AVISO+ Satellite Altimetry Data

Users Newsletter

#20

June 2022

SUMMARY

Jason-CS/Sentinel-6

The new reference altimetry mission

Gilles Tavernier and Project Team, CNES

The **Jason-CS/Sentinel-6 Michael Freilich** satellite was successfully launched on **21 November 2020** from Vandenberg by a SpaceX Falcon 9 rocket.

This is the eighth in-flight satellite of the COPERNICUS constellation and the first of the new Jason-CS/Sentinel-6 series dedicated to the continuous measurement of ocean topography and the climate, taking over from the emblematic TOPEX/Jason altimetry series. The satellite reached its nominal orbit on 17 December 2020, 30 seconds apart from Jason-3 as planned, for a tandem phase. The two satellites took near-simultaneous measurements during the mission's checkout phase to allow engineers to precisely calibrate the Jason-CS/Sentinel-6 Michael Freilich instruments.

Developed by ESA and Airbus Friedrichshafen, Jason-CS/Sentinel-6 is built around a spacecraft bus similar to that used for CryoSat. The main mission instrument is the **Poseidon-4 altimeter** built by Thales Alenia Space, which measures the range from the satellite to the ocean surface in both Low Resolution (LR) and High Resolution (HR) modes. The satellite is also carrying a **GNSS-POD** (Precise Orbit Determination) receiver developed by RUAG, along with a CNES-designed **DORIS** orbit determination system. NASA/JPL developed and supplied a **GNSS-RO** (Radio-occultation) receiver, a **Laser Retroreflector Array** (LRA) and an **Advanced Microwave Radiometer** – Climate Quality (AMR-C) featuring a new High-Resolution Microwave Radiometer (HRMR-RF) and a Supplementary Calibration System (SCS).

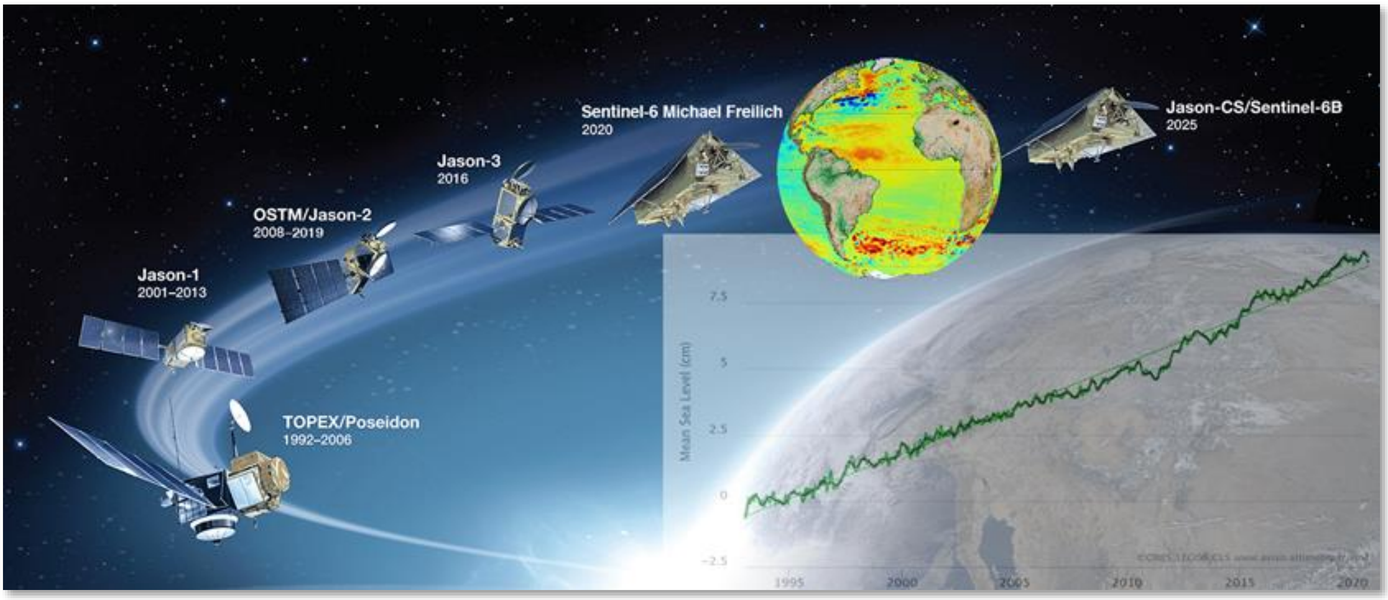


Fig.2 : Ocean topography missions and mean sea level rise in centimetres since 1992 (© NASA, CNES, Legos, CLS)

In-Orbit Verification phase

The Satellite In-Orbit Verification (IOV) checkpoint organised by ESA took place on 26 and 27 January 2021.

All tasks were completed and most of the corresponding data were collected, allowing analyses of the results and preparation of the final report scheduled for delivery in March.

The switch-on and check-out of the Satellite In-Orbit platform and instruments were successful. Numerous data have been collected and analysed by the project team, industry and other partners.

All the calibration activities planned as part of the Satellite IOV Phase have been completed and checked in flight, with the exception of the post-calibration checks for star tracker 1 alignment. This operation requires all three star tracker heads to be on simultaneously, which was possible only in July 2021 when none of the star tracker heads were in sun blinding conditions.

All planned measurement verification activities have been completed, paving the way for the commissioning and Cal/Val activities. All the components of the measurement system for the primary mission have satisfied requirements.

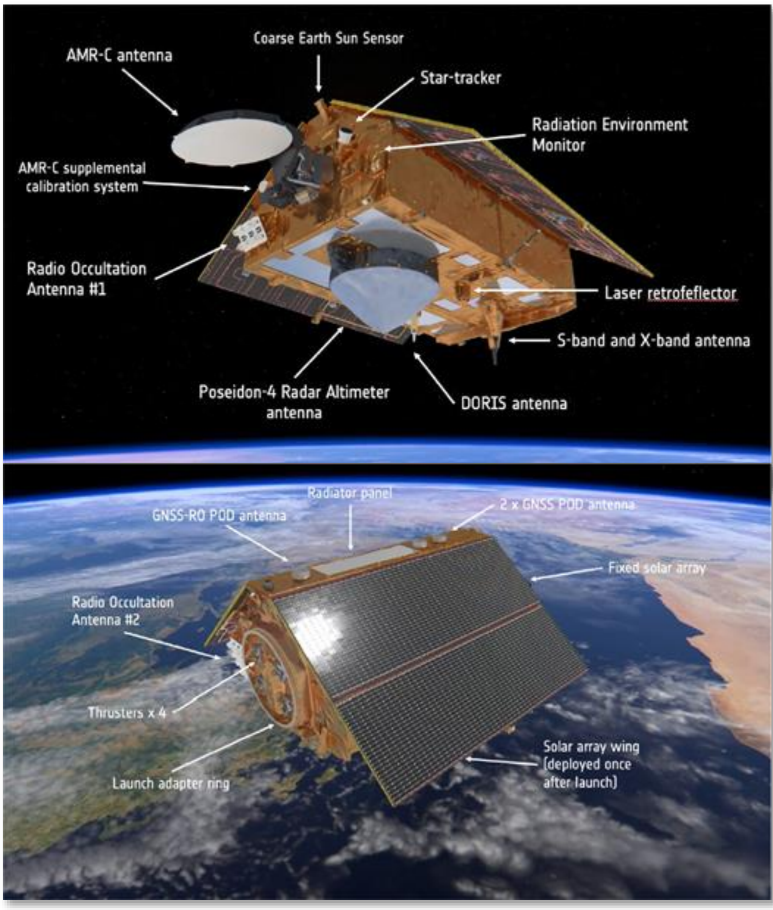


Fig.3 : External features of the Jason-CS/Sentinel-6 Michael Freilich satellite (© ESA, Airbus).

System In-Orbit Verification Review

The System In-Orbit Verification Review (SysIOVR) organised by EUMETSAT in June 2021 confirmed the results of the system ramp-up, demonstrating that mission operations can be adequately supported, that the relevant product validation meets end-user requirements and that the system verification process has been completed, showing the system to meet requirements.

First data public release

This paved the way for the public release of the first data from Jason-CS/Sentinel-6, low-rate Near-Real-Time (NRT) and Short-Time-Critical (STC) data products.

Among a number of Cal/Val activities, ESA, CNES and CLS monitored the **power decay** of the Poseidon-4 High Power Amplifier (HPA). In July 2021, the power decrease was estimated at -0.76 dB/year with a total loss of -3dB over five years.

A Joint Steering Group meeting held on 2 September 2021 decided to switch Altimeter sides (from A to B), a proactive measure considered as low risk, in order to mitigate a potentially costly loss/discontinuity of the 30-year sea-level climate data record should it be necessary to switch out of the tandem phase. The objective was to calibrate side B of Poseidon-4 during the tandem flight with Jason-3. Given that precise calibration requires six months of tandem flight, the period had to be extended to the end of March 2022. This request was endorsed by the Jason-3 Joint Steering Group meeting on 25 October.

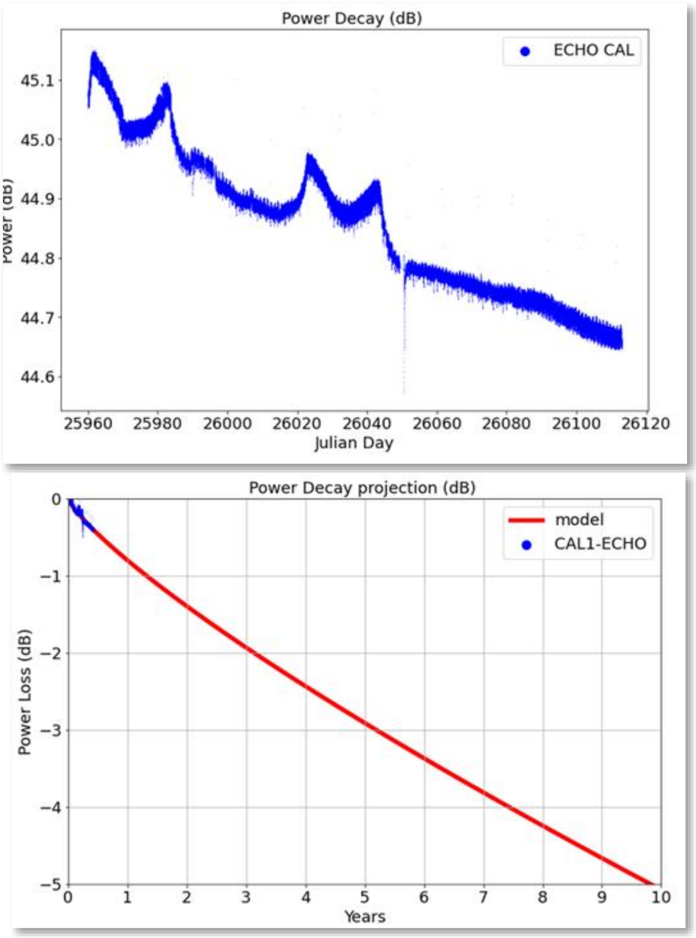


Fig.4 : HPA power decay since launch with projected figures (© CNES, CLS).

The switch to Poseidon-4 Side B was carried out on 14-15 September 2021.

System In-Orbit Commissioning Review

The System In Orbit Commissioning Review (IOCR) organised by EUMETSAT in November 2021 confirmed the operational qualification of the operational infrastructure, including re-processing capability and Partner contributions, with the completion of all activities as described in the work packages set out in the Commissioning Plan. The review also confirmed the compliance of product quality and operational availability (including completeness and timeliness) with the End User Requirements Document at the end of the commissioning phase.

This paved the way for the public release of new data from Jason-CS/Sentinel-6, low-rate Non-Time-Critical (NTC) and high-rate Near-Real-Time (NRT), Short-Time-Critical (STC) data products. Access from the **Product Sheet** on AVISO+ website.

ESA, CNES and CLS continued to monitor the power decay of the Poseidon-4 High Power Amplifier (HPA) on side B, comparing it to the figures observed on side A. In March 2022, the power loss within 4.7 years (dB) was estimated to be -2.5 dB or -2.1 dB depending on the method used (See Fig. 5, next page). The projected Signal-to-Noise ratio (SNR), taking into account a period of ~4.6 years on side B (mission length of 5.5 years with side A) was ~14.7 dB at end-of-mission, compared to a requirement of SNR>11dB @sigma0=11dB.

Concerning Poseidon-4 instrument performance, long-term PDAP monitoring shows that even though Poseidon-4 is temperature-sensitive, all the instrument specification requirements are met. LR requirements (Table 1, next page) are fulfilled for all latencies, and data products show good continuity with Jason-3. Inter-mission bias is well characterised after about six months, with Global Mean Sea Level (GMSL) data expected to show continuity with Jason-3, although a longer time series is needed to fully demonstrate this.

(see next paragraph on page 5)

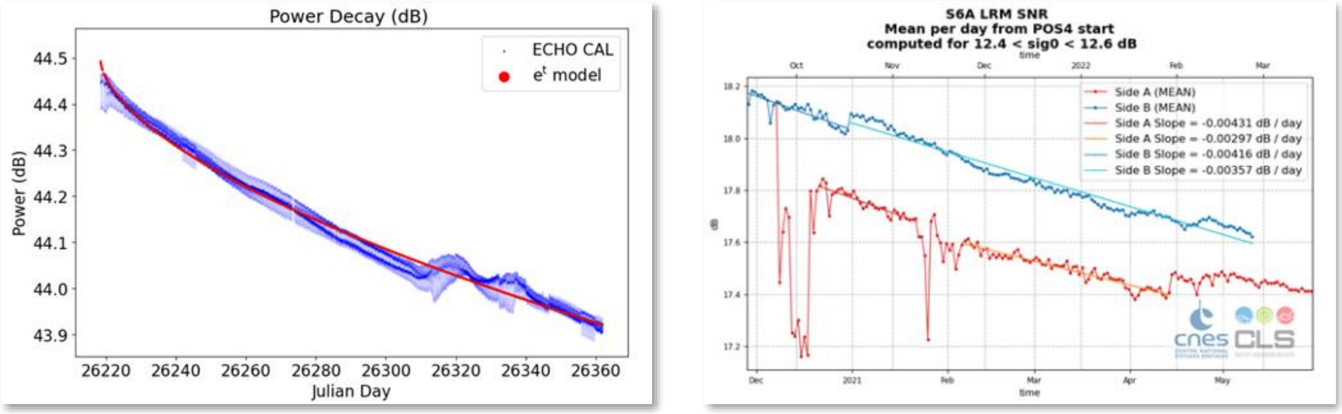


Fig.5 : HPA power decay since launch with projected figures (© CNES, CLS).

	NRT 3 hours	***STC 36 hours***	***NTC 60 days***	***Observed***
Altimeter noise (Ku)	[1.2, 1.5, 2.4, 3.2]cm at [1, 2, 5, 8] m SWH			[1.25, 1.44, 1.93, 2.41] cm
Altimeter noise (C)	[4.5, 5.7, 9.1, 12.0]cm at [1, 2, 5, 8] m SWH			[4.5, 5.2, 7.9, 10.1] cm
Ionosphere	0.5 cm			0.1 cm
Sea State Bias	2.0 cm			0.6 cm (compared with JA3)
Dry troposphere	0.8 cm	0.7 cm	0.7 cm	Based on historical analysis
Wet troposphere	1.2 cm	1.2 cm	1.0 cm	0.2 cm (compared with JA3) 0.8 cm (compared with ECMWF)
Altimeter range RSS	2.93 cm	2.90 cm	2.83 cm	< 2.5 cm with bias < 1 cm
RMS Orbit (Radial component)	5 cm	2 cm	1.5 cm	NRT: < 2 cm STC: ~1 cm NTC: ~0.8 cm
Total RSS sea surface height	5.79 cm	3.53 cm	3.20 cm	NRT: 3.3 cm *(improved in latest L2 processor)* STC: 2.8 cm *(improved in latest L2 processor)* NTC: 2.5 cm
Significant wave height	15 cm + 5%			Far below 15 cm + 5%
Wind speed	1.5 m/s			0.5 m/s
Sigma naught	0.3 dB			0.18 dB

Table 1 : LR Error Budget based on input from the Sentinel-6 Validation Team.

	NRT	STC	NTC 60 days	Observed
Altimeter noise (Ku)	[0.7, 0.8, 1.3, 2.0] cm at [1, 2, 5, 8] m SWH			[0.62, 0.75, 1.46, 2.42] cm Sensitivity to swell at higher SWH
Sea State Bias	2.0 cm			< 5 mm
Altimeter range RSS	2.64 cm	2.61 cm	2.53 cm	Fulfilled in STC and NTC (NRT to be assessed)
Total RSS sea surface height	5.65 cm	3.29 cm	2.94 cm	NRT: 3.84 over Pacific Ocean (5.44 cm global) STC: 2.18 cm over Pacific Ocean (3.81 cm global) NTC: 2.15 cm over Pacific Ocean (3.78 cm global)
Significant wave height	15 cm + 5%			KO but way forward identified (correction for Vertical Wave velocity)
Wind speed	1.5 m/s			Fulfilled
Sigma naught	0.3 dB			< 0.15 dB

Table 2 : HR Error Budget based on input from the Sentinel-6 Validation Team.

HR requirements (Table 2, above) are also satisfied for all latencies, except for Significant Wave Height (SWH), which is overestimated at high wave heights owing to vertical wave velocity impacts (an issue recognised in SAR altimetry). HR data on-board compression, known as Range Migration Correction (RMC), was also assessed and was seen to be very similar to HR Raw data performance over the open ocean and in coastal regions.

The new Reference Altimetry Mission

Following the recommendations made by project scientists at the last Ocean Surface Topography Science Team meeting on 24 March 2022, CEOS Ocean Surface Topography Virtual Constellation (OST-VC) members declared Jason-CS/Sentinel-6 Michael Freilich to be the new Reference Altimetry Mission for the worldwide altimetry constellation.

Jason-3 started its repositioning manoeuvres on 7 April 2022 at the very beginning of cycle 227. The objective of these manoeuvres was to reach an interleaved orbit on 25 April, for a Jason-CS/Sentinel-6 Michael Freilich offset reference grid, and a separation of approximately five days with Jason-CS/Sentinel-6 Michael Freilich for measurements, thereby doubling measurement capability on the reference orbit. Jason-3 remains available for a future tandem phase with Jason-CS/Sentinel-6 Michael Freilich, in order to assess potential drift.

Operational Readiness Review

The Operational Readiness Review (ORR) of the S6 L2P/L3 services implemented by CNES as organised by EUMETSAT in March 2022 paved the way for the public release of L2P and L3 products in NRT and STC timeliness. The release of L2P and L3 products in NTC timeliness is planned for later this year, once these products are also fully ready.

Following the launch of Jason-CSA/Sentinel-6A on 21 November 2020, its twin, Jason-CSB/Sentinel-6B, integrated by Airbus Defence and Space in Friedrichshafen, is scheduled to join it and take over in November 2025 at the earliest.

This will make it possible to seamlessly continue essential work on measuring the **mean sea level rise**, which is caused by human-induced global warming. Faced with melting ice and thermal expansion, rising sea levels have become a powerful reminder of how quickly humans are changing the climate. Following on from its predecessors, TOPEX/Poseidon and the Jason missions, the Jason-CS/Sentinel-6 series is continuing to monitor the pulse of global climate change.

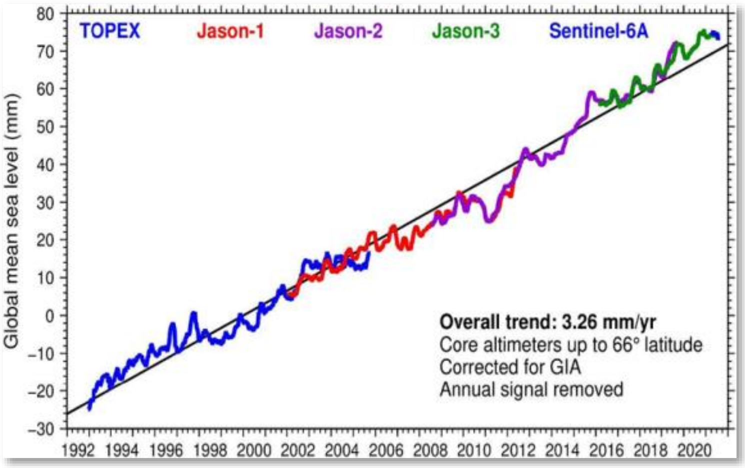


Fig.6 : 30-year record of Mean Sea-Level data (© EUMETSAT).

Jason-3 on an interleaved orbit

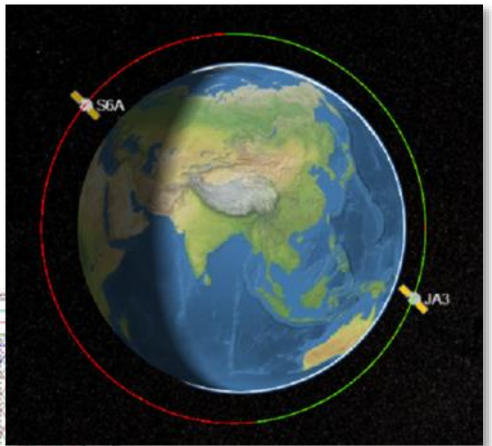
Christophe Maréchal, CNES

On 25 April 2022, **Jason-3** was relocated to an interleaved orbit with Jason-CS/Sentinel-6 Michael Freilich (Sentinel-6 hereafter), thereby doubling its measurement capability in the reference altimetry orbit due to the five-day time lag and an offset grid. The mission resumed nominally from cycle 300, when the Poseidon altimeter was restarted.

This change of orbit follows the recommendations of the OSTST and the decision of CEOS OST-VC to consider Sentinel-6A as the new Reference Altimetry Mission for global ocean altimetry (further information in the previous article). After completing its mission to calibrate Sentinel-6, Jason-3 was able to leave its location on 7 April and move to this new position, where its measurements will be more useful. It will most likely remain there for the next two or three years.

After this time, and depending on the requirements of the Sentinel-6 project, it may once again take up a tandem position with Sentinel-6, for a short bias calibration period.

The Jason-3 project team wishes Sentinel-6A a long and successful life.



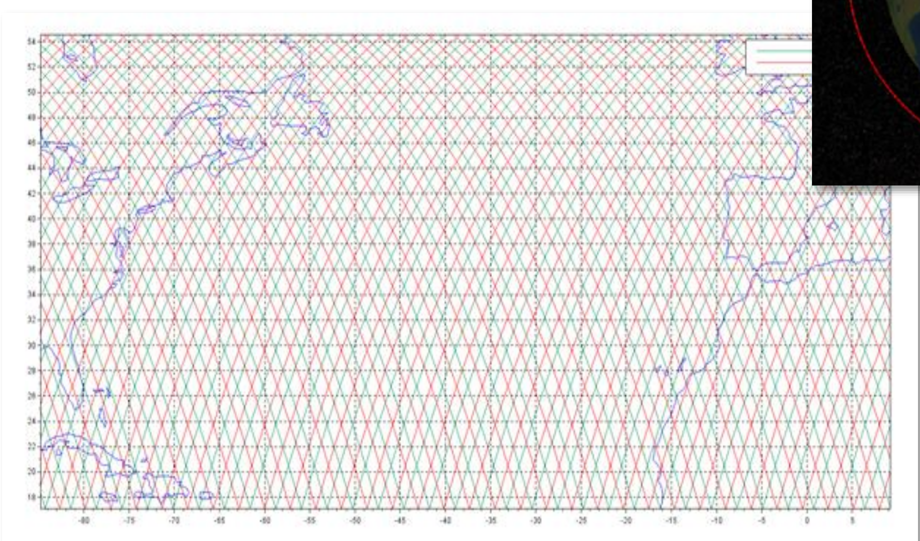


Fig. 1 : Jason-3 and CS/Sentinel-6 Michael Freilich in orbit (top) and their ground tracks over the Atlantic Ocean (left). ©CNES

New sargassum detection data

Marion Sutton, Jacques Stum, CLS - Gérald Dibarboure, CNES - Francois Steinmetz, Hygeos

Two datasets of sargassum detection data have been added to the AVISO+ catalogue, based on two types of satellite observations: sun-synchronous and geostationary satellites.

Since 2011, unprecedent massive landings of sargassum seaweed (*Sargassum fluitans* and *Sargassum natans*) have been observed along the shorelines of a huge area encompassing the Gulf of Mexico, the Caribbean Sea and West Africa, with a huge negative impact on local communities.

Satellite imagery is able to detect floating sargassum. It plays a key role in helping scientists to understand the origin and seasonality of sargassum movements in the Atlantic, and to support local communities in managing the next sargassum influxes. The pioneering work of Gower et *al.* (2006), and Hu (2009) demonstrated the capacity of ocean colour satellites to detect sargassum rafts.

Sargassum is detected by an increase in the reflectance spectrum between the red and near infra-red wavelengths. Most of the well-known sargassum indices found in the literature, such as the **Maximum Chlorophyll Index** (MCI, by Gower et *al.*, 2006), the **Floating Algae Index** (FAI, by Hu, 2009), and the **Alternative Floating Algae Index** (AFAI, by Wang and Hu, 2016), are based on the same mathematical statement:

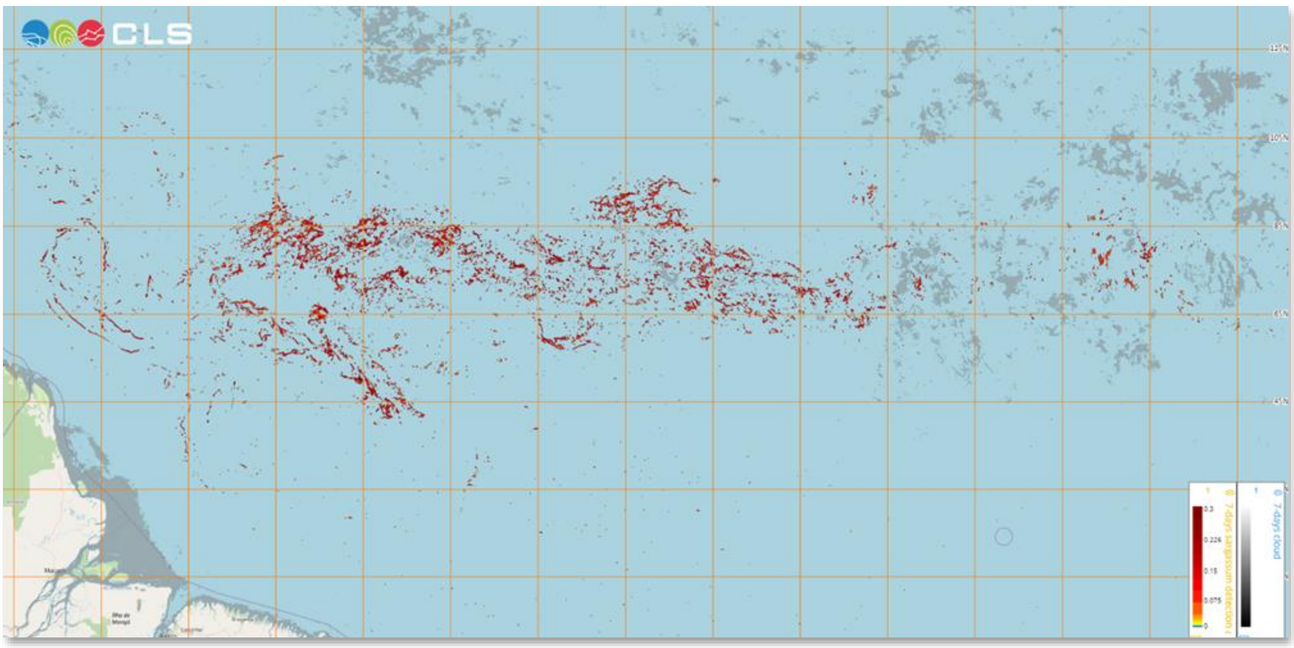
$$\text{Index} = \rho NIR - \rho' NIR$$

Where **ρNIR** denotes a reflectance (or radiance) partially (or not) corrected for atmospheric effects in the near infra-red band, and **ρ' NIR** is the equivalent NIR reflectance that would be measured at the same point in the absence of sargassum. **ρ' NIR** is approximated by a linear interpolation between the two reflectances measured at nearby wavelengths in the red and SWIR bands.

Sun-synchronous ocean colour satellites: Sentinel-3A&3B

As part of the European e-shape project, CLS conducted a reanalysis of sargassum detection data using observations from the OLCI sensor on board **Sentinel-3A** and **Sentinel-3B**. The one-year time series uses a normalised version of the **FAI**, introducing normalisation by the sum of reflectances to mitigate the variability of the **FAI** resulting from atmospheric conditions and observation geometry, in the same way as for the NDVI over land surfaces:

$$NFAI = (\rho NIR - \rho' NIR) / (\rho NIR + \rho' NIR)$$



Detection of sargassum on weekly maps of OLCI for July 15th 2019. Sargassum mats are shown in red, cloud is shown in grey. ©CLS

Although sun-synchronous ocean colour satellites are well suited to detecting floating sargassum in the ocean, daily images are often polluted by cloud cover. To understand the seasonal cycles of sargassum presence in the Atlantic, data are therefore shown as average weekly data.

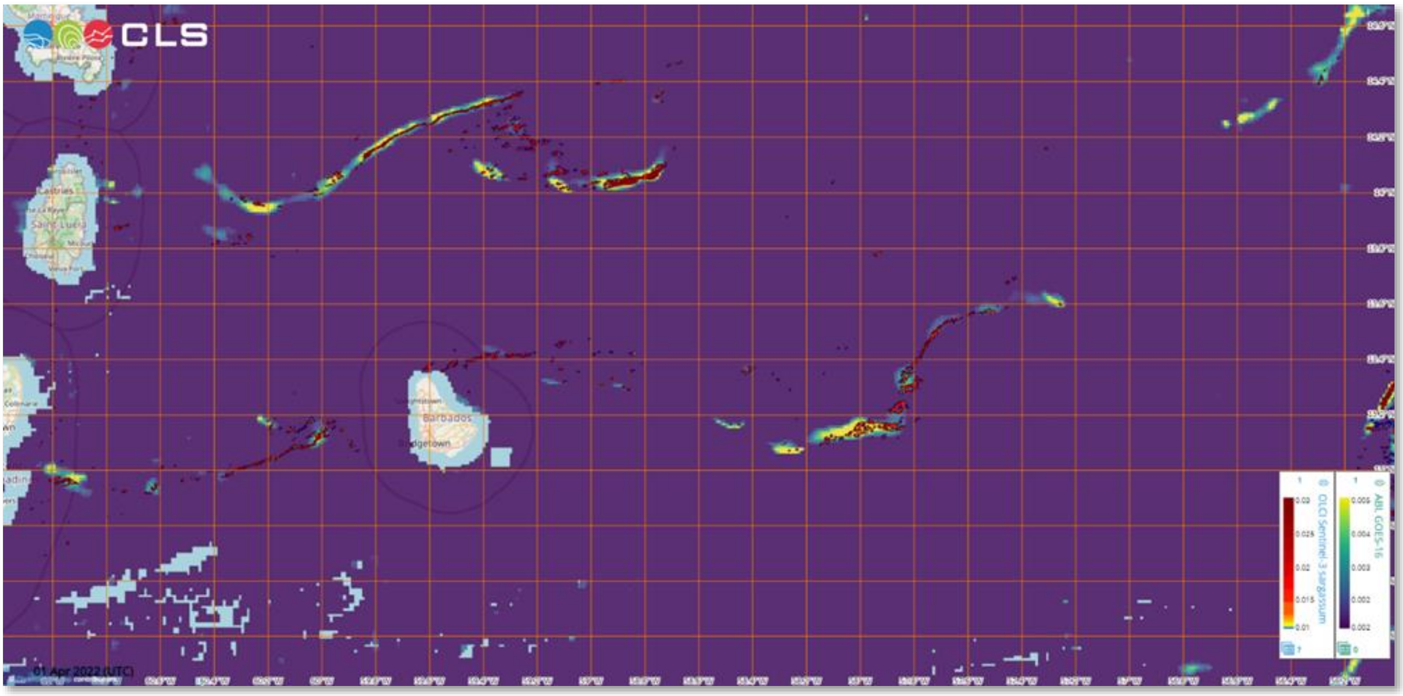
The weekly composite of sargassum index provides the **normalised floating algae index** (**NFAI**) averaged over seven days of data on a 1-km grid. It is computed from the high-resolution products computed daily at a resolution of 300 m.

The index is a composite product based on OLCI Sentinel-3A and B data covering the whole of the Tropical Atlantic Basin and Gulf of Mexico for the full year in 2019.

Geostationary satellite

To complement this reanalysis dataset, a near-real time sargassum product has been added to the AVISO catalogue. CLS and Hygeos have been contracted by CNES to process and distribute one year of sargassum products derived from the Advanced Baseline Imager (ABI) on board the **GOES-16** geostationary satellite. Core processing is carried out by the new software designed by Hygeos and operated by CLS in March 2022.

The main advantage of this geostationary satellite lies in its ability to acquire one image every 10 minutes across a visibility circle centred on the 75W meridian, thereby covering the Atlantic Ocean from the Gulf of Mexico to the offshore of Western Africa. This capability ensures a far higher probability of measuring the ocean surface in one day, which is not the case for sun-synchronous satellites. Daily spatial coverage is improved by a factor of between 2 and 3 as a result of daily cloud movement, compared to single slot operation, and this should be useful for the long-term monitoring of the sargassum situation. Multi-temporal observation can also be used to monitor changes in the position of sargassum.



Detection of sargassum data at 1-km from GOES16 in yellow, validated with OLCI sensor at 300-m resolution in red for April 1st 2022. © CLS

Product	Dataset	DOI	Area	Frequency	Spatial resolution	Data period
Sargassum detection - Floating Algae Index - **Sentinel-3A&B OLCI**	OLCI instrument on Sentinel-3A and Sentinel-3B	10.24400/527896/a01-2022.007	Tropical Atlantic -5°S/30°N, 100°W/15°E	Weekly	1 km	From 2018/12/26 to 2019/12/31
Sargassum algae detection index - **GOES-16 ABI**	hr dataset: Sargassum FAI anomaly maps calculated between 10am and 7:50pm ITC every 10 min, with 60 maps for each day dm dataset: daily means of the 60 instantaneous maps of Sargassum FAI anomaly.	10.24400/527896/a01-2022.008	Tropical Atlantic -5°S/40°N, 100°W/12° W	Daily	1 km	From 01/03/2022 - ongoing

Dataset comparison.

References

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- Hu, C., 2009 : A novel ocean color index to detect floating algae in the global oceans. Rem. Sensing of Environment 113, 2118-2129 10.1016/j.rse.2009.05.012

- Stum, J., Tebri, H., Sutton, M., and Granier, N., 2019: NRT satellite detection and drift forecast of sargassum algae in the Equatorial Atlantic, Poster presented at the IOCS meeting in Busan (pdf)

- Wang, M., and C. Hu, 2016: Mapping and quantifying sargassum distribution and coverage in the central west Atlantic using MODIS observations. Rem. Sensing of Environment 182. 10.1016/j.rse.2016.04.019

Product sheet : Characteristics, product access, handbook, citation, example, references, … can be found **here**.

Learning database for ocean SAR imagery

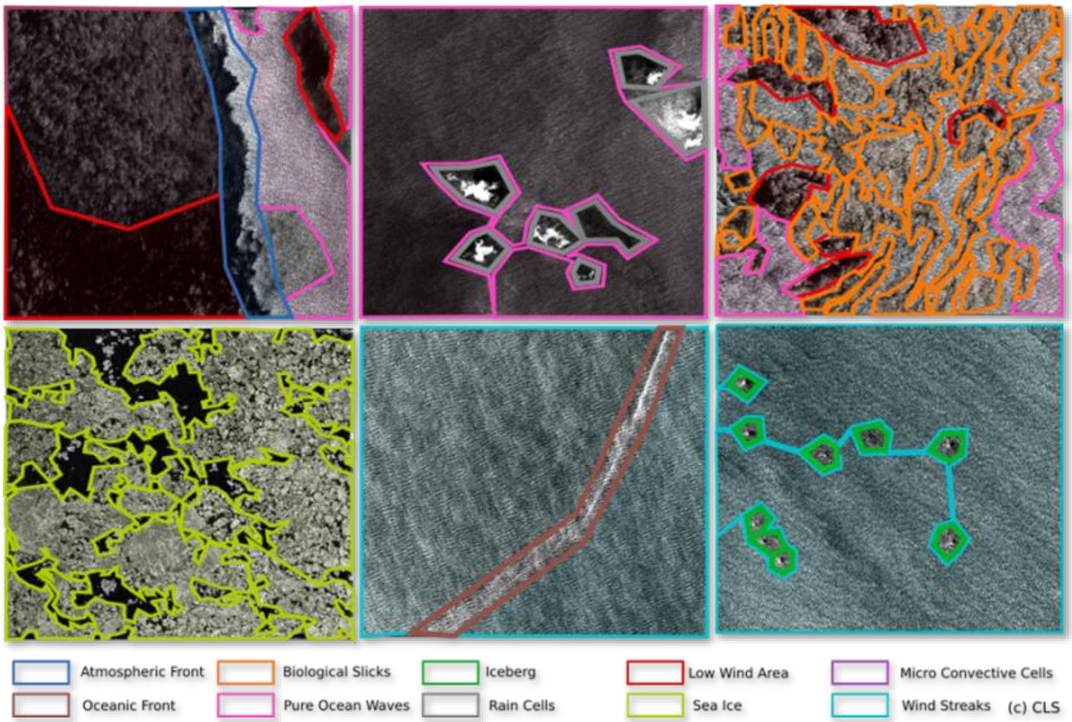
Charles Peureux, Amine Benchaabane, François Soulat, Aurélien Colin, CLS

Synthetic Aperture Radar (SAR) systems such as Sentinel-1 generate several million square kilometres of ocean imagery every month. After analysis, they reveal a wide range of meteorological and oceanic phenomena, including the presence of surfactants, sea ice, rain, convection zones and atmospheric fronts (see Figure below). While these phenomena can be detected by an experienced analyst in a limited number of cases, it is currently impossible to exploit all SAR measurements without the assistance of artificial intelligence [1]. This database is designed to provide a set of examples of this type of detection for learning purposes. It will be produced as an extension of current databases [2] by two CLS engineers. Medium-term applications include the mapping of ocean surface states and a better understanding of air-sea interaction processes.

References

[1] Colin A., Fablet R., Tandeo P., Husson R., Peureux C.,Longépé N., Mouche A., Semantic Segmentation of Metoceanic Processes Using SAR Observations and Deep Learning, Remote Sensing, 14, 4, 2022. [10.3390/rs14040851](10.3390/rs14040851)

[2] Wang C., Mouche A., Tandeo P.,Stopa J., Longépé N., Erhard G., Foster R.,Vandemark D., Chapron B., A labelled ocean SAR imagery dataset of ten geophysical phenomena from Sentinel-1 wave mode, Geoscience Data Journal, 6, 2, 2019. [10.1002/gdj3.73](10.1002/gdj3.73)



Events

September 12-14 2022, Saint-Malo, France, CFOSAT 3rd International Science Team meeting

October 31 - November 4 2022 OSTST, Venice, Italy

February 6-10 2023, Cadiz, Spain 13th Coastal Altimetry Workshop

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