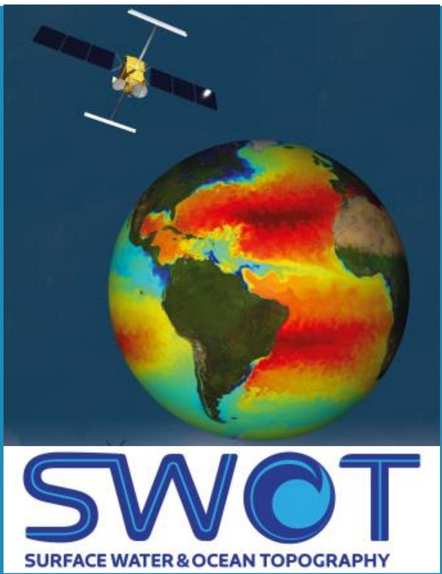
AVISO+
Satellite Altimetry Data

Users Newsletter

#23

December 2024



SUMMARY

Project news

The Missions Project Team (CNES)

SWOT

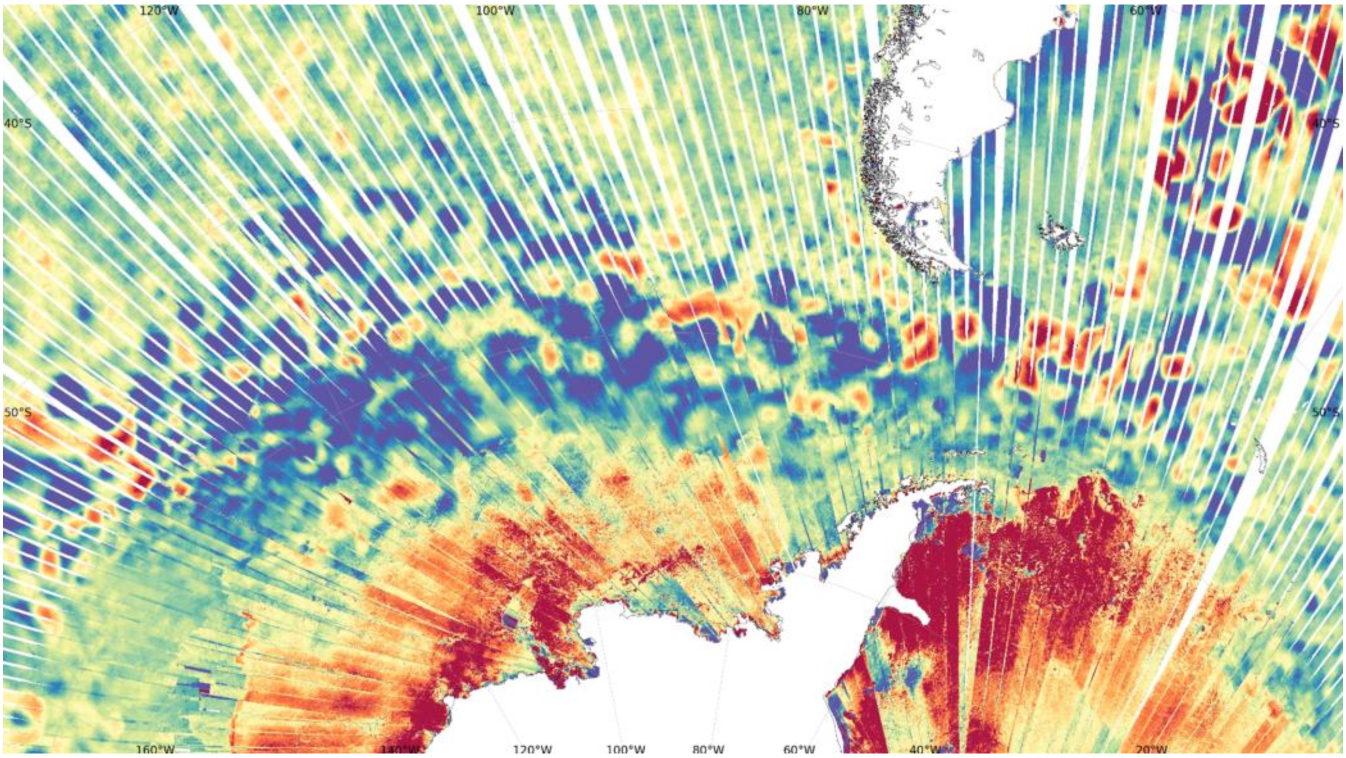
Shortly after its successful launch on December 16, 2022, the international **Surface Water and Ocean Topography** (SWOT) satellite mission successfully launched all its instruments. The nadir altimeter (Poseidon-3C), the Advanced Microwave Radiometer (AMR), the payload for the precise orbit tracking systems (DORIS and GPS sensors) and the innovative instrument KaRIn (short for Ka-band Radar Interferometer) all performed excellently. From the very first days, SWOT provided impressive images of the ocean surface topography with a spatial resolution 10 times higher than that obtained by the combination of the seven active nadir altimeter satellites in operation at the time.

The commissioning phase was successfully completed in April 2023, and the calibration phase began on a 1-day repeat orbit. While the daily observations of the calibration sites ensured good instrument calibrations, **the measurements from this period revealed small, never-before-observed ocean phenomena with unprecedented repeatability**. The science phase then started on July 26, 2023, and the first pre-validated ocean and hydrology products were gradually distributed from September 8 (NADIR products) to November 30, 2023 (ocean and some hydrology products). After an update of the processing algorithms, a new version was released at the end of November 2023 and the full reprocessing of the products was started with the aim of a product validation by the SWOT Science Team. The latest version of the SWOT products (PI/PGC0) was declared validated during the SWOT Science Team meeting in Chapel Hill on June 21, 2024.

As of December 2024, the spacecraft is still performing well and the teams are preparing for the new versions of the products to be released in early 2025 and another full post-launch reprocessing.

Further information

- **Links and references on SWOT** : publications in peer-reviewed journals, conferences, ...
- **SWOT : products, applications and services**, tips for choosing and using SWOT products



10-day SWOT KaRIn topography over the Southern Ocean and sea ice without interpolation or smoothing. Credit CNES/CLS

Date	Orbit and Mission Phase
December 16, 2022	Launch
December 16 - 24, 2023	Launch and Early Operations Phase (LEOP)
Dec. 16 – Jan. 14, 2023	Orbit Maneuvers and Drift
January 14, 2023	Start of 1-day Repeat Orbit
Jan. 3 – March 30, 2023	Commissioning Phase
March 30 – July 10, 2023	Calibration Phase
July 11 – July 20, 2023	Orbit Maneuvers and Drift
July 21, 2023	Start of 21-day Repeat Orbit
July 21, 2023	Science Phase Begins (no useful KaRIn data until July 26)
November 2023	Ocean product Version B - beta release for early CalVal evaluation
March 2024	Ocean product Version C - first "Science" release
August 2024	Ocean product Version C declared as validated by the SWOT project

SWOT timeline : Orbit, phase and product releases.

CFOSAT

The French-Chinese **CFOSAT** satellite, launched on October 28, 2018, celebrated its fifth anniversary in orbit, which is longer than its nominal period. In fact, the nominal lifetime was 3 years. The first mission extension will end in 2024. A second extension is under discussion for the next 2 years, 2025-2026. This event was an opportunity to perform the first evaluation of this innovative mission, which carries two scatterometers: one for waves (SWIM) and the other for wind (SCAT).

Unfortunately, the SCAT antenna stopped rotating at the end of 2022. But we can already see significant results both from an operational point of view, with data being used daily by weather forecasting agencies for assimilation into sea state prediction models, and from a scientific point of view. These excellent results are being validated by an international scientific team that has met four times since launch and will be further improved as the mission continues over the coming months and years. The scientific processing is constantly being improved and has already led to two full reprocessing campaigns of SWIM data, with a new one planned for 2025. The products of these campaigns are available, and the last one will be available in the near future. We can also expect new applications and products in the coming months, such as Stokes drift estimates, sea ice detection gridded products. Improvements will also be made to the filtering of parasitic peaks in the slope and elevation spectra, and the modulation spectrum will be made available in the wavelength range from 22.5-m to 1112-m.

SARAL

SARAL/AltiKa is still part of the altimetry constellation and fully operational after more than 11 years in orbit. Providing Ka-band measurements, it remains the only nadir altimeter operating at this frequency. In addition to its routine mission to serve oceanography, polar oceans, hydrology and hurricane forecasting, it is also used for cross-calibration with SWOT low-rate data over the ocean... The 2024 exploitation review held in June highlighted an amazing performance for such an "old" satellite and its associated ground segment: availability 100% and data collection over the ocean higher than 97%....

Considering this excellent performance, ISRO and CNES have jointly decided to operate SARAL/AltiKa until the end of 2025.

SWOT : products, applications and services

Tips for choosing and using SWOT products

Cyril Germineaud and Gerald Dibarboure (CNES)

Summary presentation of available products, examples of applications in different themes and CNES AVISO services for accessing, displaying and processing SWOT ocean data.

NASA and CNES, with contributions from the Canadian and the UK Space Agencies, are collaborating on the SWOT mission, which was launched on December 16, 2022. Thanks to its new technical concept, a wide-swath interferometric altimeter (KaRIn), the SWOT mission represents a major design breakthrough in space altimetry. It brings innovation in technology, science and applications.

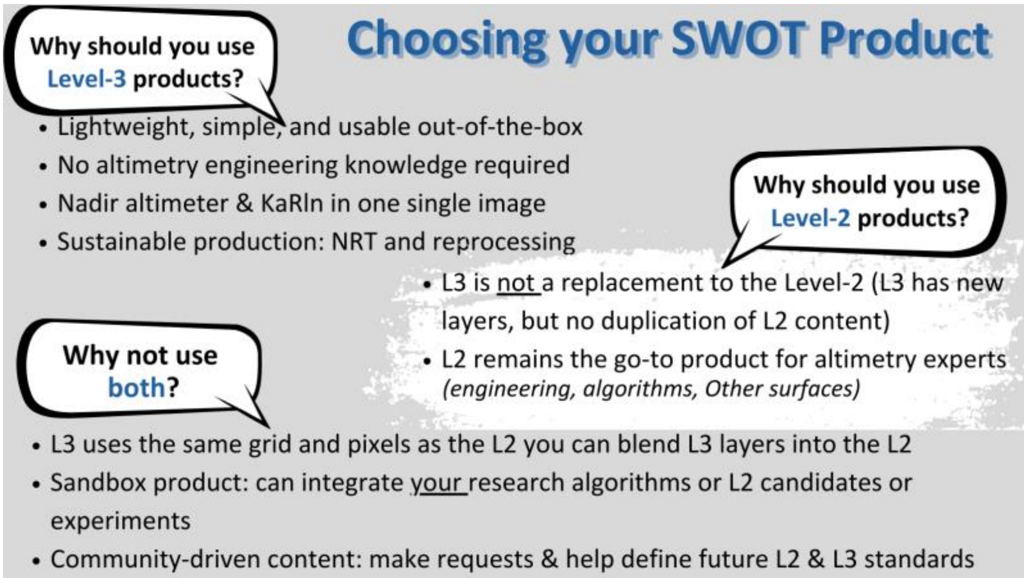
Products

Identical **Level-2 (Nadir and KaRIn) SWOT data** are available from both the CNES and NASA PO.DAAC data centers. The **SWOT KaRIn ocean Level-3 product** is distributed by the AVISO Data and Service Center from CNES. It is produced by the AVISO/ DUACS team (CNES, industry and laboratories) as part of the SWOT Science Team's DESMOS project in collaboration with the SWOT project (NASA/JPL and CNES). It is a research-grade extension derived from the SWOT KaRIn Level-2 ocean product with multi-mission calibration, state-of-the-art research-grade algorithms and corrections from the scientific community, and a sophisticated editing procedure (especially near the coast). As such, Level-3 should be considered a community research project, rather than an operational agency product.

Use Level-2 or Level-3 products ?

The **Level-2** product is a standalone SWOT product (no multi-mission calibration) with all reference algorithms and corrections. It is the reference product and is the go-to product for technical, expert, and algorithmic analysis, as well as instrument and algorithm research.

The **Level-3** is a multi-mission, cross-calibrated product with just the ocean topography content needed for oceanography research. It may be the better suited for applications where the user wants a very simple, out-of-the-box, product that can be mixed with other missions (e.g., CMEMS Level-3 multi-mission nadir altimetry products, https://doi.org/10.48670/moi-00147). In this respect, the joint use of the Level-2 and Level-3 products can be seen as a sandbox in which the SWOT Science Team can explore and test new standards, corrections, algorithms and editing procedures.



Source : Blending 2D topography images from SWOT into the altimeter constellation with the Level-3 multi-mission DUACS system, G.Dibarboure et al., 2024.

2022
16 Dec.
Launch
30 March
10 July 2023
CalVal orbit
2023
21 July
Science orbit
today
SWOT
SURFACE WATER & OCEAN TOPOGRAPHY
OCEAN PRODUCTS
L2-NALT
nadir
nadir Altimeter GDRs
Poseidon-3C
OGDR
IGDR
GDR
L3
nadir
L3 nadir
nadir
DOI 10.48670/moi-00147
L4
nadir
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DOI 10.48670/moi-00149
L1B-LR
KaRIn
L2-LR
KaRIn
Low Rate SSH
KaRIn
Basic - 2 km
WindWave - 2 km
Expert - 2 km
Unsmoothed - 250 m
L3-LR
nadir
KaRIn
L3 SSH
KaRIn + nadir
Basic - 2 km
Expert - 2 km
Unsmoothed - 250 m
L4
nadir
KaRIn
Gridded L4
multimissions
KaRIn + nadir
Gridded L4 (L3-LR
combined with L3 NALT)
High volumetry files

Applications

Over the ocean, the resolution of the KaRIn altimeter is improved by a factor of 10 compared to conventional altimetry, providing access to observations at finer spatial scales ranging from 10 km to a few hundred km. The range of applications is unrivaled, whether in the open ocean or in coastal areas. The dynamics and structure of mesoscale eddies are essential for understanding the vertical transport of carbon, heat and nutrients in the ocean, which is the main regulator of climate.

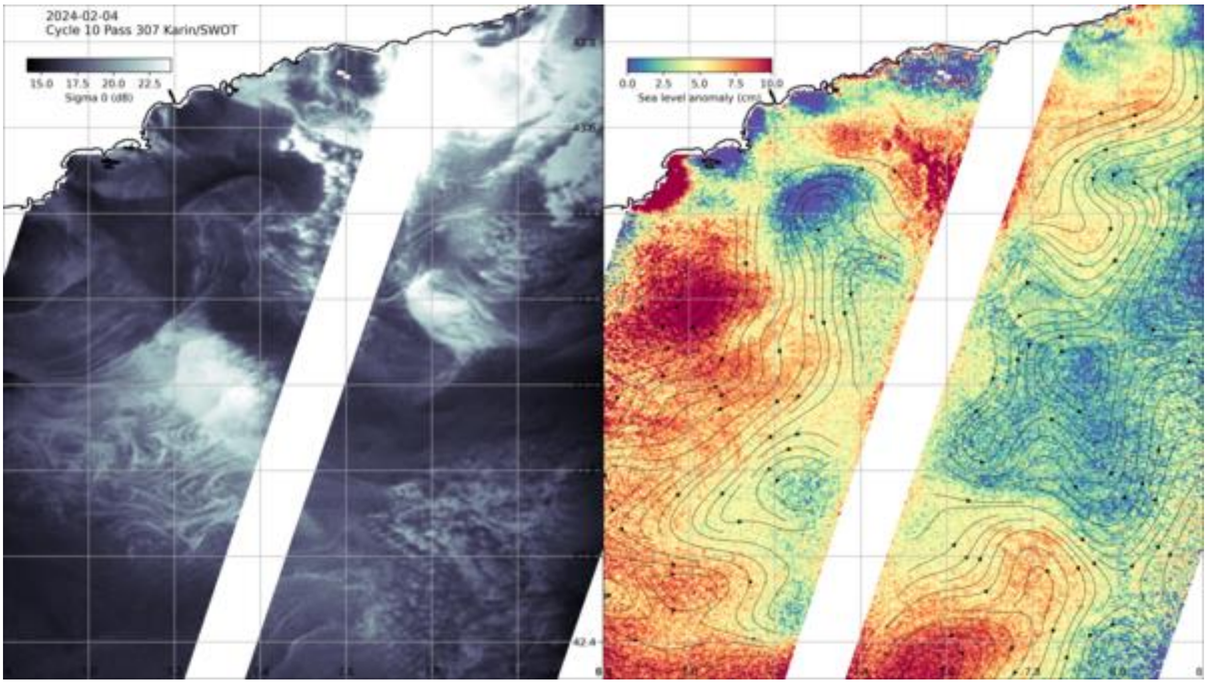
Portfolio of SWOT first results by theme :

- coastal oceanography,
- ocean circulation,
- polar regions,
- geodesy
- wind/waves & swells.

Coastal oceanography

One of the most eagerly awaited results from SWOT about the oceans is at their boundaries: near the coast. SWOT observes across its two 60 km wide swaths, covering most coastal areas. In addition, the 250 m resolution of the near-shore data reveals fine scale details of coastal ocean dynamics.

Coastal areas have the most anthropogenic interactions, the highest socio-economic and environmental stakes. Regular monitoring of coastal ocean dynamics through SWOT is essential to address these challenges.



Further information on AVISO+:
- [SWOT close to the coasts]

Left, SWOT KaRIn reflected radar power (sigma0) and, right, in color, the SWOT Level-3 KaRIn 250 m sea level anomalies with derived geostrophic currents overlaid (black lines with arrows).

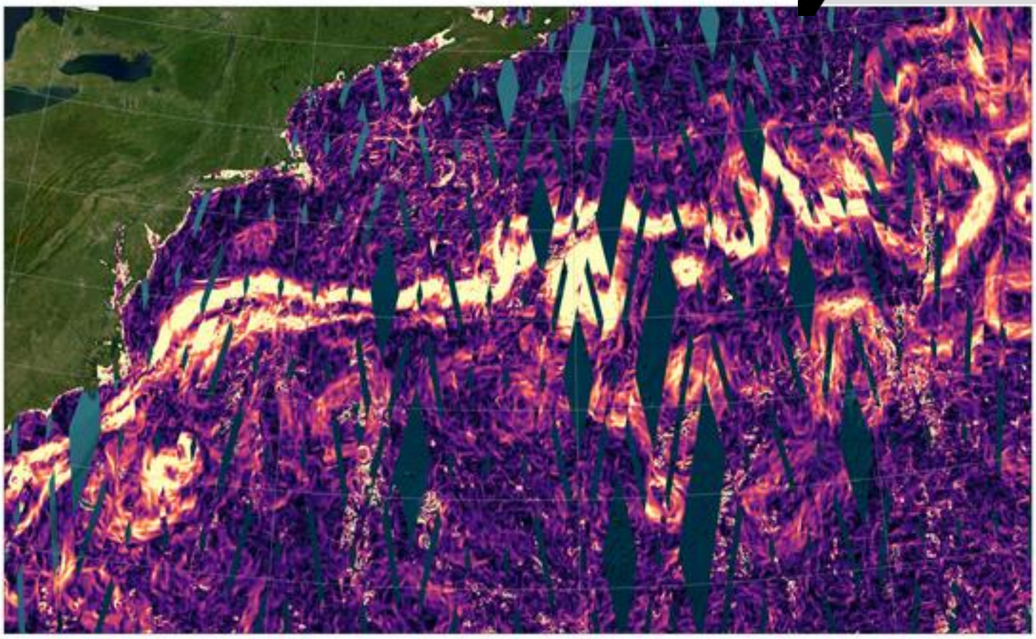
Under low wind conditions, SWOT captures very small-scale roughness changes (white filaments in sigma0). These are the tracers of ocean turbulence generated by small-scale ocean eddies, as seen in the sea level anomaly map. Credit CNES/CLS.

Ocean circulation

SWOT natively provides its measurements in two dimensions along its two wide swaths, so that 2D geostrophic currents can be derived directly from the sea surface height measurements. In very strong and turbulent currents, such as the Gulf Stream, the Kuroshio, or the Agulhas Current, these simultaneous measurements are particularly interesting, as they exhibit numerous rapidly changing eddies and meanders.

Further information on AVISO+:

- Currents in 2 dimensions



Gulf Stream geostrophic velocities as derived from KaRIn SSH (Level-3 data, no interpolation).

Credit CNES/CLS.

Ocean circulation

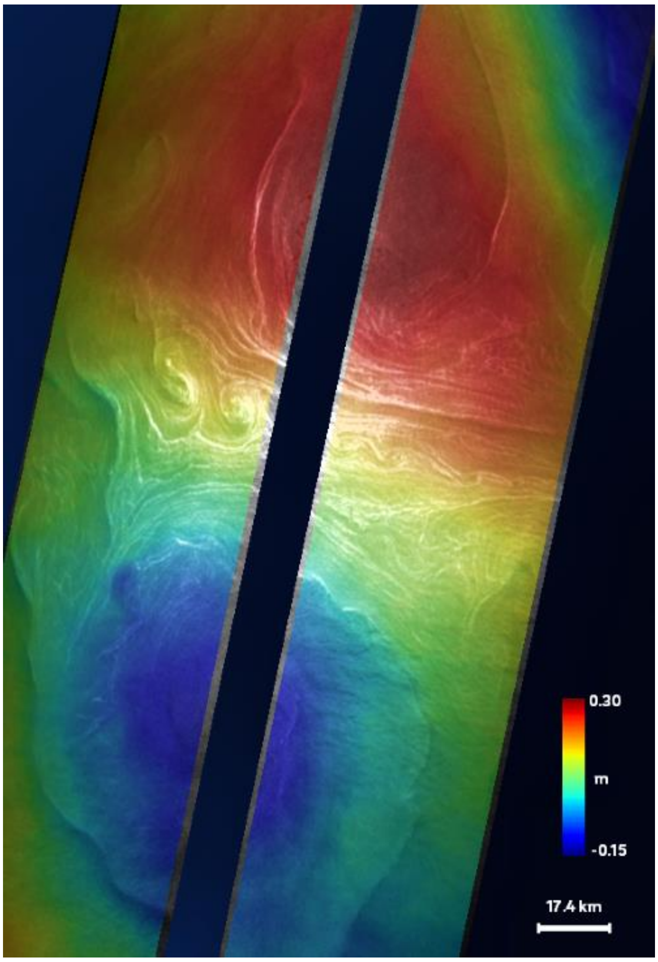
The SWOT mission, developed by CNES and NASA/JPL, detects small mesoscale eddies never observed by previous nadir altimetry missions, thanks to the high resolution of its measurements and the wide coverage of its main instrument, KaRIn.

Right: SWOT backscatter (sigma0) superimposed by Sea Level Anomalies (color) at 250 m spatial resolution on June 10, 2023 (cycle 548, track 9) near the U.S. East coast in the Gulf Stream region.

Credit OceanDataLab/CNES.

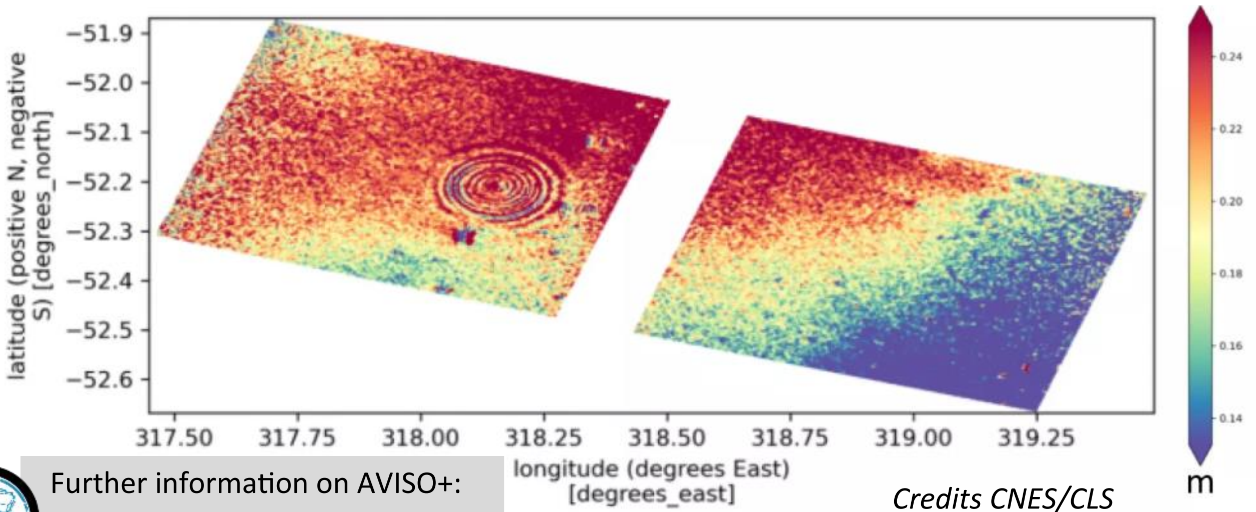
Further information on AVISO+:

- Changing scale in eddy observation



Polar regions

Gravity waves on the surface of the Southern Atlantic Ocean observed in 2D by the SWOT KaRIn altimeter caused by the tilting or fragmentation of an iceberg, resulting in a mini-tsunami. These mini- tsunamis displace huge quantities of water, like a stone entering a pond, but are of modest amplitude (in this case around ten centimeters) and then disperse over tens to hundreds of kilometers. They always have one or more icebergs at their center.



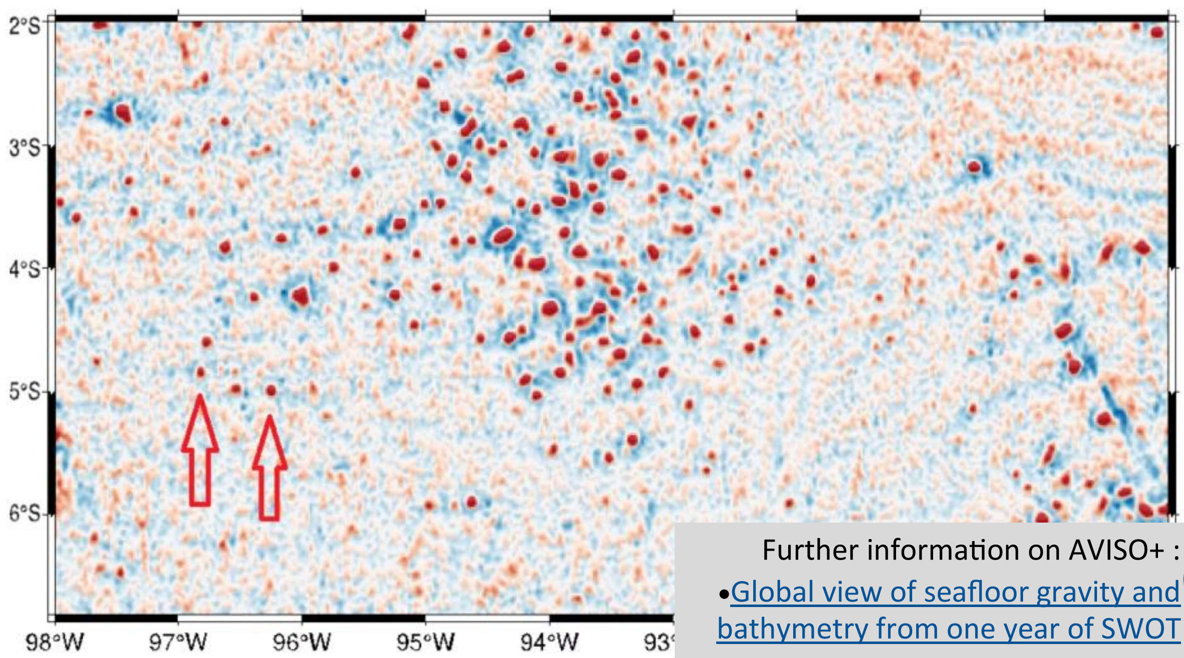
Credits CNES/CLS

Further information on AVISO+:
- [Mega-icebergs seen by SWOT]

Geodesy

The KaRIn instrument aboard the SWOT satellite measures the ocean surface topography with very high resolution and accuracy, down to a swath of 120 km. This resolution makes it possible to discover thousands of unknown seamounts. The red dots on this map of an area 500 km by 1000 km west of the Peruvian coast in the Pacific Ocean are the surface signature of seamounts on the ocean floor. The red arrows indicate mounts around 1000 m high that were previously unknown.

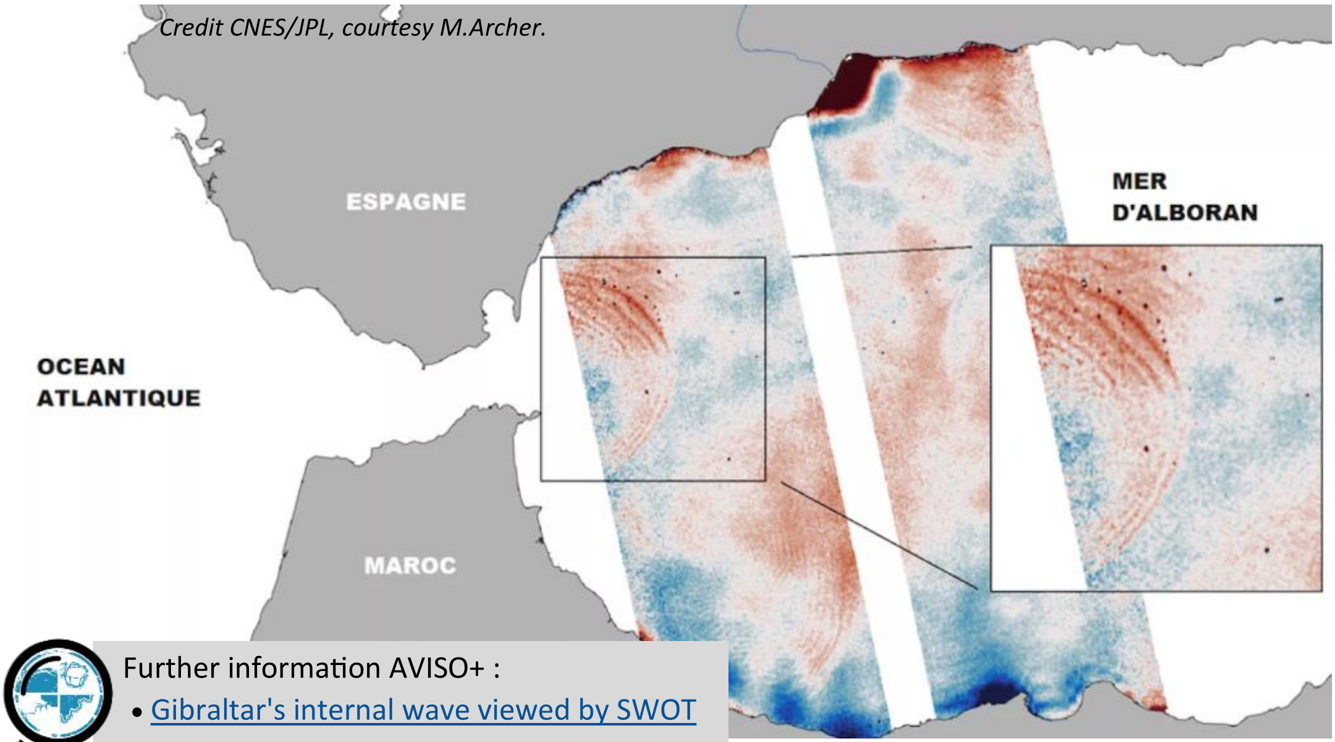
Credits Scripps Institution of Oceanography, courtesy of Y. Yu & D. Sandwell



Further information on AVISO+ :
- [Global view of seafloor gravity and bathymetry from one year of SWOT]

Internal waves

The SWOT mission is able to see the surface signal of internal waves, here a detailed observation of this phenomenon in the Strait of Gibraltar. The configuration of the coastline and the relief of the seafloor generate waves in the wake of the Strait. The data acquired by SWOT KaRIn in shades of blue and red represent sea surface height anomalies, revealing wave trains moving towards the interior of the Mediterranean Sea.

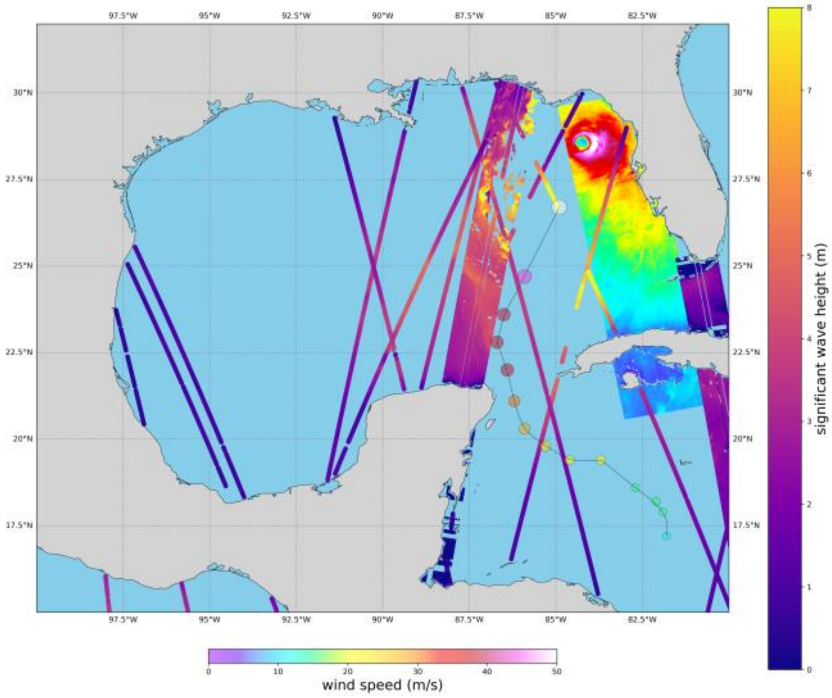


Credit CNES/JPL, courtesy M.Archer.

Further information AVISO+ :

- [Gibraltar's internal wave viewed by SWOT]

Wind-Waves and swells



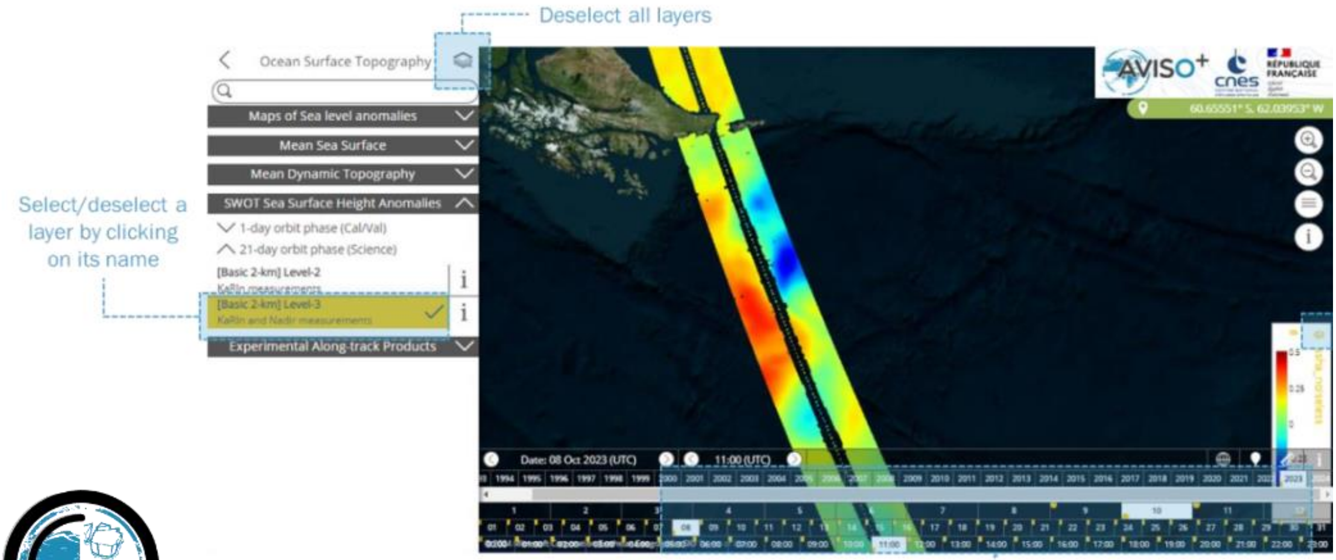
Significant wave height (in color) derived from SWOT KaRIn on September 26, 2024 during the Hurricane Helene in the Gulf of Mexico prior to landfall on the Florida Gulf Coast. SWOT observations can be used to track such extreme weather events, and improve existing weather and ocean forecasting models.

Significant wave heights (color) from all nadir altimeters (lines) and from SWOT KaRIn. Wind speed from SAR Sentinel-1A is superimposed (top right). The hurricane trajectory in dots are also colored by wind speed.
Credit CNES/AVISO - ESA/CYMS.

Services

Seewater

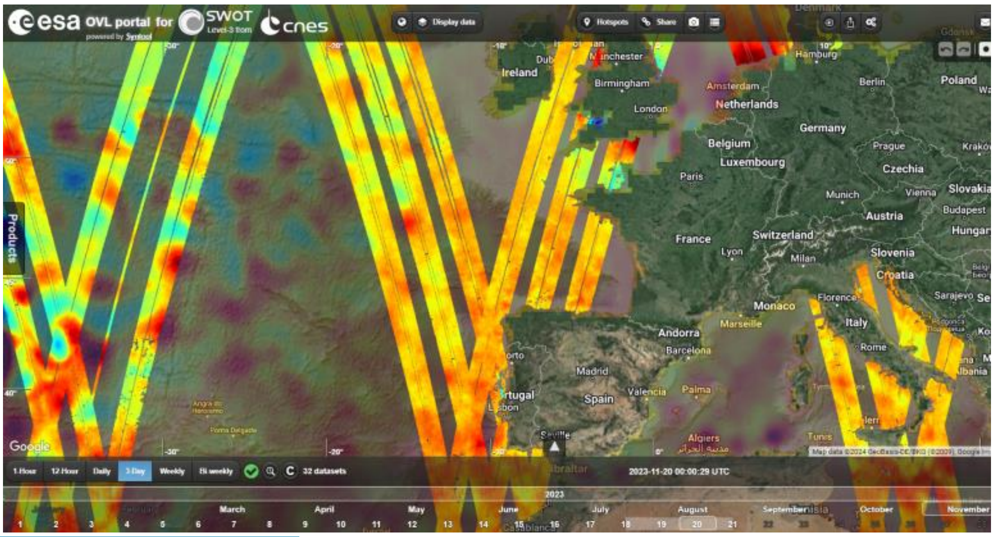
Seewater is the new **AVISO Product Visualizer** released on March 2024, and funded by CNES and powered by CLS. This online application allows to visualize AVISO products such as along-track, gridded products and also SWOT KaRIn sea level anomalies. The products are presented in four sections: Ocean Surface Topography (mainly sea level observations), Oceanic Wind and Waves, Ocean Other Variables (e.g., maps of Sargassum detection index) and Atmosphere.



Access to Seewater

OVL portal for SWOT

The **Ocean Virtual Laboratory** (OVL) virtual platform can also be used to discover and visualize SWOT Level-3 observations over both CalVal and Science phases.



Access to SWOT OVL portal

CNES Cloud Support for SWOT projects hosting

The CNES HPC/Cloud ecosystem allows :

- **A data-centric approach for efficient research**

Bring your algorithms directly to the CNES cloud platform, enabling efficient algorithm execution on SWOT ocean data without costly local transfers. Streamline your workflows and reduce latency, ensuring optimal utilization of computational resources.

- **Access to an integrated SWOT data and specialized tools**

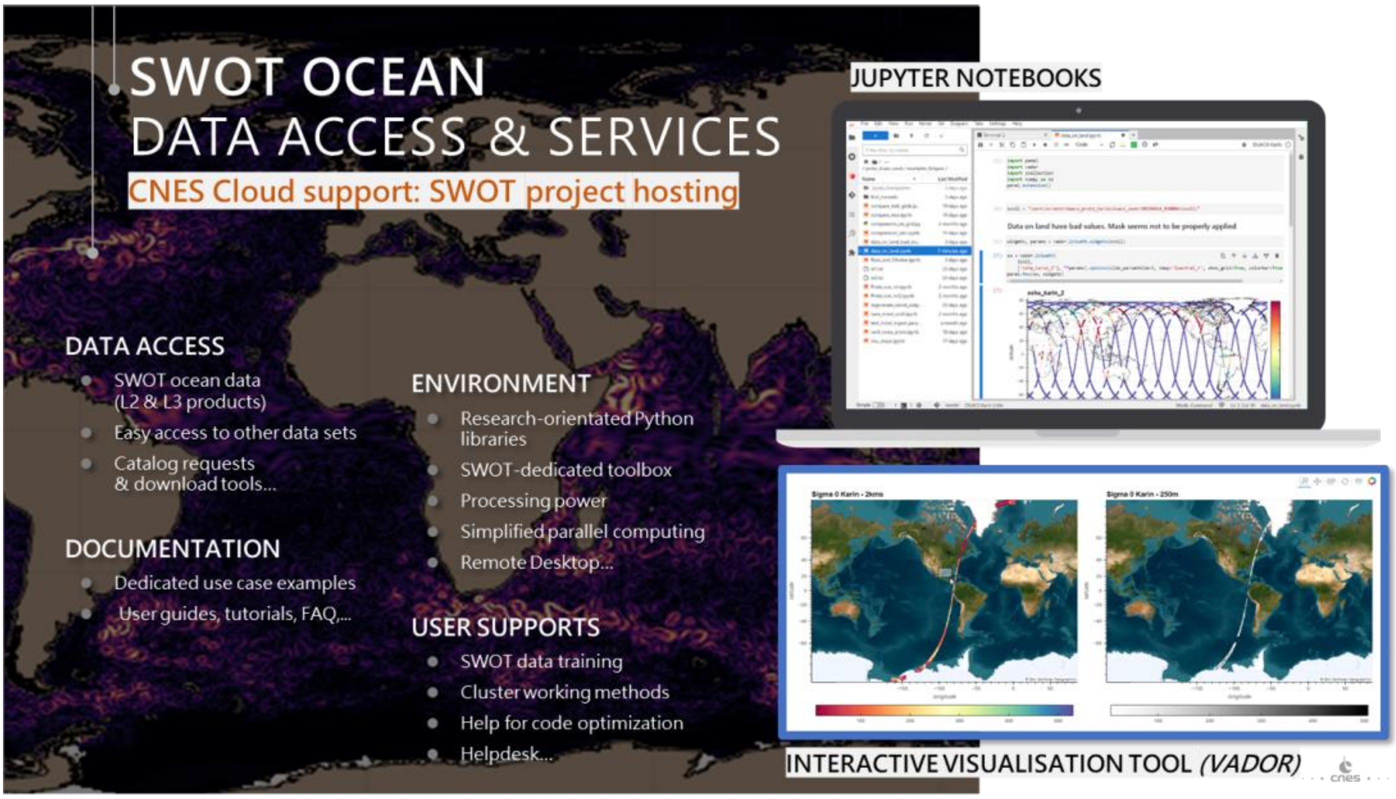
integrated SWOT data and tailored tools : Python Pangeo software packages, augmented with SWOT-specific libraries (Zcollection, Swot Calval, Pyinterp, Casys, and Vador) for seamless SWOT ocean swath data access and related data processing and analysis.

- **Access to additional resources**

Additional datasets, libraries, and tools upon request. Customize your virtual work environment to meet your unique research requirements, while ensuring optimal utilization of allocated SWOT Science Team project resources.

- **Technical support for smooth sailing**

A dedicated helpdesk is at your service, offering technical support ranging from basic HPC/Cloud assistance to expert-level guidance in handling cloud-optimized (e.g., ZARR/DASK) data formats.



How to apply

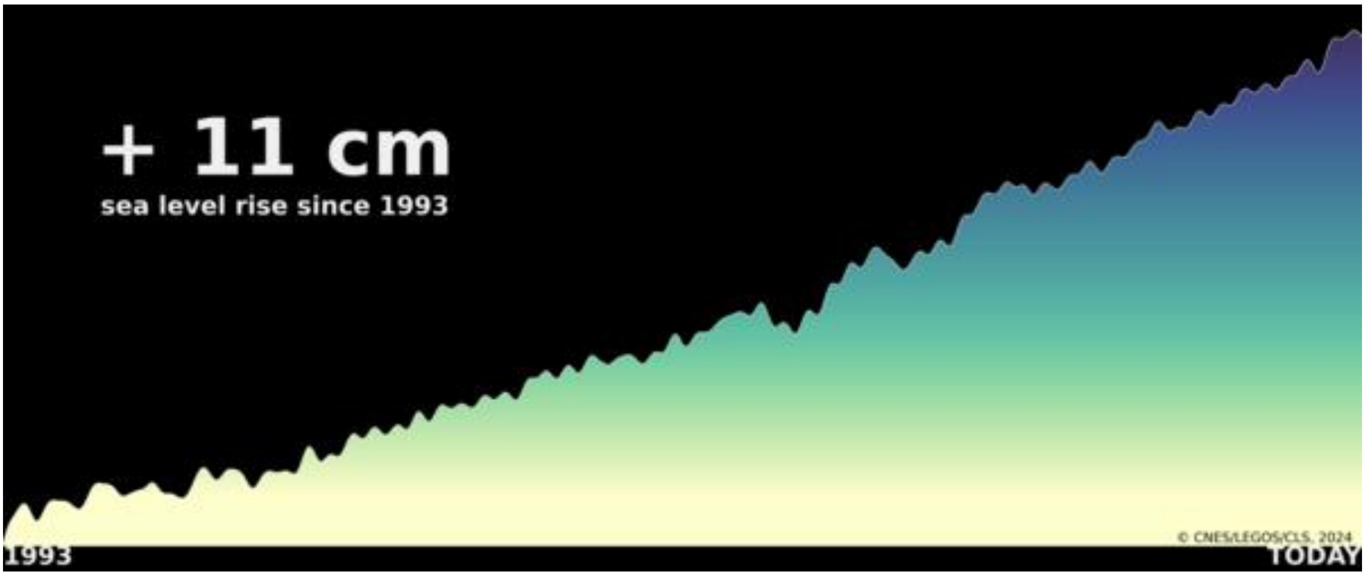
To get started, submit your application by completing the form : concise project description and contact information. Once the access has been granted, our team will help you setup your project environment and get you started on SWOT data analysis.

Global Sea Level Rise is accelerating

Sea level is one of the main indicators of climate change. Long-time series of altimetry data, from 1993 to 2024, show a global sea level rise of more than 10 cm since 1993, with a sharp acceleration over the past decade and major regional disparities.

Continuous altimetry observations from 1993 to the present have made it possible to determine an important climate indicator: the rise in Global Mean Sea Level (GMSL). Two main factors related to global warming explain this GMSL rise: the expansion of the ocean volume and the influx of freshwater from melting ice and glaciers. The GMSL averages 3.6 mm per year (+/-0.3 mm/yr, 90%CI) over the globe and the entire altimeter record. There is also clear evidence that the rate of sea level rise is accelerating over the altimeter record (e.g., Nerem et *al.*, 2018, Guérou et *al.*,2023). Indeed, this acceleration of global sea level rise has doubled from the decade 1993-2003 (2.1 +/- 1 mm/year, 90%CI) to the decade 2013-2023 (4.4 +/- 0.5 mm/year, 90% CI).

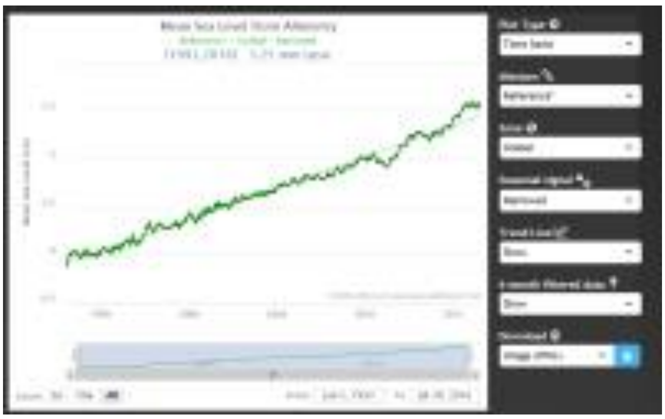
Since the beginning of satellite altimetry measurements in 1993, the GMSL has risen by more than 11 cm.



The reference global mean sea level (GMSL) based on data from satellite altimetry from January 1993 to present, after removing the annual and semi-annual signals, applying a 6-month filter and a correction for postglacial rebound. Credits CNES/LEGOS/CLS, 2024.

Data access and product information

Interactive vizualisation and downloading



Further information on AVISO+

- Mean Sea Level

Understanding uncertainties in coastal sea level altimetry data: insights from a round robin analysis

Florence Birol, François Bignalet-Cazalet, Mathilde Cancet, Jean-Alexis Daguze, Wassim Fkaier, Ergane Fouchet, Fabien Léger, Claire Maraldi, Fernando Niño, Marie-Isabelle Pujol, and Ngan Tran

The satellite radar altimetry record of sea level has now surpassed 30 years in length. These observations have greatly improved our knowledge of the open ocean and are now an essential component of many operational marine systems and climate studies. But use of altimetry close to the coast remains a challenge from both a technical and scientific point of view.

Close to the coast

In a study submitted to Ocean Science, we take advantage of the recent availability of many new algorithms developed for altimetry sea level computation to analyze the sources of uncertainties of this procedure when approaching the coast.

To achieve this objective, we did a **round robin** analysis of radar altimetry data, testing **a total of 21 solutions** for waveform retracking, correcting sea surface heights and finally deriving sea level variations.

Uncertainties associated with each of the components used to calculate the altimeter sea surface heights are estimated by measuring the dispersion of sea level values obtained using the various algorithms considered in the round robin for this component.

We intercompare these uncertainty estimates and analyze how they evolve when we go from the open ocean to the coast.

At regional scale, complementary analyses are performed through comparisons to independent tide gauge observations.

Results

The results show that tidal corrections and mean sea surface can be significant contributors to sea level data uncertainties in many coastal regions.

However, improving quality and robustness of the retracking algorithm used to derive both the range and the sea state bias correction, is today the main factor to bring accurate altimetry sea level data closer to the shore than ever before.

The main results found in this study are summarized on the table (next page) for the different SLA components.

On April 2023, a previous AVISO+ Users Newsletter introduced the development of a new global coastal product : "Towards the routine use of coastal altimetry from a Round Robin exercise to a new global pro- duct for sea surface heights". Note that a correction was published to better explain the choice of algorithms selected to calculate the Alticap product from the Round Robin results.

References

- Birol, F., Bignalet-Cazalet, F., Cancet, M., Daguze, J.-A., Fkaier, W., Fouchet, E., Léger, F., Maraldi, C., Niño, F., Pujol, M.-I., and Tran, N.: Understanding uncertainties in coastal sea level altimetry data: insights from a round robin analysis, EGUsphere. DOI 10.5194/egusphere-2024-2449

SLA component	Uncertainty estimate	Coastal zone impacted
Ionospheric correction	0.7 – 2.8 cm 0.2 – 0.7 cm < 0.2 cm	0 – 10 km 10 – 40 km > 40 km
Wet tropospheric correction	0.5 – 1.7 cm 0.3 – 0.5 cm < 0.3 cm	0 – 7.5 km 7.5 – 40 km > 40 km
Ocean tide correction (*)	1 (2) – 4 (5) cm 0.5 (1) – 1 (2) cm 0.5 (1) cm	0 – 10 km 10 – 75 km > 75 km
MSSH	1 – 4 cm 0.5 – 1 cm < 0.5 cm	0 – 8 km 8 – 20 km > 20 km
Retracking (range + SSB)	1.5 – 4 cm 0.5 – 1.5 cm < 0.5 cm	0 – 10 km 10 – 60 km > 60 km
SSB correction	1.8 – 6.2 cm 1 – 1.8 cm < 1 cm	0 – 10 km 10 – 60 km > 60 km

SLA components included in the study (column 1), maximum spread of the differences in the STD(SLA) (uncertainty estimate) observed when we change the solution for this component (column 2) and oceanic region where these differences are observed (column 3).

(*) For the ocean tide correction, the values in brackets correspond to uncertainty estimates considering the EOT20 model, while the other values correspond to the FES2014 and regional models only. Source : Table 2 in https://doi.org/10.5194/egusphere-2024-2449

Events

- EGU 2025 General Assembly, Vienna, Austria, 27 April - 2 May 2025
- One Ocean Science Congress, Nice, France, 3-6 June 2025
- ODATIS Ocean Data Hub - General Assembly, Toulouse, France, 20 -21 May 2025
- Living Planet Symposium 2025, Vienna, Austria, 23 - 27 June 2025

AVISO+ Users Newsletter

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