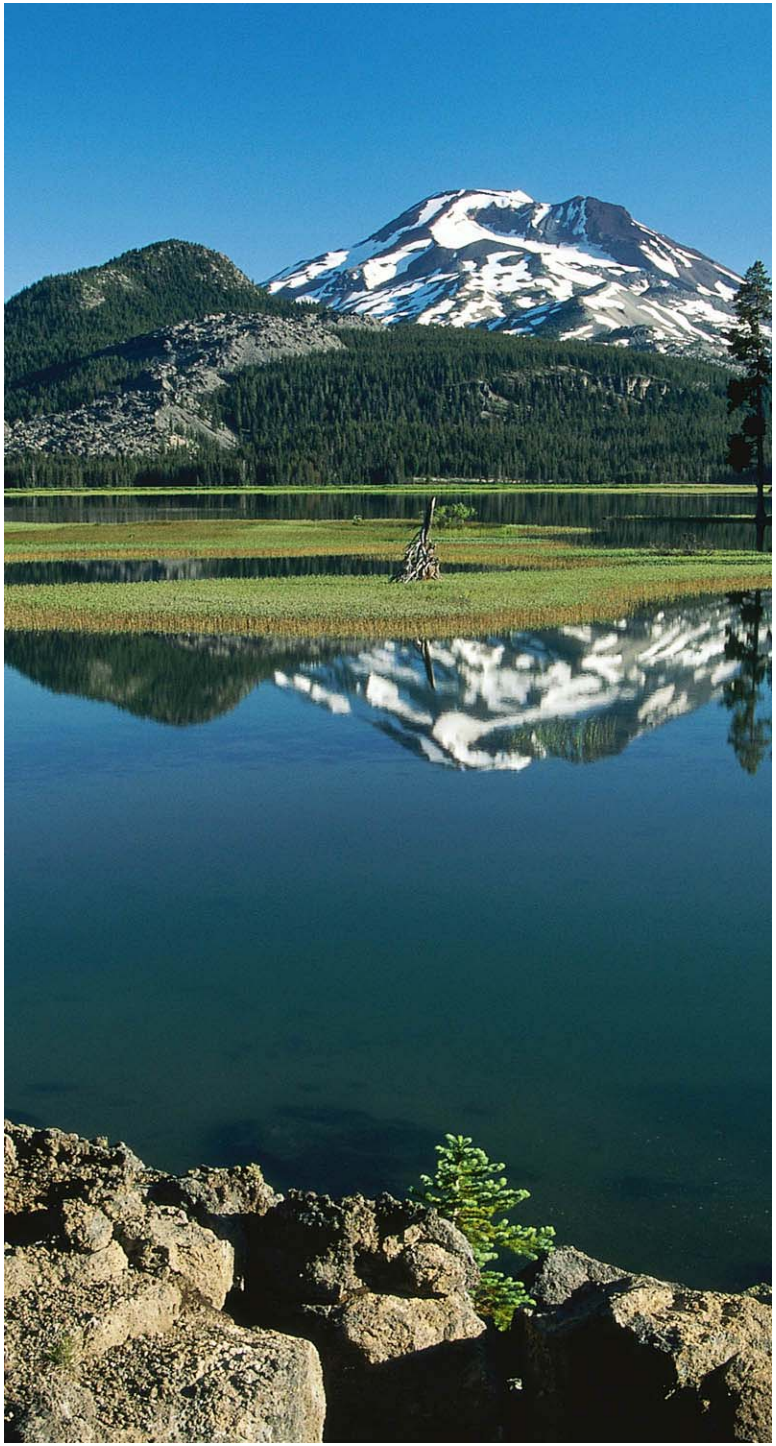


ELECTRIC POWER RESEARCH INSTITUTE

The 2003 North American Blackout: A Baseball Fan's Perspective on Air Quality

Presented by Eladio Knipping
Electric Power Research Institute (EPRI)

MIT Endicott House Symposium
August 16-17, 2006

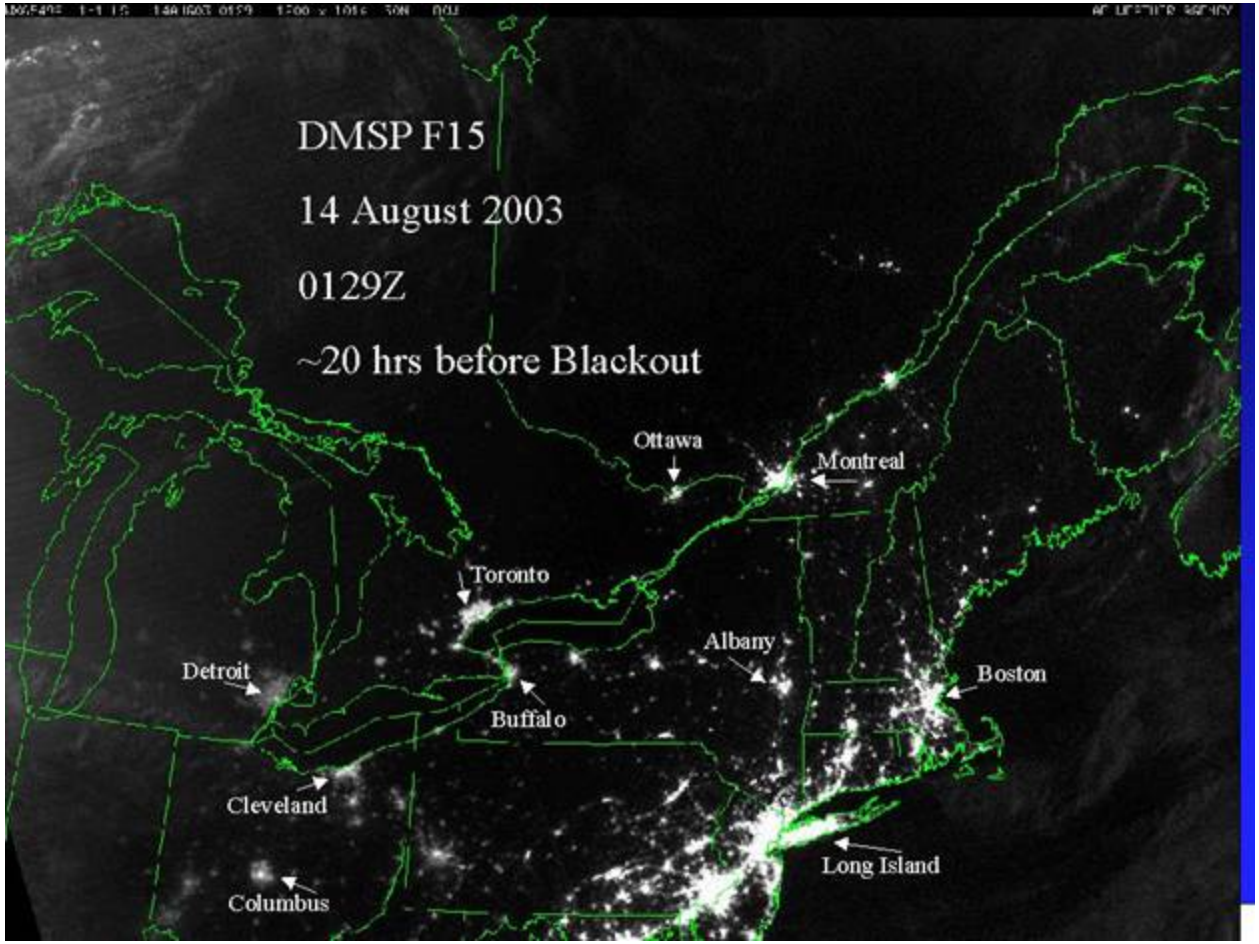
Alan Hansen, Naresh Kumar
Electric Power Research Institute (EPRI)
Dianne Miller, Clinton MacDonald
Sonoma Technology, Inc. (STI)
Yongtao Hu, Talat Odman, Ted Russell
Georgia Institute Of Technology

Actual Unintended Consequence of the Blackout

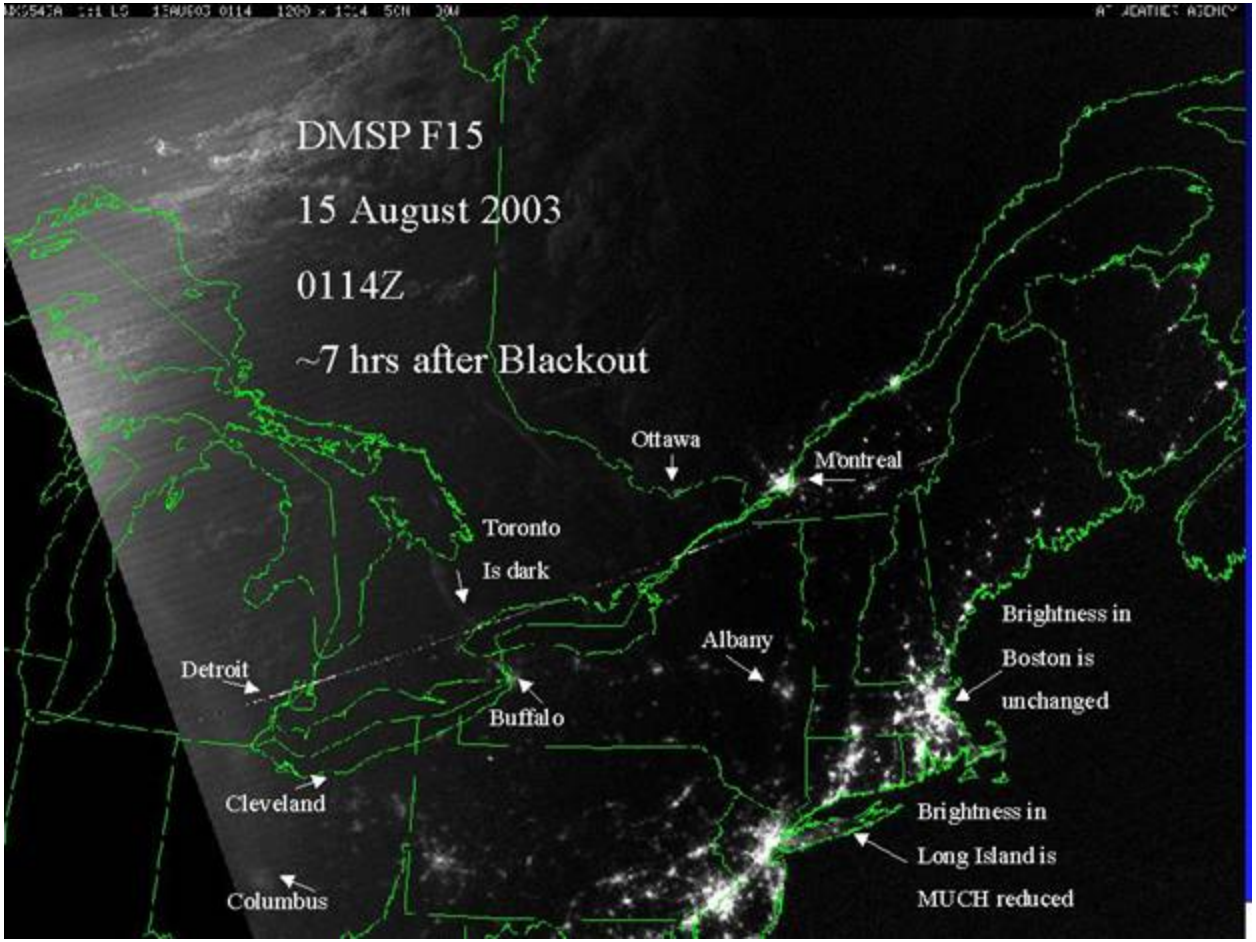
Suddenly, knowing a lot about the U.S. power grid became sexy at cocktail parties.

“It ain’t over ‘til it’s over.”

August 14, 2003

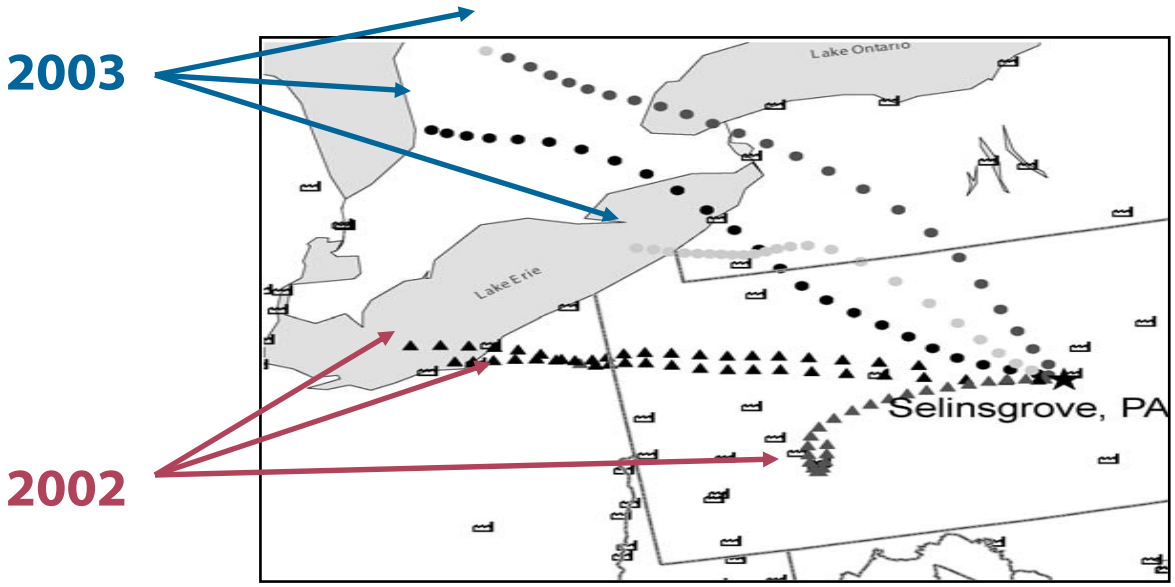


August 15, 2003



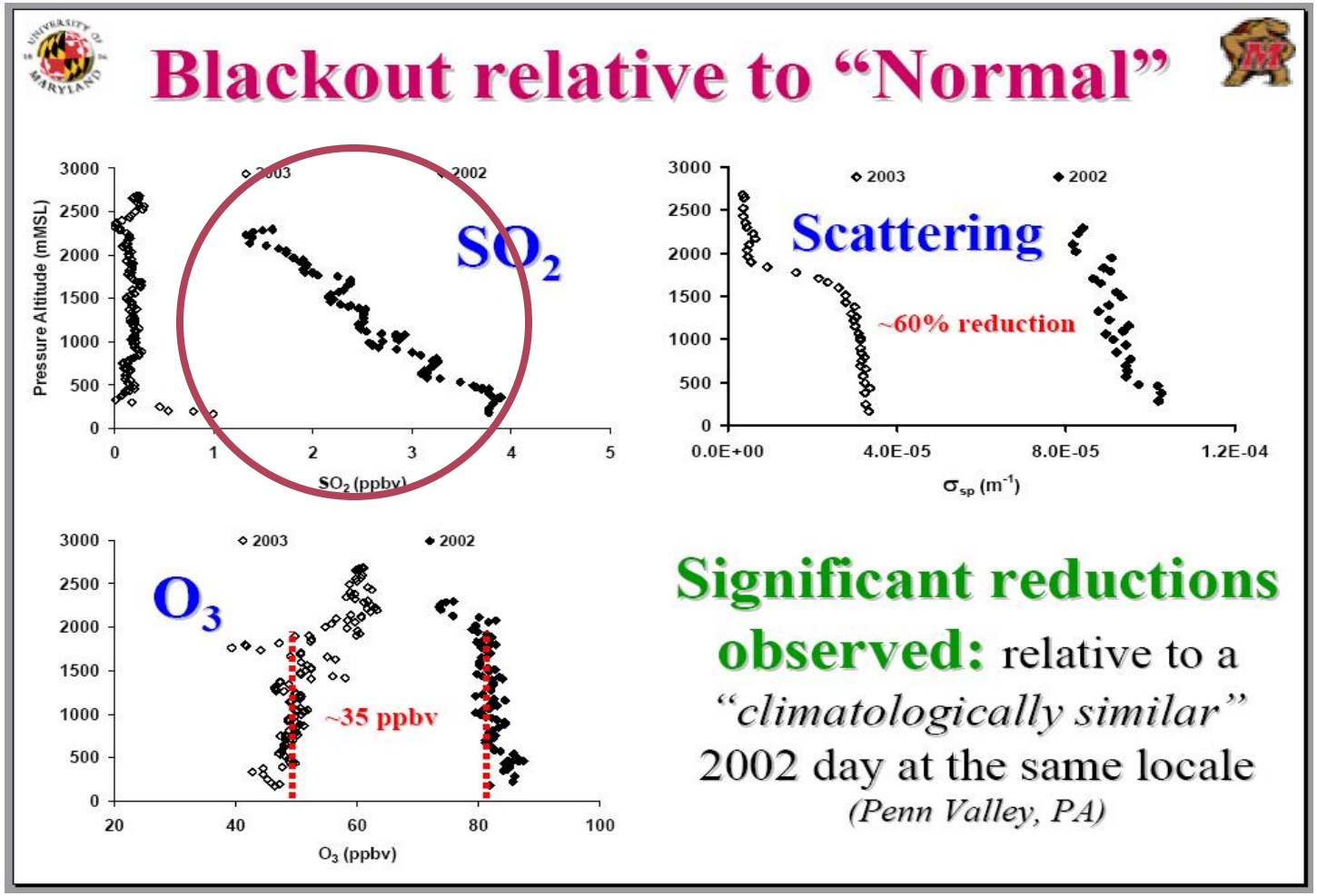
Trajectories (from Marufu et al., GRL, 2004)

Back trajectories were used to attribute the observed reductions to estimated drops in power-plant emissions (2003 to 2002)



Forward trajectories (not shown) were then used to attribute the results to downwind regions over the entire Northeastern US

Analysis "Relative to Normal" (from UMD's 2004 EUEC Presentation)



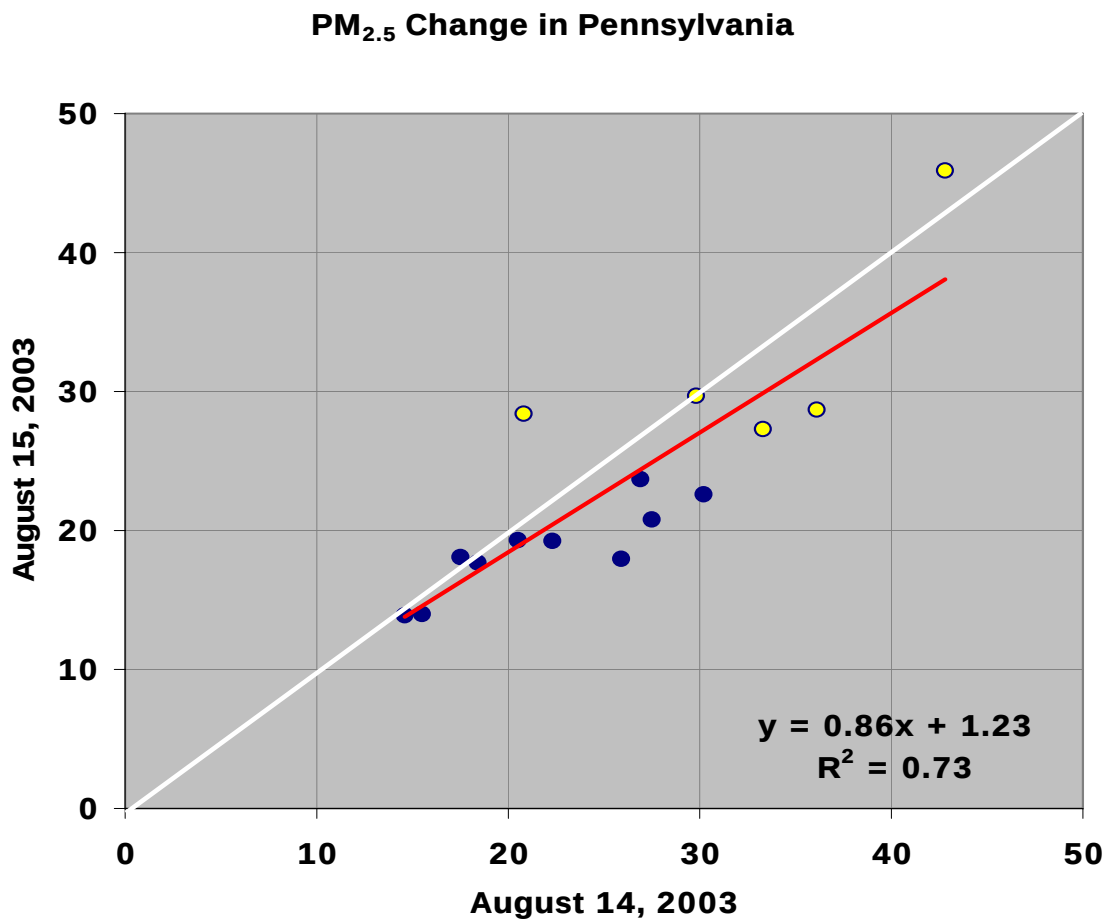
Summary of Original UMD GRL Publication

- Deployed their instrumented aircraft the day after the generator trips
- Made one spiral over Selinsgrove, PA, where they had made a spiral approximately one year before on a putatively meteorologically similar day.
- Attributed the differences in air quality measured during the two spirals
  - >90% in SO_2,
  - 50% in O_3, and
  - 70% in b_{scat} (light scattering).

  to the emissions reductions from the generator trips.
- Concluded "This clean air benefit was realized over much of the eastern U.S."

Regions Affected by Blackout

But Pennsylvania had Electricity and therefore Surface Measurements!



"I didn't really say everything I said."

Summary of EPRI Comments to GRL, 2005

- With respect to surface impacts, the UMD approach was problematic due to **unrepresentativeness of single-location** measurements for a large region and **non-comparability of comparison days.**

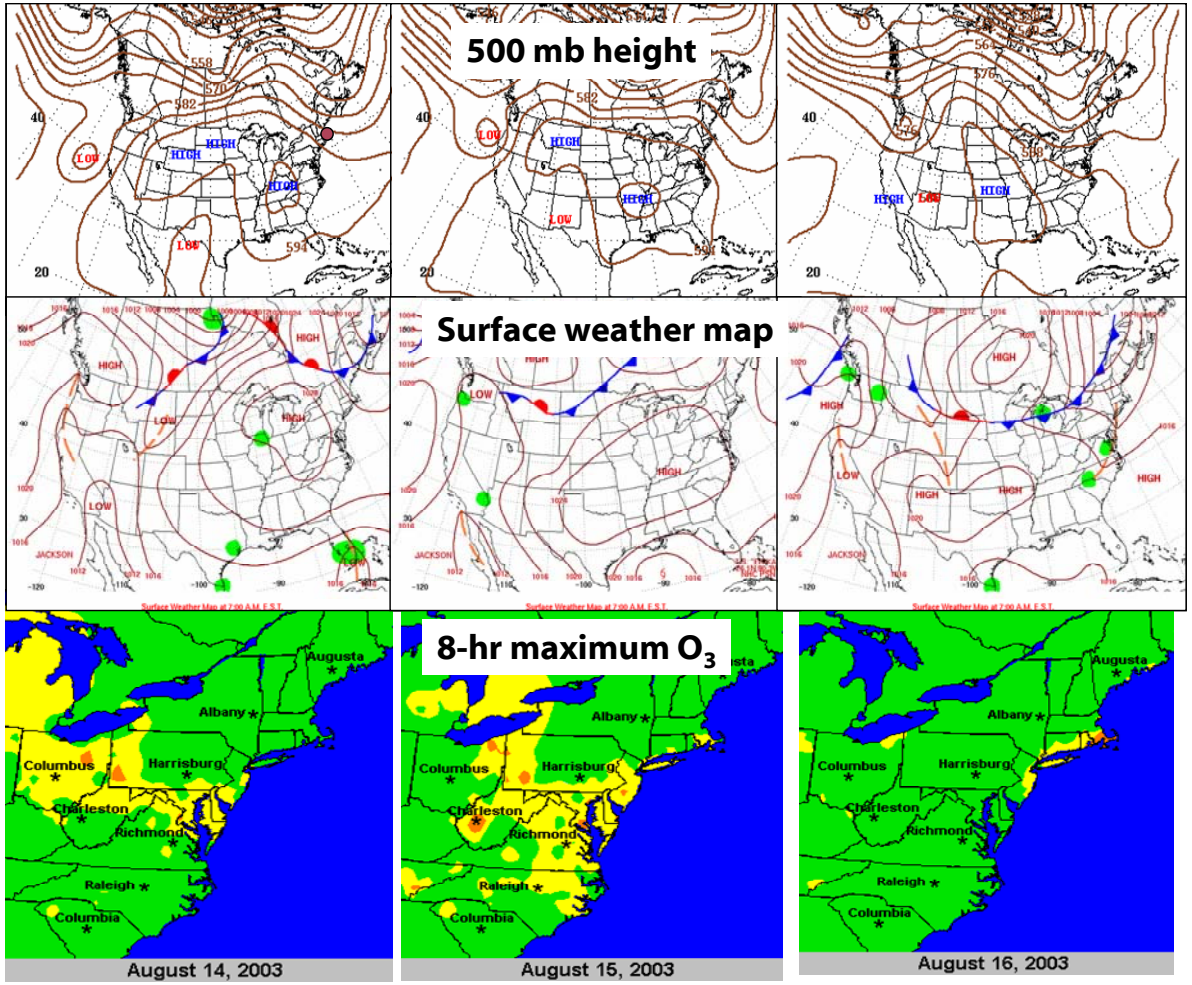
- EPRI suggested that **analysis of observed concentrations of atmospheric constituents across a broader range of locations performed over several meteorologically similar time periods** would help to better understand the influence of the blackout on pollutant levels.

- **Comments by Alan Hansen, Eladio Knipping and Naresh Kumar**

So Let's Attempt to Compare Surface Air Quality on "Meteorologically Similar" Days

- Compare air quality on several meteorologically similar days at several locations in the Northeast to days before and after the blackout. Attribute differences to the blackout.
- Focus: Detroit (DTW), New York (JFK), Pittsburgh (PIT), Philadelphia (PHL) and Washington, DC (IAD)
- Restrict analyses to days in July, August and September of 2002, 2003, and 2004.
- Subjectively compare on basis of available meteorological information (shown in next slides).
- Conduct cluster analysis using the following variables: maximum daily surface temperature, average cloud fraction from 0600 to 1800 EST, average relative humidity from 1600 to 1800 EST, u and v wind vectors at 850 mb at 00Z, 500 mb ht at 12Z, 850 mb temperature at 12Z, Shear, and average u and v vectors of surface wind from 0600 to 1800 EST
  - **Shear = 1000 $((u_{850} - u_{surf})^2 + (v_{850} - v_{surf})^2)^{1/2}$ / (850 mb ht – surf elev)**
- Rank days on goodness of match
  - Rank 1 = days that were good matches both statistically and subjectively.
  - Rank 2 = good matches subjectively but not statistically
  - Rank 3 = days that were good matches statistically and fair matches subjectively
  - Rank 4 = fair matches subjectively but not statistically (ignored hereafter)
- Meteorological matches that did not match weekdays with weekdays or weekend days with weekend days were excluded.
- **Analysis performed by Dianne Miller and Clinton MacDonald**
  - **Sonoma Technology, Inc. (STI)**

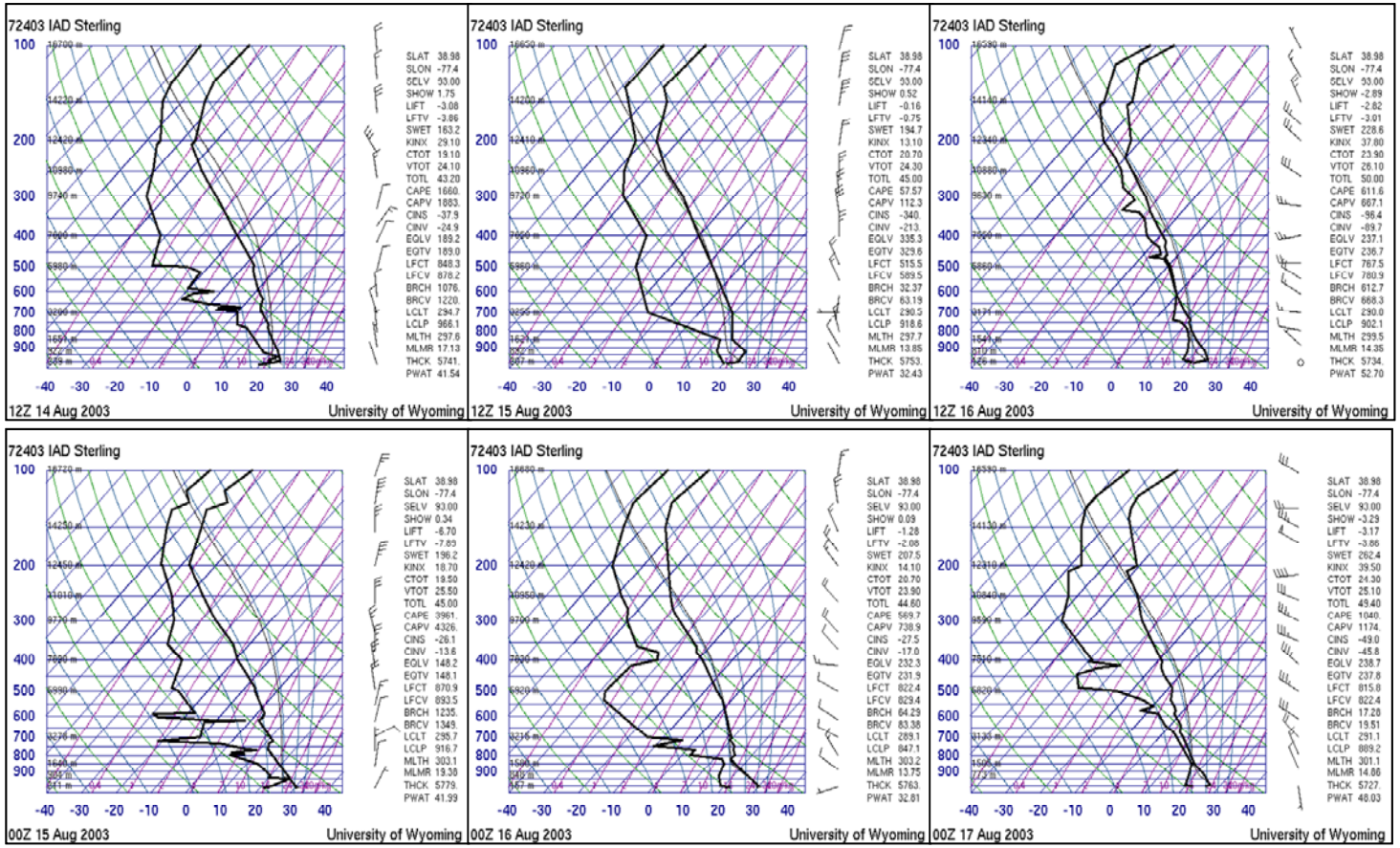
Meteorological and AIRNow Data



Thursday **Friday** **Saturday**

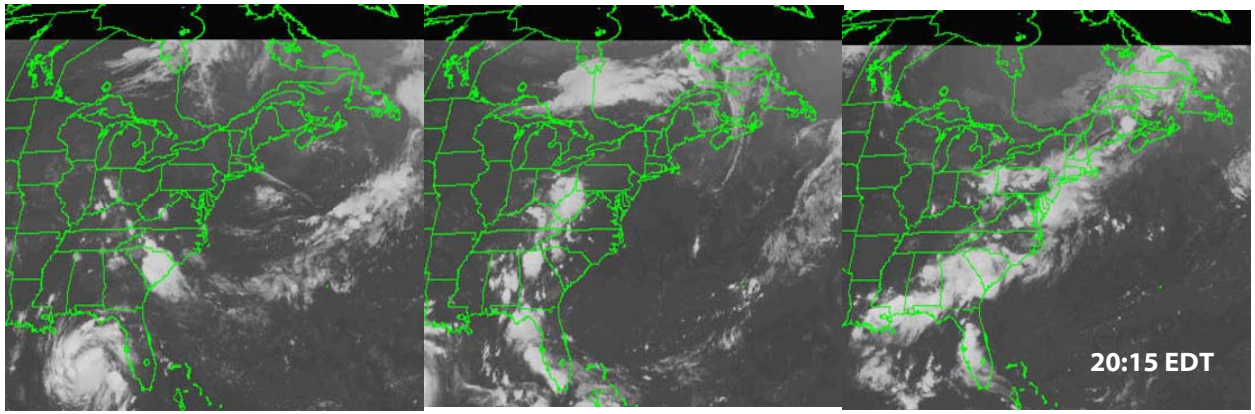
Twice Daily Soundings

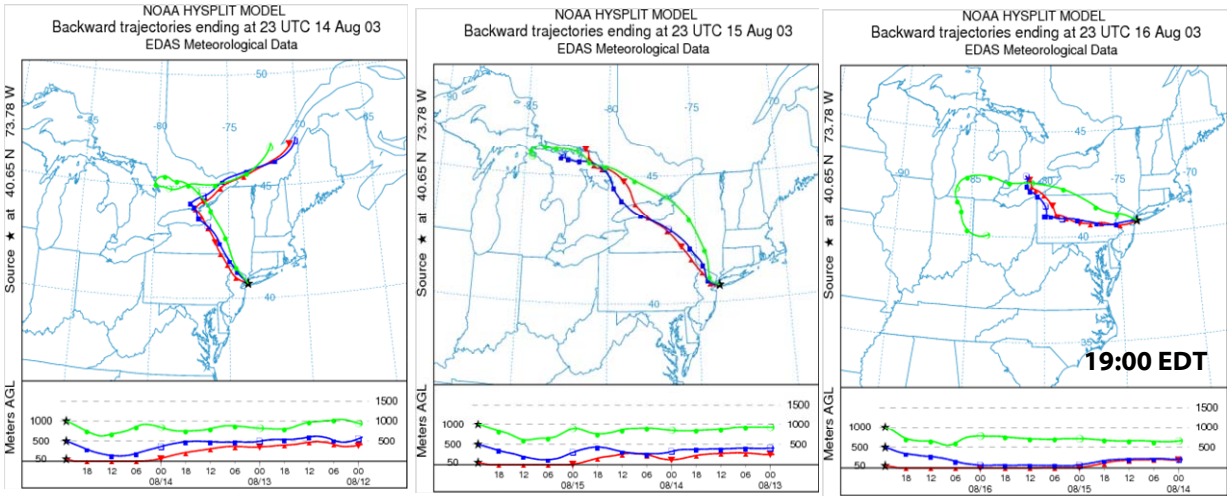
Aug 14 | Aug 15 | Aug 16



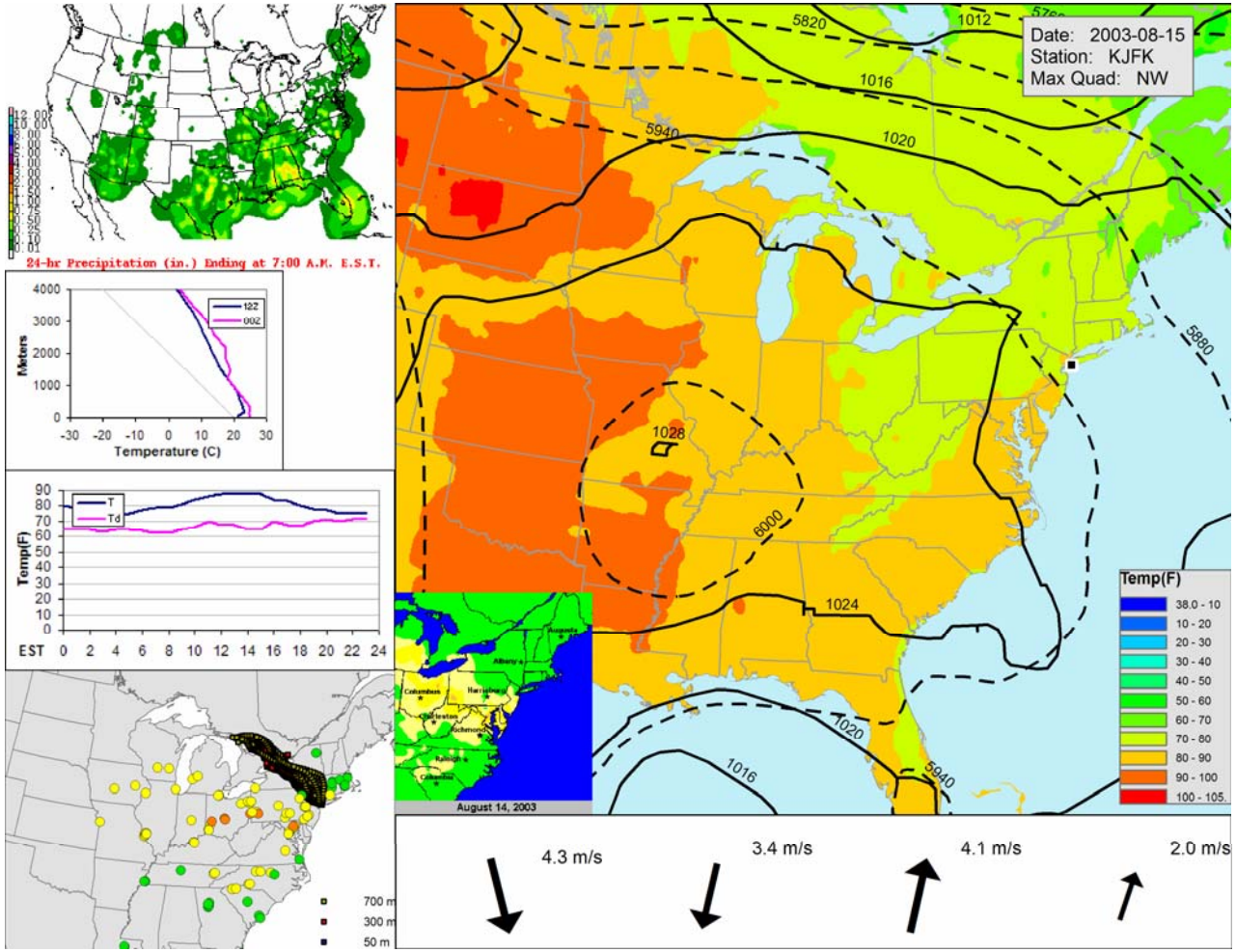
Satellite IR Imagery and Back Trajectory Data

Aug 14 | Aug 15 | Aug 16

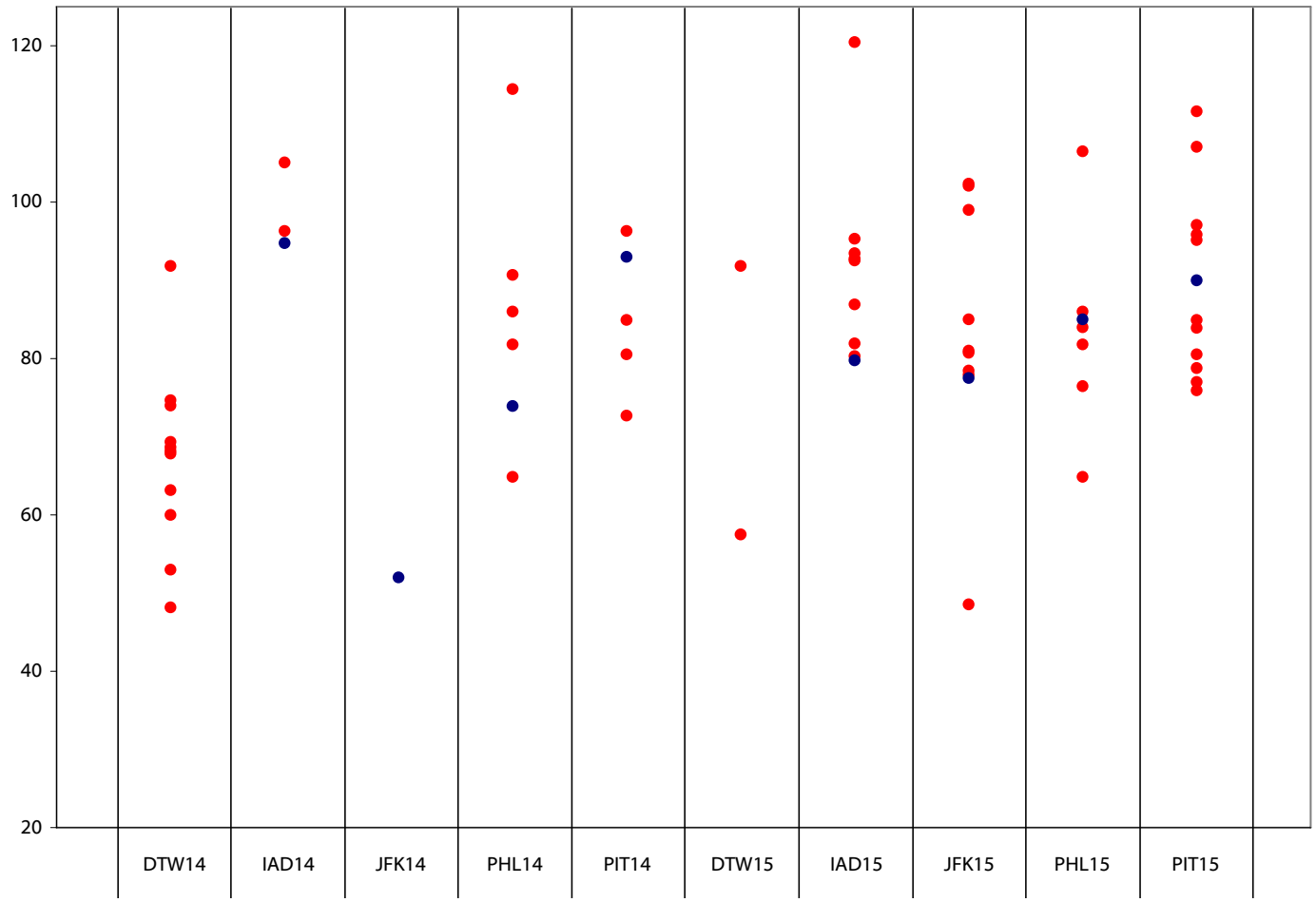




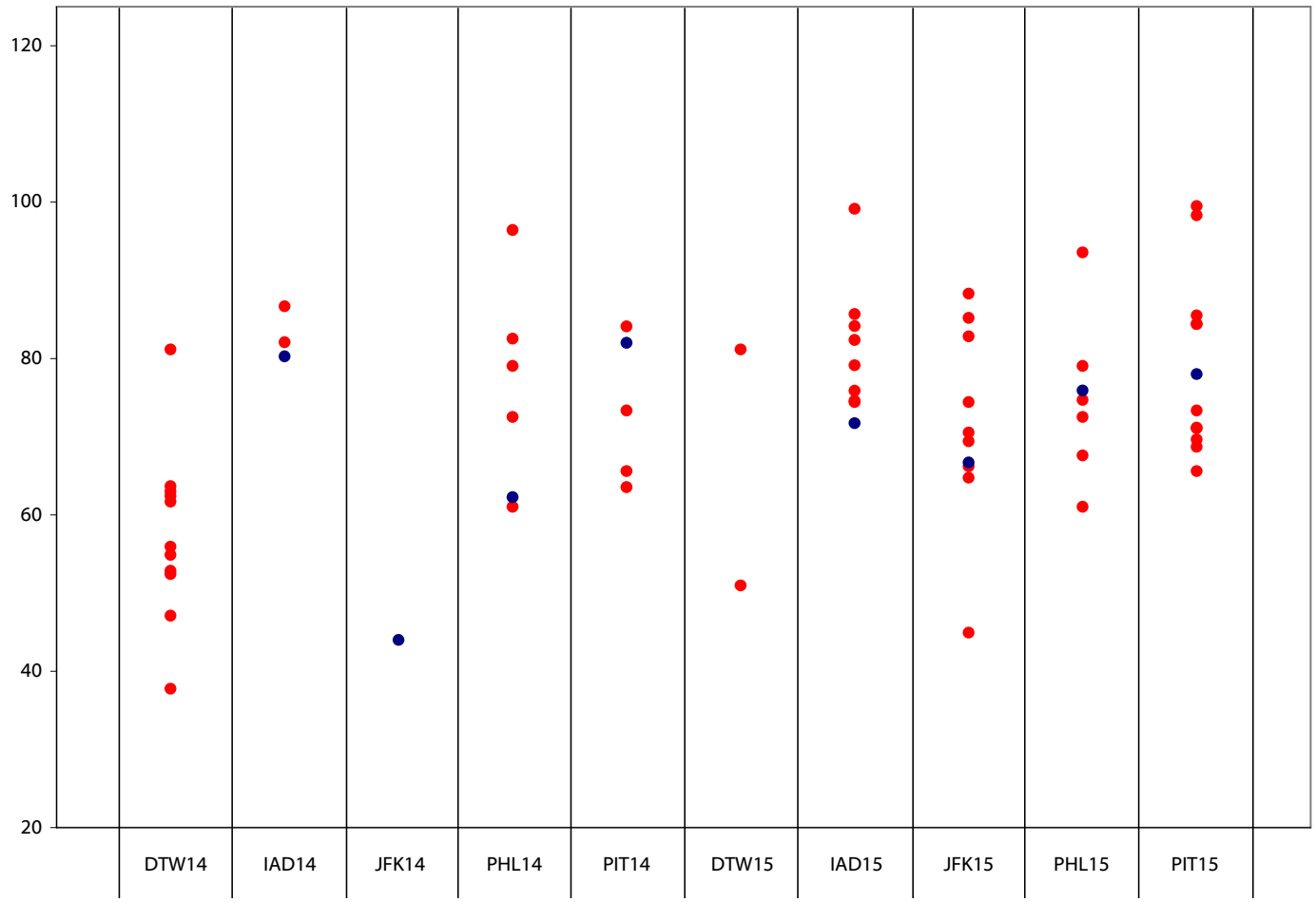
Synoptic Weather Condition Summary



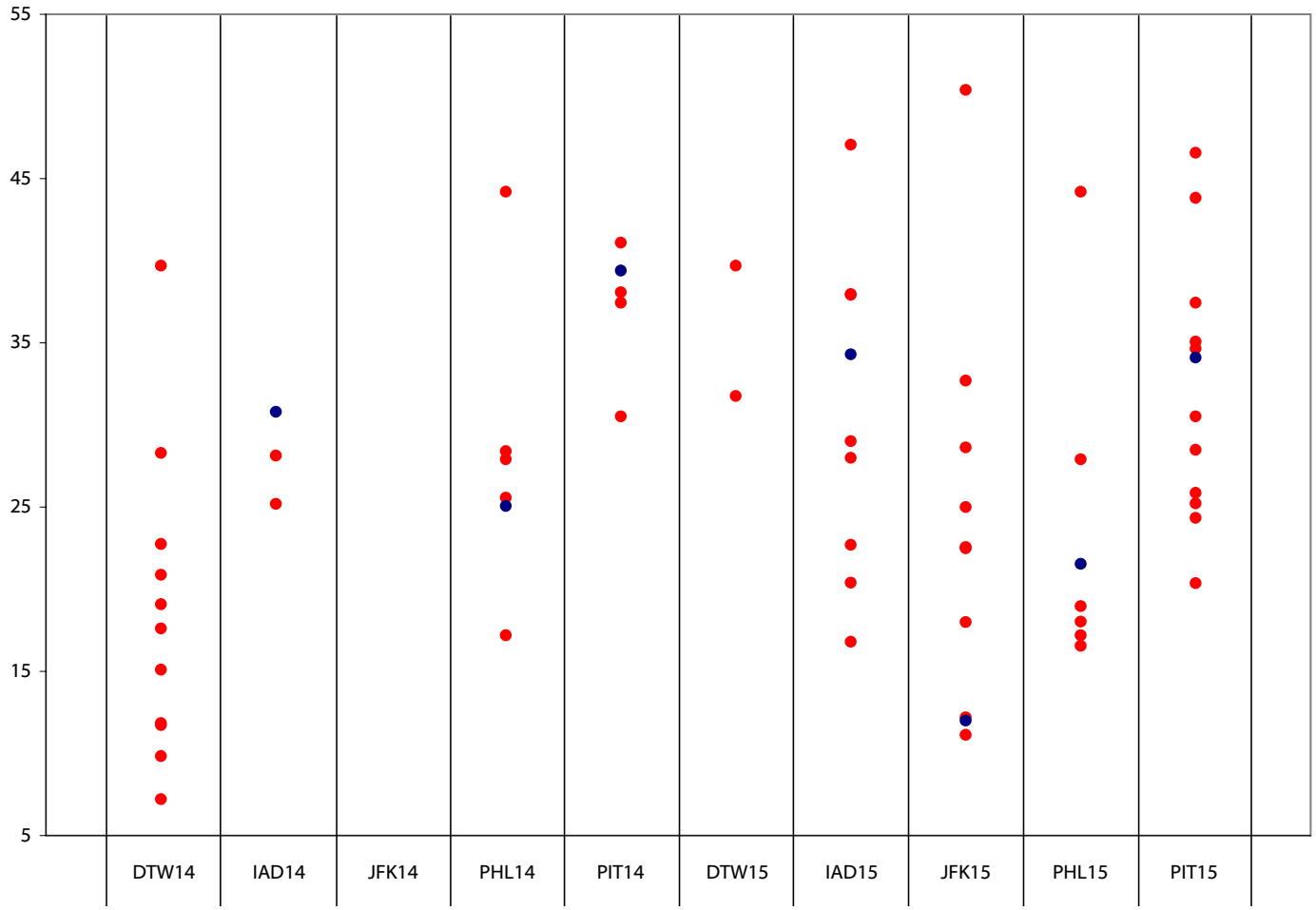
Cluster Analysis Results: 1-Hour Ozone (ppb)



Cluster Analysis Results: 8-Hour Ozone (ppb)



Cluster Analysis Results: $PM_{2.5}$ ($\mu g/m^3$)



Summary Table

Site	Number of Matches Ranks 1-3		Obs 14 Aug 2003 (Matching Day Range) Obs 15 Aug 2003 (Matching Day Range)		
	14 Aug 2003	15 Aug 2003	24-hr $PM_{2.5}$	1-hr O_3	8-hr O_3
IAD	2	8	31 (25-28) 34 (17-47)	95 (96-105) 80 (80-120)	80 (82-87) 72 (74-99)
JFK	0	9	- 12 (11-50)	- 78 (49-102)	- 67 (45-88)
PHL	5	6	25 (17-44) 22 (17-44)	74 (65-114) 86 (65-106)	62 (61-96) 76 (61-94)
PIT	4	11	39 (31-41) 34 (24-47)	93 (73-96) 90 (76-112)	82 (64-84) 78 (66-100)

Summary Text

IAD:

- 24-hr $PM_{2.5}$ on 14 Aug 2003 higher than on matching days; on 15 Aug 2003 in mid-range of that on matching days: **Unable to infer** any influence of generator trips.
- 1-hr maximum O_3 on 14 Aug 2003 lower than on matching days; on 15 Aug 2003 at low end of range of that on matching days: **No distinguishable effect** of generator trips since match is worse on 14th than 15th.
- 8-hr maximum O_3 on 14 and 15 Aug 2003 2 ppb lower than on either matching day: **No discernable effect** of generator trips

JFK

- 24-hr $PM_{2.5}$ on 15 Aug 2003 at lower end of range of that on matching days: **Possible, but inconclusive** indication that $PM_{2.5}$ is lower because of generator trips.
- 1-hr and 8-hr maximum O_3 on 15 Aug 2003 in mid-range of that on matching days: **Unable to infer any influence** of generator trips.

PHL

- 24-hr $PM_{2.5}$ on 14 and 15 Aug 2003 both in lower third of range of that on matching days: **Unable to infer any influence** of generator trips.
- 1-hr and 8-hr maximum O_3 on 14 Aug 2003 near lower end of range of that on matching days; but higher and in mid range of that on matching days on 15 Aug 2003: **Possible, but inconclusive** indication that O_3 is higher because of generator trips.

PIT

- 24-hr $PM_{2.5}$ on 14 Aug 2003 near high end of range of that on matching days; on 15 Aug 2003 in mid range of that on matching days: **Possible, but inconclusive** indication that $PM_{2.5}$ is lower because of generator trips.
- 1-hr maximum O_3 on 14 Aug 2003 is near low end of range of that on matching days; on 15 Aug 2003, it is at mid range of that on matching days: **Possible, but inconclusive** indication that O_3 is higher because of generator trips.
- 8-hr maximum O_3 on 14 Aug 2003 is near high end of range of that on matching days; on 15 Aug 2003 it is in the lower third of the range of that on matching days: **Possible, but inconclusive** indication that O_3 is lower because of generator trips.

Summary

- We used an **extensive suite of criteria to identify many days meteorologically similar to the blackout days in several cities**, but were unable to draw quantitative conclusions regarding **the effect of the August 2003 blackout on surface air quality** in the eastern United States by comparing air quality on meteorologically similar days.

- This suggests that there are **too many stochastic variables** influencing air quality to be able to distinguish the effect of **emission changes of the magnitude experienced during the blackout** from the effects of all the other variables **using this approach**.

Scientific Community Feedback: Editor's Choice, 2004. *Science, 305,* 755.

cancerous states are linked with changes in somatic cell ploidy; and some species of sturgeon can even exhibit octoploidy.

Nuismer and Otto contend that selection favors diploidy in host species and haploidy in parasitic species when there is a single ploidy locus. The reason is that parasites that express a narrow array of antigens or elicitors are more successful at evading the host immune system, whereas hosts with a wide variety of recognition molecules are more apt to catch invading parasites. In this scenario, alleles that increase host resistance tend to be dominant, and those that enhance parasite virulence tend to be recessive. A survey of many thousands of heterotrophic protests showed that those with parasitic lifestyles were three to four times more likely to be haploid than diploid. A striking example is the diploid parasite *Trypanosoma brucei*, which sequesters its large family of variant surface glycoprotein genes within haploid regions of its genome. — CA

Proc. Natl. Acad. Sci. U.S.A. **101**, 11036 (2004).

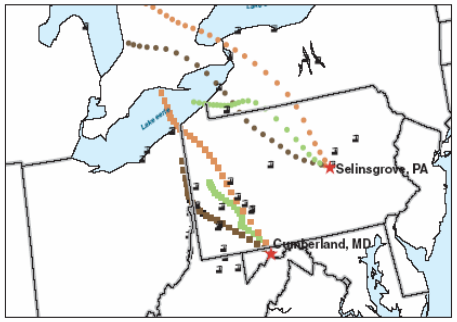
ATMOSPHERIC SCIENCE

Serendipitous Surcease

The electrical blackout that affected the northeastern United States and southeastern Canada in August 2003 dramatically reduced the output of polluting species—sulfur dioxide (SO_2), which produces fine particles, and nitrogen oxides (NO_x), which produce ozone (O_3)—from more than 100 power plants. This created a rare opportunity for evaluating directly the contribution of power plant emissions to the formation of regional haze and smog.

Marufu *et al.* report the results of a series of measurements made from airplanes that flew over central Pennsylvania (inside the affected region) and western Maryland (outside) about 24 hours after the beginning of the blackout. Concentrations of SO_2 and O_3 in Pennsylvania were much lower than those measured over western Maryland earlier that day and in comparison to the same location in Pennsylvania a year earlier. Light scattering due to small particles decreased, yielding an improvement in visibility of >40 km. These observations provide a test case for assessing how well numerical models can reproduce the contributions of specific pollution sources to regional air quality. — HJS

Geophys. Res. Lett. **31**, 10.1029/2004GL019771 (2004).



Modeling emission trajectories upwind of central Pennsylvania and western Maryland.

- This created a rare opportunity for **evaluating directly** the contribution of power plants emissions to the formation of regional haze and smog.
- These observations provide a "test case" for assessing how well numerical models can reproduce the contributions of **specific pollution sources** to regional air quality.
- **I think we can all agree to that.**

“If you come to a fork in the road, take it.”

Georgia Tech takes the fork in the road!

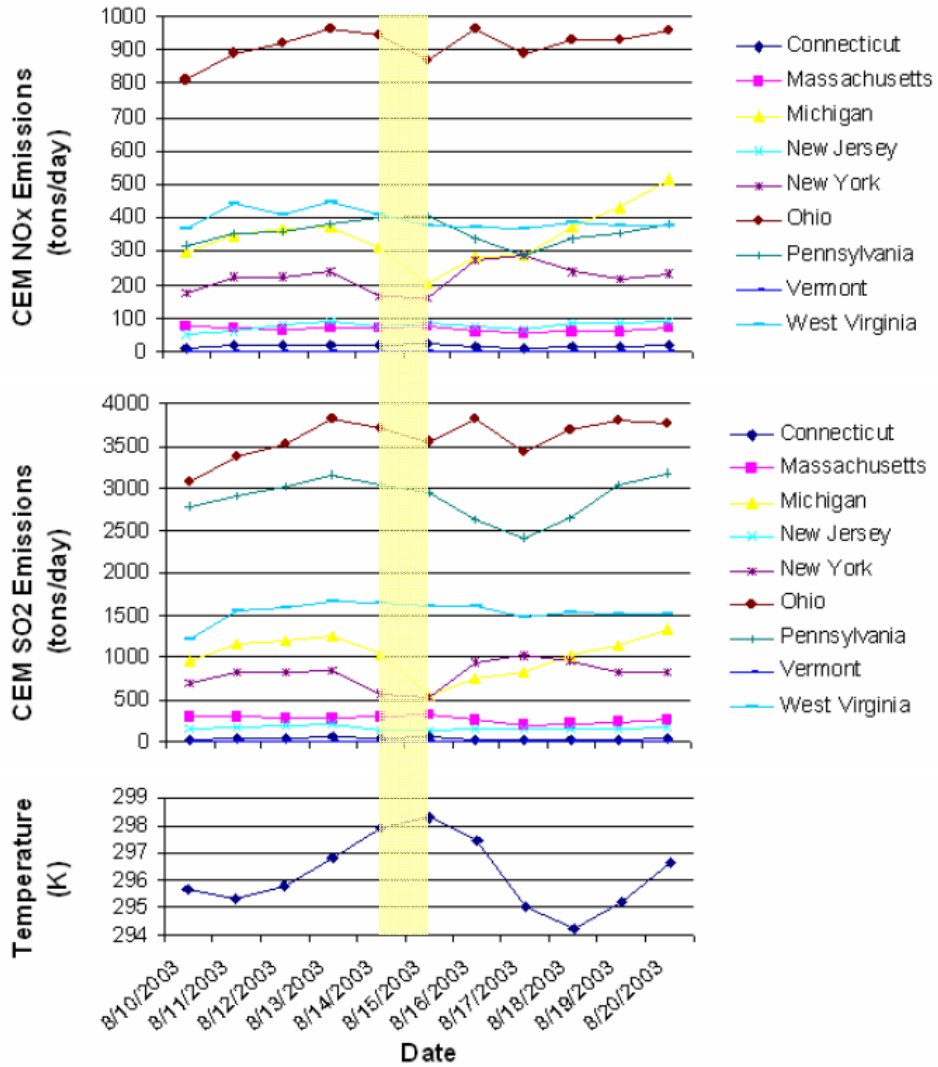
- Georgia Tech adopted a modeling approach using CMAQ with a direct sensitivity technique (DDM-3D) to quantify how emissions reductions from different sources impacted ozone and particulate matter.
- Model reproduced regional air quality well days before and after blackout.
- **Blackout Case:**
  - Used Actual CEM Data for SO_2 and NOx from EGUs in United States. Estimated emissions reductions in Canada.
  - To represent the likely reduced emissions associated with traffic and other source emissions during the blackout, August 15, 2003 (Friday) was treated as a weekend day in SMOKE **in the blackout affected areas.**
- **Non-Blackout Case**
  - Used projected SO_2 and NOx emissions based on load demand as a function of weather in both U.S. and Canada.
  - Default weekday emissions for all regions in modeling domain for mobile and other sources.

Daily CEM and Temperature Data (Highlighting Friday August 15, 2006)

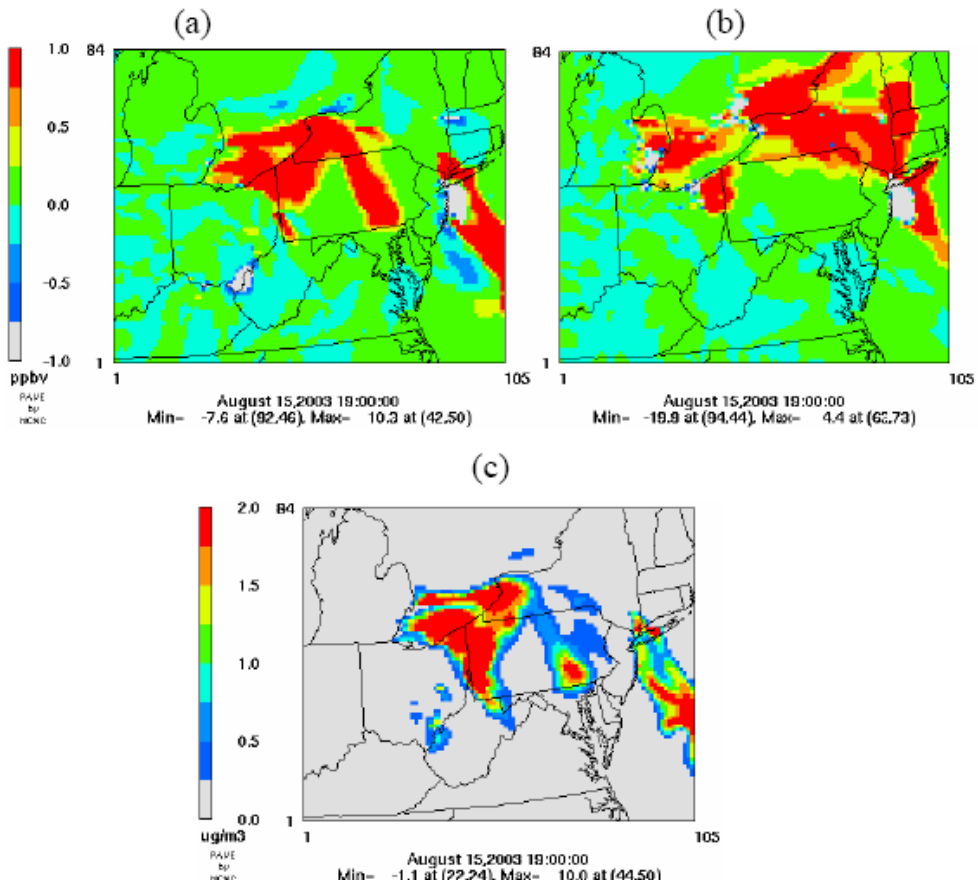
From Hourly Data:

- Only minor perturbations in **MA and PA.**
- Perturbations in **OH** were minor in a relative sense but large in an absolute sense.
- Major, precipitous emissions reductions in **MI, NY, and CT** (relative sense for **CT**).
- Restart of fossil units in **OH, NY and CT** was relatively quick.
- It took longer in **MI** than in other states to restart generators.

Nuclear stations in **US** and **Canada** took up to 72 hours to restart.

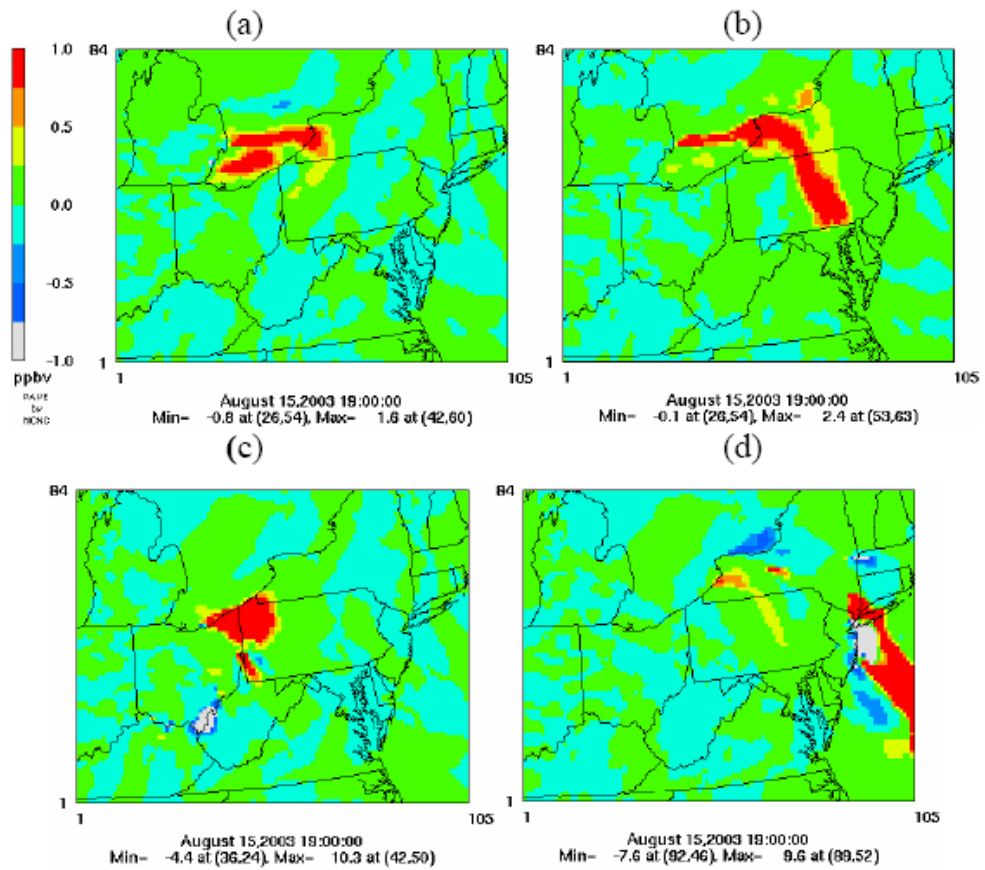


CMAQ-DDM Results



DDM-3D calculated contributions to hourly surface concentration from emission reductions from blackout affected areas: (a) EGU NOx to O_3; (b) On-road NOx to O_3; (c) EGU SO_2 to sulfate.

CMAQ-DDM Results: Subregion Impacts



DDM-3D results: impacts on hourly O_3 concentration from NOx emissions reductions from EGU sources in: (a) MI (b) ON (c) OH and (d) NY/NE.

Summary of Georgia Tech Analysis

- Simulated air quality fields were able to reproduce both the regular surface air quality observations and airborne measurements before and during the blackout.
  - Could not replicate SO_2 profile on August 15, 2003 at Selinsgrove.
- Sensitivity results show that blackout-linked power plant SO_2 emissions reductions led to a **sulfate concentration reduction of 22% at Selinsgrove**, Pennsylvania, while power plant NOx emissions reductions had **very limited (~ 4%) impacts on O_3**.
- Results also suggest that over much of the region **on-road mobile NOx emissions reductions** linked to the blackout **had a larger impact on ozone**. Results suggest that more **benefits can be obtained through regional on-road mobile NOx control** than the local control alone.
- Thanks to Yongtao Hu, Talat Odman and Ted Russell for allowing me to present their results at this symposium.

Take-Home Message: Conservation and Efficiency

Some Final Thoughts from Yogi

- **About the Blackout:**
  - "You can observe a lot just by watching."
- **About Emissions:**
  - "It's tough to make predictions, especially about the future."
- **About Research:**
  - "You've got to be very careful if you don't know where you're going, because you might not get there."
- **About this Presentation:**
  - "If you ask me anything I don't know, I'm not going to answer."