Big Bend Regional Aerosol and Visibility Observational (BRAVO) Study Emissions Inventory

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EXECUTIVE SUMMARY

A modeling emissions inventory has been assembled for the U.S.-Mexican Border Region to better understand the sources of visibility impairment at the Big Bend National Park. The BRAVO-EI covers 14 states in the U.S. (Texas, Arkansas, Louisiana, Oklahoma, New Mexico, Colorado, Utah, Arizona, Kansas, Missouri, Illinois, Kentucky, Tennessee, and Mississippi), 10 states in Mexico (San Luis Potosi, Baja California Norte, Sonora, Chihuahua, Coahuila de Zaragoza, Nuevo Leon, Tamaulipas, Sinaloa, Durango, and Zacatecas) and offshore platforms in the Gulf of Mexico. The emissions inventory for Mexico is the first regional scale inventory for this area.

The National Emissions Inventory for base year 1999 version 100 (NEI99) was used as a starting point for the U.S. emissions inventory. The database of annual and ozone season day (OSD) emissions was reduced to contain only the emissions from the 14 BRAVO states. The Texas Natural Resources Conservation Commission provided improved emissions data for onroad mobile sources, commercial ships, construction equipment, and oil field equipment in the state of Texas. The NEI emissions inventory was updated with these locally produced emissions datasets.

Hourly emissions data from Continuous Emissions Monitors (CEM's) on power plants were obtained from the U.S. E.P.A.'s Clean Air Market Program. These SO_2 and NO_x emissions data were reconciled with the NEI datasets by matching facility process emissions in the NEI to stack emissions from the CEM's. The matched emissions account for 89% of all SO_2 and 86% of all NO_x emitted from external combustion power generators in the14 BRAVO states.

A national emissions inventory for criteria pollutants does not currently exist for the country of Mexico. Data was assembled from a variety of sources in order produce the BRAVO EI. Urban scale emissions inventories have been assembled for the cities of Tijuana, Mexicali, Juarez, and Monterrey as part of Mexico's Program to Improve Air Quality.[5] Area and mobile emissions factors were calculated for these cities based on five activity indicators: population, number of households, total number of registered vehicles, agricultural acreage, and number of head of cattle.[6,2] Activity data obtained from the Mexican Census Borough (INEGI) was used to estimate emissions for the uninventoried areas of Mexico within the BRAVO domain.

Emissions from power plants were estimated from fuel usage and facility type data obtained as part of the Center for Environmental Cooperation's "Taking Stock" program.[7] These data were generated as part of an ongoing hazardous air pollutant emission inventory for North America. Emissions for these facilities were calculated using AP-42 emissions factors. Emissions for manufacturing facilities were calculated using emissions factors based on manufacturing sector employment from the Sistema Nacional de Informacion de Fuentes Fijas (SNIF) database maintained by the Mexican Instituto Nacional de Ecologia (INE). Employment data was obtained from INEGI for the top 4 manufacturing sectors for each Mexican state.

Average annual emissions from the active Popocatepetl Volcano for 1999 were acquired from scientists at the Centro Nacional de Prevencion de Desastres (CENAPRED) in Mexico. SO_2 emissions from the volcano are measured with a correlation spectrometer (COSPEC) two to three times per week. The highest measured SO_2 emissions from the crater since 1994 were 50,000 tons per day while typical emissions are approximately 3000-5000 tons per day.[8] Annual volcanic emissions were estimated for PM_{10}, $PM_{2.5}$, and SO_2 only. These estimates are highly uncertain and should be considered as order of magnitude approximates of the true emissions. Aggregate emissions from Mexico City and the industrialized area of Tula-Vitro-Apaxco were included into the inventory as point sources. No source classification was given to these cities.

All Mexican emissions data were integrated into a unified database of both area and point emissions. Precautions were taken to prevent double counting of emissions derived from separate sources.

The Minerals Management Service Outer Continental Shelf Activity Database (MOAD3) inventories emissions for the development of outer continental shelf petroleum resources in the Gulf of Mexico. The MOAD3 catalogs emissions from the development of petroleum resources in the Gulf of Mexico for base year 1992. Sources are based activities occurring on 1857 platforms. Emissions of CO, SO_x, NO_x, PM, and VOC's are reported for several activities in the gulf. Only VOC emissions are reported for the majority of flaring emissions. As a result, the inventory may grossly underestimate CO, SO_2, NO_x, and PM emissions from flaring.

All emissions data are integrated into a common database. Major sources of each pollutant are identified for each source region (i.e. U.S., Mexico, and Offshore). Emissions maps are presented to identify major source areas of all pollutants. The largest sources of sulfur dioxide in the BRAVO EI are: the Popocatepelt Volcano (Mexico), Northeast Texas power plants (U.S.), the Tula Industial Park (Mexico), the Carbon I/II power plants (Mexico), and Coal fired power plants in the Midwest U.S.

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1. INTRODUCTION

The field study portion of the Big Bend Regional Aerosol and Visibility Observational (BRAVO) Study occurred during July through October 1999 in the region surrounding Big Bend National Park (BBNP) in Texas. The study involved speciated air quality monitoring at more than 30 sites in Texas as well as measurements of upper air meteorology. An artificial tracer was also released from 3 sites in Texas and monitored at many of the air quality sites. Air quality transport, chemical, and dispersion models will be applied to the region to assess the impacts of major sources on the visibility at BBNP. The field measurement data from the study will be used to validate the accuracy of the air quality models.

The BRAVO Study Emissions Inventory (BRAVO-EI) will be used as input for the air quality models and will accomplish the following tasks as part of the overall BRAVO Study:

- Serve as a basis for modeling ambient particulate matter (PM) air concentrations in and around Big Bend National Park
- Identify major emissions sources, general emissions levels, spatial patterns, and temporal trends.
- Identify and document gaps and inadequacies in our current knowledge of emissions in both the United States and Mexico.

The BRAVO-EI is compiled from existing emissions inventories in the U.S., Gulf of Mexico, and Mexico. The major scope of the current project involves acquiring existing datasets, evaluating their appropriateness, and reformatting the data to be input into the Sparse Matrix Operator Kernel Emissions Modeling System (SMOKE). SMOKE is an advanced emissions processing software package that can be used to prepare modeling inventory files for a variety of air quality models.

Concurrent with the development of the emissions inventory, the four dimensional data assimilation meteorological model MM5 is being applied to the majority of the United States, Mexico, and Canada (Seaman and Anthes, 1981; Stauffer and Seaman, 1994). The wind fields output by the MM5 model will be used to simulate the transport of the emissions from the BRAVO-EI. Two models are scheduled to be run over the study domain. REMSAD (SAI, 1998) will be run for the entire United States and Mexico to simulate the air quality for the year 1999. CMAQ is a detailed extension of the Models-3 program and will be applied to a more limited domain to investigate specific episodes of poor air quality at Big Bend National Park.

1.1 Guide to Report

Section 1 is the current section. Section 2 describes the EI domain and outlines the data sources used to assemble the emissions inventory. The BRAVO EI is subdivided into three independent inventories based on geographic area (i.e. the Southern Middle United States, Gulf of Mexico, and Northern Mexico.) Sections 3 – 5 present the methodology used to assemble each of these subdivisions. Section 6 presents the integrated emissions inventory using gridded maps to show areas of high emissions as well as tables to indicate the most prevalent sources of each pollutant.

2. EMISSIONS INVENTORY DOMAIN

The meteorological model MM5 is run over the modeling domain using a nested grid system. The map in Figure 2-1 shows the locations of the three nested grids. The specifications of the grids are shown in Table 2-1. The domain of the REMSAD simulation corresponds to the 36 km grid scale. The domain of the CMAQ simulation extends throughout the 12 km grid area. The center of the entire modeling grid is located at 33.5 deg N and –97.0 deg E. The projection of the grid is Lambert Conformal. "IX" and "IJ" represent the number of grid cells in the North-South and East-West directions, respectively. "NESTI" and "NESTJ" are the coordinates (in terms of the next larger grid system) of the lower left grid cell of each nest. For example, the 12 km grid domain is 142 cells in the north-south direction, 154 cells in the east-west direction, and its lower left grid cell is in the lower left corner of the 36 km grid cell located 30 cells from the western edge and 45 cells from the southern edge of the 36 km domain.

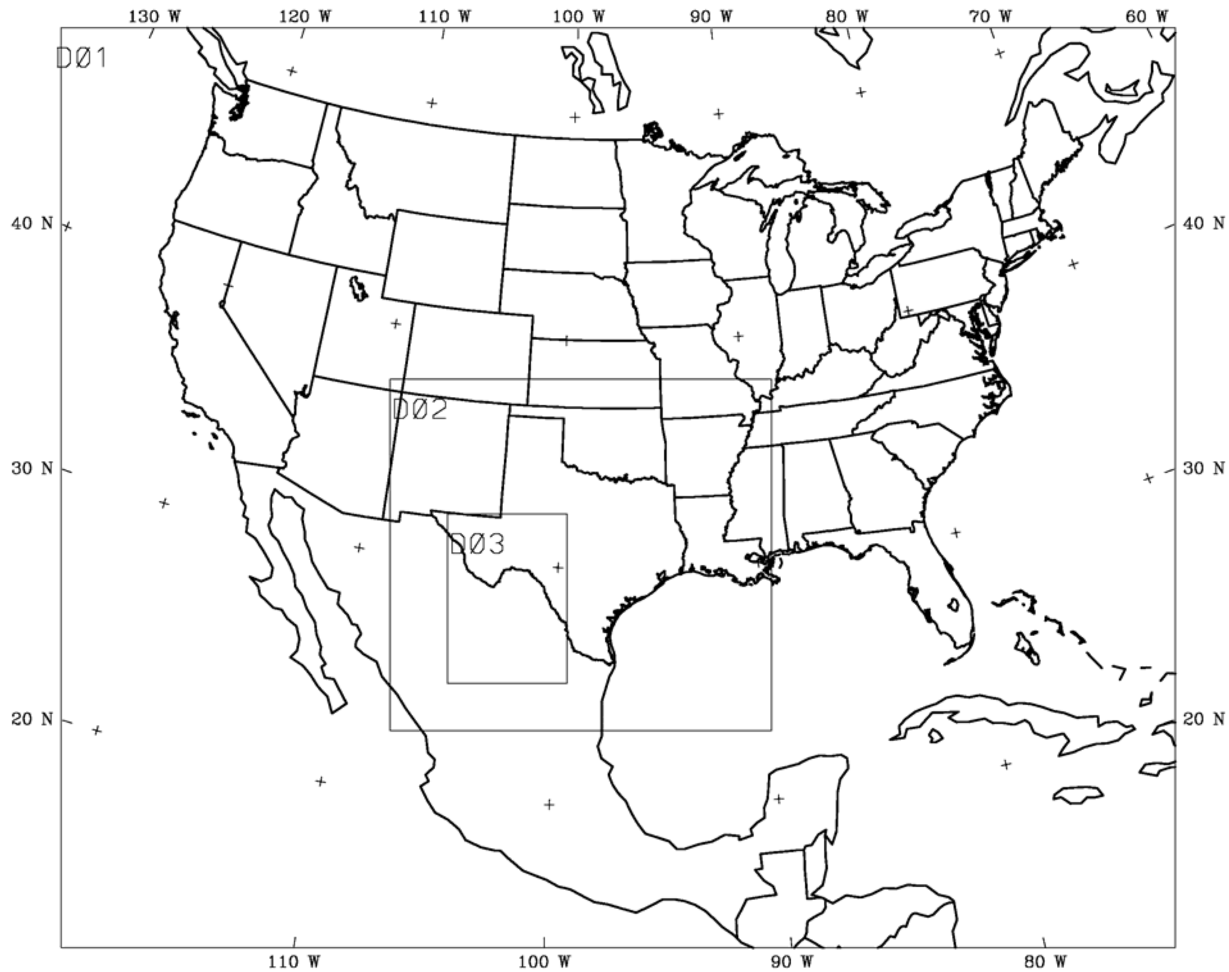


Figure 2-1. MM5 Meteorological Nested Modeling Domain.

Table 2-1. MM5 Grid Cell Specifications.

Grid Size	IX	JX	NESTI	NESTJ
36 km	124	150	1	1
12 km	142	154	30	45
4 km	205	145	20	24

The area that represented in the BRAVO EI is composed of the states of Texas, Arkansas, Louisiana, Oklahoma, New Mexico, Colorado, Utah, Arizona, Kansas, Missouri, Illinois, Kentucky, Tennessee, and Mississippi. The inventory will also account for emissions from the offshore activities in the Gulf of Mexico overseen by the Minerals Management Service. Emissions from Mexican sources will be included for the states of San Luis Potosi, Baja California Norte, Sonora, Chihuahua, Coahuila de Zaragoza, Nuevo Leon, Tamaulipas, Sinaloa, Durango, and Zacatecas.

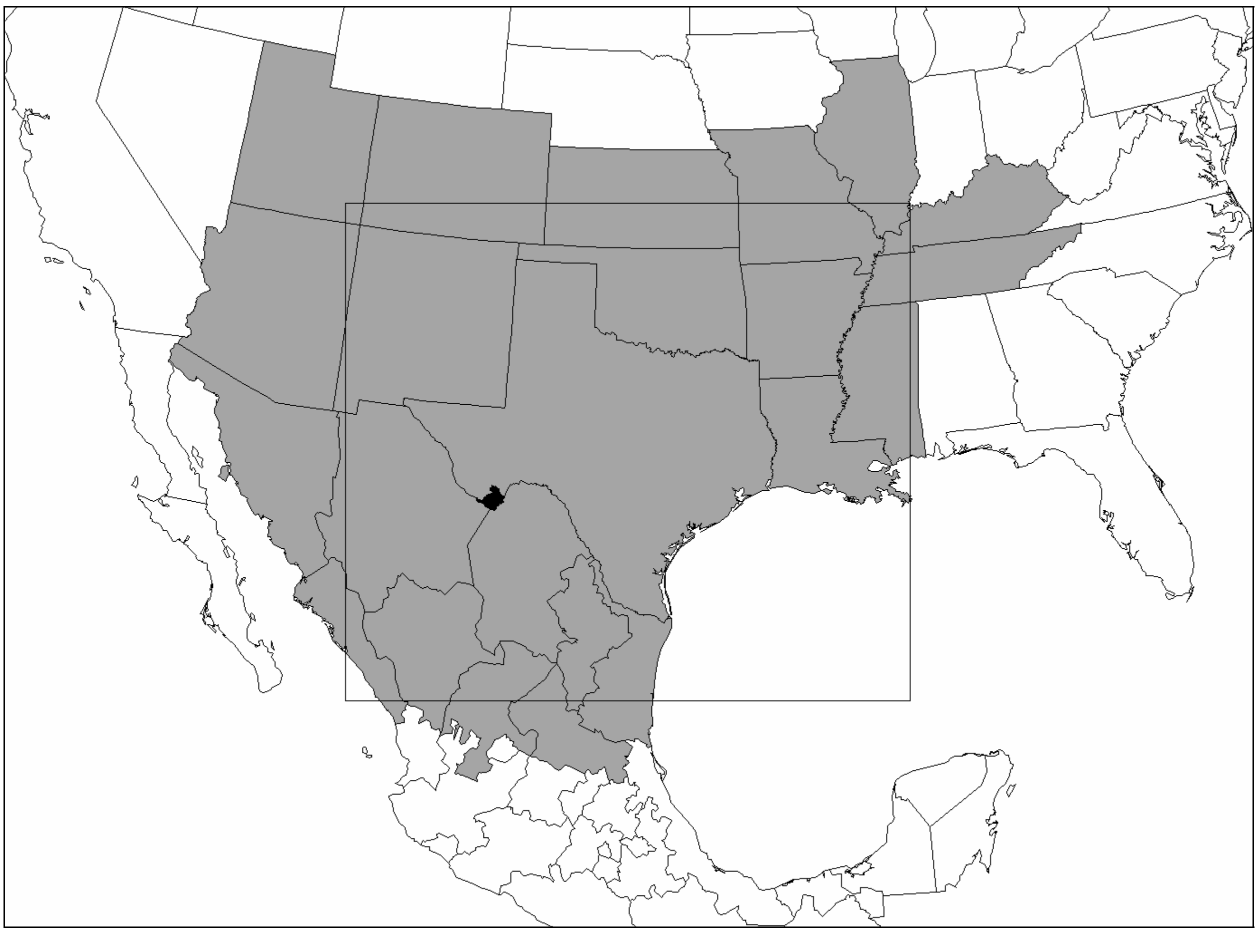


Figure 2-2. Domain of the BRAVO Study EI.

The base period of the EI is the four months July, August, September, and October of 1999. The EI is assembled from existing inventories that document the emissions of the following species: NO_x, SO_2, VOC, PM_{10}, $PM_{2.5}$, and NH_3.

The inventory documents the emissions of point, area, and mobile sources. All emissions data are presented with units of U.S. tons (909.1 kg) in order to maintain consistency with the National Emissions Inventory format.

The emissions inventory is assembled in the Inventory Data Analysis (IDA) format which is compatible with the Sparse Matrix Operator Kernel Emissions (SMOKE) Modeling System. The SMOKE emissions processing software facilitates the spatial and temporal allocation of the emissions. SMOKE outputs the emissions inventory in a standard format that can be directly read into CMAQ and REMSAD.

Emissions data have been aggregated from a wide variety of data providers in order to best estimate both natural and anthropogenic sources within the study domain. Emissions data sources can be divided into three groups based on their regional coverage: (1) United States, (2) Mexico, and (3) Offshore. Table 2-2 shows the sources of data for each general source type in the United State, Mexico, and offshore. The following sections describe the data used to generate inventories for each of these domains.

Table 2-2. List of data providers that will supply information for each general source type in the United States, Mexico, and offshore.

Source Region	United States	Mexico	Off Shore
Area	• NET database for AR, AZ, CO, LA, MO, NM, OK, KS, KY, MS, IL, TN, TX, and UT. • Replace TX sources for Construction and Oil and Gas using NONROAD model with TNRCC Activity • Ammonia emissions from UTA report	• ERG Emissions Factors from TJ, CJ, and Mexicalli supplemented with Monterrey emissions • Extrapolate emissions across non inventoried areas based on activity from MX Census	• N/A
Mobile	• NET county level database for AR, AZ, CO, LA, MO, NM, OK, KS, KY, MS, IL, TN, TX, and UT. • Replace TX onraod mobile with 1996 base year emissions from TTI	• ERG Emissions Factors from TJ, CJ, and Mexicalli supplemented with Monterrey emissions • Extrapolate emissions across non inventoried areas based on activity from MX Census	• N/A
Point	• CEM database for point sources in 14 BRAVO states • NET Point sources from 14 BRAVO states	• Acosta y Associados-42 Power plants based on fuel use and type. • ERG-Cabon I/II and Nacazari • Watson/Profepa-20 SO2 sources • CENAPRED-Popocatepetl Volcano • INEGI-Mexico City and Tula	• MMS MOAD3 database
Biogenic	• Calculated by MCNC in SMOKE	• Calculated by MCNC in SMOKE	• N/A

3. UNITED STATES EMISSIONS

This section describes the data sources and methods used to generate the BRAVO EI for the 14 states in the U.S. spanned by the BRAVO modeling domain. The National Emissions Inventory for base year 1999 (version 100) was used as a starting point for the emissions inventory. The database was reduced to contain only the emissions from the 14 BRAVO states. Data were formatted to adhere to the SMOKE input guidelines. In some cases, the NEI data was replaced with emissions data from the Texas National Resources Conservation Commission (TNRCC). These cases are described in more detail below.

3.1 Area Sources

3.1.1 Construction, Mining, and Oil Field Equipment

Area source data was principally derived from the 1999 NEI version 100 database. Personal communications with Sam Wells of TNRCC indicated that NEI estimates of construction emissions were substantially different from those estimated by the Houston Construction Project in March 2000. Mr. Wells supplied improved activity and equipment population files for the state of Texas. These files were generated as part of the Houston and Dallas Diesel Construction Emissions Projects (Baker, 2000; Wells, 2000).

The improved equipment population and activity files were used to run EPA's NONROAD emissions model (Environ, 1998). NONROAD is used to calculate fuel based emissions (e.g. exhaust and evaporation) for the 1999 NEI v100. Fugitive dust emissions are not calculated by the NONROAD model. The model was rerun with the Texas specific files for base year 1999. The sums of the annual emissions from "Construction and Mining" sources in Texas are compared in Table 3-1 for the TNRCC and NEI databases. For most species, the revised TNRCC emissions estimates are one half of the original NEI 1999 estimates.

Improved allocation files were also supplied for "Oil and Gas Field" equipment. The revised files changed statewide emissions by less than 20% and are also shown in Table 3-1.

Table 3-1. Comparison of annual emissions from Construction and Mining sources (non fugitive dust) for the state of Texas.

	Construction Equipment		Oil and Gas Equipment	
	NEI 99 (tpy)	TNRCC (tpy)	NEI 99 (tpy)	TNRCC (tpy)
CO	114191	82368	109531	104519
NH_3	114	*57	20	*18
NO_X	95286	47911	16972	15204
PM_{10}	9979	5171	812	750
PM_{25}	9181	4758	748	690
SO_2	19896	12316	1989	2184
VOC	17881	10667	3564	4317

*Estimated by ratio of NH_3 to NO_x from NEI99.

Ammonia emissions are not estimated by the NONROAD model. Emissions of ammonia were inferred from the TNRCC NO_x emissions by multiplying NO_x by the ratio of NH_3 to NO_x

for Construction and Mining Sources in the NEI99. Since, priority is given to locally produced emissions estimates, the default NEI99 emissions from "Construction and Mining" and "Oil Field" equipment sources were replaced with the Texas NONROAD model calculations.

3.1.2 Commercial Marine Vessels

The commercial marine emissions inventory in the Houston-Galvaston Area (i.e. Harris, Galveston, Chambers, and Brazoria Counties) has undergone extensive evaluation as part of the Ozone State Implementation Plan. The domain of this inventory covers the Houston Ship Channel and the Inter-coastal Waterway extending out past the "sea bouy" outside the Bolivar Straight. The Houston Galveston Area Vessel Emissions Inventory (HGAVEI) prepared by Starcrest Consulting Group (Starcrest, 2000) estimated emissions from three primary vessel categories: ocean going vessels, towboats, and harbor vessels in the four Texas counties. This inventory used vessel counts, surveys, and interviews to improve emissions estimates for commercial marine sources. The inventory was produced for base year 1997 and spatially apportions ship emissions throughout the Houston ship channel and inter coastal waterway. The HGAVEI is the latest and most sophisticated in a series of commercial marine inventories produced over the 1990's.

The first inventory for the area, the 1990 Base Year Emissions Inventory was produced by the EPA and used AP-42 emissions factors tied to marine fuel sales to estimate emissions. The second study, the Booz-Allen Hamilton Inventory was prepared for EPA in 1991. For this study, emissions were based on 1988 Texas vessel registries and counts as well as AP-42 emissions factors. The 1999 NEI uses the same methods as the 1990 Base Year EI estimating emissions based on marine fuel sales. The NEI99 groups commercial marine sources into two categories based on fuel use: diesel and residual oil. Table 3-2 compares these emissions inventories with the HGAVEI. The tables shows the EI's based on fuel sales (i.e. Base Year EI and NEI99) are consistently higher than inventories based on vessel registries and counts. This is to be expected since the fuel sales are likely to reflect the activity of all local vessels as well as the ocean going vessels while the vessel count based inventory should be related to the activity within the inventory domain.

Table 3-2. Comparison of Commercial Marine Emissions Estimates in the Houston-Galveston Area.

Study	Base Year EI (EPA)	Booz-Allen Hamilton	NEI99 (EPA)	HGAVEI (Starcrest, 2000)
Base Year	1990	1988	1999	1997
CO (tpy)	11,800	2,128	21,883	1,679
NH_3 (tpy)	NA	NA	115	*10
NO_X (tpy)	27,485	14,611	135,739	11,461
PM_{10} (tpy)	NA	NA	2,118	690
$PM_{2.5}$ (tpy)	NA	NA	1,948	**635
SO_2 (tpy)	NA	NA	19,132	*1615
VOC (tpy)	5,366	1,391	4,397	292

*Emissions inferred from NEI99 ratio of NH_3 or SO_2 to NO_x.

**Emissions inferred from NEI99 ratio of $PM_{2.5}$ to PM_{10}.

The HGAVEI estimates emissions of VOC, NOx, CO, and PM. The HGAVEI spatially allocates emissions based on shipping lanes and estimated trips throughout the water system. The BRAVO EI incorporates the HGAVEI emissions of VOC, NOx, CO, and PM for the counties of Harris, Galveston, Chambers, and Brazoria. Emissions are allocated to each county based on the spatial allocation of NO_X in the NEI99. Emissions of NH_3 and SO_2 are estimated based on the ratio of NH_3 and SO_2 to NO_x in the NEI99. Emissions of $PM_{2.5}$ are estimated based on the ratio of $PM_{2.5}$ to PM_{10} in the NEI99. All NEI99 Commercial Marine emissions were deleted from the NEI99 for the four counties in the Houston-Galveston area and replaced by the total emissions from the HGAVEI for base year 1997.

3.1.3 Ammonia Emissions

A detailed review of NH_3 emissions for the state of Texas was prepared for TNRCC by the University of Texas Austin for the base year 1996 (Corsi et al., 2000). A thorough literature review was conducted for research relating to NH_3 emissions from both natural and anthropogenic sources. Emissions factors for all sources categories in Texas were evaluated and single factors were selected for each source based on the literature review. The revised factors were then applied to activity data from the state of Texas to produce an annual emissions inventory. The results of this annual inventory (UTA96) are compared with emissions estimates from the NEI 1999 v100 database in Table 3-3.

Table 3-3. Comparison of non point source NH_3 emissions from Texas from the University of Texas Austin (UTA96) emissions inventory and the National Emissions Inventory (NEI99).

	UTA96	NEI99 v100
Base Year	1996	1999
Source Catagory	**NH_3 (tpy)**	**NH_3 (tpy)**
Animal Husbandry	397907	419584
Domestic	29687	0
Fertilizer Application	40420	62683
Non Road Sources	113	719
Highway Vehicles	11536	21643
Wastewater Treatment	6632	6280
TOTAL	486295	510908

The sum of NH_3 emissions from the UTA96 inventory is within 5% of the sum of emission from the NEI99 v100 emissions inventory. The major source of ammonia emissions in both inventories is Animal Husbandry with is dominated by cattle production. This source category accounts for more than 80% of the ammonia emissions in both inventories. In the NH_3 inventory database supplied with the UTA96 report, county level emissions were reported base on the five source categories listed in the table above. These categories correspond to multiple SCC codes that are not amenable to grouping by a generalized SCC code. Because, the net emissions for the listed sources are quite similar, the decision was made to retain the NEI99 NH_3 emissions in the BRAVO EI.

In addition to the sources listed in Table 3-3, the UTA96 inventory identified natural sources of NH_3 as a major source category. Natural sources include biogenic emissions from forests, pastures, and grasslands and were estimated to emit 535,000 tons of NH_3 per year. These emissions are approximately equal to the sum of all other non point NH_3 sources in Texas. The emission from the natural biogenic sources were formatted into the SMOKE input format. Biogenic emissions will be modeled for the BRAVO domain using a module within SMOKE. If this module does not include NH3 emissions from these sources, the UTA96 biogenic inventory should be appended to the existing list of area sources.

3.2 Mobile Sources

Mobile source emissions from the 1999 NEI version 100 are produced by EPA Office of Transportation and Air Quality. Emissions are estimated either by growing the emissions from the 1996 NEI according to economic growth for each state or by recalculating emissions using revised vehicle miles traveled (VMT) and EPA emissions factors (i.e. MOBILE5 and PART5 emissions models). In addition to the NEI mobile inventories, the Texas Transportation Institute (TTI) produced a separate Texas based mobile emissions inventory for base year 1996. The mobile EI was produced in two components: one for the sixteen ozone nonattainment counties and one for the rest of the state. The emissions are based on locally produced emissions factors and activity data for on road sources including gasoline vehicles and trucks, diesel vehicles and trucks, and motorcycles. The TTI mobile EI was calculated only for CO, NO_x, and VOC species. The 1996 TTI, 1996 NEI, and 1999 NEI mobile emissions results for the state of Texas are shown in Table 3-4.

Table 3-4. Comparison of the sum of Mobile Emissions for the State of Texas for on road vehicles.

	TTI96 (tpy)	NEI99 (tpy)	NEI96 (tpy)
CO	3,007,174	2,189,728	2,064,976
NH_3	*13,923	12,785	9,799
NO_x	364,731	249,811	220,615
PM_{10}	*7,179	5,337	4,687
$PM_{2.5}$	*4,441	3,175	2,909
SO_2	*14,821	12,296	10,065
VOC	308,513	265,698	220,843

* Calculated based on NEI96 emissions ratios of NH_3, PM_{10}, $PM_{2.5}$, and SO_2 to NO_x emissions for each vehicle class.

The table shows that the TTI96 mobile emissions are between 15% and 50% higher than the 1999 NEI and between 41% and 63% higher than the 1996 NEI emissions for species CO, NO_x, and VOC. Because the TTI96 mobile EI was produced using locally generated activity and emissions factors, it is the preferred mobile inventory for the state of Texas.

For the Mobile U.S. emissions component of the BRAVO EI, the NEI99 data set is used for all states. In Texas however, the NEI99 mobile emissions were updated with the corresponding emissions of CO, NH_3, NO_x, PM_{10}, $PM_{2.5}$, SO_2, and VOC from the TTI96 EI.

3.3 Point Sources

3.3.1 Annual and Ozone Season Day Emissions

U.S. point source emissions were obtained from the NEI 1999 v100 for typical ozone season day and annual emissions. Raw data was obtained in the new NIF 2.0 format. Data were formatted into the PTINV format as describe in the SMOKE users manual. A total of ~175,000 individual point source processes are listed in the PTINV table. Of those, ~16,000 sources were not properly geocoded with appropriate latitude and longitude coordinates. Using the geographic coordinates of other sources at the same facility, latitudes and longitudes were assigned to ~7,000 additional point sources. The emissions from the remaining point sources without geographic coordinates are summarized in shown in Table 3-5. The sources account for less than 10% of the non CEM U.S. point source emissions and only exist in the states of Arkansas, Louisiana, and Mississippi. In order to be processed by the SMOKE emissions processor, a point source must have a location in degrees latitude and longitude. The records for the sources without coordinate positions were deleted from the PTINV table and not included in the BRAVO EI.

Table 3-5. Summary of U.S. point sources deleted from BRAVO EI because the location of the sources were unknown. "All Point Sources" refers to all point sources that are reported as annual emissions rather than hourly emissions (See next section).

	CO	NH_3	NO_X	PM_{10}	$PM_{2.5}$	SO_2	VOC
Points Sources w/o Coordinates	163838	478	188043	7504	6108	35638	50990
All Point Sources	2047371	109336	2057776	361857	210879	1910434	971422
Percent of Total	8.0%	0.4%	9.1%	2.1%	2.9%	1.9%	5.2%

No additional changes were made to the point source database with the exception of modifications to the sources that matched the CEM sources. These modifications are described in the next section.

3.3.2 Continuous Emissions

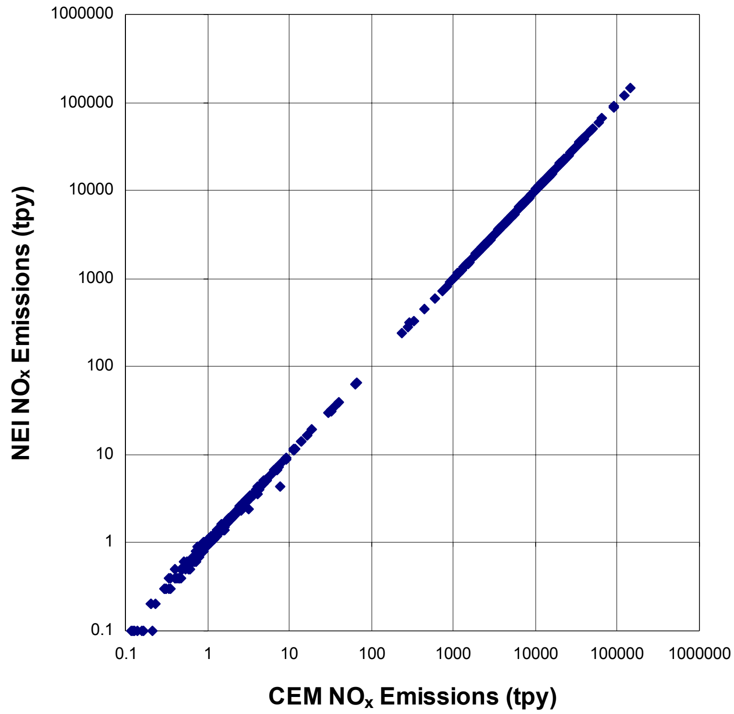
Hourly emissions data from the Continuous Emissions Monitoring (CEM) program were obtained from the Clean Air Markets division of EPA's Office of Air and Radiation (OAR). These data are reported by the facility managers to OAR as consequence of the Acid Rain Program. Stack emissions are measured directly at the source using automated sampling to provide very accurate point sources emissions of NO_x, SO_2, and CO_2. CEM data reported to the OAR arrive in Electronic Data Reporting (EDR) format. These tables are then read into a mainframe computer where the statistical package SAS performs QA checks and calculate of quarterly emissions for each stack. The CEM data incorporated into the BRAVO EI was obtained from the SAS mainframe tables rather than the raw EDR data.

At the time of writing this report EPA had not reconciled the CEM database with the annual State's point source database from in the NEI. As a result, no common table exists linking the CEM data with the point source data in the NEI. In order to incorporate the CEM data into the BRAVO EI, a direct link between the point sources in both datasets must be established. If this does not exist, the same sources may be double counted in the final database input into the SMOKE emissions processor.

The CEM database indexes sources using both an ORIS number (assigned to each facility by the Department of Energy and a Unit/Stack ID (assigned to each stack by the facility managers). CEM data is generally representative of emissions from an individual stack since the data is produced from monitoring equipment physically mounted on the stack itself.

The NEI database uses a separate set of indexes to define unique sources. Each sources is defined by its processes. For example, a piece of equipment that burns both coal and natural gas may be indexed as two sources (i.e. coal burning source and gas burning source) even though the same piece of equipment is the source. The two methods of indexing sources cause a one to many relationship to exist between the CEM stack data and the NEI point source data. That is multiple processes indexed in the NEI database may share the same stack equipped with CEM equipment. Matters are further complicated in that some facilities may split the emissions of a single process into multiple stacks or pipes. In database terms, this is referred to as a "many to many" relationship since one CEM may relate to one or more processes and one process may relate to one or more CEM's. This type of relationship should be avoided in database management since there is no hierarchy to the tables.

In order to accurately link the CEM database with the NEI, electric generating sources with external combustion boilers (i.e. SCC of type 101*****) were matched based on the ORIS number. Subsequently individual processes in the NEI and unit-stacks in the CEM database were matched using the POINTID field from the NEI with the UNIT-STACK field of the CEM database. This method left many sources unmatched since the slight misspellings in either of these fields would prevent a match. Additional matches were identified by manually examining all of the unmatched records. Annual NO_x and SO_2 emissions values were then compared to confirm the match. A match was considered valid if the CEM and NEI NOx emissions agreed to within 10%. If a match could not be found for a particular stack in the CEM database, these records were not used in the hourly emissions inventory database. A comparison of the NEI and CEM NOx and SO2 emissions are shown in Figure 3-1.



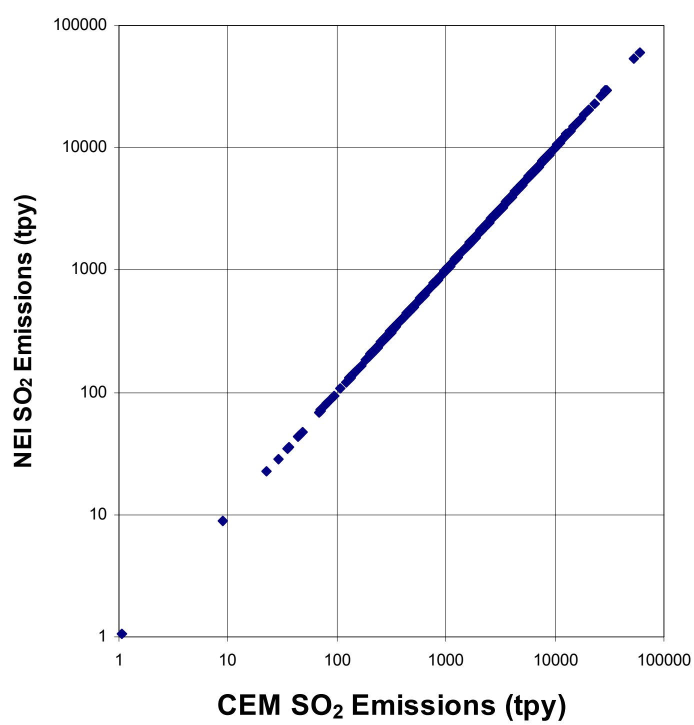


Figure 3-1. Comparison of SO_2 and NO_x emissions from matched sources from the NEI 1999 and CEM 1999 databases.

There are many sources affected by the Ozone Transport Commission NOx Budget Program that are only required to submit data to the OAR for the ozone season (May-Sep). These sources were not included in the hourly emissions inventory because the annual dataset was incomplete. The emissions from these sources are reported in the annual and ozone season day point source inventory.

Matches were found for a total of 1.8 million tons per year of NO_x and 3.2 million tons per year of SO_2. The matched emissions account for 89% of all SO_2 and 86% of all NO_x emitted from external combustion power generators in the14 BRAVO states. This also represents 47% of all NO_X and 63% of all SO_2 from all types of point sources in the same area. A total of 477 unique sources were matched between the two databases. A map showing the location of SO_2 sources with CEM monitors is shown in Figure 3-2.

Matched records were then aggregated so that one CEM dataset corresponded to a single process from the NEI. Links were established between the two databases based on the fields that determine the sources primary key (i.e. State, County, Plant, Point, Stack, and Segment). Tables were preserved in the processing databases that relate the aggregated process ID to its original processes.

To prevent double counting of emissions, the emissions from sources in the BRAVO PTINV table matching the CEM sources were replaced with zeros. Information such as location and stack parameters are preserved in the PTINV file, but all emissions are obtained from the hourly emissions tables PTHOUR. In addition, emissions of species not tracked by the continuous emissions monitoring system (i.e. CO, NH_3, PM_{10}, $PM_{2.5}$, and VOC) were estimated on an hourly basis by scaling their annual emissions NEI to the NO_x hourly emissions.

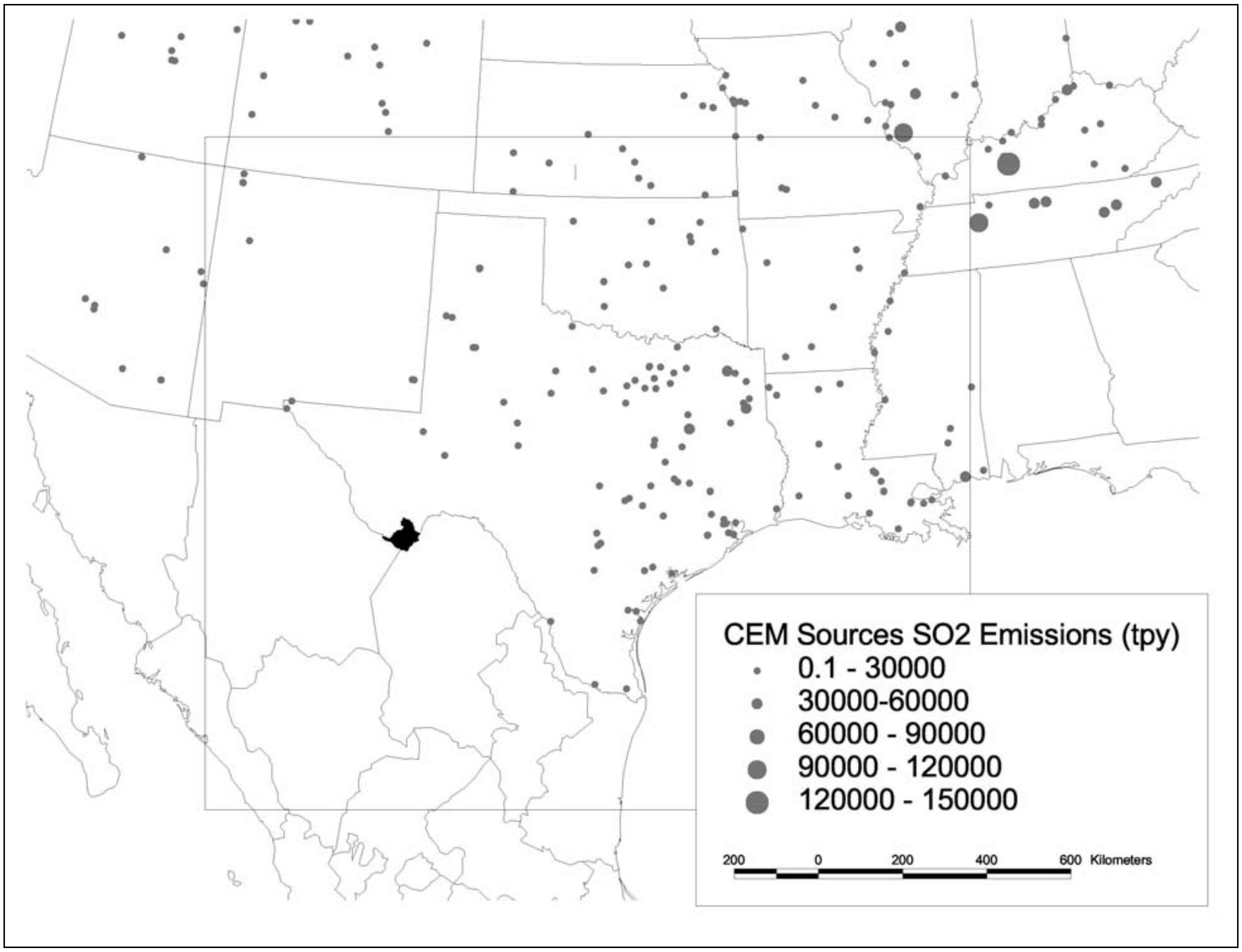


Figure 3-2. Map of CEM sources producing SO_2 within the BRAVO EI domain.

4. MEXICO EMISSIONS

This section describes the data sources and methods used to generate the BRAVO EI for the 10 states in Northern Mexico.

4.1 Domain and FIPS Coding

The domain of the BRAVO Northern Mexico Emissions Inventory includes the 10 Mexican states listed below in Table 4-1. The Mexican emissions data is organized with the same state and county FIPS format as the US counties. Since the current IDA text file format used to store the emissions data does not include a country code, emissions from the Gulf of Mexico, the United States, and Mexico are stored is separate files.

Table 4-1. List of States in BRAVO Northern Mexico EI.

State	MX State ID
San Luis Potosi	24
Baja California Norte	2
Sonora	26
Chihuahua	8
Coahuila De Zaragoza	5
Nuevo Leon	19
Tamaulipas	28
Sinaloa	25
Durango	10
Zacatecas	32

States in Mexico are subdivided into “municipios”. The geographic area of the municipios varies depending on the location of natural borders (i.e. rivers and mountains) and population density. In general municipios are comparable in size to counties in the U.S. The Mexican government refers to municipios using a similar convention to the U.S. FIPS coding. Each state has a unique 2 digit ID and each municipio has a unique 3 digit ID. For the purpose of the BRAVO emissions inventory, each municipio is designated with its 2 digit Mexican state ID and the Mexican 3 digit municipio ID.

4.2 Emissions Data Sources

At present, there is no municipio level national emissions inventory for Mexico for area and mobile sources. These emissions must be extrapolated from existing Mexican EI’s that are limited to a small number of urban areas.

The process is further complicated by regulatory restrictions in Mexico that prevent the reporting of emissions from individual Mexican point source facilities. As a result, estimates of point source emissions cannot be reconciled at the facility level and are therefore are likely to be more uncertain than emissions in the United States.

The list of data sources used to assemble the BRAVO EI for Mexico is presented below.

4.2.1 Instituto Nacional de Ecologia (INE)

Emissions inventories were produced for a limited number of cities by the National Environmental Protection Agency Instituto Nacional de Ecologia (INE) in Mexico (INE, 2001).

These inventories were constructed for base years 1994-1996 for the urban areas shown in Table 4-2. Emissions are calculated for PM, SO_2, NO_x, hydrocarbon (HC), and CO.

Table 4-2. INE emissions inventories for 20 major cities in Mexico. Emissions are in U.S. tons per year.

City	Base Year	PM	SO_2	CO	NO_x	HC
Cd.Juárez	1996	51,267	4,561	498,036	28,727	83,745
Tijuana	1998	30,176	35,230	345,798	34,942	91,837
Tula - Vito –Apaxco	1994	22,405	355,158	2,418	50,937	13,781
Mexicalli	1996	93,488	4,177	293,412	20,402	56,552
Zona Metropolitana de Guadalahara	1996	331,962	8,894	987,845	40,904	158,219
Zona Metropolitana de Monterrey	1995	897,191	33,513	998,538	58,603	137,913
Zona Metropolitana del Valle Mexico	1995	496,775	50,015	2,593,955	141,511	1,128,335
Zona Metropolitana del Valle Toluca	1996	135,713	11,574	295,616	23,528	51,129

Emissions from the three municipios Tula, Vito, and Apaxco are the largest grouping of SO_2 sources in Mexico. Because of the high emissions at this location, a separate point inventory file was created for this source area. The centroid of the Tula municipio (20.048 deg N, -99.365 deg E) was assigned as the geographic reference of the source. Tula-Vito-Apaxco's emissions are largely due to industrial sources including power generation, oil refining, glass manufacturing, and concrete manufacturing (Ortiz, 1997). Emissions from Mexico City (Zona Metropolitana del Valle Mexico) were also appended as a separate record in this file. Mexico City emissions were geocoded to (19.45 deg N, –99.18 deg E). Since multiple sources are responsible for the emissions from these areas an artificial SCC of "0000000000" was assigned to represent all emissions.

Emissions inventories categorized by source type are available on the INE webpage for the later four metropolitan areas listed in Table 4-2 (INE, 2001). The emissions inventory for the Zona Metropolitana de Monterrey has a base year of 1995 and covers the entire metropolitan area of Monterrey which includes the six municipios: Apodaca, San Pedro Garza Garcia, General Escobedo, Guadalupe, Monterrey, and San Nicolas de Los Garza.

4.2.2 System Nacional de Informacion de Fuentes Fijas (Manufacturing Emissions)

Emissions factors for Mexican manufacturing sources was downloaded from the World Bank New Ideas in Pollution Regulation web page (World Bank, 2001). This dataset has been produced by DECRG-IE of the World Bank in collaboration with Mexico's Instituto Nacional de Ecologia (INE), using a database they provided, the Sistema Nacional de Informacion de Fuentes Fijas (SNIF). The SNIF database was updated in November 1997 and lists average emissions factors from over 5300 manufactures in Mexico. Emissions factors for CO, NO_x, SO_2, PM, and hydrocarbons (HC) are aggregated by number of employees employed and business type based on International Standard Industrial Classification (ISIC) code. The source data files used to assemble the SNIF database are not publicly available and therefore could not be used to assemble the BRAVO EI.

Activity data on employment in each manufacturing sectors was obtained from the INEGI Economic Census report for base year 1998 (INEGI, 1999). The report lists the number of people employed by business size in each state based on the top four manufacturing sectors in that state. The report also lists the number of people employed in Industrial parks, cities, and corridors in each of the municipios. These data were used to estimate the number of people employed in each of the top four manufacturing sectors for small, medium, and large businesses in each municipio.

The emissions factors were applied to the employment activity data to calculate emissions for each municipio. The mapping of ISIC codes to SCC codes was performed using the transformation shown in Table 4-3.

Table 4-3. Conversion between international standard industrial classification (ISIC) codes and source classification codes (SCC).

ISIC3	Description	SCC Code	SCC Genearal Description	SCC Specific Description
311	Food products	2302000000	Food and Kindred Products: SIC 20	All Processes
312	Other food products	2302000000	Food and Kindred Products: SIC 20	All Processes
313	Beverages	2302000000	Food and Kindred Products: SIC 20	All Processes
314	Tobacco	2302000000	Food and Kindred Products: SIC 20	All Processes
321	Textiles	2330000000*		
322	Wearing apparel, except footware	2330000000*		
323	Leather products	2330000000*		
324	Footwear, except rubber or plastic	2330000000*		
331	Wood products, except furniture	2307000000	Wood Products: SIC 24	All Processes
332	Furniture, except metal	2307000000	Wood Products: SIC 24	All Processes
341	Paper and products	2307000000	Wood Products: SIC 24	All Processes
342	Printing and publishing	2360000000*		
351	Industrial chemicals	2301000000	Chemical Manufacturing: SIC 28	All Processes
352	Other chemicals	2301000000	Chemical Manufacturing: SIC 28	All Processes
353	Petroleum refineries	2306000000	Petroleum Refining: SIC 29	All Processes
354	Miscellaneous petroleum and coal products	2306000000	Petroleum Refining: SIC 29	All Processes
355	Rubber products	2308000000	Rubber/Plastics: SIC 30	All Processes
361	Pottery, china, earthenware	2325040000	Mining and Quarrying: SIC 14	Clay, Ceramic, and Refractory
362	Glass and products	2305014010*		
369	Other non-metallic mineral products	2305000000	Mineral Processes: SIC 32	All Processes
371	Iron and steel	2303020000	Primary Metal Production: SIC 33	Iron and Steel Foundries
372	Non-ferrous metals	2304050000	Secondary Metal Production: SIC 33	Nonferrous Foundries (Castings)
381	Fabricated metal products	2309000000	Fabricated Metals: SIC 34	All Processes
382	Machinery, except electrical	2312000000	Machinery: SIC 35	All Processes
383	Machinery, electric	2312000000	Machinery: SIC 35	All Processes
384	Transport equipment	2314999990*		
385	Professional and scientific equipment	2399000000	Industrial Processes: NEC	Industrial Processes: NEC
390	Other manufacturing products	2399000000	Industrial Processes: NEC	Industrial Processes: NEC

*Not official SCC Code

Because, no detailed process information was available for these sources, assumptions were made about the characterization of the particle size distribution and the ratio of volatile organic carbon to hydrocarbons. Emissions of hydrocarbons were assumed to be identical to those volatile organic carbon (VOC). PM_{10} was arbitrarily assumed to be 100% of the total particulate emissions while $PM_{2.5}$ was assumed to be 50% of the total particulate emissions.

4.2.3 Eastern Research Group (Area, Mobile, and Point Sources)

Eastern Research Group (ERG) developed an emissions inventory for the northwestern states of Mexico: Chihuahua, Sonora, and Baja California Norte. The ERG EI was prepared for the Western Regional Air Partnership (WRAP) with a base year of 1996 (Wolf and Fields, 2001). The inventory will be used to assess the impact on visual air quality in Class I visibility-protected areas in the Western United States.

Area and mobile source emissions factors were extracted from existing emissions inventories in Tijuana, Mexicalli, and Juarez (GBC et al., 1999; GBC et al., 2000; GCh et al., 1998). Average emissions factors were calculated for major source categories for each of these inventories based on the activity parameters: population, households, total number of registered vehicles, agricultural acreage, and number of cattle. Activity data was acquired from the Mexican Census Agency Instituto Nacional De Estadistica Geografia E Informatica (INEGI, 2000). These factors were then used with the activity data to calculate emissions for areas of the states not represented by the urban emissions inventories.

Point emissions were obtained from three separate sources and included emissions from Carbon I/II Power Plants (Yarborough, 2000), Cananea and Nacozari Smelters (P&BE, 1999a; P&BE, 1999b), and 15 SO_2 sources in the states of Chihuahua, Coahuila, Nuevo Leon, and Tamalipas (Watson, 1998).

4.2.3.1 BRAVO EI Mexican Area and Mobile Sources

The approach used in the ERG EI to calculate area and mobile emissions was modified slightly for the BRAVO EI. Average emissions factors were calculated using the inventories from Tijuana, Mexicalli, and Juarez. Data from the Monterrey emissions inventory (INE, 2001) was also included in calculating the average emissions factors. The emissions factors for each source are shown in Appendix A. For the Monterrey EI, emissions from trucks were not categorized by fuel type as they were for Tijuana, Mexicali, and Monterrey. The emissions from trucks in Monterrey were therefore not used in the calculation of average emissions factors.

Population data for Mexico in 1999 was interpolated using the 1990 and 2000 Mexican census data (INEGI, 2001) for each municipio in the modeling domain. Household data was estimated by reducing the 2000 Census household data by the percent reduction in population between 2000 and 1999. Total vehicle registration data was available for base year 1999 using the INEGI SIMBAD database (INEGI, 2000). The number of agricultural hectares and head of cattle in 1999 were reported at the state level for 1999 by the Mexican Center of Agricultural Statistics (SAGAR, 1999). Agricultural hectares were spatially allocated to the municipio level by multiplying the 1999 state number of hectares by the fraction of state hectares within the municipio based on the 1991 Agricultural Census (INEGI, 1994). Similarly, the number of cattle was allocated to municipios based on their spatial distribution in the 1991 Agricultural Census.

Municipio level area and mobile source data were applied to areas not covered by the original emissions inventories in Monterrey, Juarez, Tijuana, and Mexicalli. Emissions for these cities for base year 1999 were calculated using the city specific emissions factors from the original emissions inventories. Activity data for 1999 from these areas was used to grow the emissions in these cities to the BRAVO EI base year.

The Metropolitan Area of Monterrey covers 6 municipios. Emissions for non point sources were spatially allocated based on the 1999 activity data from each municipio. Since no information was available about individual point sources in Monterrey, all point source data was allocated to the municipio of Monterrey. All truck emissions including Heavy Duty Diesel, Heavy Duty Gas, and Light Duty Diesel in the greater Monterrey area are categorized as Heavy Duty Diesel with the SCC 2230070000.

4.2.3.2 BRAVO EI Mexican Point Sources

An annual estimate of CO, NO_x, SO_2, and PM_{10} emissions from the Carbon I and Carbon II coal fired power plants was provided by U.S. E.P.A. Region VI staff (Yarborough, 2000). This estimate was for 1994, but it is assumed that emissions for 1999 are of a similar magnitude. The emissions from these two facilities are listed in the Table 4-4. Wolf and Fields (2001) estimated $PM_{2.5}$ emissions based on the assumption that 37.5% of PM_{10} from coal-powered electricity generation is $PM_{2.5}$ (ARB, 1999).

No information is available about the seasonal or diurnal temporal profiles of the Carbon I/II facilities. In addition, there is no information available regarding periods when the plant operation may have been interrupted due to routine maintenance or process upset. Because of their low power costs, most coal-fired power plants are base loaded (i.e. operating a full capacity 24 hours per day).

The Carbon I/II purchases some coal from mines in the western United States however much of the coal burned on site is mined from the lignite belt that runs Northeast-Southwest through the eastern side of Texas and Mexico. The Carbon I/II power plants were assigned an SCC of 10100300 that corresponds to an external combustion boiler burning pulverized lignite coal.

The Cananea copper smelter in the state of Sonora was shut down in April 1999 and is not included in the BRAVO EI since it was not operating during the field study period between July and October 1999. The Cananea smelter operated with no emissions controls. The Nacozari smelter is also located in Sonora, but utilizes emission controls (i.e., double-contact sulfuric acid plants) in order to reduce SO_2 emissions. Wolf and Fields (2001) estimated the annual emissions of SO_2 from the Nacozari smelter to be 13,600 tons. Emissions of other species were not estimated for this facility. The Nacozari smelter was geocoded to the center of the Nacozari de Garcia municipio in the state of Sonora. The smelter was assigned the SCC of 30300500 for general copper smelting.

An additional set of point source sulfur dioxide information was provided by Watson (2000). A partially complete table from an internal report was obtained from a staff member at PROFEPA in Mexico. The table was dated March 1997. The table lists 34 sources in the states of Tamaulipas, Nuevo Leon, Chihuahua, and Coahuila. Of these sources, 23 are either power generation facilities whose emissions are estimated in the following subsection, located in a city that has already incorporated their emissions in the emissions inventory, low emitting sources with less than 30 tpy of SO_2, or were not listed with a location so they can not be geocoded. The remaining 11 sources are shown in Table 4-4. The location of these sources was geocoded to the centroid of the municipio in which they are located.

Table 4-4. Emissions from major point sources in Northern Mexico.

PLANT	State	Locality	Process	SCC	Lat (deg)	Lon (deg)	CO (tpy)	NO_x (tpy)	PM_{10} (tpy)	$PM_{2.5}$ (tpy)	SO_2 (tpy)	VOC (tpy)
Carbon I	Coahuila	De Nava	Coal fired power plant	10100300	28.47	-100.68	2,112	36,786	9,002	3,384	111,942	NA
Carbon II	Coahuila	De Nava	Coal fired power plant	10100300	28.47	-100.68	2,577	42,919	11,259	4,232	129,341	NA

Nacozari Smelter	Sonora	Nacozari de Garcia	Copper smelter	2303005000	30.516	-109.457	NA	NA	NA	NA	13,600	NA
Cementos Chihuahua S.A. de C.V.	Chihuahua	Chihuahua	Cement manufacturing	2305000000	28.8728	-106.175	NA	NA	NA	NA	107	NA
Papelera de Chihuahua, S.A. de C.V.	Chihuahua	Chihuahua	Paper and pulp	2307000000	28.8728	-106.175	NA	NA	NA	NA	212	NA
Pemex Refinería, Ing. Héctor Lara Sosa	Nuevo Leon	Cadereyta, Jimenez	Petroleum refining	2306000000	25.51453	-99.96602	NA	NA	NA	NA	18,269	NA
Altos Hornos de México, S.A. de C.V.	Coahuila	Monclova	Iron and steel foundary	2303020000	26.91491	-101.25944	NA	NA	NA	NA	10,986	NA
Cementos Apasco S.A. de C.V.	Coahuila	Ramos Arizpe	Cement manufacturing	2305000000	25.88485	-101.08416	NA	NA	NA	NA	933	NA
Met-Mex Peñoles, S.A. de C.V.	Coahuila	Torreón	Nonferrous foundry	2304050000	25.23742	-103.34429	NA	NA	NA	NA	7,411	NA
Industria Minera México, S.A. de C.V.	Coahuila	San Juan de Sabinas	Coking	2390009000	28.08954	-101.38134	NA	NA	NA	NA	355	NA
Refinería de Cd. Madero	Tamaulipas	Cd. Madero	Petroleum refining	2306000000	22.31405	-97.84345	NA	NA	NA	NA	29,621	NA
Dupont S.A. de C.V.	Tamaulipas	Altamira	Chemical manufacturing	2301000000	22.51381	-98.09277	NA	NA	NA	NA	712	NA
Química Fluor	Tamaulipas	Matamoros	Chemical manufacturing	2301000000	25.5556	-97.49681	NA	NA	NA	NA	4,527	NA
Polimar S.A. de C.V.	Tamaulipas	Puerto Industrial Altamira	Chemical manufacturing	2301000000	22.51381	-98.09277	NA	NA	NA	NA	438	NA

4.2.4 Acosta y Associados (Power Plant Emissions)

Data on power output, fuel use, fuel type, and fuel sulfur content for public Mexican power generation facilities in the BRAVO inventory domain were provided by Acosta y Associados (Acosta, 2001). These data were obtained from PEMEX to produce a mercury emissions inventory for Northern Mexico. The mercury report is being prepared for the Center of Environmental Control (CEC) and will be completed later in 2001. The base year of this dataset is 1999.

Data on volume of diesel, natural gas, and heavy fuel oil usage were obtained for 37 sources in the Mexican states of the BRAVO EI domain as well as Baja California Norte and Sonora. Facilities were categorized as “Steam”, “Gas Turbine”, or “Combined Cycle”. Emissions factors for the power generation facilities were obtained from the AP-42 (U.S. E.P.A., 1998; U.S. E.P.A., 2000). Sulfur content of fuels is required to calculate SO_2 emissions from diesel and heavy oil combustion. Acosta (2001) indicated that the maximum sulfur content of heavy fuel oil is 2% based on CFE test results. Material Safety Data Sheets for diesel fuel from PEMEX state that sulfur content of diesel fuel is 0.05%. Sulfur contents of 2% and 0.05% were used to calculate emissions from fuel oil and diesel sources, respectively. The default sulfur content of natural gas from AP-42 was use to estimate SO_2 emissions. Annual average emissions were calculated based on totals of each type of fuel consumed at each facility. Ozone season day emissions were calculated by dividing the annual emissions by 365 days. Source classification codes were assigned to the process of burning each fuel type in each facility type. Emissions are only estimated for the combustions processes and do not include fugitive emissions from fuel handling or spills.

Acosta (2000) also indicated that unconfirmed sources reported the Carbon I power plant also burned between 9-12 million liters of diesel in 1999 in addition to coal. Since this source can not be confirmed at this time, this data was not included in the emissions inventory. The emissions from burning 10 million liters of diesel are quite small (32 tpy of NO_X and 10 tpy of SO_2) with respect to the emissions from coal combustion at this facility (88,000 tpy of NO_x and 265,000 tpy of SO_2).

The locations of each facility were assigned based on the center of the municipio in which they are located. Total emissions from each facility along with their location are shown in Table 4-5.

Table 4-5. List of criteria pollutant emissions from power generation facilities in Northern Mexico.

PLANT	State	Locality	Latitude (deg)	Longitude (deg)	CO (tpy)	Nox (tpy)	PM10 (tpy)	PM2.5 (tpy)	SO2 (tpy)	VOC (tpy)
Altamira	Tamaulipas	Tampico	25.833	-97.954	968	7,340	2,115	1,548	42,588	122
Arroyo de Coyote	Tamaulipas	N. Laredo	27.484	-99.518	1	5	0	0	0	0
Benito Juarez	Chihuahua	C. Juarez	28.632	-106.072	319	2,421	698	511	14,050	40
Caborca Industrial	Sonora	Caborca	29.099	-110.954	9	31	1	1	2	0
Cd. Obregón II	Sonora	C. Obregón (Cajeme)	30.716	-112.159	2	8	0	0	1	0
Chavez	Coahuila	Fco. I. Madero	28.421	-100.768	8	27	1	1	2	0
Chihuahua	Chihuahua	Chihuahua	17.604	-93.196	6	23	1	1	2	0
Culiacán	Sinaloa	Culiacán	24.799	-107.384	7	24	1	1	2	0
E. Portes Gil	Tamaulipas	Río Bravo	22.396	-97.937	465	3,525	1,016	744	20,455	59
Esperanzas	Coahuila	Múzquiz	28.280	-101.931	1	3	0	0	0	0
Fco. Villa	Chihuahua	Delicias	28.186	-105.471	483	3,663	1,056	773	21,257	61
Fundidora I	Nuevo Leon	Monterrey	25.785	-100.051	4	14	0	0	1	0
Gómez Palacios	Durango	Gómez Palacios	25.536	-103.524	463	1,806	39	39	506	12
GuadalupeVictoria	Durango	Lerdo	25.561	-103.498	458	3,473	1,001	733	20,150	58
Guaymas I	Sonora	Guaymas	27.489	-109.935	40	304	88	64	1,765	5
Guaymas II	Sonora	Guaymas	29.906	-112.683	560	4,250	1,225	897	24,661	71
Hermosillo	Sonora	Hermosillo	27.918	-110.899	83	297	9	9	22	4
Huinalá	Nuevo Leon	Pesquería	25.671	-100.308	909	3,545	77	77	993	23
J. Aceves Pozos	Sinaloa	Mazatlán	25.630	-109.056	709	5,378	1,549	1,134	31,203	89
La Laguna	Durango	Gómez Palacios	25.561	-103.498	49	294	67	50	1,314	5
Leona	Nuevo Leon	Monterrey	25.671	-100.308	8	29	1	1	2	0
Los Cipreses	BCN	Ensenada	32.519	-115.385	5	20	1	1	1	0
Mexicali	BCN	Mexicali	32.491	-115.425	4	13	0	0	1	0
Monclova	Coahuila	Monclova	28.606	-100.640	10	34	1	1	3	0
Monterrey	Nuevo Leon	San Nicolas de los Garza	23.806	-100.427	581	4,404	1,269	929	25,551	73
P. Ind. Zaragoza (Industrial)	Chihuahua	C. Juarez	28.632	-106.072	1	4	0	0	0	0
P. Ind. Zaragoza (Parque)	Chihuahua	Chihuahua	28.632	-106.072	10	37	1	1	3	1
Pres. Juárez I	BCN	Rosarito	32.342	-117.056	547	4,148	1,195	875	24,070	69
Pres. Juárez II	BCN	Rosarito	32.663	-115.468	69	248	8	8	18	3

Pto. Libertad	Sonora	Pto. Libertad (Pitiquito)	27.918	-110.899	762	5,782	1,666	1,220	33,550	96
Samalayuca	Chihuahua	Chihuahua	31.735	-106.478	1,497	5,843	127	127	1,636	38
San Jerónimo	Nuevo Leon	Monterrey	25.671	-100.308	42	319	92	67	1,851	5
Tecnológico	Nuevo Leon	Monterrey	25.671	-100.308	2	7	0	0	1	0
Topolobampo II	Sinaloa	Topolobampo (Ahome)	23.236	-106.415	411	3,116	898	657	18,080	52
Universidad	Nuevo Leon	Monterrey	25.671	-100.308	8	28	1	1	2	0
V. de Reyes	SLP	SLP	22.151	-100.976	753	5,711	1,646	1,205	33,139	95
Total					10,253	66,176	15,848	11,677	316,881	985

4.2.5 Instituto de Geofisica (Popocatepetl Volcano Emissions)

The Popocatepetl volcano is located 70 km southeast of downtown Mexico City at 19.02 deg N, -98.62 deg E, 5452 m a.s.l. Carbon 14 measurements of pyroclastic deposits near the crater show that over the last 22 thousand years, the volcano has erupted at time intervals ranging from 1000 to 3000 years (Siebe et al., 1996). Historic records indicate that the volcano has remained relatively dormant between 1927 and 1993, however increased seismic activity and fumaroles (emissions of gases and ash) have been observed since late 1993 (Goff et al., 1998). Popocatepetl is currently one of the world's largest emitters of SO_2 and other volcanic gases. The proximity of the volcano to urban areas prompted a monitoring program of volcanic activity to provide emergency warnings to nearby residents. The Centro Nacional de Prevencion de Desastres (CENAPRED) sponsors routine monitoring of seismic activity and gas emissions from this source.

SO_2 emissions from the volcano are measured with a correlation spectrometer (COSPEC) two to three times per week. The highest measured SO_2 emissions from the crater since 1994 were 50,000 tons per day while typical emissions are approximately 3000-5000 tons per day (Smithsonian Institute, 2000). These emissions are approximately 6 to 75 times greater than the SO_2 emissions from the Carbon I/II power facilities. In addition to SO_2, hydrochloric and hydrofluoric acids are also emitted from the volcano. Large amounts of ash and dust are also emitted. Galindo et al., (1998) estimated particle emissions rates of 38,000 tpd for total particulate matter and 5000 tpd for SO_2 from Popocatepetl for an eruption occurring between December 24 and December 27, 1995. Air borne particle size distribution measurements indicated high variability in the particle size distribution. The PM_{10} fraction of the total particulate matter ranged from 3 to 80% with a mass weighted average of ~10%.

In the same study, chemical speciation using X-Ray Fluorescence was also performed on filters collected at the Puebla airport 45 km east of the volcano. Most of the particulate mass was crustal material however, major non crustal species of the samples collected include phosphorus, sulfur, chlorine, and potassium. This data set may be useful for Chemical Mass Balance source attribution studies.

SO_2 missions from the volcano for the base year 1999 had not been completely process at the time of this report. Delgado (2001) estimated annual SO_2 emissions from the volcano at 1.7 million tons with daily emissions of 5000 +/- 3000 tons.

A point source emissions record was added to the BRAVO EI. The SCC for volcanic emissions was applied and the annual and daily estimates of SO2 emissions from Delgado (2001) were used. PM_{10} and $PM_{2.5}$ emissions were estimated based on the results of the Gilando et al.,

(1998) study. From that study, the ratio of total particulate matter to SO_2 emissions was 7.5 to 1. The fraction of PM_{10} and $PM_{2.5}$ to total particulate matter in the volcano emissions were chosen to be 10% and 2%, respectively. The annual emissions for PM_{10} and $PM_{2.5}$ from the volcano for 1999 are estimated to be 3750 and 750 tons per day, respectively. Typical plumes from the volcano rise 1 km above the crater. A stack height of 1000 m was assigned to the source.

It should be emphasized that the measurement of emissions from volcanoes are highly uncertain due to the logistic difficulties of conducting these tests. In addition, the activity of the volcano is dynamic and changes rapidly from hour to hour. The emissions presented here are rough estimates. For a particular day real emissions from the volcano are likely to differ from these estimates by more than an order of magnitude.

4.3 Mexican Emissions Integration

This subsection describes how emissions from the Mexican data sources were combined to create the emissions inventory for the BRAVO states in Mexico. Care was taken to prevent double counting of emissions when integrating data from the multiple sources listed above.

4.3.1 Area and Mobile Sources

Although, emissions from manufacturing processes were included in the inventories for Tijuana, Mexicali, Juarez, and Monterrey, these emissions were not allocated to areas outside of the urban areas. As a result, manufacturing emissions (Section 4.2.2) calculated from the SNIF database and economic census data are nearly exclusive from the area and mobile emissions database (Section 4.2.3) calculated using the modified ERG emissions factors.

The only exception is food production (i.e. SCC 2302000000). For this category, the SNIF database categorized emissions of "agricultural product milling" and "non-processed food production". The Area and Mobile database allocates emissions from "charbroiling" and "baking" based on population. In general, emissions from these categories are in general quite small (less than 5% of particulate emissions from Heavy Duty Diesel Trucks). In order to prevent double counting, all emissions relating to food production from the SNIF database were removed from the BRAVO EI.

Area and mobile source data for Mexico were assembled beginning with municipio level emissions calculated using the modified ERG emissions factors (Section 4.2.3). These emissions were replaced with the 1999 base year urban emissions inventories that also include point source emissions for the cities of Monterrey, Tijuana, Mexicali, and Juarez. Finally, manufacturing emissions from the SNIF data corresponding municipios outside of the inventoried cities were appended to the mobile and area sources database.

4.4 Source Classification Coding (SCC) of Mexican Sources

Since the method and source data used to produce the Mexican Emissions inventory differed from the US NEI, in some cases not enough information was available to assign an accurate SCC for each source. Fictitious SCC's were created for these sources. A description of these SCC's is provided in Table 4-6.

Table 4-6. Description of fictitious SCC's.

SCC	Data Source	Source Description
2101000000	ERG EI	Point Source (Electricity Generation, Fuel Not Specified)
2103000000	ERG EI	Commercial/Institutional Fuel Combustion (unknown fuel type)
2104000000	ERG EI	Residential Fuel Combustion (unknown fuel type)
2201001900	ERG EI	Border Crossings
2230070900	ERG EI	Bus Terminals
2305014010	SNIF	Glass Manufacturing
2305090000	ERG EI	Brick Manufacturing
2313000000	ERG EI	Point Source (Miscellaneous Consumer Products)
2314000000	ERG EI	Point Source (Printing Products)
2314999990	SNIF	Transportation Equipment Manufacturing (Not Specified)
2315000000	ERG EI	Point Source (Vegetable and Animal Products)
2330000000	SNIF	Wearing apparel except footwear
2801700000	ERG EI	Fertilizer Application
2845000000	ERG EI	Domestic Ammonia Emissions
99999999	DRI	Miscellaneous SCC for all emissions from Mexico City and Tula-Vitro-Apaxco

5. GULF OF MEXICO EMISSIONS

The Minerals Management Service Outer Continental Shelf Activity Database (MOAD3) inventories emissions for the development of outer continental shelf petroleum resources in the Gulf of Mexico (Steiner et al., 1994; Brown, 1998). The MOAD3 catalogs emissions from the development of petroleum resources in the Gulf of Mexico for base year 1992. Sources are based activities occurring on 1857 platforms. Emissions of CO, SO_x, NO_x, PM, and VOC's are reported for activities in the gulf. Particles emissions are only reported for diesel engines and boilers. As a result, the inventory may grossly underestimate particulate emissions from flaring.

An updated emissions inventory is currently being prepared using a more recent base year. The results of this inventory were not completed in time to be incorporated in the BRAVO EI database (Peuler, 2001). All sources in MOAD3 are treated as point sources representing the location of the platform in the Gulf of Mexico. Figure 5-1 shows the location of the platforms off the coast of Mississippi, Louisiana, and Texas.

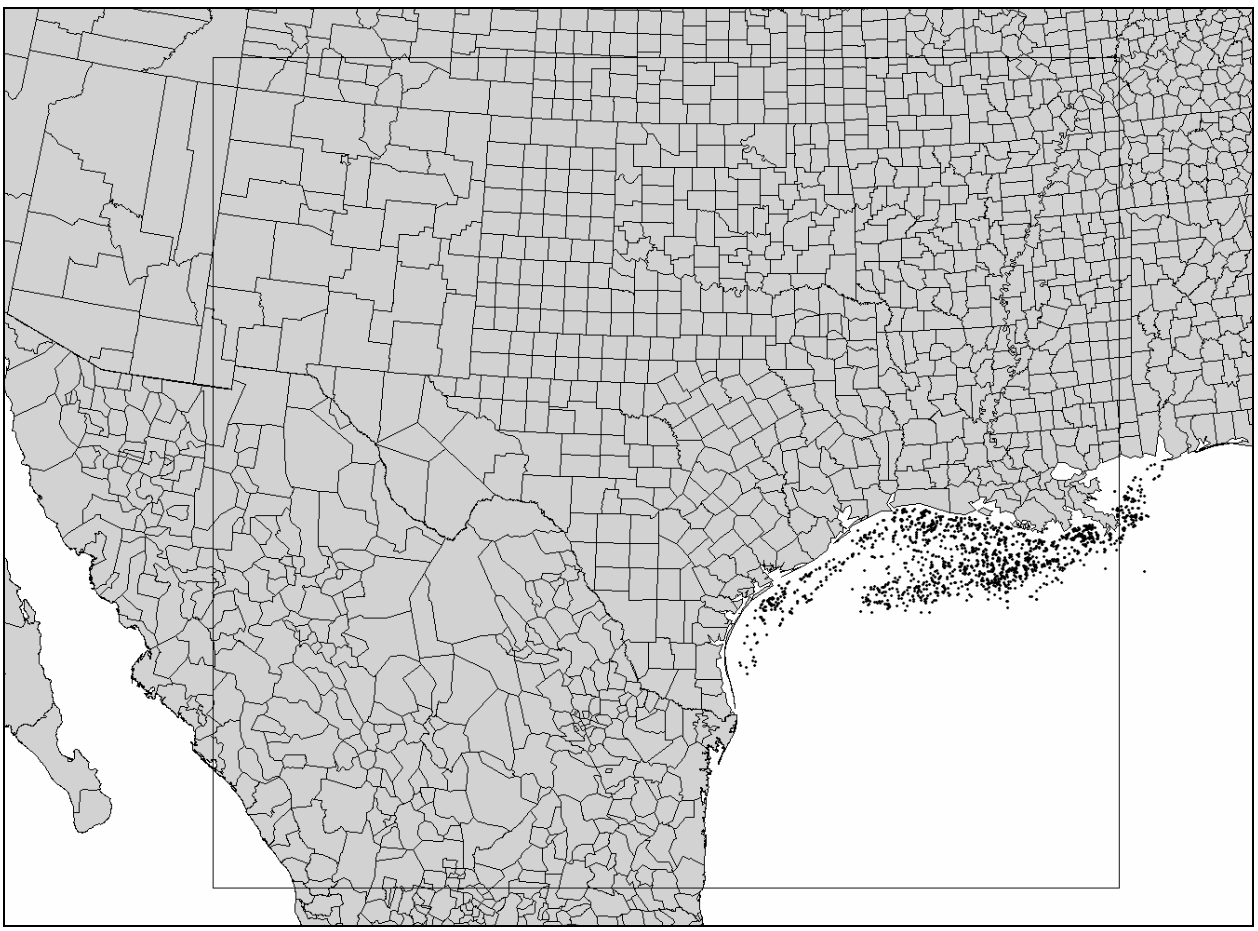


Figure 5-1. Map of US counties, Mexican municipios, and offshore platforms in the BRAVO emissions inventory.

The MOAD3 EI was reformatted into a point source inventory using all existing data. $PM_{2.5}$ emissions were calculated as 92% of the PM_{10} emissions. All sources of emissions on the platforms are based on engines, boilers, storage tank off gassing, or flares. The ratio of $PM_{2.5}$ to

PM_{10} is identical to the ratio used to estimate $PM_{2.5}$ emissions from Off Highway Diesel Vehicles (OHV) in EPA's NONROAD model. Table 5-1 shows the sum of all emissions from platform activities reported in the Gulf of Mexico.

Table 5-1. Aggregate emissions from offshore platforms from MOAD3.

Pollutant	Emissions (tpy)
CO	21,885
NO_x	93,235
PM_{10}	1,725
$PM_{2.5}$	1,587
SO_2	182
VOC	278,170

MOAD3 does not include emissions off the coast of Mexico since this is outside of the jurisdiction of the Minerals Management Service. Extensive reserves of oil are being recovered off the east coast of Mexico, but quantitative emissions of these operations are not publicly available at the time of writing this report.

6. SUMMARY OF RESULTS

This section describes the integration of the emissions inventory for each of the three source regions: United States, Mexico, and the Gulf of Mexico.

6.1 Major Source Categories by Region

The entire BRAVO EI is summarized in Table 6-1. Emissions of each species is shown from each source region categorized by area, mobile, and point sources. For all species, emissions from the United States portion of the inventory domain are more than twice as large as the emissions from the BRAVO EI states in Mexico and the Gulf of Mexico. Offshore emissions are quite small compared to emissions from the United States and Mexico. It should be emphasized that the Offshore inventory only accounts for emissions from platforms under the jurisdiction of the Minerals Management Service and that particulate emissions from flaring is not inventoried.

Table 6-1. Total Emissions from each source region in the BRAVO EI for base year 1999.

Region	Source Category	CO (tpy)	NH_3 (tpy)	NO_x (tpy)	PM_{10} (tpy)	$PM_{2.5}$ (tpy)	SO_2 (tpy)	VOC (tpy)
14 US BRAVO States	Area	10,289,533	1,914,084	2,670,048	9,360,206	2,118,692	659,016	3,004,166
	Mobile	16,348,722	78,283	2,806,990	93,321	72,904	111,357	1,774,397
	Point	2,027,327	111,632	3,656,641	413,099	238,445	4,972,738	936,814
	Total	**28,665,582**	**2,103,999**	**9,133,679**	**9,866,626**	**2,430,041**	**5,743,111**	**5,715,378**
10 Mexican BRAVO States	Area & Mobile	7,192,916	317,132	424,084	883,934	310,008	221,157	1,408,594
	Point	15,435	0	154,250	38,236	20,072	670,671	985
	Tula Industrial Park and Mexico City	2,596,153	0	187,817	517,143	258,571	372,885	1,140,863
	Popocatepetl Volcano	0	0	0	3,750	750	1,701,309	0
	Total	**9,804,505**	**317,132**	**766,151**	**1,443,064**	**589,400**	**2,966,023**	**2,550,442**
Off Shore	**Total**	**21,885**	**NA**	**93,235**	**1,725**	**1,587**	**182**	**278,170**
Entire Study Area	**Grand Total**	**38,491,971**	**2,421,131**	**9,993,066**	**11,311,415**	**3,021,029**	**8,709,316**	**8,543,990**

The following subsections describe the locations and majors source types within each of the three emissions inventory regions.

6.1.1 United States

The sum of annual emissions for each of the U.S. BRAVO inventory states are shown in Table 6-2. Texas has the highest emissions of all species while Utah has the lowest emissions.

Table 6-2. Sum of point, mobile, and area emissions from each U.S. State in the BRAVO EI for base year 1999.

State Name	CO (tpy)	NH_3 (tpy)	NO_x (tpy)	PM_{10} (tpy)	$PM_{2.5}$ (tpy)	SO_2 (tpy)	VOC (tpy)
Arizona	2,163,800	34,715	482,405	366,752	154,728	198,463	300,216
Arkansas	1,176,697	151,098	303,698	446,617	115,648	160,403	247,198
Colorado	1,467,242	114,216	416,199	420,901	108,986	126,120	281,407
Illinois	3,163,874	145,729	1,106,981	922,427	241,899	1,035,786	749,663
Kansas	1,107,584	239,203	500,616	781,089	171,703	156,235	228,628
Kentucky	1,507,434	95,932	691,337	295,534	95,751	776,752	330,210
Louisiana	2,111,206	80,951	709,755	324,820	126,914	432,721	352,323

Mississippi	1,546,322	99,654	403,103	409,562	124,028	246,903	313,448
Missouri	1,845,597	225,021	533,425	1,020,524	216,567	432,161	368,146
New Mexico	920,401	49,803	325,266	813,337	153,418	181,921	144,485
Oklahoma	1,578,710	228,148	465,453	789,907	156,934	158,940	276,488
Tennessee	2,303,910	83,603	738,523	318,122	118,492	684,395	548,773
Texas	6,913,715	518,972	2,163,437	2,721,273	581,013	1,066,113	1,429,412
Utah	859,089	36,955	293,483	235,762	63,961	86,198	144,981

6.1.1.1 CO Emissions

The major source types of CO emissions for U.S. sources are shown in Table 6-4. CO emissions are largely associated with improperly tuned engines. Gasoline powered vehicles are the dominant emitter of CO (54%).

Table 6-3. Major source types of CO emissions in the 14 BRAVO U.S. States.

Source Category	Source Type	CO (tpy)	Percent of Total Emissions
Mobile	Gasoline Highway Vehicles	15,646,803	54%
Area	4-Stroke Gasoline Lawn and Garden Equipment	2,624,917	9%
Area	Perscribed Burning Forest Management	1,504,538	5%
	All Other Sources	8,889,324	31%
	Total	**28,665,582**	**100%**

6.1.1.2 NH_3 Emissions

The three largest sources of NH_3 emissions in the U.S. are shown in Table 6-5. Emissions from Cattle and Calves urine and excrement account for the largest source of NH_3 emissions. Biogenic NH_3 emissions are not included here. In the state of Texas, NH_3 emissions from plant respiration account for half of the total NH_3 emissions from all sources.

Table 6-4. Major source types of NH_3 emissions in the 14 BRAVO U.S. States. Biogenic NH_3 from plants is not included in this summary.

Source Category	Source Type	NH_3 (tpy)	Percent of Total Emissions
Area	Cattle and Calves	1,217,706	58%
Area	Fertilizer Application	307,727	15%
Area	Hogs and Pigs	163,273	8%
	All Other Sources	415293	20%
	Total	**2,103,999**	**100%**

6.1.1.3 NO_x Emissions

Major NO_x emission source types are presented in Table 6-5. Unlike CO and NH_3, the major sources of NOx are more equally balanced between gasoline and diesel powered highway vehicles (18% and 12%, respectively) and coal fired power plants (15%). Thermal NO_x is formed in combustion process when ambient nitrogen and oxygen react with each other at high temperature.

Table 6-5. Major source types of NO_X emissions in the 14 BRAVO U.S. States.

Source Category	Source Type	NO_x (tpy)	Percent of Total Emissions
Mobile	Gasoline Highway Vehicles	1,672,502	18%
Point	Electric Generation Coal Combustion (CEM)	1,408,938	15%
Mobile	Diesel Highway Vehicles	1,134,487	12%
	All Other Sources	4,917,752	54%
	Total	**9,133,679**	**100%**

6.1.1.4 PM_{10} Emissions

The largest source types of PM_{10} are shown in Table 6-6. Unpaved and paved roads are the first and third largest sources of PM_{10} accounting for 47% and 8% of the total emissions. Agricultural tilling is the second largest PM_{10} source and has a strong seasonal cycle with peaks in the spring fall months. Major PM_{10} sources are fugitive dust that is composed predominantly coarse particles.

Table 6-6. Major source types of PM_{10} emissions in the 14 BRAVO U.S. States.

Source Category	Source Type	PM_{10} (tpy)	Percent of Total Emissions
Area	Unpaved Roads	4,633,977	47%
Area	Agricultural Production – Crop Tilling	1,878,369	18%
Area	Paved Roads	826,449	8%
	All Other Sources	2,547,831	27%
	Total	**9,866,626**	**100%**

6.1.1.5 $PM_{2.5}$ Emissions

The three major sources of $PM_{2.5}$ are identical to those of PM_{10} (Table 6-7). Unpaved roads account for a smaller fraction of the total $PM_{2.5}$ emissions (28%) when compared to 47% of the total PM_{10} emissions. Combustion sources emit fine particles that are both PM_{10} and $PM_{2.5}$. While the combustion sources are not the dominant source types of PM2.5, they compose a larger fraction of the $PM_{2.5}$ emissions than the PM_{10} emissions.

Table 6-7. Major source types of $PM_{2.5}$ emissions in the 14 BRAVO U.S. States.

Source Category	Source Type	$PM_{2.5}$ (tpy)	Percent of Total Emissions
Area	Unpaved Roads	695,097	28%
Area	Agricultural Production – Crop Tilling	374,651	16%
Area	Paved Roads	206,614	8%
	All Other Sources	1,153,679	48%
	Total	**2,430,041**	**100%**

6.1.1.6 SO_2 Emissions

Table 6-8 shows the three major sources of SO_2 in the U.S. region of the BRAVO EI. Various forms of coal combustion are the three individual largest sources of SO_2.

Table 6-8. Major source types of SO_2 emissions in the 14 BRAVO U.S. States.

Source Category	Source Type	SO_2 (tpy)	Percent of Total Emissions
Point	Electric Generation Coal Combustion (with CEMs)	2,743,767	47%
Point	Electric Generation Coal Combustion (Non CEM Sources)	411,942	7%
Point	Industrial Coal Comustion	300,865	5%
	All Other Sources	2,286,537	39%
	Total	**5,743,111**	**100%**

6.1.1.7 VOC Emissions

The three largest sources of VOC's are shown in Table 6-9. On road gasoline vehicles and solvent utilization emissions are similar in total size and account for 29% and 22% of the total VOC emissions in the BRAVO U.S. region.

Table 6-9. Major source types of VOC emissions in the 14 BRAVO U.S. States.

Source Category	Source Type	VOC (tpy)	Percent of Total Emissions
Mobile	Gasoline Highway Vehicles	1,683,512	29%
Area	Solvent Utilization (Commercial and Consumer)	1,266,133	22%

Area	Gasoline Service Stations	278,364	5%
	All Other Sources	2,487,369	43%
	Total	**5,715,378**	**100%**

6.1.2 Mexico

Total emissions from each of the inventoried Mexican states are shown for each pollutant in Table 6-10. Emissions from the states of Hidalgo, Mexico, and Puebla are only partially complete and represent the emission of the major source in that state. Of the remaining 9 states, emissions from Nuevo Leon are the largest primarily due to the high population in the city of Monterrey.

Table 6-10. Sum of point, mobile, and area emissions from each Mexican State in the BRAVO EI for base year 1999.

State Name	CO (tpy)	NH_3 (tpy)	NO_x (tpy)	PM_{10} (tpy)	$PM_{2.5}$ (tpy)	SO_2 (tpy)	VOC (tpy)
Baja California Norte	854,944	13,325	73,415	152,723	42,019	67,648	185,691
Coahuila De Zaragoza	498,744	13,081	119,016	77,590	24,764	304,306	106,940
Chihuahua	1,177,321	42,588	77,667	111,965	37,610	56,673	211,723
Durango	336,442	26,793	23,547	44,047	17,191	33,173	72,901
Hidalgo*	2,198	0	46,306	20,368	10,184	322,871	12,528
Mexico**	2,593,955	0	141,511	496,775	248,387	50,014	1,128,335
Nuevo Leon	1,495,922	17,064	91,371	172,437	70,822	88,199	215,359
Puebla***	0	0	0	3,750	750	1,701,309	0
San Luis Potosi	419,150	20,262	31,038	51,275	17,811	52,159	97,063
Sinaloa	573,144	53,117	38,253	77,081	31,519	68,658	125,219
Sonora	514,892	27,166	42,892	64,167	23,114	90,546	141,935
Tamaulipas	974,120	67,013	62,938	122,710	45,571	120,122	178,435
Zacatecas	363,672	36,722	18,196	48,175	19,659	10,345	74,312

*Single source in state: Tula Industrial Park
** Single source in state: Mexico City
*** Single source in state: Popocatepetl Volcano

The following subsections describe the major source types responsible for the emissions of each chemical species in the Mexican emissions inventory. Emissions from the Tula Industrial Park and Mexico City were not categorized by individual source type in the BRAVO EI. Emissions from these two areas and the Popocatepetl Volcano were not included as part of the following analysis so that the major source types could be identified for the 10 Northern Mexican States.

6.1.2.1 CO Emissions

Major source of CO emissions in Mexican states are shown in Table 6-11. As with U.S. CO emissions, the largest source of CO is Gasoline powered on road vehicles. Crop burning can emit large amounts of both CO and particulate matter during short events throughout the year.

Table 6-11. Major source types of CO emissions in the 10 BRAVO Northern Mexico States.

Source Category	Source Type	CO (tpy)	Percent of Total Emissions
Mobile	Gasoline Highway Vehicles	6,264,995	87%
Area	Crop Burning	617,991	9%
Area	Diesel Highway Vehicles	207,988	3%
	All Other Sources	117,377	1%
	Total	**7,208,351**	**100%**

6.1.2.2 NH_3 Emissions

Table 6-12 shows the predominant emissions of ammonia in the 10 northern Mexican states. Cattle and Calve emissions are the largest source of ammonia in Mexico.

Table 6-12. Major source types of NH_3 emissions in the 10 BRAVO Northern Mexico States.

Source Category	Source Type	NH_3 (tpy)	Percent of Total Emissions
Area	Cattle and Calves	175,082	55%
Area	Fertilizer Application	118,196	37%
Area	Domestic Ammonia	20,487	6%
	All Other Sources	3,367	1%
	Total	**317,132**	**100%**

6.1.2.3 NO_x Emissions

Onroad vehicles and power production are the three largest sources of NO_x in the 10 northern Mexican states (Table 6-13). Due to plentiful oil reserves, residual oil combustion is the primary source of electric power in Mexico.

Table 6-13. Major source types of NO_x emissions in the 10 BRAVO Northern Mexico States.

Source Category	Source Type	NO_x (tpy)	Percent of Total Emissions
Mobile	Gasoline Highway Vehicles	283,632	49%
Mobile	Diesel Highway Vehicles	73,658	13%
Point	Electric Generation Residual Oil	46,949	8%
	All Other Sources	174,095	30%
	Total	**578,334**	**100%**

6.1.2.4 PM_{10} Emissions

Table 6-14 shows the three largest emitters of PM_{10}. Unpaved and paved roads are the dominant source of PM_{10}. The BRAVO Mexican EI contains emissions from crop burning but not crop tilling while BRAVO EI for the U.S. region contains both. Crop burning is the second largest source of primary PM_{10} in Mexico.

Table 6-14. Major source types of PM_{10} emissions in the 10 BRAVO Northern Mexico States.

Source Category	Source Type	PM_{10} (tpy)	Percent of Total Emissions
Area	Unpaved Roads	538,240	58%
Area	Agricultural Production – Crop Burning	92,451	10%
Area	Paved Roads	62,150	7%
	All Other Sources	229,329	25%
	Total	**922,170**	**100%**

6.1.2.5 $PM_{2.5}$ Emissions

Major sources of $PM_{2.5}$ emissions in Mexico are shown in Table 6-15. The top three major sources of $PM_{2.5}$ are the same as the top three sources of PM_{10}. Crop burning accounts for a larger fraction of the total $PM_{2.5}$ emissions because it is a combustion source that is composed of fine particles less than 2.5 micron.

Table 6-15. Major source types of $PM_{2.5}$ emissions in the 10 BRAVO Northern Mexico States.

Source Category	Source Type	$PM_{2.5}$ (tpy)	Percent of Total Emissions
Area	Unpaved Roads	114,115	35%
Area	Agricultural Production – Crop Burning	88,164	27%
Area	Paved Roads	10,494	3%
	All Other Sources	117,307	36%
	Total	**330,080**	**100%**

6.1.2.6 SO_2 Emissions

The major sources of SO_2 in northern Mexico are shown in Table 6-16. As in the U.S. power production is the largest sources of SO_2. Since the fuel oil used in the majority of Mexican power plants contains some sulfur, this is the largest source of SO_2 in the region. Emissions from coal combustion at the Carbon I/II power plant are the second largest source of SO_2.

Table 6-16. Major source types of SO_2 emissions in the 10 BRAVO Northern Mexico States.

Source Category	Source Type	SO_2 (tpy)	Percent of Total Emissions
Point	Electric Generation Residual Oil	313,660	35%
Point	Electric Generation Coal Combustion	266,619	30%
Point	Commercial/Institutional Power Production	134,265	15%
	All Other Sources	177,284	20%
	Total	**891,828**	**100%**

6.1.2.7 VOC Emissions

The major sources of VOC emissions in Mexico are identical to those in the U.S. (Table 6-17). The petroleum storage source includes gasoline station emissions. Gasoline highway vehicles account for 50% of the total VOC emissions.

Table 6-17. Major source types of VOC emissions in the 10 BRAVO Northern Mexico States.

Source Category	Source Type	VOC (tpy)	Percent of Total Emissions
Mobile	Gasoline Highway Vehicles	698,929	50%
Area	Petroleum Storage	145,317	10%
Area	Solvent Utilization (Consumer)	112,262	8%
	All Other Sources	450,071	32%
	Total	**1,406,579**	**100%**

6.1.3 Gulf of Mexico

Major pollution emitting activities in the Gulf of Mexico differ greatly from the dominant sources of pollutants onshore. The primary sources of pollution offshore are associated with oil extraction and platform operations. Emissions of all pollutants from natural gas flares is likely to be underestimated since only VOC emissions were reported for the majority of flares.

6.1.3.1 CO Emissions

The major source of CO in the Gulf of Mexico are the natural gas engines used to power the platform operations (Table 6-18). CO forms when hydrocarbon fuels are incompletely combusted to CO_2.

Table 6-18. Major source types of CO emissions in the Gulf of Mexico.

Source Category	Source Type	CO (tpy)	Percent of Total Emissions
Point	Reciprocating Natural Gas Engines	17,734	81%
Point	Natural Gas Turbines	2,720	12%
Point	Gas Flares	567	3%
	All Other Sources	864	4%
	Total	21,885	100%

6.1.3.2 NO_x Emissions

The major sources of offshore NOx emissions are shown in Table 6-19. Natural gas combustion on the platforms is the largest source of inventoried NO_x in the Gulf of Mexico.

Table 6-19. Major source types of NO_x emissions in the Gulf of Mexico.

Source Category	Source Type	NO_x (tpy)	Percent of Total Emissions
Point	Reciprocating Natural Gas Engines	81,521	87%
Point	Natural Gas Turbines	5,394	6%
Point	Natural Gas Boilers	3,432	4%
	All Other Sources	2,888	3%
	Total	93,235	100%

6.1.3.3 PM_{10} Emissions

Table 6-20 shows the three largest sources of inventoried PM_{10} in the Gulf of Mexico. Power production for the platforms is the largest source of PM_{10}.

Table 6-20. Major source types of PM_{10} emissions in the Gulf of Mexico.

Source Category	Source Type	PM_{10} (tpy)	Percent of Total Emissions
Point	Reciprocating Natural Gas Engines	1,001	58%
Point	Natural Gas Turbines	529	31%
Point	Reciprocating Diesel Engines	156	9%
	All Other Sources	40	2%
	Total	1,725	100%

6.1.3.4 $PM_{2.5}$ Emissions

The largest sources of offshore $PM_{2.5}$ emissions are shown in Table 6-21. Because emissions from PM_{10} sources were assumed to be 92% $PM_{2.5}$, the relative contribution of $PM_{2.5}$ emissions is identical to PM_{10}.

Table 6-21. Major source types of $PM_{2.5}$ emissions in the Gulf of Mexico.

Source Category	Source Type	$PM_{2.5}$ (tpy)	Percent of Total Emissions
Point	Reciprocating Natural Gas Engines	921	58%
Point	Natural Gas Turbines	486	31%
Point	Reciprocating Diesel Engines	143	9%
	All Other Sources	37	2%
	Total	1,587	100%

6.1.3.5 SO_2 Emissions

Inventoried emissions of SO_2 from offshore activities are quite small and associated with power production on the platforms (Table 6-22).

Table 6-22. Major source types of SO_2 emissions in the Gulf of Mexico.

Source Category	Source Type	SO_2 (tpy)	Percent of Total Emissions
Point	Reciprocating Natural Gas Engines	145	79%
Point	Natural Gas Turbines	18	10%
Point	Reciprocating Diesel Engines	9	5%
	All Other Sources	11	6%
	Total	182	100%

6.1.3.6 VOC Emissions

Table 6-23 shows the three largest sources of VOC's emissions in the Gulf of Mexico. Gas vents of uncombusted natural gas are largest sources of VOC's accounting for 82% of the inventoried emissions.

Table 6-23. Major source types of VOC emissions in the Gulf of Mexico.

Source Category	Source Type	VOC (tpy)	Percent of Total Emissions
Point	Gas Vents	229,121	82%
Point	Tank Breathing	37,185	13%
Point	Reciprocating Natural Gas Engines	10,532	4%
	All Other Sources	1,332	0%
	Total	278,170	100%

6.2 Gridded Emissions Visualizations

The BRAVO EI was integrated into a single spatial coverage using the ARCGIS program with dynamic linking to the emissions inventory database. Emissions from area and mobile sources were resolved at the county and municipio level only. These data were gridded to 0.5 by 0.5 degree grid cells by weighting the emissions from a county by the fraction of its area within each grid cell. Point sources emissions were linked with the grid cell where they reside. Emissions from point, area, and mobile sources were then summed for each grid cell. The resulting total emissions were mapped using the ARC Scene 3-D map Viewer and are shown in Figure 6-1 through Figure 6-7 below. The figures show the relative strengths of emissions over a large spatial area. This visualization facilitates identification of the largest sources of emissions close to Big Bend National Park (shown as the black area in southwestern Texas).

CO emissions are mapped in Figure 6-1. As discussed above, most of the CO emissions in the inventory domain are due to on road mobile sources. The figures shows that most CO emissions are focused in metropolitan areas where vehicle travel is greatest. In contrast, NH_3 emissions are primarily associated with cattle production that typically occurs in rural areas. Figure 6-2 shows that ammonia emissions are more uniformly distributed across the region. Areas that receive low rainfall (e.g. West Texas, Northern Arizona, and Northern New Mexico) are not productive graze lands and therefore have low NH_3 emissions. Large NH_3 emissions in Louisiana and Mississippi are associated with point sources manufacturing ammonia and urea.

Figure 6-3 is a map of NO_x emissions. NO_x is primarily emitted by on road motor vehicles and power plants. The spatial distribution of NOx emissions is similar to that of CO, except for the presence of power plants sited in non-urban locations. The Carbon I/II power facility located ~200 km southeast of Big Bend National Park is an example of a large point source that dominates the emissions from a single grid cell.

PM_{10} and $PM_{2.5}$ emissions (Figure 6-4 and Figure 6-5, respectively) are predominantly due to paved and unpaved road emissions and agricultural activity. In the U.S., particulate emissions are smoothly distributed across counties with moderate to high population. Areas with low population density may still have substantial PM emissions due to unpaved roads. In Mexico, all road dust emissions are estimated based on the number of registered vehicles within a municipio. As a result, PM emissions are focused around major metropolitan areas. The distribution of PM emissions in Mexico is not as smooth as in the U.S.

Figure 6-6 shows the gridded emissions of SO_2 in the BRAVO inventory domain. SO_2 is emitted primarily from point sources and had a distinctly different spatial distribution than all other species. The largest source of SO_2 shown on the map is the Popocatepetl Volcano south east of Mexico City. Other important source areas include: the Tula industrial facility north of

Mexico City; the Carbon I/II power plants south west of Big Bend; Power plants in north east Texas; and power plants in the Midwestern U.S.

VOC emissions are associated the large number of motor vehicles registered in Monterrey and Mexico City (Figure 6-7). In the U.S., VOC emissions are more uniformly distributed across the more densely populated eastern states.

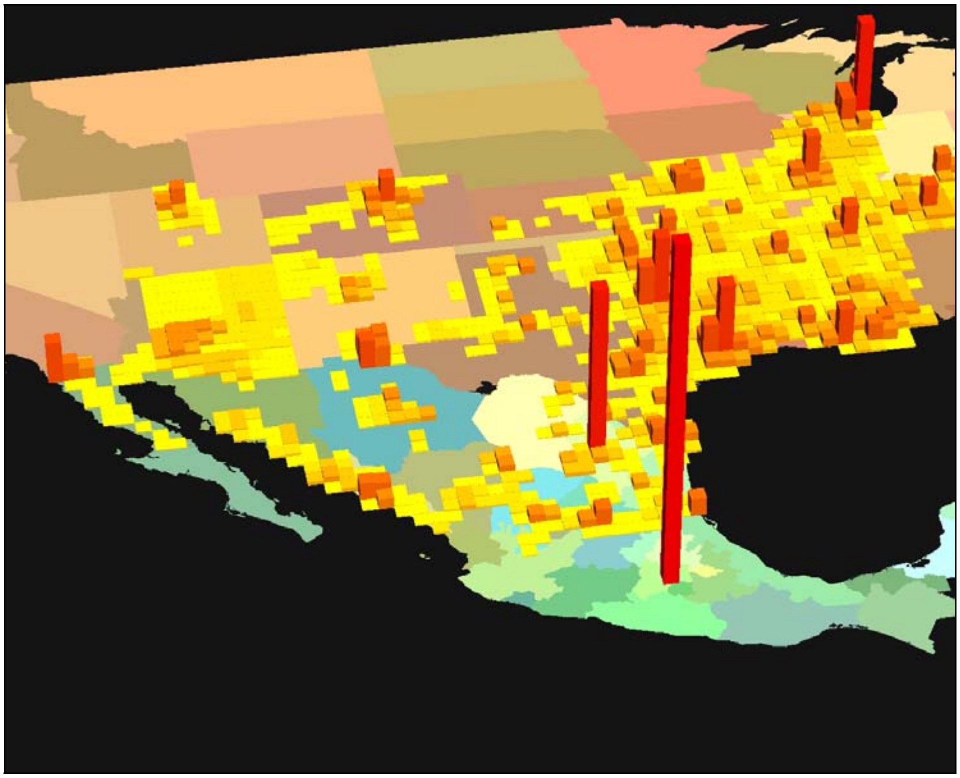


Figure 6-1. Gridded carbon monoxide emissions for the BRAVO EI base year 1999. Each grid cell is 0.5 degrees by 0.5 degrees.

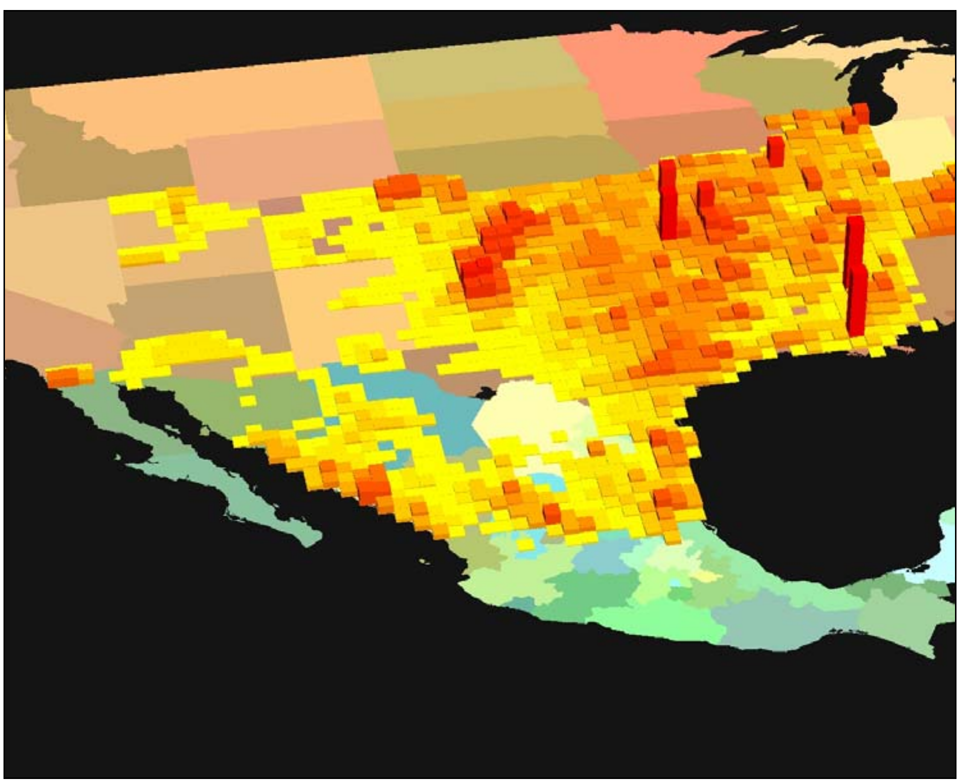


Figure 6-2. Gridded ammonia emissions for the BRAVO EI base year 1999. Each grid cell is 0.5 degrees by 0.5 degrees. Biogenic emissions from plant respiration are not shown.

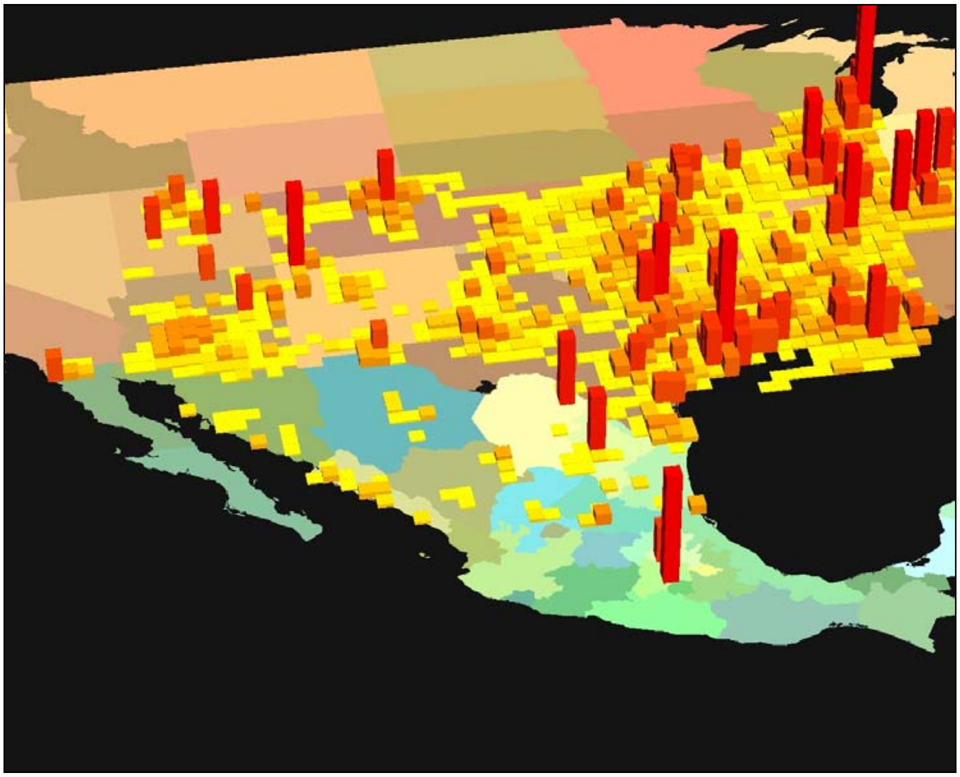


Figure 6-3. Gridded nitrogen oxide emissions for the BRAVO EI base year 1999. Each grid cell is 0.5 degrees by 0.5 degrees.

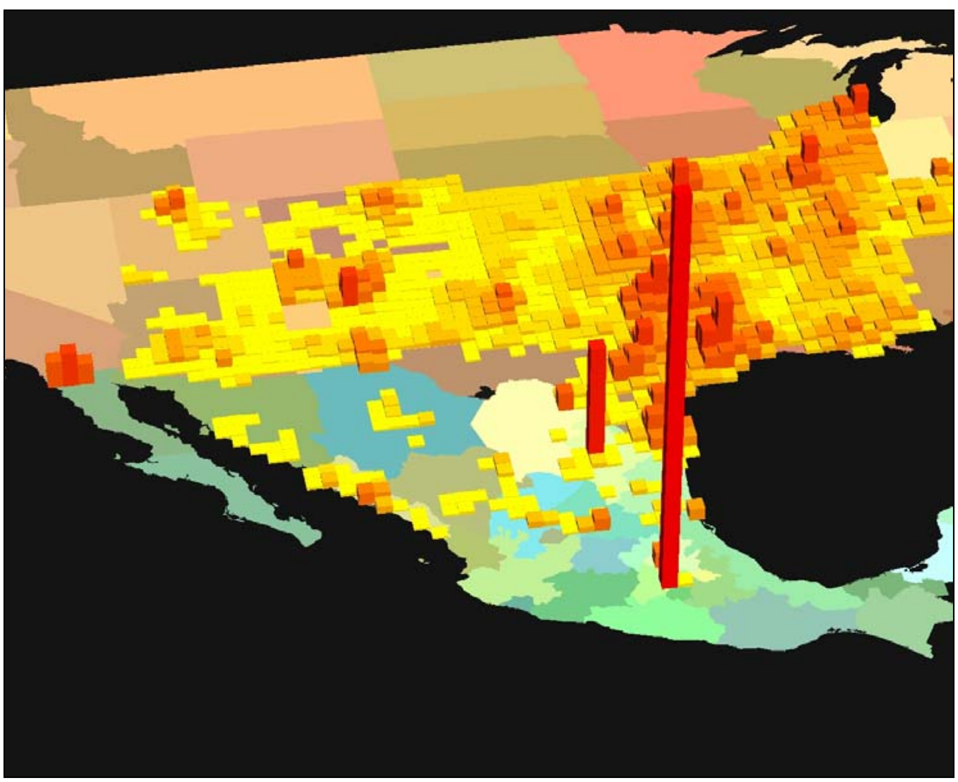


Figure 6-4. Gridded PM_{10} emissions for the BRAVO EI base year 1999. Each grid cell is 0.5 degrees by 0.5 degrees.

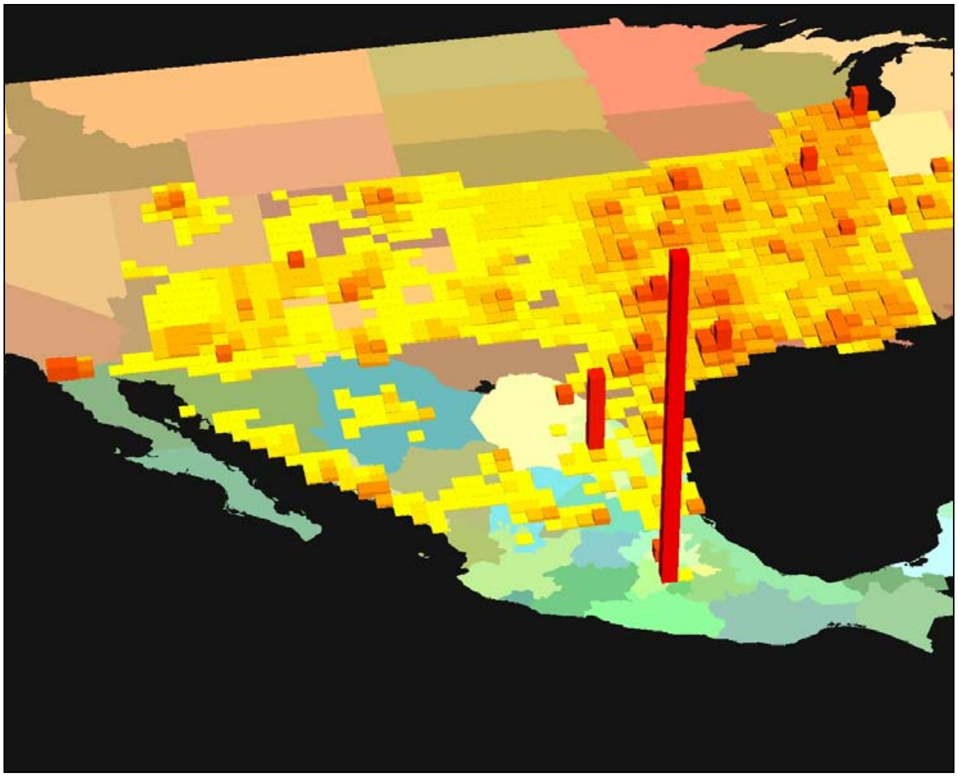


Figure 6-5. Gridded $PM_{2.5}$ emissions for the BRAVO EI base year 1999. Each grid cell is 0.5 degrees by 0.5 degrees.

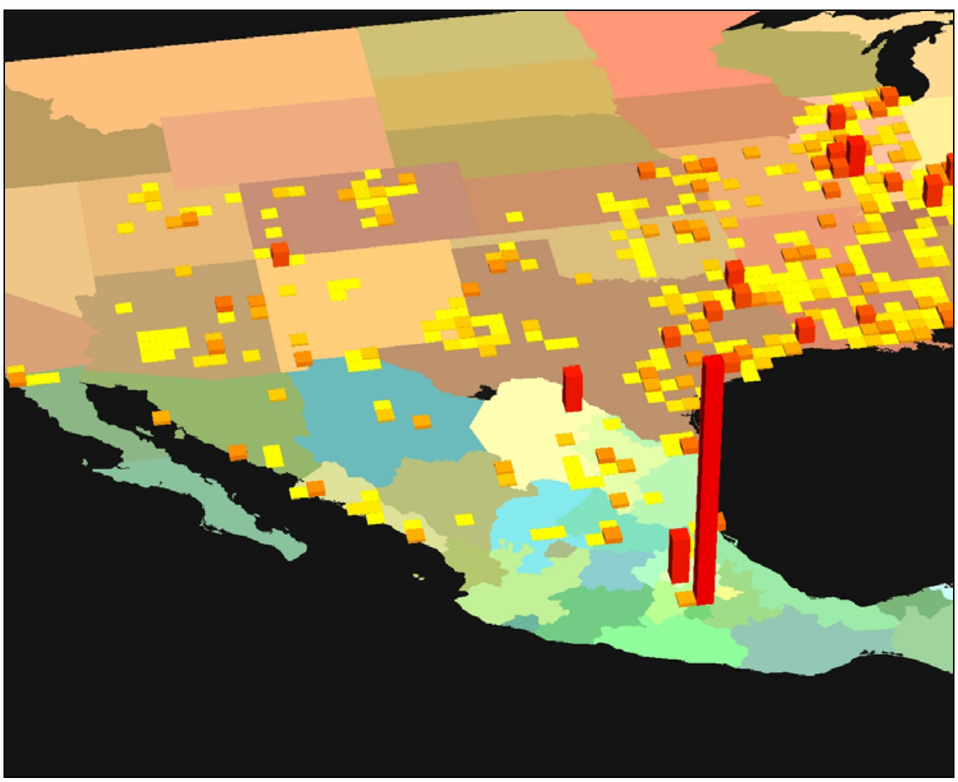


Figure 6-6. Gridded sulfur dioxide emissions for the BRAVO EI base year 1999. Each grid cell is 0.5 degrees by 0.5 degrees.

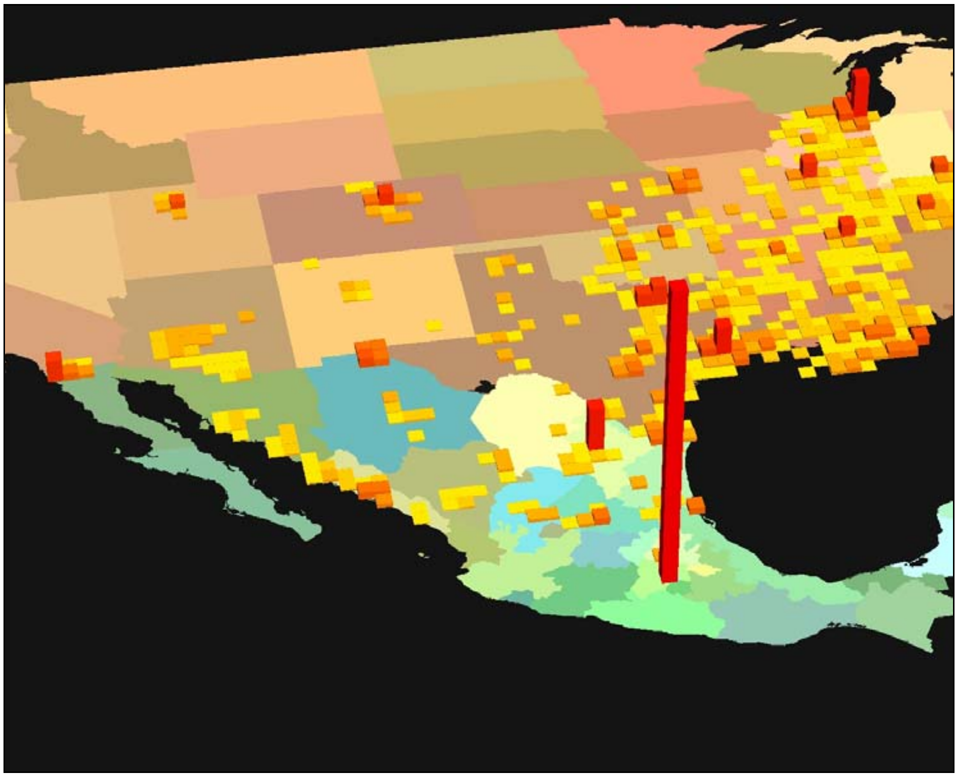


Figure 6-7. Gridded volatile organic carbon emissions for the BRAVO EI base year 1999. Each grid cell is 0.5 degrees by 0.5 degrees.

7. CONCLUSIONS

The BRAVO EI has been assembled from a large number of data sources and covers 14 states in the U.S., 10 states in Mexico, and offshore platforms in the Gulf of Mexico. The emissions inventory for Mexico is the first regional scale inventory for this area. Inventoried species include CO, NH_3, NO_x, PM_{10}, $PM_{2.5}$, SO_2, and VOC.

Offshore emissions are less than 1% of the total emissions of all species with the exception of VOC's that account for ~3% of the total emissions. Emissions data from continuous emissions monitors on major power plants in the U.S. were include in the BRAVO EI.

Major emissions sources types in Mexico are similar to those in the U.S. On and off road motor vehicles are the largest sources of CO, NOx, and VOC's in both countries. Primary particulate emissions of both PM_{10} and $PM_{2.5}$ are due to unpaved road and paved road travel in both countries. Crop tilling is the second largest emitter of PM in the U.S. In Mexico, crop tillng is not inventoried but crop burning is the second largest source of PM.

Cattle husbandry is the largest source of NH_3 in both countries. Biogenic NH_3 emissions from plant respiration were not inventoried although estimates for the state of Texas indicate that ~50% of the total NH_3 may be biogenic. Both sources place the majority of NH_3 emissions in areas with sufficient rainfall to support forests or graze lands.

SO_2 emissions are predominantly associated with point sources in both countries. The largest SO_2 source in the inventory domain is the Popocatepetl Volcano that emits ~1.4 million tons of SO_2 per year (4 times larger than the next largest SO_2 source). Other important SO_2 sources include: the Tula industrial facility north of Mexico City; the Carbon I/II power plants south west of Big Bend; Power plants in north east Texas; and power plants in the Midwestern U.S.

The inventory was integrated in to a common data format to be process using the SMOKE emissions processor. The output of SMOKE will be input into the CMAQ and REMSAD air quality simulation models. In turn, these models will be used to assess the major emissions sources and chemical mechanisms that determine visual air quality in Big Bend National Park.

8. RECOMMENDATIONS

Emissions inventories are living databases. Over time emissions estimates evolve based on (1) real changes in human activities and emissions and (2) improvements in emissions estimation techniques. A list of recommendations is provided here as a basis for the improvement of future emissions inventories in the U.S./Mexico Border Region.

- Biogenic ammonia emissions should be calculated for the entire inventory domain based on land used databases. At present, the BRAVO EI does not account for biogenic ammonia emissions and is likely to underestimate the total ammonia emissions by 50%.
- Fugitive dust emissions are among the most uncertain sources in the BRAVO EI. Windblown dust emissions are estimated on an annual basis for Mexico, but are not included in the U.S. region of the emissions inventory. Improved methods of estimating large-scale fugitive dust emissions from natural and disturbed lands are needed. Due to the intermittent nature of these emissions, it is recommended that they be modeled with the emissions processor based on land use/soil type data and meteorological conditions including wind speed and time since last rain fall.
- Biomass burning emissions estimation is improving throughout the United States as regional fire offices are keeping improved GIS databases of the size, date, and duration of fires. Record keeping in the state of Texas should be improved to account for prescribed and wild fires on both public and private lands.
- Improved emissions for Mexico are needed in the following areas:
    - Agricultural activity. The BRAVO EI accounts for agricultural burning, but does not consider particulate emissions from tilling. Emissions factors based on U.S. activities may not be appropriate for Mexican emissions since the two nations may use different agricultural practices.
    - Mobile exhaust emissions. The BRAVO EI bases on road mobile emissions from exhaust on the total number of registered vehicles. Errors in the inventory may arise from a large number of unregistered vehicles. Emissions based on fuel sales in the various municipios are likely to be more accurate since fuels sales are taxed and therefore are well documented.
    - Paved and unpaved road emissions. This is the dominant source of PM_{10} and $PM_{2.5}$ emissions. Emissions are calculated from the total number of registered vehicles. This method is prone to error since areas with large numbers of registered vehicles tend to be urbanized and have much less paved roads. Future inventories were benefit if emissions were assigned to roadway segments based on road type, length, and average daily travel. At the time of preparation of this emissions inventory, such a roadway database for all of Mexico was not readily available.
    - Point source emissions of all species need to be calculated for each facility with emissions greater than 100 tons per year. The current inventory has a limited number of point sources. The relative completeness of this collection of sources

is unknown. An improved EI based on facility permits is needed for all major point sources in Mexico.

  - Biomass burning emissions should be inventoried at the national level for both prescribed and wild fires. Given the large resources need to effectively accomplish this task, alternative estimation techniques may be more cost effective. Remote sensing using satellite imagery should be investigated as a means of improving biomass-burning emissions for all of North America. This technique could be calibrated for regions in the U.S. that have adequate prescribed and wild fire records and then applied to the entire inventory domain.

- The major shortcoming of the offshore emissions is the emissions from flaring operations. Improved emissions should be estimated based on the quantity of gas flared and accurate emissions factors for all species from flaring activities.

9. REFERENCES

Acosta, G. (2001). Personal communication between Gildardo Acosta (Acosta y Asociados, Agua Prieta, Sonora, Mexico) and Hampden Kuhns (DRI). July 12-July 17, 2001.

ARB, 1999. PM size fractions from the California Emission Inventory Development and Reporting System (CEIDARS). Internet address – http://arbis.arb.gov/emisinv/speciate/PMSIZEFRList.htm. Last updated March 24, 1999; accessed November 13, 2000.

Baker, R. (2000) Development of a revised emissions inventory for construction equipment in the Houston-Galveston Ozone Non-attainment Area. Draft report prepared by Eastern Research Group for the Houston-Galveston Area Council and the TNRCC Area and Mobile Source Emissions Assessment Section, March 20, 2000.

Brown, M. (1998) MMS OCS Activity Database, Version 3 (MOAD3), Addendum to "User's Guide: Minerals Management Service Outer Continental Shelf Activity Database (MOAD). OCS Study MMS 94-0018." U.S. Department of Interior, Minerals Management Service, Gulf of Mexico OCS Regional Office, New Orleans.

Corsi, R.; V. Torres; G. Carter; S. Dombrowski; M. Dondelle; S. Fredenberg; S. Takahama; and T. Taylor (2000) Nonpoint Source Ammonia Emissions in Texas: A First Estimate, Draft report prepared for the Texas Natural Resources Conservation Commission by the University of Texas Austin, February 22, 2000.

Delgado H. (2001) Personal communication between H. Delgado (Instituto del Geofisica, Universidad Nacional Autonoma de Mexico) and Hampden Kuhns (DRI), May 18, 2001.

Environ (1998) User's guide for the National Nonroad Emissions Model. Prepared by Environ International Corporation, Novato, CA 94945. Prepared for U.S. E.P.A. National Vehicle and Fuel Emissions Laboratory, Ann Arbor, MI 48105.

Galindo, I.; L. Ivlev; A. Gonzalez; and R. Ayala (1998) Airborne measurements of particle and gas emissions from the December 1994-January 1995 eruption of Popocatepetl volcano (Mexico). *J. of Volcanology and Geothermal Research* **83**, 197-217.

GBC et al. (1999) *Programa para Mejorar la Calidad del Aire de Mexicali 2000-2005*. Gobierno del Estado de Baja California; Gobierno Municipal de Mexicali; Secretaría de Medio Ambiente, Recursos Naturales y Pesca; and Secretaría de Salud. December.

GBC et al. (2000) *Programa para Mejorar la Calidad del Aire Tijuana Rosarito 2000-2005*. Gobierno del Estado de Baja California, Gobierno Municipal de Tijuana, Gobierno Municipal de Playas de Rosarito, Gobierno Municipal de Juárez; Secretaría de Medio Ambiente, Recursos Naturales y Pesca; and Secretaría de Salud. August.

GCh et al., (1998) *Programa de Gestión de la Calidad del Aire de Ciudad Juárez 1998-2002*. Gobierno del Estado de Chihuahua; Gobierno Municipal de Juárez; Secretaría de Medio Ambiente, Recursos Naturales y Pesca; and Secretaría de Salud. May 15.

Goff F.; J. Cathy; H. Delgado; C. Werner; D. Counce; J. Stimac; C. Siebe; S. Love; S. Williams; T. Fischer; and L. Johnson (1998) Geochemical surveillance of magmatic volatiles at Popocatepetl volcano, Mexico. *GSA Bulletin* **110**, 695-710.

INE (2001) Inventarios por ciudad. http://www.ine.gob.mx/dggia/cal_aire/espanol/invent.html

INEGI (1994) Sector Agropecuario. Resultados Definitivos. Censo Agrícola, Ganadero y Ejidal, 1991. Instituto Nacional de Estadística, Geografía e Informática (INEGI). Internet address – http://www.inegi.gob.mx/.

INEGI (1999) Cencos Economico 1999. Report prepared by Instituto Nacional de Estadística, Geografía e Informática (INEGI). Internet address – http://www.inegi.gob.mx/.

INEGI (2000) XII Censo General de Población y Vivienda 2000, Circulación, Sistema Municipal de Bases de Datos (SIMBAD). Instituto Nacional de Estadística, Geografía e Informática (INEGI). Internet address – http://www.inegi.gob.mx/.

Ortiz, E. (1997) Personal communications with Hampden Kuhns (DRI) and Enrique Ortiz (University of Monterrey) October 22, 1997.

P&BE (1999a) Technical Basis for Appendices to Annex IV of the La Paz Agreement. Prepared for the U.S.-Mexico Border Information Center on Air Pollution (Centro Información sobre Contaminación de Aire) (CICA) by Powers Engineering, Escondido, California and Border Ecology Project, Bisbee, Arizona. October 25. Internet address – http://www.epa.gov/ttn/catc/dir2/lapaz_e.pdf.

P&BE (1999b) Technical Basis for Appendices to Annex IV of the La Paz Agreement, Appendices A-J. Prepared for the U.S.-Mexico Border Information Center on Air Pollution (Centro Información sobre Contaminación de Aire) (CICA) by Powers Engineering, Escondido, California and Border Ecology Project, Bisbee, Arizona. October 25. Internet address – http://www.epa.gov/ttn/catc/dir2/lapaz_ap.pdf.

Peuler, E. (2000) Personal communications with Hampden Kuhns (DRI) and Elizabeth Peuler (Minerals Management Service, New Orleans, Louisiana) December, 2000.

SAGAR (1999) Anuario Estadístico de la Producción Agrícola de los Estados Unidos Mexicanos, 1999. Internet address – http://hda-sagar.sagar.gob.mx/

SAI (1998) User's Guide to the Regulatory Modeling System for Aerosols and Deposition (REMSAD). Report prepared by Systems Applications International, San Rafael, CA.

Seaman, N.L. and R.A. Anthes (1981) A mesoscale semi-implicit numerical model. *Quart. J. Roy. Meteor. Soc.* 107, 167-190.

Siebe, C; M. Abrhams, J. Macias; and J. Obenholper (1996) Repeated volcanic disasters in Prehispanic time at Popocatepetl, central Mexico: Past key to the future. *Geology* **24**, 399-402.

Smithsonian Institute (2000) Popocatepetl Volcanic Acitivity Report for May 1998 – Current. http://www.volcano.si.edu/gvp/volcano/region14/mexico/popo/var_03.htm.

Stauffer, D.R. and N.L. Seaman, (1994) Multiscale four-dimensional data assimilation. J. Appl. Meteor., **33**, 416-434.

Steiner, C; M. Causley; and M. Yocke (1994) User's Guide: Minerals Management Service Outer Continental Shelf Activity Database (MOAD). OCS Study MMS 94-0000. U.S.

Department of Interior, Minerals Management Service, Gulf of Mexico OCS Regional Office, New Orleans (14 pp).

Starcrest (2000) Houston-Galveston Area Vessel Emissions Inventory. Report prepared by Starcrest Consulting Group, LLC., Houston, TX. Prepared for Port Authority of Houston and the Texas Natural Resources Conservation Commission.

U.S. E.P.A. (1998) AP42 Emissions Factors Report. Section 1.3 External Combustion Sources Fuel Oil Combustion and Section 1.4 External Combustion Sources Natural Gas Combustion. U.S. E.P.A. Emissions Factor Inventory Group, Research Triangle Park, North Carolina.

U.S. E.P.A. (2000) AP42 Emissions Factors Report. Section 3.1 Internal Combustion Sources Stationary Gas Turbines. U.S. E.P.A. Emissions Factor Inventory Group, Research Triangle Park, North Carolina.

Watson J. (1998) Personal communications between John Watson (DRI) and staff of PROFEPA, Mexico. Map and list of SO_2 sources in Northern Mexico.

Wolf, M. and P. Fields (2001) Methodology and Results of an Emissions Inventory for Northwestern Mexico. Technical memorandum prepared by Eastern Research Group for Mark Seger (Pacific Environmental Systems), February 5, 2001.

World Bank (2001) New Ideas in Pollution Regulation. Internet address: http://www.worldbank.org/nipr/index.htm

Yarbrough (2000) Personal communication between Jim Yarbrough (U.S. EPA Region VI) and Paula Fields (ERG). October 23.

10.APPENDIX A.

Table 10-1. Hydrocarbon emissions factors for Mexican mobile and area sources

Type	Category	AMS Code	Overall (1996) HC (per unit)	Method of Calculation	Overall (w/Monterrey) HC (per unit)	Method of Calculation	Units
Area	Agricultural Burning	2801500000	11.70	Mxcl only			kg/hectare
Area	Architectural Surface Coatings	2401001000	2.12	Avg. CJ/Mxcl/Tij	1.92	Avg. CJ/Mxcl/Tij/Mon	kg/person
Area	Asphalt Paving	2461021000	2.75	Avg. Mxcl/Tij	1.86	Avg. Mxcl/Tij/Mon	kg/person
Area	Automobile Painting	2401005000	0.66	Avg. CJ/Mxcl/Tij	0.59	Avg. CJ/Mxcl/Tij/Mon	kg/person
Area	Bakeries	2302050000	0.14	Avg. CJ/Mxcl/Tij	0.17	Avg. CJ/Mxcl/Tij/Mon	kg/person
Area	Charbroiling	2302002000	0.05	Avg. Mxcl/Tij			kg/person
Area	Commercial/Institutional Combustion	2103000000	0.01	Avg. CJ/Mxcl/Tij	0.01	Avg. CJ/Mxcl/Tij/Mon	kg/person
Area	Dry Cleaning	2420000000	0.61	Avg. CJ/Mxcl/Tij	0.64	Avg. CJ/Mxcl/Tij/Mon	kg/person
Area	Fuel Storage and Distribution	2501000000	2.13	Avg. CJ/Mxcl/Tij	2.22	Avg. CJ/Mxcl/Tij/Mon	kg/person
Area	Graphic Arts	2425000000	0.59	Avg. Mxcl/Tij			kg/person
Area	Marketing and Distribution of LPG	2505000000	22.13	Avg. CJ/Mxcl/Tij	18.79	Avg. CJ/Mxcl/Tij/Mon	kg/household
Area	Municipal Waste Burning	2601000000	0.30	Mxcl only			kg/person
Area	Other Non-road Mobile Sources	2270000000	0.11	Mxcl only			kg/person
Area	Pesticide Application	2461850000	3.52	Mxcl only			kg/hectare
Area	Residential Combustion	2104000000	0.08	Avg. CJ/Mxcl/Tij	0.07	Avg. CJ/Mxcl/Tij/Mon	kg/household
Area	Solvent Consumption	2465000000	4.49	Avg. CJ/Mxcl/Tij	4.32	Avg. CJ/Mxcl/Tij/Mon	kg/person
Area	Structural Fires	2810030000	0.02	Avg. Mxcl/Tij			kg/household
Area	Traffic Painting	2401008000	0.04	Avg. CJ/Mxcl/Tij	0.08	Avg. CJ/Mxcl/Tij/Mon	kg/person
Area	Washing and Degreasing	2415000000	2.40	Avg. CJ/Mxcl/Tij	2.22	Avg. CJ/Mxcl/Tij/Mon	kg/person
Area	Wastewater Treatment	2630000000	0.09	Avg. Mxcl/Tij			kg/person
Motor Vehicle	Heavy-Duty Diesel Vehicle	2230070000	2.39	Avg. CJ/Mxcl/Tij	6.98	Avg. CJ/Mxcl/Tij/Mon	kg/vehicle
Motor Vehicle	Heavy-Duty Gas Vehicle	2201070000	6.66	Avg. Mxcl/Tij			kg/vehicle
Motor Vehicle	Light-Duty Diesel Truck	2230060000	0.07	CJ only			kg/vehicle
Motor Vehicle	Light-Duty Gas Truck	2201060000	26.58	Avg. CJ/Mxcl/Tij	32.58	Avg. CJ/Mxcl/Tij/Mon	kg/vehicle
Motor Vehicle	Light-Duty Gas Vehicle	2201001000	90.79	Avg. CJ/Mxcl/Tij	90.77	Avg. CJ/Mxcl/Tij/Mon	kg/vehicle
Motor Vehicle	Motorcycles	2201080000	0.78	Avg. Mxcl/Tij	0.70	Avg. Mxcl/Tij/Mon	kg/vehicle

Table 10-2. Nitrogen oxide emissions factors for Mexican mobile and area sources

Type	Category	AMS Code	Overall (1996) NOx (per unit)	Method of Calculation	Overall (w/Monterrey) NOx (per unit)	Method of Calculation	Units
Area	Commercial/Institutional Combustion	2103000000	0.30	Avg. CJ/Mxcl/Tij	0.23	Avg. CJ/Mxcl/Tij/Mon	kg/person
Area	Fuel Storage and Distribution	2501000000	0.00	Tij only			kg/person
Area	Municipal Waste Burning	2601000000	0.06	Mxcl only			kg/person
Area	Other Non-road Mobile Sources	2270000000	0.45	Mxcl only			kg/person
Area	Residential Combustion	2104000000	1.60	Avg. CJ/Mxcl/Tij	1.36	Avg. CJ/Mxcl/Tij/Mon	kg/household
Area	Structural Fires	2810030000	0.01	Mxcl only			kg/household
Area	Traffic Painting	2401008000	0.00	Tij only			kg/person
Motor Vehicle	Heavy-Duty Diesel Vehicle	2230070000	14.44	Avg. CJ/Mxcl/Tij	12.96	Avg. CJ/Mxcl/Tij/Mon	kg/vehicle
Motor Vehicle	Heavy-Duty Gas Vehicle	2201070000	3.12	Avg. Mxcl/Tij			kg/vehicle
Motor Vehicle	Light-Duty Diesel Truck	2230060000	0.43	CJ only			kg/vehicle
Motor Vehicle	Light-Duty Gas Truck	2201060000	10.06	Avg. CJ/Mxcl/Tij	12.74	Avg. CJ/Mxcl/Tij/Mon	kg/vehicle
Motor Vehicle	Light-Duty Gas Vehicle	2201001000	36.67	Avg. CJ/Mxcl/Tij	36.82	Avg. CJ/Mxcl/Tij/Mon	kg/vehicle
Motor Vehicle	Motorcycles	2201080000	0.07	Avg. Mxcl/Tij	0.12	Avg. CJ/Mxcl/Tij/Mon	kg/vehicle

Table 10-3. Carbon monoxide emissions factors for Mexican mobile and area sources

Type	Category	AMS Code	Overall (1996) CO (per unit)	Method of Calculation	Overall (w/Monterrey) CO (per unit)	Method of Calculation	Units
Area	Agricultural Burning	2801500000	86.01	Mxcl only			kg/hectare
Area	Commercial/Institutional Combustion	2103000000	0.05	Avg. CJ/Mxcl/Tij			kg/person
Area	Fuel Storage and Distribution	2501000000	0.00	Tij only			kg/person
Area	Municipal Waste Burning	2601000000	0.84	Mxcl only			kg/person
Area	Other Non-road Mobile Sources	2270000000	0.73	Mxcl only			kg/person
Area	Residential Combustion	2104000000	0.39	Avg. CJ/Mxcl/Tij	0.29	Avg. CJ/Mxcl/Tij/Mon	kg/household
Area	Structural Fires	2810030000	0.24	Avg. Mxcl/Tij			kg/household
Motor Vehicle	Heavy-Duty Diesel Vehicle	2230070000	9.74	Avg. CJ/Mxcl/Tij	63.79	Avg. CJ/Mxcl/Tij/Mon	kg/vehicle
Motor Vehicle	Heavy-Duty Gas Vehicle	2201070000	65.60	Avg. Mxcl/Tij			kg/vehicle
Motor Vehicle	Light-Duty Diesel Truck	2230060000	0.29	CJ only			kg/vehicle
Motor Vehicle	Light-Duty Gas Truck	2201060000	202.84	Avg. CJ/Mxcl/Tij	289.75	Avg. CJ/Mxcl/Tij/Mon	kg/vehicle
Motor Vehicle	Light-Duty Gas Vehicle	2201001000	731.72	Avg. CJ/Mxcl/Tij	795.62	Avg. CJ/Mxcl/Tij/Mon	kg/vehicle
Motor Vehicle	Motorcycles	2201080000	2.29	Avg. Mxcl/Tij	3.52	Avg. Mxcl/Tij/Mon	kg/vehicle

Table 10-4 Sulfur dioxide emissions factors for Mexican mobile and area sources

Type	Category	AMS Code	Overall (1996) SO2 (per unit)	Method of Calculation	Overall (w/Monterrey) SO2 (per unit)	Method of Calculation	Units
Area	Commercial/Institutional Combustion	2103000000	6.40	Tij only			kg/person
Area	Municipal Waste Burning	2601000000	0.01	Mxcl only			kg/person
Area	Residential Combustion	2104000000	0.14	Avg. CJ/Mxcl			kg/household
Motor Vehicle	Heavy-Duty Diesel Vehicle	2230070000	0.23	Avg. CJ/Mxcl/Tij	0.52	Avg. CJ/Mxcl/Tij/Mon	kg/vehicle
Motor Vehicle	Heavy-Duty Gas Vehicle	2201070000	0.14	Avg. Mxcl/Tij			kg/vehicle
Motor Vehicle	Light-Duty Diesel Truck	2230060000	0.01	CJ only			kg/vehicle
Motor Vehicle	Light-Duty Gas Truck	2201060000	0.71	Avg. CJ/Mxcl/Tij	0.84	Avg. CJ/Mxcl/Tij/Mon	kg/vehicle
Motor Vehicle	Light-Duty Gas Vehicle	2201001000	2.51	Avg. CJ/Mxcl/Tij	2.44	Avg. CJ/Mxcl/Tij/Mon	kg/vehicle
Motor Vehicle	Motorcycles	2201080000	0.02	Avg. Mxcl/Tij	0.02	Avg. Mxcl/Tij/Mon	kg/vehicle

Table 10-5. Ammonia emissions factors for Mexican mobile and area sources

Type	Category	AMS Code	Fictional AMS	Overall (1996) NH3 (per unit)	Method of Calculation	Units
Area	Domestic Ammonia	2845000000	x	0.79	Avg. Mxcl/Tij	kg/person
Area	Fertilizer Application (Ammonia)	2801700000	x	16.48	Mxcl only	kg/hectare
Area	Livestock (Ammonia)	2805000000		24.59	Avg. Mxcl/Tij	kg/head

Table 10-6. Particulate Matter emissions factors for Mexican mobile and area sources

Type	Category	AMS Code	Overall (1996) PM10 (per unit)	Overall (1996) PM2.5 (per unit)	Method of Calculation	Overall (w/Monterrey) PM10 (per unit)	Overall (w/Monterrey) PM2.5 (per unit)	Method of Calculation	Units
Area	Agricultural Burning	2801500000	12.87	12.27	Mxcl only				kg/hectare
Area	Agricultural Tilling	2801000003	7.70	1.71	Mxcl only				kg/hectare
Area	Charbroiling	2302002000	0.24	0.24	Avg. Mxcl/Tij				kg/person
Area	Commercial/Institutional Combustion	2103000000	0.09	0.09	Avg. CJ/Mxcl/Tij	0.07	0.07	Avg. CJ/Mxcl/Tij/Mon	kg/person
Area	Construction Activities	2311000000	0.23	0.05	Tij only				kg/person
Area	Municipal Waste Burning	2601000000	0.16	0.15	Mxcl only				kg/person
Area	Other Non-road Mobile Sources	2270000000	0.08	0.08	Mxcl only				kg/person
Area	Paved Roads	2294000000	11.72	1.98	Avg. Mxcl/Tij				kg/vehicle
Area	Residential Combustion	2104000000	0.06	0.06	Avg. CJ/Mxcl/Tij	0.05	0.05	Avg. CJ/Mxcl/Tij/Mon	kg/household
Area	Structural Fires	2810030000	0.02	0.02	Avg. Mxcl/Tij				kg/household
Area	Unpaved Roads	2296000000	103.66	21.98	Avg. CJ/Mxcl/Tij				kg/vehicle
Motor Vehicle	Heavy-Duty Diesel Vehicle	2230070000	1.55	1.48	Avg. CJ/Mxcl/Tij	3.31	3.16	Avg. CJ/Mxcl/Tij/Mon	kg/vehicle
Motor Vehicle	Heavy-Duty Gas Vehicle	2201070000	0.02	0.02	Avg. Mxcl/Tij				kg/vehicle
Motor Vehicle	Light-Duty Diesel Truck	2230060000	0.09	0.09	CJ only				kg/vehicle
Motor Vehicle	Light-Duty Gas Truck	2201060000	0.17	0.17	Avg. CJ/Mxcl/Tij	0.49	0.49	Avg. CJ/Mxcl/Tij/Mon	kg/vehicle
Motor Vehicle	Light-Duty Gas Vehicle	2201001000	1.00	0.99	Avg. CJ/Mxcl/Tij	1.07	1.07	Avg. CJ/Mxcl/Tij/Mon	kg/vehicle
Motor Vehicle	Motorcycles	2201080000	0.00	0.00	Avg. Mxcl/Tij	0.01	0.01	Avg. Mxcl/Tij/Mon	kg/vehicle