Understanding Episodes of High Airborne Particulate Matter in Iowa

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A report commissioned by the Bi-State State Regional Commission

IIHR Hydroscience & Engineering

The University of Iowa

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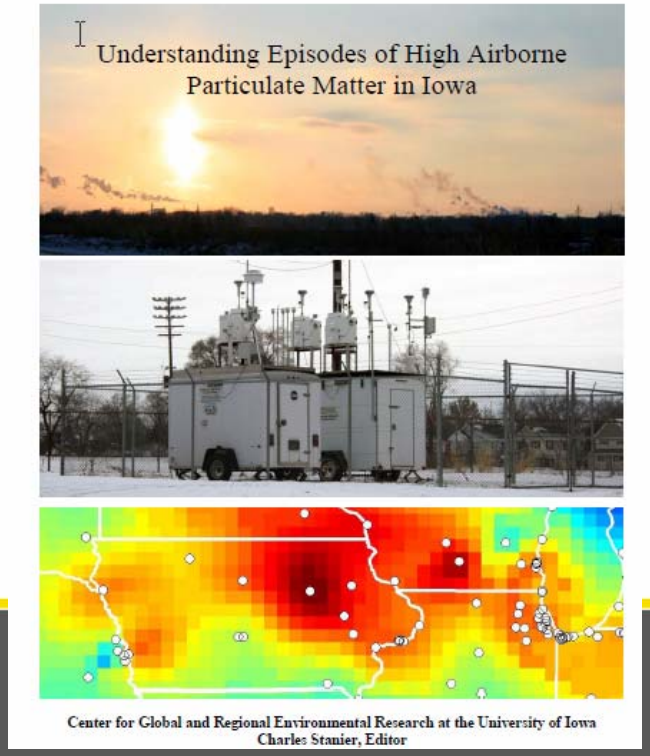
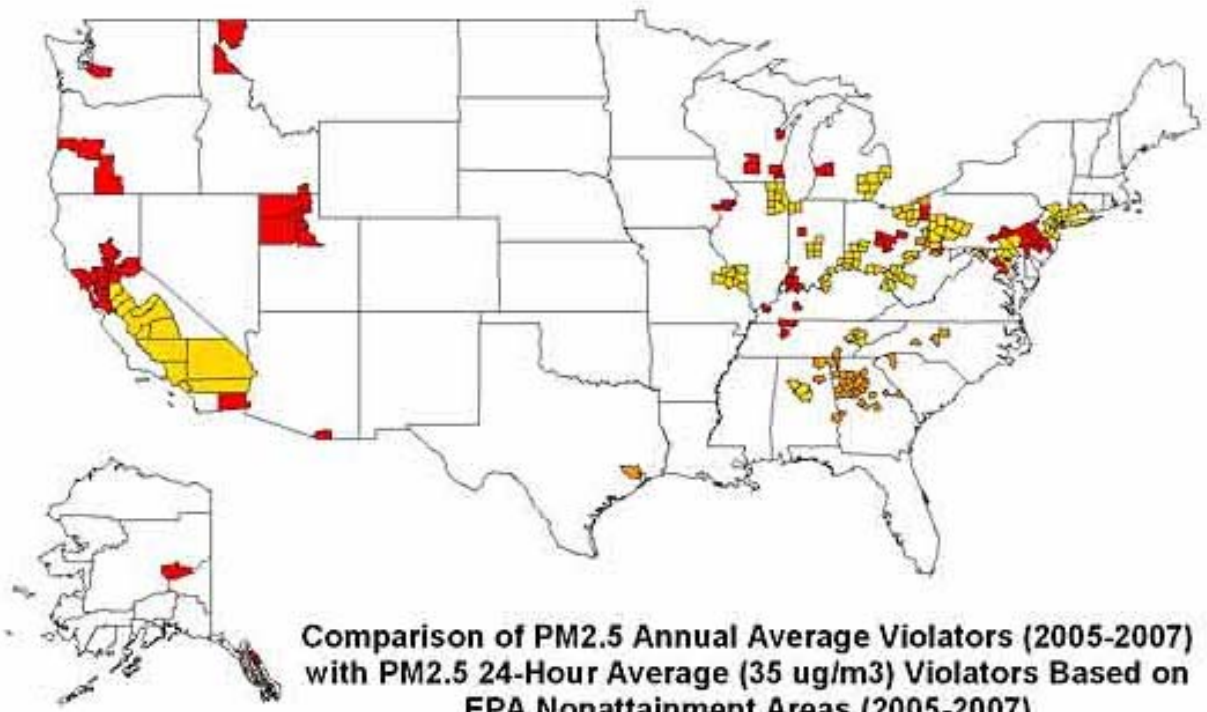
Report Available Online

- http://www.engineering.uiowa.edu/~cs_proj/iowa_pm_project/iowa_pm.htm



- Old standard (1997)
  - Annual average of 15 μg m^{-3}
  - 24 hour average (98^{th} percentile) of 65 μg m^{-3}
- New standard (2006)
  - Annual average of 15 μg m^{-3}
  - 24 hour average (98^{th} percentile) of 35 μg m^{-3}

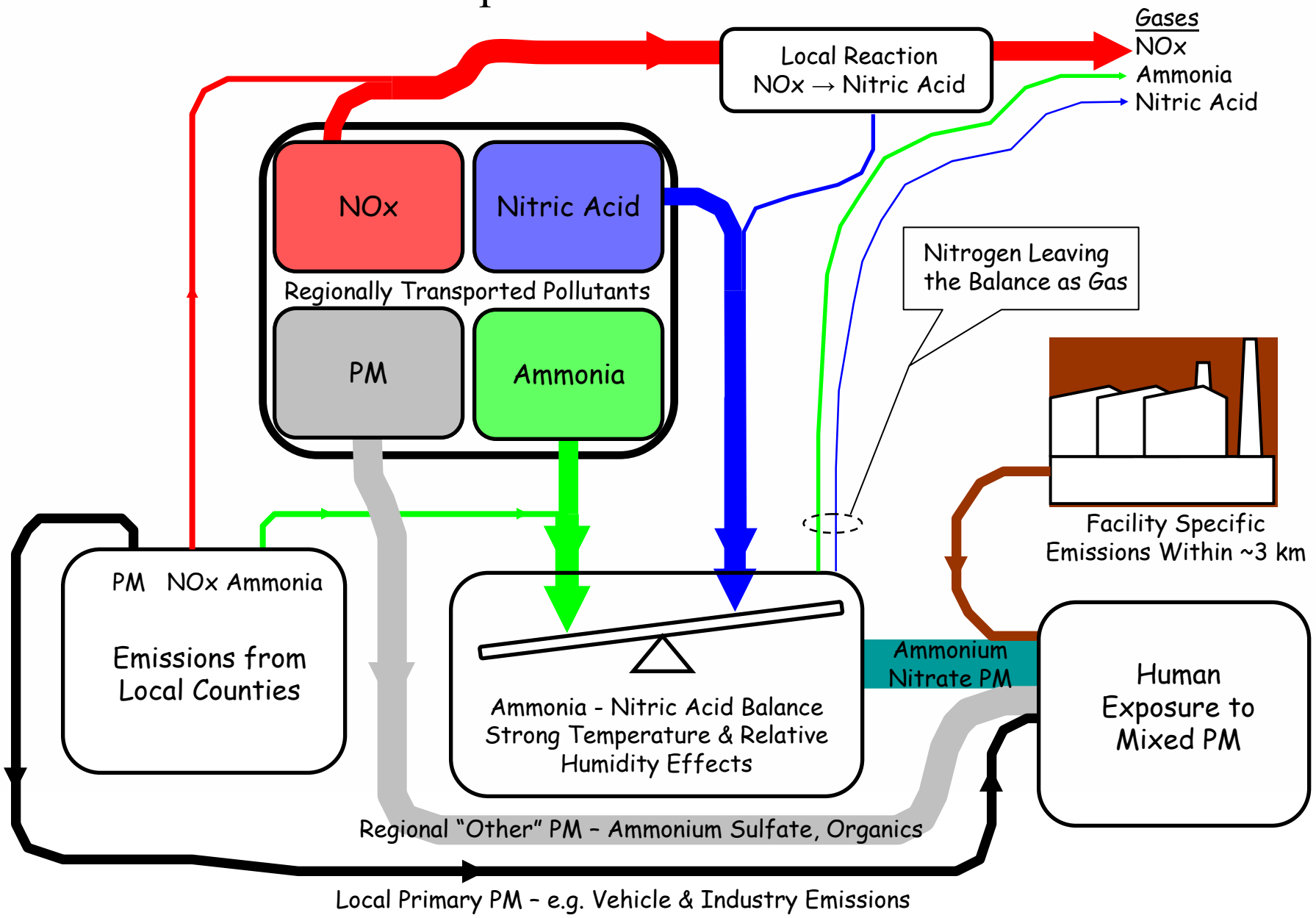
Non-attainment vs. 24-hour standard of 35 μg m^{-3}



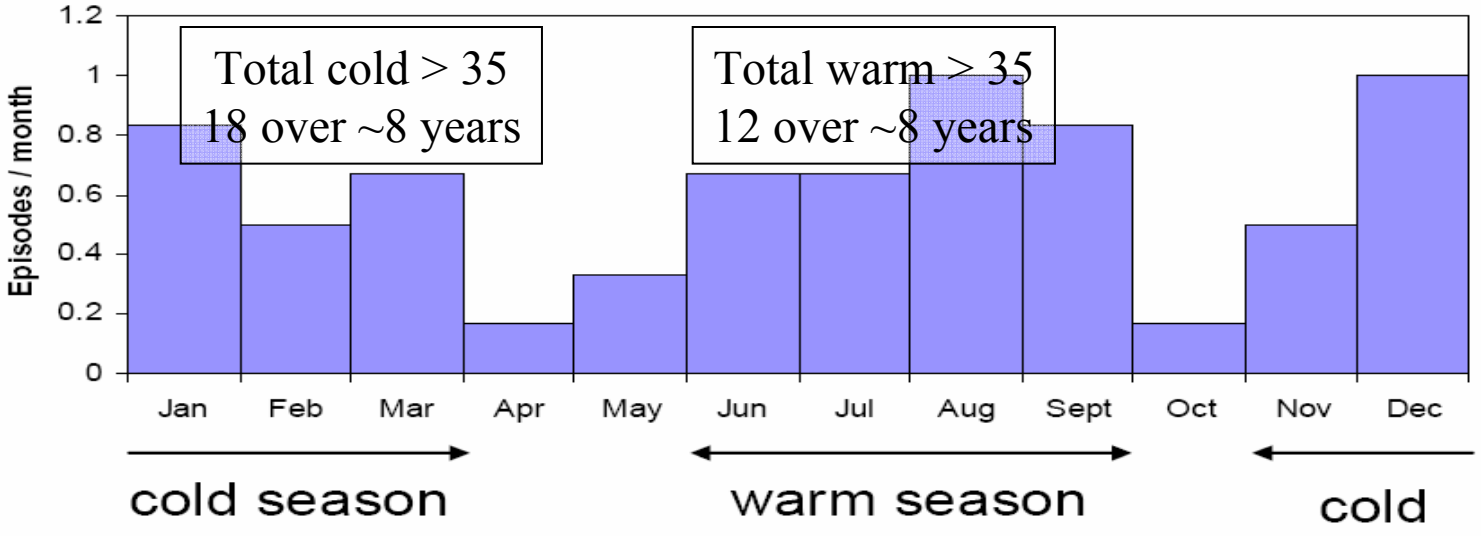
What's in our report

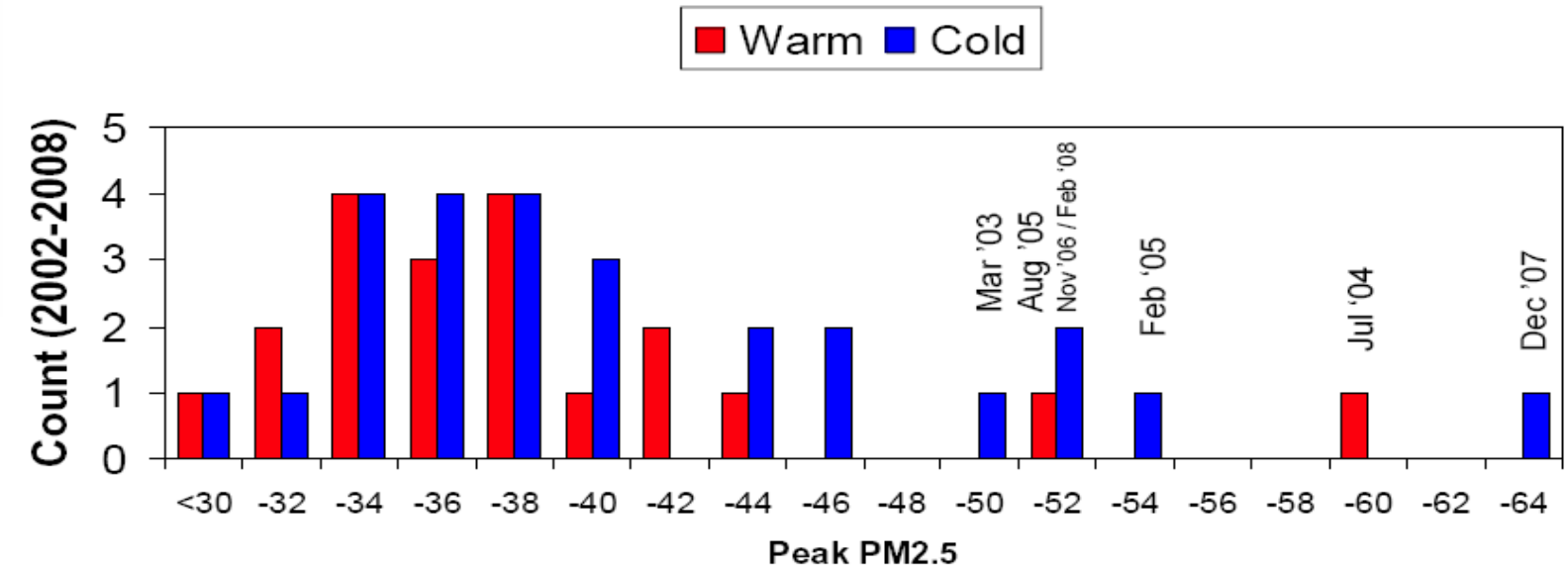
Review existing publications on Midwestern air quality	Quantify and catalog regional warm and cold weather episodes	Quantify regional versus local events	Explain conceptual model of Iowa PM formation
Compare background and individual monitor values	Estimate likelihood of future compliance with and without controls	Review IDNR measurements of aerosol chemistry	Indentify and quantify directional sources
Determine limiting reagent to ammonium nitrate formation	Examine nitric acid formation pathways	Examine effect of fog	Examine meteorology surrounding episodes
Characterize model performance during episodes	Recommend next steps		

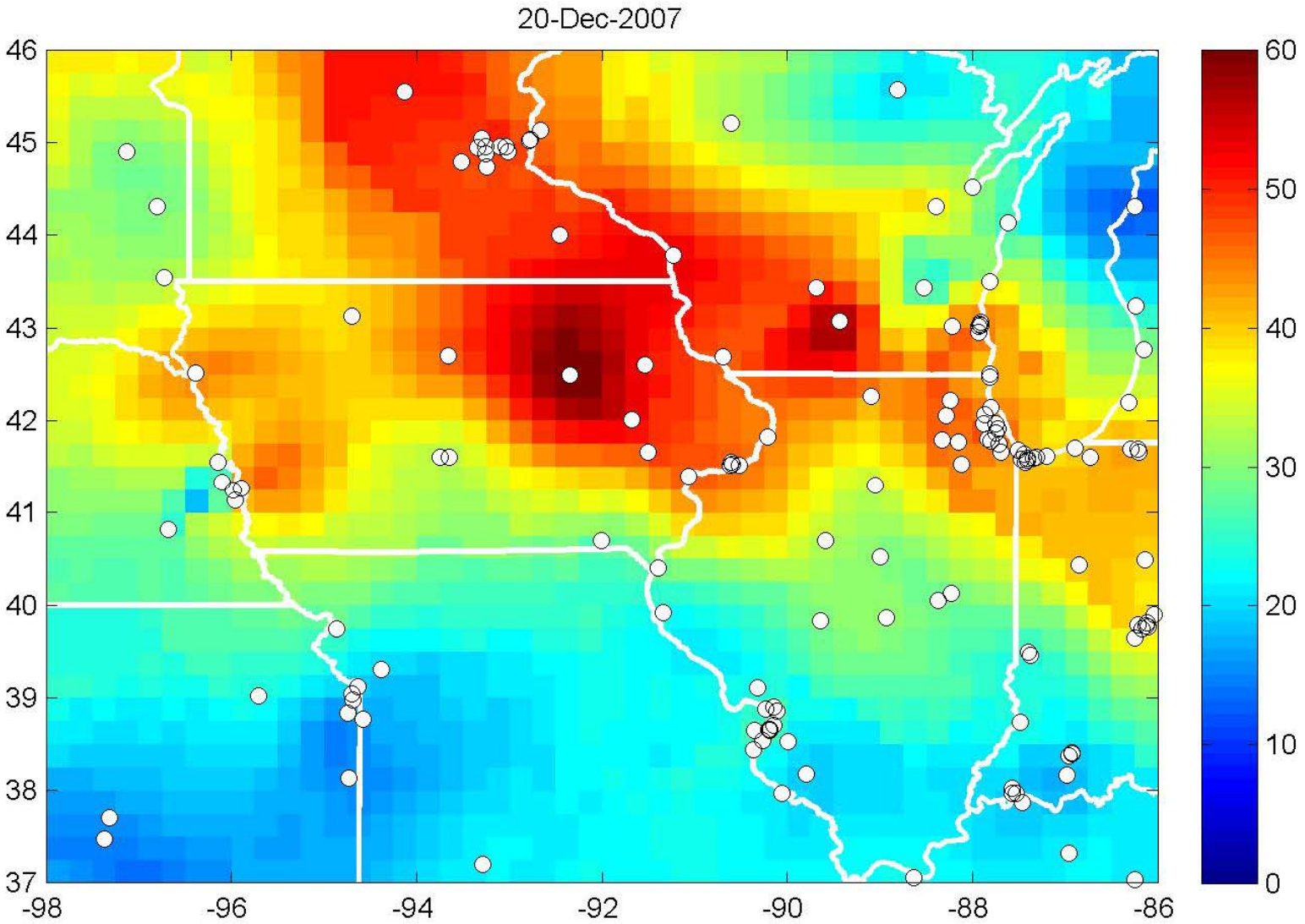
Literature Review & Conceptual Model



PM episodes occur during both warm and cold seasons. The warm and cold weather episodes are of comparable magnitude and impact on compliance with air quality standards.






20-Dec-2007
46
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38
37
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-96
-94
-92
-90
-88
-86
60
50
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20
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Episode List Available

Table 4-2. Key high PM episodes spanning 3 or more monitors identified by the University of Iowa. Full list in Appendix A.

Ranking (by multi-monitor average)	Univ. of Iowa Episode Code	Season (Cold / Warm)	Estimated Start Date	Estimated End Date	Peak FRM Measurement	Location – Peak FRM Measurement	Multisite (~5) $PM_{2.5}$ Avg.	Notes
1	2007-20	C	12/17/07	12/21/07	63.0	Waterloo	49.6	b, c
2	2006-7	C	11/21/06	11/27/06	50.9	Clinton - 23rd & Camanche	42.6	b,c
3	2005-5	C	1/27/05	2/3/05	53.2	Waterloo	40.3	b,c
4	2005-7	W	7/31/05	8/3/05	50.5	Davenport – Wellman St.	40.1	c
5	2003-6	W	4/15/03	4/19/03	43.9	Muscatine	39.7	
6	2004-4	W	7/1/04	7/4/04	59.3	Muscatine	39.4	
7	2003-9	W	9/6/03	9/11/03	44.0	Cedar Rapids - Wenig Rd Ne	39.4	
8	2004-7	C	12/26/04	12/30/04	42.3	Clinton - Roosevelt St.	39.3	b
9	2008-5	C	2/21/08	2/25/08	50.5	Clinton - Roosevelt St.	38.8	c
10	2004-2	C	2/16/04	2/20/04	42.3	Mason City	38.6	b,c
11	2007-4	C	3/6/07	3/10/07	44.2	Davenport - Wellman St.	37.9	c
12	2005-8	W	9/5/05	9/13/05	40.5	Davenport - Wellman St.	36.5	
13	2005-10	C	12/20/05	12/25/05	39.7	Clinton - Roosevelt St.	36.3	b
14	2003-2	C	2/27/03	3/1/03	39.7	Davenport - 10th & Vine	36.1	b
15	2008-4	C	1/31/08	2/4/08	37.6	Sioux City	35.9	
16	2003-8	W	8/12/03	8/14/03	39.4	Des Moines Iowa - Carpenter	35.7	
17	2003-3	C	3/11/03	3/20/03	48.7	Cedar Rapids - Wenig Rd Ne	35.0	
18	2005-6	W	6/23/05	6/29/05	41.7	Davenport - Wellman St.	34.6	
19	2004-1	C	1/8/04	1/11/04	34.5	Des Moines Iowa - Carpenter	33.1	
20	2004-6	W	10/26/04	10/29/04	34.3	Clinton - Roosevelt St.	32.5	

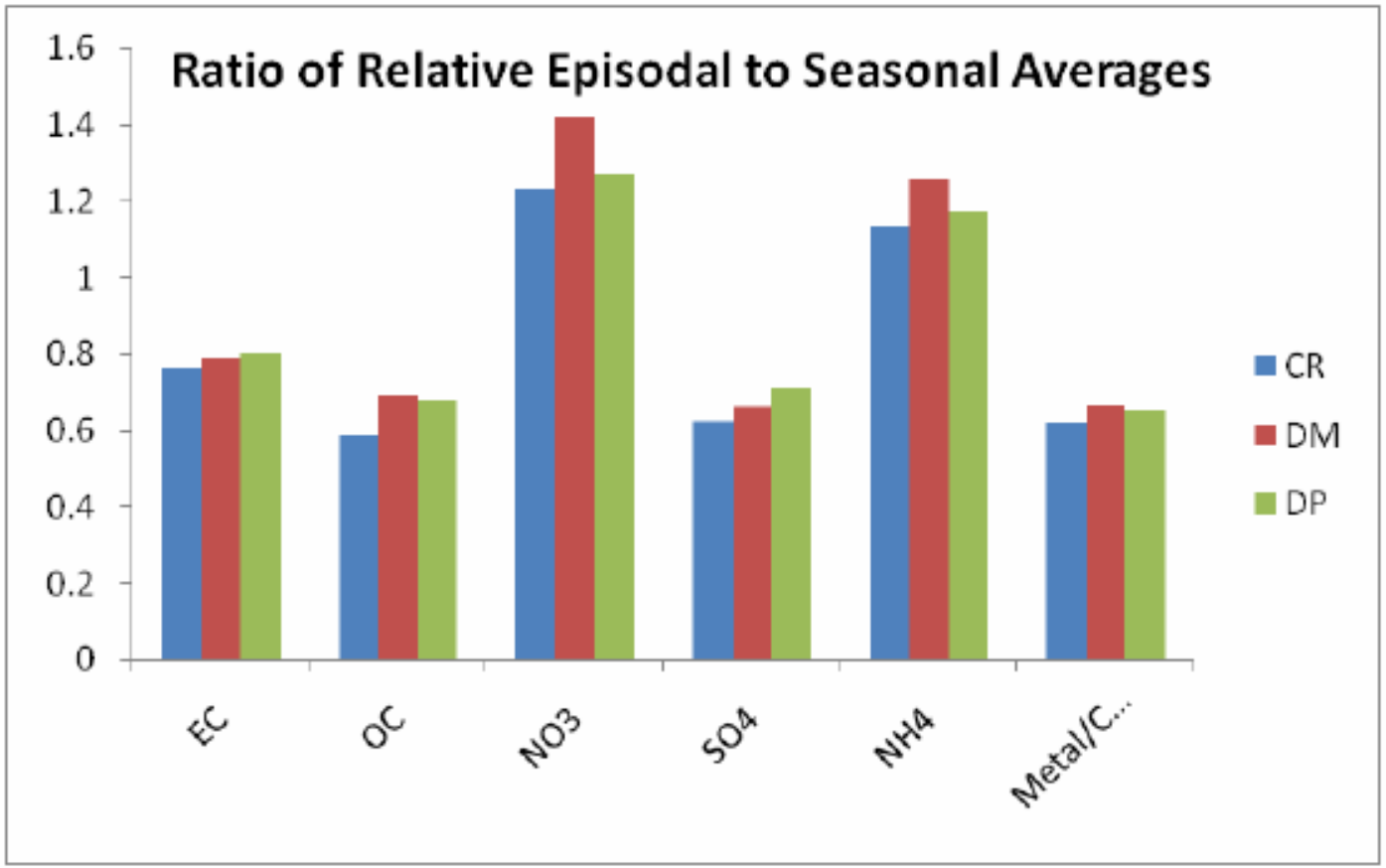


Figure 5-3. Enrichment ratios for six aerosol species during episodes. Values greater than 1 indicate an increase in the fraction of the aerosol attributable to that species during episodes. (e.g. 10% by mass on average, and 15% by mass during episodes would be a ratio of 1.5).

Regional episodes in excess of 35 μg m^{-3} are probably not frequent enough to, by themselves, put Eastern Iowa into noncompliance. The accuracy of this conclusion is predicated on the assumption that the period 2002-2008 is representative of future conditions.

Emmetsburg	100.0%
Montgomery County - Viking Lake	100.0%
Clive	100.0%
Clarion	100.0%
Lake Sugema State Park	100.0%
Des Moines Iowa - Carpenter	100.0%
Sioux City	100.0%
Des Moines - NE 3rd St - Saylor Twp	100.0%
Cedar Rapids - Wenig Rd Ne	99.3%
Van Buren County - Lacey Trail	100.0%
Waterloo	100.0%
Backbone St. Park	84.3%
Cedar Rapids - 11st St. Nw	100.0%
Council Bluffs	100.0%
Iowa City	96.3%
Davenport - Adams Elemntary - N Division St.	99.5%
Cedar Rapids - Pioneer Ave	100.0%
Davenport - 10th & Vine	100.0%
Clinton - Roosevelt St.	99.6%
Muscatine	42.6%
Keokuk	100.0%
Clinton - 23rd & Camanche	51.2%
Davenport - Blackhawk Foundry Monitor - Wellman St.	24.7%

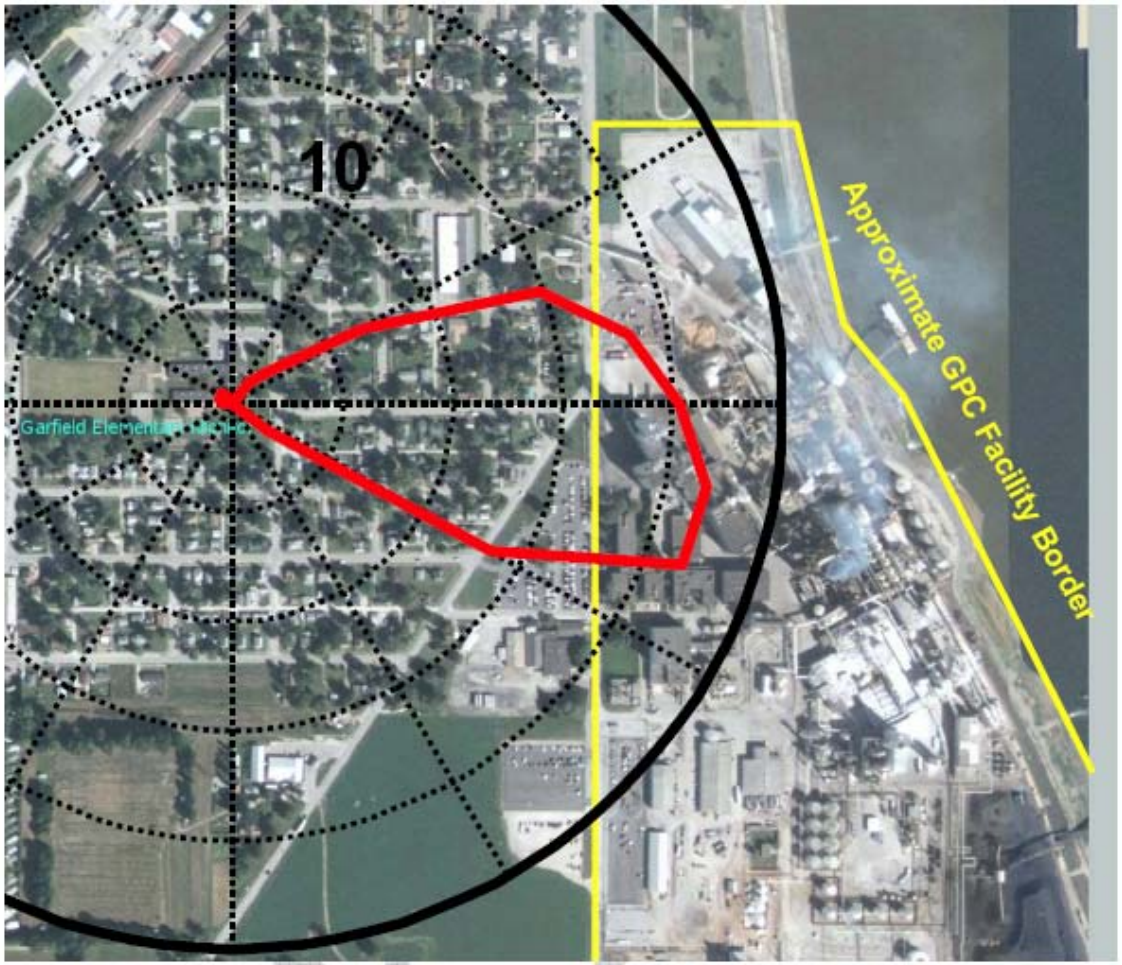
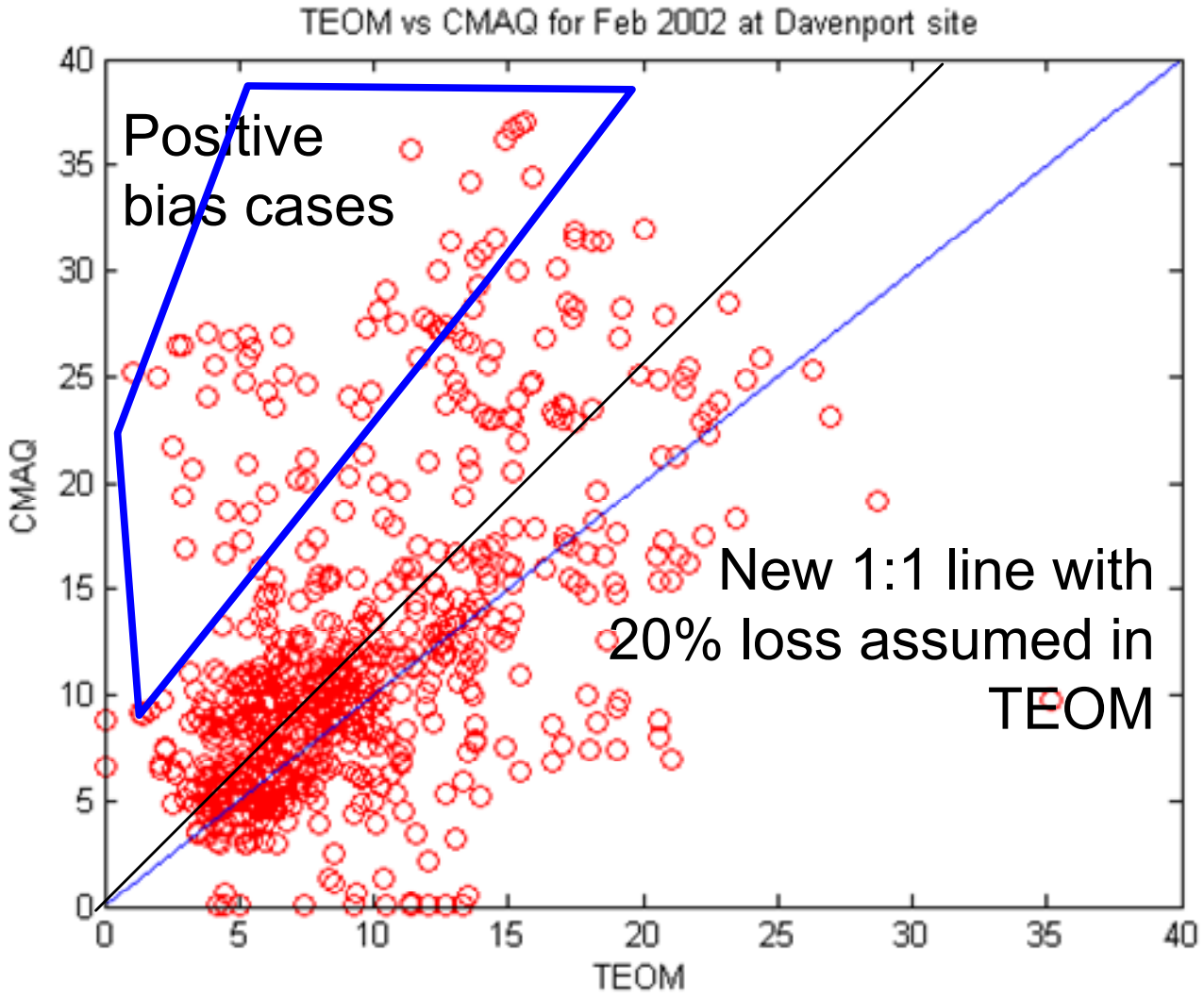


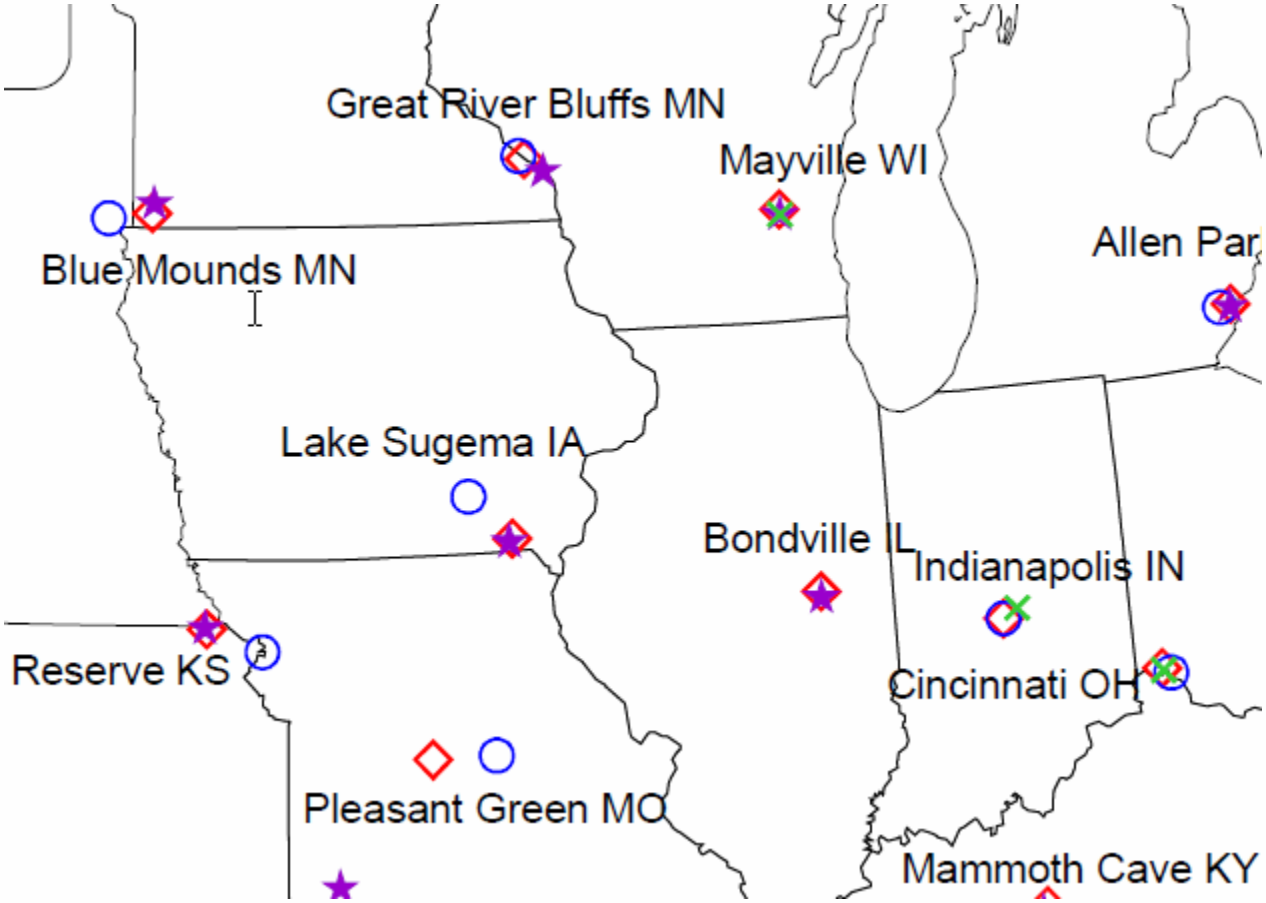
Figure 7-15. Overlay of the regression-based $PM_{2.5}$ increment vs. direction from figure 7-11 on aerial photograph of Muscatine. The polar plot is centered on the monitoring location. The rings refer to increments of 5, 10, 15, 20, and 25 μg m^{-3} on FRM measurements (over the regional median level). These values are equivalent to the best prediction of the extra mass on the FRM filter for a constant 24-hr wind direction.

- Two episodes in 2002 were compared to their corresponding model predictions from a regional implementation of the CMAQ air quality model.
  - The model reproduced the episodes fairly well.
  - Spatial patterns of total PM2.5 and nitrate, as well as temporal patterns agree.
  - The model does exhibit some high bias
  - The agreement is sufficient to explore control scenarios for reducing average and peak daily concentrations.


TEOM vs CMAQ for Feb 2002 at Davenport site
Positive
bias cases
New 1:1 line with
20% loss assumed in
TEOM
CMAQ
TEOM
0
5
10
15
20
25
30
35
40

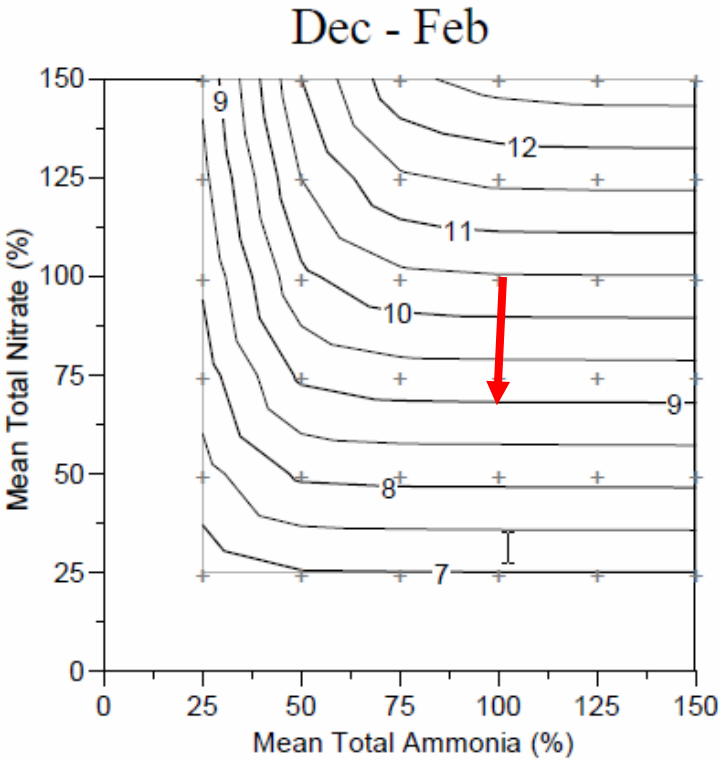
- Many authors have looked in general at the sensitivity of PM levels to total nitric acid and ammonia
  - Most analyses have not been directly applicable to wintertime episodes in the Midwest. (focus rather on long term PM, eastern U.S., and nitrate replacement).

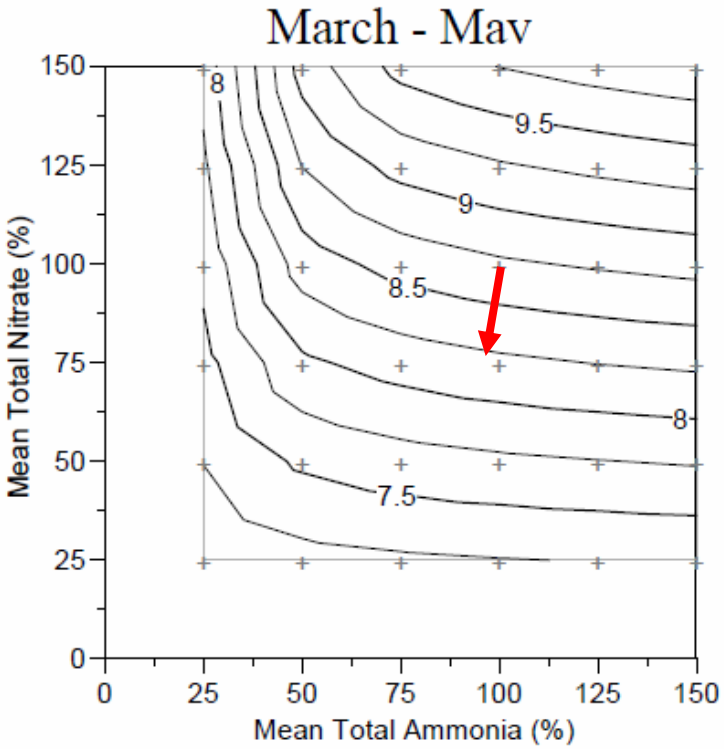
- Authors who have looked at the wintertime Midwest have some disagreement on nitric acid vs. ammonia sensitivity.
  - Dennis et al. (2008) have in their model that the Midwest in winter (Jan 2002) has an adjusted gas ratio in the range of ~1.1 to 1.7, and thus ammonia is somewhat in excess.
  - Chu et al. (2004) found that ammonia was present in excess in areas west of the Ohio river during the Feb 6-8, 2002 episode.
  - Blanchard 2008



Blanchard. 2008. Analysis of Inorganic Particulate Matter Formation in the Midwestern United States (Draft)

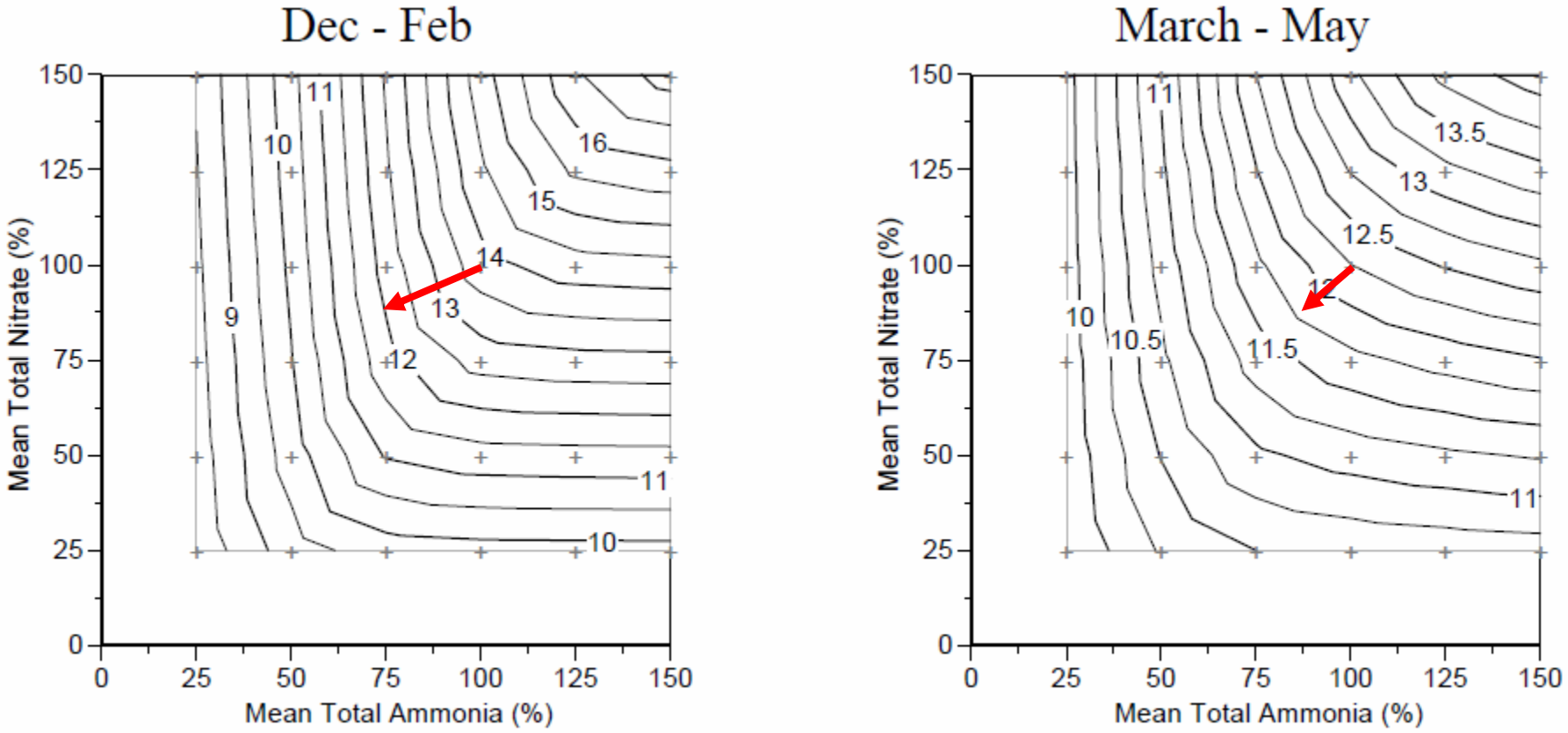
Blue Mounds, Minnesota





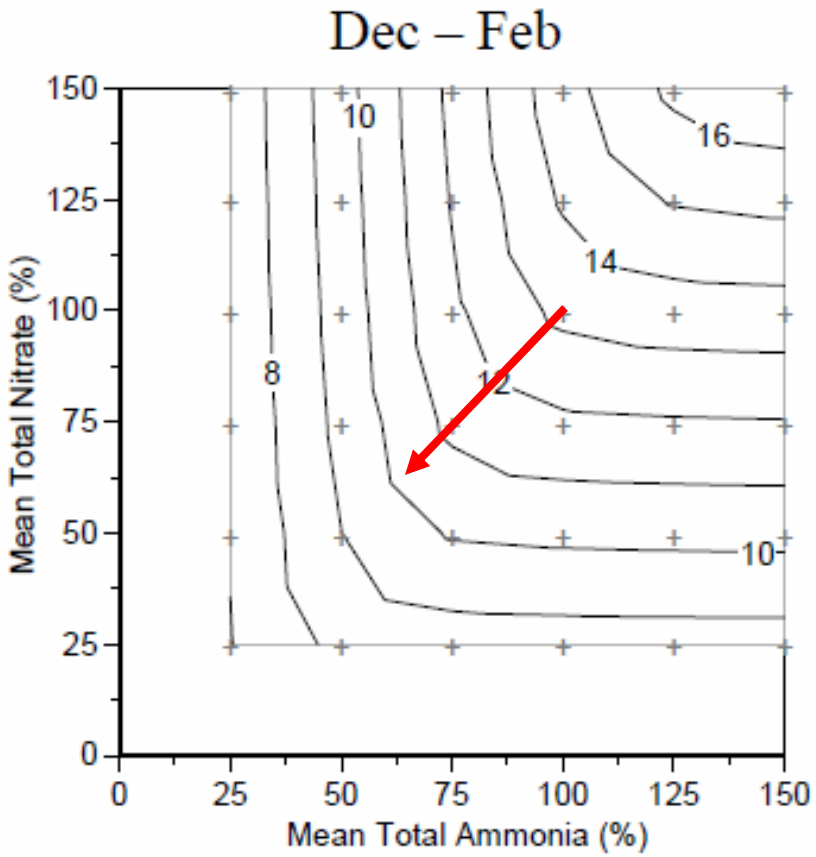
Blanchard. 2008. Analysis of Inorganic Particulate Matter Formation in the Midwestern United States (Draft)

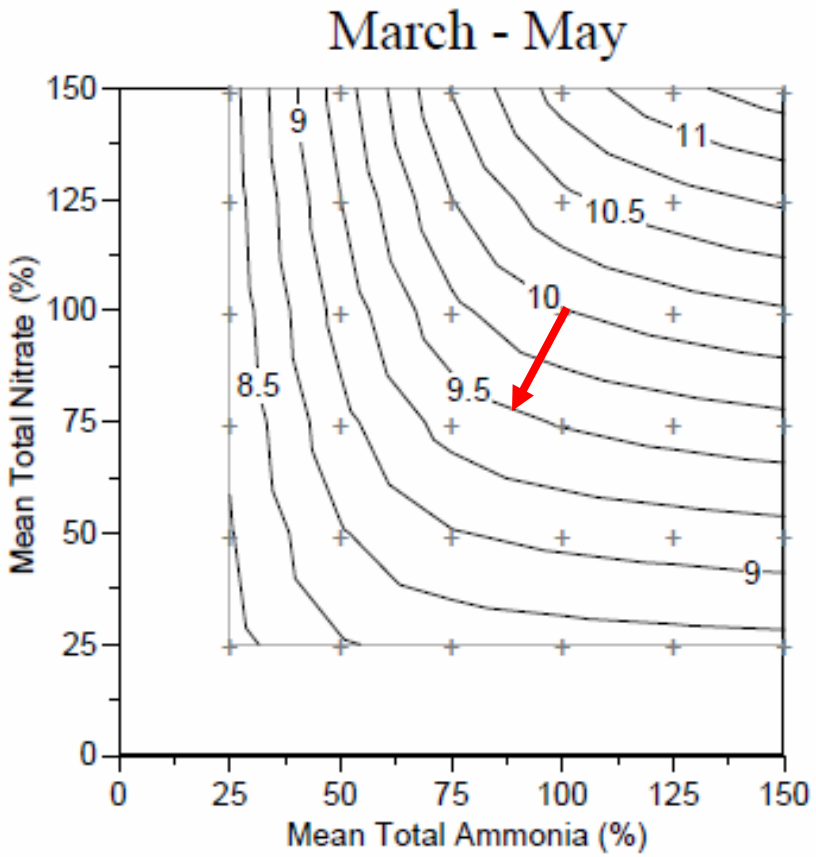
Bondville IL



Blanchard. 2008. Analysis of Inorganic Particulate Matter Formation in the Midwestern United States (Draft)

Lake Sugema Iowa





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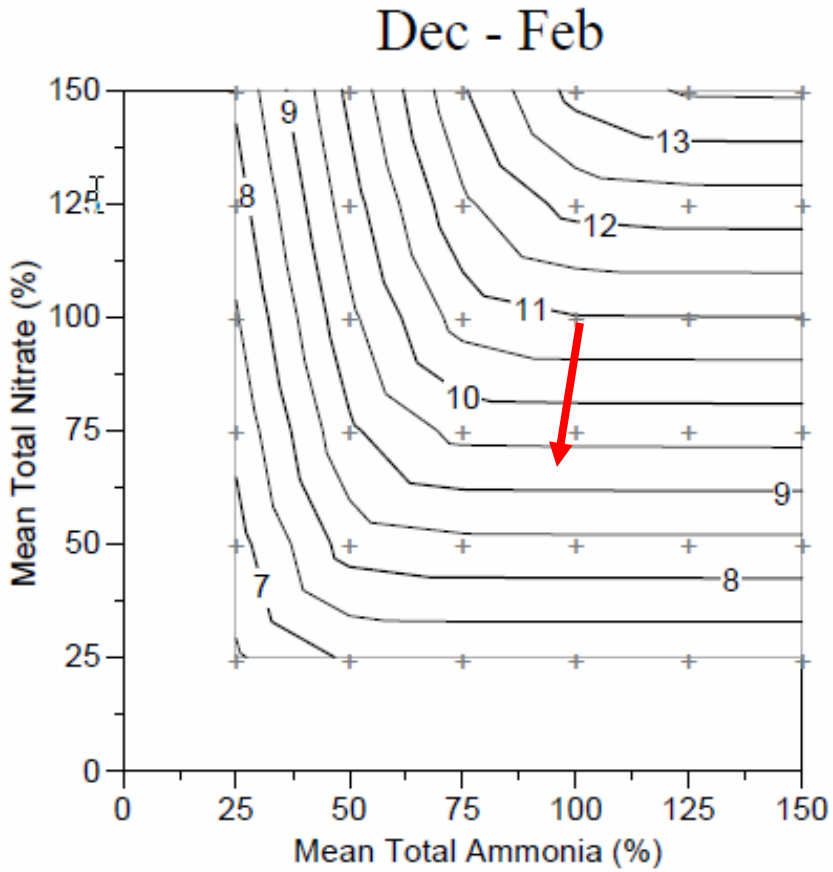
Mayville WI



Blanchard. 2008. Analysis of Inorganic Particulate Matter Formation in the Midwestern United States (Draft)

Last day of episode 2005-5. 3rd highest regional episode in UofI list

Table 8. SCAPE model results for February 3, 2005.

Sites not shown did not have complete monitoring data on this date.

State	Location	Mean PM_{25} Mass Concentration (µg/m3)				
		Base Case	50% Reduction Sulfate	50% Reduction Total Nitrate	50% Reduction Total Ammonia	50% Reduction Sulfate, Total Nitrate, and Total Ammonia
IA	Lake Sugema	30.6	27.2	22.5	19.5	18.4
IL	Bondville	32.4	29.2	23.2	18.9	17.6
KS	Reserve	6.9	6.3	5.4	6.6	4.6
KY	Mammoth Cave	20.8	16.4	20.3	17.9	14.2
MI	Allen Park	54.9	50.6	44.9	38.8	37.3
MN	Blue Mounds	6.4	6.2	4.2	6.3	3.8
MN	Great River Bluffs	24.7	22.9	17.6	17.2	15.1
MO	Pleasant Green	20.4	20.1	17.8	14.9	14.2
OH	Athens	22.1	18.7	20.4	16.6	14.5

- Rural sensitivity on long (monthly timescales) Eastern Iowa is
  - either balanced in sensitivity to nitric acid and ammonia
  - or slightly with ammonia in excess;
- No consensus (other studies say clearly ammonia excess);
- Less clear when moving to episodic timescales and urban locations;
- Quad Cities on transition line between ammonia excess (to the northwest) and ammonia limitation (to the southeast)?
- Sensitivity may change from event to event depending on season and meteorology.

- *What we were able to establish or confirm*
  - Major role for ammonium nitrate during wintertime episodes
  - Fog episodes probably not important
  - Cold weather regional episodes generally occur on the back end of a warm front.
  - Nitric acid from the NO3 radical and N2O5 are important
  - Model-based investigations of PM vs. NOx and ammonia cuts are have high probability of error due to uncertainty in sensitivity.
  - The above limitation can be overcome by combining nitrogen field measurements with models.
  - PM of local origin (from NOx, primary sources, and vehicles) is significant but not dominant during episodes.
    - Based on extrapolation from Chicago and St. Louis and needs validation. Some convergence in literature on ~25% of nitrate as local.

Knowledge Gap	Solution
Nitric acid or ammonia limiting (whether to reduce NO_x or ammonia)	***Reanalysis of existing Iowa nitrogen data and newer studies*** Intensive N sampling winter 2009-2010
Is there a trend in regional episode occurrence? Is this related to shifts in ammonia, NOx, and SO2 emissions?	***Regional modeling and additional data analysis***
Control NO_x/NH_3 in the affected county, in Iowa, or on a more broad regional scale?	***Regional modeling***
Local fraction of PM during episodes (25% ?) but with very high uncertainty, balance of primary and secondary, and source categories with most leverage	***Regional modeling*** ***Source apportionment study***

Thank you

Questions