

Sentinel-3 Mission Overview – MARINE

Bruno Lucas and Altimetry team @ EUM
EUMETSAT

OSTST
San Juan, Puerto Rico, 7-11 November 2023



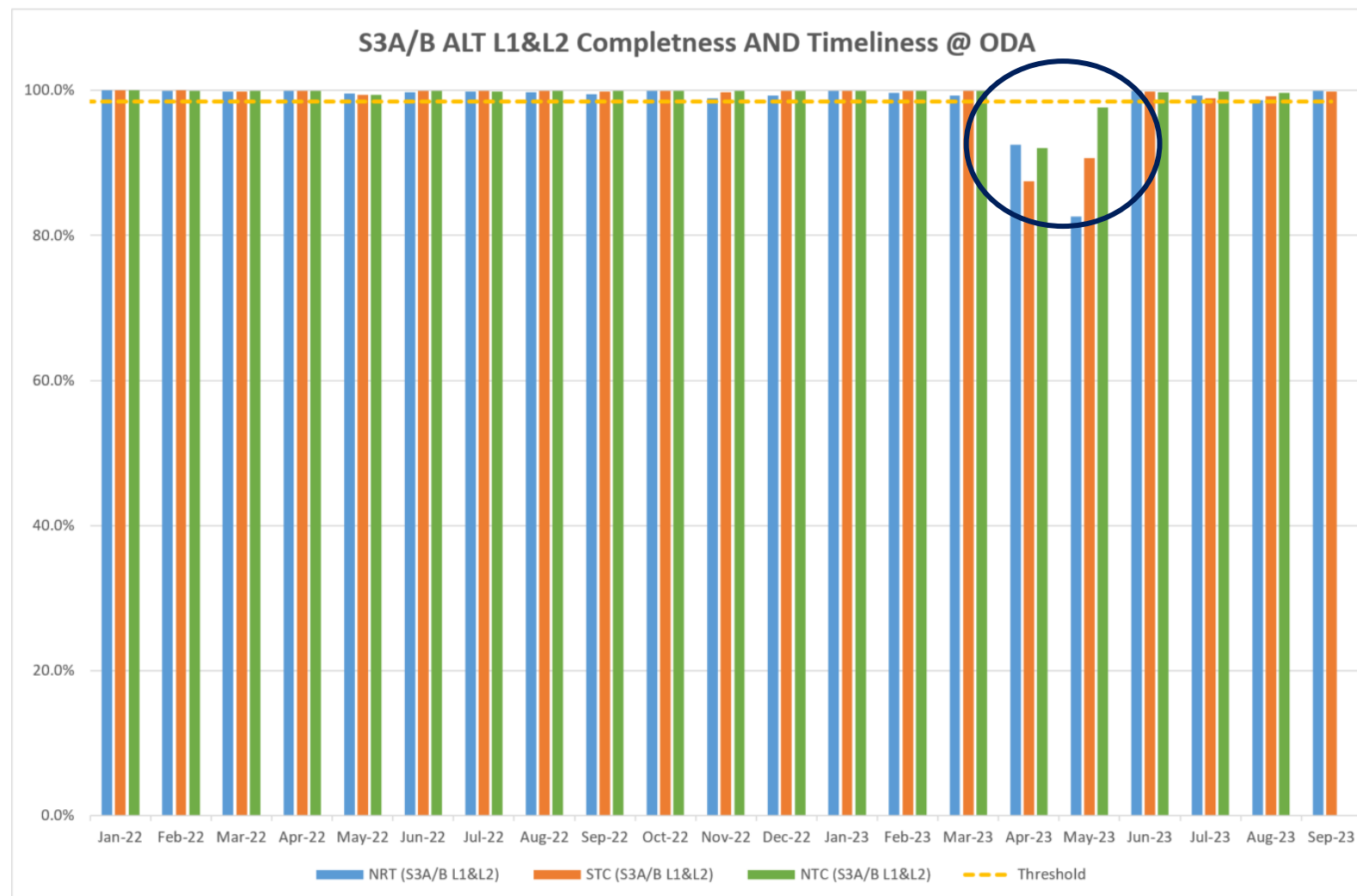


- Regular operations are performed:
 - SRAL Transponders
 - Crete (S3A/B), Gavdos (S3A)
 - Catalina (S3A)
 - Leonessa (S3A/B)
 - *isardSAT Corner Reflector (S3B)*
 - KREMS safe
 - 100 KMs around KREMS military radar for MWR
 - OLTC Updates (impacting in-land waters mostly)
 - S3A: 25/09/2023
 - S3B: 23/08/2023
 - New ZDB (acquisition mask)
 - SRAL Annual Calibrations
 - Continue to show stability of the instrument
 - Routine manoeuvres to keep the ground track

Altimetry payloads well performing

- Lunar Calibrations (in 2023, each month one Sat S3A/B, announced to the user via UNS
 - For altimetry outage of about 30 min (current) to 1:30 hours (older processing)

- Timeliness and completeness of the altimetry products are generally above requirements
 - Major issue in the ground segment late April/May
- Dataset meets quality requirements



- DAC correction is based on TUGO since late August 2023
- CPOD updates in 2023 impacting mostly NRT orbits (ROE)
- New ground segment to go live soon... late 2023
- **Dismissal of ODA for S3VT**
 - All data is already available in EUMETSAT Data Store
 - <https://data.eumetsat.int/>
 - Technical details (API, Command line, etc.):
 - <https://eumetsatspace.atlassian.net/wiki/spaces/DSDS/overview>

- User Notification Service
 - <https://uns.eumetsat.int/>
 - Receive information on outages and evolutions
- Knowledge Base
 - Altimetry (S3+S6)
 - Replaces Product Handbook
 - Contains Cyclic/Quarterly/Annual Reports
 - [Sentinel-3 cyclic reports - Product Quality and Evolutions – Confluence](#)
 - Produced operationally under COPAS contract
- A new user portal is coming soon...



- A **consistent** Sentinel-3A and -3B marine dataset is available to the users, processed with the Baseline collection BC 005.02:



- <https://www.eumetsat.int/release-sentinel-3-altimetry-marine-bc005-reprocessed-dataset>
- A **stable** Sentinel-3A and -3B marine dataset with improved ssha/wind/wave **long-term stability**, and **more information** to the users at product level.

More details in Nencioli et al.

Validation of the latest S3A/B surface topography baseline collection BC_005 over ocean

- Sea Ice concentration from OSI-SAF
- Wave information
 - Forecast and Analysis global ocean sea surface waves based on Météo-France WAVE Model (“MFWAM”)
 - Swell and SWH height, direction & period added to the products
 - *Note: Wave induced Vertical velocity effects correction not yet be available*
- **Minor evolution:** operational 20/11/2023
 - no reprocessing



Improved Polar Ocean retrievals, Sea Level in to the Sea Ice leads, consistent with “open” ocean:

- Zero Padding, Hamming/Other Window, Samosa +, waveform classification
- Standards aligned to GDR-G
- Improve Sea Level for Climate quality (even more)
 - Fast time calibration, Range Walk CZT
- **Major evolution** end 2024/2025; full mission reprocessing



Improved Coastal Processing

- Numerical retracking
- Implementation of the outcome of dedicated scientific studies on coastal zone.
- **Major evolution 2026/27 (TBC); full mission reprocessing**



- Mission Performance Service:
 - Cyclic/Quarterly/Annual reports available to all users:
 - [Sentinel-3 altimetry cyclic reports - Product Quality and Evolutions - Confluence \(atlassian.net\)](#)
- Scientific studies supporting operational evolutions:
 - Polar Ocean evolutions
 - Range Walk CZT
 - Etc.

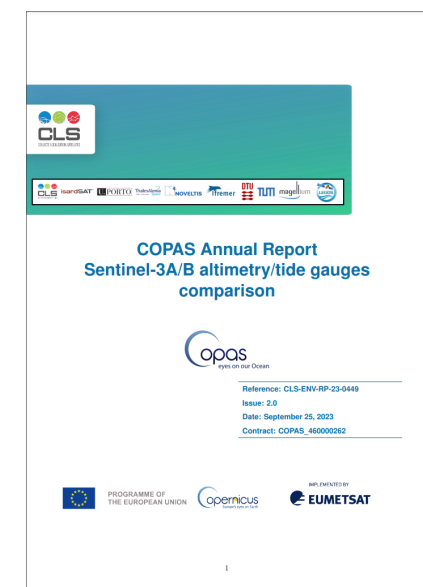
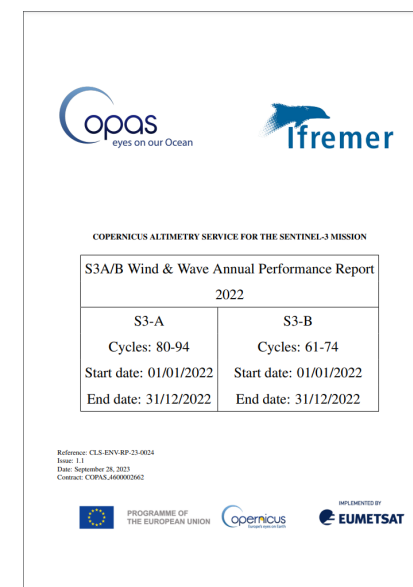
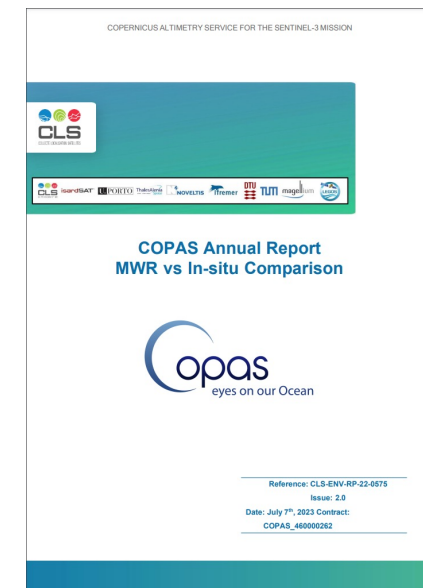
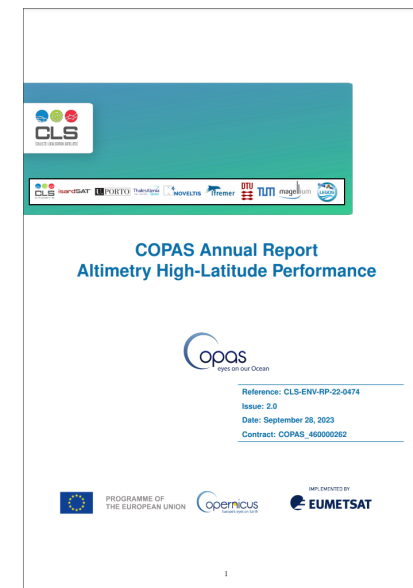




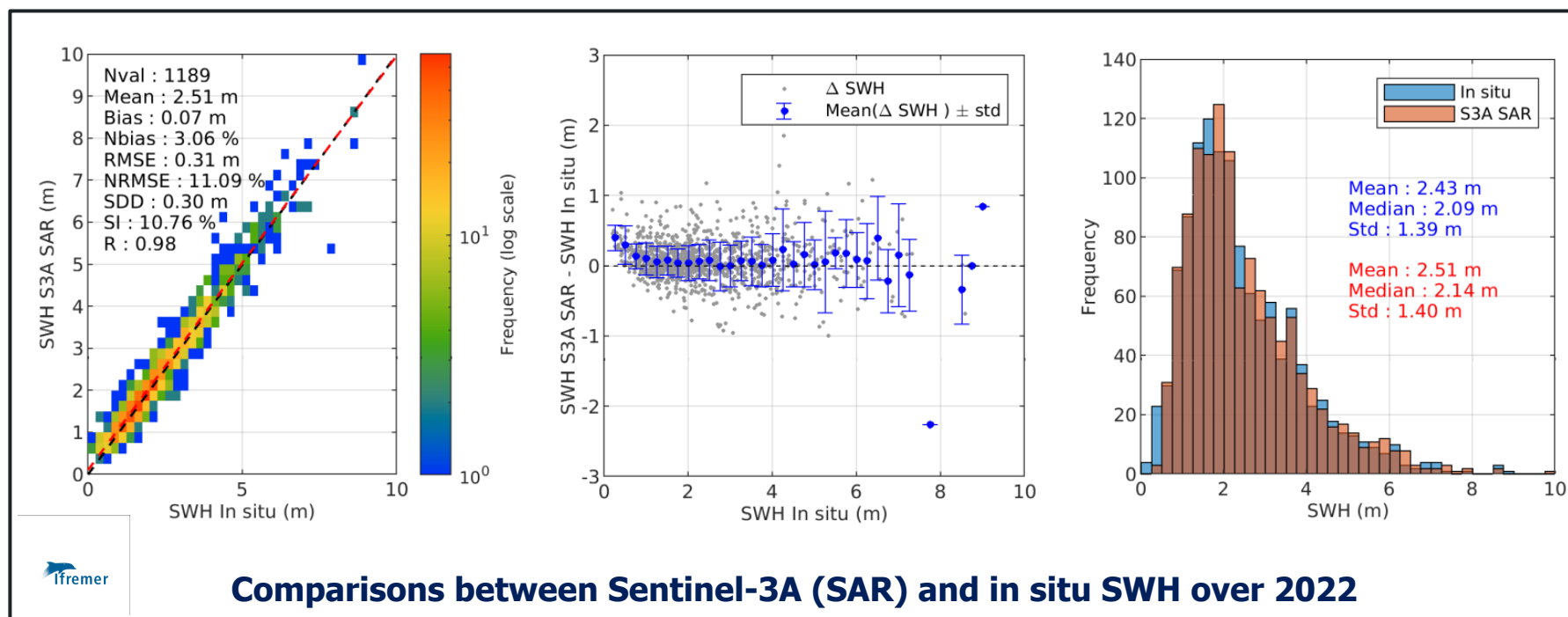
Four annual reports that provide quality assessment:

- S3 Altimetry comparison with tide gauges
- S3 Altimetry Wind & Waves performance
- S3 Altimetry high-latitude performance
- S3 MWR assessment and comparison with in-situ

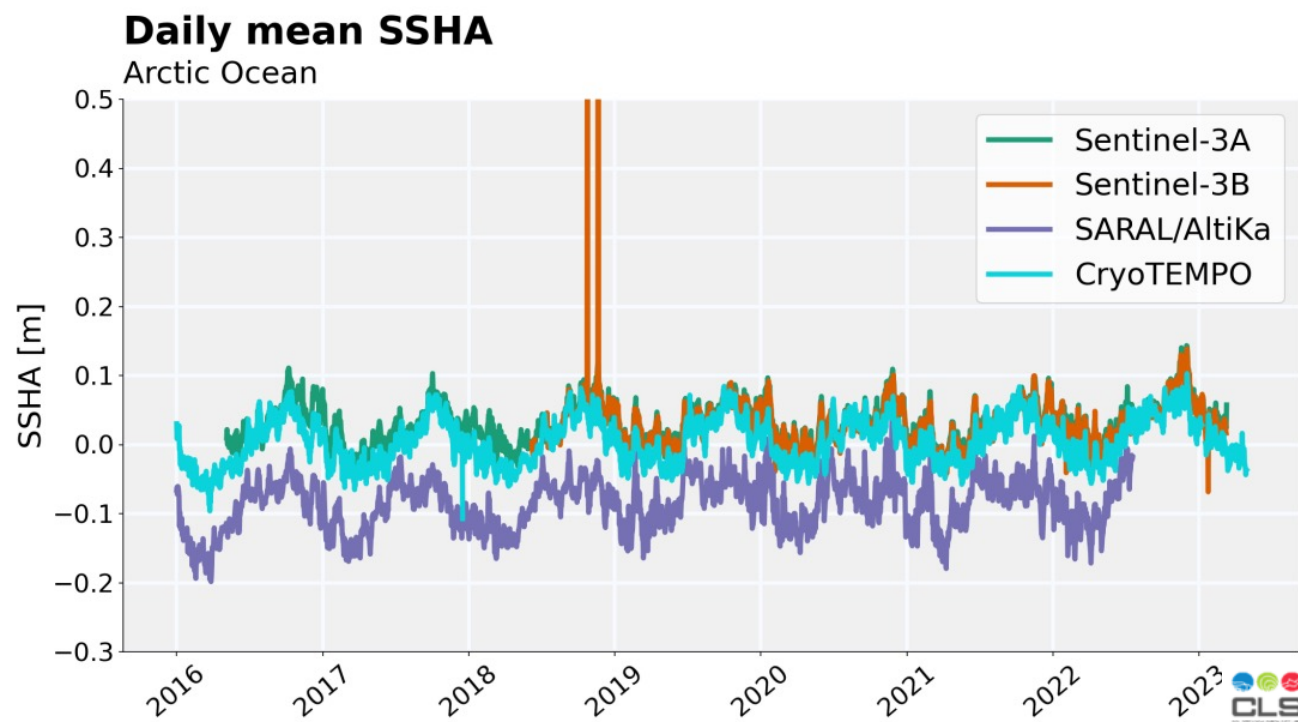
<https://www.eumetsat.int/release-sentinel-3-altimetry-marine-bc005-reprocessed-dataset>



- Overall good quality of Sentinel-3 (SARM & PLRM) wind speed and SWH
- Systematic and random errors are comparable to reference Jasons missions
- Very stable performance over the full mission
- Recent mission reprocessing (BC 005) is improving S3 Wind & Waves

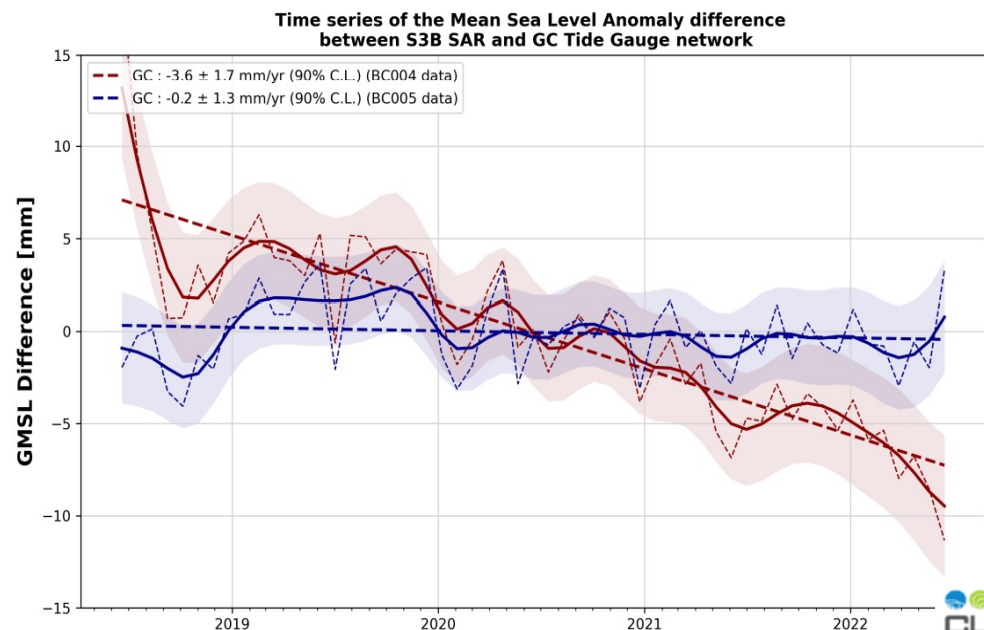
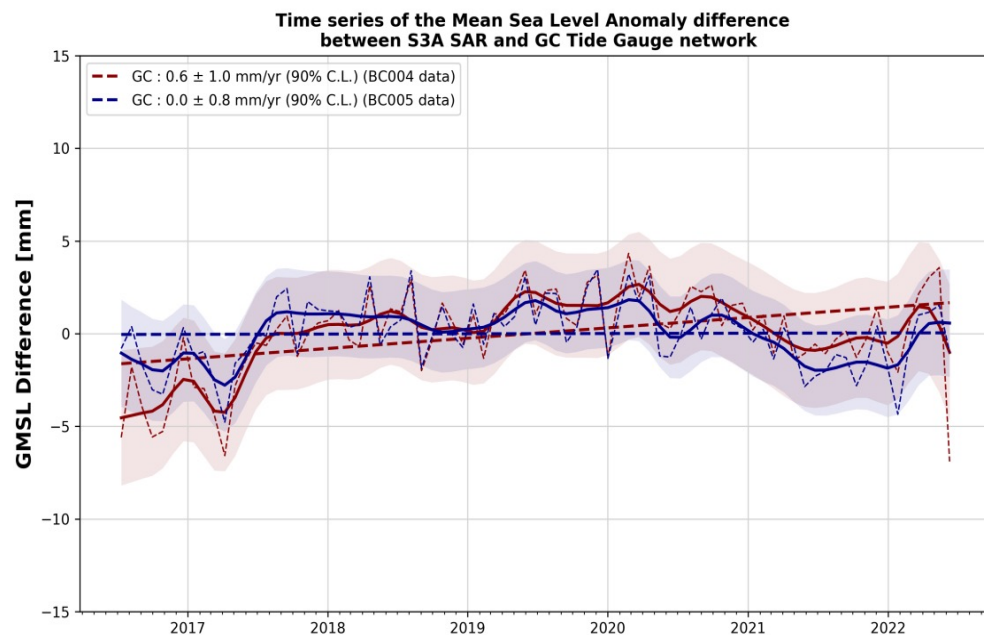


- S3 is able to observe ice-covered ocean SSHA variability
- Higher level of noise w.r.t. polar altimetry missions



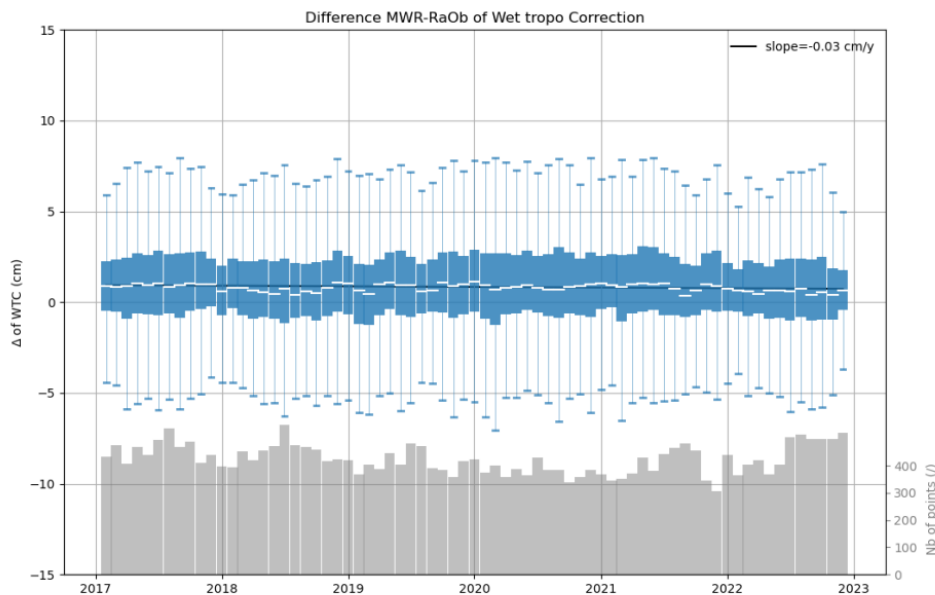
Polar Ocean products will be improved
in BC 006 (scheduled for 2025)

- No significant drift of S3A or S3B can be detected with respect to tide gauges
- The recent reprocessing of S3 shows an improvement in long-term stability (bias no longer present on BC 005 w.r.t BC 004)

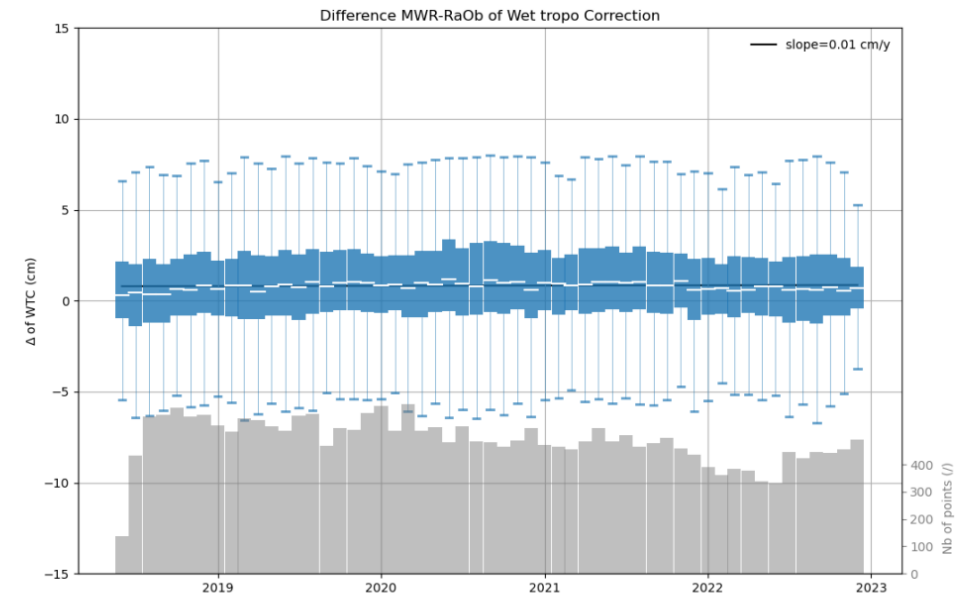


Bias drift estimates for Sentinel-3A (left) and Sentinel-3B (right) with respect to GLOSS/Clivar tide gauges for SAR mode

- Stable WTC delay observed by comparing to radiosonde observations and GPS

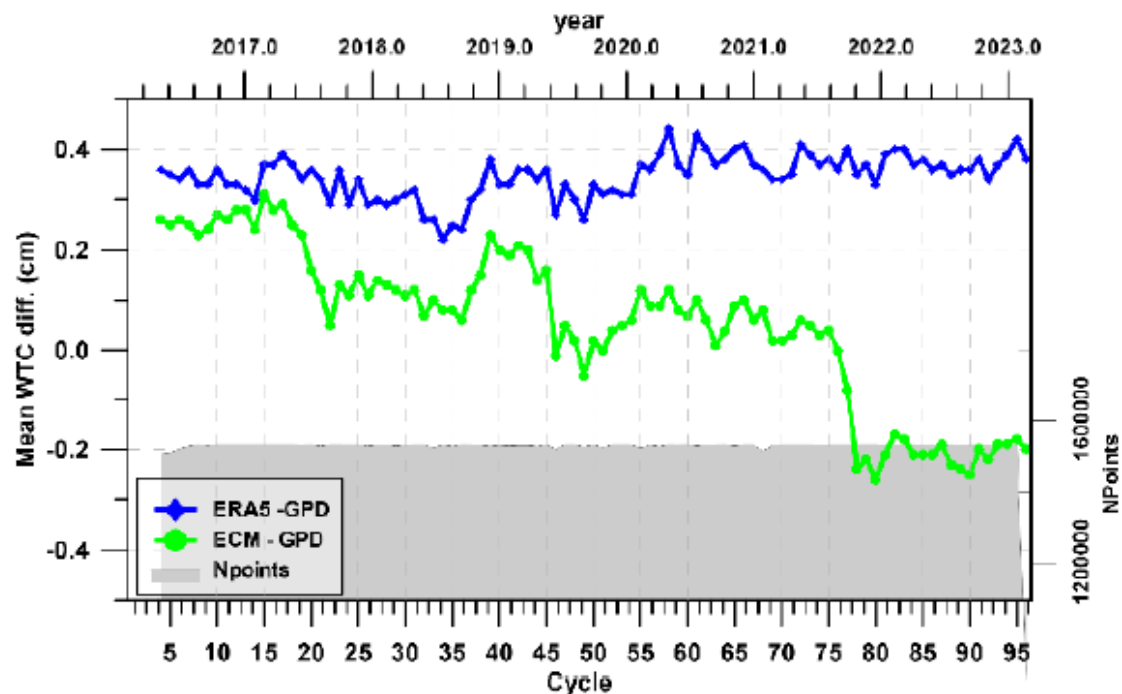


Timeseries of S3A's MWR-RaOb path delays for selected stations from IGRA network (selection criteria: $\text{dist} \leq 315\text{km}$ and $\text{dT} \leq 6\text{h}$)

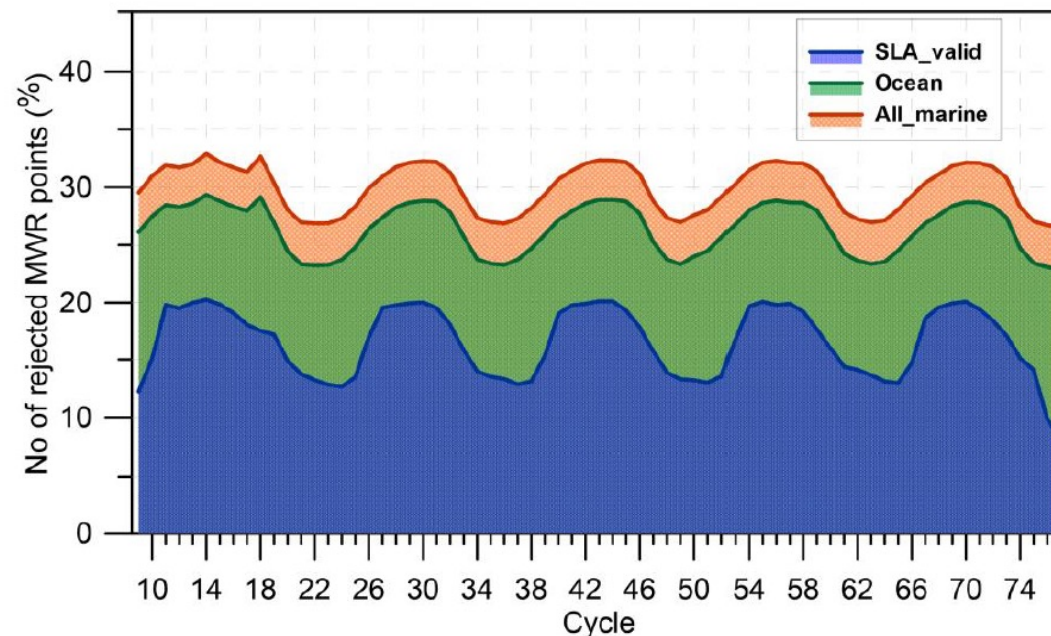


Timeseries of S3B's MWR-RaOb path delays for selected stations from IGRA network (selection criteria: $\text{dist} \leq 315\text{km}$ and $\text{dT} \leq 6\text{h}$)

- GPD+ Wet Tropo Correction is available in NTC and in the Reprocessed dataset BC005. Provided by University of Porto.



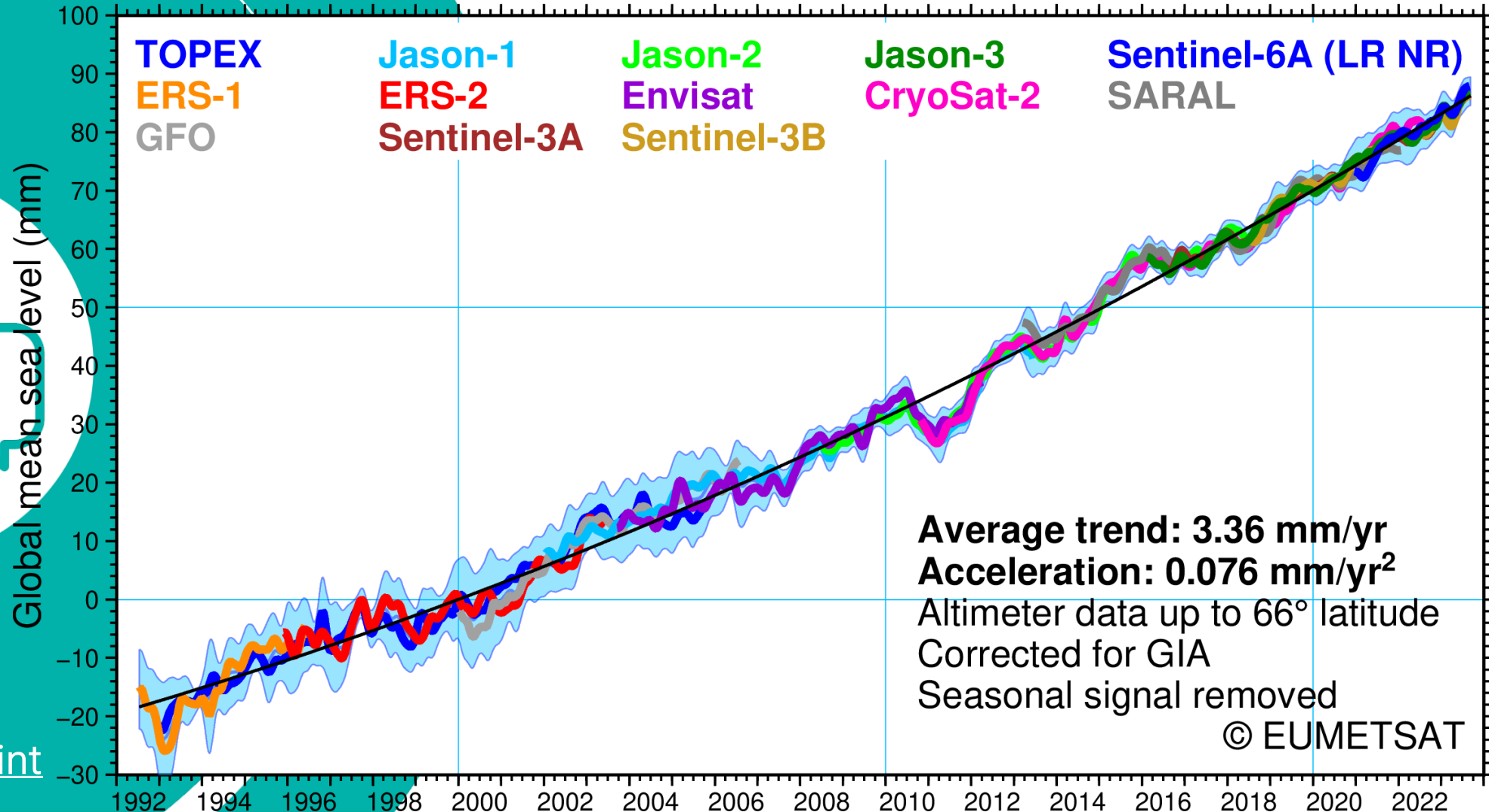
S3A GPD+ WTC versus ERA5 and ECMWF Op
good stability over time



Recovered points by GPD+, for each S3B cycle. Points present in the marine product (orange), for the whole set of ocean measurements (green) and for points with valid SLA (blue).

- **No issues with the S3 altimeter payload**
- **Sentinel-3 Marine data is being produced within the requirements in terms of timelines, availability and quality**
- **Improvements have been made to the product quality recently (BC005), mostly focused on Sea Level Anomaly stability**
- **Full mission reprocessing is available and provides the users a consistent time-series aligned with current operational production**
- **Further work (Polar Ocean, Coastal, etc.) is in preparation**
- **EUM is working towards the best possible alignment between S6 and S3, in terms of processing and standards, towards altimetry multi-mission processing**

Thank you!



s3.stm@eumetsat.int



Baseline Collection (005) for S3 Marine Altimetry

copernicus.eumetsat.int

More stable for climate applications

Better L2 out-of-the-box

More information to the user

- Correction of SAR Range drift (mostly impacting S3A)
- Improved standards
 - MSS
 - Polar Tide
 - DAC in NRT
 - GPD+ WTC in NTC
 - SSB from S3 data
- Wind from 2 parameters (swh,sig0)– like S6
- Better instrument processing
 - Removal of CAL2 application to CAL1.
 - New CAL2 normalization
 - Real Zero Masking from L1B data applied at SAR L2
- Improved 1Hz generation (based on strict MQE criteria)
- Quality flags
- More information to the user available on the netcdf:
 - Processing Baseline; All system bias; etc.
- Sea Ice concentration @1Hz
- SRAL Acquisition mode @ 1Hz
- [Go back](#)

Major update for Sea Level retrievals

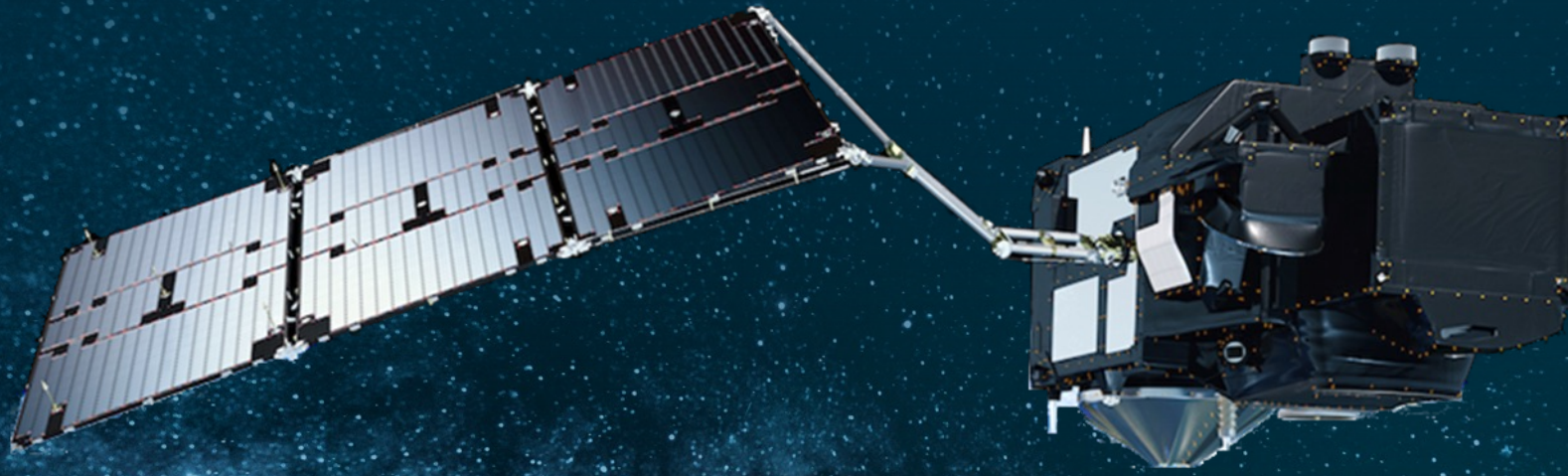
- Correction of SAR Range drift (mostly impacting S3A)
 - Range Walk (applied at SAR L1, only NTC).
 - Adapted CoG CAL1
- Correction of USO sign (impacting only S3B)
 - Correct reading at L1
- GPD+ WTC correction applied at NTC
 - If used instead radiometer WTC allows for the recovery of about 10-15% more valid data points
 - <https://www.eumetsat.int/new-algorithm-gpd-improves-s3-sral-mwr-wtc>
 - Now default WTC for NTC SSHA calculation (since SM__WAT.005.02)
 - Operational service implemented by University of Porto for EUMETSAT
- Mean WTC updated (mostly S3A), now better consistency between S3A/B and ECMWF model
 - (since SM__WAT.005.02)
- Dynamic Atmospheric Correction (DAC/MOG2D) available in NRT and applied to the SSHA.
 - SLA error reduction of 2 cm rms
- New Sea State Bias (Tran 2021) derived from S3A SAR/PLRM for Ku-band, instead of Jason-2. For C-band J2 SSB remains.
- New Mean Sea Surface Models
 - Combined 21 (SIO, CNES/CLS 15, DTU 15) – new default model
 - DTU 21
- Tide updates
 - New Pole Tide (Desai 2017)
 - Internal tides and long tide non-equilibrium now applied to calculate SSHA.
- Improved 1Hz generation (based on strict MQE criteria)
 - Preventing bad 20Hz data to be used
- Quality flag for SSHA
 - quality_ssha_01_ku & quality_ssha_01_plrm_ku
- Elevation from sea-ice/ocog retracers now uses high frequency dynamic atmospheric pressure correction



- Better instrumental Processing
 - Removal of CAL2 application to CAL1.
 - New CAL2 normalization, by plateau instead of max
 - Real Zero Masking from L1B data applied at SAR L2 (all timeliness).
 - Impacts mostly wave retrieval
- Wind Speed calculated also from Sigma0 and SWH (like S6)
- Updates to mean values of SWH and Wind Speed due to Range Walk, Zero Masking and system bias updates for better alignment
- Improved 1Hz generation (based on strict MQE criteria)
 - Preventing bad 20Hz data to be used
- Quality flag for Winds and Waves
 - quality_swh_ocean_01_ku quality_swh_ocean_01_plrm_ku
 - quality_wind_speed_alt_01_ku quality_wind_speed_alt_plrm_ku
 - quality_wind_speed_alt_2p_01_ku quality_wind_speed_alt_2p_plrm_ku

- More information to the user available on the netcdf:
 - Processing Baseline; All system bias; etc.
- No-more (land-)ice variables being generated by Marine products.
- Correction of the geoid model, still EGM2008 but now correct on the Marine products
- Sea Ice concentration @1Hz
- SRAL Acquisition mode @ 1Hz





Sentinel-3 Mission Overview – LAND mission

Pierre Féménias (ESA)

Filomena Catapano (ESA), Jérôme Bouffard (ESA), Nic Mardle (ESA)

S3 STM Mission Performance Cluster Team,

Copernicus POD Team

San Juan, Puerto Rico, 7-11 November 2023

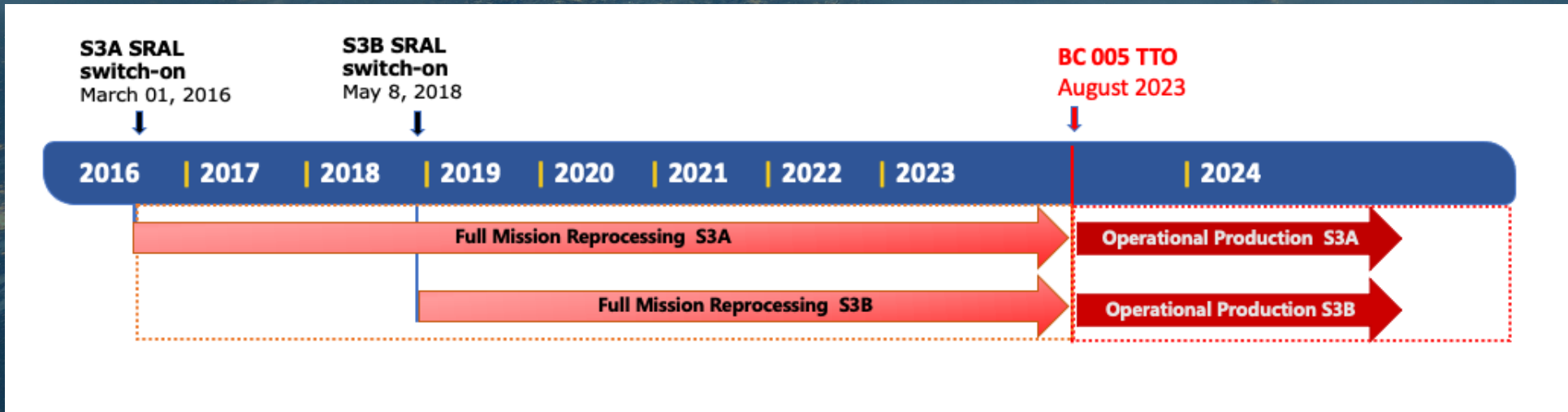
OSTST Conference

Sentinel-3 Mission DATA product responsibilities



What's new since OSTST 2022 in Venice?

- Sentinel-3 Land Altimetry Data Set is fully consistent in Baseline Collection 005



- Full Mission Data Set for the three HYDRO-CRYO Thematic products (Inland Waters, Sea-Ice, Land Ice) available from the ESA CDSE user interface
- Major improved performances for each S3 HYDRO-CRYO Altimetry Thematic product

WHAT'S NEW IN BC 005



Inland waters:

Dedicated mask over inland water areas
Zero-padding processing for improved water surface height (WSH)
Hamming window filter to reduce waveform contamination

Pole-to-pole
products



Sea Ice:

Dedicated mask over sea ice areas
Zero-padding processing to improve waveform sampling
Hamming window filter to reduce waveform contamination

Equator-to-
equator
products



Land Ice:

Dedicated mask over inland water areas
Extended window for waveform processing

Equator-to-
equator
products

- ❖ Full Mission Reprocessing (FMR) with Baseline Collection BC005
- ❖ Three new thematic products replacing the old Land BC004 products
- ❖ Homogeneous BC005 coverage from beginning of the mission up to date

And many other improvements as described in S3 SRAL Land User Handbook

@ <https://sentinel.esa.int/en/web/sentinel/user-guides/sentinel-3-altimetry/document-library>

BC = Baseline Collection

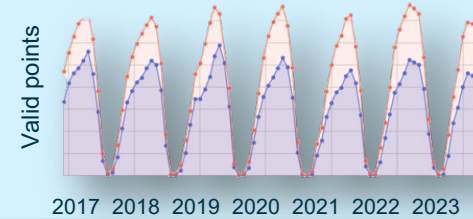
INLAND WATERS



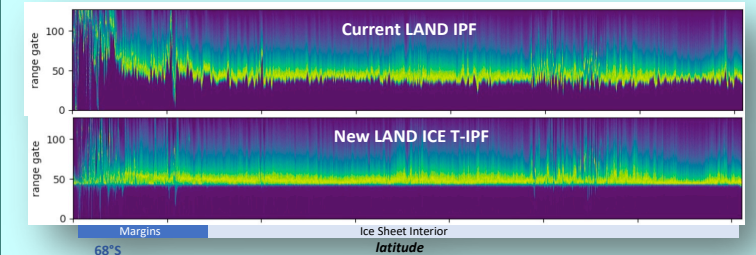
SEA ICE

S3 NEW THEMATIC PRODUCTS
S3 OLD PRODUCTS

Arctic



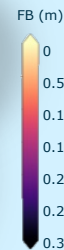
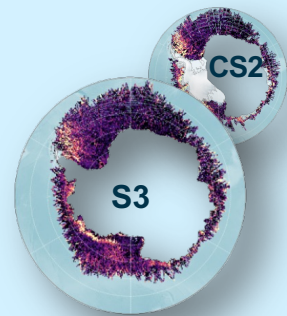
LAND ICE



SEE

Presentation in Science IV @ 17:30 by Filomena Catapano
Posters SC42023-001 /002 /003

smaller

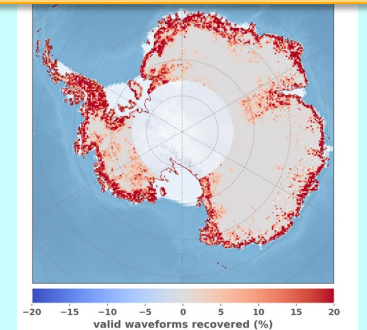


FB agreement with
CryoSat-2 (CS2)
improved up to ...

90%

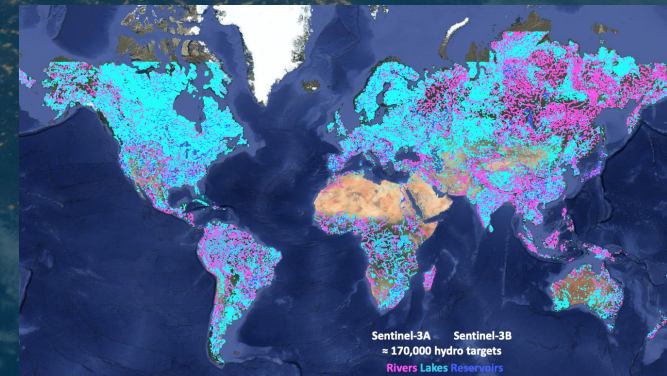
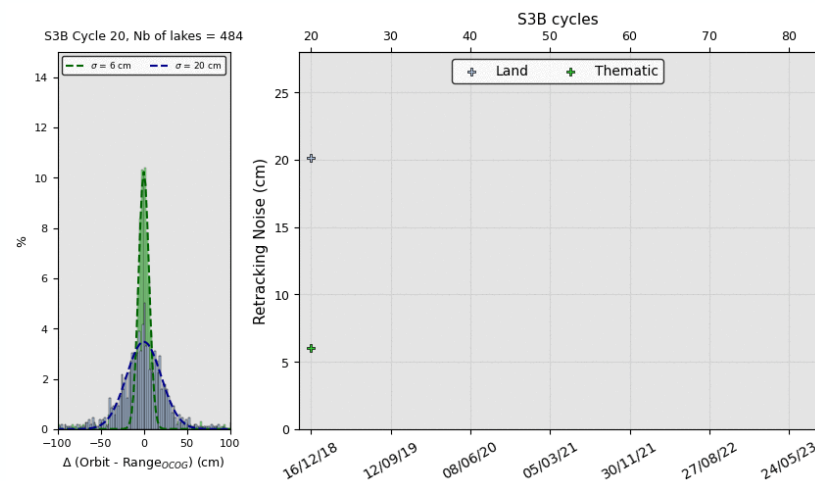
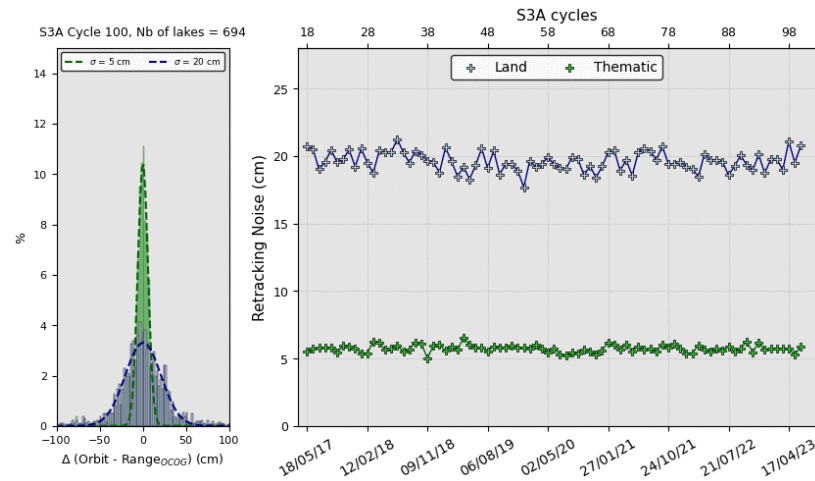
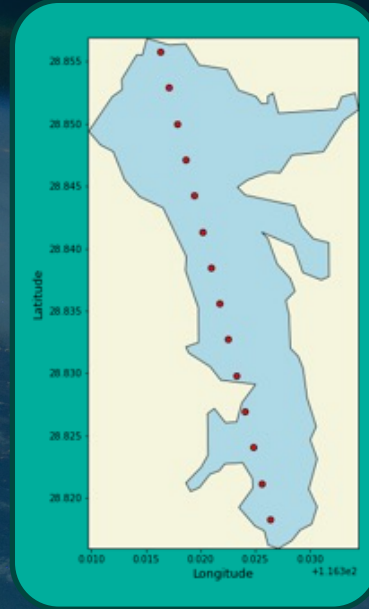
Over ice margins
data coverage
improved up to ...

25%



Improved Water Surface Height from Thematic Processing

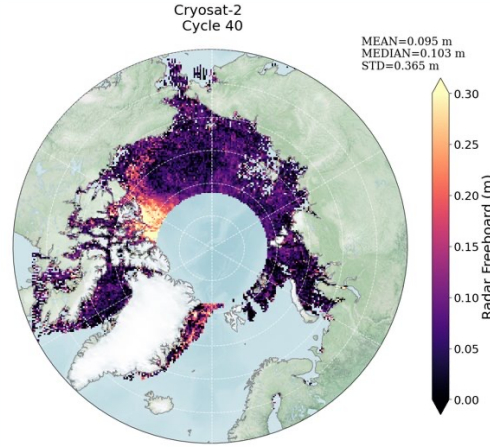
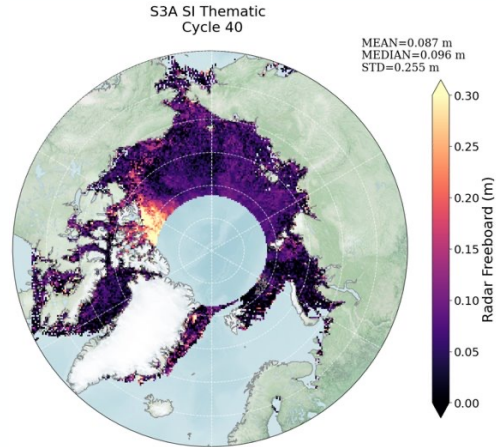
- Decrease of the retracking noise for thematic products (from ~20cm to 5cm) !
- More than 170.000 Hydro Targets for Rivers, Lakes, Reservoirs, Glaciers
- Benefit of consistent times series over S3 Land Altimetry mission with BC005



Altimeter OLTC for Hydrology
<https://altimetry-hydro.eu/>

Improved Freeboard from Thematic Processing

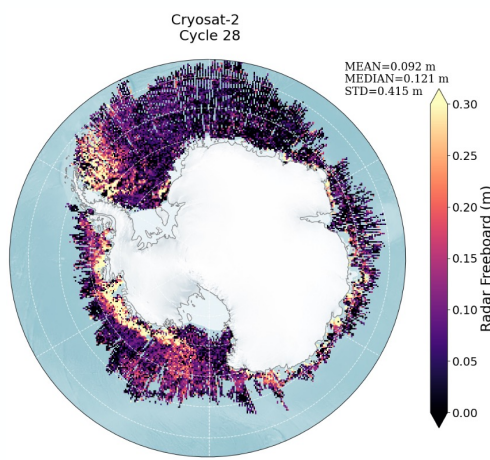
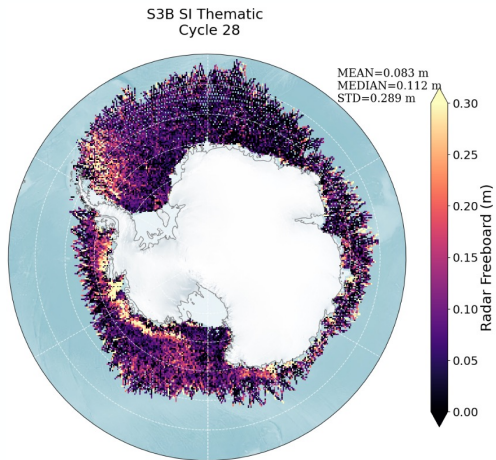
Comparison to Cryosat-2 Baseline-E



Arctic



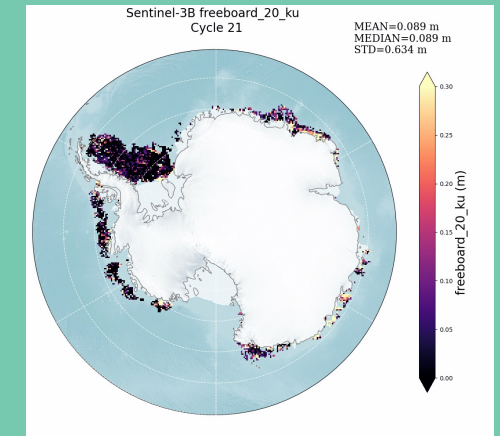
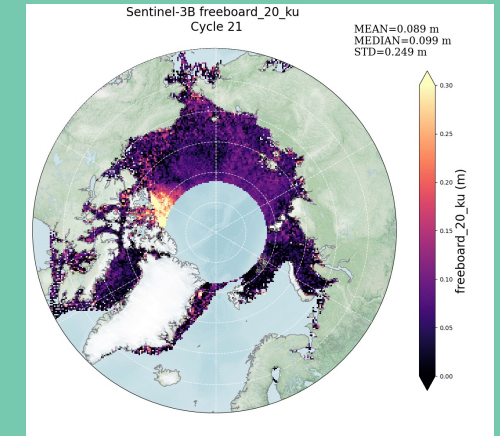
- Freeboard patterns are now very close to Cryosat-2 and noise is significantly reduced
- S3 brings very high density of data over Arctic, 6 times more than CryoSat !



Antarctic



Sentinel-3 Freeboard

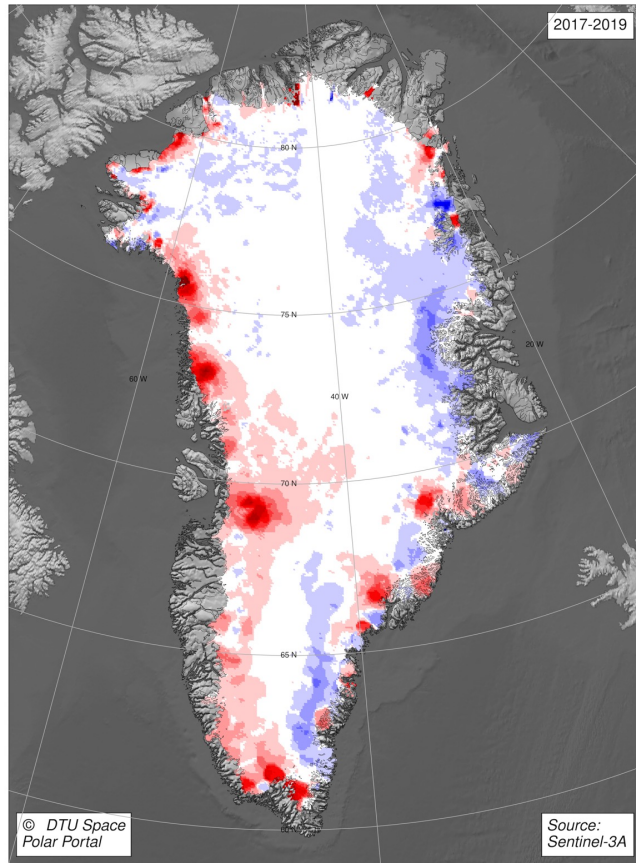


Improved Surface Elevation Change from Thematic Processing

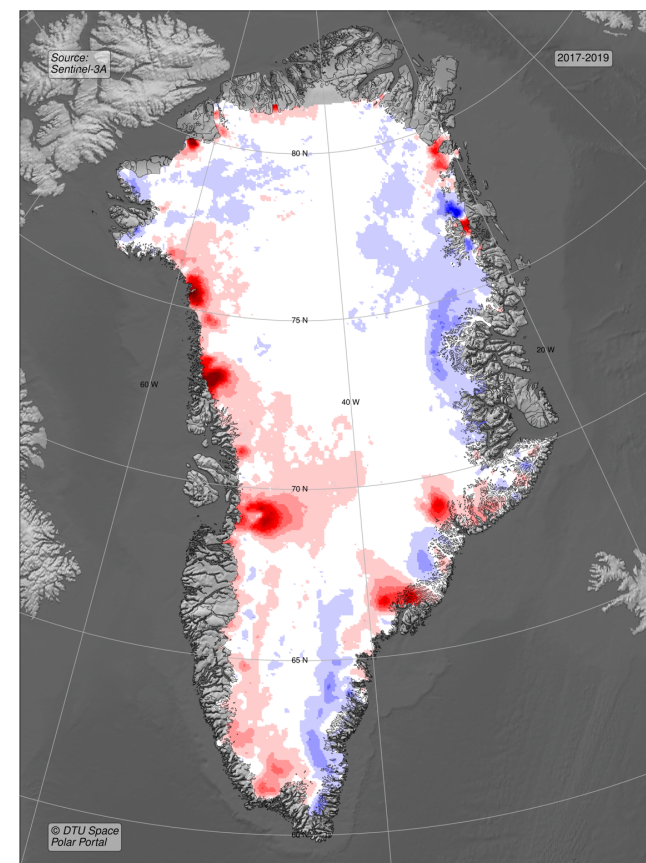
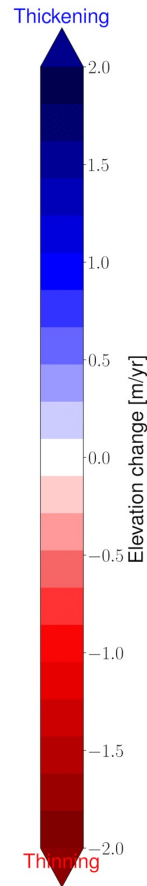


S3 Land Altimetry SEC

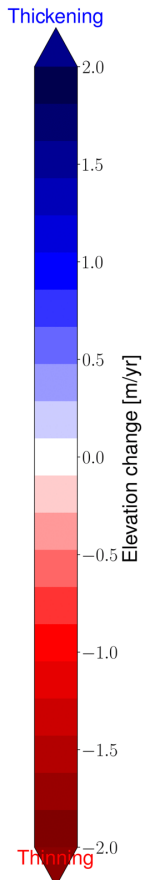
Improved noise in coastal areas as expected !



Old Land processing



New Thematic Land Ice



S-3 Altimetry – St3TART project

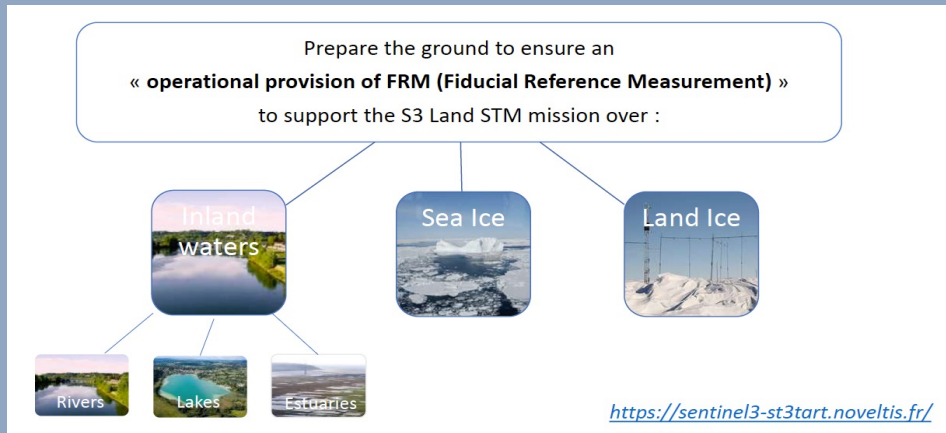


PROGRAMME OF
THE EUROPEAN UNION



Operational Provisioning of FIDUCIAL REFERENCE MEASUREMENTS (FRM) for S-3 STM SEA ICE, LAND ICE & INLAND validation purpose

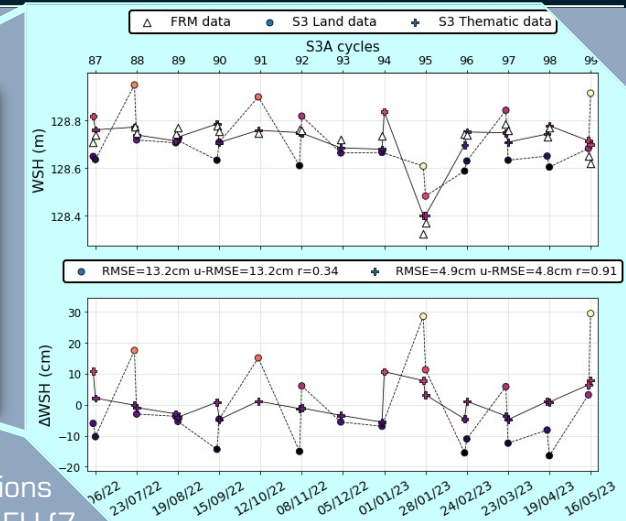
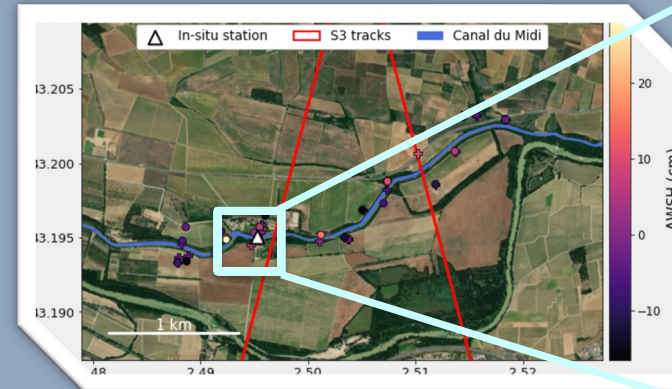
St3TART (S-3 Topography mission Assessment through Reference Techniques) main objective:



Main project outcomes:

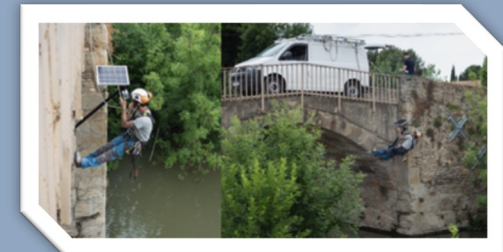
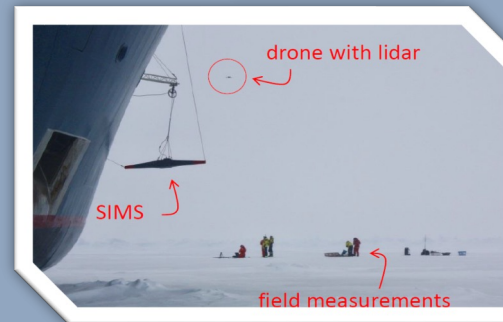
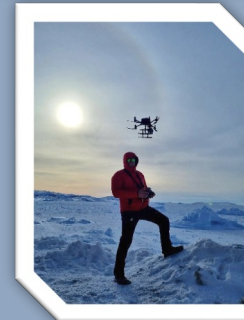
- FRM protocols and procedures definition
- Roadmap and Strategy for FRM operational provision
- St3TART FO for FRM operational provision
→ ITT issue in Q1 2024

More info: <https://sentinel3-st3tart.noveltis.fr/>

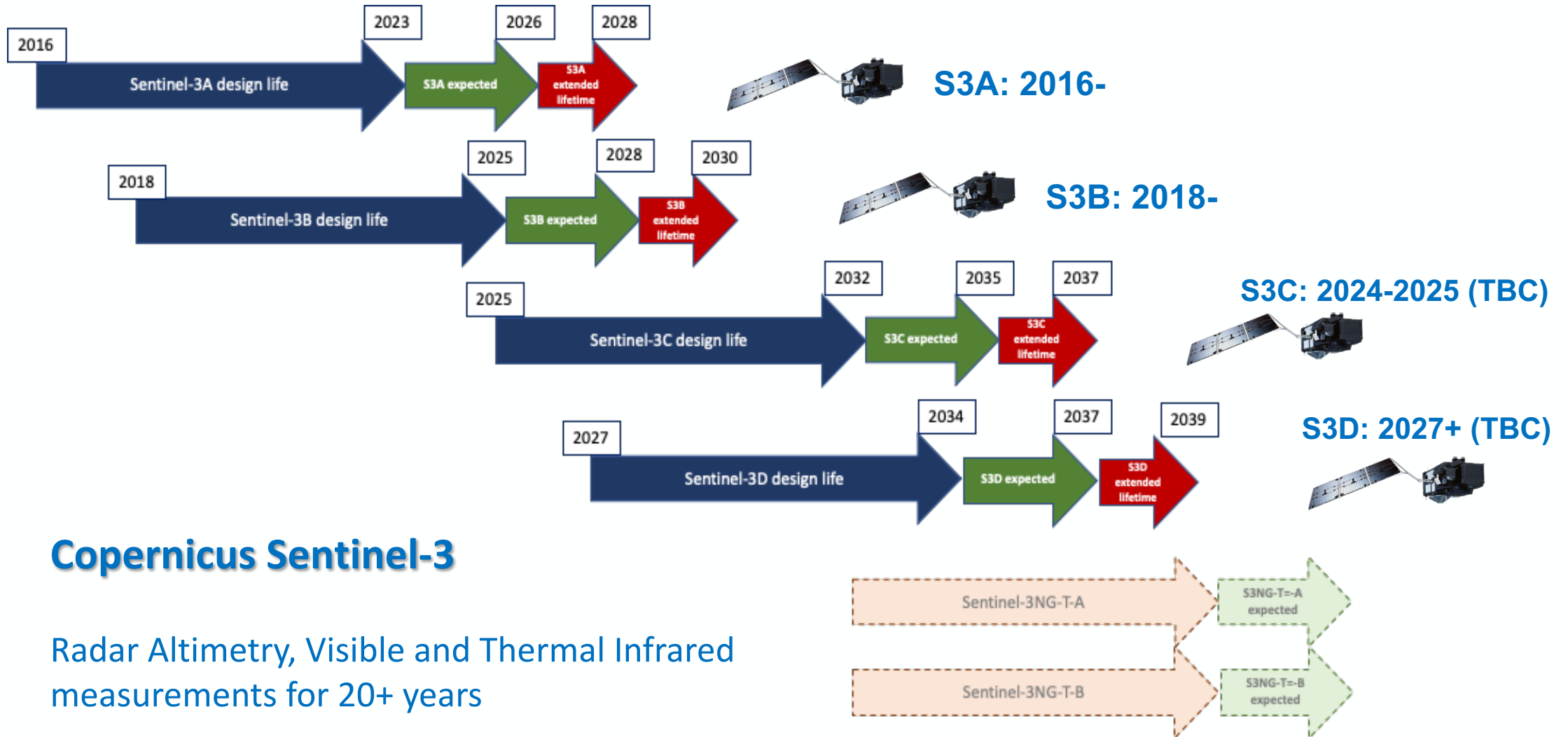


In numbers:

- 12 micro stations deployed over EU (7 pressure sensors) for inland waters
- 20 in-situ campaigns performed
- 250 km of drone flights over sea ice and inland waters



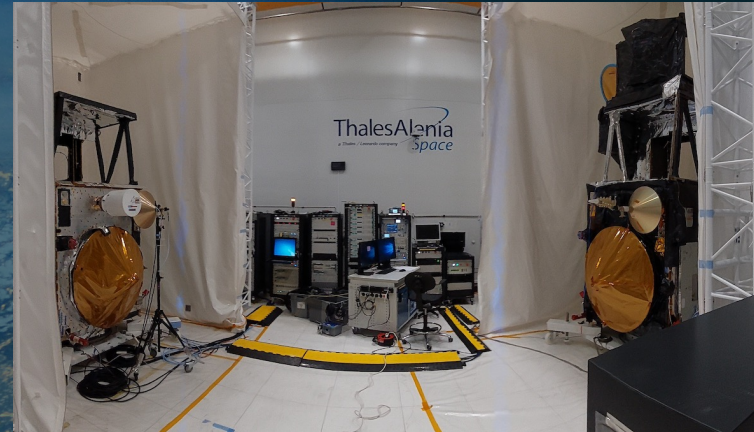
Sentinel-3 Constellation Overall Schedule



Sentinel-3 C/D Satellite Status

Sentinel-3C

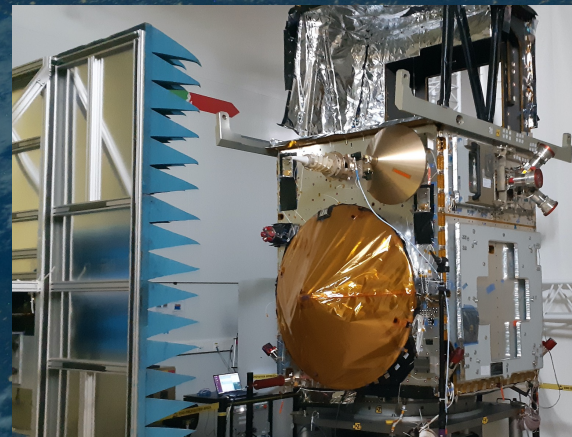
- Sentinel-3C satellite activities complete
 - Environmental campaign completed in Autumn 2021
- Flight Acceptance Review Board Feb 2022
- Satellite Storage Configuration
 - Satellite in tent, with N2 purging
 - SLSTR in storage in Leonardo
- Periodic maintenance at satellite level performed every 6 months



S3-C under Tent

Sentinel-3D

- Satellite partially integrated (PF/TOPO)
 - Platform, SRAL, MWR, DORIS, GNSS
 - All testing completed up to this build level
 - Pre-Storage Review completed, satellite in storage
- Satellite (PF/TOPO) Storage configuration:
 - Satellite in tent, with N2 purging
 - Periodic maintenance performed Oct 2023
 - MWR & SRAL tests as per S3C
 - As part of satellite level periodic maintenance



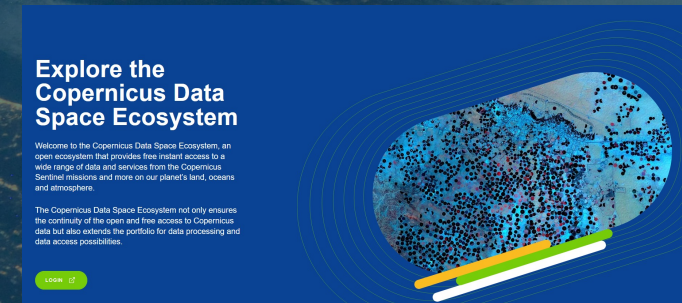
SRAL instrument

Sentinel-3C/D Satellite Major Milestones

Satellite Activity Milestone dates:

- S3C Flight Acceptance Review : Feb 2022 (Board)
- S3D Pre-Storage Reviews;
 - PF/TOPO & OLCI : Q1/Q2 2022
 - SLSTR-D : Q1 2023
- Storage formally started after associated reviews
 - 6 & 12 monthly tests at s/c & instrument level
- Launch window under discussion with EC and Arianespace considering Z40 Static Test Firing Failure
- Satellite/instrument destorage & Phase E1 activities start at L-12
 - Procurement of hydrazine, organisation of transport, etc
 - Reintegration of SLSTR, functional testing, return to pre-storage configuration, delta-FAR
 - Commissioning activities preparation

- The **S3A & S3B STM Hydro-Cryo (LAND)** products are fulfilling the **S3 Altimetry mission requirements** over all surfaces (e.g. Inland Waters, Land ice & Sea-Ice)
... beyond expectations!
- Three “**New**”, “**Enhanced**” & “**Thematic**” **Hydro-Cryo Altimetry L2 Core Data Products** are available:
 - Inland Waters
 - Sea Ice
 - Land Ice
- **S3A and S3B Hydro-Cryo Altimetry L2 Thematic Full Mission Data Set** available in Baseline Collection 005 from ESA CDSE @ <https://dataspace.copernicus.eu>
- S3C and S3D are ready to take over from S3A and S3B to extend the time series





Thank you !

Invitation to submit Manuscript for a Special-Issue of Remote Sensing MDPI



The screenshot shows the MDPI Remote Sensing journal website. At the top left is the MDPI logo. Below it, on the left sidebar, is the 'remote sensing' logo and three buttons: 'Submit to Special Issue', 'Submit Abstract to Special Issue', and 'Review for Remote Sensing'. The main content area features the title of the special issue: 'Special Issue "Copernicus Sentinels Missions Calibration, Validation, FRM and Innovation Approaches in Satellite-Data Quality Assessment"'. To the right of the title are two circular badges: 'IMPACT FACTOR 5.349' and 'CITESCORE 7.4'. Below these are icons for sharing and a comment bubble. The breadcrumb trail at the top reads: 'Special Issues / Copernicus Sentinels Missions Calibration, Validation, FRM and Innovation Approaches in...'.

Expected topic areas covered by Copernicus Sentinels missions but are not limited to:

- remote sensing of atmospheric composition, land, ocean, snow and ice surface,
- calibration and sensors' intercomparison,
- validation of geophysical data products,
- innovations to products' retrieval algorithms and Cal/Val techniques,
- Fiducial Reference Measurements (FRM) for satellite data validation.

Guest-Editors:
Dr. B. Alhammoud, Dr. S. Clerc, Dr. S. Dransfeld,
Dr. J-C. Lambert, Mr. P. Féménias

Extended Deadline for manuscript submissions:
31 March 2024

https://www.mdpi.com/journal/remotesensing/special_issues/J3CYH3OQV0#editors

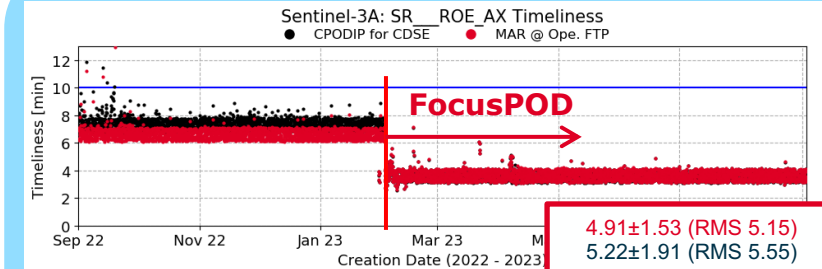
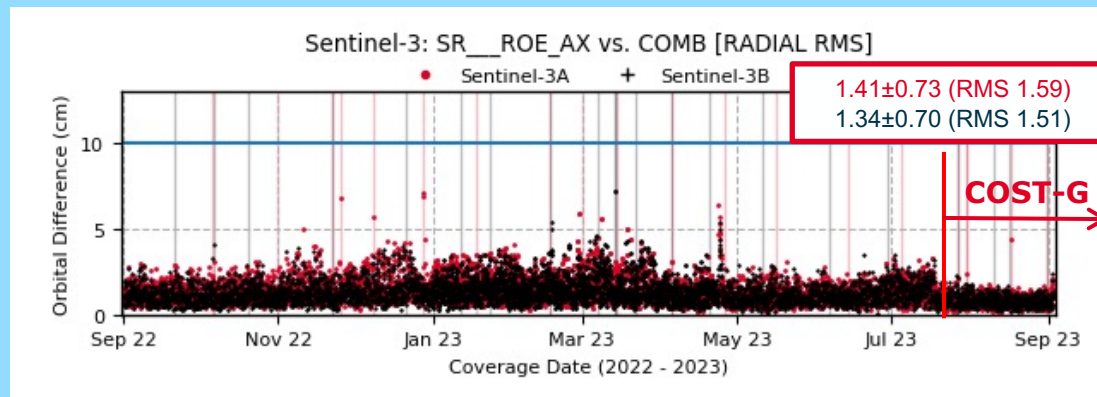
CPOD Performance – 2023

Major CPOD Service evolutions in 2023

- POD SW migration to a GMV in-house new product: **FocusPOD** in January (↓ **timeliness**, ~accuracy)
- Transition from EIGEN-GRGS.RL04 gravity model to the time-variable **COST-G FSM** in July (↑ **accuracy**)

NRT CPOD Products

~1.5 cm RADIAL RMS



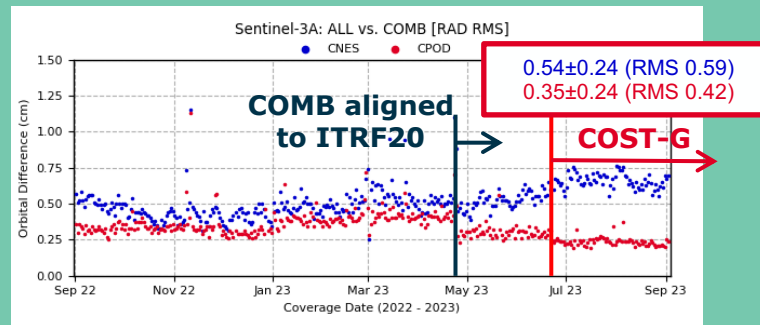
~5' timeliness



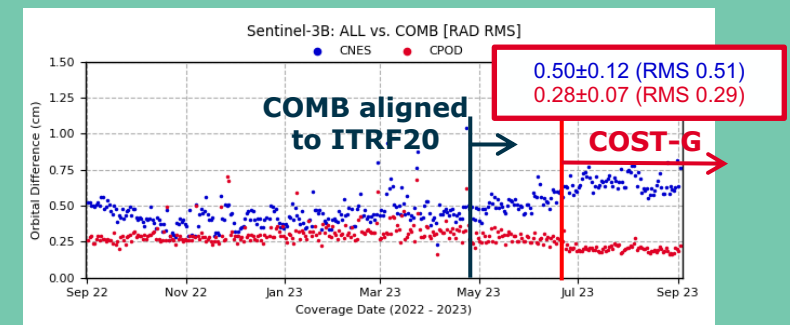
S3A

NTC POD products

~0.5 cm RADIAL RMS



S3B

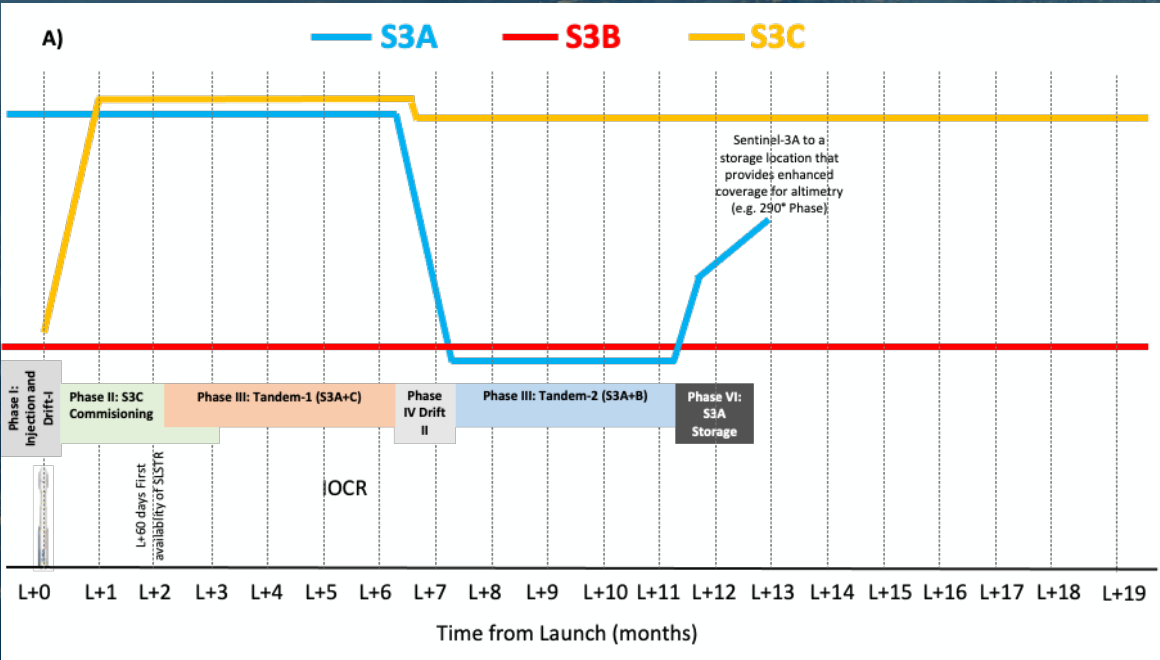


Tandem Phase Scenario

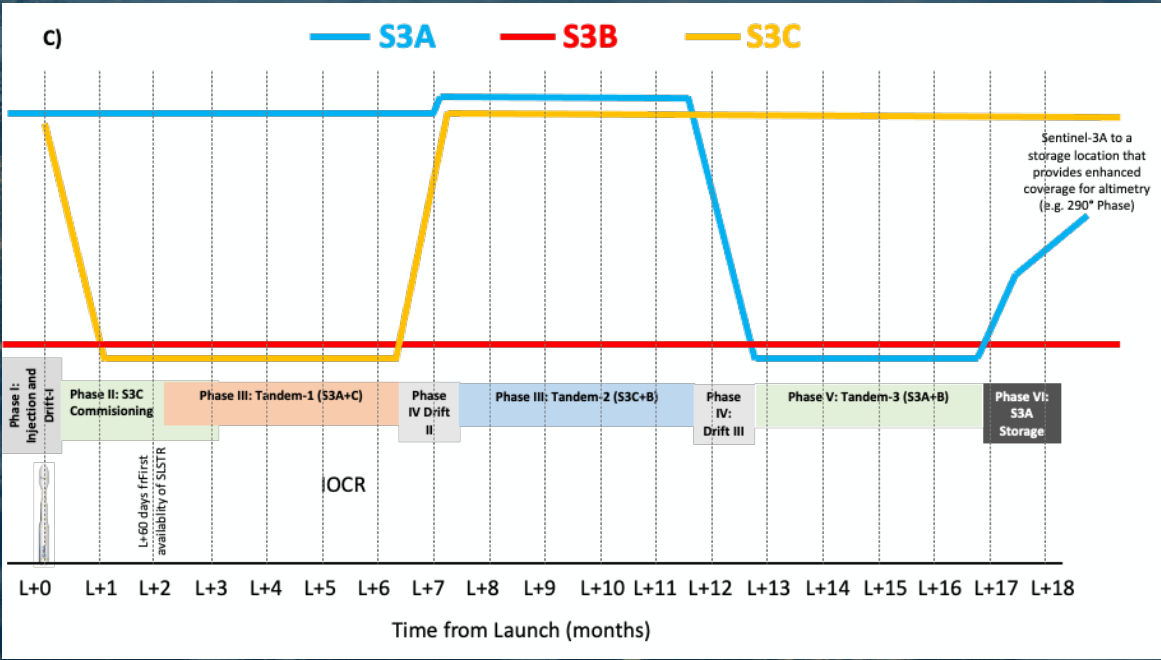


Different scenario being studied...

Scenario A)



Scenario C)



Objective to converge on Tandem Phase Scenario by Q2 2024 !