UMAP Lidars (UMBC Measurements of Atmospheric Pollution)

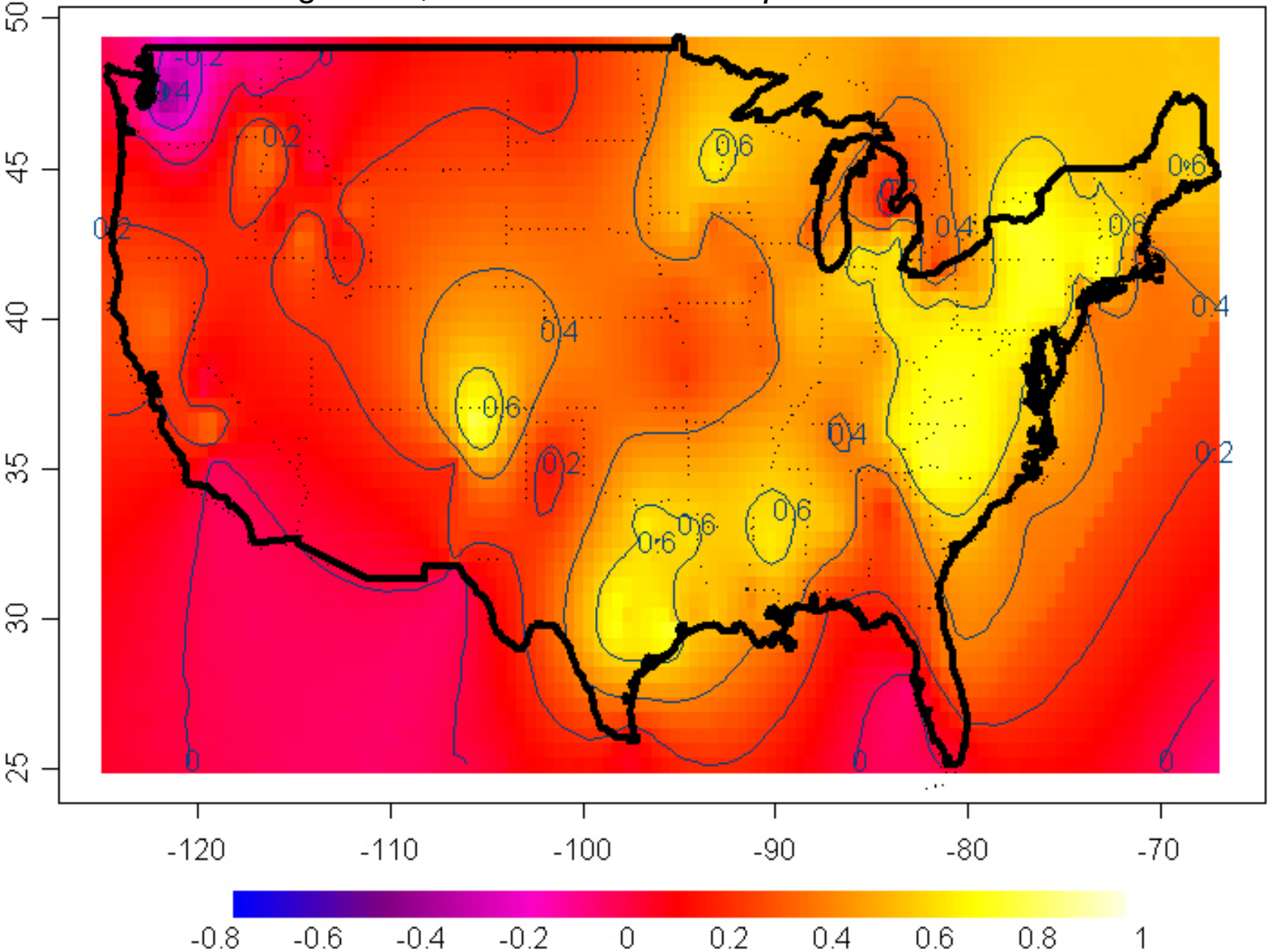
Raymond Hoff

Ruben Delgado, Tim Berkoff, Jamie Compton, Kevin McCann, Patricia Sawamura, Daniel Orozco,

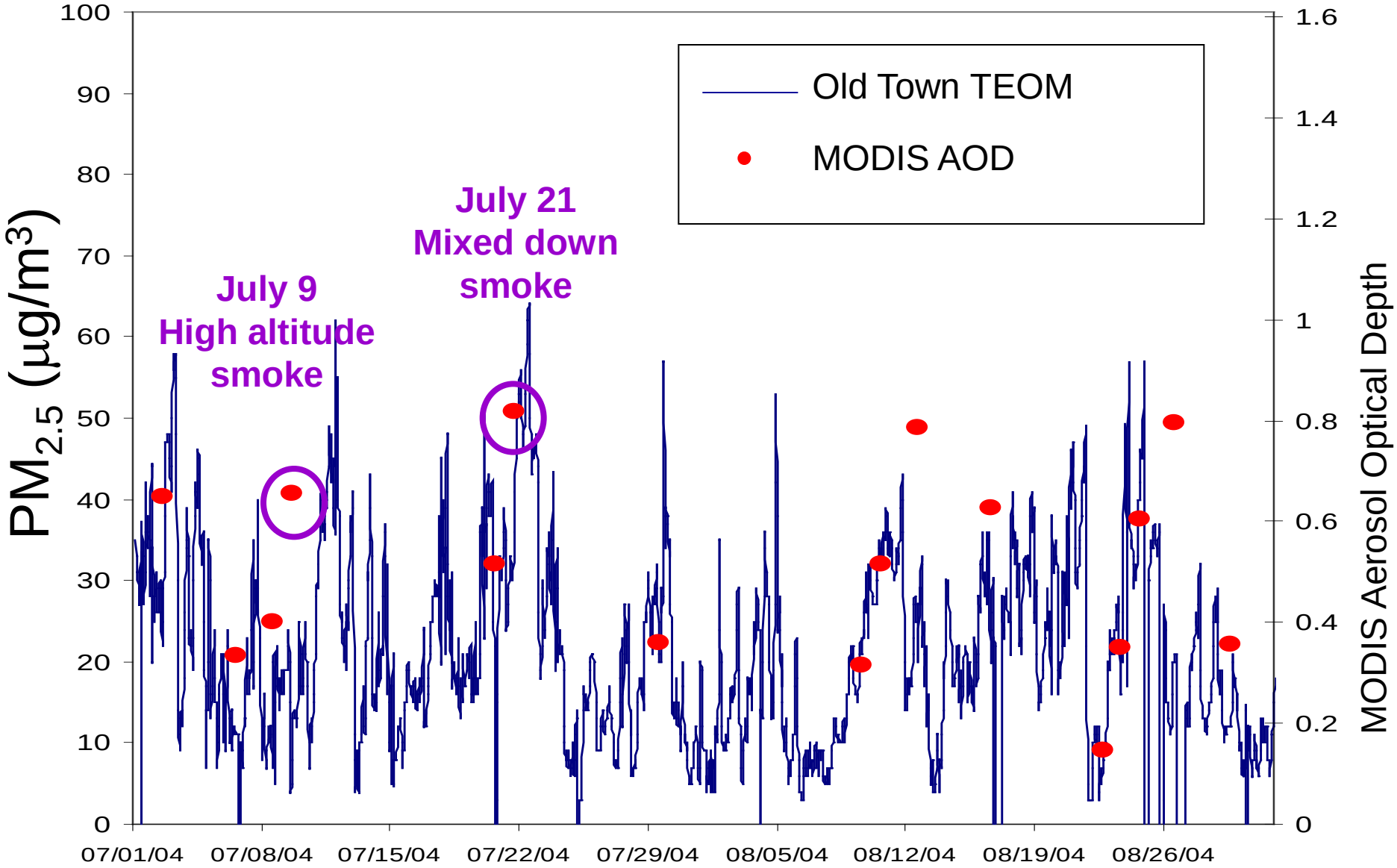
UMBC

Correlations between AOD and PM2.5(hourly)

Engel-Cox, J. *et.al*. 2004. *Atmospheric Environment*.



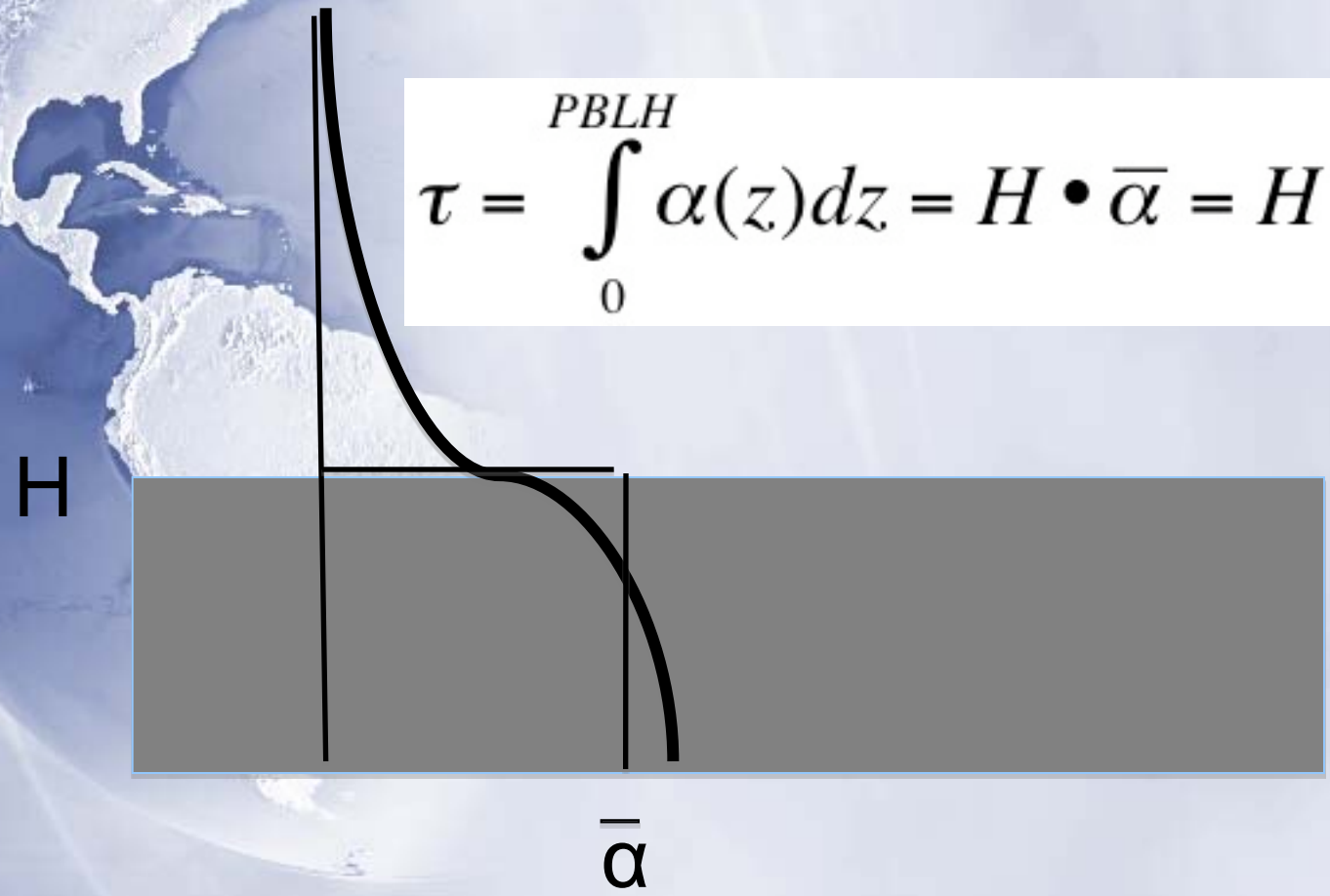
Baltimore, MD Summer 2004



Courtesy EPA/UWisconsin

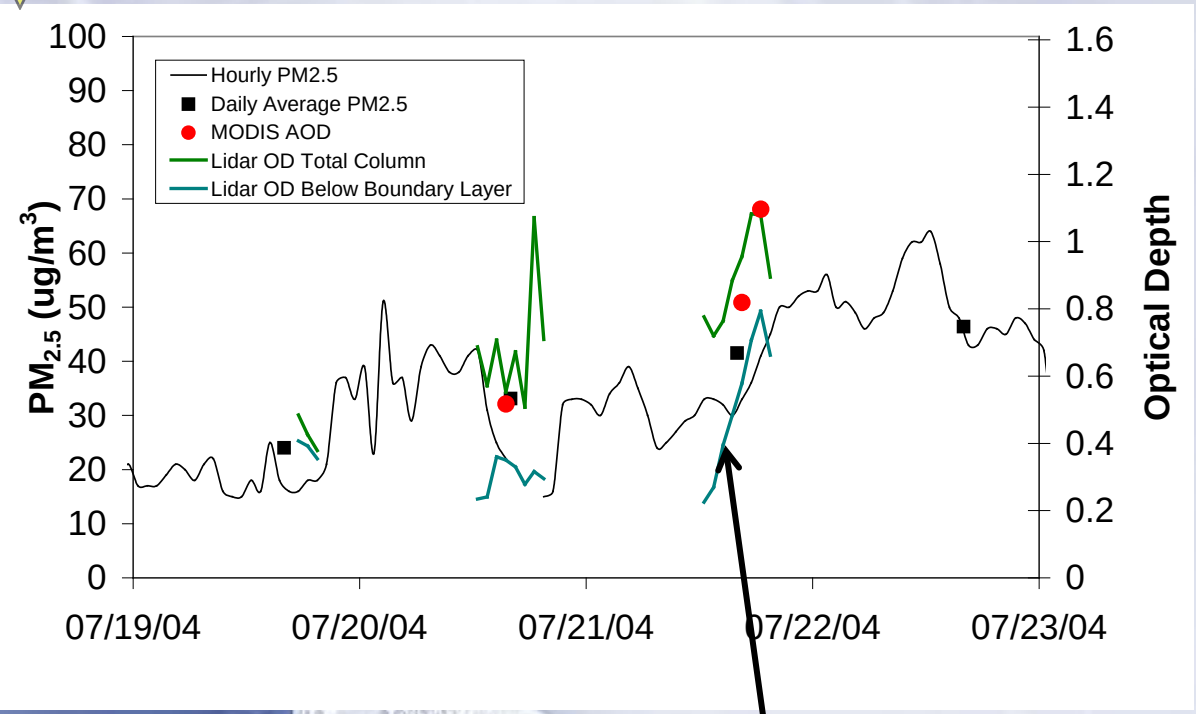
Conceptually simple idea

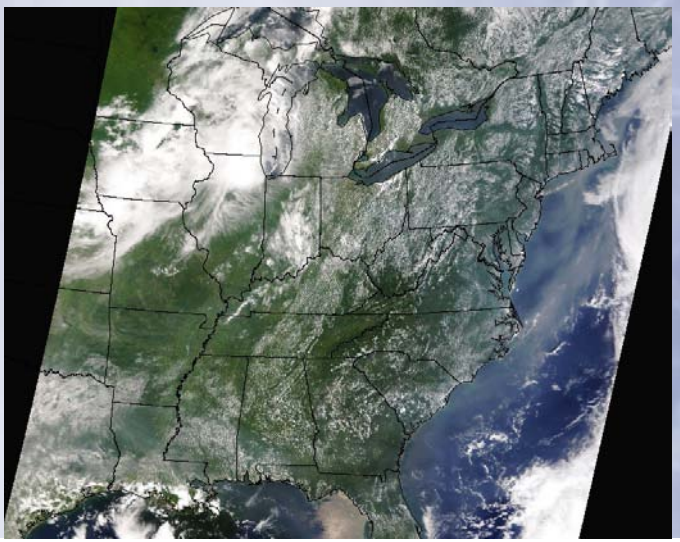
$$\tau = \int_0^{PBLH} \alpha(z)dz = H \bullet \overline{\alpha} = H \bullet PM \bullet C$$

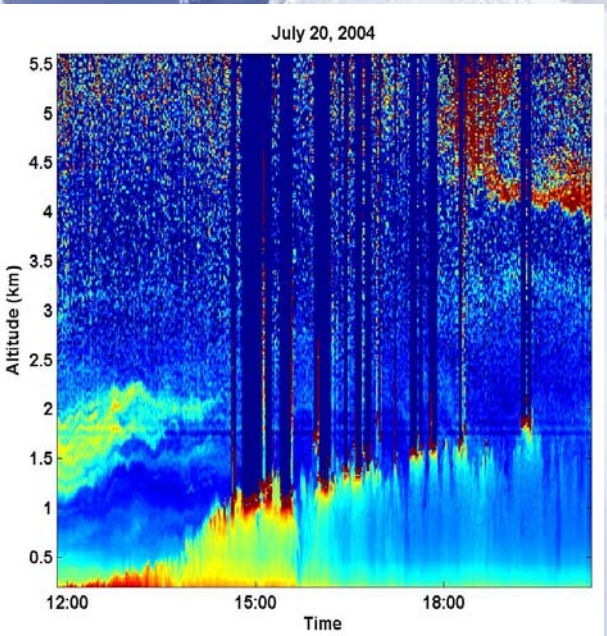


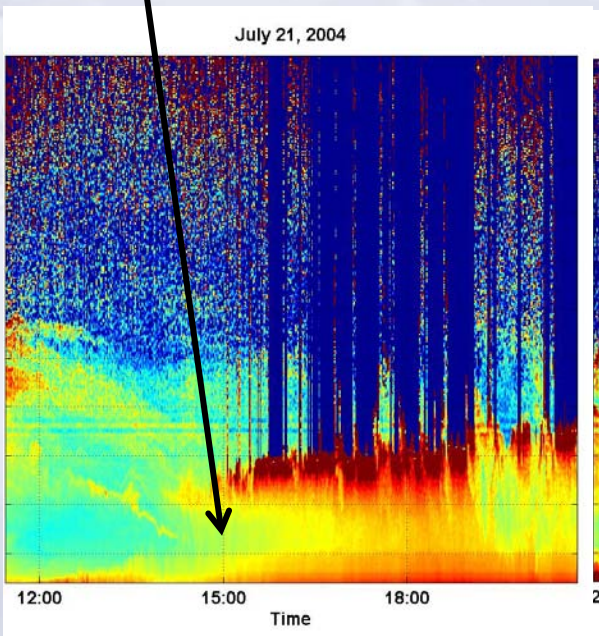
Extinction Profile and PBL H

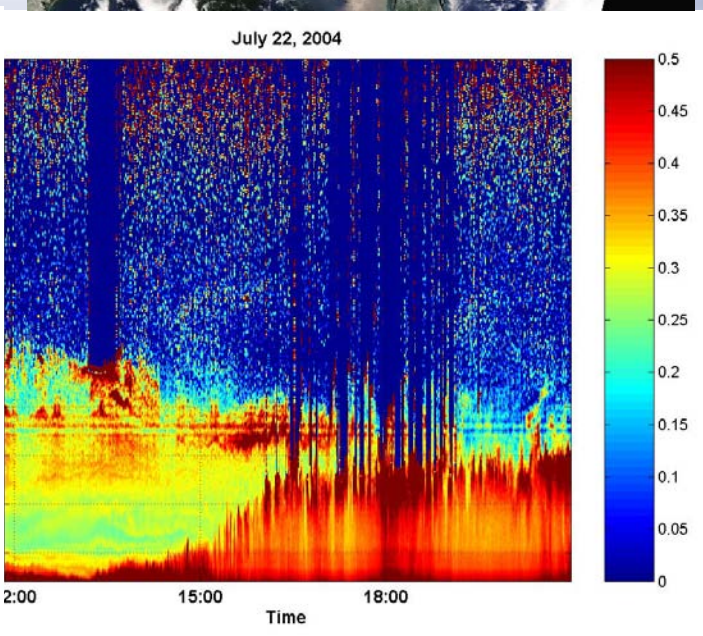
Smoke mixing in Maryland 20-22 July 2004



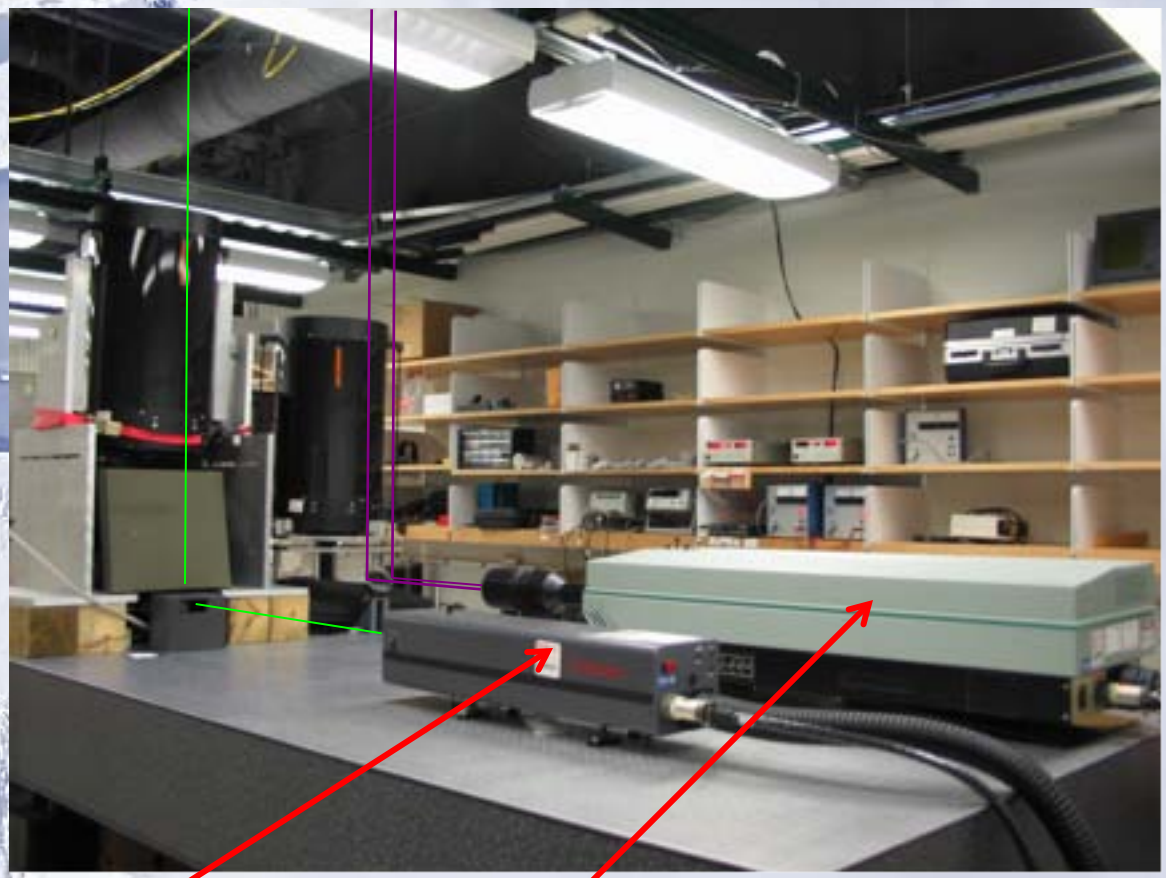








Before upgrading: 2008 Existing



ALEX - UV N_2, H_2O Raman lidar - 355, 389, 407 nm
ELF - 532($\perp$,$||$), 1064 elastic lidar

GALION needs

- QA/QC site for lidars in US
- Have all the wavelengths that people might use routinely
- Ability to cross-calibrate instruments
- Need to add MPL and LEOSPHERE

Micropulse Lidar

Leosphere

UMBC Monitoring of Atmospheric Pollution (UMAP)
(NASA Radiation Sciences Supported Project)

Weblinks to instruments

Instruments

Satellites
Description

ELF
Description
Data

ALEX
Description
Data

MPL
Description
Data

Leosphere
Description
Data

Radiosonde
Description
Data

TEOM
Description
Data

BAM
Description
Data

Sulfate Analyser
Description
Data

Profiling Air Quality over Baltimore - UMBC Monitoring of Atmospheric Pollution (UMAP)

Building off experiments which have been conducted at UMBC since 1995 and augmented by a major NASA grant, the UMBC Monitoring of Atmospheric Pollution (UMAP) project is designed to provide a three-dimensional evaluation of the aerosol pollution environment over Baltimore. Combining

http://alg.umbc.edu/UMAP

Data available

Leosphere Operations Calendar

2010

January 2010						
Su	Mo	Tu	W	Th	Fr	Sa
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

February 2010						
Su	Mo	Tu	W	Th	Fr	Sa
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28						

March 2010						
Su	Mo	Tu	W	Th	Fr	Sa
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

April 2010						
Su	Mo	Tu	W	Th	Fr	Sa
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

May 2010						
Su	Mo	Tu	W	Th	Fr	Sa
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

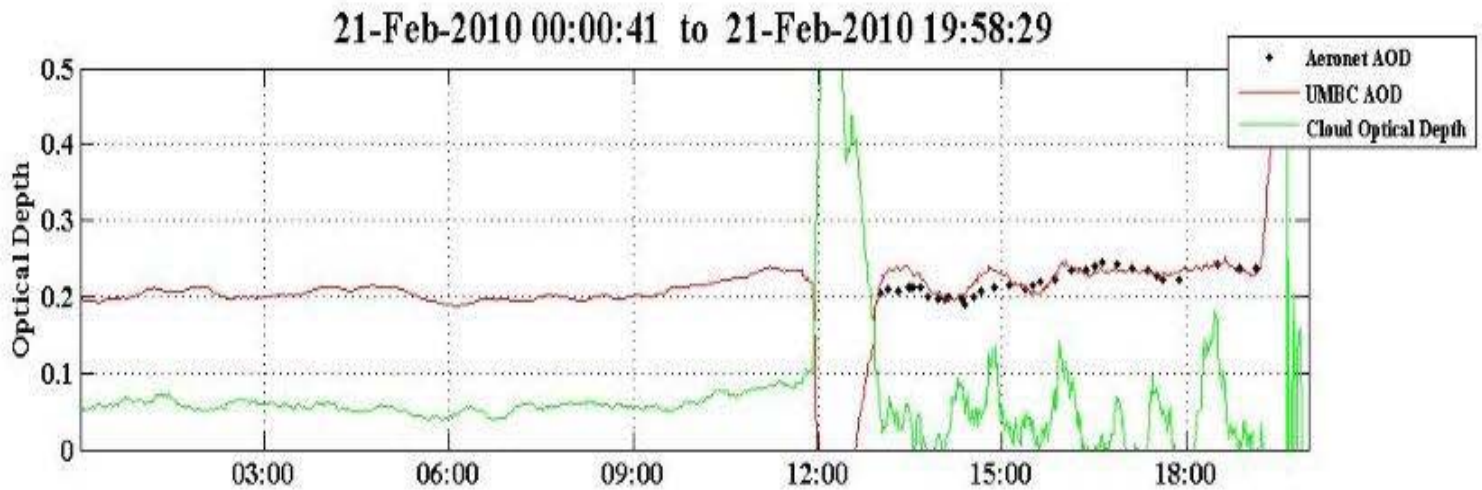
June 2010						
Su	Mo	Tu	W	Th	Fr	Sa
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

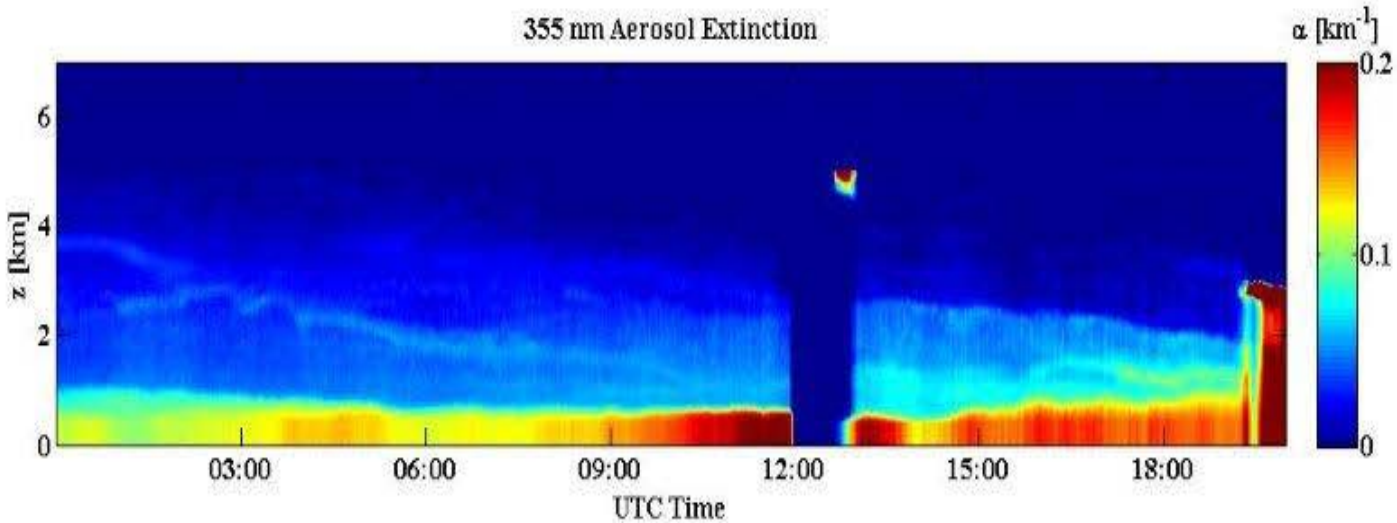
July 2010						
Su	Mo	Tu	W	Th	Fr	Sa
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

August 2010						
Su	Mo	Tu	W	Th	Fr	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

355 nm Leosphere retrieval (new)

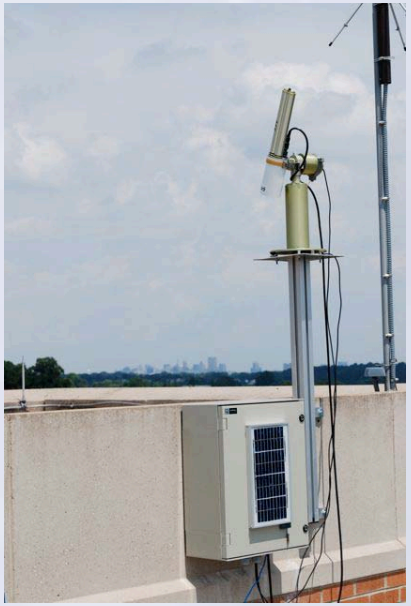
UMBC LIDAR Group





New instruments

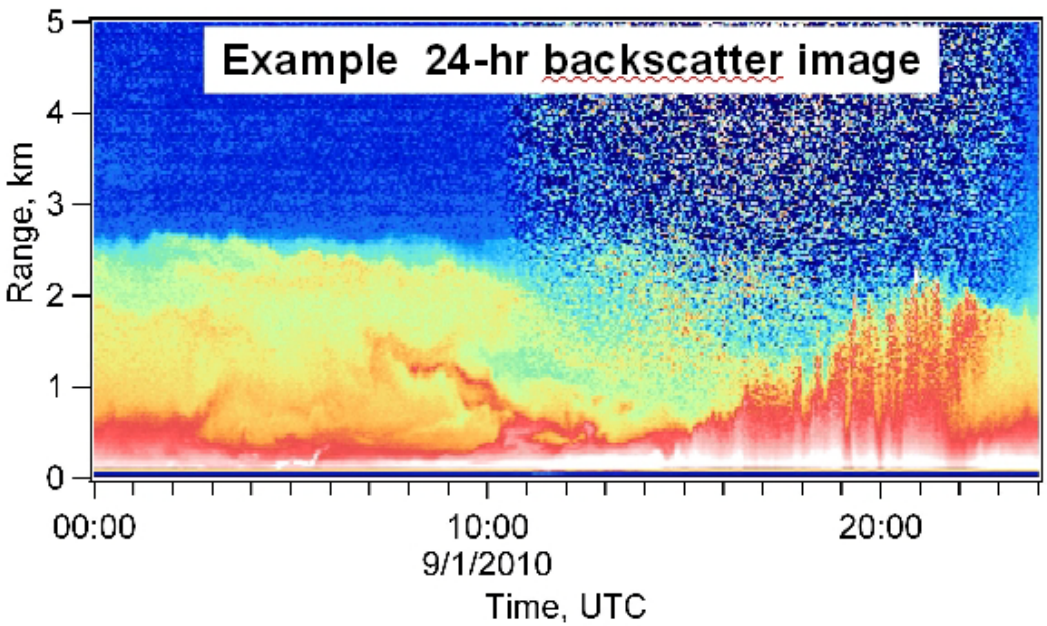
- BAM and TEOM (PM2.5 continuously)
- TSI 3683 (3λ nephelometer)
- CIMEL (8λ AOD, size distribution)
- LICEL (new detector package for ALEX)



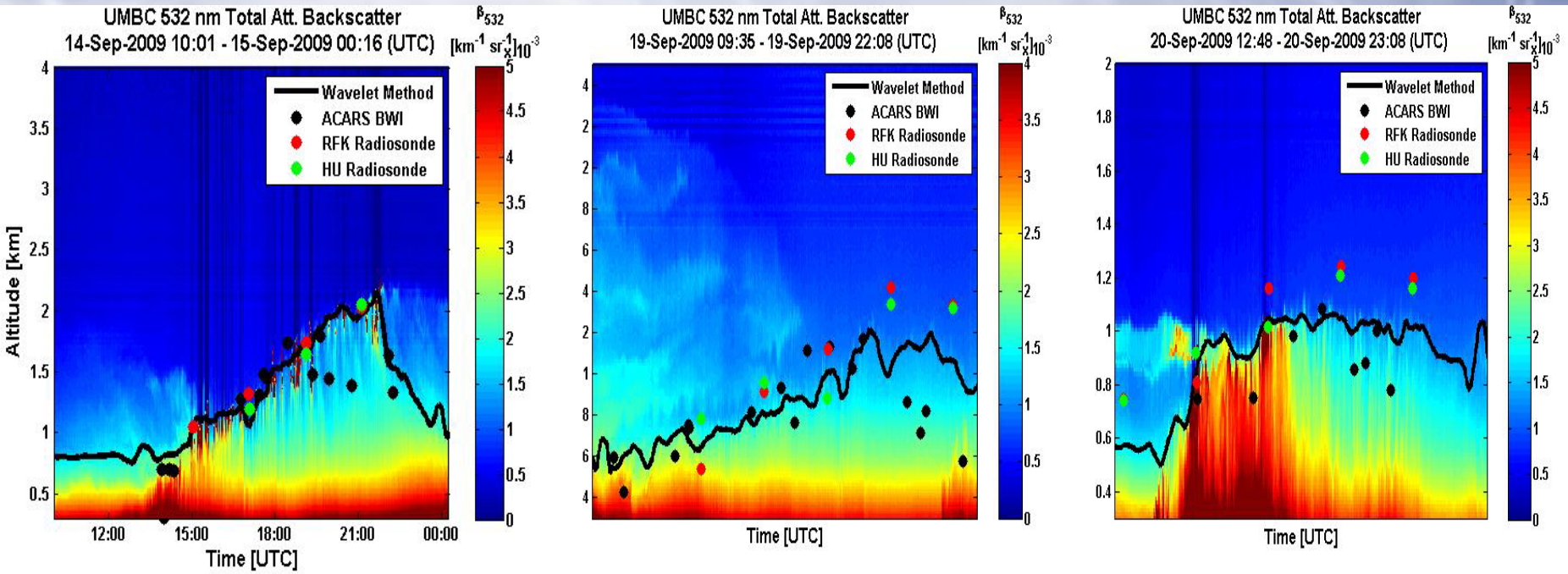
Shareware lidar concept: entry-level network system for lower troposphere measurements

- Very simple, low-cost single-wavelength system
- Eye-safe, 532 nm wavelength
- Overlap eliminated (<300 m)
- Modular design
- Public domain, "kit"instructions to be available for system replication by groups with no lidar experience

More data examples & performance evaluation, see Berkoff et al, AMS Conference, Seattle (Jan 2011)
berkoff@umbc.edu



Example small-diam. wide- angle FOV receiver



Lidar and radiosonde measurements were also used to evaluate nearby ACARS PBLH estimates at RFK and BWI airports.

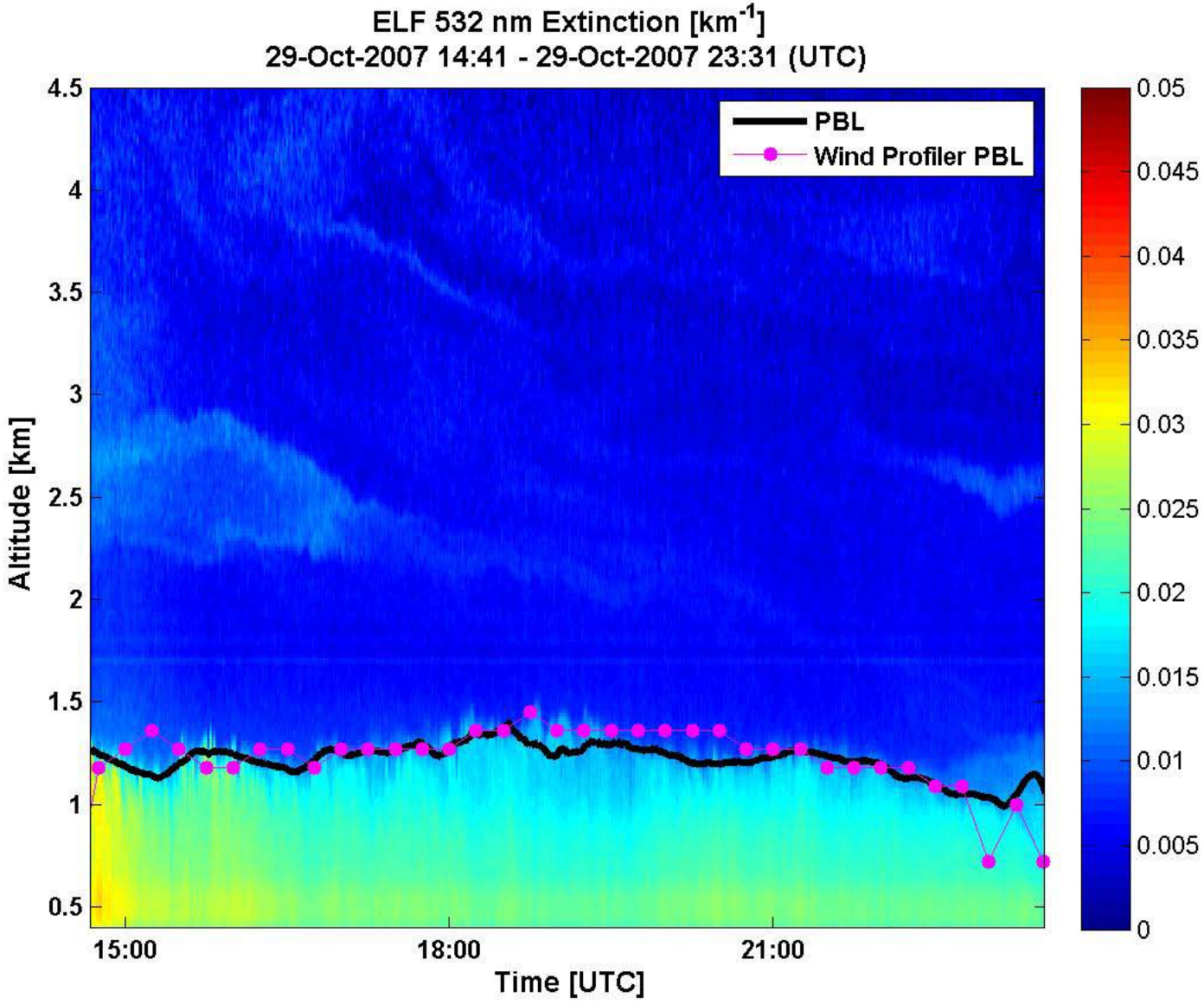
Problem was identified with automatic PBLH calculation aircraft profiles during the evening transition.

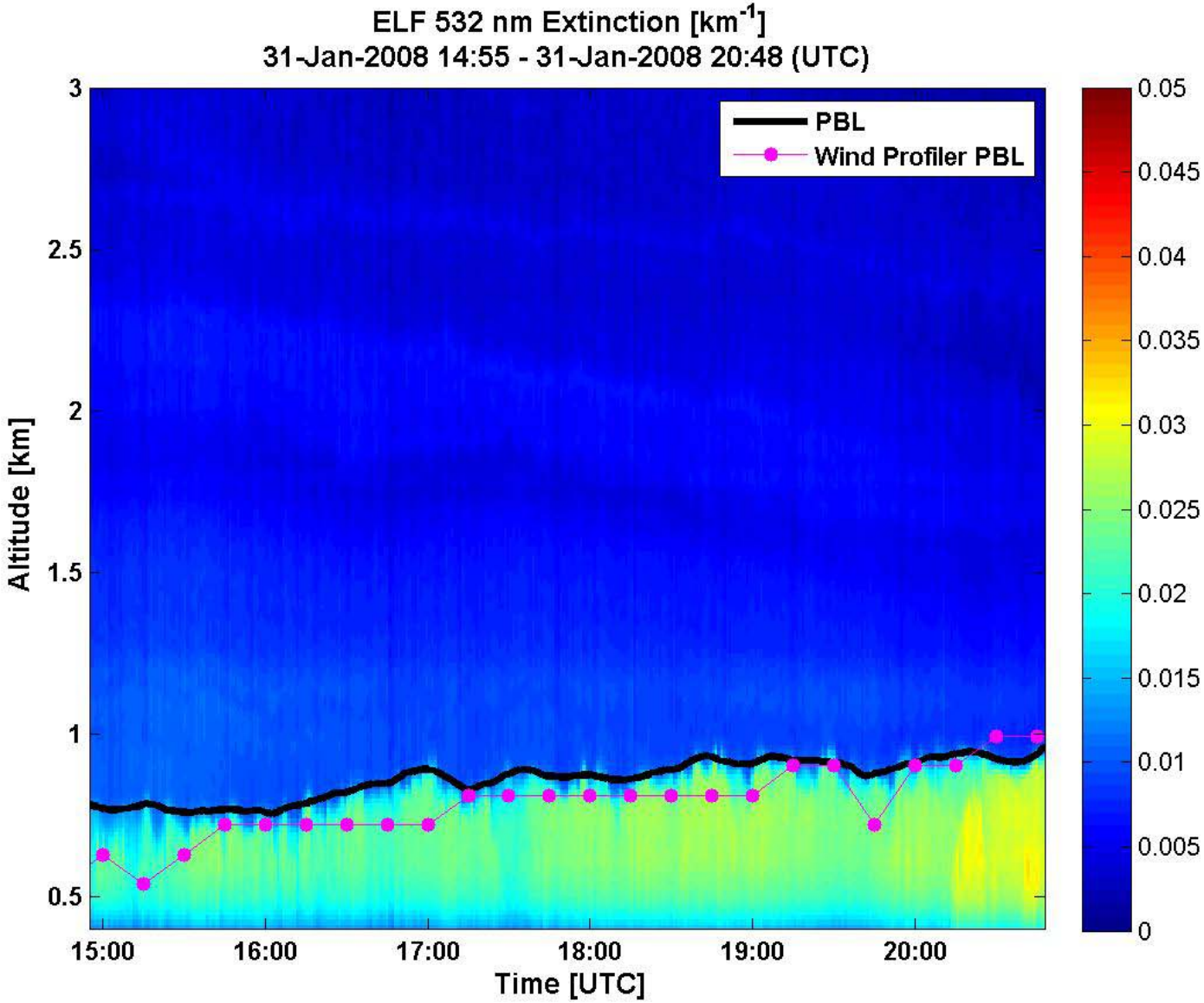
The ACARS bulk RI # algorithm was modified to minimize incorrect specification of very low PBLs with weakly shallow inversions or during the early evening PBL transition period.

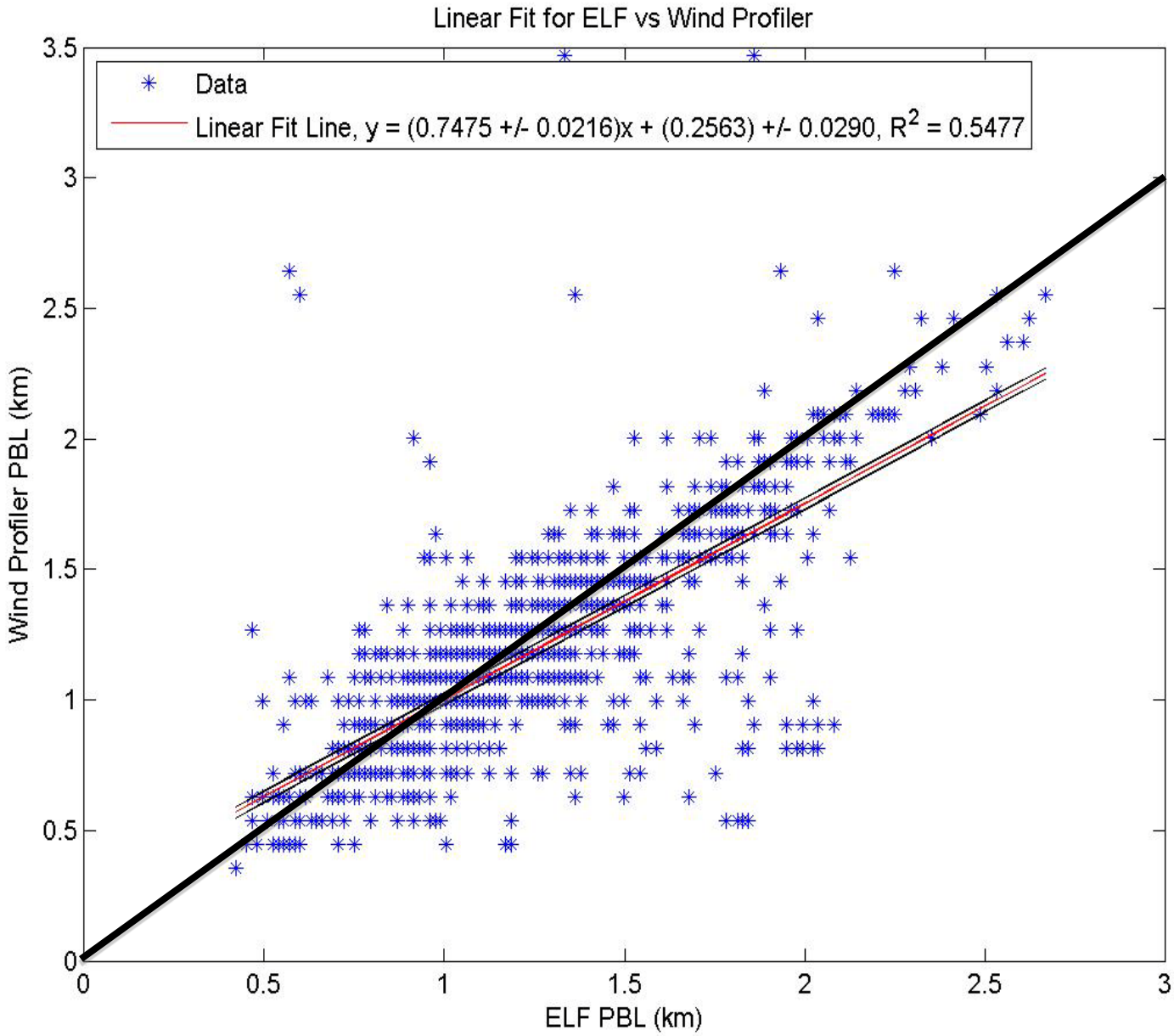
Wind Profiler PBL Determination Method

- The PBL from wind profiler is found by taking the median of the SNR profiles and then finding the height at which the peak occurs (Angevine et al. 1994).

- Angevine, W. M., A. B. White, and S. K. Avery, 1994: Boundary layer depth and entrainment zone characterization with a boundary layer profiler. Bound.-Layer Meteor., 68, 375–385.


ELF 532 nm Extinction [km-1]
29-Oct-2007 14:41 - 29-Oct-2007 23:31 (UTC)
PBL
Wind Profiler PBL
Altitude [km]
4.5
4
3.5
3
2.5
2
1.5
1
0.5
15:00
18:00
21:00
Time [UTC]
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0


ELF 532 nm Extinction [km-1]
31-Jan-2008 14:55 - 31-Jan-2008 20:48 (UTC)
PBL
Wind Profiler PBL
Altitude [km]
3
2.5
2
1.5
1
0.5
15:00
16:00
17:00
18:00
19:00
20:00
Time [UTC]
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0


Linear Fit for ELF vs Wind Profiler
Data
Linear Fit Line, y = (0.7475 +/- 0.0216)x + (0.2563) +/- 0.0290, R2 = 0.5477
Wind Profiler PBL (km)
ELF PBL (km)
0
0.5
1
1.5
2
2.5
3
3.5

Summary

- Lidar will give the profile and the PBL height
- We can constrain expectations on the agreement between AOD and the PM at the surface from these measurements
- Lidar should also be able to help Pandora measurements in assumptions of horizontal homogeneity

References:

- Weber, S. A., J. A. Engel-Cox, R. M. Hoff, A. Prados, H. Zhang, 2010. An improved method for estimating surface fine particle concentrations using seasonally-adjusted MODIS, MISR, and GASP aerosol optical depth values, *J. Air & Waste Manage. Assoc.* **60**, 574-585
- Zhang, H., Hoff, R.M., Engel-Cox, J.A. 2009: The relation between Moderate Resolution Imaging Spectroradiometer (MODIS) aerosol optical depth and PM2.5 over the United States: a geographical comparison by EPA regions, *J.Air & Waste Manage. Assoc.* **59**, 11, 1358 -1369.
- Hoff, R. H. Zhang, N. Jordan, A. Prados, J. Engel-Cox, A. Huff, S. Weber, E. Zell, S. Kondragunta, J. Szykman, B. Johns, F. Dimmick, A. Wimmers, J. Al-Saadi, and C. Kittaka, 2009. Applications of the Three-Dimensional Air Quality System (3D-AQS) to Western U.S. Air Quality: IDEA, Smog Blog, Smog Stories, AirQuest, and the Remote Sensing Information Gateway. J. Air & Waste Manage. Assoc. **59**, 980–989, DOI:10.3155/1047-3289.59.8.980.
- Hoff, R. M. and S. A. Christopher, 2009. The 34th AWMA Critical Review: Remote Sensing of Particulate Pollution from Space: Have We Reached the Promised Land? *J. Air & Waste Manage. Assoc.* **59**,645–675, DOI:10.3155/1047-3289.59.6.645.
- Engel-Cox, Jill A., Raymond M. Hoff, Raymond Rogers, Fred Dimmick, Alan C. Rush, James J. Szykman, Jassim Al-Saadi, D. Allen Chu, and Erica R. Zell, 2006. Integrating Lidar and Satellite Optical Depth with Ambient Monitoring for 3-Dimensional Particulate Characterization, *Atmos. Environ.* **40**, 8056-8067.
- Engel-Cox, Jill A., Gregory S. Young and Raymond M. Hoff, 2005 Application of satellite remote sensing data for analysis of fine particulate matter transport events, *J.A.W.M.A.*, **55**, 1389-1397.
- Engel-Cox, J.A. and R. M. Hoff, 2005. Science-Policy Data Contract Model: Use of Environmental Monitoring Data for Air Quality Policy, *Environ. Science and Policy, **8**,* 115-131.
- Engel-Cox, J. A., R.M. Hoff, and A.D.J. Haymet, 2004. Recommendations on the Use of Satellite Sensor Data for Urban Air Quality, *J. A.W.M.A,* **54**, 1360-1371.
- Engel-Cox, J. A., C. H. Holloman, B. W. Coutant, and R. M. Hoff, 2004. Qualitative and quantitative evaluation of MODIS satellite sensor data for regional and urban scale air quality, *Atmos. Environ.* **38**, 16, 2495-2509 doi:10.1016/j.atmosenv.2004.01.039.

Backup

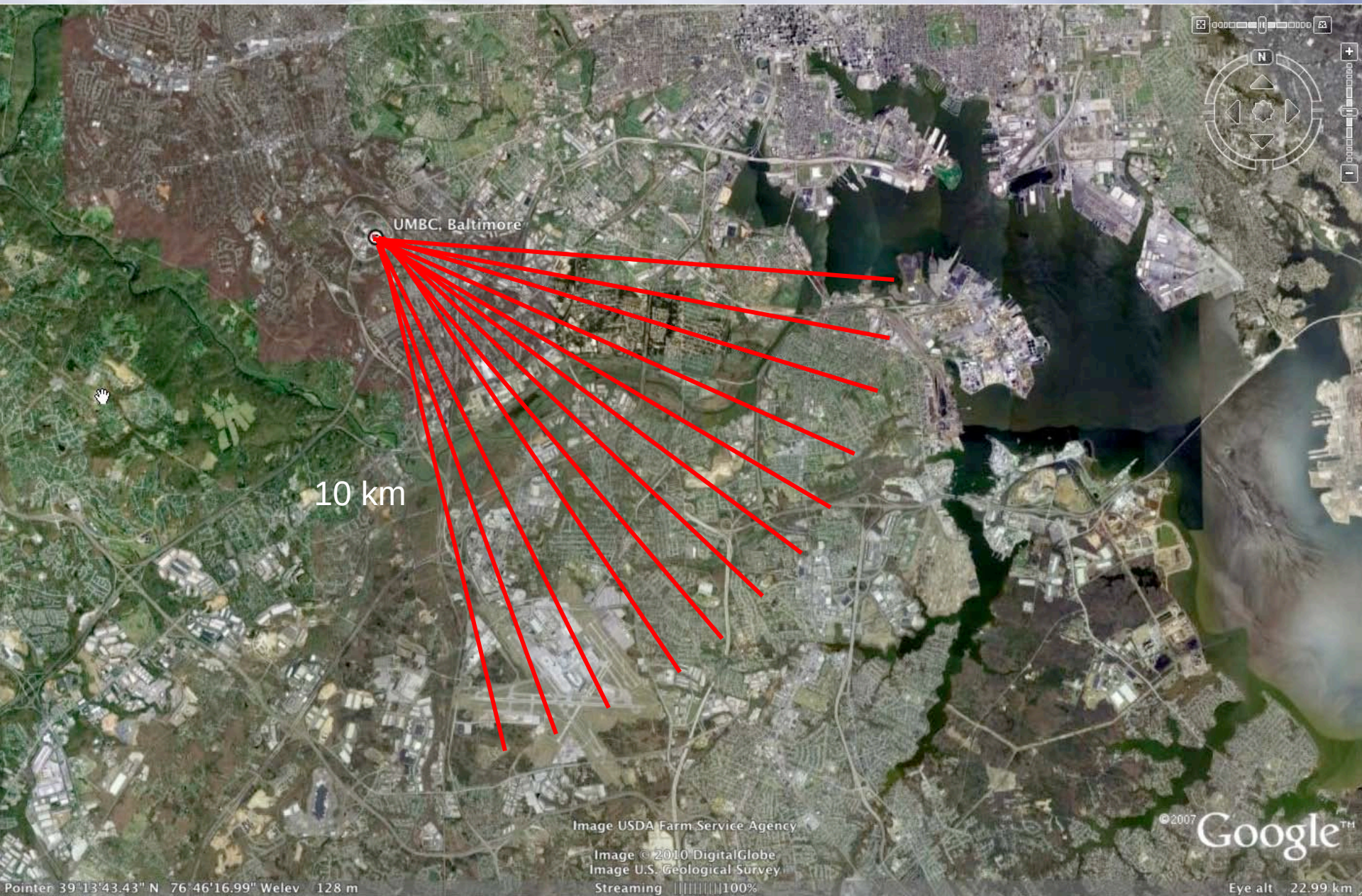
Leosphere's second application

Q. What fraction of the aerosol load over Baltimore is locally generate and what fraction is transported in?

Q. Can we improve the use of satellite remote sensing over urban areas by understanding the surface reflectivity and what the AOD should be?

- Profiling aerosols over Baltimore
- Horizontal VAD scans (like the REAL system)
- Isolates local sources
- Horizontal spatial extent of haze over the city
- Eye safe operation ... can't do this at 532/1064 nm

Eye safe 355 nm scanning lidar over Baltimore



Planetary Boundary Layer

- Haar function

$$h\left(\frac{z-b}{a}\right) = \begin{cases} -1: & b - \frac{a}{2} \le z \le b \\ 1: & b \le z \le b + \frac{a}{2} \\ 0: & elsewhere, \end{cases}$$

- *z=vertical distance in this application*
- *a=spatial extent dilation of the function*
- *b=center of Haar function- translation of the function*

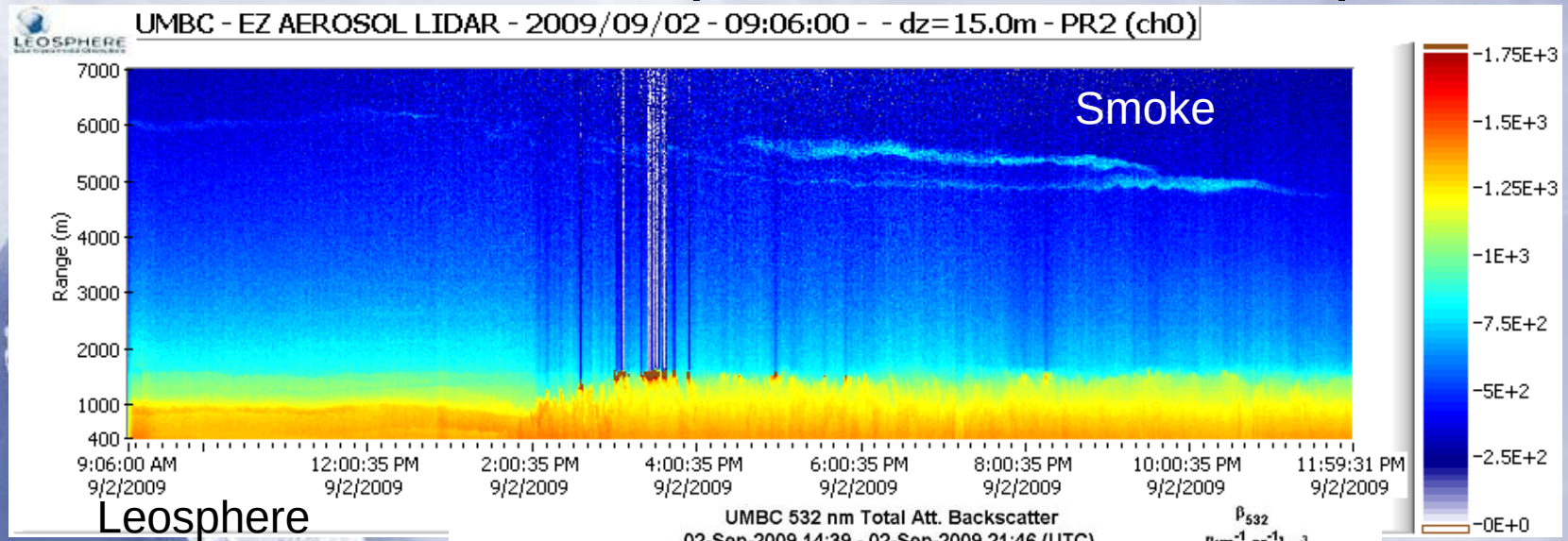
- Covariance transform defined by Gamage and Hagelberg (1993):

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

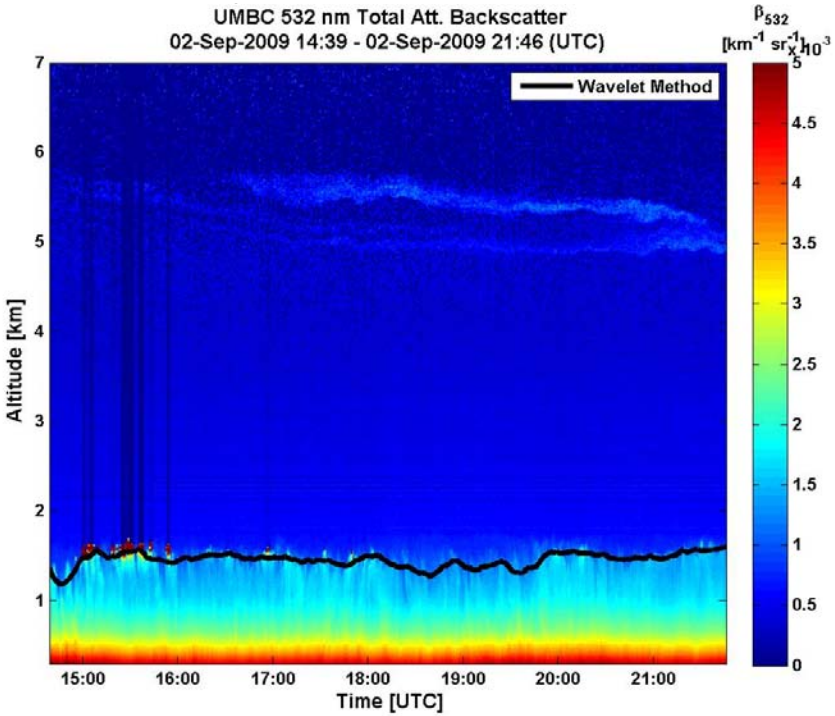
- *z_t and z_b are the top and bottom altitudes in the lidar backscatter profile*
- *f(z)is the lidar backscatter profile as a function of altitude, z*
- *a^{-1} is the normalization factor*

- To determine the PBL the following algorithm is used:
  - Compute convolution of the backscatter profile, *f(z)*, and the Haar function,
  - Taking a lidar backscattering profile, calculate a local minimum in $W_f(a,b)$ using a scale of a located at $z = b$
  - This process is repeated for all individual lidar backscatter profiles to create a time series of boundary locations.

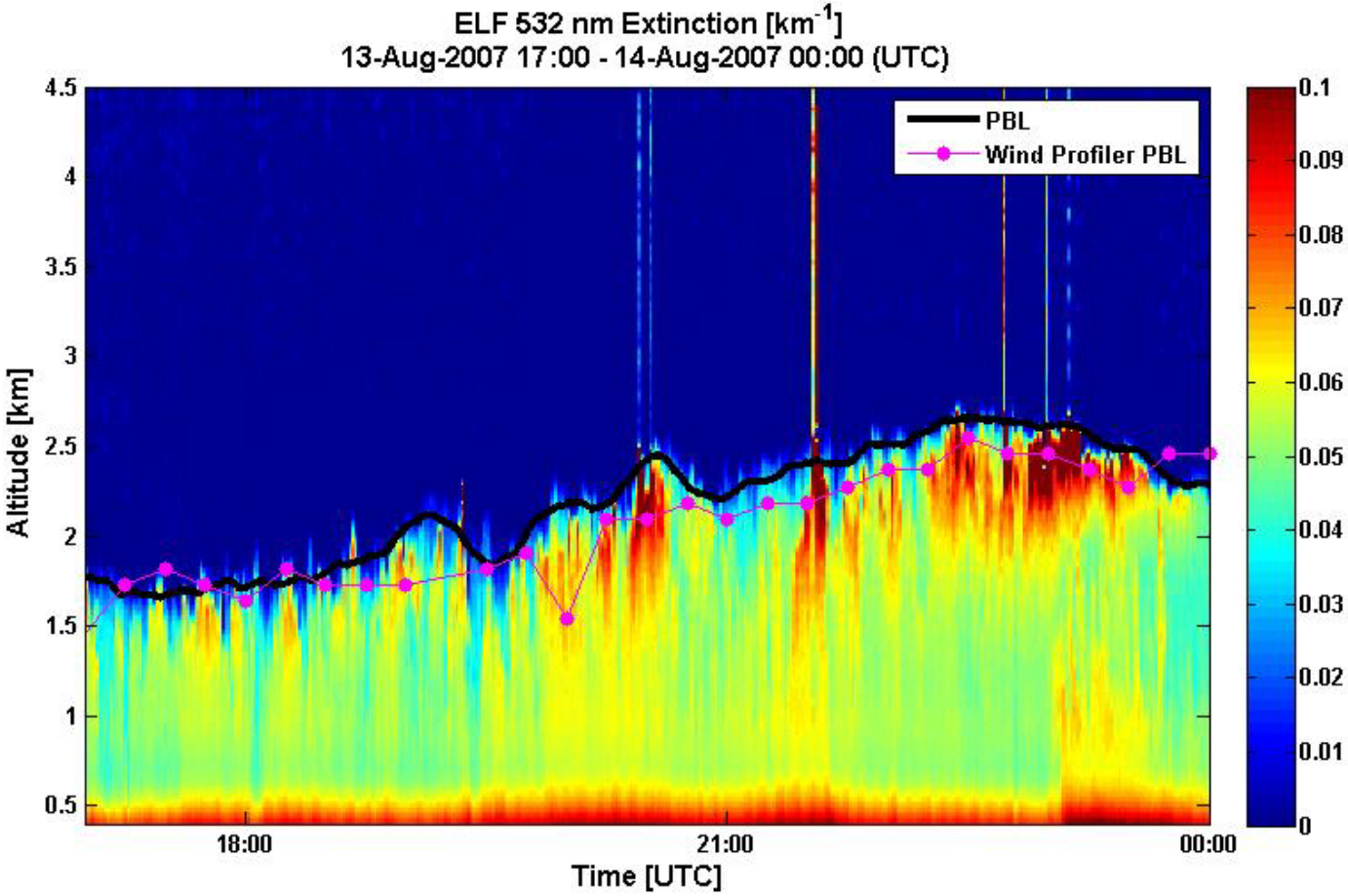
Sept. 2, 2009 Intercomparison



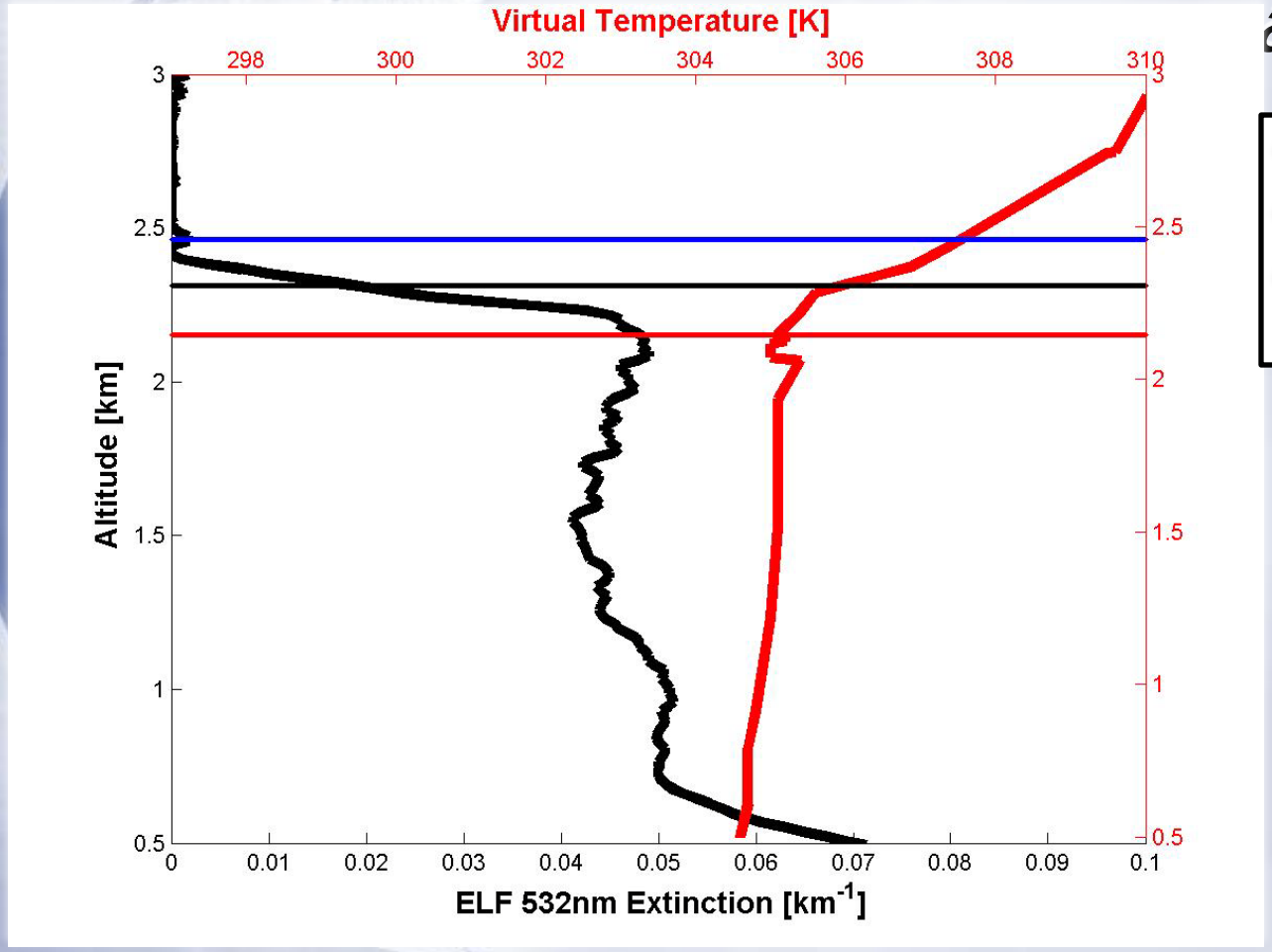
Leosphere



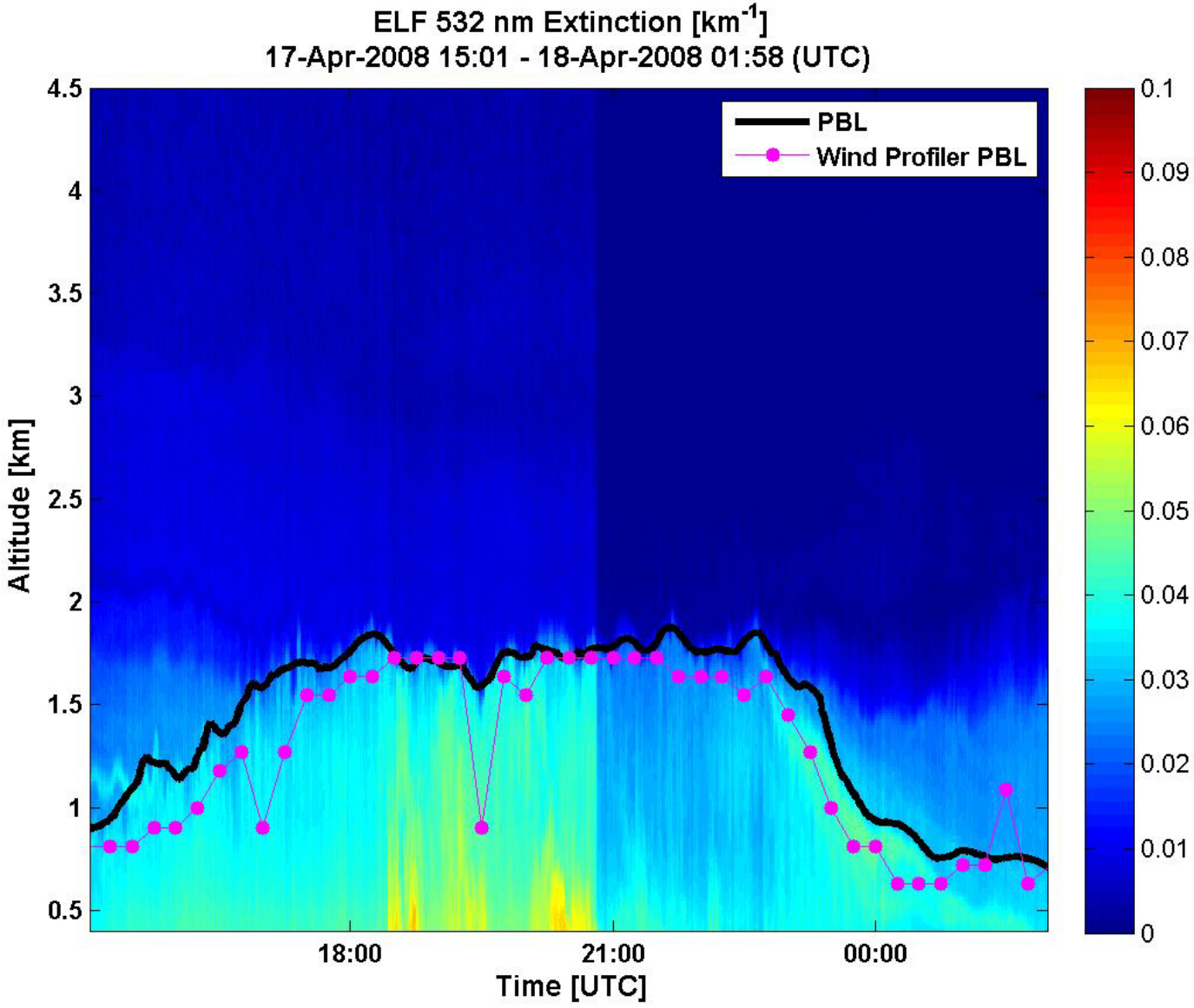
ELF

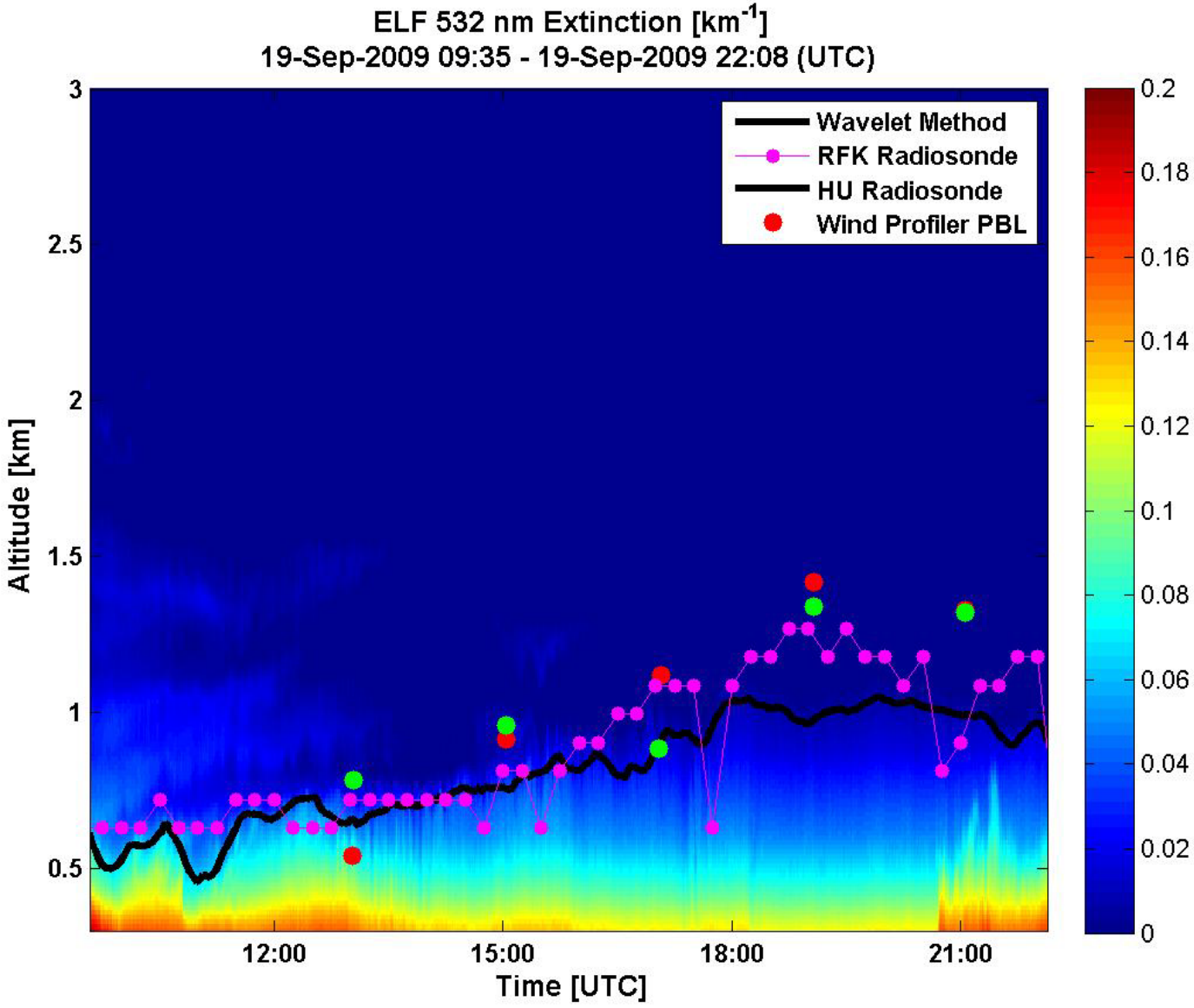
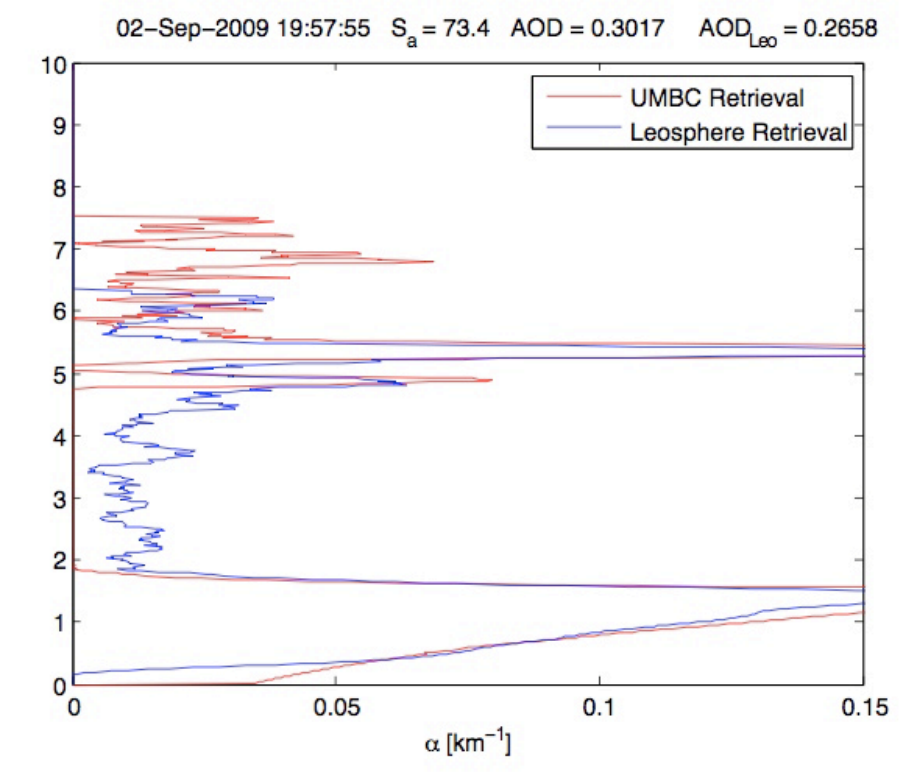
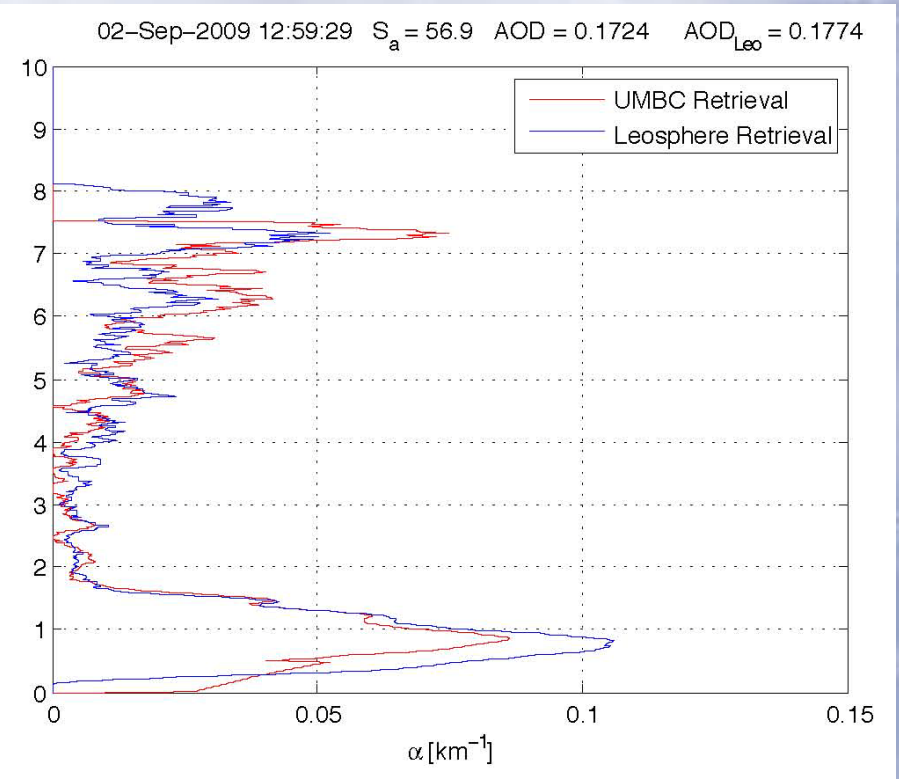

ELF 532 nm Extinction [km-1]
13-Aug-2007 17:00 - 14-Aug-2007 00:00 (UTC)
PBL
Wind Profiler PBL
Altitude [km]
4.5
4
3.5
3
2.5
2
1.5
1
0.5
18:00
21:00
00:00
Time [UTC]
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0

Lidar Extinction Profile and Radiosonde Virtual Temperature Profile for 8/14/2007 at 0:00 UTC



SNR
ELF
Radiosonde (Dulles)


ELF 532 nm Extinction [km-1]
17-Apr-2008 15:01 - 18-Apr-2008 01:58 (UTC)
PBL
Wind Profiler PBL
Altitude [km]
4.5
4
3.5
3
2.5
2
1.5
1
0.5
18:00
21:00
00:00
Time [UTC]
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0


ELF 532 nm Extinction [km-1]
19-Sep-2009 09:35 - 19-Sep-2009 22:08 (UTC)
Wavelet Method
RFK Radiosonde
HU Radiosonde
Wind Profiler PBL
Altitude [km]
3
2.5
2
1.5
1
0.5
12:00
15:00
18:00
21:00
Time [UTC]
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0

Leosphere - ELF Sept. 02, 2009 intercomparison