# CryoSat Data: Quality Status and Roadmap for the Future

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# Outlines

Context and Generalities

Ocean Data Quality

Ice Data Quality

Next Evolutions

Conclusions

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# CryoSat Mission Objectives

- Address key environmental and **Climate** issues

SECONDARY OBJECTIVE

## Open Polar Coastal
*Ocean topography*

GLOBAL & REGIONAL MSL TREND / CLIMATE (IPCC)

METEO (WAVE,WIND)

MESOSCALE , CROSS-SHELF EXCHANGES & IMPACTS

PRIMARY MISSION OBJECTIVES

## Sea Ice
*Freeboard*

REGIONAL TRENDS & SEASONAL VARIATIONS

THERMOHALINE CIRCULATION ….

## Land Ice
*Ice Elevation*

ICE SHEET/CAPS/GLACIERS THICKNESS VARIATIONS

CONTRIBUTION TO GLOBAL & REGIONAL SEA-LEVEL …

SECONDARY OBJECTIVE

## River & Lake
*Water Height*

VARIATION OF INLAND WATER STORAGE

RIVER DISCHARGES AND IMPACT ON COASTAL ECOSYSTEM …

INTERCONNECTED

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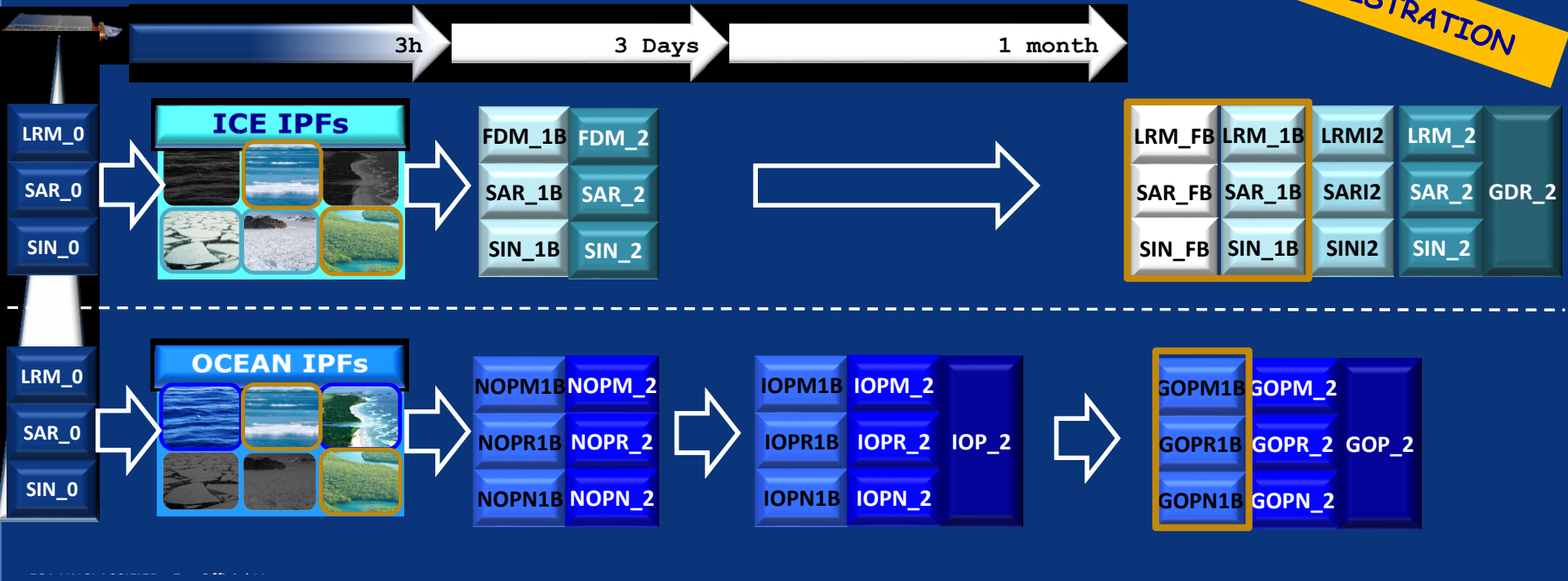
# ESA operational processors

- **2 independent** processors for ice and ocean surfaces

NO REGISTRATION




DATA PROCESSED OVER ALL SURFACES BY FEW EXPERTS OR *ON DEMAND* (GPOD)

# ESA Operational product evolutions

2010

2011

2011

L1 & FBR

2012

NRT MeteOcean

2013

L2i

2014

Ocean Processor

2015

Ice Baseline C

2017

Ocean Baseline C

2019

Ice Baseline D

2020

Thematic Products

2021

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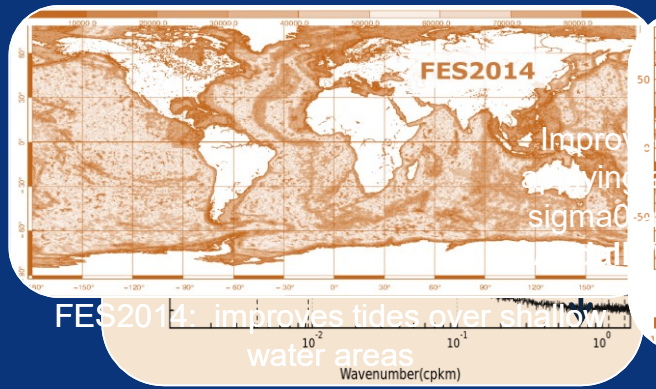
# COP Baseline C in few words

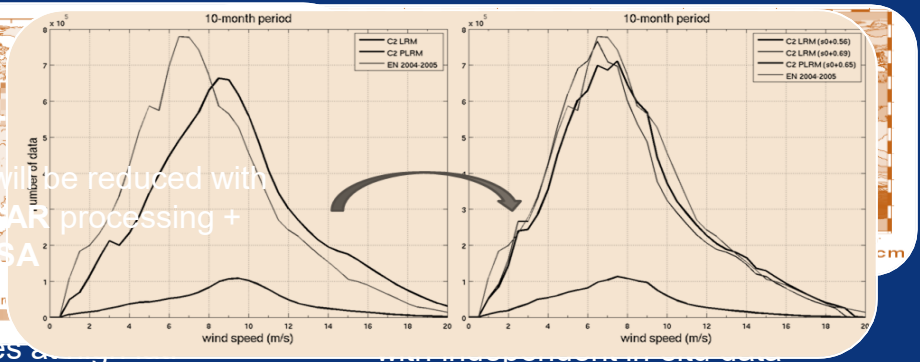
- **Major evolution** when compared to COP Baseline B

Ocean Baseline-C brings several improvements, including netCDF format, the addition of SAR processing and the upgrade of key geo.l corrections.

- NetCDF - V4 Format
- SAR/SARin processing
- 6 Updated Models
- New parameters
- Issues fixed




FES2014: improves tides over shallow water areas




Noise will be reduced with SAR processing + SAMOSA

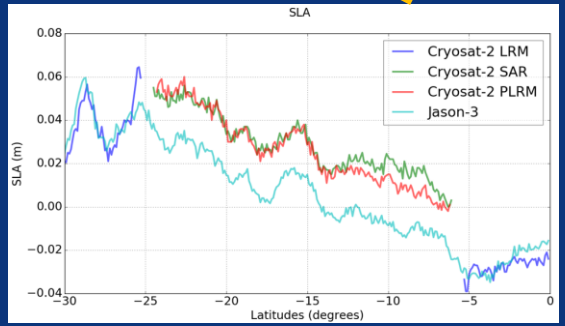
# COP Baseline C data quality status

- The COP data quality remains very **good** showing improved space-time resolutions and better characterization of mesoscale and coastal dynamics

**Mode-dependent biases** are however observed and are under investigation (SSH: ~1,5 cm LRM/SAR, SWH: of ~5 to 10 cm between ASC & DSC passes, Sigma0: ~0.1 dB)

**NOP** (from the COP) **are also performing well** and even surpass quality of FDM.

NOP **gaps** however observed and due to improper selection rule in the use of DOR_NAV. Issue to be fixed with the new EE CFI to be delivered to PDGS in June.

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# COP next steps

## Short and long term plan

Implementation of BUFR converter for NOP is on-going (ECMWF). Then, NOP will adequately replace the FDM which should be discontinued after Q3 2019 (TBC).

Baseline C COP reprocessing campaign (CNES) is on-going and should be finished on Q2 2020, no major issues (QC nominal up to 04-2013).

New Orbit Files (POE-F) will be used in operation. Possible – minor-bias with Reprocessed GOP (using POE-E) to be verified.

Mode-depend bias observed are under investigation and could be mitigated by using empirical correction (mid term) or by using SAMOSA DPM 2.5 (see results of CP4O project)

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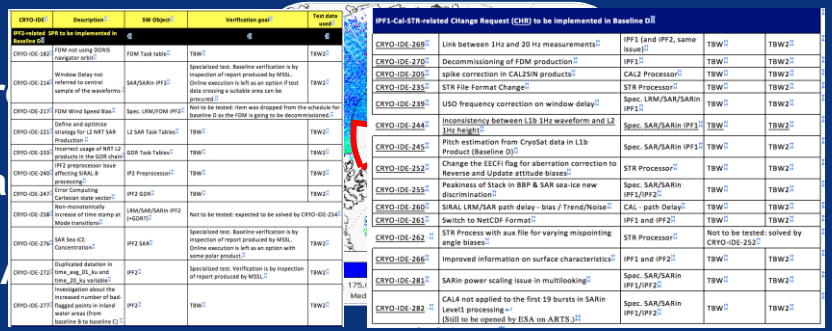
# Ice Baseline D in few words

- The ice Baseline-D includes a significant number of fixes and **science algorithm evolutions** with respect to the ice Baseline-C.

**NetCDF - V4 Format** | **Previous issues fixed** | **Updated slope model** | **Improved Freeboard** | **NRT L1/L2 products**

| CRYO-IDE | Description | SW Object | Verification goal | Test data used |
|---|---|---|---|---|
| **IPF1-Cal-STR-related SPR to be implemented in Baseline D** | | | | |
| CRYO-IDE-223 | Issue in L1b time increment | Spec. SAR/SARin IPF1 | TBW | TBW2 |
| CRYO-IDE-229 | Sporadic failure in the STR processor | STR Processor | TBW | TBW2 |
| CRYO-IDE-237 | Reprocessing Task 'IPF1_SRNP' finished with exit code 128 but expected 0 | Spec. SAR/SARin IPF1 | TBW | TBW2 |
| CRYO-IDE-241 | Discrepancy in L1B and L2 Filename Validity Times | IPF1 and IPF2 Post Processor | TBW | TBW2 |
| CRYO-IDE-242 | Datation outside processing window due to out of range Offset counter | L1b SAR/SARin Pre&Post | TBW | TBW2 |
| CRYO-IDE-243 | Memory issues in Specialized SAR/SARin IPF1 | Spec. SAR/SARin IPF1 | TBW | TBW2 |
| CRYO-IDE-248 | Error in writing function of CAL2 Flag in MCD | Spec. SAR/SARin IPF1 | TBW | TBW2 |
| CRYO-IDE-251 | Problematic SIR1SAR_FR files | IPF1 pre-processing | TBW | TBW2 |
| CRYO-IDE-253 | Unknown failure in Rep. Campaign | Spec. SAR/SARin IPF1 | TBW | TBW2 |
| CRYO-IDE-254 | Time anomaly in last SS in L1b product | Spec. SAR/SARin IPF1 | TBW | TBW2 |
| CRYO-IDE-271 | FBR LRM Product remove from Inventory List | IPF1 LRM Task Table | TBW | TBW2 |
| CRYO-IDE-272 | Duplicated datation in time_avg_01_ku and time_20_ku variable | Spec. SAR/SARin IPF1 | TBW | TBW2 |
| CRYO-IDE-273 | Missing xref global attributes | IPF1 post-processing | TBW | TBW2 |
| CRYO-IDE-274 | Unexpected Values for AGC ch 1 | LRM IPF1 | TBW | TBW2 |
| CRYO-IDE-275 | Interburst alignment | Spec. SAR/SARin IPF1 | TBW | TBW2 |



| CRYO-IDE | Description | SW Object | Verification goal | Test data used |
|---|---|---|---|---|
| **IPF2-related SPR to be implemented in Baseline D** | | | | |
| CRYO-IDE-182 | FDM not using DORIS navigator orbit | FDM Task table | TBW | TBW2 |
| CRYO-IDE-214 | Window Delay not referred to central sample of the waveforms | SAR/SARin IPF2 | Specialized test. Baseline verification is by inspection of report produced by MSSL. Online execution is left as an option if test data crossing a suitable area can be procured. | TBW2 |
| CRYO-IDE-217 | FDM Wind Speed Bias | Spec. LRM/FDM IPF2 | Not to be tested: item was dropped from the schedule for baseline D as the FDM is going to be decommissioned. | |
| CRYO-IDE-221 | Define and optimise strategy for L2 NRT SAR Production | L2 SAR Task Tables | TBW | TBW2 |
| CRYO-IDE-233 | Incorrect usage of NRT L2 products in the GDR chains | GDR Task Tables | TBW | TBW2 |
| CRYO-IDE-240 | IPF2 preprocessor issue affecting SIRAL-B processing | IP2 Preprocessor | TBW | TBW2 |
| CRYO-IDE-247 | Error Computing Cartesian state vector | IPF2 GDR | TBW | TBW2 |
| CRYO-IDE-258 | Non-monotonically increase of time stamp at Mode transitions | LRM/SAR/SARin IPF2 (+GDR?) | Not to be tested: expected to be solved by CRYO-IDE-254 | |
| CRYO-IDE-276 | SAR Sea ICE Concentration | IPF2 SAR | Specialized test. Baseline verification is by inspection of report produced by MSSL. Online execution is left as an option with some polar product | TBW2 |
| CRYO-IDE-272 | Duplicated datation in time_avg_01_ku and time_20_ku variable | IPF2 | Specialized test. Verification is by inspection of report produced by MSSL | TBW2 |
| CRYO-IDE-277 | Investigation about the increased number of bad-flagged points in inland water areas (from baseline B to baseline C) | IPF2 | TBW | TBW2 |

| **IPF1-Cal-STR-related CHange Request (CHR) to be implemented in Baseline D** | | | | |
|---|---|---|---|---|
| CRYO-IDE-269 | Link between 1Hz and 20 Hz measurements | IPF1 (and IPF2, same issue) | TBW | TBW2 |
| CRYO-IDE-270 | Decommissioning of FDM production | IPF1 | TBW | TBW2 |
| CRYO-IDE-201 | spike correction in CAL2SIN products | CAL2 Processor | TBW | TBW2 |
| CRYO-IDE-235 | STR File Format Change | STR Processor | TBW | TBW2 |
| CRYO-IDE-239 | USO frequency correction on window delay | Spec. LRM/SAR/SARin IPF1 | TBW | TBW2 |
| CRYO-IDE-244 | Inconsistency between L1b 1Hz waveform and L2 1Hz height | Spec. SAR/SARin IPF1 | TBW | TBW2 |
| CRYO-IDE-245 | Pitch estimation from CryoSat data in L1b Product (Baseline D) | Spec. SAR/SARin IPF1 | TBW | TBW2 |
| CRYO-IDE-252 | Change the EECFI flag for aberration correction to Reverse and Update attitude biases | STR Processor | TBW | TBW2 |
| CRYO-IDE-255 | Peakiness of Stack in BBP & SAR sea-ice new discrimination | Spec. SAR/SARin IPF1/IPF2 | TBW | TBW2 |
| CRYO-IDE-260 | SIRAL LRM/SAR path delay - bias / Trend/Noise | CAL - path Delay | TBW | TBW2 |
| CRYO-IDE-261 | Switch to NetCDF Format | IPF1 and IPF2 | TBW | TBW2 |
| CRYO-IDE-262 | STR Process with aux file for varying mispointing angle biases | STR Processor | Not to be tested: solved by CRYO-IDE-252 | |
| CRYO-IDE-266 | Improved information on surface characteristics | IPF1 and IPF2 | TBW | TBW2 |
| CRYO-IDE-281 | SARin power scaling issue in multilooking | Spec. SAR/SARin IPF1/IPF2 | TBW | TBW2 |
| CRYO-IDE-282 | CAL4 not applied to the first 19 bursts in SARin Level1 processing (Still to be opened by ESA on ARTS.) | Spec. SAR/SARin IPF1/IPF2 | TBW | TBW2 |

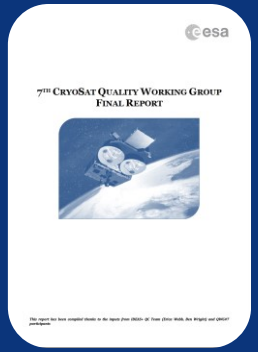
| **IPF2-related CHange Request (CHR) to be implemented in Baseline D** | | | |
|---|---|---|---|
| CRYO-IDE-269 | Link between 1Hz and 20 Hz measurements | IPF2 (and IPF1, same issue) | TBW2 |
| CRYO-IDE-278 | New Snow Depth correction dedicated to sea-ice areas and land ice areas | LRM/SAR/SARin IPF2 | Not to be tested: this was investigated by MSSL during the development process, and no method was available for implementation. It isn't expected as part of this delivery. |
| CRYO-IDE-219 | Freeboard computation in SARin sea-ice area | Spec. SAR/SARin IPF2 | Specialized test. Baseline verification is by inspection of report produced by MSSL. Online execution is left as an option if SARin data crossing the Wingham box in the arctic can be procured. |
| CRYO-IDE-232 | New improved Slope Correction/DEM for LRM (i.e Bamber, Helm, SPIRIT ? other ?) | LRM /SARin IPF2 | Specialized test. Verification is by inspection of report produced by MSSL. |
| CRYO-IDE-239 | USO frequency correction on window delay | Spec. LRM/SAR/SARin IPF1 | Specialized test. To be tested in an E2E. Verification goal TBW. |
| CRYO-IDE-261 | Swich to NetCDF Format | IPF1 and IPF2 | TBW |
| CRYO-IDE-264 | Tune/Improve of the existing Baseline C retracker over sea-ice (Arctic + Antarctic) and Land Ice | Spec. LRM/SAR/SARin IPF2 | Specialized test. Verification is by inspection of report produced by MSSL. (No improvements were found for the land-ice retracker, so nothing has changed (but the slope model will improve land results) |
| CRYO-IDE-255 | Peakiness of Stack in BBP & SAR sea-ice new discrimination | Spec. SAR/SARin IPF1/IPF2 | Specialized test. Verification is by inspection of report produced by MSSL. |
| CRYO-IDE-256 | Uncorrected range and altitude to be included in L2/L2/GDR | IPF2 | Specialized test. To be tested in an E2E. Verification goal TBW. |
| CRYO-IDE-266 | Improved information on surface characteristics | IPF1 and IPF2 | TBW |

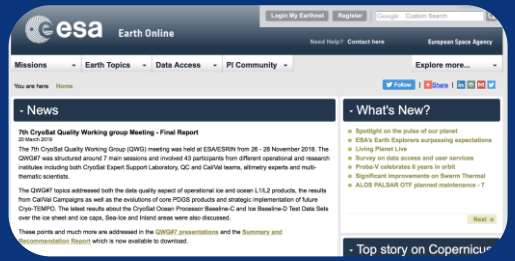
Area previously operating in SARIn with **no freeboard**

**6 MONTH TDS GENERATED AND MADE AVAILABLE TO EXPERTS FOR IN-DEPTH QCV**

# Ice Baseline D data quality

- Results presented at **CryoSat QWG#7 Meeting** and summarize in Final Report. (see next **Marco Talk + Future Paper**)




SARIn elevations show slight improvement (**roll angle issue fixed**), whilst LRM is similar. The new **surface type mask** and **slope model** around Antarctica also shows better results.

**SARIn freeboard** now computed and SAR freeboard computation **refined** (less noisy & no more overestimated).

Baseline-D shows welcome improvements with a **large increase of valid observations** and large **biases removed**

**QWG ENDORSED THE IMPLEMENTATION OF BASELINE-D INTO OPERATIONS**

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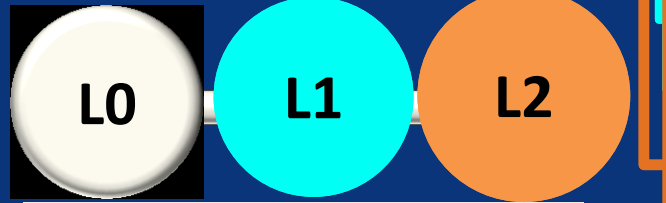
# CryoSat Thematic Products – Why ?

- **L1 & L2 Products <u>can not</u> fulfill <u>all</u> needs of thematic end-users**




- ✓ **SCIENTIFIC & OPERATIONAL END-USERS** NEED FEW KEY GEO PARAMETERS FOR THEIR APPLICATIONS (E.G. FREEBOARD, ADT)
- ✓ **QUALITY INDICATORS** AND/OR **UNCERTAINTY** CAN NOT BE DIRECTLY ASSOCIATED TO EACH L2 GEOPHYSICAL PARAMETERS
- ✓ EACH GEO PARAMETER WOULD REQUIRE SPECIALIZED PROCESSING ALGORITHMS + CAL/VAL **SPECIFIC TO EACH THEMATIC** AREA

**Altimetry Experts**

**Thematic End users**

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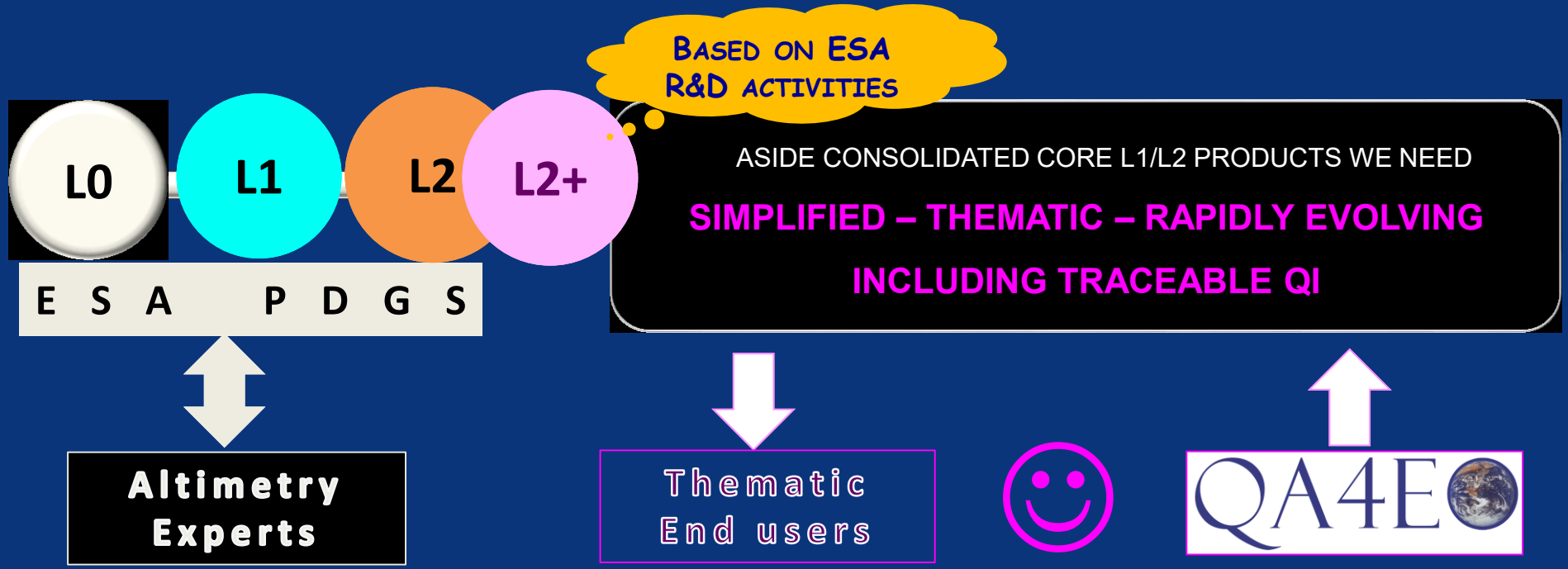


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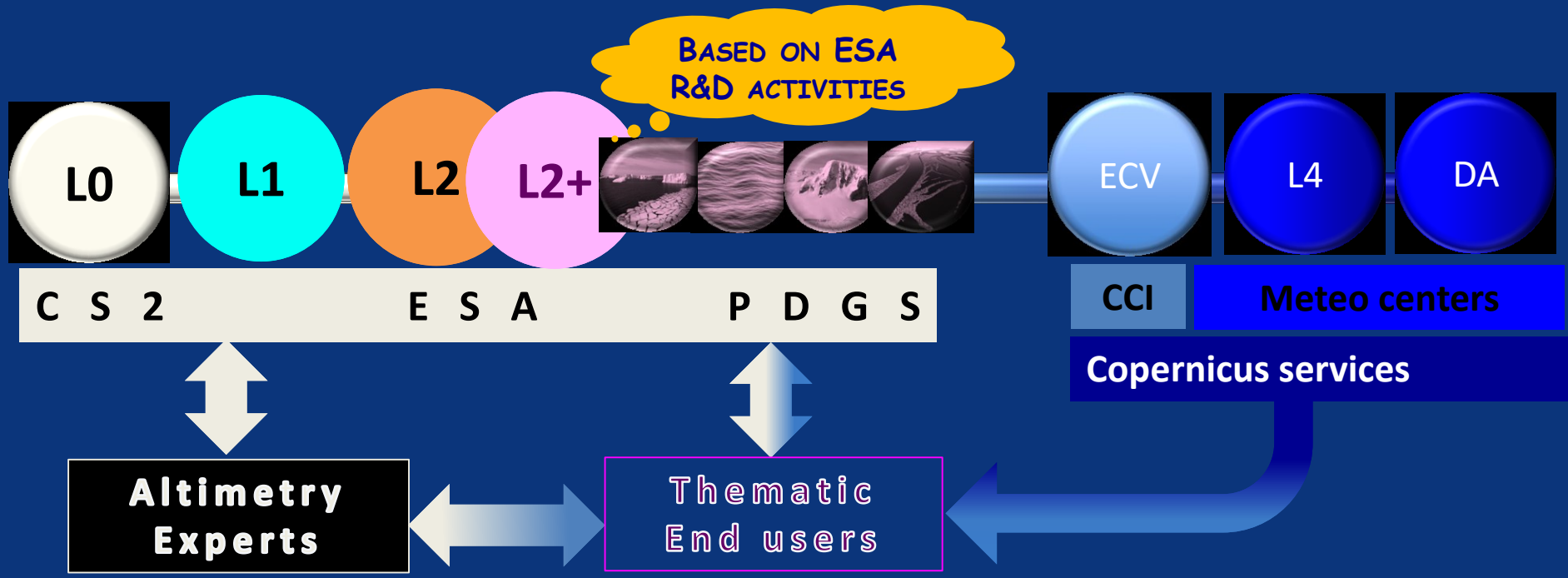
# CryoSat Thematic Products – How ?

- Coordinate groups of EO scientists to generate thematic CS Products

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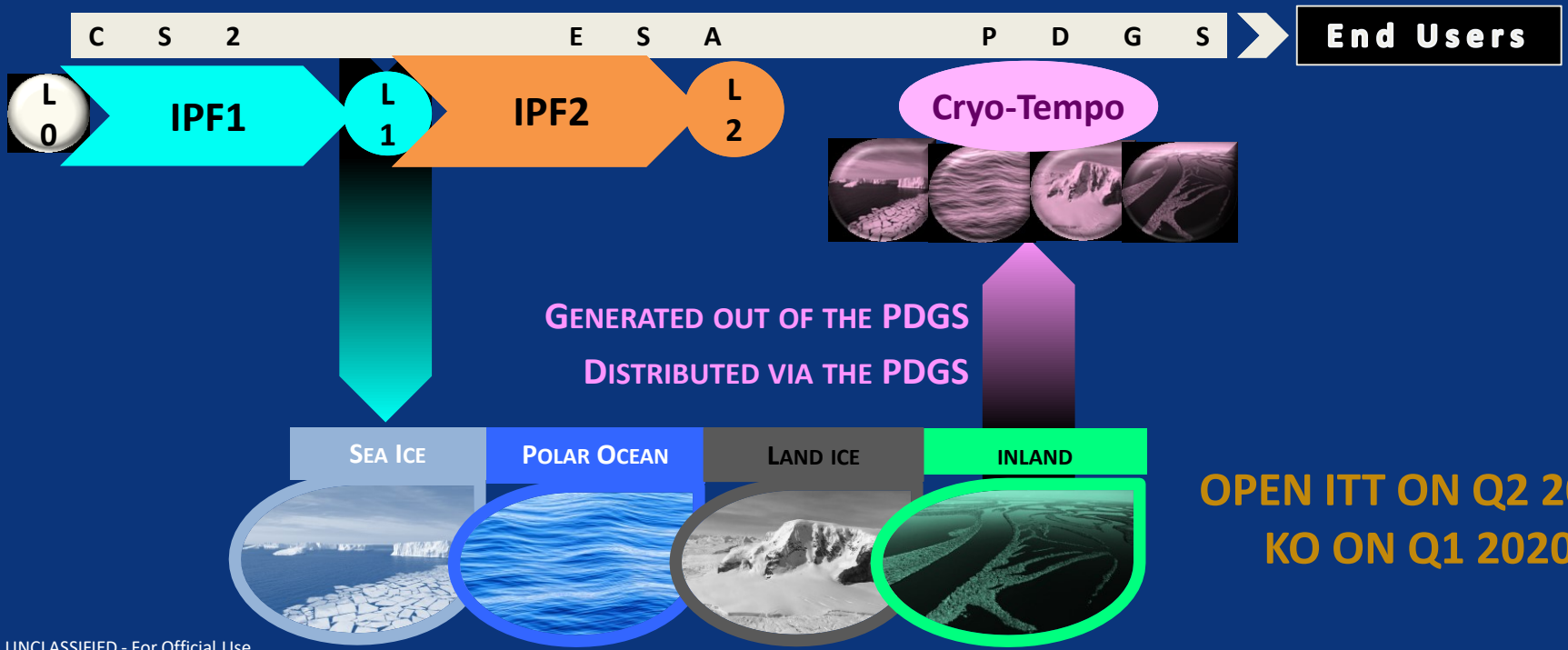
# CryoSat Thematic Products – How ?

## Implementations wrt the CryoSat PDGS environment




**OPEN ITT ON Q2 2019**
**KO ON Q1 2020**

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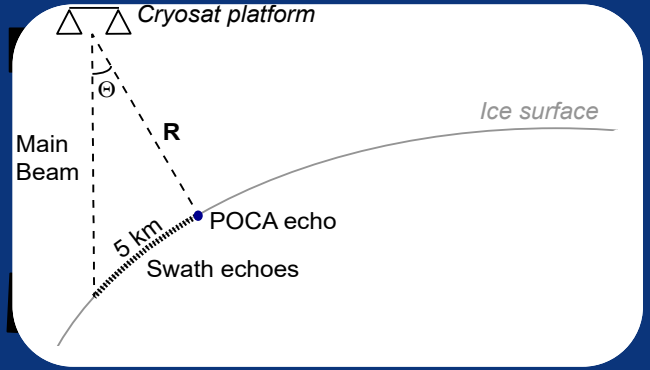
# First Cryo-TEMPO – Land Ice Swath

## <u>Operational</u> Swath products + reprocessing over glaciated areas

Based on the heritage of STSE Cryotop/ evolution ESA projects




First Greenland/Antarctica Product on Q1 2020 (+ evolution)

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# CryoSat data for Magnetic field !!!!

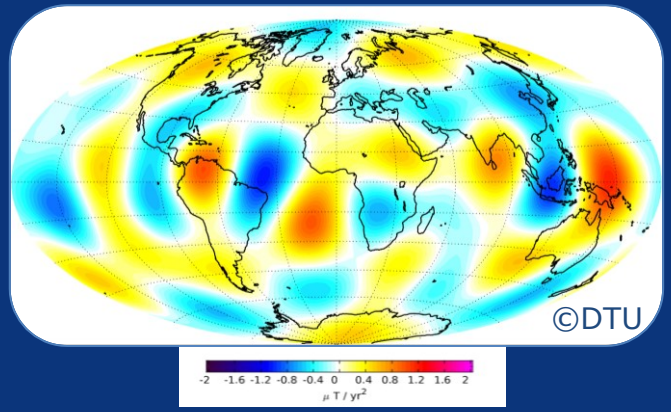
- Fluxgate magnetometers and Star Tracker Images are high scientific quality very interesting

  Core field studies by bridging the gap between CHAMP († Sept 2010) and Swarm (Nov 2013 -)

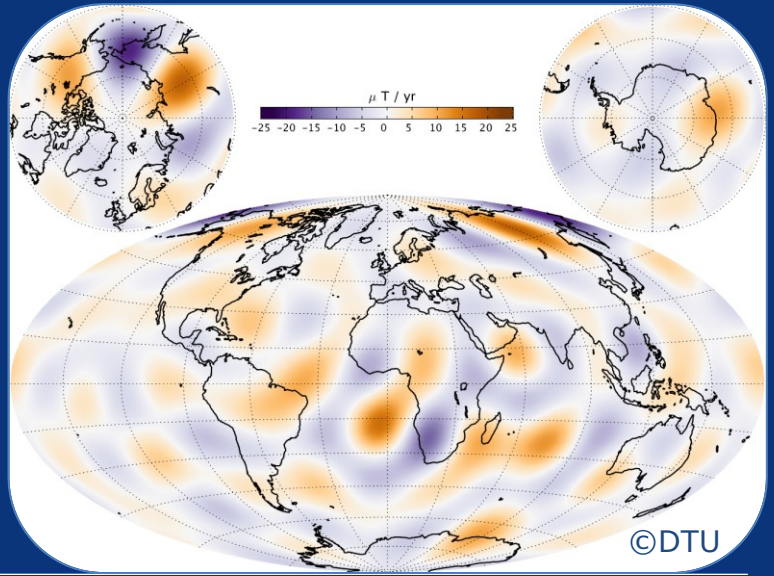
  FAC & Ionospheric Ring-Currents monitoring

"I MUST CONFESS THAT I WAS NOT VERY CONVINCED AT THE BEGINNING BUT GOT REALLY EXCITED WHEN I SAW THE FIRST DATA - THESE ARE THE BEST MAGNETIC DATA FROM A NON-MAGNETIC SATELLITE THAT I EVER SAW !" PROF. NILS OLSEN (DTU), SWARM MISSION PI

*Cryosat-Based secular* ***acceleration*** *at the* ***Core Mantle Boundary***




*CryoSat –based secular* ***variation*** *at the* ***Core Mantle Boundary***




## L1B CRYOSAT MAGNET TDS (2010-2014)

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# In a nutshell

- The quality of CryoSat ice and ocean data is **excellent** and allows to fully achieve the mission objectives and much more …
- Ice **Baseline D TTO** is scheduled on 27/05/19**,** will include significant improvements (fmt + algo) and **NRT capability** for SAR & SARin
- Next step: Develop **Simplified** and **Rapidly** evolving **CryoTEMPO** which will including **quality index** and target **larger science community**

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Thank you for your attention