Observations of vertical distribution of aerosols using airborne HSRL

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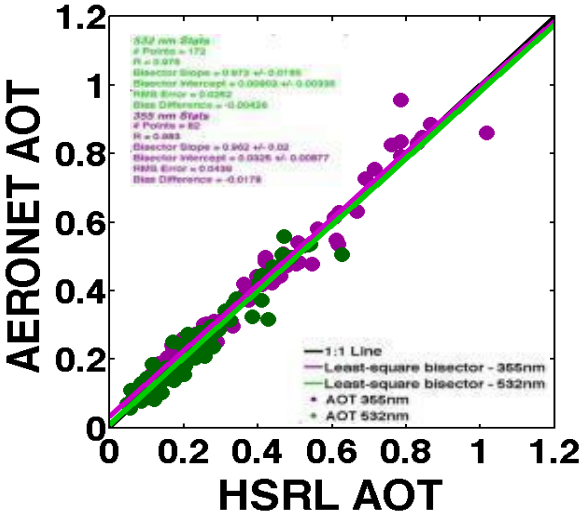
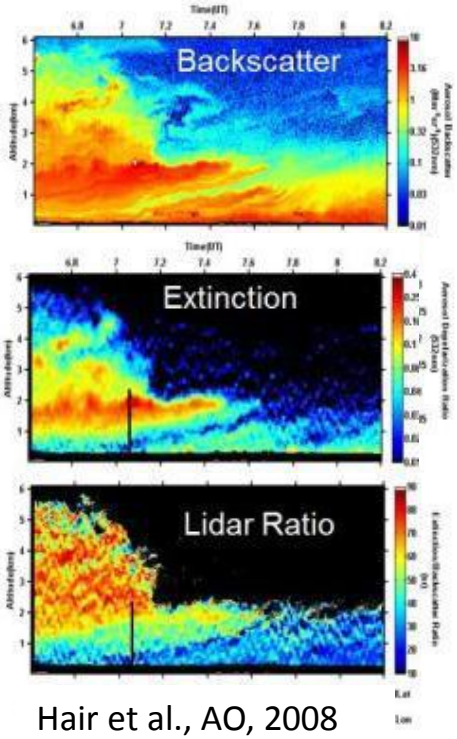
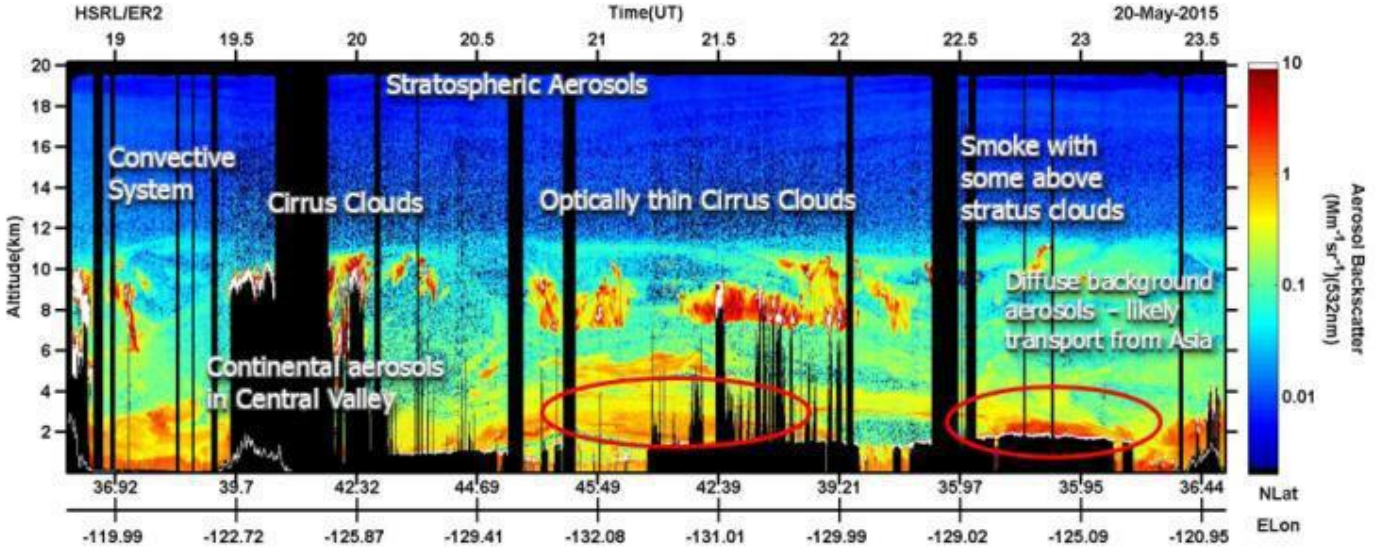
High Spectral Resolution Lidar (HSRL) provides more accurate aerosol measurements

- Measures total and molecular signals and so provide a means to derive profiles of:
  - Calibrated aerosol backscatter
  - Aerosol extinction and optical thickness
  - More accurate aerosol measurements in PBL
  - Extinction/backscatter ratio (lidar ratio)
- NASA LaRC airborne HSRL's have extensive (~10 year) record of such measurements



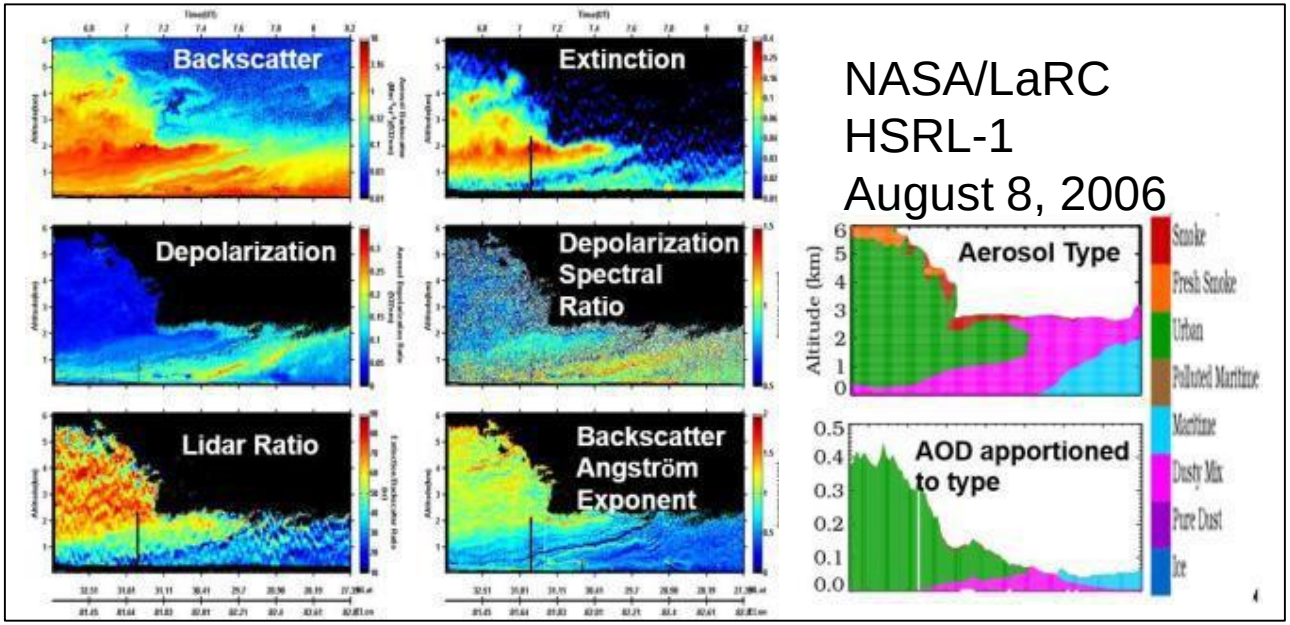


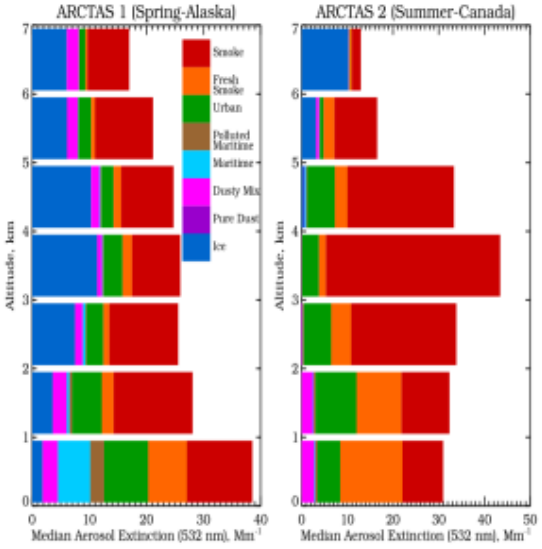
Hair et al., AO, 2008



Aerosol classification using HSRL

- Multiwavelength HSRL measurements provide aerosol intensive parameters for classifying aerosols and apportioning AOT to type
- Suite of aerosol intensive parameters (lidar ratio, color ratios, depolarization) provide more robust aerosol classification
- Reveals significant vertical variability of aerosol types not apparent in passive retrievals

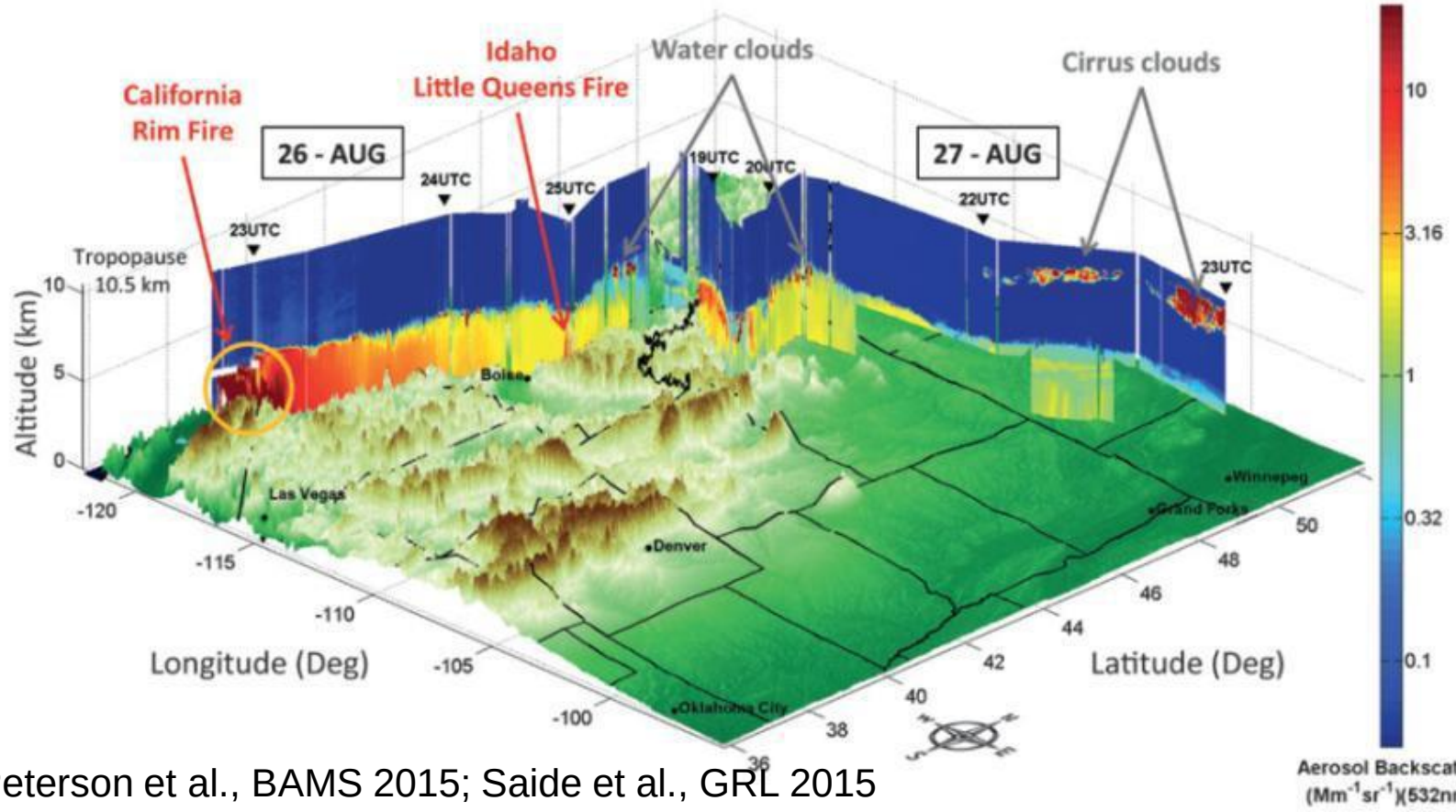




Burton et al., AMT, 2012

Airborne DIAL-HSRL Measurements track smoke from California Rim Fire (2013)

- Smoke particles were well mixed from the surface to a weak stable layer at 3–5 km (AGL) with the highest backscatter near the fire
- Majority of smoke transport remained within the mixed layer
- Slight increase in backscatter between 5-7 km AGL near the fire, which is likely a result of diffuse smoke particles lofted during sporadic periods of pyroCu formation.



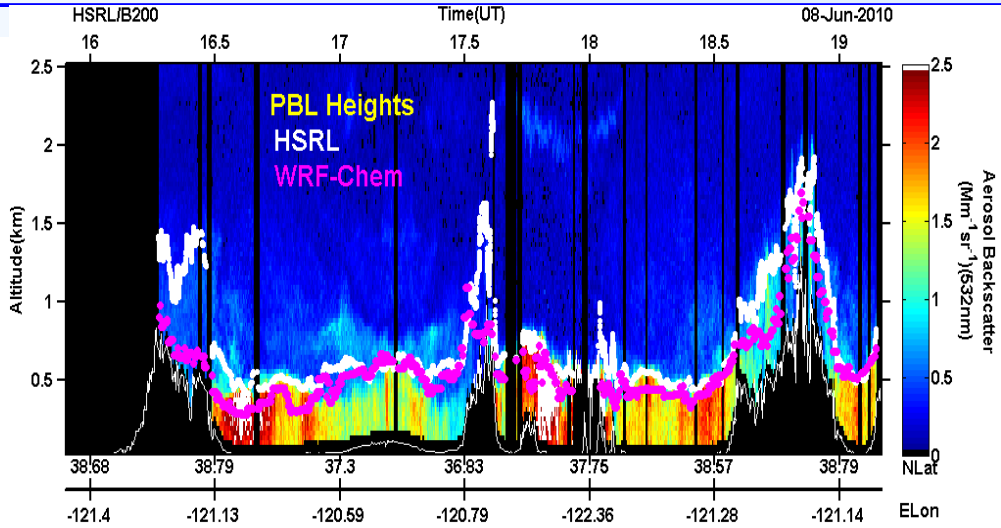
Peterson et al., BAMS 2015; Saide et al., GRL 2015

HSRL data used to determine Planetary Boundary Layer (PBL) height and fraction of AOT within PBL

HSRL data used to determine:

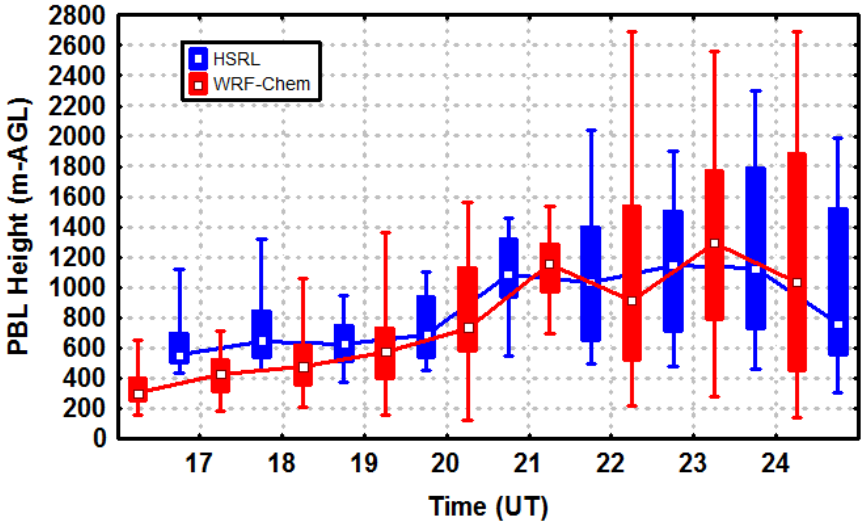
- **PBL height**
- **Upper and lower limits of the backscatter transition (i.e. entrainment) zone**
- **Fraction of aerosol optical thickness within PBL**

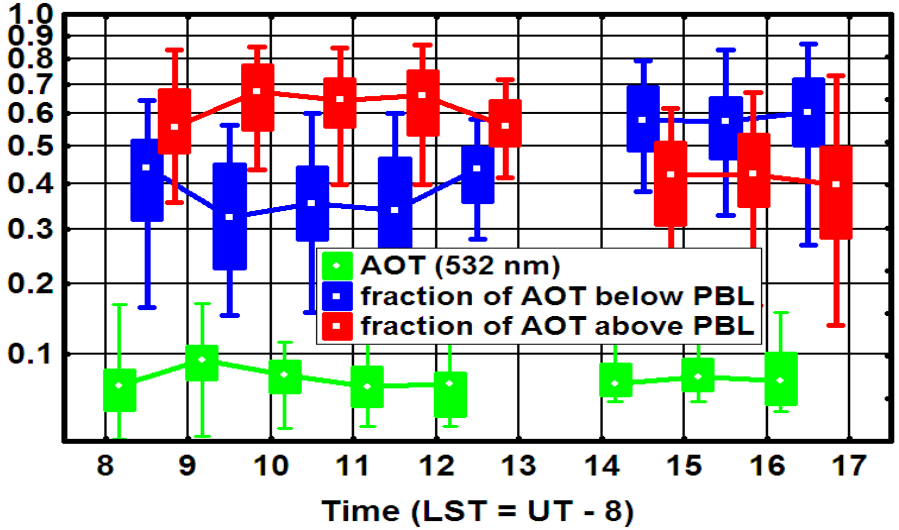
HSRL PBL heights now routinely requested by other investigators



During DOE CARES Mission(Sacramento)

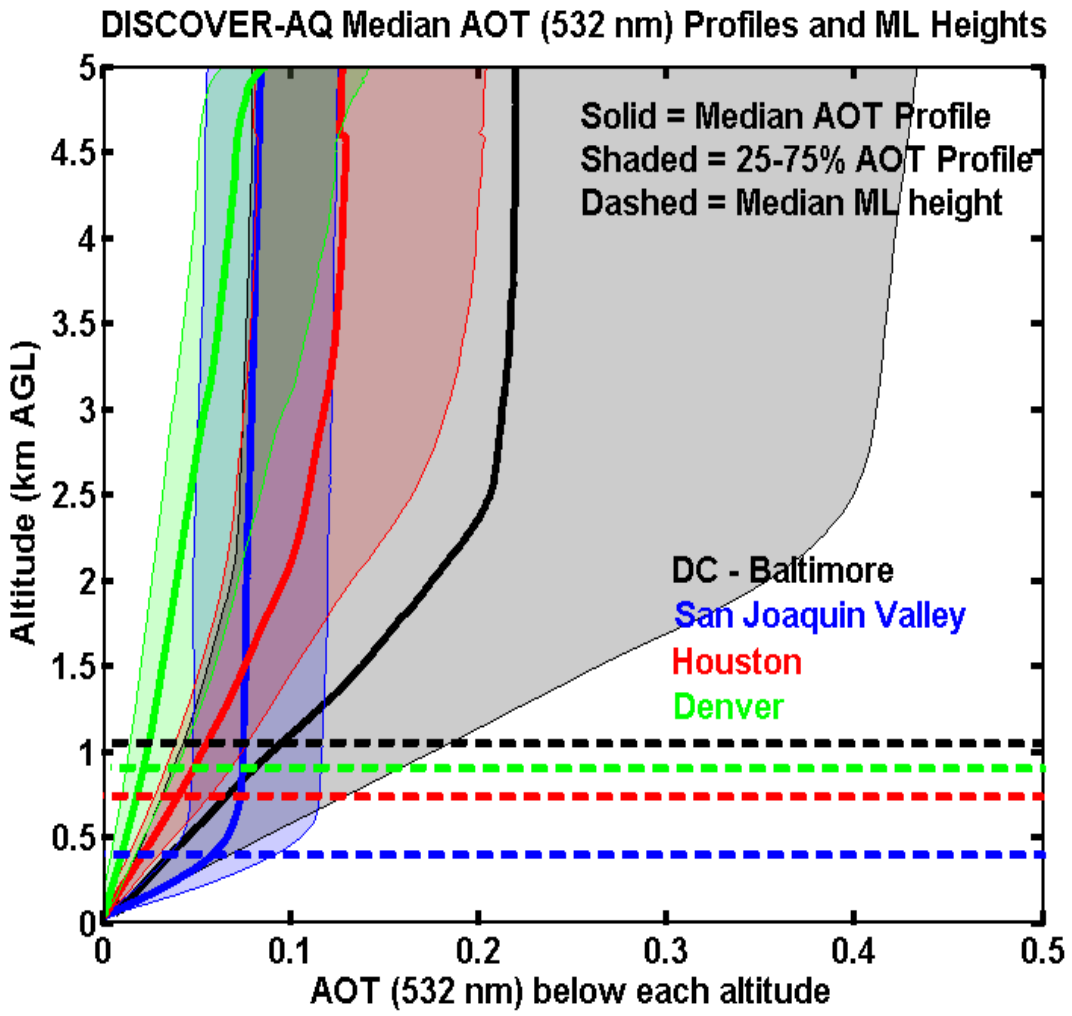
- **HSRL and WRF-Chem PBL heights are in reasonably good agreement in afternoon**
- **Much of AOT remains above PBL**





(Fast et al., 2012, ACP; Scarino et al., 2015)

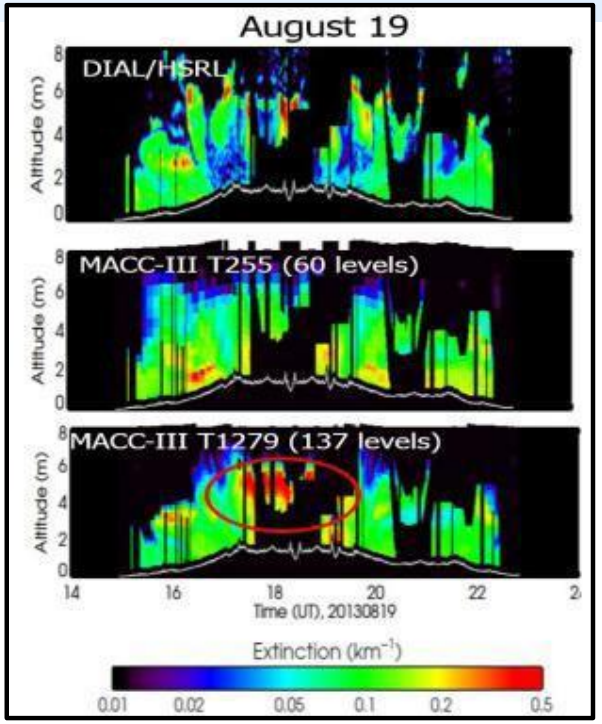
HSRL DISCOVER-AQ measurements show much of AOT is often above the daytime mixed layer



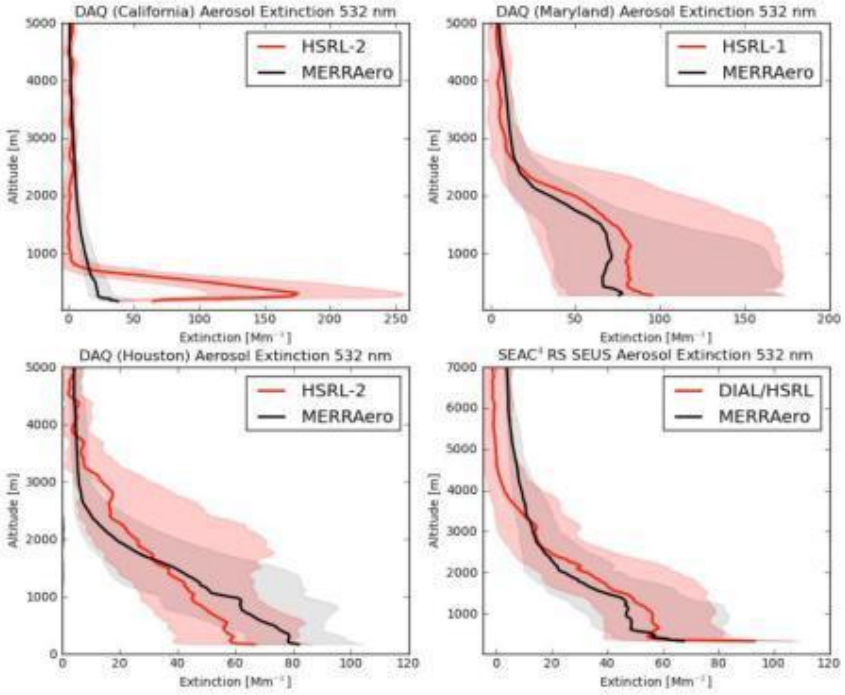
- AOT profiles and ML heights computed for four DISCOVER-AQ missions
- DC-Baltimore had largest median column AOT values
- Median AOT values in the later three campaign were comparable
- With exception of San Joaquin Valley, median profiles show that about only about 20-65% of AOT was within mixed layer; much of AOT was above mixed layer
- In San Joaquin Valley, most (>80%) of AOT was within mixed layer

Assessing Aerosol Data Assimilation Products Using HSRL Measurements

- HSRL aerosol profiles are being used to assess and improve aerosol data assimilation systems (NASA GEOS-5 and MERRAero, ECMWF/MACC-III)
- Median ECMWF/MACC-III model extinction profile agrees with median DIAL-HSRL profile
- Increased MACC-III model resolution sometimes improves agreement

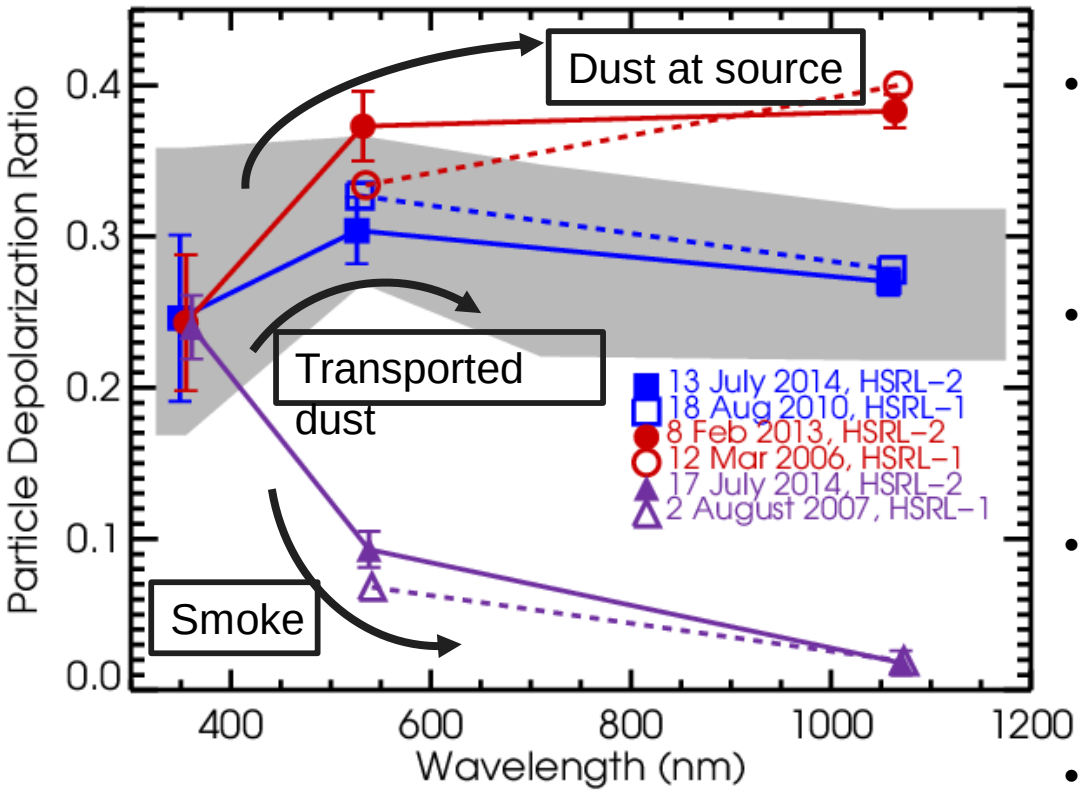


- With exception of California San Joaquin Valley, MERRAero mean aerosol extinction profiles are in general agreement with HSRL



Buchard et al., 2015, Atmos. Environ.

Spectral depolarization reveals information about particle size distribution

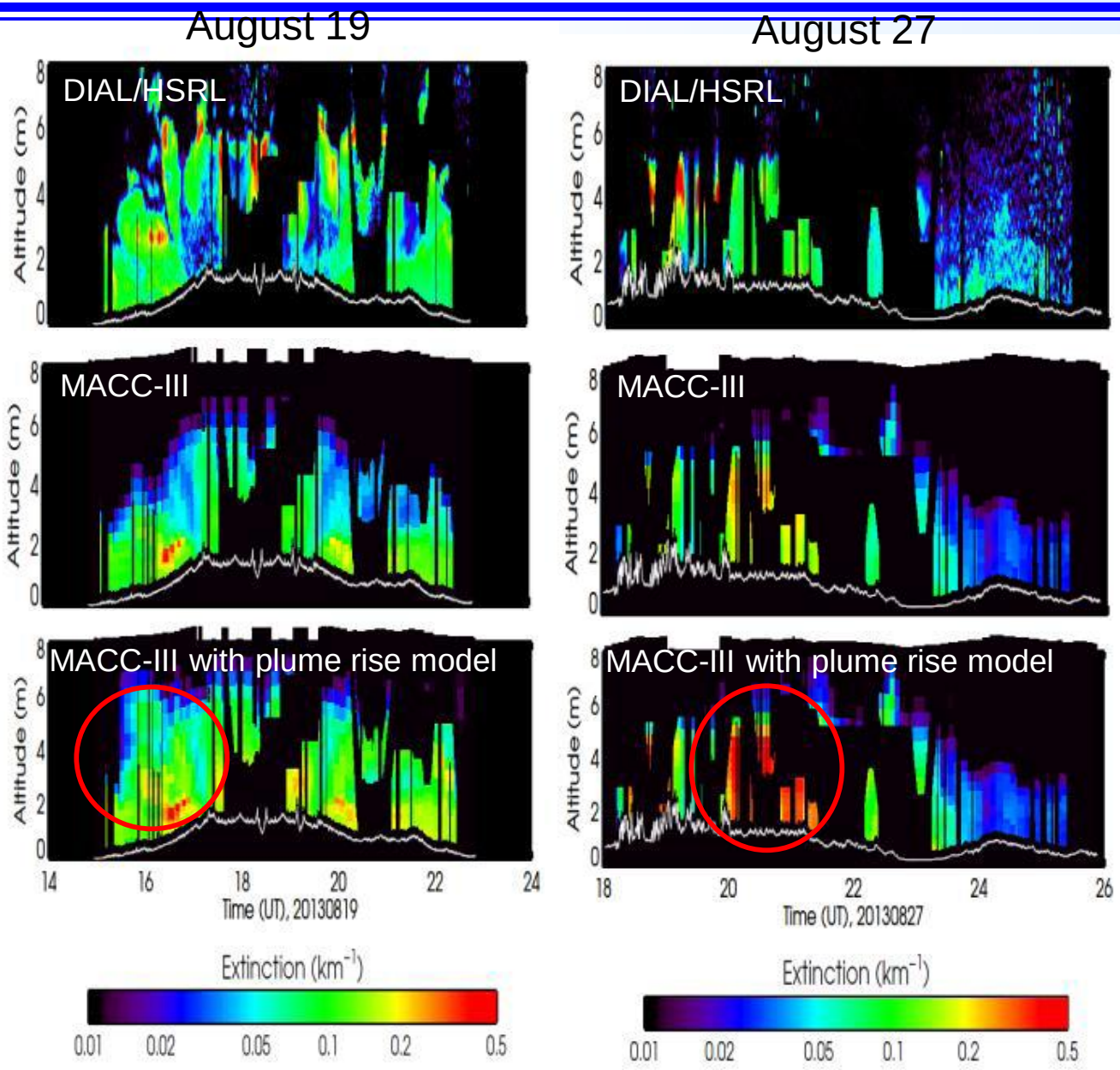


3 case studies from HSRL-2 (3 wavelength) + 3 from HSRL-1 (2 wavelength)

Burton et al., ACP, 2015

- Wavelength dependence of particle depolarization reveals information about particle size
- North American dust at the source includes very large particles, monotonically increasing depol
- Transported Saharan dust cases peak at mid-wavelength, largest particles were lost during transport
- Non-spherical smoke particles (coated soot aggregates) have decreasing wavelength dependence, smaller particles
- 532 and 1064 previously used for distinguishing smoke & urban
- 355 nm may be particularly useful for understanding smoke
- 355 nm alone not sufficient for separating dust and smoke

Evaluating the impacts of smoke injection heights computed from plume rise model



- HSRL measurements acquired during NASA SEAC4RS mission used to evaluate ECMWF/MACC-III model
- Injection heights for smoke emissions are estimated using Plume rise model (Paugam et al., 2015, in preparation, based on Freitas et al., 2007)
- Initial comparisons show that both aerosol extinction and AOT increase throughout the profile, not necessarily at smoke height shown in DIAL/HSRL profile

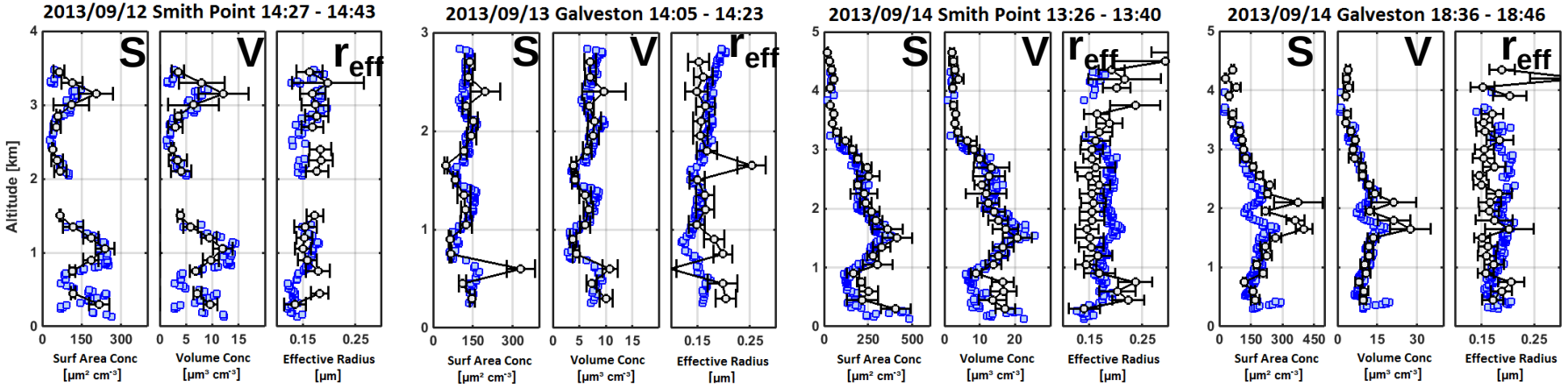
Remy et al., ACPD 2016

HSRL-2 multi-wavelength aerosol retrievals evaluation

HSRL-2 retrievals of size parameters were compared to vertically-resolved in situ measurements. The measurements were obtained during DISCOVER-AQ California and Texas in 2013.

- In situ measurements of particle size were corrected to account for aerosol hygroscopicity.
- Size range of particles were the same for HSRL-2 and in situ measurements (D < 1μm)

- These results demonstrate HSRL-2's capability to provide vertically-resolved retrievals of submicron aerosol size parameters such as effective radius, and surface-area and volume concentrations

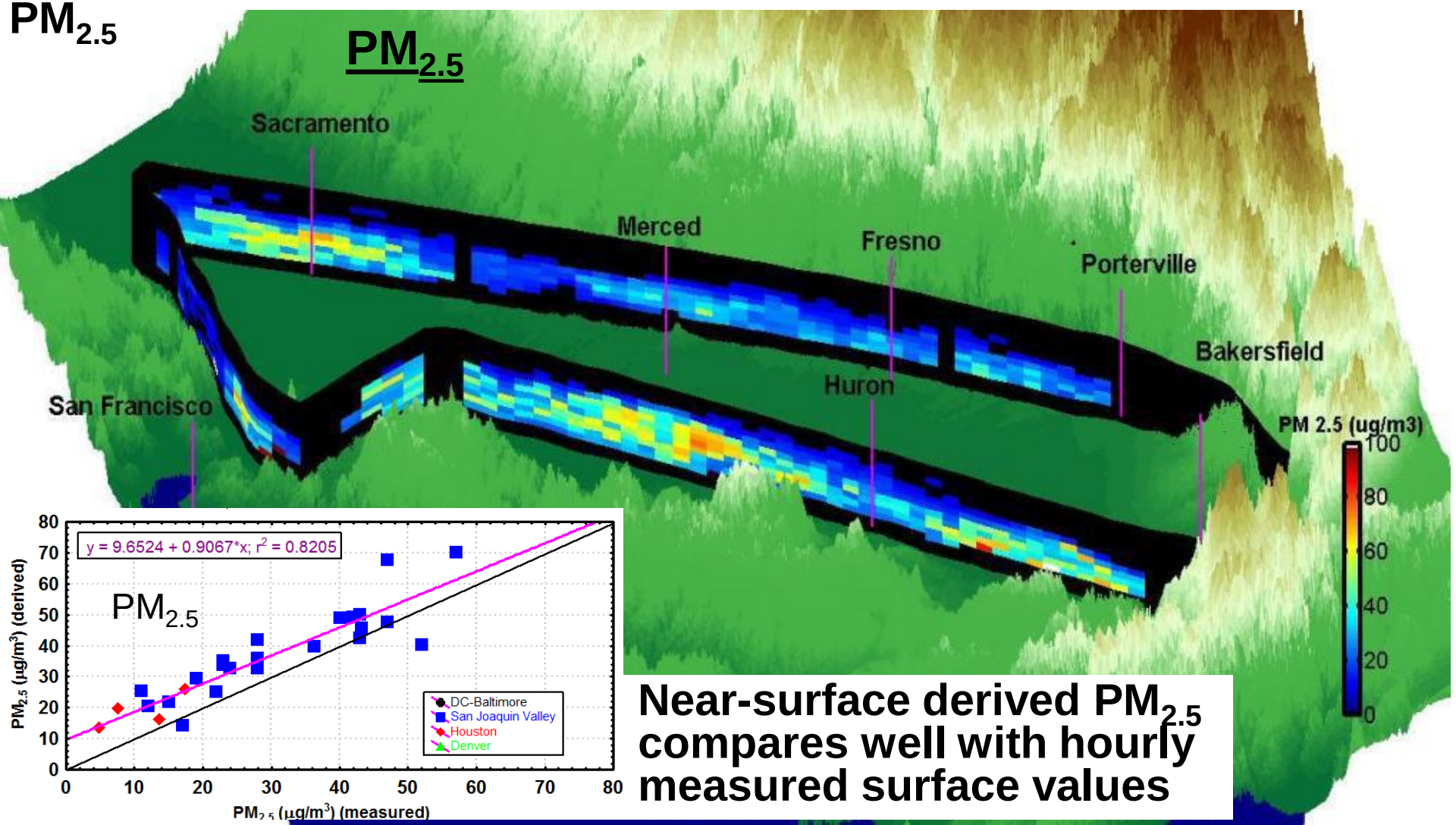


Examples from DAQ TX

Sawamura et al., 2016, in prep

HSRL-2 Retrievals of $PM_{2.5}$ Over Central California (Jan. 31, 2013)

HSRL-2 multiwavelength retrievals of fine mode volume concentration were used with assumed particle density to derive $PM_{2.5}$



Near-surface derived $PM_{2.5}$ compares well with hourly measured surface values