October 10, 2007

Base M/Round 5 Modeling: Summary (DRAFT)

The purpose of this document is to summarize the results of the latest 2005 base year (Base M) and 2008, 2009, 2012, and 2018 future year (Round 5) modeling[1]. Based on these results, several key findings should be noted:

- Model performance for ozone and PM2.5 (most species) is acceptable and, thus, use of the model for planning purposes is appropriate. Comparisons of modeled and monitored ozone and PM2.5 (most species) concentrations generally shows good agreement. PM2.5-organic carbon concentrations, however, are not well represented by the model.

- For ozone, the regional modeling shows attainment by 2009 at all sites, except Holland (MI), and attainment at all sites by 2012.

- For PM2.5, the 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 new (Round 5 2005 base year) modeling results look better than the previous (Round 4 2002 base year) modeling, due to lower base year design values.

- The attainment demonstration for ozone and PM2.5 should reflect a "weight of evidence" approach, with consideration of the Round 4 2002 base year and Round 5 2005 base year modeling, and monitoring-based analyses.

- The regional modeling also shows that the new PM2.5 24-hour standard (and new ozone standard?) will not be met, even by 2018, with existing controls.

- For regional haze, the regional modeling shows the Michigan Class I areas (and several Class I areas in the Northeast) to be above the uniform rate of visibility improvement line by 2018. Many other Class I areas in the eastern U.S. are below the line by 2018.

Additional analyses will be performed using the Base M/Round 5 emissions, including ozone and PM2.5 source apportionment. These analyses are summarized in separate documents.

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[1] Additional details about the modeling, including grid projections and domain, model inputs, and quality assurance, are provided in "Addendum Modeling Protocol: Technical Details", Lake Michigan Air Directors Consortium, August 22, 2006???????

Overview of Modeling Platform

The CAMx air quality model (version 4.5) was used in the modeling. Recent updates to the model include CB05 chemistry, updated biogenic secondary organic aerosol (SOA) chemistry, and a new dry deposition scheme (AEROMOD) with gridded monthly leaf area index data. Figure 1 shows the spatial coverage of the modeling domain. Modeling for PM2.5 and regional haze was conducted for the full calendar year for the 36 km domain, while modeling for ozone was conducted for the summer months (May – September) for the 36/12 km domain.

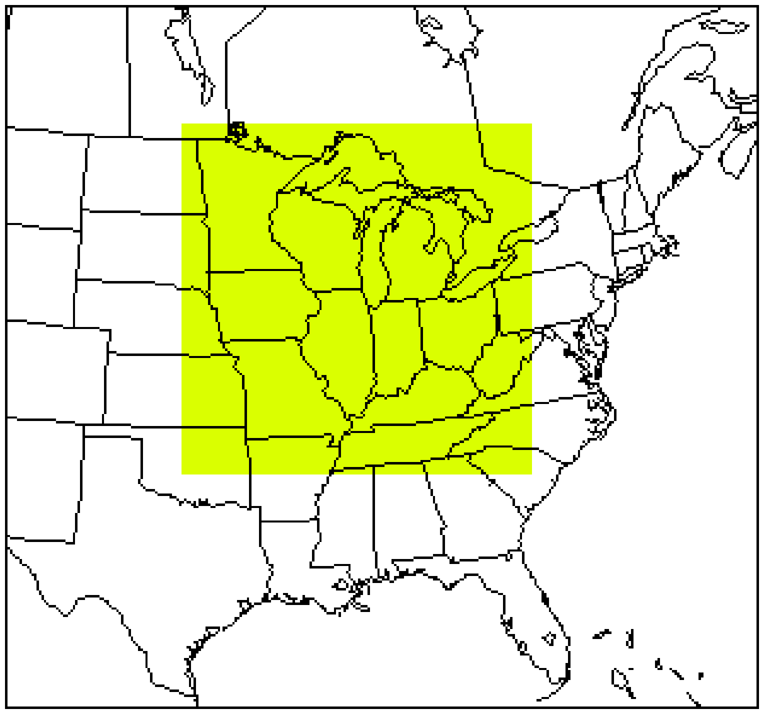

Figure 1. Modeling domain

Base Year Modeling Results

The purpose of the base year modeling is to evaluate model performance by comparing modeled and monitored concentrations.

Emissions for the 2005 base year modeling are discussed in "Base M Strategy Modeling: Emissions (Revised)", October 8, 2007.

Ozone: Spatial and time series plots are provided for a high ozone period in June 2005 (see Figure 2). The plot shows 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.

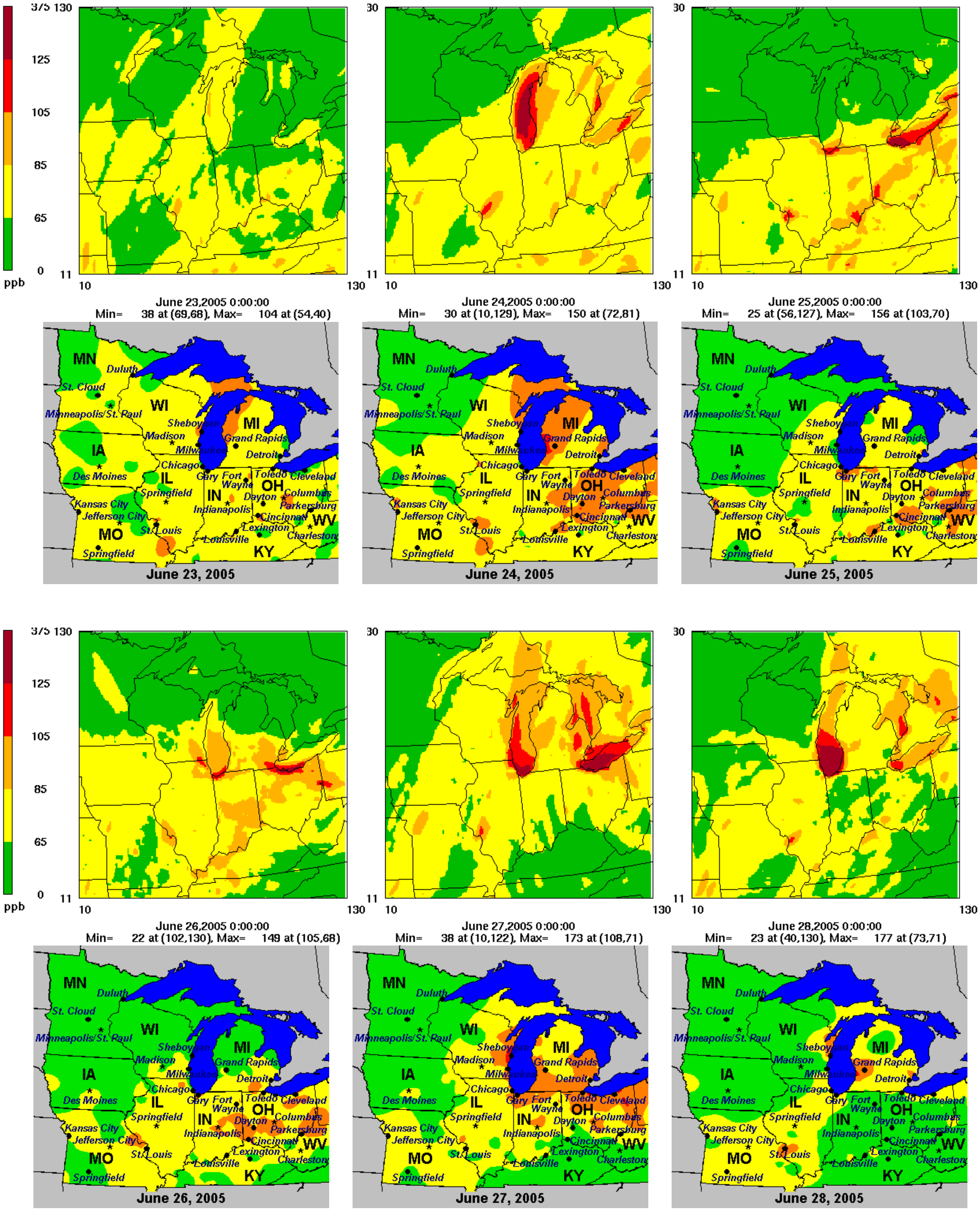

Figure 2 Modeled (top) v. Monitored (bottom) 8-Hour Ozone Concentrations: June 23– 28 2005

Standard model performance statistics were generated for the entire 12 km domain, and by day and by monitoring site. The domain-wide mean bias for the 2005 base year is similar to that for the 2002 base year and is generally within 30% (see Figure 3).

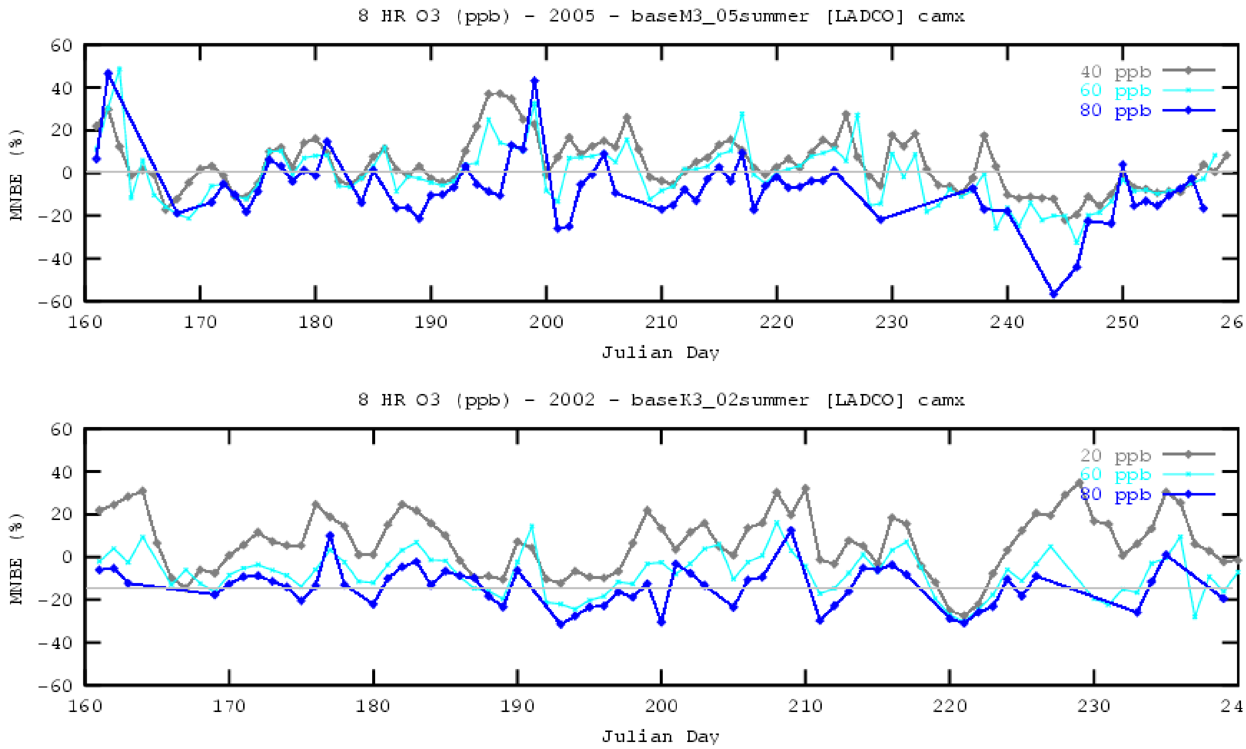

Figure 3. Mean bias for summer 2005 (Base M) and summer 2002 (Base K)

Station-average metrics (over the entire summer) are shown in Figure 4. The bias results further demonstrate the model's tendency to underestimate absolute ozone concentrations.

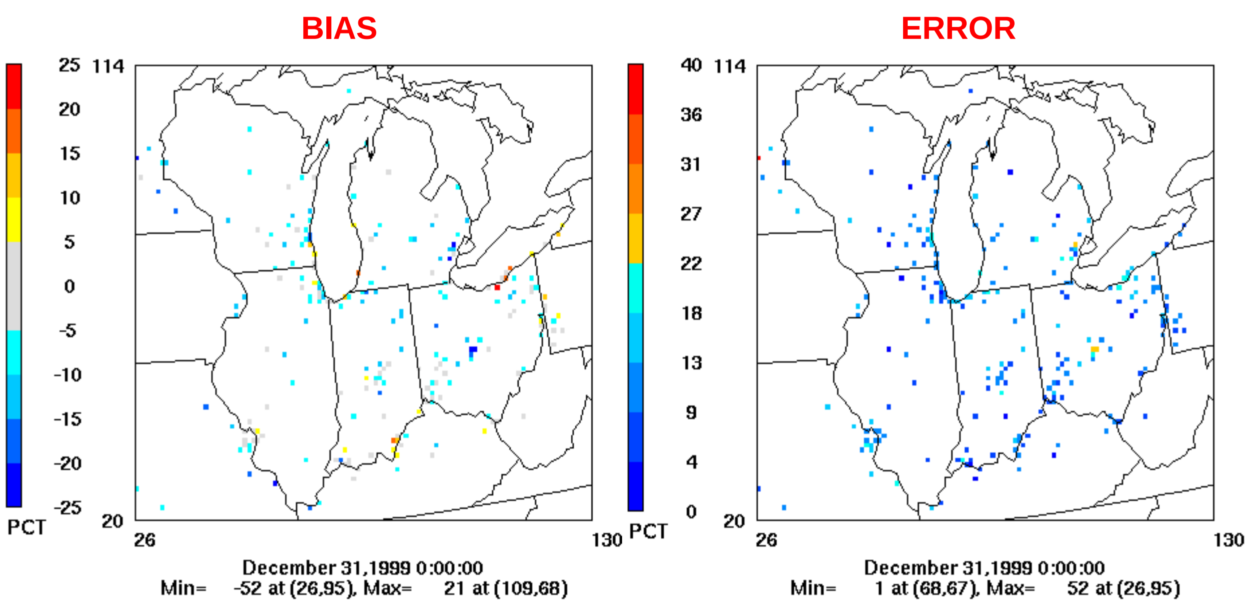

Figure 4. Mean bias (left) and gross error (right) for summer 2005

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 5. 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%), not as good as the Base K results.

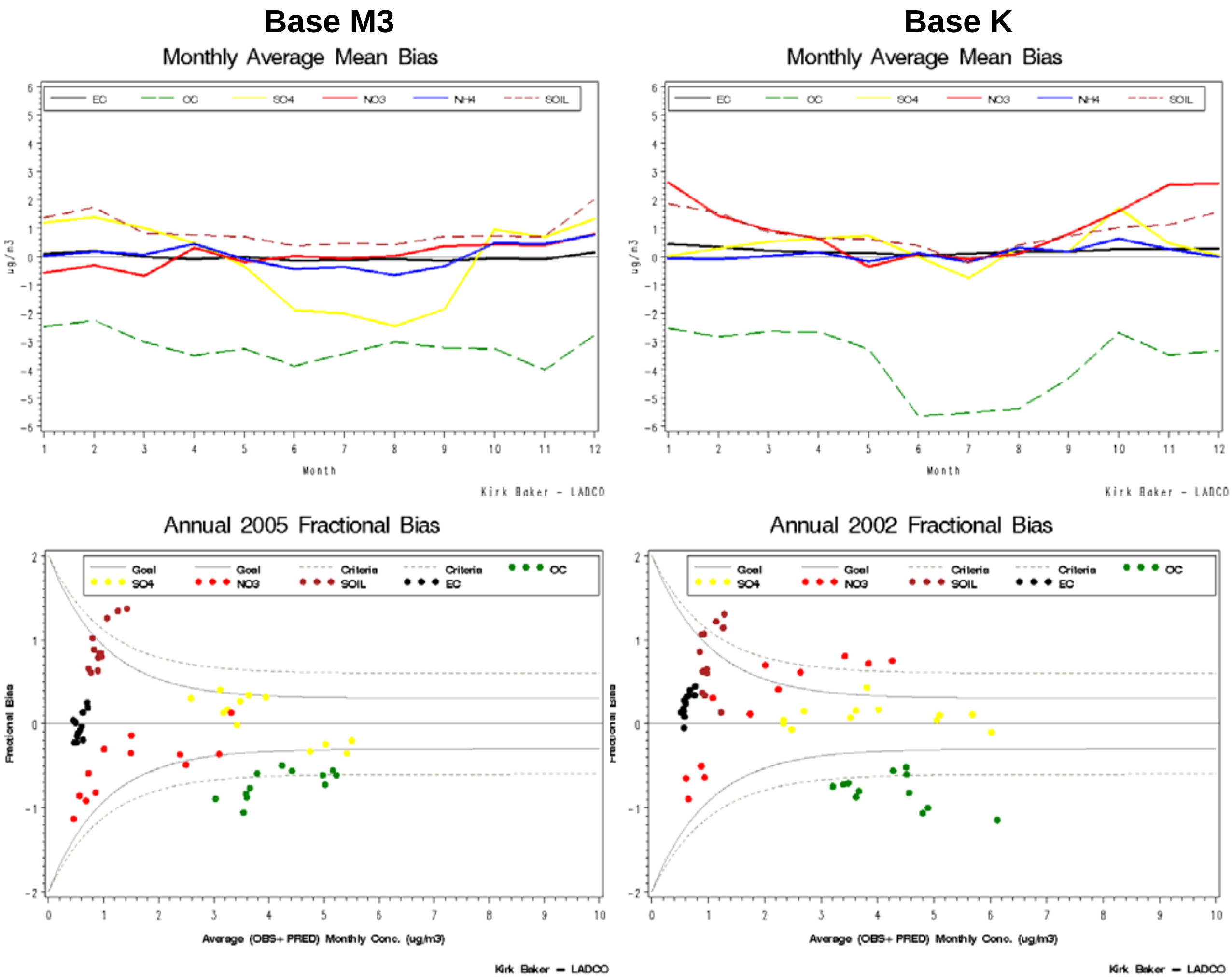

Figure 5. PM2.5 Model Performance - Monthly Average Mean Bias and Annual Fractional Bias for Base M (left column) and Base K (right column)

Two analyses were undertaken to understand sulfate model performance:

- 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 (see "An Evaluation of an Annual 2005 MM5 Simulation to Support Photochemical and Emissions Modeling Applications", January 10, 2007, Baker, McNally, and Ji). Because CAMx does not explicitly use the rainfall output by MM5, this may or may not result in over-prediction of sulfate wet deposition. A sensitivity run was performed with wet deposition turned-off in July, August, and September (see Figure 6). Directionally, the results are encouraging, and suggest that further evaluation of wet deposition (and MM5 precipitation fields) may be warranted.

- Assess Emissions Influences: The major contributor to sulfate concentrations in the region is SO2 emitted from EGUs. The basecase 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. Comparison of the derived typical days with actual day-specific CEM data shows some slight differences by month. A sensitivity run was performed using the day-specific emissions prepared for MOG (see Figure 6). As can be seen, use of day-specific emissions had little effect on model performance.

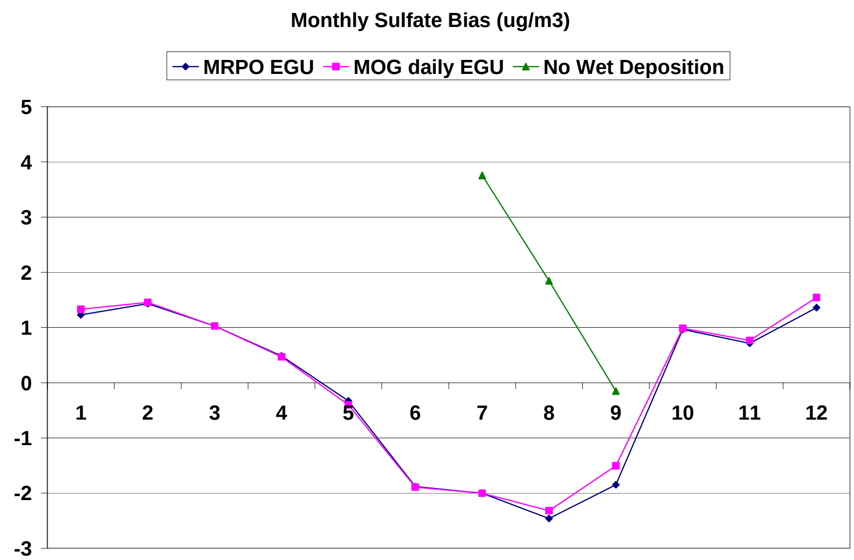

Figure 6. Monthly sulfate bias for Base M (MRPO EGU) v. two sensitivity analyses

Based on these results, it is concluded that while sulfate model performance is currently acceptable, improvements may be possible through further analysis of wet deposition (and MM5 precipitation fields), but the degree of improvement is uncertain and this work will take several months.[2]

Time series plots of daily sulfate, nitrate, elemental carbon, and organic carbon concentrations for four locations (Chicago and Indianapolis) are presented in Figure 7. 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).

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[2] A model sensitive run was conducted with wet deposition turned-off in Quarters 2-3 for the base year and 2018. Future year design values changed by generally less than 0.2 ug/m^3. Consequently, even with an improved wet deposition treatment, little change in the future year modeling results is expected.

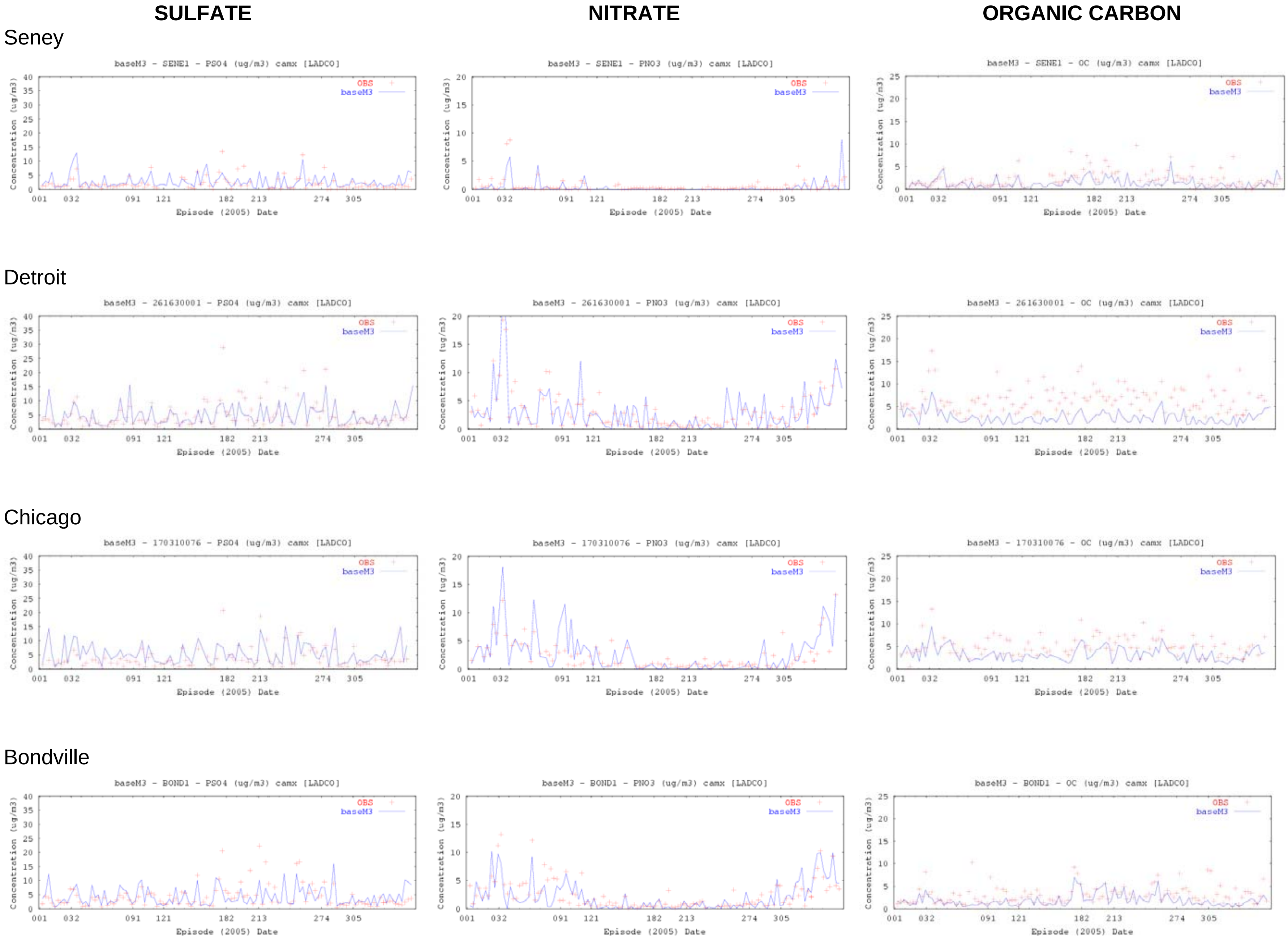

Figure 7. Time series of sulfate, nitrate, and organic carbon at four Midwest sites

Future Year Modeling Results

The purpose of the future year modeling is to assess the effectiveness of existing and possible additional control programs. For Round 5, the primary modeling scenario represents the following existing ["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

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

Other Point Sources
- VOC 2-, 4-, 7-, and 10-year MACT standards
- Combustion turbine MACT
- Industrial boiler/process heater/RICE MACT

Area Sources
- Aerosol coatings (new rule)
- Architectural and industrial maintenance coatings (amendments)
- Household and institurional consumer products (amendments)
- Portable fuel containers (Mobile Source Air Toxics rule)

Three CAIR scenarios were addressed:
- 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., 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).

The attainment test was applied consistent with USEPA's modeling guidance. The base year design values for ozone and PM2.5 were calculated as the weighted average of the design values for three 3-year periods (2003-2005, 2004-2006, 2005-2007). The relative reduction factors for ozone were calculated using the peak 3x3 grid cell around the monitor and assuming a threshold of 85 ppb. (Note, if there were less than 10 days above this threshold, then the threshold was lowered until either there were 10 days or threshold reached 70 ppb.)

The ozone and PM2.5 modeling results are provided in the following tables for select monitors (high concentration sites) in the 5-state region for the following future years of interest: 2008 (ozone only)[3], 2009, 2012, and 2018. Spatial maps of the projected ozone and PM2.5 concentations are provided in Figures 8-10.

[3] The inventory for the 2008 modeling reflects several approximations (e.g., emissions for some sectors were derived by adjusting the 2005 emissions by the Base K trends in the 2002 v. 2009 emissions). Thus, the 2008 modeling results are less reliable than the results for the other future years.

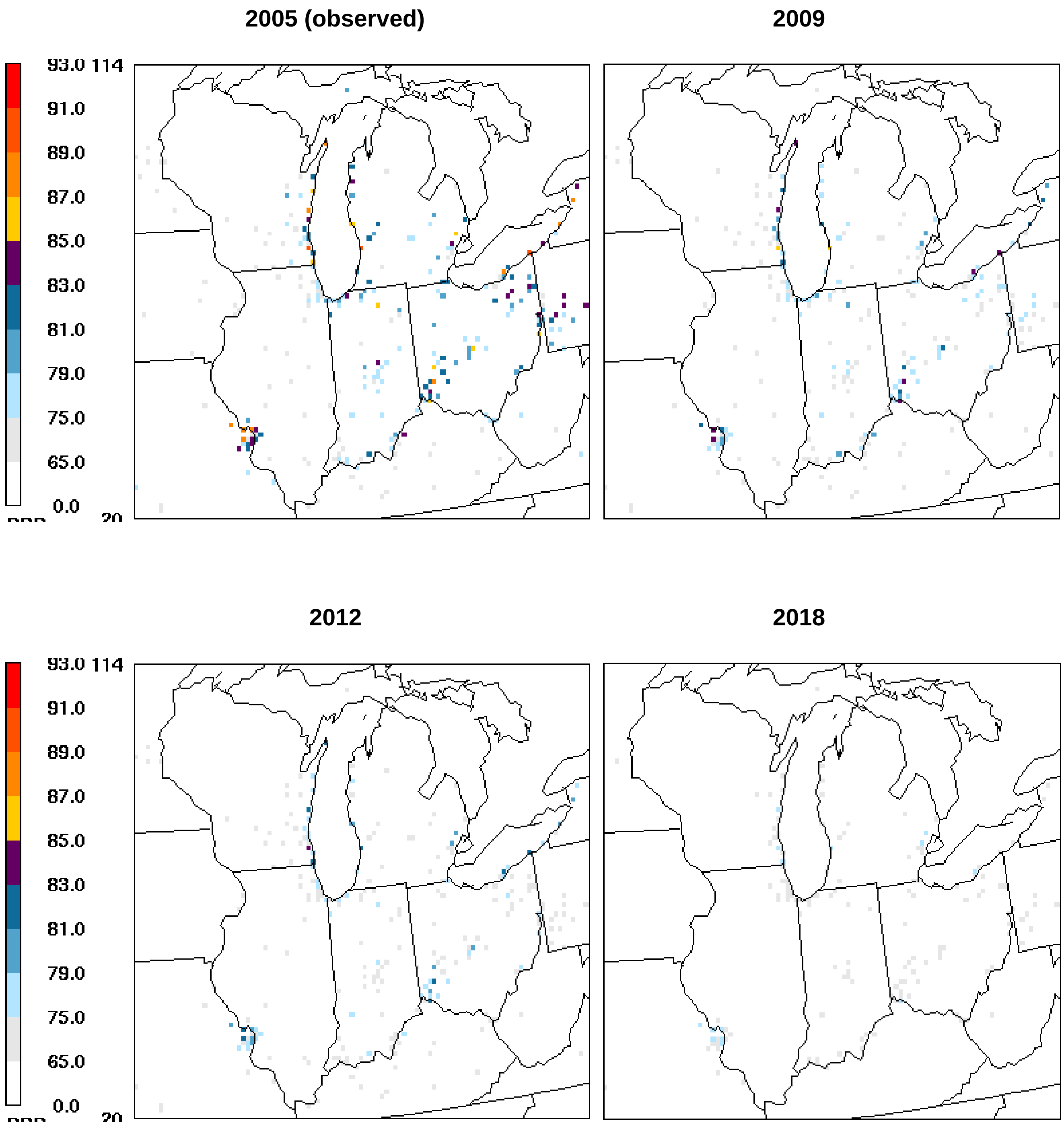

Figure 8. Observed base year and projected future year design values for ozone

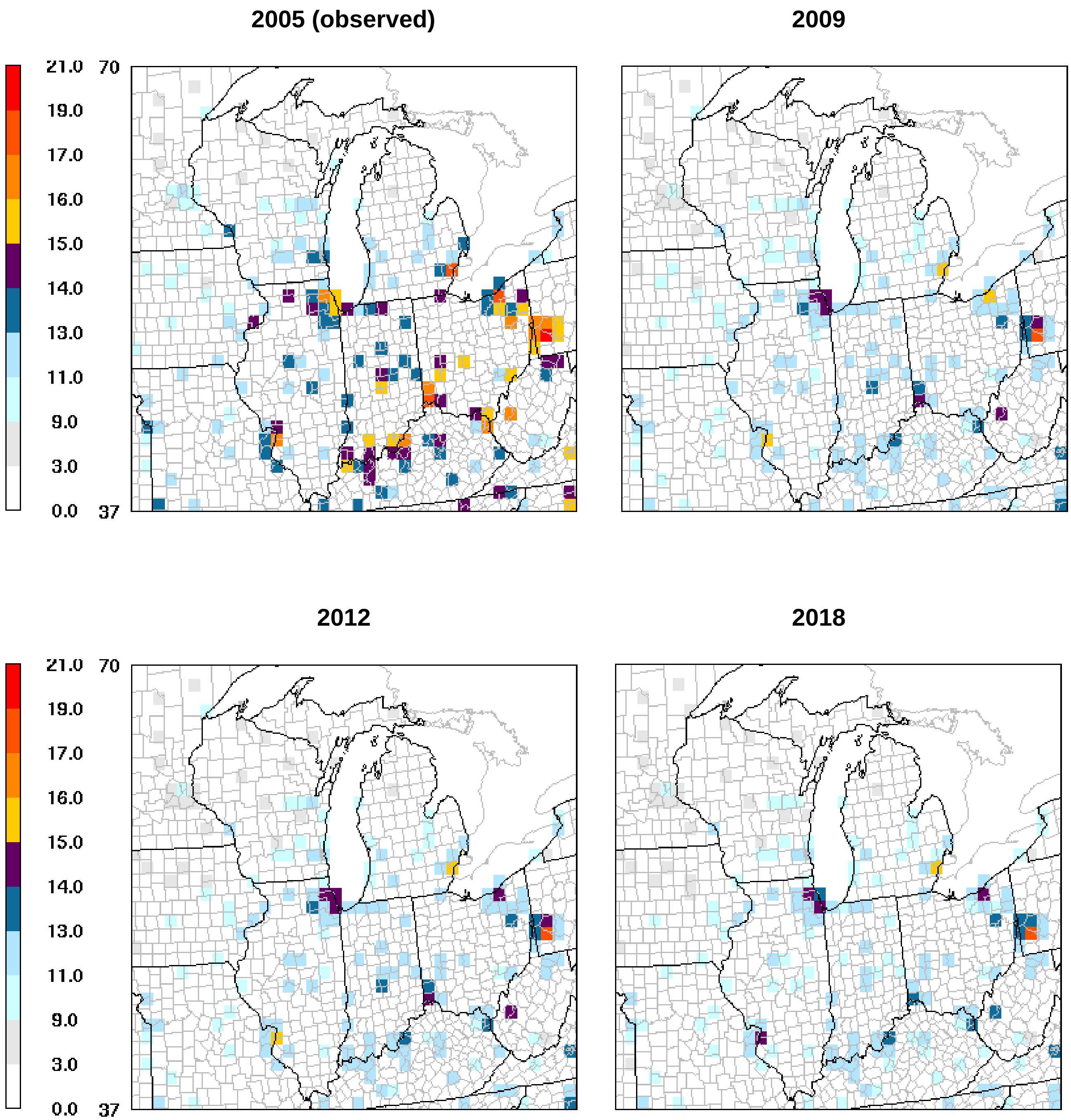

Figure 9. Observed base year and projected future year design values for PM2.5 (annual average)

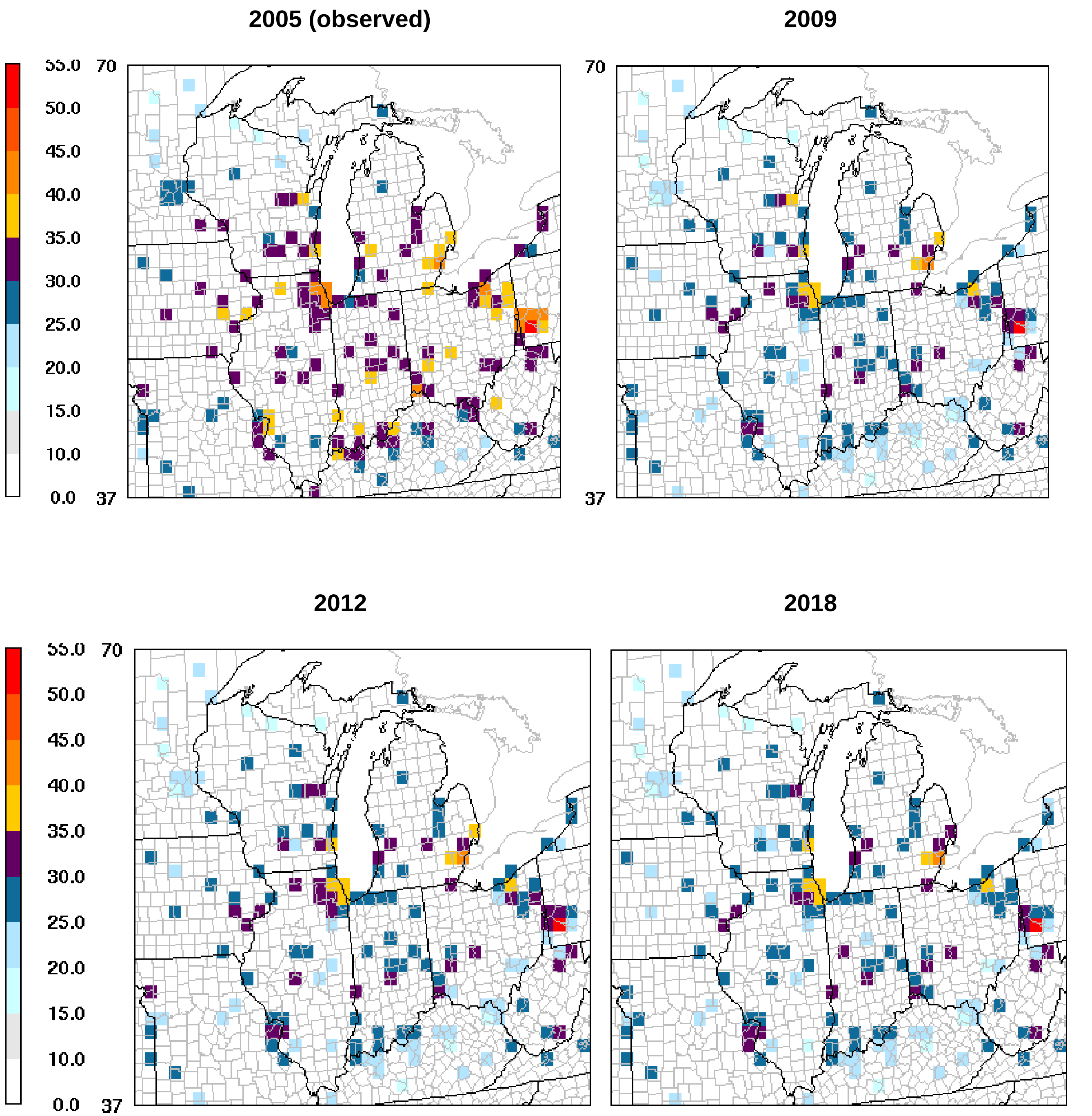

Figure 10. Observed base year and projected future year design values for PM2.5 (24-hour average)

Several key findings should be noted

- 2008: This year was modeled because it represents the planning year for basic ozone nonattainment areas (attainment date of 2009). The modeling shows that one basic nonattainment area (Allegan County [Holland], MI) is projected to be above the standard, and several other basic nonattainment areas are close, but below the standard (e.g., Cincinnati, OH; Columbus, OH; and Door County, WI).

- 2009: This year was modeled because it represents the planning year for moderate ozone and PM2.5 nonattainment areas (attainment date of 2010). The modeling shows existing control programs will improve air quality for ozone and $PM_{2.5}$, but will not be enough to provide for attainment at the following locations: Holland, MI (ozone), Granite City, IL (PM2.5), Detroit, (PM2.5), and Cleveland, OH (PM2.5).

- 2012: This year was modeled to assess the effect of further emission reductions expected from existing control programs. The modeling shows that all sites are expected to attain for ozone, but two sites are still not attainment for PM2.5: Granite City, IL and Detroit, MI.

- 2018: This year was modeled to assess the effect of further emission reductions expected from existing control programs (e.g., full implementation of CAIR). The modeling shows that all sites are expected to attain for ozone, but one site is still not attainment for PM2.5: Detroit, MI.

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

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

	Ozone				**PM2.5**			
State	2005	2009	2012	2018	2005	2009	2012	2018
IL	0	0	0	0	9	1	1	0
IN	0	0	0	0	7	0	0	0
MI	3	1	0	0	2	1	1	1
OH	4	0	0	0	25	1	0	0
WI	2	0	0	0	0	0	0	0
	9	1	0	0	43	3	2	1

For regional haze, the calculcation of future year conditions assumed: (a) baseline concentrations based on 2000-2004 IMPROVE data, with updated (subsitituted) data for Mingo, Boundary Waters, Voyageurs, Isle Royale, and Seney (see "Impact of Missing Data on Worst Days at Midwest Northern Class 1 Areas", March 12, 2007 (revised 6/19/07)); (b) use of the new IMPROVE light extinction equation, and (c) use of USEPA default values for natural conditions, based on the new IMPROVE light extinction equation.

Pursuant to USEPA's regional haze rule, states must consider several factors in establishing reasonable progress goals for their Class I areas, including the uniform rate of visibility improvement.[4] 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" for Class I areas in the eastern U.S. are presented in Figure 11. A tabular summary of measured baseline and modeled future year deciview values for these Class I areas are provided in the following table.

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).

[4] The other factors that must considered are the costs of compliance, the time necessary for compliance, the energy and non-air quality environmental impacts of compliance, and the remaining useful life of any potentially affected sources. These factors are addressed elsewhere – see, for example, "Reasonable Progress for Class I Areas in the Northern Midwest – Factor Analysis", Drat Final Technical Memorandum, July 18, 2007).

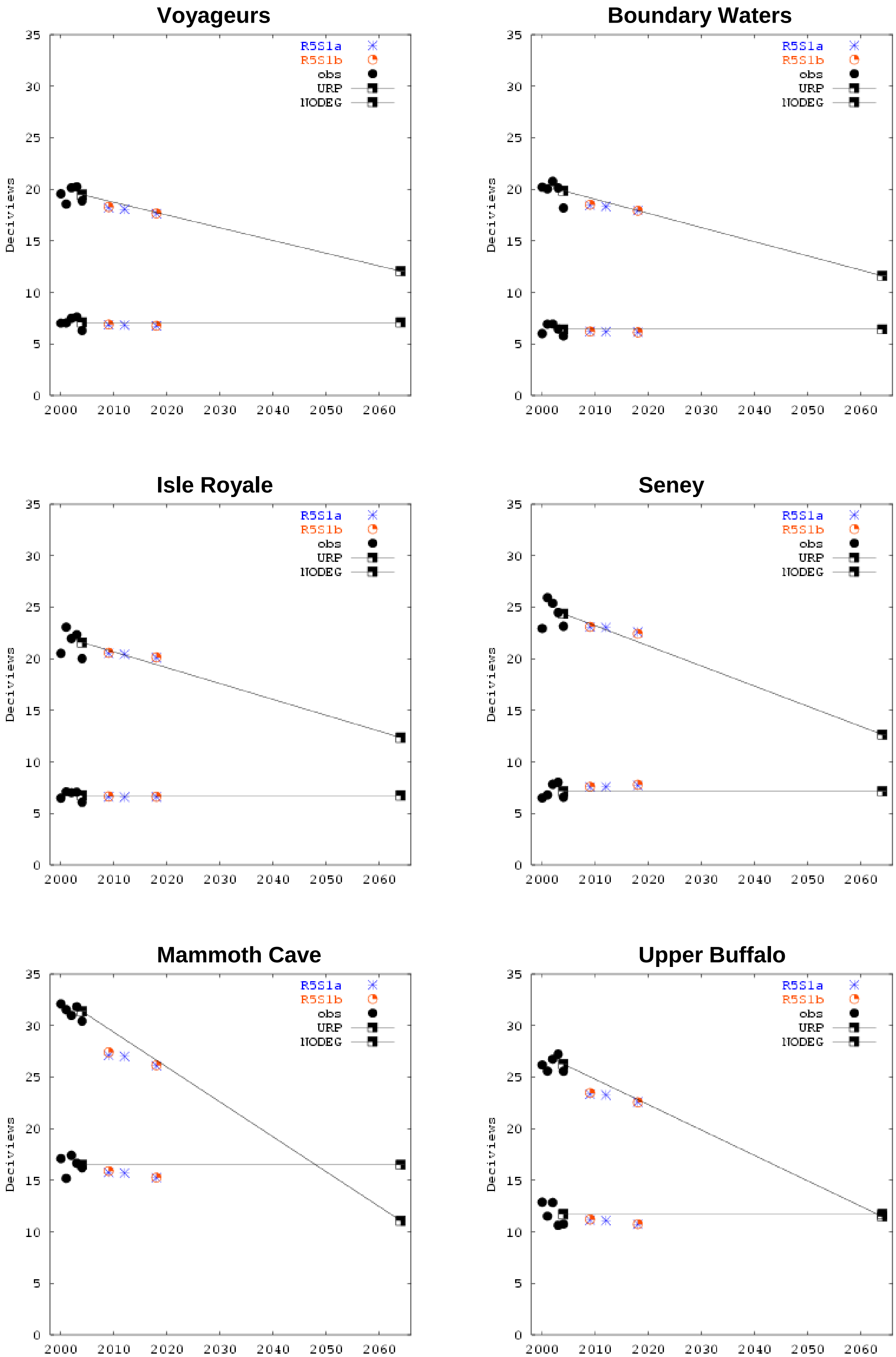

Figure 11. Visibility modeling results for Class I areas in eastern U.S.

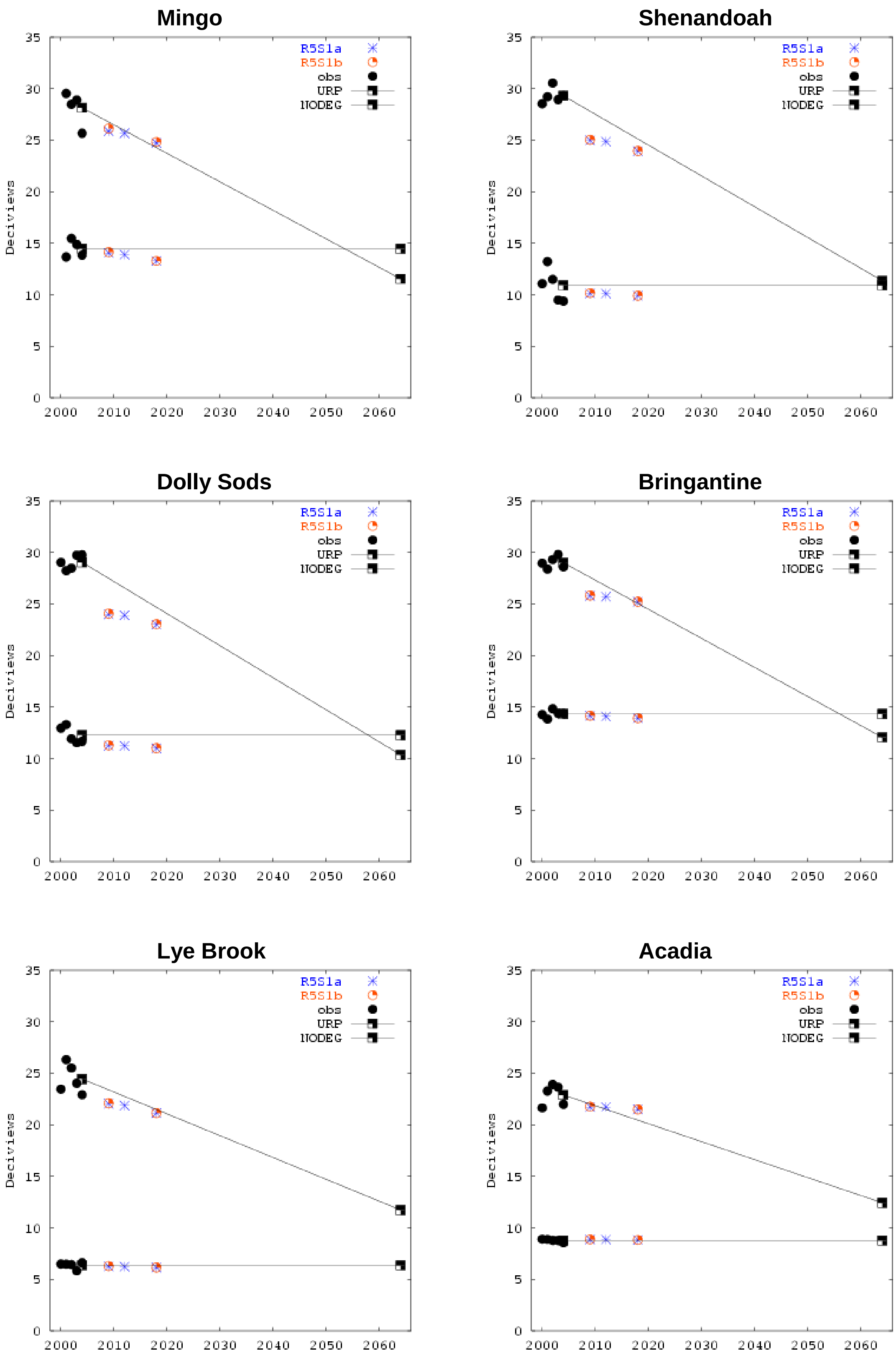

Figure 11 (cont.) Visibility modeling results for Class I areas in eastern U.S.