Changes in Regional Ozone Patterns

Duc Nguyen, Senior Meteorologist

Presented at:
MARAMA Data Analysis Workshop
College Park, MD
January 19-20, 2011
<table>
<thead>
<tr>
<th>OBJECTIVE</th>
<th>OUTLINE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deliver Good News on Regional Ozone Trends.</td>
<td>Air Quality Cycle</td>
</tr>
<tr>
<td>Seek Help on Surrogates to Represent Mobile Emissions.</td>
<td>EGU Emissions</td>
</tr>
<tr>
<td></td>
<td>Mobile-Source Emissions</td>
</tr>
<tr>
<td></td>
<td>Pre/Post NO\textsubscript{x} Controls</td>
</tr>
<tr>
<td></td>
<td>Impact of Bermuda High &amp; Polar Jet Patterns</td>
</tr>
<tr>
<td></td>
<td>Outlook for 2011</td>
</tr>
<tr>
<td></td>
<td>Summary</td>
</tr>
</tbody>
</table>
Maryland 8-Hour Ozone Exceedances Days vs. 90° Days at BWI

2010 data are preliminary.
Maryland’s **8-hour ozone exceedance days** (OEDs) and **90° F days** at BWI follow a **periodic cycle** through 2002 ($R = 0.68$).

- OEDs below normal since 2002 regardless of temperature data.
- Air quality improvements have bee driven by effective control strategies. 
Controls in Action …
Ozone Season NOx Emissions

Compared to 1990 emissions, ozone season NOx emissions cut by 61% in 2003-2004.

NOx emissions decreased 77% by 2008 and 82% by 2009 (for units covered by CAIR).

Notes: “Dropout” units are those units that were included in the NBP but did not participate in the 2009 CAIR NOx ozone season program.

The 2009 total includes only former NBP units now covered by CAIR.


Figures extracted from EPA’s Clean Air Interstate Rule 2009 Progress Reports.
Ozone Season NO$_x$ Emissions by State

NO$_x$ SIP Call
Help DECREASE
Upwind NO$_x$
Emissions!

Map created by Maryland Department of the Environment using data extracted from Clean Air Markets - Data and Maps website.
# Characteristics of AQ Cycle

<table>
<thead>
<tr>
<th>EXCEEDANCE TENDENCY</th>
<th>UPPER-LEVEL PRESSURE/HEIGHT</th>
<th>CORRESPONDING SFC TEMPERATURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>More Days (Orange and Red)</td>
<td>Above Normal (Shades of Red)</td>
<td>Warmer Weather</td>
</tr>
<tr>
<td>Near Average (Gray)</td>
<td>Near Normal (White)</td>
<td>Near Normal</td>
</tr>
<tr>
<td>Less Days (Green and Blue)</td>
<td>Below Normal (Shades of Blue)</td>
<td>Cooler Weather</td>
</tr>
</tbody>
</table>

**Remark**

These characteristics can be observed spatially and temporally.
Air Quality Cycle (2000-2002)

- Months: Jun-Aug

This cycle has all the classic characteristics described on previous slide!

Maps created using data extracted from AirNowTech and ESRL PSD Plotting and Analysis. Some preliminary AQ data were used in the analysis.
Slightly Below Normal & Normal Pressure BUT Many Below Normal Counts

Relationship starting to break …

Higher Pressure BUT Many Below Normal Counts

Slightly Lower Pressure ~ Below Normal Counts

Normal & Higher Pressure BUT Many Below Normal Counts

Lower Pressure ~ Below Normal Counts

Analysis in 2008 indicated that air quality improvements have been driven by effective control strategies (e.g. NOx SIP Call)!

Maps created using data extracted from AIRNowTech and ESRL PSD Plotting and Analysis. Some preliminary AQ data were used in the analysis.
Pre/Post NO$_x$ SIP Call OEDs
(Baltimore, MD MSA)

8-Hour Ozone Exceedance Days (Jun-Aug)

Pre NO$_x$ SIP Call OEDs

Post NO$_x$ SIP Call OEDs

Some preliminary data are included.
Some preliminary data are included.
Pre/Post NOₓ SIP Call OEDs
(Philadelphia, PA-NJ MSA)

8-Hour Ozone Exceedance Days (Jun-Aug)

Number of Days

Pre NOₓ SIP Call OEDs

Post NOₓ SIP Call OEDs


Some preliminary data are included.
Pre/Post NO\textsubscript{x} SIP Call OEDs
(Boston, MA-NH MSA)

8-Hour Ozone Exceedance Days (Jun-Aug)

Periphery of I-95 Ozone Plume

Some preliminary data are included.
Pre/Post NO\textsubscript{x} SIP Call OEDs (Columbus, OH MSA)

8-Hour Ozone Exceedance Days (Jun-Aug)

Upwind of Maryland and OTC States

Some preliminary data are included.
Air Quality Cycle (2003-2007) (Adjusted for Recent Data)

Maps created using data extracted from AIRNowTech and ESRL PSD Plotting and Analysis. Some preliminary AQ data were used in the analysis.

Next Step: Compare ozone exceedances pre/post NOx SIP Call to estimate its effectiveness.
Similar meteorology between 2004 and 2009 allows us to estimate the **minimum** benefits for the NO$_x$ SIP Call.

Substantial number of MSAs observe OEDs improve by one category.  
(i.e “Normal” ⇒ “Below Normal” ⇒ “Well Below Normal”)

Air Quality Improvements
Pre/Post NO\textsubscript{x} SIP Call (2 of 2)

- East of Mississippi experienced reduction of 30% or more in OEDs (highest reductions in rural settings).
- 7 MSAs increase in OEDs but small averages and mainly located west of Mississippi.
- Need another round of EMISSION REDUCTIONS to help OTC states and major cities attain new stringent ozone standard.

Maps were created using preliminary data extracted from AIRNowTech.
Data suggest that 2008 and 2009 were the beginning of a new cycle consisting of 2 beginning low years.

2010 data were below normal despite ozone conducive meteorology.

More research needed!

- Under estimation benefits of controls?
- Changes in mobile source emissions?
Steady increase 1990-2003

Fairly constant post-2004 period.

No significant differences in VMT post-2004 summers.

Tier 2 Vehicle and Gasoline Program implemented 2004 (reduced mobile emissions should have occurred by 2010).

More DATA & research needed!
Motor Gasoline Sales Volume (GSV) (Surrogate #2 for Mobile Emissions)

- Significant decrease post-2004 in 4 out of 5 US regions.
- Remarkable decrease in GSV for East Coast sub-regions post-2004 with 2010 being the lowest.
- Possible links: Tier 2 Vehicle & Gasoline Program, Gas Price Increase & Economy.

Should be linked to Significant ↓ for NOx + VOCs ULTIMATELY Below Normal Ozone Levels!
Large-Scale Circulations

- Large-scale circulation creates strong subsidence around 30° N.
- Subsidence creates semi-permanent Subtropical highs at the surface around the globe.
- Over the Atlantic Ocean, it’s referred to as “Azores / Bermuda High.”
- Strength of High increases with height.

Source: http://www.suu.edu/faculty/collberg/Hazards/Weather/04_GlobalWind.swf
Bermuda High: Classic Mid-Atlantic Air Pollution Weather
Shifting of Bermuda High During Low vs High Ozone Seasons

Bermuda High is Responsible for Wind Flow & Pollution Transport Patterns in Maryland and the Mid-Atlantic.
**Outlook for 2011**

**ENCEP coupled forecast system model (CFS) predicts strong Cool ENSO (La Niña) conditions to persist through 2011 summer.**

**Other dynamical & statistical models favor Cool ENSO (La Niña) for 2011 summer.**

**If forecast verifies, the Mid-Atlantic region will likely be experiencing below normal temperatures and/or wet conditions during the 2011 summer air quality season.**

**Tendency for ✫ (normal or below normal) ozone exceedance days for summer 2011.**

Sources: CFS Seasonal Climate Forecasts | IRI ENSO Quicklook
Maryland OEDs can be broken down into 3-5 year periods, trending with the 90 degree days cycle to minimize the year-to-year fluctuations in meteorology. OEDs by each period showed continuous improvements. Significant improvements are observed after implementation of a large-scale multi-state NOx control program (NOx SIP Call).

- As much as 30-90% reductions in OEDs are observed in MSAs across the eastern U.S post NOx SIP Call.
- Significant AQ improvements require that AQ Cycle post 2002 be adjusted for trends in regional ozone patterns.

Shifting of the Bermuda high creates fluctuations in seasonal weather patterns and combined with reduced emissions causes changes in regional ozone patterns.

- At the surface, the Appalachian lee-side trough is enhanced along the I-95 corridor during high pollution years, indicating short and mid-range transport patterns from south/southwest are pronounced.
- The enhanced trough line is associated with Maryland OEDs and potentially the development of the Nocturnal Low Level Jet (NLLJ).
Shifting of the Bermuda high creates an **anomalous high** over the **upwind states** (Plains, Great Lakes and Midwest) during high pollution years.

- On average, the anomalous high is **3.5 deg F warmer** for a column of air from the surface to 850-mb level and results in **high ozone production** in upwind states.

- The **enhanced ozone concentrations** during high pollution years in the Mid-Atlantic and Northeast are driven by **local** pollutant sources and to a **greater extend transported pollution**.

Below normal ozone exceedance days in the East in 2010 despite the conducive ozone weather conditions are likely linked to low mobile source emissions (possibly the lowest on record since motor gasoline sale volume [MGV] was at its lowest) and lowest power plants emissions to date.

Need **NATIONAL control programs on top of local controls** to attain a more stringent 8-hour standard!
Contact

Duc Nguyen
Senior Meteorologist
Ambient Air Monitoring Program
Air and Radiation Management Administration

dnguyen@mde.state.md.us
410-537-3275
References

1. AIRNowTech | National real-time repository of real-time air quality data provided by EPA AIRNow program (http://www.airnowtech.org).
2. CFS Seasonal Climate Forecasts web site (http://www.cpc.noaa.gov/products/people/wwang/cfs_fcst/).
4. Clean Air Markets | Data and Maps web site (http://camddataandmaps.epa.gov/gdm/).
7. Interactive plotting and analysis pages by ESRL / PSD / CDC (http://www.esrl.noaa.gov/psd/cgi-bin/data/getpage.pl).
10. U.S. Energy Information Administration | Prime Supplier Sales Volumes (http://www.eia.gov/dnav/pet/pet_cons_prim_a_EPM0_P00_Mgalpd_m.htm).
Extra Slides

- Extra slides related to mobile emissions.
Weekly Gas Prices

Weekly Gas Price (All Grades)

- Total U.S.
- East Coast
- MidWest
- Rocky Mountain
- West Coast

Gas Price Hiked!

Data Source: EIA
Motor Gasoline Sales Volume (GSV) for Selected States

Data Source: EIA
Prime Supplier Sales Volumes of Motor Gasoline (PSV)

Data Source: EIA