

# **Regional Air Quality Analyses for Ozone, PM<sub>2.5</sub>, and Regional Haze:**

## **Technical Support Document**



December 5, 2007

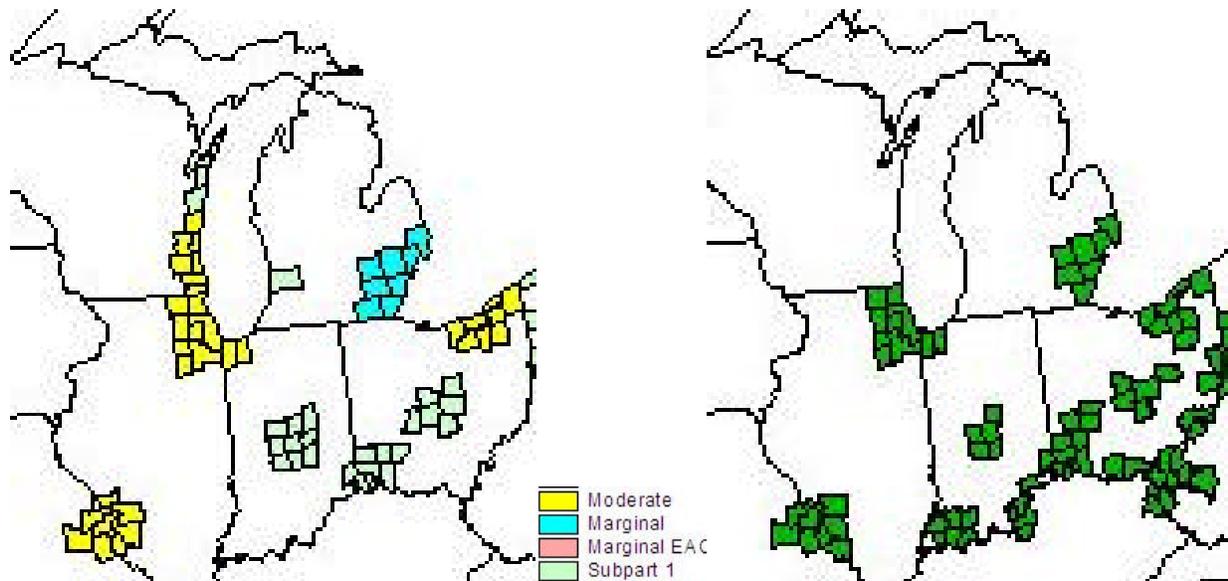
States of Illinois, Indiana, Michigan, Ohio, and Wisconsin

# Table of Contents

Section-Title	Page
<b>Executive Summary</b>	ii
<b>1.0 Introduction</b>	1
1.1 SIP Requirements	2
1.2 Organization	2
1.3 Technical Work: Overview	3
<b>2.0 Ambient Data Analyses</b>	4
2.1 Ozone	4
2.2 PM <sub>2.5</sub>	20
2.3 Regional Haze	33
<b>3.0 Air Quality Modeling</b>	44
3.1 Selection of Base Year	44
3.2 Future Years of Interest	44
3.3 Modeling System	45
3.4 Domain/Grid Resolution	45
3.5 Model Inputs: Meteorology	46
3.6 Model Inputs: Emissions	49
3.7 Base Year Modeling Results	56
<b>4.0 Attainment Demonstration for Ozone and PM<sub>2.5</sub></b>	67
4.1 Future Year Modeling Results	67
4.2 Supplemental Analyses	77
4.3 Weight of Evidence Determination for Ozone	77
4.4 Weight of Evidence Determination for PM <sub>2.5</sub>	85
<b>5.0 Reasonable Progress Assessment for Regional Haze</b>	88
5.1 Future Year Modeling Results	88
5.2 Weight of Evidence Determination for Regional Haze	93
<b>6.0 Summary</b>	99
<b>7.0 References</b>	102

## EXECUTIVE SUMMARY

States in the upper Midwest face a number of regional air quality challenges. More than 60 counties are currently classified as nonattainment for the 8-hour ozone and fine particle ( $PM_{2.5}$ ) federal air quality standards (1997 version). A map of these nonattainment areas is provided in the figure below. In addition, visibility impairment due to  $PM_{2.5}$  (i.e., regional haze) is a problem in the larger national parks and wilderness areas (i.e., Class I areas). There are 156 Class I areas in the U.S., including two in northern Michigan.



**Figure I. Current nonattainment counties for ozone (left) and  $PM_{2.5}$  (right)**

To support the development of State Implementation Plans (SIPs) for ozone,  $PM_{2.5}$ , and regional haze in the States of Illinois, Indiana, Michigan, Ohio, and Wisconsin, technical analyses were conducted by the Lake Michigan Air Directors Consortium (LADCO), its member states, and various contractors. The analyses include preparation of regional emissions inventories and meteorological data, evaluation and application of regional chemical transport models, and review of ambient monitoring data.

Analyses of monitoring data were conducted to produce a conceptual understanding of the air quality problems. Key findings of the analyses include:

### Ozone

- Current monitoring data show about 20 sites in violation of the 8-hour ozone standard. Historical ozone data show a steady downward trend over the past 15 years, especially since 2001-2003, due in part to federal and state emission control programs.
- Ozone concentrations are strongly influenced by meteorological conditions, with more high ozone days and higher ozone levels during summers with above normal temperatures.
- Inter- and intra-regional transport of ozone and ozone precursors affects many portions of the five states.

### PM<sub>2.5</sub>

- Current monitoring data show about 40 sites in violation of the annual PM<sub>2.5</sub> standard. Nonattainment sites are characterized by an elevated regional background (on the order of 12 – 14 ug/m<sup>3</sup>) and a significant local (urban) increment (on the order of 2 – 3 ug/m<sup>3</sup>). Historical PM<sub>2.5</sub> data show a slight downward trend since deployment of the PM<sub>2.5</sub> monitoring network in 1999.
- PM<sub>2.5</sub> concentrations are less influenced by meteorology (compared to ozone), but, nevertheless, are affected by atmospheric conditions (e.g., stagnation events, especially during the winter) and transport patterns.
- On an annual average basis, PM<sub>2.5</sub> chemical composition consists mostly of sulfate, nitrate, and organic carbon in similar proportions.

### Haze

- Current monitoring data show visibility levels in the Class I areas in northern Michigan are on the order of 22 – 24 deciviews. The goal of USEPA's visibility program is to achieve natural conditions, which is on the order of 12 deciviews for these Class I areas, by the year 2064.

Air quality models were applied to support the regional planning efforts. Two base years were used in the modeling analyses: 2002 and 2005. Basecase modeling was conducted to evaluate model performance (i.e., assess the model's ability to reproduce the observed concentrations). This exercise was intended to build confidence in the model prior to its use in examining control strategies. Model performance for ozone and PM<sub>2.5</sub> was found to be generally acceptable.

Future year strategy modeling was conducted to determine whether existing ("on the books") controls would be sufficient to provide for attainment of the standards for ozone and PM<sub>2.5</sub> and if not, then what additional emission reductions would be necessary for attainment. Based on the modeling and other supplemental analyses, the following general conclusions can be made:

- Existing controls are expected to produce significant improvement in ozone and PM<sub>2.5</sub> concentrations and visibility levels.
- The choice of the base year affects the future year model projections. A key difference between the base years of 2002 and 2005 is meteorology. For example, the 3-year (design value) period centered on 2002 was more ozone conducive than the 3-year (design value) period centered on 2005. The choice of which base year to use as the basis for the SIP is a policy decision (i.e., how much safeguard to incorporate).
- Most sites are expected to meet the current 8-hour standard by the applicable attainment date, except, for sites in western Michigan and, possibly, in eastern Wisconsin and northeastern Ohio.
- Most sites are expected to meet the current PM<sub>2.5</sub> standard by the applicable attainment date, except for sites in Detroit, Cleveland, and Granite City, and, possibly, Chicago, Cincinnati, Louisville, Portsmouth (OH), and Steubenville.

The regional modeling for PM<sub>2.5</sub> does not reflect any air quality benefit expected from local controls. States are conducting local-scale analyses and will use these results, in conjunction with the regional-scale modeling, to support their attainment demonstrations for PM<sub>2.5</sub>.

- Attainment by the applicable attainment date is dependent on actual future year meteorology (e.g., if the weather conditions are consistent with [or less severe than] 2005, then attainment is likely) and actual future year emissions (e.g., if the emission reductions associated with the existing controls are achieved, then attainment is likely). On the other hand, if either of these conditions is not met, then attainment may be less likely.
- The modeling shows that the new PM<sub>2.5</sub> 24-hour standard (and, probably, a new lower ozone standard) will not be met at any sites, even by 2018, with existing controls.
- Visibility levels in a few Class I areas in the eastern U.S. are expected to be greater than the uniform rate of visibility improvement values in 2018, including those in northern Michigan and some in the northeastern U.S. Visibility levels in many other Class I areas in the eastern U.S. are expected to be less than the uniform rate of visibility improvement values in 2018.

## Section 1.0 Introduction

This Technical Support Document summarizes the final air quality analyses conducted by the Lake Michigan Directors Consortium (LADCO)<sup>1</sup> and its contractors to support the development of State Implementation Plans (SIPs) for ozone, fine particles (PM<sub>2.5</sub>), and regional haze in the States of Illinois, Indiana, Michigan, Ohio, and Wisconsin. The analyses include preparation of regional emissions inventories and meteorological modeling data for two base years (2002 and 2005), evaluation and application of regional chemical transport models, and analysis of ambient monitoring data.

Two aspects of the analyses should be emphasized. First, a regional, multi-pollutant approach was taken in addressing ozone, PM<sub>2.5</sub>, and haze for technical reasons (e.g., commonality in precursors, emission sources, atmospheric processes, transport influences, and geographic areas of concern), and practical reasons (e.g., more efficient use of program resources). Furthermore, USEPA has consistently encouraged multi-pollutant planning in its rule for the haze program (64 FR 35719), and its implementation guidance for ozone (70 FR 71663) and PM<sub>2.5</sub> (72 FR 20609). Second, a weight-of-evidence approach was taken in considering the results of the various analyses (i.e., two sets of modeling results -- one for a 2002 base year and one for a 2005 base year -- and ambient data analyses) in order to provide a more robust assessment of expected future year air quality.

The report is organized in the following sections:

- 1.0 Introduction – Provides an overview of regulatory requirements and background information on regional planning
- 2.0 Ambient Data Analyses - Reviews the ambient monitoring data and presents a conceptual model of ozone, PM<sub>2.5</sub>, and haze for the region
- 3.0 Air Quality Modeling – Discusses the air quality modeling analyses, including development of the key model inputs (emissions inventory and meteorological data), and basecase model performance evaluation
- 4.0 Attainment Demonstration for Ozone and PM<sub>2.5</sub> – Presents results of USEPA's modeled attainment tests, along with relevant data analyses considered as part of the weight-of-evidence determination
- 5.0 Reasonable Progress Assessment for Regional Haze – Presents results of USEPA's modeled reasonable progress tests, along with relevant data analyses considered as part of the weight-of-evidence determination
- 6.0 Summary – Reviews key study findings

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<sup>1</sup> A sub-entity of LADCO, known as the Midwest Regional Planning (MRPO), is responsible for the regional haze activities of the multi-state organization.

## 1.1 SIP Requirements

For ozone, USEPA promulgated designations on April 15, 2004 (69 FR 23858, April 30, 2004). In the 5-state region, more than 100 counties were designated as nonattainment.<sup>2</sup> The designations became effective on June 15, 2004. SIPs for ozone are due no later than three years from the effective date of the nonattainment designations (i.e., by June 2007). The attainment date for ozone varies as a function of nonattainment classification. For the region, the attainment dates are either June 2007 (marginal nonattainment areas), June 2009 (basic nonattainment areas), or June 2010 (moderate nonattainment areas).

For PM<sub>2.5</sub>, USEPA promulgated designations on December 17, 2004 (70 FR 944, January 5, 2005). In the 5-state region, 70 counties were designated as nonattainment.<sup>3</sup> The designations become effective on April 5, 2005. SIPs for PM<sub>2.5</sub> are due no later than three years from the effective date of the nonattainment designations (per section 172(b) of the Clean Air Act) (i.e., by April 2008) and for haze no later than three years after the date on which the Administrator promulgates the PM<sub>2.5</sub> designations (per the Omnibus Appropriations Act of 2004) (i.e., by December 2007). The applicable attainment date for PM<sub>2.5</sub> nonattainment areas is five years from the date of the nonattainment designation (i.e., by April 2010).

For haze, the Clean Air Act sets “as a national goal the prevention of any future, and the remedying of any existing, impairment of visibility in Class I areas which impairment results from manmade air pollution.” In the 5-state region, there are two Class I areas: Isle Royale National Park, MI, and Seney National Wildlife Refuge, MI. USEPA’s visibility rule (64 FR 35714, July 1, 1999) requires reasonable progress to achieving “natural conditions” by the year 2064. As noted above, the first regional haze SIP is due in December 2007 and must address the initial 10-year implementation period (i.e., reasonable progress by the year 2018). SIP requirements (pursuant to 40 CFR 51.308(d)) include establishing reasonable progress goals, determining baseline conditions, determining natural conditions, providing a long-term control strategy, providing a monitoring strategy (air quality and emissions), and establishing BART emissions limitations and associated compliance schedule.

## 1.2 Organization

LADCO was established by the States of Illinois, Indiana, Michigan, and Wisconsin in 1989. The four states and USEPA signed a Memorandum of Agreement (MOA) that initiated the Lake Michigan Ozone Study (LMOS) and identified LADCO as the organization to oversee that study. Additional MOAs were signed by the States in 1991 (to establish the Lake Michigan Ozone Control Program), January 2000 (to broaden LADCO’s responsibilities), and June 2004 (to update LADCO’s mission and reaffirm the commitment to regional planning). In March 2004, Ohio joined LADCO. LADCO consists of a Board of Directors (i.e., the State Air Directors), a technical staff, and various workgroups. The main purposes of LADCO are to provide technical assessments for and assistance to its member states, and to provide a forum for its member states to discuss regional air quality issues.

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<sup>2</sup> Based on more recent air quality data, many counties in Indiana, Michigan, and Ohio have been subsequently redesignated as attainment. Currently, there are a little more than 60 counties designated as nonattainment in the region.

<sup>3</sup> Based on more recent air quality data, a few counties in Indiana and Ohio have been subsequently redesignated as attainment. Currently, there are a little more than 60 counties designated as nonattainment in the region.

MRPO is a similar entity led by the five LADCO States and involves the federally-recognized tribes in Michigan and Wisconsin, USEPA, and Federal Land Managers (i.e., National Park Service, U.S. Fish & Wildlife Agency, and U.S. Forest Service). In October 2000, the States of Illinois, Indiana, Michigan, Ohio, and Wisconsin signed a MOA that established the Midwest RPO. In March 2001, the operating principles for MRPO, which describe the roles and responsibilities of states, tribes, federal agencies, and stakeholders, were agreed to. MRPO has a similar purpose as LADCO, but is focused on visibility impairment due to regional haze in the Federal Class I areas located inside the borders of the five states, and the impact of emissions from the five states on visibility impairment due to regional haze in the Federal Class I areas located outside the borders of the five states. MRPO works cooperatively with the RPOs representing other parts of the country. The RPOs sponsored several joint projects and, with assistance by USEPA, maintain regular contact on technical and policy matters.

### **1.3 Technical Work: Overview**

To ensure the reliability and effectiveness of its planning process, LADCO has made data collection and analysis a priority. More than \$7M in RPO grant funds were used for special purpose monitoring, preparing and improving emissions inventories, and conducting air quality analyses<sup>4</sup>. An overview of the technical work is provided below.

**Monitoring:** Numerous monitoring projects were conducted to supplement on-going state and local air pollution monitoring. These projects include rural monitoring (e.g., comprehensive sampling in the Seney National Wildlife Refuge, MI and in Bondville, IL); urban monitoring (e.g., continuation of the St. Louis Supersite); aloft (aircraft) measurements; regional ammonia monitoring; and organic speciation sampling in Seney, Bondville, and five urban areas.

**Emissions:** Baseyear emissions inventories were prepared for 2002 and 2005. States provided point source and area source emissions data, and MOBILE6 input files and mobile source activity data. LADCO and its contractors developed the emissions data for other source categories (e.g., select nonroad sources, ammonia, fires, and biogenics) and processed the data for input into an air quality model. To support control strategy modeling, future year inventories were prepared. The future years of interest include 2008 (planning year to address the 2009 attainment year for basic ozone nonattainment areas), 2009 (planning year to address the 2010 attainment year for PM<sub>2.5</sub> and moderate ozone nonattainment areas), 2012 (planning to address a 2013 alternative attainment date), and 2018 (first milestone year for regional haze).

**Air Quality Analyses:** The weight-of-evidence approach relies on extensive data analysis and modeling. Air quality data analyses were used to provide both a conceptual model (i.e., a qualitative description of the ozone, PM<sub>2.5</sub>, and regional haze problems) and supplemental information for the attainment demonstration. Given uncertainties in emissions inventories and modeling, especially for PM<sub>2.5</sub>, these data analyses are a necessary part of the overall technical support.

Modeling includes baseyear analyses for 2002 and 2005 to evaluate model performance and strategy analyses to assess candidate control strategies. The analyses were conducted in accordance with USEPA's modeling guidelines (USEPA, 2007a). The PM/haze modeling covers the full calendar year (2002 and 2005) for an eastern U.S. 36 km domain, while the ozone modeling focuses on the summer period (2002 and 2005) for a Midwest 12 km subdomain. The same model (CAMx) was used for ozone, PM<sub>2.5</sub>, and regional haze.

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<sup>4</sup> Since 1999, MRPO has received almost \$10M in RPO grant funds from USEPA.

## Section 2.0 Ambient Data Analyses

An extensive network of air quality monitors in the 5-state region provides data for ozone (and its precursors), PM<sub>2.5</sub> (both total mass and individual chemical species), and visibility. These data are used to determine attainment/nonattainment designations, support SIP development, and provide air quality information to public (see, for example, [www.airnow.gov](http://www.airnow.gov)).

Analyses of the data were conducted to produce a conceptual model, which is a qualitative summary of the physical, chemical, and meteorological processes that control the formation and distribution of pollutants in a given region. This section reviews the relevant data analyses and describes our understanding of ozone, PM<sub>2.5</sub>, and regional haze with respect to current conditions, data variability (spatial, temporal, and chemical), influence of meteorology (including transport patterns), precursor sensitivity, and source culpability.

### 2.1 Ozone

In 1979, USEPA adopted an ozone standard of 0.12 ppm, averaged over a 1-hour period. This standard is attained when the number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is equal to or less than 1.0, averaged over a 3-year period. An alternative means of judging attainment is to take the 4<sup>th</sup> highest daily 1-hour value over a 3-year period (i.e., the design value). An exceedance is defined as a peak 1-hour ozone concentration equal to or greater than 0.12 ppm and a violation is defined as a design value equal to or greater than 0.12 ppm.

In 1997, USEPA tightened the ozone standard to 0.08 ppm, averaged over an 8-hour period<sup>5</sup>. The standard is attained if the 3-year average of the 4<sup>th</sup>-highest daily maximum 8-hour average ozone concentrations (i.e., the design value) measured at each monitor within an area is less than 0.08 ppm (or 85 ppb).

*Current Conditions:* A map of the 8-hour ozone design values at each monitoring site in the region for the 3-year period 2005-2007 is shown in Figure 1. The “hotter” colors represent higher concentrations, where yellow and orange dots represent sites with design values above the standard. Currently, there are 19 sites in violation of the 8-hour ozone NAAQS in the 5-state region, including sites in the Lake Michigan area, Detroit, Cleveland, Cincinnati, and Columbus.

Table 1 provides the 4<sup>th</sup>-highest daily 8-hour ozone values and the associated design values since 2001 for several high monitoring sites throughout the region.

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<sup>5</sup> On June 20, 2007, USEPA proposed to tighten further the 8-hour ozone standard to increase public health protection and prevent environmental damage from ground-level ozone. USEPA proposed to set the primary (health) standard to a level within the range of 0.070-0.075 ppm (70-75 ppb), averaged over an 8-hour period, and proposed two options for the secondary (welfare) standard: establish a cumulative standard (daily ozone concentrations over a 3-month period) or make the secondary standard identical to the proposed primary standard.

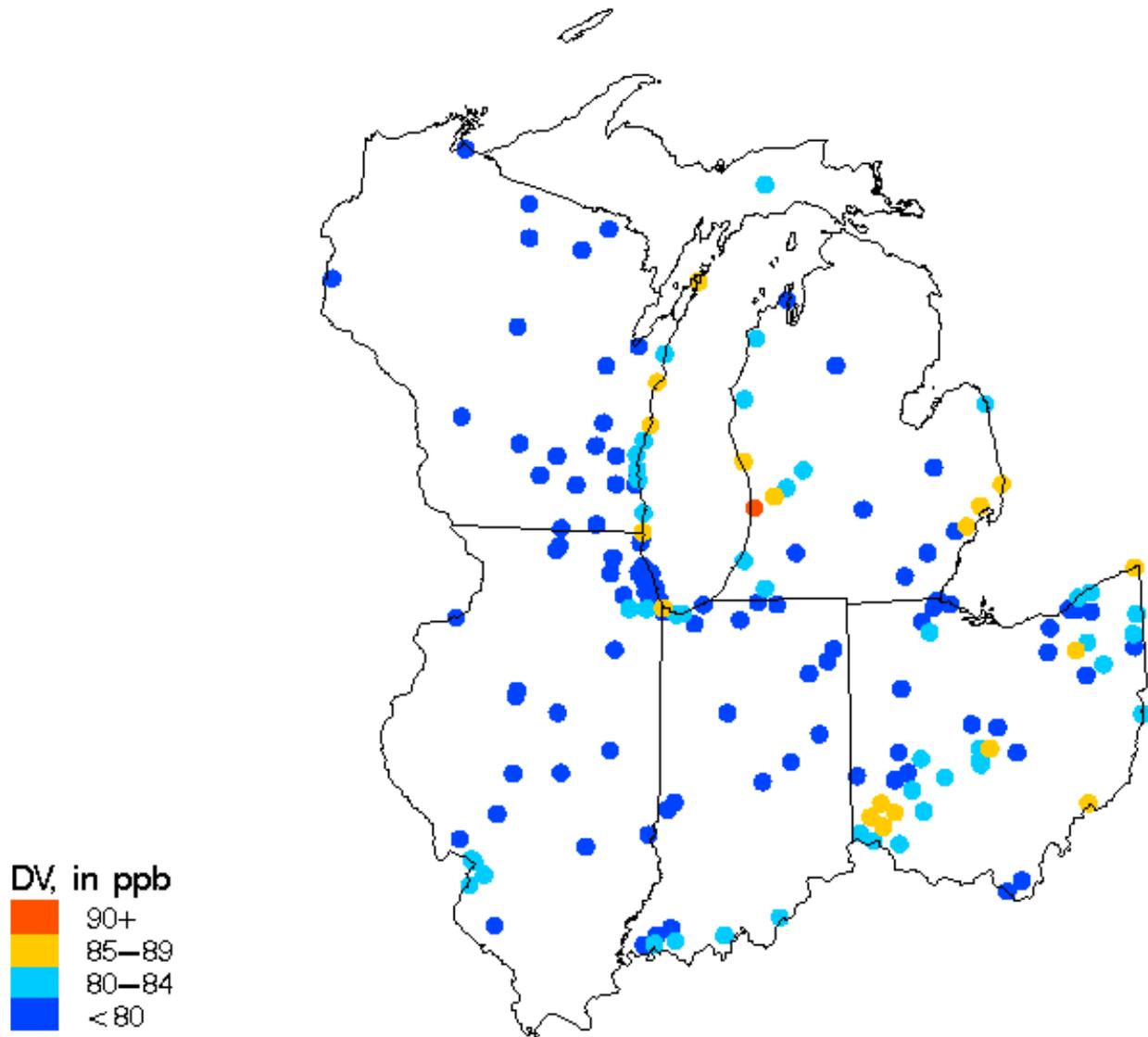


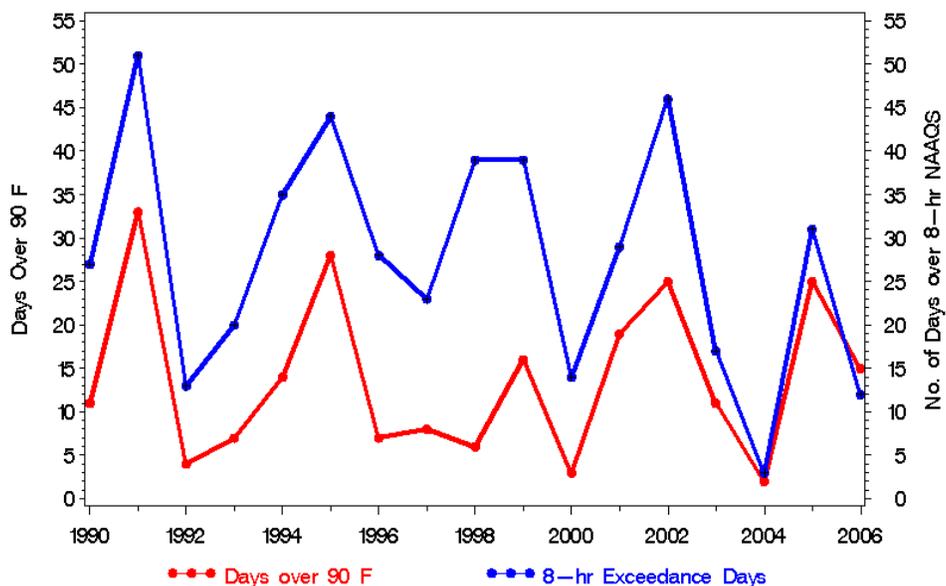
Figure 1. 8-hour ozone design values (2005-2007)

## Ozone Data for Select Sites in 5-State Region

*Final 2007 data (preliminary)*

Key Sites	4th High 8-hour Value							Design Values				
	'01	'02	'03	'04	'05	'06	'07	'01-'03	'02-'04	'03-'05	'04-'06	'05-'07
<b>Lake Michigan Area</b>												
Chiwaukee	99	116	88	78	93	79	85	101	94	86	83	85
Racine	92	111	82	69	95	71	77	95	87	82	78	81
Milwaukee-Bayside	93	99	92	73	93	73	83	94	88	86	79	83
Harrington Beach	102	93	99	72	94	72	84	98	88	88	79	83
Manitowoc	97	83	92	74	95	78	84	90	83	87	82	85
Sheboygan	102	105	93	78	97	83	88	100	92	89	86	89
Kewaunee	90	92	97	73	88	76	85	93	87	86	79	83
Door County	95	95	93	78	101	79	92	94	88	90	86	90
Hammond	90	101	81	67	87	75	77	90	83	78	76	79
Whiting				64	88	81	88				77	85
Michigan City	90	107	82	70	84	75	72	93	86	78	76	77
Ogden Dunes	85	101	77	69	90	70	84	87	82	78	76	81
Holland	92	105	95	79	94	91	95	97	93	89	88	93
Jenison	86	93	91	69	86	83	89	90	84	82	79	86
Muskegon	95	96	94	70	90	91	88	95	86	84	83	89
<b>Indianapolis Area</b>												
Noblesville	88	101	101	75	87	79	84	96	92	87	80	83
Fortville	89	101	92	72	80	76	81	94	88	81	76	79
Fort B. Harrison	87	100	91	73	80	76	83	92	88	81	76	79
<b>Detroit Area</b>												
New Haven	95	95	102	81	88	79	92	97	92	90	82	86
Warren	94	92	101	71	89	78	90	95	88	87	79	85
Port Huron	84	100	86	74	88	78	89	90	86	82	80	85
<b>Cleveland Area</b>												
Ashtabula (Conneaut)	97	103	99	81	93	86	92	99	94	91	86	90
Notre Dame (Geauga)	99	115	97	75	88	70	68	103	95	86	77	75
Eastlake (Lake)	89	104	92	79	97	83	74	95	91	89	86	84
Akron (Summit)	98	103	89	77	89	77	91	96	89	85	81	85
<b>Cincinnati Area</b>												
Wilmington (Clinton)	93	99	96	78	83	81	82	96	91	85	80	82
Sycamore (Hamilton)	88	100	93	76	89	80	90	93	89	86	81	86
Hamilton (Butler)	83	100	94	75	86	79	91	92	89	85	80	85
Middleton (Butler)	87	98	83	76	88	76	91	89	85	82	80	85
Lebanon (Warren)	85	98	95	81	92	86	88	92	91	89	86	88
<b>Columbus Area</b>												
London (Madison)	84	97	90	75	81	76	83	90	87	82	77	80
New Albany (Franklin)	90	103	94	78	92	82	87	95	91	88	84	87
Franklin (Franklin)	83	99	84	73	86	79	79	88	85	81	79	81
<b>Ohio Other Areas</b>												
Marietta (Washington)	85	95	80	77	88	81	86	86	84	81	82	85
<b>St. Louis Area</b>												
W. Alton (MO)	85	99	91	77	89	91	89	91	89	85	85	89
Orchard (MO)	88	98	90	76	92	92	83	92	88	86	86	89
Sunset Hills (MO)	88	98	88	70	89	80	89	91	85	82	79	86
Arnold (MO)	86	93	82	70	92	79	87	87	81	81	80	86
Margaretta (MO)	80	98	90	72	91	76	91	89	86	84	79	86
Maryland Heights (MO)					88	84	94					88

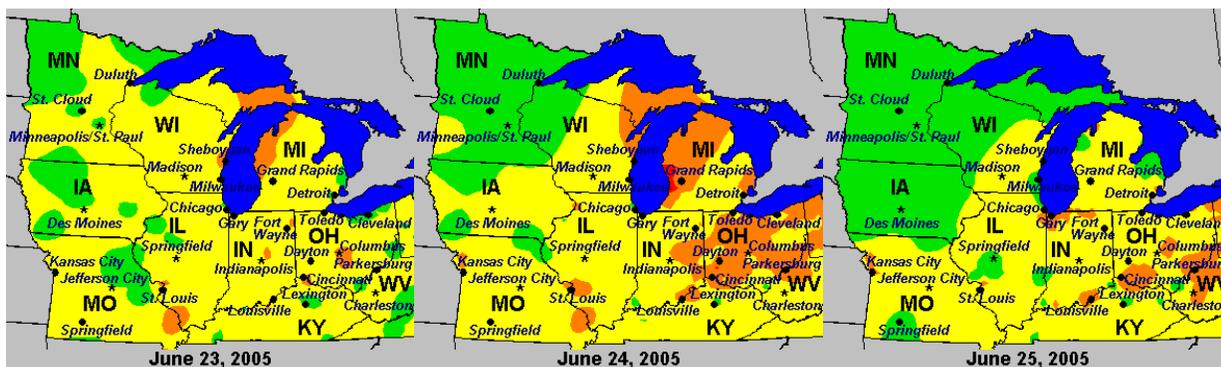
*Meteorology and Transport:* Most pollutants exhibit some dependence on meteorological factors, especially wind direction, because that governs which sources are upwind and thus most influential on a given sample. Ozone is even more dependent, since its production is driven by high temperatures and sunlight as well as precursor concentrations (see, for example, Figure 2).



**Figure 2. Number of hot days and 8-hour “exceedance” days in Lake Michigan area (1990 – 2006)**

Qualitatively, ozone episodes in the region are associated with hot weather, clear skies (sometimes hazy), low wind speeds, high solar radiation, and southerly to southwesterly winds. These conditions are often a result of a slow-moving high pressure system to the east of the region. The relative importance of various meteorological factors is discussed later in this section.

Transport of ozone (and its precursors) is a significant factor and occurs on several spatial scales. Regionally, over a multi-day period, somewhat stagnant summertime conditions can lead to the build-up in ozone and ozone precursor concentrations over a large spatial area. This pollutant air mass can be advected long distances, resulting in elevated ozone levels in locations far downwind. An example of such an episode is shown in Figure 3.



**Figure 3. Example of elevated regional ozone concentrations (June 23 – 25, 2005)**

Locally, emissions from urban areas add to the regional background leading to ozone concentration hot spots downwind. Depending on the synoptic wind patterns (and local land-lake breezes), different downwind areas are affected (see, for example, Figure 4).

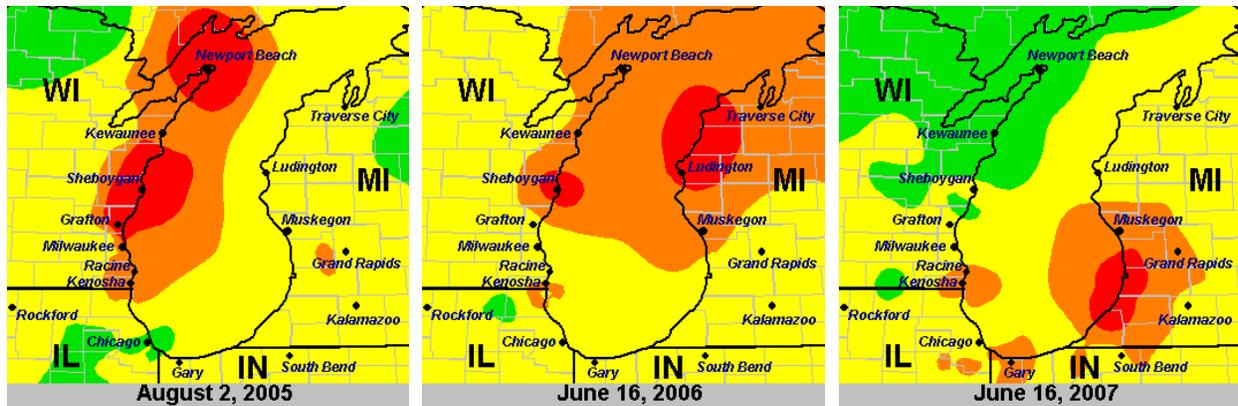


Figure 4. Examples of recent high ozone days in the Lake Michigan area

Altoft (aircraft) measurements in the Lake Michigan area also provide evidence of elevated regional background concentrations and “plumes” from urban areas. For one example summer day (August 20, 2003 – see Figure 5), the incoming background ozone levels were on the order of 80 – 100 ppb and the downwind ozone levels over Lake Michigan were on the order of 100 – 150 ppb (STI, 2004).

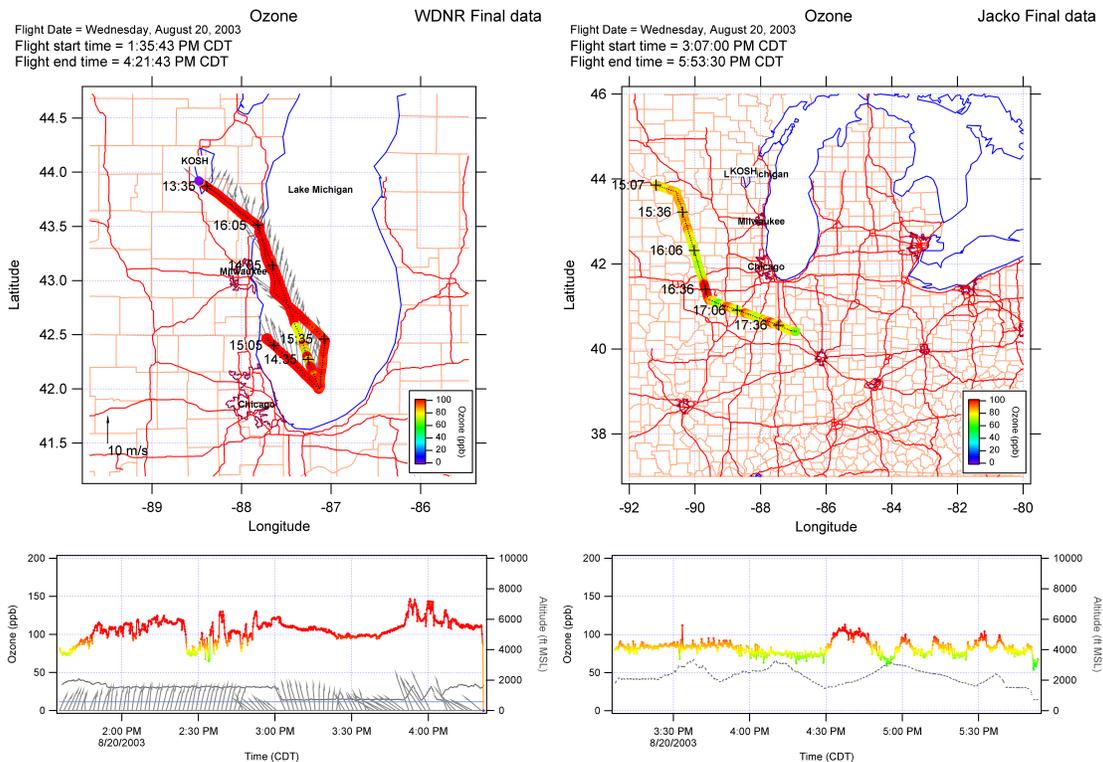
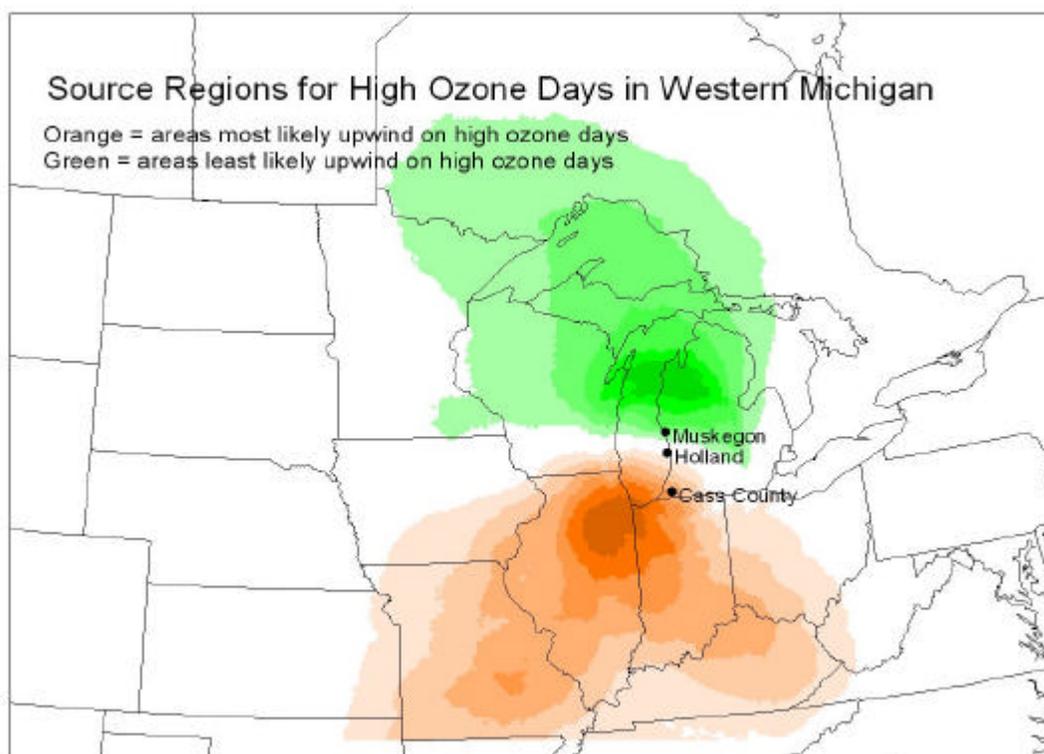


Figure 5. Aircraft ozone measurements over Lake Michigan (left) and along upwind boundary (right) – August 20, 2003 (Note: aircraft measurements reflect instantaneous values)

To further examine high ozone conditions in the Lake Michigan area, two simple transport-related analyses were performed. The analyses provide information on the source regions likely impacting high ozone concentrations in western Michigan and estimate the impact of these source regions<sup>6</sup>.

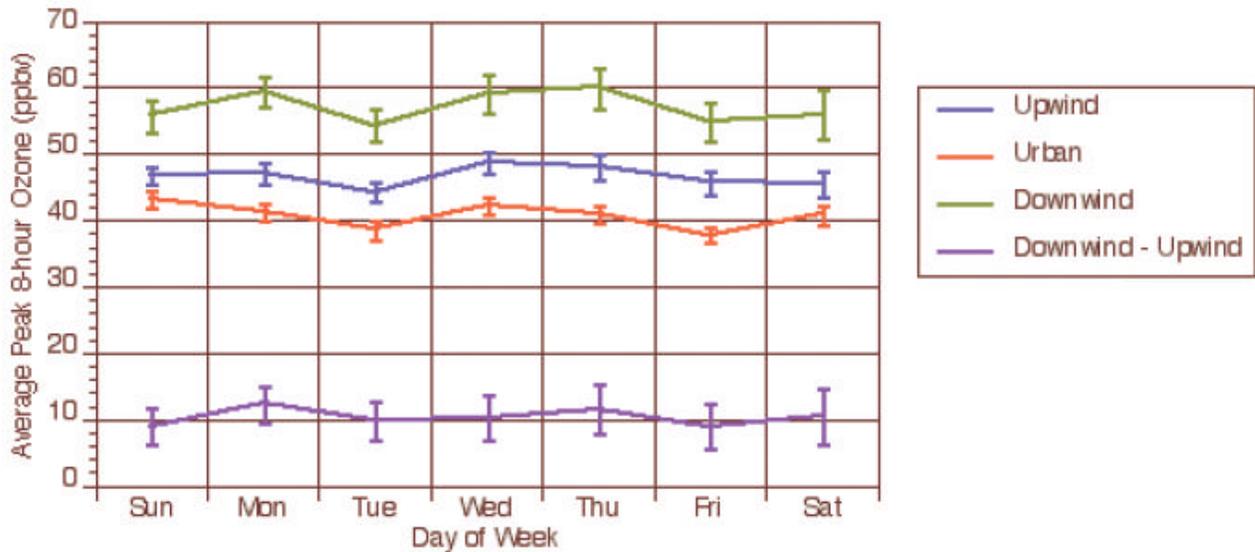
First, back trajectories were constructed using the HYSPLIT model for high ozone days (8-hour peak > 80 ppb) during the period 2002-2006 in western Michigan to characterize general transport patterns. Composite trajectory plots for all high ozone days based on data from three sites (Cass County, Holland, and Muskegon) are provided in Figure 6. The plots point back to areas located to the south-southwest (especially, northeastern Illinois and northwestern Indiana) as being upwind on these high ozone days.



**Figure 6 Back trajectory analysis showing upwind areas associated with high ozone concentrations**

Second, to assess the impact from Chicago/NW Indiana, Blanchard (2005) performed a simple comparison of ozone concentrations upwind (Braidwood, IL), within Chicago (ten sites in the City), and downwind (Holland and Muskegon) for days in 1999 – 2002 with southwesterly winds - i.e., transport towards western Michigan. Figure 7 shows the distribution of daily peak 8-hour ozone concentrations by day-of-week, with a line connecting the mean values. The difference between day-of-week mean values at downwind and upwind sites indicates that Chicago/NW Indiana contribute about 10-15 ppb to downwind ozone levels.

<sup>6</sup> As discussed in Section 4.1, future year air quality modeling results show that western Michigan is likely to remain nonattainment for ozone past the attainment date.

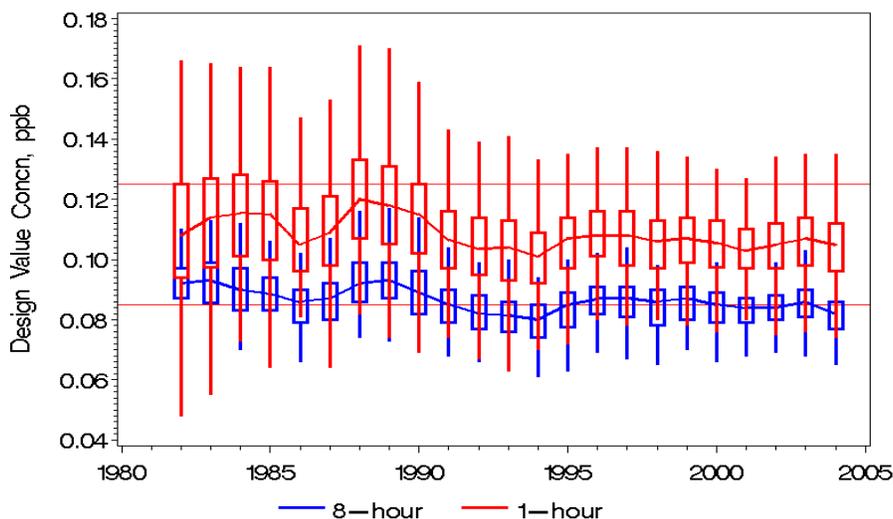


**Figure 7. Mean day-of-week peak 8-hour ozone concentrations at sites upwind, within, and downwind of Chicago, 1999 – 2002 (southwesterly wind days)**

Based on this information, the following key findings related to transport can be made:

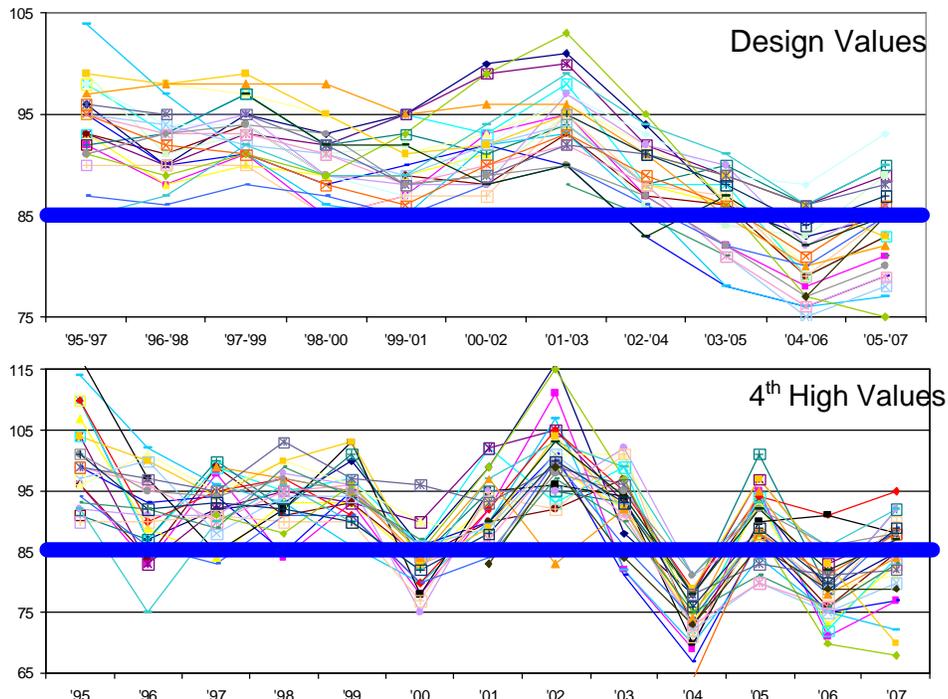
- Ozone transport is a problem affecting many portions of the eastern U.S. The Lake Michigan area (and other areas in the LADCO region) both receive high levels of incoming (transported) ozone and ozone precursors from upwind source areas on many hot summer days, and contribute to the high levels of ozone and ozone precursors affecting downwind receptor areas.
- The presence of a large body of water (i.e., Lake Michigan) influences for the formation and transport of ozone in the Lake Michigan area. Depending on large-scale synoptic winds and local-scale lake breezes, different parts of the area experience high ozone concentrations. For example, under southerly flow, high ozone can occur in eastern Wisconsin, and under southwesterly flow, high ozone can occur in western Michigan.
- Downwind shoreline areas around Lake Michigan are affected by both regional transport of ozone and subregional transport from major cities in the Lake Michigan area. Counties along the western shore of Michigan (from Benton Harbor to Traverse City, and even as far north as the Upper Peninsula) are impacted by high levels of incoming (transported) ozone.

*Data Variability:* Since 1980, considerable progress has been made by federal and state ozone control programs to meet the previous 1-hour ozone standard. Figure 8 shows the decline in both the 1-hour and 8-hour design values for the 5-state LADCO region over the last 25 years.



**Figure 8 Ozone design value trends in 5-State region**

The trend is more dramatic for several ozone monitoring sites in the 5-state region (see Figure 9). This plot shows a pronounced downward trend since the 2001-2003 period, due, in part, to the very low 4<sup>th</sup> high values in 2004.



**Figure 9. Trend in ozone design values and 4<sup>m</sup> high values for higher ozone sites in region**

The improvement in ozone concentrations is also seen in the decrease in the number of sites measuring nonattainment over the past 15 years in the Lake Michigan area (see Figure 10).

Ozone Design Values, 1995\_1997

Ozone Design Values, 2000\_2002

Ozone Design Values, 2005\_2007

DV, in ppb  
90+  
85-89  
80-84  
<80

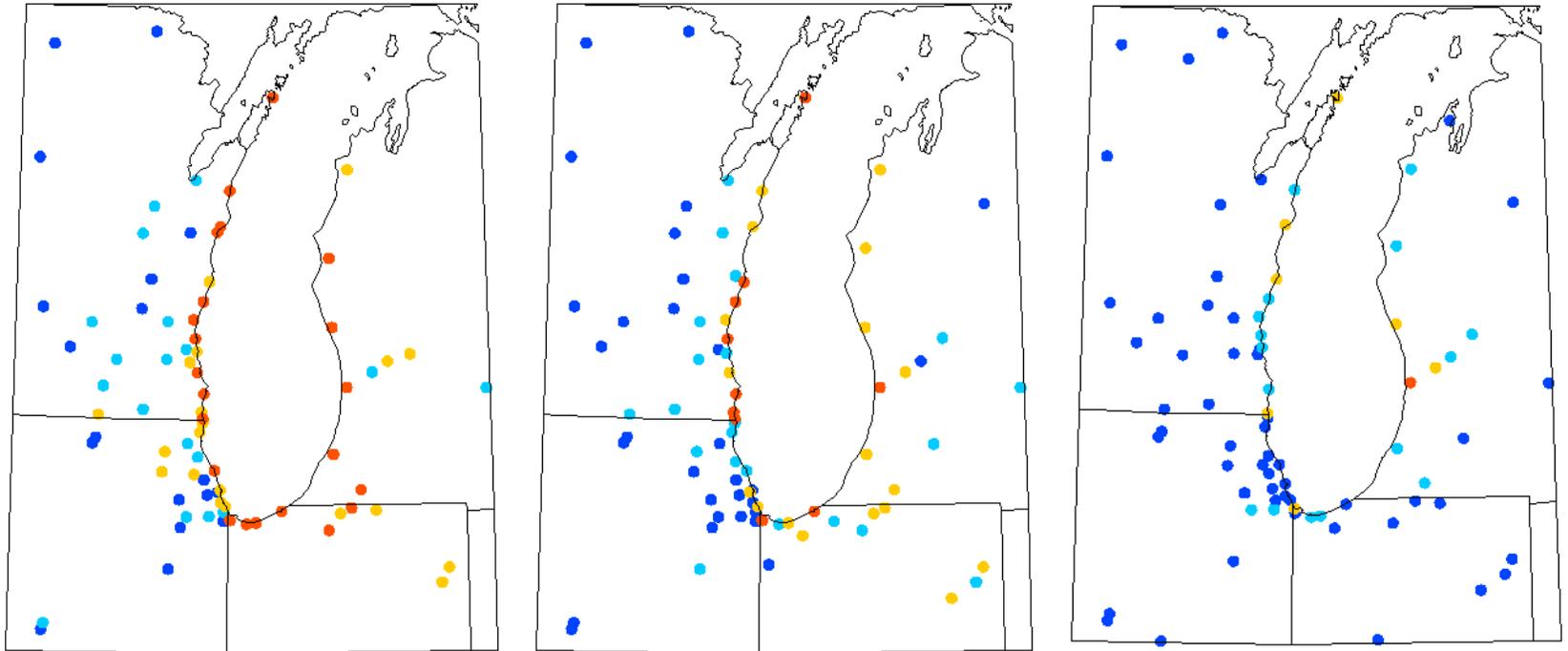


Figure 10. Ozone design value maps for 1995-1997, 2000-2002, and 2005-2007

Given the effect of meteorology on ambient ozone levels, year-to-year variations in meteorology can make it difficult to assess trends in ozone air quality. Two approaches were considered to adjust ozone trends for meteorological influences: an air quality-meteorology statistical model developed by USEPA (i.e., Cox method), and statistical grouping of meteorological variables performed by LADCO (i.e., Classification and Regression Trees, or CART).

*Cox Method:* This method uses a statistical model to ‘remove’ the annual effect of meteorology on ozone (Cox and Chu, 1993). A regression model was fit to the 1996-2005 data to relate daily peak ozone concentrations to seven daily meteorological variables (daily maximum temperature, midday average relative humidity, morning and afternoon wind speed and wind direction, and morning mixing height), plus seasonal and annual factors. The model is then used to predict 4<sup>th</sup> high ozone values. By holding the meteorological effects constant, the long-term trend can be examined independent of meteorology. Presumably, this trend reflects the effect of ozone precursor emissions.

Figure 11 shows the meteorologically-adjusted 4<sup>th</sup> high ozone concentrations for monitors near the major urban areas in the region. The plots indicate a general downward trend since the late 1990s for most cities, indicating that recent emission reductions have had a positive effect in improving ozone air quality. It should be noted, however, that the met-adjusted trends are less pronounced than the actual (unadjusted) trends – compare Figures 9 and 11 – suggesting that meteorology has also had an effect on the recent ozone levels.

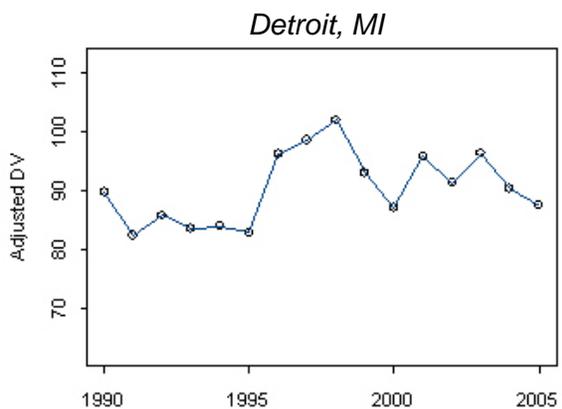
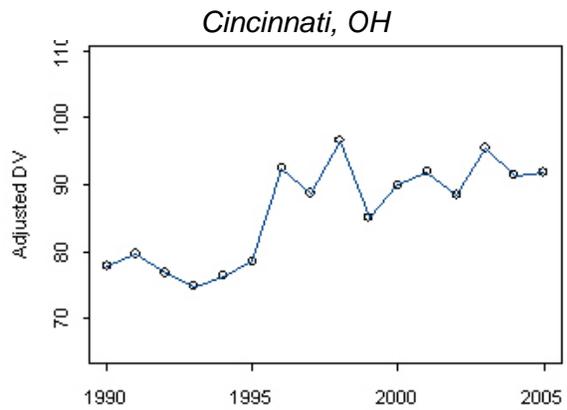
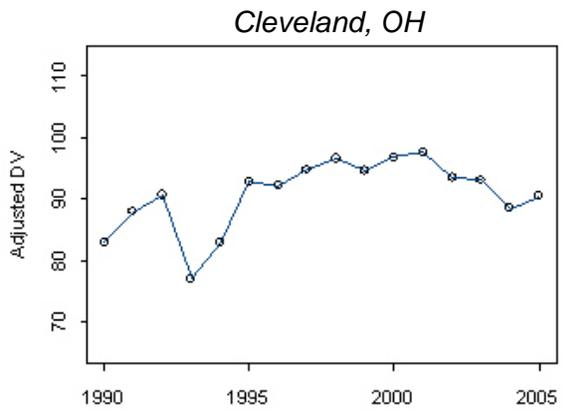
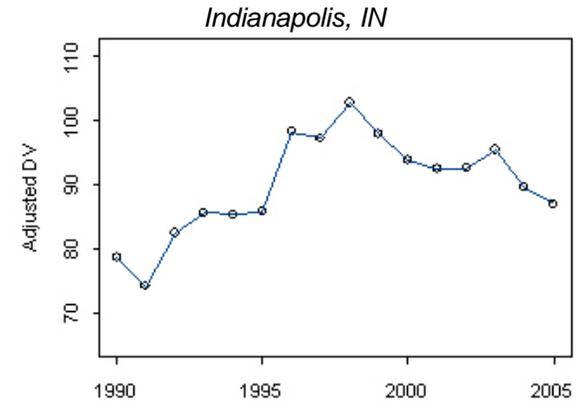
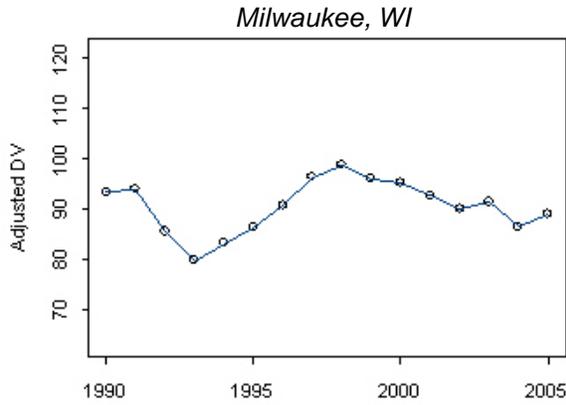
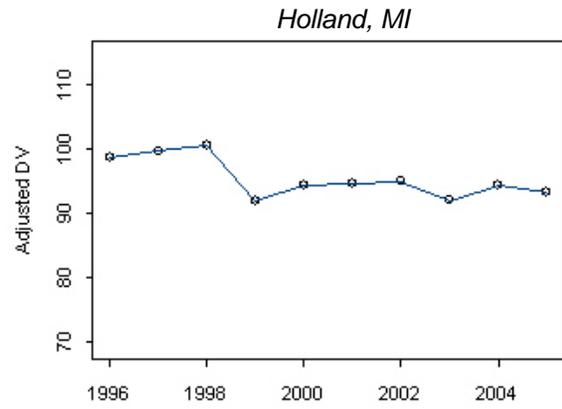
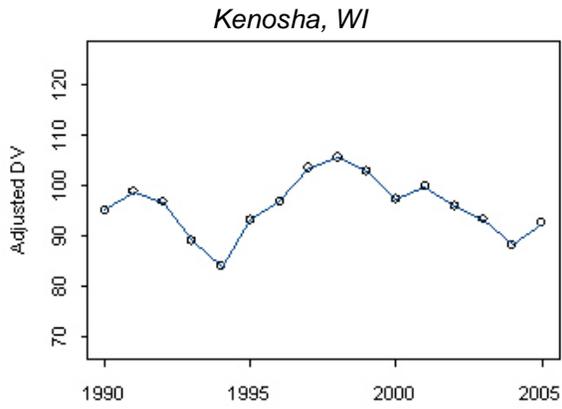


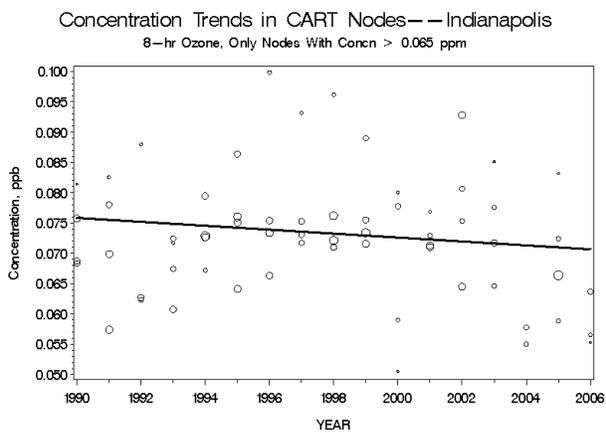
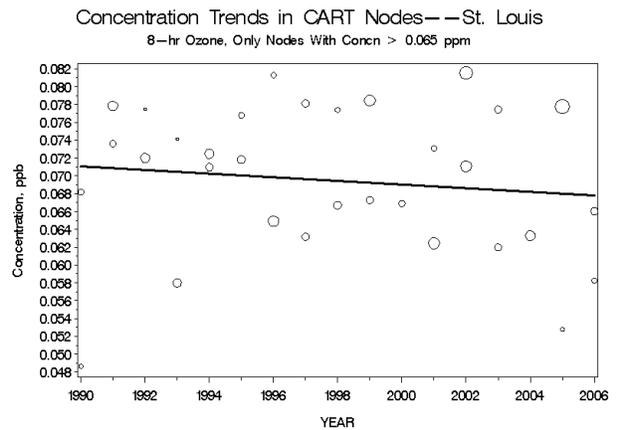
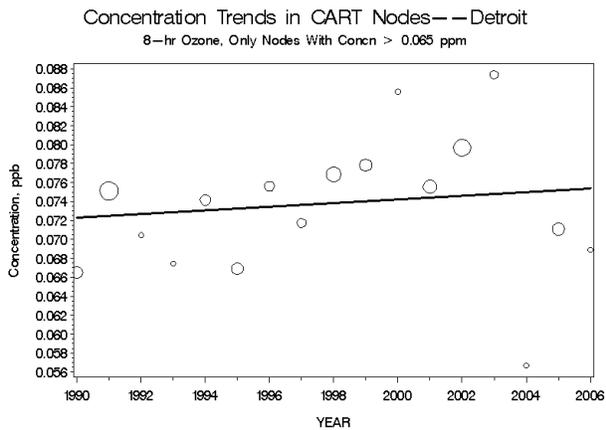
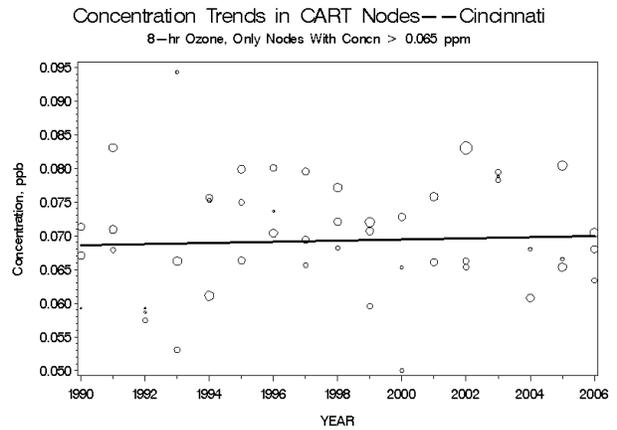
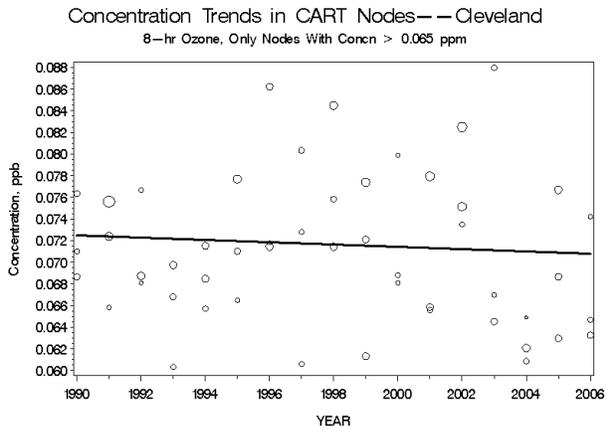
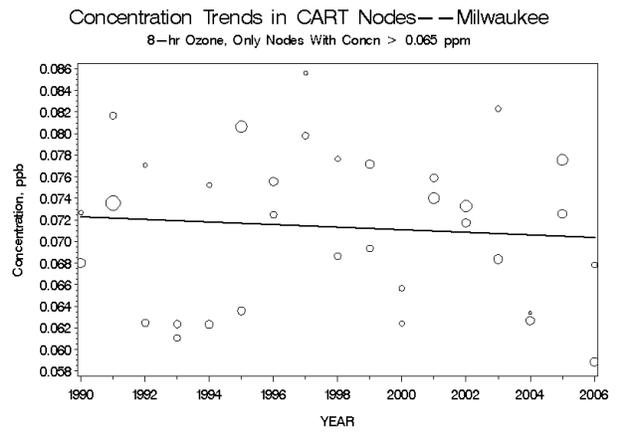
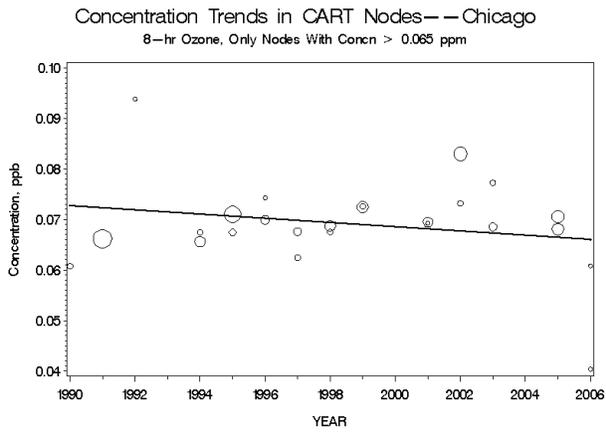
Figure 11. Meteorologically-adjusted 4<sup>th</sup> high 8-hour ozone concentrations for select monitoring sites in 5-state region

*CART*: Classification and Regression Tree (*CART*) analysis is another statistical technique which partitions data sets into similar groups (Breiman et al., 1984). With this model, days are sorted into groups based on similar meteorological characteristics. The meteorological variables included in the model include surface and aloft wind direction, wind speed, relative humidity, temperature, dewpoint, pressure, mixing height, solar radiation, and cloud cover. Ozone data were examined for the period 1990-2005.

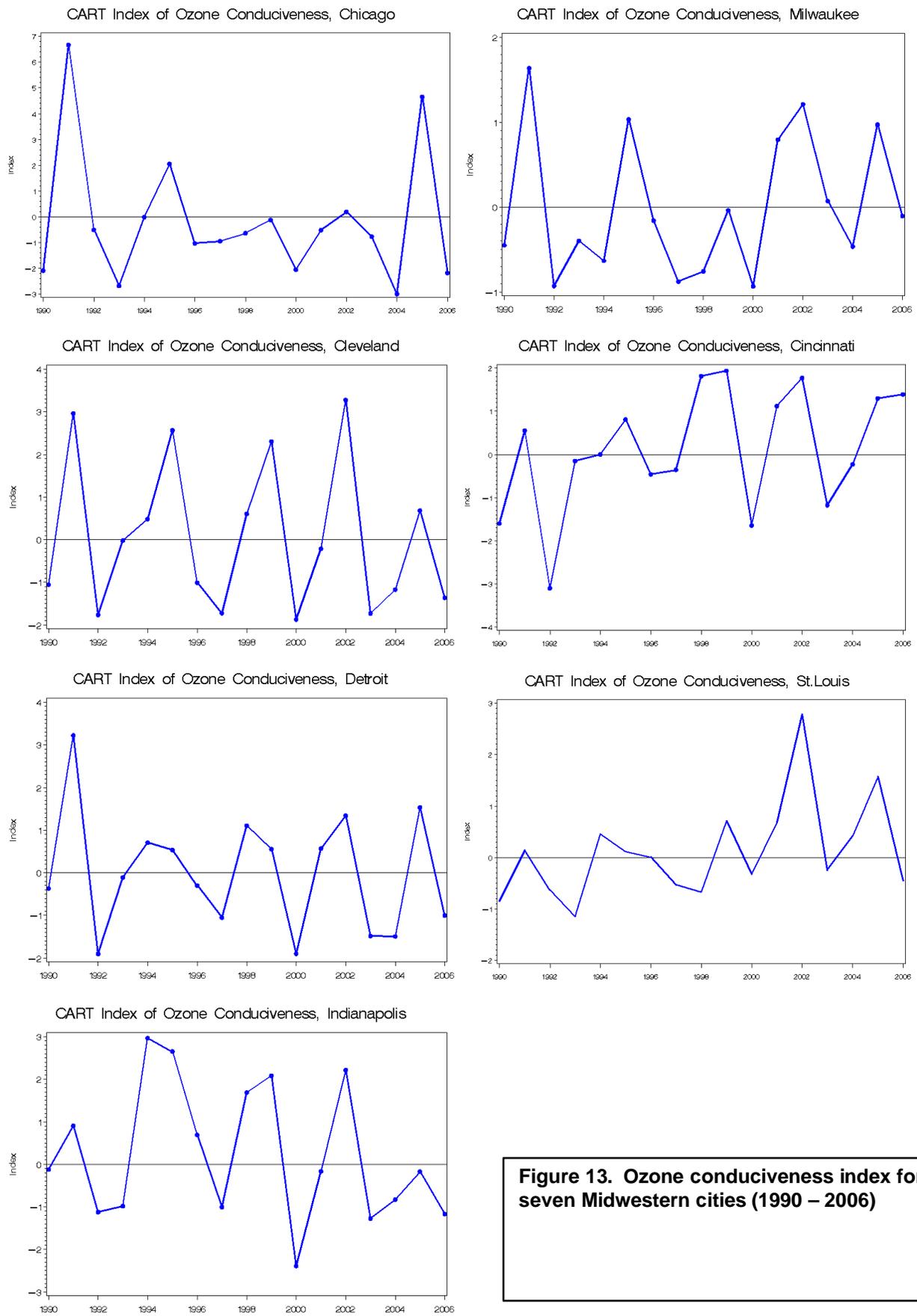
The trends within these groups are then examined. Because the meteorology within each group is similar, the trends over time are 'adjusted' for meteorology and should show trends in ozone precursor emissions. The results for the higher concentration groups for seven cities in the region are presented in Figure 12 and show a general downward trend, especially since about 2000, consistent with the results of the Cox method (Kenski, 2007).

The effect of meteorology was further examined by using an ozone conduciveness index (Kenski, 2007). This metric reflects the variability from the 17-year average in the number of days in the higher ozone concentration groups. As expected, hotter summers (e.g., 1991, 1995, 2002, and 2005) generally have an above average number of ozone conducive days, and cooler summers (e.g., 1992, 2000, and 2004) have a below average number of ozone conducive days (see Figure 13). Also worth noting is that for most Midwest cities, the 2004-2006 period was somewhat less ozone conducive than the period 2001-2003, again suggesting that meteorology also had an effect on the recent ozone trends. Other factors, such as differences in transport patterns from one year to the next, also should be taken into account.

In summary, the Cox and *CART* analyses show that the recent improvement in ozone air quality is due to a combination of emission reductions and less ozone conducive meteorology.



**Figure 12. Trends for higher ozone CART groups (average ozone > 86 ppb) for seven Midwestern cities (1990 – 2006)**  
**Note: line represents linear best fit**



**Figure 13. Ozone conduciveness index for seven Midwestern cities (1990 – 2006)**

*Precursor Sensitivity:* Ozone is formed from the reactions of hydrocarbons and nitrogen oxides under meteorological conditions that are conducive to such reactions (i.e., warm temperatures and strong sunlight). In areas with high VOC/NO<sub>x</sub> ratios, typical of rural environments (with low NO<sub>x</sub>), ozone tends to be more responsive to reductions in NO<sub>x</sub>. Conversely, in areas with low VOC/NO<sub>x</sub> ratios, typical of urban environments (with high NO<sub>x</sub>), ozone tends to be more responsive to VOC reductions.

An analysis of VOC and NO<sub>x</sub>-limitation was conducted with the ozone MAPPER program, which is based on the Smog Production (SP) algorithm (Blanchard, et al., 2004a). The “Extent of Reaction” parameter in the SP algorithm provides an indication of VOC and NO<sub>x</sub> sensitivity:

Extent Range	Precursor Sensitivity
< 0.6	VOC-sensitive
0.6 – 0.8	Transitional
> 0.8	NO <sub>x</sub> -sensitive

A map of the Extent of Reaction values for high ozone days is provided in Figure 14. As can be seen, ozone is usually VOC-limited in cities and NO<sub>x</sub>-limited in rural areas. (Data from aircraft measurements suggest that ozone is usually NO<sub>x</sub>-limited over Lake Michigan and away from urban centers on days when ozone in the urban centers is VOC-limited.) Further analysis showed that the highest ozone days tend to be NO<sub>x</sub>-limited. This analysis suggests that a NO<sub>x</sub> reduction strategy would be effective in reducing ozone levels. Examination of day-of-week concentrations, however, appears to contradict this finding.

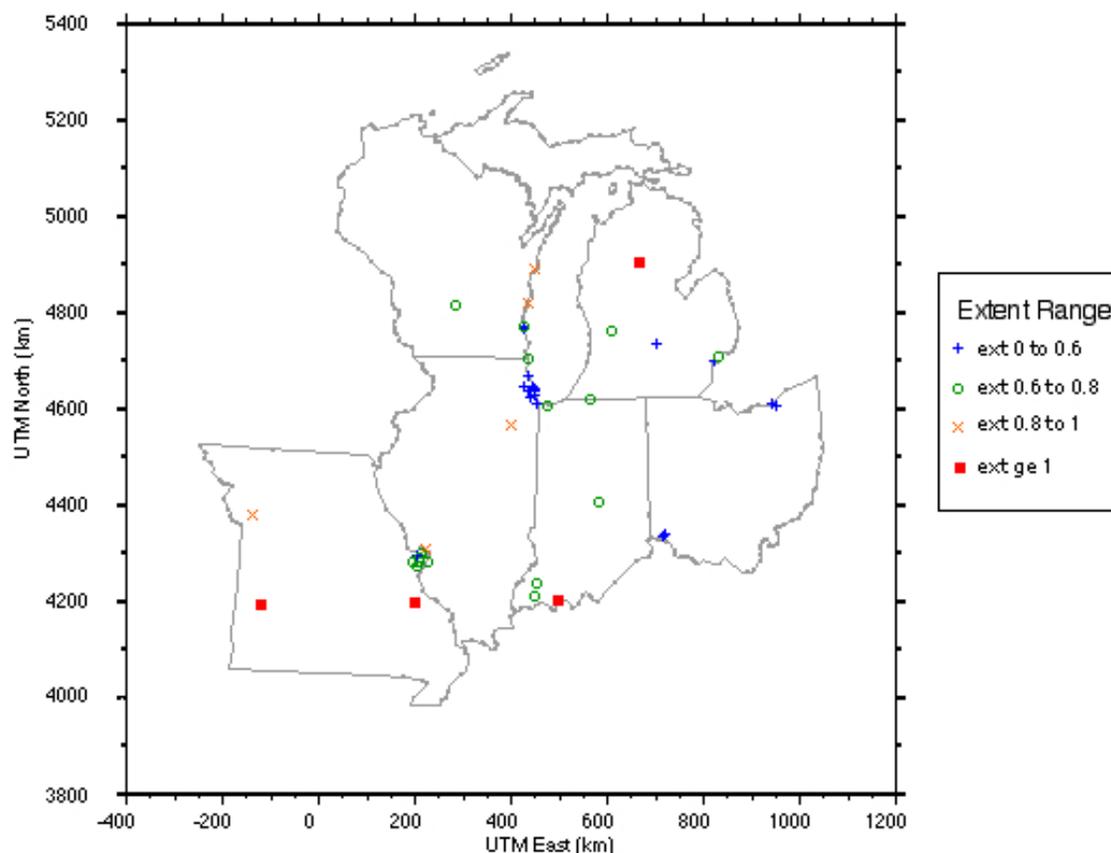
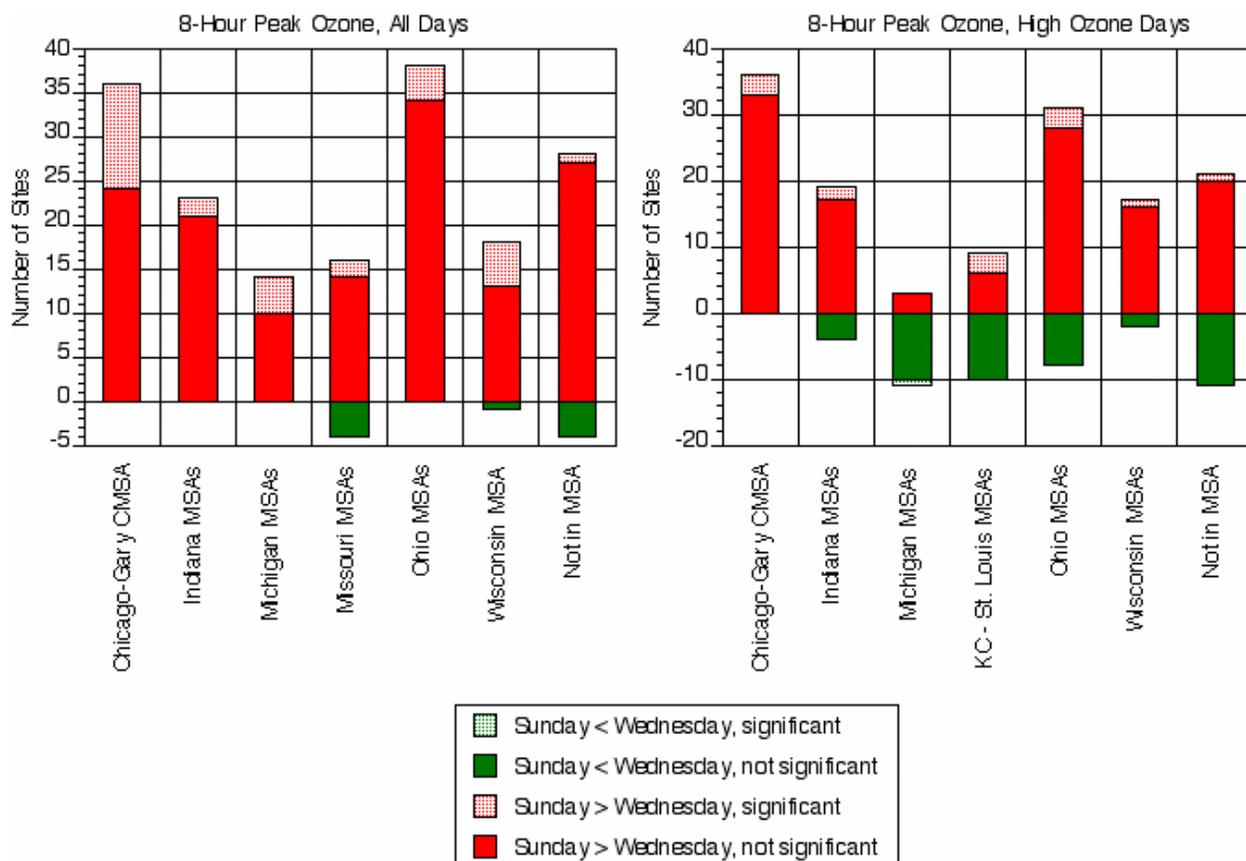


Figure 14. Mean afternoon extent of reaction (1998 – 2002)

Blanchard (2004a and 2005) examined weekend-weekday differences in ozone and NO<sub>x</sub> in the Midwest. All urban areas in these studies exhibited substantially lower (40-60%) weekend concentrations of NO<sub>x</sub> compared to weekday concentrations. Despite the lower NO<sub>x</sub>, weekend ozone concentrations were not lower; in fact, most urban sites had higher concentrations of ozone, although the increase was generally not statistically significant (see Figure 15). This small but counterproductive change in **local** ozone concentrations suggests that **local** urban-scale NO<sub>x</sub> reductions alone may not be very effective.



**Figure 15. Weekday/weekend differences in 8-hour ozone – number of sites with weekend increase (positive values) v. number of sites with weekend decreases (negative values)**

Blanchard (2005) looked at the effect of changes in precursor emissions in Chicago on downwind ozone levels in western Michigan. For the transport days of interest (i.e., southwesterly flow during the summers of 1999 – 2002), mean NO<sub>x</sub> concentrations in Chicago are about 50% lower and mean ozone concentrations at the (downwind) western Michigan sites are about 1.5 – 5.2 ppb (3 – 8 %) lower on Sunday compared to Wednesday. This degree of change in downwind ozone levels suggests a positive, albeit non-linear response to urban area emission reductions.

Further information on weekend-weekday ozone differences is available in a recent modeling study for southeastern Michigan (Environ, 2007c). This study found that: weekend changes in ozone precursor emissions cause both increases and decreases in Southeast Michigan ozone, depending upon location and time:

- Weekend increases in 8-hour maximum ozone occur in and immediately downwind of the Detroit urban area (i.e., in VOC-sensitive areas).
- Weekend decreases in 8-hour maximum ozone occur outside and downwind of the Detroit urban area (i.e., in NO<sub>x</sub>-sensitive areas).
- At the location of the peak 8-hour ozone downwind of Detroit, ozone was lower on weekends than weekdays.
- Ozone benefits (reductions) due to weekend emission changes in Southeast Michigan can be transported downwind for hundreds of miles.
- Southeast Michigan benefits from lower ozone transported into the region on Saturday through Monday because of weekend emission changes in upwind areas.

In summary, these analyses suggest that urban VOC reductions and regional (urban and rural) NO<sub>x</sub> reductions will be effective in lowering ozone concentrations. Local NO<sub>x</sub> reductions can lead to local ozone increases (i.e., NO<sub>x</sub> disbenefits), but this effect does not appear to pose a problem with respect to attainment of the standard. It should also be noted that urban VOC and regional NO<sub>x</sub> reductions are likely to have multi-pollutant benefits (e.g., lower ozone and lower PM<sub>2.5</sub> impacts).

## **2.2 PM<sub>2.5</sub>**

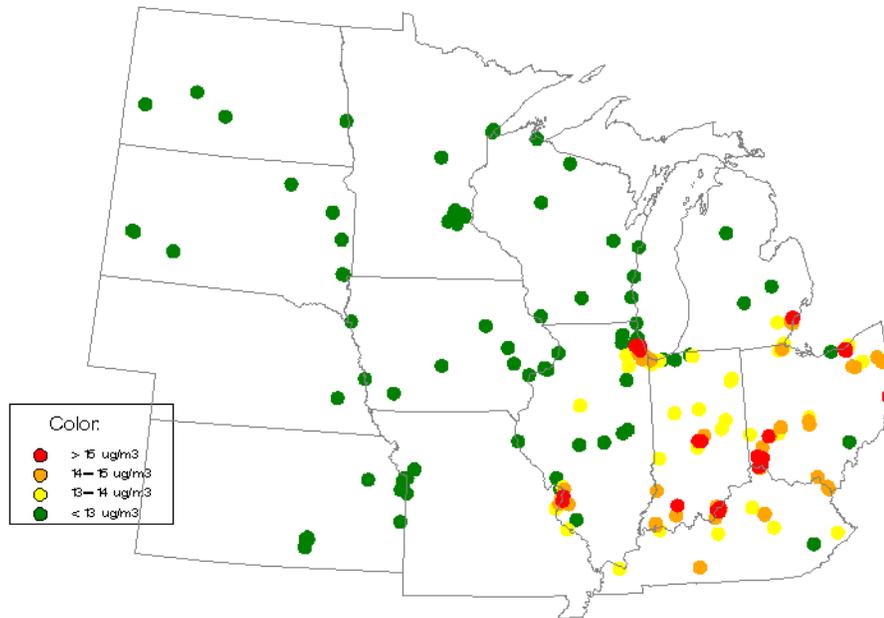
In 1997, USEPA adopted the PM<sub>2.5</sub> standards of 15 ug/m<sup>3</sup> (annual average) and 65 ug/m<sup>3</sup> (24-hour average). The annual standard is attained if the 3-year average of the annual average PM<sub>2.5</sub> concentration is less than or equal to the level of the standard. The daily standard is attained if the 98th percentile of 24-hour PM<sub>2.5</sub> concentrations in a year, averaged over three years, is less than or equal to the level of the standard.

In 2006, USEPA revised the PM<sub>2.5</sub> standards to 15 ug/m<sup>3</sup> (annual average) and 35 ug/m<sup>3</sup> (24-hour average).

*Current Conditions:* Maps of annual and 24-hour PM<sub>2.5</sub> design values for the 3-year period 2004-2006 are shown in Figure 16. The “hotter” colors represent higher concentrations, where red dots represent sites with design values above the annual standard. Currently, there are 38 sites in violation of the annual PM<sub>2.5</sub> standard.

## PM2.5 FRM Mean Concentration, 2004–2006

Preliminary Data -- Not Official!  
Includes some sites with incomplete data



## PM2.5 FRM 98th Percentile Concentration, 2004–2006

Preliminary Data -- Not Official!  
Includes some sites with incomplete data

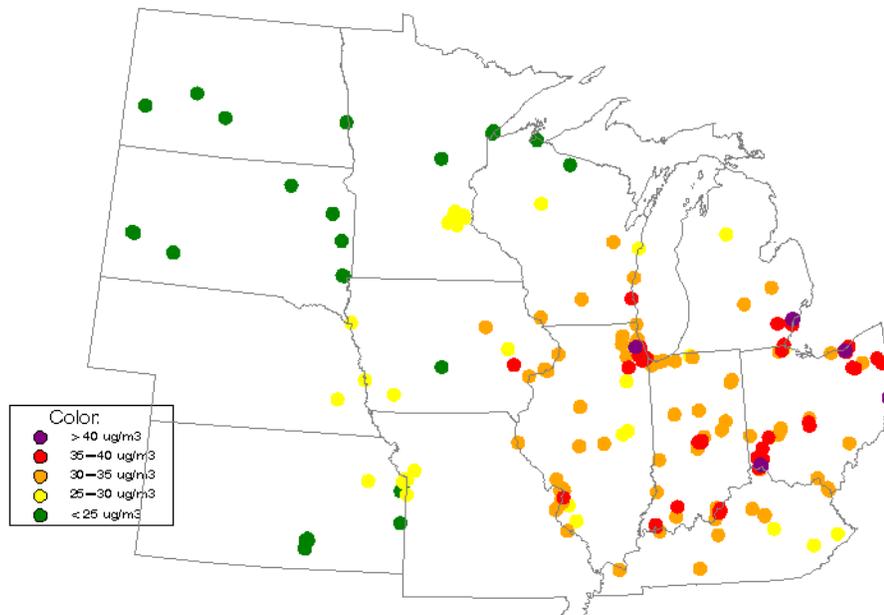
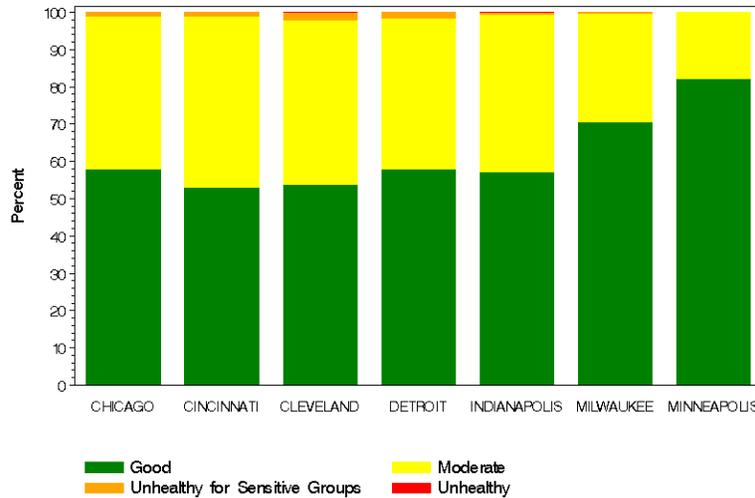


Figure 16. PM2.5 design values - annual average (top) and 24-hour average (bottom)– 2004-2006

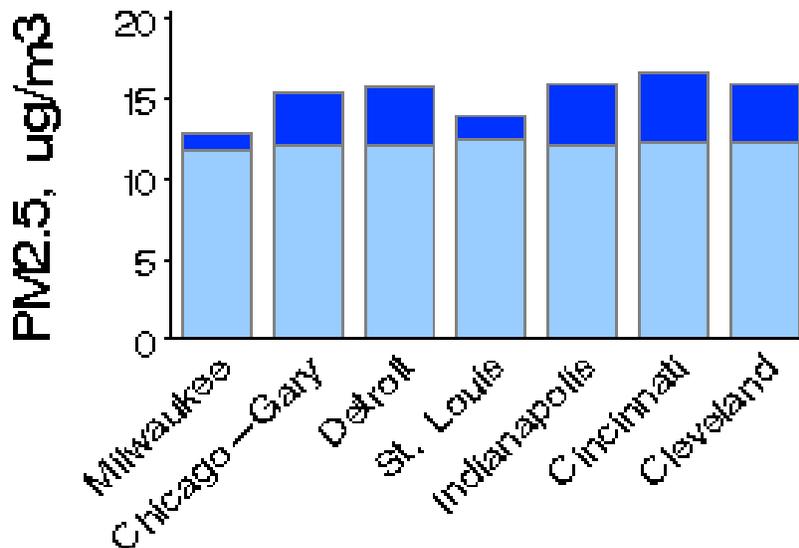
Although concentrations rarely exceed the 24-hour standard of  $65 \mu\text{g}/\text{m}^3$ , daily average concentrations in urban areas are frequently in the moderate ( $15\text{-}40 \mu\text{g}/\text{m}^3$ ) range and occasionally fall in the 'Unhealthy for Sensitive Groups' (USG) ( $40\text{-}65 \mu\text{g}/\text{m}^3$ ) range of the Air Quality Index (AQI) scale. Figure 17 shows the frequency of these excursions for major metropolitan areas in the region. Moderate/USG levels can occur at any time of the year.



**Figure 17. Percent of days in AQI categories for PM<sub>2.5</sub> (2002-2004)**

*Data Variability:* PM<sub>2.5</sub> concentrations vary spatially, temporally, and chemically in the region. This variability is discussed further below.

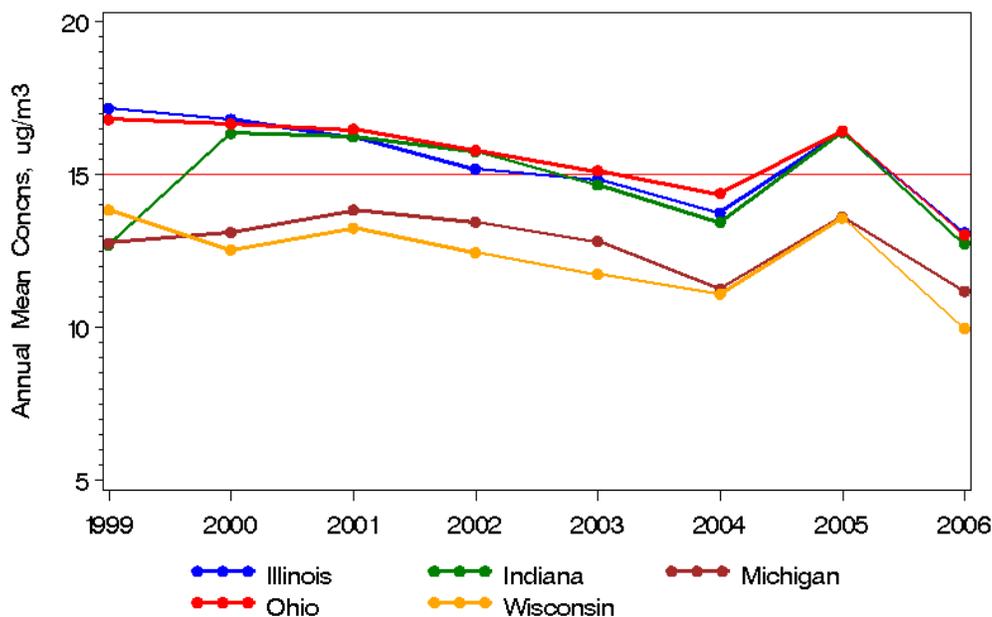
On an annual basis, PM<sub>2.5</sub> exhibits a distinct and consistent spatial pattern. As seen in Figure 16, across the Midwest, annual concentrations follow a gradient from low ( $5\text{-}6 \mu\text{g}/\text{m}^3$ ) in the northern and western reaches – Minnesota and northern Wisconsin – to high ( $17\text{-}18 \mu\text{g}/\text{m}^3$ ) in Ohio and along the Ohio River. In addition, concentrations in urban areas are higher than in rural areas upwind, indicating that local urban sources add a significant increment to the regional background, usually on the order of  $2\text{-}3 \mu\text{g}/\text{m}^3$  (see Figure 18).



**Figure 18. Local v. regional components of annual average PM<sub>2.5</sub> concentrations**

Because monitoring for PM<sub>2.5</sub> only began in earnest in 1999, after promulgation of the PM<sub>2.5</sub> standard, only limited data are available to assess trends. Time series based on federal reference method (FRM) PM<sub>2.5</sub>-mass data show a promising downward movement that is generally consistent from state to state (see Figure 19).

PM<sub>2.5</sub> Annual Mean Trends, LADCO States, 1999–2006



PM<sub>2.5</sub> 98th %ile Trends, LADCO States, 1999–2006

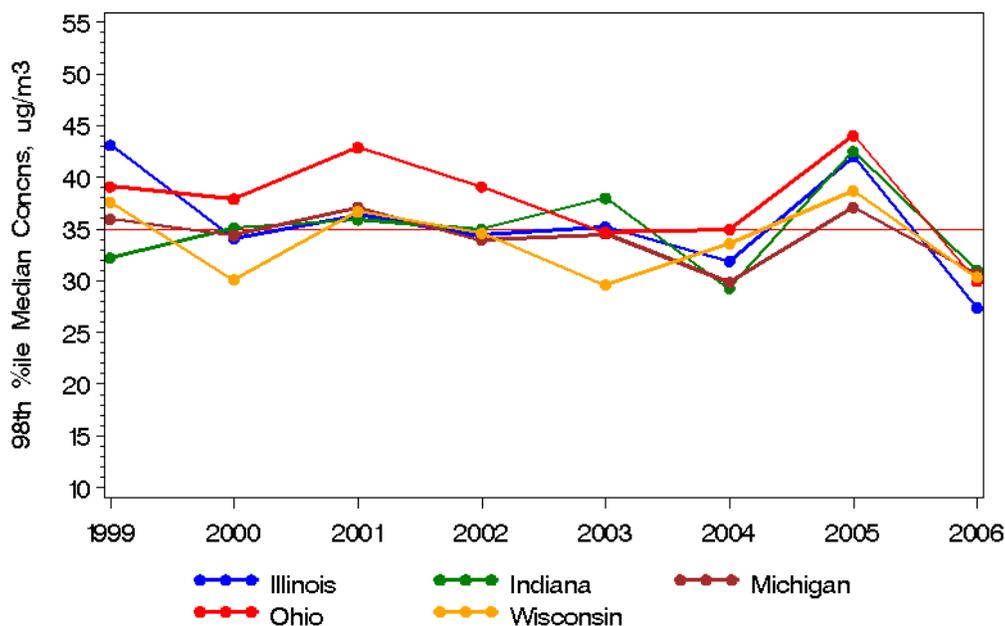
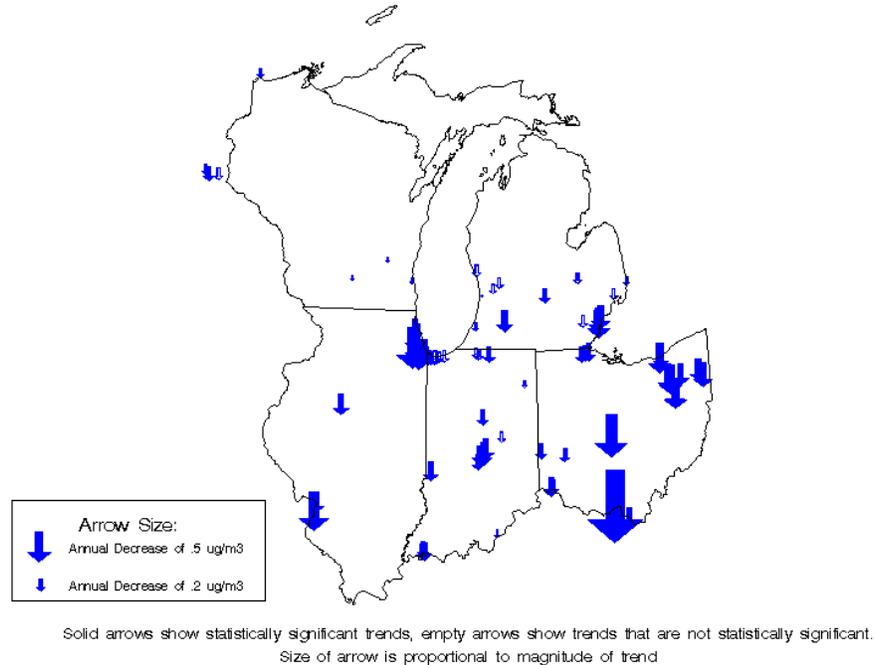


Figure 19 PM<sub>2.5</sub> trends in annual average (top) and daily concentrations (bottom)

A statistical analysis of PM<sub>2.5</sub> trends was performed using the nonparametric Theil test for slope (Hollander and Wolfe, 1973). Trends were generally consistent around the region, for both PM mass and for the individual components of mass. Figure 20 shows trends for PM<sub>2.5</sub> based on FRM data at sites with six or more years of data since 1999. The size and direction of each arrow shows the size and direction of the trend for each site; solid arrows show statistically significant trends and open arrows show trends that are not significant. Region-wide decreases are widespread and consistent; all sites had decreasing concentration trends (13 of the 38 were statistically significant). The average decrease for this set of sites is -0.24 ug/m<sup>3</sup>/year.

Theil Trends for FRM PM<sub>2.5</sub>, 1999—2006

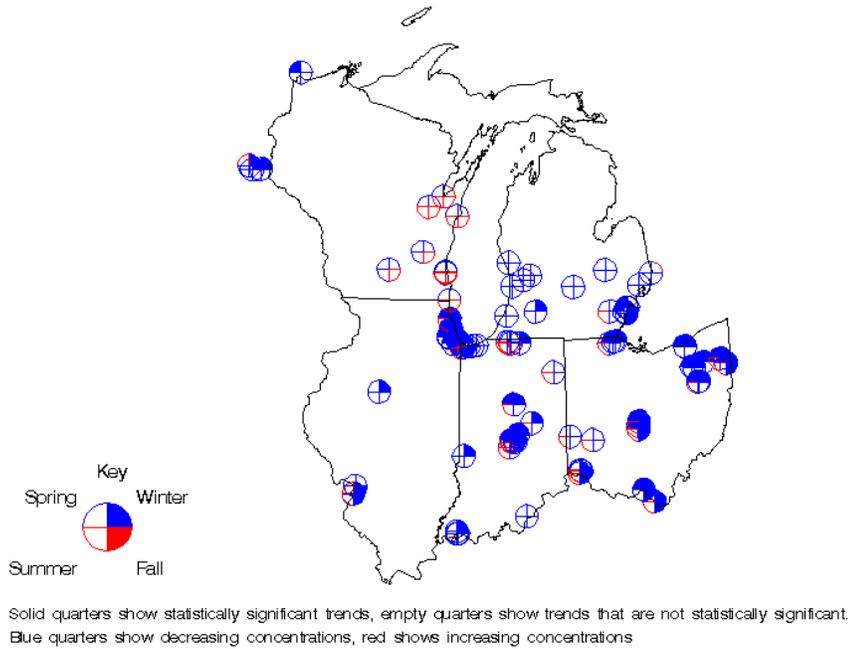


**Figure 20. Annual trends in PM<sub>2.5</sub> mass (1999 – 2006)**

Seasonal trends show mostly similar patterns (Figure 21). Trends were downward at most sites and seasons, with overall seasonal averages varying between -0.15 to -0.56 ug/m<sup>3</sup>/year. The strongest and most significant decreases took place during the winter quarter (January - March). No statistically significant increasing trends were observed.

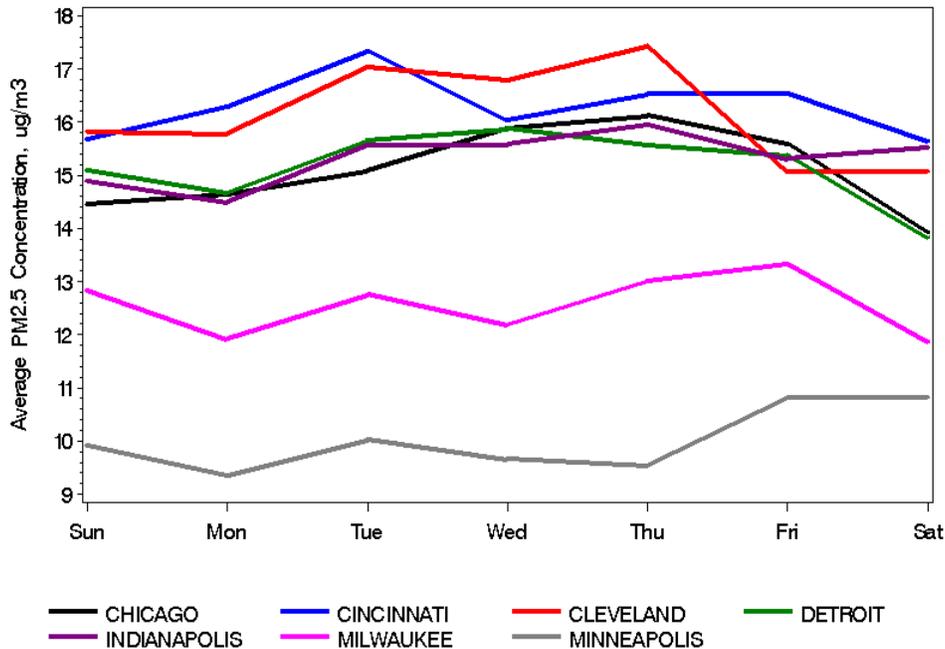
## Seasonal Trends for FRM PM<sub>2.5</sub>, 1999–2006

Based on Seasonal Daily Data



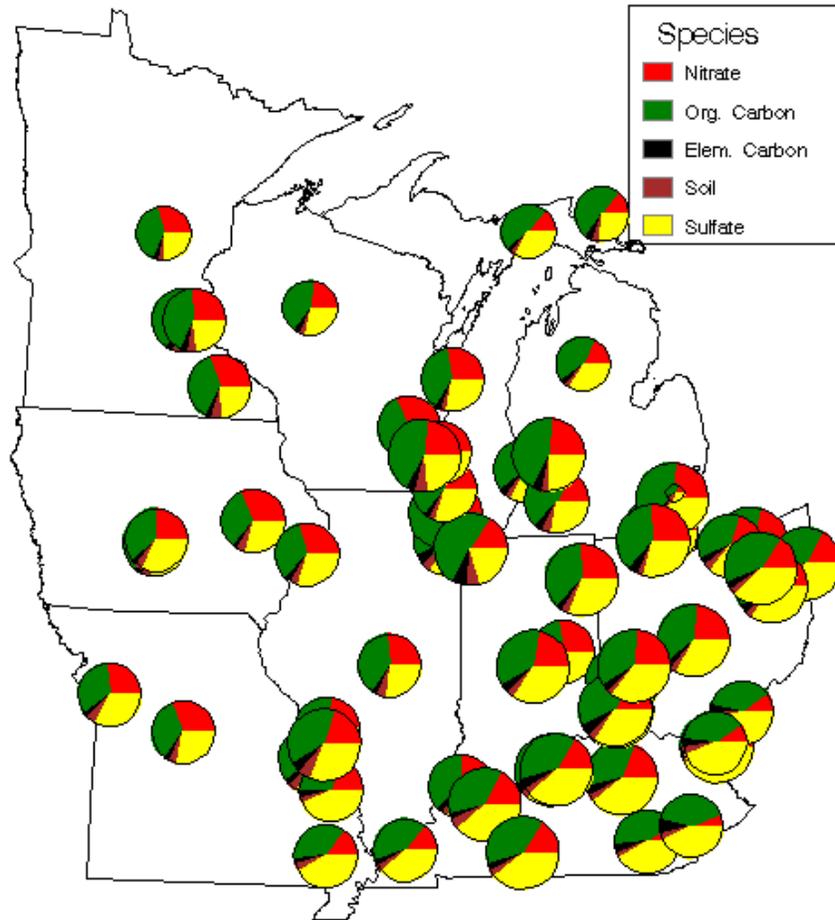
**Figure 21. Seasonal trends in PM<sub>2.5</sub> mass (1999 – 2006)**

PM<sub>2.5</sub> shows a slight variation from weekday to weekend, as seen in Figure 22. Although most cities have slightly lower concentrations on the weekend, the difference is usually less than 1  $\mu\text{g}/\text{m}^3$ . There is a more pronounced weekday/weekend difference at monitoring sites that are strongly source-influenced. Rural monitors tend to show less of a weekday/weekend pattern than urban monitors.



**Figure 22 Day-of-week variability in PM<sub>2.5</sub> (2002-2004)**

In the Midwest, PM<sub>2.5</sub> is made up of mostly ammonium sulfate, ammonium nitrate, and organic carbon in approximately equal proportions on an annual average basis. Elemental carbon and crustal matter (also referred to as soil) contribute less than 5% each. The three major components vary spatially and seasonally across the region (Figure 23 and 24), and these patterns account for much of the annual variability in PM<sub>2.5</sub> mass noted above.



**Figure 23. Spatial map of PM<sub>2.5</sub> chemical composition in the Midwest (2002-2003)**

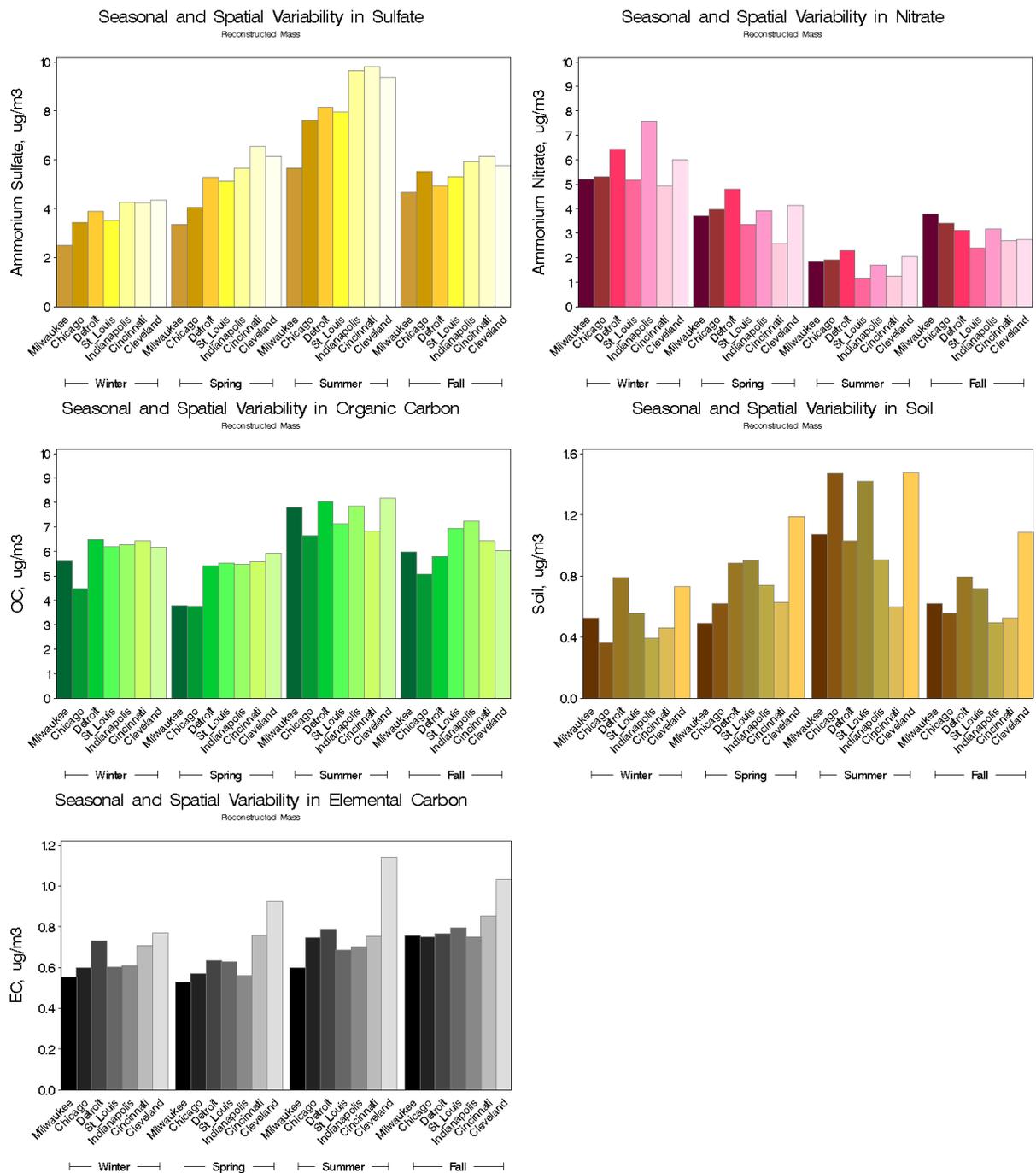


Figure 24 Seasonal and spatial variability in PM2.5 components

Ammonium sulfate peaks in the summer and is highest in the southern and eastern parts of the Midwest, closest to the Ohio River Valley. Sulfate is primarily a regional pollutant; concentrations are similar in rural and urban areas and highly correlated over large distances. It is formed when sulfuric acid (an oxidation product of sulfur dioxide) and ammonia react in the atmosphere, especially in cloud droplets. Coal combustion is the primary source of sulfur dioxide; ammonia is emitted primarily from animal husbandry operations and fertilizer use.

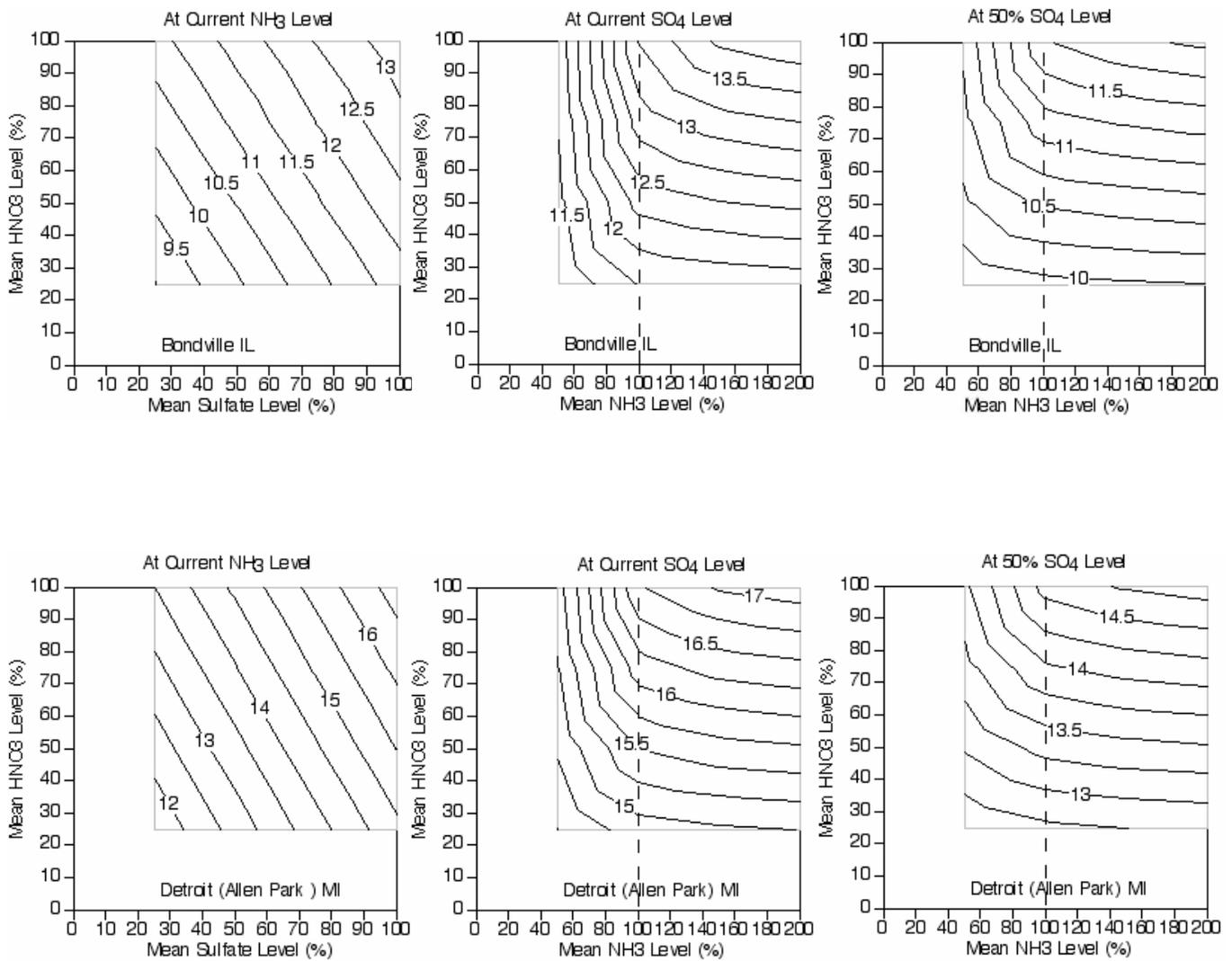
Ammonium nitrate has almost the opposite spatial and seasonal pattern, with the highest concentrations occurring in the winter and in the northern and western parts of the region. Nitrate seems to have both regional and local sources, because urban concentrations are higher than rural upwind concentrations. Ammonium nitrate forms when nitric acid reacts with ammonia, a process that is enhanced when temperatures are low and humidity is high. Nitric acid is a product of the oxidation of nitric oxide, a pollutant that is emitted by combustion processes.

Organic carbon is more consistent from season to season and city to city, with no clear pattern emerging; concentrations are generally slightly higher in the summer. Like nitrate, organic carbon has both regional and local components. Particulate organic carbon can be emitted directly from cars and other fuel combustion sources or formed in a secondary process as volatile organic gases react and condense.

*Precursor Sensitivity:* Data from the regional ammonia monitoring network were analyzed with thermodynamic equilibrium models to assess the effect of changes in precursor gas concentrations on PM<sub>2.5</sub> concentrations (Blanchard, 2005). These analyses indicate that particle formation responds in varying degrees to reductions in sulfate, nitric acid, and ammonia (see Figure 25):

- PM<sub>2.5</sub> mass is sensitive to reductions in sulfate at all times of the year and all parts of the region. Even though sulfate reductions cause more ammonia to be available to form ammonium nitrate (PM-nitrate increases slightly when sulfate is reduced), this increase is generally offset by the sulfate reductions, such that PM<sub>2.5</sub> mass decreases.
- PM<sub>2.5</sub> mass is also sensitive to reductions in nitric acid and ammonia. The greatest PM<sub>2.5</sub> decrease in response to nitric acid reductions occurs during the winter, when nitrate is a significant fraction of PM<sub>2.5</sub>.
- Under conditions with lower sulfate levels (i.e., proxy of future year conditions), PM decreases less in response to ammonia reductions.
- Ammonia becomes more limiting as one moves from west to east across the region.

Examination of weekend/weekday difference in PM-nitrate and NO<sub>x</sub> concentrations in the Midwest demonstrate that reductions in local (urban) NO<sub>x</sub> do not lead to proportionate reductions in PM-nitrate (Blanchard, 2004b). This result is consistent with analyses of continuous PM-nitrate from several US cities, including St. Louis (Millstein, et al, 2007).

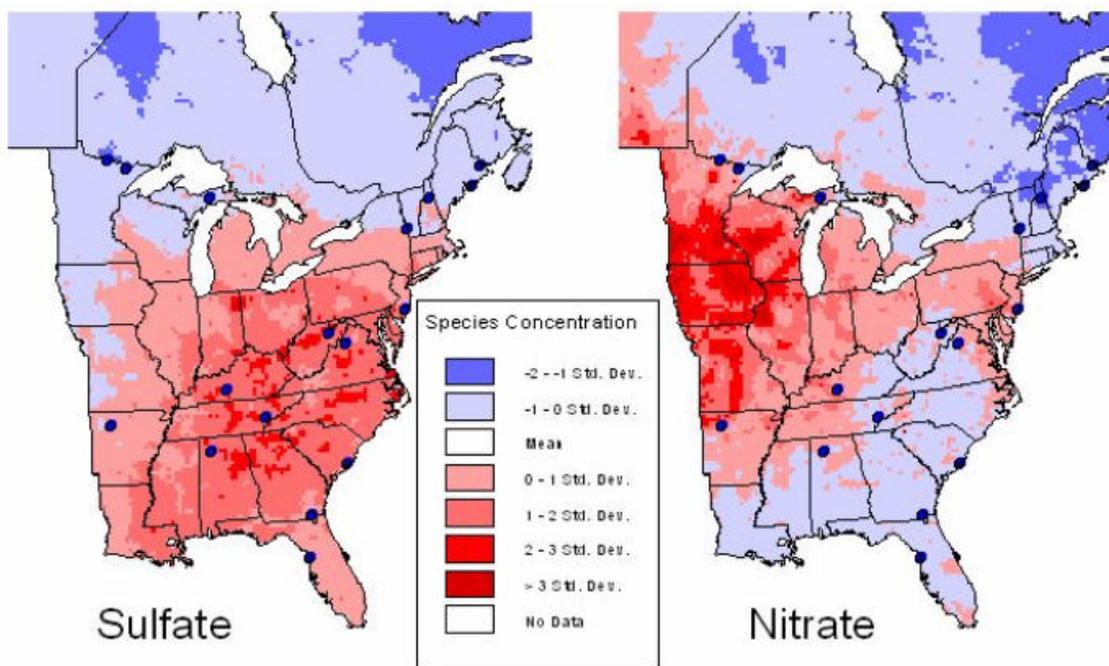


**Figure 25. Predicted mean PM fine mass concentrations at Bondville, IL (top) and Detroit (Allen Park), MI (bottom) as functions of changes in nitric acid (HNO<sub>3</sub>), sulfate, and ammonie (NH<sub>3</sub>)**

*Meteorology:* PM<sub>2.5</sub> concentrations are not as strongly influenced by meteorology as ozone, but the two pollutants share some similar meteorological dependencies. In the summer, conditions that are conducive to ozone (hot temperatures, stagnant air masses, and low wind speeds due to stationary high pressure systems) also frequently give rise to high PM<sub>2.5</sub>. In the case of PM, the reason is two-fold: (1) stagnation and limited mixing under these conditions cause PM<sub>2.5</sub> to build up, usually over several days, and (2) these conditions generally promote higher conversion of important precursors (SO<sub>2</sub> to SO<sub>4</sub>) and higher emissions of some precursors, especially biogenic carbon. Wind direction is another strong determinant of PM<sub>2.5</sub>; air transported from polluted source regions has higher concentrations.

Unlike ozone, PM<sub>2.5</sub> has occasional winter episodes. Conditions are similar to those for summer episodes, in that stationary high pressure and (relatively) warm temperatures are usually factors. Winter episodes are also fueled by high humidity and low mixing heights.

PM<sub>2.5</sub> chemical species show noticeable transport influences. Trajectory analyses have demonstrated that high PM-sulfate is associated with air masses that traveled through the sulfate-rich Ohio River Valley (Poirot, et al, 2002 and Kenski, 2004). Likewise, high PM-nitrate is associated with air masses that traveled through the ammonia-rich Midwest. Figure 26 shows results from an ensemble trajectory analysis of 17 rural eastern IMPROVE sites.



**Figure 26. Sulfate and nitrate source regions, based on ensemble trajectory analysis**

When these results are considered together with analyses of precursor sensitivity (e.g., Figure 26), one possible conclusion is that ammonia control in the Midwest could be effective at reducing nitrate concentrations. The thermodynamic equilibrium modeling shows that ammonia reductions would reduce PM concentrations in the Midwest, but that nitric acid reductions are more effective, especially when the probable reductions in future sulfate levels are considered. In the eastern U.S., where PM<sub>2.5</sub> is more sensitive to ammonia reductions, nitrate constitutes a smaller percentage of annual PM<sub>2.5</sub> mass, so Midwestern ammonia reductions likely would have a small effect on eastern PM<sub>2.5</sub>.

Other factors to consider in deciding whether to pursue control measures for ammonia include:

- There are technical uncertainties, including the reliability of emission estimates, treatment of ammonia by current photochemical modeling systems, and lack of ambient measurements. It is worth noting, however, that MRPO have attempted to address these uncertainties by supporting development of a new process-based emissions model, conducting model sensitivity studies of ammonia deposition, and collecting ambient ammonia data as part of the Midwest regional ammonia network.
- As noted by USEPA in its final CAIR rulemaking, “reductions in ammonia emissions alone would also tend to increase the acidity of PM2.5 and precipitation.... this might have untoward environmental or health consequences.” (70 FR 25182)

*Source Culpability:* Three source apportionment studies were performed using speciated PM2.5 monitoring data and statistical analysis methods (Hopke, 2005, STI, 2006b, and STI, 2007). Figure 27 summarizes the source contributions from these studies. The studies show that a large portion of PM2.5 mass consists of secondary, regional impacts, which cannot be attributed to individual facilities or sources (e.g., secondary sulfate, secondary nitrate, and secondary organic aerosols). Nevertheless, wind analyses (e.g., Figure 26) provide information on likely source regions. Regional- or national-scale control programs may be the most effective way to deal with these impacts. USEPA's Clean Air Interstate Rule, for example, will provide for substantial reductions in SO2 emissions over the eastern half of the U.S., which will reduce sulfate (and PM2.5) concentrations and improve visibility levels.

The studies also show that a smaller, yet significant portion of PM2.5 mass is due to emissions from nearby (local) sources. Local (urban) excesses occur in many urban areas for organic and elemental carbon, crustal matter, and, in some cases, sulfate. The statistical analysis methods help to identify these sources and quantify their impact. This information is valuable to States wishing to develop control programs to address local impacts. A combination of national/regional-scale and local-scale emission reductions may be necessary to provide for attainment.

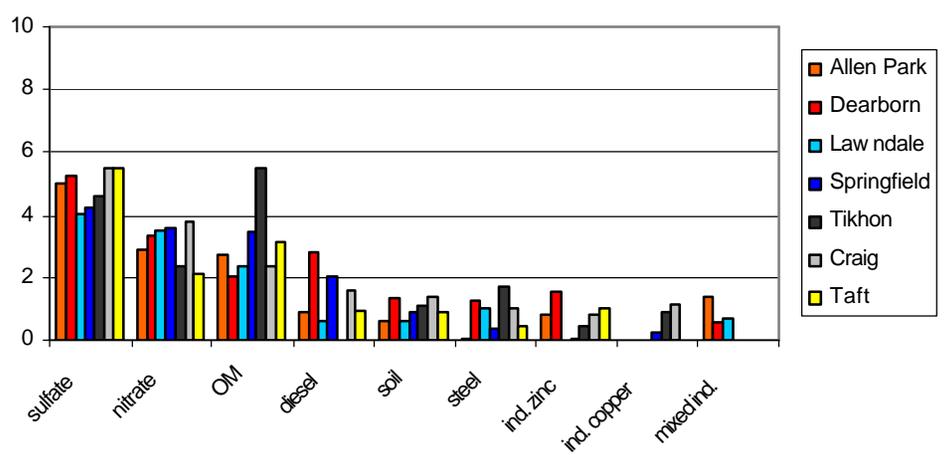
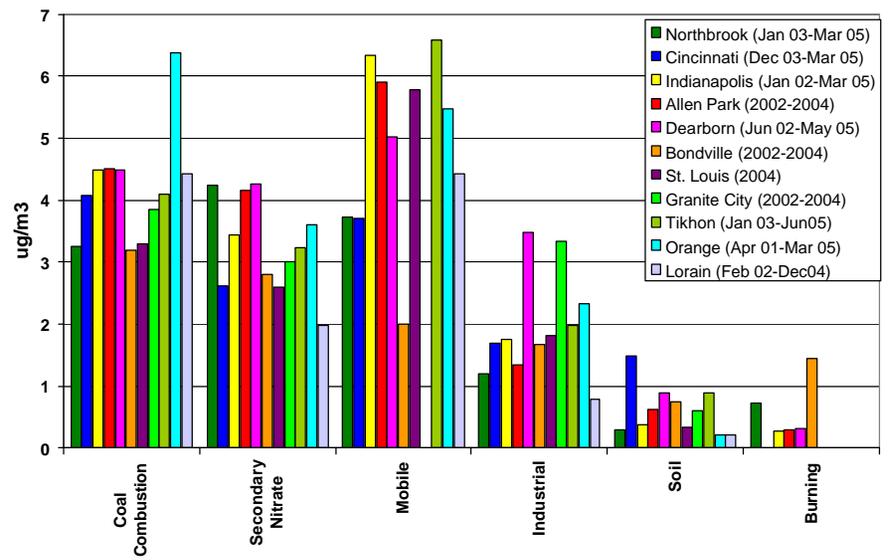
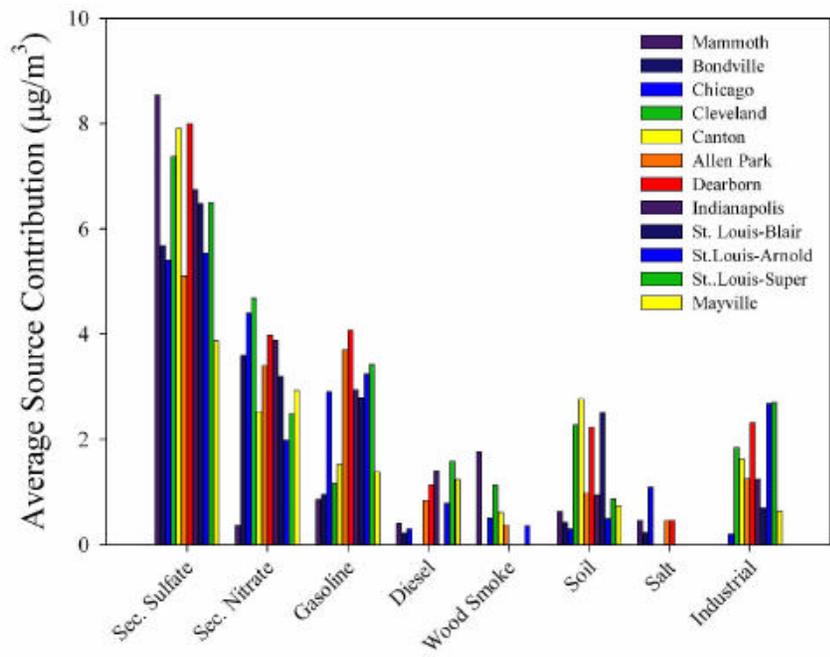


Figure 27. Major Source Contributions in the Midwest based on Hopke 2005 (upper left), STI, 2006 (upper right), and STI, 2007 (lower left)

### 2.3 Haze

Section 169A of the Clean Air Act sets as a national goal “the prevention of any future and the remedying of any existing, impairment of visibility in mandatory Class I Federal areas which implementation results from manmade air pollution”. To implement this provision, in 1999, USEPA adopted regulations to address regional haze visibility impairment (USEPA, 1999). USEPA’s rule requires states to “make reasonable progress toward meeting the national goal”. Specifically, states must establish reasonable progress goals, which provide for improved visibility on the most impaired (20% worst) days sufficient to achieve natural conditions by the year 2064, and for no degradation on the least impaired (20% best) days

The primary cause of impaired visibility in these Class I areas is pollution by fine particles that scatter light. The degree of impairment, which is expressed in terms of visual range, light extinction (1/Mm), or deciviews (dv), depends not just on the total PM<sub>2.5</sub> mass concentration, but also on the chemical composition of the particles and meteorological conditions.

*Current Conditions:* A map of the average light extinction values for the most impaired (20% worst) visibility days for the 5-year baseline period (2000-2004) is shown in Figure 28.

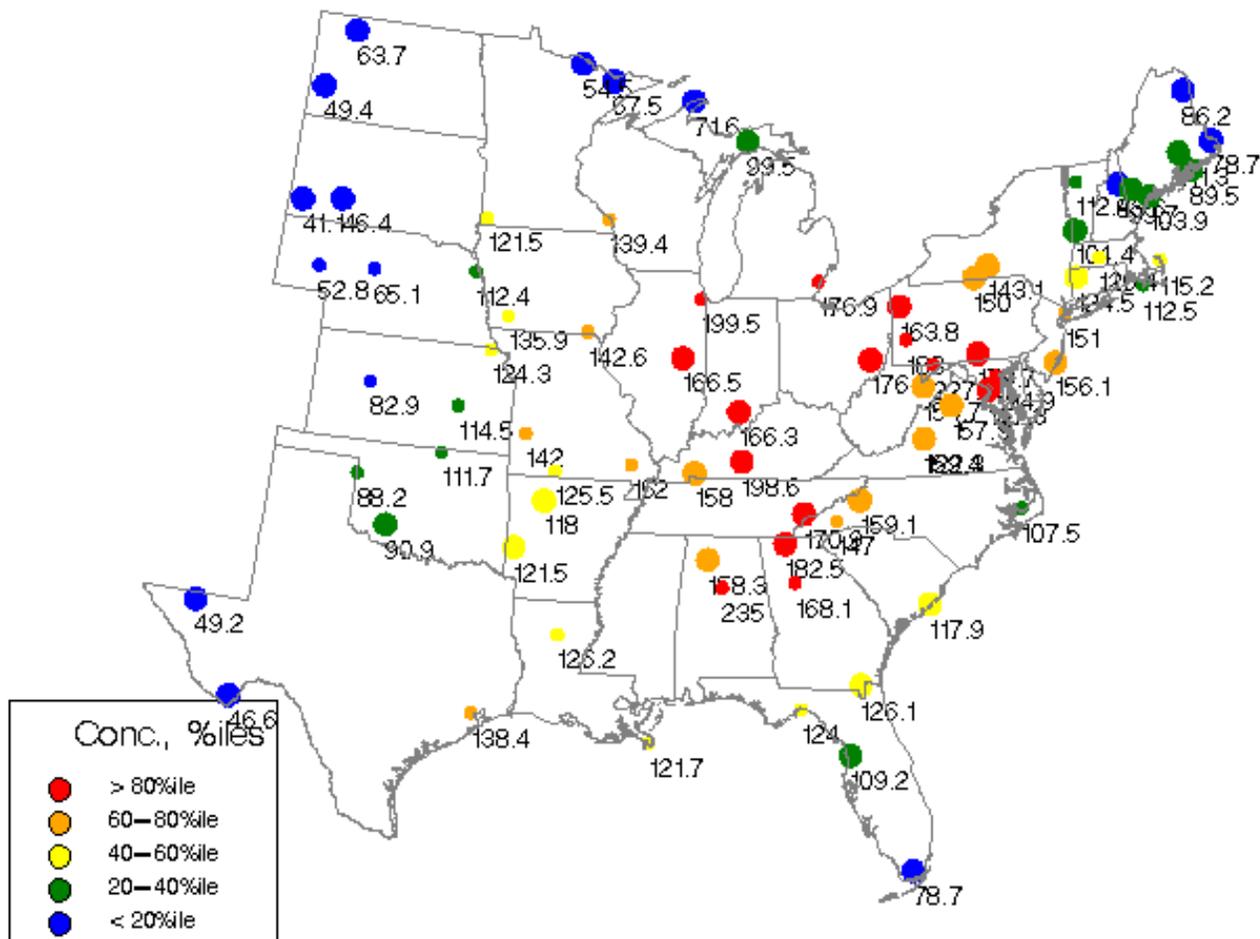


Figure 28. Baseline Visibility Levels for 20% Worst Days (2000 – 2004), units:  $Mm^{-1}$

Initially, the baseline (2000 – 2004) visibility condition values were derived using the average for the 20% worst and 20% best days for each year, as reported on the VIEWS website: <http://vista.cira.colostate.edu/views/Web/IMPROVE/SummaryData.aspx> . These values were calculated using the original IMPROVE equation for reconstructed light extinction.

Three changes were made to the baseline calculations to produce a new set of values. First, the reconstructed light extinction equation was revised by the IMPROVE Steering Committee in 2005. The new IMPROVE equation was used to calculate updated baseline values.

Second, due to sampler problems, the 2002-2004 data for Boundary Waters were invalid for certain chemical species. (Note, sulfate and nitrate data at Boundary Waters were valid.) A “substituted” data set was developed by using values from Voyageurs for the invalid species.

Third, LADCO identified a number of days during 2000-2004 where data capture at the Class I monitors was incomplete (e.g., coarse mass and soil were missing species). The missing data cause the days to be excluded from the baseline calculations. However, the light extinction due to the remaining measured species is significant (i.e., above the 80<sup>th</sup> percentile). It makes sense to include these days in the baseline calculations, because they are largely dominated by anthropogenic sources. (Only one of these days is driven by high organic carbon, which might indicate non-anthropogenic aerosol from wildfires.) As seen in Table 2, inclusion of these days in the baseline calculation results in a small, but measurable, effect on the baseline values (i.e., values increase from 0.2 to 0.8 dv).

**Table 2. Average of 20% worst days, with and without missing data days**

	Average Worst Day DV, per RHR	Average Worst Day DV, with Missing Data Days	Difference
BOWA	19.59	19.86	0.27
ISLE	20.74	21.59	0.85
SENE	24.16	24.38	0.22
VOYA	19.27	19.48	0.21

A summary of the initial and updated baseline values for the Class I areas in northern Michigan and northern Minnesota are presented in Table 3. The updated baseline values reflect the most current, complete understanding of visibility impairing effects and, as such, will be used for SIP planning purposes.

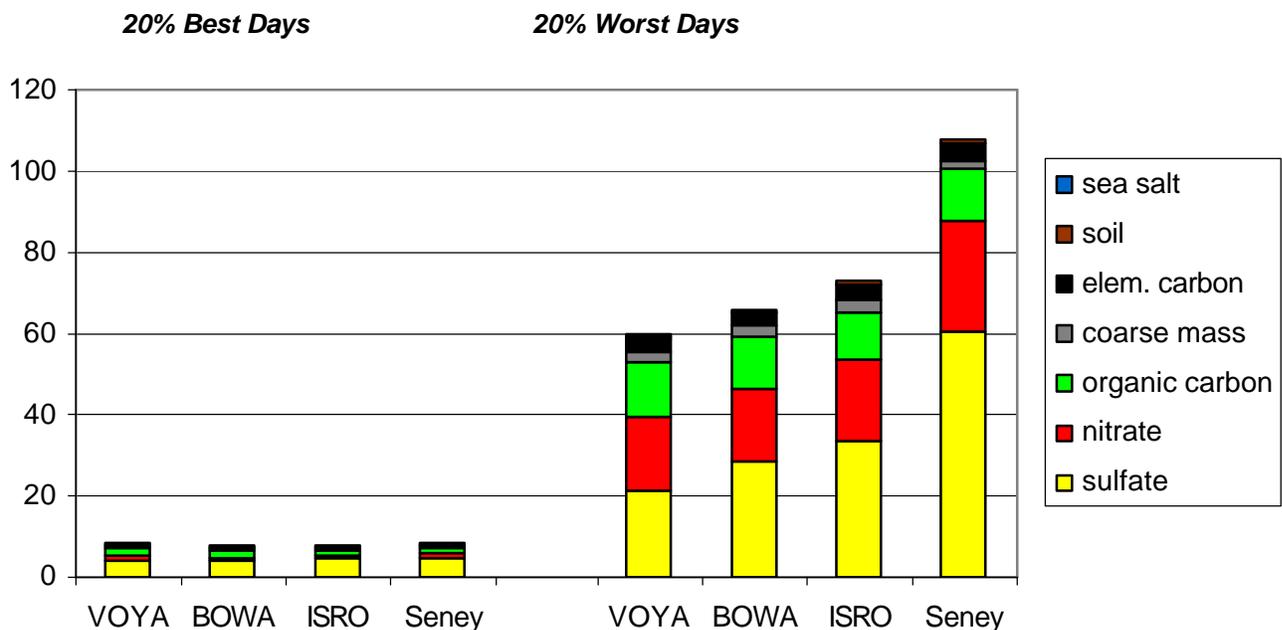
**Table 3. Summary of visibility metrics (deciviews) for northern Class I areas**

<b>Old IMPROVE Equation (Cite: VIEWS, November 2005)</b>									
<b>20% Worst Days</b>									
	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>Baseline Value</b>	<b>2018 URP Value</b>	<b>Natural Conditions</b>	
Voyageurs	18.50	18.00	19.00	19.20	17.60	18.46	16.74	11.09	
BWCA	19.85	19.99	19.68	19.73	17.65	19.38	17.47	11.21	
Isle Royale	20.00	22.00	20.80	19.50	19.10	20.28	18.17	11.22	
Seney	22.60	24.90	24.00	23.80	22.60	23.58	20.73	11.37	
<b>20% Best Days</b>									
	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>Baseline Value</b>	<b>2018 URP Value</b>	<b>Natural Conditions</b>	
Voyageurs	6.30	6.20	6.70	7.00	5.40	6.32		6.32	
BWCA	5.90	6.52	6.93	6.67	5.61	6.33		6.33	
Isle Royale	5.70	6.40	6.40	6.30	5.30	6.02		6.02	
Seney	5.80	6.10	7.30	7.50	5.80	6.50		6.50	
<b>New IMPROVE Equation (Cite: VIEWS, March 2006)</b>									
<b>20% Worst Days</b>									
	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>Baseline Value</b>	<b>2018 URP Value</b>	<b>Natural Conditions</b>	
Voyageurs	19.55	18.57	20.14	20.25	18.87	19.48	17.74	12.05	
BWCA	20.20	20.04	20.76	20.13	18.18	19.86	17.94	11.61	
Isle Royale	20.53	23.07	21.97	22.35	20.02	21.59	19.43	12.36	
Seney	22.94	25.91	25.38	24.48	23.15	24.37	21.64	12.65	
<b>20% Best Days</b>									
	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>Baseline Value</b>	<b>2018 URP Value</b>	<b>Natural Conditions</b>	
Voyageurs	7.01	7.12	7.53	7.68	6.37	7.14		7.14	
BWCA	6.00	6.92	7.00	6.45	5.77	6.43		6.43	
Isle Royale	6.49	7.16	7.07	6.99	6.12	6.77		6.77	
Seney	6.50	6.78	7.82	8.01	6.58	7.14		7.14	
Notes: (1) BWCA values for 2002 - 2004 reflect "substituted" data. (2) New IMPROVE equation values include Kenksi, 2007 adjustment for missing days									

As noted above, the goal of the visibility program is to achieve natural conditions. Initially, the natural conditions values for each Class I area were taken directly from USEPA guidance (USEPA, 2003). These values were calculated using the original IMPROVE equation. This equation was revised by the IMPROVE Steering Committee in 2005, and the new IMPROVE equation was used to calculate updated natural conditions values. The updated values are reported on the VIEWS website.

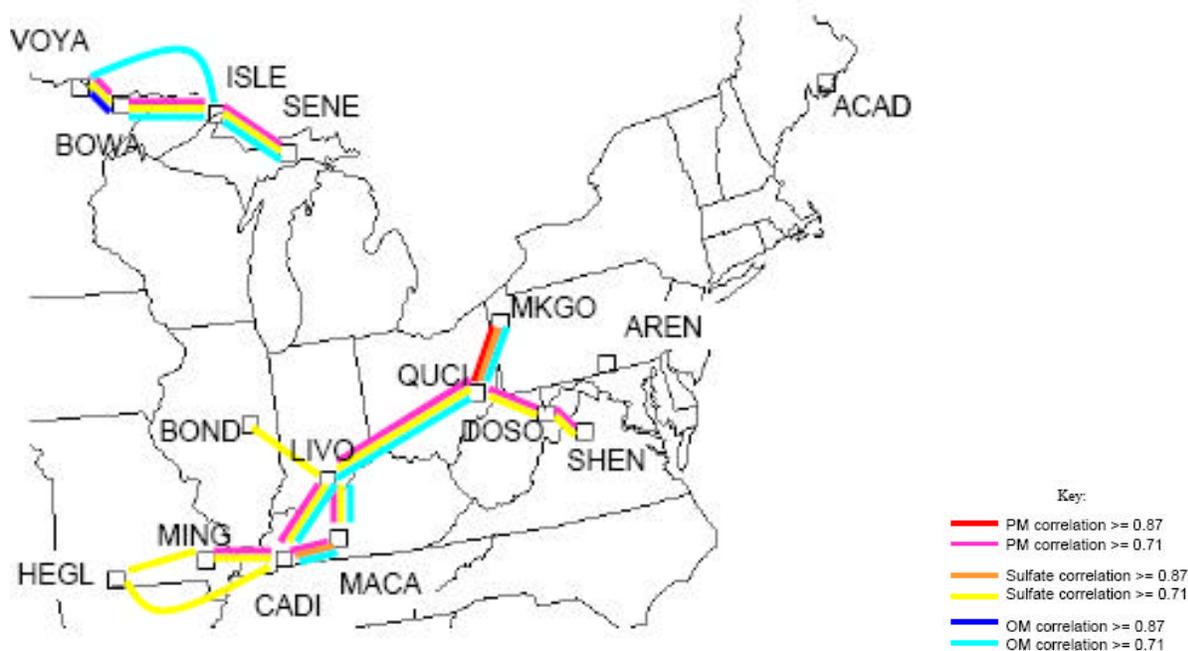
A summary of the initial and updated natural conditions values are presented in Table 2. The updated natural conditions values (based on the new IMPROVE equation) will be used for SIP planning purposes.

*Data Variability:* For the four northern Class I areas, the most important PM<sub>2.5</sub> chemical species are ammonium sulfate, ammonium nitrate, and organic carbon. The contribution of these species on the 20% best and 20% worst visibility days (based on 2000 – 2004 data) is provided in Figure 29. For the 20% worst visibility days, the contributions are: sulfate = 35-55%, nitrate = 25-30%, and organic carbon = 12-22%. Although the chemical composition is similar, sulfate increases in importance from west to east and concentrations are highest at Seney (the easternmost site). It should also be noted that sulfate and nitrate contribute more to light extinction than to PM<sub>2.5</sub> mass because of their hygroscopic properties.



**Figure 29. Chemical composition of light extinction for 20% best visibility days (left) and 20% worst visibility days (right) in terms of Mm<sup>-1</sup>**

Analysis of PM<sub>2.5</sub> mass and chemical species for rural IMPROVE (and IMPROVE-protocol) sites in the eastern U.S. showed a high degree of correlation between PM<sub>2.5</sub>-mass, sulfate, and nitrate levels (see Figure 30). The Class I sites in northern Michigan and northern Minnesota, in particular, are highly correlated for PM<sub>2.5</sub> mass, sulfates, and organic carbon mass.



**Figure 30. Correlations among IMPROVE (and IMPROVE-protocol) monitoring sites in Eastern U.S.**

Long-term trends at Boundary Waters (the only regional site with a sufficient data record) show significant decreases in total PM<sub>2.5</sub> (-0.005 ug/year) and SO<sub>4</sub> (-0.04 ug/year) and an increase in NO<sub>3</sub> (+0.01 ug/year). These PM<sub>2.5</sub> and SO<sub>4</sub> trends are generally consistent with long-term trends at other IMPROVE sites in the eastern U.S., which have shown widespread decreases in SO<sub>4</sub> and PM<sub>2.5</sub> (DeBell, et al, 2006). Detecting changes in nitrate has been hampered by uncertainties in the IMPROVE data for particular years and thus this estimate should be considered tentative.

Haze in the Midwest Class I areas has no strong seasonal pattern. Poor visibility days occur throughout the year, as indicated in Figure 31. (Note, in contrast, other parts of the country, such as Shenandoah National Park in Virginia, show a strong tendency for the worst air quality days to occur in the summer months.) This figure, as well as Figure 32 (which presents the monthly average light extinction values based on all sampling days), also show that sulfate and organic carbon concentrations are higher in the summer, and nitrate concentrations are higher in the winter, suggesting the importance of different sources and meteorological conditions at different times of the year.

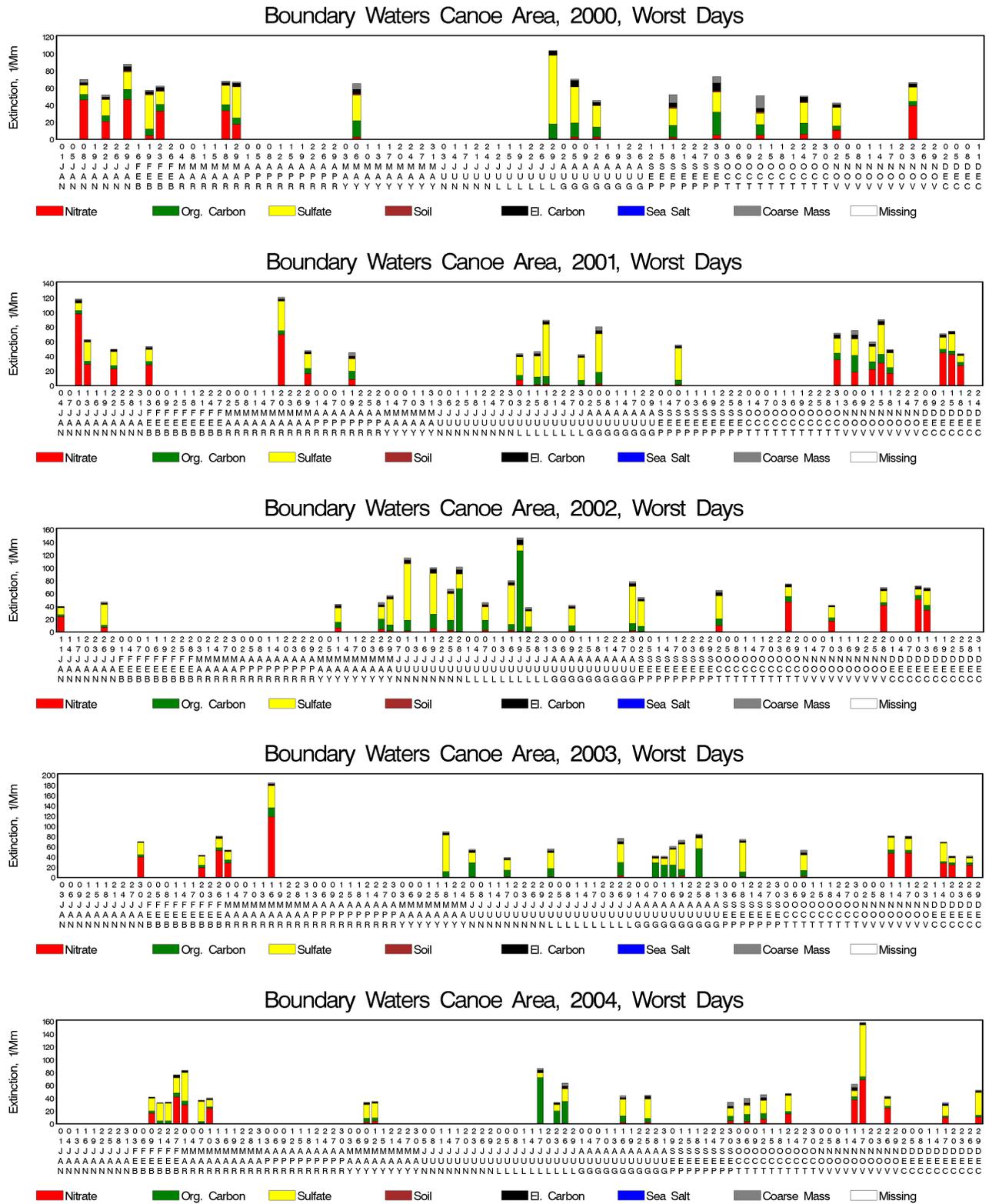
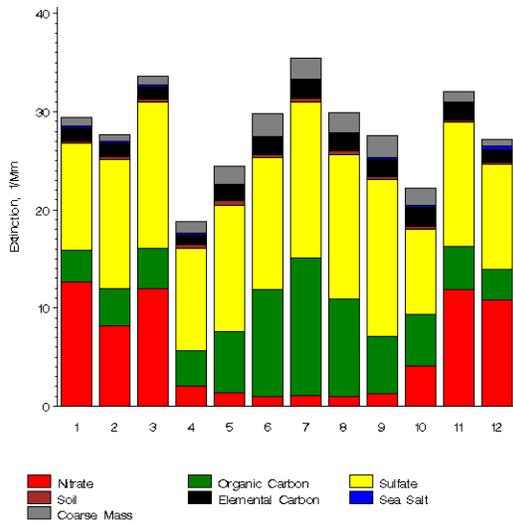
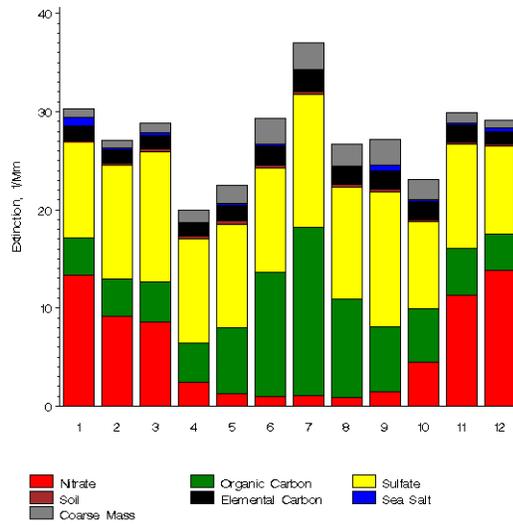


Figure 31. Daily light extinction values for 20% worst days at Boundary Waters (2000 – 2004)

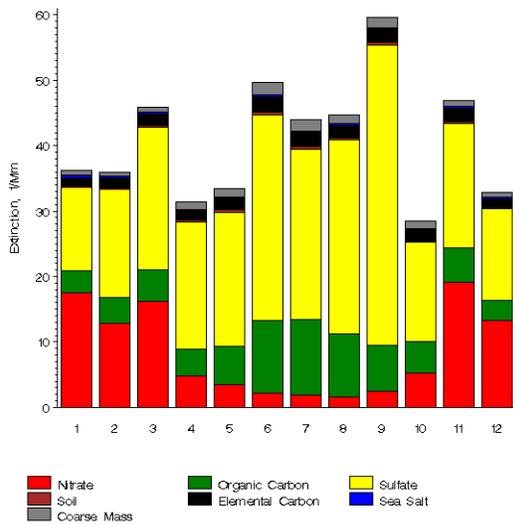
Monthly Extinction, Boundary Waters Canoe Area



Monthly Extinction, Voyageurs National Park 2



Monthly Extinction, Seney



Monthly Extinction, Isle Royale National Park (New)

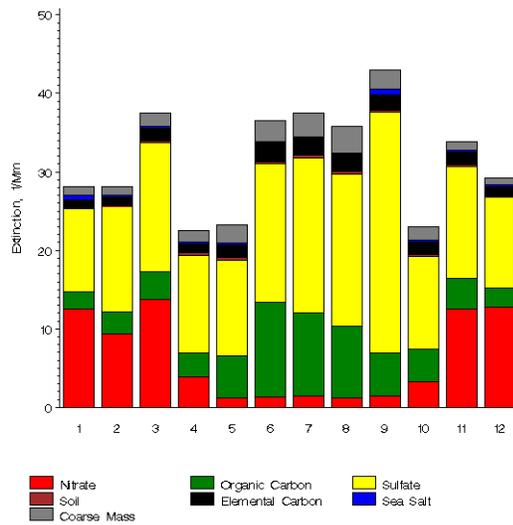
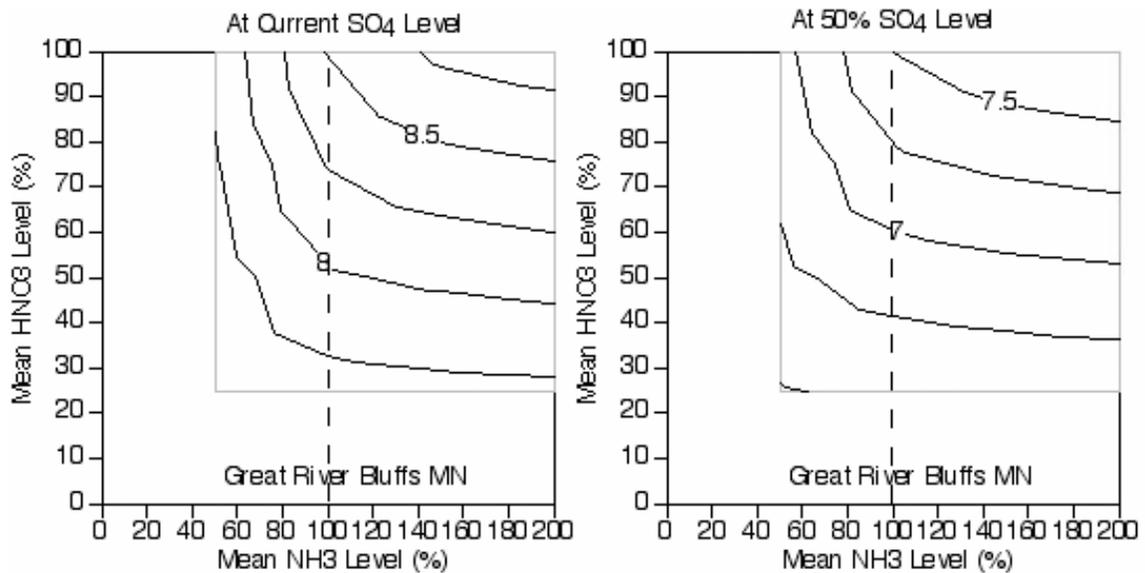


Figure 32. Monthly average light extinction values for northern Class I areas

*Precursor Sensitivity:* Results from two analyses using thermodynamic equilibrium models provide information on the effect of changes in precursor gas concentrations on PM<sub>2.5</sub> concentrations (and, in turn, visibility levels). First, a preliminary analysis using data collected at Seney indicated that PM<sub>2.5</sub> there is most sensitive to reductions in sulfate, but also responsive to reductions in nitric acid (Blanchard 2004b).

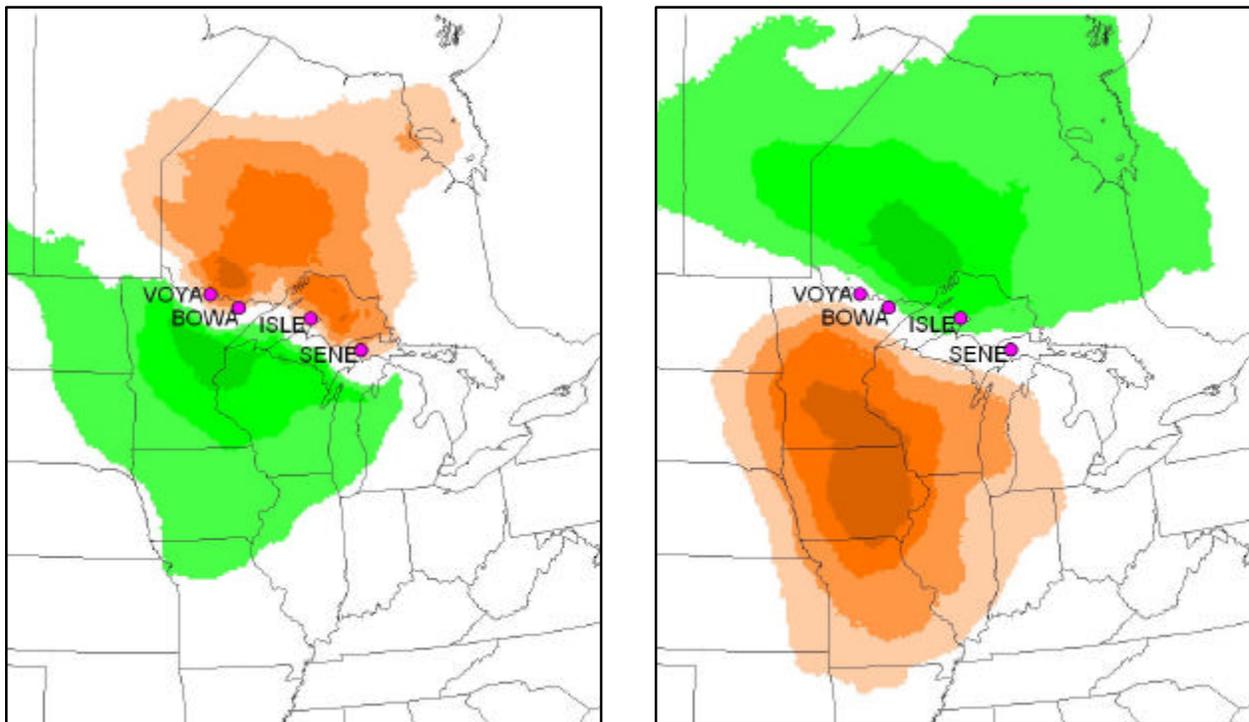
Second, an analysis using data from the Midwest ammonia monitoring network for a site in Minnesota (i.e., Great River Bluffs, which is the closest ammonia monitoring site to the northern Class I areas) suggested that reductions in sulfate, nitric acid, and ammonia concentrations will lower PM<sub>2.5</sub> concentrations and improve visibility levels in the northern Class I areas (see Figure 33). (Blanchard, 2005)



**Figure 33. Predicted PM<sub>2.5</sub> mass concentrations at Great River Bluffs, MN as functions of changes in ammonia and nitric acid at fixed sulfate levels**

*Meteorology and Transport:* The role of meteorology in haze is complex. Wind speed and wind direction govern the movement of air masses from polluted areas to the cleaner wilderness areas. As noted above, increasing humidity increases the efficiency with which sulfate and nitrate aerosols scatter light. Temperature and humidity together govern whether ammonium nitrate can form from its precursor gases, nitric acid and ammonia. Temperature and sunlight also play an indirect role in emissions of biogenic organic species that condense to form particulate organic matter; emissions increase in the summer daylight hours.

Trajectory analyses were performed to understand transport patterns for the 20% worst and 20% best visibility days. The composite results for the four northern Class I areas are provided in Figure 34. The orange areas are where the air is most likely to come from, and the green areas are where the air is least likely to come from on. As can be seen, bad air days are generally associated with transport from regions located to the south, and good air days with transport from Canada.

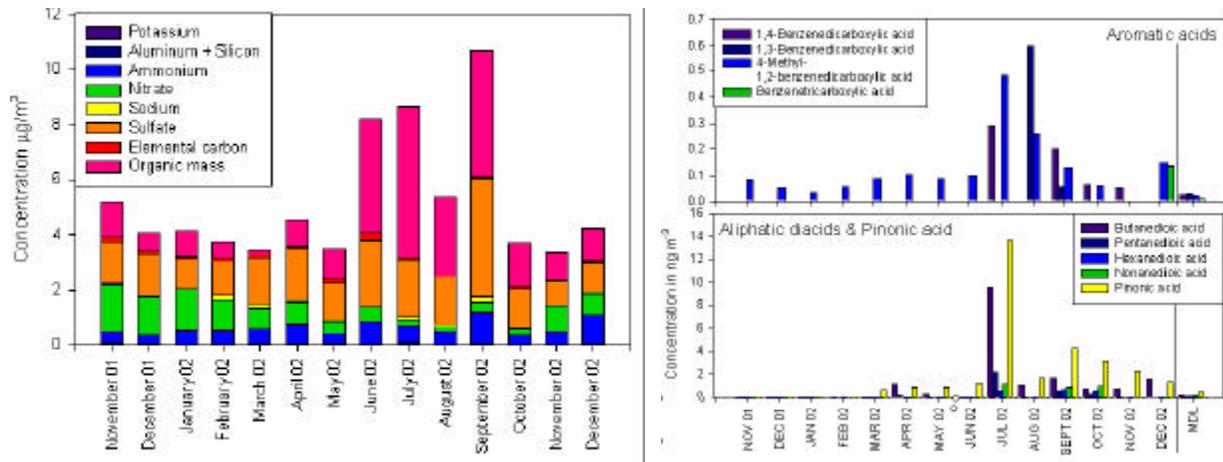


**Figure 34. Composite back trajectories for light extinction- 20% best visibility days (left) and 20% worst visibility days (right) (2000 – 2005)**

*Source Culpability:* Air quality data analyses (including the trajectory analyses above) and dispersion modeling were used to provide information on source region and source sector contributions to regional haze in the northern Class I areas (see MRPO, 2007). Based on this information, the most important contributing states are Michigan, Minnesota, and Wisconsin, as well as Missouri, North Dakota, Iowa, and Illinois (see, for example, Figure 34 above). The most important contributing pollutants and source sectors are SO<sub>2</sub> emissions from electrical generating units (EGUs) and certain non-EGUs, which lead to sulfate formation, and NO<sub>x</sub> emissions from a variety of source types (e.g., motor vehicles), which lead to nitrate formation. Ammonia emissions from livestock waste and fertilizer applications are also important, especially for nitrate formation.

A source apportionment study was performed using monitoring data from Boundary Waters and statistical analysis methods (DRI, 2005). The study shows that a large portion of PM<sub>2.5</sub> mass consists of secondary, regional impacts, which cannot be attributed to individual facilities or sources (e.g., secondary sulfate, secondary nitrate, and secondary organic aerosols). Industrial sources account for only 3-4% of PM<sub>2.5</sub> mass and mobile sources only 4-7%.

A special study was performed in Seney to identify sources of organic carbon (Sheesley, et al, 2004). Study results are presented in Figure 35.



**Figure 35. Monthly concentrations of PM<sub>2.5</sub> species (top) and biogenic-related organic carbon species in Seney (bottom)**

The highest PM<sub>2.5</sub> concentrations occurred during the summer, with OC being the dominant species. The higher summer OC concentrations were attributed mostly to secondary organic aerosols of biogenic origin based on the following:

- The contribution of primary emission sources (e.g., biomass burning, motor vehicles, and road dust) was fairly low – e.g., generally less than 10% during the summer. Biomass burning, in particular, contributed less than 1% on an annual average basis. (Note, burning-related emissions do, however, produce high OC concentrations on a few days in the northern Class I areas – see discussion below.)
- Concentrations of known biogenic-related species (e.g., aromatic acids and pinonic acid) were also higher during the summer.

To assess further whether fire activity is a significant contributor to visibility impairment in the northern Class I areas, the PM<sub>2.5</sub> chemical speciation data were examined for days with high OC and EC concentrations, which are indicative of biomass burning impacts. A handful of such days were identified:

**Table 4. Days with high OC/EC concentrations in northern Class I areas**

Site	2000	2001	2002	2003	2004
Voyageurs	---	---	1-Jun 28-Jun 19-Jul	25-Aug	17-Jul
Boundary Waters	---	---	28-Jun 19-Jul	25-Aug	17-Jul
Isle Royale	---	---	1-Jun 28-Jun	25-Aug	---
Seney	---	---	28-Jun	---	---

Back trajectories on these days point mostly to wildfires in Canada. Elimination of these high OC concentration days has a small effect in lowering the baseline visibility levels in the northern Class I areas:

**Table 5. Baseline visibility levels for northern Class I areas**

	<b>20% worst days</b>	<b>20% worst days (w/o high OC days)</b>
Voyageurs	19.27 (19.52)*	18.96 (19.19)
Boundary Waters	19.59 (19.86)	19.34 (19.56)
Isle Royale	20.74 (21.62)	20.52 (21.43)
Seney	24.16 (24.48)	24.16 (24.48)

This suggests that fire activity, although significant on a few days, is on average a relatively small contributor to visibility impairment in the northern Class I areas.

## Section 3.0 Air Quality Modeling

Air quality models are relied on by federal and state regulatory agencies to support their planning efforts. Used properly, models can assist policy makers in deciding which control programs are most effective in improving air quality, and meeting specific goals and objectives. For example, models can be used to conduct “what if” analyses, which provide information for policy makers on the effectiveness of candidate control programs.

The modeling analyses were conducted in accordance with USEPA’s modeling guidelines (USEPA, 2007). Further details of the modeling are provided in two protocol documents: LADCO, 2007a and LADCO, 2007b.

This section reviews the development and evaluation of the modeling system used for the multi-pollutant analyses. Application of the modeling system (i.e., attainment demonstration for ozone and PM<sub>2.5</sub>, and reasonable progress assessment for haze) is covered in the following sections.

### 3.1 Selection of Base Year

Two base years were used in the modeling analyses: 2002 and 2005. USEPA’s modeling guidance recommends using 2002 as the baseline inventory year, but also allows for use of an alternative baseline inventory year, especially a more recent year. Initially, LADCO conducted modeling with a 2002 base year (i.e., Base K/Round 4 modeling, which was completed in 2006). A decision was subsequently made to conduct modeling with a 2005 base year (i.e., Base M/Round 5, which was completed in 2007). As discussed in the previous section, 2002 and 2005 both had above normal ozone conducive conditions, although 2005 was less severe compared to 2002. Examination of multiple base years provides for a more complete technical assessment. Both sets of model runs are discussed in this document.

### 3.2 Future Years of Interest

To address the multiple attainment requirements for O<sub>3</sub> and PM<sub>2.5</sub>, and reasonable progress goals for regional haze, several future years are of interest:

- 2008 Planning year for O<sub>3</sub> basic nonattainment areas (attainment date 2009)<sup>7</sup>
- 2009 Planning year for O<sub>3</sub> moderate nonattainment areas and PM<sub>2.5</sub> nonattainment areas (attainment date 2010)
- 2012 Planning year for O<sub>3</sub> moderate nonattainment areas and PM<sub>2.5</sub> nonattainment areas, with 3-year extension (attainment date 2013)
- 2018 First milestone for regional haze planning

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<sup>7</sup> According to USEPA’s ozone implementation rule (USEPA, 2005), emission reductions needed for attainment must be implemented by the beginning of the ozone season immediately preceding the area’s attainment date. The PM<sub>2.5</sub> implementation rule contains similar provisions – i.e., emission reductions should be in place by the beginning of the year preceding the attainment date (USEPA, 2007). The logic for requiring emissions reductions by the year (or season) immediately preceding the attainment year follows from language in the Clean Air Act, and the ability for an area to receive up to two 1-year extensions. Therefore, emissions in the year **preceding** the attainment year should be at a level that is consistent with attainment. It also follows that the year preceding the attainment year should be modeled for attainment planning purposes.

Detailed emissions inventories were developed for 2009 and 2018. To support modeling for other future years, less rigorous emissions processing was conducted (e.g., 2012 emissions were estimated for several source sectors by interpolating between 2009 and 2018 emissions).

### 3.3 Modeling System

The air quality analyses were conducted with the CAMx model, with emissions and meteorology generated using EMS (and CONCEPT) and MM5, respectively. The selection of CAMx as the primary model is based on several factors: performance, operator considerations (e.g., ease of application and resource requirements), technical support and documentation, model extensions (e.g., 2-way nested grids, process analysis, source apportionment, and plume-in-grid), and model science. CAMx model set-up for Base M and Base K is summarized below:

#### Base M (2005)

- CAMx v4.50
- CB05 gas phase chemistry
- SOA chemistry updates
- AERMOD dry deposition scheme
- ISORROPIA inorganic chemistry
- SOAP organic chemistry
- RADM aqueous phase chemistry
- PPM horizontal transport

#### Base K (2002)

- \* CAMx 4.30
- \* CB-IV with updated gas-phase chemistry
- \* No SOA chemistry updates
- \* Wesley-based dry deposition
- ISORROPIA inorganic chemistry
- SOAP organic chemistry
- RADM aqueous phase chemistry
- PPM horizontal transport

### 3.4 Domain/Grid Resolution

The National RPO grid projection was used for this modeling. A subset of the RPO domain was used for the LADCO modeling. For PM<sub>2.5</sub> and haze, the large eastern U.S. grid at 36 km (see box on right side of Figure 36) was used. A PM<sub>2.5</sub> sensitivity run was also performed for this domain at 12 km. For ozone, the smaller grid at 12 km (see shaded portion of the box on the right side of Figure 36) was used for most model runs. An ozone sensitivity run was also performed with a 4km sub-grid over the Lake Michigan area and Detroit/Cleveland.

The air quality model will resolve the atmosphere up to 15 km with 16 vertical layers, with higher resolution in the boundary layer.

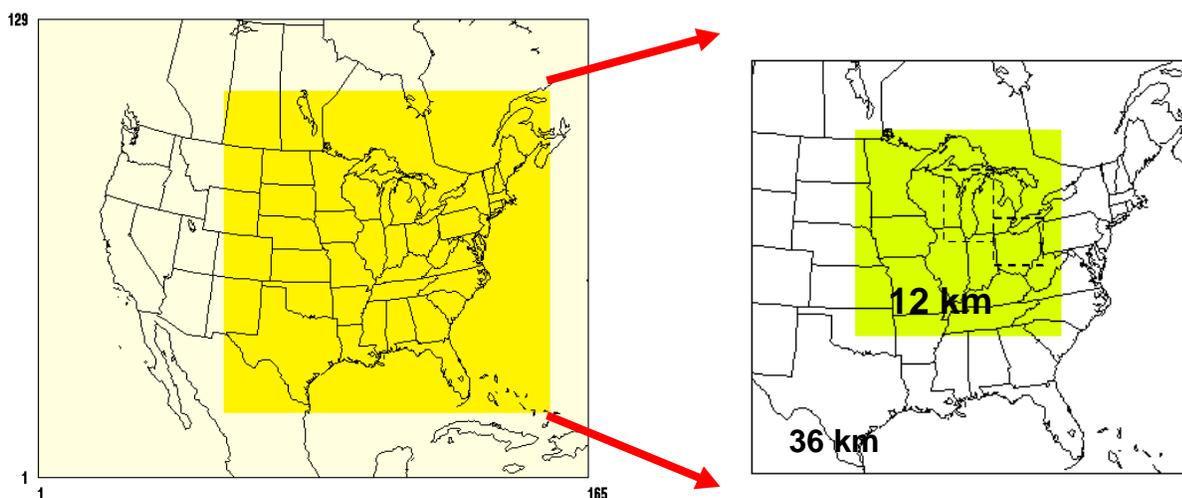


Figure 36. Modeling grids – RPO domain (left) and LADCO modeling domain (right)

### 3.5 Model Inputs: Meteorology

Meteorological inputs were derived using the Fifth-Generation NCAR/Penn State Meteorological Model (MM5) – version 3.6.3 for the years 2001–2003, and version 3.7 for the year 2005. The MM5 modeling domains are consistent with the National RPO grid projections (see Figure 37).

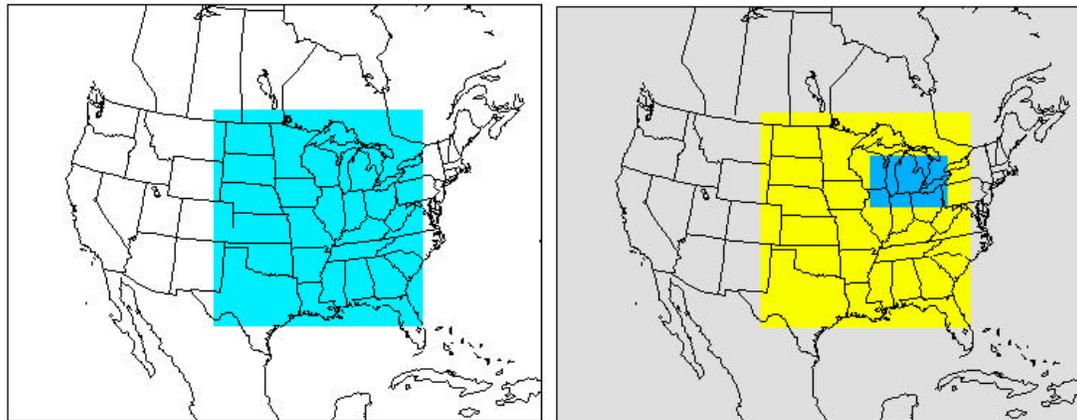


Figure 37. MM5 modeling domain for 2001-2003 (left) and 2005 (right)

The annual 2002 36 km MM5 simulation was completed by Iowa DNR. The 36/12 km 2-way nested simulation for the summers of 2001, 2002, and 2003 were conducted jointly by Illinois EPA and LADCO. The 36 km non-summer portion of the annual 2003 simulation was conducted by Wisconsin DNR. The annual 2005 36/12 km (and summer season 4 km) MM5 modeling was completed by Alpine Geophysics. Wisconsin DNR also completed 36/12 km MM5 runs for the summer season of 2005.

Model performance was assessed quantitatively with the METSTAT tool from Environ. The metrics used to quantify model performance include mean observation, mean prediction, bias, gross error, root mean square error, and index of agreement. Model performance metrics were calculated for several sub-regions of the modeling domain (Figure 38) and represent hourly spatial averages of multiple monitor locations. Additional analysis of rainfall is done on a monthly basis.

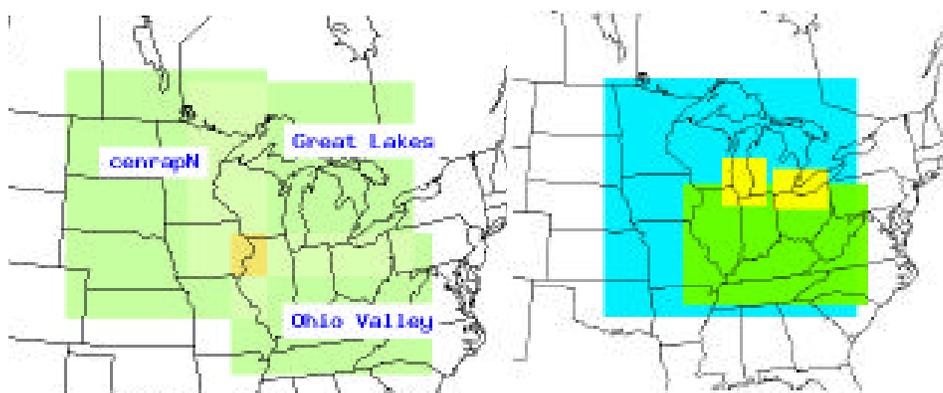
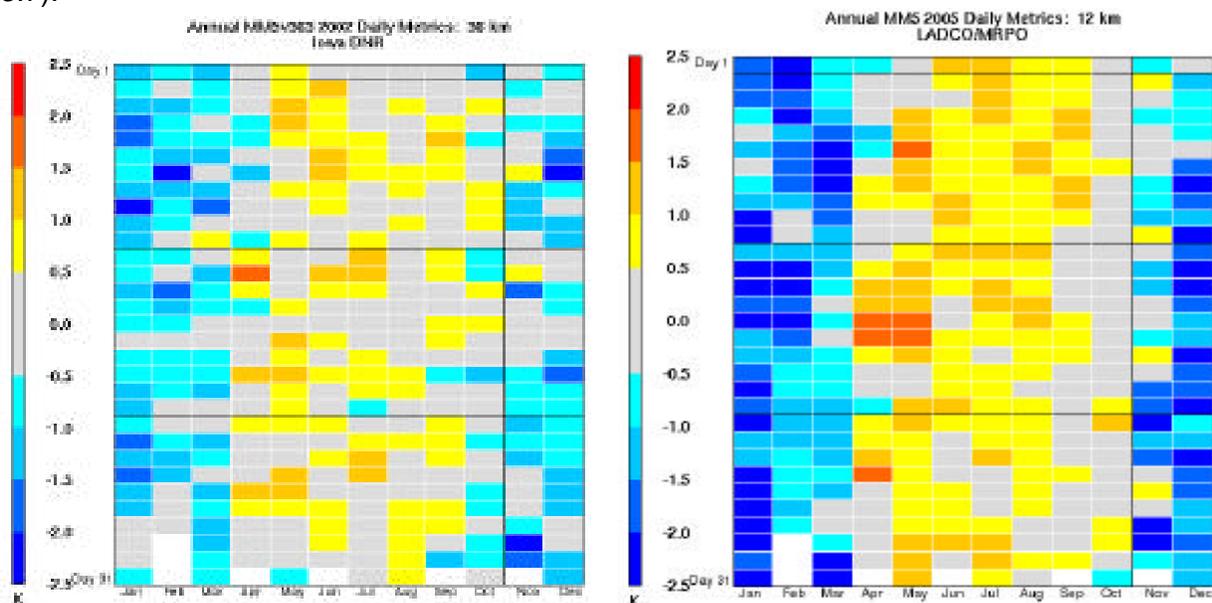


Figure 38. Sub-domains used for model performance for 2001-2003 (left) and 2005 (right)

A summary of the performance evaluation results for the meteorological modeling is provided below. Further details are provided in two summary reports (LADCO, 2005 and LADCO, 2007a).

*Temperature:* The biggest issue with the performance in the upper Midwest is the existence of a cool diurnal temperature bias in the winter and warm temperature bias over night during the summer (see Figure 39). These features are common to other annual MM5 simulations for the central United States and do not appear to adversely affect model performance (see Section 3.7).



**Figure 39. Daily temperature bias for 2002 (left) and 2005 (right) - Note: months are represented from left to right (January to December) and days are represented from top to bottom (1 to 30(31) – i.e., upper left hand corner is January 1 and lower right hand corner is December 31**

*Wind Fields:* The wind fields are generally good. Wind speed bias is less than 0.5 m/sec and wind speed error is consistently between 1.0 and 1.5 m/sec. Wind direction error is generally within 15-30 degrees.

*Mixing Ratio:* The mixing ratio (a measure of humidity) is over-predicted in the late spring and summer months, and mixing ratio error is highest during this period. There is little bias and error during the cooler months when there is little moisture in the air.

*Rainfall:* The modeled and observed rainfall totals show good agreement spatially and in terms of magnitude in the winter, fall, and early spring months. There are, however, large over-predictions of rainfall in the late spring and summer months (see Figure 40). These over-predictions are seen spatially and in magnitude over the entire domain, particularly in the Southeast United States, and are likely due to excessive convective rainfall being predicted in MM5. This over-prediction of rainfall in MM5 does not necessarily translate into over-prediction of wet deposition in the photochemical model (Baker and Scheff, 2006). CAMx does not explicitly use the convective and non-convective rainfall output by MM5, but estimates wet scavenging by hydrometers using cloud, ice, snow, and rain water mixing ratios output by MM5.

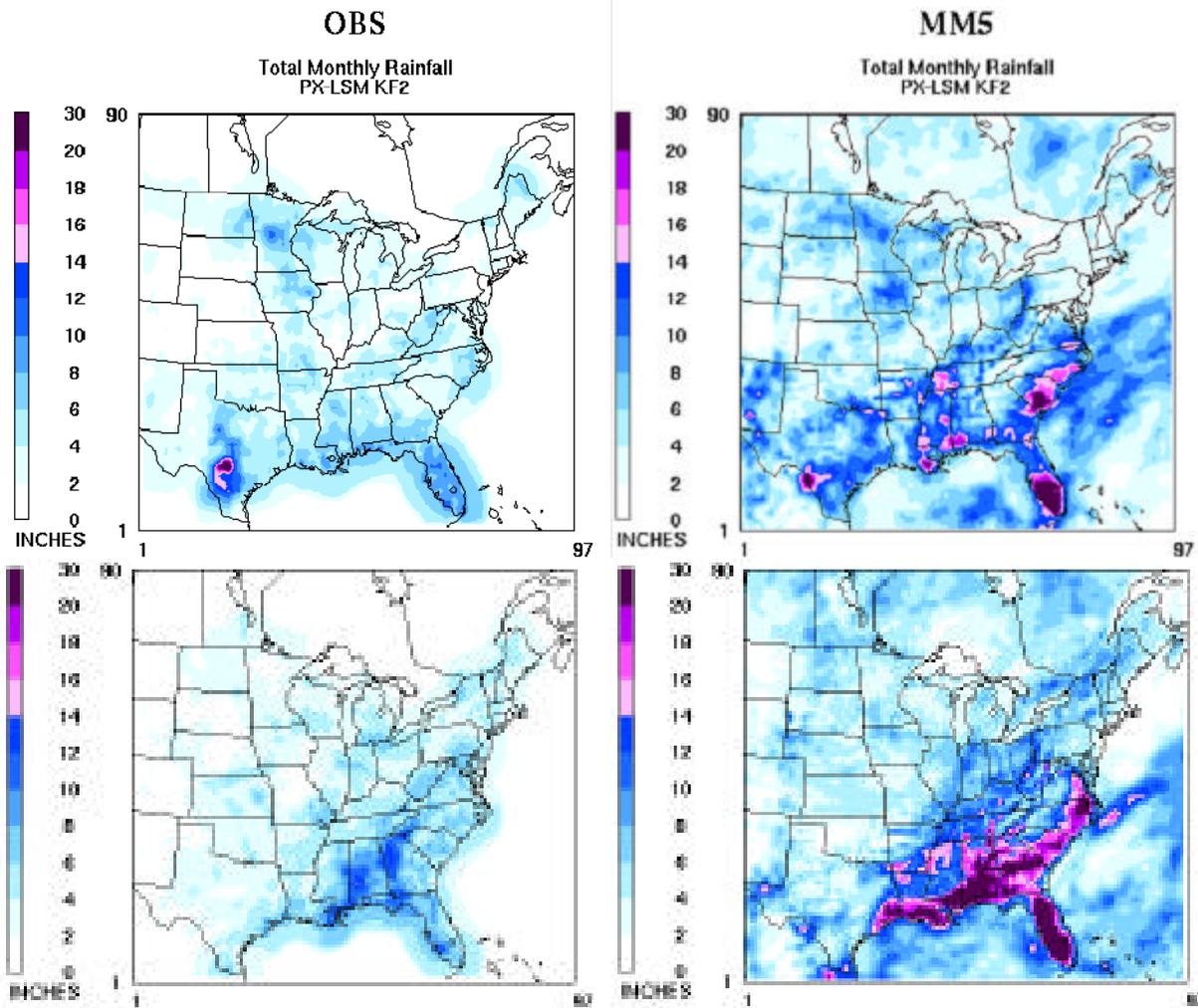


Figure 40. Comparison of observed (left column) and modeled (right column) monthly rainfall for July 2002 (top) and July 2005 (bottom)

### 3.6 Model Inputs: Emissions

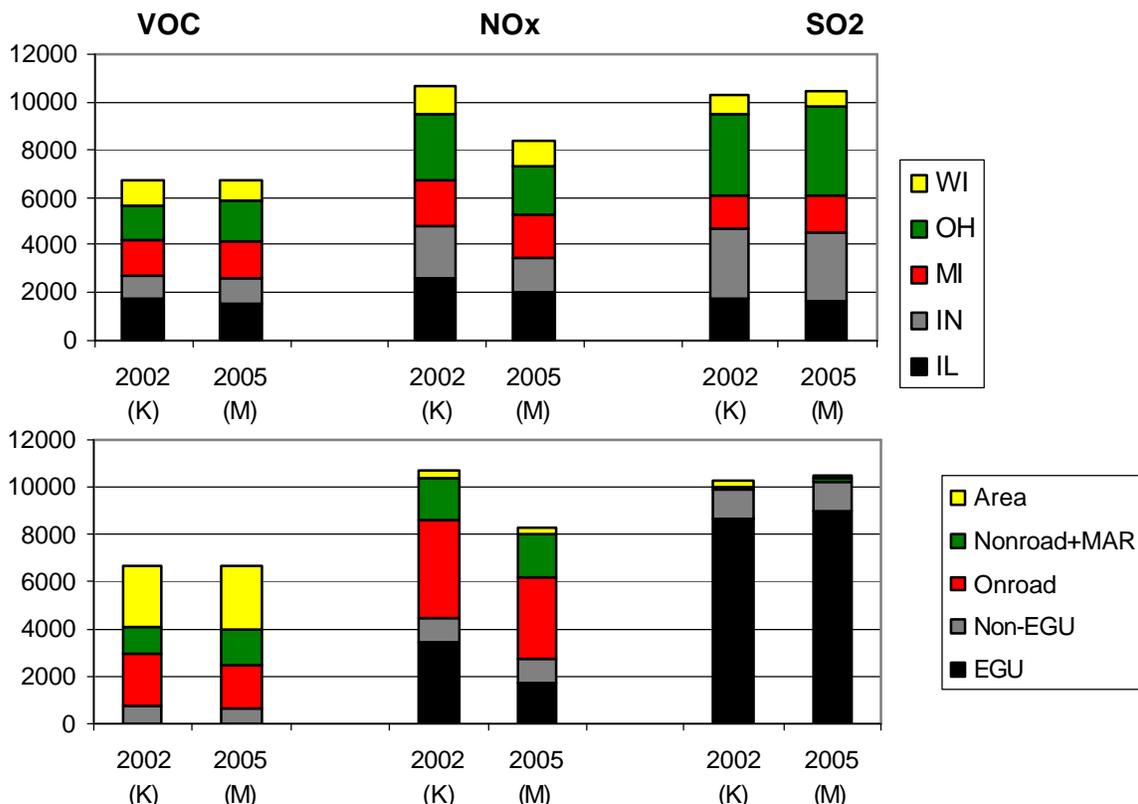
Emission inventories were prepared for two base years: 2002 (Base K) and 2005 (Base M), and several future years: 2008, 2009, 2012, and 2018. Further details of the emission inventories are provided in two summary reports (LADCO, 2006 and LADCO, 2007z) and the following pages of the LADCO web site:

[http://www.ladco.org/tech/emis/basek/BaseK\\_Reports.htm](http://www.ladco.org/tech/emis/basek/BaseK_Reports.htm)

[http://www.ladco.org/tech/emis/r5/round5\\_reports.htm](http://www.ladco.org/tech/emis/r5/round5_reports.htm)

For on-road, nonroad, ammonia, and biogenic sources, emissions were estimated by models. For the other sectors (point sources, area sources, and MAR [commercial marine, aircraft, and railroads]), emissions were prepared using data supplied by the LADCO States and other Regional Planning Organizations.

*Base Year Emissions:* State and source sector emission summaries for 2002 (Base K) and 2005 (Base M) are compared in Figure 41. Additional detail is provided in Table 6.



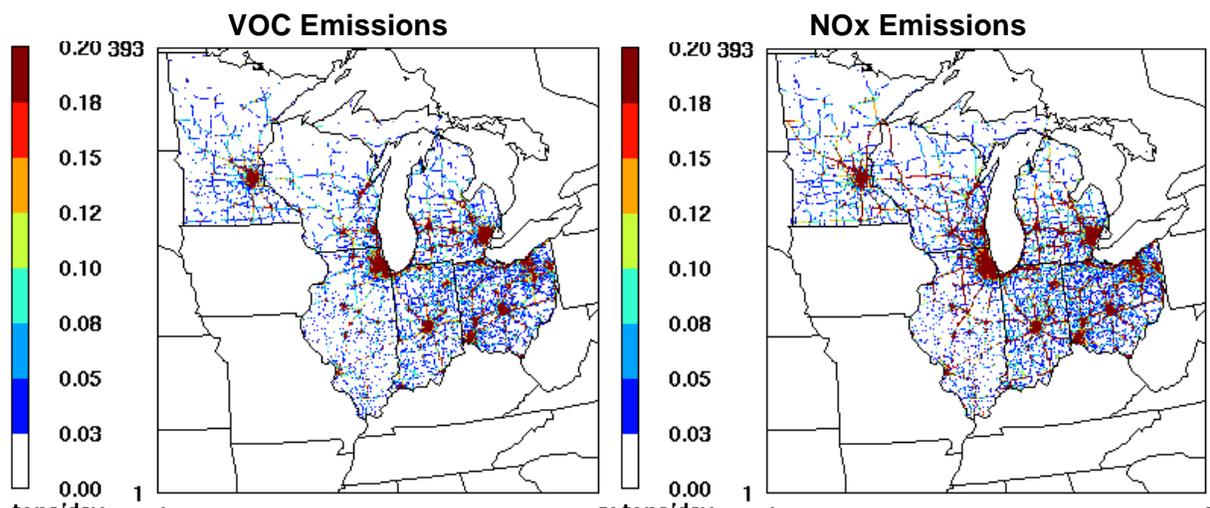
**Figure 41. Base K and Base M emissions for 5-state LADCO region by state (top) and source sector (bottom), units: tons per summer weekday**

A summary of the base year emissions by sector for the LADCO States is provided below.

**On-road Sources:** For 2002, EMS was run by LADCO using VMT and MOBILE6 inputs supplied by the LADCO States. EMS was run to generate 36 days (weekday, Saturday, Sunday for each month) at 36 km, and 12 days (weekday, Saturday, Sunday for June – August) at 12 km.

	VOC	Base M	BaseK	Base M	BaseK	Base M	BaseK	NOx	Base M	BaseK	Base M	BaseK	Base M	BaseK	SOX	Base M	BaseK	Base M	BaseK	Base M	BaseK	Base M	PM2.5	Base M	BaseK	Base M	BaseK	Base M	BaseK	Base M					
July	2002	2005	2009	2009	2012	2018	2018	2002	2005	2009	2009	2012	2018	2018	2002	2005	2009	2009	2012	2018	2018	2002	2005	2009	2009	2012	2018	2018	2002	2005	2009	2009	2012	2018	2018
Nonroad																																			
IL	224	321	164	257	149	130	213	324	333	263	275	224	154	155	31	33	5	5	0.6	0.4	0.4				30		24							14	
IN	125	195	94	160	95	95	128	178	191	142	158	141	141	89	17	19	3	3	3	0.3	0.2				17		13							7	
MI	348	414	307	350	276	222	271	205	239	159	197	133	93	112	19	22	3	3	0.5	0.3	0.3				22		18							11	
OH	222	356	161	294	145	126	238	253	304	195	246	162	109	135	23	29	4	5	0.5	0.3	0.4				27		22							13	
WI	214	238	194	203	175	140	157	145	157	114	129	97	69	77	13	15	2	2	0.3	0.2	0.2				14		12							7	
5-State Total	1133	1524	920	1264	840	713	1007	1105	1224	873	1005	757	566	568	103	118	17	18	4.9	1.5	1.5				110		89							52	
U.S. Total	8463	9815	5442	8448		5244	6581	6041	9060	6057	8120		5832	5100	505	654	117	153		104	13				573		750							475	
MAR																																			
IL	10	11	10	10	10	10	6	277	246	201	228	195	186	165	0	22	0	19	0	0	17				7		6							4	
IN	5	5	5	5	5	5	3	123	93	89	87	87	84	65	0.2	8	0.2	7	0.2	0.2	6				2		2								2
MI	7	7	7	7	7	8	7	114	87	112	82	111	110	65	0.6	21	0.7	14	0.7	0.8	8				3		3								2
OH	8	7	8	7	8	8	5	177	134	128	126	126	122	94	0.4	14	0.3	12	0.3	0.3	10				4		4								2
WI	4	4	4	4	4	4	3	79	58	59	54	59	57	41	12.7	8	9.5	6	9.5	8.7	5				2		2								1
5-State Total	34	34	34	33	34	35	24	770	618	589	577	578	559	430	13.9	73	10.7	58	10.7	10	46				18		17								11
U.S. Total	307	317	321	157	329	346	334	4968	4515	4002	1813	3964	3919	3812	620	512	509	122	509	503	290				147		57								165
OtherArea																																			
IL	679	675	688	594	700	738	582	62	48	68	48	70	73	49	11	11	12	16	12	13	16				40		64								69
IN	354	391	365	358	373	398	384	62	56	65	58	67	69	59	158	32	150	32	151	153	32				2		2								2
MI	518	652	516	562	520	541	549	49	49	52	50	53	54	51	71	29	68	29	68	68	28				111		114								120
OH	546	604	550	506	558	593	487	50	93	59	108	60	62	108	22	6	34	15	35	35	14				19		35								34
WI	458	315	467	290	474	506	293	32	37	34	37	34	35	37	9	17	9	13	10	10	13				11		12								12
5-State Total	2555	2637	2586	2310	2625	2776	2295	255	283	278	301	284	293	304	271	95	273	105	276	279	103				183		227								237
U.S. Total	17876	21093	18638	18683		20512	24300	3856	4899	4100	4220		4418	5357	2075	2947	2062	2559		2189	2709				2735		2621								2570
On-Road																																			
IL	446	341	314	268	260	197	151	890	748	578	528	474	300	201		9		4			3				13		10								6
IN	405	282	237	235	193	150	138	703	541	425	402	313	187	173		11		3			2				9		7								2
MI	522	351	335	269	303	217	163	926	722	680	501	619	385	204		14		4			3				12		9								3
OH	574	680	365	424	340	238	242	1035	934	609	693	512	270	274		18		4			4				16		12								4
WI	238	175	144	119	117	88	68	481	457	303	322	226	118	138		9		2			2				8		6								2
5-State Total	2185	1829	1395	1315	1213	890	762	4035	3402	2595	2446	2144	1260	990		61		17			14				58		44								17
U.S. Total	14263				7825			23499				13170																							
EGU																																			
IL	9	7	8	6	8	9	7	712	305	227	275	244	231	224	1310	1158	944	958	789	810	869				13		34								77
IN	6	6	6	6	7	6	6	830	393	406	370	424	283	255	2499	2614	1267	1033	1263	1048	1036				16		73								74
MI	12	6	11	4	11	12	4	448	393	218	242	219	247	243	1103	1251	1022	667	1031	1058	725				15		25								29
OH	5	4	6	5	7	7	6	1139	408	330	280	322	271	285	3131	3405	1463	1326	994	701	983				28		94								80
WI	3	5	3	2	4	4	3	293	213	146	165	139	147	177	602	545	512	460	492	500	435				0		22								25
5-State Total	35	28	34	23	37	38	26	3422	1712	1327	1332	1348	1179	1184	8645	8973	5208	4444	4569	4117	4048				72		248								285
U.S. Total	214	140	195	124	197	215	138	14371	10316	7746	7274	7721	7007	6095	31839	34545	20163	16903	17629	14727	14133				685		1131								1571
Non-EGU																																			
IL	313	221	286	218	305	350	258	356	330	334	218	338	343	235	373	423	251	335	257	249	346				16		17								19
IN	150	130	160	137	170	199	167	238	179	212	175	216	225	178	292	218	270	216	274	290	180				35		36								44
MI	123	116	115	119	122	139	140	216	240	208	242	214	229	271	162	158	166	148	171	185	163				20		21								25
OH	77	84	75	87	79	90	104	177	175	157	166	160	167	178	240	289	231	288	210	216	293				27		28								33
WI	88	84	97	87	104	120	106	98	97	91	93	92	94	81	163	156	154	152	155	156	85				0		0.1								0.1
5-State Total	751	635	733	648	780	898	775	1085	1021	1002	894	1020	1058	943	1230	1244	1072	1139	1067	1096	1067				98		102								121
U.S. Total	4087	3877	4409		4700	5378		6446	6730	6129		6435	6952		5759	5630	6093		6340	6970							1444								1777
IL	1681	1576	1470	1353	1432	1434	1217	2621	2010	1671	1572	1545	1287	1029	1725	1656	1212	1337																	

For 2005, CONCEPT was run by a contractor (Environ) using transportation data (e.g., VMT and vehicle speeds) supplied by the state and local planning agencies in the LADCO States and Minnesota for 24 networks. These data were first processed with T3 (Travel Demand Modeling [TDM] Transformation Tool) to provide input files for CONCEPT to calculate link-specific, hourly emission estimates (Environ, 2007d). CONCEPT was run with meteorological data for a July and January weekday, Saturday, and Sunday (July 15 – 17 and January 16 – 18). A spatial plot of emissions is provided in Figure 42.



**Figure 42. Motor vehicle emissions for VOC (left) and NOx (right) for a July weekday (2005)**

Off-road Sources: For 2002 and 2005, NMIM and NMIM2005, respectively, were run by Wisconsin DNR. Additional off-road sectors (i.e., commercial marine, aircraft, and railroads [MAR]) were handled separately. Local data for agricultural equipment, construction equipment, commercial marine, recreational marine, and railroads were prepared by contractors (Environ and E.H. Pechan). For Base M, updated local data for railroads and commercial marine were prepared by a contractor (Environ, 2007a and Environ, 2007b) Table 7 compares the Base M 2005 and Base K 2002 emissions. The new 2005 emissions reflect substantially lower commercial marine emissions and lower locomotive NOx emissions.

**Table 7. Locomotive and commercial marine emissions for 2002 and 2005 base years**

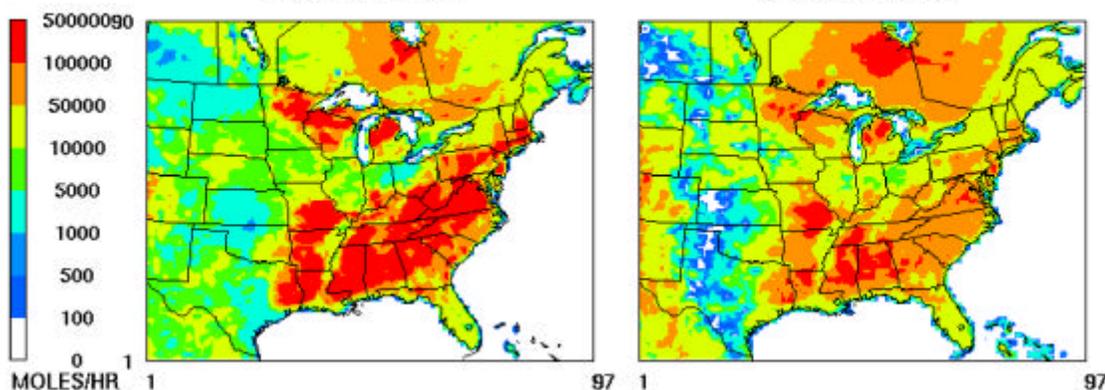
	Railroads (TPY)		Commercial Marine (TPY)	
	2002	2005	2002	2005
VOC	7,890	7,625	1,562	828
CO	20,121	20,017	8,823	6,727
NOx	182,226	145,132	64,441	42,336
PM	5,049	4,845	3,113	1,413
SO2	12,274	12,173	25,929	8,637
NH3	86	85	----	----

Area Sources: For 2002 and 2005, EMS was run by LADCO using data supplied by the LADCO States to produce weekday, Saturday, and Sunday emissions for each month. For 2005, special attention was given to two source categories: industrial adhesive and sealant solvents

(which were dropped from the inventory to avoid double-counting) and outdoor wood boilers (which were added to the inventory).

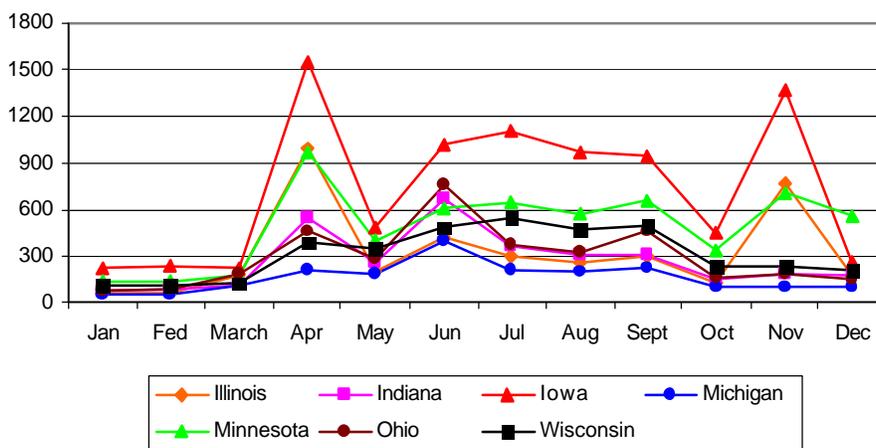
**Point Sources:** For 2002 and 2005, EMS was run by LADCO using data supplied by the LADCO States to produce weekday, Saturday, and Sunday emissions for each month. For EGUs, the annual and summer season emissions were temporalized for modeling purposes using profiles prepared by Scott Edick (Michigan DEQ) based on CEM data.

**Biogenics:** For Base M, a contractor (Alpine) provided an updated version of the CONCEPT/MEGAN biogenics model. Compared to the previous (EMS/BIOME) emissions, there is more regional isoprene using MEGAN compared to the BIOME estimates used for Base K (see Figure 43). Also, with the secondary organic aerosol updates to the CAMx air quality model, Base M includes emissions for monoterpenes and sesquiterpenes, which are precursors of secondary PM2.5 organic carbon mass.



**Figure 43. Isoprene emissions for Base M (left) v. Base K (right)**

**Ammonia:** For Base M, the CMU-based 2002 (Base K) ammonia emissions were projected to 2005 using growth factors from the Round 4 emissions modeling. These emissions were then adjusted by applying temporal factors by month based on the process-based ammonia emissions model. A plot of the average daily emissions by state and month is provided in Figure 44. A spatial of emissions is provided in Figure 45.



**Figure 44. Average daily ammonia emissions for Midwest States by month (2005)**

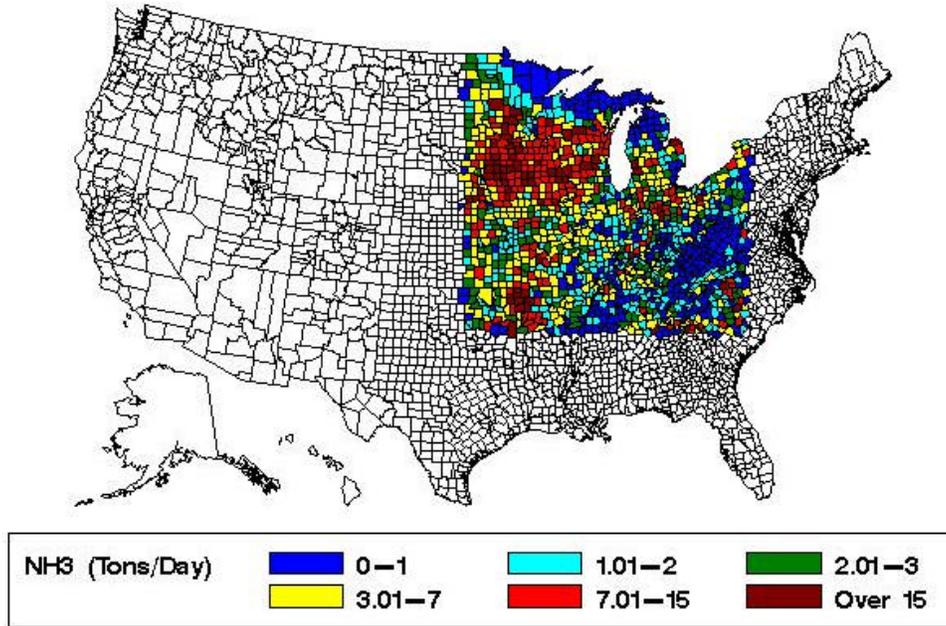


Figure 45. Ammonia emissions for a July weekday (2005) – 12 km modeling domain

Canadian Emissions: For Base M, Scott Edick (Michigan DEQ) processed the 2005 Canadian National Pollutant Release Inventory, Version 1.0 (NPRI). Specifically, a subset of the NPRI data (i.e., emissions and stack parameters) relevant to the air quality modeling were reformatted. The resulting emissions represent a significant improvement in the base year emissions. Due to the lack of growth and control factors, however, future year emissions were assumed to be the same as these base year emissions.

A spatial plot of point source SO<sub>2</sub> and NO<sub>x</sub> emissions is provided in Figure 46. Additional plots and emission reports are available on the LADCO website (<http://www.ladco.org/tech/emis/basem/canada/index.htm>).

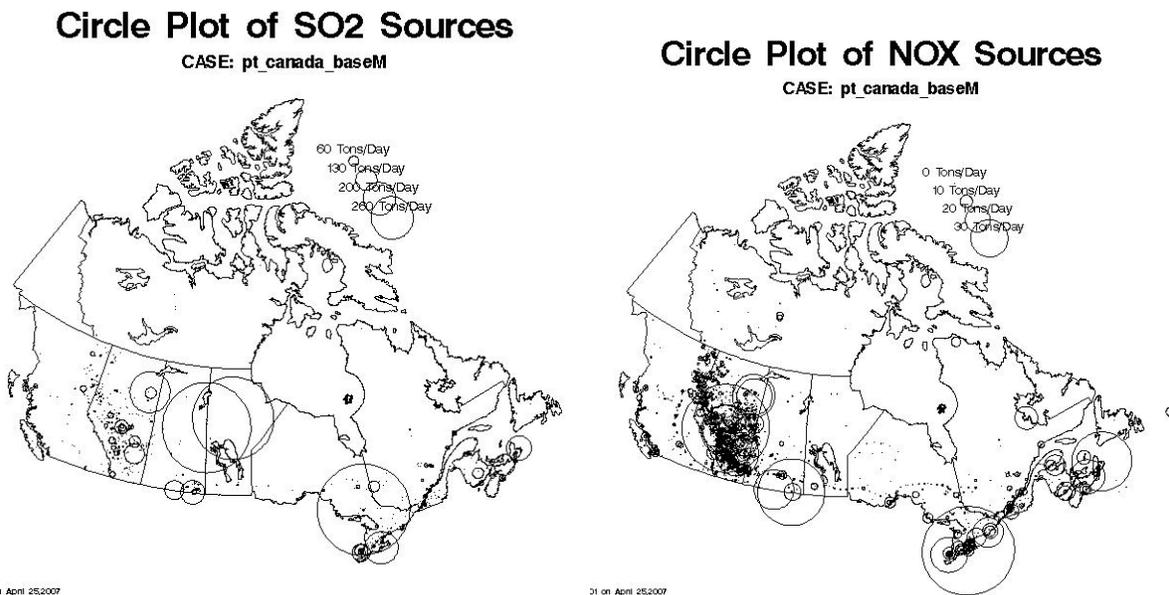
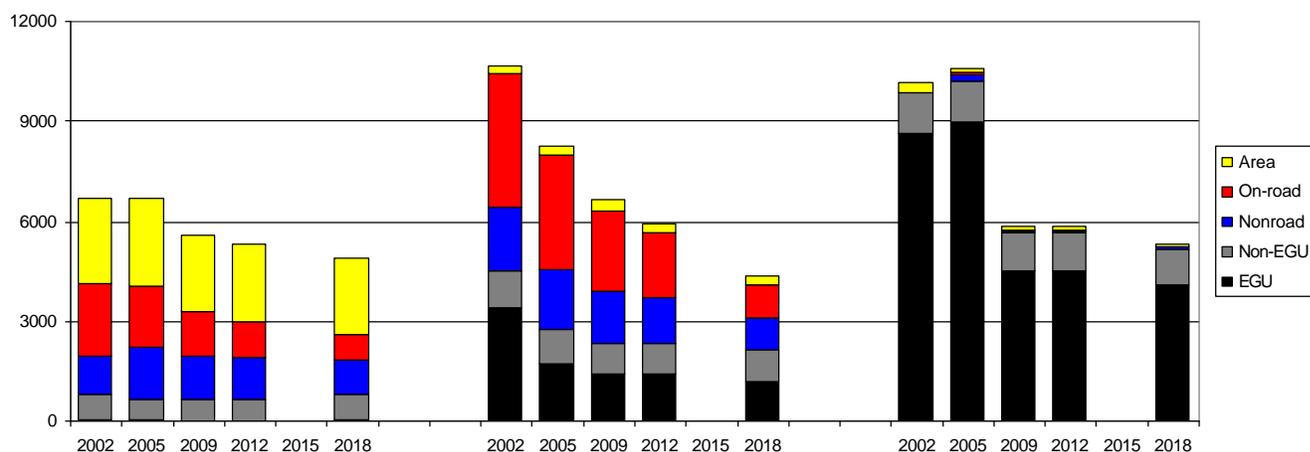


Figure 46. Canadian point source emissions for SO<sub>2</sub> (left) and NO<sub>x</sub> (right)

Fires: For Base K, a contractor (EC/R) developed a 2001, 2002, and 2003 fire emissions inventory for eight Midwest States (five LADCO states plus Iowa, Minnesota, and Missouri), including emissions from wild fires, prescribed fires, and agricultural burns. Projected emissions were also developed for 2010 and 2018 assuming “no smoke management” and “optimal smoke management” scenarios. An early model sensitivity run showed very little difference in modeled PM2.5 concentrations. Consequently, the fire emissions were not included in subsequent modeling runs (i.e., they were not in the Base K or Base M modeling inventories).

*Future Year Emissions:* Complete emission inventories were developed for several future years: Base K – 2009, 2012, and 2018, and Base M – 2009 and 2018. In addition, 2008 (Base K and Base M) and 2012 (Base M) proxy inventories were estimated based on the 2009 and 2018 data.

Source sector emission summaries for the base years and future years are shown in Figure 47. Additional detail is provided in Table 6.



**Figure 47. Base year and future year emissions for 5-State LADCO Region (TPD, July weekday)**

For on-road, and nonroad, the future year emissions were estimated by models (i.e., EMS/CONCEPT and NMIM, respectively).

For EGUs, IPM2.1.9 modeling completed by the RPOs in July 2005 was used for Base K and IPM3.0 completed by EPA in February 2007 was used for Base M. Several CAIR scenarios were assumed:

**Base K**

- 1a: IPM2.1.9, with full trading and banking
- 1b: IPM2.1.9, with restricted trading (compliance with state-specific emission budgets) and full trading
- 1d: IPM2.1.9, with restricted trading (compliance with state-specific emission budgets)

**Base M**

- 5a: EPA’s IPM3.0 was assumed as the future year base for EGUs.
- 5b: EPA’s IPM3.0, with several “will do” adjustments identified by the States. These adjustments should reflect a legally binding commitment (e.g., signed contract, consent decree, or operating permit).

5c: EPA's IPM3.0, with several "may do" adjustments identified by the States. These adjustments reflect less rigorous criteria, but should still be some type of public reality (e.g., BART determination or press announcement).

For other sectors (area, MAR, and non-EGU point sources) the future year emissions for the LADCO States were derived by applying growth and control factors to the base year inventory. These factors were developed by a contractor (E.H. Pechan, 2005 and E.H. Pechan, 2007). For the non-LADCO States, future year emission files were based on data from other Regional Planning Organizations.

Growth factors were based initially on EGAS (version 5.0), and were subsequently modified (for select, priority categories) by examining emissions activity data.

A "base" control scenario was prepared for each future year based on the following "on the books" controls:

**On-Highway Mobile Sources**

- Tier II/Low sulfur fuel
- Inspection/Maintenance programs (nonattainment areas)
- Reformulated gasoline (nonattainment areas)

**Off-Highway Mobile Sources**

- Federal control programs incorporated into NONROAD model (e.g., nonroad diesel rule), plus the evaporative Large Spark Ignition and Recreational Vehicle standards
- Heavy-duty diesel (2007) engine standard/Low sulfur fuel
- Federal railroad/locomotive standards
- Federal commercial marine vessel engine standards

**Area Sources (Base M only)**

- Consumer solvents
- AIM coatings
- Aerosol coatings
- Portable fuel containers

**Power Plants**

- Title IV (Phases I and II)
- NOx SIP Call
- Clean Air Interstate Rule
- Clean Air Mercury Rule

**Other Point Sources**

- VOC 2-, 4-, 7-, and 10-year MACT standards
- Combustion turbine MACT

Other controls included in the modeling include: consent decrees (refineries, ethanol plants, and ALCOA)<sup>8</sup>, NOx RACT in Illinois and Ohio<sup>9</sup>, and BART for a few non-EGU sources in Indiana and Wisconsin.

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<sup>8</sup> E.H. Pechan's original control file included control factors for three sources in Wayne County, MI. These control factors were not applied in the regional-scale modeling to avoid double-counting with the State's local-scale analysis for PM2.5

<sup>9</sup> Wisconsin believes that NOx RACT for their sources is included in the 2005 basecase and EGU "will do" scenario, and Indiana provided NOx RACT information for inclusion as a no-EGU "may do" scenario.

For Base K, several additional control scenarios were considered:

Scenario 2 – “base” controls plus additional SO<sub>2</sub> and NO<sub>x</sub> candidate control measures identified in the White Paper for EGUs

Scenario 3 – Scenario 2 plus additional White Papers for stationary and mobile sources

Scenario 4 – “base” controls plus additional candidate control measures under discussion by State Commissioners

Scenario 5 – “base” controls plus additional candidate control measures identified by the LADCO Project Team

### **3.7 Basecase Modeling Results**

The purpose of the basecase modeling is to evaluate model performance (i.e., assess the model's ability to reproduce the observed concentrations). The model performance evaluation focused on the magnitude, spatial pattern, and temporal of modeled and measured concentrations. This exercise was intended to build confidence in the model prior to its use in examining candidate control strategies. Increased confidence in the model increases the role of the modeling results in the design and establishment of any eventual control strategies.

Model performance was assessed by comparing modeled and monitored concentrations. The following operational evaluations were conducted:

- Statistical: normalized (and fractional) bias and normalized (and fractional) gross error
- Graphical: scatter plots, side-by-side spatial plots, and time series plots

No rigid acceptance/rejection criteria were used for this study. Instead, the statistical guidelines recommended by USEPA and other modeling studies (e.g., modeling by the other RPOs) were used to assess the reasonableness of the results. The model performance results presented here describe how well the model replicates observed ozone and PM<sub>2.5</sub> concentrations after a series of iterative improvements to model inputs.

*Ozone:* Spatial plots are provided for high ozone periods in June 2002 and June 2005 (see Figures 48-49). The plots show that the model is doing a reasonable job of reproducing the magnitude, day-to-day variation, and spatial pattern of ozone concentrations. There is a tendency, however, to underestimate the magnitude of regional ozone levels.

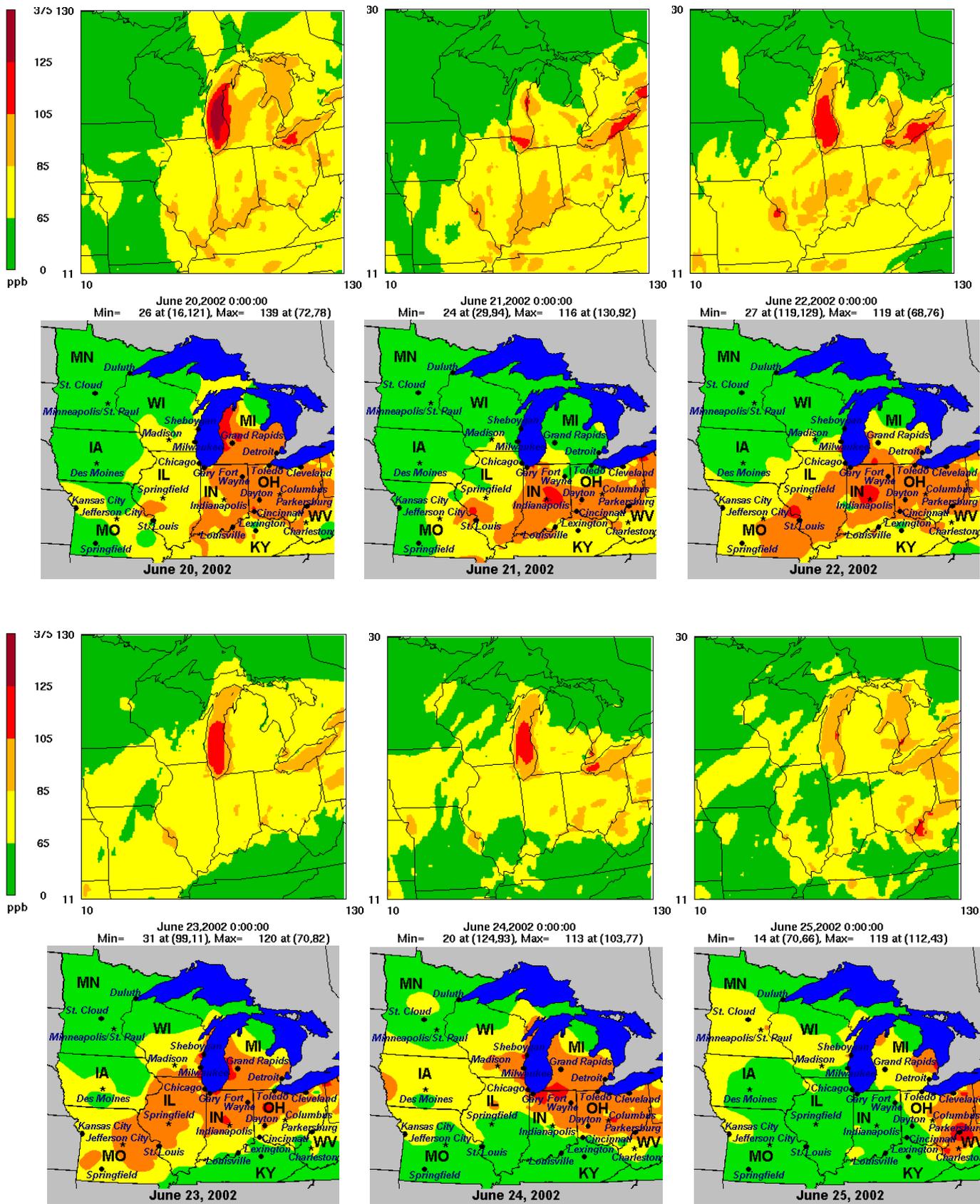


Figure 48. Modeled (top) v. monitored (bottom) 8-hour ozone concentrations: June 20 – 25, 2002

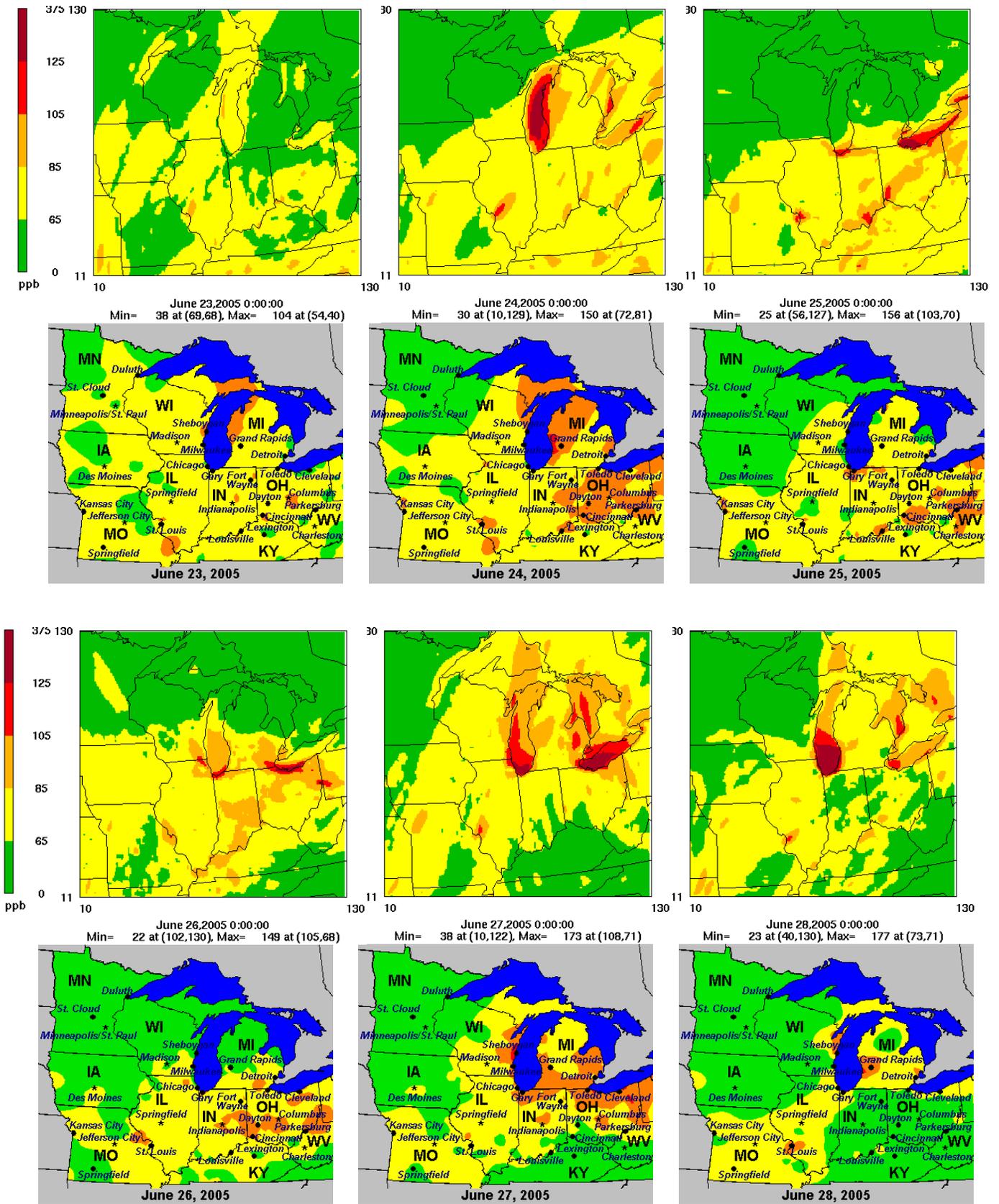
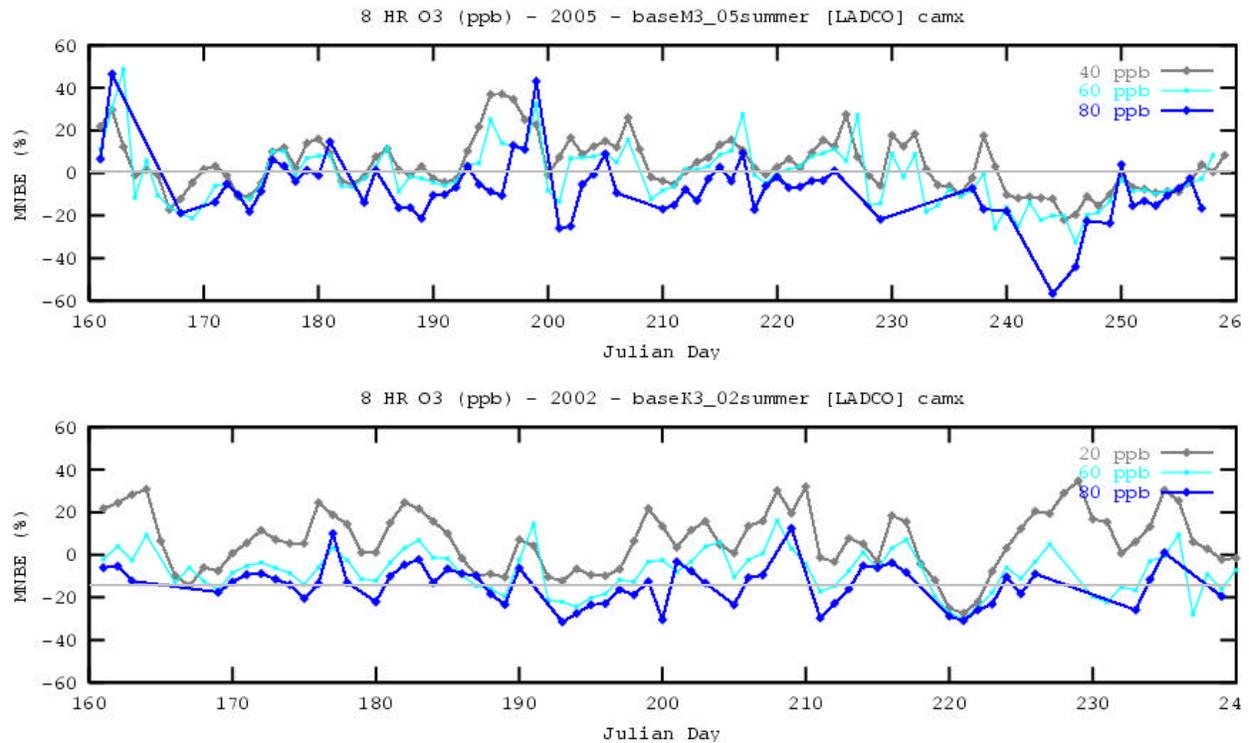


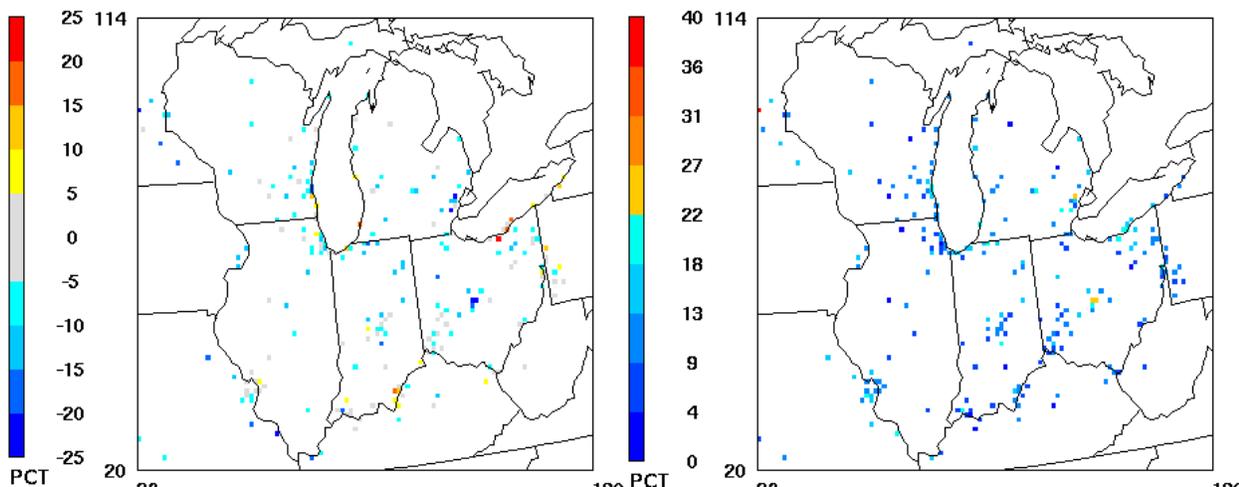
Figure 49 Modeled (top) v. monitored (bottom) 8-hour ozone concentrations: June 23– 28 2005

Standard model performance statistics were generated for the entire 12 km domain, and by day and by monitoring site. The domain-wide mean normalized bias for the 2005 base year is similar to that for the 2002 base year and is generally within 30% (see Figure 50).



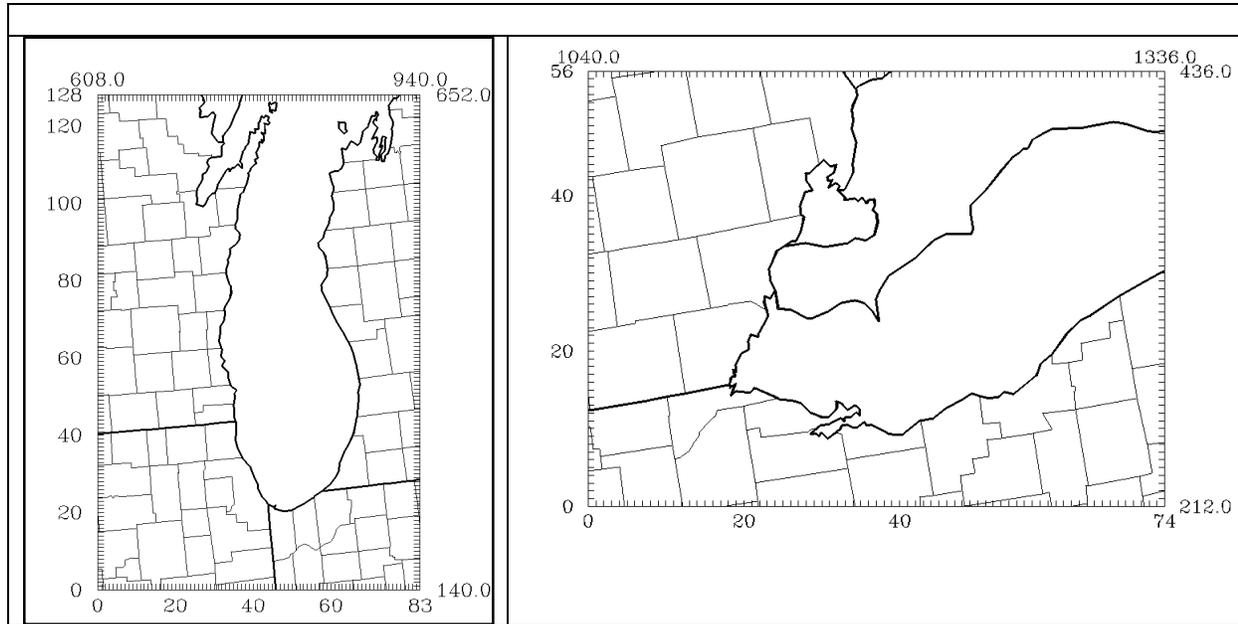
**Figure 50. Mean bias for summer 2005 (Base M) and summer 2002 (Base K)**

Station-average metrics (over the entire summer) are shown in Figure 51. The bias results further demonstrate the model's tendency to underestimate absolute ozone concentrations.



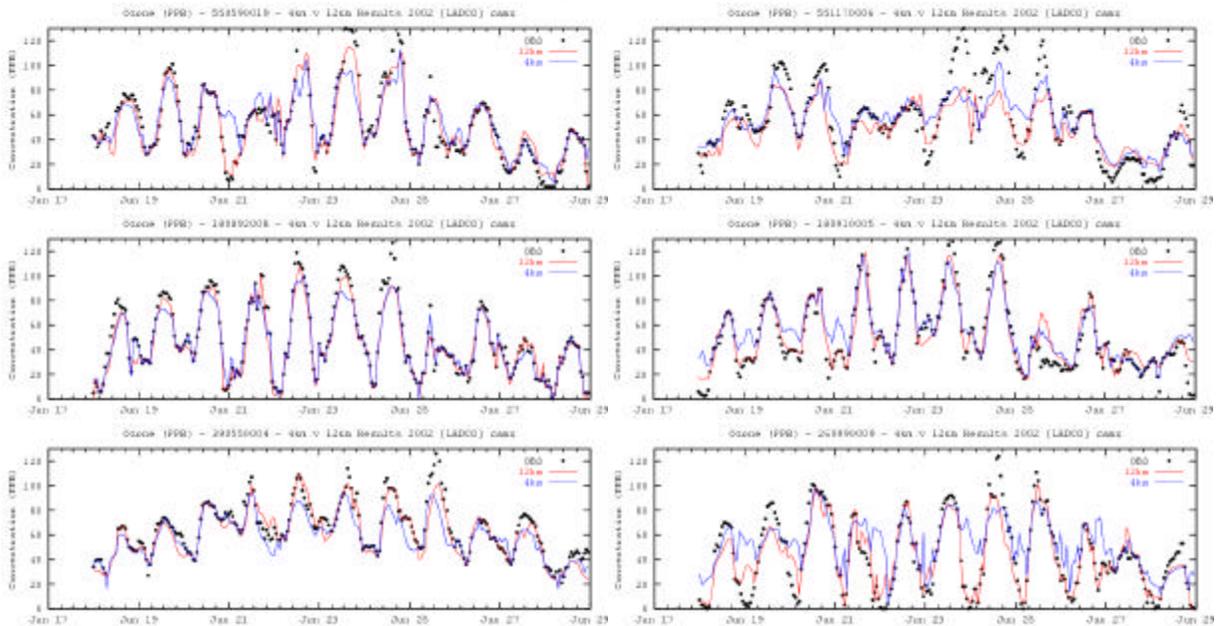
**Figure 51. Mean bias (left) and gross error (right) for summer 2005**

A limited 4 km ozone analysis was performed by LADCO to address the effect of grid spacing. For this modeling, 4 km grids were placed over Lake Michigan and the Detroit-Cleveland area (see Figure 52). Model inputs included 4 km emissions developed by LADCO (consistent with Base K/Round 4) and the 4 km meteorology developed by Alpine Geophysics.



**Figure 52. 4 km grids for Lake Michigan region and Detroit-Cleveland region**

Hourly time series plots were prepared for several monitors (see Figure 53). The results are similar at 12 km and 4 km, with some site-by-site and day-by-day differences.



**Figure 53. Ozone time series plots for 12 km and 4 km modeling (June 17-29, 2002)**

An additional diagnostic analysis was performed to assess the response of the modeling system to changes in emissions (Baker and Kenski, 2007). Specifically, the 2002-to-2005 change in observed ozone concentrations was compared to the change in modeled ozone concentrations based on the 95<sup>th</sup> percentile (and above) concentration values for each monitor. This analysis was also done with the inclusion of model performance criteria which eliminated poorly performing days (i.e., error > 35%). The results are provided in Figure 54. There is good agreement in the modeled and monitored ozone concentration changes (e.g., ozone improves by about 9-10 ppb between 2002 and 2005 according to the model and the measurements).

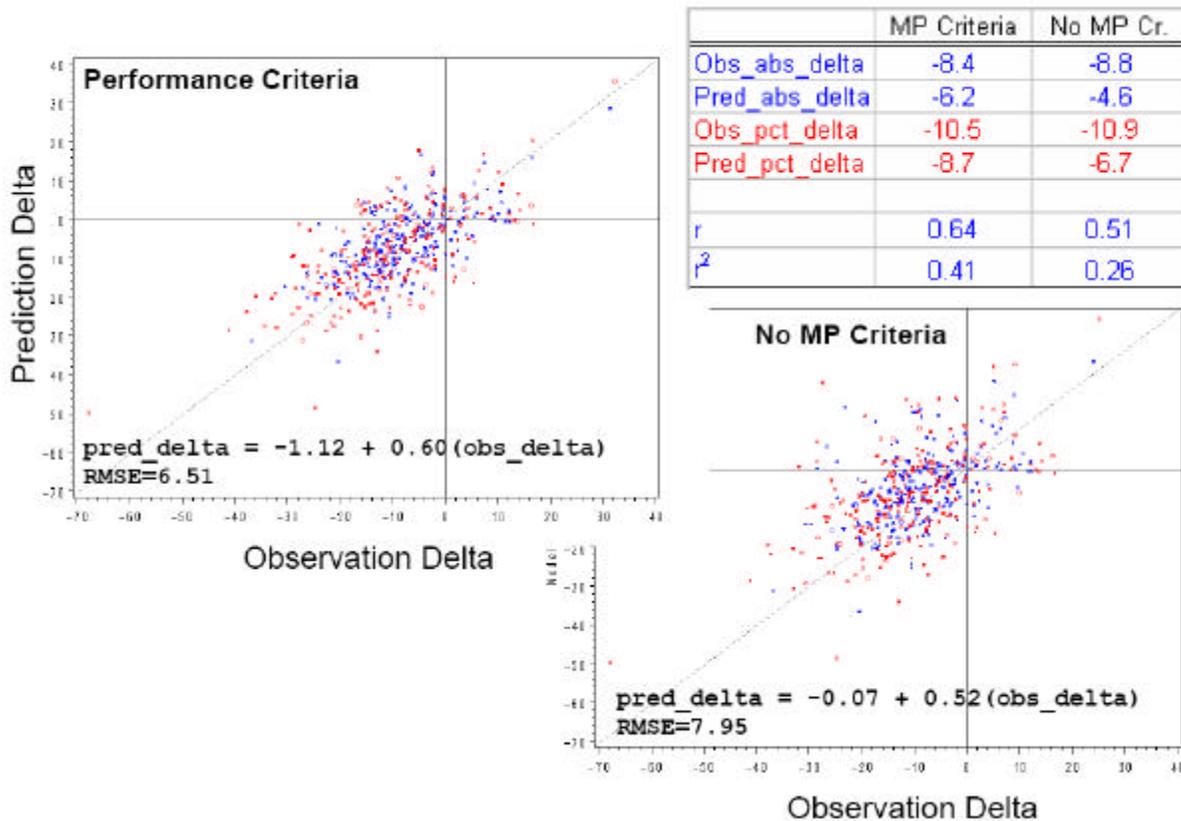


Figure 54. Comparison of change in predicted and observed ozone concentrations (2002 v. 2005)

PM2.5: Time series plots of the monthly average mean bias and annual fractional bias for Base M (and Base K) are shown in Figure 55. As can be seen, the Base M model performance results for most species are fairly good (i.e., close to “no bias” throughout most of the year), with two main exceptions. First, the Base M (and Base K) results for organic carbon are poor, suggesting the need for more work on primary organic carbon emissions. Second, the Base M results for sulfate, while acceptable (i.e., bias values are within 35%), are not as good as the Base K results (e.g., noticeable underprediction during the summer months).

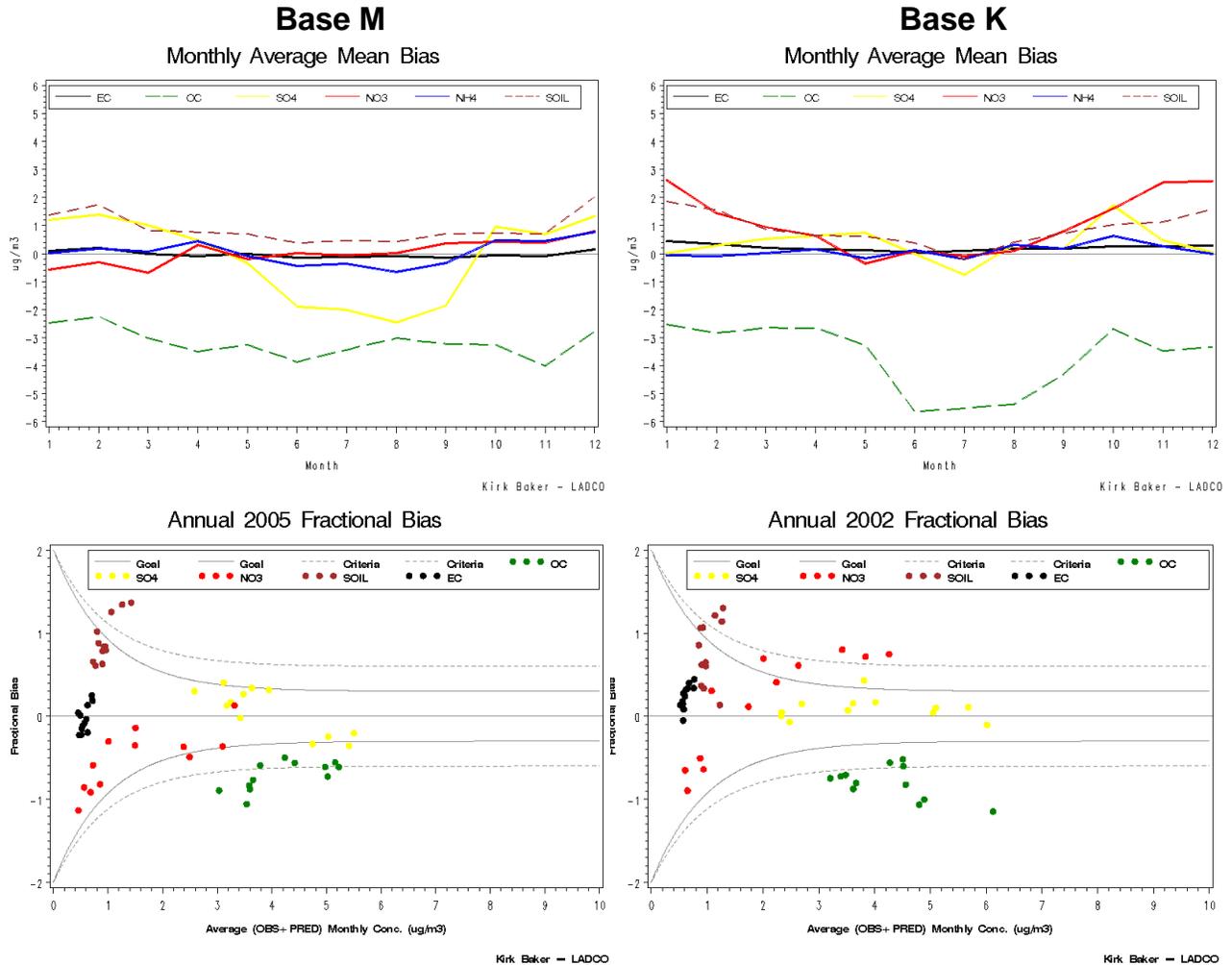
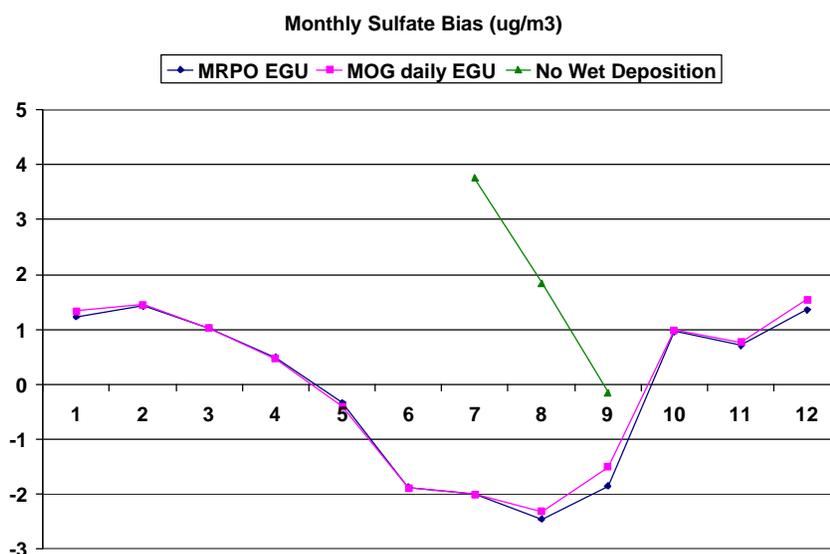


Figure 55. PM2.5 Model performance - monthly average mean bias and annual fractional bias for Base M (left column) and Base K (right column)

Two analyses were undertaken to understand sulfate model performance for 2005:

- **Assess Meteorological Influences:** The MM5 model performance evaluation showed that rainfall is over-predicted by MM5 over most of the domain during the summer months (LADCO, 2007a). Because CAMx does not explicitly use the rainfall output by MM5, this may or may not result in over-prediction sulfate wet deposition (and under-prediction of sulfate concentrations). A sensitivity run was performed with no wet deposition for July, August, and September. The resulting model performance (see green line in Figure 56) showed a noticeable difference from the basecase (i.e., higher sulfate concentrations), and suggests that further evaluation of MM5 precipitation fields may be warranted.
- **Assess Emissions Influences:** The major contributor to sulfate concentrations in the region is SO<sub>2</sub> emitted from EGUs. The base year modeling inventory for EGUs is based on annual emissions, which were allocated to a typical weekday, Saturday, and Sunday by month using CEM-based temporal profiles. A second sensitivity run was performed using day-specific emissions. The resulting model performance (see purple line in Figure 56) showed little difference from the basecase.



**Figure 56. Monthly sulfate bias for Base M (MRPO EGU) v. two sensitivity analyses (Note: positive values indicate over-prediction, negative values indicate under-prediction)**

Based on these results, it is concluded that while sulfate model performance is currently acceptable, improvements may be possible through further analysis of MM5 precipitation fields. Regardless, another model sensitivity run showed that this issue should not affect the model projected future year design values.<sup>10</sup> Consequently, even with an improved wet deposition treatment, the current (Base M) strategy results are not expected to change.

Time series plots of daily sulfate, nitrate, elemental carbon, and organic carbon concentrations for three Midwestern locations are presented in Figures 57 (2002) and 58 (2005). These results are consistent with the model performance statistics (i.e., good agreement for sulfates and nitrates and poor agreement [large underprediction] for organic carbon).

<sup>10</sup> This sensitivity run reflected no wet deposition in Quarters 2-3 for the base year (2005) and 2018. The resulting future year design values were consistent with those from the current strategy run – i.e., less than a 0.2 ug/m<sup>3</sup> difference.

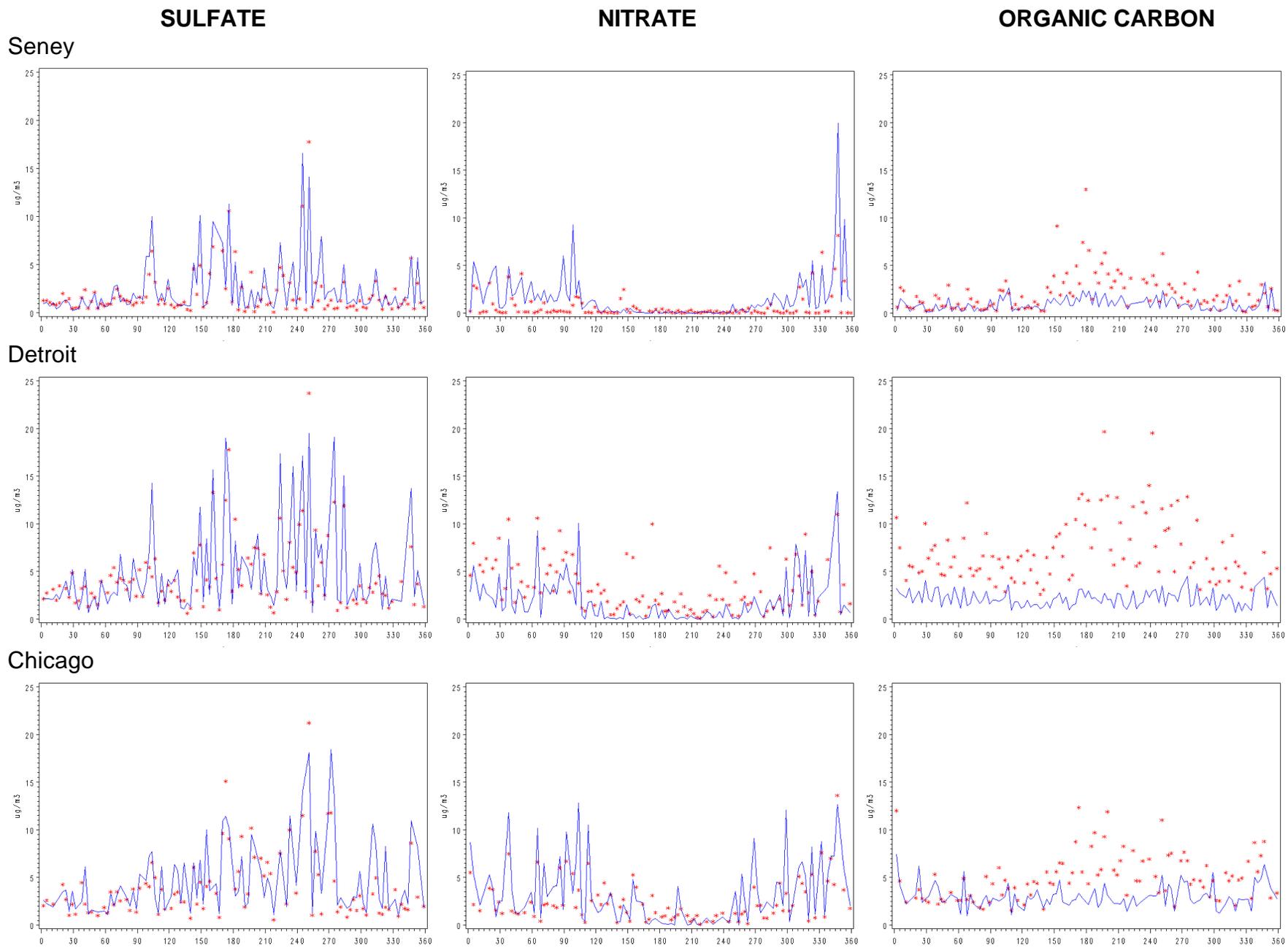


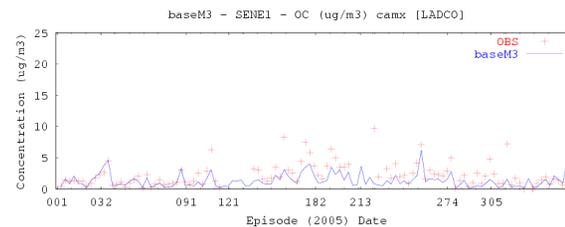
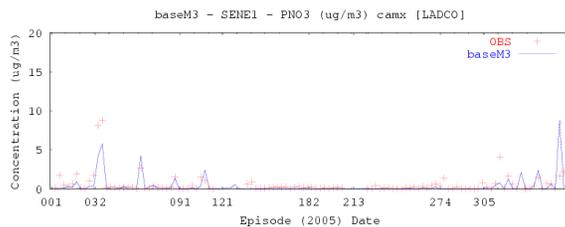
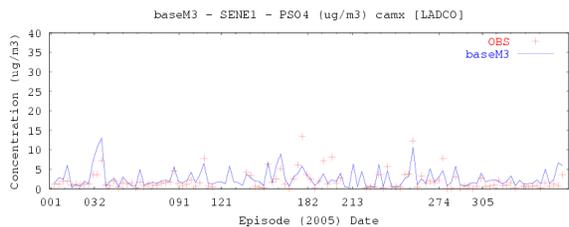
Figure 57. Time series of sulfate, nitrate, and organic carbon at three Midwest sites for 2005

## SULFATE

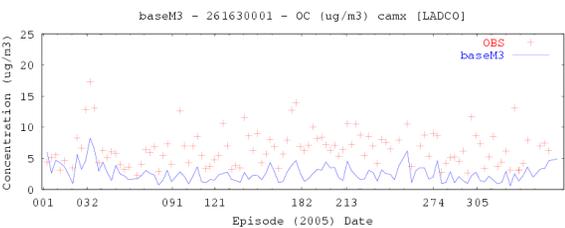
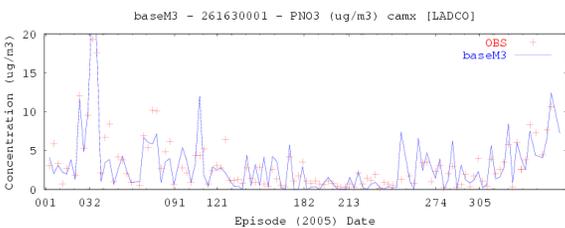
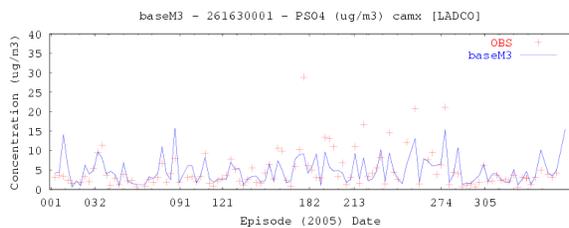
## NITRATE

## ORGANIC CARBON

### Seney



### Detroit



### Chicago

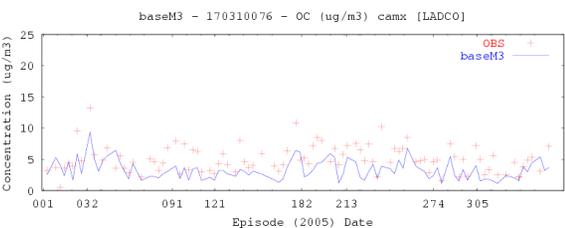
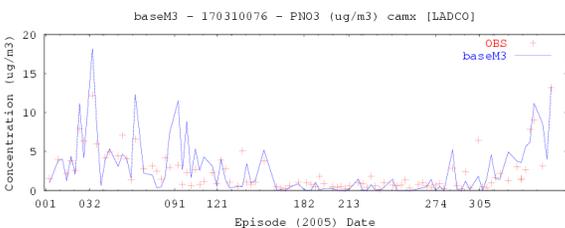
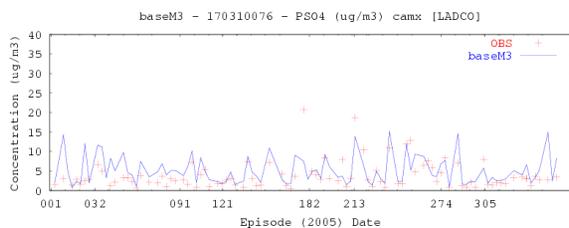


Figure 58. Time series of sulfate, nitrate, and organic carbon at three Midwest sites for 2005

In summary, model performance for ozone and PM<sub>2.5</sub> is generally acceptable and can be characterized as follows:

#### Ozone

- Good agreement between modeled and monitored concentration for higher concentration levels (> 60 ppb) – i.e., bias within 30%
- Regional modeled concentrations appear to be underestimated in the 2002 base year, but show better agreement (with monitored data) in the 2005 base year due to model and inventory improvements.
- Day-to-day and hour-to-hour variation in and spatial patterns of modeled concentrations are consistent with monitored data
- Model accurately simulates the change in monitored ozone concentrations due to reductions in precursor emissions.

#### PM<sub>2.5</sub>

- Good agreement in the magnitude of fine particle mass, but some species are overestimated and some are underestimated
  - Sulfates: good agreement in the 2002 base year, but underestimated in the 2005 base year due probably to meteorological factors
  - Nitrates: slightly overestimated in the winter in the 2002 base year, but good agreement in the 2005 base year due to model and inventory improvements
  - Organic Carbon: grossly underestimated in the 2002 and 2005 base years due likely to missing primary OC emissions
- Day-to-day and hour-to-hour variation in and spatial patterns of modeled concentrations are consistent with monitored data

## Section 4.0 Attainment Demonstration for Ozone and PM<sub>2.5</sub>

Air quality modeling and other information were used to determine whether existing (“on the books”) controls would be sufficient to provide for attainment of the NAAQS for O<sub>3</sub> and PM<sub>2.5</sub> and if not, then what additional emission reductions would be necessary for attainment. Traditionally, attainment demonstrations involved a “bright line” test in which a single modeled value was compared to the ambient standard. To provide a more robust assessment of expected future year air quality, USEPA’s modeling guidelines call for consideration of supplemental information. This section summarizes the results of the primary (guideline) modeling analysis and a weight of evidence determination based on the modeling results and other supplemental analyses.

### 4.1 Future Year Modeling Results

The purpose of the future year modeling is to assess the effectiveness of existing and possible additional control programs. The model was used in a relative sense to project future year design values, which are then compared to the standard to determine attainment/nonattainment. Specifically, the modeling test consists of the following steps:

- (1) Calculate base year design values: For O<sub>3</sub> and PM<sub>2.5</sub>, the base year design values were derived by averaging the three 3-year periods centered on the emissions base year:  
  
2002 base year: 2000-2002, 2001-2003, and 2002-2004  
2005 base year: 2003-2005, 2004-2006, and 2005-2007<sup>11</sup>
- (2) Estimate the expected change in air quality: For each grid cell, a relative reduction factor (RRF) is calculated by taking the ratio of the future year and baseline modeling results.
- (3) Calculate future year design values: For each grid cell (with a monitor), the RRFs are multiplied by the base year design values to project the future year design values
- (4) Assess attainment: Future year design values are compared to the NAAQS to assess attainment or nonattainment.

A comparison of the 2002 and 2005 base year design values for ozone and PM<sub>2.5</sub> is provided in Figure 59. In general, the figure shows that the 2005 base year design values are much lower than the 2002 base year design values, especially for ozone.

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<sup>11</sup> For PM<sub>2.5</sub>, 2007 data were not available, so the 2005-2007 period was represented by the 2005-2006 average.

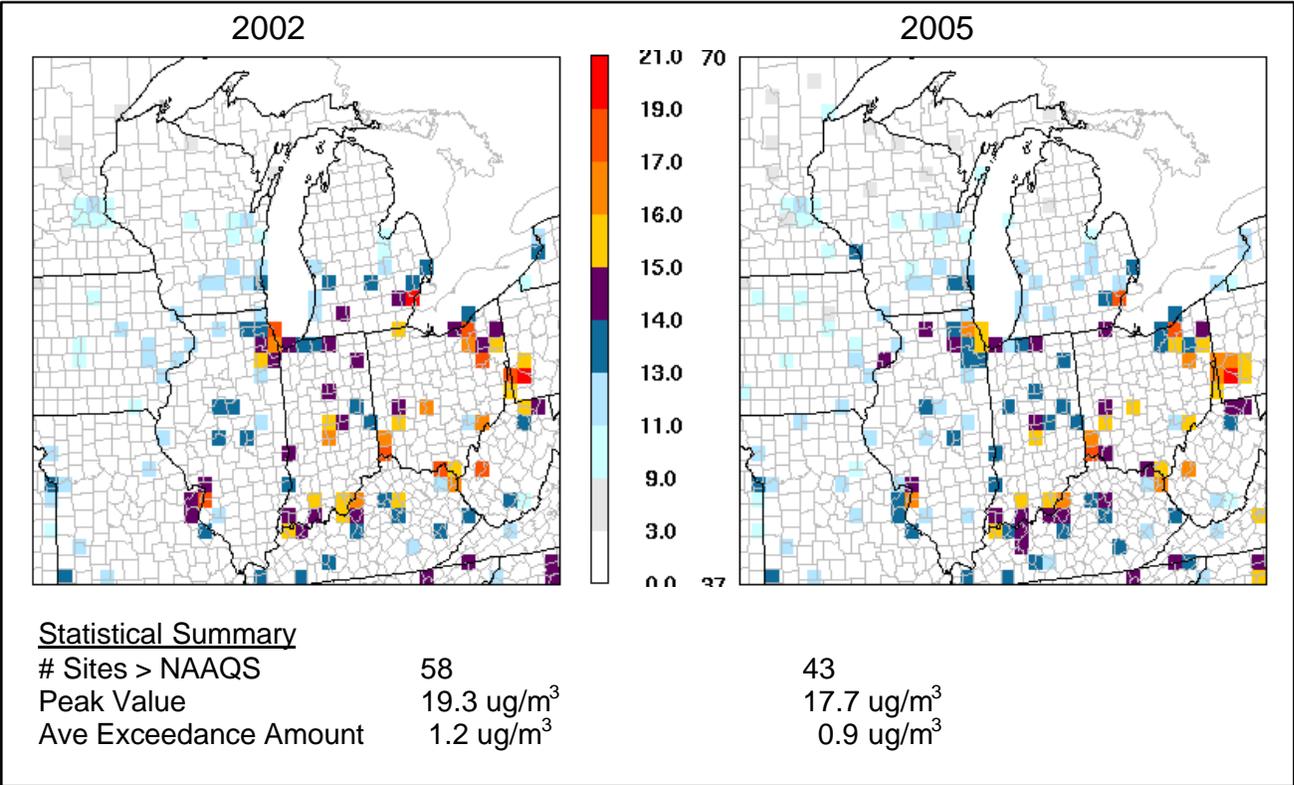
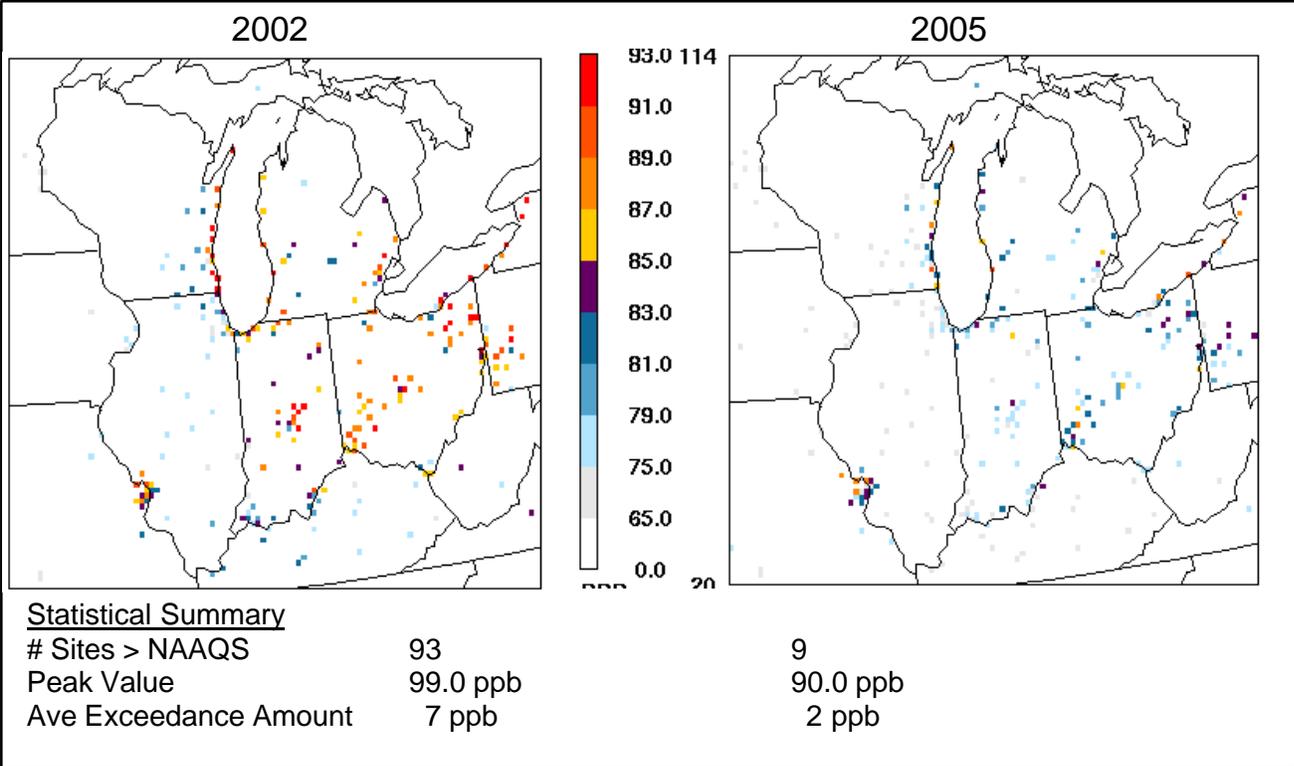


Figure 59. 2002 v. 2005 base year design values for ozone (top) and PM2.5 (bottom)

Ozone results are provided for those grid cells with ozone monitors. The RRF calculation considers all nearby grid cells (i.e., 3x3 for 12 km modeling) and a threshold of 85 ppb. (If there were less than 10 days above this value, then the threshold was lowered until either there were 10 days or the threshold reached 70 ppb.) PM<sub>2.5</sub> results are provided for those grid cells with FRM (PM<sub>2.5</sub>-mass) monitors. Spatial mapping was performed to extrapolate PM<sub>2.5</sub>-speciation data from STN and IMPROVE sites to FRM sites.

Additional, hot-spot modeling will be performed by the states for certain PM<sub>2.5</sub> nonattainment areas (e.g., Detroit, Cleveland, and Granite City) to address primary emissions from local point sources which may not be adequately accounted for by the regional grid modeling. This modeling will consist of Gaussian dispersion modeling (e.g., AERMOD) performed in accordance with USEPA's modeling guidance (see Section 5.3 of the April 2007 guidance document).

The ozone and PM<sub>2.5</sub> modeling results are provided in Appendix I for select monitors (high concentration sites) in the 5-state region for the following future years of interest: 2008 (ozone only), 2009, 2012, and 2018. A summary of the modeling results is provided in Table 8 (ozone) and Table 9 (PM<sub>2.5</sub>), and spatial maps of the Base M future year concentrations are provided in Figures 60-62.

The number of monitors with design values above the standard are as follows:

**Table 10. Number of sites above standard**

<b>Ozone</b>									
State	2002	2005	2009		2012		2018		
	BaseK	Base M							
IL	3	0	0	0	0	0	0	0	0
IN	22	0	0	0	0	0	0	0	0
MI	15	3	1	1	0	0	0	0	0
OH	40	4	1	0	1	0	0	0	0
WI	13	2	4	0	3	0	1	0	0
Total	93	9	6	1	4	0	1	0	0
<b>PM<sub>2.5</sub></b>									
State	2002	2005	2009		2012		2018		
	BaseK	Base M							
IL	11	9	3	1	3	1	2	0	0
IN	10	7	1	0	1	0	0	0	0
MI	6	2	3	1	2	1	0	0	0
OH	31	25	7	1	4	0	1	1	1
WI	0	0	0	0	0	0	2	0	0
Total	58	43	14	3	10	2	5	1	1

Key Sites		2008		2009		2012		2018
		Round 5	Round 4	Round 5	Round 4	Round 5	Round 4	Round 5
<b>Lake Michigan Area</b>								
Chiwaukee	550590019	82.0	93.0	82.3	92.0	80.9	90.3	76.2
Racine	551010017	77.6	85.9	77.5	84.9	76.1	82.9	71.2
Milwaukee-Bayside	550190085	79.6	85.4	79.8	84.9	78.1	82.3	72.7
Harrington Beach	550890009	80.0	86.7	80.1	85.4	78.3	82.9	72.5
Manitowoc	550710007	81.0	80.3	80.5	78.9	78.3	76.3	72.2
Sheboygan	551170006	84.4	90.0	84.0	88.9	81.9	86.4	75.4
Kewaunee	550610002	78.9	82.5	78.1	81.0	76.0	79.1	69.9
Door County	550290004	84.8	83.6	83.9	81.8	81.6	79.3	74.7
Hammond	180892008	75.4	86.9	75.4	86.6	74.6	86.3	71.6
Whiting	180890030	77.0		77.0		76.2		73.1
Michigan City	180910005	74.2	87.4	73.9	86.5	72.5	85.4	68.1
Ogden Dunes	181270020	75.7	82.3	75.6	82.8	74.4	82.0	70.8
Holland	260050003	85.6	84.9	85.3	83.4	82.9	81.0	76.1
Jenison	261390005	78.2	78.7	77.4	77.6	75.2	75.5	69.0
Muskegon	261210039	81.2	82.7	80.8	81.5	78.6	79.4	72.2
<b>Indianapolis Area</b>								
Noblesville	189571001	78.7	85.2	78.8	83.7	76.3	82.0	69.3
Fortville	180590003	74.6	85.1	74.5	83.8	72.2	82.1	65.7
Fort B. Harrison	180970050	74.8	84.8	75.1	83.7	73.4	82.4	69.1
<b>Detroit Area</b>								
New Haven	260990009	82.7	86.3	81.4	85.3	80.2	83.5	76.1
Warren	260991003	82.2	84.3	81.0	83.3	80.4	81.9	77.3
Port Huron	261470005	78.7	80.5	77.1	79.1	75.3	77.0	70.6
<b>Cleveland Area</b>								
Ashtabula	390071001	84.9	84.7	83.4	82.7	81.0	80.2	75.1
Geauga	390550004	75.7	90.3	74.7	88.8	72.7	86.2	67.3
Eastlake	390850003	82.8	84.2	81.9	82.8	80.5	80.6	76.2
Akron	391530020	79.3	83.0	78.1	81.4	75.6	78.5	68.7
<b>Cincinnati Area</b>								
Wilmington	390271002	77.8	84.8	77.5	83.5	75.1	81.1	68.3
Sycamore	390610006	81.4	85.4	81.6	84.7	80.0	82.9	74.3
Lebanon	391650007	83.6	80.1	83.0	79.0	80.8	77.0	74.2
<b>Columbus Area</b>								
London	390970007	75.4	79.9	75.0	78.4	72.7	76.5	66.3
New Albany	390490029	82.4	84.1	81.8	82.6	79.6	80.2	73.0
Franklin	290490028	77.0	77.7	75.9	76.5	74.2	74.7	69.0
<b>St. Louis Area</b>								
W. Alton (MO)	291831002	82.4	86.1	81.0	85.2	79.5	84.0	74.9
Orchard (MO)	291831004	83.3	83.3	82.0	82.2	80.4	80.4	76.2
Sunset Hills (MO)	291890004	79.5	82.8	78.7	81.9	77.4	80.6	73.9
Arnold (MO)	290990012	78.7	78.4	77.2	77.4	75.8	75.8	72.0
Margaretta (MO)	295100086	79.8	84.0	79.3	83.4	77.9	82.5	74.4
Maryland Heights (MO)	291890014	84.5		83.4		81.9		78.1

County	Site ID	2009		2012		2018	
		Round 5	Round4	Round 5	Round4	Round 5	Round4
Cook	170310022	13.9	14.8	13.8	14.6	13.6	14.4
Cook	170310052	14.2	15.8	14.2	15.5	13.8	15.0
Cook	170310057	13.7	14.5	13.7	14.3	13.5	14.1
Cook	170310076	13.7	14.5	13.7	14.3	13.5	14.1
Cook	170312001	13.6	14.5	13.5	14.3	13.5	14.1
Cook	170313103	14.9		14.8		14.3	
Cook	170313301	14.1	14.8	14.0	14.6	13.8	14.4
Cook	170316005	14.4	15.3	14.3	15.1	14.1	14.9
Madison	171191007	15.2	16.0	15.1	15.8	14.5	15.5
St. Clair	171630010	14.0	14.9	13.8	14.7	13.2	14.5
Clark	180190005	13.6	15.5	13.6	15.0	13.2	14.4
Dubois	180372001	12.4	13.8	12.3	13.5	11.7	13.0
Lake	180890031	12.9		12.7		12.3	
Marion	180970078	12.7	14.5	12.5	14.2	11.9	13.7
Marion	180970083	13.2	14.8	13.0	14.9	12.4	14.0
Wayne	261630001	13.0	14.5	12.9	14.1	12.4	13.3
Wayne	261630015	14.2	15.8	14.0	15.3	13.5	14.4
Wayne	261630016	13.0	14.1	12.9	13.7	12.4	13.0
Wayne	261630033	15.7	17.7	15.5	17.1	15.0	16.1
Wayne	261630036	13.0	15.1	12.9	14.7	12.4	13.9
Butler	390170003	13.3	14.2	13.2	13.7	12.6	13.1
Butler	390170016	13.0	13.5	13.0	12.9	12.4	12.2
Cuyahoga	390350027	13.4	14.4	13.2	13.8	12.6	12.9
Cuyahoga	390350038	15.1	16.1	14.8	15.4	14.2	14.4
Cuyahoga	390350045	14.2	14.6	14.0	14.0	13.4	13.1
Cuyahoga	390350060	14.8	15.3	14.6	14.7	14.0	13.7
Cuyahoga	390350065	13.7	14.1	13.5	13.5	12.9	12.6
Franklin	390490024	12.8	14.6	12.6	14.0	11.9	13.0
Franklin	390490025	12.6	14.1	12.4	13.5	11.8	12.5
Franklin	390490081	11.7	14.0	11.5	13.4	10.9	12.5
Hamilton	390610014	14.4	15.5	14.3	14.8	13.7	14.0
Hamilton	390610040	12.7	13.6	12.6	13.0	12.1	12.3
Hamilton	390610042	13.9	14.6	13.8	14.0	13.2	13.2
Hamilton	390610043	12.9	13.6	12.8	13.0	12.3	12.2
Hamilton	390617001	13.3	14.2	13.2	13.6	12.7	12.8
Hamilton	390618001	14.6	15.2	14.5	14.6	13.9	13.8
Jefferson	390810016	12.5	16.3	12.5	15.9	12.5	16.2
Jefferson	390811001	13.4	15.5	13.3	15.0	13.3	15.3
Lawrence	390870010	12.7	14.2	12.7	13.7	12.2	13.2
Montgomery	391130032	13.0	13.7	12.8	13.2	12.2	12.3
Scioto	391450013	12.2	15.4	12.1	14.8	11.6	14.2
Stark	391510017	13.9	15.0	13.7	14.3	13.1	13.6
Stark	391510020	12.4	13.6	12.2	13.0	11.7	12.2
Summit	391530017	12.9	14.4	12.8	13.6	12.2	12.9
Summit	391530023	12.1	13.6	12.0	13.0	11.4	12.2

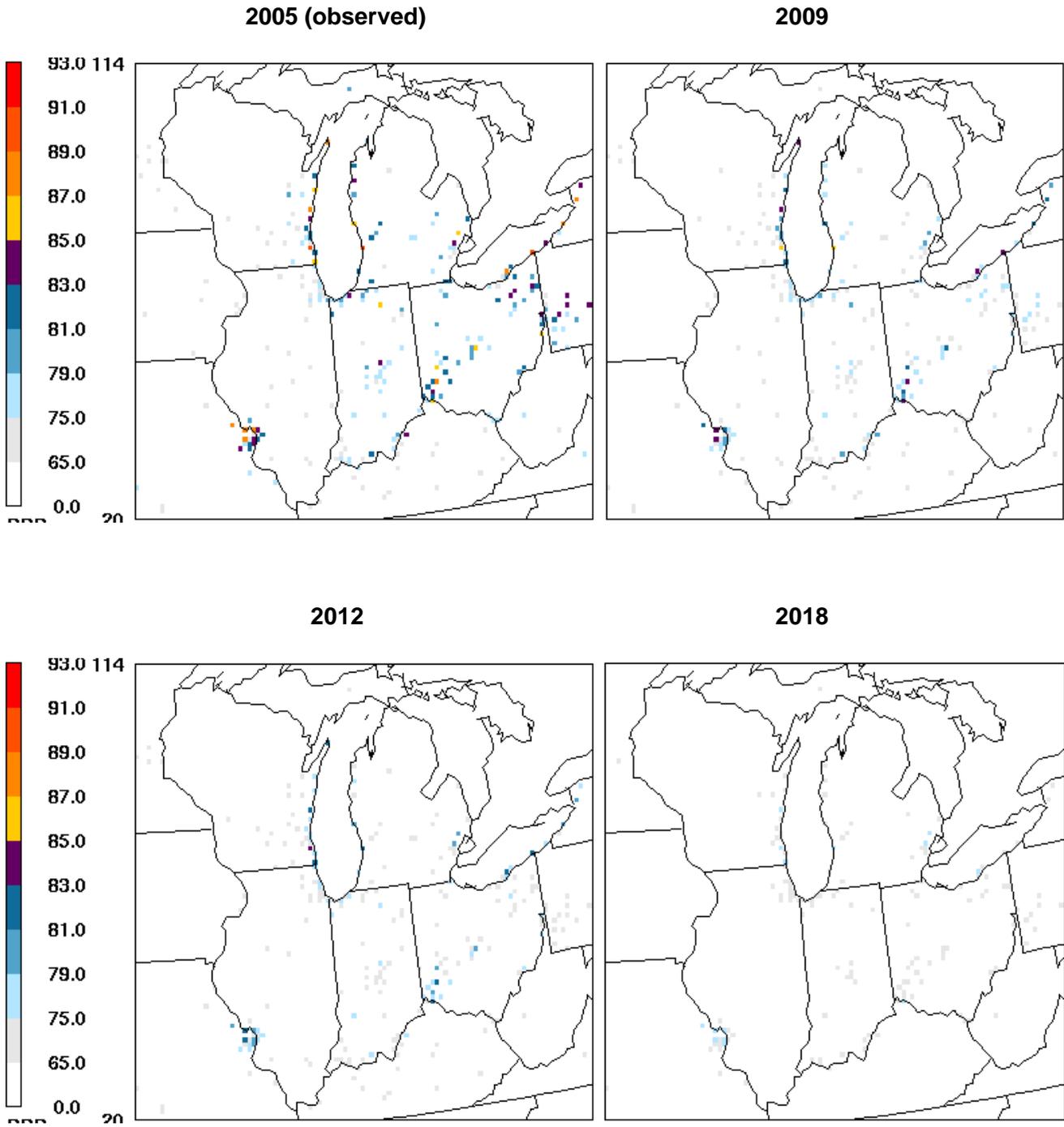


Figure 60. Observed base year and projected future year design values for ozone – Base M

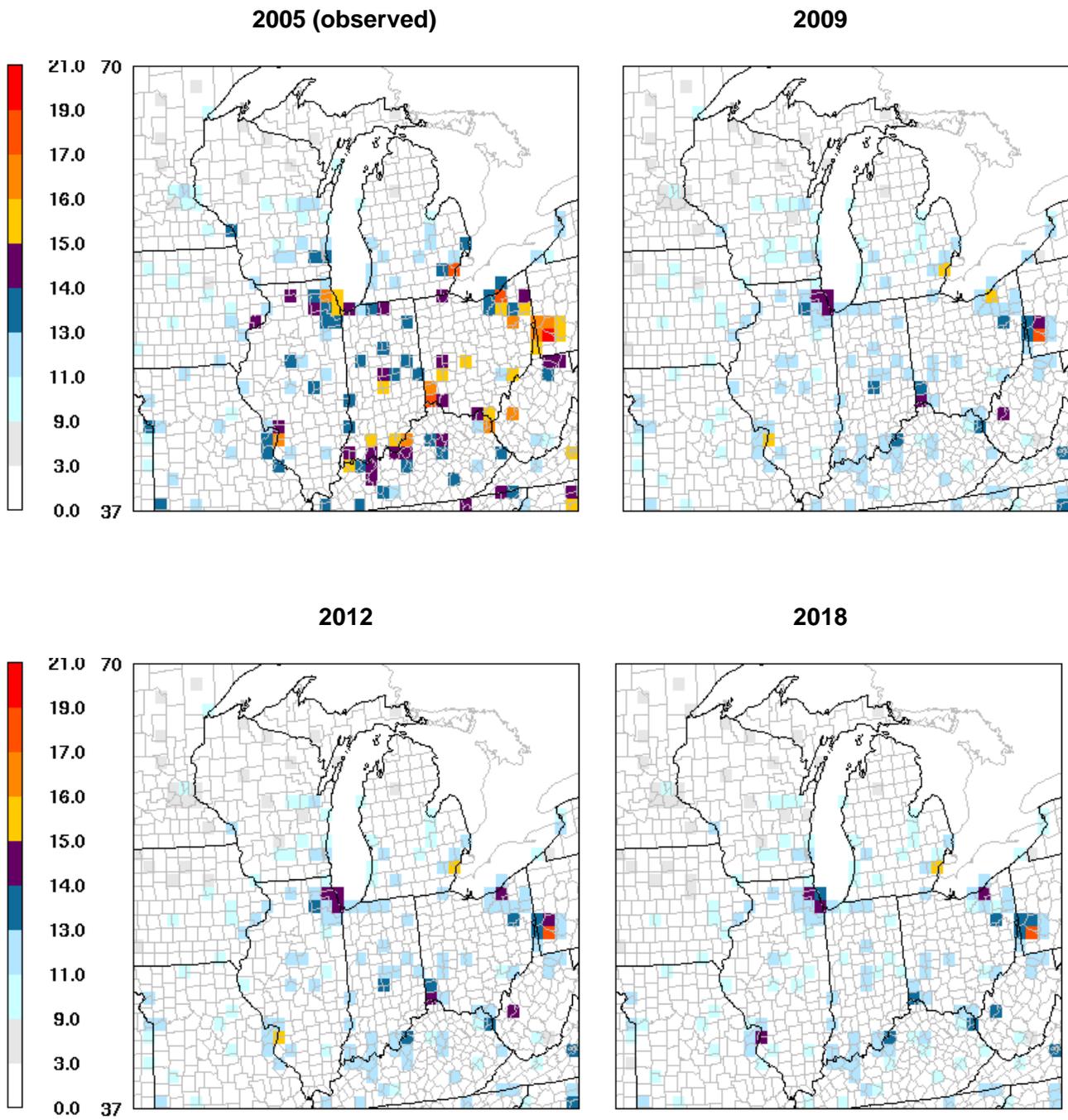


Figure 61. Observed base year and projected future year design values for PM2.5 (annual average)–Base M

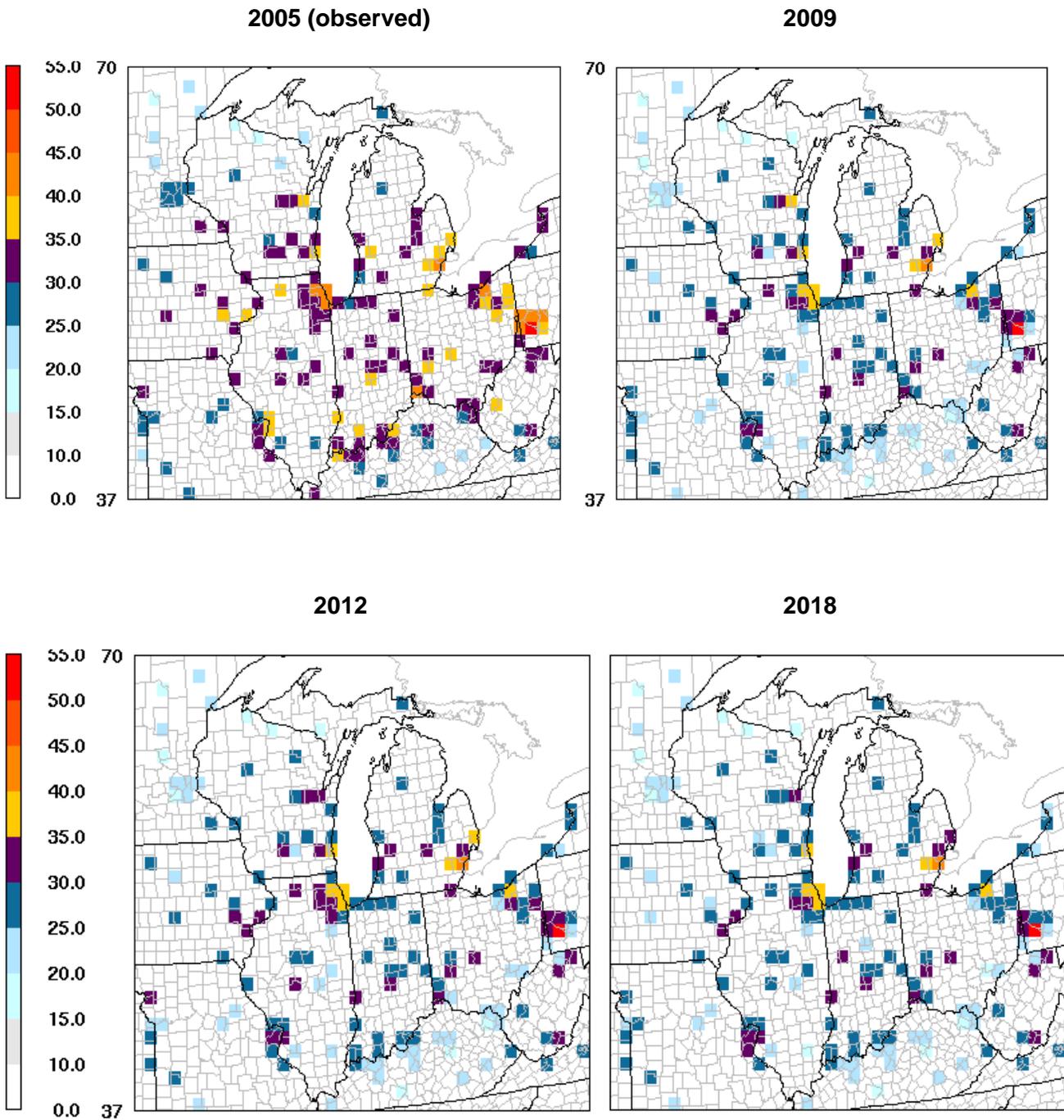
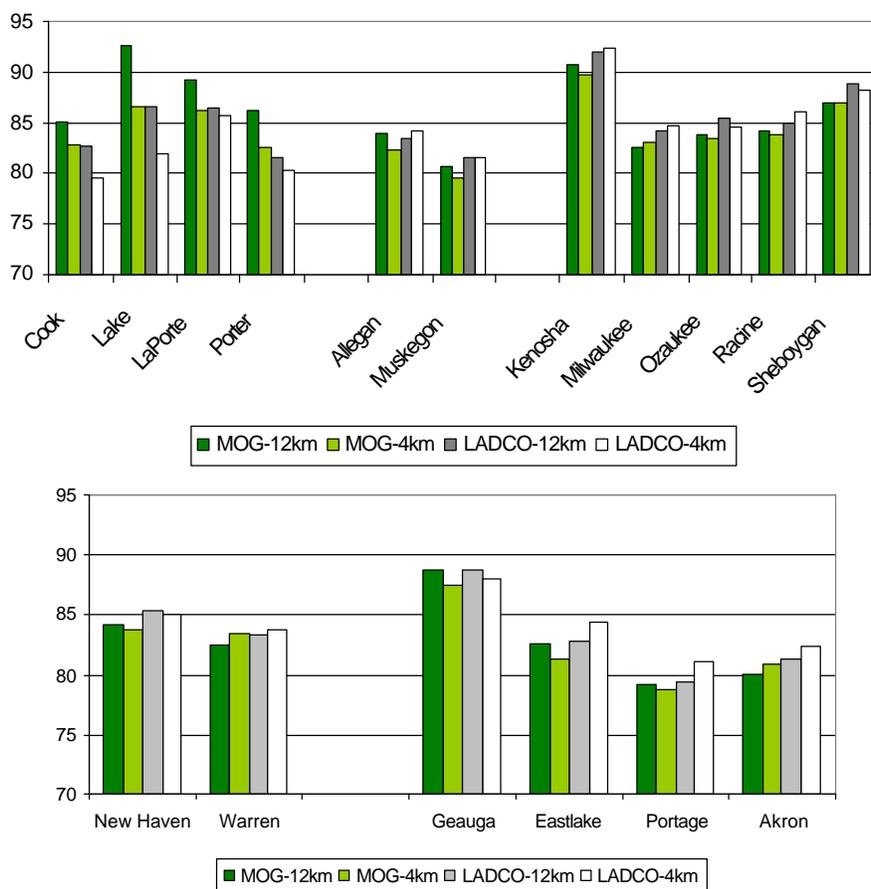


Figure 62. Observed base year and projected future year design values for PM<sub>2.5</sub> (24-hr average)-Base M

The limited 4 km ozone modeling performed by LADCO included a future year analysis for 2009. The figures below show the 2009 design values with 12 km and 4 km grid spacing for the LADCO modeling and similar modeling conducted by a stakeholder group (MOG).



**Figure 63. Future year (2009) design values for Lake Michigan area (top) and Detroit-Cleveland region (bottom)**

Based on these results, the following findings should be noted:

- The 12 km and 4 km design values are similar, with the most notable changes in northwestern Indiana and northeastern Illinois (e.g., 4 km values are as much as 4 ppb lower than 12 km values).
- The differences in the southern part of the Lake Michigan area are plausible, given the tight emissions gradient there (i.e., finer grid resolution appears to provide more appropriate representation).

In light of these findings, 12 km grid spacing can continue to be used for ozone modeling, but the Base K/Round 4 results for northwestern Indiana/northeastern Illinois should be viewed with caution (i.e., probably 1 – 4 ppb too high).

In summary, the ozone modeling provides the following information for the nonattainment areas in the region (see Table 11):

**Table 11. Ozone Nonattainment Areas in the LADCO Region (as of October 10, 2007)**

Area Name	Category	Number of Counties	Attainment Date
Detroit-Ann Arbor, MI	Marginal	8	2007
Chicago-Gary-Lake County, IL-IN	Moderate	10	2010
Cleveland-Akron-Lorain, OH	Moderate	8	2010
Milwaukee-Racine, WI	Moderate	6	2010
Sheboygan, WI	Moderate	1	2010
St Louis, MO-IL	Moderate	4	2010
Allegan Co, MI	Subpart 1	1	2009
Cincinnati-Hamilton, OH-KY-IN	Subpart 1	6	2009
Columbus, OH	Subpart 1	6	2009
Door Co, WI	Subpart 1	1	2009
Indianapolis, IN	Subpart 1	9	2009
Kewaunee Co, WI	Subpart 1	1	2009
Manitowoc Co, WI	Subpart 1	1	2009
		<b>62</b>	

Marginal Areas (2007 attainment date): No modeling was conducted for the 2006 SIP planning year. Rather, 2005 – 2007 air quality data are available to determine attainment.

Basic (Subpart 1) Areas (2009 attainment date): The modeling results for the 2008 SIP planning year show:

- Base K: all areas in attainment, except Cincinnati and Indianapolis
- Base M: all areas in attainment, except Holland (Allegan County)

Moderate Areas (2010 attainment date): The modeling results for the 2009 SIP planning year show:

- Base K: all areas still in nonattainment
- Base M: all areas in attainment

The PM2.5 modeling results show:

- Base K: all areas in attainment, except for Chicago, Cincinnati, Cleveland, Detroit, Granite City (IL), Louisville, Portsmouth (OH), and Steubenville
- Base M: all areas in attainment, except for Cleveland, Detroit, and Granite City (IL)

With respect to the proposed, lower 8-hour ozone standard, the modeling shows more than 110 sites in 2012 and more than 40 sites in 2018 with design values greater than 70 ppb. With respect to the new, lower 24-hour PM2.5 standard, the modeling shows about 20 sites in 2012 and 2018 with design values greater than 35 ug/m3.

## 4.2 Supplemental Analyses

USEPA's modeling guidelines recommend that attainment demonstrations consist of a primary (guideline) modeling analysis and supplemental analyses. Three basic types of supplemental analyses are recommended:

- additional modeling
- analyses of trends in ambient air quality and emissions, and
- observational models and diagnostic analyses

Furthermore, according to USEPA's guidelines, if the future year modeled design values are "close" to the standard (i.e., 82 – 87 ppb for ozone and 14.5 – 15.5 ug/m<sup>3</sup> for PM2.5), then the results of the primary modeling should be reviewed along with the supplemental information in a "weight of evidence" assessment of whether each area is likely to achieve timely attainment.

A WOE determination for ozone and PM2.5 is provided in the following sections. Special attention is given to the following areas with future year modeled design values that exceed or are "close" to the ambient standard (see Appendix I):

Ozone	PM2.5
Lake Michigan area	Chicago, IL
Cleveland, OH	Cleveland, OH
Cincinnati, OH	Cincinnati, OH
	Granite City, IL
	Detroit, MI

## 4.3 Weight-of-Evidence Determination for Ozone

The WOE determination for ozone consists of the primary modeling and other supplemental analyses (some of which were discussed in Section 2). A summary of this information is provided below.

*Primary (Guideline) Modeling:* The guideline modeling is presented in Section 4.1. Key findings from this modeling include:

- Base M regional modeling shows attainment by 2008 and 2009 at all sites, except Holland (MI), and attainment at all sites by 2012.
- Base K modeling results reflect generally higher future year design values, and show more sites in nonattainment compared to the Base M modeling. The difference in the two modeling analyses is due mostly to lower base year design values in Base M.
- Base K and Base M modeling analyses are considered "SIP quality", so the attainment demonstration for ozone should reflect a weight-of-evidence approach, with consideration of monitoring based information.
- Base M modeling also shows that the proposed lower 8-hour standard will not be met at many sites, even by 2018, with existing controls.

*Additional Modeling:* Three additional modeling analyses were considered: (1) the primary modeling redone with different assumptions, (2) an unmonitored area analysis, and (3) USEPA's latest regional ozone modeling. Each of these analyses is described below.

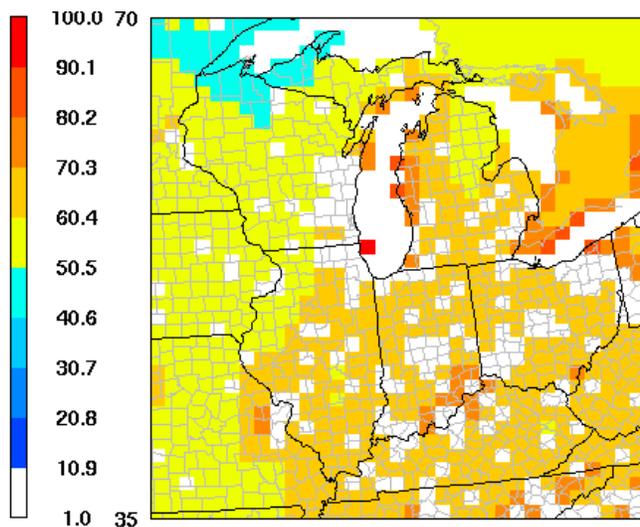
First, the primary modeling analysis was revised using two different types of assumptions:

- (1) Base year design values were recalculated using (a) the 3-year period centered on base year, and (b) the highest 3-year period that includes the base year
- (2) Relative reduction factors (RRF) were recalculated using all days with a base year modeled value > 70 ppb, and using all days with a base year modeled value > 85 ppb, with at least 10 days and “acceptable” model performance (Note: this was only done for Base K)

The results for several high concentration sites are presented in Table 12 for 2009. The different modeling assumptions produce eight new estimates of future year ozone concentrations. The highest estimates are associated with base year design values representing the 3-year average for 2001-2003, and the lowest estimates are associated with base year design values representing the 3-year average 2004-2006. The different RRF approaches produce little change in future year ozone concentrations for Base K; consequently, the different RRF approaches were not considered for Base M. This suggests that future year concentration estimates are most sensitive to the choice of the base year (and the methodology used to derive the base year design values).

Second, USEPA’s modeling guidelines recommend that an “unmonitored area analysis” be included as a supplemental analysis, particularly in nonattainment areas where the monitoring network just meets or minimally exceeds the size of the network required to report data to the Air Quality System. The purpose of this analysis is to identify areas where future year design values are predicted to be greater than the NAAQS.

Based on examination of the spatial plots in Figures 48 and 49, the most notable areas of high modeled concentrations ozone concentrations are over the Great Lakes. Over-water monitoring, however, is not required by USEPA<sup>12</sup>. There are also policy issues about the applicability of the NAAQS over water. A cursory analysis of unmonitored areas for ozone was performed by LADCO using an earlier version of the 2002 base year modeling (i.e, Base I) (Baker, 2005). Base year and future “observed” values were derived for unmonitored grid cells using the absolute modeled concentrations (in all grid cells) and the observed values (in monitored grid cells). A spatial map of the estimated 2009 values is provided in Figure 64. As can be seen, there are very few (over land) grid cells where additional monitors may be desirable. This indicates that the current modeling analysis, which focuses on monitored locations, is addressing areas of high ozone throughout the region.



**Figure 64. Estimated Future Year Design Values (unmonitored grid cells)**

<sup>12</sup> Air quality measurements over Lake Michigan were collected by LADCO previously to understand ozone transport in the area (see, for example, Figure 5). Due to cut-backs in USEPA funding, however, these measurements were discontinued in 2003.

**Table 12a. Primary and Additional Ozone Modeling Results – Lake Michigan and Cleveland Areas (2009)**

2009 Modeling Results	Lake Michigan Area							Cleveland Area		
	Chiwaukee 550590019	Harr.Beach 550890009	Sheboygan 551170006	DoorCounty 550290004	Holland 260050003	Hammond 180892008	MichiganCity 180910005	Ashtabula 390071001	Geauga 390550004	Eastlake 390850003
<b>Attainment Test (based on EPA guidance-2002 baseyear)</b>										
Base Year Design Value (average of three 3-year periods)	98.3	93.0	97.0	91.0	94.0	88.3	90.3	95.7	99.0	92.7
RRF (all days > 85 ppb, or at least 10 days)	0.935	0.918	0.916	0.899	0.888	0.980	0.958	0.865	0.897	0.894
Future Year Design Value	91.9	85.4	88.9	81.8	83.5	86.5	86.5	82.8	88.8	82.9
<b>Attainment Test (based on EPA guidance-2005 baseyear)</b>										
Base Year Design Value (average of three 3-year periods)	84.7	83.3	88.0	88.7	90.0	77.7	77.0	89.0	79.3	86.3
RRF (all days > 85 ppb, or at least 10 days)	0.972	0.961	0.955	0.946	0.948	0.971	0.960	0.937	0.942	0.949
Future Year Design Value	82.3	80.1	84.0	83.9	85.3	75.4	73.9	83.4	74.7	81.9
<b>Weight of Evidence (alternative approaches-2002baseyear)</b>										
Alt 1 - Base Year Des. Value (3-year period centered on 2002)	101.0	98.0	100.0	94.0	97.0	90.0	93.0	99.0	103.0	95.0
Alt 2 - Base Year Des. Value (Highest 3-year period including 2002 )	101.0	98.0	100.0	94.0	97.0	92.0	93.0	99.0	103	95.0
RRF (all days > 85 ppb, or at least 10 days)	0.935	0.918	0.916	0.899	0.888	0.980	0.958	0.865	0.897	0.894
Alt 1 - Future Year Projected Value	94.4	90.0	91.6	84.5	86.1	88.2	89.1	85.6	92.4	84.9
Alt 2 - Future Year Projected Value	94.4	90.0	91.6	84.5	86.1	90.2	89.1	85.6	92.4	84.9
Alt 1 - RRF (all days > 70 ppb)	0.933	0.918	0.912	0.907	0.893	0.969	0.947	0.876	0.907	0.900
Alt 1 - Future Year Projected Value	94.2	90.0	91.2	85.3	86.6	87.2	88.1	86.7	93.4	85.5
Alt 2 - Future Year Projected Value	94.2	90.0	91.2	85.3	86.6	89.1	88.1	86.7	93.4	85.5
Alt 2 - RRF (all days > 85 ppb, or at least 10 days; with acceptable model performance)	0.945	0.904	0.910	0.904	0.887	0.976	0.964	0.866	0.896	0.894
Alt 1 - Future Year Projected Value	95.4	88.6	91.0	85.0	86.0	87.8	89.7	85.7	92.3	84.9
Alt 2 - Future Year Projected Value	95.4	88.6	91.0	85.0	86.0	89.8	89.7	85.7	92.3	84.9
<b>Weight of Evidence (alternative approaches-2005baseyear)</b>										
Alt 1 - Base Year Des. Value (3-year period centered on 2005)	83.0	79.0	86.0	86.0	88.0	76.0	76.0	86.0	77.0	86.0
Alt 2 - Base Year Des. Value (Highest 3-year period including 2005)	86.0	88.0	89.0	90.0	93.0	79.0	78.0	91.0	86.0	89.0
Alt 1 - Future Year Projected Value	80.7	75.9	82.1	81.4	83.4	73.8	73.0	80.6	72.5	81.6
Alt 2 - Future Year Projected Value	83.6	84.6	85.0	85.1	88.2	76.7	74.9	85.3	81.0	84.5

**Table 12b. Primary and Additional Ozone Modeling Results – Cincinnati, Columbus, St. Louis, Indianapolis, and Detroit (2009)**

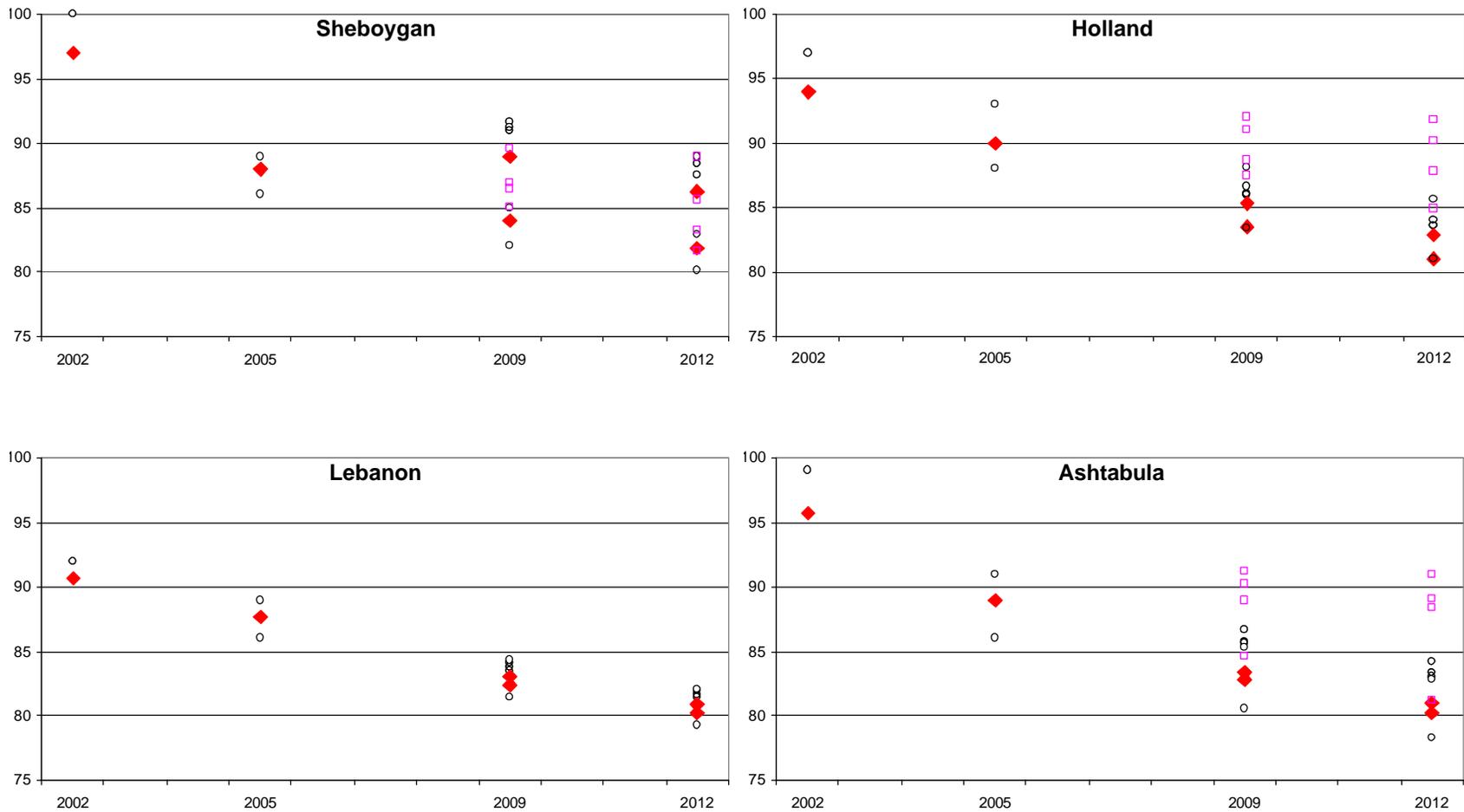
2009 Modeling Results	Cincinnati Area			Columbus	St. Louis Area		Indianapolis Area		Detroit Area
	Wilmington	Lebanon	Sycamore	NewAlbany	W. Alton	OrchardFarm	Noblesville	Fortville	New Haven
	390271002	39165007	390610006	390490029	291831002	291831004	180571001	18059003	260990009
<b>Attainment Test (based on EPA guidance-2002 baseyear)</b>									
Base Year Design Value (average of three 3-year periods)	94.3	90.7	90.7	94.0	90.0	90.0	93.7	91.3	92.3
RRF (all days > 85 ppb, or at least 10 days)	0.885	0.908	0.938	0.888	0.947	0.914	0.894	0.918	0.924
Future Year Design Value	83.5	82.4	85.1	83.5	85.2	82.3	83.8	83.8	85.3
<b>Attainment Test (based on EPA guidance-2005 baseyear)</b>									
Base Year Design Value (average of three 3-year periods)	82.3	87.7	84.3	86.3	86.3	87.0	83.3	78.7	86.0
RRF (all days > 85 ppb, or at least 10 days)	0.941	0.947	0.967	0.947	0.938	0.942	0.945	0.947	0.947
Future Year Design Value	77.4	83.1	81.5	81.7	80.9	82.0	78.7	74.5	81.4
<b>Weight of Evidence (alternative approaches-2002baseyear)</b>									
Alt 1 - Base Year Des. Value (3-year period centered on 2002)	96.0	92.0	93.0	95.0	91.0	92.0	96.0	94.0	97.0
Alt 2 - Base Year Des. Value (Highest 3-year period including 2002 )	96.0	92.0	93.0	96.0	91.0	92.0	96.0	94.0	97.0
RRF (all days > 85 ppb, or at least 10 days)	0.885	0.908	0.938	0.888	0.947	0.914	0.894	0.918	0.924
Alt 1 - Future Year Projected Value	85.0	83.5	87.2	84.4	86.2	84.1	85.8	86.3	89.6
Alt 2 - Future Year Projected Value	85.0	83.5	87.2	85.2	86.2	84.1	85.8	86.3	89.6
Alt 1 - RRF (all days > 70 ppb)	0.885	0.914	0.940	0.901	0.945	0.911	0.912	0.907	0.918
Alt 1 - Future Year Projected Value	85.0	84.1	87.4	85.6	86.0	83.8	87.6	85.3	89.0
Alt 2 - Future Year Projected Value	85.0	84.1	87.4	86.5	86.0	83.8	87.6	85.3	89.0
Alt 2 - RRF (all days > 85 ppb, or at least 10 days; with acceptable model performance)	0.880	0.911	0.940	0.886	0.951	0.913	0.894	0.916	0.935
Alt 1 - Future Year Projected Value	84.5	83.8	87.4	84.2	86.5	84.0	85.8	86.1	90.7
Alt 2 - Future Year Projected Value	84.5	83.8	87.4	85.1	86.5	84.0	85.8	86.1	90.7
<b>Weight of Evidence (alternative approaches-2005baseyear)</b>									
Alt 1 - Base Year Des. Value (3-year period centered on 2005)	80.0	86.0	81.0	84.0	85.0	86.0	80.0	76.0	82.0
Alt 2 - Base Year Des. Value (Highest 3-year period including 2005)	85.0	89.0	86.0	88.0	89.0	89.0	87.0	81.0	90.0
Alt 1 - Future Year Projected Value	75.3	81.4	78.3	79.5	79.7	81.0	75.6	72.0	77.7
Alt 2 - Future Year Projected Value	80.0	84.3	83.2	83.3	83.5	83.8	82.2	76.7	85.2

Finally, USEPA's latest regional ozone modeling was considered as corroborative information. This modeling was performed as part of the June 2007 proposal to revise the ozone standard (USEPA, 2007b). USEPA applied the CMAQ model with 2001 meteorology to first estimate ozone levels in 2020 based on the current standard and national rules in effect or proposed (i.e., the baseline), and then to evaluate strategies for attaining a more stringent (70 ppb) primary standard. Baseline (2020) ozone levels were predicted to be below the current standard in 481 of the 491 counties with ozone monitors. Of the 10 counties predicted to be above the standard, there is one county in the LADCO region (i.e., Kenosha County, WI at 86 ppb). This result is consistent with LADCO's Base K modeling, which has a similar base year (2001 v. 2002).

*Analysis of Trends:* USEPA's modeling guidelines note that while air quality models are generally the most appropriate tools for assessing the expected impacts of a change in emissions, it may also be possible to extrapolate future trends based on measured historical trends of air quality and emissions. To do so, USEPA's guidance suggests that ambient trends should be normalized to account for year-to-year variations in meteorological conditions, actual VOC and NOx emissions should be known for the given area and the relevant surrounding area, and a conceptual model of ozone formation is needed (e.g., VOC- v. NOx-limited conditions) (USEPA, 2002).

Meteorologically-adjusted 4<sup>th</sup> high 8-hour ozone concentrations were derived using an air quality – meteorological statistical model developed by USEPA (i.e., Cox method – see Section 2.1). The historical trend in these met-adjusted ozone concentrations can be extrapolated to estimate future year ozone concentrations. Four extrapolation approaches were used: straight-line or emissions-weighted with either a 1995 or 1998 start year. Both VOC and NOx emissions affect ozone concentrations. Given that observation-based methods show that urban areas in the region are generally VOC-limited and rural areas in the region are NOx-limited, urban VOC emissions and regional (i.e., statewide) NOx emissions are considered important.

Figure 65 summarizes the model- and trends-based future year ozone concentrations for sites in the Lake Michigan, Cleveland, and Cincinnati areas. The results reflect a fairly wide scatter, but, on balance, the supplemental information is supportive of the primary modeling results (i.e., sites in the Lake Michigan area and Cleveland are expected to be close to the standard).

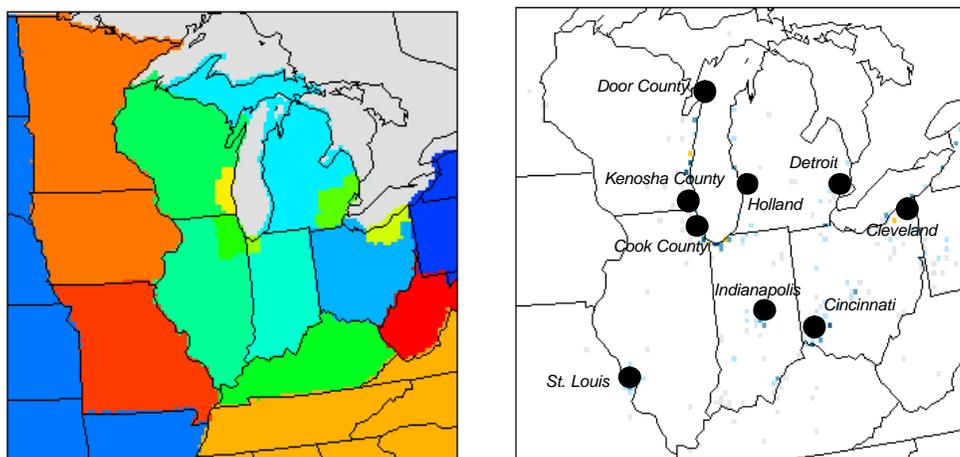


**Figure 65. Estimates of Future Year Ozone Concentrations – Lake Michigan Area (Sheboygan and Holland), Cincinnati (Lebanon), and Cleveland (Ashtabula)**

**Note: Primary (guideline) modeling value is represented by a large red diamond, additional modeling values by small black circles, and trends-based values by small green squares**

*Observational Models and Diagnostic Analyses:* The observation-based modeling (i.e., MAPPER) is presented in Section 3. The key findings from this modeling are that most urban areas are VOC-limited and rural areas are NOx-limited.

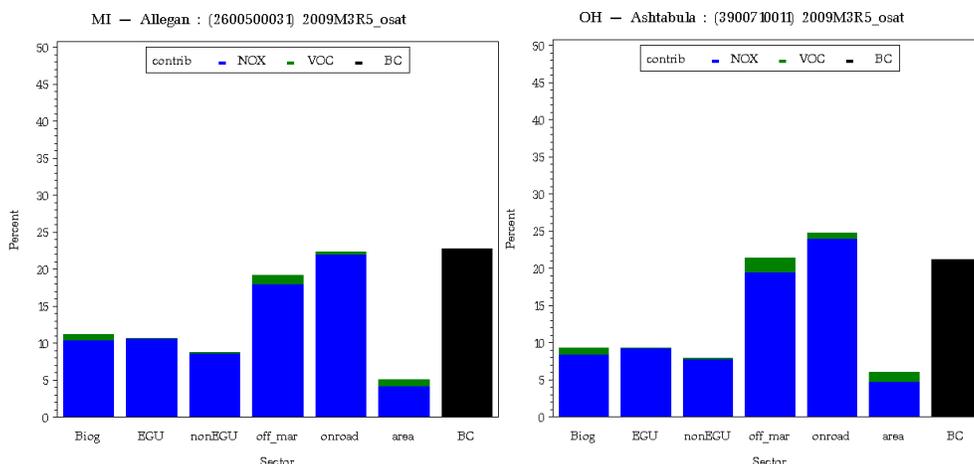
The primary diagnostic analysis is source apportionment modeling with CAMx to provide more quantitative information on source region (and source sector) impacts. Specifically, the model estimated the impact of 18 geographic source regions (which are identified in Figure 66) and 6 source sectors (EGU point, non-EGU point, on-road, off-road, area, and biogenic sources) at ozone monitoring sites in the region.



**Figure 66. Source regions (left) and key monitoring sites (right) for ozone modeling analysis**

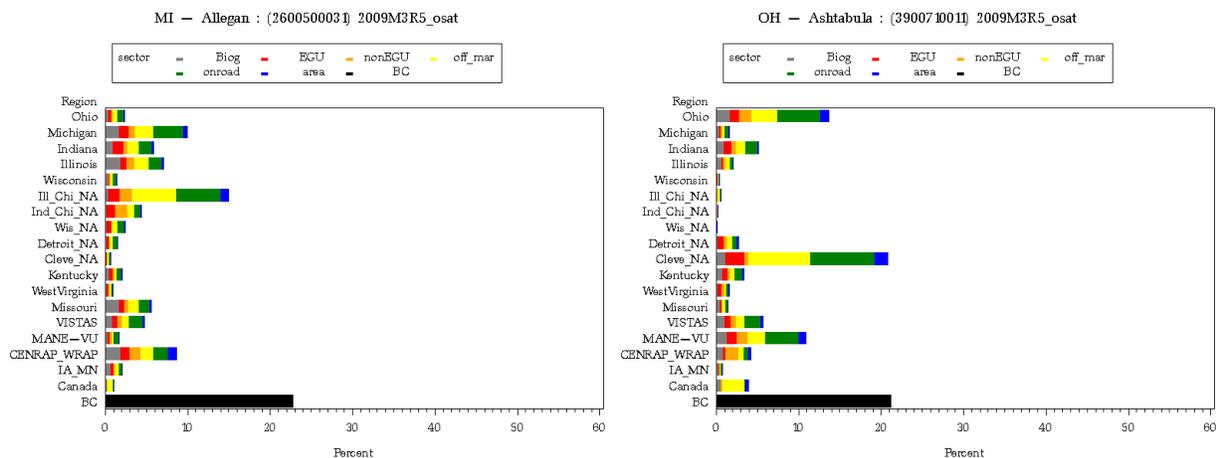
Modeling results for 2009 (Base M) and 2012 (Base K) are provided in Appendix II for several key monitoring sites. For each monitoring site, there are two graphs: one showing sector-level contributions, and one showing source region and sector-level contributions in terms of percentages. (Note, in the sector-level graph, the contribution from NOx emissions are shown in blue, and from VOC emissions in green.)

The sector-level results (see, for example, Figure 67) show that on-road and nonroad NOx emissions generally have the largest contributions at the key monitor locations (> 15% each). EGU and non-EGU NOx emissions are also important contributors (> 10% each). The source group contributions vary by receptor location due to emissions inventory differences.



**Figure 67. Source-sector results for Holland (left) and Ashtabula (right) monitors – 2009 (Base M)**

The source region results (see, for example, Figure 68) show that while nearby areas generally have the highest impacts (e.g., the northeastern IL/northwestern IN/southeastern WI nonattainment area contributes 25-35% to high sites in the Lake Michigan area, and Cleveland nonattainment counties contribute 20-25% to high sites in northeastern Ohio), there is an even larger regional impact (i.e., contribution from other states).



**Figure 68. Source-region results for Holland (left) and Ashtabula (right) monitors – 2009 (Base M)**

**Summary:** Air quality modeling and other supplemental analyses were performed to estimate future year ozone concentrations. Based on this information, the following general conclusions can be made:

- Existing (“on the books”) controls are expected to produce significant improvement in ozone air quality.
- The choice of the base year affects the future year model projections. A key difference between the base years of 2002 and 2005 is meteorology. For example, the 3-year (design value) period centered on 2002 was more ozone conducive than the 3-year (design value) period centered on 2005. The choice of which base year to use as the basis for the SIP is a policy decision (i.e., how much safeguard to incorporate).
- Most sites are expected to meet the current 8-hour standard by the applicable attainment date, except, for sites in western Michigan and, possibly, in eastern Wisconsin and northeastern Ohio.
- Attainment by the applicable attainment date is dependent on actual future year meteorology (e.g., if the weather conditions are consistent with [or less severe than] 2005, then attainment is likely) and actual future year emissions (e.g., if the emission reductions associated with the existing controls are achieved, then attainment is likely). On the other hand, if either of these conditions is not met, then attainment may be less likely.

### 4.3 Weight-of-Evidence Determination for PM2.5

The WOE determination for PM2.5 consists of the primary modeling and other supplemental analyses. A summary of this information is provided below.

*Primary (Guideline) Modeling:* The results of the guideline modeling are presented in Section 4.1. Key findings from this modeling include:

- Base M regional modeling shows attainment by 2009 at all sites, except Detroit, Cleveland, and Granite City, and attainment at all sites by 2012, except for Detroit and Granite City.

The regional modeling for PM2.5 does not reflect any air quality benefit expected from local controls. States are conducting local-scale analyses and will use these results, in conjunction with the regional-scale modeling, to support their attainment demonstrations for PM2.5

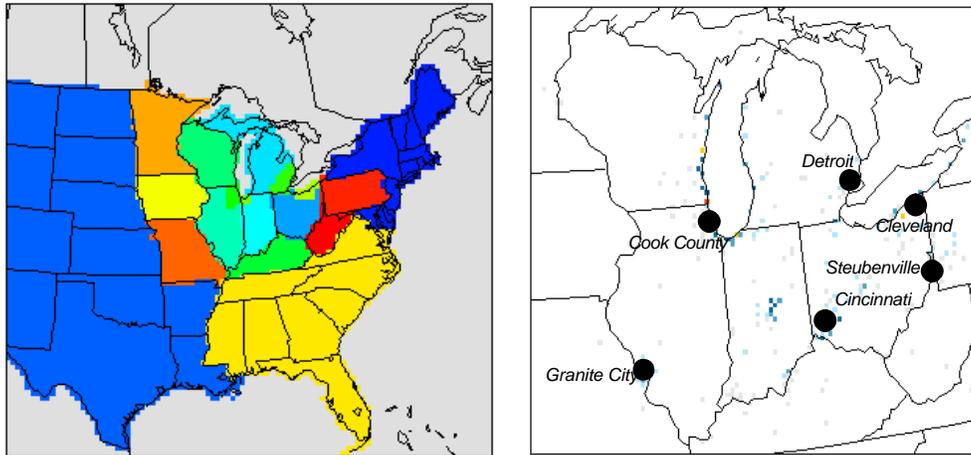
- Base K modeling results reflect generally higher future year design values, and show more sites in nonattainment in 2009 and 2012 compared to the Base M modeling. The difference in the two modeling analyses is due mostly to lower base year design values in Base M.
- Base K and Base M modeling analyses are considered “SIP quality”, so the attainment demonstration for PM2.5 should reflect a weight-of-evidence approach, with consideration of monitoring based information.
- Base M modeling also shows that the new PM2.5 24-hour standard will not be met at many sites, even by 2018, with existing controls.

*Additional Modeling:* USEPA’s latest regional PM2.5 modeling was considered as corroborative information. This modeling was performed as part of the September 2006 revision to the PM2.5 standard (USEPA, 2006). USEPA applied the CMAQ model with 2001 meteorology to estimate PM2.5 levels in 2015 and 2020 first with national rules in effect or proposed, and then with additional controls to attain the current standard (15 ug/m<sup>3</sup> annual/65 ug/m<sup>3</sup> daily). Additional analyses were performed to evaluate strategies for attaining more stringent standards in 2020 (15/35, and 14/35). Baseline (2015) PM2.5 levels were predicted to be above the current standard in four counties in the LADCO region: Madison County, IL (15.2 ug/m<sup>3</sup>), Wayne County, MI (17.4), Cuyahoga County, OH (15.4), and Scioto County, OH (15.6). These results are consistent with LADCO’s Base K modeling, which has a similar base year (2001 v. 2002).

*Observational Models and Diagnostic Analyses:* The observation-based modeling (i.e., application of thermodynamic equilibrium models) is presented in Section 3. The key findings from this modeling are that PM2.5 mass is sensitive to reductions in sulfate, nitric acid, and ammonia concentrations. Even though sulfate reductions cause more ammonia to be available to form ammonium nitrate (PM-nitrate increases slightly when sulfate is reduced), this increase is generally offset by the sulfate reductions, such that PM<sub>2.5</sub> mass decreases. Under conditions with lower sulfate levels (i.e., proxy of future year conditions), PM decreases less in response to ammonia reductions.

The primary diagnostic analysis is source apportionment modeling with CAMx to provide more quantitative information on source region (and source sector) impacts. Specifically, the model

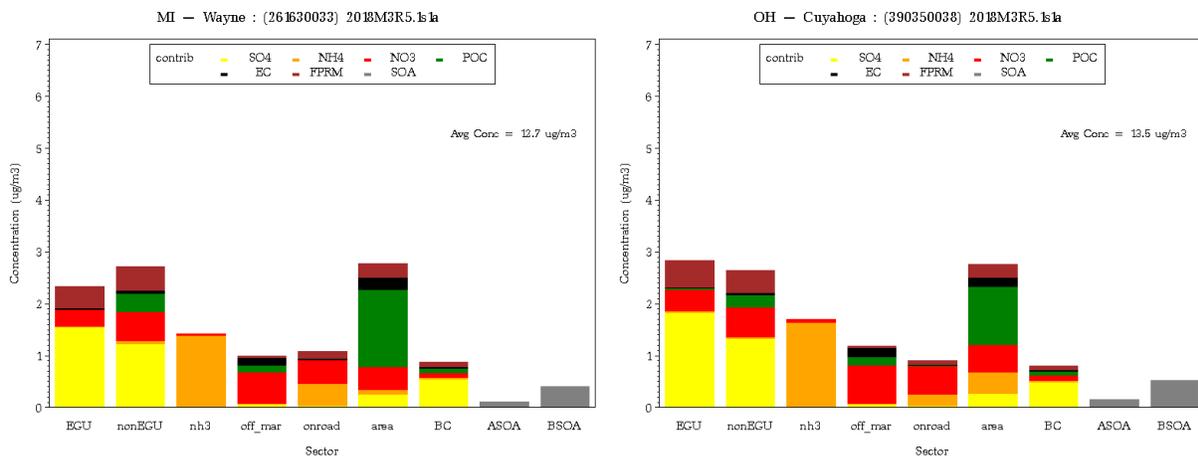
estimated the impact of 18 geographic source regions (which are identified in Figure 69) and 6 source sectors (EGU point, non-EGU point, on-road, off-road, area, and biogenic sources) at PM2.5 monitoring sites in the region.



**Figure 69. Source regions (left) and key monitoring sites (right) for PM2.5 modeling analysis**

Modeling results for 2012 (Base K) and 2018 (Base M) are provided in Appendix III for several key monitoring sites. For each monitoring site, there are two graphs: one showing sector-level contributions, and one showing source region and sector-level contributions in terms of absolute modeled values.

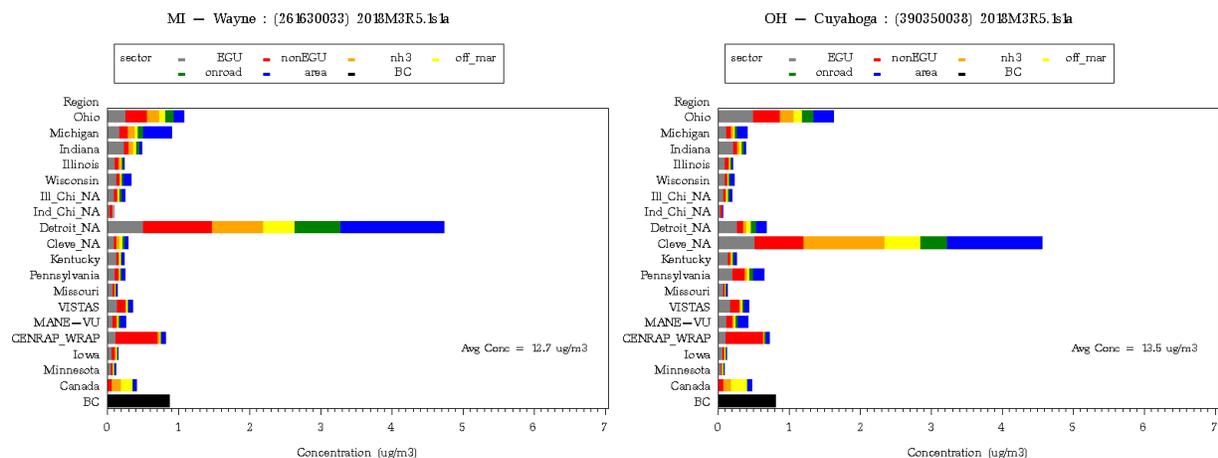
The sector-level results (see, for example, Figure 70) show that EGU sulfate, non-EGU-sulfate, and area OC emissions generally have the largest contributions at the key monitor locations (> 15% each). Ammonia emissions are also important contributors (> 10% each). The source group contributions vary by receptor location due to emissions inventory differences.



**Figure 70. Source-sector results for Detroit (left) and Cleveland (right) monitors – 2018 (Base M)**

The source region results (see, for example, Figure 71) show that while nearby areas generally have the highest impacts (e.g., Detroit nonattainment counties contribute 40% to high sites in

southeastern Michigan, and Cleveland nonattainment counties contribute 35% to high sites in northeastern Ohio), there is an even larger regional impact (i.e., contribution from other states).



**Figure 71. Source-region results for Detroit (left) and Cleveland (right) monitors – 2018 (Base M)**

*Summary:* Air quality modeling and other supplemental analyses were performed to estimate future year PM<sub>2.5</sub> concentrations. Based on this information, the following general conclusions can be made:

- Existing (“on the books”) controls are expected to produce significant improvement in PM<sub>2.5</sub> air quality.
- The choice of the base year affects the future year model projections. It is not clear how much of this is attributable to differences in meteorology, because, as noted in Section 3, PM<sub>2.5</sub> concentrations are not as strongly influenced by meteorology as ozone.
- Most sites are expected to meet the current PM<sub>2.5</sub> standard by the applicable attainment date, except for sites in Detroit, Cleveland, and Granite City, and, possibly, Chicago, Cincinnati, Louisville, Portsmouth (OH), and Steubenville.
- Attainment by the applicable attainment date is dependent on actual future year meteorology (e.g., if the weather conditions are consistent with [or less severe than] 2005, then attainment is likely) and actual future year emissions (e.g., if the emission reductions associated with the “on the books” controls are achieved, then attainment is likely). On the other hand, if either of these conditions is not met, then attainment may be less likely.

## Section 5. Reasonable Progress Assessment for Regional Haze

Air quality modeling and other information were used to assess the improvement in visibility that would be provided by existing (“on the books”) controls and possible additional control programs. In determining reasonable progress for regional haze, Section 169A of the Clean Air Act and USEPA’s visibility rule requires states to consider five factors:

- costs of compliance
- time necessary for compliance
- energy and non-air quality environmental impacts of compliance
- remaining useful life of any existing source subject to such requirements
- uniform rate of visibility improvement needed to attain natural visibility conditions by 2064

The uniform rate of visibility improvement requirement can be depicted graphically in the form of a “glide path” (see Figure 72).

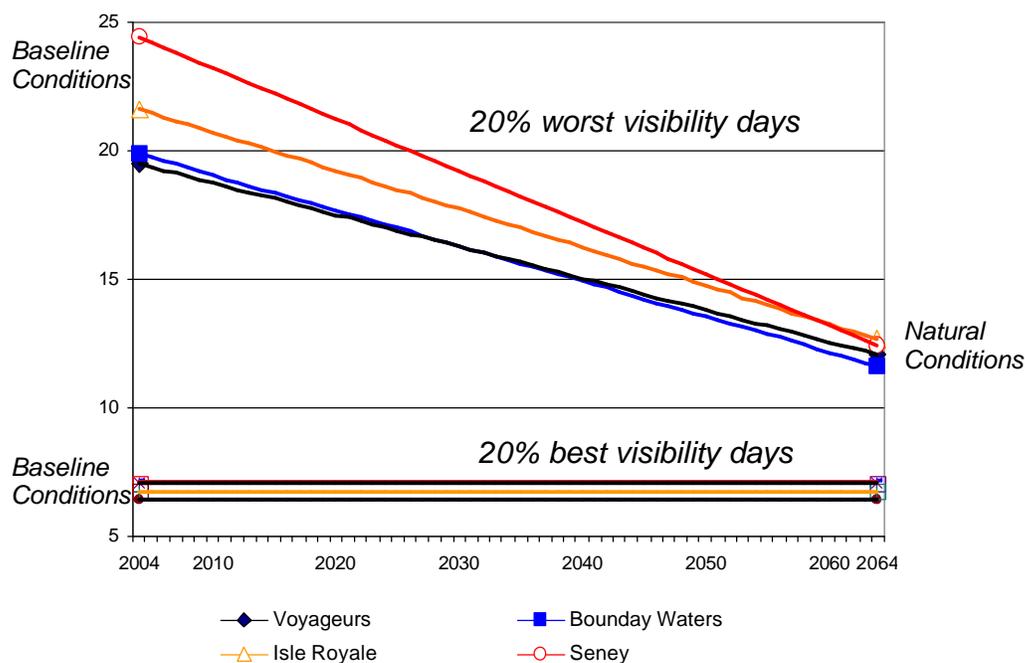


Figure 72. Visibility “glide paths” for northern Class I areas

Information on the first four factors is provided elsewhere (EC/R, 2007). This section summarizes the modeling and other analyses conducted to address the fifth factor (i.e., uniform rate of visibility improvement).

### 5.1 Future Year Modeling Results

For regional haze, the calculation of future year conditions assumed:

- baseline concentrations based on 2000-2004 IMPROVE data, with updated (substituted) data for Mingo, Boundary Waters, Voyageurs, Isle Royale, and Seney (see Section 2.3);
- use of the new IMPROVE light extinction equation; and
- use of USEPA default values for natural conditions, based on the new IMPROVE light extinction equation.

The uniform rate of visibility improvement values for the 2018 planning year were derived (for the 20% worst visibility days) based on a straight line between baseline concentration value (plotted in the year 2004 -- end year of the 5-year baseline period) and natural condition value (plotted in the year 2064 -- date for achieving natural conditions). Plots of these “glide paths” with the Base M modeling results are presented in Figure 73 for Class I areas in the eastern U.S. A tabular summary of measured baseline and modeled future year deciview values for these Class I areas are provided in Table 13 (2002 base year) and Table 14 (2005 base year).

The haze results show that several Class I areas in the eastern U.S. are expected to be greater than the uniform rate of visibility improvement values (in 2018), including those in northern Michigan and several in the northeastern U.S. Many other Class I areas in the eastern U.S. are expected to be less than the uniform rate of visibility improvement values (in 2018). As noted above, states should consider these results, along with information on the other four factors, in setting reasonable progress goals.

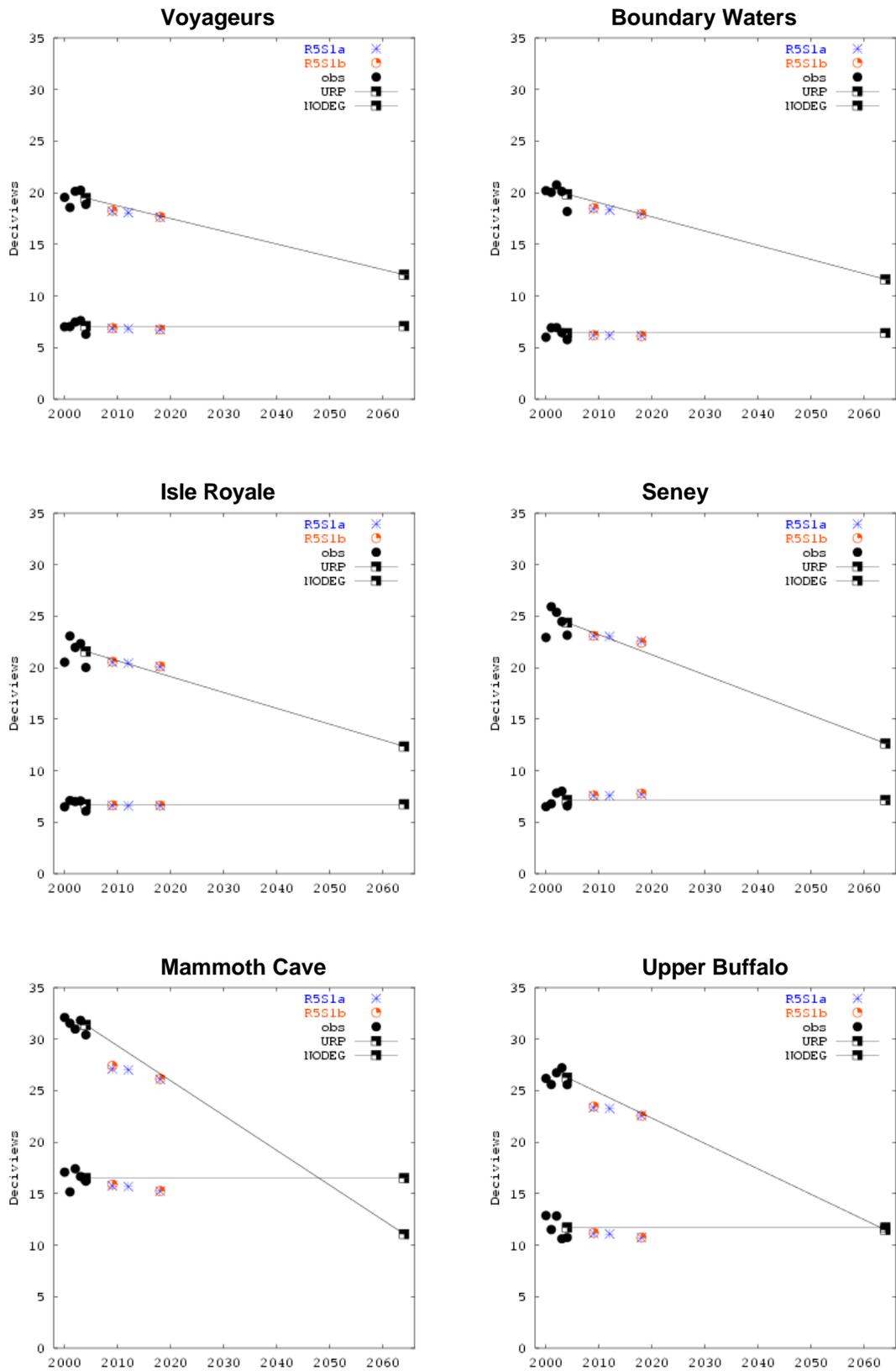


Figure 73. Visibility modeling results for Class I areas in eastern U.S.

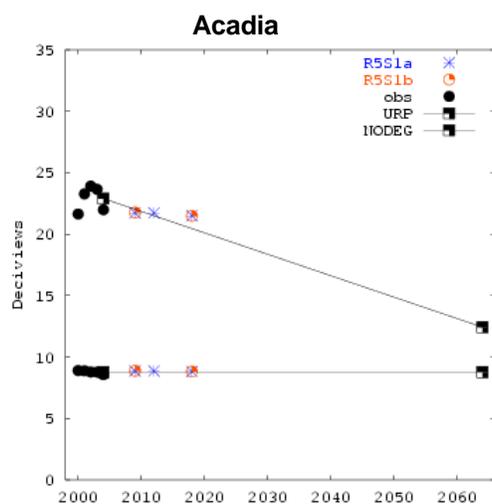
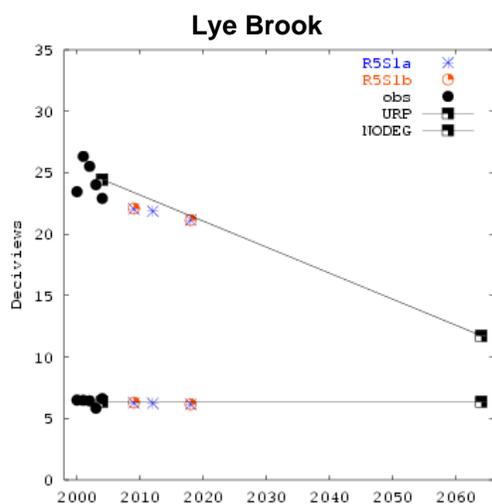
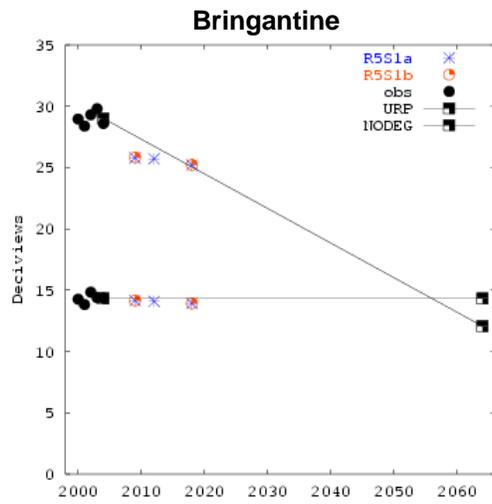
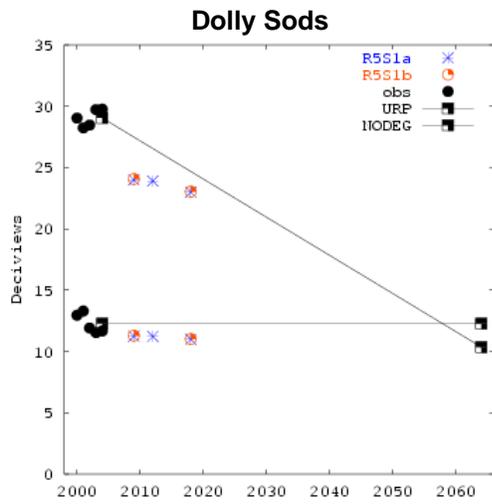
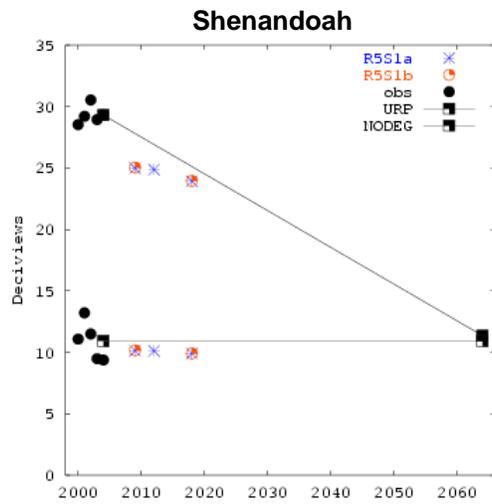
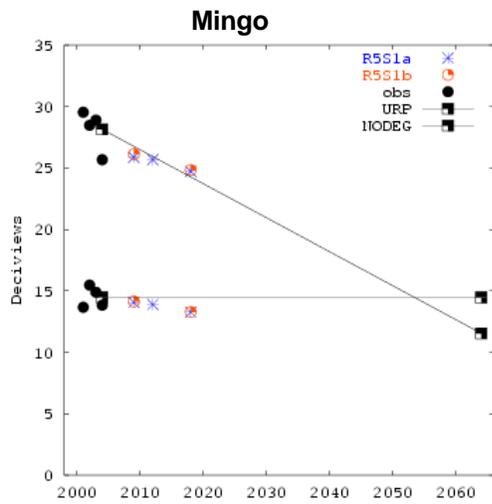


Figure 73 (cont.) Visibility modeling results for Class I areas in eastern U.S.

## Haze Results - Round 5.1 (Based on 2000-2004)

Haze Results - Round 5.1 (Based on 2000-2004)							
Worst 20%		2018	2009	2009	2012	2018	2018
Site	Baseline	URP	OTB	OTB+Will DO	OTB	OTB	OTB+Will DO
BOWA1	19.86	17.94	18.45	18.51	18.33	17.94	17.92
VOYA2	19.48	17.75	18.20	18.28	18.07	17.63	17.66
SENE1	24.38	21.64	23.10	23.10	23.04	22.59	22.42
ISLE1	21.59	19.43	20.52	20.58	20.43	20.09	20.13
ISLE9	21.59	19.43	20.33	20.37	20.22	19.84	19.82
HEGL1	26.75	23.13	24.72	24.82	24.69	24.22	24.17
MING1	28.15	24.27	25.88	26.13	25.68	24.74	24.83
CACR1	26.36	22.91	23.39	23.55	23.29	22.44	22.40
UPBU1	26.27	22.82	23.34	23.47	23.27	22.59	22.55
MACA1	31.37	26.64	27.11	27.41	27.01	26.10	26.15
DOSO1	29.05	24.69	24.00	24.06	23.90	23.00	23.04
SHEN1	29.31	25.12	24.99	25.04	24.87	23.92	23.95
JARI1	29.12	24.91	25.17	25.25	25.01	24.06	24.12
BRIG1	29.01	25.05	25.79	25.83	25.72	25.21	25.22
LYBR1	24.45	21.48	22.04	22.08	21.86	21.14	21.14
ACAD1	22.89	20.45	21.72	21.75	21.72	21.49	21.49
Best 20%		2018	2009	2009	2012	2018	2018
Site	Baseline	Max	OTB	OTB+Will DO	OTB	OTB	OTB+Will DO
BOWA1	6.42	6.42	6.21	6.20	6.19	6.14	6.12
VOYA2	7.09	7.09	6.86	6.89	6.83	6.75	6.76
SENE1	7.14	7.14	7.57	7.59	7.58	7.71	7.78
ISLE1	6.75	6.75	6.62	6.64	6.59	6.60	6.62
ISLE9	6.75	6.75	6.56	6.57	6.55	6.52	6.50
HEGL1	12.84	12.84	12.51	12.56	12.32	11.66	11.64
MING1	14.46	14.46	14.07	14.13	13.89	13.28	13.29
CACR1	11.24	11.24	10.88	10.95	10.85	10.52	10.52
UPBU1	11.71	11.71	11.13	11.19	11.08	10.73	10.74
MACA1	16.51	16.51	15.76	15.88	15.69	15.25	15.25
DOSO1	12.28	12.28	11.25	11.29	11.23	11.00	11.01
SHEN1	10.93	10.93	10.13	10.16	10.11	9.91	9.91
JARI1	14.21	14.21	13.38	13.43	13.38	13.14	13.14
BRIG1	14.33	14.33	14.15	14.16	14.08	13.92	13.92
LYBR1	6.37	6.37	6.25	6.28	6.23	6.14	6.15
ACAD1	8.78	8.78	8.86	8.88	8.86	8.82	8.82

## 5.2 Weight-of-Evidence Determination for Haze

The WOE determination for haze consists of the primary modeling and other supplemental analyses. A summary of this information is provided below.

*Primary (Guideline) Modeling:* The results of the guideline modeling are presented in Section 4.1. Key findings from this modeling include:

- Base M modeling results show that the northern Minnesota Class I areas are close to the glide path, whereas the northern Michigan Class I areas are above the glide path in 2018. Other sites in the eastern U.S. are close to (or below) the glide path, except for Mingo (MO), Brigantine (NJ), and Acadia (ME).
- Base K modeling results show that the northern Minnesota and northern Michigan Class I areas are above the glide path in 2018. Other sites in the eastern U.S. are close to (or below) the glide path.
- The difference in the two modeling analyses is due mostly to differences in future year emission projections, especially for EGUs (e.g., use of IPM2.1.9 v. IPM3.0).
- Base K and Base M modeling analyses are considered “SIP quality”, so the attainment demonstration for haze should reflect a weight-of-evidence approach, with consideration of monitoring based information.

*Additional Modeling:* Three additional modeling analyses were considered: (1) the primary modeling redone with different baseline values, (2) a special analysis by the State of Minnesota which looked at different receptor locations in the northern Class I areas, and (3) another special analysis by the State of Minnesota which used 12 km grid resolution. Each of these analyses is described below.

First, the primary modeling analysis (Base M) was revised using an alternative baseline value. Specifically, the data for the period 2000-2005 were used to calculate the baseline, given that the Base M modeling reflects a 2005 base year. The results of this alternative analysis (see Table 15) are generally consistent with the primary modeling (see Table 14).

**(Note, the results of the two Minnesota analyses will be provided in mid-December.)**

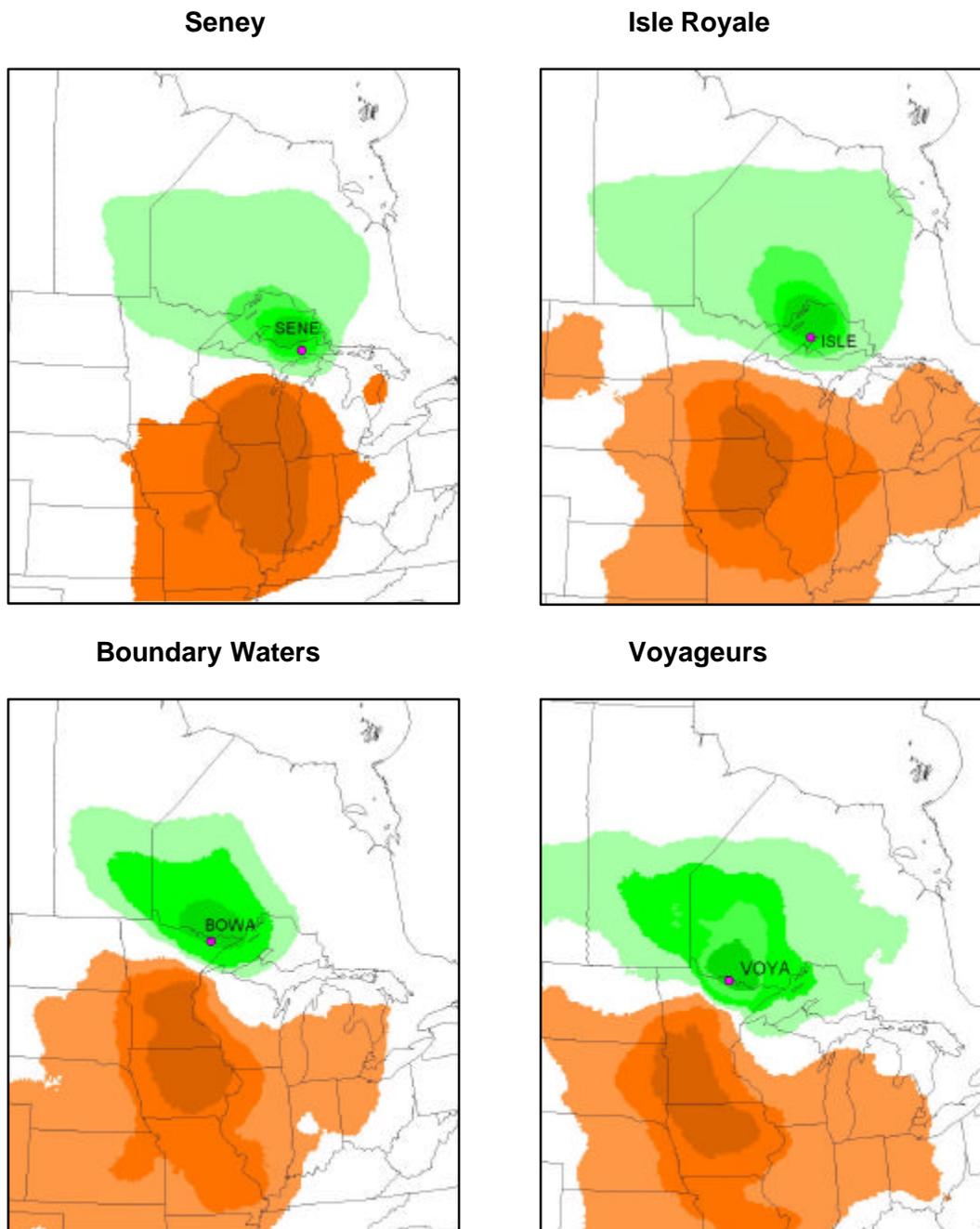
## Haze Results - Round 5.1 (Based on 2000-2005)

Haze Results - Round 5.1 (Based on 2000-2005)							
Worst 20%			2009	2009	2012	2018	2018
Site	Baseline	URP	OTB	OTB+Will DO	OTB	OTB	OTB+Will DO
BOWA1	20.10	18.12	18.63	18.70	18.51	18.12	18.09
VOYA2	19.62	17.86	18.27	18.36	18.15	17.70	17.72
SENE1	24.77	21.94	23.44	23.45	23.39	22.94	22.77
ISLE1	21.95	19.71	20.84	20.91	20.76	20.41	20.44
ISLE9	21.95	19.71	20.65	20.70	20.55	20.15	20.13
HEGL1	27.45	23.67	25.30	25.41	25.27	24.79	24.73
MING1	28.92	24.86	25.88	26.13	25.68	24.74	24.83
CACR1	27.05	23.44	23.88	24.04	23.78	22.92	22.86
UPBU1	26.97	23.36	23.92	24.05	23.85	23.14	23.09
MACA1	31.76	26.93	27.42	27.72	27.32	26.39	26.44
DOSO1	29.36	24.92	24.20	24.27	24.11	23.19	23.23
SHEN1	29.45	25.23	25.06	25.11	24.94	23.98	24.01
JARI1	29.40	25.13	25.32	25.40	25.17	24.22	24.28
BRIG1	29.12	25.14	25.84	25.88	25.77	25.26	25.26
LYBR1	24.71	21.69	22.22	22.26	22.06	21.36	21.36
ACAD1	22.91	20.47	21.72	21.75	21.72	21.49	21.49
Best 20%			2009	2009	2012	2018	2018
Site	Baseline	URP	OTB	OTB+Will DO	OTB	OTB	OTB+Will DO
BOWA1	6.40	6.40	6.20	6.19	6.17	6.13	6.10
VOYA2	7.05	7.05	6.82	6.84	6.78	6.71	6.71
SENE1	7.20	7.20	7.60	7.62	7.61	7.73	7.80
ISLE1	6.80	6.80	6.67	6.69	6.64	6.65	6.66
ISLE9	6.80	6.80	6.62	6.62	6.61	6.57	6.55
HEGL1	13.04	13.04	12.71	12.75	12.51	11.85	11.82
MING1	14.68	14.68	14.07	14.13	13.89	13.28	13.29
CACR1	11.62	11.62	11.24	11.31	11.20	10.86	10.86
UPBU1	11.99	11.99	11.41	11.47	11.36	11.01	11.02
MACA1	16.64	16.64	15.88	16.01	15.82	15.37	15.38
DOSO1	12.24	12.24	11.21	11.25	11.19	10.96	10.97
SHEN1	10.85	10.85	10.04	10.07	10.02	9.82	9.83
JARI1	14.35	14.35	13.51	13.56	13.51	13.27	13.27
BRIG1	14.36	14.36	14.17	14.18	14.10	13.94	13.94
LYBR1	6.21	6.21	6.11	6.14	6.09	6.01	6.01
ACAD1	8.57	8.57	8.67	8.68	8.66	8.62	8.62

*Observational Models and Diagnostic Analyses:* The observation-based modeling (i.e., application of thermodynamic equilibrium models) is presented in Section 3. The key findings from this modeling are that PM<sub>2.5</sub> mass is sensitive to reductions in sulfate, nitric acid, and ammonia concentrations. Even though sulfate reductions cause more ammonia to be available to form ammonium nitrate (PM-nitrate increases slightly when sulfate is reduced), this increase is generally offset by the sulfate reductions, such that PM<sub>2.5</sub> mass decreases. Under conditions with lower sulfate levels (i.e., proxy of future year conditions), PM decreases less in response to ammonia reductions.

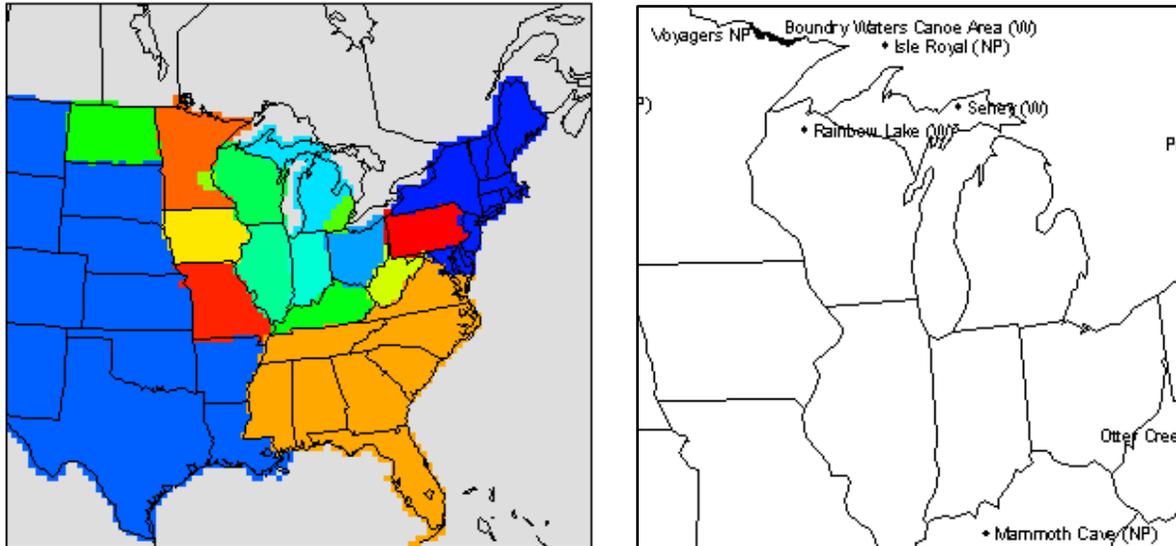
As discussed in Section 2, thermodynamic equilibrium modeling based on data collected at Seney indicates that PM<sub>2.5</sub> there is most sensitive to reductions in sulfate, but also responsive to reductions in nitric acid (Blanchard 2004b). An analysis using data from the Midwest ammonia monitoring network for a site in Minnesota (i.e., Great River Bluffs, which is the closest ammonia monitoring site to the northern Class I areas) suggested that reductions in sulfate, nitric acid, and ammonia concentrations will lower PM<sub>2.5</sub> concentrations and improve visibility levels in the northern Class I areas.

Trajectory analyses for the 20% worst visibility days for the four northern Class I areas are provided in Figure 74. (Note, this figure is similar to Figure 34, but the trajectory results for each Class I area are displayed separately.) The orange areas are where the air is most likely to come from, and the green areas are where the air is least likely to come from on. Darker shading represents higher frequency. As can be seen, bad air days are generally associated with transport from regions located to the south, and good air days with transport from Canada.



**Figure 74. Trajectory analysis results for northern Class I areas on 20% worst visibility days**

The primary diagnostic analysis is source apportionment modeling with CAMx to provide more quantitative information on source region (and source sector) impacts. Specifically, the CAMx model was applied to provide source contribution information. Specifically, the model estimated the impact of 18 geographic source regions (which are identified in Figure 75) and 6 source sectors (EGU point, non-EGU point, on-road, off-road, area, and ammonia sources) at visibility/haze monitoring sites in the eastern U.S.



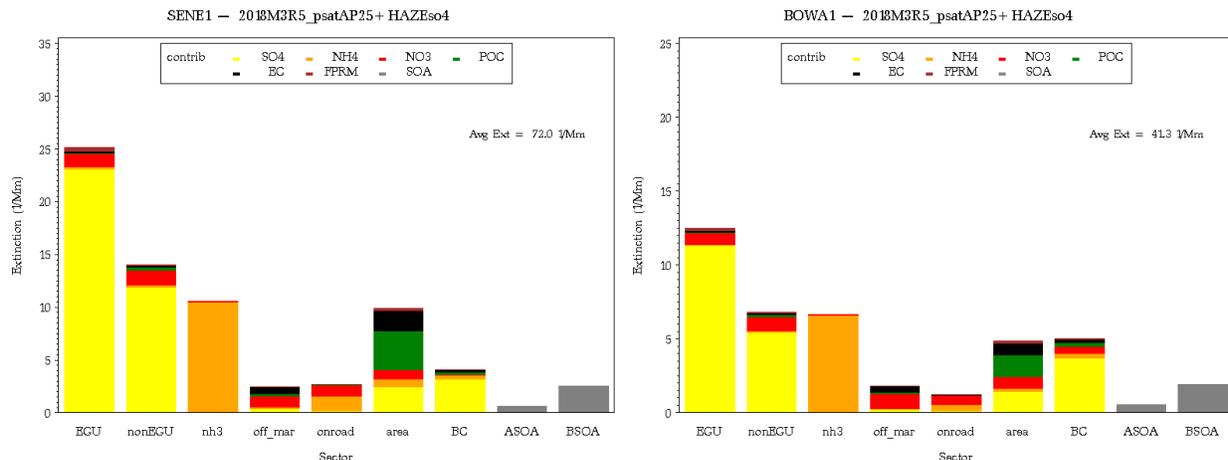
**Figure 75. Source regions (left) and key monitoring sites (right) for haze modeling analysis**

Modeling results for 2018 (Base K and Base M) are provided in Appendix IV for several key monitoring sites (Class I areas). For each monitoring site, there are two graphs: one showing sector-level contributions, and one showing source region and sector-level contributions in terms of absolute modeled values.

The species- and sector-level results (see, for example, Figure 75) show that EGU sulfate,

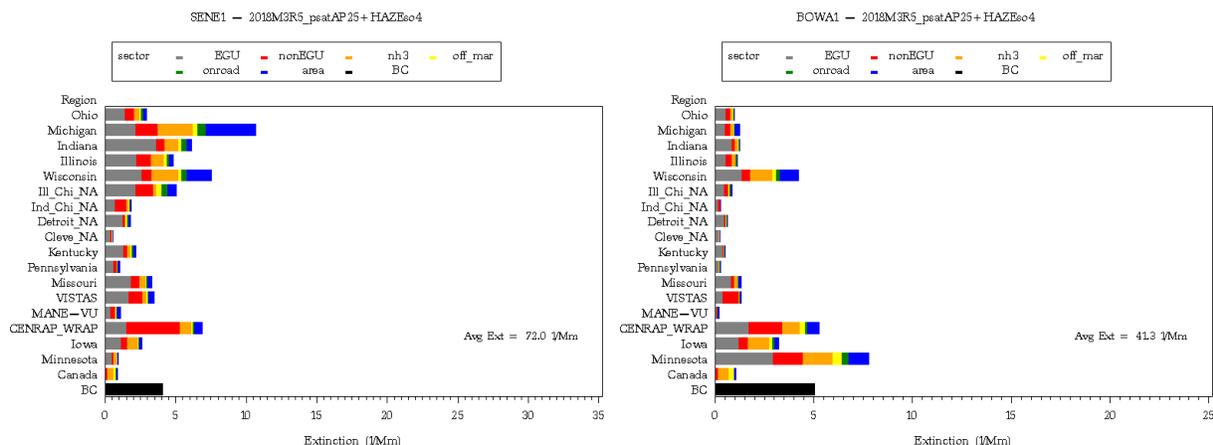
on-road and nonroad NO<sub>x</sub> emissions generally have the largest contributions to nitrate concentrations. EGU and non-EGU NO<sub>x</sub> emissions are also important contributors. The source group contributions vary by receptor location due to emissions inventory differences.

The sector-level results (see, for example, Figure 75) show that EGU sulfate, non-EGU-sulfate, and ammonia emissions generally have the largest contributions at the key monitor locations. The source group contributions vary by receptor location due to emissions inventory differences.



**Figure 75. Source-sector results for Seney (left) and Boundary Waters (right) – 2018 (Base M)**

The source region results (see, for example, Figure 76) show that emissions from a number of nearby states contribute to regional haze levels.



**Figure 76. Source-region results for Seney (left) and Boundary Waters (right) – 2018 (Base M)**

*Summary:* Air quality modeling and other supplemental analyses were performed to estimate future year visibility levels. Based on this information, the following general conclusions can be made:

- Existing (“on the books”) controls are expected to improve visibility levels in the northern Class I areas.
- Visibility levels in a few Class I areas in the eastern U.S. are expected to be greater than the uniform rate of visibility improvement values in 2018, including those in northern Michigan and some in the northeastern U.S.
- Visibility levels in many other Class I areas in the eastern U.S. are expected to be less than the uniform rate of visibility improvement values in 2018.

## Section 6. Summary

To support the development of SIPs for ozone, PM<sub>2.5</sub>, and regional haze in the States of Illinois, Indiana, Michigan, Ohio, and Wisconsin, technical analyses were conducted by LADCO, its member states, and various contractors. The analyses include preparation of regional emissions inventories and meteorological modeling data for two base years, evaluation and application of regional chemical transport models, and review of ambient monitoring data.

Analyses of monitoring data were conducted to produce a conceptual model, which is a qualitative summary of the physical, chemical and meteorological processes that control the formation and distribution of pollutants in a given region. Key findings of the analyses include:

### Ozone

- Current monitoring data show about 20 sites in violation of the 8-hour ozone standard. Historical ozone data show a steady downward trend over the past 15 years, especially since 2001-2003, due in part to federal and state emission control programs.
- Ozone concentrations are strongly influenced by meteorological conditions, with more high ozone days and higher ozone levels during summers with above normal temperatures.
- Inter- and intra-regional transport of ozone and ozone precursors affects many portions of the five states.

### PM<sub>2.5</sub>

- Current monitoring data show about 40 sites in violation of the annual PM<sub>2.5</sub> standard. Nonattainment sites are characterized by an elevated regional background (on the order of 12 – 14 ug/m<sup>3</sup>) and a significant local (urban) increment (on the order of 2 – 3 ug/m<sup>3</sup>). Historical PM<sub>2.5</sub> data show a slight downward trend since deployment of the PM<sub>2.5</sub> monitoring network in 1999.
- PM<sub>2.5</sub> concentrations are less influenced by meteorology (compared to ozone), but, nevertheless, are affected by atmospheric conditions (e.g., stagnation events, especially during the winter) and transport patterns.
- On an annual average basis, PM<sub>2.5</sub> chemical composition consists of mostly sulfate, nitrate, and organic carbon in similar proportions.

### Haze

- Current monitoring data show visibility levels in the Class I areas in northern Michigan are on the order of 22 – 24 deciviews. The goal of USEPA's visibility program is to achieve natural conditions, which is on the order of 12 deciviews for these Class I areas, by the year 2064.

Air quality models were applied to support the regional planning efforts. Two base years were used in the modeling analyses: 2002 and 2005. USEPA's modeling guidance recommends using 2002 as the baseline inventory year, but also allows for use of an alternative baseline inventory year, especially a more recent year. Initially, LADCO conducted modeling with a 2002

base year (i.e., Base K modeling, which was completed in 2006). A decision was subsequently made to conduct modeling with a 2005 base year (i.e., Base M, which was completed in 2007). Statistical analyses showed that 2002 and 2005 both had above normal ozone-conducive conditions, although 2002 was more severe compared to 2005. Examination of multiple base years provides for a more complete technical assessment. Both sets of model runs are discussed in this document.

Basecase modeling was conducted to evaluate model performance (i.e., assess the model's ability to reproduce the observed concentrations). This exercise was intended to build confidence in the model prior to its use in examining candidate control strategies. Model performance for ozone and PM<sub>2.5</sub> was found to be generally acceptable and can be characterized as follows:

#### Ozone

- Good agreement between modeled and monitored concentration for higher concentration levels (> 60 ppb) – i.e., bias within 30%
- Regional modeled concentrations appear to be underestimated in the 2002 base year, but show better agreement (with monitored data) in the 2005 base year due to model and inventory improvements.
- Day-to-day and hour-to-hour variation in and spatial patterns of modeled concentrations are consistent with monitored data
- Model accurately simulates the change in monitored ozone concentrations due to reductions in precursor emissions.

#### PM<sub>2.5</sub>

- Good agreement in the magnitude of fine particle mass, but some species are overestimated and some are underestimated
  - Sulfates: good agreement in the 2002 base year, but underestimated in the 2005 base year due probably to meteorological factors
  - Nitrates: slightly overestimated in the winter in the 2002 base year, but good agreement in the 2005 base year due to model and inventory improvements
  - Organic Carbon: grossly underestimated in the 2002 and 2005 base years due likely to missing primary OC emissions
- Day-to-day and hour-to-hour variation in and spatial patterns of modeled concentrations are consistent with monitored data

Future year strategy modeling was conducted to determine whether existing (“on the books”) controls would be sufficient to provide for attainment of the standards for ozone and PM<sub>2.5</sub> and if not, then what additional emission reductions would be necessary for attainment. Traditionally, attainment demonstrations involved a “bright line” test in which a single modeled value (based on USEPA guidance) was compared to the ambient standard. To provide a more robust assessment of expected future year air quality, other information was considered. Furthermore, according to USEPA’s modeling guidance, if the future year modeled design values are “close” to the standard (i.e., 82 – 87 ppb for ozone and 14.5 – 15.5 ug/m<sup>3</sup> for PM<sub>2.5</sub>), then the results of the primary modeling should be reviewed along with the supplemental information in a “weight

of evidence” (WOE) assessment of whether each area is likely to achieve timely attainment. Key findings of the WOE determination include:

- Existing controls are expected to produce significant improvement in ozone and  $PM_{2.5}$  concentrations and visibility levels.
- The choice of the base year affects the future year model projections. A key difference between the base years of 2002 and 2005 is meteorology. For example, the 3-year (design value) period centered on 2002 was more ozone conducive than the 3-year (design value) period centered on 2005. The choice of which base year to use as the basis for the SIP is a policy decision (i.e., how much safeguard to incorporate).
- Most sites are expected to meet the current 8-hour standard by the applicable attainment date, except, for sites in western Michigan and, possibly, in eastern Wisconsin and northeastern Ohio.
- Most sites are expected to meet the current  $PM_{2.5}$  standard by the applicable attainment date, except for sites in Detroit, Cleveland, and Granite City, and, possibly, Chicago, Cincinnati, Louisville, Portsmouth (OH), and Steubenville.

The regional modeling for  $PM_{2.5}$  does not reflect any air quality benefit expected from local controls. States are conducting local-scale analyses and will use these results, in conjunction with the regional-scale modeling, to support their attainment demonstrations for  $PM_{2.5}$ .

- Attainment by the applicable attainment date is dependent on actual future year meteorology (e.g., if the weather conditions are consistent with [or less severe than] 2005, then attainment is likely) and actual future year emissions (e.g., if the emission reductions associated with the existing controls are achieved, then attainment is likely). On the other hand, if either of these conditions is not met, then attainment may be less likely.
- The modeling shows that the new  $PM_{2.5}$  24-hour standard (and, probably, a new lower ozone standard) will not be met at many sites, even by 2018, with existing controls.
- Visibility levels in a few Class I areas in the eastern U.S. are expected to be greater than the uniform rate of visibility improvement values in 2018, including those in northern Michigan and some in the northeastern U.S. Visibility levels in many other Class I areas in the eastern U.S. are expected to be less than the uniform rate of visibility improvement values in 2018.

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<http://vista.cira.colostate.edu/views/>

## **APPENDIX I**

### **Ozone and PM2.5 Modeling Results**

Key Sites		4th High 8-hour Value					Des. Values (truncated)			2005 BY	2002 BY	2008 - OTB		
		'03	'04	'05	'06	'07	'03-'05	'04-'06	'05-'07	Average	Average	RRF	Round 5	
<b>Lake Michigan Area</b>														<b>Lake Michigan Area</b>
Chiwaukee	550590019	88	78	93	79	85	86	83	85	84.7	98.3	0.968	82.0	Chiwaukee
Racine	551010017	82	69	95	71	77	82	78	81	80.3	91.7	0.966	77.6	Racine
Milwaukee-Bayside	550190085	92	73	93	73	83	86	79	83	82.7	91.0	0.963	79.6	Milwaukee-Bayside
Harrington Beach	550890009	99	72	94	72	84	88	79	83	83.3	93.0	0.960	80.0	Harrington Beach
Manitowoc	550710007	92	74	95	78	84	87	82	85	84.7	87.0	0.957	81.0	Manitowoc
Sheboygan	551170006	93	78	97	83	88	89	86	89	88.0	97.0	0.959	84.4	Sheboygan
Kewaunee	550610002	97	73	88	76	85	86	79	83	82.7	89.3	0.954	78.9	Kewaunee
Door County	550290004	93	78	101	79	92	90	86	90	88.7	91.0	0.956	84.8	Door County
Hammond	180892008	81	67	87	75	77	78	76	79	77.7	88.3	0.971	75.4	Hammond
Whiting	180890030		64	88	81	88	76	77	85	79.3		0.971	77.0	Whiting
Michigan City	180910005	82	70	84	75	72	78	76	77	77.0	90.3	0.964	74.2	Michigan City
Ogden Dunes	181270020	77	69	90	70	84	78	76	81	78.3	86.3	0.967	75.7	Ogden Dunes
Holland	260050003	95	79	94	91	95	89	88	93	90.0	94.0	0.951	85.6	Holland
Jenison	261390005	91	69	86	83	89	82	79	86	82.3	86.0	0.950	78.2	Jenison
Muskegon	261210039	94	70	90	91	88	84	83	89	85.3	90.0	0.951	81.2	Muskegon
<b>Indianapolis Area</b>														<b>Indianapolis Area</b>
Noblesville	189571001	101	75	87	79	84	87	80	83	83.3	93.7	0.944	78.7	Noblesville
Fortville	180590003	92	72	80	76	81	81	76	79	78.7	91.3	0.948	74.6	Fortville
Fort B. Harrison	180970050	91	73	80	76	83	81	76	79	78.7	90.0	0.951	74.8	Fort B. Harrison
<b>Detroit Area</b>														<b>Detroit Area</b>
New Haven	260990009	102	81	88	79	92	90	82	86	86.0	92.3	0.962	82.7	New Haven
Warren	260991003	101	71	89	78	90	87	79	85	83.7	90.0	0.982	82.2	Warren
Port Huron	261470005	86	74	88	78	89	82	80	85	82.3	88.0	0.956	78.7	Port Huron
<b>Cleveland Area</b>														<b>Cleveland Area</b>
Ashtabula	390071001	99	81	93	86	92	91	86	90	89.0	95.7	0.954	84.9	Ashtabula
Geauga	390550004	97	75	88	70	68	86	77	75	79.3	99.0	0.954	75.7	Geauga
Eastlake	390850003	92	79	97	83	74	89	86	84	86.3	92.7	0.959	82.8	Eastlake
Akron	391530020	89	77	89	77	91	85	81	85	83.7	93.3	0.948	79.3	Akron
<b>Cincinnati Area</b>														<b>Cincinnati Area</b>
Wilmington	390271002	96	78	83	81	82	85	80	82	82.3	94.3	0.945	77.8	Wilmington
Sycamore	390610006	93	76	89	80	90	86	81	86	84.3	90.3	0.965	81.4	Sycamore
Lebanon	391650007	95	81	92	86	88	89	86	88	87.7	87.0	0.954	83.6	Lebanon
<b>Columbus Area</b>														<b>Columbus Area</b>
London	390970007	90	75	81	76	83	82	77	80	79.7	88.7	0.946	75.4	London
New Albany	390490029	94	78	92	82	87	88	84	87	86.3	93.0	0.954	82.4	New Albany
Franklin	290490028	84	73	86	79	79	81	79	81	80.3	86.0	0.958	77.0	Franklin
<b>St. Louis Area</b>														<b>St. Louis Area</b>
W. Alton (MO)	291831002	91	77	89	91	89	85	85	89	86.3	90.0	0.954	82.4	W. Alton (MO)
Orchard (MO)	291831004	90	76	92	92	83	86	86	89	87.0	90.0	0.958	83.3	Orchard (MO)
Sunset Hills (MO)	291890004	88	70	89	80	89	82	79	86	82.3	88.3	0.966	79.5	Sunset Hills (MO)
Arnold (MO)	290990012	82	70	92	79	87	81	80	86	82.3	84.7	0.956	78.7	Arnold (MO)
Margaretta (MO)	295100086	90	72	91	76	91	84	79	86	83.0	87.7	0.962	79.8	Margaretta (MO)
Maryland Heights (MO)	291890014			88	84	94	88	86	88	87.3		0.967	84.5	Maryland Heights (MO)

Key Sites		4th High 8-hour Value					Des. Values (truncated)			2005 BY	2002 BY	2009 - OTB			2009 - Will Do		
		'03	'04	'05	'06	'07	'03-'05	'04-'06	'05-'07	Average	Average	RRF	Round 5	Round 4	RRF	Round 5	
<b>Lake Michigan Area</b>																	<b>Lake Michigan Area</b>
Chiwaukee	550590019	88	78	93	79	85	86	83	85	84.7	98.3	0.972	82.3	92.0	0.971	82.2	Chiwaukee
Racine	551010017	82	69	95	71	77	82	78	81	80.3	91.7	0.965	77.5	84.9	0.964	77.4	Racine
Milwaukee-Bayside	550190085	92	73	93	73	83	86	79	83	82.7	91.0	0.965	79.8	84.9	0.964	79.7	Milwaukee-Bayside
Harrington Beach	550890009	99	72	94	72	84	88	79	83	83.3	93.0	0.961	80.1	85.4	0.960	80.0	Harrington Beach
Manitowoc	550710007	92	74	95	78	84	87	82	85	84.7	87.0	0.951	80.5	78.9	0.949	80.3	Manitowoc
Sheboygan	551170006	93	78	97	83	88	89	86	89	88.0	97.0	0.955	84.0	88.9	0.953	83.9	Sheboygan
Kewaunee	550610002	97	73	88	76	85	86	79	83	82.7	89.3	0.945	78.1	81.0	0.943	78.0	Kewaunee
Door County	550290004	93	78	101	79	92	90	86	90	88.7	91.0	0.946	83.9	81.8	0.945	83.8	Door County
Hammond	180892008	81	67	87	75	77	78	76	79	77.7	88.3	0.971	75.4	86.6	0.970	75.3	Hammond
Whiting	180890030		64	88	81	88	76	77	85	79.3		0.971	77.0		0.970	77.0	Whiting
Michigan City	180910005	82	70	84	75	72	78	76	77	77.0	90.3	0.960	73.9	86.5	0.959	73.8	Michigan City
Ogden Dunes	181270020	77	69	90	70	84	78	76	81	78.3	86.3	0.965	75.6	82.8	0.964	75.5	Ogden Dunes
Holland	260050003	95	79	94	91	95	89	88	93	90.0	94.0	0.948	85.3	83.4	0.947	85.2	Holland
Jenison	261390005	91	69	86	83	89	82	79	86	82.3	86.0	0.940	77.4	77.6	0.939	77.6	Jenison
Muskegon	261210039	94	70	90	91	88	84	83	89	85.3	90.0	0.947	80.8	81.5	0.945	80.6	Muskegon
<b>Indianapolis Area</b>																	<b>Indianapolis Area</b>
Noblesville	189571001	101	75	87	79	84	87	80	83	83.3	93.7	0.945	78.8	83.7	0.946	78.8	Noblesville
Fortville	180590003	92	72	80	76	81	81	76	79	78.7	91.3	0.947	74.5	83.8	0.948	74.6	Fortville
Fort B. Harrison	180970050	91	73	80	76	83	81	76	79	78.7	90.0	0.955	75.1	83.7	0.956	75.2	Fort B. Harrison
<b>Detroit Area</b>																	<b>Detroit Area</b>
New Haven	260990009	102	81	88	79	92	90	82	86	86.0	92.3	0.947	81.4	85.3	0.947	81.4	New Haven
Warren	260991003	101	71	89	78	90	87	79	85	83.7	90.0	0.968	81.0	83.3	0.969	81.1	Warren
Port Huron	261470005	86	74	88	78	89	82	80	85	82.3	88.0	0.937	77.1	79.1	0.938	77.2	Port Huron
<b>Cleveland Area</b>																	<b>Cleveland Area</b>
Ashtabula	390071001	99	81	93	86	92	91	86	90	89.0	95.7	0.937	83.4	82.7	0.941	83.7	Ashtabula
Geauga	390550004	97	75	88	70	68	86	77	75	79.3	99.0	0.942	74.7	88.8	0.945	75.0	Geauga
Eastlake	390850003	92	79	97	83	74	89	86	84	86.3	92.7	0.949	81.9	82.8	0.954	82.4	Eastlake
Akron	391530020	89	77	89	77	91	85	81	85	83.7	93.3	0.934	78.1	81.4	0.935	78.2	Akron
<b>Cincinnati Area</b>																	<b>Cincinnati Area</b>
Wilmington	390271002	96	78	83	81	82	85	80	82	82.3	94.3	0.941	77.5	83.5	0.942	77.6	Wilmington
Sycamore	390610006	93	76	89	80	90	86	81	86	84.3	90.3	0.967	81.6	84.7	0.968	81.6	Sycamore
Lebanon	391650007	95	81	92	86	88	89	86	88	87.7	87.0	0.947	83.0	79.0	0.948	83.1	Lebanon
<b>Columbus Area</b>																	<b>Columbus Area</b>
London	390970007	90	75	81	76	83	82	77	80	79.7	88.7	0.941	75.0	78.4	0.942	75.0	London
New Albany	390490029	94	78	92	82	87	88	84	87	86.3	93.0	0.947	81.8	82.6	0.948	81.8	New Albany
Franklin	290490028	84	73	86	79	79	81	79	81	80.3	86.0	0.945	75.9	76.5	0.948	76.2	Franklin
<b>St. Louis Area</b>																	<b>St. Louis Area</b>
W. Alton (MO)	291831002	91	77	89	91	89	85	85	89	86.3	90.0	0.938	81.0	85.2	0.932	80.5	W. Alton (MO)
Orchard (MO)	291831004	90	76	92	92	83	86	86	89	87.0	90.0	0.942	82.0	82.2	0.939	81.7	Orchard (MO)
Sunset Hills (MO)	291890004	88	70	89	80	89	82	79	86	82.3	88.3	0.956	78.7	81.9	0.954	78.5	Sunset Hills (MO)
Arnold (MO)	290990012	82	70	92	79	87	81	80	86	82.3	84.7	0.938	77.2	77.4	0.937	77.1	Arnold (MO)
Margaretta (MO)	295100086	90	72	91	76	91	84	79	86	83.0	87.7	0.955	79.3	83.4	0.955	79.3	Margaretta (MO)
Maryland Heights (MO)	291890014			88	84	94	88	86	88	87.3		0.955	83.4		0.954	83.3	Maryland Heights (MO)

Key Sites		4th High 8-hour Value					Des. Values (truncated)			2005 BY	2002 BY	2012 - OTB			2018 - OTB		
		'03	'04	'05	'06	'07	'03-'05	'04-'06	'05-'07	Average	Average	RRF	Round 5	Round 4	RRF	Round 5	
<b>Lake Michigan Area</b>																	<b>Lake Michigan Area</b>
Chiwaukee	550590019	88	78	93	79	85	86	83	85	84.7	98.3	0.956	80.9	90.3	0.900	76.2	Chiwaukee
Racine	551010017	82	69	95	71	77	82	78	81	80.3	91.7	0.947	76.1	82.9	0.886	71.2	Racine
Milwaukee-Bayside	550190085	92	73	93	73	83	86	79	83	82.7	91.0	0.945	78.1	82.3	0.880	72.7	Milwaukee-Bayside
Harrington Beach	550890009	99	72	94	72	84	88	79	83	83.3	93.0	0.939	78.3	82.9	0.870	72.5	Harrington Beach
Manitowoc	550710007	92	74	95	78	84	87	82	85	84.7	87.0	0.925	78.3	76.3	0.853	72.2	Manitowoc
Sheboygan	551170006	93	78	97	83	88	89	86	89	88.0	97.0	0.931	81.9	86.4	0.857	75.4	Sheboygan
Kewaunee	550610002	97	73	88	76	85	86	79	83	82.7	89.3	0.919	76.0	79.1	0.845	69.9	Kewaunee
Door County	550290004	93	78	101	79	92	90	86	90	88.7	91.0	0.920	81.6	79.3	0.843	74.7	Door County
Hammond	180892008	81	67	87	75	77	78	76	79	77.7	88.3	0.961	74.6	86.3	0.922	71.6	Hammond
Whiting	180890030		64	88	81	88	76	77	85	79.3		0.961	76.2		0.922	73.1	Whiting
Michigan City	180910005	82	70	84	75	72	78	76	77	77.0	90.3	0.941	72.5	85.4	0.884	68.1	Michigan City
Ogden Dunes	181270020	77	69	90	70	84	78	76	81	78.3	86.3	0.950	74.4	82.0	0.904	70.8	Ogden Dunes
Holland	260050003	95	79	94	91	95	89	88	93	90.0	94.0	0.921	82.9	81.0	0.846	76.1	Holland
Jenison	261390005	91	69	86	83	89	82	79	86	82.3	86.0	0.913	75.2	75.5	0.838	69.0	Jenison
Muskegon	261210039	94	70	90	91	88	84	83	89	85.3	90.0	0.921	78.6	79.4	0.846	72.2	Muskegon
<b>Indianapolis Area</b>																	<b>Indianapolis Area</b>
Noblesville	189571001	101	75	87	79	84	87	80	83	83.3	93.7	0.915	76.3	82.0	0.831	69.3	Noblesville
Fortville	180590003	92	72	80	76	81	81	76	79	78.7	91.3	0.918	72.2	82.1	0.835	65.7	Fortville
Fort B. Harrison	180970050	91	73	80	76	83	81	76	79	78.7	90.0	0.933	73.4	82.4	0.879	69.1	Fort B. Harrison
<b>Detroit Area</b>																	<b>Detroit Area</b>
New Haven	260990009	102	81	88	79	92	90	82	86	86.0	92.3	0.932	80.2	83.5	0.885	76.1	New Haven
Warren	260991003	101	71	89	78	90	87	79	85	83.7	90.0	0.961	80.4	81.9	0.924	77.3	Warren
Port Huron	261470005	86	74	88	78	89	82	80	85	82.3	88.0	0.914	75.3	77.0	0.858	70.6	Port Huron
<b>Cleveland Area</b>																	<b>Cleveland Area</b>
Ashtabula	390071001	99	81	93	86	92	91	86	90	89.0	95.7	0.910	81.0	80.2	0.844	75.1	Ashtabula
Geauga	390550004	97	75	88	70	68	86	77	75	79.3	99.0	0.916	72.7	86.2	0.848	67.3	Geauga
Eastlake	390850003	92	79	97	83	74	89	86	84	86.3	92.7	0.932	80.5	80.6	0.883	76.2	Eastlake
Akron	391530020	89	77	89	77	91	85	81	85	83.7	93.3	0.904	75.6	78.5	0.821	68.7	Akron
<b>Cincinnati Area</b>																	<b>Cincinnati Area</b>
Wilmington	390271002	96	78	83	81	82	85	80	82	82.3	94.3	0.912	75.1	81.1	0.830	68.3	Wilmington
Sycamore	390610006	93	76	89	80	90	86	81	86	84.3	90.3	0.949	80.0	82.9	0.881	74.3	Sycamore
Lebanon	391650007	95	81	92	86	88	89	86	88	87.7	87.0	0.922	80.8	77.0	0.846	74.2	Lebanon
<b>Columbus Area</b>																	<b>Columbus Area</b>
London	390970007	90	75	81	76	83	82	77	80	79.7	88.7	0.912	72.7	76.5	0.832	66.3	London
New Albany	390490029	94	78	92	82	87	88	84	87	86.3	93.0	0.922	79.6	80.2	0.845	73.0	New Albany
Franklin	290490028	84	73	86	79	79	81	79	81	80.3	86.0	0.924	74.2	74.7	0.859	69.0	Franklin
<b>St. Louis Area</b>																	<b>St. Louis Area</b>
W. Alton (MO)	291831002	91	77	89	91	89	85	85	89	86.3	90.0	0.921	79.5	84.0	0.868	74.9	W. Alton (MO)
Orchard (MO)	291831004	90	76	92	92	83	86	86	89	87.0	90.0	0.924	80.4	80.4	0.876	76.2	Orchard (MO)
Sunset Hills (MO)	291890004	88	70	89	80	89	82	79	86	82.3	88.3	0.940	77.4	80.6	0.897	73.9	Sunset Hills (MO)
Arnold (MO)	290990012	82	70	92	79	87	81	80	86	82.3	84.7	0.921	75.8	75.8	0.874	72.0	Arnold (MO)
Margaretta (MO)	295100086	90	72	91	76	91	84	79	86	83.0	87.7	0.939	77.9	82.5	0.896	74.4	Margaretta (MO)
Maryland Heights (MO)	291890014			88	84	94	88	86	88	87.3		0.938	81.9		0.894	78.1	Maryland Heights (MO)

Key Site	County	Site ID	Annual Average Conc.					Design Values			2005 BY	2002 BY	2009 Modeling Results			Key Site		
			'03	'04	'05	'06	'07	'03 - '05	'04 - '06	'05 - '07	Average w/o 2007	Average	Round 5 OTB	Round 5 Will Do	Round4			
Chicago - Washington HS	Cook	170310022	15.6	14.2	16.9	13.2				15.6	14.8	15.1	15.1	15.9	13.9	13.9	14.8	Chicago - Washington HS
Chicago - Mayfair	Cook	170310052	15.9	15.3	17.0	14.5				16.1	15.6	15.8	15.8	17.1	14.2	14.3	15.8	Chicago - Mayfair
Chicago - Springfield	Cook	170310057	15.6	13.8	16.7	13.5				15.4	14.7	15.1	15.0	15.6	13.7	13.8	14.5	Chicago - Springfield
Chicago - Lawndale	Cook	170310076	14.8	14.2	16.6	13.5				15.2	14.8	15.1	15.0	15.6	13.7	13.8	14.5	Chicago - Lawndale
Blue Island	Cook	170312001	14.9	14.1	16.4	13.2				15.1	14.6	14.8	14.8	15.6	13.6	13.6	14.5	Blue Island
Schiller Park	Cook	170313103		16.0	17.6	14.8				16.8	16.1	16.2	16.4		14.9	15.0		Schiller Park
Summit	Cook	170313301	15.6	14.2	16.9	13.8				15.6	15.0	15.4	15.3	16.0	14.1	14.1	14.8	Summit
Maywood	Cook	170316005	16.8	15.2	16.3	14.3				16.1	15.3	15.3	15.6	16.4	14.4	14.4	15.3	Maywood
Granite City	Madison	171191007	17.5	15.4	18.2	16.3				17.0	16.6	17.3	17.0	17.3	15.2	15.3	16.0	Granite City
E. St. Louis	St. Clair	171630010	14.9	14.7	17.1	14.5				15.6	15.4	15.8	15.6	16.2	14.0	14.1	14.9	E. St. Louis
Jeffersonville	Clark	180190005	15.8	15.1	18.5	15.0				16.5	16.2	16.8	16.5	16.3	13.6	13.9	15.5	Jeffersonville
Jasper	Dubois	180372001	15.7	14.4	16.9	13.5				15.7	14.9	15.2	15.3	16.1	12.4	12.6	13.8	Jasper
Gary	Lake	180890031			16.8	13.3				16.8	15.1	15.1	15.6		12.9	13.0		Gary
Indy-Washington Park	Marion	180970078	15.5	14.3	16.4	14.1				15.4	14.9	15.3	15.2	16.2	12.7	12.8	14.5	Indy-Washington Park
Indy- Michigan Street	Marion	180970083	16.3	15.0	17.5	14.1				16.3	15.5	15.8	15.9	16.4	13.2	13.4	14.8	Indy- Michigan Street
Allen Park	Wayne	261630001	15.2	14.2	15.9	13.2				15.1	14.4	14.6	14.7	15.8	13.0	13.1	14.5	Allen Park
Southwest HS	Wayne	261630015	16.6	15.4	17.2	14.7				16.4	15.8	16.0	16.0	17.3	14.2	14.3	15.8	Southwest HS
Linwood	Wayne	261630016	15.8	13.7	16.0	13.0				15.2	14.2	14.5	14.6	15.5	13.0	13.1	14.1	Linwood
Dearborn	Wayne	261630033	19.2	16.8	18.6	16.1				18.2	17.2	17.4	17.6	19.3	15.7	15.8	17.7	Dearborn
Wyandotte	Wayne	261630036	16.3	13.7	16.4	12.9				15.5	14.3	14.7	14.8	16.6	13.0	13.1	15.1	Wyandotte
Middleton	Butler	390170003	17.2	14.1	19.0	14.1				16.8	15.7	16.6	16.4	16.5	13.3	13.5	14.2	Middleton
Fairfield	Butler	390170016	15.8	14.7	17.9	14.0				16.1	15.5	16.0	15.9	15.9	13.0	13.2	13.5	Fairfield
Cleveland-28th Street	Cuyahoga	390350027	15.4	15.6	17.3	13.0				16.1	15.3	15.2	15.5	16.5	13.4	13.5	14.4	Cleveland-28th Street
Cleveland-St. Tikhon	Cuyahoga	390350038	17.6	17.5	19.2	14.9				18.1	17.2	17.1	17.5	18.4	15.1	15.3	16.1	Cleveland-St. Tikhon
Cleveland-Broadway	Cuyahoga	390350045	16.4	15.3	19.3	14.1				17.0	16.2	16.7	16.6	16.7	14.2	14.4	14.6	Cleveland-Broadway
Cleveland-E14 & Orange	Cuyahoga	390350060	17.2	16.4	19.4	15.0				17.7	16.9	17.2	17.3	17.6	14.8	15.0	15.3	Cleveland-E14 & Orange
Newburg Hts - Harvard Ave	Cuyahoga	390350065	15.6	15.2	18.6	13.1				16.5	15.6	15.9	16.0	16.2	13.7	13.9	14.1	Newburg Hts - Harvard Ave
Columbus - Fairgrounds	Franklin	390490024	16.4	15.0	16.4	13.6				15.9	15.0	15.0	15.3	16.5	12.8	13.0	14.6	Columbus - Fairgrounds
Columbus - Ann Street	Franklin	390490025	15.3	14.6	16.5	13.8				15.5	15.0	15.2	15.2	16.0	12.6	12.8	14.1	Columbus - Ann Street
Columbus - Maple Canyon	Franklin	390490081	14.9	13.6	14.6	12.9				14.4	13.7	13.8	13.9	16.0	11.7	11.8	14.0	Columbus - Maple Canyon
Cincinnati - Seymour	Hamilton	390610014	17.0	15.9	19.8	15.5				17.6	17.1	17.7	17.4	17.7	14.4	14.6	15.5	Cincinnati - Seymour
Cincinnati - Taft Ave	Hamilton	390610040	15.5	14.6	17.5	13.6				15.9	15.2	15.6	15.6	15.7	12.7	12.9	13.6	Cincinnati - Taft Ave
Cincinnati - 8th Ave	Hamilton	390610042	16.7	16.0	19.1	14.9				17.3	16.7	17.0	17.0	17.3	13.9	14.1	14.6	Cincinnati - 8th Ave
Sharonville	Hamilton	390610043	15.7	14.9	16.9	14.5				15.8	15.4	15.7	15.7	16.0	12.9	13.1	13.6	Sharonville
Norwood	Hamilton	390617001	16.0	15.3	18.4	14.4				16.6	16.0	16.4	16.3	16.3	13.3	13.5	14.2	Norwood
St. Bernard	Hamilton	390618001	17.3	16.4	20.0	15.9				17.9	17.4	18.0	17.8	17.3	14.6	14.8	15.2	St. Bernard
Steubenville	Jefferson	390810016	17.7	15.9	16.4	13.8				16.7	15.4	15.1	15.7	17.7	12.5	12.6	16.3	Steubenville
Mingo Junction	Jefferson	390811001	17.3	16.2	18.1	14.6				17.2	16.3	16.4	16.6	17.5	13.4	13.4	15.5	Mingo Junction
Ironton	Lawrence	390870010	14.3	13.7	17.0	14.4				15.0	15.0	15.7	15.2	15.7	12.7	12.8	14.2	Ironton
Dayton	Montgomery	391130032	15.9	14.5	17.4	13.6				15.9	15.2	15.5	15.5	15.9	13.0	13.2	13.7	Dayton
New Boston	Scioto	391450013	14.7	13.0	16.2	14.3				14.6	14.5	15.3	14.8	17.1	12.2	12.3	15.4	New Boston
Canton - Dueber	Stark	391510017	16.8	15.6	17.8	14.6				16.7	16.0	16.2	16.3	17.3	13.9	14.0	15.0	Canton - Dueber
Canton - Market	Stark	391510020	15.0	14.1	16.6	11.9				15.2	14.2	14.3	14.6	15.7	12.4	12.5	13.6	Canton - Market
Akron - Brittain	Summit	391530017	15.4	15.0	16.4	13.5				15.6	15.0	15.0	15.2	16.4	12.9	13.1	14.4	Akron - Brittain
Akron - W. Exchange	Summit	391530023	14.2	13.9	15.7	12.8				14.6	14.1	14.3	14.3	15.6	12.1	12.3	13.6	Akron - W. Exchange

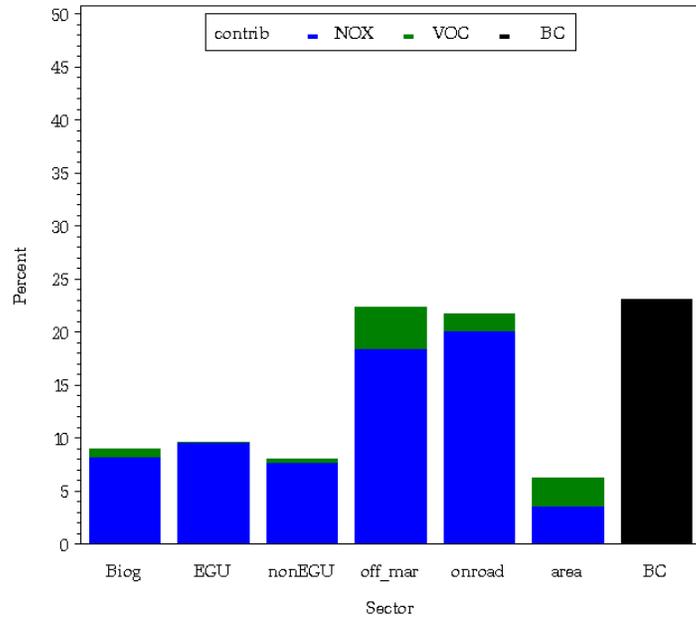
Key Site	County	Site ID	Annual Average Conc.					Design Values			2005 BY	2002 BY	2012 Modeling Results			Key Site	
			'03	'04	'05	'06	'07	'03 - '05	'04 - '06	'05 - '07	Average w/o 2007	Average	Round 5 OTB	Round 5 Will Do	Round4		
Chicago - Washington HS	Cook	170310022	15.6	14.2	16.9	13.2				15.6	14.8	15.1	15.1	15.9	13.8	14.6	Chicago - Washington HS
Chicago - Mayfair	Cook	170310052	15.9	15.3	17.0	14.5				16.1	15.6	15.8	15.8	17.1	14.2	15.5	Chicago - Mayfair
Chicago - Springfield	Cook	170310057	15.6	13.8	16.7	13.5				15.4	14.7	15.1	15.0	15.6	13.7	14.3	Chicago - Springfield
Chicago - Lawndale	Cook	170310076	14.8	14.2	16.6	13.5				15.2	14.8	15.1	15.0	15.6	13.7	14.3	Chicago - Lawndale
Blue Island	Cook	170312001	14.9	14.1	16.4	13.2				15.1	14.6	14.8	14.8	15.6	13.5	14.3	Blue Island
Schiller Park	Cook	170313103		16.0	17.6	14.8				16.8	16.1	16.2	16.4		14.8		Schiller Park
Summit	Cook	170313301	15.6	14.2	16.9	13.8				15.6	15.0	15.4	15.3	16.0	14.0	14.6	Summit
Maywood	Cook	170316005	16.8	15.2	16.3	14.3				16.1	15.3	15.3	15.6	16.4	14.3	15.1	Maywood
Granite City	Madison	171191007	17.5	15.4	18.2	16.3				17.0	16.6	17.3	17.0	17.3	15.1	15.8	Granite City
E. St. Louis	St. Clair	171630010	14.9	14.7	17.1	14.5				15.6	15.4	15.8	15.6	16.2	13.8	14.7	E. St. Louis
Jeffersonville	Clark	180190005	15.8	15.1	18.5	15.0				16.5	16.2	16.8	16.5	16.3	13.6	15.0	Jeffersonville
Jasper	Dubois	180372001	15.7	14.4	16.9	13.5				15.7	14.9	15.2	15.3	16.1	12.3	13.5	Jasper
Gary	Lake	180890031			16.8	13.3				16.8	15.1	15.1	15.6		12.7		Gary
Indy-Washington Park	Marion	180970078	15.5	14.3	16.4	14.1				15.4	14.9	15.3	15.2	16.2	12.5	14.2	Indy-Washington Park
Indy- Michigan Street	Marion	180970083	16.3	15.0	17.5	14.1				16.3	15.5	15.8	15.9	16.4	13.0	14.9	Indy- Michigan Street
Allen Park	Wayne	261630001	15.2	14.2	15.9	13.2				15.1	14.4	14.6	14.7	15.8	12.9	14.1	Allen Park
Southwest HS	Wayne	261630015	16.6	15.4	17.2	14.7				16.4	15.8	16.0	16.0	17.3	14.0	15.3	Southwest HS
Linwood	Wayne	261630016	15.8	13.7	16.0	13.0				15.2	14.2	14.5	14.6	15.5	12.9	13.7	Linwood
Dearborn	Wayne	261630033	19.2	16.8	18.6	16.1				18.2	17.2	17.4	17.6	19.3	15.5	17.1	Dearborn
Wyandotte	Wayne	261630036	16.3	13.7	16.4	12.9				15.5	14.3	14.7	14.8	16.6	12.9	14.7	Wyandotte
Middleton	Butler	390170003	17.2	14.1	19.0	14.1				16.8	15.7	16.6	16.4	16.5	13.2	13.7	Middleton
Fairfield	Butler	390170016	15.8	14.7	17.9	14.0				16.1	15.5	16.0	15.9	15.9	13.0	12.9	Fairfield
Cleveland-28th Street	Cuyahoga	390350027	15.4	15.6	17.3	13.0				16.1	15.3	15.2	15.5	16.5	13.2	13.8	Cleveland-28th Street
Cleveland-St. Tikhon	Cuyahoga	390350038	17.6	17.5	19.2	14.9				18.1	17.2	17.1	17.5	18.4	14.8	15.4	Cleveland-St. Tikhon
Cleveland-Broadway	Cuyahoga	390350045	16.4	15.3	19.3	14.1				17.0	16.2	16.7	16.6	16.7	14.0	14.0	Cleveland-Broadway
Cleveland-E14 & Orange	Cuyahoga	390350060	17.2	16.4	19.4	15.0				17.7	16.9	17.2	17.3	17.6	14.6	14.7	Cleveland-E14 & Orange
Newburg Hts - Harvard Ave	Cuyahoga	390350065	15.6	15.2	18.6	13.1				16.5	15.6	15.9	16.0	16.2	13.5	13.5	Newburg Hts - Harvard Ave
Columbus - Fairgrounds	Franklin	390490024	16.4	15.0	16.4	13.6				15.9	15.0	15.0	15.3	16.5	12.6	14.0	Columbus - Fairgrounds
Columbus - Ann Street	Franklin	390490025	15.3	14.6	16.5	13.8				15.5	15.0	15.2	15.2	16.0	12.4	13.5	Columbus - Ann Street
Columbus - Maple Canyon	Franklin	390490081	14.9	13.6	14.6	12.9				14.4	13.7	13.8	13.9	16.0	11.5	13.4	Columbus - Maple Canyon
Cincinnati - Seymour	Hamilton	390610014	17.0	15.9	19.8	15.5				17.6	17.1	17.7	17.4	17.7	14.3	14.8	Cincinnati - Seymour
Cincinnati - Taft Ave	Hamilton	390610040	15.5	14.6	17.5	13.6				15.9	15.2	15.6	15.6	15.7	12.6	13.0	Cincinnati - Taft Ave
Cincinnati - 8th Ave	Hamilton	390610042	16.7	16.0	19.1	14.9				17.3	16.7	17.0	17.0	17.3	13.8	14.0	Cincinnati - 8th Ave
Sharonville	Hamilton	390610043	15.7	14.9	16.9	14.5				15.8	15.4	15.7	15.7	16.0	12.8	13.0	Sharonville
Norwood	Hamilton	390617001	16.0	15.3	18.4	14.4				16.6	16.0	16.4	16.3	16.3	13.2	13.6	Norwood
St. Bernard	Hamilton	390618001	17.3	16.4	20.0	15.9				17.9	17.4	18.0	17.8	17.3	14.5	14.6	St. Bernard
Steubenville	Jefferson	390810016	17.7	15.9	16.4	13.8				16.7	15.4	15.1	15.7	17.7	12.5	15.9	Steubenville
Mingo Junction	Jefferson	390811001	17.3	16.2	18.1	14.6				17.2	16.3	16.4	16.6	17.5	13.3	15.0	Mingo Junction
Ironton	Lawrence	390870010	14.3	13.7	17.0	14.4				15.0	15.0	15.7	15.2	15.7	12.7	13.7	Ironton
Dayton	Montgomery	391130032	15.9	14.5	17.4	13.6				15.9	15.2	15.5	15.5	15.9	12.8	13.2	Dayton
New Boston	Scioto	391450013	14.7	13.0	16.2	14.3				14.6	14.5	15.3	14.8	17.1	12.1	14.8	New Boston
Canton - Dueber	Stark	391510017	16.8	15.6	17.8	14.6				16.7	16.0	16.2	16.3	17.3	13.7	14.3	Canton - Dueber
Canton - Market	Stark	391510020	15.0	14.1	16.6	11.9				15.2	14.2	14.3	14.6	15.7	12.2	13.0	Canton - Market
Akron - Brittain	Summit	391530017	15.4	15.0	16.4	13.5				15.6	15.0	15.0	15.2	16.4	12.8	13.6	Akron - Brittain
Akron - W. Exchange	Summit	391530023	14.2	13.9	15.7	12.8				14.6	14.1	14.3	14.3	15.6	12.0	13.0	Akron - W. Exchange

Key Site	County	Site ID	Annual Average Conc.					Design Values			2005 BY	2002 BY	2018 Modeling Results			Key Site
			'03	'04	'05	'06	'07	'03 - '05	'04 - '06	'05 - '07	Average w/o 2007	Average	Round 5 OTB	Round 5 Will Do	Round4	
Chicago - Washington HS	Cook	170310022	15.6	14.2	16.9	13.2		15.6	14.8	15.1	15.1	15.9	13.6	13.5	14.4	Chicago - Washington HS
Chicago - Mayfair	Cook	170310052	15.9	15.3	17.0	14.5		16.1	15.6	15.8	15.8	17.1	13.8	13.7	15.0	Chicago - Mayfair
Chicago - Springfield	Cook	170310057	15.6	13.8	16.7	13.5		15.4	14.7	15.1	15.0	15.6	13.5	13.3	14.1	Chicago - Springfield
Chicago - Lawndale	Cook	170310076	14.8	14.2	16.6	13.5		15.2	14.8	15.1	15.0	15.6	13.5	13.3	14.1	Chicago - Lawndale
Blue Island	Cook	170312001	14.9	14.1	16.4	13.2		15.1	14.6	14.8	14.8	15.6	13.5	13.2	14.1	Blue Island
Schiller Park	Cook	170313103		16.0	17.6	14.8		16.8	16.1	16.2	16.4		14.3	14.2		Schiller Park
Summit	Cook	170313301	15.6	14.2	16.9	13.8		15.6	15.0	15.4	15.3	16.0	13.8	13.7	14.4	Summit
Maywood	Cook	170316005	16.8	15.2	16.3	14.3		16.1	15.3	15.3	15.6	16.4	14.1	14.0	14.9	Maywood
Granite City	Madison	171191007	17.5	15.4	18.2	16.3		17.0	16.6	17.3	17.0	17.3	14.5	14.4	15.5	Granite City
E. St. Louis	St. Clair	171630010	14.9	14.7	17.1	14.5		15.6	15.4	15.8	15.6	16.2	13.2	13.2	14.5	E. St. Louis
Jeffersonville	Clark	180190005	15.8	15.1	18.5	15.0		16.5	16.2	16.8	16.5	16.3	13.2	13.3	14.4	Jeffersonville
Jasper	Dubois	180372001	15.7	14.4	16.9	13.5		15.7	14.9	15.2	15.3	16.1	11.7	11.8	13.0	Jasper
Gary	Lake	180890031			16.8	13.3		16.8	15.1	15.1	15.6		12.3	12.2		Gary
Indy-Washington Park	Marion	180970078	15.5	14.3	16.4	14.1		15.4	14.9	15.3	15.2	16.2	11.9	11.9	13.7	Indy-Washington Park
Indy- Michigan Street	Marion	180970083	16.3	15.0	17.5	14.1		16.3	15.5	15.8	15.9	16.4	12.4	12.5	14.0	Indy- Michigan Street
Allen Park	Wayne	261630001	15.2	14.2	15.9	13.2		15.1	14.4	14.6	14.7	15.8	12.4	12.5	13.3	Allen Park
Southwest HS	Wayne	261630015	16.6	15.4	17.2	14.7		16.4	15.8	16.0	16.0	17.3	13.5	13.5	14.4	Southwest HS
Linwood	Wayne	261630016	15.8	13.7	16.0	13.0		15.2	14.2	14.5	14.6	15.5	12.4	12.4	13.0	Linwood
Dearborn	Wayne	261630033	19.2	16.8	18.6	16.1		18.2	17.2	17.4	17.6	19.3	15.0	15.0	16.1	Dearborn
Wyandotte	Wayne	261630036	16.3	13.7	16.4	12.9		15.5	14.3	14.7	14.8	16.6	12.4	12.4	13.9	Wyandotte
Middleton	Butler	390170003	17.2	14.1	19.0	14.1		16.8	15.7	16.6	16.4	16.5	12.6	12.7	13.1	Middleton
Fairfield	Butler	390170016	15.8	14.7	17.9	14.0		16.1	15.5	16.0	15.9	15.9	12.4	12.5	12.2	Fairfield
Cleveland-28th Street	Cuyahoga	390350027	15.4	15.6	17.3	13.0		16.1	15.3	15.2	15.5	16.5	12.6	12.7	12.9	Cleveland-28th Street
Cleveland-St. Tikhon	Cuyahoga	390350038	17.6	17.5	19.2	14.9		18.1	17.2	17.1	17.5	18.4	14.2	14.3	14.4	Cleveland-St. Tikhon
Cleveland-Broadway	Cuyahoga	390350045	16.4	15.3	19.3	14.1		17.0	16.2	16.7	16.6	16.7	13.4	13.5	13.1	Cleveland-Broadway
Cleveland-E14 & Orange	Cuyahoga	390350060	17.2	16.4	19.4	15.0		17.7	16.9	17.2	17.3	17.6	14.0	14.1	13.7	Cleveland-E14 & Orange
Newburg Hts - Harvard Ave	Cuyahoga	390350065	15.6	15.2	18.6	13.1		16.5	15.6	15.9	16.0	16.2	12.9	13.0	12.6	Newburg Hts - Harvard Ave
Columbus - Fairgrounds	Franklin	390490024	16.4	15.0	16.4	13.6		15.9	15.0	15.0	15.3	16.5	11.9	12.0	13.0	Columbus - Fairgrounds
Columbus - Ann Street	Franklin	390490025	15.3	14.6	16.5	13.8		15.5	15.0	15.2	15.2	16.0	11.8	11.8	12.5	Columbus - Ann Street
Columbus - Maple Canyon	Franklin	390490081	14.9	13.6	14.6	12.9		14.4	13.7	13.8	13.9	16.0	10.9	11.0	12.5	Columbus - Maple Canyon
Cincinnati - Seymour	Hamilton	390610014	17.0	15.9	19.8	15.5		17.6	17.1	17.7	17.4	17.7	13.7	13.8	14.0	Cincinnati - Seymour
Cincinnati - Taft Ave	Hamilton	390610040	15.5	14.6	17.5	13.6		15.9	15.2	15.6	15.6	15.7	12.1	12.2	12.3	Cincinnati - Taft Ave
Cincinnati - 8th Ave	Hamilton	390610042	16.7	16.0	19.1	14.9		17.3	16.7	17.0	17.0	17.3	13.2	13.3	13.2	Cincinnati - 8th Ave
Sharonville	Hamilton	390610043	15.7	14.9	16.9	14.5		15.8	15.4	15.7	15.7	16.0	12.3	12.3	12.2	Sharonville
Norwood	Hamilton	390617001	16.0	15.3	18.4	14.4		16.6	16.0	16.4	16.3	16.3	12.7	12.8	12.8	Norwood
St. Bernard	Hamilton	390618001	17.3	16.4	20.0	15.9		17.9	17.4	18.0	17.8	17.3	13.9	14.0	13.8	St. Bernard
Steubenville	Jefferson	390810016	17.7	15.9	16.4	13.8		16.7	15.4	15.1	15.7	17.7	12.5	12.5	16.2	Steubenville
Mingo Junction	Jefferson	390811001	17.3	16.2	18.1	14.6		17.2	16.3	16.4	16.6	17.5	13.3	13.3	15.3	Mingo Junction
Ironton	Lawrence	390870010	14.3	13.7	17.0	14.4		15.0	15.0	15.7	15.2	15.7	12.2	12.3	13.2	Ironton
Dayton	Montgomery	391130032	15.9	14.5	17.4	13.6		15.9	15.2	15.5	15.5	15.9	12.2	12.3	12.3	Dayton
New Boston	Scioto	391450013	14.7	13.0	16.2	14.3		14.6	14.5	15.3	14.8	17.1	11.6	11.7	14.2	New Boston
Canton - Dueber	Stark	391510017	16.8	15.6	17.8	14.6		16.7	16.0	16.2	16.3	17.3	13.1	13.2	13.6	Canton - Dueber
Canton - Market	Stark	391510020	15.0	14.1	16.6	11.9		15.2	14.2	14.3	14.6	15.7	11.7	11.7	12.2	Canton - Market
Akron - Brittain	Summit	391530017	15.4	15.0	16.4	13.5		15.6	15.0	15.0	15.2	16.4	12.2	12.3	12.9	Akron - Brittain
Akron - W. Exchange	Summit	391530023	14.2	13.9	15.7	12.8		14.6	14.1	14.3	14.3	15.6	11.4	11.5	12.2	Akron - W. Exchange

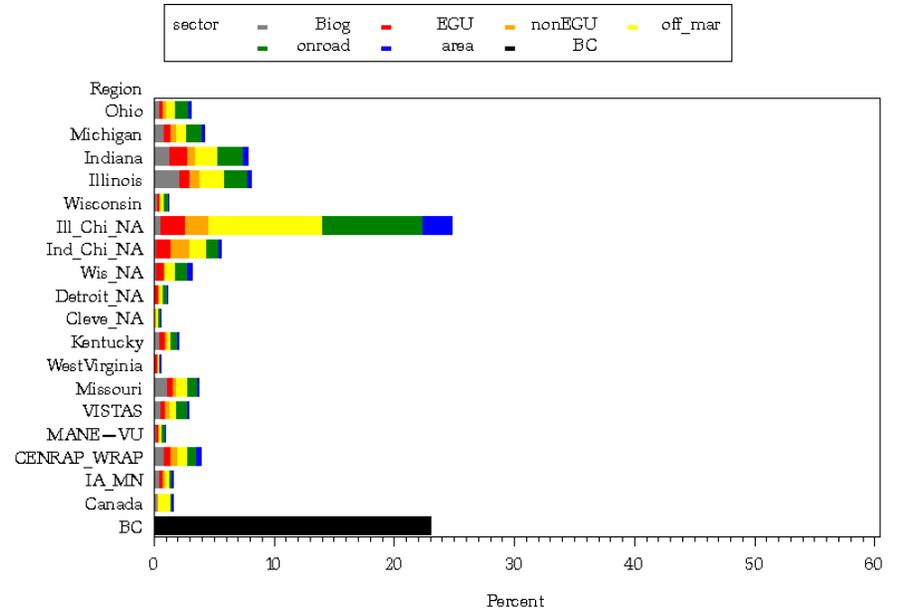
## **APPENDIX II**

### **Ozone Source Apportionment Modeling Results**

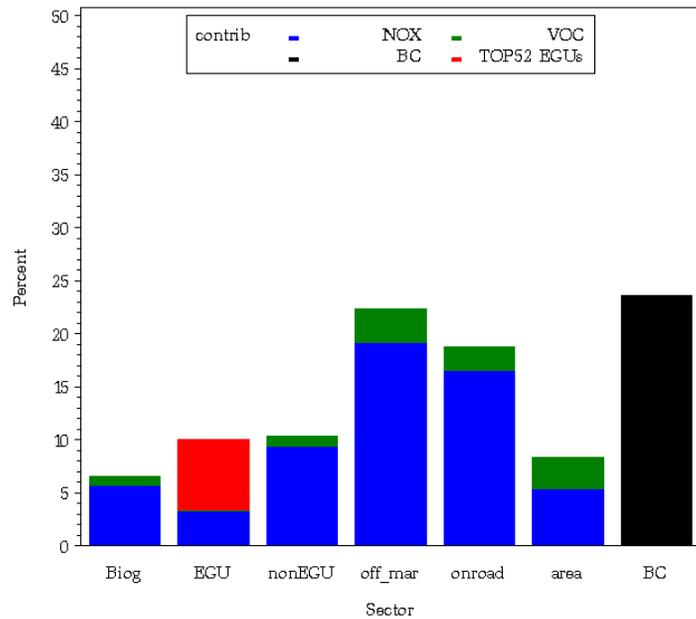
WI — Kenosha : (5505900191) 2009M3R5\_osat



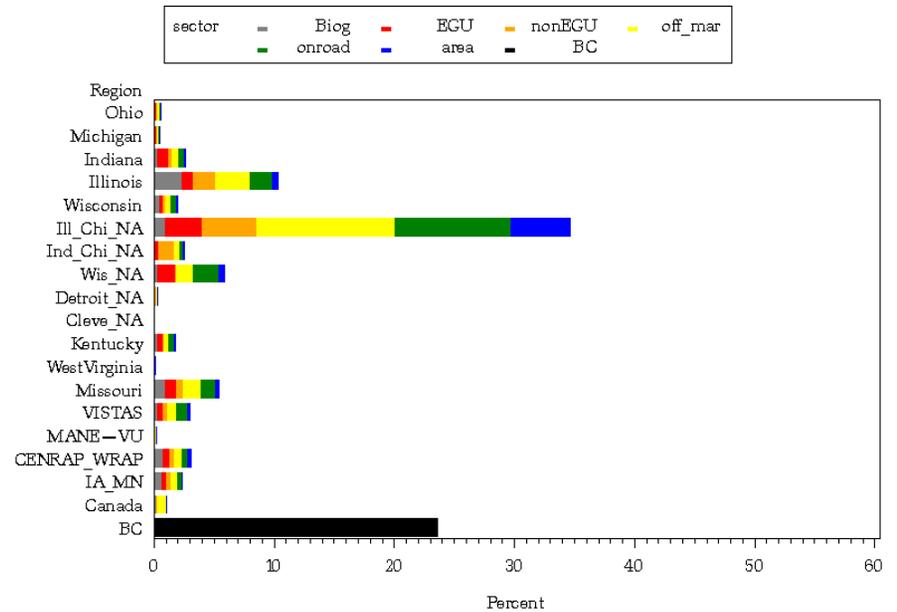
WI — Kenosha : (5505900191) 2009M3R5\_osat



WI — Kenosha : (5505900191) K2012R4S1a\_APCA\_nopig

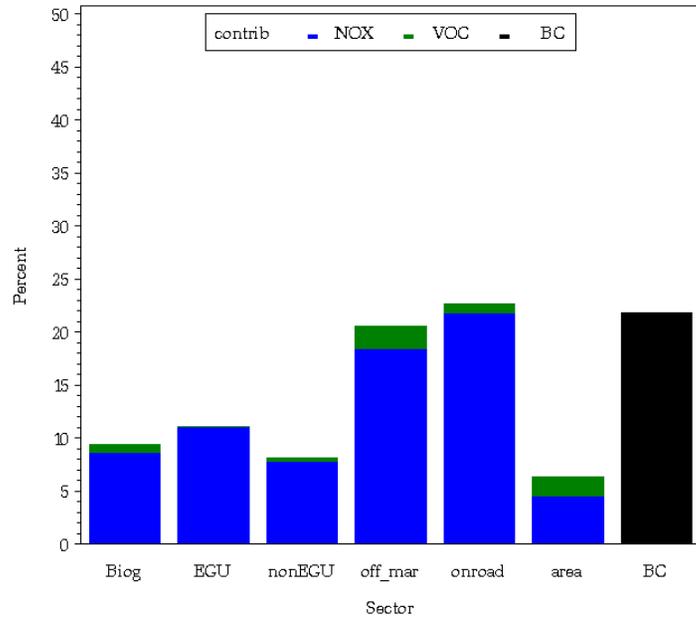


WI — Kenosha : (5505900191) K2012R4S1a\_APCA\_nopig

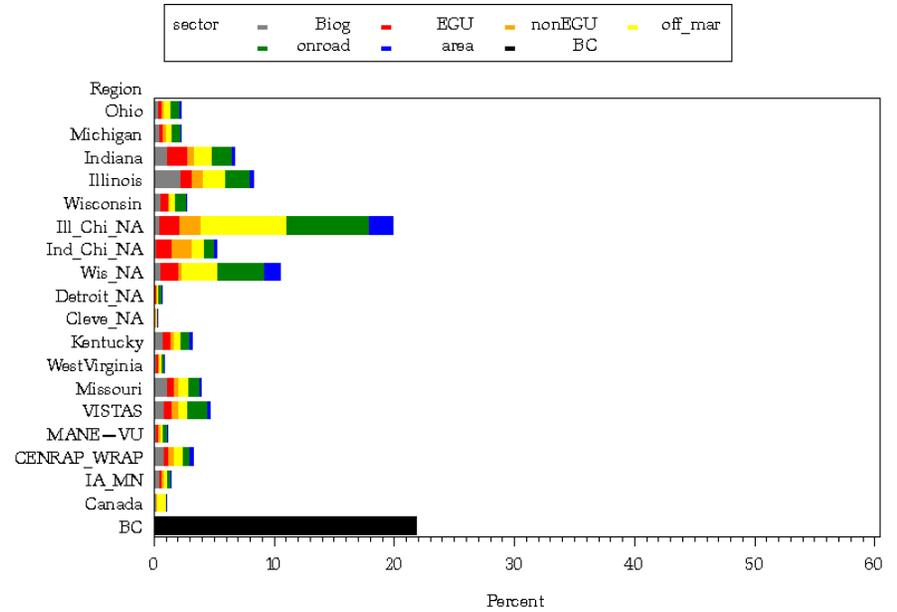




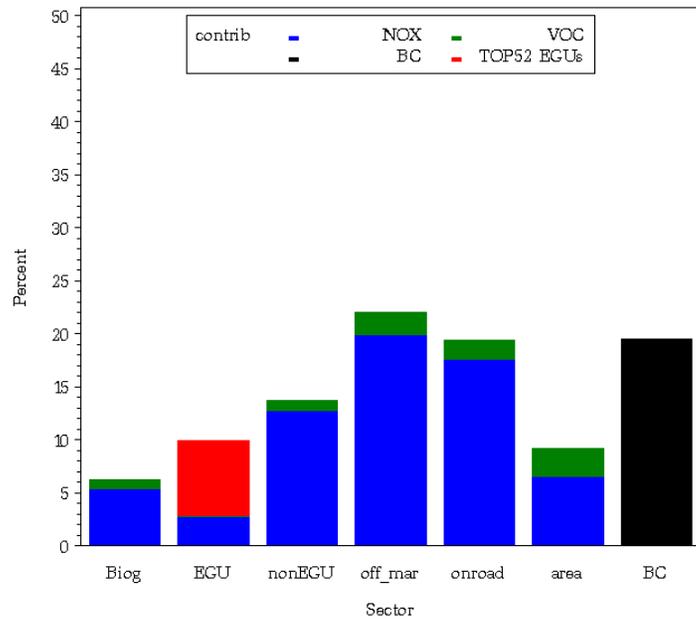
WI — Sheboygan : (5511700061) 2009M3R5\_osat



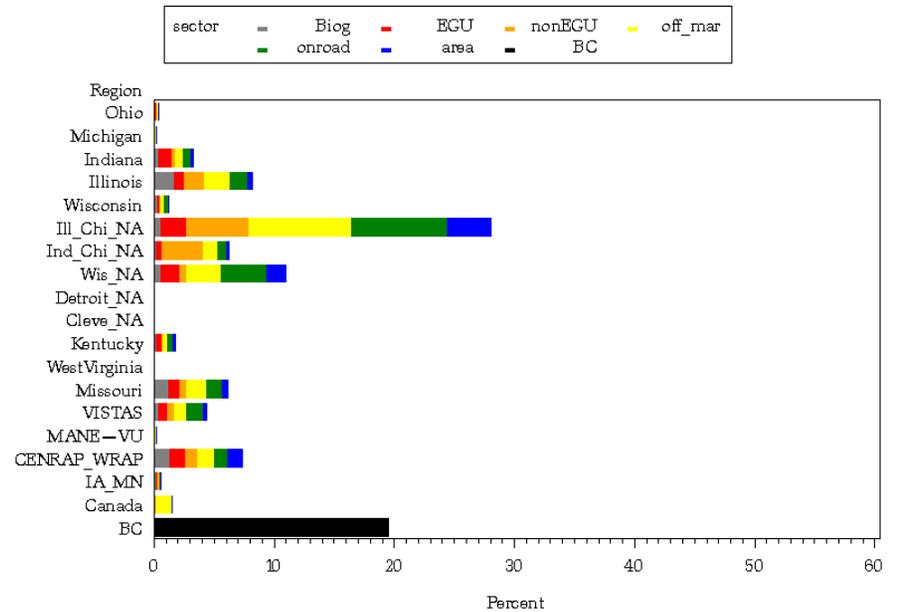
WI — Sheboygan : (5511700061) 2009M3R5\_osat



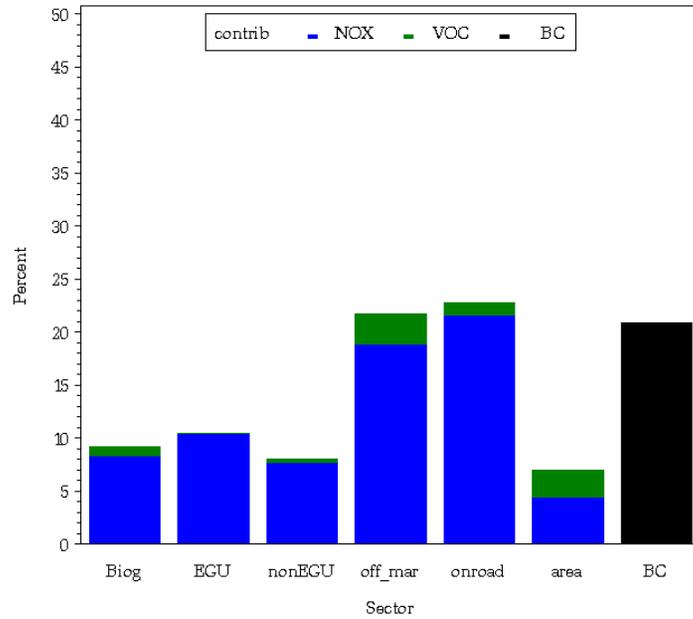
WI — Sheboygan : (5511700061) K2012R4S1a\_APCA\_nopig



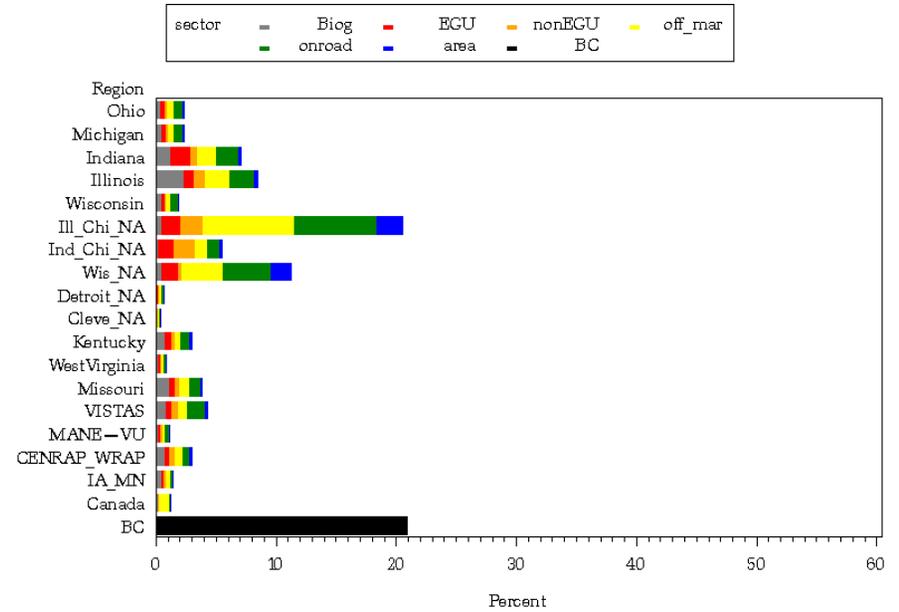
WI — Sheboygan : (5511700061) K2012R4S1a\_APCA\_nopig



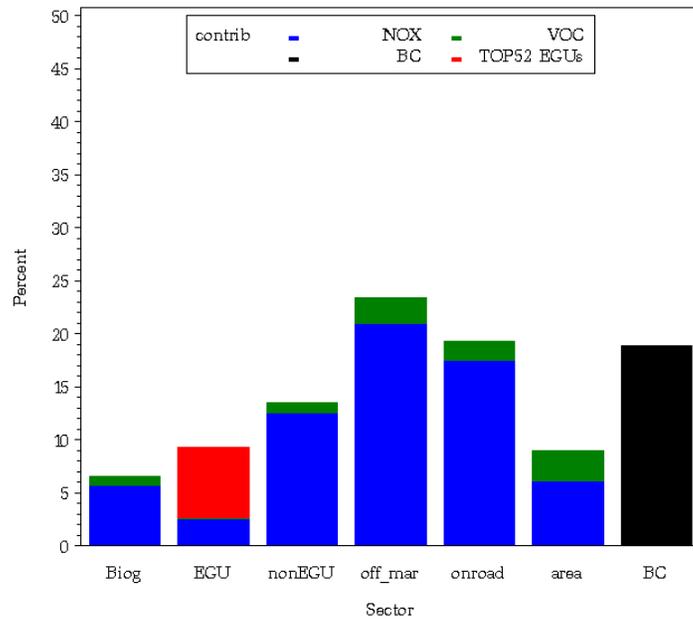
WI — Ozaukee : (5508900091) 2009M3R5\_osat



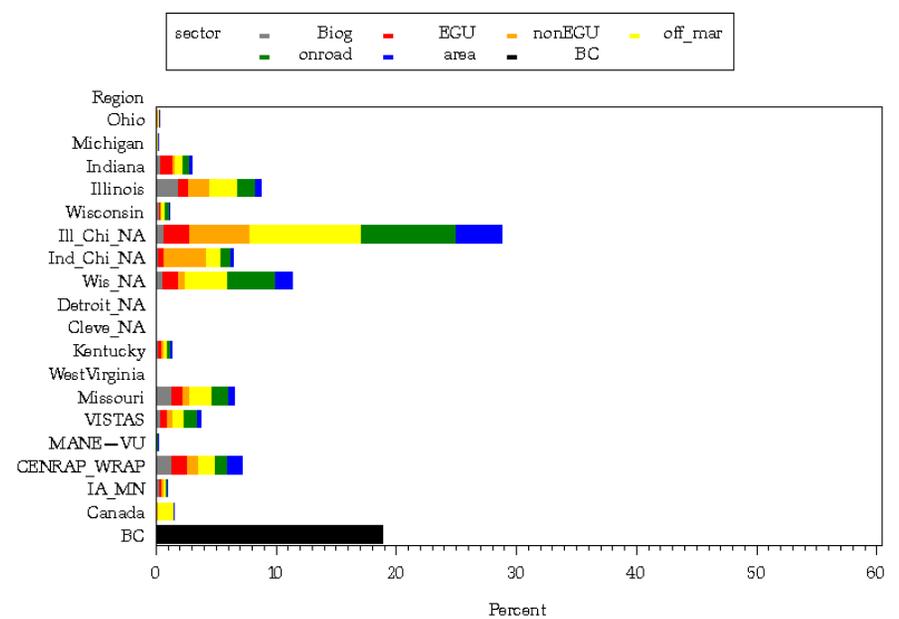
WI — Ozaukee : (5508900091) 2009M3R5\_osat



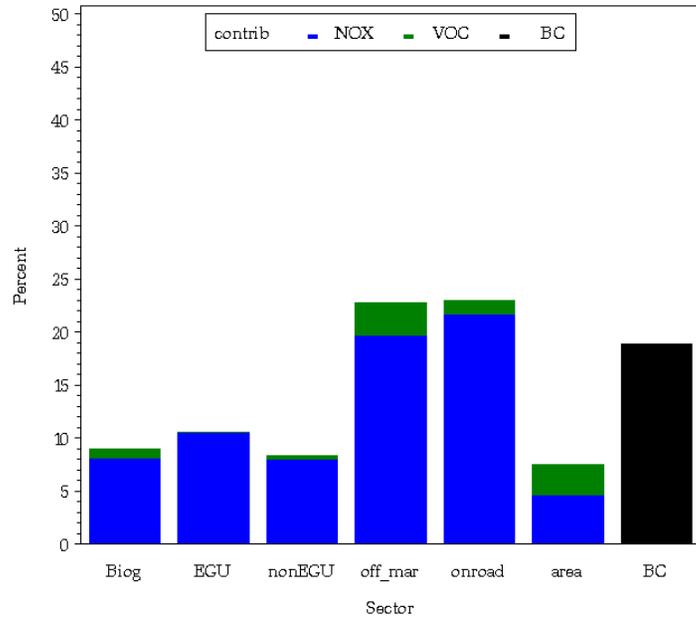
WI — Ozaukee : (5508900091) K2012R4S1a\_APCA\_nopig



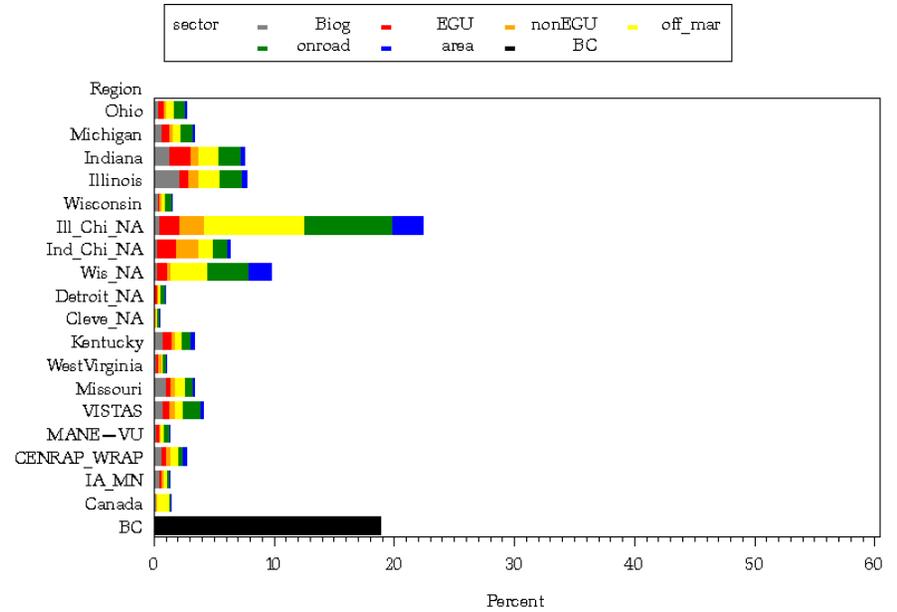
WI — Ozaukee : (5508900091) K2012R4S1a\_APCA\_nopig



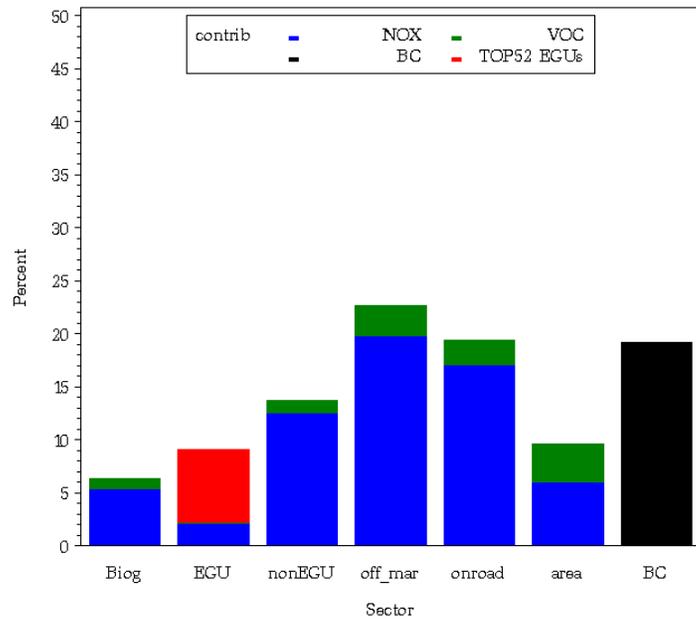
WI — Milwaukee : (550790085J) 2009M3R5\_osat



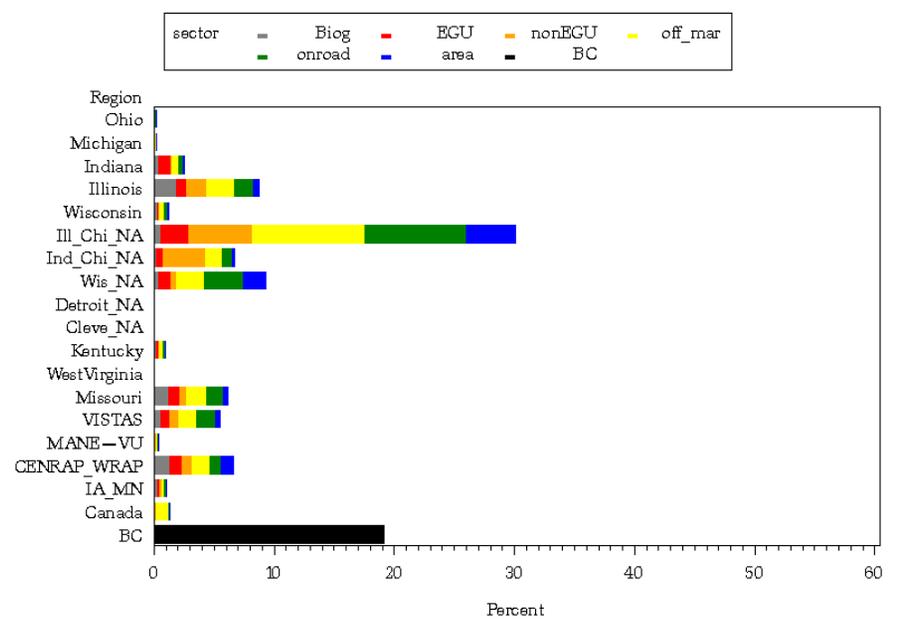
WI — Milwaukee : (550790085J) 2009M3R5\_osat



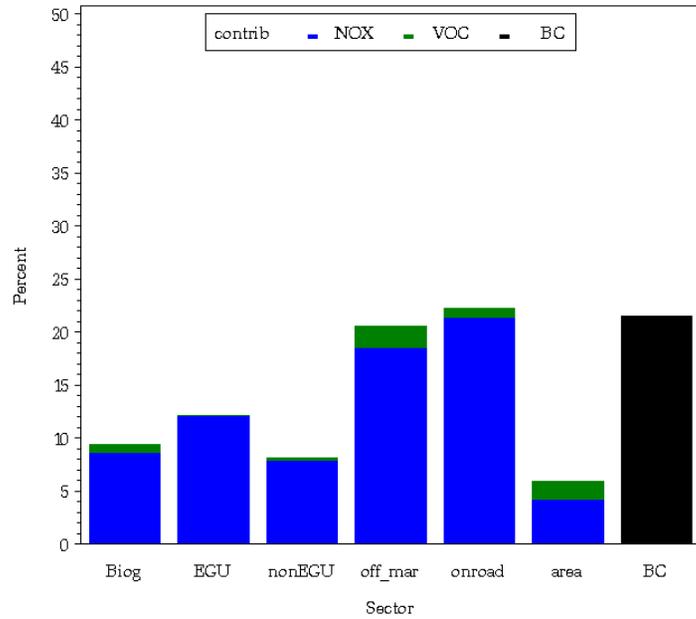
WI — Milwaukee : (550790085J) K2012R4S h\_APCA\_nopig



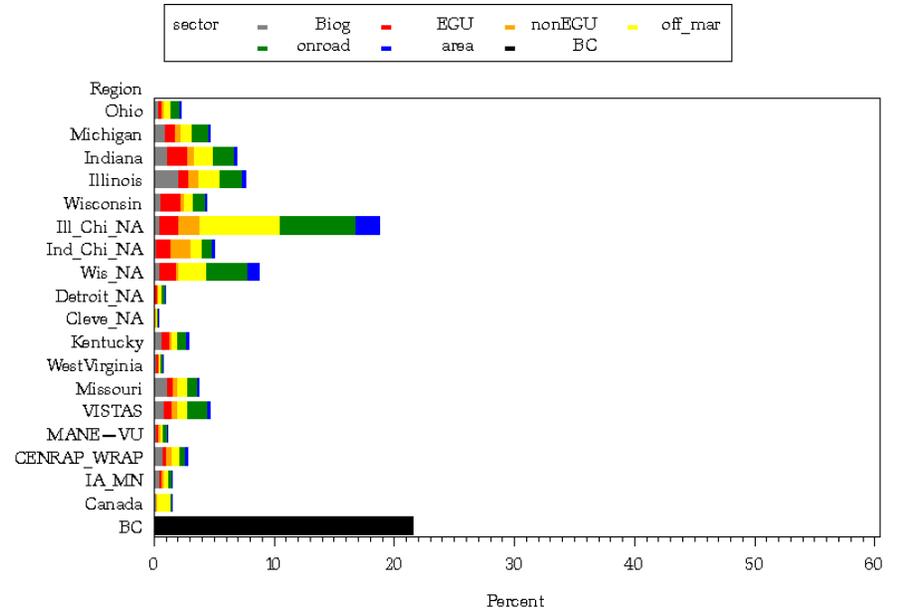
WI — Milwaukee : (550790085J) K2012R4S h\_APCA\_nopig



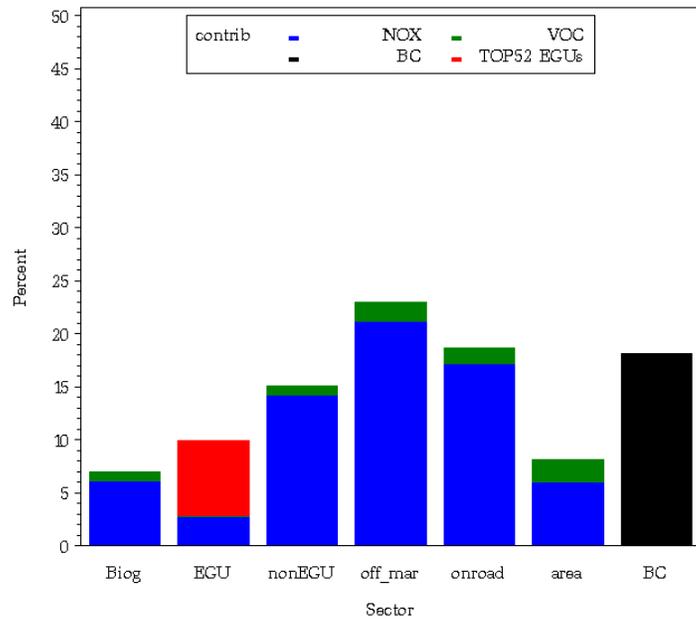
WI — Manitowoc : (5507100071) 2009M3R5\_osat



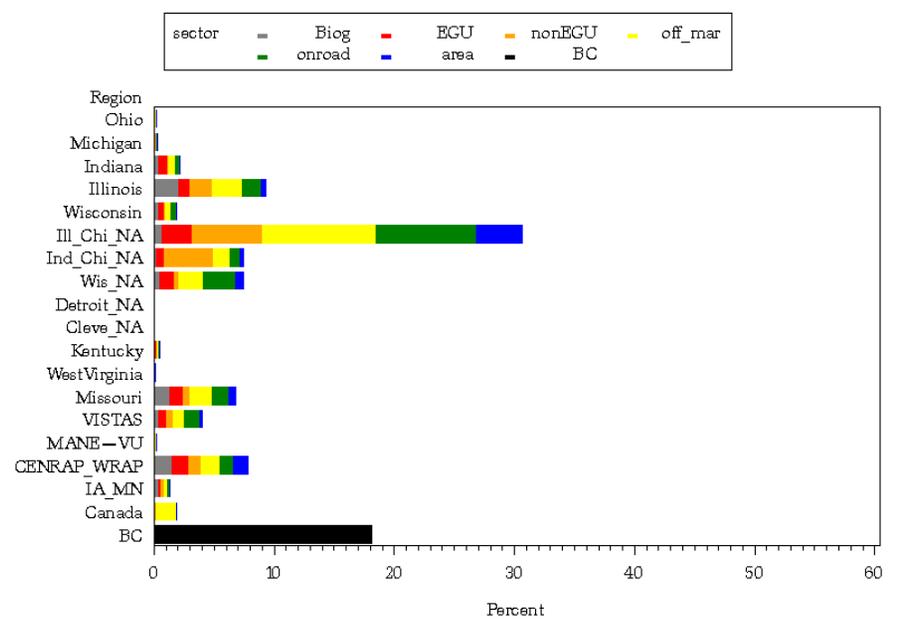
WI — Manitowoc : (5507100071) 2009M3R5\_osat



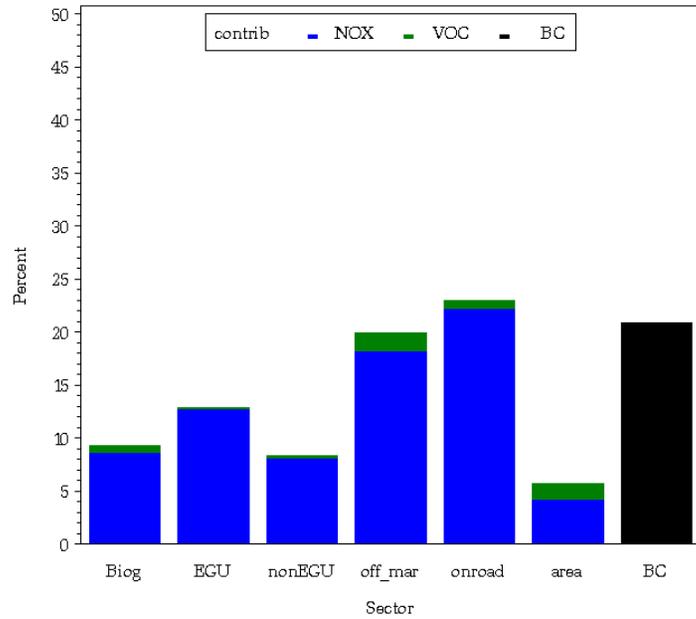
WI — Manitowoc : (5507100071) K2012R4S h\_APCA\_nopig



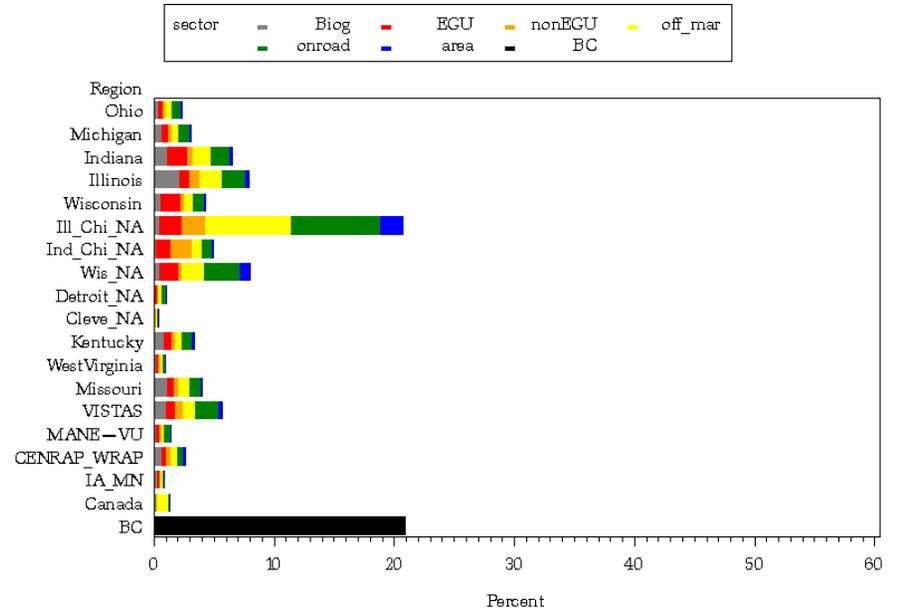
WI — Manitowoc : (5507100071) K2012R4S h\_APCA\_nopig



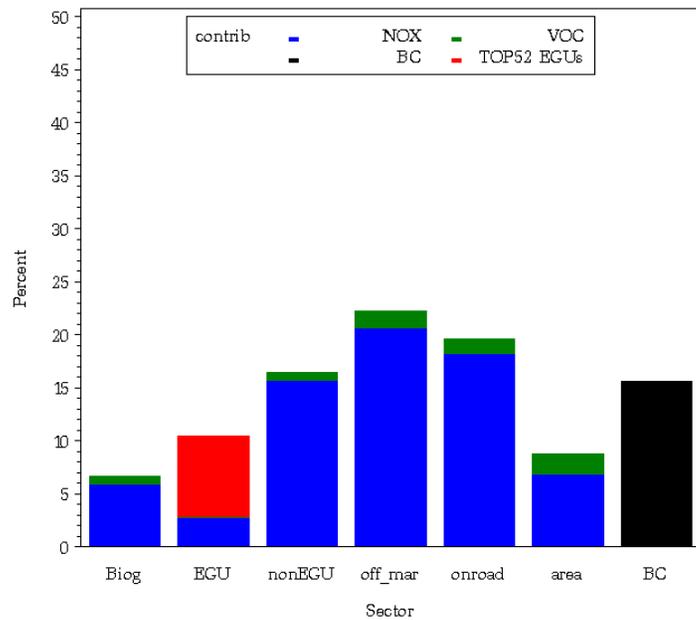
WI — Kewaunee : (5506100021) 2009M3R5\_osat



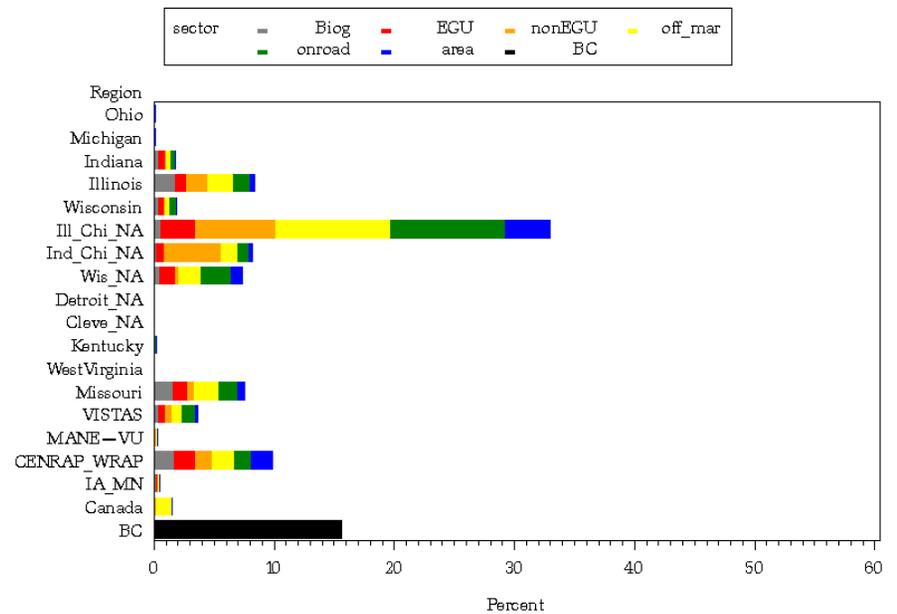
WI — Kewaunee : (5506100021) 2009M3R5\_osat



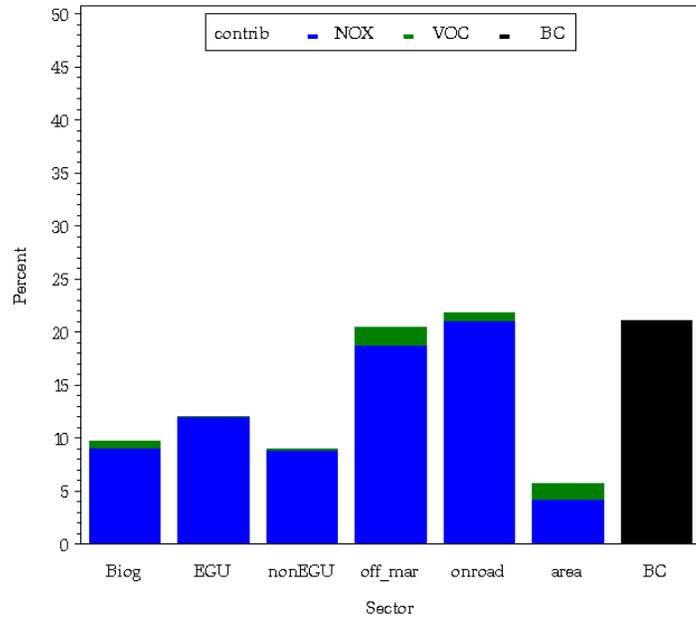
WI — Kewaunee : (5506100021) K2012R4S1a\_APCA\_nopig



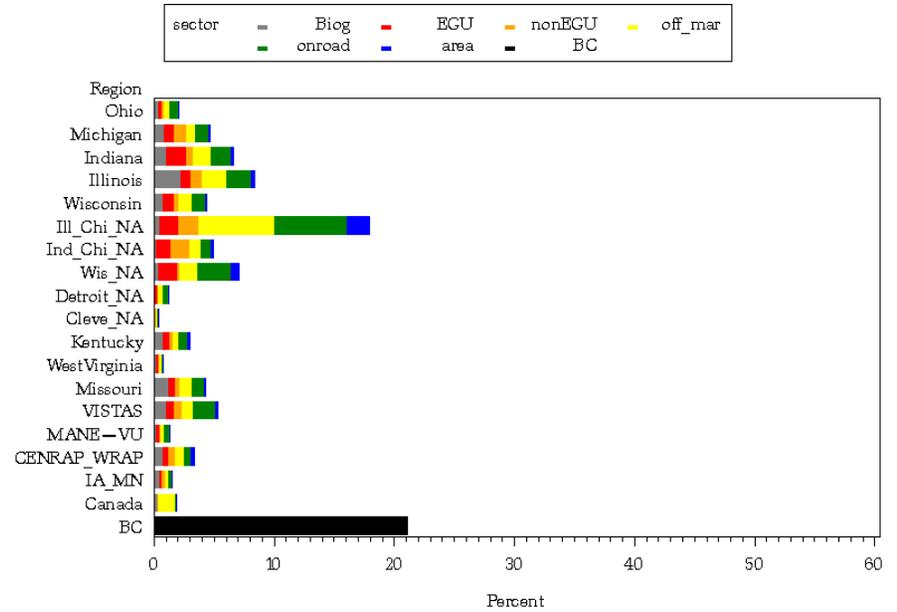
WI — Kewaunee : (5506100021) K2012R4S1a\_APCA\_nopig



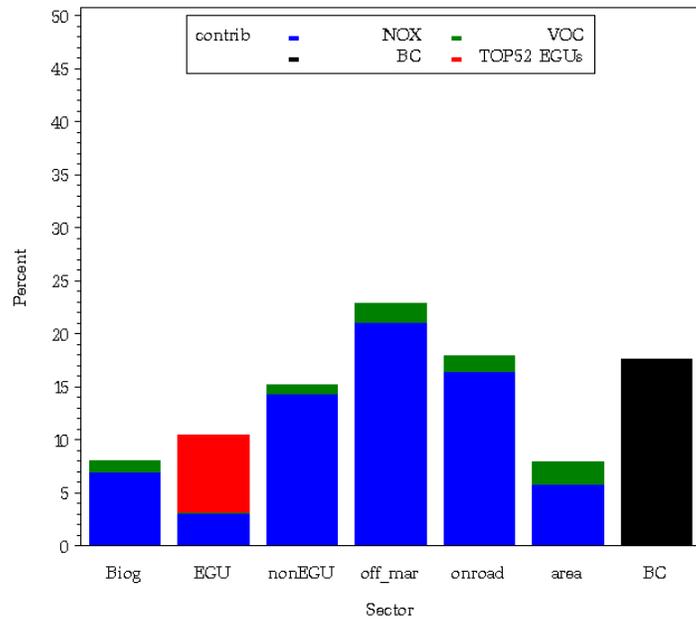
WI — Door : (5502900041) 2009M3R5\_osat



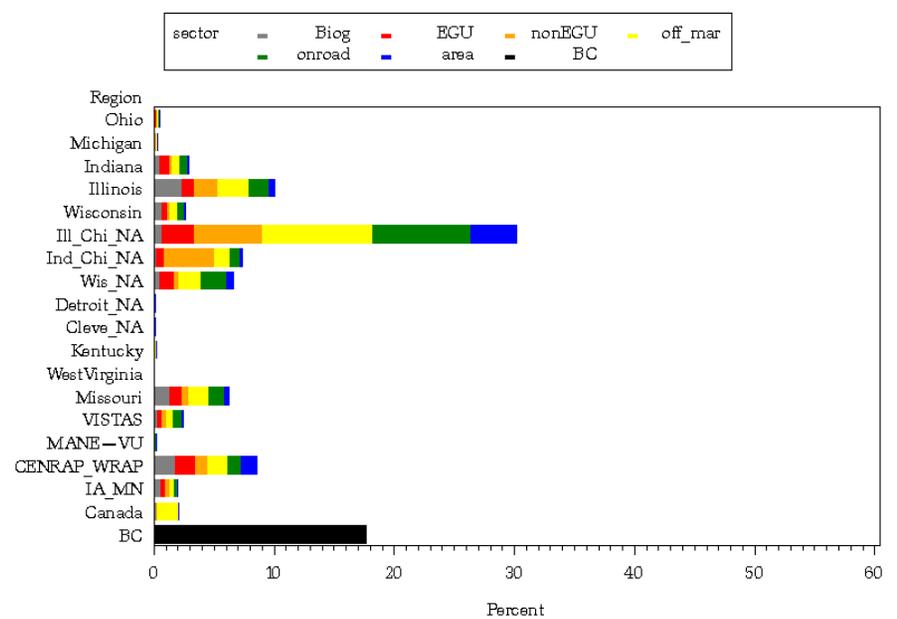
WI — Door : (5502900041) 2009M3R5\_osat



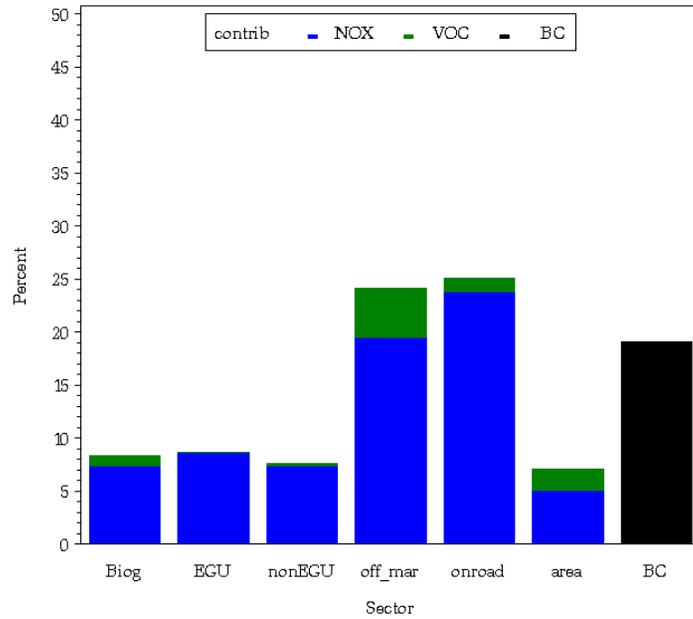
WI — Door : (5502900041) K2012R4S1a\_APCA\_nopig



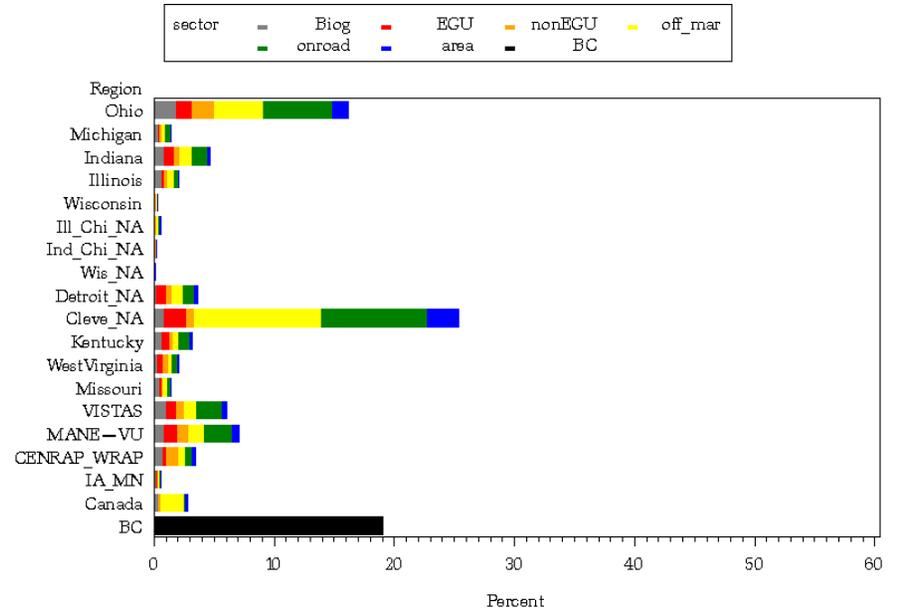
WI — Door : (5502900041) K2012R4S1a\_APCA\_nopig



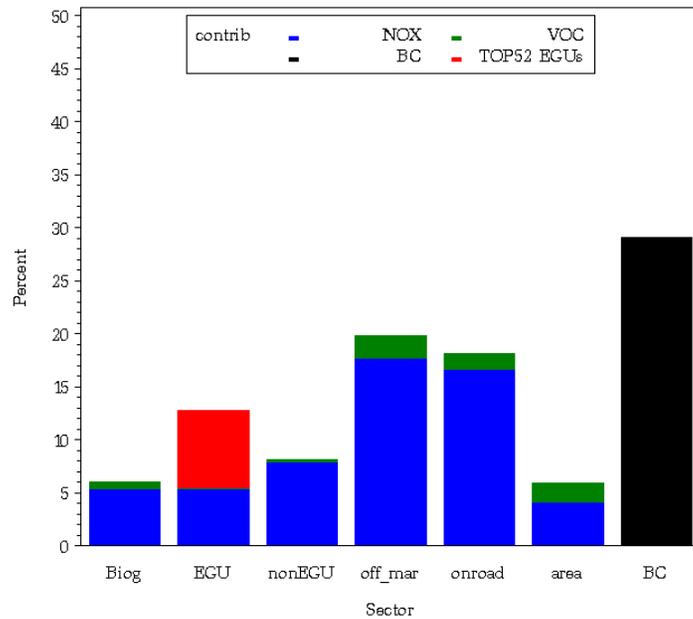
OH — Lake : (3908500031) 2009M3R5\_osat



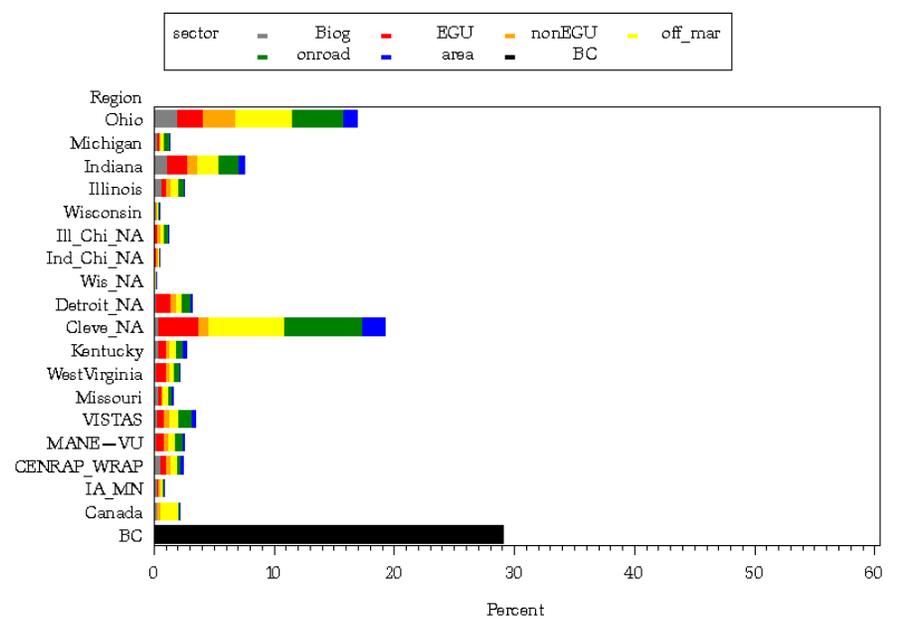
OH — Lake : (3908500031) 2009M3R5\_osat



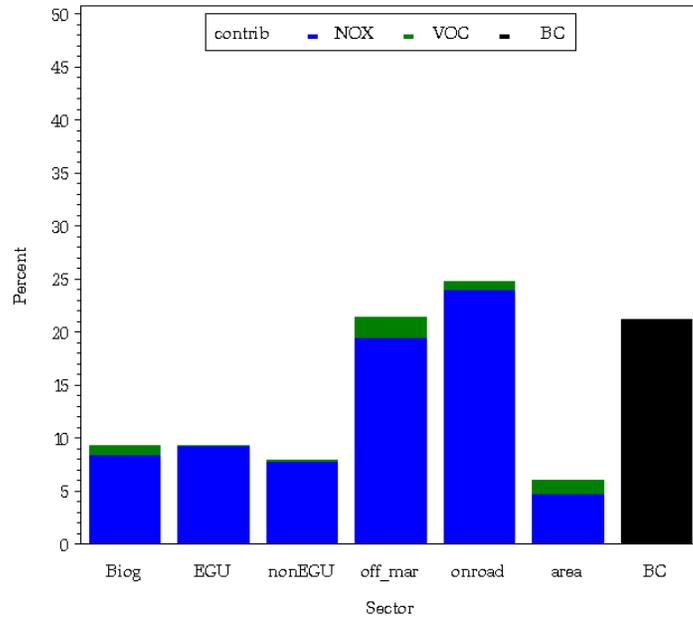
OH — Lake : (3908500031) K2012R4S1a\_APCA\_nopig



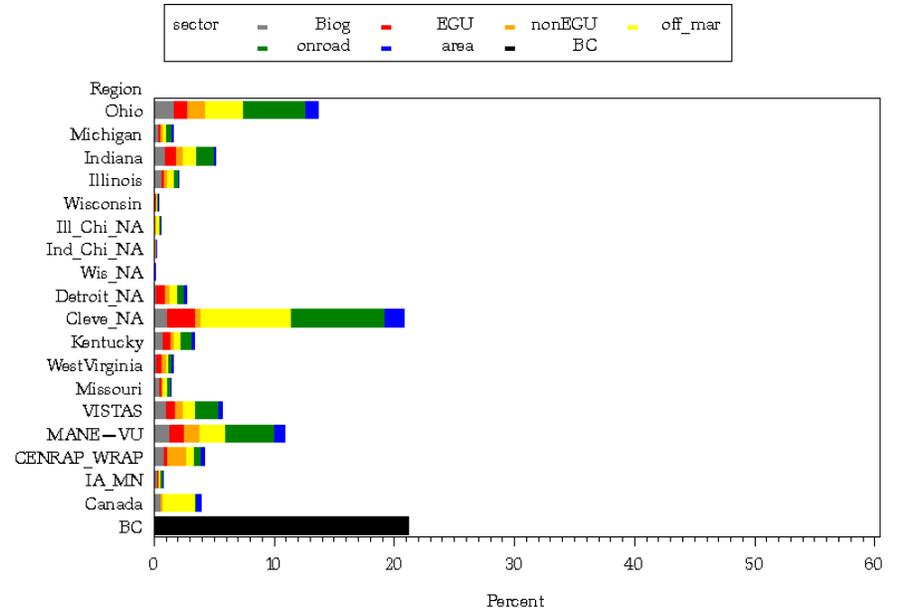
OH — Lake : (3908500031) K2012R4S1a\_APCA\_nopig



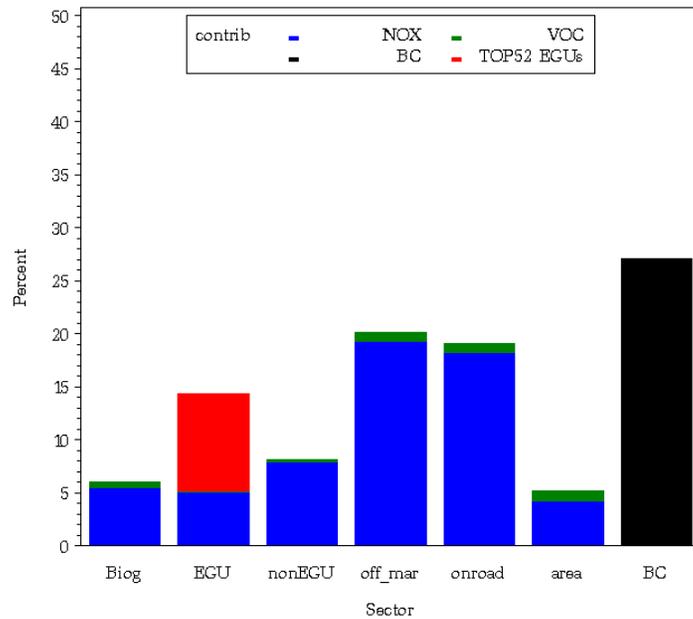
OH - Ashtabula : (3900710011) 2009M3R5\_osat



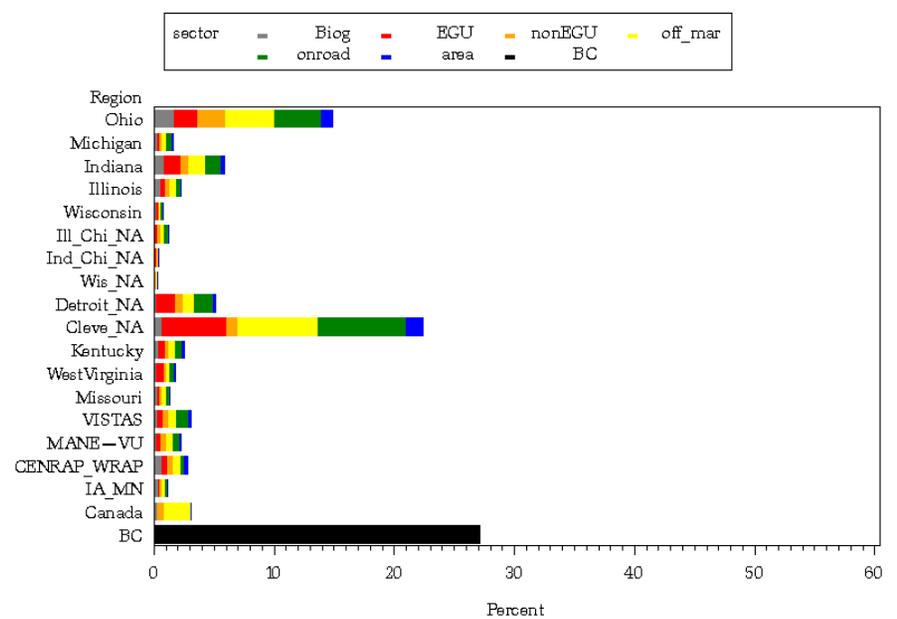
OH - Ashtabula : (3900710011) 2009M3R5\_osat



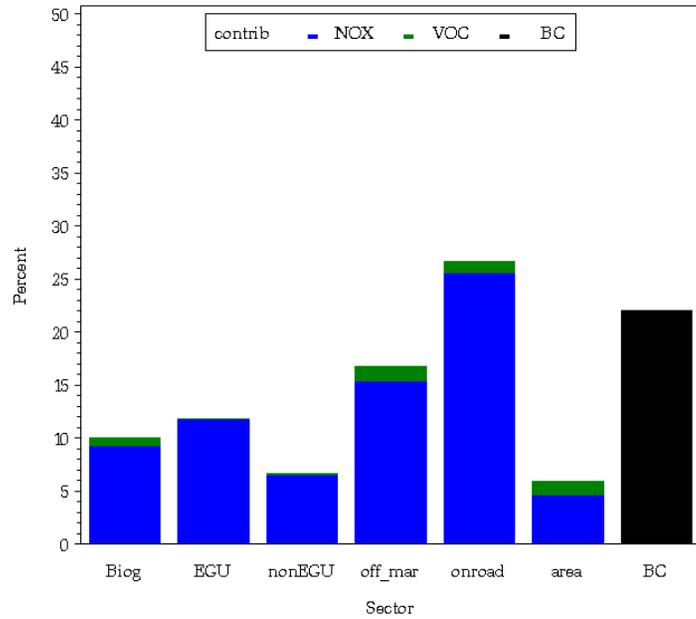
OH - Ashtabula : (3900710011) K2012R4S h\_APCA\_nopig



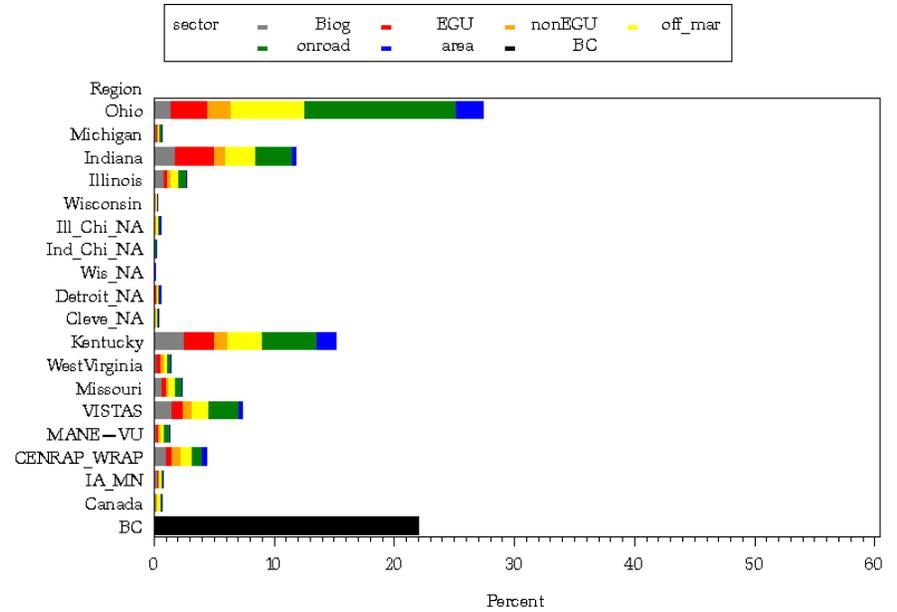
OH - Ashtabula : (3900710011) K2012R4S h\_APCA\_nopig



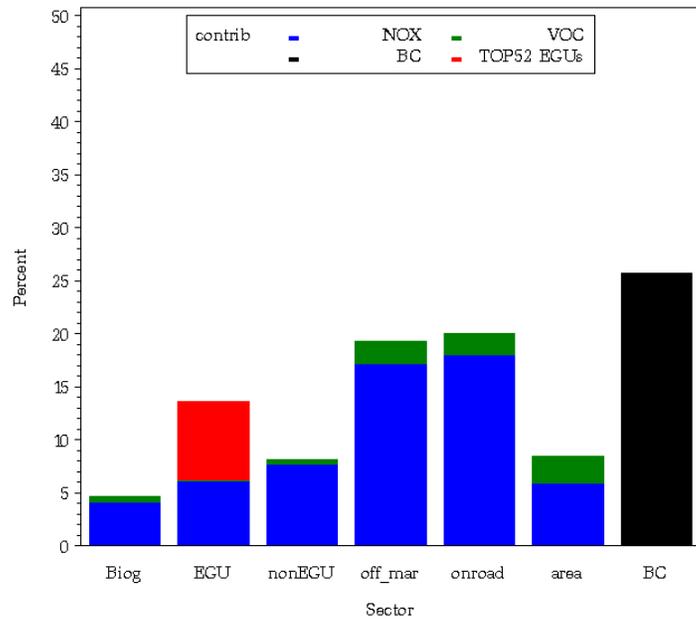
OH — Hamilton : (3906100061) 2009M3R5\_osat



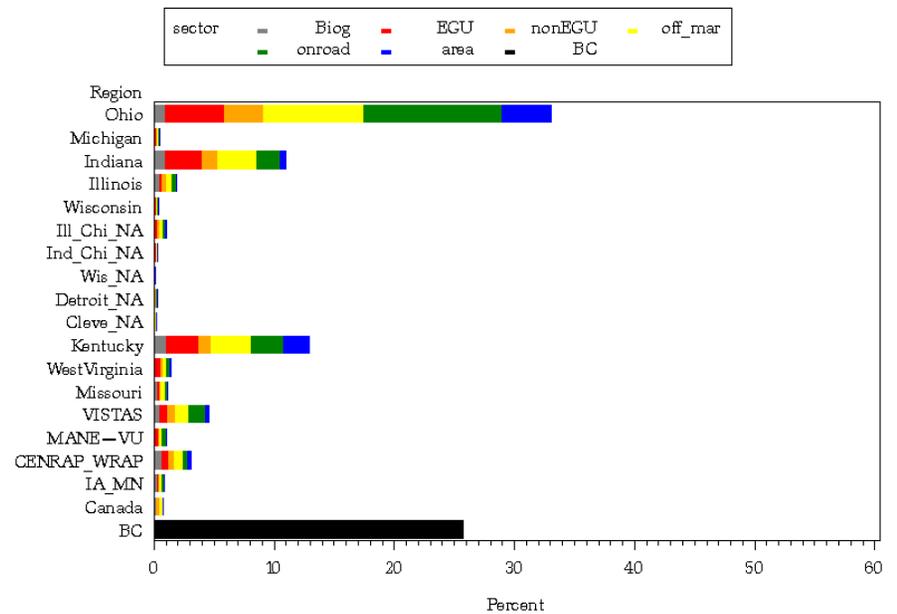
OH — Hamilton : (3906100061) 2009M3R5\_osat



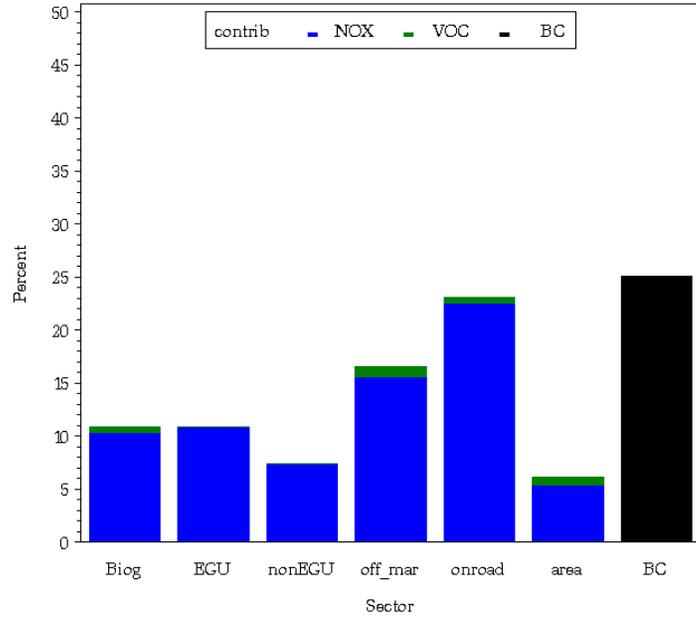
OH — Hamilton : (3906100061) K2012R4S1a\_APCA\_nopig



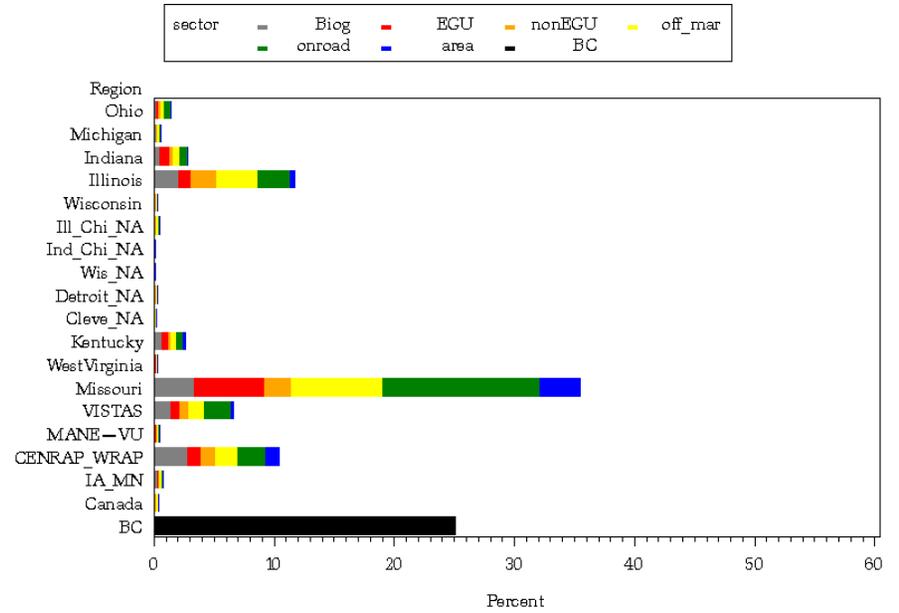
OH — Hamilton : (3906100061) K2012R4S1a\_APCA\_nopig



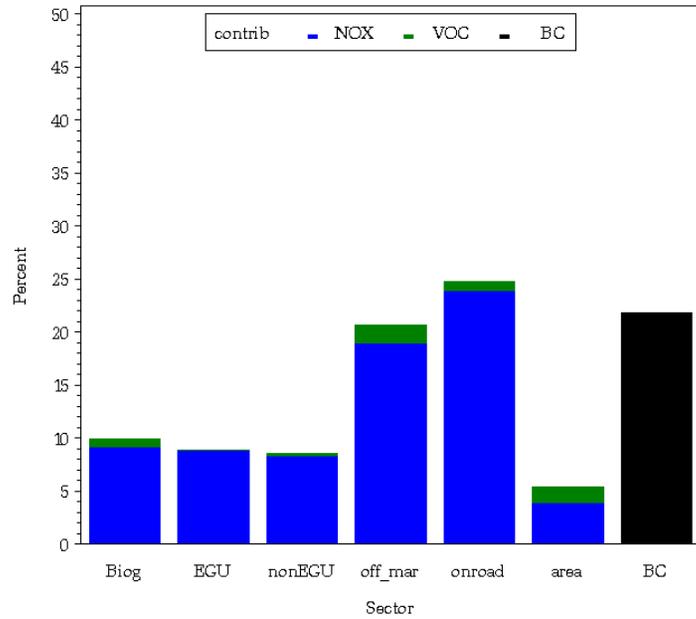
MO — St.Charles : (2918310021) 2009M3R5\_osat



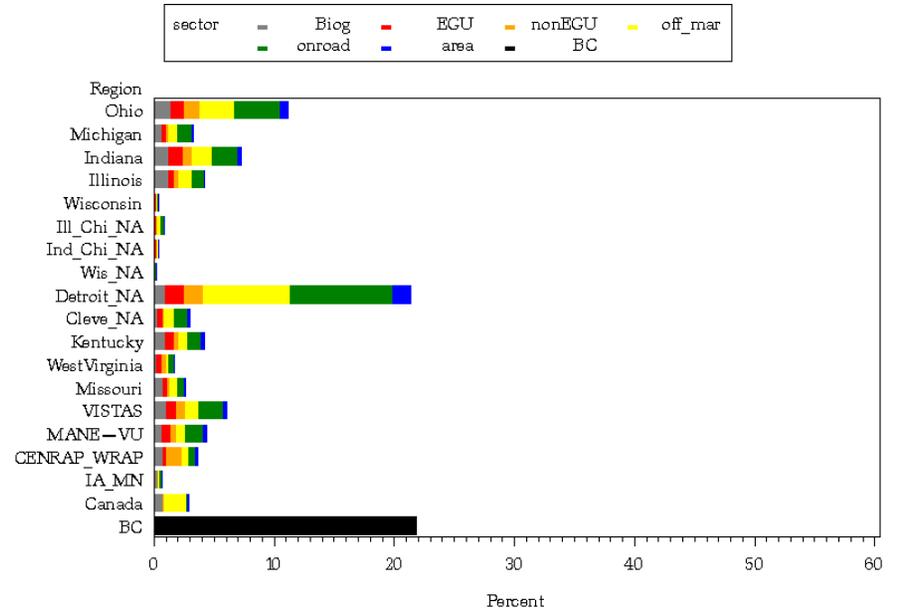
MO — St.Charles : (2918310021) 2009M3R5\_osat



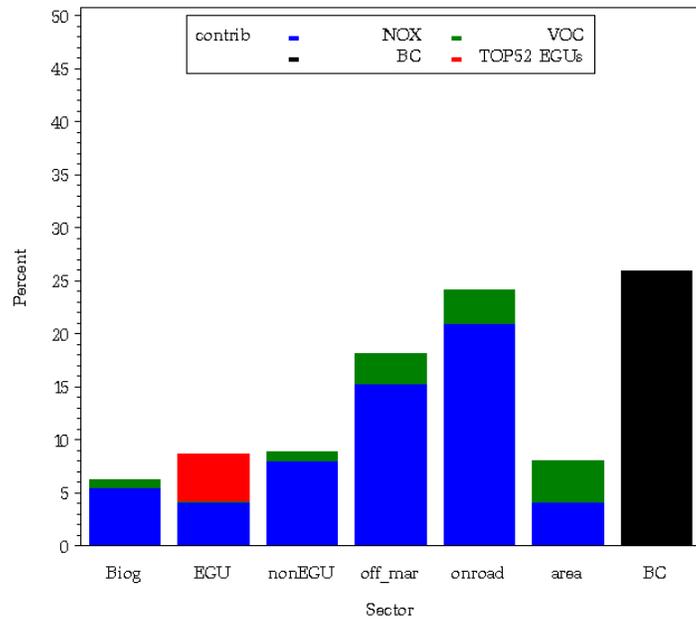
MI - Macomb : (2609900091) 2009M3R5\_osat



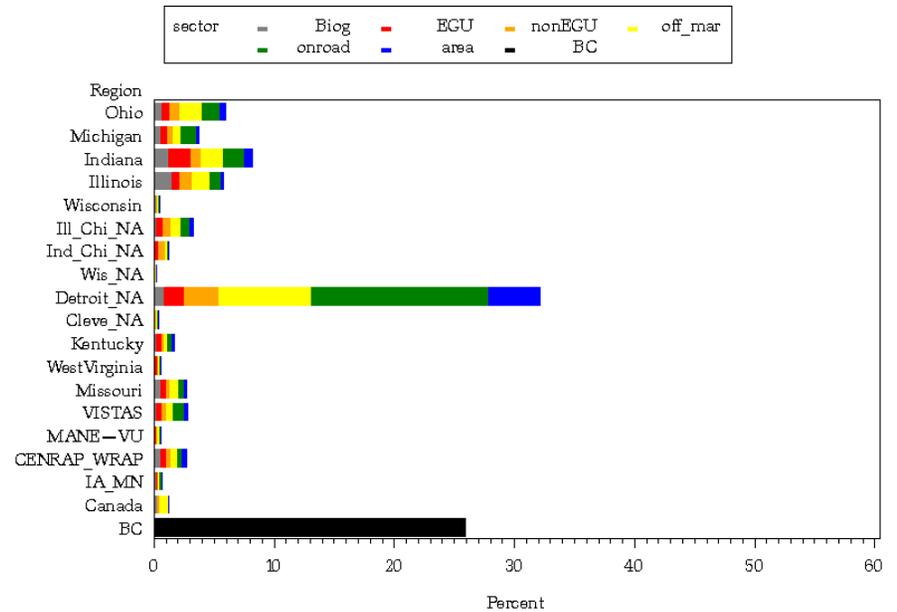
MI - Macomb : (2609900091) 2009M3R5\_osat



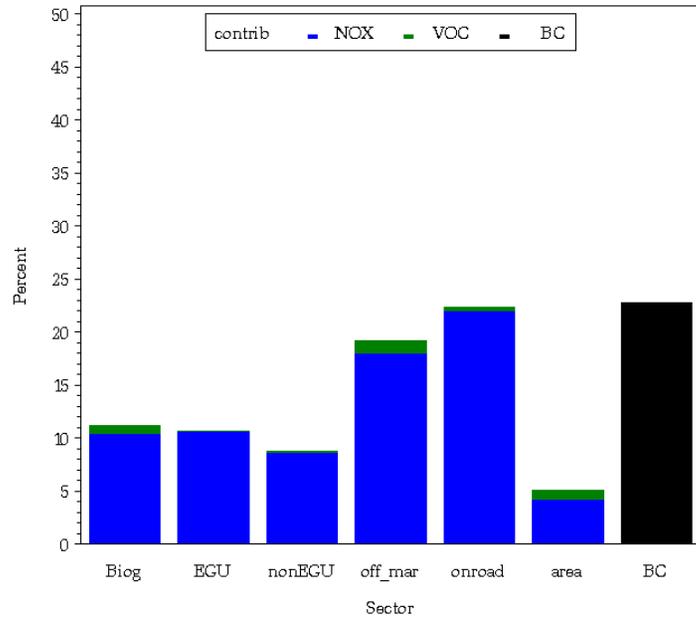
MI - Macomb : (2609900091) K2012R4S1a\_APCA\_nopig



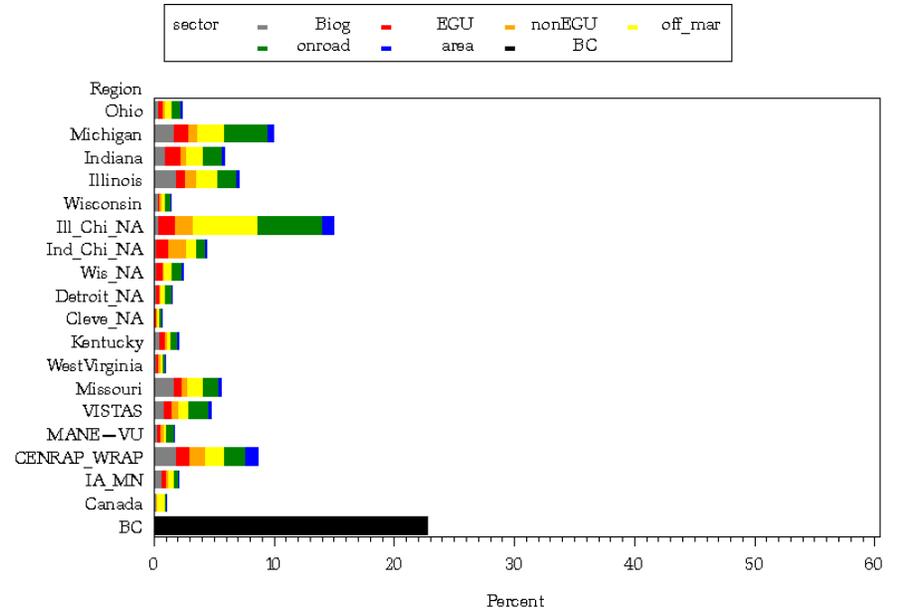
MI - Macomb : (2609900091) K2012R4S1a\_APCA\_nopig



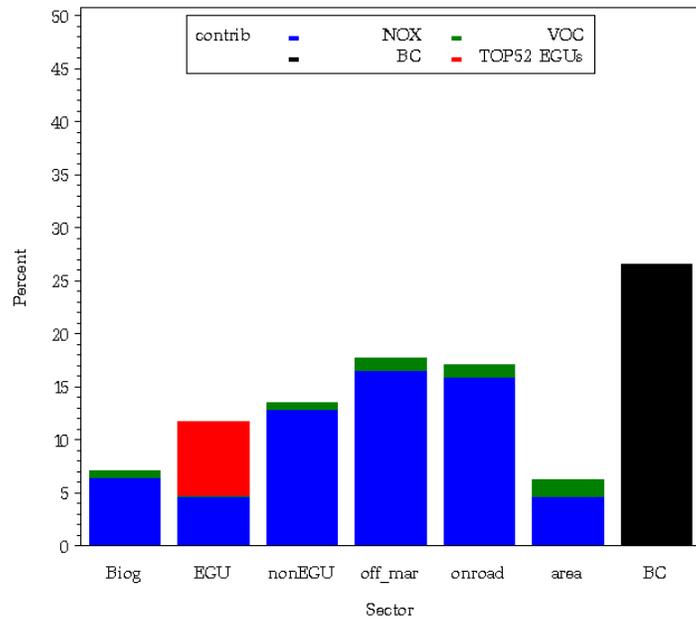
MI — Allegan : (260050003 I) 2009M3R5\_osat



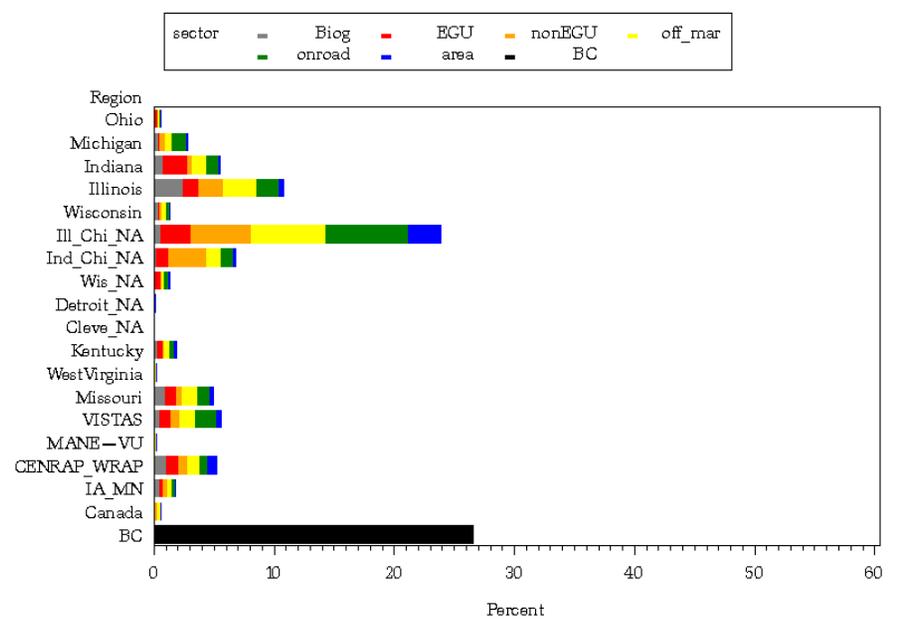
MI — Allegan : (260050003 I) 2009M3R5\_osat



MI — Allegan : (260050003 I) K2012R4S1a\_APCA\_nopig

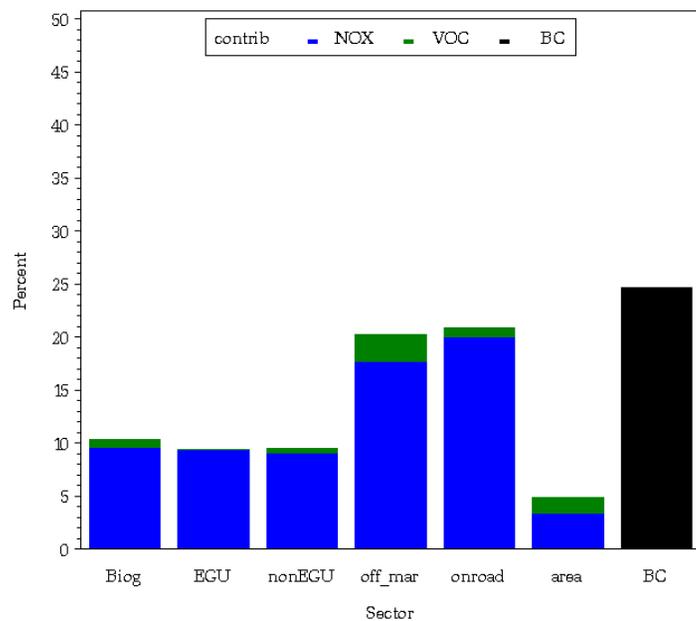


MI — Allegan : (260050003 I) K2012R4S1a\_APCA\_nopig

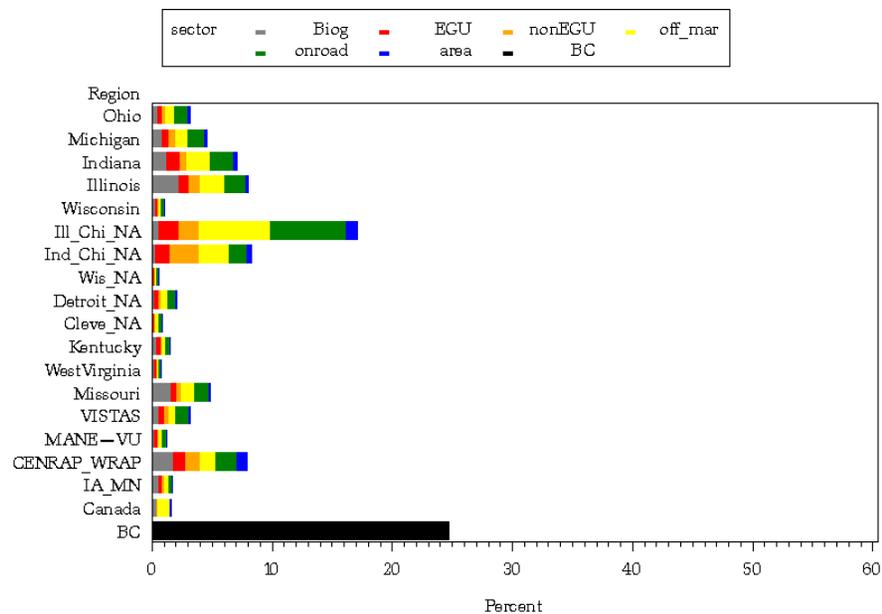




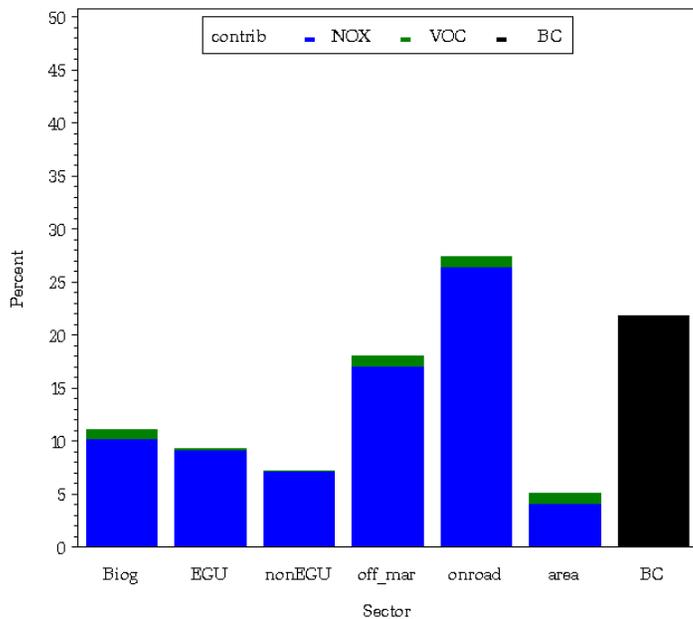
IN - Lake : (180892008) 2009M3R5\_osat



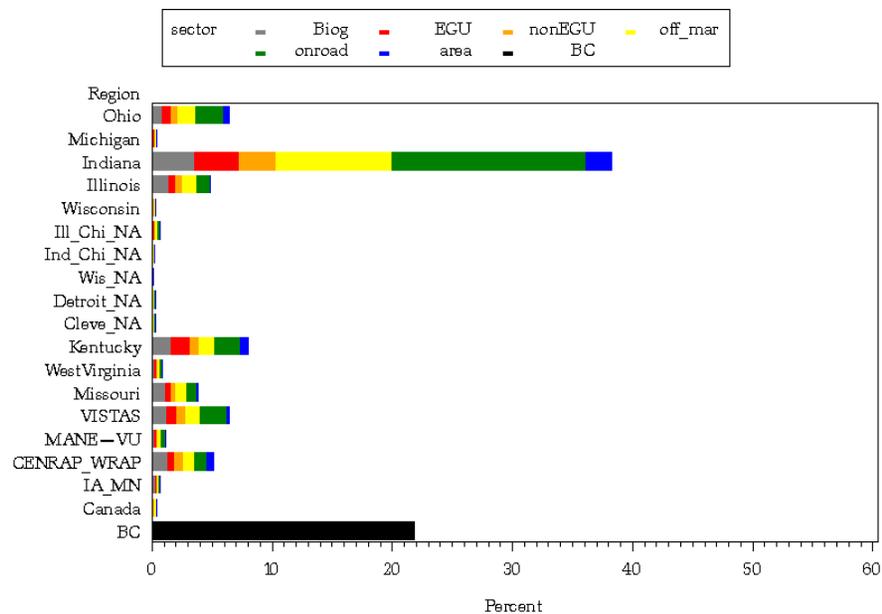
IN - Lake : (180892008) 2009M3R5\_osat



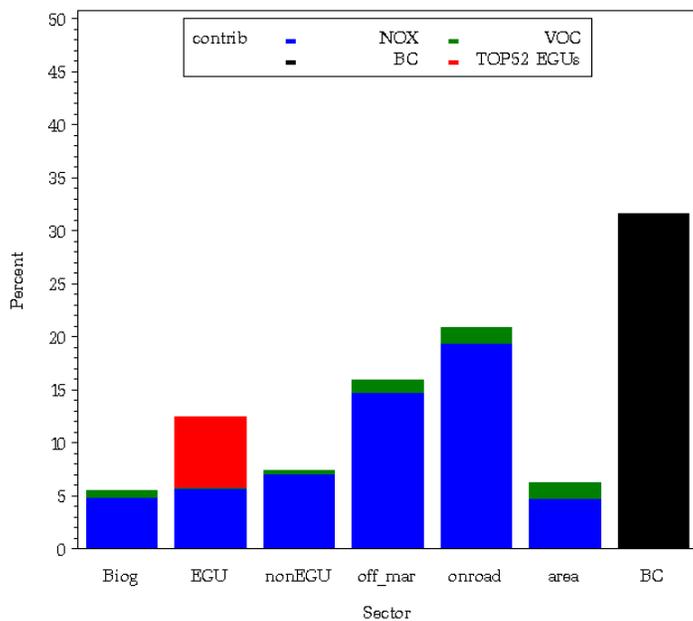
IN - Hamilton : (1805710011) 2009M3R5\_osat



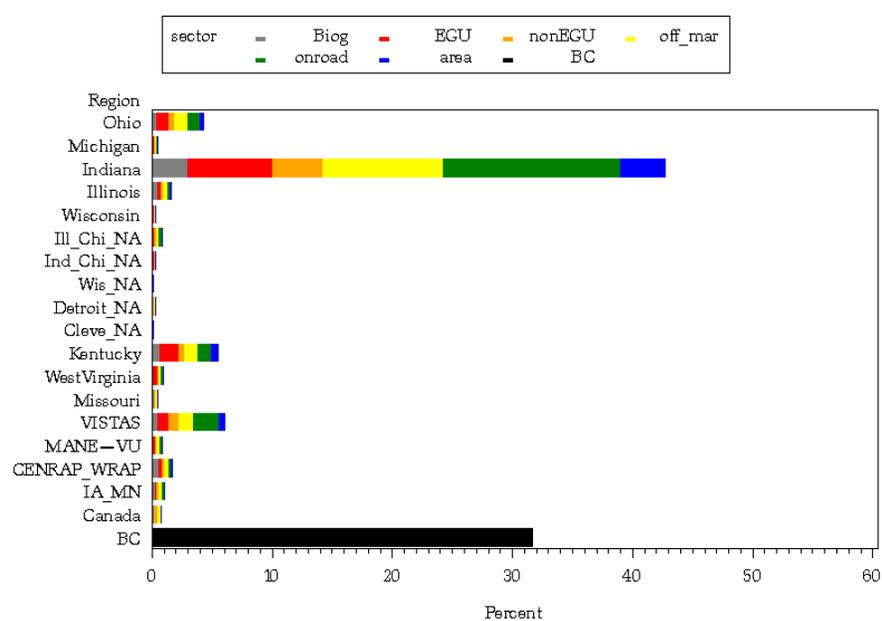
IN - Hamilton : (1805710011) 2009M3R5\_osat



IN - Hamilton : (1805710011) K2012R4S1a\_APCA\_nopig



IN - Hamilton : (1805710011) K2012R4S1a\_APCA\_nopig



## **APPENDIX III**

### **PM2.5 Source Apportionment Modeling Results**

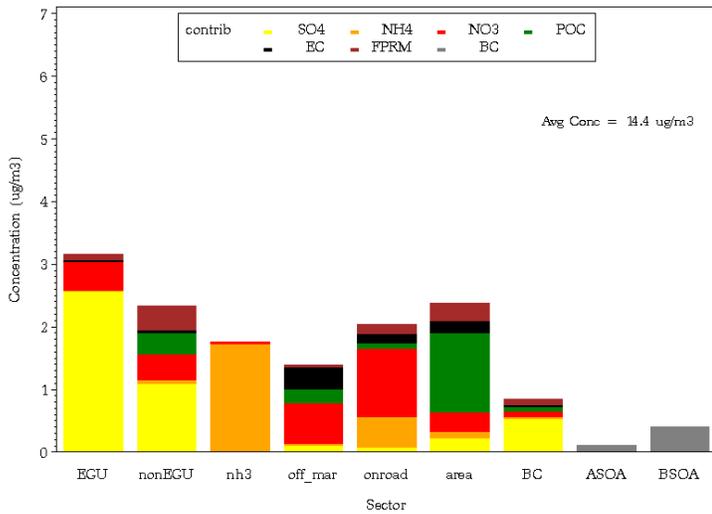




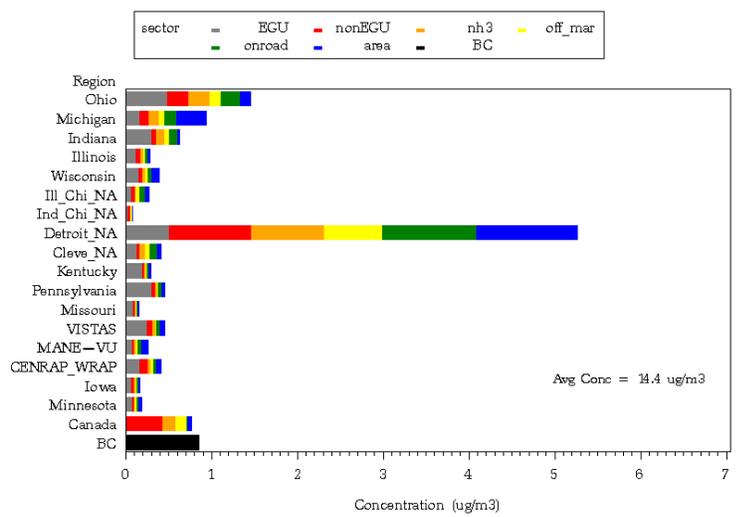
# Dearborn, Michigan

## 2005 (Round 5)

MI - Wayne : (261630033) baseM3

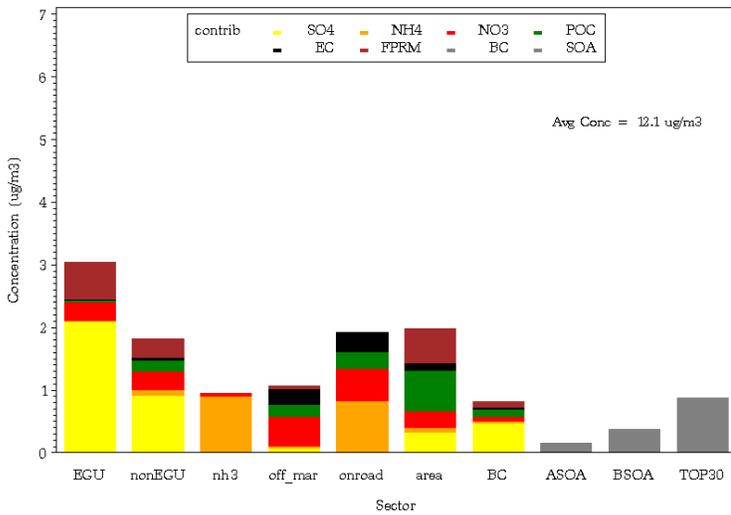


MI - Wayne : (261630033) baseM3

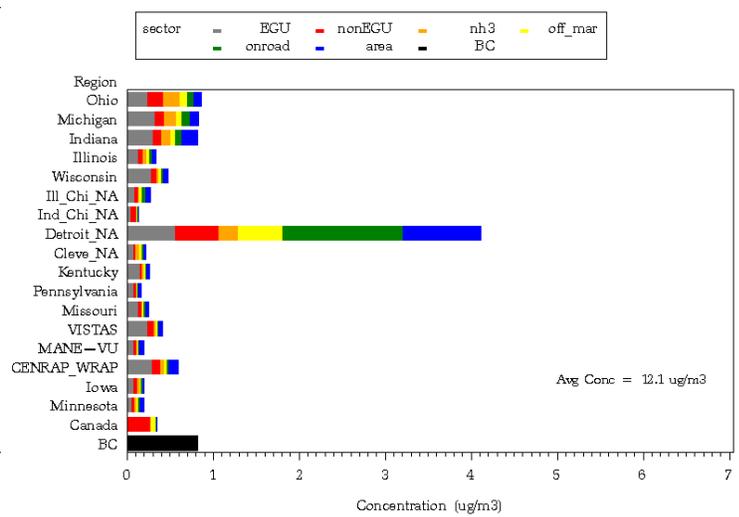


## 2012 (Round 4)

MI - Wayne : (261630033) K2012R4S1a

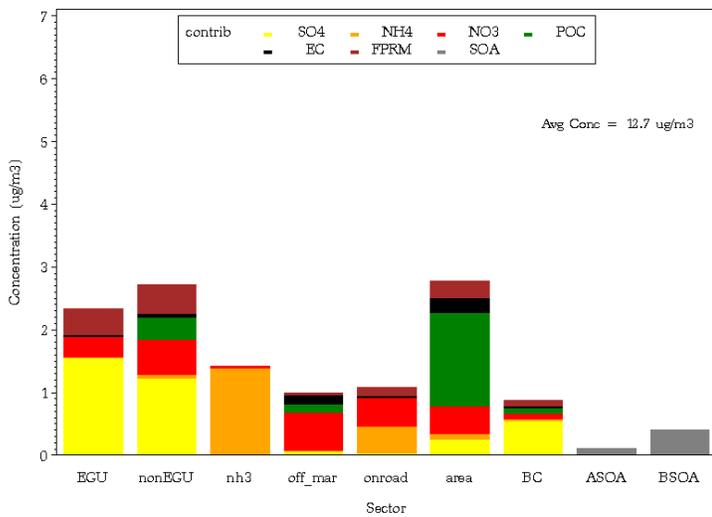


MI - Wayne : (261630033) K2012R4S1a

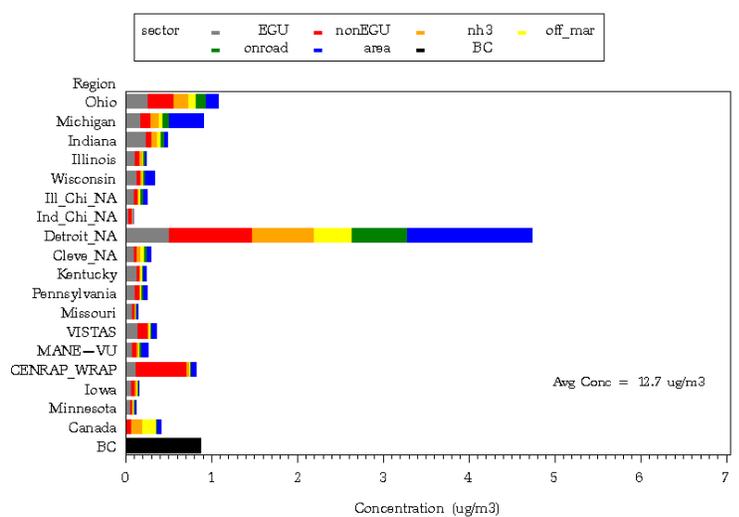


## 2018 (Round 5)

MI - Wayne : (261630033) 2018M3R5.1s1a



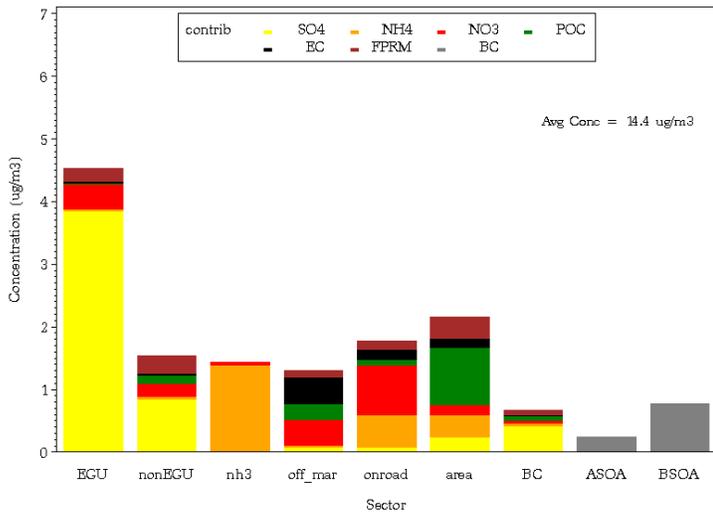
MI - Wayne : (261630033) 2018M3R5.1s1a



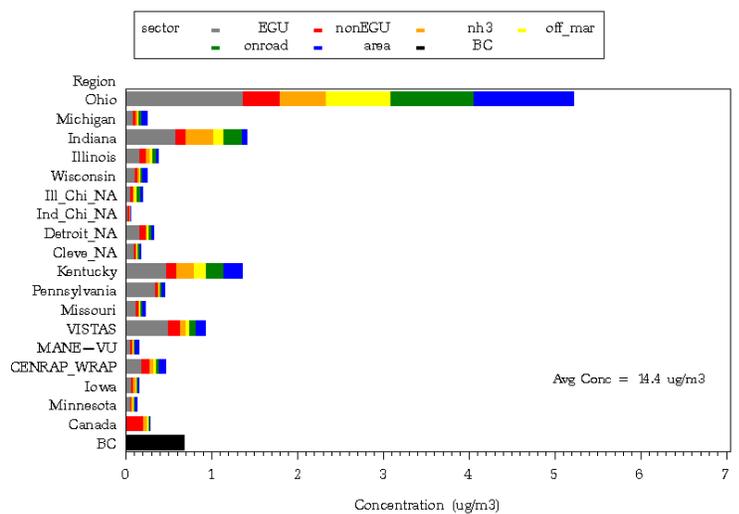
# Cincinnati, Ohio

## 2005 (Round 5)

OH - Hamilton : (390618001) baseM3

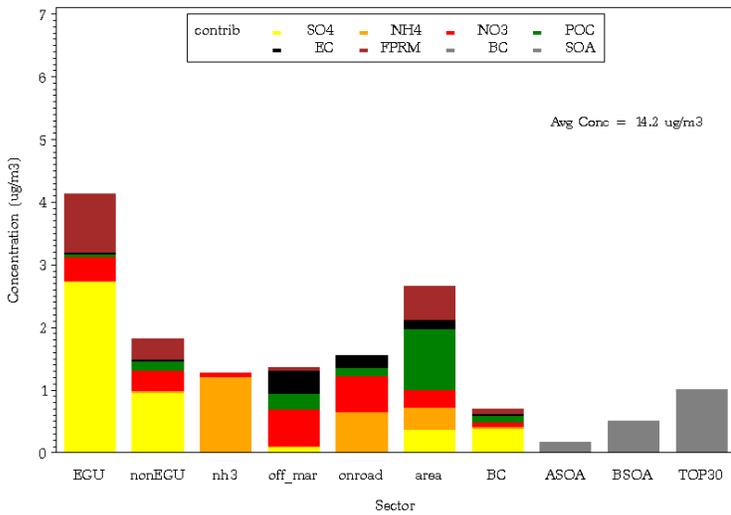


OH - Hamilton : (390618001) baseM3

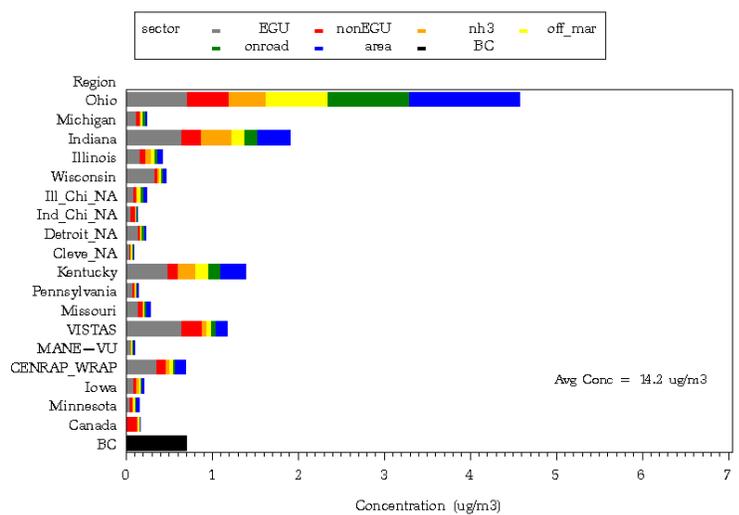


## 2012 (Round 4)

OH - Hamilton : (390618001) K2012R4S1a

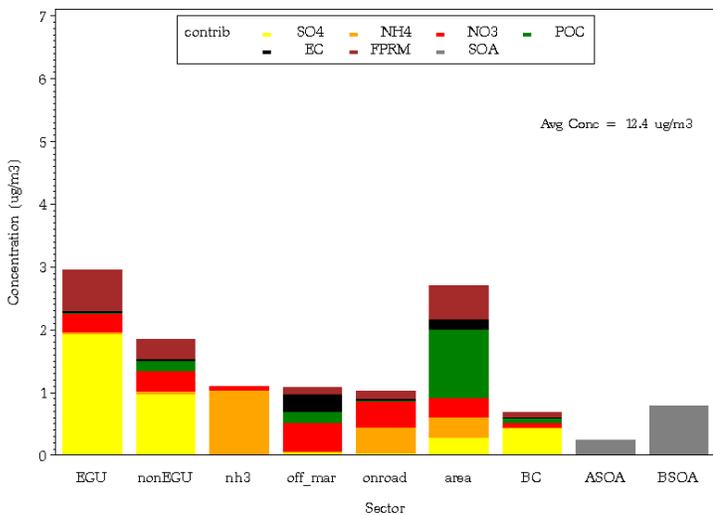


OH - Hamilton : (390618001) K2012R4S1a

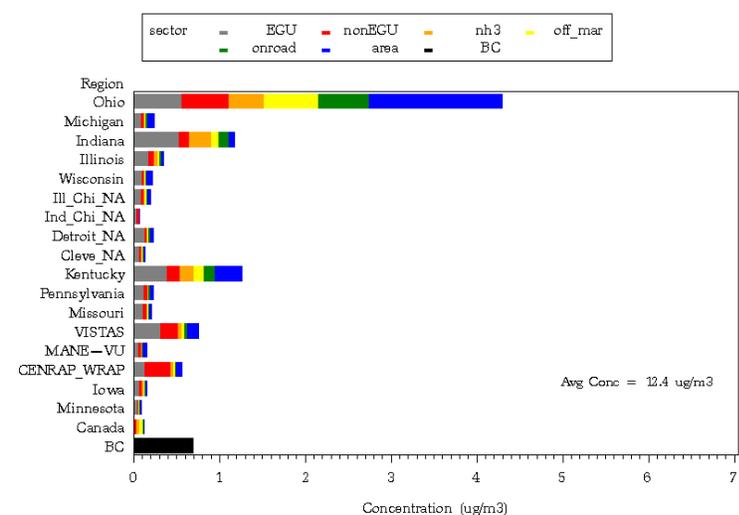


## 2018 (Round 5)

OH - Hamilton : (390610014) 2018M3R5.1s1a



OH - Hamilton : (390610014) 2018M3R5.1s1a







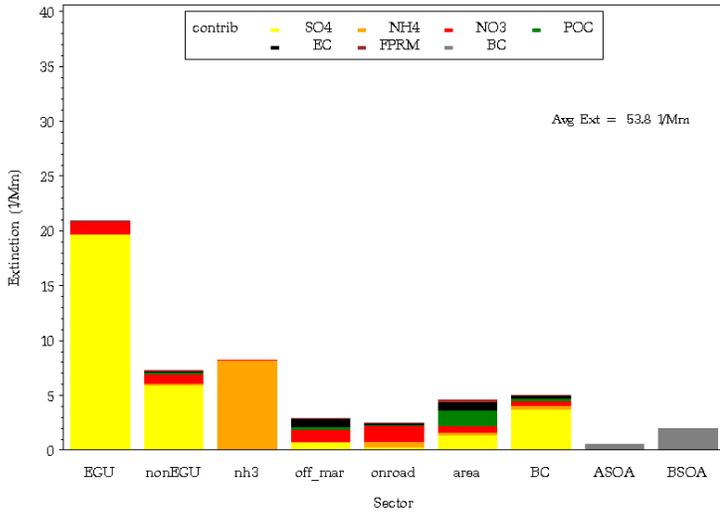
## **APPENDIX IV**

### **Haze Source Apportionment Modeling Results**

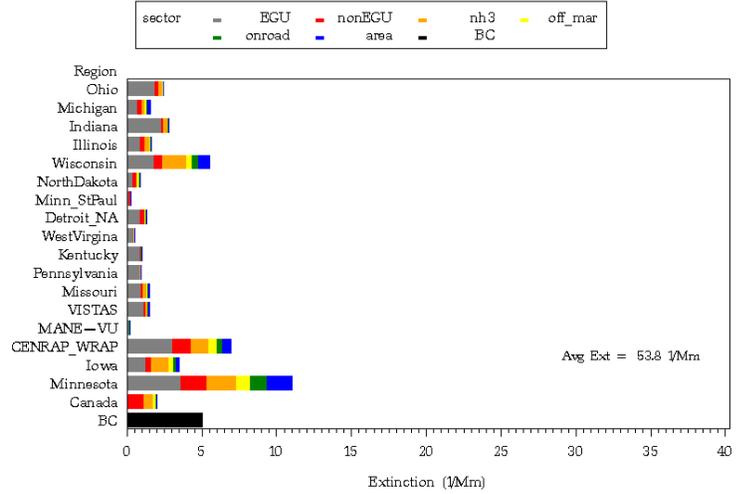
# Boundary Waters, Minnesota

## 2005 (Round 5)

BOWA1 — baseM3\_psatAP25so4

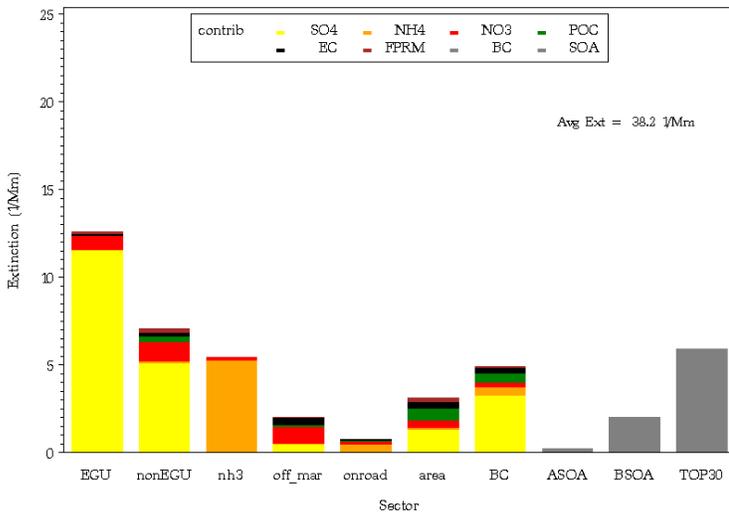


BOWA1 — baseM3\_psatAP25so4

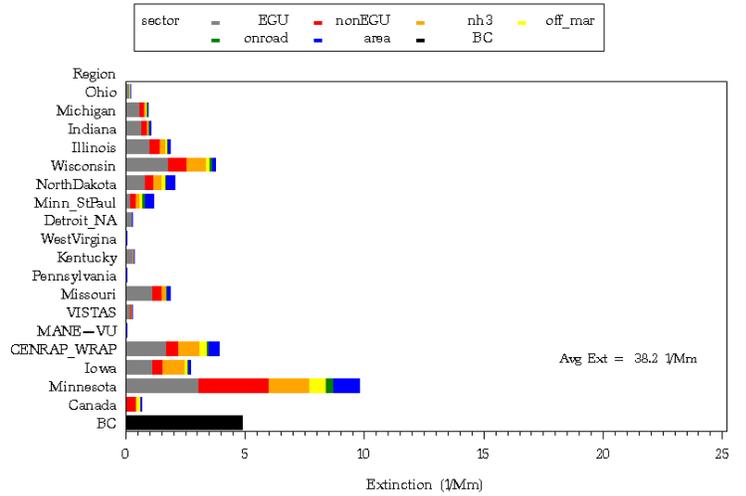


## 2018 (Round 4)

BOWA1 — K2018R4S1a

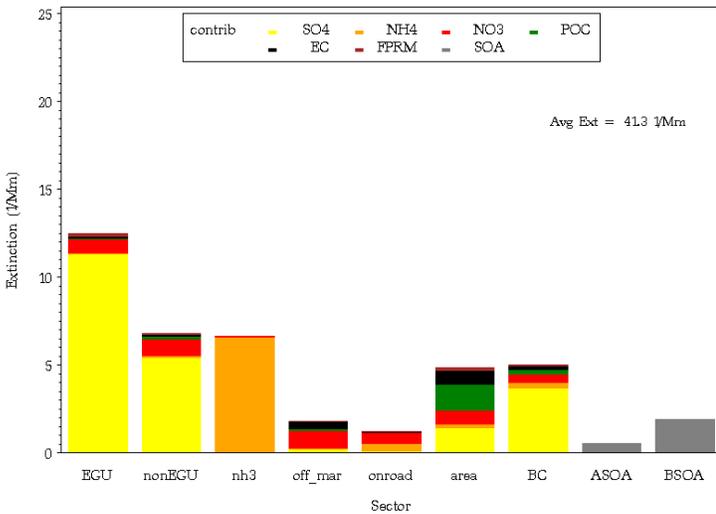


BOWA1 — K2018R4S1a

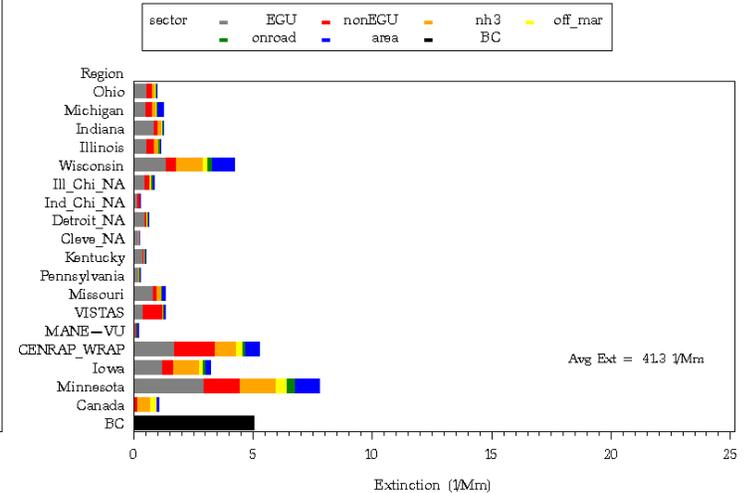


## 2018 (Round 5)

BOWA1 — 2018M3R5\_psatAP25+ HAZEso4



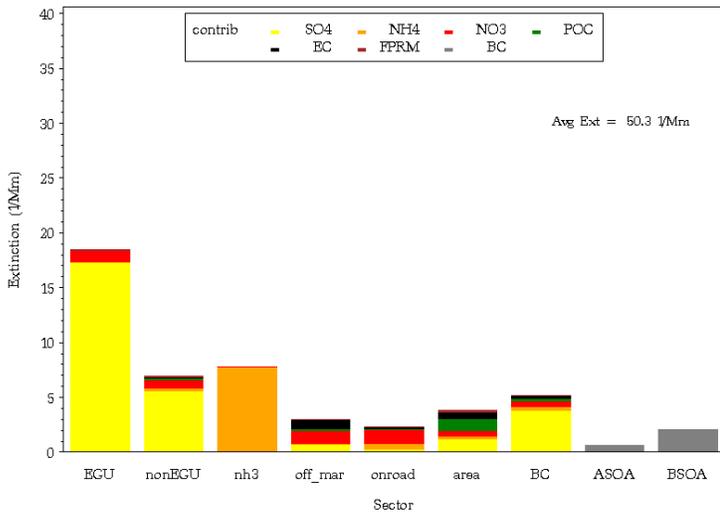
BOWA1 — 2018M3R5\_psatAP25+ HAZEso4



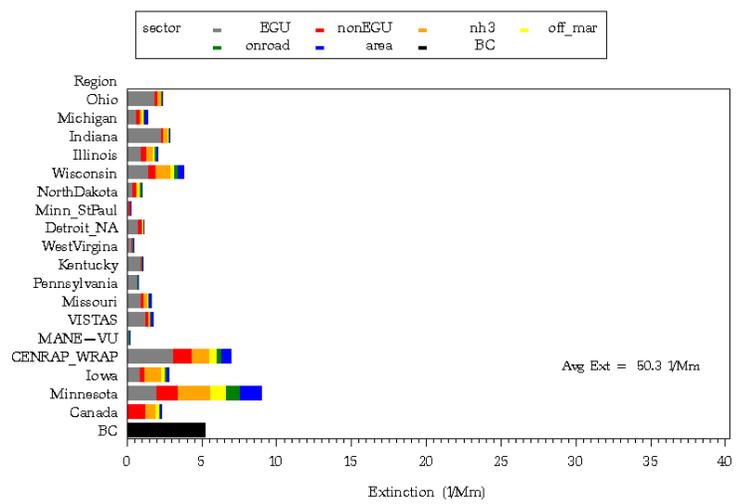
# Voyageurs, Minnesota

2005 (Round 5)

VOYA2 - baseM3\_psatAP25so4

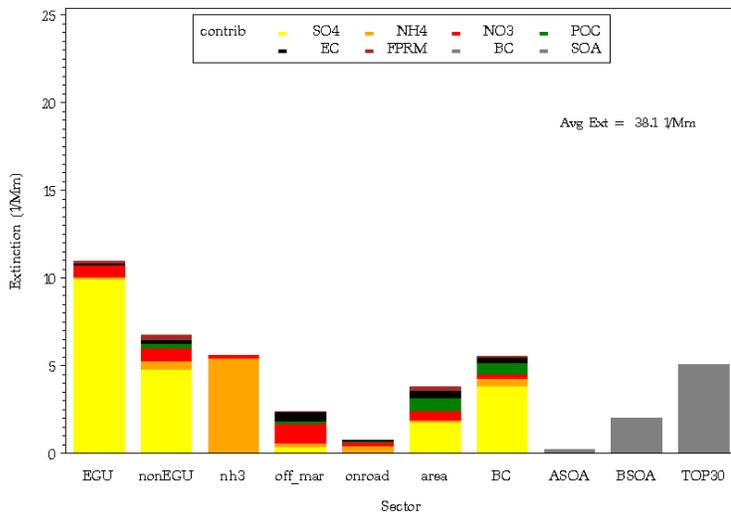


VOYA2 - baseM3\_psatAP25so4

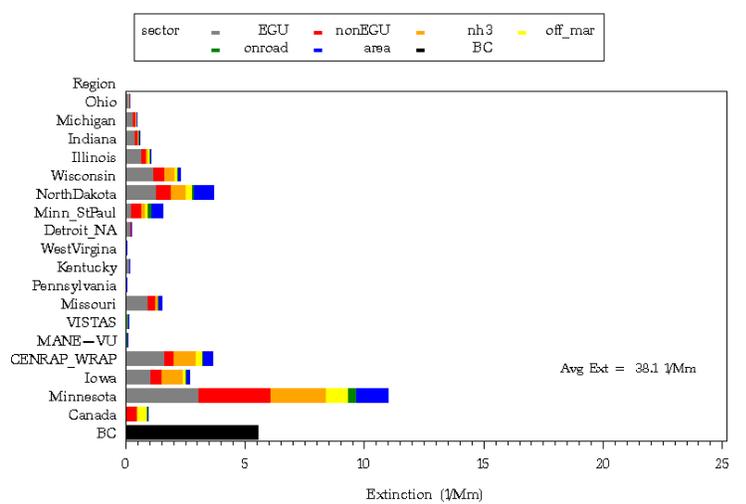


2018 (Round 4)

VOYA2 - K2018R4S1a

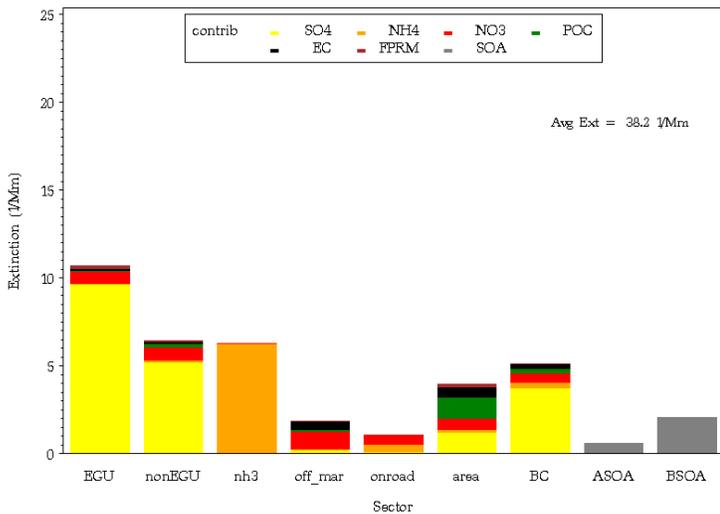


VOYA2 - K2018R4S1a

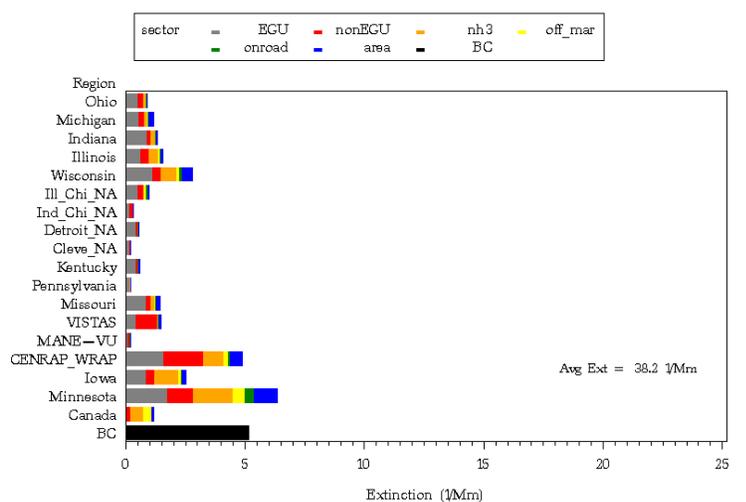


2018 (Round 5)

VOYA2 - 2018M3R5\_psatAP25+HAZEso4



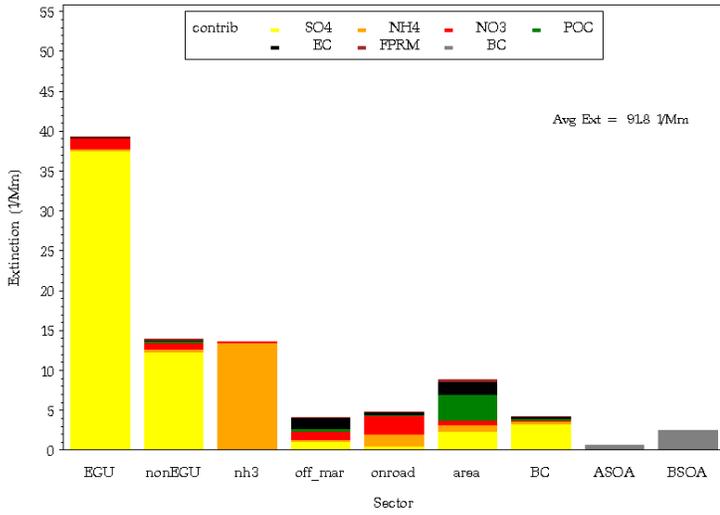
VOYA2 - 2018M3R5\_psatAP25+HAZEso4



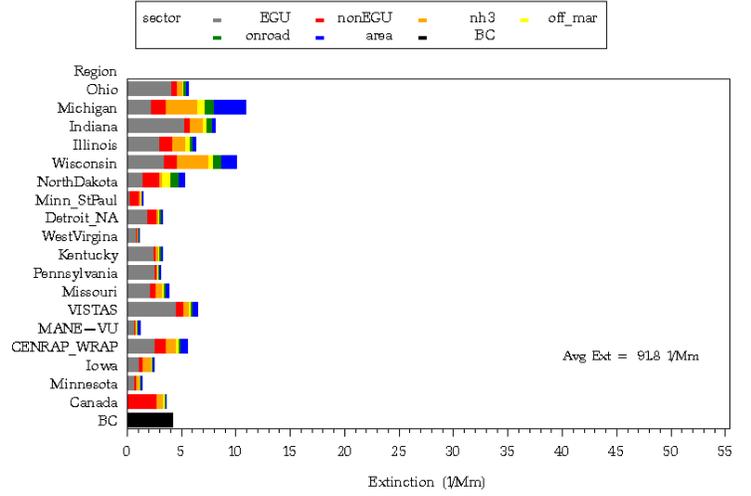
# Seney, Michigan

2005 (Round 5)

SENE1 - baseM3\_psatAP25so4

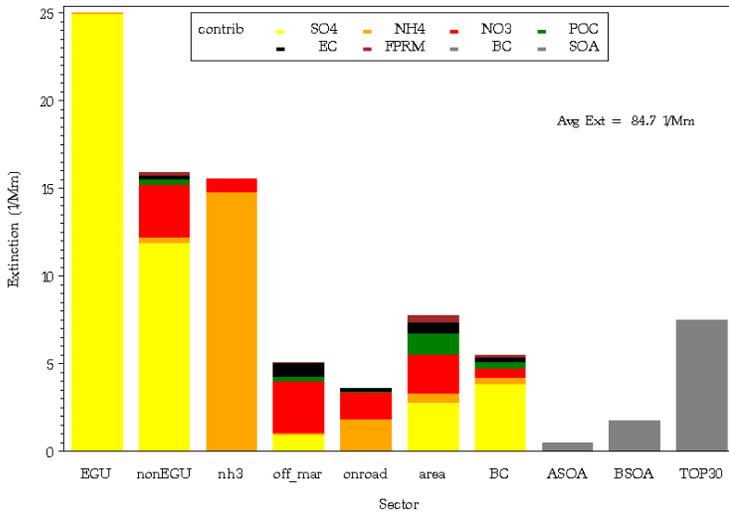


SENE1 - baseM3\_psatAP25so4

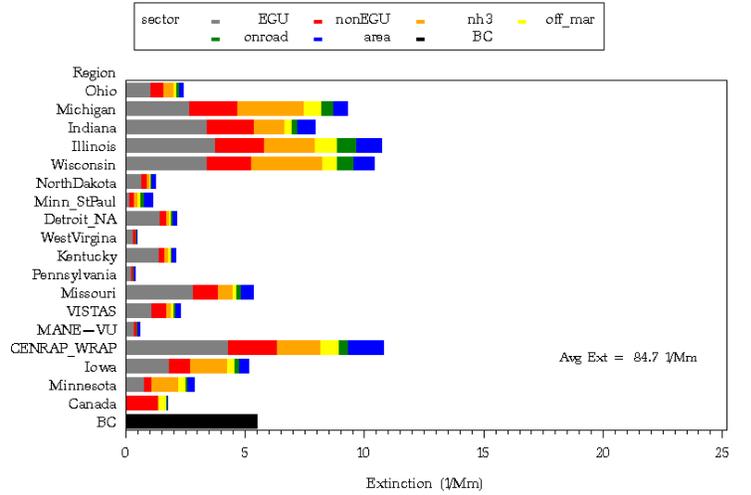


2018 (Round 4)

SENE1 - K20BR4S1a

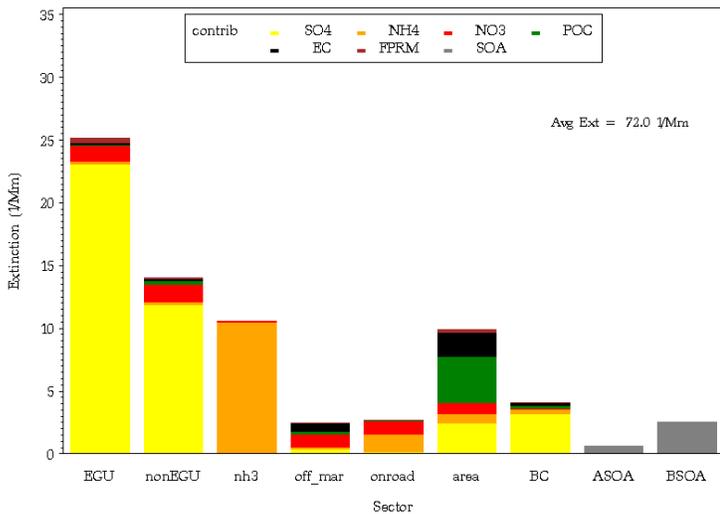


SENE1 - K2018R4S1a

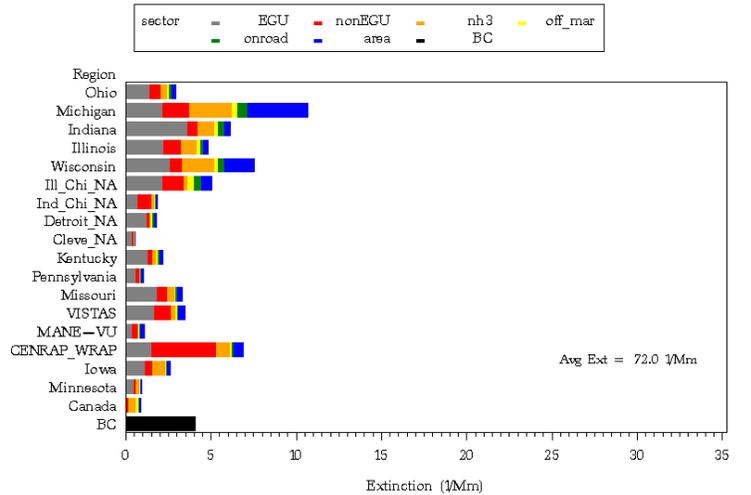


2018 (Round 5)

SENE1 - 2018M3R5\_psatAP25+HAZEso4



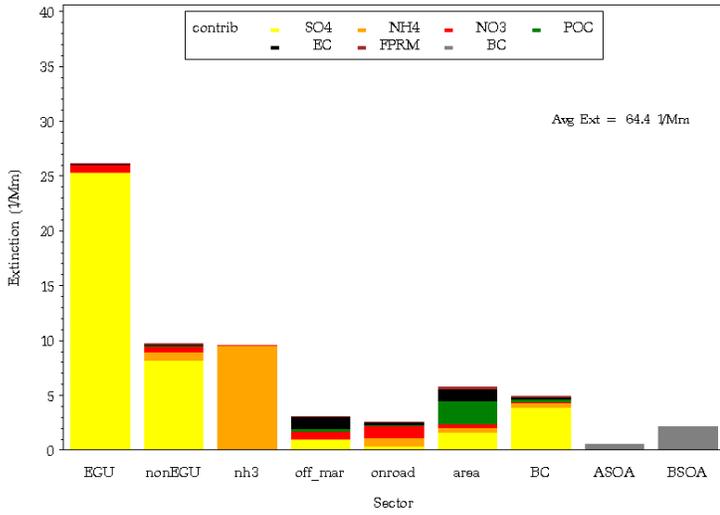
SENE1 - 2018M3R5\_psatAP25+HAZEso4



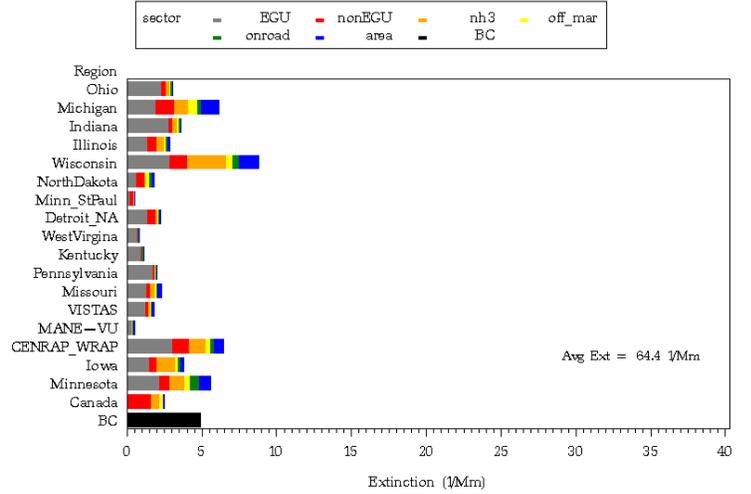
# Isle Royale, Michigan

2005 (Round 5)

ISLE1 - baseM3\_psatAP25so4

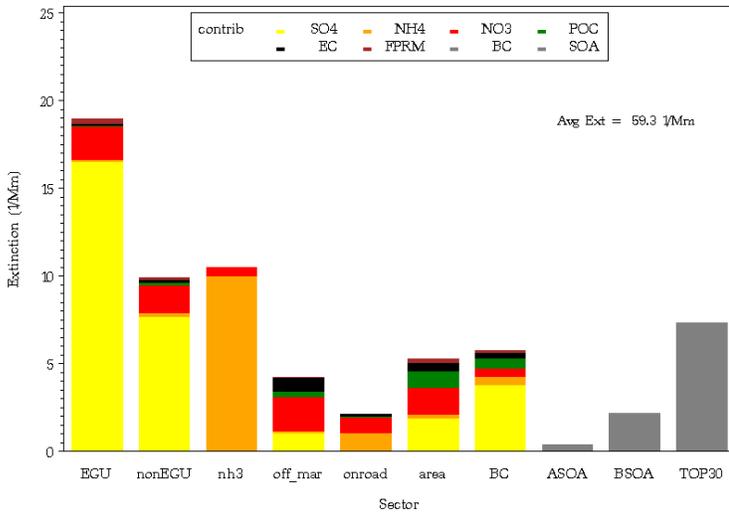


ISLE1 - baseM3\_psatAP25so4

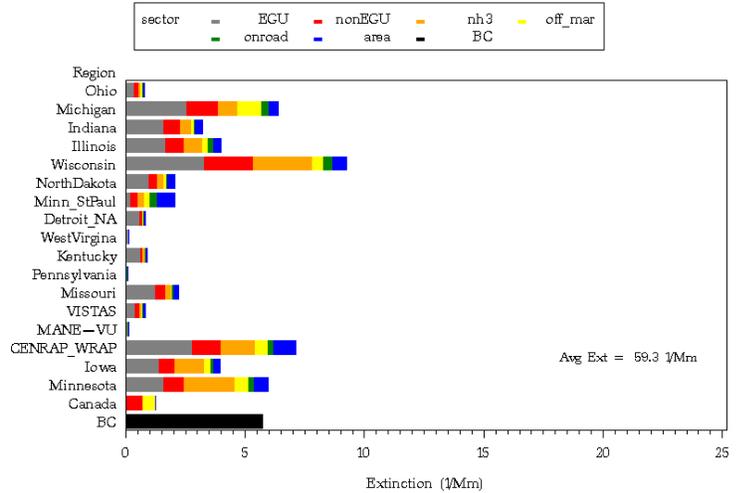


2018 (Round 4)

ISLE1 - K2018R4S1a

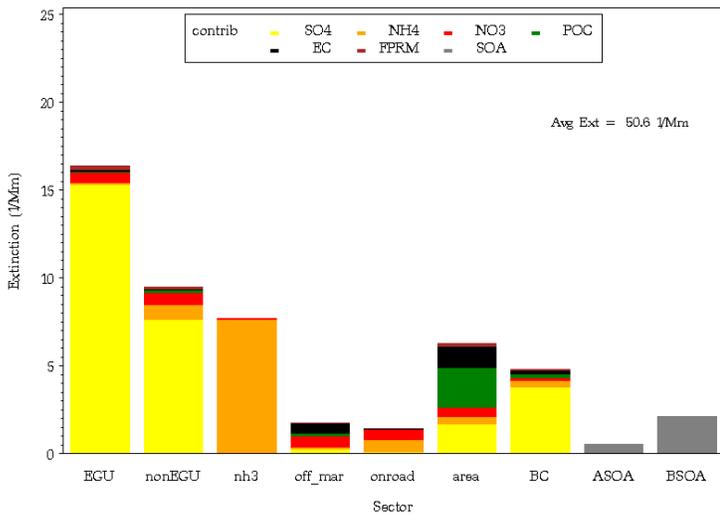


ISLE1 - K2018R4S1a

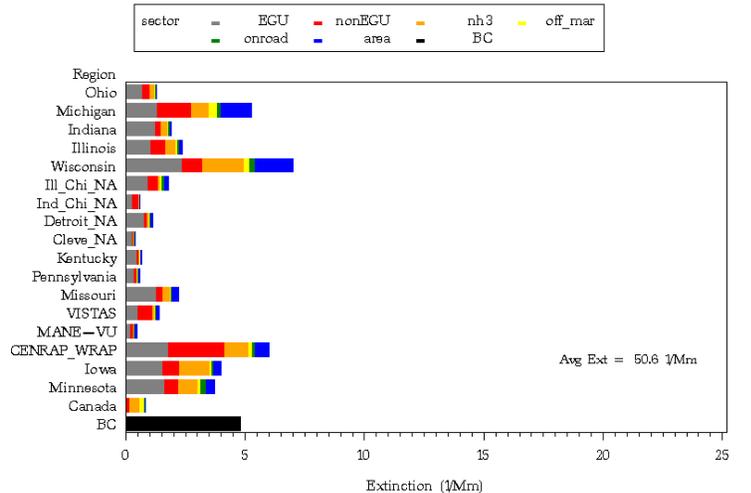


2018 (Round 5)

ISLE1 - 2018M3R5\_psatAP25+HAZEso4



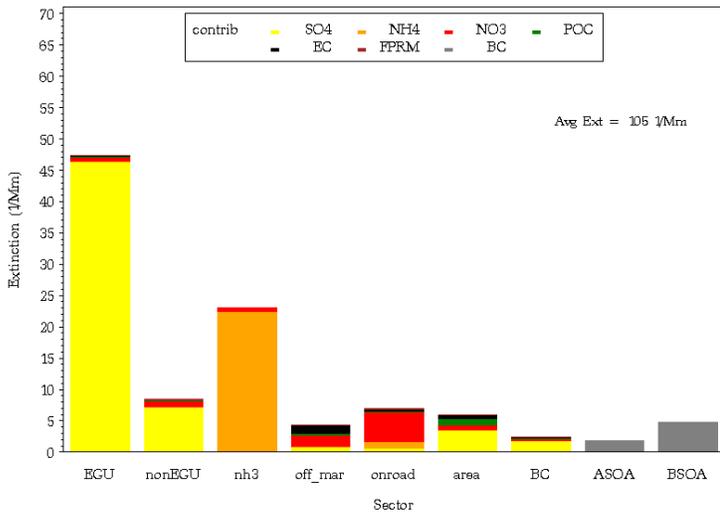
ISLE1 - 2018M3R5\_psatAP25+HAZEso4



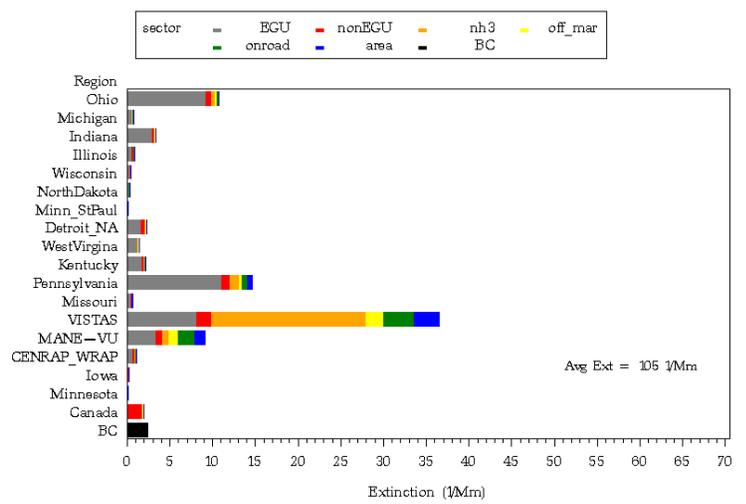
# Shenandoah, Virginia

2005 (Round 5)

SHEN1 - baseM3\_psatAP25so4

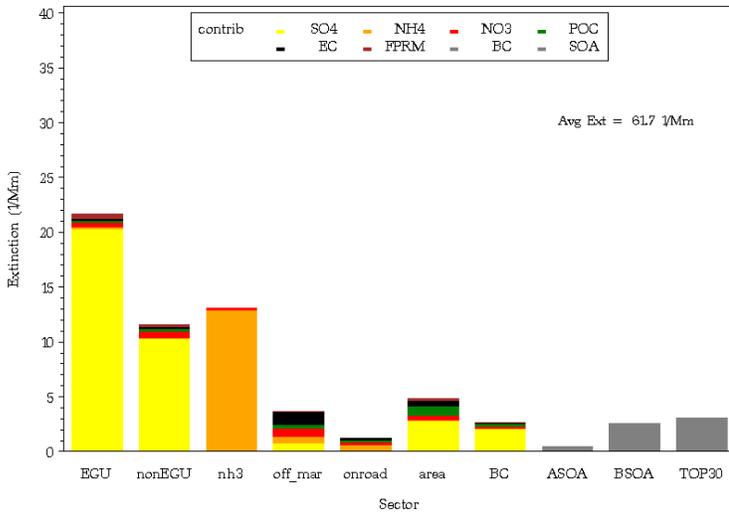


SHEN1 - baseM3\_psatAP25so4

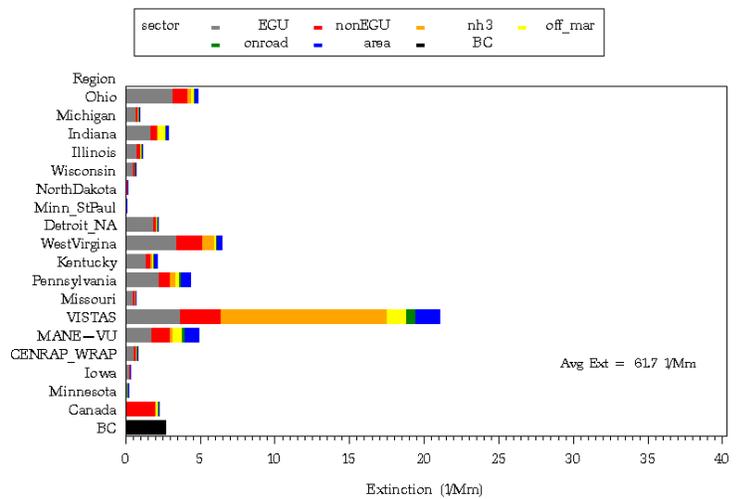


2018 (Round 4)

SHEN1 - K2018R4S1a

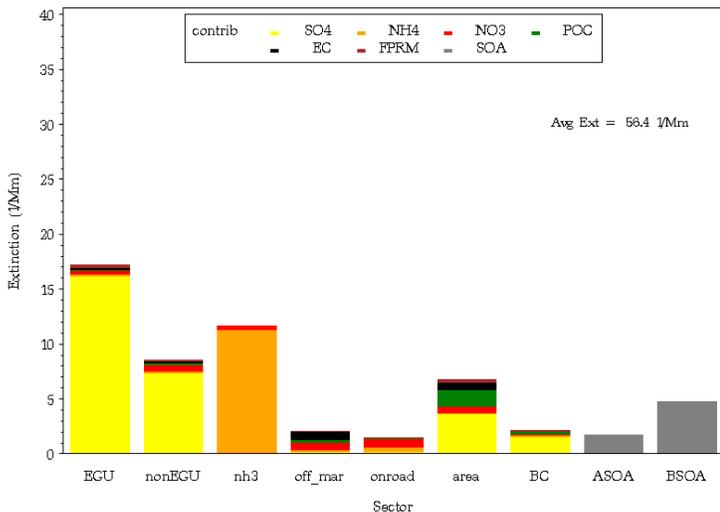


SHEN1 - K2018R4S1a

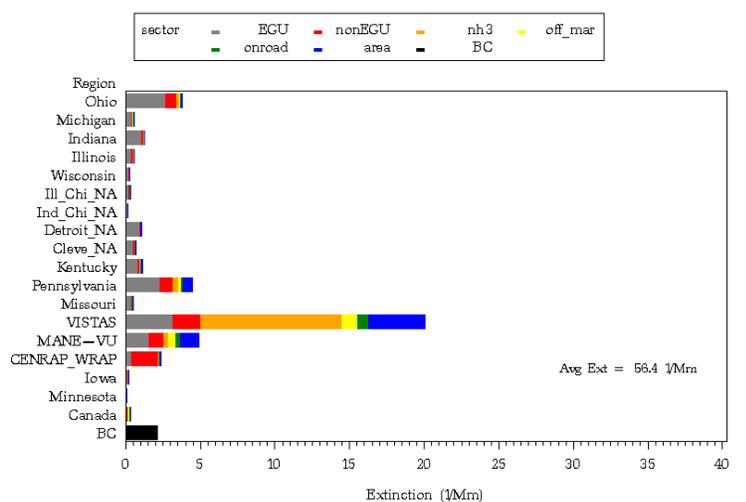


2018 (Round 5)

SHEN1 - 2018M3R5\_psatAP25+HAZEso4



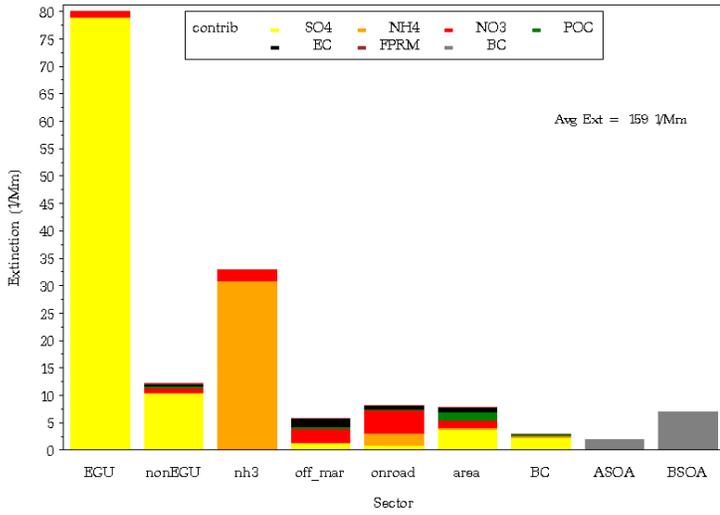
SHEN1 - 2018M3R5\_psatAP25+HAZEso4



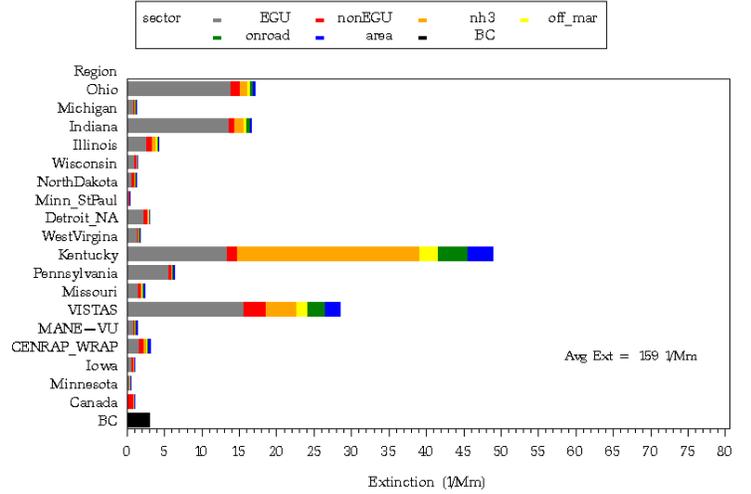
# Mammoth Cave, Kentucky

2005 (Round 5)

MACA1 - baseM3\_pstatAP25so4

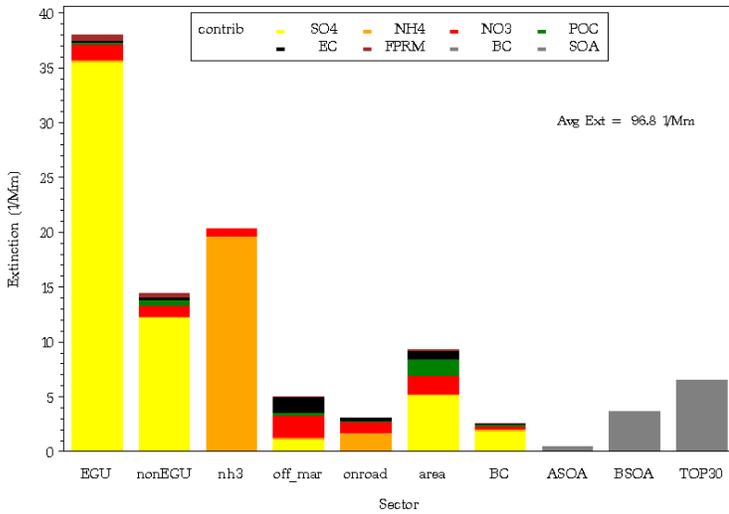


MACA1 - baseM3\_pstatAP25so4

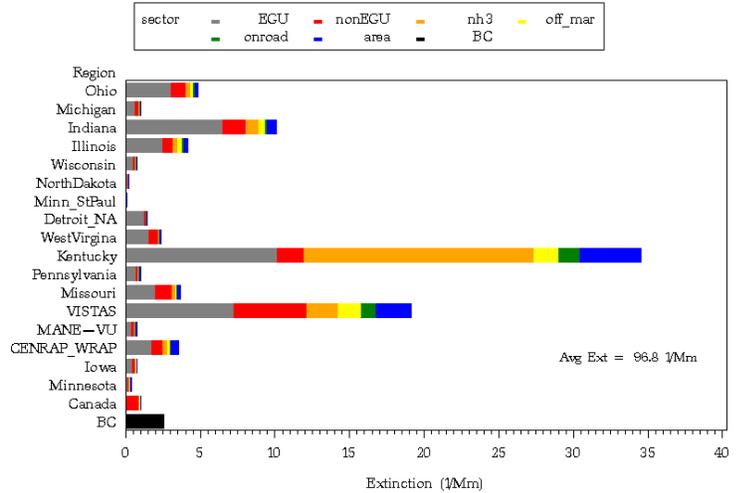


2018 (Round 4)

MACA1 - K2018R4S1a

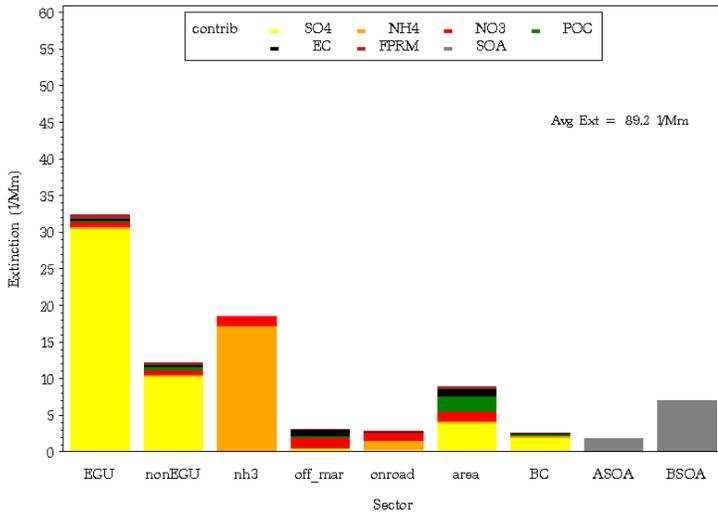


MACA1 - K2018R4S1a

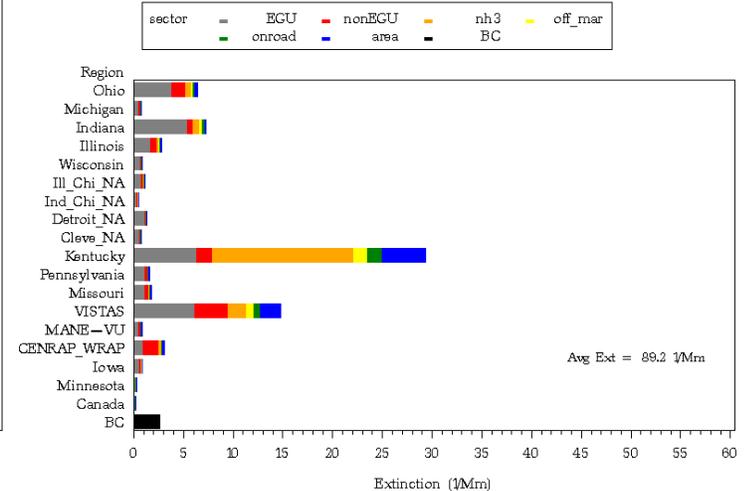


2018 (Round 5)

MACA1 - 2018M3R5\_pstatAP25+ HAZEso4



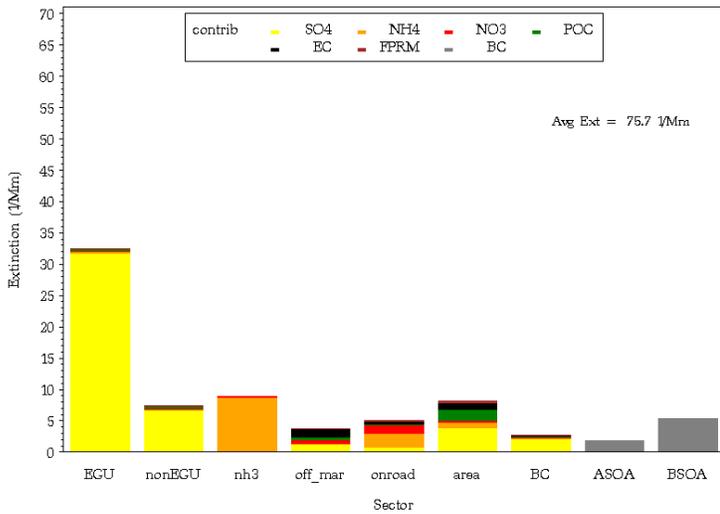
MACA1 - 2018M3R5\_pstatAP25+ HAZEso4



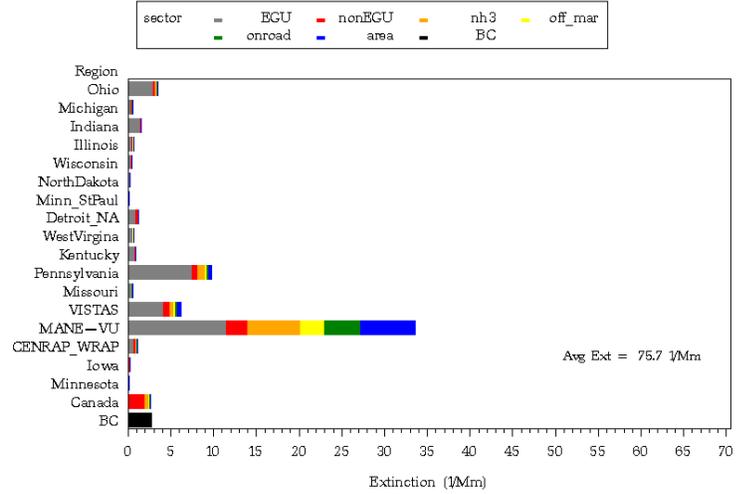
# Lye Brook, Vermont

## 2005 (Round 5)

LYBR1 - baseM3\_psatAP25so4

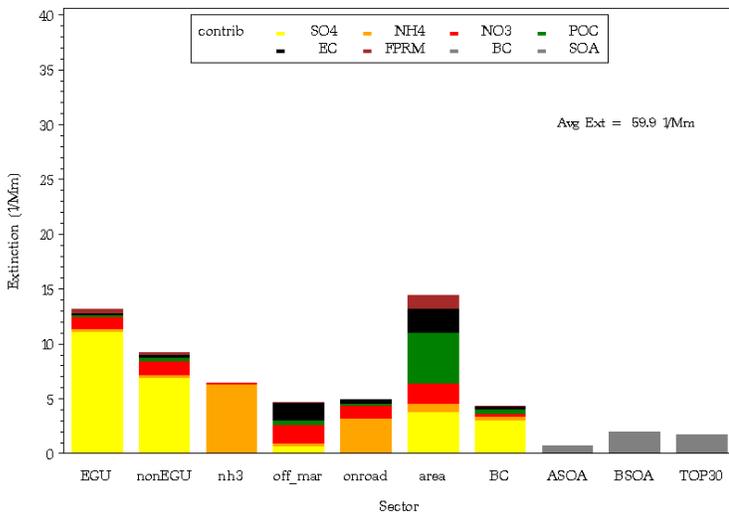


LYBR1 - baseM3\_psatAP25so4

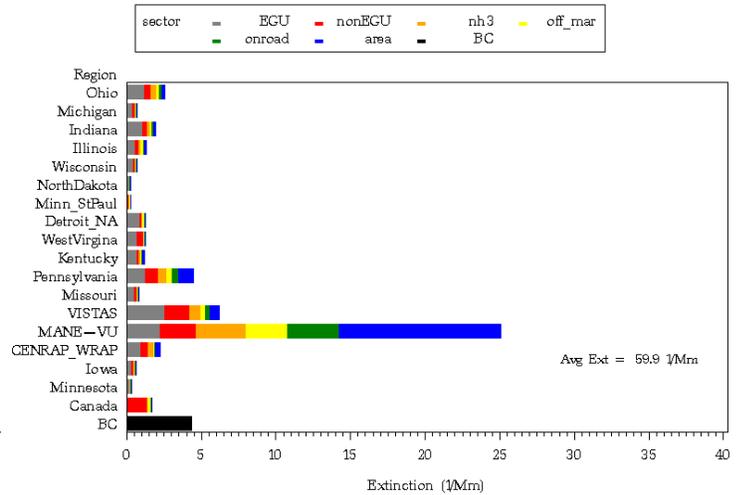


## 2018 (Round 4)

LYBR1 - K2018R4S1a

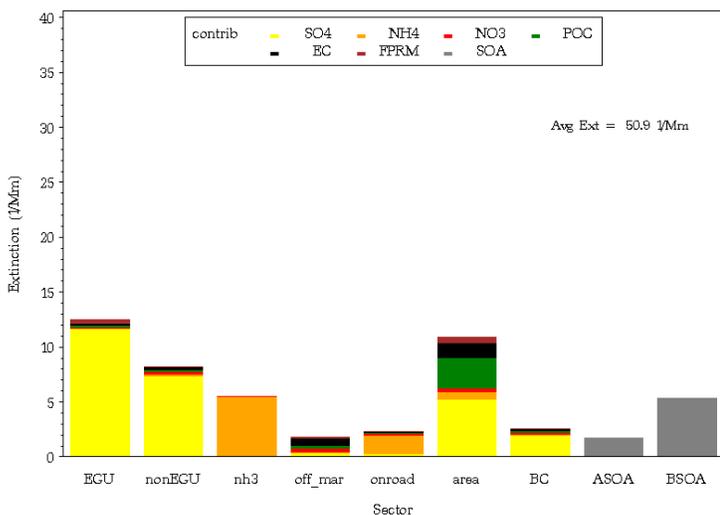


LYBR1 - K2018R4S1a



## 2018 (Round 5)

LYBR1 - 2018M3R5\_psatAP25+ HAZEso4



LYBR1 - 2018M3R5\_psatAP25+ HAZEso4

