APPENDIX B

Ground-Level Ozone

A Path Forward for the Eastern United States

30 Years of Research and Progress: What's worked … What We've Learned … Where to Go Next

by George (Tad) Aburn, Jr., Russell R. Dickerson, Jennifer C. Hains, Duane King, Ross Salawitch, Timothy Canty, Xinrong Ren, Anne M. Thompson, and Michael Woodman

The Maryland Department of Environment partners with the University of Maryland at College Park, NASA, and other researchers to study how meteorology, photochemistry, and geography conspire to make the ozone problem so challenging.

Maryland has struggled with ozone nonattainment for over 30 years. We've seen success, we've seen some setbacks, and we've learned a lot. There are many current issues linked to ground-level ozone being discussed across the nation. The top six policy-relevant conclusions from our 30-year struggle are:

1. We understand the fundamental, policy-relevant science of ozone production in the East, and believe that continuing significant progress can be achieved.
2. An updated ozone standard is appropriate and achievable.
3. An enhanced partnership with the U.S. Environmental Protection Agency (EPA) will be essential for making continued progress with ozone because the regional contribution to ozone in almost all areas is now dominant and

is predicted to become more so as the standards tighten.

4. Stronger partnerships between state and local governments and stakeholders will also be critical.
5. The private sector and environmental advocates can make a major contribution to insuring environmental and economic progress by being strategic about litigation.
6. International transport is becoming an important issue, but not one that should be used to delay continuing progress.

Background

For more than 30 years, Maryland has struggled with meeting the federal ozone standard. During that period, the Maryland Department of Environment (MDE) has partnered with the University of Maryland at College Park, NASA, and other researchers to study how meteorology, photochemistry, and geography conspire to make the ozone problem in the Mid-Atlantic so challenging. Processes on both the local and regional scale influence ozone formation and transport.[1-10] This research has played a significant role in the progress we have made in reducing exposure to ozone (and other pollutants) and provides a clear path forward for continuing to reduce ozone levels in the eastern half of the United States. Ozone issues west of the Mississippi appear to have some similarities to those in the East, but there are also some significant differences in meteorology and geography that create different challenges. This article focuses on ozone in the East, an area of lush forests where field experiments and numerical models have shown that nitrogen oxide (NO_x) emissions combined with biogenic hydrocarbons are sufficient to generate ozone events.[11-14]

After struggling with making progress with ozone in the 1970s, 1980s, and 1990s, ozone levels in Maryland, like the rest of the East, dropped dramatically over the past 10 years (see Figure 1 on page 20). Why?

From Maryland's perspective two major shifts in eastern ozone policy drove this change:

1. An increased focus on NO_x reductions; and
2. An increased focus on significant regional reductions of NO_x across the East from mobile sources, electric generating units (EGUs), and other large emission sectors.

The classic 1990 report from the National Academy of Sciences foreshadowed the importance of these issues: the data show they were right.[15]

Local emission reduction programs have helped and will continue to help reduce ozone, but the large-scale regional NO_x reduction programs are what drove the noticeable improvements in ozone seen starting around 2003. Why?

Where Does Ozone in the Mid-Atlantic States Come From?

Ozone in the Mid-Atlantic is complicated. This issue can be understood by examining the two primary pieces of the problem: regional transport (i.e., ozone and ozone precursors from upwind sources across a large portion of the East) and local sources. In general terms, on bad ozone days in Baltimore, MD, approximately 70% of the problem is regional transport and approximately 30% is local.[16] As part of our research efforts, we measure "incoming" ozone levels with ozonesondes and airplanes that routinely approach or exceed the current 75 parts per billion (ppb) ozone standard.[17-20]

The regional transport component of our problem, builds up and collects in an "elevated reservoir" of ozone and ozone precursors that exists about

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1,000 m above the Mid-Atlantic and much of the East from May to September.[21,22] Ozone levels in the elevated reservoir can routinely be 70 ppb or greater on episode days.[23]

The influence of the elevated reservoir can best be seen by analyzing the morning "surge" of ozone reported in the ground-level monitoring data between 8:00 a.m. and 11:00 a.m. At night, ground-level monitors measure low ozone concentrations while monitors aloft measure much higher levels. At night, the elevated reservoir is separated from the surface by the nocturnal inversion. As the next day begins, temperatures increase, the inversion begins to collapse and the elevated ozone reservoir begins mixing down to the surface. In general, the ozone levels measured aloft at night mix down and create a regional transport contribution seen in ground-level monitors across the region. This "regional transport signal" can often approach or exceed 75 ppb. Local emissions begin to contribute to ozone production in the morning as well. Regional transport and local emissions combine to drive daily peak ozone levels in the late afternoon (see Figure 2).[24-27]

A classic, real-world case study helps demonstrate how regional NO_x reduction efforts can significantly lower ozone levels in the East. In 1997, 37 states and the District of Columbia participated in a collaborative effort, called the Ozone Transport Assessment Group (OTAG), to look at the transport of ozone in the East. Partially driven by that effort, in 1999 EPA adopted a federal program, called the NO_x State Implementation Plan (SIP) Call, to address ozone transport and help states satisfy the "good neighbor" requirements of the U.S. Clean Air Act (CAA). The NO_x SIP Call required a first round of meaningful NO_x reductions from EGUs in the 2003 to 2004 time frame. Around the same time, the federal Tier II vehicle standards also began to add NO_x reductions (volatile organic compounds [VOCs] were the focus of earlier federal standards).[28]

As Figure 3 shows, controls were added, regional NO_x emissions went down, ozone levels in the elevated reservoir were reduced, and ground-level ozone levels dropped dramatically.[10,29,30]

Filling the Reservoir

Which states and sources contribute to filling the elevated reservoir? The answer is that it varies from day to day. There are, however, some general observations that appear to be supported by Maryland's research and modeling.

Westerly transport is often a major factor when high pressure is located over the Southeast and the resulting aloft winds flow, clockwise, over the Ohio River Valley.[31,32] This classic ozone weather pattern often carries transported ozone and ozone precursors from power plants into the Mid-Atlantic region. This scenario can cover multiple days.

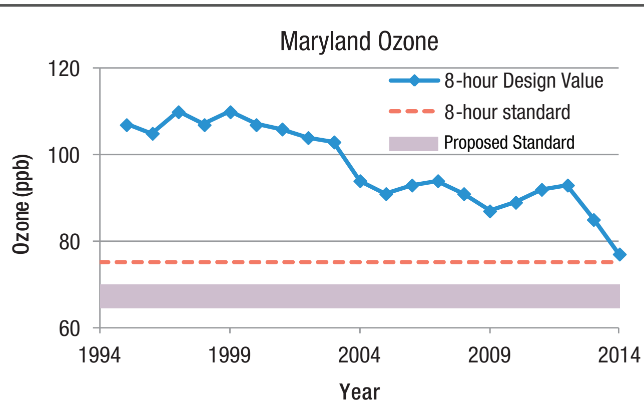

Figure 1. Trend chart for Maryland ozone.

Notes: Ozone design values in Maryland have steadily decreased since 1994 and in 2014 Maryland is close to meeting the current standard. Note the scale does not start at zero.

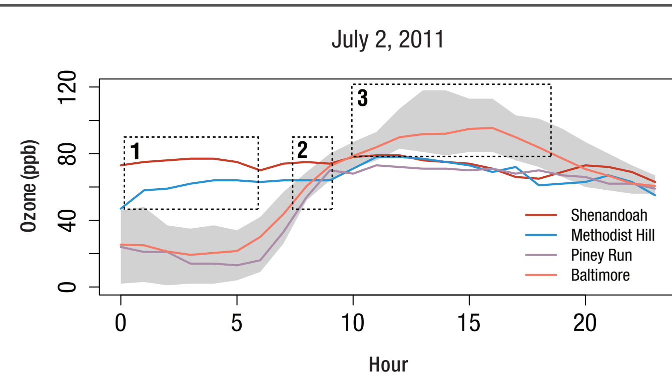

Figure 2. Daily evolution of ozone.

Notes: Hourly ozone collected on July 2, 2011. Box 1 highlights ozone measured in the elevated reservoir at night; Box 2 shows the regional transport signal and highlights the breakdown of the nocturnal inversion when the aloft ozone is mixed to the surface; and Box 3 highlights the contribution of locally produced ozone on top of the regional pollution.

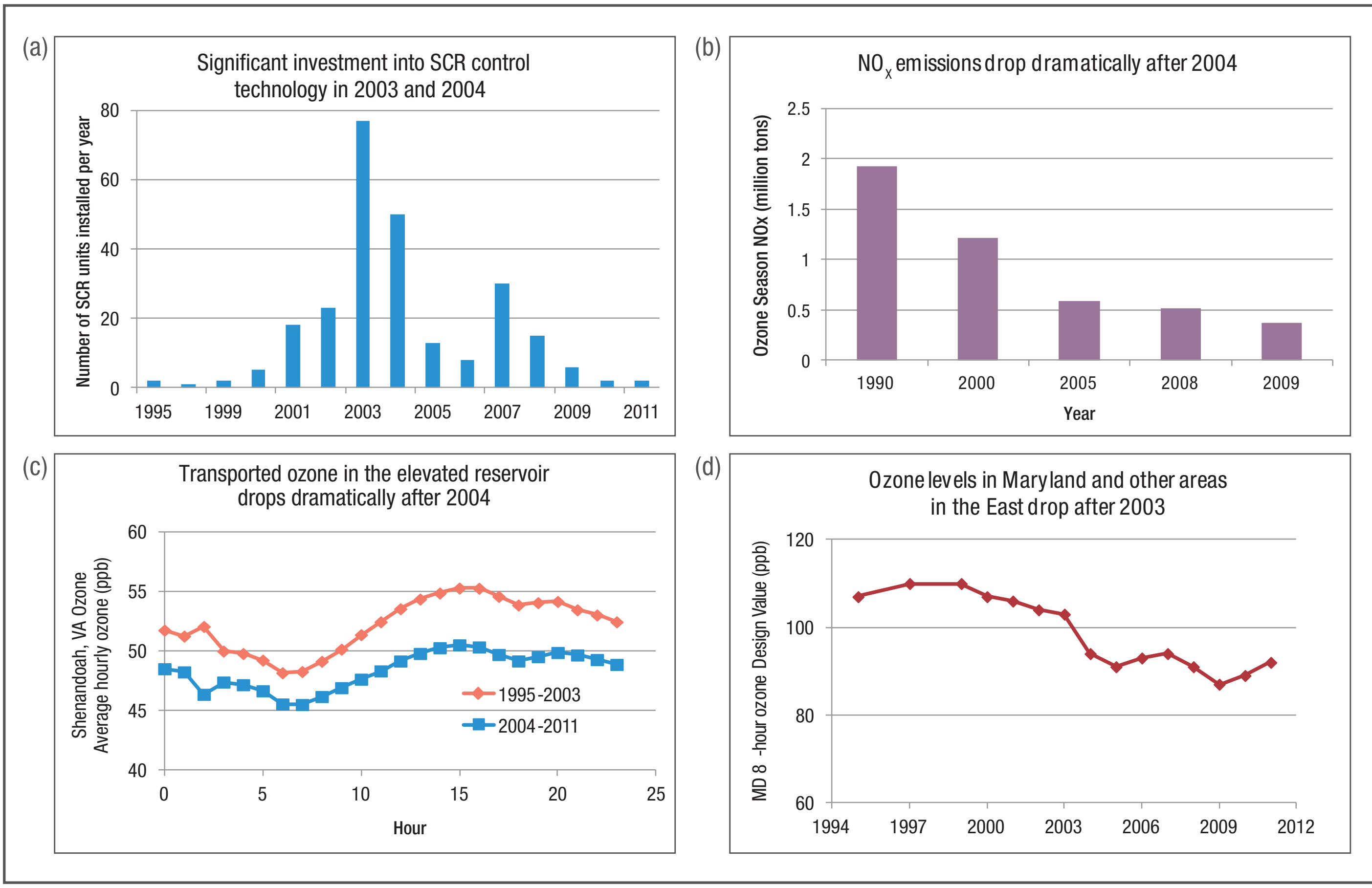

Figure 3. Why regional NO_x controls work.

Notes:

(a) NO_x SIP Call drives significant investment in selected catalytic reduction (SCR) NO_x control technology, 2003–2004;

(b) NO_x emissions in the area covered by the NO_x SIP Call drop dramatically around 2004;

(c) Transported ozone in the elevated reservoir drops dramatically after 2004. Note that the scale does not start at zero; and

(d) Ozone levels in Maryland and other areas in the East drop dramatically after 2003.

Southerly transport at night also appears to be important. On most bad ozone days, wind profilers along the East Coast show nighttime aloft winds moving from the south to the north funneled by the Appalachian Mountains on the west and the Atlantic Ocean on the east.

This nocturnal low level jet, measured by wind profilers, can reach wind speeds as high as 35 mph.[33,34] Nighttime ozonesonde launches show that ozone levels being carried by the nocturnal low level jet are routinely in the 50–70-ppb range and can get as high as 100 ppb.[35] It appears that this type of transport can move ozone for several hundred miles over night and has a significant mobile source fingerprint. In addition, the effects of a bay-breeze are often observed at monitoring stations near Baltimore. During the bay-breeze, air masses with both local and imported ozone pass from the western shore to the Chesapeake. Over the bay, ozone continues to form, until the winds reverse and ozone-enriched air returns to shore. During a 30-day aircraft and ozonesonde measurement campaign in July 2011, one monitoring site recorded eight ozone violations for which the bay-breeze was a factor.[36,37] The bottom line is that the contribution to the elevated ozone reservoir changes with weather. Westerly, southerly, sometimes northwesterly, and occasionally northeasterly flows are all important. EGUs, mobile sources, and other source sectors all appear to play a significant role in creating the elevated ozone reservoir.

The other type of important transport is city-to-city or short-range transport. For example, Baltimore's plume floating at ground level into Philadelphia and Washington's plume floating into Baltimore. This type of short-range transport is separate from the elevated ozone reservoir, but it is another significant way that emissions from close-by, upwind states contribute to downwind problem areas.[23]

The Path Forward

In the East, the formula is simple: Cost-effective regional NO_x control programs complimented by smart local efforts that target each area's unique

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Regional Transport

As states move forward and begin to develop plans to continue making progress with ground-level ozone, a new level of partnership with EPA will be needed. The CAA is often recognized as a good example of cooperative federalism where state and local governments work with EPA in partnership to provide clean air in a way that fosters economic prosperity. This partnership is now more important than ever.

Between 2005 and 2010, EPA and the states worked together to identify priority source categories that would have the largest eastern and national emissions of NO_x, sulfur dioxide (SO_2), and mercury (Hg) remaining in 2020. This effort identified six source categories that represented 75% of the remaining NO_x emissions that could be targeted for additional reductions. These categories included EGUs; on-road mobile sources; institutional, industrial, and commercial (ICI) boilers; cement kilns; marine engines; and locomotives. These six categories also represented 85% of the SO_2, and 75% of the Hg emissions left to control in 2020.[38-42]

EPA has moved forward with initiatives to reduce national or regional NO_x emissions from many of these priority source categories and much of the recent progress on ozone reduction is linked to these actions. Earlier actions on marine and locomotive engines, the Tier 2 Vehicle Standards, and the NO_x SIP Call combined with more recent efforts like the Tier 3 Vehicle and Fuel Standards, the Mercury and Air Toxics Standard (MATS), Boiler MACT, and a series of mobile source actions on greenhouse gases that will provide ozone co-benefits have, and will continue to, help lower ozone levels.[43] It's clear that regional NO_x reductions drive down ozone across the East. So how do we continue to do more of that?

The state/EPA partnership on prioritizing important sectors by potential future multipollutant reductions provides a model to identify the next set of national or super-regional reduction programs that may be needed. The effort should be designed to analyze strategies to find the "biggest bang for the buck" and to look at multipollutant benefits. In many cases, at the national or super-regional level, a small set of source categories dominate emission contributions for ozone, fine particulates, SO_2, NO_2, Hg, haze, and greenhouse gases.

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One of the issues that continues to be discussed over the new ozone standard is that many new areas, particularly less populated areas, will be forced to try and solve a problem that they simply cannot solve alone because local emissions are relatively small. The need for regional controls is important for historically difficult nonattainment areas like Baltimore and New York, but they are actually much more important to new areas that may be nonattainment for ozone in the future.

Local Transport

Addressing the local contribution to ozone is important, but if done alone, without addressing the regional contribution, will fail. It is critical for local strategies to be "smart". What works in the Mid-Atlantic may not work in the South. As an example, Maryland and other Northeast states are working to drive down local mobile source emissions of NO_x along the I-95 corridor. Emissions for major point sources are accurately monitored, but substantial uncertainties remain in emissions for mobile sources.[44] Our research tells us that a focus on mobile sources is an important area to drive future progress.

Examples of the kind of local efforts being made in this area include the recent efforts by eight states on Zero Emission Vehicles (ZEVs), the OTC Aftermarket Catalyst model rule, and nontraditional initiatives to enhance SMARTWAYs efforts and to work with ports. The common thread in all of these is reducing NO_x, but all of these efforts also have multipollutant benefits.[44-48]

Maryland is also working with neighboring states to further reduce VOC emissions, which continue to be a meaningful contributor to ozone at our urban monitors. Recent efforts include updates to three model rules developed by the Ozone Transport Commission for consumer products, paints, and auto body shops. This is a good example of a strategy that would be smart for some areas, but less likely to be successful in other areas like the South where biogenic VOCs are dominant when compared to anthropogenic VOCs.

Enhanced Collaboration

Two more observations from the past 30 years: Legal challenges by the environmental community occasionally slow down environmental progress; and legal challenges by the private sector can lead to inefficient regulatory processes and a planning landscape for the business community that is impossible to navigate. Both hurt the nation's economy. This seems like an area that needs to be

It's clear that regional NO_x reductions drive down ozone across the East.

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explored and may be as important to future environmental and economic progress as the science giving us a clear technical path forward.

Having worked collaboratively with other government agencies, the environmental advocacy community and the private sector, we believe an enhanced effort to collaborate is critical and that such an effort could work. The CAA is a very powerful and functional legal framework to work from. Sometimes the solutions to the problems we struggle with lie within the gray areas of the law and require buy-in from multiple parties if they are to work. Clear environmental progress is essential. We cannot let perfection be the enemy of the very good.

Critical Emerging Ozone Research

One of the most policy-relevant, emerging research areas MDE is working on with the University of Maryland involves changes to the atmosphere over the past 15 years that may be affecting the chemistry of ozone production. These changes appear to support the hypothesis that we have reached a tipping point, where a ton of NO_x reduction in the 2015–2025 time frame will generate meaningfully more ozone reduction than it did just 15 years ago. This is a critical issue as we move toward a new standard. Stay tuned.

Evolving Markets

When markets change, market-based programs sometimes need to be tweaked. Over the past few years, changes in the electricity markets have created a situation where installed EGU control equipment for ozone does not need to be used effectively during bad ozone periods because of the flexibilities built into the market-based regulatory system under which many of these sources operate. This issue is already being discussed and appears to be moving toward resolution. That said, investing in billions of dollars worth of ozone controls and then not using them when it matters, is an issue that must be fixed.

Conclusion

Maryland is thoroughly convinced that continued significant progress on reducing ground-level ozone is within our grasp. The science linked to what else we need to do is solid. Continued progress in the future will, however, take a new level of partnership involving states and local agencies, EPA, the private sector, and the environmental advocacy community. **em**

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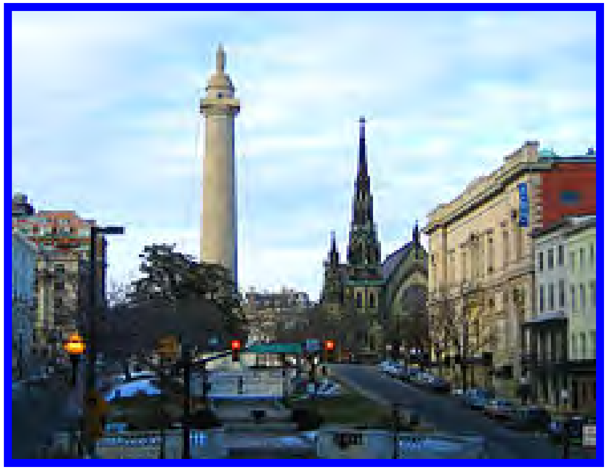
Solving the Ozone Transport Problem

An Overview of Maryland's Research and Policy Relevant Findings: A Path Forward



New Jersey Webinar - October 30, 2015
Tad Aburn, Air Director, MDE

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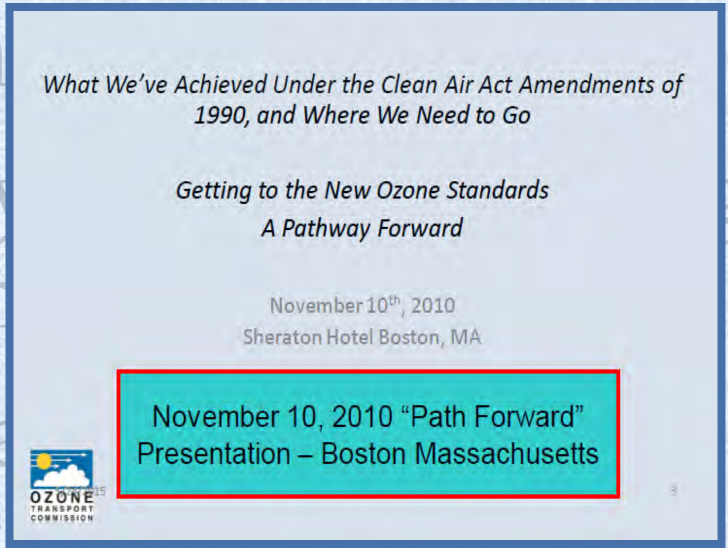
Maryland's Ozone Research Effort

- MDE works in partnership with local universities (UMD at College Park, UMBC, Penn State and Howard University) to study air pollution issues in Maryland and the Mid-Atlantic
  - Airplanes
  - Balloons
  - Lidar
  - Profilers
  - Satellites
  - Special monitors
  - Modeling
  - More
- The focus of this research has been to provide policy relevant findings related to air pollution transport

The Path Forward

2010



2013

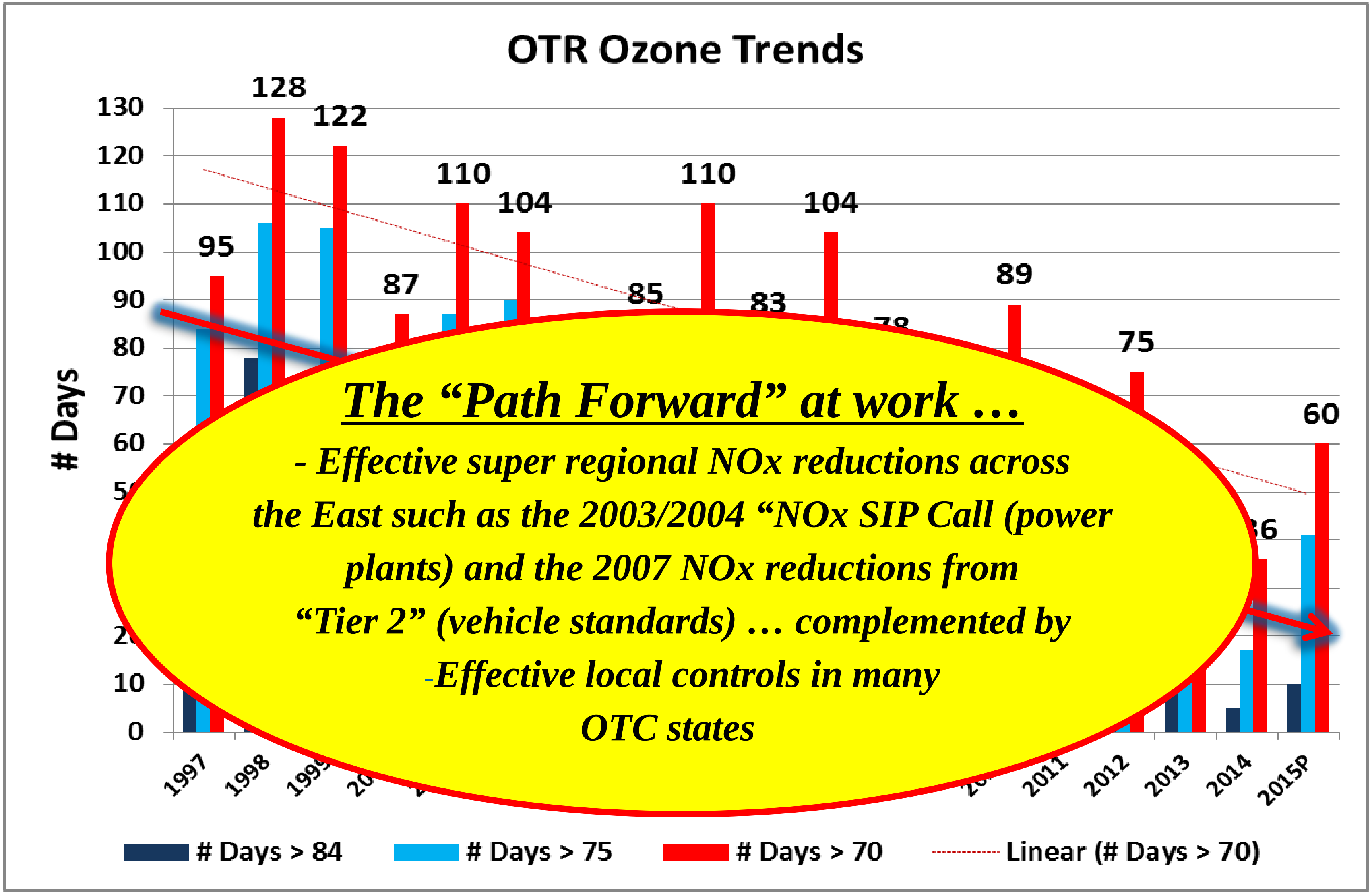
Conclusions From the Past

- We understand the science of ozone better than ever
  - We've implemented programs that have worked in the real world
- We need a two-part strategy …
- A Path Forward:
  1. We must reduce transport from across the entire East
     - Reduce regional NOx emissions
  2. We must reduce local emissions along the I-95 corridor
     - NOx and VOC reductions
- Both are important, but number 2 will not work alone

October 2015

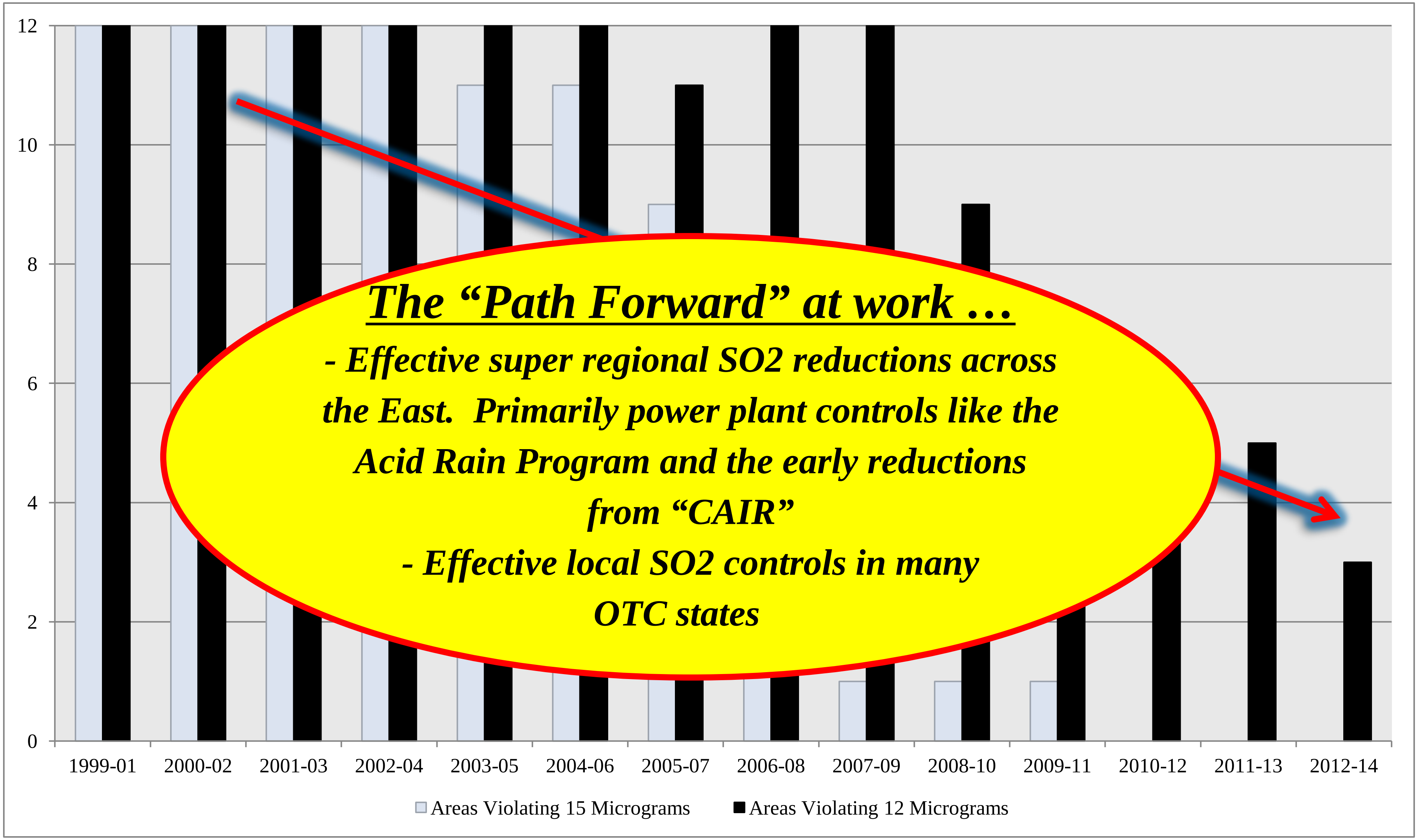
- Our path forward to solve the problem has not changed
  - It will also solve our fine particle and regional haze problems
- Data shows - We continue to make progress
  - We're poised to make even greater progress
- We have very good science that shows our efforts will work
- We also have some very significant challenges
  - More progress in southern Ozone Transport Region
    - Why is this?
    - What can we learn from this?

Ozone Progress 1997-2015



Created by Tom Downs, Maine DEP-BAQ - 9/4/2012

Fine Particulate - Many Fewer Problem Areas



http://www3.epa.gov/airtrends/values.html

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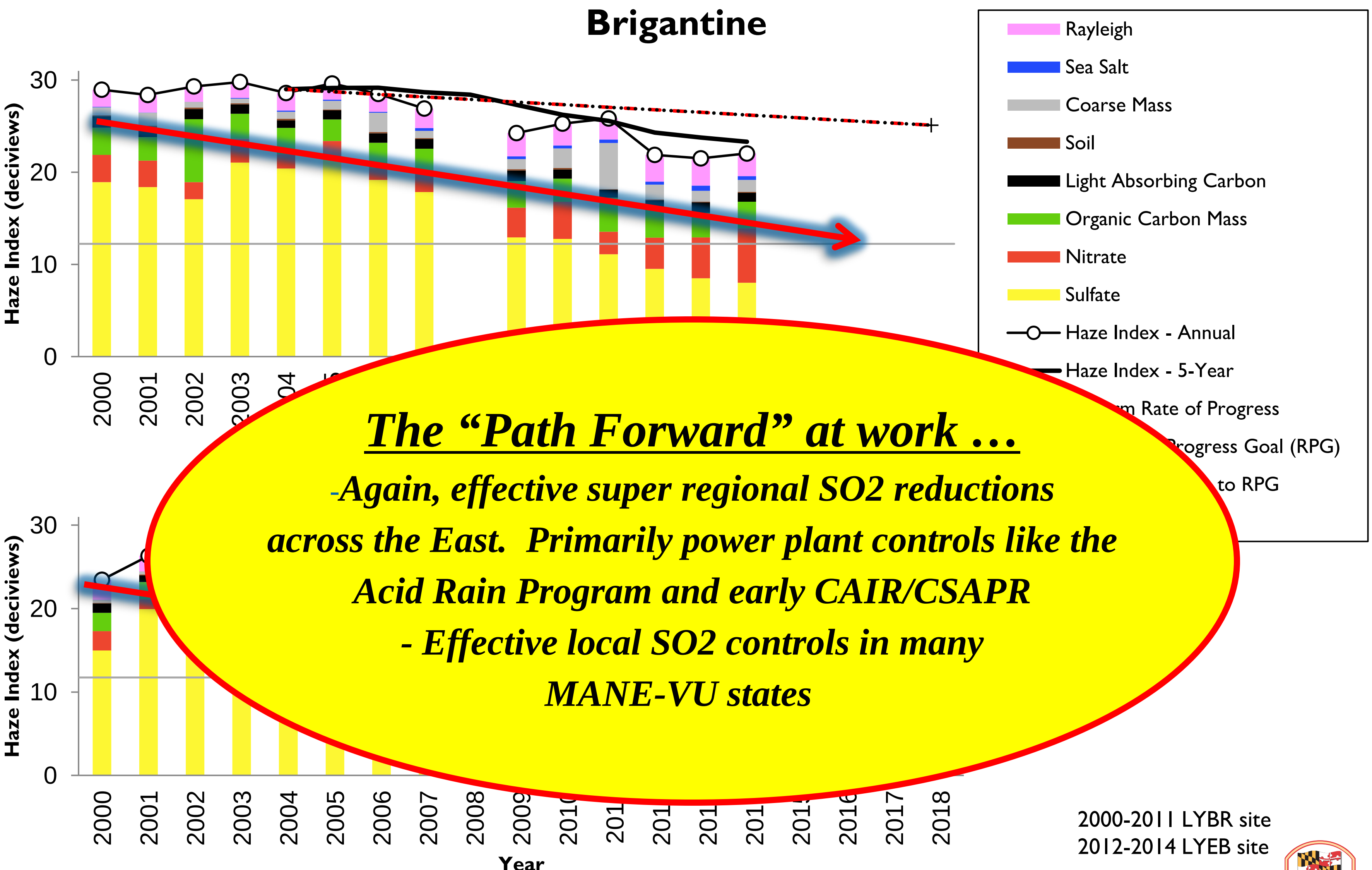
Regional Haze - Way Ahead of Schedule



<u>The "Path Forward" at work …</u>

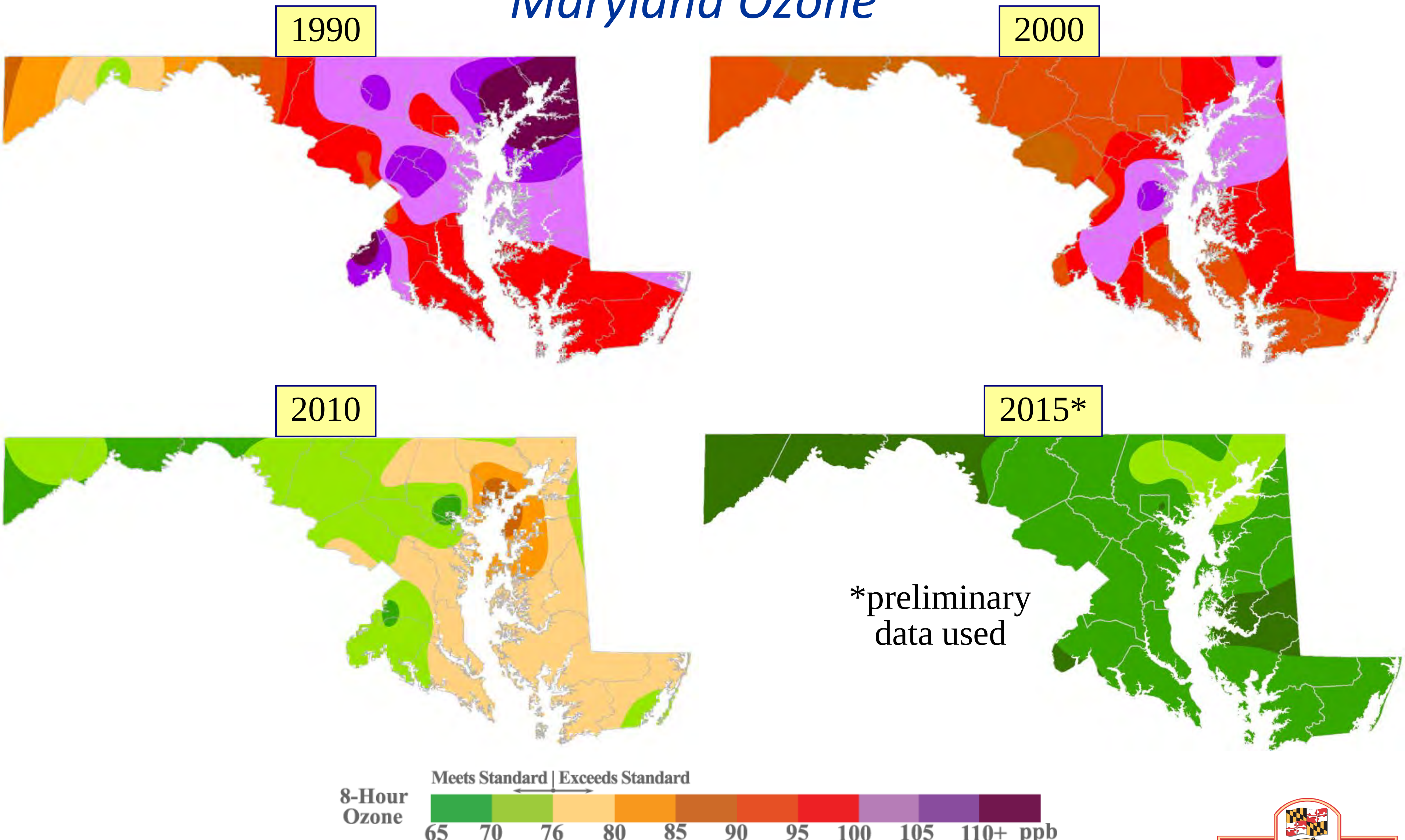
-Again, effective super regional SO2 reductions across the East. Primarily power plant controls like the Acid Rain Program and early CAIR/CSAPR

- Effective local SO2 controls in many MANE-VU states

2000-2011 LYBR site
2012-2014 LYEB site

Lower Concentrations & Smaller Problem Areas

Maryland Ozone



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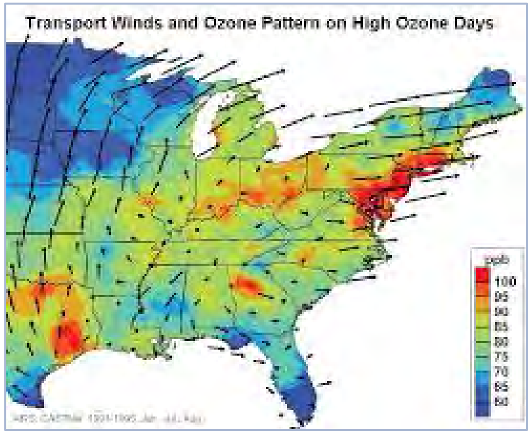
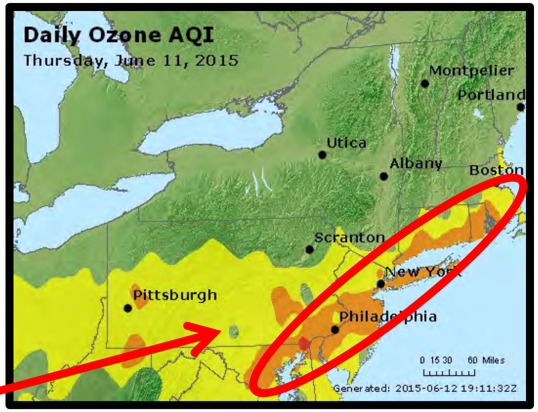
So … What Can We Learn …

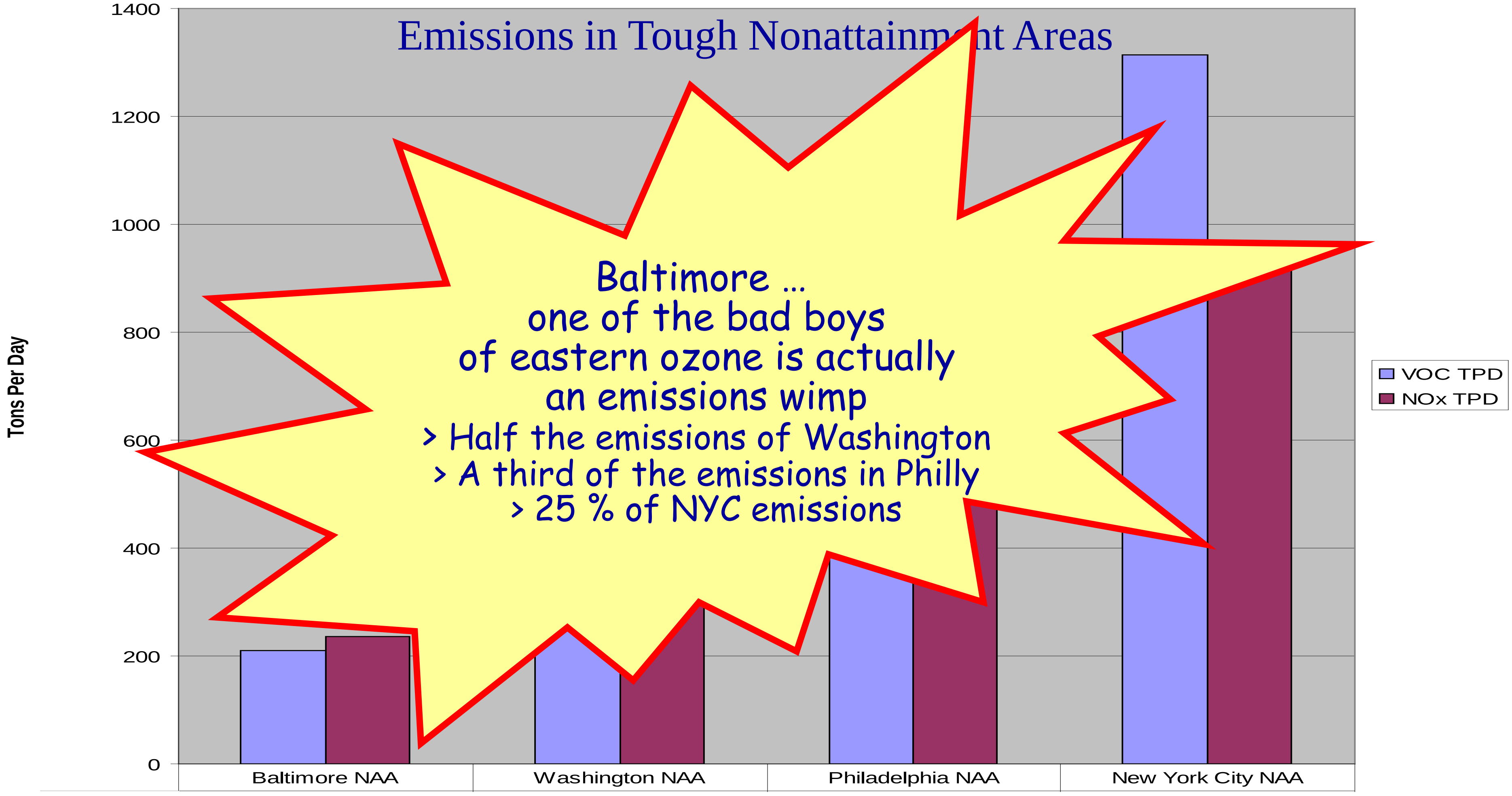
… from all of this progress

- The solution is not that complicated
  - Hard … but not complicated
- We know what has worked
- We simply need to do more of it
- There are clearly two pieces of our ozone problem
  - A widespread regional transport piece, and
  - A smaller scale, local or sub-regional piece





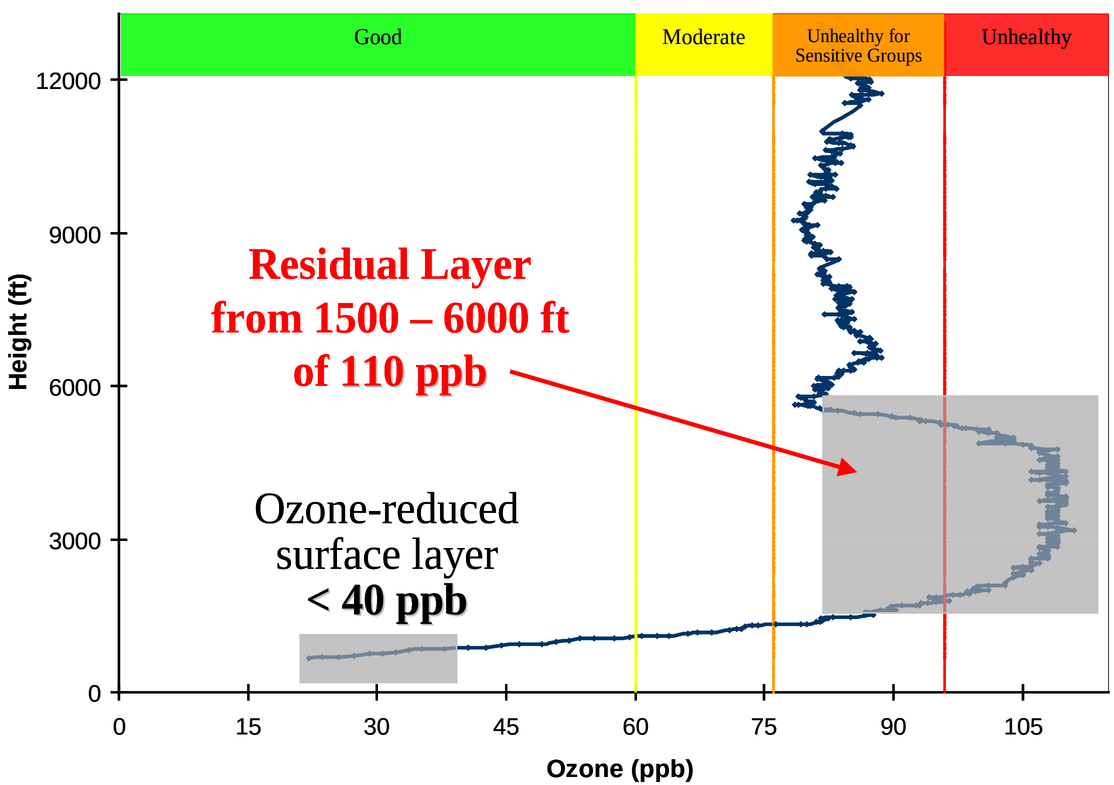
Baltimore – The Poster Child of Transport



So What the Heck is Going On?

Why does Baltimore measure some of the worst ozone in the East?

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



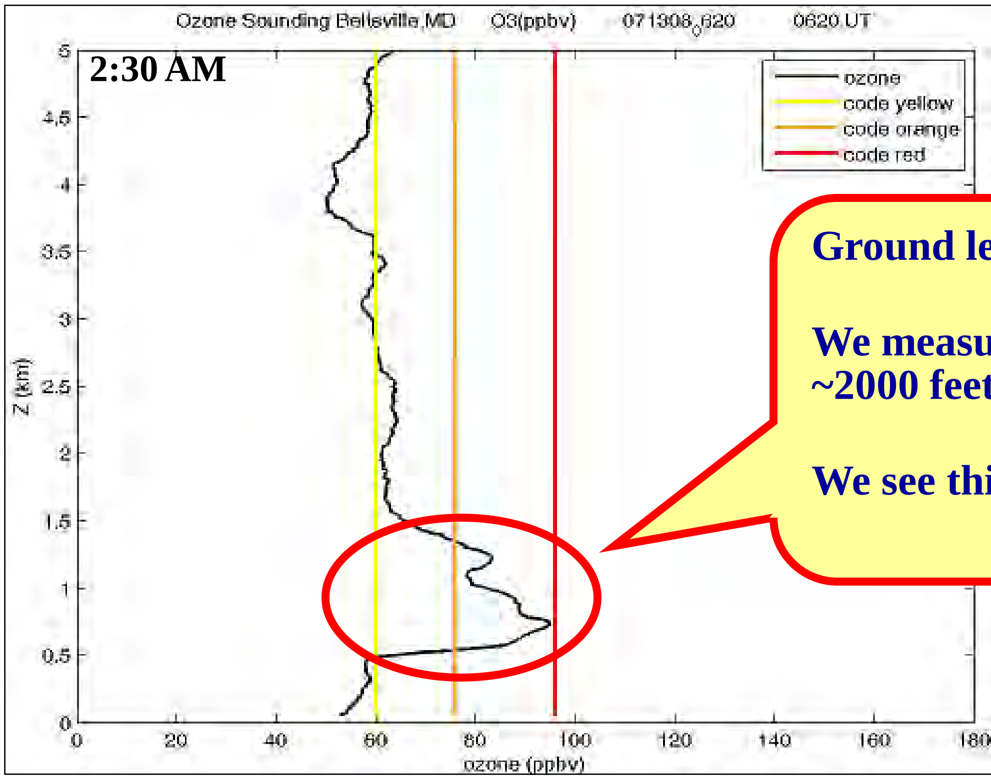
Source: Maryland Department of the Environment & Howard University

Understanding Ozone Transport

- It's complicated … but not that complicated … some key concepts
- An "elevated reservoir" of ozone
  - A transport cloud
  - An elevated "ocean" of ozone
  - The residual layer
- Three different types of transport
  - Westerly Transport – Power plants are a contributor
  - Night-time, Southerly Transport – Vehicles, power plants, more
  - City-to-City – An urban soup … Washington to Baltimore … Baltimore to Philly … Philly to NYC … etc. etc. etc

What is This Reservoir?

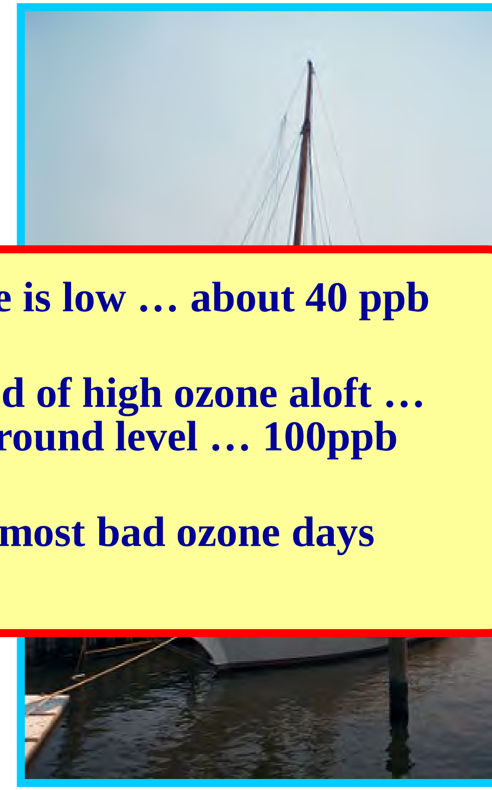
A balloon launch at 2:30 am south of Baltimore … north of Washington



Ground level ozone is low … about 40 ppb

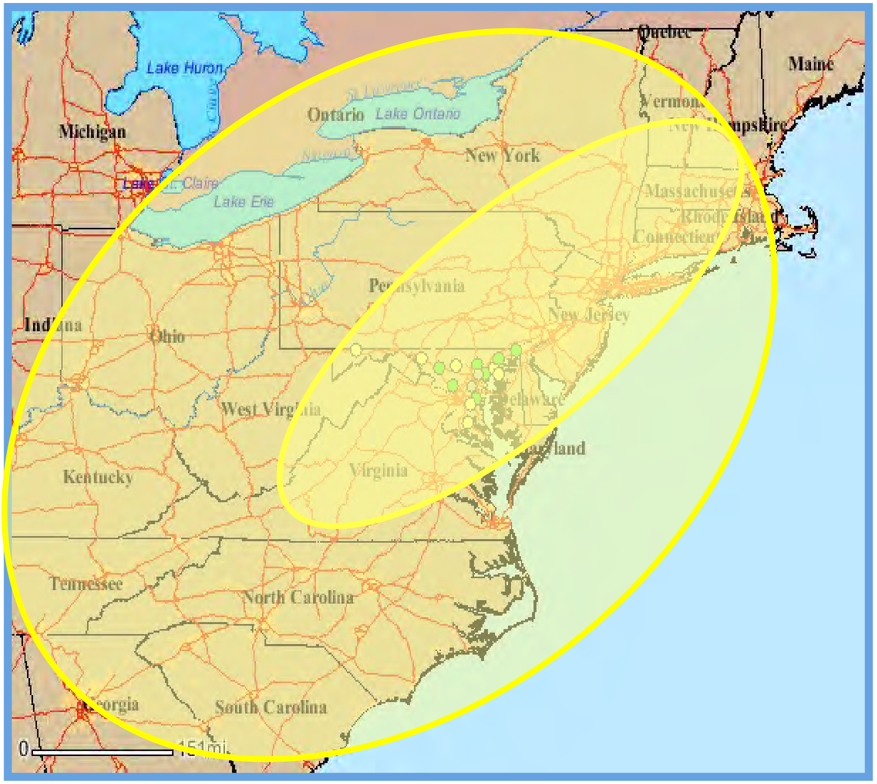
We measure a cloud of high ozone aloft … ~2000 feet above ground level … 100ppb

We see this before most bad ozone days



The Elevated Ozone Reservoir

- On most bad ozone days, in the morning hours, a large reservoir of ozone sits above Maryland and the Mid-Atlantic 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 "nocturnal inversion" breaks down … and
  - Ozone in the elevated reservoir mixes down to the surface and degrades air quality



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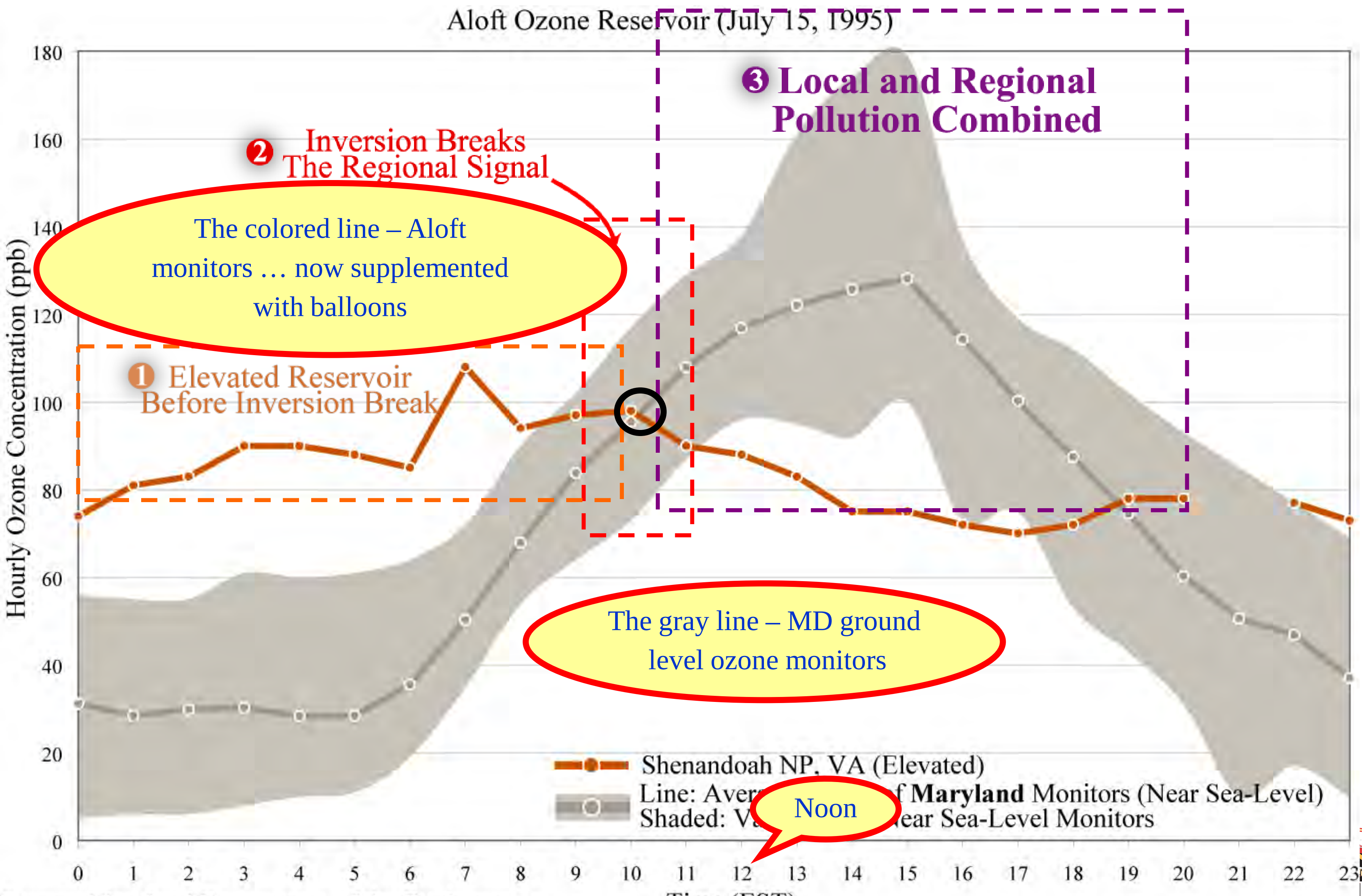
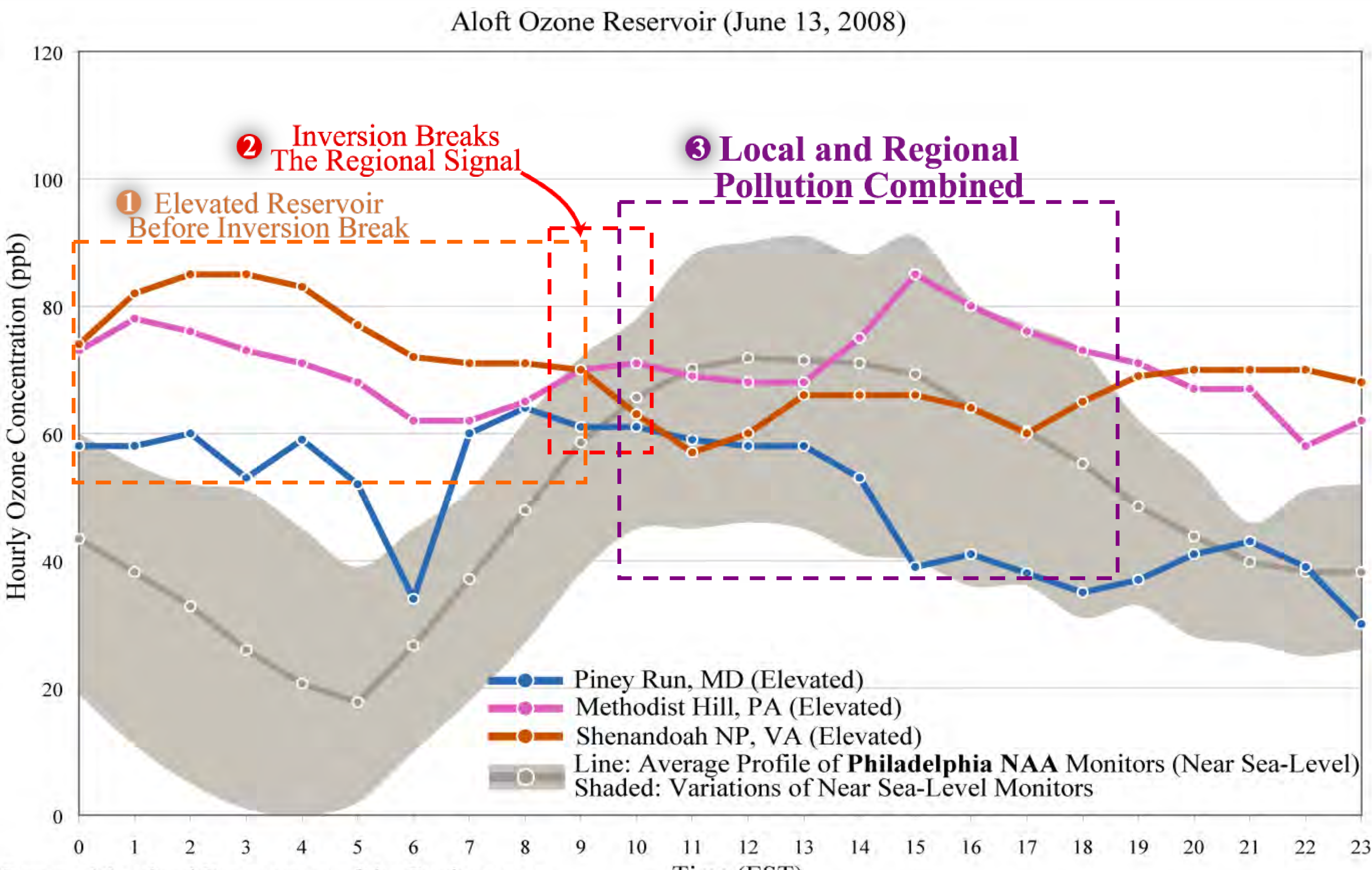
The Elevated Reservoir – The 90's



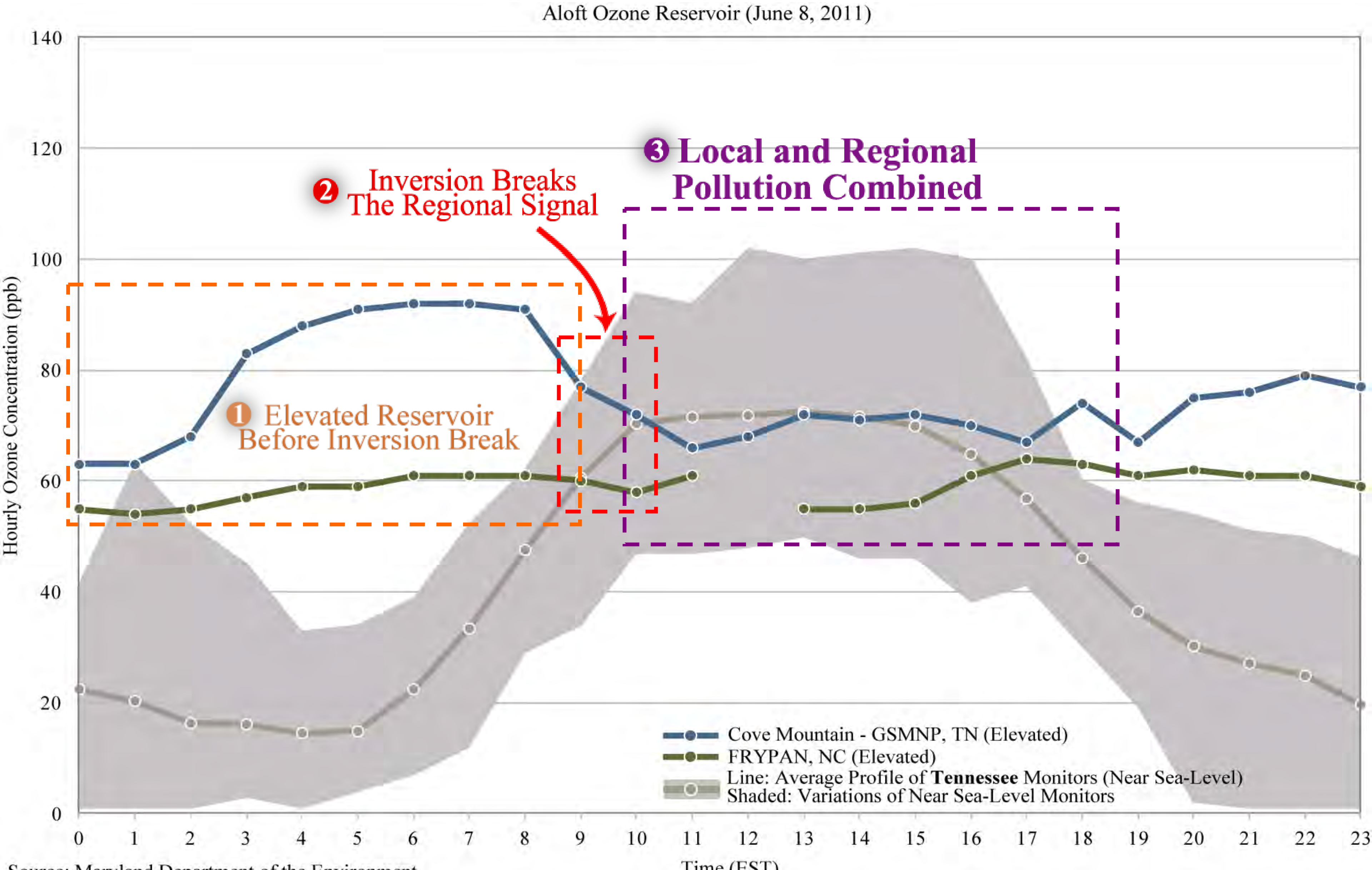
Source: Maryland Department of the Environment

Same Signal – Philly/NJ 2008



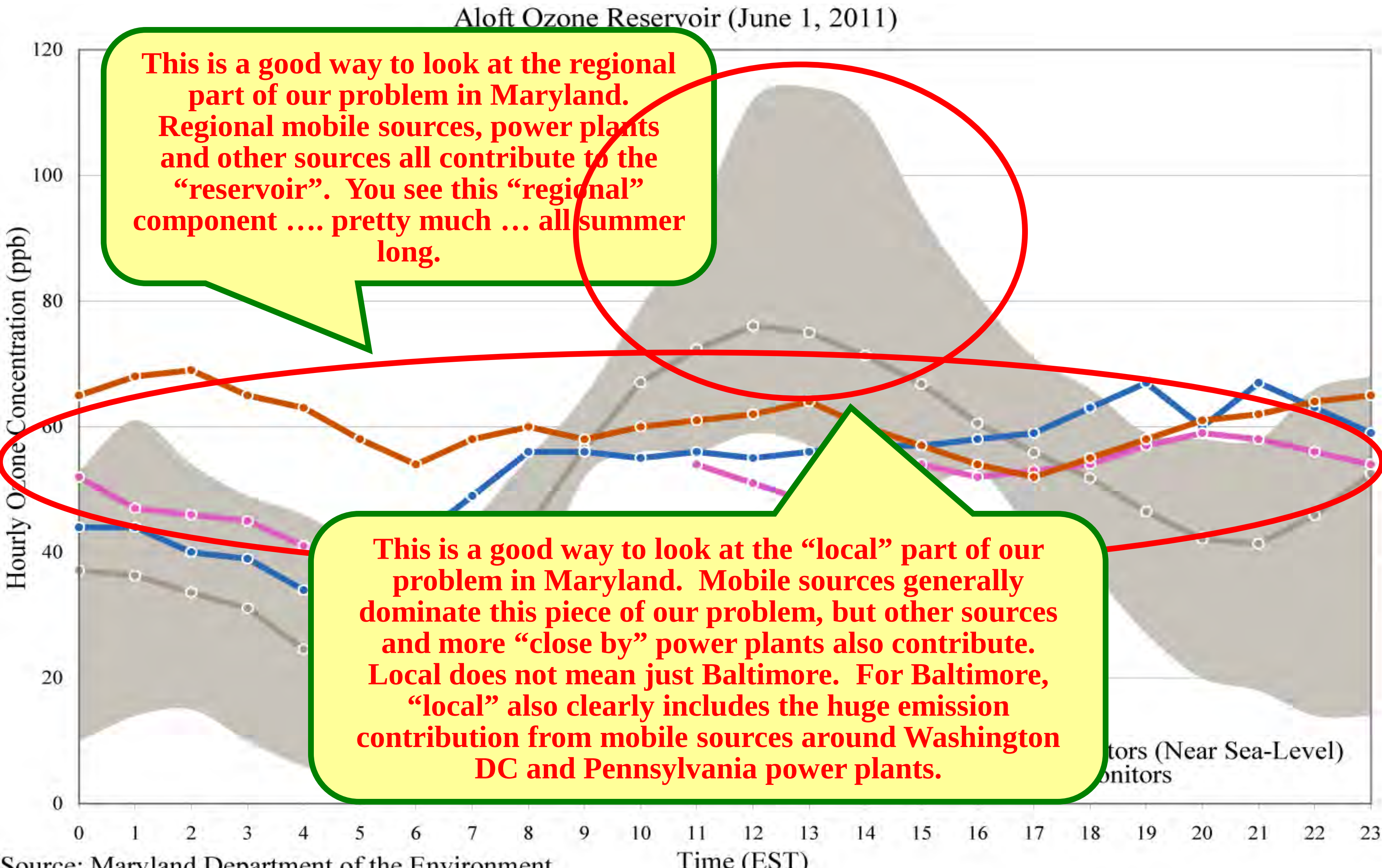
Source: Maryland Department of the Environment

Same Signal – Tennessee 2011



Source: Maryland Department of the Environment

Same Signal – Maryland 2011

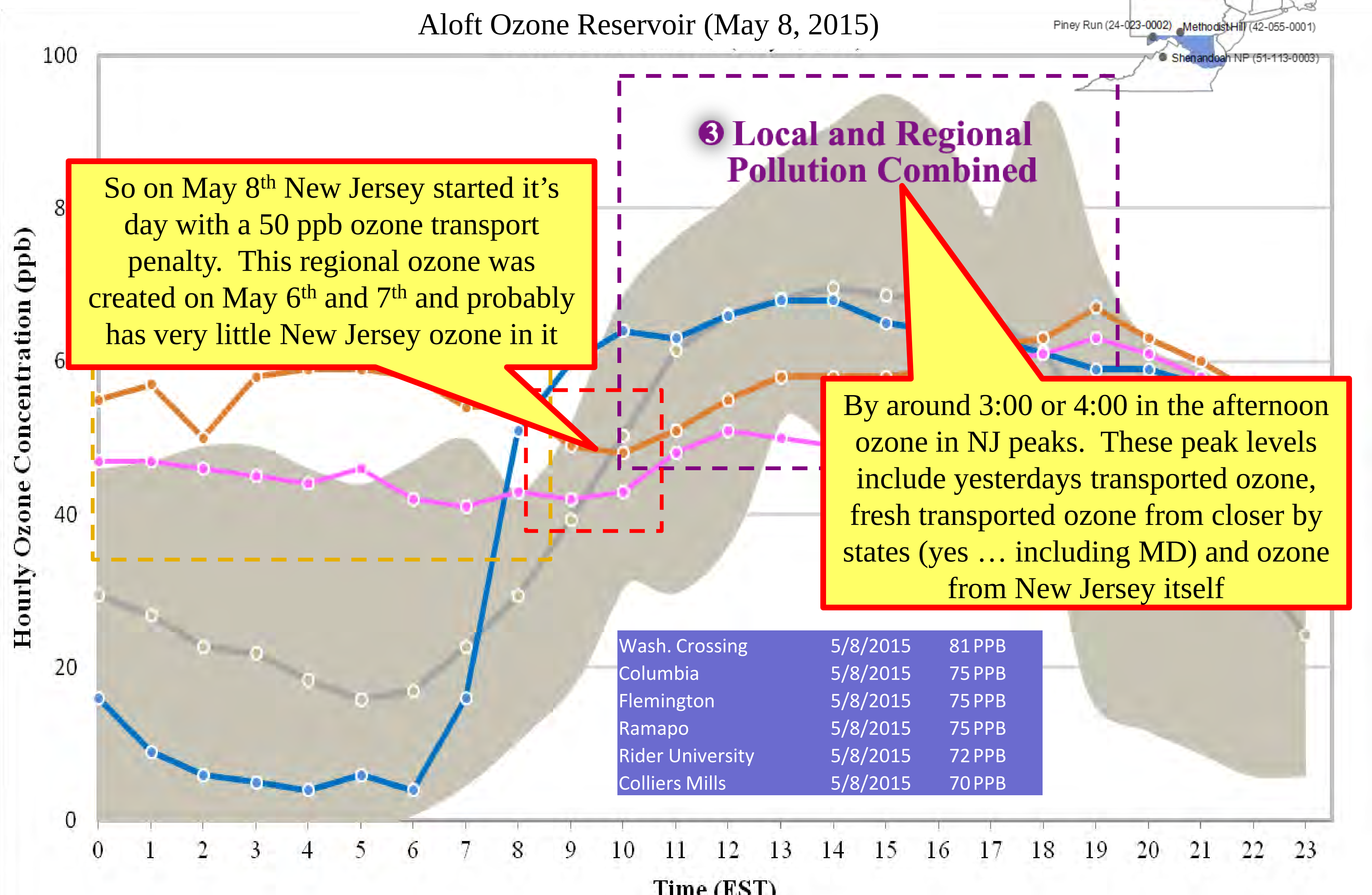


This is a good way to look at the regional part of our problem in Maryland. Regional mobile sources, power plants and other sources all contribute to the “reservoir”. You see this “regional” component …. pretty much … all summer long.

This is a good way to look at the “local” part of our problem in Maryland. Mobile sources generally dominate this piece of our problem, but other sources and more “close by” power plants also contribute. Local does not mean just Baltimore. For Baltimore, “local” also clearly includes the huge emission contribution from mobile sources around Washington DC and Pennsylvania power plants.

Source: Maryland Department of the Environment

New Jersey 2015



Source: Maryland Department of the Environment

Filling the Reservoir

- Transport from the West, transport from the South and local emissions all help fill the reservoir
  - Yes - it depends on where the wind is blowing from
- Three classic types of transport
  - Westerly Transport – Power plants are a contributor
  - Night-time, Southerly Transport – Vehicles, power plants … more
  - City to City – An urban soup … Washington to Baltimore … Baltimore to Philly … Philly to NYC … etc. etc. etc

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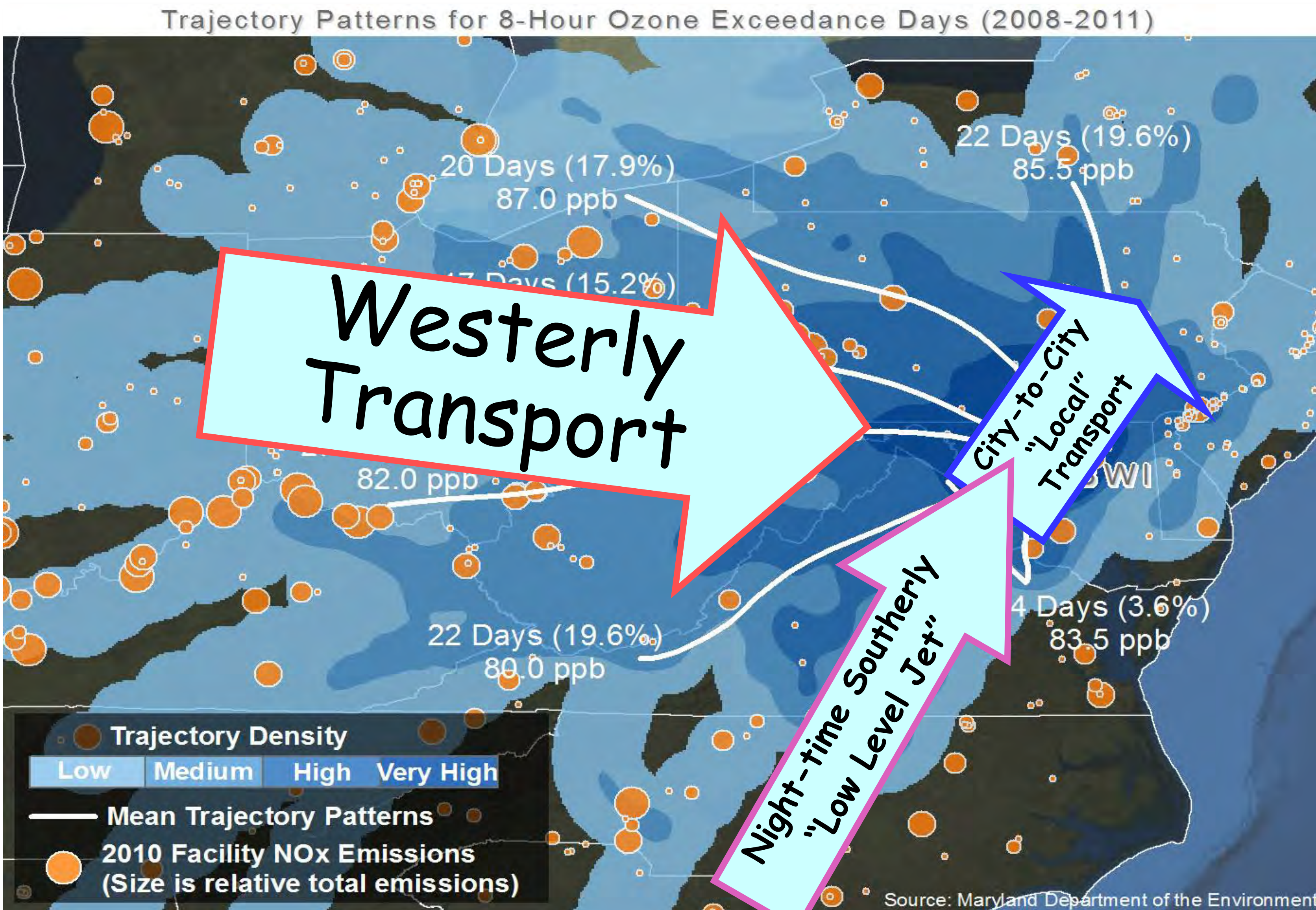
The Three Different Types of Transport



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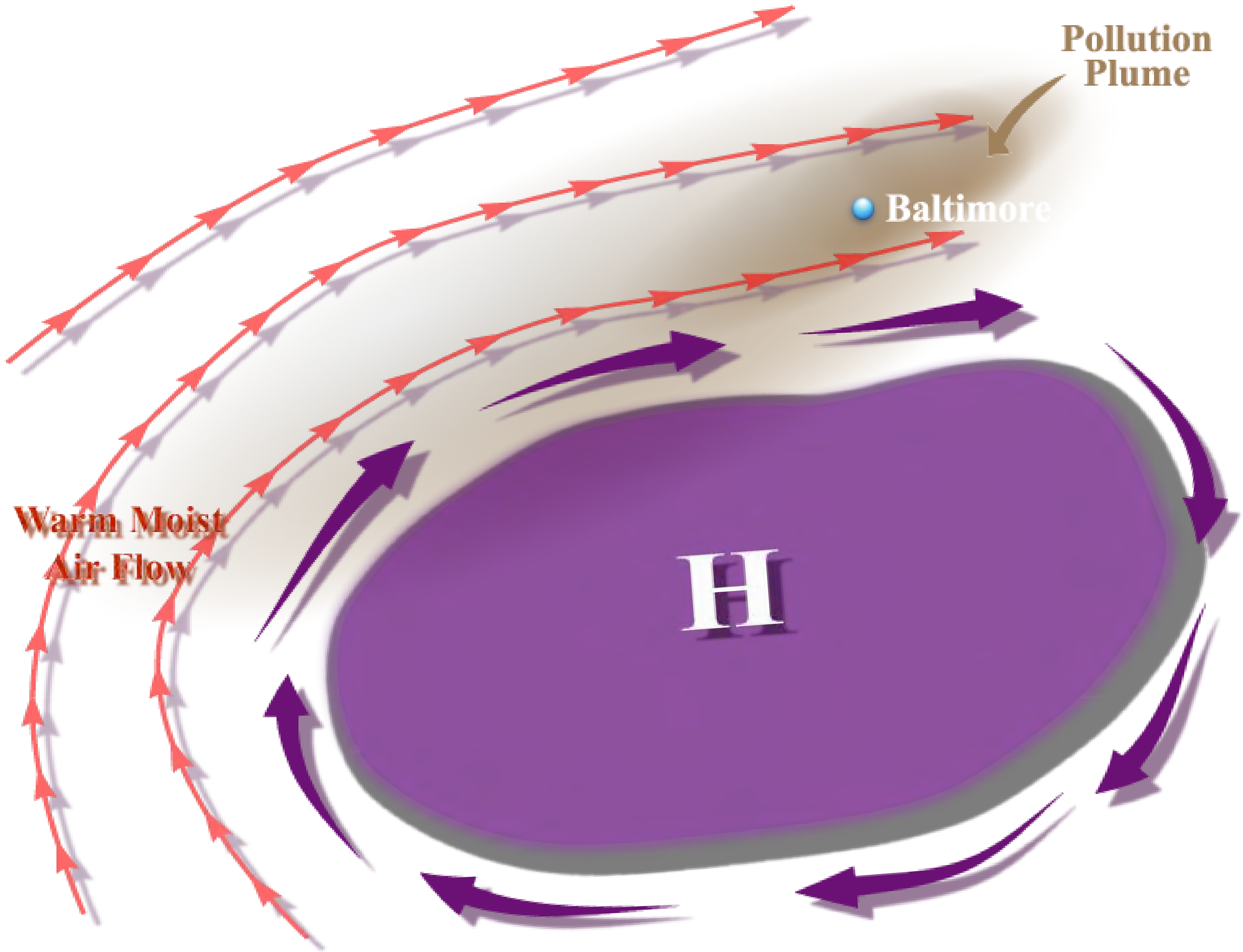
Westerly Transport



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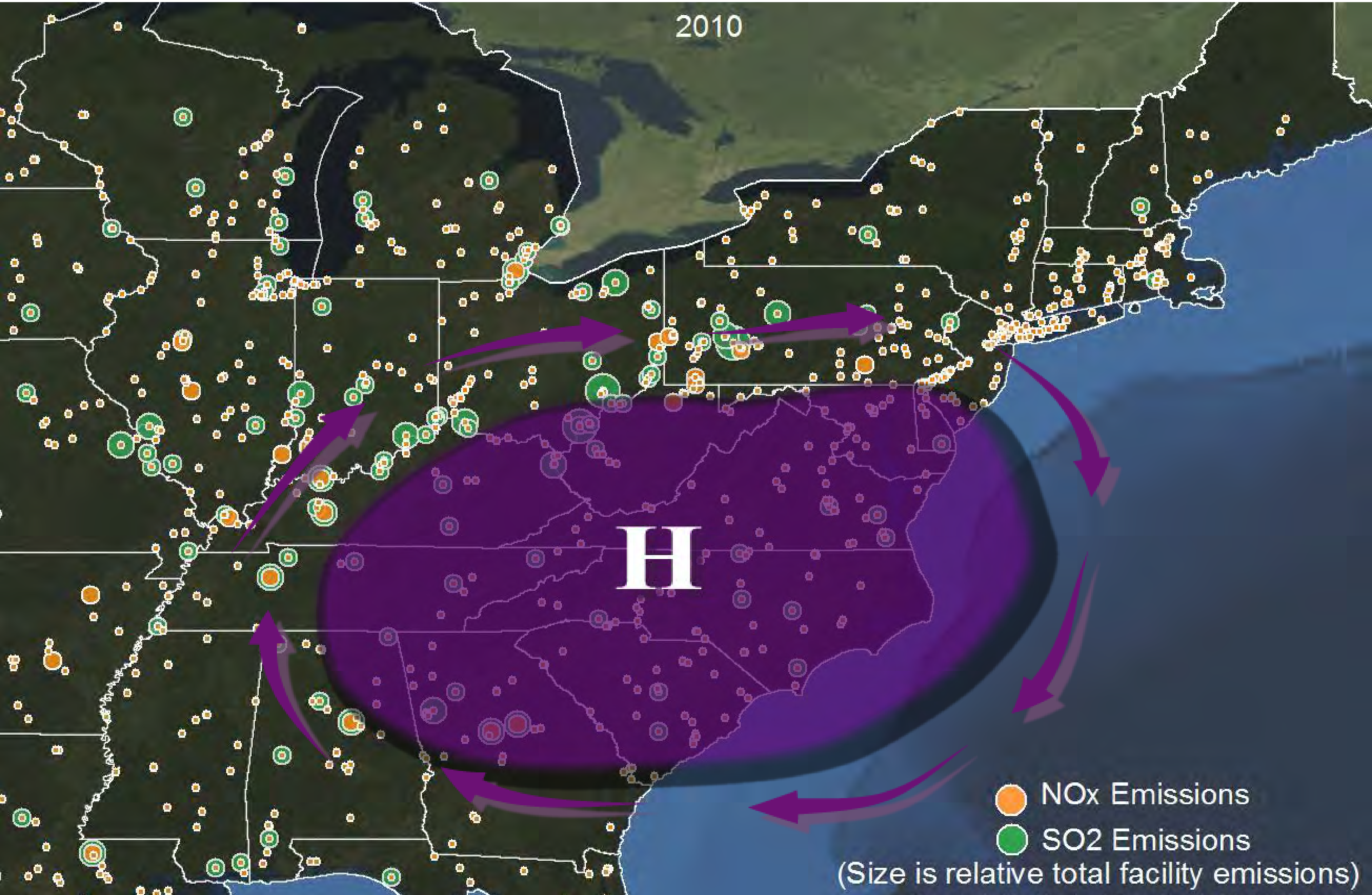
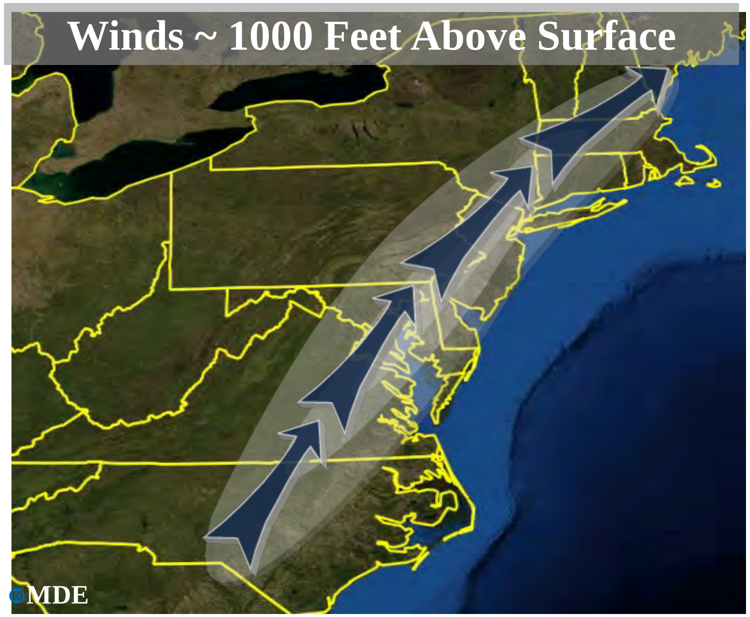
Power Plant Pollution Pushed West to East



Southerly Transport at Night

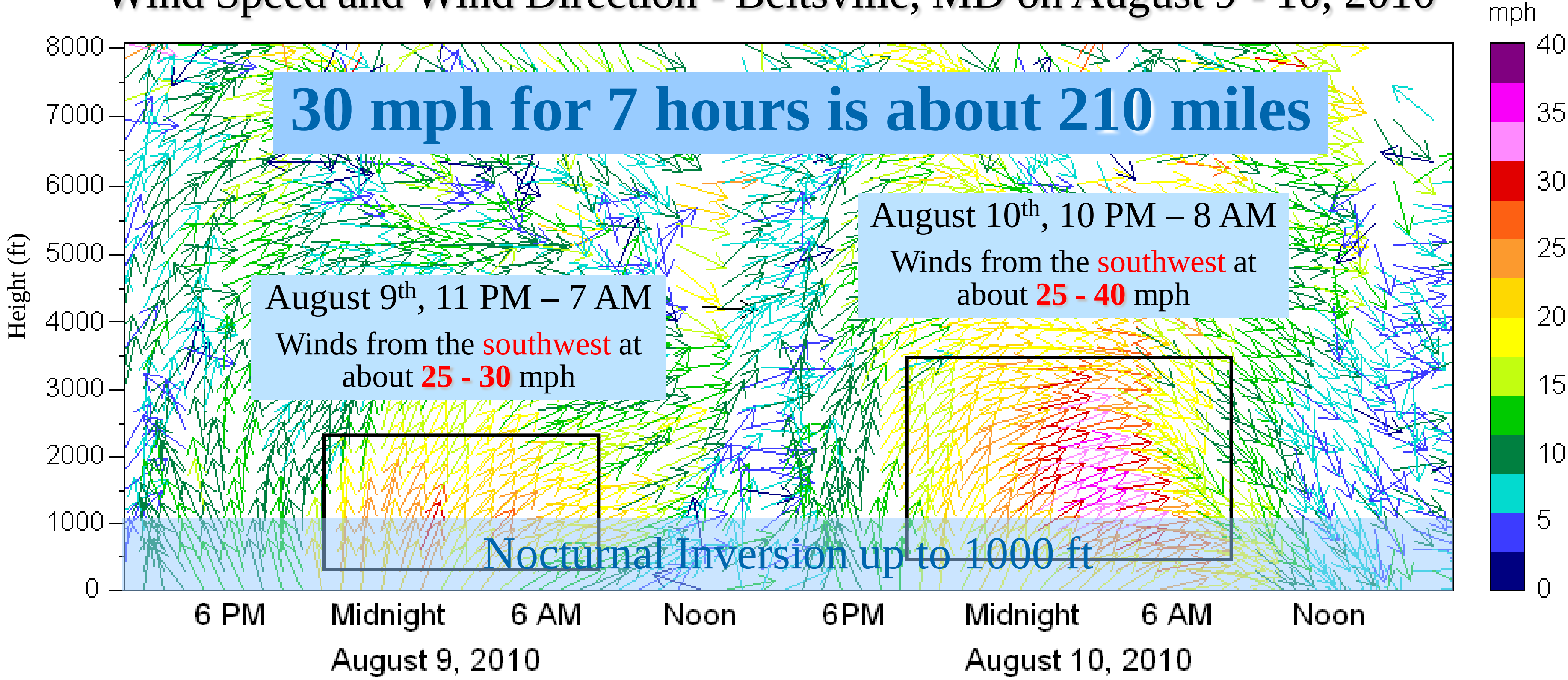
The Nocturnal Low Level Jet (NLLJ)



- 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.
- Previously seen during many, Mid-Atlantic summer-time air pollution events.
  - Some form of NLLJ on code orange or red days
- Earlier findings indicated that:
  - Presence of a NLLJ increased Baltimore maximum ozone by 7 ppb.
  - Ozone concentrations of 90 – 100 ppb have been measured in the NLLJ.
- More recently:
  - NLLJ into MD appears to be less significant
  - Natural gas in VA?

Measuring the Nocturnal Low Level Jet

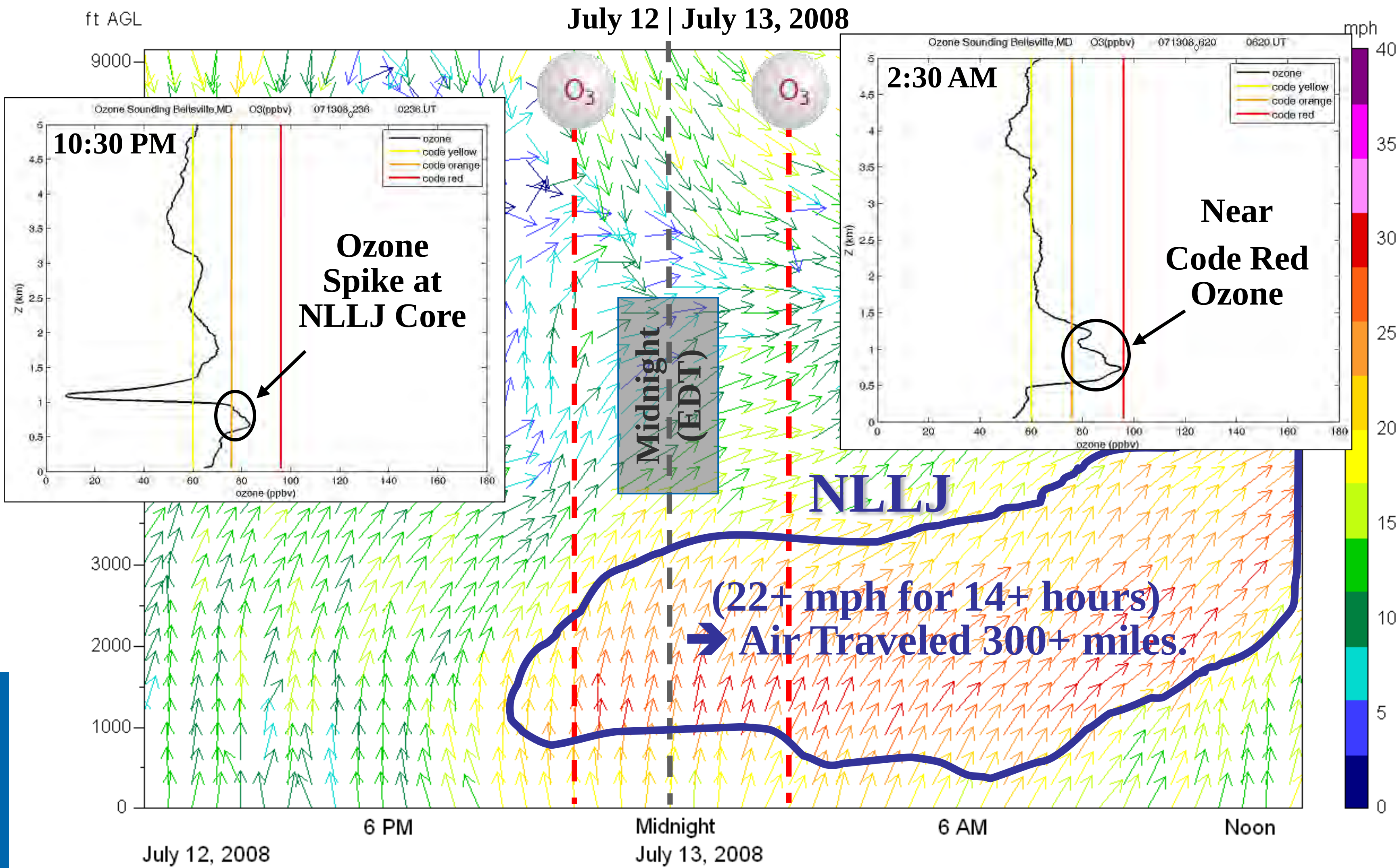
Wind Speed and Wind Direction - Beltsville, MD on August 9 - 10, 2010



What does this graph tell us?
- Wind direction
- Wind speed
- From the ground up

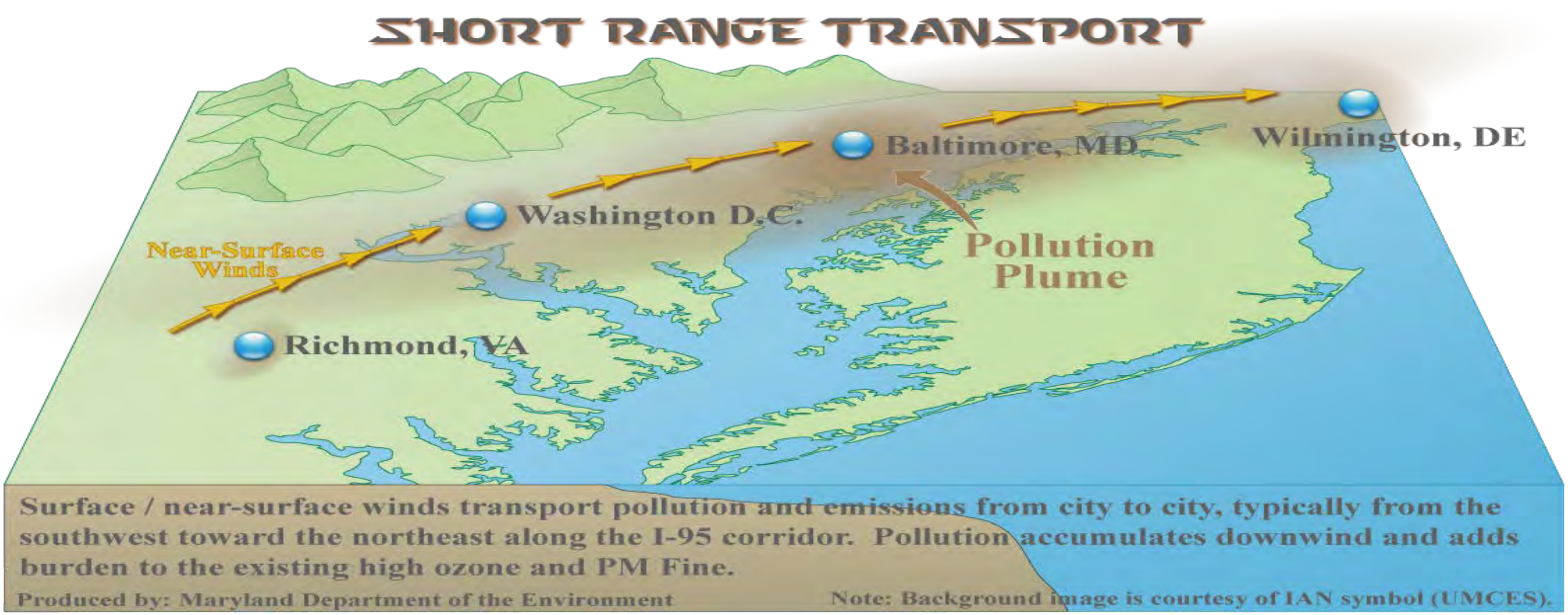
Measuring Ozone Transport in the NLLJ

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 NLLJ event, as captured by MDE's Wind Profiler.

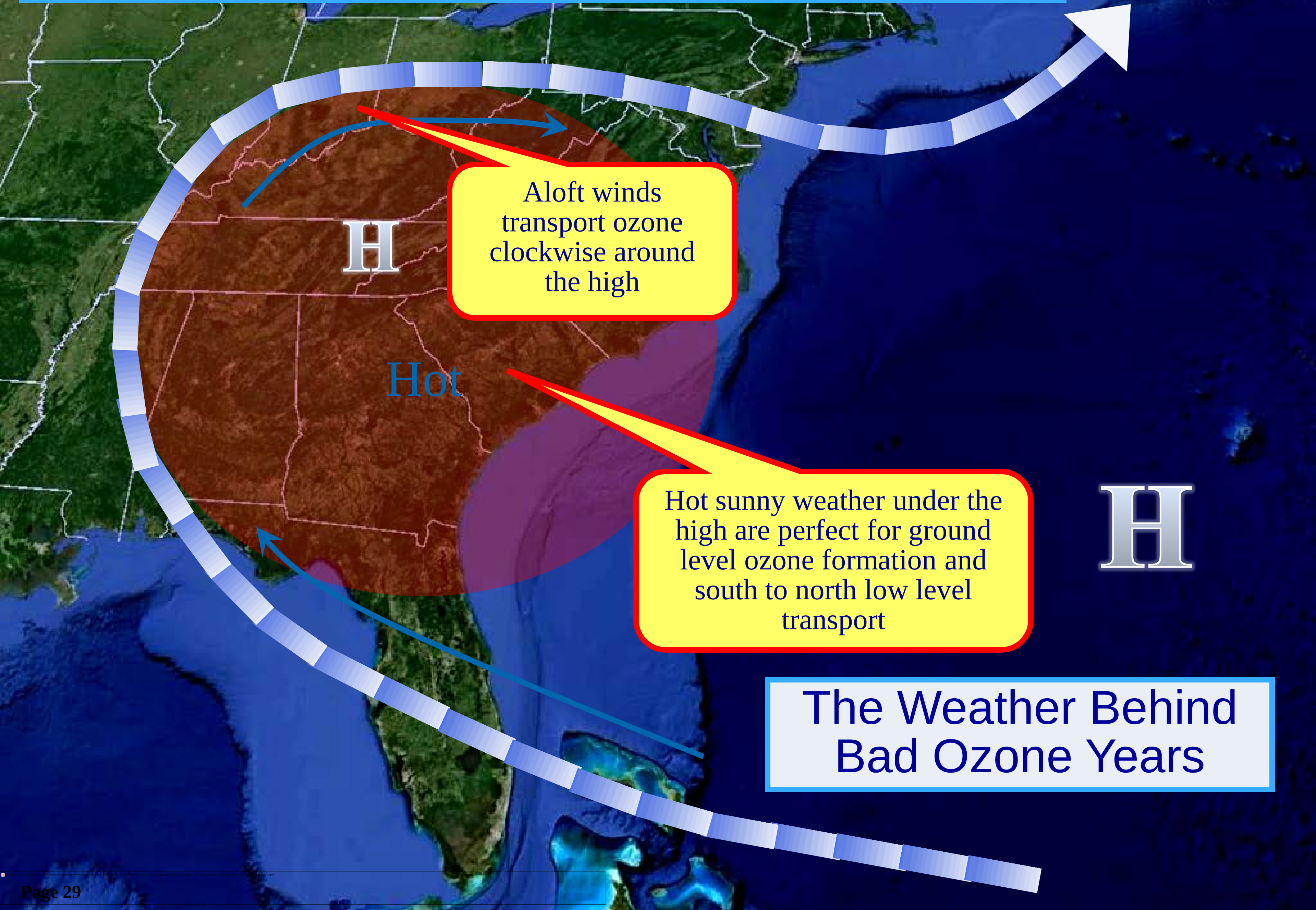


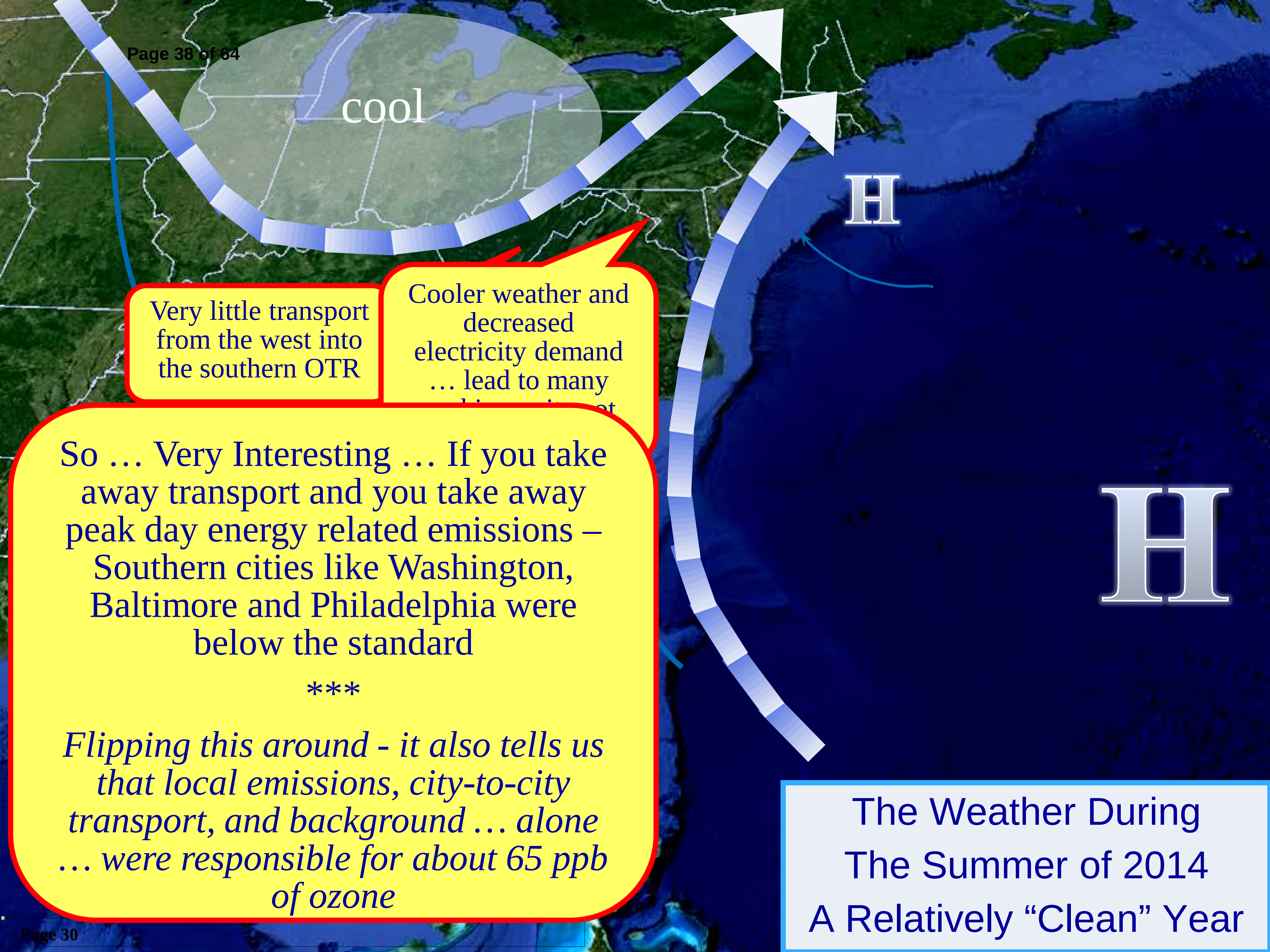
City-to-City "Local" Transport

- 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 VA ⇨ DC ⇨ Baltimore ⇨ Philadelphia ⇨ NJ ⇨ NY ⇨ CT ⇨ and so on and so on
- Emissions from cars, area sources, and stationary sources all contribute.



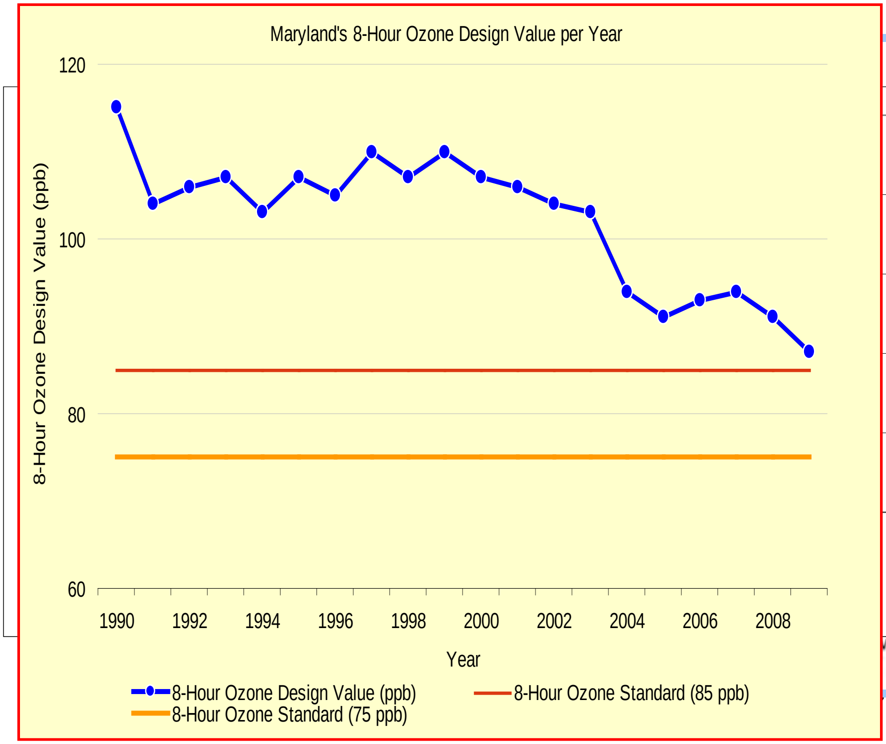
A City-to-City Transport Case Study




cool
H
H
Very little transport from the west into the southern OTR
Cooler weather and decreased electricity demand … lead to many
So … Very Interesting … If you take away transport and you take away peak day energy related emissions – Southern cities like Washington, Baltimore and Philadelphia were below the standard
***
Flipping this around - it also tells us that local emissions, city-to-city transport, and background … alone … were responsible for about 65 ppb of ozone
The Weather During The Summer of 2014 A Relatively “Clean” Year

Reducing Regional NOx Emissions – Will It Work?

Ground Level Ozone Drops Dramatically in the Same Time Frame



- The 2003/2004 "NOx SIP Call" (EGU controls) is a classic case study. Nitrogen oxide (NOx) reductions from Federal Tier 2 Vehicle Standards also occurring in this same time frame
  - A real world ozone transport success story
  - Incoming ozone levels collect in an elevated reservoir over night
  - Real world programs like the NOx SIP Call (power plants) and the Tier 2 Vehicle Standards show that:
    - Adding regional controls …
    - Results in regional NOx emission reductions …
    - Which leads to reduced ozone in the elevated reservoir …
    - Which lead to lower ozone at ground level and public health protection!

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What is Going On in the Southern OTR?

- In the Southern OTR (Washington, Baltimore, Philadelphia) ozone levels have dropped dramatically over the past few years
  - Much more significant ozone reduction than in the Northern OTR (NY/CT/NJ)
- Why is this happening? What can we learn from this?
  1. Some of it's weather (and by extension: transport patterns)
  2. Some of it's NOx reductions from upwind EGUs (Electricity Generating Units or power plants)
  3. Some of it is local reductions
  4. And some of it may be that the chemistry in the Southern OTR has passed a tipping point
     - The emissions simply may not be making as much ozone !!!

	Key Ozone Value (Design Value)		
	2011	2012	2015
Baltimore Area	92	93	71
New York	84	85	75
New Jersey	82	87	76
Connecticut	81	87	84

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2013 to 2015 - Some Strange Weather

- For many, many years, Baltimore recorded very, very high ozone
- "Classic" Bermuda High weather patterns played a major role in creating that high ozone
  - Aloft winds literally pushed transported ozone from Ohio River Valley power plants for hundreds of miles from west to east … right into Maryland
- That has not happened like it used to for the past three years
- Cooler temperatures and higher than average rain have also played a role, but where the high pressure systems have been setting up is critical

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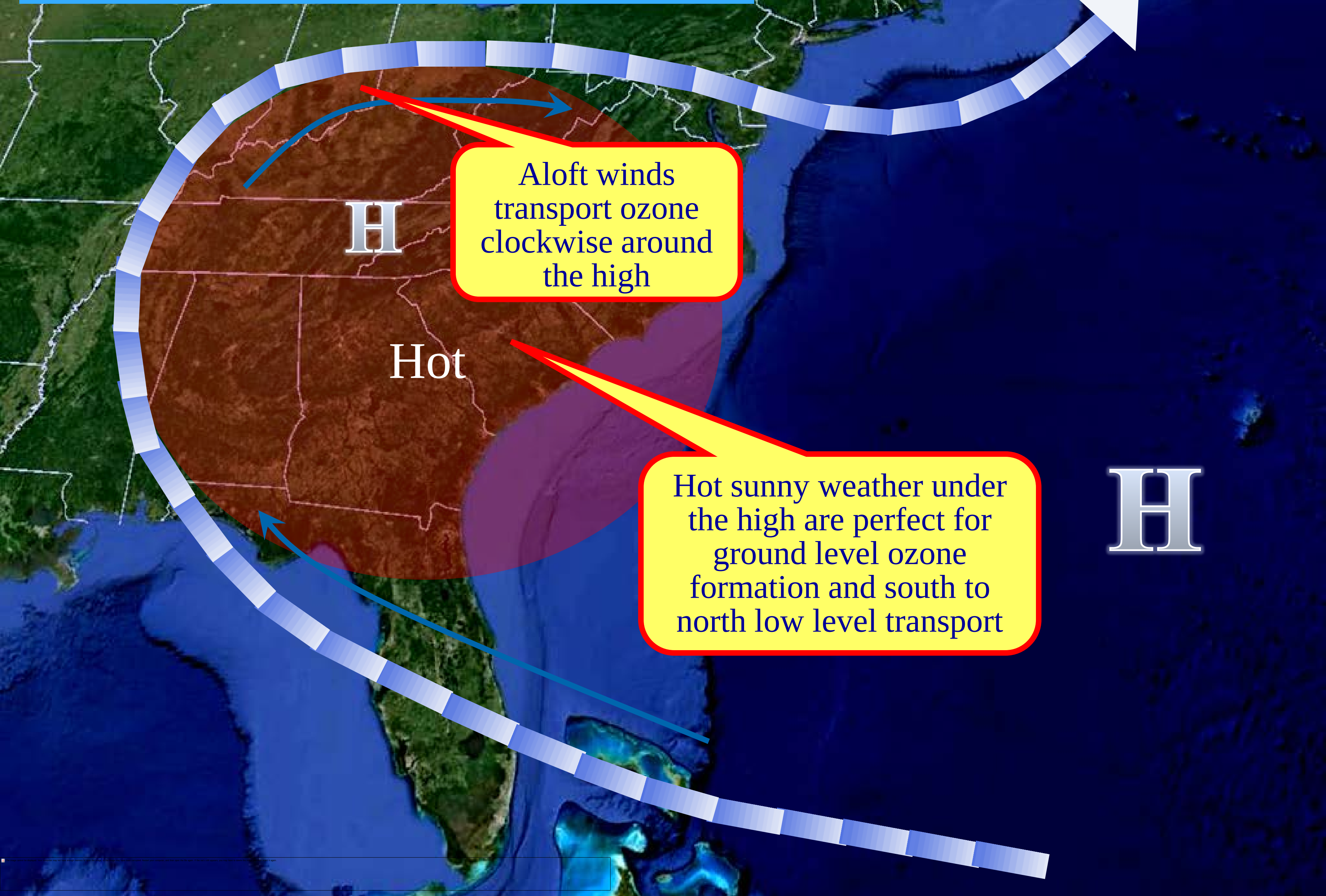
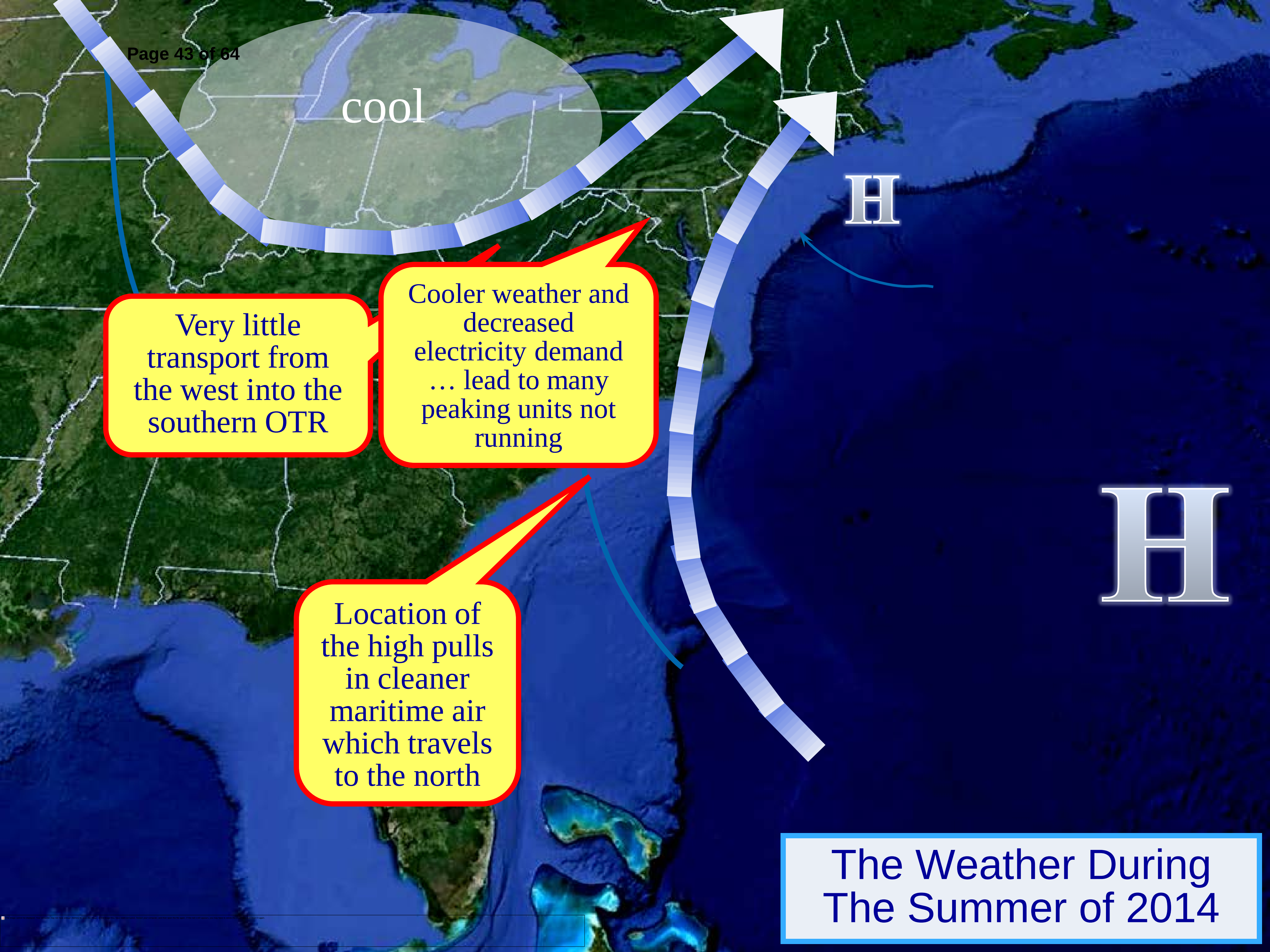
The Weather Behind Bad Ozone Years in Baltimore




cool
H
H
Very little transport from the west into the southern OTR
Cooler weather and decreased electricity demand … lead to many peaking units not running
Location of the high pulls in cleaner maritime air which travels to the north
The Weather During The Summer of 2014

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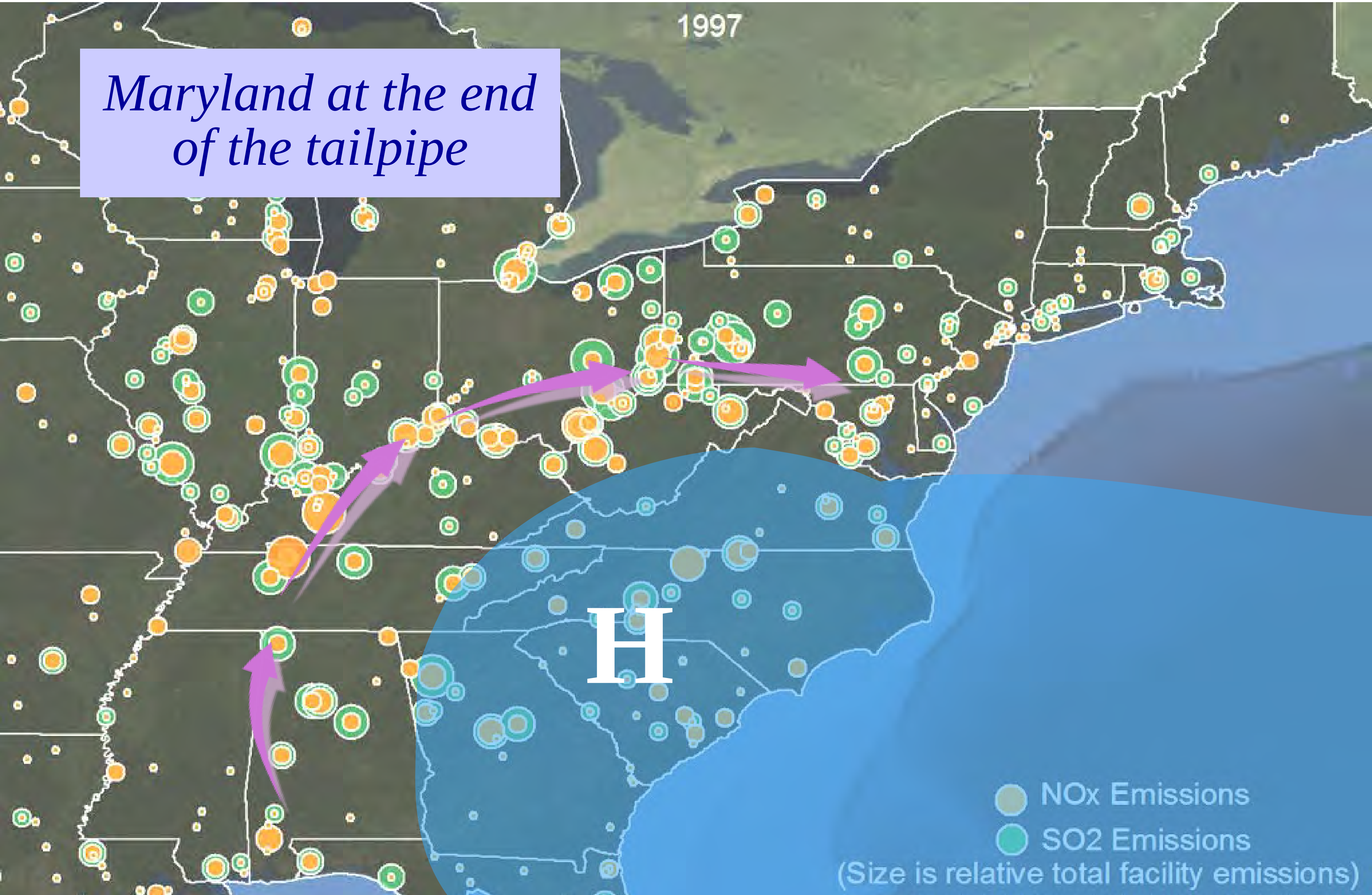
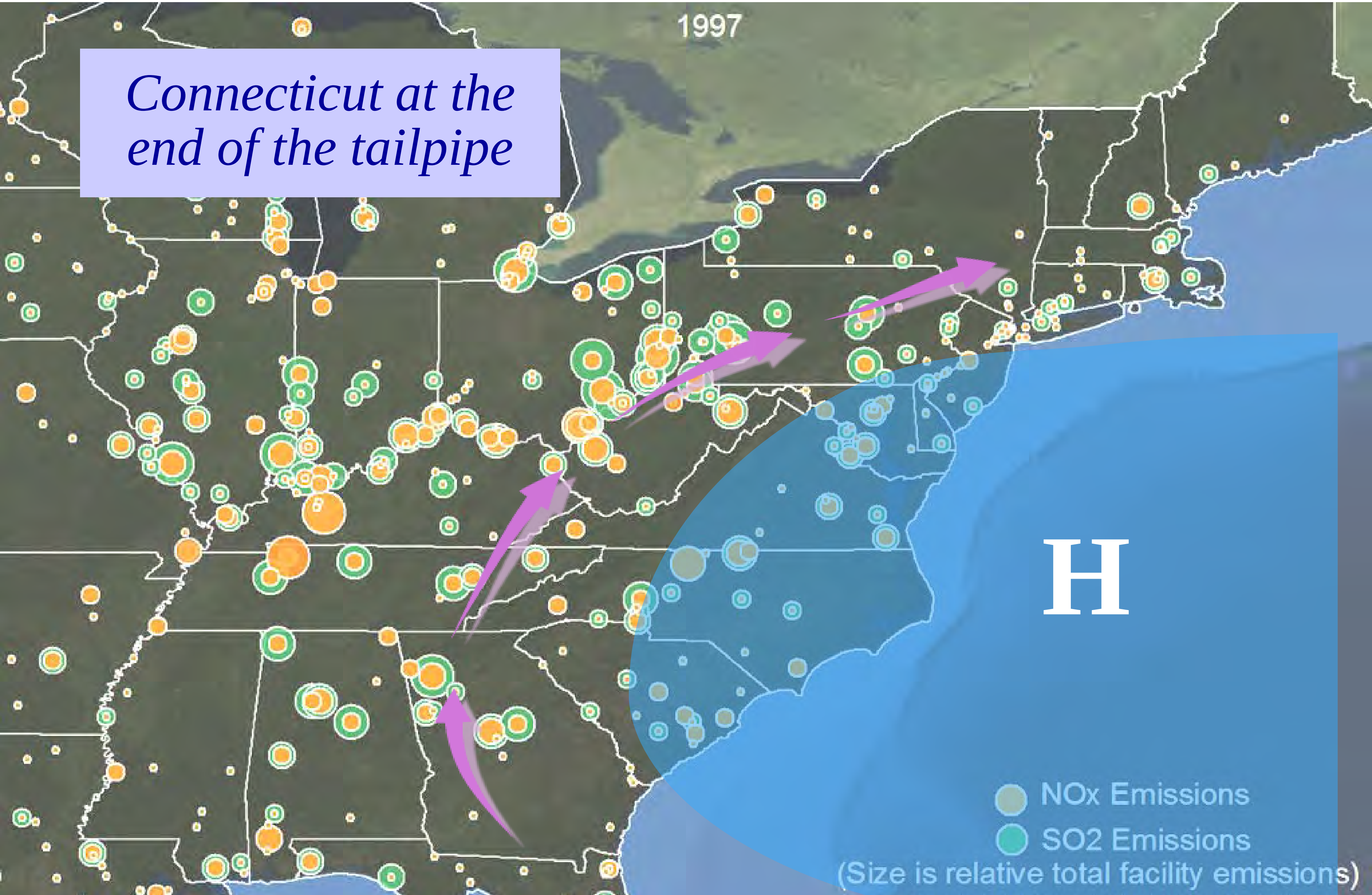
Typical High Pressure Over the Carolinas

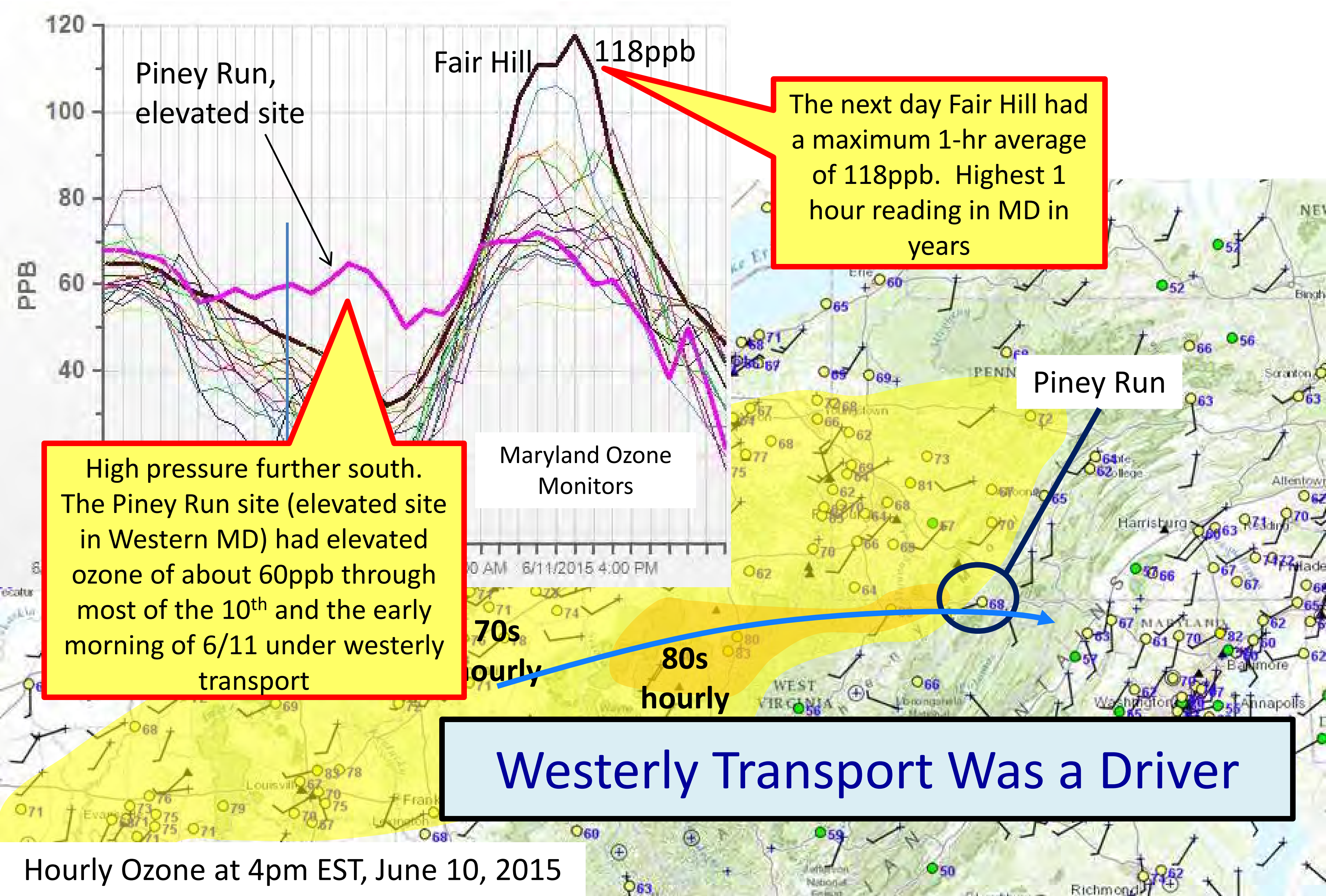
Maryland at the end of the tailpipe



Last Few Years - High Pressure Further North and East



2015 - When it Did Get High in MD …



The next day Fair Hill had a maximum 1-hr average of 118ppb. Highest 1 hour reading in MD in years

High pressure further south. The Piney Run site (elevated site in Western MD) had elevated ozone of about 60ppb through most of the 10th and the early morning of 6/11 under westerly transport

Westerly Transport Was a Driver

Hourly Ozone at 4pm EST, June 10, 2015

Ozone Season EGU NOx is Down

… at least in areas directly upwind of MD

- For the area directly upwind of Maryland, the EGU sector has seen dramatic change
  - Many shutdowns, many conversions to gas, most sources operating at much lower capacity
- Seasonal NOx emissions are down, while … on some of the worst days … peak day emissions are up
- Ozone season NOx emissions are what creates the elevated ozone reservoir seen pretty much all summer
- Peak day emissions contribute significant to the daily ozone piece of the problem

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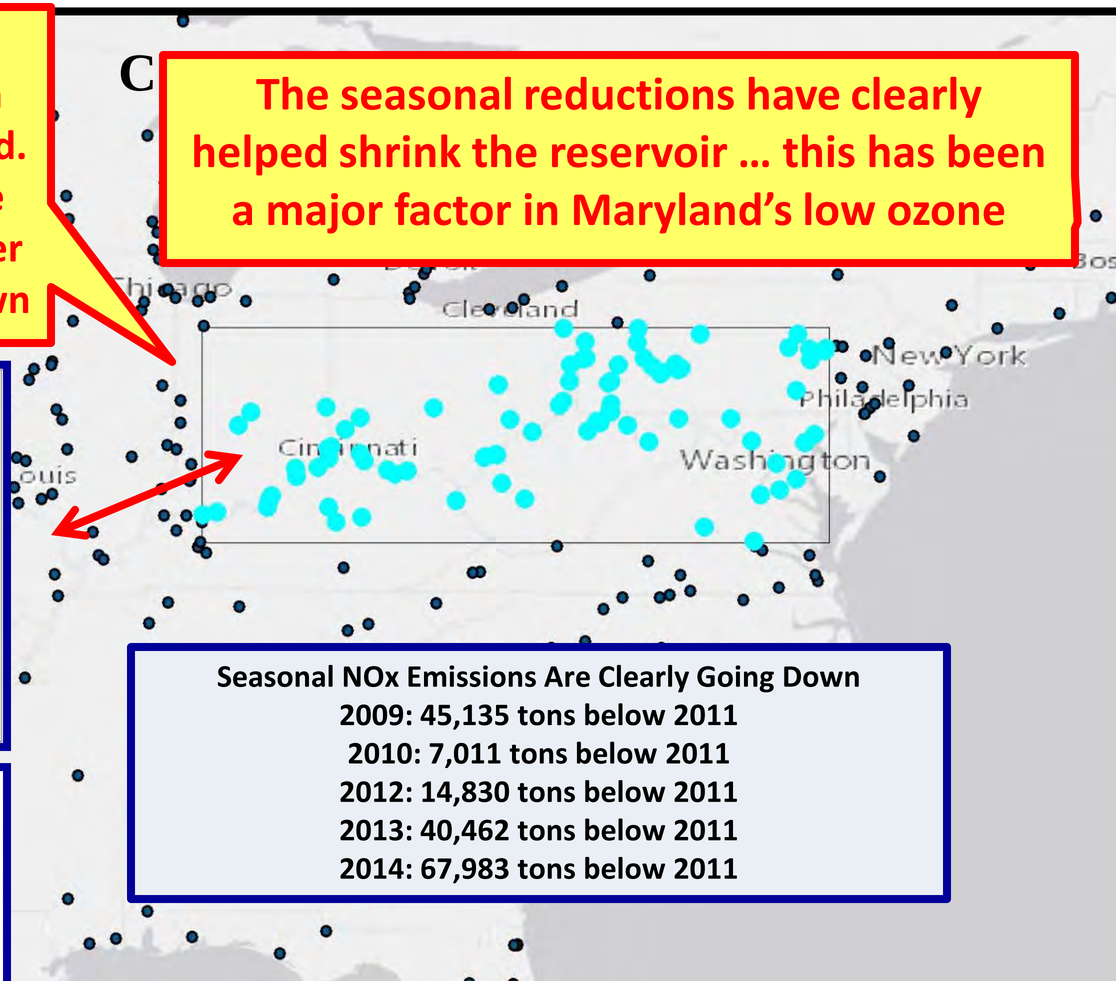
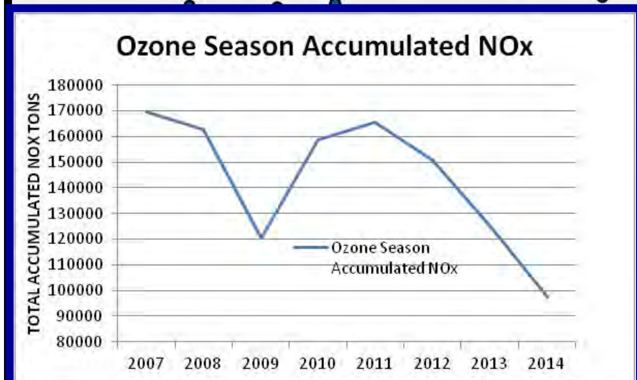
Lower "Ozone Season" EGU Emissions

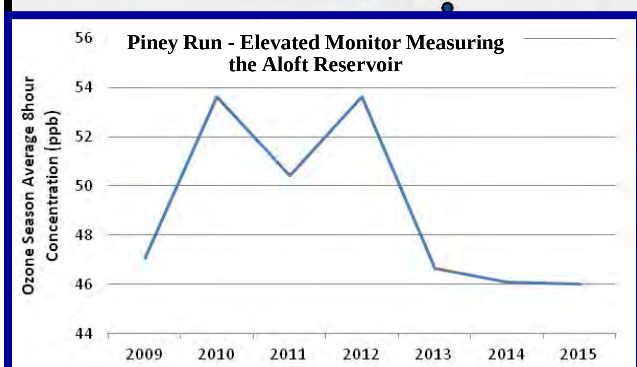
In the key upwind area for Maryland

There have been many shutdowns and operational changes at EGUs in the key area just upwind of Maryland. Peak day emissions may actually be much higher, but total emissions over the entire ozone season are way down

The seasonal reductions have clearly helped shrink the reservoir … this has been a major factor in Maryland's low ozone







Seasonal NOx Emissions Are Clearly Going Down
2009: 45,135 tons below 2011
2010: 7,011 tons below 2011
2012: 14,830 tons below 2011
2013: 40,462 tons below 2011
2014: 67,983 tons below 2011

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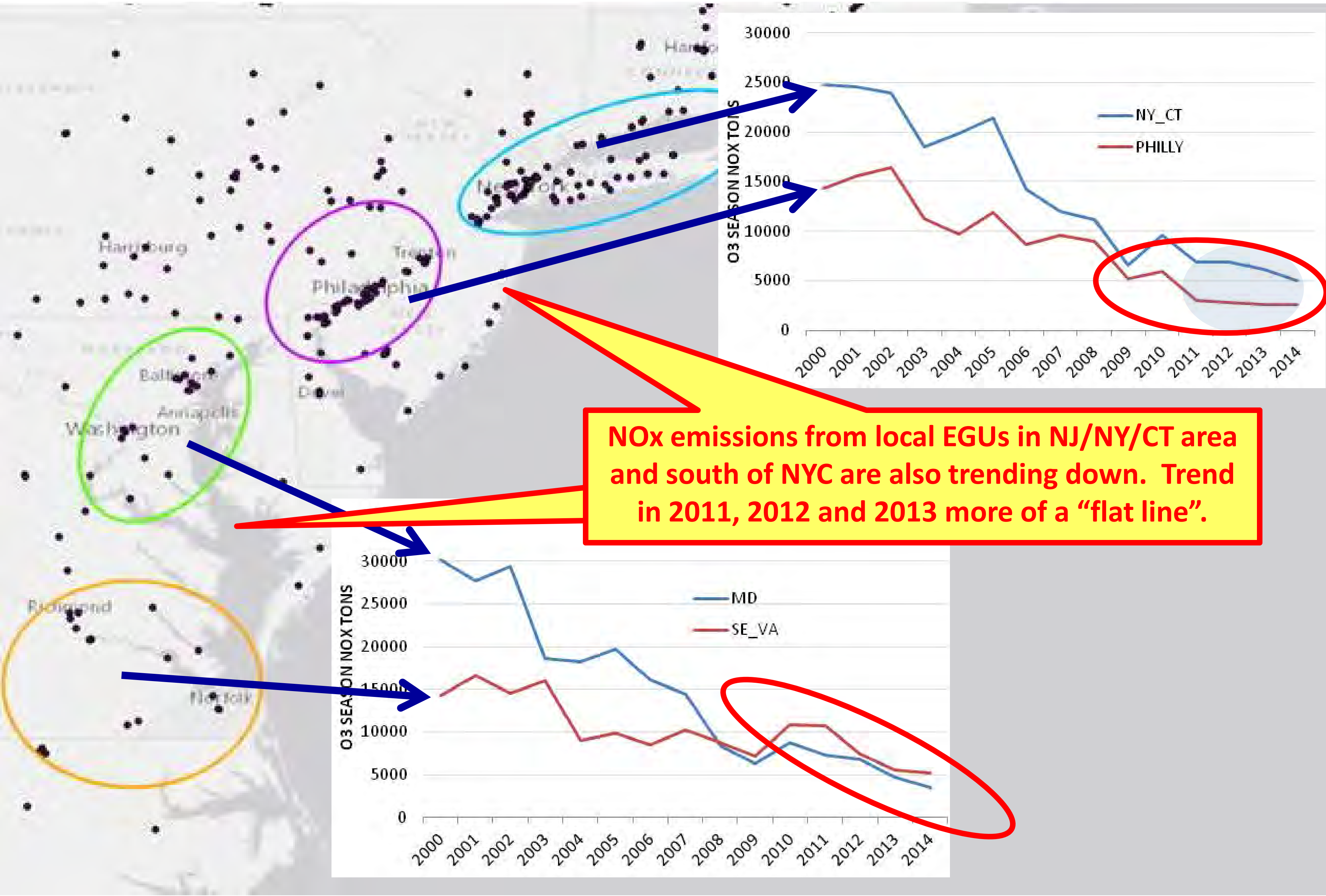
Local Seasonal EGU NOx is Also Down

… upwind of Baltimore … not so much for NJ/NY/CT

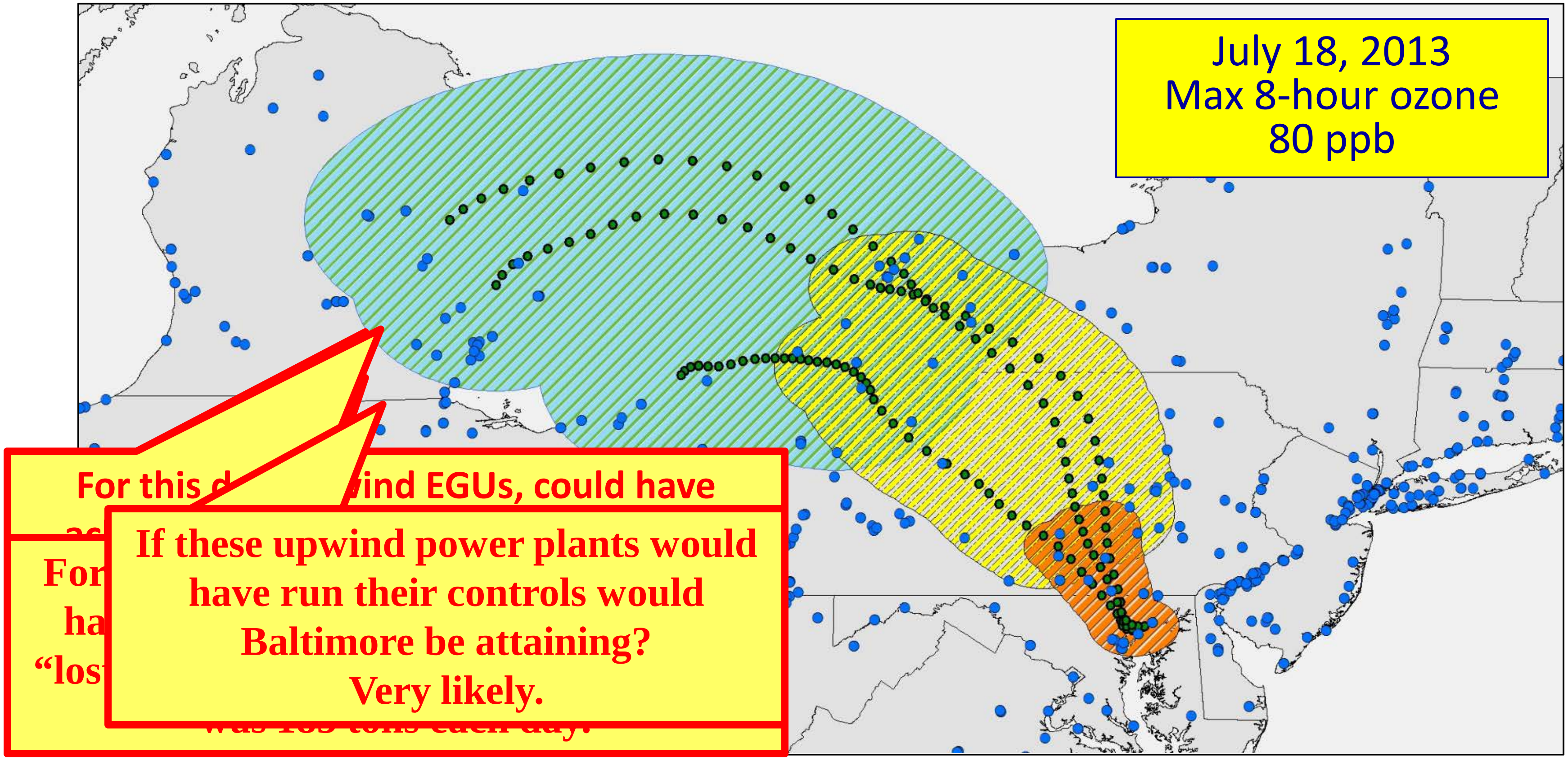
- Ozone season NOx emissions from EGUs are also trending down in the Baltimore and south of Baltimore area
- Not so for local NOx in NY/NJ/CT or south of the New York City area
- Ozone season long NOx reductions help to reduce the regional reservoir of aloft ozone that mixes down each morning
- New analysis in the works looking at how “closer by” EGUs in the eastern half of PA that are not running controls optimally on peak days may be increasing the local … “day of” … contribution to Baltimore ozone
- Regional contribution going down … is the local contribution going up?

Local NOx Emissions Also Trending Down



NOx emissions from local EGUs in NJ/NY/CT area and south of NYC are also trending down. Trend in 2011, 2012 and 2013 more of a "flat line".

Hot Off the Presses - New Work Looking at Most Critical Days for the New Standard



<u>Domain (3-Day Total):</u>
- Total NOx Mass: 12,909 Tons
  - 47% controlled
  - 53% uncontrolled
- Potential savings: 2,488 Tons
- <u>3-Day Average:</u>
- Daily NOx Mass: 4,303 Tons
- Daily Savings: 829 Tons/day

<u>Region 1 (Day Of):</u>
- Total NOx Mass: 91 Tons
  - 44% controlled
  - 56% uncontrolled
- Potential savings: 14 Tons
- Bin 1 unit count: 2
- Bin 2 unit count: 3
- Bin 3 unit count: 1

<u>Region 2 (Day Before):</u>
- Total NOx Mass: 164 Tons
  - 66% controlled
  - 34% uncontrolled
- Potential savings: 68Tons
- Bin 1 unit count: 1
- Bin 2 unit count: 5
- Bin 3 unit count: 3

<u>Region 3 (2 Days Before):</u>
- Total NOx Mass: 260 Tons
  - 36% controlled
  - 64% uncontrolled
- Potential savings: 51 Tons
- Bin 1 unit count: 3
- Bin 2 unit count: 7
- Bin 3 unit count: 3

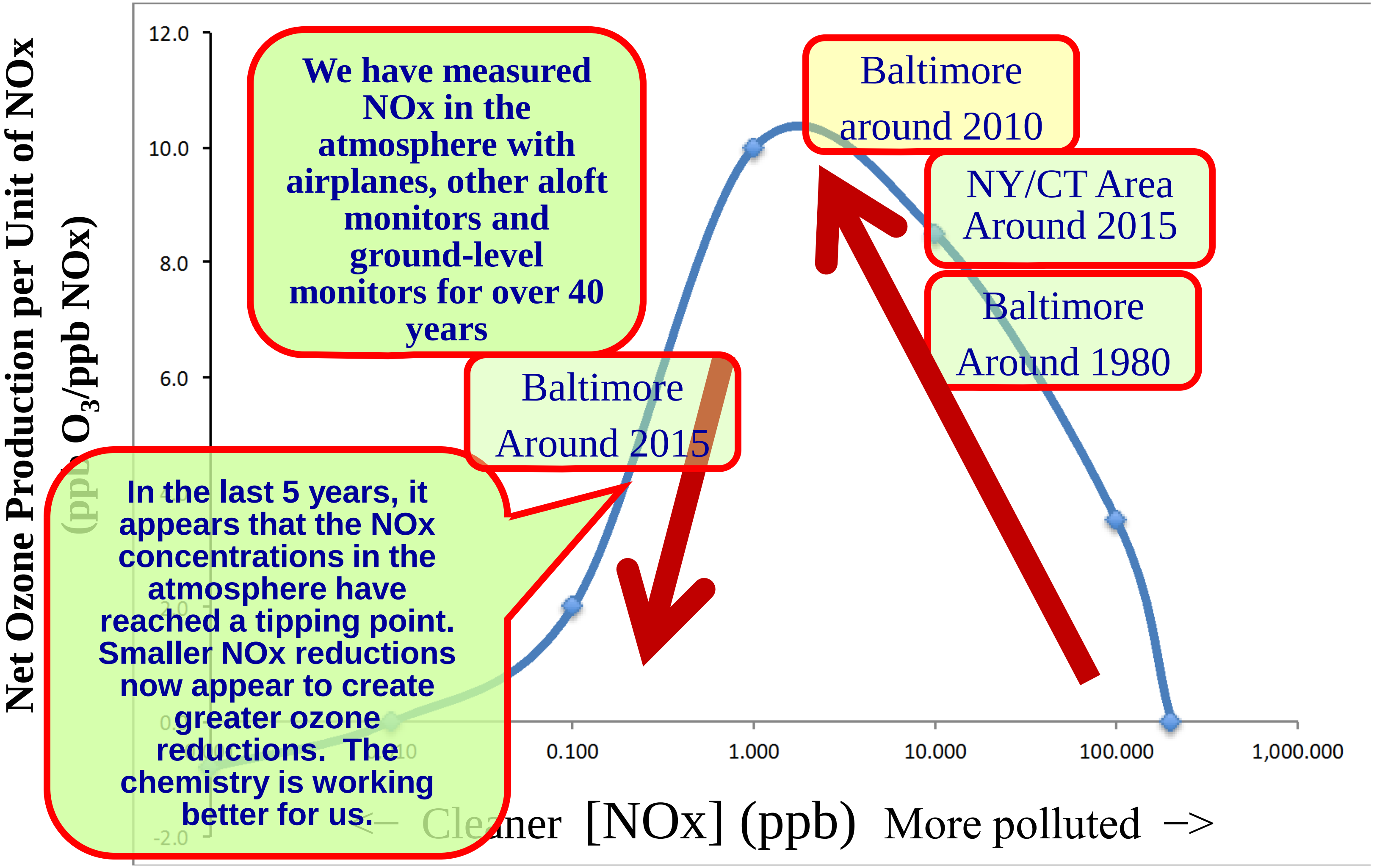
Ozone Chemistry Also Appears to Be Changing

… at least in the Mid-Atlantic

- One of the most interesting research areas we are working on involves a hypothesis that as we've taken NOx out of the system over the past 15 years the "ozone creating" chemistry appears to have changed in the Mid-Atlantic region
- Unfortunately, that change does not appear to be true in the CT area.
- Too much mobile source NOx around NYC?

Have We Reached a Tipping Point with NOx?

Schematic diagram of ozone production efficiency for the eastern US. - Getting over the hump



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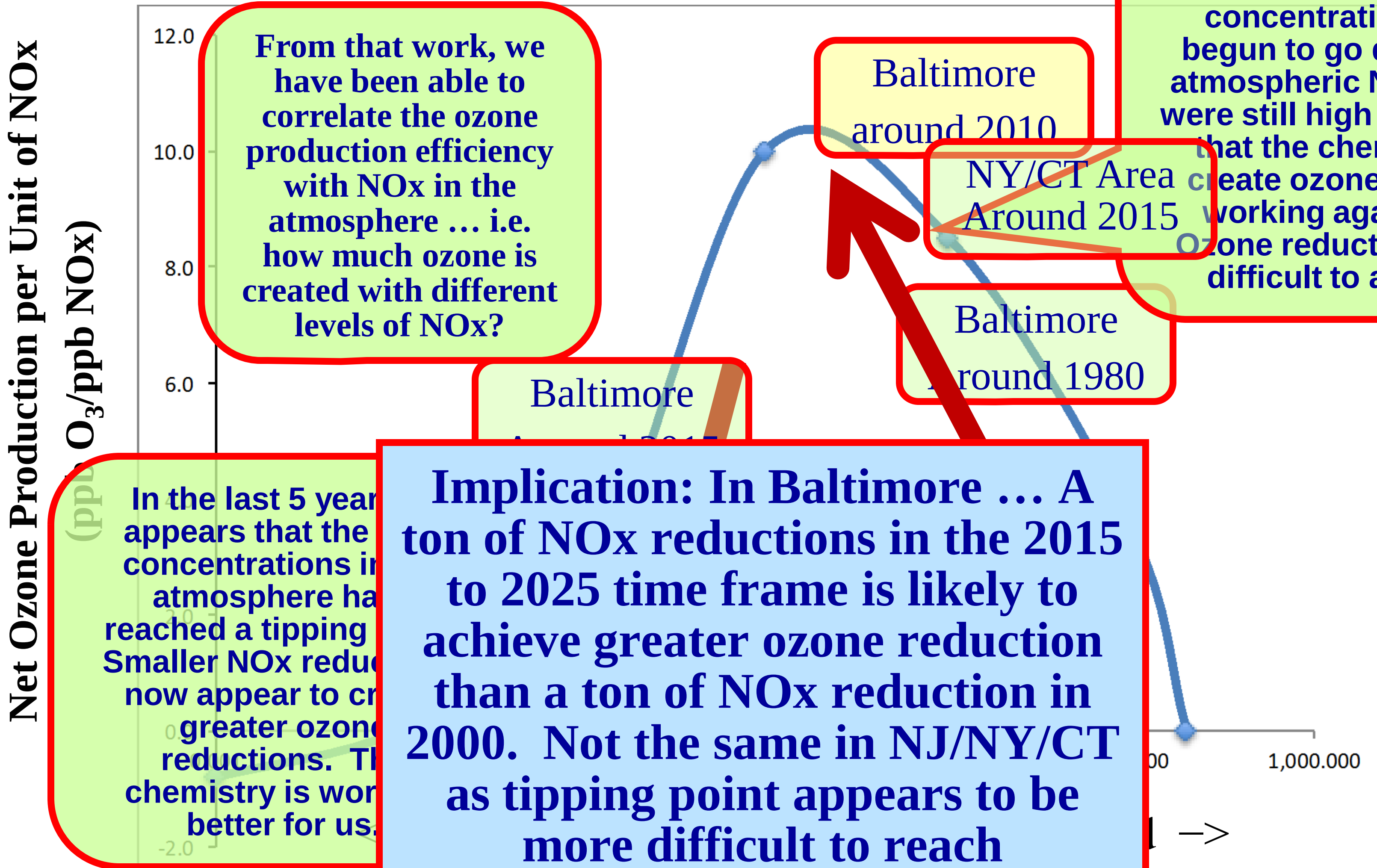
Have We Reached a Tipping Point with NOx?

Schematic diagram of ozone production efficiency for the eastern US. - Getting over the hump



From that work, we have been able to correlate the ozone production efficiency with NOx in the atmosphere … i.e. how much ozone is created with different levels of NOx?

Even though NOx emissions and NOx concentrations had begun to go down, the atmospheric NOx levels were still high enough so that the chemistry to create ozone was still working against us. Ozone reductions were difficult to achieve.

In the last 5 year appears that the concentrations in atmosphere ha reached a tipping Smaller NOx redu now appear to cr greater ozone reductions. Th chemistry is wor better for us.

Implication: In Baltimore … A ton of NOx reductions in the 2015 to 2025 time frame is likely to achieve greater ozone reduction than a ton of NOx reduction in 2000. Not the same in NJ/NY/CT as tipping point appears to be more difficult to reach

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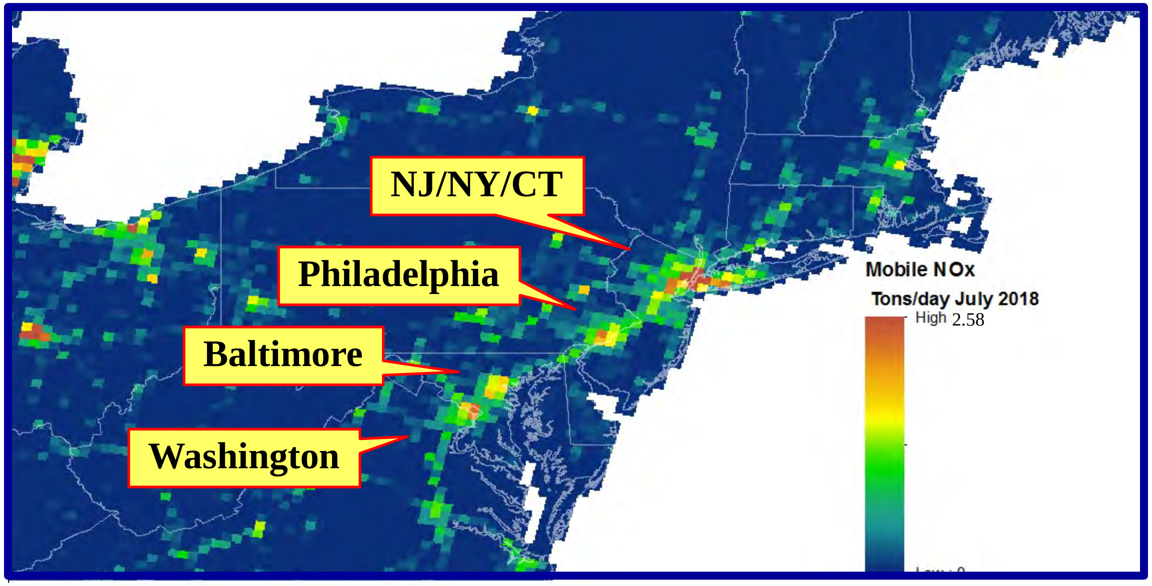
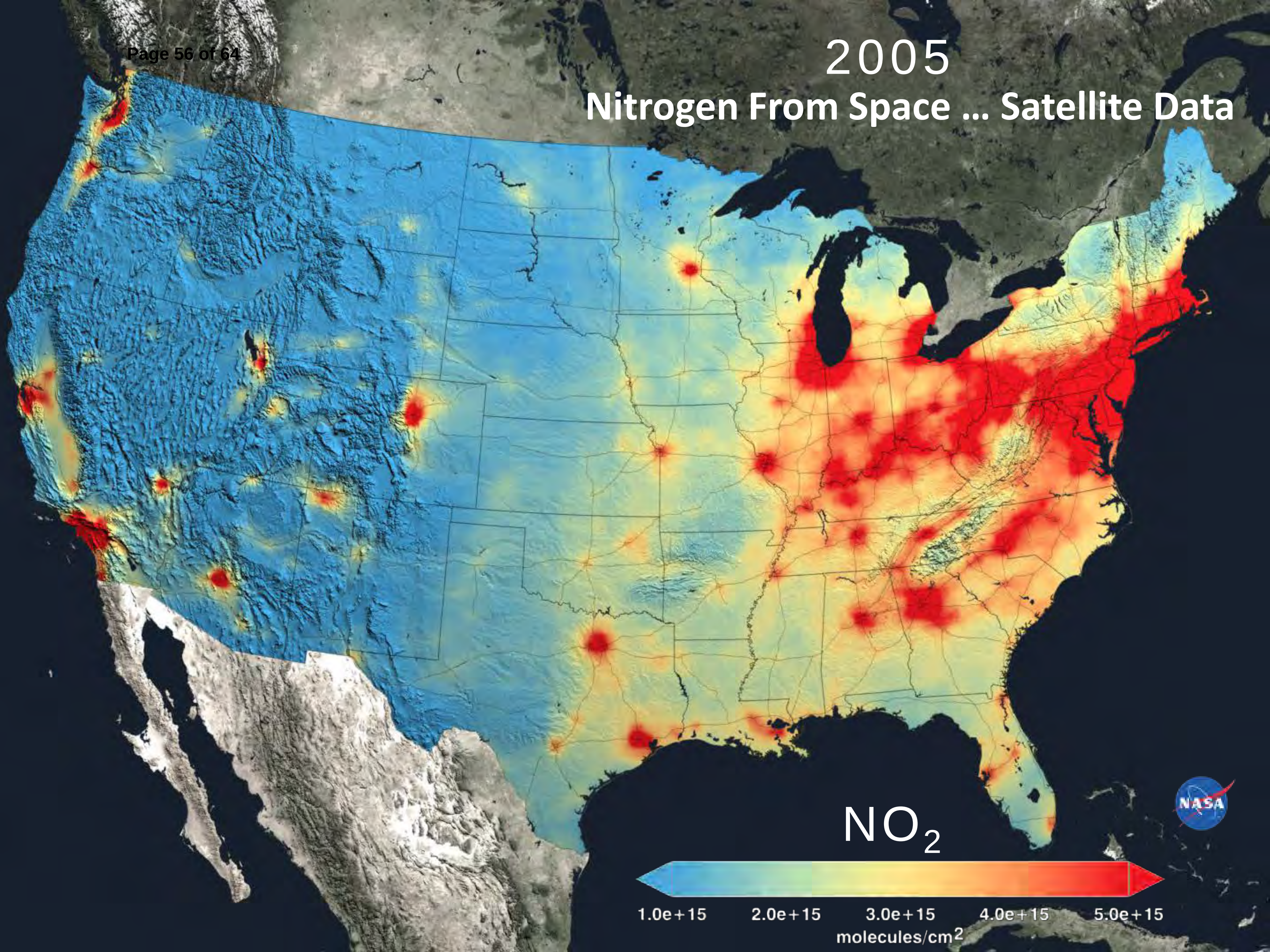
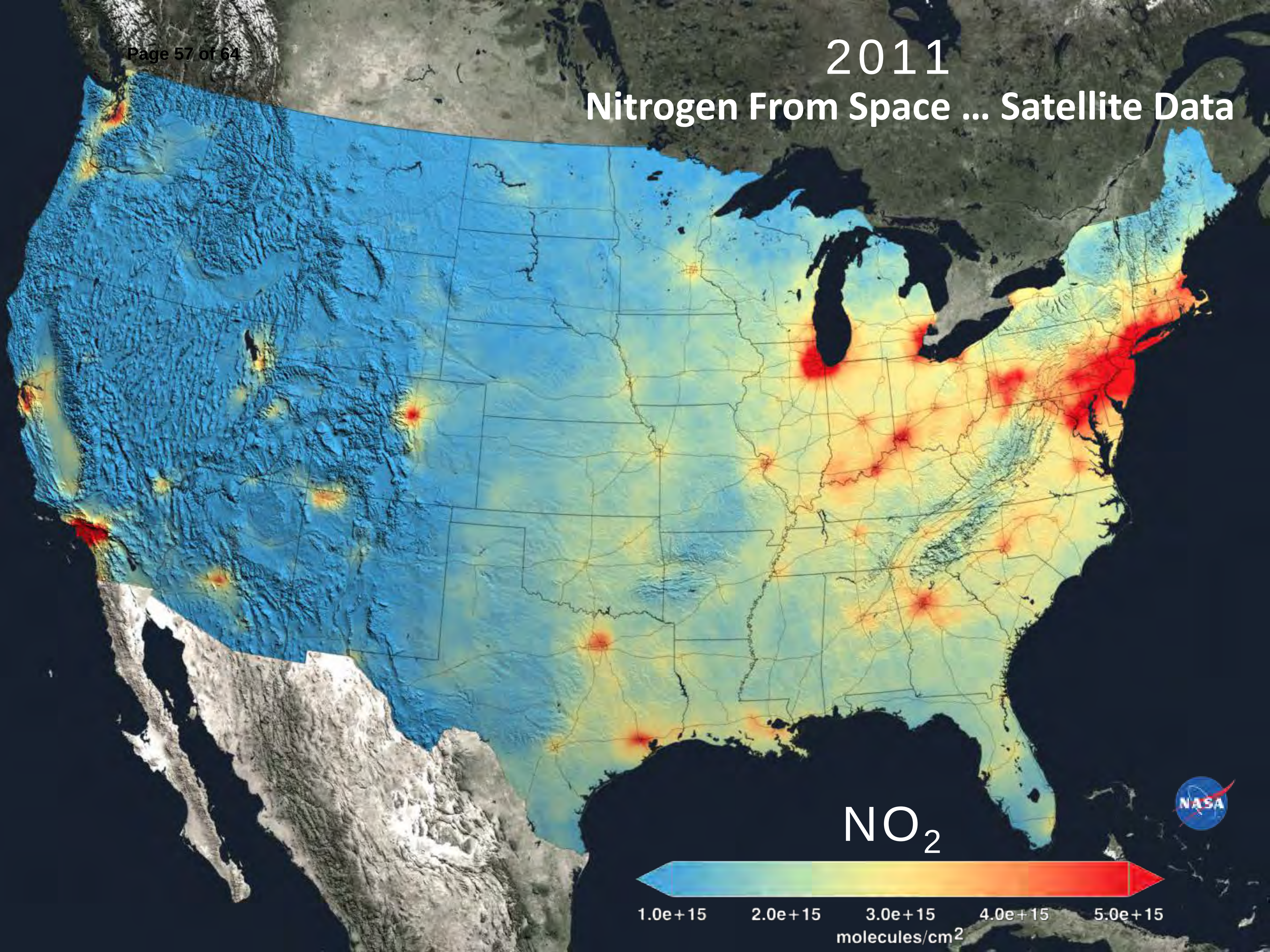
Emissions Density and Ozone Chemistry

- The density of NOx emissions in the New York City area may be part of the reason that the “friendlier” ozone chemistry we appear to be seeing in Baltimore is not being seen in NJ/NY/CT area
- This is a tough issue as density is driven by mobile sources and EPA holds most of the legal authorities to meaningfully drive NOx down from mobile sources … Need help




2005
Nitrogen From Space … Satellite Data
NASA
NO_2
1.0e+15
2.0e+15
3.0e+15
4.0e+15
5.0e+15
molecules/cm^2


2011
Nitrogen From Space … Satellite Data
NO2
1.0e+15
2.0e+15
3.0e+15
4.0e+15
5.0e+15
molecules/cm2
NASA

So Where Does This Take Us?

- We know what to do … the Path Forward
  - Widespread regional NOx reductions to reduce the elevated ozone reservoir and ozone transport
  - More focused reductions of NOx and VOC along the I-95 corridor to reduce our local contribution to ozone and city-to-city transport
- MDE believes the following need to be high priorities
  - Efforts needed to continue reducing the elevated ozone reservoir
    - Federal Tier 3 reductions in 2017 are key
    - Huge NOx reductions from SCOOT EGU strategy
    - Force EPA to finally get the "Good Neighbor" SIP piece of the Clean Air Act right
    - Continue to push EPA for more mobile source NOx reductions
  - Efforts needed to address local contribution
    - OTC NOx Initiatives
      - Aftermarket catalysts
      - On- and Off-Road Idling
      - Small generators and EGUs on "Peak" ozone days

Top 4 Regional Transport Strategies

- Widespread, regional, season-long NOx reductions will reduce ozone in the elevated reservoir and help lower ozone across the East
  1. Federal Tier 3 vehicle and 2017 fuel standards are key
     - Almost 500 tons of NOx reductions … each day … across the East in 2017 … already in the bank
  2. SCOOT - “Just Run the Dern Controls Strategy”
     - Another 400 to 500 ton/day NOx reduction across the East
     - Still lots of work to do, but we can achieve this goal
  3. More mobile source NOx reductions from EPA
     - Need to push and push and continue to push
     - Critical for areas like NJ/NY/CT because of huge volume of vehicles
  4. Push EPA to finally get the “Good Neighbor” piece of the Clean Air Act right
     - The Supreme Court has spoken … no excuse for EPA to bungle
     - Will be important for many, many years to come

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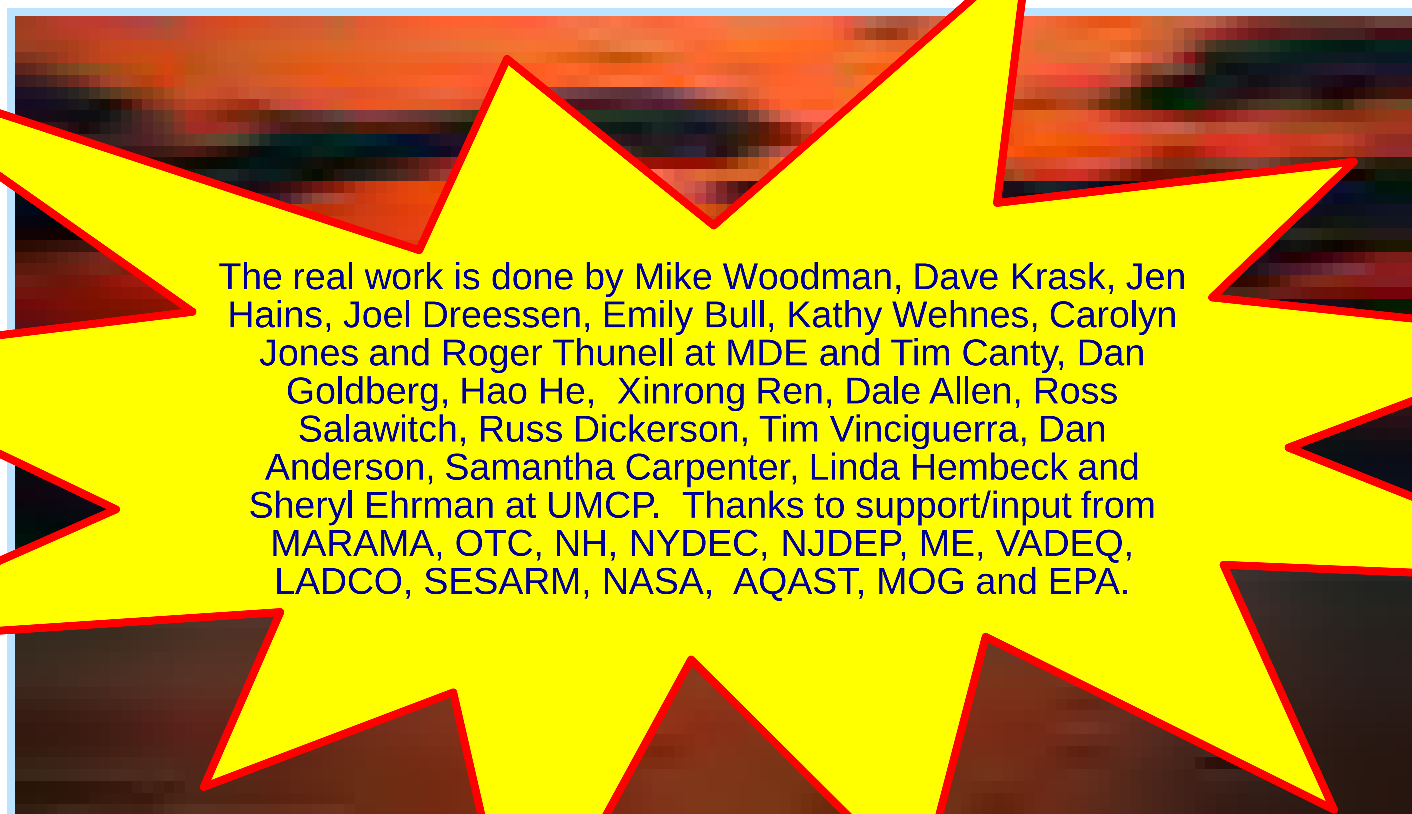
Top 3 "Local" or "City-to-City" Transport Strategies

- The states in the OTC have identified a suite of new "local" control programs for consideration - 9 ready for prime time
  - Will address daily "local" contribution and transport from "close-by" neighbors
  - Of those 9, MDE believes the following 4 are the highest, most logical priorities:
    1. Enhancing existing efforts on idling
       - Approximately 100 tpd of NOx reduction possible from more thoughtful implementation of this common sense measure
       - NJ already near the top
    2. Push forward with "Aftermarket Catalyst" rules
       - Approximately 50 tpd of NOx reductions possible
       - Several states need to be moving forward to put pressure on EPA for federal action - This effort will work best if done by EPA
    3. Smaller power plants and other generators that emit primarily on the worst (high electricity demand) days of the summer
       - Technical staff believe peak day NOx emission reduction potential is very high
       - May be particularly important for NJ/NY/CT because of the large number of small distributed generation sources around NYC
    4. Daily limits on "close-by" EGUs (primarily PA)

Thanks



The real work is done by Mike Woodman, Dave Krask, Jen Hains, Joel Dreessen, Emily Bull, Kathy Wehnes, Carolyn Jones and Roger Thunell at MDE and Tim Canty, Dan Goldberg, Hao He, Xinrong Ren, Dale Allen, Ross Salawitch, Russ Dickerson, Tim Vinciguerra, Dan Anderson, Samantha Carpenter, Linda Hembeck and Sheryl Ehrman at UMCP. Thanks to support/input from MARAMA, OTC, NH, NYDEC, NJDEP, ME, VADEQ, LADCO, SESARM, NASA, AQAST, MOG and EPA.

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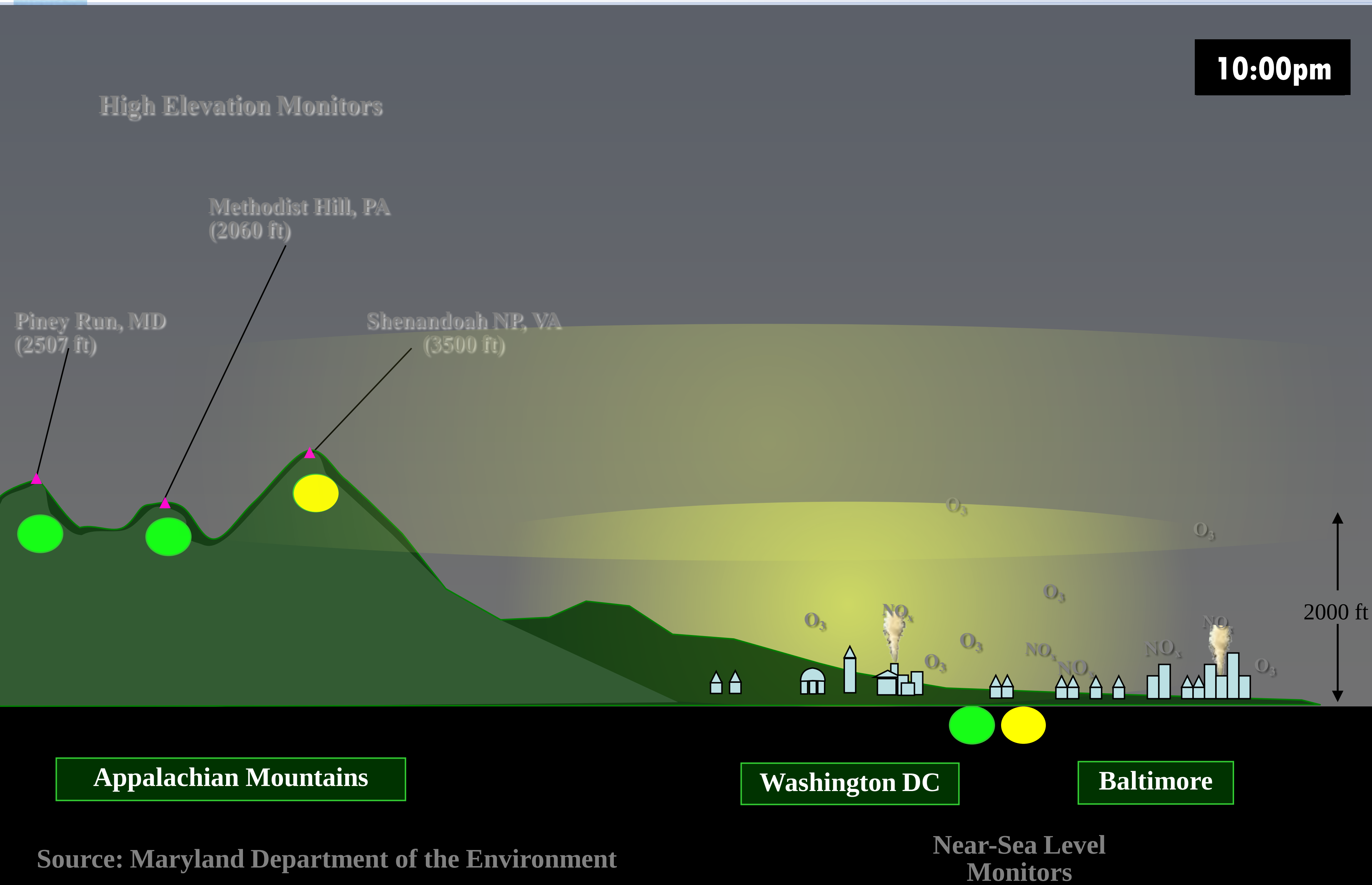
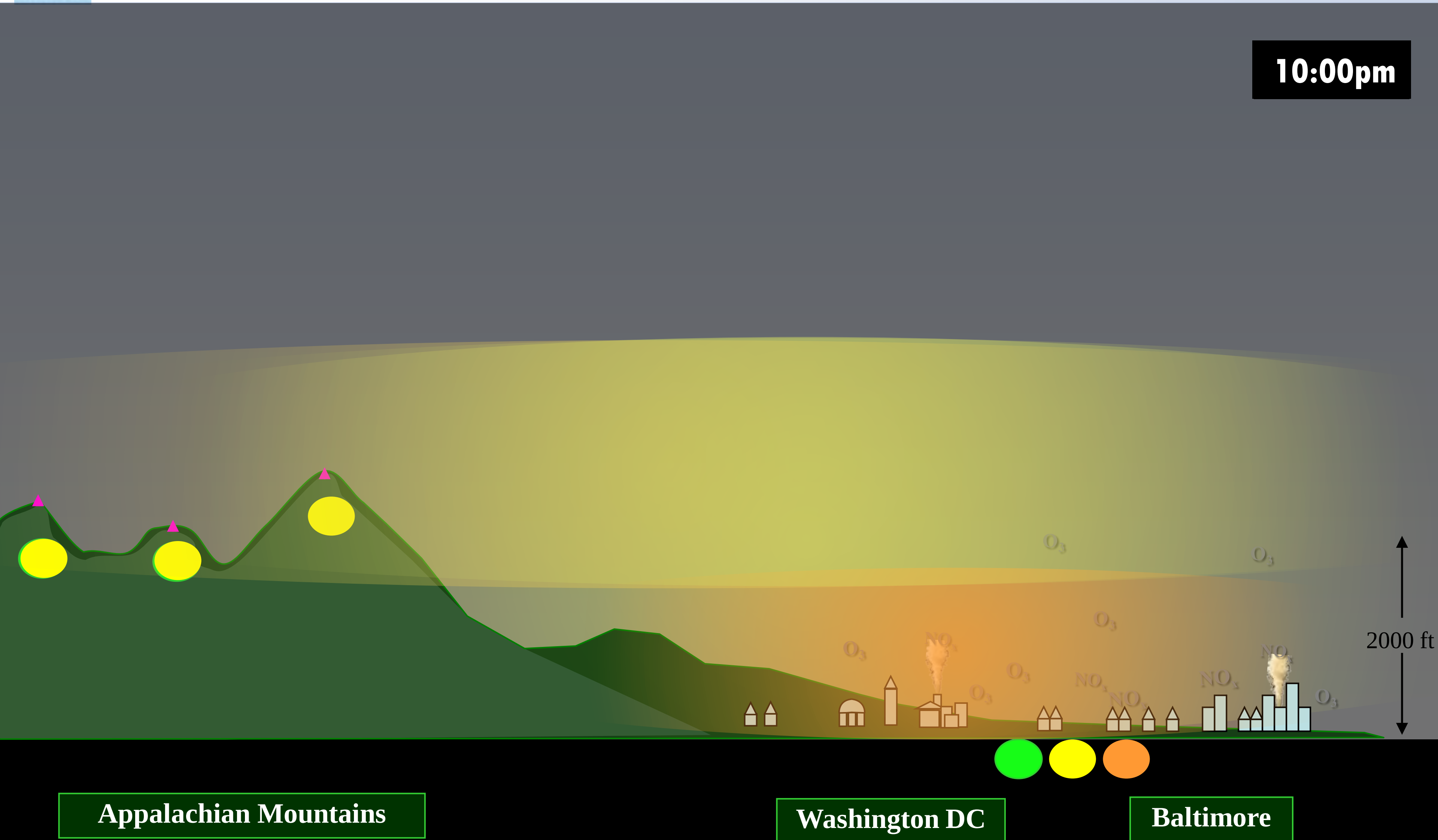
Typical Ozone Episode: Day 1



Source: Maryland Department of the Environment

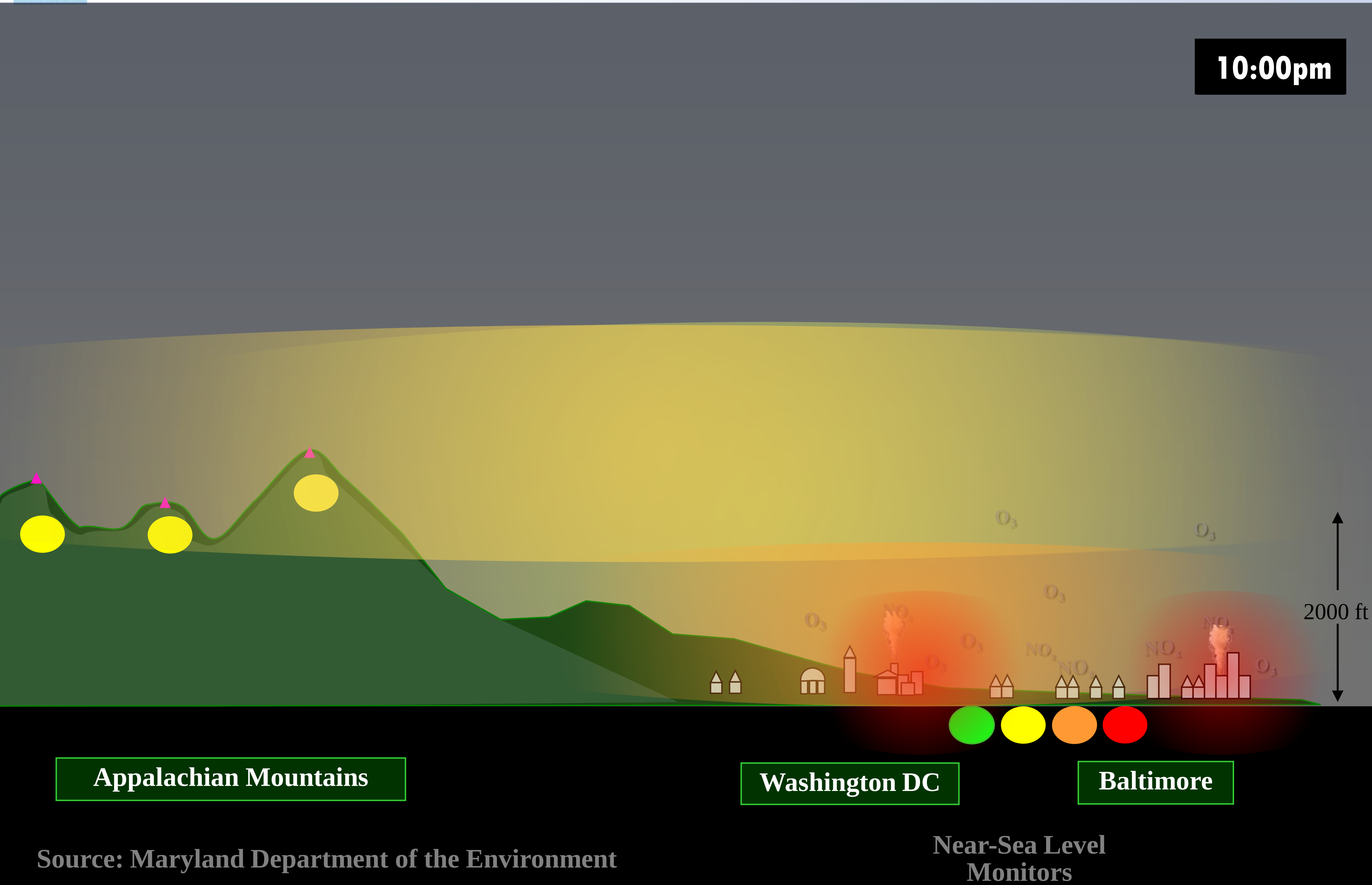
Typical Ozone Episode: Day 2



Near-Sea Level Monitors

Source: Maryland Department of the Environment

Typical Ozone Episode: Day 3



Source: Maryland Department of the Environment