Chapter 3: Air Quality Analysis

Synopsis

This chapter describes the approach used to calculate 2020 baseline SO_2 design values and the amount of emissions reductions needed to attain the alternative 1-hour SO_2 NAAQS. The NAAQS being analyzed are 50, 75, and 100 ppb based on design values calculated using the 3-year average of the 99th percentile 1-hour daily maximum concentrations based on the monitoring network described in Chapter 2. The projected 2020 baseline SO_2 design values are used to identify 2020 nonattainment counties and to calculate, for each such county, the amount of reduction in SO_2 concentration necessary to attain the alternative NAAQS. This chapter also describes the approach for calculating "ppb SO_2 concentration per ton SO_2 emissions" ratios that are used to estimate the amount of SO_2 emissions reductions that may be needed to provide for attainment of the alternative SO_2 standards. As described below, the air quality analysis relies on SO_2 emissions from simulations of the Community Multiscale Air Quality (CMAQ) model coupled with ambient 2005-2007 design values and emissions data to project 2020 SO_2 design value concentrations and the "ppb per ton" ratios. A description of CMAQ is provided in the Ozone NAAQS RIA Air Quality Modeling Platform Document (EPA, 2008).

3.1 2005-2007 Design Values

The proposed standard is based on the 3-year average of the 99th percentile concentration of the daily 1-hour maximum concentration for a year. The design value for each percentile is calculated as:

- Identify daily 1-hour maximum concentration for each day for each year
- Calculate 99th percentile values of the daily 1-hour maximum concentrations for each year
- Average the 99th percentile values for the three years.

Monitors that had valid measurements for at least 75% of the day, 75% of the days in a quarter and all 4 quarters for all three years were included in the analysis[1]. The resulting 3-year averaged 99th percentile daily 1-hour maximum concentrations are shown in Figure 3.1 for 229 monitored counties. Counties in blue, green, and dark red would exceed the lowest alternative standard considered in the RIA, 50 ppb. Monitors with design values of 50.0 to 50.4 ppb would not exceed the standard 50 ppb as those concentrations would round to 50 ppb.

[1] Email from Rhonda Thompson to James Thurman, January 22, 2009.

Concentrations 50.5 ppb and higher are considered exceeding the lowest alternative standard. Similar rounding is done for the 75, and 100 ppb alternative standards (75.4 and 100.4 are the cut-offs for nonattainment). A summary of the number of counties exceeding the alternative standards for 2005-2007 is shown in Table 3.1. Appendix 3 contains the complete list of 2005-2007 design values used in calculation of the 2020 design values. Table 3.2 lists the top ten counties for the 99^{th} percentile design values for 2005-2007.

Figure 3.1. 2005-2007 3-year averaged design values (ppb) for 99th percentile daily 1-hour maximum SO_2 concentrations. Values shown are county maxima.

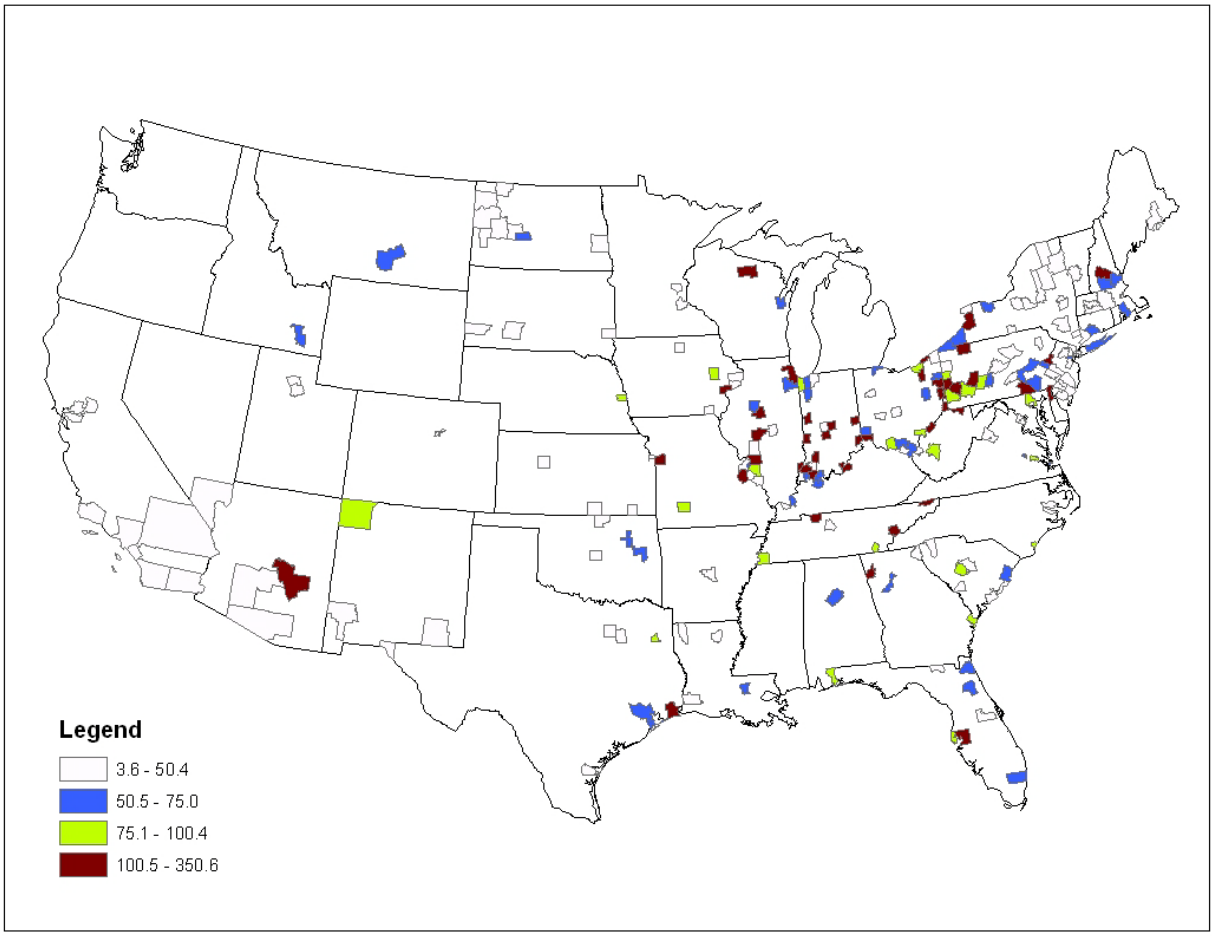


Table 3.1. Number of monitors and counties exceeding 50, 75, and 100 ppb alternative standards for the 99th percentile design values for 2005-07.

Alternative standard (ppb)	Number of monitors	Number of counties
50	169	119
75	95	70
100	59	46

Table 3.2. Top 10 2005-07 counties 99th percentile design values.

State	County	Design value (ppb)
MO	Jefferson	350.6
AZ	Gila	286.0
IL	Tazewell	222.3
PA	Warren	214.0
TN	Blount	196.3
PA	Northampton	187.0
IN	Fountain	183.0
OH	Lake	180.3
WI	Oneida	179.0
IN	Floyd	176.3

3.2 Calculation of 2020 Projected Design Values

The 2020 baseline design values were determined using CMAQ gridded emissions for 2005 and 2020. Gridded emissions were utilized instead of county emissions because of the influence of stationary sources on SO_2 concentrations. For monitors near county boundaries, stationary sources in a neighboring county may have more influence over the monitor than a stationary source in the monitor's home county. The SO_2 emissions in the CMAQ runs reflect reductions from the following controls and programs shown in Table 3.3.

Table 3.3. Controls in the 2020 SO_2 inventory.

Control Strategies	Approach or Reference:
Non-EGU Point Controls	
Consent decrees apportioned to several plants	
DOJ Settlements: plant SCC controls Alcoa, TX Premcor (formerly MOTIVA), DE	1
Refinery Consent Decrees: plant/SCC controls	2
Closures, pre-2007: plant control of 100% Auto plants Pulp and Paper Large Municipal Waste Combustors Small Municipal Waste Combustors Plants closed in preparation for 2005 inventory	3
Small Municipal Waste Combustors (SMWC)	4
Solid Waste Rules (Section 129d/111d) Hospital/Medical/Infectious Waste Incinerator Regulations	EPA, 2005
MACT rules, plant-level, PM & SO_2: Lime Manufacturing	5
Stationary Area Assumptions	
Residential Wood Combustion Growth and Changeouts to year 2020	6
EGU Point Controls	
Clean Air Interstate Rule	7; EPA, 2005
Onroad Mobile and Nonroad Mobile Controls (list includes all key mobile control strategies but is not exhaustive)	
Tier 2 Rule	EPA, 1999
2007 Onroad Heavy-Duty Rule	EPA, 2000
Final Mobile Source Air Toxics Rule (MSAT2)	EPA, 2007
Renewable Fuel Standard	EPA, 2010
Clean Air Nonroad Diesel Final Rule – Tier 4	8, EPA, 2004
Control of Emissions from Nonroad Large-Spark Ignition Engines and Recreational Engines (Marine and Land Based): "Pentathalon Rule" Clean Bus USA Program Control of Emissions of Air Pollution from Locomotives and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder	8,9,10
Aircraft, Locomotives, and Commercial Marine Assumptions	
Aircraft: Itinerant (ITN) operations at airports to year 2020	11
Locomotives: Energy Information Administration (EIA) fuel consumption projections for freight rail Clean Air Nonroad Diesel Final Rule – Tier 4 Locomotive Emissions Final Rulemaking, December 17, 1997 Control of Emissions of Air Pollution from Locomotives and Marine	EPA, 2009; 12; 9

Control Strategies	Approach or Reference:
Commercial Marine: EIA fuel consumption projections for diesel-fueled vessels OTAQ ECA C3 Base 2020 inventory for residual-fueled vessels Clean Air Nonroad Diesel Final Rule – Tier 4 Emissions Standards for Commercial Marine Diesel Engines, December 29, 1999 Tier 1 Marine Diesel Engines, February 28, 2003	12; EPA, 2009

1. For ALCOA consent decree, used http:// cfpub.epa.gov/compliance/cases/index.cfm; for MOTIVA: used information sent by State of Delaware
2. Used data provided by Brenda Shine, EPA, OAQPS
3. Closures obtained from EPA sector leads; most verified using the world wide web.
4. Used data provided by Walt Stevenson, EPA, OAQPS
5. Percent reductions recommended are determined from the existing plant estimated baselines and estimated reductions as shown in the Federal Register Notice for the rule. SO_2 % reduction will therefore be 6147/30,783 = 20% and PM10 and PM2.5 reductions will both be 3786/13588 = 28%
6. Expected benefits of woodstoves change-out program: http://www.epa.gov/woodstoves/index.html
7. http://www.epa.gov/airmarkets/progsregs/epa-ipm/docs/summary2006.pdf
8. http://www.epa.gov/nonroad-diesel/2004fr.htm
9. http://www.epa.gov/cleanschoolbus/
10. http://www.epa.gov/otaq/marinesi.htm
11. Federal Aviation Administration (FAA) Terminal Area Forecast (TAF) System, December 2007: http://www.apo.data.faa.gov/main/taf.asp
12. http://www.epa.gov/nonroad-diesel/2004fr.htm

In brief, these CMAQ emissions were at 12 km horizontal resolution for two modeling domains which, collectively, cover the lower 48 States and adjacent portions of Canada and Mexico. The boundaries of these two domains are shown in Figure 3.2. The spatial distribution of the emissions for 2005 and 2020 can be seen in Figures 3.3 and 3.4 respectively. In both figures, the lines radiating from the coast are the commercial marine vessel emissions. Figure 3.5 shows the reduction in emissions between 2005 (16.3 million tons) and 2020 (9.6 million tons) by source sector (EGU, non-EGU point, commercial marine vessel, and other sources) with the decrease from 2005 to 2020 due mostly to decreases in EGU emissions.

3.2.1 2020 Design Value Calculation Methodology

Ambient monitored data were assigned to CMAQ grid cells using ArcGIS. Since there were areas of the country where the eastern and western domains overlapped, monitors in these overlapping areas were assigned to the eastern or western grid cells by using a "combined grid." This combined grid was a mesh of the eastern and western domains, with overlapping areas assigned eastern grid cells or western grid cells based on the location relative to the dividing line shown in Figure 3.2. Figure 3.2 shows the assignment of monitors to the two domains. An example of monitors in both domains was the El Paso County monitors. These monitors were assigned to the western domain. The gridded 2006 and 2020 emissions were also assigned to the combined grid based on the same grid assignments as the monitors.

Figure 3.2. Monitor domain assignments. Western domain is outlined in blue and eastern domain outlined in red. Black vertical line denotes dividing line between eastern and western domains for monitor assignments. Monitors in blue were assigned to the western domain and monitors in red were assigned to the eastern domain.

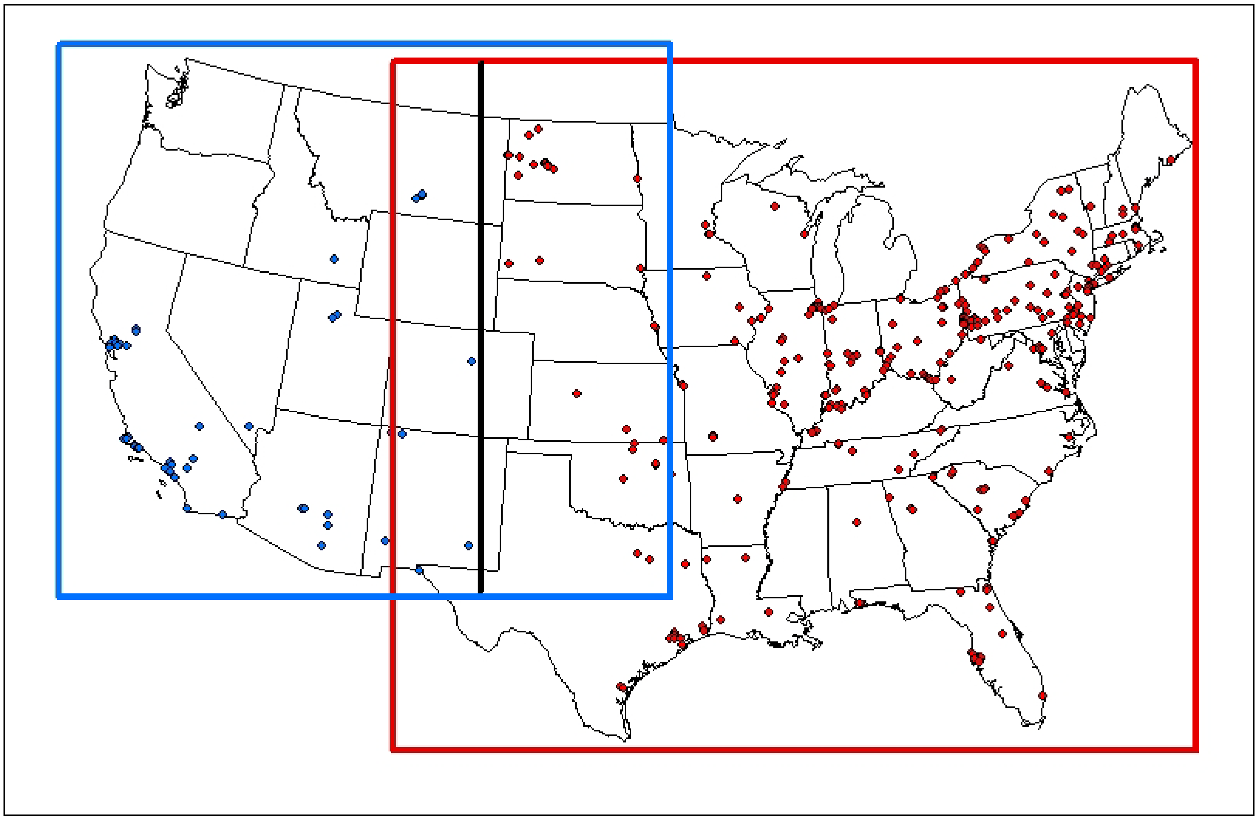


Figure 3.3. 2005 annual 12 km gridded SO_2 emissions (tons).

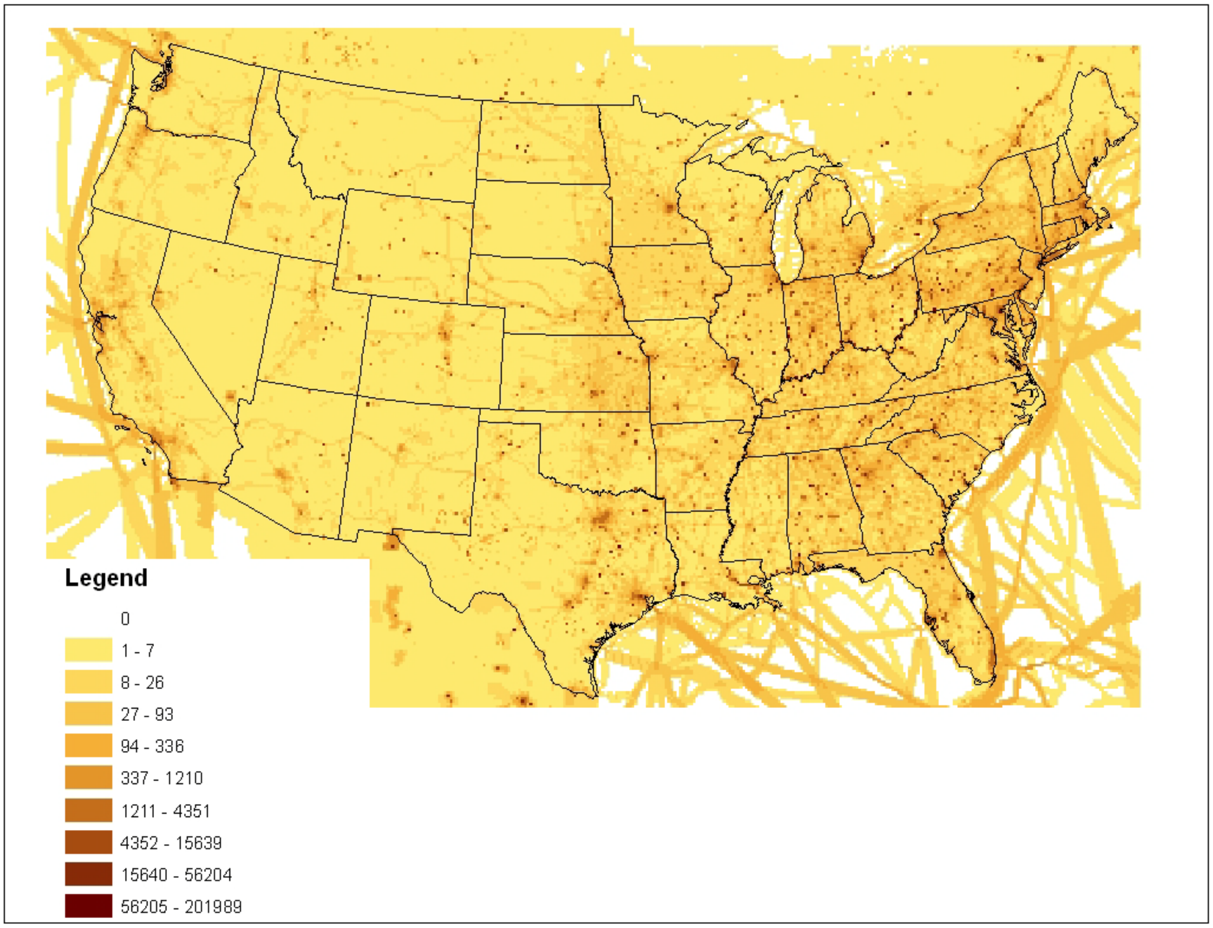


Figure 3.4. 2020 annual 12 km gridded SO_2 emissions (tons).

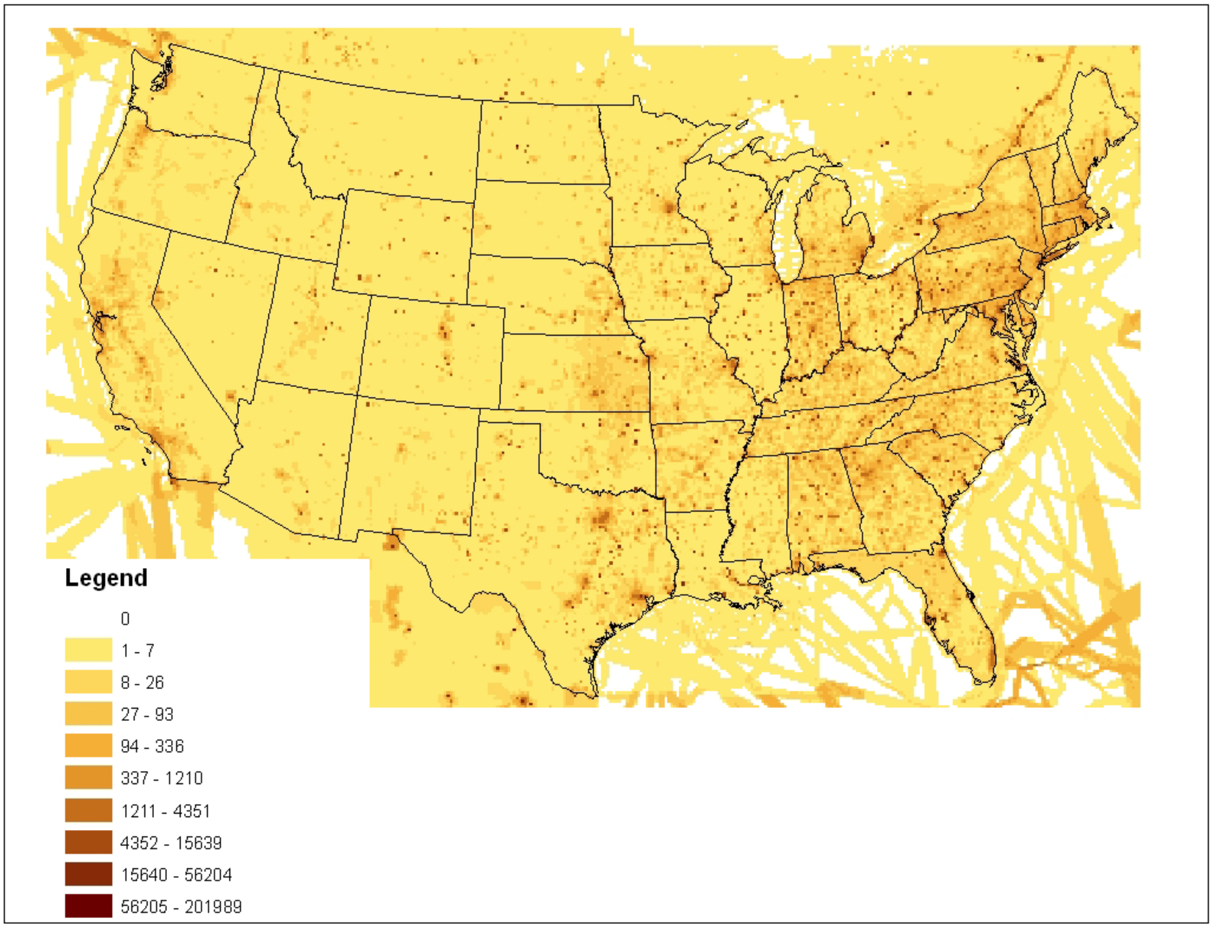
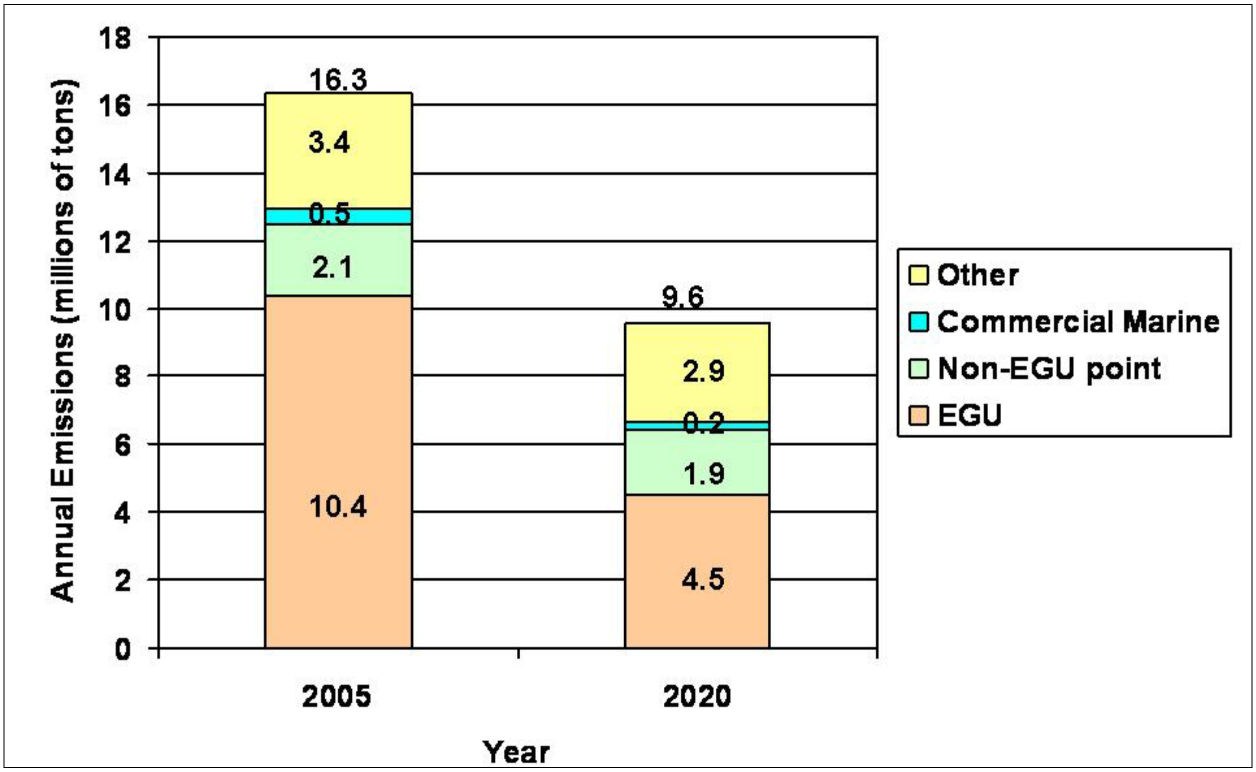
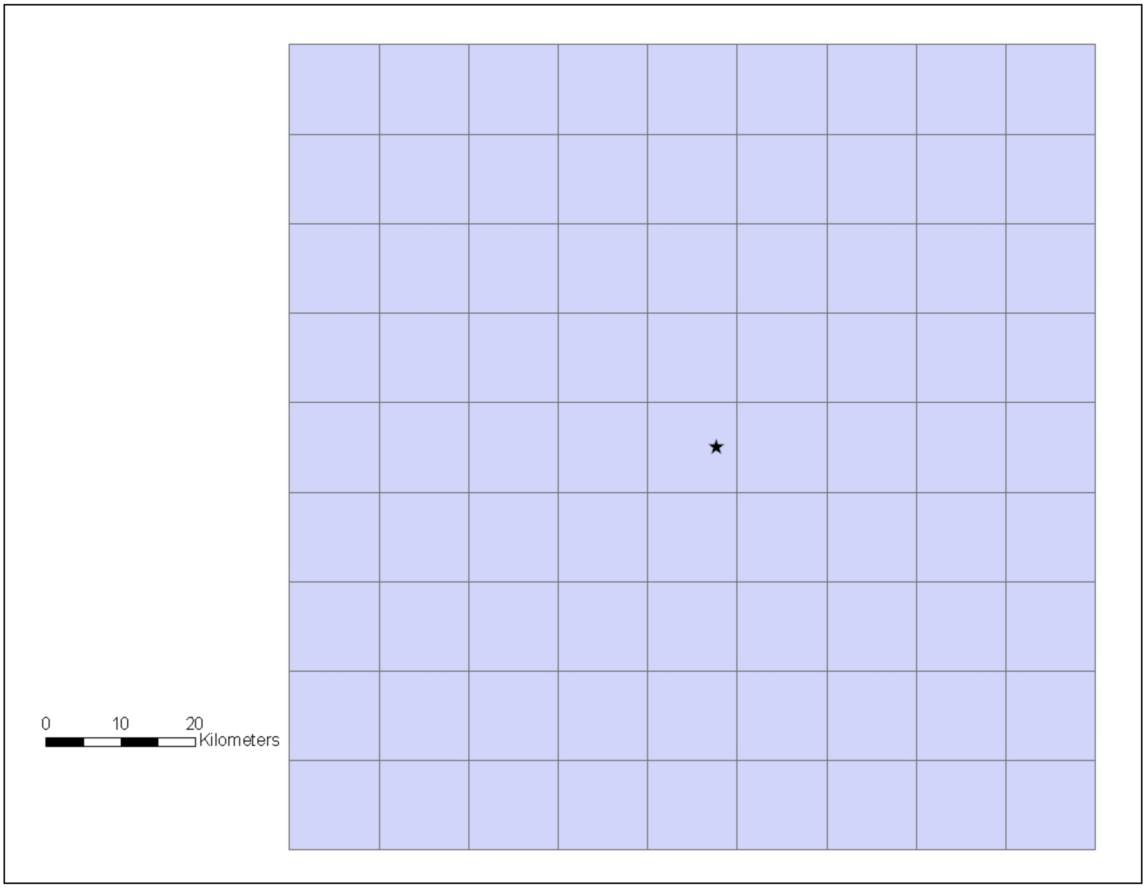


Figure 3.5. 2005 and 2020 SO_2 emissions (tons) by source sector.



Once the monitors and emissions were assigned to the combined grid, for each monitor, a 9x9 matrix of grid cells was selected, centered on the monitor's grid cell. An example is shown in Figure 3.6. The 9x9 matrix represented an approximate domain of emissions extending out 50 km from the monitor, the upper range of near-field dispersion. Since the design values were based on hourly concentrations, extending the radius of influential emissions on the monitor grid cell to 50 km was considered appropriate.

Figure 3.6. 9 x 9 matrix of 12km grid cells centered on CMAQ cell containing an SO_2 monitor (star).



Once the matrices of grid cells were created for each monitor, the 2005 and 2020 gridded emissions were summed for each year across the 81 grid cells to result in total 2005 and 2020 emissions for each monitor. The summed 2020 emissions were then divided by the 2005 emissions to get an emissions change ratio:

$$E_{ratio} = \frac{E_{2020}}{E_{2005}} \tag{3.1}$$

Where E_{2020} are the summed 81 grid cell emissions for 2020, E_{2005} are the summed 81 grid cell emissions for 2005 and E_{ratio} is the ratio of 2020 emissions to 2005 emissions.

The 2005-2007 99th percentile design value concentrations were then multiplied by the emissions ratio to calculate the 2020 design values.

$$DV_{2020"99} = DV_{2005-2007:99} \times E_{ratio} \tag{3.2}$$

Where E_{ratio} is as defined above, $DV_{2005-2007:99}$ is the 2005-2007 3-year averaged design value for the 99th percentile, and $DV_{2020:99}$ is the projected 2020 design value for the 99th percentile.

After calculating the 2020 design values, a ppb/ton estimate was calculated by:

$$ppb/ton_{99} = \left(DV_{20205:99} - DV_{2005-2007:99}\right) \Big/ \left(E_{2020} - E_{2005}\right) \tag{3.3}$$

Where E_{2020} and E_{2005} are the summed emissions as defined for Equation 3.1, $DV_{2005-2007:99}$ and $DV_{2020:99}$ are as defined above and ppb/ton_{99} is the ppb/ton estimate for the 99th percentile.

Residual nonattainment estimates for the three alternative standards of 50, 75, and 100 ppb were calculated by subtracting the alternative standard from the 2020 design value. The absolute values of the alternative standards (50, 75, or 100 ppb) were not subtracted but rather the highest value that would meet the standards (50.4, 75.4, and 100.4 ppb) if design values were rounded to the nearest whole ppb. Once residual nonattainment was calculated for each alternative standard, for monitors exceeding the standards, tons needed for control were calculated by dividing residual nonattainment by the ppb/ton estimate:

$$Tons_{99:AS} = \frac{NA_{99:AS}}{ppb/ton_{99}} \tag{3.4}$$

Where ppb/ton_{99} is as defined above, $NA_{99:AS}$ is the residual nonattainment for alternative standard AS (50, 75, or 100 ppb) for the 99th percentile, and $Tons_{99:AS}$ are the tons needed to reach attainment for alternative standard AS for the 99th percentile.

3.2.2 Methodology Limitations

While the approach described in Section 3.2.1 is reasonable for a national analysis, there are limitations to the approach that may be better addressed by other methods such as near-field dispersion modeling on a case by case basis or fine scale CMAQ modeling. Given the number of monitors in the analysis, dispersion modeling for all monitors would not be feasible. Also, given that the CMAQ concentrations associated with the emissions used in this analysis are at 12 km horizontal resolution and that SO_2 is affected by nearby stationary sources, the CMAQ results may not be reasonable for this analysis, due to allocation of individual emission points within the grid cell. Limitations of this analysis include:

- Distance from source to monitor is not factored in the emissions sums used in Equation 3.1. All emission sources, regardless of distance and tonnage, are weighted equally.

Using Figure 3.6 as an example, a source may be located in the most northwestern grid cell and a source may be located in the same grid cell that contains the monitor. No distance weighting is applied to either source, based on its proximity to the monitor. They are both added to the emissions sum as is. Some monitors' emission sums may include large emission sources that are farther away from the monitor than smaller emission sources but the large emissions sources dominate the emissions used to calculate the ratio in Equation 3.1. These large sources, may have large changes in emissions from 2005 to 2020 and these changes could drastically affect the emissions ratio. Given the nature of the projection approach described in Section 3.2.1, these large emission changes may overestimate or underestimate the concentration change at the monitor given the distance from the source to the monitor and the factors mentioned in the points below, meteorology and terrain.

- Meteorology and terrain influences are not factored into the analysis. A source may not have a significant impact on a monitor because the prevailing wind direction is not from the source to the monitor, or the terrain between the source and monitor is configured such that the source does not have a significant impact on the monitor. This would also depend on building downwash effects and stack parameters such as stack height, exit temperature, stack diameter, and exit velocity.

3.3 Results

3.3.1. Nonattainment results

Table 3.4 lists the number of monitors and counties exceeding the three alternative standards for the 99th percentile 2020 design values. The number of counties exceeding each of the alternative standards decreased from 2005-2007 to 2020. Figure 3.7 shows the maximum 2020 design value for monitored counties for the 99th percentile design values. Counties in blue, green, and scarlet exceed the 50 ppb alternative standard. Table 3.5 lists the top 10 counties in 2020 for the 99th percentile design value along with residual nonattainment and tons needed for control to meet attainment. A complete list of 2020 design values for all monitors can be found in Appendix 3.

Table 3.4. Number of monitors and counties exceeding 50, 75, and 100 ppb alternative standards for the 99th percentile design values for 2020.

Alternative standard (ppb)	Number of monitors	Number of counties
50	71	56
75	27	24
100	11	9

Figure 3.7. 2020 design values (ppb) for 99th percentile daily 1-hour maximum SO_2 concentrations. Values shown are county maxima.

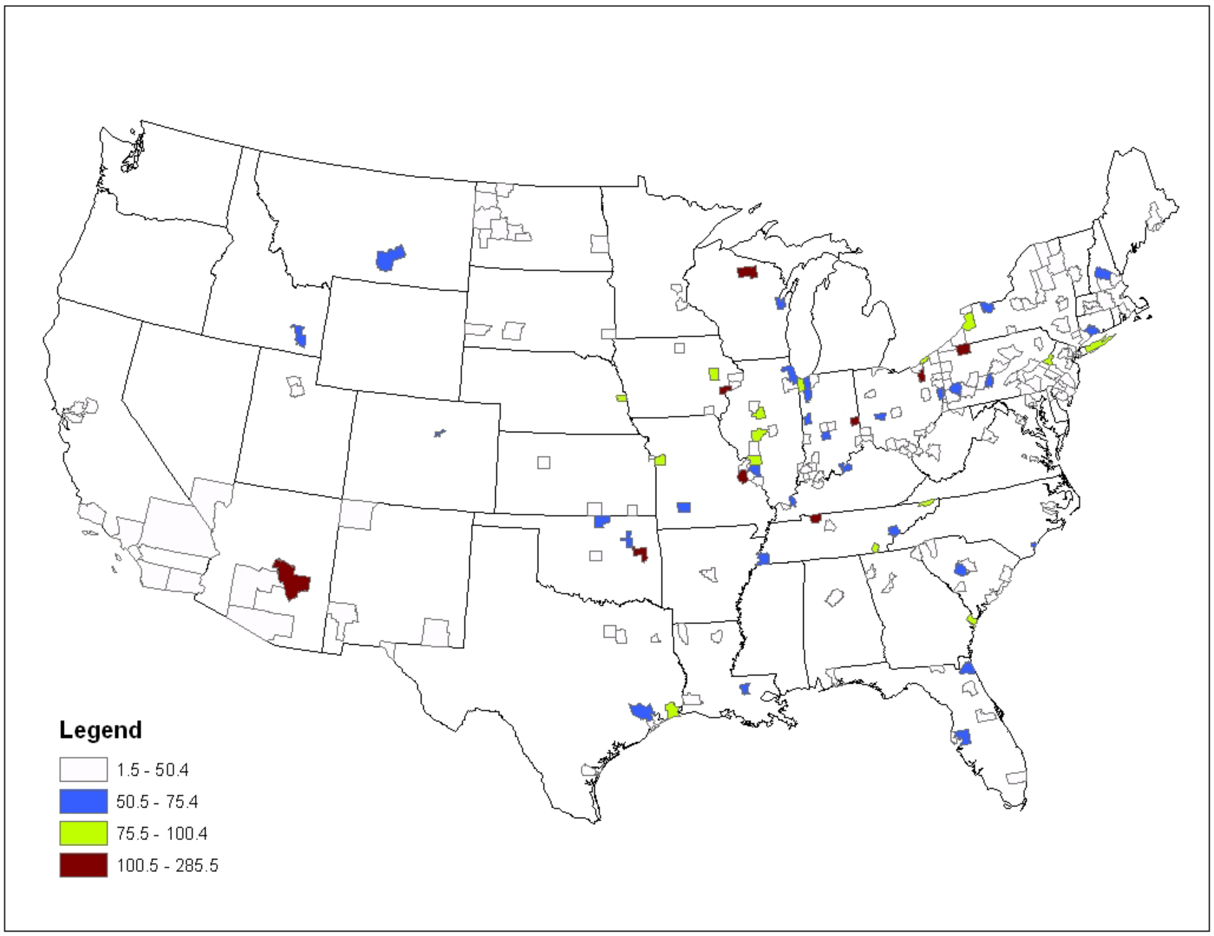


Table 3.5. Top 10 2020 counties 99th percentile design values (ppb).

			Alternative standards (ppb)					
			50		75		100	
State	County	2020 DV	Residual nonattainment	Tons for control	Residual nonattainment	Tons for control	Residual nonattainment	Tons for control
MO	Jefferson	285.5	235.1	139,033	210.1	124,249	185.1	109,464
AZ	Gila	284.8	234.4	21,930	209.4	19,591	184.4	17,252
PA	Warren	217.2	166.8	10,379	141.8	8,824	116.8	7,268
WI	Oneida	175.3	124.9	6,866	99.9	5,491	74.9	4,117
TN	Montgomery	144.3	93.9	19,764	68.9	14,502	43.9	9,240
IN	Wayne	134.3	83.9	24,088	58.9	16,911	33.9	9,733
IA	Muscatine	126.2	75.8	27,365	50.8	18,340	25.8	9,314
OK	Muskogee	104.9	54.5	45,542	29.5	24,651	4.5	3,760
OH	Summit	103.9	53.5	26,690	28.5	14,218	3.5	1,746
PA	Northampton	100.4	50.0	20,652	25.0	10.326	-	-

3.3.2 Example monitors

This section describes the emissions changes for two monitors' 99th percentile design values shown in Figures 3.8 and 3.9. One monitor's design value, Tazewell County, IL decreased from 2005-2007 to 2020 (Figure 3.8) and the other monitor's (Montgomery County, TN) design value increased from 2005-2007 to 2020 (Figure 3.9). Emissions summaries in the 81 cell matrices for both monitors are shown in Figure 3.10.

Figure 3.8. Location of monitor in Tazewell County, IL.

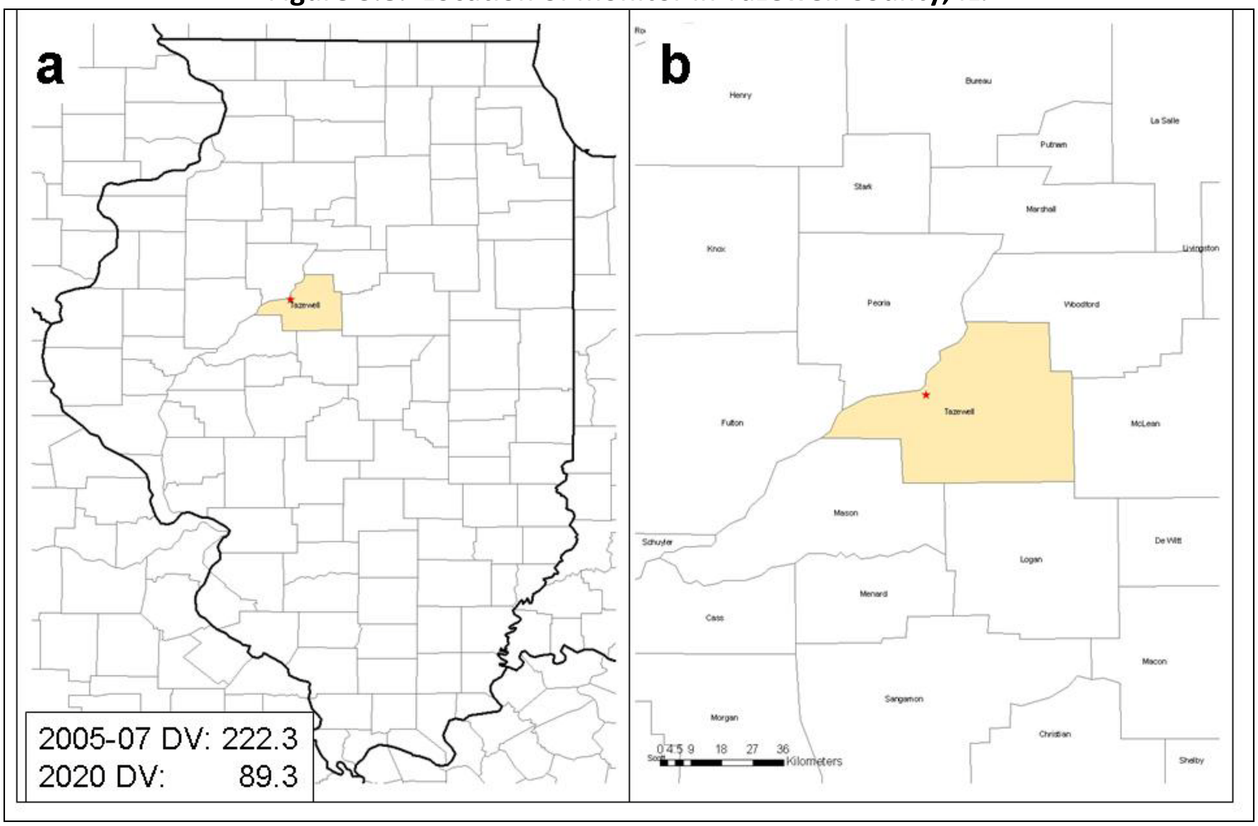


Figure 3.9. Location of monitor in Montgomery County, TN.

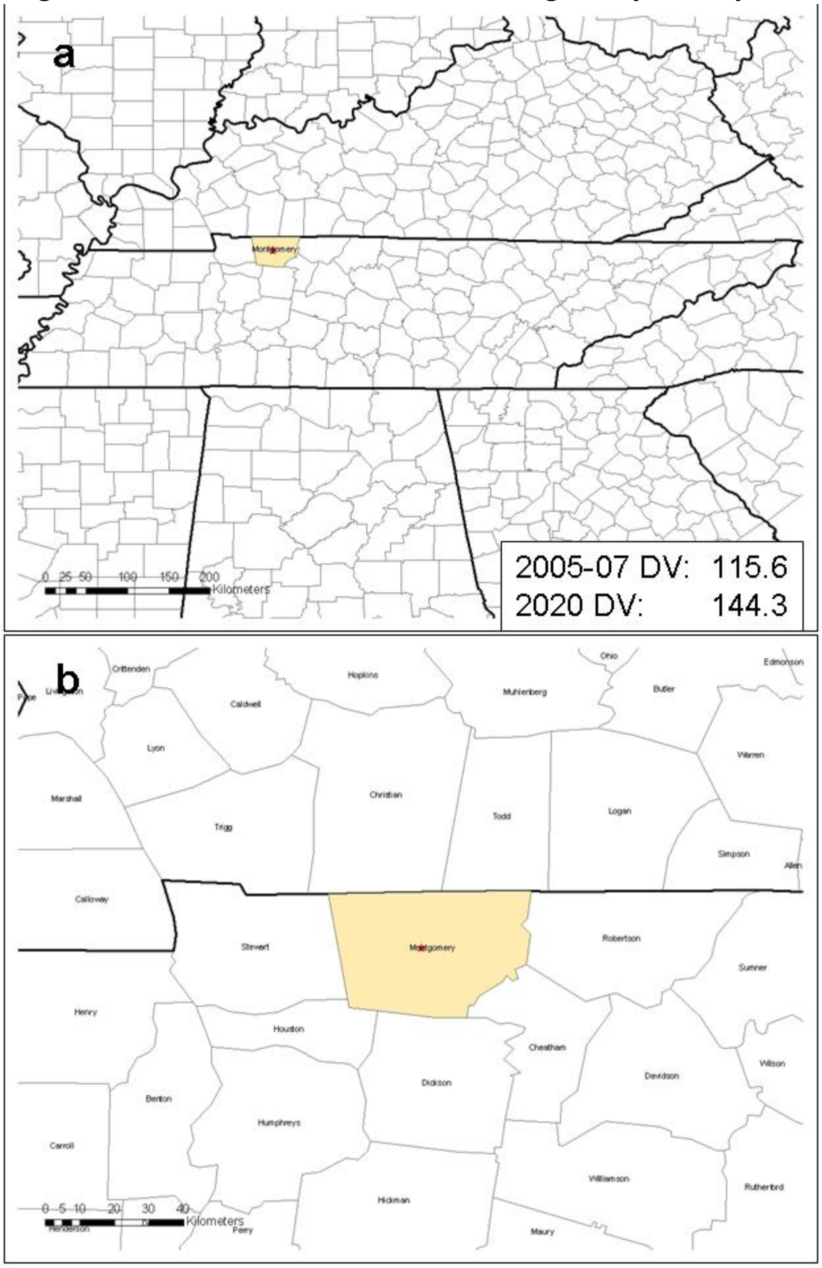
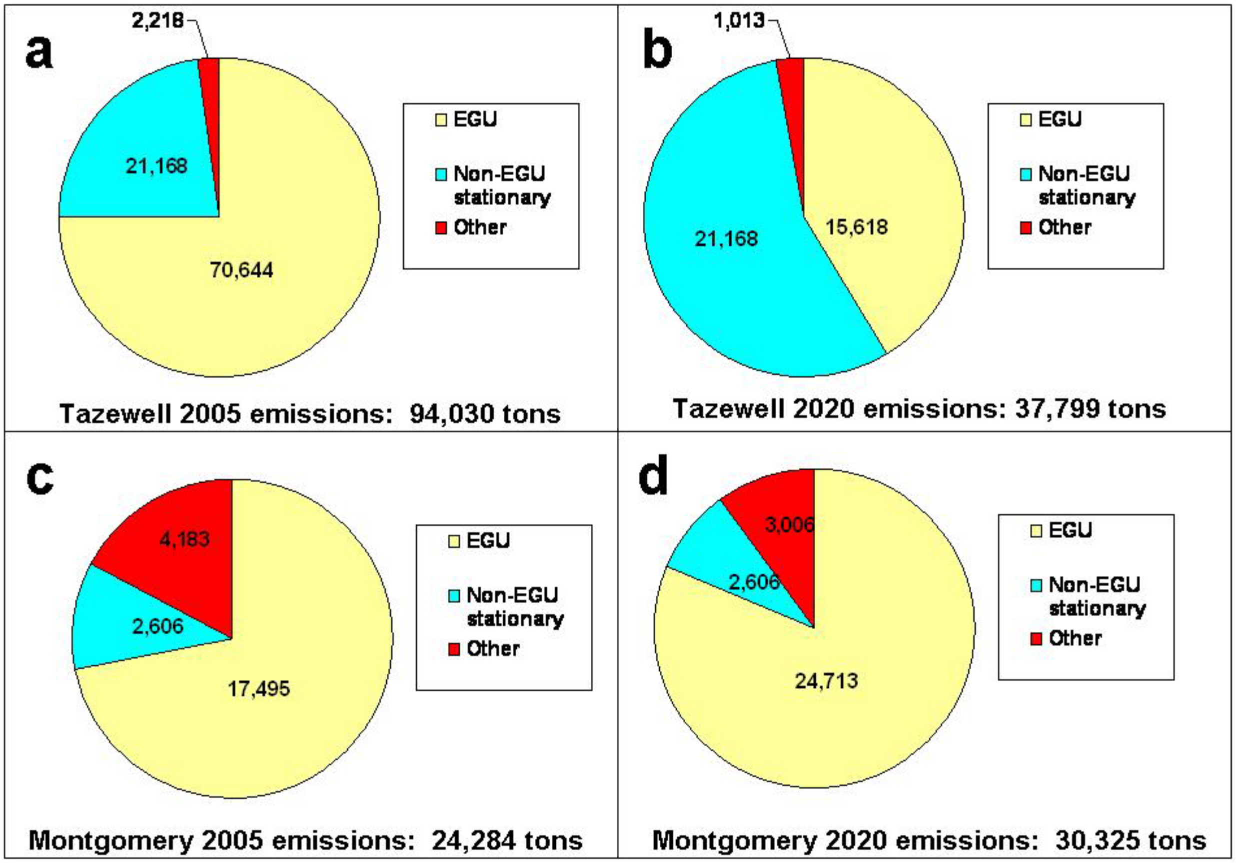


Figure 3.10. Tazewell County, IL and Montgomery County, TN monitors emissions (tons) for 2005 and 2020.



3.3.2.1 Tazewell County

Emissions affecting the Tazewell County monitor decreased from approximately 94,000 tons in 2005 to approximately 38,000 tons in 2020 (Figure 3.10 a and b). The decrease was mostly due to decreases in EGU emissions. The decrease caused the EGU sector drop from about 75% of the emissions to around 40% of the emissions. Figure 3.11 shows the spatial distribution of 2005 total emissions (all sources) within 50 km of the monitor and Figure 3.12 shows the spatial distribution of 2020 total emissions within 50 km of the monitor. The decrease in emissions can be seen as the emissions become more uniform outside of the "hotspot" grid cells.

Figure 3.11. 2005 12 km grid cell SO_2 total emissions (tons) for Tazewell County monitor. The red star represents the monitor location.

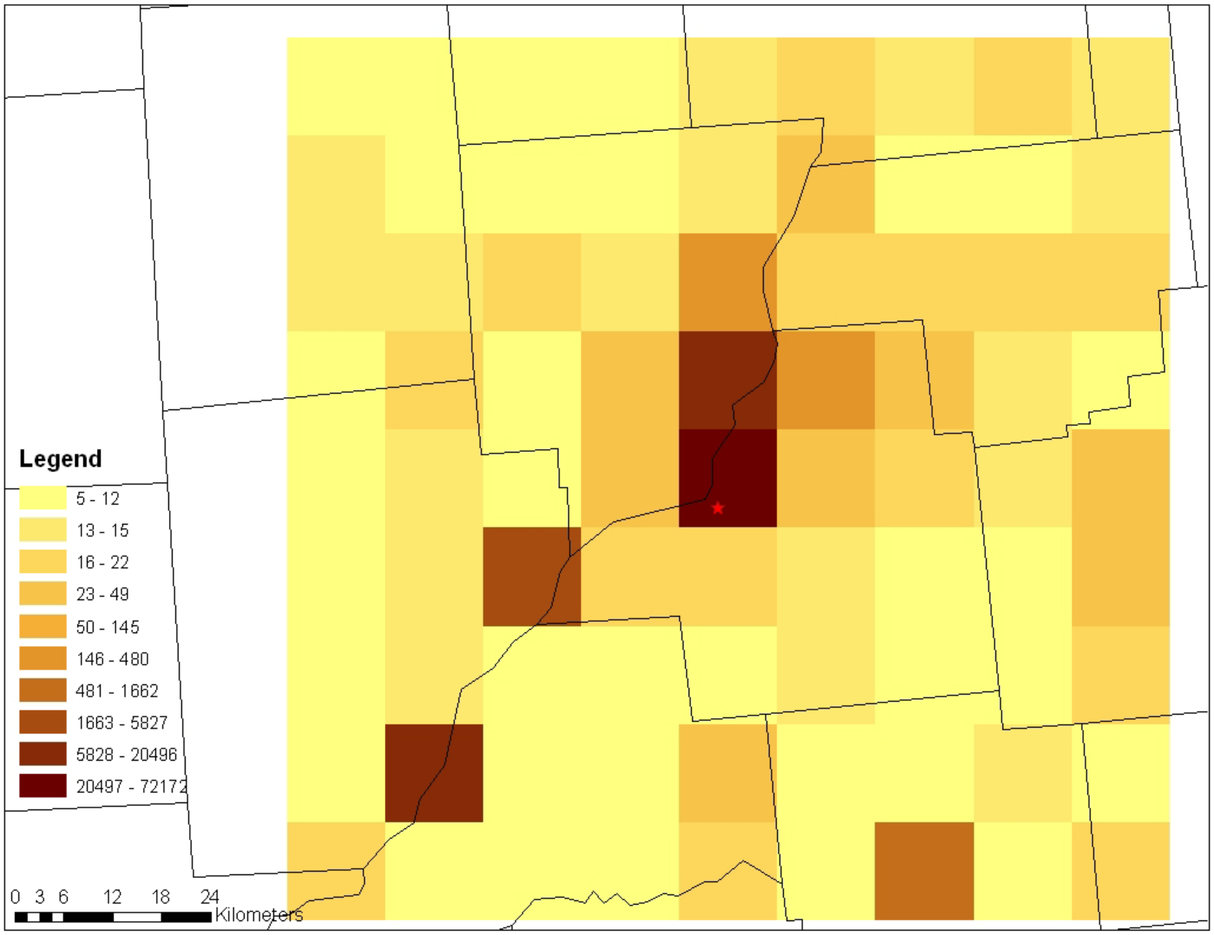
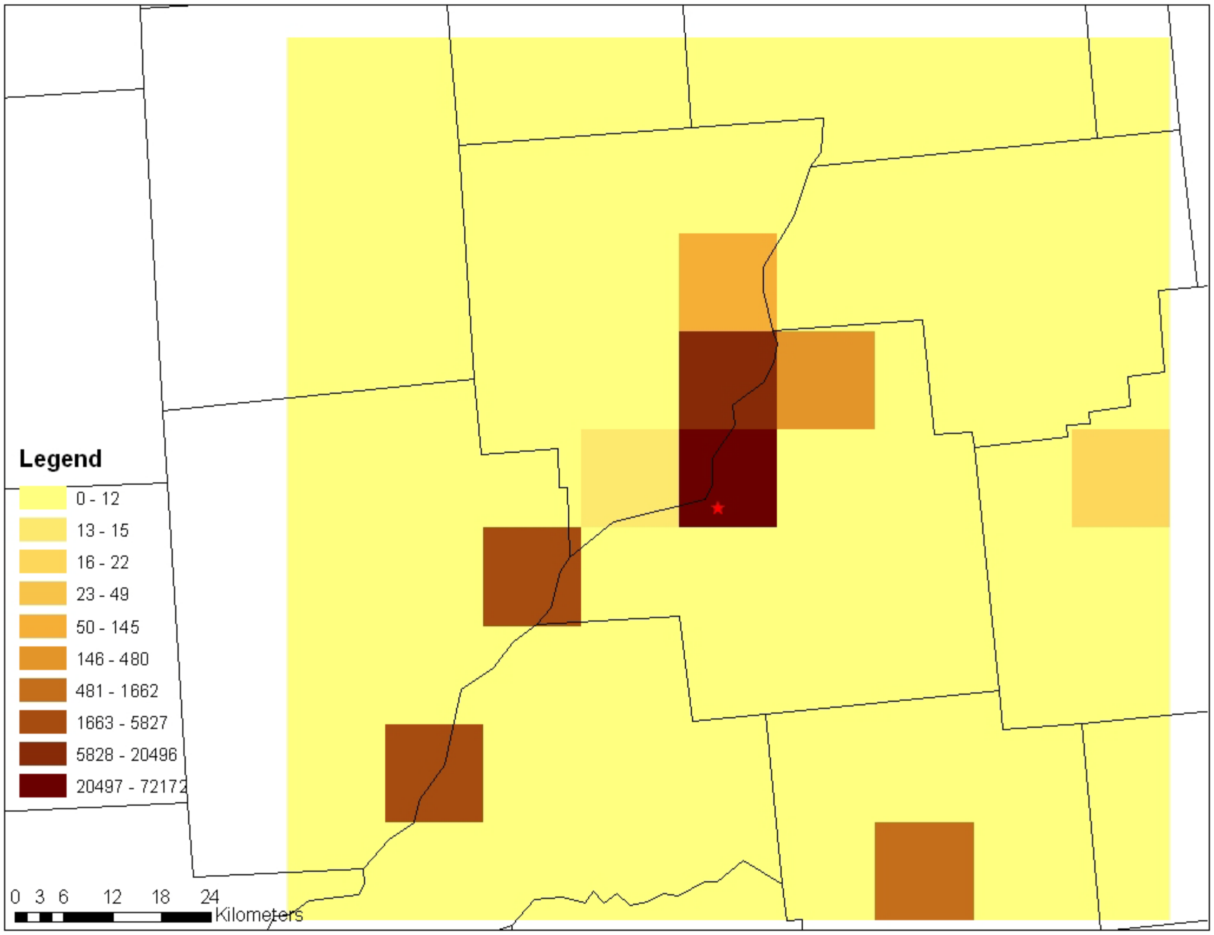


Figure 3.12. 2020 12 km grid cell SO_2 total emissions (tons) for Tazewell County monitor. The red star represents the monitor location.



3.3.2.2 Montgomery County

The design value for Montgomery County increased from 2005-07 to 2020 due to an increase in EGU emissions (Figure 3.10 c and d). Figures analogous to Figure 3.11 and Figure 3.12 are shown in Figure 3.13 and Figure 3.14. While emissions decrease outside the “hotspot” grid cells, the emissions within those hotspots increase from 2005 to 2020, as these are the locations of EGU facilities and the emissions increase from 2005 to 2020.

Figure 3.13. 2005 12 km grid cell SO_2 total emissions (tons) for Montgomery County monitor. The red star represents the monitor location.

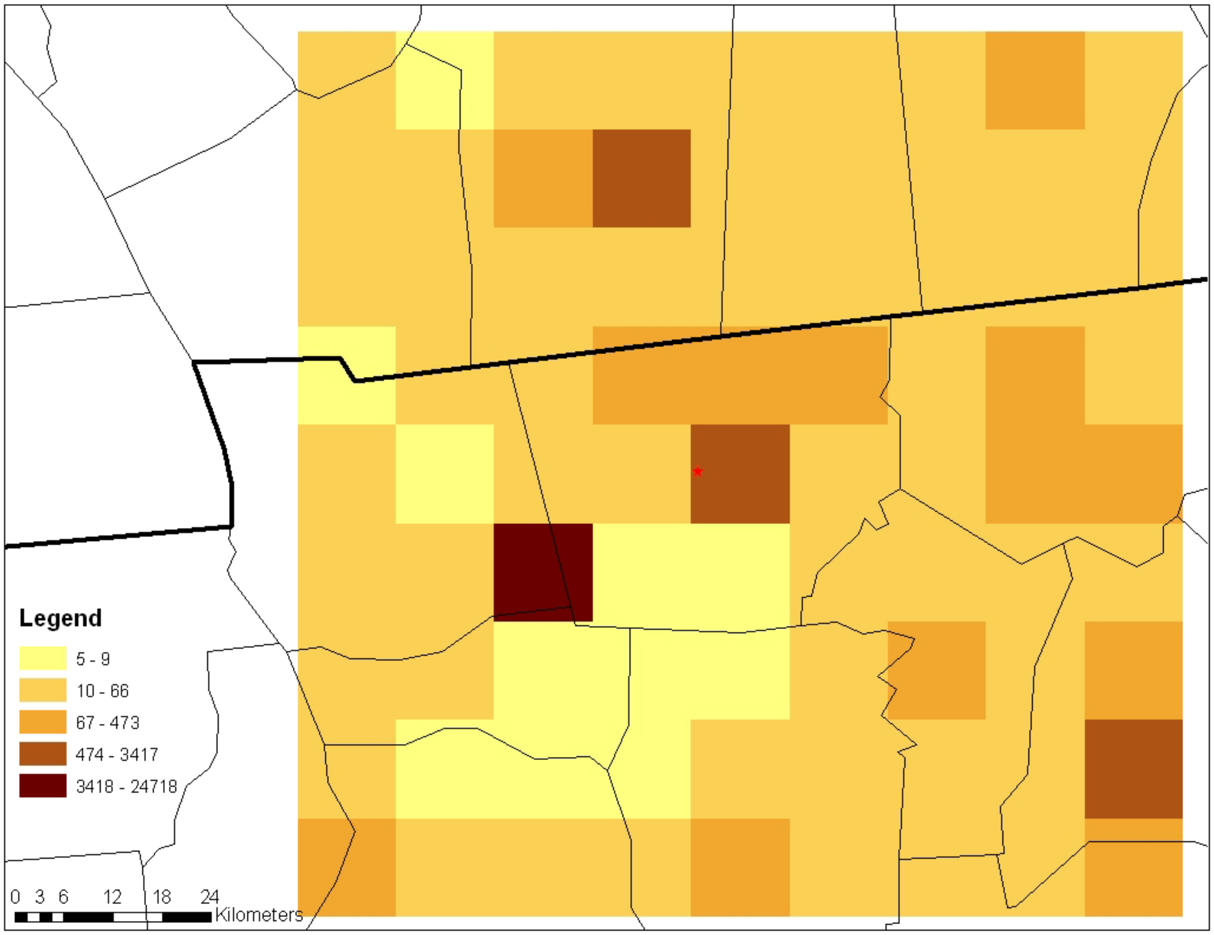
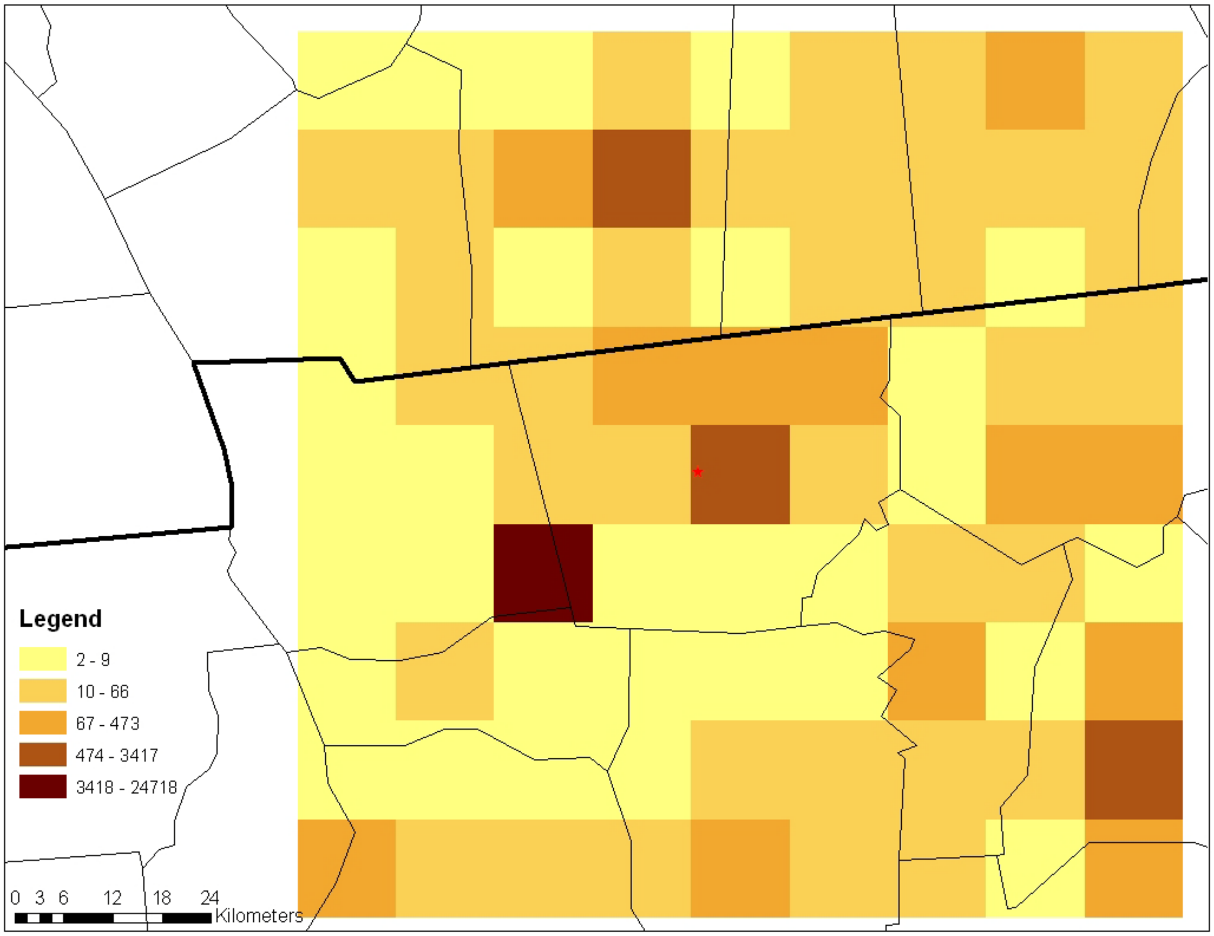


Figure 3.14. 2020 12 km grid cell SO_2 total emissions (tons) for Montgomery County monitor. The red star represents the monitor location.



3.4 Summary

In summary, 2020 baseline NO_2 design value concentrations were projected from 2005-2007 observed design values using CMAQ emissions output from 2005 and 2020. Results of the projections showed that, in 2020, nonattainment occurred for all three alternative standards (50, 75, and 100 ppb). However, the number of counties exceeding the standards dropped from the 2005-2007 period.

3.5 References

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