NASA PACE-OCI Suspended Particulate Matter Algorithms Comparison for the Caribbean/Orinoco Region.

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Abstract

Ocean color is an important tool to characterize the marine ecosystem. Recent developments in new sensors allow us to understand the changes in water quality and biophysiochemical properties at a regional and global scale. The research project that intent to performed is a comparison between suspended particulate matter (SPM) algorithms comparison for the Caribbean/Orinoco region using NASA PACE-OCI. Our study will consist in the use of the latest ocean color sensor, the Ocean Color Instrument (OCI) of the Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) platform. PACE is an Earth observing satellite that studies the ocean, atmosphere and ocean-atmosphere interactions using hyperspectral data. The optical water properties are divided into two: apparent optical properties (AOP) and inherent optical properties (IOP). The use of these two properties for ocean parameters such as SPM have been widely discuss. The goal of this proposed study will be to understand the different algortihms of suspended particulate matter that use water optical properties and it use for NASA PACE-OCI sensor for Caribbean measurments and ENVI software. A methodology was develop using Remote Sensing Reflectance (R_{rs}) and particulate backscattering coefficient (B_{bp}) to obtain SPM. Different algorithms (NECHAD10, TSM-NN, SOLID, HAN SPM Low) were compared to understand how they respond to data obtained from OCI sensor. Results show that HAN and SOLID method correspond to high and low values, but the estimation need to be verified. The method NECHAD10 and TSM-NN show promise but highly likely error in R_{rs} do not allow us to verify them.

Introduction

Ocean color is an important tool to characterize the marine ecosystem. Recent developments in new sensors allow us to understand the changes in water quality and biophysiochemical properties at a regional and global scale. The research project that intent to performed is a comparison between suspended particulate matter (SPM) algorithms comparison for the Caribbean/Orinoco region using NASA PACE-OCI. For this study, our objectives will be:
i) Develop a methodology for a newly deploy sensor for ocean color, and
ii) Compare different accepted algorithms for PACE OCI.

Our study will consist in the use of the latest ocean color sensor, the Ocean Color Instrument (OCI) of the Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) platform. PACE is an Earth observing satellite that studies the ocean, atmosphere and ocean-atmosphere interactions using hyperspectral data. In general, PACE, that was launch in 2024, will give us information of ocean health, aerosols and clouds. The sensor OCI is a spectrometer that measure electromagnetic spectrum at a high spectral resolution that can provide global data at a daily rate. The sensor resolution consists of a spectral resolution of hyperspectral range of 315 nm to 895 nm in 2.5nm, a temporal resolution provides us data of a global coverage in 2 days with a spatial resolution of 1 km by 1 km. This high spatiotemporal resolution makes this sensor a good opportunity to understand sediment dynamics in the Caribbean such as the Orinoco River plume. Dierssen et al (2023) presented that PACE and other two missions in the future will provide an advancement in aquatic science data products. After one year of data collection various validation articles have proved that PACE-OCI provides sufficient quality data to support aquatic research in suspended matter (Paulino et. Al. 2026).

The optical water properties are divided into two: apparent optical properties (AOP) and inherent optical properties (IOP). AOP are properties that depend both on the medium and the ambient light around it were IOP properties are independent of the sun's position or the viewing angle. In our study we will focus on specific properties, these are: Remote Sensing Reflectance (R_{rs}) and particulate backscattering coefficient (B_{bp}). R_{rs} is the ratio of the light going into the ocean (the spectral plane downwelling irradiance at the surface) to the light coming out of the ocean (water-leaving irradiance) and (B_{bp}) quantifies light that is scattered by particles into a backwards-facing hemisphere relative to the path of an incoming beam of light. The use of these two properties for ocean parameters such as SPM have been widely discuss.

The Caribbean waters are naturally oligotrophic, but the Orinoco plume delivers a large amount of nutrients and minerals that can alter the biogeochemistry that can impact the coastal waters of Puerto Rico and its ecosystem. The goal of this proposed study will be to understand the different algortihms of suspended particulate matter that use water optical properties and it use for NASA PACE-OCI sensor for Caribbean measurments and ENVI software.

Methodology

NASA's PACE OCI data was obtained from NASA EARTH DATA (https://search.earthdata.nasa.gov). The search engine provides you to filter data for temporal, spatial, instrumentations, sensors and level. As OCI is a new sensor, the temporal filter was not use. The spatial filters were use by selecting the square region of the Caribbean (between Puerto Rico and Colombia). The instrument, sensor and level were PACE, OCI and Level-2, respectively. The search output was multiple products Level 2 including AOP, IOP, biogeochemical parameters, atmospheric products and more. For this study we selected the AOP and IOP for May 28, 2026, for the northern and southern Caribbean tiles. Even though these files have more than 30% cloud coverage but was the best date available. The product was a NETCDF 4 file format, a massive 150 Mbytes of size for each product. In total we obtained 4 files, 2 AOP and 2 IOP (north and south for that day). After obtaining the data, we started using ENVI software for the image analysis process. First, we selected the geophysical parameters that we needed for this study. For the AOP we used Remote Sensing Reflectance (R_{rs}) and for IOP we used particulate backscattering (B_{bp}). Then, the pre-processing includes an atmospheric correction using dark subtraction method (by definition Level-2 product have an atmospheric correction, but values were negative, indicating overestimation) and later georeferenced from IGM. After the images are georeferenced, a mosaicking was used (Seamless Mosaic) using the images the images from north and south, to create one continuously image for analysis. The atmospheric corrected-georeferenced image was then used to estimate the suspended particulate matter using 4 different algorithms and band math. The final product was a SPM data file based on (R_{rs}) and (B_{bp}).

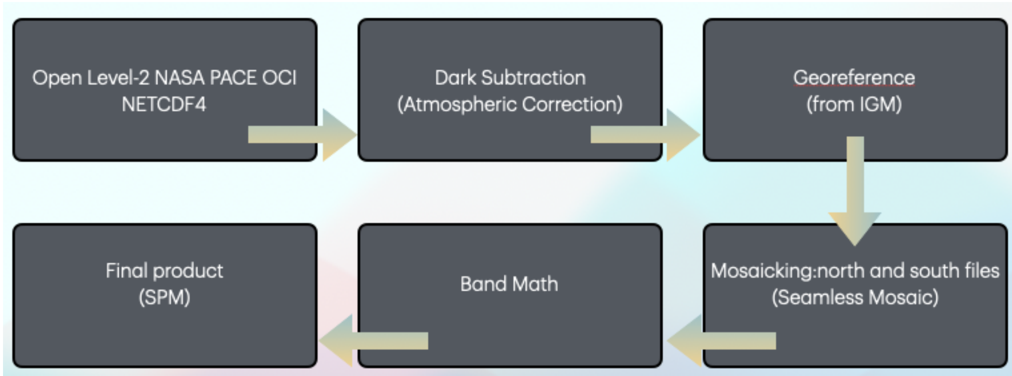

Figure 1. Summary of the generalized workflow to obtain the final product (suspended particulate matter) from NASA's PACE OCI NETCDF 4 data.

Table 1 present a summary of all the algorithms used for this study. For the SPM based on R_{rs} we used the Nechad10 model (Nechad el al. 2010) that use R_{rs} for the red (665 nm) band. The other method used with the AOP was the Han SPL Low (Han et al 2016) method that used the same red band R_{rs}. To calculate SPM using B_{bp} we needed to use the power/hyperbola law (Hout et al. 2007) to change the wavelength, the product provides us with B_{bp} (442 nm) and we needed other values such as B_{bp} (443 nm) and B_{bp} (753 nm). For this estimation, we needed the Bbp (442 nm) and the B_{bp_slope}. The B_{bp_slope} is the spectral slope of the particulate backscattering detected from the sensor.

Table 1. Equations for the different algorithms used in this study and its reference.

Name	Equation	Reference
Power/Hyperbola Law	$Bbp(x) = Bbp(442) * (442/x)^{Bbp\_slope}$	Hout, Y et al. (2007)
Nechad10	SPM = 1.74+ (355.85 * Rrs(665))/(1-(Rrs(665) /0.1728))	Nechad et al. (2010)
Han SPL Low	SPM = (396.005 * Rrs(665)) / (1 - (Rrs(665) /0.5))	Han et al. (2016)
SOLID Type I-II	$SPM = 53.736 * Bbp(753)^{0.8559}$	Balasubramanian et al. (2020)
TSM-NN	$SPM = 1.06 * Bbp(443)^{0.942}$	Hieronymi M. (2017)

Figure 2 show the initial process in our methodology used to obtain our research final product. To open the file, *File/Open as/Scientific Format/NetCDF4*. The file has different geophysical parameters and we selected the R_{rs}, B_{bp_slope} and B_{bp} (442nm) rasters. Additionally, for the georeferenced method we selected the *Latitude* and *Longitude* rasters Figure 2 shows the NETCDF4 open and the collection of the rasters. After selecting the rasters, we applied the workflow show in Figure 1.

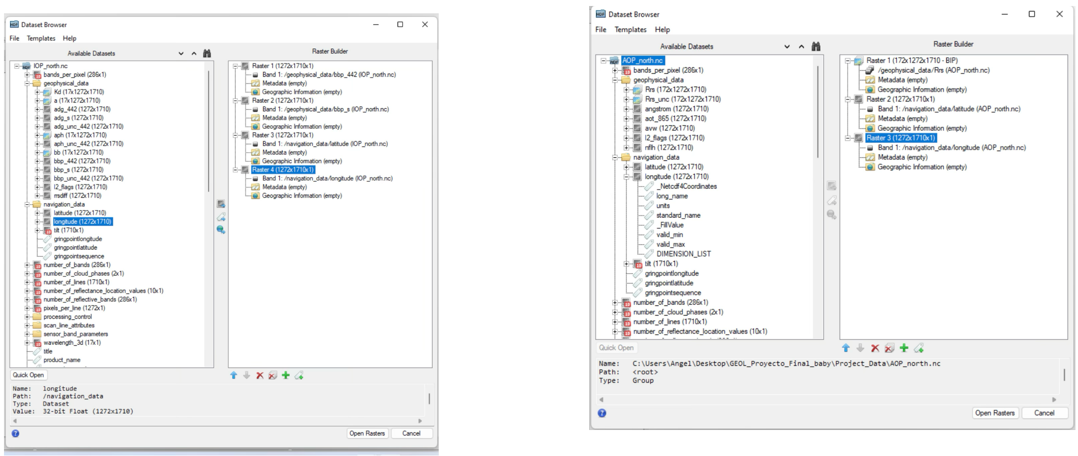

Figure 2. Geophysical parameters in the AOP/ IOP NETCDF 4 files.

Results and Discussion

Inherent Optical Properties

Figure 3 show the level-2 product of the north and south result of B_{bp} (442nm) which was used to derive the B_{bp} (443nm) and B_{bp} (753 nm) using the power/hyperbola law equation show in Table 1. To obtain the relative band we used Band Math to extrapolate the B_{bp} of the new wavelength. The result of this calculation after merging is presented in Figure 4. As shown, the B_{bp} (753 nm) have a range of -18 to 0.41 m^{-1}. These negatives values are not possible and after dark subtraction correction still appear in the results. Even that, we continue the workflow to obtain a methodology to calculate SPM using different methods. Figure 5 show the results of the SOLID and TSM-NN method. These methods use IOPs B_{bp} of different bands to obtain SPM (see Table 1). The SOLID method shows a scale 0 to 28 g/m^3 while TSN-MM method shows a much lower value of 0 to 0.75 g/m^3. The high and low sediment values correspond to the same location, but the values are extremely different. Both methods used an extrapolation of B_{bp} and then an algorithm (showed in Table 1), an exponential factor of the band. These are analytical results and cannot be verified in situ.

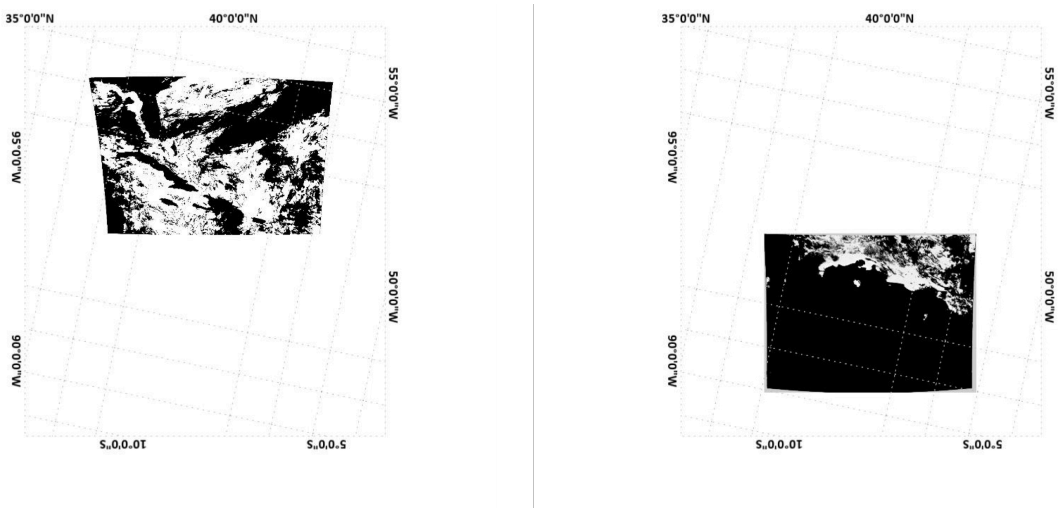

Figure 3. Results for the north and south IOP B_{bp} (442nm).

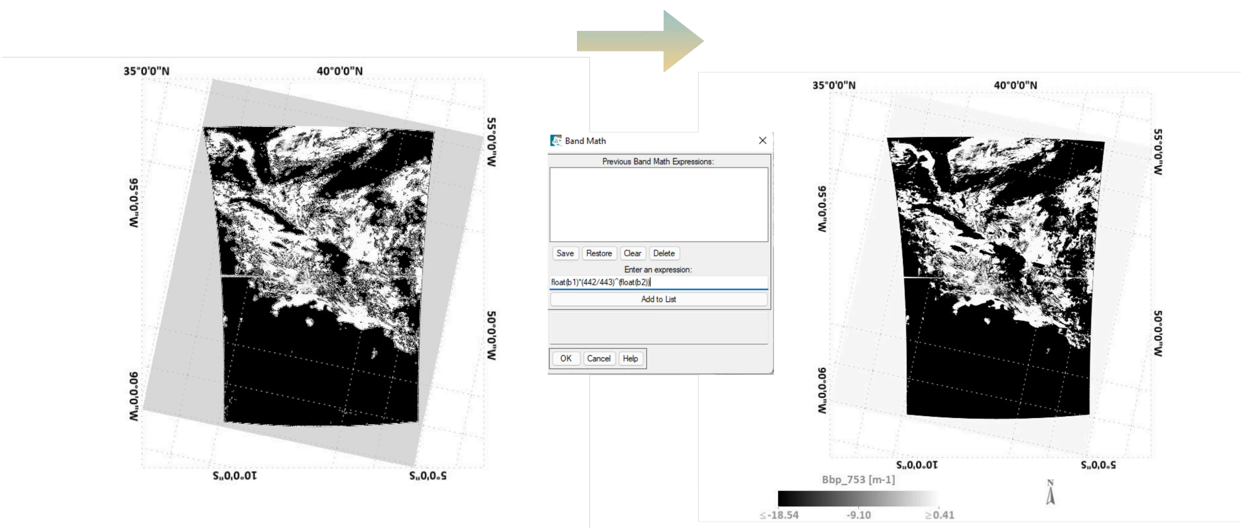

Figure 4. Example the estimation of B_{bp} (753 nm) by using Band Math (power/hyperbola law)n to B_{bp} (442nm).

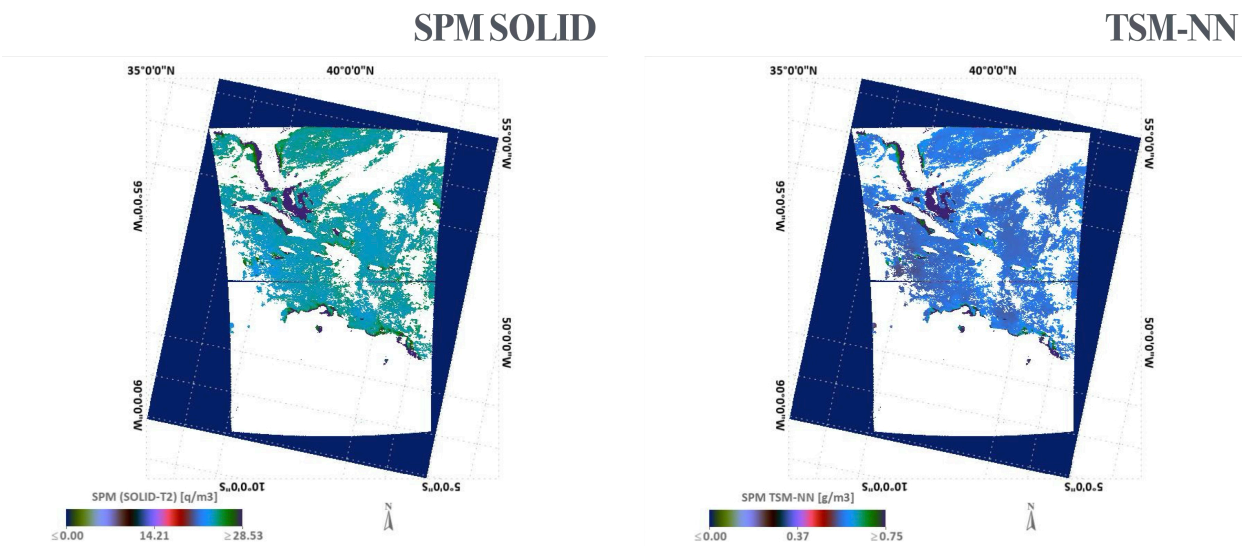

Figure 5. Results of the estimation of SPM using the SPM SOLID and TSM-NN method.

Apparent Optical Properties

Figure 6 show the AOP R_{rs} obtained after pre-processing the level-2 data. The pre-processing was the same that the IOP. In this case, the R_{rs} can provide us with a true-color image that represent a RGB that we can see, but as it is show, when we use the RGB bands for this product (red-122, green-89 and blue-34) we obtain a partial result. The north part of the image do not show the correct RGB color while the south does. Both images were processed using the same parameters and method, and still the north part of the image gave us that error. This process was also performed to the image after georeferenced and have the same error. For purpose of this project, we continue the methodology using the NECHAD10 and HEN SPM Low methods for the estimation of SPM. Figure 7 show the results of these findings. The color scale are the same for both the north and south image, and the error can be seen. The process was repeated multiple times, and the error always appear and was consistent.

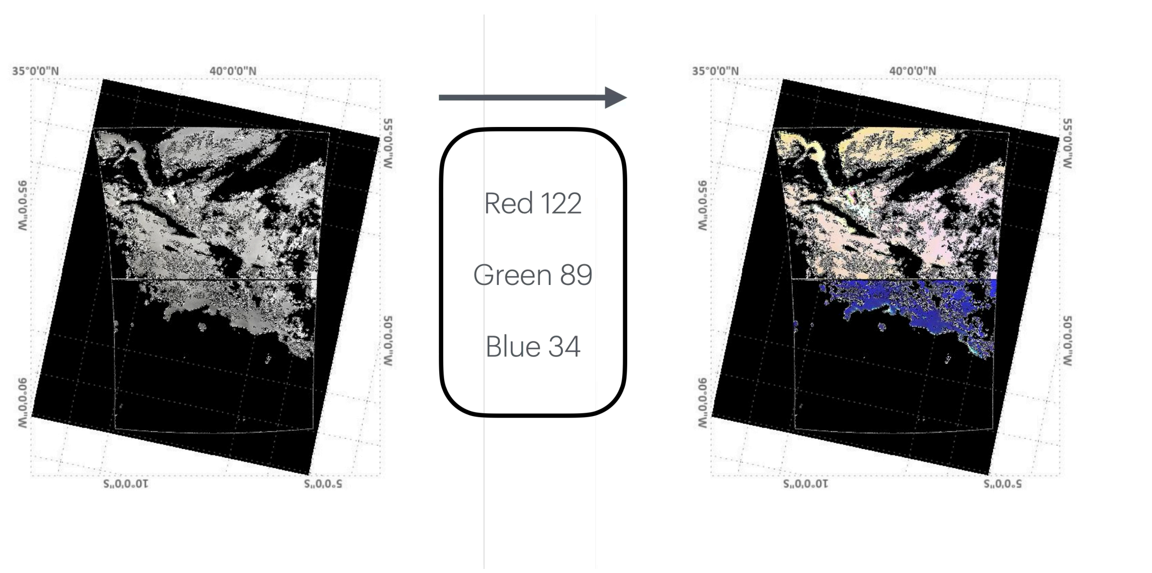

Figure 6. Results of R_{rs} and converted to true-color using the RGB bands.

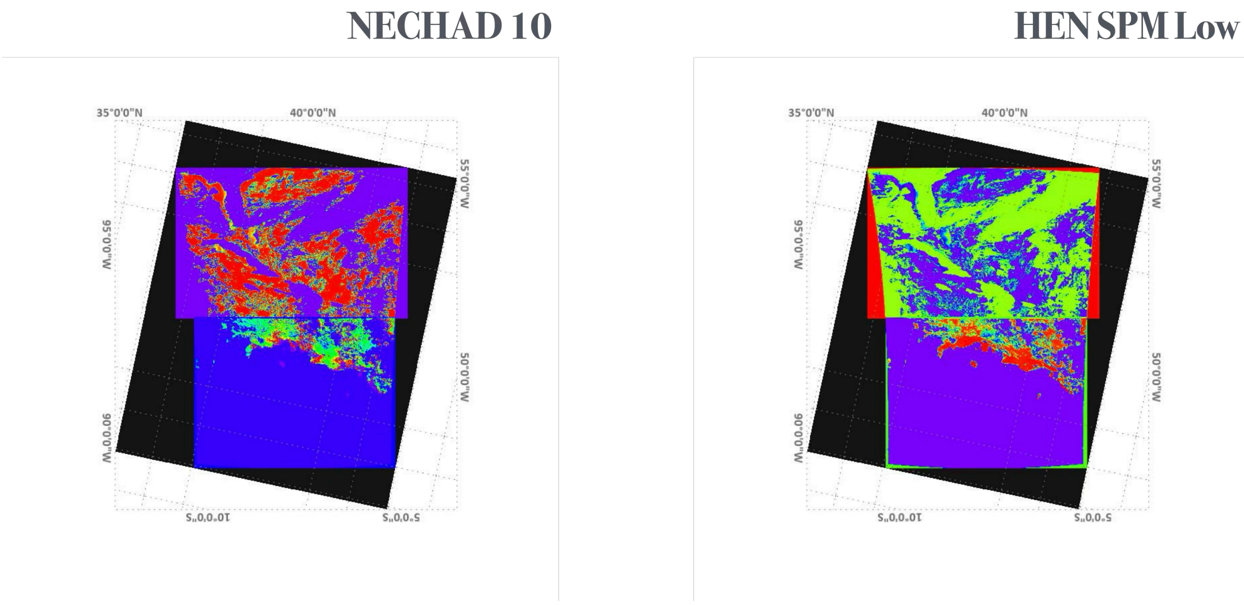

Figure 7. SPM estimation using NECHAD10 and HEN SPM Low methods.

Conclusions and Recommendations

This study presented a workflow to determine suspended particulate matter (SPM) using NASA's hyperspectral PACE OCI sensor utilizing existing inherent/apparent optical properties (IOP/AOP). An analysis of the Level-2 products revealed a high frequency of negative remote sensing reflectance (R_{rs}) and particulate backscattering (B_{bp}) indicating overestimation of the atmospheric correction. Another issue with Level-2 data is that the pre-processing includes a land mask that can affect data collected near the coast (spatial resolution is 1 km). A possible recommendation is to use future and better define Level-2 data or use Level-1 as initial data set. The problem will be that advance algorithms need to be used for Level-1 and land masking will be manually. Furthermore, the NETCDF4 file is massive and demand a high-performance computer to apply the workflows. For example, the georeferenced merging of both tiles took around 2 hours. Finally, a workflow for SPM is possible but a liable data is needed to obtain good results.

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