Some Aspects of the 2005 Ozone Season

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2005 MARAMA Monitoring Committee Meeting
Ocean City, Maryland
November 15-17, 2005
Three Topics of Interest

• Was 2005 a typical summer $O_3$ season?
  – Is it enough to just be hot?

• Are $O_3$ concentrations falling in response to regional $NO_x$ controls?
  – Is the ground moving under our feet?

• Improvements in $O_3$ forecast capability.
  – Now a reliable forecast tool?
Philadelphia Mean Daily Peak O₃

2005 mean is 5 ppbv (~ 8%) lower than the 1994-2002 average.
Philadelphia O$_3$ Concentrations by Color Code

1994-2004

In 2005, less Code Orange and more Code Green

2005
Frequency of Days $\geq$ 85 ppbv


Number of Code Orange or Red days in 2005 is 45% less than 1994-2002
But It Was a Hot Summer.....
Hot Even by Recent Standards

Temperature Percentile Value Relative to 1971–2000
Jun to Aug 2005

Map of the United States showing temperature percentile values with a color scale from blue (5%) to red (95%).
Hot and Dry….Usually Means Bad Air
Is Hot Weather Enough for High O₃?

Average maximum temperature for Code Red cases in Baltimore (1990-2000) is 93°F

For PHL average maximum temperature is also 93°F (1994-2004)
Hot Days Very Frequent in 2005
Hot Weather is Necessary but not Sufficient for Code Red – though usually for Code Orange

Only 30% of all cases where maximum temperature reaches or exceeds 90°F reach the Code Red threshold.

For PHL ~ 29% of hot days are Code Red but 74% are at least Code Orange. (1994-2004)
Why Doesn’t Hot Weather Always Mean High $\text{O}_3$?

Cloud cover, rain and wind associated with convection (thunderstorms).

Strong winds alone can be enough to keep $\text{O}_3$ below the Code Red range.

Source of the air mass can matter, onshore winds with maritime air mass characteristics are low in $\text{O}_3$ and precursors.
No Significant Difference in Transport Pattern Aloft in 2005

HYSPLIT (NOAA/ARL) back trajectory model results. 24-hour back trajectories terminating at 1000 m above ground level at 1200 UTC (0800 am local).
But, More Likely to Have Stagnation and Reverse Corridor Flow at Low Levels
Very Hot in 2005 but Weaker O₃ Response

While departure from normal temperature was > 2° F (similar to 1999, 2001-2002), number of days > 85 ppbv was 40% less frequent
Since 2003, the Number of Days $\geq 90$ °F Exceed the Number of Days $\geq 85$ ppbv
Are We Seeing the Impact of the 22 State NO\textsubscript{x} Rule?
Regional NO$_x$ Controls and Local O$_3$

The working scientific hypothesis for O$_3$ control was:

O$_3$ concentrations are limited by NO$_x$ for most of the eastern US – excluding urban and near-urban areas.

Point source NO$_x$ controls will decrease regional-scale (baseline) O$_3$.

A lower baseline concentration would make it less likely for urban area O$_3$ spikes to exceed the NAAQS standard.
Phase in of Regional NO\textsubscript{x} Controls
Expected NO\textsubscript{x} Reductions are Significant

Figure 114. Nitrogen oxide emissions from electricity generation, 1990-2025 (million short tons)

Figure courtesy of DOE:  http://www.eia.doe.gov/oiaf/aeo/
What Predictions from Hypothesis?

• If “baseline” $O_3$ is falling:
  – Should see fewer total Code Red and Code Orange days
  – While urban areas will still have local emissions sufficient for Code Red, should see fewer extreme $O_3$ cases
  – Urban “plume” of high O3 should be smaller so that fewer monitors exceed Code Red or Code Orange for any given bad air day.
  – Rural monitors should show lower $O_3$. 
Number of Code Orange or Red Days (PHL)

Recall: Number of Code Orange or Red days in 2005 is 45% less than 1994-2002
In MARAMA Region, Number of Monitors Exceeding 85 ppbv Much Reduced

But 2003 and 2004 were not O_3 conducive although 2005 was.
And the Number of Monitors Exceeding 85 ppbv per Code Orange (or Red) Day are Lower as Well
Total number of extreme O$_3$ Days (8-hour O$_3$ $\geq$ 110 ppbv) for all MARAMA states
Mean O$_3$ and Frequency of High O$_3$ Days at Shenandoah NP
Caveats

• No statistical significance with small data sample containing strong serial correlation.
• Although 2005 was hot and dry, “classical” high O$_3$ patterns not as frequent as 2002.
• 2003 and 2004 were low O$_3$ summer weather-wise.
NOAA O$_3$ Forecast Models: Current Configuration
NOAA Forecast Model Assumes Large NO\textsubscript{x} Reductions

Source: Department of Energy Annual Energy Outlook
http://www.eia.doe.gov/oiaf/aeo/index.html
Overall Performance of Model Encouraging

Figure Courtesy of Rohit Mathur (ARL/NOAA)
Analysis of Forecast Skill in PHL

- Performance in “Difficult” Cases Was Good
  - Onset of high O$_3$ episode
  - Termination of high O$_3$ episode
  - “Non-standard” high O$_3$ cases
  - Code Red Cases

- Large Error Cases Caught by Other Methods

- Systematic Errors Did Occur
  - Urban core over-prediction
  - High concentrations at sea/land boundary
## Forecast Accuracy for O\textsubscript{3} Episode Days in PHL (Developmental Model – 5X)

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July 26: Code Red Forecast Verifies

But over-prediction in the urban corridor from Wilmington through Philadelphia.
July 22: Code Red Forecast Verifies

The opposite problem was found in 2003 (see below).

Downtown PHL: 61-90 ppbv observed
August 12: Missed Code Red
Slight Westward Displacement of High O₃ Plume
August 4: Missed Code Red – Convection in NJ Forecast

Convection observed as forecast, no one told northern Delaware though.........
“Non-Standard” Case: Low level winds drain from north to south
Systematic Errors: Abnormally high O$_3$ at bay/land interfaces
Large Error Case: False Alarm of Code Orange

NAM-12 did not forecast cloud cover, statistical models handled case well.
Large Error Case: Offshore circulation causes stagnation near I-95
Conclusions for NOAA Model

• Performance in high O$_3$ episodes very promising:
  – Onset and termination of high O$_3$ episodes well forecast
  – Code Red cases identified
  – Over-prediction in near-urban environment, adjusted for by post-processing?

• Large error cases occurred but caught by other forecasting approaches (e.g., statistical models) so didn’t impact operational forecasting

• Problems remain with water surfaces: Atlantic coast and Chesapeake and Delaware Bays
Overall Conclusions

• 2005 was a hot summer and generally conducive to high O$_3$ although frequency of westerly transport a bit less.

• Peak O$_3$ concentrations lower, given the weather, than we would have expected. Suggestion, not proof, of NO$_x$ Rule impact.

• NOAA O$_3$ Forecast model shows promise but all bets off next year (WRF).