Round 1 Strategy Modeling: Summary

The purpose of this document is to summarize the results of the Round 1 strategy modeling, including several sensitivity runs.

Strategy Modeling

The Round 1 modeling includes two strategies: Strategy 1 - "on the books" controls, and Strategy 2 – "on the way" controls (i.e., CAIR). Two future years were modeled: 2009 (modeling attainment year for PM2.5 nonattainment areas and ozone moderate nonattainment areas), and 2018 (first milestone for regional haze).

The VOC, NOx, and SOx emissions for the 5-state region are shown below in Figure 1.

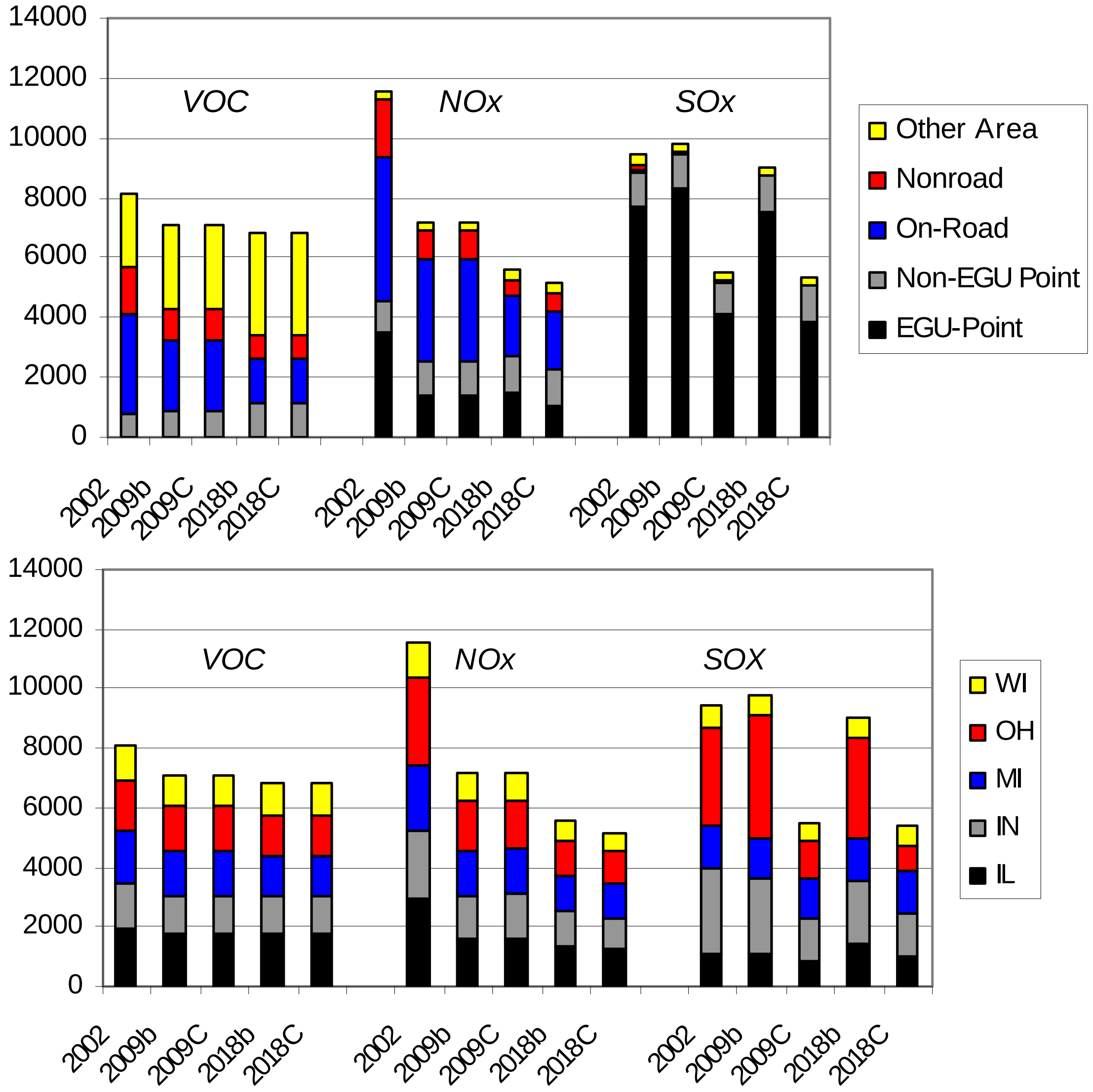


Figure 1. VOC, NOx, and SOx emissions for 5-state region by source sector (top) and state (bottom)

The modeling analysis consisted of applying the CAMx model with MM5-based meteorology for calendar year 2002. The modeling domain (see figure 2) included a 36 km grid over the eastern U.S. and a 12 km grid over the upper Midwest (which was used only for summertime ozone modeling). The modeling was performed in accordance with USEPA guidance: "Guidance for Demonstrating Attainment of Air Quality Goals for PM2.5 and Regional Haze", draft 2.1, Jan. 2001, and "Guidance on the Use of Models and Other Analyses in Attainment Demonstrations for the 8-Hour Ozone NAAQS", Draft Final, Feb. 17, 2005.

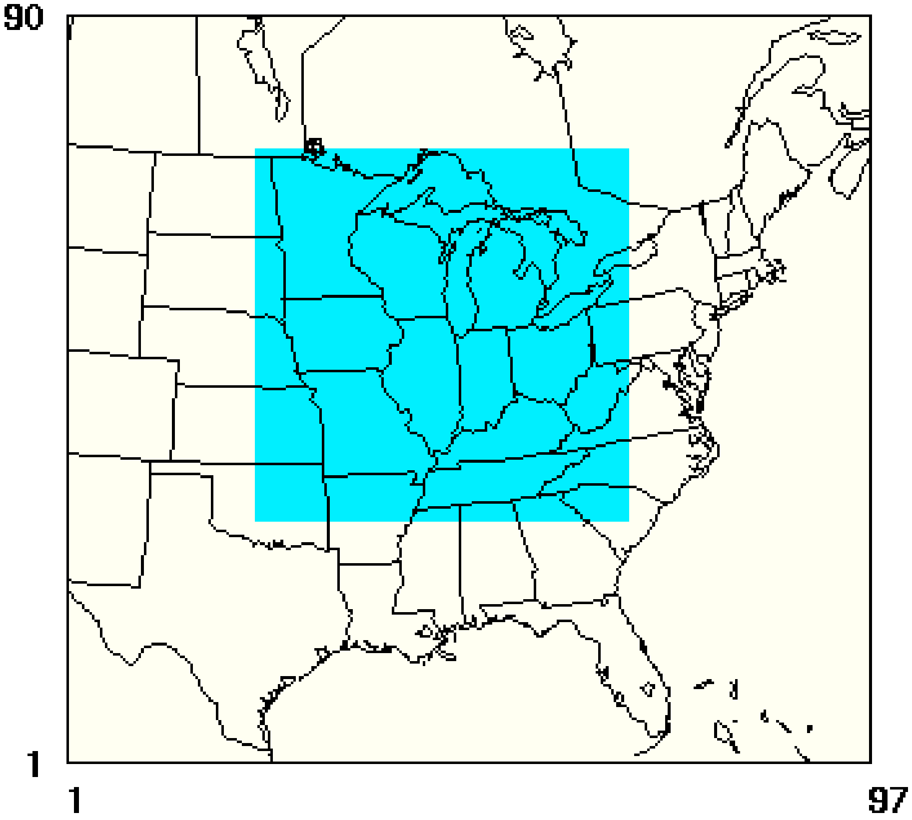


Figure 2. Modeling domain

USEPA's attainment tests were applied to the results of the strategy modeling to determine whether a given strategy is sufficient to provide for attainment of the NAAQS for O_3 and $PM_{2.5}$ and meet the reasonable progress goals for haze. USEPA guidelines recommend using the model in a relative sense to project future year design values. This is done through the use of a relative reduction factor (RRF), which is defined as the ratio of the future year and baseline modeling results. The RRFs are multiplied by the observed base year design values to project the future year design values, which are then compared to the NAAQS to assess attainment. For O_3 and $PM_{2.5}$, the base year design values will be based on the average of the three 3-year periods which contain

2002 (i.e., 2000-2002, 2001-2003, and 2002-2004). For haze, the baseline visibility levels will be based on 2000-2004 data, in accordance with 40 CFR 51.308(d)(2)(i).[1]

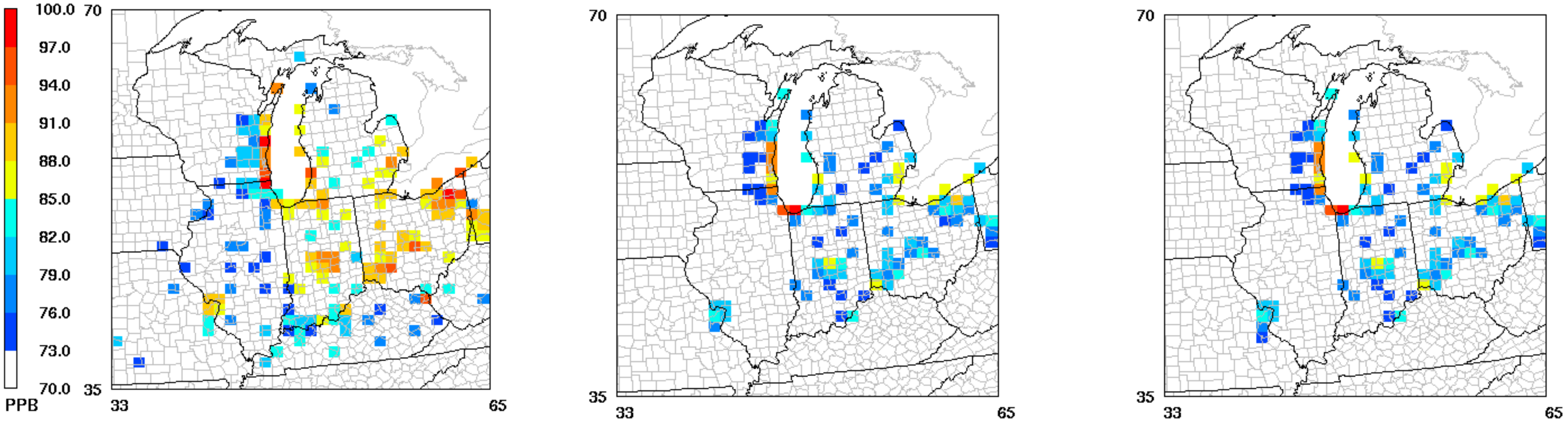
Several PM$_{2.5}$ monitors are classified as “source-oriented”. Pursuant to 40 CFR Part 58, Appendix D, 2.8.1.2.2, “PM$_{2.5}$ data collected from SLAMS and special purpose monitors that are representative, not of area-wide but rather, of relatively unique population-oriented micro-scale, or localized hot-spot, or unique population-oriented middle-scale impact sites are only eligible for comparison to the 24-hour PM$_{2.5}$ NAAQS.” The following sites have been designated by the states as being source-oriented middle-scale (or micro-scale) sites and should not be compared to the annual NAAQS:

170311016 – McCook
170990007 – Oglesby
180890022 - Gary (IITRI)
180970043 – Indianapolis (S. West St.)
170213103 - Schiller Park
171190023 - Granite City
180890026 - Gary (Burr Ave.)
180970066 - Indianapolis (English Ave.)

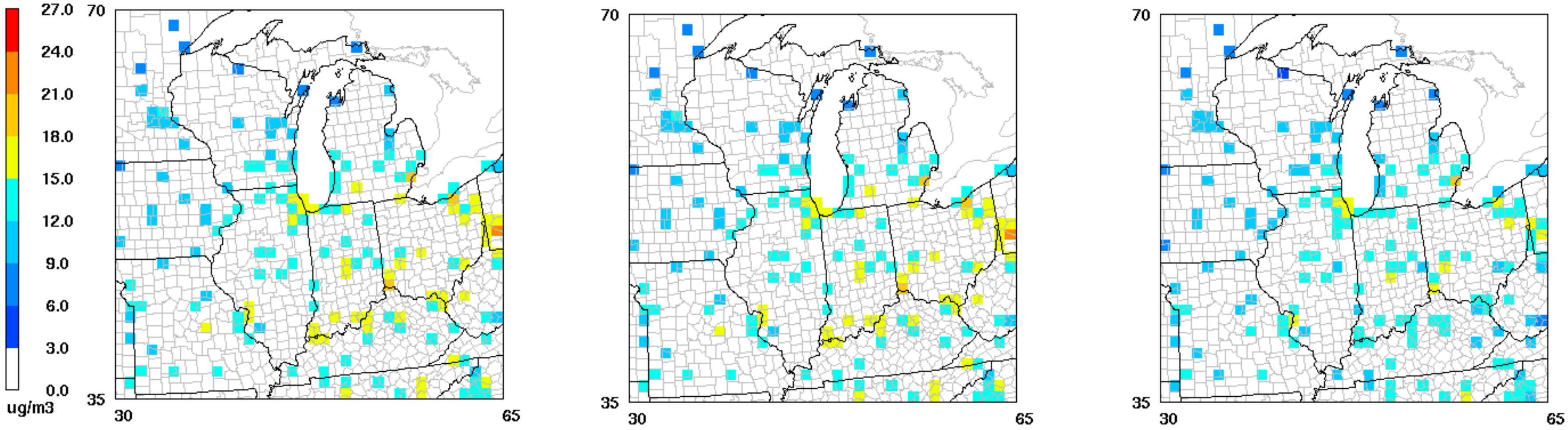
The modeled future year ozone and PM$_{2.5}$ design values for the two strategies are shown in Figures 3 and 4, along with the observed (base year) design values. The figures show that the “on the books” and “on the way” controls will substantially improve air quality. It also shows that despite this improvement, there are residual nonattainment problems and additional emission reductions will be needed to meet the NAAQS. Even with full implementation of CAIR in 2018, there are residual nonattainment problems (i.e., for ozone, at least Cleveland, Detroit, Kenosha, and Sheboygan are projected to be above the NAAQS; and for PM$_{2.5}$, at least Chicago, Detroit, and St. Louis are projected to be above the NAAQS).

---

[1] 2004 data are not yet available for PM$_{2.5}$ and visibility. Thus, the PM$_{2.5}$ attainment test is applied here using the average of two 3-year periods: 2000-2002 and 2001-2003, and the haze test is applied here using 2000-2003 data.

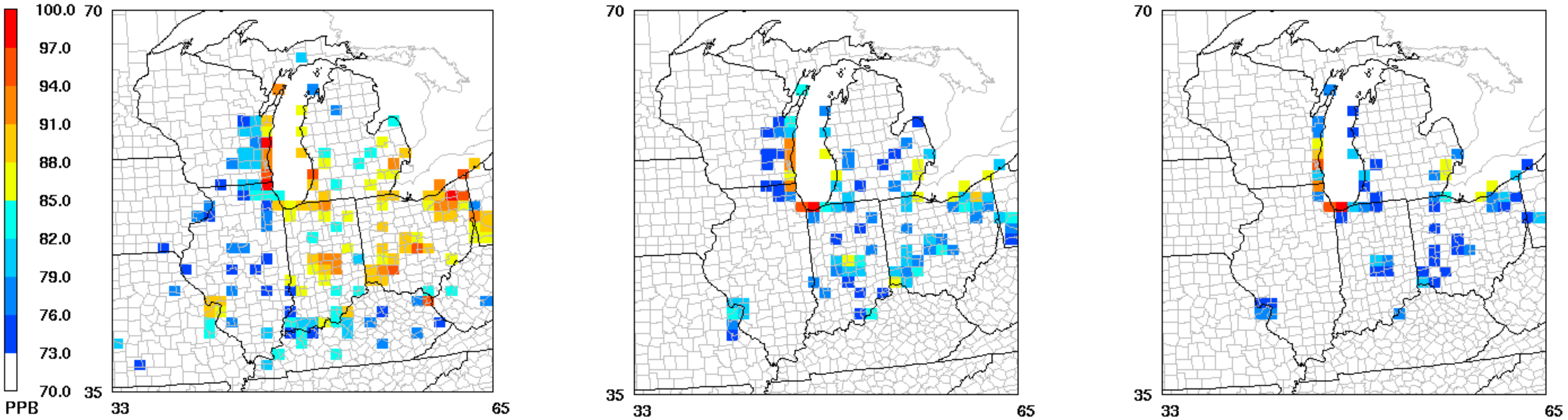


Observed (base year) **2009-Strategy 1** **2009 – Strategy 2**

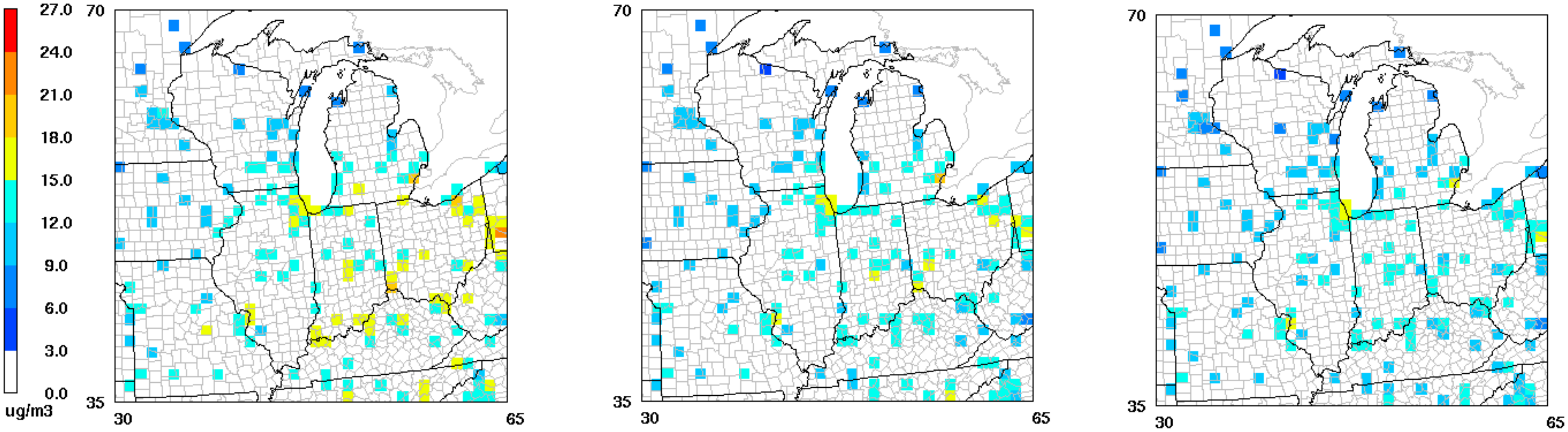


Observed (base year) **2009-Strategy 1** **2009 – Strategy 2**

Figure 3. Ozone (top) and PM2.5 (bottom) design values for base year (2002) and 2009



Observed (base year) **2009-Strategy 2** **2018 – Strategy 2**



Observed (base year) **2009-Strategy 2** **2018 – Strategy 2**

Figure 4. Ozone (top) and PM2.5 (bottom) design values for base year (2002), 2009, and 2018

The model results in Figure 3 also show ozone increases in many 36 km grid cells in the Chicago and Milwaukee metropolitan areas. This response is due at least in part to the coarse grid resolution (36 km) for the shoreline urban grid cells – i.e., the high emissions and a high fraction of water land use create a modeling artifact. The meteorological model assigns these grid cells a low boundary layer height because they contain mostly water. The high emissions and low boundary heights lead to an apparent “disbenefit” response in the model. Strategy 2 was re-run with a 12 km grid with emissions apportioned from the 36 km grid, but emissions over water were moved to the nearest land grid cell. This did not degrade model performance for ozone and greatly reduced the disbenefit response (see Figure 5). This preliminary analysis shows that 12 km emissions are critical to obtain the proper model response for ozone in shoreline grid cells with high emissions.

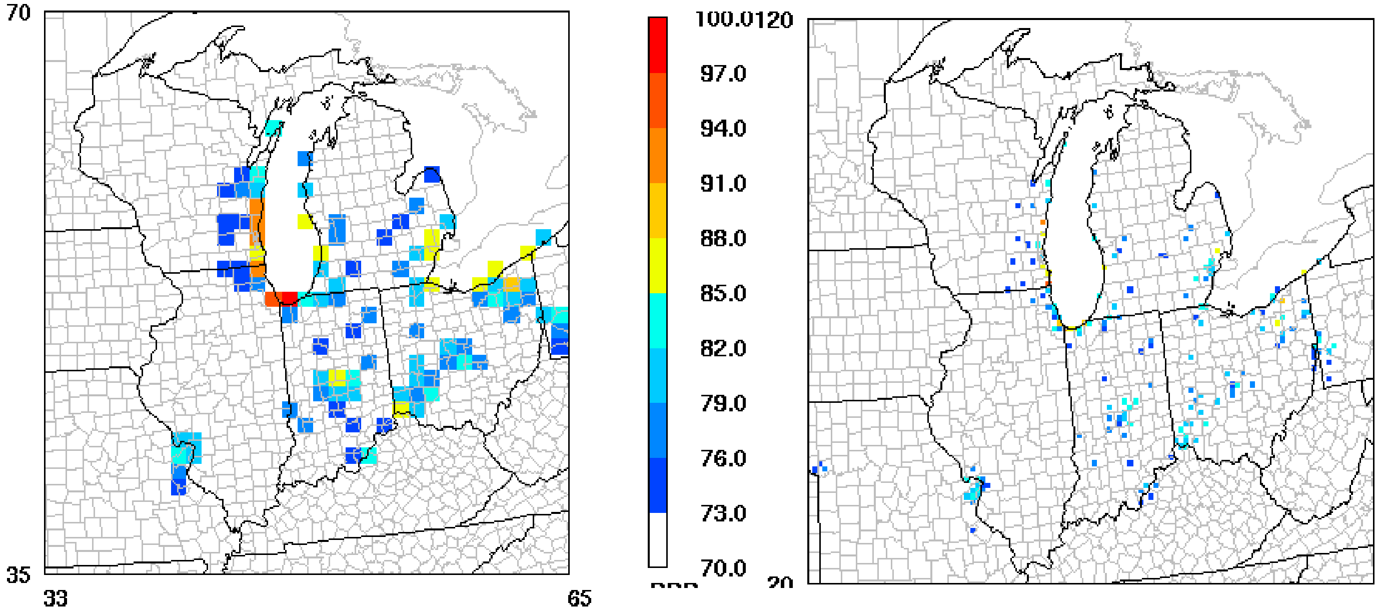


Figure 5. Ozone design value for 2009 – Strategy 2 at 36 km (left) and 12 km (right)

Table 1 shows the monitoring sites with modeled future year design values above the NAAQS for Strategy 2. For ozone, many of the predicted future year “nonattainment” sites are within 1 – 2 ppb of the standard (see also Figure 6). The more significant nonattainment problems are western Lake Michigan (Chicago/Milwaukee) and northeastern Ohio (Cleveland) – i.e., future year design values equal to or greater than 90 ppb. For $PM_{2.5}$, almost all of the predicted future year “nonattainment” sites are within 1 ug/m^3 of the standard (see also Figure 6). The more significant nonattainment problems are Detroit (Dearborn), Chicago (Mayfair Pumping Station), and Cleveland (Tikhon Street). Further local analyses (e.g., application of source apportionment and hot-spot modeling) should be considered for these three sites.

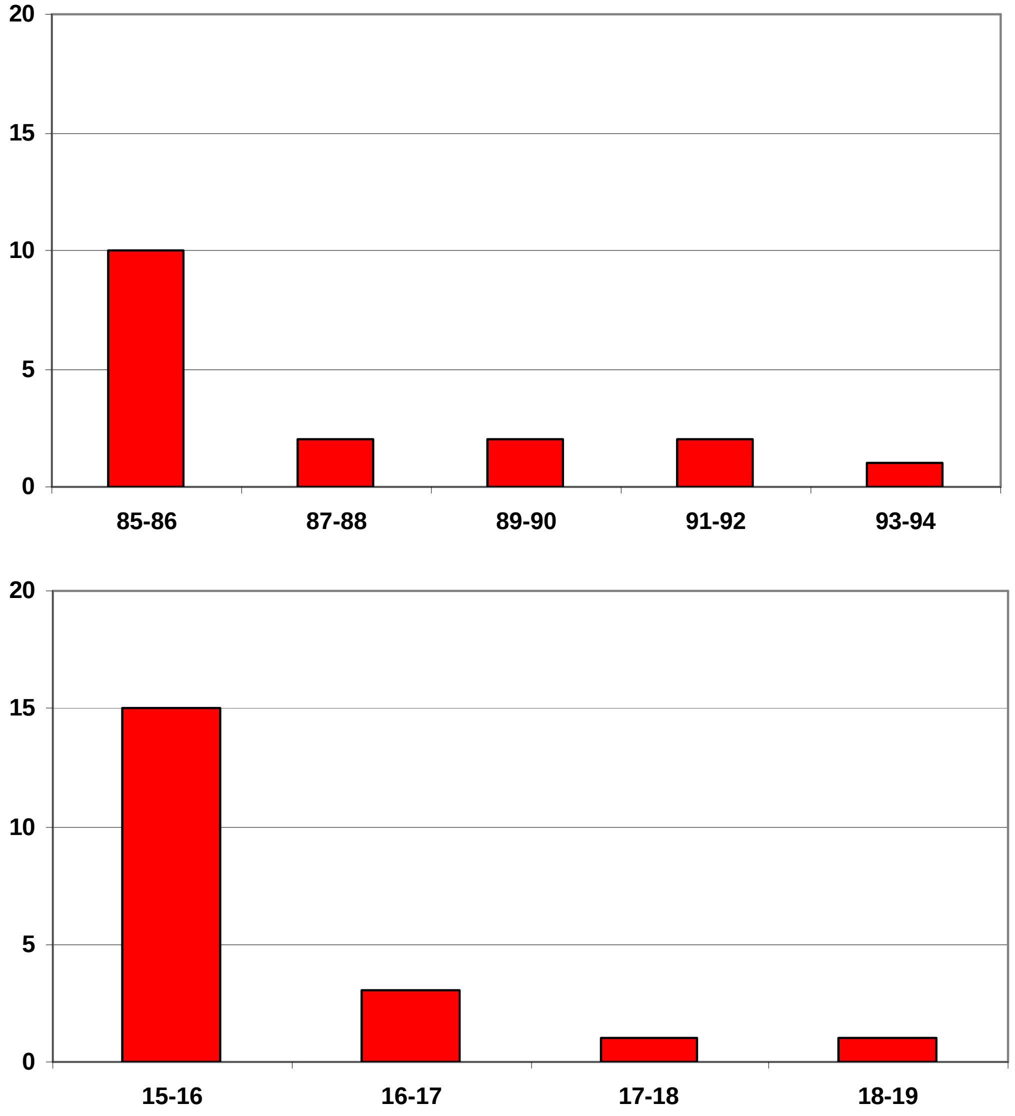


Figure 6. Ozone (top) and $PM_{2.5}$ (bottom) design values above NAAQS for Strategy 2

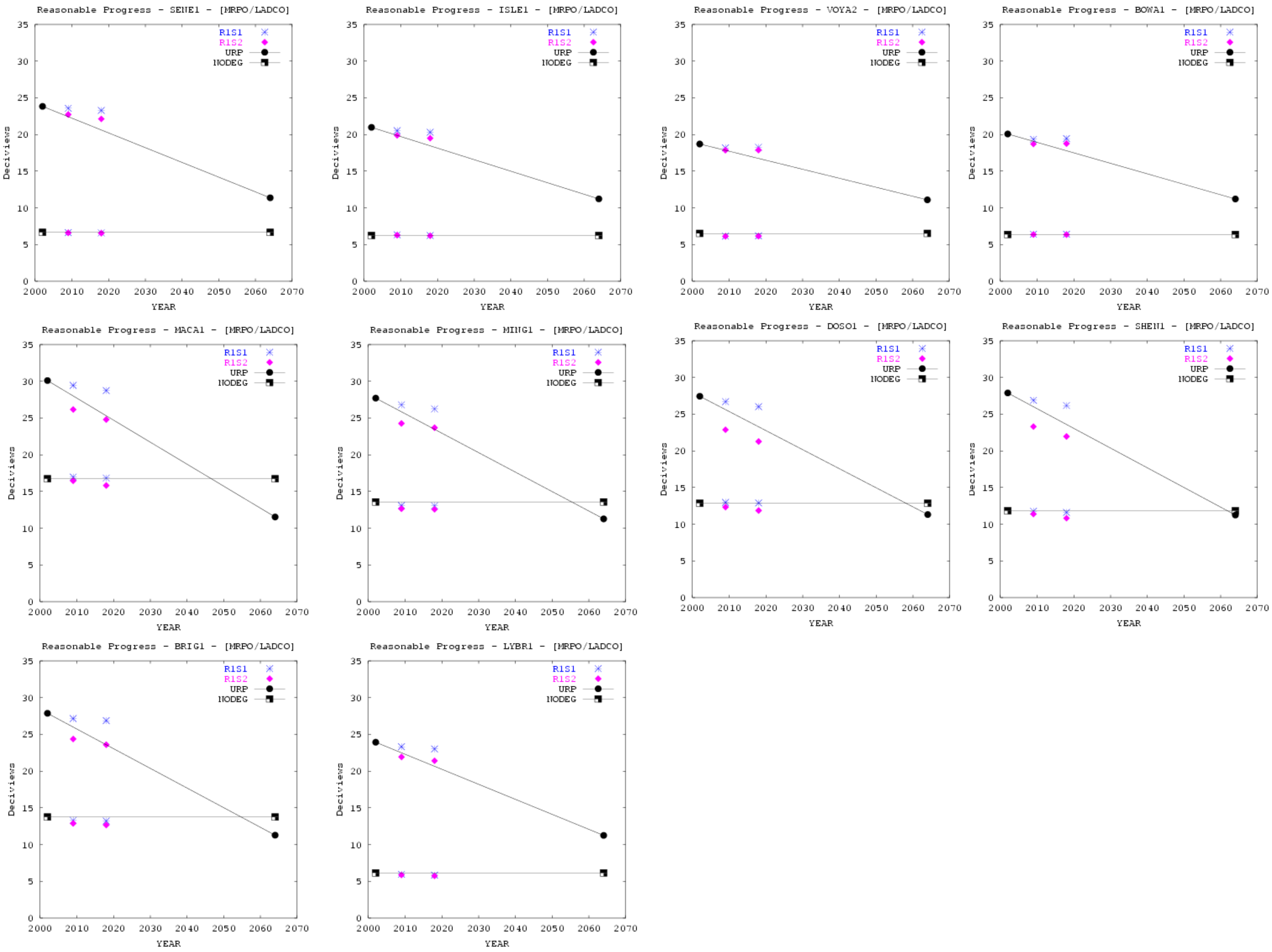
The visibility metric (deciviews) was calculated for several nearby Class I areas for both strategies and future years (see Table 2 and Figure 7). As can be seen, the 2018 calculated values for Strategy 2 (CAIR) are better than those associated with the uniform rate of progress (“2018 goal”) for several Class I areas (i.e., Mammoth Cave, Dolly Sods, Shenandoah, and Brigantine). The 2018 calculated values for the northern Class I areas in Michigan and Minnesota are slightly above those associated with the uniform rate of progress (“2018 goal”). Further analyses, including updated Integrated Planning Model (IPM) emissions estimates for electric generating units (EGUs) and consideration of additional control strategies, will be pursued to determine if the 2018 reasonable progress goal for these northern Class I areas will be met.

Table 1. Modeled Future Year Design Values: 2009 CAIR

	Ozone Design Values					**PM$_{2.5}$ Design Values**		
		Observed	**2009CAIR**				**Observed**	**2009CAIR**
Chicago	170310032	85.3	89.9 (91.6)	*	Chciago	170310014	16.0	15.1
						170310022	16.4	15.4
						170310052	17.7	17.1
NW Indiana	180890022	82.0	85.4 (94.8)	*		170310057	16.0	15.0
	180892008	88.3	93.6 (94.8)	*		170312001	16.1	15.1
	180910005	90.3	88.7			170313001	16.3	15.3
	181270024	86.3	87.7 (99.9)	*		170314006	15.3	15.0
						170316005	16.7	15.7
					Granite City	171191007	17.5	15.8
					Indianapolis	180970083	16.9	15.1
Holland	260050003	94.0	87.7		Detroit	261630001	16.2	15.3
Detroit	260990009	92.3	86.2			261630015	17.7	16.7
						261630033	19.7	18.6
						261630036	17.1	16.2
Cleveland	390071001	95.7	85.4		Cleveland	390350013	17.5	15.1
	390550004	99.0	90.2			390350038	18.7	16.2
Akron	391530020	93.3	85.0			390350060	17.7	15.3
					Cincinnati	390610014	18.1	15.3
					Dayton	391130014	17.9	15.6
					Canton	391510017	17.6	15.0
Kenosha	550590002	96.0	92.2					
	550590019	98.3	94.4					
Racine	551010017	91.7	86.6					
Milwaukee	550790085	91.0	86.3 (92.7)	*				
	550791025	91.0	85.4					
Manitowoc	550890009	93.0	87.4					
Sheboygan	551170006	97.0	91.0					
		**** =12km (36km) results***						

Table 2. Visibility Metric (deciviews) for Nearby Class I Areas

site	flag	baseline	2009R1S1	2009R1S2	2018R1S1	2018R1S2		natural conditions
ISLE1	Best 20%	6.24	6.04	5.80	6.11	5.91		11.22
SENE1	Best 20%	6.66	6.62	6.59	6.59	6.54		11.37
BOWA1	Best 20%	6.38	6.40	6.36	6.41	6.35		11.21
VOYA2	Best 20%	6.52	6.14	6.13	6.18	6.15		11.09
MING1	Best 20%	13.58	13.09	12.65	13.06	12.57		11.27
MACA1	Best 20%	16.74	16.96	16.45	16.82	15.81		11.53
DOSO1	Best 20%	12.87	12.97	12.33	12.89	11.86		11.32
SHEN1	Best 20%	11.83	11.77	11.38	11.61	10.83		11.25
BRIG1	Best 20%	13.75	13.30	12.89	13.22	12.67		11.28
LYBR1	Best 20%	6.14	5.95	5.86	5.84	5.73		11.25
site	**flag**	**baseline**	**2009R1S1**	**2009R1S2**	**2018R1S1**	**2018R1S2**		**2018 Goal**
ISLE1	Worst 20%	20.97	21.26	21.10	20.96	20.80		18.45
SENE1	Worst 20%	23.83	23.57	22.71	23.27	22.12		20.61
BOWA1	Worst 20%	20.07	19.34	18.70	19.44	18.75		17.79
VOYA2	Worst 20%	18.70	18.17	17.85	18.25	17.87		16.74
MING1	Worst 20%	27.20	26.31	23.82	25.76	23.25		23.09
MACA1	Worst 20%	30.10	29.44	26.16	28.74	24.79		25.31
DOSO1	Worst 20%	27.44	26.70	22.88	26.02	21.28		23.28
SHEN1	Worst 20%	27.89	26.89	23.31	26.17	21.95		23.60
BRIG1	Worst 20%	27.87	27.16	24.37	26.87	23.58		23.59
LYBR1	Worst 20%	23.93	23.32	21.93	23.02	21.40		20.66


Reasonable Progress - SENE1 - [MRPO/LADCO]

Reasonable Progress - ISLE1 - [MRPO/LADCO]

Reasonable Progress - VOYA2 - [MRPO/LADCO]

Reasonable Progress - BOWA1 - [MRPO/LADCO]

Reasonable Progress - MACA1 - [MRPO/LADCO]

Reasonable Progress - MING1 - [MRPO/LADCO]

Reasonable Progress - DOSO1 - [MRPO/LADCO]

Reasonable Progress - SHEN1 - [MRPO/LADCO]

Reasonable Progress - BRIG1 - [MRPO/LADCO]

Reasonable Progress - LYBR1 - [MRPO/LADCO]

Figure 7. Visibility metric (deciviews) for nearby Class I areas

Sensitivity Modeling

Two sets of sensitivity runs for 2009 were performed as part of the Round 1 modeling. The first set consisted of:

Run 11. Scenario 2 plus
- -15% VOC and -15% OC all sectors in MRPO nonattainment counties

Run 12. Scenario 2 plus
- -15% VOC and -15% OC all sectors in MRPO nonattainment counties
- -35% SOX and -50% NOX elevated EGU point throughout 5-state MRPO region

Run 13. Scenario 2 plus
- -15% VOC and -15% OC all sectors in MRPO nonattainment counties
- -35% SOX and -50% NOX elevated EGU point throughout 5-state MRPO region
- -15% NOX onroad, offroad, other area, lowp throughout 5-state MRPO region

Run 14. Scenario 2 plus
- -15% VOC and -15% OC all sectors in MRPO nonattainment counties
- -35% SOX and -50% NOX elevated EGU point throughout 12-state region[2]
- -15% NOx onroad, offroad, other area, lowp throughout 12-state region

Run 15. Scenario 2 plus
- -30% VOC and -30% OC all sectors in MRPO nonattainment counties
- -55% SOX and -60% NOX elevated EGU point throughout 5-State MRPO region
- -30% NOx onroad, offroad, other area, lowp throughout 5-state MRPO region

The emission reductions in these runs approximate those in the White Papers being prepared for the Midwest RPO (e.g., the EGU1 SOx and NOx reductions in runs 12-14 and the EGU2 SOx and NOx reductions in run 15 approximate, on an annual average basis, the candidate control measures in "Interim White Paper – Midwest RPO Candidate Control Measures, Source Category: Electric Generating Units", January 14, 2005). The effect of particular emission reductions can be estimated by comparing sensitivity runs.

The figure below summarizes the five-state emission totals for these sensitivity runs.

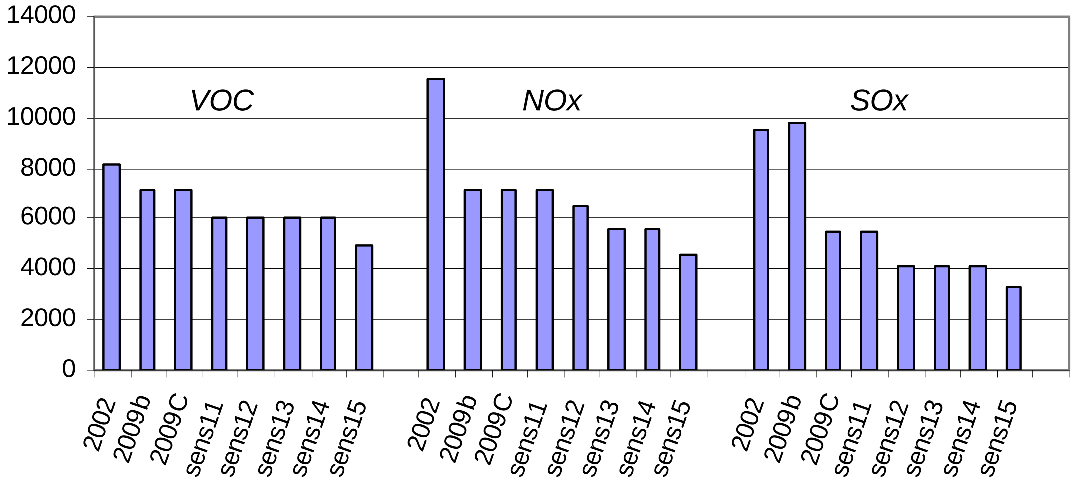


Figure 8. VOC, NOx, and SOx emissions for 5-state region

---

[2] 12-state region = 5-state MRPO region, plus MN, IA, MO, KY, TN, WV, and PA

For NOx, there are actually seasonal differences in the EGU reductions given the existence of the NOx SIP call, which reflects "summer" NOx reductions. To provide a more exact estimate of the EGU reductions, another set of runs were performed:

New Run 12 (EGU1). Scenario 2 plus

- -15% VOC and -15% OC all sectors in MRPO nonattainment counties
- Elevated EGU point: -35% SOX and -20% summer/-60% winter NOX throughout 5-state MRPO region

Run 12a (EGU1). Scenario 2 plus

- -15% VOC and -15% OC all sectors in MRPO nonattainment counties
- Elevated EGU point: -35% SOX in 5-state MRPO region and -40% SOX in other 8 states in MWGA region, and -20% summer/-60% winter NOX in 5-state MRPO region and -50% summer/-60% winter in other 8 states in MWGA region[3]

Run 12b (EGU2). Scenario 2 plus

- -15% VOC and -15% OC all sectors in MRPO nonattainment counties
- Elevated EGU point: -55% SOX and -35% summer/-70% winter NOX throughout 5-state MRPO region

The modeled future year design values for the sensitivity runs are shown in Figures 9a and 9b (regional plots), and Figures 10a and 10b (select urban areas). A few comments on these figures should be noted:

- CAIR has little effect for ozone, but lowers $PM_{2.5}$ design values by about 1.5 ug/m^3

- EGU1[4] in the five MRPO states lowers design values by an additional (i.e., beyond CAIR) 0.5 ppb for ozone and 0.8 ug/m^3 for $PM_{2.5}$

- EGU1 in the seven neighboring states (MN, IA, MO, KY, TN, WV, and PA) lowers design values by an additional (i.e., beyond CAIR) 1 ppb for ozone and 0.5 ug/m^3 for $PM_{2.5}$

- EGU1 in the other eight Midwest Governors Association states (ND, SD, NE, KS, MN, IA, MO, and KY) lowers design values by an additional (i.e., beyond CAIR) 0.5 ppb for ozone and 0.25 ug/m^3 for $PM_{2.5}$

- EGU2[5] lowers design values by an additional (i.e., beyond CAIR) 0.5 – 1.0 ppb for ozone and 1 ug/m^3 for $PM_{2.5}$

- Low-level VOC and NOx reductions each provide about a 0.5 – 1.5 ppb benefit for ozone, although low-level NOx reductions also produce a slight

---

[3] 13-state region = 5-state MRPO region, plus MN, IA, MO, KY, ND, SD, NE, and KS

[4] EGU1: 2009 – SOx: 0.36 lb/MMBUT, NOx: 0.15 lb/MMBTU
2018 – SOx: 0.15 lb/MMBTU, NOx: 0.10 lb/MMBTU

[5] EGU2: 2009 – SOx: 0.24 lb/MMBUT, NOx: 0.12 lb/MMBTU
2018 – SOx: 0.10 lb/MMBTU, NOx: 0.07 lb/MMBTU

disbenefit in the Chicago and Detroit areas. Low-level NOx reductions also provide a slight benefit for $PM_{2.5}$.

- The ozone model response for shoreline grid cells (e.g., those in Chicago and Northwest Indiana), as seen in Figure 9a, is an artifact of the 36 km grid spacing. As noted above, 12 km modeling is necessary to provide a more reasonable model response. Thus, the 36 km sensitivity modeling results for these grid cells were not considered.

These changes in ozone and $PM_{2.5}$ design values, compared to the degree of nonattainment (i.e., most future year design values are within 1-2 ppb or ug/m^3 of the ambient standard), are notable.

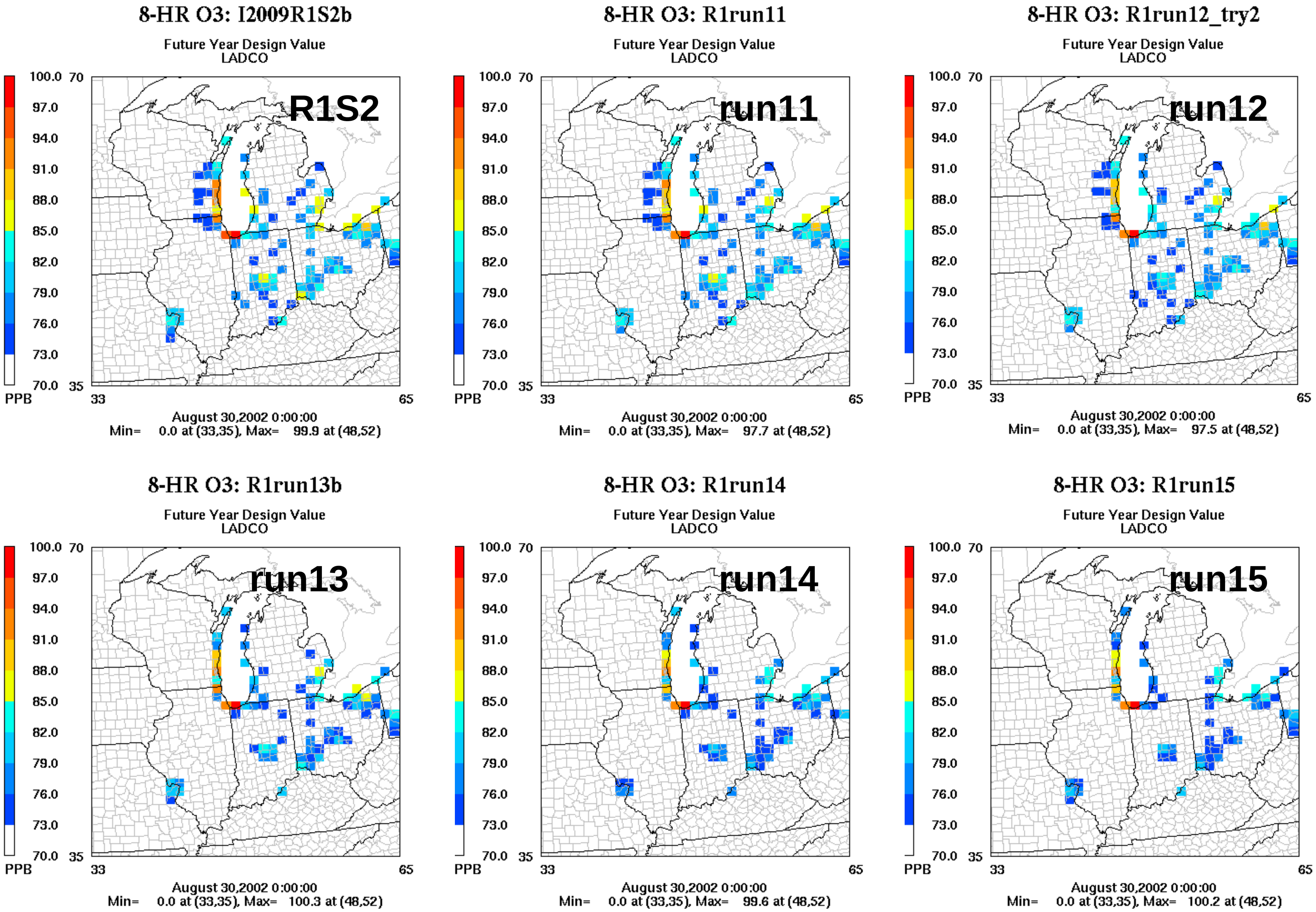


Figure 9a. Spatial plots of 2009 ozone design values

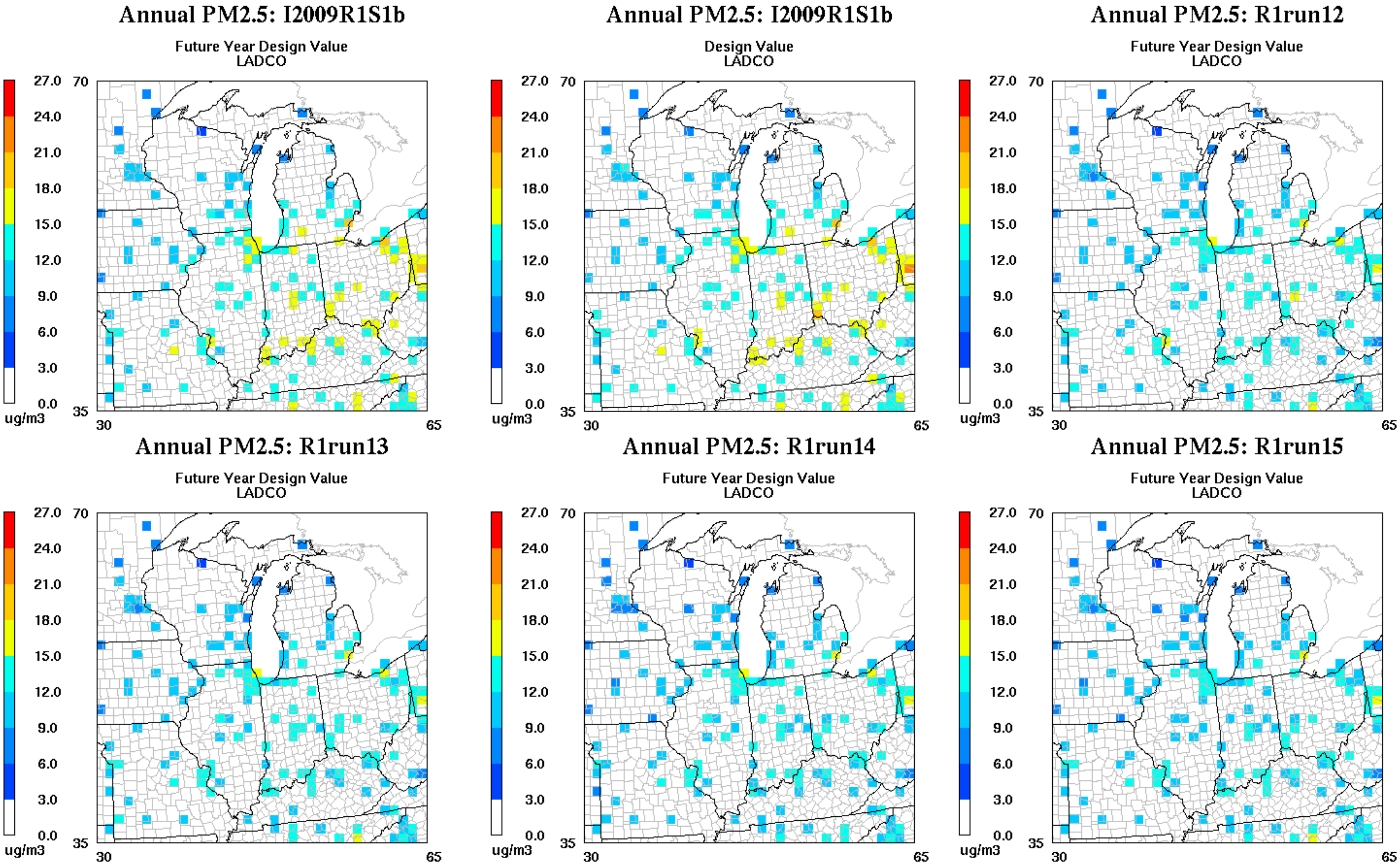
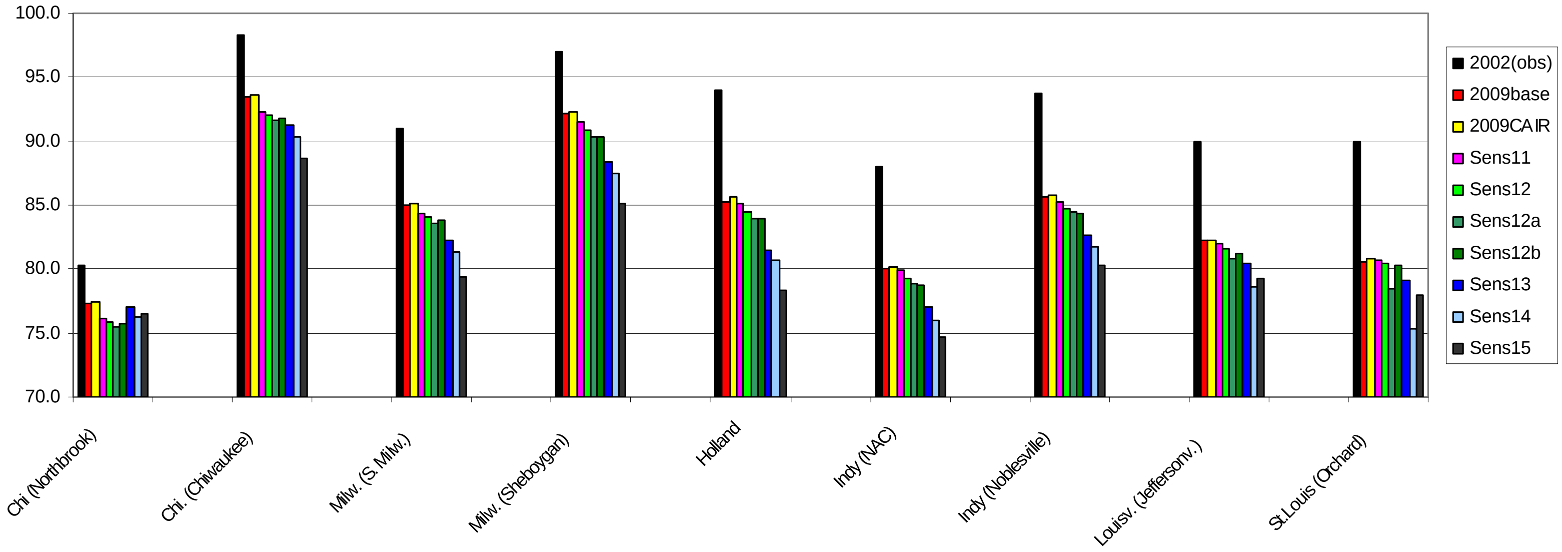


Figure 9b. Spatial plots of 2009 $PM_{2.5}$ design values



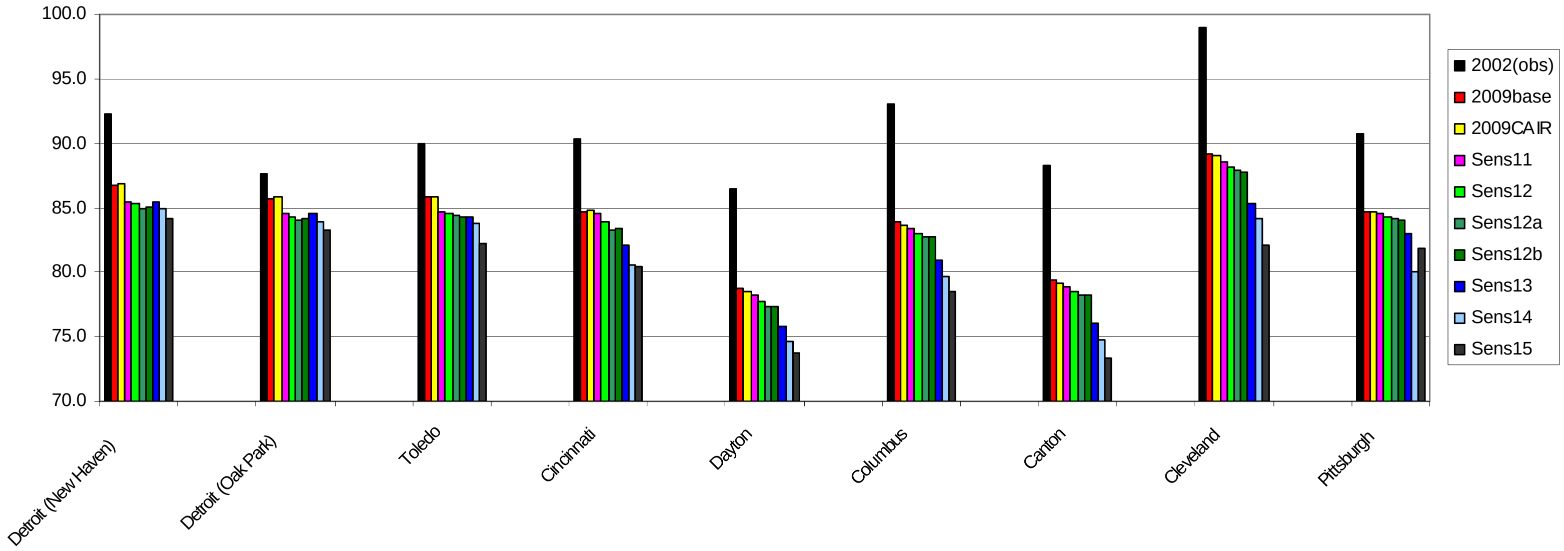


Figure 10a. Modeled design values for ozone

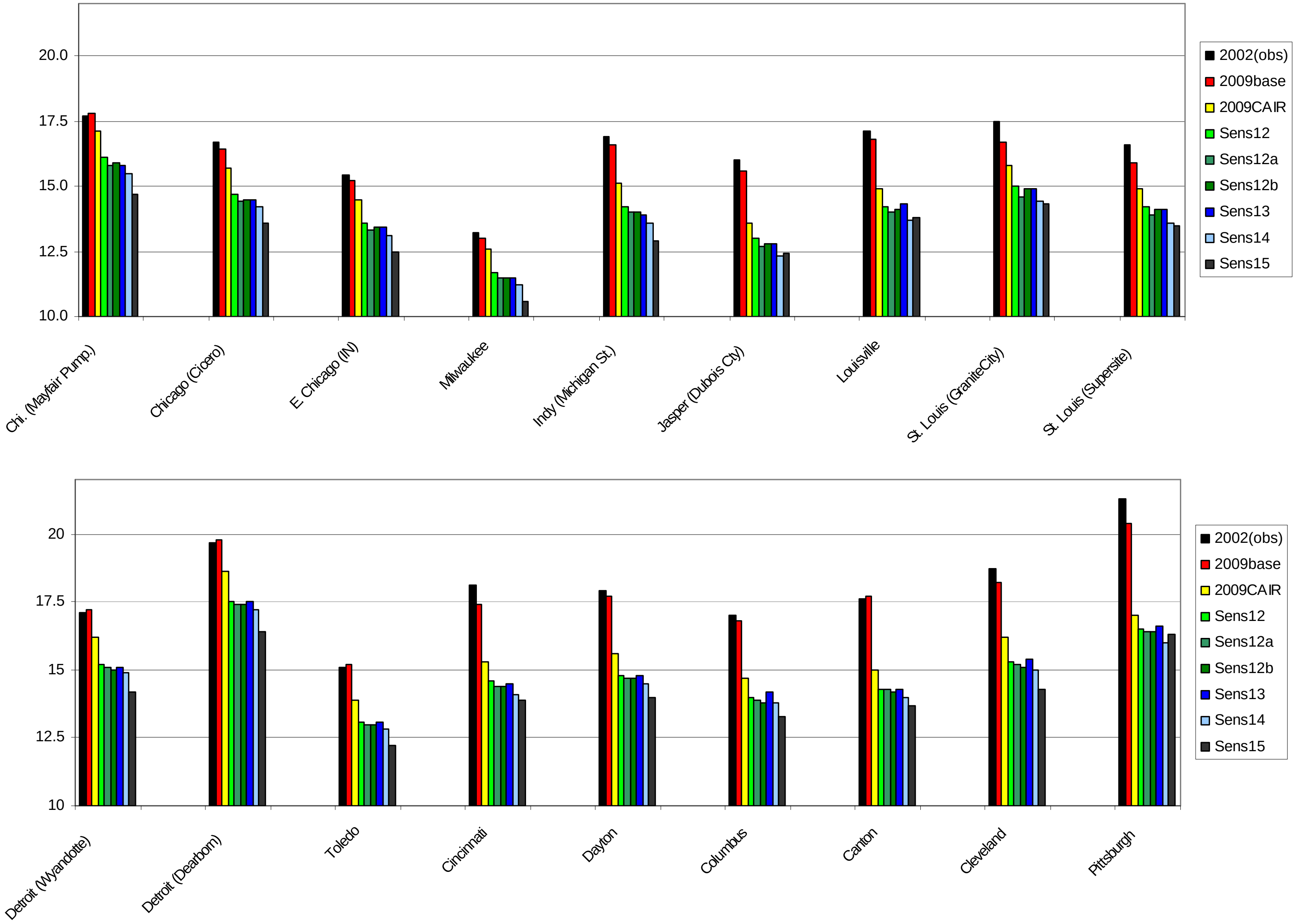


Figure 10b. Modeled design values for $PM_{2.5}$