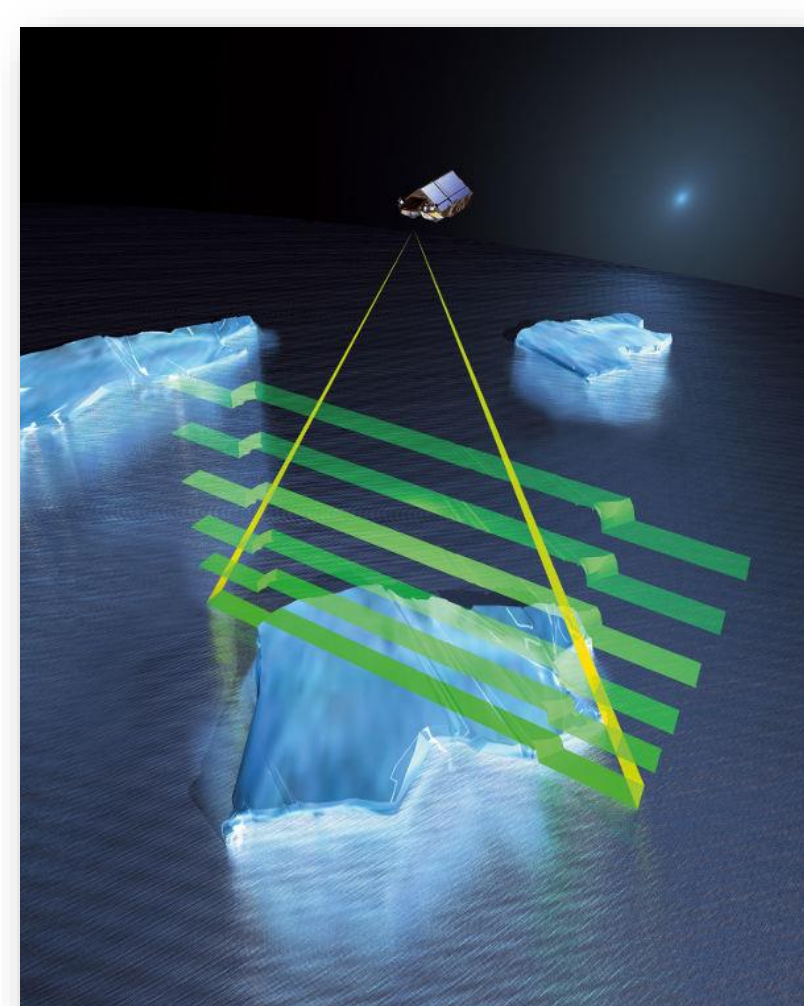


E. Webb⁽¹⁾, B. Wright⁽¹⁾, M. Meloni⁽²⁾, J. Bouffard⁽³⁾, T. Parrinello⁽³⁾, S. Baker⁽⁴⁾, D. Brockley⁽⁴⁾, T. Geminale⁽⁵⁾, M. Scagliola⁽⁶⁾, M. Fornari⁽⁷⁾

⁽¹⁾ Telespazio VEGA UK Ltd (UK), e-mail: Erica.Webb@telespazio.com; ⁽²⁾ SERCO c/o ESA/ESRIN (Italy); ⁽³⁾ ESA/ESRIN (Italy); ⁽⁴⁾ Mullard Space Science Laboratories (MSSL) (UK); ⁽⁵⁾ Exprivia (Italy); ⁽⁶⁾ ARESYS (Italy); ⁽⁷⁾ RHEA c/o ESA/ESRIN (UK).

CryoSat Mission

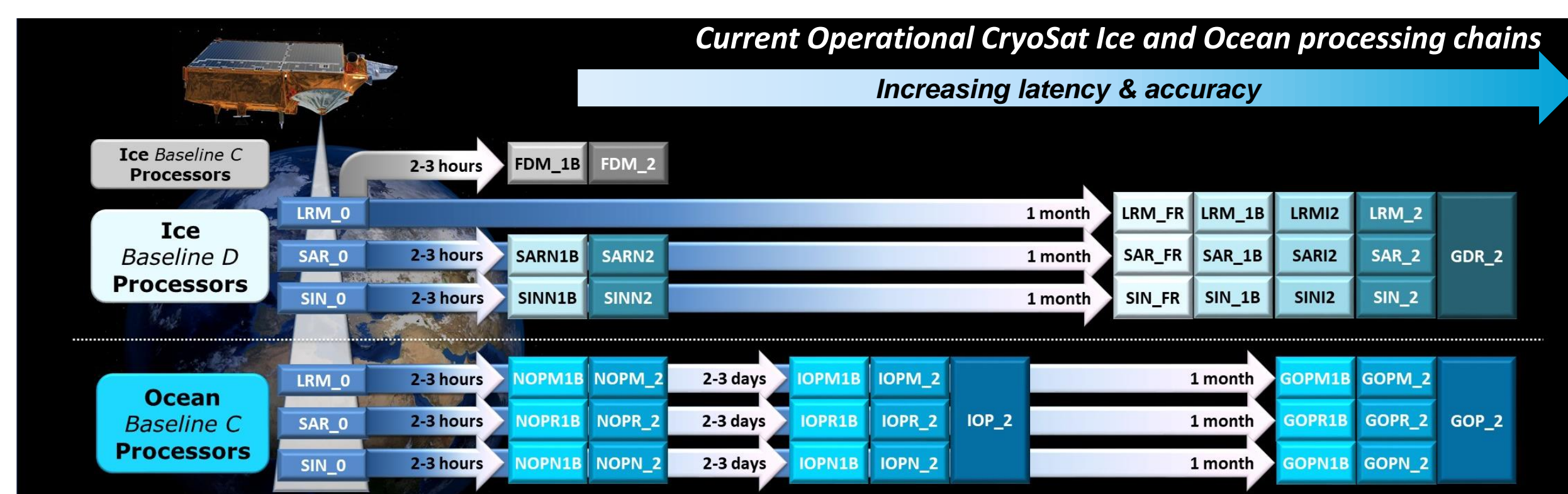
- Launched in April 2010, CryoSat is **ESA's dedicated ice mission**.
- It was specifically designed to measure changes in the thickness of polar sea ice and the elevation of the ice sheets and mountain glaciers.
- Going beyond its original mission objectives, CryoSat is now a valuable source of data for the oceanographic community.
- CryoSat's sophisticated **SAR Interferometric Radar Altimeter (SIRAL)** can measure high-resolution geophysical parameters from the open ocean to the coast.
- To enable their full scientific and operational exploitation, the CryoSat products are continuously evolving, through updates and improvements to the **Instrument Processing Facilities (IPFs)**.



CryoSat: 10 years in orbit! Mission extension now confirmed until 2021.

Data Processing

- SIRAL** operates in three modes: Low Resolution Mode (LRM), Synthetic Aperture Radar (SAR) mode and SAR Interferometric (SARIn) mode.
- CryoSat Level 0 (L0) data is processed operationally to science Level 1B (L1B) and Level 2 (L2) products using two independent processing chains: **Ice** and **Ocean**. Both processors generate a range of operational products with increasing latencies and accuracies.



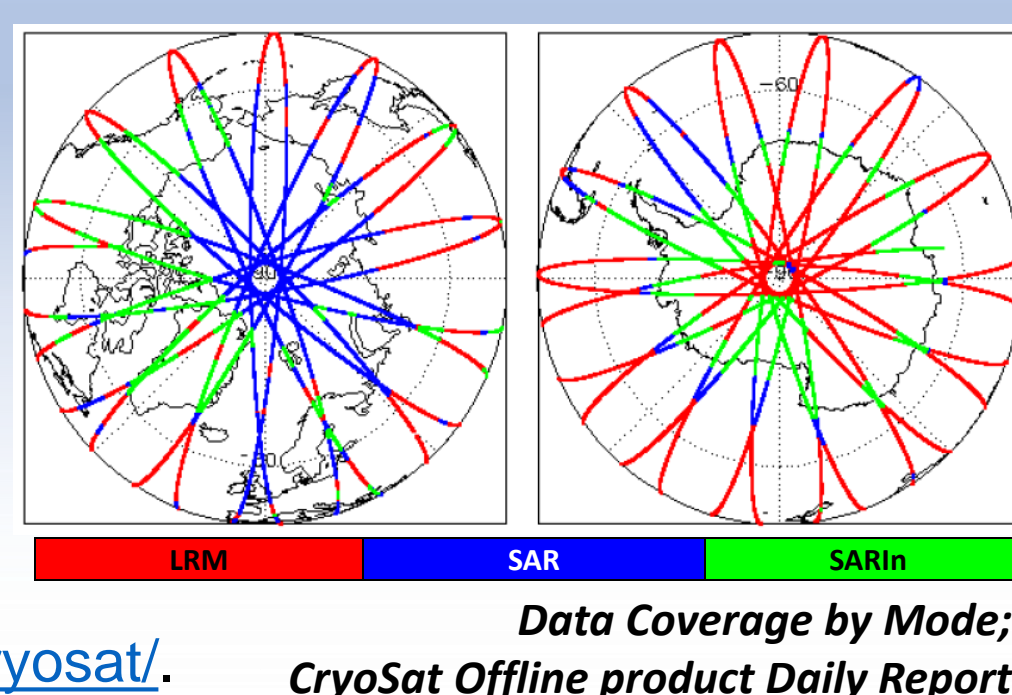
Operational Quality Control

- The Quality Assurance for Earth Observation (**QA4EO**) service (formerly IDEAS+) is a Telespazio VEGA UK lead consortium providing support to the ESA/ESRIN Sensor Performance and Algorithms (SPPA) office.
- Since launch, QA4EO has performed routine **Quality Control (QC)** on all operational and reprocessed CryoSat products.
- QA4EO also plays an important role throughout the **IPF evolution** and validation process, providing support to software development, test data set generation and verification.

Daily Product Quality Monitoring

- Production completeness & processing failures monitoring
- Product format, header and quality checks
- Auxiliary Data File (ADF) availability and usage
- Analysis of key measurement parameters

Daily QC reports are uploaded to the ESA CryoSat webpage
<https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/cryosat/>.

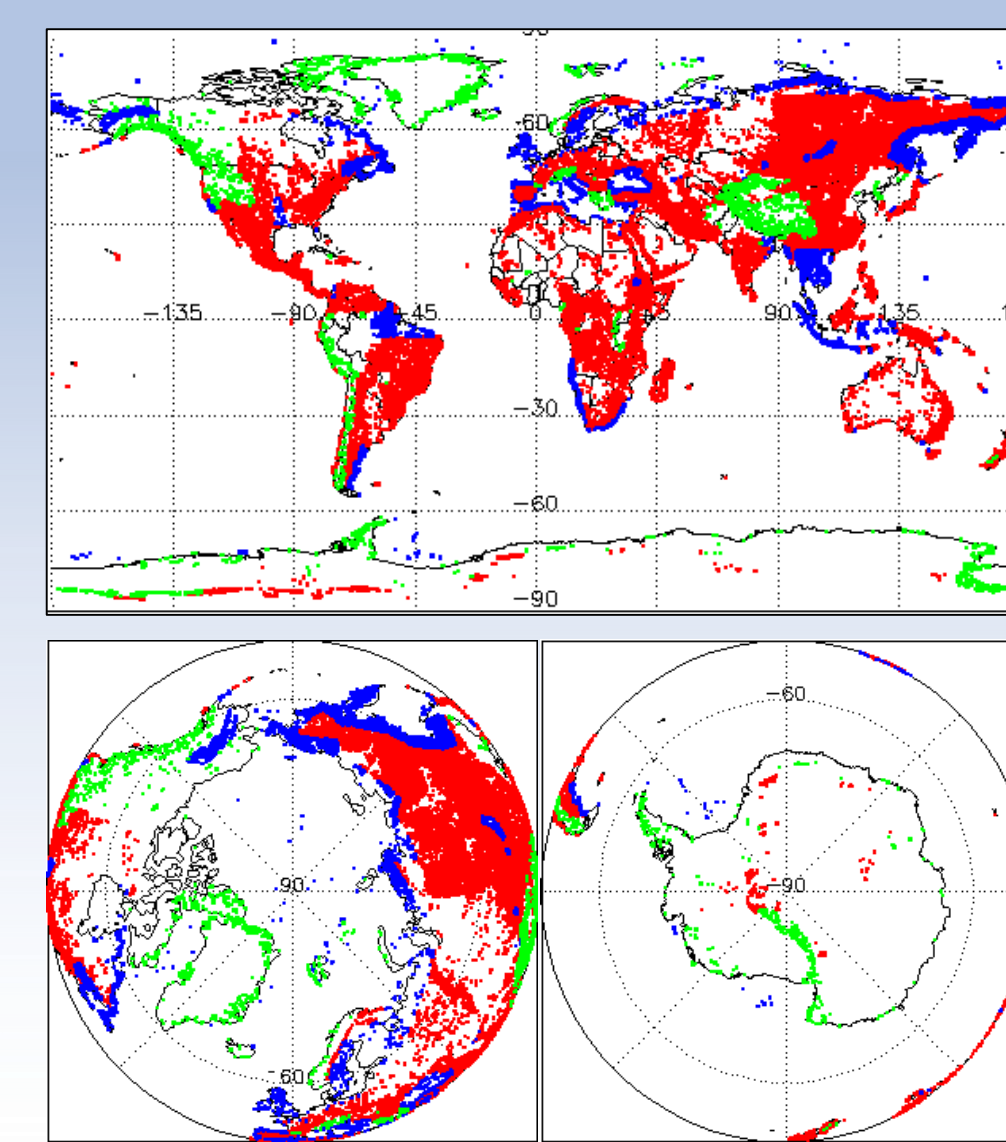


Long Term Product Quality Monitoring

QA4EO use C2QC, the Horus Tool, and MSSL Quality Assurance (QA) monitoring facility for long term analysis of:

- SIRAL instrument health and data availability
- Star tracker attitude parameters
- Key L2 parameters, such as freeboard and Sea Surface Height Anomaly
- Retracker failure statistics and L2 quality flags
- Crossover analysis
- Availability and magnitude of external corrections

Results are presented in Monthly Quality reports, and uploaded to the ESA CryoSat webpage:
<https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/cryosat/cyclic-reports>



Loss of Track in L0 data during February 2020

Current CryoSat Ice Processor: Baseline-D

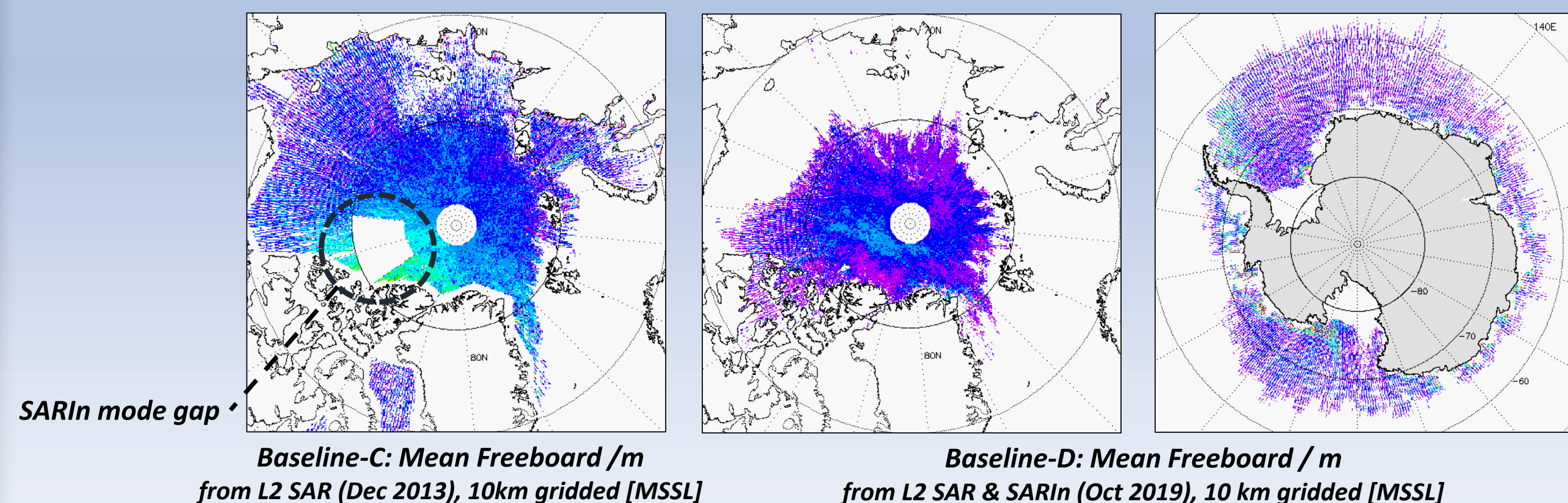
IPF1 vN1.1

IPF2 vN1.2

Since **May 2019** the CryoSat ice products are generated with **Baseline-D**. This major processor upgrade implemented several improvements to the L1B and L2 products, which are expected to have a positive impact on the scientific exploitation of CryoSat measurements over land ice and sea ice.

Key features of Baseline-D:

- Generation of NRT SAR & SARIn products in **near real time** (2-3 hours after acquisition) with the L0 Star Tracker products instead of delayed STR_ATTREF.
- L2 SARIn freeboard** computation activated to provide freeboard values over the Arctic Ocean and marginal polar regions.



- Laxon-Ridout sea ice retracker** improved for Arctic and Antarctic sea ice retracking
- Tuning of the **UCL land ice retracker**
- These changes are expected to bring a reduction in noise and number of bad-flagged data points compared with Baseline-C.

	LRM	SAR	SARIn
R1	CFI	UCL Sea Ice	UCL Margins
R2	UCL Land Ice		
R3	OCOg		

CryoSat Baseline-D Retracker

- New **stack peakiness** parameter added to L1B SAR & SARIn products (*stack_peakiness_20_ku*), useful for detecting leads and could aid sea ice discrimination and freeboard computation at L2.
- Product format change from Earth Explorer Format to Network Common Data Form (**netCDF**).

Current CryoSat Ocean Processors: Baseline-C

COP IPF1 v3.7

COP IPF2 v3.9

Since **November 2017** the CryoSat ocean products are generated with **Baseline-C**. This major processor upgrade implemented evolutions to improve the CryoSat ocean product quality and performance and to promote their application to oceanographic and climate studies.

Key features of Baseline-C:

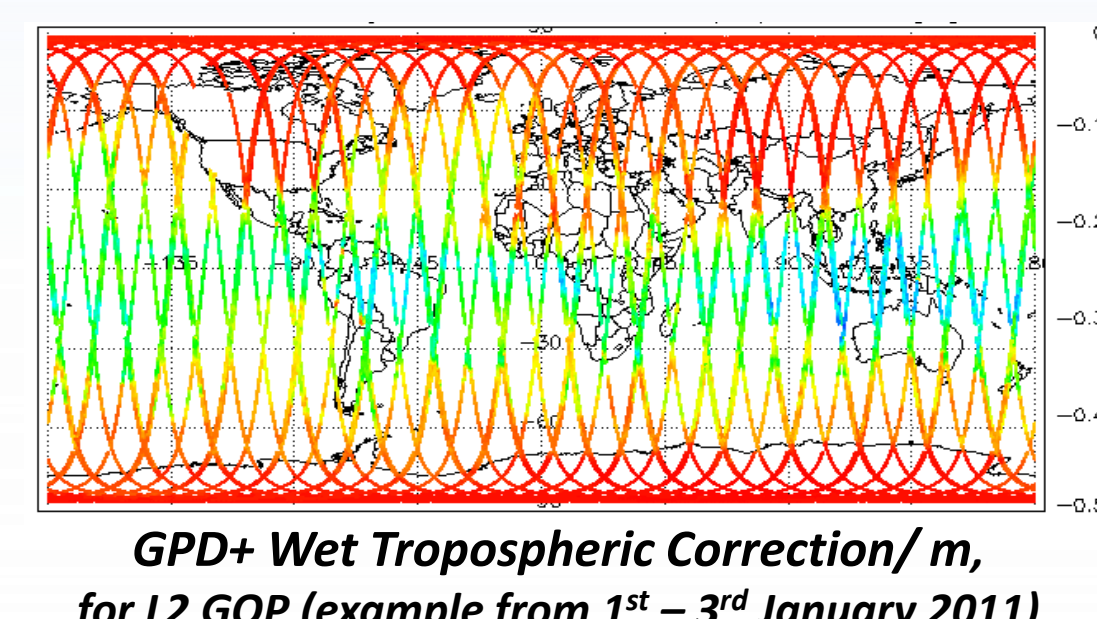
- Generation of ocean products for **all data acquisition modes** (LRM, SAR and SARIn), therefore providing complete data coverage for ocean users.
- Near Real Time Ocean Products (NOP)**, generated 2-3 hours after data sensing acquisition.
- Pole-to-Pole (P2P) products** for Intermediate Ocean Products (IOP) and Geophysical Ocean Products (GOP). These are concatenated multi-mode L2 products with half-orbit coverage.
- Pseudo-LRM (PLRM) estimates** included in SAR & SARIn ocean products which show good consistency with LRM measurements.
- Innovative new **SAR and SARIn retracking algorithm**: SAR Altimetry MOde Studies & Applications (SAMOSA).
- Existing LRM retracker refined.
- Improved models and corrections.**
- New **Wet Tropospheric Correction (WTC)** computed from the GNSS-derived Path Delay Plus (**GPDP**) algorithm, which combines all available observations to improve WTC for radar altimetry. Developed by University of Porto.

LRM	SAR	SARIn
Ocean MLE-4	SAMOSA	SAMOSA
Ice OCOg	DPM 2.3	DPM 2.3

Ocean Baseline-C Retracker

	New Baseline-C Models	
Mean Sea Surface	CNES-CLS15	DTU15
Ocean Loading Tide Height	GOT 4.10c	FES2014b
Non-Equilibrium Ocean Tide	FES2014b	
Mean Dynamic Topography	DTU15	
Ocean Depth/ Land Elevation	ACE-2	
	New Baseline-C Corrections	
Wet Tropospheric Correction	GPD+	
Sea State Bias Correction	Empirical solution from CryoSat Baseline-B LRM data	

New models and corrections at Baseline-C



GPDP+ Wet Tropospheric Correction/ m, for L2 GOP (example from 1st - 3rd January 2011)

CryoSat 3rd Ice Reprocessing Campaign

IPF1 vN1.1

IPF2 vN1.1

- The 3rd CryoSat Ice Reprocessing campaign is underway at the **Climate, Environment & Monitoring from Space (CEMS)** facility to reprocess all CryoSat Ice products to Baseline-D.
- Reprocessing campaign coverage: **16th July 2010 – 28th April 2019**
- QA4EO supported the reprocessing team during integration and testing of the IPFs, data consolidation, verification of test data and investigation of processing anomalies.
- QA4EO are now performing systematic QC of a 3-day data sample from each month generated, investigating any product anomalies and monitoring processing failures.
- Reprocessing is in the final stage and due to be completed by mid-May 2020.

2010	2011	2012	2013	2014	2015	2016	2017	2018	2019

Processing in progress
Data processing & QC complete
Data processing & QC complete;
Data available to users

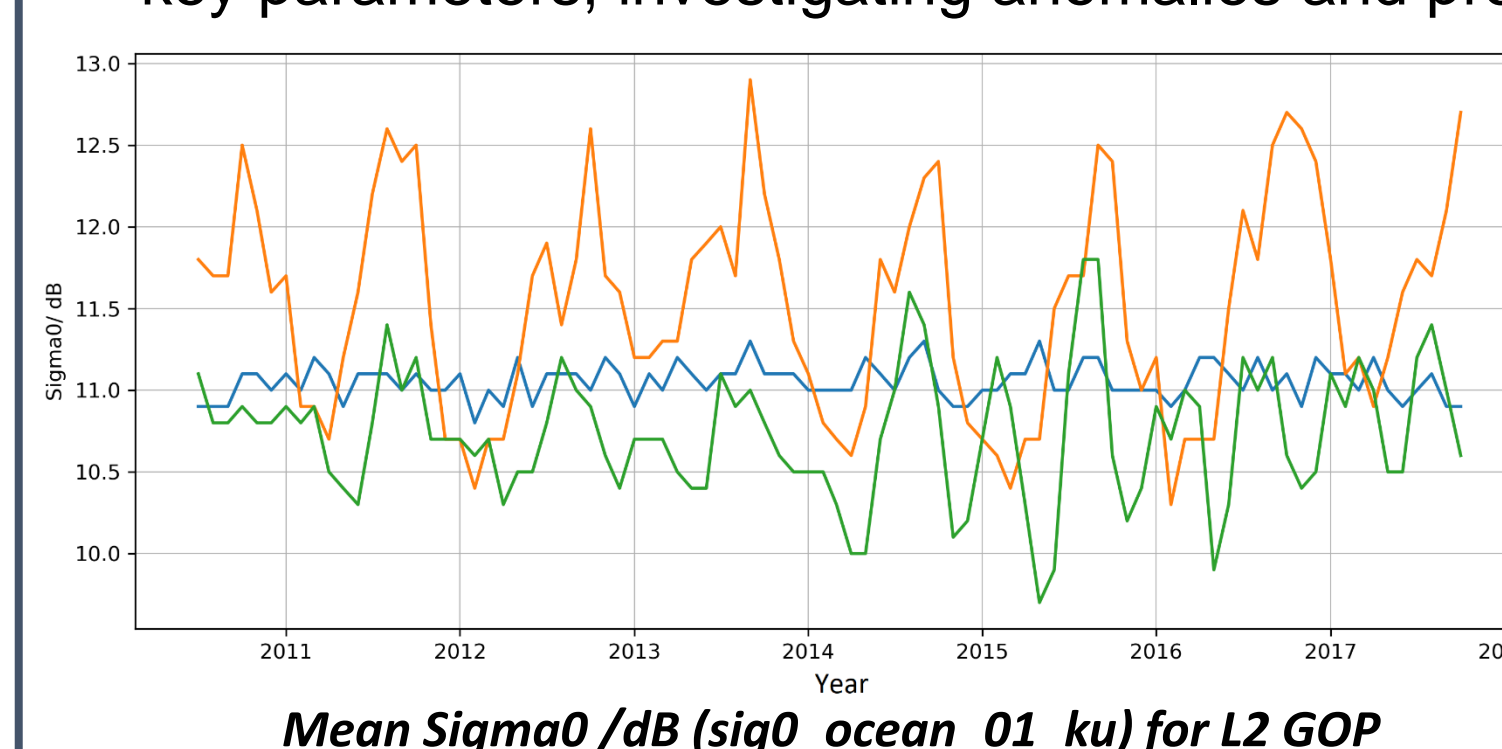
Data Access: Registered users can access the reprocessed Ice and Ocean products from the CryoSat Science Server (science-pds.cryosat.esa.int). Data is uploaded after reprocessing of each 6-month batch is complete.

CryoSat 2nd Ocean Reprocessing Campaign

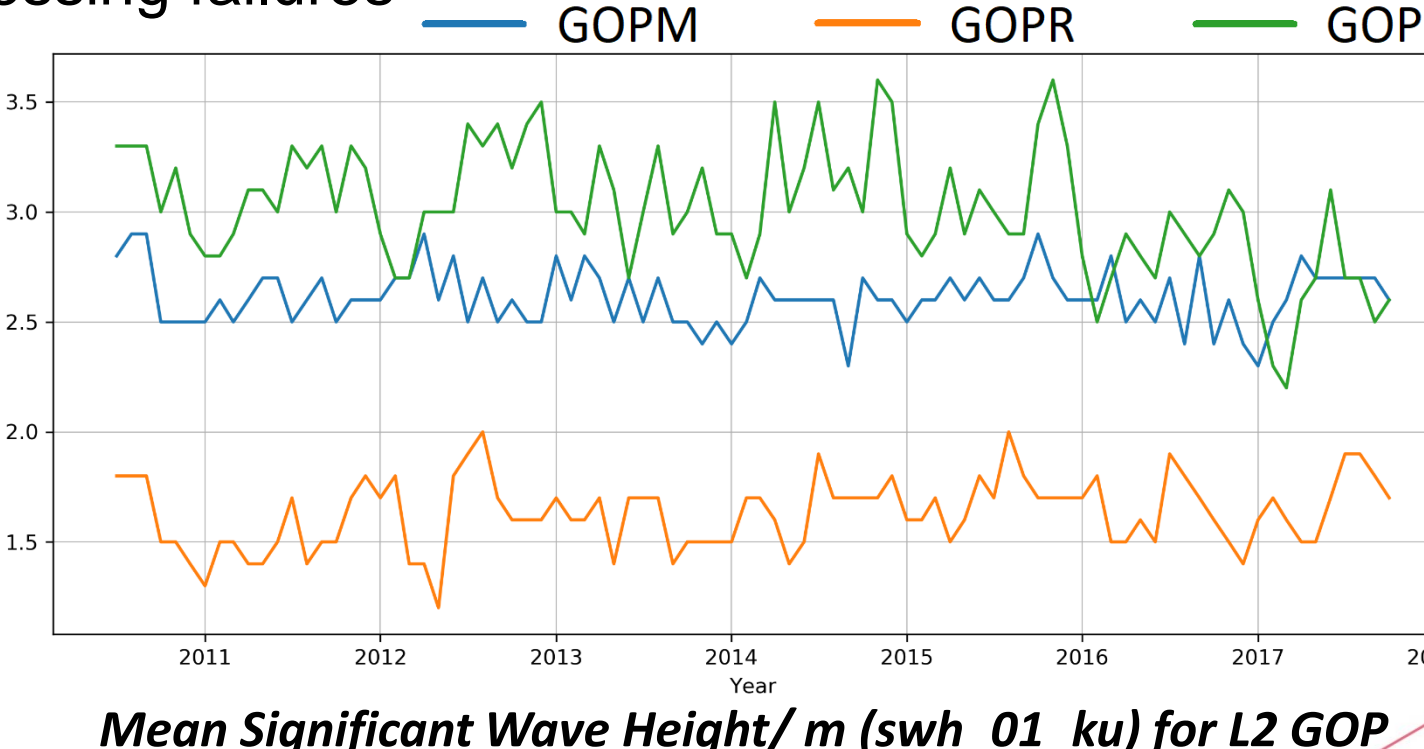
COP IPF1 v3.7

COP IPF2 v3.9

- The 2nd CryoSat Ocean Reprocessing campaign recently completed at the **Centre National d'Etudes Spatiales (CNES)** to reprocess all GOP data to Baseline-C.
- All L1B, L2 and P2P GOP for the period **16th July 2010 – 7th October 2017** have now been reprocessed and disseminated to users.
- QA4EO performed systematic QC of a 3-day data sample from each month generated, monitoring key parameters, investigating anomalies and processing failures



Mean Sigma0/dB (sig0_ocean_01_ku) for L2 GOP



Mean Significant Wave Height/ m (sw_h_01_ku) for L2 GOP

Known Data Anomalies: Users can access a full list of the known anomalies and planned evolutions for the current Ice and Ocean processors here:
<https://earth.esa.int/web/guest/missions/cryosat/product-status>