Airborne Multi-wavelength High Spectral Resolution Lidar Observations and Applications from TCAP-I

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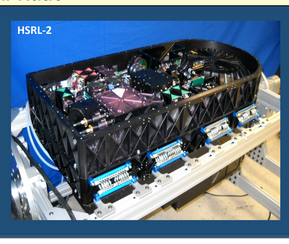
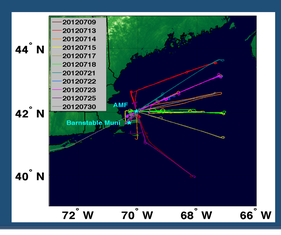
Introduction

- NASA Langley has developed the first airborne multi-wavelength high spectral resolution lidar (HSRL) instrument, "HSRL-2"
- The Two-Column Aerosol Project (TCAP) was the first deployment of HSRL-2
- The NASA GISS Research Scanning Polarimeter (RSP) measures polarized radiances and enables cloud and aerosol column retrievals and future combined lidar + polarimeter retrievals
- Data from TCAP are used to retrieve vertically resolved aerosol microphysical parameters using the "3β + 2α" technique
- Aerosol classification using four aerosol intensive parameters from the 532 and 1064 nm channels and compared with the single particle mass spectrometer, miniSPLAT, which provides in situ measurements of aerosol size and mixing state from the G-1 aircraft
- HSRL-2 data products are also used to help evaluate WRF-Chem model simulations of aerosol backscatter and extinction

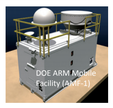
High Spectral Resolution Lidar (HSRL-2)	
Extensive Aerosol Data Products	
Extinction	355, 532 nm
Backscatter	355, 532, 1064 nm
Intensive Aerosol Data Products (used for Aerosol Classification)	
Depolarization	355, 532, 1064 nm
Depolarization spectral dependence	1064/532, 532/355
Backscatter spectral dependence	1064/532, 532/355
Extinction spectral dependence	532/355
Lidar Ratio	355, 532 nm



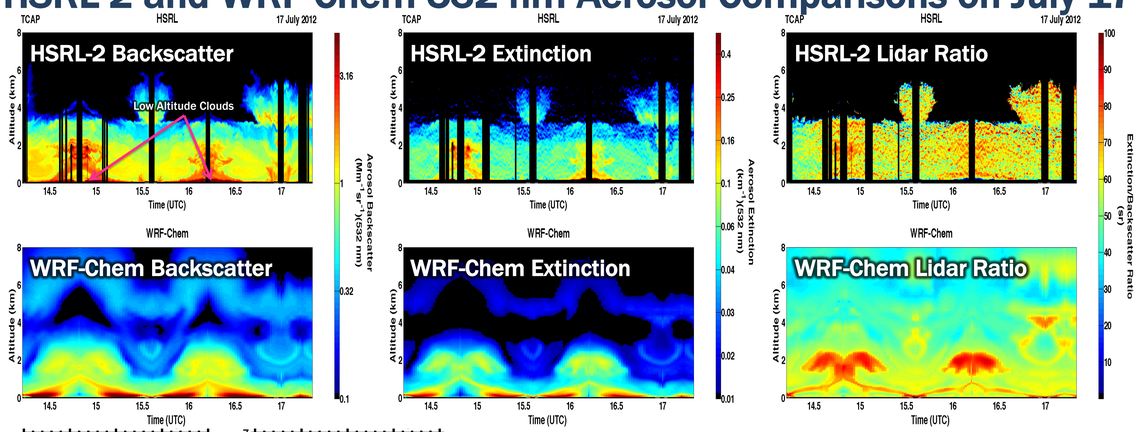


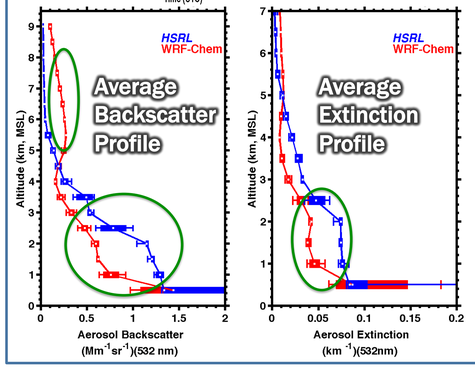
Two-Column Aerosol Project (TCAP)

- Conducted by the DOE's Atmospheric Radiation Measurement (ARM) program over 7-29 July 2012 from base Cape Cod, MA
- Involved aircraft, surface measurements, and modeling
  - DOE G-1 aircraft deploying aerosol in situ and remote sensors
  - NASA King Air B200 deploying HSRL-2 and RSP
  - DOE ARM Mobile Facility
  - DOE Mobile Aerosol Observing Facility
- Objectives
  - Cloud condensation nuclei studies
  - Local and columnar radiation closure studies
  - Cloud-aerosol interaction studies
  - Climate modeling studies



HSRL-2 and WRF-Chem 532 nm Aerosol Comparisons on July 17

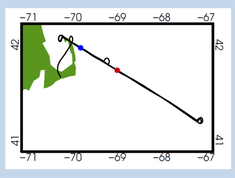


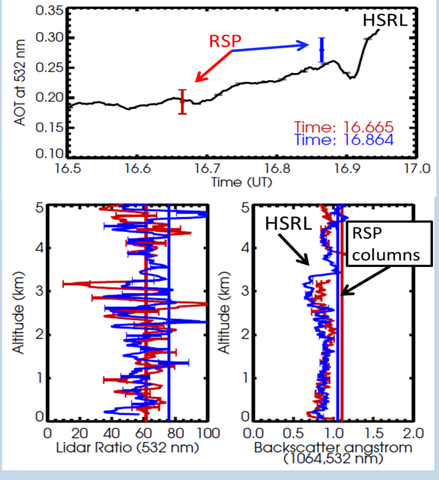


- Overall, the WRF-Chem simulations show similar characteristics to HSRL measurements
- On average, WRF-Chem tends to over-estimate in the free troposphere and under-estimate in the residual layer
  - This is shown in the curtain plots and in the average profiles for the July 17th flight
- Using the simulated backscatter and extinction, a lidar ratio was calculated to compare with the HSRL lidar ratio and gives reasonable agreement

RSP aerosol and cloud retrievals on July 17

RSP polarized reflectance from 410 to 2250 nm are used in optimal estimation retrievals to obtain cloud and aerosol optical depth and column microphysical properties. The RSP retrievals of aerosol lidar properties are compared with HSRL-2.

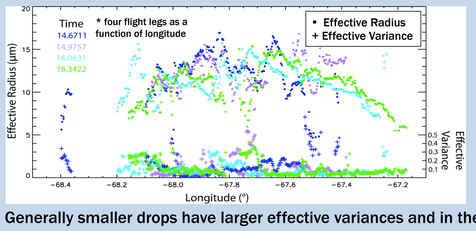




RSP Retrievals for July 17, 2012

Observation	Time = 16.665	Time = 16.864
Aerosol Optical Thickness (532,1064)	0.193, 0.041	0.280, 0.075
Scattering (532,1064)	0.190, 0.041	0.268, 0.070
Backscattering (532,1064)	0.040, 0.018	0.046, 0.022
Lidar Ratio (532,1064)	61.5, 28.2	75.9, 42.1
SSA (532,1064)	0.981, 0.989	0.959, 0.939
Angstrom Extinction (532/1064)	1.55	1.32
Angstrom Scattering (532/1064)	1.54	1.34
Angstrom Absorption (532/1064)	2.07	0.92

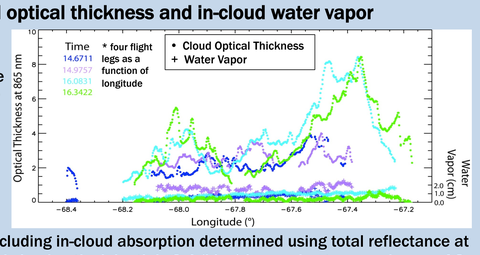
Retrieved cloud effective radius and effective variance



Generally smaller drops have larger effective variances and in the afternoon the effective variance is less than 0.1 with effective radii of 10-15 μm, indicative of stratocumulus cloud.

Retrieved cloud optical thickness and in-cloud water vapor

In-cloud water vapor is retrieved from the difference between the water vapor above cloud determined using polarized reflectance of the cloud bow at 865/960 nm and the total column including in-cloud absorption determined using total reflectance at 865/960 nm. Initial cloud optical depth is 2-4 (blue) increasing to a maximum of 8. Average above cloud water vapor was 4.9, 4.6, 4.8 and 5.0 cm for the four legs.

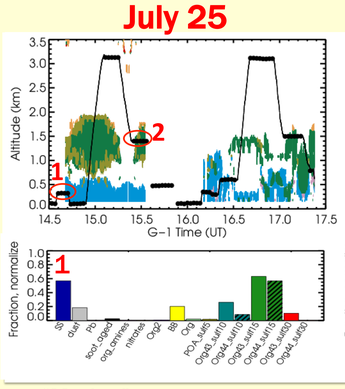


HSRL-2 vs miniSPLAT comparison

- HSRL-2 aerosol intensive parameters are combined to infer aerosol type by comparison with cases of known types from prior missions (Burton et al. 2012, AMT). Single particle mass spectrometer, miniSPLAT, measures the composition of individual aerosols with sizes ranging from ~50 to 2000 nm and classifies them to 16 species based on the mass spectra. Here we compare HSRL-2 typing with miniSPLAT compositions.
- In the HSRL-2 aerosol type "curtains" we have reordered the HSRL-2 profiles according to coincidence with the G-1, and the G-1 flight track is shown overlaid. HSRL-2 and G-1 data shown at the same time ("G-1 time") are the closest available coincident pairs.
- The miniSPLAT data are presented as fractional contributions normalized by the minimum and maximum of each species for the entire mission, to visually bring out differences in composition between cases.

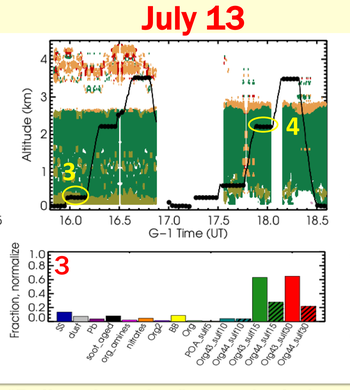
HSRL-2 Aerosol Types
- Pure Dust
- Dusty Mix
- Marine
- Polluted Marine
- Urban
- Fresh Smoke
- Smoke

July 25



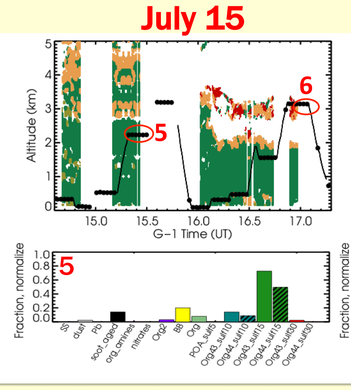
"Marine" case, characterized by sea salt in miniSPLAT data

July 13



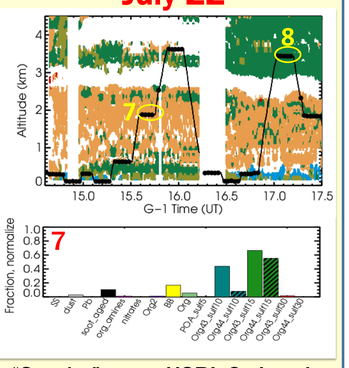
"Polluted marine" case, includes some sea salt in addition to organics and sulfates

July 15

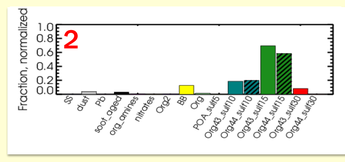


"Urban" case. Same dominant species as case 2, but some BB and aged soot suggest possibly misclassified smoke

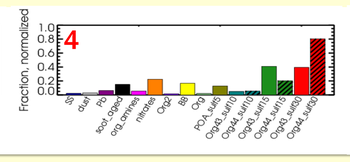
July 22



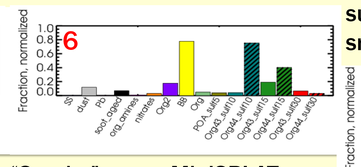
"Smoke" case. HSRL-2 class is called "fresh smoke" based on previous experience. But aged soot and SOA in miniSPLAT suggest that this is aged smoke instead.



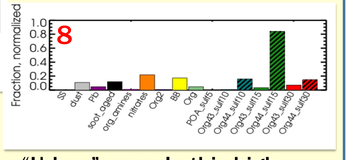
"Urban" case, includes mostly organics and sulfates



"Urban" case. On 7/13, greater amounts of sulfates than on other days. This layer also includes some nitrates



"Smoke" case. MiniSPLAT measures significant biomass burning (BB) aerosols and high fraction of Org44_sulf10. Org44 (m/z ratio = 44) is characteristic of secondary organic aerosols.



"Urban" case. In this high altitude layer with relatively low particle concentrations, Org44_sulf15 dominates all other species.

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