Cryo-TEMPO: A new era of CryoSat-2 Thematic Products over Ice, Ocean and Inland Water

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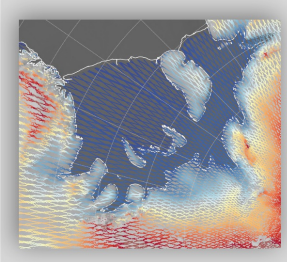
Summary

- The aim of Cryo-TEMPO is to catalyse the exploitation of CryoSat-2 datasets by new communities beyond the traditional altimetry expert.
- Cryo-TEMPO develops and operates **agile**, **robust** and **state-of-the-art** processing workflows, which generate CryoSat-2 Thematic Data Products (TDP's) **dedicated to five Thematic Areas**.
- The project brings together an international team of 13 institutions, comprising altimetry experts, systems and software engineers, and thematic users.
- Each thematic product is rapidly evolved on an annual basis, to ensure the rapid transfer of the state-of-the-art to operations.
- Evolutions are guided by both technical and user experts, ensuring that product development is driven by user needs.
- Data can be accessed via the ESA science servers: https://science-pds.cryosat.esa.int/.

Cryo-TEMPO Land Ice



- The Cryo-TEMPO **Land Ice** product provides ice sheet surface elevation measurements across Greenland and Antarctica.
- Innovations introduced in version 1 include consistent retrackers for LRM and SARIn, dedicated ice sheet surface type classification, glaciological basin identifiers, and reference elevations from high resolution Digital Elevation Models.
- Future updates will include improvements to the SARIn retracking, the LRM and SARIn Angle of Arrival computation, the auxiliary datasets such as the Digital Elevation Models and tide models, and the uncertainty estimation.

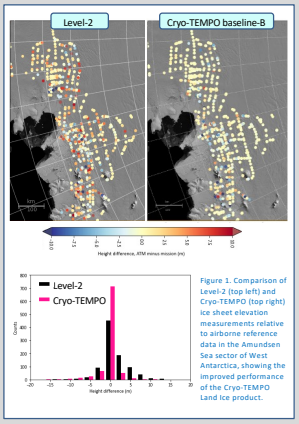
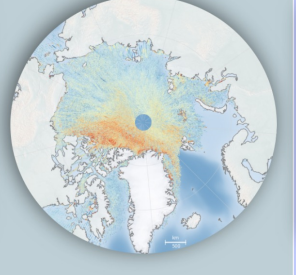


Figure 1. Comparison of Level-2 (top left) and Cryo-TEMPO (top right) ice sheet elevation measurements relative to airborne reference data in the Amundsen Sea sector of West Antarctica, showing the improved performance of the Cryo-TEMPO Land Ice product.

Cryo-TEMPO Sea Ice



- The Cryo-TEMPO **Sea Ice** product provides freeboard and snow depth information for all CryoSat-2 orbits in the northern hemisphere.
- Innovations introduced in version 1 include the availability of sea ice freeboard and radar freeboard (without snow layer corrections), improved snow depth and density climatology outside the central Arctic, merged SAR/SARIn data, and uncertainty estimates. Improved sea surface heights are developed in close collaboration with the Polar Ocean product.
- Future updates will include improved freeboard using the SAMOSA+ physical waveform model, extension to the southern hemisphere, and the development of a summer sea ice product.

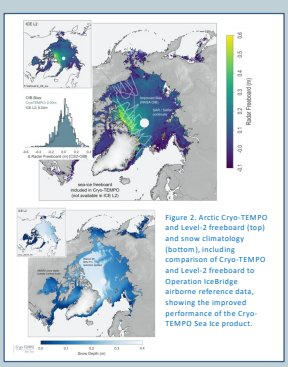
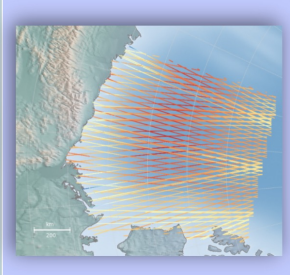


Figure 2. Arctic Cryo-TEMPO and Level-2 freeboard (top) and snow climatology (bottom), including comparison of Cryo-TEMPO and Level-2 freeboard to Operation IceBridge airborne reference data, showing the improved performance of the Cryo-TEMPO Sea Ice product.

Cryo-TEMPO Polar Oceans



- The Cryo-TEMPO **Polar Oceans** product provides Sea Level Anomalies and Dynamic Ocean Topography for all CryoSat-2 orbits in the northern hemisphere.
- Innovations introduced in version 1 include the use of a state-of-the-art TFMRA retracker that is optimised for the Polar Ocean, and uncertainty estimates for all geophysical variables.
- Future updates will include improved retracking using a physical waveform model (SAMOSA+), an updated Mean Sea Surface, incorporation of a new Arctic tide model and extension to the southern hemisphere.

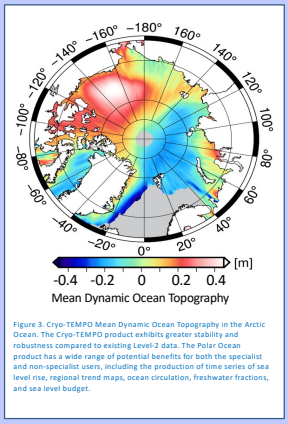
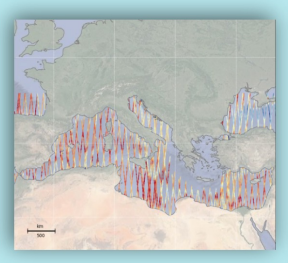


Figure 3. Cryo-TEMPO Mean Dynamic Ocean Topography in the Arctic Ocean. The Cryo-TEMPO product exhibits greater stability and robustness compared to existing Level-2 data. The Polar Ocean product has a wide range of potential benefits for both the specialist and non-specialist users, including the production of time series of sea level rise, regional trend maps, ocean circulation, freshwater fractions, and sea level budget.

Cryo-TEMPO Coastal Oceans



- The Cryo-TEMPO **Coastal Oceans** product provides Sea Level Anomalies and Absolute Dynamic Ocean Topography, together with associated uncertainties and measurement validity flags.
- Currently, data are produced over the Mediterranean Sea; future additions are planned to cover the Black Sea and the North Atlantic.
- Innovations introduced in version 1 include a physical waveform model (SAMOSA+), and region-specific corrections such as a new high frequency adjustment and Sea State Bias correction.
- Future updates will include processing of SARIn acquisitions, minimisation of inter-mode biases and improved filtering.

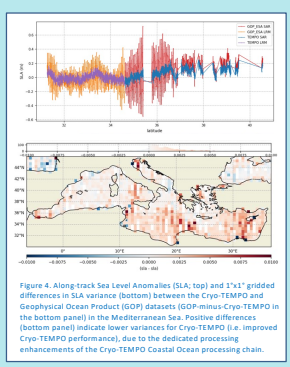


Figure 4. Along-track Sea Level Anomalies (SLA; top) and 1°x1° gridded differences in SLA variance (bottom) between the Cryo-TEMPO and Geophysical Ocean Product (GOP) datasets (GOP-minus-Cryo-TEMPO in the bottom panel) in the Mediterranean Sea. Positive differences (bottom panel) indicate lower variances for Cryo-TEMPO (i.e. improved Cryo-TEMPO performance), due to the dedicated processing enhancements of the Cryo-TEMPO Coastal Ocean processing chain.

Cryo-TEMPO Inland Water

- The Cryo-TEMPO **Inland Water** product provides water surface height measurements and associated quality metrics for selected lake and river targets.
- Currently, data are produced over the Po River Basin, and selected US and Canadian Lakes; future additions are planned to cover Sweden and South America.
- Water heights are based on various retrackers (MLE4, OCOG, TFMRA) and a Machine Learning (Neural Network) classifier is used to identify measurement reliability.
- Future updates will include the implementation of a physical waveform model (SAMOSA+), the addition of a TFMRA SARIn retracker and improved uncertainty estimation.

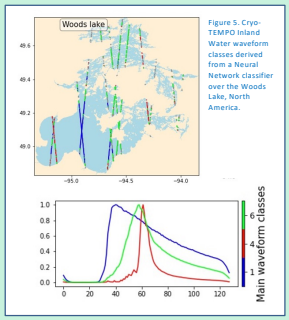


Figure 5. Cryo-TEMPO Inland Water waveform classes derived from a Neural Network classifier over the Woods Lake, North America.

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Project website: http://cryosat.mssl.ucl.ac.uk/tempo
Data viewer: http://www.cpom.ucl.ac.uk/cryotempo