Remote Sensing of Dark Water Events in Puerto Rican Oligotrophic Environments

***Suhey Ortiz-Rosa[1,3], Roy A. Armstrong[1,3], William J. Hernández[1,2], Omar López[3]**

[1]NOAA- CESSRST, Bio-optical Oceanography Laboratory, Department of Marine Sciences, University of Puerto Rico, PO Box 9000, Mayagüez, Puerto Rico 00981

[2]City College New York (CUNY) - NOAA CESSRST, New York City, NY 10031 U.S.A.

[3]Bio-optical Oceanography Laboratory, Department of Marine Sciences, University of Puerto Rico, PO Box 9000, Mayagüez, Puerto Rico 00981

*Correspondence to: suhey.ortiz@upr.edu

Abstract

Dark water events (DWE) are common in coastal areas associated with wetlands or river outfalls, rich in organic humic matter. In Puerto Rico, DWE can be found along the insular shelf and in oligotrophic waters. DWE were identify in 13 Sentinel-3A images in 2017-2018. A dark water index combining (B1+B2)/B6 was used to discriminate these events from the surrounding clear, oligotrophic waters. Preliminary data suggest an index < 7 define DWE. The S3A ADG443_NN values inside the DWE (mean = 0.037) are double the values of clear waters. Reflectance values of Band 1 outside the DWE is two times (mean = 0.025) the values inside the DWE. The data suggests that the highest contribution to the DWE optical signal is by CDOM.

Summary

Colored Dissolved Organic Matter (CDOM) is the major factor influencing the DWE, which can be traced with a band ratio (B1+B2)/B6 from S3A imagery.

Introduction

Coastal areas as wetlands and rivers outputs are common sources of dark waters events (DWE). These areas are related to discharges from water treatment plants or algal blooms. These events have been associated with phytoplankton blooms and colored dissolve organic matter (CDOM) *(1, 2)*. A DWE in Florida (USA) offshore waters in 2002 was related to corals and sponges decline [1]. Colored detrital matter has been identified as an important factor attenuating the light in the ocean having a potential impact in sea surface temperature and mitigating ocean warming *(1)*. This study uses satellite imagery to detect and trace DWE and determine its source.

Background

In Puerto Rico, dark water events are common in coastal and oligotrophic waters beyond the insular shelf. These dark water masses are not always directly related to field-measured biogeochemical parameters such as chlorophyll and CDOM.

Approach

Field samples were collected and the corresponding Sentinel 3A (S3A) pixels values were extracted at insular and offshore waters within and offshore in southwestern PR. This area is known for well-developed coral reefs systems and seagrass beds and is characterized by the absence of direct river inputs. DWE were identified in 13 S3A images from August 2017 to September 2018. The SNAP visualizer and tools were used to obtain the mean value of 7x7 pixels for bands reflectances and OLCI products. All S3A pixels were selected outside of the insular platform to avoid bottom reflectance contamination. Simple band math ratios were produced between OLCI band (B1/B6, B2/B6 and B1+B2/B6) to determine the best Dark Water Index (DWI) in this region. We used the ratio combining B1+ B2 and dividing the result by B6. The values within and outside of the DWE were analyzed to establish statistical differences. A filter (median7x7) was applied to the DWI images to improve the traceability of different water masses and values. In addition, the DWI was compared with other S3A products such as ADG443_NN, CHL_NN, CHL_OC4, bands reflectance, Optical Water Type classification (OWT) and the Forel-Ule Algorithm (FU). Statistical analysis based on correlations between the various satellite products and the DWI were performed to determine differences within and outside of the DWE.

Results

DWE are dynamic in time and space in this region (Fig. 2 and 3). The variances and means for DWI and ADG443_NN values are significantly different inside and outside of the DWE. The highest DWI peak (18.3) was found in April, which corresponds to the dry season (Fig 4 and 5). At the same area, this peak decreased to close to six during the wet season. Preliminary data suggests an index of 7 or less (mean = 5.7) define DWE, while values above 7 (mean = 12.4) are associated with clear waters. The S3A ADG443_NN satellite product value inside the DWE (mean = 0.037) is double the values of clear waters. Reflectance values of S3A Band 1 (400 nm) outside the DWE is two times (mean = 0.025) the values inside the DWE. The DWI values out of DWE are consistent with lower ADG443 and Kd490 values while these parameters are not consistent with values inside the DWE (Fig 4 and 5). October 2017 was an unusually wet month with nearly 280 mm of rain for PR, while a bloom of Sargasso was present in June 2018 over the study area, decreasing the DWI only inside the DWE. These higher values for these two dates were observed on ADG443_NN, Kd490 and CHL_OC4 values. However, this was not the case for the June CHL_NN product. Spearman rank correlations show a negative correlation between DWI and ADG443 (All values, r = -0.69; Outside DWE, r = -0.77; Inside DWE r = 0.17). Only one parameter, Kd490, is comparable with some of the values presented in the literature *(2)*. with a Kd range between 0.023 m-1outside of the DWE to 0.073 m-1 inside the DWE.

Discussion

DWE can be identified using Enhanced RGB (ERGB) imagery, S3A reflectance values, and the FU product. In addition, the hu_angle product produced similar results. The DWI could provide a quantitative satellite product that can be used to trace biogeochemical parameters relevant to carbon dynamics. Preliminary data suggests that CHL_NN values are more accurate than the

CHL_OC4 product for estimating chlorophyll. The CHL_OC4 algorithm overestimates chlorophyll values in this area. These data suggests that the DWI can be considered an alternative product for ADG443 in oligotrophic waters. Additional data will be analyzed to obtain further match ups between satellite imagery and field samples to validate this hypothesis.

Conclusions

The DWI is being validated using field bio-optical and biochemical data. The optical properties of these dark water masses are being analyzed to establish its composition and origin. Its origin could be mainly from *in-situ* production or inner shelf processes, or produced on the seafloor by benthic communities and lifted by vertical ocean currents *(1)*. The effects of the DWE on coral reefs in this region should be explored due to possible impacts on coral and sponges diseases and mortality *(2)*. Another important impact of DWE is the possible relationship with global climate change due to changes in light absorption and scattering *(1)*. DWE can be traced using high-temporal resolution S3 imagery, although cloud cover remains a limiting factor for this tropical region.

Acknowledgments

This study is supported and monitored by The National Oceanic and Atmospheric Administration – Cooperative Science Center for Earth System Sciences and Remote Sensing Technologies under the Cooperative Agreement Grant #: NA16SEC4810008. The authors would like to thank The City College of New York and NOAA Office of Education, Educational Partnership Program with Minority Serving Institutions (EPP/MSI) for full fellowship support for Suhey Ortiz Rosa. 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.

References

(1) Sidder A. (2018) Yellow detritus in the oceans may help reduce warming. Eos. 99, https://doi.org/10.1029/2018EO106459. Published on 25 September 2018.

(2) Zhao Jun, Chuanmin Hu, Brian Lapointe, Nelson Melo, Elizabeth M. Johns and Ryan H. Smith. (2013) Satellite-observed black water events off southwest Florida: implications for coral reef health in the Florida Keys National Marine Sanctuary. Remote Sensing 2013, 5, 415-431; doi:10.3390/rs5010415

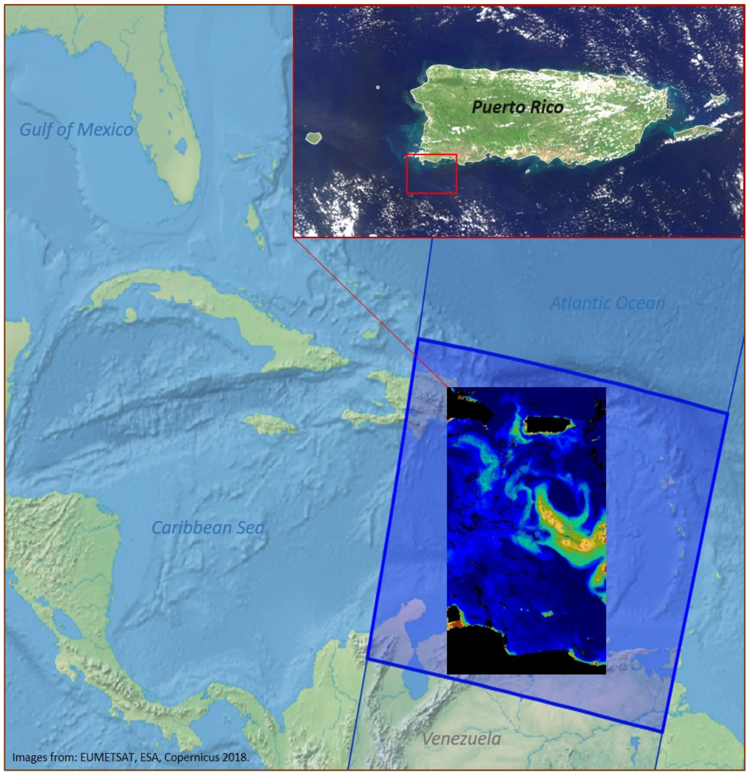

Figure 1. Study area, southwestern Puerto Rico.

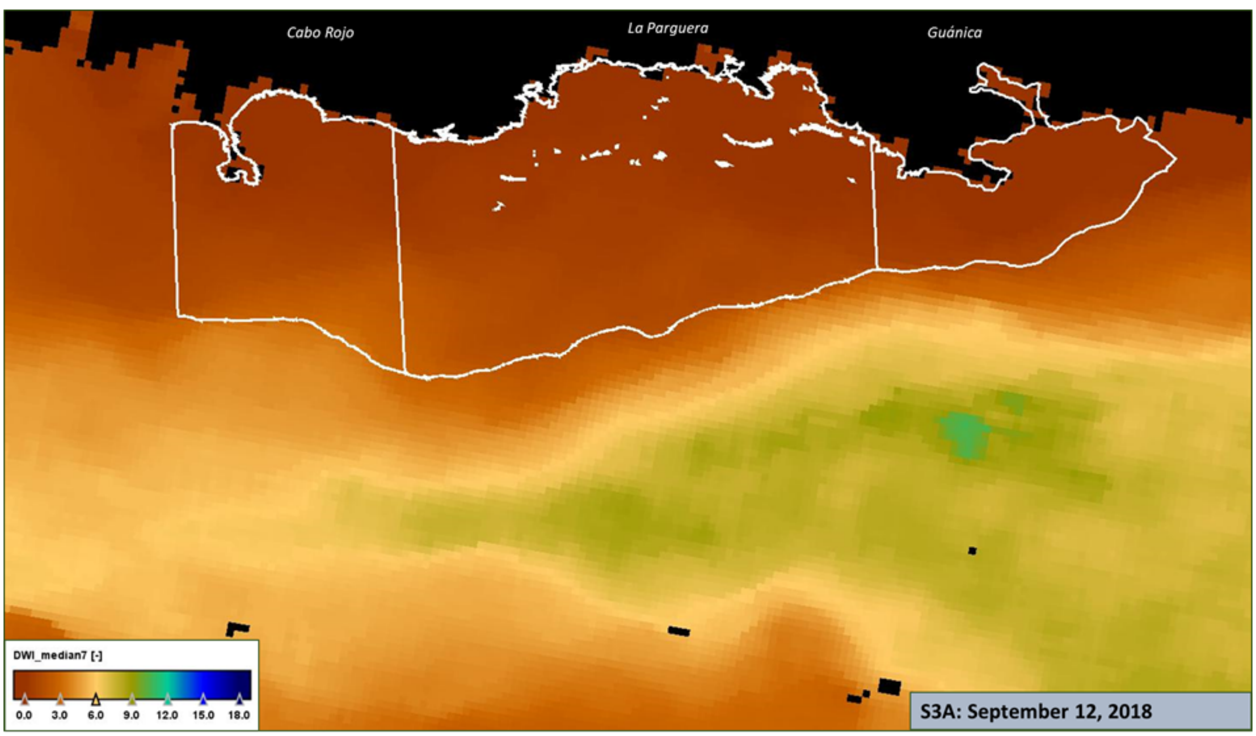

Figure 2. DWI produced from Sentinel 3A reflectance bands, September 12, 2018.

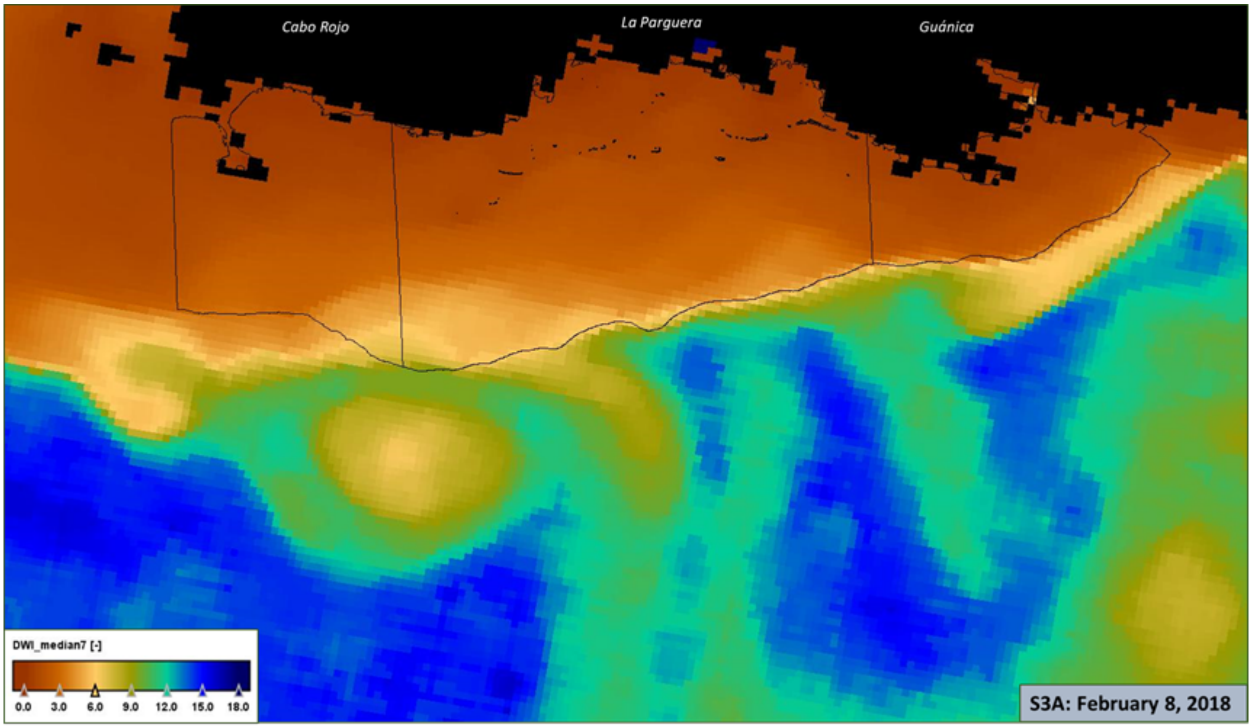

Figure 3. DWI produced from Sentinel 3A reflectance, February 8, 2018.

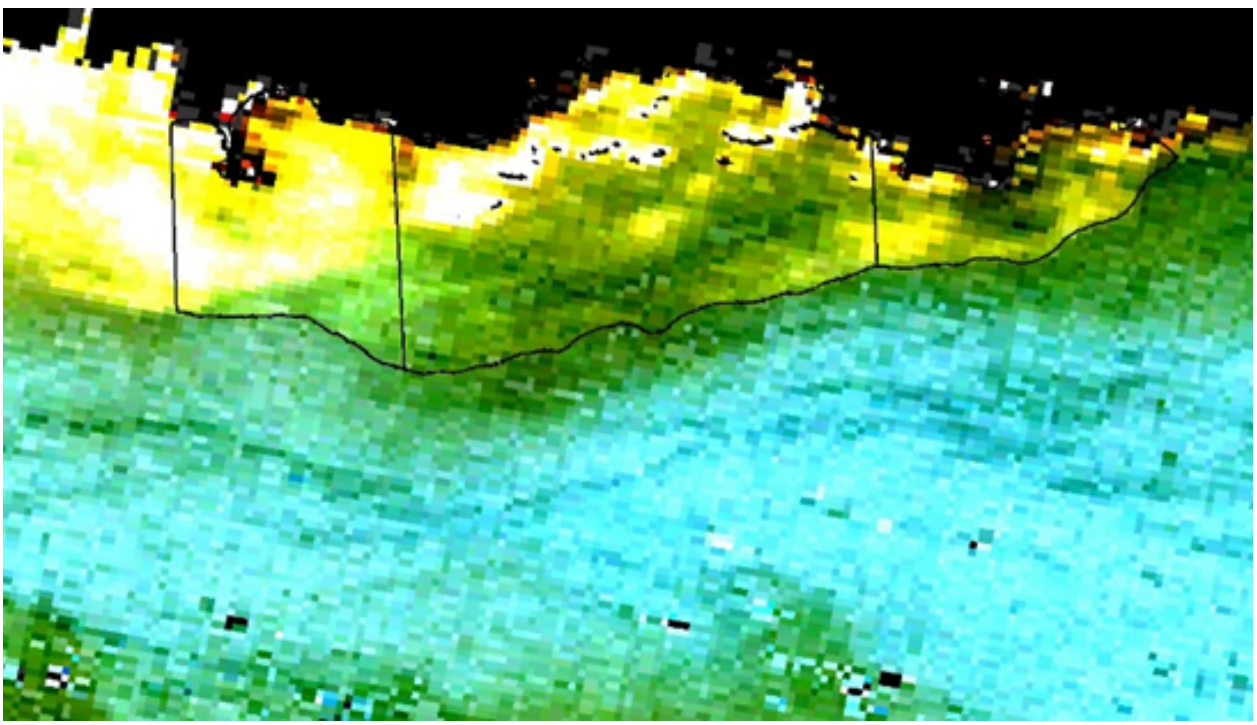

Figure 4. ERGB created with S3A bands, Sept 12, 2018

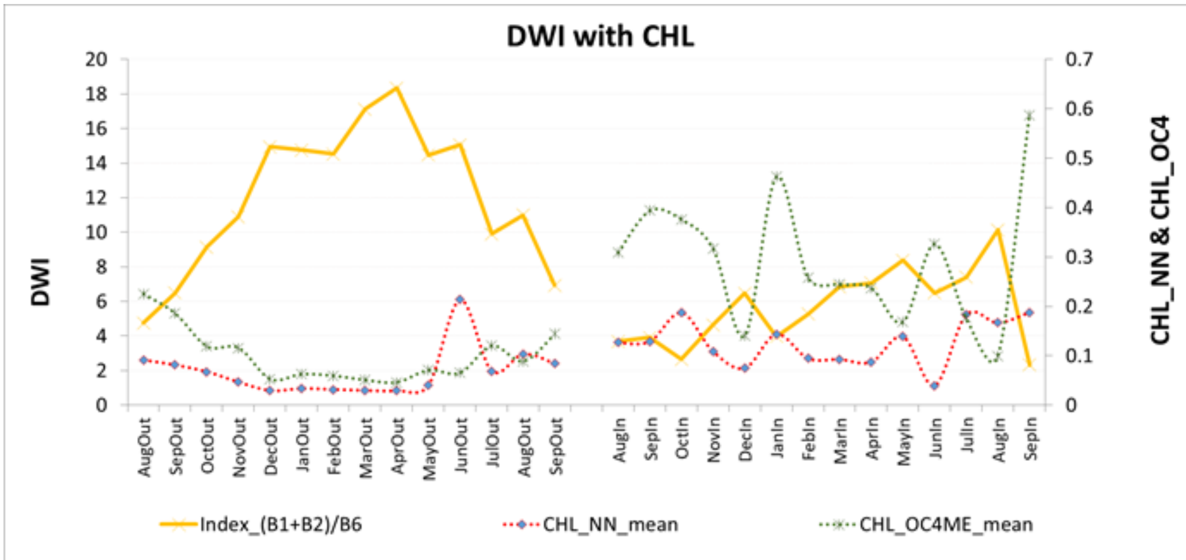

Figure 5. Monthly values for CHL_OC4 and CHL_NN products in and out the DWE for selected points and DWI. Extracted and produced from S3A bands.

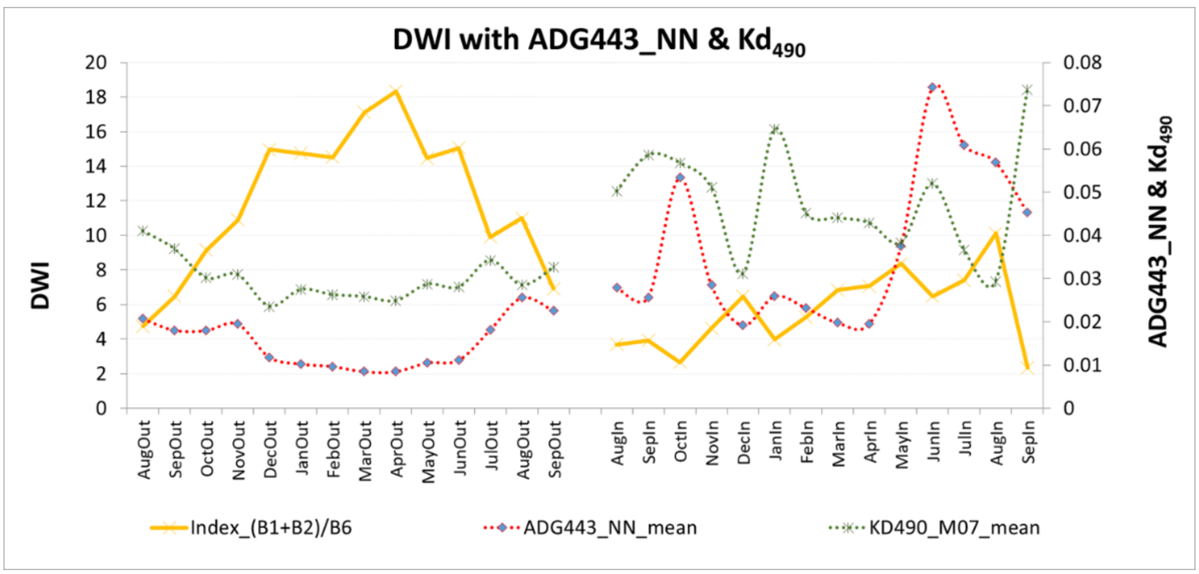

Figure 6. Monthly values for ADG443_NN and KD490_M07 products in and out the DWE for selected points and DWI. Extracted and produced from S3A bands.