2000 negus	
6	TIPI	
7	NAA Banks	
8	EXOLE file	
9	List of capped sites	
10	Carter, 2005, emitdb	ftp://ftp.cert.ucr.edu/pub/carter/emitdb/

Spatial Resolution

Uncertainty in the spatial resolution of ground position is not generally an issue for VOC point source emissions since these emissions come from well defined facilities. Approximately half of the emissions come from stacks at specific locations, while the remainder (fugitives) are associated with a facility, but not a specific point (spatial resolution of approximately 0.5-1 km). The spatial distribution of low level and elevated VOC point source emissions on a typical weekday are shown in Figures 12 and 13. The emission data are shown for 1300 HR.

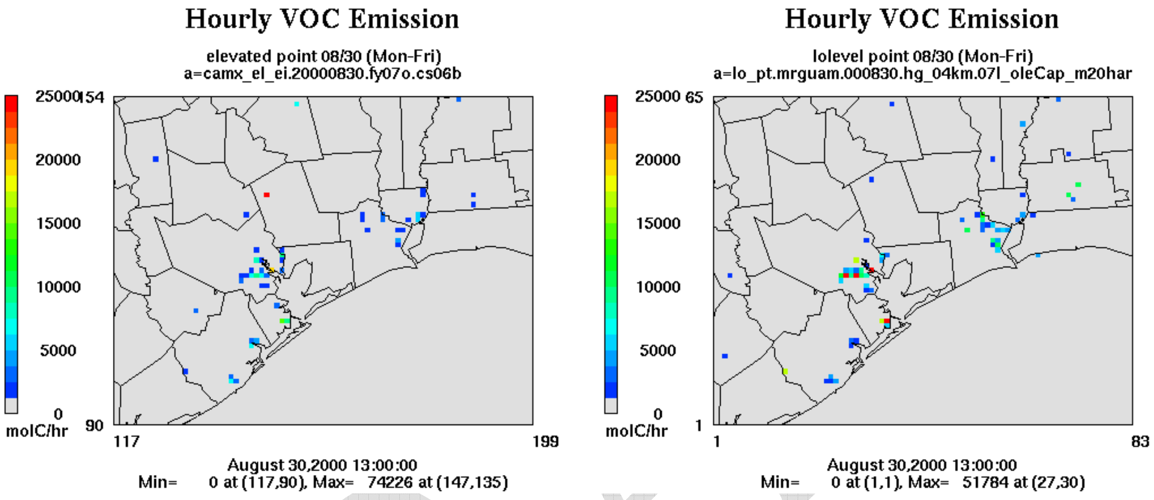
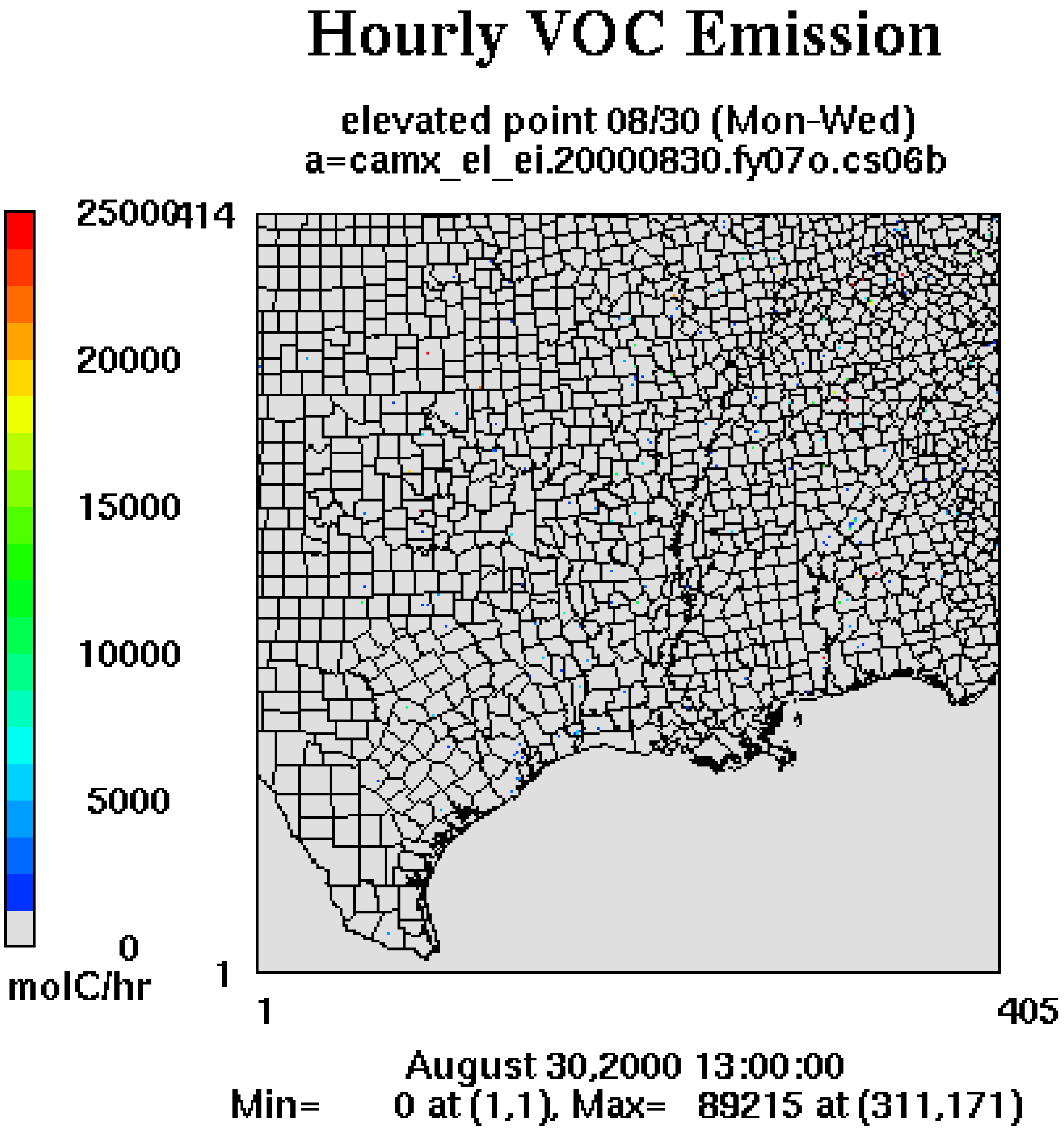


Figure 12. Spatial distributions of VOC emissions from elevated (left) and low level (right) point sources in the attainment demonstration inventory on a typical weekday, at 1300 HR. Data are for the portion of the domain modeled at 4-km resolution.

Figure 13. Spatial distributions of VOC emissions from elevated point sources in the attainment demonstration inventory on a typical weekday, at 1300 HR. Data are for the entire domain



Temporal resolution

There are a number of industrial point sources in the Houston area that have emissions that are episodic in nature. The basic emissions inventory is reported as annual emissions and ozone season daily emissions. The 24-hour average of emissions may be significantly different from the maximum hourly emission rate and the profile of hourly emissions. Examples of episodic emissions include batch processing, loading and unloading activities, cooling tower emissions, wastewater and process vent emissions. Episodic releases may also include events that are non-routine in nature, such as releases due to start-ups, shut-downs and non-routine maintenance activities. Included in the Appendices is a sampling of images of industrial VOC plumes detected by a thermal imaging camera. Although these releases can be detected using devices such as thermal imaging cameras, they are difficult to quantify. Nevertheless, estimates have been made. To provide an indication of the potential significance of daily and hourly variations of emissions from annual averages, estimates of emissions from non-routine releases will be described.

Murphy and Allen (2005) have described emission events reported through an on-line database maintained by the Texas Commission on Environmental Quality (TCEQ). For the period from January 31st, 2003 to January 30th, 2004 (the first full year of operation of the database) a total of 1887 events were reported for TCEQ region 12, which includes the Houston-Galveston region. Approximately 40 % (763) of the events involved HRVOCs, and 761 out of 763 HRVOC events occurred in only four counties, Harris, Brazoria, Galveston and Chambers. Total event HRVOC emissions within these 4 counties in the one year period was 85l tons while the total annual HRVOC emissions (base inventory) were approximately 8000 tons. Annual event emissions of volatile organic compounds (VOCs) were 2066 tons (4.0 % of the annual emissions of 52,000 tons), and NOx event emissions were 158 tons (0.12 % of annual emissions of 133,000 tons). Table 8 provides a summary of these emission events.

Table 8. TCEQ Region 12 events starting between January 31, 2003 and January 30, 2004 (Murphy and Allen, 2005)

County	All Events	VOC Events	HRVOC Events	Event HRVOCs		Point Source HRVOCs TPY (2000) ŧ	Point Source VOCs TPY (2000) ŧ
				lbs	tons		
Harris	1,017	706	455	834,836	417	5,617	33,645
Brazoria	352	248	197	768,607	384	1,589	5,656
Galveston	367	202	93	73,118	37	674	10,143
Chambers	65	44	16	25,403	13	369	2,175
4 County Total	1,801	1,200	761	1,701,964	851	8,249	51,619
Fort Bend	42	11				76	993
Montgomery	22	21				48	577
Liberty	1	1	1	558	<1	26	235
Waller	2					14	813
HG Total	1,868	1,233	762	1,702,522	851	8,413	54,237
Matagorda *	12	8	1	1	<1	51	311
Colorado *	4	4				29	496
Wharton *	2	2				16	574
Walker *	1	0				1	356
Austin *	0	0				2	412
Region 12 Total	1,887	1,247	763	1,702,523	851	8,512	56,386

* Not required to report events unless greater than 5000 lbs above permitted level in 24 hour period.

ŧTCEQ 2000 Speciated VOC Emissions Inventory, ozone season daily, version 15b (TCEQ, 2003b)

While the percentage of the mass of the annual emissions due to events is small, the effect of an event on the emissions at the time and location of the event can be large. To assess this effect, Murphy and Allen (2005) developed time series for event emissions. The time series were developed by determining flow rates for various contaminants and groups of contaminants during each of the 8760 one-hour time blocks that define a one year time period. In this analysis, flow rates were assumed to be uniform throughout the duration of the event and the minimum unit of time was one hour. Thus, flow rate was the total event mass emitted divided by the event duration in hours, rounded up to the nearest hour. Figure 14 presents a time series of all NO_X emissions associated with events that began between January 31, 2003 and January 30, 2004. In addition, the average annual flow rate in pounds per hour for all non-electric generating (negu) facilities in the 4 county region has been calculated from the 2000 TCEQ base case emissions inventory (TCEQ, 2003b) and is graphed as a horizontal line at 30,241 lbs/hr. As can be seen in the Figure, only two events exceed a NO_X flow rate of 1000 lbs/hr and each of those events, at 7665 and 12,232 lbs/hr are less than half of the routine and continuous emissions (based on annual averages). In the case of NO_X emissions, it appears that individual events do not significantly add to the magnitude of the inventory. Furthermore, the total mass of NO_X contributed by events is only 158 tons (315,529 lbs) per year or 0.1% of the 132,456 tons per year emitted by negu point sources located within the four counties. Thus the magnitude of NO_X from events appears not to be significant relative to that of non-event emissions, either singularly or collectively.

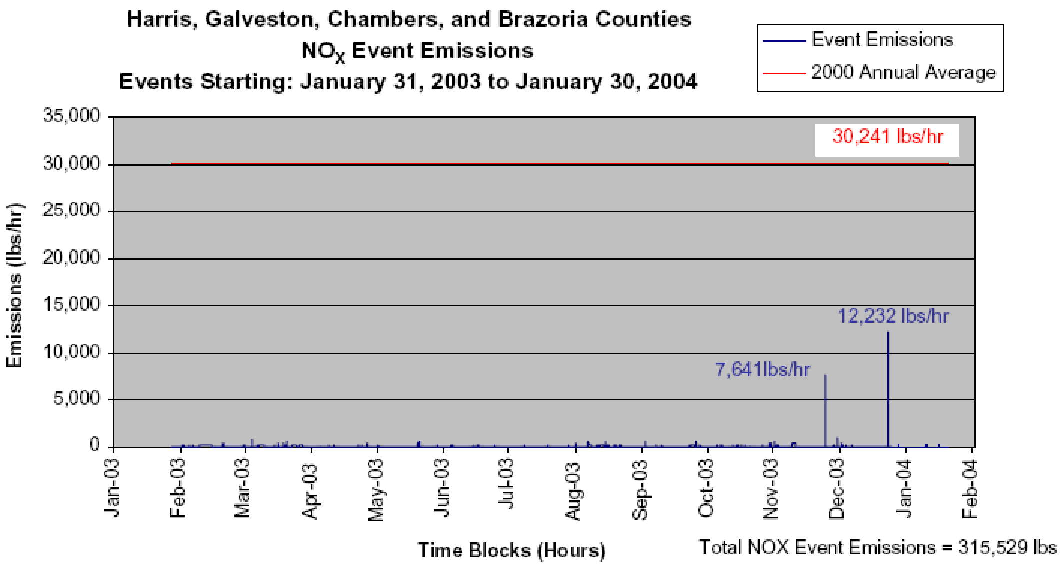


Figure 14. NO_X emissions (lbs/hr) from events and as an annual average (for the year 2000) are presented in a time series using 8760 one-hour time blocks for a single year. During the twelve-month time period, NO_X event emissions exceed 1000 lbs/hr only twice and never exceed the 2000 annual average of 30,241 lbs/hr for all NEGU facilities in the 4 county area. Event emission data are from the Air Emission Event Reports (TCEQ, 2004a) and the 2000 annual average is calculated from the speciated emissions inventory (TCEQ, 2003b). (Murphy and Allen, 2005)

Figure 15 presents a time series of VOC event emissions in the same format as for NO_X. The average annual flow rate for all of the negu facilities in the 4 county region, 11,785 lbs/hr, appears as a horizontal line. In contrast to NO_X, there are 12 times during the twelve-month period in which event emissions exceed the annual average. This means that for those hours, the emissions from just one or a few facilities reporting event emissions exceeded the regular emissions from all non-egu facilities in the 4-county area. The time involved is 18 hours. In four instances, the flow rate of event emissions is roughly five to eight times the annual average with a maximum of 86,557 lbs/hr. The total mass of greater than 4 millions pounds (2066 tons) contributes only slightly more than 4% to the 51,618 tons of VOC emitted during a single year from point sources in the four counties (2000 base case inventory); however, the event emissions concentrate the emissions in time and space, and therefore have the potential to influence the concentrations of ozone precursors episodically, even though the event emissions do not add significantly to the annual, regional inventory.

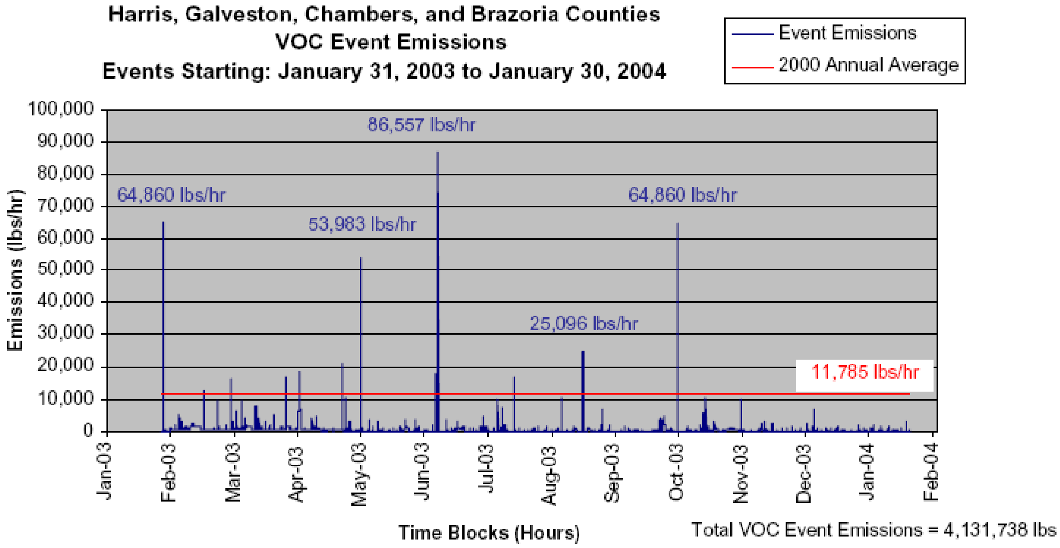


Figure 15. VOC emissions (lbs/hr) from events and as an annual average (for the year 2000) are presented in a time series using 8760 one-hour time blocks for a single year. There are 12 times (occurring over a total of 18 hours) during the twelve-month time period when VOC event emissions exceed the 2000 annual average of 11,785 lbs/hr for all NEGU facilities in the 4 county area. Event emission data are from the Air Emission Event Reports (TCEQ, 2004a) and the 2000 annual average is calculated from the speciated emissions inventory (TCEQ, 2003b). (Murphy and Allen, 2005)

A time series for HRVOC emissions is shown in Figure 16. The annual average is calculated from the 2000 negu speciated emissions inventory (TCEQ, 2003a,b), which identifies the mass of VOC emissions by compound, based on the speciation profiles currently used in photochemical modeling. The flow of HRVOC event emissions exceeds the 2000 annual average 21 times during the twelve-month period (almost 2 times per month), impacting a total of 73 hours. There are 7 times (8 hours) when the flow is more than 4 to 20 times that of the annual average, with a maximum of 39,340 lbs/hr. HRVOC event emissions also account for more than an estimated 10% of the total mass emitted over the year, based on the 851 tons (1.7 million pounds) of event emissions in the twelve-month study period and 8248 total tons reported in the 2000 regular speciated emissions inventory (TCEQ, 2003a,b). For events beginning between January 31, 2003 and January 30, 2004, the total 1,3-butadiene event mass is 55,093 pounds, the total butene event mass is 108,158 pounds, the total propene mass is 561,532, and the total ethene mass is 977,846 pounds.

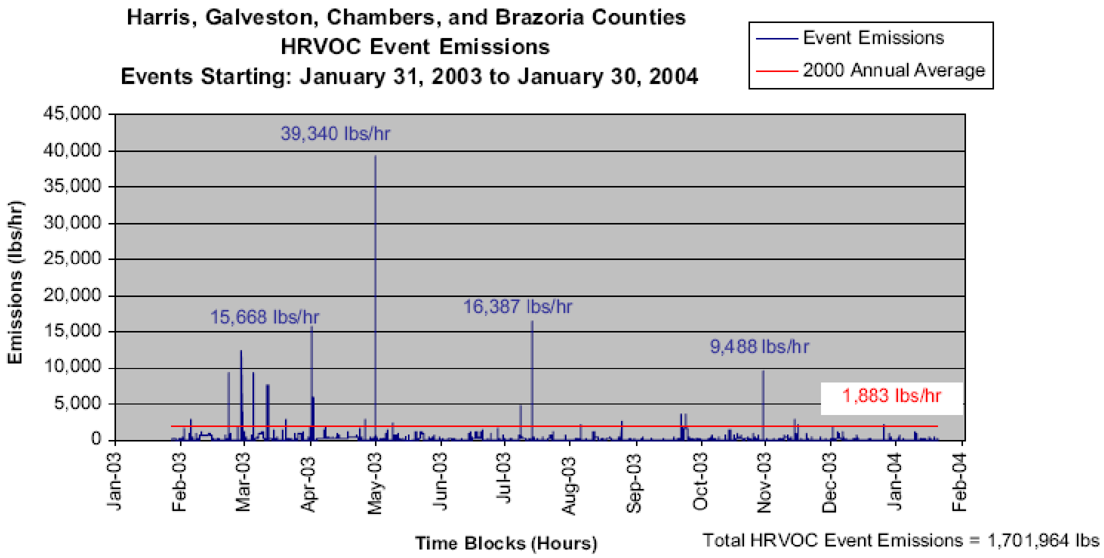


Figure 16. HRVOC emissions (lbs/hr) from events and as an annual average (for the year 2000) are presented in a time series using 8760 one-hour time blocks for a single year. There are 21 times (occurring over a total of 73 hours) during the twelve-month time period when HRVOC event emissions exceed the 2000 annual average of 1,883 lbs/hr for all NEGU facilities in the 4 county area. Event emission data are from the Air Emission Event Reports (TCEQ, 2004a) and the 2000 annual average is calculated from the speciated emissions inventory (TCEQ, 2003b). (Murphy and Allen, 2005)

More details regarding the specific sources of events, event duration, and the timing of the events is provided by Murphy and Allen. These events are NOT a part of the 2007 attainment demonstration inventory or the TexAQS base case emissions inventory.

ON-ROAD MOBILE SOURCES

NOx On-road Mobile Sources

On-road mobile source emissions are based on information from local travel demand models and MOBILE emission factors (Dresser, 2000). Local travel demand models are used to determine speeds and vehicle miles traveled (VMT). For the area covered with a travel demand model, the emissions calculations have been based on information on each specific link in the road system. Emission factors are determined from the mix of vehicle classes and model years, the speed and temperature. Details of the procedures used are available in the Appendix.

Emissions Magnitude

For each link in the road system, emissions are determined by multiplying the emissions factor for the link by the VMT in link. During the TexAQS study, data were collected at a tunnel under the ship channel. These data were used to determine fuel based emission inventories. The results have been reported by McGaughey, et al (2004)

Speciation

Speciation of mobile emissions of NO_x are based on information in the MOBILE6 model, with some corrections for humidity (see reports in the Appendix).

Spatial resolution

Travel demand models have been used to develop the spatial distribution of emissions over the urban portions of the modeling domain. Since on-road mobile emissions are calculated for each link in the road system, the location of these links is used to distribute these emissions over the modeling domain.

Temporal resolution

Diurnal patterns of emissions based on traffic surveys have been used to develop the temporal distribution of traffic densities used in the travel demand model. The on-road emissions are calculated hourly. Distribution of vehicle class is based on 24-hour averages. Data collected in the Washburn Tunnel (McGaughey, et al., 2004) suggest that this will overestimate the number of heavy duty trucks during the rush periods, and underestimate the number during the late evening and early morning hours.

NMOC On-road Sources

Only those issues not addressed in the section on NO_x on-road mobile emissions will be described here.

Emissions magnitude

During the TexAQS study, data on vehicular emissions were collected in the Washburn Tunnel and these data suggest that the NMOC emissions from the Houston light duty fleet are slightly higher than national averages (McGaughey, et al., 2004).

Speciation

NMOC species for on-road mobile emissions are developed based on national profiles. During the TexAQS study, data on exhaust emission, whole gasoline composition and gasoline vapor composition were collected (McGaughey, et al., 2004). These data have been incorporated into the inventories.

AREA AND NON-ROAD MOBILE SOURCES

NOx Area and Non-road Mobile Sources

Emissions Magnitude

In 1991, non-road mobile source emissions were quantified by EPA for a number of ozone nonattainment counties (EPA, 1991). These emissions were based on default activity data that in some cases was found to be inaccurate. Since that study, EPA has released the NONROAD model that is designed to calculate non-road mobile emissions (U.S. EPA, 2006a). The model may be used with default data or specific survey data may be used. Non-road mobile emissions in the HG area have been calculated with default values except for categories that have survey data. An extensive survey was conducted for the Houston port equipment to determine emissions from these sources. Extensive survey data were collected for diesel construction equipment in the HG area and this information used to determine non-road mobile emissions from this source category (TCEQ, 2000). Detailed data are available on queuing times for aircraft at some airports in the region and an extensive study of marine activity, including movements of specific vessels and their engine specifications, was conducted in the HG area.

Speciation

Speciation of NOx emissions has been based on typical products of combustion.

Spatial resolution

The location of various non-road sources can vary significantly with time. For example large road construction projects will move from one area to another over time. Location of these activities can be determined when developing a historical emissions inventory for photochemical grid model base case development, but it is almost impossible to accurately predict locations for future year inventories. Emissions from commercial marine traffic have been based on traffic counts on waterway links. Emissions from aircraft have been based on landings and takeoff from the various airports in the area.

Temporal resolution

Temporal resolution of emissions is important since some proposed control strategies involve the time that construction equipment is operated.

NMOC Area and Non-road Sources

See the section on NO_x non-road mobile emissions.

BIOGENIC SOURCES

NOx Biogenic Sources

Biogenic NOx emissions have been estimated with the GloBEIS model (ENVIRON, 2001). These emissions are small relative to other sources and will not be discussed in detail.

NMOC Biogenic Sources

Emissions Magnitude

Biogenic emissions of hydrocarbons dominate the emission inventory for NMOC in the Houston-Galveston area. Wiedinmyer et al. (2001a) have shown that similar high levels of biogenic NMOC emissions can be expected throughout the eastern half of the state. Because of the magnitude of these emissions, the TCEQ and its contractors have expended great effort over the past 10 years in improving biogenic emission estimates.

A number of detailed reviews of biogenic emissions have been performed (for example, Guenther, et al., 2000) and these reviews describe in detail the dependence of biogenic emissions on land cover, leaf biomass densities, temperature and photosynthetically active radiation (PAR). Systematic efforts have been made to collect the data necessary to estimate biogenic emissions in Texas. Detailed data on vegetative land covers have been developed for the entire state (Wiedinmyer, 1999, 2000, 2001a). PAR has been estimated based on data retrieved from satellites, and ground temperatures have been estimated based on interpolations of surface temperatures or the predictions of meteorological models (Vizuete, et al., 2002). These input data have then been used in models that combine leaf emission factors with models of the behavior of the tree canopy to predict emissions. In Texas, the GloBEIS (Global Biosphere Emissions and Interactions System) model has been used (ENVIRON, 2001). Nevertheless, despite all of this effort, significant uncertainties may still remain in the inventory.

The magnitude of biogenic emissions predictions depends strongly on the input parameters and on the emission factors and canopy models built into GloBEIS. For example, because species specific emission factors (emissions per unit leaf biomass) can vary over three orders of magnitude, emissions predictions are very sensitive to land cover distributions. Because emissions can change exponentially with temperature, small temperature changes or even changes in the interpolation schemes used in estimating temperatures can cause changes in emissions of 25-50% (Vizuete, et al., 2002).

Because biogenic emissions are so sensitive to these parameters, any biogenic emission inventory will have significant uncertainty associated with it, and field verification of emissions is desirable. In Texas, only limited field studies of emission fluxes have been performed. Wiedinmyer, et al. (2001b) report the results of a field study conducted in Central Texas (in a region 100-250 km northwest of Houston) in which biogenic emissions and their reaction products were measured. The data suggest that emission rates predicted by the current inventories available for Texas are correct to within a factor of about 2.

Data on aloft concentrations of biogenic hydrocarbon concentrations were obtained by aircraft during the summer of 2000, and these measurements can also be compared to the biogenic emission estimates. Since parallel ground measurements of biogenic hydrocarbon concentrations are not available, emission fluxes cannot be directly estimated, however, the geographical distribution of concentrations observed by the aircraft and selected ground sites can be compared qualitatively to the geographical distribution of predicted emission fluxes. For the 2000 base case inventory, comparisons between aircraft measurements of isoprene concentrations and model predicted aloft concentrations generally showed significant variability but no bias. In contrast, ground measurements predicted by the model 2007 tended to be a factor of 2-3 higher than observations. Reasons for these differences have been discussed by Song, et al (2006).

An additional complicating factor is that emissions may depend on water availability. In the 2000 base case period, the area was very dry compared to normal conditions and temperatures were very high. On many days, temperatures reached historical highs for that date. The biogenic emissions factors may not accurately represent changes in plant metabolism caused by prolonged and extremely hot and dry conditions.

The biogenics emission inventory for the 2007 attainment demonstration was assumed to be identical to that created for 2000. This ignores potential changes in land covers, but new emission inventories based on updated land covers may become available.

Speciation
Biogenic emissions in Texas are dominated by isoprene, a five carbon diolefin that is very reactive with hydroxyl radical and has a high ozone incremental reactivity. Isoprene is emitted primarily by broadleaf tree species. Oaks are the most significant contributor in Texas (Wiedinmyer, et al., 2000, 2001a). Other species are emitted by conifers. Species emitted by conifers include monoterpenes such as α- and β-pinene and sesquiterpenes. These 10 and 16 carbon compounds may be significant in the formation of fine particles. Additional non-terpenoid emissions occur, including large quantities of methanol, but many of these emission rates are not well characterized, particularly for vegetation found in Texas.

Spatial resolution
The spatial distribution of biogenic emissions is influenced by spatial distributions of land cover, PAR and temperature. These parameters can change over relatively short distances. Shown in Figure 17 is the spatial distributions of emissions predicted for southeast Texas

Temporal resolution
Temporal distribution is based on variations in PAR and temperature, as described in the SIP documentation.

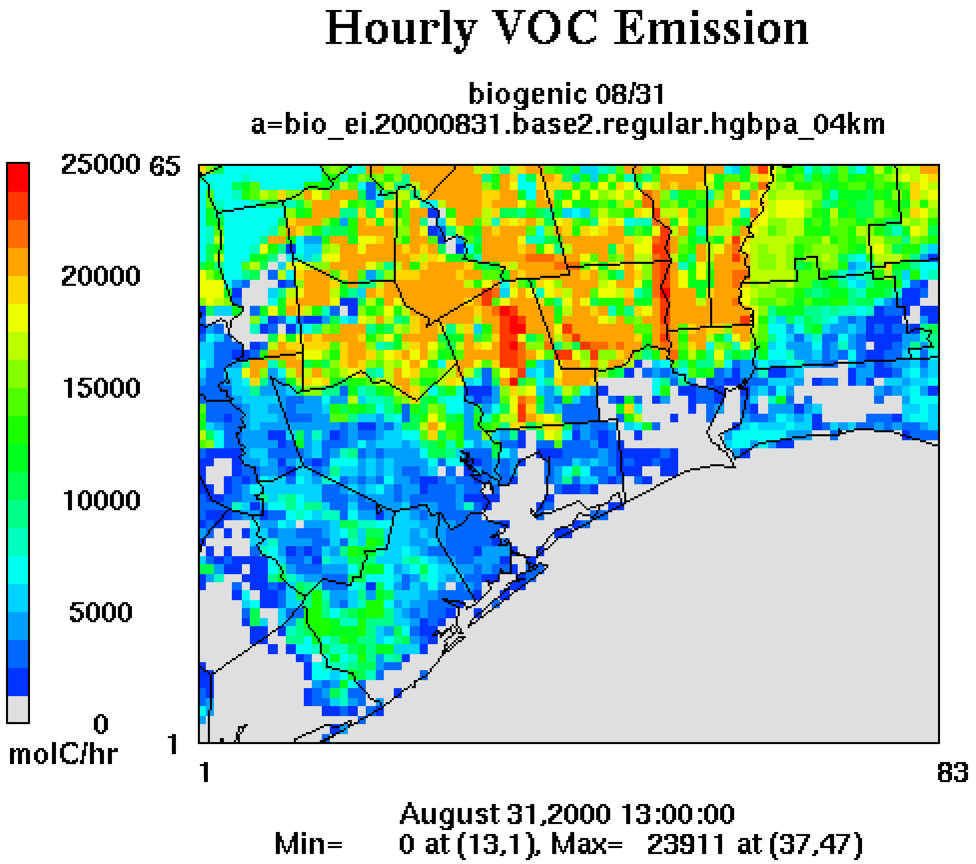


Figure 17. Biogenic emissions at 13000 hr for the 4-km domain

OZONE PRECURSORS OTHER THAN NMOC AND NO_x: CHLORINE

Recent work indicates that anthropogenic emissions of molecular chlorine and/or hypochlorous acid (which are precursors for atomic chlorine) may have a significant effect on ozone formation in the HG area (Tanaka et al, 2000, 2003; Chang and Allen, 2006). A critical element for the integration of the chlorine chemistry into air quality planning and management is the development of an emissions inventory that can be used for photochemical grid model analysis. The University of Texas has developed a preliminary emission inventory for atomic chlorine precursors (Chang and Allen, 2006, and references cited therein). The preliminary analysis suggests that several sources may be important. These include volatilization from cooling towers (where chlorine is used as a biocide), volatilization from swimming pools (where chlorine is used as a disinfecting agent), point sources and molecular chlorine released as a result of the reactions of chloride in sea salt.

A description of this inventory is available in the Appendix.

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ADDITIONAL APPENDICES AVAILABLE ELECTRONICALLY

Chlorine emission inventory: Supporting information to accompany Chang and Allen (2006).
Cl_inventory_Supporting_info.pdf

Humidity corrections for diesel engine emissions
File name: NOx_humidity_corr_diesel_ENVIRON.pdf

Humidity corrections for spark ignition engines
File name: NOx_humidity_Corr_Spark_ENVIRON.pdf

TCEQ Attachment 2 to the December 2004 HGB SIP revisions: Meteorological Modeling of the TexAQS 2000 Episode, August 25, 2000 - September 1, 2000
File name: met_model_TCEQ.pdf

TCEQ Appendix D to the December 2004 HGB SIP revisions: Point Source Modeling Inventory Development
File name: HGB2004Point SourceEI_Methods.pdf

TCEQ: Supporting Information for the December 2004 HGB SIP revisions: SUMMARY OF DEVELOPMENT AND PROCESSING OF ONROAD MOBILE SOURCE INVENTORIES USED FOR PHOTOCHEMICAL MODELING EFFORTS IN TEXAS
File name: Onroad_emission_est_methods_TCEQ.pdf

Texas Transportation Institute: Development and Production of On-Road Mobile Source, Photo-Chemical Model Ready, 2007 Future Case Emissions Inventories for the Houston-Galveston Eight-Hour Ozone Nonattainment Counties, Report to the TCEQ
File name: Onroad_emission_est_TTI.pdf

Thermal camera images of VOC releases
File name: Thermal Camera Images of VOC releases.wmv