SWOT Level-3 Product (alpha v0.x)
Frequently Asked Questions

1. What is this Level-3 product and why should you care?

Simply put, we packed what we think is the most convenient early research-grade SWOT topography for oceanographers into a lightweight product. Just the 2D SWOT basic ocean topography you need: directly usable, calibrated, noise-reduced, with the most recent corrections and algorithms (see below). Open it, do your research. No hassle.

Here are few examples of the difference with other SWOT products:

- State of the art research-grade corrections (e.g. tides) and references (e.g. mean sea surface, mean dynamic topography), including some very recent post-launch papers.
- Multi-mission calibration: the Level-3 benefits from better calibration procedures, as well as better consistency with nadir altimeters (e.g. Sentinel-3 & 6, SARAL, or HY-2B, Copernicus CMEMS L3 & L4).
- Noise mitigation: it is no secret that KaRIn yields very precise measurements (better than the requirements or simulated data). Yet in the presence of high-waves, even KaRIn topography does contain random noise (albeit less than all recent nadir altimeters). This noise is generally negligible on topography, but it is amplified by derivatives. Using an AI-based algorithm, the Level-3 products provide measurements that are even more precise. Note that the AI noise mitigation is not just basic smoothing: noise is reduced, but SSHA content is preserved as much as possible.
- No more complex quality flags: we have baked various sophisticated layers of editing flags/procedures into an already-made product. This should take care of spurious pixels of all origins. We try to find the delicate balance between keeping as much “okayish” pixels as we can while taking out blatant anomalies.
- Both SWOT KaRIn and nadir instruments are blended into a single 2-km product, and a single consistent grid: the nadir is a pixel line between KaRIn images, and both are calibrated to minimize discrepancies. Using each instrument separately (or both of them concurrently) should be trivial.
- As an early research experiment, this product is continuously evolving. This first beta release will be followed by various upgrades (e.g. better algorithm, 250-m posting) and reprocessing, as we integrate your feedback or the outcome of ongoing ST studies and L2 Project releases.

2. (v0.x specific) Where can I get this product?

The alpha/beta versions of the Level-3 product are not distributed publicly yet. They are shared with the SWOT Science and Adopt-A-Crossover (AdAC) teams only for early evaluation, validation and feedback. If you have access to this FAQ and some sample L3 products, please do not redistribute them.

3. How do I get the data I need for my region/period of interest?

The filename contains the cycle and pass numbers and the date/time extent of each file.

If you are interested in a specific pass region, you might want to use the PODAAC Swath Visualizer, or the AVISO Orbit files (KML & shapefile) to get the pass numbers for your region of interest.
Cycles 400+ correspond to the 1-day or CalVal orbit (January to July 11th, 2023): each cycle is 0.99 days and 14 revolutions (28 passes).

4. What is the product format and content?

The Level-3 product comes in two different flavors:

- L3 basic (or lightweight): As per the name, this product contains only SSHA and mean dynamic topography.
- L3 expert (or extended): This version contains each L3 algorithm, provided as a separate layer (see below). If you don’t want to use our editing procedure, calibration or corrections, you can customize them individually and still benefit from the others.

Both flavors are delivered in the netCDF format (COARDS, CF 1.7) with one file per pass. Generally, the format is a mix between CMEMS Level-3 products from nadir altimetry with some adjustment to be more consistent with the SWOT Level-2 format.

Ocean topography measurements from the nadir altimeter and interferometer images are merged into a single variable. Measurements from KaRIn swaths are on each side of the image. Measurements from the nadir altimeter are in the center columns. Expect to find default values in the pixels between the nadir track and the 2 KaRIn swaths, as well as on the outer edges of each swath (KaRIn is used only for cross-track distance ranging from 10 to 60 km).

Each file contains the following items: black items are in the basic & expert products; grey items are in the expert product only.

Dimension name	**Content / comment**
num_lines	Along-track direction index (image lines)
num_pixels	Cross-track direction index (image columns)

Variable name	**Content / comment**
time	Time of measurement in seconds since 1 Jan 2000 0:00h UTC
latitude	Latitude of measurement
longitude	Longitude of measurement
mdt	CNES/CLS 2022 mean dynamic topography
ssha	Height of the sea surface anomaly with all Level-2 & Level-3 corrections applied. Blends the SSHA of both SWOT instruments.
ssha_noiseless	Height of the sea surface anomaly with all Level-2 & Level-3 corrections applied and denoised using an AI noise mitigation algorithm.
ssha_unedited	Height of the sea surface anomaly with all Level-2 & Level-3 corrections applied but without any form of editing of spurious pixels. This variable can be used to develop your own editing procedure if the default flag does not suit your needs.
quality_flag	Quality flag (valid/invalid)
ocean_tide	Geocentric ocean tide height from the FES2022 model. Can be used to remove this correction from the corrected SSHA in order to apply your own model.
mss	Mean sea surface above the reference ellipsoid (hybrid model blending CLS/SIO/DTU version 2023). Can be used to remove this reference from the SSHA in order to apply your own model.
dac	Dynamic atmospheric correction from the MOG2D/TUGO model. Can be used to remove this correction from the corrected SSHA in order to apply a different model.
calibration	Pseudo phase-screen and calibration models (Level-3 multi-mission). Can be used to remove this correction from the corrected SSHA in order to apply your own calibration model.
ugos & vgeos	Absolute geostrophic velocity (U & V components) derived from the sum of the SSHA noiseless + MDT variables.
ugosa & vgeosa	Geostrophic velocity anomaly (U & V components) derived from the sum of the SSHA noiseless variable.
sigma0	Normalized radar cross section (sigma0) from KaRIn in real, linear units (not decibels) from the Level-2 product. Provided for convenience and context (interpretation of the SSHA).
i_num_line & i_num_pixels	Identifies the image pixels where the nadir altimeter is stored (center columns). Can be used to select & to isolate measurements from the nadir altimeter only as a 1D segment (see tutorial code)
cross_track_distance	Distance of sample from nadir. Negative values indicate the left side of the swath, and positive values indicate the right side of the swath.

5. (v0.x specific) What can I do with this product?

The current alpha/beta version of the Level-3 is generated as part of the Cal/Val effort. The L3 pictures were distributed by AVISO (link) to support the Adopt-A-Crossover (AdAC) CLIVAR group and SWOT ocean validation campaigns. The numerical L3 product samples are delivered to the SWOT community experts so that they can help with the early evaluation of SWOT products in their area of expertise.

Generally speaking, SWOT products have not been cleared by Project & Program management for science and applications. So please do not circulate L3 products, and do not use them for publications: alpha/beta release is intended for you only and maybe for select collaborators of your ST Project, and for evaluation / validation and feedback only (support to SWOT validation, no science, no publication).

All L3 products fall under the same disclaimers and restrictions as the L2 products from the project. The L3 product should not be circulated nor used beyond the limits defined by the Project for their L2 products (see Project announcements). When in doubt, please feel free to contact the AVISO helpdesk for clarifications.

When current limitations on the Level-2 & Level-3 are lifted by SWOT Program & Project Management, the Level-3 will fall under the standard AVISO license: free access, AVISO account needed, you can do pretty much what you want (research, ops, business, publication…) except redistribute the product.

6. Who is creating this product?

The Level-3 product is provided by the AVISO/DUACS team from CNES in collaboration with the SWOT Project teams from JPL & CNES and industry (e.g. CLS, DATLAS).

It is a research-grade extension derived from the L2 products from the NASA/CNES Project. This product integrates algorithms, corrections and external models from the scientific community (e.g. OSTST, SWOT ST). To that extent, the Level-3 should be seen as a community research project, rather than an operational Agency product.

Questions and communications should be directed to the dedicated AVISO support: aviso-swot@altimetry.fr

7. Do you recommend using this Level-3 product instead of the Level-2?

No. Each product serves a specific purpose.

The Level-2 product is a SWOT standalone product (no multi-mission) with all reference algorithms and corrections. It is the one-and-only reference product, and it is the go-to product for technical and expert and algorithm analyses, 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 and applications, as well as some thematic research (e.g. tidal models). It might be the better suited for thematic research (e.g. oceanography, geodesy, etc.) when the user wants a very simple, out-of-the-box, product that can be mixed with other missions (e.g. CMEMS multi-mission altimetry products, DOI here).

Note that the Level-3 is a research-grade extension derived from the L2 from the NASA/CNES project. To that extent, the joint use of L3 and L2 products can be a sandbox where the Science Team can explore and test new standards/corrections to be recommended to the Project. Any feedback you provide on L2 or L3 items is very welcome.

8. (v0.x specific) What are the references for this product

A technical note or data paper will document the Level-3 algorithms and content in the near future. Until then, the following references describe the overall Level-3 philosophy inherited from nadir altimetry product from DUACS & CMEMS, as well as some recent models or KaRIn algorithms that are unique to SWOT.

Note that two alpha versions of both basic and expert Level-3 products have been generated so far:

- Level-3 products (alpha v0.1, August 2023) are derived from early Level-3 algorithms and **non-reprocessed beta pre-validated** Level-2 KaRIn Low Rate ocean products (not distributed; CNES internal usage only).

- Level-3 products (alpha v0.2, September 2023) are derived from updated Level-3 algorithms and **reprocessed** beta-prevalidated Level-2 KaRIn Low Rate ocean products.

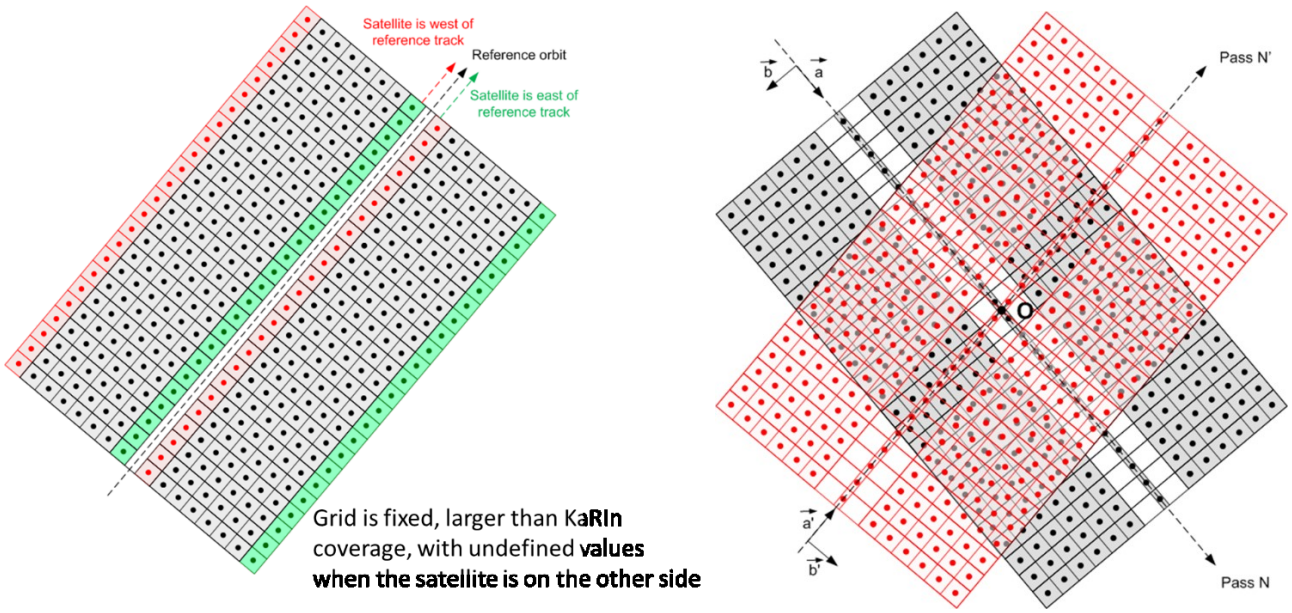
https://doi.org/10.3390/rs15030793 (Pujol et al., 2023: overall L3 sequence, nadir processing)
https://doi.org/10.3390/rs14236070 (Dibarboure et al., 2023: L3 calibration of KaRIn images)
https://doi.org/10.3390/rs15082183 (Treboutte et al., 2023 : KaRIn noise mitigation)
https://doi.org/10.24400/527896/a03-2022.3292 (Jousset et al., 2022: MDT CNES/CLS v2022)
https://doi.org/10.24400/527896/a03-2022.3287 (Carrere et al., 2023: FES v2022), Lyard et al., SWOT Science Team, 2023
https://doi.org/10.3390/rs15112910 (Schaeffer et al., 2023: Hybrid MSS CLS/Scripps/CNES/DTU v2023); Schaeffer et al, SWOT Science Team 2023
https://doi.org/10.5194/egusphere-egu22-7479 (Faugère et al, 2022: consistent multi-mission approach)
Dibarboure et al., SWOT ST 2023 poster
Dibarboure et al., SWOT ST 2023 presentation

9. How do you define the Level-3 grid pixels?

The Level-3 pixels are located on the same grid pixels as the KaRIn Level-2 products. The grid is geographically fixed (same location for each cycle) and defined relative to the theoretical nadir track. See the Level-2 documentation for more details (link).

Note that over crossover regions, the pixels with the ascending and descending swaths will not be aligned. In addition, because all satellite tracks move around their theoretical definition, you will see that pixels on the swath edge might be defaulted when the satellite is actually located to the East/West of the grid baseline.

The center columns of the Level-3 product contain sea surface height measurement from the nadir altimeter: both instruments are merged into a single netCDF variable. The grid columns between the nadir altimeter track and the interferometer swaths are empty.



10. (v0.x specific) What about caveats and disclaimers?

For alpha/beta versions of the Level-3 product, users must keep in mind that the SWOT mission is still in phase E1 (a.k.a CalVal phase). To that extent both the nadir instrument and the KaRIn interferometer might exhibit some artifacts and limitations, suboptimal ground algorithms and corrections, as well as the occasional unflagged spurious pixels.

Similarly, the Level-3 algorithms are an active research project. It is possible, if not likely, that you will encounter some limitations and deficiencies in the editing, calibration, or AI-based noise-reduction algorithms. We believe we identified and fixed the biggest issues, but not all of them. By all means, please feel free to report any anomaly you encounter or suspect to the AVISO support.

Known issues:

- KaRIn measurements (L2 & L3) are limited by the accuracy of current geophysical models. Even the latest MSS, MDT and tide models used in the Level-3 are sometimes not enough in coastal regions. Nadir altimetry suffers from the same limitations but they become obvious in KaRIn images. If you encounter an artifact that is correlated with bathymetry, then KaRIn is likely not the main suspect.

- Very strong internal tides (and internal waves) are visible in the KaRIn images. The current product uses a nadir-derived model of stationary internal tides that strongly underestimate what is observed in KaRIn pictures. The current state-of-the-art algorithms in altimetry are unable to separate balanced and unbalanced motions. We will try to implement better algorithms as they become available. Any suggestion you might have about this is most welcome.

- Like all altimeters, SWOT products are affected by rain cells and surface waves. The former are generally edited out when the event is strongly, and left as is when the corruption is weak. The latter is corrected by the Project in the Level-2 but we can provide research-driven alternatives upon request. This is an active topic of research and we will try to implement better algorithms as they become available. If you think improvements can be made on the SWOT products, your inputs are most welcome.

- The calibration can be imperfect in sea-ice covered regions and some complex coastal regions. Feel free to report major issue you encounter. Your feedback and examples will help us improve the Level-3 calibration algorithms.

- Some algorithm layers and corrections have not been optimized to handle some longitude transitions (e.g. 0/360°). If you encounter a N/S line of default pixel, we are probably already working on a fix on the Level-2 or Level-3 layer causing this.

11. Do Projects hosted on the CNES HPC infrastructure need to download their own copy?

No. The Level-2 and Level-3 datasets are on the CNES infrastructure already. They exist in the external netCDF format, as well as in the faster zarr/zcollection format. Please check the user documentation or contact the AVISO helpdesk.

12. Where can I find more help and answers?

If you need more help about the product content, format or usage, please feel free to contact our dedicated support team on AVISO (aviso-swot@altimetry.fr).