VALIDATION OF REMOTE SENSING REFLECTANCE FROM OC SENSORS

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Background:

Ocean color (OC) in coastal areas provides valuable information about environmental conditions, including carbon fluxes, pollutant transport, and other biogeochemical processes. Remote sensing reflectance (Rrs) is a key parameter in ocean color studies, used to estimate water constituents such as chlorophyll concentration and turbidity. However, retrieving accurate Rrs can be challenging due to factors like complex water properties, interference from nearby land, and varying atmospheric conditions. To support accurate measurements, AERONET (AErosol RObotic NETwork) sensors have been deployed in coastal regions worldwide to provide ground-based Rrs observations. AERONET-OC, in particular, uses automated radiometers that are carefully calibrated, making it one of the most reliable sources of in-situ Rrs data for validating satellite OC observations. With the launch of NASA's PACE mission in 2024, validating new satellite data is increasingly important. AERONET data can be used to compare with satellite measurements from sensors such as PACE-OCI and VIIRS-SNPP. Such comparisons ensure the accuracy of satellite-derived Rrs, helping to confirm that the data reflects real-world conditions. In this study, MATLAB programs will be used to filter, match, and process the data, followed by statistical analyses to evaluate the accuracy and precision of these satellite sensors. Comparing and assessing measurements from different satellite platforms enhances the reliability of remote sensing reflectance over coastal waters. Accurate and validated ocean color data can ultimately benefit fields such as marine science, ecosystem monitoring, and water quality management.

Research Objectives:

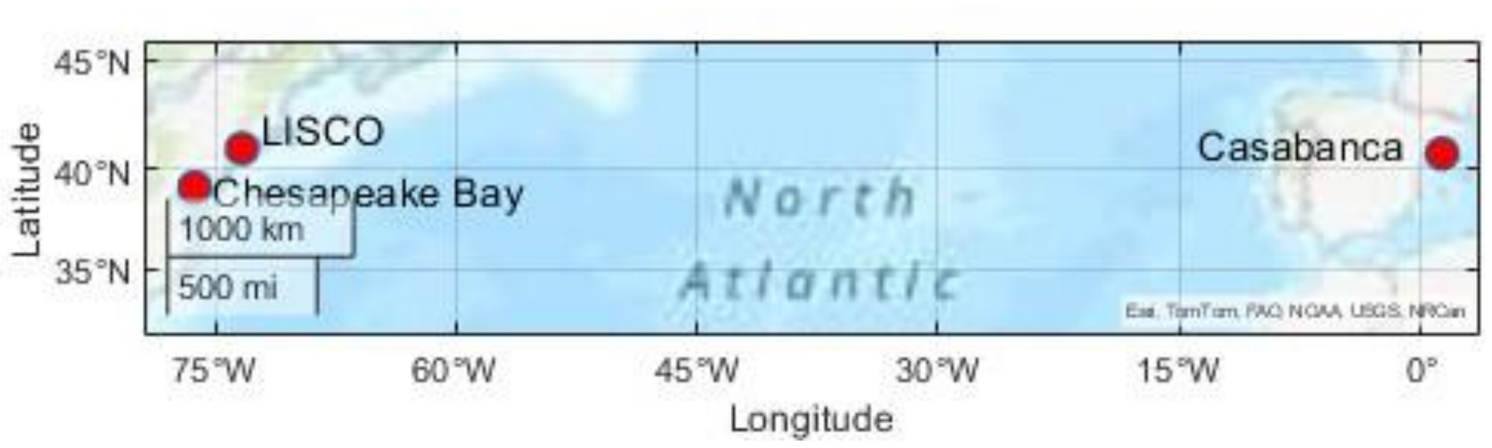
Motivation: This research aims to ensure the accuracy and reliability of ocean color (OC) sensors from NASA, and NOAA in measuring remote sensing reflectance (Rrs) in dynamic coastal environments, using trusted reference data from AERONET-OC, to support real-time water quality monitoring and validate satellite algorithms.

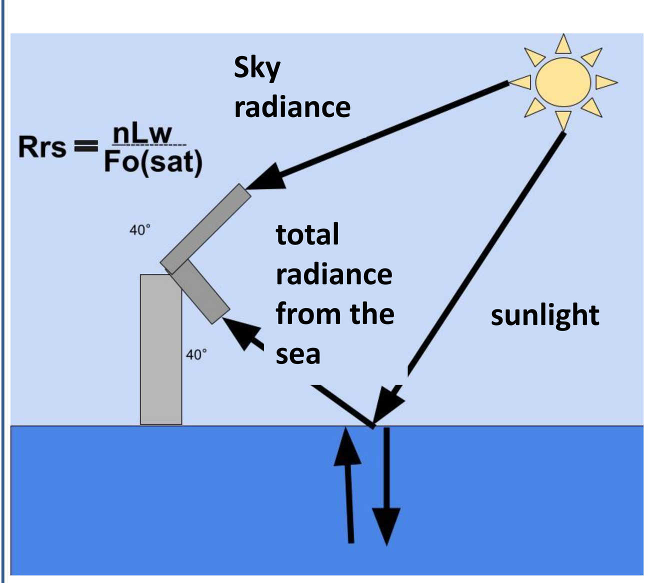
Research Question: Will PACE-OCI offer accuracy and precision comparable to or better than existing ocean color satellites, such as VIIRS-SNPP, and ground-based measurements?

Study Area and Field Sampling:

- This study uses data from 3 AERONET-OC stations located at Long Island Sound Coastal Observatory (LISCO), New York; Chesapeake Bay, Maryland; and Casablanca, Spain. All AERONET data have been cloud-filtered to ensure quality.
- Level 2 satellite data collected from VIRRS-SNPP and PACE-OCI between Mar 2024 - Jul 2025
  - VIIRS-SNPP has 5 wavelengths with pixels res. that are 750m (NOAA coastwatch website)
  - PACE_OCI has 172 wavelengths with pixels res. that are 1200 m (NASA earthdata website)

The study will utilize data from three coastal regions equipped with AERONET-OC sensors.



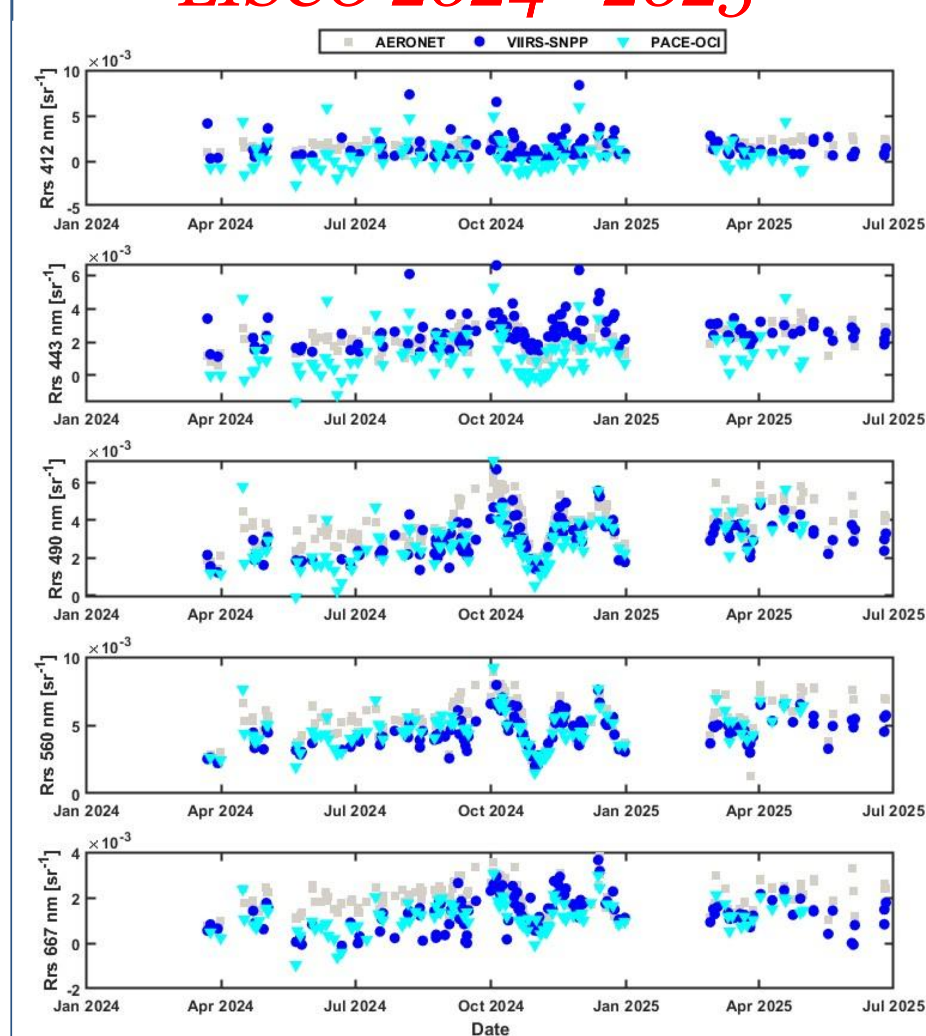


Each AERONET-OC sensor is installed at a coastal site and is programmed to tilt ±40 degrees to measure total radiance from the sea surface and sky radiance. Water-leaving radiance (nLw) is derived from these measurements, and remote sensing reflectance (Rrs) is then calculated by dividing nLw by the extraterrestrial solar irradiance (Fo) obtained from satellite data.

AERONET-OC sensor at LISCO with an Osprey nest next to it

Results and Observations:

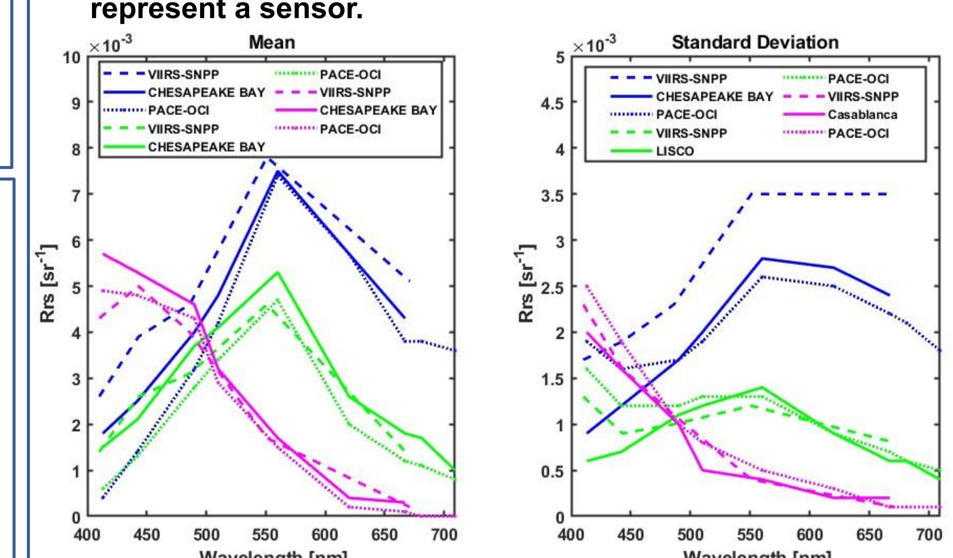
LISCO 2024 - 2025



Time series analysis of AERONET-OC, VIIRS-SNPP, and PACE-OCI sensor performance across five wavelengths (412 nm, 443 nm, 490 nm, 560 nm, and 667 nm) from January 2024 to July 2025.

Mean and Standard Deviation

Each color represent a station and each type of line represent a sensor.



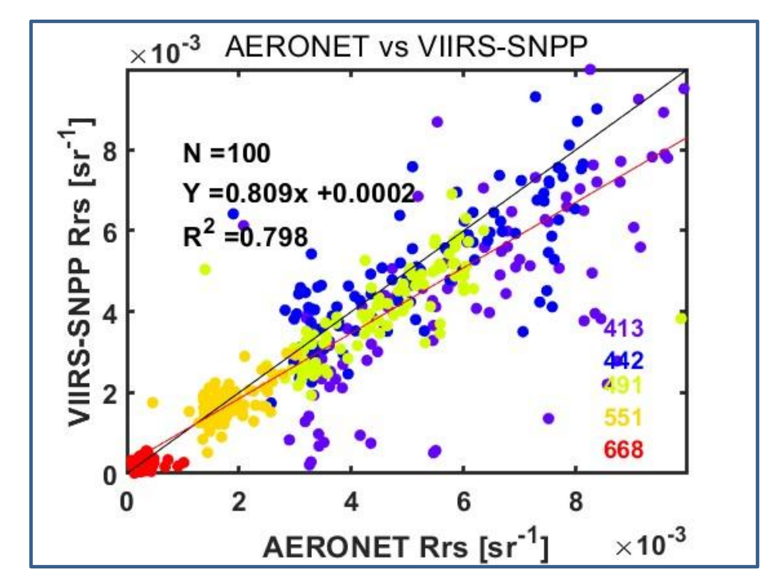
Mean and standard deviation (std) values for each wavelength were analyzed for all sensors across the study sites.LISCO and Chesapeake Bay, being coastal regions, reflect more green light, whereas Casablanca, located closer to open ocean, reflects more blue light. Greater discrepancies between sensor measurements and reference data were observed in the blue spectral bands compared to other wavelengths. Notably, the mean and standard deviation values from PACE-OCI more closely match those of AERONET, suggesting higher agreement in both accuracy and precision.

Conclusions and Discussions:

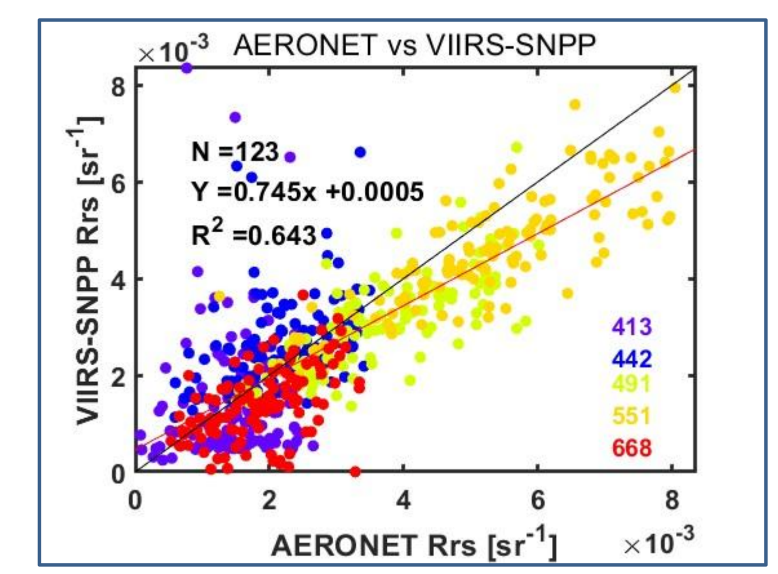
- PACE-OCI demonstrated strong correlations with AERONET data across all sites, only slightly trailing VIIRS-SNPP at Chesapeake Bay. The mean Rrs values from PACE-OCI were consistently closer to AERONET measurements than those from VIIRS-SNPP, indicating that OCI may offer greater accuracy at the three studied stations. Similarly, the standard deviation of OCI data aligned more closely with AERONET, suggesting improved precision compared to VIIRS-SNPP.
- However, all sites revealed significant errors in the blue spectral bands, particularly at Casablanca, highlighting the need for further satellite algorithm refinement in these wavelengths. While PACE-OCI shows promise in accuracy and precision at these locations, additional validation across diverse coastal environments worldwide is necessary to confirm its overall performance.

(VIIRS -SNPP)

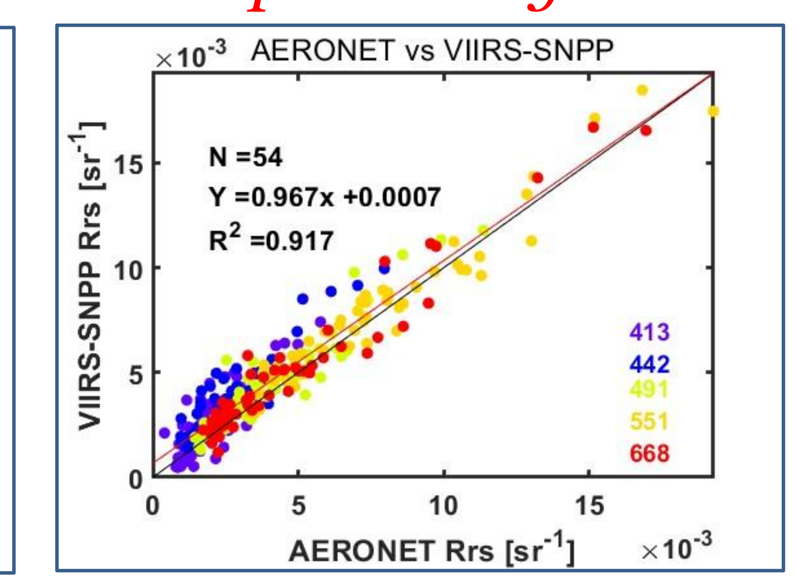
Casablanca:



LISCO:

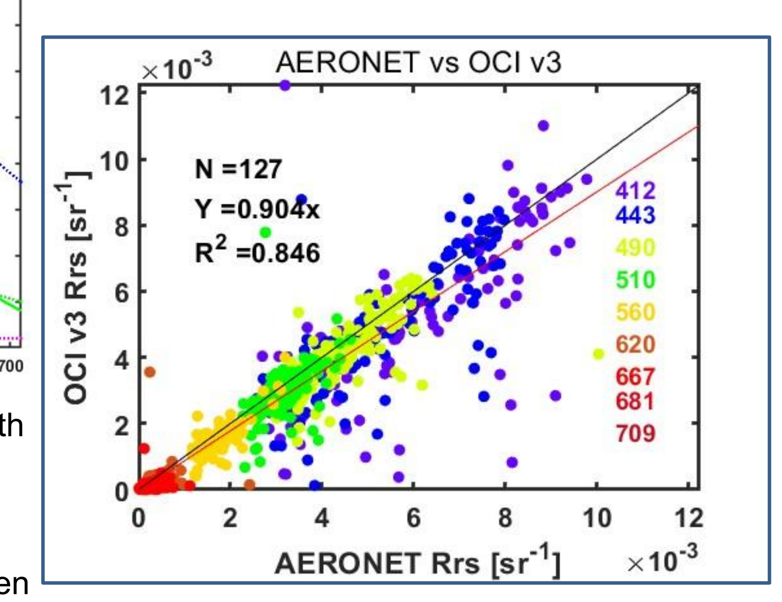


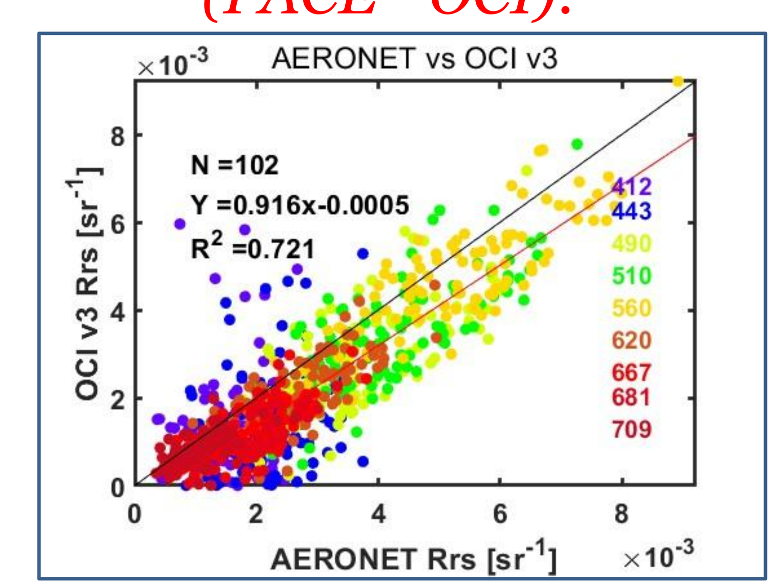
Chesapeake Bay:

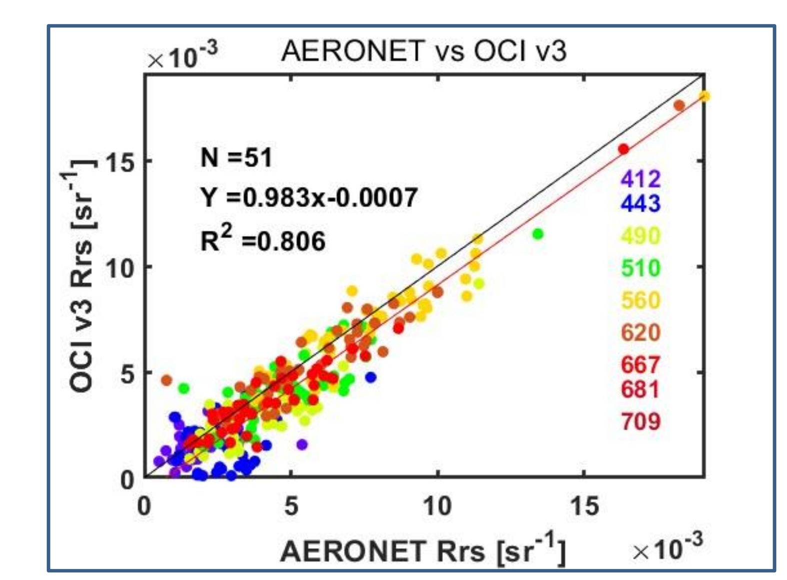


Correlation between AERONET and VIIRS-SNPP data at LISCO, Chesapeake Bay, and Casablanca. The black line represents a perfect correlation, while the red line shows the actual correlation between AERONET and VIIRS-SNPP datasets. Closer alignment of these lines indicates higher correlation. The colors correspond to the five wavelengths analyzed between AERONET and VIIRS-SNPP. Among the sites, LISCO exhibits the lowest correlation (0.643), Casablanca shows a moderate correlation (0.798), and Chesapeake Bay demonstrates the highest correlation (0.917).Some outliers are present, primarily at the 412 nm and 442 nm wavelengths. At Casablanca, these outliers are below the main trend line, indicating that VIIRS-SNPP tends to underestimate reflectance values at these bands, while at LISCO, they are overestimated.

(PACE - OCI):







AERONET vs PACE-OCI data. PACE-OCI has a greater number of wavelengths than VIIRS-SNPP, allowing for more detailed spectral comparisons with AERONET. Correlation with AERONET data varies across sites, LISCO shows the lowest correlation (0.721), Chesapeake Bay has a moderate correlation (0.806), and Casablanca demonstrates the highest correlation (0.846).As with VIIRS-SNPP, most outliers occur in the blue wavelengths—particularly at 412 nm and 443 nm—indicating greater variability in these bands. Notably, PACE-OCI shows stronger correlation than VIIRS-SNPP at LISCO and Casablanca, but slightly lower correlation at Chesapeake Bay.

Methods:

1. Use cloud-filtered, processed AERONET-OC measurements and convert them to remote sensing reflectance (Rrs).
2. Filtering and Processing NASA and NOAA data by using quality flags (Quality Flags: land, high sunlight, high sensor viewing and solar zenith angles, straylight, cloud or ice, bad navigation) to make usable satellite data.
3. The processed data is: +/- 120 minutes of satellite overpass, to decrease environmental changes, spatial averaging over a 3x3 pixel box, requiring that >50% are valid pixels, and negative Rrs values are removed.
4. Perform statistical analysis on the quality-filtered data to evaluate sensor performance and consistency

Future Studies:

- *Further validation of other AERONET-OC site across the world*
- *Correction of Ocean Color Sensors using neural networks*

References:

- *Gilerson, A., Herrera, E., Klein, Y.,Gross, B., Arnone, R., Foster, R., & Ahmed, S. (2017). Characterization of aerosol parameters over ocean from the Ocean Color satellite sensors and AERONET-OC data. 19–19.* https://doi.org/10.1117/12.2279150
- *Hlaing, S., Harmel, T., Gilerson, A., Foster, R. D., Weidemann, A., Arnone, R., Wang, M., & Ahmed, S. (2013). Evaluation of the VIIRS ocean color monitoring performance in coastal regions. Remote Sensing of Environment, 139, 398–414.* https://doi.org/10.1016/j.rse.2013.08.013

This summer research project was supported by Pinkerton Foundation (HIRES). The authors would like to express their gratitude to their faculty advisor Dr. Alex Gilerson and mentor Dr. Eder Herrera. The statements contained within the poster are not the opinions of the funding agency or the U.S. government but reflect the author's opinions.