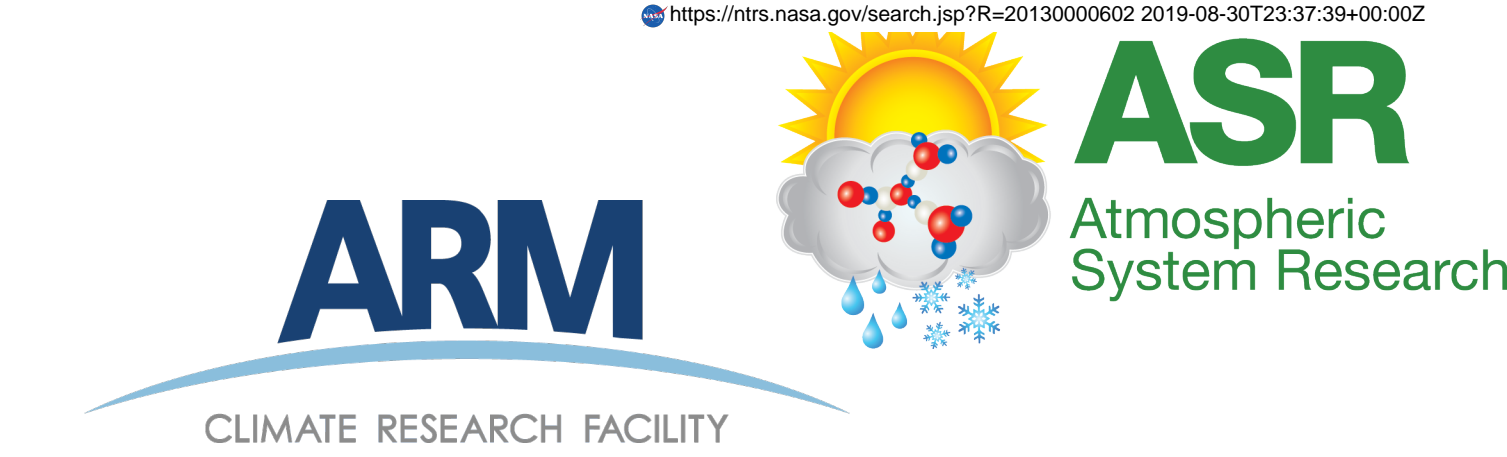




# A13K-0336: Airborne Multi-wavelength High Spectral Resolution Lidar for Process Studies and Assessment of Future Satellite Remote Sensing Concepts



Chris Hostetler<sup>1</sup> (Chris.A.Hostetler@nasa.gov), Richard Ferrare<sup>1</sup>, John Hair<sup>1</sup>, Anthony Cook<sup>1</sup>, David Harper<sup>1</sup>, Terry Mack<sup>2</sup>, Rich Hare<sup>1</sup>, Craig Cleckner<sup>1</sup>, Ray Rogers<sup>1</sup>, Detlef Müller<sup>3</sup>, Eduard Chemyakin<sup>4</sup>, Sharon Burton<sup>1</sup>, Michael D. Obland<sup>1</sup>, Amy Jo Scarino<sup>3</sup>, Brian Cairns<sup>5</sup>, Phil Russell<sup>6</sup>, Jens Redemann<sup>6</sup>, Yohei Shinozuka<sup>7</sup>, Beat Schmid<sup>8</sup>, Jerome Fast<sup>8</sup>, Larry Berg<sup>8</sup>, Connor Flynn<sup>8</sup>, Rick Wagener<sup>9</sup>, Laurie Gregory<sup>9</sup>

<sup>1</sup>NASA Langley Research Center, Hampton, VA, USA; <sup>2</sup>Lockheed-Martin, NASA Langley Research Center, Hampton, VA, USA; <sup>3</sup>Science Systems and Applications, Inc., Hampton, VA, USA; <sup>4</sup>Oak Ridge Associated Universities (ORAU), NASA Langley Research Center Hampton, VA 23681, USA; <sup>5</sup>NASA Goddard Institute for Space Studies, New York, NY, USA; <sup>6</sup>NASA Ames Research Center, Moffett Field, CA, USA; <sup>7</sup>Bay Area Environmental Research Institute NASA Ames Research Center, Moffett Field, CA; <sup>8</sup>Pacific Northwest National Laboratory, Richland, WA, USA; <sup>9</sup>Brookhaven National Laboratory, Upton, NY, USA

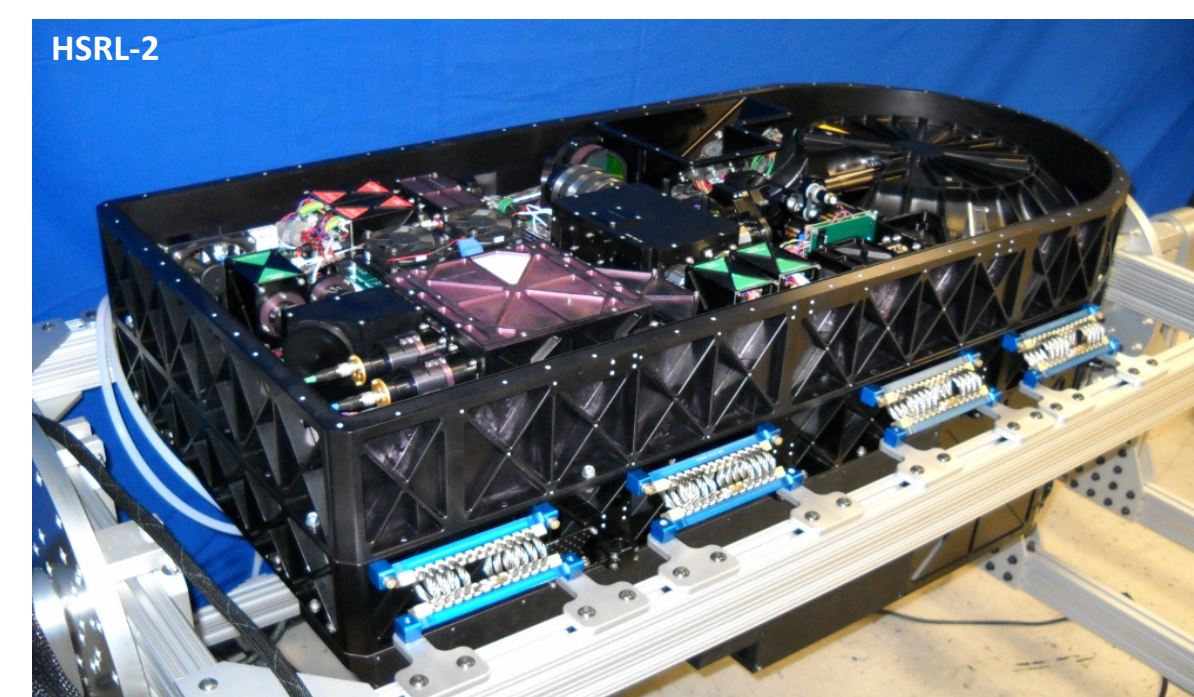
## Introduction

- 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

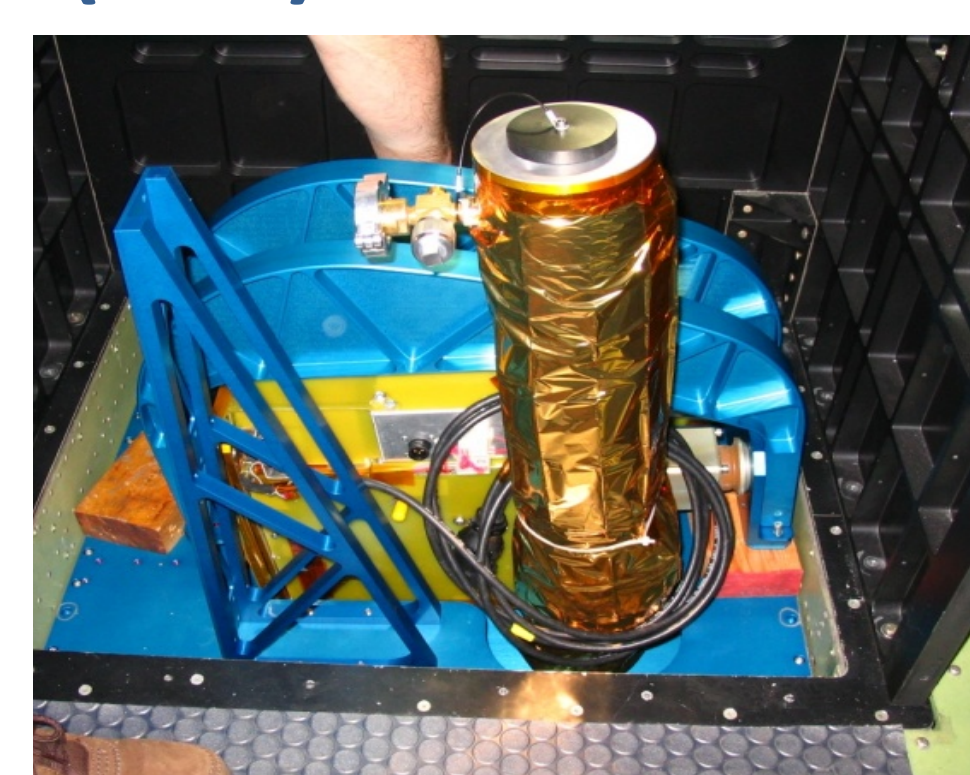


3β+2α retrievals

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 linear polarization	<0.2%

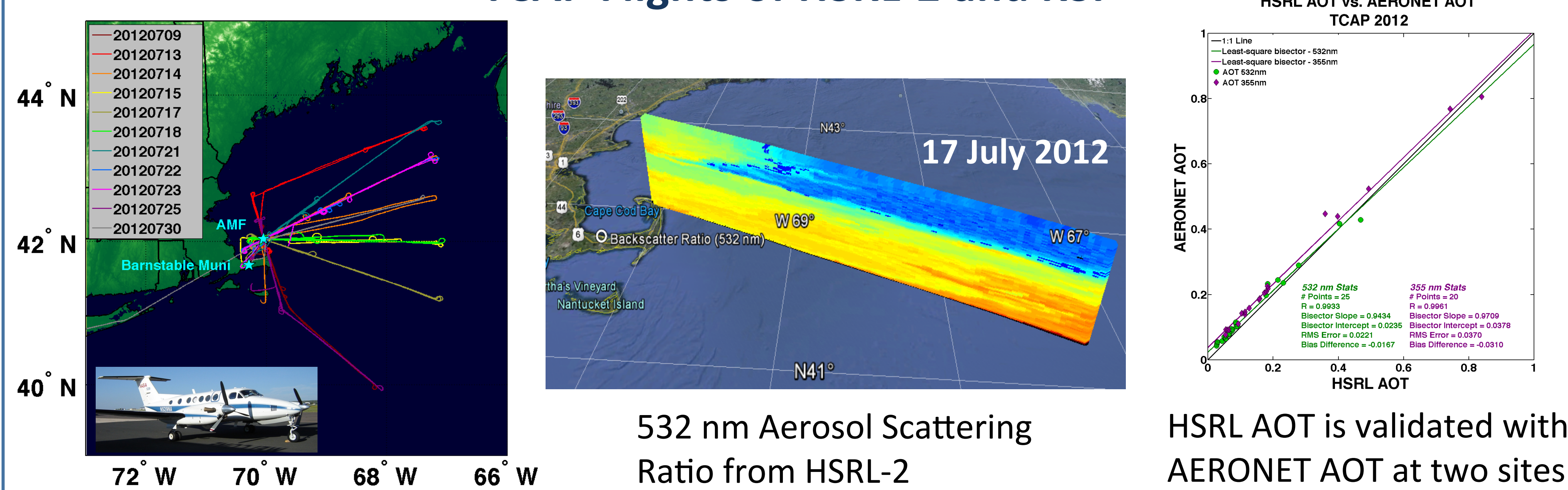


## Two-Column Aerosol Project (TCAP)

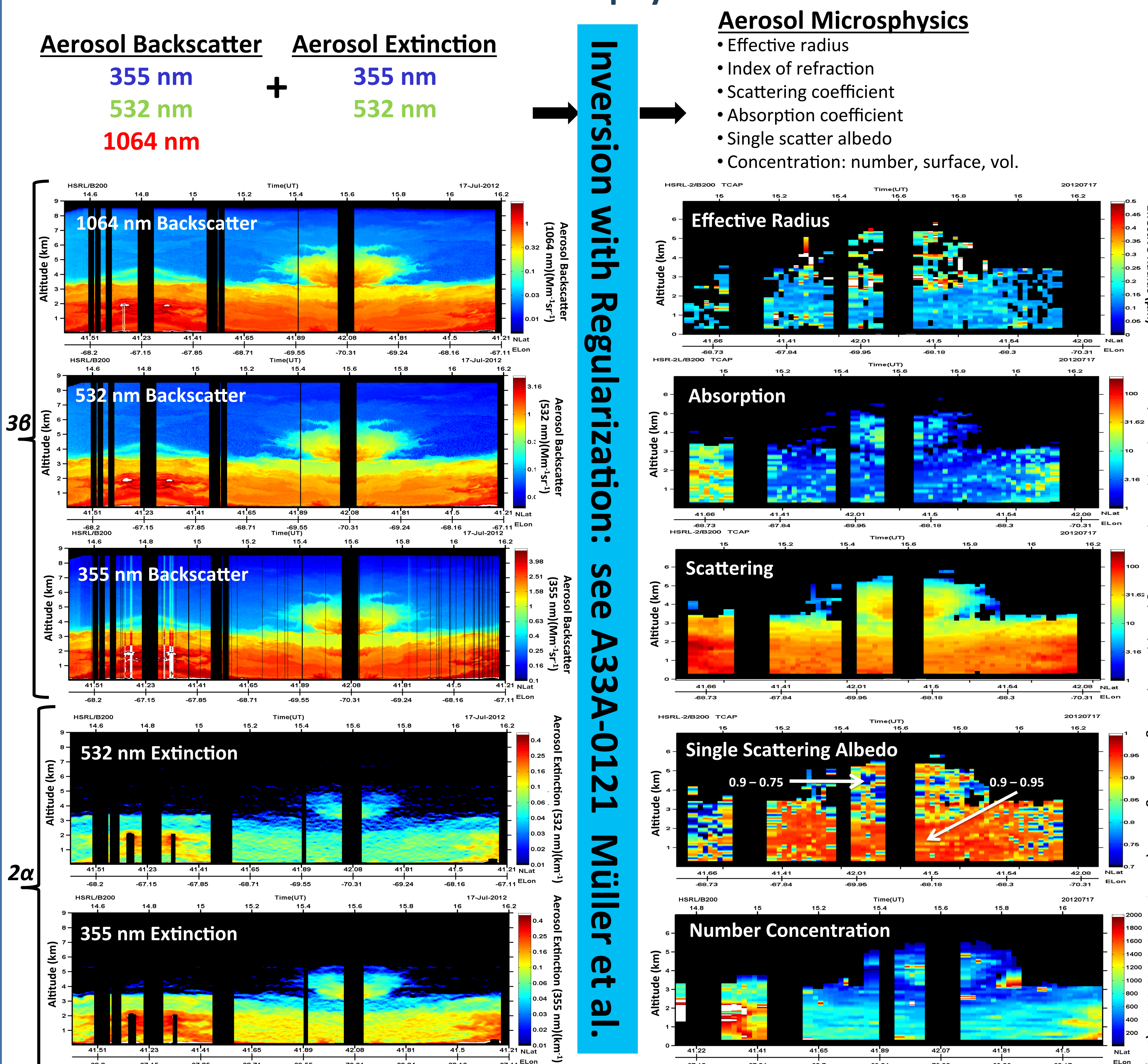
- Conducted by the DOE's Atmospheric Radiation Measurement (ARM) program over 7-29 July 2012 from base Cape Cod, MA
- Involved aircraft, surface measurements, and modeling
- DOE G-1 aircraft deploying aerosol in situ and remote sensors
- NASA King Air B200 deploying HSRL-2 and RSP
- DOE ARM Mobile Facility
- 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



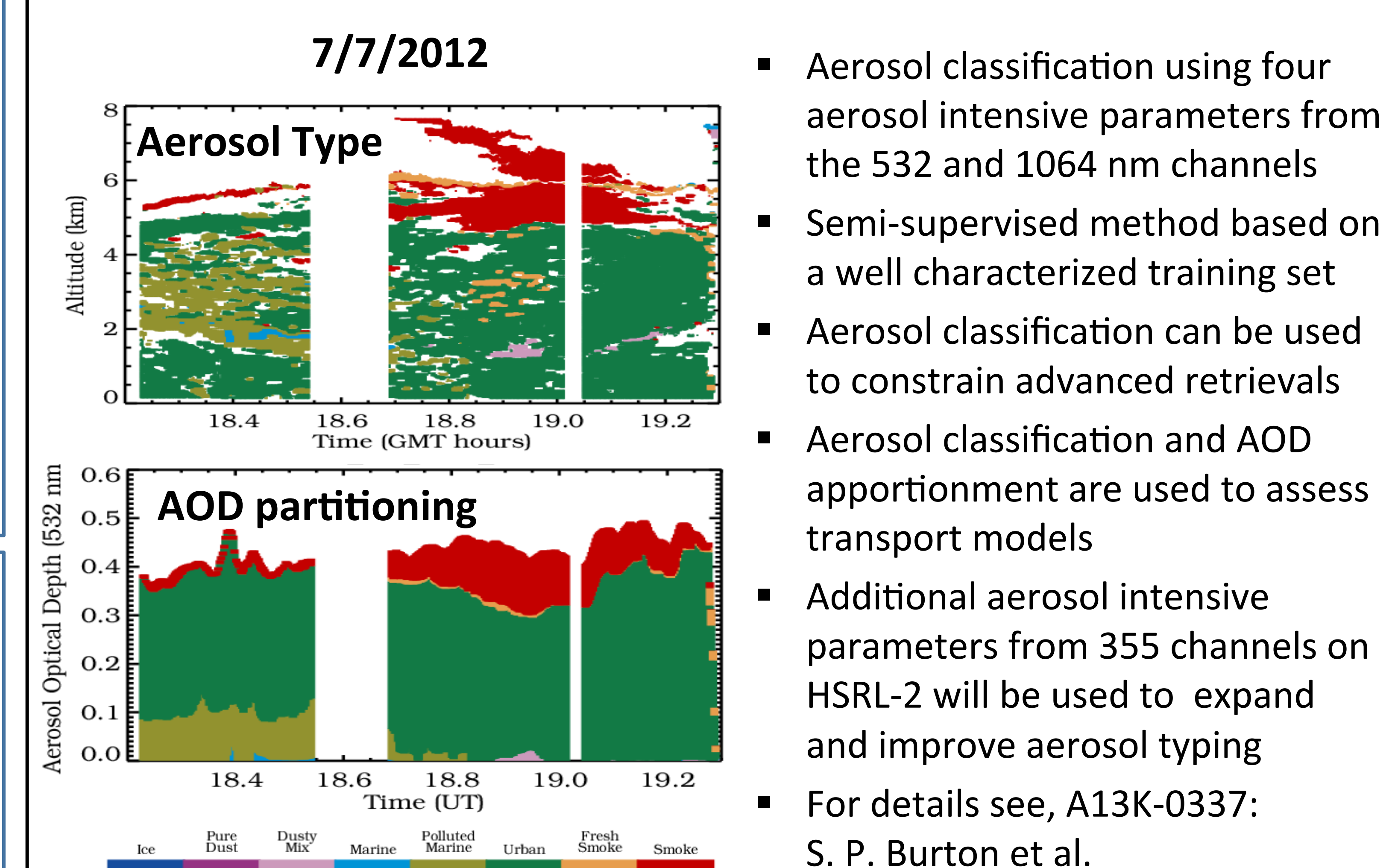
## 3β+2α Aerosol Microphysics Retrievals



## 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 predictions of aerosol effects on radiation, clouds, precipitation, and air quality

## Aerosol classification and AOD apportionment



## 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

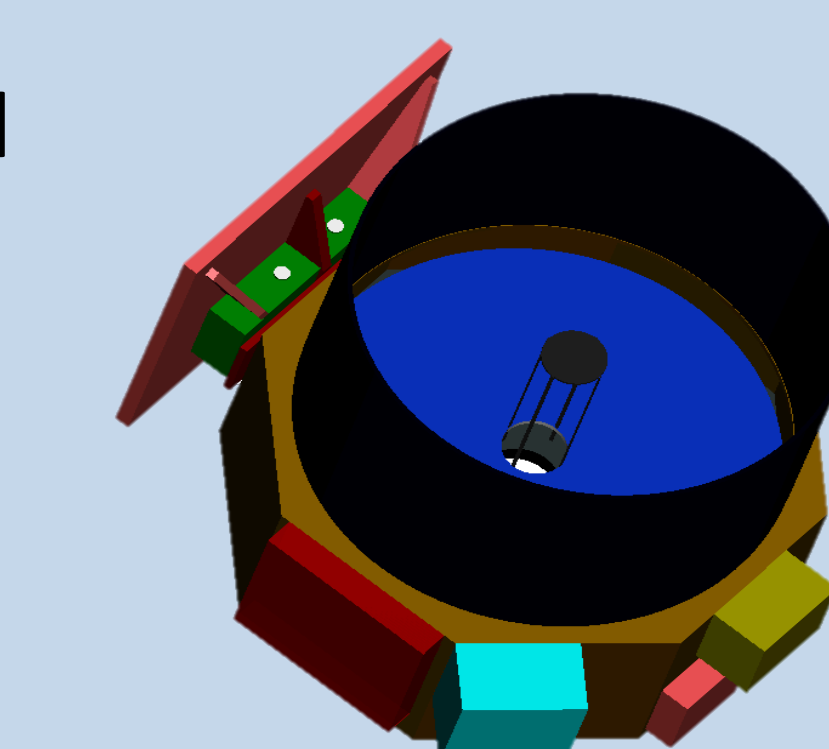
- Objective: develop advanced aerosol microphysical retrievals that provide more accurate altitude-resolved profiles of aerosol microphysics
- Co-deployment of HSRL and RSP on aircraft provide data for retrieval assessment
  - Past aircraft deployments with HSRL-1 and RSP
  - TCAP and future deployments 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 AT Lidar (355 nm), providing a source of coincident data to relate measurements from the two satellite instruments as well as AT Lidar validation

### Aerosols-Clouds-Ecosystems (ACE) Decadal 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



## Acknowledgements

The authors thank the NASA Langley B200 King Air flight crew for their outstanding work supporting research flights. Support for the HSRL and RSP flight operations on TCAP was provided by the DOE ARM program. Support for data analysis was provided in part by the DOE Atmospheric System Research program. Support for the development of HSRL-2 and ACE-related mission studies was provided by the NASA Science Mission Directorate, ESTO, AITT, and Radiation Science Program.