Regional Air Quality Analyses for Ozone, $PM_{2.5}$, and Regional Haze: Base C Emissions Inventory (September 12, 2011)

The Lake Michigan Air Directors Consortium, in conjunction with its member states, are conducting air quality modeling for ozone and fine particles ($PM_{2.5}$) in preparation for future State Implementation Plan (SIP) work. The modeling analyses are focused on examining model performance (by comparing base year modeled and monitored concentrations) and providing strategy-relevant information (through a series of model sensitivity runs). This document describes the development of the latest base year emissions inventory (Base Cv7). Improvements to the base year inventory are summarized in the table below.

Table 1. Summary of Base C Inventory Improvements

Sector	Activity
Point	Updated State data (Indiana, Iowa, Minnesota, Ohio, Wisconsin)
	Updated EGU-nonEGU splitting
Area	Updated State data (Indiana, Iowa, Minnesota, Ohio, Wisconsin)
	Improved PM speciation profiles
	Revised woodburning emissions
Nonroad	Incorporated ERTAC rail data
Other	Reviewed and identified appropriate speciation profiles

Overview

The primary base year selected for initial modeling is 2007.[1] Meteorology was developed for using MM5 and WRF. (Note: WRF meteorology is being used in the latest base year modeling.) The base year inventory was developed in phases, as summarized in Table 2.

Outstanding emissions inventory issues include:

- Reliability of the MOVES-based on-road emission estimates. (Note, a separate effort is underway to do a top-down evaluation of these emissions using ambient monitoring data.)
- Reliability of new MEGAN biogenic emission estimates
- Development of improved agricultural ammonia emission estimates
- Use of improved PM and VOC speciation profiles
- Appropriateness of assumed transportable dust fraction (i.e., 90%)
- Inclusion of both PM-filterable and PM-condensible emissions
- Inclusion of fire emissions

[1] Limited modeling was also performed for a 2008 base year, but a decision was made to focus on 2007 because of generally higher air quality concentrations in that year. In addition, the LADCO States recently decided to update the modeling base year to 2011. Work is underway to prepare emissions and meteorology for this year. Until the new inventory and meteorology are ready, LADCO will continue to use the 2007 base year data in its regional modeling analyses.

Table 2. Contents of Basecase Inventory

Sector	Base B	Base Cv2	Base Cv4	Base Cv7
EGU Point	2007 CEM data (annualized w/ 2005-2007 temporal)	2007 CEM data (annualized w/ updated temporal) (updated EGU-nonEGU splitting)		Improved Translation from Staging tables to NIF(IL,OH)
Non-EGU Point	2008 State data	2008 State data (updated EGU-nonEGU splitting and PM-condensibles)	Updated State data	Improved Translation from Staging tables to NIF(IL,OH)
Area	2008 State data	Improved PM speciation profiles	Updated State data Modified woodburning emissions	
Nonroad	2007 NONROAD2008			
MAR	Base M	Rail – ERTAC Marine – Base M (w/ 2005 Sip inventory growth) Aircraft – 2008 State date		
Agricultural Ammonia	Base M			
Biogenics	MEGAN			
On-road	Base M (new grid) B+: initial MOVES emissions	MOVES w/ nat'l ldefaults (MW states only)	MOVES w/ nat'l defaults (all states)	
Fires	(not included)	(not included)	(not included)	
Non-LADCO Region	Base M			

Note: The other versions of Base C (Cv3, Cv5, Cv6) reflected minor corrections to individual sectors.

Summary of Base Year Emissions

The emissions base year for the current regional modeling is 2008. 2008 emissions were provided for EGU point, nonroad, on-road, and biogenics, and 2008 emissions (only) were provided for the other sectors (non-EGU point and area). Based on consultation with the States and examination of various emission surrogates (e.g., population, employment, and VMT), 2008 emissions for these sectors were used "as is" to represent 2007 emissions.

For on-road, off-road, ammonia, and biogenic sources, emissions were estimated using emission models. Three other off-road categories are not accounted for by the NONROAD emissions model: commercial marine, aircraft, and rail. Marine emissions will continue to be based on LADCO's Base M (2005) inventory. Aircraft emissions for 2008 were provided by the States. Rail emissions were based on the new 2008 inventory prepared by ERTAC. For point and area sources, emissions were prepared using data supplied by the States. Further discussion is provided below for each source sector in the LADCO region. For the rest of the modeling domain, Base M inventories will be used until more recent inventories are available from other regional organizations.

A summary of annual emissions by pollutant and source sector is provided in Figure 1. A more complete emissions summary is provided in Attachment 1.

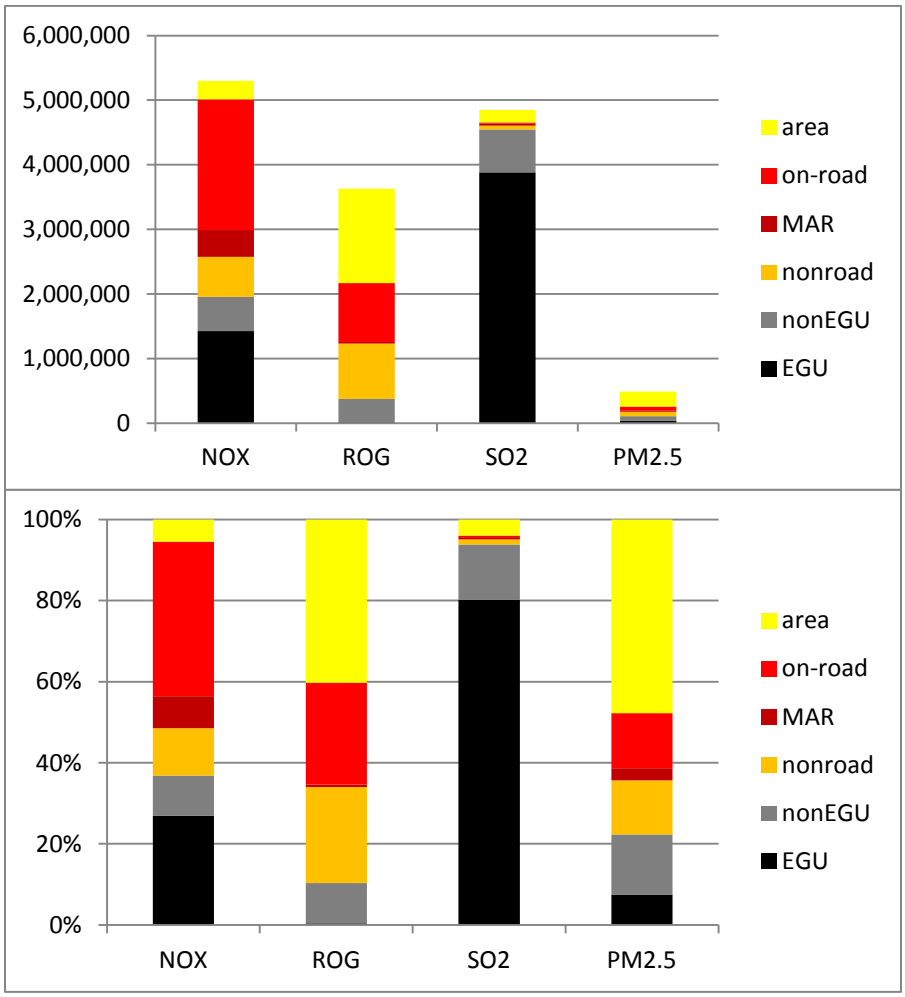


Figure 1. Annual emissions summary by pollutant and source sector

On-Road Sources: Emission estimates were derived using EPA's new MOVES2010a model for on-road motor vehicles. MOVES2010a was developed for state/local air quality and transportation agencies to use in preparing on-road inventories for SIPs and transportation conformity. MOVES2010 replaced the previous model for estimating on-road mobile source emissions, MOBILE6.2. EPA guidance is for states to use MOVES2010a "in ozone, CO, PM, and NO2 SIP development as expeditiously as practicable."

MOVES2010a was developed principally to be run in an "inventory" mode (i.e., monthly average, county-level emission estimates), which is what state/local agencies need for their SIP inventories and conformity demonstrations. For photochemical modeling, however, more refined temporal and spatial information is desired. Two options exist for providing this more refined information: (1) running MOVES2010a for each hour (using concurrent meteorological conditions) to provide the appropriate emission factor, or (2) developing MOVES2010a "look-up" tables which cover the expected ranges of key meteorological variables and then using the tables to provide the emission factor for each hour based on the concurrent meteorological conditions. Initial PC-based modeling showed that the first option was prohibitive. Subsequent Linux-based modeling produced a factor of 2 decrease in model run times, but still suggested that the look-up table option was preferable.

Using a Linux-based version of MOVES2010a created by Wisconsin DNR, on-road motor vehicle inventories were prepared based on a multi-step process:

Step 1: A state-level run was conducted to produce temporal profiles for each state for weekday and weekend emissions as a function of pollutant, emission type (exhaust and evaporative), and vehicle type (gasoline and diesel).

Step 2: A county-level run was conducted for each representative county for January and July to produce a weekday and weekend emission estimate for these two months.

Step 3: The monthly profiles were applied to the representative county results to generate a weekday and weekend emission estimate for all months.

For Base Cv4, national defaults were used in the MOVES runs. State-specific inputs were supplied by most LADCO States, but were not used to produce a modeling inventory.[2] The resulting county-level weekday and weekend emission estimates for each month were then modeled as an area source in EMS. Emission processing assumptions include:

Temporal: Weekday emissions assigned to Monday-Friday, and weekend emissions assigned to Saturday-Sunday. It should be noted that the emission files already reflect hourly values.

Spatial: Applied 2002 surrogates based on roadway type.

Speciation: Exhaust and evaporative emissions by vehicle type (gasoline and diesel) were speciated separately.

[2] Preliminary MOVES runs for a few cities (Cleveland, Milwaukee, and E.St.Louis) indicate that the emission estimates are about 8-10% higher using state-specific inputs.

Off-Road Sources: NMIM2008 was run (using default monthly temperatures) by Wisconsin DNR for the 2007 and 2008 for the five LADCO States plus MN, IA, and MO. Local data for agricultural equipment, construction equipment, commercial marine, recreational marine, and railroads were prepared previously by contractors (Environ, 2004, E.H. Pechan, 2004, and Environ, 2007a, 2007b).

Three other off-road categories are not accounted for by the NMIM emissions model: commercial marine, aircraft, and rail. Marine emissions will continue to be based on LADCO's Base M (2005) inventory (Environ, 2007a). A summary of the annual emissions by vessel type for the 5-state LADCO region are provided in Table 3.

Table 3. Annual Commercial Marine Emissions for 2005 (LADCO Region)

Vessel Type	HC[1]	CO	NOx	PM[1]	SO2
Deep Draft Vessels at Ports	69	122	1,400	82	651
Deep Draft Vessels (mid-Lake)	47	1,055	12,955	652	5,489
Push Boats on Rivers and Lakes	472	4,023	21,689	525	1,905
Tugs	98	857	4,575	110	397
Ferries	26	223	1,107	29	85
Other special (excursion) vessels	7	41	289	6	23
Support vessels	1	10	54	1	5
Dredges	2	22	122	3	66
Commercial Fishing	29	110	7	2	1
Military vessels (Coast Guard)	77	264	138	3	15

[1] HC converted to VOC and PM-total to PM10 and PM2.5 using EPA factors.

Aircraft emissions for 2008 were provided by the States.

Rail emissions were based on the new 2008 inventory prepared by ERTAC. Emissions data were developed for rail yards and line haul operations. Documentation for the rail emissions is available at http://www.ertac.us/rail/index.html

Area and Point Sources: EMS was run by LADCO using data supplied by the LADCO States and Minnesota to produce weekday, Saturday, and Sunday emissions for each month. The ERTAC recommendations on area sources were followed in preparing these data.

Two significant area source improvements were made in developing Base Cv4: application of appropriate PM speciation profiles, and adjustment of residential wood combustion (RWC) emissions. First, several PM area source categories, which were using the default speciation profile, were assigned SCC-specific profiles based on several recent references (CMU, 2004, EC/R, 2005, and Turner, 2010). This resulted in significantly more primary OC and EC emissions.

Second, Michigan DEQ adjusted EPA's RWC tool to reallocate the indoor furnaces and outdoor hydronic heaters (*8510 and *8610, respectively) to nonMSA counties. Counties that are part of an MSA, were assigned zero appliances for both categories. Additionally, an issue with double counting some county activity data in WI and MI was addressed. Table 4 shows the statewide changes in emissions from the standard tool to the revised tool. These changes resulted in a shift in the spatial distribution of emissions, and (due to the double counting) a reduction in statewide emissions in some states.

Table 4. Standard and Adjusted Residential Wood Combustion Emissions

		Standard RWC Tool	Adjusted RWC Tool		Adjusted RWC Tool	Adjusted RWC Tool	Adjusted RWC Tool	Adjusted RWC Tool
State	**Pollutant**	**Emissions**	**Emissions**		**2104008400**	**2104008510**	**2104008610**	**sum**
17	Primary PM10	13,880	14,012		51	4,570	2,454	7,075
18	Primary PM10	11,729	11,724		37	3,762	3,274	7,073
26	Primary PM10	35,143	27,255		91	4,537	6,630	11,257
27	Primary PM10	17,741	17,741		45	879	3,860	4,784
39	Primary PM10	25,703	23,332		80	7,919	5,890	13,889
55	Primary PM10	23,407	20,311		53	2,887	6,156	9,096

For EGU point sources, the annual and summer season emissions were temporalized for modeling purposes using profiles prepared by Scott Edick (Michigan DEQ) based on CEM data. Figure 3 shows the location (and magnitude) of non-EGU and EGU point sources.

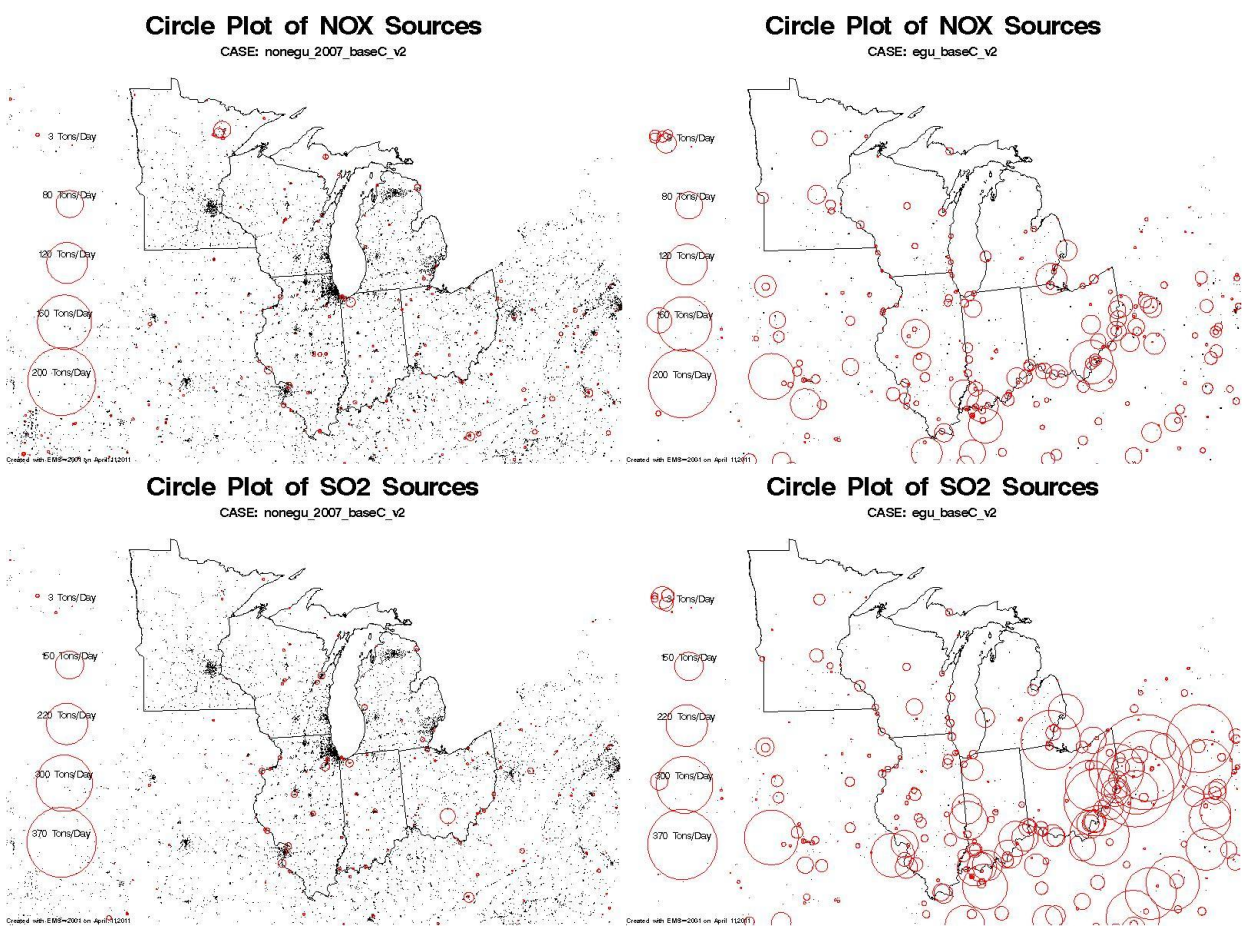


Figure 3. Spatial plot of non-EGU (left) and EGU (right) sources

Biogenics: Environ, under contract to the Midwest Ozone Group, produced day-specific biogenic emissions for the full modeling domain using the CONCEPT/MEGAN biogenics model for 2007 and 2008 (Guenther, et al, 2006, and Sakulyanontvittaya, et al, 2008). MEGAN2.03a was used, which is a modified version of MEGANv2.03 available from http://acd.ucar.edu/~guenther/MEGAN/MEGAN.htm. The improvements for the modified version include:

- Enabling input of temperature and solar radiation data from various sources. Previous versions of MEGAN obtained these data only from MCIP model outputs. Environ developed code to allow input of solar radiation from satellite data and temperature from MM5 and MM5CAMX models.
- Pre-processors were developed to allow the use of alternative modeling grids developed in ArcGIS.
- The MEGAN code is currently capable of outputting model-ready data for CMAQ. The MEGAN code was modified to include outputting of CAMx model-ready data.
- Modification of the MEGAN FORTRAN code that runs on Linux to accept observed temperature data and satellite radiation data and generate emissions for grid-definitions that are developed using ArcGIS.

Figure 4 compares the biogenic isoprene and NO emission estimates for 2007 with those for 2005 (Base M).

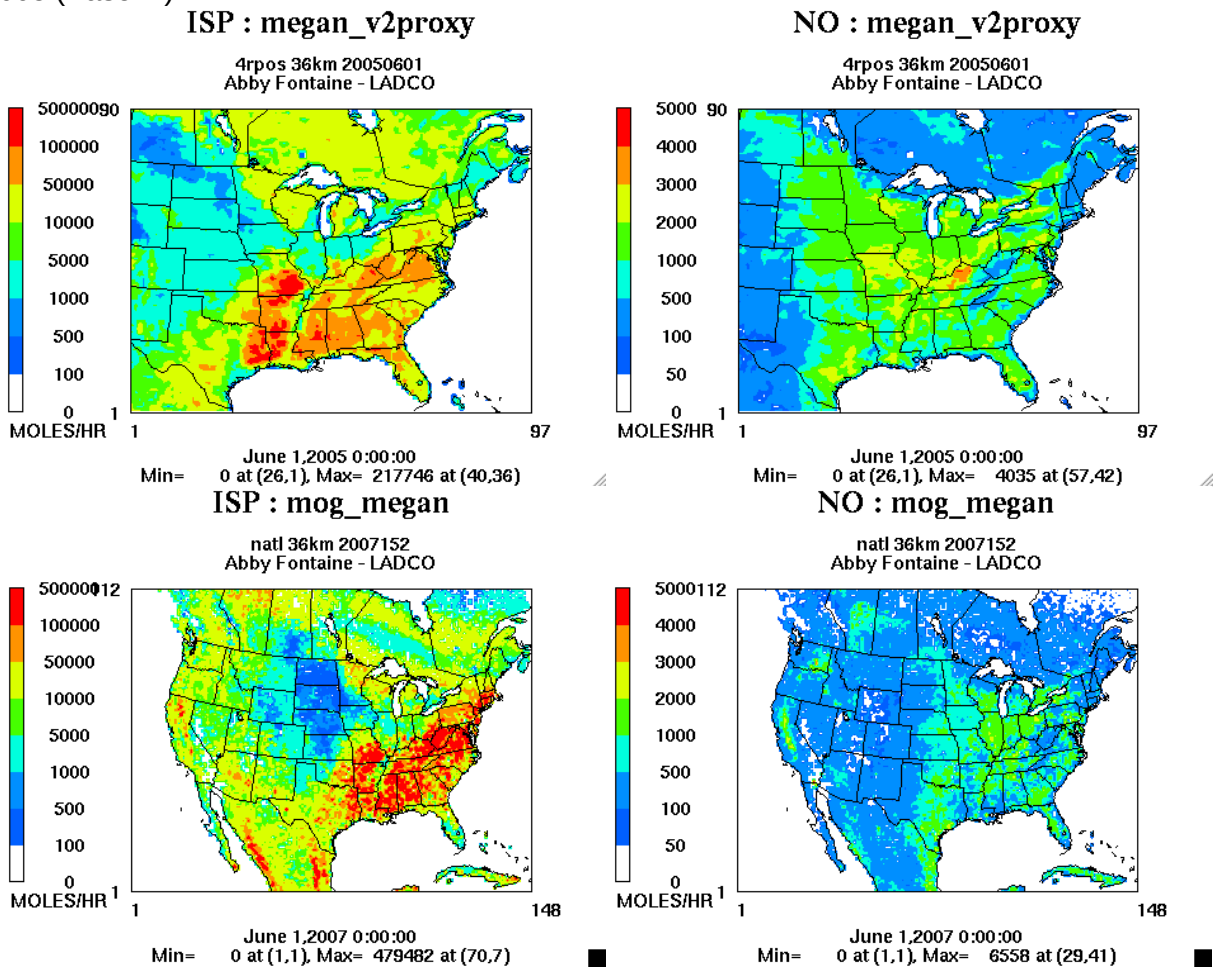
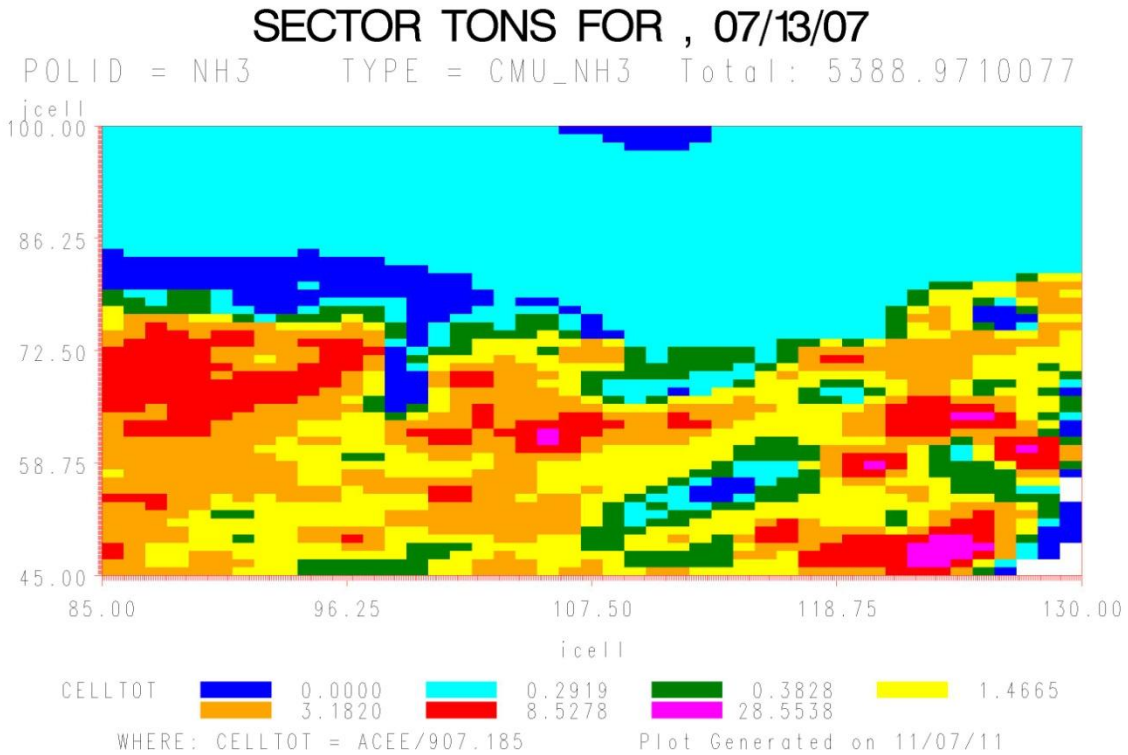


Figure 4. Biogenic emissions: isoprene (left column) and NO (right column) for 2005 (top) and 2007 (bottom)

Ammonia: The agricultural ammonia emissions were based on Carnegie Mellon University's Ammonia Emission Inventory for the Continental United States (http://www.cmu.edu/ammonia).

Specifically, the CMU annual emissions for 2002 were first grown to reflect 2007 conditions based on the methodology use to create the 2005 LADCO SIP inventories. A new process-based ammonia emissions model developed for LADCO (see Zhang, et al, 2005, and Mansell, et al, 2005) was then used to develop temporal factors – i.e., month of year, and hour of day to reflect the impact of average meteorology on livestock emissions.

Emissions Tile plot for Livestock Ammonia in the Upper Midwest and Mid Atlantic States.



Canadian Emissions: Scott Edick (Michigan DEQ) processed the 2005 Canadian National Pollutant Release Inventory, Version 1.0 (NPRI). A subset of the NPRI data (emissions and stack parameters) relevant to the air quality modeling were reformatted and used in the regional modeling.

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