Conceptual Model of Daily PM2.5

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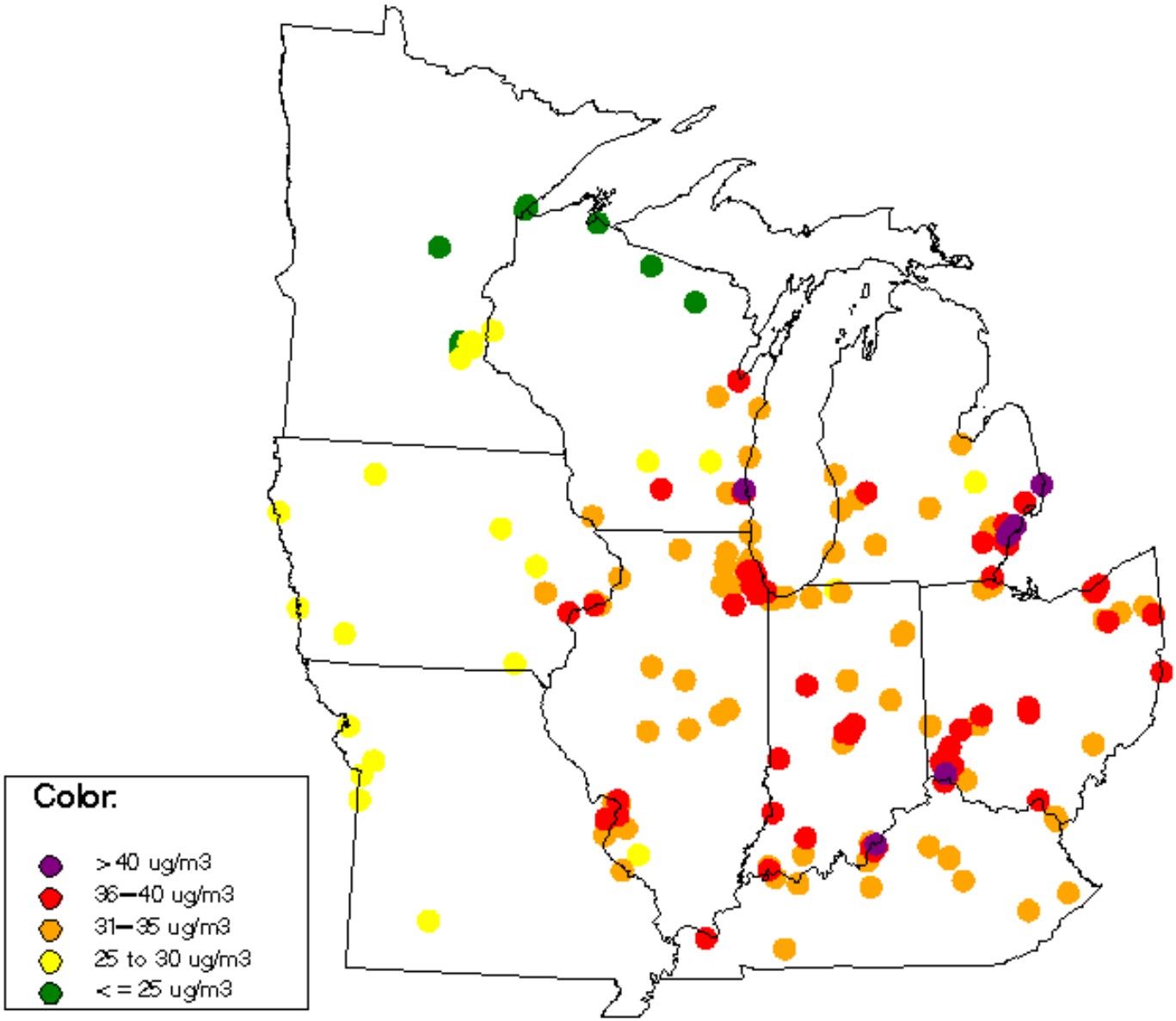
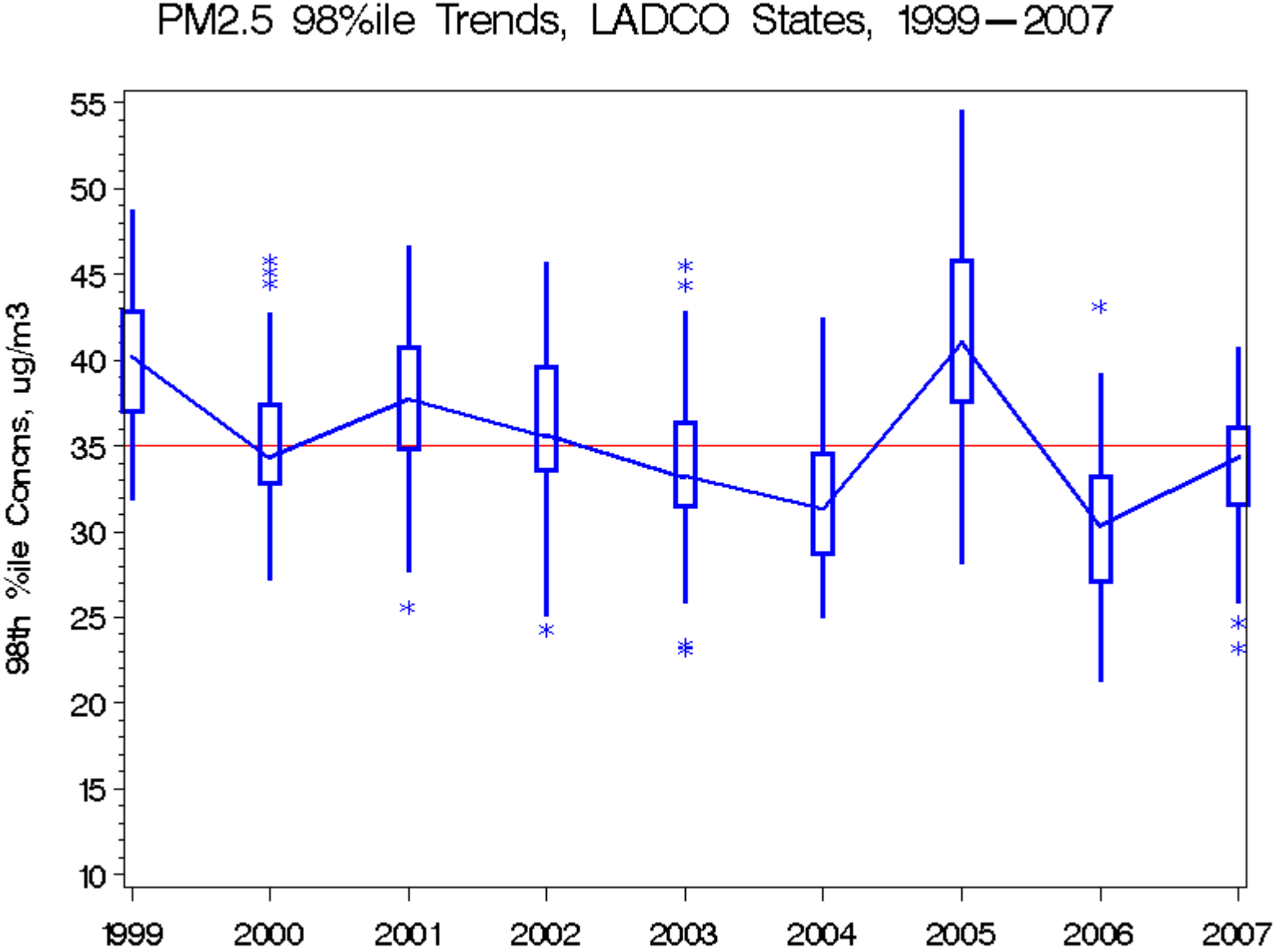
Elements

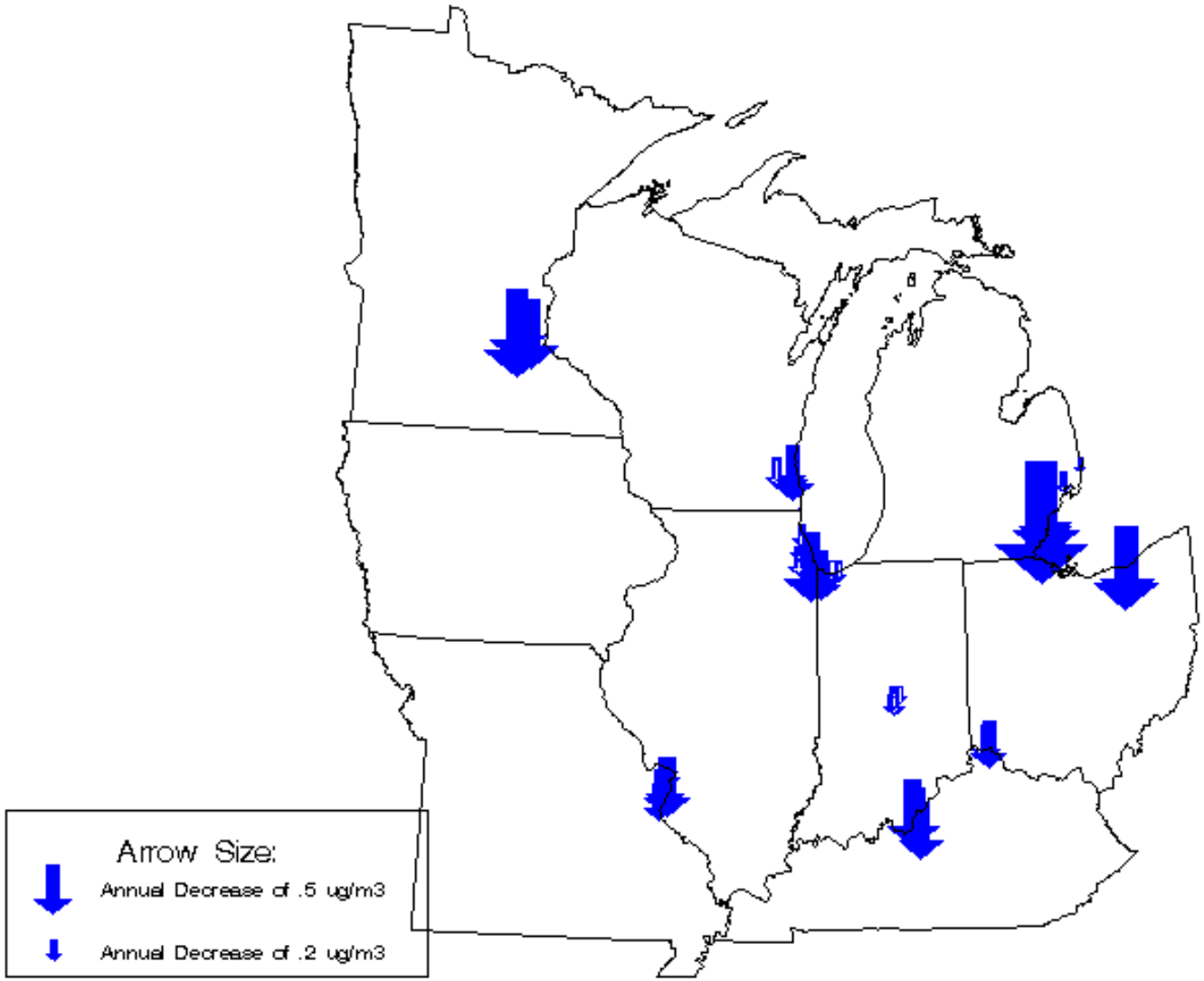
- Current concentrations and trends
- Frequency and timing of elevated concentrations – seasonality, day of week
- Spatial extent of high concentrations
- Urban-rural differences during high concentration events
- Chemical composition of elevated concentrations and seasonal patterns in composition
- 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



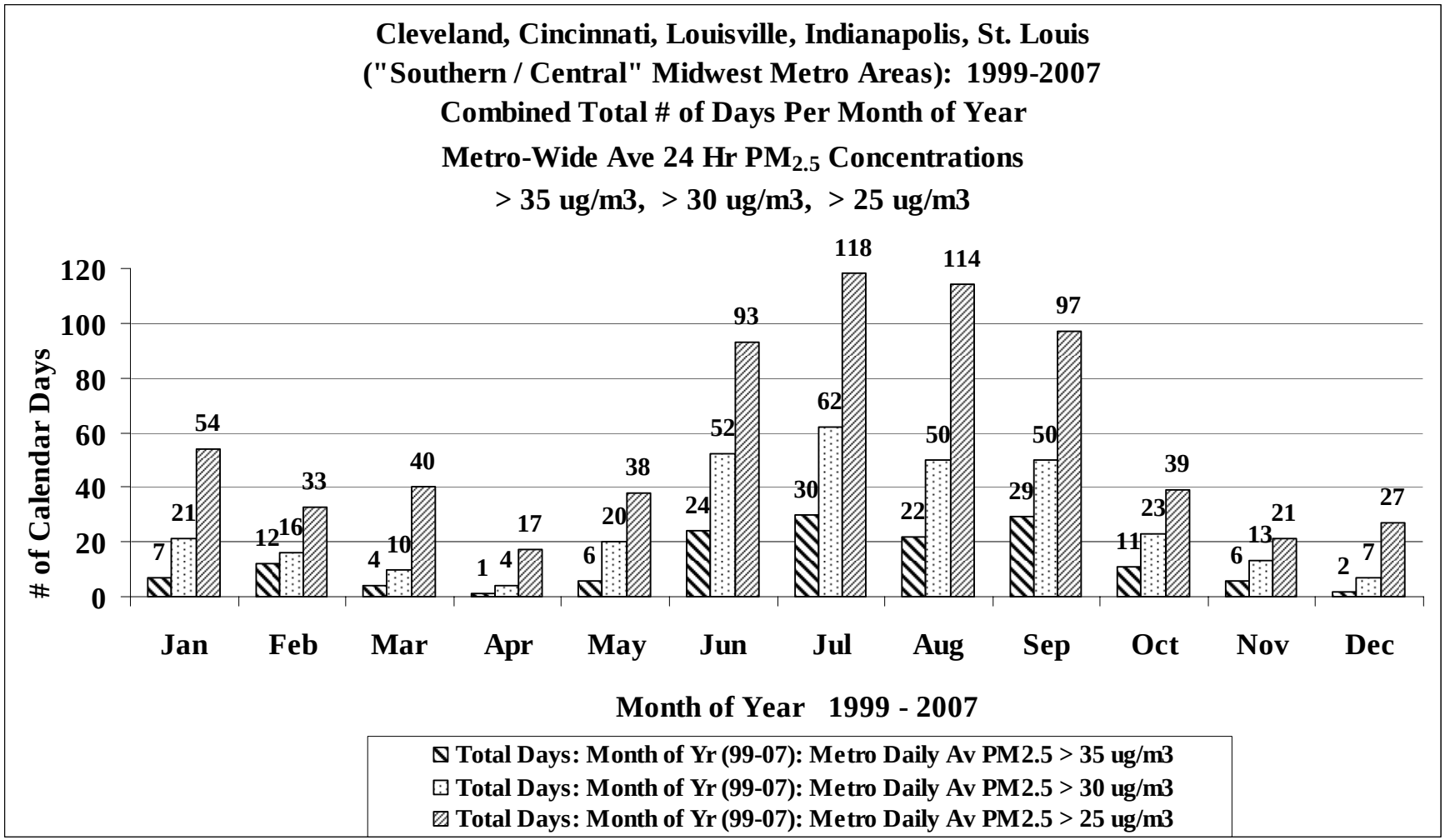

PM2.5 98%ile Trends, LADCO States, 1999—2007
98th %ile Concns, ug/m3
55
50
45
40
35
30
25
20
15
10
1999
2000
2001
2002
2003
2004
2005
2006
2007

Theil Trends for FRM PM2.5 10% Highest Days, 1999—2007

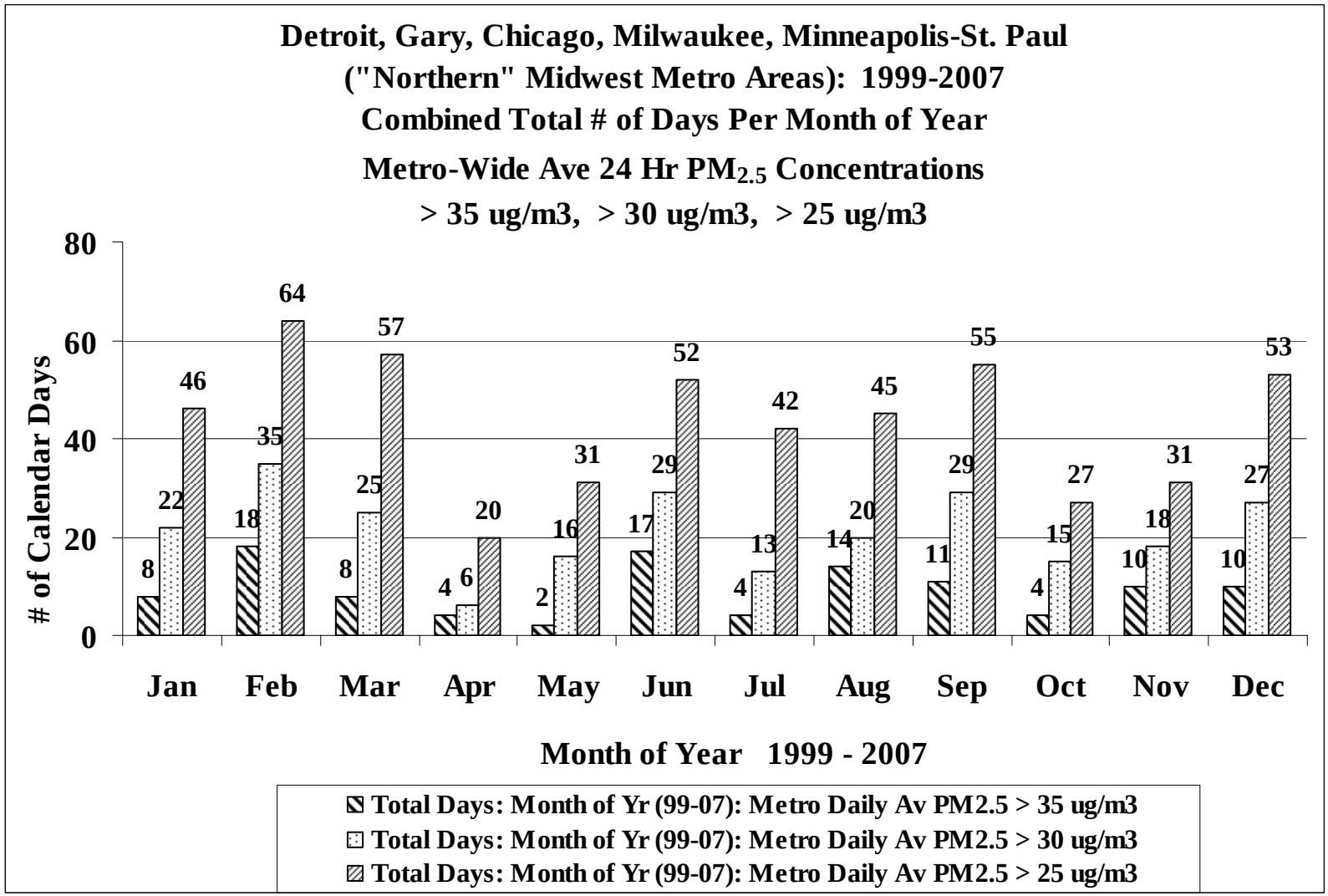


Solid arrows show statistically significant trends, empty arrows show trends that are not statistically significant.
Height of arrow is proportional to magnitude of trend

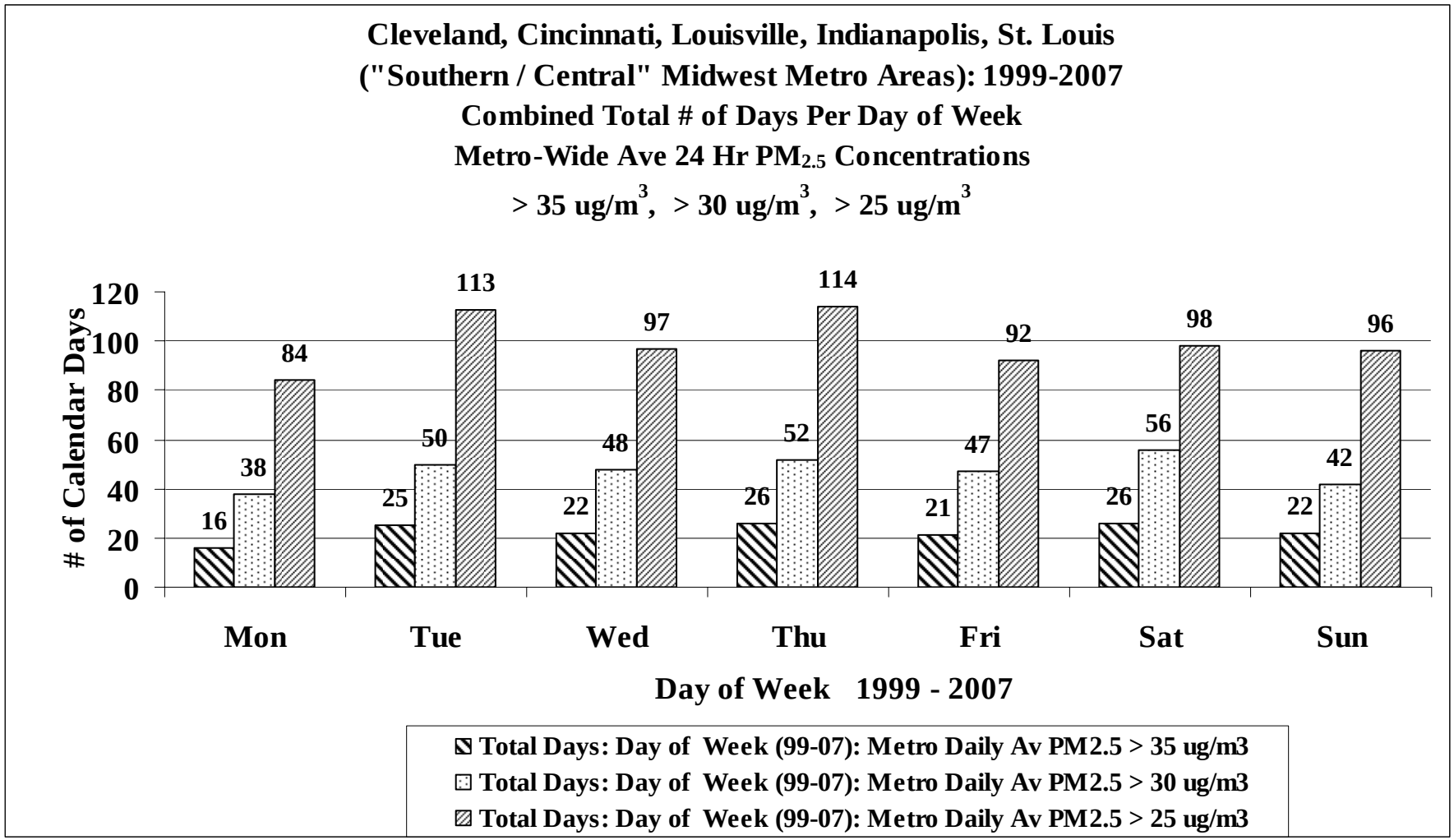
Seasonality in Southern Cities



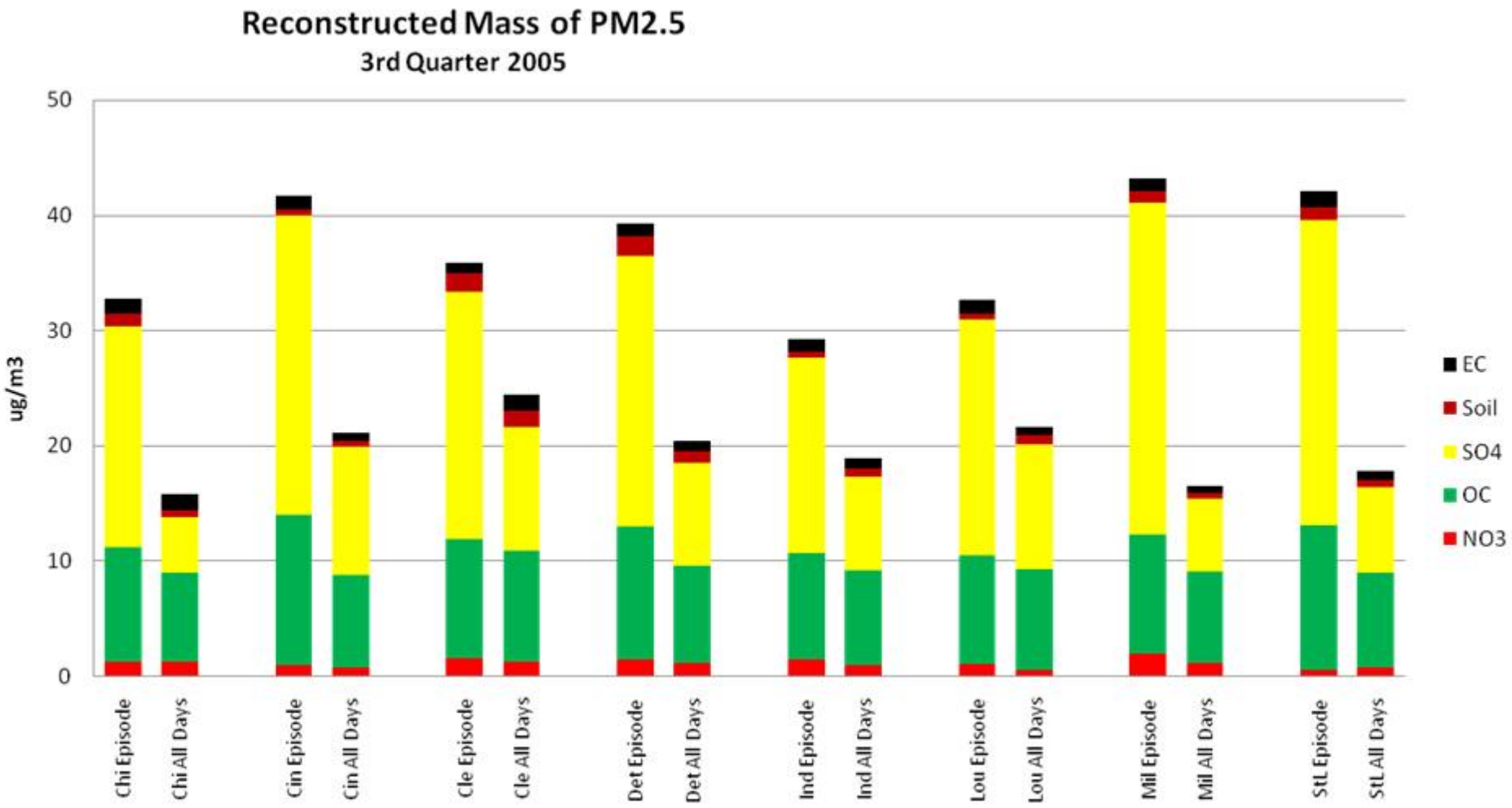
Seasonality in Northern Cities



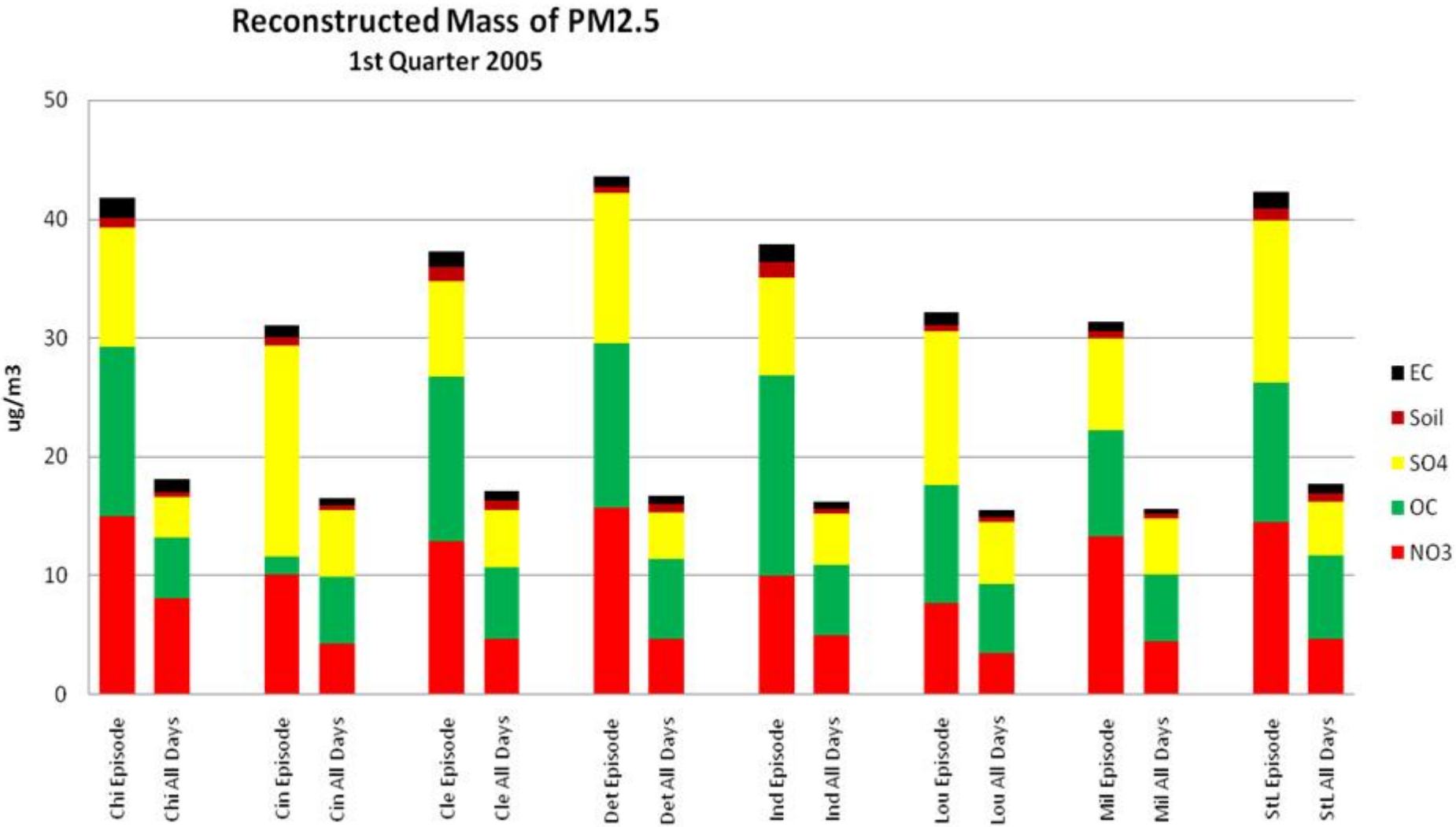
Day of Week Patterns



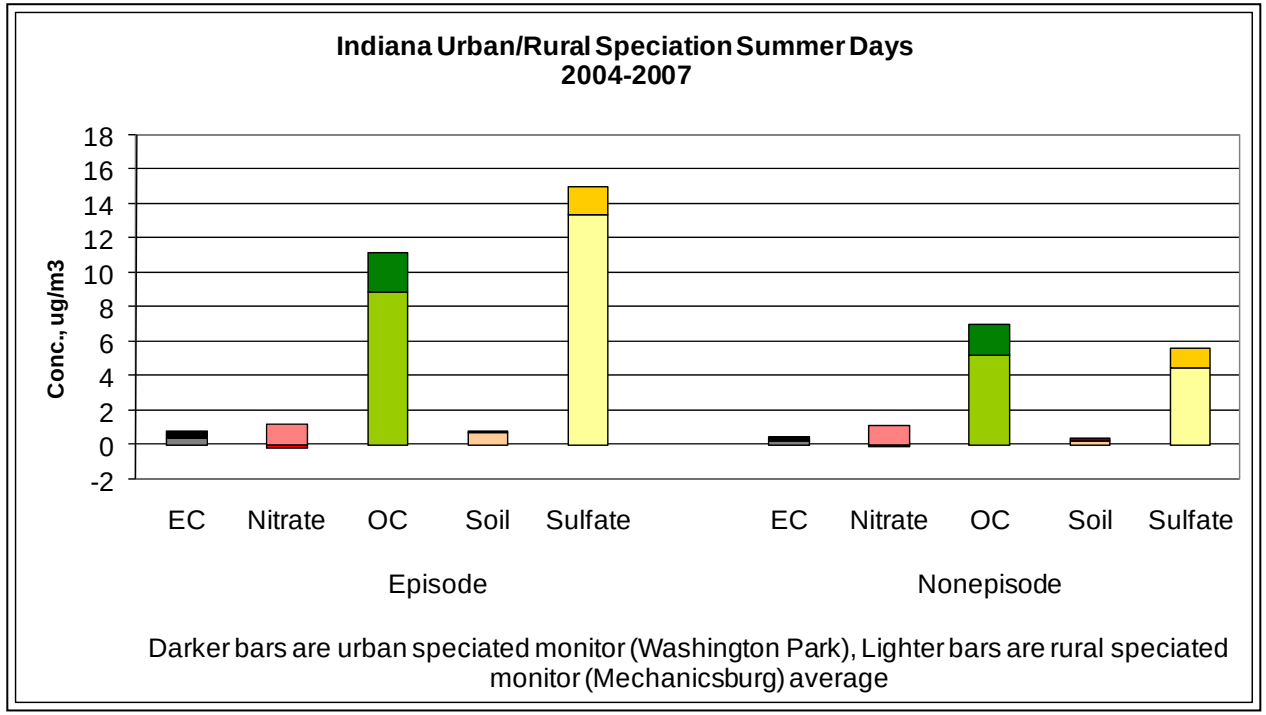
Composition on Summer Episode Days

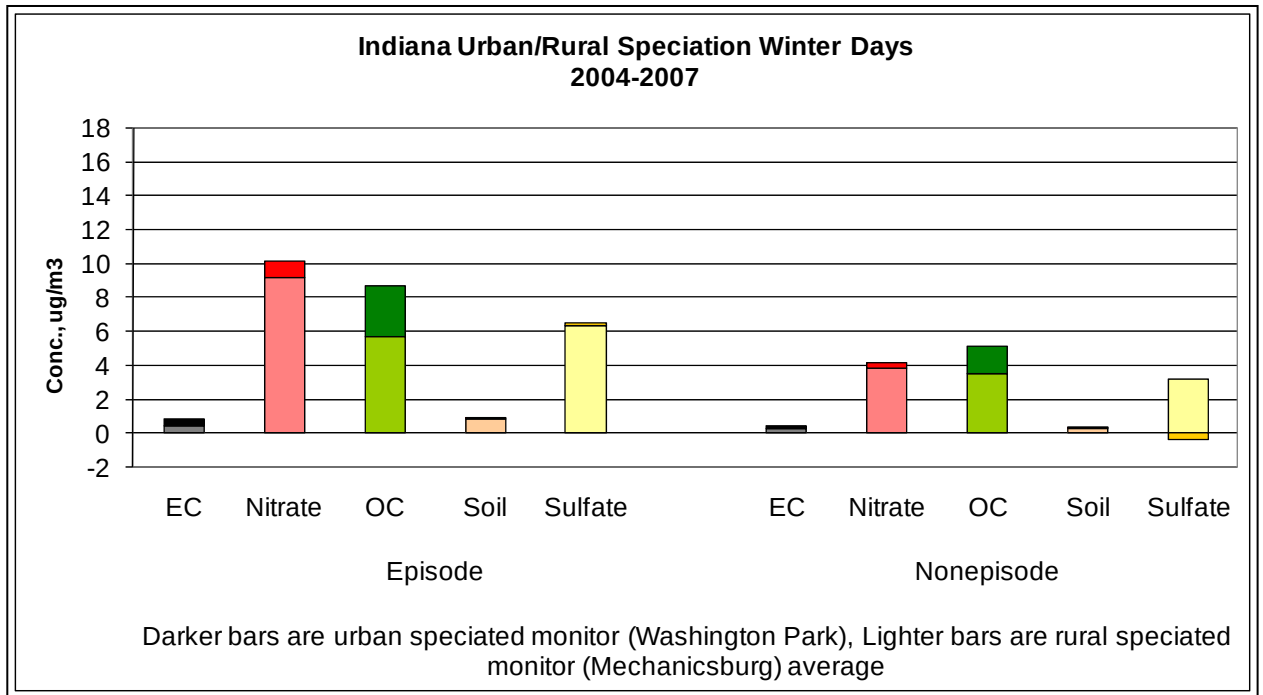


Composition on Winter Episode Days

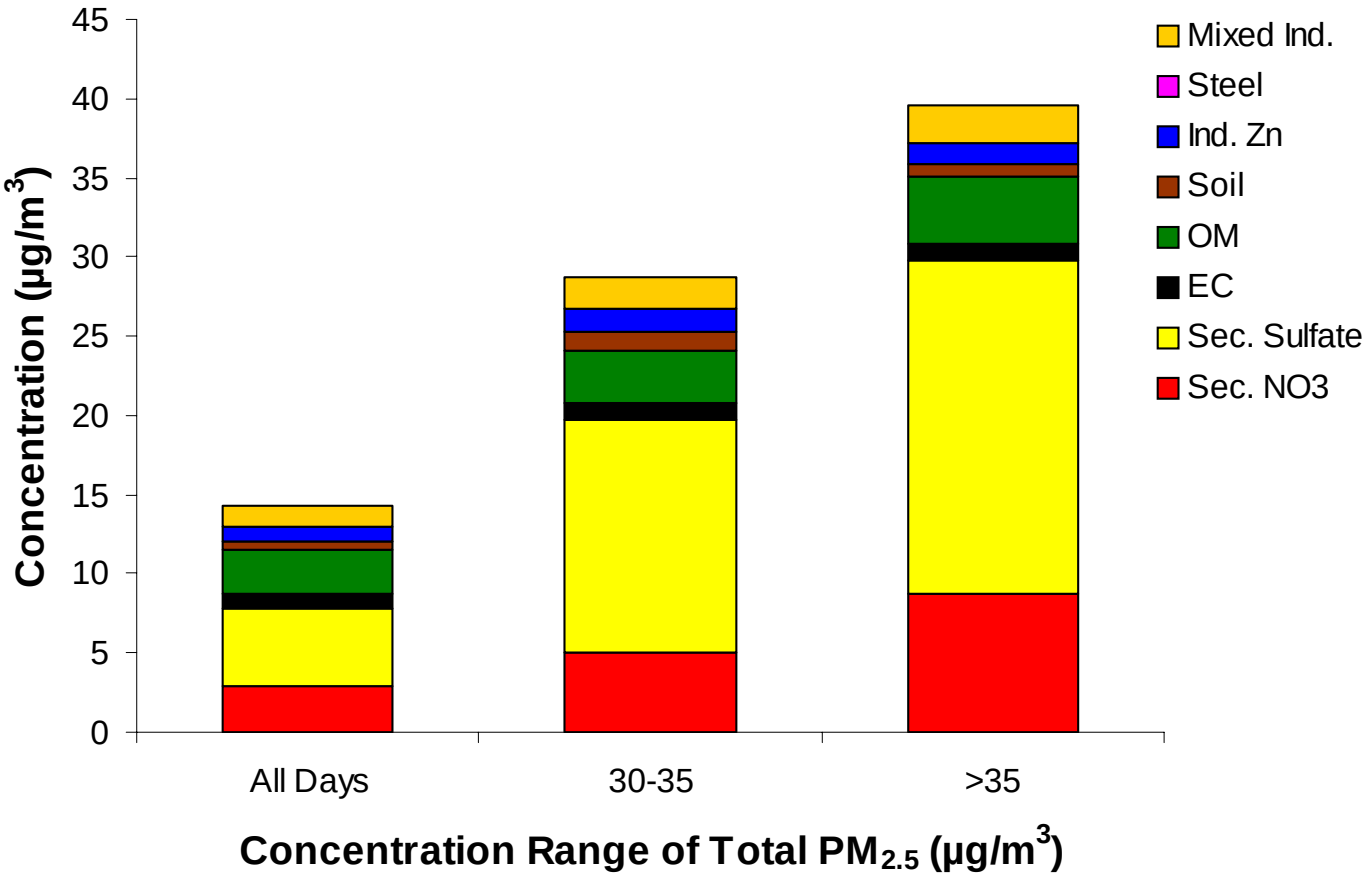


Seasonal Patterns in Urban/Rural Differences



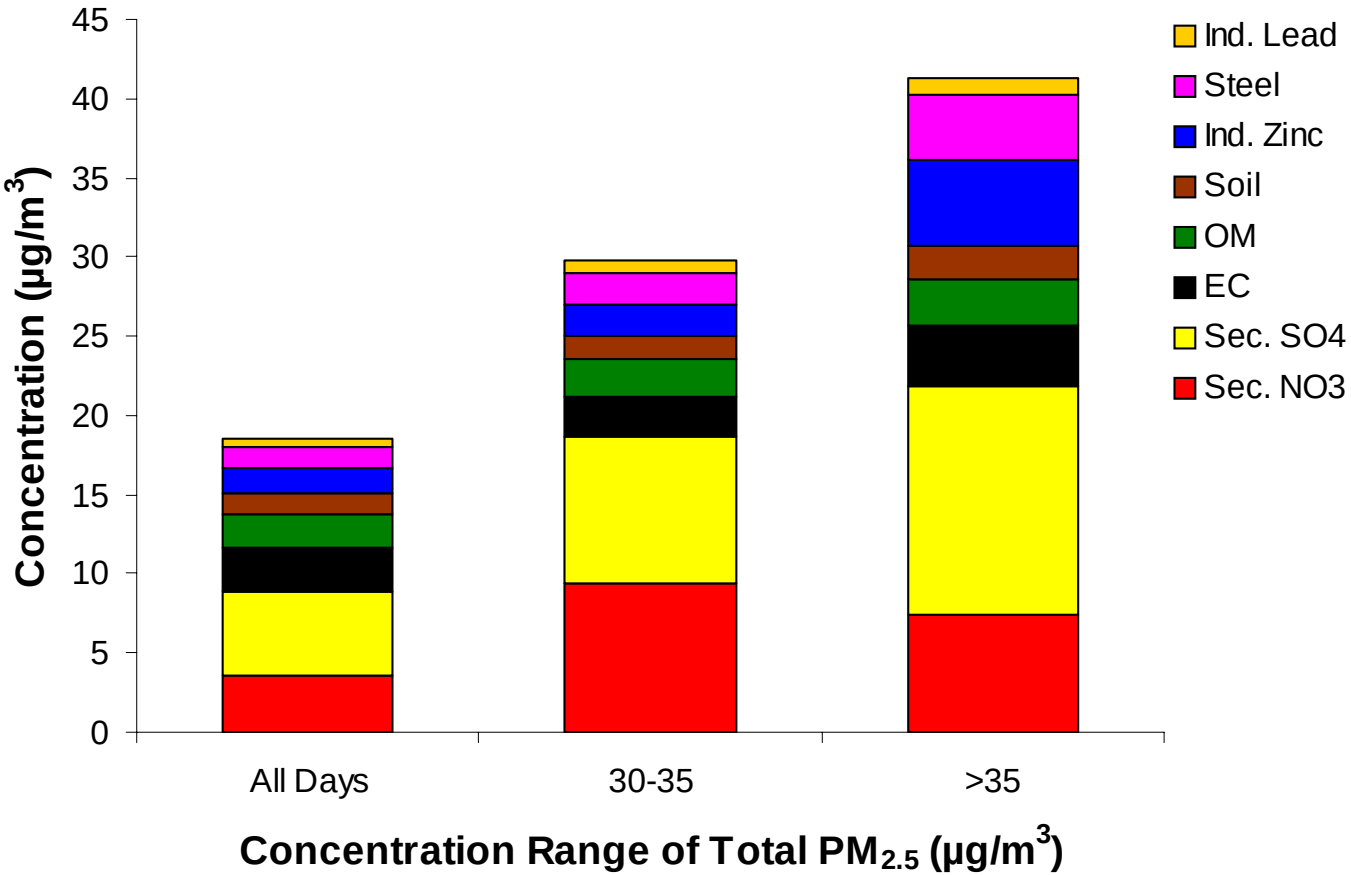


Allen Park: PMF Contributions



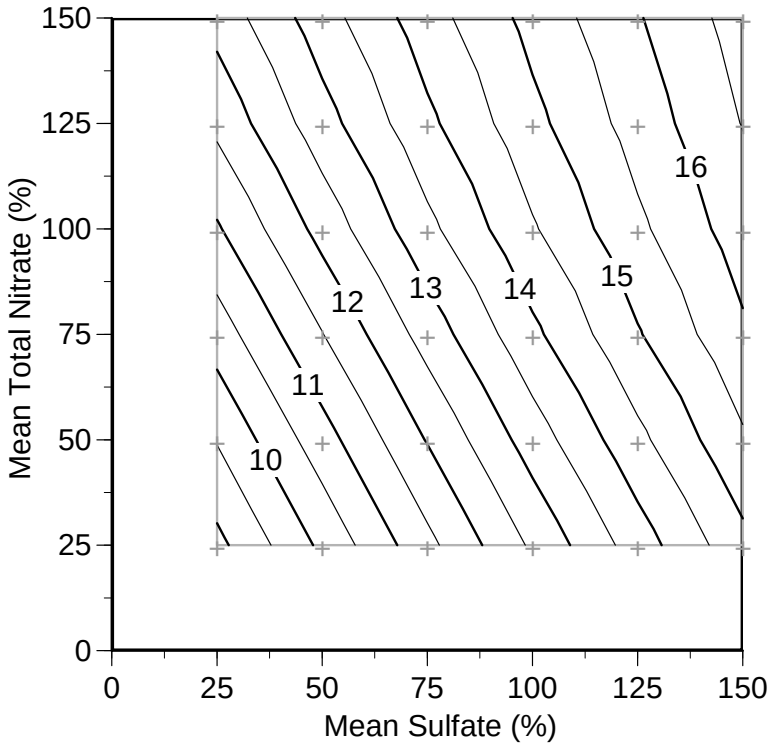
- As with the ambient data, PMF contributions mainly show an increase in secondary sulfate and secondary nitrate in the “high day” groups.

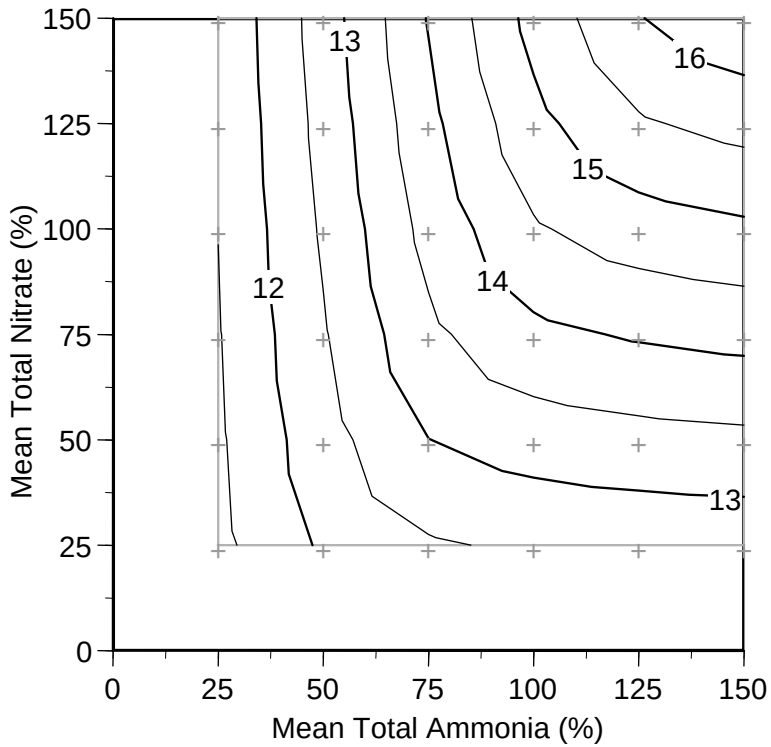
Dearborn: PMF Contributions



- PMF contributions mainly show an increase in secondary sulfate and secondary nitrate contributions in the “high day” groups. In the >35µg/m^3 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

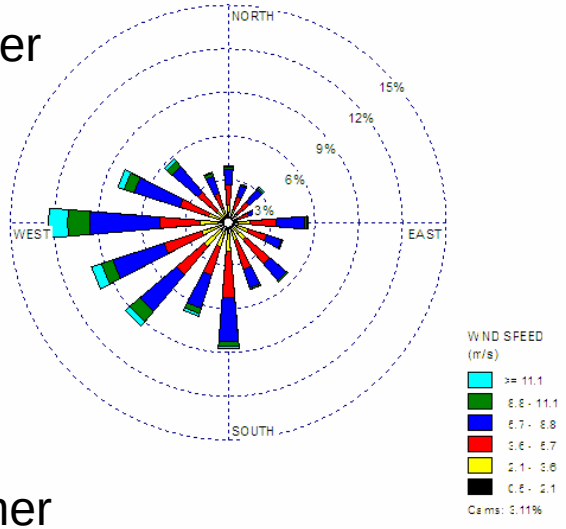
From Charlie Blanchard, 2008

Meteorology

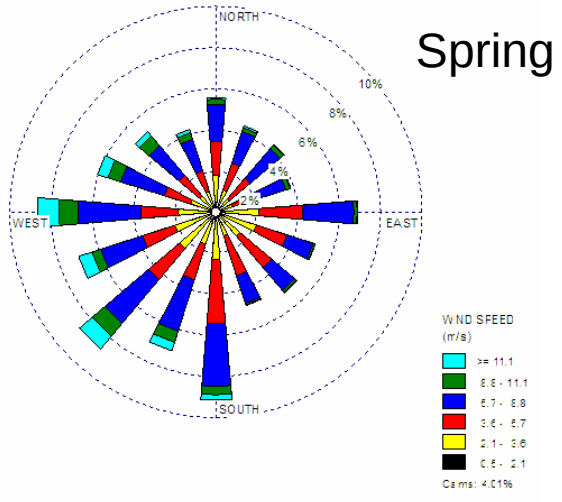
Indianapolis, IN

Indianapolis International Airport MET

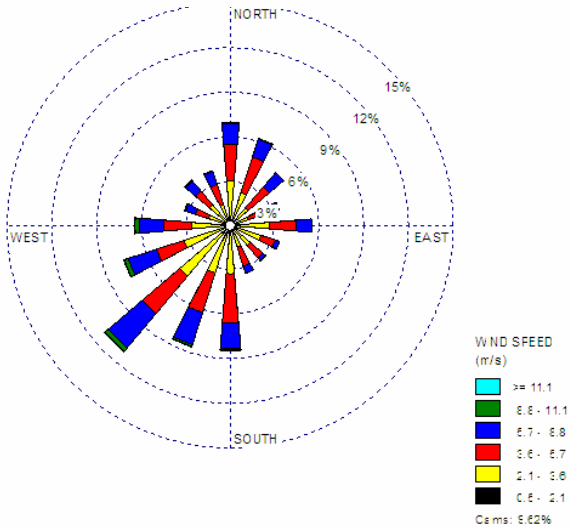
Winter



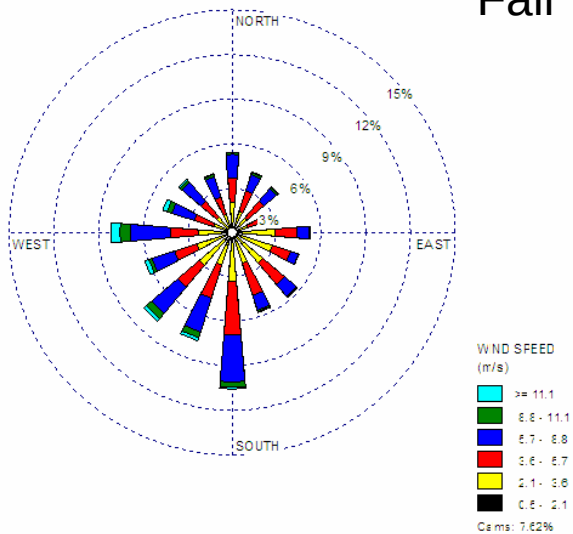
Spring



Summer

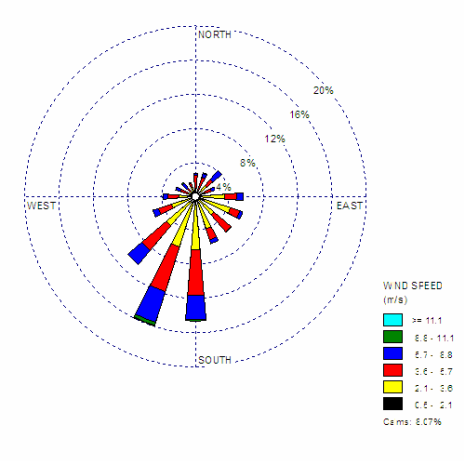


Fall



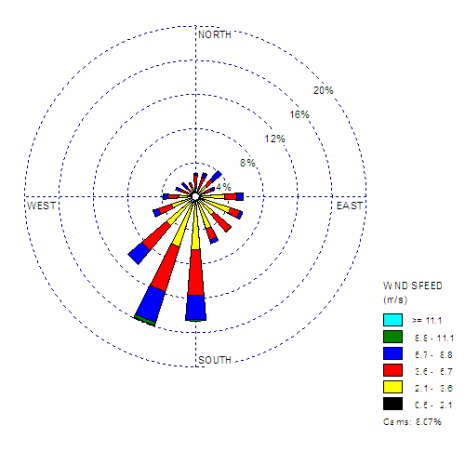
Episode Day Windroses

Indianapolis

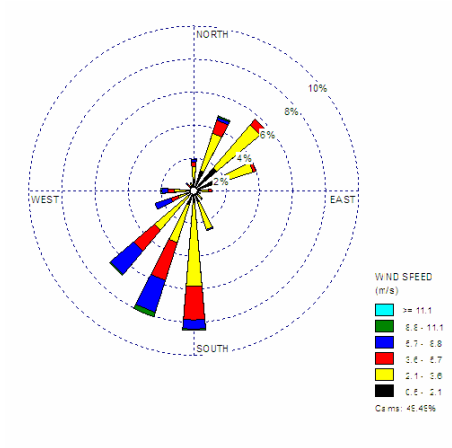


Episode Day Windroses

Indianapolis

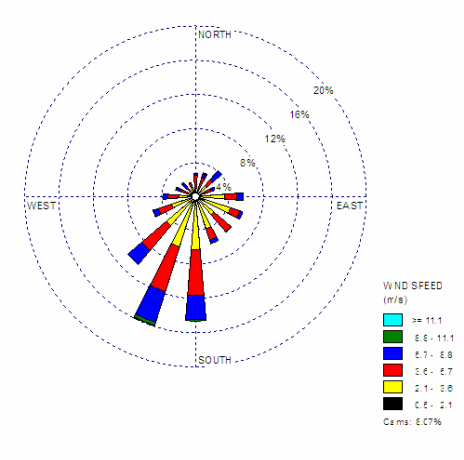


Cincinnati

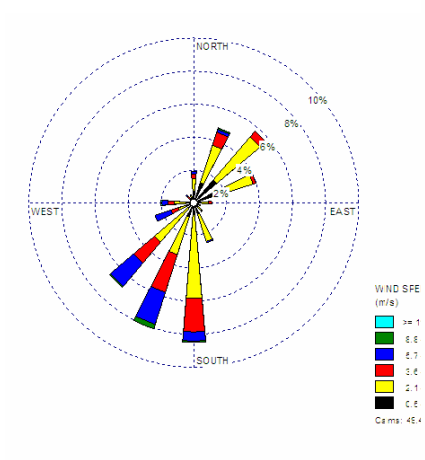


Episode Day Windroses

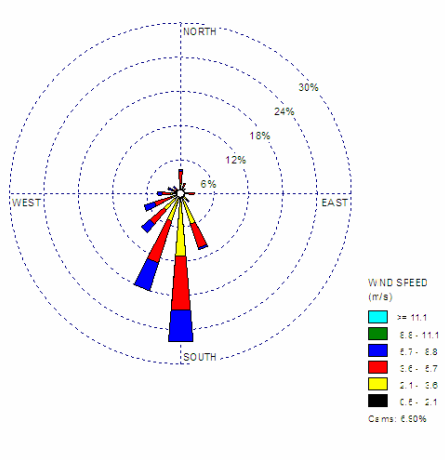
Indianapolis



Cincinnati

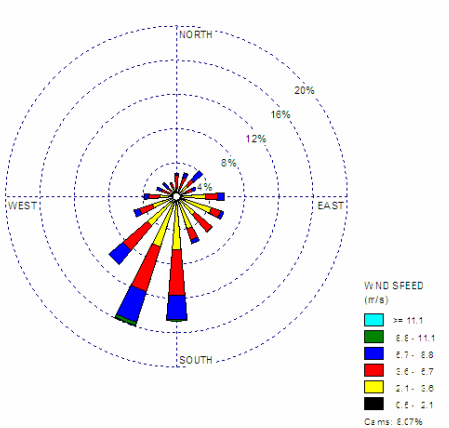


Cleveland

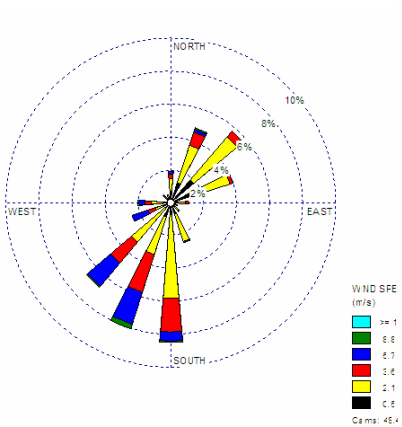


Episode Day Windroses

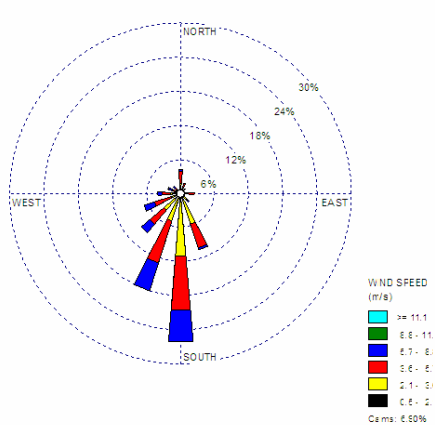
Indianapolis



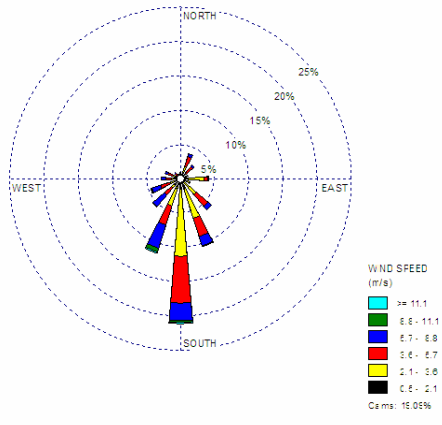
Cincinnati



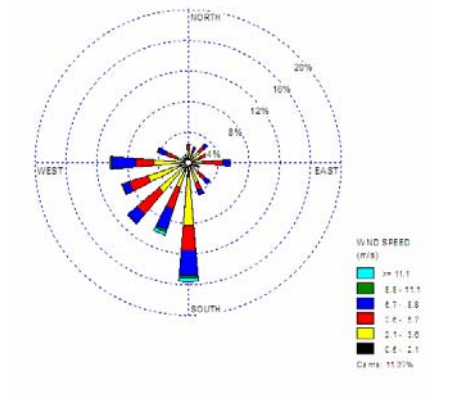
Cleveland



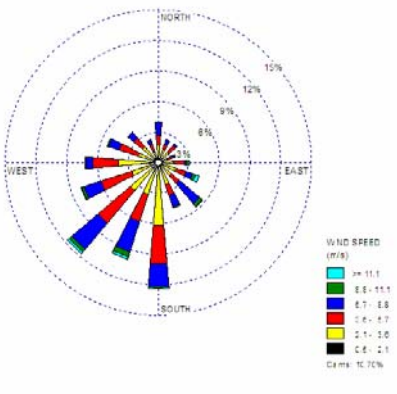
Detroit



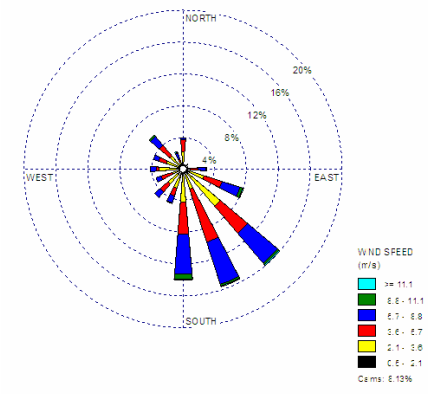
Chicago



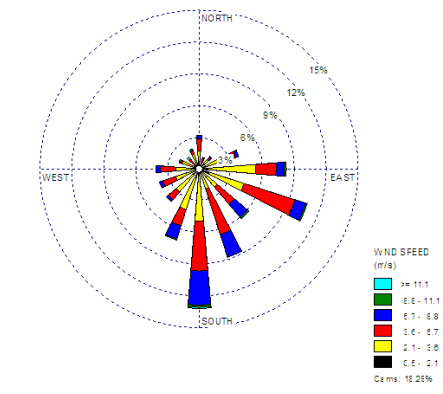
Milwaukee



Minneapolis

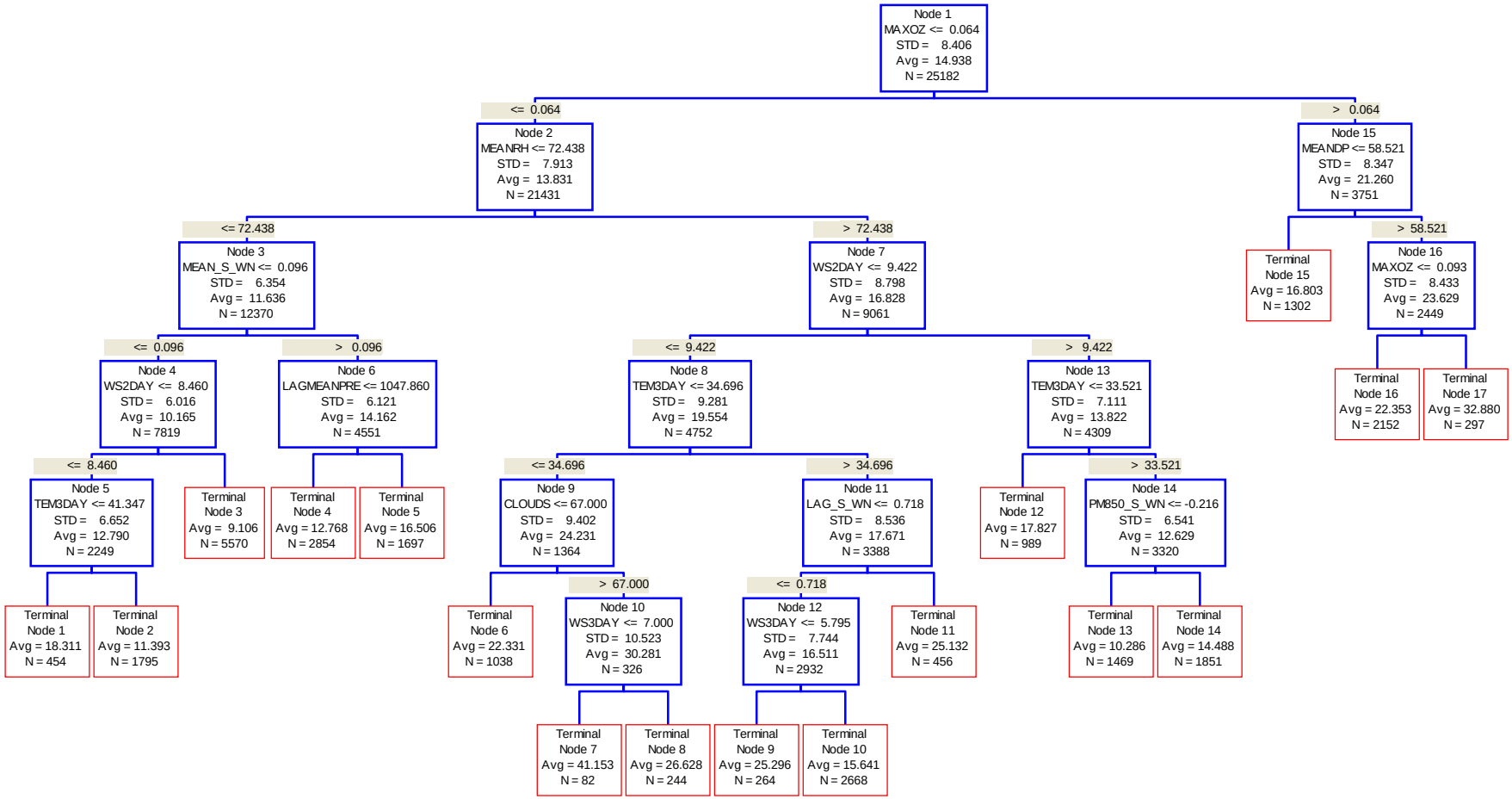


St. Louis



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

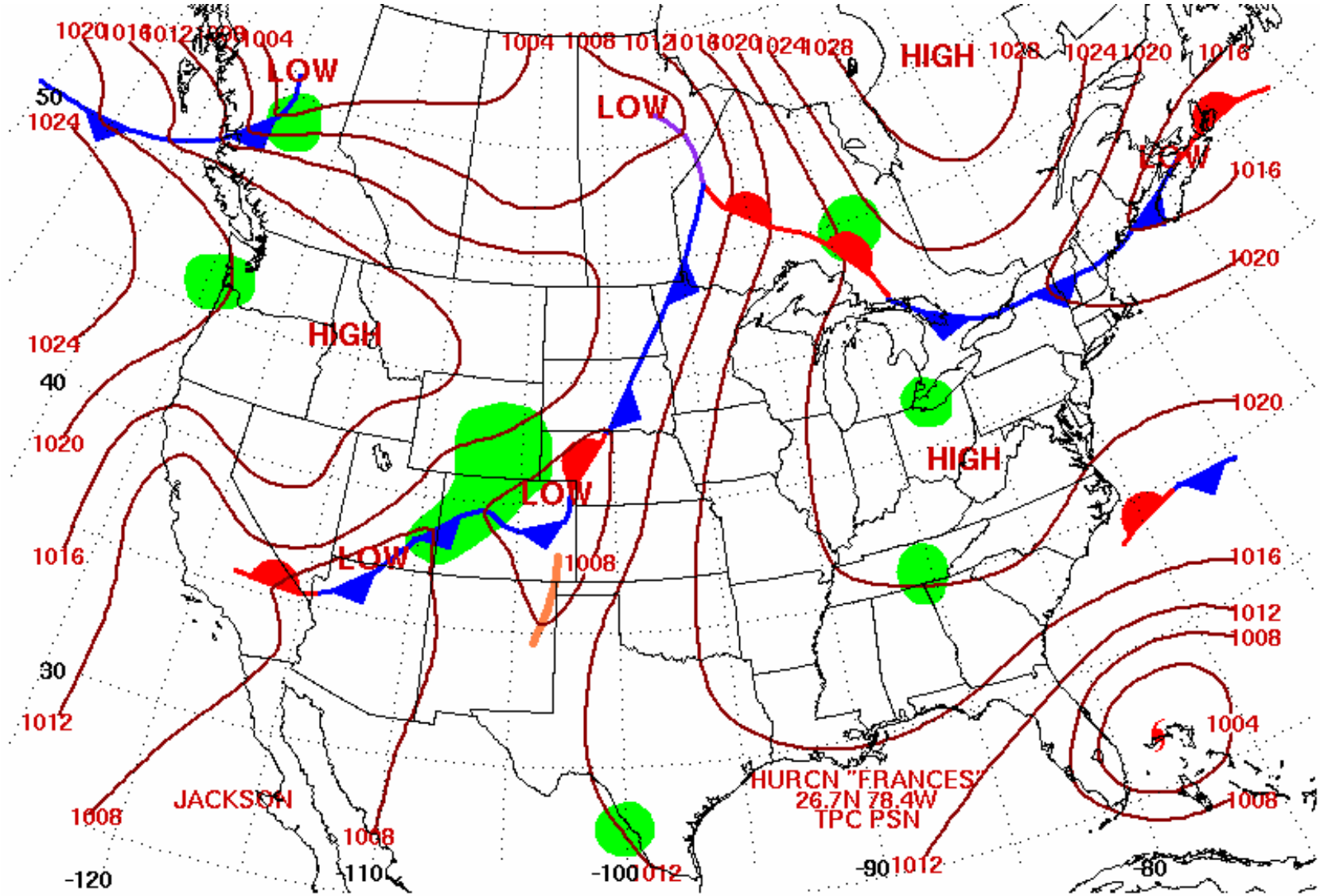

Node 1
MAXOZ <= 0.064
STD = 8.406
Avg = 14.938
N = 25182
<= 0.064
Node 2
MEANRH <= 72.438
STD = 7.913
Avg = 13.831
N = 21431
> 0.064
Node 15
MEANDP <= 58.521
STD = 8.347
Avg = 21.260
N = 3751
<= 72.438
Node 3
MEAN_S_WN <= 0.096
STD = 6.354
Avg = 11.636
N = 12370
> 72.438
Node 7
WS2DAY <= 9.422
STD = 8.798
Avg = 16.828
N = 9061
Terminal
Node 15
Avg = 16.803
N = 1302
> 58.521
Node 16
MAXOZ <= 0.093
STD = 8.433
Avg = 23.629
N = 2449
<= 0.096
Node 4
WS2DAY <= 8.460
STD = 6.016
Avg = 10.165
N = 7819
> 0.096
Node 6
LAGMEANPRE <= 1047.860
STD = 6.121
Avg = 14.162
N = 4551
<= 9.422
Node 8
TEM3DAY <= 34.696
STD = 9.281
Avg = 19.554
N = 4752
> 9.422
Node 13
TEM3DAY <= 33.521
STD = 7.111
Avg = 13.822
N = 4309
Terminal
Node 16
Avg = 22.353
N = 2152
Terminal
Node 17
Avg = 32.880
N = 297
<= 8.460
Node 5
TEM3DAY <= 41.347
STD = 6.652
Avg = 12.790
N = 2249
Terminal
Node 3
Avg = 9.106
N = 5570
Terminal
Node 4
Avg = 12.768
N = 2854
Terminal
Node 5
Avg = 16.506
N = 1697
<= 34.696
Node 9
CLOUDS <= 67.000
STD = 9.402
Avg = 24.231
N = 1364
> 34.696
Node 11
LAG_S_WN <= 0.718
STD = 8.536
Avg = 17.671
N = 3388
Terminal
Node 12
Avg = 17.827
N = 989
> 33.521
Node 14
PM850_S_WN <= -0.216
STD = 6.541
Avg = 12.629
N = 3320
Terminal
Node 1
Avg = 18.311
N = 454
Terminal
Node 2
Avg = 11.393
N = 1795
Terminal
Node 6
Avg = 22.331
N = 1038
> 67.000
Node 10
WS3DAY <= 7.000
STD = 10.523
Avg = 30.281
N = 326
<= 0.718
Node 12
WS3DAY <= 5.795
STD = 7.744
Avg = 16.511
N = 2932
Terminal
Node 11
Avg = 25.132
N = 456
Terminal
Node 13
Avg = 10.286
N = 1469
Terminal
Node 14
Avg = 14.488
N = 1851
Terminal
Node 7
Avg = 41.153
N = 82
Terminal
Node 8
Avg = 26.628
N = 244
Terminal
Node 9
Avg = 25.296
N = 264
Terminal
Node 10
Avg = 15.641
N = 2668

Conclusions from CART analysis

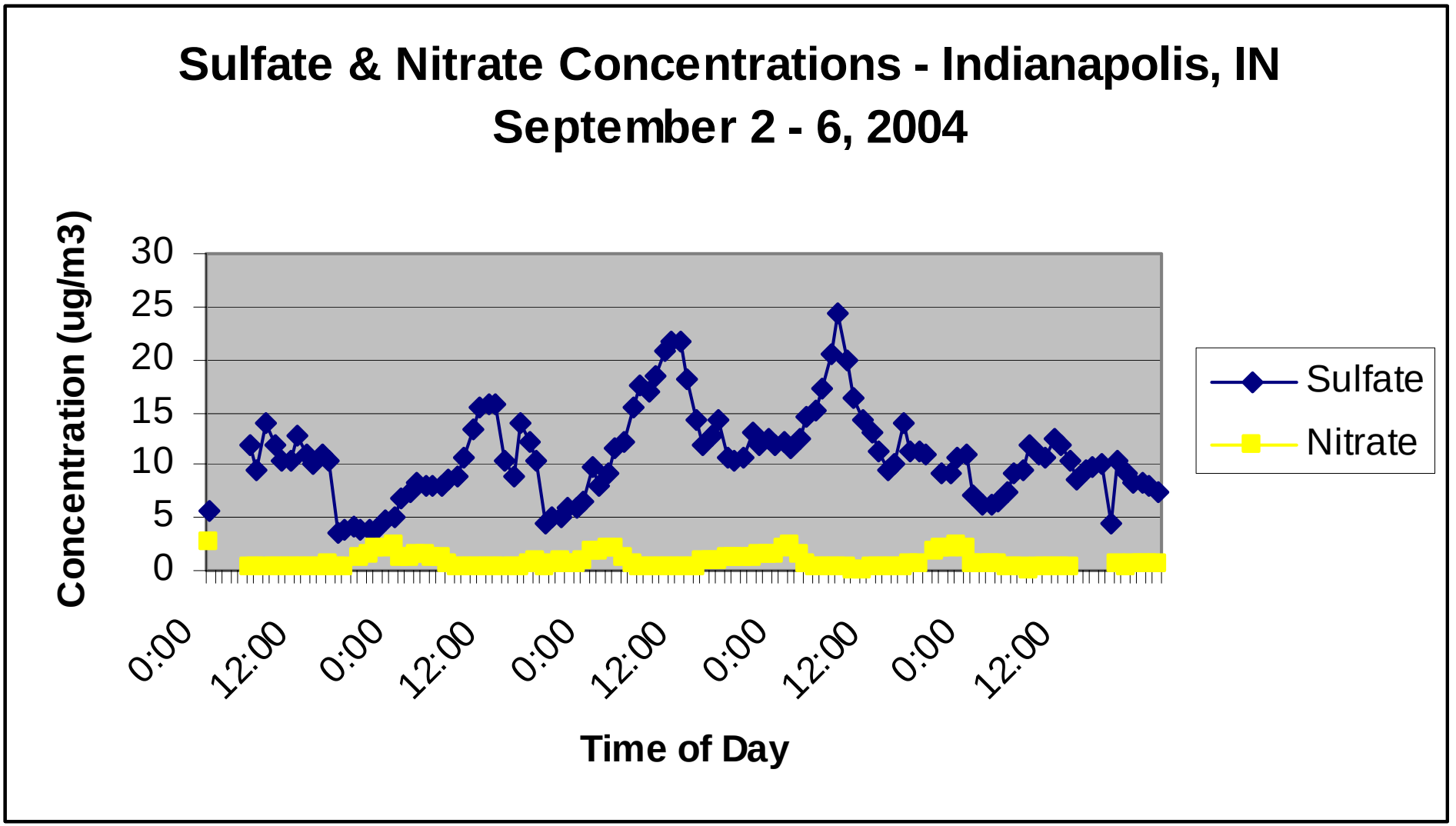
- Extended periods of slow wind speeds are the most common factor in high PM across the region
- Ozone is an important predictor in summer episodes (especially Chicago and St. Louis), and RH and dewpoint are important year-round
- Southerly wind flow is important in most areas, except east winds in St. 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.


Sulfate & Nitrate Concentrations - Indianapolis, IN
September 2 - 6, 2004
Concentration (ug/m3)
30
25
20
15
10
5
0
0:00
12:00
0:00
12:00
0:00
12:00
0:00
12:00
0:00
12:00
Time of Day
Sulfate
Nitrate

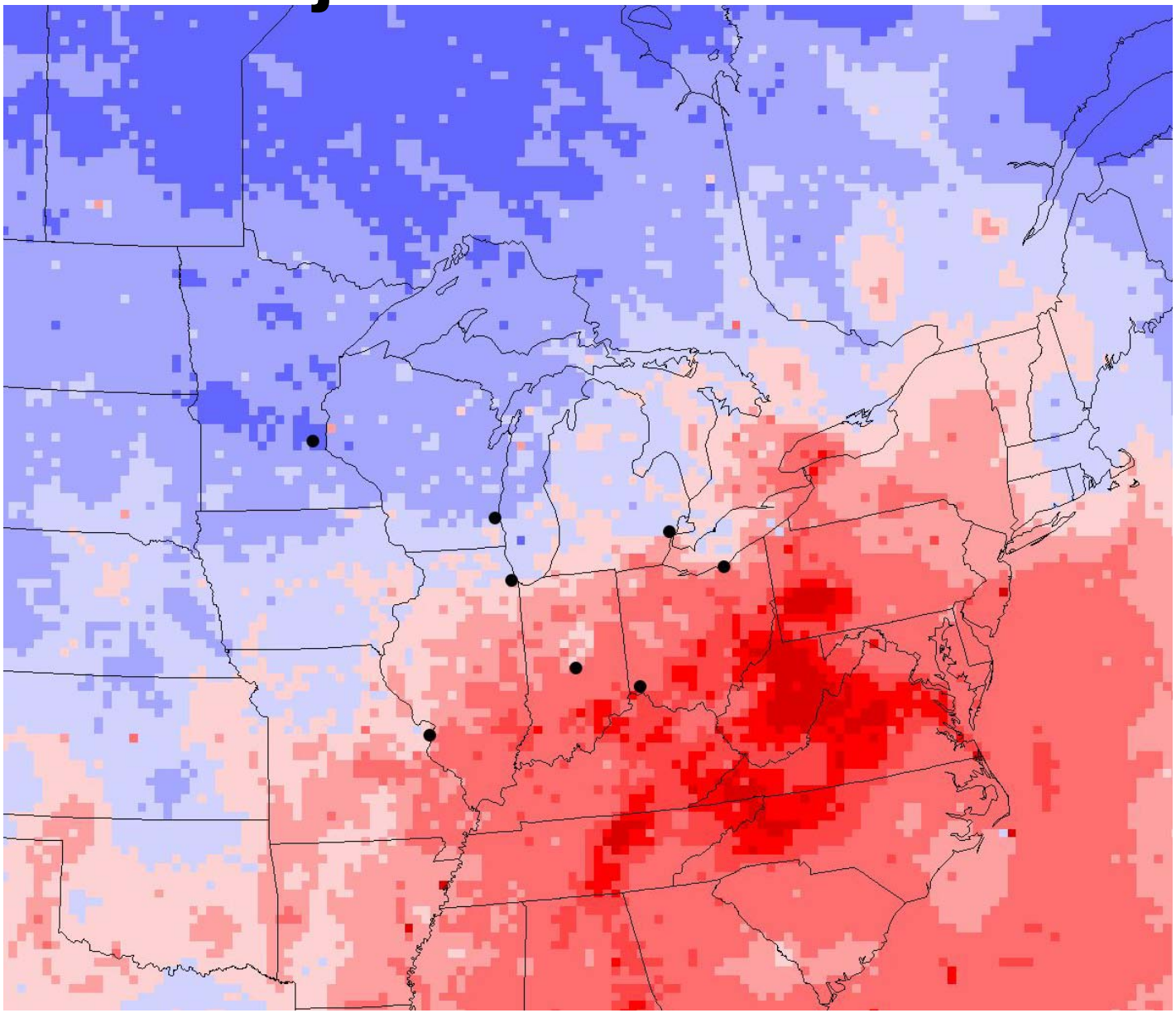
Episode Commonalities

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

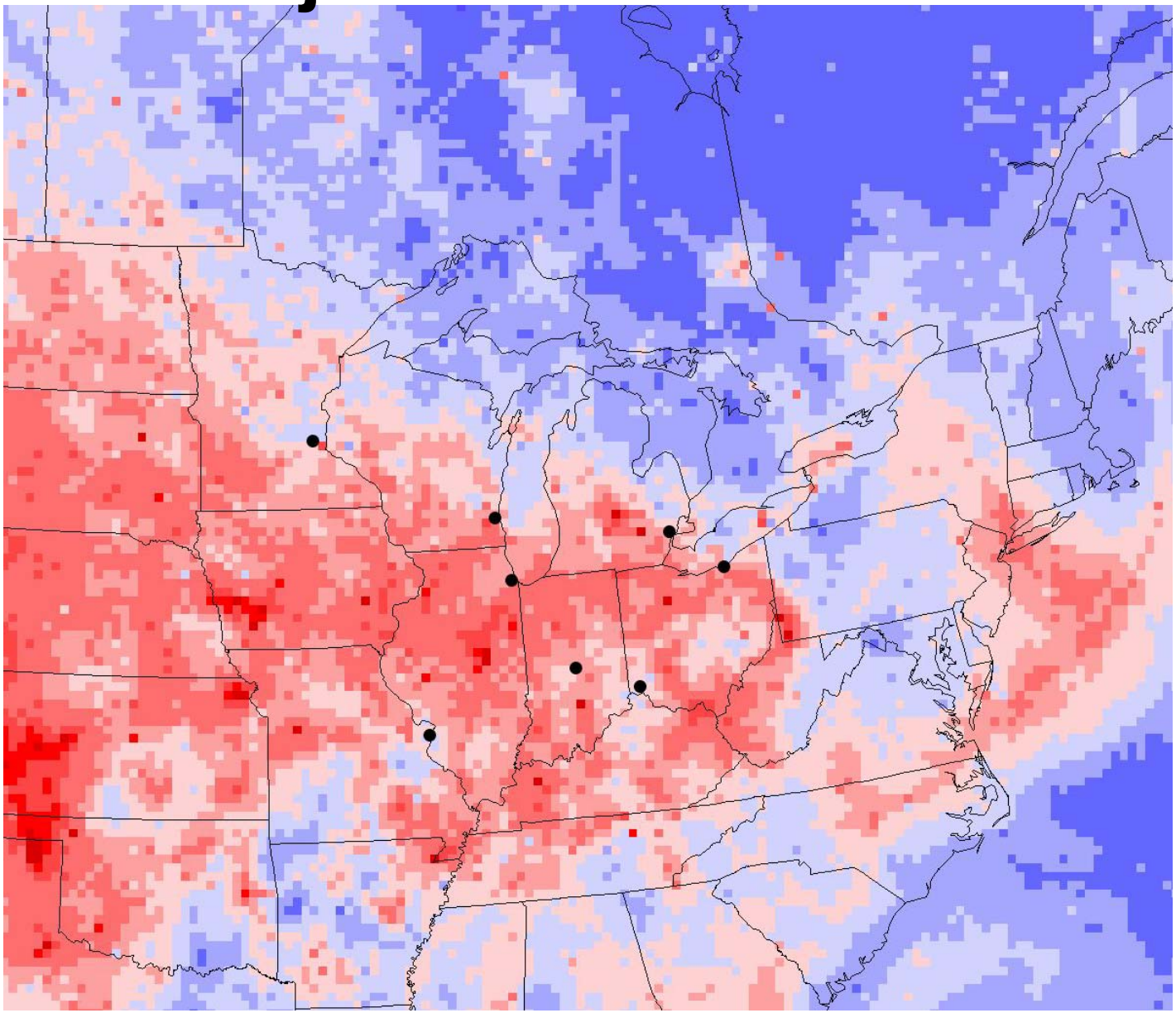
Trajectory Analysis

- 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 PM2.5 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 PM2.5 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 PM2.5 Daily Concentrations

- Regional reductions in SO2 should be effective year-round
- Regional reductions in NOx 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