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Sargassum proliferation in the Western Atlantic: What impacts and results for the French West Indies ?

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INTRODUCTION

In 2018, in the French West Indies (AF), the massive influxes and strandings of sargassum were unprecedented: dozens of bays were filled in a few hours.

A new regional phenomenon, whose origin is not completely scientifically elucidated.

These strandings result in high biomass accumulations, leaving the authorities without immediate responses with undersized means in view of the large of the ecological and socio-economic damages induced.

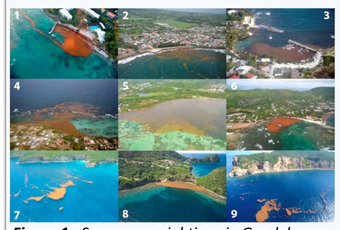
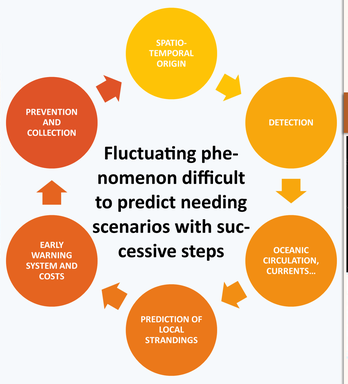


Figure 1 : Sargassum sightings in Guadeloupe Island (French Antilles), from helicopter survey on 22th May 2015 (Photos courtesy of F. Mazéas). 1–5: Guadeloupe. 6: Désirade. 7: Marie Galante. 8–9 Les Saintes [1].



SURFACE OCEANIC CIRCULATIONS IN THE STUDIED AREA: IMPACTS OF AMAZON RIVER?

At large scale, the main currents are [5]:

- The North Atlantic Equatorial Current (NC) from the Atlantic,
- The North Brazil Current (NBC) induced by the South Equatorial Current (SEC).

The NBC splits in two currents: the Guyana current (GC) along the shelf , and the North Equatorial Countercurrent (NECC).

The current rings of about a hundred kilometers in diameter generated by the retroflexion of the NBC.

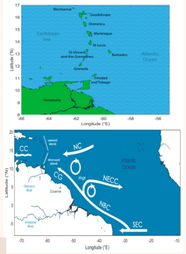
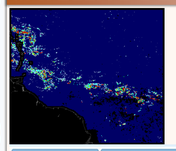


Figure 2 : Studied area

SATELLITE DETECTION



Sensor	Revisit Frequency	Spacial Resolution (m)	Spectral bands for floating algae (nm)	Spectral bands for color index	Period
MODIS/Terra	Near daily	1000	667, 748, 869	469, 555, 645	2000 — present
MODIS/Aqua	Near daily	1000	667, 748, 869	469, 555, 645	2002 — present
VIIRS	Daily	750	671, 745, 862	443, 551, 671	2012 — present
Landsat 8 OLI	16 day	30	655, 865, 1609	443, 561, 655	2013 — present

Table 1 : The table shows the four satellite sensors that are currently used in Sargassum Watch System (SaWS), with the first three sharing similar characteristics.

TEMPORAL VARIABILITY

Inter-annual variability :

In the French Antilles, strandings are grouped over 8 to 10 successive years [6]. Figure 6 shows observations of strandings during four years, with high intensities in 2015, 2018 and low intensities in 2014, 2016-17.

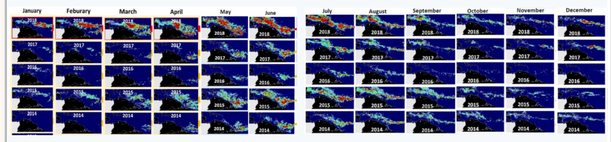


Figure 6 : Monthly mean Sargassum density maps for bloom years between 2014 and 2018 [8].

Annual variability :

The episodes increase in number and intensity from March onwards, peak in May-June and decrease drastically in September.

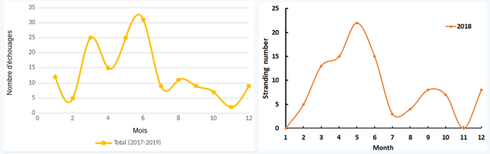


Figure 7 : Monthly number of strandings, left for 2017-2018 and right for 2018.

STRANDING SITES: THE CASE OF GUADELOUPE

1. Diversity of stranding conditions due to the typology of the impacted areas (beaches, mangroves, enclosed bays...), [9].
2. Windward coasts are most impacted,
3. Numerical forecast of stranding are quasi-similar [10].

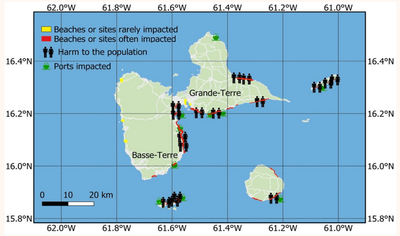


Figure 8 : Recurrent stranding sites observed since 2014-2015 [9].

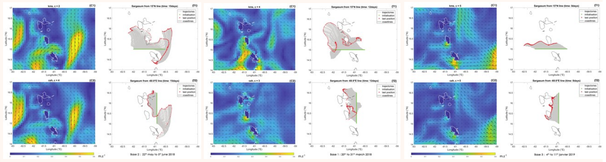


Figure 9 : Numerical forecasts of strandings (red points) calculated according to cluster type and offshore sources (green points).

MULTISCALE DETECTION OF SARGASSUM DISTRIBUTION: SATELLITES AND NUMERICAL MODELS

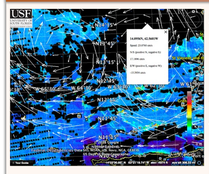


Figure 3: Satellite image and surface currents of the hycom hybrid ocean model.

System 1: Satellite-based Sargassum Watch System (SaWS)

1. Download AFAI VIIRS/MODIS satellite products, Virtual Antenna System (VAS),
2. Identify sargassum by computing the Alternative Floating Algae Index (AFAI) [2],
3. Addition of surface currents from the global model HYCOM,Maping and interpretation.

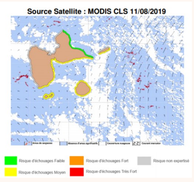


Figure 4 : Map from the monitoring and forecasting bulletin for the stranding of pelagic "Sargassum" pelagic species, Guadeloupe.

System 2: Bulletin for monitoring and forecasting the stranding of pelagic " Sargassum " species

1. Download AFAI VIIRS/MODIS satellite products, Virtual Antenna System (VAS),
2. Identify sargassum computing the Alternative Floating Algae Index (AFAI) [2,3] and color index [4], on Sentinel 2 and Sentinel 3 images,
3. Addition of surface currents from global models: HYCOM, Mothy,
4. Expert quality control,
5. Maping and interpretation,

- Phytoplankton artifact,
- Overestimations of sargassum mats induced by low-resolution images (VIIRS/MODIS at 1 km).

NEW PROPOSAL: DETECTION OF ATTRACTORS BY CLUSTERING

To explore the sensitivity of daily outputs giving surface current velocities and find recurrent patterns we will use unsupervised learning methods: K-means and CAH algorithms. The goal is to find similar spatio-temporal fields into k clusters using the Euclidean distance for K-means and the Ward method for CAH respectively.

Clustering entry matrix : 154 daily observations of strandings, 29 May 2017 to 15 March 2019 [6], 14,279 components or meshes containing u,v, surface ocean current. Daily and global operational ocean forecast outputs of the PSY4V3R1 Mercator analysis system, at 1/12° in 3D, which integrates version 3.1 of the NEMO ocean model, with some bias reduction [7]. Data include assimilation from both multi-instrument in situ observations and satellite remote sensing observations, Average time fields for the currents using components U and V of (depth of 50 cm).

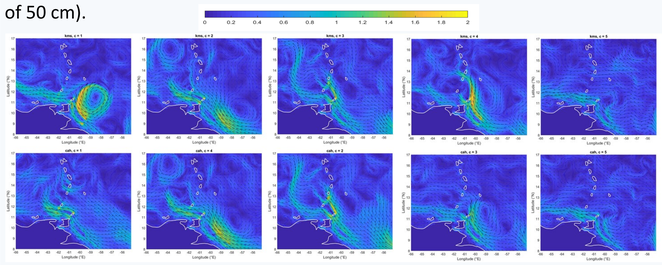
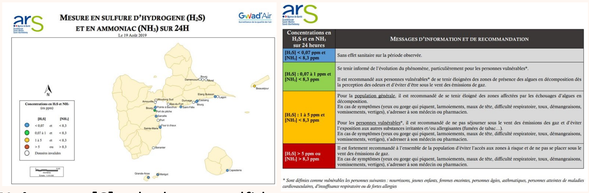


Figure 5 : Six spatio-temporal fields of typical currentological situations lead to massive stranding on the eastern Caribbean coasts.

HEALTH IMPACTS



Nuisances [6] : hydrogen sulfide (H2S), ammonia, dimethyl sulfide and mercaptan.

Level for populations:

- Olfactory discomfort for 0.2-0.3 ppm,
- Temporary health problems for 20-30 ppm or continuous exposure of 5 ppm for 24 hours,

Corrosion of metals.

RISKS

Chronic exposure, unknown health impacts with a deterioration in quality of life during mass strandings.

CONCLUSION

Improve and complete methods for detecting and modelling the arrival and stranding of sargassum (small-scale modelling).

Few effective collection and processing actions that will have to evolve and be selected on the basis of technical, economic and environmental criteria to reduce impacts (human health...).

Include the risk of sargassum strandings and scenarios with successive steps, in a plan to prevent foreseeable natural hazards.

CASES OF A CRISIS YEAR: ESTIMATED VOLUMES [6,10]

- Crisis year: >=15 strandings/year or 6,000 m^3 per day to be collected in the stakes zone.
- Incorrect estimation of the volumes of Sargassum to be collected, linked to the diversity of stranding conditions, the state of the algae and the plurality of stakeholders.
- **Estimated annual total :** 500,000 m^3 or 80 to 85 collection days per year.

Figure 10 : Sargassum collection by the municipalities

		PICK-UP m^3/j	COLLECTION m^3/j	DYE PENETRANT m^3/j
CRISIS YEAR	GUADELOUPE	6 900	345 000	113 850
	MARTINIQUE	6 000	300 000	99 000
INTERMEDIATE YEAR	GUADELOUPE	6 900	69 000	22 770
	MARTINIQUE	6 000	60 000	19 800

SOCIO-ECONOMIC IMPACTS

- Reduced attractiveness and tourist activities,
- Obstacle to artisanal activities (fishing, cabotage, shipbuilding...),
- Declarative acts but few indicators for estimating financial losses.

Crisis management costs in a : €10 million.

Figure 11 : Example of Obstruction of the fishing port of Terre de bas, les Saintes (2016).

		PICK-UP k€	TRANSPORT k€	TREATEMENT k€	TOTAL COST k€
CRISIS YEAR	GUADELOUPE	5 934	586	646	7.166
	MARTINIQUE	8 100	495	87	8.682
INTERMEDIATE YEAR	GUADELOUPE	1 505	114	228	1.847
	MARTINIQUE	1 740	99	10	1.849

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