

Conceptual Model of Daily PM_{2.5}

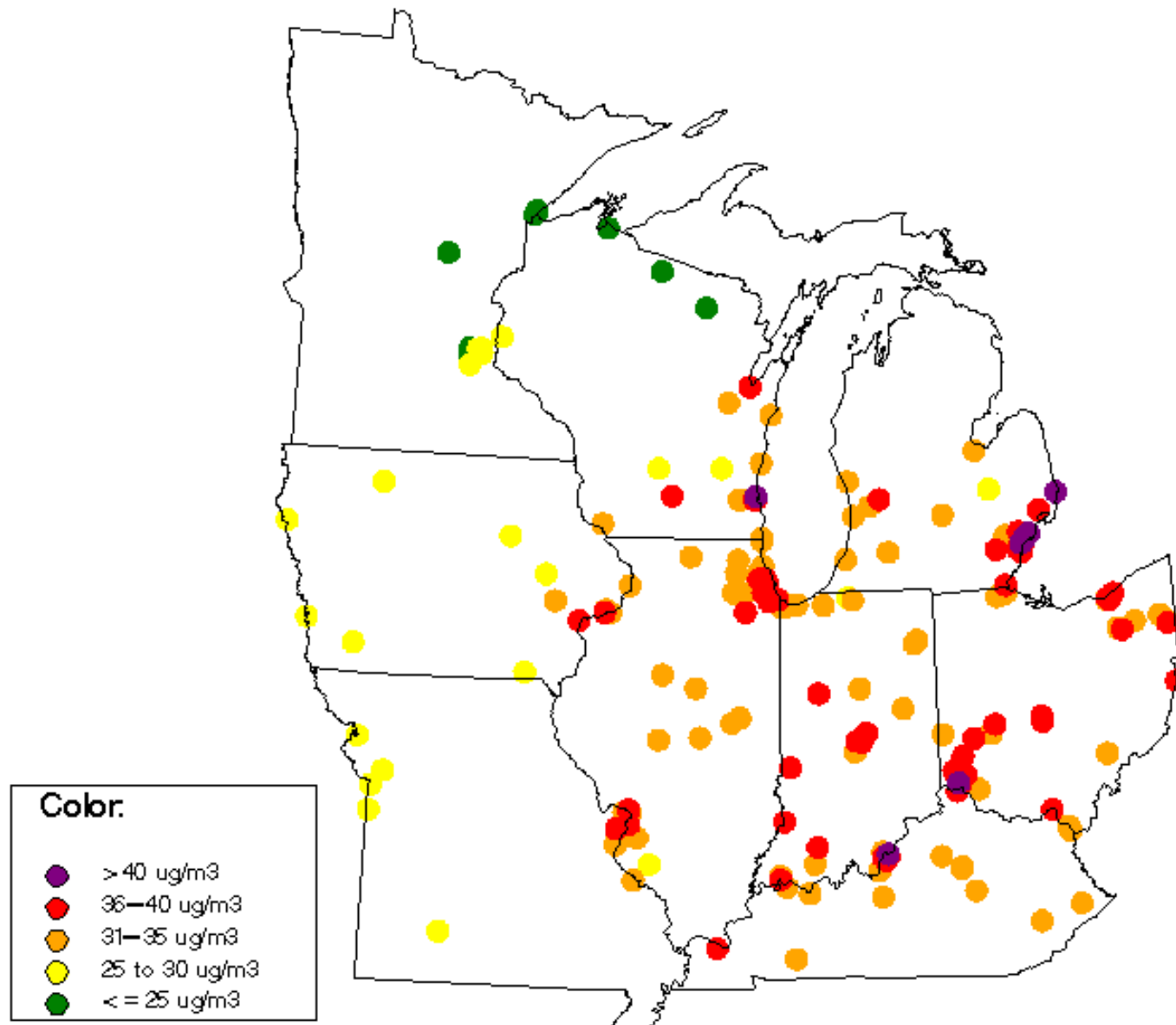
A collaborative effort by the PM Data Analysis Workgroup, including:
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Michael Compher, R5 EPA
Jim Haywood and Cindy Hodges, MDEQ
Sam Rubens, Akron Regional AQMD
Bart Sponseller and Bill Adamski, WDNR
Donna Kenski, LADCO

Presented to Regional Air Quality Workshop
October 16, 2008

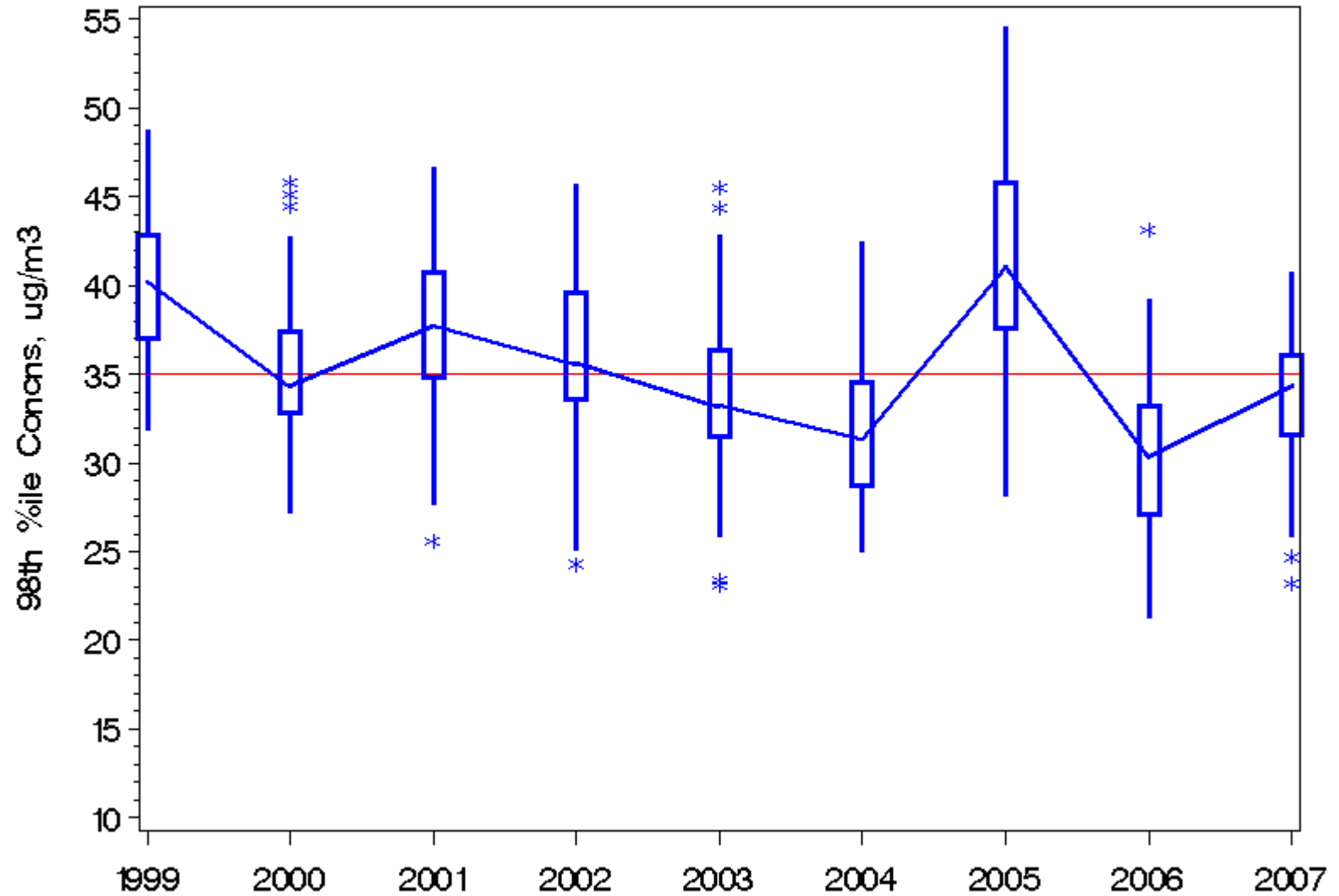
Elements

- Current concentrations and trends
- Frequency and timing of elevated concentrations – seasonality, day of week
- Spatial extent of high concentrations
- Urban-rural differences during high concentration events
- Chemical composition of elevated concentrations and seasonal patterns in composition
- Source apportionment; what sources contribute disproportionately during events?
- Meteorological conditions associated with high concentrations
 - Wind roses
 - Synoptic analysis
 - CART
 - Trajectories

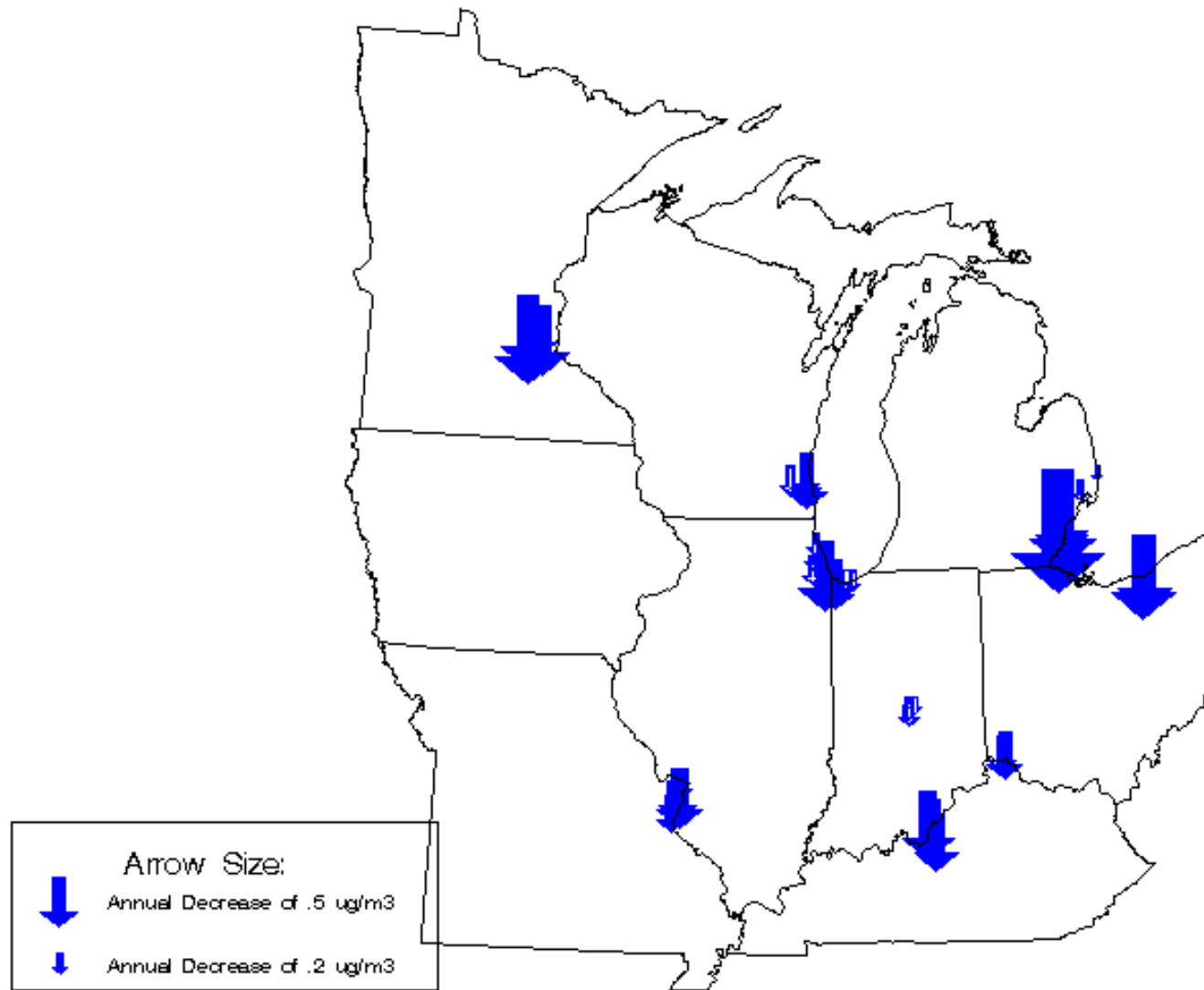
PM2.5 FRM 98th Percentile Concentration, 2005–2007



PM2.5 98%ile Trends, LADCO States, 1999–2007



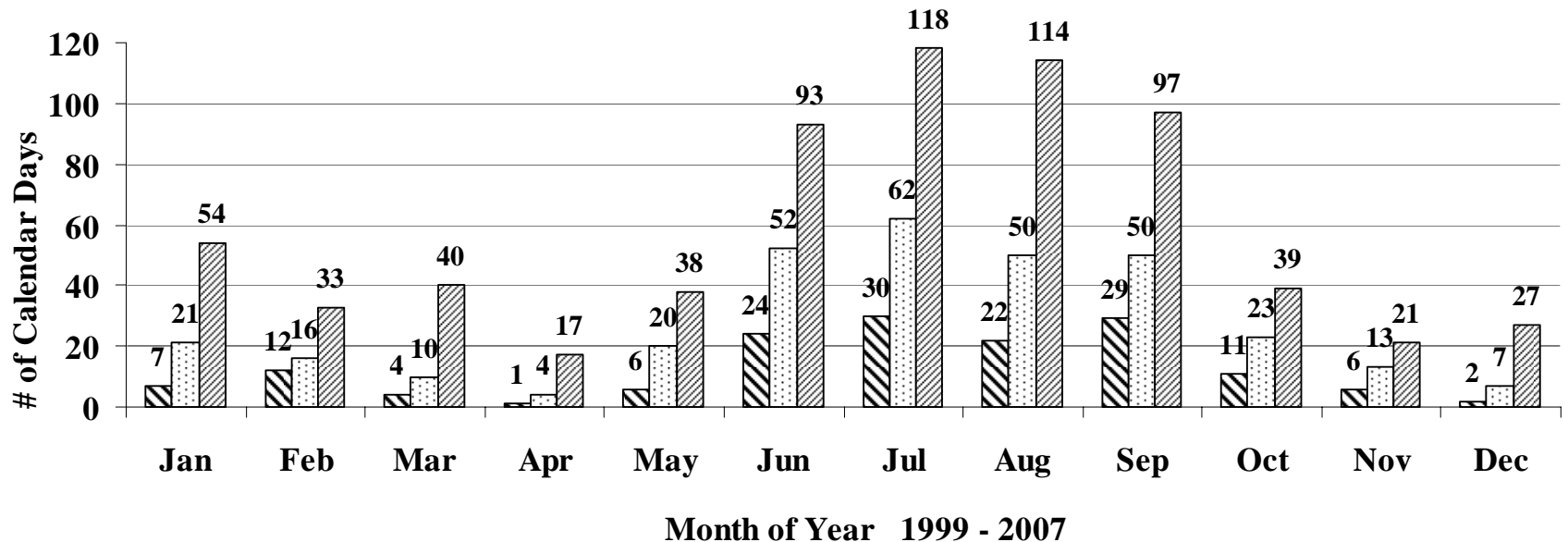
Their Trends for FRM PM_{2.5} 10% Highest Days, 1999–2007



Solid arrows show statistically significant trends, empty arrows show trends that are not statistically significant.
Height of arrow is proportional to magnitude of trend

Seasonality in Southern Cities

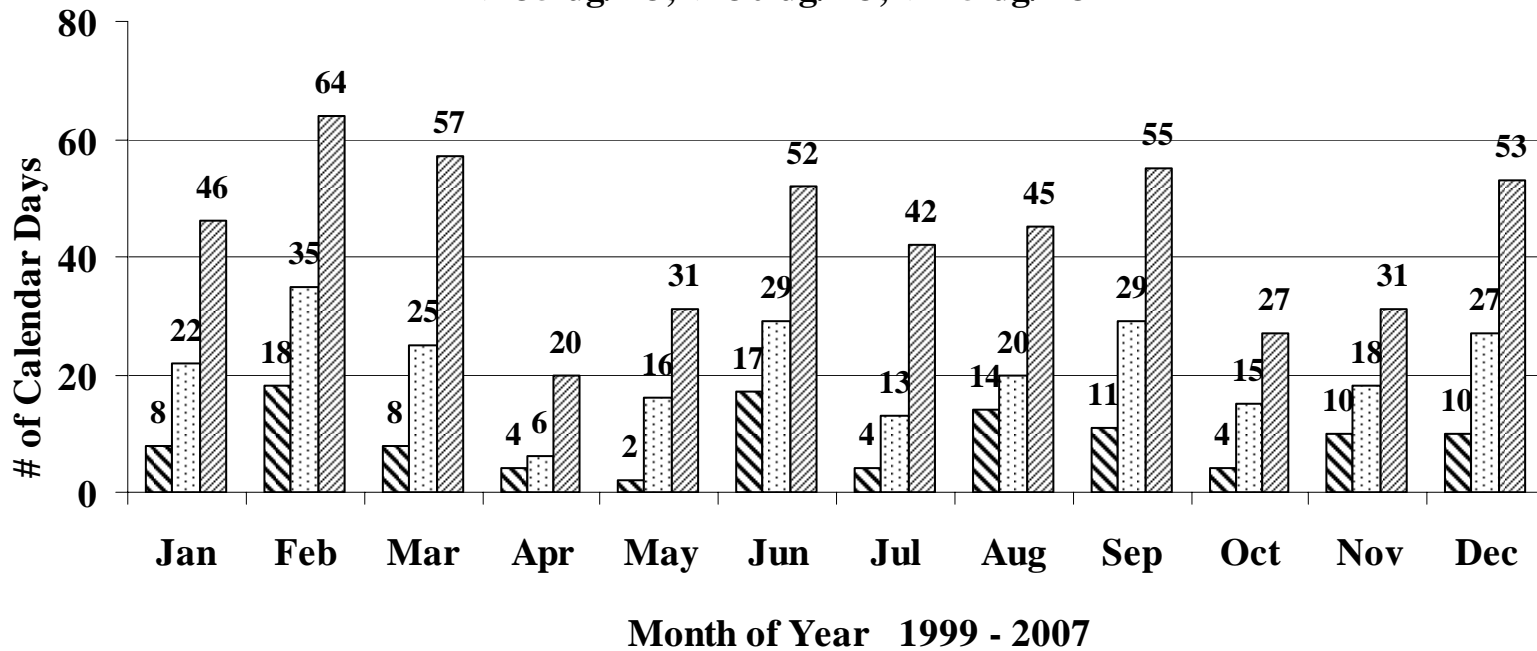
Cleveland, Cincinnati, Louisville, Indianapolis, St. Louis
 ("Southern / Central" Midwest Metro Areas): 1999-2007
 Combined Total # of Days Per Month of Year
 Metro-Wide Ave 24 Hr PM_{2.5} Concentrations
 > 35 ug/m³, > 30 ug/m³, > 25 ug/m³



■ Total Days: Month of Yr (99-07): Metro Daily Av PM_{2.5} > 35 ug/m³
 □ Total Days: Month of Yr (99-07): Metro Daily Av PM_{2.5} > 30 ug/m³
 ▨ Total Days: Month of Yr (99-07): Metro Daily Av PM_{2.5} > 25 ug/m³

Seasonality in Northern Cities

Detroit, Gary, Chicago, Milwaukee, Minneapolis-St. Paul
 ("Northern" Midwest Metro Areas): 1999-2007
Combined Total # of Days Per Month of Year
Metro-Wide Ave 24 Hr PM_{2.5} Concentrations
 > 35 ug/m³, > 30 ug/m³, > 25 ug/m³

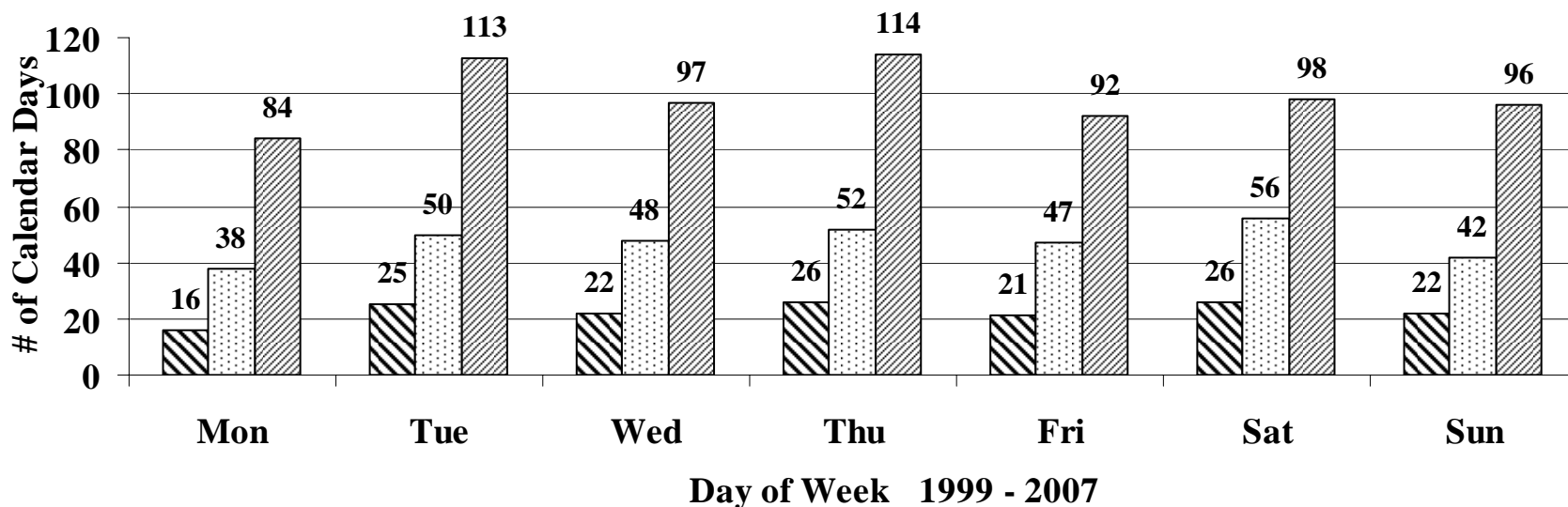


▨ Total Days: Month of Yr (99-07): Metro Daily Av PM_{2.5} > 35 ug/m³
 ▩ Total Days: Month of Yr (99-07): Metro Daily Av PM_{2.5} > 30 ug/m³
 ▪ Total Days: Month of Yr (99-07): Metro Daily Av PM_{2.5} > 25 ug/m³

Day of Week Patterns

Cleveland, Cincinnati, Louisville, Indianapolis, St. Louis
 ("Southern / Central" Midwest Metro Areas): 1999-2007

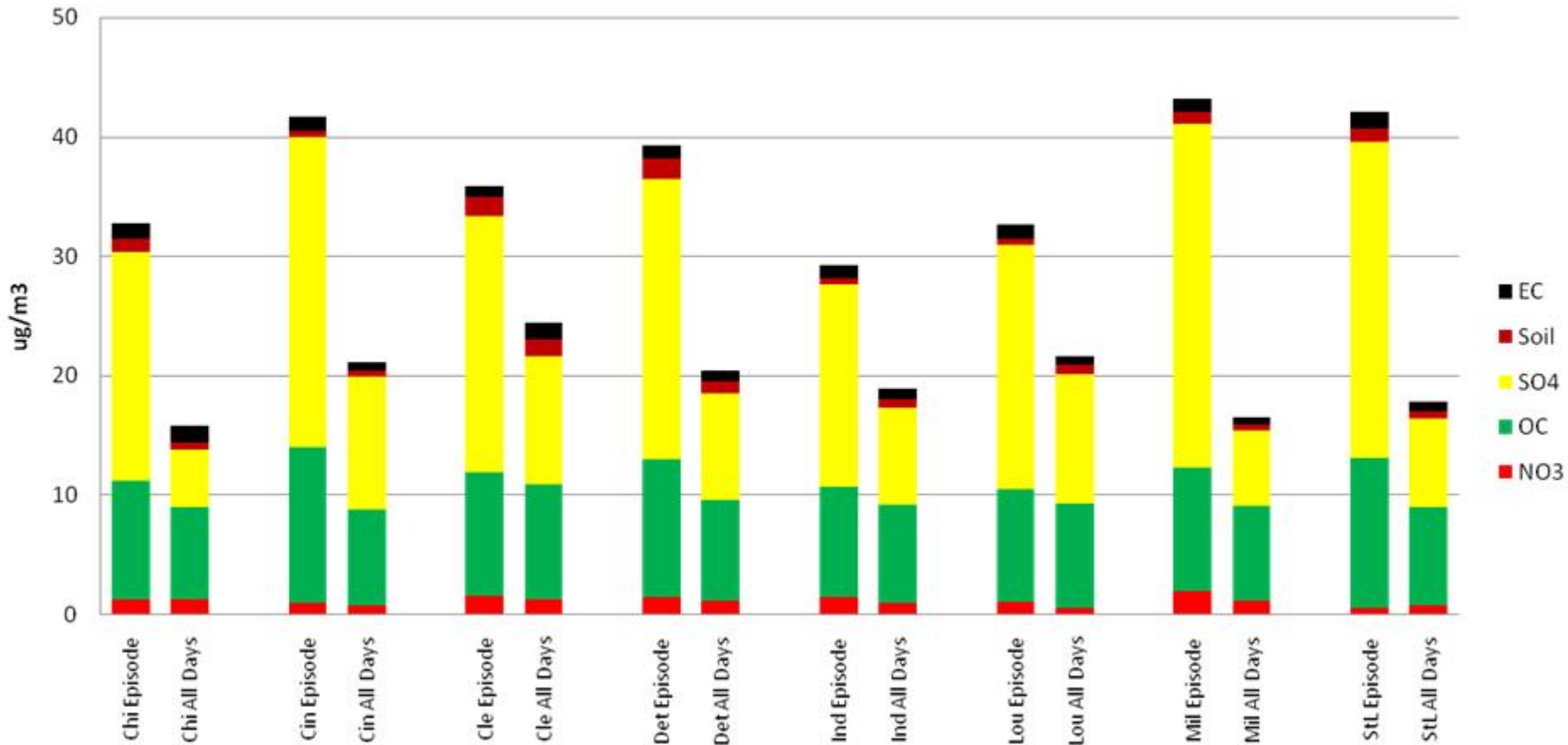
Combined Total # of Days Per Day of Week
 Metro-Wide Ave 24 Hr PM_{2.5} Concentrations
 > 35 ug/m³, > 30 ug/m³, > 25 ug/m³



- ▨ Total Days: Day of Week (99-07): Metro Daily Av PM_{2.5} > 35 ug/m³
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- ▩ Total Days: Day of Week (99-07): Metro Daily Av PM_{2.5} > 25 ug/m³

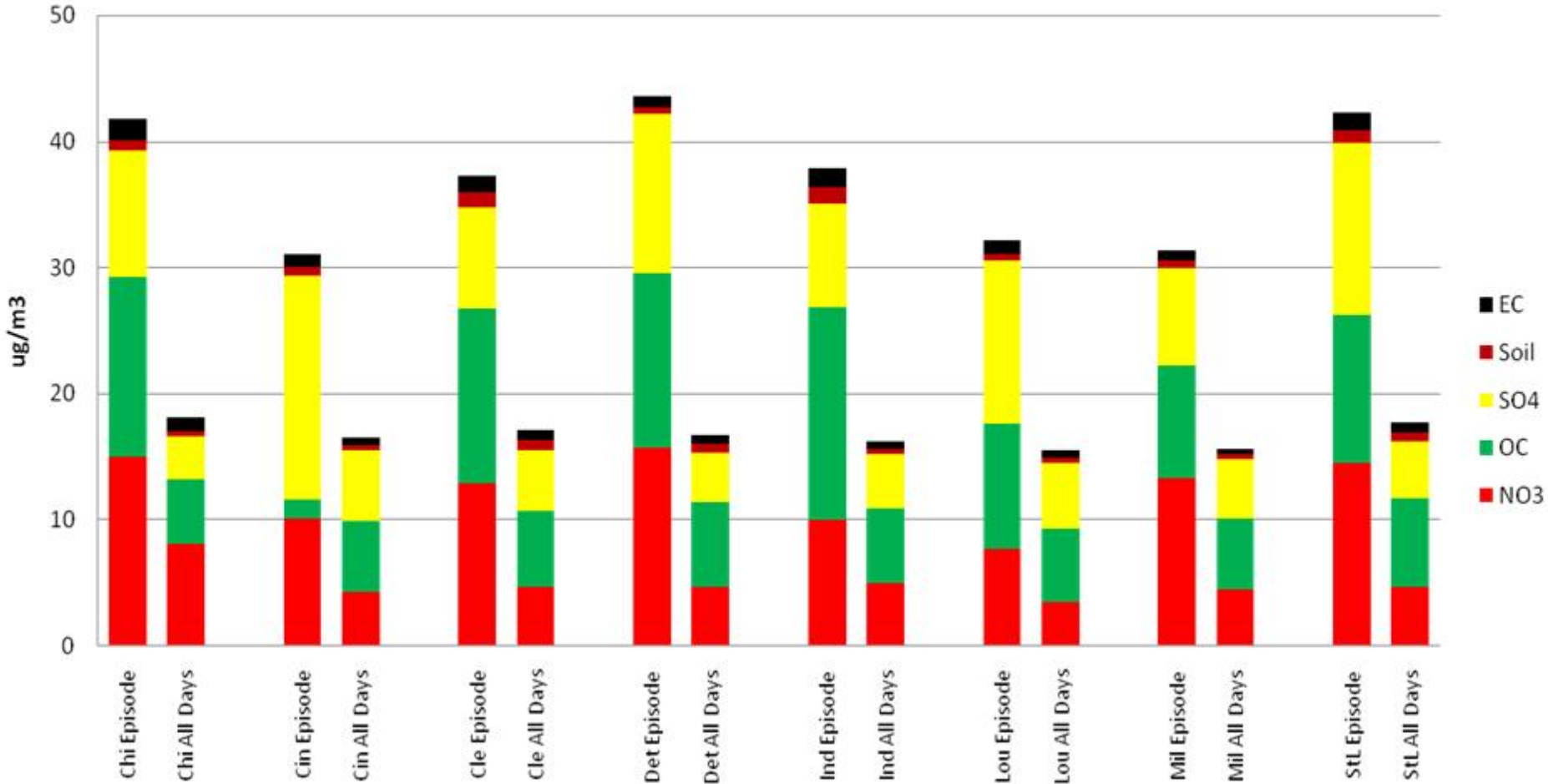
Composition on Summer Episode Days

Reconstructed Mass of PM2.5
3rd Quarter 2005

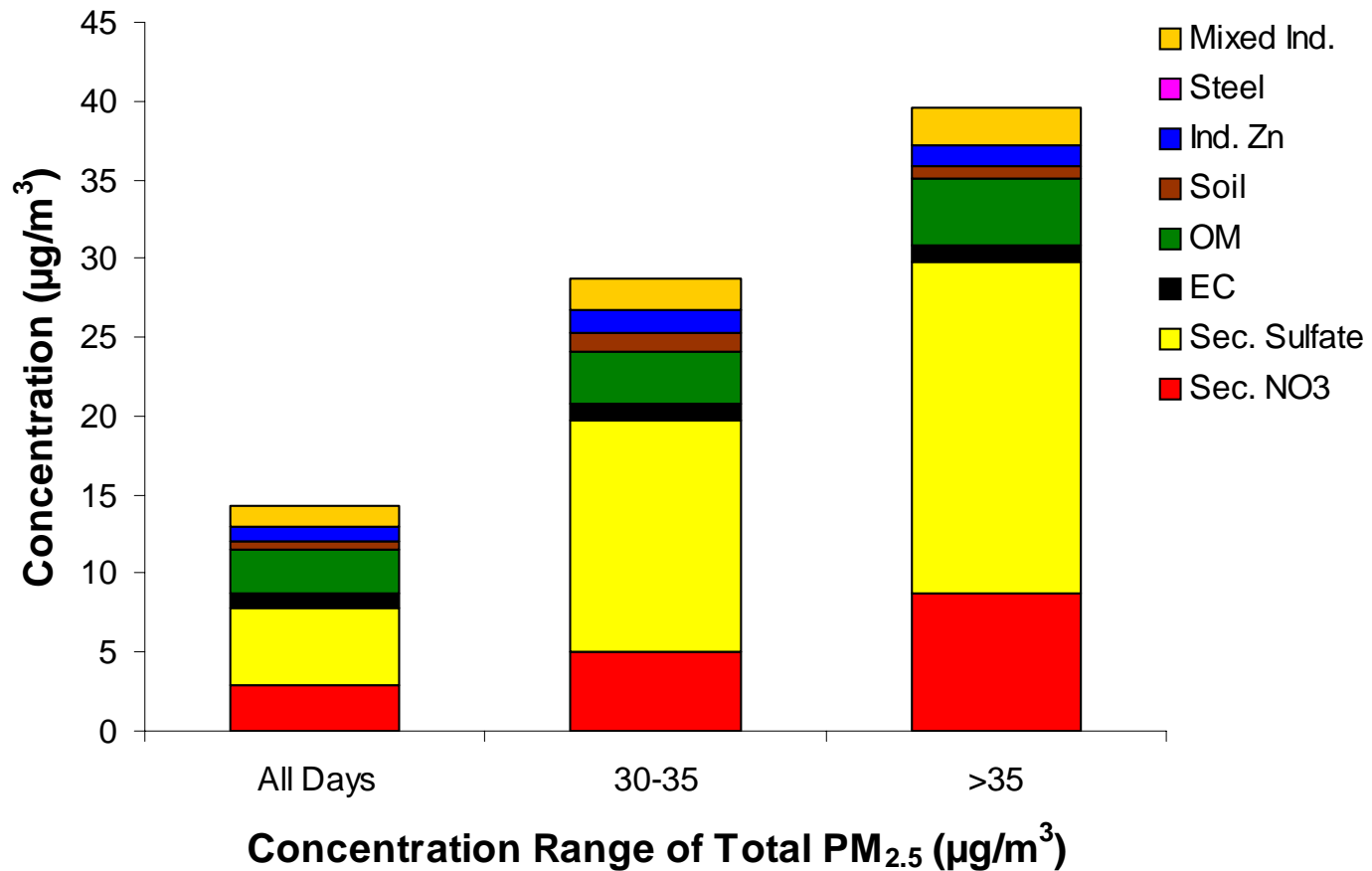


Composition on Winter Episode Days

Reconstructed Mass of PM2.5
1st Quarter 2005

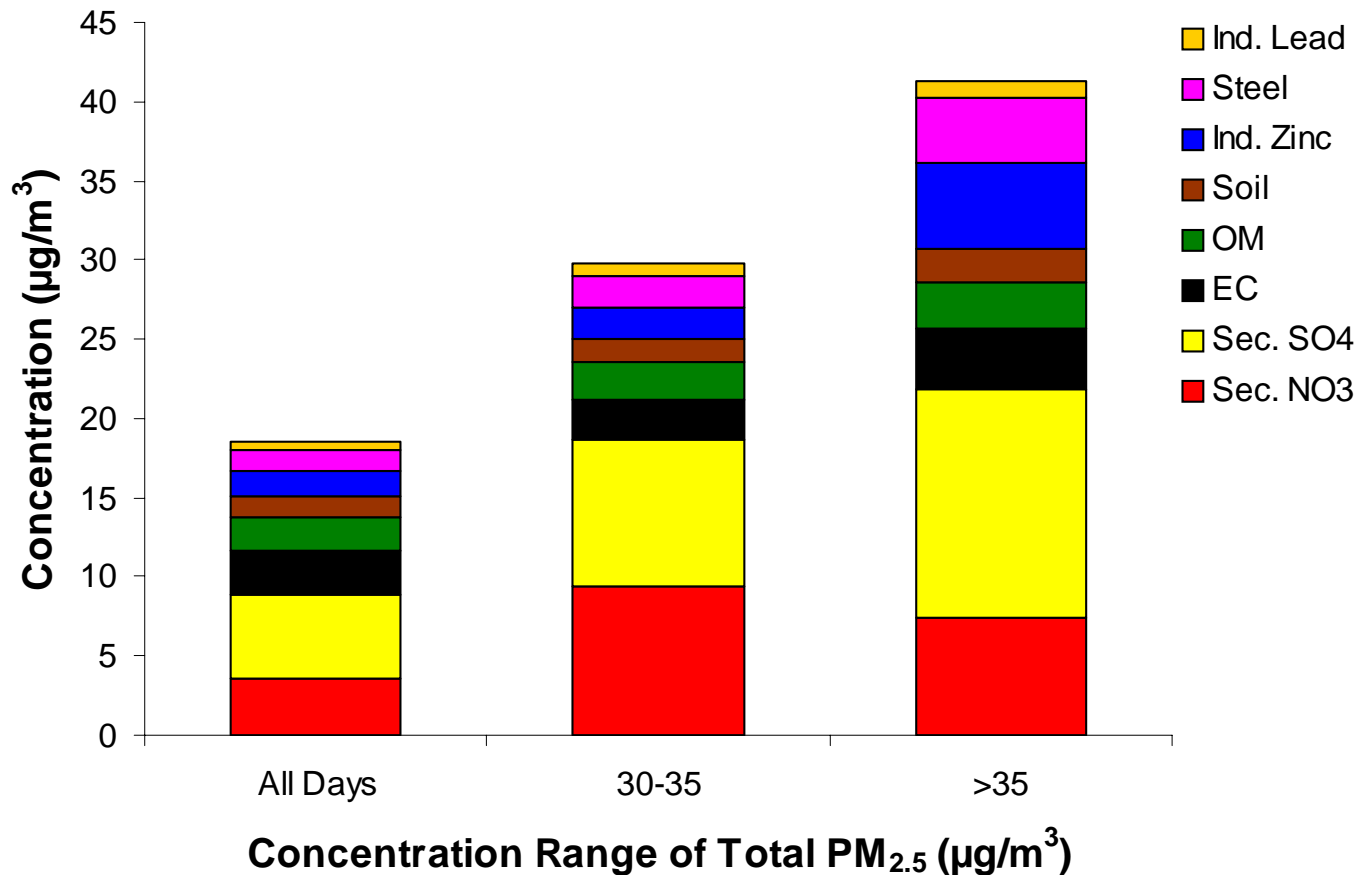


Allen Park: PMF Contributions



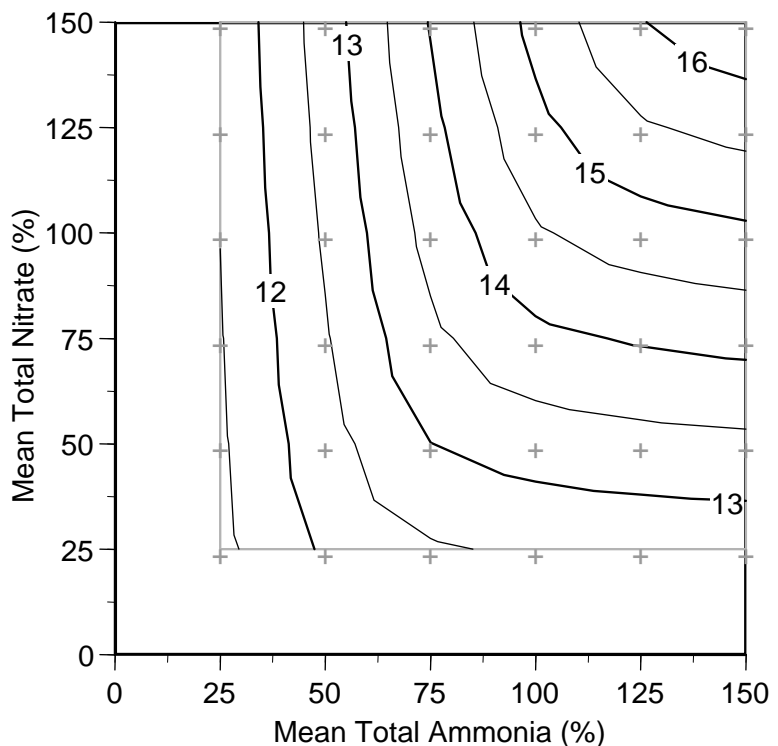
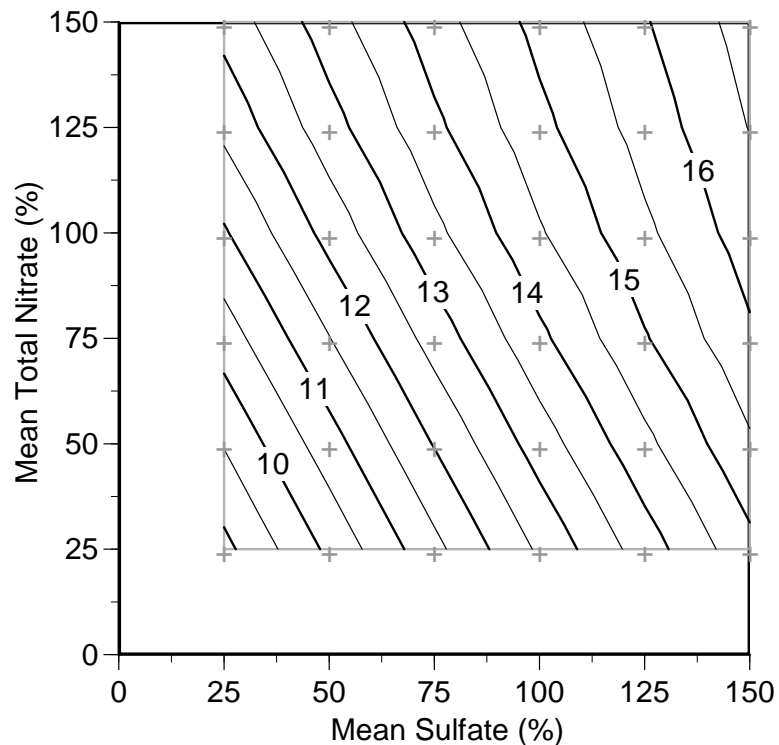
- As with the ambient data, PMF contributions mainly show an increase in secondary sulfate and secondary nitrate in the “high day” groups.

Dearborn: PMF Contributions



- PMF contributions mainly show an increase in secondary sulfate and secondary nitrate contributions in the “high day” groups. In the >35µg/m³ group, zinc and steel contributions are noticeably higher than average as well.

Results for Bondville – Predicted Mean PM_{2.5} Mass (N=111 days)



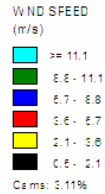
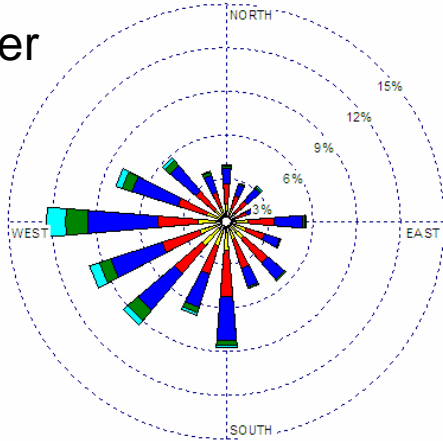
Note: Current concentrations occur at “100%” points

Meteorology

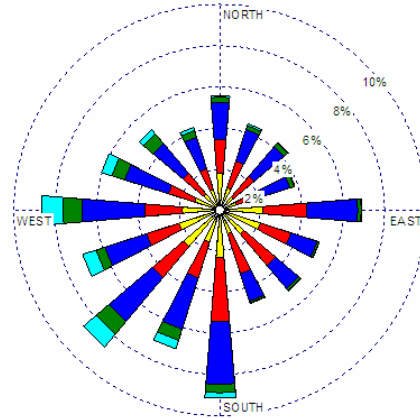
Indianapolis, IN

Indianapolis International Airport MET

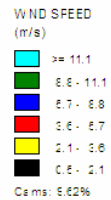
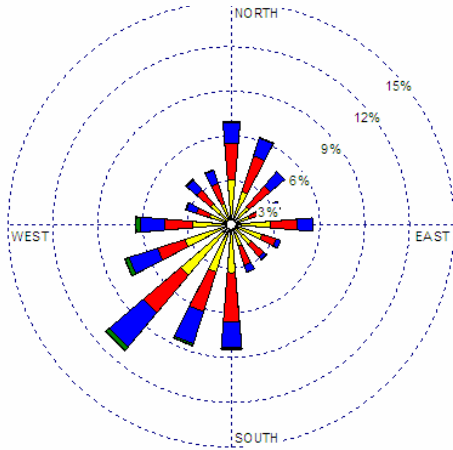
Winter



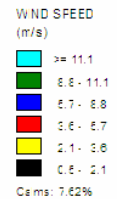
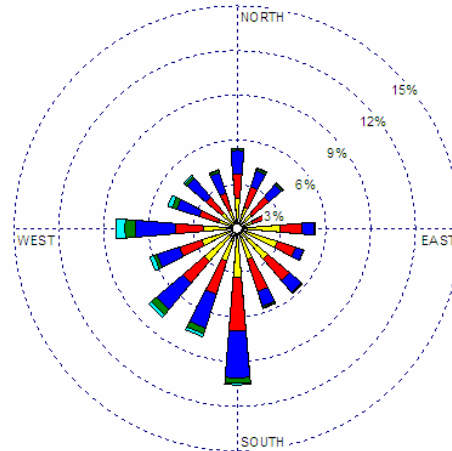
Spring



Summer

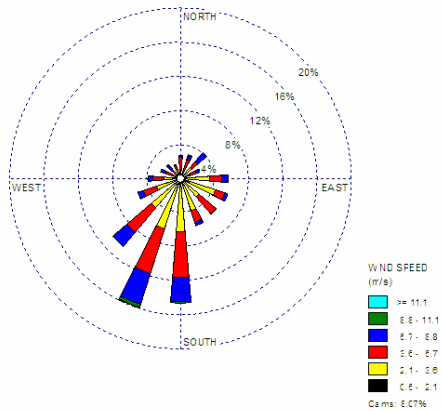


Fall



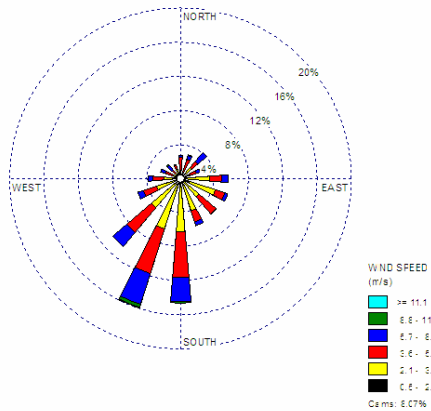
Episode Day Windroses

Indianapolis

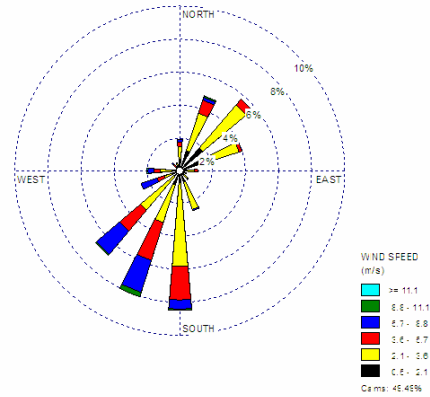


Episode Day Windroses

Indianapolis

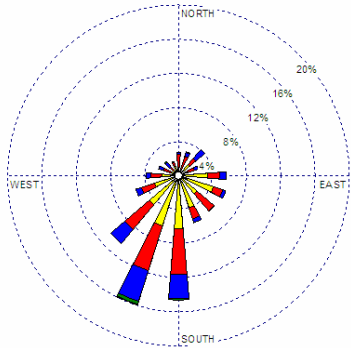


Cincinnati



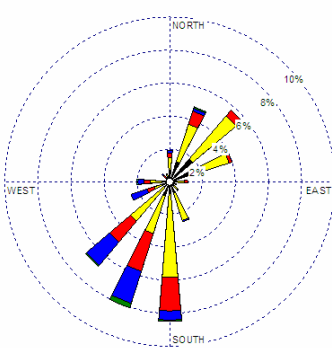
Episode Day Windroses

Indianapolis



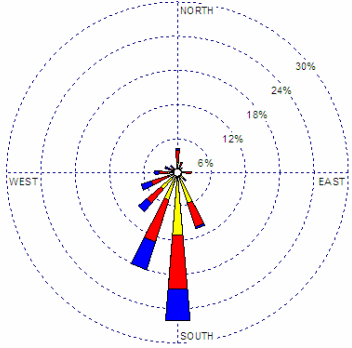
WIND SPEED (m/s)
 ≥ 11.1
 8.8 - 11.1
 6.7 - 8.8
 4.6 - 6.7
 2.5 - 4.6
 0.0 - 2.5
 Cals: 6.07%

Cincinnati



WIND SPE (m/s)
 ≥ 11.1
 8.8
 6.7
 4.6
 2.5
 0.0
 Cals: 4.6%

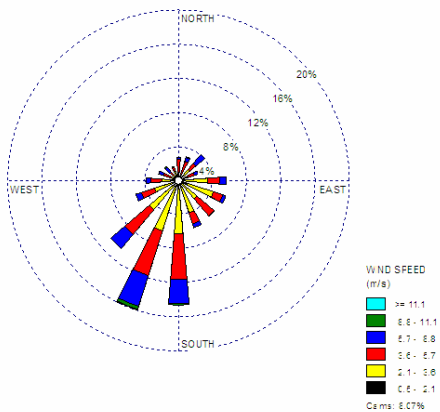
Cleveland



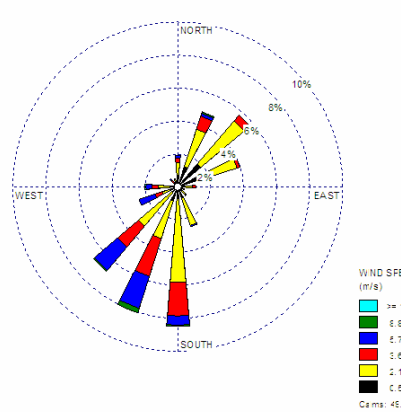
WIND SPEED (m/s)
 ≥ 11.1
 8.8 - 11.1
 6.7 - 8.8
 4.6 - 6.7
 2.5 - 4.6
 0.0 - 2.5
 Cals: 6.60%

Episode Day Windroses

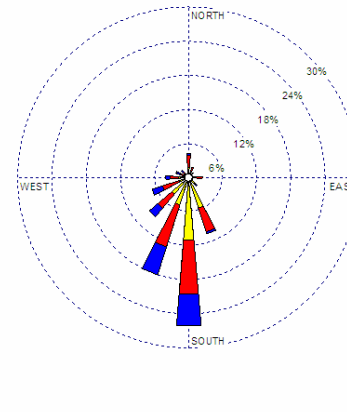
Indianapolis



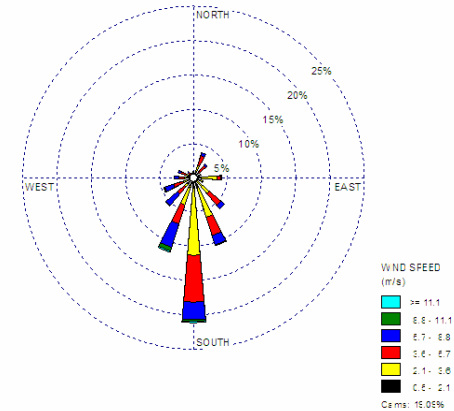
Cincinnati



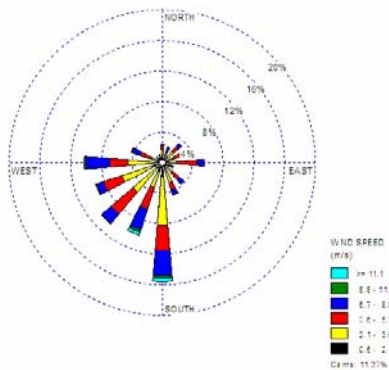
Cleveland



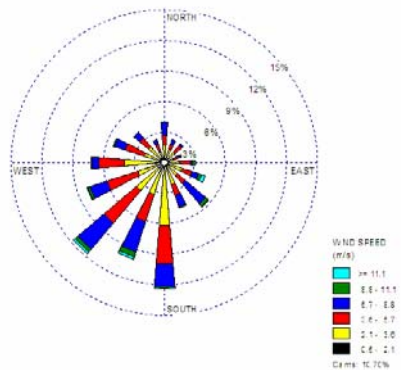
Detroit



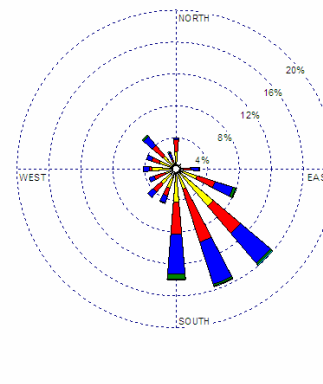
Chicago



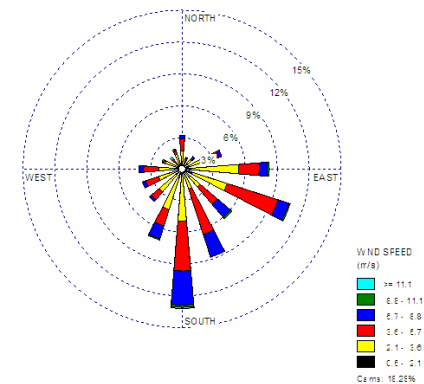
Milwaukee



Minneapolis

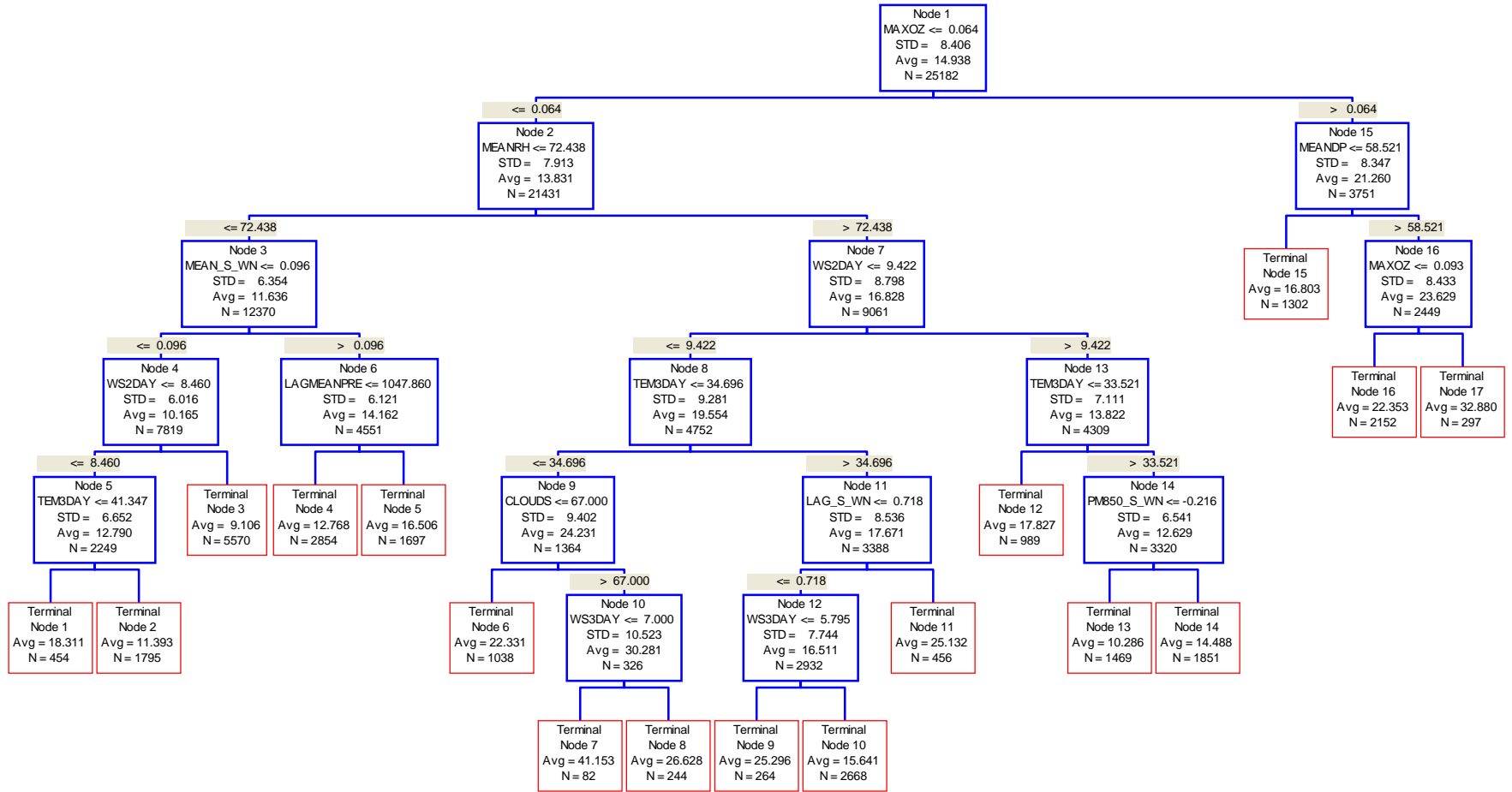


St. Louis



CART Model

- Incorporates 58 meteorological variables
- Goal is to categorize each day by PM2.5 concentration and associated met conditions
- Results in a decision tree with 15-20 branches, each describing the meteorological conditions associated with a particular PM2.5 concentration
- Applied to 1999-2007 data for 8 urban areas

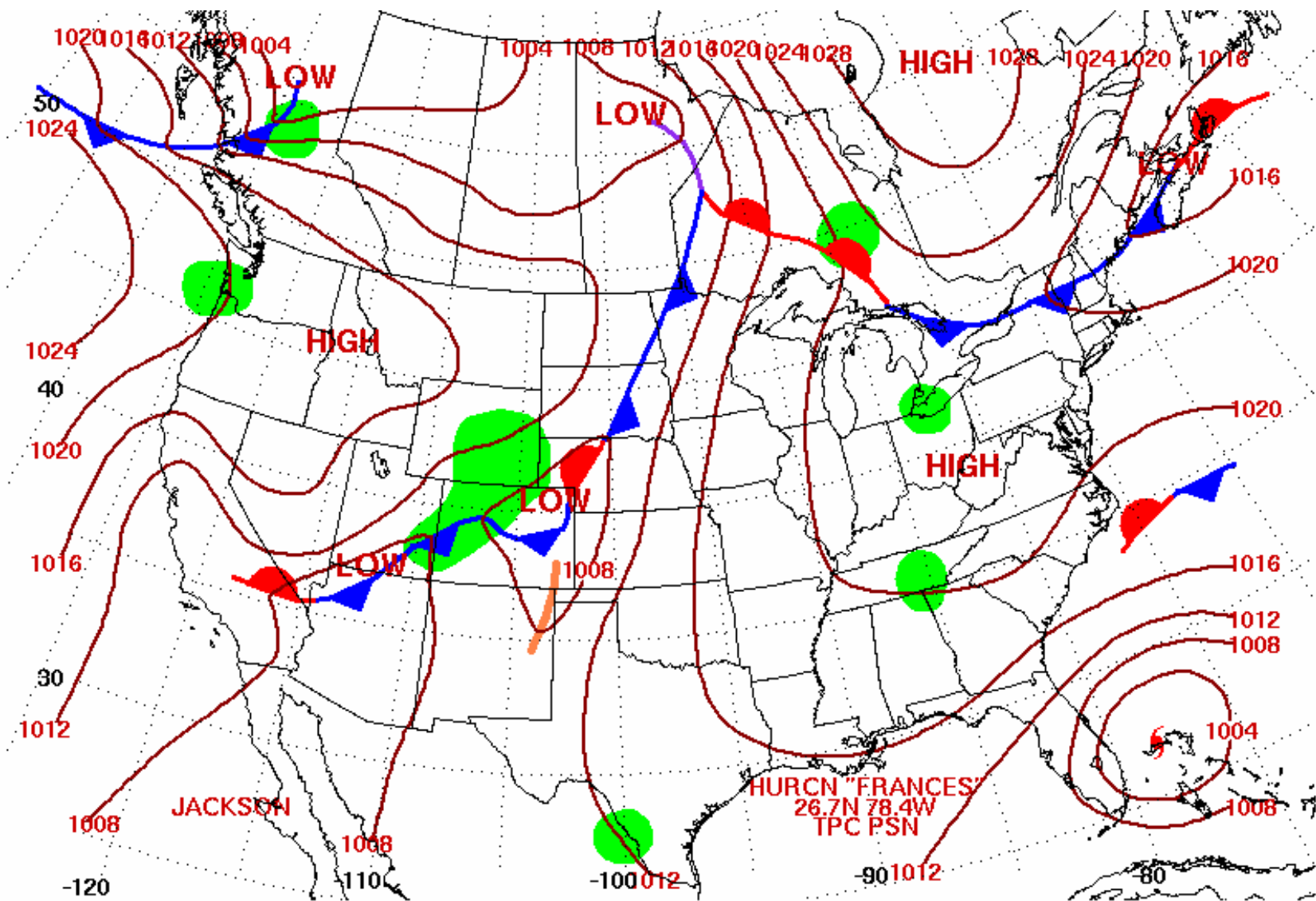


Conclusions from CART analysis

- Extended periods of slow wind speeds are the most common factor in high PM across the region
- Ozone is an important predictor in summer episodes (especially Chicago and St. Louis), and RH and dewpoint are important year-round
- Southerly wind flow is important in most areas, except east winds in St. Louis
- Temperature, mixing height, stability, winds aloft are useful as well
- CART model is approximately equivalent to a regression model averaging 0.6 R-square (from 0.44 in Minneapolis to 0.68 in Milwaukee)

Synoptic Analysis

- Detailed review of large-scale meteorology of 4 regional episodes
- Sept 2004, Feb 2005, June 2005, Dec 2007
- Analyzed surface and aloft weather maps in combination with continuous and gravimetric PM concentrations, atmospheric soundings, and speciation data



Surface Weather Map at 7:00 A.M. E.S.T.

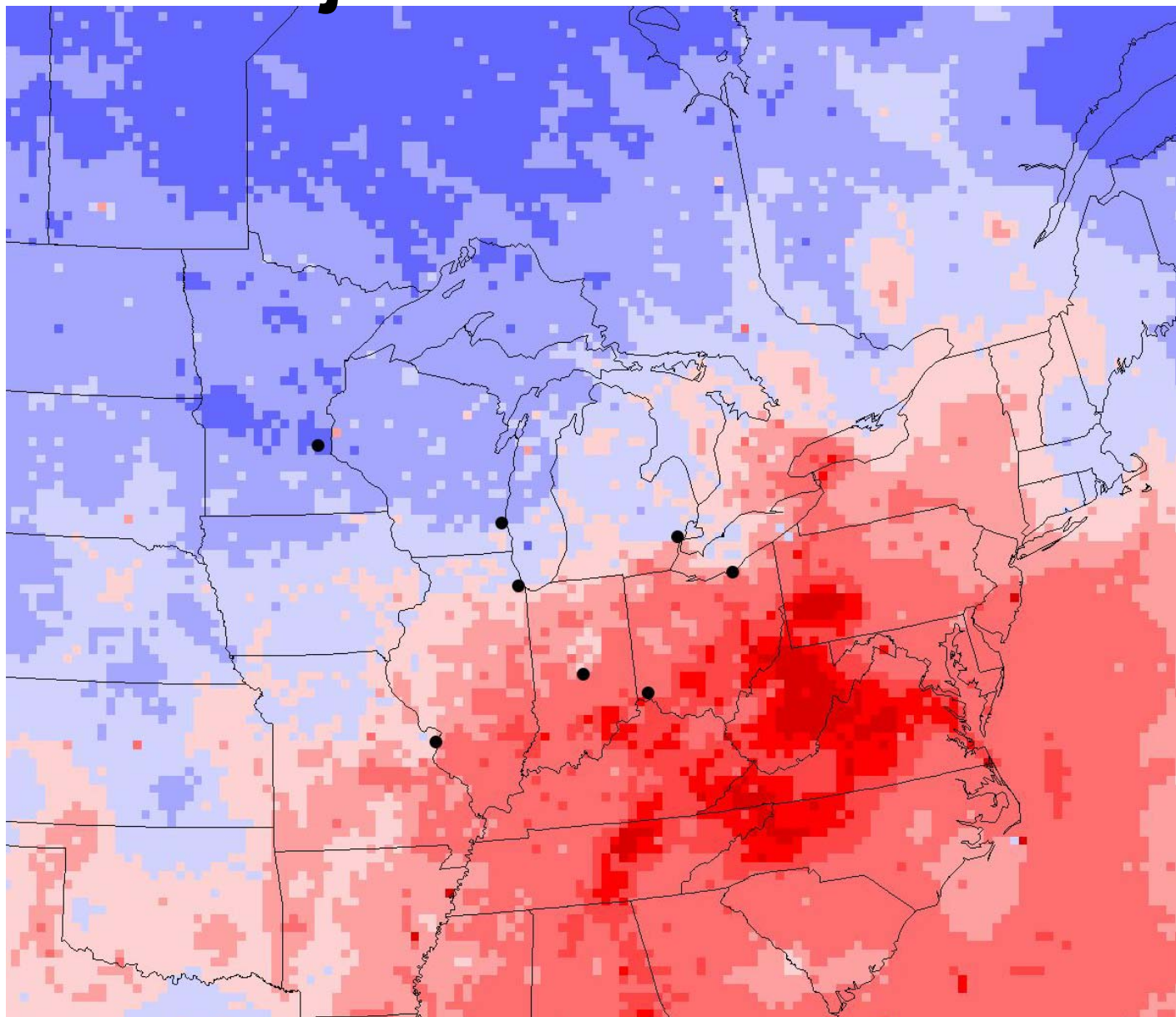
Episode Commonalities

- High pressure
- Subsidence
- Strongly stable or inversion conditions
- Light winds
- High relative humidity
- Winter: snow cover
- Summer: ozone

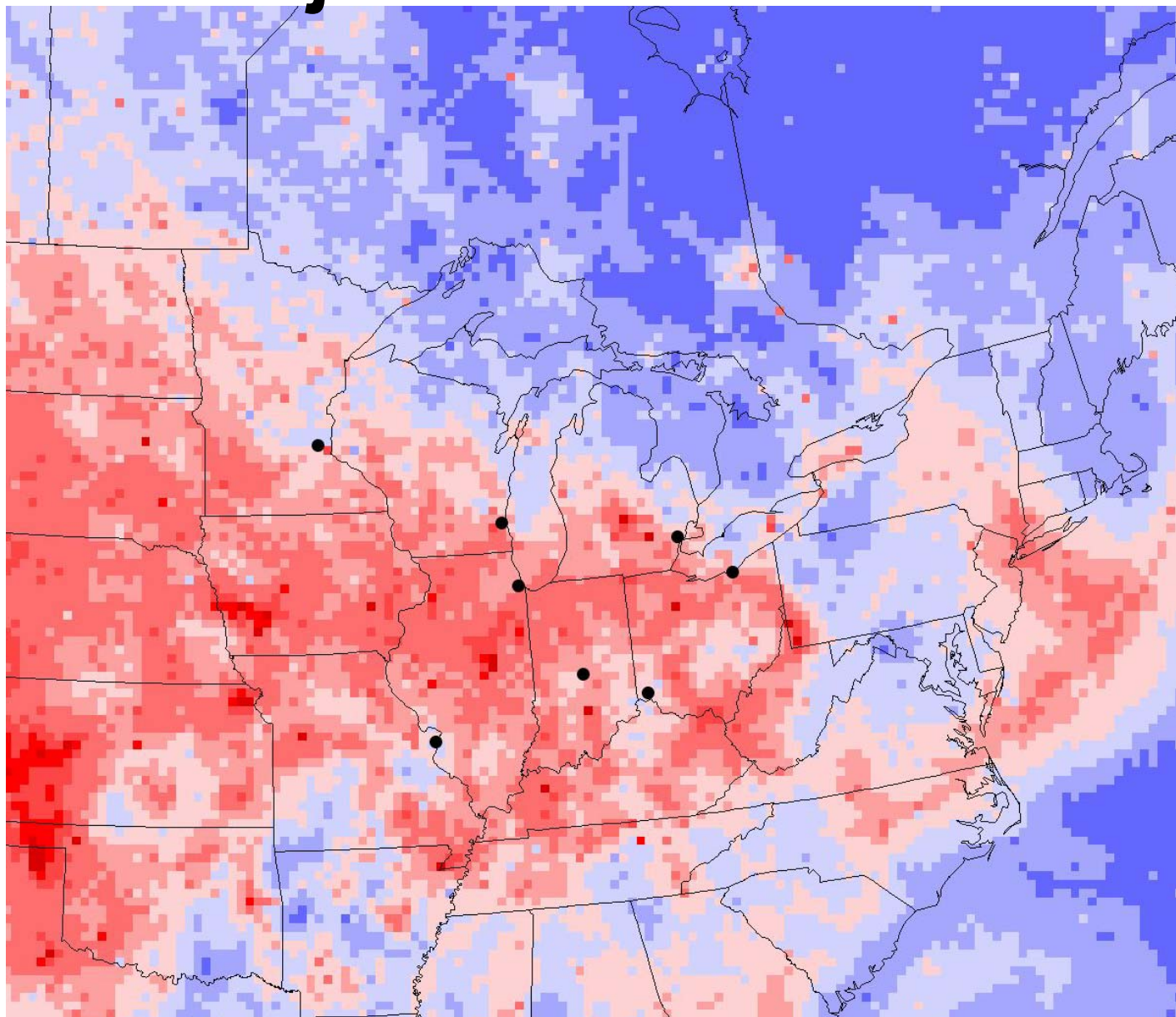
Trajectory Analysis

- A trajectory tracks the position of a parcel of air as it is transported by the wind.
- Trajectories give us information about source regions that might influence a receptor area; i.e., what pollution sources did an air parcel travel over in its journey to a receptor?
- Concentration-weighted trajectories for PM_{2.5} and each component species were generated for 72 hours back in time for each sample, 2000-2007

Sulfate Trajectories



Nitrate Trajectories



Conclusions

- 57 of 126 PM_{2.5} monitors in LADCO states exceeded the 24-hr NAAQS in 2005-2007 (complete data only)
- Concentrations on highest 90% days have fallen by ~0.5ug/m³/year
- High daily concentrations depend on
 - Specific met conditions: stagnant air masses with high pressure, slow wind speeds, high relative humidity, southerly winds
 - Regional contributions: primarily sulfate, especially in summer, and nitrate in winter
 - No evidence for local drivers except in very few locations

Approaches for Addressing PM_{2.5} Daily Concentrations

- Regional reductions in SO₂ should be effective year-round
- Regional reductions in NO_x and/or NH₃ most effective in the winter (stay tuned for more info on winter chemistry)
- Urban reductions in primary OC and EC emissions
- In a few locations, reductions in local source emissions are indicated