The Electrical Blackout over Eastern North America
August 14-16 2003:
An Accidental Experiment in Air Chemistry

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0114Z
~7 hrs after Blackout

Brightness in Boston is unchanged
Brightness in Long Island is MUCH reduced
Question: What would happen to air quality if emissions from power plants were suddenly eliminated?
Problem: Many of the pollution monitors were without power.
Experimental Control

Compare pollutant concentrations in the blackout region to those of:

• Blackout day, south of the blackout area.
• Meteorologically similar, non-blackout day in same location.
• All flights (1997-2003) with similar meteorology selected by an objective back trajectory clustering technique.
Power plants upwind of Cumberland were operating normally.

SO\textsubscript{2} 34\%, NO\textsubscript{x} 23\%
Ozone and Flight Altitude 08/15/03

Cumberland, MD

Fort Meade, MD

Central PA

UTC (EST + 5hr)
Back Trajectories

(24 hr @ 500, 1000, and 1500 m)
Weather on the day of the blackout – High pressure means hot, sunny, stagnant, and (usually) smoggy.
Weather on reference day – Also High pressure.
(err on the side of caution)
Idled power plants means improved air quality.

Observations over central Pennsylvania.
48 hour back trajectories ending at 2 km for all flights from cluster 1

$[O_3] = 73 \text{ ppb near 1000 m}$
48 hour back trajectories ending at 2 km for all flights from cluster 2

$[O_3] = 65 \text{ ppb near 1000 m}$
48 hour back trajectories ending at 2 km for all flights from cluster 3

\[ [O_3] = 65 \text{ ppb near 1000 m} \]
48 hour back trajectories ending at 2 km for all flights from cluster 4

$[O_3] = 58$ ppb near 1000 m
48 hour back trajectories ending at 2 km for all flights from cluster 5

\[ [O_3] = 73 \text{ ppb near 1000 m} \]
48 hour back trajectories ending at 2 km for all flights from cluster 6

$[O_3] = 74$ ppb near 1000 m
48 hour back trajectories ending at 2 km for all flights from cluster 7

\[ [O_3] = 47 \text{ ppb near 1000 m} \]
48 hour back trajectories ending at 2 km for all flights from cluster 1

$[O_3] = 73$ ppb near 1000 m
48 hour back trajectories ending at 2 km for all flights from Cluster 1

\[ [O_3] = 73 \text{ ppb near 1000 m} \]
\[ = 50 \text{ ppb during blackout} \]
O$_3$ Median (10% & 90%) for afternoon Cluster 1 (62 profiles)

Flights during Blackout in color.
SO$_2$ Median for afternoon Cluster 1 (54 profiles)

Pressure derived altitude (m)

SO$_2$ (ppb)

with 10$^{th}$ and 90$^{th}$ percentiles
Particle scattering Median for **afternoon** Cluster 1 (42 profiles)

Pressure derived altitude (m)

Particle scattering at 550 nm (m\(^{-1}\))

with 10\(^{th}\) and 90\(^{th}\) percentiles
Particle absorption Median for **afternoon** Cluster 1 (52 profiles)

Pressure derived altitude (m)

Particle absorption at 550 nm (m\(^{-1}\))

with 10\(^{th}\) and 90\(^{th}\) percentiles
CO Median for afternoon Cluster 1 (39 profiles)

Pressure derived altitude (m)

CO (ppb)

with 10th and 90th percentiles
During the Blackout:

- Ozone was in the lowest 5\textsuperscript{th} percentile of all observations; 25 ppb below median.
- SO\textsubscript{2} was below 5\textsuperscript{th} percentile of all observations; a fraction of the median.
- Aerosol scattering in lowest 10\textsuperscript{th} percentile; a factor of 3 below the median.
- Visual range increased by >40 km (25 mi).
- CO and b\textsubscript{ap} (black carbon) were near the median.
- Forecast O\textsubscript{3} (regression equation) 115 ppb, observed 90 ppb.
Major Findings:

• Emissions from power plants can dominate aerosol loading over eastern North America.

• Long range transport (100’s of km) played a major role in haze and photochemical smog (O₃) formation over the East Coast.

• Reduction in ozone exceeded that expected.
Why was the ozone so low?

Are there processes not well simulated by CMAQ?  
Is the $O_3$ production efficiency higher aloft than in PBL?

• More UV radiation for $NO_2$ photolysis aloft (Science, 1997).

• Reactions of $NO_3$ and VOC’s at night remove odd oxygen and NOx (Brown et al., GRL, 2006). Could make EGU NOx more efficient than urban NOx.
Altitude profiles of photolysis rate coefficients for solar zenith angles of 60° and 0° and aerosol optical depths of 0.0, 0.5, 1.0, 1.5, and 2.0.

\[ \text{NO}_2 + \text{hv} (+\text{O}_2) \rightarrow \text{NO} + \text{O}_3 \]

Area 3. Plot of nighttime chemistry of an urban plume showing permanent ozone destruction at night (blue points) with $\sim 1.6$ O$_3$ destroyed for each molecule of NOy. Faster than in a power plant plume.
Mechanisms

\[ 2\text{NO}_2 + \text{PM(H}_2\text{O}) \rightarrow \text{HNO}_3 + \text{HNO}_2 \]

or

\[ \text{NO} + \text{O}_3 \rightarrow \text{NO}_2 + \text{O}_2 \]
\[ \text{NO}_2 + \text{O}_3 \rightarrow \text{NO}_3 + \text{O}_2 \]
\[ \text{NO}_3 + \text{RCHO} \rightarrow \text{HNO}_3 + \text{RCH} \cdot \]

Net \[ \text{NO} + 2\text{O}_3 + \text{RCHO} \rightarrow \text{HNO}_3 + \text{RCH} \cdot \]
Take home messages.

• Using three methods to control for weather, ozone was tens of ppb below normal during the blackout.

• CO and $b_{ap}$ remained high suggesting that other (s.a. mobile) sources were emitting normally.

• Why was ozone low during the heat wave this (2006) summer?
Cumulative distribution functions of the daily maximum 8-hr ozone concentrations at site ABT147 during the ‘pre’ and the ‘post’ SIP Call periods, based on: (a) raw data, (b) met-adj. data. Gego et al. JAMC, in review 2006.
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