Mixed Layer Heights and Aerosol Products derived from the NASA LaRC Airborne High Spectral Resolution Lidar during the First DISCOVER-AQ Field Mission

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NASA Langley Airborne High Spectral Resolution Lidar (HSRL)

DISCOVER-AQ (July 2011)

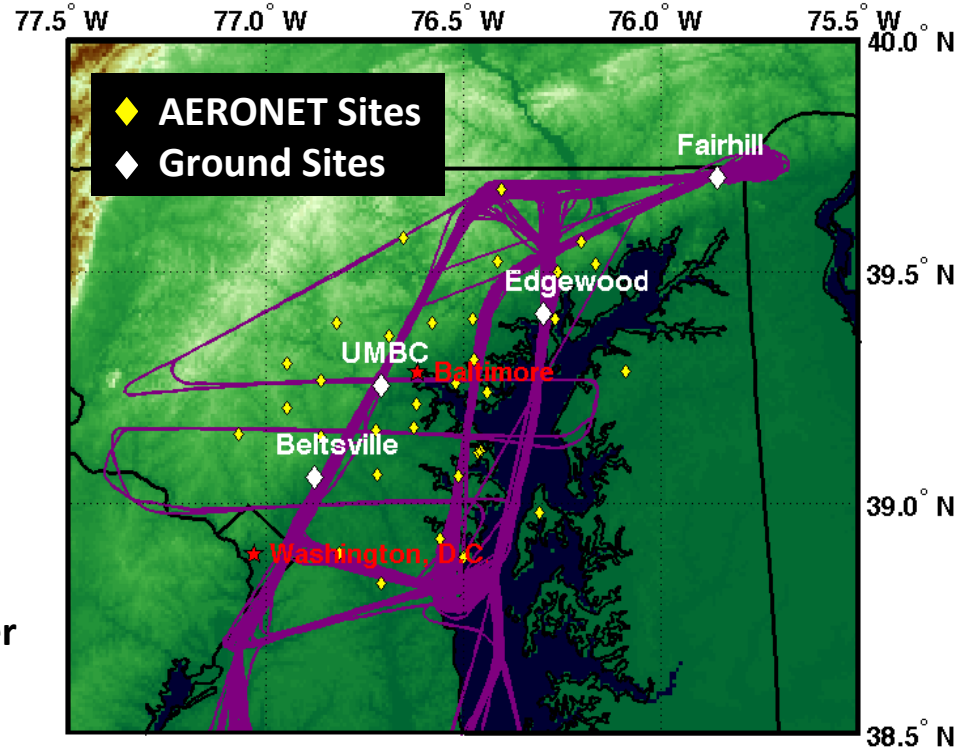
- Deployed on NASA/LaRC UC12 aircraft
- Flight altitude ~ 9 km
- Nadir pointing lidar
- 25 science flights (~100 science hours)
- Overflights of DISCOVER-AQ ground stations and AERONET "DRAGON" sites

HSRL Technique

- Relies on spectral separation of aerosol and molecular backscatter in lidar receiver
- Independently measures aerosol backscatter, extinction, and optical thickness
- Internally calibrated independent of atmosphere
- Provides intensive aerosol parameters to help determine aerosol type

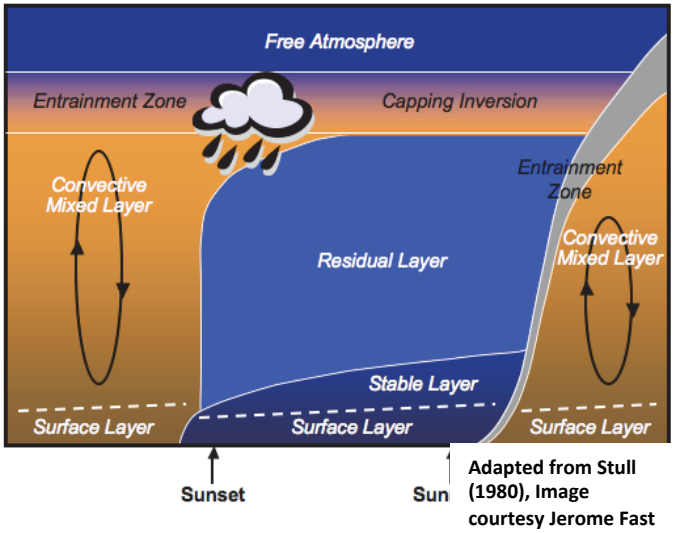
HSRL Aerosol Data Products

- Backscatter coefficient (532, 1064 nm)
- Extinction Coefficient (532 nm)
- Optical depth (532 nm)
- Depolarization (532, 1064 nm)
- Mixed Layer (ML) Height from aerosol backscatter gradients

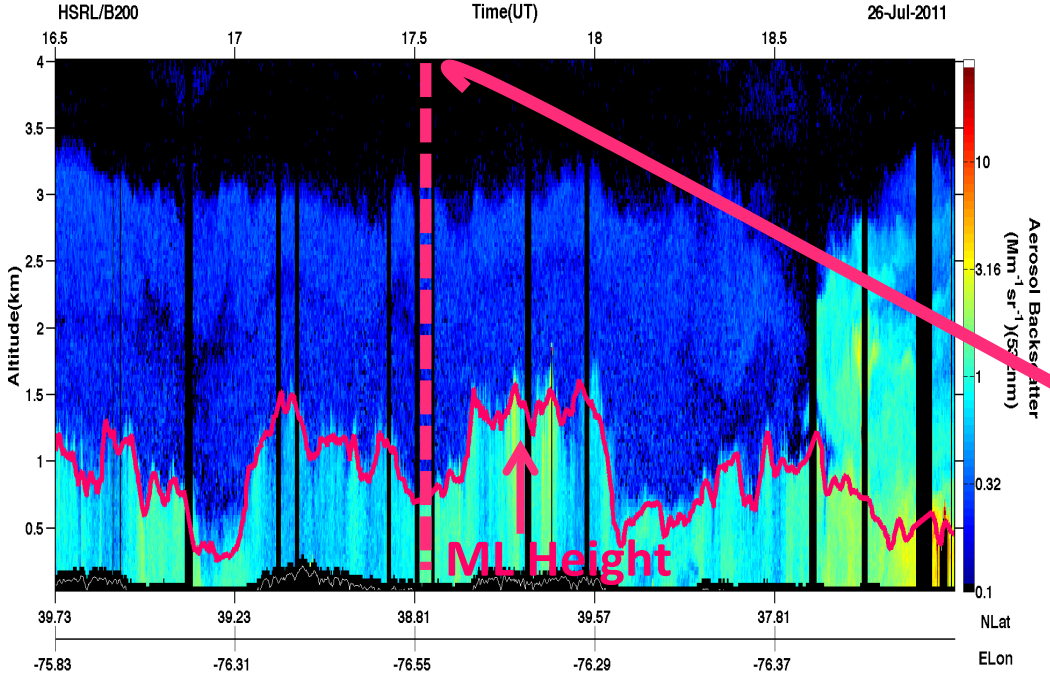


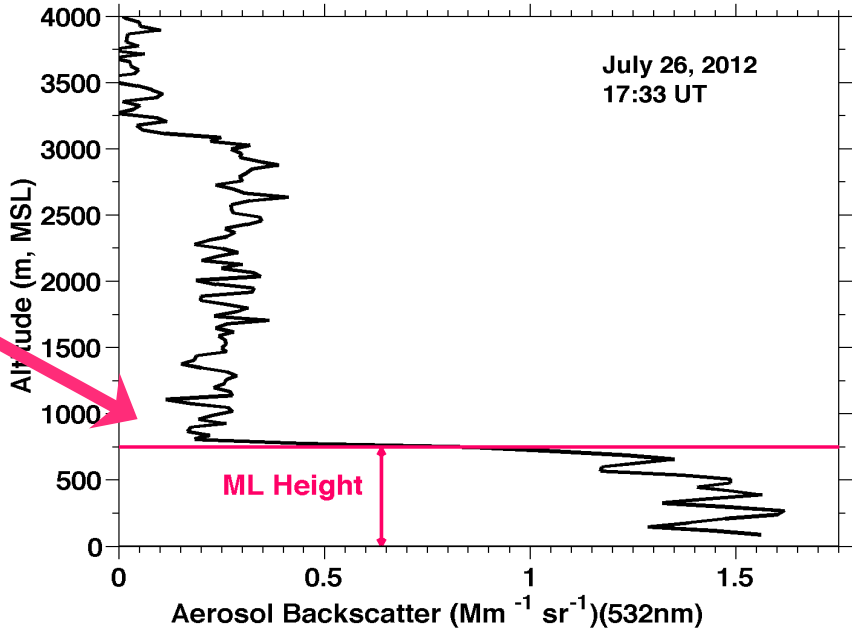
HSRL data used to find height of Mixed Layer

- Mixed Layer (ML) heights derived from daytime-only cloud-screened aerosol backscatter profiles measured by the airborne HSRL; ML heights are a good proxy for PBL heights during the daytime
- Automated technique uses a Haar wavelet covariance transform with multiple wavelet dilations to identify sharp gradients in aerosol backscatter at the top of the ML (adapted from Brooks, JAOT, 2003)
- HSRL ML heights combine results from automated algorithm and manual inspection of HSRL backscatter profiles
- Height of maximum aerosol gradient also identified to provide an alternative height to describe the depth of the aerosol layer
- These heights often correspond to gradients in potential temperature



Adapted from Stull (1980), Image courtesy Jerome Fast

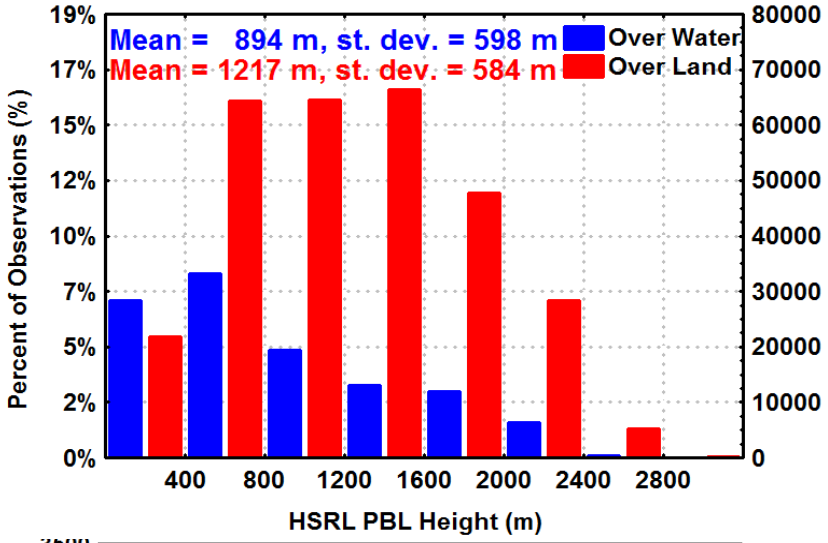


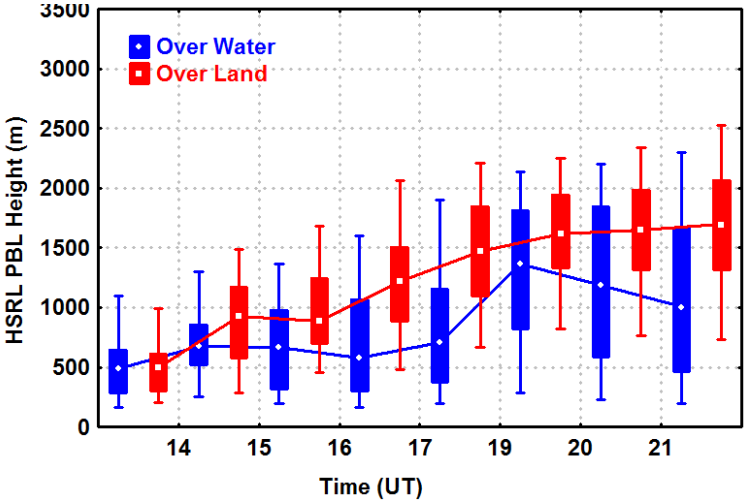


HSRL ML heights over land and water

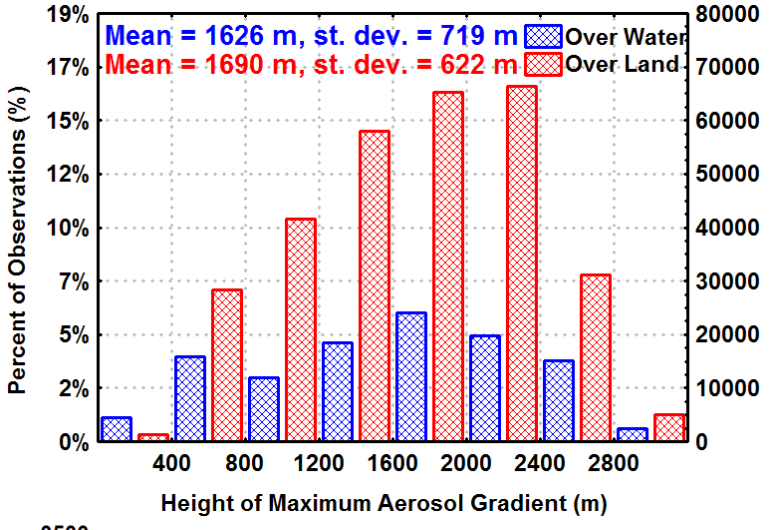
- ML heights are generally higher over land than over water (Chesapeake Bay)
- Height of maximum aerosol gradient about the same over land and water
- ML height and height of maximum aerosol gradient increased during the day

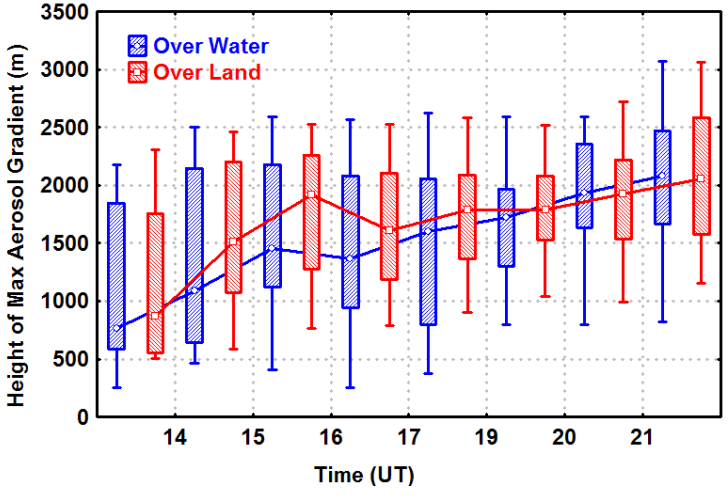
ML Height





Height of max aerosol gradient

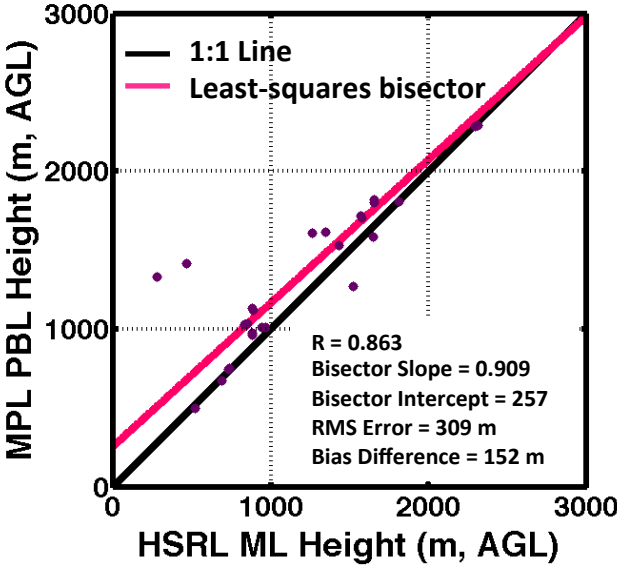




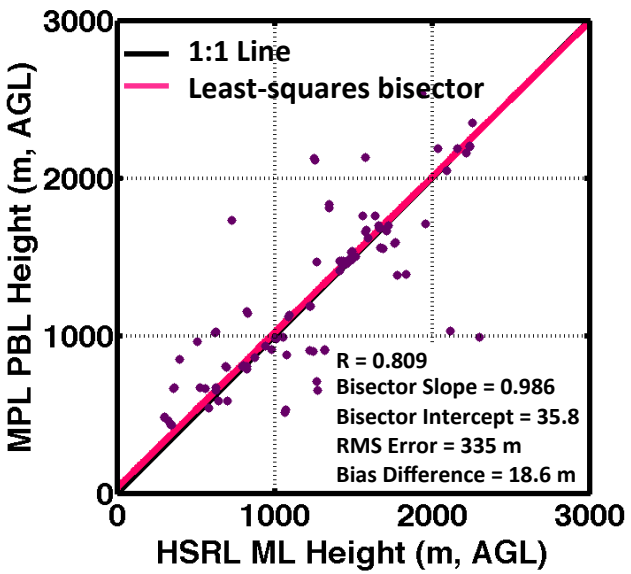
HSRL ML heights compared to PBL heights from MPL

- MPL at three ground sites during DISCOVER-AQ: Beltsville, Edgewood and Fairhill
- Comparisons are done when HSRL was within 2.5 km of the ground site and 10 min from the MPL measurement
- Overall, there is agreement between the HSRL ML heights and MPL PBL heights at all sites
  - Outliers are most likely due to variability in the location of the PBL height due to clouds and geographic location, as well as differences in the algorithm deciding what is the ML height versus the maximum aerosol gradient

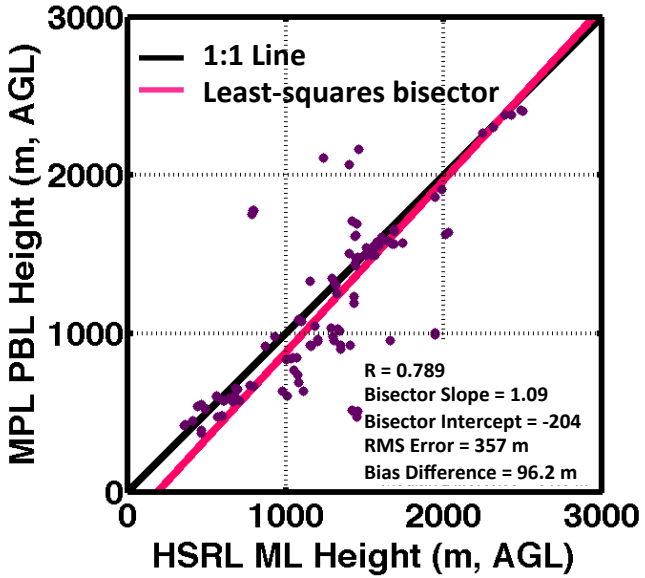
Beltsville



Edgewood

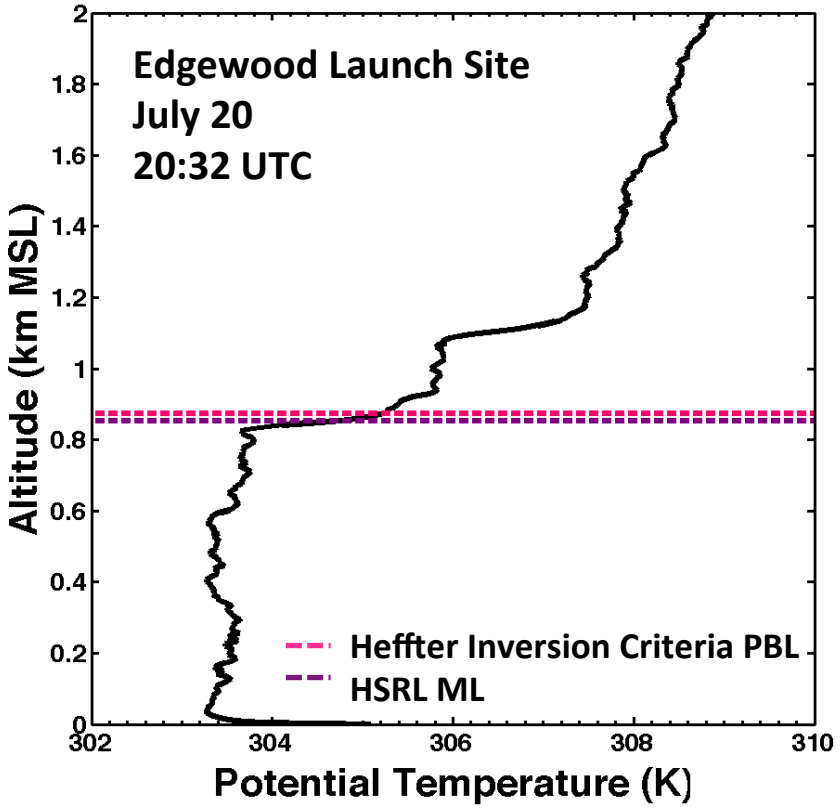


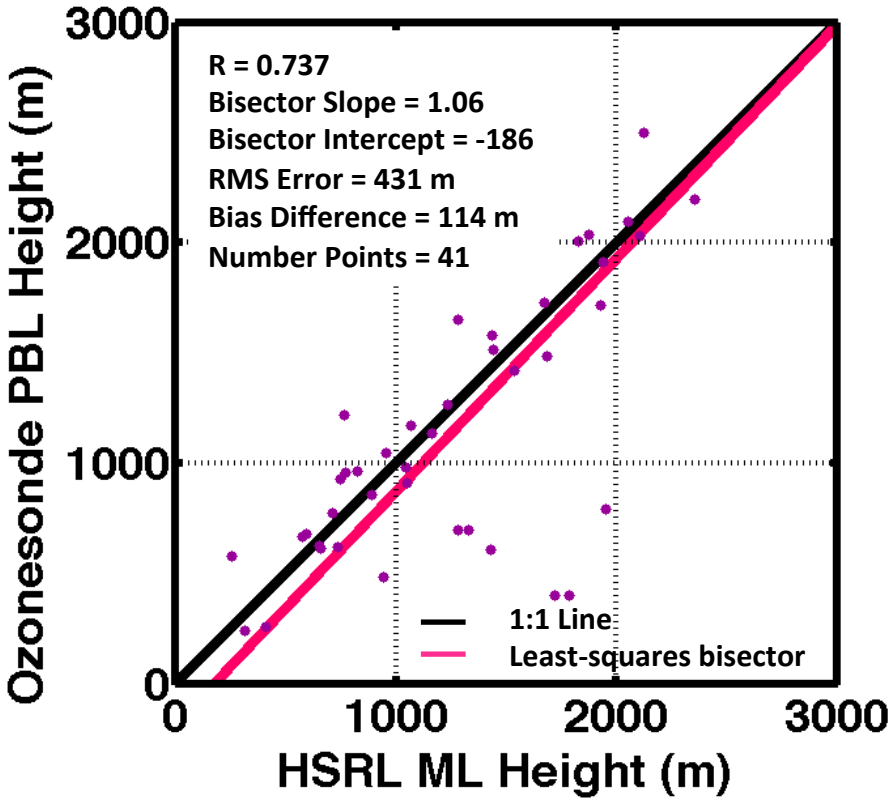
Fairhill



HSRL ML heights compared the PBL heights from Ozonesonde Potential Temperature Profile

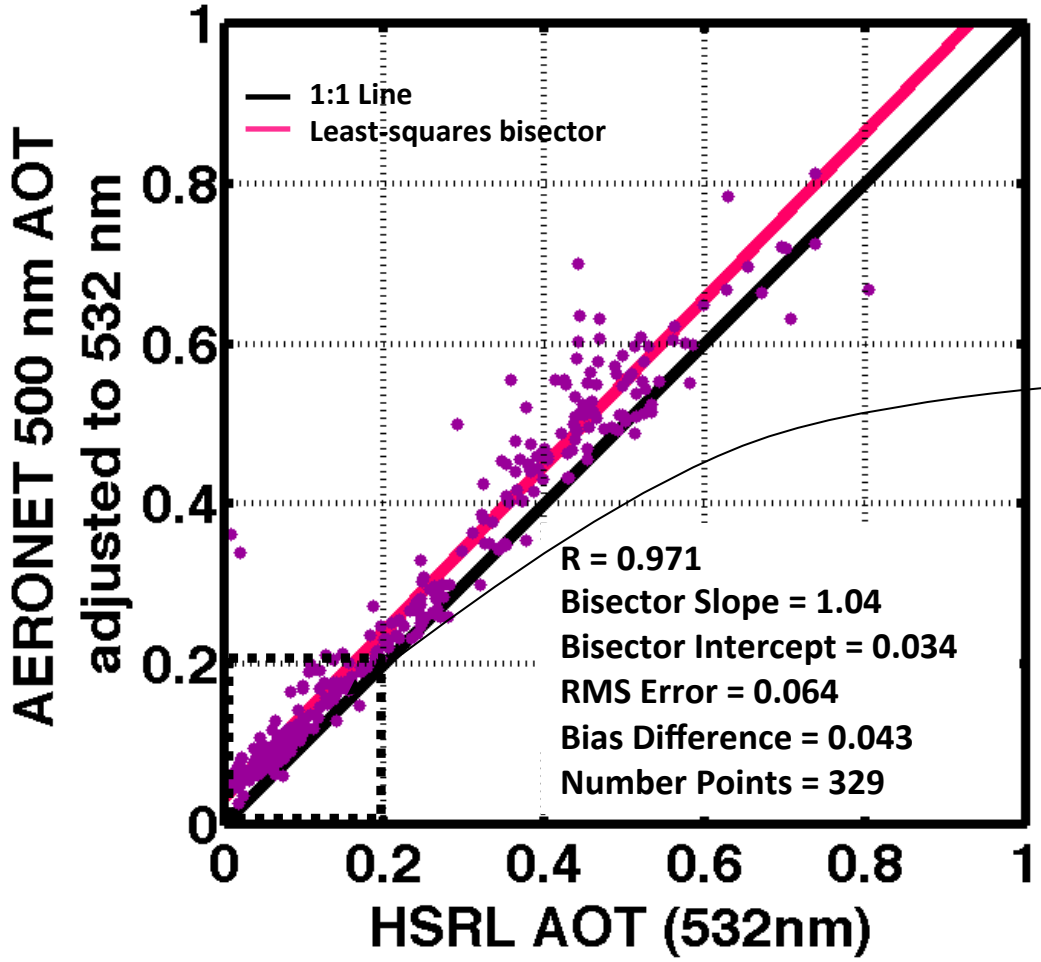
- Ozonesondes were launched ~2 times a day at the Beltsville and Edgewood ground sites
- PBL heights are determined where there is a sharp gradient in the potential temperature profile and when inversion criteria are met (Heffter, 1980)
- Comparison is done when HSRL was within 30 km of the ground site and 30 min from the sonde launch time



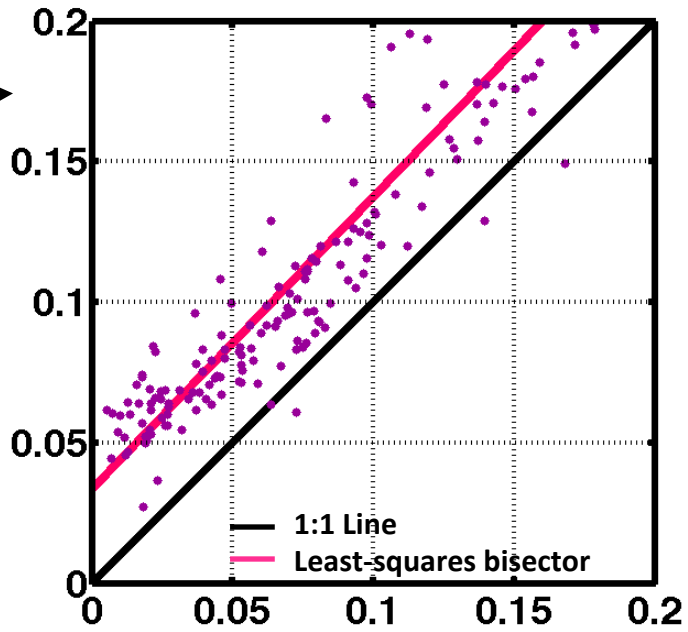


HSRL and AERONET AOD Comparisons

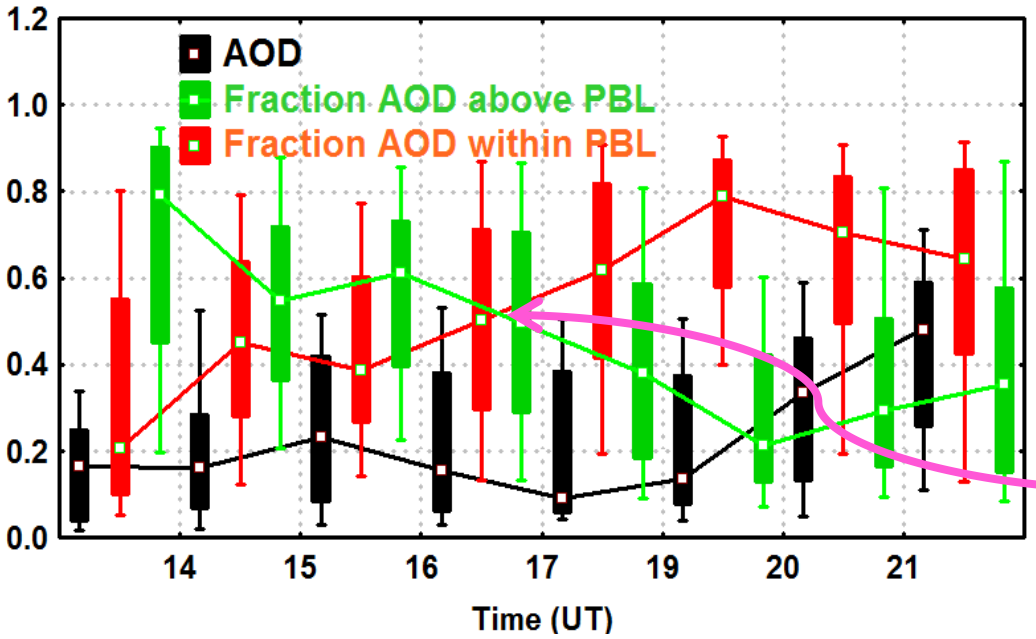
- HSRL 0-7 km layer AOD (532 nm) values were compared with column AOD values from 17 AERONET "DRAGON" sites
- Comparison is done when HSRL was within 2.5 km of the ground site and 10 min from the AERONET measurement

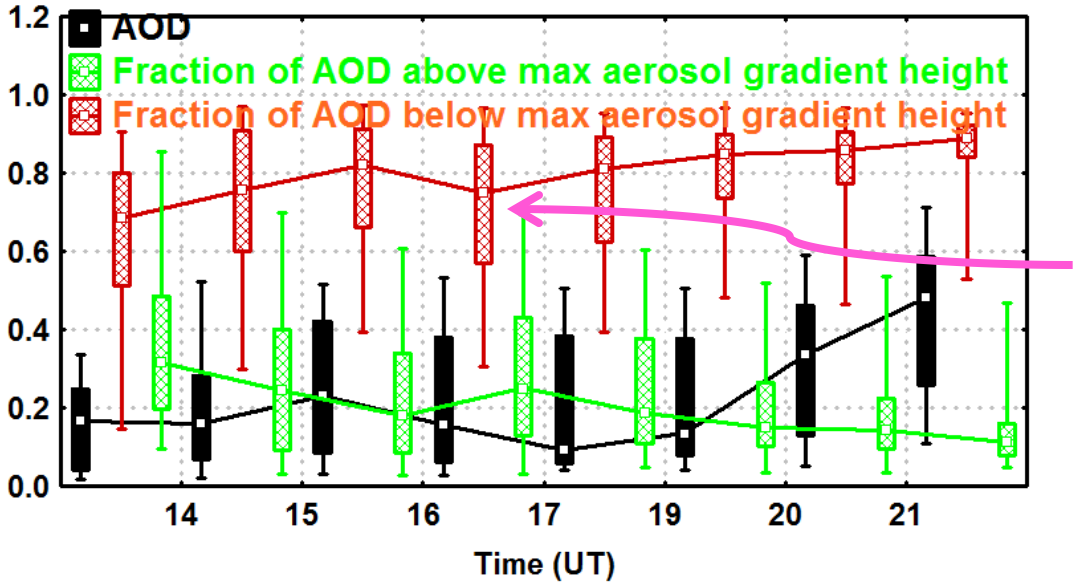


- HSRL layer AOD values were highly correlated with AERONET column AOD
- Small (~0.03-0.04) offset may be due in part (~0.02) to aerosol above 7 km from June 2011 Nabra volcano eruption (Sawamura et al., 2012, ERL)



AOD above and within ML and Maximum Aerosol Layer

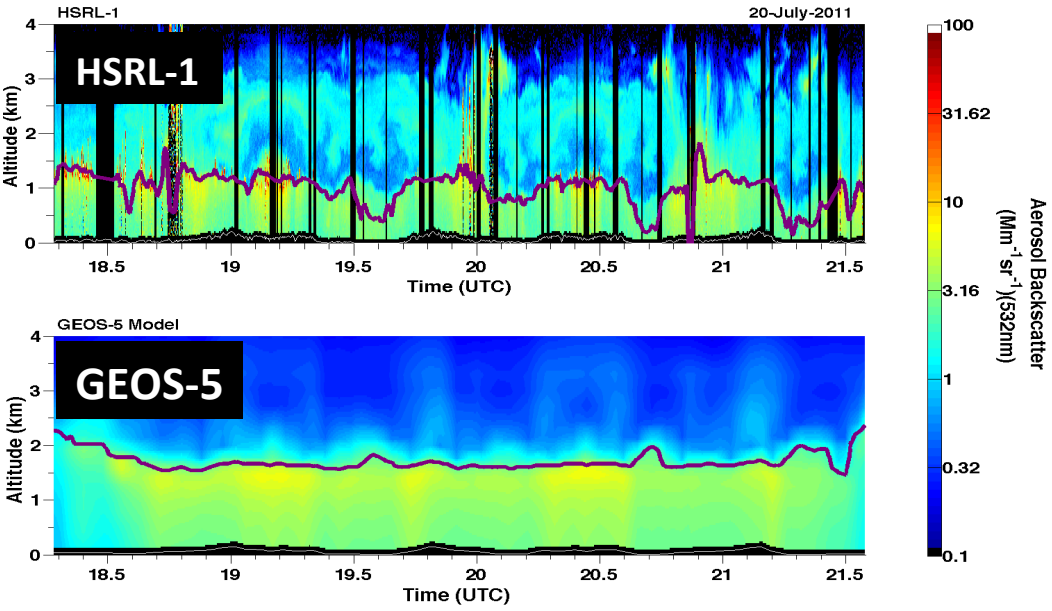


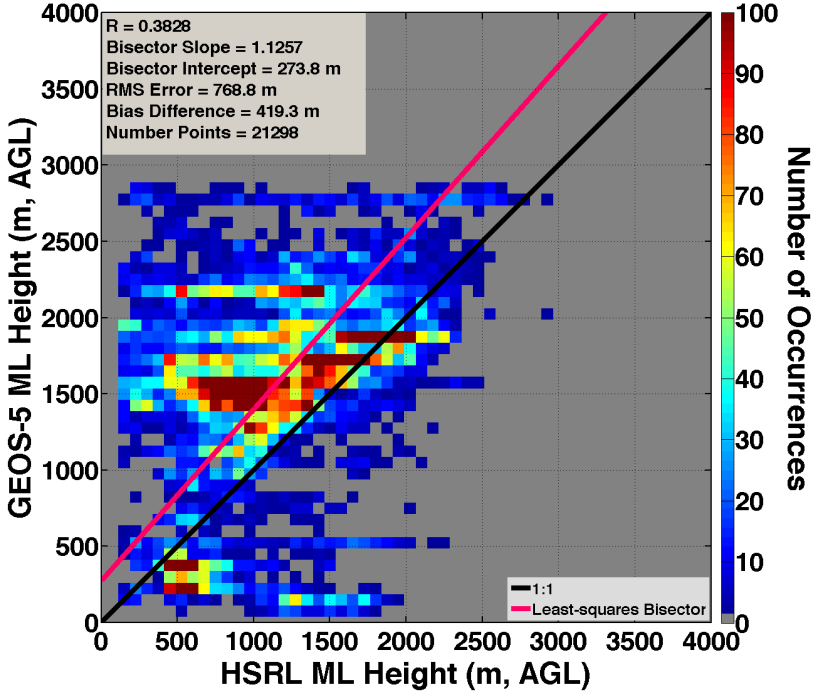


- HSRL measurements are used to determine the fraction of AOD in 0-7 km layer that is:
  - Below and above the ML height
  - Below and above the height of the maximum aerosol gradient
- Before about local noon (~16 UTC), more AOD above ML than within ML
- After about local noon (~16 UTC), more AOD within ML than above ML
- About 70-90% of AOD was below the height of the maximum aerosol gradient
- Significant increase in AOD after 19 UTC

HSRL ML Heights compared to GEOS-5 ML and PBL Heights

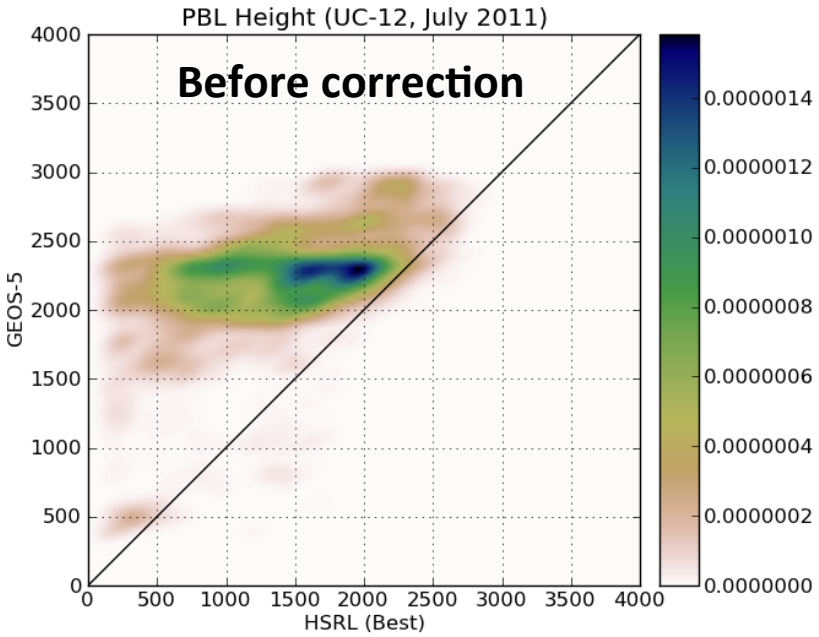
- Simulated aerosol backscatter from the GEOS-5 model along the HSRL flight tracks was processed through the wavelet covariance transform algorithm to produce ML heights using the same methodology as used for the HSRL-1 ML heights
- On average, the GEOS-5 ML heights are about 300-500 m higher than the HSRL ML heights, as demonstrated by the afternoon flight on July 20th and also in the scatter density plot that compares ML heights across all flights during the mission

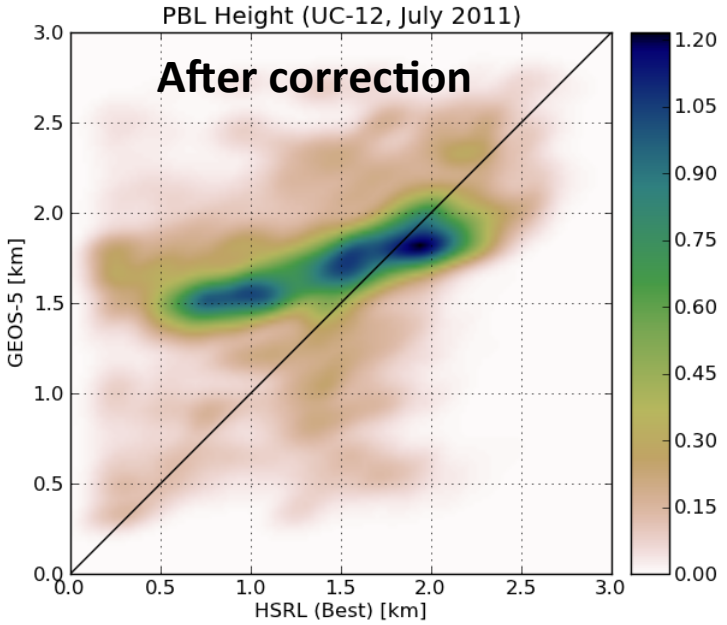




HSRL ML Heights compared to GEOS-5 ML and PBL Heights

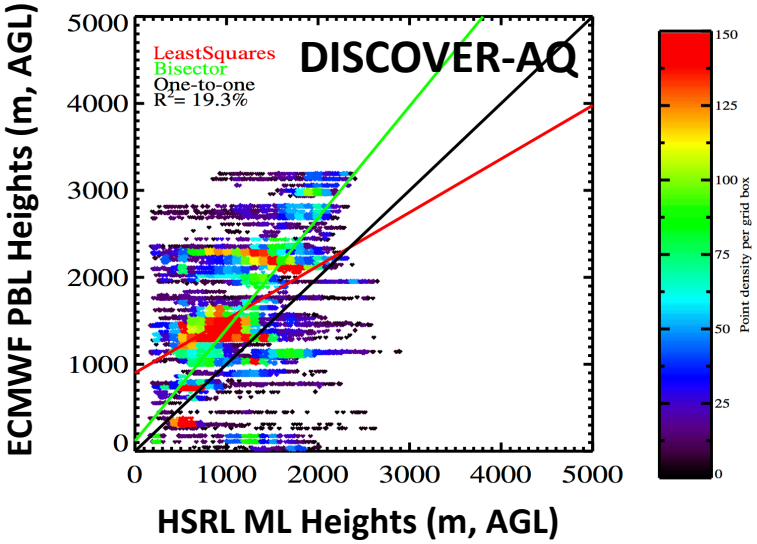
- The use of HSRL ML heights to evaluate the GEOS-5 PBL heights for the July 2011 DISCOVER-AQ mission led to the discovery of issues in land surface characterization in this model
- Initial comparisons indicated that the model PBL heights were too deep **(left figure)**; further investigation revealed that this was due to overly dry land surfaces in response to a precipitation deficit in spring
- Revising the land surface initial condition improved not only the PBL heights **(right figure)** but also led to better heat flux ratios, near-surface temperatures, and aerosol vertical distributions

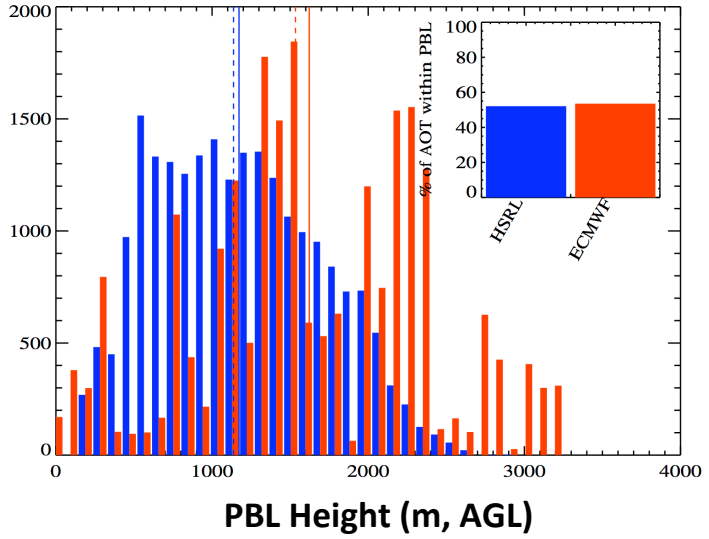




HSRL ML Heights compared to ECMWF –MACC PBL Heights

- ECMWF model results and HSRL measurements were compared along the King Air flight tracks for 14 field missions conducted over North America since 2006, including DISCOVER-AQ
- PBL heights derived using the parcel lifting method until a critical Richardson Number is reached
- AOD from HSRL and ECMWF, is used to determine what percentage of AOD is located within the PBL
- While ECMWF PBL heights were 100-200 m higher than the HSRL ML heights, the fraction of AOD within the PBL was about the same for ECMWF and HSRL





Thanks to Angela Benedetti (ECMWF) for providing the model data to us

Summary

- PBL height is a key parameter for simulating climate processes and assessing model simulation of aerosol pollutant concentrations and transport
- ML heights from airborne lidar are a good proxy for the daytime PBL heights and are useful for evaluating PBL heights from ground site instruments and from numerical weather and air quality models
- ML heights vary with land vs. water and time of day
- Fraction of AOD within ML varies from 20-80% depending on time
- Fraction of AOD below the height of maximum aerosol gradient varies from 70-90%
- HSRL ML heights were important for assessing and improving GEOS-5 model
- Despite good agreement in general, there remain differences in ML and PBL heights due to differences in definition and how the ML/PBL are determined

Additional Studies

- DISCOVER-AQ part two in beginning next week in San Joaquin Valley, CA and part three will be in Houston, TX during September
- Similar ML/PBL comparisons will be done for the San Joaquin Valley and Houston regions
- WRF-Chem and Lidar ML comparison work (Ray Hoff)
- Paper is in the preliminary stages for the DISCOVER-AQ work in the DC/Baltimore region

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