Sentinel-3 Mission Overview - MARINE

Bruno Lucas
EUMETSAT

OSTST 2022
31 October 2022 at Venice, Italy

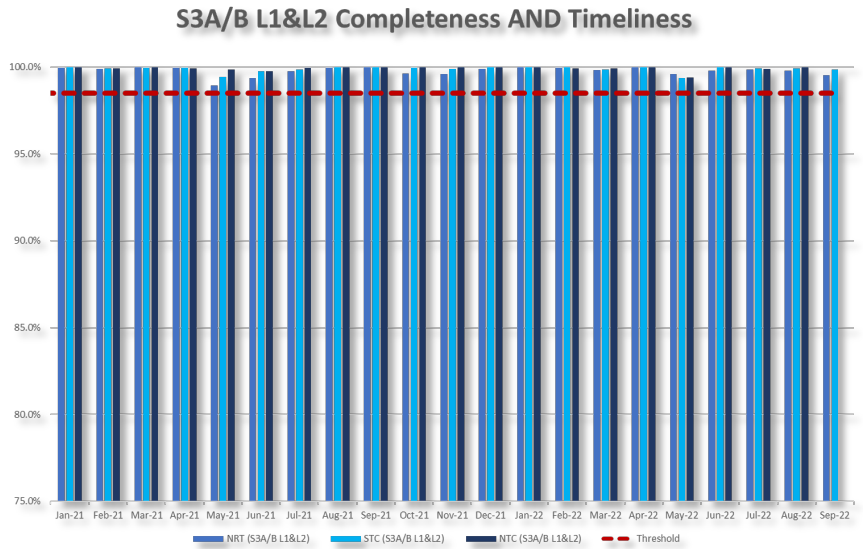
Space segment

- Regular operations
  - SRAL Transponders
    - Crete
    - Gavdos (added 2021/11)
    - Catalina (added 2022/03)
    - More in prep.
  - KREMS safe
    - 100 KMs around KREAMS military radar for MWR
  - OLTC Updates (impacting in-land waters mostly)
    - S3A: 12/09/2022 (first new data)
    - S3B: 19/09/2022 (first new data)
  - SRAL Annual Calibrations
    - Continue to show stability of the instrument
  - Routine manoeuvres to keep the ground track

- No major issue with the Altimetry payloads
  - S3A SRAL Thermistor retired (2022/06)

- Special operations:
  - Lunar Calibrations (in 2022, each month one Sat, announced to the user via UNS: https://uns.eumetsat.int/
  - For altimetry outage of about 30 min (current) to 1:30 hours (older processing)

Ground Segment (Altimetry)

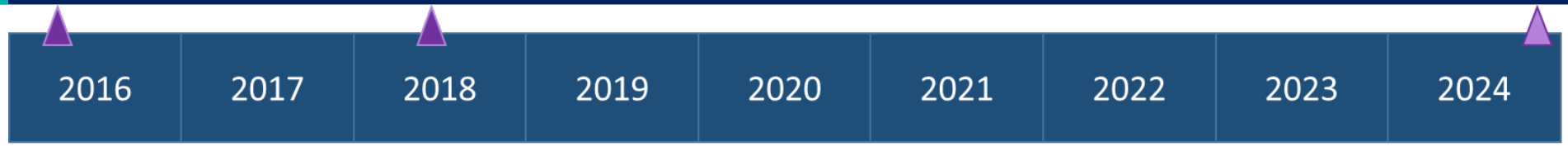


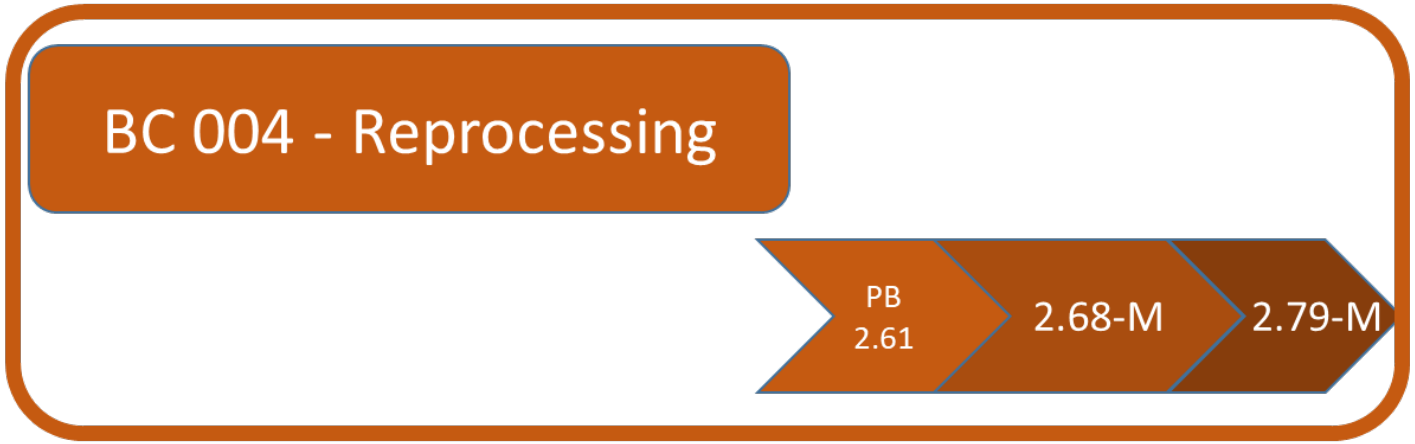
- Above the KPIs for timeliness and completeness
  - No systematic issues with production
- Dataset meets quality requirements

- Improved timeliness for NRT due to the usage of the CPOD Service NRT orbits (since 2022/09)
  - Same quality as before
  - Products are available 3-4 minutes earlier than before
- Operational availability of GPD+ Wet Tropo Correction for NTC (2022/07)
- Operational availability of MOG2D in NRT

- Recent ALT PB updates (SR1+MW1+SM2):
  - 2021/12/14 - PB 2.79-Marine (old nomenclature, BC004)
  - 2022/07/07 - SM__WAT.005.01 (new nomenclature, BC005)

Processing Baselines – Past, present, future



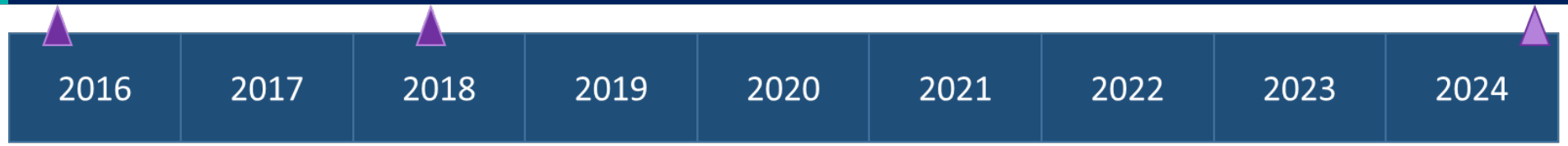


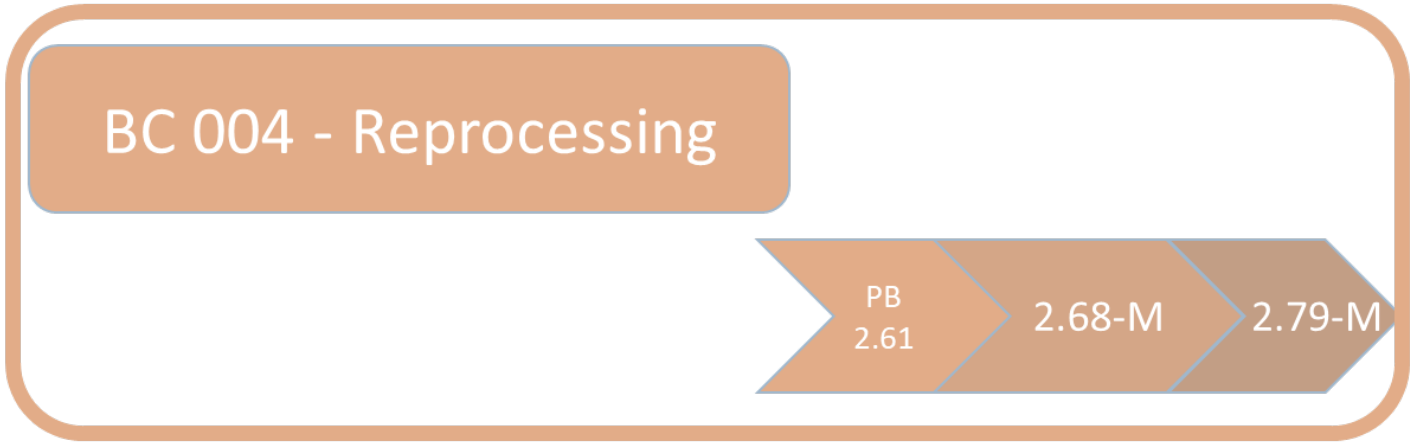
Reprocessing BC 004 - released in 2020

Followed up by several minor/medium PBs

Consistency between beginning of mission and “live” Operational data

Processing Baselines – Past, present, future





Reprocessing BC 005
- preview released to S3VT (2022)
- Final release Q1/2023 for all users

Consistency between beginning of mission and “live” Operational data (once the reprocessing is done)

New Baseline Collection (005) for S3 Marine Altimetry

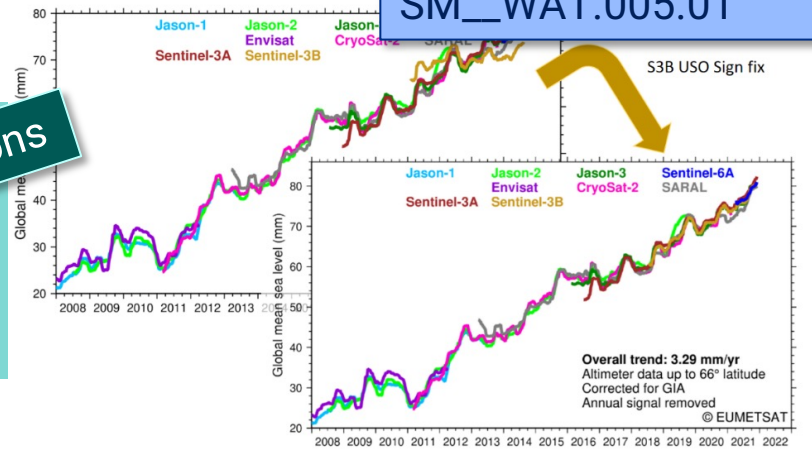
Processing Baseline

SM__WAT.005.01

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

More stable for climate applications



- 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

- Dynamic Atmospheric Correction (DAC/MOG2D) available in NRT and applied to the SSHA.
  - SLA error reduction of 2 cm rms
- 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.

Better L2 out-of-the-box (same as L2P)

New Baseline Collection (005) for S3 Marine Altimetry

Processing Baseline

SM__WAT.005.01

More info: https://www.eumetsat.int/new-sentinel-3-altimetry-processing-baseline-collection-005

Better instrumental Processing

- New Sea State Bias (Tran 2021) derived from S3A SAR/PLRM for Ku-band, instead of Jason-2. For C-band J2 SSB remains.
- Real Zero Masking from L1B data applied at SAR L2 (all timeliness).

- Removal of CAL2 application to CAL1.
- New CAL2 normalization, by plateau instead of max

- Wind and Waves: Updates to mean values of SWH and Wind Speed due to Range Walk, Zero Masking and system bias updates for better alignment

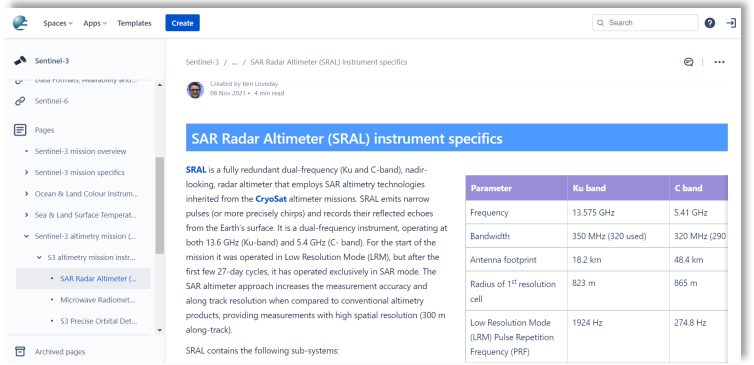
- More information to the user:
- Processing Baseline; All system bias; etc.
- No-more (land-)ice variables being generated by Marine products.

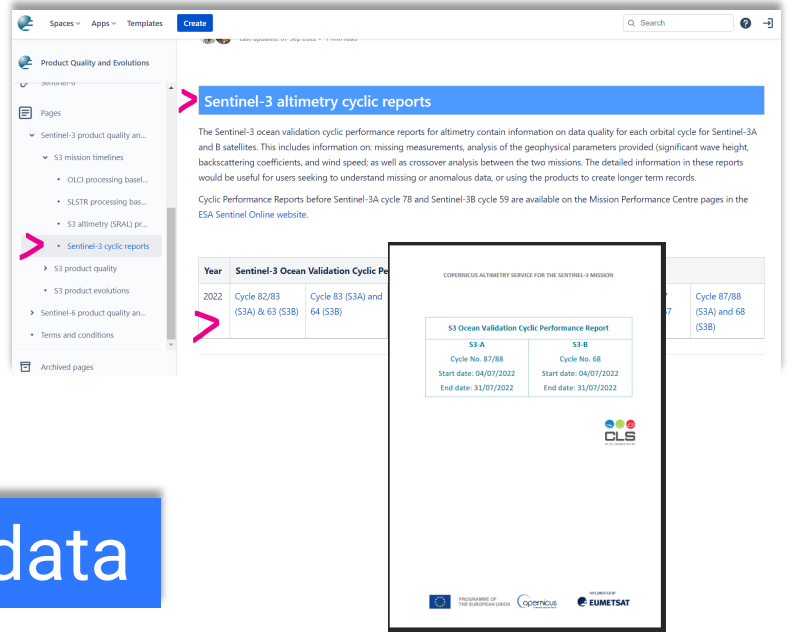
Future

- Medium Term (BC 006) ~2024
  - Improved Polar Ocean retrievals
    - Sea Level in to the Sea Ice leads, consistent with “open” ocean
  - Improved Coastal Processing
    - Dedicated processing
  - Improve Sea Level for Climate quality (even more)
    - Numerical retracking for SAR (and PLRM)
  - Improved models
    - MSS, Tides, etc.

New Knowledge Base

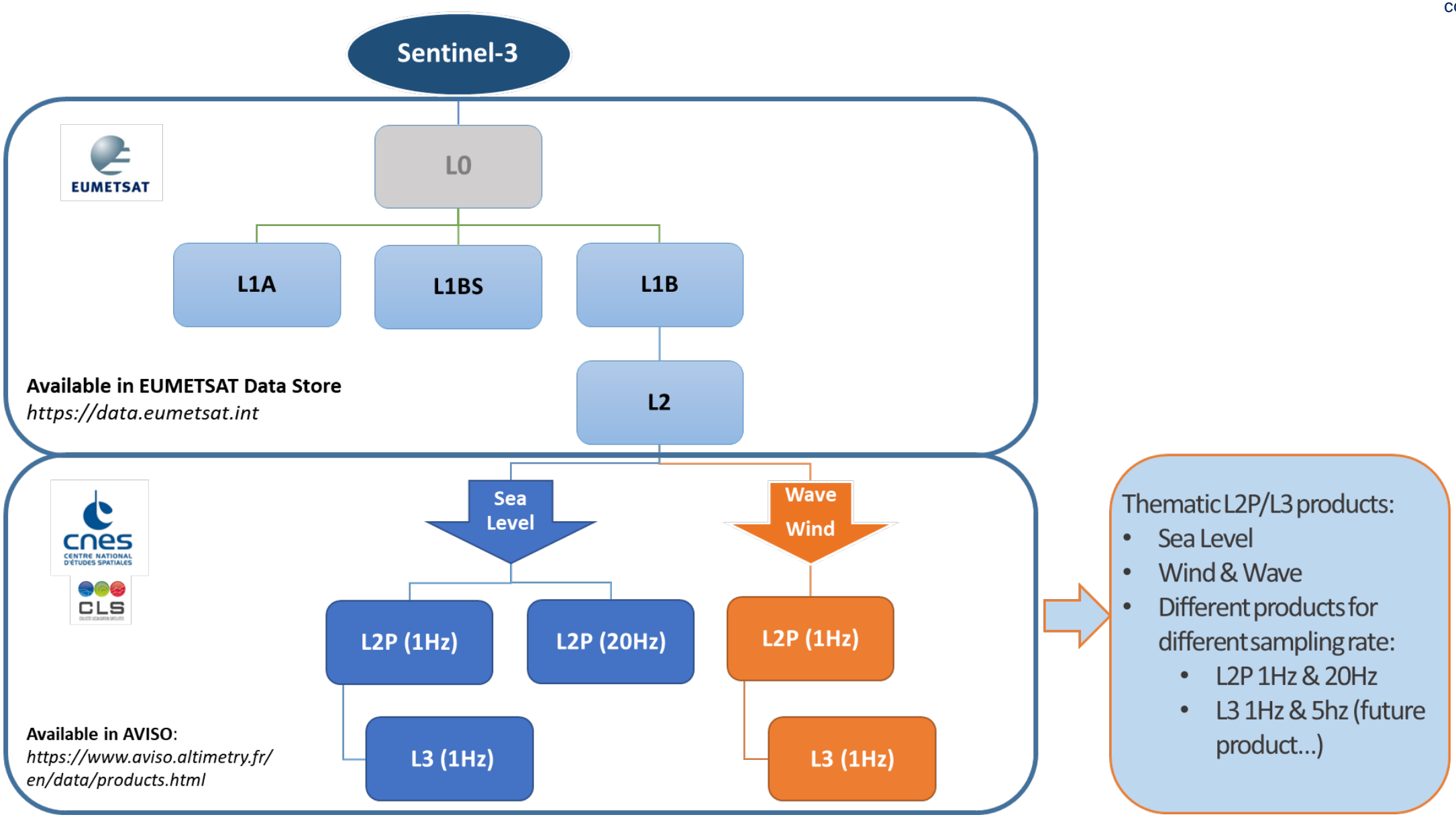
- New Knowledge Base website for Altimetry
  - Replaces Product Handbook
  - Contains new Cyclic and Annual Reports
    - Sentinel-3 cyclic reports - Product Quality and Evolutions - Confluence
  - Contains Product Notices
    - Still available at: https://www.eumetsat.int/altimetry-resources





Check new data access to marine data

S3 Altimetry Product Portfolio

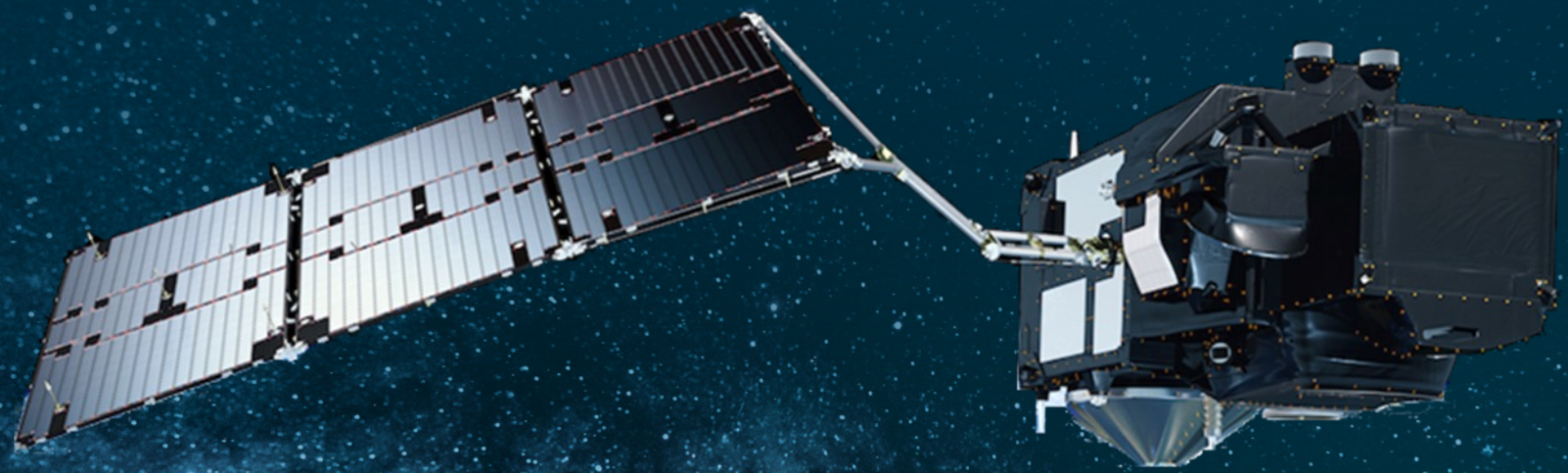


Thank you!

s3.stm@eumetsat.int

Take home message:

- 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)
- Full mission reprocessing is on-going to provide to the users a consistent time-series
- Further work (Polar Ocean, Costal, etc.) is in preparation.



Sentinel-3 Mission Overview – LAND mission

Pierre Féménias (ESA),

S3 STM Mission Performance Cluster Team,

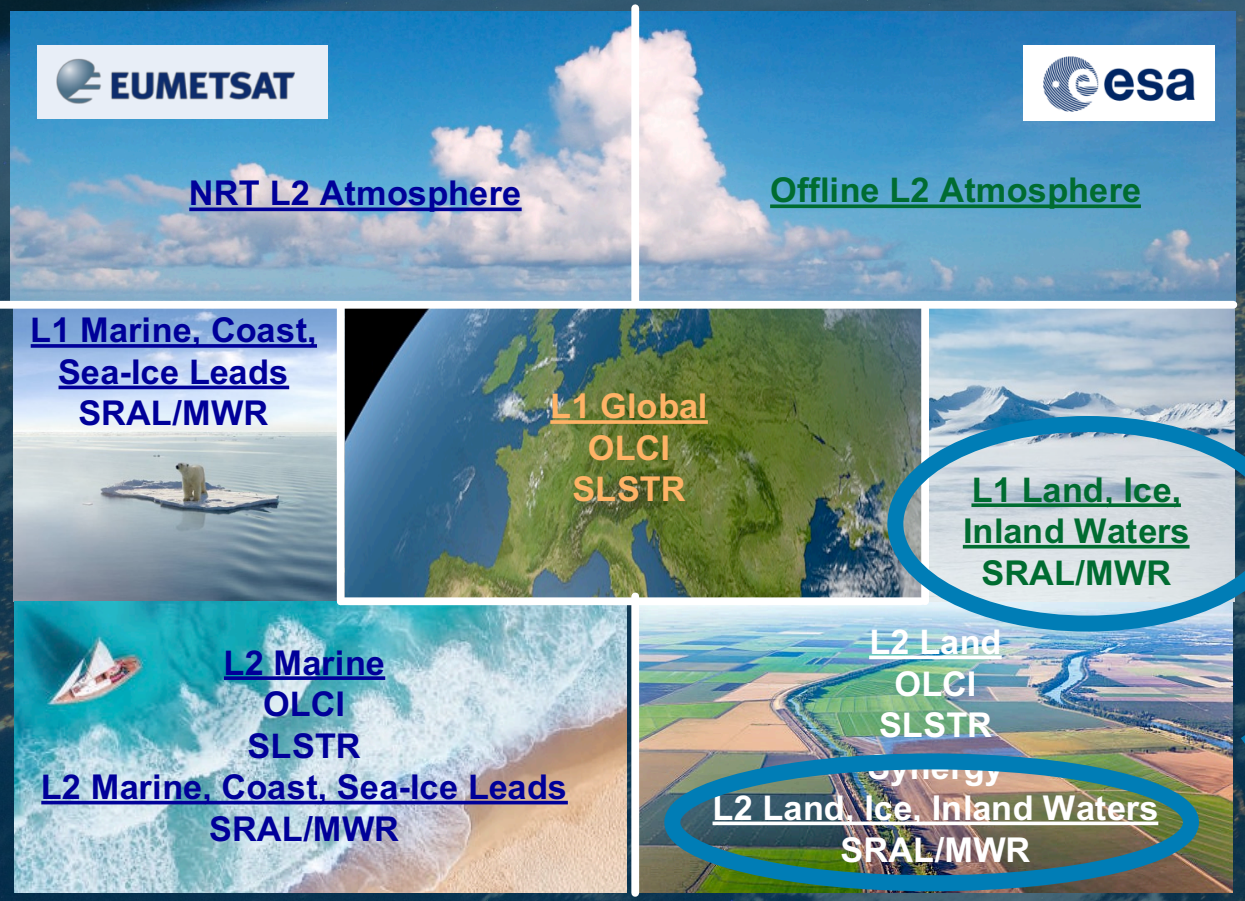
S3 Validation Team,

S3 Altimetry Quality Working Group

Venice, 31 October 2022

2022 OSTST Conference

Sentinel-3 Mission DATA product responsibilities

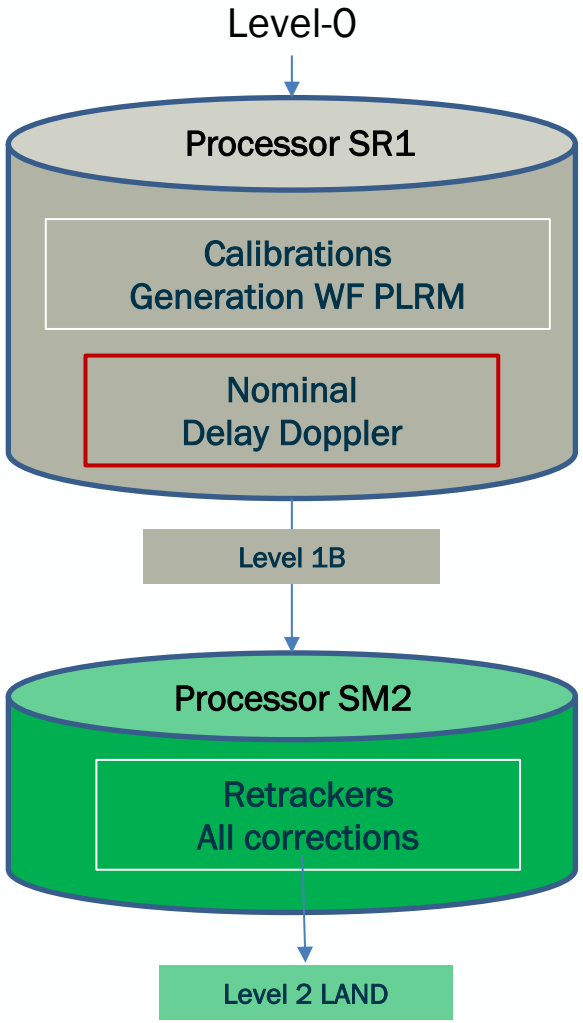


ESA S3 Land Surface Topography Mission (STM) core data products cover:

- Continental Surfaces
- Inland Waters
- Sea Ice
- Land Ice

New Sentinel-3 LAND Altimetry Thematic Products

Current operational processor



Level 1: **One** SR1 processor.
Level 2: **One** SM2 processor.

Nominal Delay Doppler applied at Level 1

One global **user product** as L1 output:

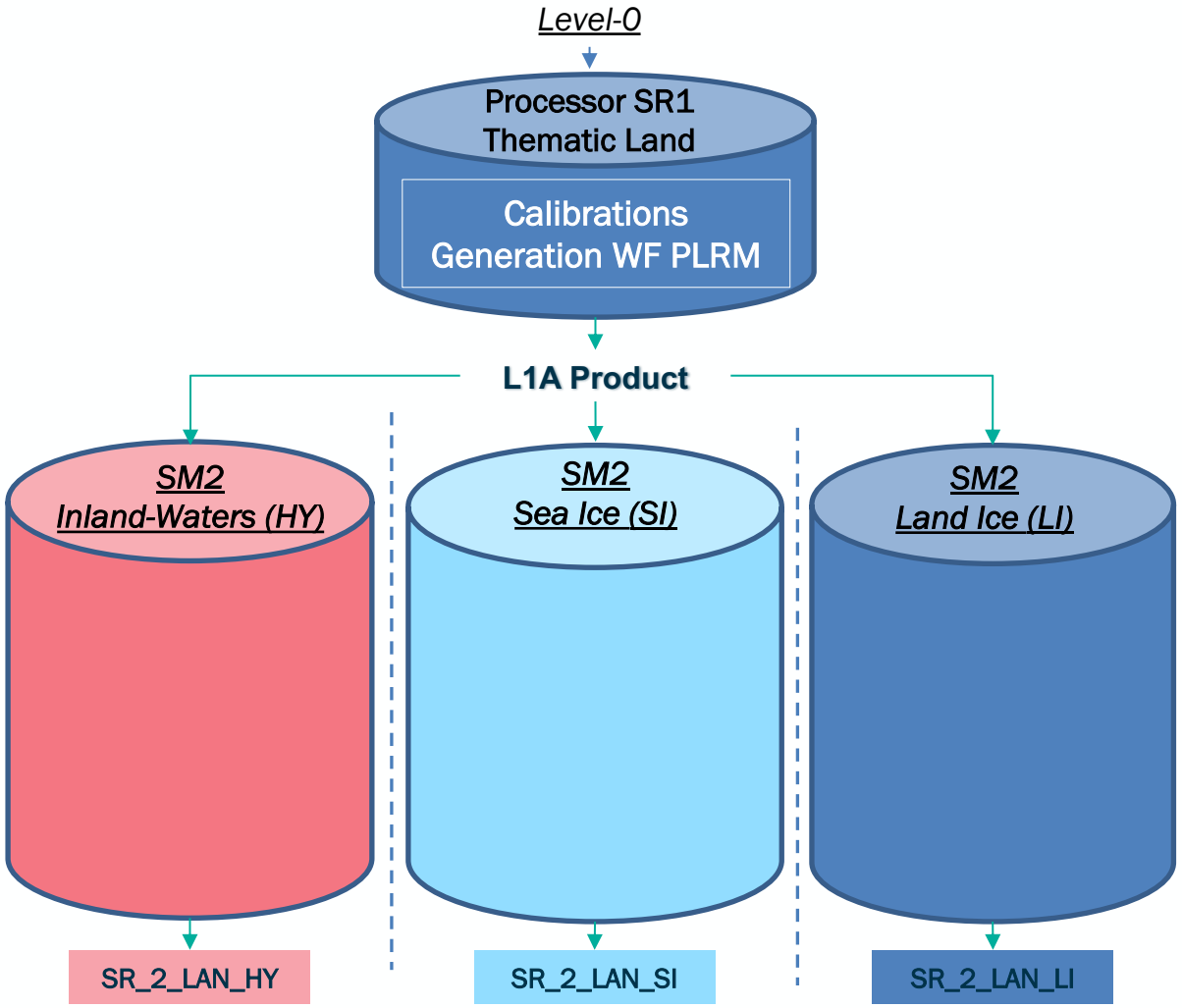
- ❑ **Level 1B.**

One **L2 LAND product**

- ❑ **Standard_measurement** file, containing the main variables (geophysical estimations, geophysical and instrumental corrections),
- ❑ **Enhanced_measurement**, which contains additional information for expert users (radar waveforms, MWR brightness temperatures),
- ❑ **Reduced_measurement** file, containing a subset of the main 1-Hz variables.

New Sentinel-3 LAND Altimetry Thematic Products

New Thematic Processors for LAND surfaces



Level 1: One SR1 processor with one user product as L1 outputs:

- **Level 1A**

Level 2: Three independent SM2 processors, with three L2 Thematic Products covering the surfaces:

- **L2 Hydrology** : S3*_SR_2_LAN_HY
- **L2 Sea-Ice**: S3*_SR_2_LAN_SI
- **L2 Land-Ice** : S3*_SR_2_LAN_LI

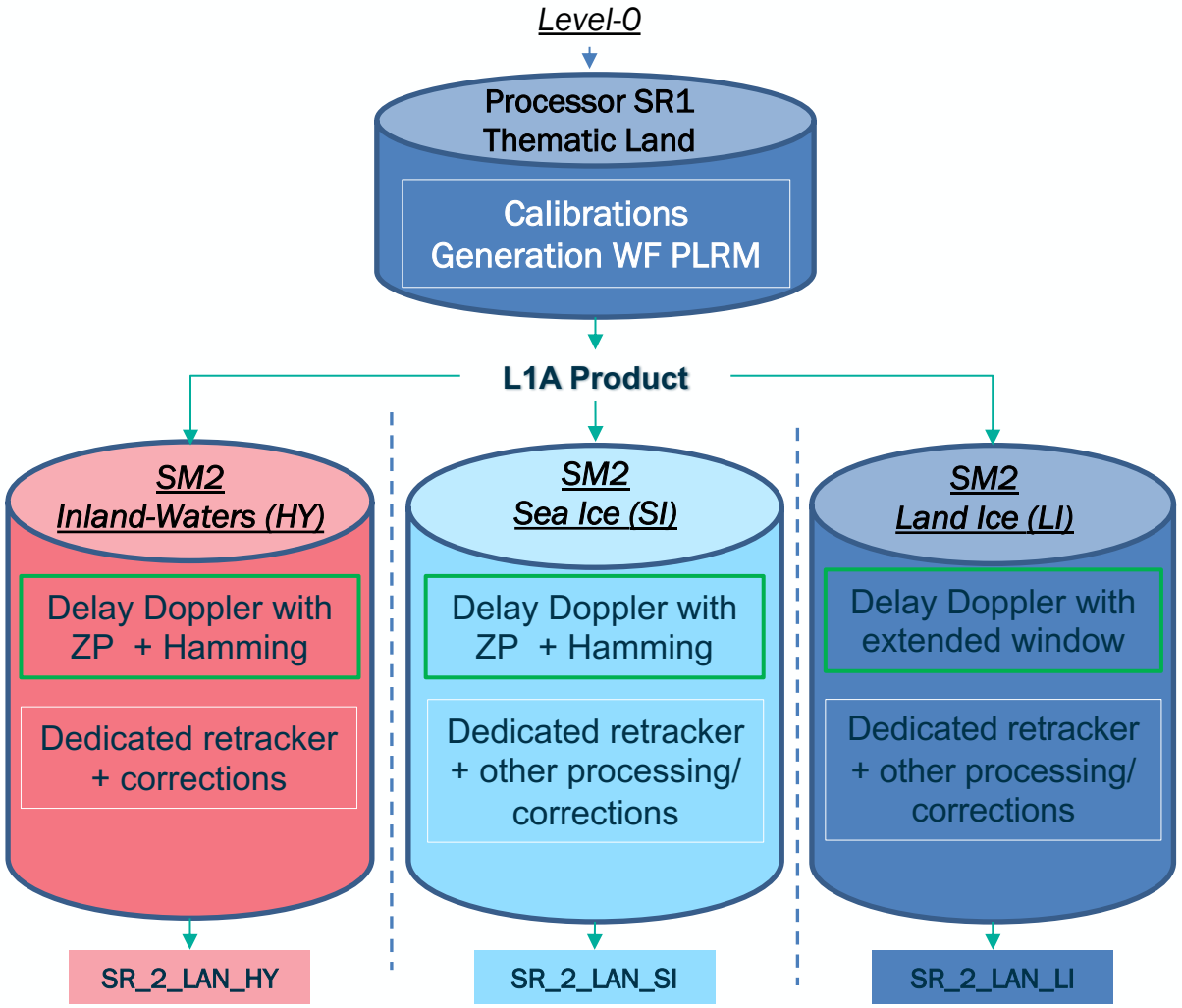
Two NetCDF files for each thematic products:

- **Standard_measurement**
- **Enhanced_measurement**

The operational production is planned to start in Q2 2023, but S3 Land Altimetry Thematic products are anyway generated and **available since August 2022 from the ESA Open Access Hub !**

New Sentinel-3 LAND Altimetry Thematic Products

New Thematic Processors for LAND surfaces



Separated/dedicated delay-Doppler for each processor

- ❑ Better flexibility to upgrade each processing chain, to address the particularities of the three thematic surfaces
- ❑ The Sentinel-3 LAND Thematic Products will evolve and improve more efficiently over time

SI and **HY** include **Zero-Padding** and **Hamming filtering**

- ❑ Better sampling sharp leading edges, and
- ❑ Reduces the effect of the side-lobes of the azimuth impulse response over specular surfaces.

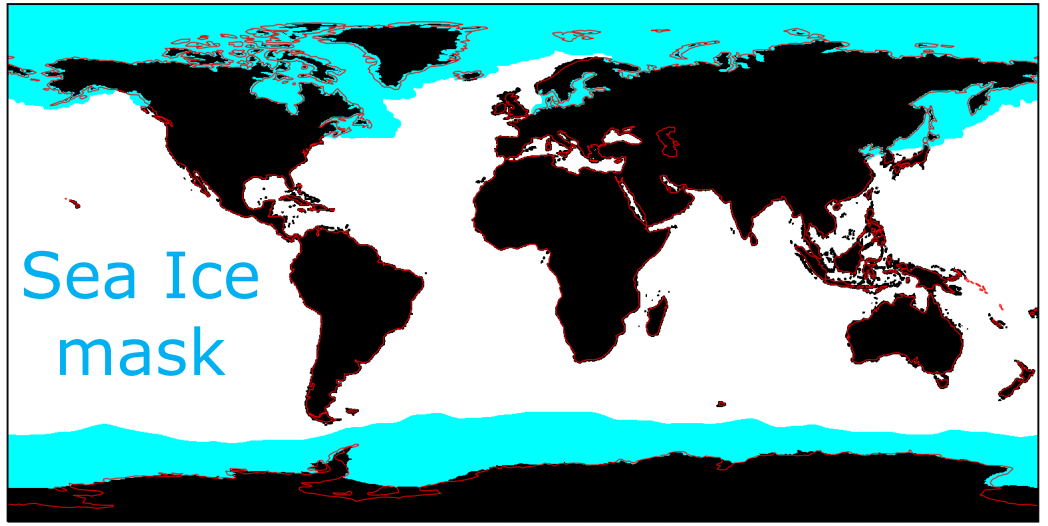
LI includes a delay-Doppler processing with "**extended-window**", to improve the data coverage over the ice margins

Overview of the Sentinel-3 Thematic Mask

Data Coverage and Partitioning

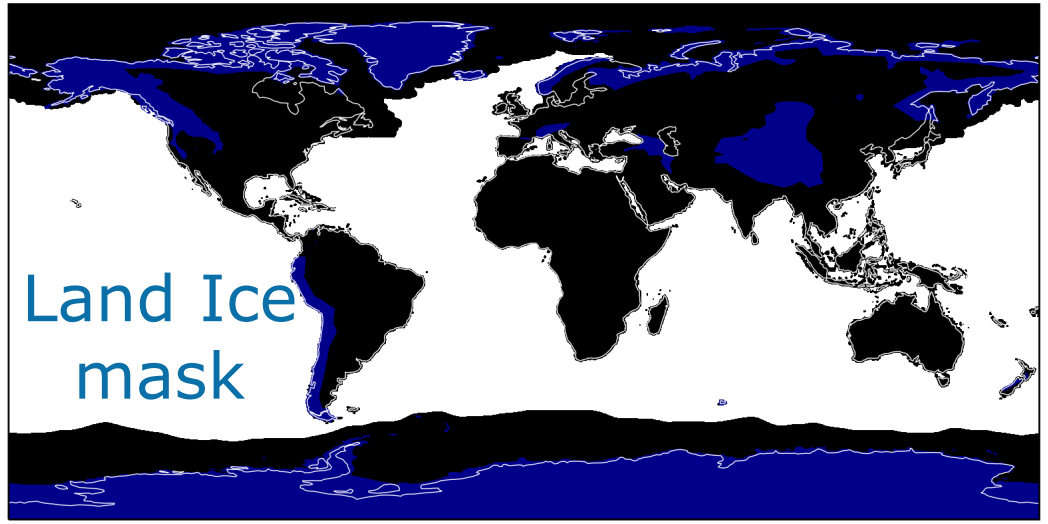
- Each Sentinel-3 Land Altimetry Thematic product covers dedicated areas, defined as **Thematic Mask**
- While the tracks of the current global LAND products are processed and delivered “Pole-to-Pole”:
  - Thematic Sea Ice and Land Ice products will be “**Equator-to-Equator**” (to ensure data continuity over the poles).
  - Thematic Hydrology products will remain “**Pole-to-Pole**”

E2E



P2P

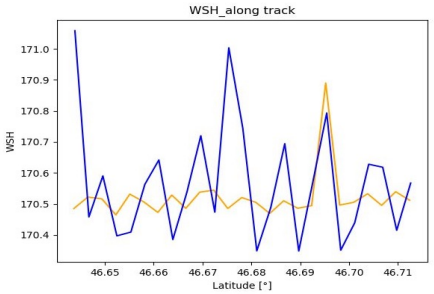
E2E

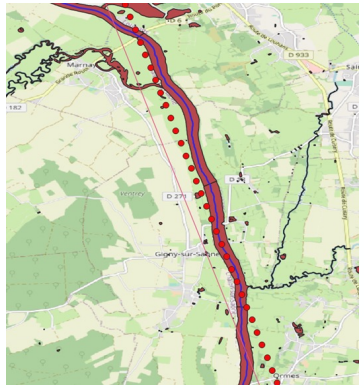


Assessment of the S-3 Land Altimetry Thematic Products

- ✓ First analyses performed by the S3 MPC Expert Support Laboratories (ESL) show that **performances meet the expectations,** the data quality has **greatly improved** over the 3 surfaces !
- ✓ New Processing Baseline (PB) evolutions planned as defined in S3 Land Altimetry PB Evolution Roadmap

Hydrology

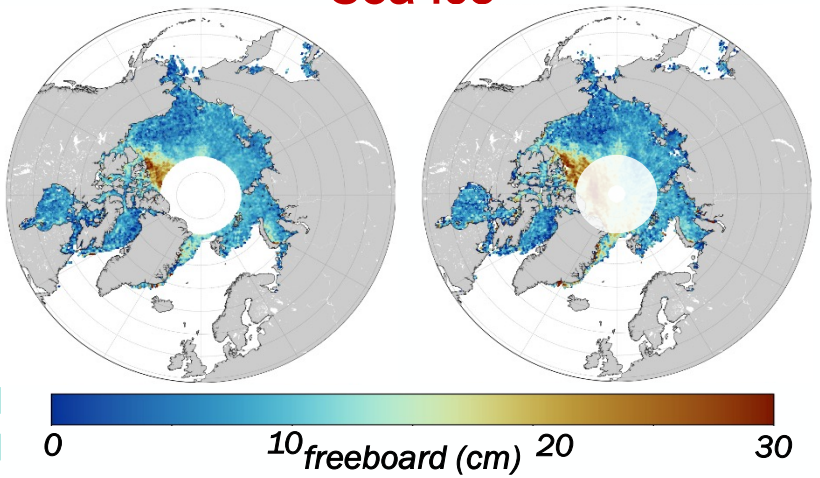




WSH along a river section:
blue = current LAND products
orange = new HY thematic products

Over lakes, average noise level of WSH decreases by about 15%. Precision over rivers strongly enhanced too

Sea Ice

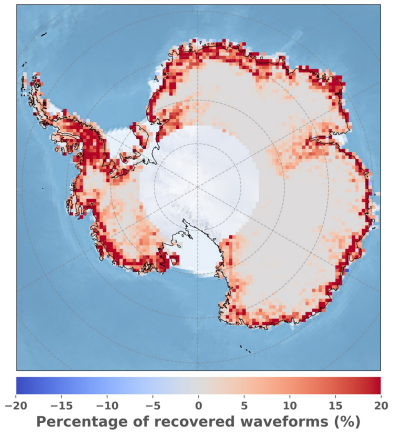


January/February 2020 gridded freeboard

Freeboard is now in overall agreement with CS-2
(CS2: ICE Baseline-D, limited to 81° here)

Land Ice

*Maps showing the percentage of recovered valid waveforms**

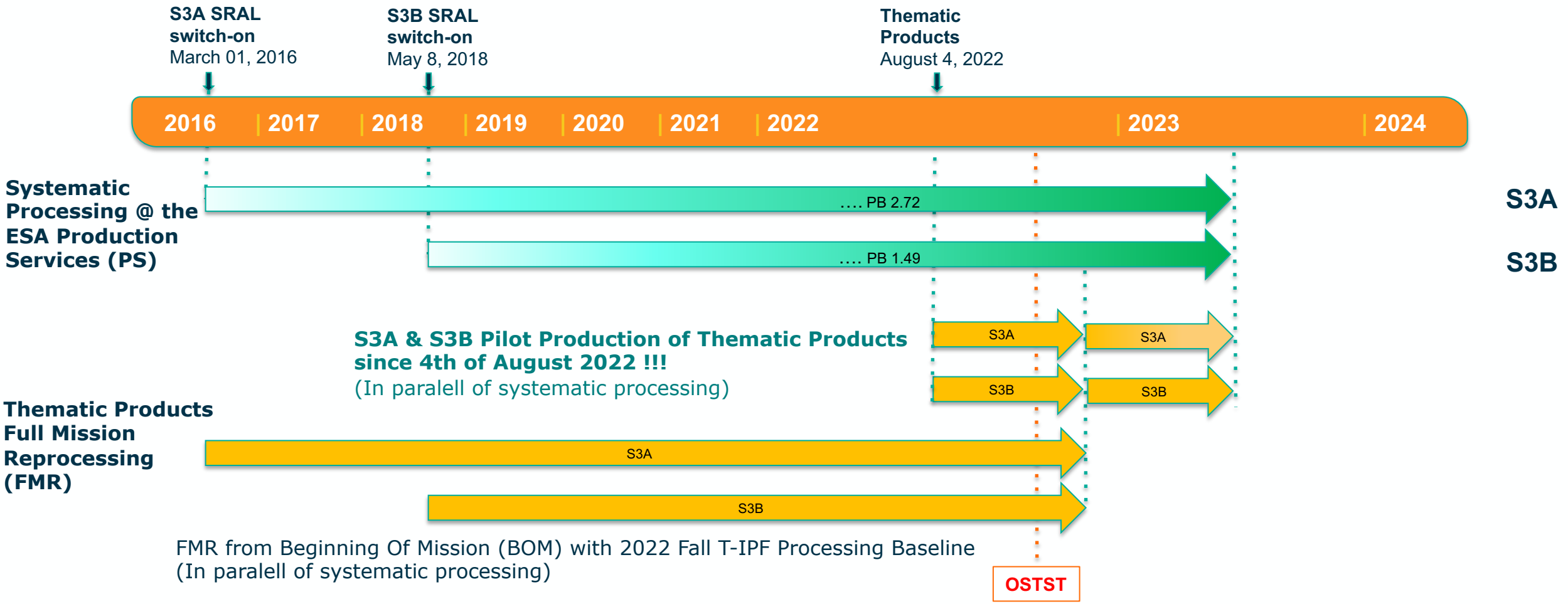


**Significant amount of valid waveforms are recovered over the ice margins*

**based on SNR and waveform quality flag*

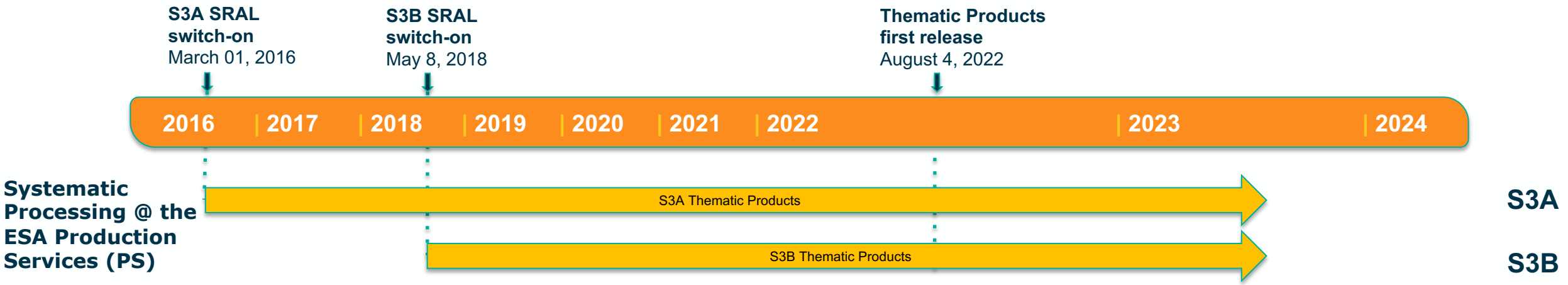
New Sentinel-3 LAND Altimetry Thematic Products

S3A & S3B STM: LAND Mission Data Set



New Sentinel-3 LAND Altimetry Thematic Products

S3A & S3B STM: LAND Mission Data Set



→ **Available from ESA Copernicus Open Access Hub**

→ **Will be switched to operational Processing Baseline after Full Mission Reprocessing (FMR)**

Full consistent Mission Data Set of S3 Thematic Products:
- Inland Waters
- Sea Ice
- Land Ice

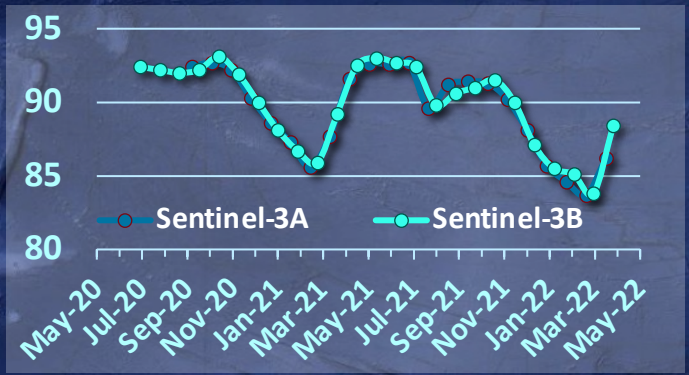
by Q2 2023

S3 Altimeter Operations and OLTC

Sentinel-3 OLTC Tables Status
(CNES/LEGOS/NOVELTIS)

New updates in 2022 !
S3A v6.2 (Sept. 8) and **S3B** v3.2 (Sept. 15)

Signal quality performance is monitored every cycle



Jason-3-int
≈ 60,000

Sentinel-3A Sentinel-3B
≈ 148,000 hydro targets

Sentinel-6-MF
≈ 64,000

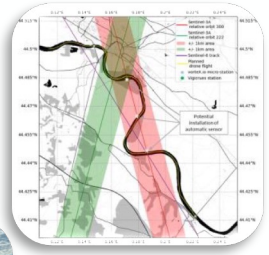
Rivers Lakes Reservoirs

St3TART Project - FRM Operational Provisioning

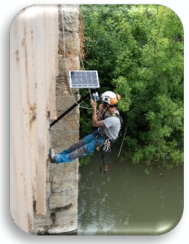
Looking toward an operational provision of FRM !

St3TART duration: 18m KOM: July 2021
St3TART Follow-On to be initiated in 2023 → **S3 FRM Roadmap Implementation**

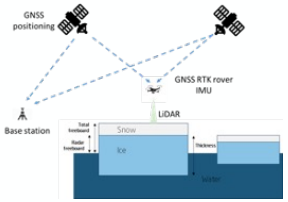
1. Sites identification

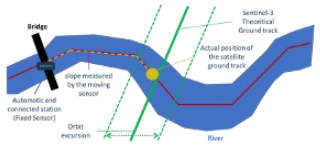


2. Campaigns



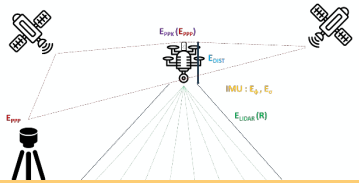
3. FRM Strategy Definition





$$WSH_{FRM}(t) = WSH_{FS}(t + \delta_{ts}) + (\Delta WSH_{slope} - Corr_{evo\_tempo})$$

3. Uncertainties Definition

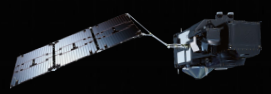


	Land waters	Sea Ice	Land Ice
	 © vorteX.io	 © DTU	 © IGE
Validation, FRM protocols & procedures	• Define and consolidate **methods and protocols for the validation** of the Sentinel-3 Altimetry Land products **with Fiducial Reference Measurements** (FRMs)		
Roadmap for S3 STM Land FRM operational provision	• Identify existing networks and **assess the needs** for permanent sensors and campaigns. • **Prepare a roadmap for the operational provision of FRM data to support the Sentinel-3 Altimetry Land validation**		
FRM campaign preparation and execution	• **Deploy and operate** in-situ sensors, perform campaigns to collect FRM data • **Provide FRM data** to the Copernicus Sentinel-3 STM		

See Science IV: Altimetry for Cryosphere and Hydrology - Elodie Da Silva et al - **Towards FRM observations for hydrology and cryosphere Sentinel-3 Cal/Val activities: the St3TART project** - Thursday 3 November 2022

Copernicus Sentinel-3

Visible, Thermal Infrared and radar altimetry measurements for 20+ years

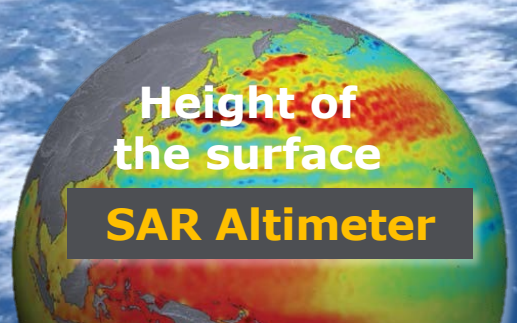


S3D: 2027+ (TBC)

S3C: 2024 (TBC)

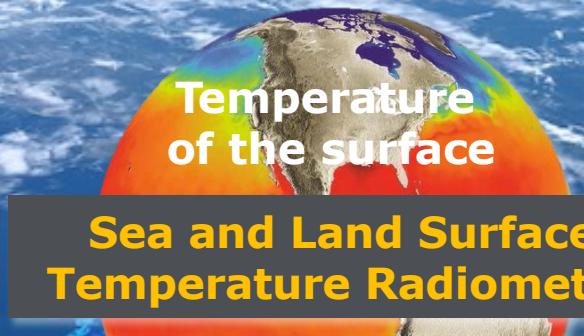
S3B: 2018-

S3A: 2016-



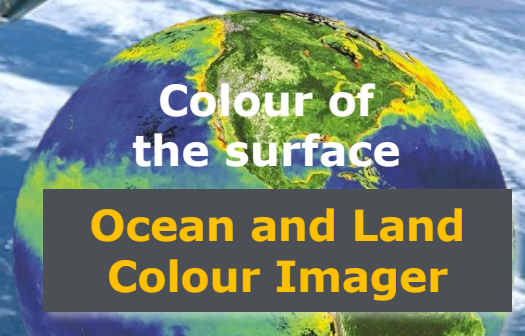
Height of the surface

SAR Altimeter



Temperature of the surface

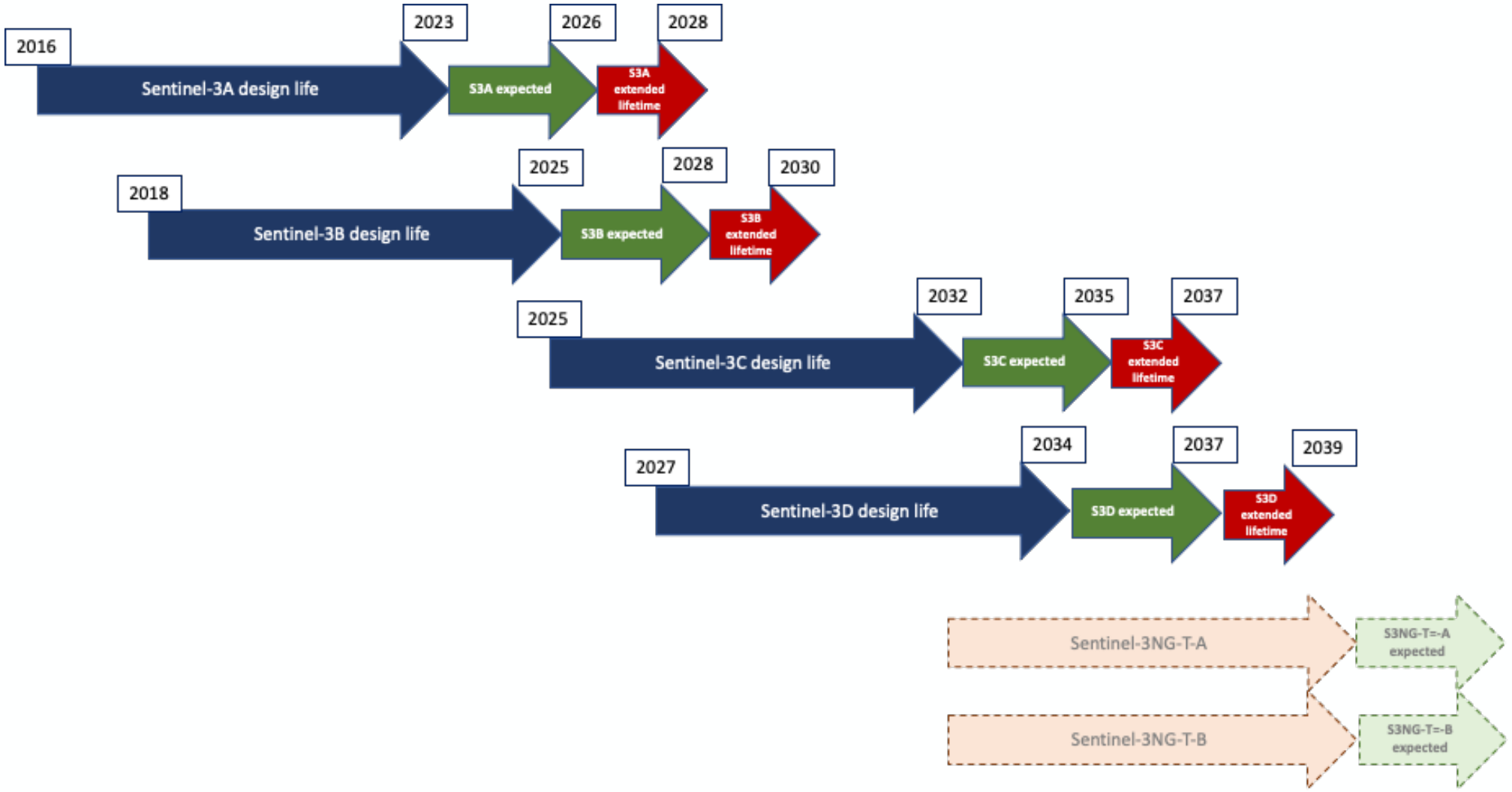
Sea and Land Surface Temperature Radiometer



Colour of the surface

Ocean and Land Colour Imager

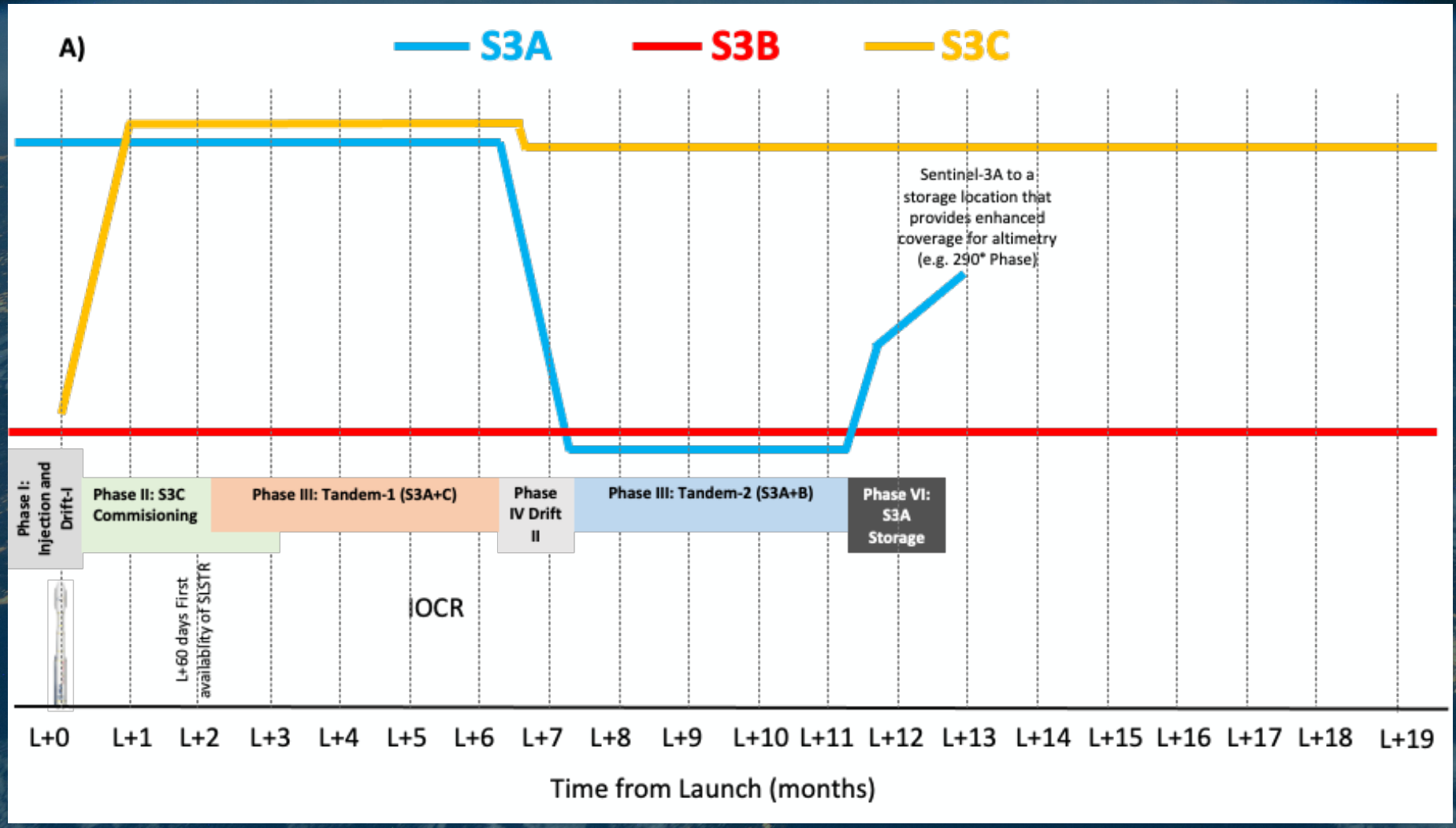
Sentinel-3 Constellation Overall Schedule



Tandem Phase Scenario

WORK IN PROGRESS

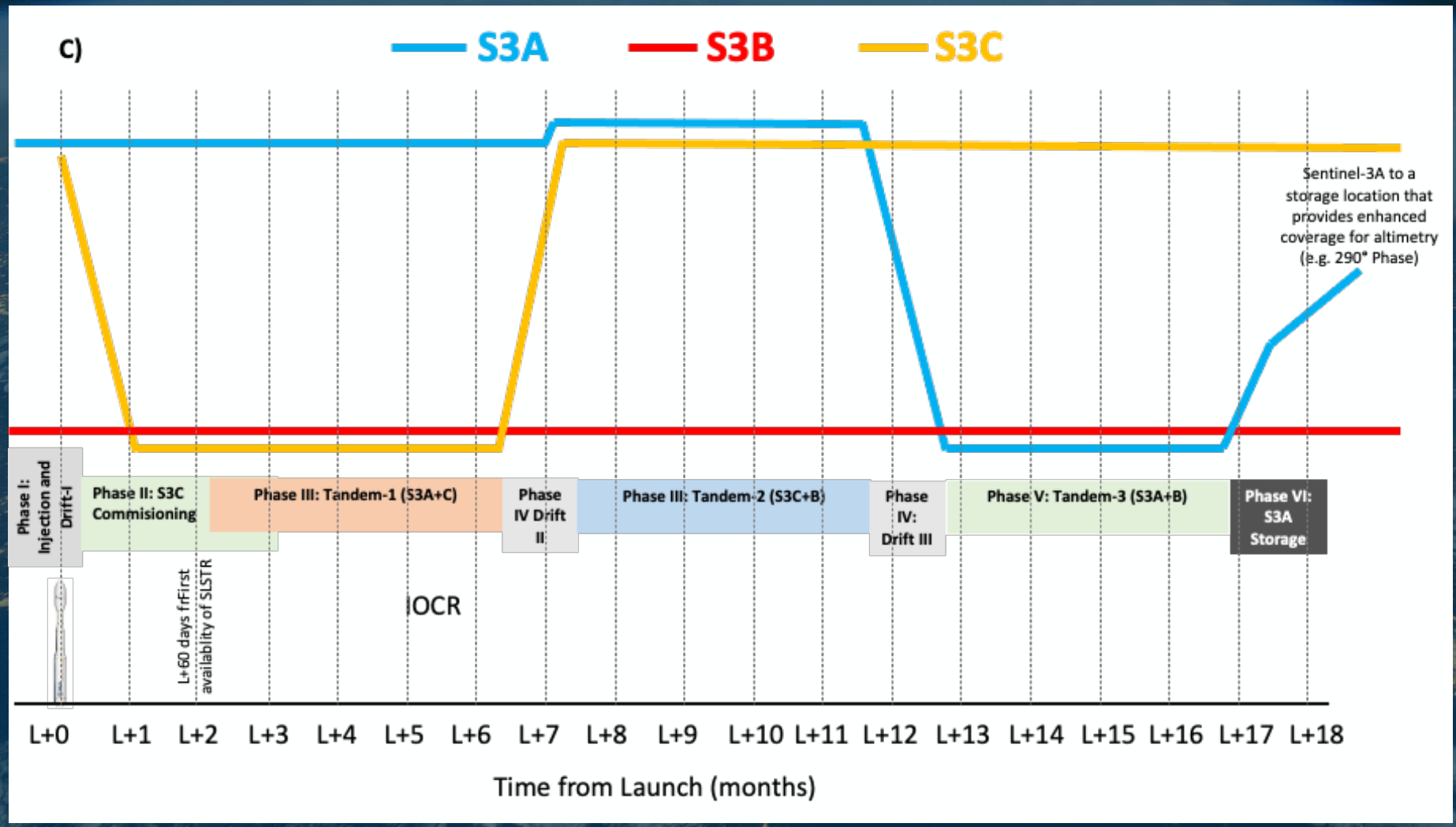
Scenario A)



Tandem Phase Scenario

WORK IN PROGRESS

Scenario C)

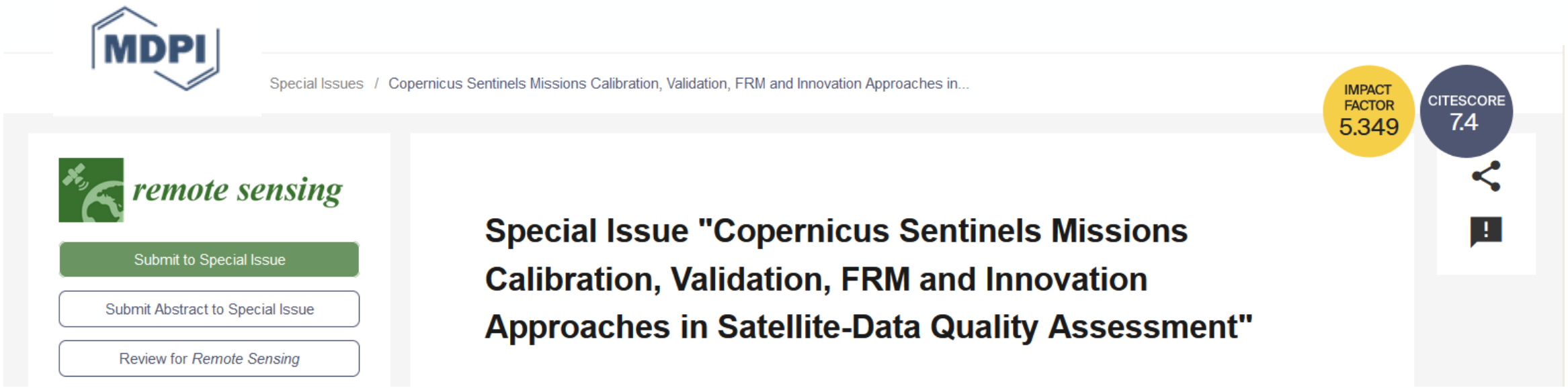


Conclusions

- The **S3A & S3B STM LAND products are today fulfilling the S3 mission requirements** over all surfaces (e.g. Inland Waters, Land ice & Sea-Ice)
- Tailored and dedicated **L0-to-L2 Thematic Processors** are providing “Enhanced” Land Altimetry **L2 Thematic Products** since 4th of August 2022
- A **Full Mission Reprocessing (FMR)** of the **S3A and S3B Land Altimetry L2 Thematic Products** will be completed by Q2 2023 and available from the ESA Open Access Hub
- S3C and S3D are ready to take over from S3A and S3B to extend the time series

Thanks !

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



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

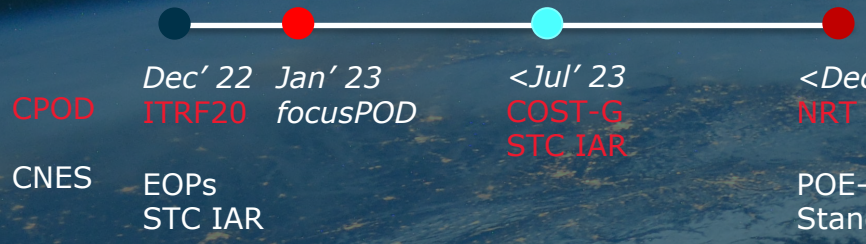
- **remote sensing of atmospheric composition, land, ocean, snow and ice surface,**
- **calibration and sensors' intercomparison,**
- **validation of geophysical data products,**
- **innovations to products' retrieval algorithms and Cal/Val techniques,**
- **Fiducial Reference Measurements (FRM) for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

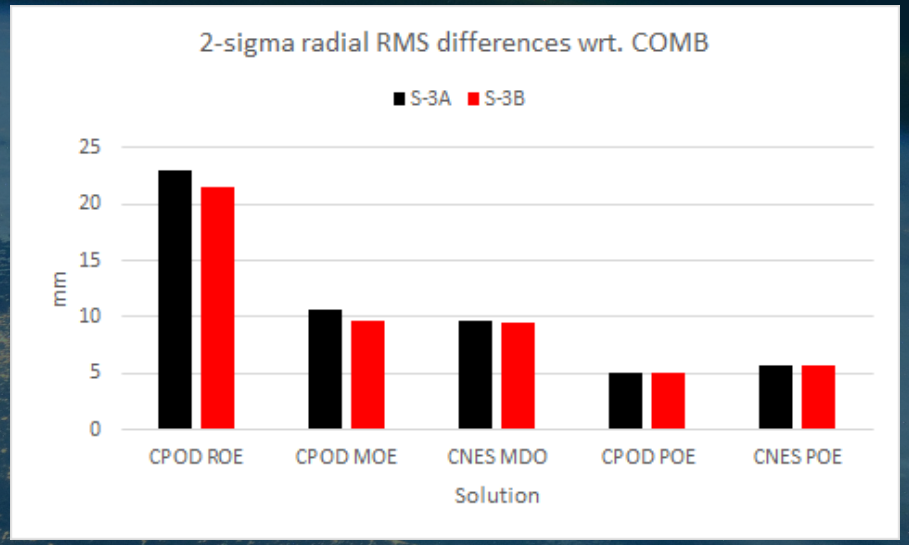
https://www.mdpi.com/journal/remotesensing/special_issues/J3CYH3OQV0#editors

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

Deadline for manuscript submissions:
30 June 2023

Sentinel-3 Precise Orbit Determination – S3 POD





CPOD Next steps

- ITRF20: New reference frame (< Dec' 22)
- *focusPOD*: New POD SW in substitution of NAPEOS (< Jan´23)
- COST-G: New geopotential in substitution of EIGEN.GRGS.RL04 TVG (< Jul´23)
- IAR: Integer Ambiguity Resolution in STC and NRT (< Dec´23)

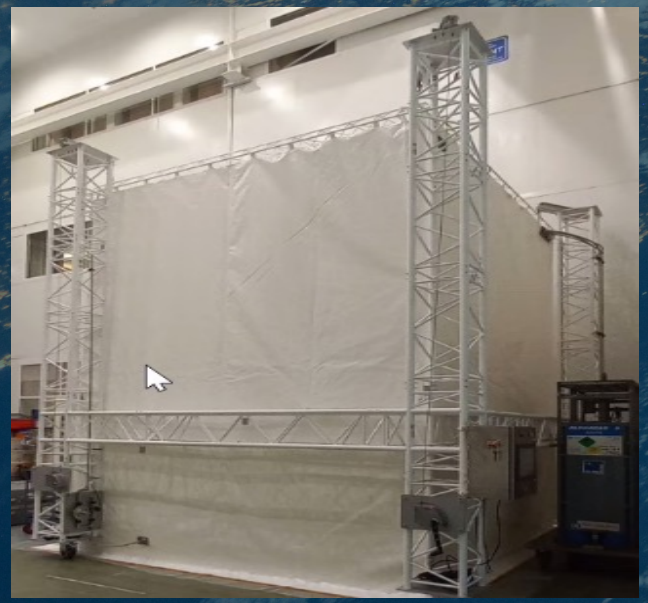
CNES Next steps

- STC: Adopt daily updates of Earth Orientation Parameters (< Dec' 22) and integer ambiguity resolution.
- STC/NTC: Switch to the new POE-G Standards (< Dec' 23):
  - Displacement of reference points: ITRF/DPOD/SLRF2020,
  - DORIS: relativistic correction and improved phase data-screening,
  - GNSS: improved ambiguity-fixing strategy, use of IGS satellite attitude quaternions (ORBEX),
  - Geopotential: updated time-varying gravity field model,
  - Surface forces: Earth radiation pressure model based on CERES data, new DTM2020/NRLMSIS2.0 thermosphere models.

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
  - Close-out April
  - All actions completed June 2022

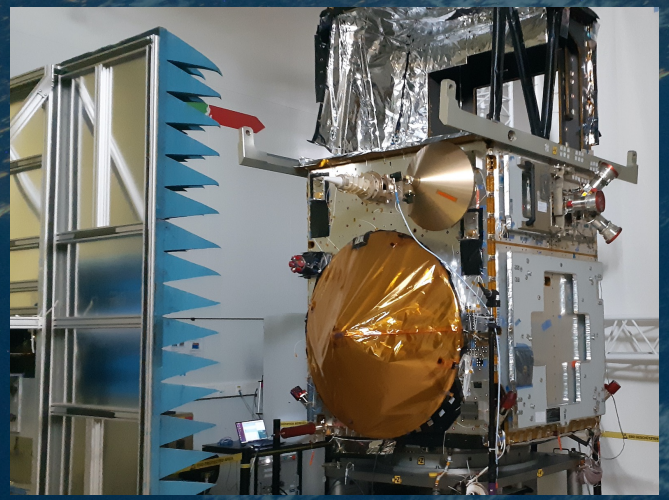


- Satellite in Storage
  - Satellite in tent, with N2 purging
  - SLSTR-C in storage in Leonardo
- Periodic maintenance performed Oct/Nov 2022
  - SRAL & MWR full functional tests
  - MWR Blanking signal
  - SRAL Cal1, Cal2

Sentinel-3 C/D Satellite Status

Sentinel-3D

- Satellite partially integrated (PF/TOPO)
  - Platform, SRAL, MWR, DORIS, GNSS
  - All testing completed up to this build level
  - Pre Storage Review completed
- Optical instruments integrated onto satellite after storage
  - OLCI PSR completed
  - SLSTR radiometric calibration in RAL, UK on-going



- Satellite (PF/TOPO) in Storage
  - Satellite in tent, with N2 purging
  - Periodic maintenance performed Oct 2022
    - MWR tests as per S3C
    - SRAL Cal1 & Cal2 performed in frame of RF reference tests
    - Functional test as part of periodic maintenance
- OLCI periodic maintenance performed Oct 2022

Sentinel-3 C/D Satellite Status

Satellite Activity Milestone dates:

- S3C Flight Acceptance Review : Feb 24 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 agreement with EC and ArianeSpace
  - In the window Dec 2024 – end 2025
- De-storage notification at L-17
  - Team ramp-up (Prime & subcos)
- Satellite/instrument de-storage & Phase E1 activities start at L-12