# Increased Air Pollution over the Chesapeake Bay and its Effect on Deposition to the Bay

Presentation by:
Dan Goldberg

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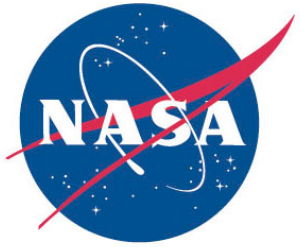
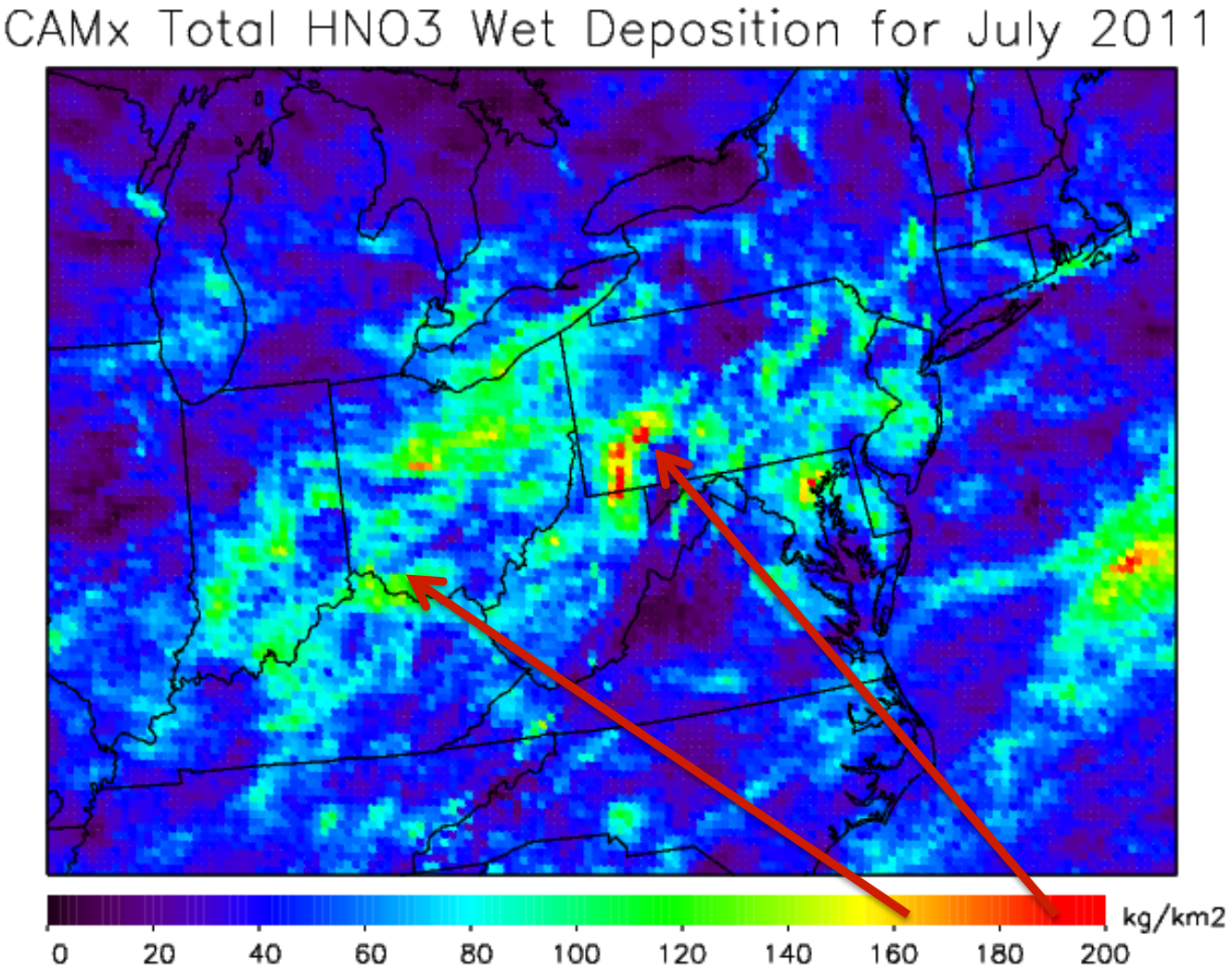
Presented at: NADP Fall Meeting 2014
Wednesday October 22, 2014

UNIVERSITY OF MARYLAND

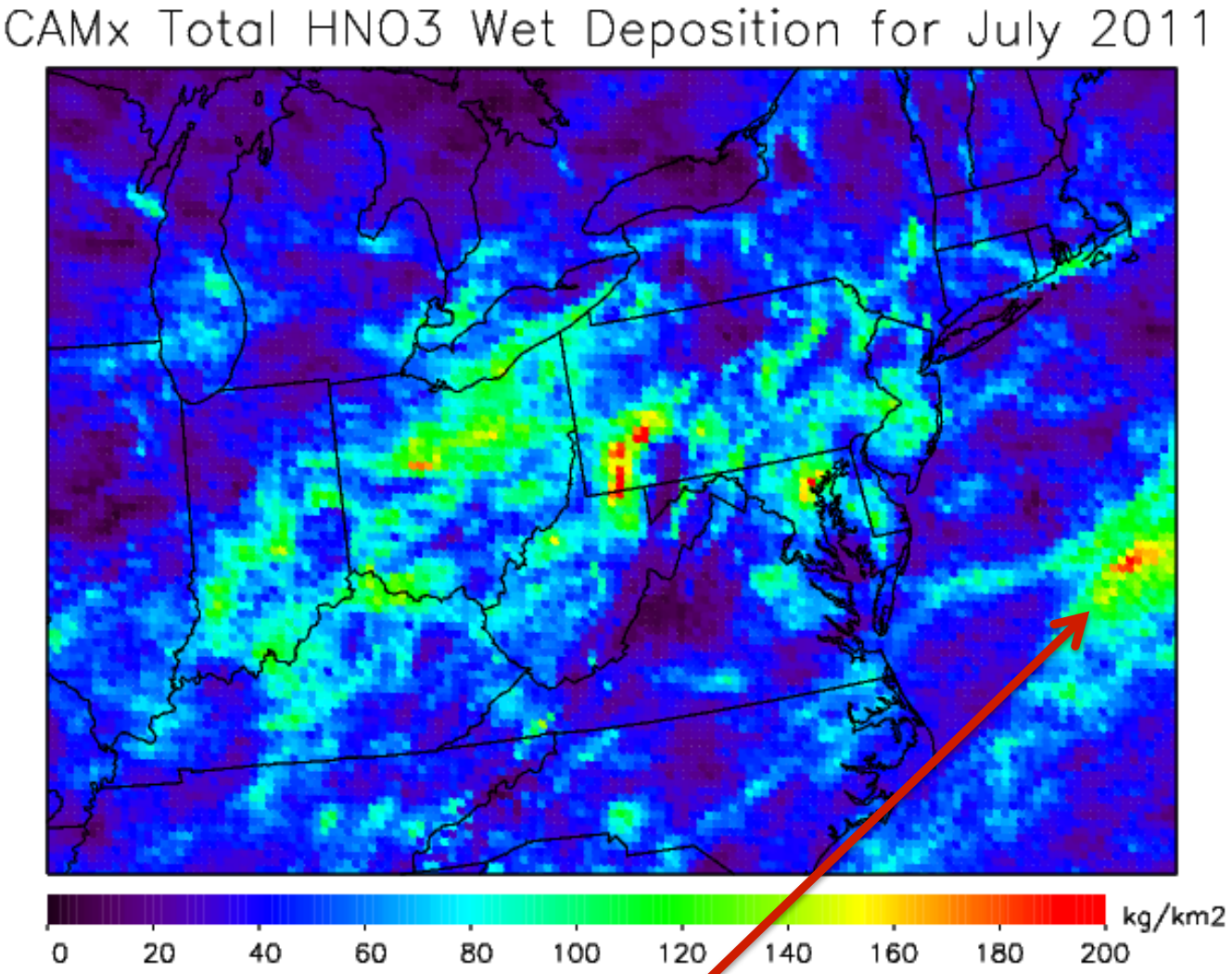


# Deposition in the 12-km CAMx Air Quality model




Peaks in nitrogen deposition in the Ohio River Valley

# Deposition in the 12-km CAMx Air Quality model




Peaks in nitrogen deposition in the Ohio River Valley, Gulf Stream storm tracks...

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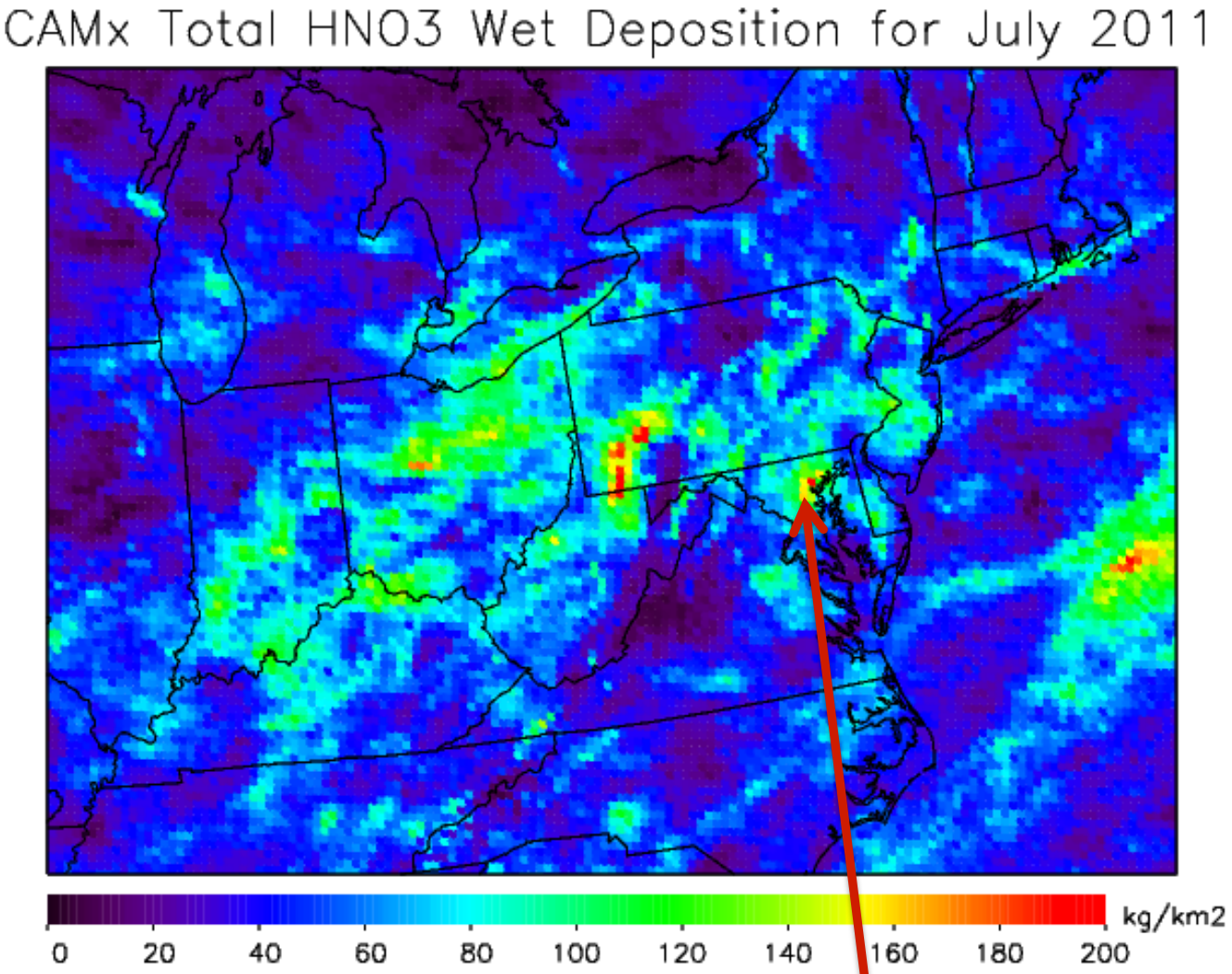


Peaks in nitrogen deposition in the Ohio River Valley, Gulf Stream storm tracks... **& Baltimore!**

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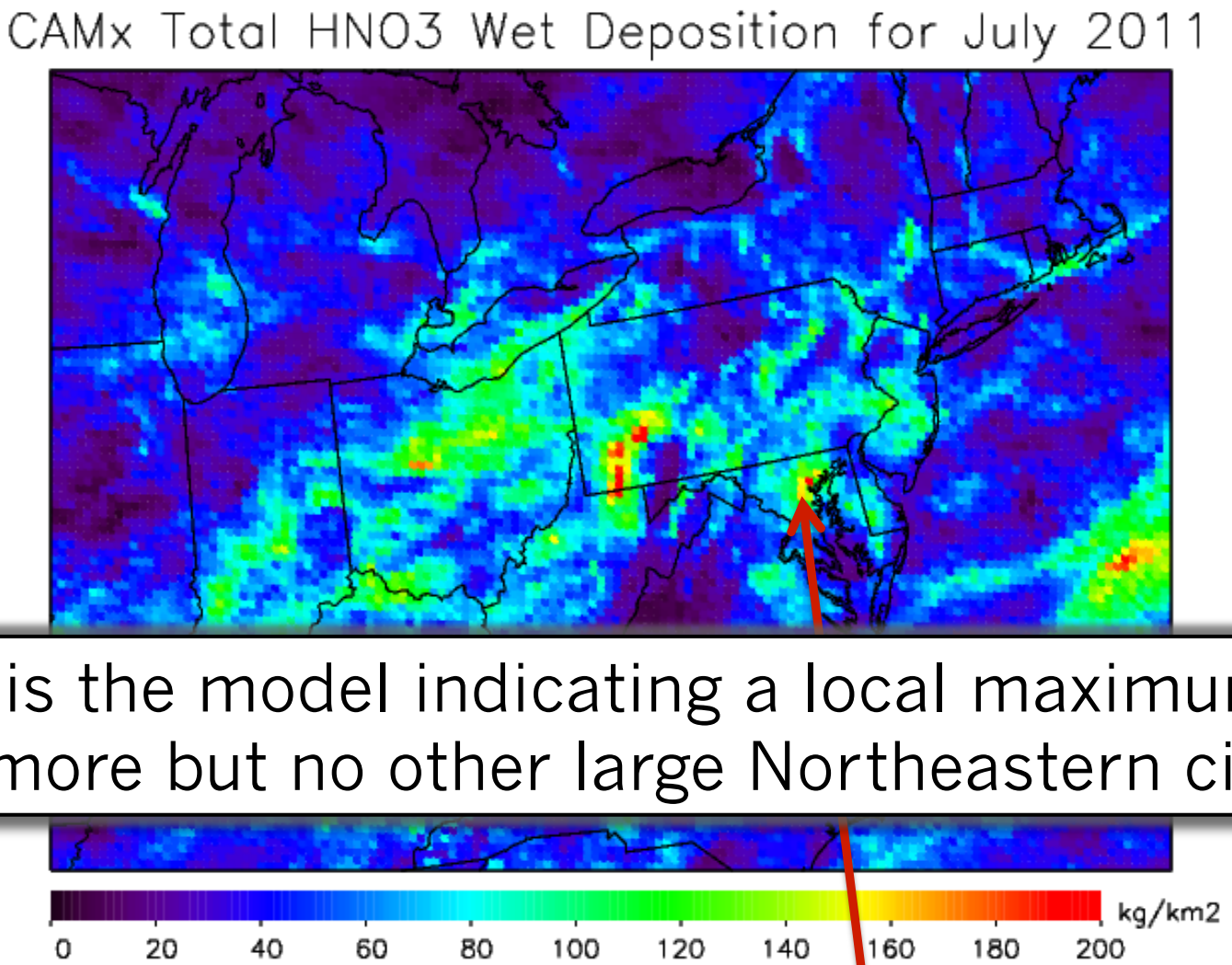



Why is the model indicating a local maximum in Baltimore but no other large Northeastern cities?

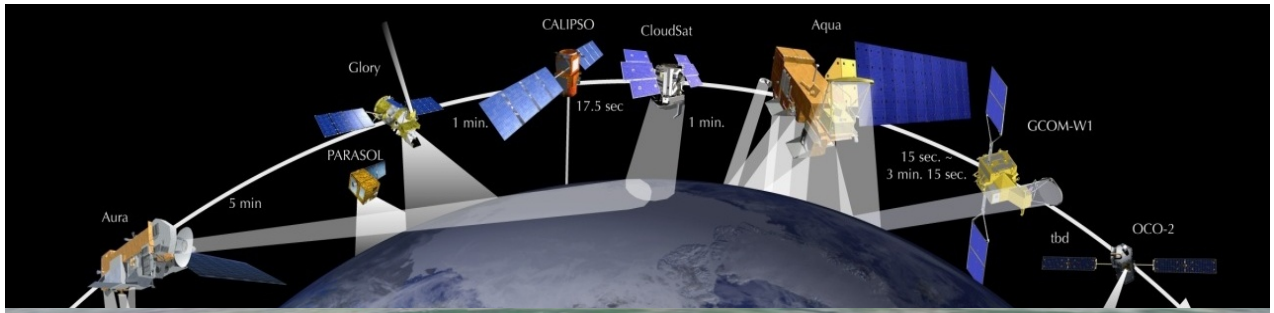
Peaks in nitrogen deposition in the Ohio River Valley, Gulf Stream storm tracks... **& Baltimore!**

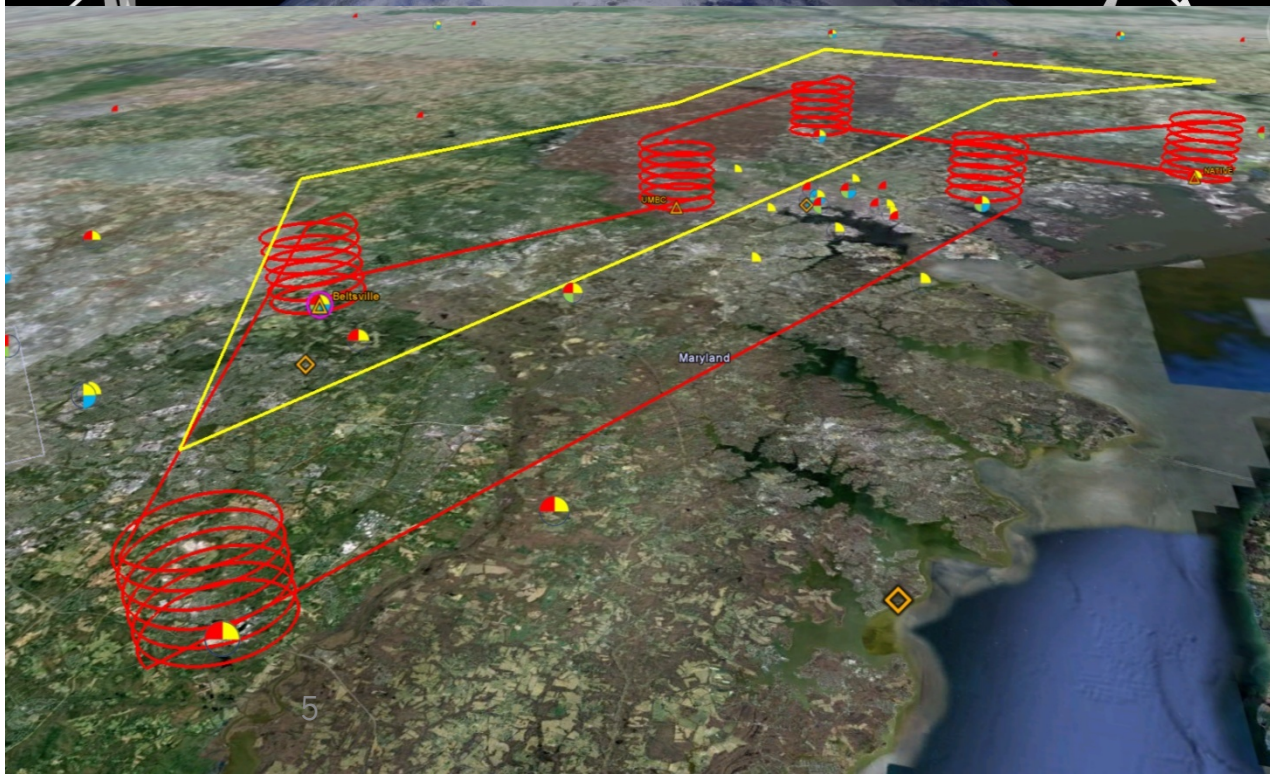
DISCOVER-AQ

# Maryland Observing Strategy
## July 2011

DISCOVER-AQ: Deriving Information on Surface conditions from Column and Vertically Resolved Observations Relevant to Air Quality

Three major observational components:



DISCOVER-AQ

# Maryland Observing Strategy
## July 2011

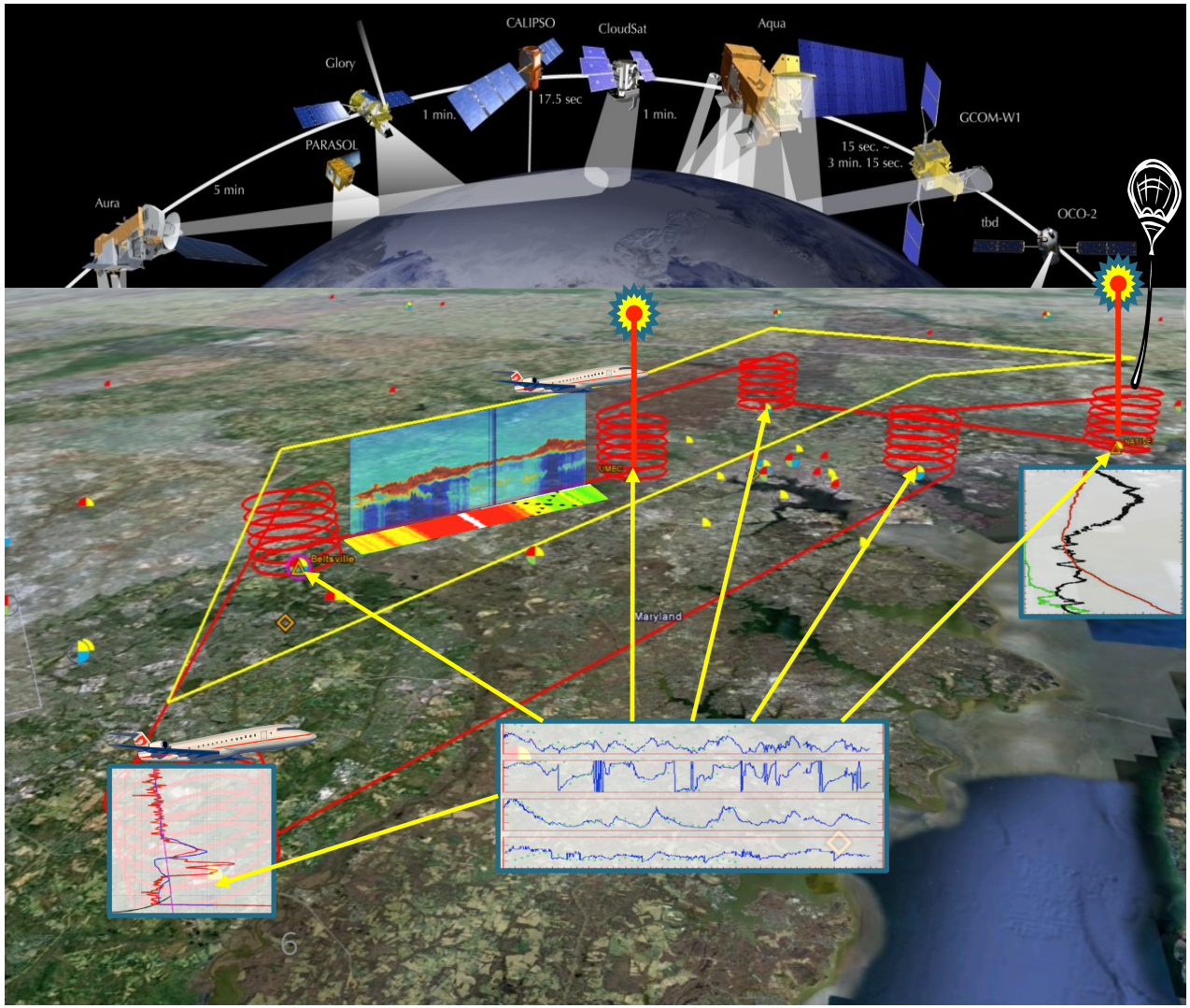
DISCOVER-AQ: Deriving Information on Surface conditions from Column and Vertically Resolved Observations Relevant to Air Quality

Three major observational components:

NASA UC-12 (Remote sensing)
Continuous mapping of aerosols with HSRL and trace gas columns with ACAM

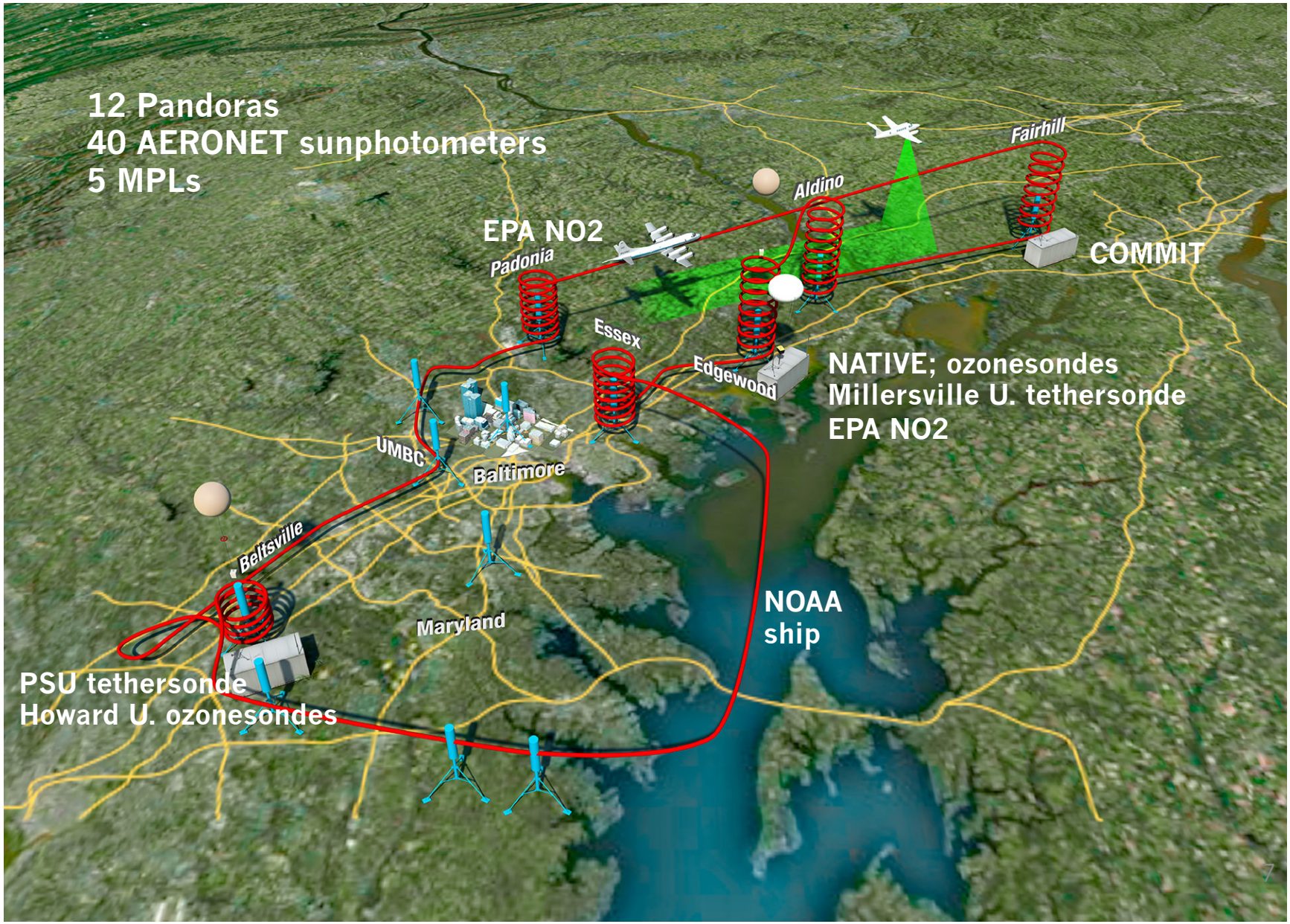
NASA P-3B (in situ meas.)
In situ profiling of aerosols and trace gases over surface measurement sites

Ground sites
In situ trace gases and aerosols
Remote sensing of trace gas and aerosol columns
Ozonesondes
Aerosol lidar observations



DISCOVER-AQ

# P-3B flights spiral over surface sites (typically 3 times per day, 2 hours apart)



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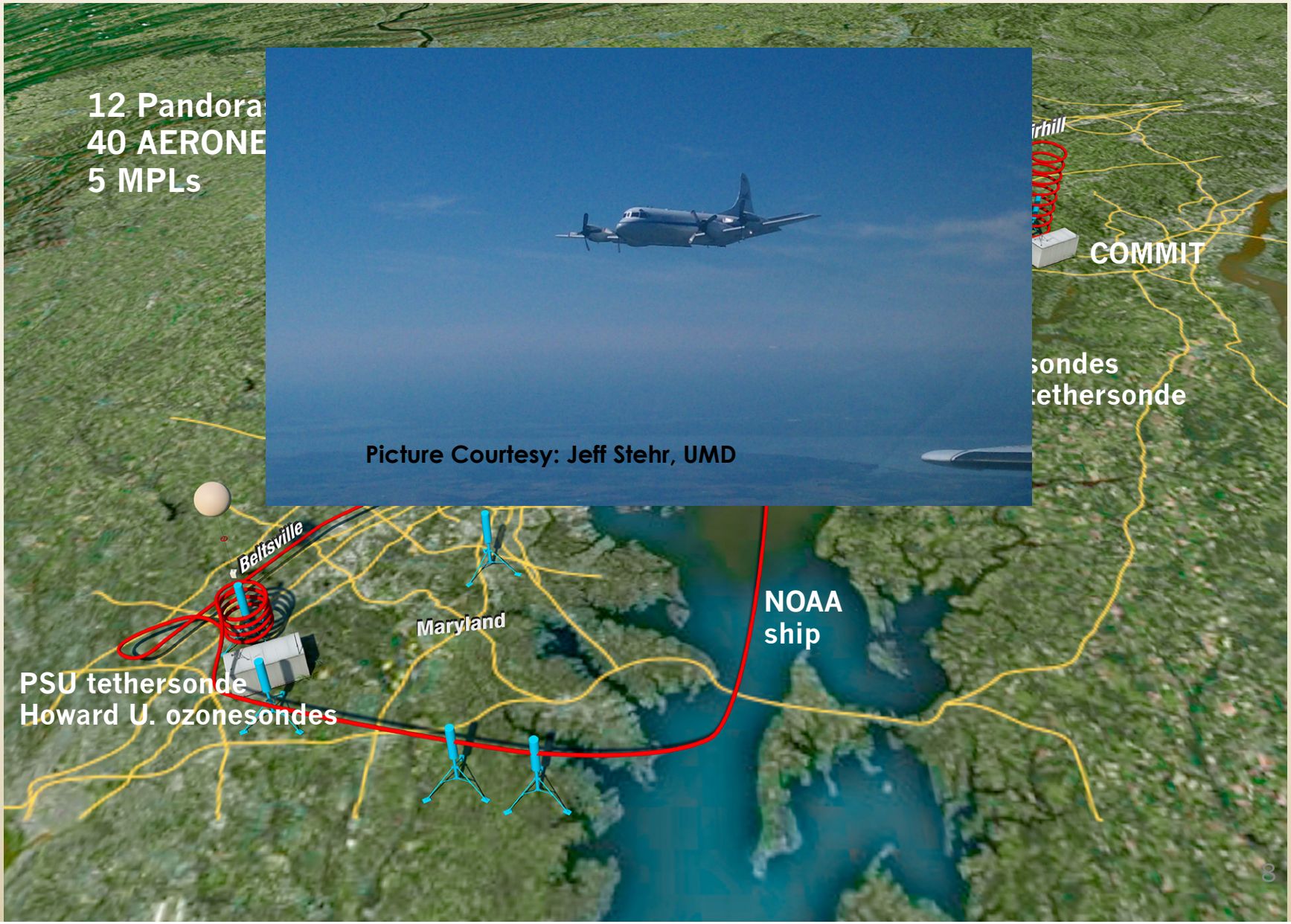

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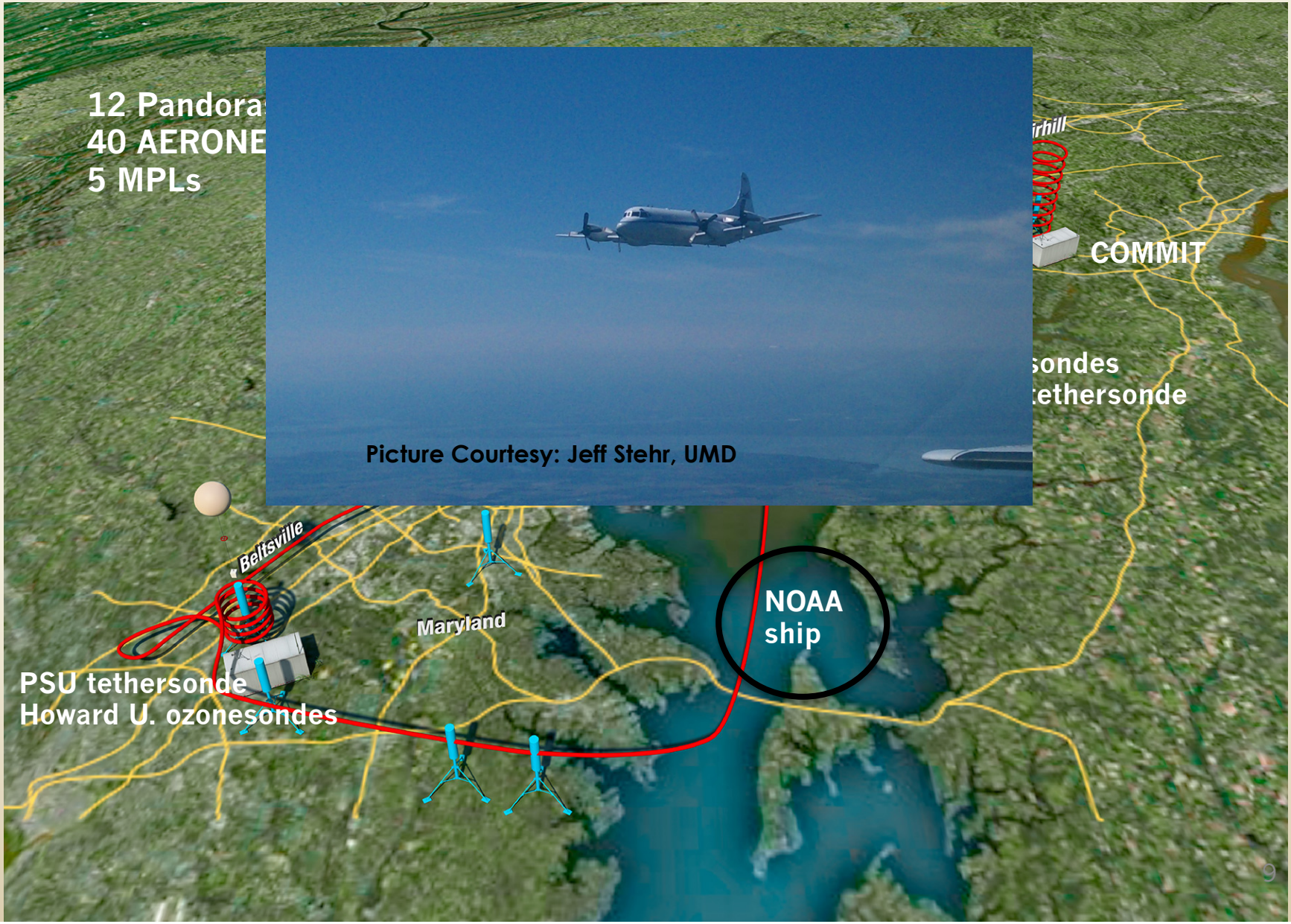


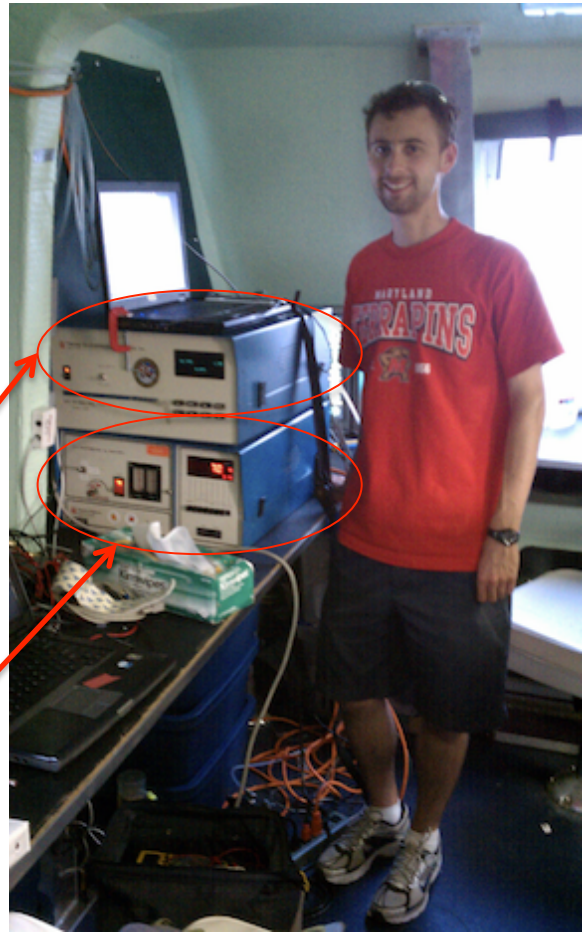
# NOAA SRVx (Small Research Vessel)

- 10-day boat campaign in Chesapeake Bay from July 11 – 20, 2011
- Measured $O_3$ & $NO_y$

Picture Courtesy: Maria A. Tzortziou, NASA

**NO / $NO_y$ Analyzer**

**Ozone Analyzer**



**Inside cabin**

Picture Courtesy: Chris Loughner, NASA

# Surface ozone over Bay vs Land

**8-hour maximum surface $O_3$ is consistently *10 – 20 ppb higher* at the surface of the Chesapeake Bay than the closest upwind ground site**

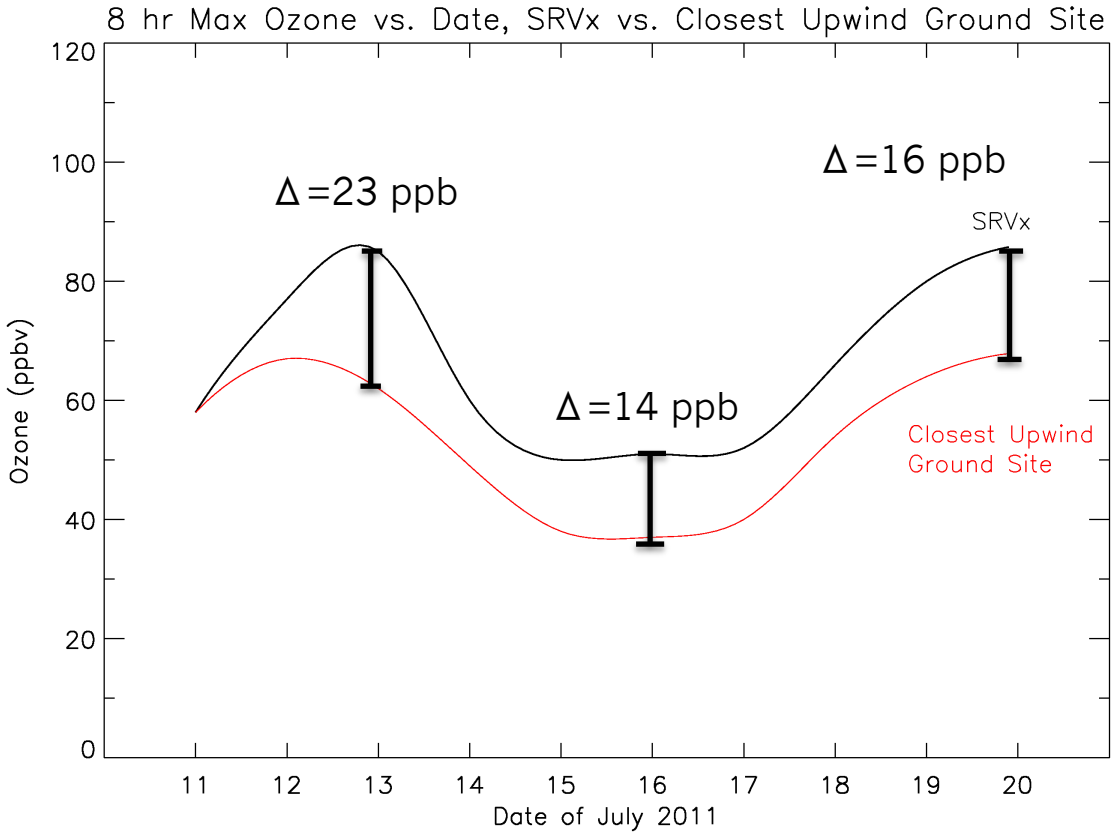



**Figure 4 from Goldberg et al. 2014**

# Late Afternoon High Anomaly

- Remarkably similar until 3 PM, then there is a noticeable split in the 2 lines
- By 6 PM, on average, there is a 20 ppb difference

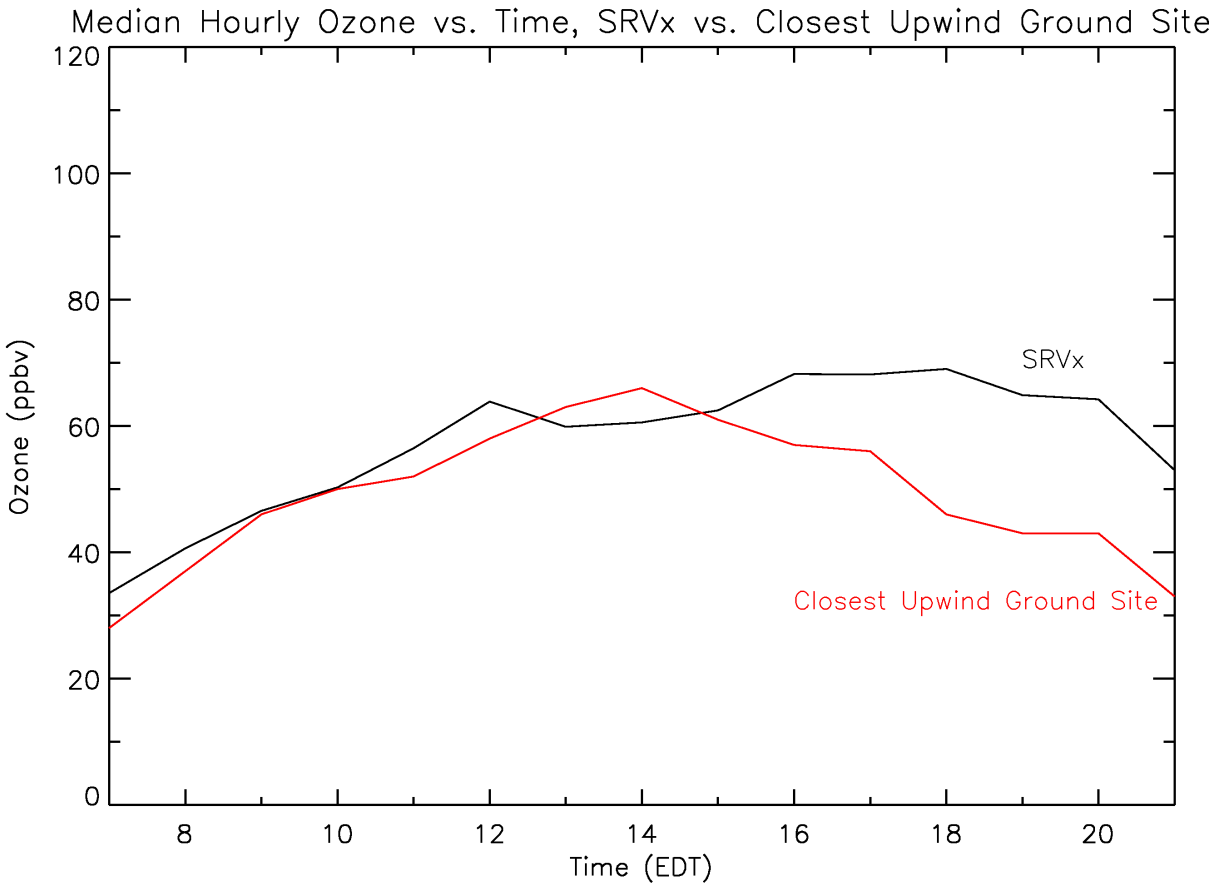


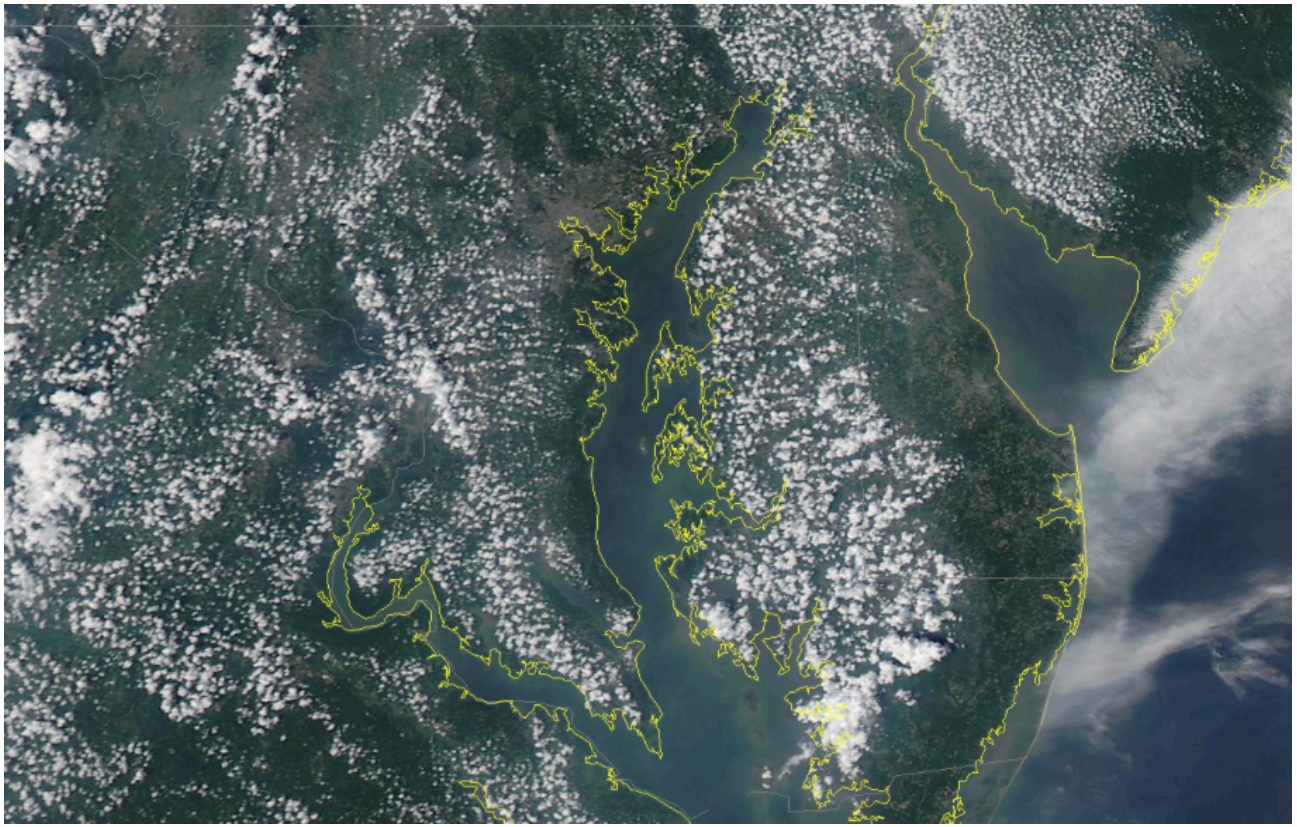

**Figure 5 from Goldberg et al. 2014**

# What are the potential reasons for more ozone over the Chesapeake Bay:

- Fewer fair-weather cumulus clouds over the Bay allowing for increased photolysis
- **Slower $O_3$ dry deposition rates over water**
- **Shallower PBL over the Bay causing emissions to be trapped closer to the surface**
- **Decreased boundary layer venting due to meso-high pressure over the Bay**

# July 20, 2011: MODIS Imagery

No clouds over the Chesapeake & Delaware Bays!



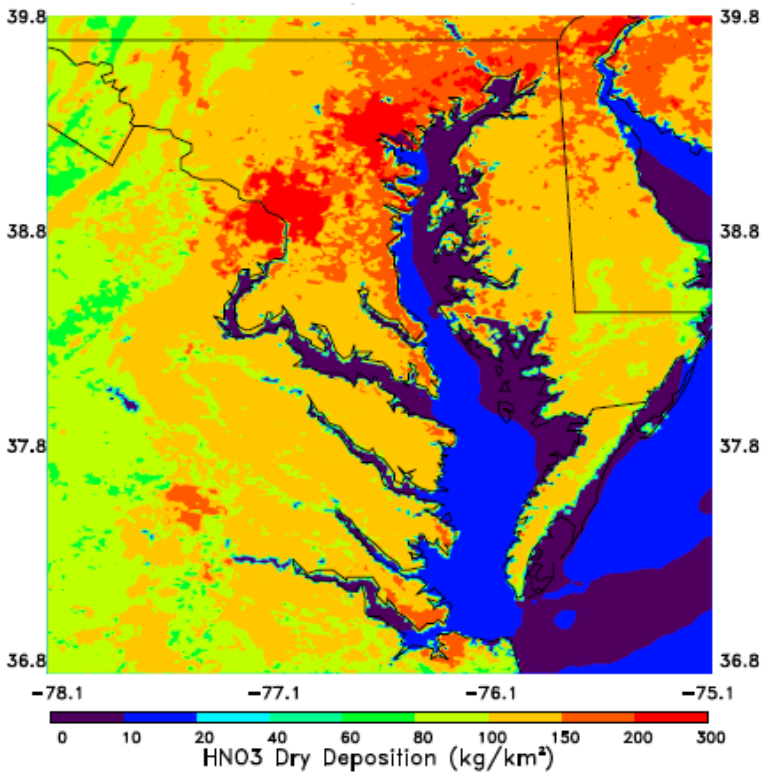
MODIS imagery from the AQUA satellite at 1:30 PM on July 20, 2011

**Increased photolysis over the Bay!**

# Differences in Dry Deposition Rates

Dry deposition of pollutants over water is up to 10 times slower!

**When air is stagnant, there can be a significant accumulation of pollutants over the Chesapeake Bay**

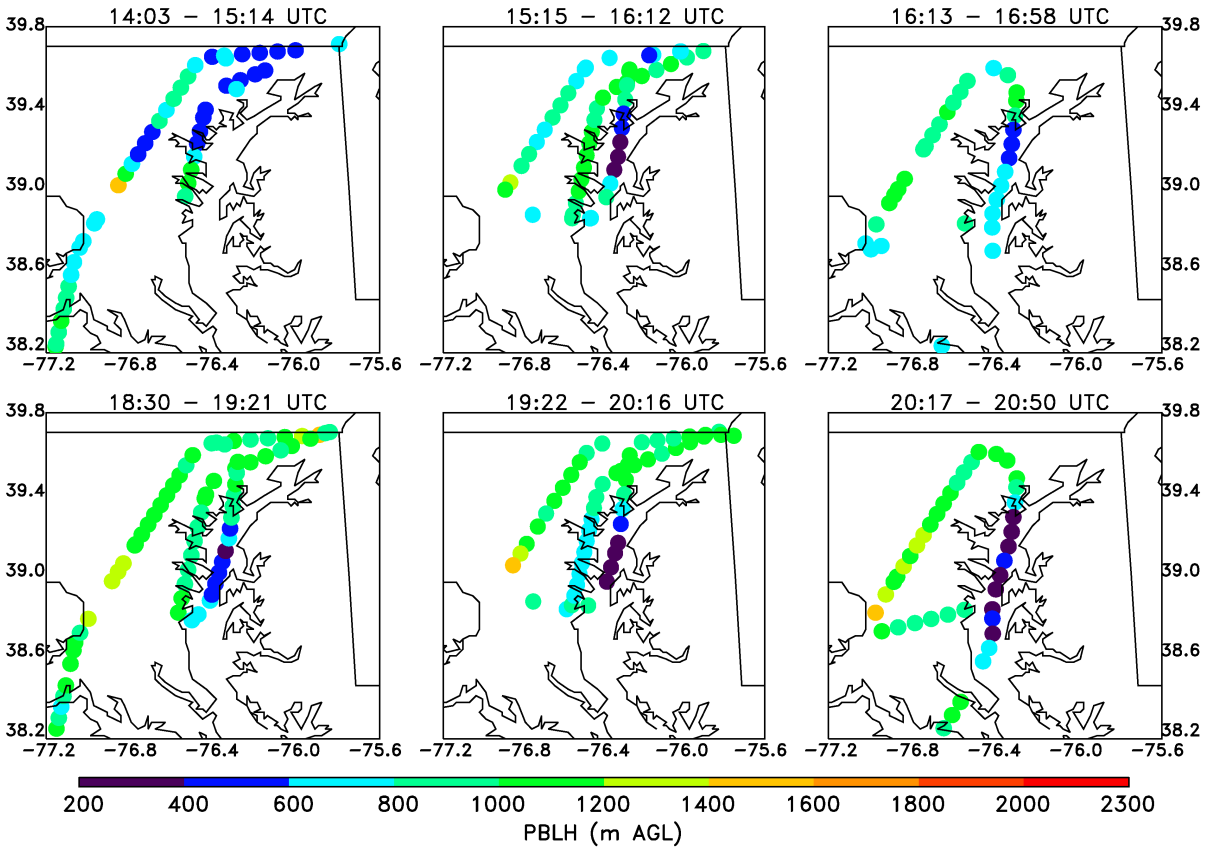



| | Forest | Coastal | Ocean |
|---|---|---|---|
| Nowak (2006) | 0.5 cm/s | - | - |
| Wesely (2000) | 0.8 cm/s | - | - |
| Chang (2004) | - | - | 0.05 cm/s |
| Gallagher (2001) | - | 0.148 cm/s | - |

**Ozone Dry Deposition rates for Forested, Coastal and Oceanic areas from various literature sources**

# Measurements of PBL height using HSRL from the UC-12 aircraft

**Figure 12 from Goldberg et al. 2014**




*PBL – Planetary boundary layer

Aerosol-based boundary layer:

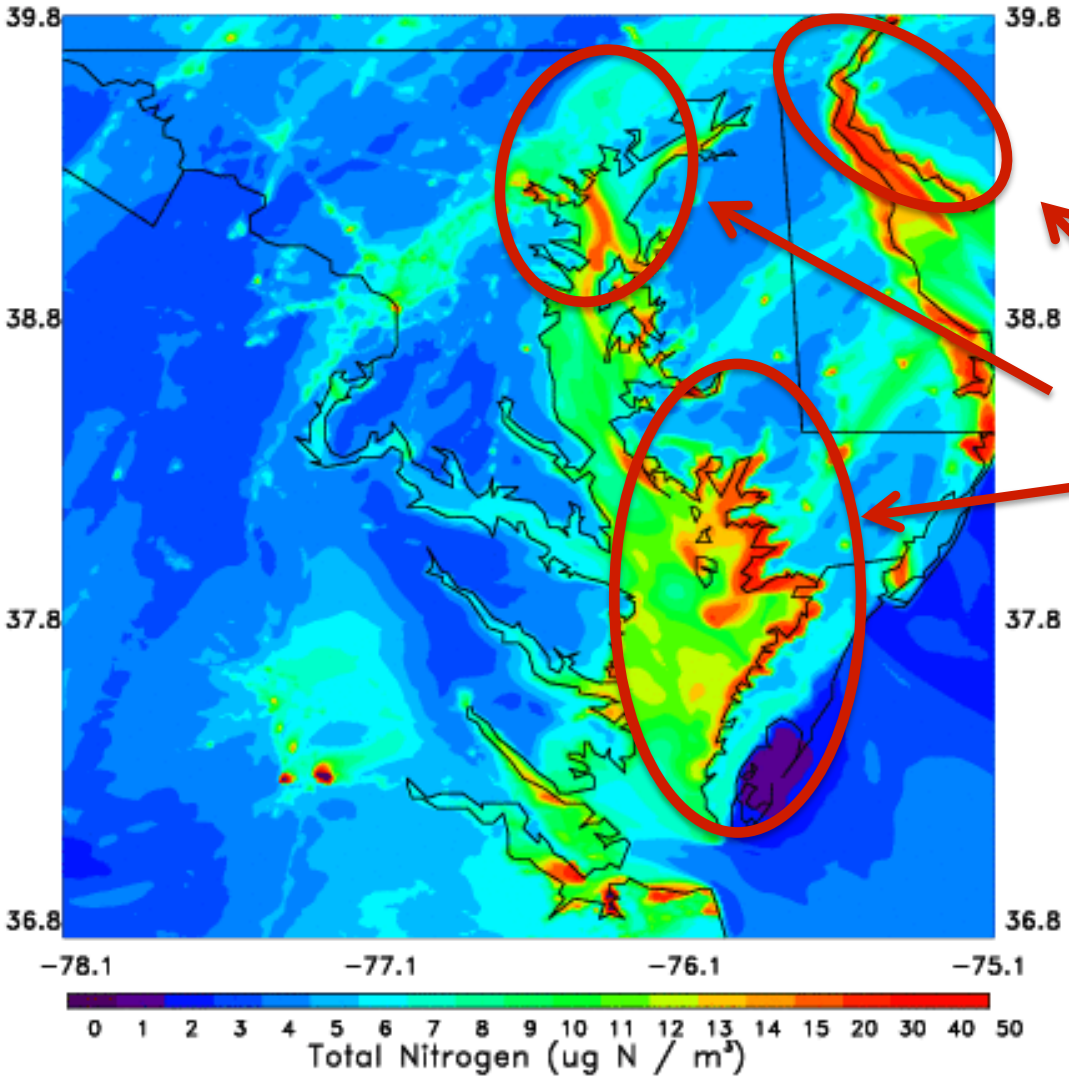
Over land: ~1000 m

Over bay: ~500 m

**Thanks to Rich Ferrare & Chris Hostetler for the HSRL measurements and Amy Jo Scarino for the mixed layer heights**

# Near surface nitrate aerosols in the 1-km CMAQ Air Quality model

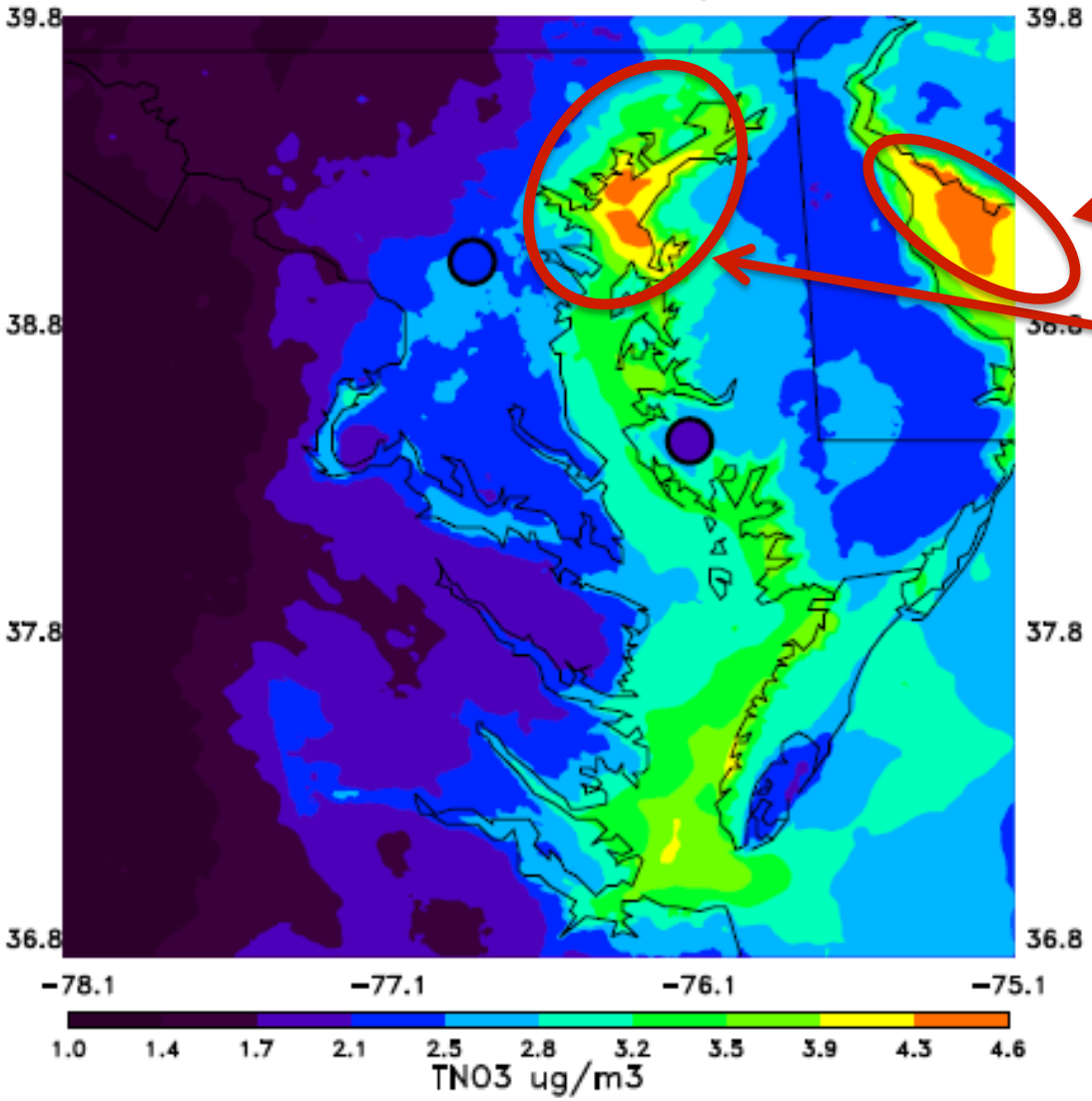
Total Nitrogen near the surface at 1:00 PM on July 2, 2011




**Stagnation and low deposition rates results in pollutant buildup over the bay**

# Near surface nitrate aerosols in the 1-km CMAQ Air Quality model

**Mean nitrogen aerosol concentration from 9 AM June 28, 2011 through July 5, 2011 8 AM**

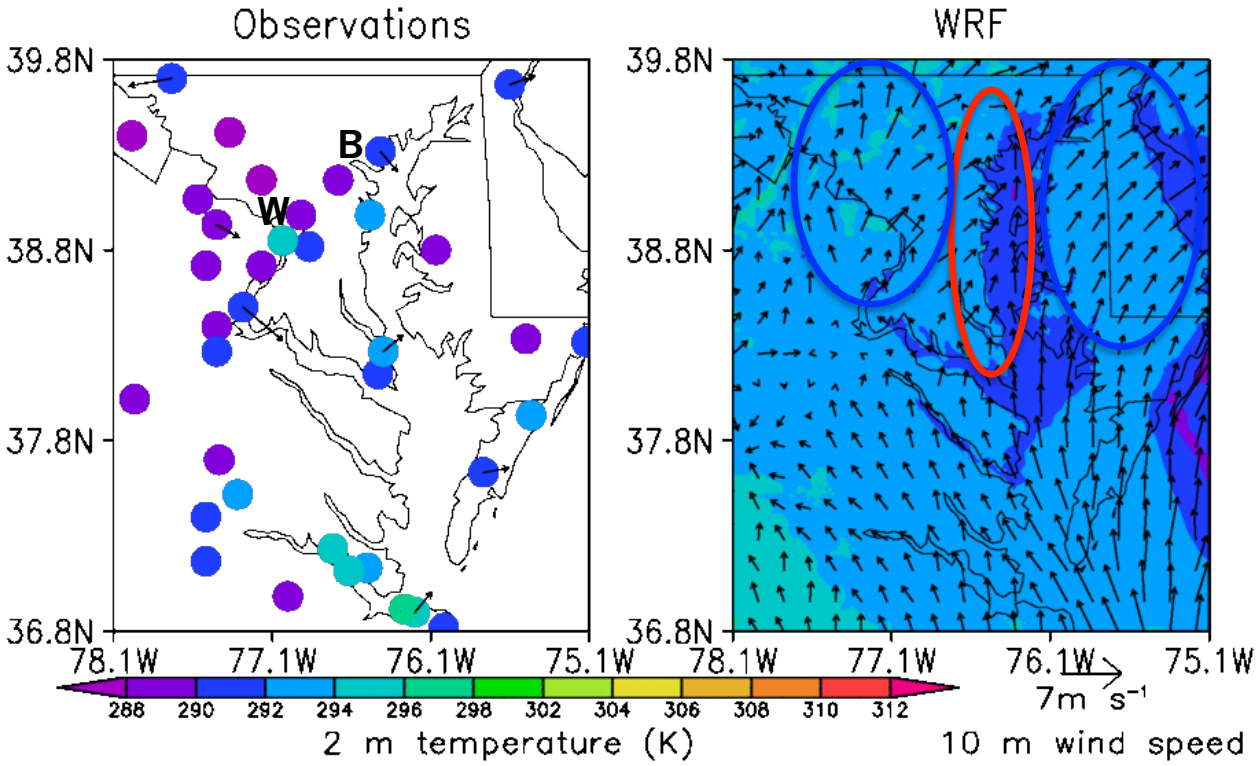



Higher total nitrogen aerosol over the bays

**Observations from the CASTNET sites do not pick up on this fine spatial gradient!**

# Impact of the Chesapeake Bay breeze

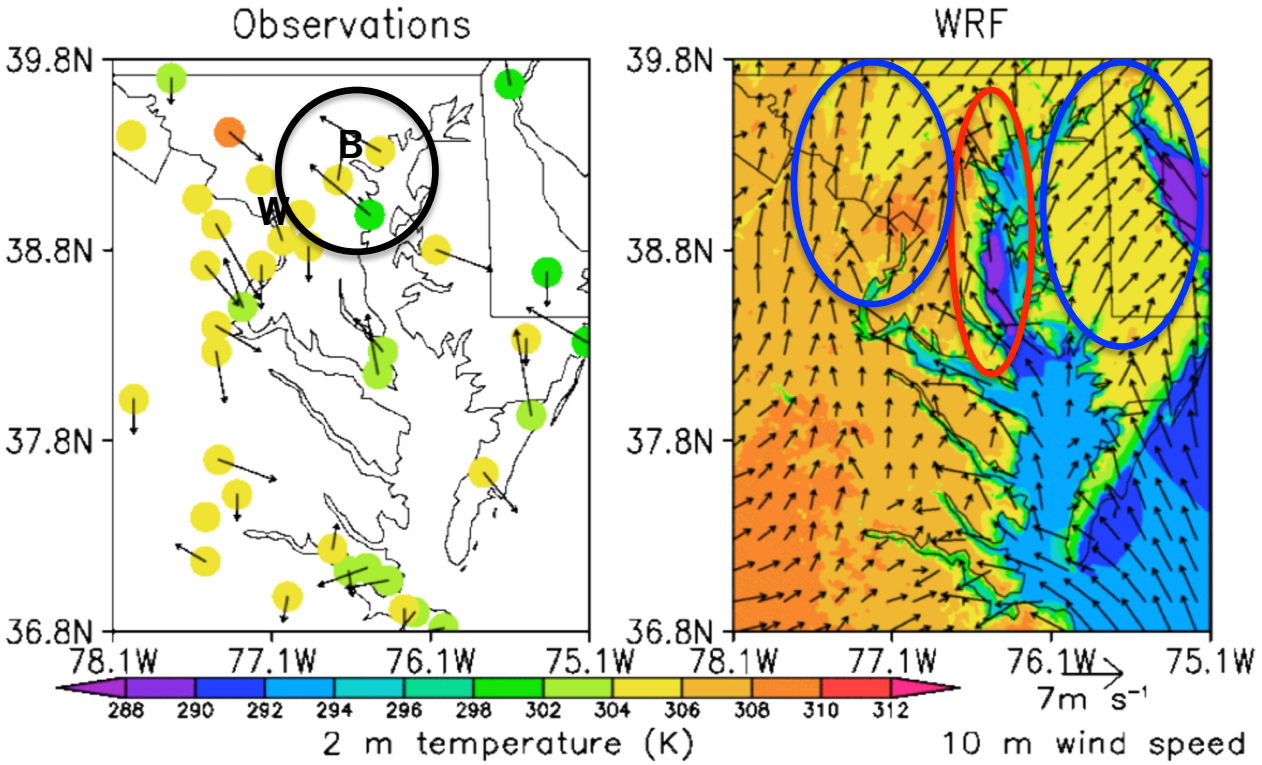
July 2, 2011 4:00 AM Local time




Temperatures primarily between 14 – 20° C (57 – 68° F)
Wind speeds light (1 – 3 m/s) and primarily from south and west

# Impact of the Chesapeake Bay breeze

July 2, 2011 1:00 PM Local time

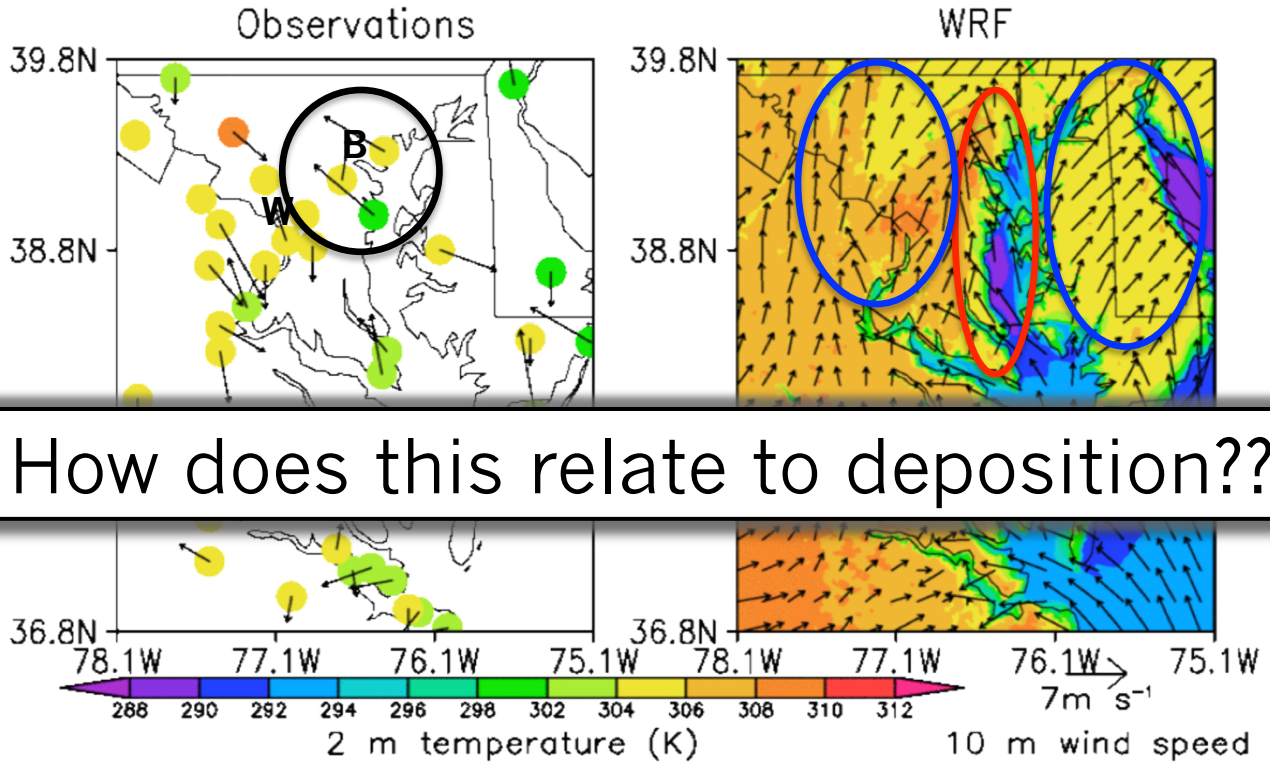



Temperatures primarily between 31 – 37° C (88 – 99° F)
Wind speeds moderate (>5 m/s) and primarily from southwest over land & from the east over the Bay and Ocean!

**Notice the easterly component of the wind along the western shore of the Chesapeake Bay!**

# Impact of the Chesapeake Bay breeze

July 2, 2011 1:00 PM Local time



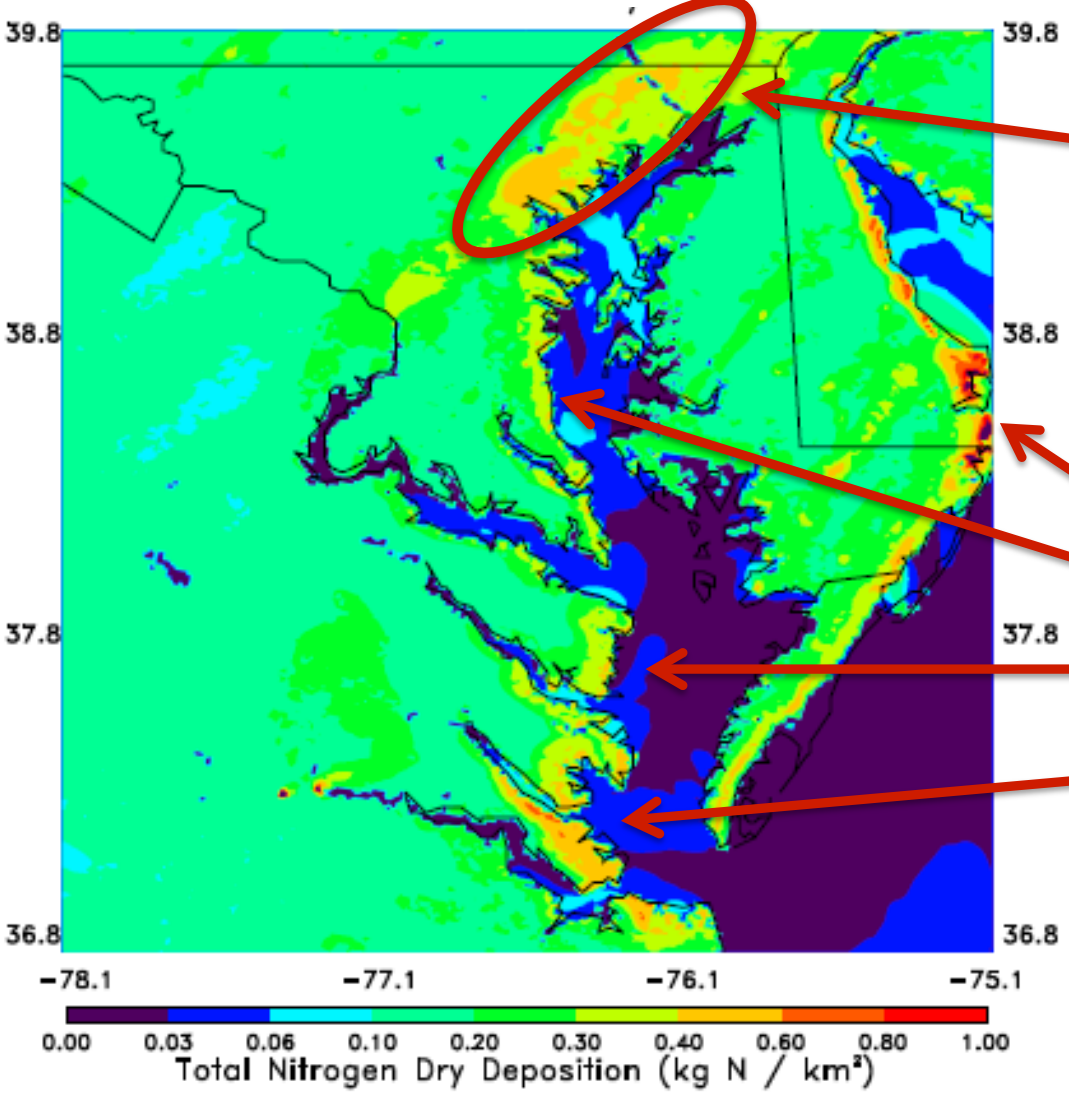

How does this relate to deposition???

Temperatures primarily between 31 – 37° C (88 – 99° F)
Wind speeds moderate (>5 m/s) and primarily from southwest over land & from the east over the Bay and Ocean!

**Notice the easterly component of the wind along the western shore of the Chesapeake Bay!**

# Nitrogen dry deposition in the 1-km CMAQ Air Quality model

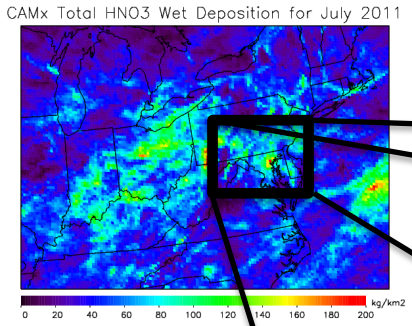
Total Nitrogen Dry deposition at 1:00 PM on July 2, 2011



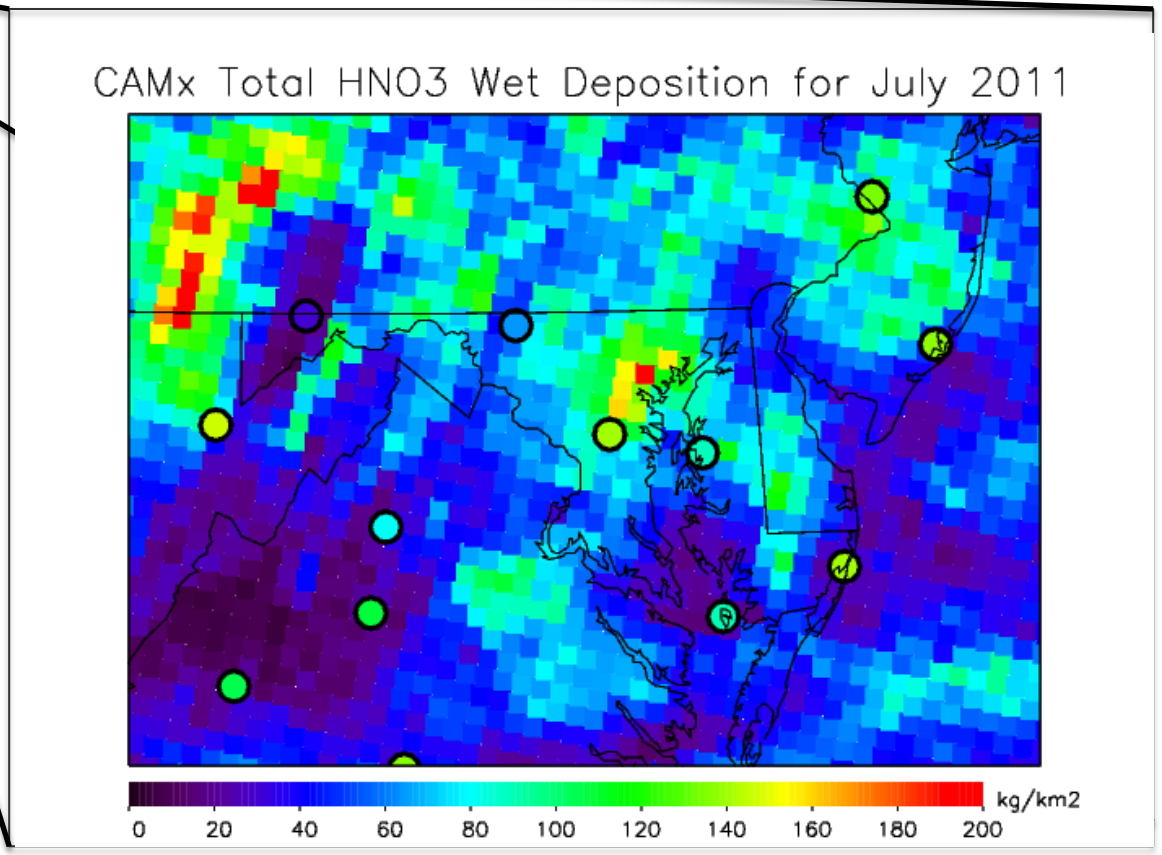

**Local maximum in dry deposition at the bay breeze convergence zone!**

**Also, a local maximum in dry deposition on all eastern-facing shorelines**

# Deposition in the 12-km CAMx Air Quality model



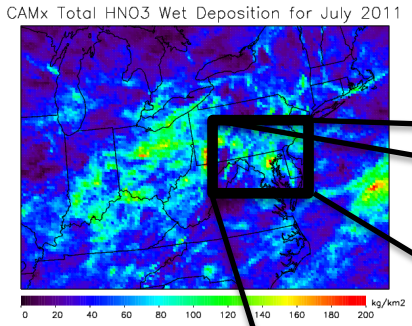

Total $NO_3$ Wet deposition during July 2011




Observations of wet deposition from the NTN NADP Network are overlaid

**Also, a local maximum in wet deposition at the bay breeze convergence zone!**

# Deposition in the 12-km CAMx Air Quality model

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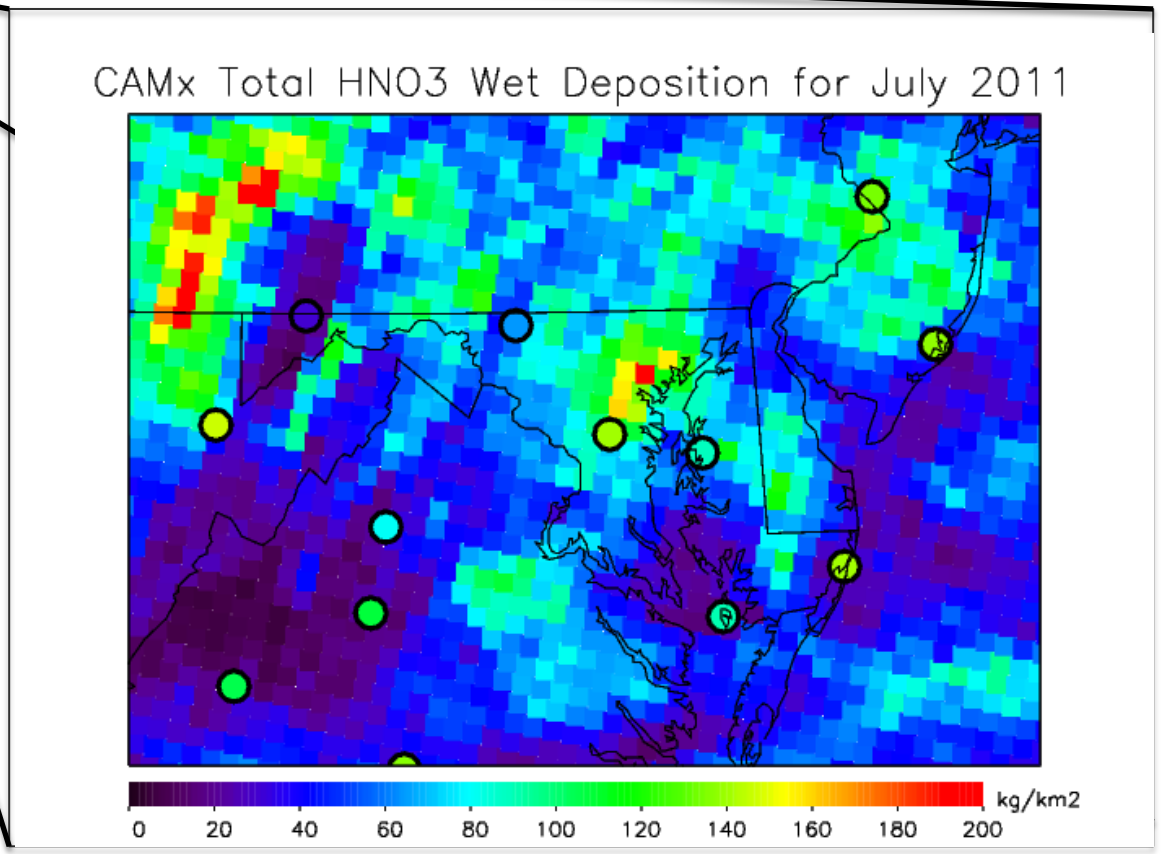
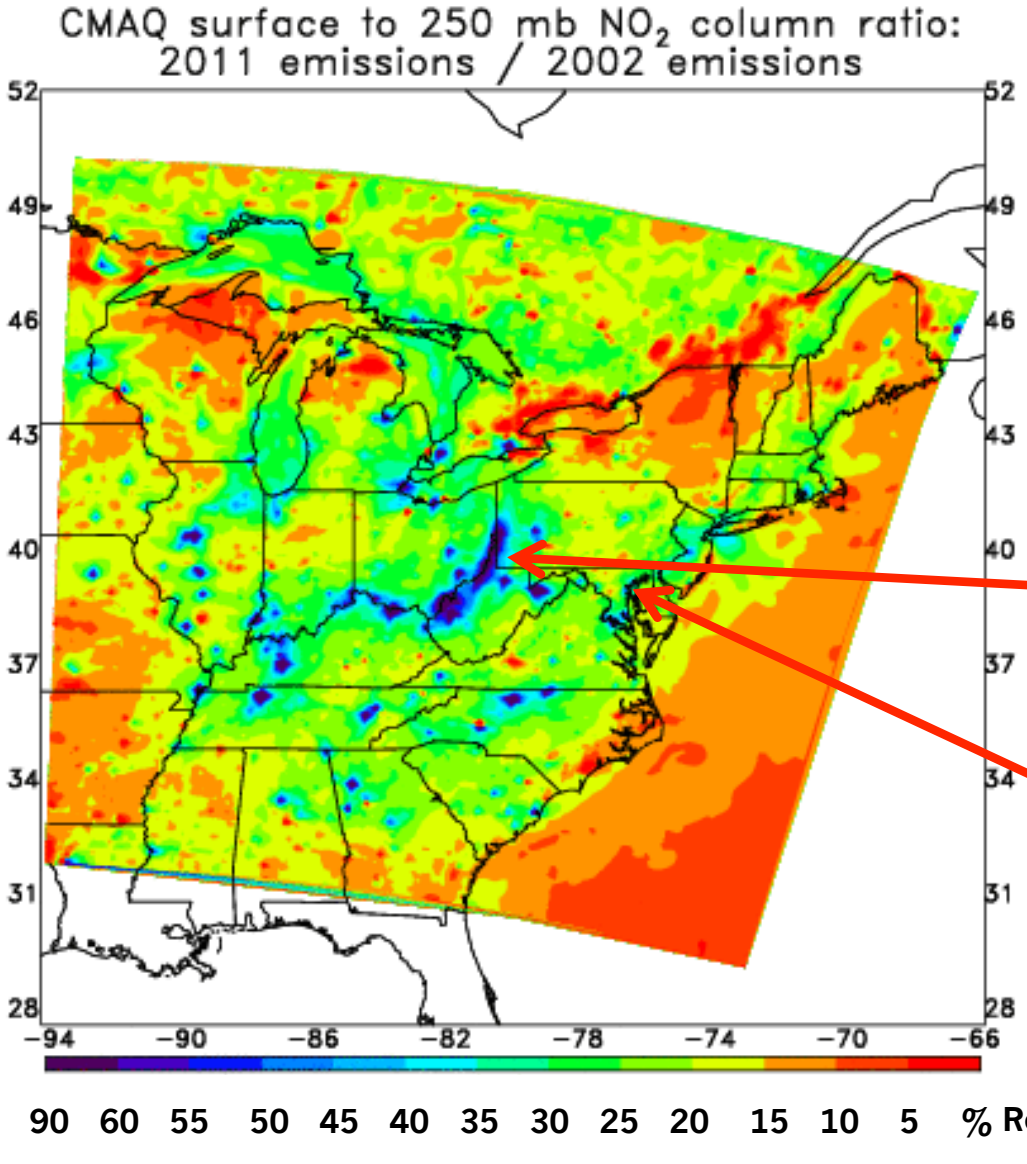



Observations of wet deposition from the NTN NADP Network are overlaid

Preliminary analysis: Air quality models *may be* underestimating rural nitrogen deposition

# CMAQ simulated $NO_2$ decreases due to emissions reductions




**CMAQ surface to 250 mb $NO_2$ column percent reduction from simulation with 2011 emissions to simulation with 2002 emissions at OMI overpass time**

**50% decrease**

**30% decrease**

**Similar reductions are seen from the OMI satellite! (2005 – 2011)**

# Conclusions

- Higher concentrations of pollutants over the Chesapeake Bay have been confirmed.
- Likely reasons for this high anomaly:
  - Higher photolysis rates
  - Slower dry deposition rates
  - Shallower PBL
  - Decreased PBL venting
- **Increased nitrogen wet & dry deposition along the western Chesapeake Bay shore, which is not be captured by the NADP network.**
- Nitrogen deposition is decreasing!

# For more information please see:

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Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv


## Higher surface ozone concentrations over the Chesapeake Bay than over the adjacent land: Observations and models from the DISCOVER-AQ and CBODAQ campaigns

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## Impact of Bay-Breeze Circulations on Surface Air Quality and Boundary Layer Export

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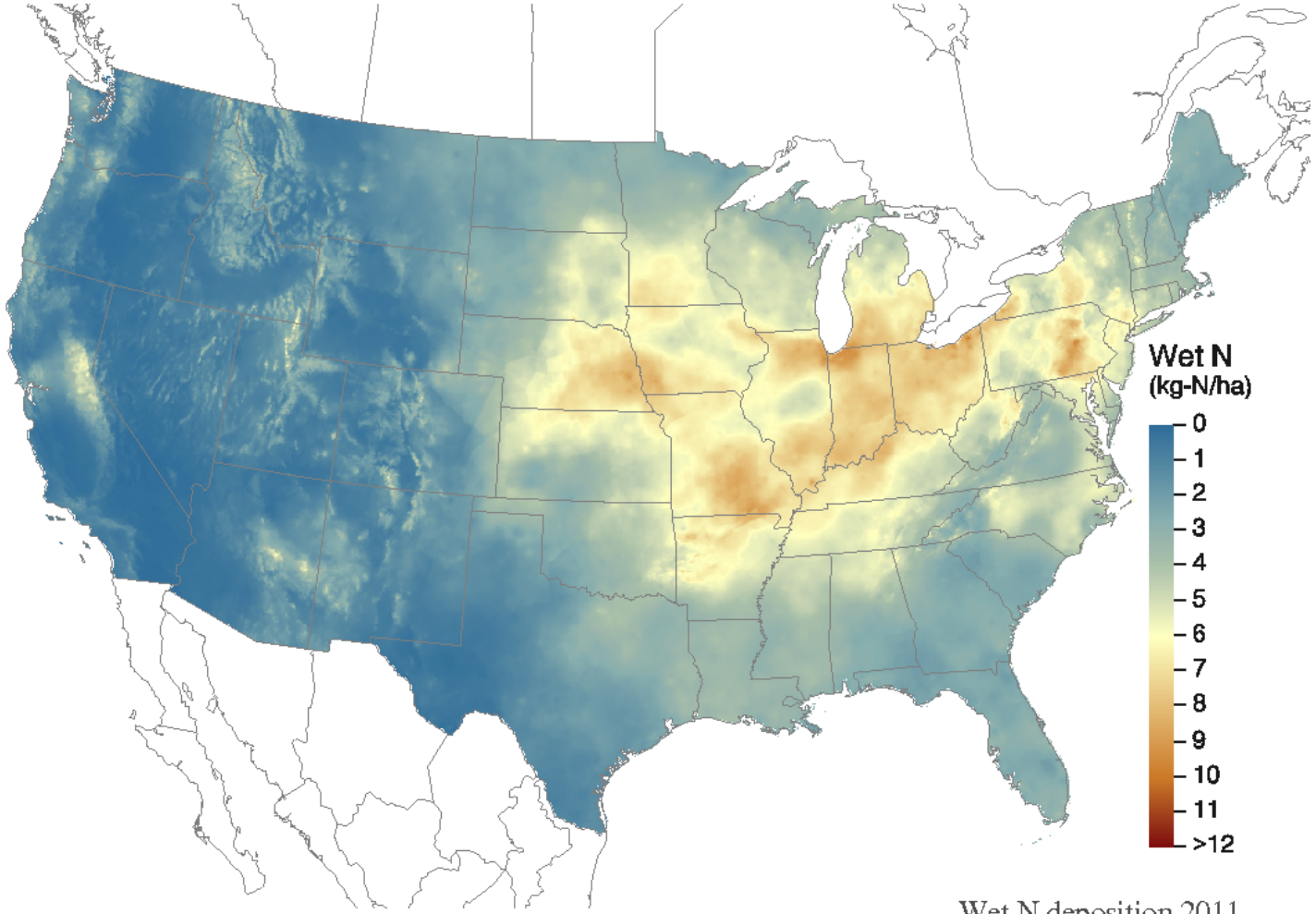
# BONUS MATERIAL

DISCOVER-AQ

# *P-3B flights spiral over surface sites (typically 3 times per day, 2 hours apart)*

| P-3B In Situ Airborne Measurements | |
|---|---|
| Bruce Anderson, NASA LaRC | aerosol optical, microphysical, and chemical properties |
| Andrew Weinheimer, NCAR | $O_3$, $NO_2$, NO, $NO_y$ |
| Ronald Cohen, UC Berkeley | $NO_2$, ANs, PNs, $HNO_3$ |
| Alan Fried, NCAR | HCHO |
| Glenn Diskin, NASA LaRC | $H_2O$, CO, $CH_4$ |
| Stephanie Vay, NASA LaRC | $CO_2$ |
| Armin Wisthaler, Innsbruck | Non-methane hydrocarbons |

# NADP Nitrogen Wet Deposition: 2011




Wet N deposition 2011

Source: CASTNET/CMAQ/NTN/AMON/SEARCH

USEPA 03/25/14

# July 2011 Rainfall