



MARYLAND'S CONCEPTUAL MODEL

Where does the air pollution in the OTR come from and what do we need to do to fix it?

Warm Moist Air Flow

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**Tad Aburn, Director
Air and Radiation Management Administration**

Presented at the OTC Annual Meeting

June 9 and 10, 2009



Why a Conceptual Model?

Driving Policy With Science



- The first step in developing a new State Implementation Plan (SIP) is to assess the current air quality and what it will take to meet Maryland's air quality goals.
- How much of the problem is caused by local sources?
 - How much is transported from upwind states?
- What pollutants? What sources?
- How aggressive do we need to be with new local control programs?
 - Who will we need help from?

Maryland - The Canary in the Coal Mine for the OTR

Baltimore Haze Cam

Bad Day - July 9, 2007



Good Day - August 18, 2007

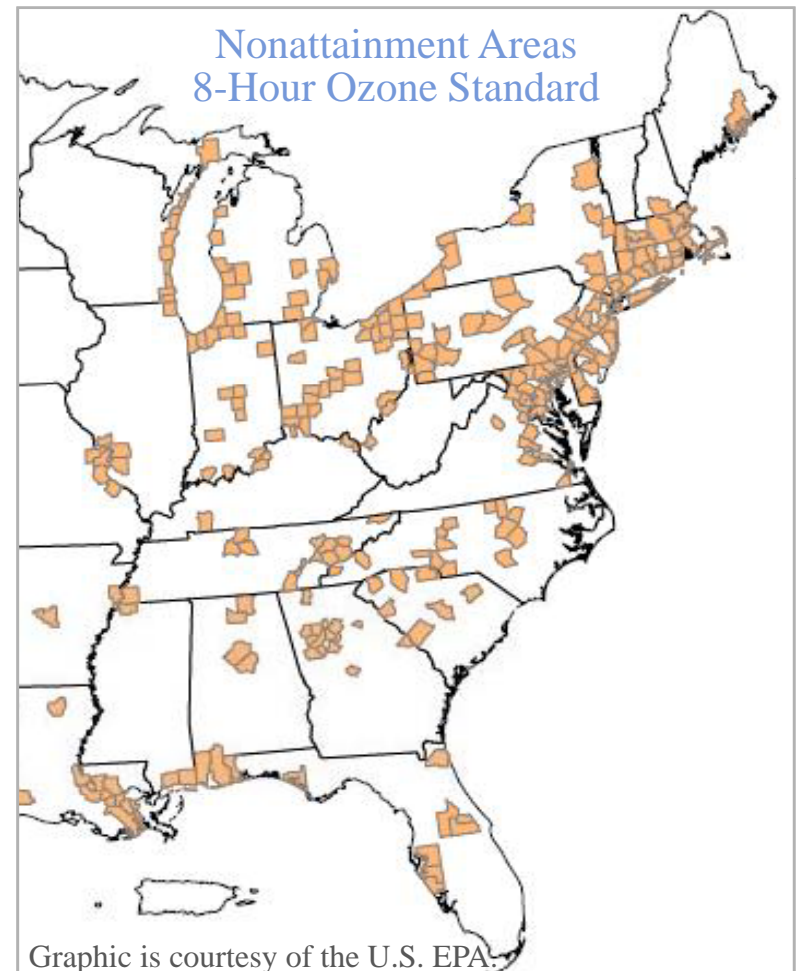




Conclusions from this Presentation

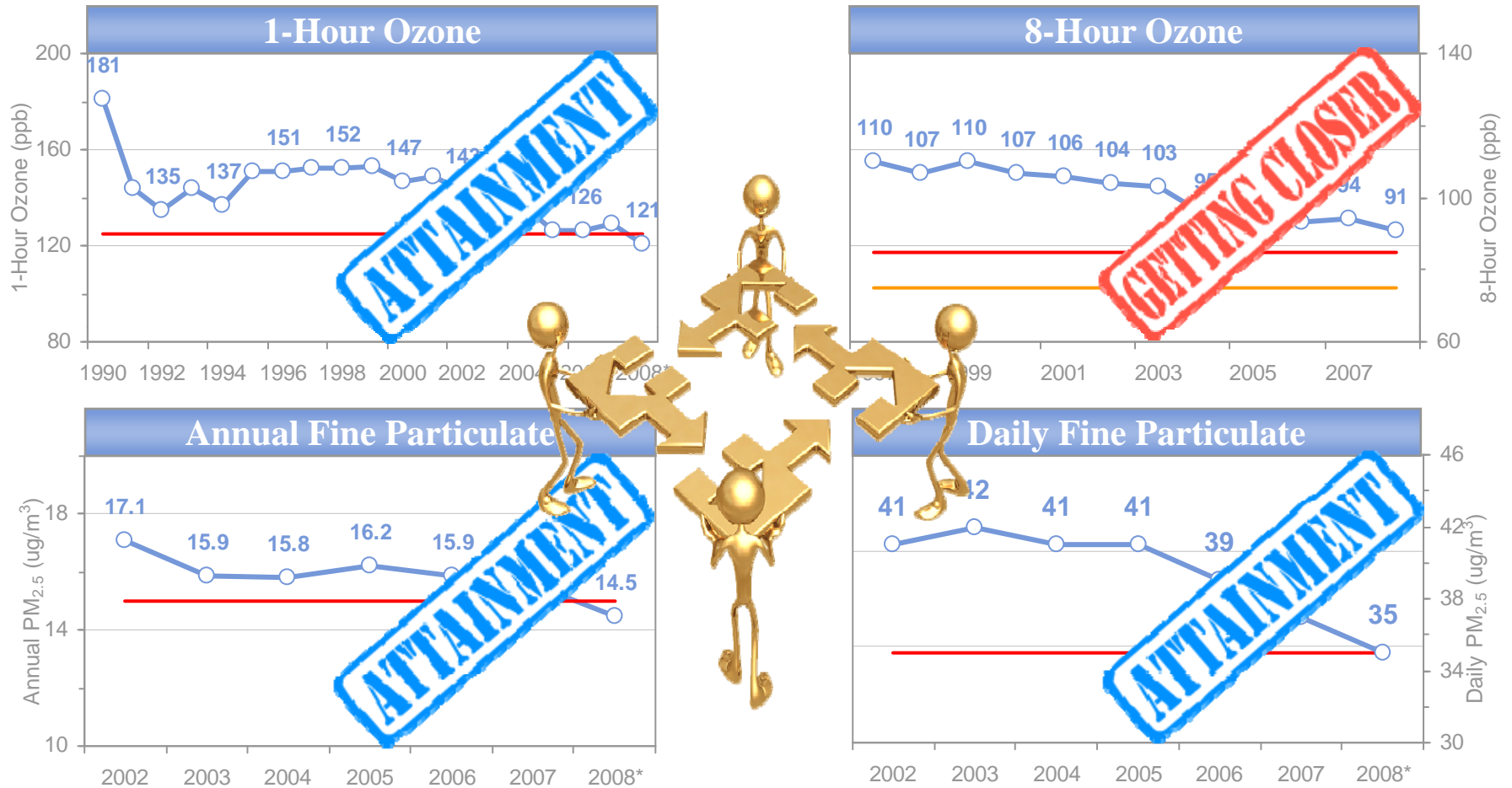
We Cannot Attain the New Ozone Standard Without Significant, Timely Help from EPA

- ❑ “Incoming” ozone levels already violate the new standard
- ❑ Science tells us that the upwind contribution to ozone in nonattainment areas in the Ozone Transport Region (OTR) can cause more than 50% of the problem
- ❑ We need to continue to do all we can to reduce local emissions.
- ❑ We need significant help from EPA to require aggressive and timely super-regional emission reduction programs
 - Across most of the East
 - Power plants, boilers, cement kilns and multiple other source sectors that can further reduce NO_x and VOC emissions.





Progress in Cleaning Maryland's Air



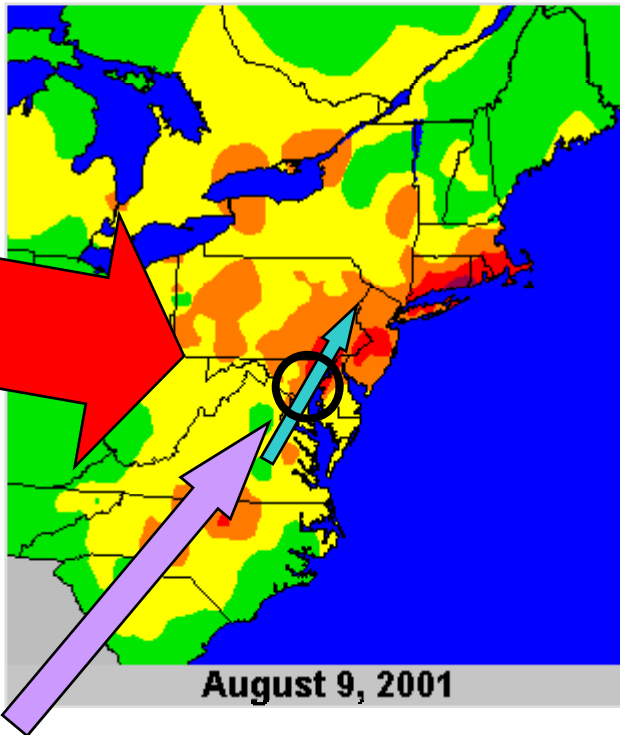
*2008 data are preliminary.

What Have We Learned
from All of This?



So...Where Does Our Air Pollution Come From?

Four Distinct Parts



- ❑ Local emissions in Cities (nonattainment areas)
 - Reducing local emissions is **very, very, very**, important
- ❑ Three distinct types of transport
 - Short range - City to city
 - “Ground level” transport
 - Washington to Baltimore Baltimore to Philadelphia, etc.
 - Westerly, Low Level Jet (LLJ) (ground-down)
 - “Aloft”
 - General
 - Southerly, Nocturnal Low Level Jet (NLLJ)
 - “Aloft” transport at night !!!
 - 100s of miles
 - SW to NE along the Atlantic



MARYLAND'S CONCEPTUAL MODEL



Two Significant New Findings

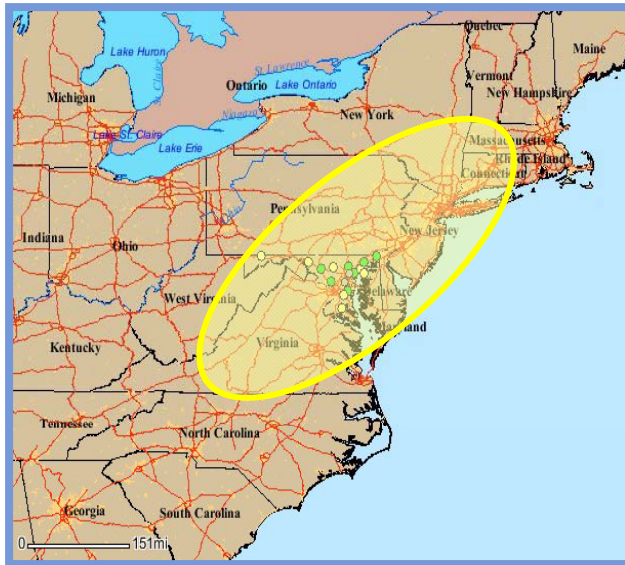
- ❑ Recent research has identified two new concepts that significantly affect:
 - Our understanding of the daily cycle of how ozone forms and builds up in Mid-Atlantic and Northeast cities and
 - The emission reduction programs needed to provide for clean air

- ❑ These new areas are:
 - The existence of an **“Elevated Reservoir”** of high ozone sitting above the Mid-Atlantic and Northeast areas during the morning hours on bad ozone days
 - The **transport** and build-up of ozone and ozone precursors **at night**

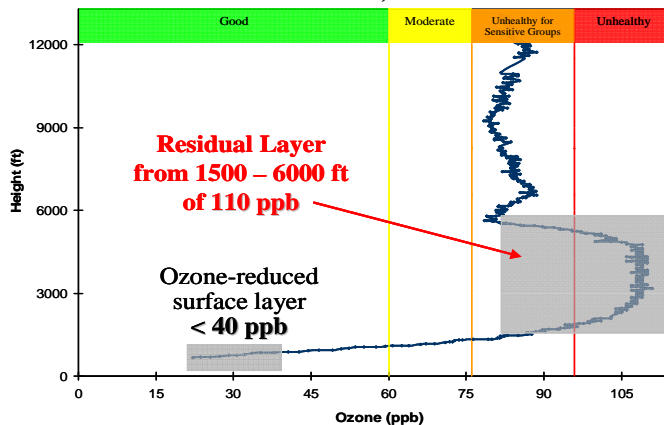




The Elevated Ozone Reservoir



Incoming Ozone
August 2, 2005 (7:00 AM EDT)
Beltsville, MD



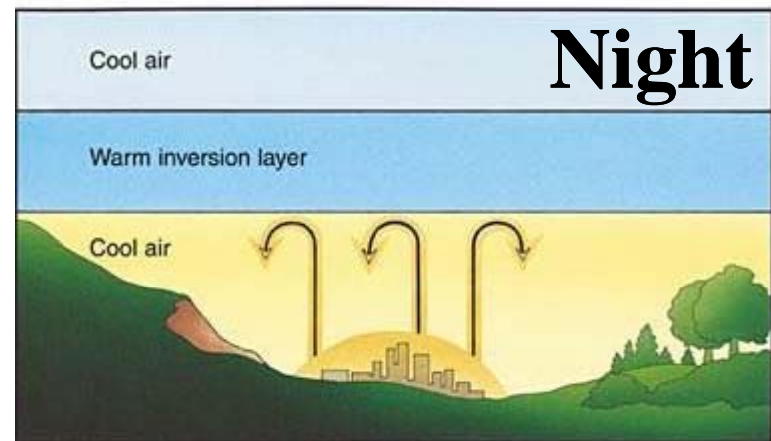
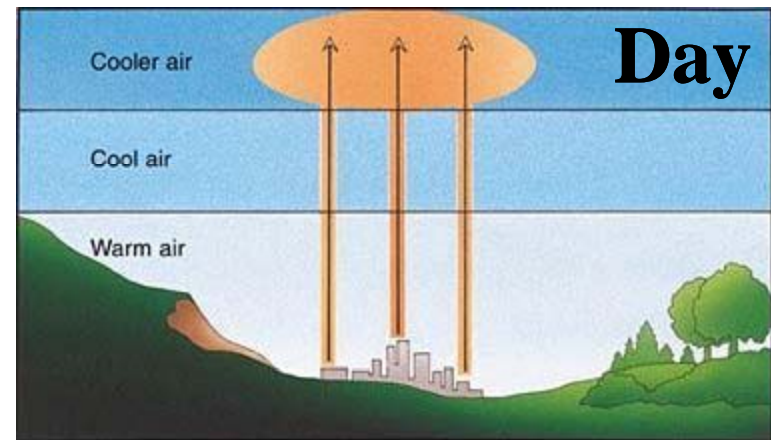
Source: Maryland Department of the Environment & Howard University

- Every bad ozone day, in the morning hours, a large reservoir of ozone sits above Maryland and the Mid-Atlantic area waiting to mix down.
 - Ozone levels in the reservoir can routinely reach 60 to 100 ppb.
 - In the morning, ozone levels at the surface are very low.
- Around 10:00 or 11:00, the ozone in the reservoir mixes down to the surface and degrades air quality.



What Creates the Reservoir?

- ❑ Ozone created during the day is able to mix upward from the surface and vice versa.
- ❑ At night the earth cools and a “nocturnal inversion” is created several hundred meters above the surface.
- ❑ Ozone, created earlier in the day, is trapped above the inversion and moved to the north by night-time winds.
- ❑ Ozone below the inversion drops to very low levels.

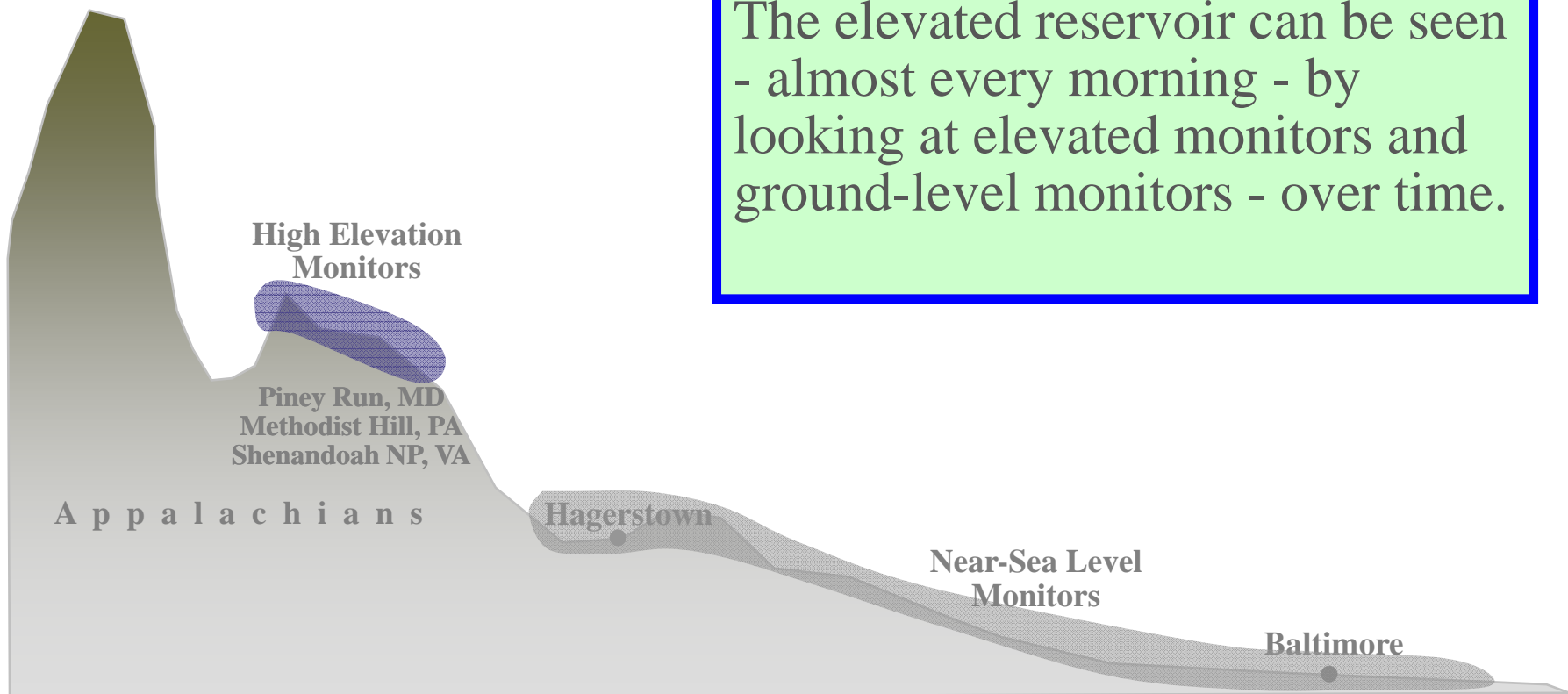


Source: SERC at Carleton College



Measuring the Elevated Reservoir

The elevated reservoir can be seen - almost every morning - by looking at elevated monitors and ground-level monitors - over time.

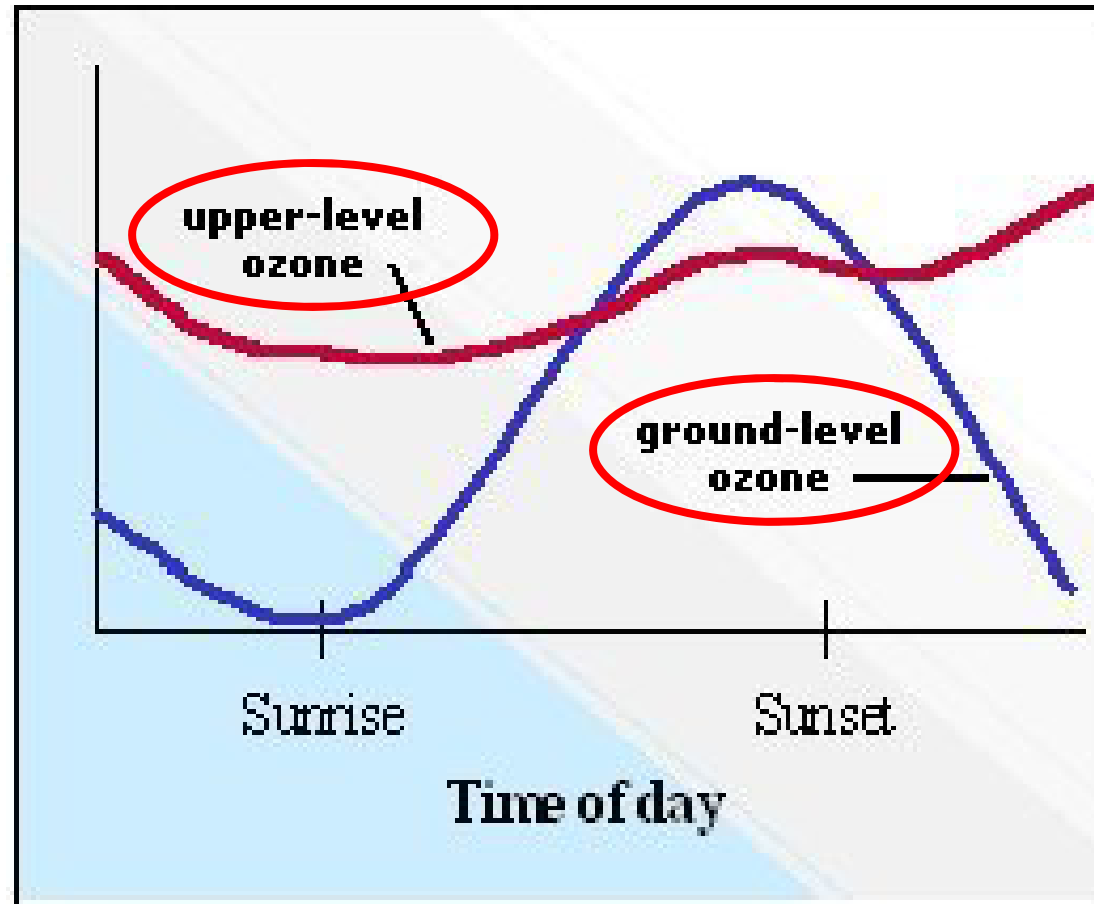


Source: Maryland Department of the Environment





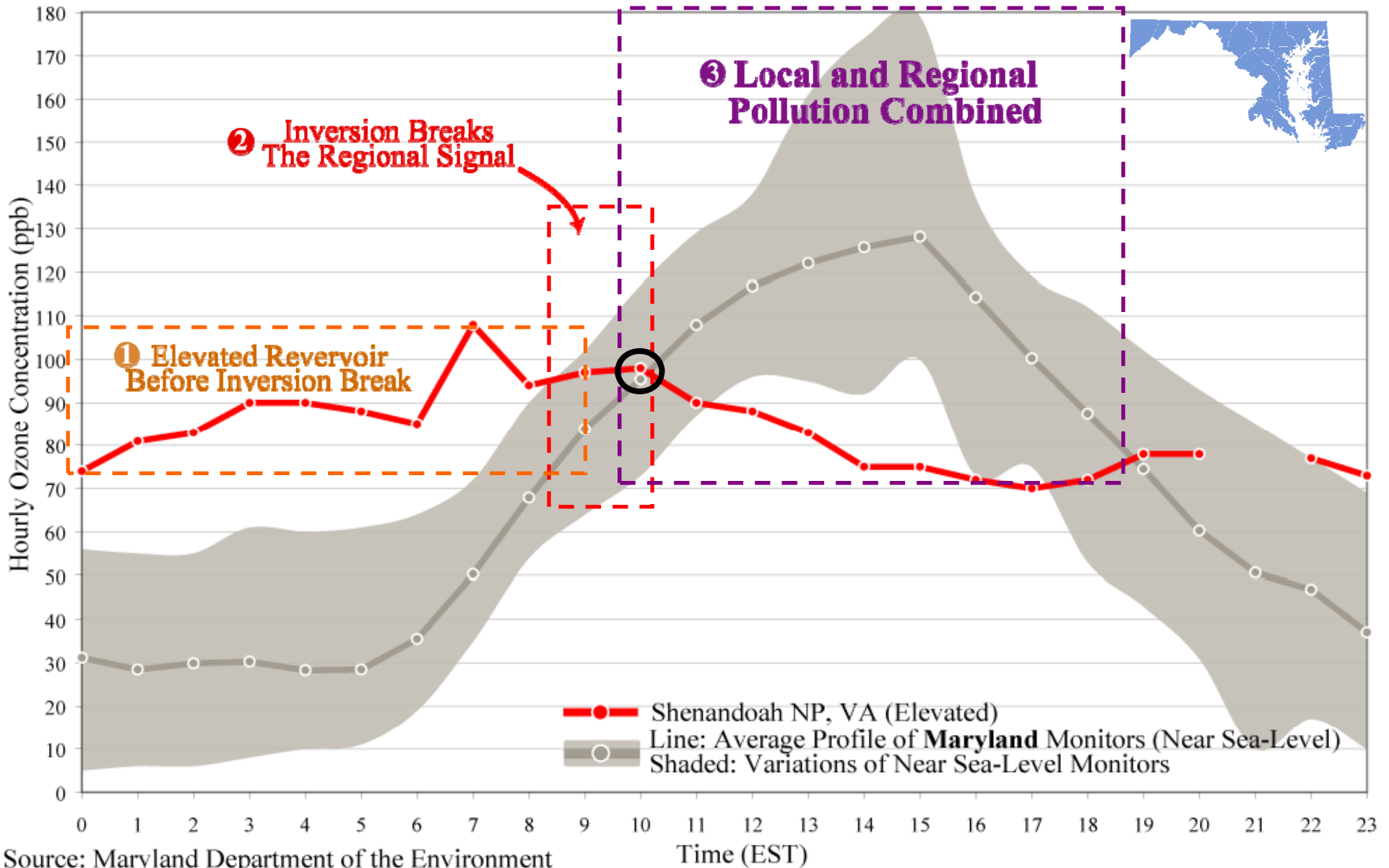
Typical Day/Night Ozone Cycle





Back in 1990's

Aloft Ozone Reservoir (July 15, 1995)

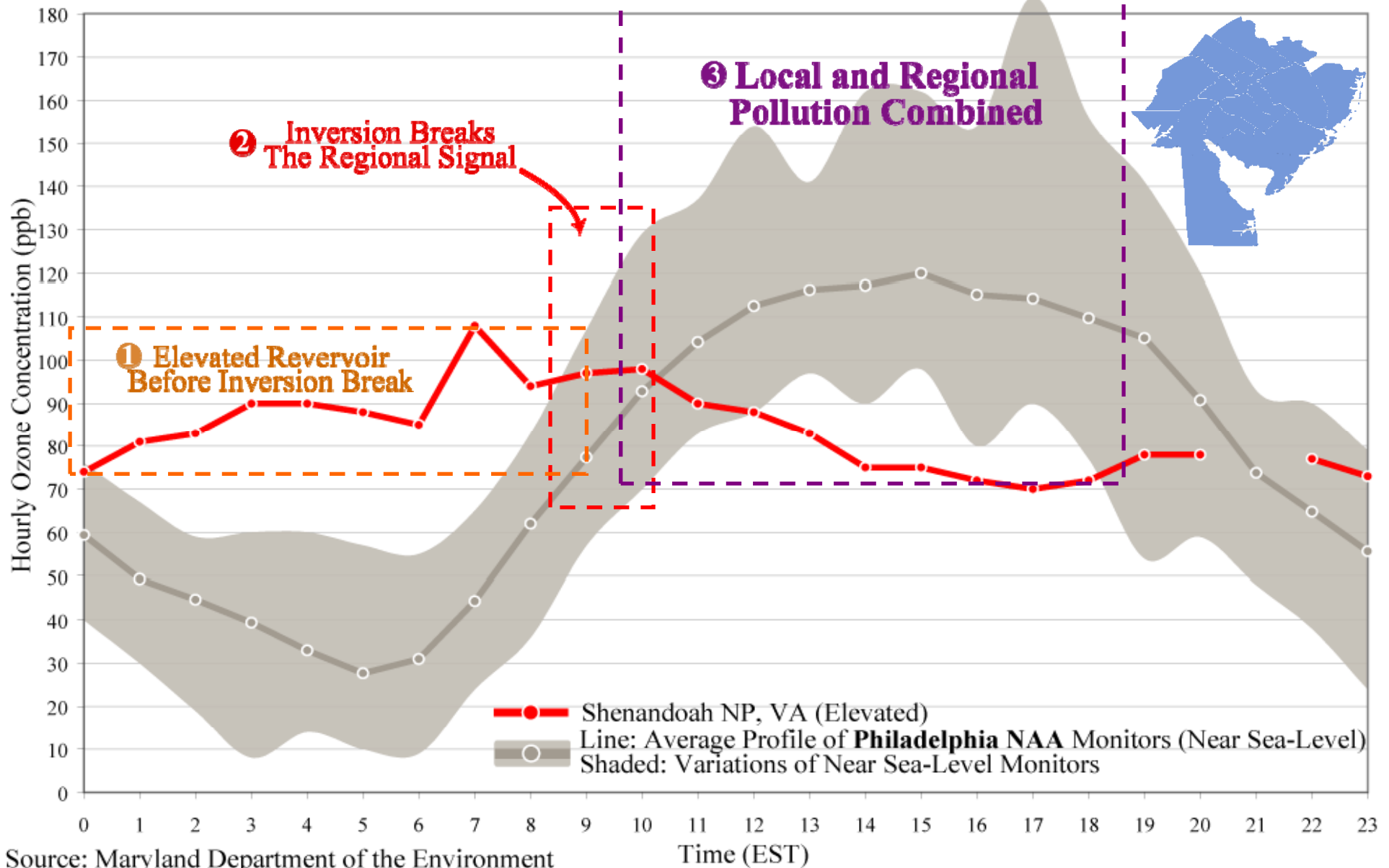


Source: Maryland Department of the Environment



Same Signal – Philly – 1995

Aloft Ozone Reservoir (July 15, 1995)

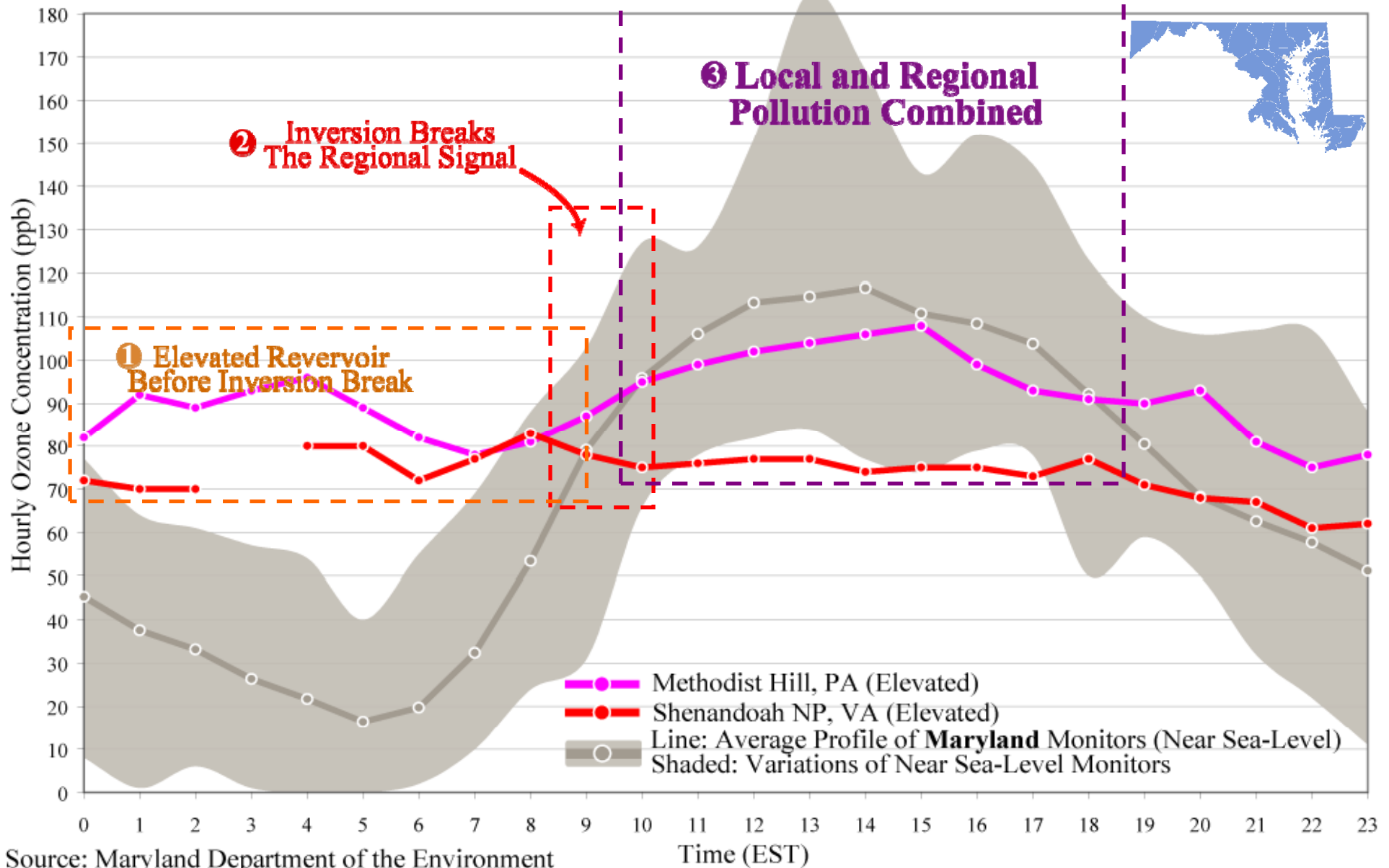


Source: Maryland Department of the Environment



Same Signal – MD - 1997

Aloft Ozone Reservoir (July 15, 1997)

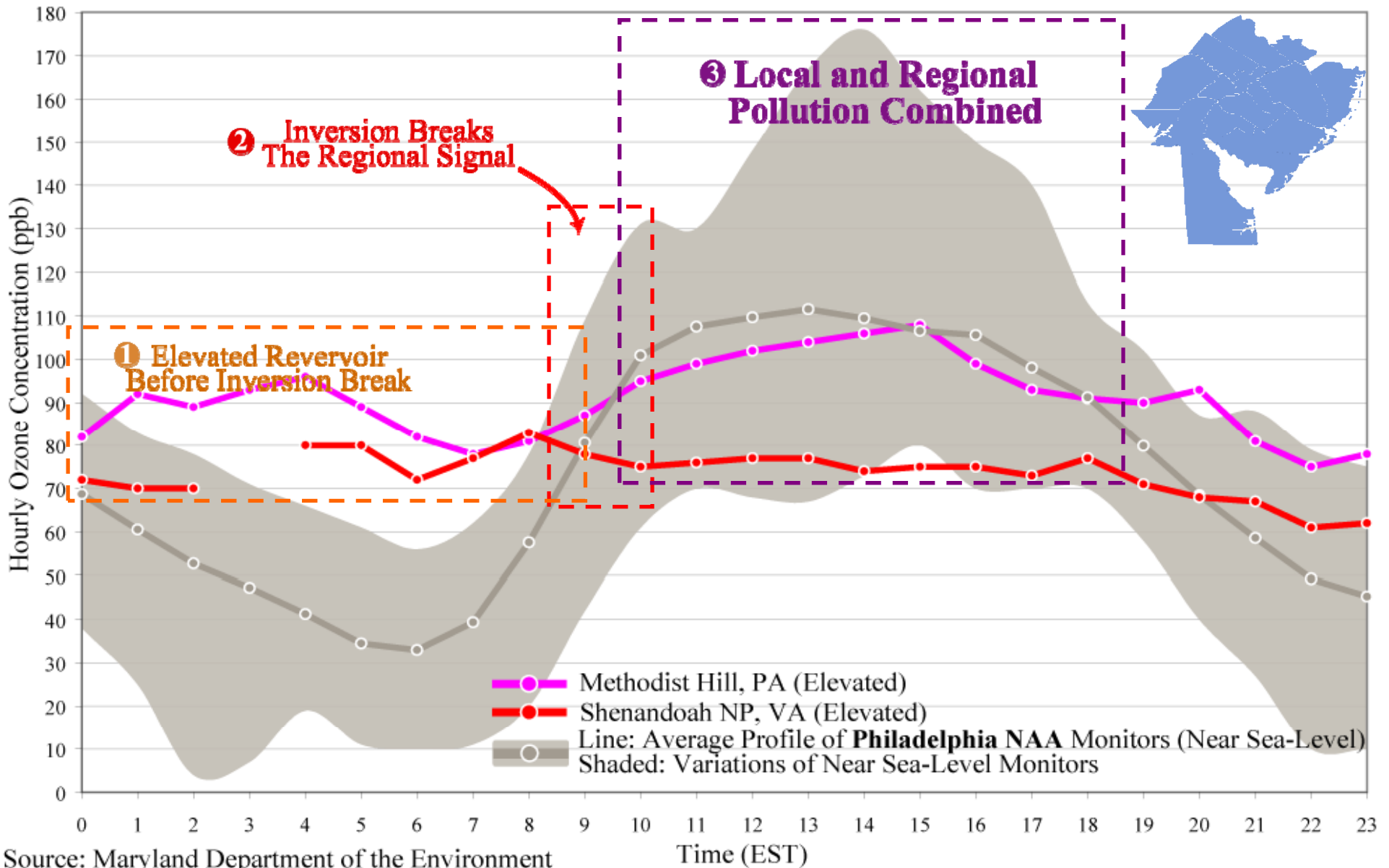


Source: Maryland Department of the Environment



Same Signal – Philly - 1997

Aloft Ozone Reservoir (July 15, 1997)

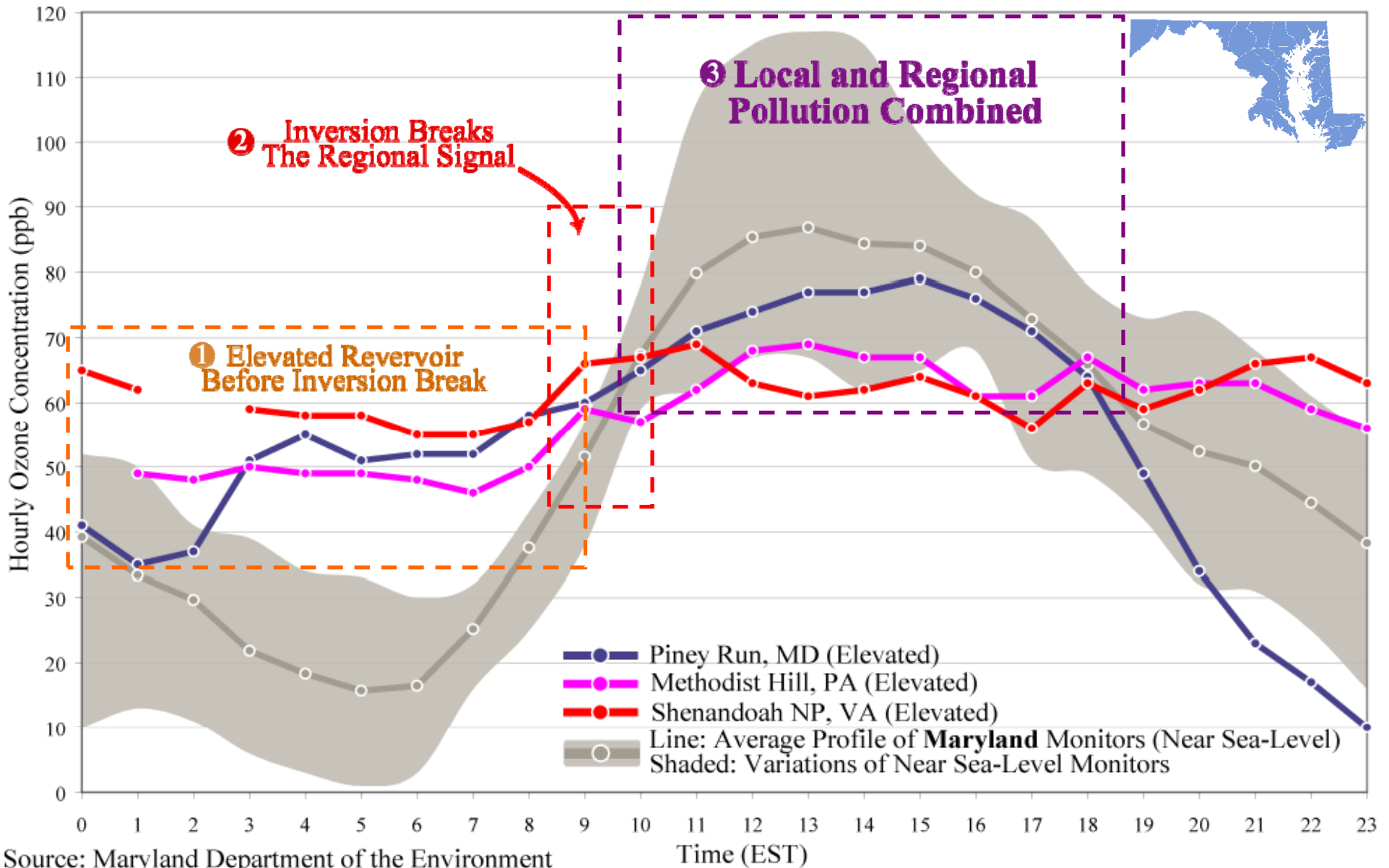


Source: Maryland Department of the Environment



Still Happening in 2000's

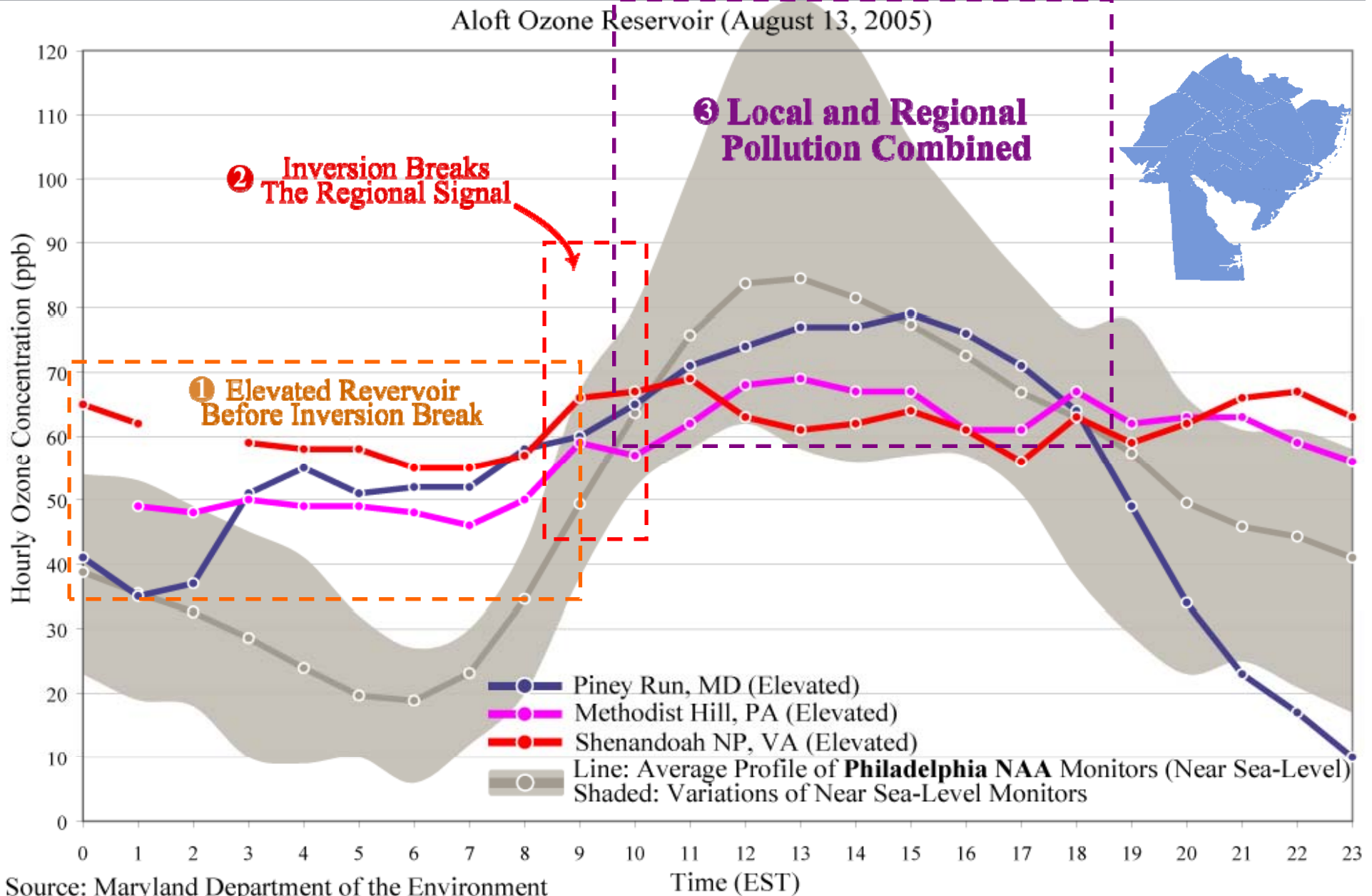
Aloft Ozone Reservoir (August 13, 2005)



Source: Maryland Department of the Environment



Same Signal – Philly 2005

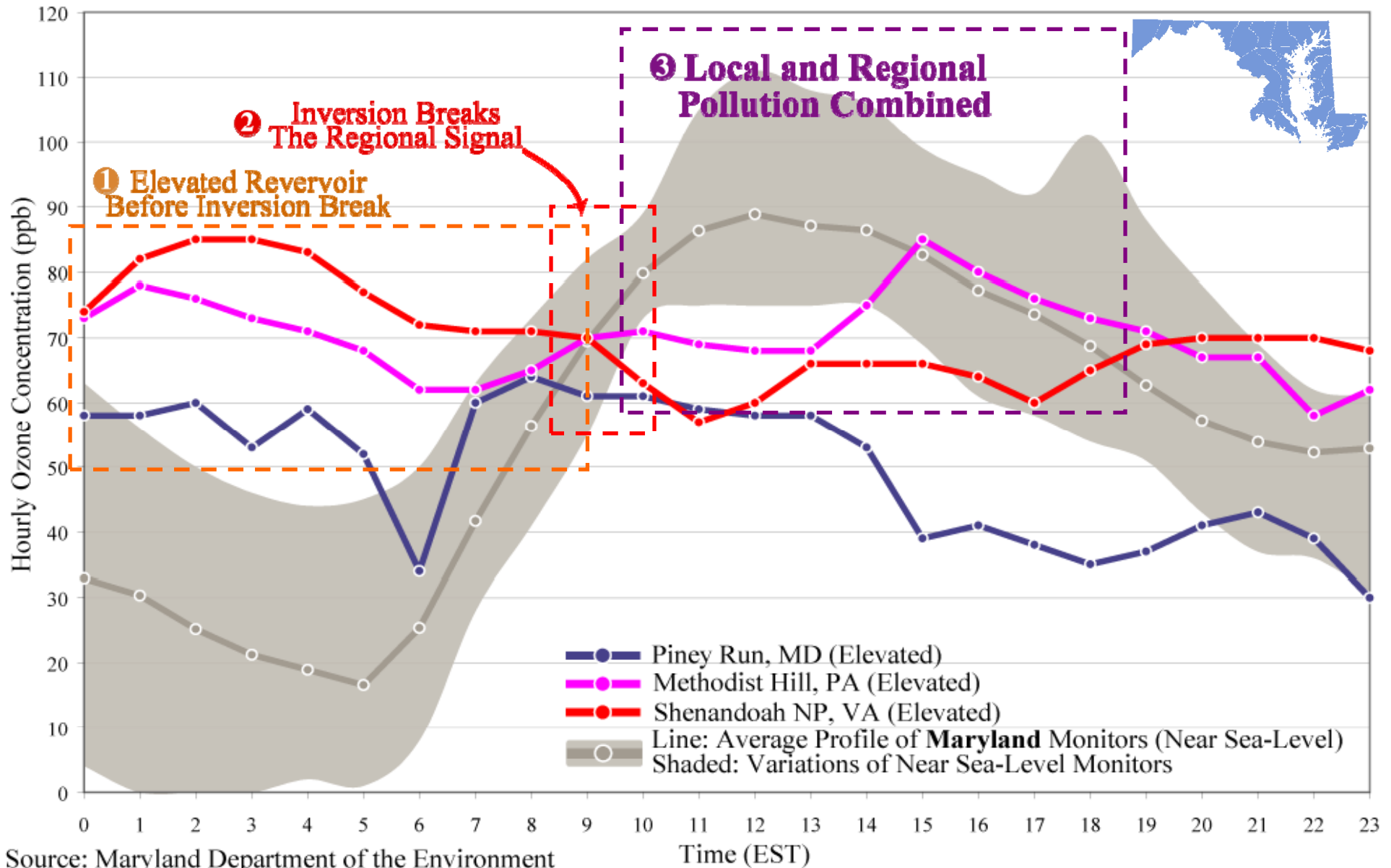


Source: Maryland Department of the Environment



Same Signal – MD - 2008

Aloft Ozone Reservoir (June 13, 2008)

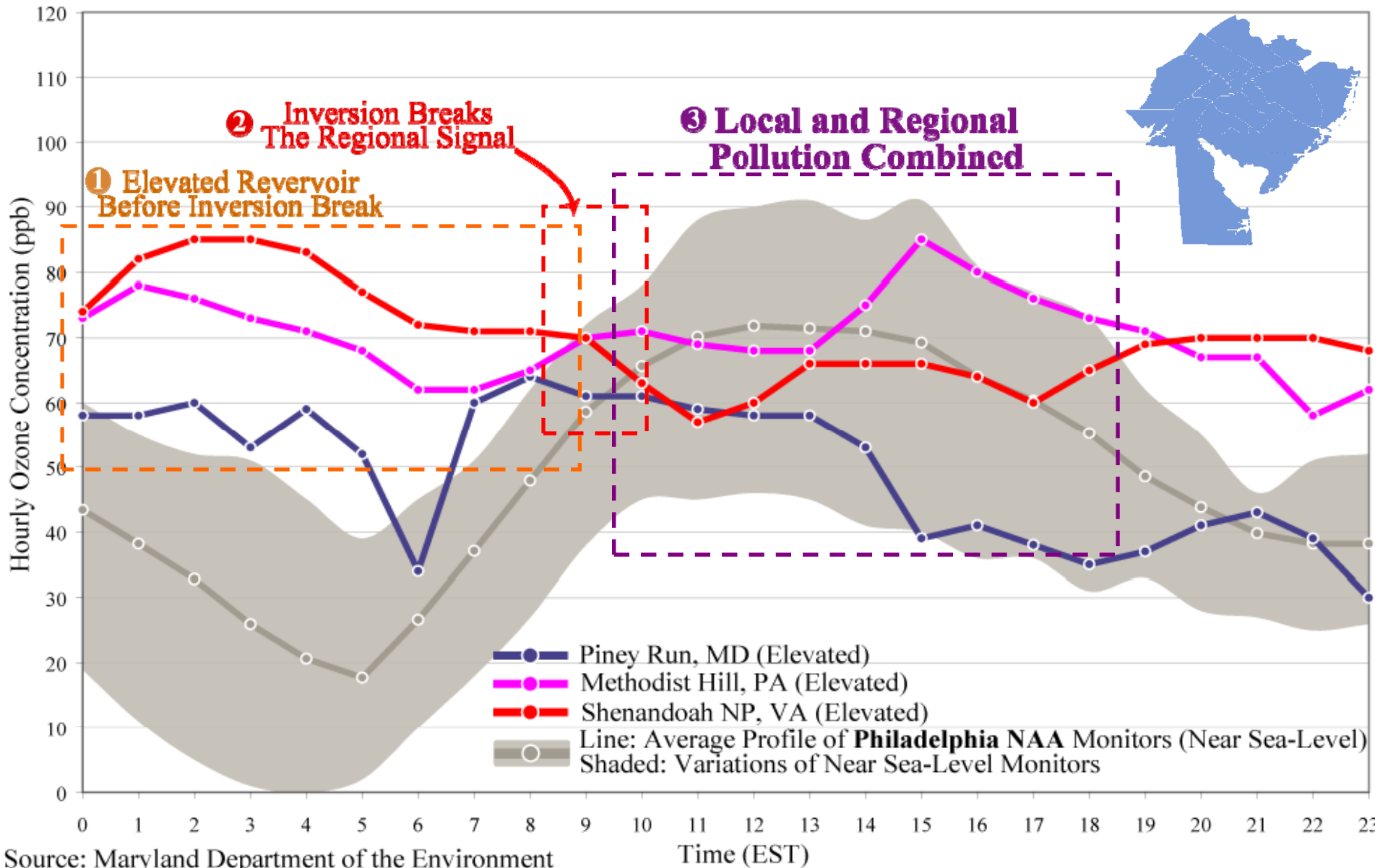


Source: Maryland Department of the Environment



Same Signal – Philly - 2008

Aloft Ozone Reservoir (June 13, 2008)



Source: Maryland Department of the Environment

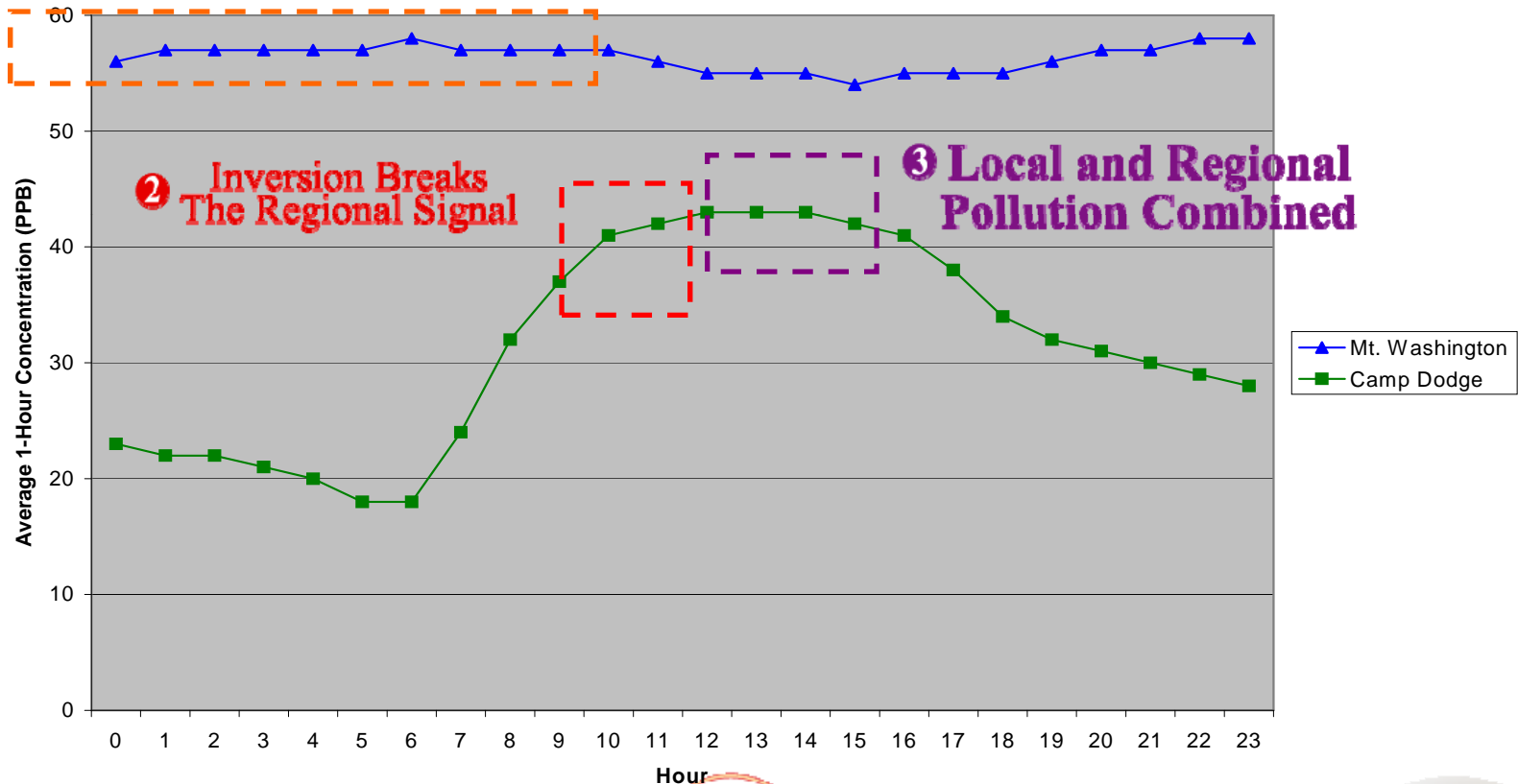


Similar Signal – New Hampshire

Diurnal Ozone Concentrations 2004-2008
Mt. Washington Summit versus Camp Dodge Base
Based on Days with Maximum 8-Hour Averages ≥ 60 ppb on the Summit

This chart includes data from every hour of days with a max 8hr ≥ 75 ppb only when the day's data capture = 100% for both sites.

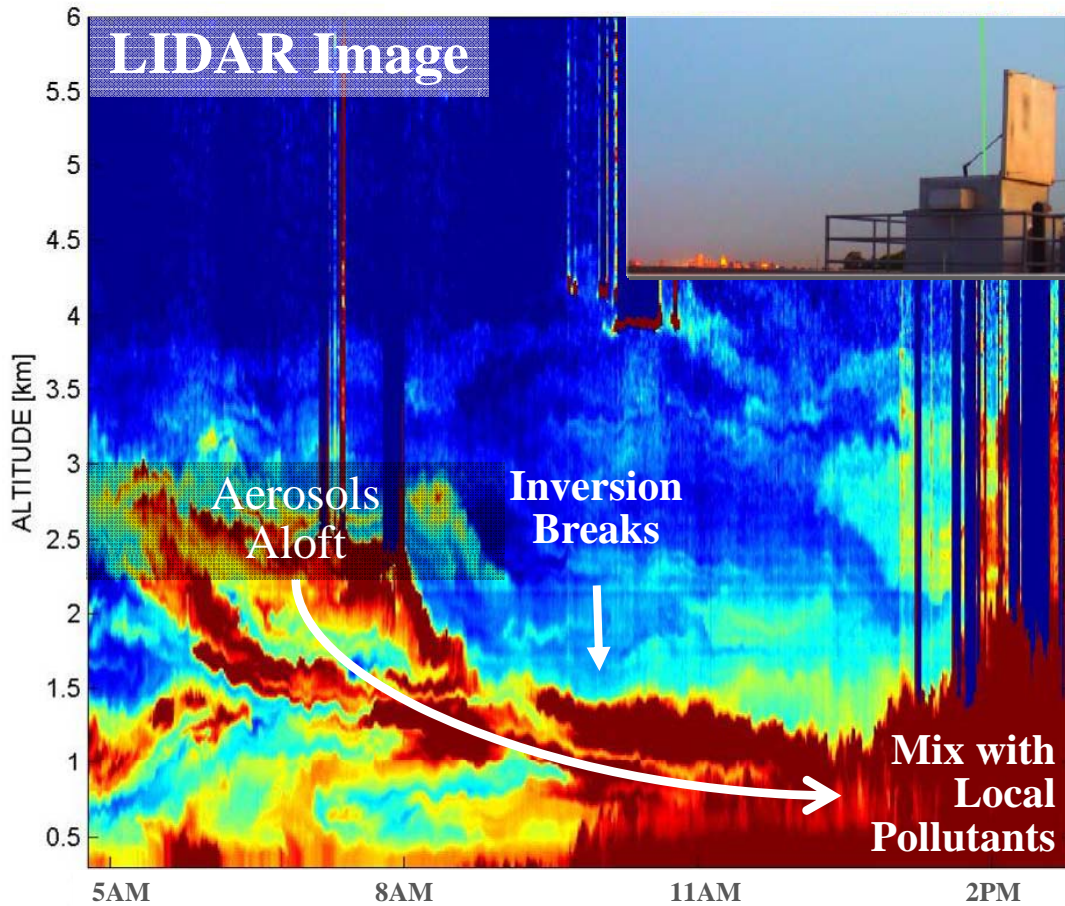
① Elevated Reservoir Before Inversion Break



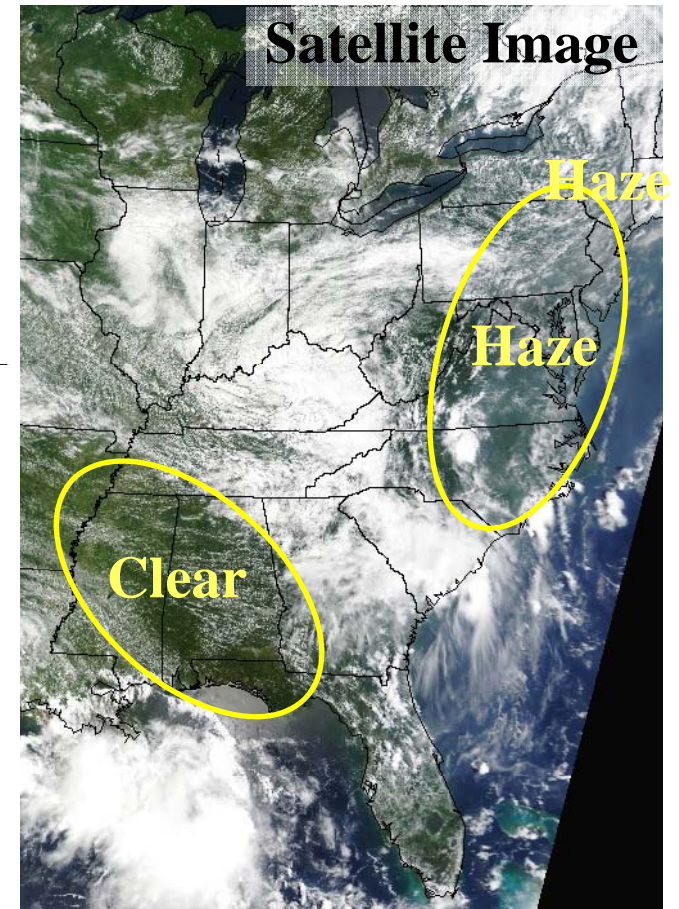


Same Signal – Fine Particles

July 28, 2007



Source: The Smog Blog (UMBC)



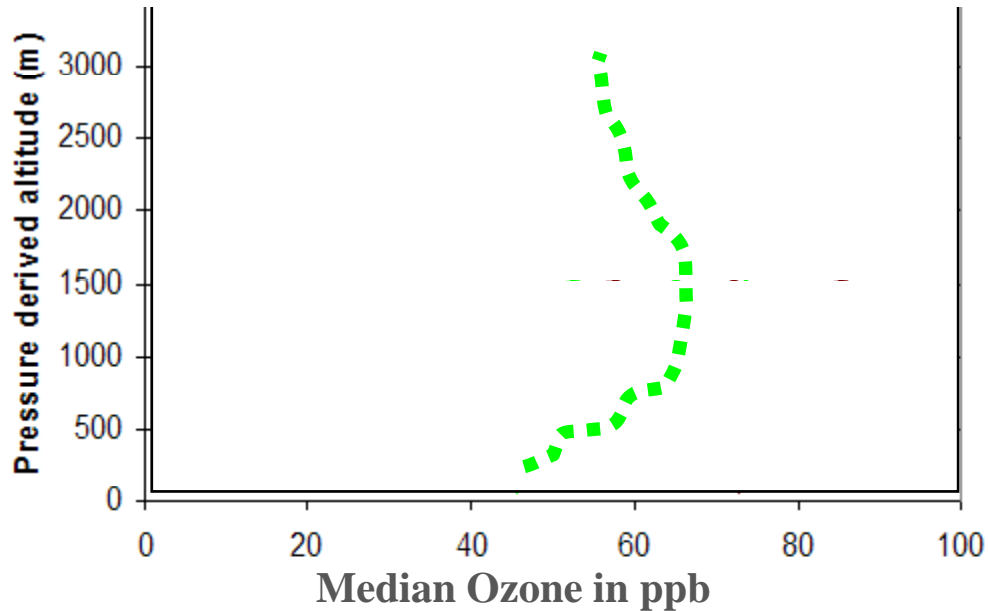
Source: SSEC at University of Wisconsin-Madison





Who's Filling the Reservoir?

Aircraft Data – All Morning Ozone Profiles
(1996 – 2004)



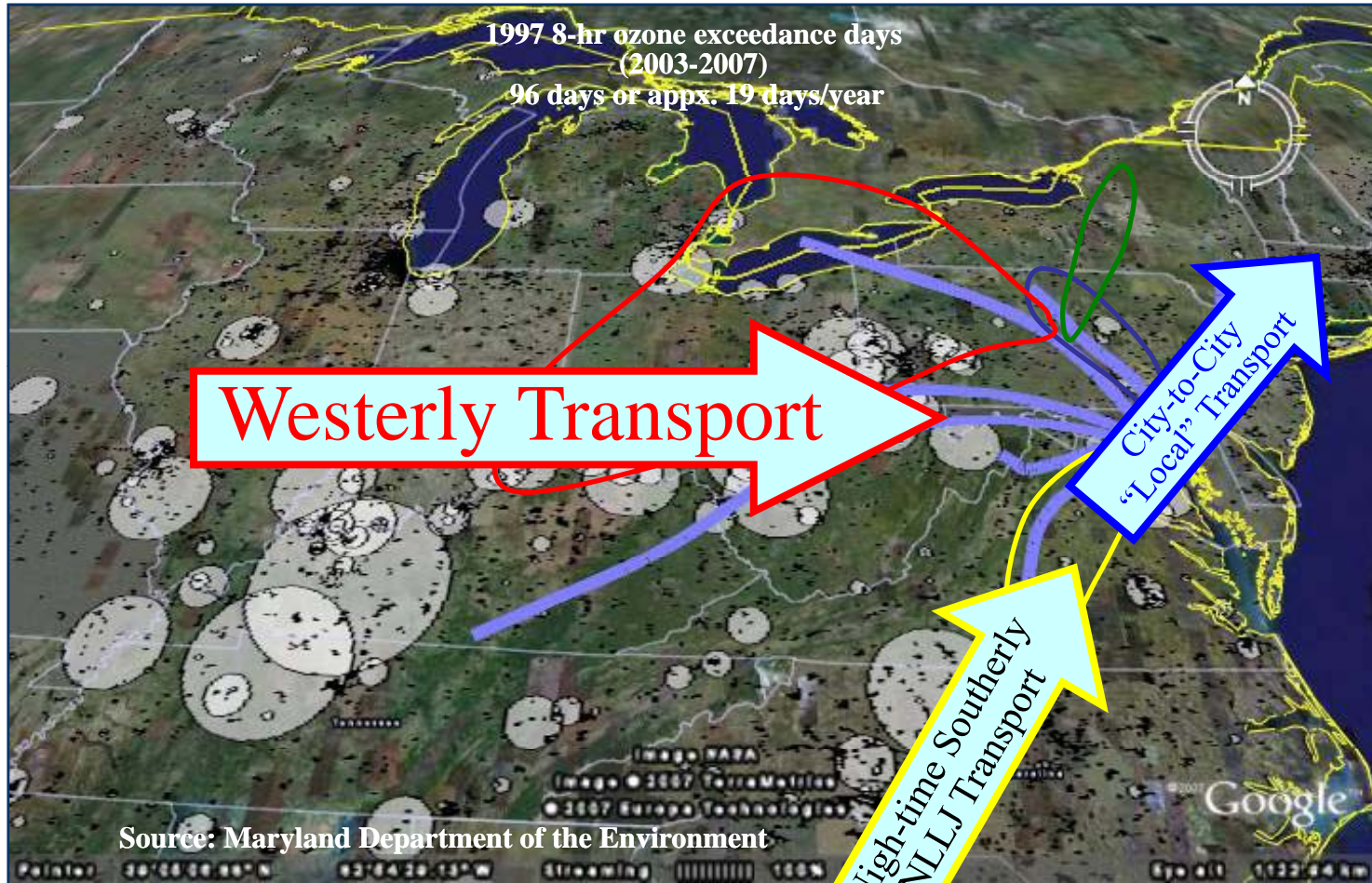
Courtesy of Jennifer Hains
University of Maryland

- What's over MD on Tuesday started off in Ohio and North Carolina on Monday.
 - MD's pollution soup floats to New Jersey and New York.
 - New York's pollution floats to New England
- Power plants, cars, trucks and other sources are all contributors to the elevated pollutant reservoir.
- Filled with ozone and ozone precursors.





The Three Different Types of Transport





How Much Comes From Out of State?

Ozonesonde Measurements (HU)



Aircraft Measurements (UMD)



Upper-Air Radar Wind Profiler & RASS (MDE)



LIDAR - Aerosol Measurements (UMBC)



MDE works in partnership with local universities (UMD at College Park, UMBC, and Howard University) to measure and analyze pollution being transported into Maryland.

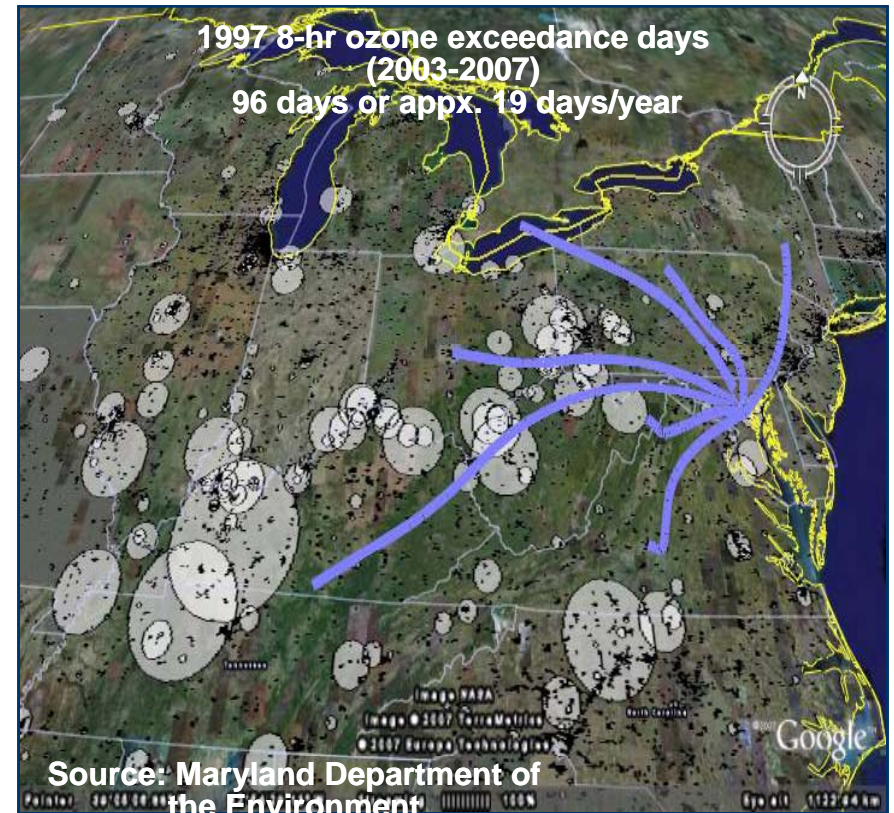
- Prior to the NO_x SIP Call (1990s), we measured ozone around **110 parts per billion (ppb)** floating into Maryland, primarily from the **West**.
- After the NO_x SIP Call, we measure ozone around **90 ppb** floating into the State from the **South, West, and Northwest**.
- Reminder: 2008 8-Hour Ozone Standard is **75 ppb**.





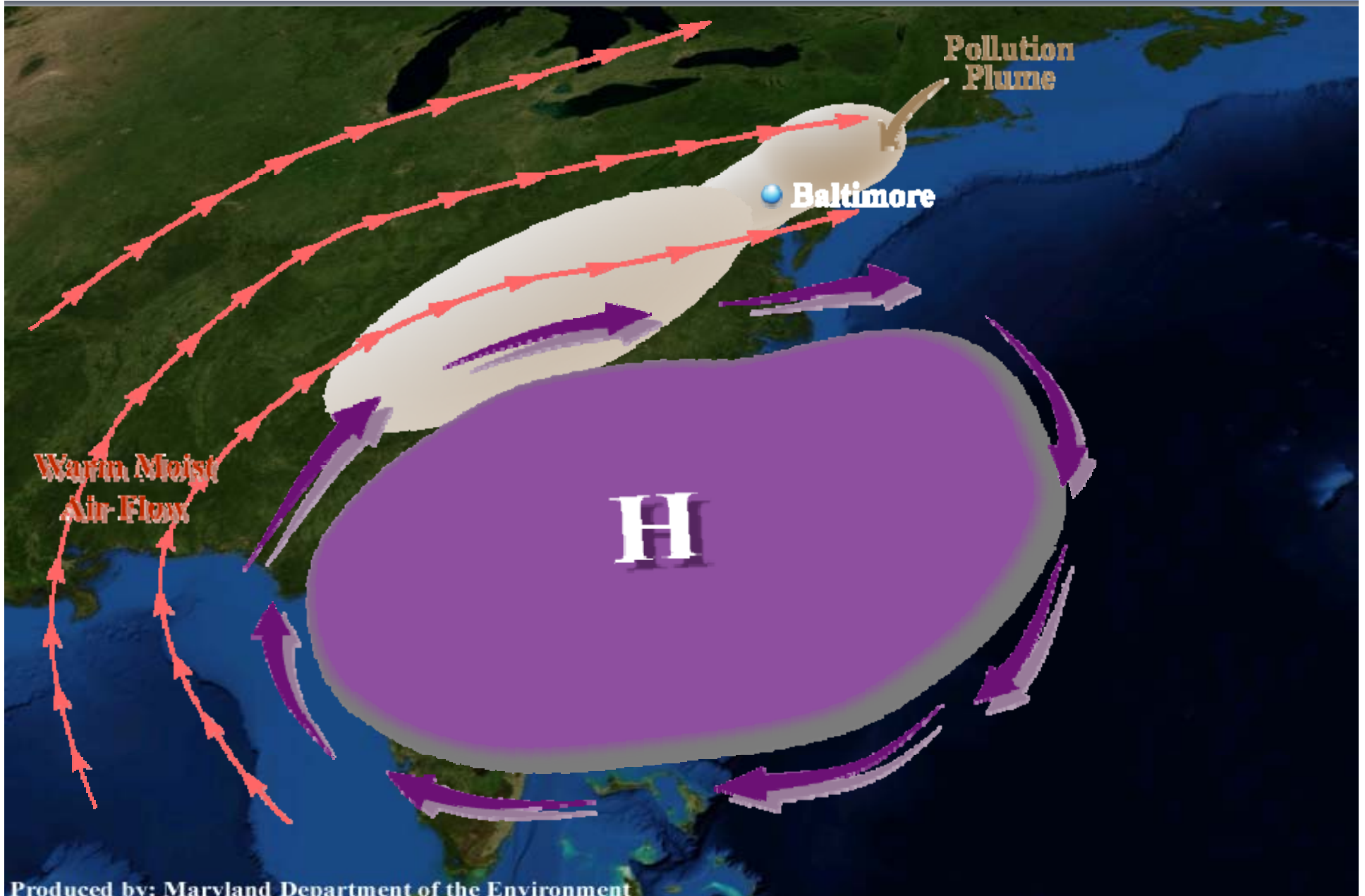
Baltimore: How Much is Transport?

- Varies with changes in meteorology but best guess is something like
 - 30 to 40% Westerly transport
 - 10 to 20% City-to-City “local” transport
 - 10 to 20% Night-time, southerly NLLJ transport
 - 10 to 20% local
- Local controls on local emissions can only address this last 10 to 20%.



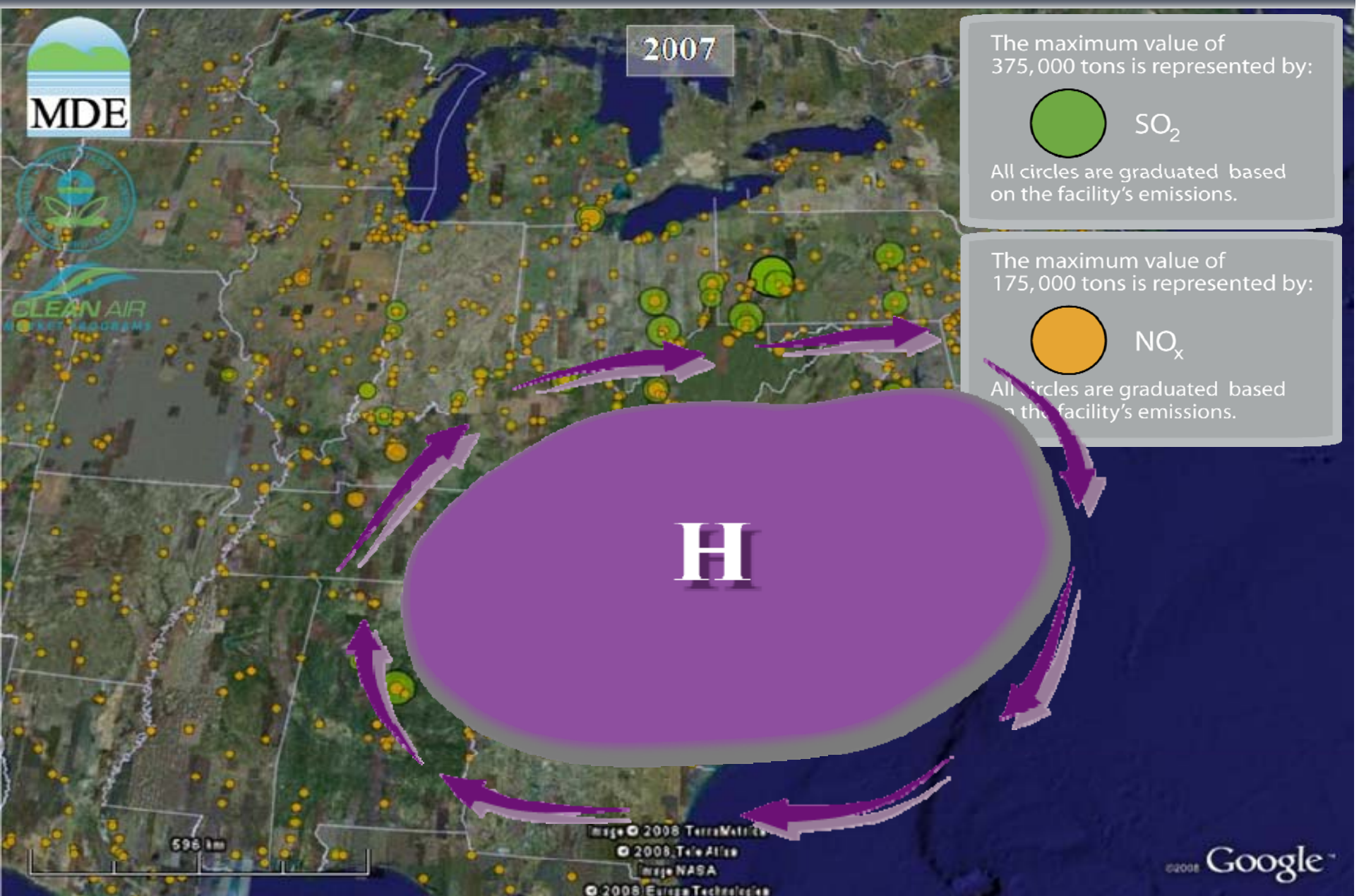


Classic Mid-Atlantic Ozone Weather



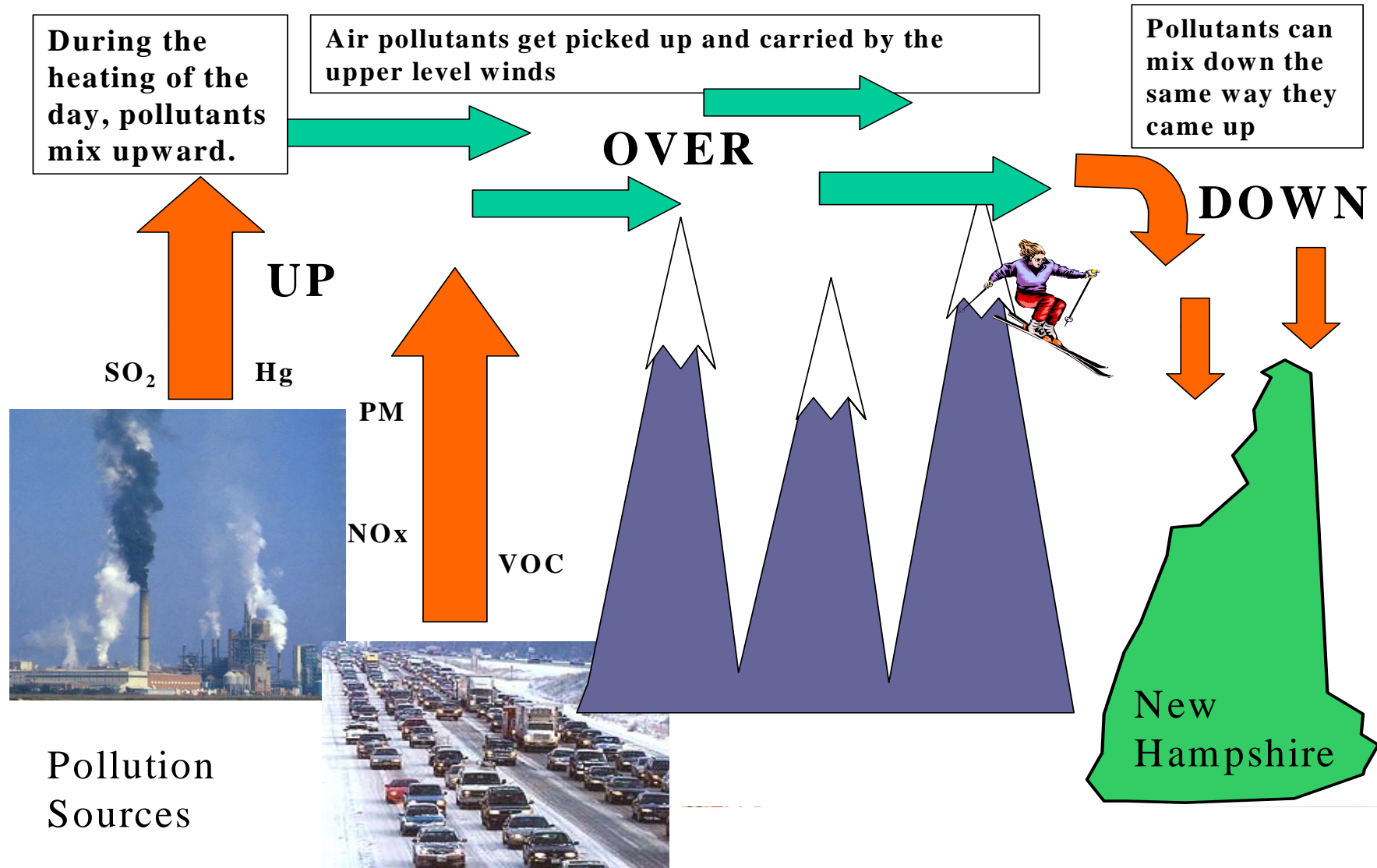


Westerly Transport





Westerly Transport - "Up ... Over ... Down"

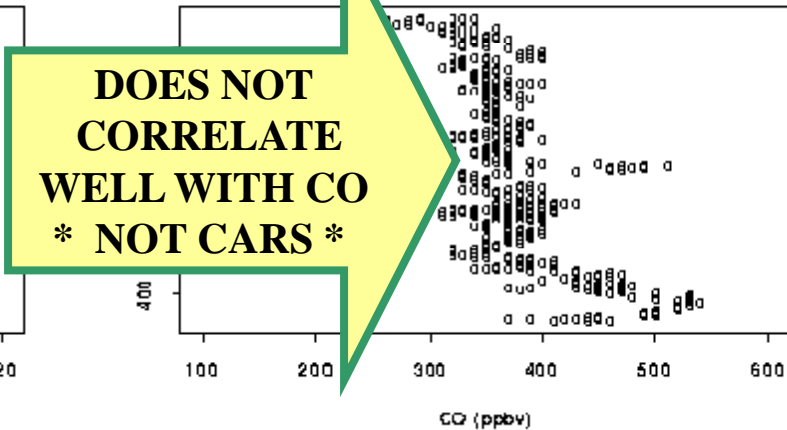
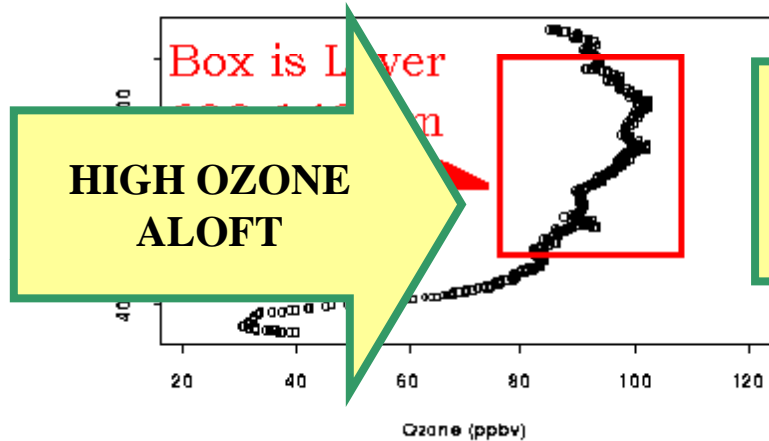




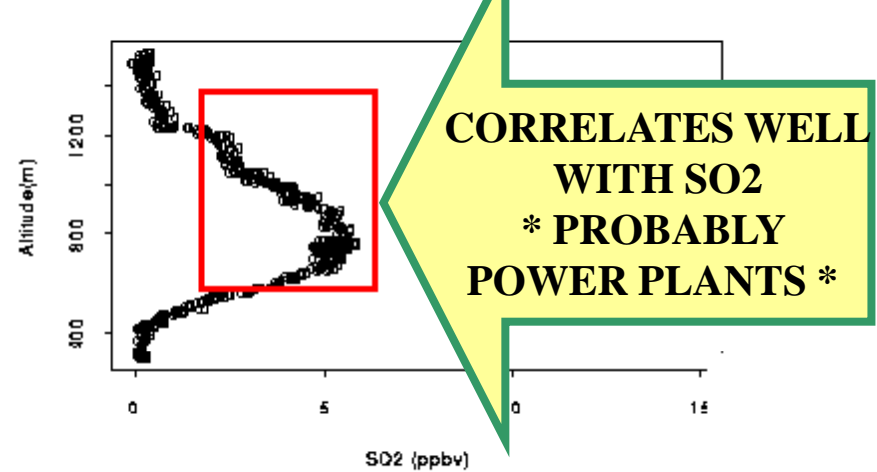
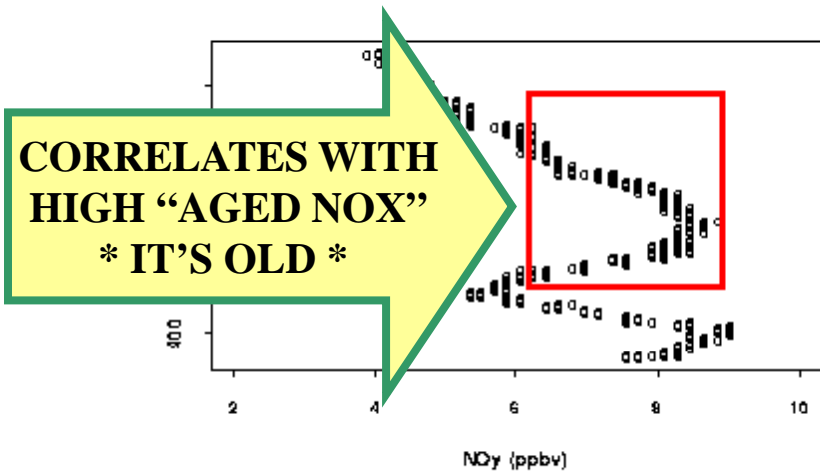
Fingerprinting Westerly Transport

What Does the Data Tell us About Its Origin?

Vertical Profiles of Ozone, CO, NOy and SO2: Central VA (July 15, 1995)

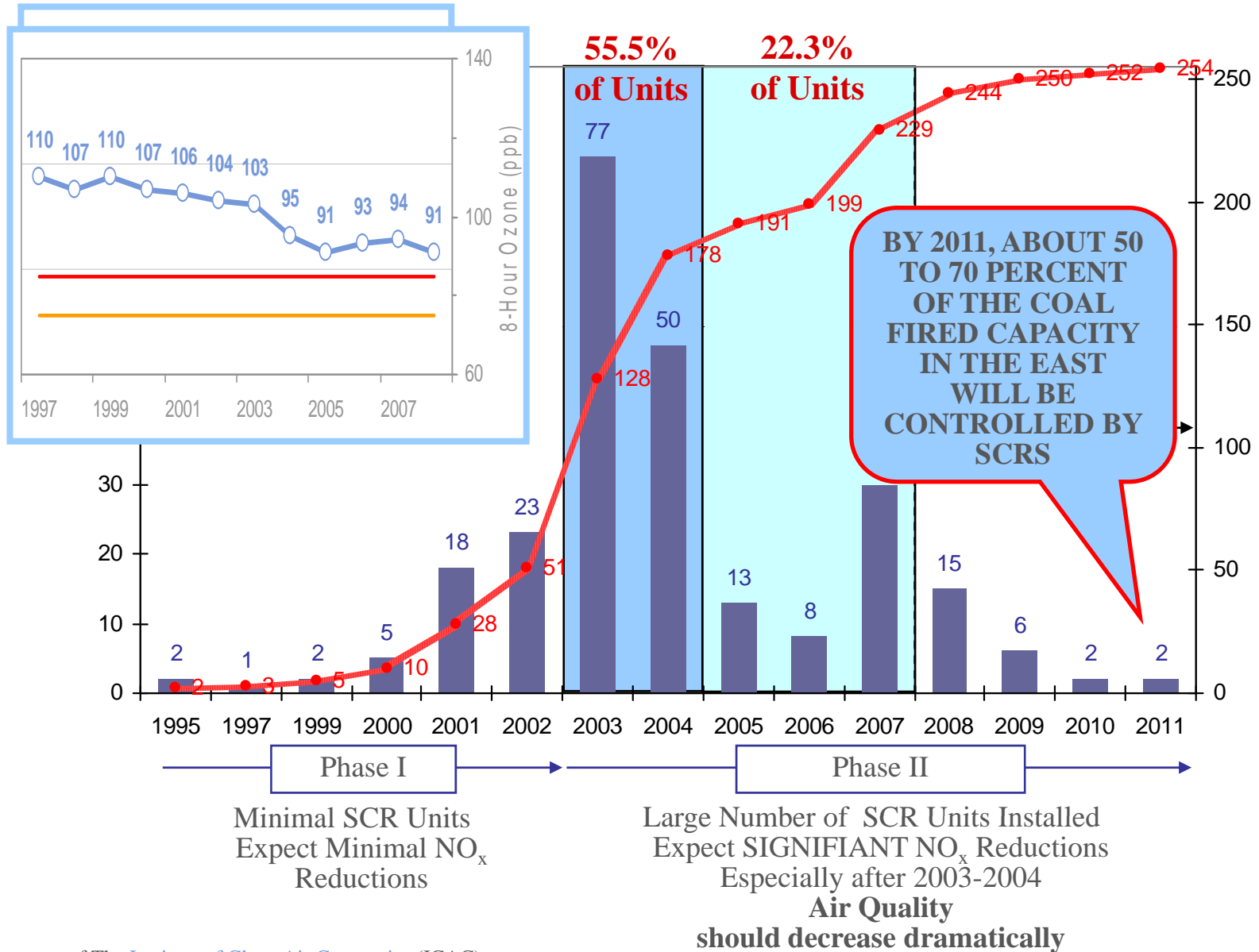


Ozone is 80-100 ppbv Aloft with High NOy and SO2





Reducing Westerly Transport



Data courtesy of The [Institute of Clean Air Companies](http://www.icac.org) (ICAC).



Westerly Transport - Lessons Learned?

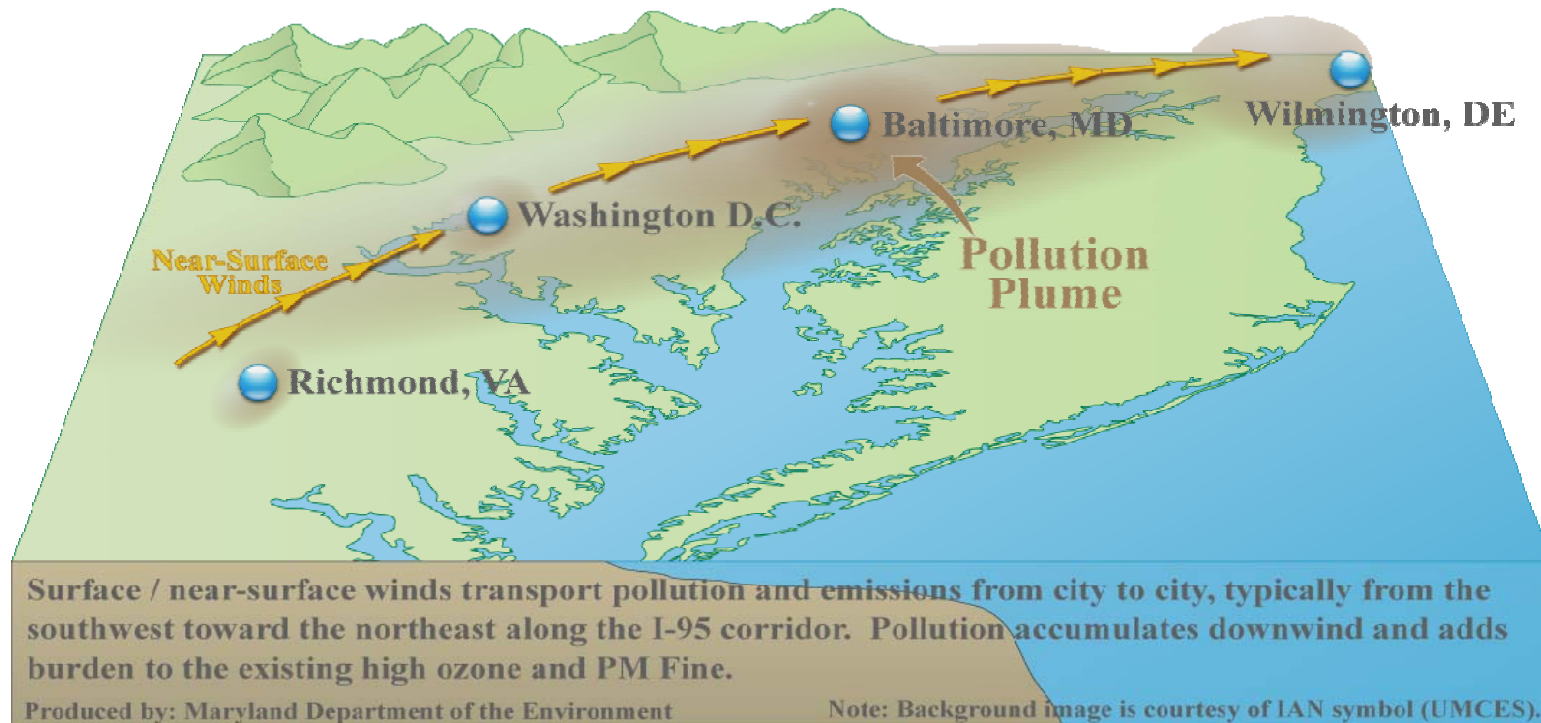
- Ozone has been reduced dramatically as super-regional power plant NO_x controls have been installed
- About 50 to 70 percent of the coal fired capacity in the East has added SCR controls
- About 30 to 50 percent has not added SCR controls
- Is there any reason to believe that more NO_x reductions would not lead to lower ozone?





City-to-City “Local” Transport

SHORT RANGE TRANSPORT

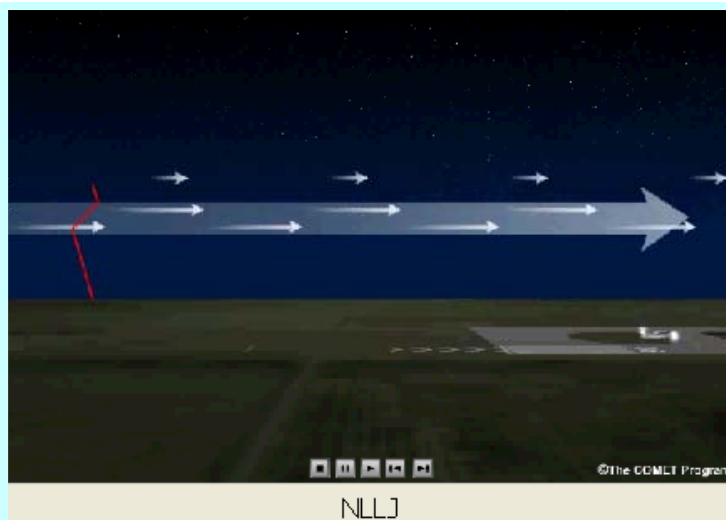
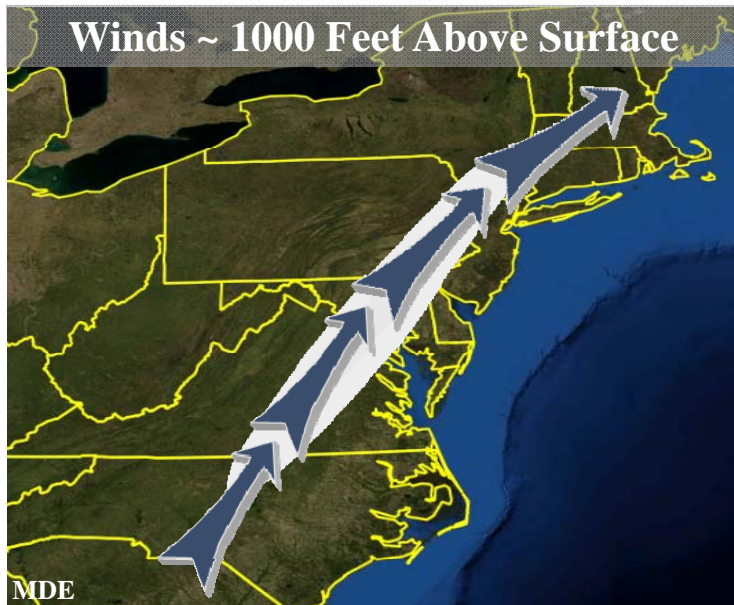


- Surface winds are typically from the southwest to the northeast.
- The morning pollution in Washington stays at ground level and floats downwind to become part of the afternoon pollution in Baltimore.
 - Pollution from Central/Northern VA ⇒ DC ⇒ Baltimore ⇒ Philadelphia and so on.
- Emissions from cars, area sources and stationary sources all contribute.



Southerly Transport at Night

The Nocturnal Low Level Jet (NLLJ)



- ❑ Fast-moving, narrow “river” of air typically around 1000 feet above the surface
- ❑ In the Mid-Atlantic, typically observed during the night between Appalachians and the Atlantic Ocean.
 - Wind speeds can reach 40 mph or more.
 - Stretches from NC to MD to NJ and further up the east coast.
- ❑ Seen during most, Mid-Atlantic summer-time air pollution events.
 - Some form of NLLJ on virtually all code orange or red days
- ❑ Recent findings indicate:
 - Presence of a NLLJ increased Baltimore maximum ozone by 7 ppb.
 - Ozone concentrations of 90 – 100 ppb have been measured in the NLLJ.



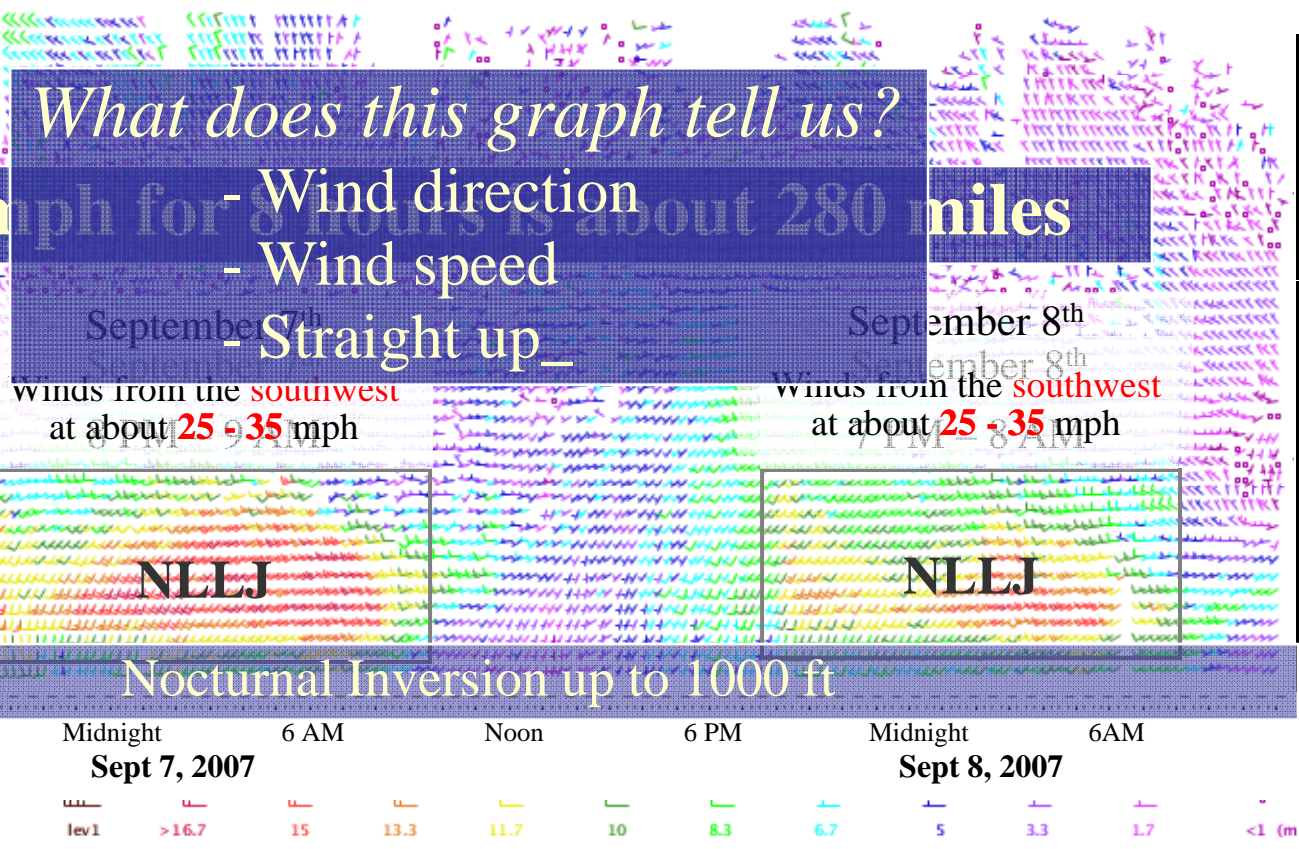
Measuring the NLLJ

Upper-Air Radar Wind Profiler & RASS (MDE)



Wind Speed and Wind Direction

Beltsville, MD on September 6 – 8, 2007



Source: Maryland Department of the Environment & MADIS

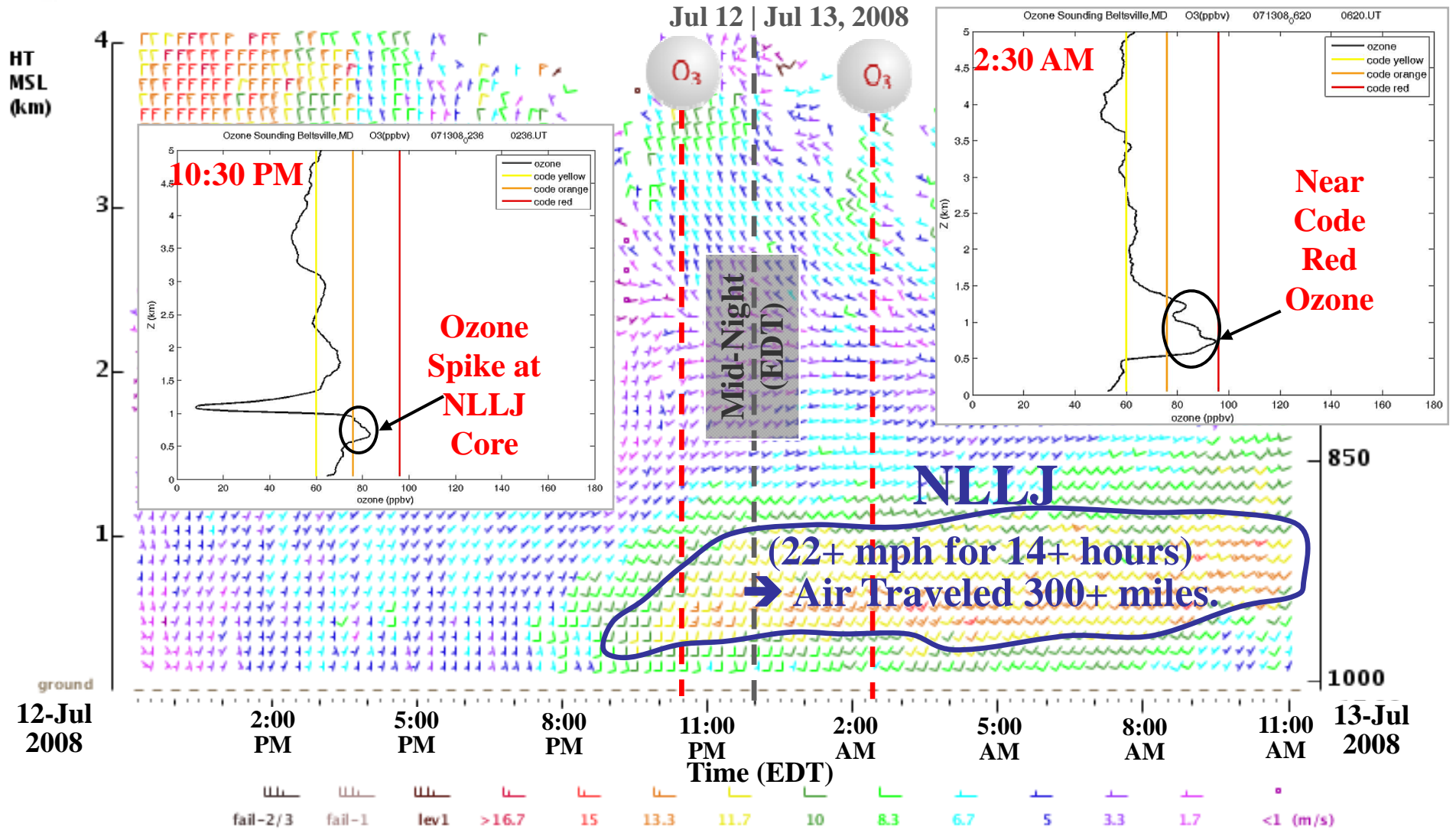




Measuring Ozone Transport in the NLLJ



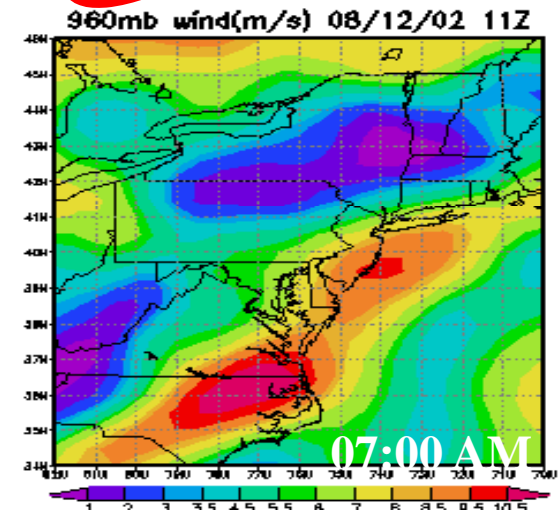
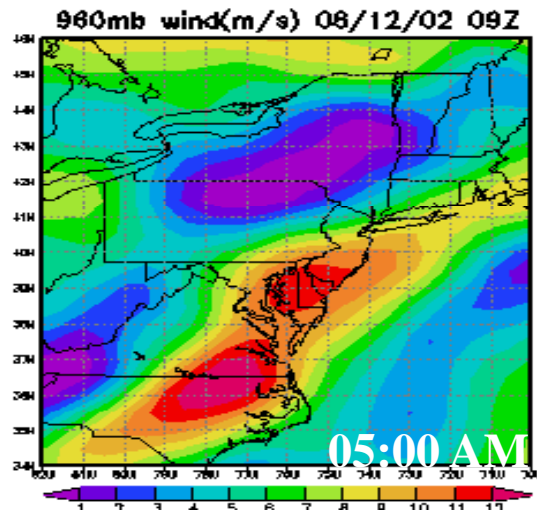
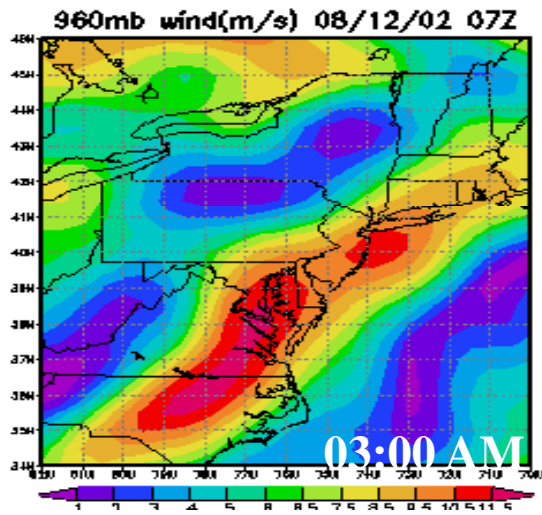
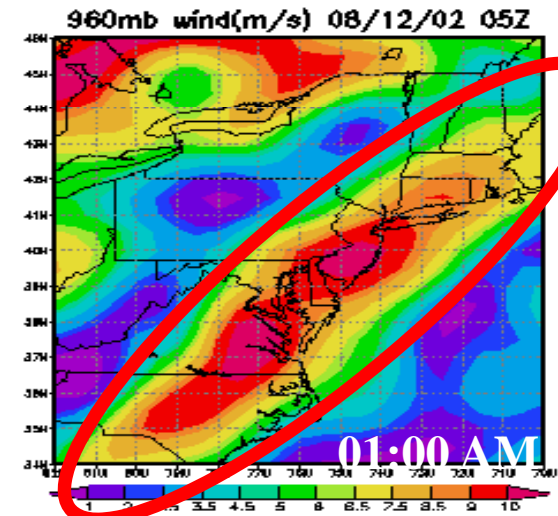
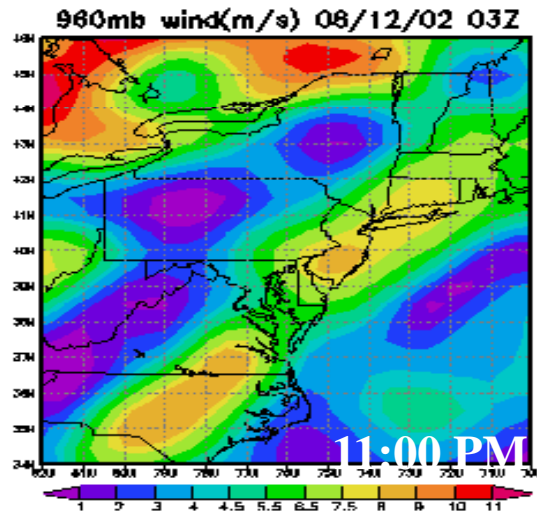
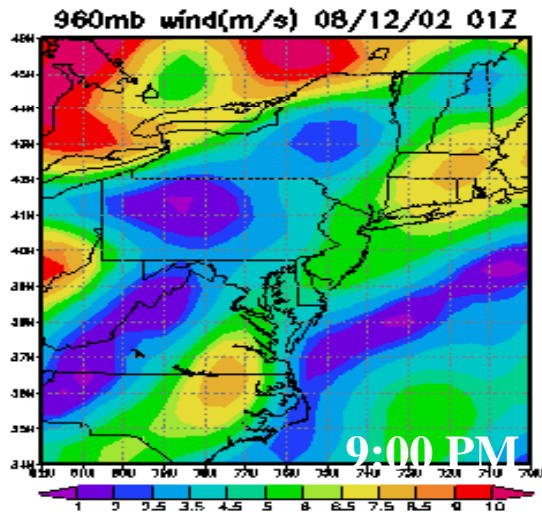
Howard University launched 4 ozonesondes on July 12-13, 2008. The 10:30 PM (Saturday, July 12th) and 2:30 AM (Sunday, July 13th) occurred during a **Nocturnal Low Level Jet (NLLJ)** event, as captured by MDE's upper-air Radar Wind Profiler.





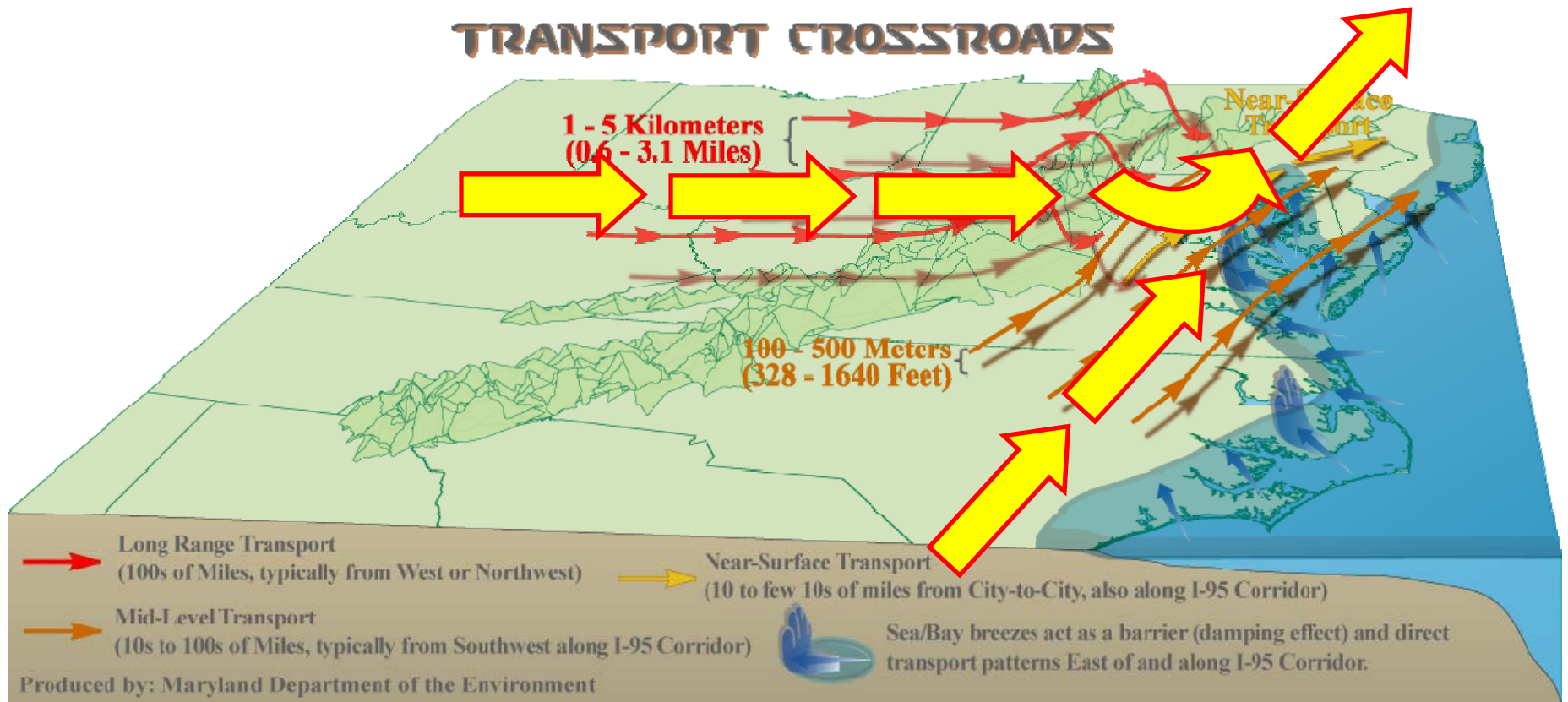
How Big is the NLLJ?

MM5 Model Run – Highest Wind Speeds in Red





When Transport Patterns Collide

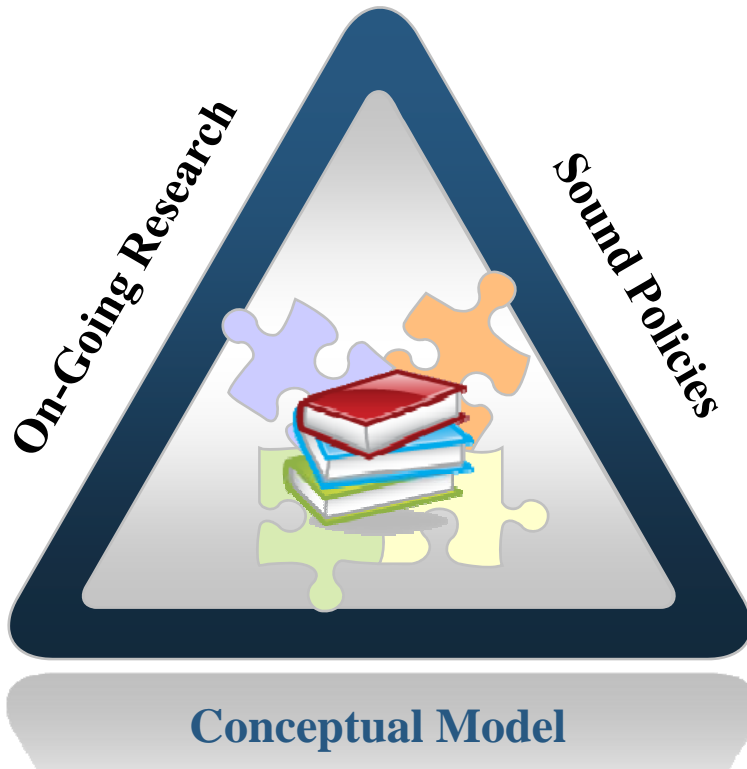


- ❑ Westerly, local and southerly/NLLJ transport converge on the Mid-Atlantic area.
- ❑ Sea and bay breezes act as a barrier or wall and funnel ozone and other air pollutants up the Northeast Corridor.



Driving Policy With Science

So What Have We Learned?



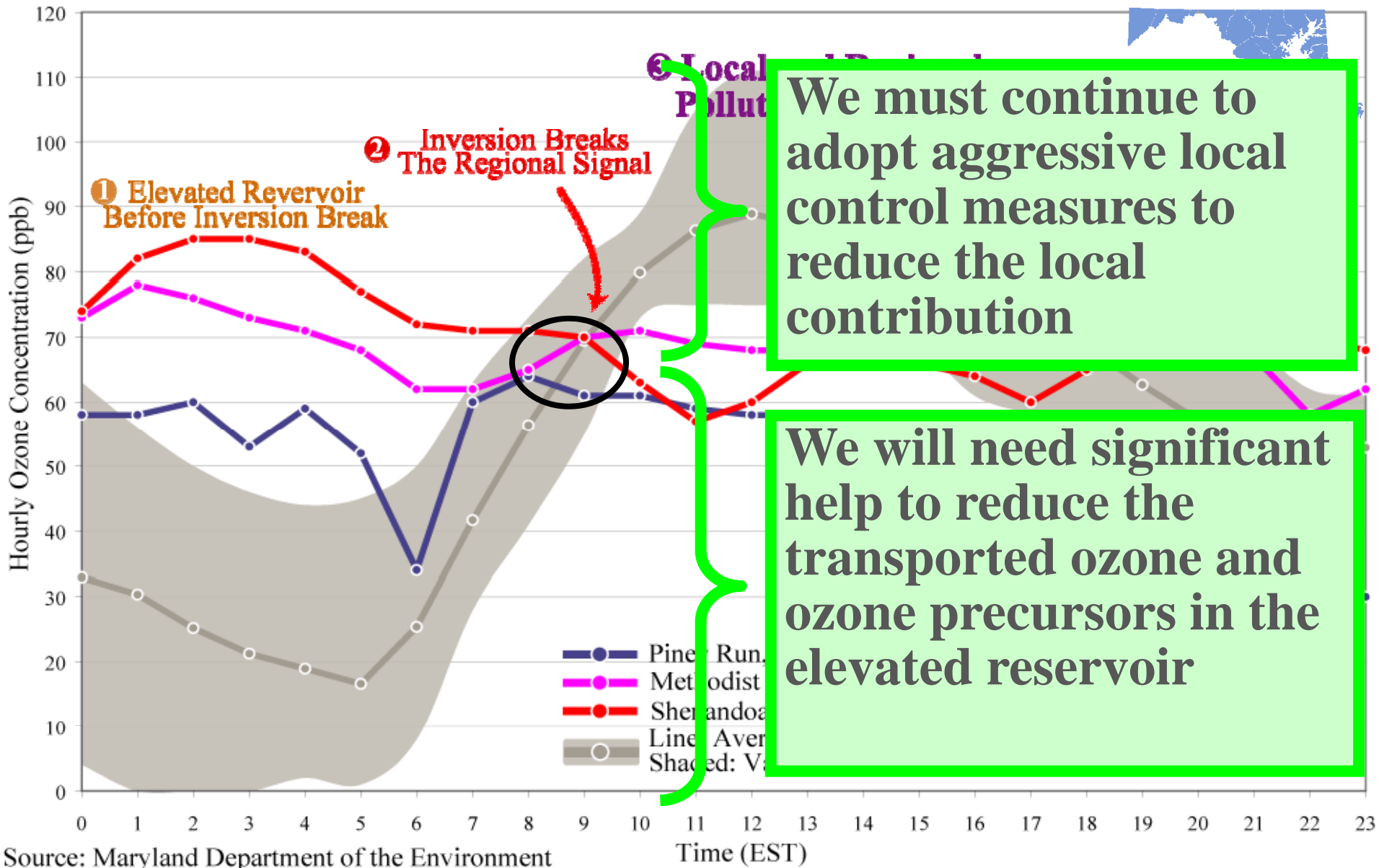
- Air pollution is complicated!!!
 - On any given day, Maryland's ozone problem can be blamed on:
 - Local emissions
 - Westerly Transport
 - Southerly transport
 - All of the above
- The NO_x SIP Call and other regional control programs have reduced ozone levels dramatically over the past 10 years.
 - The regional NO_x reduction programs of the of the 1990s really, really worked.
 - The 1990 Clean Air Act may depend too much on local emission reductions.
- We will need significant additional **national** or **super-regional control programs to reduce transport** to attain the new ozone standard.





A Two Part Control Strategy

Aloft Ozone Reservoir (June 13, 2008)



We must continue to adopt aggressive local control measures to reduce the local contribution

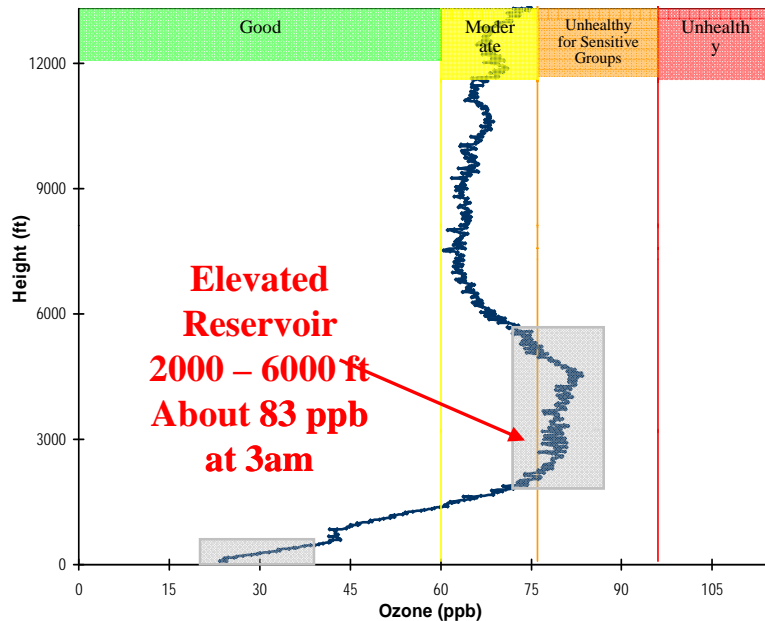
We will need significant help to reduce the transported ozone and ozone precursors in the elevated reservoir

Source: Maryland Department of the Environment



Local Versus Regional Contribution

Vertical Profile of Ozone
June 18, 2006 (3:10 AM EDT)
Beltsville, MD



Source: Maryland Department of the Environment & Howard University

- Work to adopt innovative, aggressive local control programs already begun – more later
- “Incoming” ozone already exceeds the new ozone standard
- To reduce transported ozone in the elevated reservoir we need help from EPA to lower NO_x and VOC emissions from a host of upwind source categories and upwind source regions
- There are many control programs being implemented in nonattainment areas across the country that are cost-effective, common sense and proven control techniques
- We need EPA’s help to level the playing field

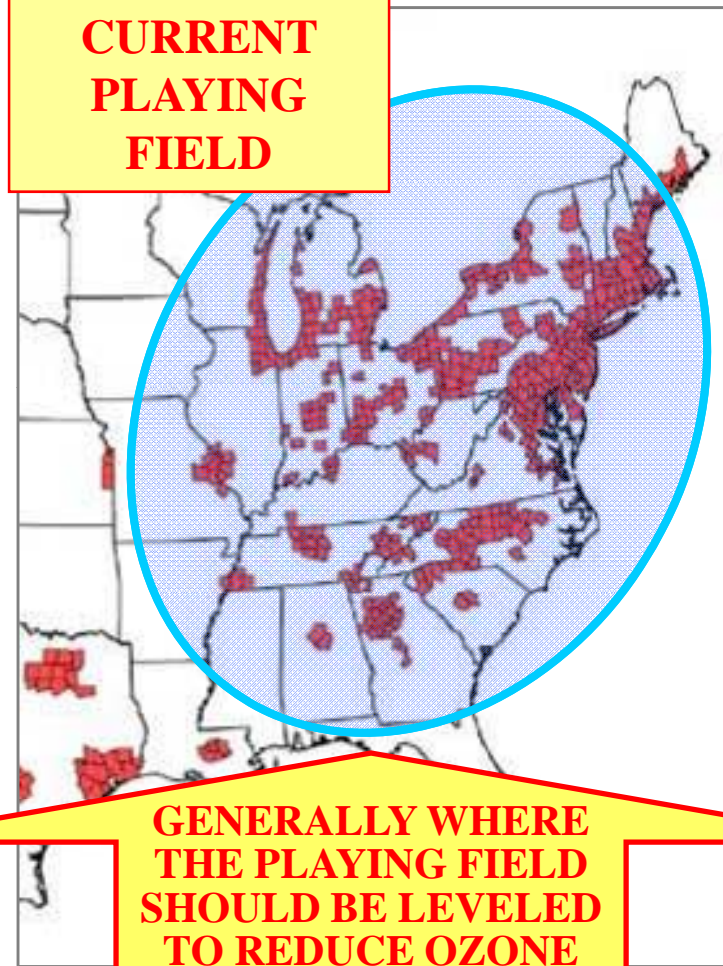




“Leveling the Playing Field”

- Examples of control programs that need to be implemented across most of the East to reduce transported ozone in the elevated reservoir
 - The next phase of NO_x and SO_x reductions from power plants
 - Industrial, Institutional and Commercial (ICI) boilers (NO_x and SO_x)
 - Cement kilns (NO_x and SO_x)
 - 25 ton per year NO_x and VOC RACT (Reasonably Available Control Technology)
 - OTC area source control measures (paints, consumer products, etc.)
 - Mobile sources
 - Numerous other source sectors

**CURRENT
PLAYING
FIELD**



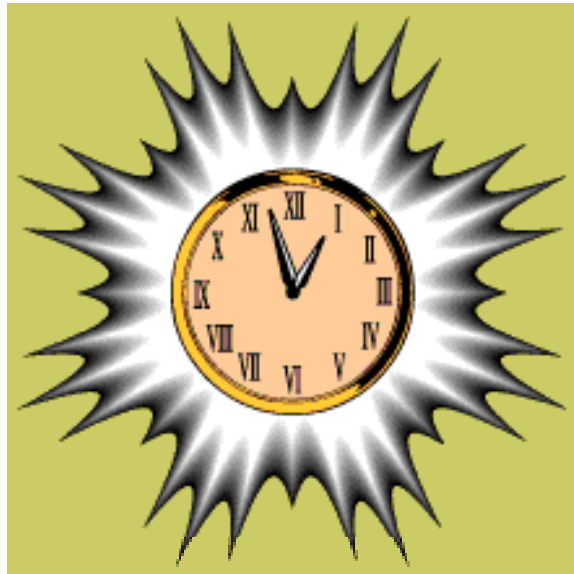
**GENERALLY WHERE
THE PLAYING FIELD
SHOULD BE LEVELED
TO REDUCE OZONE
IN THE ELEVATED
RESERVOIR**



MARYLAND'S CONCEPTUAL MODEL



Our Schedule



- 2016
 - Likely attainment date for many OTC states
- Summers 2013, 2014 and 2015
 - Clean air recorded by monitors
- May 2013
 - Latest date for new state, regional and national control programs to become effective and generate reductions
- 2010 and 2011
 - State, regional and national rules fully adopted





Questions?

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