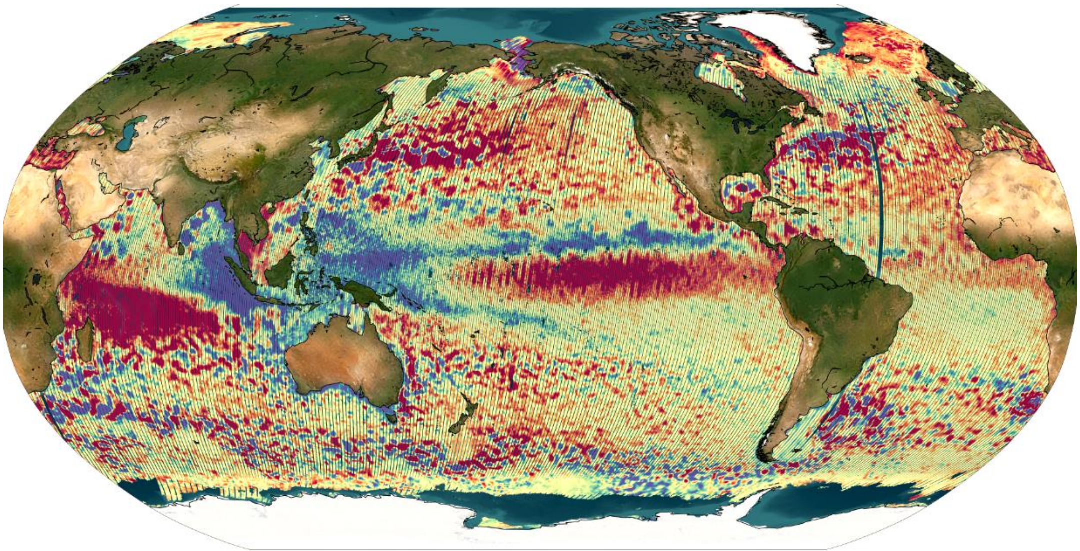
DUACS Level-3 SWOT KaRIn (L3_LR_SSH) User Handbook



Nomenclature: SALP-MU-P-EA-23629-CLS
Issue:2.0

Date: March 2025

Chronology Issues:			
Issue:	Date:	Validated by	Reason for change:
1.0	September 2023		First issue
1.1	May 2024		Updated product release (V1.0)
1.2	June 2024		Addition of Unsmoothed products
1.3	September 2024		Add product versions changes V1.0.1 and V1.0.2 (Basic and Expert datasets)
1.4	October 2024		Add Unsmoothed v1.0.2 Complete information on V1.0.2 temporal availability
1.5	January 2025		Add V2.0 Basic and Expert datasets
2.0	March 2025		Add v2.0.1 Basic and Expert and Unsmoothed products

List of Acronyms

Aviso+	Archiving, Validation and Interpretation of Satellite Oceanographic data
CLS	Collecte, Localisation, Satellites
CNES	Centre National d'Etudes Spatiales
SLA	Sea Level Anomaly
DAC	Dynamical atmospheric correction
L2	Level-2 product
L2P	Level-2+ product
L3	Level-3 product

Table of Contents

1 Introduction

This user manual describes the products named "Swot L3 KaRIn". The Level-3 (L3) products are formally part of the Science Team Project DESMOS and funded by the French Early Adopter Program (i.e. PIA). Those products are lightweight, simple, and usable out-of-the-box; moreover, Nadir altimeter & KaRIn measurements are displayed in one single image.

The Value-added compared to SWOT L2 KaRIn (L2_LR_SSH) products are:

- State of the art research-grade upgrades (incl. very recent & submitted papers)
- Multi-mission calibration (SWOT is consistent with other altimeters)
- Noise-mitigation for SSHA derivatives (experimental, AI-based)
- Pre-made sophisticated editing procedure KaRIn and nadir instruments blended into a single image
- L3 has new layers (optional) that can blend with L2 fields

3 types of files are distributed: Basic, Expert and Unsmoothed.

- Basic L3_LR_SSH includes only SSHA (Sea Surface Height Anomaly) and mean dynamic topography (MDT).
- Expert L3_LR_SSH includes the backscatter coefficient (sigma0), the mean sea surface (MSS) and geostrophic currents (absolute and anomalies) in addition to SSHA and mean dynamic topography (MDT). It also integrates algorithms, corrections and external models as separate layers.
- Unsmoothed L3_LR_SSH includes the MSS, MDT and geostrophic currents (absolute and anomalies) in addition to the SSHA and MDT on the 250-m KaRIn native grid. Like the Expert subproduct, it also integrates a quality flag, corrections and external models as separate layers.

Publications should include the following statement in the Acknowledgments:

Citation Basic L3_LR_SSH:

"The SWOT_L3_LR_SSH product, derived from the L2 SWOT KaRIn Low rate ocean data products (L2_LR_SSH) (NASA/JPL and CNES), is produced and made freely available by AVISO and DUACS teams as part of the DESMOS Science Team project". AVISO/DUACS., 2023. SWOT Level-3 SSH Basic (v2.0.1) [Data set]. CNES. https://doi.org/10.24400/527896/A01-2023.017

Citation Expert L3_LR_SSH:

"The SWOT_L3_LR_SSH product, derived from the L2 SWOT KaRIn low rate ocean data products (L2_LR_SSH) (NASA/JPL and CNES), is produced and made freely available by AVISO and DUACS teams as part of the DESMOS Science Team project". AVISO/DUACS, 2023. SWOT Level-3 SSH Expert (v2.0.1) [Data set]. CNES. https://doi.org/10.24400/527896/A01-2023.018

Citation Unsmoothed L3_LR_SSH:

"The SWOT_L3_LR_SSH product, derived from the L2 SWOT KaRIn low rate ocean data products (NASA/JPL and CNES), is produced and made freely available by AVISO and DUACS teams as part of the DESMOS Science Team project". AVISO/DUACS, 2024. SWOT Level-3 KaRIn Low Rate SSH Unsmoothed (v2.0.1) [Data set]. CNES. https://doi.org/10.24400/527896/A01-2024.003

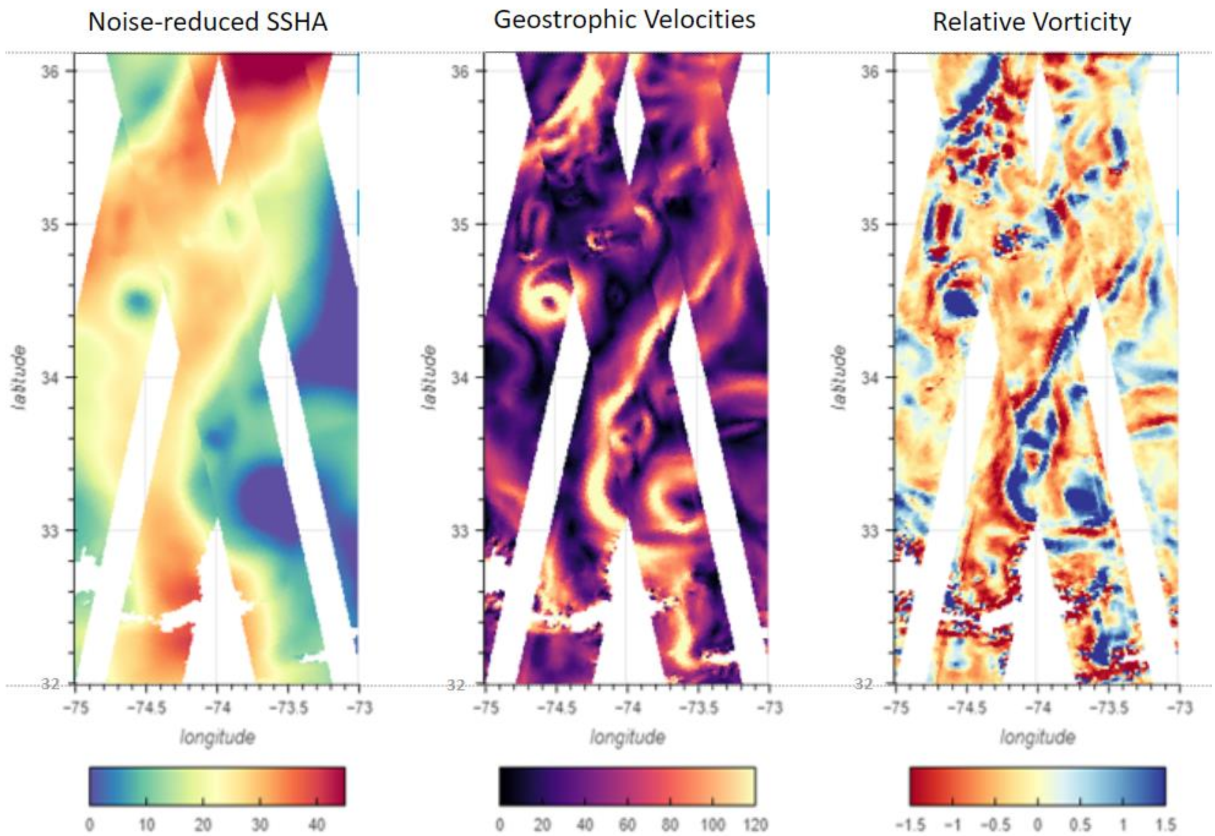


Figure 1: Example of SSHA (after noise reduction) (left), geostrophic velocities (middle) and relative vorticity (right) obtained with SWOT measurements contained in the SWOT L3 KaRIn ocean product.

1.1 Data Policy and conditions of use

The SWOT L3 KaRIn ocean product is available free of charge for scientific studies and commercial activities.

2 Processing

This section describes the processing of the SWOT L3 KaRIn (L3_LR_SSH) product. This product contains the KaRIn measurements as well as the Nadir measurements (only in Expert and Basic products): KaRIn and Nadir instruments are blended into a single image.

Note that a presentation dedicated to the processing named “SWOT Level-3 Overview and link with L2 products”, from Dibarboure et al., have been presented at the SWOT Science Team in June 2024.
The processing methodology for SWOT level 3 products is outlined in a paper by Dibarboure et al. (2024).

2.1 Processing method

The following figure provides an overview of the system for the generation of the SWOT L3 KaRIn ocean product. The Nadir component follows the same processing as the other altimeters as described in Pujol et al., 2023, and the L3 KaRIn processing sequence is given. The resultant L3 KaRIn ocean product contain both KaRIn and Nadir measurements.

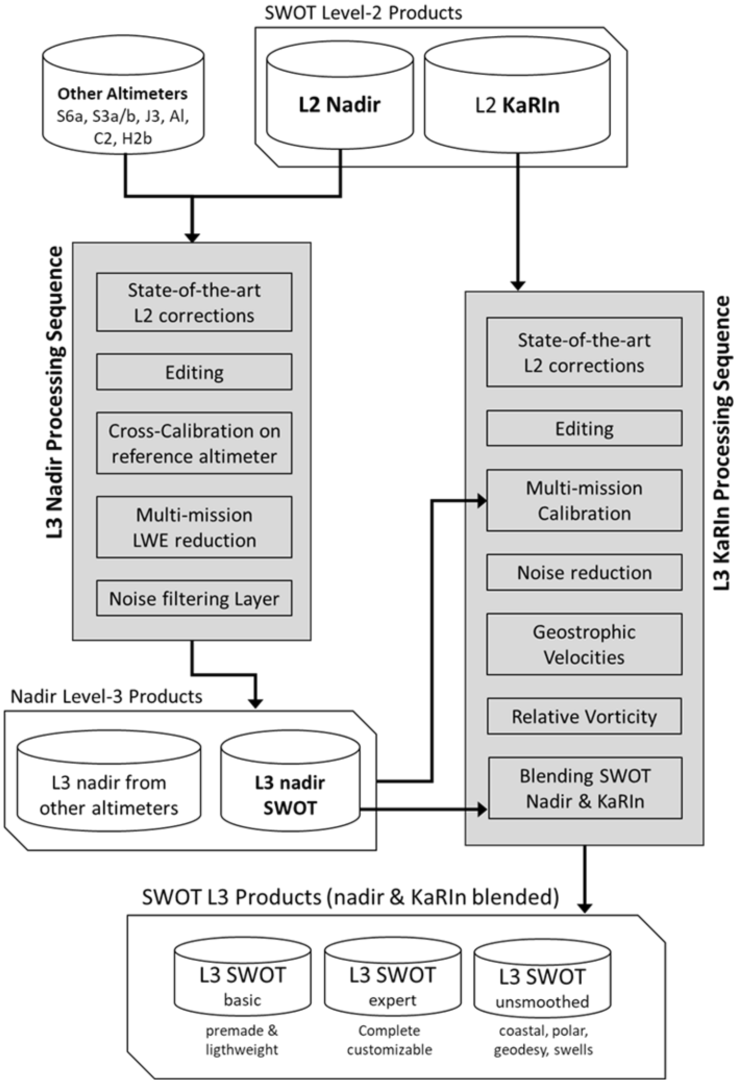


Figure 2: DUACS and SWOT L3 KaRIn and Nadir system processing

2.1.1 Input data

The input data used to compute the SWOT L3 KaRIn ocean product is the SWOT L2_LR_SSH, defined with a 2x2km or 250x250m spatial posting rate and distributed by the CDS-AVISO (https://doi.org/10.24400/527896/a01-2023.015). The version of these products evolves with time. The Table 1 lists the L2_LR_SSH product version used in the L3_LR_SSH production.

2.1.2 Up-to-date standards

The measurements are then updated with the standards as follows:

	SWOT L3_LR_SSH v1.0	SWOT L3_LR_SSH v1.0.2	SWOT L3_LR_SSH v2.0 and v2.0.1
Product standard ref	PGC0 before 23/11/2023 PIC0 after	PGC0 before 10/01/2024 PIC0 after (see section 4)	
Orbit	POE-F		
Ionospheric	GIM model computed from vertical Total Electron Content maps (Chou et al. 2023) rescaled on the orbit altitude with IRI95 model (https://irimodel.org/)		
Wet troposphere	Model computed from ECMWF Gaussian grids		
Sea State Bias	Non-parametric SSB from AltiKa GDR-F (Tran 2019)		Non-parametric SSB from AltiKa GDR-F (Tran 2019) with corrected SWH MFWAM model field
Mean Profile/ Mean Sea Surface	Hybrid MSS (SIO22,CNES/CLS22,DTU21) (Schaeffer et al. 2023; Laloue et al. 2024)		
Mean Dynamic Topography	MDT CNES_CLS_2022 (Jousset and Mulet 2020; Jousset et al. 2022) available on AVISO+ https://doi.org/10.24400/527896/a01-2023.003		MDT CNES_CLS_2022 (Jousset and Mulet 2020; Jousset et al. 2022) with a -5cm offset
Dry troposphere	Model computed from ECMWF Gaussian grids (new S1 and S2 atmospheric tides are applied)		
DAC	DAC v4.0: TUGO forced with ECMWF pressure and wing fields (S1 and S2 were excluded) + inverse barometer computed from rectangular grids		
Ocean tide	FES2022: (Lyard et al. 2023; Loren Carrère et al. 2023) (https://doi.org/10.24400/527896/a01-2024.004)		
Internal tide	(Zaron 2019) (HRETv8.1 tidal frequencies: M2, K1, S2, O1)		(Zaron E. et Elipot S. 2024) (blend of HRET14 & HRET8.1; tidal frequencies: M2, K1, S2, O1, N2)
Pole tide	(Desai, Wahr, et Beckley 2015)& Mean Pole Location		
Solid earth tide	Elastic response to tidal potential (Cartwright et Edden 1973; Cartwright et Tayler 1971)		
Loading tide	FES2022: (Lyard et al. 2023; Loren Carrère et al. 2023)		

Table 1: Altimeter standards used in the L3 KaRIn production

2.1.3 Cross Calibration

The correction is computed with the XCAL algorithm. The reference for the XCAL algorithm is Dibarboure et al., June 2022, SWOT Science Team meeting, SWOT simulated Level-2 and Level-3 data-driven calibration and Dibarboure et al., Sep 2023, SWOT Science Team meeting, Crossover Calibration Status and Examples.

The methodology was improved in the L3 V1.0 version with an updated phase screen correction with two components (varying with beta angle and in-orbit position) and an improved interpolation method for short segments

- In the v2.0 version, the calibration has been improved with the aim of reducing the leakage of the ocean dynamic signal and taking into account the improvements made to the data selection processing: A large part of the data selection is newly applied before calibration
- Data eclipse transition segments are used in the calibration
- Fewer degrees of freedom are used
- (L3 pseudo phase screen corrections remain unchanged w.r.t v1.0.2)

The correction applied on the 250x250m product is an interpolation of the solution computed using 2x2km data.

2.1.4 Editing

The editing process mainly consists in applying the flags that are in the L2_LR_SSH input files. The variables taken into account are:

- ancillary_surface_classification_flag (to keep only ocean data),
- ssha_KaRIn_2_qual (L2 product flags)
- ssh_KaRIn_uncert (measurement uncertainty)
- distance_to_coast (for the coastal flag)
- cross_track_distance (distance from the nadir)
- Ice_concentration (for the polar flag)
- sig0_karin_2 (for the sea-ice classification of the Unsmoothed product)

From the L3_LR_SSH v1.0, a flag expert was created. Each step of the editing process can be activated or deactivated. The following table gives the different flag values available for the different product versions.

Quality flag values in v1.0	Quality flag values in v2.0 and v2.0.1
• Flag #102: No SSHa values available • Flag #101: Pixels over land. • Flag #100: Edges of swath. Only values between 10 to 60 km to the nadir are considered as valid data. • Flag #70: Pixels impacted by spacecraft events. • Flag #50: Abnormally high SSHA values. • Flag #30: SSHA pixels out of the expected statistical distribution. • Flag #20: Suspected sea-ice pixels. • Flag #10: Suspected coastal pixels. • Flag #5: SSHA pixels out of the local distribution. • Flag #0: Valid data.	• Flag #102: No SSHa values available • Flag #101: Pixels over land. • Flag #100: Edges of swath. Only values between 10 to 60 km to the nadir are considered as valid data. • Flag #70: Pixels impacted by spacecraft events. • Flag #50: Abnormally high SSHA values. • Flag #30: SSHA pixels out of the expected statistical distribution. • Flag #20: Sea-ice pixels • Flag #19: Unsure sea-ice pixels (only for the unsmoothed product) • Flag #18: Unsure ocean pixels in polar areas (only for the unsmoothed product) • Flag #10: Suspected coastal pixels. • Flag #5: SSHA pixels out of the local distribution. • Flag #3: Eclipses. • Flag #0: Valid data.

Table 2: Quality flag values in L3 KaRIn products

More details about each flag are available in Dibarboure et al (2024). The following figures show some cases of use of the flag expert. For most studies, we recommend keeping only flag #0 to flag #3.

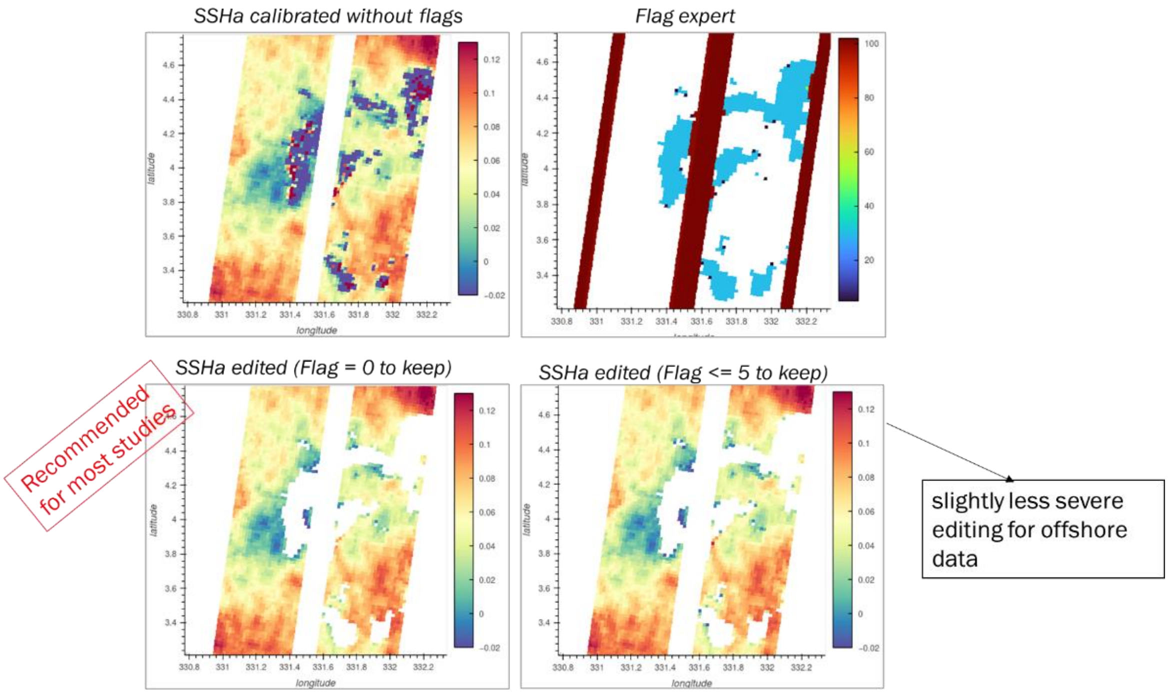


Figure 3: Example of editing of the rain cells. Keeping flags #0 to #3 is recommended.

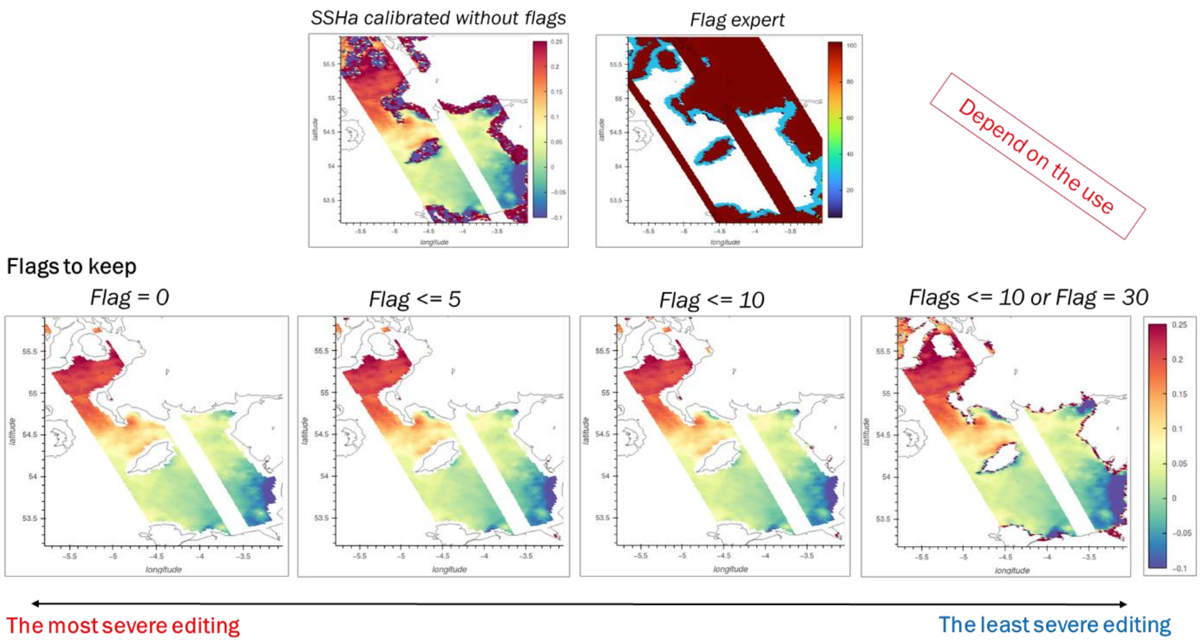


Figure 4: Example of editing of coastlines

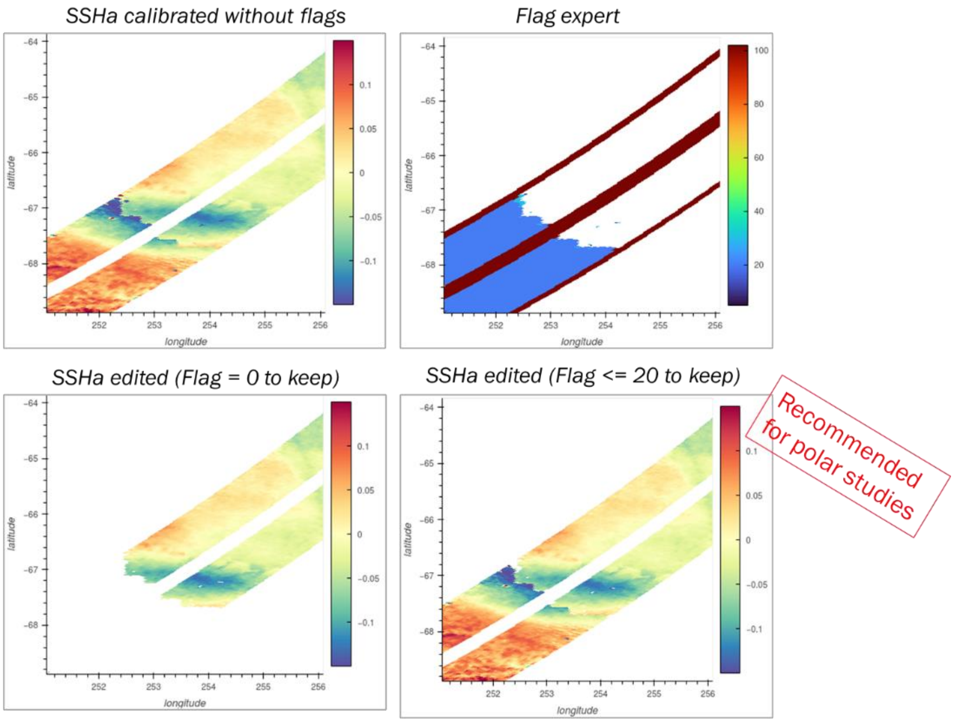


Figure 5: Example of editing of polar areas

2.1.5 Filtering

Despite its unprecedented precision, SWOT's Ka-band Radar Interferometer (KaRIn) still exhibits a substantial amount of random noise. A filtering method is then applied, it is described in Treboutte et al., 2023. It consists of a Neural Network which is based on a U-Net architecture and is trained and tested with simulated data from the North Atlantic. The following table presents the differences between the L3_LR_SSH v0.3 and the L3_LR_SSH v1.0 or v2.0 :

	Version 0.3	Version 1.0, 1.0.1, 1.0.2,2.0 and 2.0.1
Training dataset	Based on the eNATL60 ocean model without tides Noise generated by the SWOT simulator	Based on the eNATL60 ocean model with tides Correlated Noise generated by style transfer to be as realistic as possible
Use of the [Gomez et al, 2020] algorithm	Yes after the UNet	No

Table 3: Filtering method applied for the SWOT L3_LR_SSH v1.0 and v2.0

More details about the training dataset are available in Dibarboure et al. (2024).

The **Figure 6** shows the impact of the filtering in the resultant current and the vorticity.

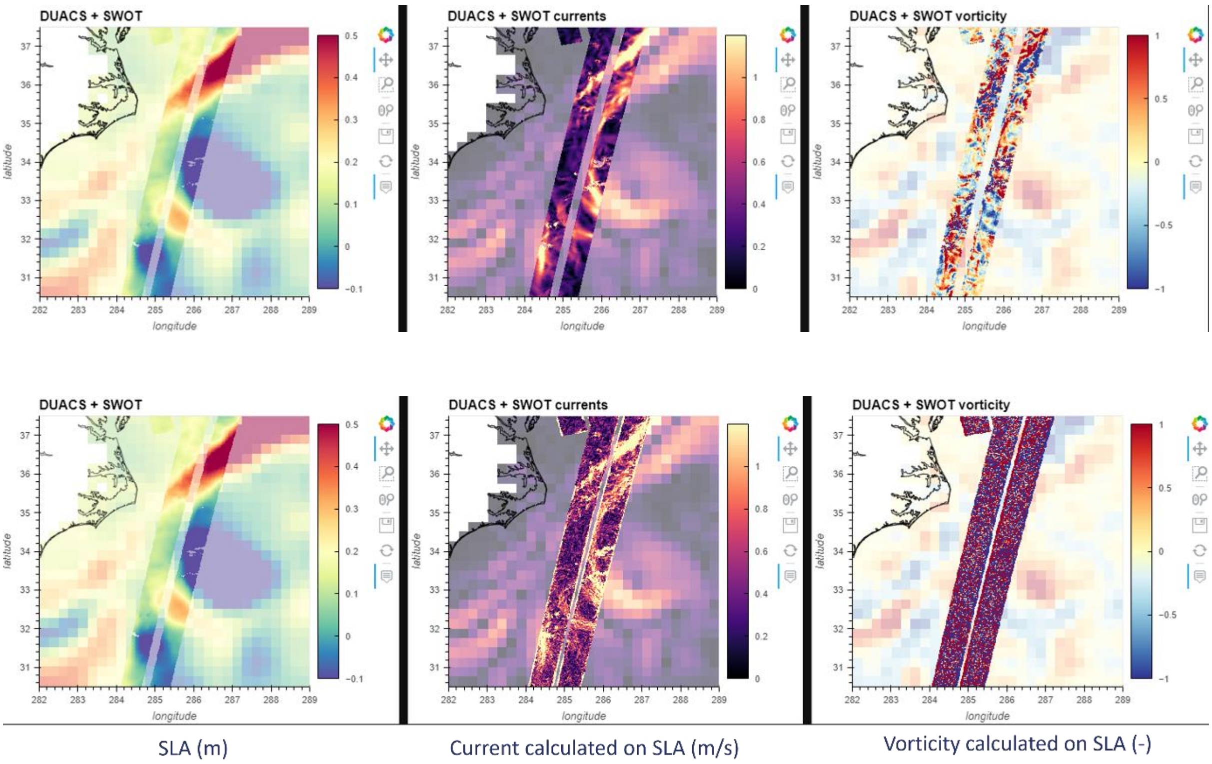


Figure 6: Sea Level Anomalies of DUACS and SWOT measurements (left), deduced current (middle) and vorticity (right) with the filtering applied (top) and without (bottom)

3 SWOT L3 KaRIn (L3_LR_SSH) Products

3.1 Temporal availability

Table 4 indicates the first and last dates available (and the corresponding cycle number).

	V1.0	V1.0.2	V2.0	V2.0.1
1-day CalVal phase	C474/T003 - C578/T004 28^{th} March 2023 - 10^{th} July 2023	C474/T003 - C578/T004 28^{th} March 2023 - 10^{th} July 2023	C474/T003 - C578/T004 28^{th} March 2023 - 10^{th} July 2023	C474/T003 - C578/T004 28^{th} March 2023 - 10^{th} July 2023
21-day Science phase	C001/T149 - C017/T557 26^{th} July 2023 - 8^{th} July 2024	*(Basic/Expert)* C001/T149 - C27/T091 26^{th} July 2023 - 16th January 2025 *(Unsmoothed)* C001/T149 - C016/T554 26^{th} July 2023 - 17^{th} June 2024	*(Basic/Expert)* C001/T149 - C029/T127 26^{th} July 2023 - 28^{th} February 2025	*(Basic/Expert)* C001/T149 - now 26^{th} July 2023 - now *(Unsmoothed)* C001/T149 - C016/T554 26^{th} July 2023 - 17^{th} June 2024

Table 4: Temporal availability of the SWOT L3 KaRIn time series

3.2 List of variables

Name of variable	Signification	Unit	Datasets
time	Time of measurement in seconds in the UTC time scale since 1 Jan 1950 00:00:00 UTC.	s	All
longitude	Longitude	Degrees East	All
latitude	Latitude	Degrees North	All
ssha_unfiltered	sea surface height anomaly	meters	All
ssha_filtered	sea surface height anomaly without noise	meters	All
ssha_unedited	sea surface height anomaly without editing	meters	Expert/Unsmoothed
ocean_tide	geocentric ocean tide height (FES)	meters	Expert/Unsmoothed
mdt	mean dynamic topography	meters	All
mss	mean sea surface height above the reference ellipsoid	meters	Expert/Unsmoothed
dac	dynamic atmospheric correction	meters	Expert/Unsmoothed
internal_tide	Coherent internal ocean tide	meters	Expert/Unsmoothed
ugos_filtered,vgos_filtered	Absolute geostrophic velocity: zonal and meridian component, derived from ssha_filtered and absolute mean current associated with MDT	meters/second	Expert/Unsmoothed
ugosa_unfiltered,vgosa_unfiltered	Geostrophic velocity anomalies derived from ssha_unfiltered: zonal and meridian component	meters/second	Expert/Unsmoothed
ugosa_filtered,vgosa_filtered	Geostrophic velocity anomalies derived from ssha_filtered: zonal and meridian component	meters/second	Expert/Unsmoothed
sigma0	normalized radar cross section (sigma0) from KaRIn	-	Expert/Unsmoothed
cross_track_distance	Distance of sample from nadir.	meters	Expert/Unsmoothed
calibration	phase screen + xcal	meters	Expert/Unsmoothed
i_num_line	alongtrack indice of the nearest KaRIn pixel from the nadir data	count	Basic/Expert
i_num_pixel	acrosstrack indice of the nearest KaRIn pixel from the nadir data	count	Basic/Expert
quality_flag	Quality flag (see section 2.1.4 for details)	-	Expert/Unsmoothed

Table 5: List of variables in the NetCDF files for v2.0.1 (the variable names changed in v2.0 and 2.0.1 see section 4.4.1.4, 4.5.2.3 and 4.5.3.5). 'All' means the variable is available in Basic, Expert and Unsmoothed datasets of the L3_LR_SSH product

3.3 Nomenclature of files

The nomenclature used for these products is:

SWOT_L3_LR_SSH_<FileIdentifier>_<CCC>_<PPP>_<DateBegin>_<DateEnd>_v<Version>.nc

Where:

FileIdentifier is 'Basic' or 'Expert' or 'Unsmoothed'

CCC is the number of cycle on 3 digits

PPP is the number of pass on 3 digits

DateBegin and DateEnd are the begin and end dates in UTC of the measurements in each file.

Version is '0.3' or '1.0' or '1.0.1' or '1.0.2' or '2.0' or '2.0.1'

4 Releases change notes

This chapter presents the changes introduced by the successive new product versions

4.1 Version 1.0.0

This section is not exhaustive and does not reflect all the changes brought to the product from V0.3 to V1.0.0

4.1.1 Basic and Expert

4.1.1.1 Land sea mask

The mask provided in the L2 product is sometimes incorrect (known limitation, regionally dependent; example in Figure). A tentative improvement was made in v1.0 with the use of a mask derived from Open Street Map (OSM).

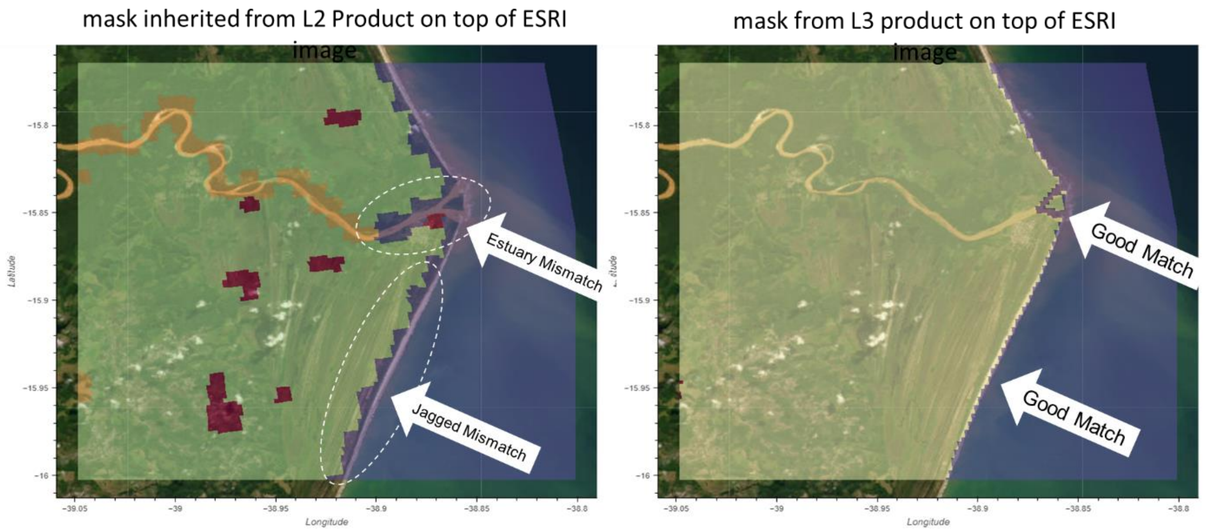


Figure 7: Example of Land-Sea mask from L2 KaRIn (left) and L3 (right) superimposed with ESRI image. Yellow to red pixels correspond to non-ocean surface type (i.e. rejected in L3)

A tentative improvement was made in v1.0 with the use of a mask derived from Open Street Map. If this version fixes most of the known L2 issues, albeit with some failures in estuaries (see 5.1).

4.2 Version 1.0.1

4.2.1 Unsmoothed

An anomaly was detected in the Unsmoothed V1.0 netcdfs. The geophysical corrections (ocean_tide, DAC), the MSS, MDT and sigma0 values in the product had an inverted sea/land mask.

Below is an illustration of the anomaly and its correction:

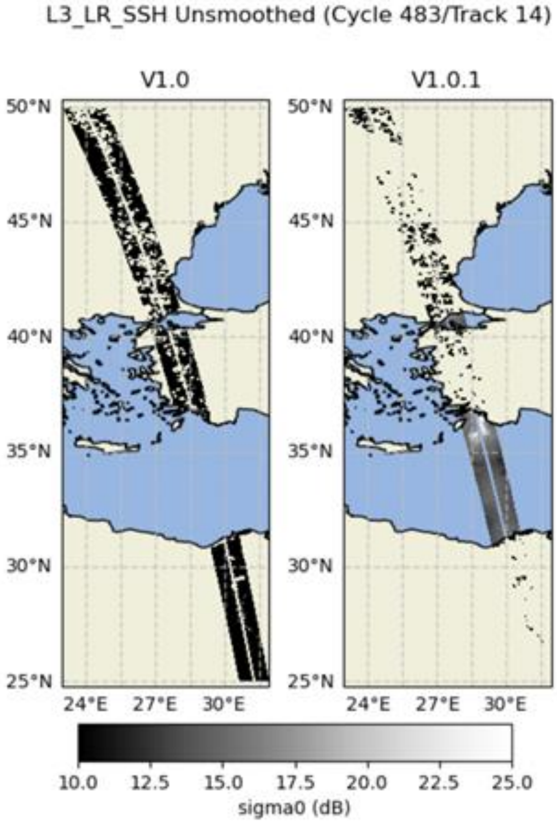


Figure 7: illustration of a badly filled field in V1.0 (left) and its correction in V1.0.1 (right)

4.3 Version 1.0.2

4.3.1 Basic, Expert and Unsmoothed

4.3.1.1 M0 wave removal

The M0 wave has been removed from the ocean tide correction FES2022 configuration. This change has a very small impact for users using the calibrated Sea Level Anomaly, because this large scale signal is absorbed by the calibration error in the V1.0.0.

The following figure illustrates the impact of removing the M0 wave over the ocean tide correction (left) and over the calibration (right). The patterns are similar, confirming the small impact over the calibrated Sea Level Anomaly.

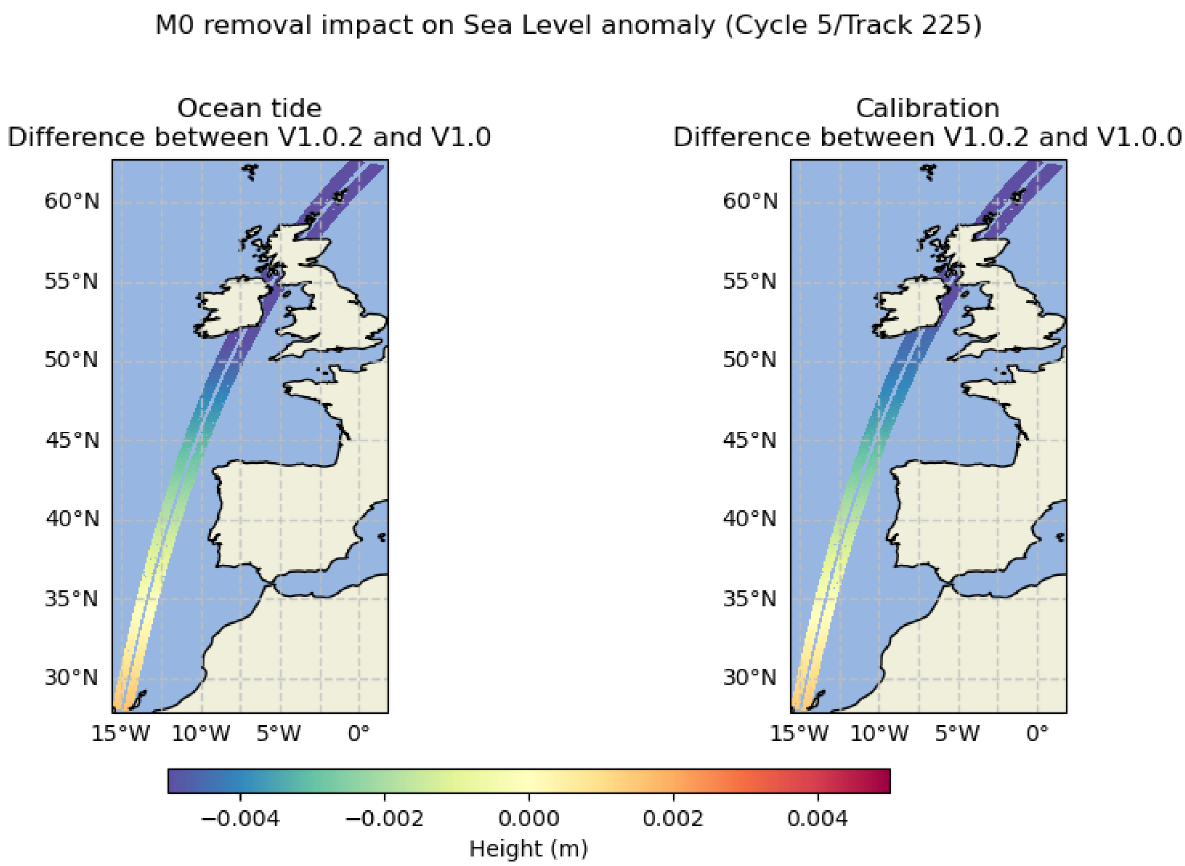


Figure 8: illustration of the M0 wave absorption by the calibration correction

4.3.2 Basic and Expert

4.3.2.1 Editing near the coast

The V1.0 introduced a newer and finer land-sea mask (Open street Map based). The editing parametrization for pixels near the coast was not properly adjusted, which can cause wrongly-edited lines in the quality flag near the coast. The new parametrization fixes this issue in the V1.0.2

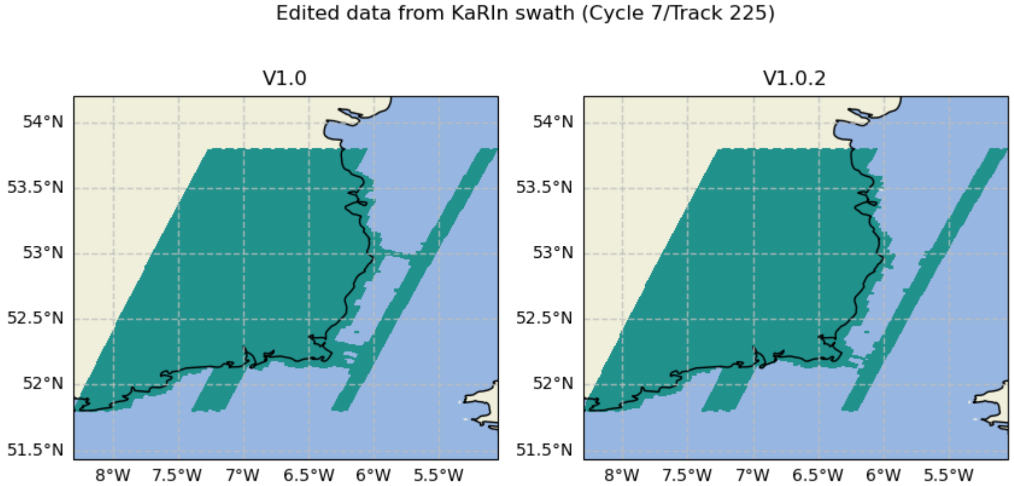


Figure 9: change in editing parametrization. The V1.0 (left) exhibits lines near the coast that should not by edited and are not present in the V1.0.2 (right)

4.3.2.2 Ocean tide in Sea Level Anomaly

For products based on PIC upstream data, the ocean tide correction has been wrongly applied. The ocean_tide field contains the expected FES2022 model, but the sea level anomaly has been corrected using an alternative FES2014 field. The V1.0.2 fixes the tide correction in the sea level anomaly.

This issue only impacts Basic and Expert datasets starting from cycle 7

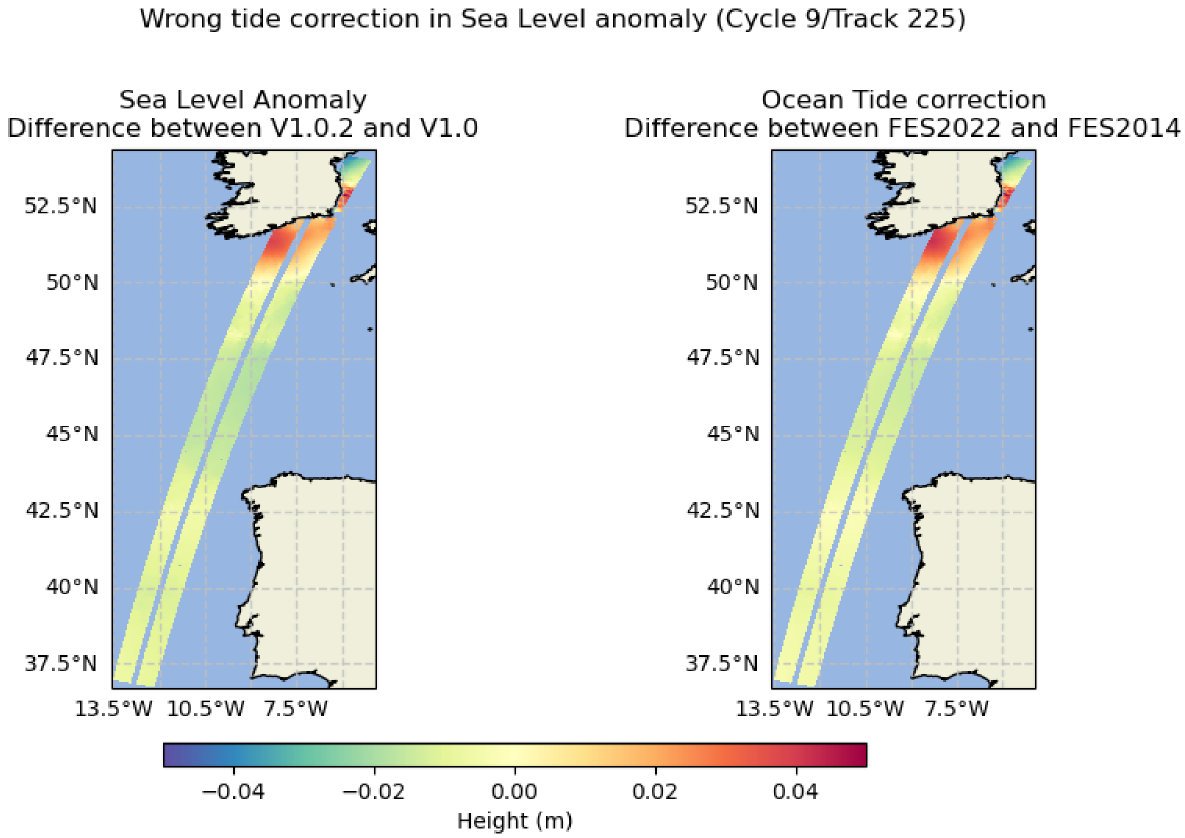


Figure 10: illustration of the Sea Level Anomaly change caused by a proper application of the ocean tide between V1.0 and V1.0.2

4.3.2.3 Sea state bias filling

Regions with ice have a default value for the Sea State Bias (SSB) correction. This default value introduced a bias on the non edited Sea Level Anomaly between the high latitudes and the rest of the ocean. This is of no consequence over the edited ssha or filtered Sea Level Anomaly ssha_noiseless because these regions are edited. However, this can be seen on the calibrated Sea Level Anomaly ssha_unedited. The SSB filling method has changed to mitigate this effect.

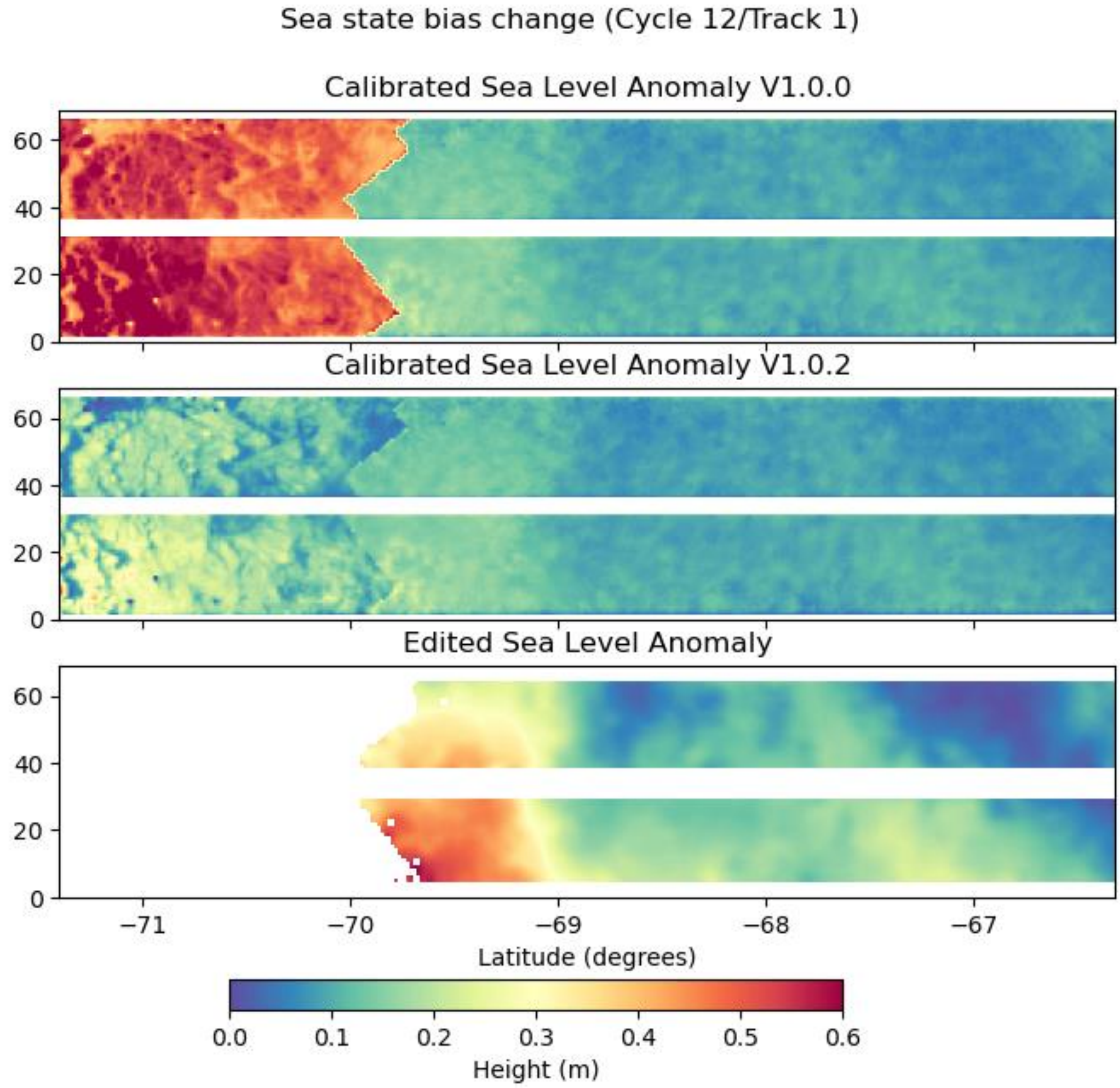


Figure 11: Sea State Bias filling method illustration

This change only affects the sea state bias correction in the Basic and Expert products. The Unsmoothed product still uses the old filling method.

4.3.2.4 PIC/PGC blending

Because the PGC does not cover the most recent periods, the L3_LR_SSH upstream data is a blending of two L2_LR_SSH versions: PIC and PGC. Previously, the PGC to PIC switch was at Cycle 7 but newly available data made it possible to use PGC data up to Cycle 9.

To summarize the upstream data versions:

- PIC0 starting from Cycle 9 / Track 388
- PGC0 up to Cycle 9 / Track 387 included, minus the exceptions listed in the following table

List of PIC half orbits (ranges are inclusive)

Cycle 7	[521-531], 533, [535-536], [538-542], [544-547]
Cycle 9	[335-336], [388, 584]

4.3.3 Unsmoothed

4.3.3.1 Missing half orbits with respect to Expert dataset

The calibration field is interpolated from the Expert product. This interpolation needs a consistent uncalibrated sea level anomaly between the two products. A version discrepancy between the Expert and Unsmoothed product means that the sea level anomalies are not consistent.

Due to production constraints, some half orbits have different upstream versions for the Expert and Unsmoothed products. These half orbits have been removed and will be retrieved in a future reprocessing.

List of missing half orbits due to upstream version discrepancy (range are inclusive)

Cycle 1	561
Cycle 3	322
Cycle 4	158, 160
Cycle 6	297, 298
Cycle 7	[532-534], 537, 543
Cycle 8	[244-245]
Cycle 9	[304-331], [337-387]
Cycle 11	[381-382], 384
Cycle 13	[261-262], [544-570]
Cycle 15	70, 72, 74, 135, 137

4.4 Version 2.0

4.4.1 Basic and Expert

4.4.1.1 Change of the geophysical standards

The SSB2 correction of the L2 PIC/PGC product is used in L3 production. This solution is based on MFWAM model output that shows limitation of definition in polar and coastal areas. Consequently, a known offset of 10cm is introduced in SSB2 in these areas, impacting the resulting SSHA with introduction of net discontinuities. In the L3_LR_SSH v2.0, the SSB2 correction is extrapolated towards 0 in polar areas to remove the SSH discontinuities that may limit polar studies (e.g., Figure 12). This was done assuming the in sea-ice leads SSB is close to zero (small waves), so we enforce continuous transition from open ocean to sea-ice leads. Nevertheless, this extrapolation does not yield a correct/geophysical SSB correction. This quick fix intends to remove only the SSB2 offset in a gradual way, but the SSHA remains biased (no wave height available in these regions = SSHA bias).

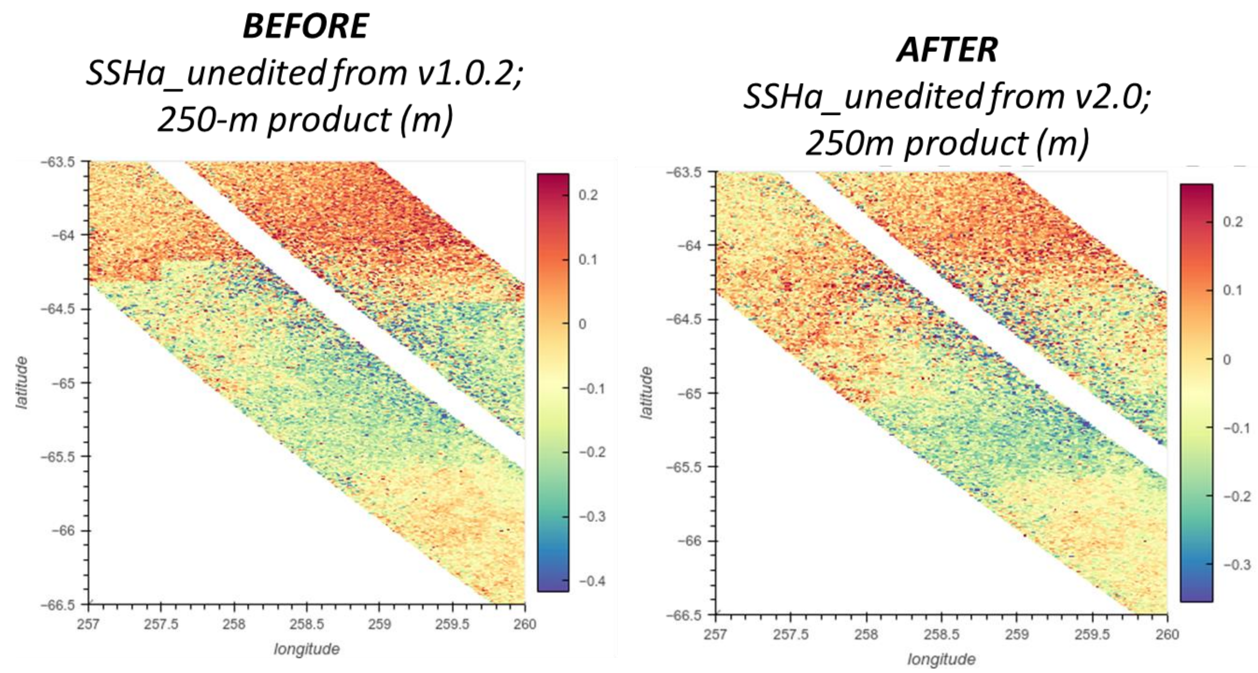


Figure 12: Example of SSB used in the L3_LR_SSH; v1.0.2 version (left) and v2.0 (right)

The internal tide correction is improved in v2.0 with the use of a blend solution between HRET14 & HRET8.1 model (Zaron, 2024), resolving the coherent tides for 5 different tidal frequencies (M2, K1, S2, O1, N2) when HRET8.1 (Zaron, 2019), resolving 4 tidal frequencies (M2, K1, S2, O1), was used in v1.0.2. The blend HRET solution is slightly more accurate than HRET 8.1 over most of the open ocean (3 mm RMS, locally 1 cm; Consistent numbers found with SWOT Nadir, SWOT KaRIn, Jason-3, Sentinel3A/B and Sentinel-6 MF missions, e.g., Figure 13). The gain is however not geographically homogeneous. As HRET8.1, the blend HRET solution is based on nadir altimetry and it does not correct for higher modes of internal tides, nonlinear waves, solitons, and non-stationary tides. The blend HRET solution is delivered in a dedicated variable of the L3_LR_SSH v2.0 product, allowing the user to uncorrect/replace it.

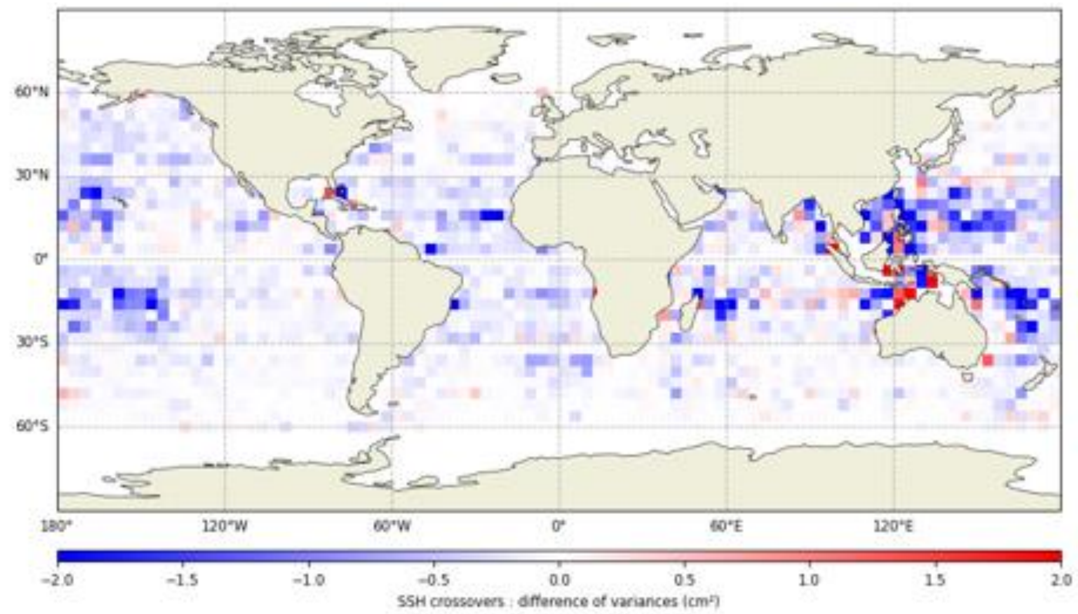


Figure 13: Difference of SSHA variance for HRET14 vs HRET8 measured with Sentinel-3A/B (cm²)

A -5cm offset was introduced in the MDT field model, and resulting ADT. This offset fixes known discrepancy between SWOT and other L3 products distributed by CMEMS. It was introduced in the DUACS/CMEMS production in 2014, following a change of the arbitrary altimeter reference period used ([1993, 1997] vs. [1993, 2012]).

4.4.1.2 Data selection changes - Spatial coverage improved

Eclipse transition segments are isolated from other SWOT mission events (e.g. maneuvers) and flagged with a specific value (flag 3; Figure 14). The performance analyses from the SWOT L2 Project CalVal and L3 teams did not observe any degradation for these segments. Consequently, the SSHA is now provided during eclipse transitions, improving the coverage by 4%. The users of expert and unsmoothed products can choose to remove these segments by using the specific flag value.

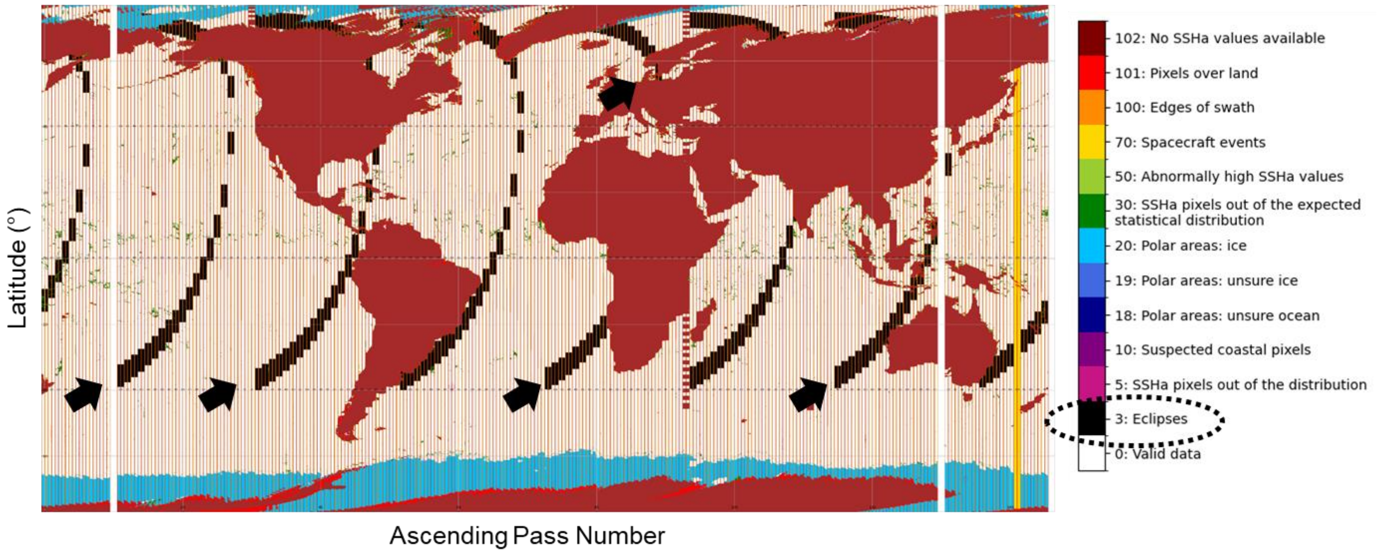


Figure 14: Example of KaRIn L3 quality flag for one cycle of ascending passes

The data selection was improved by using a new Land-Sea mask selection criterion.). Due to the introduction of a new land sea mask in V1.0, some estuaries have been lost in the process (see 4.1.1.1). In the L3 v2.0, a revised mask with manual processing of 43 major estuaries is used to retrieve them. The quality flag is updated consequently. Nevertheless, estuaries with no SSHA in the L2 cannot be retrieved in the L3 (known PIC/PGC issue, not related to land mask), and retrieved SSHA can be rejected with other statistical criteria (e.g., Figure 15).

The selection flag algorithm was revisited to reduce the occurrence of ambiguous rejection criteria (e.g. rain vs coast; example Figure 16), and to consider areas better retrieved with revised L3 SSB2 (see previous section). In that last case, only pixels with an ice concentration higher than 60% and those on the edge of the polar ocean are flagged as "suspected sea-ice pixels" (flag 20, e.g., Figure 17)

The data selection sequence is also better integrated with the L3 calibration, improving the quality of the latest.

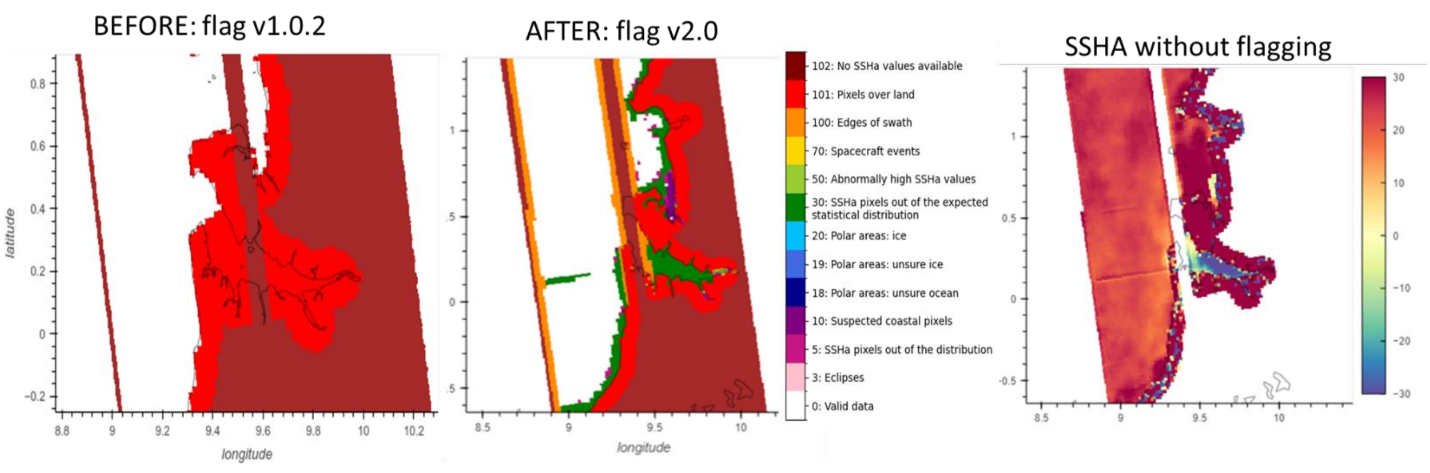


Figure 15: Example of data selection over the Gabon estuary. SSHA before selection (right), after selection in v1.0.2 version (left) and in v2.0 (middle). In that example, main part of the SSHA in the estuary is rejected on statistical criteria on SSHA (flag value 30: SSHA pixels out of the expected statistical distribution)

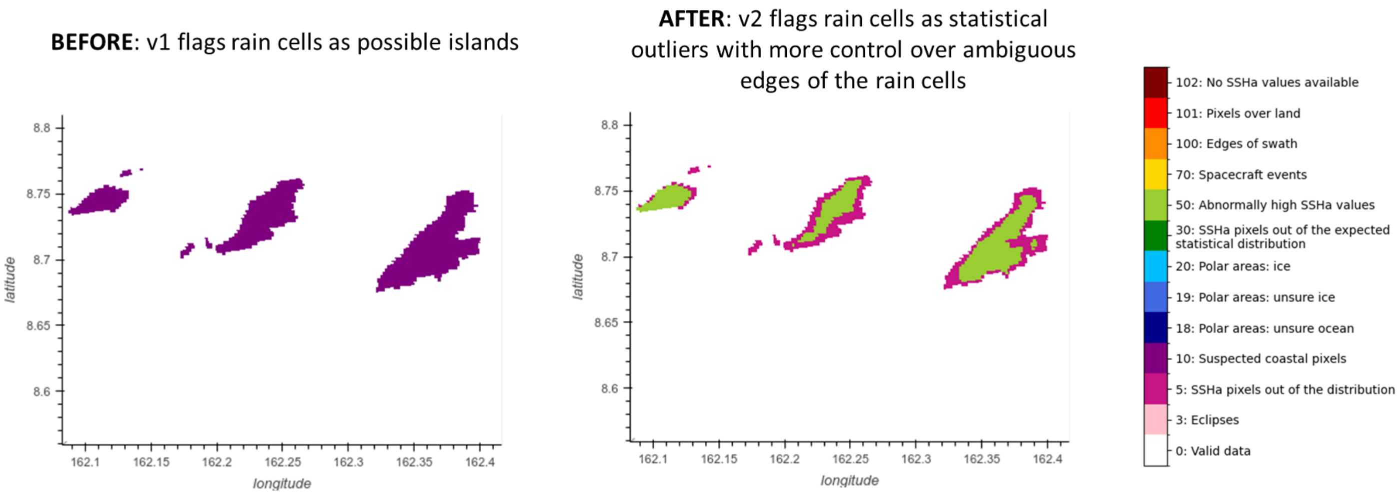


Figure 16: Example of data selection over rain cells. Flag defined in L3 v1.0 verstion (left) and v2.0 (right). In v1.0 the rain cells were identified with criteria rather representative of coastal pixels (flag 10); in v2, rejection cretaria rather rely on statistical analysis of SSHA value (flag 50: abnormally high SSHA values; and flag 5: SSHA pixels out of the local distribution)

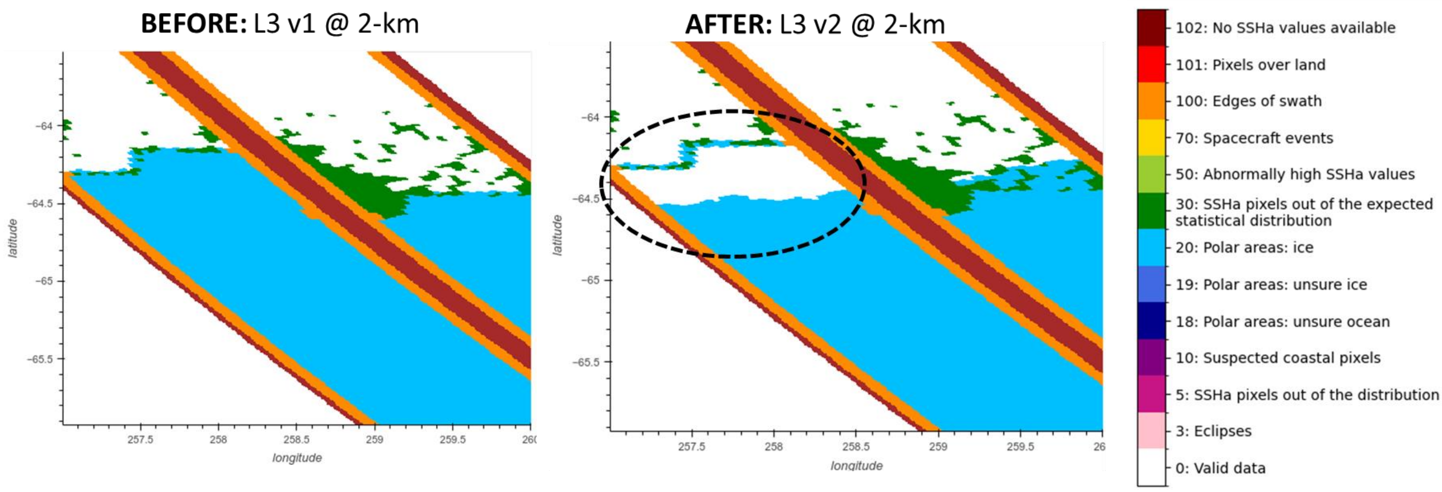


Figure 17: Example of data selection in polar areas impacted by extrapolated SSB_2 correction implemented in v2. Selection flag provided in v1 L3 version (left) and v2 (right)

4.4.1.3 Calibration

calibration v1 was absorbing other geophysical error residuals (see SWOTST 2024 Talk) and not just KaRIn systematic errors. The calibration algorytm and sequence was thus improved in v2.0 with the objective to reduce the leakage of ocean dynamical signal and consider improvement done on data selection processing:

- A large part of the data selection is newly applied before calibration
- Data eclipse transition segments are used in the calibration
- a more sophisticated handling of the bias/linear/quadratic terms and the orbital harmonics VS broadband interpolators: fewer degrees of freedom are used to calibrate only what is absolutely needed and ignore uncalibrated error sources when calibration is not possible / desirable.
- (L3 pseudo phase screen corrections remain unchanged w.r.t v1.0.2)

This results in better correction for the semi-enclosed / coastal / polar seas and Hydrology (e.g., Figure 18). On counterpart, more tidal, SSB and Wet troposphere residual signals may be observed in SSHA field.

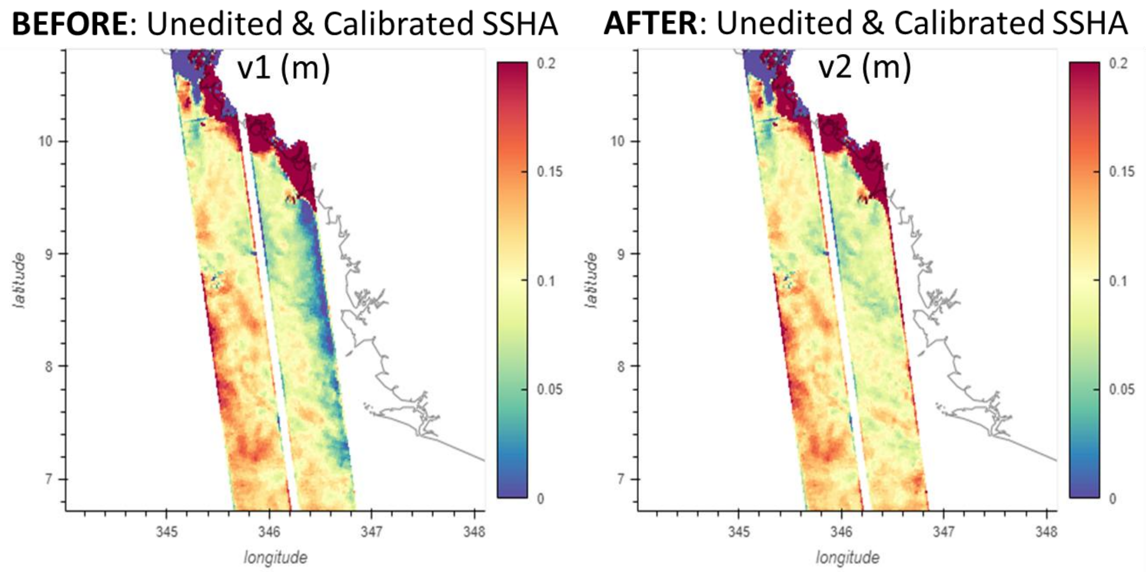


Figure 18: Example of SSHA calibrated in L3 v1.0 (left) and v2 (right). The new editing and more robust calibration implemented in v2.0 remove the coastal tilt previously observed in v1.0

4.4.1.4 Product format

Some variables are renamed, and new variables are added in the v2 product version. The evolutions are summarized in the following tables.

Variable name in v1.0.2 version	Variable name in v2.0 version
ssha	ssha_unfiltered
ssha_noiseless	ssha_filtered
ugsoa	ugosa_filtered
vgosa	ugosa_filtered

Table 6: Variable renamed in v2.0 version

Variable name in v2.0	Variable content
internal_tide	Internal tide solution applied to ssha contained in the product version (blend of HRET14 & HRET8.1 in v2.0)
ugosa_unfiltered	geostrophic velocities anomalies (zonal and meridian components) derived from the SSHA_UNFILTERED parameter (i.e. without denoising)
vgosa_unfiltered	
cross_track_distance	Distance between the swath position and the nadir position on the same line Only added in Unsmoothed dataset (already present in Basic and Expert)

Table 7: New variables added in the v2.0 version

4.5 Version v2.0.1

4.5.1 Basic, Expert and Unsmoothed

Some half orbits of the calval phase are not well calibrated and were not properly detected by the editing algorithm. The quality flag of these half orbits has been set to 30 to mark them as bad

Cycle	Half orbit range (inclusive)
567	[20-28]
568	[10-13]

Table 8: Newly edited half orbits

4.5.2 **Basic and Expert**

4.5.2.1 MDT and absolute derivatives near the coast

Due to a change in the MDT/MDU/MDV interpolator in the V2.0.0 (switched to bicubic), some points near the coast have been lost with respect to the V1.0.2 (cf figure).

In order to mitigate this issue, the source grids for MDT topography and associated absolute currents are filled using a Gaussian-Seidel method. This prevents the loss of points in the mdt, ugos and vgos fields. An example of impact is given in the following figure.

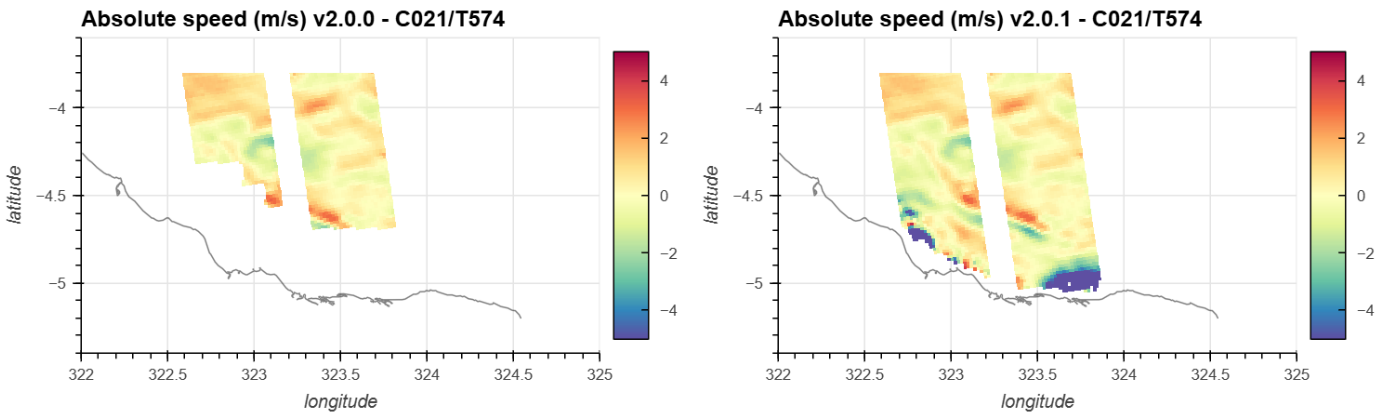


Figure 19: Example of anomaly of MDT interpolation in v2.0 and corrected field in v2.0.1

4.5.2.2 Wrong flag application in eclipses

The editing flag was wrongly applied on the sea surface height in the v2.0 netcdf products. Although the eclipses were present in the ssha_unedited field, they were wrongly removed in the ssha_unfiltered and ssha_filtered fields. This has been fixed in v2.0.1 and the eclipse data is properly available as announced in the v2.0 (see section 4.4)

4.5.2.3 Product format

Some variables are renamed in v2.0.1 product version to complete changes previously implemented in v2.0. The evolutions are summarized in the following table.

Variable name in v1.0.2 version	Variable name in v2.0 version	Variable name in v2.0.1 version
ssha	ssha_unfiltered	
ssha_noiseless	ssha_filtered	
ugsoa	ugosa_filtered	
vgosa	ugosa_filtered	
ugos	ugos	ugos_filtered
vgos	vgos	vgos_filtered

Table 9: Variable renamed in v2.0 and 2.0.1 version

4.5.3 Unsmoothed

4.5.3.1 Change of the geophysical standards

As for the basic/expert v2.0 product version, the unsmoothed v2.0.1 product benefits from the use of new altimeter standards and geophysical corrections. See section 4.4.1.1.

4.5.3.2 Land sea mask

In V1.0, we introduced a mask that fixes most of the known L2 issues (see 4.1.1.1). This mask was used in the Basic and Expert datasets but not in the Unsmoothed dataset. V2.0.1 aligns the land/sea masks between by using this mask in the Unsmoothed product. Note that the patch improvement introduced in V2.0 for the Basic and Expert datasets is also applied

4.5.3.3 Calibration

The same calibration than basis/expert v2.0 is applied for the unsmoothed v2.0.1 version. See section 4.4.1.3 for details.

4.5.3.4 Data selection changes - Spatial coverage improved

As for the basic/expert v2.0 version, the unsmoothed v2.0.1 benefits from an improved data selection:

- Eclipse transition segments are isolated from other SWOT mission events (e.g. maneuvers) and flagged with a specific value
- a new Land-Sea mask selection criterion is used: the land/sea mask used is now aligned with the basic/expert production (Open Street Map mask from v1.0 previously used)
- The selection flag algorithm was revisited to reduce the occurrence of ambiguous rejection criteria, and to consider areas better retrieved with revised L3 SSB2
- The data selection sequence is also better integrated with the L3 calibration

See section 4.4.1.2 for more details

In addition, specifically for the unsmoothed product, LEGOS has developed a sea-ice classification for polar areas. It provides several information:

- ocean (flag #0)
- ocean_unsure (flag #18)
- ice_unsure (flag #19)
- ice (flag #20)

Summer in the Arctic (May-September) is still exploratory because of the presence of melt-pounds on the sea ice. As this product is experimental, a few imperfections have been identified.

- Some passes contain mostly 'unsure' categories (Figure 20).
- Along-track lines due to radiation hits (more details in https://archive.podaac.earthdata.nasa.gov/podaac-ops-cumulus-docs/web-misc/swot_mission_docs/D-109532_SWOT_UserHandbook_20240502.pdf) may be visible and deteriorate the classification (Figure 21).
- Ice classification is only applied when the ice concentration exceeds 50%. Between 0 and 50% of ice concentration, the data is automatically edited with flag #20 (Figure 22).
- Pixels surrounding icebergs can be misclassified (Figure 23), as well as pixels in complex areas (Figure 25).

The SSHA denoised field is available on ocean pixels identified in polar areas. Although the results seem relevant (eg Figure 24), it is important to remember that the denoising algorithm has been designed and trained on open oceans and must therefore be used with care in degraded cases such as ice-covered areas, estuaries or misclassification (eg Figure 25).

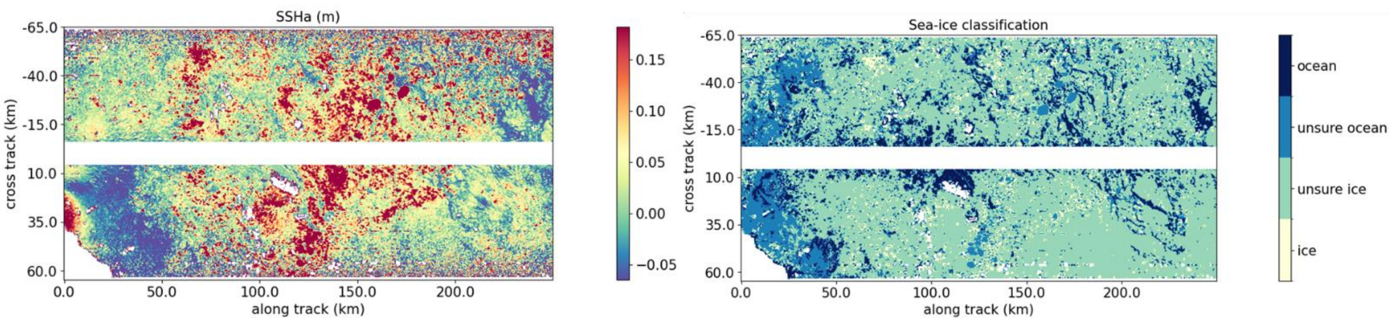


Figure 20: ***Raw SSHA (left) and sea-ice classification (right) for KaRIn C484 P9***

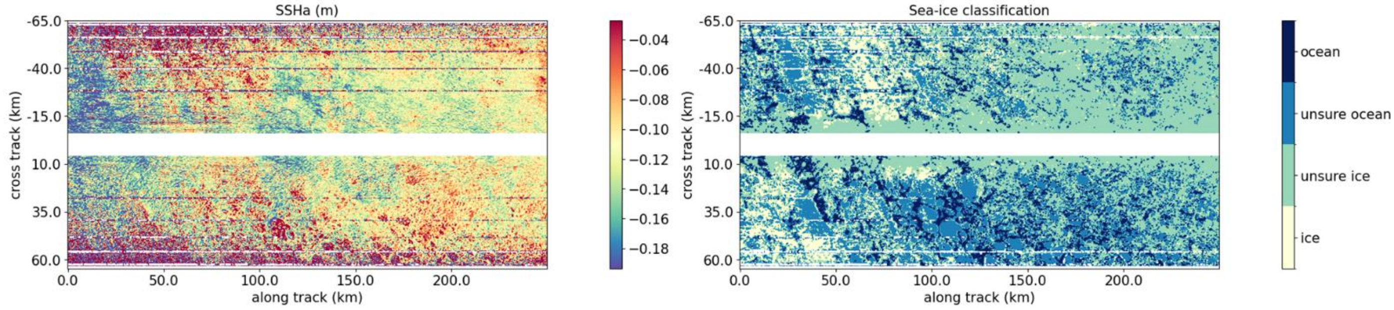


Figure 21: Same as previously, but for *C577 P24*

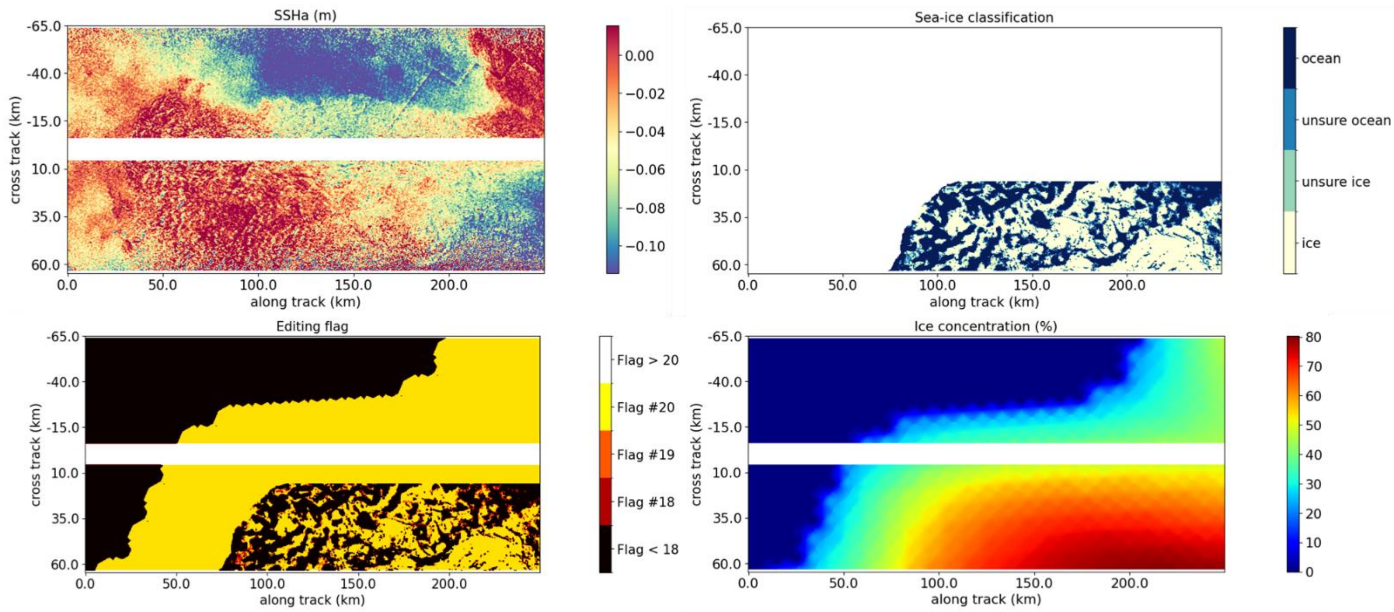


Figure 22: Raw SSHA (top left), sea-ice classification (top right), edinting flag (bottom left) and sea ice concentration (bottom right) for KaRIn C500 P2.

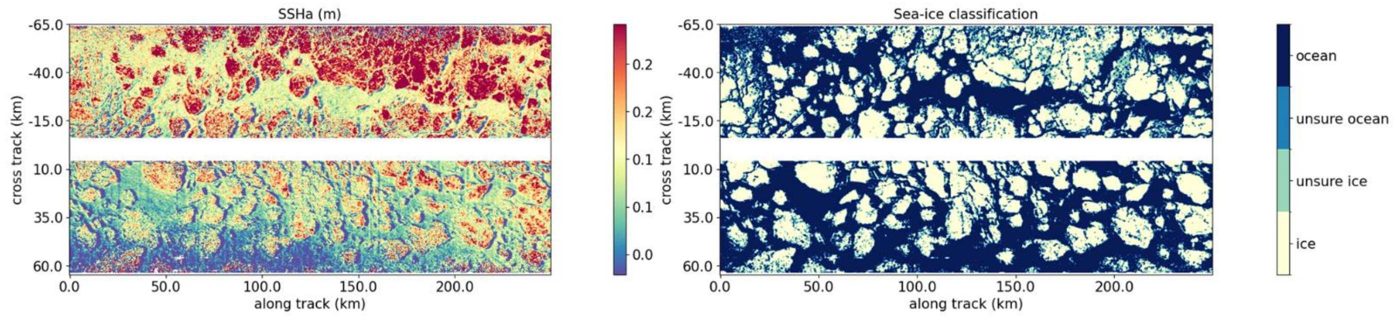


Figure 23: Same as Figure 20, but for *C474 P5*

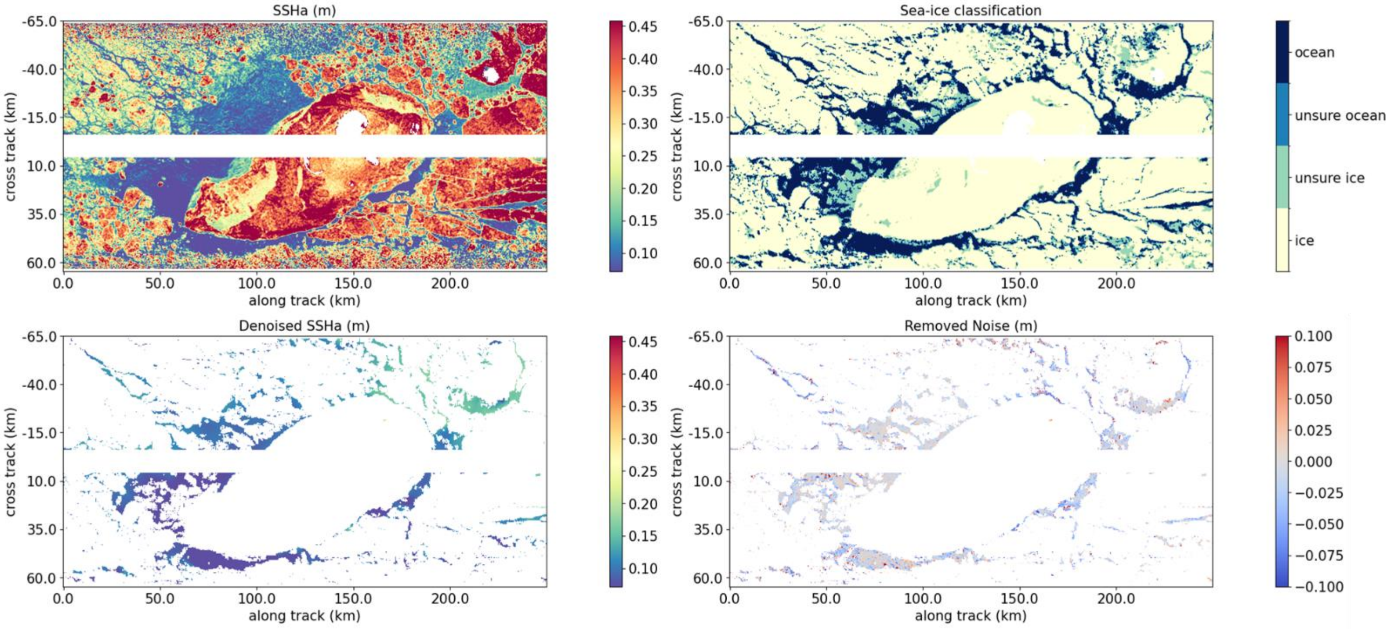


Figure 24: Raw SSHA (top left), sea-ice classification (top right), Denoised SSHA over ocean (bottom left) and Noise removed by denoising processing (bottom right) for KaRIn C507 P1

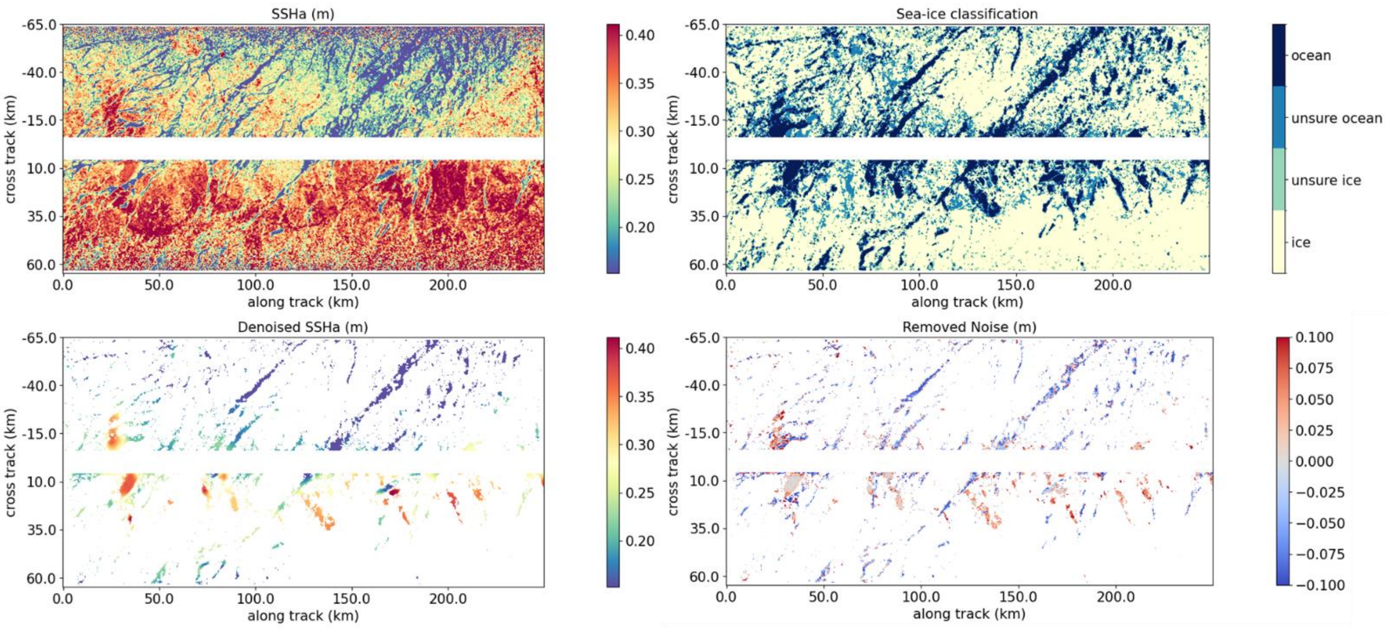


Figure 25: **Same as Figure 24, but for C474 P26**

4.5.3.5 Product format

Some variables are renamed, and new variables are added in the v2.0.1 product version. The evolutions are summarized in the following tables

Variable name in v1.0.2 version	Variable name in v2.0.1 version
ssha	ssha_unfiltered
ssha_noiseless	ssha_filtered
ugsoa	ugosa_filtered
vgosa	ugosa_filtered
ugos	ugos_filtered
vgos	vgos_filtered

Table 10: Variable renamed in v2.0.1 version

Variable name in v2.0	Variable content
internal_tide	Internal tide solution applied to ssha contained in the product version (blend of HRET14 & HRET8.1 in v2.0)
ugosa_unfiltered	geostrophic velocities anomalies (zonal and meridian components) derived from the SSHA_UNFILTERED parameter (i.e. without denoising)
vgosa_unfiltered	
cross_track_distance	Distance between the swath position and the nadir position on the same line Only added in Unsmoothed dataset (already present in Basic and Expert)

Table 11: New variables added in the v2.0.1 version

5 Known limitations and anomalies

We list in this section the known limitation or anomalies observed in the L3 KaRIn products

5.1 Missing estuaries in land-sea mask

Some areas (especially estuaries) are not well defined in OpenStreetMap and will show land where we would expect sea.

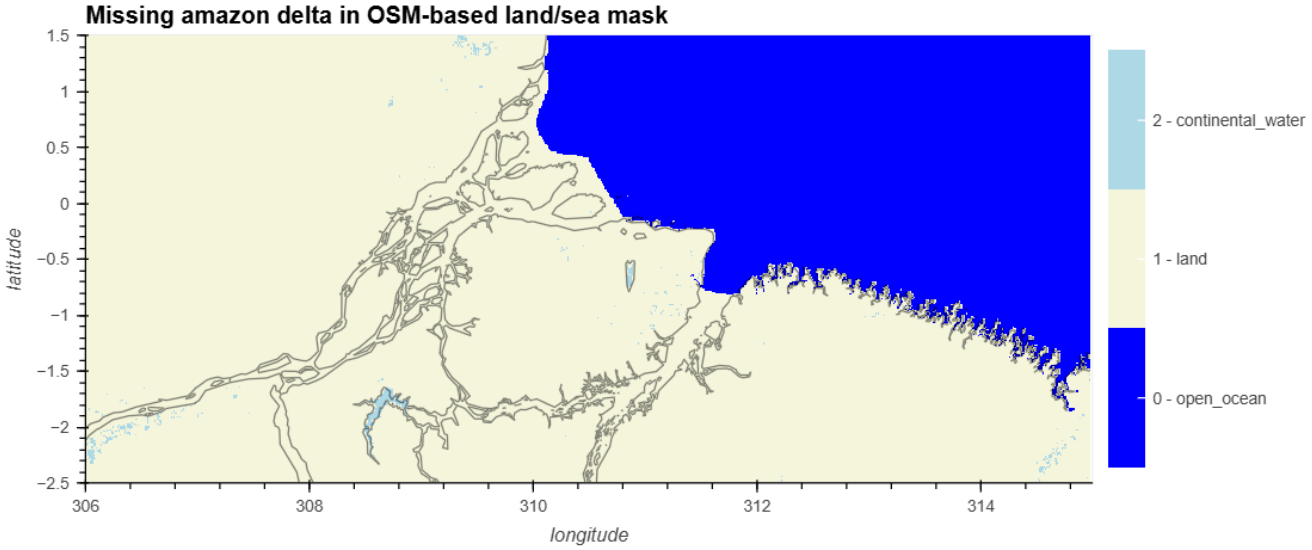


Figure 26: OpenStreetMap-derived land sea mask shows may classify some estuaries a land (yellow)

This issue has been mitigated in V2.0 (see 4.4.1.2) by blending the L2 mask over the identified problematic areas, which include 43 estuaries. Additional problematic areas spotted by the users might be communicated to the AVISO team for further patching (refer to the Contact section 8).

5.2 Discrepancy of valid domains for FES22 corrections in v2.0 and v2.0.1

In some particular areas, users might observe that some of Level-3 data is missing with respect to Level-2 data, and that the quality flag investigation is marked as no_data (see Figure 27)

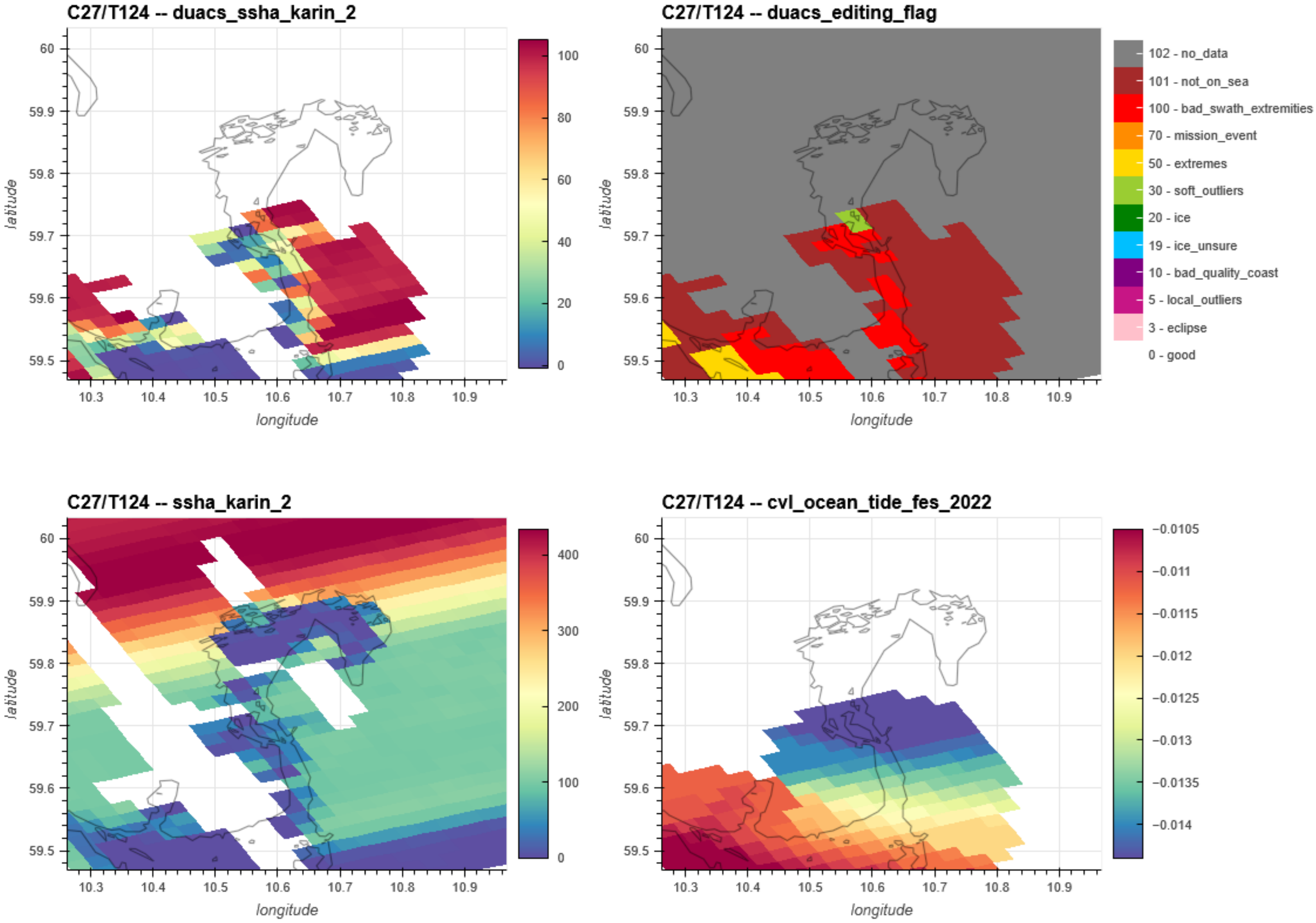


Figure 27: Missing points in L3 are observed when comparing the Sea Level Anomaly from Level-3 (top left) and Level-2 (bottom left) products. The quality flag (top right) indicates missing data in gray that are explained by missing data in the ocean tide correction (bottom right)

The missing data is introduced by the ocean tide correction FES 2022, which is not defined at the problematic location. Even if the ocean tide correction is the same in both the baseline C Level 2 product and the v2.0.1 Level 3 product, the source of the correction differs. Level-2 product uses an extrapolated cartesian grid whereas the Level-3 product uses the finite element meshes which has a smaller domain of definition. This is illustrated in the following Figure.

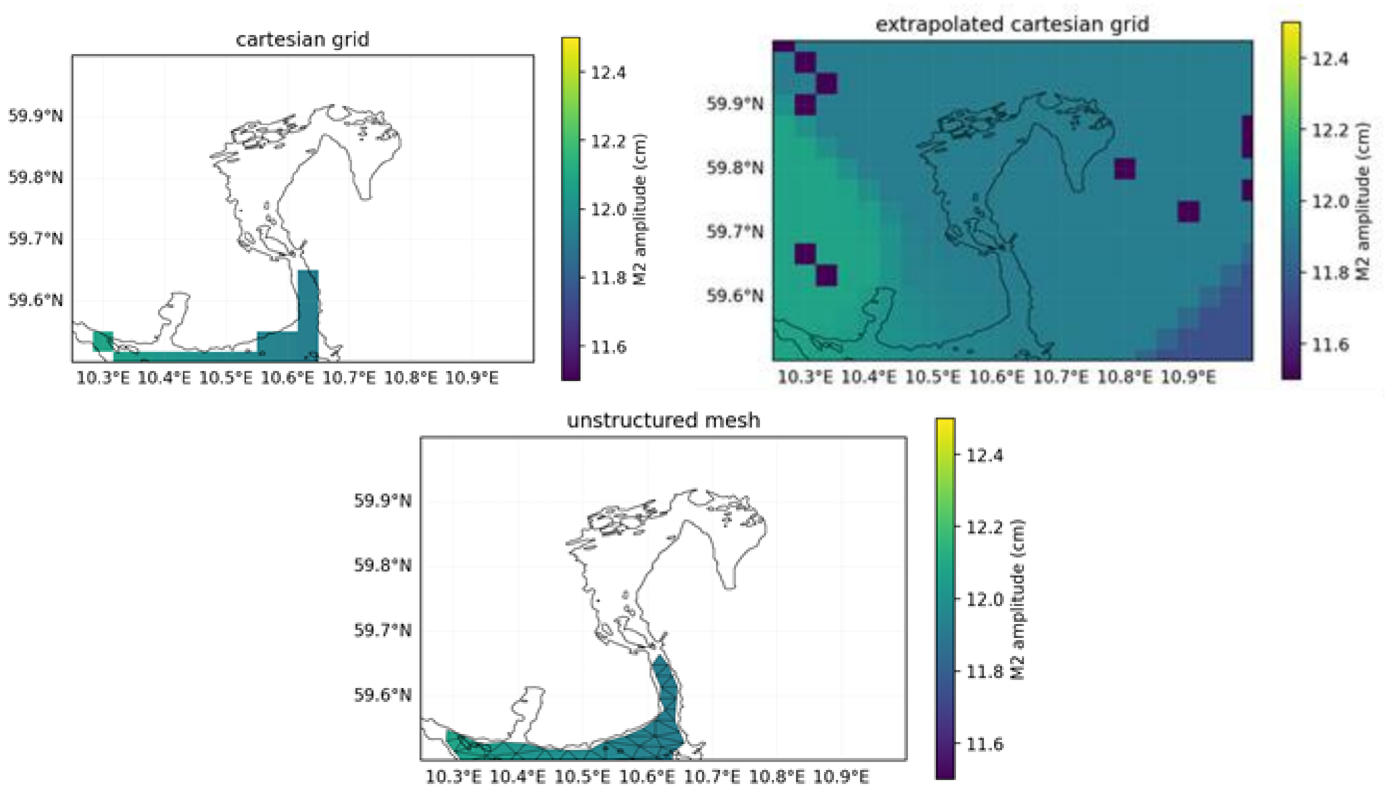


Figure 28: Difference in the definition of the FES2022 source data with (bottom) the original unstructured mesh used in the Level-3 product (top left) the cartesian grid interpolated from the mesh and (top right) the extrapolated cartesian grid used in the Level-2 product

5.3 Use of "ssha_filtered" and MSS in V2.0 and v2.0.1

The analysis of the constant content of the noise removed with the filtering can underline statics small scales structures linked to the MSS field used for the SSHA computation (see example in the following figure). Consequently, we recommend to users that may want to use a different MSS field than the one used in the L3 processing to work with the "ssha_unfiltered" field (i.e. before denoising processing) rather than "ssha_filtered" (i.e. after denoising processing)

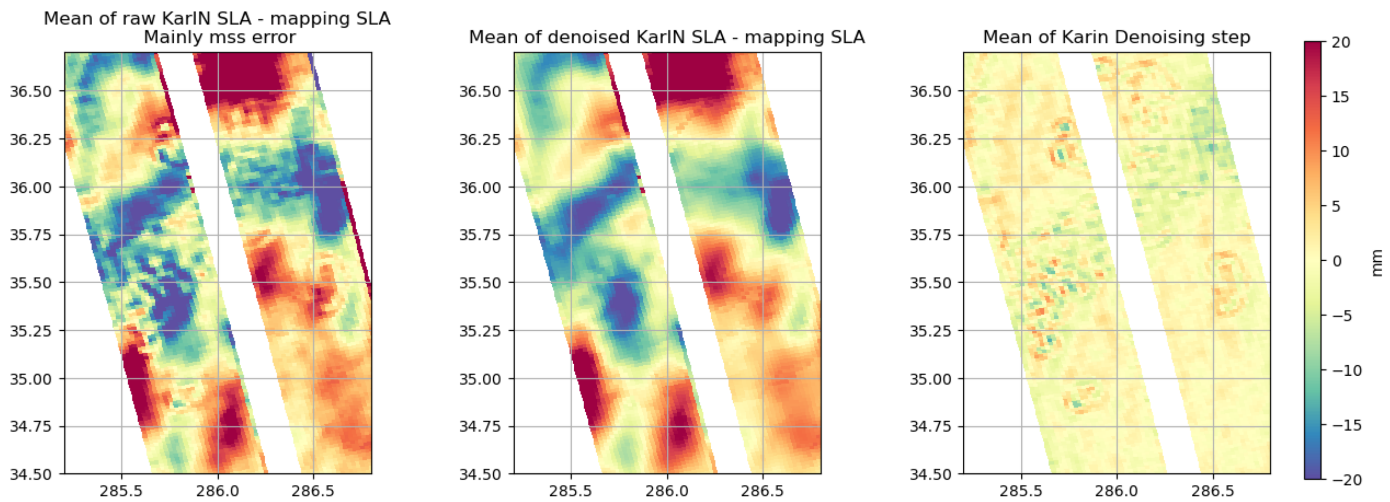


Figure 29: Mean structures remaining on SSHA during the CalVal phase period, before denoising (left) and after denoising (center). In this example, the mean content of the noise removed by the denoising processing (right) is dominated small scale static structures that are not corrected by the MSS used.

5.4 “ssha_filtered” discontinuities in v2.0 and v2.0.1

Some discontinuities in the noise filtered data were noted. This error is particularly noticeable in cycle 521, pass 11. They will be removed in a future version. These discontinuities appear during the denoising process. Investigations are ongoing to better understand the origin of the anomalies and fix them in a future version of the products.

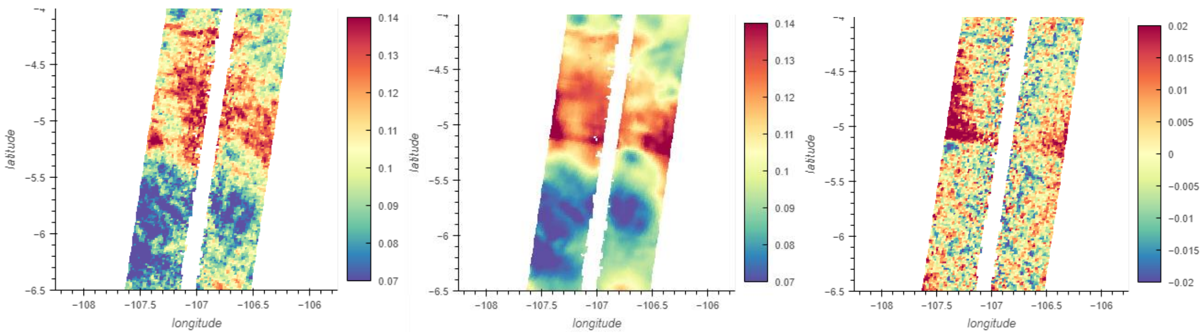


Figure 30: Example of a discontinuity visible in filtered swath. Left: unfiltered ssha variable. Middle: noise filtered ssha. Right: residuals (difference between left and middle)

5.5 SSHA restrictive quality flag during extreme events in v2.0 and v2.0.1: Example of Hurricane Milton

The cycle 22, pass 216 intersects with the path of Hurricane Milton. Some pixels are rejected with flag #30 (SSHa pixels out of the expected statistical distribution) and #5 (SSHa pixels out of local distribution). This is mainly due to rain cells. For scientists who want to work on the Hurricane or on similar cases, we suggest applying flags higher than 30 (quality_flag variable) on the ssha_unedited variable.

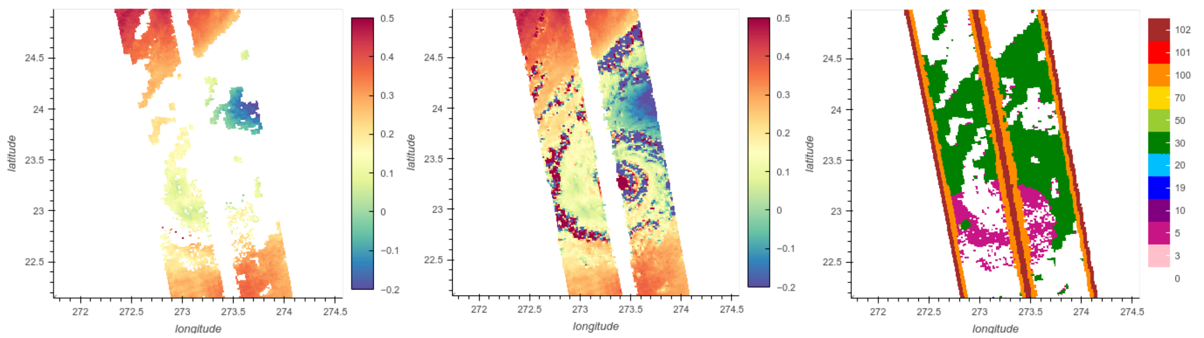


Figure 31: Example of Hurricane Milton. Left: ssha variable i.e. ssha with all flags applied. Middle: ssha with only flags > 30 applied. Right: quality flag

5.6 Small-scale discontinuities and errors in the calibration variable

In some areas, when a L2 field (sc_yaw) is not defined, some small-scale terms of the calibration are reverted. This inversion causes small-scale discontinuities and errors inside the calibration variable. As these discontinuities and errors are small-scale, they are only visible if the calibration mean is removed. This issue only occurs when SSHA is not defined, thus this issue does not affect SSHA.

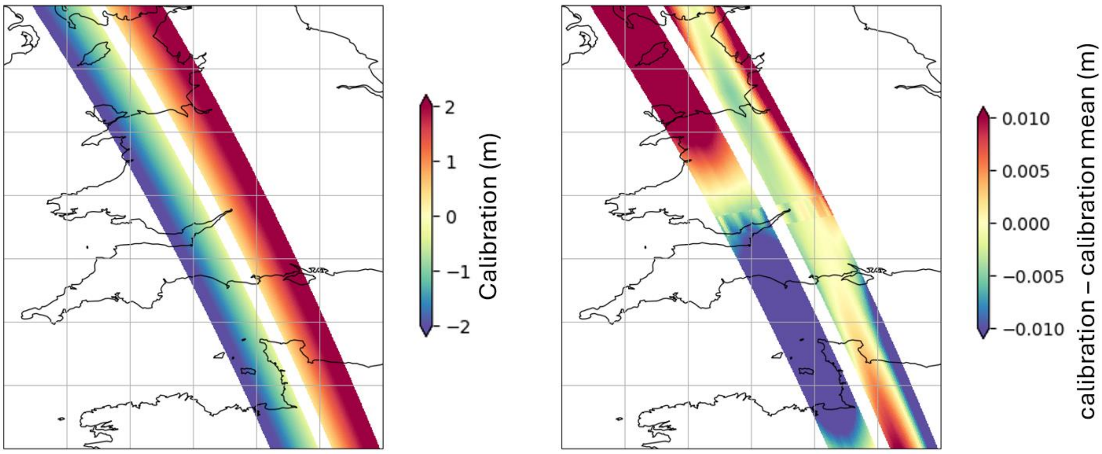


Figure 26: Example of small-scale discontinuities and errors in the calibration variable. Left: calibration variable. Right: difference between calibration variable and mean calibration variable.

5.7 Wrong editing flag in Unsmoothed product during eclipse transition

Some eclipse transitions in the Unsmoothed product are flagged with flag 30 ("SSHA pixels out of the expected statistical distribution") instead of flag 3 ("Eclipses"). These eclipses are not kept in the edited and filtered SSHA. There is therefore inhomogeneity between the Expert and Unsmoothed products.

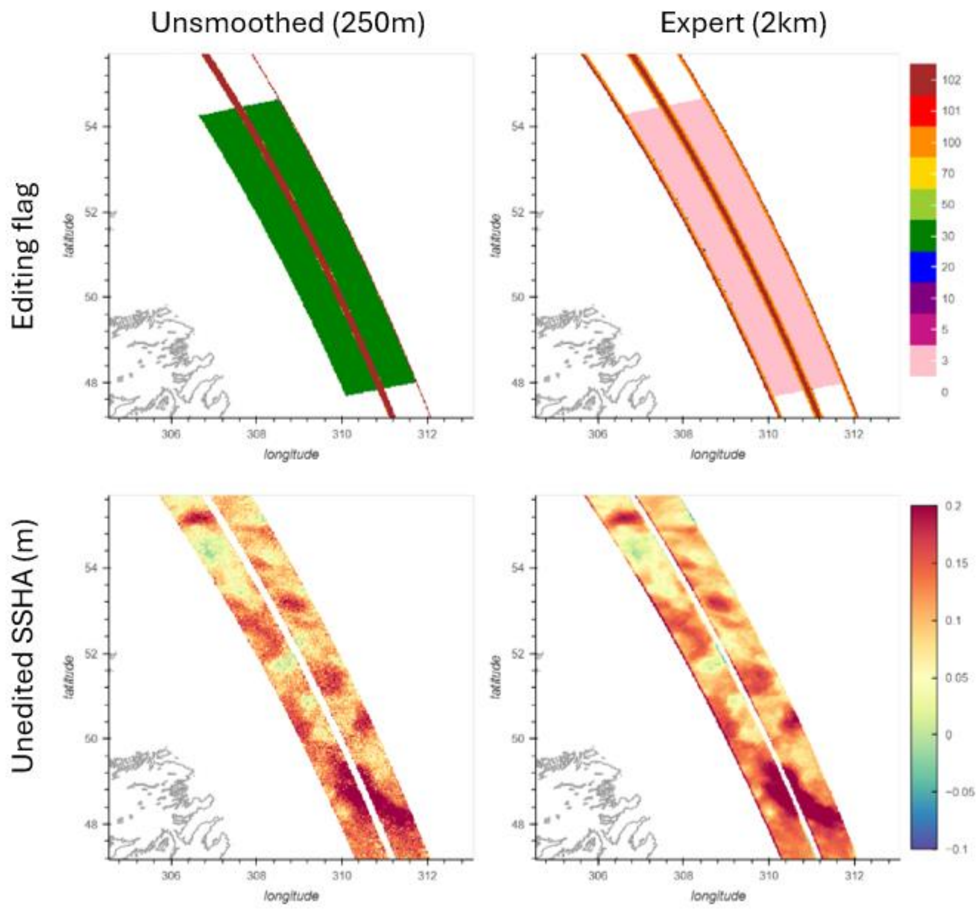


Figure 27: Example of eclipse transition with inhomogeneous flags between Expert and Unsmoothed products

6 Data format

This chapter presents the data storage format used for the products.

6.1 NetCDF

The products are stored using the NetCDF format.

NetCDF (network Common Data Form) is an interface for array-oriented data access and a library that provides an implementation of the interface. The netCDF library also defines a machine-independent format for representing scientific data. Together, the interface, library, and format support the creation, access, and sharing of scientific data. The netCDF software was developed at the Unidata Program Center in Boulder, Colorado. The netCDF libraries define a machine-independent format for representing scientific data. Please see Unidata NetCDF pages for more information, and to retreive NetCDF software package on:

https://www.unidata.ucar.edu/software/netcdf/

NetCDF data is:

- Self-Describing. A netCDF file includes information about the data it contains.
- Architecture-independent. A netCDF file is represented in a form that can be accessed by computers with different ways of storing integers, characters, and floating-point numbers.
- Direct access. A small subset of a large dataset may be accessed efficiently, without first reading through all the preceding data.
- Appendable. Data can be appended to a netCDF dataset along one dimension without copying the dataset or redefining its structure. The structure of a netCDF dataset can be changed, though this sometimes causes the dataset to be copied.
- Sharable. One writer and multiple readers may simultaneously access the same netCDF file.

The products are stored in **NetCDF** defined by the Cooperative Ocean/Atmosphere Research Data Service (COARDS) and Climate and Forecast (CF) metadata conventions.

The CF convention generalises and extends the COARDS convention but relaxes the COARDS constraints on dimension and order and specifies methods for reducing the size of datasets. A wide range of software is available to write or read NetCDF/CF files. API are made available by UNIDATA http://www.unidata.ucar.edu/software/netcdf:

- C/C++/Fortran
- Java
- MATLAB, Objective-C, Perl, Python, R, Ruby, Tcl/Tk

In addition to these conventions, the files are using a common structure and semantic as shown in the example below for expert product:

```
netcdf SWOT_L3_LR_SSH_Expert_026_001_20241223T202047_20241223T211213_v2.0.0 {
dimensions:
    num_lines = 9860 ;
    num_pixels = 69 ;
    num_nadir = 1513 ;
variables:
    double time(num_lines) ;
        time:comment = "Time of measurement in seconds in the UTC time scale since 1 Jan 2000 00:00:00 UTC. [tai_utc_difference] is the difference between TAI and UTC reference time (seconds) for the first measurement of the data set. If a leap second occurs within the data set, the attribute leap_second is set to the UTC time at which the leap second occurs." ;
        time:leap_second = "0000-00-00T00:00:00Z" ;
        time:long_name = "time in UTC" ;
        time:standard_name = "time" ;
        time:tai_utc_difference = 37. ;
        time:calendar = "gregorian" ;
        time:units = "seconds since 2000-01-01 00:00:00.0" ;
    int calibration(num_lines, num_pixels) ;
        calibration:_FillValue = -2147483647 ;
        calibration:scale_factor = 0.0001 ;
        calibration:comment = "phase screen + phase_screen_static + phase_screen_orbit + xcal. the uncorrected ssha can be computed as follows: [uncorrected ssha]=[ssha from product] - [calibration]; see the product user manual for details.\n" ;
        calibration:coordinates = "longitude latitude" ;
        calibration:long_name = "satellite calibration" ;
        calibration:units = "m" ;
    double cross_track_distance(num_pixels) ;
        cross_track_distance:comment = "Distance of sample from nadir. Negative values indicate the left side of the swath, and positive values indicate the right side of the swath.\n" ;
        cross_track_distance:coordinates = "longitude latitude" ;
        cross_track_distance:long_name = "cross track distance" ;
        cross_track_distance:units = "km" ;
        cross_track_distance:valid_max = 75. ;
```

```
		cross_track_distance:valid_min = -75. ;
	short dac(num_lines, num_pixels) ;
		dac:_FillValue = -32767s ;
		dac:scale_factor = 0.0001 ;
		dac:comment = "Model estimate of the effect on sea surface topography due to high frequency air pressure and wind effects and the low-frequency height from inverted barometer effect. The ssha in this file is already corrected for the dac; the uncorrected ssha can be computed as follows: [uncorrected ssha]=[ssha from product]+[dac]; see the product user manual for details.\n" ;
		dac:coordinates = "longitude latitude" ;
		dac:institution = "LEGOS/CNES/CLS" ;
		dac:long_name = "dynamic atmospheric correction" ;
		dac:source = "MOG2D" ;
		dac:units = "m" ;
	int internal_tide(num_lines, num_pixels) ;
		internal_tide:_FillValue = -2147483647 ;
		internal_tide:scale_factor = 0.0001 ;
		internal_tide:comment = "The ssha in this file is already corrected for the internal_tide; the uncorrected ssha can be computed as follows: [uncorrected ssha]= [ssha from product]+[internal_tide]; We recommend to apply on ssha_unfiltered field. See the product user manual for details\n" ;
		internal_tide:coordinates = "longitude latitude" ;
		internal_tide:long_name = "Internal Tide signal from HRET14/HRET8 blend: coherent mode M2/K1/O1/S2/N2" ;
		internal_tide:source = "HRET14/HRET8 blend" ;
		internal_tide:units = "m" ;
		internal_tide:disclaimer = "There are limitations of HRET14 in specific regions (see L3 handbook). Will likely be replaced by a new HRET algorithm in a future release\n" ;
	int latitude(num_lines, num_pixels) ;
		latitude:scale_factor = 1.e-06 ;
		latitude:comment = "Latitude of measurement [-80,80]. Positive latitude is North latitude, negative latitude is South latitude." ;
		latitude:long_name = "latitude (positive N, negative S)" ;
		latitude:standard_name = "latitude" ;
		latitude:units = "degrees_north" ;
	int longitude(num_lines, num_pixels) ;
		longitude:scale_factor = 1.e-06 ;
		longitude:comment = "Longitude of measurement. East longitude relative to Greenwich meridian." ;
		longitude:long_name = "longitude (degrees East)" ;
		longitude:standard_name = "longitude" ;
		longitude:units = "degrees_east" ;
	int mdt(num_lines, num_pixels) ;
		mdt:_FillValue = -2147483647 ;
		mdt:scale_factor = 0.0001 ;
		mdt:comment = "The mean dynamic topography is the sea surface height above geoid; it is used to compute the absolute dynamic topography adt=ssha+mdt. A -5cm bias is added to the MDT for consistency with DUACS nadir products. This bias is inherited from the change of reference period implemented in 2014 when DUACS products went from a 7-year reference [1993, 1997] to a 20-year reference [1993, 2012]\n" ;
		mdt:coordinates = "longitude latitude" ;
		mdt:long_name = "mean dynamic topography" ;
		mdt:source = "HYBRID-CNES-CLS22-CMEMS2020 (https://doi.org/10.24400/527896/a01-2024.010)" ;
		mdt:standard_name = "mean_dynamic_topography_cnes_cls" ;
		mdt:units = "m" ;
	int mss(num_lines, num_pixels) ;
		mss:_FillValue = -2147483647 ;
		mss:scale_factor = 0.0001 ;
		mss:comment = "Mean sea surface height above the reference ellipsoid. The value is referenced to the mean tide system, i.e. includes the permanent tide (zero frequency)\n" ;
		mss:coordinates = "longitude latitude" ;
		mss:long_name = "mean sea surface height (CNES/CLS)" ;
		mss:source = "Hybrid SIO/CNES_CLS22/DTU21 (https://doi.org/10.24400/527896/a01-2024.002)" ;
		mss:units = "m" ;
	int ocean_tide(num_lines, num_pixels) ;
		ocean_tide:_FillValue = -2147483647 ;
		ocean_tide:scale_factor = 0.0001 ;
		ocean_tide:comment = "Geocentric ocean tide height. Includes the total sum of the ocean tide, the corresponding load tide and equilibrium long-period ocean tide height. The ssha in this file is already corrected for the ocean_tide; the uncorrected ssha can be computed as follows: [uncorrected ssha]=[ssha from product]+[ocean_tide]; see the product user manual for details.\n" ;
		ocean_tide:coordinates = "longitude latitude" ;
		ocean_tide:institution = "LEGOS/CNES" ;
		ocean_tide:long_name = "geocentric ocean tide height (FES)" ;
		ocean_tide:source = "FES2022 (https://doi.org/10.24400/527896/A01-2024.004)" ;
		ocean_tide:units = "m" ;
	ubyte quality_flag(num_lines, num_pixels) ;
		quality_flag:comment = "Deduced from L3 DUACS processing; see the product user manual for details.\n" ;
		quality_flag:coordinates = "longitude latitude" ;
		quality_flag:flag_masks = 0LL, 3LL, 5LL, 10LL, 18LL, 19LL, 20LL, 30LL, 50LL, 70LL, 100LL, 101LL, 102LL ;
		quality_flag:flag_meanings = "good eclipse local_outliers bad_quality_coast ocean_unsure ice_unsure ice soft_outliers extremes mission_event bad_swath_extremities not_on_sea no_data" ;
		quality_flag:long_name = "Quality Flag" ;
		quality_flag:standard_name = "valid_flag_for_data" ;
	int sigma0(num_lines, num_pixels) ;
		sigma0:_FillValue = -2147483647 ;
		sigma0:scale_factor = 0.0001 ;
```

```
		sigma0:comment = "Normalized radar cross section (sigma0) from KaRIn in real, linear units (not decibels). The value may be negative due to noise subtraction. The value is corrected for instrument calibration and atmospheric attenuation. A meteorological model provides the atmospheric attenuation (sig0_cor_atmos_model).\"\n" ;
		sigma0:coordinates = "longitude latitude" ;
		sigma0:long_name = "normalized radar cross section (sigma0) from KaRIn)" ;
		sigma0:standard_name = "surface_backwards_scattering_coefficient_of_radar_wave" ;
		sigma0:units = "1" ;
		sigma0:valid_max = 10000000 ;
		sigma0:valid_min = -1000 ;
	int ssha_filtered(num_lines, num_pixels) ;
		ssha_filtered:_FillValue = -2147483647 ;
		ssha_filtered:scale_factor = 0.0001 ;
		ssha_filtered:comment = "Height of the sea surface anomaly with all corrections applied and with calibration, data selection and noise reduction (using Unet model) applied; see the product user manual for details.\n" ;
		ssha_filtered:coordinates = "longitude latitude" ;
		ssha_filtered:long_name = "sea surface height anomaly calibrated, edited and filtered" ;
		ssha_filtered:standard_name = "sea_surface_height_above_reference_ellipsoid" ;
		ssha_filtered:units = "m" ;
		string ssha_filtered:disclaimer = "Experimental algorithm. This parameter is the noise-mitigated counterpart of the 'ssha_unfiltered' variable. The noise was mitigated through a machine-learning algorithm (Treboutte et al., 2024). Caution is advised because the algorithm validation is still ongoing: some of the ocean features less than 50km in wavelength may also be affected by the de-noising algorithm\n" ;
	int ssha_unedited(num_lines, num_pixels) ;
		ssha_unedited:_FillValue = -2147483647 ;
		ssha_unedited:scale_factor = 0.0001 ;
		ssha_unedited:comment = "Height of the sea surface anomaly with all corrections applied and with calibration. Contains both valid and invalid measurements; see the product user manual for details.\n" ;
		ssha_unedited:coordinates = "longitude latitude" ;
		ssha_unedited:long_name = "sea surface height anomaly calibrated" ;
		ssha_unedited:standard_name = "sea_surface_height_above_reference_ellipsoid" ;
		ssha_unedited:units = "m" ;
	int ssha_unfiltered(num_lines, num_pixels) ;
		ssha_unfiltered:_FillValue = -2147483647 ;
		ssha_unfiltered:scale_factor = 0.0001 ;
		ssha_unfiltered:comment = "Height of the sea surface anomaly with all corrections applied and with calibration and data selection applied; It is equivalent to the Sea Level Anomaly (SLA) distribued in the nadir DUACS products; see the product user manual for details.\n" ;
		ssha_unfiltered:coordinates = "longitude latitude" ;
		ssha_unfiltered:long_name = "sea surface height anomaly calibrated and edited" ;
		ssha_unfiltered:standard_name = "sea_surface_height_above_reference_ellipsoid" ;
		ssha_unfiltered:units = "m" ;
	int ugos_filtered(num_lines, num_pixels) ;
		ugos_filtered:_FillValue = -2147483647 ;
		ugos_filtered:scale_factor = 0.0001 ;
		ugos_filtered:coordinates = "longitude latitude" ;
		ugos_filtered:long_name = "Absolute geostrophic velocity: zonal component" ;
		ugos_filtered:standard_name = "surface_geostrophic_eastward_sea_water_velocity" ;
		ugos_filtered:units = "m/s" ;
		ugos_filtered:comment = "Derived from [ssha_filtered] field and mean dynamic currents associated with the MDT field" ;
	int ugosa_filtered(num_lines, num_pixels) ;
		ugosa_filtered:_FillValue = -2147483647 ;
		ugosa_filtered:scale_factor = 0.0001 ;
		ugosa_filtered:coordinates = "longitude latitude" ;
		ugosa_filtered:long_name = "Geostrophic velocity anomalies: zonal component" ;
		ugosa_filtered:standard_name = "surface_geostrophic_eastward_sea_water_velocity_assuming_sea_level_for_geoid" ;
		ugosa_filtered:units = "m/s" ;
		ugosa_filtered:comment = "Derived from ssha_filtered field" ;
	int ugosa_unfiltered(num_lines, num_pixels) ;
		ugosa_unfiltered:_FillValue = -2147483647 ;
		ugosa_unfiltered:scale_factor = 0.0001 ;
		ugosa_unfiltered:comment = "Derived from ssha_unfiltered field" ;
		ugosa_unfiltered:coordinates = "longitude latitude" ;
		ugosa_unfiltered:long_name = "Geostrophic velocity anomalies: zonal component" ;
		ugosa_unfiltered:standard_name = "surface_geostrophic_eastward_sea_water_velocity_assuming_sea_level_for_geoid" ;
		ugosa_unfiltered:units = "m/s" ;
	int vgos_filtered(num_lines, num_pixels) ;
		vgos_filtered:_FillValue = -2147483647 ;
		vgos_filtered:scale_factor = 0.0001 ;
		vgos_filtered:coordinates = "longitude latitude" ;
		vgos_filtered:long_name = "Absolute geostrophic velocity: meridian component" ;
		vgos_filtered:standard_name = "surface_geostrophic_northward_sea_water_velocity" ;
		vgos_filtered:units = "m/s" ;
		vgos_filtered:comment = "Derived from [ssha_filtered] field and mean dynamic currents associated with the MDT field" ;
	int vgosa_filtered(num_lines, num_pixels) ;
		vgosa_filtered:_FillValue = -2147483647 ;
		vgosa_filtered:scale_factor = 0.0001 ;
		vgosa_filtered:coordinates = "longitude latitude" ;
		vgosa_filtered:long_name = "Geostrophic velocity anomalies: meridian component" ;
		vgosa_filtered:standard_name = "surface_geostrophic_northward_sea_water_velocity_assuming_sea_level_for_geoid" ;
		vgosa_filtered:units = "m/s" ;
```

```
		vgosa_filtered:comment = "Derived from ssha_filtered field" ;
	int vgosa_unfiltered(num_lines, num_pixels) ;
		vgosa_unfiltered:_FillValue = -2147483647 ;
		vgosa_unfiltered:scale_factor = 0.0001 ;
		vgosa_unfiltered:comment = "Derived from ssha_unfiltered field" ;
		vgosa_unfiltered:coordinates = "longitude latitude" ;
		vgosa_unfiltered:long_name = "Geostrophic velocity anomalies: meridian component" ;
		vgosa_unfiltered:standard_name = "surface_geostrophic_northward_sea_water_velocity_assuming_sea_level_for_geoid" ;
		vgosa_unfiltered:units = "m/s" ;
	short i_num_line(num_nadir) ;
		i_num_line:comment = "alongtrack indice of the nearest karin pixel from the nadir data" ;
		i_num_line:long_name = "alongtrack indice of the nearest karin pixel from the nadir data" ;
		i_num_line:units = "count" ;
	byte i_num_pixel(num_nadir) ;
		i_num_pixel:comment = "acrosstrack indice of the nearest karin pixel from the nadir data" ;
		i_num_pixel:long_name = "acrosstrack indice of the nearest karin pixel from the nadir data" ;
		i_num_pixel:units = "count" ;

// global attributes:
		:Conventions = "CF-1.7" ;
		:Metadata_Conventions = "Unidata Dataset Discovery v1.0" ;
		:cdm_data_type = "Swath" ;
		:comment = "Sea Surface Height measured by Altimetry" ;
		:data_used = "SWOT KaRIn L2_LR_SSH PGC0/PIC0/PIC2 (NASA/CNES). DOI associated: https://doi.org/10.24400/527896/a01-2023.015" ;
		:doi = "https://doi.org/10.24400/527896/A01-2023.018" ;
		:geospatial_lat_units = "degrees_north" ;
		:geospatial_lon_units = "degrees_east" ;
		:geospatial_vertical_max = 0LL ;
		:geospatial_vertical_min = 0LL ;
		:geospatial_vertical_positive = "down" ;
		:geospatial_vertical_resolution = "point" ;
		:geospatial_vertical_units = "m" ;
		:institution = "CLS, CNES" ;
		:keywords = "Oceans > Ocean Topography > Sea Surface Height" ;
		:keywords_vocabulary = "NetCDF COARDS Climate and Forecast Standard Names" ;
		:platform = "Swot" ;
		:processing_level = "L3" ;
		:product_version = "2.0.1" ;
		:project = "SSALTO/DUACS" ;
		:reference_altimeter = "S6" ;
		:references = "Handbook: https://www.aviso.altimetry.fr/fileadmin/documents/data/tools/hdbk_duacs_SWOT_L3.pdf" ;
		:source = "Altimetry measurements" ;
		:ssalto_duacs_comment = "The reference mission used for the altimeter inter-calibration processing is Sentinel-6A" ;
		:standard_name_vocabulary = "NetCDF Climate and Forecast (CF) Metadata Convention Standard Name Table v37" ;
		:time_coverage_resolution = "PT0.3S" ;
		:title = "NRT SWOT KaRIn & nadir Global Ocean swath SSALTO/DUACS Sea Surface Height L3 product" ;
		:contact = "aviso@altimetry.fr" ;
		:creator_email = "aviso@altimetry.fr" ;
		:creator_name = "DUACS - Data Unification and Altimeter Combination System" ;
		:creator_url = "https://aviso.altimetry.fr" ;
		:license = "https://www.aviso.altimetry.fr/fileadmin/documents/data/License_Aviso.pdf" ;
		:time_coverage_start = "2024-12-23T20:20:47Z" ;
		:time_coverage_end = "2024-12-23T21:12:13Z" ;
		:geospatial_lat_min = -78.271942 ;
		:geospatial_lat_max = 78.272019 ;
		:geospatial_lon_min = 5.e-06 ;
		:geospatial_lon_max = 359.999986 ;
		:date_modified = "2025-01-10T11:03:59Z" ;
		:history = "2025-01-10T11:03:59Z: Created by DUACS KaRIn prototype" ;
		:date_created = "2025-01-10T11:03:59Z" ;
		:date_issued = "2025-01-10T11:03:59Z" ;
}
```

7 Accessibility of the products

If you already have an AVISO account, data access is available through the following services:

CNES AVISO FTP/SFTP (with AVISO+ credentials)

- FTP access: ftp://ftp-access.aviso.altimetry.fr:21
- SFTP access: sftp://ftp-access.aviso.altimetry.fr:2122
    - /swot_products/l3_karin_nadir/l3_lr_ssh/

CNES AVISO THREDDS Data Server, TDS (with AVISO+ credentials)

- TDS access: https://tds-odatis.aviso.altimetry.fr/thredds/catalog/dataset-l3-swot-karin-nadir-validated/l3_lr_ssh/catalog.html

8 Contact

For more information, please contact:

Aviso+ User Services
E-mail: aviso@altimetry.fr
On Internet: https://www.aviso.altimetry.fr/

The user service is also interested in user feedback; questions, comments, proposals, requests are much welcome.

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