Determination of Planetary Boundary Layer Heights on Short Spatial and Temporal Scales from Surface and Airborne Vertical Profilers during DISCOVER-AQ

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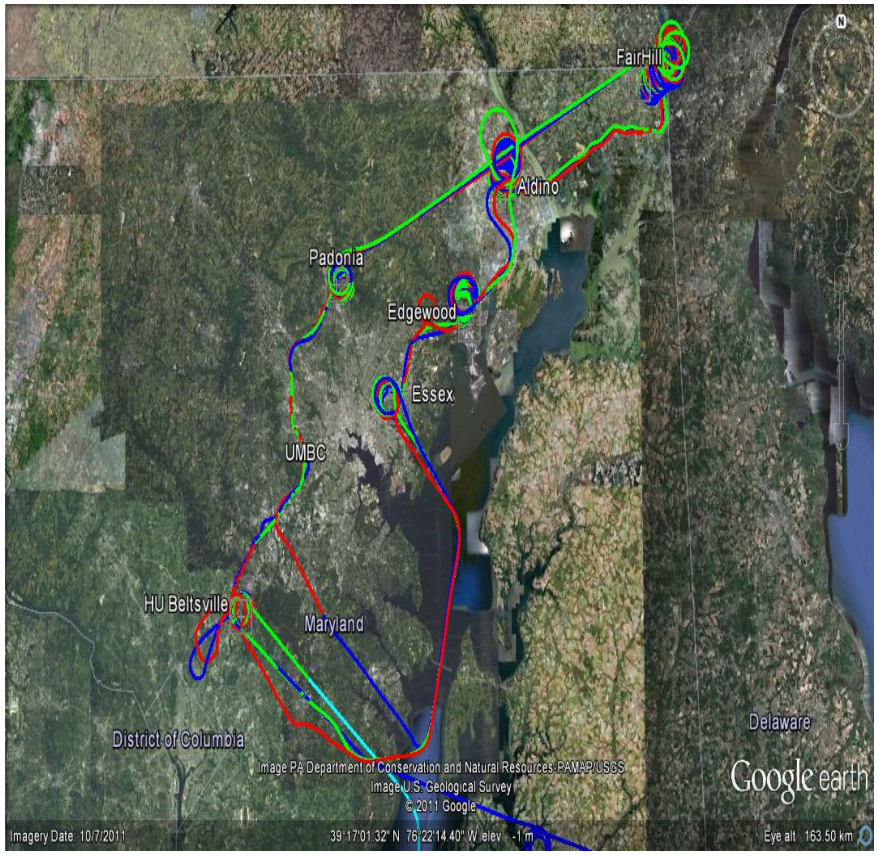
UMBC NASA-GSFC JCET

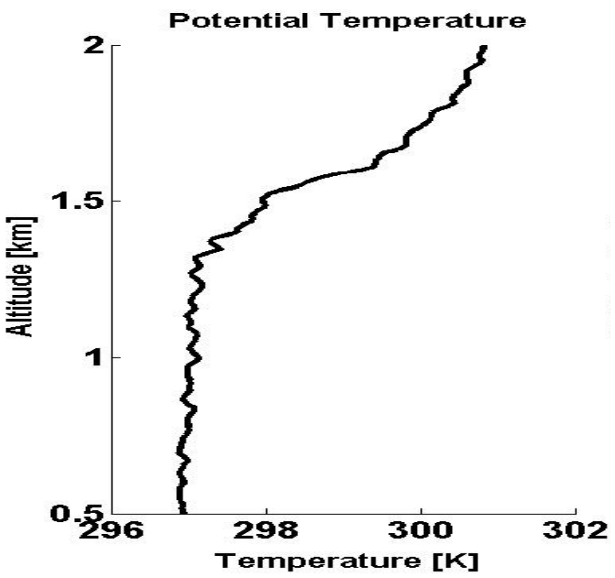
DISCOVER-AQ

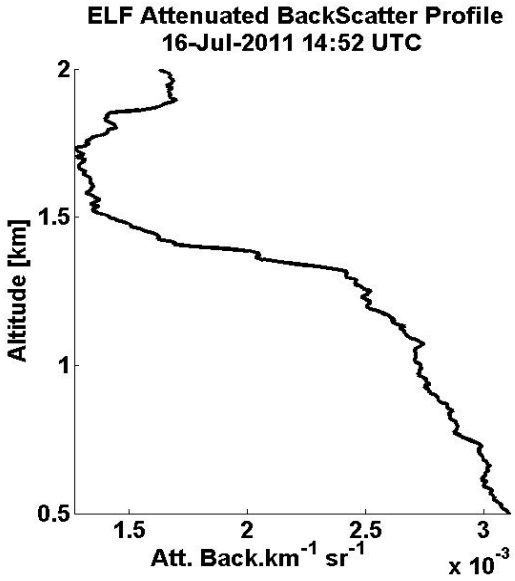
Deriving Information on Surface Conditions from Column and Vertically Resolved Observations Relevant to Air Quality (DISCOVER-AQ) is a NASA Earth Venture program funded mission designed to examine the representativeness of column optical properties from satellites to ground-based air quality. This campaign was carried out in the Baltimore-Washington metro area during July 2011.

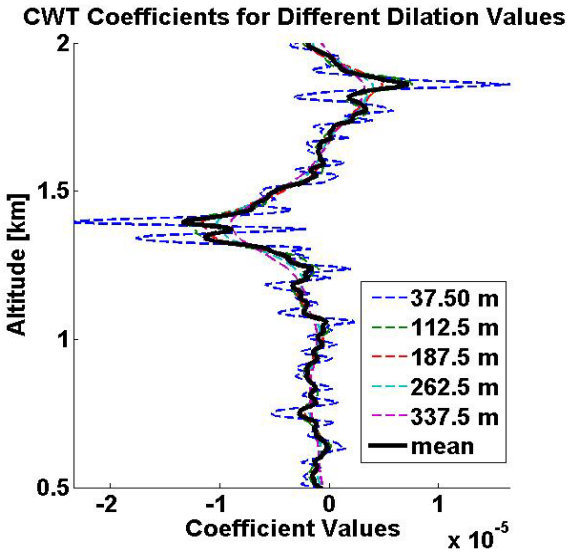


GroundSite	Lat(°)	Lon(°)
Aldino	39.5633	-76.2039
Edgewood	**39.4100**	**-76.2969**
Essex	39.3107	-76.4744
FairHill	**39.7013**	**-75.8599**
HU-Beltsville	**39.0561**	**-76.8783**
Padonia	39.4620	-76.6315
UMBC	**39.2546**	**-76.7093**

Determination of PBLH



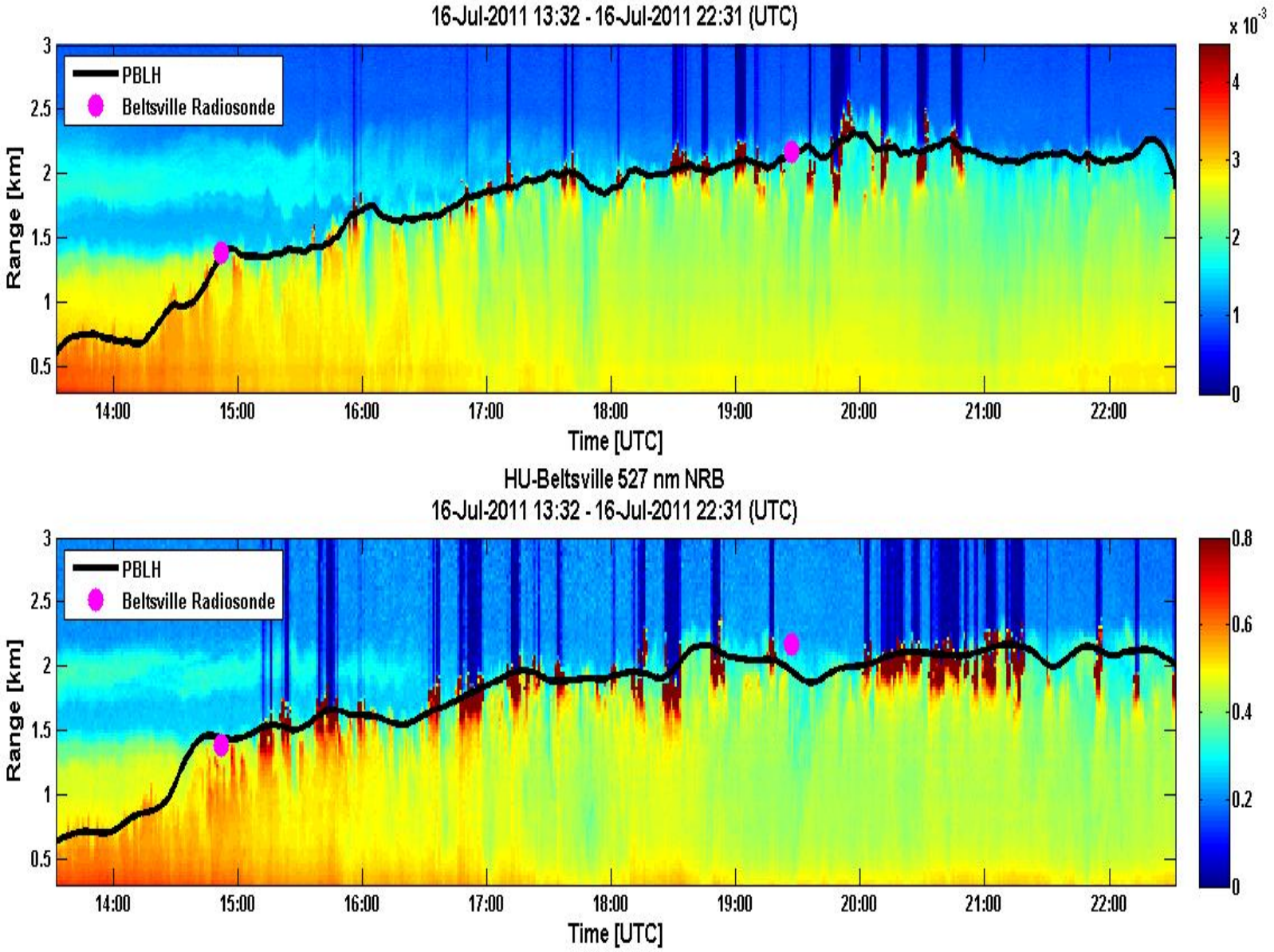


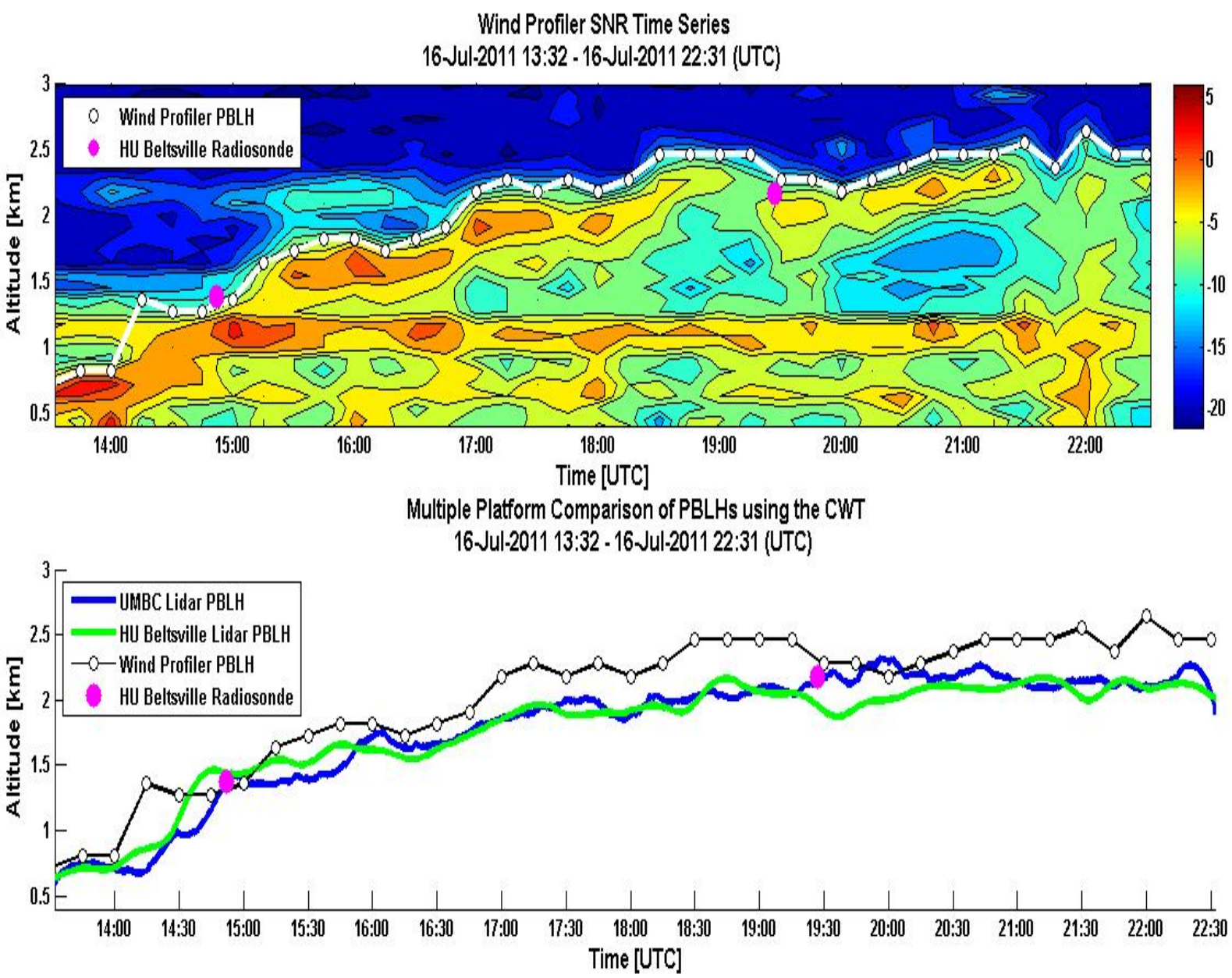


- Comparison of multi-platforms/methods:
  - Radiosondes: Potential Temperature Inversion
  - Lidar: ***Haar Covariance Wavelet Transform*** in Aerosol Backscatter
  - Wind Profiler: ***Haar Covariance Wavelet Transform*** in the SNR

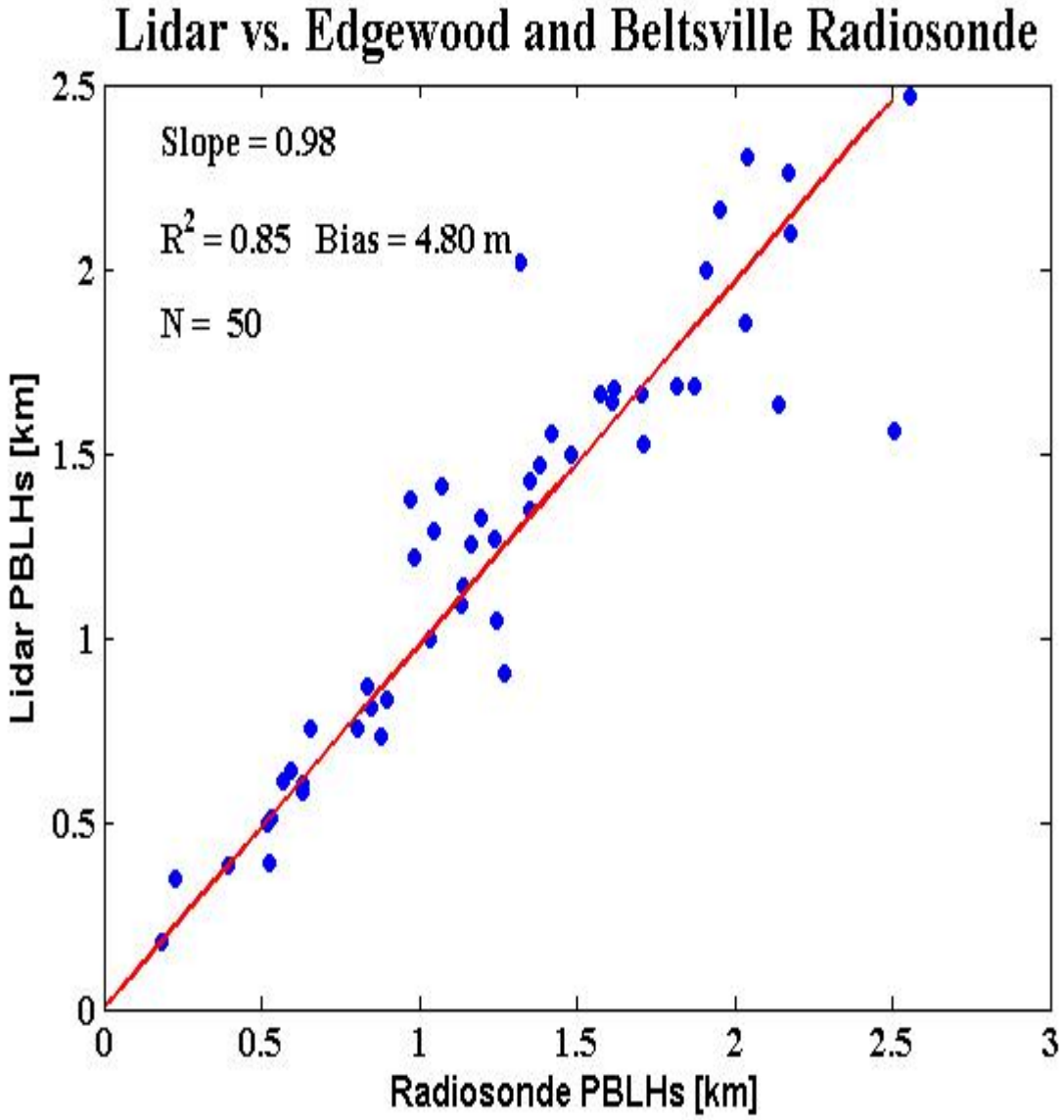
Compton et al.:

"Determining Planetary Boundary Layer Heights with Ground-based Lidar and Wind profiler on Short Spatial and Temporal Scales"


UMBC 532 nm Attenuated Backscatter
16-Jul-2011 13:32 - 16-Jul-2011 22:31 (UTC)
x 10^-3
PBLH
Beltsville Radiosonde
Range [km]
Time [UTC]
HU-Beltsville 527 nm NRB
16-Jul-2011 13:32 - 16-Jul-2011 22:31 (UTC)
PBLH
Beltsville Radiosonde
Range [km]
Time [UTC]

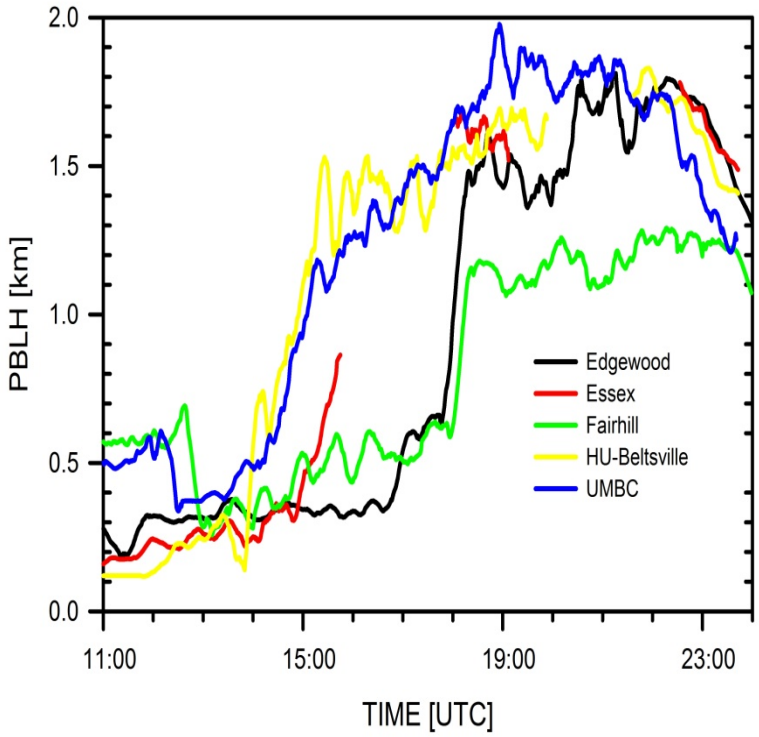


Compton, J. (UMBC), M.S. Thesis, 2012

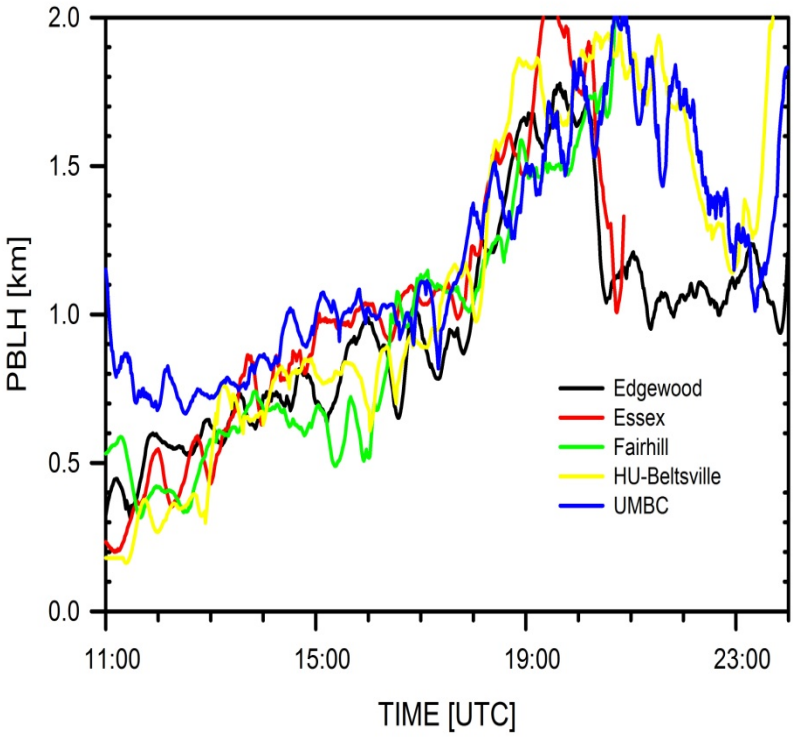

Lidar vs. Edgewood and Beltsville Radiosonde
Slope = 0.98
R2 = 0.85 Bias = 4.80 m
N = 50
Lidar PBLHs [km]
Radiosonde PBLHs [km]
0
0.5
1
1.5
2
2.5
3

Daily PBLH Variability

July 21, 2011

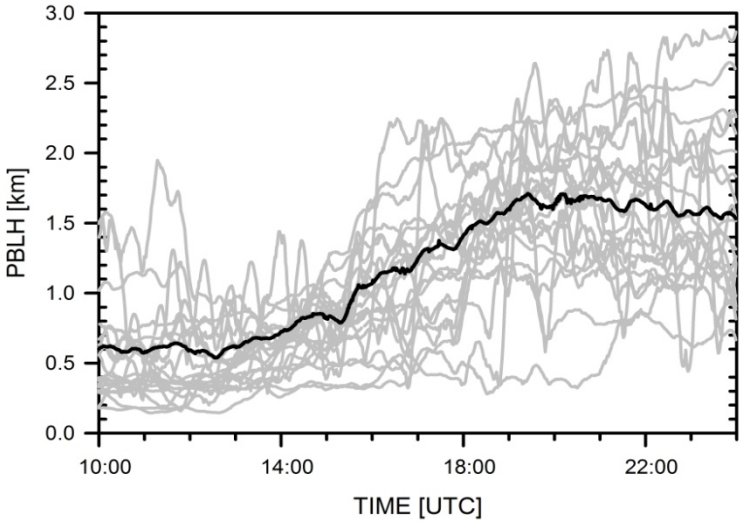


July 26, 2011

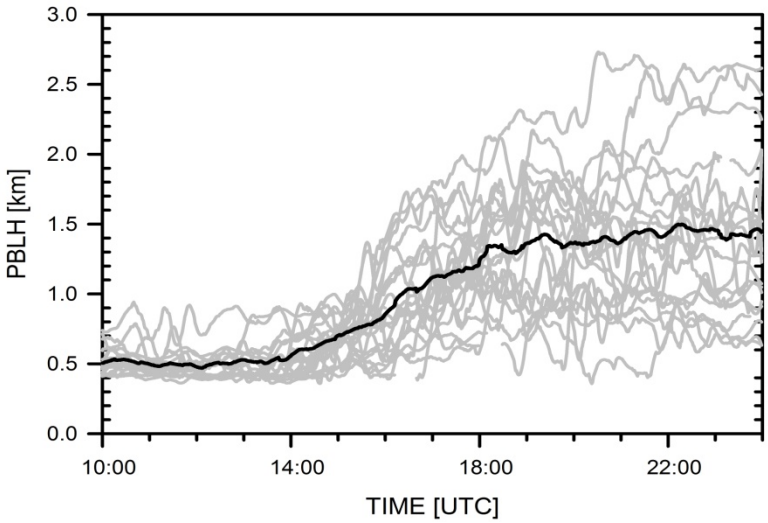


Spatial Variability

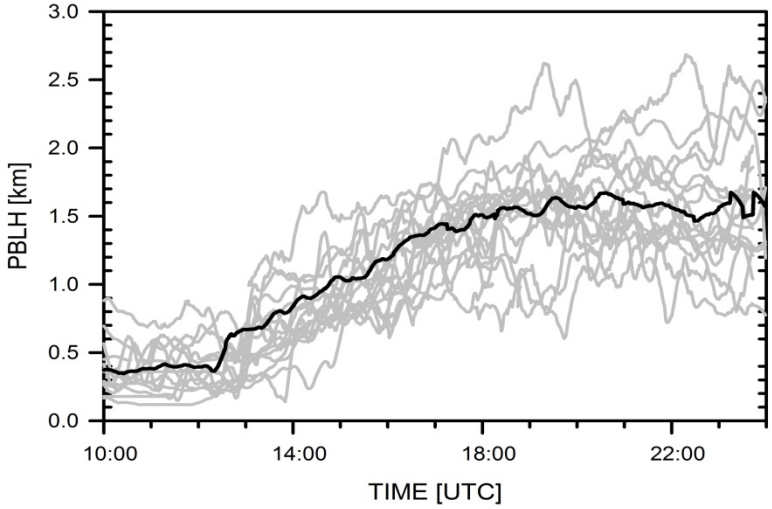
Edgewood



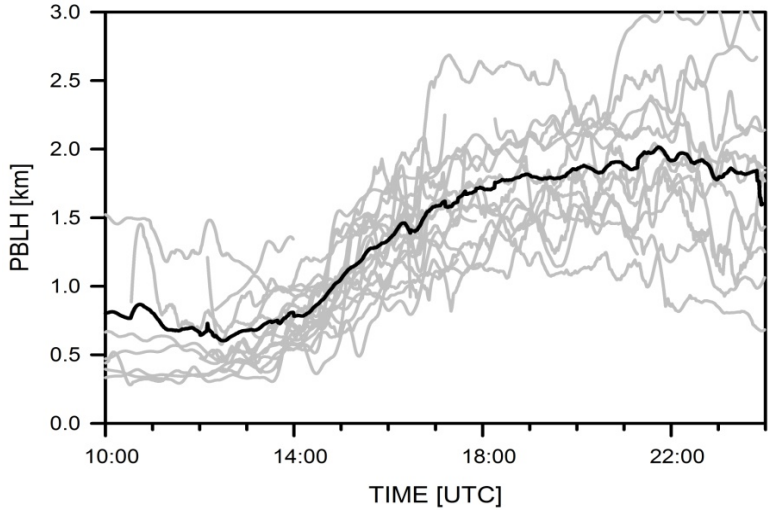
Fairhill



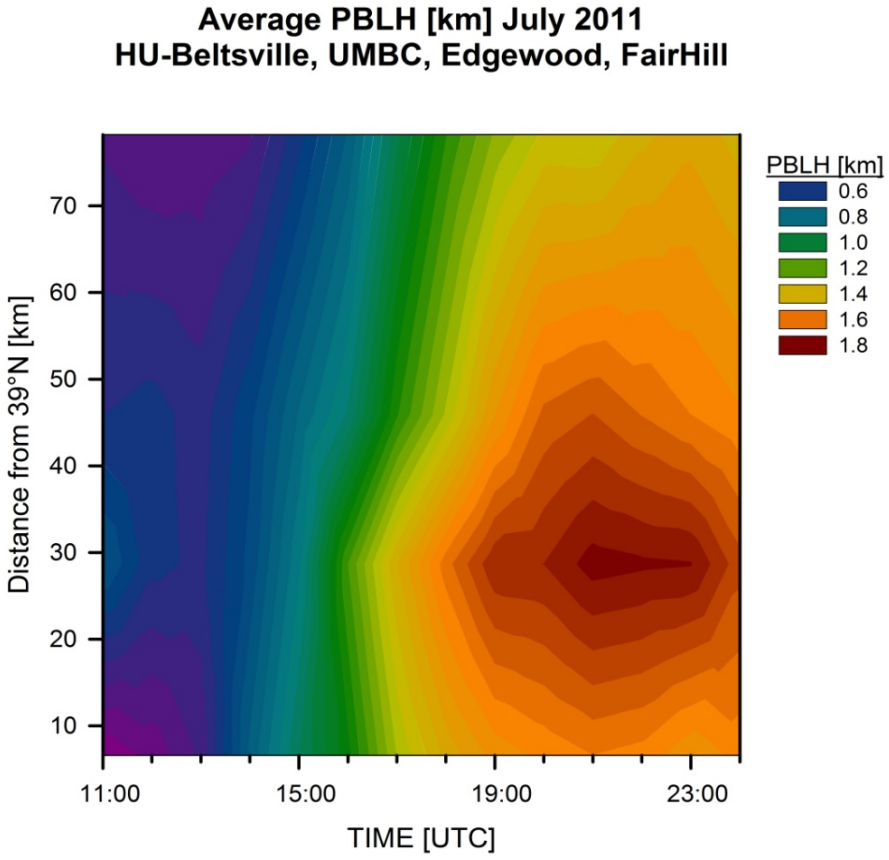
HU Beltsville

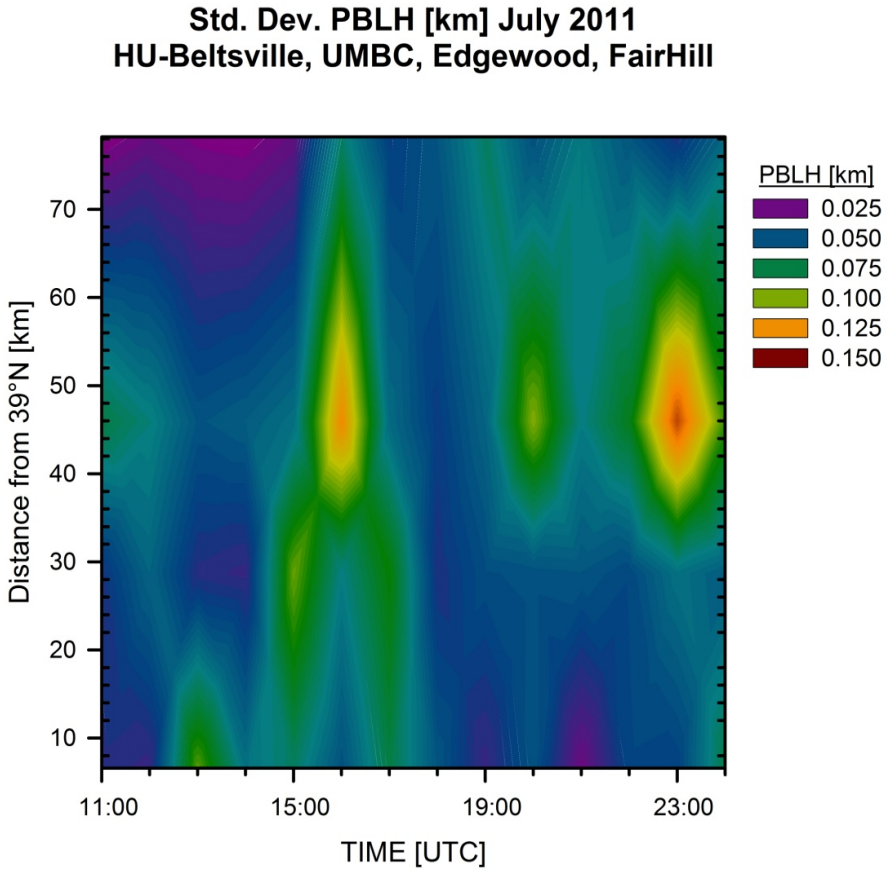


UMBC



Spatial Variability





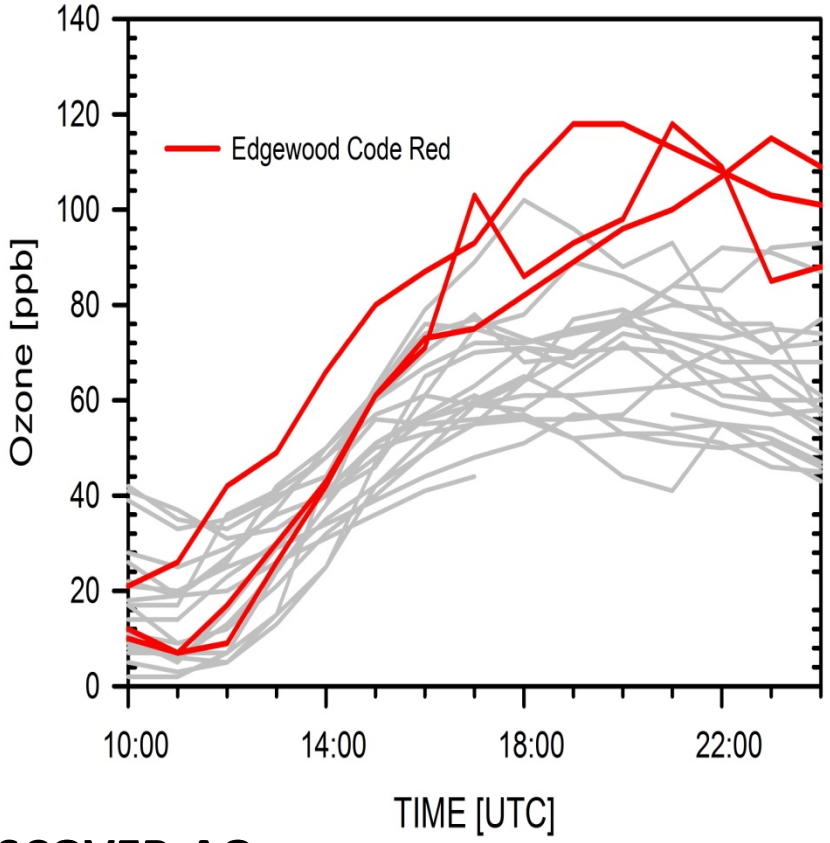
HU-Beltsville and UMBC (Urban sites):

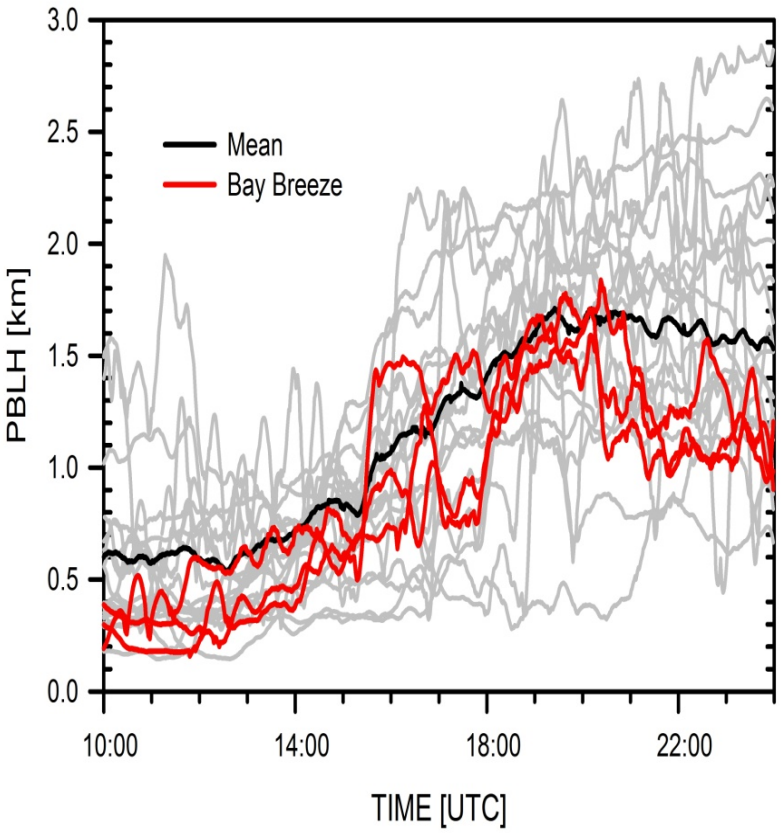
Higher surface temperatures and increased convection result in higher afternoon mixing depths and larger diurnal ranges.

Edgewood:

Greatest variability in the evolution of PBL. Forcing mechanisms (heat and moisture surface fluxes) dependent of mesoscale processes (i.e, bay breeze).

Code Red Air Quality Episodes
Bay Breeze Circulation





DISCOVER-AQ:

- Four occurrences (3 Edgewood and 1 Aldino) of [O_3] reaching Code Red AQI levels.
- Edgewood occurrences associated with Bay Breeze Circulation.

More on this topic on tonight poster session:

- Ryan Stauffer:

Bay Breeze Impact on Surface Ozone at Edgewood, MD.

- Rich Clark:

Air Chemistry Interactions with Mesoscale Sea-Breeze and Outflow Boundaries in the Edgewood, MD Area.

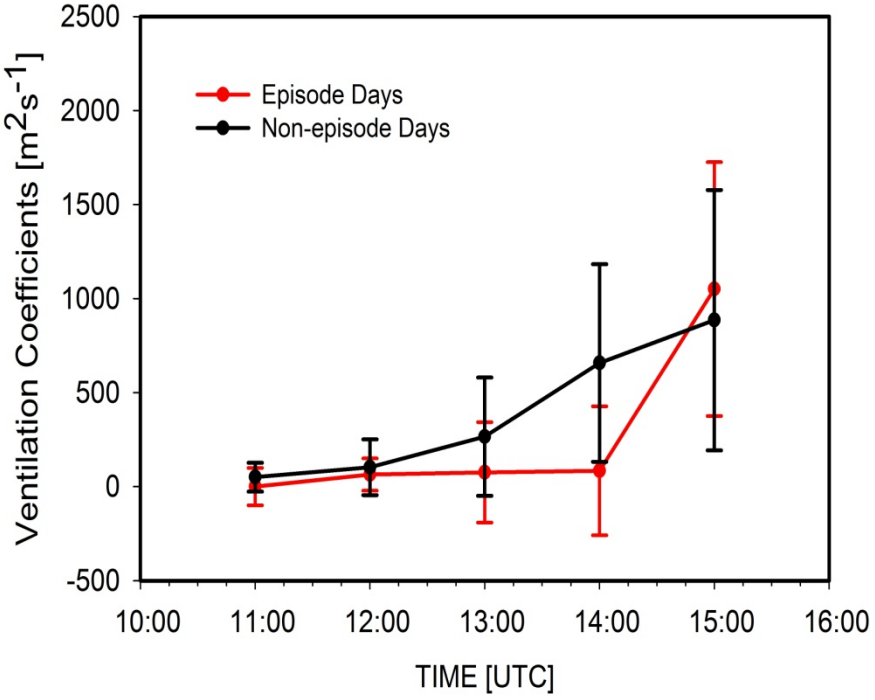
- Chris Loughner:

Evaluation of CMAQ boundary layer processes and air quality over the Chesapeake Bay and Maryland .

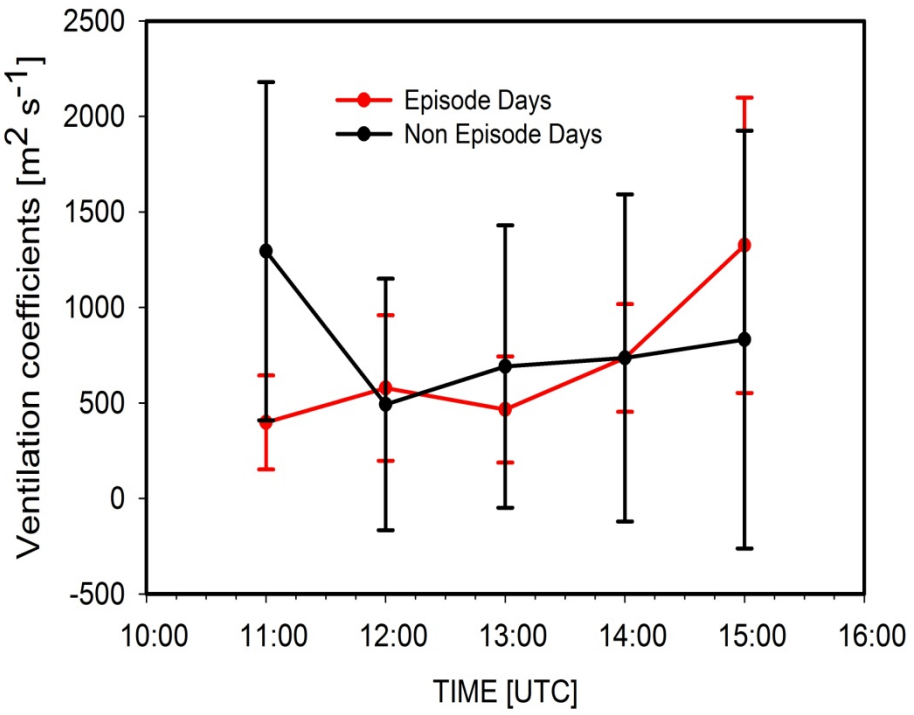
Ventilation Coefficients

•Product of the PBLH and a representative boundary layer wind speed. During the morning rush hours (0700–1100 EST) when the emission of O_3 precursors tends to be high and the PBLH is still low, surface winds are representative of dispersion near the ground.

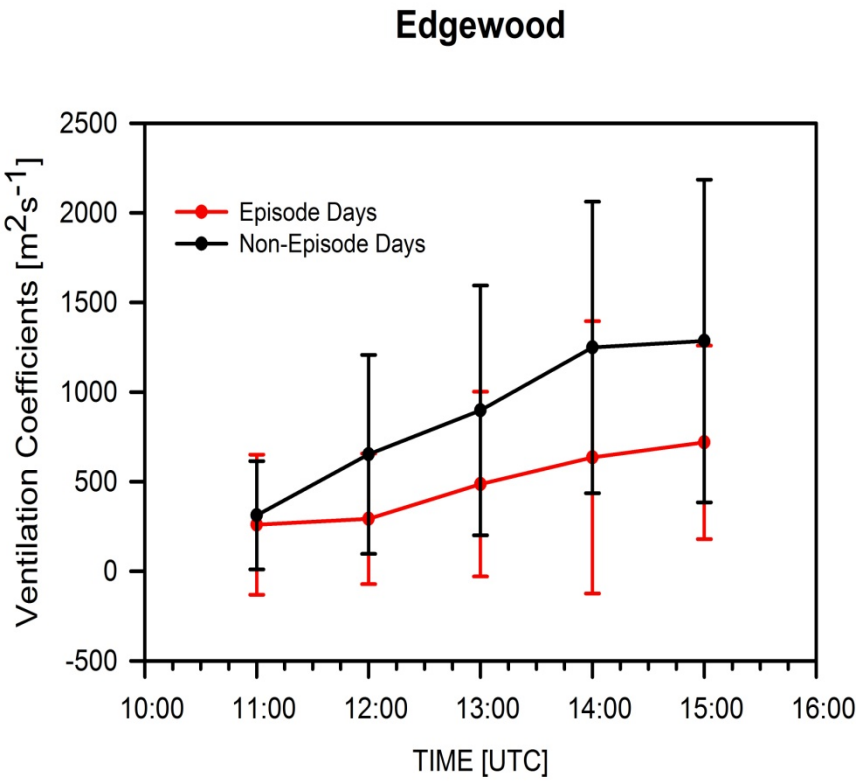
HU Beltsville

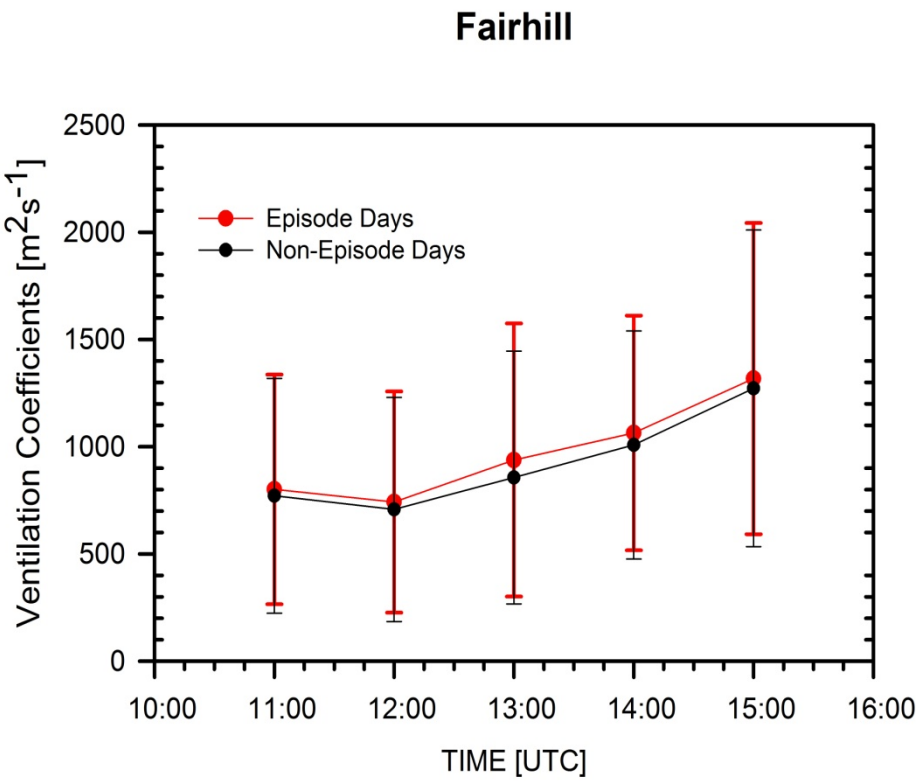


UMBC



Ventilation Coefficients





- Air quality episodes: Less dispersion of pollutants during growth of PBLH.
- Ventilation Coefficients increase 40-100% on Non-Episode Days.
- Edgewood: Greatest difference on Vent. Coefficients.
- Fairhill highest Vent. Coeff. Independent of Air Quality Episodes

Summary

- Lidar reliable tool for precise monitoring of the daytime development of the PBLH. Dataset would allow proper evaluation of model PBL schemes (assimilation).
- PBLH temporal (hourly/daily) variability within all locations due to synoptic and mesoscale processes.
- Ventilation coefficients increase rapidly after 14:00 UTC and are about 45% greater in non-episode days dispersing pollutants. Stagnation and shallow PBL on air quality episodes.
- The close proximity of Edgewood and Baltimore to the Chesapeake Bay allows to study possible mechanisms that may control the planetary boundary layer under the marine air incursion and affect the local air quality.

Work in progress

- Upcoming releases (PBLH datasets):
  - -Lidar latest revision-next week.
  - -Vaisala CL51 PBLH-next week.
  - -Wind profiler (April-May 2012).

- Formation of Thermal Internal Boundary Layer (TIBL) and its role in Mid-Atlantic air quality events.

- Airborne-Ground-Model PBL intercomparison.

ACKNOWLEDGEMENTS:

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(Contract # NA06OAR4810162)
DISCOVER-AQ
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SigmaSpace
Leosphere

*The statements contained within the manuscript are not the opinions of the funding agency or the U.S. government, but reflect the author's opinions.

Spatial Variability

	Edgewood	Fairhill	HU-Beltsville	UMBC
AQ Episodes	10	2	4	3
Max. Depth (m) (16:00-20:00 UTC)	**1700** (1570)	**1100** (1100)	**1510** (1440)	**1980** (1680)
Max. (m)	**1930** (1730)	**1700** (1640)	**1570** (1540)	**2100** (1790)
Min. (m)	**420** (430)	**450** (450)	**700** (440)	**740** (660)
Range (m)	**1490** (1300)	**1260** (1190)	**870** (1100)	**1360** (1130)

Ozone Air Quality Episode days: (8 hour O_3 > 75 ppb)

•Edgewood: PBLH to be subset to wind direction, due to sensitivity of coastal locations. Offshore flow dominates, no far inland penetration of marine layer and the PBL remains high. Conversely, onshore sea breezes carry cool marine air inland, lowering surface temperatures and decrease PBLHs.

•FairHill: No difference suggests transport of pollutants, and moisture and heat fluxes independent of synoptic and mesoscale processes.

•UMBC: Higher surface temperatures and increased convection result in higher afternoon mixing depths and larger diurnal ranges.

Planetary Boundary Layer

•The planetary boundary layer height (PBLH) is an important meteorological parameter that affects near-surface atmospheric pollutant concentrations since it determines the volume of air into which pollutants and their precursors are emitted.

•This height is also important in determining the relationship between column measures of gases and aerosols and the concentration measured at the surface, since pollutants are frequently contained within the PBL.

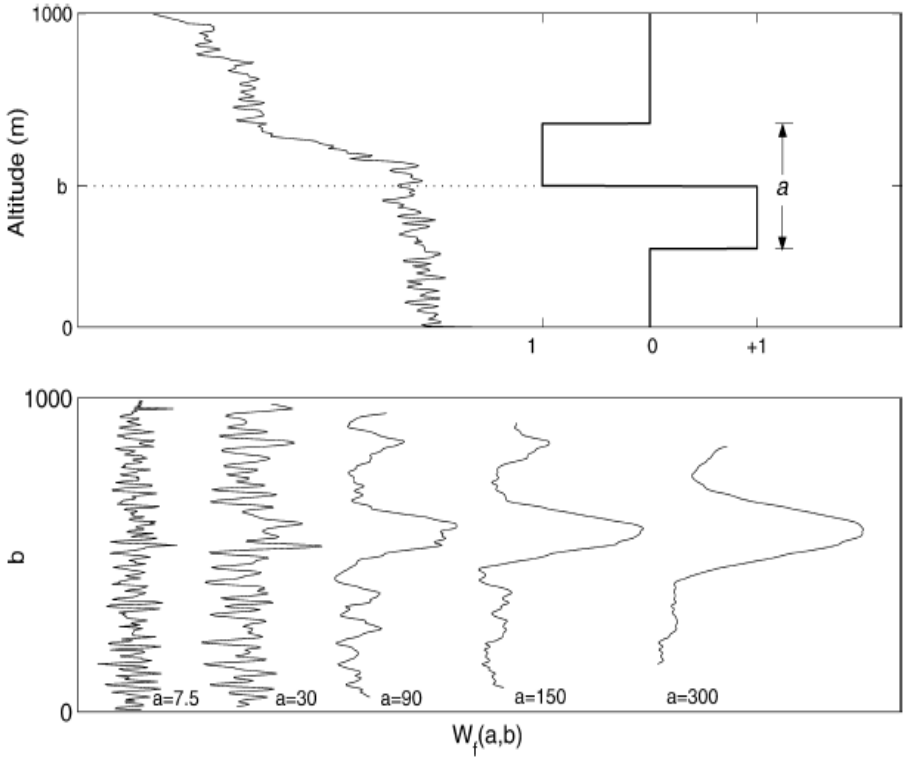
•Diagnostic variable atmospheric transport and dispersion forecasting models. Without realistic PBLH, models have large errors that result in inadequate public protection against unhealthy air quality.

Covariance Wavelet Technique

- **Covariance transform defined by Gamage and Hagelberg (1993):**

$$W_f(a,b) = a^{-1} \int_{z_b}^{z_t} f(z)\, h\left(\frac{z-b}{a}\right) dz$$

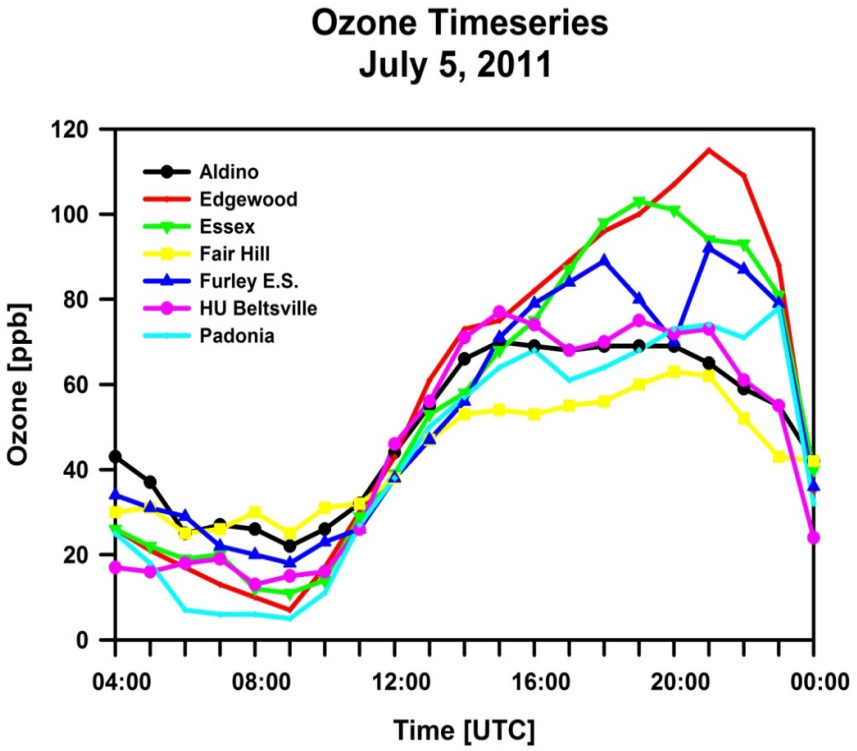
- ***z_t and z_b are the top and bottom altitudes in the lidar backscatter profile***
- ***f(z)is the lidar backscatter profile as a function of altitude, z***
- ***a^{-1} is the normalization factor***
- $h\left(\frac{z-b}{a}\right)$ ***Haar wavelet***

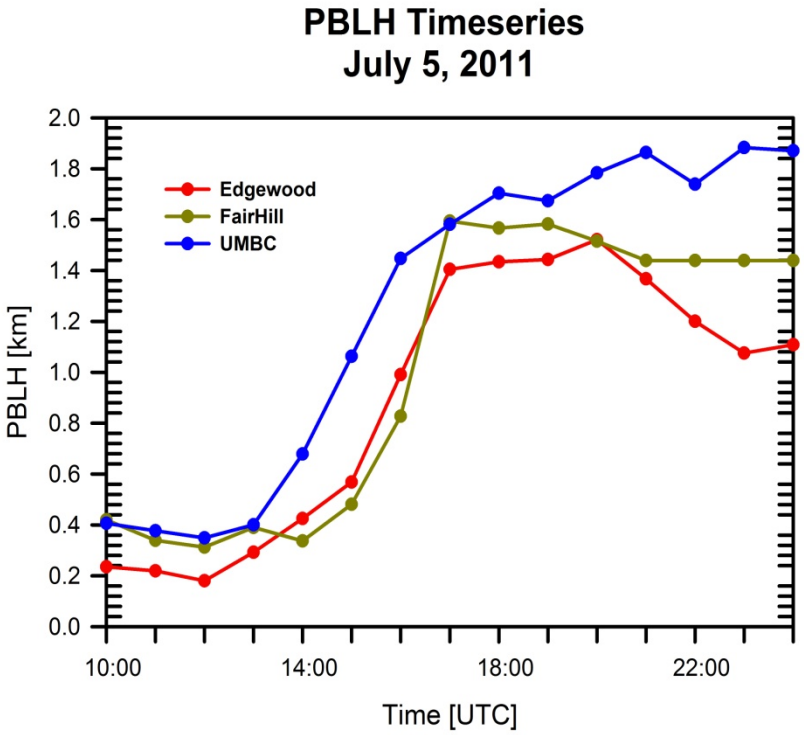


(top) Lidar backscatter profile and Haar function and (bottom) the CWT at various dilation values

Brooks, I.M., 2003. *J. of Atmospheric and Oceanic Technology, 20: 1092-1105*

July 5, 2011

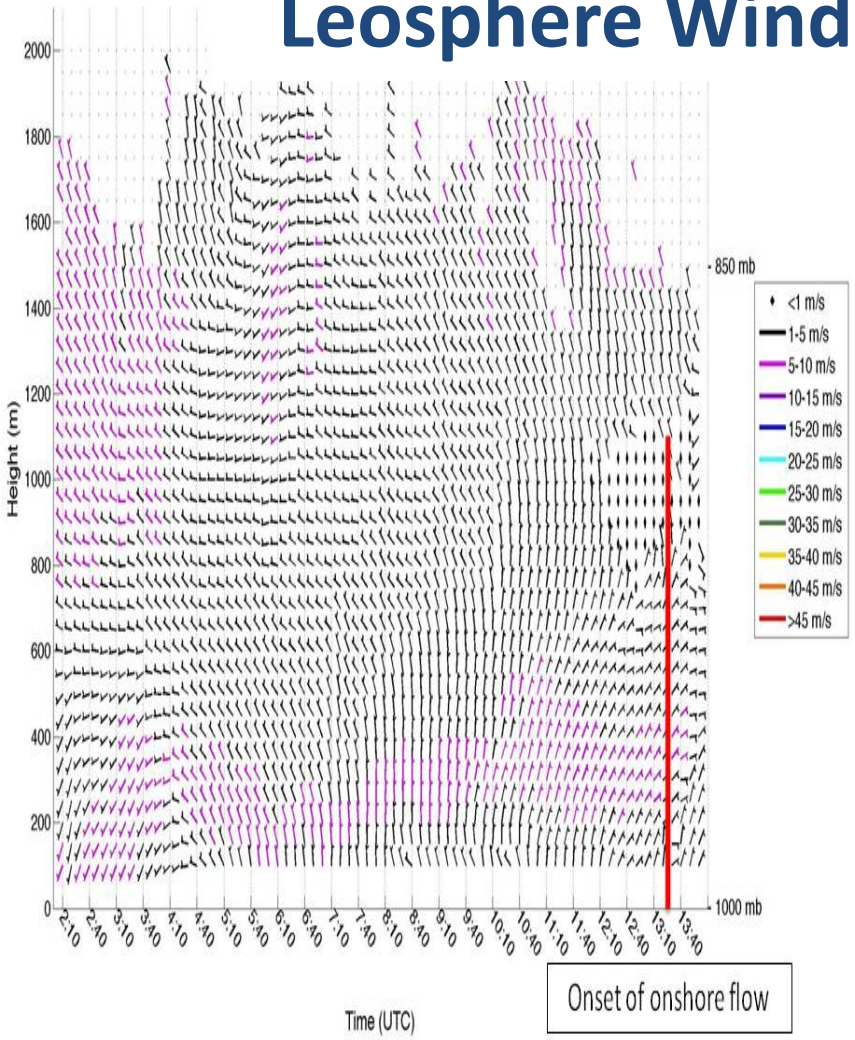


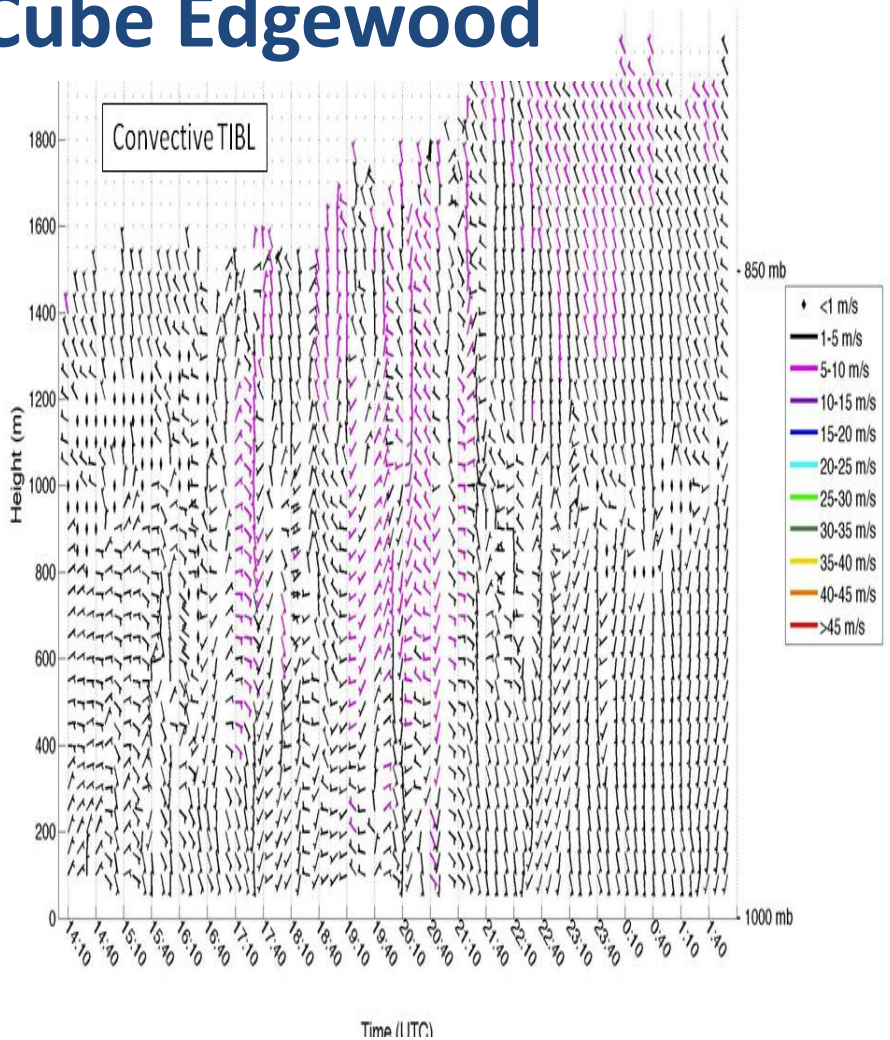


Locations along the DISCOVER-AQ flight track and the western shoreline of the Chesapeake Bay (Edgewood, Essex and Baltimore) reported 8 hour O_3 concentrations that ranged between 78 to 98 ppb, with Edgewood reporting its highest hourly concentration at 21:00 UTC (17:00 EDT), and Furley E. S. experiencing a “double dip” of high O_3 concentrations.

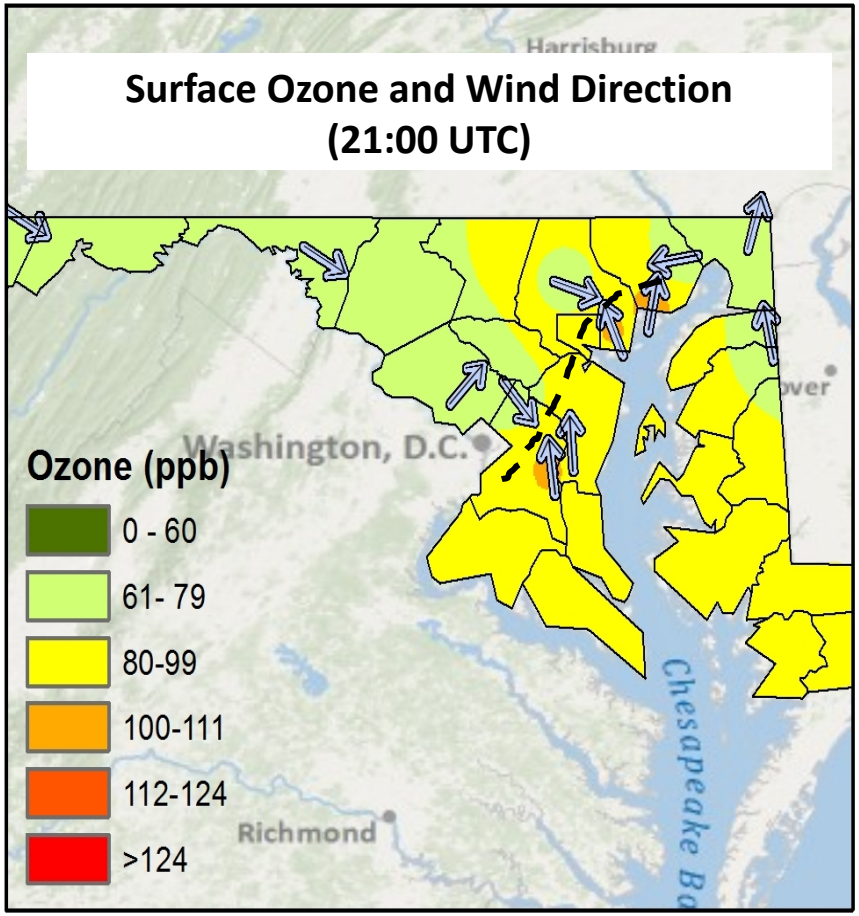
July 5, 2011 (Bay Breeze)

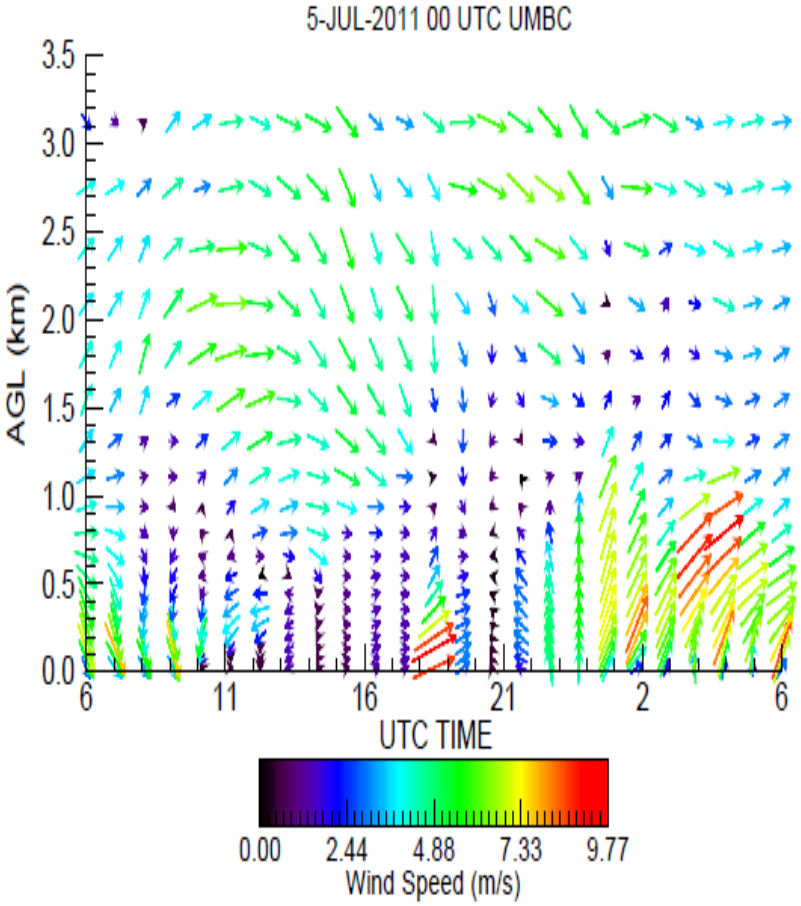
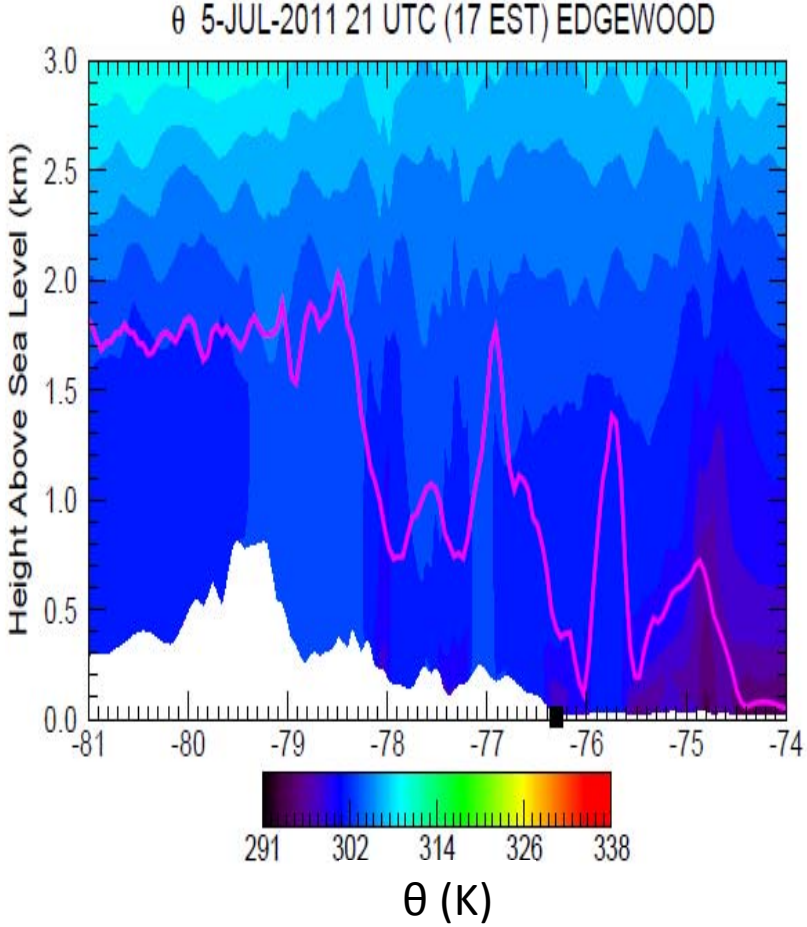
Leosphere WindCube Edgewood





July 5, 2011



The late afternoon surface ozone peak in Edgewood, Essex and Baltimore can be attributed to a stationary frontal boundary which lingered over the region and exacerbated ozone concentrations. Note the formation of the Bay Breeze circulation also induces a small-scale surface boundary and contributes to poor air quality in this region.

WRF-ARW version 3.3.1 (Preliminary runs)