6. Biogenic Sources

6.1 Introduction

Biogenic emissions have been estimated for the 2011 Periodic Emissions Inventory for PM_{10} in Maricopa County (9,223 square miles) and the PM_{10} Nonattainment Area (NAA) (2,887 square miles). The Model of Emissions of Gases and Aerosols from Nature (MEGAN) has been used to estimate the biogenic emissions. MEGAN is a state-of-the-art biogenic emissions model developed by the National Center for Atmospheric Research (NCAR). Some important corrections and improvements were made in the latest version of MEGAN2.1 (Guenther et al, 2012; Jiang et al, 2011) compared to previous versions (Guenther, 2006a, 2006b, and 2007; Guenther et al, 2006). The most important change is that higher temporal and spatial resolution of land use and land cover data for MEGAN input has become available. MEGAN, with the vegetation data released in 2011, was applied to compute biogenic emissions in Maricopa County and the PM_{10} NAA. Among the chemical species included in MEGAN, only nitric oxide (NO) is attributable to PM_{10} formation. Therefore, only NO_x emissions are included in the inventory. The MEGAN runs were executed by the Maricopa Association of Governments. The contact person for the MEGAN emission estimates is Feng Liu (602-254-6300).

6.2 Modeling domain

As a numerical model, the MEGAN inputs and outputs are given in user-defined two dimensional grid cells. To develop biogenic emissions for the 2011 Periodic Emission Inventory for PM_{10}, the 4-km modeling domain that covers the entire area of Maricopa County were employed. The target area is the PM_{10} NAA within the County. The definition of the domain in the Lambert Conformal Conic Projection (LCP) coordinate system is presented in Table 6.2–1. Since MEGAN estimates biogenic emissions for the entire modeling domain rather than specific areas, additional input files, masking areas covered by the PM_{10} NAA and Maricopa County, were developed by applying Geographic Information Systems (GIS) to calculate emissions for those two target areas. In order to represent the target area, the masking file assigns 1.0 for the grid cells fully covered by the target area, a fractional value for grid cells partially covered by the target area, and 0.0 for grid cells outside the target area. As shown in Figure 6.2–1, biogenic emissions for the PM_{10} NAA and Maricopa County were extracted from MEGAN runs for the masked grid cells in the 4-km modeling domain.

Table 6.2–1. Two modeling domains defined in the LCP coordinate system

Grid Horizontal Resolution	Grid Size	LCP Range (km)	Target Area
4-km	65 by 65	(–131.4713, –129.4593) to (127.9845, 131.1945)	PM_{10} NAA and Maricopa County

6.3 Input data

To calculate biogenic emissions using MEGAN, the following gridded input files for land cover and meteorological data were prepared:

1. EFMAP_LAI file: This file provides emission factors (EF) for 20 MEGAN species including NO_x, and 8-day average leaf index (LAI) for year 2011in each grid cell.
2. PFTF file: This input file gives percentage of four plant function types (PFT) including broadleaf trees (BT), needle leaf trees (NT), grass and crops (HB) and shrubs (SB) for each model domain grid location.
3. METCRO2D file: This file contains meteorological parameters including temperature, short wave radiation, wind speed, humidity and soil moisture for each grid.

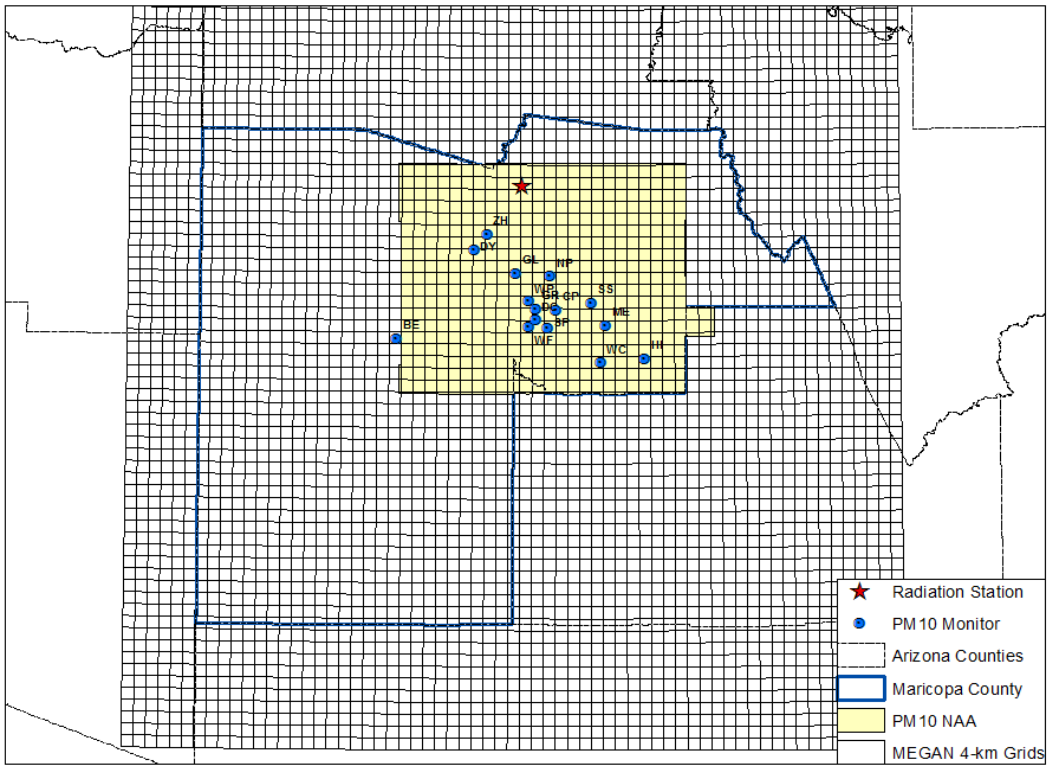

Figure 6.2–1. The masked grid cells in the 4-km modeling domain.

6.3.1 Land cover data

The land cover data, including the 8-day averaged LAI input files for North America for years 2003 to 2011 based on NASA MODIS data, monthly mean PFT, and EF, are provided by the EFMAP_LAI and PFTF files. These input data were derived from the MEGAN land cover database available at the resolution of 30 seconds latitude by 30 seconds longitude (1x1 km^2) in netCDF format (http://acd.ucar.edu/~guenther/MEGAN/MEGAN.htm).

6.3.2 Weather data

The weather data used by MEGAN are temperature, downward short wave radiation, wind speed, humidity and soil moisture. The Measurement and Instrumentation Data Center (MIDC) collects irradiance and meteorological data from nation-wide stations. One of those stations is located in northern Phoenix (33.83˚N, 112.17˚W, see red star in Figure 6.2–1) and is operated by the National Renewable Energy Laboratory (NREL). The archived hourly temperature, wind speed, humidity and radiation data from this site are available to the public. Monthly mean diurnal cycles of the weather parameters were calculated based on hourly data for the year 2011, and a netCDF file representing 24-hour data for each month was prepared for MEGAN inputs. Biogenic emissions of NO_x are first governed by temperature and then highly dependent on downward short wave radiation. Figure 6.3–1 shows the monthly mean (left panel) and annual mean diurnal cycle (right panel) of temperature. Figure 6.3–2 illustrates monthly averaged and annual mean diurnal cycle of short wave radiation. The maximum monthly temperature was recorded in August, while the highest radiation was observed in June. The maximum monthly temperature appeared two months later than the highest radiation. The peak hourly temperature was observed around 4:00–6:00 pm and lagged three hours behind the peak radiation. The delay is due to the fact that heating of the air occurs not from the sun's rays, but from heating of the earth and infrared radiation leaving the ground in the form of heat. As a result, maximum seasonal emission rates appear in the summer. The highest hourly emission rates take place in the afternoon because the emission rates are positively related to both temperature and short wave radiation (Guenther et al, 2006 and 2012). The maximum monthly NO_x biogenic emission rates would be expected to occur in the same month as the maximum temperature.

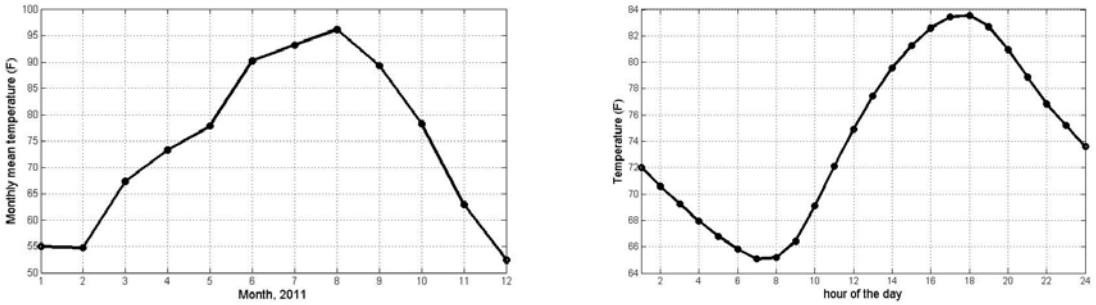

Figure 6.3–1. Monthly averaged temperature (left panel) and annual mean diurnal cycle of temperature (right panel) in 2011.

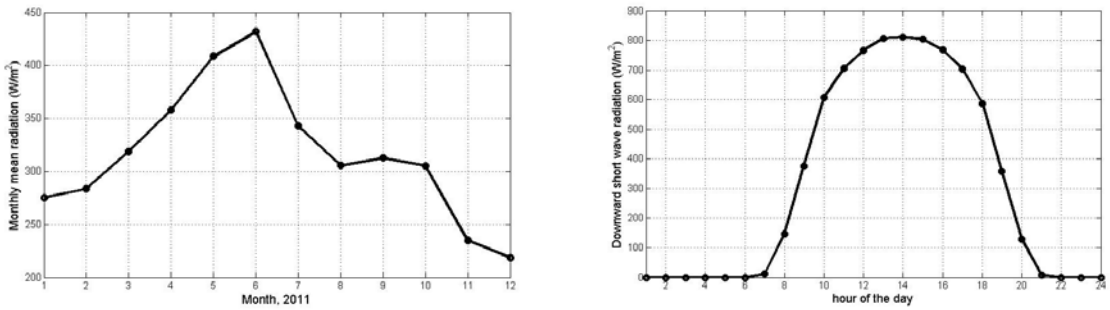

Figure 6.3–2. Monthly averaged radiation (left panel) and annual mean diurnal cycle of radiation (right panel) in 2011.

6.4 Emission estimation

MEGAN runs for the modeling domain provide hourly emission outputs for the year 2011. Figure 6.4–1 illustrates NO_x emission rates simulated by MEGAN at 17:00 MST in August, 2011. Typical daily emissions for each month in 2011 are derived by using the hourly outputs for each month. In addition, monthly total emissions were obtained by multiplying the typical daily emissions for each month by the number of days in the month. The typical daily emissions for the 12 months in 2011 are shown in Table 6.4–1 for the PM_{10} NAA and Maricopa County.

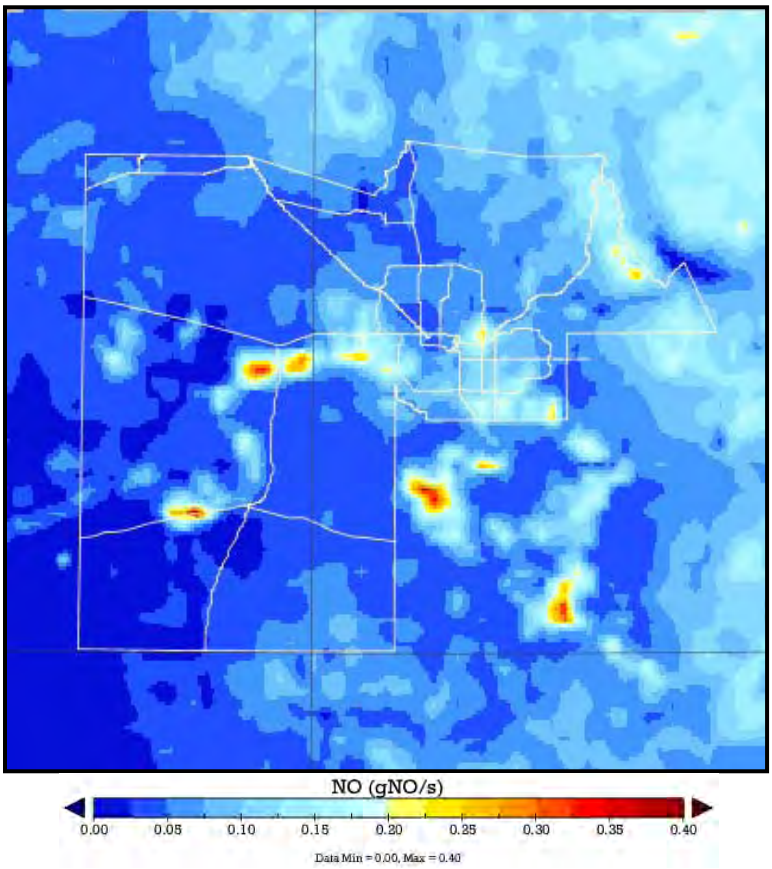

Figure 6.4–1. Estimated emission rates of NO_x at 17:00 MST, August 2011 by MEGAN model.

Table 6.4–1. Typical daily biogenic of NO_x emissions for each month in the PM_{10} NAA and Maricopa County.

	PM_{10} NAA		Maricopa County	
Month	**kg/day**	**lbs/day**	**kg/day**	**lbs/day**
January	130.8	288.4	316.3	697.3
February	227.2	500.9	524.0	1,155.2
March	503.1	1,109.1	1,152.6	2,541.0
April	553.1	1,219.4	1,330.8	2,933.9
May	681.6	1,502.7	1,641.2	3,618.2
June	1,410.6	3,109.8	3,432.5	7,567.4
July	1,744.1	3,845.1	4,207.9	9,276.8
August	2,064.8	4,552.1	5,031.7	11,093.0
September	1,332.3	2,937.2	3,278.2	7,227.2
October	609.6	1,343.9	1,506.4	3,321.0
November	194.0	427.7	462.5	1,019.6
December	105.4	232.4	252.8	557.3

Monthly mean emissions for Maricopa County and the PM_{10} NAA are illustrated in Figure 6.4–2. Monthly emission values are presented in Table 6.4–2. It can be seen that the monthly NO_x emissions reached the highest values in August because monthly mean temperatures reached the maximum levels in this month.

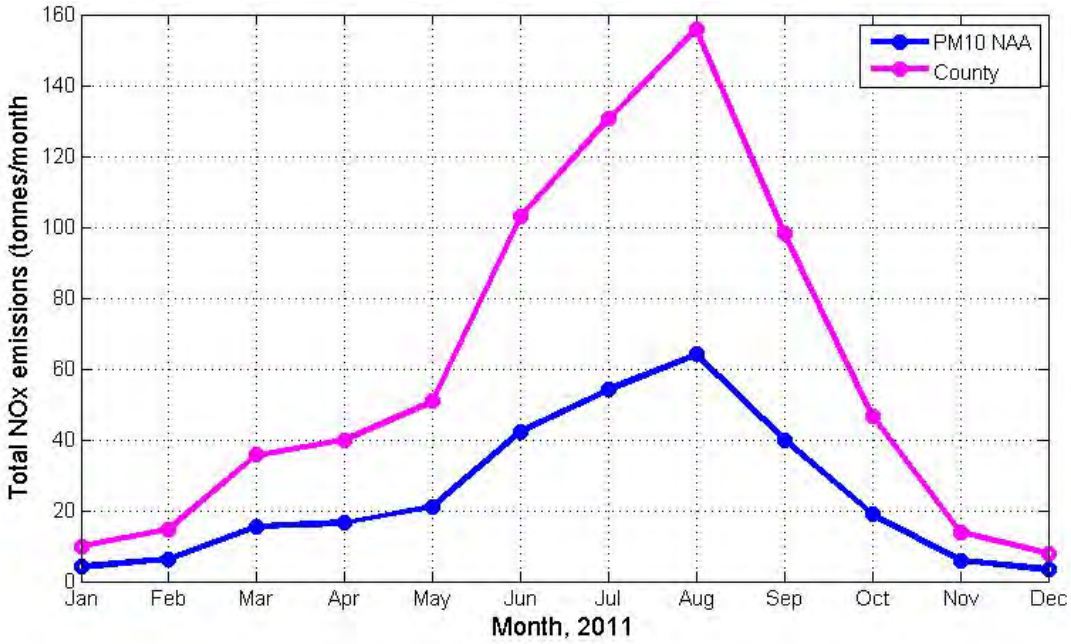

Figure 6.4–2. Monthly emissions of NO_x in Maricopa County (pink solid line, abbreviated as "County") and the PM_{10} NAA (blue solid line, abbreviated as "PM_{10} NAA").

Table 6.4–2. Monthly biogenic NO_x emissions in the PM_{10} NAA and Maricopa County

	PM_{10} NAA		Maricopa County	
Month	**Metric tons/month**	**Short tons/month**	**Metric tons/month**	**Short tons/month**
January	4.05	4.47	9.81	10.81
February	6.36	7.01	14.67	16.17
March	15.60	17.19	35.73	39.39
April	16.59	18.29	39.92	44.01
May	21.13	23.29	50.88	56.08
June	42.32	46.65	102.98	113.51
July	54.07	59.60	130.44	143.79
August	64.01	70.56	155.98	171.94
September	39.97	44.06	98.35	108.41
October	18.90	20.83	46.70	51.48
November	5.82	6.42	13.88	15.29
December	3.27	3.60	7.84	8.64

6.5 Summary of biogenic source emissions

Typical daily and annual total NO_x emissions for Maricopa County and the PM_{10} NAA in 2011 are summarized in Table 6.5–1. The peak monthly emissions that occurred in August 2011 are higher than that in July 2008. However, total NO_x emissions in 2011 are lower in both Maricopa County and the PM_{10} NAA compared to 2008. Due to the incorporation of land cover data that are more characteristic of plants located in the desert southwest, as well as improvements to the MEGAN model, the 2011 data shown in Table 6.5–1 represents a substantial improvement over previous biogenic emission estimates for Maricopa County and the PM_{10} NAA.

Table 6.5–1. Typical daily and annual NO_x emissions in 2011.

	Typical daily NO_x emissions		Annual NO_x emissions	
Geographic Area	**kg/day**	**lbs/day**	**tonnes*/yr**	**tons*/yr**
Maricopa County	1,928.1	4,250.7	707.17	779.52
PM_{10} NAA	796.4	1,755.7	292.08	321.97

* "Tonne" denotes metric ton, and "ton" denotes short (or English) ton

6.6 References

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Guenther, A., X. Jiang, C. L. Heald, T Sakulyanontvittaya, T. Duhl, L. K. Emmons, and X. Wang, 2012. The model of emissions of gases and aerosols from nature version 2.1 (MEGAN2.1): an extended and updated framework for modeling biogenic emissions, *Goesci. Model Dev. Discuss.*, 5, 1503-1560.

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