Hyperspectral UV-blue atmospheric correction for the Ocean Color Instrument (OCI)

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Introduction

UV water-leaving reflectances between ~350 to 400 nm hold crucial information to separate phytoplankton pigment absorption from CDOM absorption (*Werdell et al.,* 2019).

Retrieval of UV water leaving reflectance is challenging because most top-of-the-atmosphere (TOA) radiance is from the atmosphere, which in the UV is optically thick with stronger multiple scattering and ocean coupling. Aerosol scattering and absorption are also more complex in the UV with considerable remaining uncertainties.

We developed an advanced physics-based AC algorithm for the UV-blue, using actual hyperspectral 315-500 nm measurements from the Ozone Monitoring Instrument (OMI) on NASA's Aura satellite, which are a realistic proxy for the Ocean Color Instrument (OCI) on PACE.

We use our AC to retrieve remote sensing reflectance and validate our AC by comparing our UV-blue R_{rs} with measurements from the Marine Optical Buoy (MOBY) spectrometer system off the coast of Lanai in Hawaii.

Hyperspectral OMI data as an OCI proxy

OMI is a high-spectral resolution, UV-blue mapping spectrometer which is very well-calibrated after 20 years in orbit on Aura. The Aura spacecraft is in an afternoon orbit similar to PACE (Table 1).

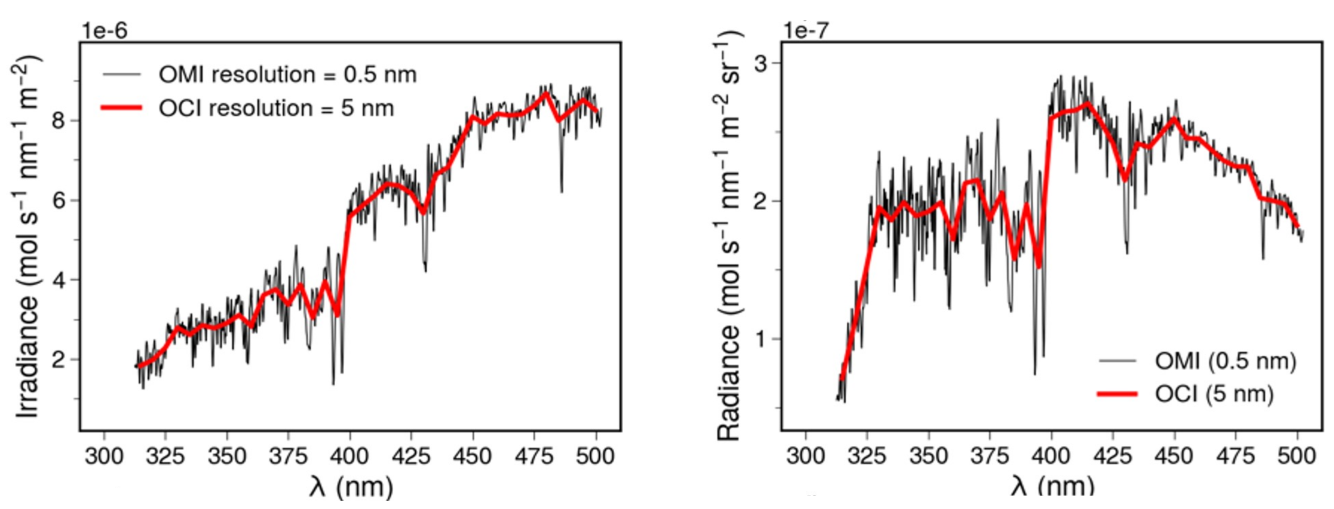


Figure 1. OMI irradiance (left) and radiance spectra (right) from 315-500 nm at native 0.5 nm resolution, and after smoothing and sampling to emulate OCI spectral characteristics.

Atmospheric Correction

We use the **Vector Linearized Discrete Ordinate Radiative Transfer (VLIDORT)** model (*Spurr and Christi* 2019) in coupled ocean-atmosphere mode for explicit physics-based atmospheric correction.

VLIDORT accounts for polarization of multiple scattered radiation in a vertically inhomogeneous pseudo-spherical atmosphere using advanced multi-point sphericity correction, polarized surface bidirectional reflectance distribution function and water-leaving supplements.

VLIDORT results agree closely with published RTM results for (*Chowdhary et al*., 2020) (AOS-I scenario) and Monte-Carlo polarized benchmarks for a spherical non-homogeneous Rayleigh atmosphere in *Korkin et al. (*2022).

Aerosol polarized optical properties are obtained from the NASA Global Modeling and Assimilation Office (GMAO) MERRA-2 reanalysis (*Randles et al*., 2017).

Table 1. Comparison of OMI/Aura and OCI/PACE characteristics.

Sensor	Ozone Monitoring Instrument	Ocean Color Instrument
Spectral coverage	270–500 nm hyperspectral	340–890 nm hyperspectral*
Spectral resolution	0.42 – 0.63 nm	5 nm
View angle	± 57°	± 60°
Ground pixel size	12×24 km² at nadir	1×1 km² at nadir
Mission	**Aura**	**PACE**
Launch	2004	2024
Status	Operational (through FY25)	Commissioning
Mission objectives	atmospheric chemistry, air quality, climate	ocean color, atmospheric science, air quality
Orbit type	Polar sun-synchronous	Polar sun-synchronous
Altitude	705 km	675 km
Equator crossing	13:45 local	13:00 local

*OCI also has NIR/SWIR bands

In-water IOP Treatment

In the RTM model we use a parameterization of UV water-leaving radiance on *Chl* only for Case I waters (*Vasilkov et al.,* 2005). Water-leaving output is reported as the exact normalized water leaving radiance, following the definition of Mobley et al. (2016). MODIS *Chl* climatology is used to estimate a first guess value for our retrieval.

UV-blue Satellite R_{rs} Retrievals

The R_{rs} retrieval algorithm is as follows:

1) Calculate an initial value of exact normalized water leaving radiance $nL_w^{ex}(Chl, V)$ and estimate ocean surface reflectance.
2) Calculate TOA radiance in the satellite direction $L_t(\theta_v, \varphi_v, \theta_s, \varphi_s, nL_w^{ex})$ and its Jacobian J by analytic differentiation, $J = \frac{\partial L_t}{\partial nL_w^{ex}}$.
3) Using J, update nL_w^{ex} so calculated TOA reflectance $\rho_{t,calc}$ matches the measured $\rho_{t,meas}$.
4) Iterate steps 3 and 4 until convergence.
5) Calculate R_{rs} according to the NASA convention, $R_{rs}(\text{NASA}) = \frac{nL_w^{ex}}{F_0}$.
6) For MOBY comparisons, adjust R_{rs} for solar position at time of OMI overpass.

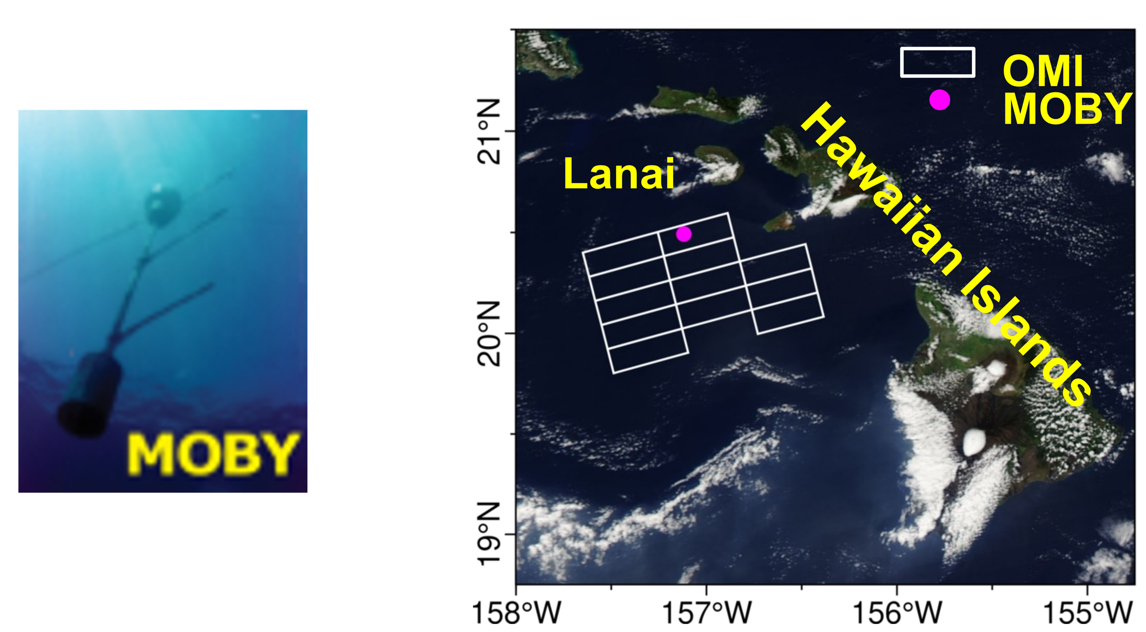


Figure 2. Location and ground pixels (FOVs) of OMI measurements near MOBY on Feb 10, 2005. True Color image from Aqua MODIS confirms these twelve OMI pixels are mostly cloud-free and glint-free observations.

UV-blue R_{rs} Comparisons with MOBY

Although the MOBY optical system was not designed for accurate UV Rrs measurements, we compare our UV-blue retrievals from 350-500 nm with MOBY. We find good agreement between OMI and MOBY in the UV and observe common spectral structures.

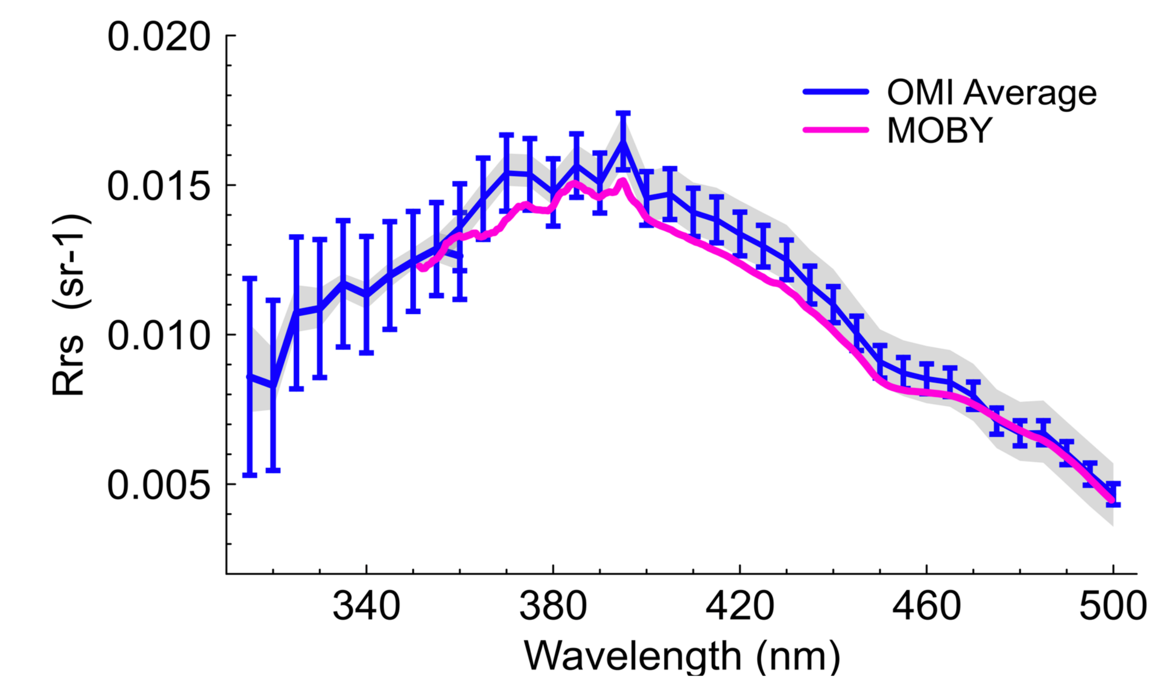
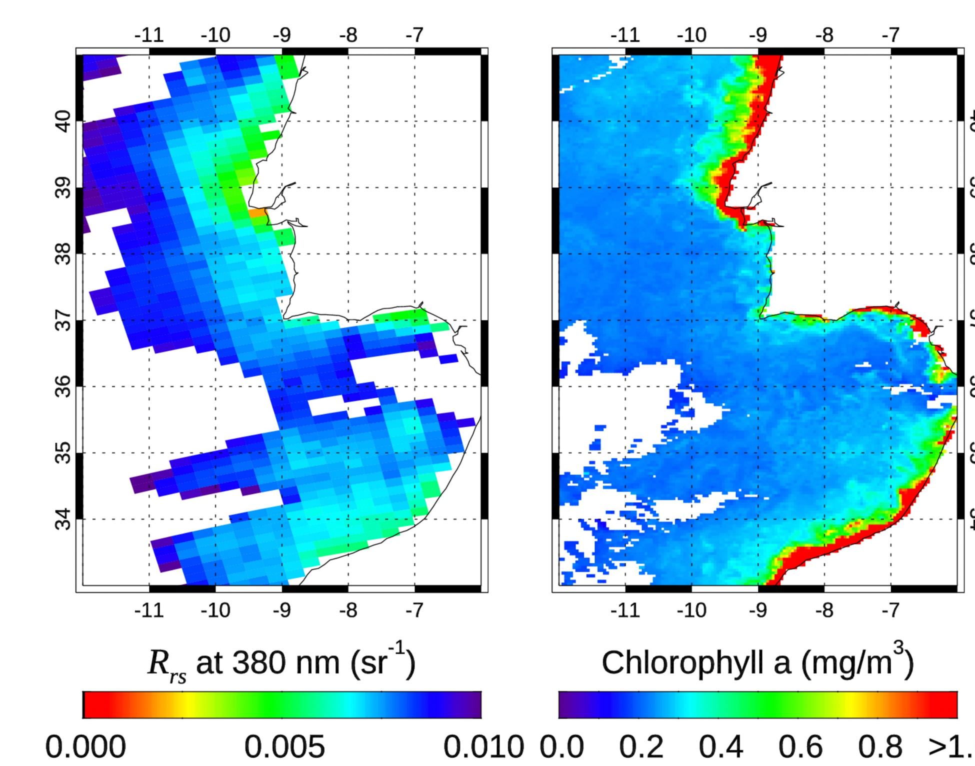


Figure 3. Average OMI $R_{rs}(\lambda)$ with estimated random uncertainties (blue line), and range (grey shading) of twelve retrievals near MOBY shown in Figure 2. OMI R_{rs}retrievals agree with the *in situ* MOBY $R_{rs}(\lambda)$ measurements (pink) within PACE requirement in the UV (20%).

OMI UV R_{rs} correlation with MODIS Chl in the Iberian-Moroccan Atlantic Region

OMI retrievals of UV R_{rs} values in these near-coastal waters are decreased relative to open ocean. Chl from MODIS is higher in the same coastal areas where UV $R_{rs}(\lambda)$ is lower, illustrating correlation between biological production and optical activity observed from satellite with our UV $R_{rs}(\lambda)$ retrieval algorithm.

Figure 4. Left: UV R_{rs} at 380 nm retrieved from OMI using our $R_{rs}(\lambda)$ algorithm in clear sky regions of the Atlantic Ocean near Portugal, Spain, and Morocco on Feb 10, 2005. Right: Chlorophyll from Aqua MODIS on the same day.



Conclusions and Future Work

- We successfully demonstrated our UV-blue atmospheric correction (AC) over Case I waters through R_{rs} comparisons with MOBY.
- The largest uncertainties in the AC are in the aerosol characterization; we plan to use the new Reanalysis for the 21st Century (R21C) aerosol property profiles when available.
- We have proposed to apply our hyperspectral UV atmospheric correction and R_{rs} retrieval to OCI on PACE, planning to accelerate our RTM computation performance significantly.
- We will support on-orbit evaluation of PACE OCI UV instrument performance through comparisons with OMI.

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