Summary of Micro-Pulse Lidar Data Obtained During NASA's DISCOVER-AQ field missions

Timothy Berkoff[1,2*], Raymond M Hoff[2], Ruben Delgado[2], Patricia Sawamura [1,2*], Jamie Compton[2], Daniel Orozco[2], John Sullivan[2], Rebecca Pauly[3], Richard Clark[3], Ricardo Uribe[3], Jean Vivola[3,] Courtney DeLong[3], Andrea Thomas[4], William Lawrence[4], Taylor Jones[5], Phil Decola[5], Savyasachee Mathur[5], Yunhui Zheng[5], Gail Wyant[6], Raymond Blucher[6], Renee Piatt[6], Mustafa Abderrahman[6], Douglas Martins[7], Hannah Halliday[7], Ryan Auvil[8], Michael Woodman[8], Rasheen Connell[9], Michael Hicks[9], Belay Demoz[9], Maria Tzortziou[10,11], Pasquale De Rosa[12], Richard Ferrare[1], Chris Hostetler[1]

1. NASA -LARC, Hampton, VA, USA
2. Univ of Maryland Baltimore Co., Baltimore, MD, USA
3. Millersville University, Millersville, PA USA
4. Bowie State University, Bowie, MD, USA
5. Sigma Space, Lanham, MD, USA,
6. Cecil College, Elkton, MD, USA
7. Pennsylvania State Univ., University Park, PA, USA
8. Maryland Dept. of the Environment, Baltimore, MD, USA
9. Howard University, Beltsville, MD, USA
10. Univ of Maryland, College Park, MD, United States
11. NASA-GSFC, Greenbelt, MD USA
12. Cardinal Point Captains llc., Long Beach, CA, United States

*Formerly with UMBC, now at NASA-LaRC

ACKNOWLEDGEMENTS

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DISCOVER-AQ
http://discover-aq.larc.nasa.gov/

- **DISCOVER-AQ (DAQ), a NASA Earth Venture program funded mission, stands for Deriving Information on Surface Conditions from Column and Vertically Resolved Observations Relevant to Air Quality**
- **Ground-based & aircraft measurements at four different regions:**
  - **Baltimore-Washington & GEO-Cape ship, MDE aircraft (July/Aug 2011)**
  - **California (Jan/Feb 2013)**
  - **Houston (Sept 2013) w/SEAC4RS**
  - **Denver (July/Aug 2014) w/FRAPPE**
- **Two key aircraft: Wallops P3 & Langley King Air**
- **MPL systems present in all four campaigns at different ground sites, but do not represent all lidars in the field campaign, many other systems (wind, HSRL, ceilometers, etc)**
- **Typically located at critical P3 aircraft "spiral" locations**
- **MPL data systems auto-linked together via Dropbox, to provide real-time display of data during field operations and instrument monitoring**

http://www.aqast-media.org/#!newsletters/c1dde

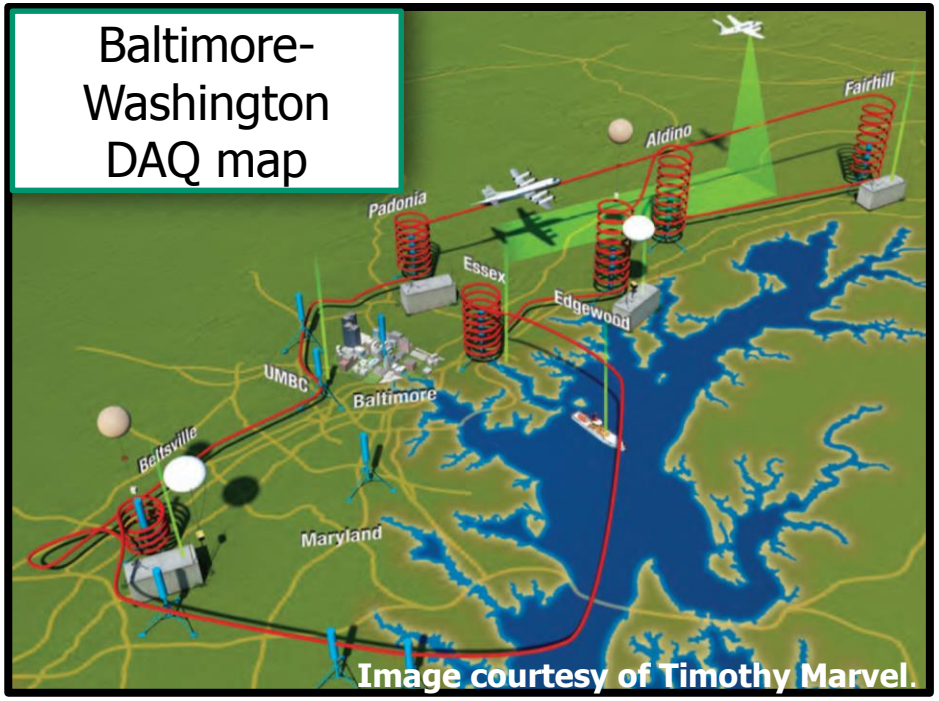


Image courtesy of Timothy Marvel.

Micro-Pulse Lidar Systems

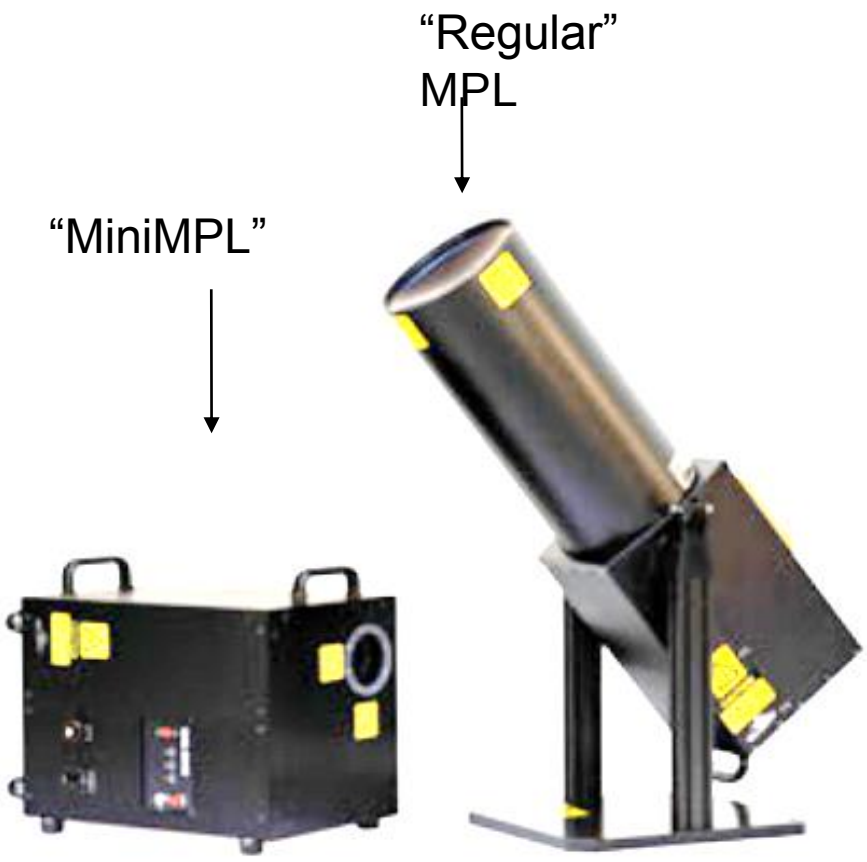
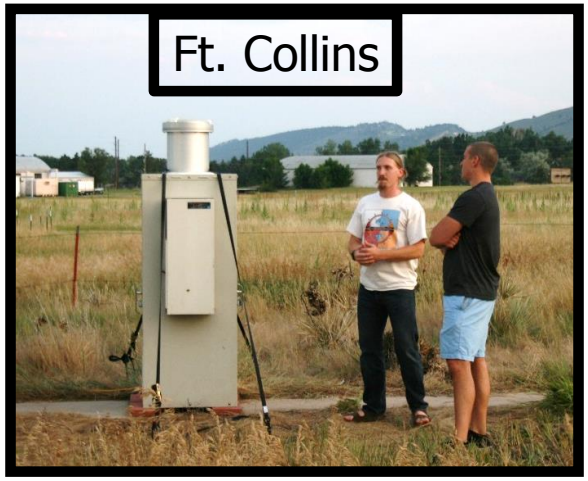
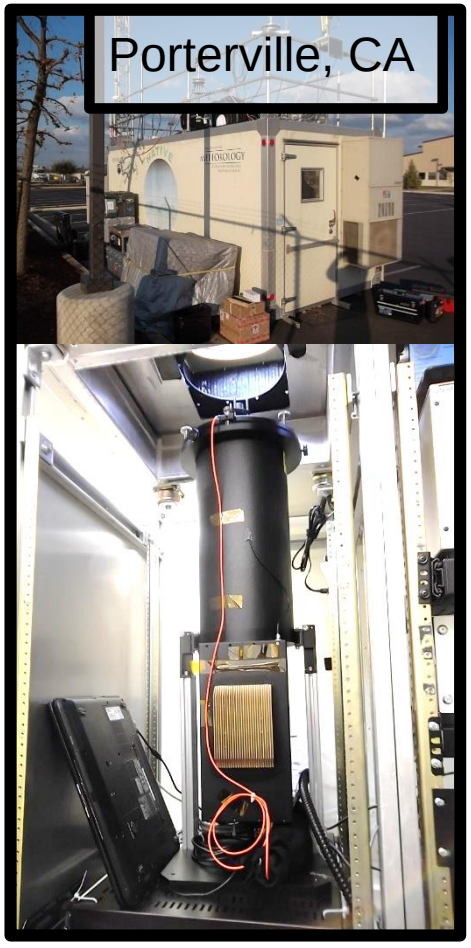


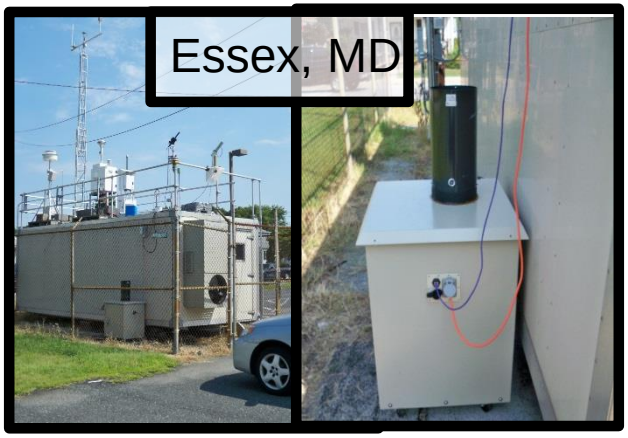
Photo credit: Sigma Space

- **Manufactured by Sigma Space http://www.sigmaspace.com/**
- **Portable & meets ANSI Class 2 "eye-safe" standard**
- **Unattended, continuous (24-7) aerosol and cloud profiling during DAQ**
- **Systems loaned by Sigma or owned by DAQ research groups (UMBC or Millersville)**
- **Two different model types: Regular MPL & "MiniMPL"**
- **Single wavelength 532 or 527 nm, for DAQ operated at 30 m vertical and 1 minute time resolutions**

MPLs in the field for DISCOVER-AQ







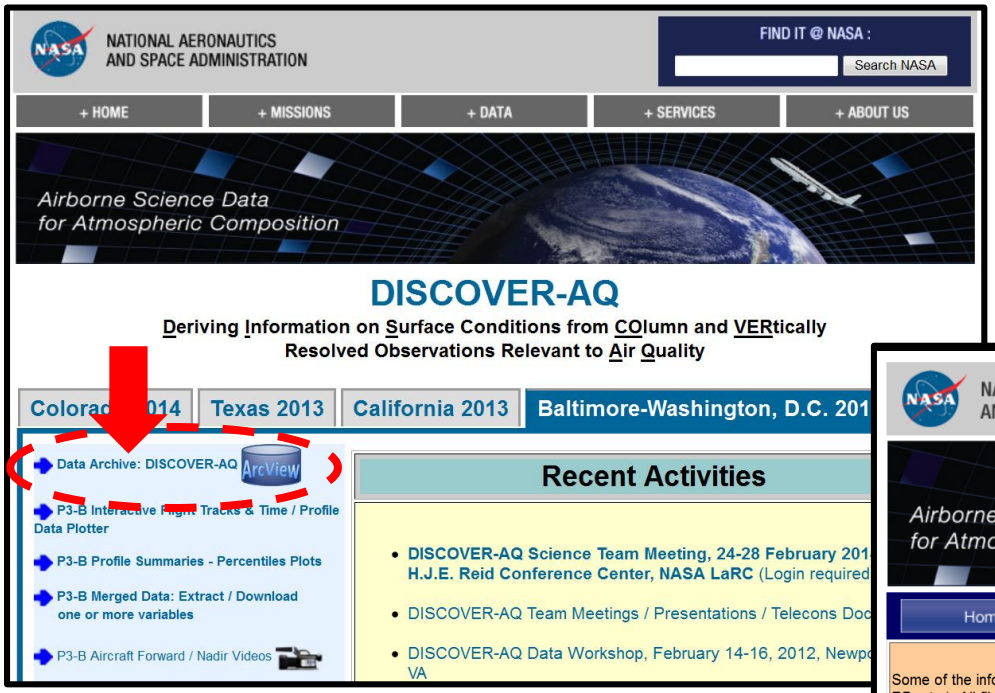
Summary of DISCOVER-AQ MPL Sites

- 30 meter vertical, 1 minute time resolution
- Typically located at P3 spiral locations
- Geo-CAPE NOAA ship in 2011 (see Tzortziou et al., Journal of Atmospheric Chemistry, April 2013)
- Additional wide-field receiver used in-field for California 2013, Houston 2013, Denver 2014 to help with near-range signal and calibration
- Sites are not part of NASA's MPLNET network, data available in DISCOVER-AQ archive
- Eleven different sites, ~600 hours of data/site, ~360,000 profiles

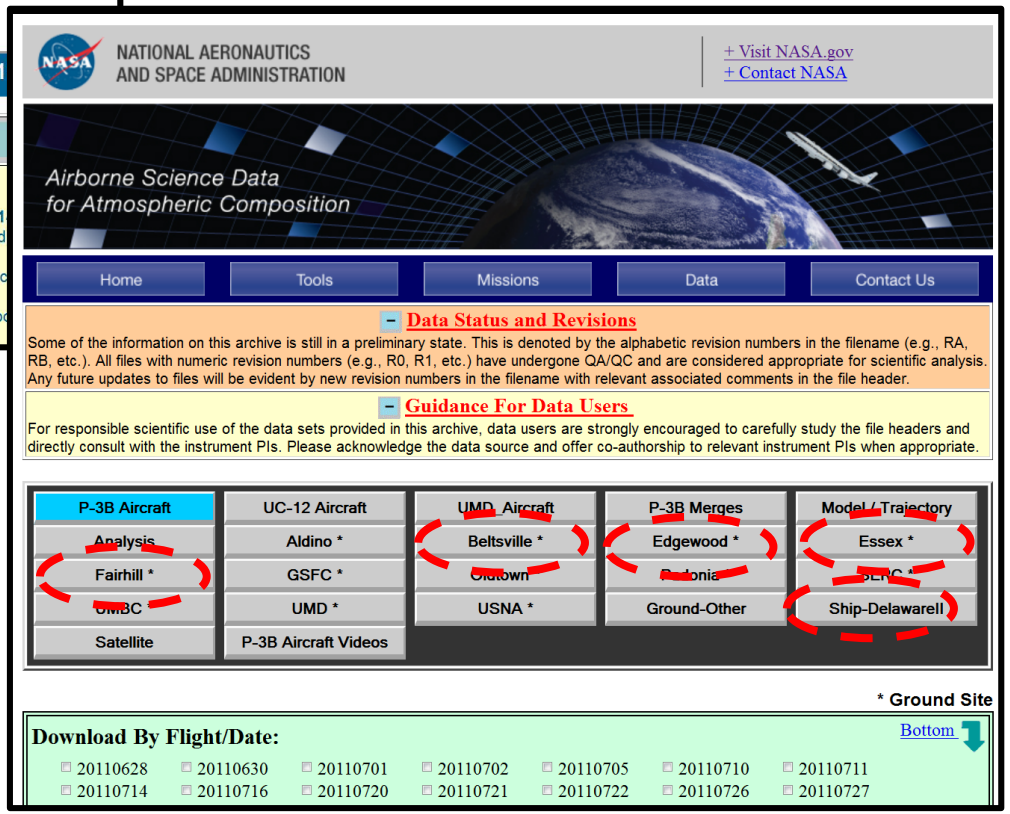
DISCOVER-AQ MPL sites

Site	Lat/Lon	Owner/Model/Serial	Dates of operation	Depol?	Host
Baltimore-Washington 2011					
Beltsville	39.0562, -76.87540	Sigma Space/ MiniMPL/5004	July 11 to Aug 2	Y	Howard Univ.
Essex	39.31095, -76.47449	Sigma Space/ MiniMPL/5003	July 21 to Aug 3	Y	MDE
Edgewood	39.41014, -76.29682	Sigma Space/ MiniMPL/5002	June 28 to Aug 15	Y	Penn State
Fairhill	39.70140, -75.85995	Sigma Space/ MPL/4111	June 29 to July 31	Y	NASA GSFC SMART trailer
NOAA ship/Chesapeake Bay	Misc	Sigma Space/ MiniMPL/5003	July 14 to July 20	Y	NOAA Vessel SRVx
California 2013					
Porterville	36.0319, -119.0551	UMBC/ MPL/4021/ Inc. extra near-range channel	Jan 11 to Feb 7	N	Penn State
Huron	36.2062, -120.1046	Millersville/ MPL/111	Jan 14 to Feb 8	N	Millersville
Houston 2013					
Smith Point	29.546, -94.7799	Millersville/ MPL/111/ Inc. extra near-range channel	Sept 1 to Sept 27	N	Millersville
Denver 2014					
Ft. Collins	40.5930, -105.1414	Millersville/ MPL/411	July 16 to Aug 9	Y	Millersville
Platteville	40.1828, -104.7261	Sigma Space/ MPL/5002	July 18 to Aug 11	Y	Penn State
NREL-Golden		UMBC/MPL/4021	July 16 to Aug 11	N	UMBC

How to Find DISCOVER-AQ MPL Data



Archive Website:
http://www-air.larc.nasa.gov/missions/discover-aq/discover-aq.html



Select campaign region
To find MPL data need to know specific site name
Then under BERKOFF.TIM/

All files are publicly available, except Colorado 2014, expected public release in early 2015

Data format is H5, daily quicklook images in .png

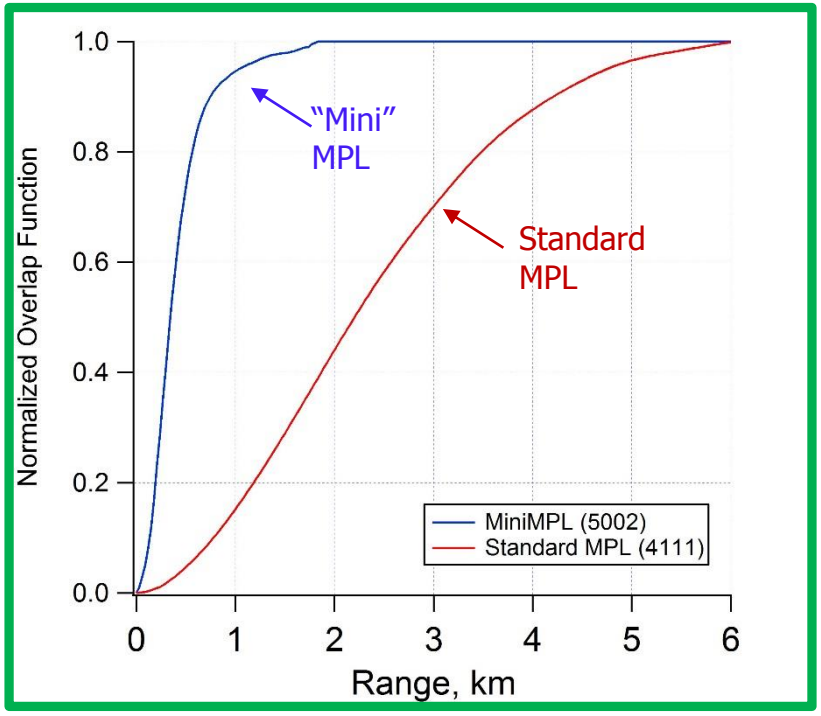
MPL Data Processing for DISCOVER-AQ

deadtime correction

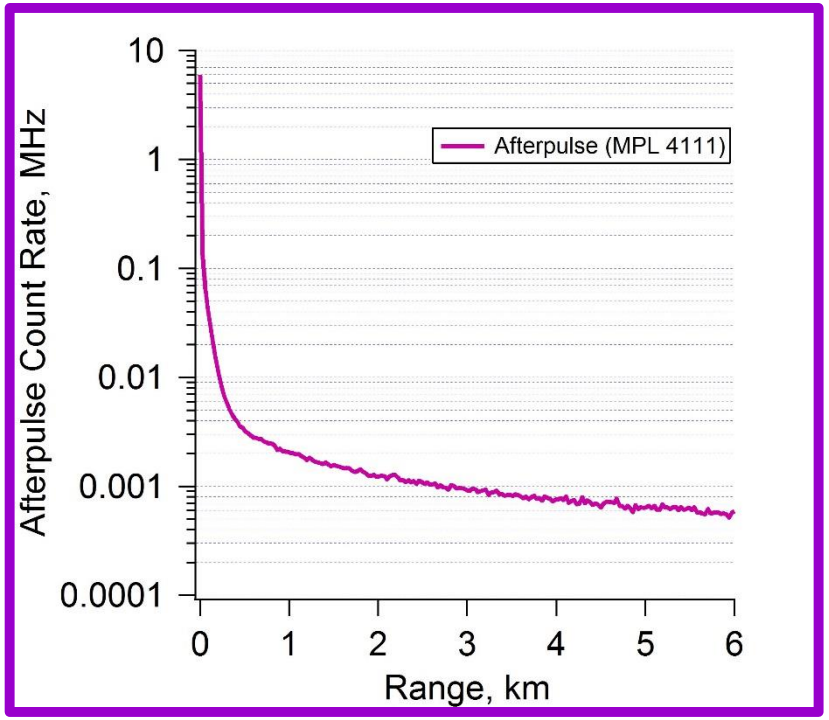
atmospheric terms

$$S(r) = D \cdot \left[\frac{O(r) \cdot E \cdot C \cdot \beta(r) \cdot T^2(r)}{r^2} + B + A(r) \right]$$

Overlap Function $O(r)$



Afterpulse Signal $A(r)$



Overlap and afterpulse for each MPL system are different, require careful calibration and validation to obtain quantitative boundary layer aerosol information.

MPL Data for DISCOVER-AQ

Post-campaign NRBs re-processed with updated overlap calibrations and placed in the archive, H5 format
Daily images also uploaded to archive

For the lidars with depolarization, raw cross-pol data was placed in the archive, but not converted quality checked data product

From the NRB data, it is possible to:

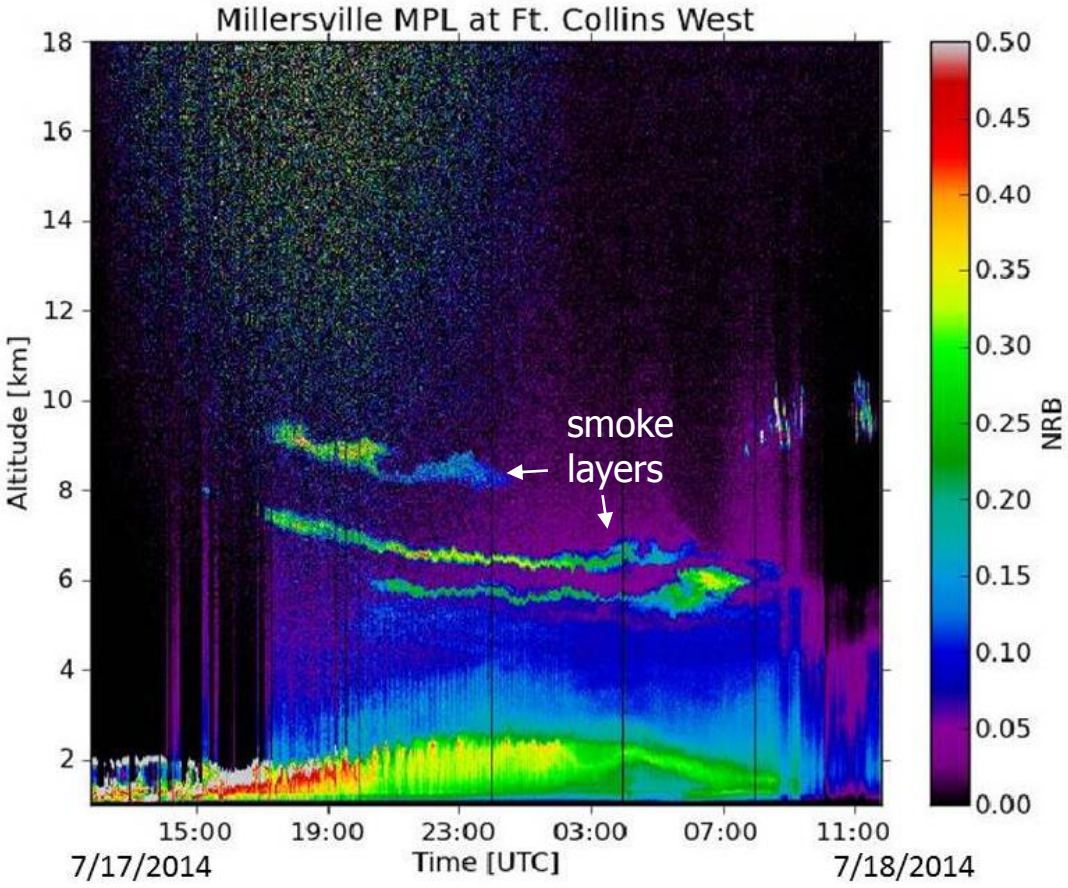
- Generate mixed layer height, an indicator of PBL height during daytime (*see Compton et al., Scarino et al.)*
- Use Fernald-Klett inversion with co-located AERONET AOD to get average S-ratio and generate aerosol backscatter β(r) & aerosol extinction T(r) profiles

<u>For descrip. of lidar inversion methods see:</u>
Fernald, F. G.: Appl. Opt., 23, 652–653, 1984.
Marenco et al. Appl. Opt., 36, 6875–6886, 1997.

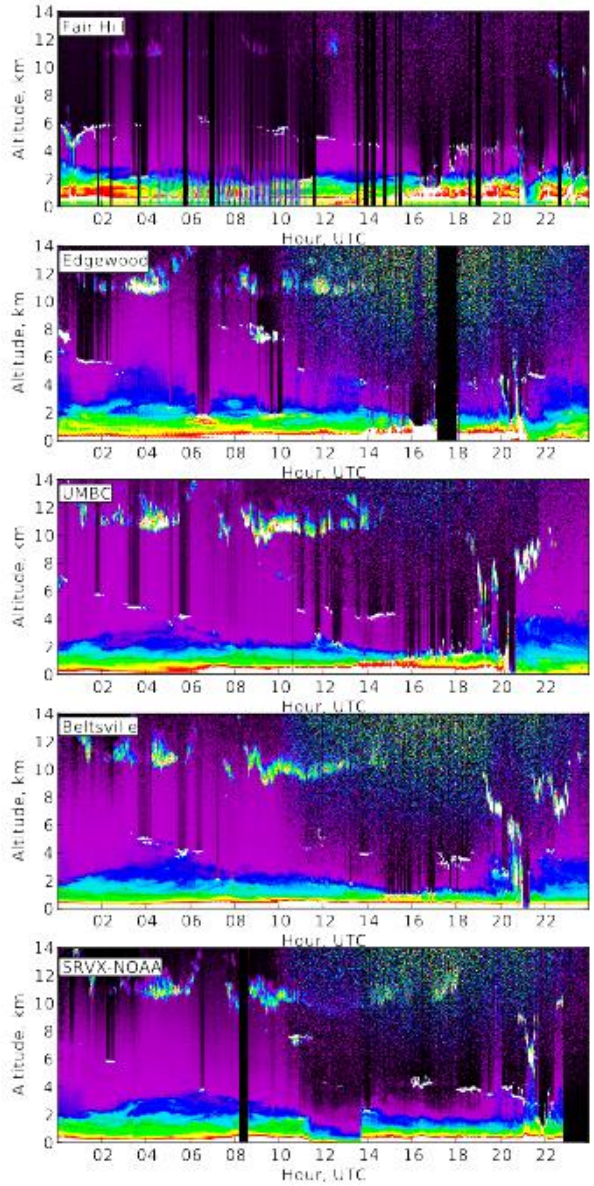
lidar constant — atmospheric terms

$$NRB(r) = C \cdot \beta(r) \cdot T^2(r)$$

Example Daily Quick-look Image

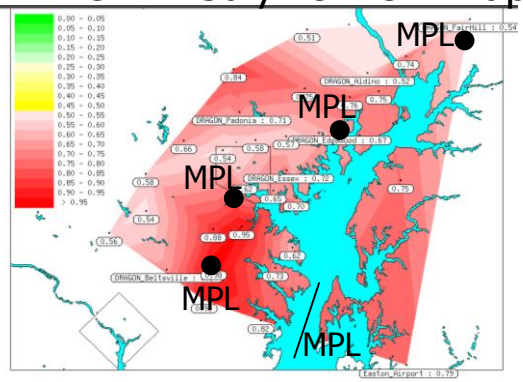


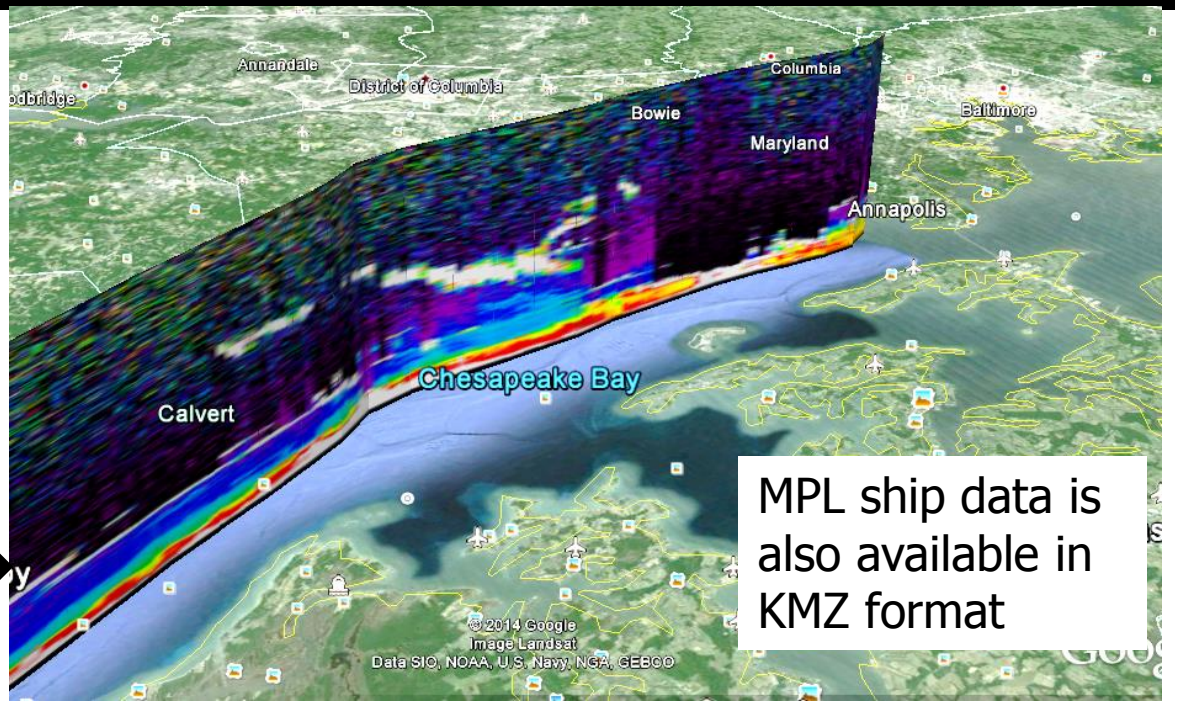
Multi-site Data Example from July 19, 2011



NOAA Vessel SRVx - National Marine 501

AERONET July 19 AOD map

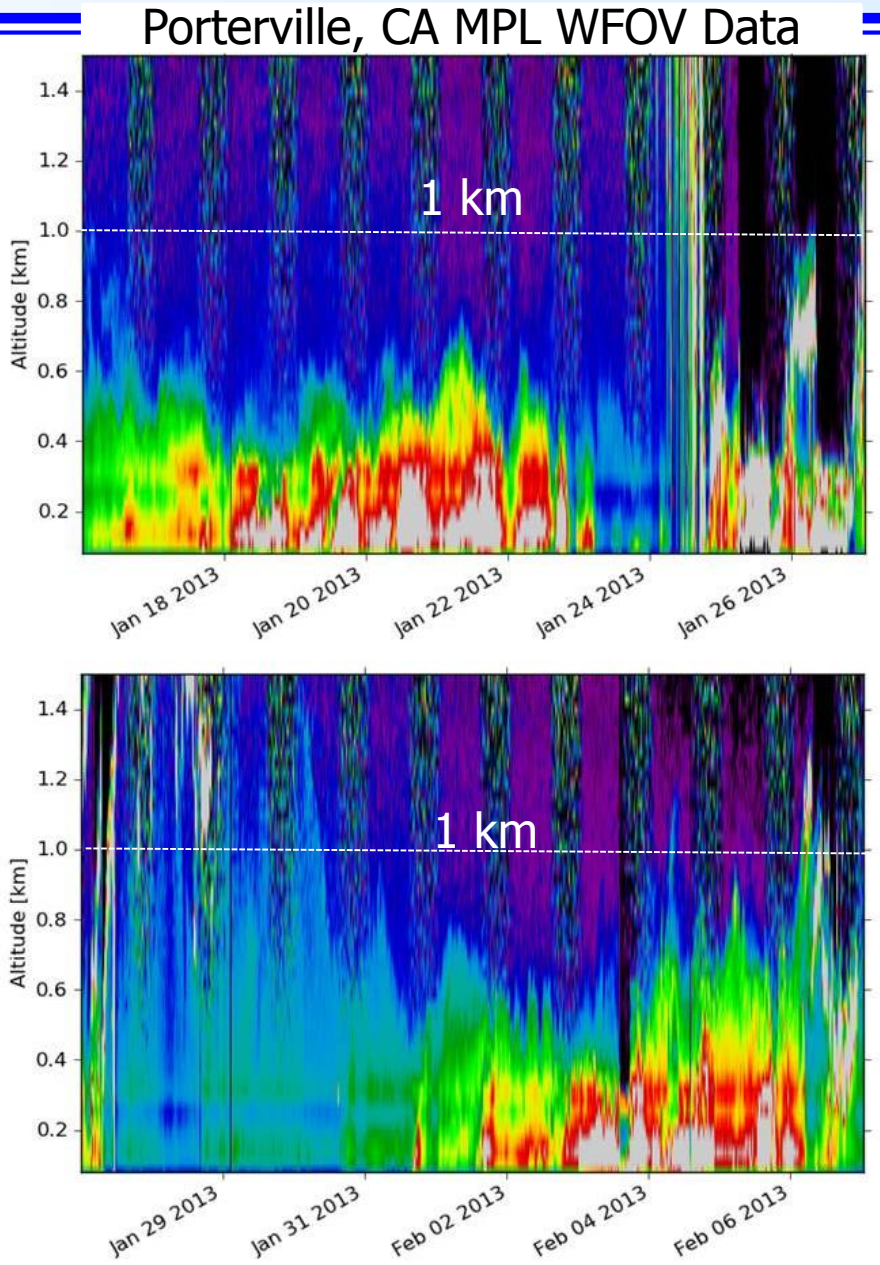




MPL ship data is also available in KMZ format

Recovery of near-surface signal with wide field-of-view (WFOV) receiver

- San Joaquin Valley has extremely low PBL, so low that standard MPL channel would not ordinarily capture aerosol dynamics
- WFOV overlap very short
- WFOV implemented at some DAQ sites in California, Houston, & Denver to enable on-site cals and better retrievals of near-field (< 1 km) aerosols



Airborne HSRL Aerosol Measurements

DISCOVER-AQ (July 2011)

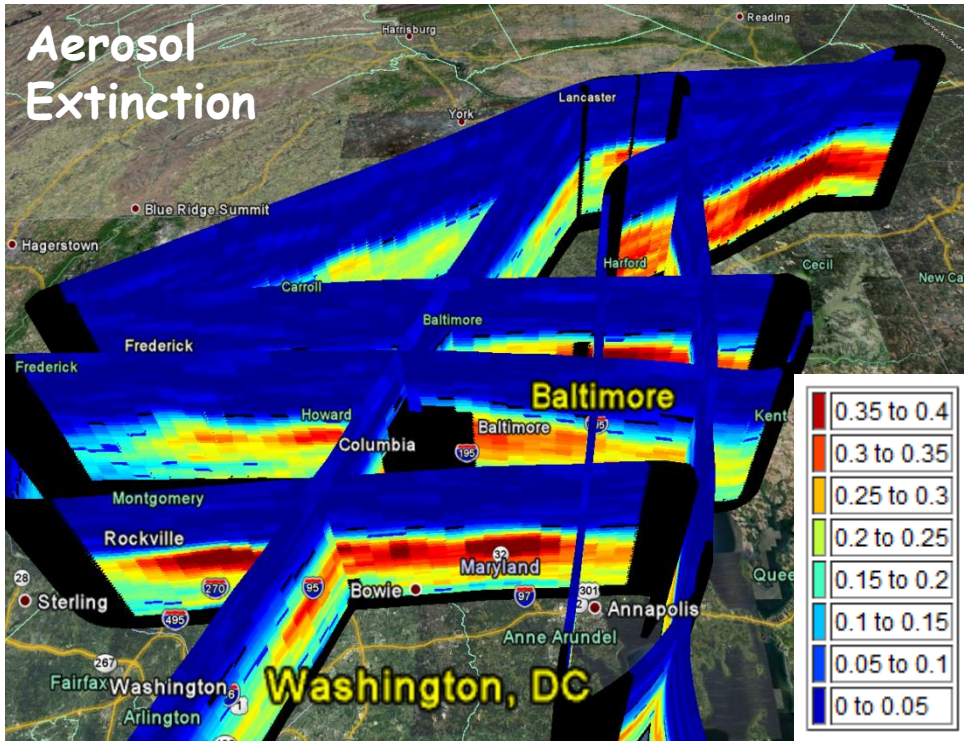
- 25 science flights
- ~100 science hours
- HSRL "curtains" provide:
  - measurement of horizontal and vertical variability over domain
  - vertical context for surface and satellite column measurements

HSRL Technique:

- Independently measures aerosol backscatter, extinction, and optical thickness

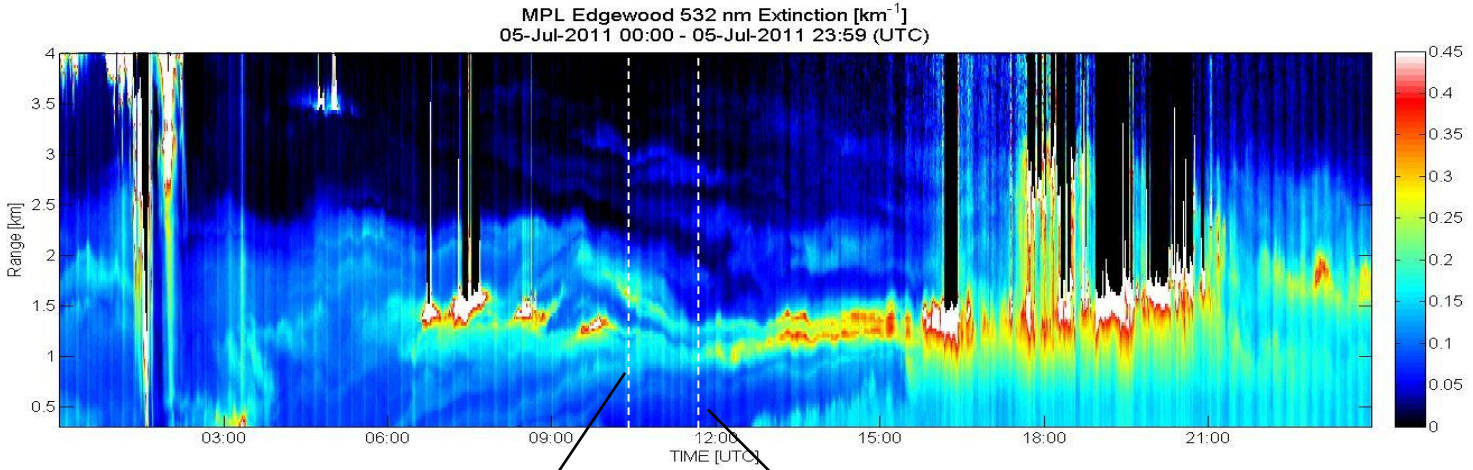
HSRL Aerosol Data Products:

- Backscatter coefficient (532, 1064 nm)
- Depolarization (532, 1064 nm)
- Extinction Coefficient (532 nm)
- Optical Depth (AOD) (532 nm)
- Planetary Boundary Layer (PBL) Height

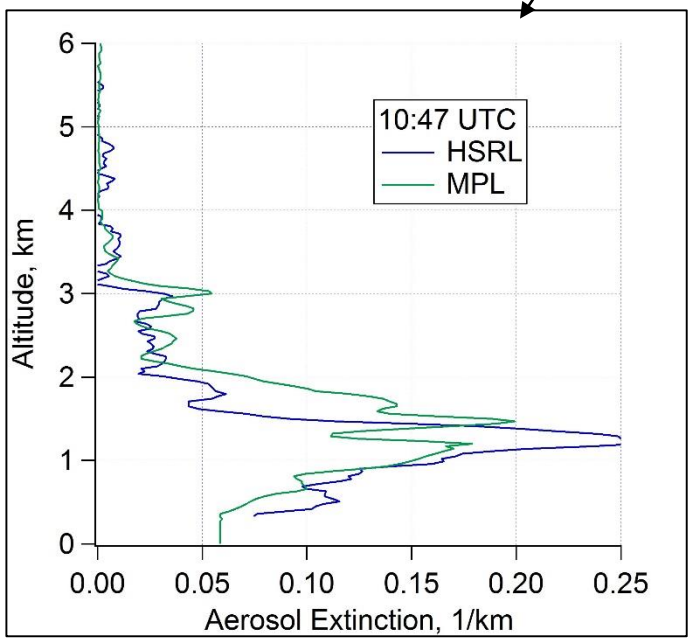


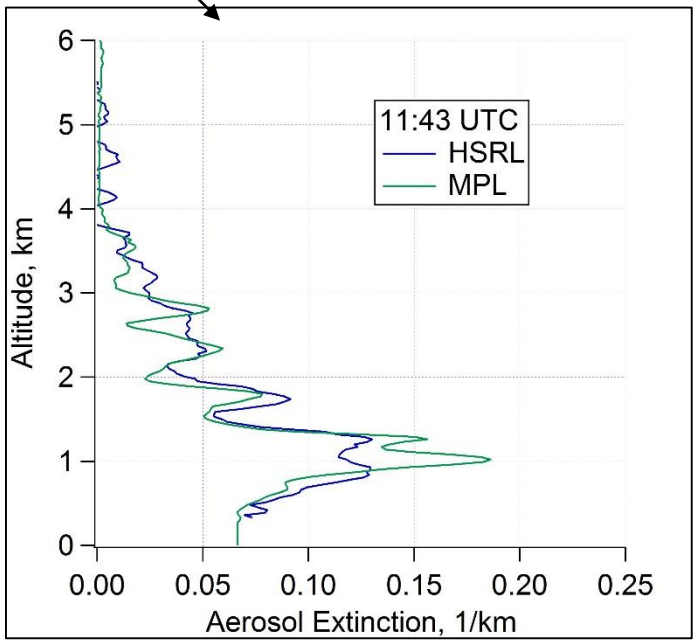
Comparisons to NASA's HSRL airborne data

Aerosol Extinction Retrieval for July 5 Edgewood "MiniMPL"



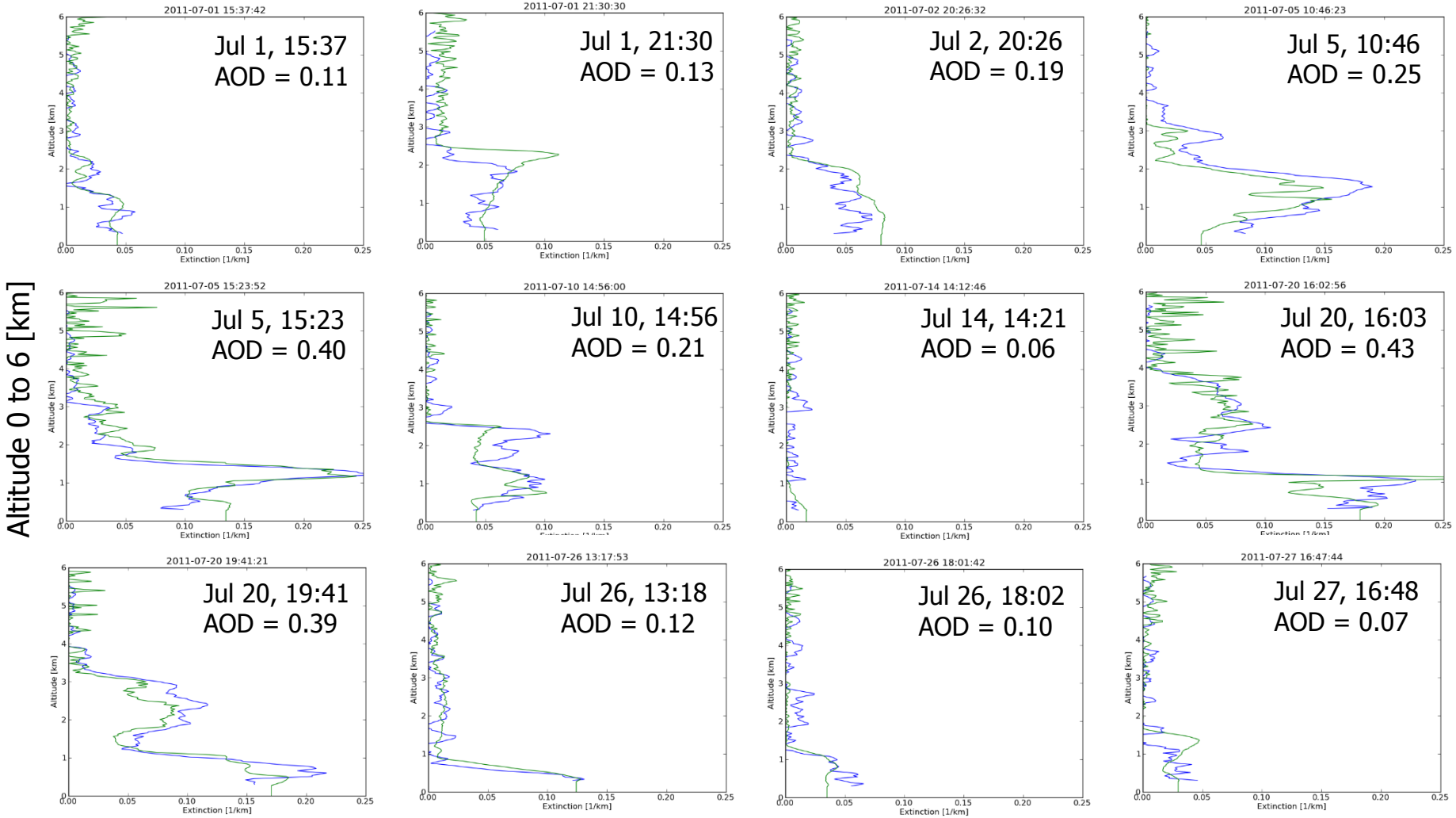
Example Aerosol Extinction Comparisons with LARC Airborne HSRL





Example MPL Comparisons to NASA's airborne HSRL spatially coincident (< 5 km) extinction profiles

Edgewood MPL (green) & airborne HSRL (blue) coincident profiles

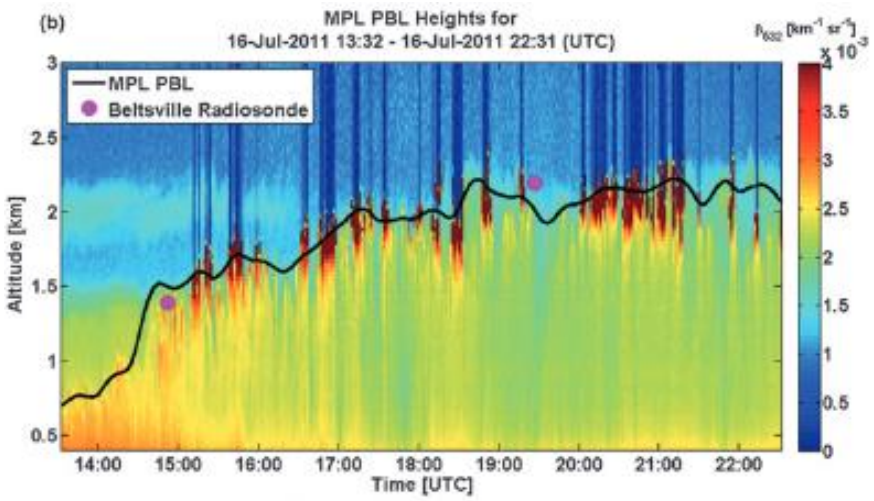


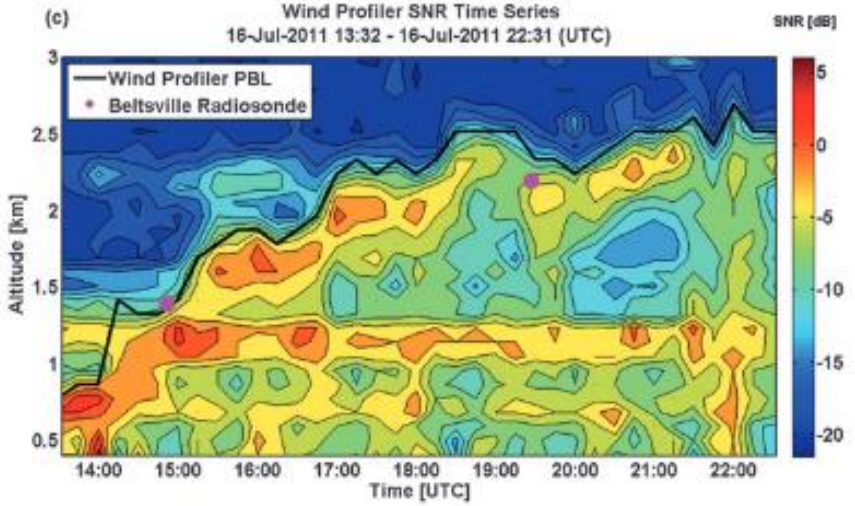
Altitude 0 to 6 [km]

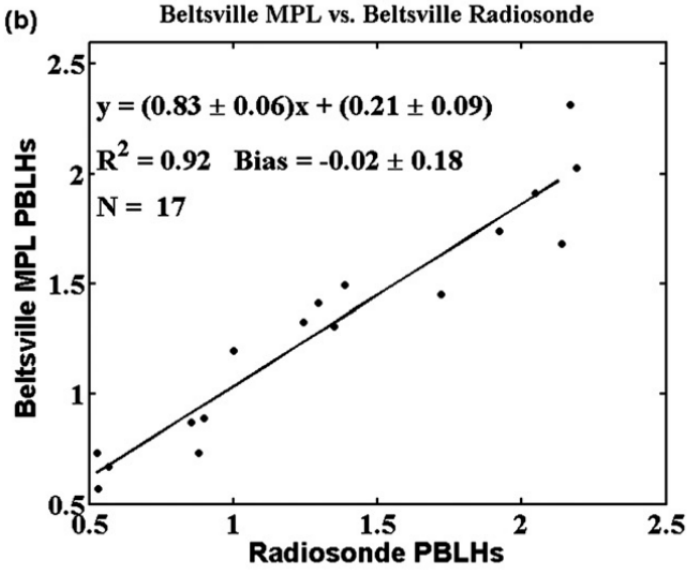
Extinction coefficient, 0 to 0.25 [km^{-1}]

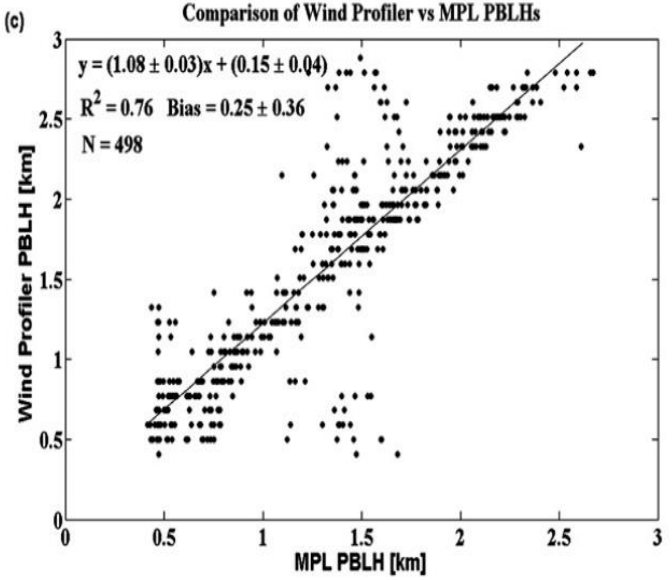
MPL Determination of Daytime PBL growth

From Compton et al., *J. Atmos. Oceanic Technol.*, **30**, 1566–1575

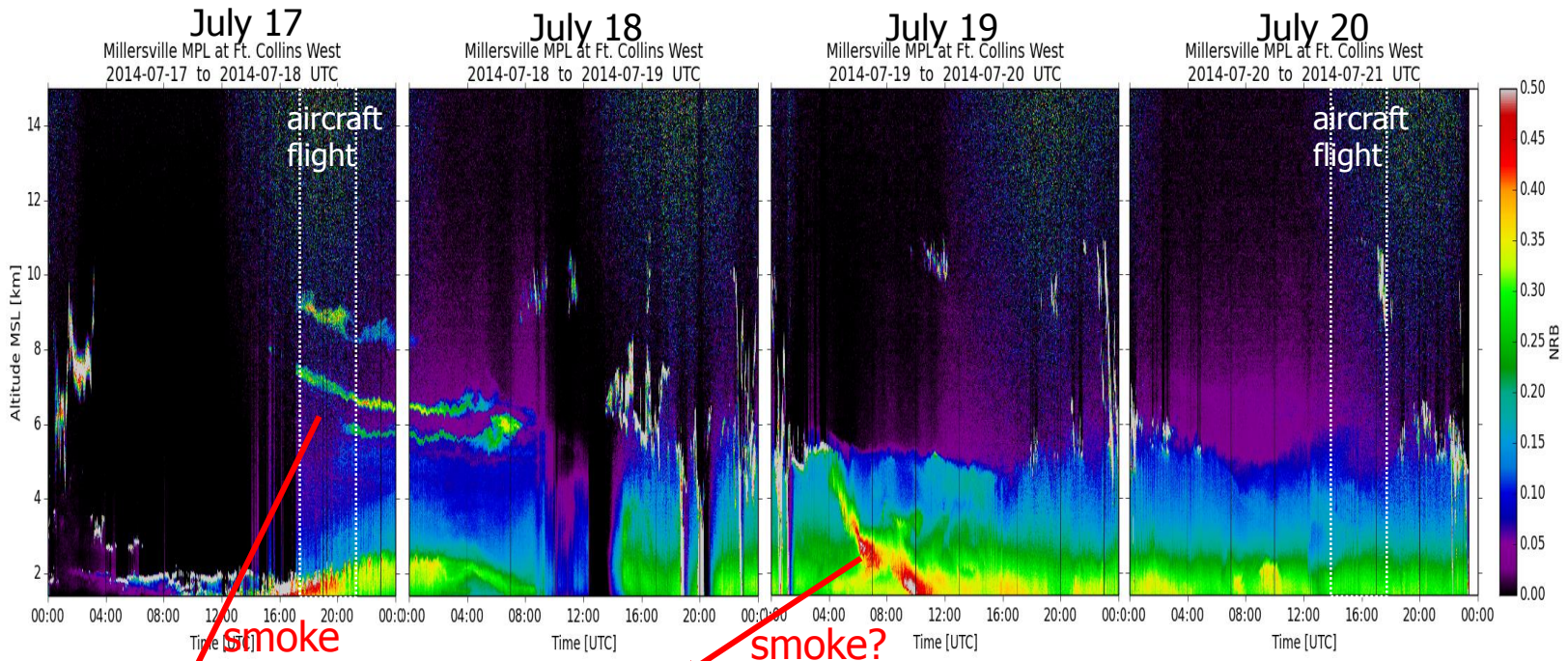


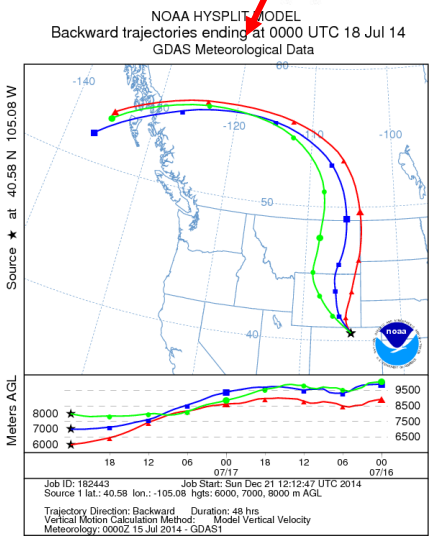


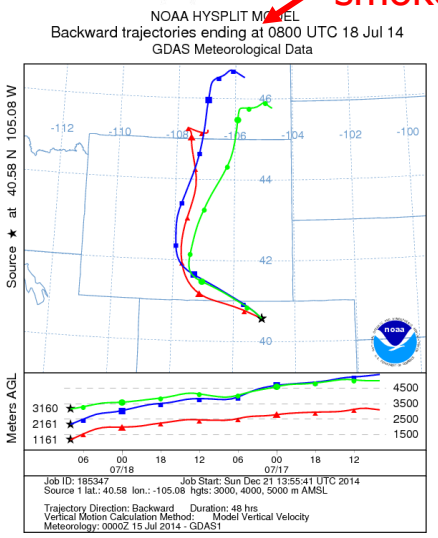


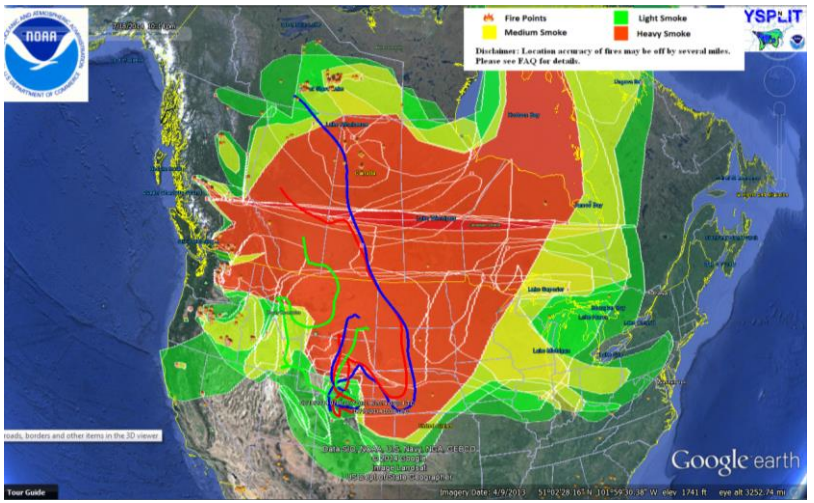


Smoke Transport Case July 17-20, 2014



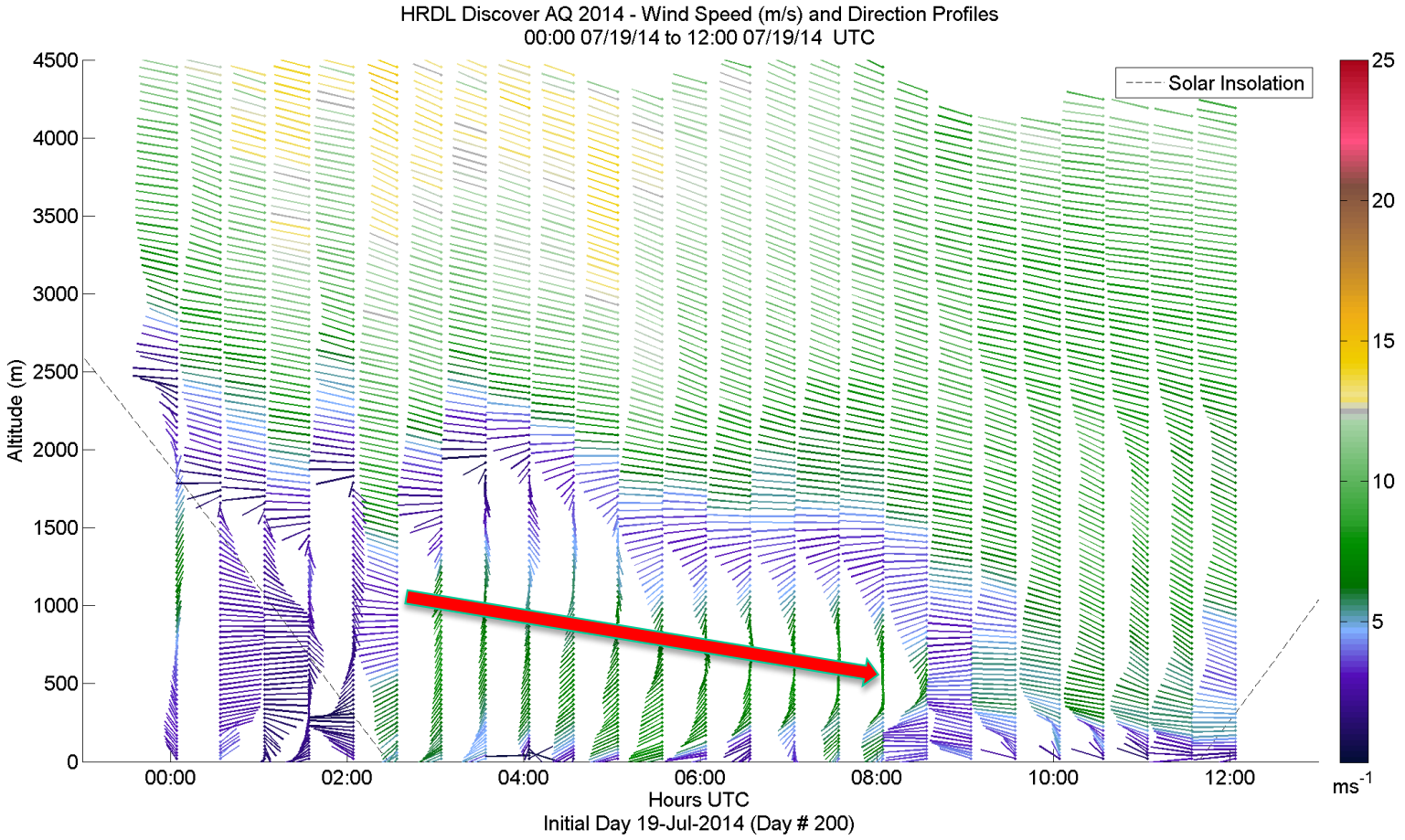






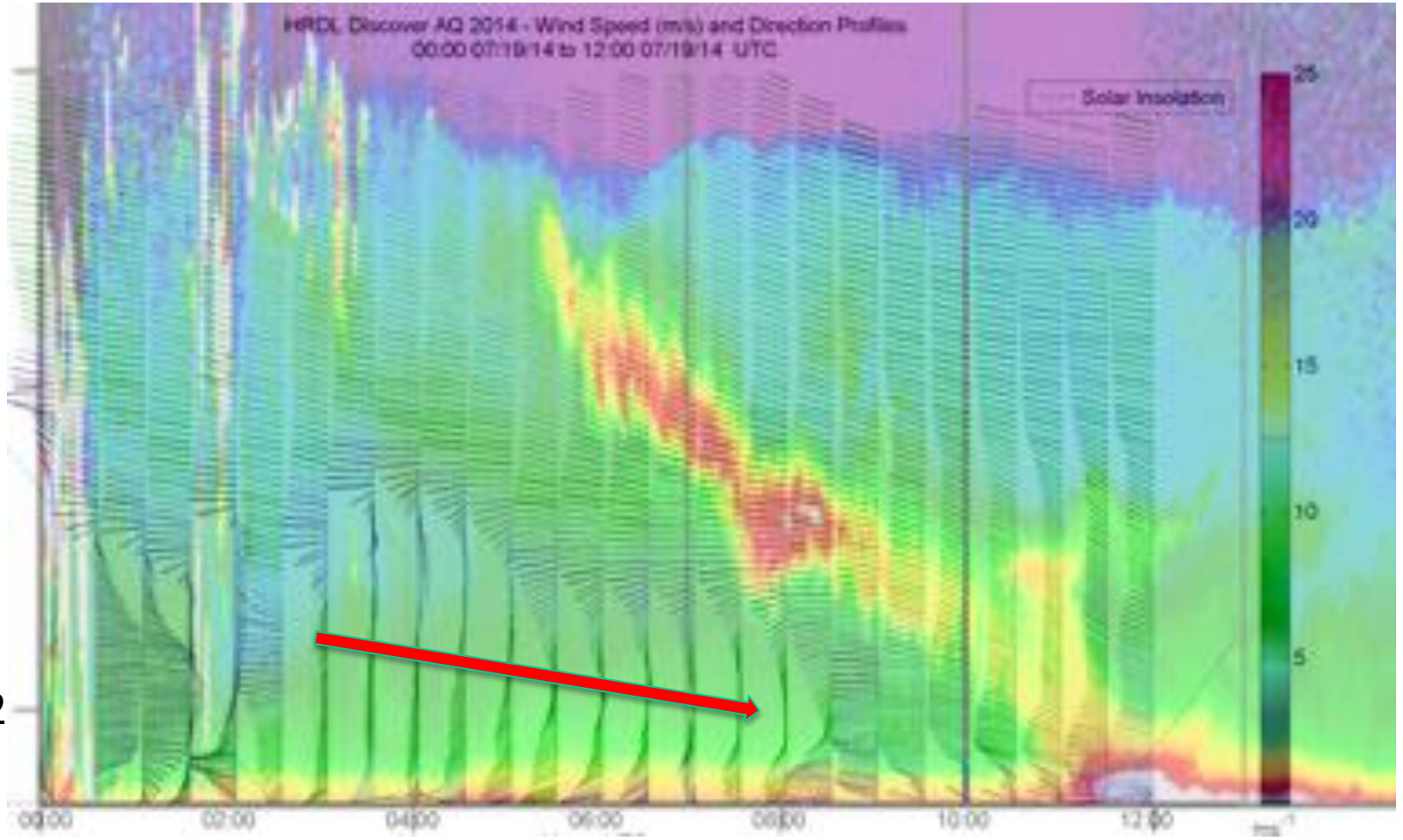
HRDL Wind Profiles (Alan Brewer at NOAA ESRL/CSD)

- Depicts a defined LLJ "core"from 04-08 UTC of >10 m/s from the surface to near 1500 m AGL. Red arrow estimates center of core.
- The dramatic turning of the winds is also apparent.



MPL Backscatter with HRDL Overlay

July 19, 2014: Porterville MPL Backscatter W/ HDRL winds



Altitude (MSL), km

Time, UTC

Studies using DISCOVER-AQ MPL data

- **Compton et al., Determination of Planetary Boundary Layer Height on Short Spatial and Temporal Scales: A Demonstration of the Covariance Wavelet Transform in Ground-Based Wind Profiler and Lidar Measurements. *J. Atmos. Oceanic Technol.*, 30, 1566–1575, 2013**
- **Eck et al., Observed Enhancements in Aerosol Optical Depth in the Vicinity of Cumulus Clouds in Maryland during DISCOVER-AQ, Atmos. Chem. Phys., 14, 11633-11656, 2014**
- **Knepp et al., Estimating surface NO2 and SO2 mixing ratios from fast-response total column observations and potential application to geostationary missions , *Journal of Atmospheric Chemistry,* DOI 10.1007/s10874-013-9257-6, 2013**
- **Reed et al., Effects of Local Meteorology and Aerosols on Ozone and Nitrogen Dioxide Retrievals from OMI and Pandora Spectrometers in Maryland, USA during DISCOVER-AQ 2011 , *Journal of Atmospheric Chemistry,* DOI 10.1007/s10874-013-9254-9, 2013**
- **Stauffer et al, Bay Breeze Influence on Surface Ozone at Edgewood, MD During July 2011 , *Journal of Atmospheric Chemistry,*** J Atmos Chem DOI 10.1007/s10874-012-9241-6, 2012
- **Hoff et al., Evaluation of Extinction Profiles and Aerosol Optical Depth from Multisensor Data in the Baltimore-Washington DISCOVER-AQ Experiment and Comparison with WRF/CHEM , In prep**
- **Scarino et al., Mixed Layer Heights and Aerosol Products derived for the NASA LaRC Airborne High Spectral Resolution Lidar during the 2011 DISCOVER-AQ Field Campaign In prep**

Summary

- During DAQ, MPLs collected data at eleven different sites resulting in ~250 days of data, ~360,000 vertical backscatter profiles
- Complimented by many other ground and aircraft trace-gas and aerosol measurements at four different DAQ regions in the U.S.
- MPL NRB data publicly available at NASA's DISCOVER-AQ archive
  http://www-air.larc.nasa.gov/missions/discover-aq/discover-aq.html
- MPL 2011 data also have aerosol extinction retrievals & mixed-layer height products, with further processing same could also be generated for remaining data (California, Houston, & Denver)
- Contributed to a range of studies including: PBL heights, cloud-aerosol interactions, trace gas, aerosol models & transport

To ensure best use of data please contact:

Tim Berkoff Email: timothy.a.berkoff@nasa.gov

Phone: 757-864-3684