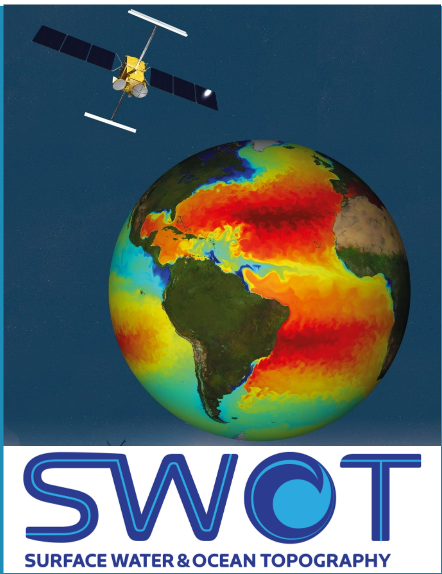
AVISO+
Satellite Altimetry Data

#21

April 2023

Users Newsletter



SUMMARY

Project news

Cyril Germineaud and Project Team, CNES

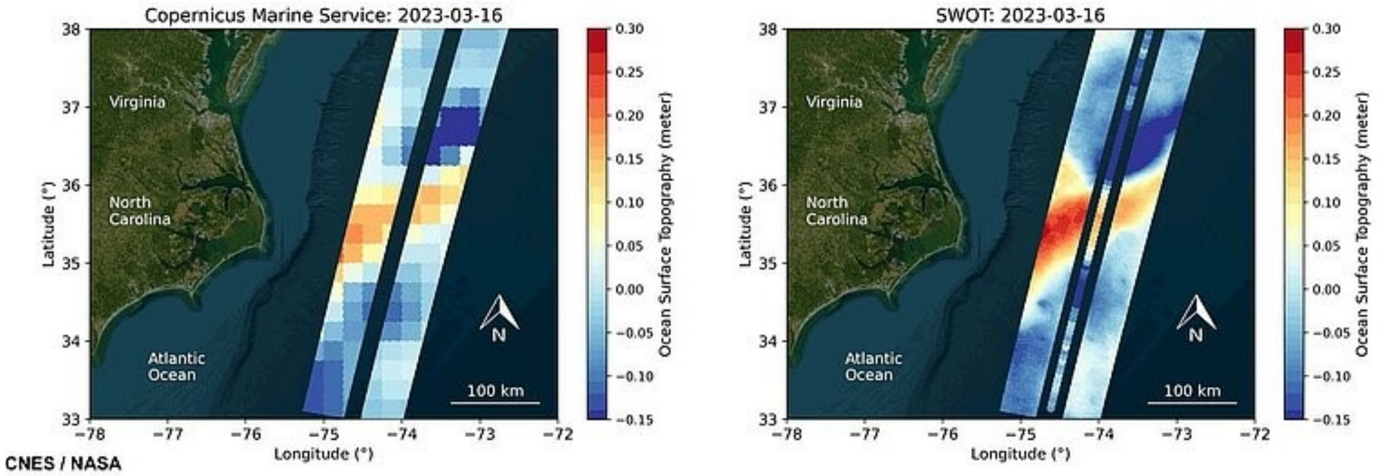
SWOT : Key milestones and ongoing activities

After a successful launch on 16 December 2022, the international **Surface Water and Ocean Topography** (SWOT) satellite mission started its about 3-month long commissioning phase. The nadir altimeter (Poseidon-3C), Advanced Microwave Radiometer (AMR), and precise orbit tracking systems payload (DORIS and GPS sensors) were switched on in early January 2023. Since then, the ground segment has begun processing the nadir altimeter, microwave radiometer and tracking systems data, providing the first nadir-related sea surface heights from SWOT. First comparisons were made with the multi-mission altimetry data (including Jason-3, Sentinel-6 Michael Freilich, SARAL, etc.) and showed the very good quality of the SWOT nadir altimeter and of the processing (see news on January 23, 2023). The innovative KaRIn (short form for Ka-band Radar Interferometer) instrument, which will provide wide-swath altimetry measurements on both sides of the nadir, was switched on in mid-January 2023. After two weeks of successful operations, one of the KaRIn instrument's subsystems known as the high-power amplifier (HPA) suddenly shut down. Following a detailed investigation by the NASA/JPL and CNES project teams (see NASA news on February 23, 2023), both teams decided to turn on the redundant (B unit) KaRIn HPA on March 9, 2023 in order to minimise risk and restore KaRIn operations as soon as possible. Since then, the HPA B unit and KaRIn are working well, with comparable levels of performance to those obtained with the primary (A unit) HPA (see NASA news on March 17, 2023).

The first ocean measurements collected by SWOT gave us striking images of the ocean surface topography, with a spatial resolution 10 times higher than images resulting from the combination of seven active nadir altimeter satellites: Sentinel-6 Michael Freilich, Jason-3, Sentinel-3A and 3B, Cryosat-2, SARAL and Hai Yang 2B (see illustration below in the Gulf Stream region off the North Carolina and Virginia coasts, U.S.A.). The SWOT's KaRIn instrument also provided remarkable views of freshwater bodies such as lakes, rivers and re- servoirs (see news on March 27, 2023). In this regard, SWOT data are thus expected to provide remarkable insights for studying fine structures (down to about 10 km) of ocean circulation, coastal processes and freshwater stock variations in lakes and rivers (larger than 100 m).

Meanwhile, the mission commissioning activities have continued to move forward, and shall be completed by the first half of April to allow the 3-month Calibration and Validation (Cal/Val) phase to begin. During this phase, operations will be conducted with a 1-day-repeat orbit allowing higher temporal resolution and crossovers (twice per day) between the SWOT ascending and descending tracks. In addition to the mission calibration and validation activities and campaigns over ocean and inland water bodies, multiple oceanography field campaigns led by the SWOT Adopt-A-Crossover (AdAC) Consortium and endorsed by CLIVAR will be performed. These commissioning and Cal/Val activities will ensure the overall performance of the satellite's platform systems and the science instrument payload.

Stay tuned for more information on the mission activities and SWOT nadir and KaRIn L2 and L3 products in the next AVISO newsletter!



KaRIn produced ocean topography data of the Gulf Stream mapped as two wide, coloured strips spanning a total swath of 120 kilometres. Red and orange areas in the image represent sea levels higher than the global average, while blue shades represent sea levels lower than the average. This imagery exhibits a significant improvement in resolution over other altimetry satellites already in orbit, revealing ocean dynamics and the amplitude of eddies for the first time over a period of several days, thanks to the daily revisits afforded by SWOT's calibration orbit. The clarity of the data illustrates the dramatic evolution in the technology used to measure sea-surface height from space. The spatial resolution of the SWOT ocean measurements is 10 times greater than a composite of sea-surface height data over the same area from seven other satellites currently in operation: Sentinel-6 Michael Freilich, Jason-3, Sentinel-3A and 3B, Cryosat-2, SARAL, and Hai Yang 2B. Credits CNES/NASA.

Sentinel-6 Michael Freilich and Jason-3

The Copernicus Sentinel-6 Michael Freilich (MF) mission (launched on 21 November 2020) is the new reference altimetry mission since April 2022. The L2P and L3 Non-Time Critical (NTC) altimetry products from Sentinel-6 MF were released in early December 2022 and late January 2023 respectively, as part of a cooperation agreement between CNES and EUMETSAT. As such, the Level-3 NTC product has been used since February 2023 (in addition to TOPEX/Poseidon, Jason-1, Jason-2 and Jason-3) to estimate the reference global mean sea level after taking into account the intermission bias between Jason-3 and Sentinel-6 MF.

The U.S.-European Jason-3 mission, the third altimetry satellite of the Jason series, celebrated its 7 years anniversary in orbit (launched on January 17, 2016), ensuring continuity in high precision sea level measurements with a focus on operational ocean and weather applications. Last year, in April 2022, Jason-3 was shifted from the "historical" TOPEX/Poseidon orbit, leaving Sentinel-6 MF alone on this orbit after the cross-calibration of the two missions. With this orbit shift, Jason-3 has been measuring halfway between historical tracks, providing additional global sea-surface height measurements with a better spatial resolution.

CFOSAT

Launched on 28 October 2018, the Franco-Chinese satellite CFOSAT recently celebrated its fourth anniversary in orbit, which is longer than its nominal service life. This event was an opportunity to conduct the first appraisal of this innovative mission, which carries two scatterometers: one for waves (SWIM) and the other for wind (SCAT). We can already see significant results from both an operational standpoint, with data being used daily by weather forecasting agencies for assimilation into sea state forecasting models, and from a scientific standpoint (see document available here). These excellent results are validated by an international scientific team that has already met three times since the launch, and will be further improved by the continuation of the mission over the coming months and years. Scientific processing is constantly being improved, and has already led to two full reprocessing campaigns of SWIM data, the last of which is nearing completion. The products of these campaigns will be available in the near future. We can also expect to see new applications and products over the coming months including, for example, measurements of Stokes drift and the presence of sea ice.

SARAL

The Franco-Indian SAtellite for ARgos and ALtiKa mission, known as SARAL, celebrated its 10 years anniversary (launched on February 25, 2013)! The satellite's Small Satellite Bus platform was supplied by the Indian Space Research Organisation (ISRO), while the science instrument payload made up of ARGOS-3 and ALtiKa instruments (altimeter, radiometer, DORIS and LRA) was provided by the French Center of Space Studies (CNES).

Still working perfectly despite a 10 day interruption in late January-early February 2023, the ALtika (Ka-band) altimeter continues to provide high quality measurements of global sea-surface height over the oceans, but also in coastal zones and above sea ice. Thanks to the constant investment of ISRO, CNES and EUMETSAT operational teams, SARAL is relentlessly pursuing its work as an ocean surveyor for the benefit of the international scientific community (in oceanography, hydrology and glaciology) and the Copernicus Marine Service. ISRO and CNES committed to maintaining SARAL operations at least until the end of 2023 and will jointly study this year a possible extension of the mission up to 2024 and beyond.

HY-2

The HY-2 satellites are a series of Chinese satellites, involving Franco-Chinese cooperation between CNES and NSOAS for altimetry (DUACS) and orbitography applications. The HY-2A satellite mission launched in August 2011 has now been terminated. It was followed by HY-2B launched in October 2018, HY-2C launched in September 2020 and most recently HY-2D launched in May 2021. With the exception of **HY-2B**, all the satellites in the series carry a DORIS instrument for precise orbit determination, the processing of which is carried out by CNES/CLS. Since 2020, the HY-2B mission has been part of the altimetry constellation processed in DUACS. The HY-2C mission is scheduled for integration in the near future. Concerning the HY-2D mission, NSOAS has yet to provide the altimetry products necessary to assess product quality.

Towards the routine use of coastal altimetry

from a Round Robin exercise to a new global product for sea surface heights

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Round Robin exercise on altimetry measurements in coastal ocean areas: 25 algorithms were tested to calculate the different components of sea level anomaly. This has led to the ongoing development of a new global coastal product that will soon be available on AVISO+.

In a context of climate change, measuring coastal sea levels has become an issue of social and economic importance. Tide gauge records are the main source of information on this question, but there are still too few of them at the global scale: the length of the available time series varies considerably from one place to another and vast coastal areas have no records at all. Alongside this information from tide gauges, it is therefore essential to make greater use of 30 years of altimeter measurements of variations in sea level close to the coastline.

Although spatial altimetry was originally developed for measurements on the open sea, it can be used in a coastal context, even though this type of use is far more complex. Part of the problem lies in the contamination of radar observation by the presence of land in the last few kilometres from the coast. In the last few dozen kilometres approaching the coastline, this problem is further aggravated by the poor quality of some of the geophysical corrections applied. The international community and space agencies have been trying to resolve this issue for 15 years. Following extensive work and studies, a number of processing algorithms have been put forward and a few experimental products integrating the various algorithms have illustrated the significant potential of coastal altimetry. The challenge now is to integrate the most efficient solutions into operational processing systems in order to move towards the routine use of sea level altimetry measurements along the coastal strip on a global scale.

In Toulouse, a number of organisations (CNES, the LEGOS research laboratory, the SMEs CLS and Noveltis) have widely recognised expertise and a long history of projects in the field of coastal altimetry (PISTACH, PEACHI, X-TRACK, ESA CCI Sea Level, etc.). Under the impetus of CNES and with its support, a cross-cutting working group was set up in 2021 to bring together all the expertise, identify the technical and scientific obstacles limiting the use of coastal altimetry measurements, and then define and develop a product to effectively meet requirements. To this end, this working group conducted a Round Robin exercise to test as many of the available algorithms as possible in order to calculate the various components of the altimetric sea level anomaly (see Table 1, page 6). For each component, the aim was to objectively determine the algorithm which gives the best results in the reprocessing of altimetry measurements in coastal ocean areas.

25 algorithms tested

A total of 25 algorithms were tested. For each one, a significant number of diagnostics were carried out at global and regional levels in order to measure:

- the internal consistency of each algorithm with respect to the benchmark solution, as well as its performance in terms of the final restitution of sea surface height data and the associated reduction in variance, based on the distance from the coastline;
- the impact of each algorithm on the quality of altimetry data on near-shore sea surface heights by comparing them with independent tide gauge observations.
- the consistency of all the results for the different altimetry missions, based on a comparison of the Jason-2 and Jason-3 missions for all the results obtained.

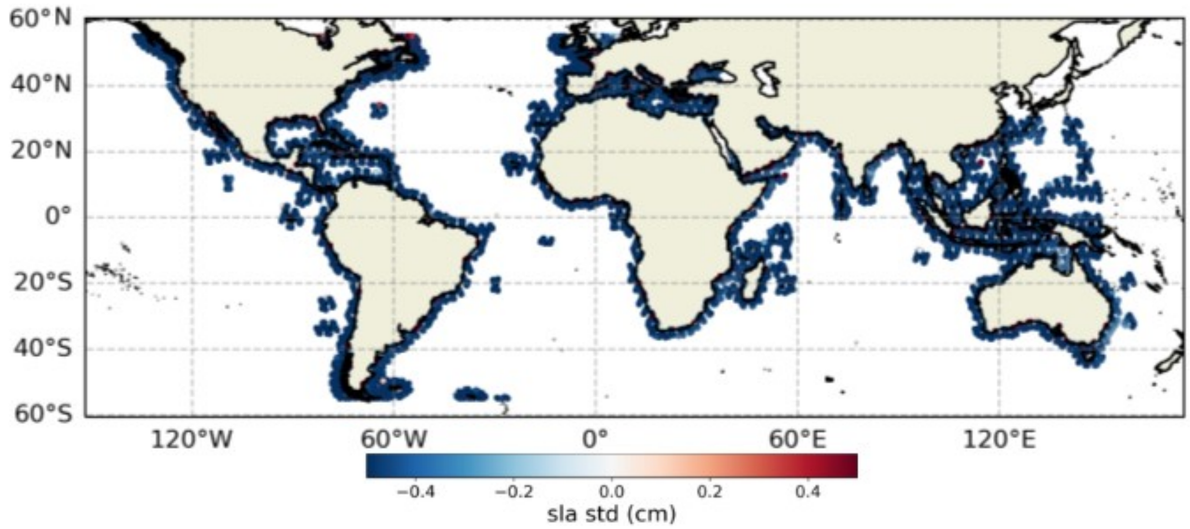

Figure 1: *Map showing the difference (in cm) between the SLA standard deviation obtained by calculating an SSB correction at 20 Hz and the SLA standard deviation obtained by calculating an SSB correction at1 Hz and then interpolating it at 20Hz (standard solution). The calculation is only carried out for data on the 200 km coastal strip. Credits CTOH/LEGOS, CNES, Noveltis, CLS*

Based on an analysis of the results obtained on a 200 km coastal strip at global level, we were able to select a set of algorithms for calculating a new product dedicated to coastal applications. The choice made is finally a compromise between:

- The capability of each algorithm to provide the best sea level data set over the entire strip between 0 and 200 km from the coast (and not necessarily in the most coastal zone).
- The availability of the algorithm on several altimetry missions.
- A guarantee of product continuity in the future.

These algorithms are shown in red in Table 1. **They represent a significant change compared to the algorithms currently used to calculate operational products, in that they are able to keep over 85% of sea surface height data at a distance of 5 km from the coast as a global mean for the Jason-3 mission**.

A new global coastal product

The most immediate outcome of this study is the ongoing development of a **new global coastal product that will be available on the AVISO+ portal in Fall 2023**. Integrated with the Jason-3 mission in the first instance, this product will rapidly be included with other space missions in order to extend the use of the product in time and space, and above all to ensure long-term implementation. Its distribution will be supported by training workshops for the international community (virtual schools with case studies in the form of Python notebooks) in order to promote the product and, above all, to support its development in order to better meet the needs of coastal users.

As well as providing a new product for the community, this work has led to a better understanding of altimetry measurements in coastal sea areas, as well as of the factors that can improve the way they are used.. For example, fresh studies were conducted on the methodology used to calculate various geophysical corrections. To give an example, Figure 1 shows the SLA noise reduction (in cm) obtained over a 200 km coastal strip, simply by increasing the computational frequency of the sea state bias correction (from 1Hz to 20Hz). We can see that this change not only reduces data noise near the coast but also benefits observation of the open sea.

It is important to note that all the results obtained in this study will be disseminated and written up as recommendations for CNES and ESA, so that they can transfer the knowledge acquired to operational computing centres.

Further information

- Birol et *al.*, 2022. Round Robin Assessment of altimetry algorithms for coastal sea surface height data. Oral presentation OSTST 2022. http://dx.doi.org/10.24400/527896/a03-2022.3363.

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Components used in the calculation of altimetric sea level anomalies (SLA)	List of algorithms analysed
Altimeter Range	3 solutions: MLE4 retracker, Adaptive retracker, ALES retracker
Ionospheric correction	2 solutions: Dual-frequency, filtered, GIM
Wet tropospheric correction	3 solutions: Radiometer, ECMWF model, GPD+
Ocean tide correction	9 solutions: DTU16, EOT20, FES2014 regular grid, FES2014 unstructured grid, GOT4.10, TPX09, CNES regional models (zones: NEA, Med, Australia, Arctic), FES2022 regular grid, FES2022 unstructured grid
Sea State Bias (SSB) correction	8 solutions: MLE4 2D 1Hz, MLE4 20Hz, MLE4 3D 20Hz, Adaptive 2D 20Hz, Adaptive 3D 20Hz, ALES 20Hz solution
Mean Sea Surface Height (MSSH)	3 solutions: CNES15, SIO, CNES22

Table 1: *Components of the altimetric sea level calculation included in the Round Robin exercise (column 1), with the list of algorithms tested for each one (column 2). The algorithms currently used in operational sea level products are highlighted. The solutions selected for the computation of the new global coastal product are shown in red. Note that concerning the altimeter range, in terms of noise reduction, number of data available and comparison to tide gauge sea level data, the ALES solution gives better results within 10-15 km of the coast and the Adaptive solution beyond that. However, the latter performs much better than MLE4 and was finally chosen to optimise the product over the entire oceanic zone up to 200 km from the coast.*

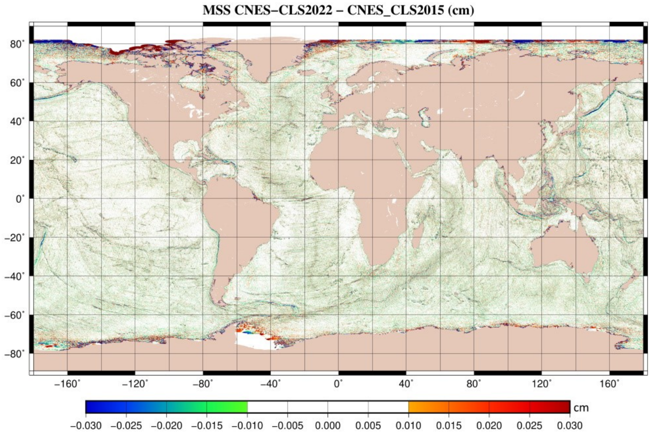
New Mean Sea Surface *MSS_CNES_CLS 2022*

Cyril Germineaud (CNES), M.Pujol (CLS), P.Schaeffer (CLS)

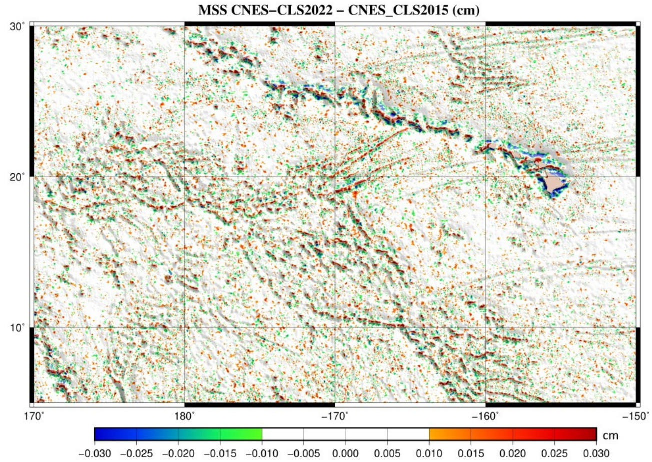
A new Mean Sea Surface product, the CNES_CLS_2022 MSS (Schaeffer et al., OSTST 2020), has been generated and will be available to AVISO users **in autumn 2023**. It is based on the integration of 29 years of altimetry measurements, using more than 10 altimeters from the several missions, including the historical TOPEX/Poseidon venture, the Jason satellite series and the Sentinel (3A/B and 6 Michael Freilich) satellites, as well as dedicated missions for geodetic purposes.

This new MSS includes significant improvements compared to the 2015 MSS version (see Figure 1 below):

- better correction of oceanic variability (notably for wavelengths < 200 km),
- a considerable improvement in the shortest wavelengths (10-50 km), consistent with the expected accuracy of SWOT,
- better mapping of the MSS in the Arctic region by combining traditional altimetry data with (Sentinel 3A, Cryosat-2 and ALtiKa) leads over 2016-2020,
- reduced degradation of sea level anomalies near the coast.



(top and below) Differences between MSS_CNES 2022 and MSS_CNES_CLS 2015, (below)with a focus on the North Pacific region of 5°N-30°N, 170°E-150°W .



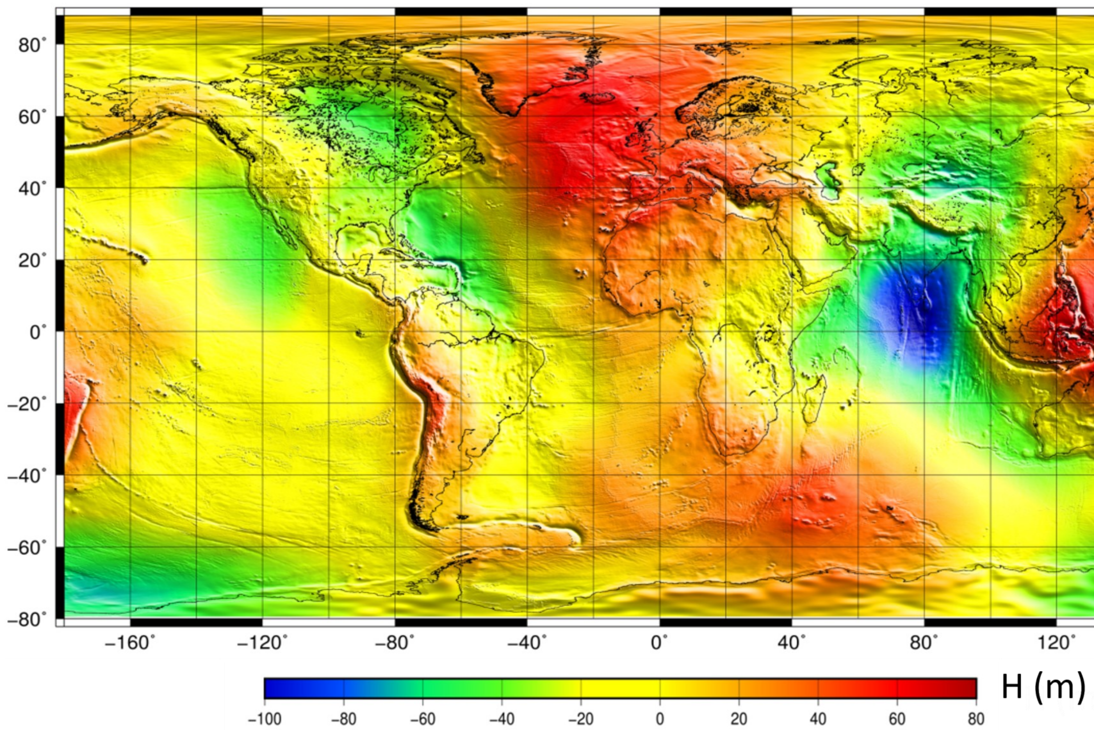


Figure 1: Mean Sea Surface MSS_CNES_CLS 2022.

SWOT on the AVISO+ and CNES websites

The AVISO+ website contains several pages of scientific and technical content on the SWOT mission and its applications in oceanography and hydrology. These pages are a valuable resource for understanding the issues and goals of the mission, with examples of useful applications for users. These pages will soon be updated to list the products available, based on the **SWOT mission data release** schedule. **New access and computing services** will also be available, in particular to enable users to process the largest products.

All links and references on SWOT

A wealth of Image of the month since 2014

Click on the links below

- 2014/05: Forecasting rivers
- 2015/10: A future insight to English Channel
- 2016/04: One thousand drifters and one (future) satellite in the Gulf of Mexico
- 2016/05: Readying for SWOT data to be used in hydrology applications
- 2016/12: Testing Algorithms
- 2017/03: Satellites see the highs and lows of the biggest lake in China
- 2017/07: Higher resolution knowledge of flooded areas over the whole Earth
- 2017/08: Waves & currents
- 2017/11: Tracking water bodies
- 2018/03: Flash flood at the river Têt mouth
- 2018/06: As the flood flows
- 2018/07: Adopting a Swot crossover for biophysical studies
- 2018/12 : Retrieving hidden water contribution to river from space
- 2019/03: Focusing on small water bodies
- 2019/04: Pantanal wetlands
- 2019/06: Modelling the flow
- 2019/09: Internal tides in the Solomon Sea change with ENSO phases
- 2020/04: Arcachon Bay between tides
- 2020/05: Lake Chad might be recovering
- 2020/09: Swot before Swot
- 2021/02: Altimetry helps to monitor the Congo basin
- 2021/04: Swot simulations of Sahelian ponds and lakes
- 2021/06: Swot and the lakes' winds
- 2022/03: Swot and the vegetation around and within lakes
- 2022/09: Internal tides off the Amazon shelf change with the seasons
- 2022/10: A new Swot mission validation site in brazilian Nordeste!
- 2022/12: Swot ready for launch

The CNESMAG « SWOT Planet Water » published in July 2022, four months before the launch, listed the technological innovations of this mission with applications of the full water cycle.

Events

April 23-28 2023, Vienna, Austria European General Assembly

October 3-5 2023, EuroGOOS International Conference

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