AVISO+ Satellite Altimetry Data

Users Newsletter

#14

December 2017

SUMMARY

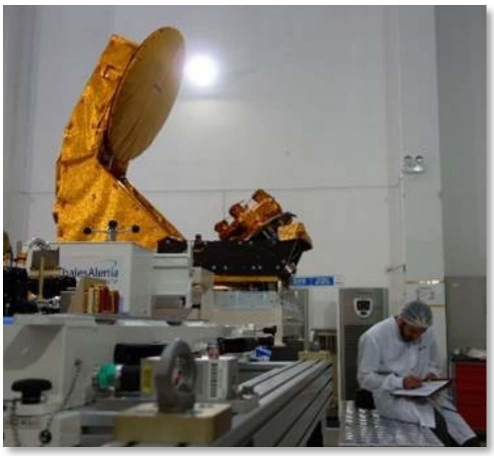
Project news

CNES project managers

Ongoing and forthcoming missions

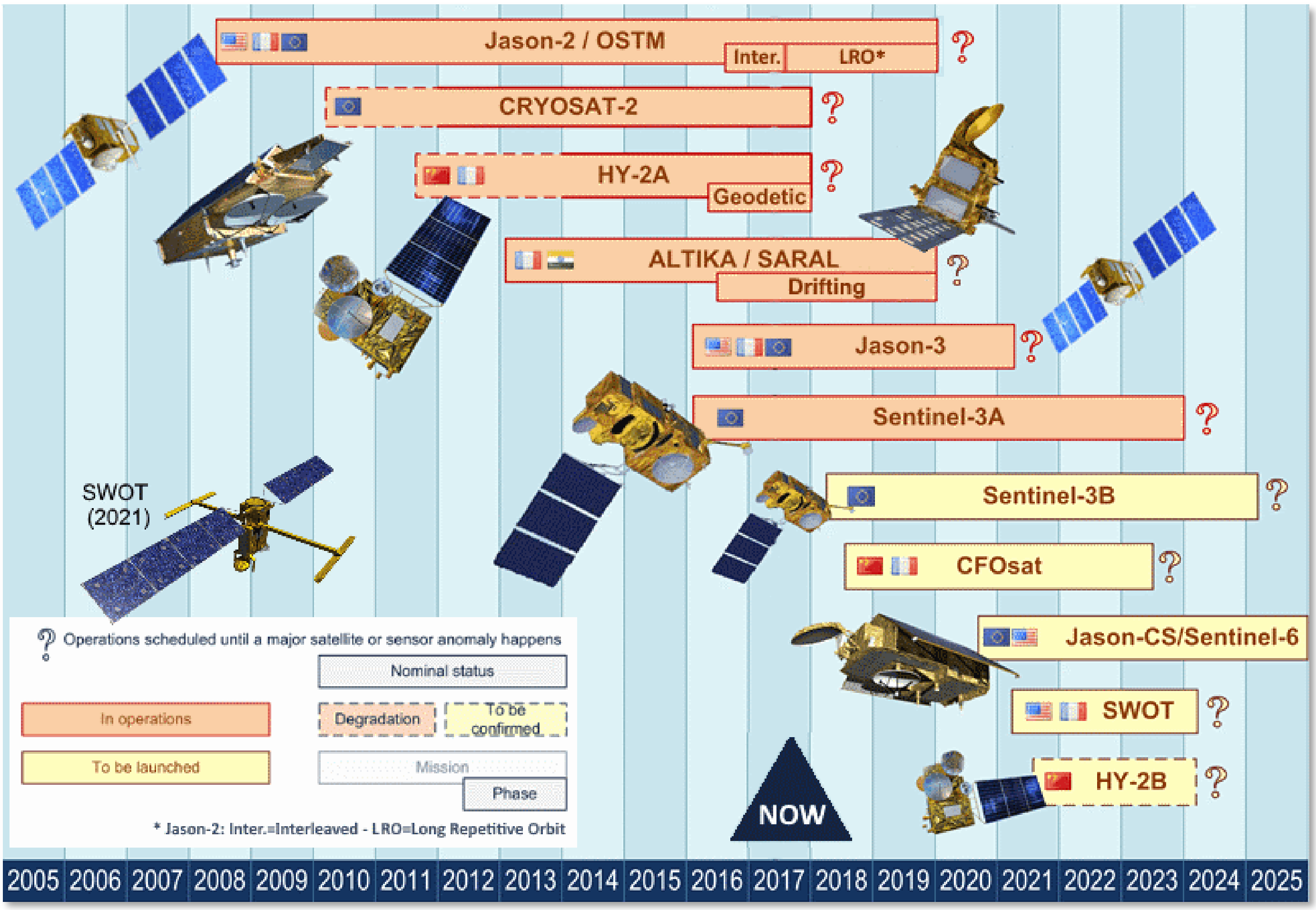
At the current time, the virtual altimeter constellation includes six operating satellites and two new missions are expected to join the constellation in 2018. They are the Sentinel-3B Copernicus mission operated by ESA and EUMETSAT and the CFOSAT mission operated by CNES and CNSA.

CFOSAT is a French-Chinese oceanography mission (CNES/CNSA) devoted to surface ocean wind and wave observation. The satellite instruments are currently being integrated in China. The launch has been scheduled for October 2018. A prototype SWIM NRT processing line has now been completed, so development of operational processing lines has begun at the French Mission Center. Since August 2017, simulated SWIM data are available to PIs for further investigation (please contact [Flavien Gouillon at CNES](#)).



CFOSAT, Credits Thales Alenia Space.

Sentinel-3 is an EC mission designed to measure sea-surface topography, sea- and land-surface temperature, and ocean- and land-surface color. Sentinel-3 belongs to [a series of satellites](#), each covering a different aspect of Earth Observation and monitoring. Sentinel-1 is an SAR-dedicated satellite while Sentinel-2 is flying an optical payload, *etc.* **Sentinel-3A**



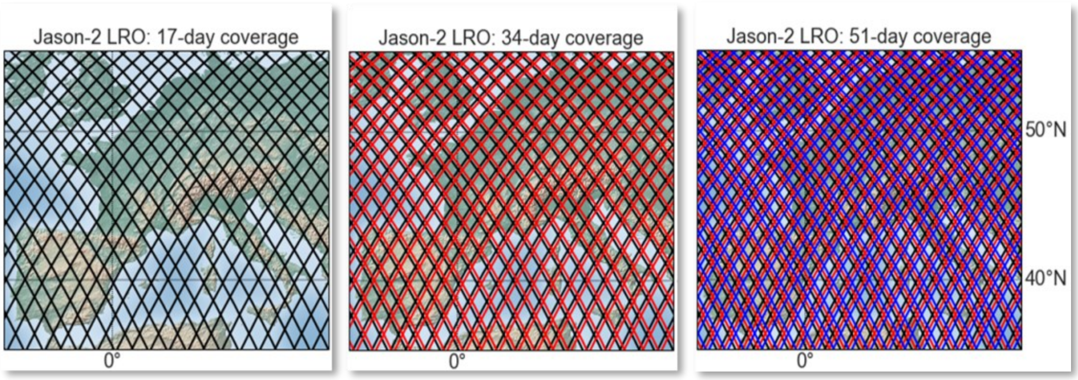
Timeline of current and forthcoming radar altimetry missions. Credits CNES.

was launched on February 27, 2016 and is currently in nominal operation handled by ESRIN and EUMETSAT. **Sentinel-3B** is expected to be launched in April 2018 with a Rockot launcher.

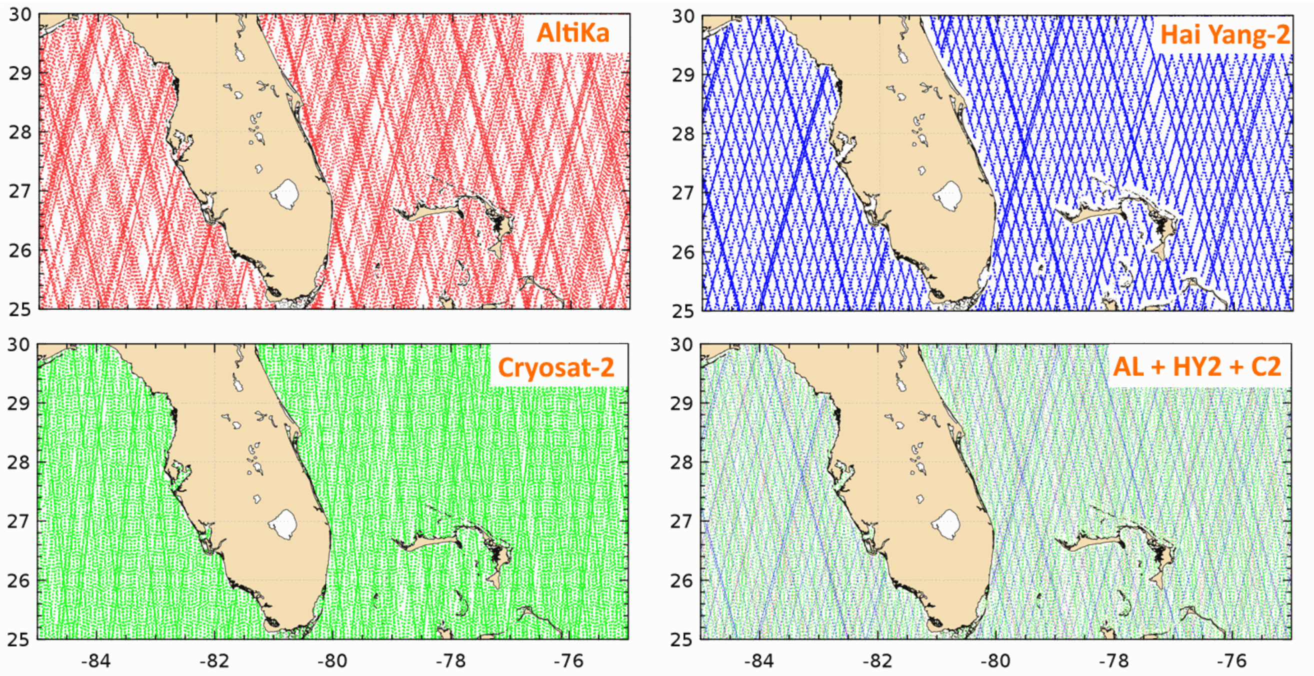
The **Jason-3** Satellite is performing nominally on its reference orbit and is the reference mission for the AVISO+ and CMEMS DUACS system. After nearly 10 years in orbit, the CNES/NASA/EUMETSAT/NOAA **OSTM/Jason-2** mission continues to provide the altimetry community with high-quality products despite a few periods during which it is unavailable due to the ageing of some components. In July 2017, Jason-2 was placed on a Long Repetitive Orbit (LRO) at an altitude of roughly 1309.5 km. Jason-2 coverage might be degraded due to the foreseen periods during which it will not be available because of the temperature of the onboard gyros which depends on the satellite-solar angle values. Project teams are doing their utmost to ensure the best coverage possible.

The French-Indian **SARAL** mission is being operated by CNES and ISRO (the Indian Space Research Organization) with the participation of EUMETSAT. SARAL was launched on February 25, 2013. The mission is working without a hitch and has provided valuable Ka-band altimetry results for more than four years now. In the summer of 2016, SARAL/AltiKa was placed on a geodetic orbit. CNES & ISRO have decided to increase the orbit's semi-major axis by 1 km and let SARAL drift (i.e. requiring no maneuvers other than for collision avoidance). This move to a drifting orbit is intended to improve geodesy and create new data to enhance Mean Sea Surface (MSS) models. SARAL successfully passed the 3rd joint Exploitation Review at the beginning of December and the exploitation phase has been formally extended up to the end of 2019.

Hy-2A, launched in August 2011, is a Chinese mission with French-Chinese collaboration between CNES and CNSA/NSOAS for altimetry (DUACS) and orbitography products (IDS). On March 23, 2016, the



Jason-2 Long Orbit Repetitive Orbit (LRO) characteristics. From 2017 OSTST presentation.



Ground coverage other geodetic missions. From 2017 OSTST presentation. Credits CNES/CLS.

Hy-2A satellite was moved from its nominal orbit to a geodetic orbit around 2 km higher. The new orbit has a 168-day cycle with 2,315 orbits in the full cycle.

ESA's **CryoSat-2** ice mission, launched on April 8, 2010, also contributes to the multi-mission SSALTO/DUACS system as a complementary mission for value-added products (Levels 3 & 4). Cryosat-2 is expected to continue up to February 2019 at least, given that there is no sign of degradation on the platform at the moment. In November ESA released a new version of the Ocean products (baseline C) which is almost aligned with Sentinel-3A products. Global reprocessing of ocean data collected from April 2010 to date, has been scheduled and will be proposed in 2018.

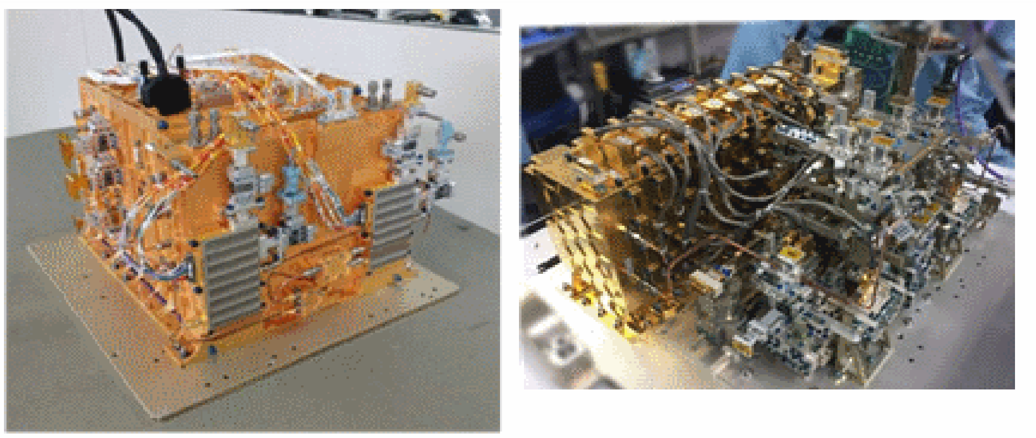
Four satellites are also in a geodetic and/or LRO orbit, thus providing a very dense coverage of the ocean surface as illustrated for the Florida region during the OSTST meeting in 2017.

Ongoing developments

SWOT (Surface Water and Ocean Topography) is a French-American mission run jointly by CNES and NASA, with the participation of UKSA and CSA, to study oceanic and inland water surfaces. Mission progress is nominal, with the first deliveries of the CNES electric model to the JPL team. The mission's critical design review (CDR) will be held early in 2018 and the first flight models are expected to be delivered in 2018.

ESA has chosen two concepts, FORUM and **SKIM** for further development, to compete for the ninth Earth Explorer mission. The Sea-surface Kinematics Multiscale monitoring (SKIM) candidate would carry a novel, wide-swath, scanning multibeam radar altimeter to measure ocean-surface currents. Uniquely, it would use a Doppler technique, which offers more direct measurements than conventional satellite altimeters. These new measurements would improve our understanding of vertical and horizontal ocean–surface dynamics over the global ocean every few days. This would increase our knowledge of how the ocean and atmosphere interact – for example, how atmospheric carbon dioxide is drawn down into the ocean.

Sentinel-6A/Jason-CS-A, the first of a two-satellite Sentinel-6 constellation, is scheduled to be launched from Vandenberg Air Force Base, California, US, late in 2020. Also known as Jason Continuity of Service (Jason-CS), the Sentinel-6 satellites will replace the Jason-3 satellite to ensure the continuity of operational oceanographic services on the reference orbit.

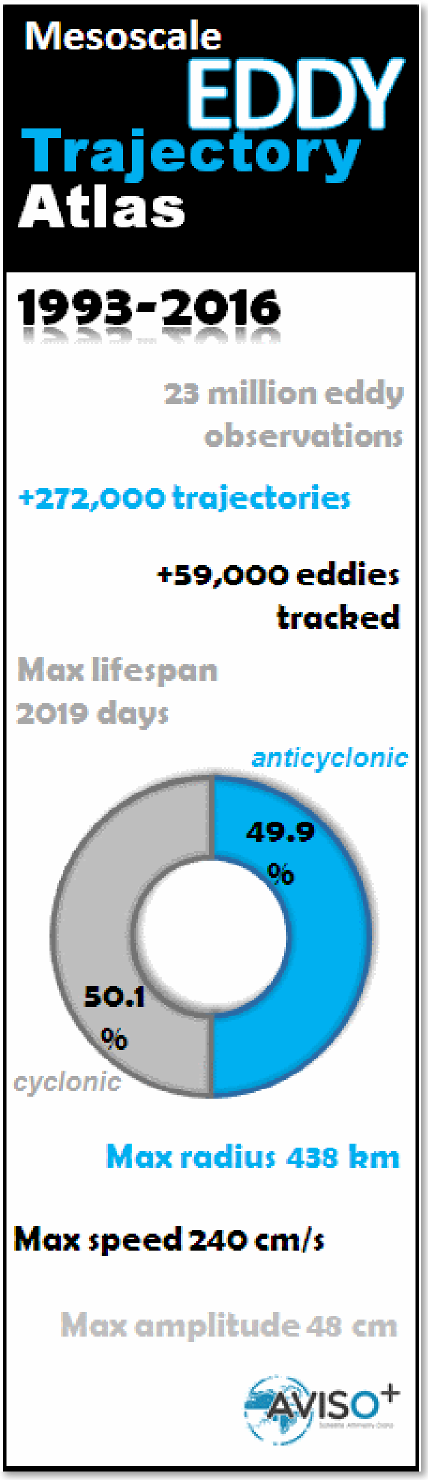


KaRin Hyberbox EM (left) and KaRin Duplexer EM (right) in SWOT payload. Credits Thales Alenia Space / Honeywell.

Tools for the Mesoscale Eddy Trajectory Atlas

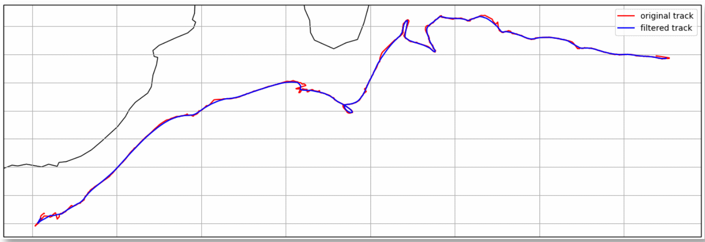
CLS, Antoine Delepoulle

A new "Mesoscale Eddy Trajectory Atlas" was released in October 2017 on the Aviso altimetry website. An example has been made available to help you handle the file and generate the visual representation of the eddy trajectories.



This dataset was produced and validated by the SSALTO/DUACS team in collaboration with D.Chelton and M.Schlax from Oregon State University. It replaces the dataset formerly produced and distributed at Oregon State University (OSU). This Mesoscale Eddy Trajectory Atlas is distributed by AVISO+ and available to subscribers from the website.

The processes of mesoscale ocean circulation, such as the formation, evolution and dissipation of eddy-like structures, are significantly affected by the ocean's kinetic energy. These processes play a vital role in the vertical and horizontal flows of the energy (heat), salts, carbon and nutrients that they carry with them. The ability to take them into account is an important breakthrough for climate studies.



First example: map of original (in red) and filtered (in blue) trajectories of a given eddy. Credits CNES/CLS.

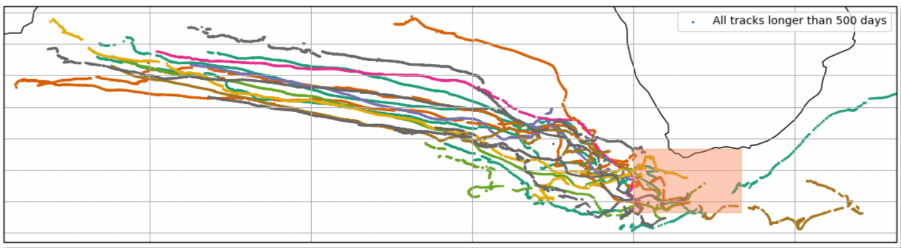
The current version of the eddy atlas has been produced from 24 years of daily altimetry maps of sea surface height (SSH) based on sampling by two satellites (1993-2016). The Aviso Eddy Trajectory Atlas is stored in a single file that contains several fields for physical values: eddy radius, eddy amplitude, eddy rotation speed and rotation type (Cyclonic/Anticyclonic). Other information is also available: time of observation, coordinates, ID of the track, and observation number (which gives the number of days of tracking).

The Atlas will be updated once or twice a year, and special care will be taken to ensure the continuity of eddy identification (same ID). The Atlas is in NetCDF format and contains a vast amount of data (302 MB), covering several different physical variables and a one-dimension counting parameter . This parameter, labelled "obs", represents the total number of observations for the period 1993-2016, with each observation corresponding to an x,y movement of an eddy. In this first edition, there is already an accumulated total number of 23,086,878 observations!

The size and structure of the file may make it difficult to manipulate the data. An example of a program written in Python is available to help you get used to handling the Atlas's data. It can be downloaded here. This program uses common libraries (xarray, numpy, cartopy and matplotlib) to compile two examples for representing eddy trajectories.

The first example tracks (figure above) the real and filtered trajectories of a given eddy. The user configures the ID of the eddy ("track" variable, eddy identification number), and the smoothing window (min_periods variable).

The second example (figure below) tracks all the eddies in a given zone whose lifetime exceeds a certain number of days. The user initialises the boundaries (lon,lat) of the zone and the lifetime (observation_number, i.e. number of days from the start of the eddy).



Second example: map of trajectories of all eddies with a lifetime longer than 500 days, in a given zone, for the entire period of 1993-2016. Credits CNES/CLS.

A database of hydrology targets for the new DEM onboard Jason-3

CNES/LEGOS/CTOH, Denis Blumstein
CNES, Sophie Le Gac

Satellite radar nadir altimeters have been widely used to measure river and lake surface water elevations for the last two decades.

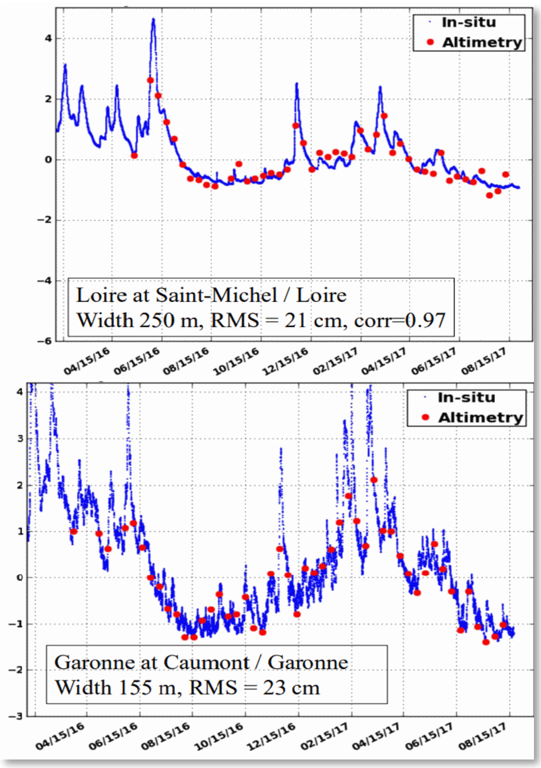
However, since these instruments are primarily designed to observe ocean surface topography, they are not always able to observe inland waters. For rivers running in valleys not wider than a few kilometers and surrounded by slopes higher than 50 meters, altimeters tend to observe the top of the surrounding topography rather than the river itself. This occurs for all river widths, but is more frequent for smaller rivers. The altimeter instrument on Jason-3, launched in January 2016, operates in "Diode/DEM" tracking mode or Open-Loop mode (OL) which is designed to overcome this issue. The altimeter uses an onboard **Digital Elevation Model** to set the echoes reception window. This tracking mode has proven efficient, however, it requires *a priori* knowledge of the target elevation with fairly good exactitude (typically a dozen or so meters). It is no minor task to collect data which meet this constraint on a global scale.

This is why, given the interest for the entire hydrology community, the CTOH and ECHOS teams working on LEGOS and CNES teams have combined their technical and scientific expertise to implement the right strategy. The database was thus recently enlarged with about 4,700 targets (lakes and rivers) all over the world to build the new Jason-3 onboard DEM which was uploaded at the end of August 2017 and has been activated since Cycle 57, track 160.

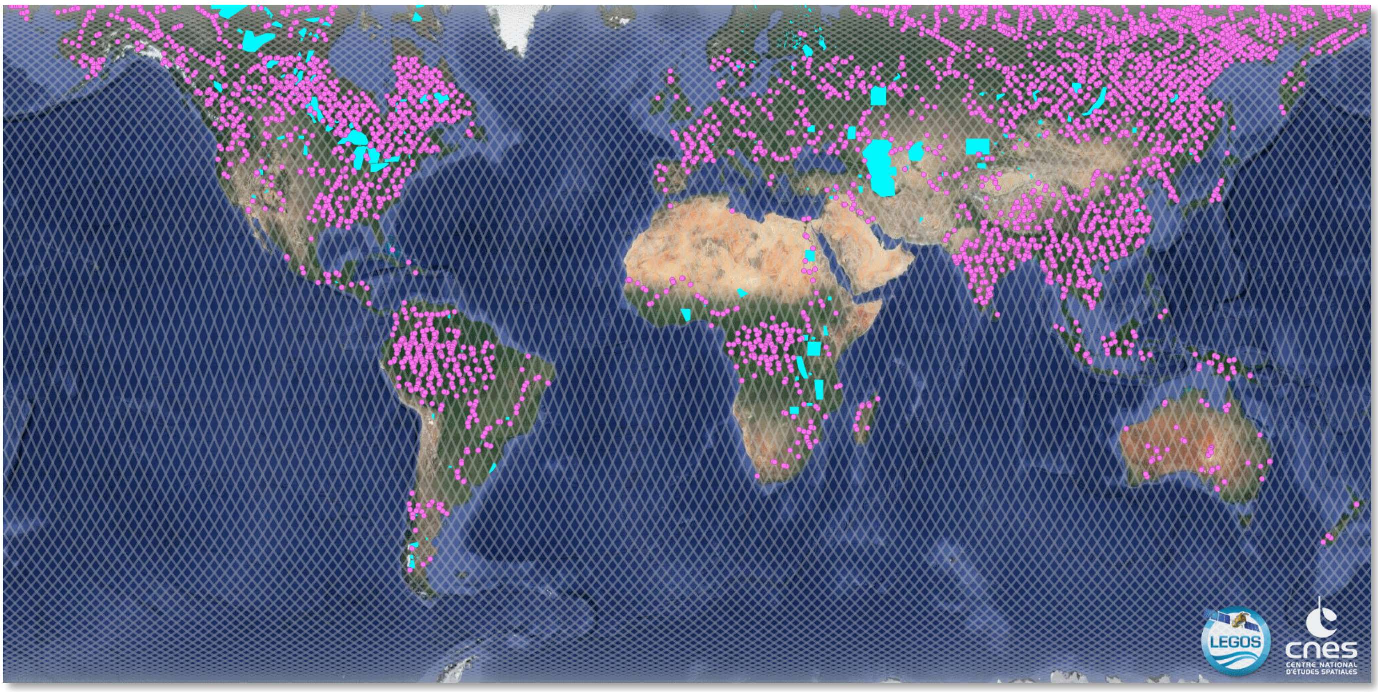
Validation

This upload was very successful and the validation done over four cycles shows that the altimeter performance over inland waters has been significantly improved. For example, it has been shown that "small" rivers such as the Loire or the Garonne in France, which had never been observed in the past by the Jason satellites, are now observed for each over-pass.

A much larger scale validation was performed in two steps. (1) Validation on a global scale using a high backscatter coefficient (sigma0) as a proxy to ensure that



Water elevation anomaly of the Loire river (top), at Saint-Michel (250 m width), and the Garonne river (bottom) at Caumont (155 m width) compared with in-situ measurements. Credits LEGOS.



Current Jason-3 onboard DEM targets operational since Cycle 57, pass 160 (August 31st, 2017), including 355 lakes from Hydroweb database (in blue) and 4,366 rivers and lakes (in pink). Credits CNES/LEGOS.

the altimeter is indeed tracking water (not shown here, see details on the poster presentation, part.5). (2) Visual validation using human expertise for a sample of 100 stations randomly located around the globe (map below). The result of this validation is shown in the table below.

Access to the database

Users are strongly encouraged "to dive" into Jason-3 data over hydrological targets. The database of targets (lakes and rivers) is available upon request in shapefile or text format. Please send your request and any comment/ proposal to Sophie Le Gac, Jason-3 DEM database manager at CNES:.

Perspectives

In the future, we plan to continue increasing the size of the database for Jason-3 and similar work is being done for Sentinel-3 A & B. We believe this is a useful contribution to the progress of hydrology using altimetry data, in preparation for SWOT. More details on how the onboard DEM database is handled and updated in order to best serve the hydrology community will be provided in an upcoming issue. Stay tuned !

References:

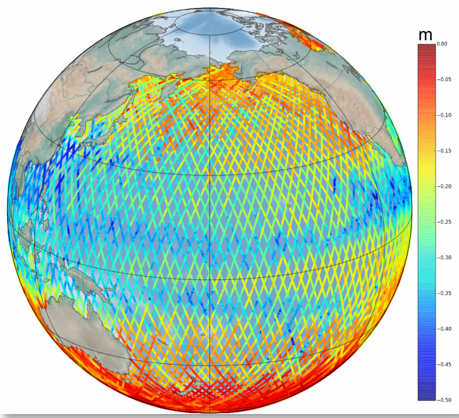
- Blumstein D., et *al.*, A Database Of Hydrology Targets For The New DEM Onboard Jason3, OSTST 2017, Miami.
- Biancamaria S. et *al.*, Validation of Jason-3 tracking modes over French rivers, RSE, in review.
- Le Gac S., Update and validation of the onboard Jason-3 DEM for enhanced acquisitions over inland water targets, OSTST 2017, Miami.

	Closed-Loop	Open Loop
Tracking water	41 (54%)	91 (91%)
Not tracking water	35 (46%)	9 (9%)
total	76 [(1)]	100

Map on the left: location of the 100 stations (yellow dots) superimposed to the Jason-3 ground tracks. Table on the right: Percentage of occurrence of water observation in the ***Open-Loop (OL)*** *mode is 91 % while it was only 54 % in the classic autonomous or so called* ***Closed - Loop (CL)*** *mode.* [(1)] *24 stations already in OL mode during cycles 53 to 56.*

Distribution of GPD+: state of the art Wet Tropospheric Correction

LEGOS/CTOH, Fernando Niño



Wet Tropospheric Correction (WTC) for Jason-2, cycle 295 (July 2016) in GPD+ dataset. Further information at the ***AVISO+ webpage for GPD****+.Credits LEGOS/CTOH.*

In 2017 the Faculty of Science, University of Porto (UPorto, Portugal) and AVISO+/CTOH began collaborating to distribute the most recent data of UPorto's GPD+ dataset (GNSS-derived Path Delay Plus).

This state-of-the-art dataset, produced at the University of Porto, retrieves improved Wet Tropospheric Corrections (WTC) for radar altimetry missions. The GPD+ WTCs are estimated by objective space-time analysis, by combining all available observations in the vicinity of the point: valid measurements from the on-board microwave radiometer (MWR), from Global Navigation Satellite System (GNSS) coastal and island stations, and from MWR imaging instruments on various remote sensing satellites. The GPD+ corrections are available both for satellite missions which do not have an on-board microwave radiometer, such as CryoSat-2 (CS-2) and for all satellite missions which carry this sensor, by addressing the various error sources inherent in the MWR-derived WTC.

To ensure long-term stability of the corrections, the large set of radiometers used in this study have been calibrated with reference to the Special Sensor Microwave Imager (SSM/I) and the SSM/I Sounder (SSM/IS). The format is NetCDF and the product has been reformatted to be compatible with all other CTOH products. Available missions are: ERS-1 and ERS-2, Envisat, Topex, Jason-1, Jason-2 and Jason-3, as well as Cryosat-2 and Saral/Altika. More data information is available at the **AVISO+ webpage for GPD+**.

15 years of observations of the thickness of Arctic sea ice using satellite altimetry

LEGOS/CTOH, Sara Fleury, Kevin Guerreiro

Research scientists at LEGOS (the ECHOS and CTOH teams), working together with CNES (PEACHI and TOSCA SICKAyS-PRIAM projects), have developed a new product, using satellite altimetry, for observing the thickness of Arctic sea ice over a 15-year period (2002-2017).

Currently, the only way of observing the thickness of sea ice at the scale of the ocean is by satellite altimetry. The principle involves measuring the difference in height between the ice and the surrounding water. From this difference it is possible to deduce the freeboard height of sea ice, i.e. the height of the emerged ice. The total thickness can then be calculated from a knowledge of the relative density of the sea ice and the seawater.

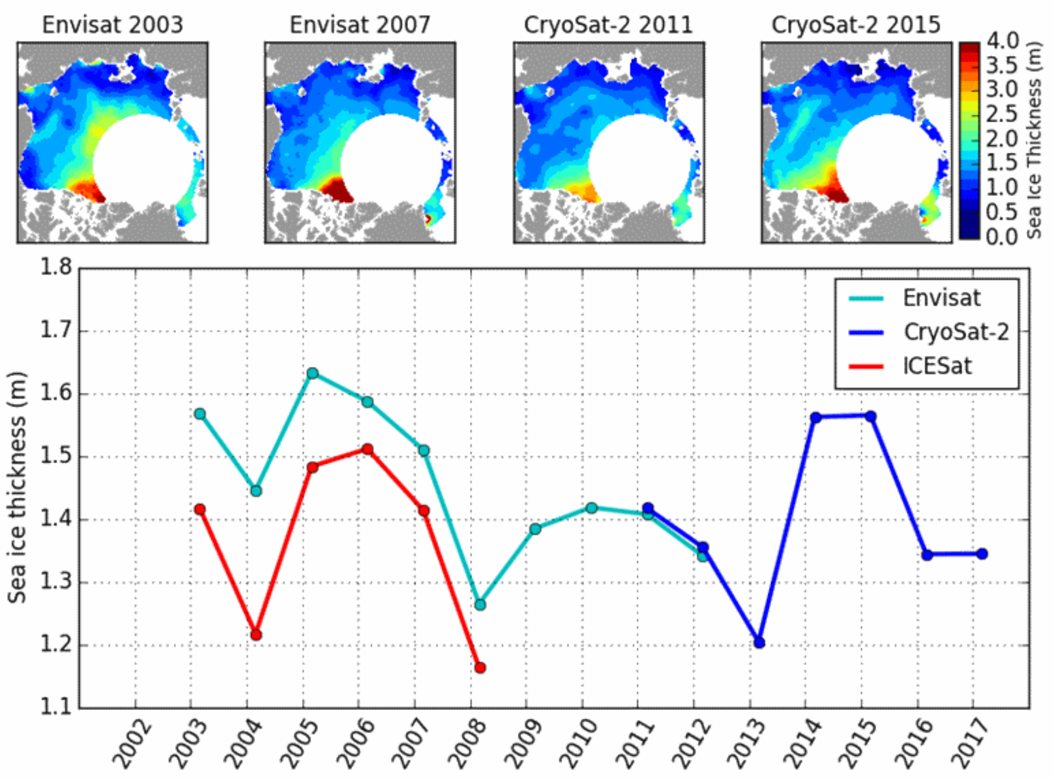
While the principle is simple, it is complicated to implement because the tangle of ice and water results in an extremely complex radar signal that can be hard to interpret, whereas the goal is to measure differences in height of just a few centimetres. This explains why it is difficult to develop such products. When different altimetry missions use different radar instruments, the problem becomes even more complex.

The LEGOS scientists showed that the differences between LRM(1) and SAR(2) radar measurements are due to the roughness of the surface, which affects the measurements since they depend on the surface illuminated by the sensing instrument (as the two techniques cover very different surfaces). They were then able to calculate a corrective factor by comparing the results for the two years when the Envisat and CryoSat-2 missions were flying simultaneously (2010-2012), thus obtaining a continuous series of measurements over 15 years for the first time.

The result, illustrated by the curve shown below, representing the thickness of the ice for the period 2002-2017, reveals a remarkable correlation with the thickness of the ice obtained by laser altimetry from the American IceSat satellite, which has a ground footprint of only 70m. This opens up prospects, currently being investigated, of extending the time series to include the period from 1995 to 2017, using the measurements taken by ERS-2.

There are many potential benefits for science: improvements to sea ice models, global climate models, polar current models, water mass budgets, *etc*.

This first multi-mission product concerning the thickness of Arctic sea ice will be available [on the AVISO+ website](#) from December 2017. It will be in the form of monthly sea ice thickness maps for the winter months (October to April) for the period 2002-2017. The spatial resolution will be 12.5 km x 12.5 km.



*Top: Sea ice thickness maps for February-March extracted from the **SIT_ENV_CS2_nh** product soon to be distributed by [AVISO+.](#) Bottom: estimated time series of mean Arctic sea ice thickness (February-March) based on Envisat (in light blue) and CryoSat-2 (in dark blue) and compared to the corresponding estimates obtained from ICESat-NSIDC (in red). Credits LEGOS/CTOH.*

References

- Guerreiro, K., Fleury, S., Zakharova, E., Kouraev, A., Rémy, F., & Maisongrande, P. (2017). Comparison of CryoSat-2 and ENVISAT radar freeboard over Arctic sea ice: toward an improved Envisat freeboard retrieval. The Cryosphere, 11(5), 2059. [doi.org/10.5194/tc-11-2059-2017](#)

(1) *LRM: Low Resolution Mode. This is currently the most widely used altimetry technique. When using the Ku-band, this technique has a ground footprint in the region of 10 km.*

(2) *SAR: Synthetic Aperture Radar. This technique is used for the "nadir" altimeters of the CryoSat-2 and Sentinel-3 missions. Using the Ku-band, the ground footprint is just a few hundred metres.*

Upcoming high-resolution SSH maps from Dynamic Interpolation

CLS, Clément Ubelmann

Several innovative mapping techniques are being developed and tested to take advantage of the dense weave of observations now available and to improve the restitution of non-linear dynamics. A dynamic interpolation method allowing propagation modelling of spatial covariance has been implemented. Tests are being done in several regions and a series of validations and comparisons with independent data are being conducted to assess performance with respect to the reference gridded maps of the Copernicus Marine Environment Monitoring Service (CMEMS).

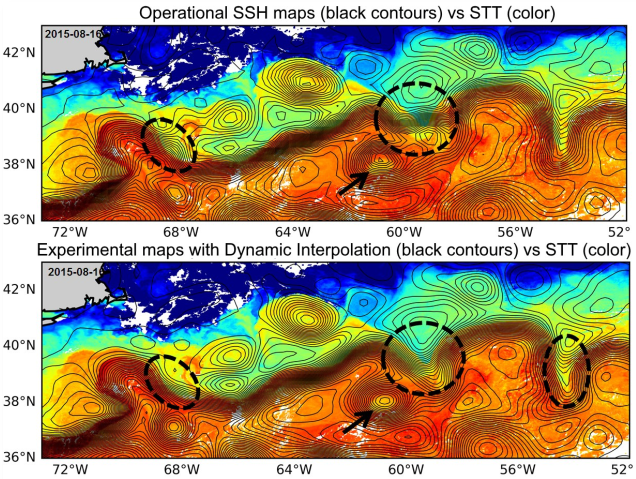
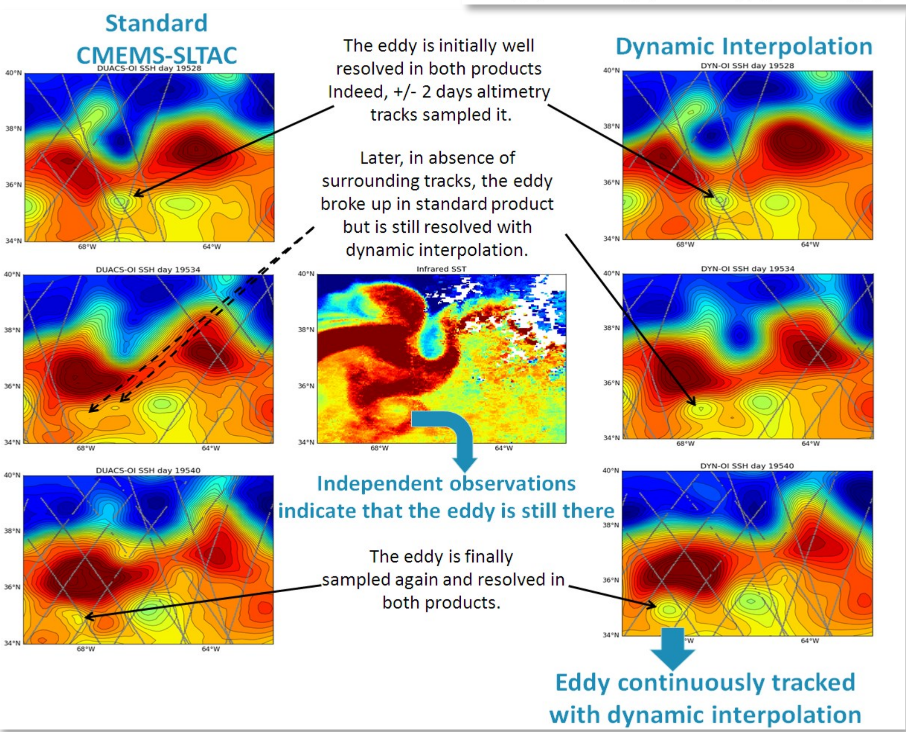


Figure 1: Comparison between topography and independent Sea Surface Temperature observed during a clear sky event in the Gulf Stream area. SST data from CLS combining data from MODIS, VIIRS (NASA Ocean Color Web) and AVHRR (NOAA). Credits CNES/CLS.



For the high energy vein of the Gulf Stream, significant improvements were obtained with a 20% reduction of mismatching as compared with independent altimetry profiles. Some comparisons with Sea Surface Temperature (figure 1, above) clearly illustrate these improvements.

The continuous eddy trajectories (figure 2, left) indicate better resolving capabilities. This experimental Ssalto/Duacs product will soon be distributed from AVISO+ website. Further information on the poster presentation on the OSTST meeting « Can we compute higher resolution AVISO+ maps? ».

Figure 2: Illustration of SSH evolution suggesting improved eddy resolving capabilities especially during temporal data gaps. Credits CNES/CLS.

Events

11-16 Feb. 2018: Ocean Science Meeting, Portland, Oregon, USA

13-15 Mar. 2018: Sentinel-3 Validation Team meeting, Darmstadt, Germany

08-13 Apr. 2018: EGU General Assembly, Vienna, Austria

24-29 Sep. 2018: 25 Years of Progress in Radar Altimetry Symposium including the annual meeting of the OSTST and the IDS workshop, Saõ Miguel Island, Azores

Dec. 2018: AGU Fall meeting, Washington DC, USA

AVISO+ Users Newsletter

AVISO+
11 rue Hermès
Parc Technologique du Canal
31520 Ramonville St Agne, France

Publication Dir.: T.Guinle, G.Dibarboure
Editor-in-chief: C.Mercier
Contributors: N.Picot, A.Delepoulle, C.Ubelmann, S.Fleury, D.Blumstein, S. Le Gac, F.Niño.

Contacts:
http://www.aviso.altimetry.fr
aviso@altimetry.fr