Maryland Department of the Environment

Profiling Air Quality over Maryland

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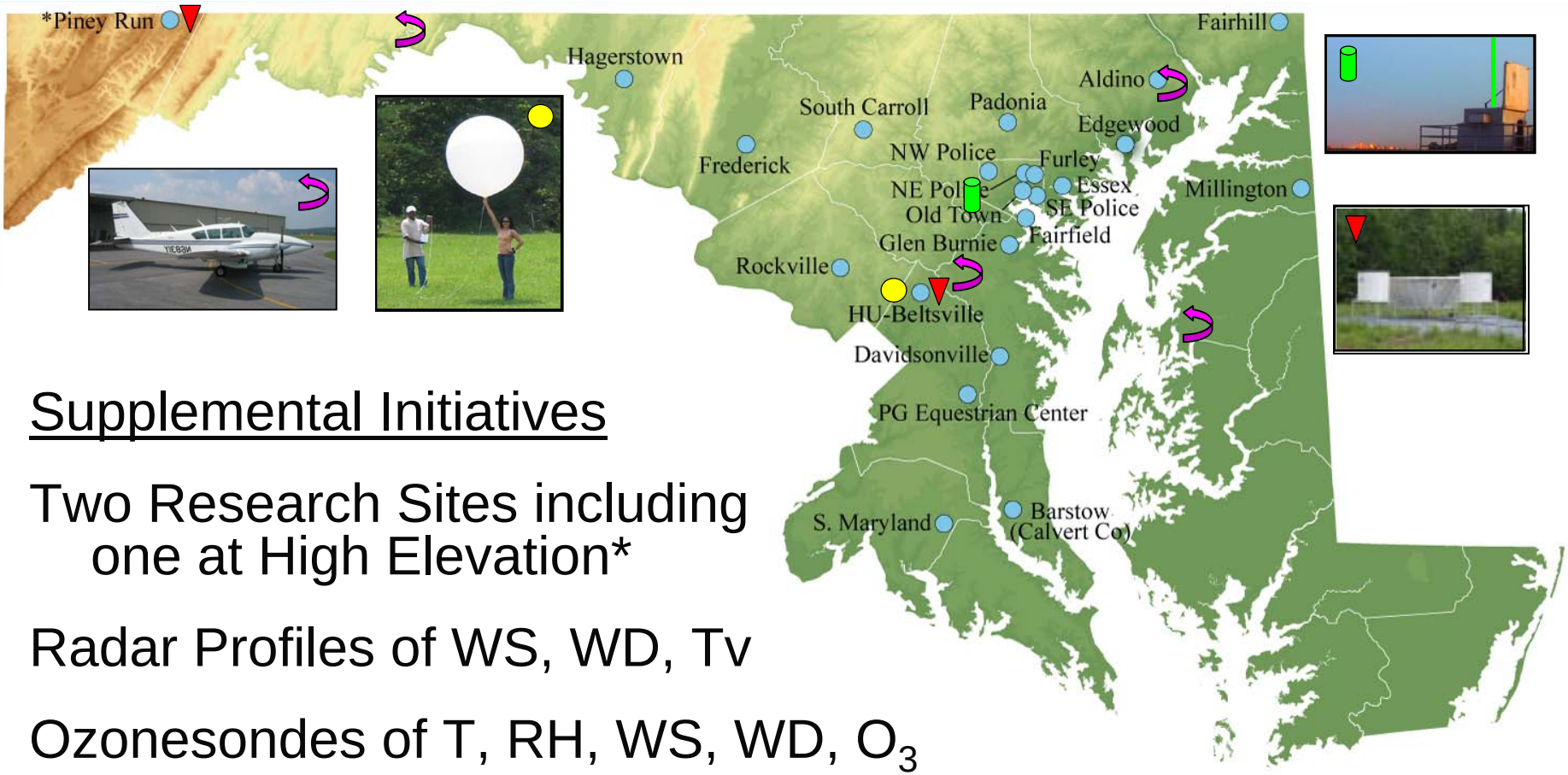
EPA NAQC, February 2007, Orlando, FL

Ambient Air Quality Monitoring



Supplemental Initiatives

Two Research Sites including one at High Elevation*

Radar Profiles of WS, WD, Tv

Ozonesondes of T, RH, WS, WD, O_3

LIDAR Profiles of Aerosols

Aircraft Spirals of Trace Gases & Aerosols

Piney Run Research Site

Transport Site
- High Elevation, Rural, Western Boundary
- Regional Background Pollutant Load

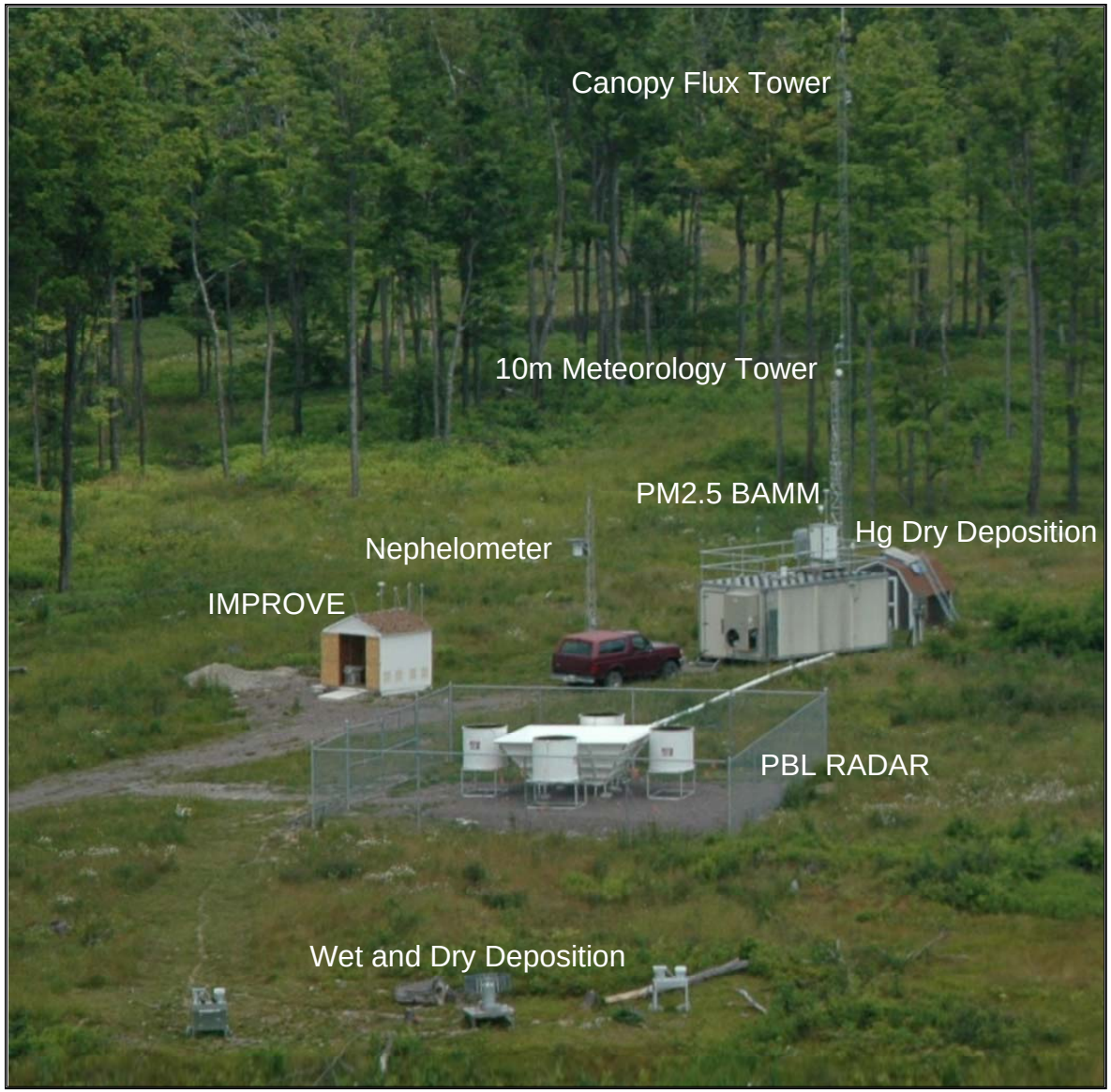
“Research Site”…

Aerosols:
- IMPROVE
- OCEC
- Continuous SO4
- Particulate & Elemental Hg

Trace Level Gases
- SO2
- CO

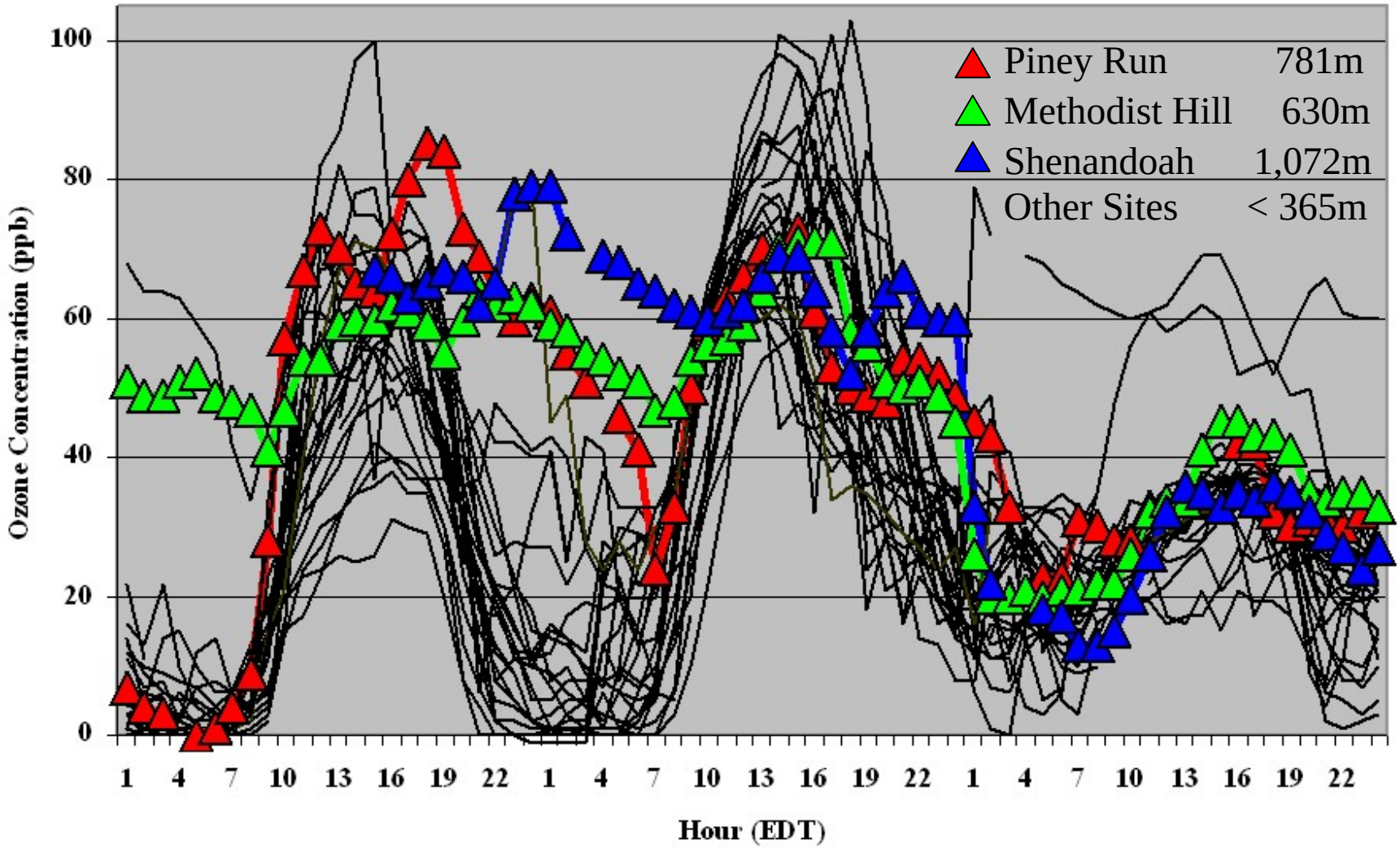
Radar Wind Profiler
- WS, WD, Tv

Network Participation
- EPA NCORE
- EPA CASTNET
- IMPROVE
- Frostburg University Bird Migration Studies



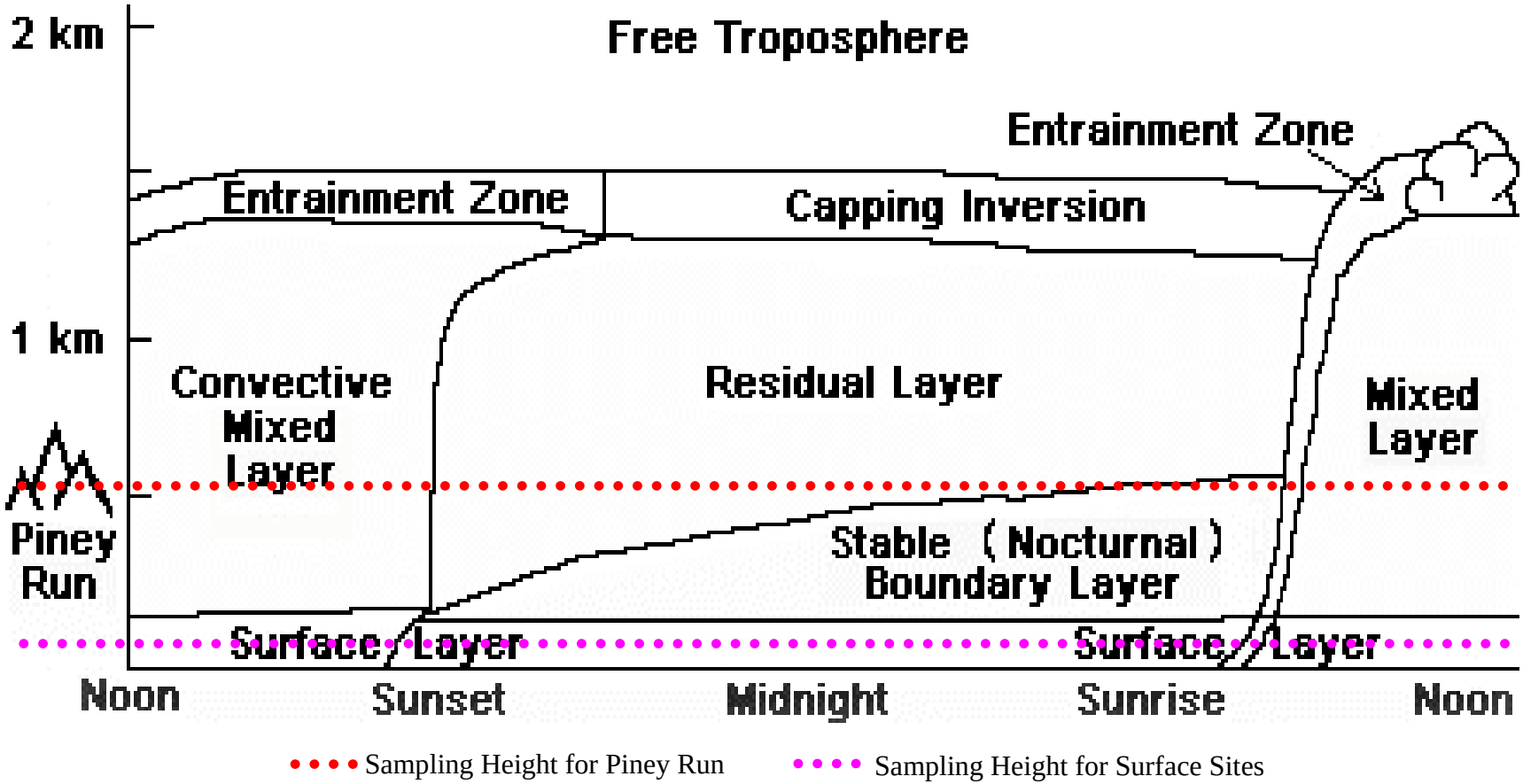
Case: High Elevation Ozone

August 3-5, 2004



Plot shows every site in Maryland and every site from other states within 100 km of Piney Run.

Layers & Mixing



The high elevation site's position above the nocturnal boundary layer decouples those sites from the ozone-depleting mechanisms. This diagram shows how Piney Run sometimes remains in the residual layer of the boundary layer.

Reference: After Stull, R.B., *An Introduction to Boundary Layer Meteorology;* Kluwer Academic, Norwell, MA, 1988

Beltsville Research Site

Metropolitan Corridor Site

- Mobile Emission Sources
- Minor Industrial Sources

Instrumentation is similar to Piney Run:

- Intensive Aerosols
- Trace-Level Gases
- Radar Wind Profiler

Network Participation

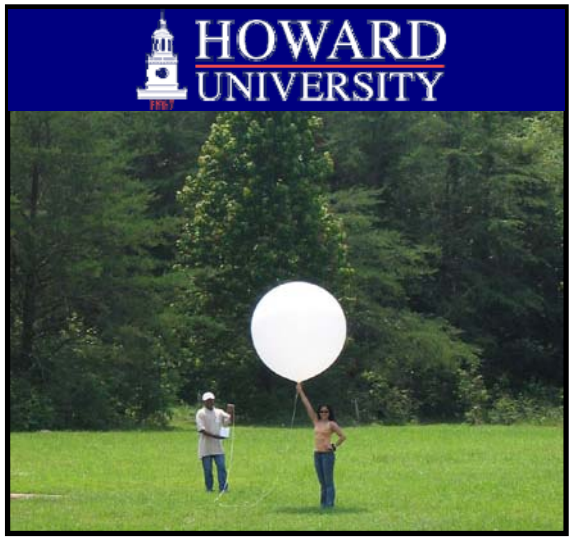
- EPA NCORE
- Nearby EPA CASTNET

Howard University site host

- H2Ov LIDAR
- Radiation studies

Home to Ozonesonde Campaign

Ozonesondes



Campaign operated by Howard University under P.I. Everette Joseph

Sonde package is suspended fifty feet below the balloon

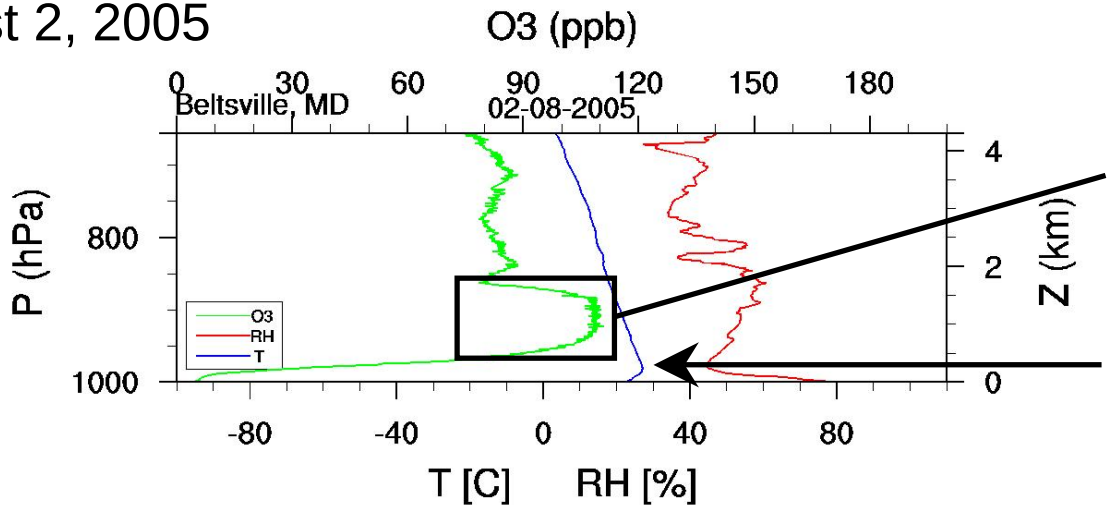
The GPS receiver provides winds and is sensitive enough to detect the swing of the sonde beneath the balloon

LAUNCHES	2005	2006
Morning (6AM – Noon)	10	3
Afternoon (Noon – 6PM)	9	12
Night (6PM – 6AM)	3	9

Case: Residual Layer & Mixing

August 2, 2005

7 AM

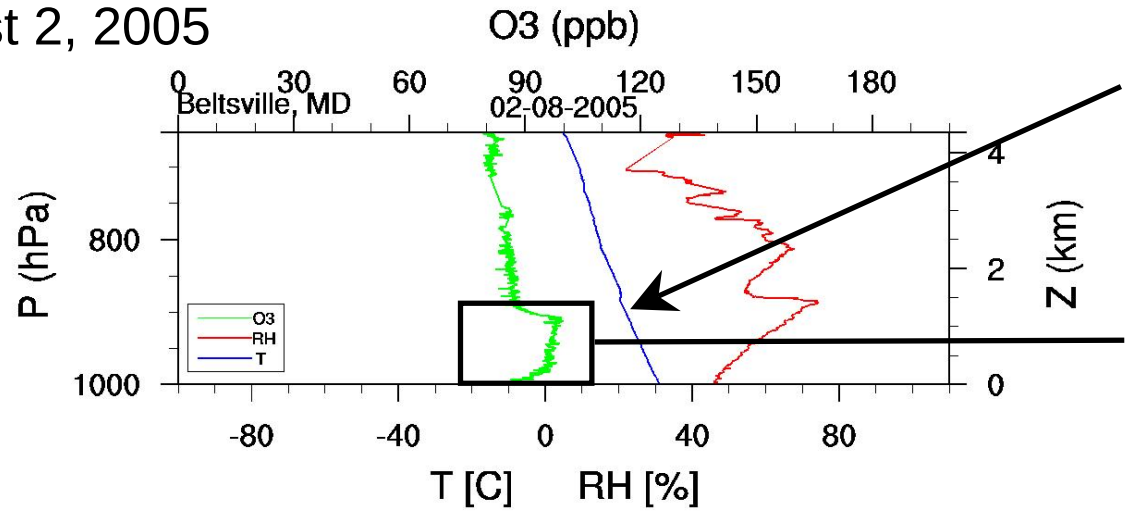


Nocturnal Residual Layer from 0.5-1.5km of **110ppb**

Inversion @ 0.3km and an ozone-poor, moist surface layer

August 2, 2005

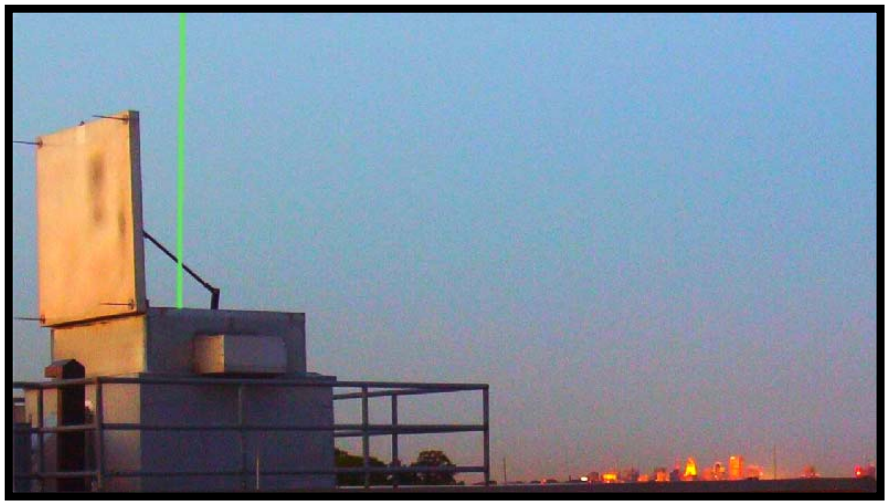
2 PM



Less stable, Turbulent Boundary Layer

Residual Layer and Surface Layer are well mixed in the late afternoon boundary layer with 90-100ppb

LIDAR



Operated at UMBC in Catonsville, MD under the direction of P.I. Ray Hoff

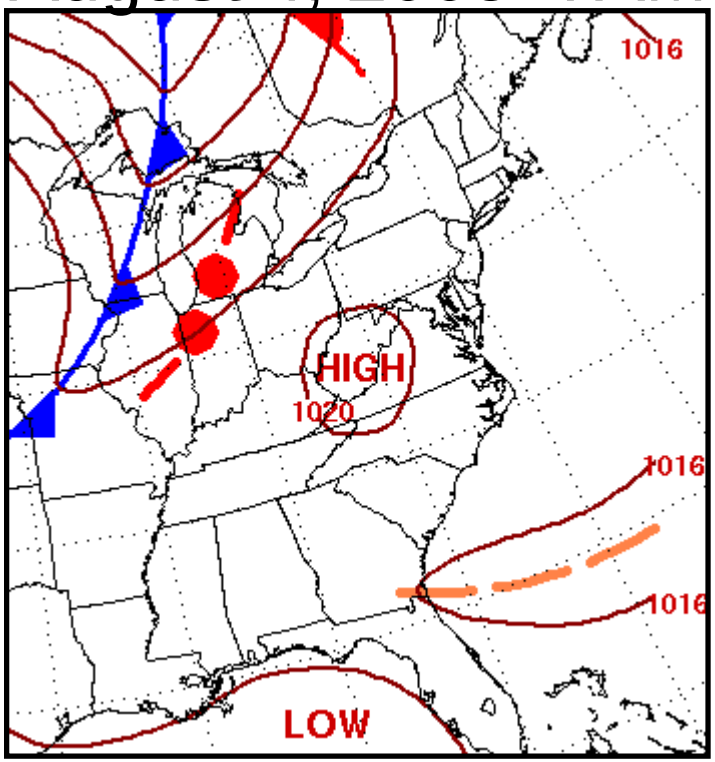
MDE joined project in 2005

Cases occur when satellite imagery shows haze over a region; but upon closer inspection surface monitors reveal that the aerosols have not mixed to the surface.

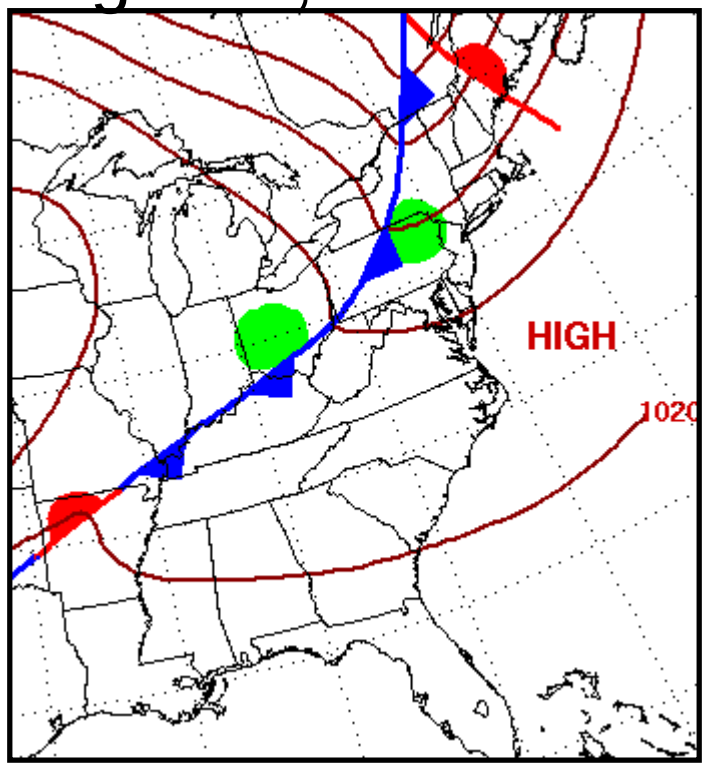
The LIDAR fills a niche by showing the proximity of the aerosols to the surface and whether the aerosols should be a greater concern for the air quality forecasters.

Case: Nocturnal Low Level Jet

August 4, 2005 7AM



August 5, 2005 7AM



This episode included two major factors: Westerly Transport under High Pressure and Pre-Frontal accumulation of pollutants.

As such, August 4-5, 2005 was a highly anticipated air quality episode, so three ozonesondes were launched at Beltsville during the two day period.

The nocturnal low level jet was observed using four independent measurement platforms: two of the in-situ ozonesondes and two remote sensors: the LIDAR and RADAR.

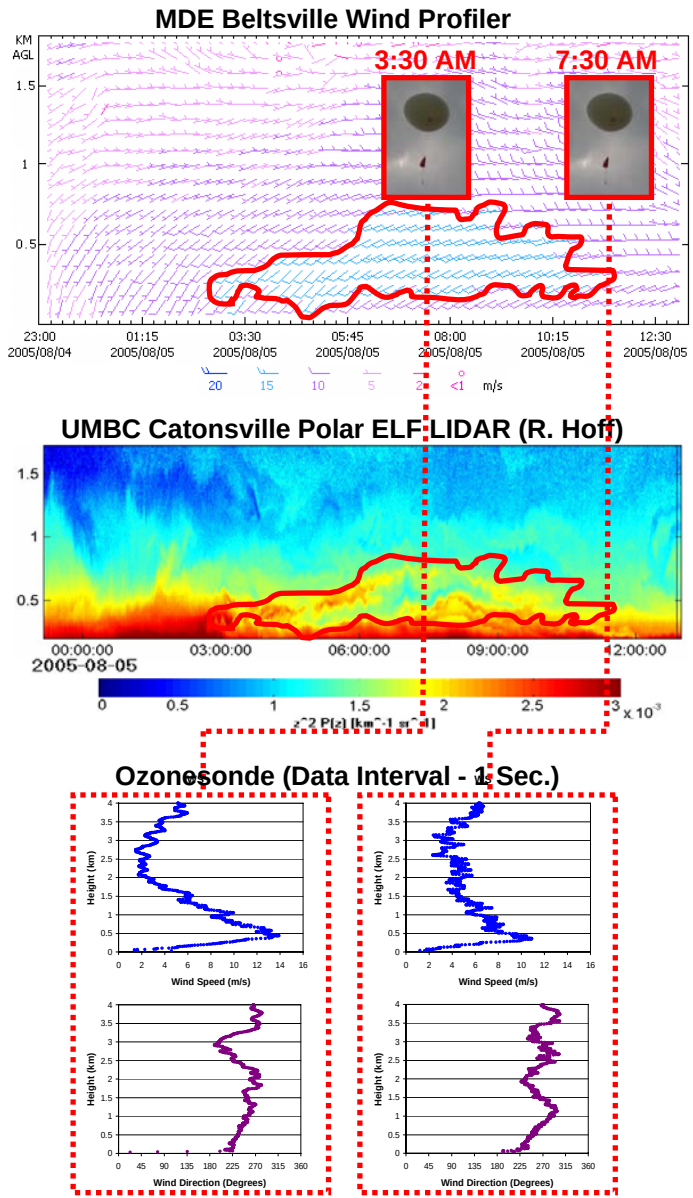
Case: Nocturnal Low Level Jet

The MDE RADAR wind profiler in Beltsville remotely detected the LLJ at a height of 0.2km-0.8km for a period of 8.5 hours

The UMBC LIDAR in Catonsville remotely detected a thick residual aerosol layer experiencing enhanced turbulent inhomogeneities and stratification at the same heights and for the same period of time

Finally, two independent ozonesondes were launched four hours apart in Beltsville and both measured the LLJ in-situ.

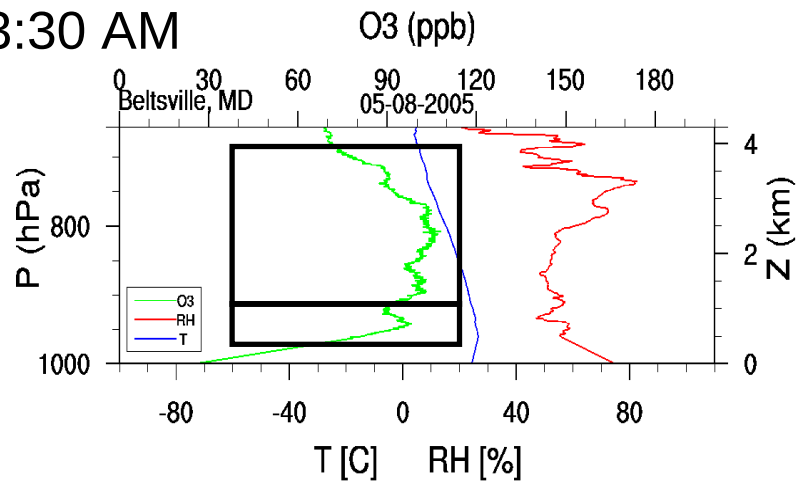
The 3:30 AM and 7:30 AM launches detected peak LLJ speeds of approximately 14m/s at 0.5km and 11m/s at 0.4km, respectively. In both cases the winds veered from the surface to the core of the LLJ and continued veering through the rest of the LLJ up to 1.3km where the winds were weak at 6m/s and began backing.



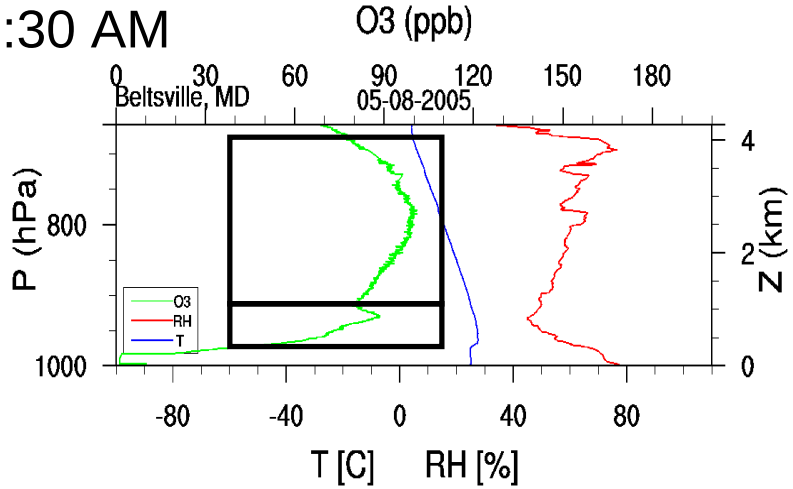
Case: NLLJ - What is in it?

- Within the NLLJ of SW winds there is a considerable local maxima of ~13ppb with a total concentration of ~95ppb
- Above the NLLJ the residual layer contains the bulk of ozone which mixes down after the sun rises and warms the surface

3:30 AM



7:30 AM



The same turbulence that the LIDAR picked up was also seen in some ozone monitors that were operating on 5 minute averages (Taubman). MDE is switching all ozone monitors to collect 5 minute averages.

Aircraft

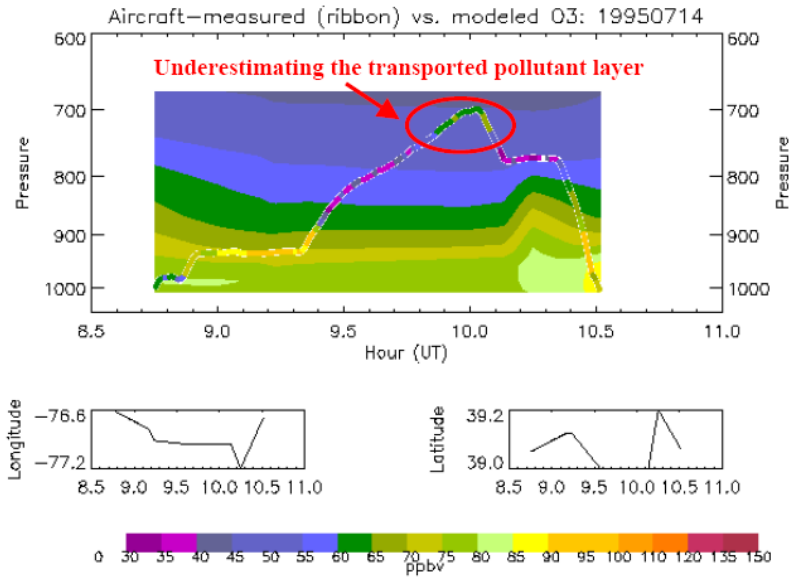
Operated by the University of Maryland under the direction of P.I. Russell Dickerson and based out of Fort Meade, Maryland

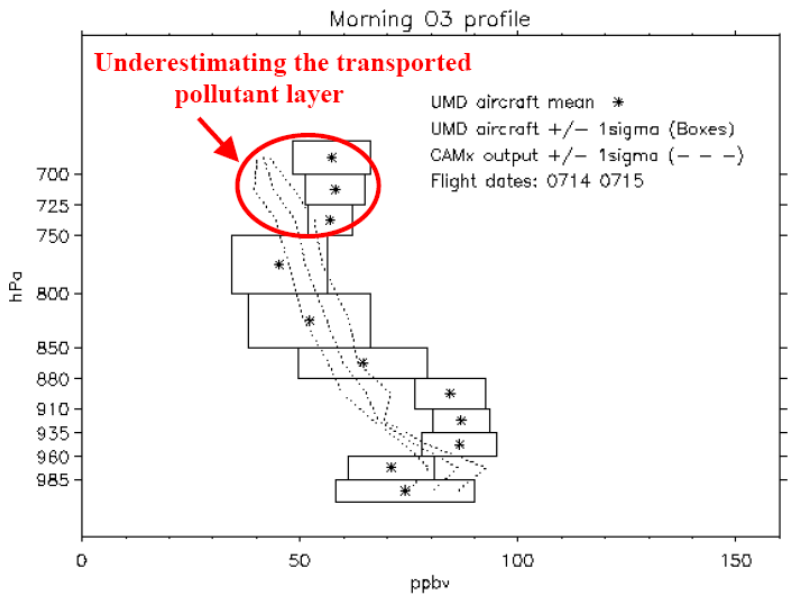
Flights have taken place since 1995

Measurements include Trace Gas concentrations and Aerosol characteristics

Case: Aircraft vs Model

- Model evaluation tool
- UMD performed an evaluation of CAMx modeling for the CAIR (née IAQR)
- Comparison showed better model performance in afternoon than in morning
- Showed model inability to capture elevated reservoir of transported ozone entering Maryland

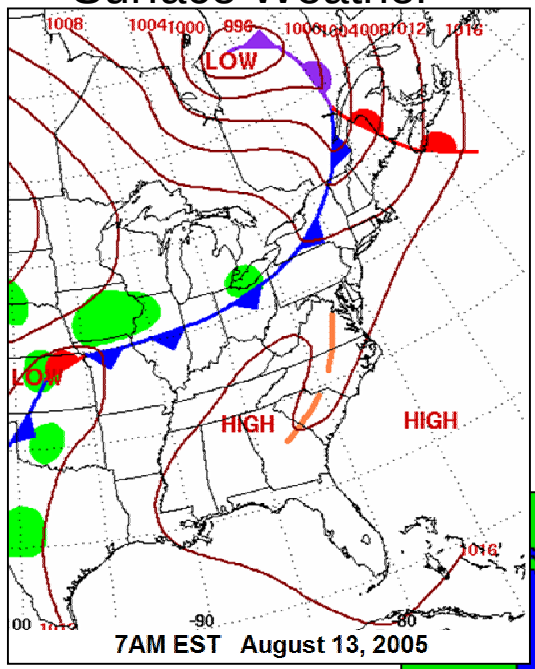




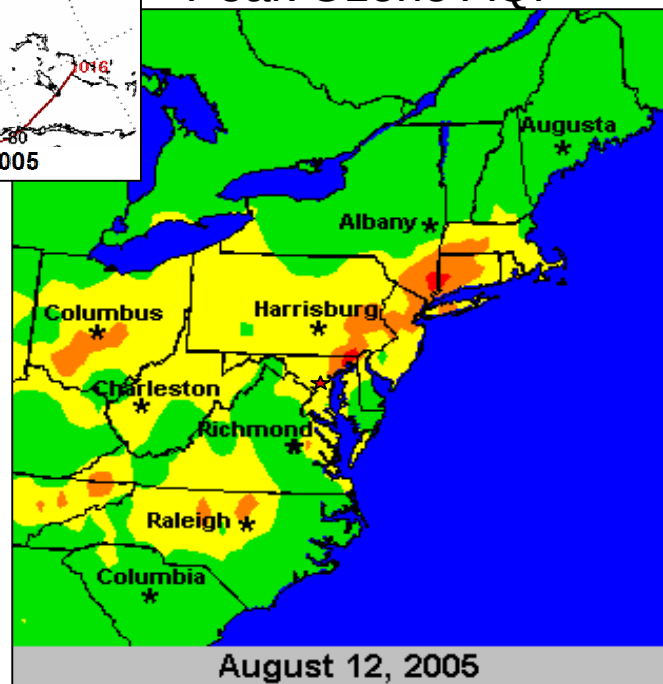
Case: Transport

- August 12-13, 2005 - a classic high ozone case evolved
  - Strong Bermuda High
  - Appalachian Lee-Side Trough
  - Local Stagnation
- The emissions contributions occurred via synoptic-scale westerly transport, regional-scale nocturnal low level jet (LLJ), and local-scale emissions
- The transport mechanisms were all in place for a tremendous ozone episode. Fortunately, the previous (August 12) day's upwind ozone AQI readings were only moderate.

Surface Weather



Peak Ozone AQI



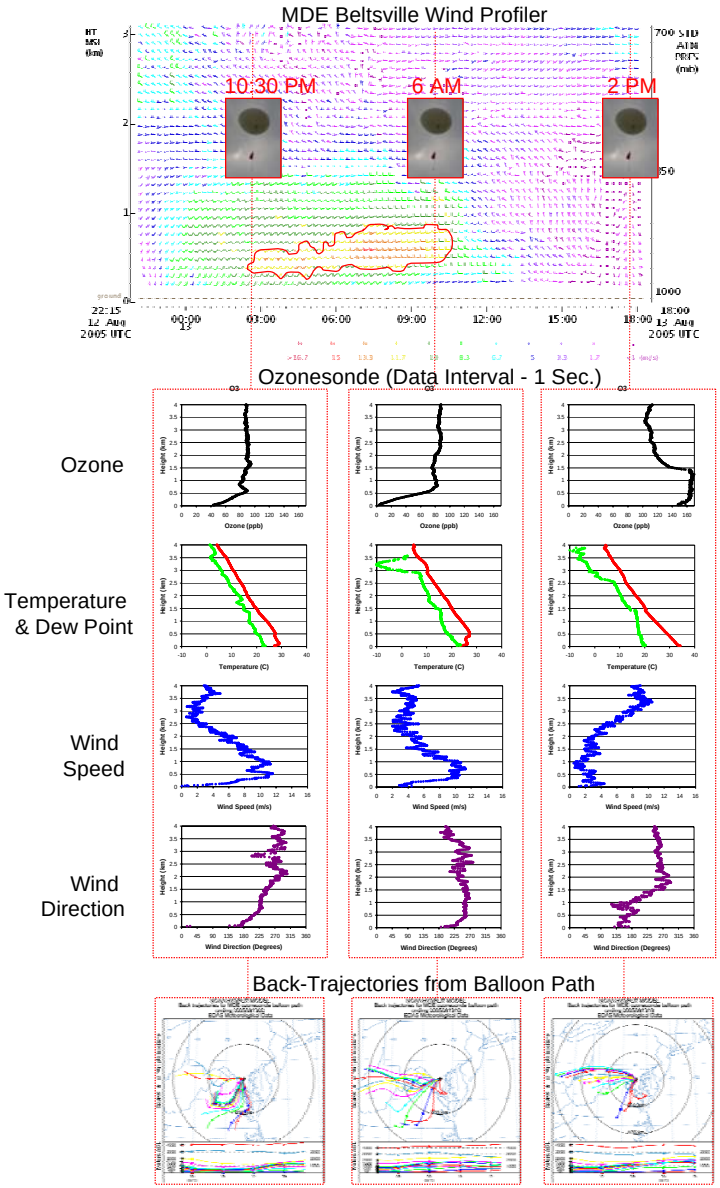
Case: Transport

Three balloon launches captured the case:

10:30 PM – Slow surface winds veer to a peak speed of 12 m/s that coincides with an ozone local maxima of 90 ppb where a nocturnal inversion is beginning to setup at 0.6 km. Near the inversion wind speeds reveal the early formation of a LLJ, with slower westerly winds aloft. Balloon path back trajectories show consistent SW winds.

6 AM – The nocturnal inversion is now more pronounced and the ozone profile shows minor increases in ozone within the LLJ. The profiler confirms the LLJ from the WSW remains strong; however the back-trajectories now show the onset of a westerly contribution.

2 PM – The afternoon atmosphere is less stable and well mixed. Winds are light as ozone concentrations build. Ozone concentrations reach a maximum of 170 ppb at 1.4km. The surface peak 8-hr AQI at Beltsville was 109 - Code Orange. Peak 1-hr ozone was 108 ppb.



Case: Transport

- Google Earth movie of 2005 aircraft transects and spirals
- The aircraft data help explain the spatial extent of the interstate transport region and the magnitude of the aloft residual reservoir

Acknowledgements

Co-Authors: Duc Nguyen, Michael Woodman

Project Support: David Krask, Tad Aburn

Contracting University Field Experiments:

Howard University, Everette Joseph – Ozonesondes

University of Maryland at Baltimore County, Ray Hoff – LIDAR

University of Maryland at College Park, Russel Dickerson – Aircraft

Visit Demonstration at Poster Session

Maryland Department of the Environment

THE END

Ambient Air Monitoring Program

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Site Parameters

23 Sites	Parameter
Aldino	NO, NO_2, NO_y, O_3, Meteorology^{10m}
Beltsville Research Site	NO, NO_2, O_3, $SO_2{}^{(T)}$, Meteorology^{10m}, Meteorology^{PBL}, $PM_{2.5}{}^{FRM}$, $PM_{2.5}{}^{BAMM}$, $PM_{2.5}{}^{TEOM/FDMS}$ $PM_{2.5}{}^{SpeciesSTN}$, $PM_{2.5}{}^{OCEC}$, $PM_{2.5}{}^{SO4}$, PAMS, Toxics
Calvert	O_3
Davidsonville	O_3, Meteorology^{10m}
Edgewood	O_3, Meteorology^{10m}, $PM_{2.5}{}^{FRM}$
Essex	CO, NO, NO_2, O_3, SO_2, Meteorology^{10m}, $PM_{2.5}{}^{FRM}$, $PM_{2.5}{}^{SpeciesSTN}$, $PM_{10}{}^{BAMM}$, PAMS, Toxics
Fairfield	$PM_{2.5}{}^{FRM}$ (Colocated), $PM_{10}{}^{FRM}$ (Colocated)
Fairhill	O_3, Meteorology^{10m}, $PM_{2.5}{}^{FRM}$, $PM_{2.5}{}^{BAMM}$
Frederick	O_3
Furley	O_3
Glen Burnie	$PM_{2.5}{}^{FRM}$, $PM_{10}{}^{BAMM}$
Hagerstown	O_3, $PM_{2.5}{}^{FRM}$, $PM_{2.5}{}^{BAMM}$
Millington	O_3, Meteorology^{10m}
NE Police	$PM_{2.5}{}^{FRM}$, Toxics
NW Police	$PM_{2.5}{}^{FRM}$
Oldtown	CO, NO, NO_2, NO_y, O_3, SO_2, $PM_{2.5}{}^{FRM}$, $PM_{2.5}{}^{BAMM}$, $PM_{2.5}{}^{TEOM/FDMS}$ $PM_{2.5}{}^{TEOM}$, Toxics
Padonia	O_3, Meteorology^{10m}, $PM_{2.5}{}^{FRM}$
PG Equestrian	O_3, Meteorology^{10m}, $PM_{2.5}{}^{FRM}$ (Colocated)
* Piney Run Research Site	$CO^{(T)}$, NO, NO_2, NO_y, O_3, $SO_2{}^{(T)}$, Meteorology^{10m}, Meteorology^{PBL}, $PM_{2.5}{}^{BAMM}$, $PM_{2.5}{}^{TEOM/FDMS}$ $PM_{2.5}{}^{SpeciesSTN}$, $PM_{2.5}{}^{SpeciesIMPROVE}$, $PM_{2.5}{}^{OCEC}$, $PM_{2.5}{}^{SO4}$, Scattering, Dry Hg
Rockville	O_3, Meteorology^{10m}, $PM_{2.5}{}^{FRM}$
SE Police	$PM_{2.5}{}^{FRM}$, $PM_{10}{}^{FRM}$
South Carroll	O_3
Southern MD	O_3

Abstract

Section: Ambient Monitoring Related to Air Quality Forecasting and Reporting

The Maryland Department of the Environment (MDE) Air Quality Monitoring Program is actively seeking to characterize the amount of interstate pollutant transport arriving in Maryland through several measurement initiatives. Vertical profiles of air quality and meteorological parameters have been measured through various techniques over the past decade either directly by MDE or indirectly through university contracts. The measurement initiatives include aircraft trace gas profiles and transects, radar wind and temperature profiles, LIDAR aerosol profiles, and most recently, an ozonesonde measurement campaign for the summers of 2005 and 2006. MDE prepared the ozonesonde scope of work, designed the data products, and proposed a seasonal and diurnal schedule, which was then carried out through a contract with The Howard University (HU) Physics Department. The launch site is located at a HU satellite campus in Beltsville, Maryland. The scope of work called for up to 30 ozonesonde launches to occur 3 times per day (pre-dawn, mid-late afternoon, and early evening) during 10 ozone episode days. The decision for which days to launch was determined by MDE meteorologists along with input from other Mid-Atlantic air quality forecasters. The goals of the campaign were three-fold: The primary goal was to collect ozone profiles to capture residual layer transport of ozone via the predominant westerly wind direction and the nocturnal low-level jet. Secondly, the transport measurements would be evaluated to provide insight to interstate pollutant transport and equitable interstate control strategies. Finally, the ozonesonde launches would be rolled into the MDE daily air quality forecasting and outreach program. A total of 22 ozonesonde launches occurred between May 30 and August 30, 2005, and 24 launches during the same time period of 2006. Data from launches during the summer of 2006 are currently being compiled. Preliminary results show evidence of large-scale residual layer transport and the occurrence of a nocturnal low-level jet as detected by ozonesonde measurements, which appear to verify with the MDE boundary layer wind profiler at Beltsville, Maryland and the LIDAR located in Catonsville, Maryland at the University of Maryland at Baltimore County. MDE has been experimenting with unique data visualization techniques to provide insight to these rich datasets.

Keyword: Ozonesonde, Transport, Residual Layer, Wind Profiler, LIDAR