A13K-0336: Airborne Multi-wavelength High Spectral Resolution Lidar for Process Studies and Assessment of Future Satellite Remote Sensing Concepts

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Introduction

- NASA Langley has developed the first airborne multi-wavelength high spectral resolution lidar (HSRL) instrument, "***HSRL-2***"
- HSRL-2 follows the heritage of the NASA Langley airborne HSRL-1, our first-generation instrument, which has been deployed extensively throughout North America since 2006
- HSRL-2 is designed as the prototype lidar for the NASA Aerosols-Clouds-Ecosystems (ACE) satellite mission which was recommended for implementation in the Decadal Survey conducted by the National Academy of Sciences
- The initial deployment of HSRL-2 occurred in July 2012 in the Two-Column Aerosol Project (TCAP) field mission sponsored by the Department of Energy (DOE).
- Data from TCAP are being used to retrieve vertically resolved aerosol microphysical parameters using the so-called "*3β + 2α*" technique
- The NASA Goddard Institute for Space Studies (GISS) Research Scanning Polarimeter (RSP) instrument was also flown on TCAP enabling future studies of combine lidar + polarimeter retrievals also relevant to the ACE mission

Instruments on NASA Langley Research Center B-200

NASA Langley HSRL-2: first airborne *3β+2α+3δ* lidar

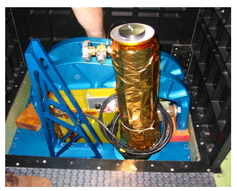
Laser	
Laser pulse energy	30 mJ @ 355 nm 13 mJ @532 nm 36 mJ @ 1064 nm
Laser Repetition Rate	200 Hz
Receiver	
HSRL technique (interferometer)	355 nm
HSRL technique (iodine filter)	532 nm
Backscatter technique	1064 nm
Polarization	355, 532, 1064 nm
FOV	1 mrad
Extensive Aerosol Data Products	
Extinction	355, 532 nm
Backscatter	355, 532, 1064 nm
Intensive Aerosol Data Products	
Depolarization	355, 532, 1064 nm
Depol. spectral dependence	1064/532, 532/355
Backscatter spectral dependence	1064/532, 532/355
Extinction spectral dependence	532/355
Lidar Ratio	355, 532 nm

3β+2α retrievals

Aerosol type

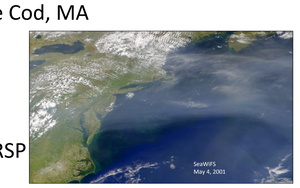
NASA GISS Research Scanning Polarimeter (RSP)

Measurements	
I, Q, U	410, 470, 550, 670, 865, 960, 1590, 1880, 2250 nm
Viewing Geometry	
Range of scan	120°
Measurements per scan	150 view angles
IFOV	14 mrad
Accuracy	
Radiometric	3%
Degree of lindear polarization	<0.2%

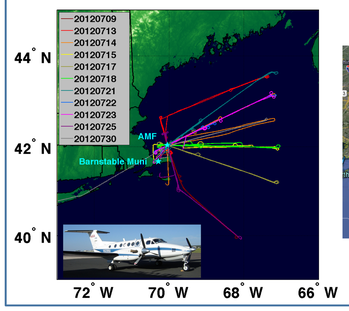


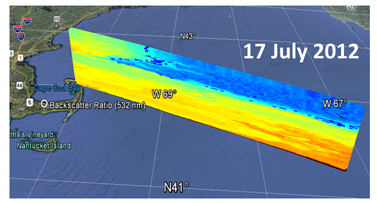
Two-Column Aerosol Project (TCAP)

- 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

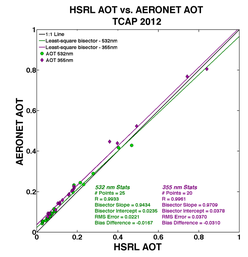


TCAP Flights of HSRL-2 and RSP





532 nm Aerosol Scattering Ratio from HSRL-2



HSRL AOT is validated with AERONET AOT at two sites

3β+2α Aerosol Microphysics Retrievals

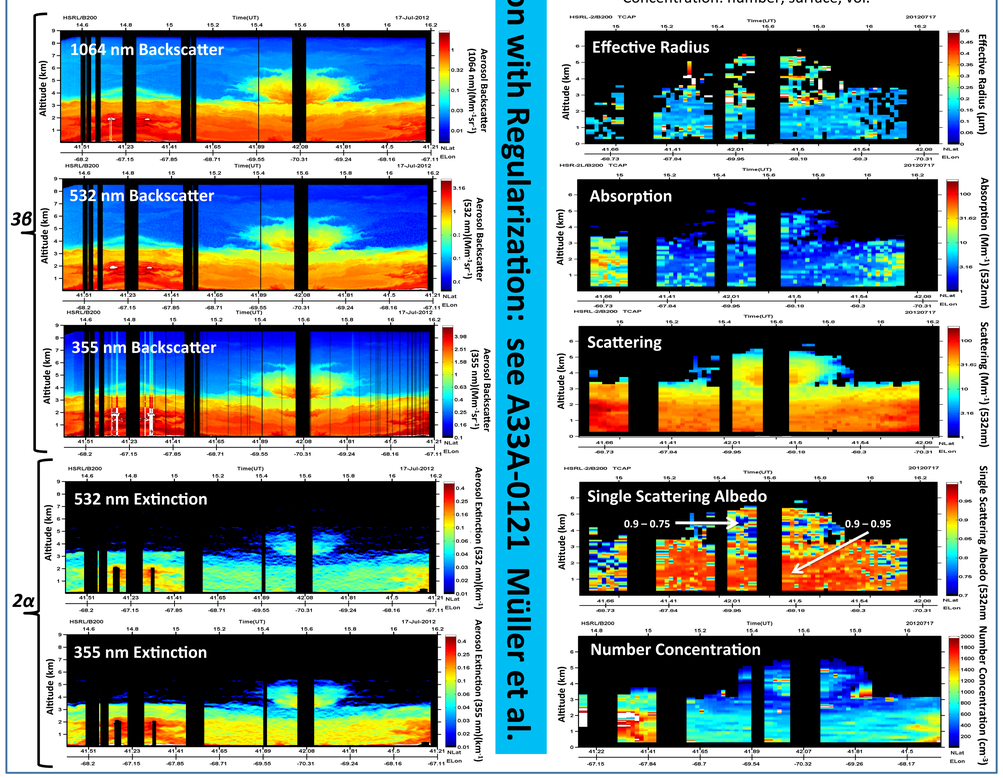
Aerosol Backscatter
355 nm
532 nm
1064 nm

+

Aerosol Extinction
355 nm
532 nm

Inversion with Regularization: see A33A-0121 Müller et al.

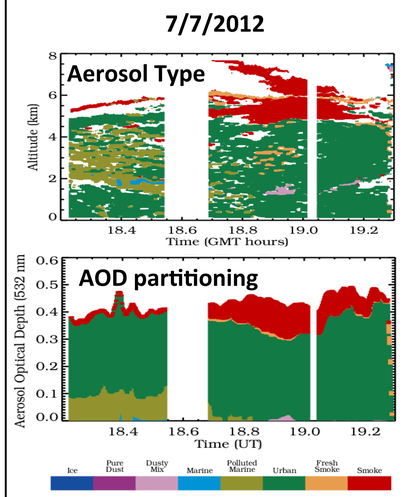
Aerosol Microsphysics
- Effective radius
- Index of refraction
- Scattering coefficient
- Absorption coefficient
- Single scatter albedo
- Concentration: number, surface, vol.



Motivation for *3β+2α* Aerosol Microphysical Retrievals

- Separate vertically-resolved retrievals of scattering and absorption are requisite for estimates of both direct and semi-direct aerosol forcing and profiles of radiative heating (including aerosols above clouds)
- Vertically-resolved absorption enables studies of the effect of aerosols on atmospheric stability
- Better quantification of aerosol type (via refractive index) and loading (via concentration) enable assessments of aerosol transport models
- Vertically-resolved retrievals of aerosol concentration and size enhance studies of aerosol-cloud interactions
- ***Ultimate goal: provide vertically-resolved aerosol properties to improve model predictions of aerosol effects on radiation, clouds, precipitation, and air quality***

Aerosol classification and AOD apportionment



- Aerosol classification using four aerosol intensive parameters from the 532 and 1064 nm channels
- Semi-supervised method based on a well characterized training set
- Aerosol classification can be used to constrain advanced retrievals
- Aerosol classification and AOD apportionment are used to assess transport models
- Additional aerosol intensive parameters from 355 channels on HSRL-2 will be used to expand and improve aerosol typing
- For details see, A13K-0337: S. P. Burton et al.

Future Applications

ER-2 Deployments

- HSRL-2 is built for deployment on ER-2 with other ACE prototype instruments
- Nominal flight altitude ~19km enables better simulation of satellite observations

Lidar + polarimeter retrieval development

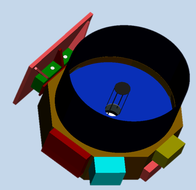
- Objective: develop advanced aerosol microphysical retrievals that provide more accurate altitude-resolved profiles of aerosol microphysics
- Co-deployment of HSRL and RSP on aircraft provide data for retrieval assessment
  - Past aircraft deployments with HSRL-1 and RSP
  - TCAP and future deployments of HSRL-2 and RSP
  - Future deployments with other polarimeters (e.g., AirMSPI, PACS)

EarthCARE Validation and CALIPSO-EarthCARE Bridge Instrument

- HSRL-2 measurements encompass those of both CALIPSO (532 and 1064 nm) and ATLID (355 nm), providing a source of coincident data to relate measurements from the two satellite instruments as well as ATLID validation

Aerosols-Clouds-Ecosystems (ACE) Decadel Survey Mission

- HSRL-2 is the airborne prototype for the multi-wavelength HSRL lidar concept of ACE
- Realization to the right is based on CALIPSO general architecture with changes for HSRL capability and increased power-aperture
  - 1.5-meter diameter telescope
  - 25 W average power transmitter



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