CLouds · CLimatE · Aerosols · Radiation

Closure of Aerosol Radiative Properties from ORACLES 4STAR and In Situ Measurements: Implications for AERONET QC Requirements

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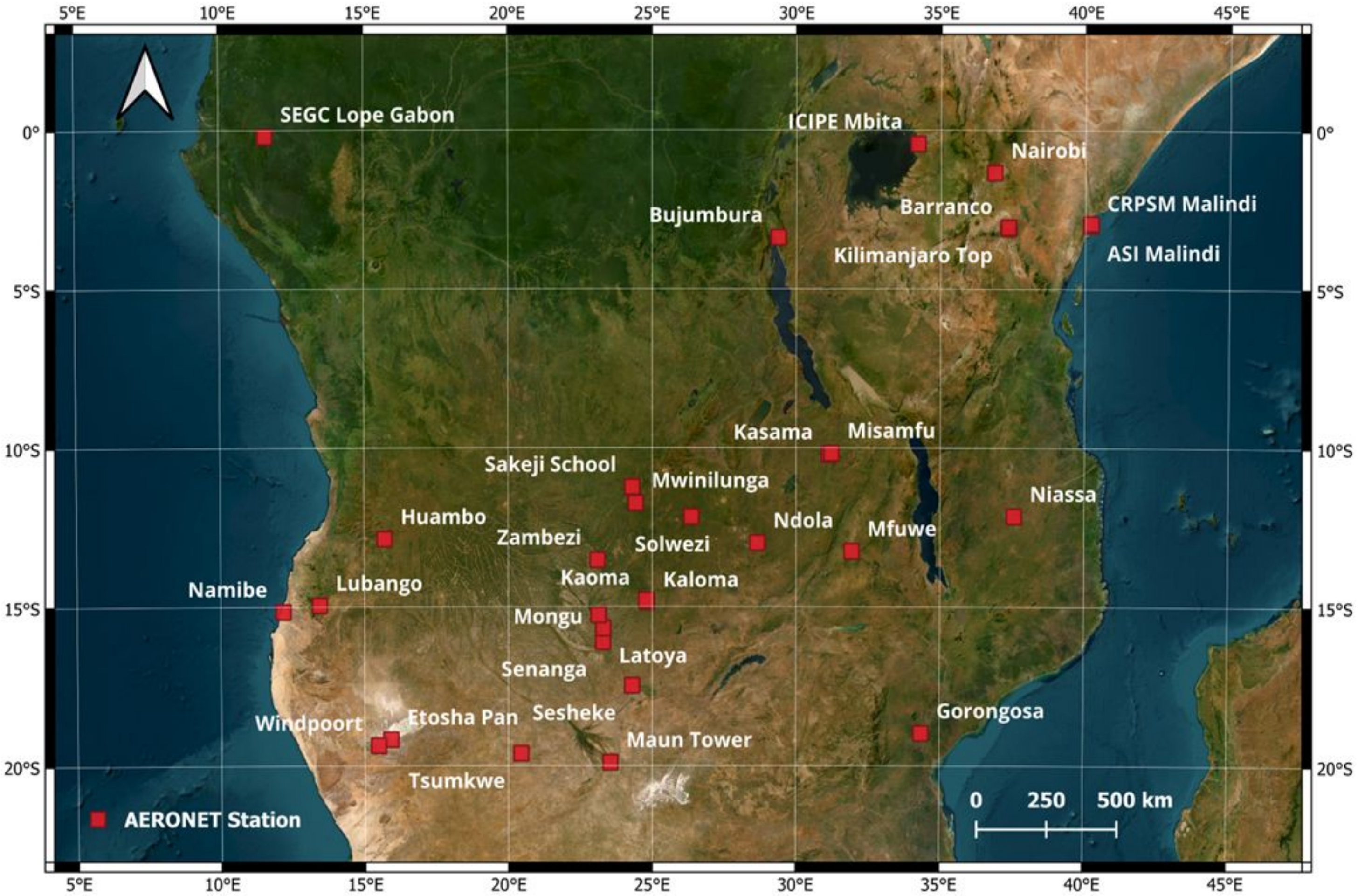
AERONET QA Requirements

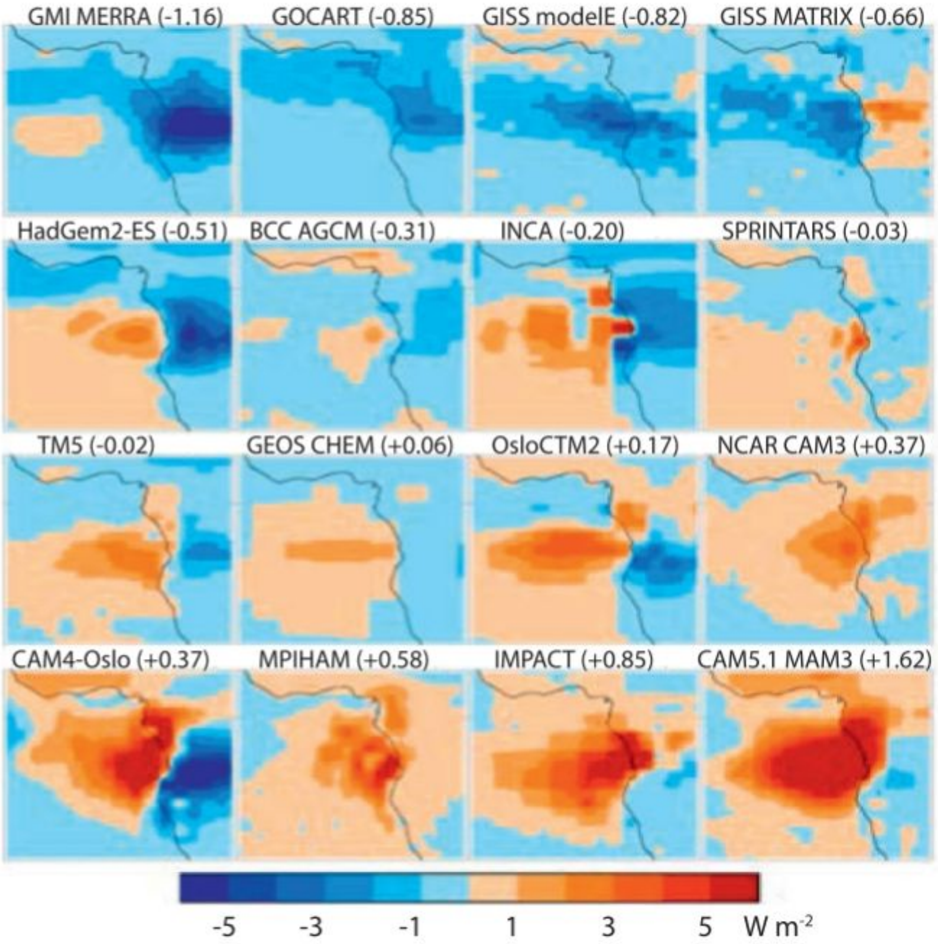
- AERONET Level 2.0 Inversions require **AOD$_{440}$ ≥ 0.4** (Dubovik et al., 2000).
- This limits the quality-assured dataset to only **high aerosol loading** events.
- However, smaller aerosol loadings are **often observed** in smoke plumes.



31 Southern African AERONET Stations

The Southeast Atlantic

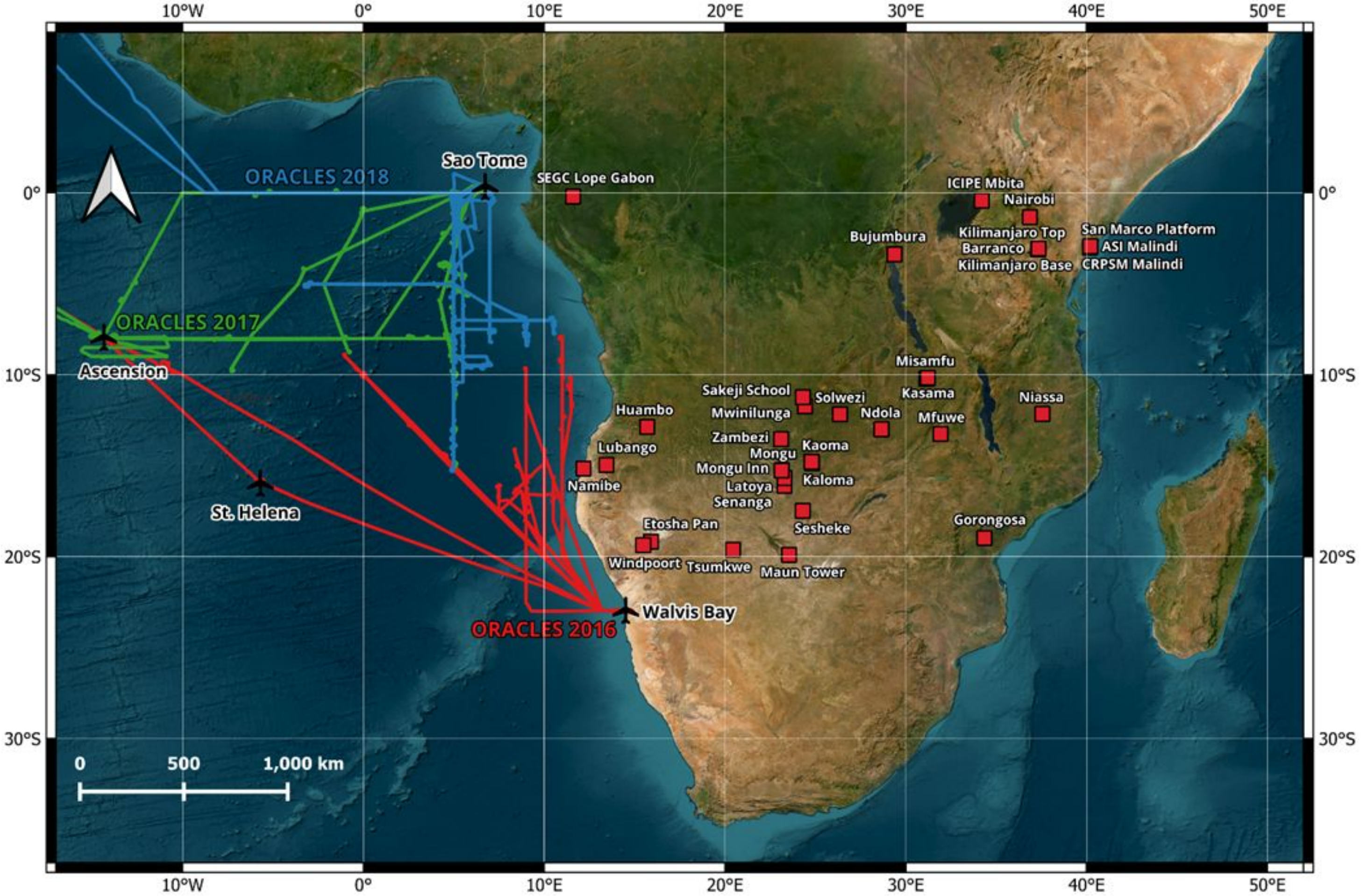
- **Biomass Burning (BB)** in Southern Africa contributes about 28% of global carbon emissions (van der Werf et al., 2010).
- BB aerosols are transported by the **Southern African Easterly Jet** to the Southeast Atlantic (Adebiyi and Zuidema, 2016).
- BB aerosols interact with a semi-permanent, subtropical **stratocumulus cloud deck** (Sakaeda et al., 2011).
- These complex interactions lead to high uncertainty over the **Southeast Atlantic.**



(Zuidema et al., 2016)

ORACLES

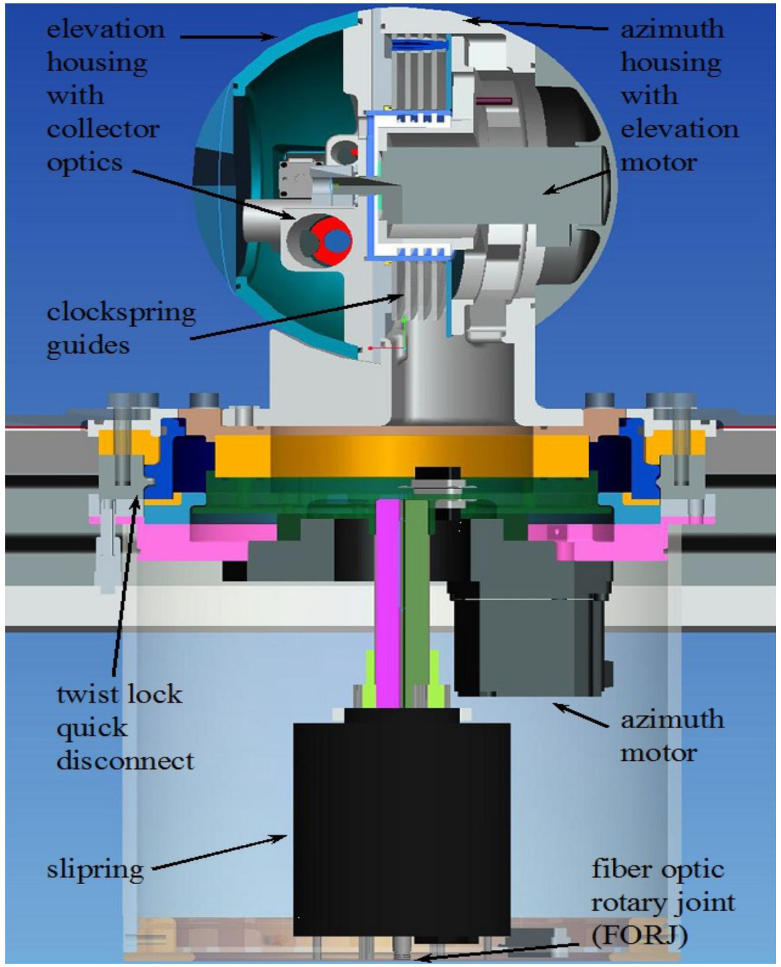
- **ObseRvations of Aerosols above CLouds and their intEractionS**
- NASA-led campaign to study **Biomass Burning (BB) aerosols** over the Southeast Atlantic.
  - **BB aerosol** effects above, within, and below the stratocumulus cloud deck.
  - **BB aerosol**-cloud-radiation interactions.
  - **BB aerosol** emission season.
  - **BB aerosol** transport.
- Three Campaigns:
  - 09/2016 (Walvis Bay, Namibia)
  - 08/2017 (São Tomé)
  - 10/2018 (São Tomé)



ORACLES 2016-2018 Flight Tracks and 31 Southern African AERONET Stations

4STAR

- **Spectrometer for Sky-Scanning, Sun-Tracking Atmospheric Research**
- Hyperspectral (355 – 1650 nm) sun-sky spectrophotometer utilized in **ORACLES.**
- We use a 4-wavelength retrieval set of 500, 675, 870, 995 nm.
- Retrieves above-aircraft, below-plume **columnar aerosol** properties via an AERONET-adapted inversion code.
- 3 Operating Modes:
  - **Sky Scanning**
    - Almucantar (ALM) and Principal Plane (PPL)
  - Sun Tracking
  - Zenith Viewing

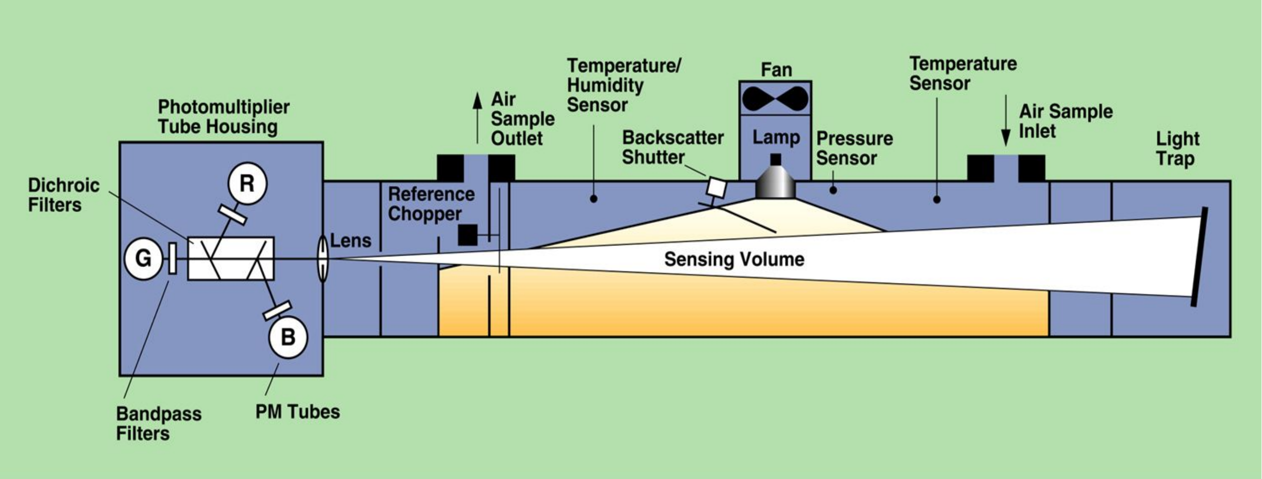


(Dunagan et al., 2013)

In Situ Measurements

- **TSI 3563 Integrating Nephelometers (Neph)**
  - Determines scattering coefficients by shining a light on suspended aerosols and measuring the light scattered back onto a detector.
  - 3 Wavelengths (450, 550, 700 nm)

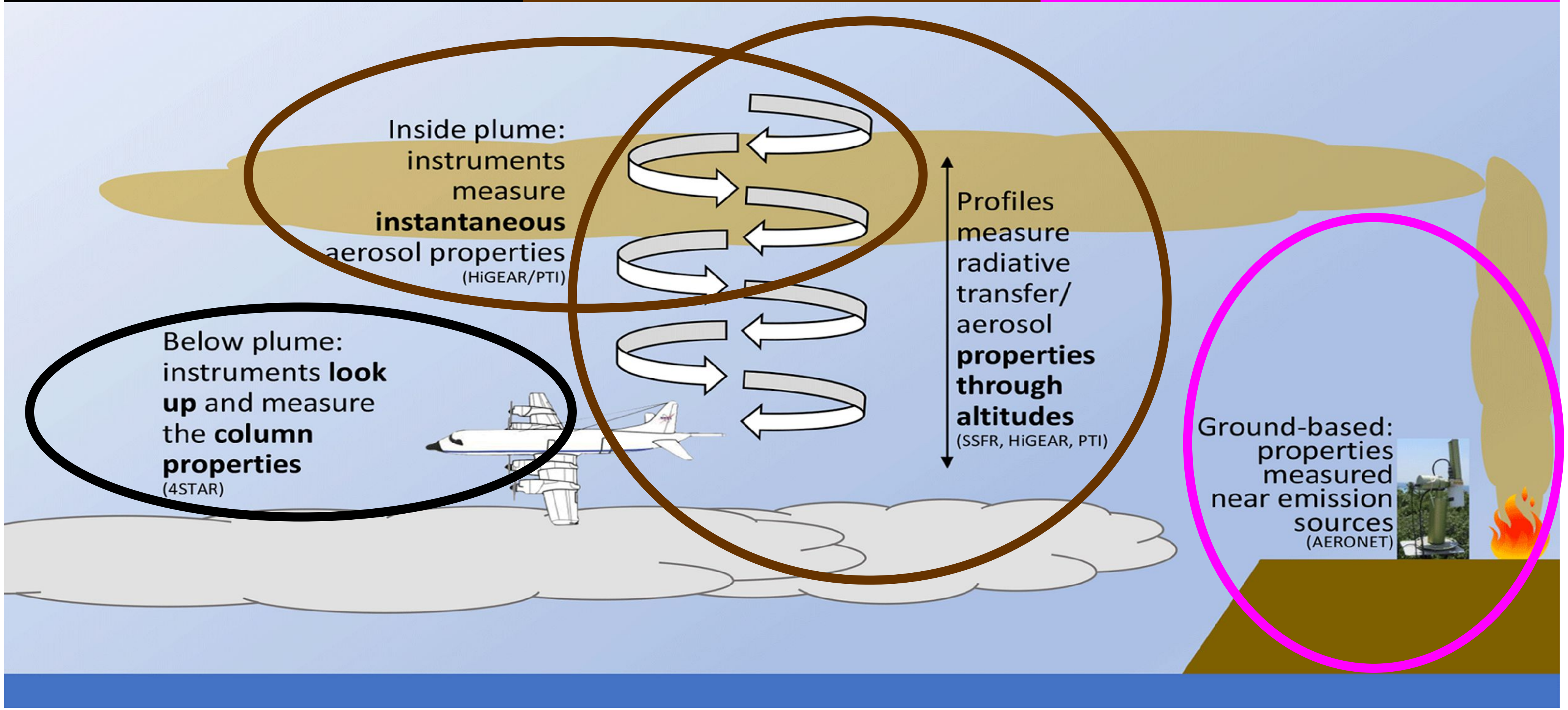
- **Particle Soot Absorption Photometers (PSAP)**
  - Determines absorption coefficients by measuring the reduction in light transmission as aerosols are deposited on a filter.
  - 3 Wavelengths (470, 530, 660 nm)



(Earth System Research Laboratories, 2021)

ORACLES Flight Diagram

4STAR Retrieval | **In Situ Measurements** | **AERONET Retrieval**



Inside plume: instruments measure **instantaneous** aerosol properties (HiGEAR/PTI)

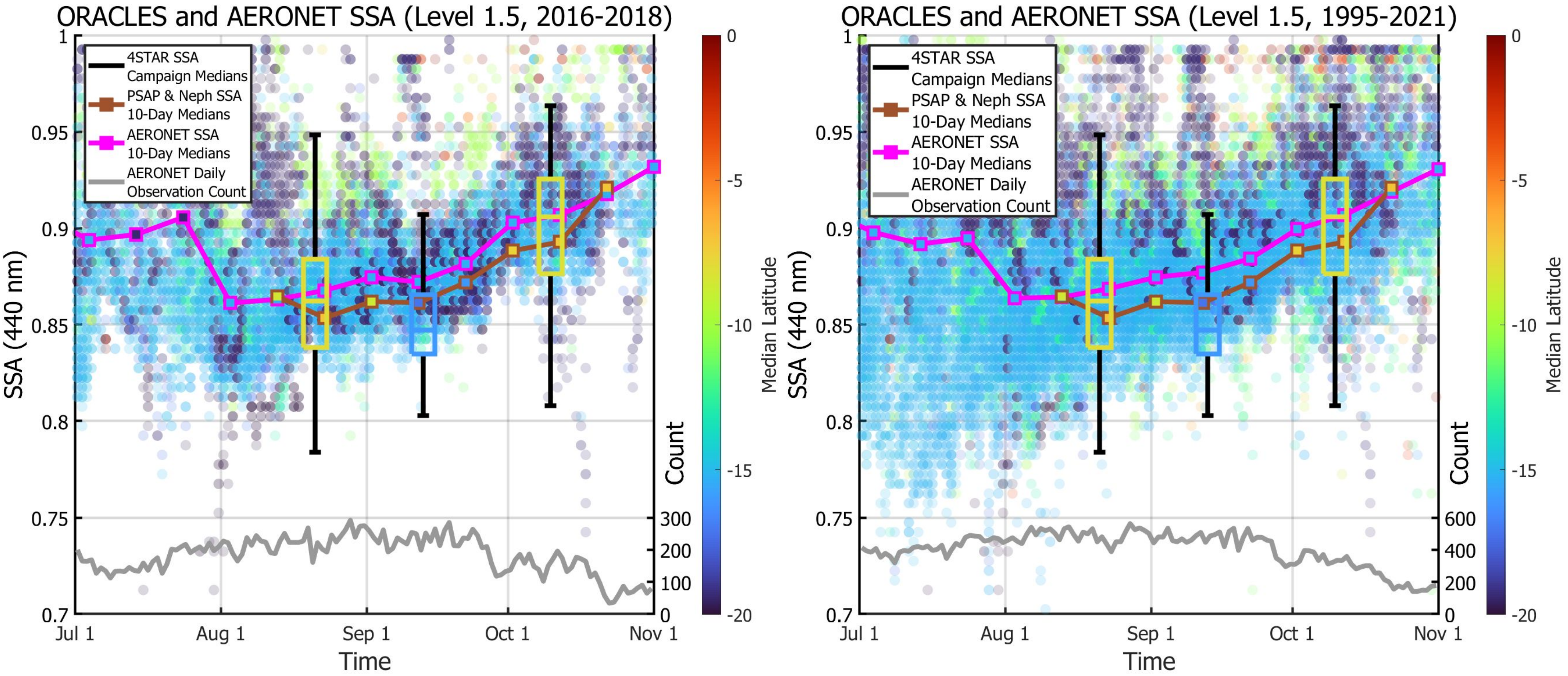
Below plume: instruments **look up** and measure the **column properties** (4STAR)

Profiles measure radiative transfer/ aerosol **properties through altitudes** (SSFR, HiGEAR, PTI)

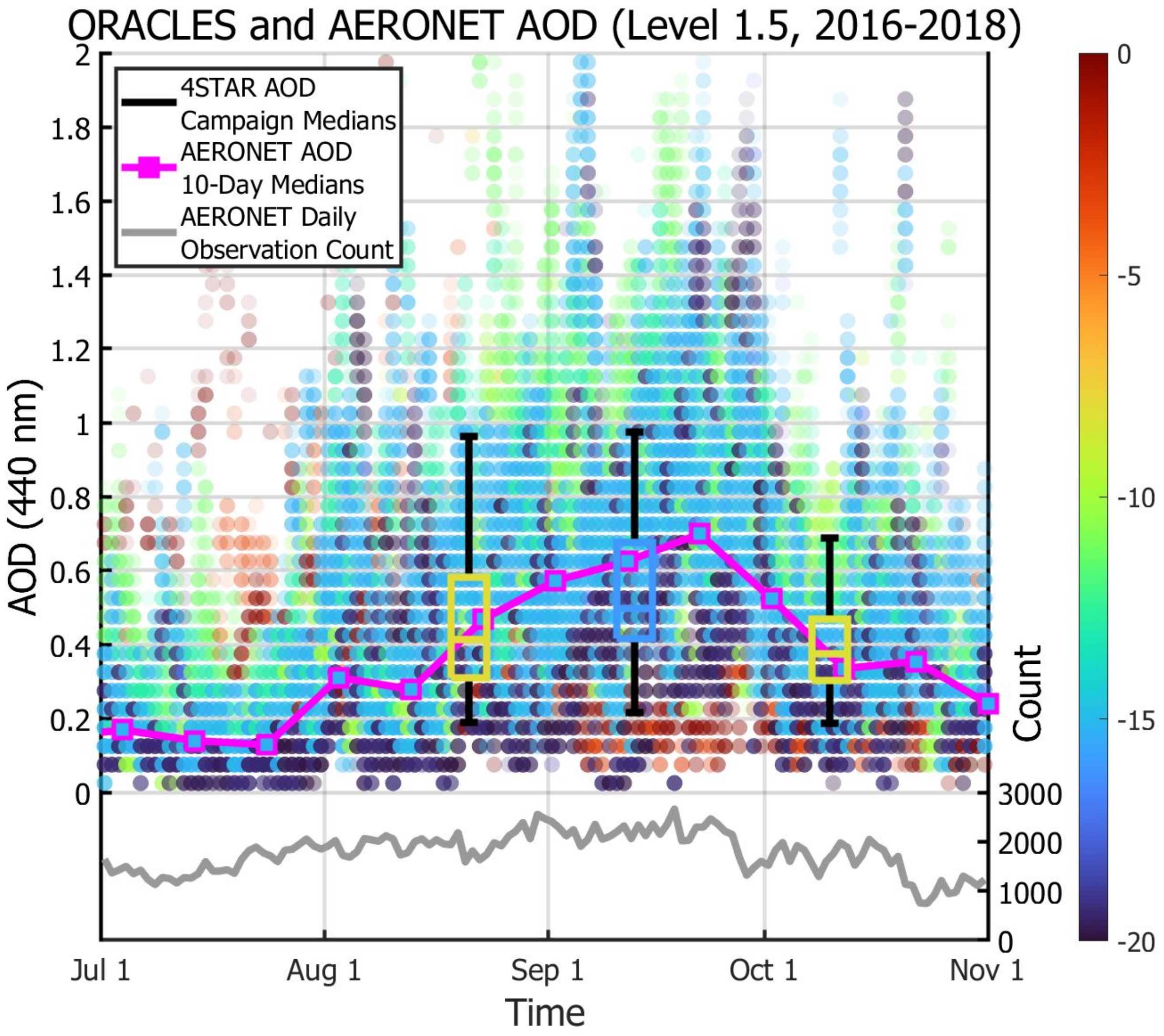
Ground-based: properties measured near emission sources (AERONET)

Adapted from Pistone et al., 2019

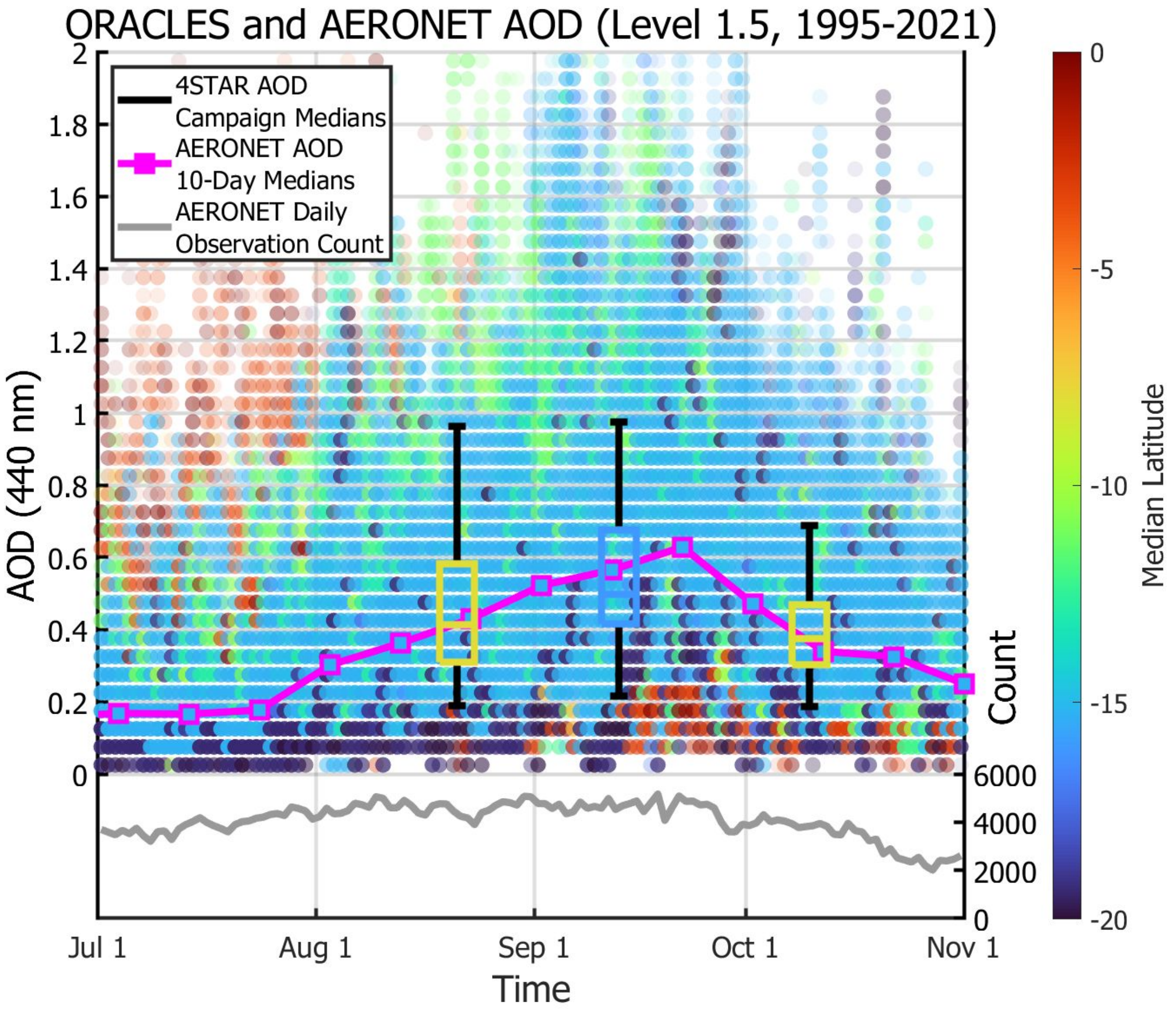
ORACLES and AERONET - SSA



ORACLES and AERONET - AOD



ORACLES and AERONET AOD (Level 1.5, 2016-2018)



ORACLES and AERONET AOD (Level 1.5, 1995-2021)

Research Question

- What is the lowest aerosol loading at which 4STAR and in situ absorption and scattering coefficients are still well correlated?
  - 4STAR and AERONET are alike in instrumentation and retrieval methods, with similar SSA and AOD values found between the adjacent regions of Southern Africa and the Southeast Atlantic.
  - A threshold of $AOD_{440} \leq 0.4$ would be lower than current AERONET Level 2.0 Inversion QC standards, greatly expanding the quality-assured AERONET SSA data record.

Data Preparation

- 4STAR sky scans have been quality controlled for:
  - Stable flight telemetry (altitude and roll)
  - Low sky radiance error as a function of scattering angle
  - Scattering angles minimally span from 6 to 50° without data gaps

- In Situ data prep includes:
  - Front and Rear PSAP are averaged together
  - Wavelength-averaged Virkkula (2010) corrections are utilized for PSAP
  - In situ data are screened by scattering coefficient (> 10 mm^{-1}) and CO concentration (> 130 ppbv) thresholds

Methods

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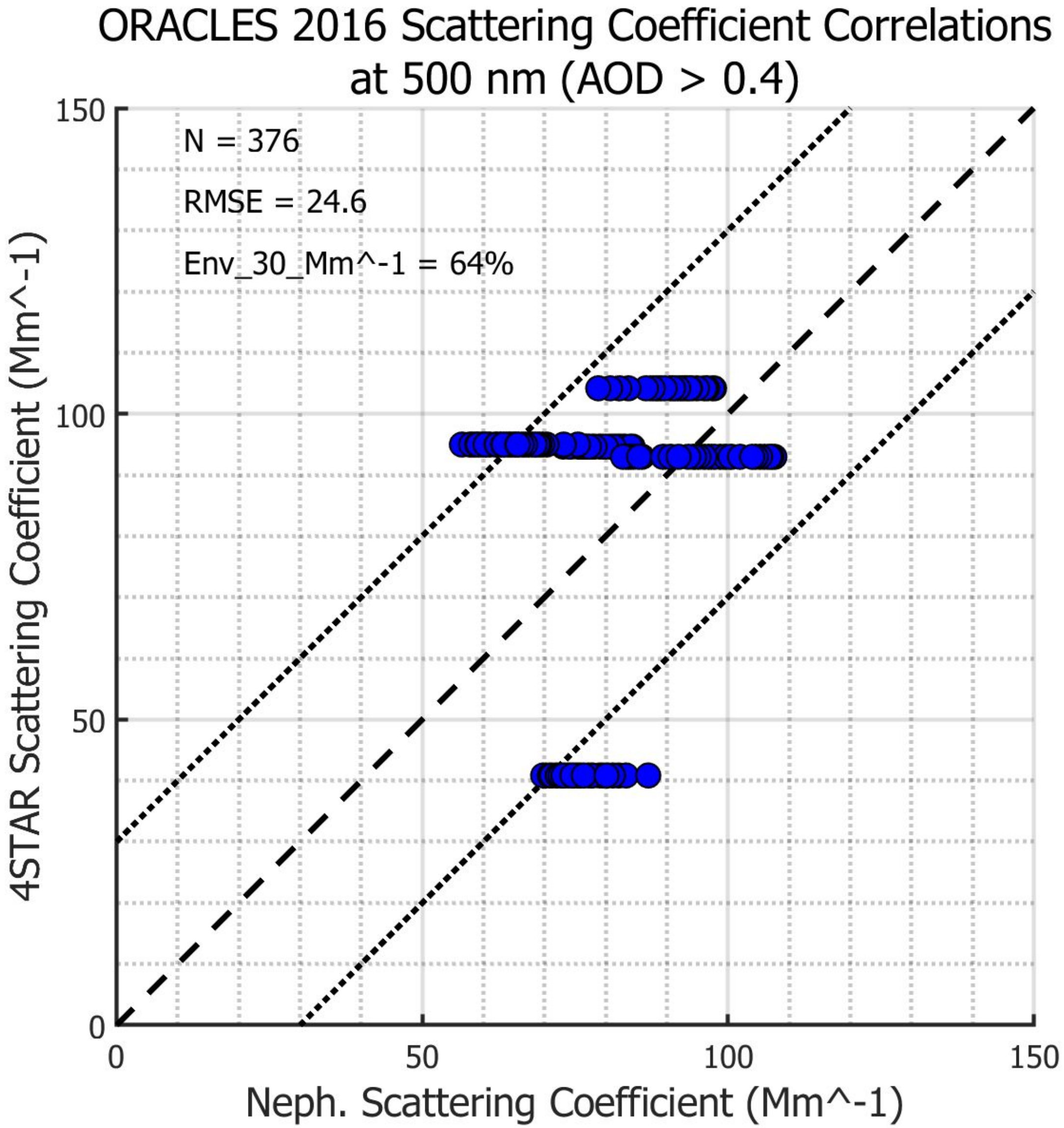
- 4STAR and in situ data are collocated by flight legs.

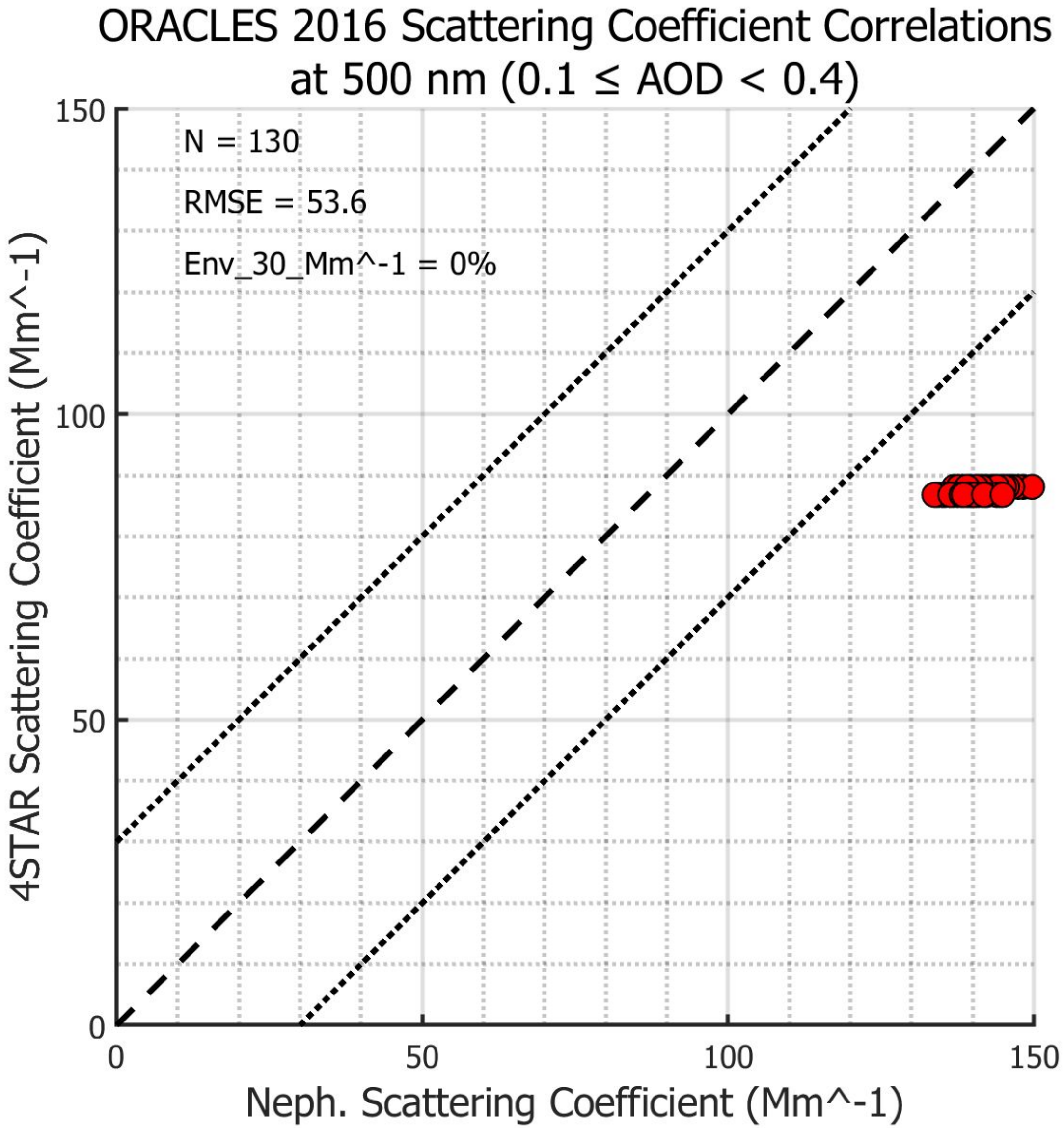
- Data is interpolated to 500 nm:
  - Neph from 450 nm and PSAP from 470 nm
  - Neph from 550 nm and PSAP from 530 nm

- Scattering coefficients are calculated via Mie Theory using 4STAR inputs:
  - Size Distribution
  - Real and Imaginary Refractive Indices

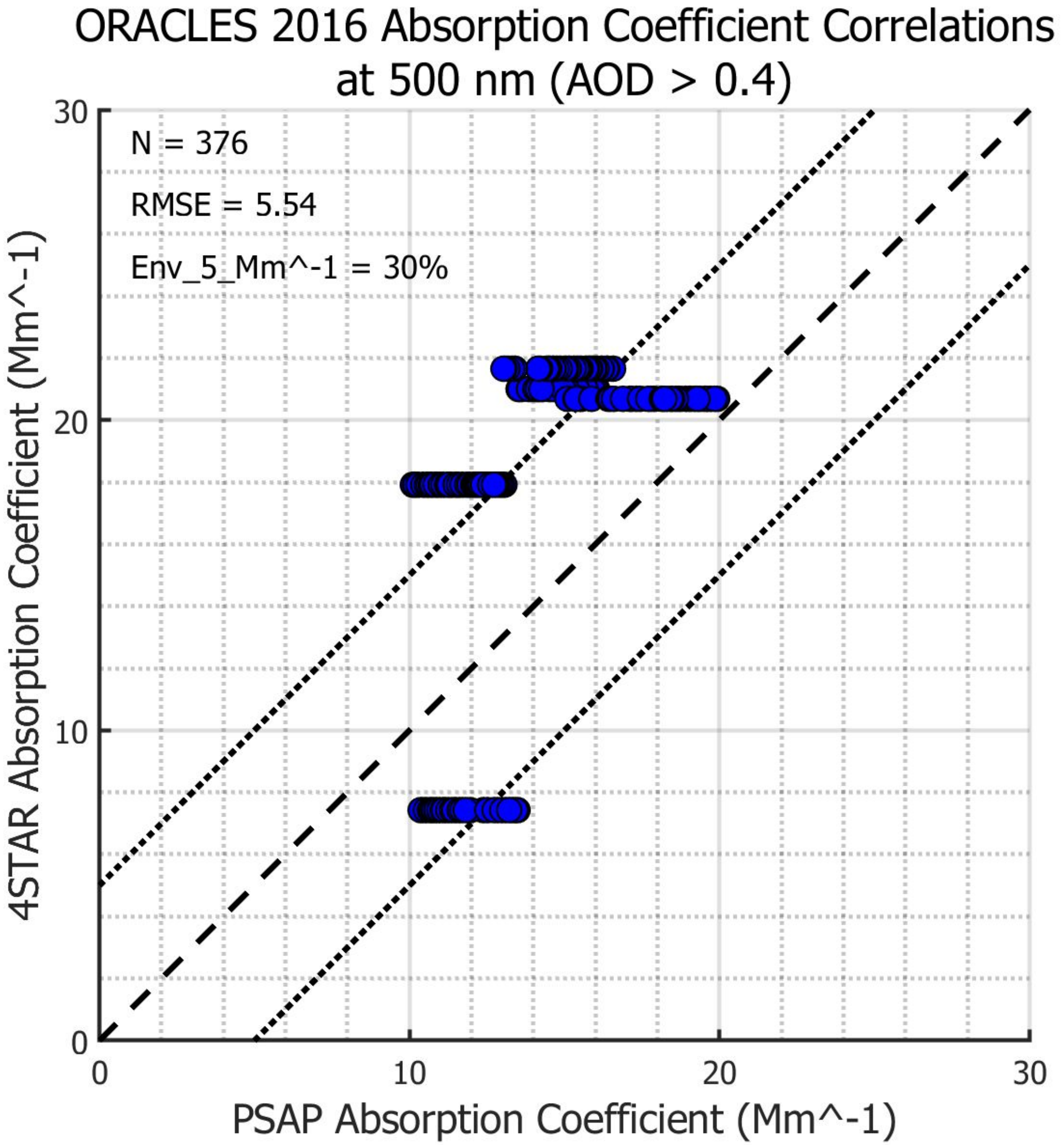
- Absorption coefficients are calculated via from 4STAR SSA:
  - $SSA = \frac{\sigma_{scat}}{\sigma_{scat}+\sigma_{abs}}$

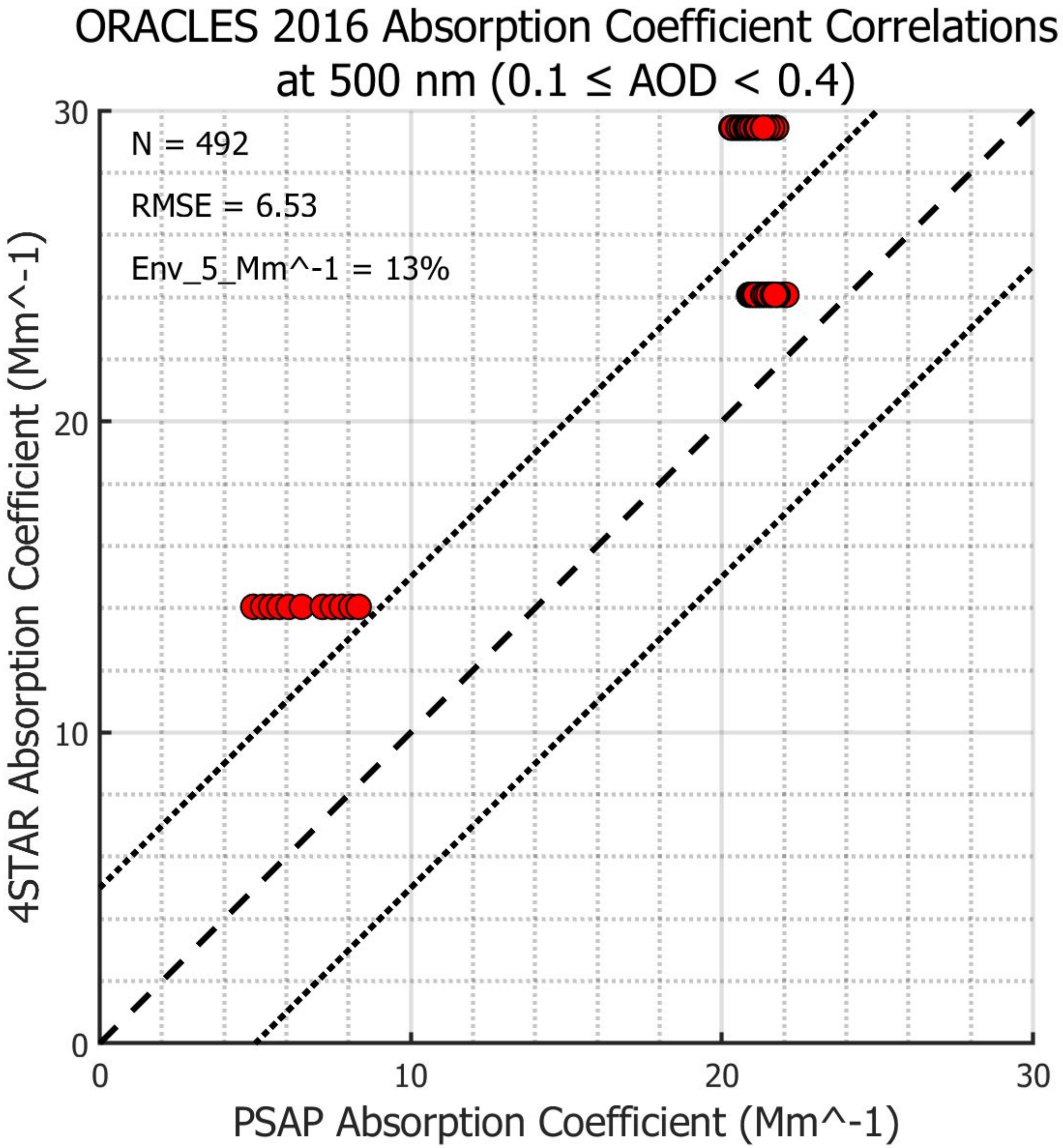
Preliminary Results - Scattering Coefficients





Preliminary Results - Absorption Coefficients





Summary

- Both ORACLES 4STAR and AERONET show a subseasonal aerosol brightening over the Southeast Atlantic and Southern Africa.

- ORACLES was well-designed to capture long-term trends also present in the AERONET extended record.

- The similarities in 4STAR instrumentation, methodology, and retrieval to AERONET make it ideal for assessing the quality of lower aerosol loading scans.

- Comparisons between 4STAR and in situ measurements will be improved via corrections and expanded into other variables.

Future Work

- In Situ data corrections:
  - Chemical Species from the AMS (Aerosol Mass Spectrometer)
  - Filter Corrections from the PTI (PhotoThermal Interferometer)

- HSRL-2 (High Spectral Resolution Lidar 2) data can also be used, resulting in the following comparisons:
  - 4STAR and in situ
  - 4STAR and lidar
  - in situ and lidar

- Closure can also be performed for the following properties:
  - Aerosol Optical Depth
  - Aerosol Backscatter

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