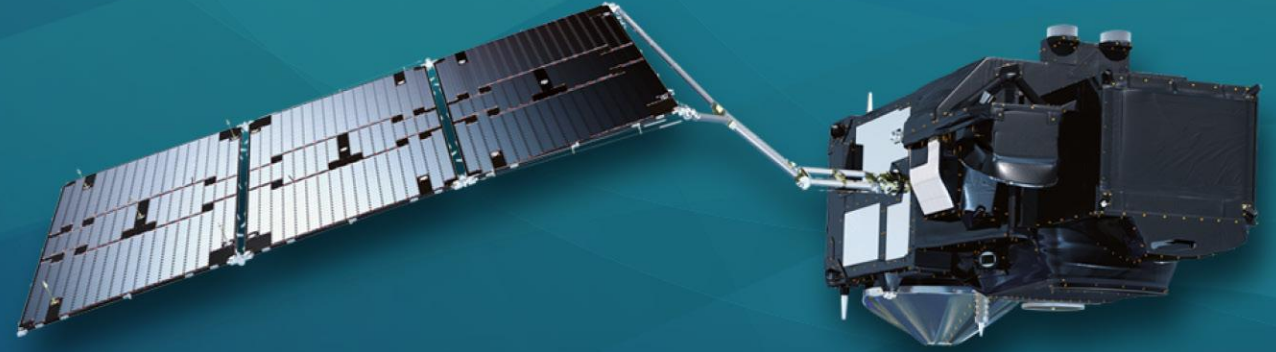




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9th Sentinel-3 Validation Team meeting 2026

30 March–01 April 2026 | ESA–ESRIN | Frascati (Rome), Italy

The Sentinel-3 Hydro-Cryo Thematic Products: current status and evolutions

*G.D'Apice, **J.Aublanc**, T.Berton, A.Chamayou, L.Amarouche (CLS/S3MPC)*

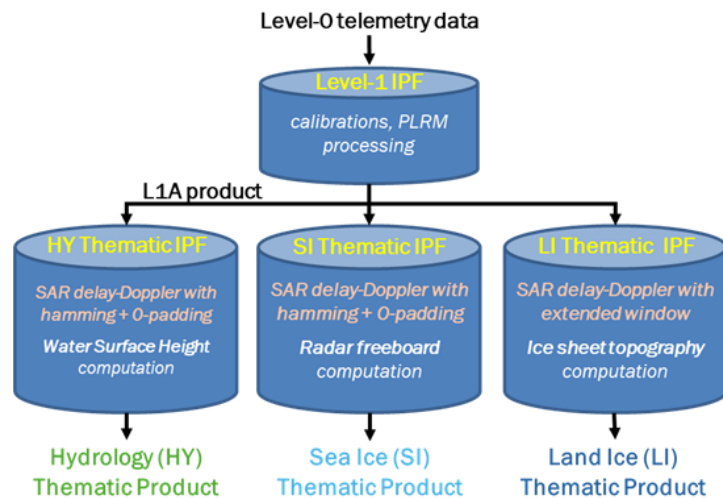
A.DiBella, M.Restano, F.Catapano (ESA)



ESA and the S3MPC are responsible for the operational level-2 altimetry processing over **LAND** (+sea ice) surfaces

Since September 2023, the level-2 processing is performed through three independent chains, generating level-2 Products over: **Inland Waters, Sea ice and Land ice.**

=> The so-called “Hydro-Cryo” Thematic Products



Thematic Processors are deployed in operation since September 2023, running in three timeliness (NRT, STC and NTC)

The **Thematic processors, and associated products**, are described in a publication wrote by the S3MPC team, available in “Nature Scientific Data”

<https://www.nature.com/articles/s41597-025-04956-3>

The screenshot shows the article page on the Nature Scientific Data website. At the top, there is a navigation bar with 'scientific data' on the left, and 'View all journals', 'Search', and 'Log in' on the right. Below this is a secondary navigation bar with 'Explore content', 'About the journal', and 'Publish with us' on the left, and 'Sign up for alerts' and 'RSS feed' on the right. The main content area shows the breadcrumb 'nature > scientific data > data descriptors > article'. The article title is 'Sentinel-3 Altimetry Thematic Products for Hydrology, Sea Ice and Land Ice', published on 29 April 2025. The authors listed are Jérémie Aublanc, Julien Renou, Fanny Piras, Karina Nielsen, Stine K. Rose, Sebastian B. Simonsen, Sara Fleury, Stefan Hendricks, Nicolas Taburet, Giovanni D'Apice, Anouk Chamayou, Pierre Féménias, Filomena Catapano & Marco Restano. A 'Download PDF' button is visible on the right. Below the title, there are tabs for 'Sections', 'Figures', and 'References'. The 'Sections' tab is active, showing links for 'Abstract', 'Background & Summary', and 'Methods'. At the bottom, it indicates the article is in 'Scientific Data' volume 12, issue number 714 (2025), with a 'Cite this article' link.

Timeline of BC-005 Hydro-Cryo Thematic Products



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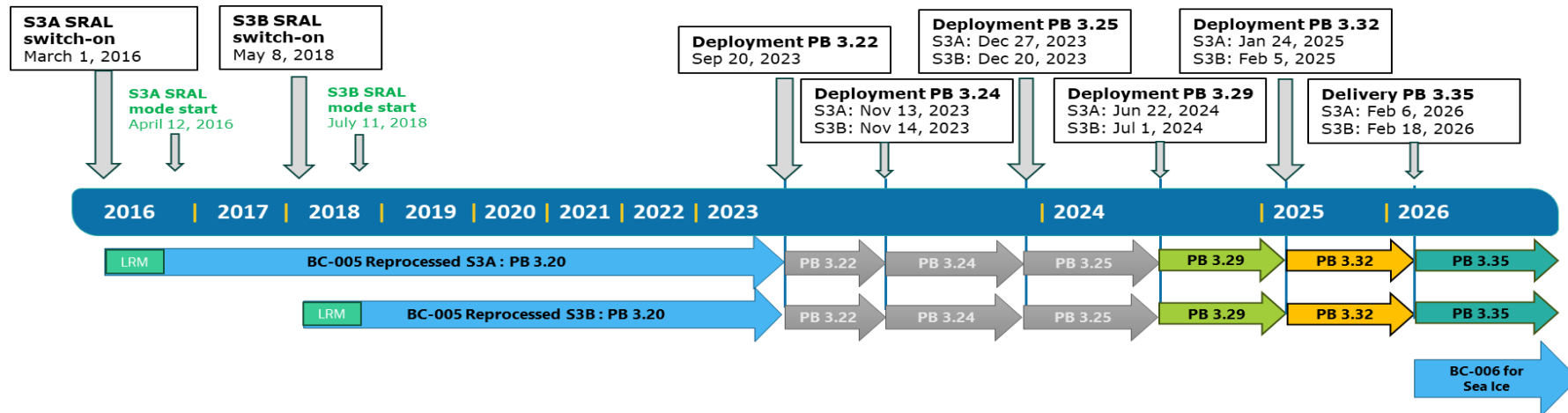
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The Hydro-Cryo Thematic Products are generated with the associated **Baseline Collection n°5 (BC-005)**. Except for Sea Ice Thematic Products (BC-006 ; since Feb 2026)

- ❖ **Sep 2023 (PB 3.20/3.22) => Reprocessing with BC-005 (PB 3.20) + Minor corrections/evolutions with PB 3.22**
- ❖ *Nov 2023 (PB 3.24) => Minor corrections/evolutions*
- ❖ *Dec 2023 (PB 3.25) => Minor corrections/evolutions*
- ❖ **Jun 2024 (PB 3.29) => Major evolutions (Land Ice Surface Type + OLTC information + Sea Ice Type)**
- ❖ *Jan 2025 (PB 3.32) => Minor corrections/evolutions*
- ❖ **Feb 2026 (PB 3.35) => Major evolutions (Sea Ice Thickness + WF classification + ...) => Sea Ice BC-006**



Processing Baseline 3.29 – deployed June 2024

Link to Product Notice (PN 3.29):

<https://sentiwiki.copernicus.eu/web/altimetry-processing#AltimetryProcessing-ProcessingBaseline>

➤ Land ice surface type information from BedMachine data set (*Land Ice Products*)

New surface flag available “**ice_sheet_surface_flag**”, to indicate if the measurement over Antarctica and Greenland is located over: (0) ocean (1) ice-free land (2) grounded ice (3) floating ice (3) Non-Greenland areas (auxiliary data from BedMachine data set)

Sources: <https://nsidc.org/data/nsidc-0756/versions/3> ; <https://nsidc.org/data/idbmg4/versions/5>

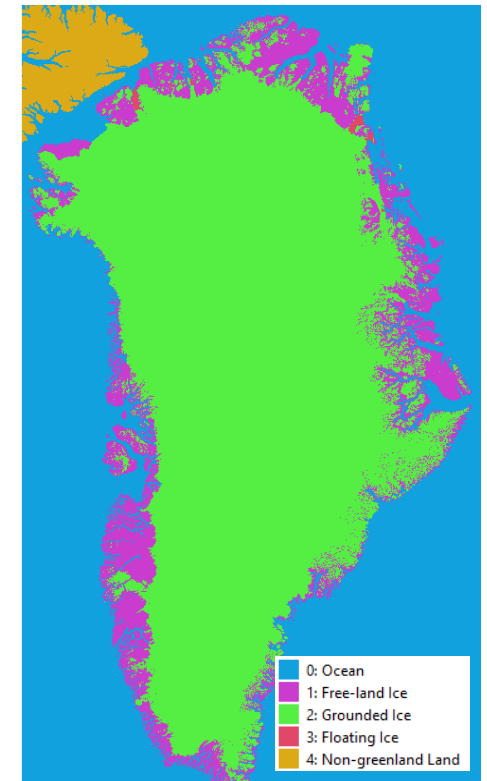
➤ OLTC information available (*Hydrology and Land Ice Products*)

Two new product variables “**oltc_target_type_20_ku**” and “**oltc_target_nadir_20_ku**” to provide information about Sentinel-3 OLTC setting.

➤ “Sea Ice Type” information in Sea Ice products (*Sea Ice Products*)

The Sea Ice type information available in the **OSI-SAF 403-d products** is interpolated and recorded in the SI Thematic Products (“**sea_ice_type_auxiliary_**”)

Source: <https://osi-saf.eumetsat.int/products/osi-403-d>



Processing Baseline 3.35 – deployed February 2026

➤ Waveform Classification from Neural Network algorithm (*Land Ice + Sea Ice + Hydrology Products*)

A class number, and its associated probability, is attributed to each 20 Hz SAR mode waveform, based on its shape, using the adapted approach from Poisson et al. (2018) **DOI:** [10.1109/TGRS.2018.2813061](https://doi.org/10.1109/TGRS.2018.2813061)

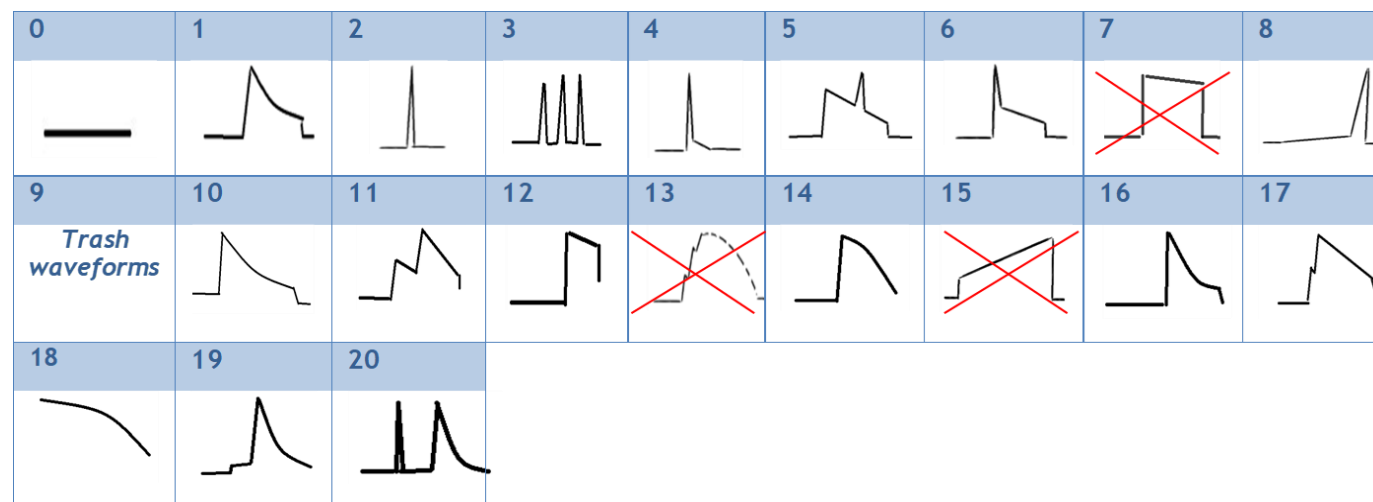


Illustration of the 20 possible echo classes

New product variables:

- “**waveform_class_rank1_20_ku**” – the most probable waveform class
- “**waveform_class_prob_rank1_20_ku**” – probability associated with the rank-1 class
- “**waveform_class_rank2_20_ku**” – the second most probable waveform class
- “**waveform_class_prob_rank2_20_ku**” – probability associated with the rank-2 class

Processing Baseline 3.35 – deployed February 2026

Sea Ice Processing chain evolution: **1** Snow Depth

Snow depth for both Arctic and Antarctic is now extracted from **static** auxiliary data and provided in the Sea Ice Thematic Products. Two snow-depth estimations are provided, variables “*snow_depth_sol1_20_ku*” and “*snow_depth_sol2_20_ku*” (along with their estimated uncertainties)

Solution 1: LEGOS

- **Methodology:** Bi-frequency empirical solution, using Ka-band (AltiKa) combined with Ku-band (CryoSat-2) measurements
- **Coverage:** Year-round across both Arctic and Antarctic domains from interpolated monthly climatology.
- Source: <https://doi.org/10.5194/tc-15-5483-2021>

Solution 2: AWI/ESA CCI

- **Methodology:** Passive microwave retrieval + Warren corrected climatologies
- **Coverage:** Monthly resolution in Arctic winter, daily resolution in Antarctica.
- Sources:
 - <https://doi.org/10.5281/zenodo.17131889>
 - <https://www.cen.uni-hamburg.de/en/icdc/data/restricted-access/esa-cci-antarctic-snow-depth.html>

Processing Baseline 3.35 – deployed February 2026

Sea Ice Processing chain evolution: **2** Sea Ice Thickness

Now that snow depth is available in the processing chain, this enables the computation of Sea Ice Thickness at 20Hz along the track. Product variable: “**sea_ice_thickness_20_ku**”.

Interpolated Snow Density (ρ_s)

Monthly interpolated using linear weighting;

- NH (Mallett 2020),
- SH (Fons 2023)

Interpolated Ice Density (ρ_{ice})

- NH: FYI=917, MYI=882, Unknown=900 kg/m³ (Alexandrov 2010);
- SH: Seasonal values, monthly interpolated using linear weighting (Fons 2023)

Corrected Freeboard (F_{ice})

$$F_{ice} = F_r + h_s \times [(c / c_s) - 1],$$

with $c_s = c \times (1 + 0.00051 \times \rho_s)^{-1.5}$

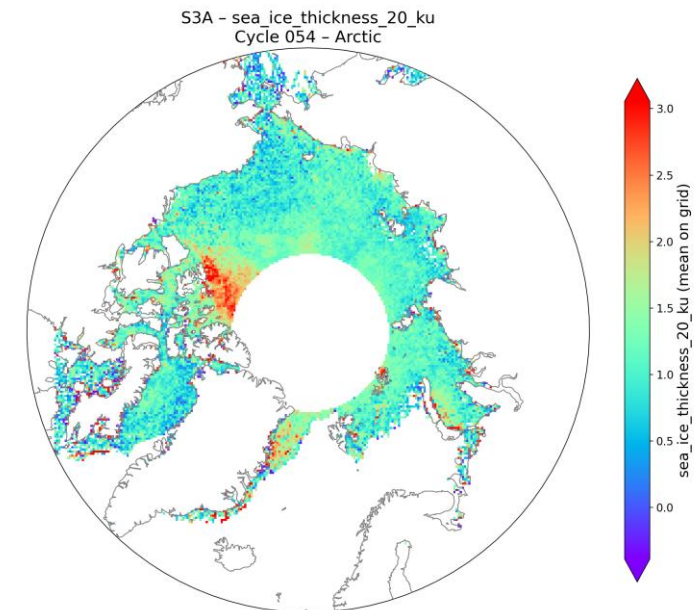
F_r = radar freeboard

h_s =snow depth

Sea Ice Thickness (SIT)

$$SIT = [F_{ice} \times \rho_w + h_s \times \rho_s] / (\rho_w - \rho_{ice}),$$

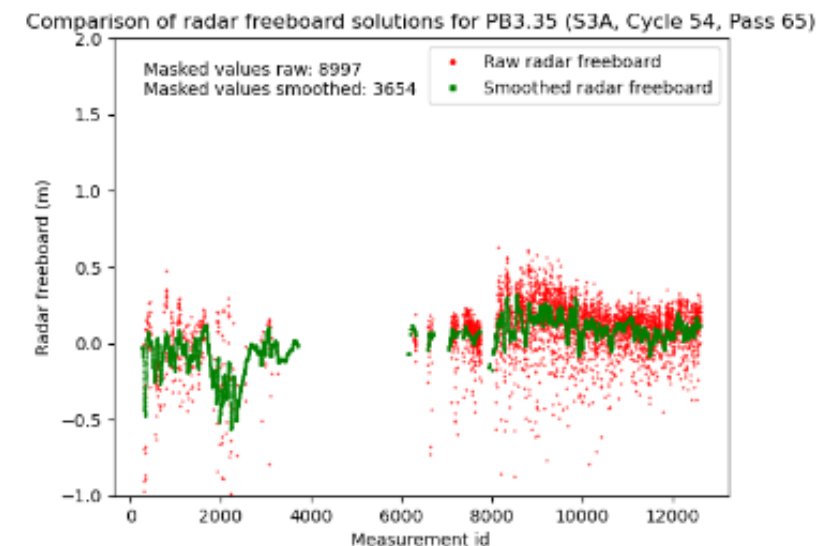
based on hydrostatic equilibrium, with ρ_w = water density



Processing Baseline 3.35 – deployed February 2026

Sea Ice Processing chain evolution: ③ Smoothed/interpolated freeboard

- Based on work made at LEGOS, smoothing/interpolation algorithms have been implemented to reduce the high frequency noise observed in the radar freeboard and Sea Ice Thickness.
- The results from the smoothing processing are recorded in new dedicated variables, among others:
 - ❖ “*radar_freeboard_smoothed_20_ku*”
 - ❖ “*sea_ice_thickness_smoothed_20_ku*”
- This is provided as “experimental” parameters. The initial 20 Hz estimations (before smoothing) remain available in the Sea Ice Thematic Products



PB 3.35 starts a new Baseline Collection for Sea Ice Thematic Products (BC-006) with a reprocessing coming in Q3 2026

=> See Talk of S.Fleury: Sentinel-3 Land STM MPC: Status and evolutions of the sea-ice product (Tuesday)

Processing Baseline 3.35 – deployed February 2026

Other evolutions/corrections in PB 3.35:

- **Update to GDR-G altimetry standards:**
 - ❖ **Mean Sea Surface:** “DTU-21” model has been corrected ; and “Hybrid-23” substitutes to “CNES/CLES-15”
 - ❖ **Oceanic Tides:** “FES-2022” substitutes to “FES-2014” model
- **Product DOI:** DOI number is now embedded in the product global attributes and manifest. In BC-006, each thematic products will have its own DOI (starting with Sea Ice).
- **Altimeter characterization update:** Updated parameter values in the CHDNAX/CHDRAX characterization files, following EUMETSAT recommendations. Impact in the Sigma-0 (*only deployed in the **Sea Ice Thematic processing at present***).
- **Land Ice Thematic Products:** Resolution of an anomaly to improve spatial coverage over the ice shelves
- **Sea ice Thematic Products:** Correction in the algorithm computing the “***open_sea_ice_flag_01_ku***” flag (Tran et al., 2009)

LPP & AMPLI Demonstration Products



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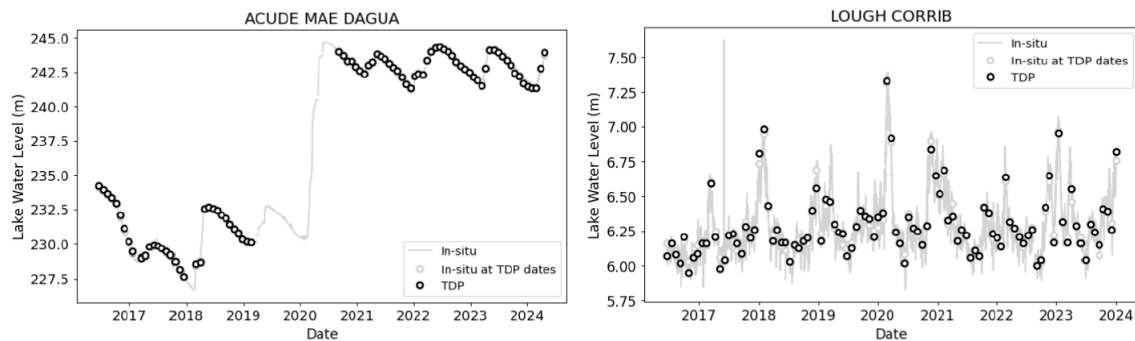
In parallel to the operational processors, ESA is also providing “Demonstration Products” with enhanced performances. **Data openly available in CDSE web portal.**

LPP Products:

Lakes and Reservoirs (SR_2_TDP_HY)

Developed at CNES. Delivers data at high posting rate (80-Hz) + exploits an advanced retracking simulation approach.

Publication: <https://doi.org/10.1109/TGRS.2021.3137034>



Comparison of lake water level time series between in-situ data and LPP altimetry data.

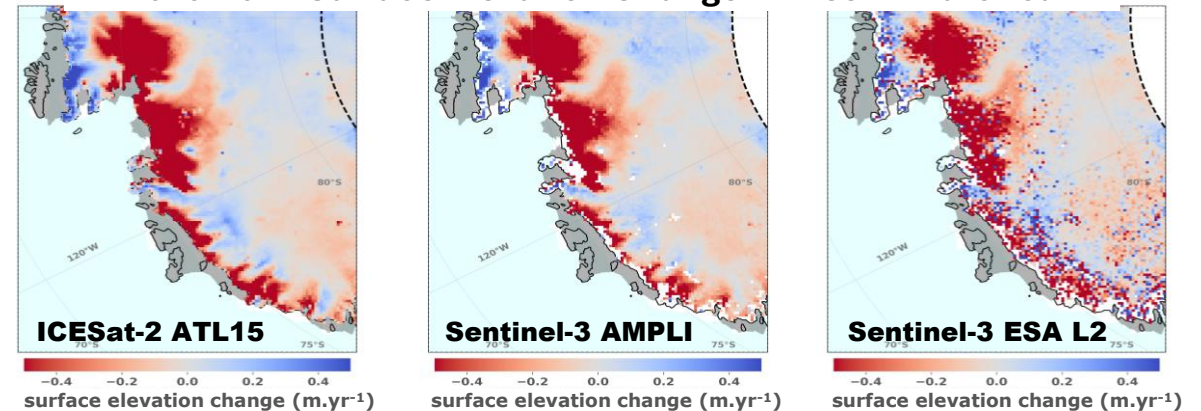
AMPLI Products:

Greenland & Antarctica (SR_2_TDP_LI)

Developed at CLS (ESA/CNES funding). Improved performance with an innovative relocation algorithm.
=> See talk from J.Aublanc, Tuesday afternoon

Publication: <https://tc.copernicus.org/articles/19/1937/2025/>

2019-2022 Surface Elevation Change in West Antarctica

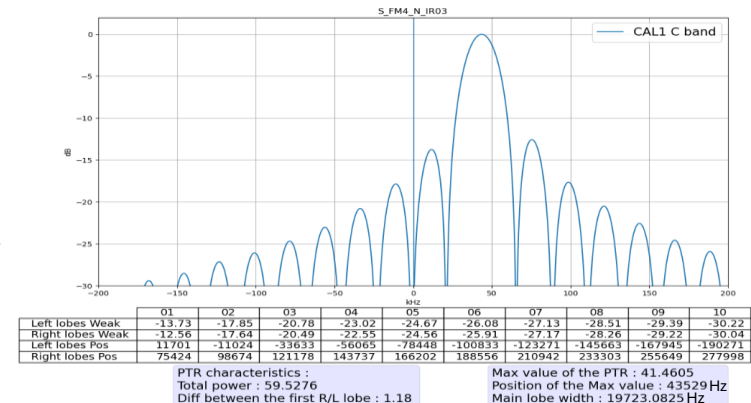


Mission reprocessing over Sea Ice with BC-006

- ❖ **BC-006 Sea Ice Thematic processor is already deployed (PB 3.35)** and the Products are therefore already operationally generated and disseminated through the ESA CDSE.
- ❖ **A full mission reprocessing will start in Q3 2026**, to produce a homogeneous S3A+S3B data set with last Sea Ice evolutions

Sentinel-3C

- ❖ **Sentinel-3C is planned to be launched in September 2026.** The IPF team has already performed analysis of AIT Data to initiate auxiliary and LTM files
- ❖ **The IPF team will also work in support of the S3C commissioning (IPF team will check the workflow and configuration used for product generation and updates auxiliary data files based on the initial S3C data)**



Hydrology:

- **New retrackers for lakes and rivers** (*QWG recommendation*) SinC and SAMOSA+ to be further evaluated by S3MPC
=> Note: LPP includes an advanced retracking simulation approach + 80 Hz posting rate
- **Water occurrence probability** (*QWG recommendation*), based for example on Pekel database
- **Lake Ice Thickness** (*QWG recommendation*), On-going work for Sentinel-3 adaptation and application
- **Geoid update** for a next mission reprocessing (*MPC recommendation*)

Land Ice:

- **Top priority is the improvement of relocation method** (*QWG recommendation*).
=> Note: Addressed within AMPLI processing chain (See Talk of J.Aublanc)
- **Waveform shape parameters estimation** (Leading edge Width & Trailing edge Slope) (*MPC recommendation*)
- **Dedicated quality flag** (*QWG recommendation*), to inform users about elevation outliers, bad quality data

Sea Ice:

- **Physical Retracking** (*MPC recommendation*) state-of-the-art review + analyses are planned to identify the suitable algorithms
- **Improved “Snow Depth” estimation from auxiliary data:** “LEGOS LaKu” solution (*MPC recommendation*)
- **Synergy with MWR for estimation of (1) Sea Ice Concentration (2) Snow Depth** (*MPC recommendation*)

Common:

- **Uncertainties** provided in the Thematic Products ; **Geophysical correction provided at 20 Hz ; 80 Hz UF-SAR processing** (to be evaluated over the cryosphere) ; **Improved « surface type » information** from WorldCover

ESA operationally generates Sentinel-3 level-2 “Hydro-Cryo” Thematic Products, covering (1) Inland Waters (2) Sea Ice (3) Land Ice

- ❖ **A complete and validated S3A+S3B time series is available within Baseline Collection n°005**
- ❖ Two main updates since Sept 2023: **PB 3.29 (June 2024)** and **PB 3.35 (Feb 2026)**, addressing recommendations from QWG. The evolutions are documented in the **Product Notices** (see link below)
- ❖ **PB 3.35 starts a new Baseline Collection for Sea Ice (BC n°006)**, including major evolutions, in particular the delivery of Sea Ice Thickness. **A Sea Ice reprocessing will start in Q3 2026 with BC-006.**
- ❖ The Hydro-Cryo Thematic Products are available in the “**ESA Copernicus Data Space Ecosystem**” (see link below)
- ❖ **LPP (lakes) and AMPLI (ice sheets)** are advanced “Demonstration Products”, also available on ESA CDSE
- ❖ The Hydro-Cryo Thematic Products will continue to evolve **to address user needs and requirements**

Useful Resources

[SentiWiki](#)[Copernicus Data Space Ecosystem](#)[Product Handbook](#)[Product Notice](#)[Product Data Format Specification](#)



BACK UP

Processing Baseline 3.35 – deployed February 2026

➤ Waveform Classification adapted from Neural Network algorithm

A class number, and its associated probability, is attributed to each 20 Hz SAR mode waveform based on its shape, using the adapted approach from Poisson et al. (2018) **DOI:** [10.1109/TGRS.2018.2813061](https://doi.org/10.1109/TGRS.2018.2813061)

