Sentinel-3 LAND Altimetry Status

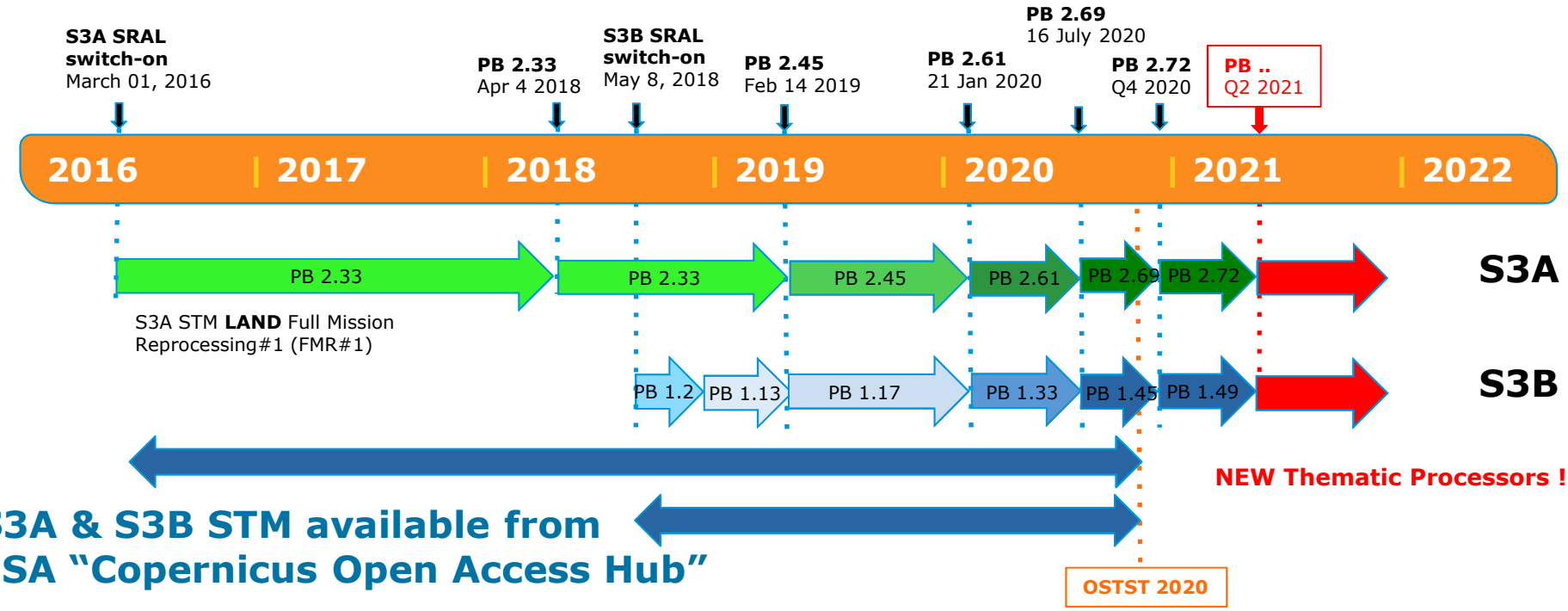
Pierre Féménias – ESA ESRIN

- the S3 Altimetry Mission Performance (MPC) Team
  - M. Raynal, G. Jettou, N. Taburet, M. Denneulin, L. Amarouche, A. Bourdeau (CLS)
  - G. Quartly (PML)
  - D. Blumstein (LEGOS)
  - P. Nilo, A. Garcia-Mondejar (isardSAT)
  - A. Muir, D. Brockley (MSSL)
- ESA ESTEC & S3 Mission Management

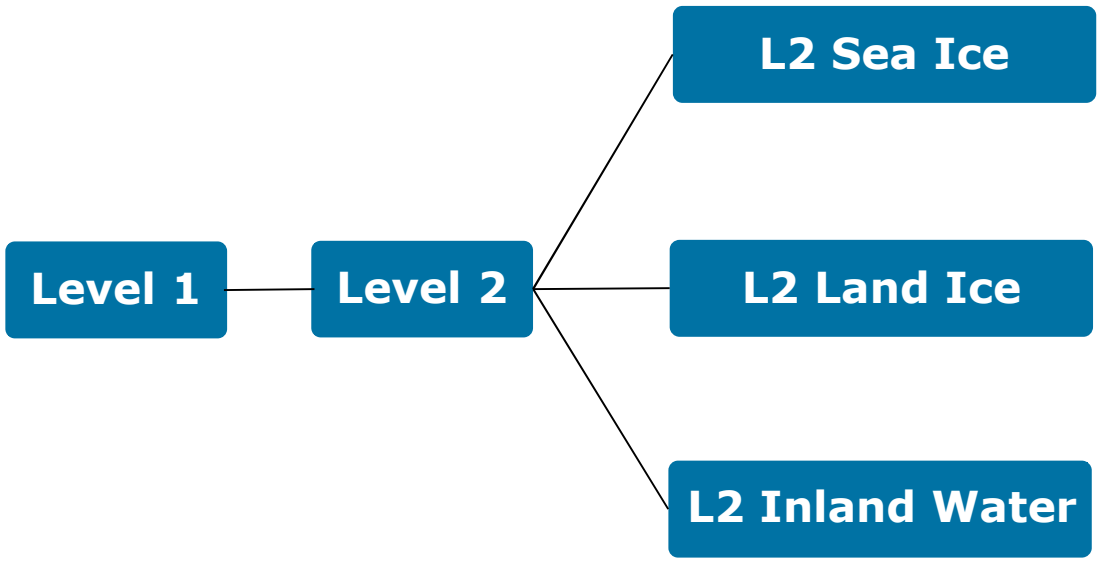
European Commission

esa

S3A&B STM: LAND Mission Data Set



S3 STM LAND Thematic Processors



Level 2 Sea Ice
Generated over Sea Ice
Includes all parameters specific to Sea Ice
WF are over-sampled

Level 2 Land Ice
Generated over Land Ice
Includes all parameters specific to Land Ice
WF extension and centring

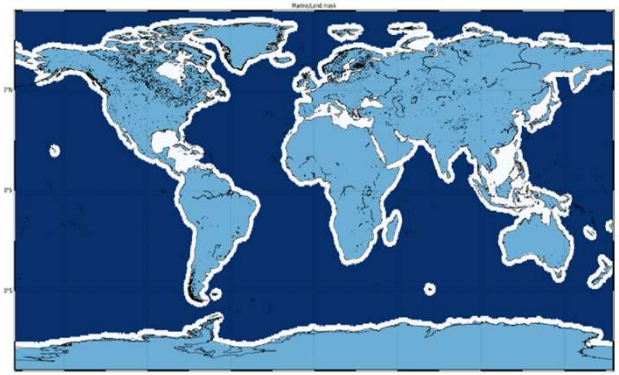
Level 2 Inland Water
Generated over Inland Water
Includes all parameters specific to Inland Water
WF are over-sampled

→ Strongly recommended by Copernicus Services (CMEMS, CGLOPS) and user community

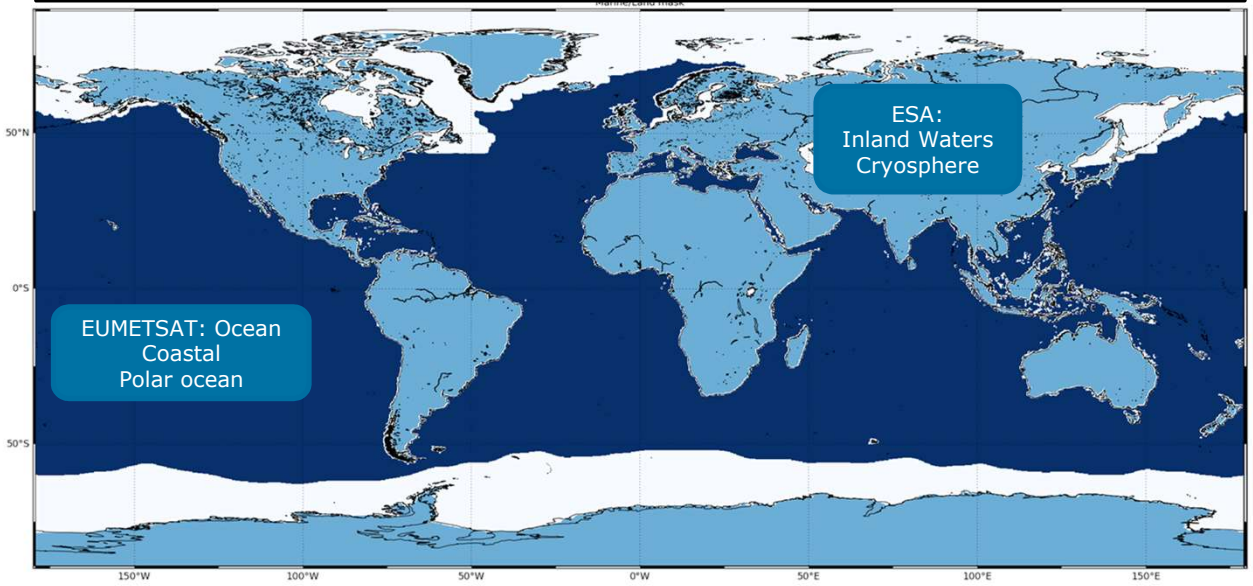
→ Allows tailoring & dedicated processing per surface type, i.e. evolutions in processing baseline and product content

S3 STM LAND/MARINE Mask

Old Land/Marine mask



New Land/Marine mask



New Mask Operational since 9 July 2020 !

Surface	Updated Mask definition
Common	Along the coastline limited to 50 km : 25 km extent on both sides of the coastline + sea ice areas + lagest lakes
Land	Inclusion of sea ice areas (arctic and Antarctic), corresponding to the maximum sea-ice extent
Marine	Inclusion of 10 largest lakes in the "Marine surface" (e.g. Lake Victoria, Lake Superior, Lake Victoria)

Marine

Land

Common

S3 LAND STM L1 & L2 Processing Baseline Evolution

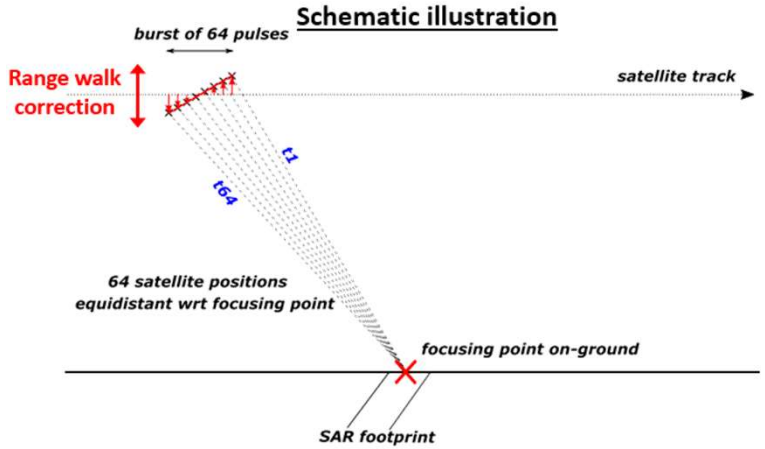
- **STM L1 Land IPF Delivery by fall 2020**
  - Bug fixing
- **STM Land L1 & L2 Thematic IPFs delivery by April 2020**
  - New Thematic IPF's shall be delivered:
    - by April 2021 for S3 Sea-Ice, Land Ice and Inland Water branches
  - Shall include as for L1 Marine
    - Truncation
    - Update of L1A Product with the additional variables
    - Implementation of Land/Sea mask at L1
- **STM Land L1 & L2 Thematic IPFs Evolutions by fall 2021**
  - Drift fix (Calibration processing update, Range walk)
  - Zero masking
  - Additional retrackers (TBC)
  - Geophysical corrections at 20Hz
  - Flag OLTC
  - …

SARM range drift investigation and correction

A significant drift has been detected on the S3A SAR GMSL trend: **about +1.7 mm/year** with an uncertainty of **1.2 mm/y (95% CL)** *(Meyssignac and Ablain presentation OSTST 2019)* ➔ ***Understood***

- **0.3 mm/year** are due to the evolution of PTR shape **in range direction** (ageing of the instrument) not correctly accounted for in the MLE4 (PLRM) and SAMOSA DPM2.5 (SARM) retrackers *(JC.Poisson / S.Dinardo OSTST 2019).* **Retrackers using the real instrument PTR allow to correct this effect (e.g.: adaptive retracker)**

- **About 1.3 mm/year** are due to the evolution of PTR shape **in azimuth direction** (ageing of the instrument). A recent study (see J. Aublanc et al. presentation in instrument processing session) showed that the implementation of the **range walk correction** (Scagliola et al., 2019) allows to correct the range drift induced. Only the SARM is impacted.



Objective of the range walk correction : to compensate the range variation during the burst acquisition wrt focusing point.

S3A & S3B STM Inland Waters & OLTC tables

S3A
- 33.261 Virtual Stations since 9 Mar 2019 (OLTC V5.0)
- **67735 Virtual Stations over rivers, lake or reservoirs since 27 Aug 2020 (OLTC V6.0)**

S3B
- 32.515 Virtual Stations since 24 Nov 2018 (OLTC V2.0)
- **69086 Virtual Stations over rivers, lake or reservoirs since 18 Jun 2020 (OLTC V3.0)**

Both altimeters in OLTC in ±60° Latitudes + targets already defined at higher latitudes (to be used after ZDB update)

→ Inclusion of a very large number of northern small lakes !

More details in Taburet et al. *Remote Sens.* **2020**, *12*(18), 3055; https://doi.org/10.3390/rs12183055

See also Le Gac S. presentation on new OLTC versions

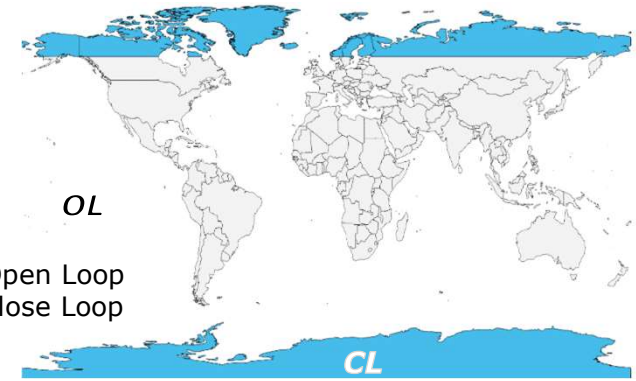
✓ More than 136.000 Virtual Stations over rivers and lakes with S3 constellation !

Visit and contribute @https://www.altimetry-hydro.eu

S3A & S3B STM - Acquisition modes

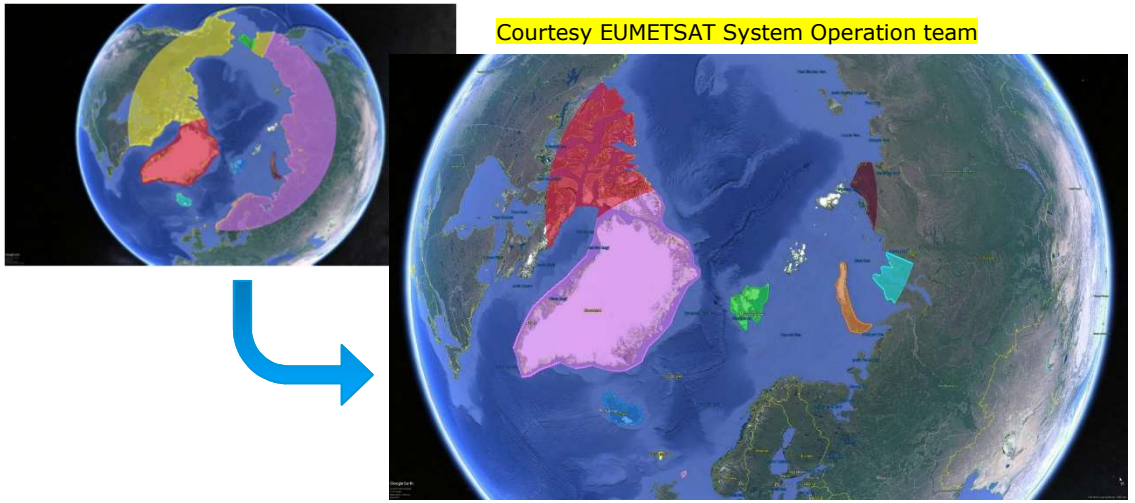
➔ OL and CL areas are defined by the Zone Data Base (ZDB) model

Sentinel-3A and Sentinel-3B ZDB



OL = Open Loop
CL = Close Loop

Courtesy Le Gac S. (CNES)



Courtesy EUMETSAT System Operation team

➔ Extension of OL zone beyond 60° N. latitude where many small lakes are defined in OLTC

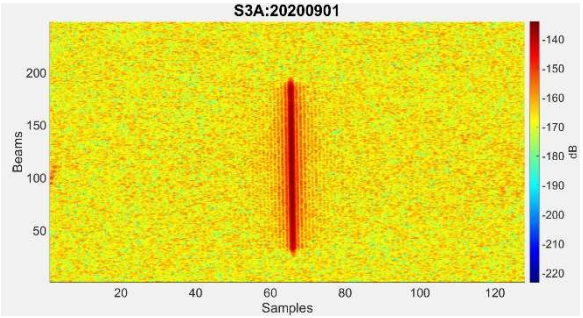
➔ S3A&B ZDB will be updated on 21/10/2020 for S3B and on 07/11/2020 for S3A

S3 Sigma0 Transponder Qualification

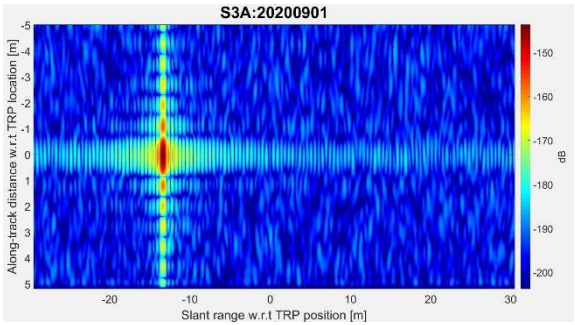
- S3 Sigma0 transponder successful FAT on 27 May 2019
- Successful field testing performed over Jan 20 to Sept 20 in Tuscany
- Deployment and operations on final calibration site will be part of the new S3 ALT-MPC contract [mid-2021-2026]

Deployment of Sig0 TRP with pedestal

Delay Doppler processed TRP signal from 1st of September 2020



Fully Focused processed TRP signal from 1st of September 2020



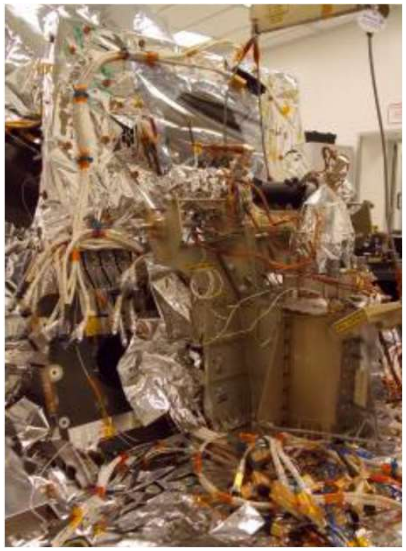
Sigma 0 results after 6 acquisitions	Delay Doppler SAR	FULLY FOCUSED SAR
Average RCS obtained [dBm^2]	68.76	68.80
Expected values from SeRAC09 doc	67.89	67.89
Bias	**0.87 dB**	**0.91 dB**
Standard Deviation	**0.92 dB**	**0.32 dB**

➔ Successful results obtained for both Delay Doppler and Fully Focused methods showing good agreement between them.

Sentinel-3CD Satellite Status

- **Sentinel-3C & -3D platforms completed and delivered to TAS, Cannes**
- **System level activities started on both satellites and progressing well**

S3D Delivery to Cannes



SLSTR CCA mounted on OME

- S3C Instrument level activities on-going
  - OLCI-C delivered and integrated onto S3C
  - MWR-C planned to be delivered Q4
  - SLSTR-C planned to be delivered Q1/2021
  - SRAL anomaly under investigation
- S3D Instrument level activities on-going
  - Instruments planned to be delivered in 2021
  - OLCI & SLSTR will not be integrated onto S3D but delivered ready for storage.

Sentinel-3CD Satellite Major Milestones

Current milestone dates: (on-going COVID restrictions may impact activities)

- **S3C Environmental campaign; Q2 2021**
- **S3C Flight Acceptance Review; Q4 2021**
- **S3D Pre-Storage Review; Q3/Q4 2021**
- **Storage for S3C & S3D starts after the associated review**

Launch date is to be defined by the Commission, but foreseen in the range

- **S3C; mid 2023 – end 2024**
- **S3D; end 2024 – end 2028**

Sentinel-3C phasing options

- A study identifying the options for a 3-satellite constellation phasing has been conducted related to the integration of Sentinel-3C in the Sentinel-3 Constellation
- A number of phasing options have been identified and analysed with 4 selected as the best candidates under the following assumptions:

a. Sentinel 3 orbital plane is unchanged : Altitude, Inclination and Local Time of the Descending Node being kept as they are

b. Sentinel-3 Models are operated within the 27 options provided by the two (A, B) active ground tracks, with the following rationale for what concerns the mission objectives

- ➔ Optical: Ensuring identical acquisitions conditions for all models
- ➔ Topo: Pursuing A duty over water and dedicated land targets after A end of life
  Ensuring Crete Transponder overflight by A, B and C

c. Optical Mission : Enhance the optical coverage up to requirements expectations

d. Topo Mission : improve the sampling of mesoscale ocean features while optimizing / reducing the inter-track minimum distance within the 4-days sub-cycle of the complete repeat cycle (27 days)

Sentinel-3C phasing options

- The Copernicus services have been asked by ESA and EUMETSAT to provide feedback on the selected options, and in the process CMEMS suggested two options which are being analysed and will be sent out to the remaining services for comments
- The feedback from the Copernicus services will be shared with the Commission, and the selected candidate(s) will be analysed for operational constrains and cost before a selection is made

Sentinel-3C phasing options

	Current	Optimizing Topo	Optimizing Optical	Optimizing Optical	Better Topo Optimized Optical
Constellation \ Acquisition	A 0° B 140°	A 0° B 140° C **293°**	A 0° B 140° C **240°**	A. 0° B 140° C **280°**	A 0° B 113° C. **240°**
OLCI Land	2.0 d	1.3	1.2	1.2	1.2
OLCI Ocean	3.0 d	2.0	1.8	1.8	1.8
SLSTR Nadir	1.5 d	0.75	0.75	0.75	0.65
SLSTR Back.	2.5 d	1.5	1.5	1.5	1.5
Minimum «4 day sub-cycle» intertrack distance	360 km	360	360	360	310
Revisit Time Topo	27 d	20	19	24	20

Recommendation from CMEMS: use 290° instead of 293.3° (Option 1) and 236.67° instead of 240° (Option 4). This will:

- Put unit C in between the two other (A, B) ground tracks (same time lag, same impact on downlink)
- Give a better spatial coverage (less duplication with unit A for mesoscale) and better space/time decorrelation
- Be relevant for new targets for geodesy (MSS improvement), polar ocean, coastal margins, and hydrology

Status for Sentinel-3 Marine Center

EUMETSAT altimetry team

and S3 management

Space segment operational status

Satellite

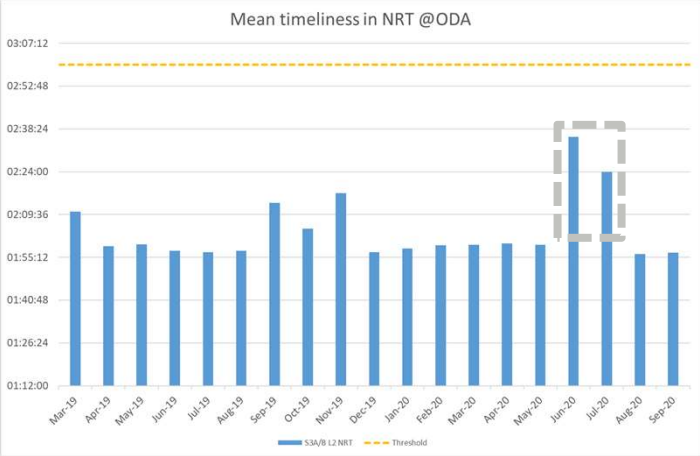
- All Sentinel-3A & B platform operations are performed nominally, including manoeuvres (In-plane and Out-of-Plane), security key changes and regular and annual calibration activities.
  - ✓ **Support to Sigma0 transponder testing**
  - ✓ **OLTC updates (S3A: 27/07/2020, S3B: 22/06/2020)**
- **Sentinel-3A&B topography instruments are all performing nominally**.

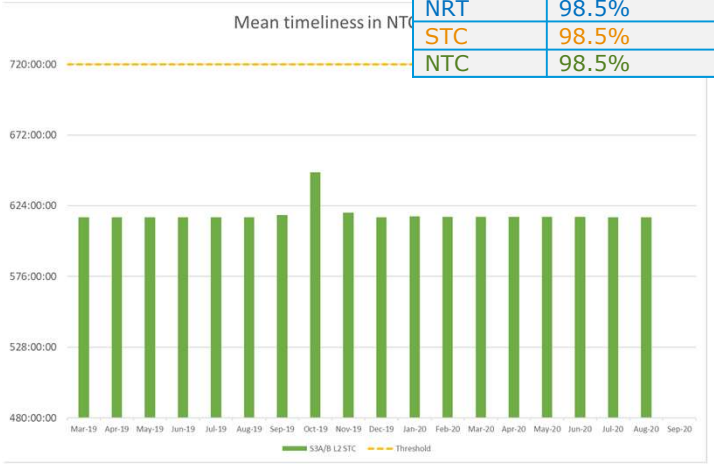
Anomalies

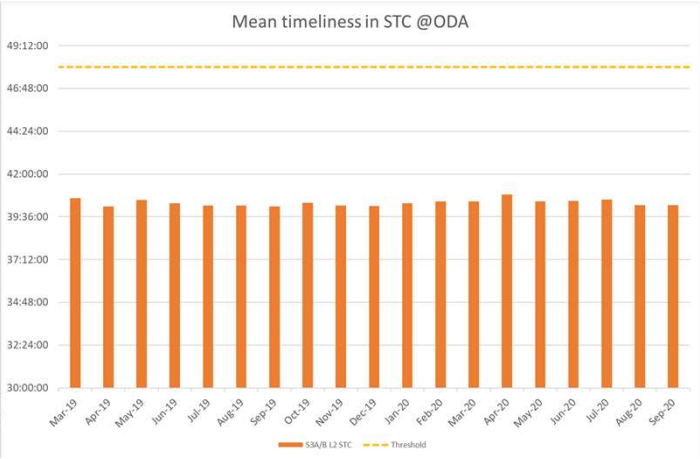
- S3B calibration issue after OLTC update (UNS 6018)
- No other relevant anomalies to report, several missing/late dumps (CGS issues) resulting in lower KPIs

Marine Center Status – Mean Timeliness

Timeliness	Completeness	Threshold
NRT	98.5%	< 3 hours
STC	98.5%	< 48 hours
NTC	98.5%	< 30 days





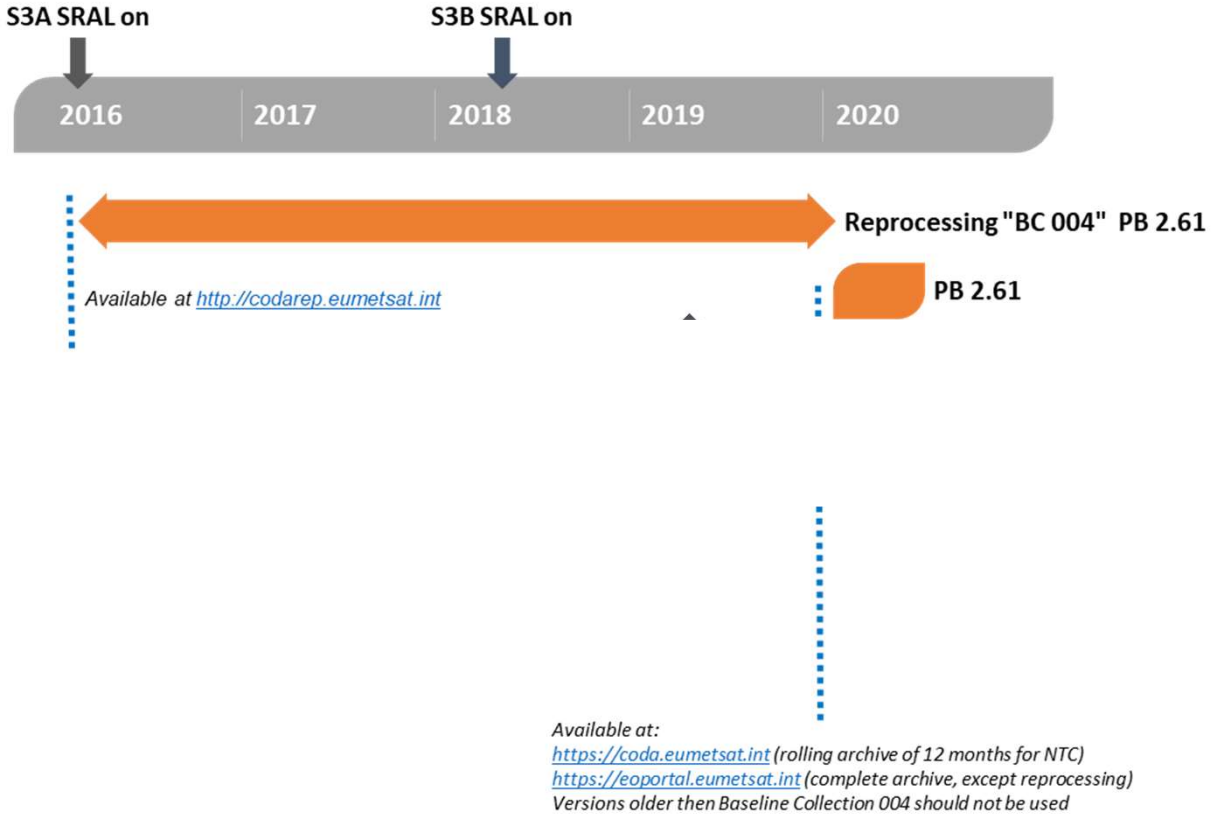


S3A and S3B
SR_2_WAT___
(Level 2)

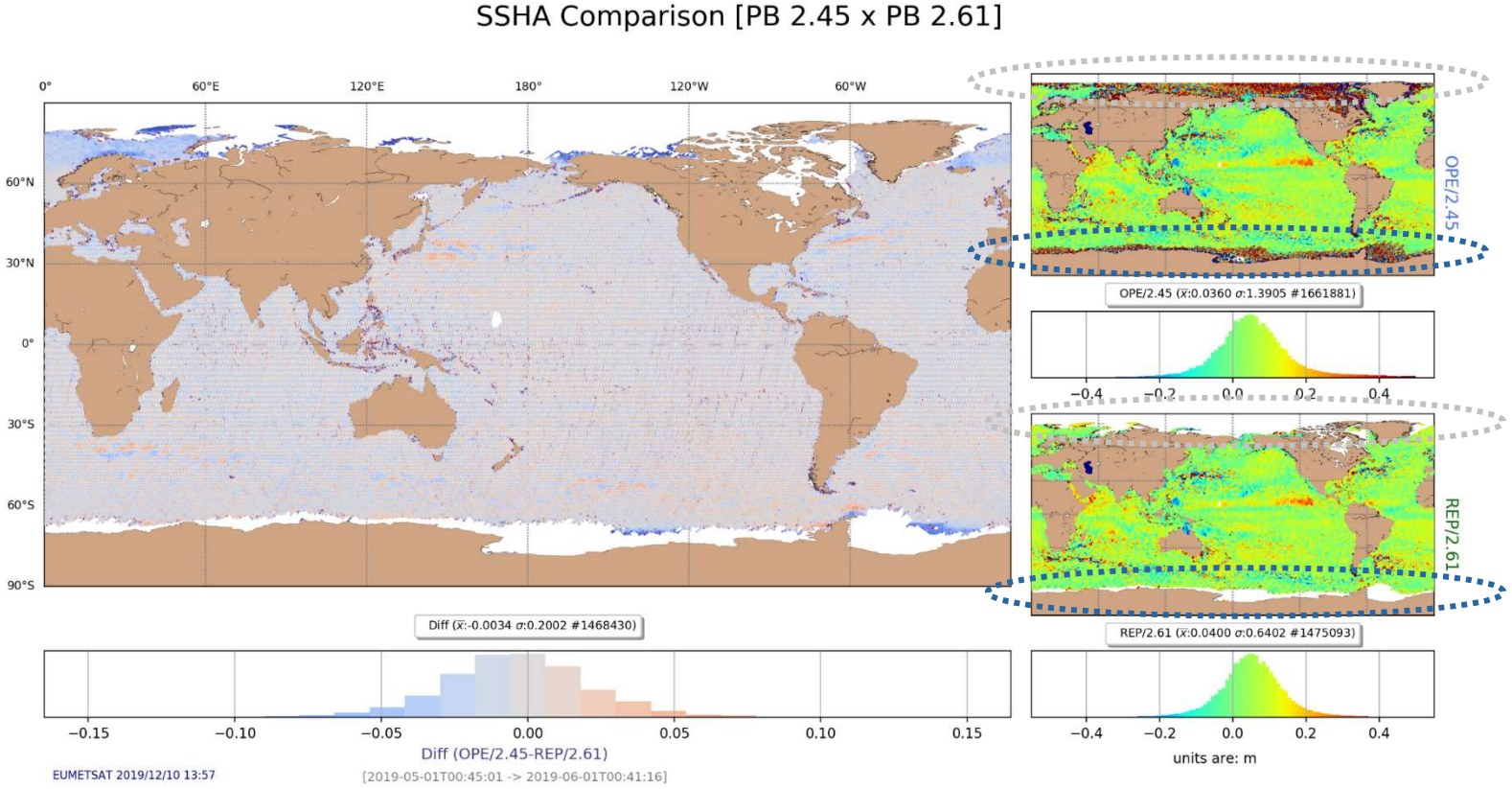
~NRT: 02:04 (H)
~STC: 40:23 (H)
~NTC: 25.27 (D)

Minor underperformance in case of:
Delayed/Lost delivery from Ground Station
Ground segment maintenance
Delayed mandatory ADFs

Marine Processing Baselines - Reprocessing



SSHA differences BC 004 (new) x BC 003 (old)



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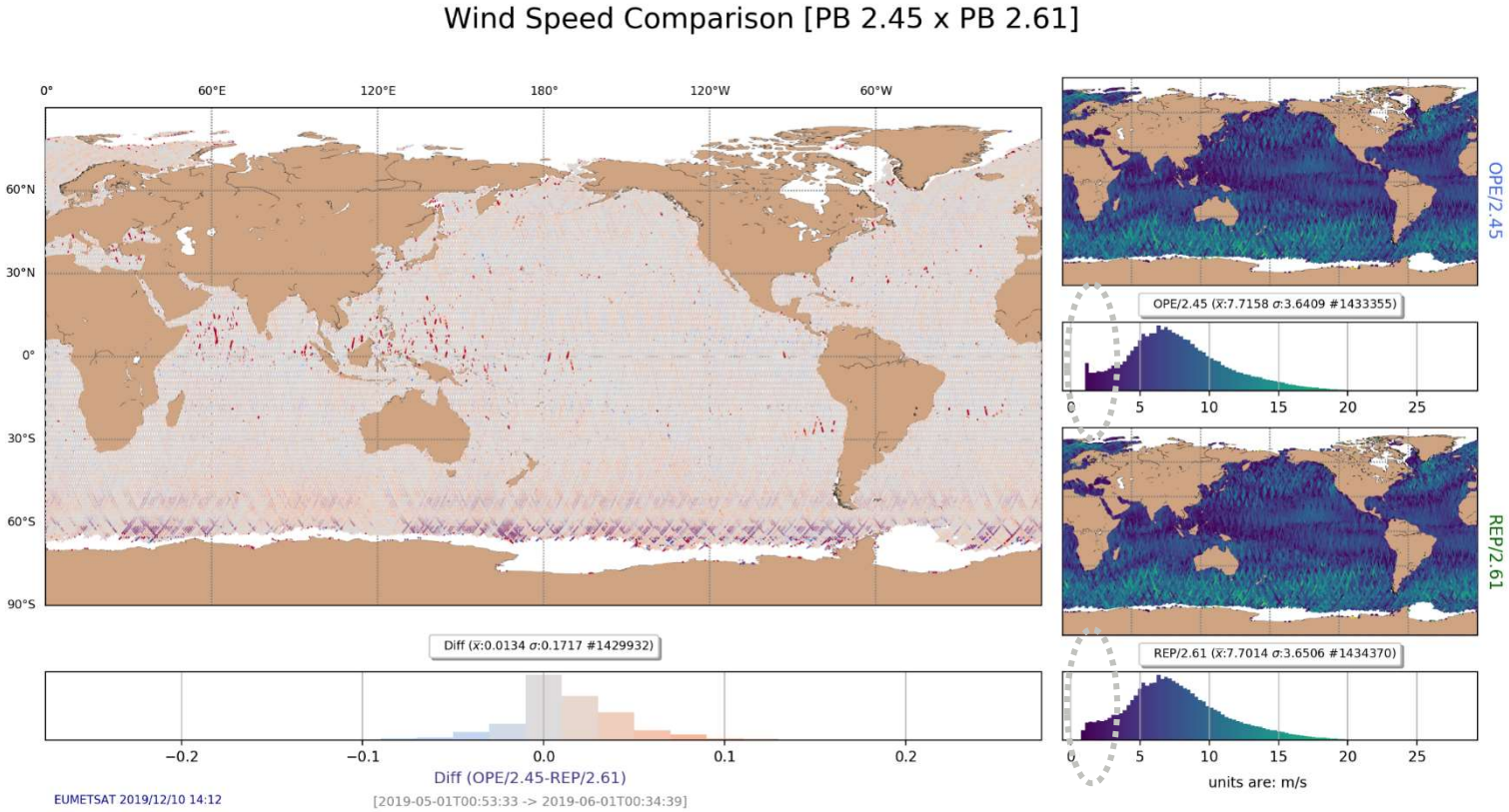
Wind Speed differences BC 004 (new) x BC 003 (old)



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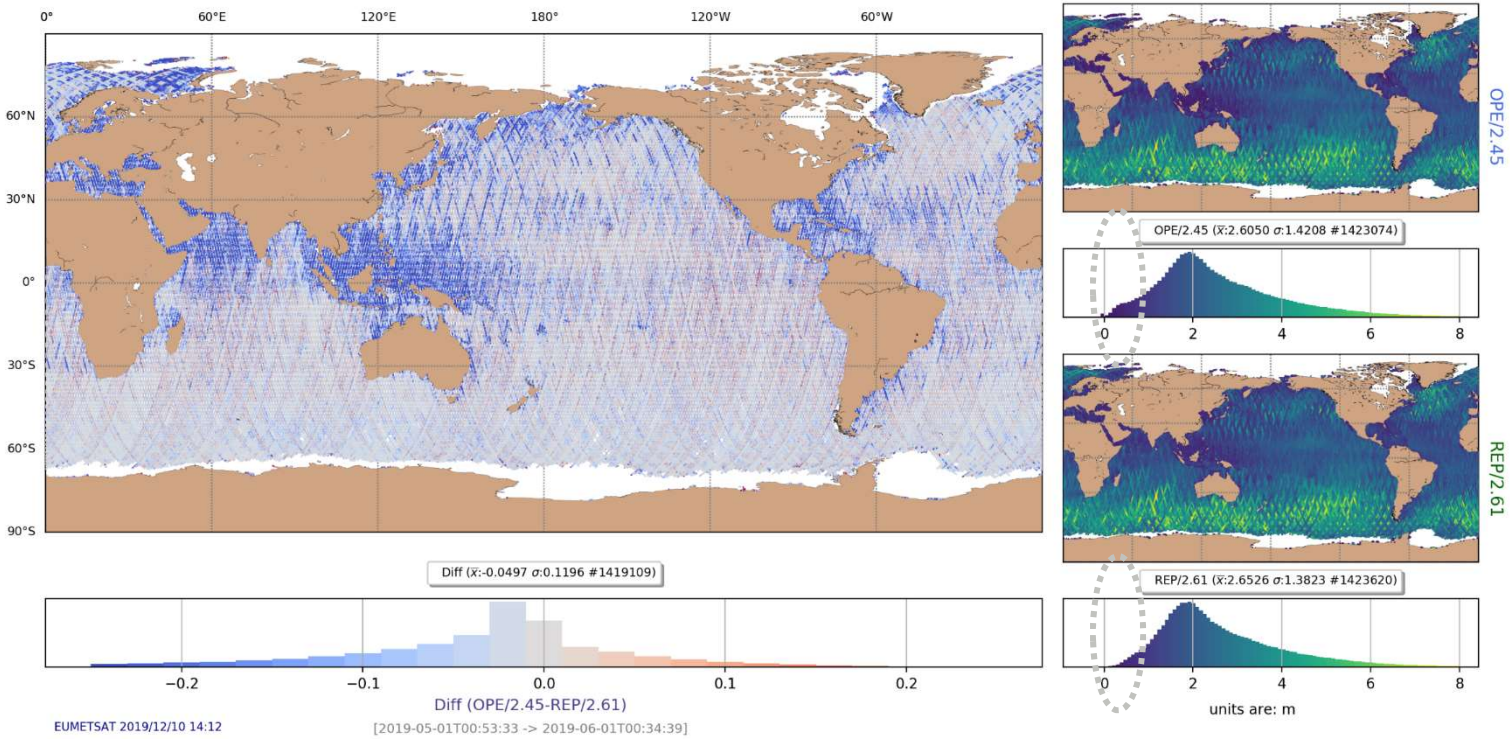
SWH differences BC 004 (new) x BC 003 (old)



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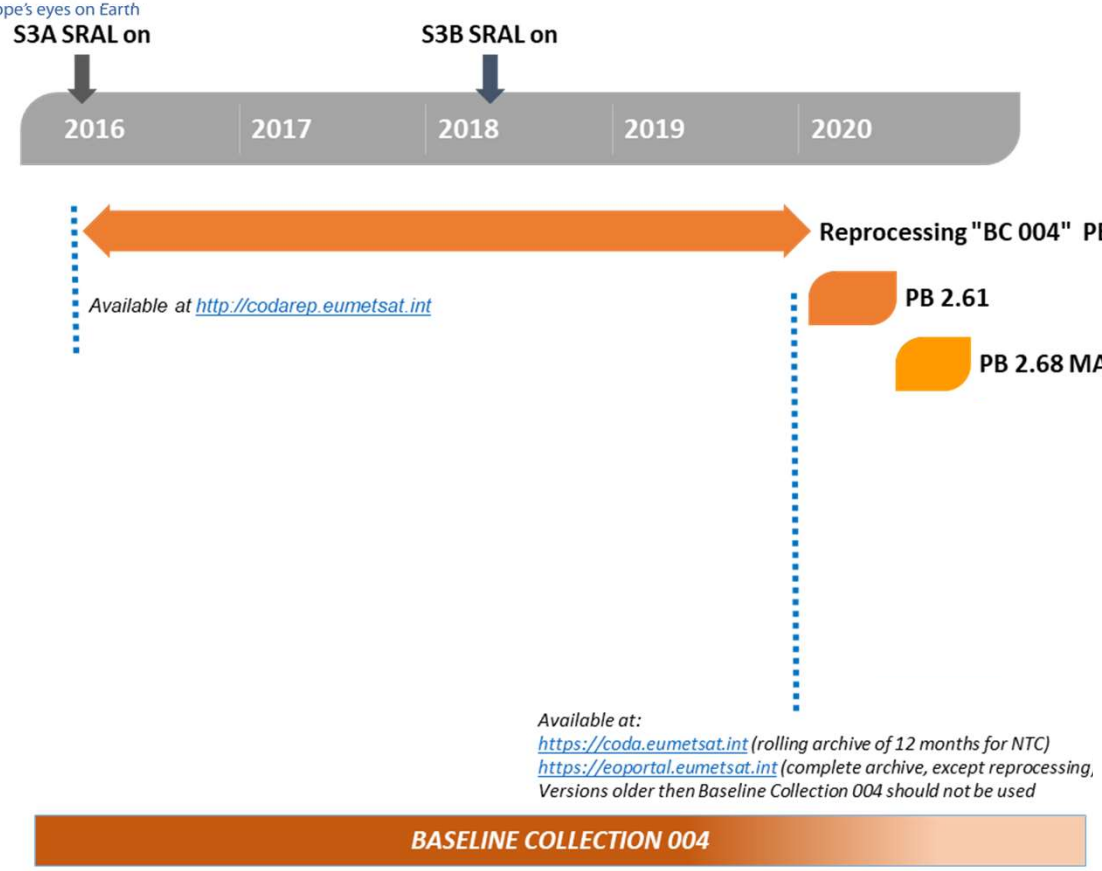
Marine Processing Baselines (Today)

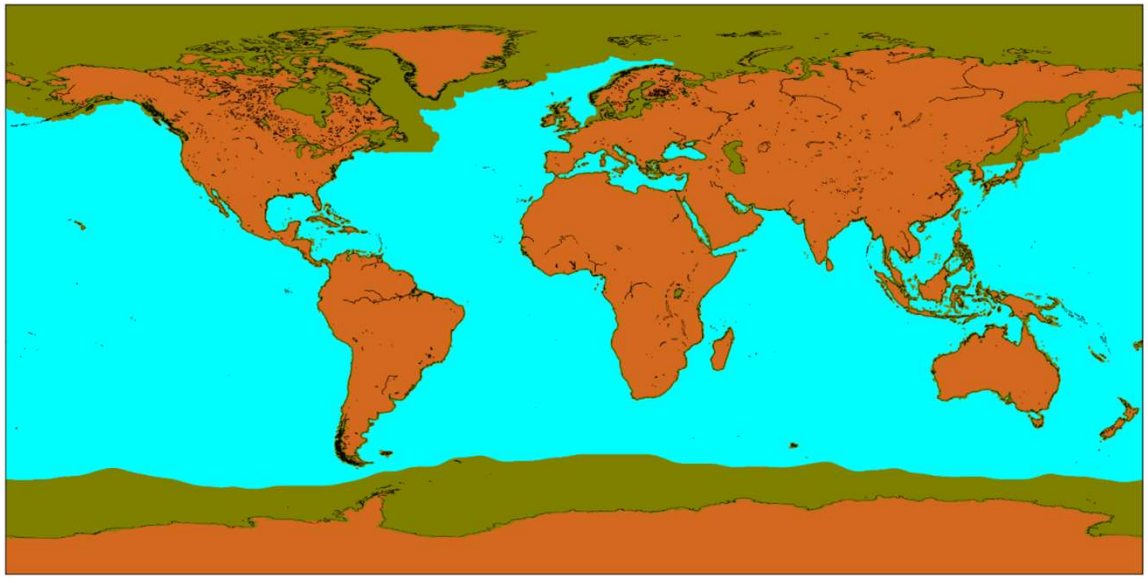


Updated L2 Land/Sea mask

- Open Ocean & Coastal Zone & Leads: EUM responsibility for evolution and maintenance of L2 Marine IPF
- Land, Inland Waters and Ice (including sea-ice freeboard): ESA responsibility

Current Mask Land/Marine

S3__SR_2_MLM_AX_20160216T000000_20991231T235959_20191209T120000_____MPC_O_AL_003.SEN3



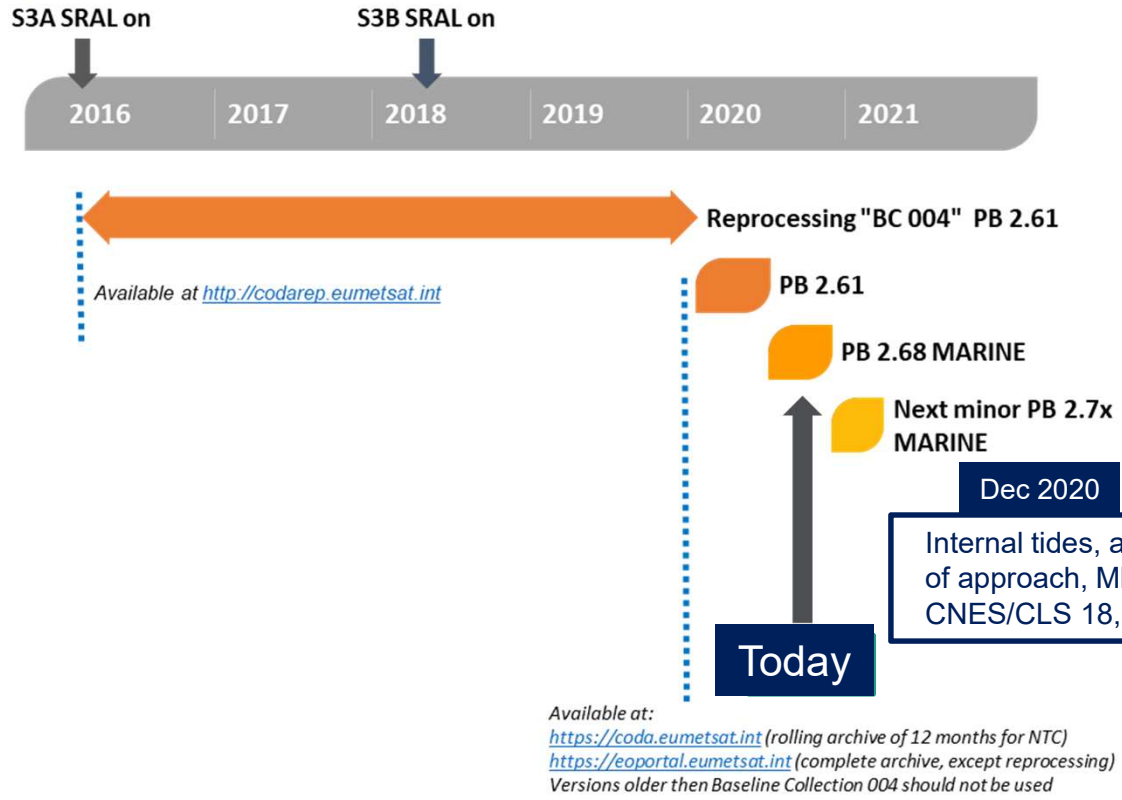
Sea Ice extent now common

Changes in the coast: Common 25k each side of the coastline

Major in-land water bodies common: Great Lakes, Caspian, Lake Victoria

Marine Centre produces data in the blue and green areas

Marine Processing Baselines (Future)



2021

PLRM updates (L1+L2)
MRN/LND mask at L1 (TBC)

Drift fix:
- Calibration Processing update
- Range Walk

Zero-Masking
Updated Pole Tide (TBC)
MSSs: DTU20, CNES-CLS 20 (TBC)

Dec 2020

Internal tides, angle of approach, MDT CNES/CLS 18, etc.

2021/2022 TBC

Correction in the products
SAR SSB
MOG2D in NRT
Sea ice concentration from OSI SAF
GPD+ wet tropo

EUMETSAT Sentinel-3 Altimetry Marine Products Portfolio

Main "S3 Altimetry" Page @ EUM
sral.eumetsat.int

Starting point to download of Marine products (S3,J3,etc.):
eoportal.eumetsat.int

Status	Product	EUMETCast *(NRT/STC)*	ODA CODA	Data Centre	AVISO+	CMEMS	Timeliness
S3A: operational **S3B: *operational* *(since December 2018)***	***SRAL L1A***		✓	✓			**STC, NTC**
	SRAL L1B	✓	✓	✓			**NRT, STC, NTC**
	SRAL L1BS		✓	✓			**STC, NTC**
	SRAL L2 WAT	✓	✓	✓			**NRT, STC, NTC**
	SRAL L2P SLA *(produced by CNES/CLS)*	✓			✓		**NRT, STC, NTC**
	SRAL L3 SLA *(produced by CNES/CLS)*					✓	**NRT/STC, NTC**
New Products *(Operational since Mid-2019)*	**SRAL L2P WAVE** *(produced by CNES/CLS)*	✓			✓		**NRT**
	SRAL L3 WAVE *(produced by CNES/CLS)*					✓	**NRT**
	SRAL L2 BUFR *(NRT only)*	✓					**NRT**

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Europe's eyes on Earth

Thanks !

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Back-up slides on:

- **S3 SRAL & MWR Sensors Performance**
- **S3 STM LAND Products Performance over:**
  - **Inland Water**
  - **Land Ice**
  - **Sea Ice**

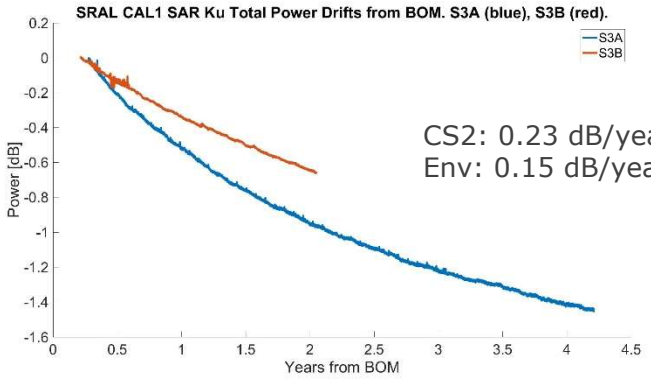
SRAL monitoring (summary)

Calibration Monitoring Summary

(Power, Delay, Width)

For both missions, modes & bands:

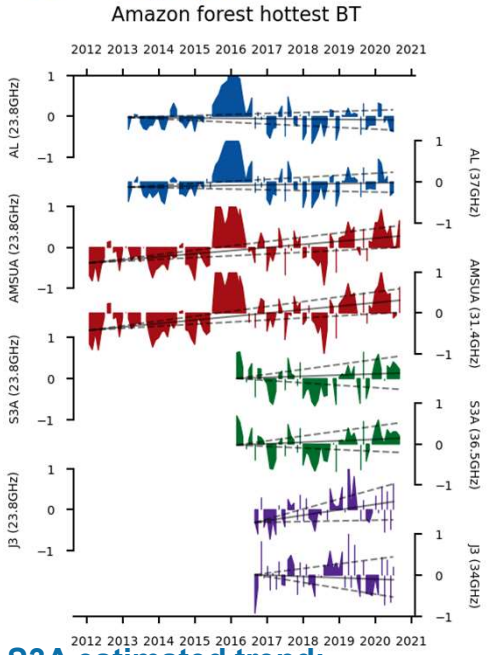
- Very similar delay and width absolute values between modes and between bands.
- Similar absolute values between missions.
- Higher drifts in Ku than in C.



S3A Calibration Parameter	Ku band			C band		
	mean	annual slope	standard deviation	mean	annual slope	standard deviation
LRM CAL1 time delay	1.0072 m	-0.41 mm	0.56 mm	0.8929 m	-0.34 mm	0.41 mm
SAR CAL1 time delay	1.0070 m	-0.28 mm	0.40 mm	0.8935 m	-0.27 mm	0.34 mm
LRM CAL1 power	57.58 dB	-0.33 dB	0.38 dB	50.90 dB	-0.03 dB	0.04 dB
SAR CAL1 power	62.01 dB	-0.33 dB	0.39 dB	48.41 dB	-0.03 dB	0.04 dB
LRM CAL1 PTR width	0.4164 m	-0.35 mm	0.41 mm	0.4543 m	-0.06 mm	0.09 mm
SAR CAL1 PTR width	0.4162 m	-0.36 mm	0.42 mm	0.4542 m	-0.07 mm	0.10 mm

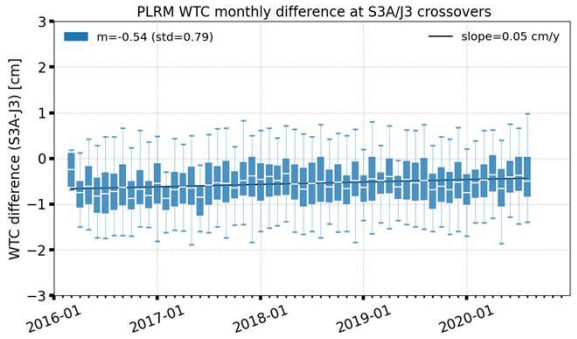
S3B Calibration Parameter	Ku band			C band		
	mean	annual slope	standard deviation	mean	annual slope	standard deviation
LRM CAL1 time delay	0.9602 m	0.10 mm	0.12 mm	0.9581 m	-0.39 mm	0.23 mm
SAR CAL1 time delay	0.9598 m	0.65 mm	0.35 mm	0.9579 m	-0.37 mm	0.22 mm
LRM CAL1 power	57.13 dB	-0.32 dB	0.17 dB	50.47 dB	0.05 dB	0.04 dB
SAR CAL1 power	61.57 dB	-0.35 dB	0.19 dB	47.83 dB	0.05 dB	0.03 dB
LRM CAL1 PTR width	0.4138 m	-0.21 mm	0.18 mm	0.4659 m	0.05 mm	0.10 mm
SAR CAL1 PTR width	0.4139 m	-0.12 mm	0.16 mm	0.4660 m	0.05 mm	0.10 mm

MWR stability and performances

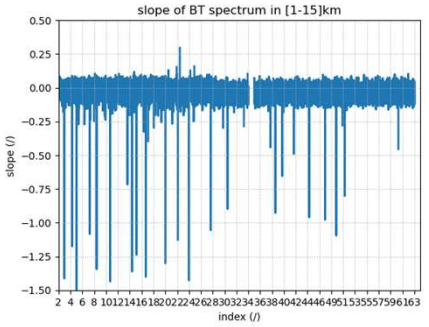


S3A estimated trend:
23.8GHz: 0.028K/yr (-0.06/0.12)
36.5GHz: 0.036K/yr (-0.04/0.12)

- **MWR Stability is checked at brightness temperatures level (Vicarious targets) and at WTC level by comparison to ECMWF and other instruments (J3, AltiKa) using crosso[illegible]points.**

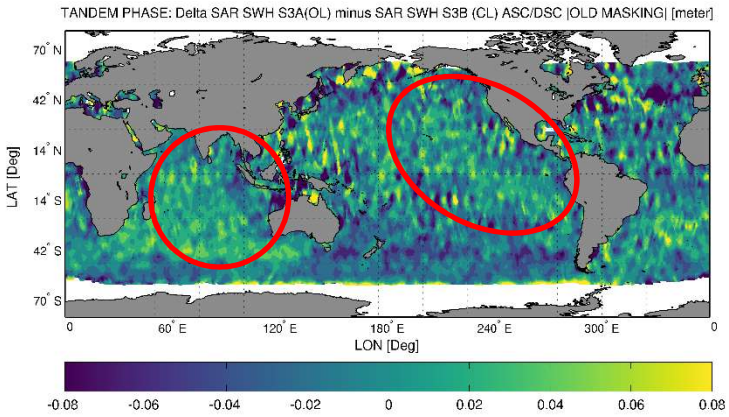


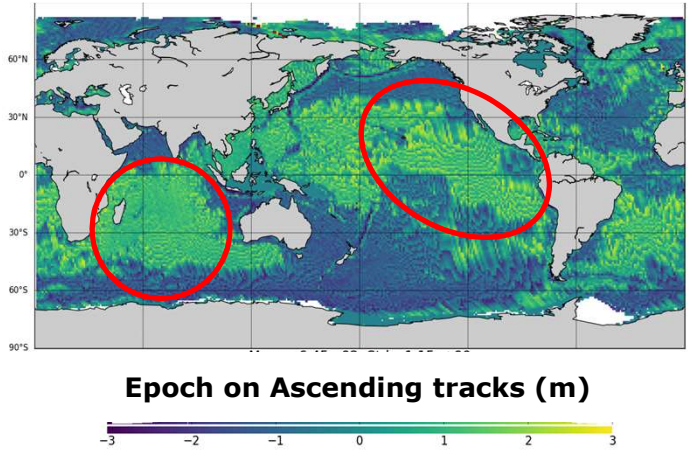
- **Investigations following the interference of S3A MWR 36.5GHz channel with KREMMS radar facility in Nov 2018, allow the detection of other interferences of smaller amplitude**



SARM sensitivity to echo's centering

Static masking



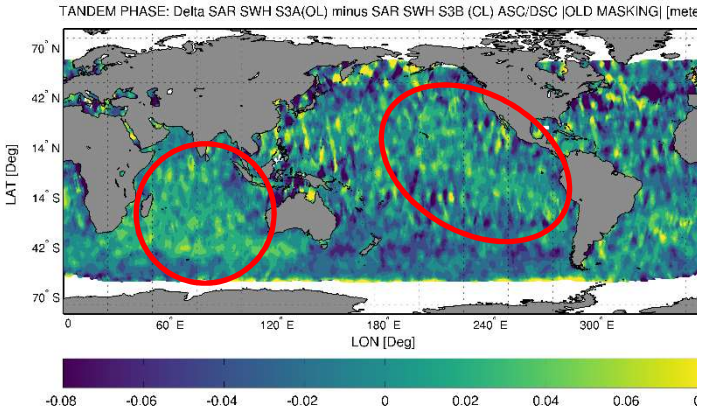


- When SRAL operates in OL mode, the waveform is moving within the tracking windows (variations of the surface height above the OLTC command). The SARM range and swh parameters are sensitive to these variations (see Raynal et al., OSTST 2019, effect is about few mm on range and few cm on SWH).

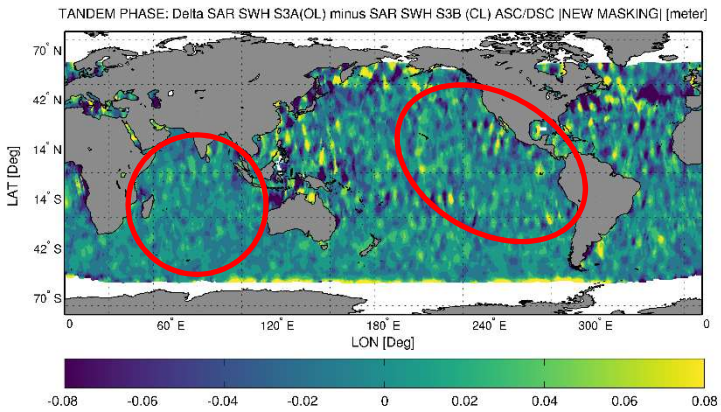
- S. Dinardo et al. recently demonstrated that the use of a dynamic exact masking instead of the current static masking allows to better follow the vertical movement of the stack and remove these errors.

SARM sensitivity to echo's centering

Static masking



dynamic masking



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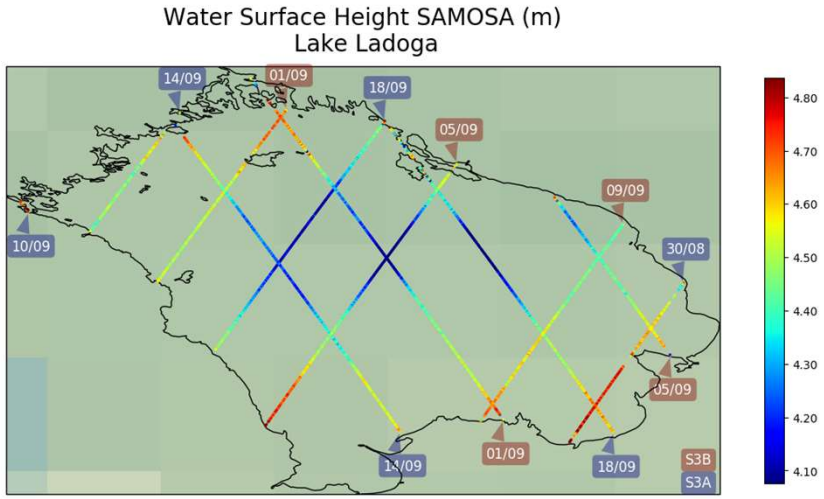
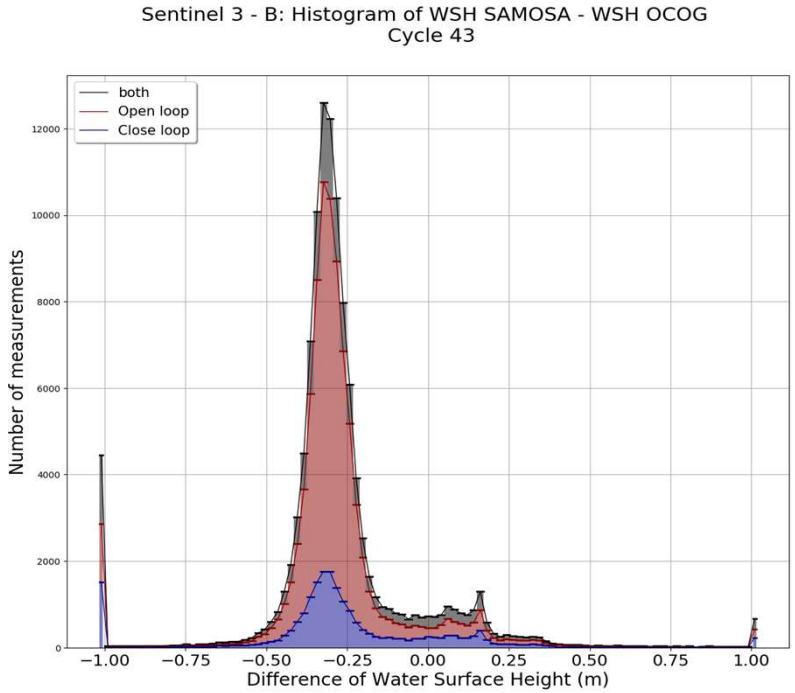
S3A & S3B STM Inland Waters - Outlook



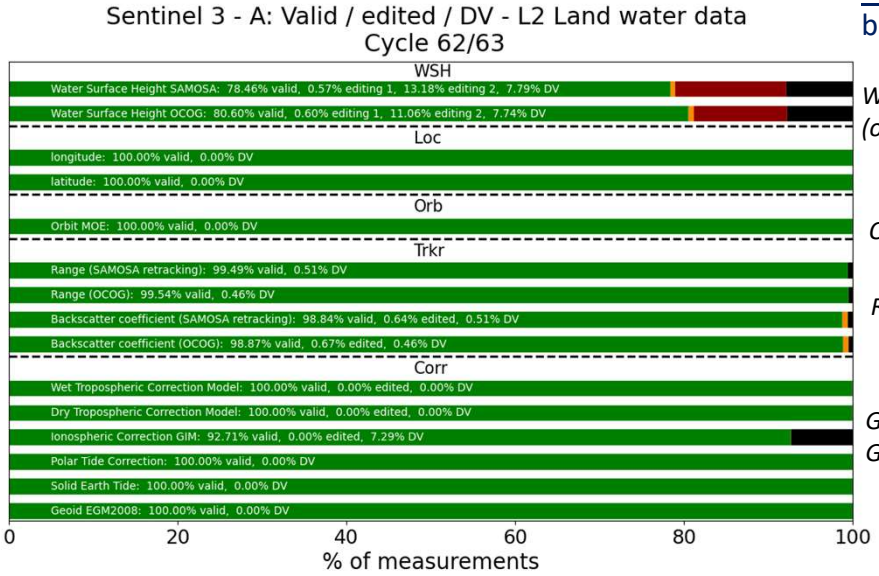


➔ **Very good agreement between both S3A (blue labels) & S3B (red labels) estimated WSH. (spatial fluctuations due to geoid undulations)**

➔ **OCOG range – SAMOSA range ≈ -27cm**

➔ Product Performance will be improved with the Thematic Processor i.e. with Implementation of Zero-Padding and Hamming Window, in a first place geophysical corrections at 20Hz, flag OLTC, etc. intended evolutions

Routine Quality Assessment over 700 lakes



METRIC : Percentage of valid (green), erroneous (tests using boundary values condition : orange and red) and NaN data (black)

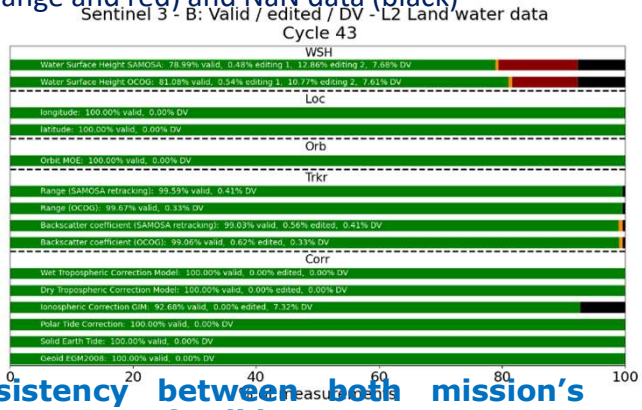
Water surface height (orbit – range – corrections – geoid)

Orbit

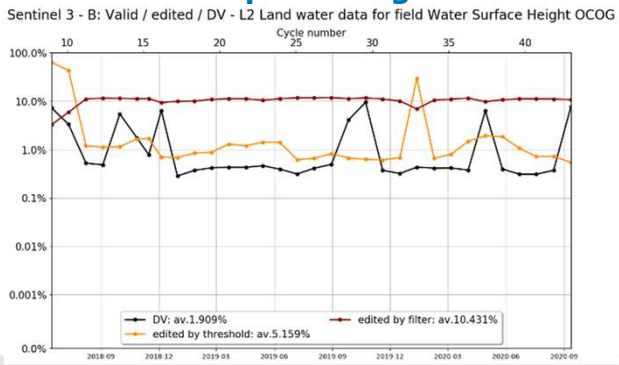
Retracking derived parameters

Geophysical corrections

Geoid model



→ **Consistency between both mission's percentages of valid measurements**

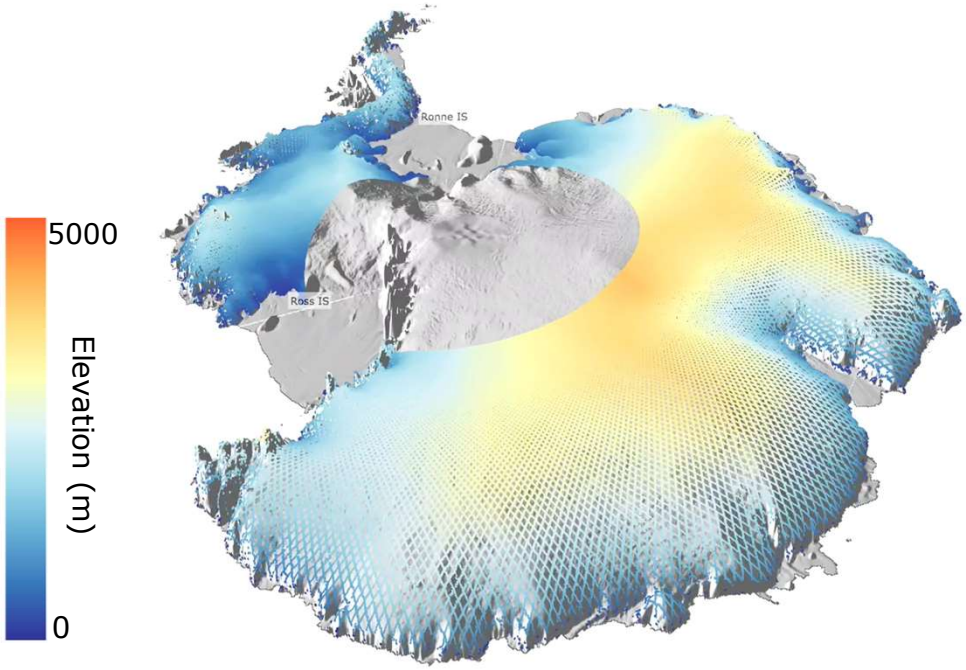


→ **DV tracking (e.g. ionospheric correction anomaly)**

→ **Long time consistency in the % of edited measurements**

See presentation **OLTC updates and improved performance of the Sentinel-3 STM constellation over Inland Waters – N. Taburet** (CLS, France)

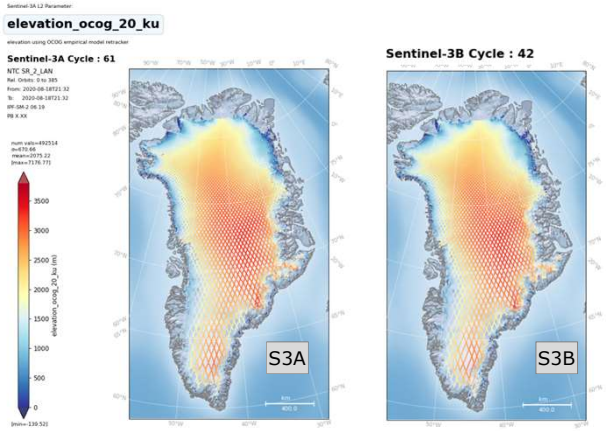
S3A & S3B STM LAND Ice Performance



S3-A : Cycle 61 (Antarctic Ice Sheet)

Excellent S3A and S3B SAR performance over the majority of the Antarctic and Greenland ice sheets (slopes < 1%)

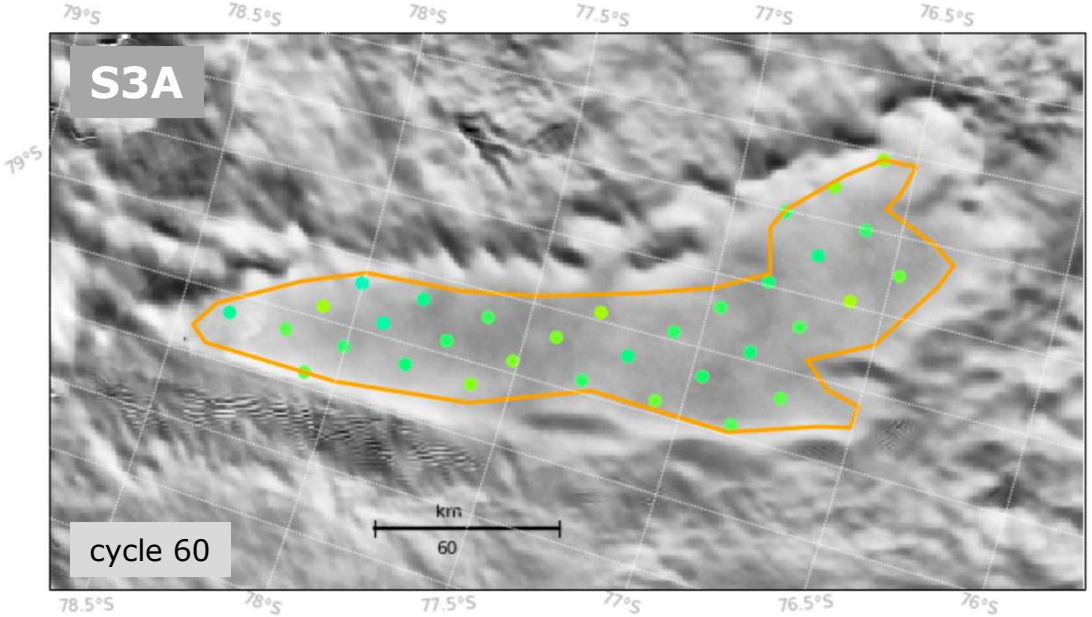
Consistent instrument tracking, accuracy, precision and measurement coverage for both S3A and S3B missions.

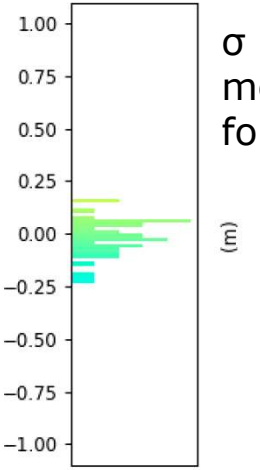


S3A & S3B STM LAND Ice Performance

Measurement of S3A Precision

Lake Vostok (E. Antarctica): low slope, flat surface





Elevation Difference at Orbit Crossover (m)

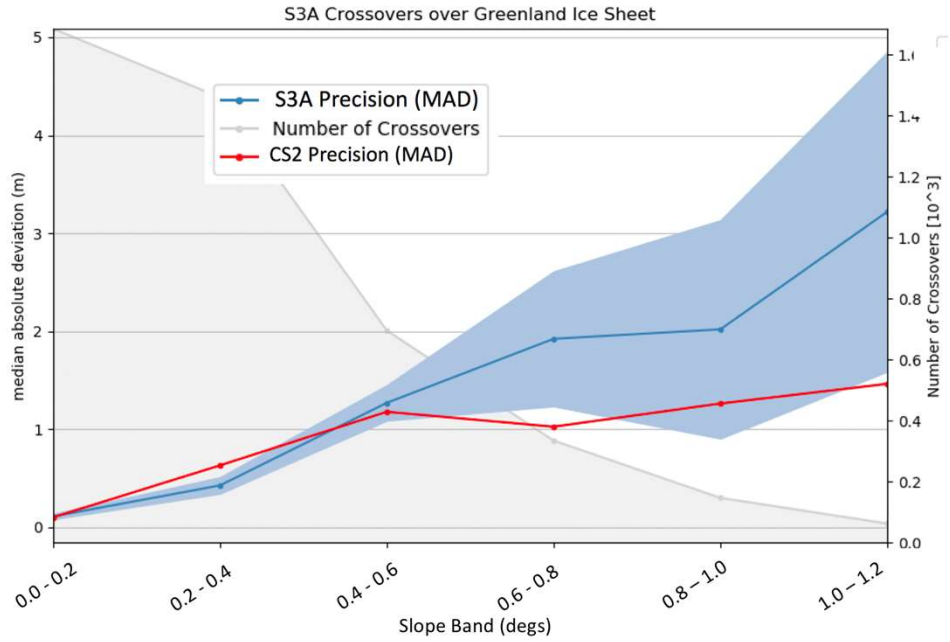
Excellent precision
(measurement repeatability)

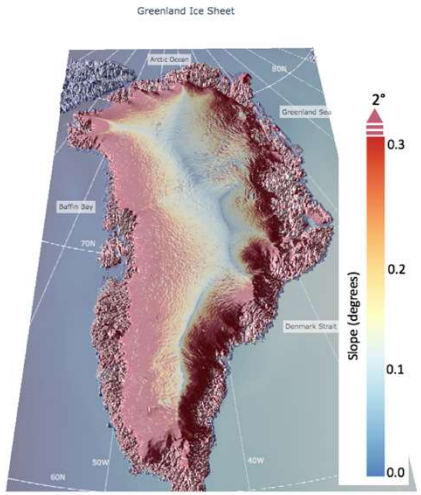
σ < 10cm
mean = 0.0cm
for **both S3A and S3B**

S3A & S3B STM LAND Ice Performance

S3 **Precision per band of Slope** as good or better than CryoSat for the majority of the ice sheets (slopes < 0.4°).

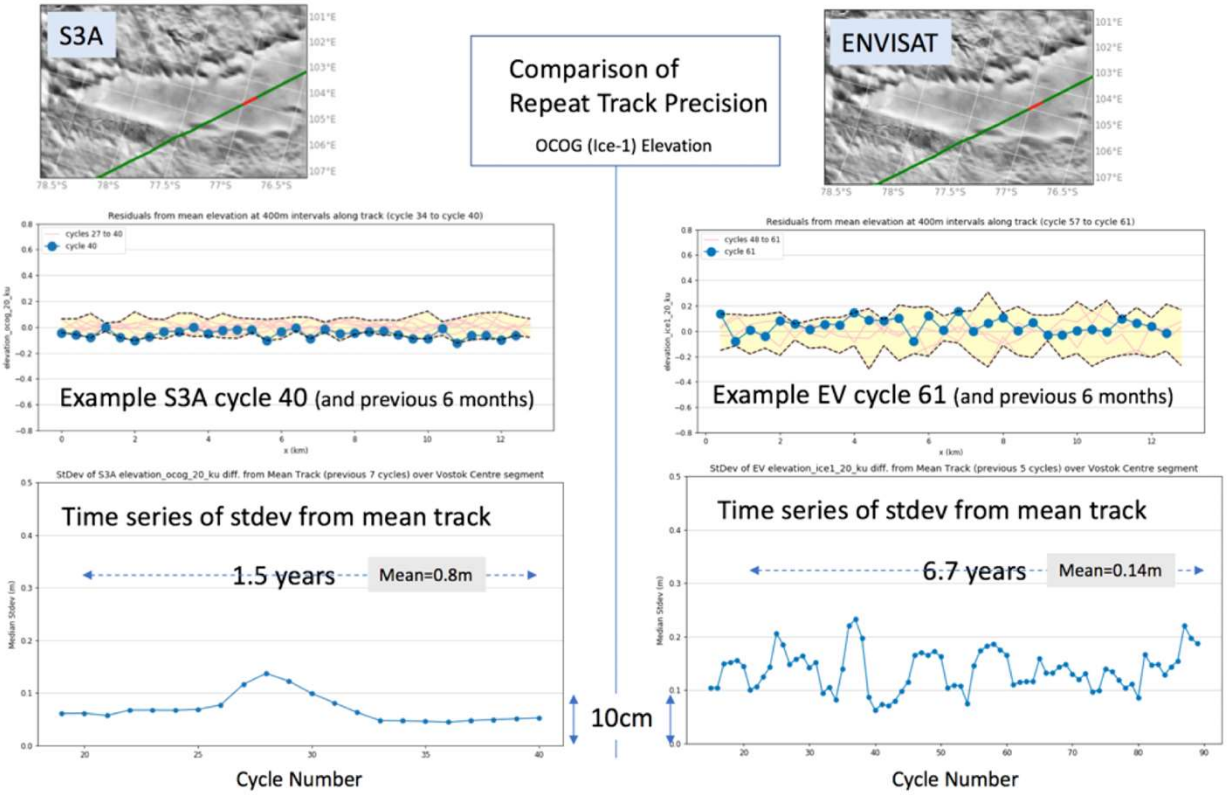
CryoSat has improved precision over high slopes (> 0.4°) due to its specialist SARin instrument mode but the gap can be narrowed by improved future S3 slope correction.





S3A & S3B STM LAND Ice Performance

S3 Land Ice Precision Repeat Track Comparison with ENVISAT



Full mission repeat track study over a test site in Lake Vostok

S3 repeat track precision: 8cm
ENVISAT precision: 14cm

➔ S3 has 1.75x better precision than ENVISAT over low slope ice sheet surfaces

European Commission

S3A & S3B STM LAND Ice Performance

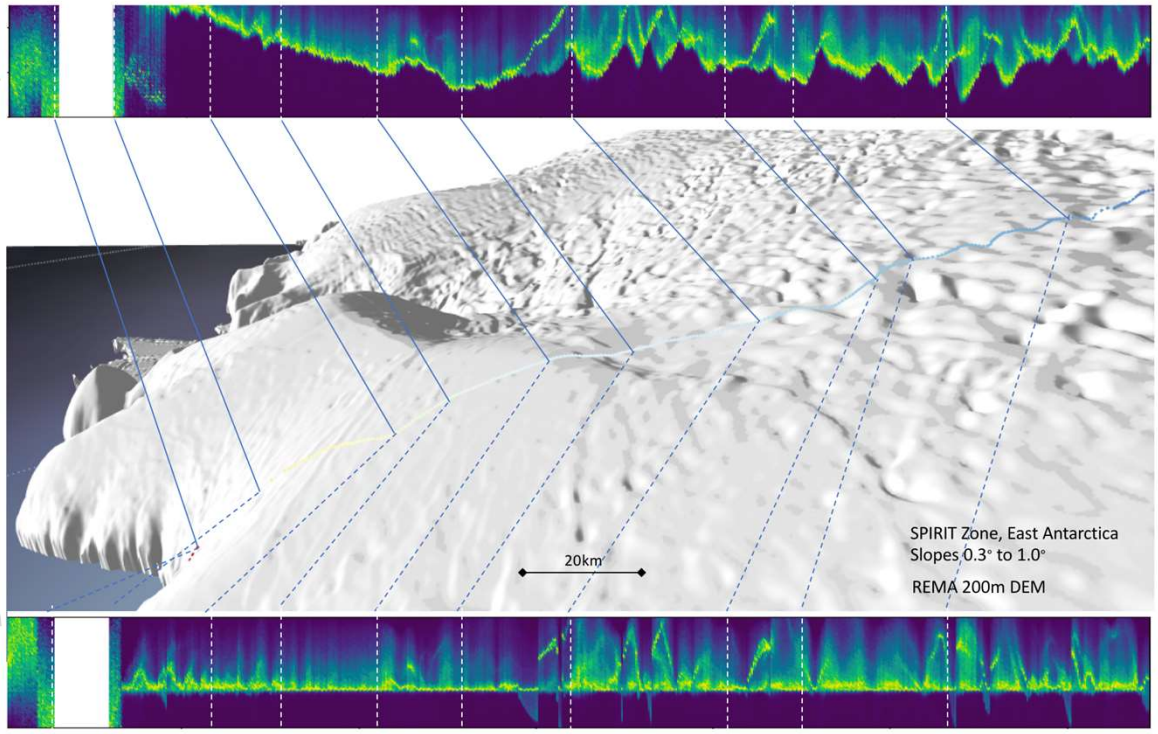
S3A Land Ice 2 year TDS showed that performance will be further improved over the ice sheet margins with dedicated land ice thematic processing

Current IPF

waveforms can be truncated causing measurement loss

Land Ice TDS

waveforms are centered from an extended window allowing maximum measurement coverage



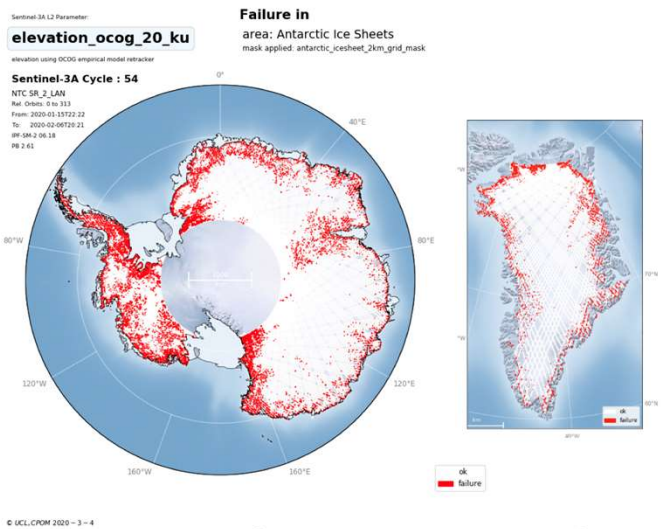
echo radargram

S3A & S3B STM LAND Ice Performance

Performance Improvement with dedicated Land Ice TDS

Measurement failure Locations

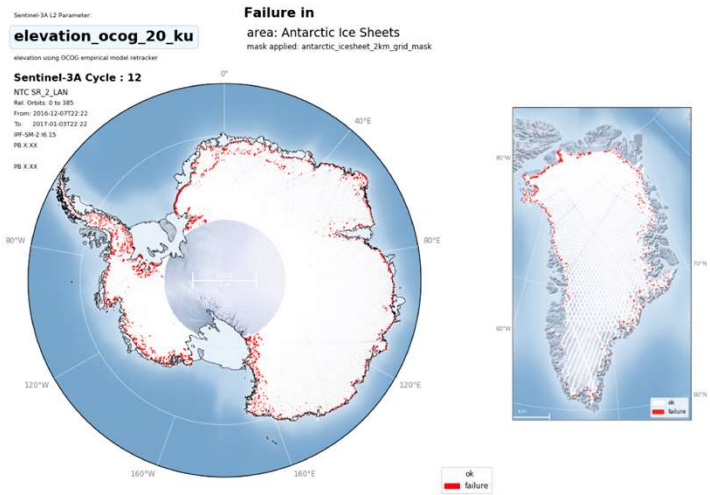
PB 2.61



3.07% Failure

4.18% Failure

PRODE Land Ice Reprocessing



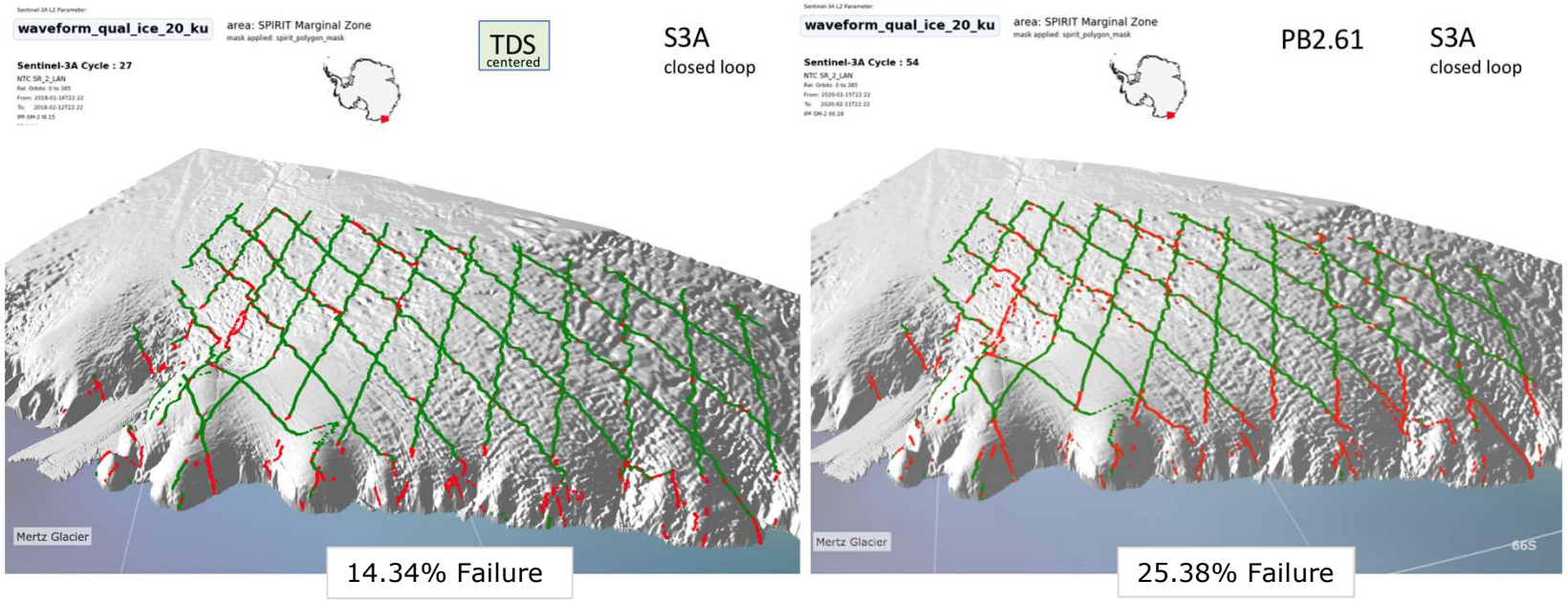
0.44% Failure

0.85% Failure

European Commission

S3A & S3B STM LAND Ice Performance

Measurement Failure over the Ice Sheet Margins improved with TDS



14.34% Failure

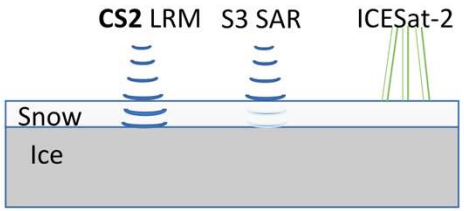
25.38% Failure

- **11.04% more valid measurements** with Land Ice TDS
- TDS has valid **measurements closer to coast**

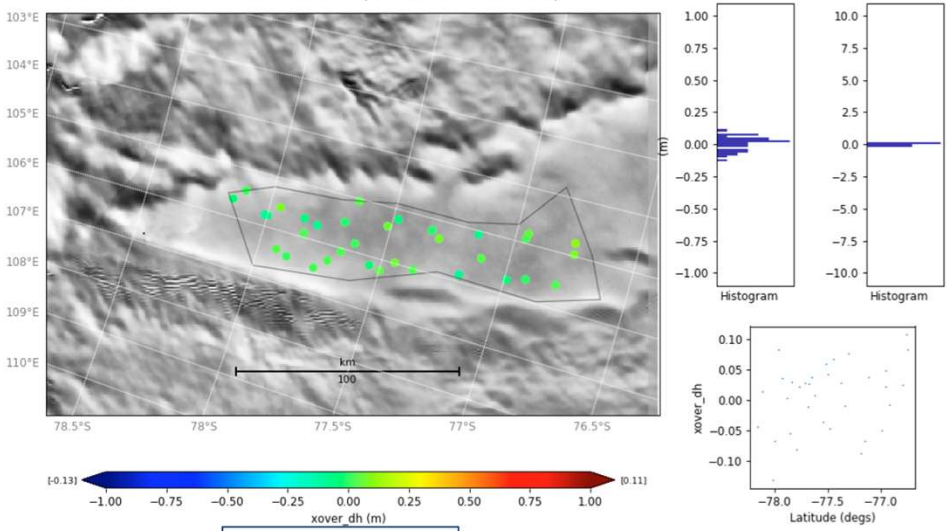
S3A & S3B STM LAND Ice Performance

Accuracy vs ICESat-2 & IceBridge

- UCL study of **S3A vs ICESat-2**: 1cm bias
- **S3A vs IceBridge** study in McMillan et al., 2019 : 1cm bias

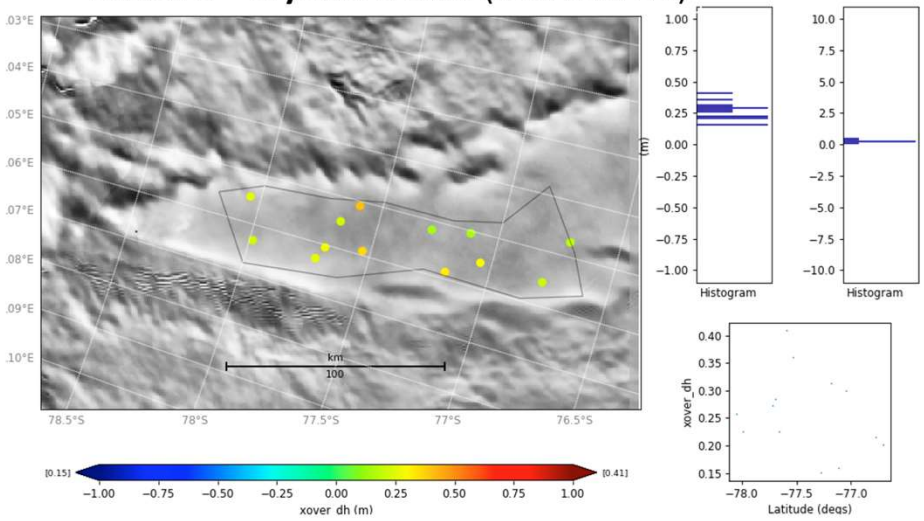


ICESat-2 – **S3A SAR** (at crossover)



Mean diff = +1cm

ICESat-2 – **CryoSat-2 LRM** (at crossover)

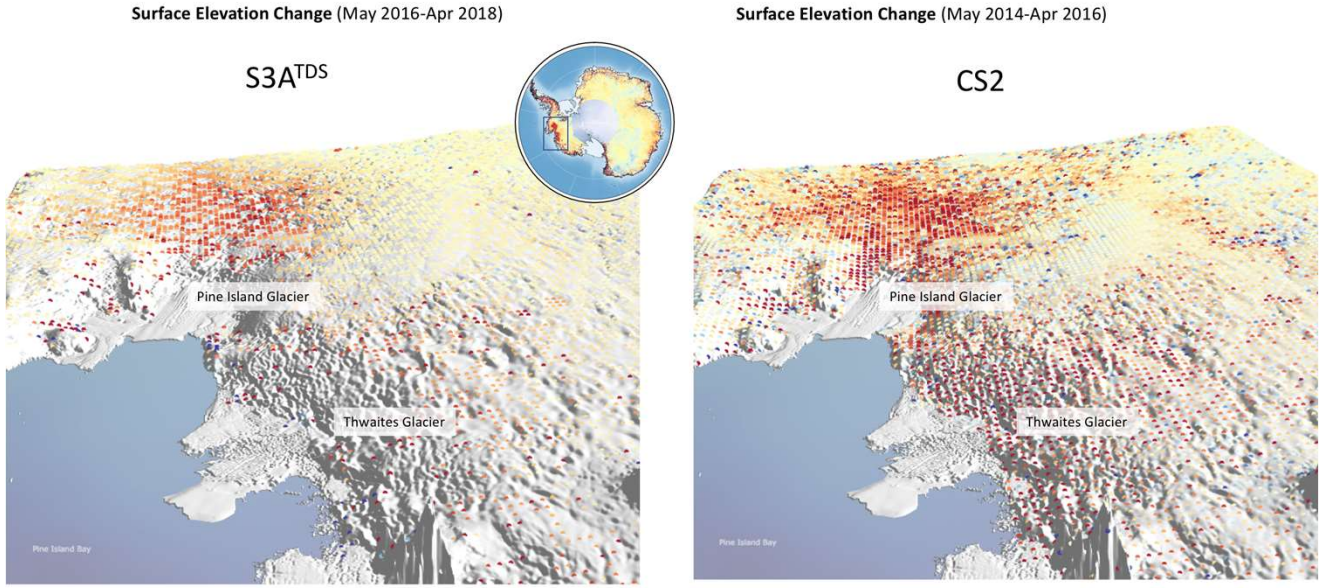


Mean diff = +26cm

European Commission

S3A & S3B STM LAND Ice Performance

S3A/B can be used to measure surface elevation change
a critical measure of climate change. Results are consistent with CryoSat-2



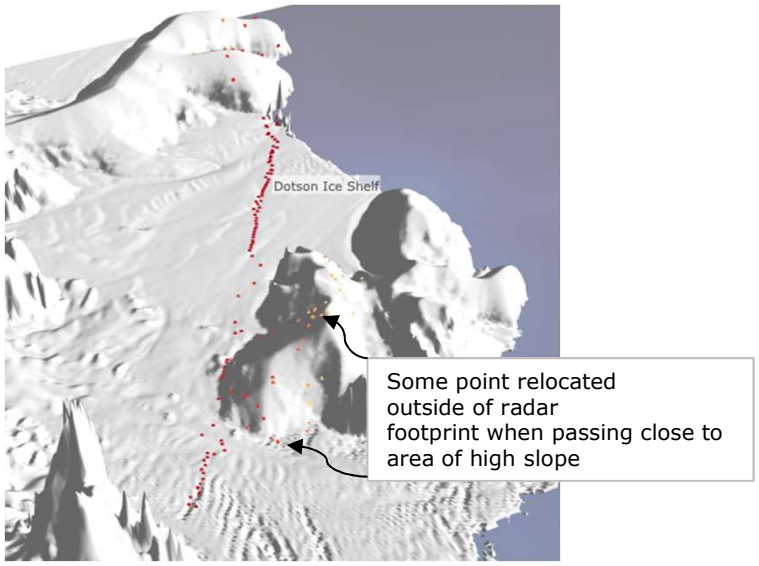
Combining S3A, S3B and CS2 will improve future measures of surface elevation change

S3A & S3B STM LAND Ice Performance

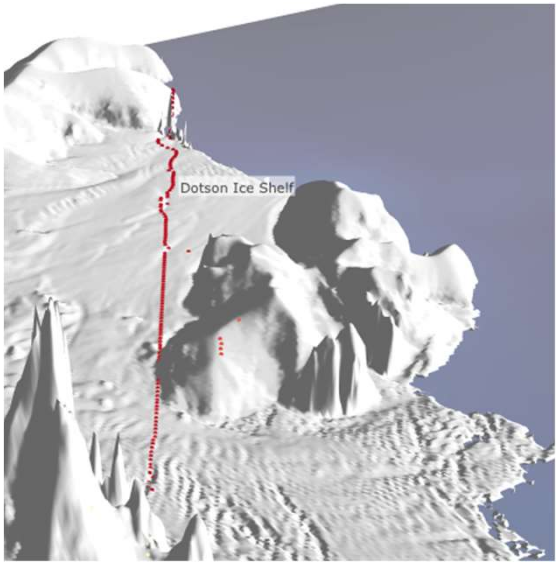
Thematic Land Ice Processing will include new Slope Model Improvements

Next slope model will improve slope corrections over surfaces near regions of very high slope

Current Slope Model (v2)

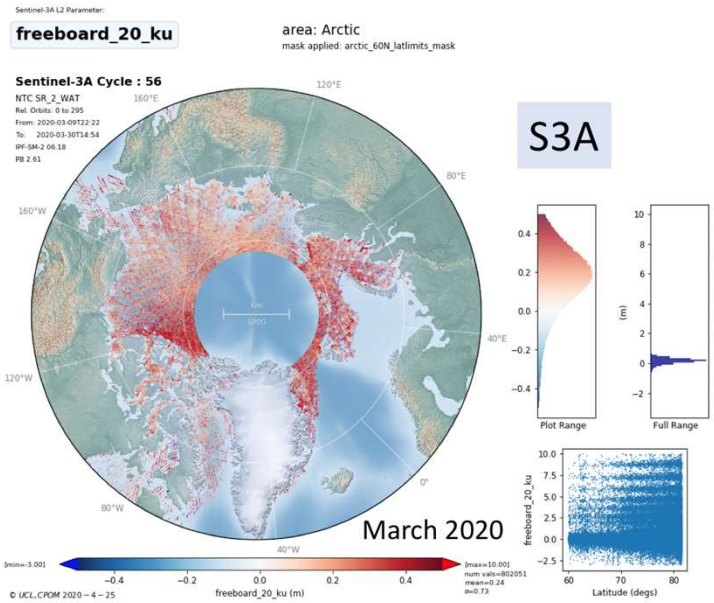


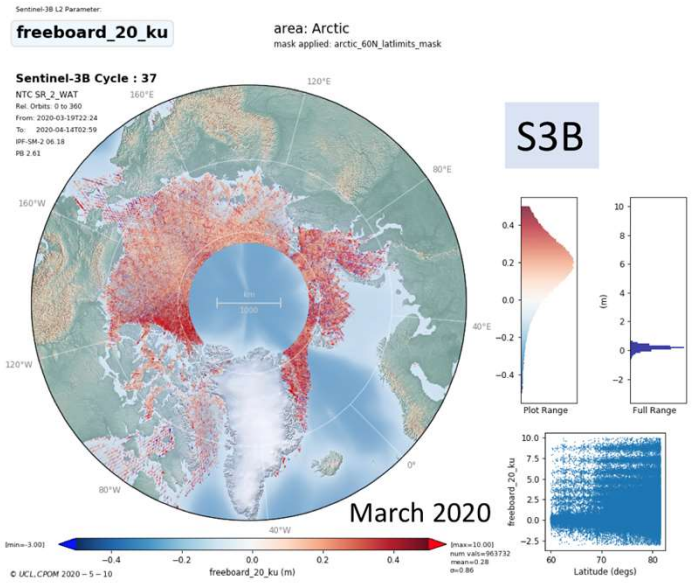
Next Slope Model (v3, Q2 2021)



S3A & S3B STM Sea-Ice Performance

- Since PB2.43 major evolutions (Feb 2019), Sea-Ice freeboard from S3A and S3B are generally consistent with expected results from other missions.
- Final Sea-Ice freeboard measurement quality in all areas will require dedicated L1 sea ice surface processing.
- No significant bias between S3A and S3B.





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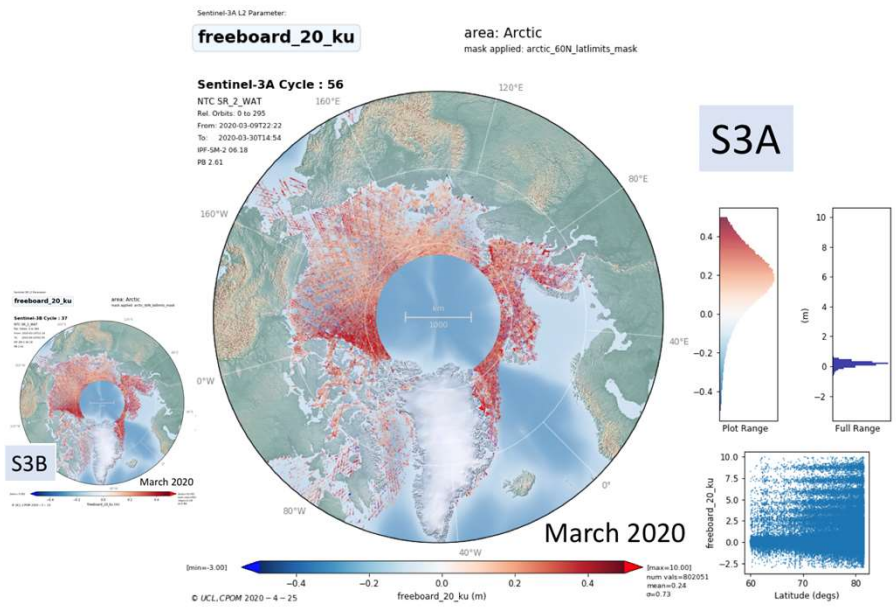
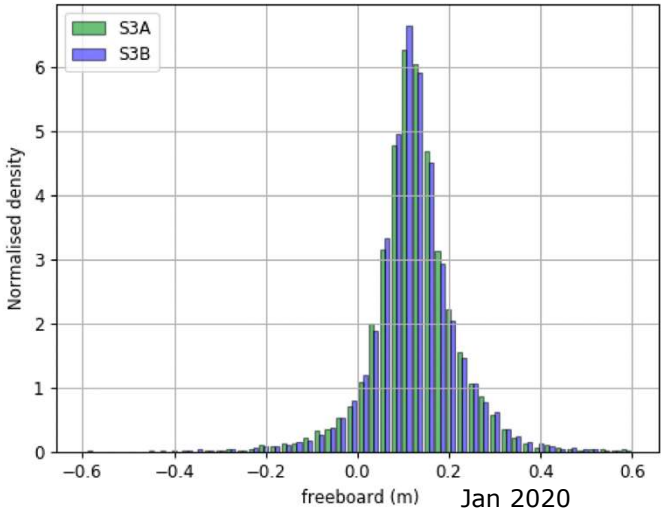


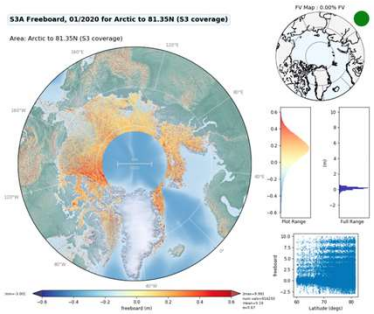
No Bias Shown with
S3A and S3B Gridded Arctic Freeboard



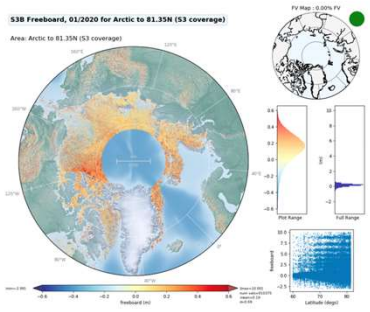
S3A & S3B STM Sea-Ice Performance

Comparison of S3A, S3B and CryoSat-2 Freeboard

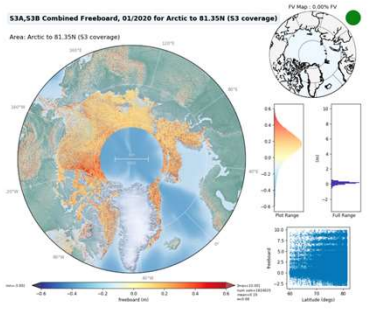
January 2020: Arctic Freeboard Maps for S3A, S3B, S3^{AB}, CS2, S3^{AB} - CS2



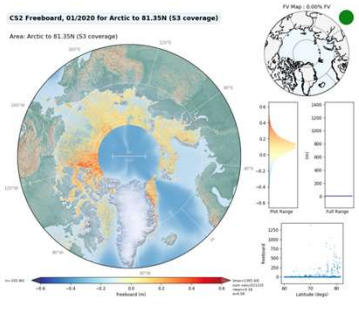
S3A



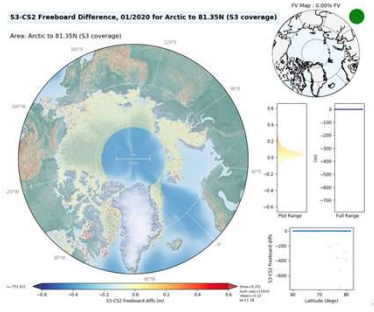
S3B



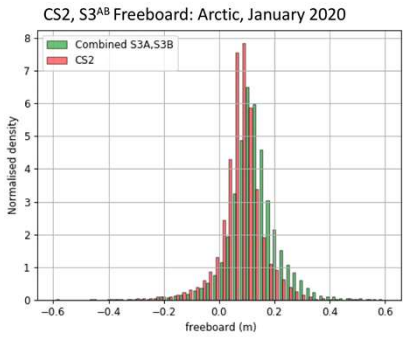
S3A,S3B



CS2



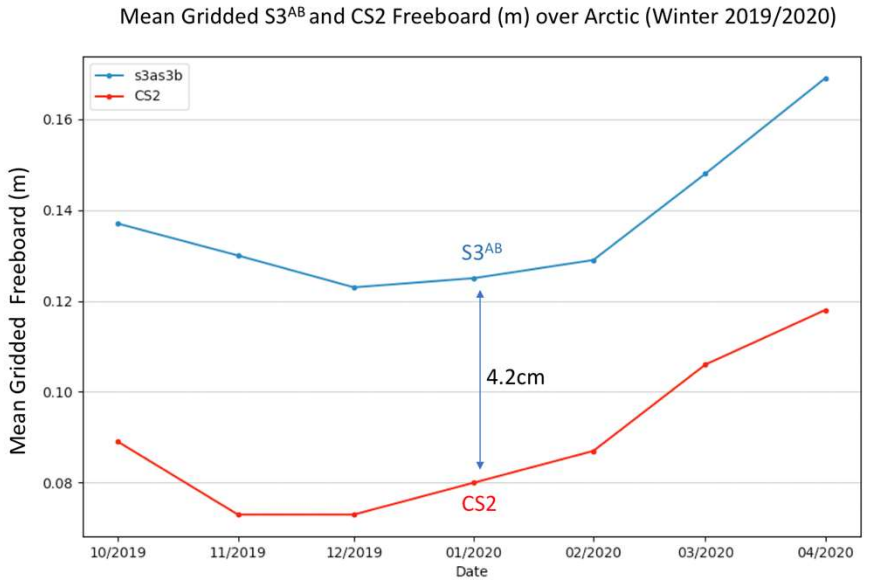
S3-CS2



Mean S3-CS2 Freeboard Difference = +4cm

S3A & S3B STM Sea-Ice Performance

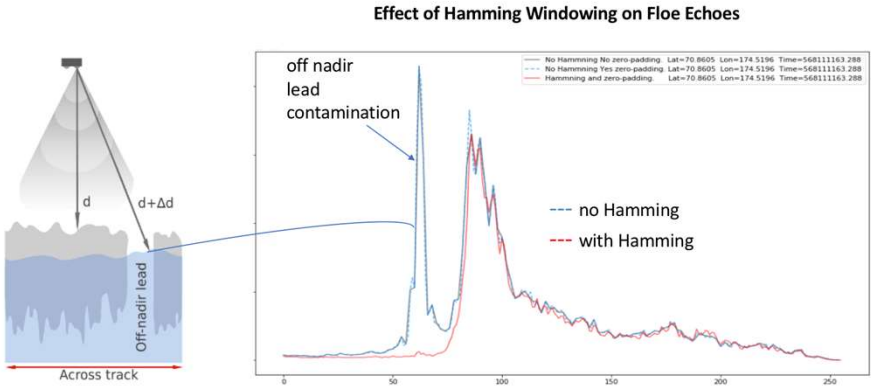
Comparison of S3A, S3B and CryoSat-2 Freeboard



S3A & S3B STM Sea-Ice Performance

Main Improvements for Sea Ice to remove ~4cm bias to CryoSat requires dedicated Sea Ice Thematic Processing at L1b

- Hamming Weighting (to correct off nadir lead contamination of floe echoes)
- Zero Padding (to correct under sampling of specular echoes over sea ice leads)
- Lawrence et al (2019) have shown that when S3 freeboard is processed using the above L1b steps then 0cm freeboard bias is achievable as compared with Cryosat-2.

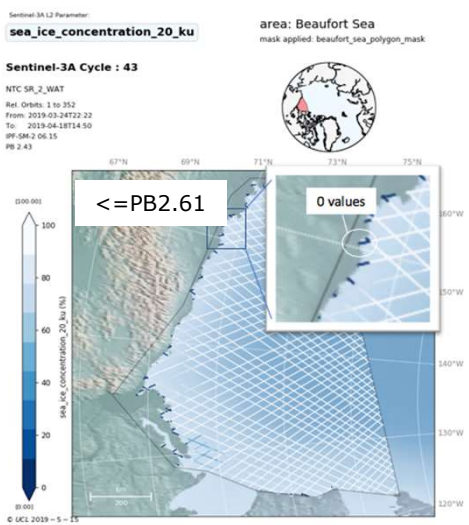


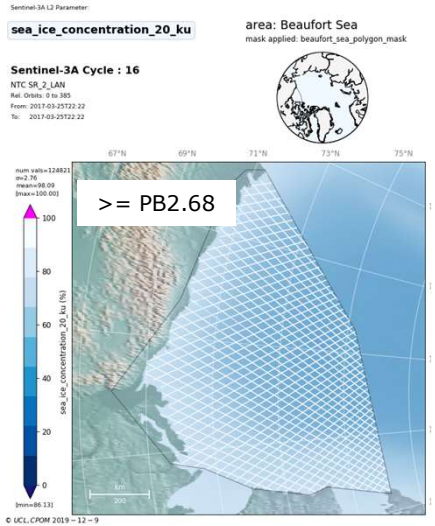
[image credit: Ricker,AWI]

S3A & S3B STM Sea-Ice Performance

Recent Evolutions for Sea Ice

- MSS updated to DTU18 in PB2.61
- Sea Ice Concentration parameter corrected around coastline





Communication

S3MPC Publications

2017 Quartly et al., Assessing altimetry close to the coast. Proc. SPIE 2017. (6pp.) **OCEAN**

Quartly et al., Ensuring that the Sentinel-3A altimeter provides climate-quality data. Proc. SPIE 2017. (16pp.) **OCEAN** **LAND** **ICE**

2019 McMillan et al., Sentinel-3 Delay-Doppler altimetry over Antarctica, The Cryosphere, 13, 709–722. **ICE**

Nencioli et al. Evaluation of Sentinel-3A wave height observations near the coast of southwest England, Remote Sens/, 11(24), 2998 (20pp.) **OCEAN**

2020 Frery et al. Sentinel-3 Microwave Radiometers: Instrument Description, Calibration and Geophysical Products Performances. Remote Sens. 12, 2590. (24pp.) **OCEAN**

Quartly et al., The roles of the S3MPC: Monitoring, xalidation and evolution of Sentinel-3 altimetry observations. Remote Sens. 12, 1763. (57pp.) **OCEAN** **LAND** **ICE**

Taburet et al., S3MPC: Improvement on Inland Water Tracking and Water Level Monitoring from the OLTC Onboard Sentinel-3 Altimeters. Remote Sens. 12, 3055. (24pp.) **LAND**