



Sargassum Monitoring System and operational algorithms

Journée Sargasses

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History of Sargassum at CLS

2015

exploring the satellite technologies to detect and monitor sargassum from space

2018-2020

NBE - CLS has started a project co-funded by ESA (open call EO science for society) : **DEVELOPMENT OF SAMTOOL**

2020

SAM tool service operational
Used by + 40 users (ESA support)
Provision of satellite data to Météo France

2017

first service for the DEAL Guadeloupe - CLS provides sargassum drift simulation to NBE for its weekly analysis

2019

CLS - NBE - I-Sea: provide sargassum satellite detection and analysis to Météo France

2021

SAMTool service supported +6 users
H2020 E-shape project:
SARGASSUM DETECTION FOR SEASONAL PLANNING

2022-2023

SAMTool supported + 20 users
CMEMS Evolution SODA
Developing added value services



Sargassum influxes in the Caribbean and African coasts

Since 2011, huge **brown pelagic algae** mass strandings (Sargassum fluitans and Sargassum natans) have occurred in the wider Caribbean region and in West African countries.



Crédit : DEAL Guadeloupe/Franck Mazéas



Societal and Environmental Impacts



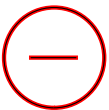
Public authorities:

- Mandates in public beach management and public health management
- In charge of cleaning beaches and monitor H2S concentration



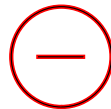
Tourism sector:

- Key source of revenue for most countries
- Sargassum ruins the visual aspect of beaches and nuisance for nautical activities



Fisheries :

- Hampered by floating sargassum, especially net fishing
- Fishermen can be trapped in port by Sargassum



Operations at sea & marine safety:

- Seismic surveys stopped by floating sargassum
- Small-size vessels, sailing boats trapped in Sargassum mats



Wildlife protection and valorisation :

- Floating sargassum is a protection for juveniles
- Collection for valorization,



SAMTool operational service: user centric designed



+40 users



Prepare and support timely sargassum **collection operations**

Daily sargassum detection

Drift forecast



User-friendly web platform

Scalable bulletins, early warning



Raise **awareness** on the upcoming sargassum strandings



Help the key users to **prepare the mitigation** plan in advance to reduce the devastating effects of sargassum on local economies

SAMTool operational service: warning system for sargassum influxes



8 satellite sensors including medium and high resolution



24/7 operational & scalable service

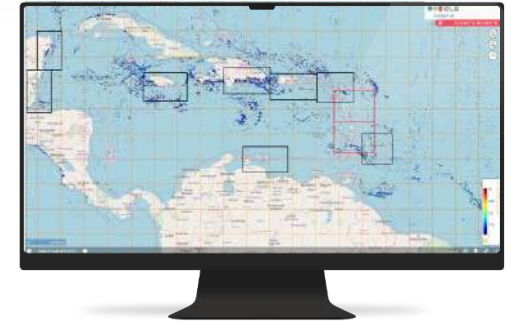
Daily sargassum detection

Drift forecast



User-friendly web platform

Scalable bulletins, early warning



5 days to **5** months forecast



+20 Experts mobilized to develop and operate CLS's sargassum service



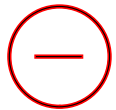
Sargassum detection from satellite

SYNERGY OF SATELLITE SENSORS FOR SARGASSUM DETECTION



3 ocean color satellite instruments with wide swath:

- MODIS on board Aqua
- OLCI on board Sentinel-3A and 3B
- extended coverage down to **300m pixel resolution** daily
- Atlantic basin: 10° E-100° W; 5° S-30° N

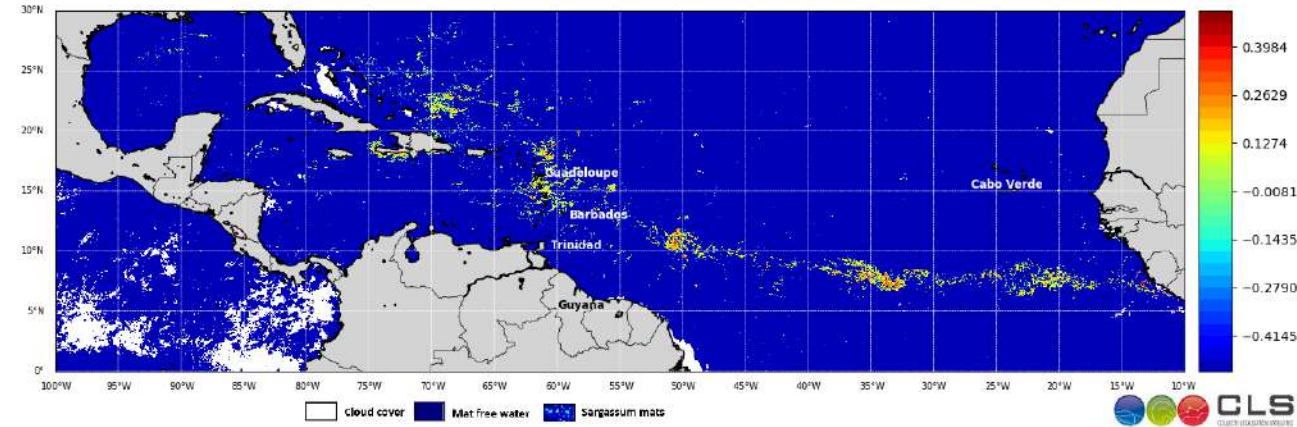


- Sensor sensible to cloud cover



- Allows to get a **general view of the overall situation in the whole Atlantic** from Gulf of Mexico to Gulf of Guinea
- New detection **every day**

OLCI / MODIS NFAI CLS 7 days Mean (2021-08-30 00:00:00 UTC)



Daily coverage of the MODIS & Sentinel-3 OLCI 300-m sargassum data

Sargassum detection from satellite

SYNERGY OF SATELLITE SENSORS FOR SARGASSUM DETECTION

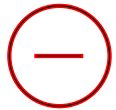
4 High resolution optical sensors



- MSI on-board Sentinel-2A and 2B
- OLI onboard Landsat-8 and -9
- detection close to shore (300 kms) and immediate landings down to **20m pixel resolution**
- **Every 2-3 days over a given área**
- **Caribbean basin: 57.5°W-89°W; 11°N-22°N**



Exemple of daily coverage of the S2 MSI 20-m sargassum data



- Sensible to cloud cover
- Low revisit



- **Allows to complete the detection at 300m and refine the shapes of the mats**



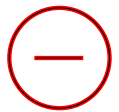
Results of sargassum detection with EU Copernicus Sentinel-2 data

Sargassum detection from satellite

SYNERGY OF SATELLITE SENSORS FOR SARGASSUM DETECTION

1 geostationary radiometric sensor

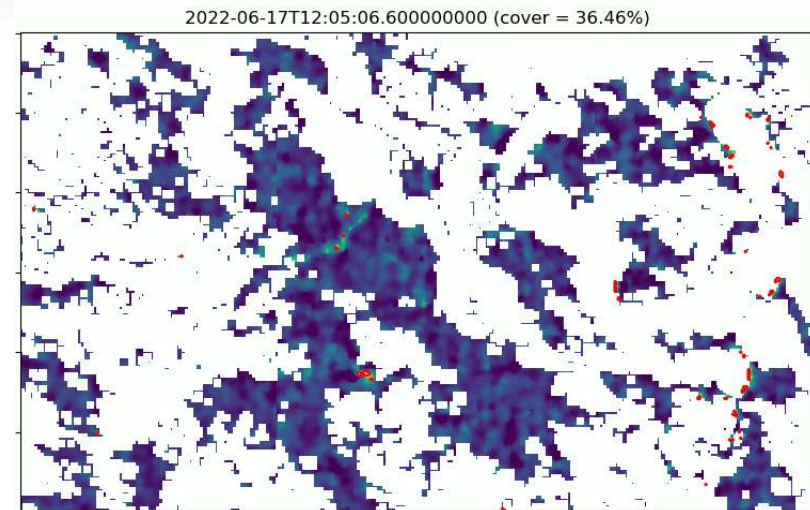
- HYGEO algorithm
- ABI on board GOES-16
- Detection on the whole Tropical Atlantid at **1 km pixel resolution**
- **Every 15 minutes**
- **Atlantic basin 10°W-100°W; 5°S-40°N**



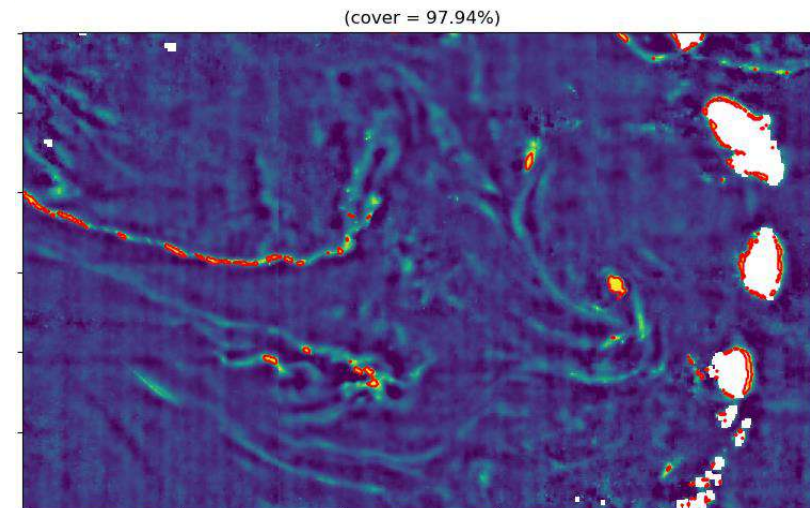
- Coarse resolution of 1 km and improvement work for a better denoising (on going)



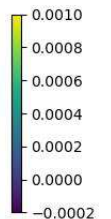
- **Increases the satellite coverage for a better monitoring in time**



Sample daily animation (2022-06-17) of Sargassum index (FAI anomaly). Red areas show the boundaries of the detected sargassum.

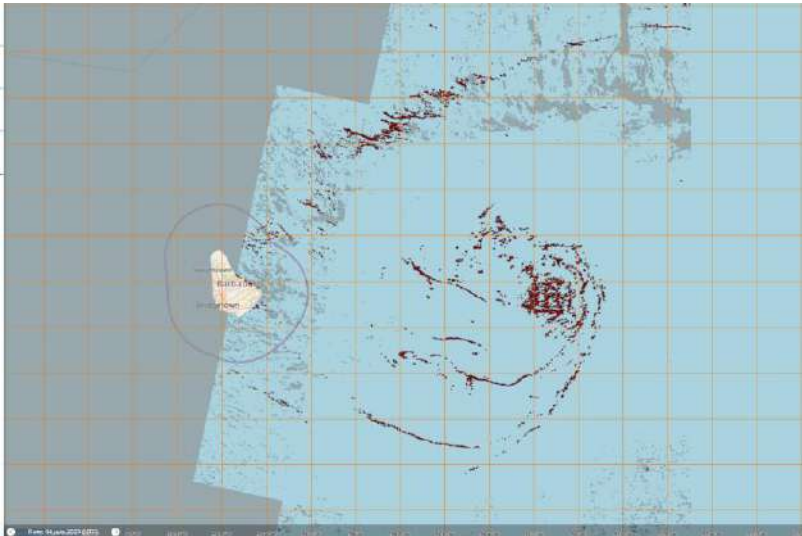


Daily composite (2022-06-17)

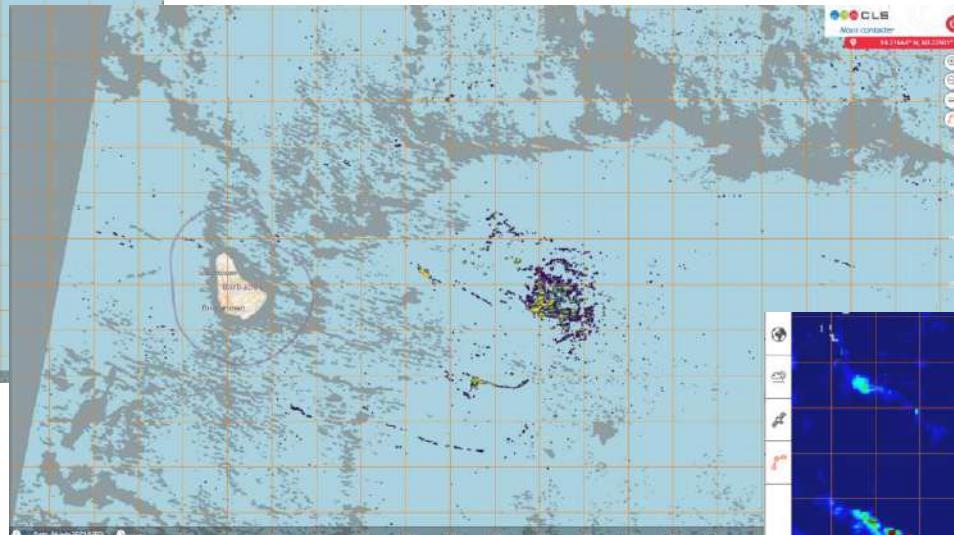


Sargassum detection from satellite

SYNERGY OF SATELLITE SENSORS FOR SARGASSUM DETECTION: MULTIPLE SENSORS TO GET THE MOST COMPLETE UNDERSTANDING

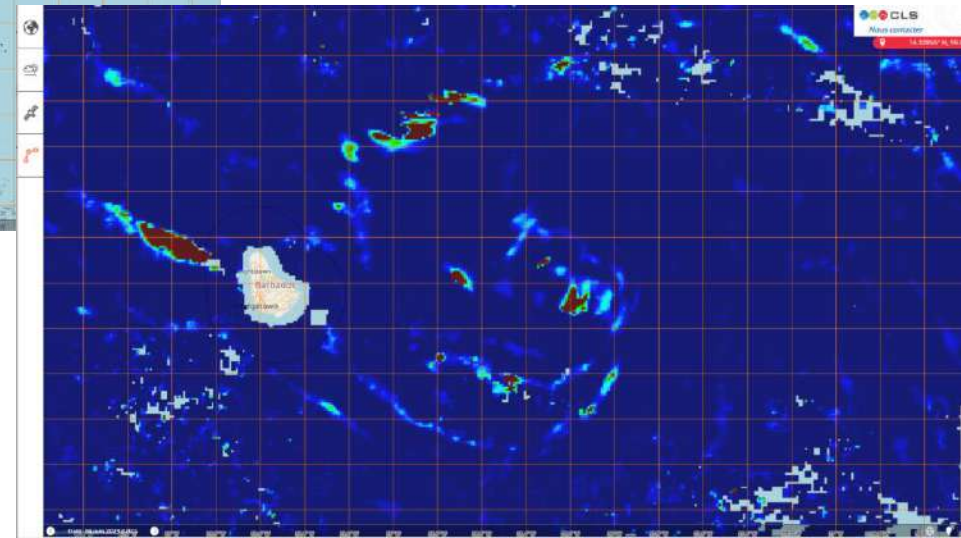


Sargassum seen by Sentinel-2 on 20m-pixel resolution



Sargassum seen by Sentinel-3 on 300m-pixel resolution

Sargassum seen by GOES-16 on 1-km pixel resolution



Sargassum drift forecast

DRIFT MODELLING OF THE DETECTED RAFTS AND ESTIMATION OF LANDINGS

- Using a validated and experienced drift model
 - Configured for the Caribbean area and for the drift of sargassum rafts
 - Model results validated with CLS drifting buoys

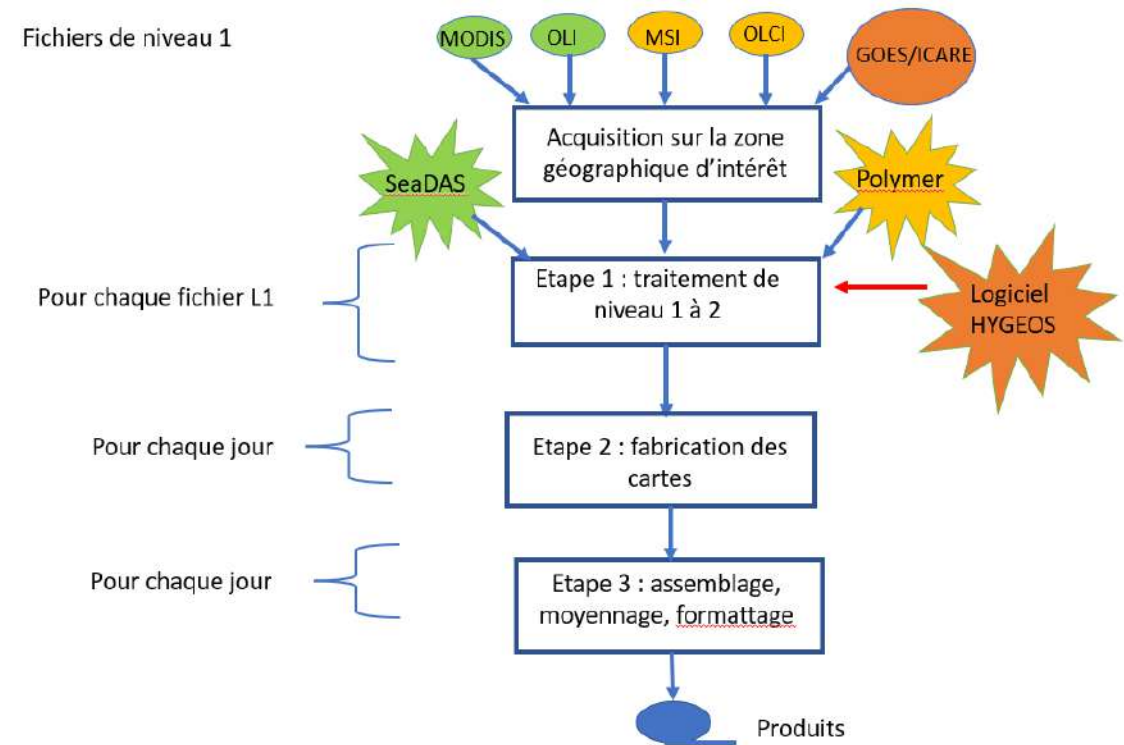
SHORT TERM PREDICTION (3-5 days) IN 10 COASTAL AREAS

→ Estimation of probability of IMMEDIATE landings



Operational system

- CLS processes every day in NRT ocean colour sensors (MODIS/Aqua, OLCI/S3A-B) at 300 m pixel resolution, and high resolution sensors (MSI/S2A-B, OLI/Landsat-8-9) at 20m resolution. Thanks to the support from CNES, CLS also processes ABI/GOES-16 data at 1-km resolution since March 2022, using the processing software provided by HYGEOS
- The input data are level 1 products, the output are level 3 products (maps)
- NetCDF daily files are produced for MODIS and OLCI, and also a 7-day mean file merging MODIS and OLCI. MSI and OLI 20-m data are binned into 300-m pixels to produce a daily merged MSI-OLI file. These daily files are the input of the Mobidrift drift model used to predict the position of the sargassum patches at different time steps.
- As far as ABI/GOES-16 is concerned, 10-mn slots are acquired at ICARE, processed with the HYGEOS software to derive the sargassum index, and are put together in a single file. A daily mean file is also computed



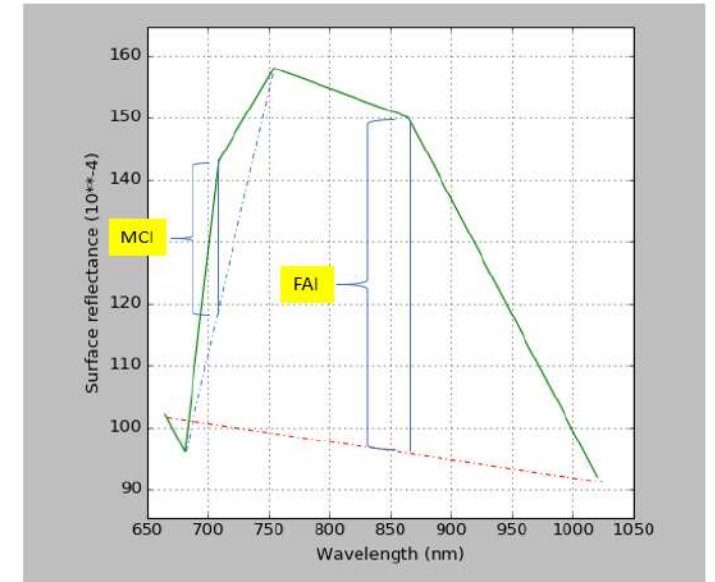
Sargassum Operational Detection Indexes

Brief description of the current sargassum indexes

So far, CLS has been using the Normalized Floating Algae Index (NFAI), which is a normalized version of the FAI proposed by Hu (2009). For that goal, reflectances measured by the instrument are corrected for gaseous absorption and molecular (Rayleigh) scattering

Another index, MCI, was introduced by Gower et al. (2006) and is applicable to OLCI only

For ABI/GOES-16, HYGEOS has designed the FAI Anomaly, which is the difference between the pixel FAI, and the background FAI value of sargassum-free FAI



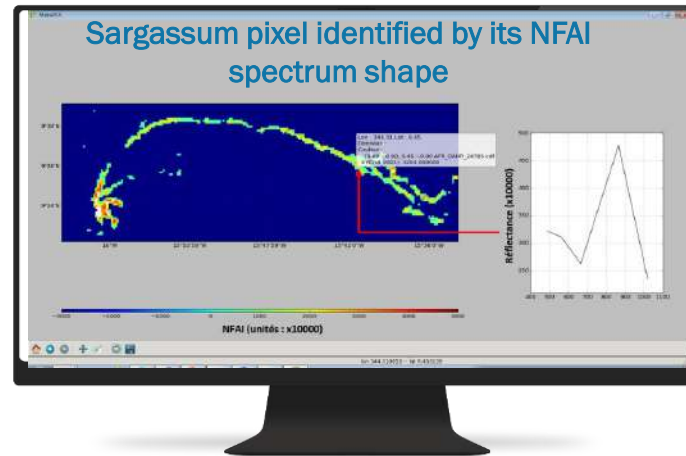
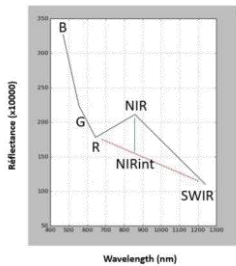
Sargassum detection : NFAI index

QUALITATIVE VS QUANTITATIVE APPROACH: CALCULATION OF FLOATING ALGAE INDEX ON THE OCEAN SURFACE

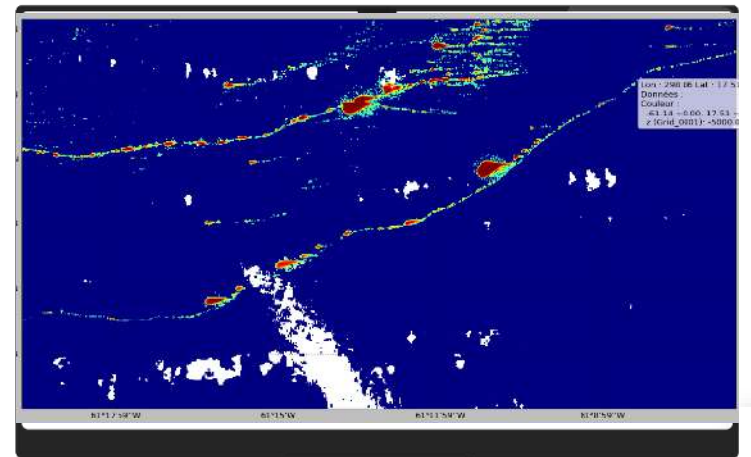
- The reflectance spectrum of sargassum algae increases between the red and infra-red wavelengths, as for land vegetation

DEVELOPMENT OF A SPECIFIC INDEX: NFAI (Normalized Floating Algae Index), inherited from Hu, 2009

$$\text{NFAI} = \frac{\text{NIR} - \text{NIRint}}{\text{NIR} + \text{NIRint}}$$



- Automatic calculation of the NFAI on the 6 optical sensors
- Atlantic Basin (300m resolution) to Island scale (20m resolution)



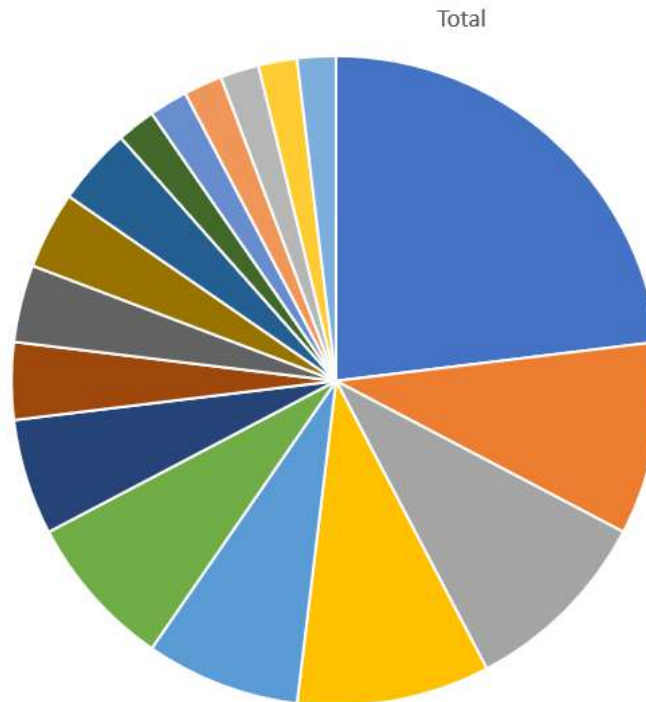
SAMTool users



+60 USERS OF THE SYSTEM SINCE 2019

+12 COUNTRIES ALREADY BENEFITED FROM SAMTool

- Universities, National Parks, National Meteorological Centers, Sargassum collection operators, etc.)



Domain

- University
- National Park
- Private Collection at sea
- National Environmental service
- Environment Company
- National Meteorological service
- National Research Center
- Coast Guards
- Scientist
- Film maker
- NGO
- Regional Fisheries Management
- Marine & Port Authority
- Journalist
- Marine & Port Authority
- Meteorological institute
- Private Company

SODA Objectives

Objectives:

- Build on existing work to **improve Sargassum Operational Detection Algorithms** to produce the best sargassum detection products:
- **Fill a gap** in the European Copernicus Marine Service Catalogue
- Extend the Copernicus Marine Service user community by **sharing the satellite detection products**



SODA Scientific Objectives

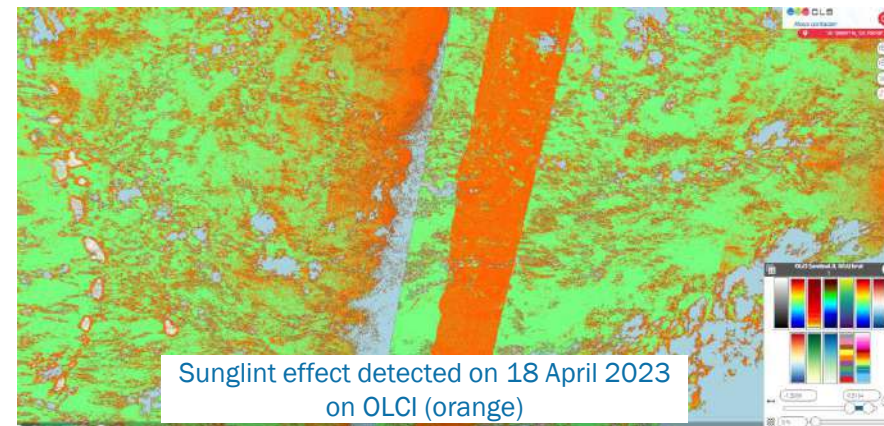
Objectives:

Build on existing work to **improve Sargassum Operational Detection Algorithms** to produce the best sargassum detection products:

- Improvement of the OLCI and MODIS Level 1 to Level 2 processing (sunglint correction)
- Adjacency effects characterization
- MSI noise characterization and filtering
- Improvement of the ABI/GOES-16 sargassum processing
- Propose a multi-sensor product



Adjacency effect detected on 8 March 2023
on OLCI (blue patches)

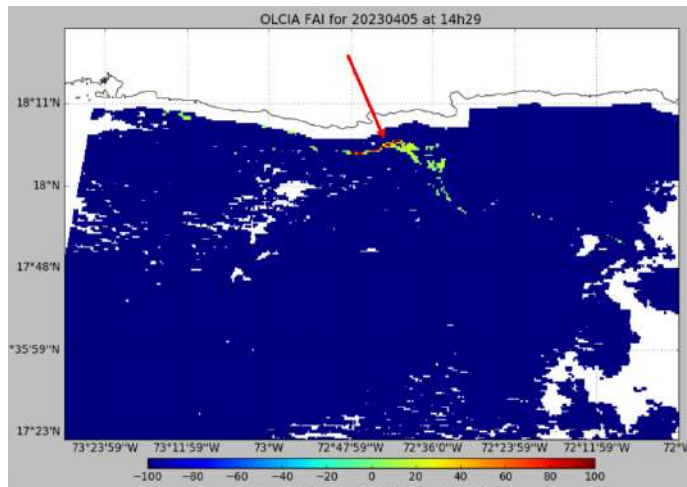


Sunglint effect detected on 18 April 2023
on OLCI (orange)

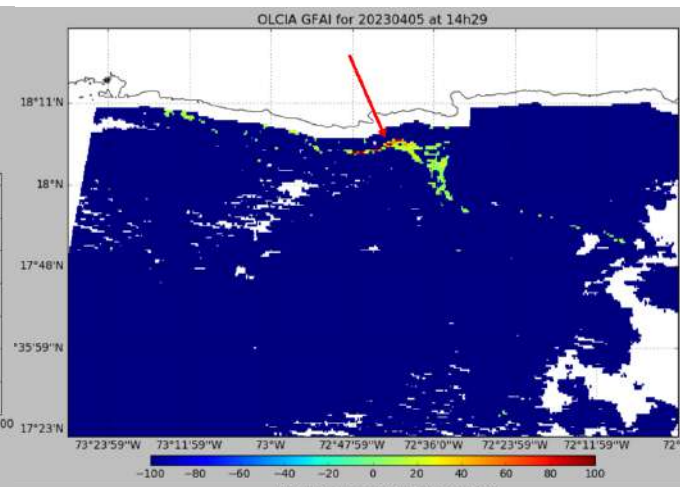
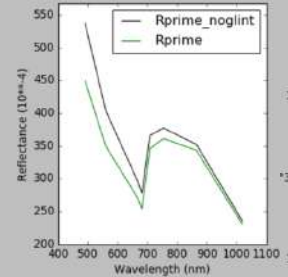
Study of a sunglint correction

OLCI : the goal is to obtain the same sargassum detection between FAI and GFAI **outside** the OLCI/S3A sunglint area, and new sargassum detections **inside** the sunglint area, to be confirmed by OLCI/S3B which overlaps the OLCI/S3A sunglint area.

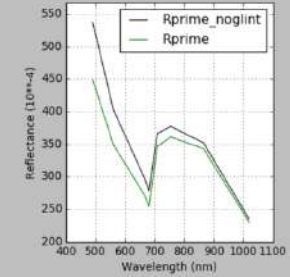
outside



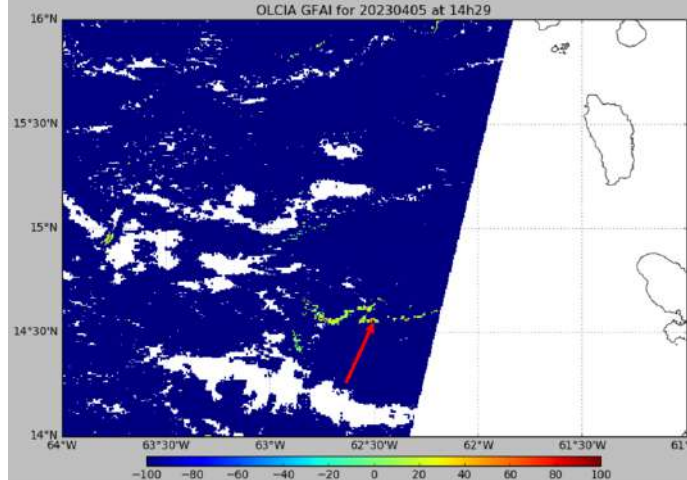
S3A FAI



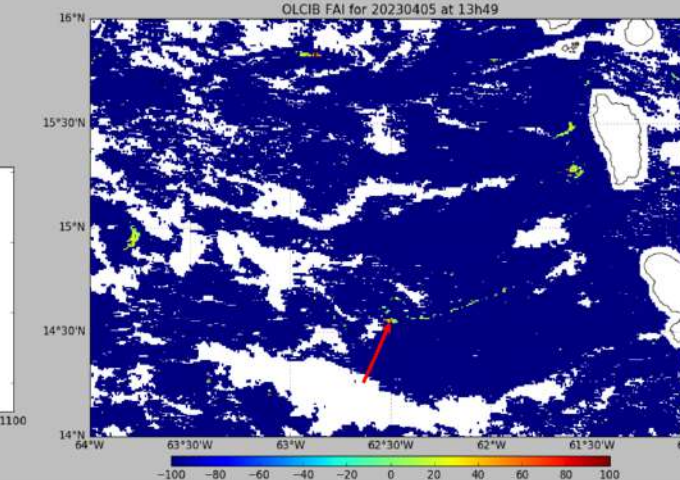
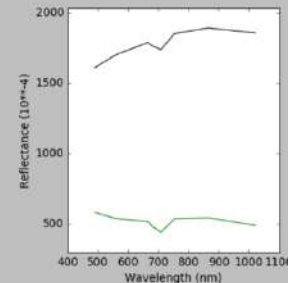
S3A GFAI



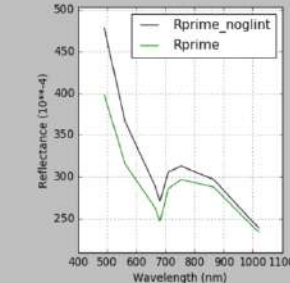
inside



S3A GFAI

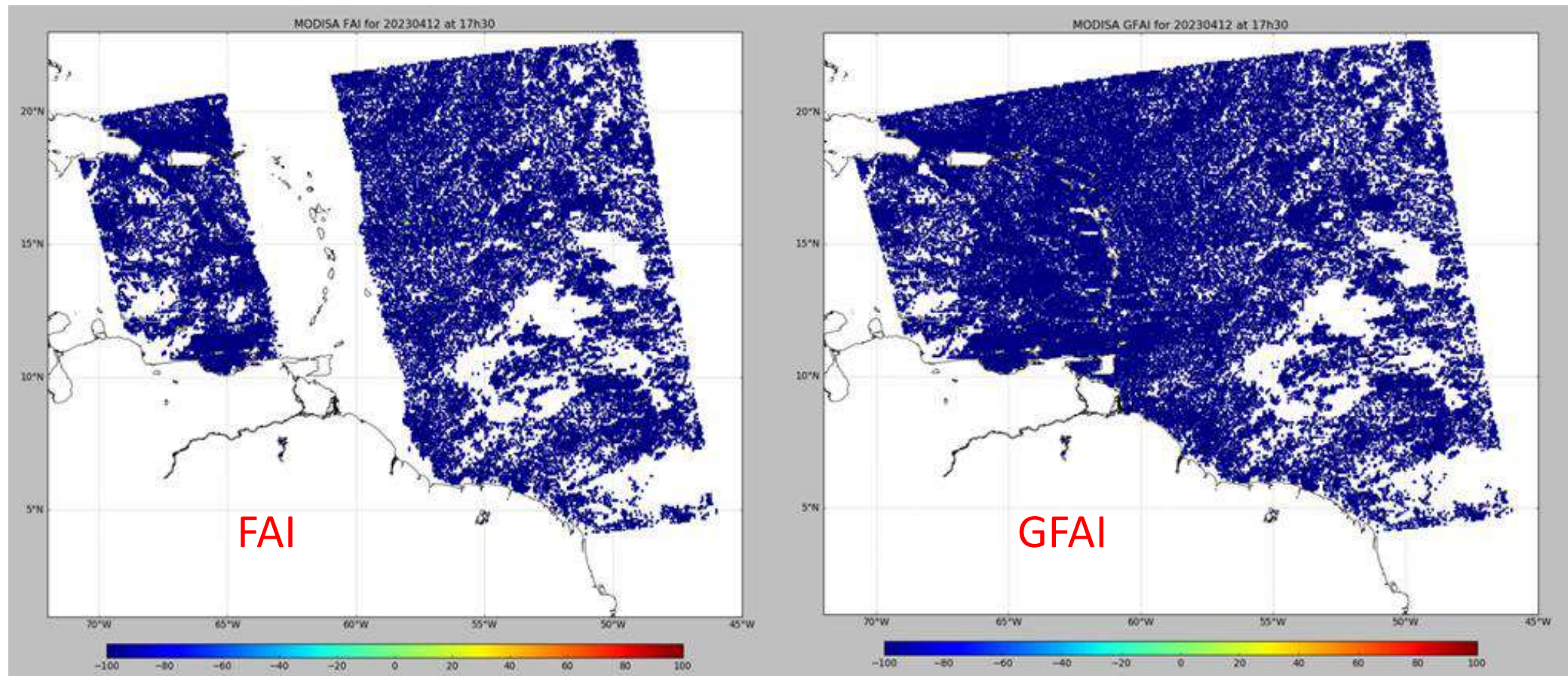


S3B FAI



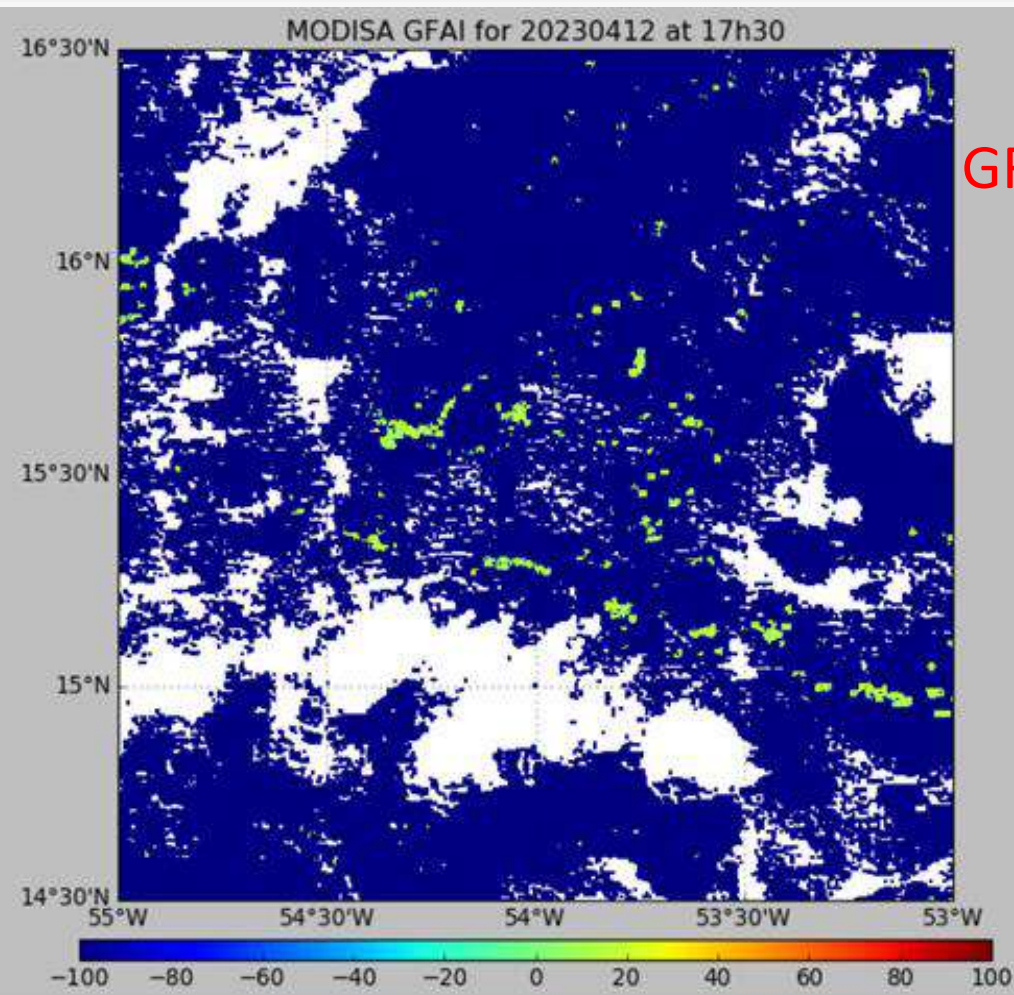
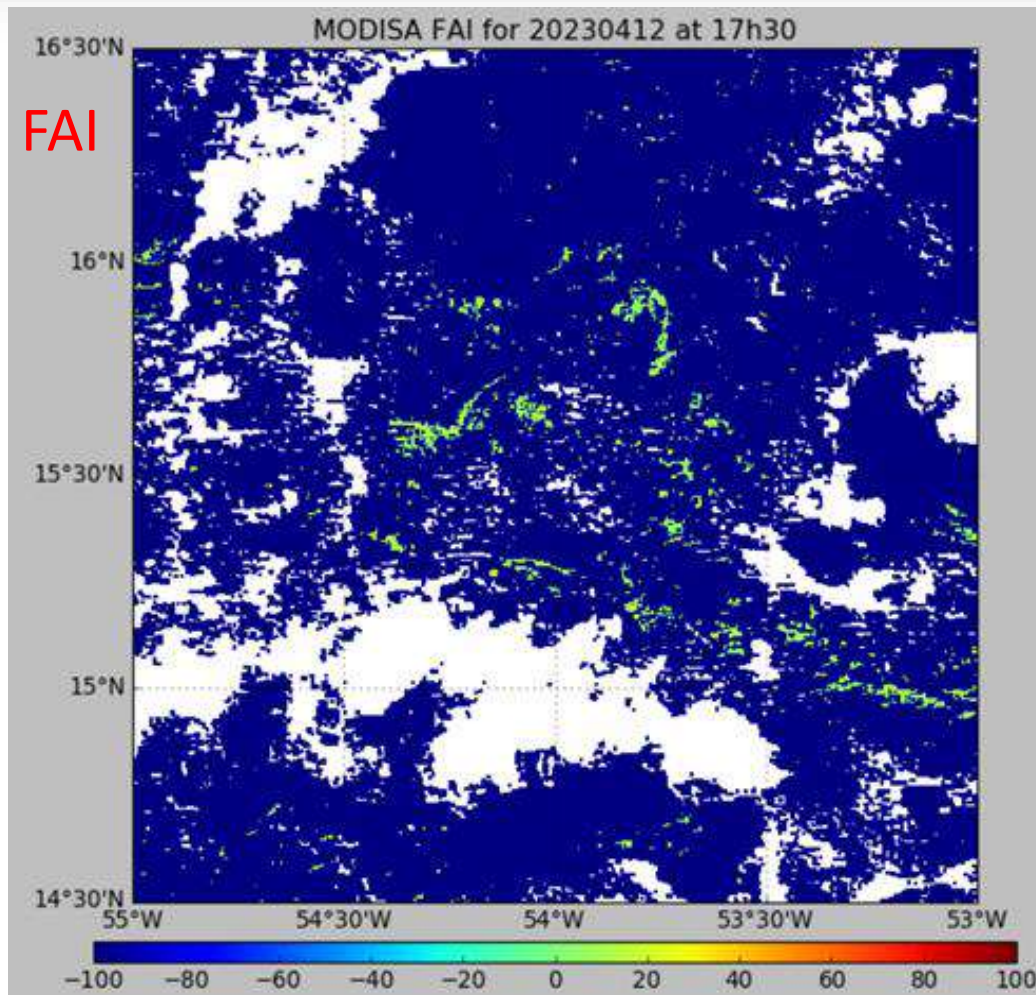
Study of a sun glint correction

MODIS : The goal is to obtain the same sargassum detection between FAI and GFAI **outside** the sun glint area, and new sargassum detections **inside** the sun glint area, to be confirmed by OLCI detections for the same day



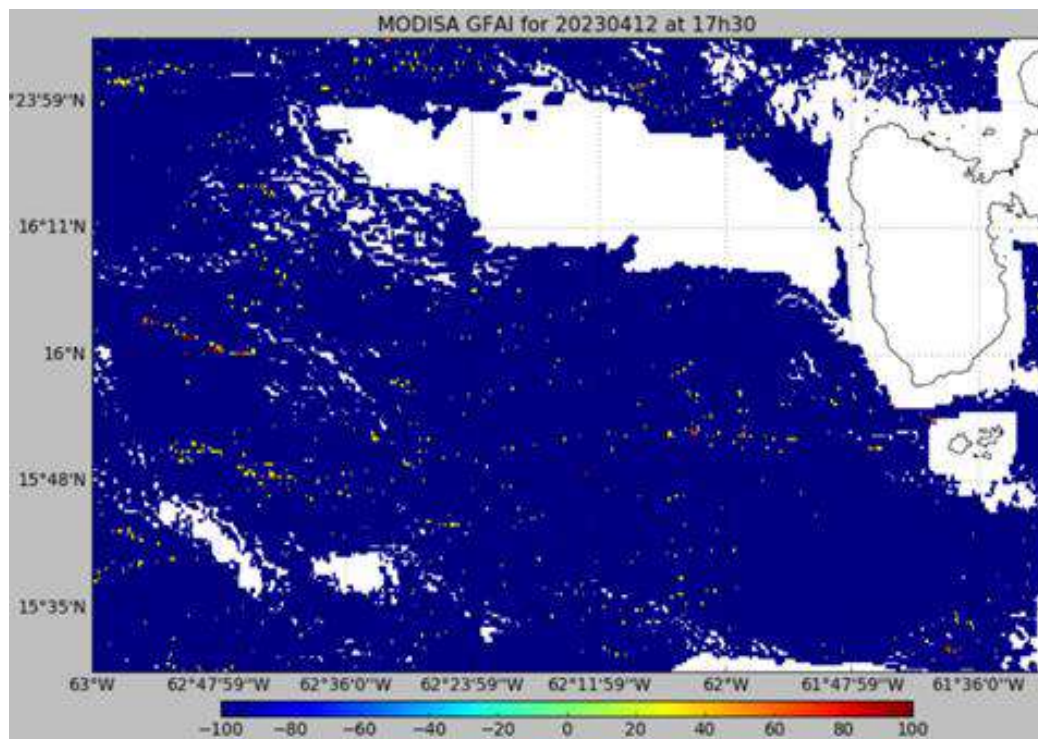
Study of a sun glint correction

Outside
Sun glint

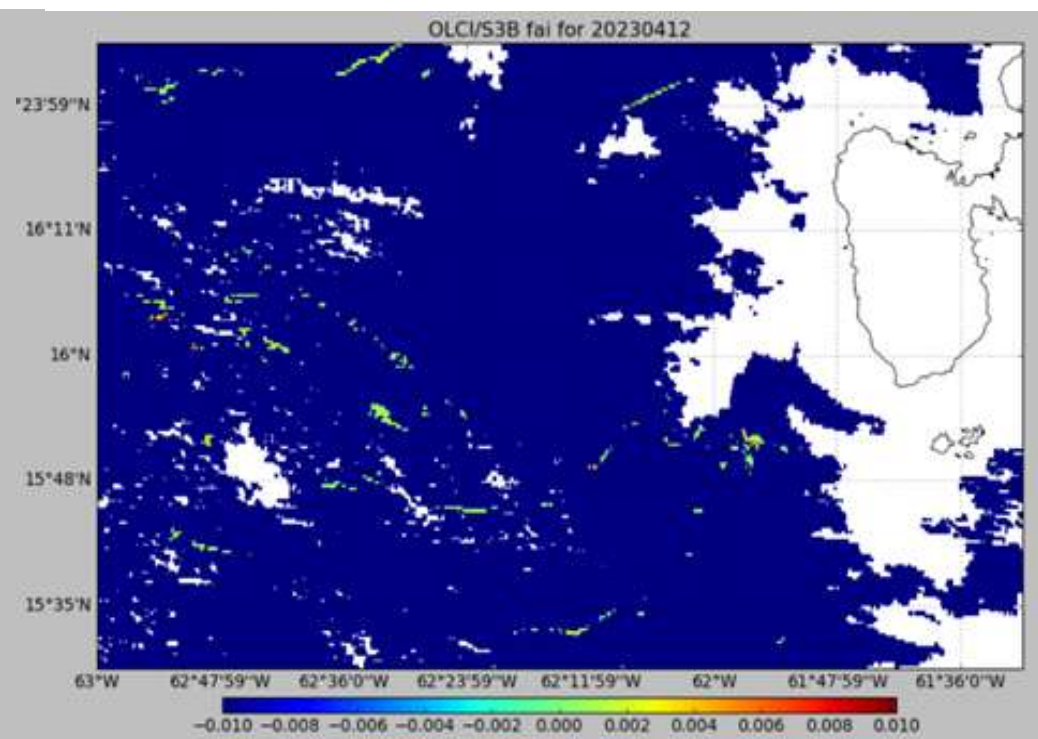


Study of a sun glint correction

MODIS GFAI



OLCI FAI



Inside
Sun glint

Study of a sun glint correction

Conclusions so far :

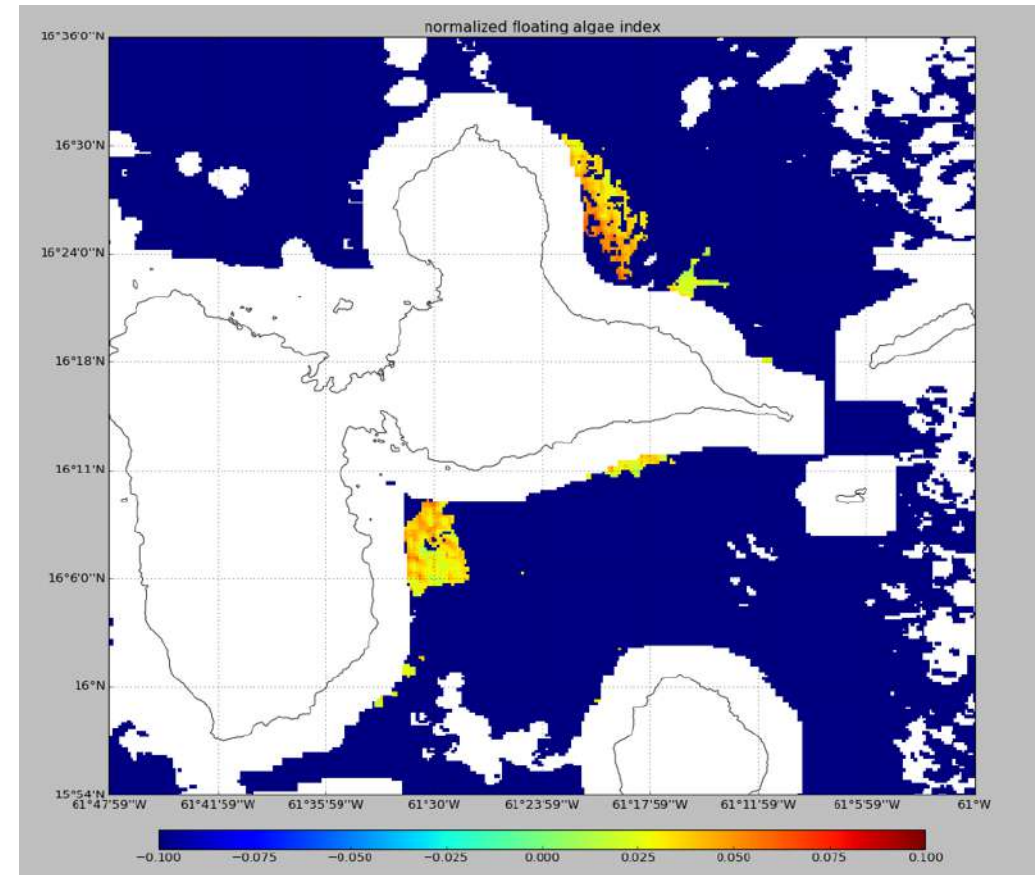
The application of a sun glint correction to the reflectances allows one to reveal true sargassum targets in the sun glint area, thus increasing the satellite ocean coverage for sargassum observation.

However, the cloud masking procedure needs to be revisited in the sun glint area, to avoid false sargassum detections (recognizable by a trained eye). This is particularly true for MODIS, because of its higher sun glint signal.

In addition to the algorithmic tuning, its implementation in an operational processing is ready (CF compliant),

Characterization of adjacency effects on MODIS and OLCI

- This task aims at characterizing the adjacency effects often detected in coastal areas, caused by unrealistic values of NFAI with a spectral signature similar to sargassum rafts, resulting in false sargassum detection



Characterization of adjacency effects on MODIS and OLCI

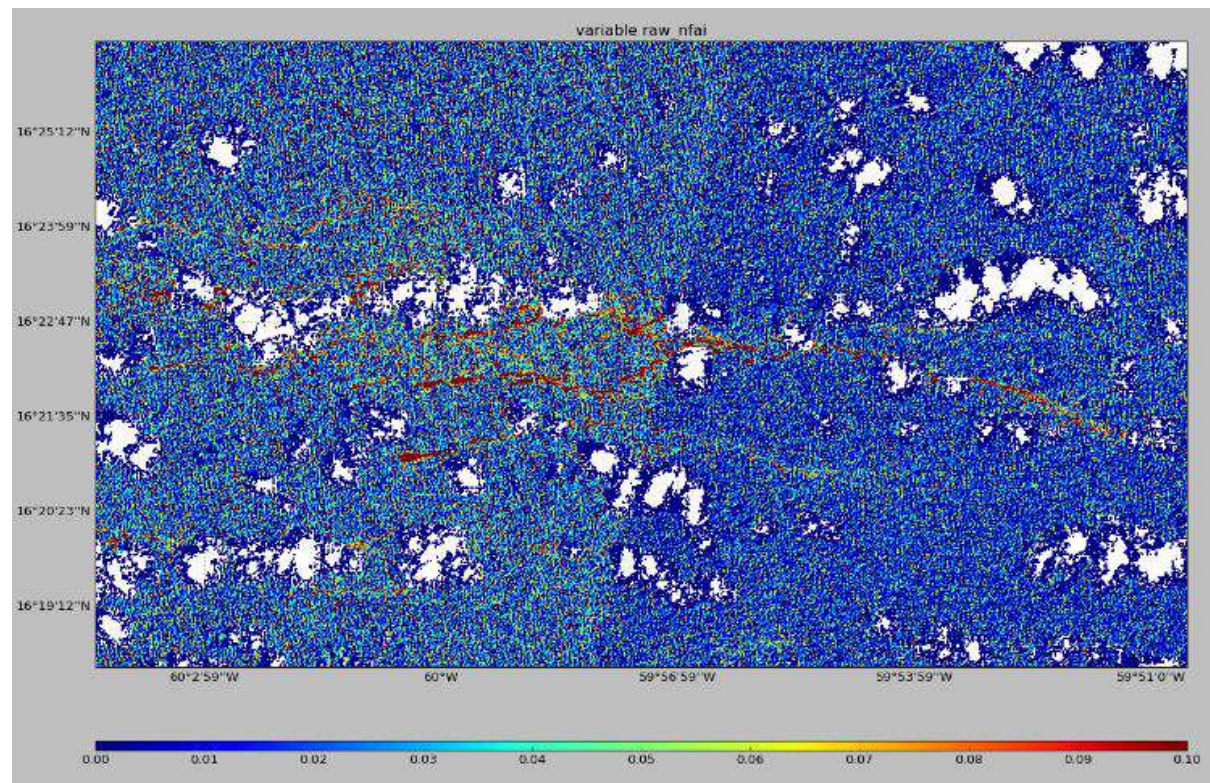
Work has just begun, the foreseen methodology consists in the following steps:

1. Building of an OLCI dataset including all positive NFAI sargassum detections:
 - Acquired in 2022 in (lat: 10N-20N, long: 65W-60W)
 - Located less than 25km from coast
2. Building of a random sample of NFAI detections, manually labelled as true or false observations
3. Exploratory data analysis, including clustering, to highlight outliers and patterns leading to false sargassum detections. The analysis will investigate the dependency with respect to different parameters (spectral signature, geographic position, seasonality, morphology...)
4. Design an editing method (supervised/unsupervised classification) based on the results of 3., with the random sample (2.) to be used as training and/or validation data

WP2300 : MSI noise characterization and filtering

NFAI maps are very noisy when sunglint is present. The actual editing procedure eliminates NFAI pixels if not close enough from high value NFAI pixels

The goal of this task is to improve this procedure, as it may edit true sargassum targets



WP2300 : MSI noise characterization and filtering

Work has just begun, with the three following steps :

Step 1 : try different band combinations to estimate NFAI

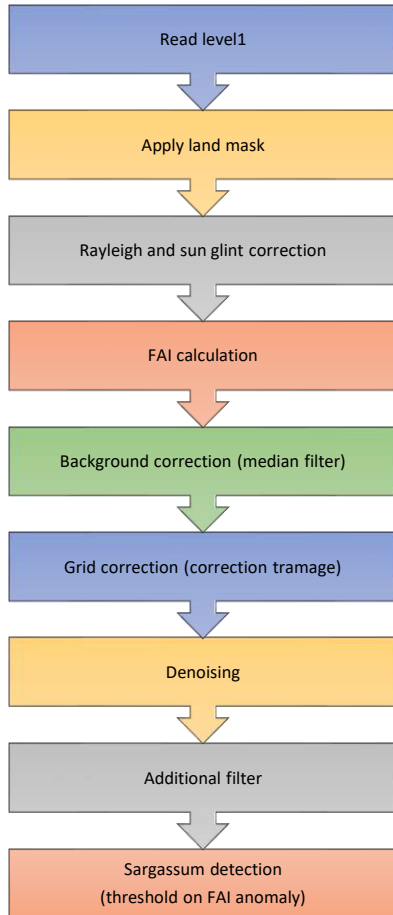
- The Polymer tool is used (Rprime_noglnt reflectances) to look for other band combinations that could be used to minimize the noise present in the NFAI maps output by the CLS operational processing (based on 665, 865 and 1610 nm bands)
- In particular, “red edge” bands (705,740, and 783 nm bands) are being considered

Step 2 : look for denoising methods of the corresponding NFAI maps

- Median filter, gaussian filter, wavelets transforms are being considered

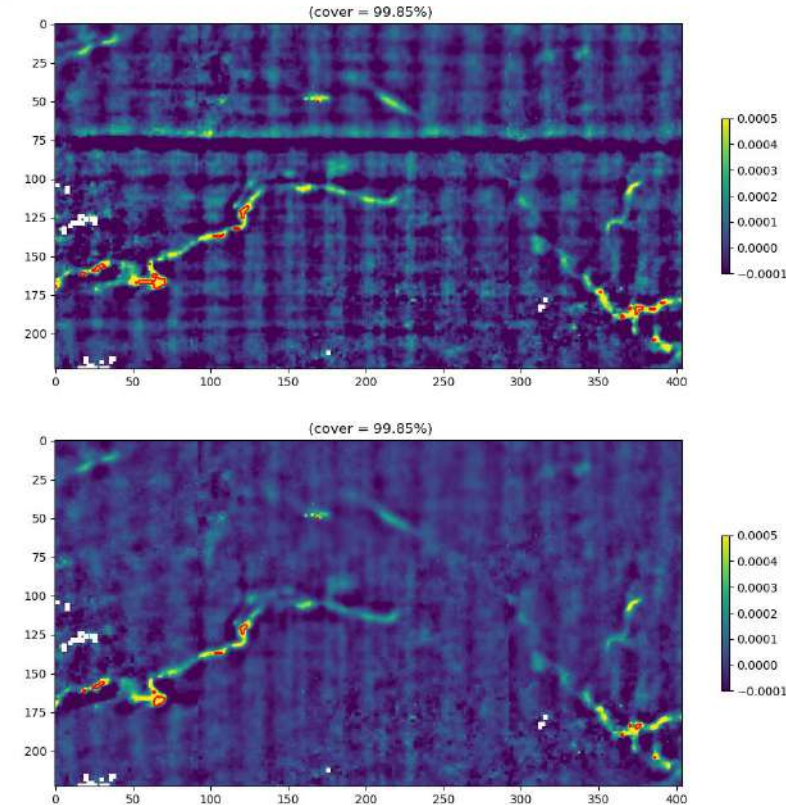
Step 3 : use statistical analyses (mean, standard deviation, noise) before and after denoising to quantify the best performing method/band combination

GOES-16/ABI sargassum processing chain



GOES Sargassum processor flowchart (level 1 → level 2)

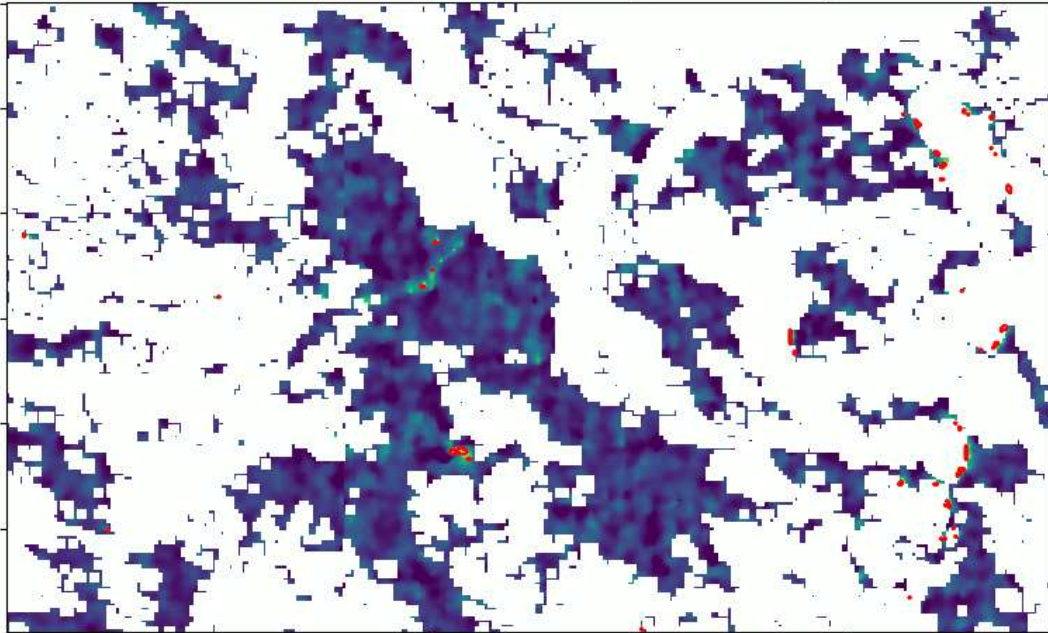
- HYGEOS has developed a sargassum processing chain based on GOES/ABI geostationary data (project funded by CNES)
 - Based on the FAI index (Floating Algae Index)
 - Requires specific developments compared to MODIS, due to the reduced radiometric performance of the GOES instrument and the low signal that we aim to detect
 - Grid correction: see example on the right
 - Denoising: uses the Total Variation Chambolle method
 - Sargassum detection minimum threshold: estimated to ~1.3% fractional coverage for GOES on a single slot (MODIS threshold : 0.23% fractional coverage)
- This product is being further characterized and improved in SODA



Example of GOES sargassum product without (top) and with (bottom) grid correction

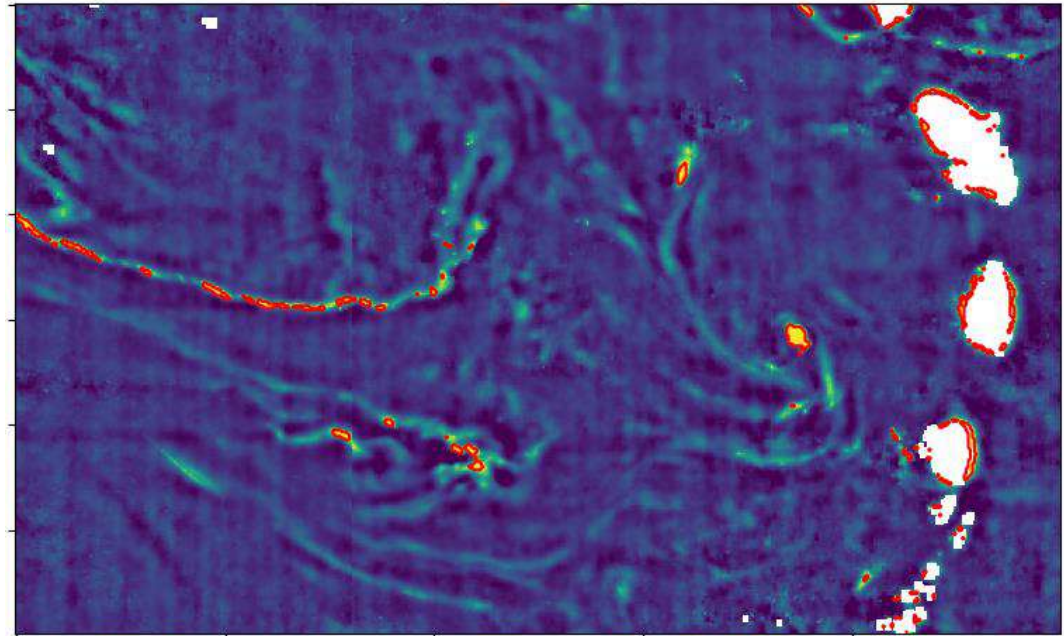
Example of GOES-16/ABI sargassum products

2022-06-17T12:05:06.600000000 (cover = 36.46%)

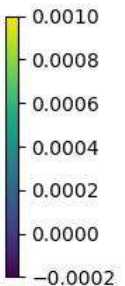


Sample daily animation (2022-06-17) of Sargassum index (FAI anomaly). Red areas show the boundaries of the detected sargassum.

(cover = 97.94%)



Daily composite (2022-06-17)



The daily composites greatly improve the spatial coverage, and allow for sargassum drift prediction.

Improvement of ABI/GOES-16 sargassum products in SODA

- Correction for false sargassum detections in coastal areas
 - Adjacency effect from vegetation increases the signal in the NIR and leads to increasing FAI near the coasts
 - Development of a vegetation adjacency correction:
 - We are developing a per-pixel monthly correction by temporal median, based on multi-year analysis
 - This correction will be applied after grid correction ; the impact on false coastal sargassum detection will be evaluated
- Analysis of the temporal (daily and seasonal) variability of the FAI.
Objective: improve temporal consistency, thresholding capacity and temporal averaging.
 - A correction for the atmospheric transmission has been implemented and is being evaluated

Next steps

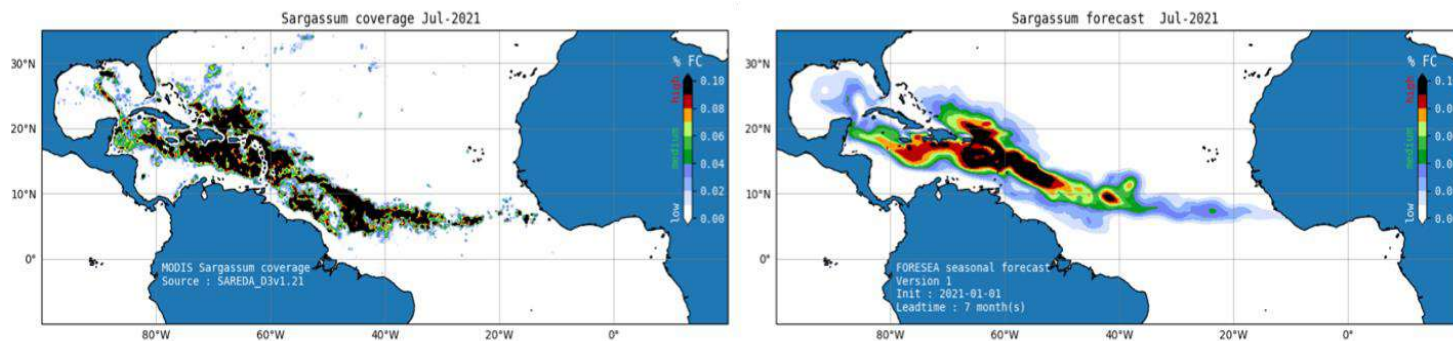
Prepare and organize the transfer to Copernicus Marine Service

During the transition: **Operational production will be maintained until 2024 with the SCO SeSAM project:**

→ Daily detection products will shortly be used for operational seasonal forecast

SeSAM is proposed under the Space Climate Observatory Program sponsored by CNES

It will produce sargassum seasonal forecast (operationalisation of the ANR ForeSea project), using operational sargassum detection produced by CLS





Questions



<https://marine.copernicus.eu/about/research-development-projects/2022-2024/soda>
<https://datastore.cls.fr/products/sargassum>



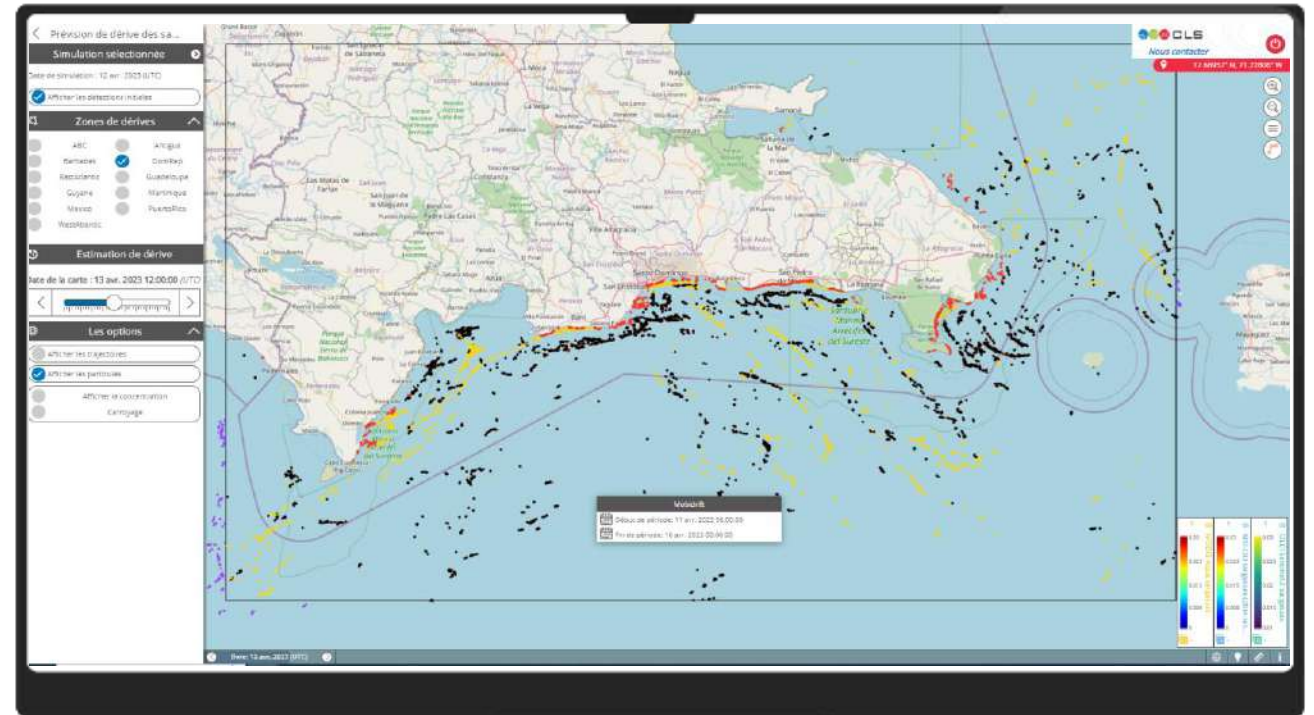
msutton@groupcls.com; shaouet@groupcls.com



Daily monitoring of sargassum influxes and immediate landings

Anticipate sargassum influxes and landings

- Public information
- Coastal management & cleaning operations



Bulletin de surveillance et de prévision
d'échouement des sargasses pélagiques
pour la Martinique



Daily support for collection operations

Localise sargassum mats in open ocean

- Detect and monitor their drift
- plan for collection operation

