Contribution Assessment

A requirement of USEPA's Regional Haze Regulations is a showing by a State that "…emissions from within the State contribute to visibility impairment in a mandatory Class I Federal Area outside the State, or that emissions from another State contribute to visibility impairment in any mandatory Class I Federal Area within the State". (40 CFR Part 51, Subpart P, section 51.308(c)(1)(ii)). This showing is referred to as a "contribution assessment". The purpose of this document is to present the results of an initial contribution assessment for the five States in the Midwest Regional Planning Organization (RPO): Illinois, Indiana, Michigan, Ohio, and Wisconsin.[1]

The results of this initial assessment show that emissions from within the five States likely contribute to visibility impairment in a mandatory federal Class I area in another state and that emissions from other states likely contribute to visibility impairment in the mandatory federal Class I areas in the Midwest RPO. Additionally, the results show that emissions from almost every state in the four eastern RPOs likely contribute to visibility impairment in at least one mandatory federal Class I area in another state in the eastern U.S. This suggests the need for a regional approach in developing effective control programs for regional haze (and fine particles) in the eastern U.S.

Background

In the preamble to the regional haze regulations, USEPA explained its conclusion that "all states contain sources whose emissions are reasonably anticipated to contribute to regional haze in a Class area" (see July 1, 1999, 64 FR 35720 – 35722). USEPA cited three factors: (1) the specific statutory language of the CAAA of 1977; (2) the weight of evidence demonstrating long-range transport of fine particle pollution that affects visibility in Class I areas; and (3) current monitored conditions in Class I areas across the country.

The "weight-of-evidence" noted above includes the following reports and their findings:

- 1991 report from the National Acid Precipitation Assessment Program (NAPAP): Comprehensive technical review of historical visibility trends

- 1993 National Academy of Sciences (NAS) report "Protecting Visibility in National Parks and Wilderness Areas": Range of fine particle transport is on the order of hundreds or thousands of kilometers

[1] In its May 24, 2002, ruling on challenges to the regional haze regulation, the U.S. District Court of Appeals for the D.C. Circuit expressed reservation about USEPA's extension of attainment dates for attainment and unclassified areas by allowing committal SIPs. (Note, the contribution assessment is one requirement of the committal SIPs.) The Court stated that "(n)otwithstanding our doubts about the validity of this provision, we decline to vacate it in light of the uncertainty that our decision invalidating the group-BART provisions of the Haze Rule will cast upon the contents of the SIPs required of the states. With the Rule and hence the contents of the SIPs now altered and subject to revision on remand, the more prudent course for this court is simply to remand the deadline-extension issue as well." Given the uncertain status of committal SIPs, the requirement for a contribution assessment is up in the air.

- USEPA studies using the RADM model: Sulfate and nitrate deposition receptors are influenced by sources located up to 600 – 800 km away

- 1996 Grand Canyon Visibility Transport Commission (GCCVTC) report "Recommendations for Improving Western Vistas": Acknowledged the role of long-range transport from sources and activities located across very large geographic areas, and its effect on the Class I areas on the Colorado Plateau

- Contractor reports prepared for USEPA: "Particulate Matter Source-Receptor Relationships Between All Point and Area Sources in the United States and PSD Class I Area Receptors", 1996, Latimer and Associates; and "Development of Revised Federal Class I Area Groups in Support of Regional Haze Regulations", 1996, Environ: Information that in USEPA's opinion preliminarily demonstrated that each state not having a Class I area had emissions contributing to impairment in at least one downwind Class I area

In March 2002, the inter-RPO Data Analysis Discussion Group prepared an outline of data analyses that would be appropriate to include in the contribution assessment ("Data Analyses for Contribution Assessment", March 2002). According to this document, the contribution assessment should: (1) not be a "high hurdle", (2) include additional data beyond USEPA's initial analyses supporting the haze rule, and (3) reflect a "weight-of-evidence" approach by considering several different qualitative and quantitative analyses. The suggested analyses are as follows: emissions analyses, meteorological analyses, time series (hour of day/day of week/seasonal) patterns, trajectory analyses, source apportionment, spatial pattern analyses, episodic analyses, data analysis infrastructure, and modeling analyses.

For the purpose of this document, trajectory analyses are used as the primary method to determine which Class I areas are affected by emissions from the Midwest RPO States (IL, IN, MI, OH, and WI), and which states affect Class I areas in the Midwest RPO (Seney National Wildlife Refuge and Isle Royale National Park in northern MI). Results from a recent source apportionment analysis are also considered.

Methodology

Back trajectories were generated using the HYSPLIT model (see http://www.arl.noaa.gov/ready/hysplit4.html). The model was run with the following assumptions:

Meteorological Data:	EDAS (and FNL)
Release Height:	200 m
Release Frequency:	6 hours
Grid Cell Size:	80 km
Trajectory "Timing":	000, 0600, 1200, 1800

Back trajectories were generated for the period 1997 – 2001 for Class I areas in the eastern half of the U.S. (see Figure 1 below):

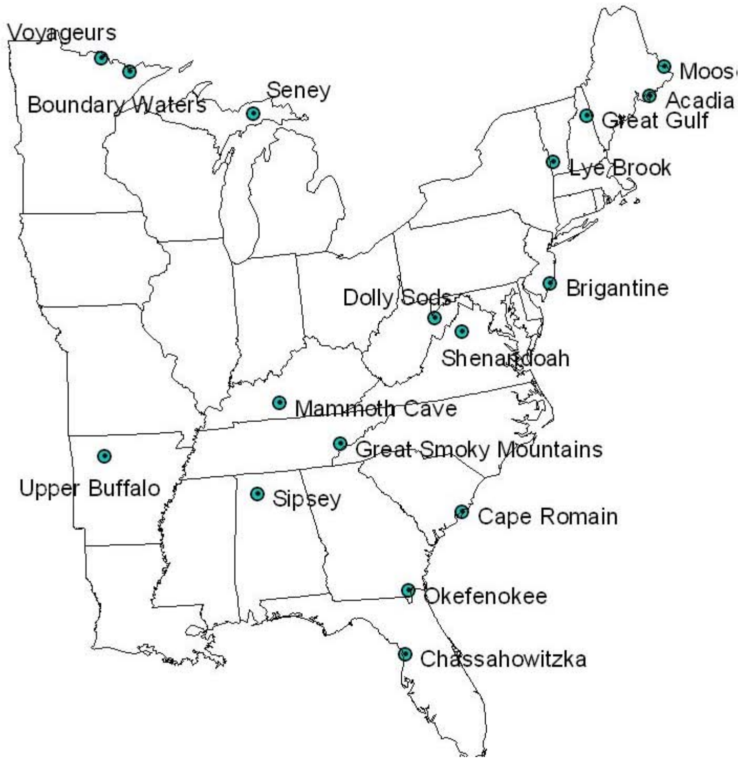


Figure 1. Select Class I Areas in the eastern U.S. (for which back trajectories were generated)

Two sets of back trajectories were prepared:

- The first set is based on 48-hour back trajectories using IMPROVE data for the 10 Class I areas in the northern half of the eastern U.S. Focusing on just these "nearby" Class I areas should be sufficient to identify the Class I areas that are potentially impacted by emissions from the five Midwest RPO States and identify the states that potentially impact the two Class I areas in the Midwest RPO States. These plots were prepared for several metrics: light extinction (20% best and 20% worst visibility days), fine particle mass concentrations, and fine particle species concentrations (sulfates, nitrates, organics, and elemental carbon).

- The second set is based on 72-hour back trajectories using IMPROVE data for all Class I areas in the eastern U.S. By considering all Class I areas, it is possible to "triangulate" back to source regions or states, and estimate the impact from these regions. That is, a time-weighted average of each state's contribution to fine particle mass in Class I areas is calculated by combining concentration (based on the IMPROVE sample at a given Class I monitor) and frequency data (based on back trajectories).

An example (48-hour) back trajectory plot for Seney NWR in northern Michigan is presented in Figure 2 below.

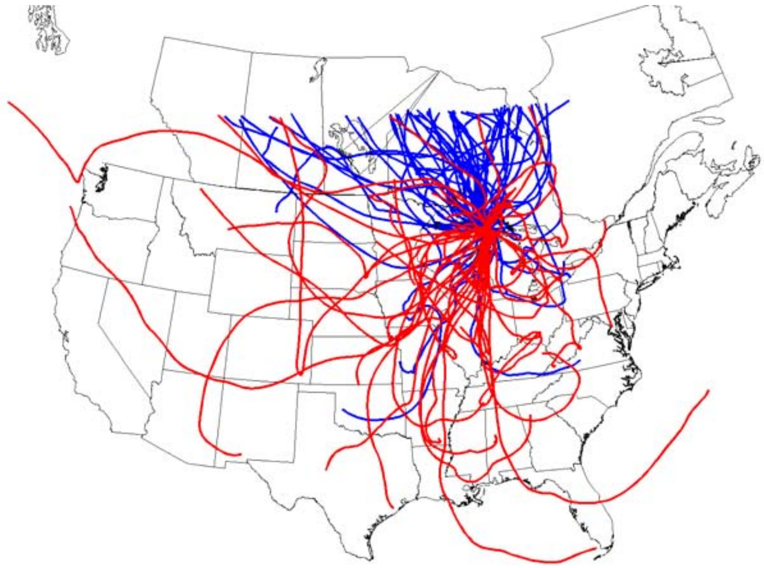


Figure 2. Back trajectories for 20% best (blue) and 20% worst (red) visibility days for Seney NWR (period 2000 – 2001)

The raw trajectory data should be gridded and contoured to provide a clearer depiction of possible upwind source regions. A summary of various metrics for contouring is provided in Attachment I.

Discussion

The (48-hour) light extinction-based back trajectory plots for the 10 Class I in the northern half of the eastern U.S. were examined to identify those (upwind) states which may be potentially impacting each Class I area. The 20% worst day and incremental probability versions of these plots for Seney, for example, are provided below. Plots for the other Class I areas are included in Attachment II.

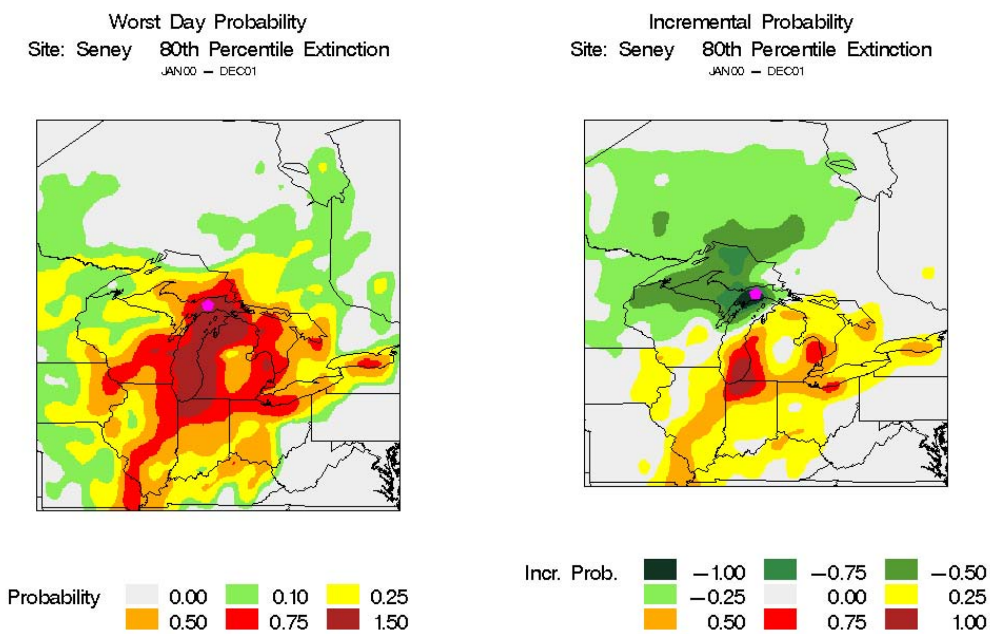


Figure 3. 20% worst visibility day plots (contoured back trajectories on left, and incremental probability on right) for Seney NWR

A state was assumed to potentially impact a Class I area if both a non-negligible portion of the state has a worst day probability > 0.50 and incremental worst day probability > 0.25. The results of this qualitative analysis are summarized in Table 1. (Note, the quantitative results presented in Table 2 generally support these findings.)

These results indicate that emissions from IL (BWCA and Seney), IN (Mammoth and Seney), MI (Voyageurs and Lye Brook), OH (Mammoth, Seney, and Lye Brook), and WI (Voyageurs, BWCA, and Seney) may contribute to visibility impairment in a Class I area in another state and that emissions from other states (IL, IN, OH, WI, MO, NY, and Ontario) may contribute to visibility impairment in the Class I areas in MI. Furthermore, the results show that most states in the four eastern RPOs may contribute to visibility impairment in at least one of the ten Class I areas considered here.

Additional insight into possible source regions is provided by considering the chemical composition of fine particle mass[2]. The figure below shows the relative chemical composition for rural IMPROVE (and IMPROVE-protocol) sites in the eastern U.S.

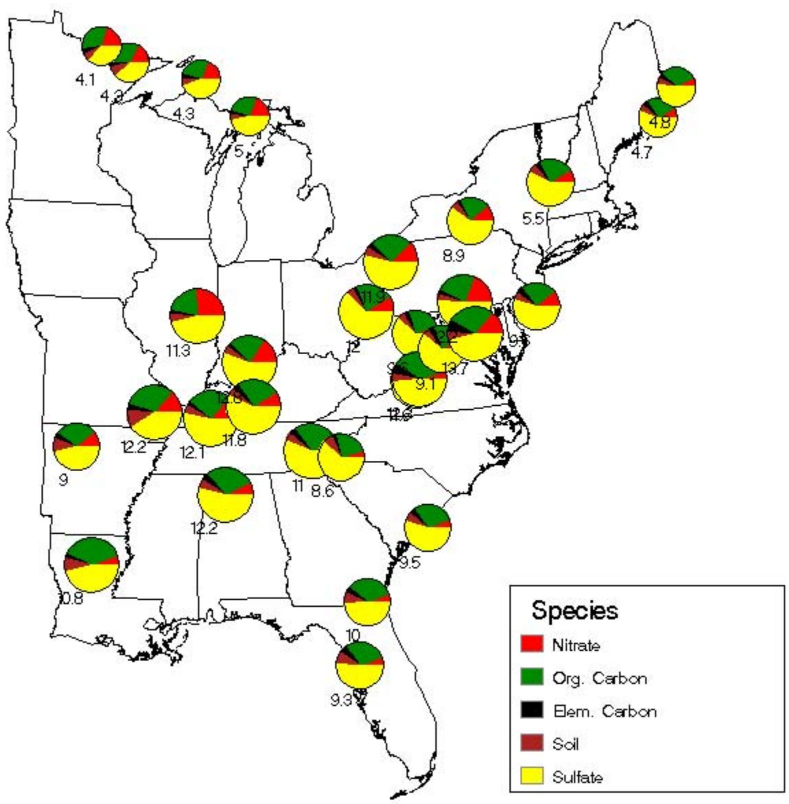


Figure 4. Chemical speciation for IMPROVE and IMPROVE-protocol sites in eastern U.S. (period 1997 – 2001)

[2] Visibility impairment is attributable to light scattering by fine particles. Fine particle mass has been shown to be highly correlated with visibility metrics, such as light extinction. This suggests that the 20% worst visibility days (and associated trajectories) are expected to be similar to those for fine particle mass.

Table 1. Possible "Outside" States Impacting Class I Areas in the Eastern U.S. (based on subjective analysis of trajectory plots)

State	Voyageurs	BWCA	IsleRoyale	Seney	Mammoth	D. Sods	Shenand.	LyeBrook	G. Gulf	Acadia	Brigantine
IL		X		X							
IN				X	X						
MI	X							X			
OH				X	X			X			X
WI	X	X		X							
MN											
IA	X	X		X							
MO	X	X		X							
AR											
LA											
ND											
SD	X										
NE											
KS											
CT								X	X	X	
DE								X	X	X	X
MA								X	X	X	
MD							X	X	X	X	X
ME											
NH									X	X	
NJ								X	X	X	
NY				X				X	X	X	
PA							X	X	X	X	X
RI									X	X	
VT										X	
AL					X						
FL											
GA					X						
KY						X	X				
MS											
NC					X	X	X	X			X
SC						X	X				
TN					X	X	X				X
VA					X	X		X		X	X
WV					X		X	X			X
Ontario				X				X	X		

The dominant species across the eastern U.S. is sulfates, comprising about 1/2 to 3/4 of annual average PM2.5 concentrations, as well as organics and nitrates. In the upper Midwest, in particular, organics and nitrates are important species.

The (48-hour) fine particle species-based back trajectories were examined to identify those (upwind) states which may be potentially impacting each Class I area on a species-by-species basis. These incremental probability plots for Seney, for example, are provided in Figure 5. Plots for the other Class I areas are included in Attachment III.

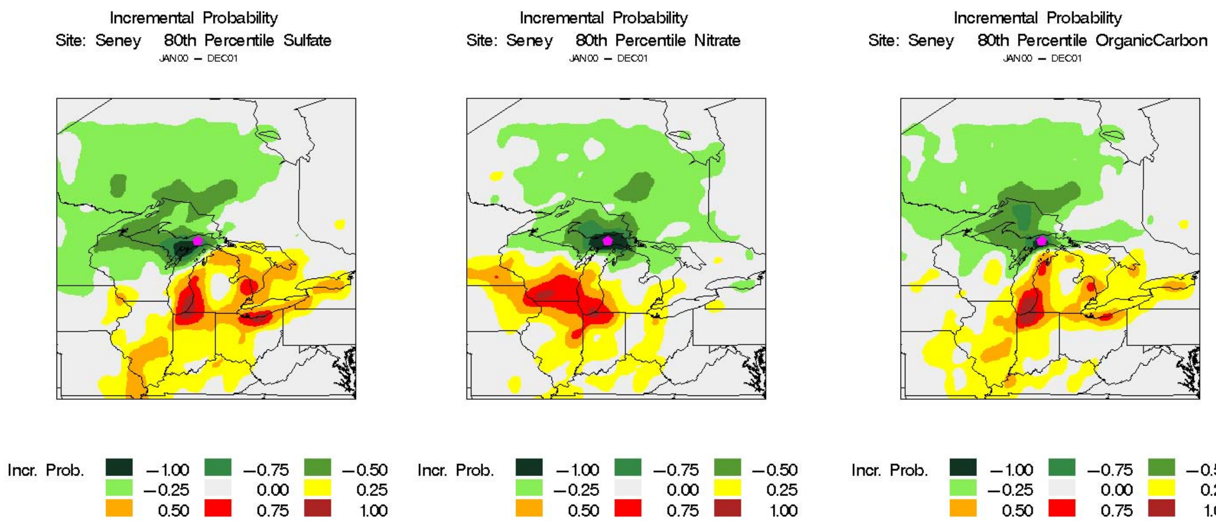


Figure 5. 20% worst visibility day plots by species (incremental probability) for Seney NWR

The plots generally show that higher sulfate concentrations are associated with regions of high sulfur emissions (e.g., Ohio River Valley), higher nitrate concentrations with the region of high ammonia emissions in the upper Plains, and higher organic concentrations with nearby urban areas.

More quantitative information from a regional perspective about source regions can be derived from the (72-hour) multi-site back trajectory plots. Figure 6 shows the average concentration for each of the major chemical species based on five years of back trajectories for the 17 rural sites shown in Figure 1[3]. Areas of higher concentration are represented by the "hotter" (or darker) colors. In general, the plots show that higher sulfate concentrations are associated with the Ohio River Valley (region of high SO2 emissions), higher nitrate concentrations with the upper Plains (region of high ammonia emissions), and higher carbon concentrations with the Southeast (region of high biogenic and fire emissions). Table 2 identifies those states with at least a 2% contribution to each Class I area. The results are similar to those in Table 1, but tend to show impacts from Midwest RPO States on additional Class I areas. (This may be due, in part, to the longer duration of these back trajectories – i.e., 72-hour v. 48-hour).

[3] Distributing concentrations along trajectories and gridding the resulting data points produces a concentration-like spatial map. This map is more consistent with the underlying data than a map derived by interpolating between monitoring sites, given the sparse nature of the network in portions of the eastern U.S. (e.g., upper Midwest)

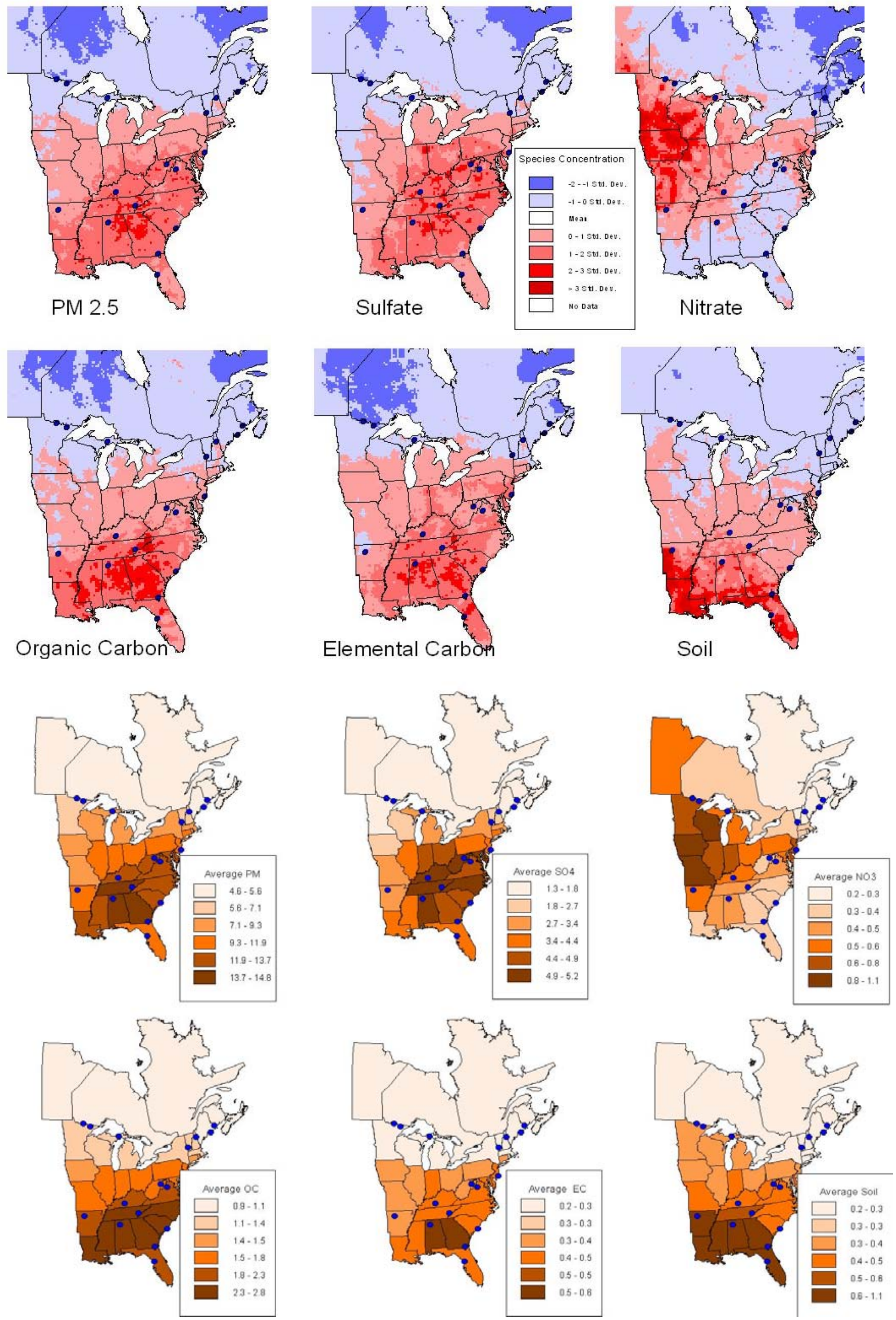


Figure 6. Multi-site contoured back trajectory plot for chemical species by grid cell (top) and state (bottom) (period 1997 – 2001)

Table 2. Percentage Impacts (> 2%) of States on Class I Areas in the Eastern U.S. (based on analysis of multi-site trajectory plots)

State	Voyageurs	B. Waters	IsleRoyale	Seney	Mammoth	D. Sods	Shenand.	LyeBrook	G. Gulf	Acadia	Brigantine
IL				4.31	5.25						
IN					6.30	3.17	2.73				
MI				14.18	2.16	2.62					2.46
OH					3.19	8.78	5.99	4.23	2.78		2.96
WI	5.65	7.61		9.93							
MN	34.37	35.16		5.20							
IA	5.83	5.02		5.49							
MO				2.50	4.08						
AR					2.71						
LA											
ND											
SD											
NE											
KS											
CT											
DE											
MA								2.17			
MD							2.31				3.51
ME									4.76	12.6	
NH									10.65		
NJ											5.19
NY								22.80	12.62	4.35	3.24
PA						5.05	5.68	6.89	4.41	3.00	8.00
RI											
VT								4.36	7.05		
AL					8.57						
FL											
GA					5.34						
KY					20.40	8.63	6.47				
MS					4.13						
NC						3.06	5.00				4.22
SC							2.44				
TN					12.19	4.91	3.59				
VA						7.64	23.44				7.40
WV						26.42	12.33				
Ontario	14.34	16.43		13.00		4.75	4.07	10.60	9.72	7.72	6.31
Quebec								8.66	16.64	17.78	3.18
Manitoba	10.26	7.29		2.41							

Further information on possible source regions is available from a source apportionment study conducted with data from 10 IMPROVE and six CASTNET sites (see map below) (Battelle, 2002).

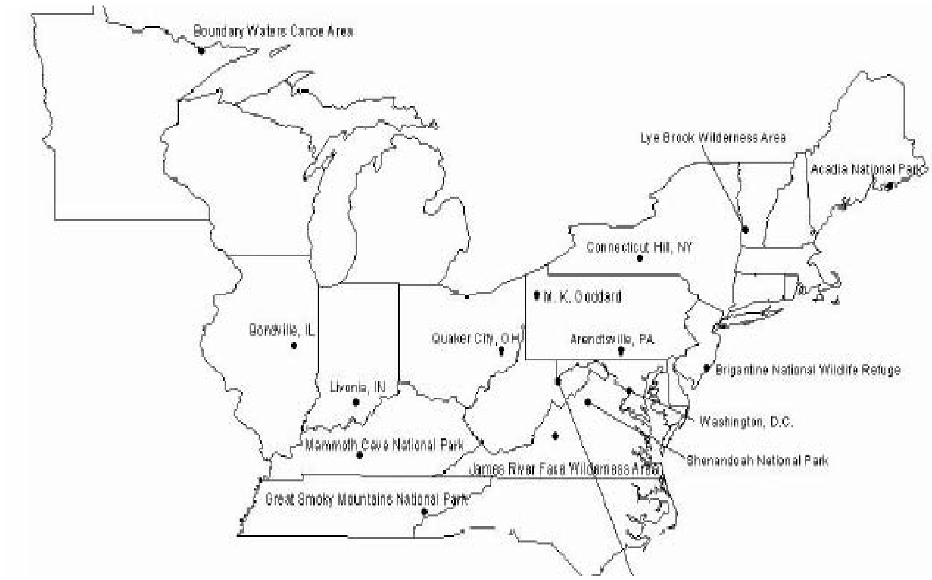


Figure 7. Map of IMPROVE and CASTNet sites considered in source apportionment study

Table 3 shows the average amount of mass attributed to various source types.

Table 3. Mass Attribution (ng/m3) by Source Types for 10 IMPROVE and 6 CASTNet Sites

Probable Source	Acadia NP	Boundary Waters	Brigantine NWR	Dolly Sods WA	Mountains NP	James River Face WA	Lye Brook WA	Mammoth Cave NP	Shenandoah NP	Washington D.C.
Crustal	73	203	112	796	556	510	502	752	177	199
Crustal limestone										
Diesel			651	226	155	405		394		935
Fe mining		200								
Incinerator	399	231		193	328	267	190			
Industrial			330					142		
Pulp mill contribution						474				
Residual oil combustion			619					686		289
Road salt		53					71			
Sea salt	393		663	1163	177				328	311
Secondary OC	3936	2188	3482	4521	6629	3701	376	6100	3222	7765
Secondary sulfate	2263	2354	5704	5042	4808	7197	3557	4932	4471	7543
Smelter							457			
Vegetative burning	341	184		729	708		2422	2998	3480	278
Woodsmoke						2164				

Probable Source	Arendstville	Bondville	Connecticut Hill	Livonia	M.K. Goddard	Quaker City
Crustal	111	102	84	492	208	918
Crustal limestone				7331	8124	7891
Diesel	37		86		318	
Fe mining						
Incinerator		133		1867	369	
Industrial						
Pulp mill contribution						
Residual oil combustion						
Road salt	41					
Sea salt						
Secondary OC	2019	272	1513	3919	4213	1956
Secondary sulfate	6216	5362	5534	6260	5786	6291
Smelter				228		
Vegetative burning	60	829		48	437	25
Woodsmoke						

(Note: areas in yellow indicate "significant" (> 15%) bext impact on worst (20%) visibility days)

The results show that at these sites, the major contributors to visibility impairment during the worst visibility days and fine particle mass are sources of secondary sulfates and secondary organics. (Note, nitrates were not considered in this study.)

Contoured (5-day) back trajectories based on ATAD for these two chemical species for Boundary Waters, Lye Brook, Shenandoah, and Washington, D.C. are provided in Figure 8 (Battelle, 2003). These back trajectories are similar to those in provided in Attachment III, but indicate additional upwind source regions due to the longer time periods associated with the ATAD trajectories compared to the HYSPLIT trajectories.

Summary

Based on consideration of back trajectories and source apportionment analyses, it can be concluded that emissions from IL, IN, OH, and WI likely contribute to visibility impairment in a Class I area in other states and that emissions from other states likely contribute to visibility impairment in the Class I areas in MI. This showing meets the statutory requirements of the contribution assessment (section 51.308(c)(1)(ii)) and provides information to support State Implementation Plan development. Additionally, it demonstrates the importance of interstate transport and the need for a regional approach in developing effective control programs for regional haze in the eastern U.S.

References

Battelle, 2002, "Source Apportionment Analysis of Air Quality Monitoring Data: Phase 1", May 2002.

Battelle, 2003, "Quick-Look Back Trajectory Analysis", draft PowerPoint presentation, January 14, 2003

LADCO, 2003, "Quantifying Transboundary Transport of PM2.5: A GIS Analysis", May 2003.

Attachment I
Ensemble Trajectory Analysis

Raw trajectory data are gridded and contoured to provide a clearer depiction of possible upwind source regions. The following metrics for contouring are used (see "Ensemble Trajectory Analysis", D. Kenski, LADCO, June 2001):

Everyday Probability (or Residence Time): Once a grid has been defined, trajectory endpoints in each cell are summed. The sum of trajectory endpoints in each grid cell (n_{ij}) represents the number of times an air parcel moved through cell i,j on its way to the receptor. The ratio of endpoints in each cell to the sum of all endpoints (N) can be thought of as the wind frequency distribution around the receptor. Everyday probability can be interpreted as the fraction or percent of time that a particular grid cell was upwind of a receptor site. Figure 1a shows a plot of everyday probability calculated from trajectories for Boundary Waters Canoe Area. The legend describes the probability as a percent calculated as (n_{ij}/N) *100. The values are displayed as six increments of the range of probabilities calculated for this set of trajectories.

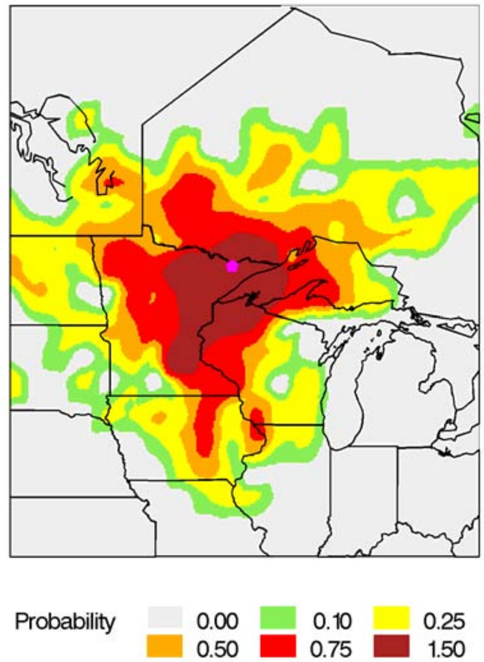


Figure 1a. Everyday Probability (BWCA)

Worst Day Probability: Another way to summarize trajectories is to look at the subset associated with a particular air quality condition of interest (e.g., 20% best and 20% worst visibility days). The probability of the worst visibility days can be assessed graphically just like everyday probability above, although in this case the worst-day probability is defined as the number of worst-day endpoints in a cell (m_{ij}) divided by the total worst-day endpoints M. This metric represents the joint probability that on any sample day the wind passed through that cell and met the definition of poor air quality. Figure 1b shows the worst-day probability, m_{ij}/M, as an unadjusted percentage, for Boundary Waters Canoe Area.

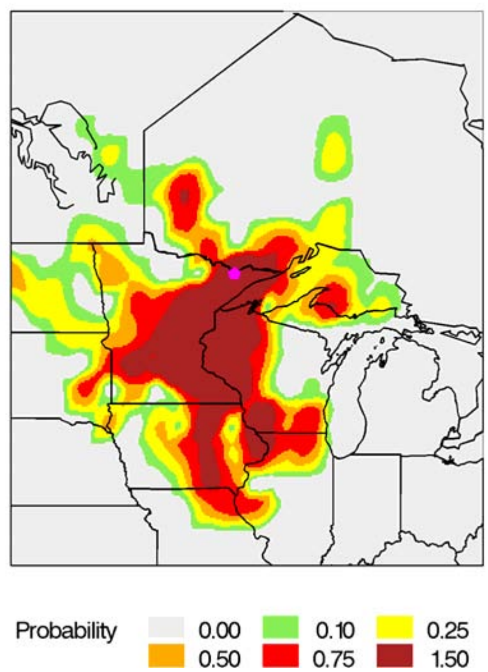


Figure 1b. Worst Day Probability for BWCA

A problem with both of the probability plots is what is referred to as the 'central tendency'. That is, because all trajectories have their starting point in the grid cell that contains the monitor site (or point of interest), the probabilities naturally increase with proximity to the site. As the distance from the site increases, the number of grid cells an endpoint could possibly be in also increases (i.e., from the central cell where all trajectories begin, the next endpoint could be in any of the 9 cells surrounding it, or in the next 'ring' of 16, etc.) and, as a result, the probability of an endpoint being in any particular cell decreases. This central tendency effect can obscure the patterns of most interest to the analyst, which are the locations where trajectories associated with high concentrations are most likely to pass through. Three methods have been used to eliminate this effect:

- Distance Weighting: This metric is calculated by applying a distance-weighting function to weight observations farther from the receptor more heavily than closer observations. A similar approach is to simply weight by distance from the monitor. This method is strictly a geometric adjustment and does not account for wind distribution.

- Source Contribution Function: This metric is calculated by dividing the worst day probability surface by the everyday probability surface. This ratio is another conditional probability (i.e., if the wind passed through the grid cell, it had an m_{ij}/n_{ij} probability of being a poor air quality day).

- Incremental Probability: This metric is calculated by subtracting the everyday probability (n_{ij}/N—how often this cell was upwind on any given day) from the worst probability (m_{ij}/M—how often this cell was upwind on poor air quality days). The resulting surface identifies where the probability of poor air quality is higher than the everyday probability. The subtraction also has the effect of removing the underlying wind frequency. An example is shown in Figure 1c for Boundary Waters Canoe Area. "Hotter" color represent areas where the incremental probability is higher (i.e., areas most likely to contain sources that affect visibility at the receptor). Because of its simplicity, this metric is used here.

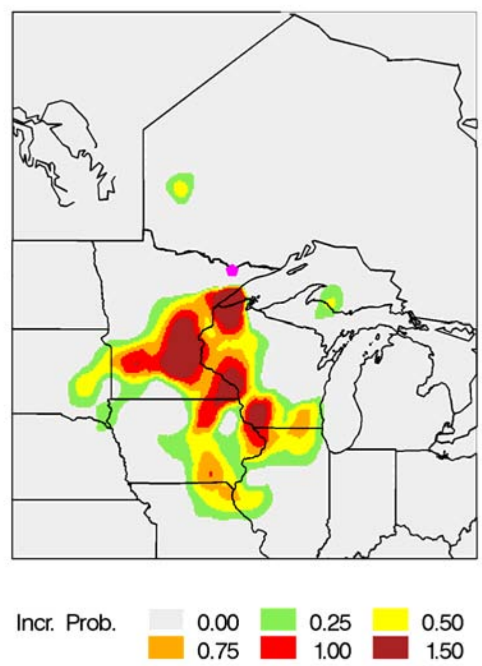
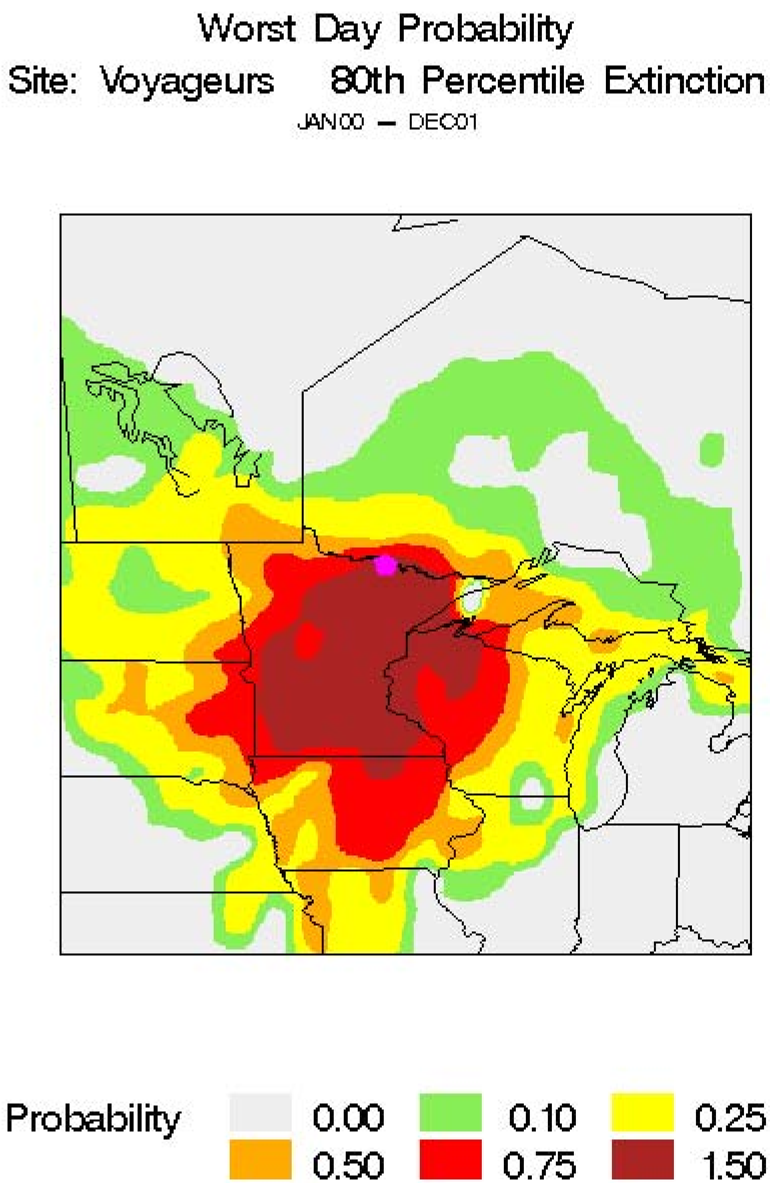


Figure 1c. Incremental Probability for BWCA

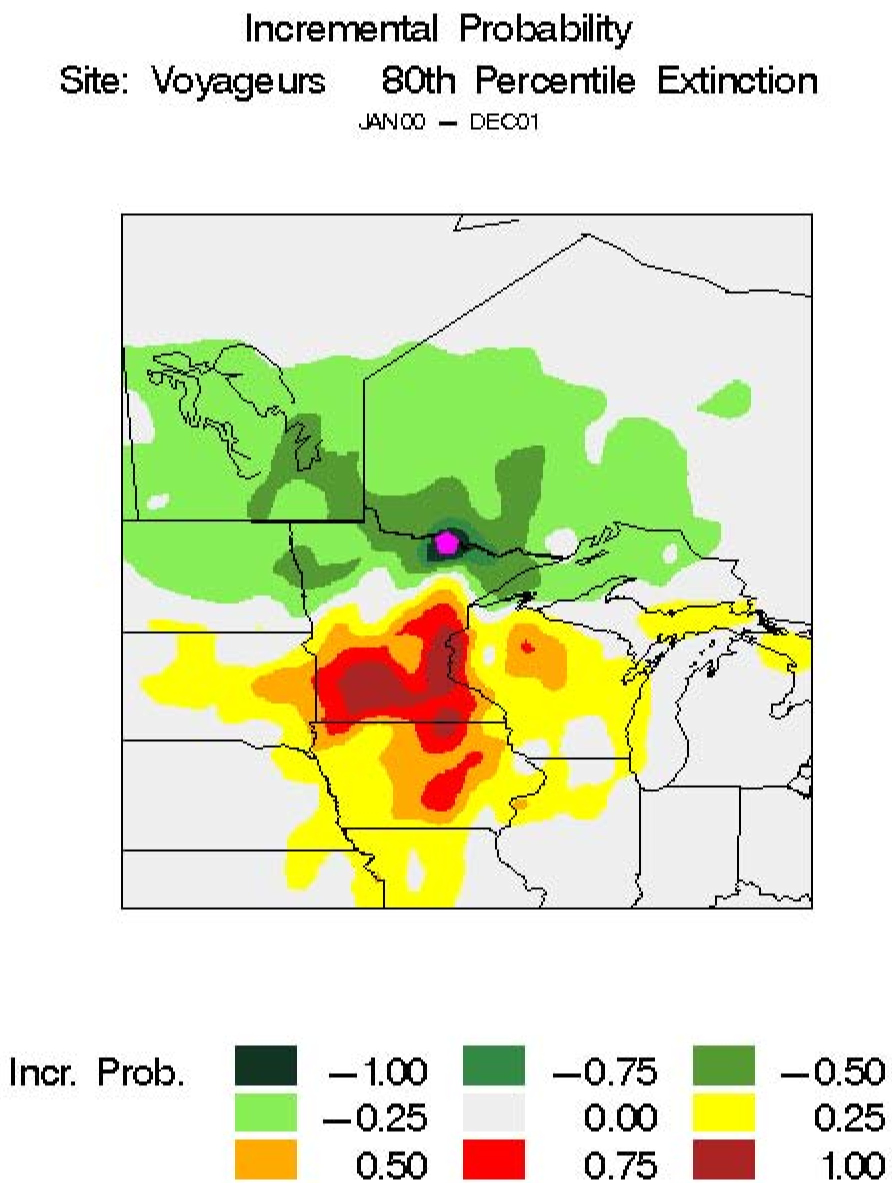
Attachment II

Contoured Trajectories Based on Light Extinction for Class I Areas in the Eastern Half of the U.S.

May 15, 2003



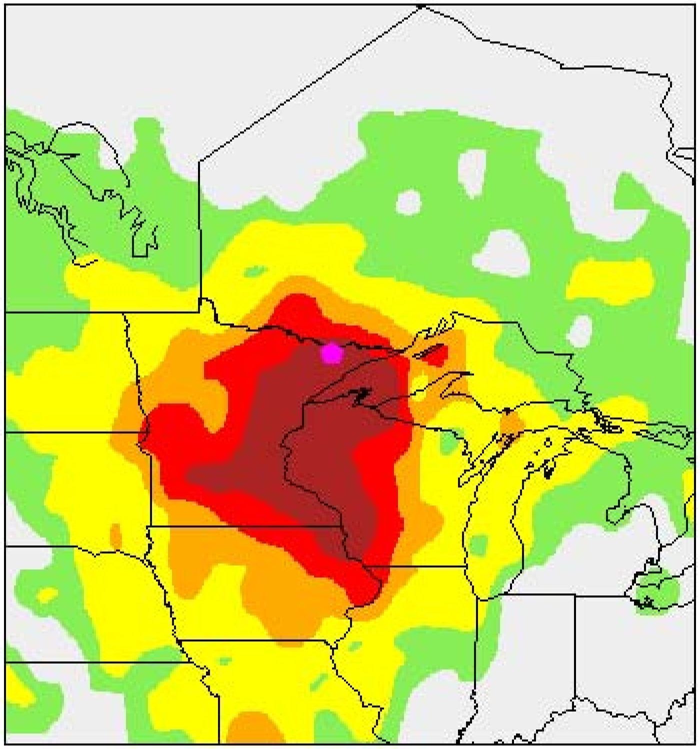
Worst Day Probability
Site: Voyageurs 80th Percentile Extinction
JAN00 – DEC01
Probability
0.00
0.10
0.25
0.50
0.75
1.50



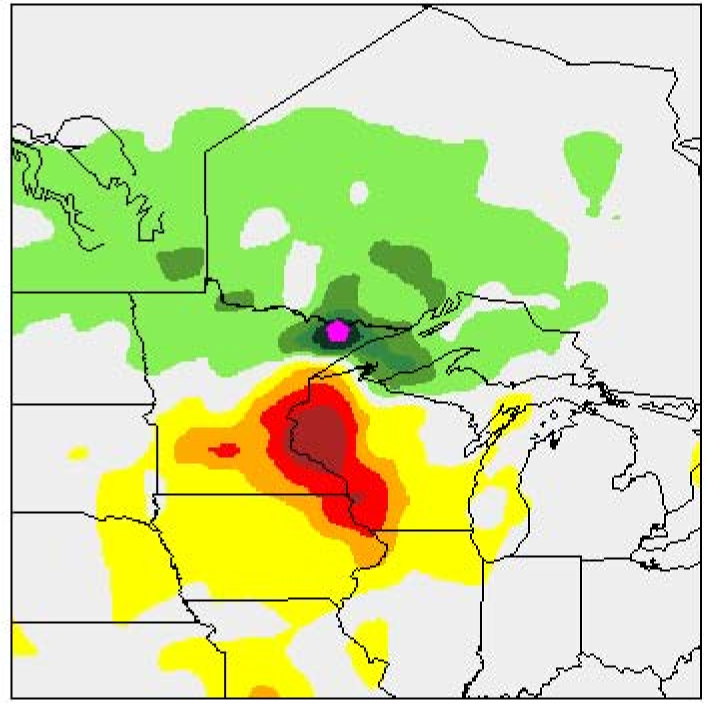
Incremental Probability
Site: Voyageurs 80th Percentile Extinction
JAN00 – DEC01
Incr. Prob.
–1.00
–0.75
–0.50
–0.25
0.00
0.25
0.50
0.75
1.00

May 15, 2003

Worst Day Probability
Site: Boundary Waters 80th Percentile Extinction
JAN97 – DEC01



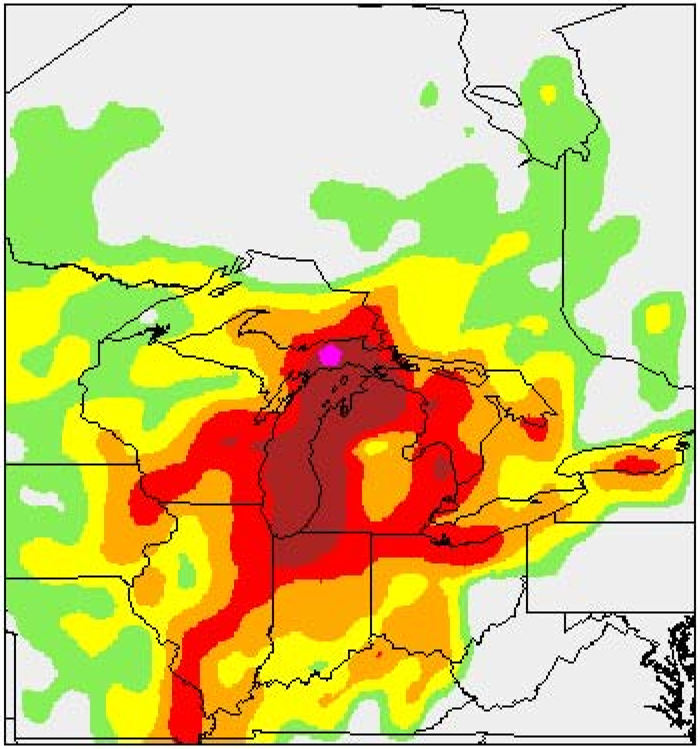
Incremental Probability
Site: Boundary Waters 80th Percentile Extinction
JAN97 – DEC01



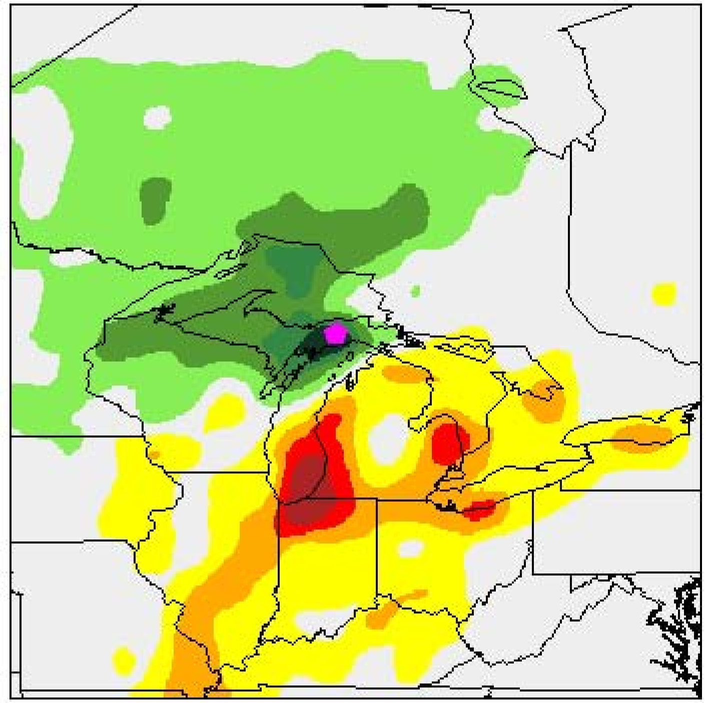
Probability 0.00 0.10 0.25 0.50 0.75 1.50

Incr. Prob. –1.00 –0.75 –0.50 –0.25 0.00 0.25 0.50 0.75 1.00

Worst Day Probability
Site: Seney 80th Percentile Extinction
JAN00 – DEC01

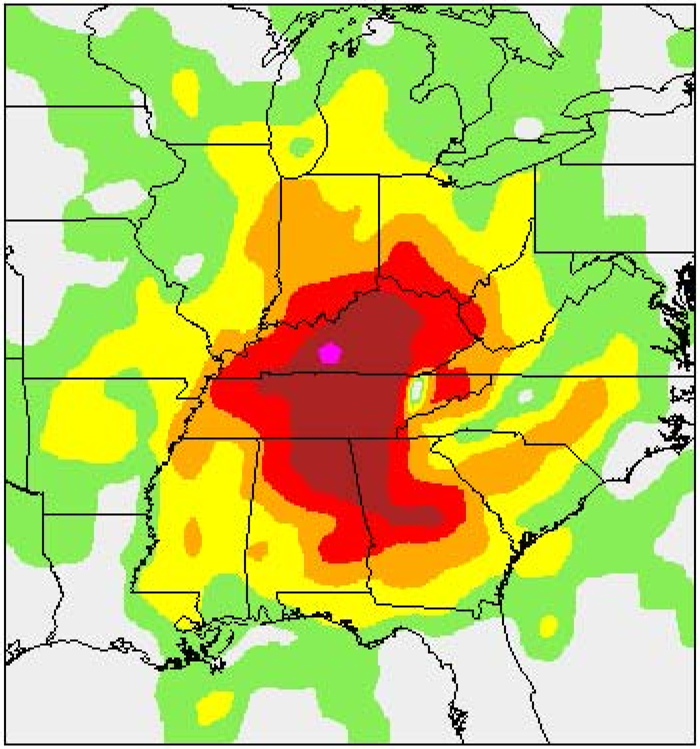


Incremental Probability
Site: Seney 80th Percentile Extinction
JAN00 – DEC01

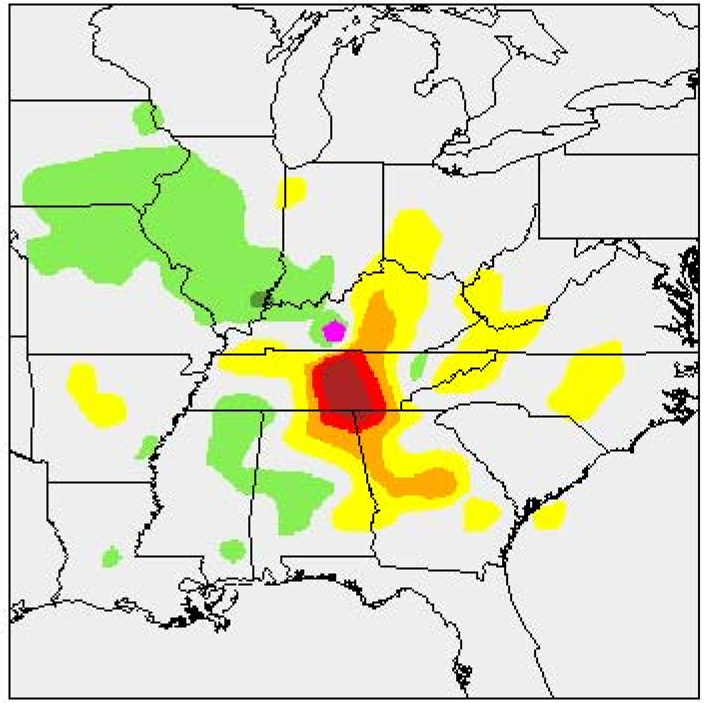


May 15, 2003

Worst Day Probability
Site: Mammoth Cave 80th Percentile Extinction
JAN97 – DEC01



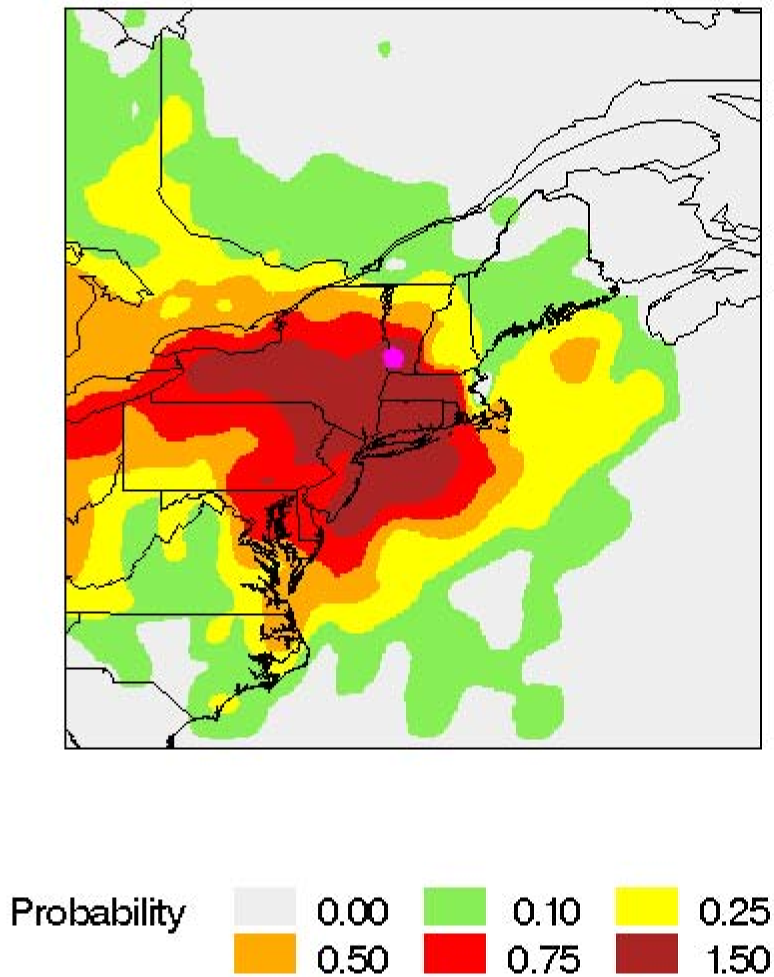
Incremental Probability
Site: Mammoth Cave 80th Percentile Extinction
JAN97 – DEC01



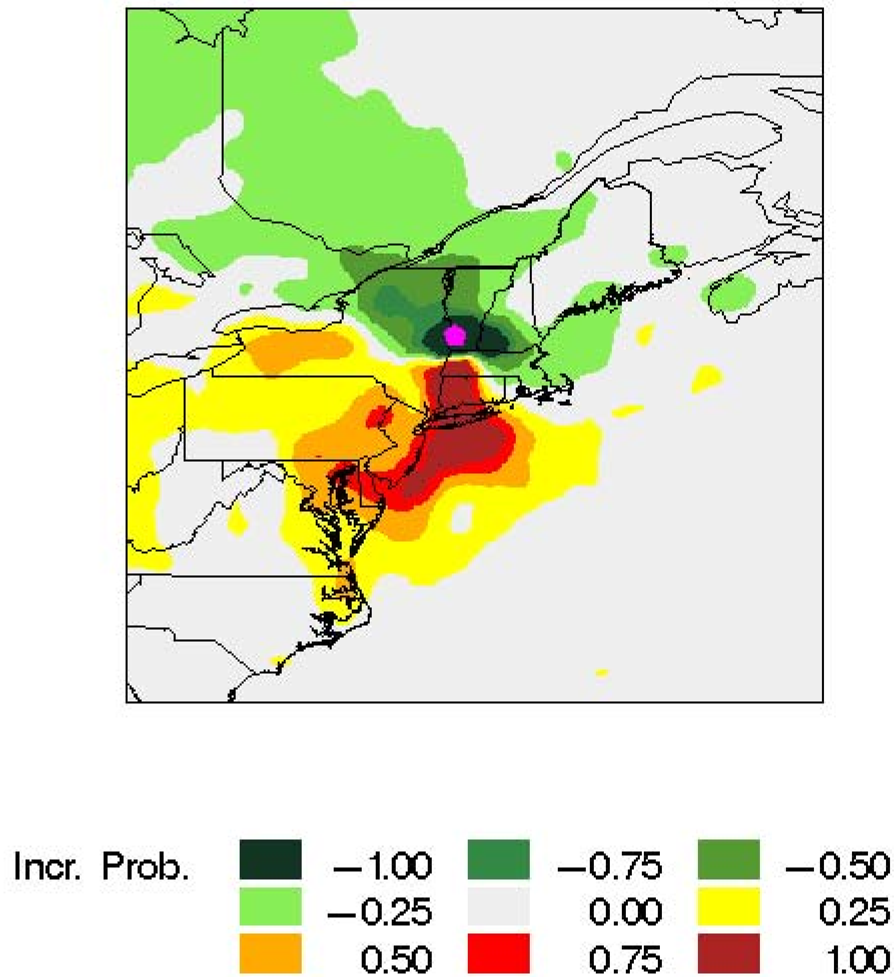
Probability			
	0.00	0.10	0.25
	0.50	0.75	1.50

Incr. Prob.			
	–1.00	–0.75	–0.50
	–0.25	0.00	0.25
	0.50	0.75	1.00

Worst Day Probability
Site: Lye Brook 80th Percentile Extinction
JAN97 – DEC01

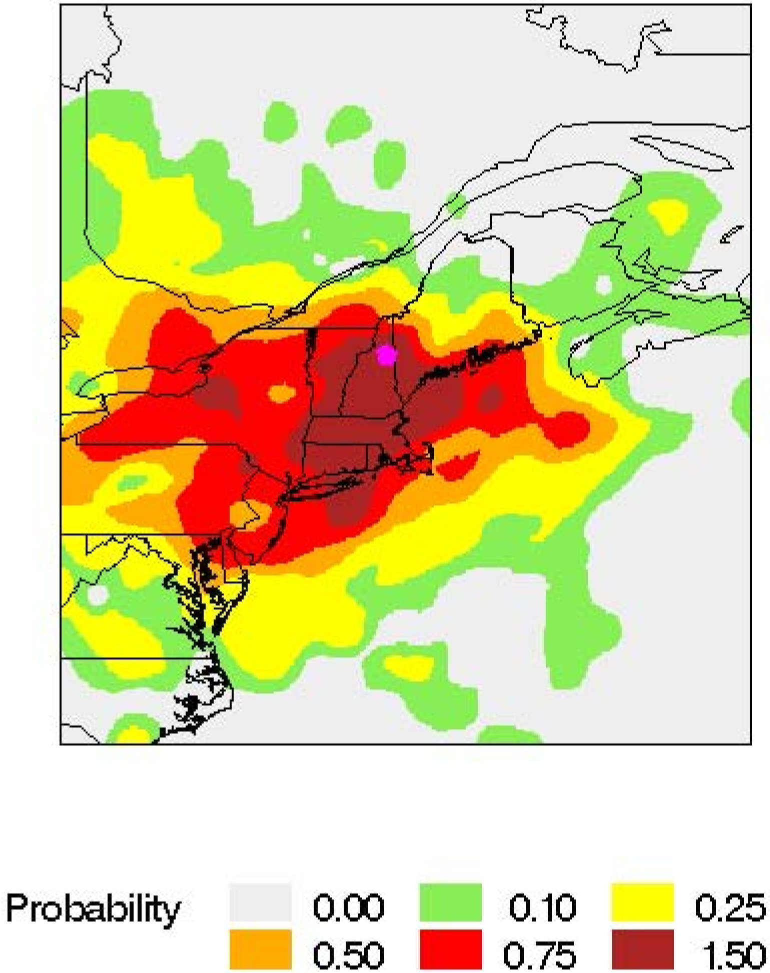


Incremental Probability
Site: Lye Brook 80th Percentile Extinction
JAN97 – DEC01

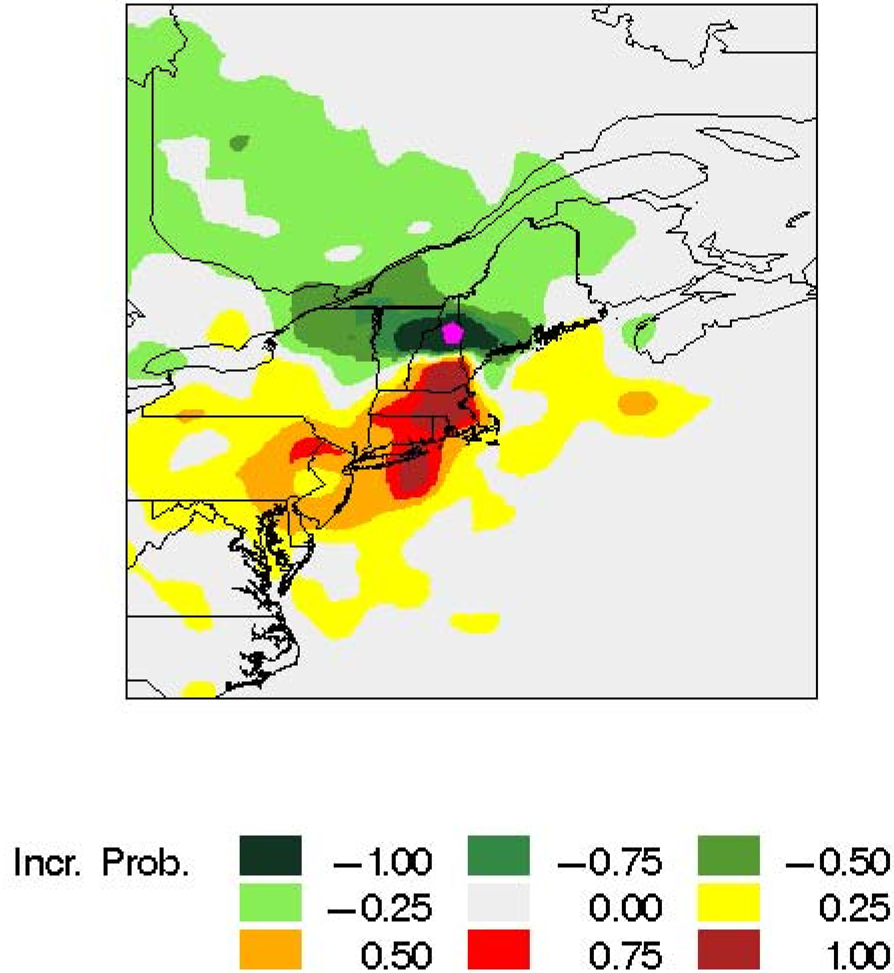


May 15, 2003

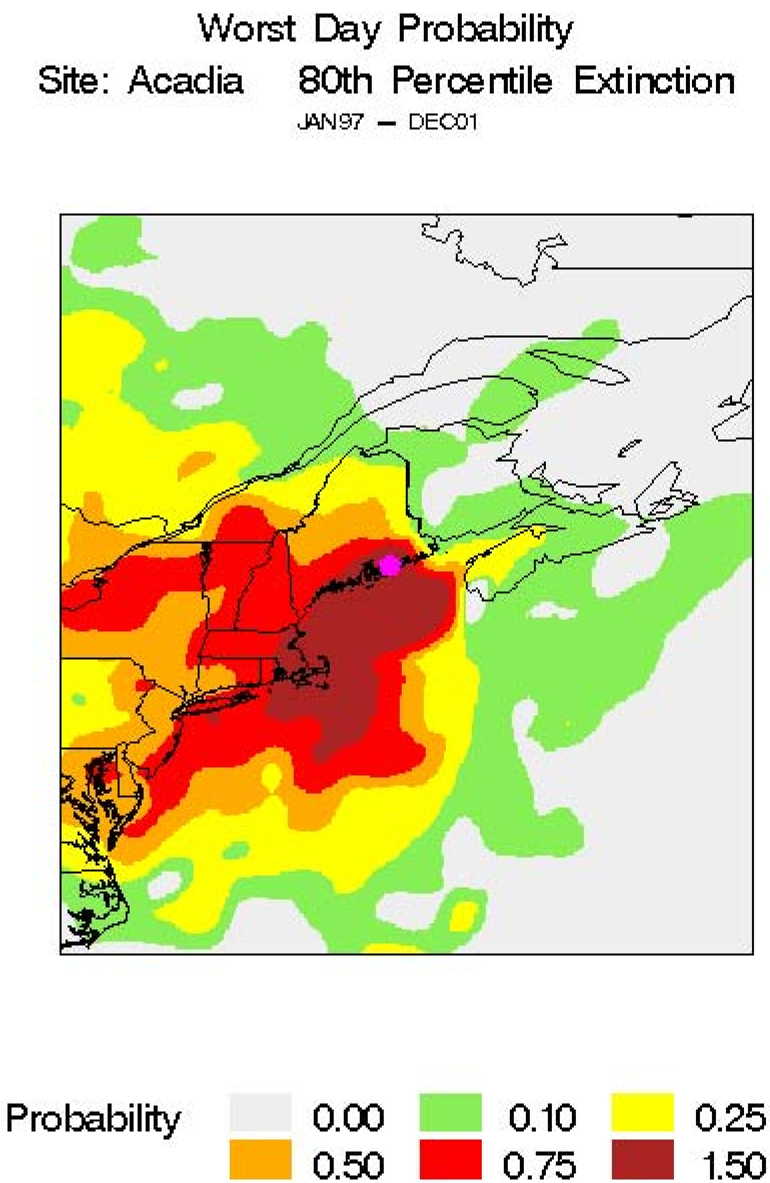
Worst Day Probability
Site: Great Gulf 80th Percentile Extinction
JAN97 – DEC01

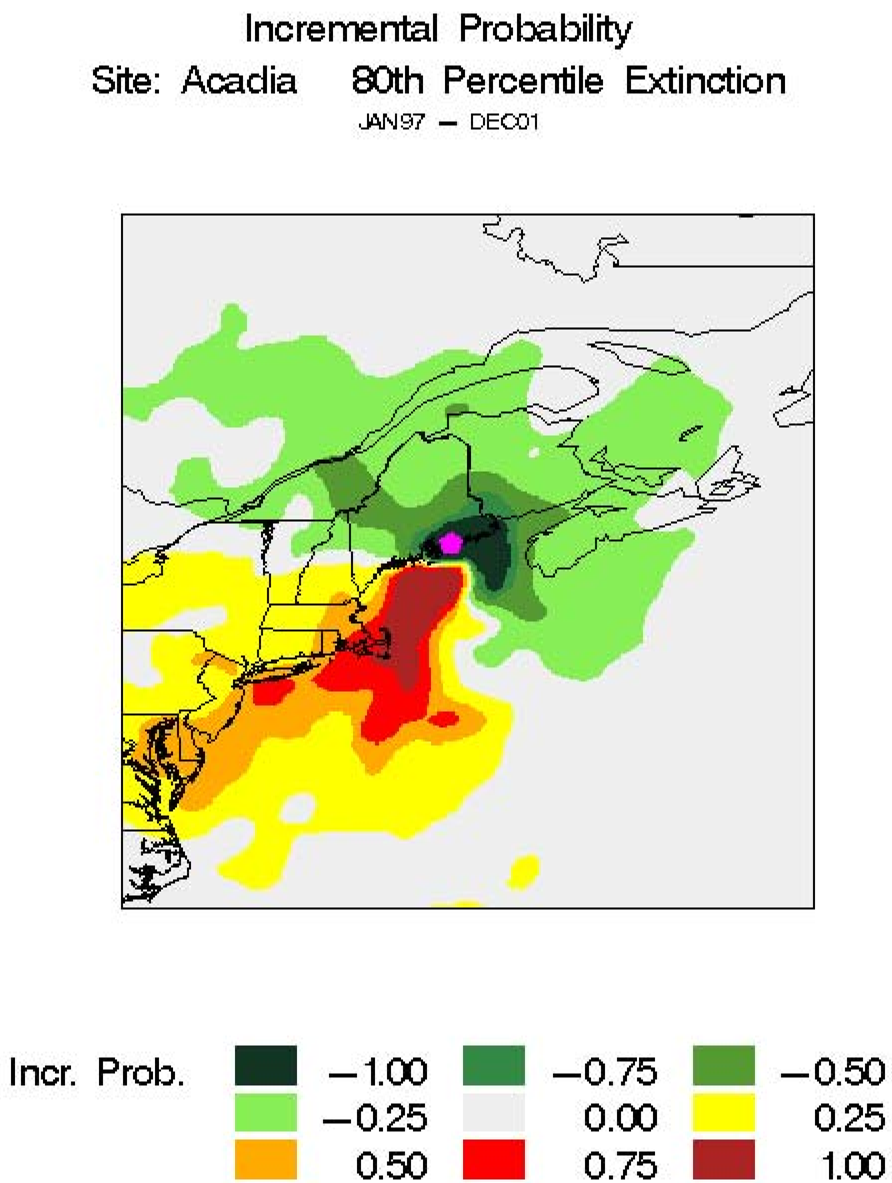


Incremental Probability
Site: Great Gulf 80th Percentile Extinction
JAN97 – DEC01

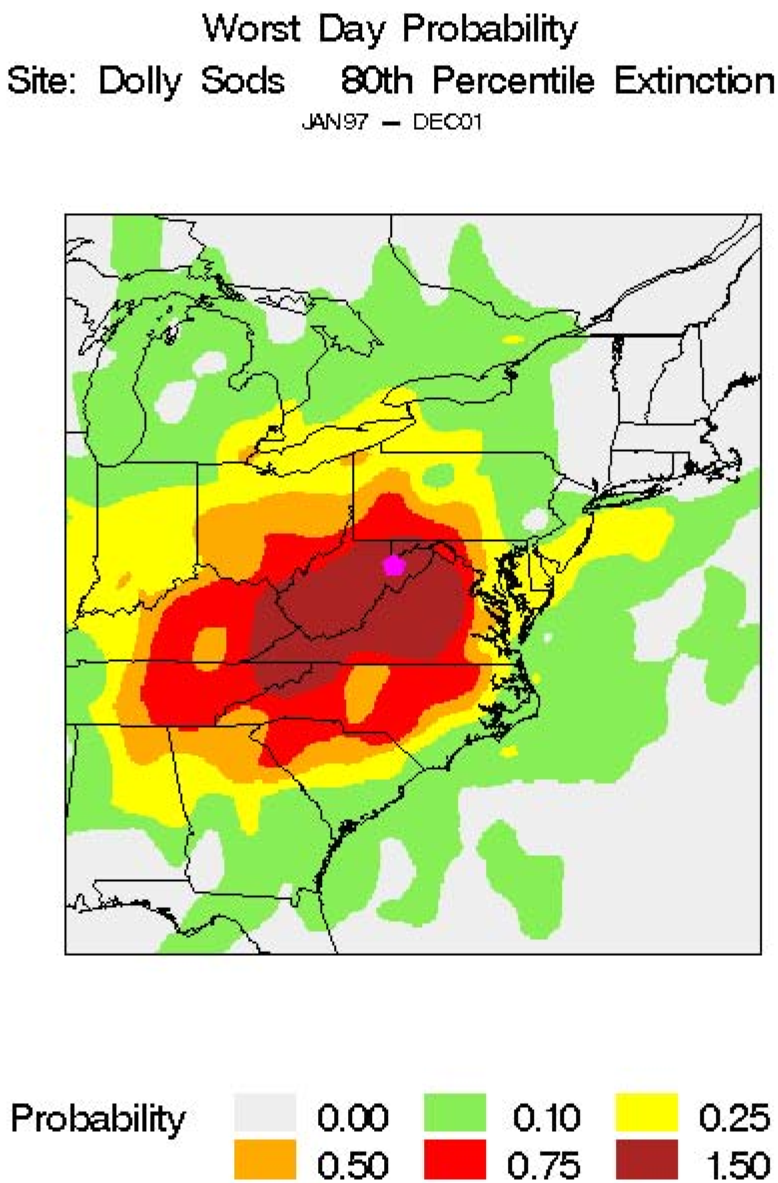


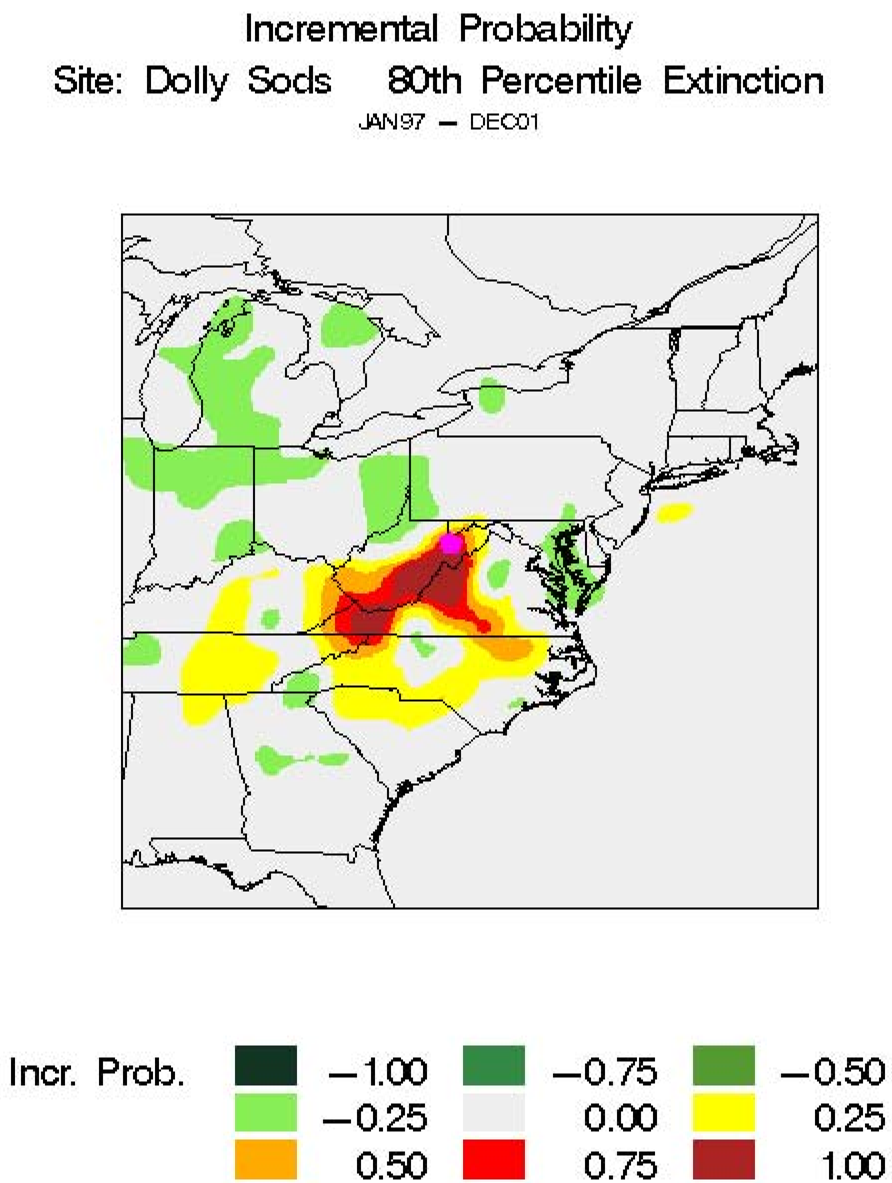
May 15, 2003

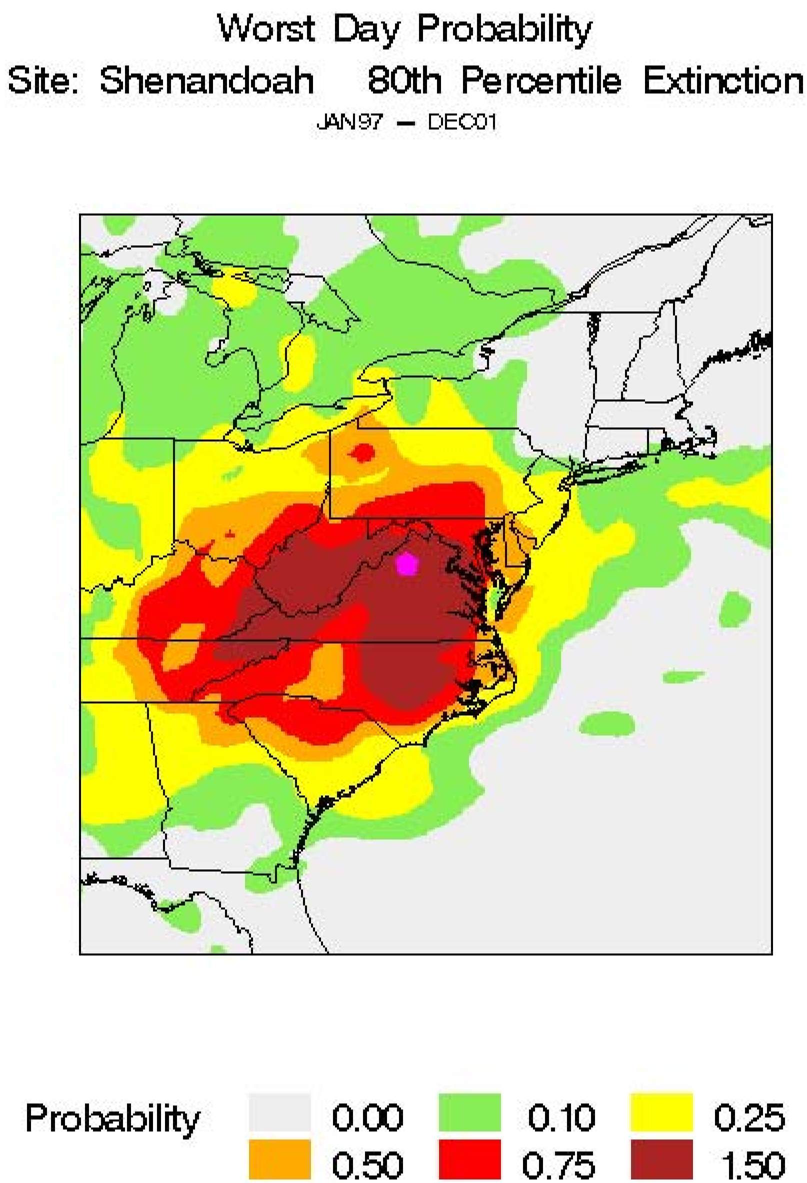

Worst Day Probability
Site: Acadia 80th Percentile Extinction
JAN97 – DEC01
Probability
0.00
0.10
0.25
0.50
0.75
1.50

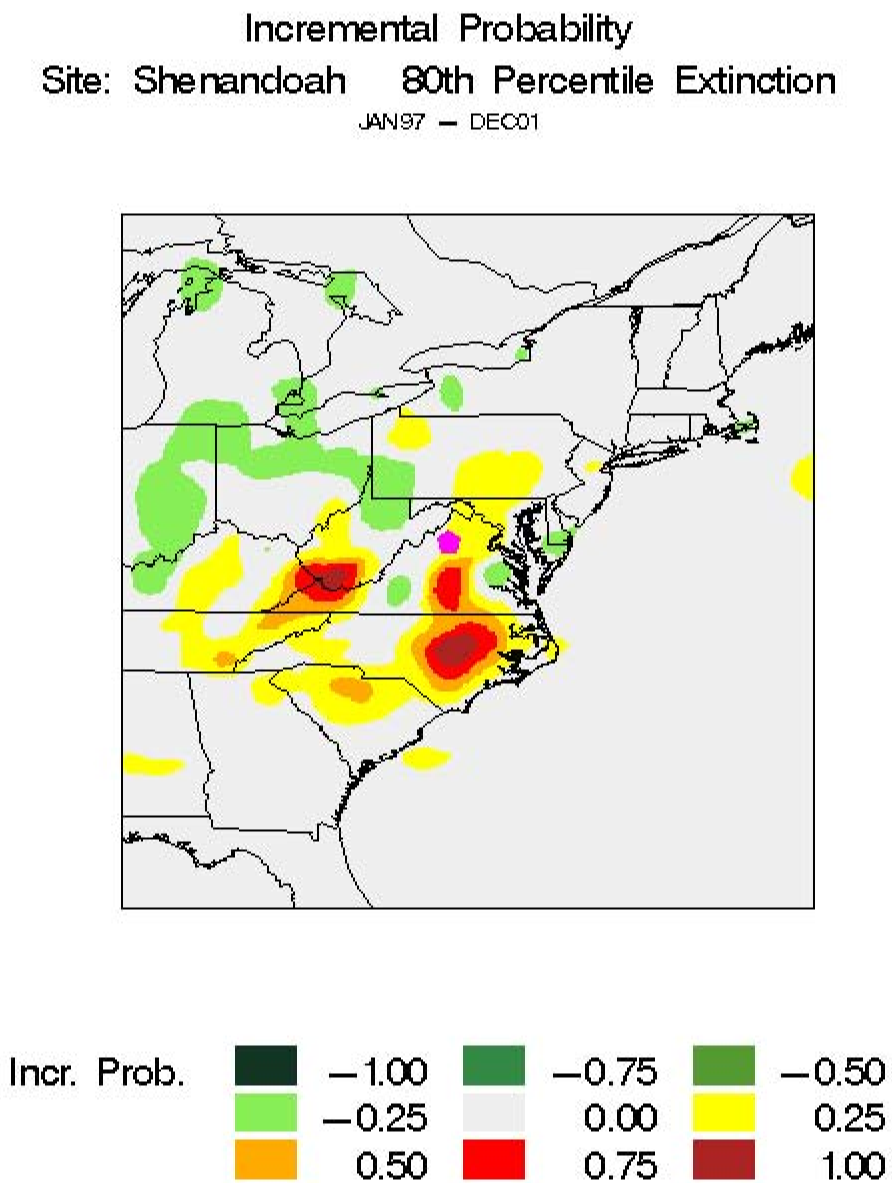

Incremental Probability
Site: Acadia 80th Percentile Extinction
JAN97 – DEC01
Incr. Prob.
–1.00
–0.75
–0.50
–0.25
0.00
0.25
0.50
0.75
1.00

May 15, 2003


Worst Day Probability
Site: Dolly Sods 80th Percentile Extinction
JAN97 — DEC01
Probability
0.00
0.10
0.25
0.50
0.75
1.50

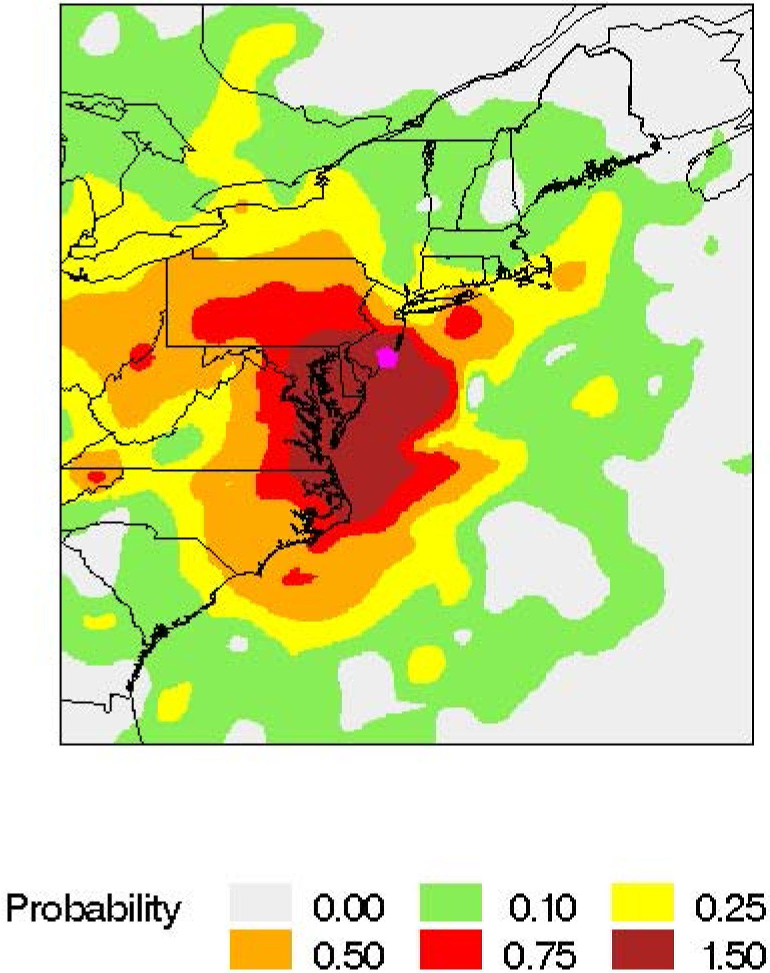

Incremental Probability
Site: Dolly Sods 80th Percentile Extinction
JAN97 — DEC01
Incr. Prob.
−1.00
−0.75
−0.50
−0.25
0.00
0.25
0.50
0.75
1.00


Worst Day Probability
Site: Shenandoah 80th Percentile Extinction
JAN97 — DEC01
Probability
0.00
0.10
0.25
0.50
0.75
1.50

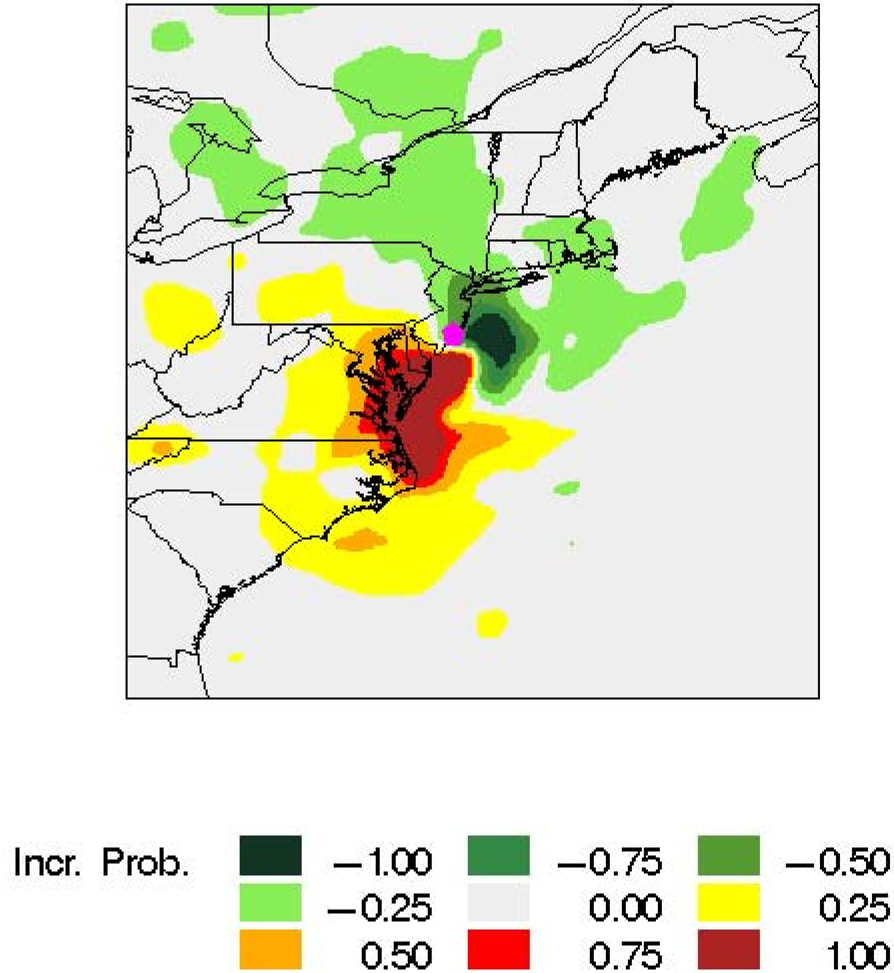

Incremental Probability
Site: Shenandoah 80th Percentile Extinction
JAN97 — DEC01
Incr. Prob.
−1.00
−0.75
−0.50
−0.25
0.00
0.25
0.50
0.75
1.00

May 15, 2003

Worst Day Probability
Site: Brigantine 80th Percentile Extinction
JAN97 — DEC01



Incremental Probability
Site: Brigantine 80th Percentile Extinction
JAN97 — DEC01

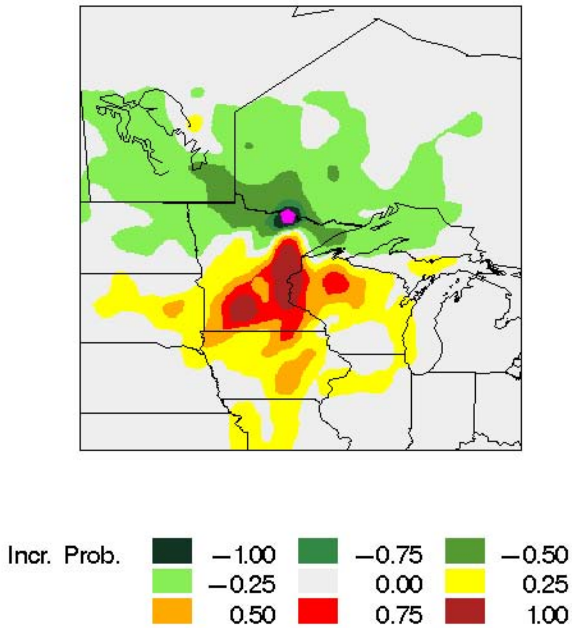


May 15, 2003

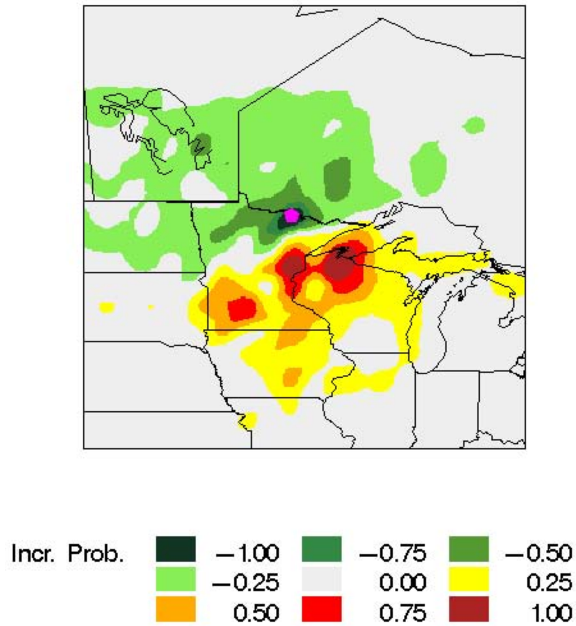
Attachment III

Contoured Trajectories Based on Chemical Species for Class I Areas in the Eastern Half of the U.S.

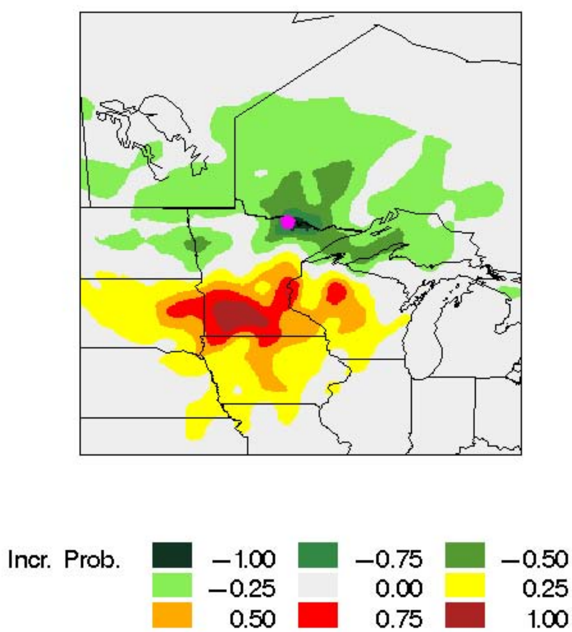
Incremental Probability
Site: Voyageurs 80th Percentile PM2.5
JAN00 – DEC01



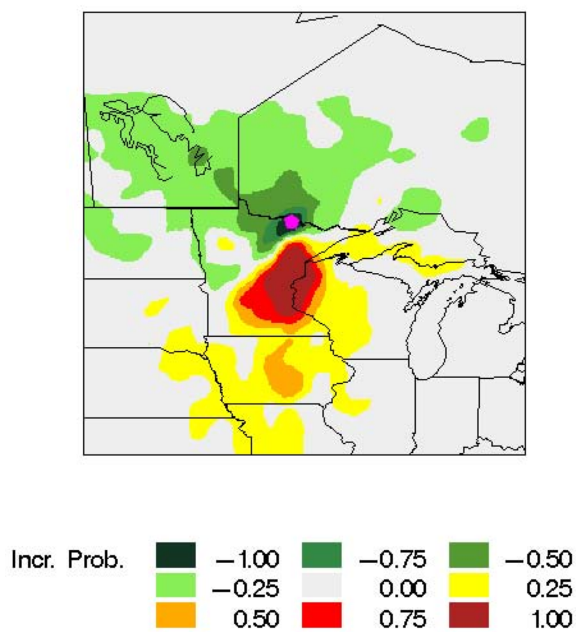
Incremental Probability
Site: Voyageurs 80th Percentile Sulfate
JAN00 – DEC01



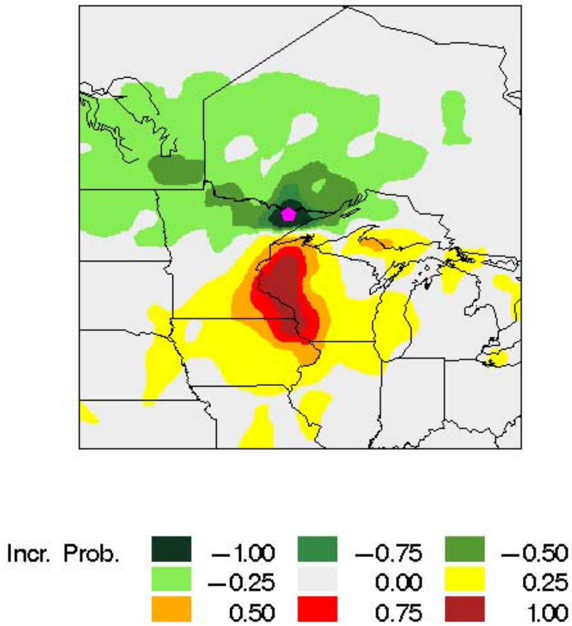
Incremental Probability
Site: Voyageurs 80th Percentile Nitrate
JAN00 – DEC01



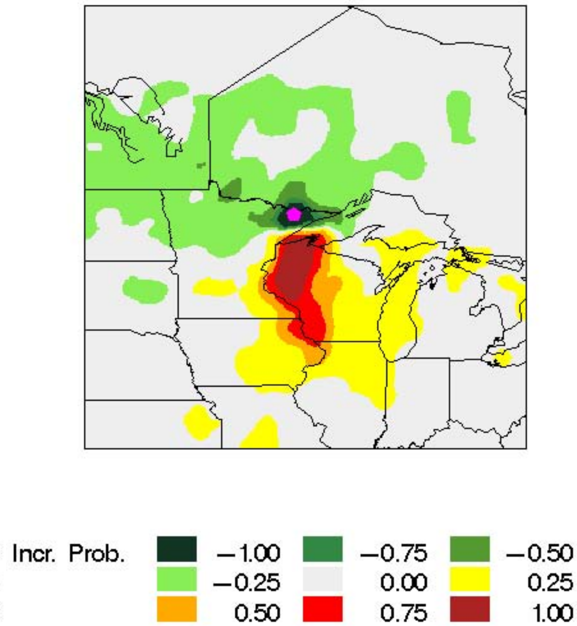
Incremental Probability
Site: Voyageurs 80th Percentile OrganicCarbon
JAN00 – DEC01



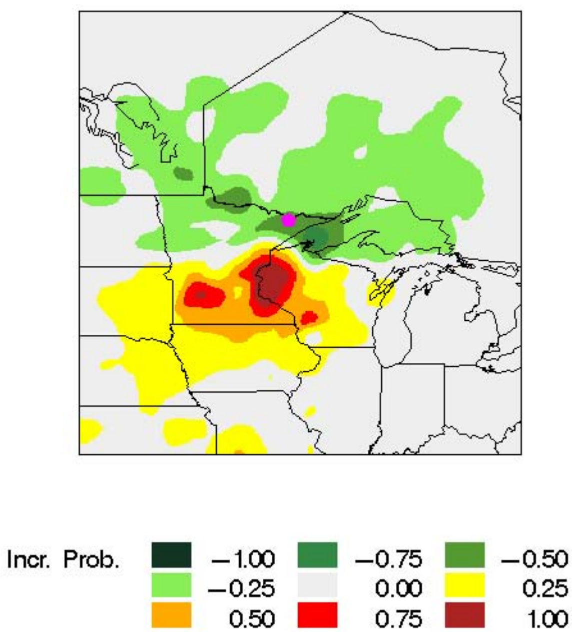
Incremental Probability
Site: Boundary Waters 80th Percentile PM2.5
JAN97 – DEC01



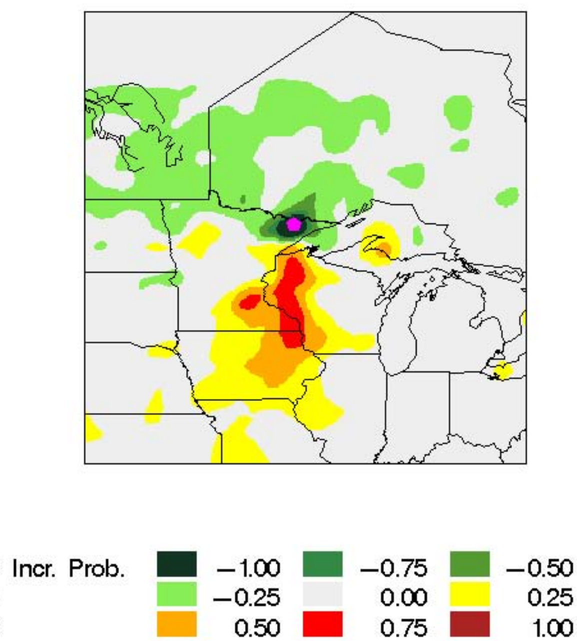
Incremental Probability
Site: Boundary Waters 80th Percentile Sulfate
JAN97 – DEC01



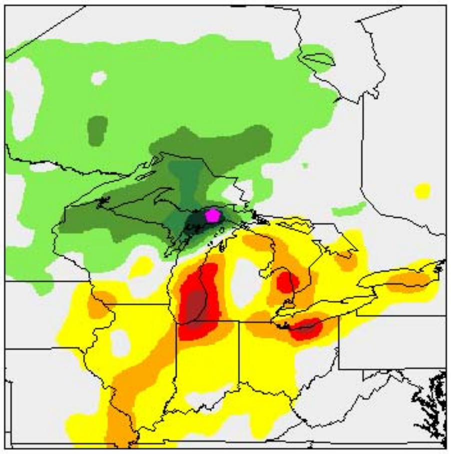
Incremental Probability
Site: Boundary Waters 80th Percentile Nitrate
JAN97 – DEC01



Incremental Probability
Site: Boundary Waters 80th Percentile OrganicCarbon
JAN97 – DEC01

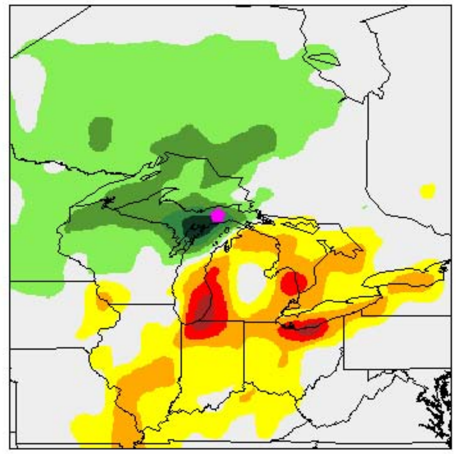


Incremental Probability
Site: Seney 80th Percentile PM2.5
JAN00 – DEC01



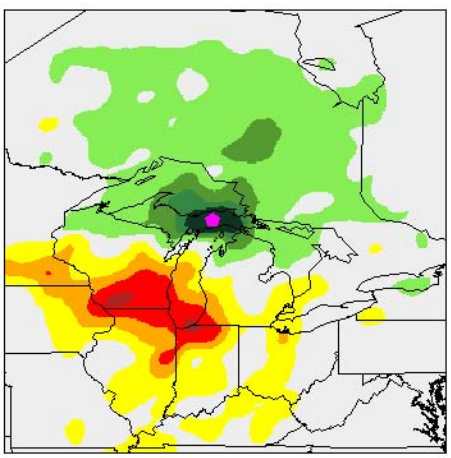
Incr. Prob. –1.00 –0.75 –0.50 –0.25 0.00 0.25 0.50 0.75 1.00

Incremental Probability
Site: Seney 80th Percentile Sulfate
JAN00 – DEC01



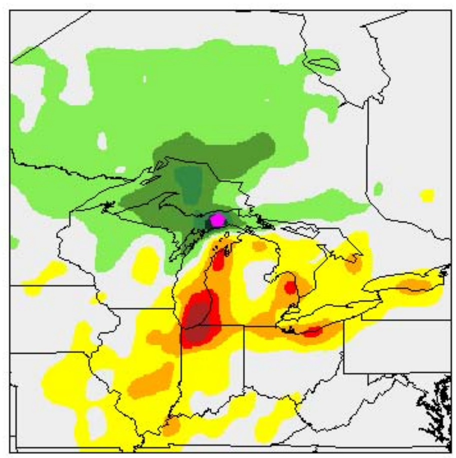
Incr. Prob. –1.00 –0.75 –0.50 –0.25 0.00 0.25 0.50 0.75 1.00

Incremental Probability
Site: Seney 80th Percentile Nitrate
JAN00 – DEC01

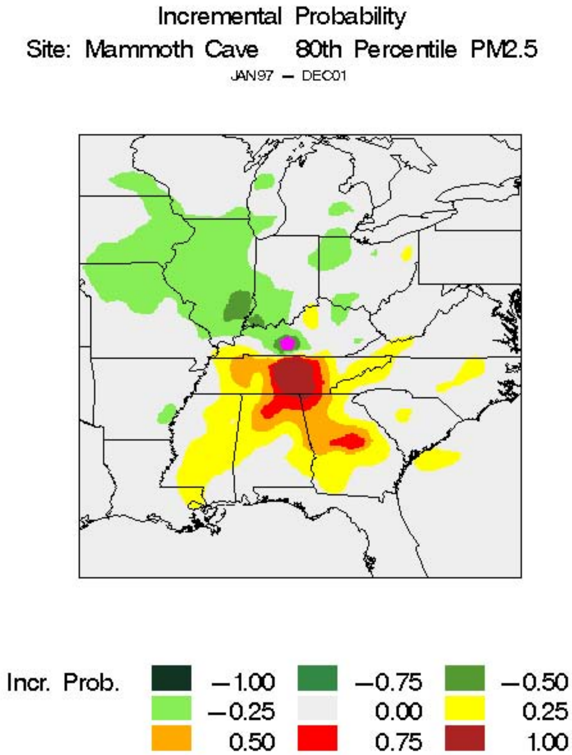


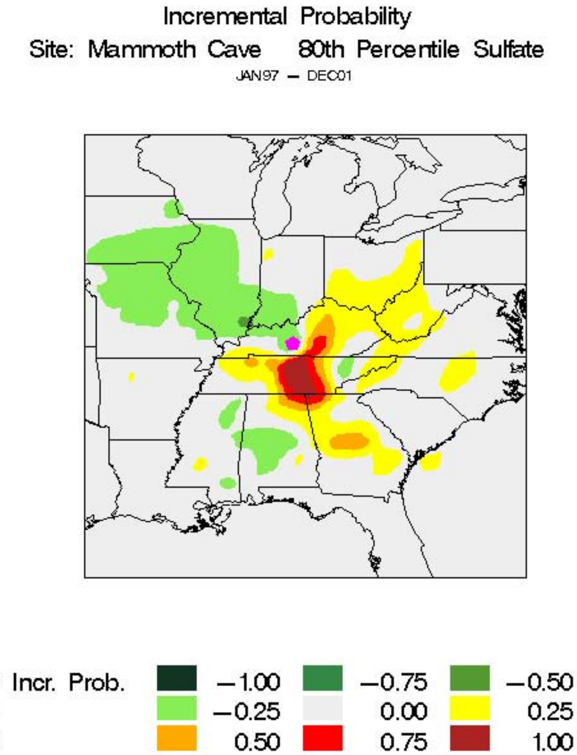
Incr. Prob. –1.00 –0.75 –0.50 –0.25 0.00 0.25 0.50 0.75 1.00

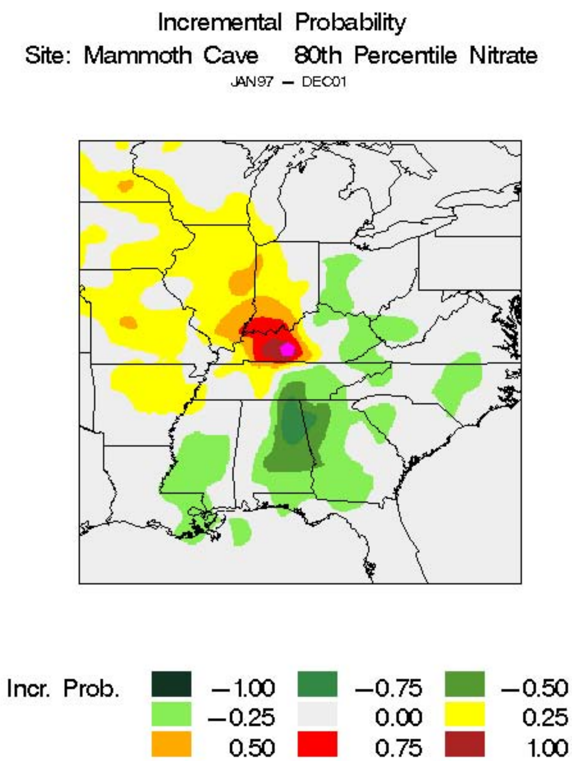
Incremental Probability
Site: Seney 80th Percentile OrganicCarbon
JAN00 – DEC01

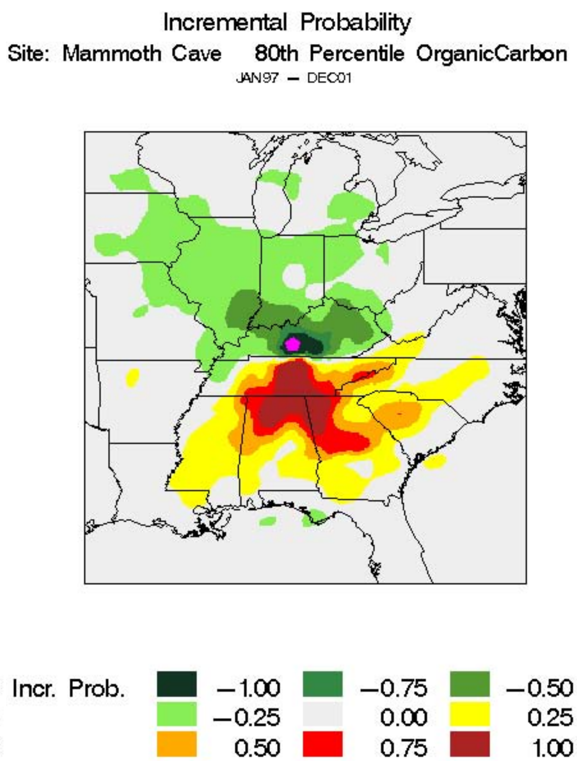


Incr. Prob. –1.00 –0.75 –0.50 –0.25 0.00 0.25 0.50 0.75 1.00

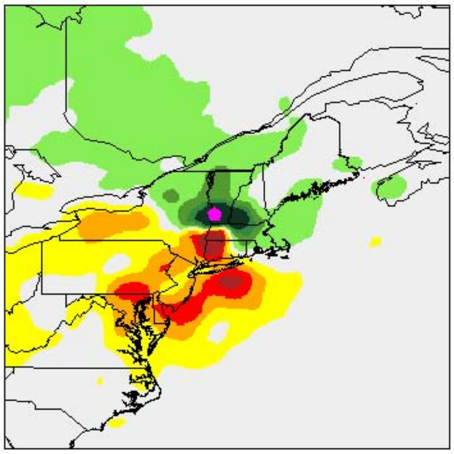

Incremental Probability
Site: Mammoth Cave 80th Percentile PM2.5
JAN97 – DEC01
Incr. Prob.
–1.00
–0.75
–0.50
–0.25
0.00
0.25
0.50
0.75
1.00


Incremental Probability
Site: Mammoth Cave 80th Percentile Sulfate
JAN97 – DEC01
Incr. Prob.
–1.00
–0.75
–0.50
–0.25
0.00
0.25
0.50
0.75
1.00


Incremental Probability
Site: Mammoth Cave 80th Percentile Nitrate
JAN97 – DEC01
Incr. Prob.
–1.00
–0.75
–0.50
–0.25
0.00
0.25
0.50
0.75
1.00

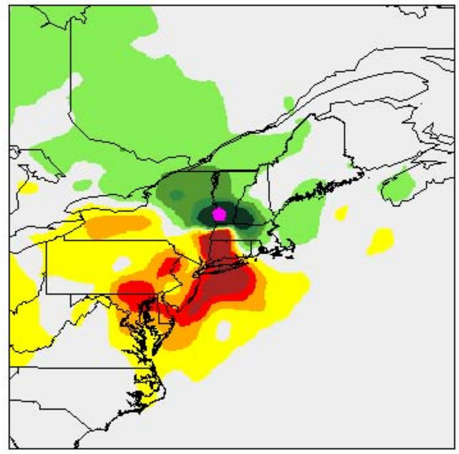

Incremental Probability
Site: Mammoth Cave 80th Percentile OrganicCarbon
JAN97 – DEC01
Incr. Prob.
–1.00
–0.75
–0.50
–0.25
0.00
0.25
0.50
0.75
1.00

Incremental Probability
Site: Lye Brook 80th Percentile PM2.5
JAN97 – DEC01



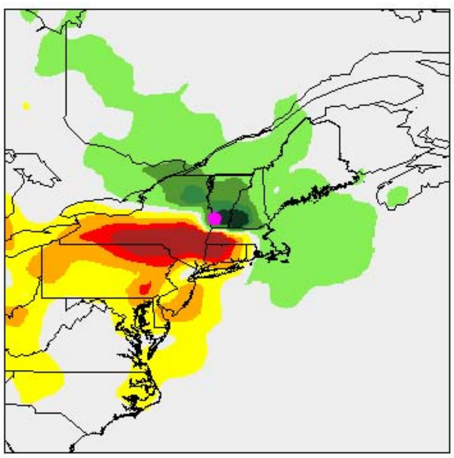
Incr. Prob. –1.00 –0.75 –0.50
–0.25 0.00 0.25
0.50 0.75 1.00

Incremental Probability
Site: Lye Brook 80th Percentile Sulfate
JAN97 – DEC01



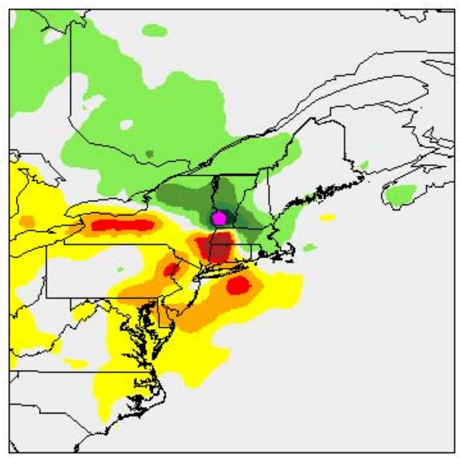
Incr. Prob. –1.00 –0.75 –0.50
–0.25 0.00 0.25
0.50 0.75 1.00

Incremental Probability
Site: Lye Brook 80th Percentile Nitrate
JAN97 – DEC01



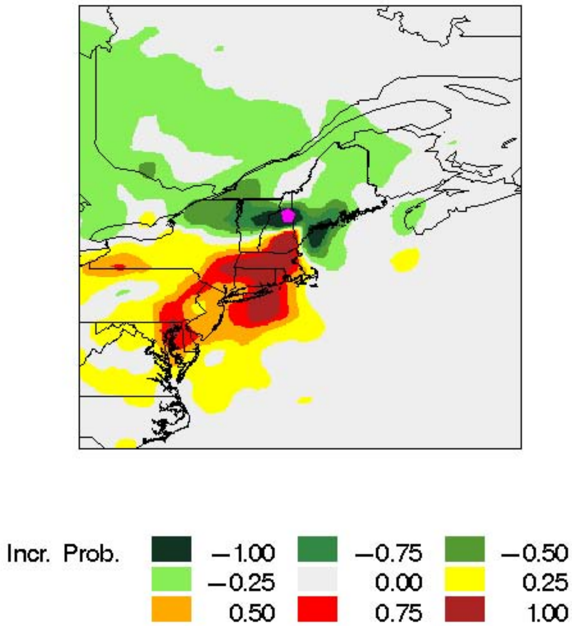
Incr. Prob. –1.00 –0.75 –0.50
–0.25 0.00 0.25
0.50 0.75 1.00

Incremental Probability
Site: Lye Brook 80th Percentile OrganicCarbon
JAN97 – DEC01

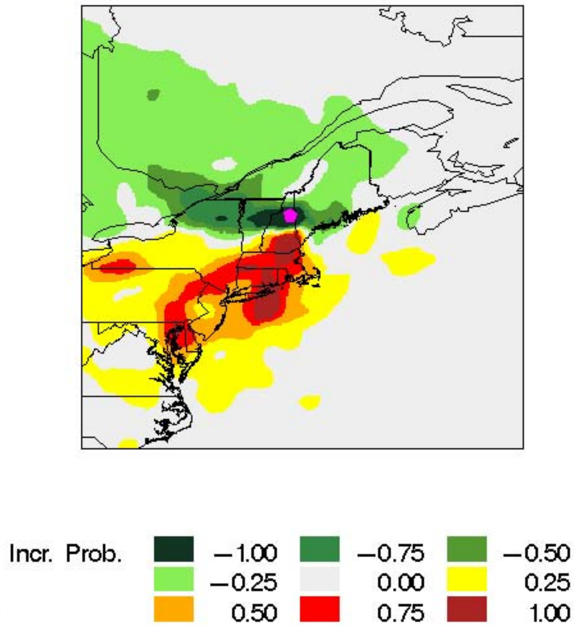


Incr. Prob. –1.00 –0.75 –0.50
–0.25 0.00 0.25
0.50 0.75 1.00

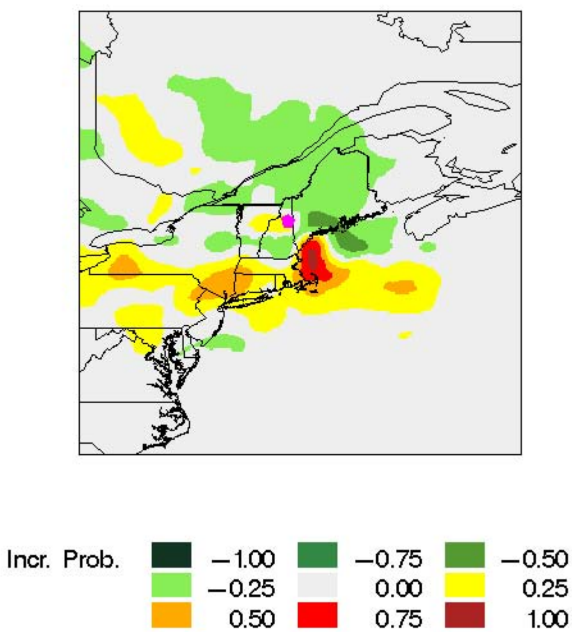
Incremental Probability
Site: Great Gulf 80th Percentile PM2.5
JAN97 – DEC01



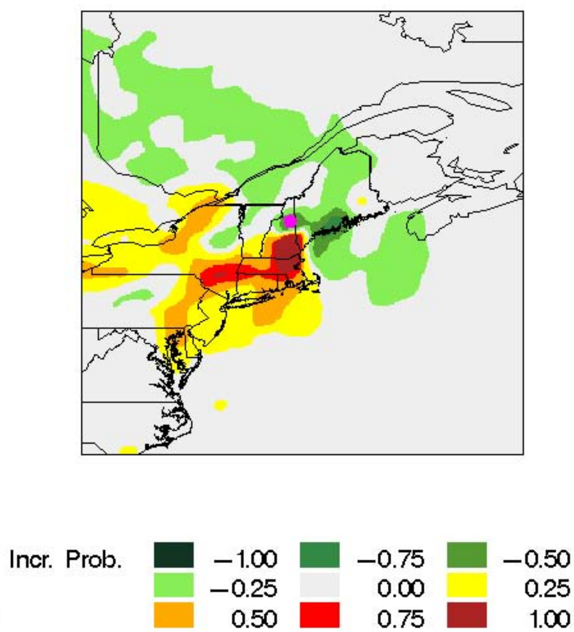
Incremental Probability
Site: Great Gulf 80th Percentile Sulfate
JAN97 – DEC01



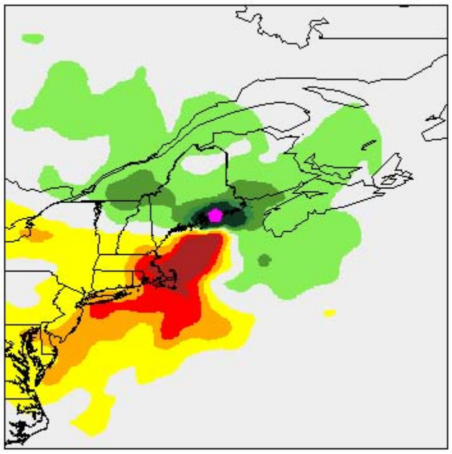
Incremental Probability
Site: Great Gulf 80th Percentile Nitrate
JAN97 – DEC01



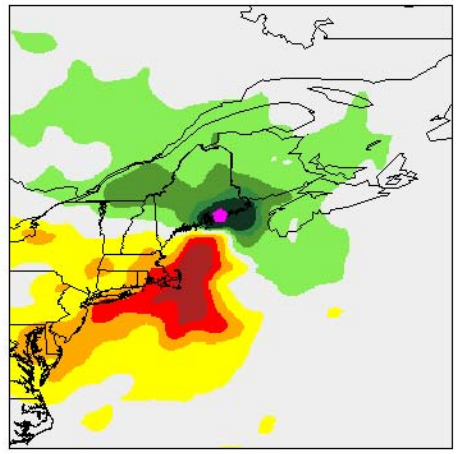
Incremental Probability
Site: Great Gulf 80th Percentile OrganicCarbon
JAN97 – DEC01



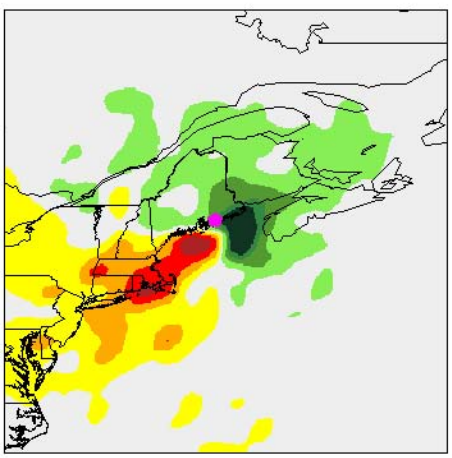
Incremental Probability
Site: Acadia 80th Percentile PM2.5
JAN97 – DEC01



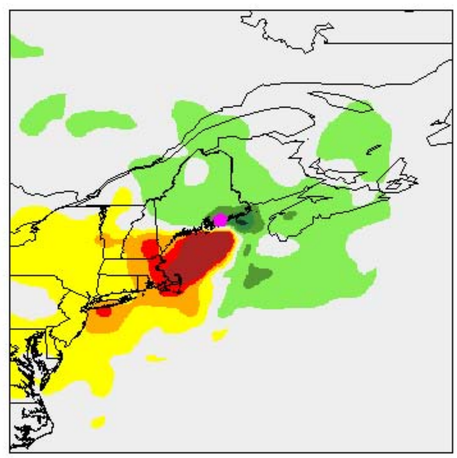
Incremental Probability
Site: Acadia 80th Percentile Sulfate
JAN97 – DEC01



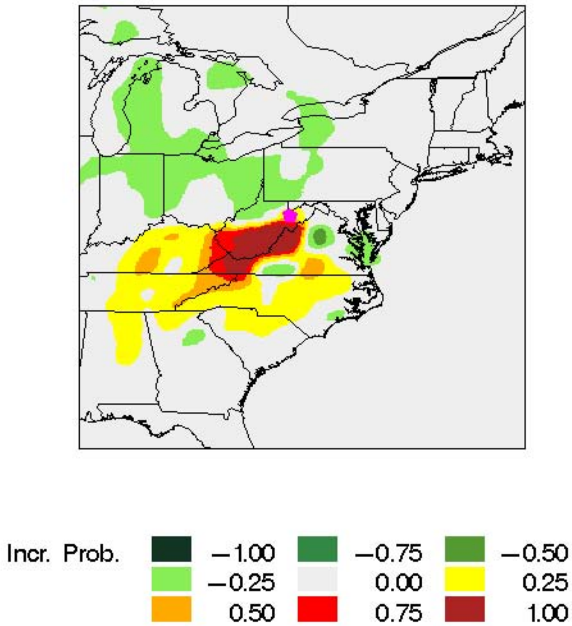
Incremental Probability
Site: Acadia 80th Percentile Nitrate
JAN97 – DEC01



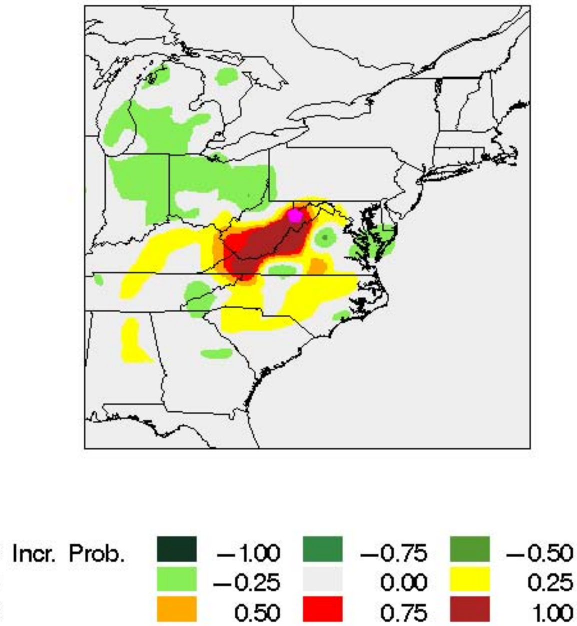
Incremental Probability
Site: Acadia 80th Percentile OrganicCarbon
JAN97 – DEC01



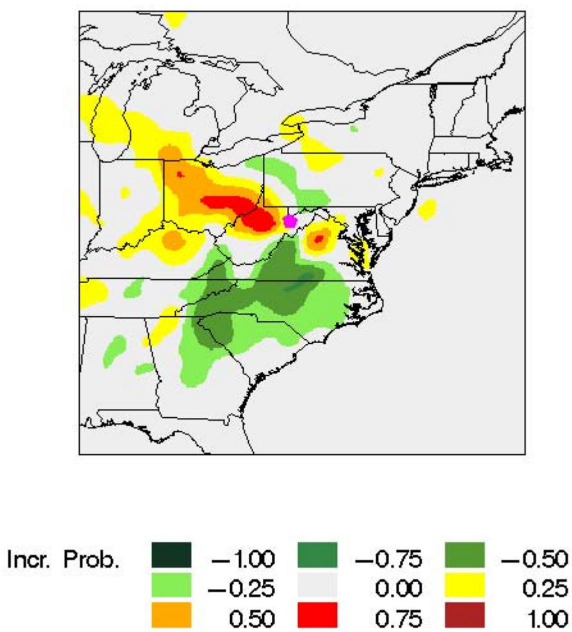
Incremental Probability
Site: Dolly Sods 80th Percentile PM2.5
JAN97 – DEC01



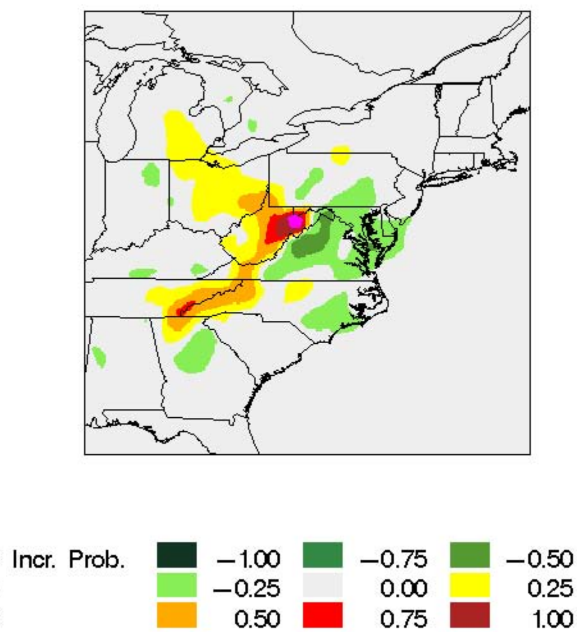
Incremental Probability
Site: Dolly Sods 80th Percentile Sulfate
JAN97 – DEC01



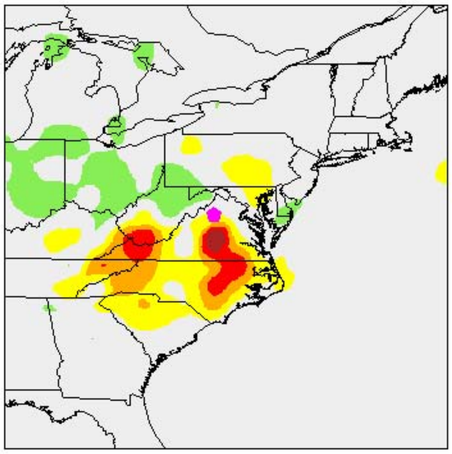
Incremental Probability
Site: Dolly Sods 80th Percentile Nitrate
JAN97 – DEC01



Incremental Probability
Site: Dolly Sods 80th Percentile OrganicCarbon
JAN97 – DEC01

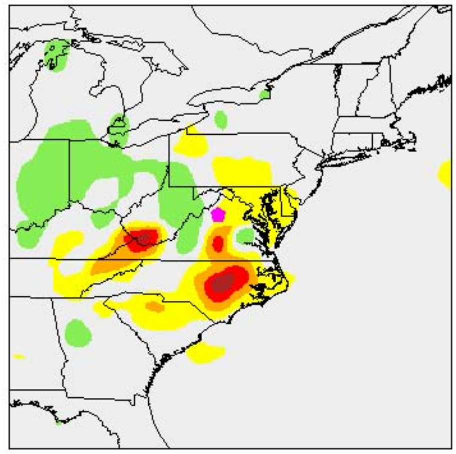


Incremental Probability
Site: Shenandoah 80th Percentile PM2.5
JAN97 – DEC01



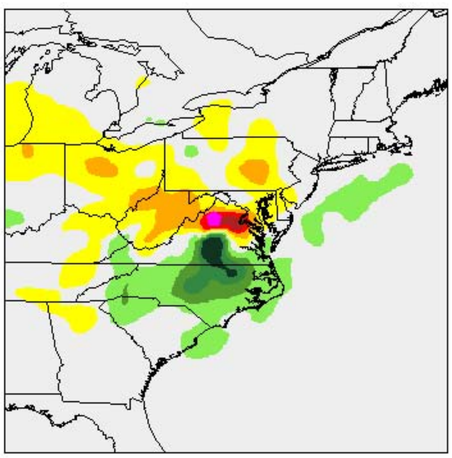
Incr. Prob. –1.00 –0.75 –0.50 –0.25 0.00 0.25 0.50 0.75 1.00

Incremental Probability
Site: Shenandoah 80th Percentile Sulfate
JAN97 – DEC01



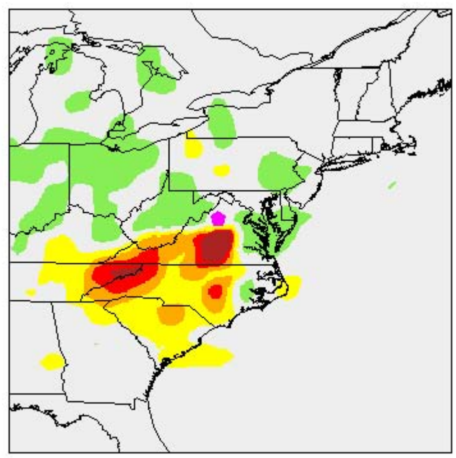
Incr. Prob. –1.00 –0.75 –0.50 –0.25 0.00 0.25 0.50 0.75 1.00

Incremental Probability
Site: Shenandoah 80th Percentile Nitrate
JAN97 – DEC01



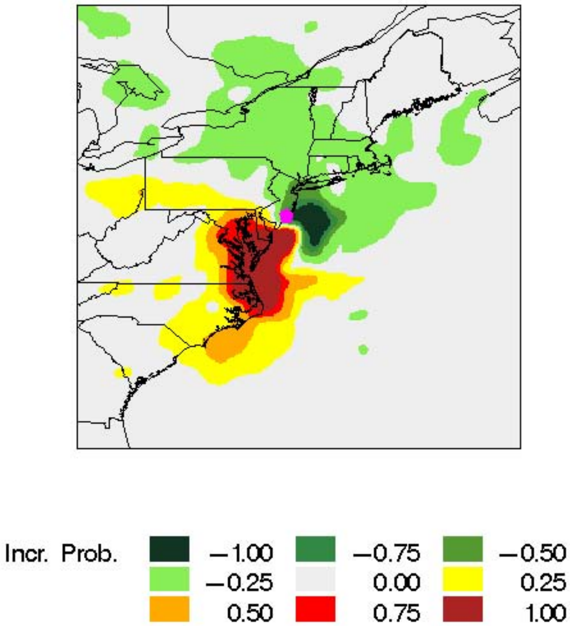
Incr. Prob. –1.00 –0.75 –0.50 –0.25 0.00 0.25 0.50 0.75 1.00

Incremental Probability
Site: Shenandoah 80th Percentile OrganicCarbon
JAN97 – DEC01

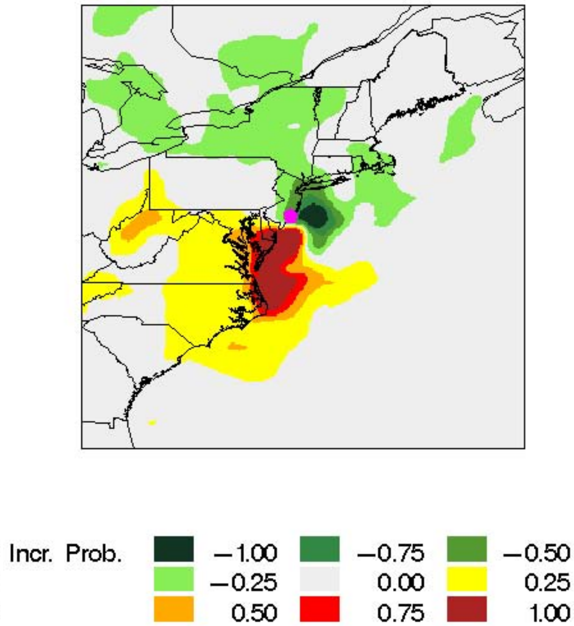


Incr. Prob. –1.00 –0.75 –0.50 –0.25 0.00 0.25 0.50 0.75 1.00

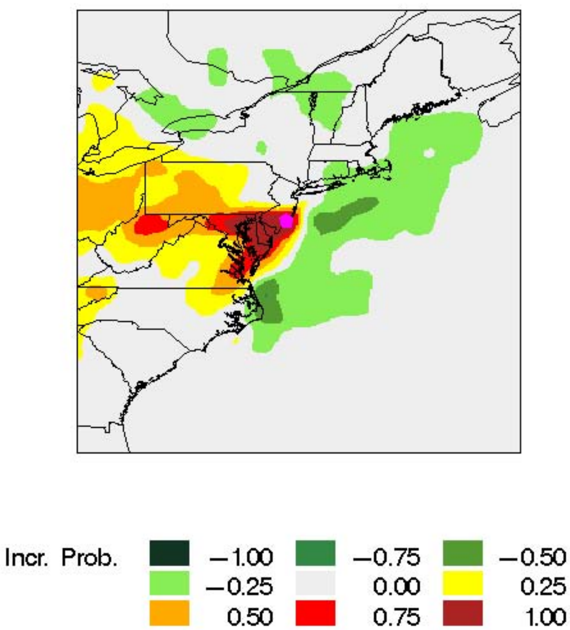
Incremental Probability
Site: Brigantine 80th Percentile PM2.5
JAN97 – DEC01



Incremental Probability
Site: Brigantine 80th Percentile Sulfate
JAN97 – DEC01



Incremental Probability
Site: Brigantine 80th Percentile Nitrate
JAN97 – DEC01



Incremental Probability
Site: Brigantine 80th Percentile OrganicCarbon
JAN97 – DEC01