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

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APOLO #2

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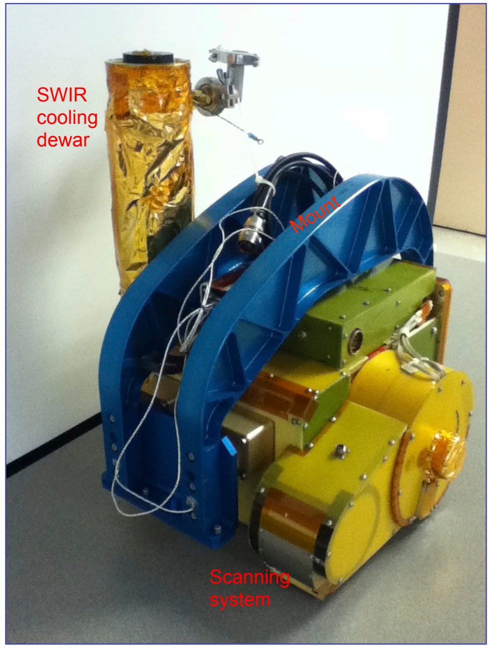
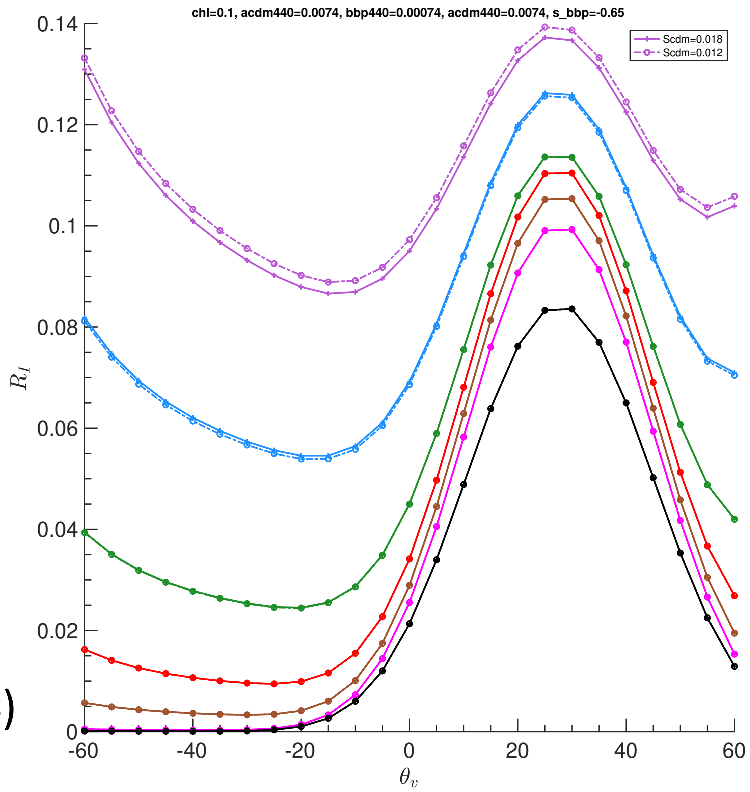
RSP-MAPP aerosol and ocean remote sensing products for NAAMES & SABOR field campaigns

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

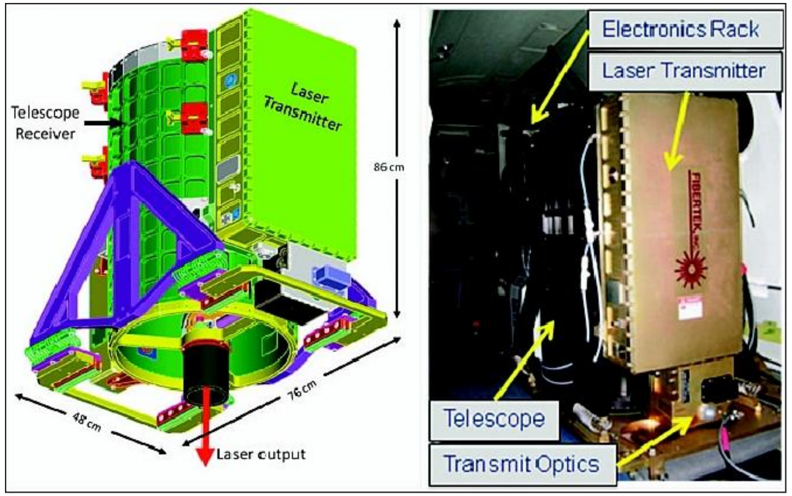
Airborne polarimeter and lidar

- 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)

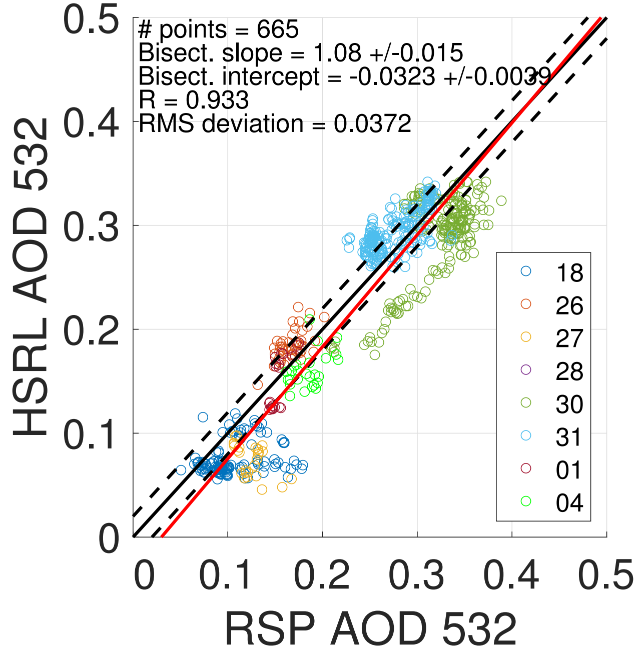


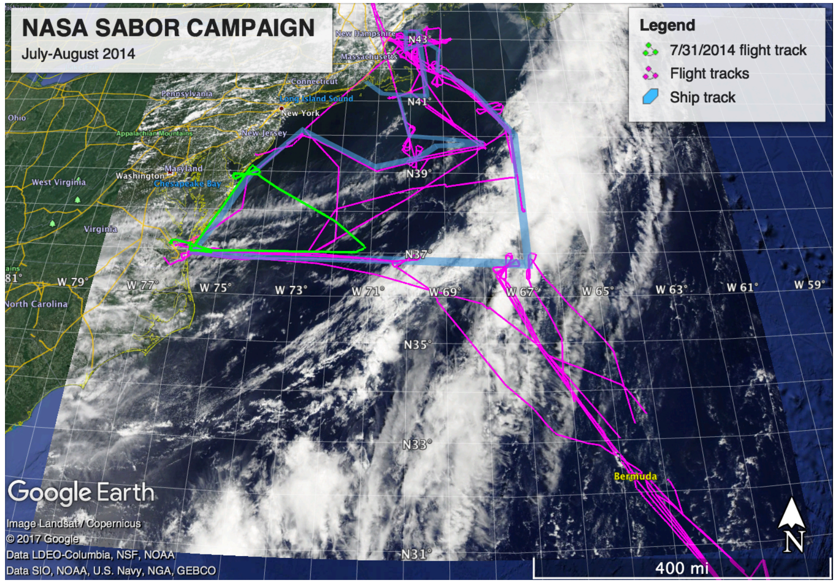
PI: Chris Hostetler (NASA LaRC)

- 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.

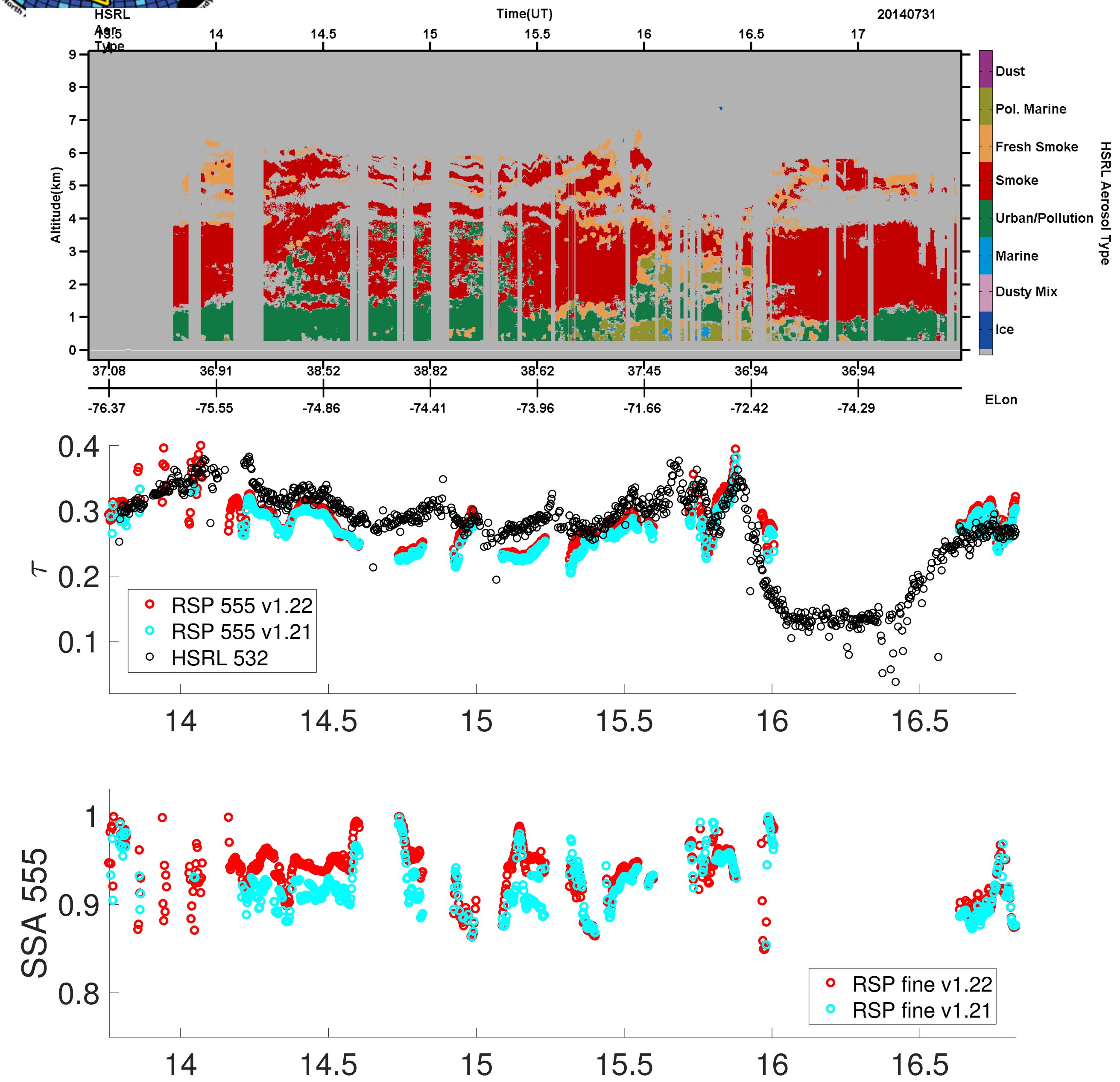
The RSP-**MAPP** approach for complex, coastal waters

- MAPP stands for Microphysical Aerosol Properties from Polarimetry. However, to get <u>accurate</u> aerosol microphysical properties, **<u>the ocean has to be accurately characterized</u>**.
- Make the "forward model" as accurate as possible:
  - Accurate vector radiative transfer: no "Rayleigh corrections" or other approximations used.
  - Accurate Mie modeling for aerosols.
  - Accurate ocean modeling via physically-consistent Mie calculations (albeit this does assume spherical particles.)
- Use optimal estimation to invert all total radiance and polarized radiance measurements simultaneously.
- Coupled atmosphere-ocean retrieval approach: e.g., retrieval of negative water-leaving radiances is physically impossible.
- *Retrieval using a coupled system is the best way to reliably and accurately retrieve ocean products in complex coastal zones.*





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.**

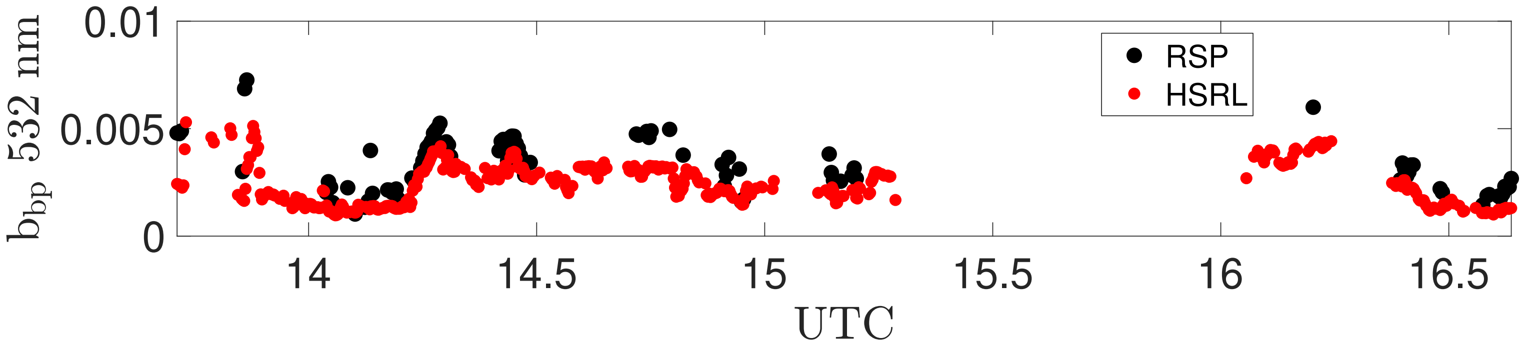
S. Stamnes, C. Hostetler, R. Ferrare, S. Burton, X. Liu, J. Hair, Y. Hu, A. Wasilewski, W. Martin, B. van Diedenhoven, J. Chowdhary, I. Cetinić, L. K. Berg, K. Stamnes, and B. Cairns, "Simultaneous polarimeter retrievals of microphysical aerosol and ocean color parameters from the "MAPP" algorithm with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

RSP-MAPP coupled ocean model

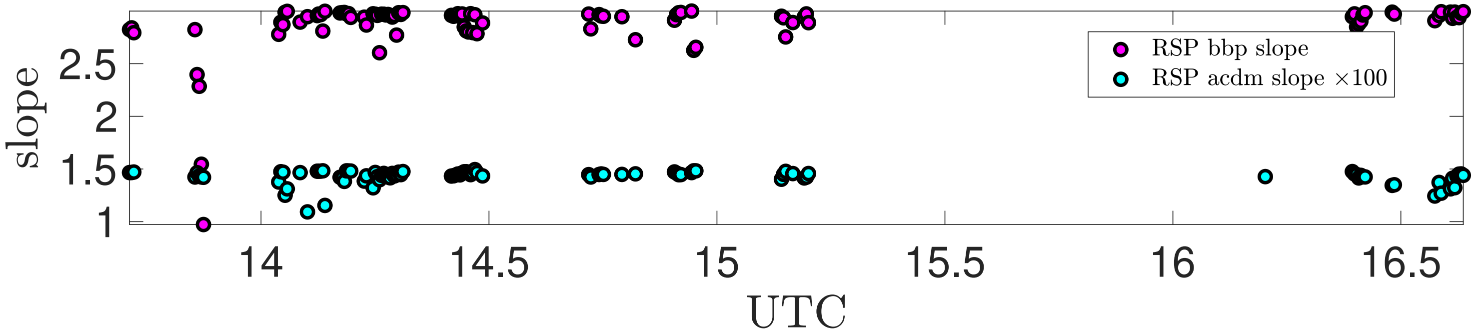
- 1-parameter model: Chla.
  We also retrieve the windspeed (surface-slope), and can model whitecaps either via a Lambertian term, or fraction of slopes that have Fresnel reflection.

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

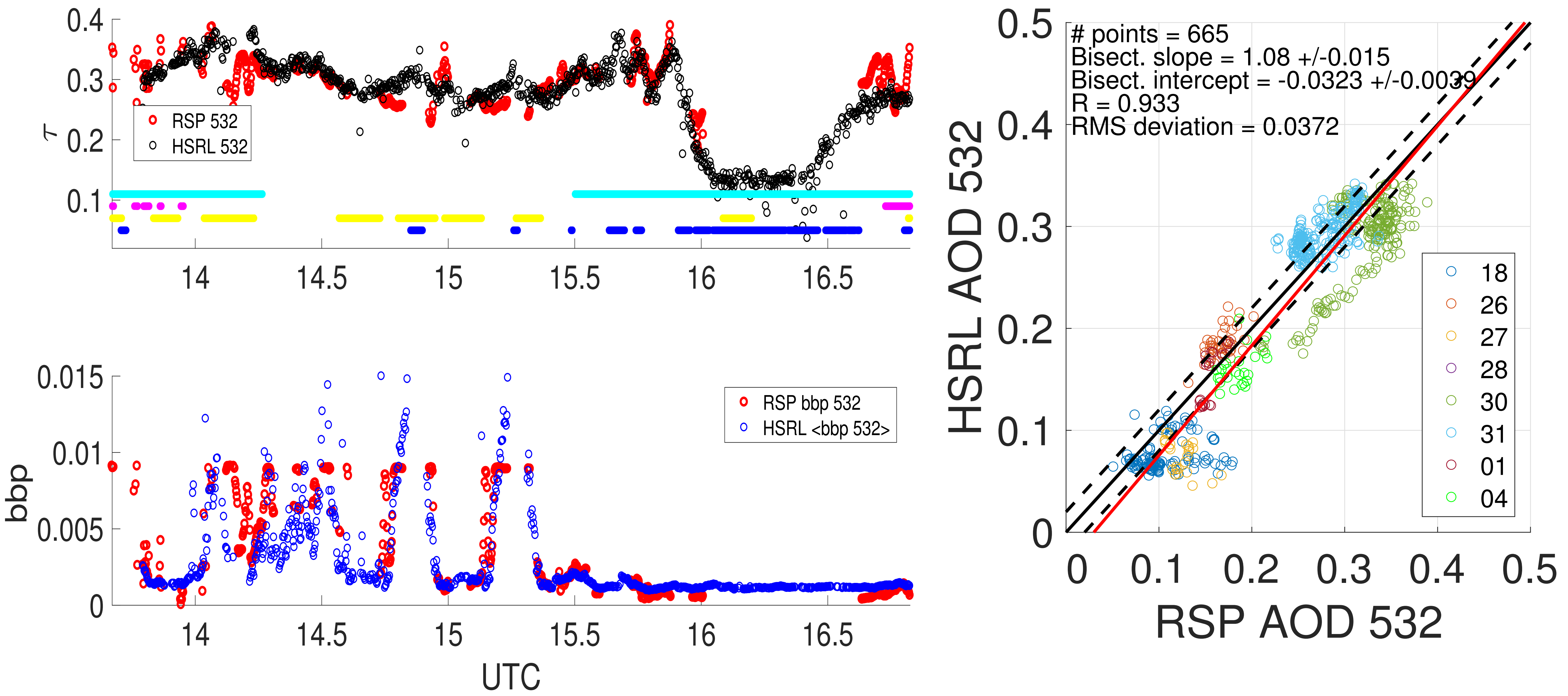
- New 5-parameter ocean model: Chla, bbp440, bbp slope, cDOM440, cDOM slope.



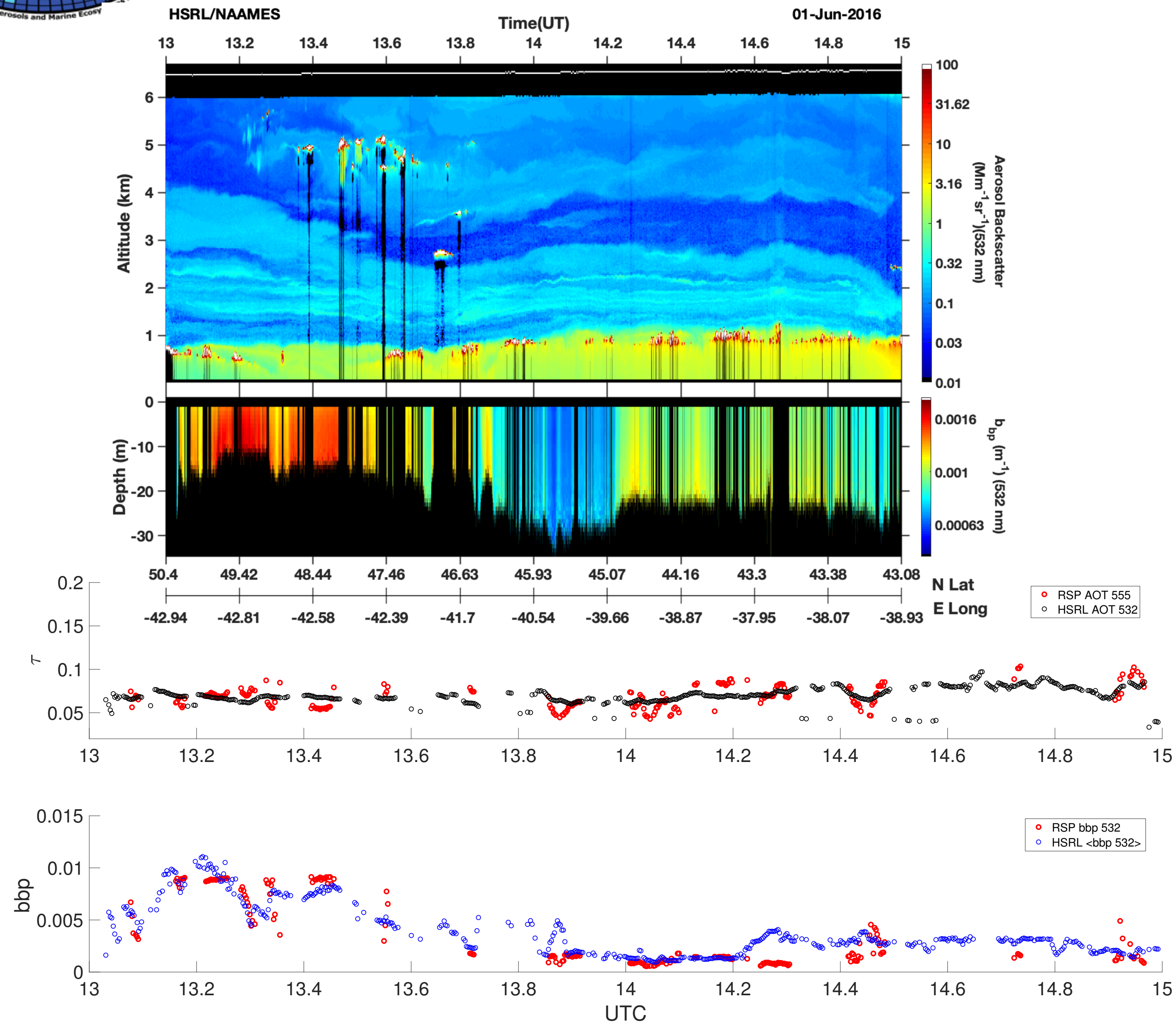
- MODIS retrievals assume a fixed cDOM slope. Bbp slope maximum at 2.0. Non-absorbing aerosols at a fixed location.

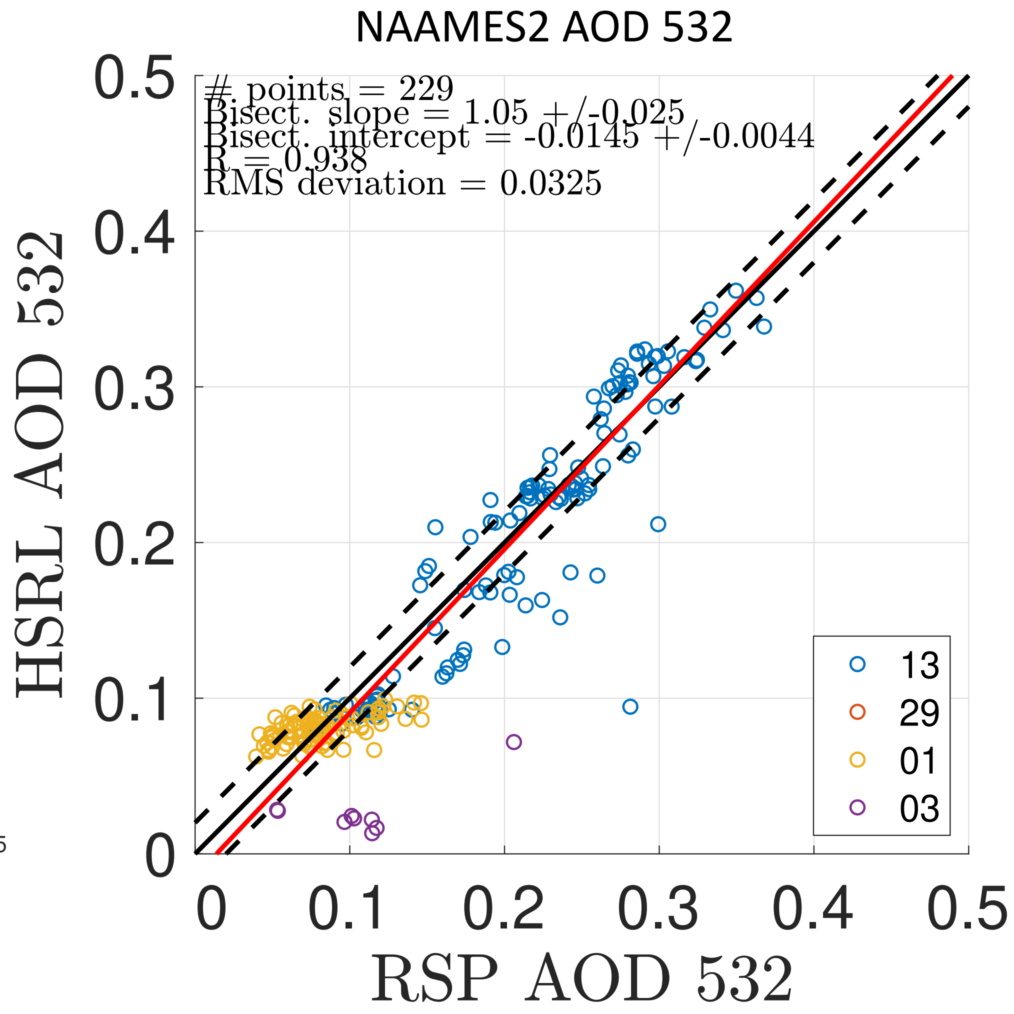


RSP-MAPP SABOR products

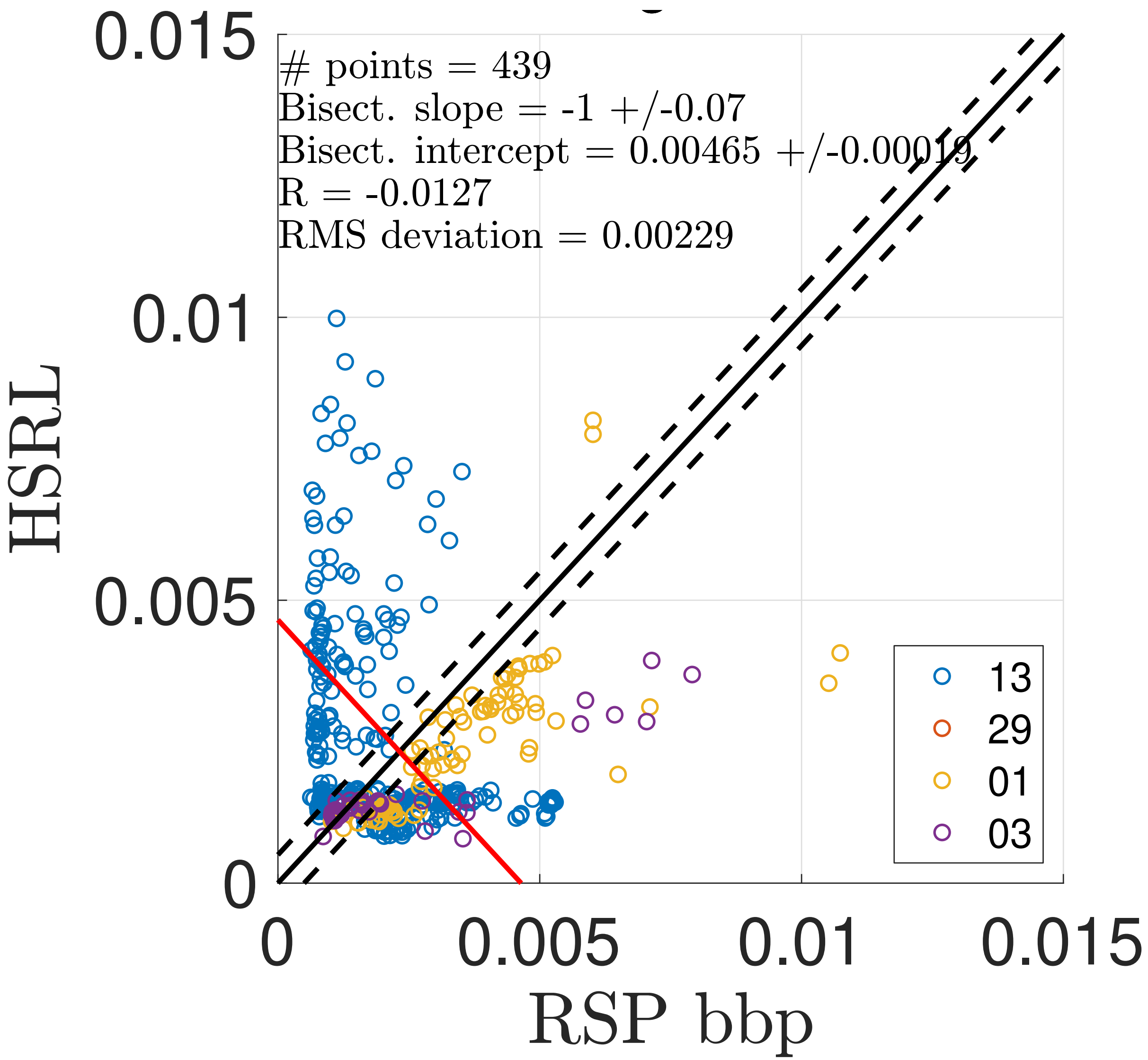


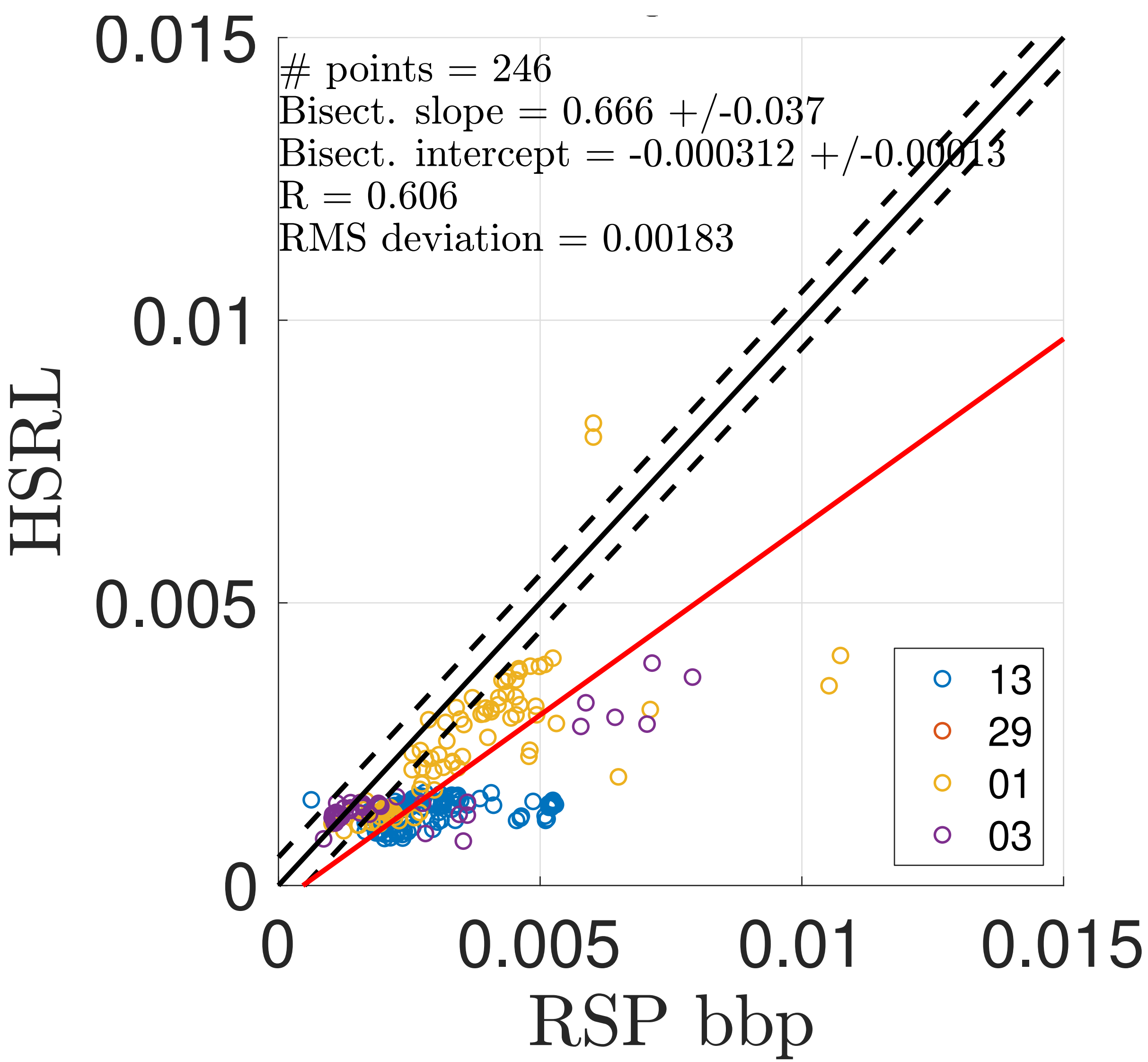
RSP-MAPP NAAMES products





The issue of thin cirrus (NAAMES 2016)

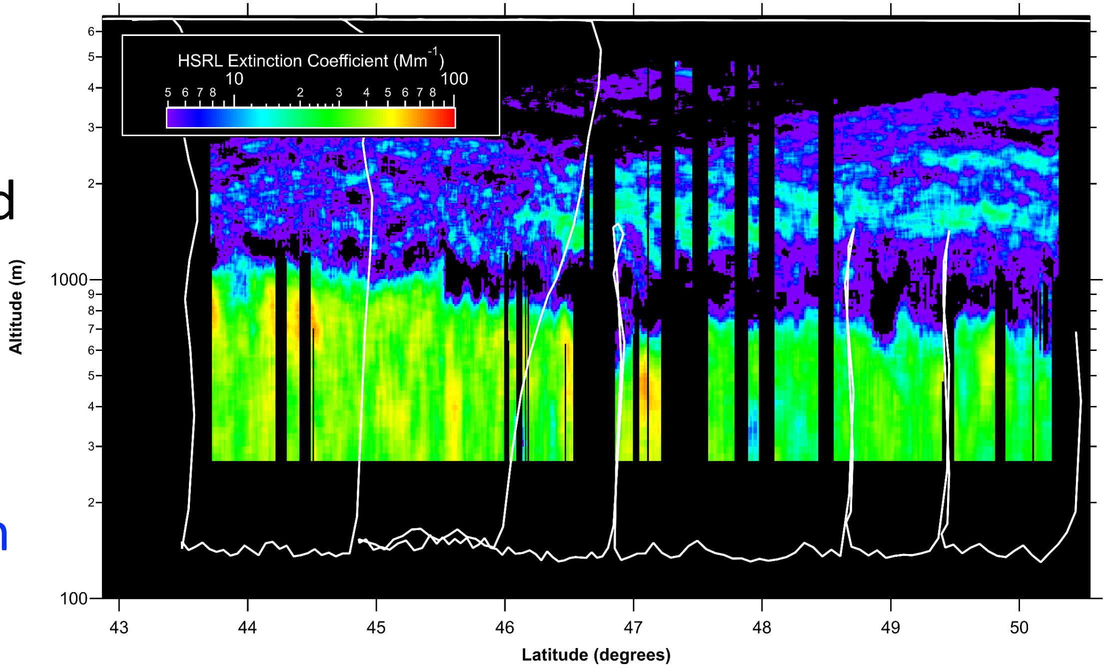


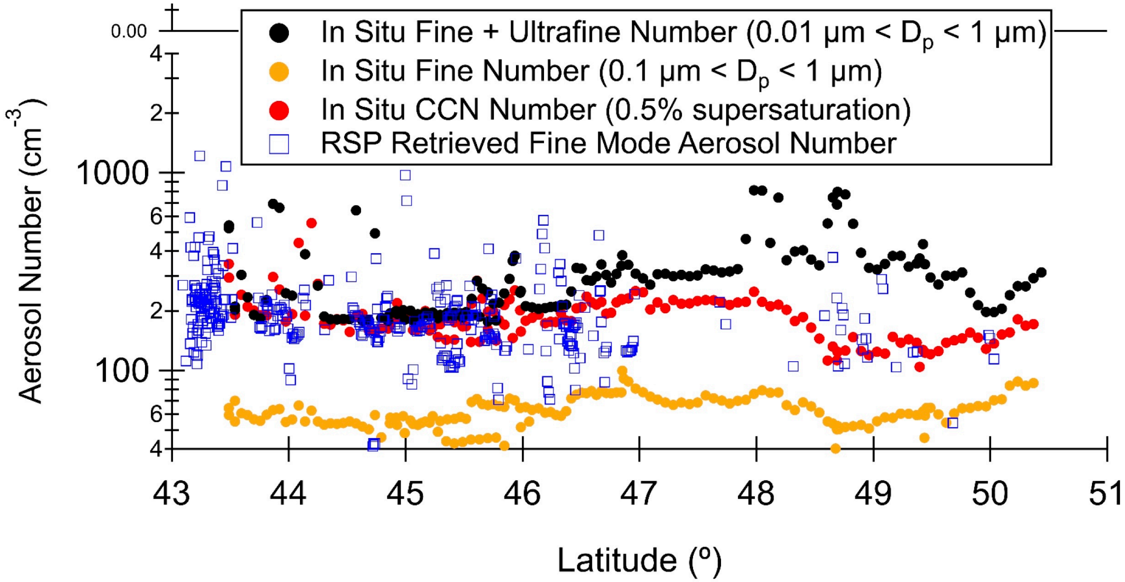


Thin cirrus is a major issue for aerosol microphysical properties (SSA) and detailed ocean properties.

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



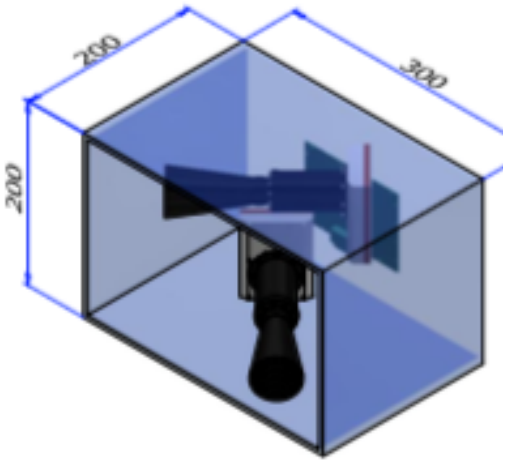


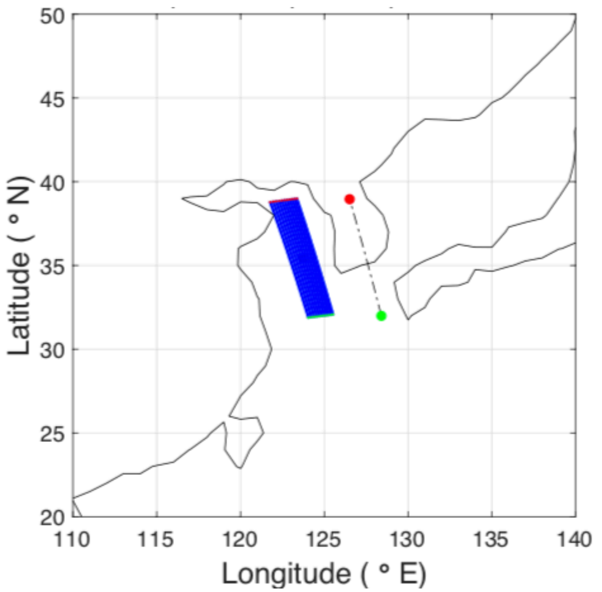
Summary

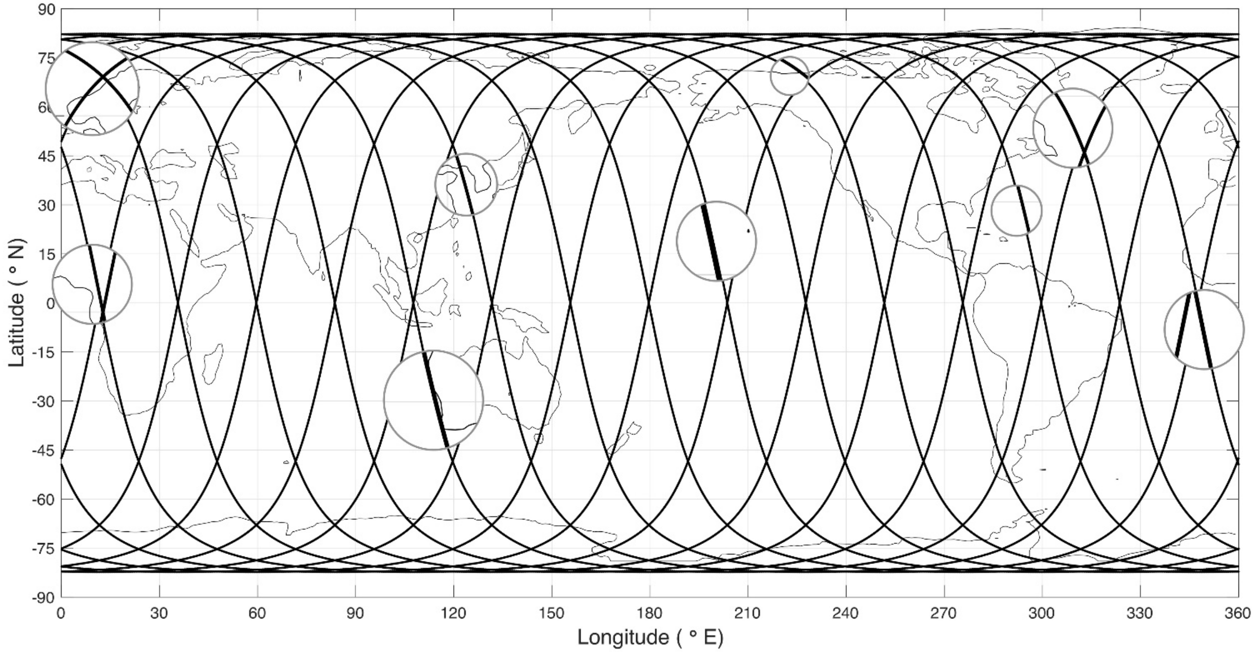
- Airborne data (HSRL and polarimeter) is critical for evaluating aerosol and ocean products, and works well when conditions are cloud-free.
- Retrieval of single-scattering albedo from polarimetry is possible, but the ocean properties need to be accurately characterized in complex waters.
- Aerosol number concentration is possible using HSRL extinction / aerosol layer heights and RSP fine and coarse mode cross sections and AOD.
- Beyond that, future work involves combined RSP, HSRL and GCAS 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
- 6-12U form factor







Thank you and references

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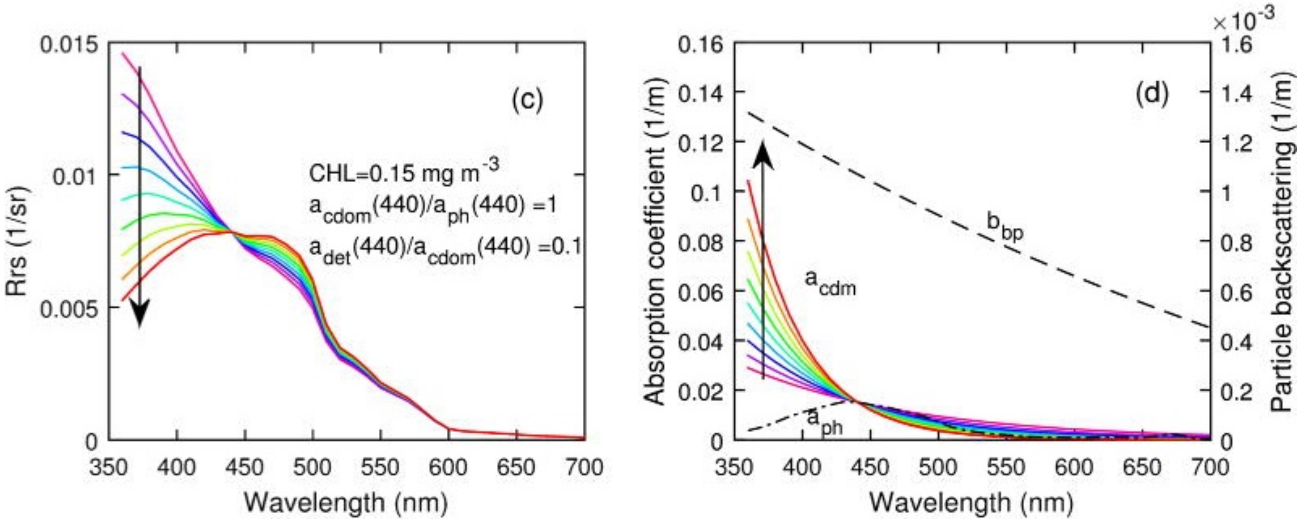
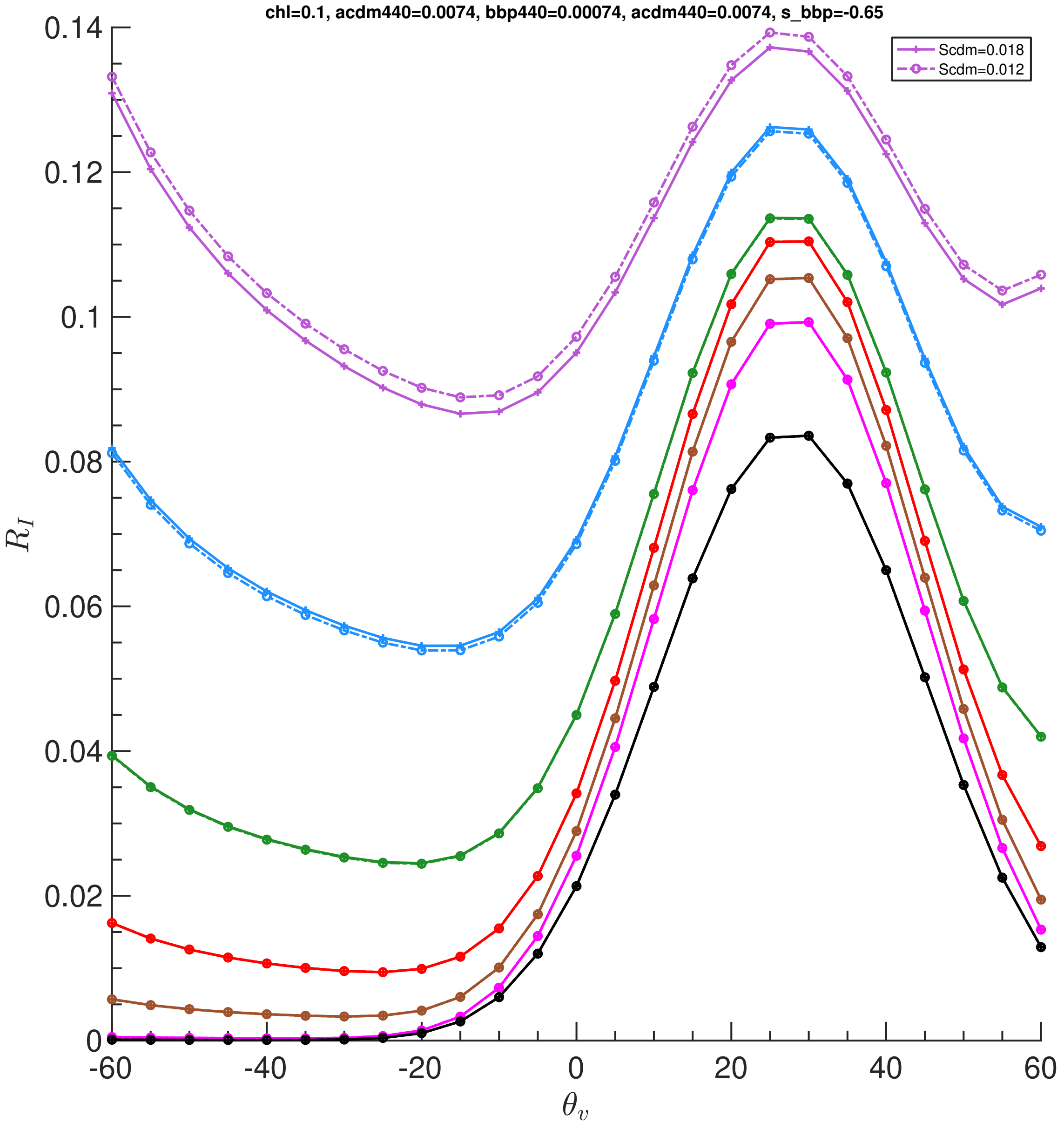
Backup slides

RSP: sensitivity to cDOM





Wei et al., 2016, "Spectral slopes of the absorption coefficient of colored dissolved and detrital material inverted from UV-visible remote sensing reflectance"