Sargassum Monitoring – Early Detection and Drift Forecast of Floating *Sargassum* Algae in the Caribbean Islands

Surveillance des *Sargasses* – Détection Précoce et Prédiction de Dérive des Algues *Sargasses* Flottantes dans les îles de la Caraïbe

Vigilencia de *Sargassum* - Detección Temprana y Predicción de *Sargasso* Algas Flotantes a en las Islas del Caribe

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EXTENDED ABSTRACT

Unprecedented massive landings of *Sargassum* are regularly registered since 2011 along the shorelines of a huge area encompassing French Guyana, the Antilles and Caribbean Sea. The phenomenon affects widely the West Indies (Guadeloupe, Martinique, Barbados ...), Dominican Republic, Mexico, etc. and many sightings have been reported. Algae arrive from the open sea as large rafts (tenths of km) after drifting over long distances in the Central Atlantic NERR, and accumulating in consolidation areas in the Brazil retroflexion current and probably the Gulf of Guinea. Compared to previous years, 2018 is far the worst year in terms of *Sargassum* landings on Caribbean islands shorelines. Washing-ashore has tremendous negative impacts on local populations, coastal marine ecosystems and the economy sector, especially tourism and fisheries that are severely affected.

CLS is developing applications for the marine domain using satellite technologies since 1986: wildlife tracking with the Argos system, managing marine resources and fisheries, detecting oil spill, identifying polluters for the maritime surveillance, traffic monitoring, illegal fishing, earth observations for environmental monitoring…

CLS started exploring remote sensing for the monitoring of floating *Sargassum* algae in the Caribbean Islands in 2015. NBE has been providing *Sargassum* forecast bulletins to the local French environmental office (DEAL) in Guadeloupe since 2013. In 2018, the consortium CLS-NBE has been awarded a project with the ESA (European Space Agency) to implement an innovative service based on Earth Observation (EO) data to *monitor floating Sargassum algae in the Caribbean area.*

High Resolution *Sargassum* Index Products

Floating macroalgae like *Sargassum* can be detected using satellite image algorithms that utilize the spectral "red-edge" behavior of vegetation (low reflectance at red wavelengths, high reflectance at near-infrared wavelengths).

Using of synergy of EO imagery in the open sea: Sentinel-2, Sentinel-3 MODIS-Aqua, MODIS-Terra, CLS computes a new Sargassum index called NFAI (Normalized Floating Algae Index) at the highest pixel resolution, namely 250 m for MODIS, 300 m for OLCI, and 20 m for MSI. The NFAI, inherited from Hu (2009), is computed as follows:

$$NFAI = (R_{PIR}^{obs} - R_{PIR}^{int})/(R_{PIR}^{obs} + R_{PIR}^{int})$$

where R_{PIR}^{obs} is the measured reflectance in the Near Infra Red (859 nm for MODIS, 865 nm for OLCI and MSI), corrected for Rayleigh scattering and atmospheric gas absorption, and R_{PIR}^{int} is its linearly interpolated value using the Red (645 nm for MODIS, 665 nm for OLCI) and Shortwave Infra Red (1240 nm for MODIS, 1020 nm for OLCI) bands.

Normalization, as done for NDVI over land, allows to reduce variability due to atmospheric uncertainty and varying geometry of observation inside a given image or long time series of images. Using the 250-m MODIS bands, although having lower signal to noise ratios than the 1-km bands, will allow to detect *Sargassum* patches with less uncertainty (less mixing with free water and cloud contamination for a given pixel).

A preliminary assessment has shown that *Sargassum* signal is viewed by Sentinel-2/MSI, but sometimes a strong noise prevents the generation of reliable maps comparable to those derived from MODIS and Sentinel-3/OLCI. In particular, the noise in the detection induced by glint, waves, and foam has to be quantified and corrected, if possible.

Improvement of Atmospheric Corrections and Cloud Masking

The scientific work of the present study will also consist in trying to improve the atmospheric correction of the floating algae index algorithm. The existing products produced by the University of Florida (USF) only used the Rayleigh correction to correct the products for the atmospheric signal. Presently no aerosol correction is applied, which can lead to errors in the reflectances, particularly in our region of interest, where Saharan dust can be the dominant atmospheric signal. This study will explore the possibility to apply an aerosol correction.

The cloud masking will also be improved to better reject pixels contaminated by clouds, using a 5-band cloud mask algorithm. Indeed, simple thresholds are not sufficient, and the spectral shape of the signal has also to be considered.

Finally, an effort will be devoted to better remove positive NFAI pixels in the cloud vicinity that create false alarms, because it is safer to select only the appropriate detections to feed the drift model operationally.

The verification approach for this development will be to compare the results of the new algorithms with the existing products provided by the University of Florida (1km resolution MODIS-based products, see section 1.4) or using in situ observations, if available, on relevant validation cases taken during the 2018 season.

An Automated Chain for Operational *Sargassum* Monitoring

NFAI is computed daily on all available sensors at the highest sensor resolution. High resolution products of sargassum index are produced daily at a regional scale on MODIS and OLCI at 250 m resolution (0.0025°) to cover 4 areas of interest, including te Caribbean islands, the Gulf of Mexico, the Atlantic Ocean, and the African coasts. Very high resolution products are produced daily with MSI 20-m at a local scale on two areas covering Martinique and Guadeloupe islands (More areas will be implemented depending on the users needs).

Derived products are also computed to complete the HR products. Low resolution products are derived at 0.1° lat-lon cell from the HR *Sargassum* for an easier identification of affected areas. MODIS and OLCI data are also combined to produce a composite weekly product over the entire area at 10-km resolution. These weekly data provide a useful overview of the situation at a more global scale (Figure 1).

The most threatening *Sargassum* rafts for beaching are selected from the daily satellite products and an estimation of their trajectories is automatically computed with a drift model, using current and wind inputs coming from numerical forecast models.

The results of the *Sargassum* index computation and of the drift simulation are disseminated to the end-user through an innovative user-friendly web interface, to provide a generic support to decision-making processes in all sectors impacted by the *Sargassum* issue.

Expected Outcomes for Society

The service shall bring valuable information in support to operations & management of the various sectors impacted by sargassum landings : bring support for decision making processes on public beach management and cleaning by public authorities, inform stakeholders from the industry (beachfront resorts, diving centers…) on landings occurrence to help optimize the response for tourism, support offshore collection operations by directing the collectors to the most populated areas, help the fishermen optimizing their fishing areas, inform maritime safety authorities so that they integrate this fact on their routine operations, and support mitigation strategies and planning in response to this environmental threat.

User Centric Approach

CLS and NBE are engaging with local communities to ensure that the results will be tailored to their needs. End-users play a key role in the development of this service. End-users requirements are being collected at the service definition stage, and the service and web interface will be developed accordingly. End-users will then participate to the validation and assessment of this service, through a two -months trial that will take place in the beginning of 2019.

Conclusion

Sargassum invasion is becoming a regular hazard in the Caribbean and Gulf region. 2018 has been from far the most intense *Sargassum* season in terms of *Sargassum* detection in the area and reported beaching on the whole Caribbean and Gulf of Mexico region. The analysis of *Sargassum* index data over the entire Atlantic indicates that more *Sargassum* is evolving in the open seas that may end their course on the Caribbean shores in the next months . The overall goal of this project is to define and develop a service tailored to the end-user needs, to provide them with tools to manage this issue like any other natural hazard.

KEYWORDS: high resolution *Sargassum* index, Atlantic basin scale, operational service, web interface, end-users engagement

LITERATURE CITED

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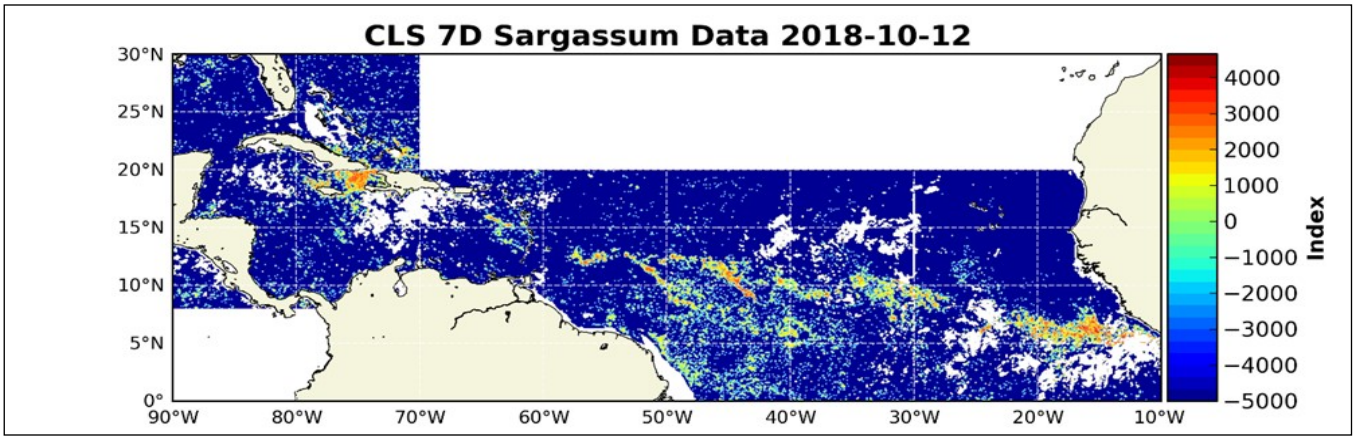

Figure 1. *Sargassum* Product (Normalized Floating Algae Index) weekly composition based on MODIS & Sentinel-3.