The *RSP-MAPP* algorithm: aerosol and ocean remote sensing using polarimetry

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APOLO #2

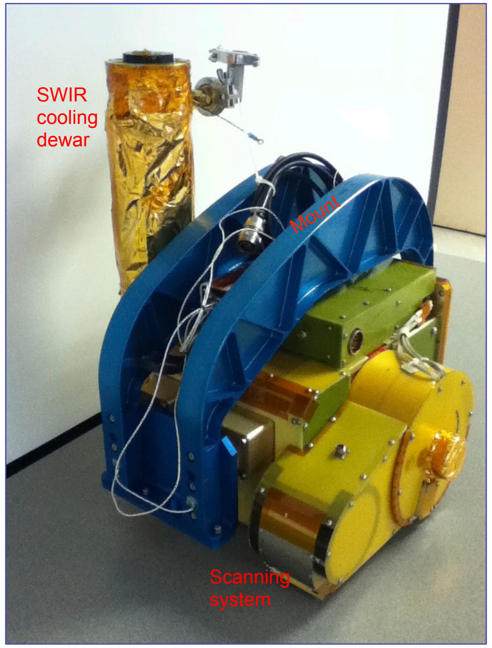
November 4, 2019

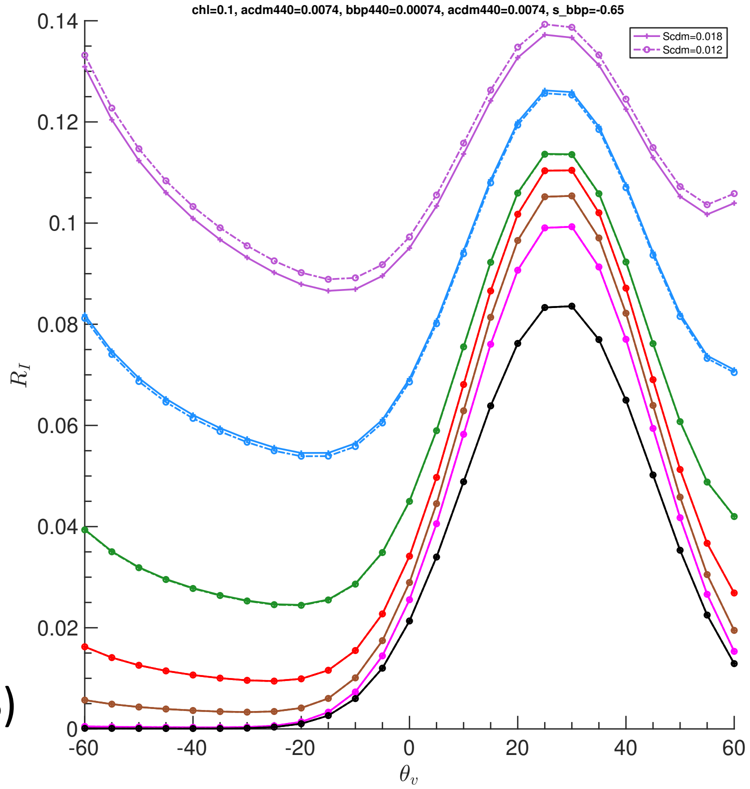
RSP-MAPP aerosol and ocean remote sensing products for NAAMES & SABOR field campaigns

- Overview of RSP (polarimeter) and HSRL (lidar) ocean products for community feedback
- RSP-MAPP philosophy and the “complex, coastal waters problem”
- RSP-MAPP Detritus-Plankton ocean model (Chowdhary)
- For researchers focused on aerosol/aerosol-cloud studies
  - Outline aerosol products and suggest an area for collaboration

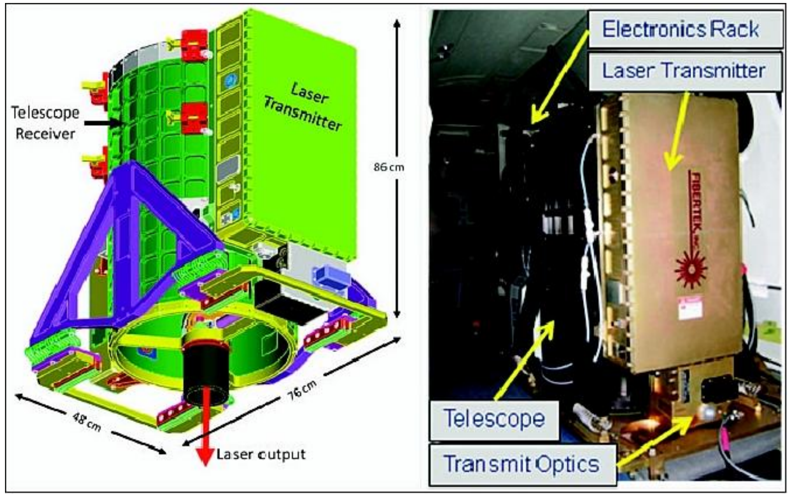
Airborne polarimeter and lidar

- RSP is a multi-channel polarimeter with 7 window channels (410-865, 1594, 2264).
- RSP is hyper-angular: it makes measurements at 100+ angles between +/- 55 degrees.





PI: Brian Cairns (NASA GISS)

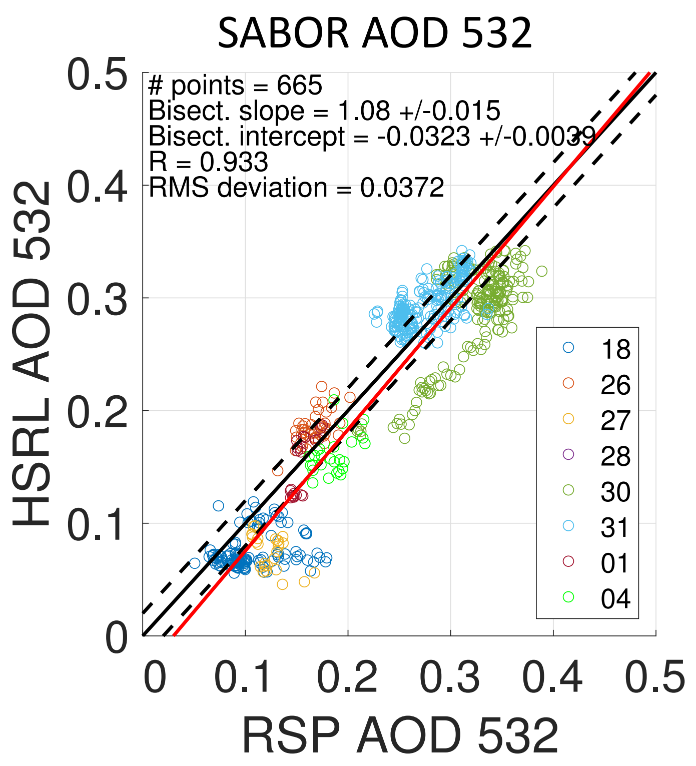


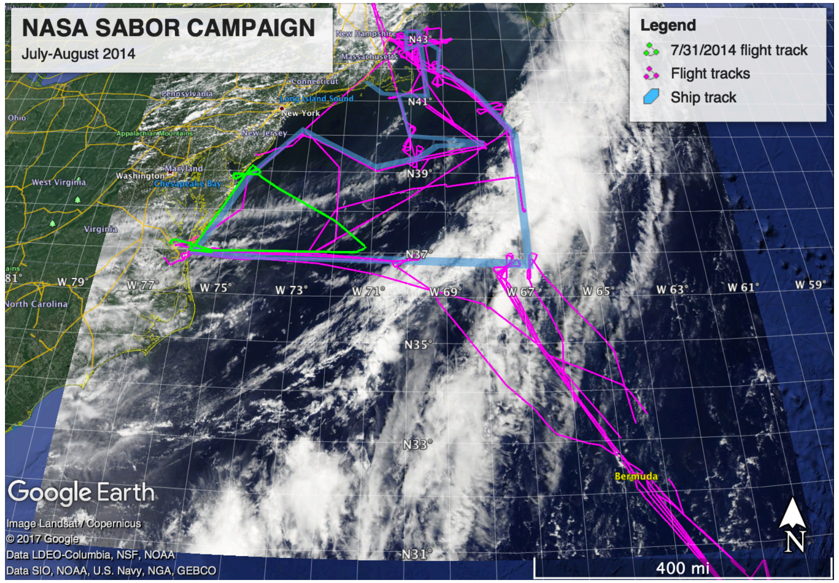
PI: Chris Hostetler (NASA LaRC)

- HSRL ocean products (Kd532 and bbp532)
  - Completely different technique that does not invoke the same assumptions.
- HSRL backscatter, extinction and lidar ratio are useful for validation and detection of aerosol type including absorbing aerosol.
  - Aerosols are the number one source of uncertainty in passive ocean remote sensing products.

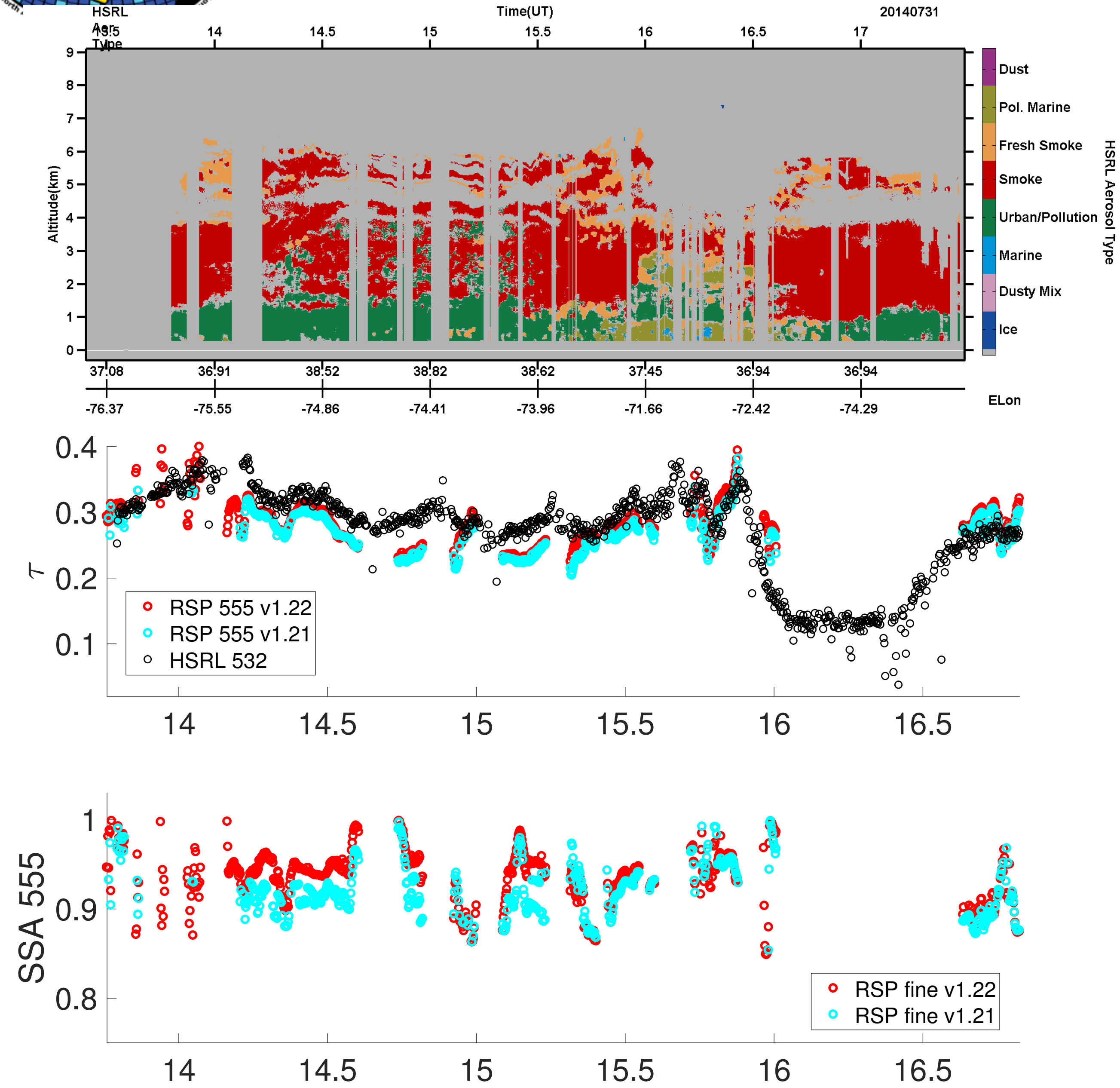
The RSP-**MAPP** approach for complex, coastal waters

- MAPP stands for Microphysical Aerosol Properties from Polarimetry. However, to get accurate aerosol microphysical properties, **the ocean has to be accurately characterized**.
- Make the "forward model" as accurate as possible:
  - Accurate vector radiative transfer: no "Rayleigh corrections" or other approximations used.
  - Bimodal lognormal aerosol size distribution: fine mode CRI is retrieved; coarse mode CRI constrained via a priori.
  - Accurate Mie modeling for aerosols.
  - Accurate ocean modeling via physically-consistent Mie calculations (particulate scattering matrix).
- Use optimal estimation to invert all total radiance and polarized radiance measurements simultaneously.
- *Retrieval using a coupled system is the best way to reliably and accurately retrieve ocean products in complex coastal zones.*
  - Negative water-leaving radiances violate the laws of physics.





Why do we need a coupled approach?



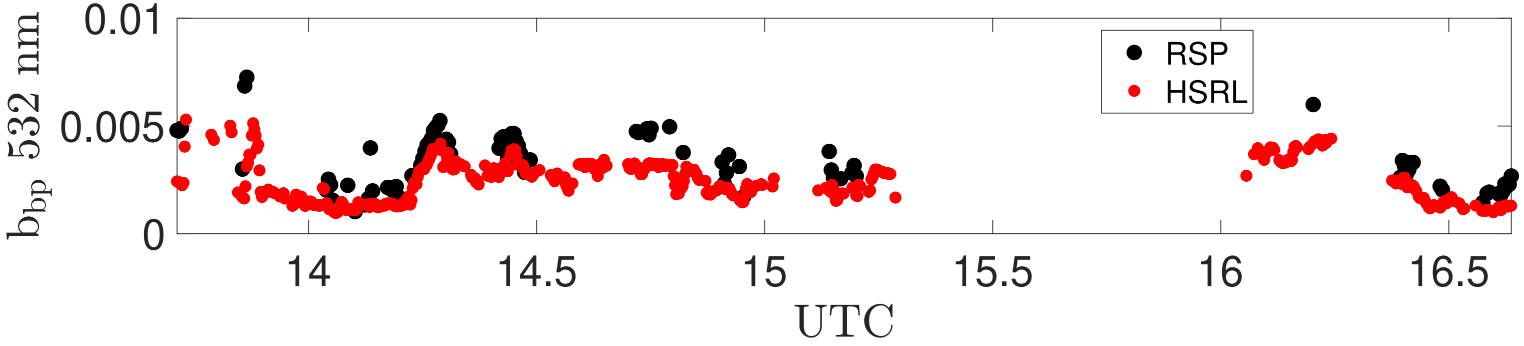
- Changing the ocean model causes retrieval differences in SSA of 0.02 or more!
- However, total aerosol optical depth is **unchanged.**

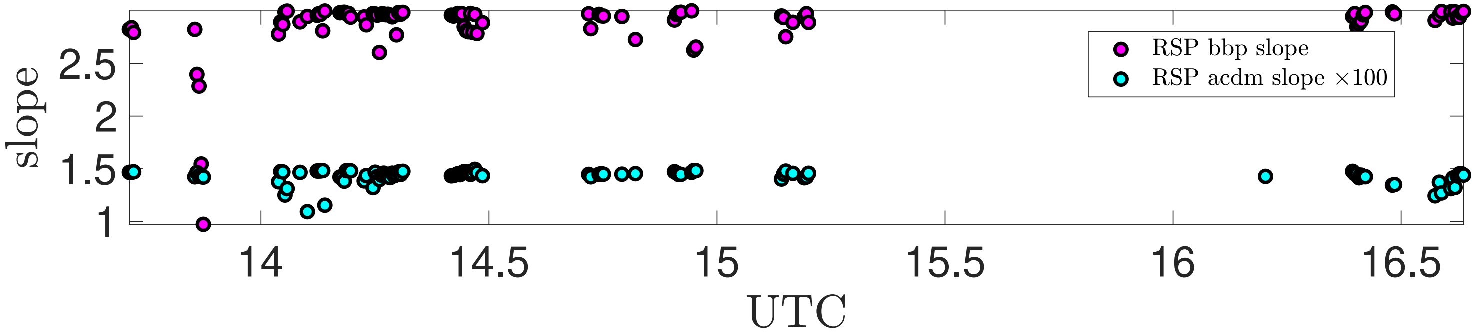
Simultaneous polarimeter retrievals of microphysical aerosol and ocean color parameters from the "MAPP" algorithm with comparison to high-spectral-resolution lidar aerosol and ocean products*, S. Stamnes, C. Hostetler, R. Ferrare, S. Burton, X. Liu, J. Hair, Y. Hu, A. Wasilewski, W. Martin, B. van Diedenhoven, J. Chowdhary, I. Cetinić, L. K. Berg, K. Stamnes, and B. Cairns, Appl. Opt. 57, 2394-2413 (2018), https://doi.org/10.1364/AO.57.002394*

RSP-MAPP **coupled** ocean model

- 1-parameter model: Chla.
  We also retrieve the windspeed (surface-slope, one-dimensional)
  - whitecaps modeled via a Lambertian term, or fraction of slopes that have Fresnel reflection.
- New 5-parameter ocean model: Chla, bbp440, bbp slope, cDOM440, cDOM slope.
- MODIS retrievals assume a fixed cDOM slope. Bbp slope maximum at 2.0 (?). ~Non-absorbing aerosols at a fixed location.

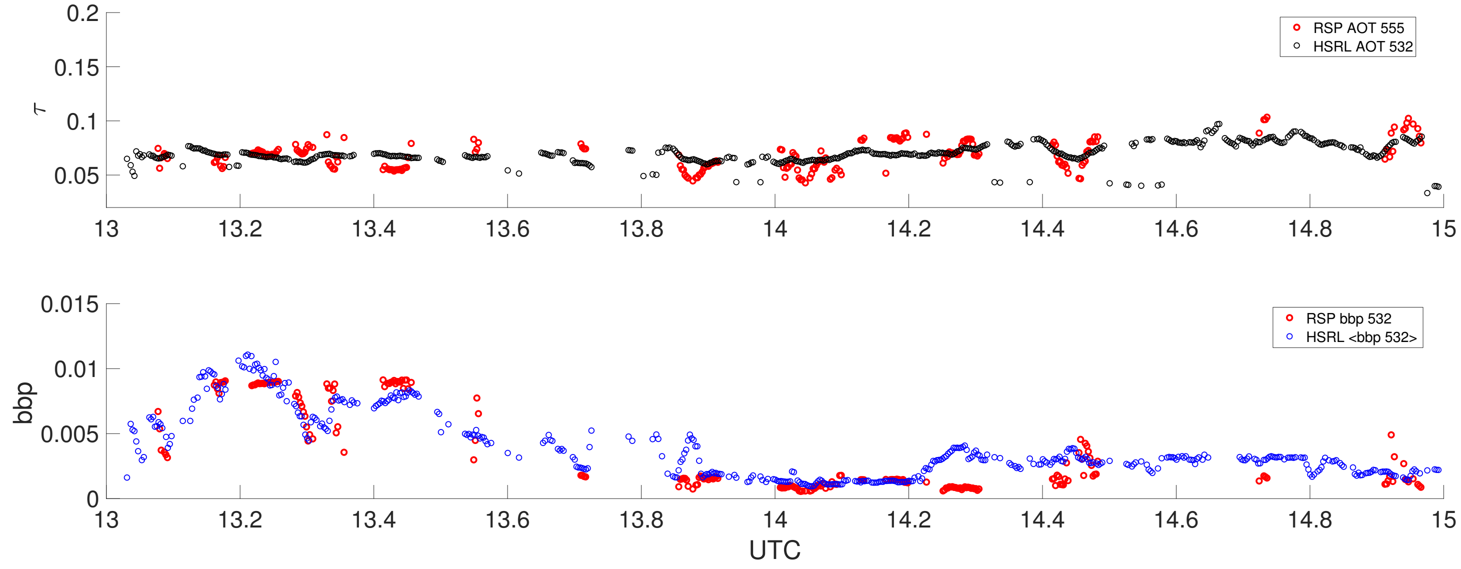
Chowdhary et al., 2006
Chowdhary et al., 2012
Detritus-Plankton series of *polarized* bio-optical models/ACROSS model
(see NASA PACE website)



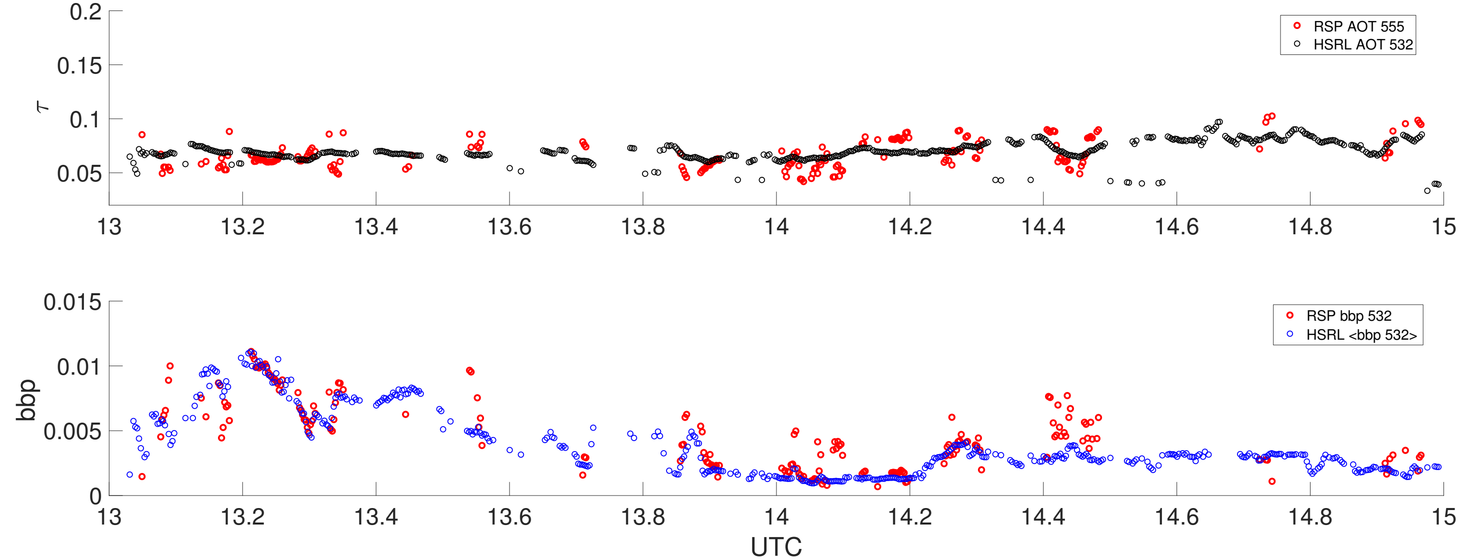


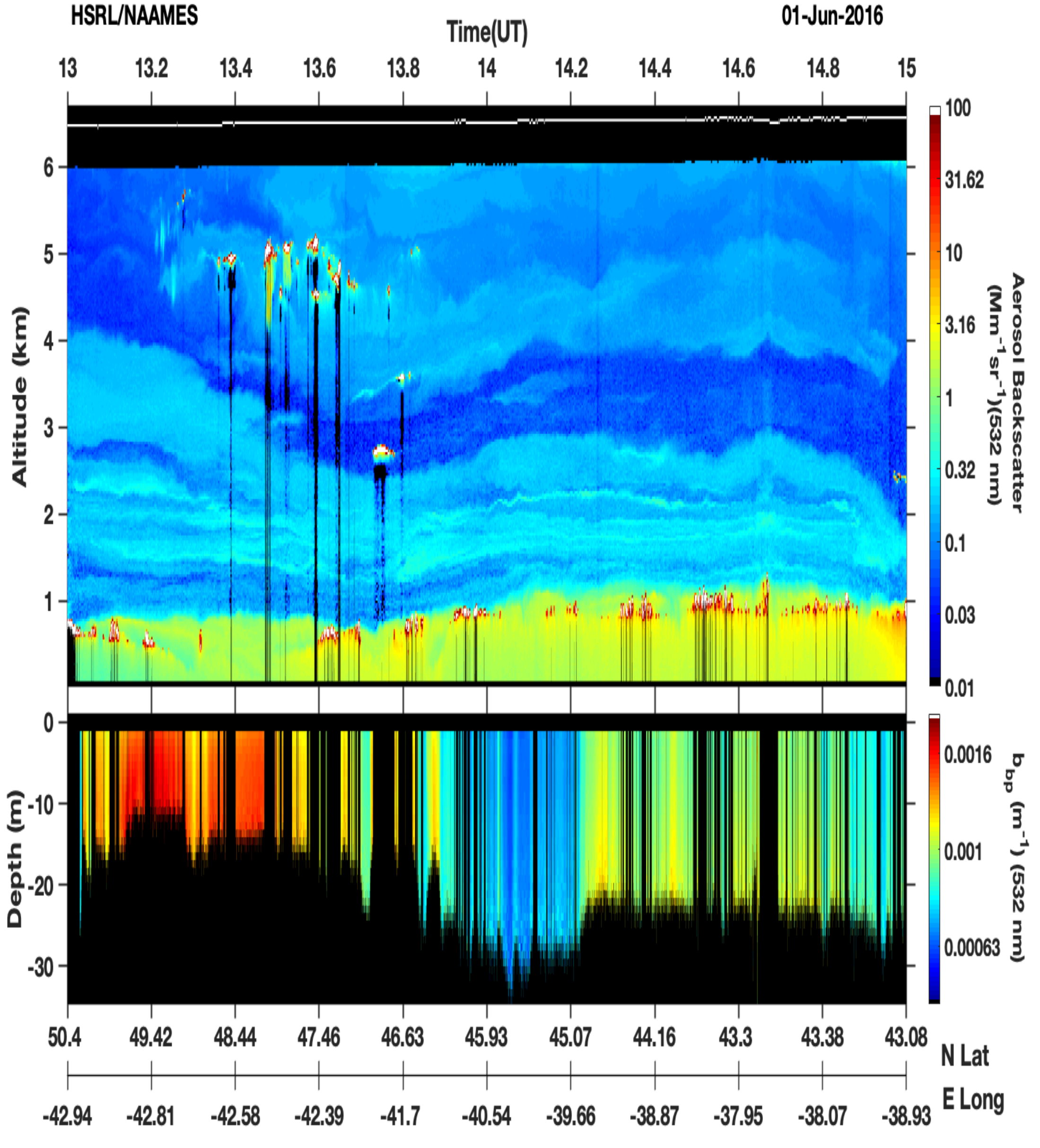
RSP-MAPP NAAMES products

NAAMES2 20160601, 753 retrievals, MAPP v1.23, 47% converged

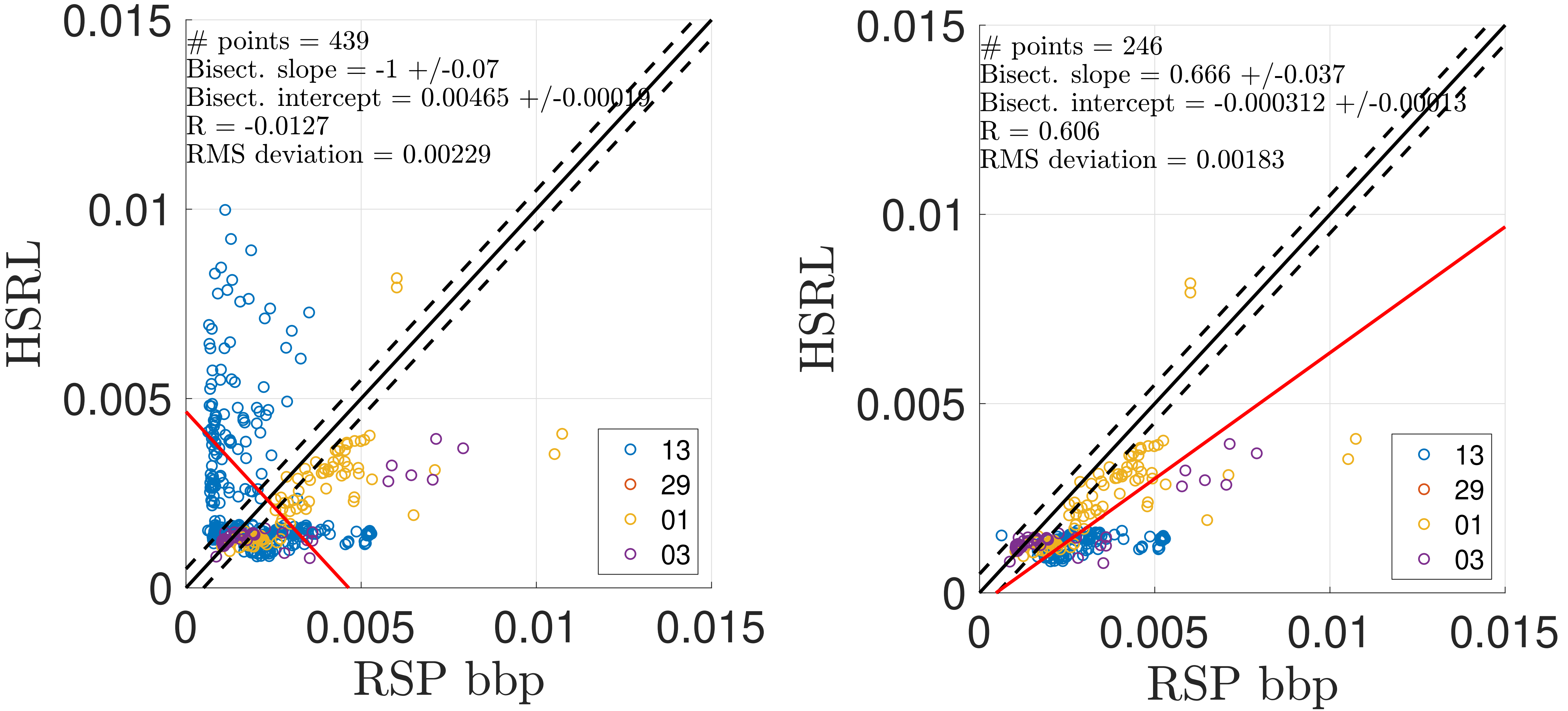


NAAMES2 20160601, 706 retrievals, MAPP v1.24, 46.2% converged





The issue of thin cirrus (NAAMES 2016)

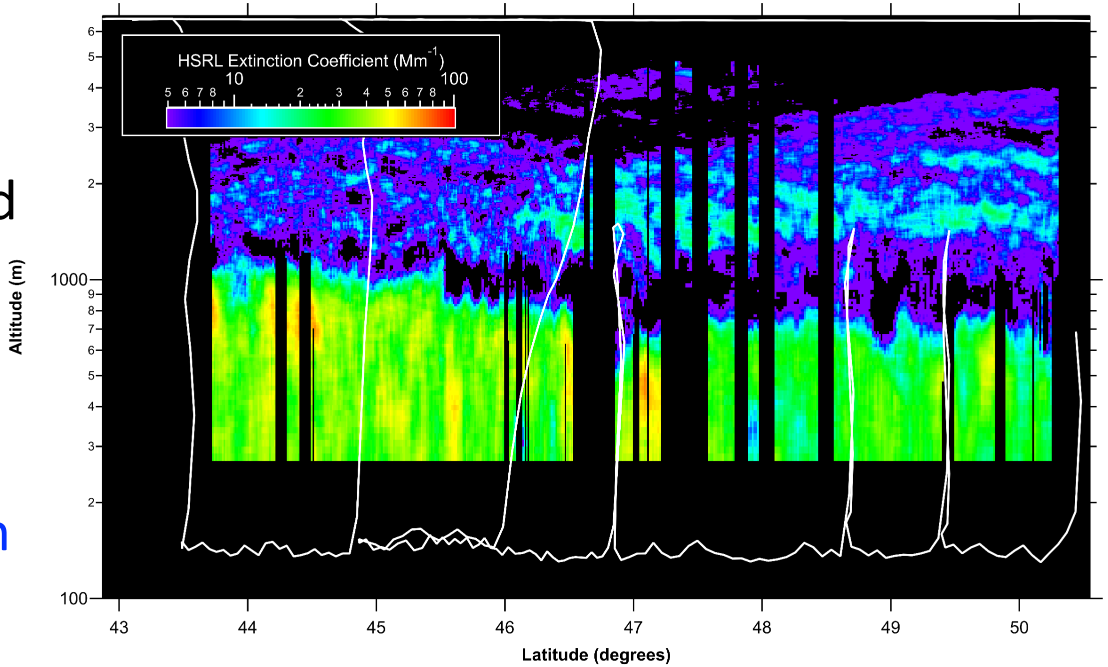


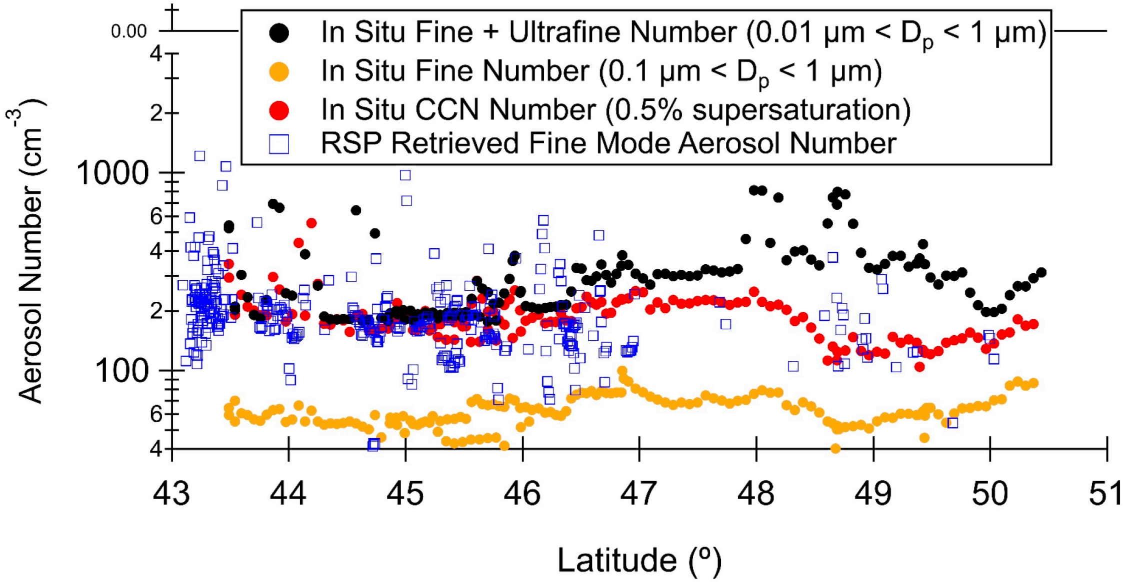
Thin cirrus is a major issue for aerosol microphysical properties (SSA) and detailed ocean properties.

Lidar + Polarimeter: Aerosol Number Concentration

- HSRL (lidar) measures the aerosol extinction coefficient (β_{ext}), aerosol vertical location, and retrieves the aerosol typing that is used to partition the coarse mode (sea salt) and fine mode aerosol extinction coefficient.
- RSP (polarimeter) retrieves the fine mode and coarse mode (sea salt) aerosol extinction cross-section (σ_{ext}).
- The aerosol number concentration is assumed to be constant throughout the planetary boundary layer (PBL), so using the RSP fine and coarse cross-sections (and AOD) we can *separate* the fine-mode extinction from the coarse mode extinction:

- $N_a = \frac{\beta_{ext,fine}}{\sigma_{ext,fine}}$



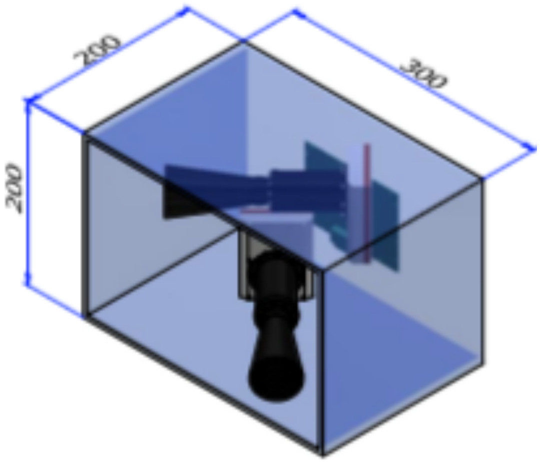


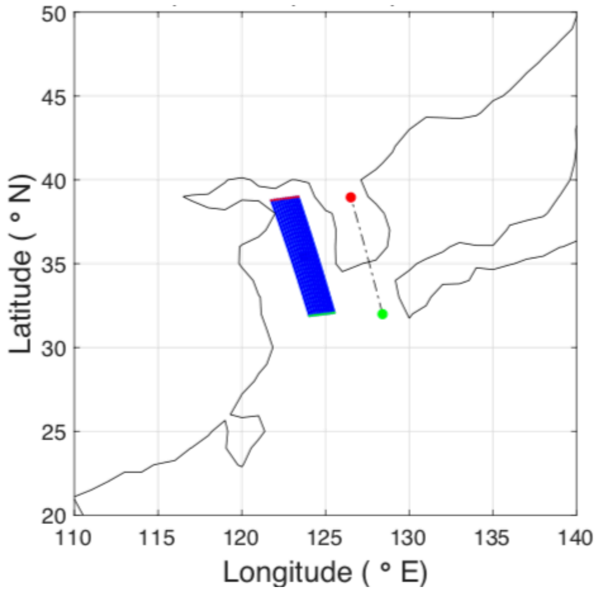
Summary

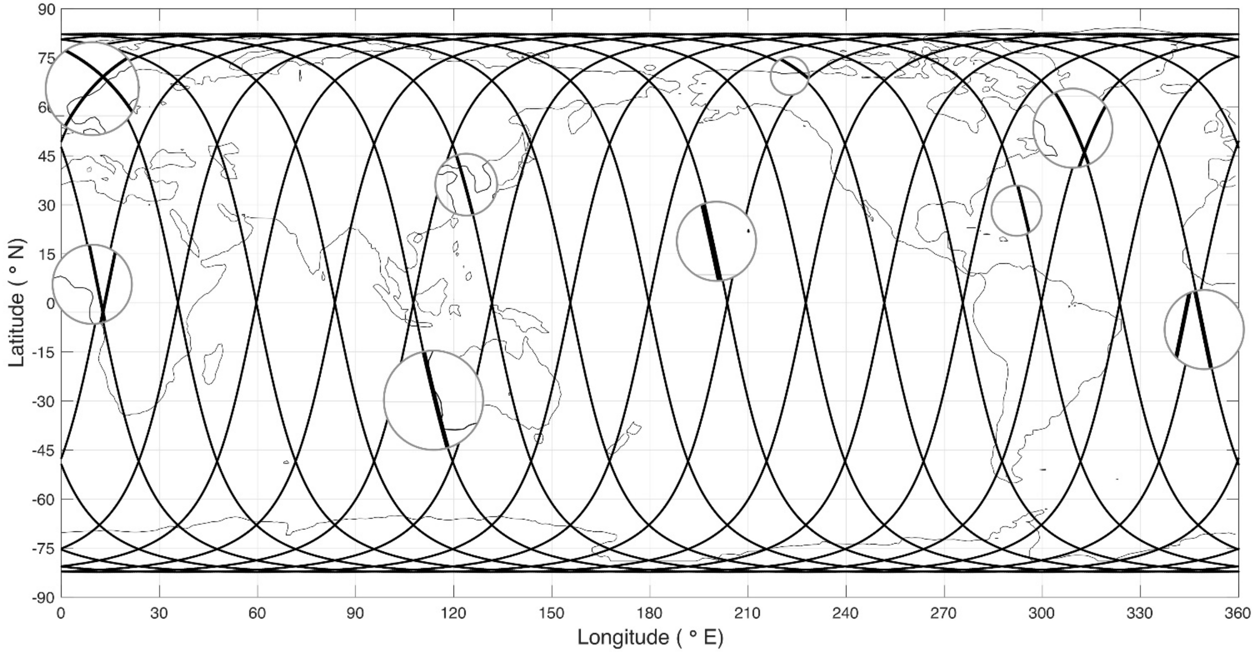
- Airborne data (HSRL and polarimeter) is critical for evaluating aerosol and ocean products, and works well when conditions are cloud-free.
- Retrieval of single-scattering albedo from polarimetry is possible, but the ocean properties need to be accurately characterized in complex waters.
- Aerosol number concentration derived using HSRL extinction / aerosol layer heights and RSP fine and coarse mode cross sections and AOD.
- Beyond that, future work involves combined RSP (polarimeter), HSRL (lidar) and GCAS (hyperspectral) retrievals. *But there are no current plans for such a field campaign, so NAAMES is everything we have.*
- Simultaneous correction for above aircraft thin cirrus, which is a major issue for low-flying aircraft remote sensing data, will be developed.

PolCube-CoastalAQ (LaRC+GISS+KASI+KAIST)

- 5 wavelengths UV-VIS-NIR (380, 440, 555, 670, 865 nm)
- 4 viewing angles
- I, Q, U Stokes components
- 3% total radiance accuracy, 0.5% DoLP accuracy
- ~190 km swath
- LaRC+GISS+KASI OE/VRT algorithm for aerosol absorption / air quality and coastal ocean properties (Stamnes et al., 2018)
- Thin cloud detection using the polarized reflectance in the backscatter direction (Sun et al., 2014)
- Ideal orbit: Sun-synchronous
  - altitude = 566.90 km
  - inclination = 97.66 deg
  - local time of ascending node 10:30 am
  - ground repeat of one day
- 1k x 1k CCD with striped wire-grid polarizers and wavelength bandpass filters
- 12U form factor, <3 kg, <15 W







Thank you and references

The data collection and algorithm development were funded by the NASA SABOR and NAAMES field campaigns, NASA ROSES Remote Sensing Theory, the NASA Aerosols-Clouds-Ecosystems mission, the US Department of Energy, and the NASA Science Innovation Fund.

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