A Brief Review of the Summer 2008 Air Quality Season in the Mid-Atlantic

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Frequency of high $O_3$ cases was lower across the region in 2008.

Weather conditions during Summer 2008
- Was lower $O_3$ due to the weather? Yes and No.

Brief results from Philadelphia and recent trends in severe $O_3$ cases.

A very interesting, long-lasting, poor air quality episode in June.

How continuous PM$_{2.5}$ monitor data is used in forecast preparation.
National Look At 2008 Ozone

2008 Ozone Season Review
(May 1 through September 30)

Figure courtesy of EPA AirNow, Scott Jackson
Smoke in the Central Valley of California
Changes in PHL Color Code Frequency Since Regional NO\textsubscript{x} SIP Rule

1994-2002

2003-2008
Severe O$_3$ Cases are Now Rare in Philadelphia
Summer Season Dry in the Mid-Atlantic

Percent of Normal Precipitation 1971–2000
Jun to Aug 2008

NOAA/ESRL PSD and CIRES–CDC
Summer Season Also Warm

Temperature Anomalies (°F)
Jun to Aug 2008
Versus 1971–2000 Longterm Average

NOAA/ESRL PSD and CIRES–CDC

-3.0 -2.0 -1.0 0.0 1.0 2.0 3.0
Average Geopotential Height at 850 mb (Height ~ Pressure)

Below:
Change from normal.
Blue = lower heights
Wind Velocity at 850 mb

Red boxes are areas with higher than normal rain.
Ozone Episodes in the Mid-Atlantic (2008)

Number Monitors > Code Orange

Date (2008)

Preliminary data!
Where is the Bermuda High?

Mean sea level pressure field for August

Sea Level Pressure (mb) Composite Mean
08/01/08 08/31/08
NCEP/NCAR Reanalysis
Sustained Northwest Flow in August Suppresses Rainfall
June 7-13, 2008 Poor Air Quality Episode

- Both PM$_{2.5}$ and O$_3$ concentrations reached the Code Orange range.
- Fires in eastern NC.
- Large day to day swings in O$_3$ concentrations:
  - Why do we care about “mesoscale convective systems” (MCS)?
  - How much of poor air quality is due to smoke?
June Episode: Bermuda High
While winds near the surface tended to be light southwest, winds aloft are stagnant near the center of the 850 mb (~ 5K ft) high (in NC) and westerly for the rest of the mid-Atlantic.
June 6: “Back Door” Cold Front Stalls, Later Reverses and Moves North

Moderate air quality along and south of stationary front on June 6
Heavy Fog in Cool Air North of Front Dissipates During Afternoon
Smoke from Fires in NC Drift North as Winds Shift to the SE on June 6
June 7: No Wind, Strong Morning Inversion, Clear Skies

Noon June 7

Afternoon June 7
June 7: Haze and Smoke in DC

June 7, 2008

Clean Day
Both Pollutants in the Code Orange Range on June 7
June 7 was one of the smoggiest days of the year in terms of a combination of all pollutants.

The forecast for June 8 was continued hot and humid weather with transport from the Ohio River Valley – the classic high O₃ and PM₂.₅ pattern.

It was, in fact, just as hot (93°F) and more humid but both O₃ and PM₂.₅ concentrations fell!

It was a Sunday but was that all?
A Few Words About the “Ring of Fire”
Storm Began Day Earlier: June 6
Squall Line Evident by Late Afternoon

Noon June 6
Late Afternoon June 6
Sun Goes Down – We Follow on Infra Red
Southern Portion of Squall Line Now Expanding

9 pm June 6

Midnight June 7
Collision of Outflow Boundaries in IL
Mesoscale System Fully Developed in IN and Drifts East

1 am June 7
Note new storms form where outflow boundaries collided

2 am June 7
Rapid intensification in IL
Next set form along Mississippi River
System Intensifies Through the Night
Outflow Boundaries Reach PA and WV

3 am June 7

5 am June 7
Just Such a System Dropped South into the Ohio River Valley on June 7th
Remnants of Convection Cross I-95 Sunday with Strong Winds Observed Aloft

Dulles (IAD) morning sounding winds 20+ knots above top of nocturnal inversion (~ 400 m)

Visible Satellite Image Sunday morning, June 8
Result: Mid-Atlantic Moderate for $O_3$
$PM_{2.5}$ Decreases Though At a Smaller Rate
June 9: Back in the Soup
Westerly Transport, Weak Vertical Mixing

Visible Satellite Image
Monday, June 9, Afternoon
High $\text{O}_3$ Returns Along I-95 on June 9
Pockets of High $\text{PM}_{2.5}$ – NC Especially
Is Poor Air Quality Fire Related?

Forward trajectories starting June 8

Back trajectories ending June 9
Forward Trajectories for June 9-10

NOAA HYSPLIT MODEL
Forward trajectories starting at 12 UTC 09 Jun 08
EDAS Meteorological Data

NOAA HYSPLIT MODEL
Forward trajectories starting at 12 UTC 10 Jun 08
EDAS Meteorological Data
A Cold Front Approaches from the West on June 10

Visible Satellite Image
Afternoon, Tuesday, June 10
Result: Both $O_3$ and PM$_{2.5}$ Code Orange
While Thickest Smoke is East of NC, Significant Haze Observed Along I-95
Mid-Atlantic PM$_{2.5}$ Concentrations

Hourly time series for selected monitors, black line is DC-PHL regional mean
PM$_{2.5}$ Monitors in southern VA
A Weak Front Arrives Early June 11

Surface Analysis 0600 UTC, June 11

Visible Satellite Image Afternoon, June 11
Smoke Circulates Back Inland on June 11
Scattered Code Orange $O_3$
Higher PM$_{2.5}$ Limited to NC/SC
Weak “Back Door” Front on June 12
Clear Skies on June 12 but Smoke Evident in southern VA and across NC
Recirculation on June 13

NOAA HYSPLIT MODEL
Backward trajectories ending at 21 UTC 12 Jun 08
EDAS Meteorological Data

Source ★ at 38.8°N 77.0°W

Meters AGL

0 06/12

18 12 00 06

1500 ★ 1000 ★ 500 ★

Job ID: 312831  Job Start: Tue Oct 21 16:03:25 GMT 2008
Source1 lat.: 38.8° lon.: -77.0° hgs.: 1500, 1000, 500 m AGL
Trajectory Direction: Backward Duration: 24 hrs. Meta Data: EDAS40
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)

NOAA HYSPLIT MODEL
Backward trajectories ending at 21 UTC 13 Jun 08
EDAS Meteorological Data

Source ★ at 38.8°N 77.0°W

Meters AGL

0 06/13

18 12 06 00

1500 ★ 1000 ★ 500 ★

Job ID: 312890  Job Start: Tue Oct 21 16:11:19 GMT 2008
Source1 lat.: 38.8° lon.: -77.0° hgs.: 1500, 1000, 500 m AGL
Trajectory Direction: Backward Duration: 24 hrs. Meta Data: EDAS40
Vertical Motion Calculation Method: Model Vertical Velocity
Produced with HYSPLIT from the NOAA ARL Website (http://www.arl.noaa.gov/ready/)
Smoke Creeps Up Eastern Slope of Appalachians
Widespread Code Orange and Red O$_3$ Beneath High Pressure Center

June 13, 2008
Approaching Cold Front Sweeps Smoke and Haze East on June 14
Burst of High PM$_{2.5}$ in DC and Rural VA Obscured in 24-Hour Average
Code Orange $O_3$ and $PM_{2.5}$
Episode Finally Ends with Change in Air Mass on June 15
Comparison of Three Monitors

PNE and Chester are MET-One BAMS (beta attenuation) monitors. Norristown is a TEOM-FDMS (modified oscillating microbalance with electrostatic precipitator).
Presumably, the FDMS measures more semi-volatile compounds.
Mean of 4 Highest Continuous Monitors is FRM-Like
Forecasts Informed by This Method Show Skill
Conclusions

- The frequency of high ozone cases was low during the Summer of 2008 across the region.
- High ozone cases continue to be less frequent since 2002.
- Fires in eastern NC impacted fine particle concentrations throughout the month of June.
Hourly Time Series and Daily Mean