Aerosol Properties above SGP Derived from CHARMS Data

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Background

During the Combined HSRL and Raman lidar Measurement Study (CHARMS), DOE ARM investigated the synergistic use of SGP Raman lidar and High Spectral Resolution Lidar (HSRL) measurements to improve the ARM observational capability of aerosols. The continuous (24/7) operation of these co-located lidars during the ten-week CHARMS mission (mid-July through September 2015) allowed the acquisition of a unique, multiwavelength ground-based lidar dataset for studying the vertical distribution of aerosol properties above the SGP. The ARM SGP Raman lidar measured profiles of aerosol backscatter, extinction and depolarization at 355 nm and profiles of water vapor mixing ratio and temperature. The UW HSRL simultaneously measured profiles of aerosol backscatter, extinction and depolarization at 532 nm and aerosol backscatter at 1064 nm.

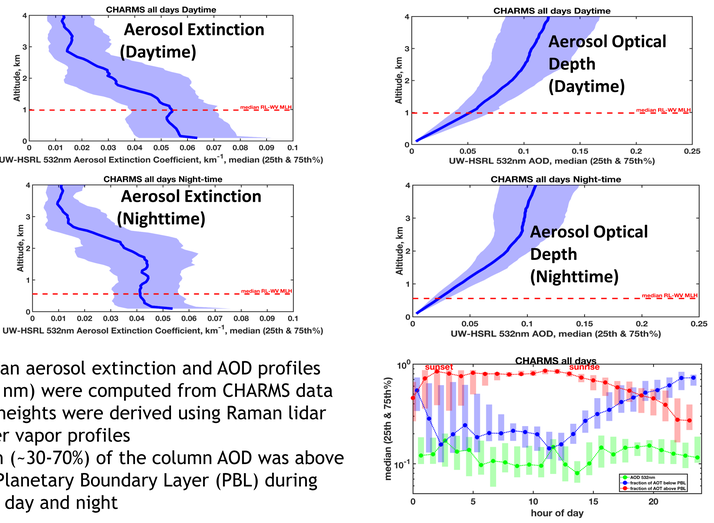
Objectives

➢ We use the lidar profiles of aerosol intensive properties (lidar ratio, depolarization ratio, backscatter color ratio), which provide information about aerosol size, shape and composition, to classify the vertical distribution of aerosols and apportion aerosol optical thickness and extinction to aerosol type.

➢ We derive profiles of aerosol microphysical (e.g. effective radius, concentration, fine mode fraction) properties aloft using the CHARMS multiwavelength lidar backscatter and extinction profiles.

➢ We examine the behavior of these aerosol properties as a function of relative humidity below shallow, daytime, boundary layer clouds.

Median Aerosol Extinction and Aerosol Optical Depth Profiles



- Median aerosol extinction and AOD profiles (532 nm) were computed from CHARMS data
- PBL heights were derived using Raman lidar water vapor profiles
- Much (~30-70%) of the column AOD was above the Planetary Boundary Layer (PBL) during both day and night

Summary

- We use the CHARMS (July-September 2015) multiwavelength lidar dataset to:
  - classify the vertical distribution of aerosols and apportion AOD to aerosol type
  - derive profiles of aerosol fine mode fraction, particle concentration, and effective radius
  - examine how aerosol properties vary with relative humidity below cloud base
- Much (~30-70%) of column AOD was above the PBL during both day and night
- Smoke/urban mix had the largest contribution to aerosol extinction and AOD
- Dusty mix had a significant (~20%) contribution to aerosol extinction and AOD
- Dusty mix contribution was largest near the surface
- CHARMS data for September 5, 2015 reveal:
  - aerosol extinction, aerosol extinction/backscatter ratio, fine mode effective radius, and fine mode volume concentration increased with RH below cloud base
  - aerosol depolarization decreased with RH below cloud base

References

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Acknowledgements

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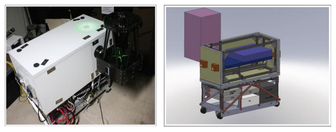
Combined HSRL and Raman lidar Measurement Study (CHARMS) Instruments and Data

SGP Raman lidar

- Aerosol backscatter, extinction (355 nm)
- Water vapor mixing ratio
- Temperature
- Relative Humidity

Measurements (3β+2α)

UW HSRL



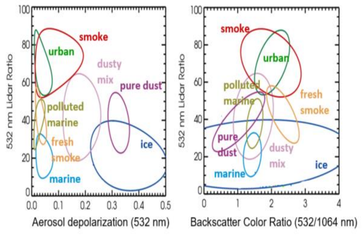
- Aerosol backscatter (532, 1064 nm)
- Aerosol extinction (532 nm)
- Depolarization (532 nm)

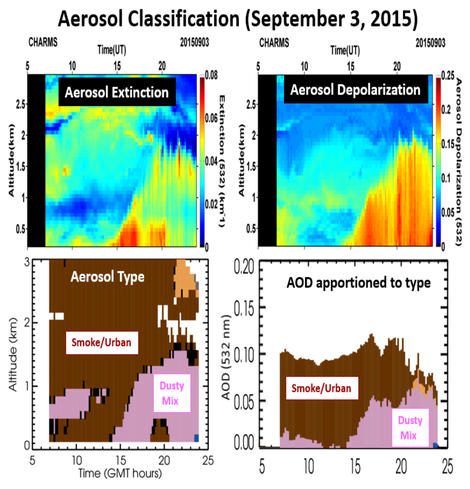
- Data collected from July 18 through September 30, 2015 at DOE ARM SGP site (northern Oklahoma)
- Aerosol extinction and backscatter profiles from both lidars were processed consistently using the FEX algorithm (Thorsen et al. 2015; Thorsen and Fu 2015)
- Difficulty in calibrating 1064 nm backscatter has currently limited 3+2 retrieval dataset to 25 days
- Images of results:
  - http://www.tylerthorsen.com/bagohsrlfex_charms/
- Processed 3+2 datasets available from the DOE ARM Archive (PI product – Ferrare)
  - http://iop.archive.arm.gov/arm-iop/0pi-data/?uid=FerrareR1&st=5aa68ac9&home=arm-archive

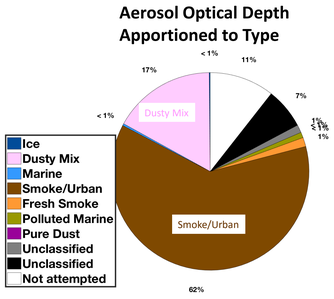
Aerosol Classification

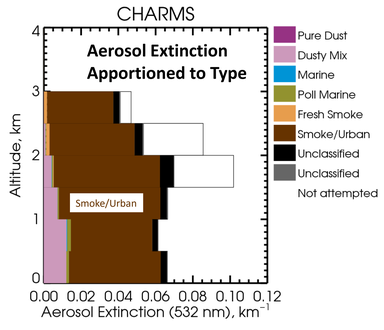
- Aerosol classification via multiwavelength lidar aerosol classification algorithm developed using airborne HSRL data (Burton et al., 2012, 2013, AMT)
- Current algorithm uses 532 & 1064 nm data
- Intensive parameters: lidar ratio, depolarization, backscatter color ratio

Ellipses represent aerosol types





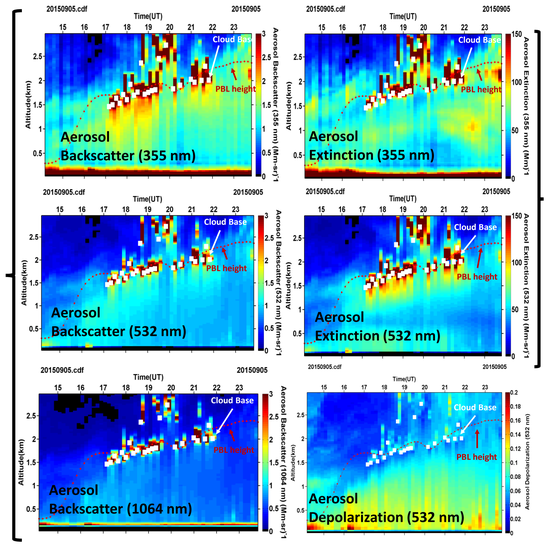




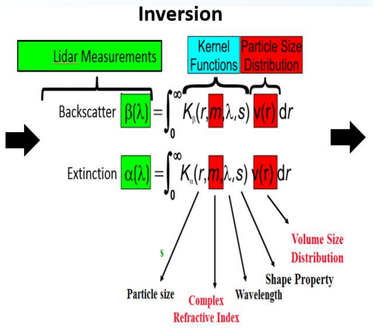
- Smoke/urban mix contributed about 62% of the Aerosol Optical Depth (AOD) during CHARMS
- Dusty mix contributed about 17% of the AOD
- The dusty mix contribution to aerosol extinction was largest near the surface
- Aerosols aloft were dominated by smoke/urban mix

Multiwavelength Lidar Aerosol Retrievals (September 5, 2015)

Input Data:
Backscatter profiles (355, 532, 1064 nm) (3β)
Extinction profiles (355, 532 nm) (2α)

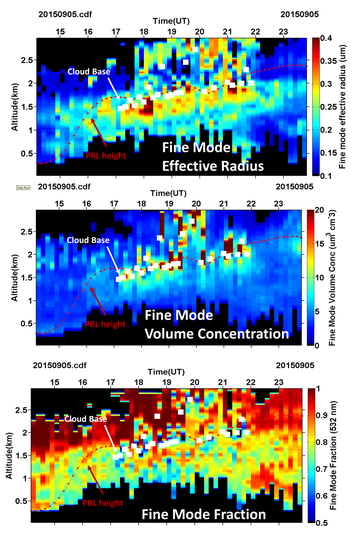


Inversion



Multiwavelength lidar retrieval algorithms; Müller et al, 1998, 1999, 2001, 2014; Veselovskii et al. 2002; several application papers

Output:
Profiles of fine mode effective radius, volume concentration, fine mode fraction



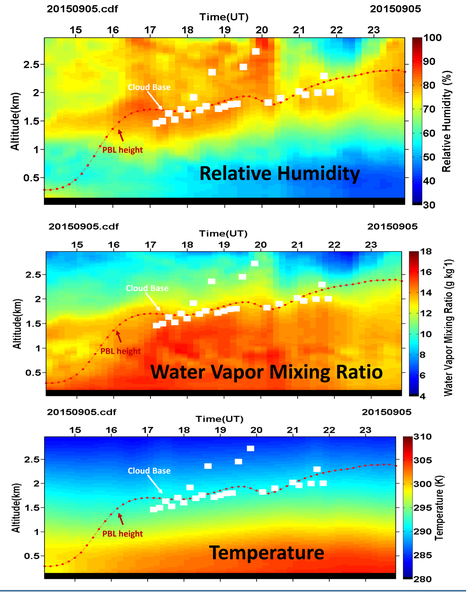
Increase in fine mode effective radius near cloud base

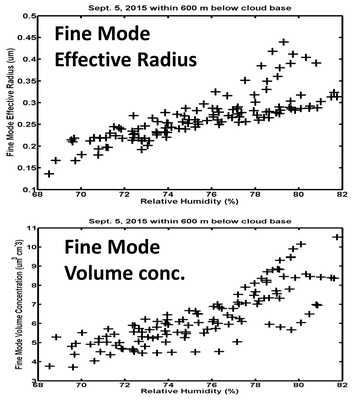
Largest fine mode volume concentrations near cloud base

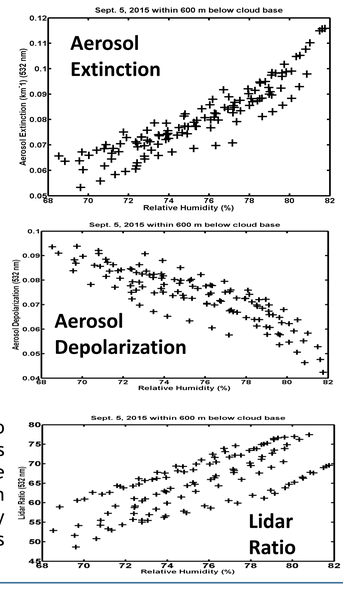
Fine mode fractions increase aloft; coarse mode particles typically closer to surface

We used the CHARMS Raman lidar and HSRL datasets of three aerosol backscatter (355, 532, 1064 nm) and two aerosol extinction (355, 532 nm) profiles to derive profiles of aerosol optical and microphysical properties (effective radius, concentration, fine mode fraction) using the automated, unsupervised 3β+2α Tikhonov Advanced Regularization Algorithm (TiARA) (Müller et al., 2014, Sawamura et al., 2017). Regions where aerosol depolarization exceeded 10% were excluded to minimize impacts from nonspherical aerosols. These retrieval results are available from the DOE ARM Archive (PI product – Ferrare) http://iop.archive.arm.gov/arm-iop/0pi-data/?uid=FerrareR1&st=5aa68ac9&home=arm-archive

Aerosol Variability with Relative Humidity (September 5, 2015)







Raman lidar water vapor and AERI temperature retrievals were combined to derive profiles of Relative Humidity (RH). The CHARMS aerosol measurements and retrievals show that, in the region within 600 m below cloud base, fine mode effective radius, fine mode volume concentration, aerosol extinction and the aerosol extinction/backscatter ratio ("lidar ratio") generally increased with RH. In contrast, aerosol depolarization decreased with RH as the particles took on water and became more spherical.