

US EPA ARCHIVE DOCUMENT

Techniques Utilizing Ambient PM_{2.5} Air Quality Data to Aid in the 24 hour Designation Process

Michael Rizzo
AQAG/AQAD/OAQPS

EPA State / Local / Tribal Training Workshop:
PM 2.5 Final Rule Implementation and 2006
PM 2.5 Designation Process

June 20-21

What are the techniques?

- SLICE
 - Stratify and quantify daily PM_{2.5} concentrations into regional and urban contributions
 - Estimate the immediate increment by site
- Residence Time Weighted Emissions
 - Use of wind trajectories to weight county level emissions
 - Highlights counties whose emissions are upwind of high sites on high days
- Urban Gradient
 - Neighboring site gradient estimator
 - Helps to identify sites with a potential local source influence on a daily basis

About the techniques

- Techniques provide important information in regard to the magnitude of area and local influences on PM_{2.5}
- None are meant to be prescriptive but are available to aid in providing a better indication of influencing areas and sources
- All are evolving by varying degrees

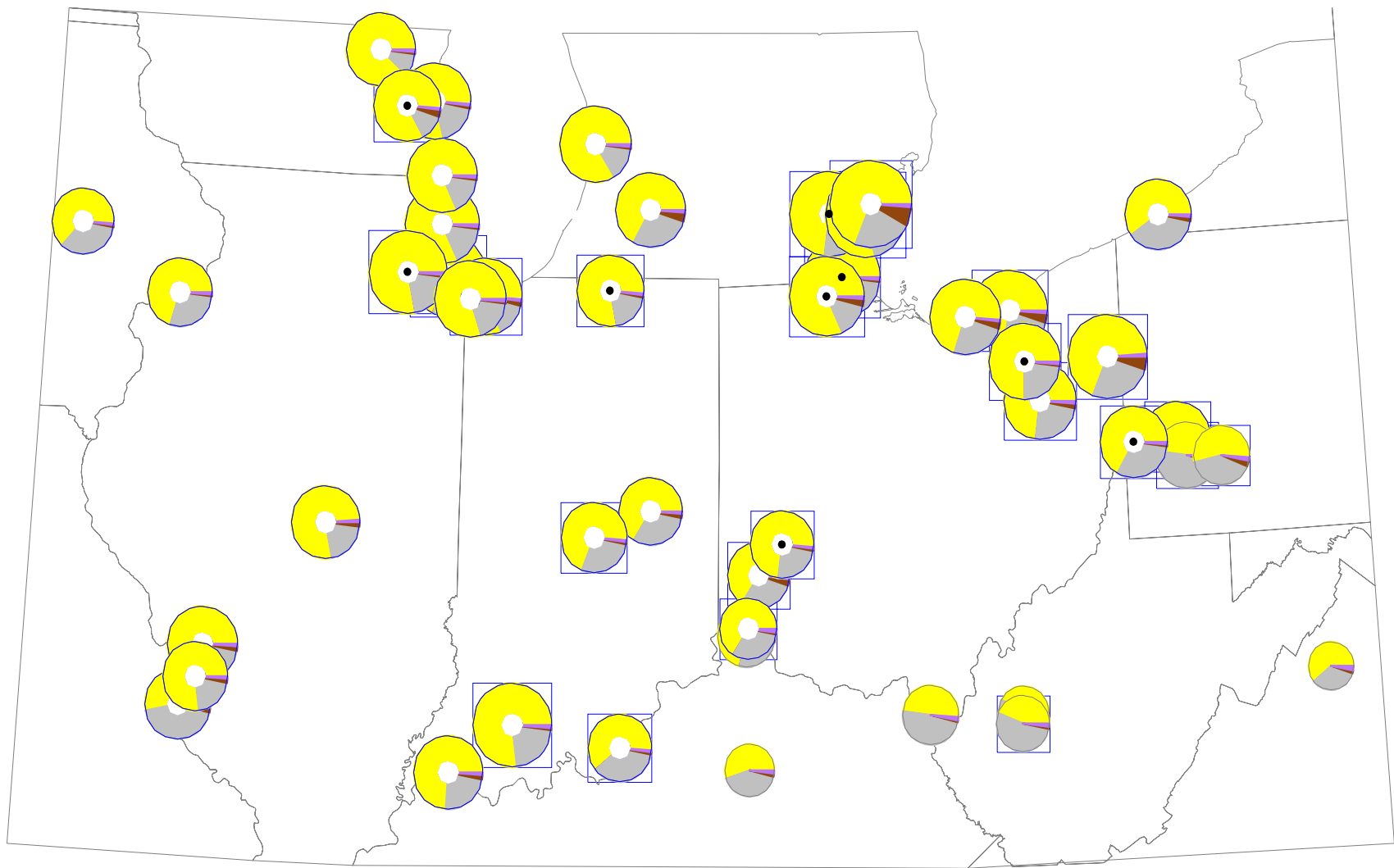
1st Technique: SLICE

(Spatially Layered Interpolated Component Estimator)

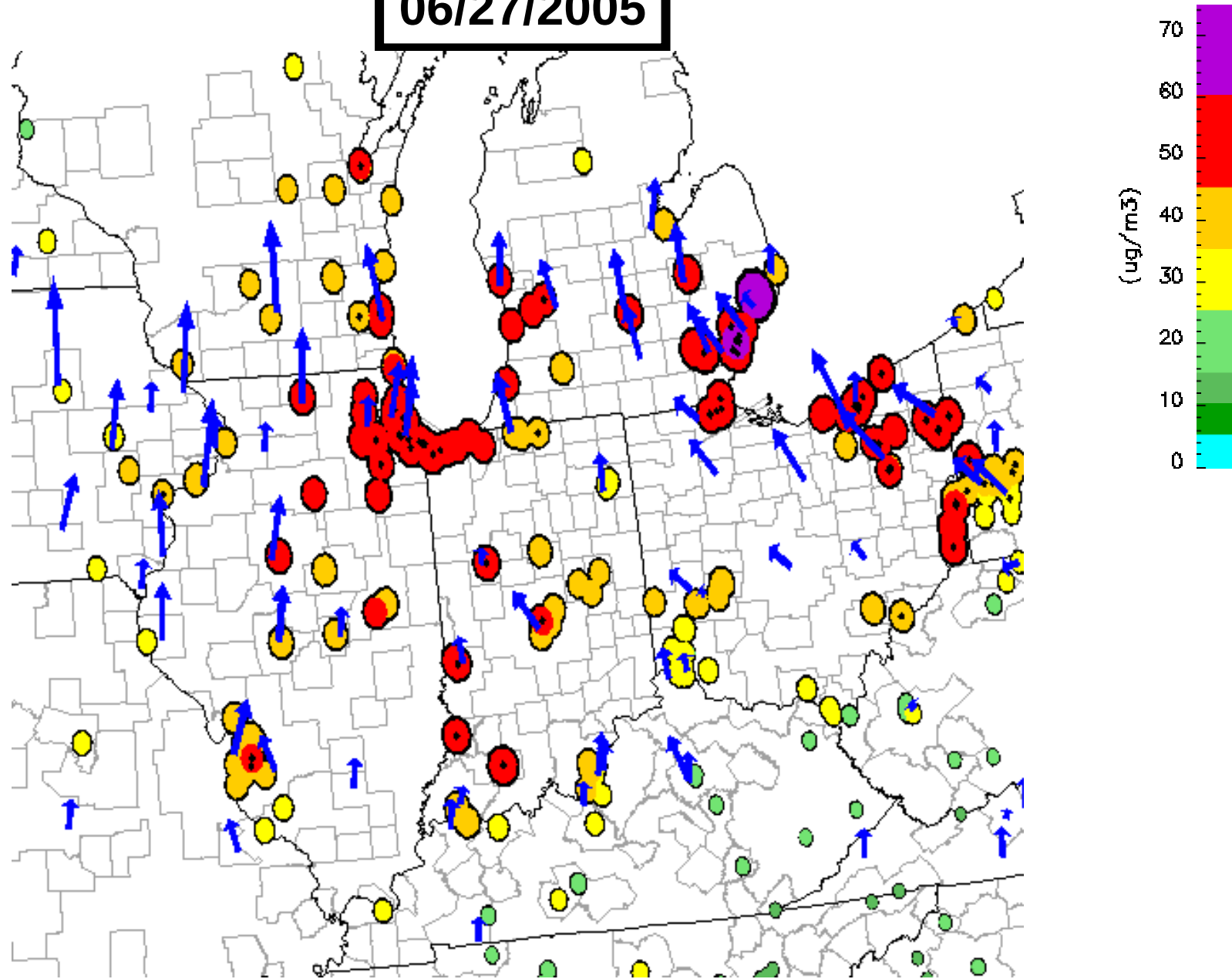
- Technique clusters ambient monitoring data into “natural” classifications allowing for increments above background to be calculated
- Indicator of possible urban emissions affecting ambient concentrations
- Technique is utilized on daily basis

FRM PM2.5 speciation - 06/27/2005

Large Regional Sulfate Event

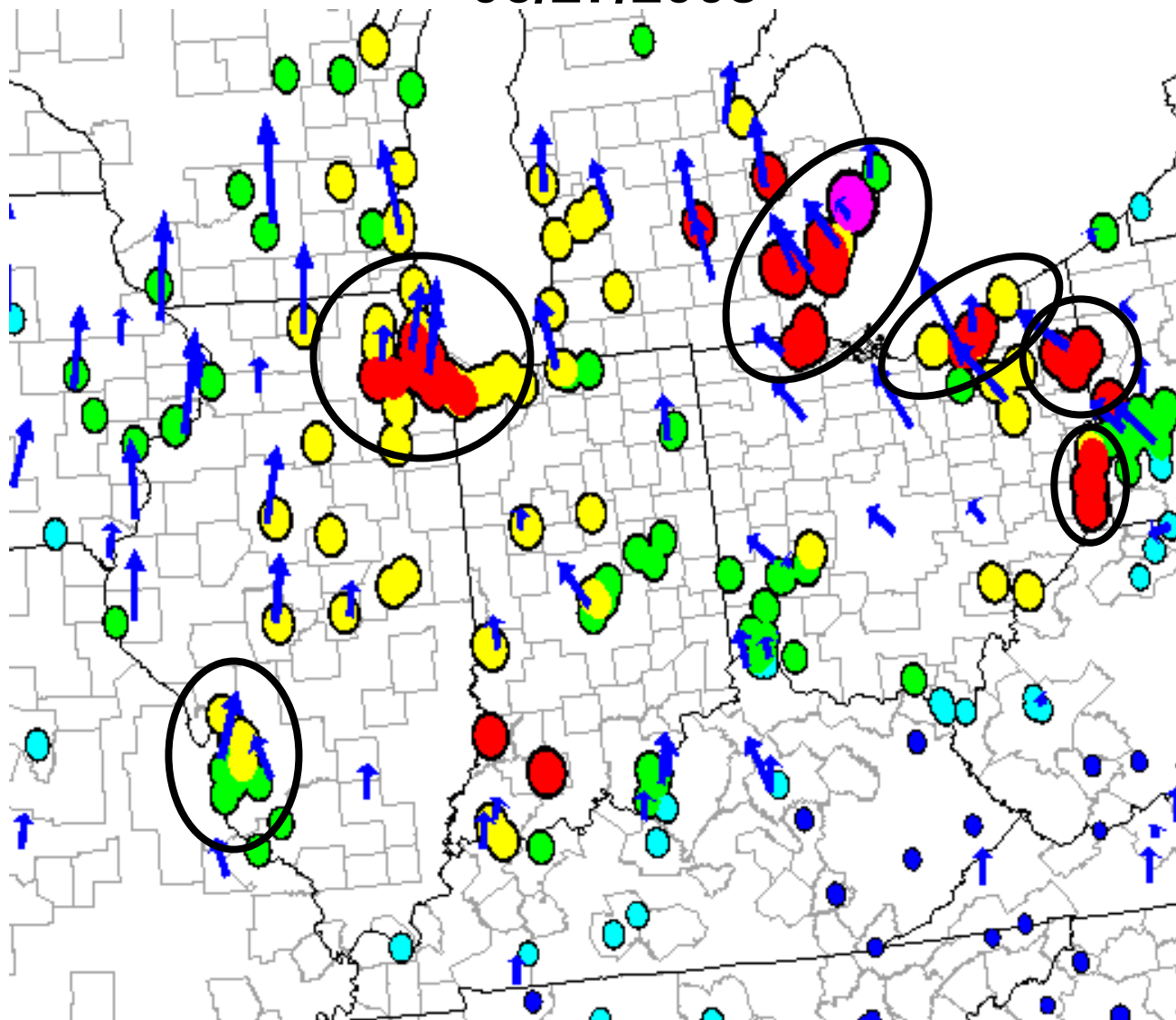


06/27/2005



Higher concentrations observed in major urban areas in the northern part of the domain

06/27/2005



6.0 - 23.0 ug/m3

23.1 - 34.3 ug/m3

34.4 - 42.5 ug/m3

42.6 - 50.3 ug/m3

50.4 - 61.1 ug/m3

61.1 - 79.2 ug/m3

Regional

Regional

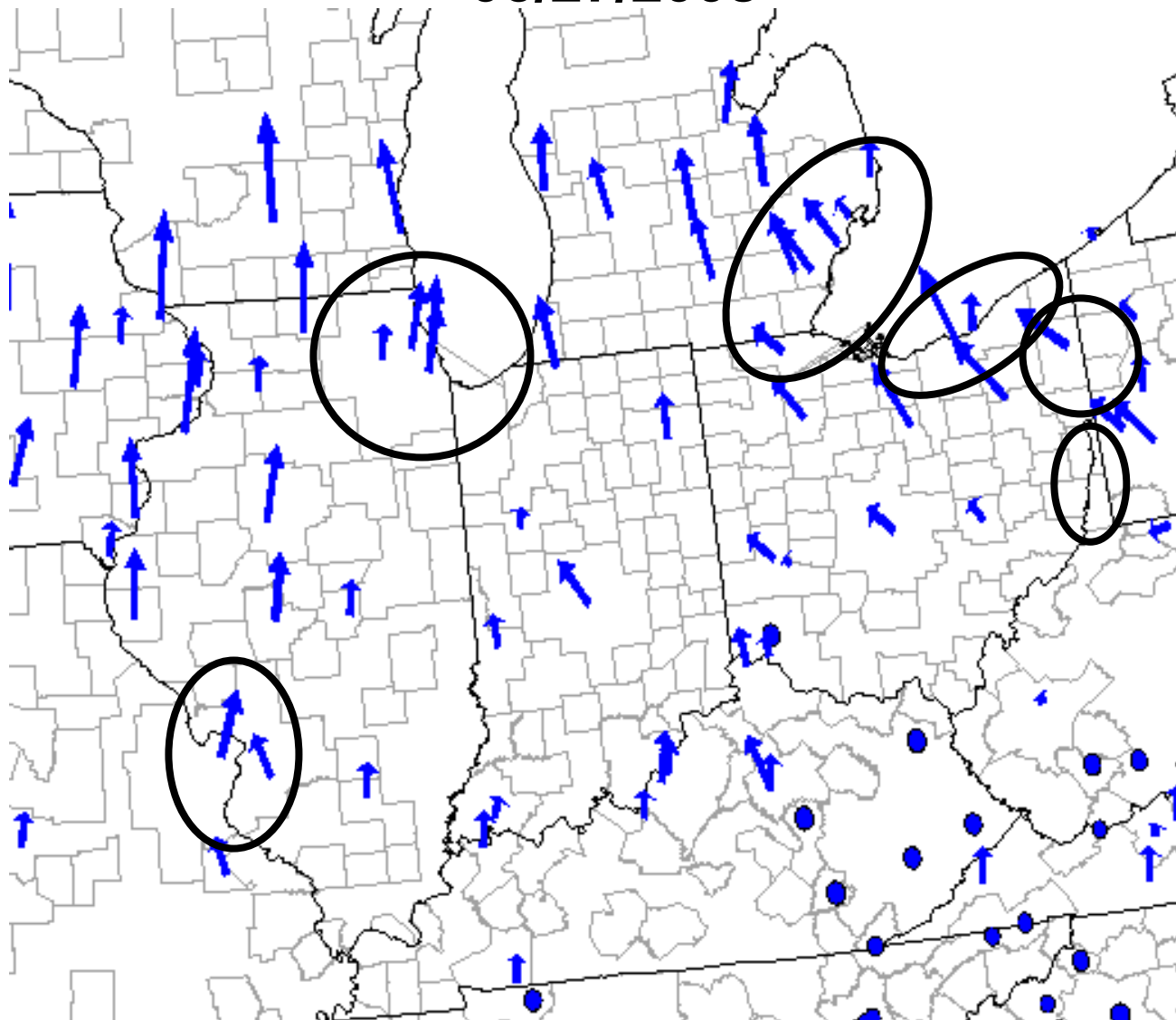
Regional

Regional/Urban

Urban

Urban/Microscale

06/27/2005



6.0 - 23.0 ug/m3

23.1 - 34.3 ug/m3

34.4 - 42.5 ug/m3

42.6 - 50.3 ug/m3

50.4 - 61.1 ug/m3

61.1 - 79.2 ug/m3

Regional

Regional

Regional

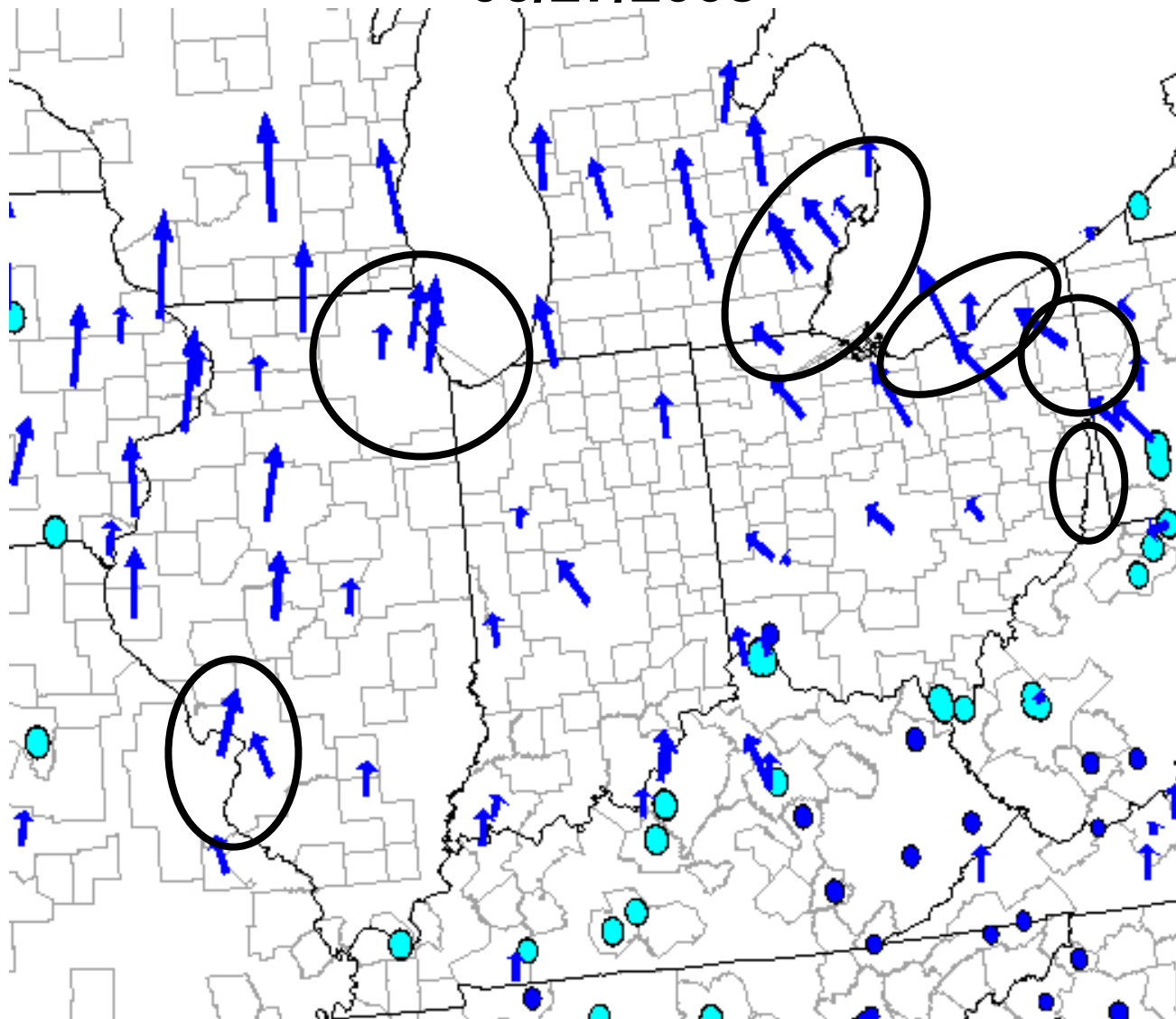
Regional/Urban

Urban

Urban/Microscale

1st Slice

06/27/2005



6.0 - 23.0 ug/m3

23.1 - 34.3 ug/m3

34.4 - 42.5 ug/m3

42.6 - 50.3 ug/m3

50.4 - 61.1 ug/m3

61.1 - 79.2 ug/m3

Regional

Regional

Regional

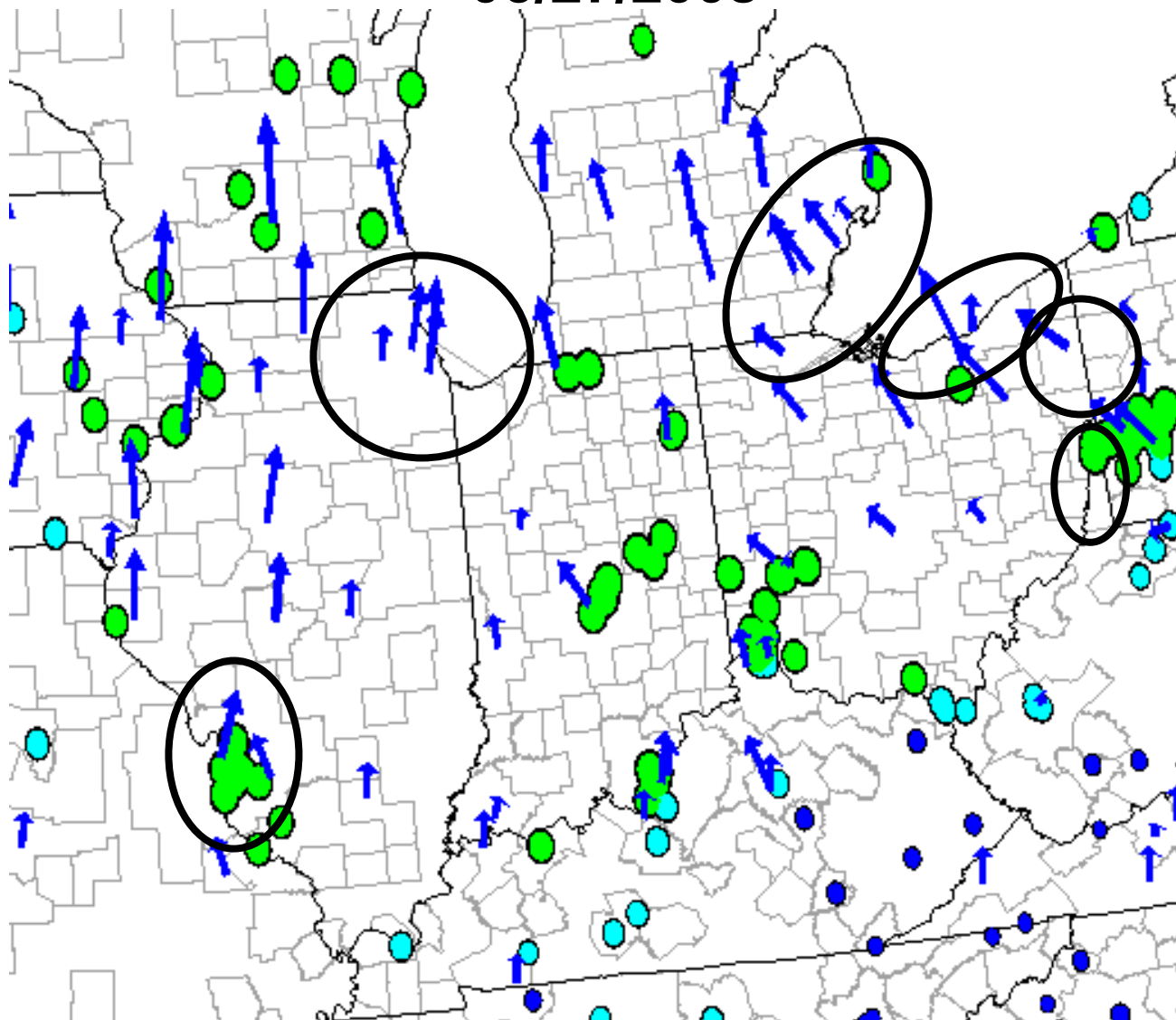
Regional/Urban

Urban

Urban/Microscale

2nd Slice

06/27/2005



6.0 - 23.0 ug/m3

23.1 - 34.3 ug/m3

34.4 - 42.5 ug/m3

42.6 - 50.3 ug/m3

50.4 - 61.1 ug/m3

61.1 - 79.2 ug/m3

Regional

Regional

Regional

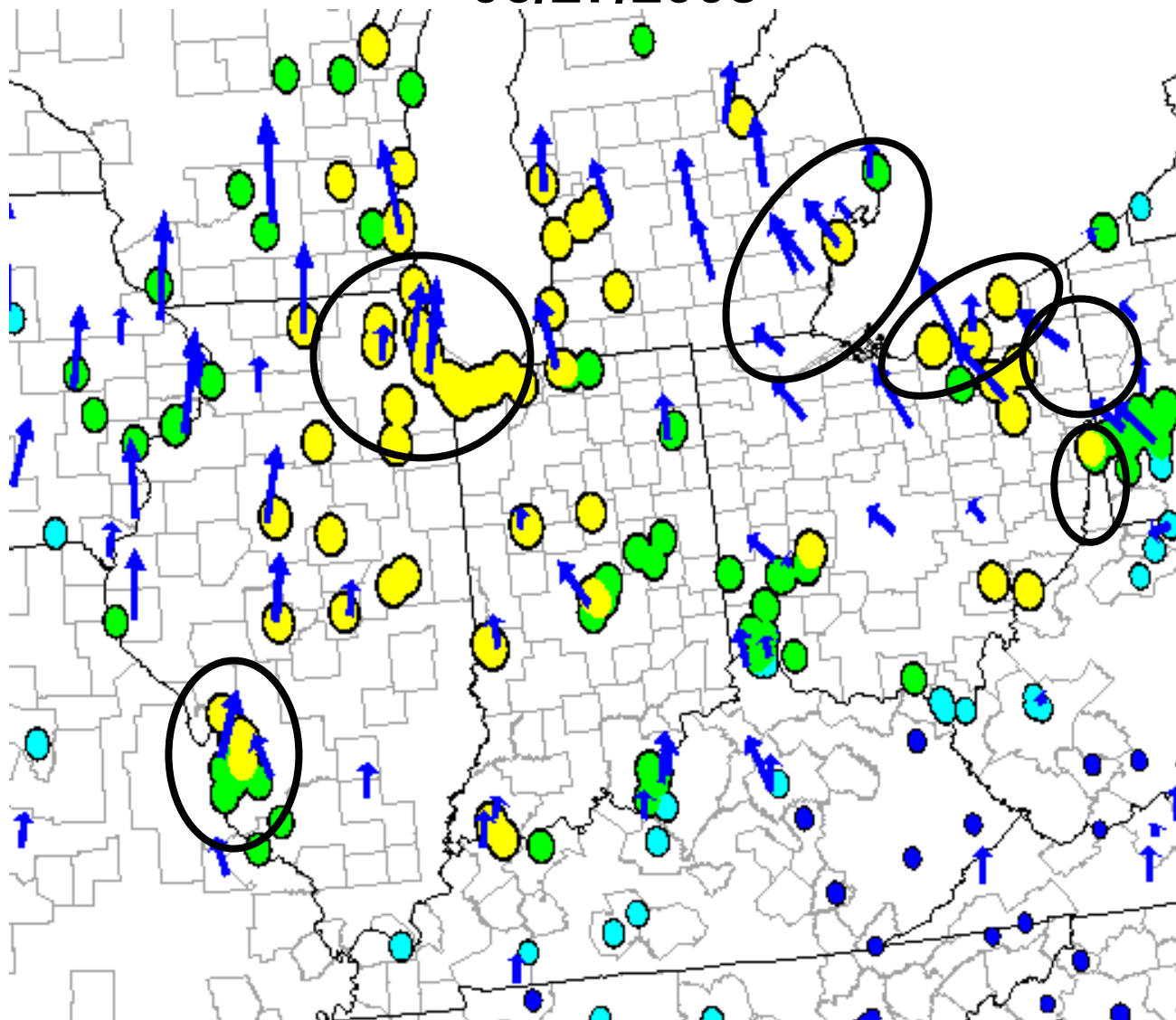
Regional/Urban

Urban

Urban/Microscale

3rd Slice

06/27/2005



6.0 - 23.0 ug/m³

23.1 - 34.3 ug/m³

34.4 - 42.5 ug/m³

42.6 - 50.3 ug/m³

50.4 - 61.1 ug/m³

61.1 - 79.2 ug/m³

Regional

Regional

Regional

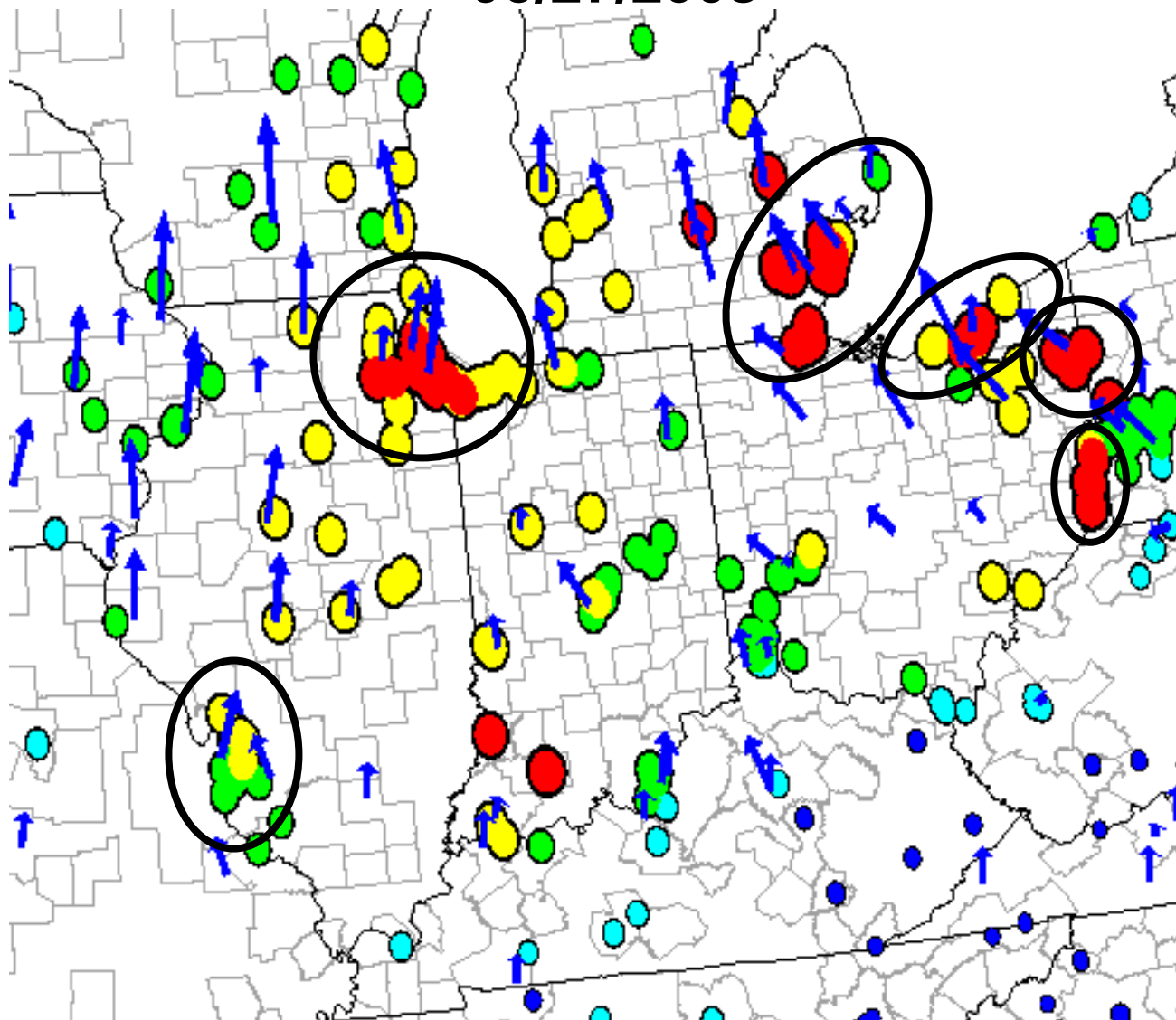
Regional/Urban

Urban

Urban/Microscale

4th Slice

06/27/2005



6.0 - 23.0 $\mu\text{g}/\text{m}^3$

23.1 - 34.3 $\mu\text{g}/\text{m}^3$

34.4 - 42.5 $\mu\text{g}/\text{m}^3$

42.6 - 50.3 $\mu\text{g}/\text{m}^3$

50.4 - 61.1 $\mu\text{g}/\text{m}^3$

61.1 - 79.2 $\mu\text{g}/\text{m}^3$

Regional

Regional

Regional

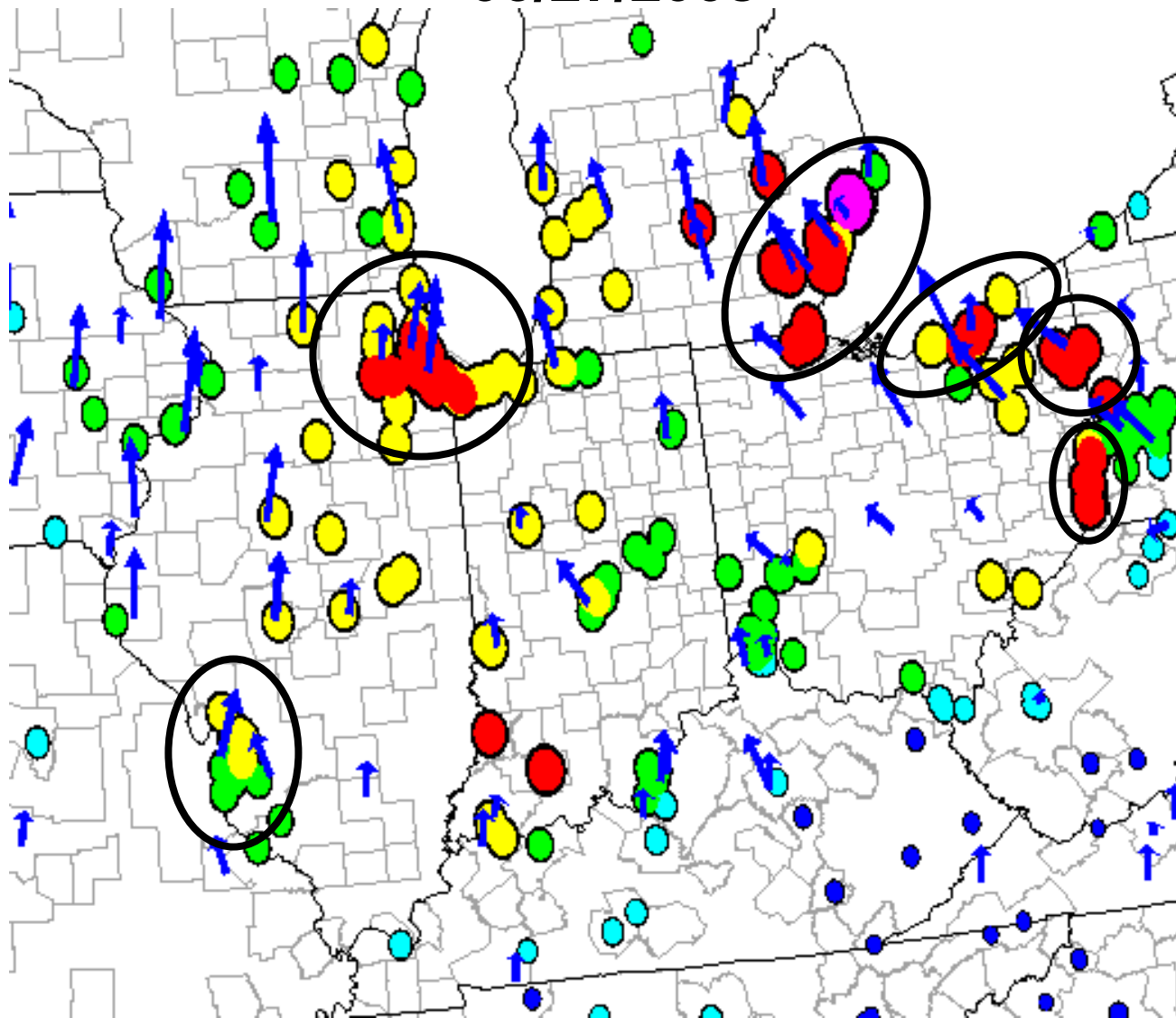
Regional/Urban

Urban

Urban/Microscale

5th Slice

06/27/2005



6.0 - 23.0 ug/m3

23.1 - 34.3 ug/m3

34.4 - 42.5 ug/m3

42.6 - 50.3 ug/m3

50.4 - 61.1 ug/m3

61.1 - 79.2 ug/m3

Regional

Regional

Regional

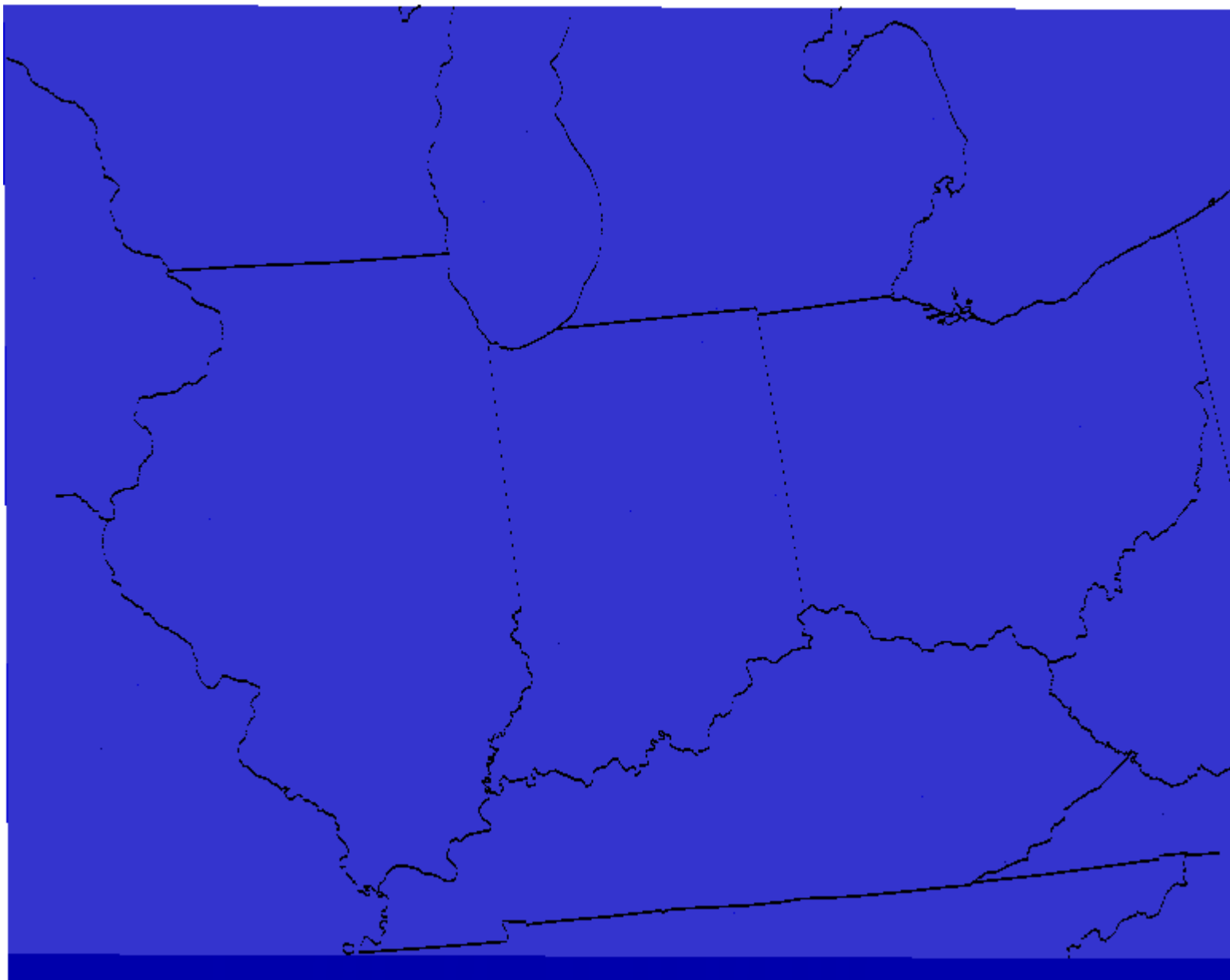
Regional/Urban

Urban

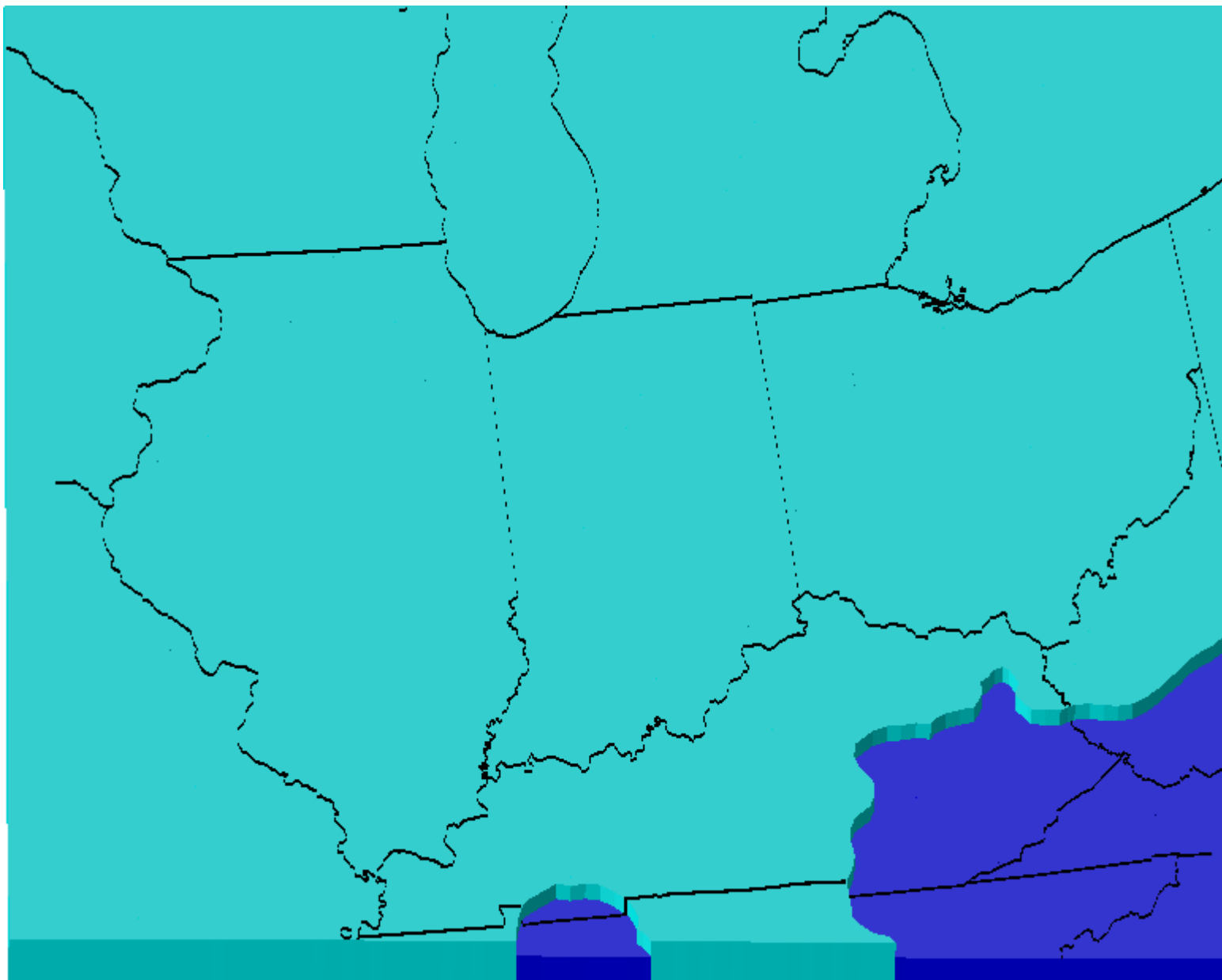
Urban/Microscale

6th Slice

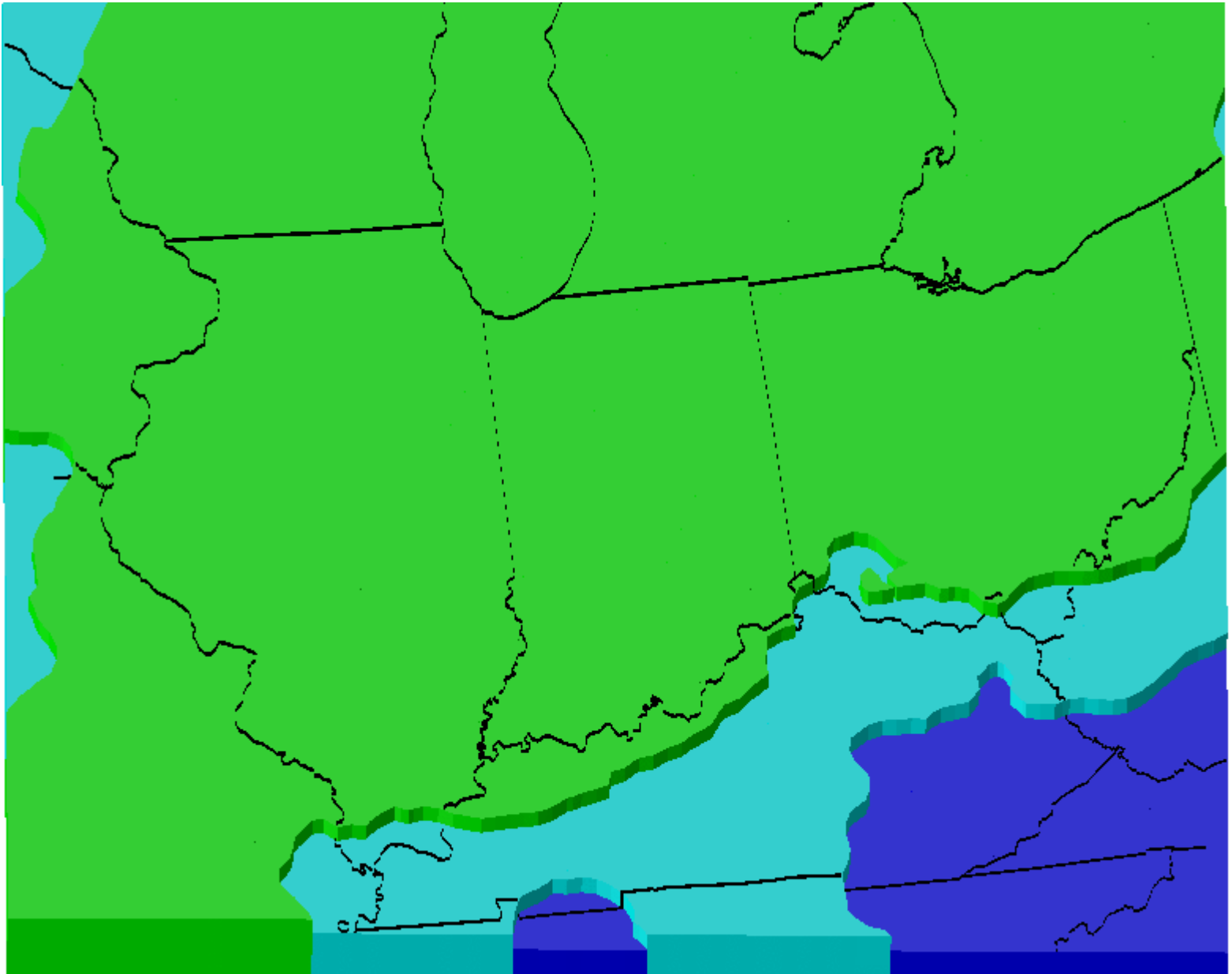
This base slice is considered to be the underlying regional layer for the domain



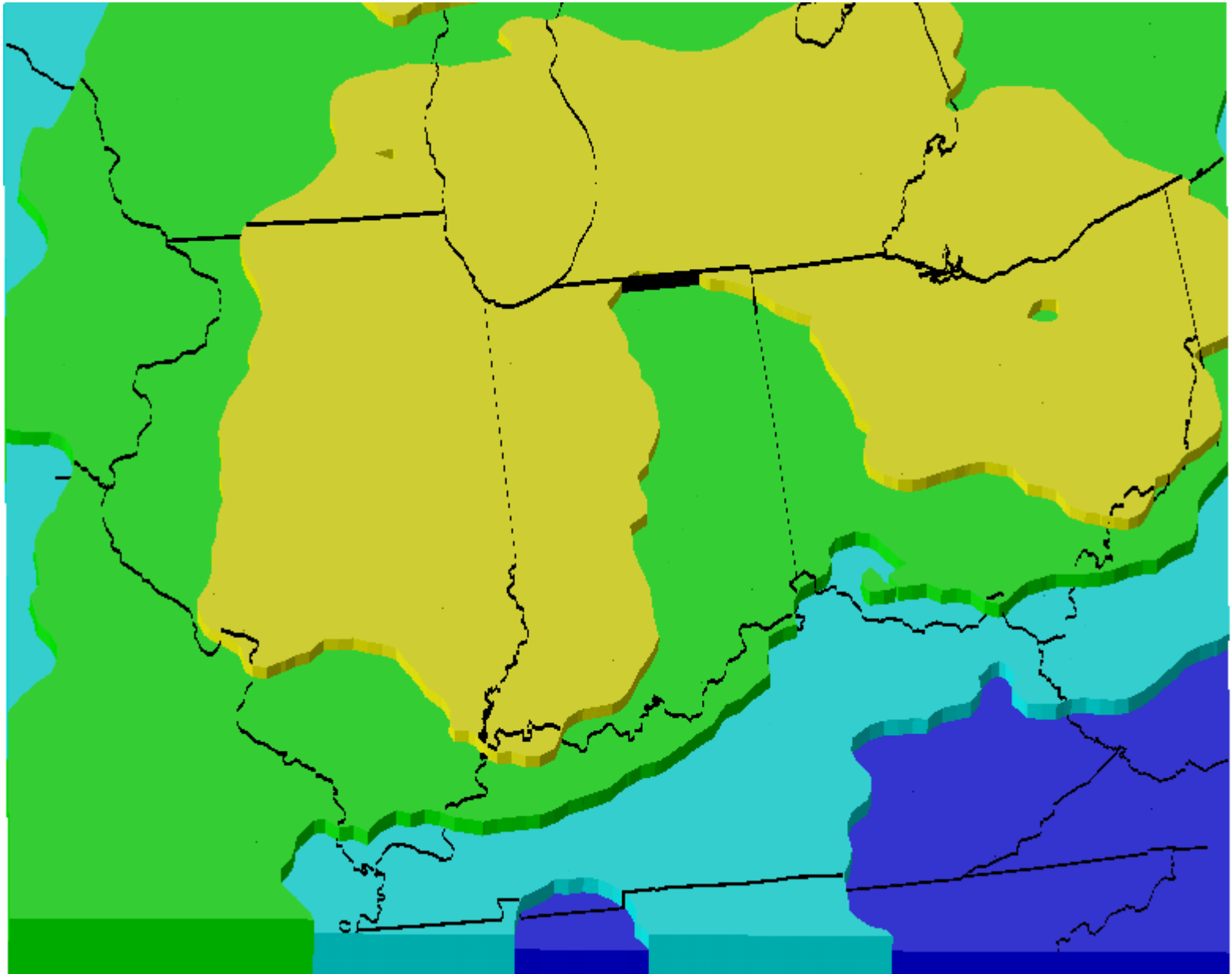
The next regional slice is added on top of the base slice



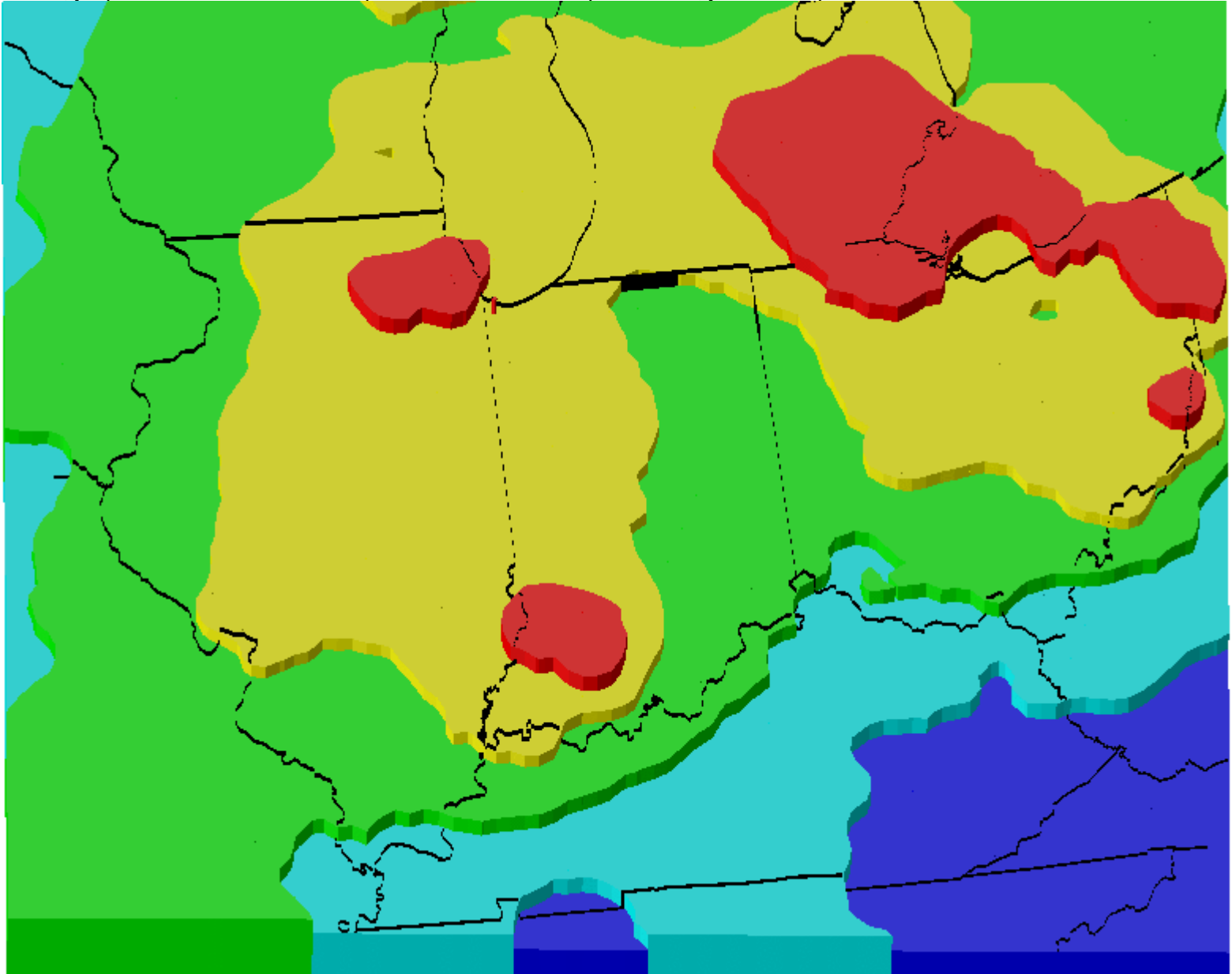
Another regional slice is added on top of the two existing slices



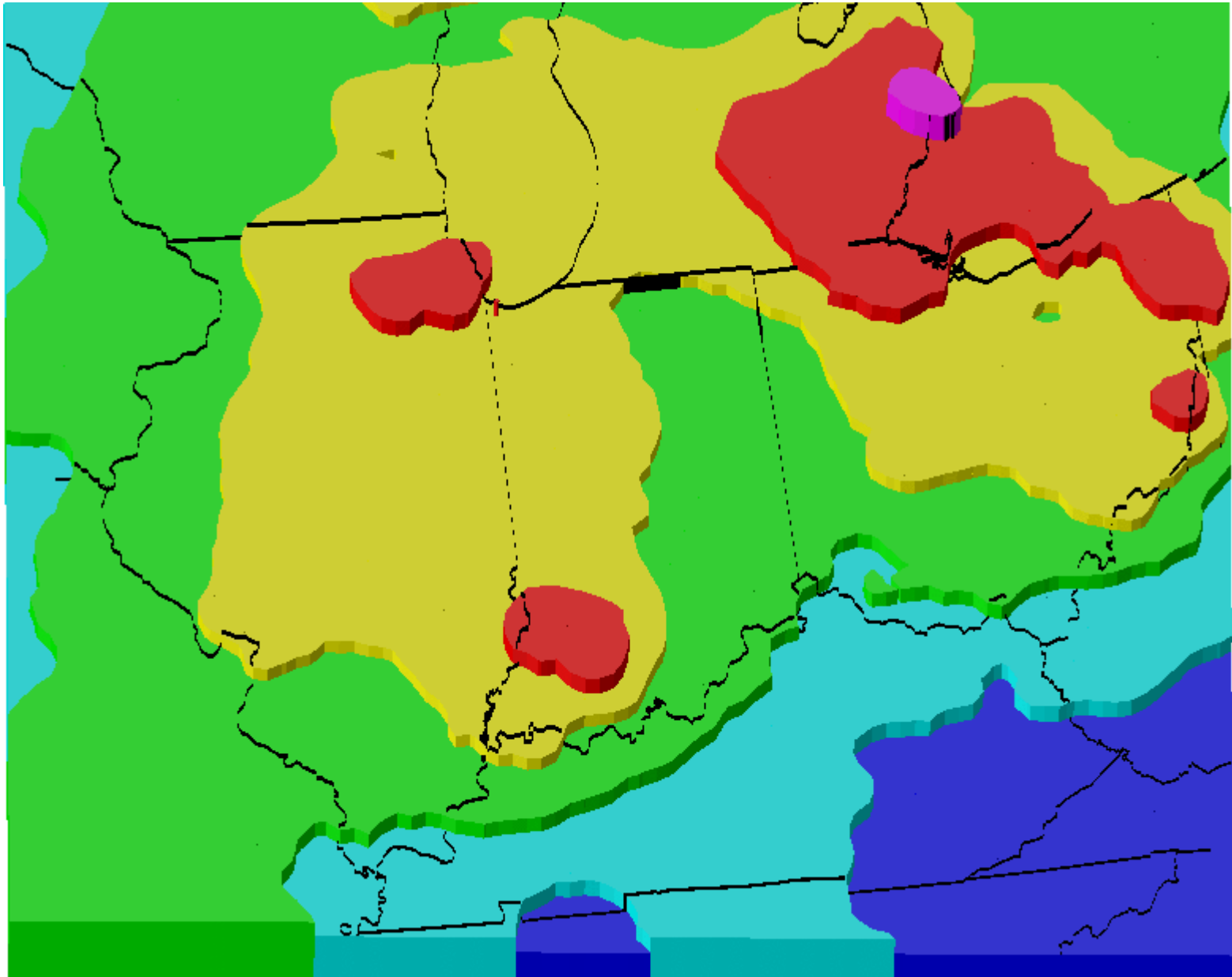
A regional/urban slice is added to the existing three layers



Urban area emissions contribute to “island” effects in
Chicago, Detroit/Toledo, Southern IN, Youngstown, Cleveland and Steubenville

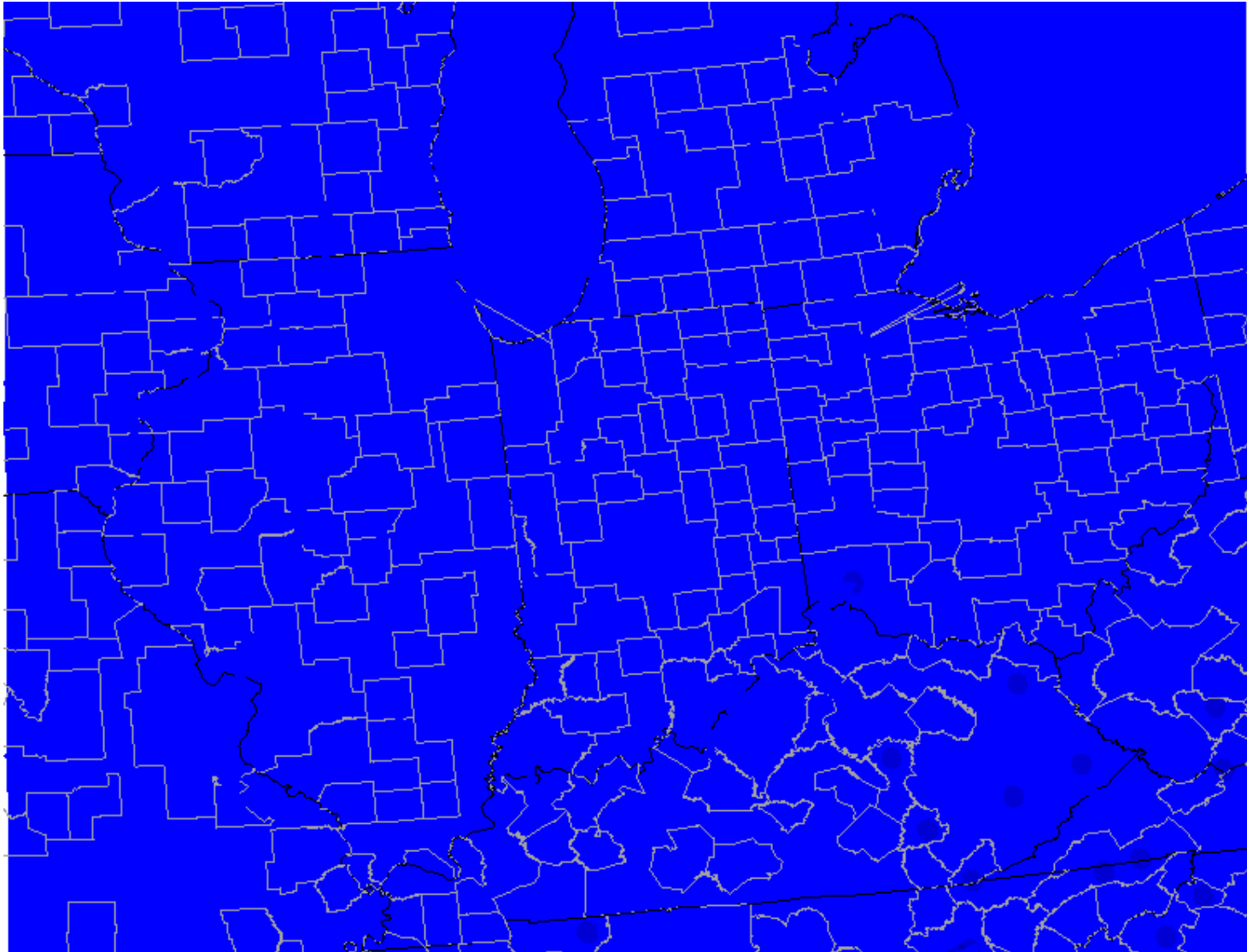


An urban/microscale “island” appears downwind of Detroit in the last slice



06/27/2005

This is
the base
layer on
which
all other
slices
are
placed

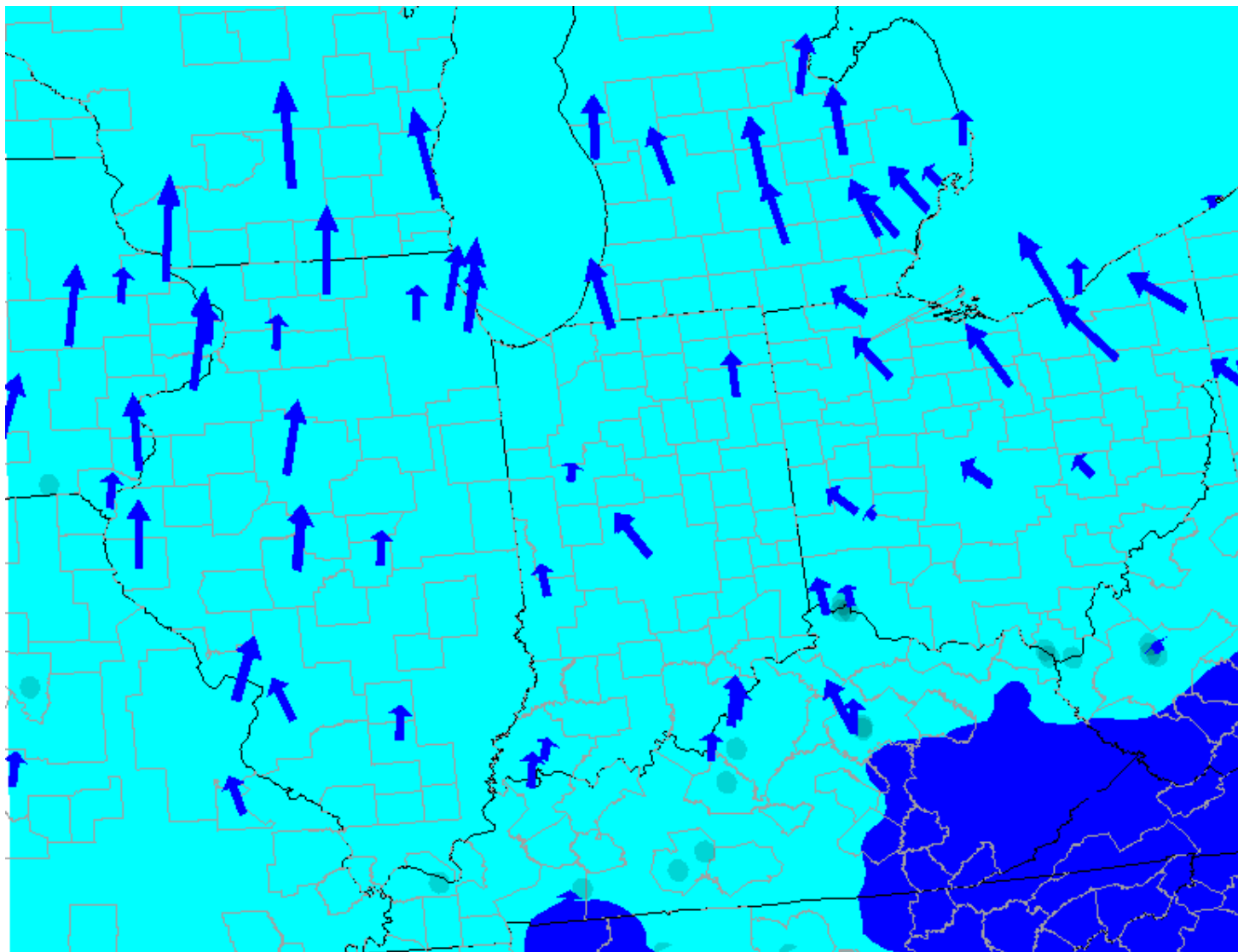


6.0 – 23.0 ug/m3



Up to 23 ug/m3

06/27/2005



6.0 – 23.0 ug/m3

Up to 11.3 ug/m3

Regional

Regional

Regional

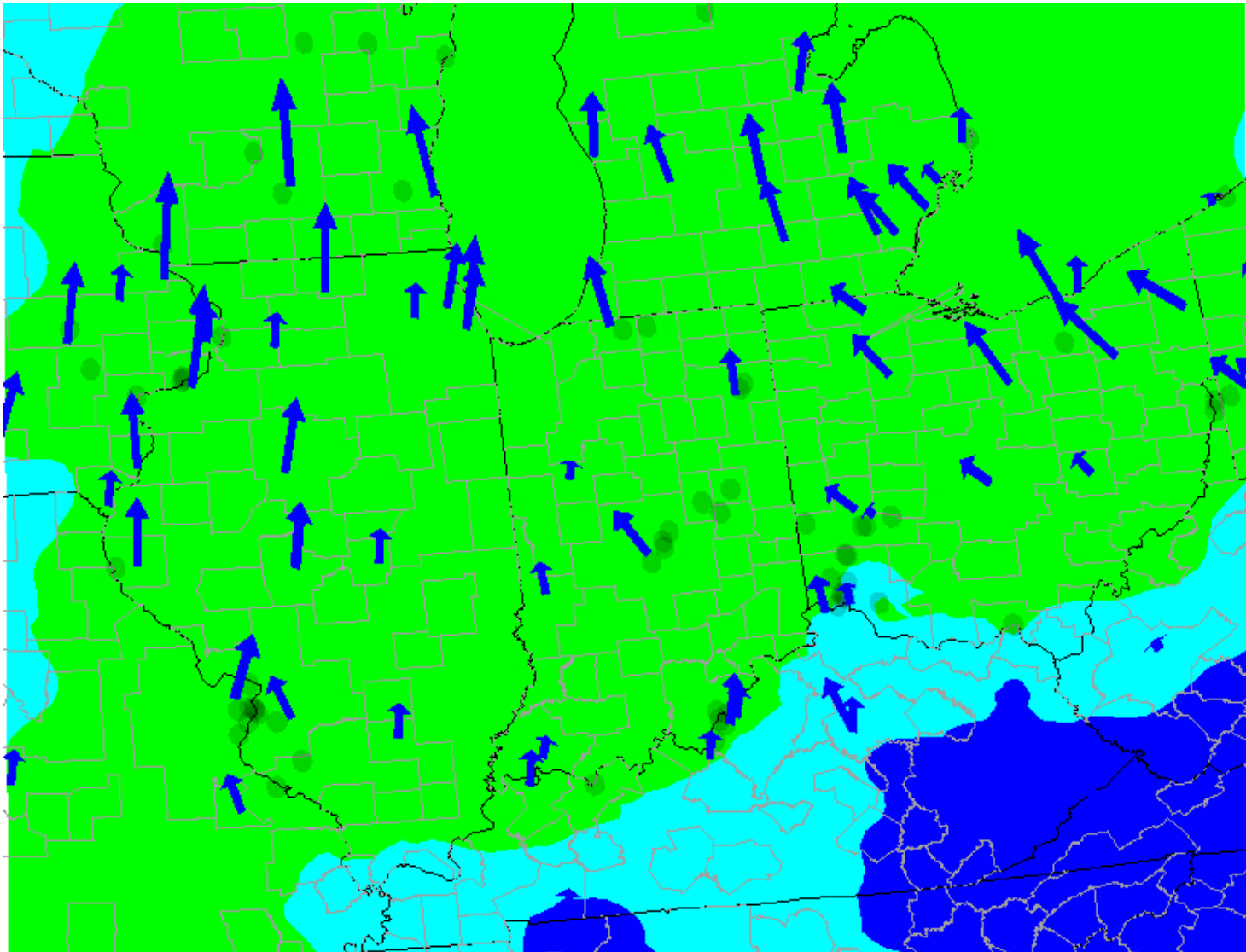
Regional/Urban

Urban

Urban/Microscale

Up to 34.3 ug/m3

06/27/2005



23.1 – 34.3 ug/m3

Up to 8.2 ug/m3

Regional

Regional

Regional

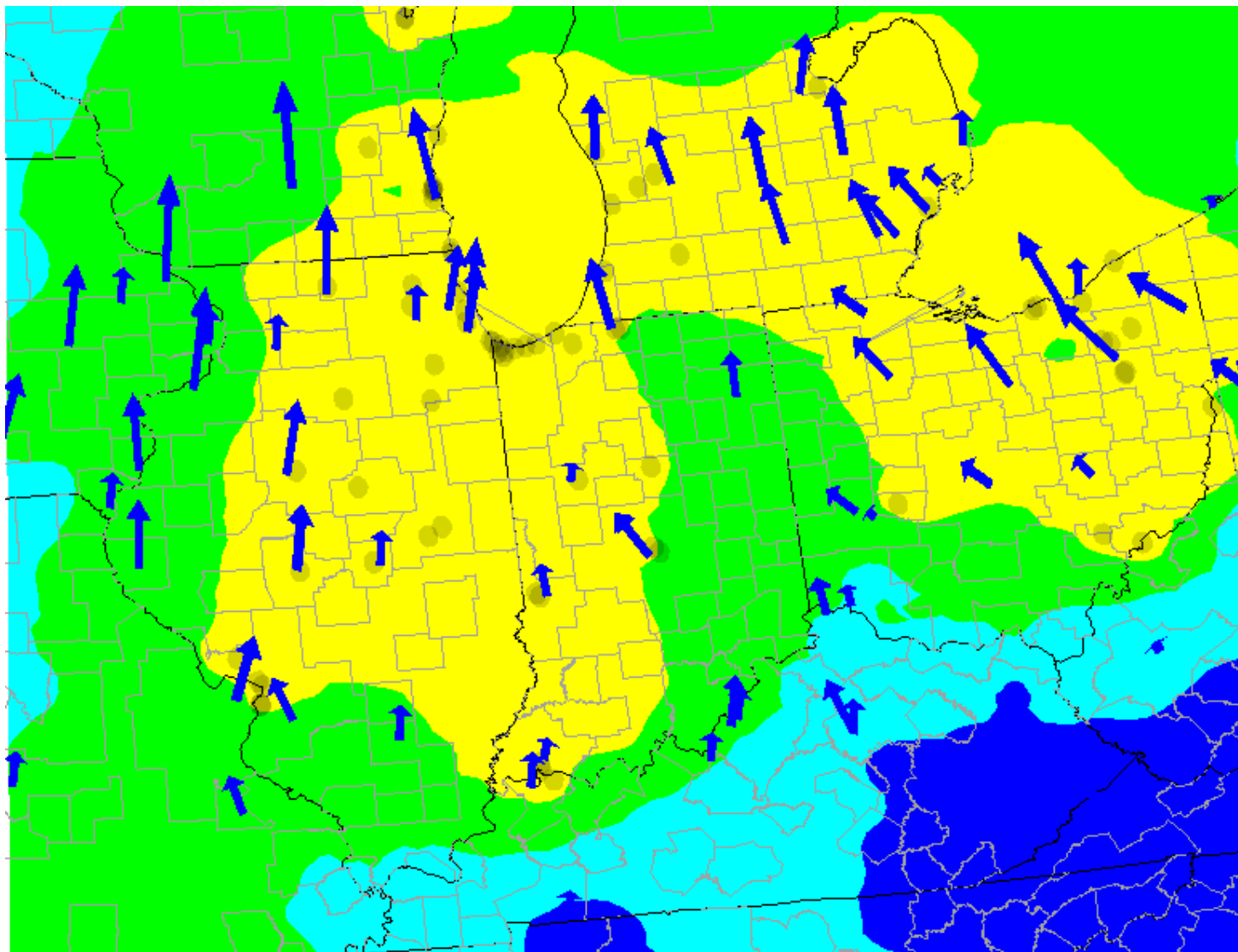
Regional/Urban

Urban

Urban/Microscale

Up to 42.5 ug/m3

06/27/2005



34.4 – 42.5 ug/m3 Up to 7.8 ug/m3

Regional

Regional

Regional

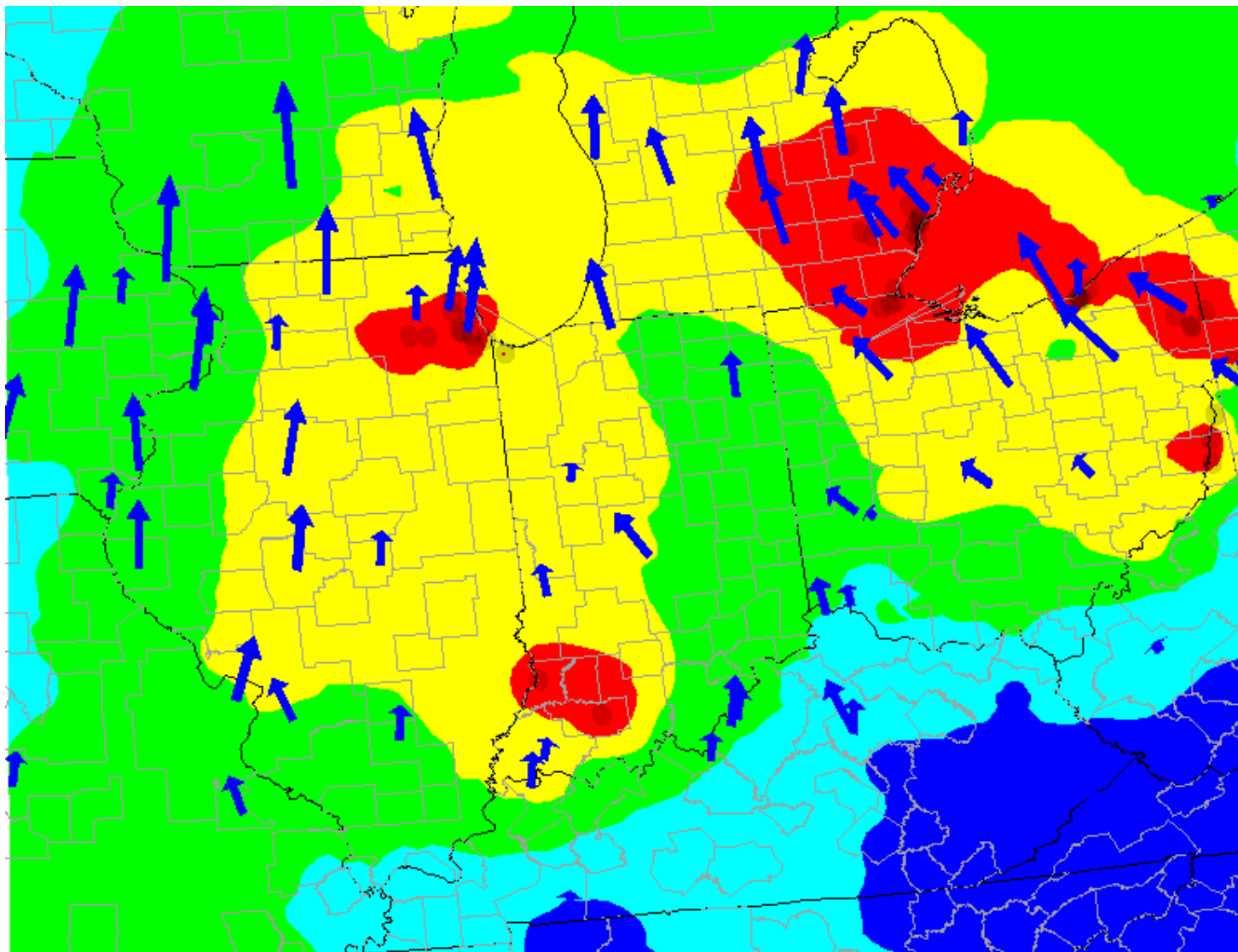
Regional/Urban

Urban

Urban/Microscale

Up to 50.3 ug/m3

06/27/2005



42.6 – 50.3 ug/m3

Up to 10.8 ug/m3

Regional

Regional

Regional

Regional/Urban

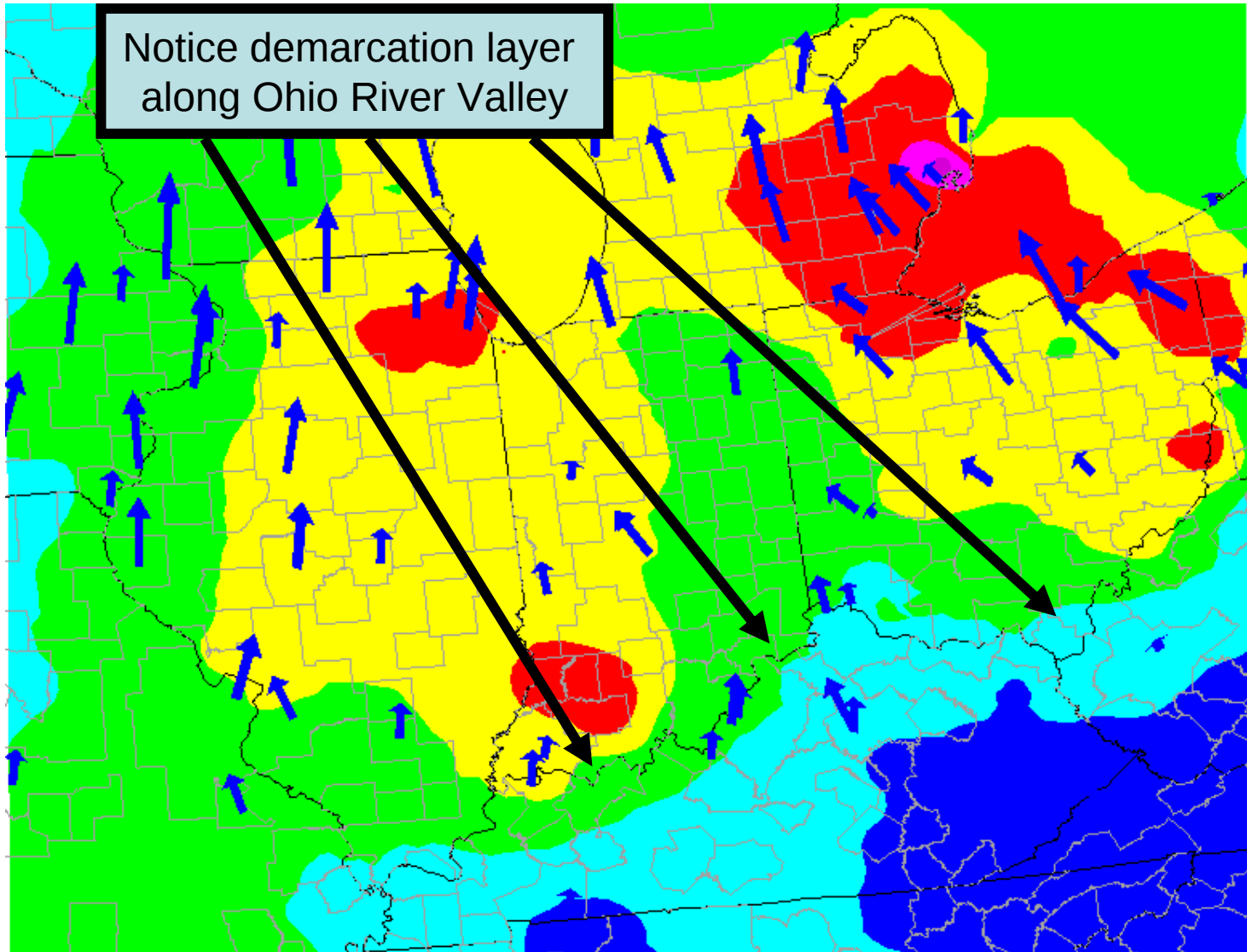
Urban

Urban/Microscale

Up to 61.1 ug/m3

06/27/2005

Notice demarcation layer
along Ohio River Valley



50.4 – 61.1 ug/m3

Up to 18.1 ug/m3

Regional

Regional

Regional

Regional/Urban

Urban

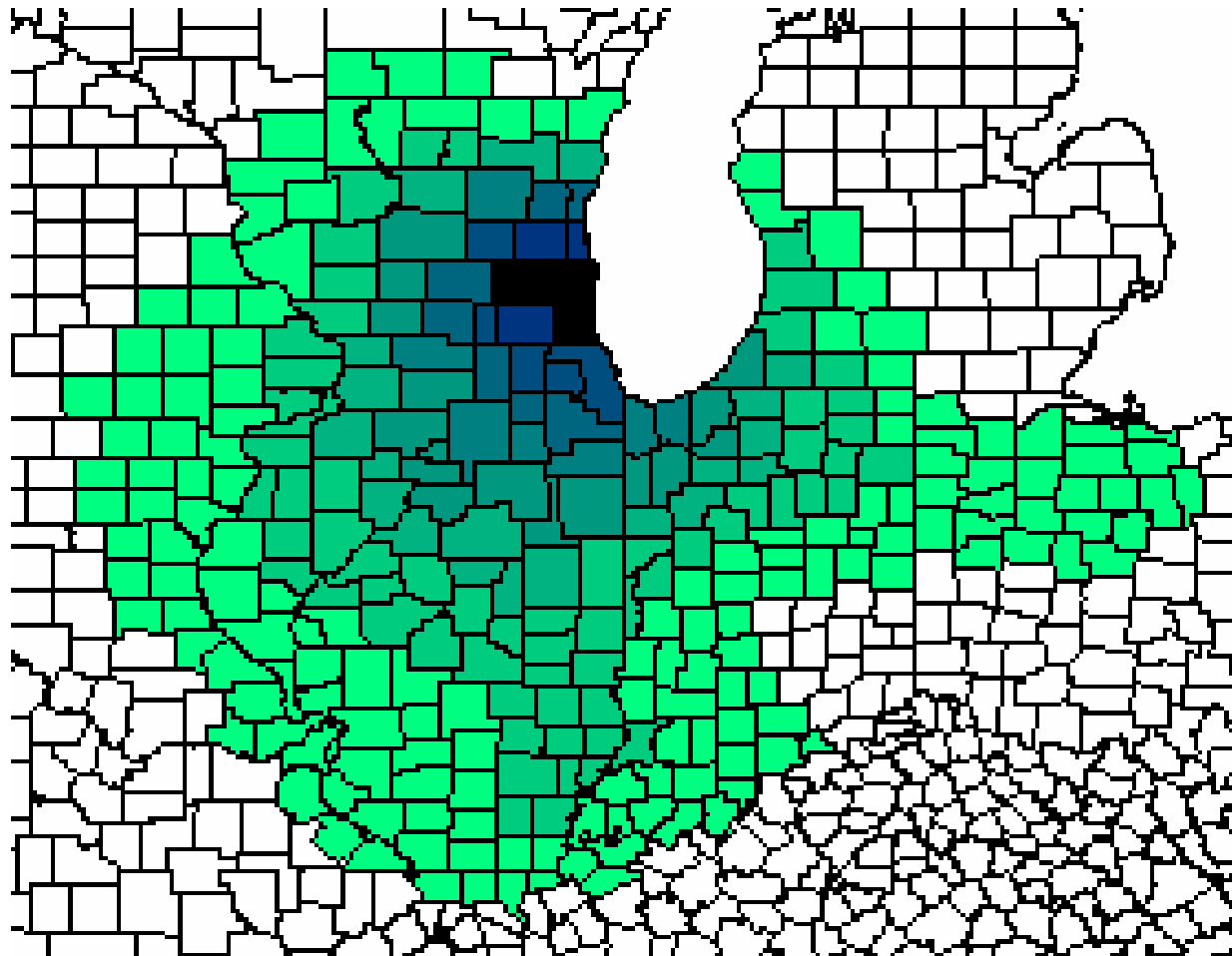
Urban/Microscale

Up to 79.2 ug/m3

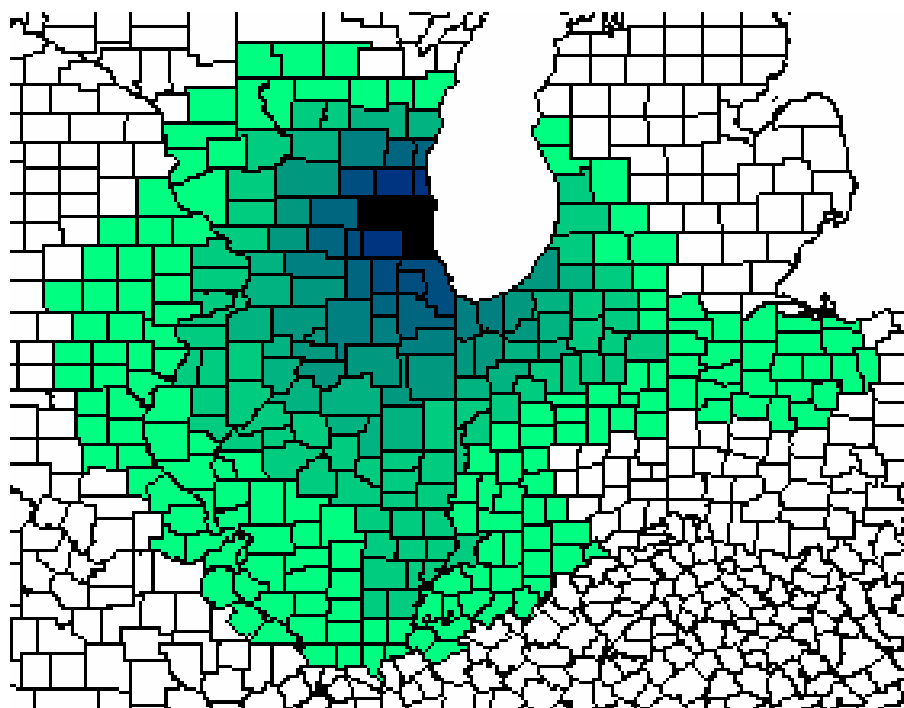
2nd Technique: Residence Time Weighted Emissions

- Utilize trajectories on days when PM_{2.5} is greater than area's lowest 98th percentile by year
- Incorporate information from SLICE to include sites within an “urban island” rather than just a single site to determine the location of air masses influencing an entire area
- Use the results from the calculated trajectories to determine a trajectory density (i.e. what areas do most of the trajectories pass through) to act as a series of weights for emissions estimates
- Utilize county level emissions estimates to determine those areas with the greatest impact
- Aggregate weighted emissions by season into a Total Influential Emissions Score for high days

Trajectory Density for High Days for 2003-2005 in Milwaukee, WI

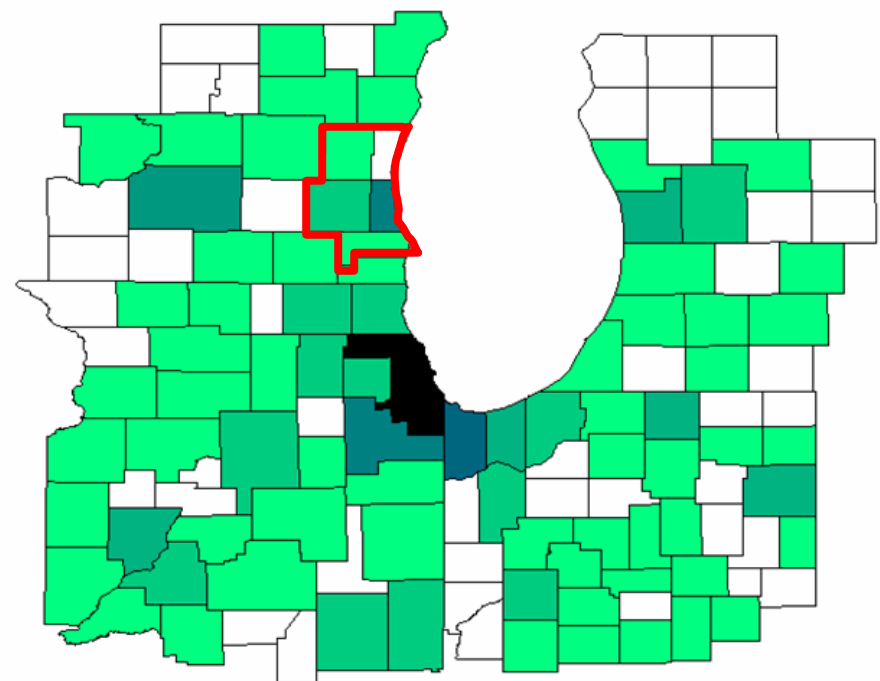


Normalized Density

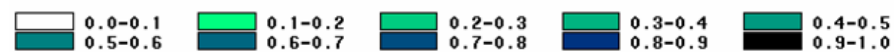


Trajectory Densities

times

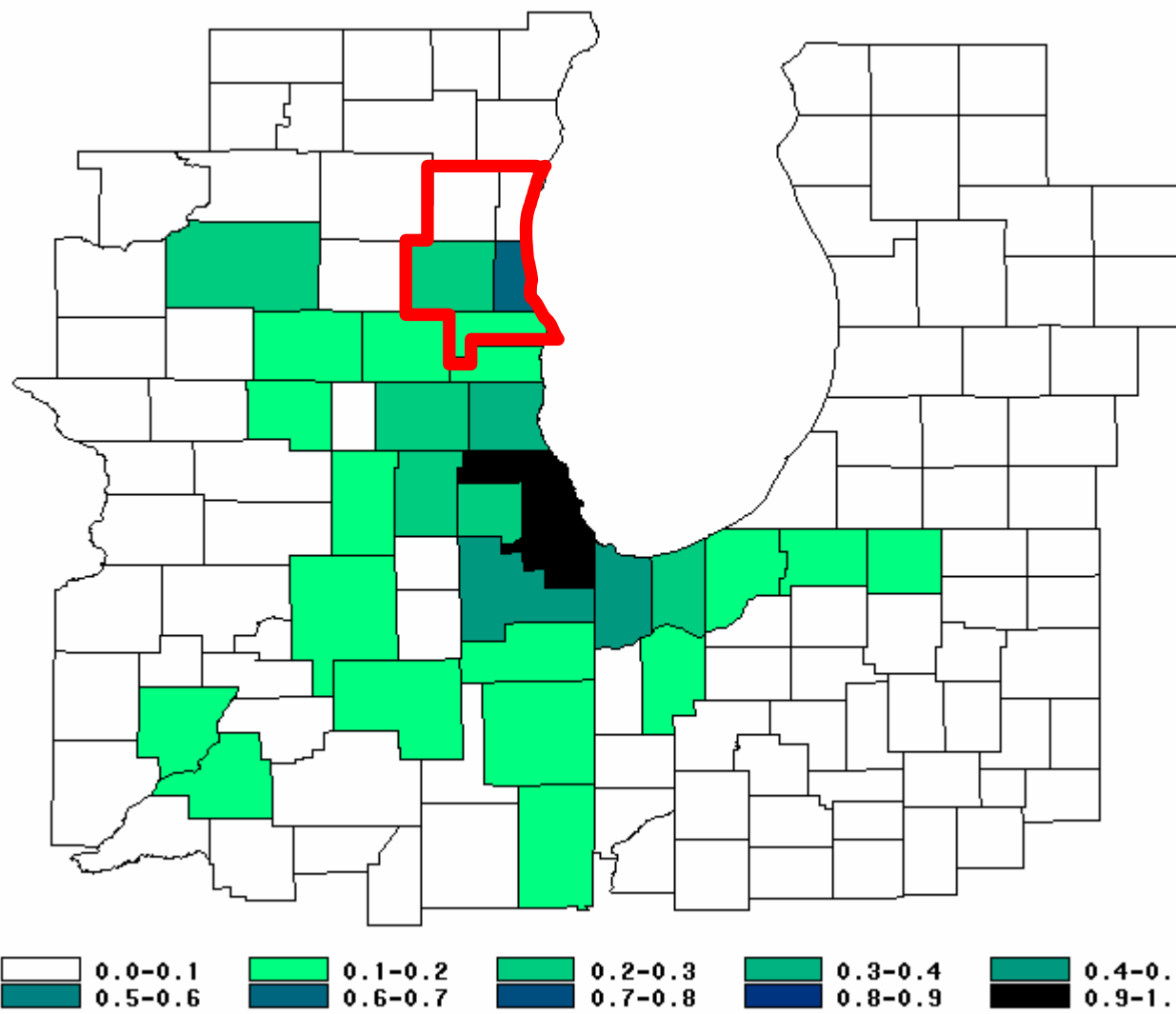


Total PM2.5 Emissions



EQUALS

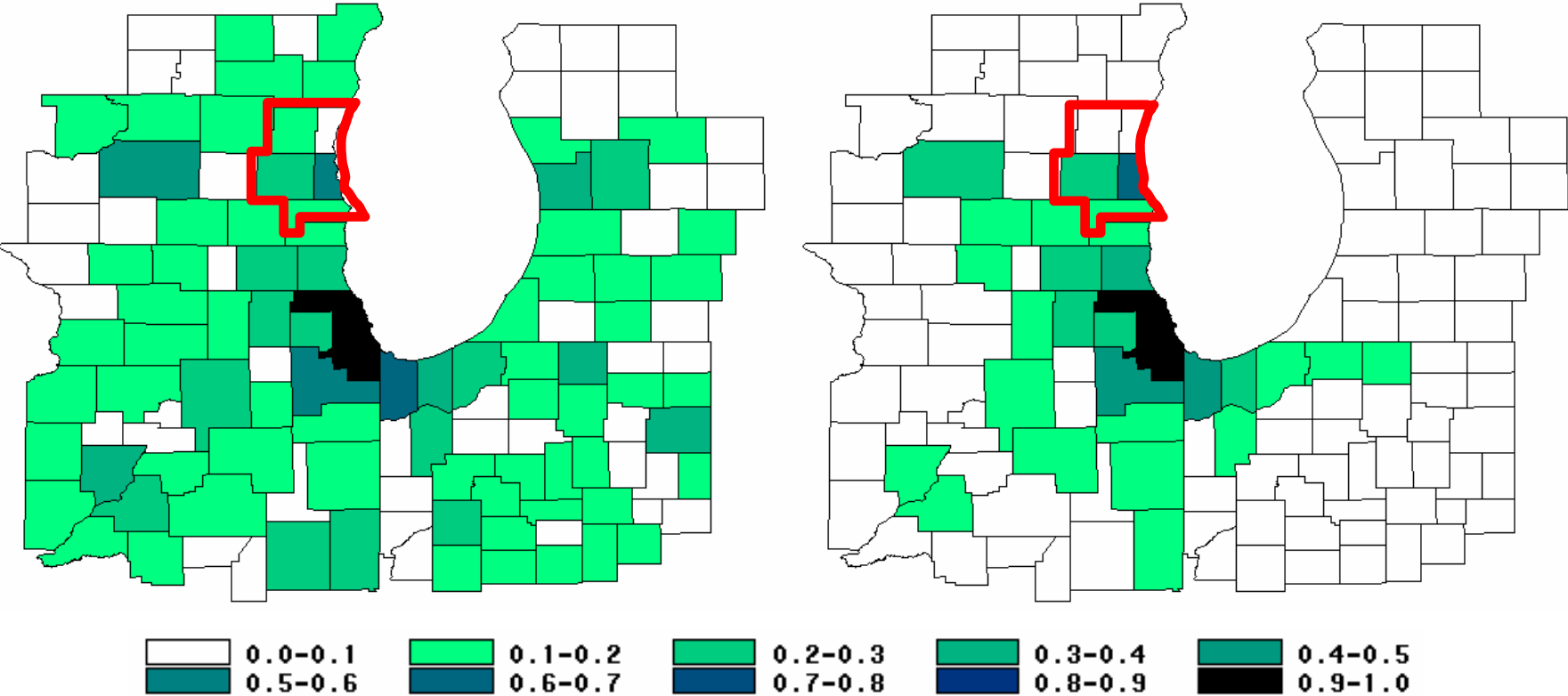
Weighted Total PM2.5 Emissions



Comparison of Milwaukee Area Total PM2.5 Emissions Before and After Weighting

Before weighting

After weighting

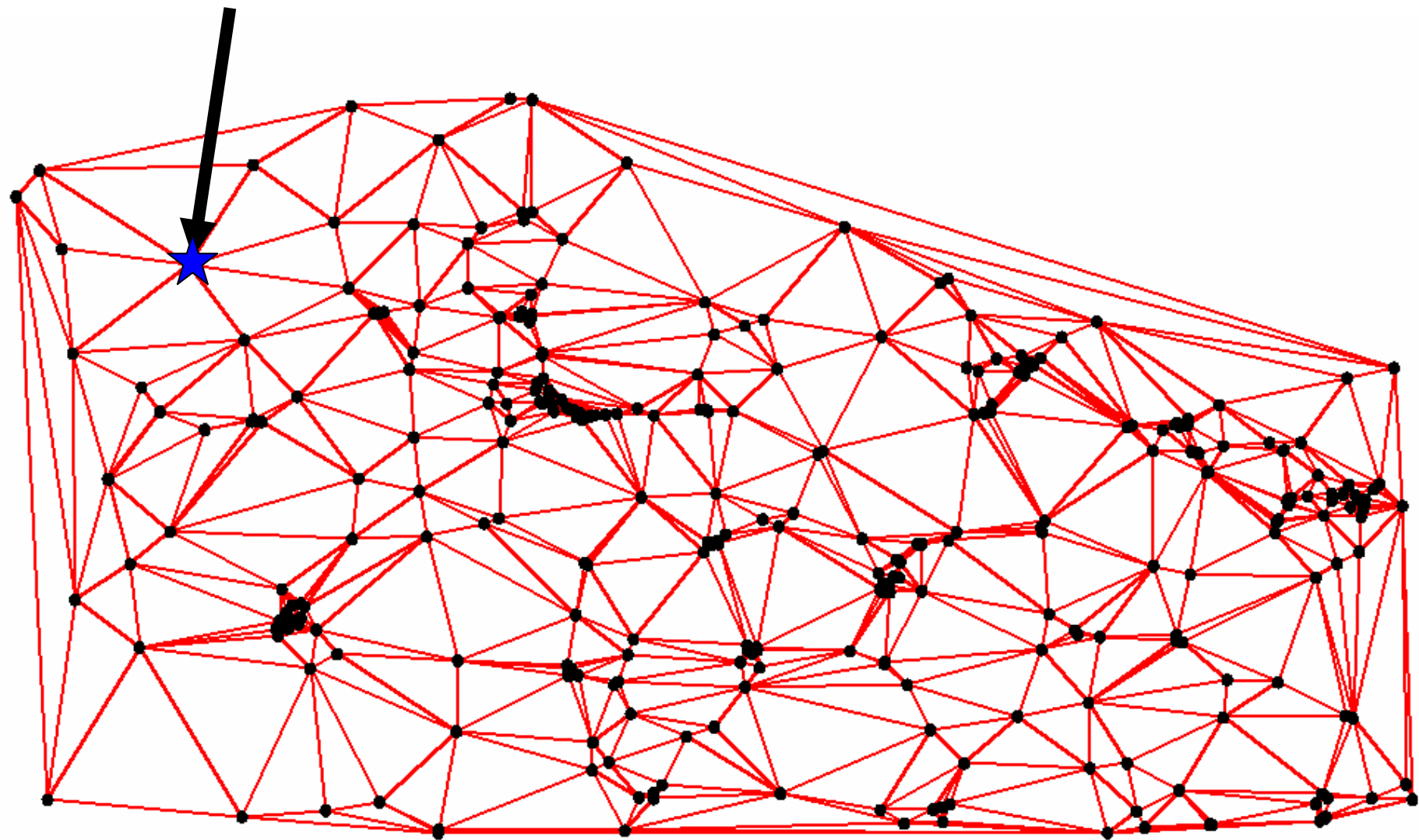


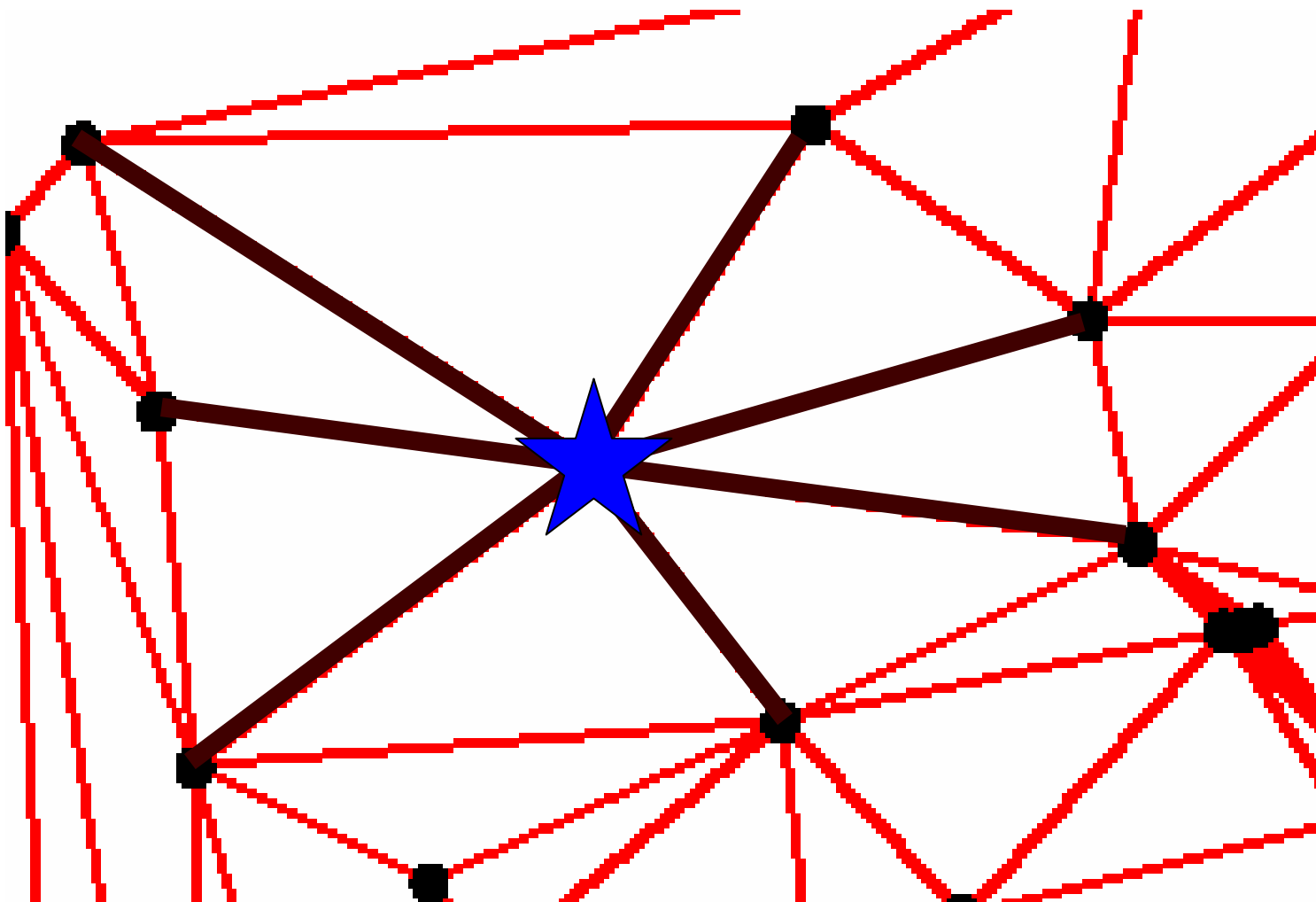
Greater emphasis is placed on those counties where air on high days passed through

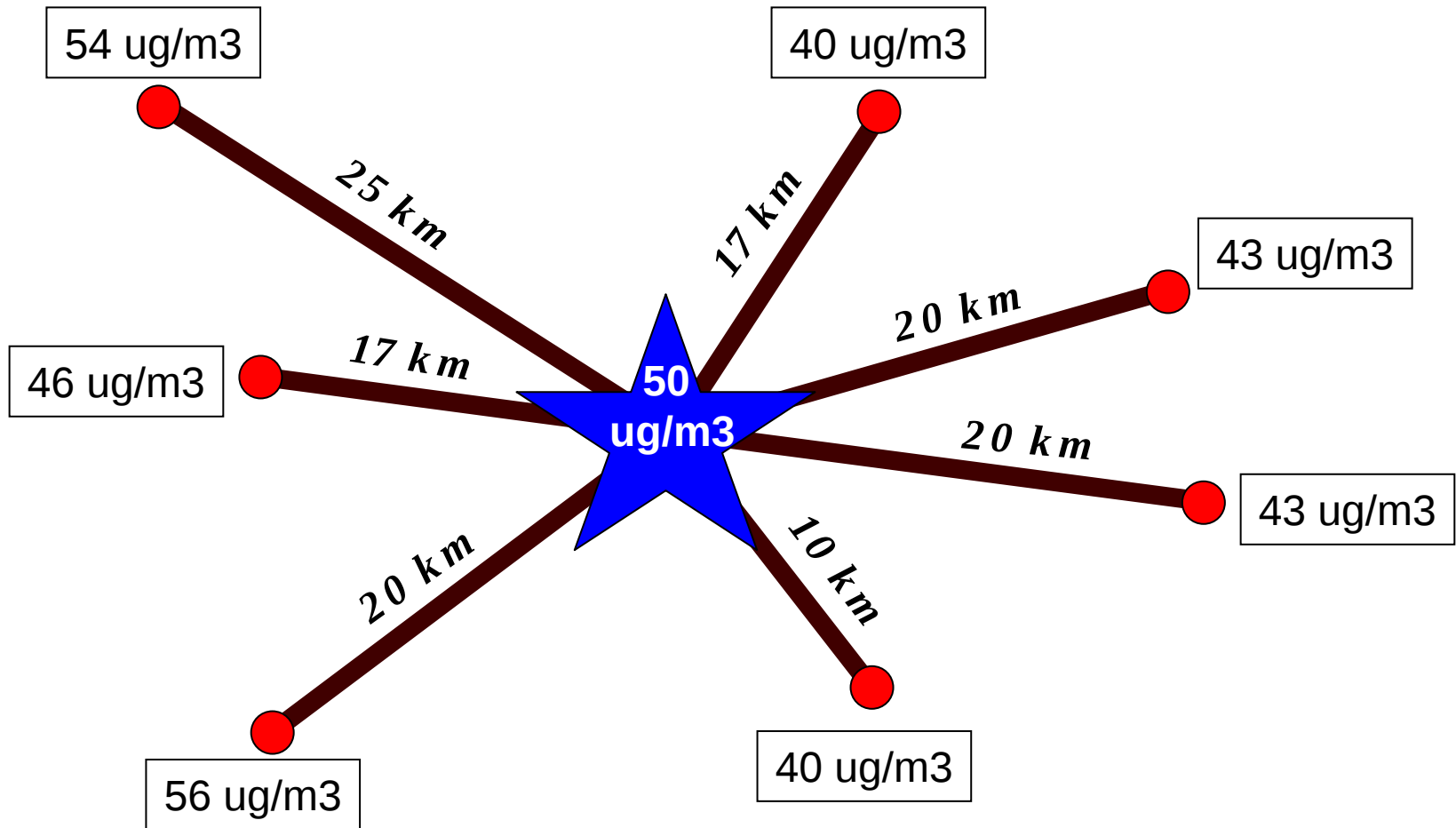
3rd Technique: Urban Gradient

- Identify sites predominantly affected by local sources
- Technique is utilized on a daily basis
- Examines total net gradient between each site and its “neighboring” sites
- Weighted by distance to take into account monitors far apart from one another
- Examine only those sites with net positive gradient
- Utilize meteorological, emissions and satellite data to examine potential sources of gradient

Let's look at one site in particular







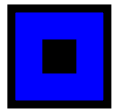
Distance weighted gradient:

$$(-4 \text{ ug/m}^3 * 0.06) + (10 \text{ ug/m}^3 * 0.13) + \dots + (4 \text{ ug/m}^3 * 0.13) = 6.2 \text{ ug/m}^3$$

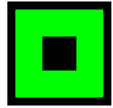
Use percentiles of the gradients' distribution to distinguish high values

Urban Gradient Legend

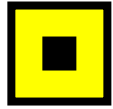
- PM2.5 Point Sources from National Emission Inventory



0.5 to 5 tons/year



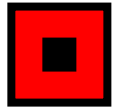
6 to 15 tons/year



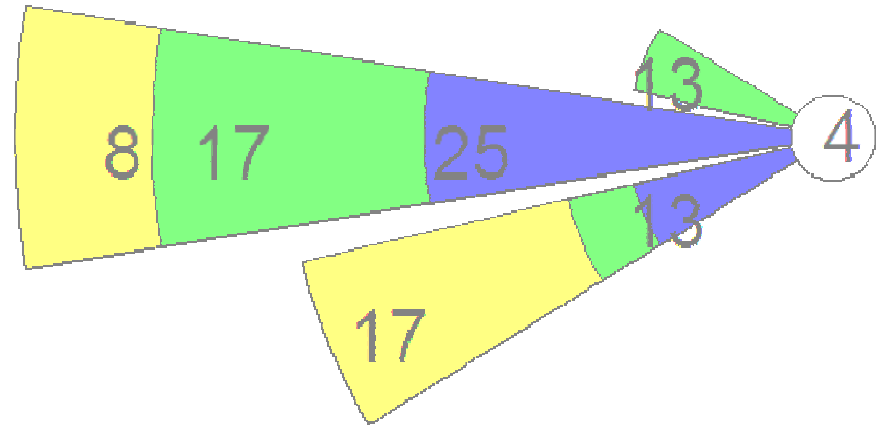
16 to 30 tons/year



31 to 50 tons/year



Greater than 50 tons/year



- Windroses
 - Frequency distribution of 24 hour measured wind speeds by wind direction
 - Numbers represent the percentage that the wind speed was coming from that direction during the day
 - Colors represent wind speeds (Cooler colors represent lower wind speeds)
 - Blue: 1-5 mph
 - Green: 5-10 mph
 - Yellow: 10-15 mph
 - Orange: 15-20 mph
 - Red: 20-25 mph
 - Purple: >25 mph

approximately 110 miles

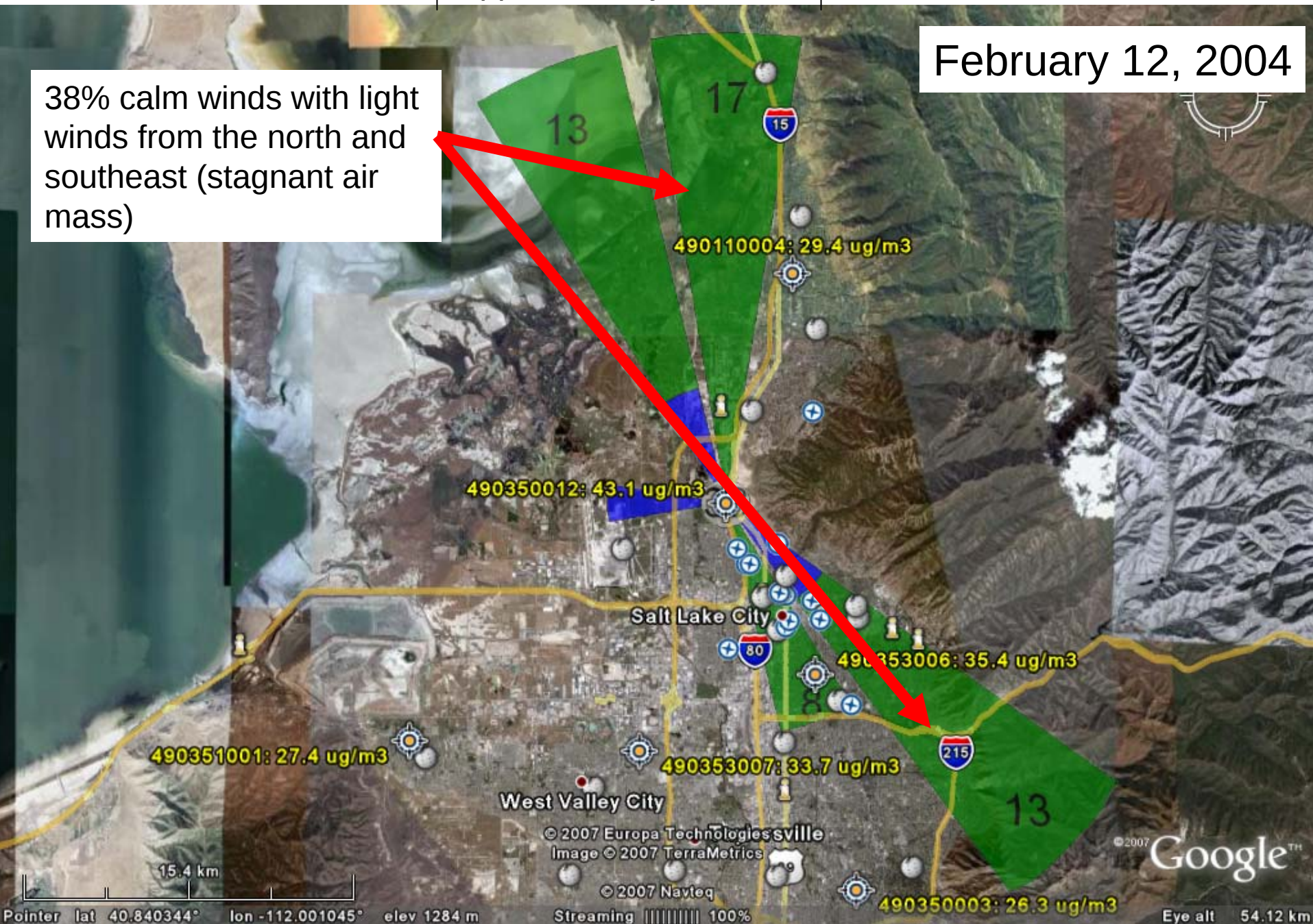
February 12, 2004



approximately 40 miles

February 12, 2004

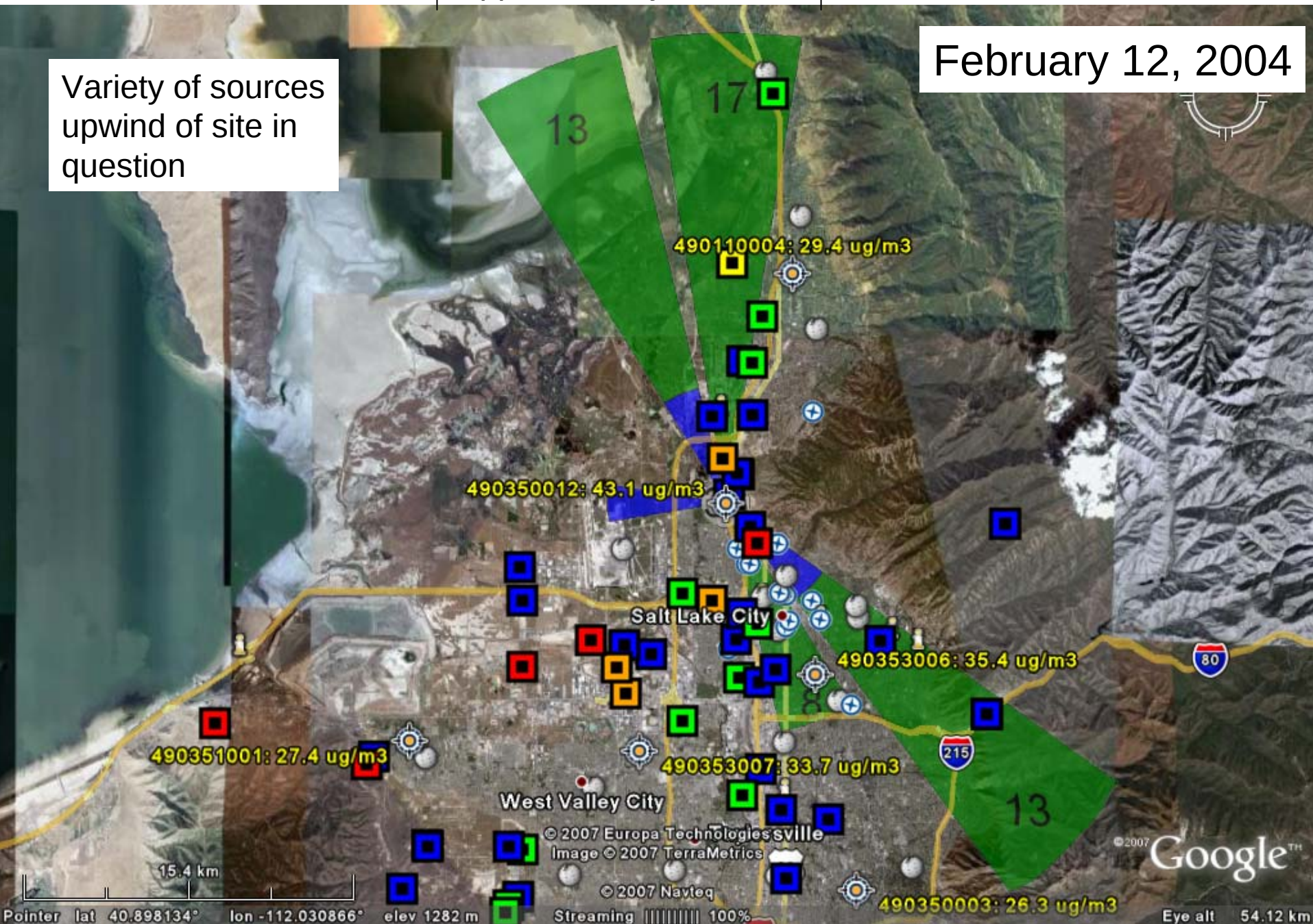
38% calm winds with light winds from the north and southeast (stagnant air mass)



approximately 40 miles

Variety of sources
upwind of site in
question

February 12, 2004



Urban Gradient

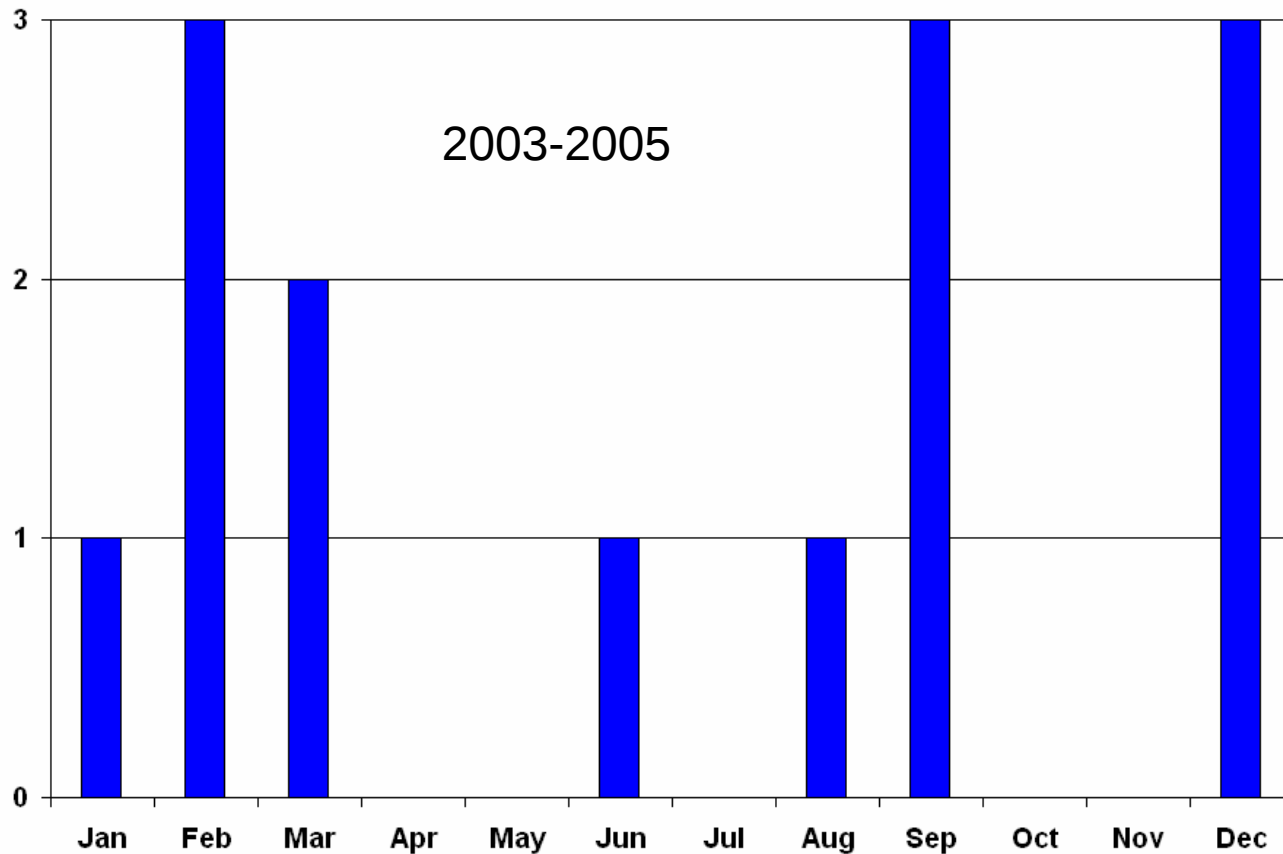
- Exploring how often gradients in areas with high 24 hour concentrations occur on days greater than 35 $\mu\text{g}/\text{m}^3$
- Attempting to quantify the magnitude of the gradient in relation to regional and urban influences to determine the local source influence above and beyond the regional and urban contributions

Integrating the Three Techniques

- Envision using all three techniques for areas across the country
 - **Residence time weighted emissions:** Isolate geographic areas which may be substantial contributors to the area's ambient PM_{2.5} concentrations on more of a regional scale
 - **SLICE + Urban Gradient:** Integrate between the two techniques to isolate specific days with gradients above and beyond the overall urban contribution

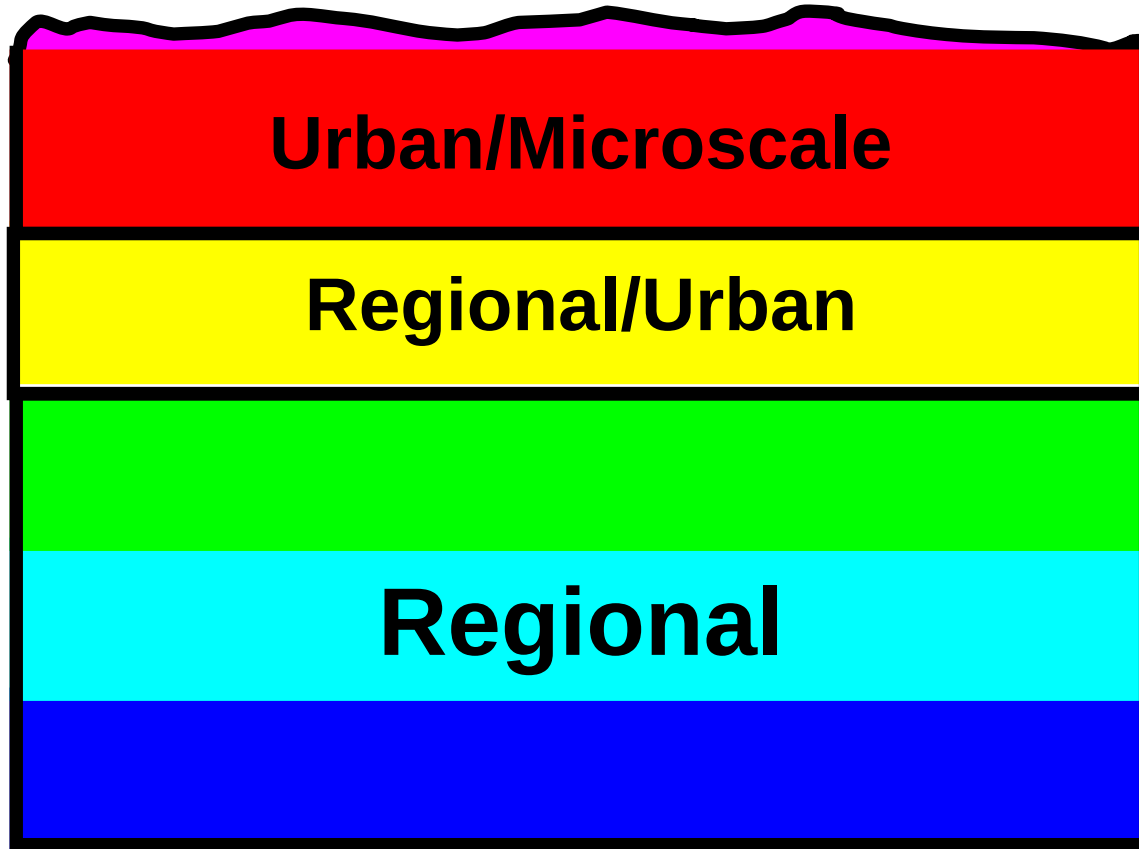
An Example of Utilizing All Three Techniques in Milwaukee, WI

- When did the high days in Milwaukee occur?



The high days in Milwaukee mostly occur during the winter months.

Milwaukee High Day SLICE Results

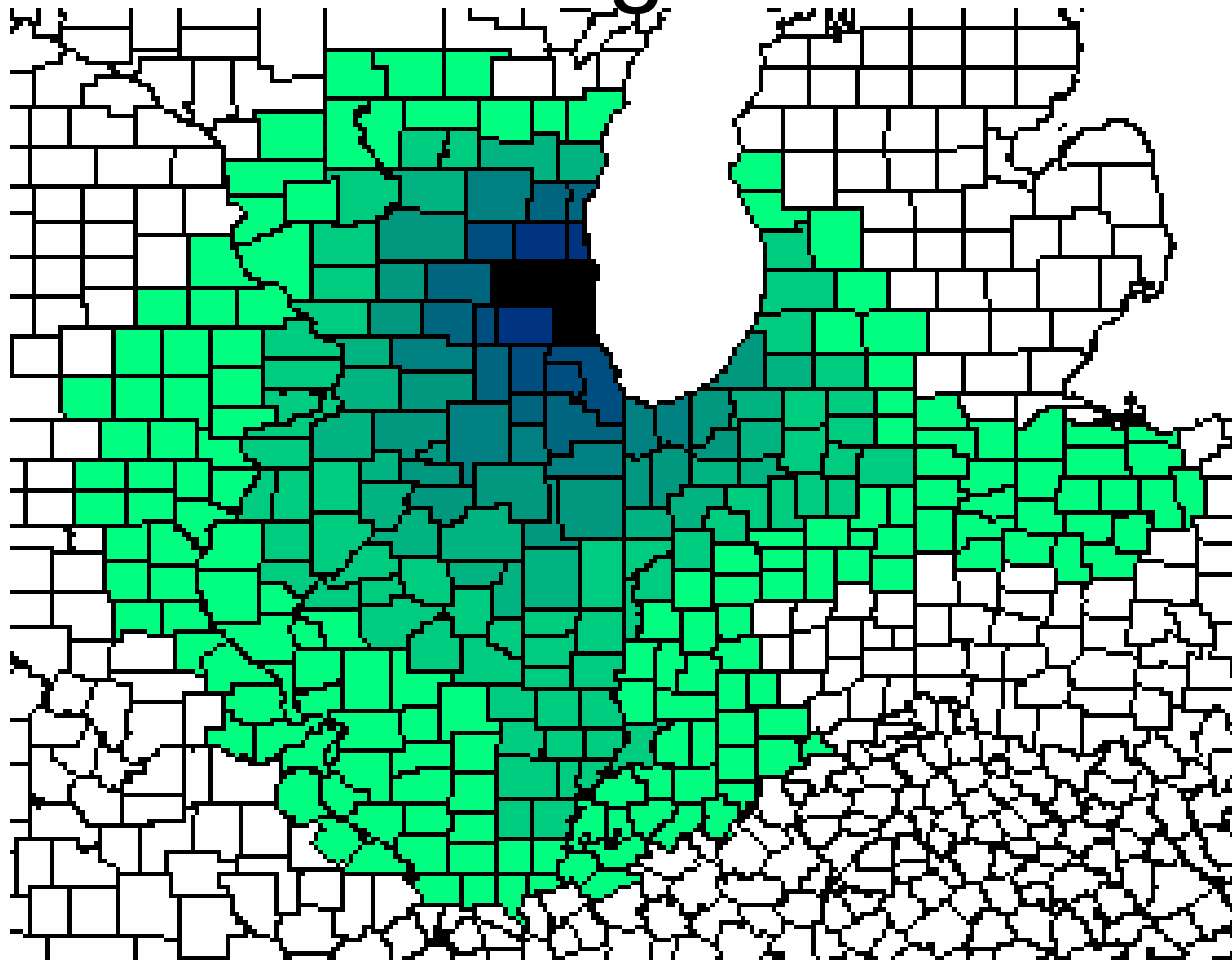


Mean: 2.9 ug/m³
Range: 0.0-16.6 ug/m³

Mean: 5.4 ug/m³
Range: 0.0-10.5 ug/m³

Mean: 28.8 ug/m³
Range: 19.9-41.0 ug/m³

Residence Time Weighted Emissions

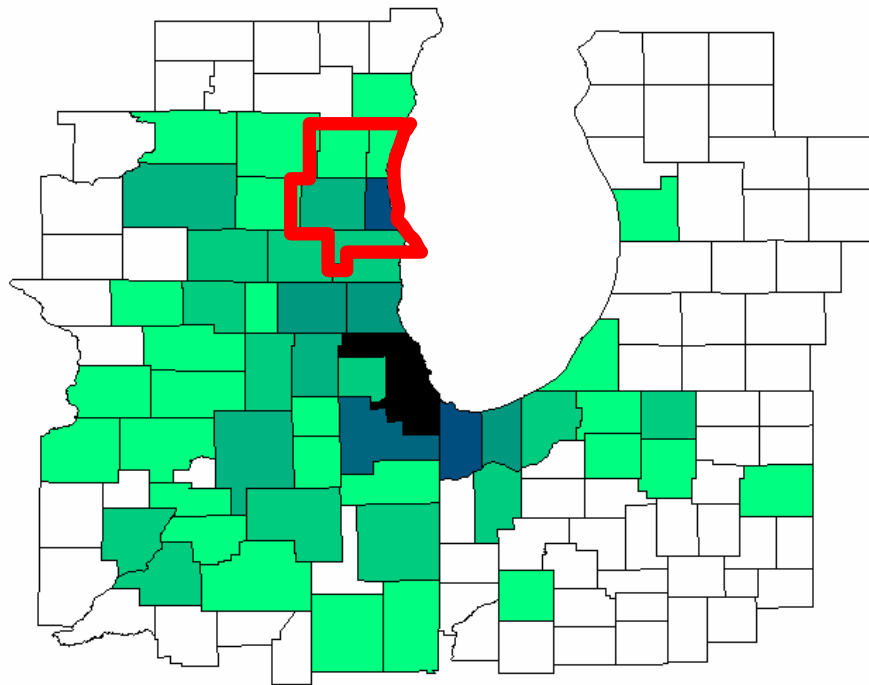


Trajectory densities
for the high days in
Milwaukee CSA.

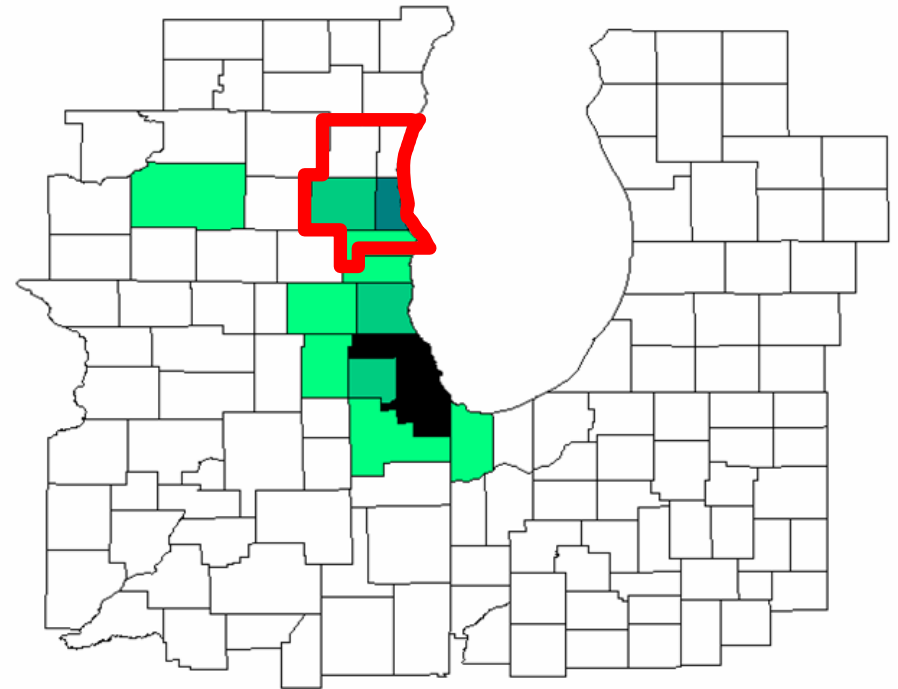
A lot of the trajectories
coming into Milwaukee
go through central Illinois
and Northwest Indiana
as well as the “collar”
counties surrounding
Milwaukee

Residence Time Weighted Emissions

Crustal weighted emissions



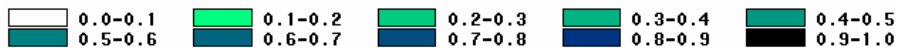
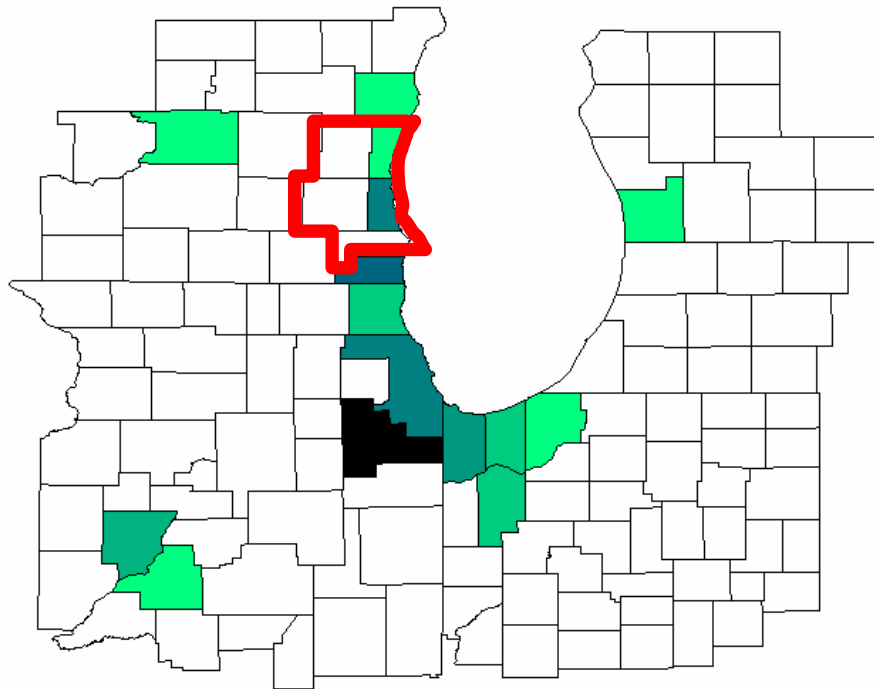
Total Carbon (EC and OC)
weighted emissions



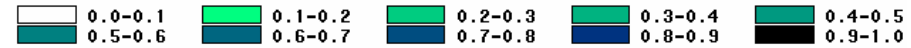
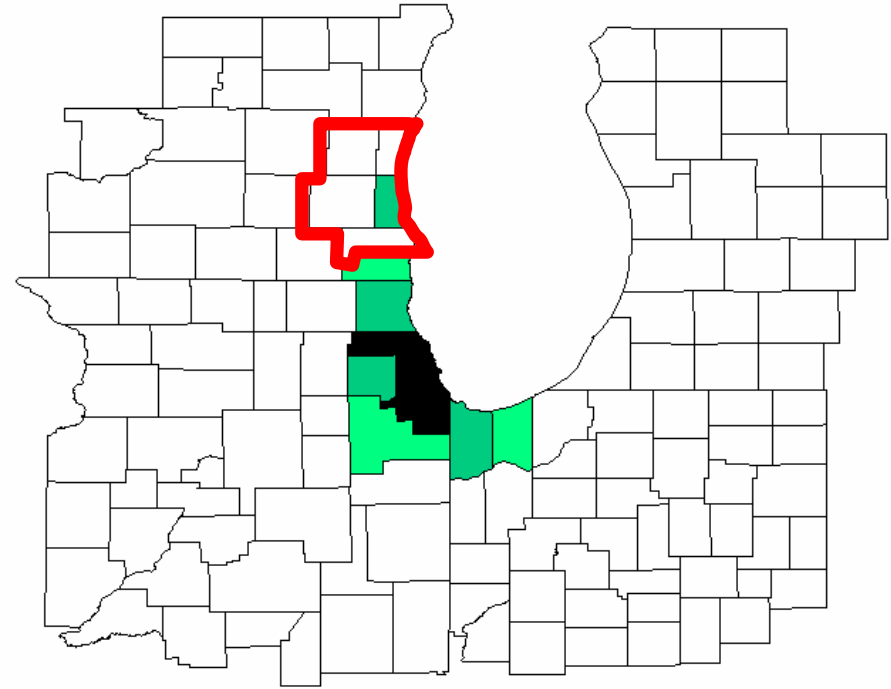
Weighted crustal and total carbon emissions would suggest local impacts from the Milwaukee CSA as well as possible impacts from Chicagoland area

Residence Time Weighted Emissions

SO2 weighted emissions



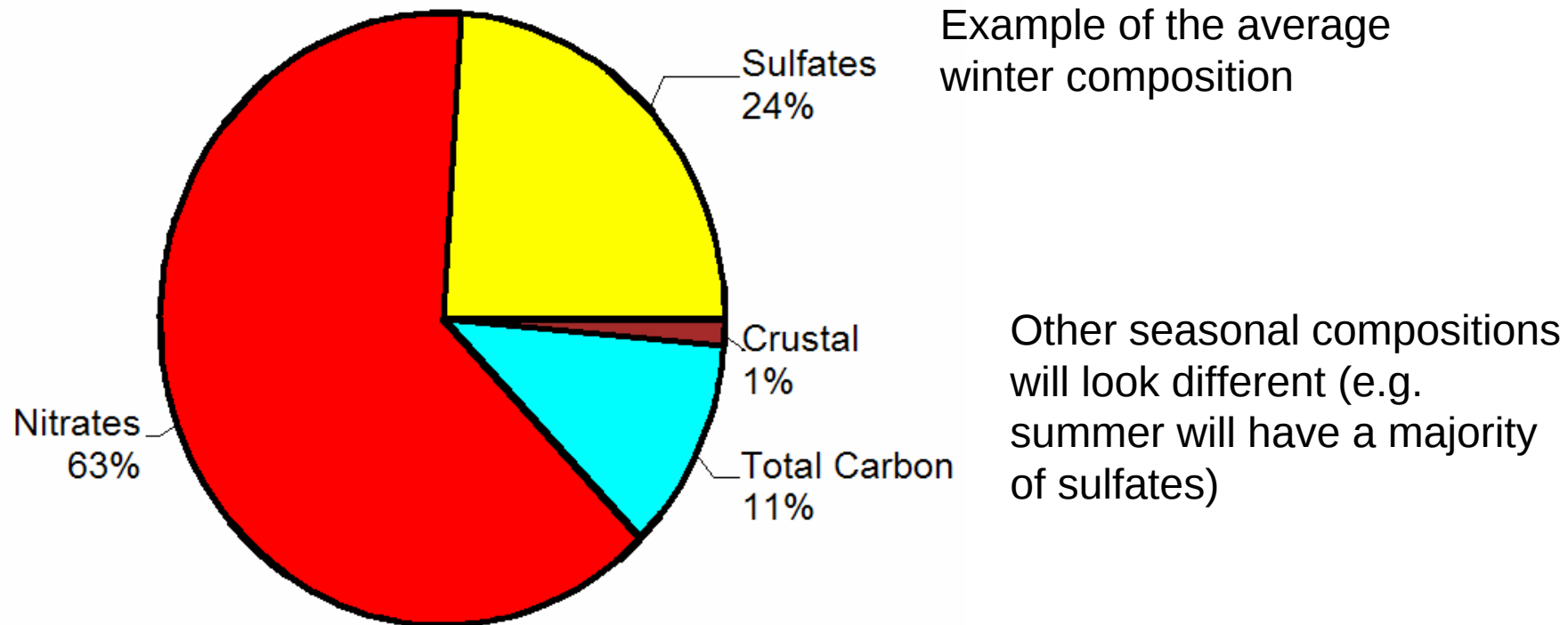
NOx weighted emissions



SO2 and NOx as an indicator of secondary PM2.5 suggest emission influences from the Chicago area with some indication that there are also contributions from emissions within Milwaukee County

Creating a Total Influential Emissions Score

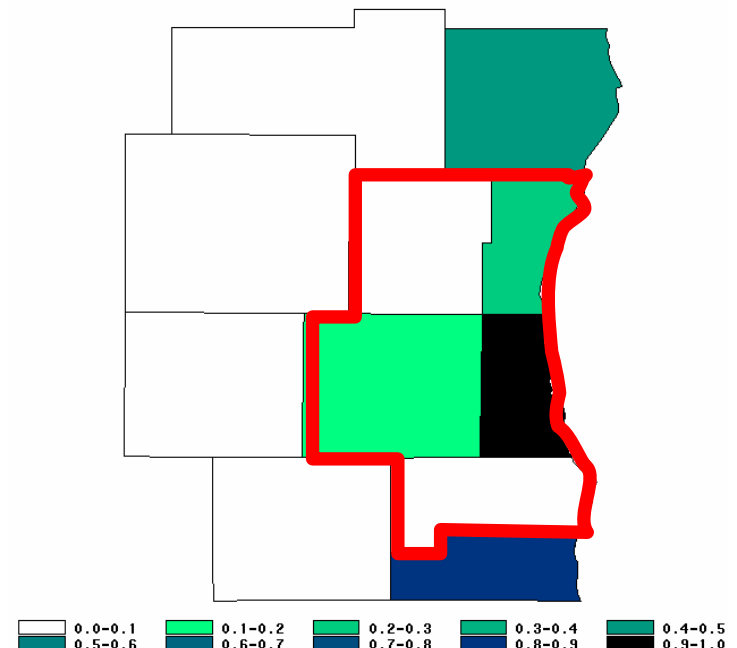
- Look at the average species composition across the high days by season for the daily increment over and above the seasonal average



Total Influential Emissions Score

- Multiplying the corresponding seasonal weight by each component and summing over all seasons give the total influential emissions score for the area **(CSA +surrounding counties)**

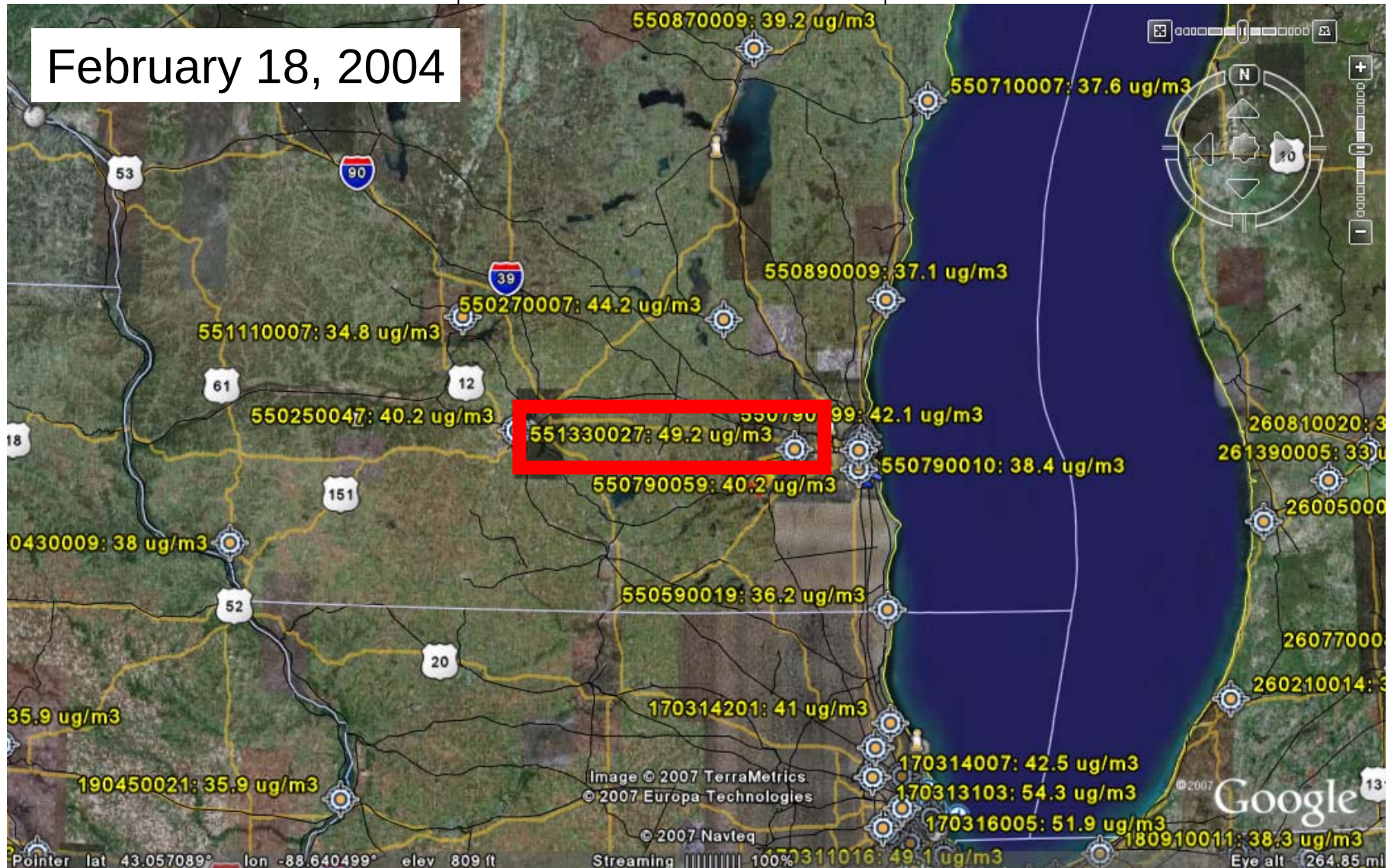
County	Total Influential Emissions Score
Dodge	3848
Fond du Lac	4010
Jefferson	4176
Kenosha	63986
Milwaukee	74107
Ozaukee	18083
Racine	6002
Sheboygan	35692
Walworth	4700
Washington	3900
Waukesha	13110



Milwaukee Site Gradients

approximately 300 miles

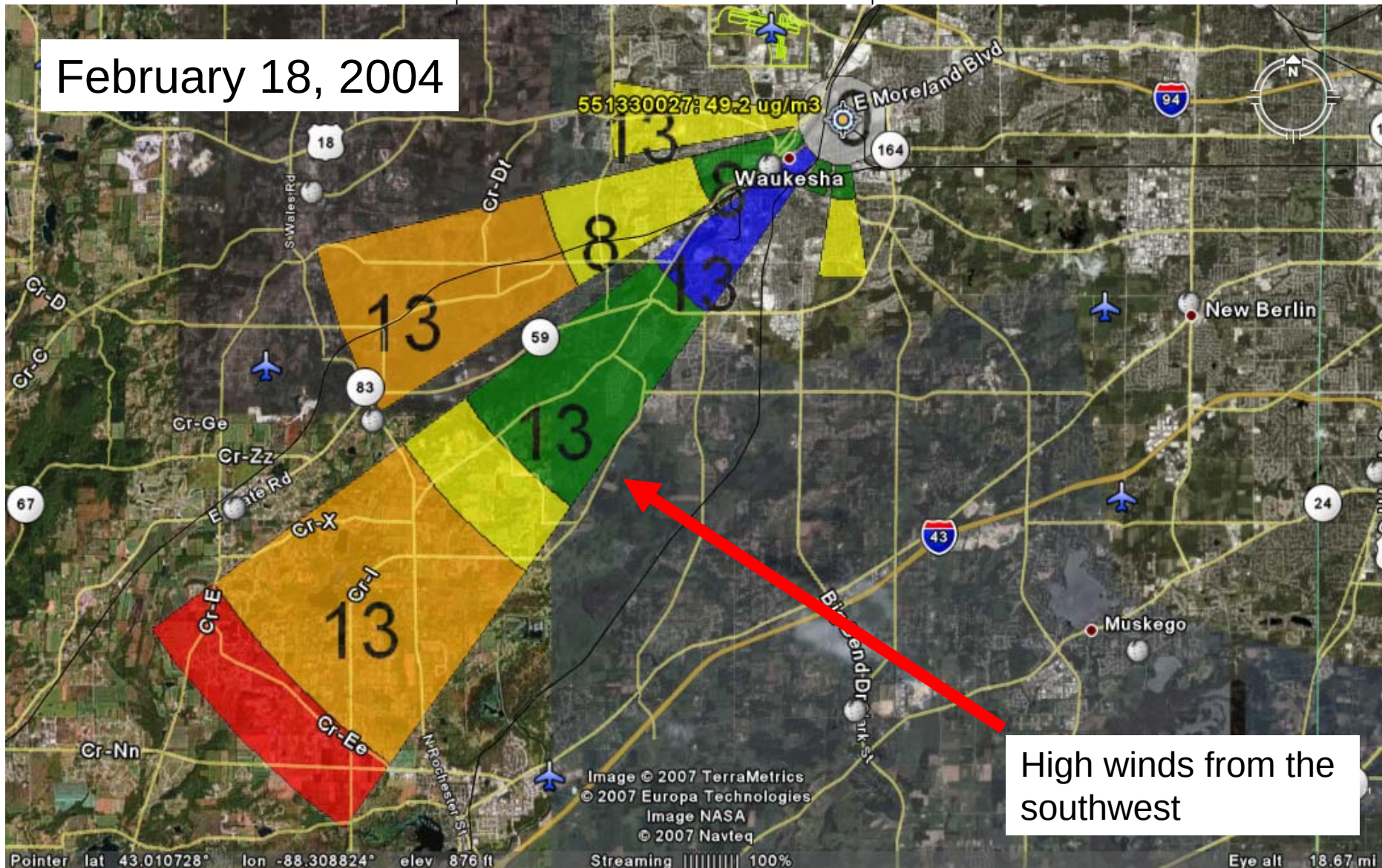
February 18, 2004



What did the winds look like?

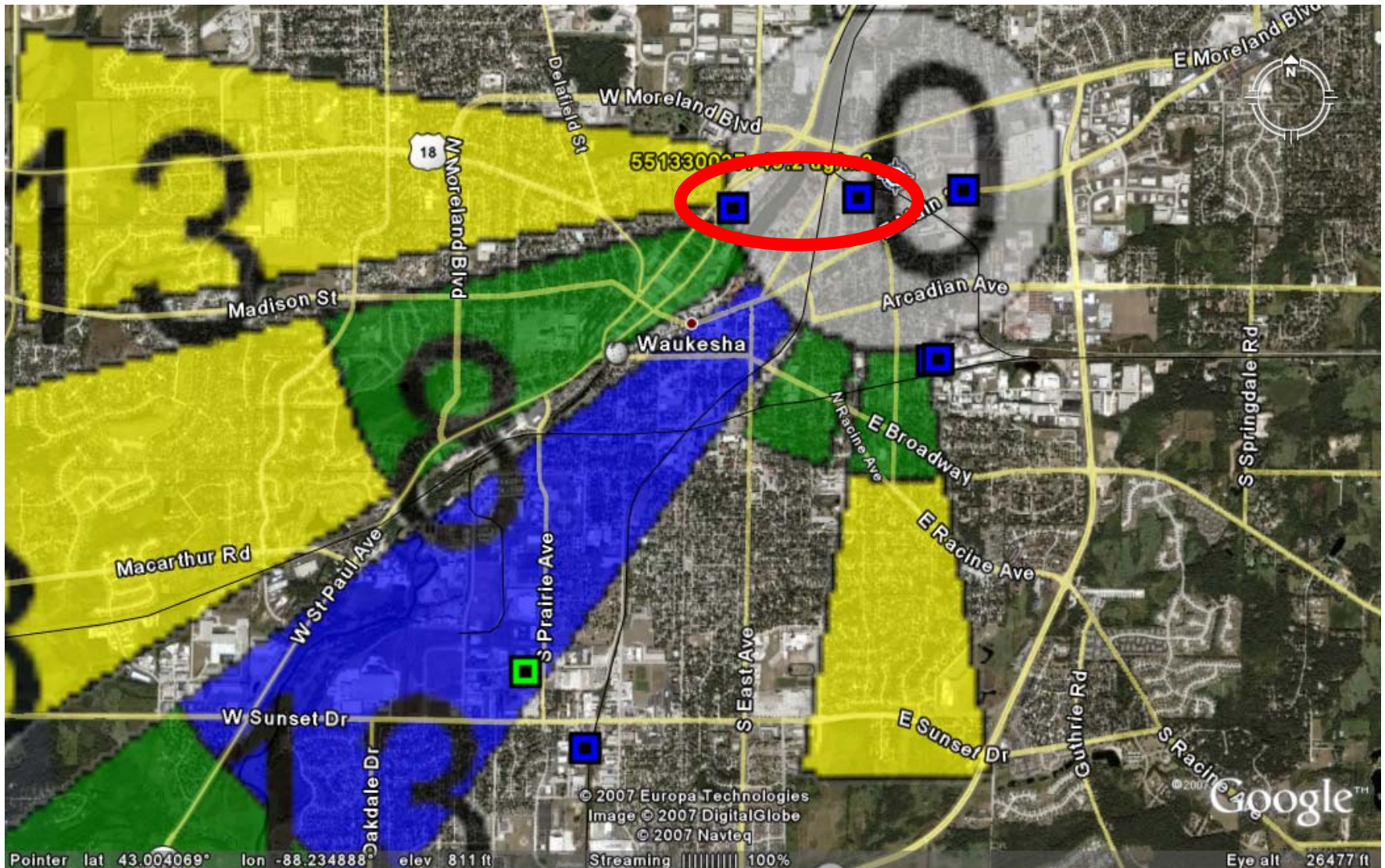
approximately 20 miles

February 18, 2004

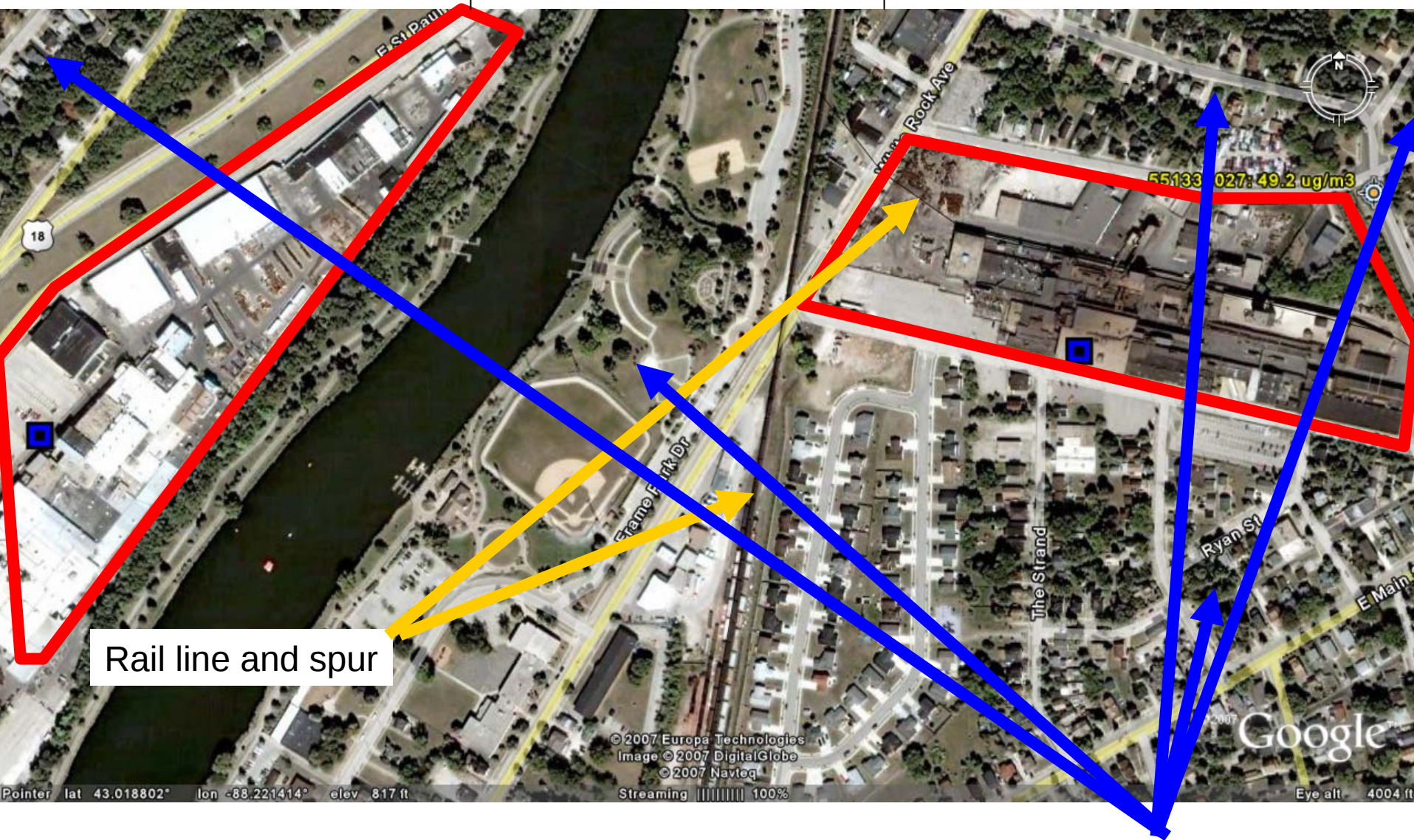


What local sources are nearby?

approximately 5-7 miles



Less than one mile



Rail line and spur

Residential neighborhoods

What does the example show?

- High days in Milwaukee can have high regional concentrations even before the urban contribution is added into the total PM_{2.5} concentration
- Winds on the high days in Milwaukee predominantly come from the south blowing across central Illinois and also includes the Chicagoland area

What does the example show?

- Total Influential Emissions Scores show that emissions from counties outside the Milwaukee CSA influence the ambient PM_{2.5} concentrations in Milwaukee
- Urban Gradients
 - More analysis is needed to determine frequency of days with higher gradients
 - Need to determine magnitude of the gradient in relation to the regional and urban contributions to better estimate the contribution from the local sources versus the regional/urban contributions for control strategy purposes