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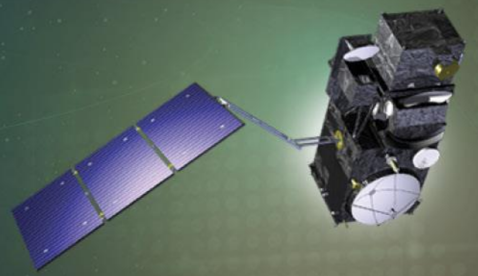

7th Sentinel-3 Validation Team Meeting 2022

18-20 October 2022 | ESA-ESRIN | Frascati (Rm), Italy

Sentinel-3 performance and thematic product for land ice

Sebastian B. Simonsen[1], Louise Sandberg Sørensen[1], Stine K. Rose[1], Jérémie Aublanc[2], Ghita Jettou[2], and Pierre Femenias[3]

[1]DTU space, DK-2800 Kgs. Lyngby, Denmark;
[2]Collecte Localisation Satellites, 31520 Ramonville Saint-Agne, France;
[3]ESA-ESRIN, 00044 Frascati RM, Italy

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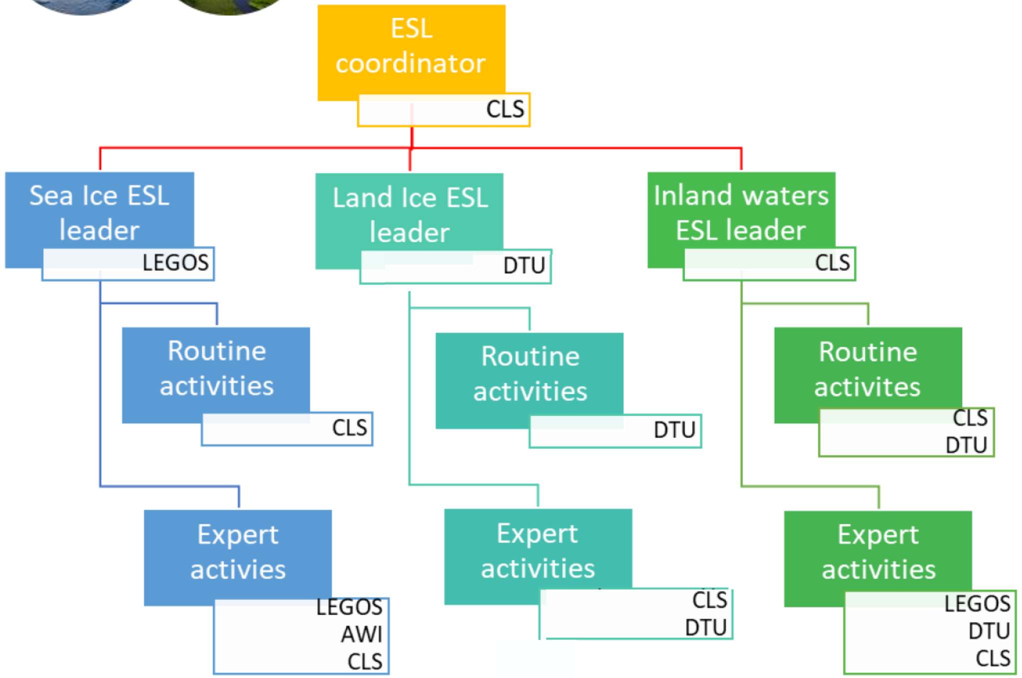
Sentinel-3
Mission Performance Cluster
of Surface Topography Mission



Sebastian B. Simonsen **Stine K. Rose** **Louise S. Sørensen**

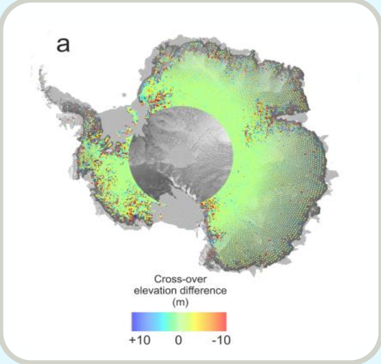
Jeremie Aublanc

CLS

Land Ice ESL – Activities

Cyclic Activities

- Monthly, per cycle, cadence.
- Internal Evaluation.
- Comparison to satellite datasets and products.



DTU

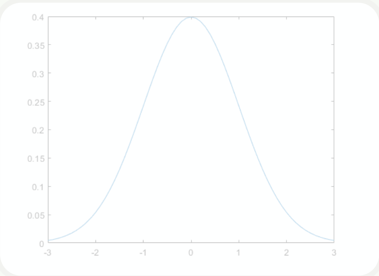
In Depth Analyses

- Annual cadence.
- External validation against airborne & in situ data.
- Benchmarking against other satellite products.

DTU CLS

Error Budget

- Uncertainty assessment and documentation via an 'Error Budget table'.
- Characterisation according to surface type.
- Reviewed and updated annually.



DTU

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Cyclic validation report

In summary

8
Geophysical corrections are monitored for Greenland/Antarctica ice sheets and 12 for Antarctic ice shelves

5
Geophysical parameters derived from altimetry monitored for two retrackers

2
Auxiliary parameters are monitored

Ice sheet wide
Crossover stability are monitored for each retracker

LIST OF CONTENTS

Parameter:	Comments:
Orbit	Nominal orbit coverage (100%)
Availability of geophysical corrections	Nominal
Availability of auxiliary data	Nominal auxiliary data availability
Geophysical parameters	Nominal performances in the altimeter-derived geophysical parameters
Specific investigations	N/A
Orbit cross-over statistics	The UCL ice sheet retracker enables fewer cross-overs to be evaluated than for the OCOG/ICE-1 retracker (Antarctica 70 %, Greenland 46 %). This is nominal in relation to the previous cyclic report. For cross-overs less than 1 meter show a mean bias of 1 cm and standard deviation ≤ 35 cm.
Status	Overall nominal data availability and nominal mission performances on this cycle

Workflow for cyclic performance report

LAND ICE

Automated housekeeping	
Daily (Processing time < 2h)	Monthly (cyclic) (Processing time < 12h)
Each day the STC and NTC products are pull to a local repository	At the end of a Sentinel-3B cycle the most reason cycles of Sentinel-3A and Sentinel-3B are evaluated and diagnostic saved

Manual intervention (cyclic)	
All diagnostics from the processing chain are evaluated and quality checked	Findings are reported in the cyclic performance report. Final report are uploaded to MPC-SharePoint and reported on JIRA
Eventual issues are reported via JIRA	

Cyclic validation report

In summary

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Geophysical corrections are monitored for Greenland/Antarctica ice sheets and 12 for Antarctic ice shelves

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LIST OF CONTENTS

S3A

Geophysical Correction	Availability (%)
iono_cor_gim_01_ku	100.00
load_tide_sol1_01	100.00
load_tide_sol2_01	100.00
mod_dry_tropo_cor_meas_altitude_01	100.00
mod_wet_tropo_cor_meas_altitude_01	100.00
ocean_tide_non_eq_01	100.00
pole_tide_01	100.00
solid_earth_tide_01	100.00

S3B

Geophysical Correction	Availability (%)
iono_cor_gim_01_ku	100.00
load_tide_sol1_01	100.00
load_tide_sol2_01	100.00
mod_dry_tropo_cor_meas_altitude_01	100.00
mod_wet_tropo_cor_meas_altitude_01	100.00
ocean_tide_non_eq_01	100.00
pole_tide_01	100.00
solid_earth_tide_01	100.00

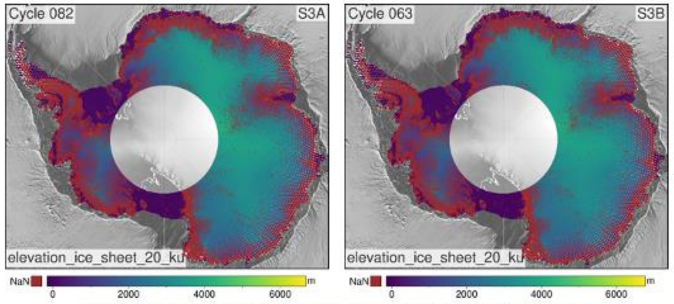
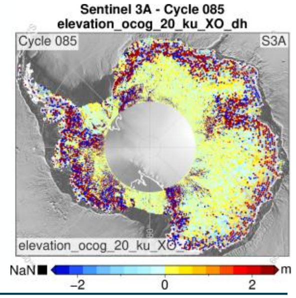
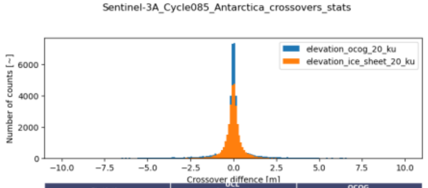


Figure 5.3 SAR mode elevation over Antarctica from the elevation_ice_sheet_20_ku parameter





Statistics	UCL ice sheet retracker	OCOG retracker
Total number Observation [#]	34170.0	48891.0
Mean [m]	1.0	0.61
Std [m]	127.99	64.72
Observ. [%] (dh < 1 m)	88.2	72.1
Mean [m] (dh < 1 m)	-0.0	-0.0
Std [m] (dh < 1 m)	0.34	0.31

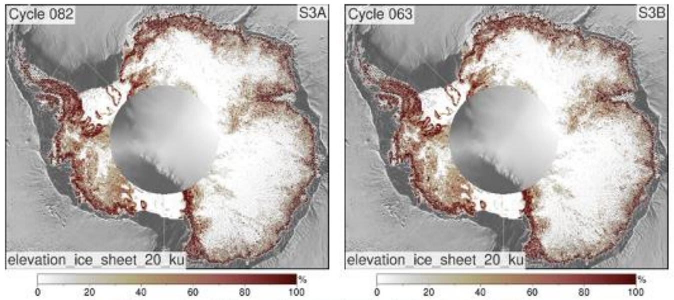
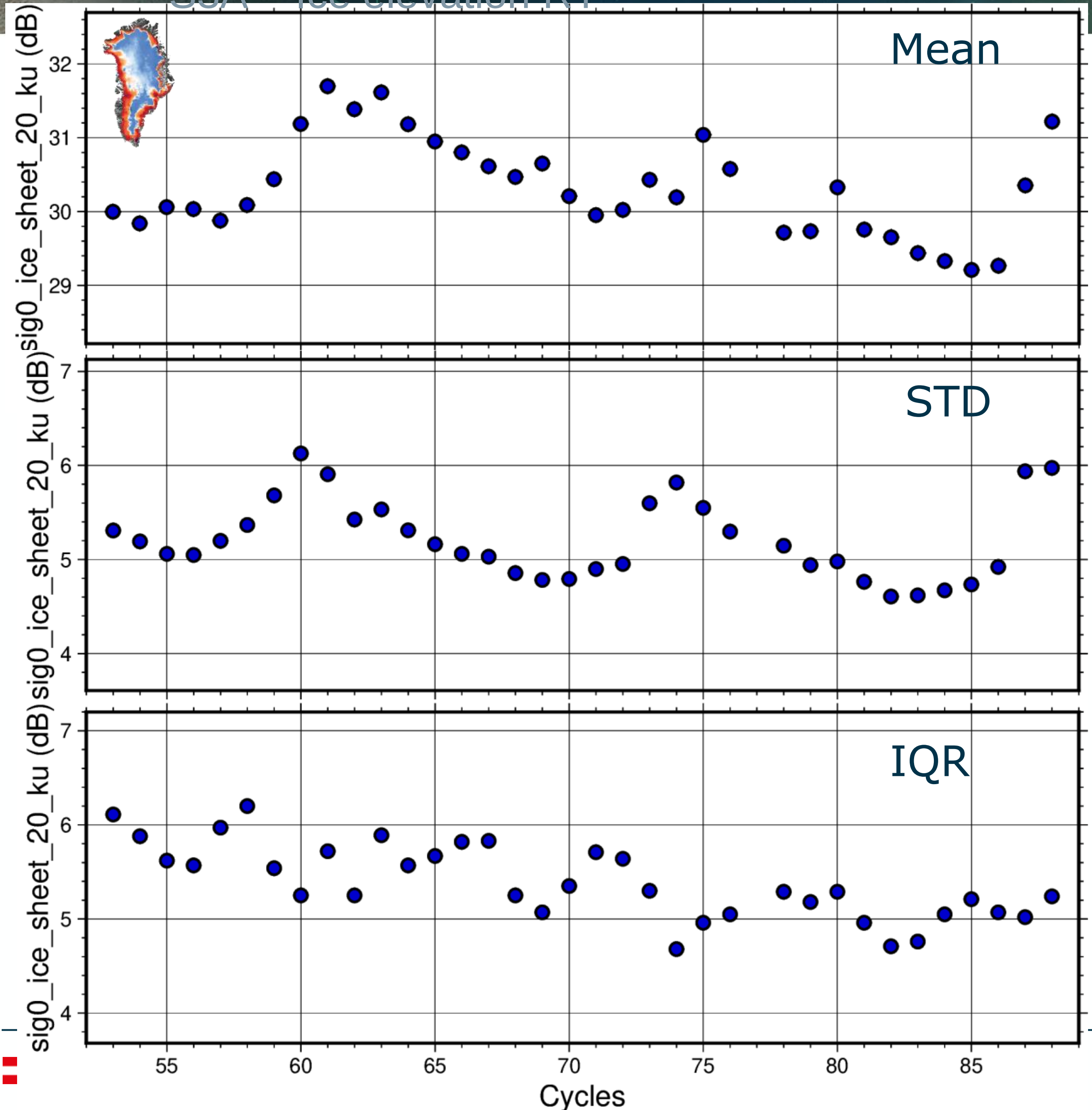
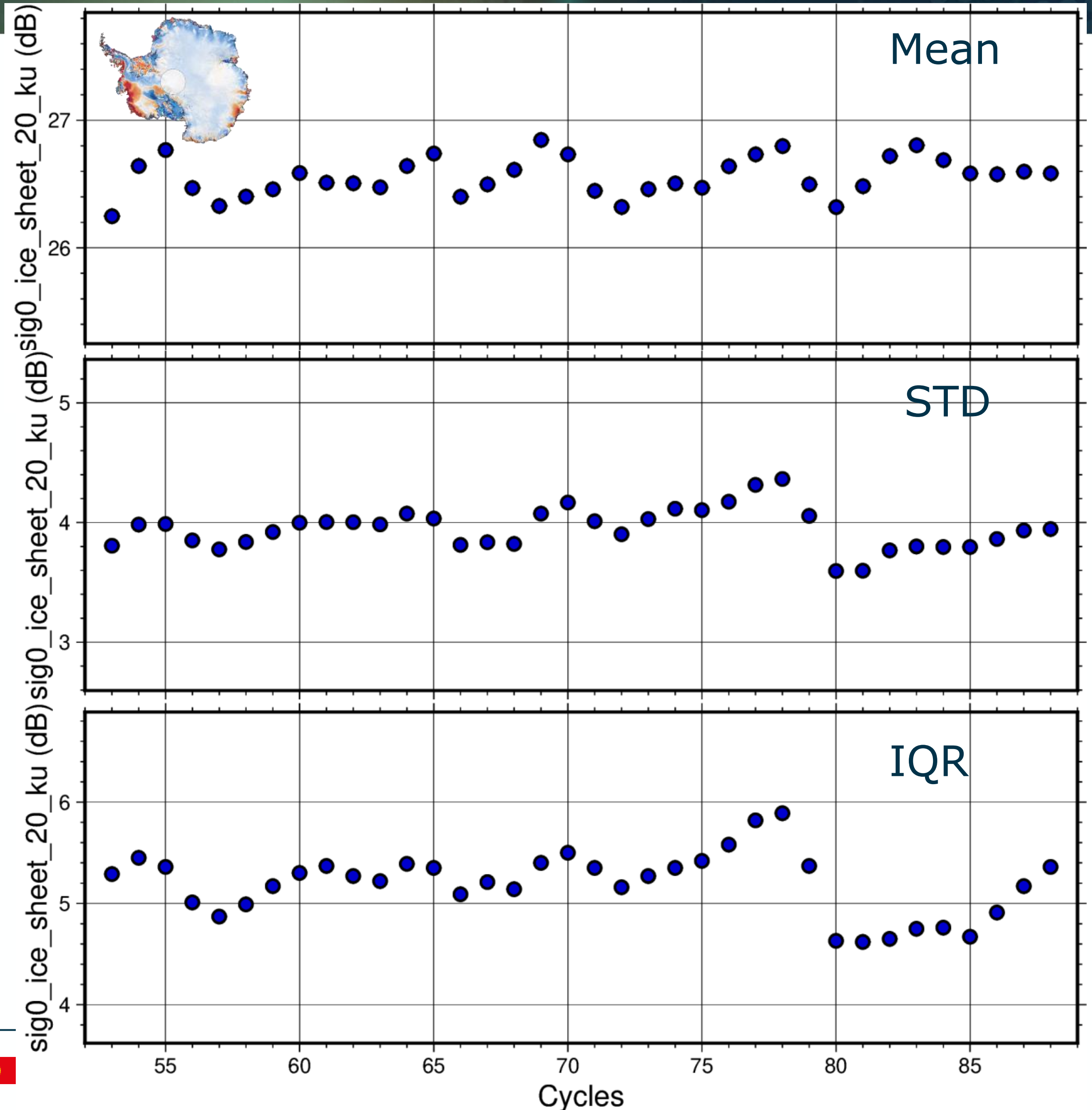


Figure 5.4 Percentage of failure over Antarctica from the elevation_ice_sheet_20_ku parameter

Land Ice ESL – Evaluation of cycles

S3A – Ice elevation RT





Sentinel-3 Mission Performance Cluster

Land Ice ESL – Evaluation of cycles

S3A – OCOG RT

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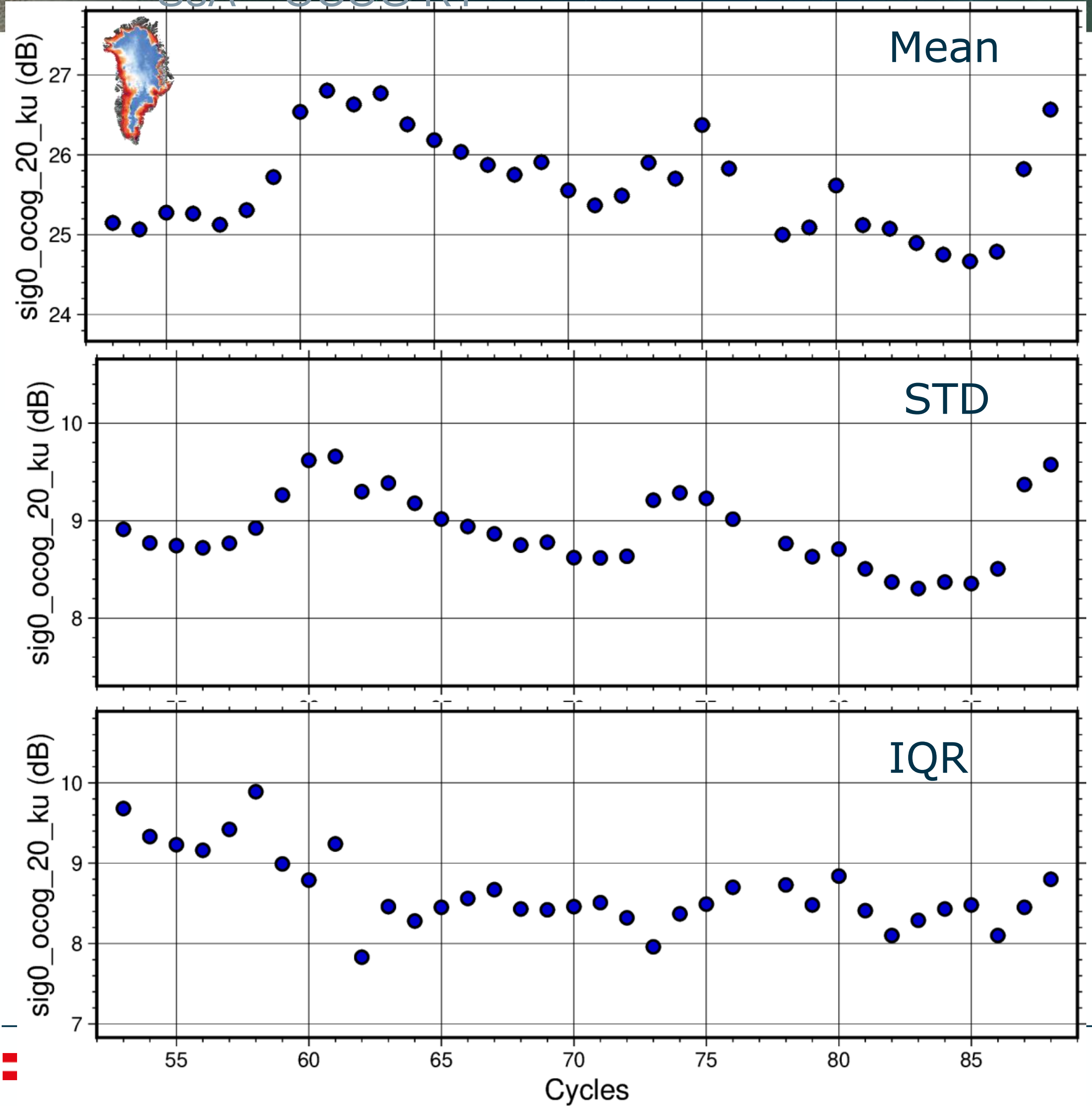
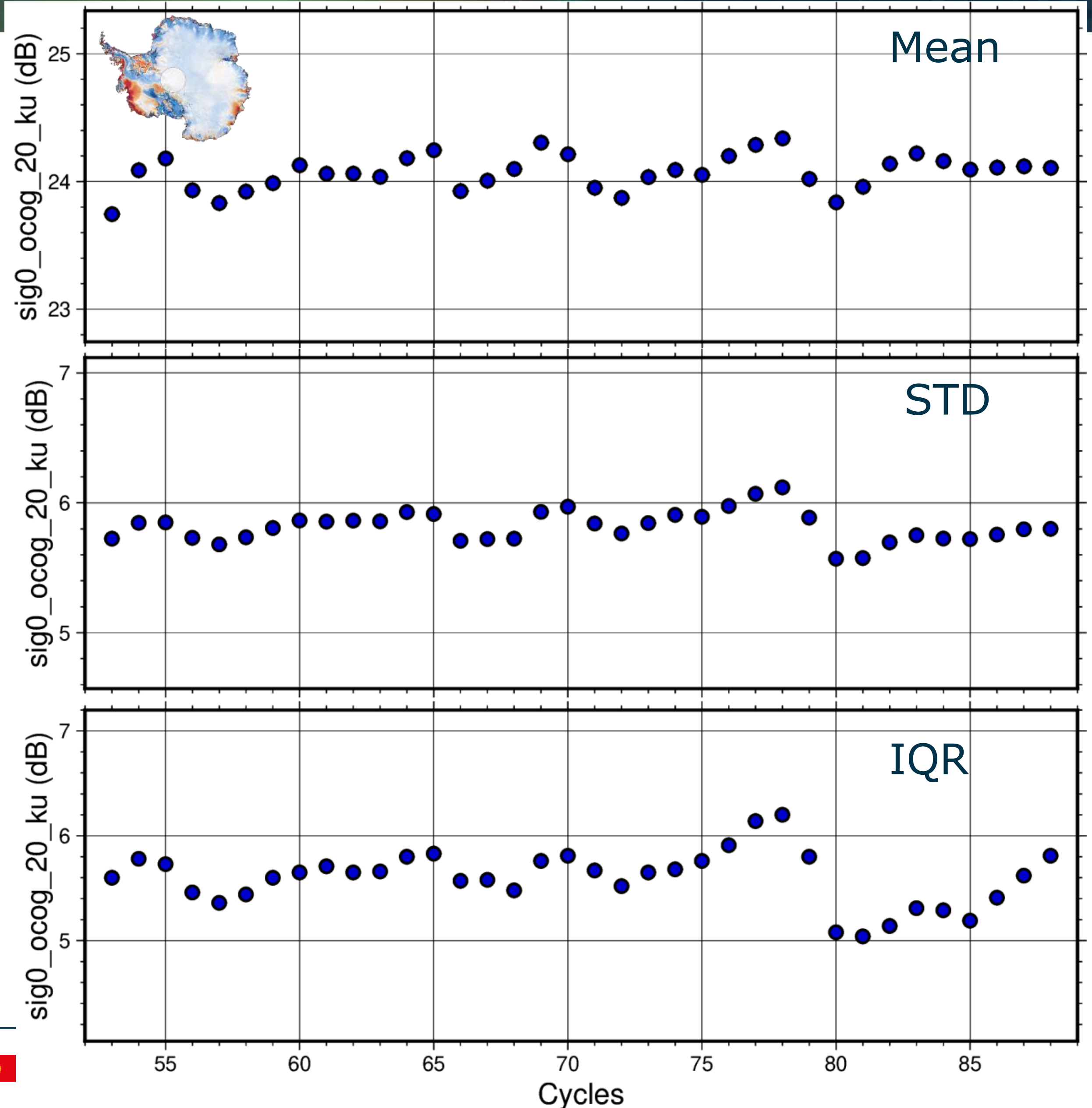
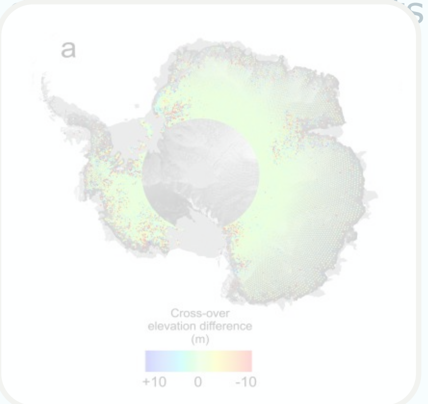




Cyclic Activities

- Monthly, per cycle, cadence.
- Internal Evaluation.
- Comparison to satellite



DTU

In Depth Analyses

- Annual cadence.
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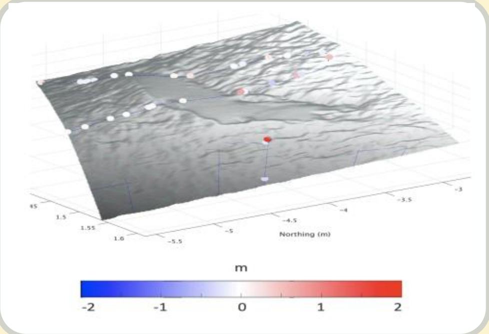
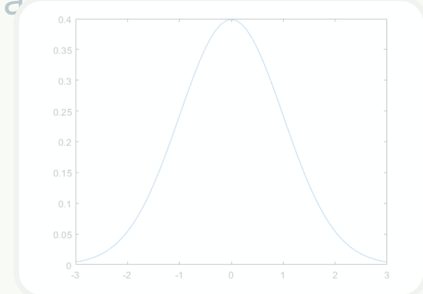


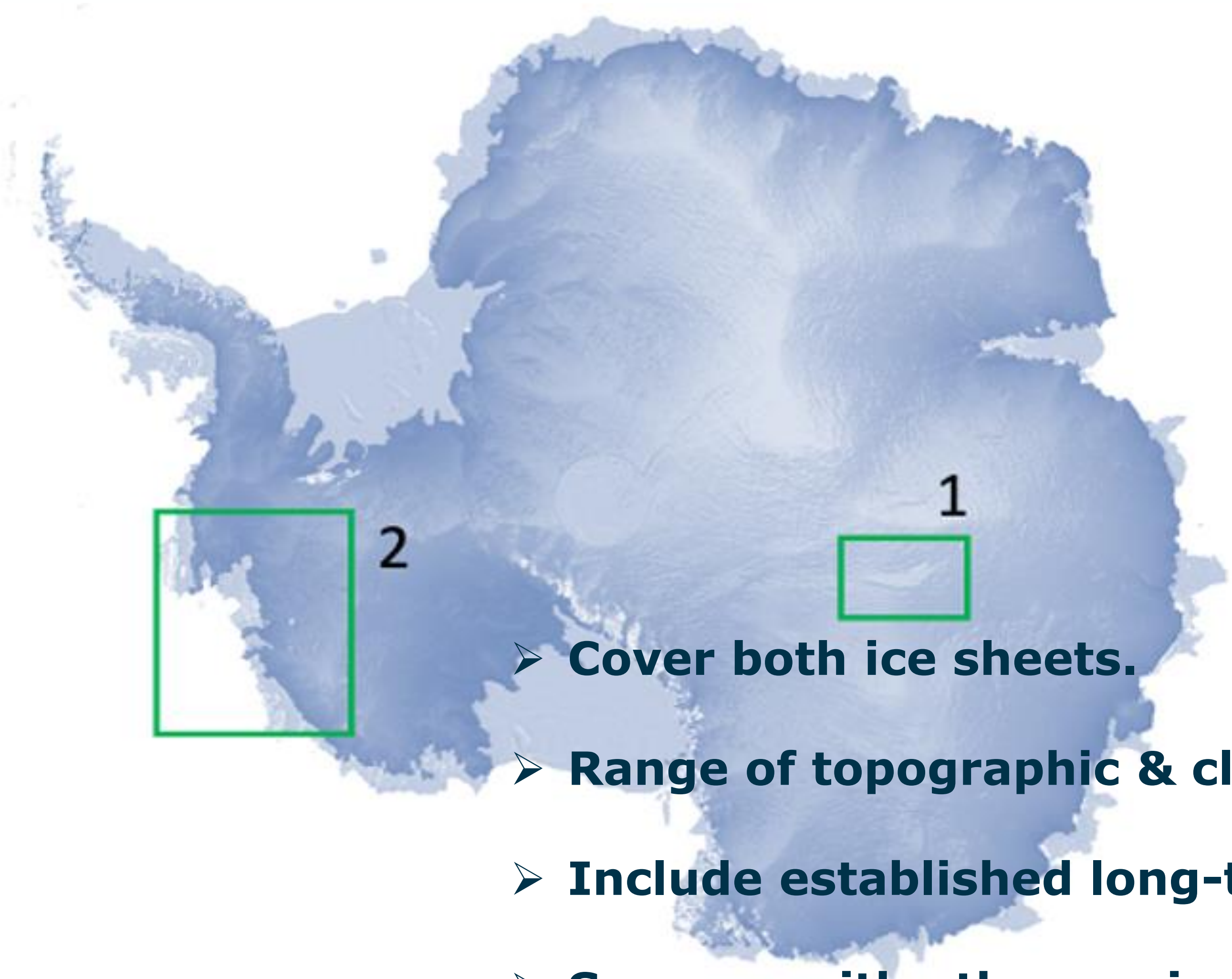
DTU CLS

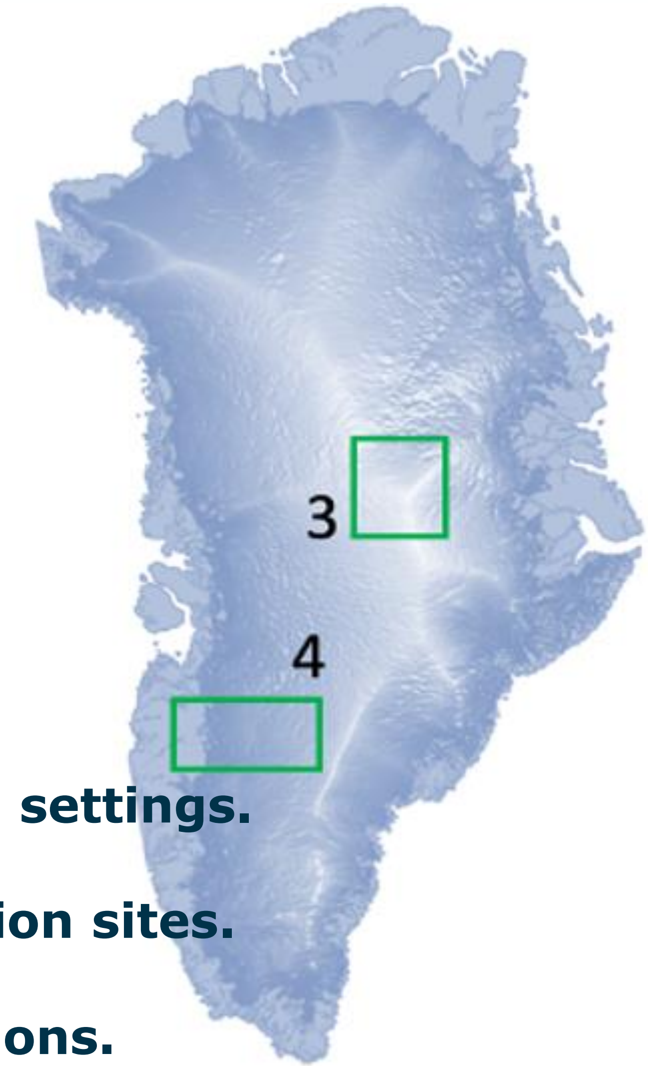
Error Budget

- Uncertainty assessment and documentation via an 'Error Budget table'.
- Characterisation according to surface type.
- Reviewed and updated



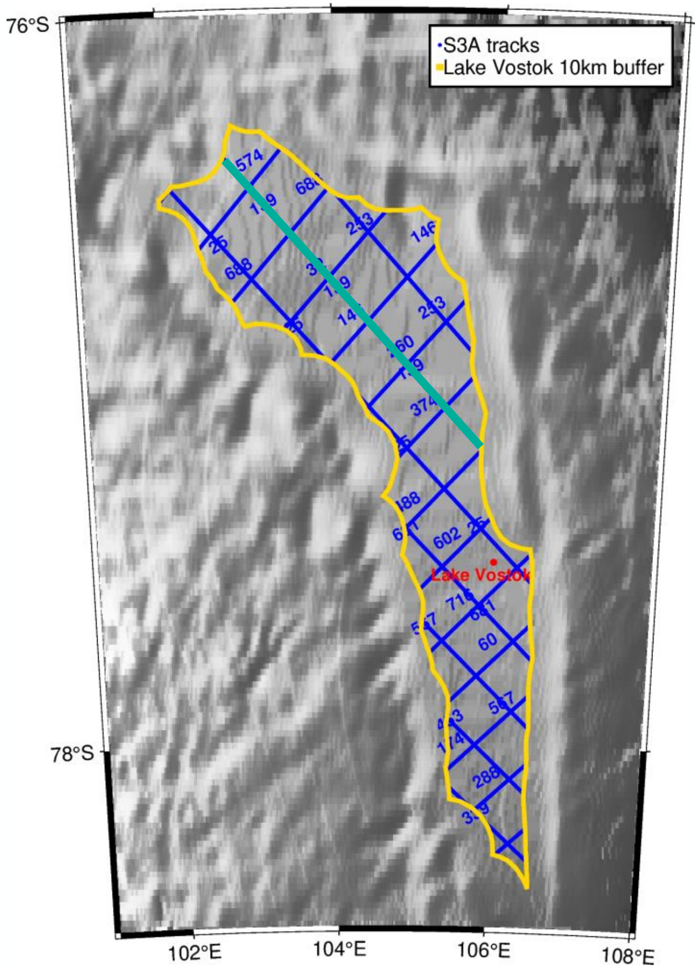
DTU





- **Cover both ice sheets.**
- **Range of topographic & climatological settings.**
- **Include established long-term validation sites.**
- **Synergy with other projects and missions.**

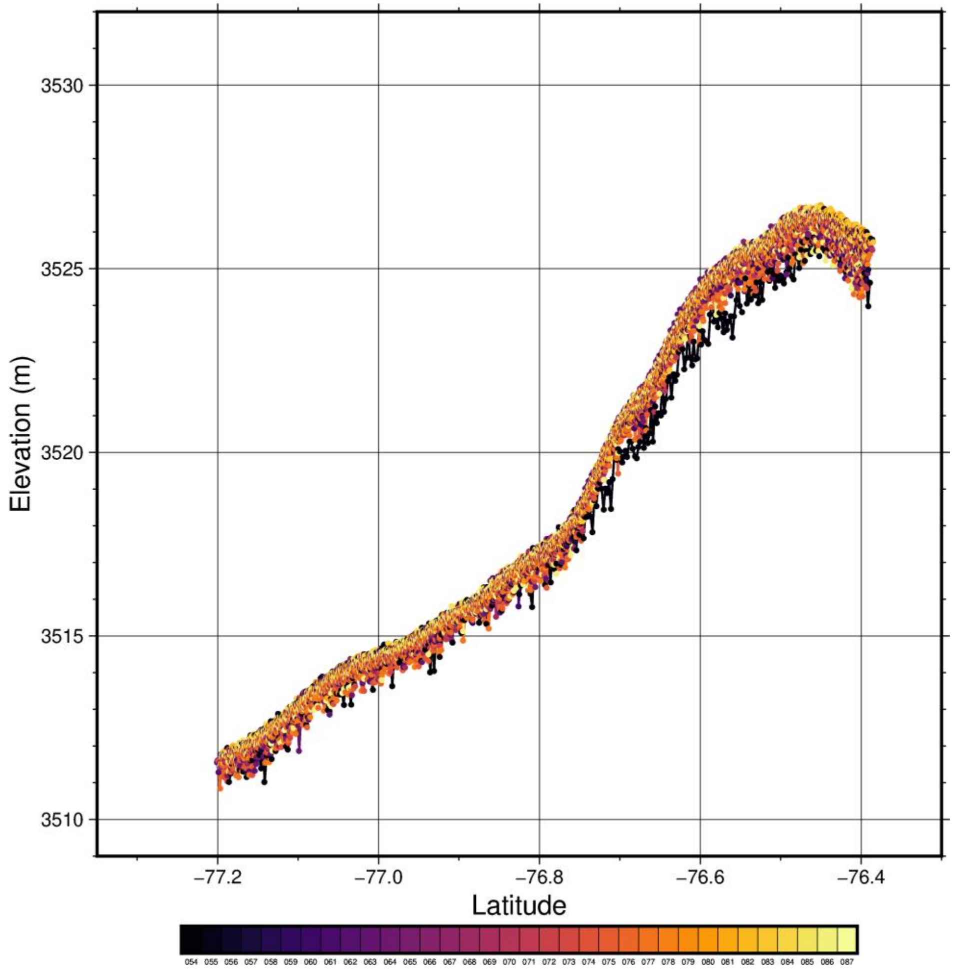
Land Ice – Vostok case study – Absolute heights

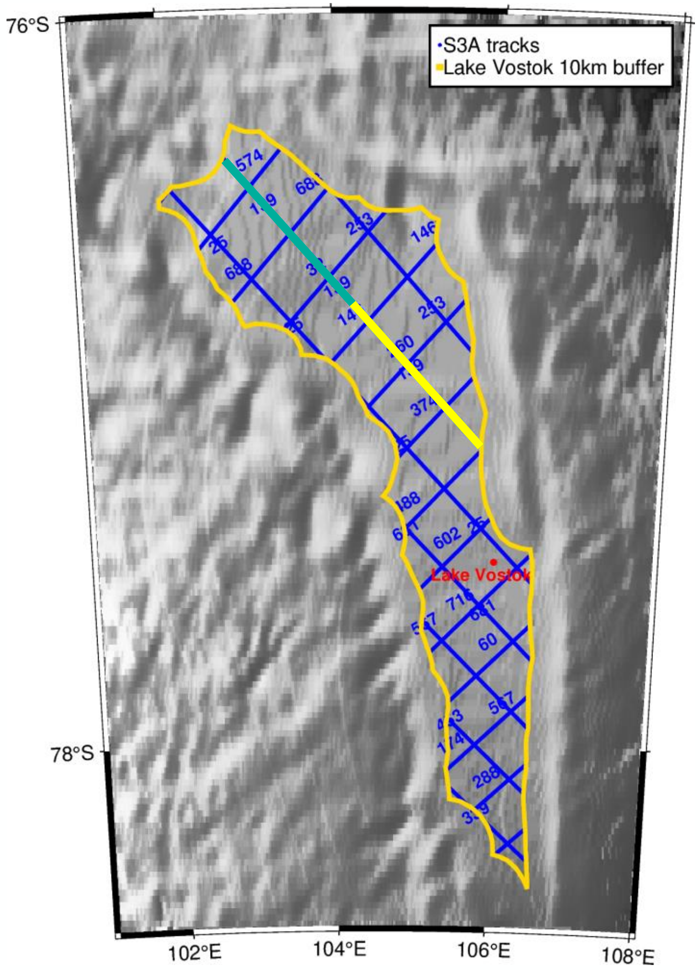


In-depth studies of the elevation's observations across the central areas of lake Vostok.

- Focusing on orbit 139 in NT cycle 54-87

S3A elevation ice sheet retracker

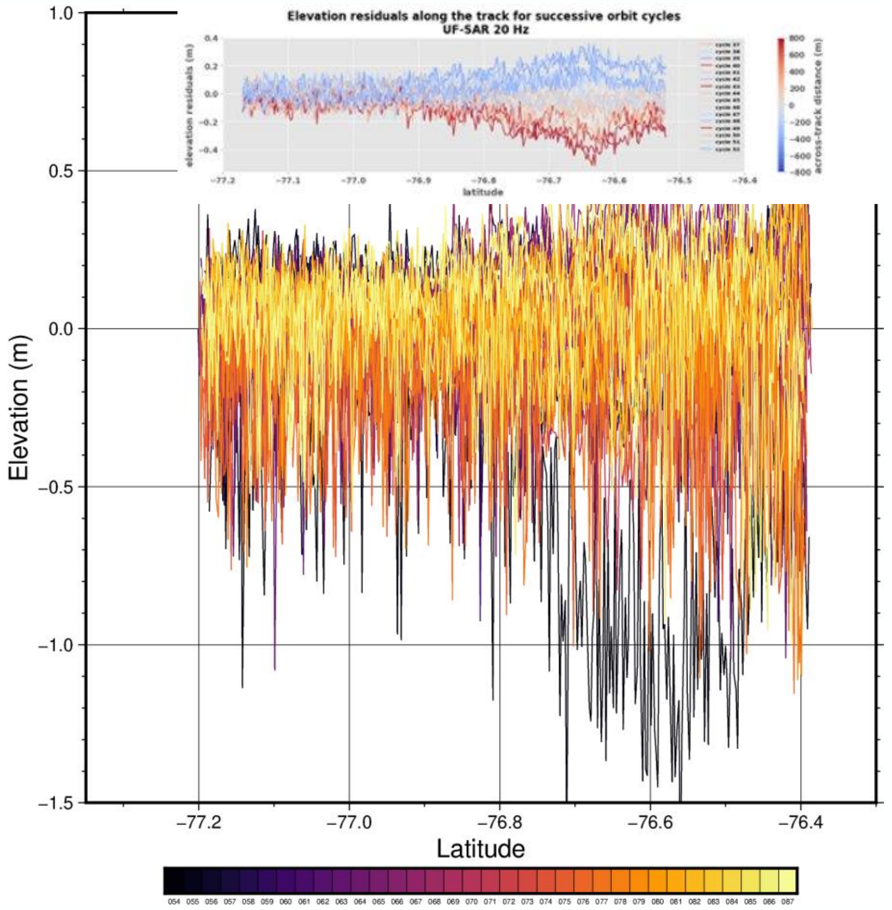


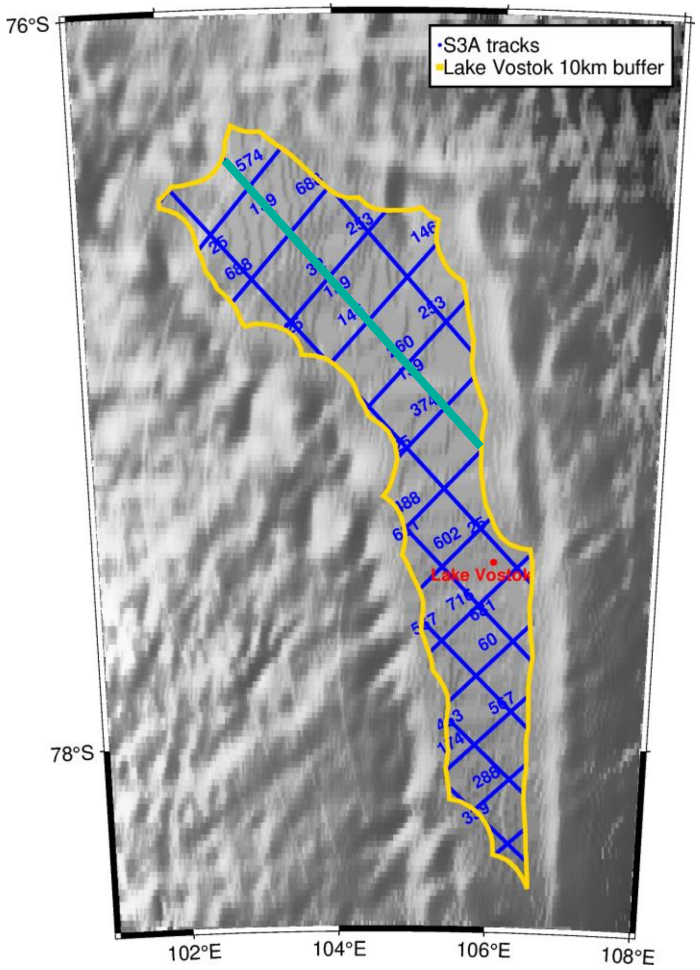


In-depth studies of the elevation's observations across the central areas of lake Vostok.

- Focusing on orbit 139 in NT cycle 54-87
- Filtering noise by removing the average elevation
- Spread in the observations measurements is combination:
  - Weather
  - Retracker stability

S3A elevation ice sheet retracker





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- Focusing on orbit 139 in NT cycle 54-87
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  - Weather
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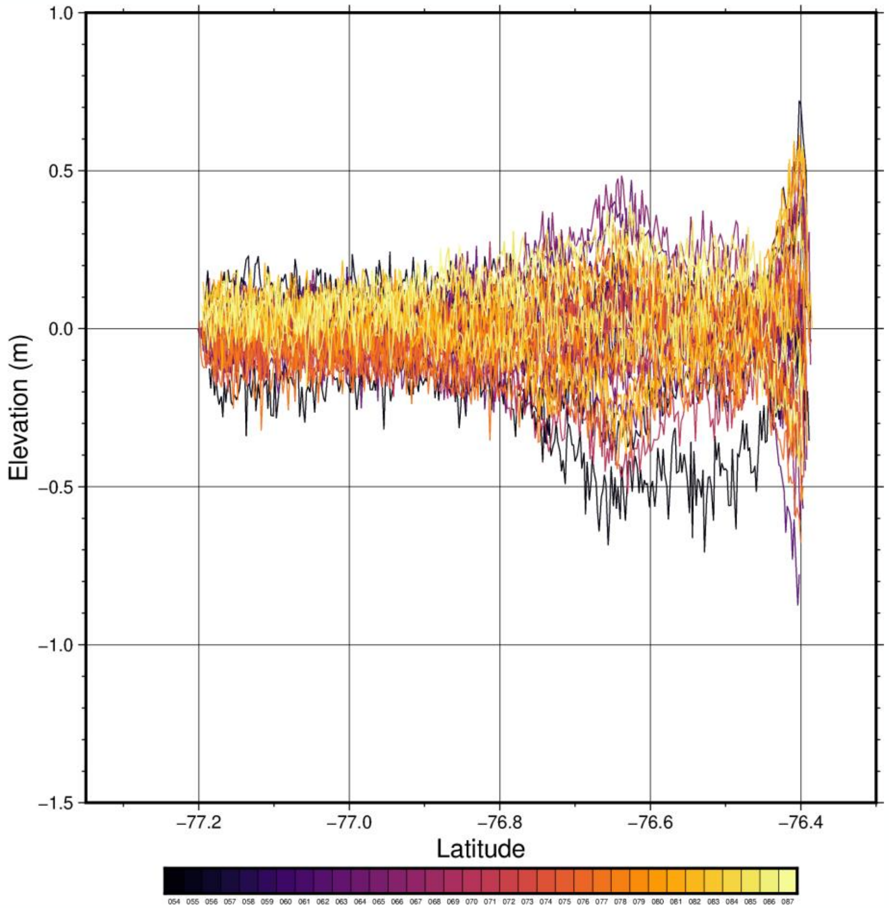
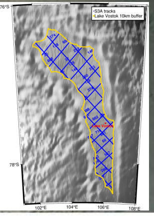
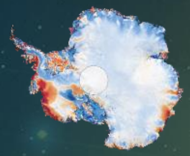
S3A elevation OCOG retracker

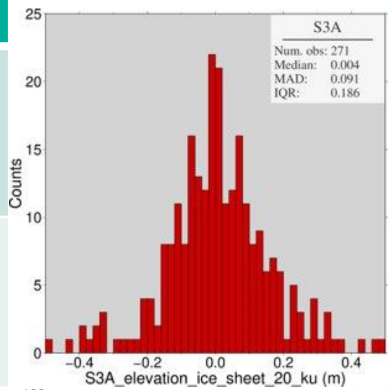


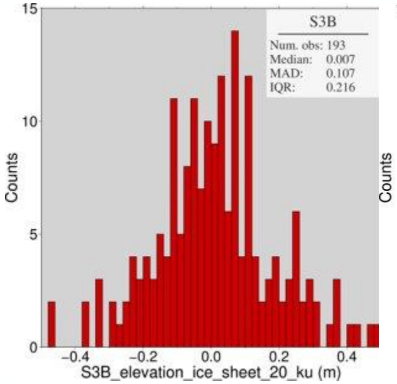


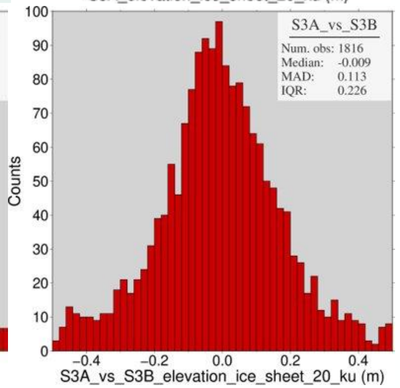
The matrix - Vostok
NT cycle S3A 54-89 and S3A 34-70

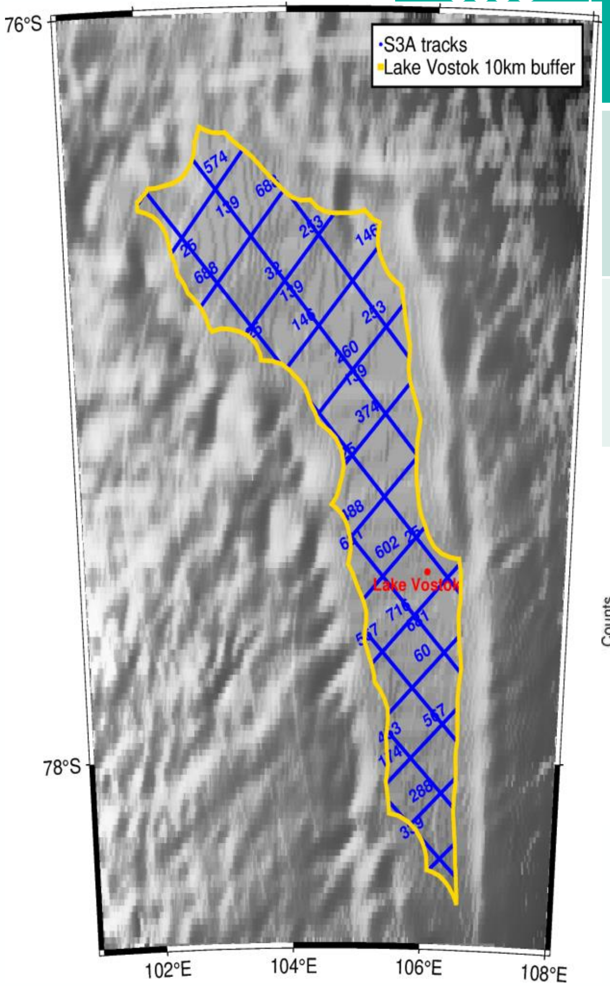


Land ice elevation MAD	S3A	S3B
S3A	9.1 cm	11.3 cm
S3B	11.3 cm	10.7 cm

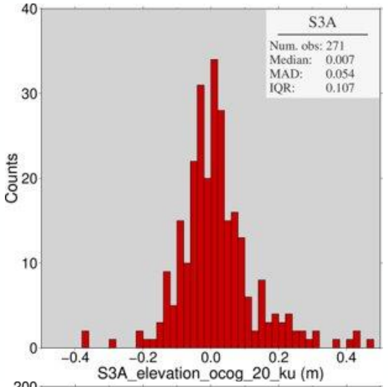


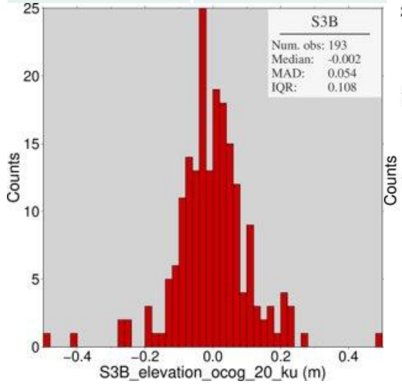


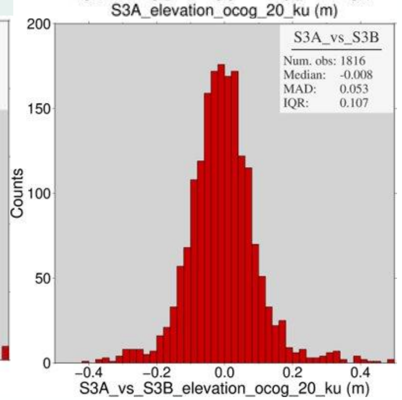


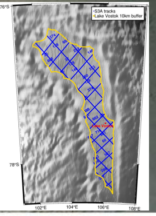


OCOG	S3A	S3B
S3A	5.4 cm	5.3 cm
S3B	5.3 cm	5.4 cm

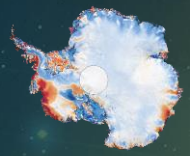








The matrix - Vostok
NT cycle S3A 54-89 and S3A 34-70



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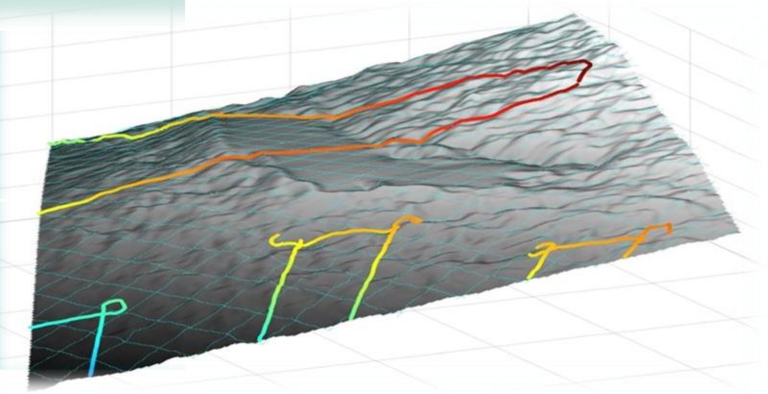
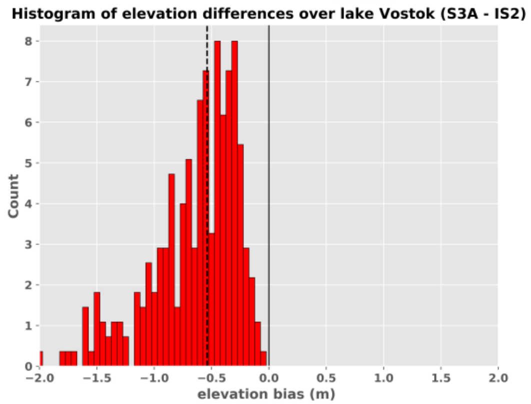
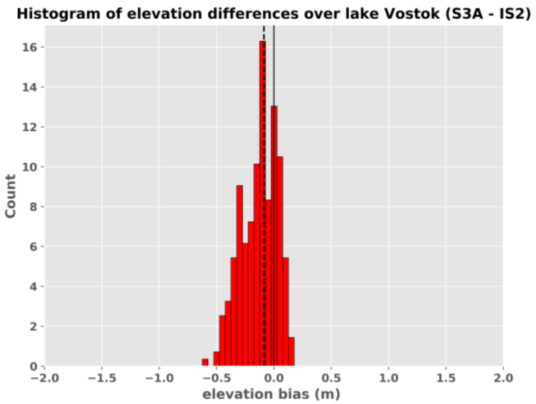
Land ice elevation MAD	S3A	S3B	OIB	IS2
S3A	9.1 cm	11.3 cm	12 cm	34.5 cm
S3B	11.3 cm	10.7 cm	10 cm	
OIB	12 cm	10 cm	0.15 cm	
IS2	34.5 cm			

OIB 2013 track



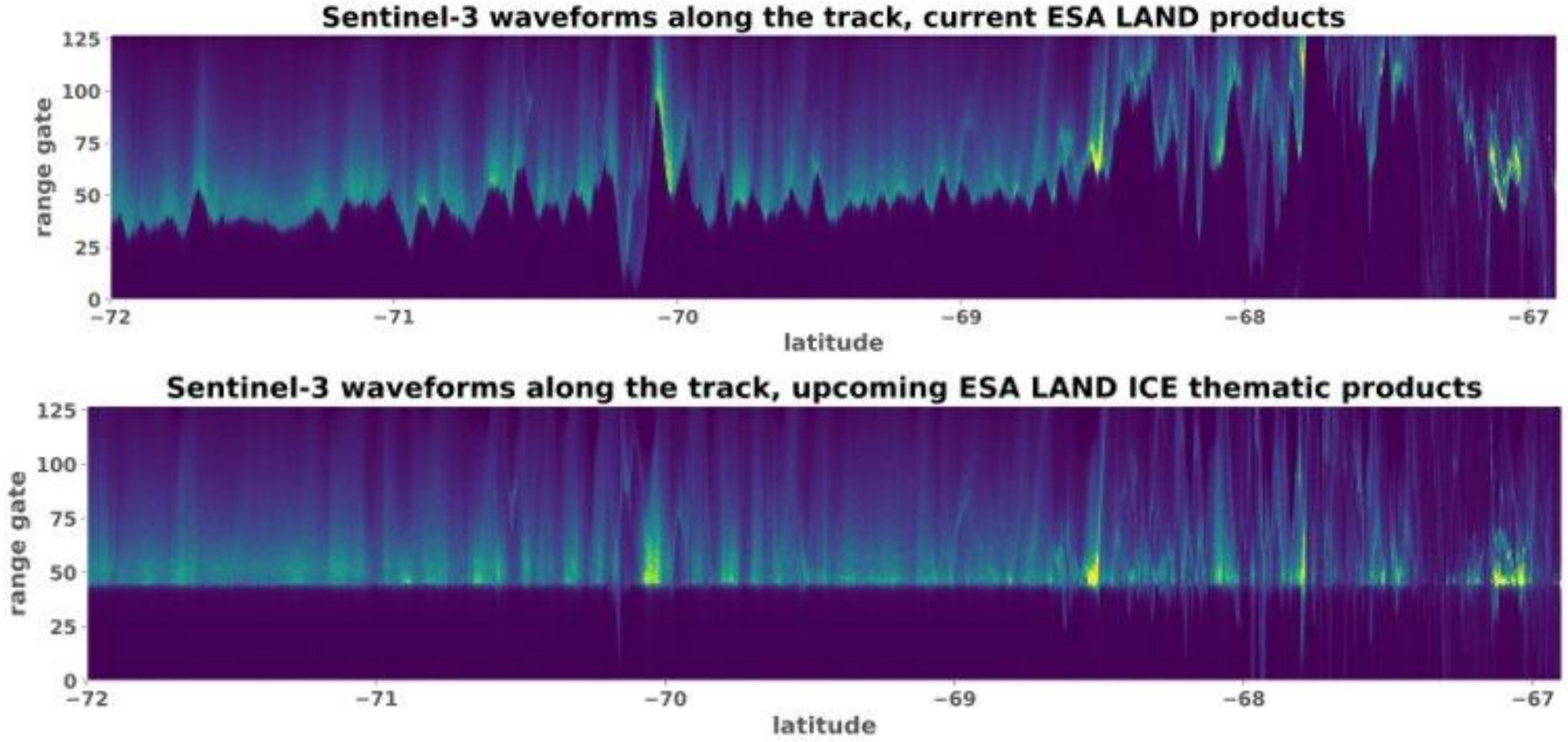


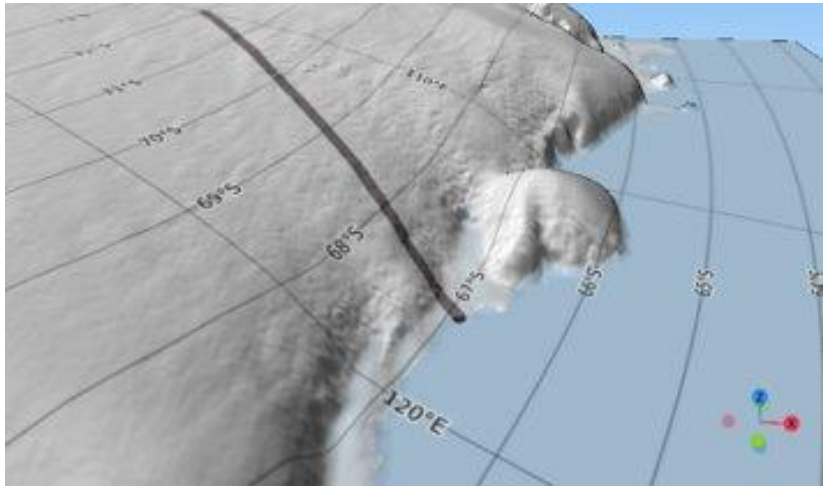
OCOG MAD	S3A	S3B	OIB	IS2
S3A	5.4 cm	5.3 cm	4 cm	17.5 cm
S3B	5.3 cm	5.4 cm	7 cm	
OIB	4 cm	7 cm	0.15 cm	
IS2	17.5 cm			



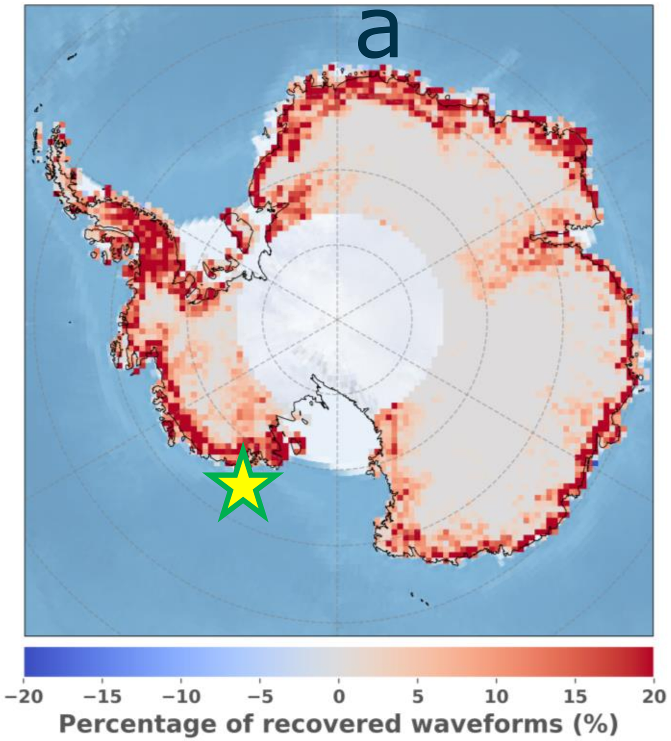
A Test Data Set was generated with the upcoming Land Ice Thematic IPF

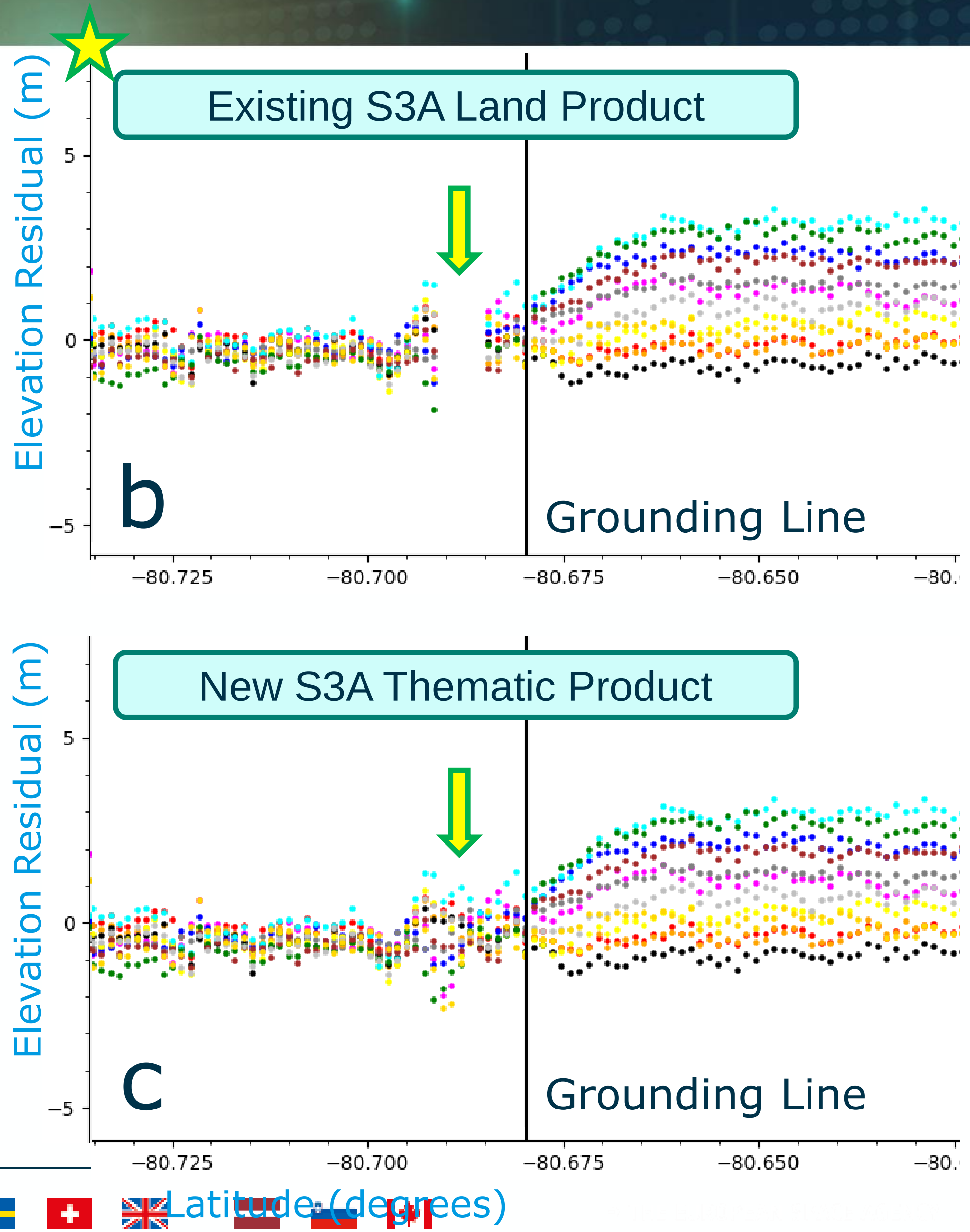
- Covering cycle 54 of the Sentinel-3A mission (from January 15th, 2020, to February 11st, 2020)
- Compared to the current IPF, the Land Ice T-IPF includes the extended window processing, and a new slope model for the POCA relocation





Improvement in coverage due to the extended window processing, especially around the coastal margin where topography is more complex.

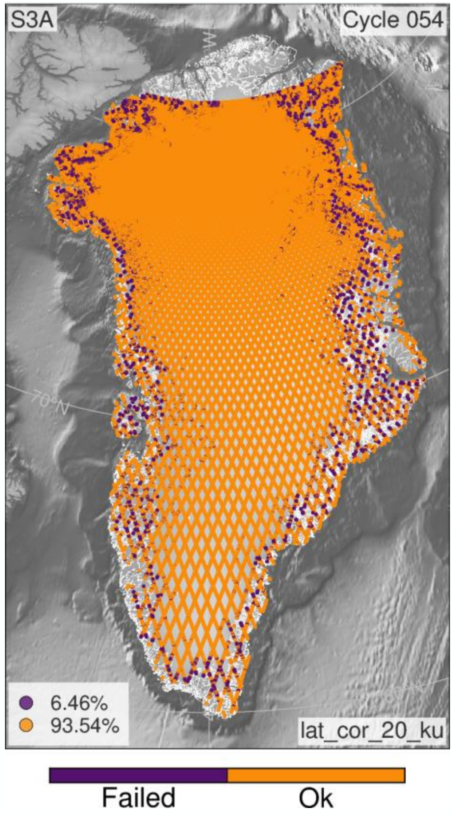




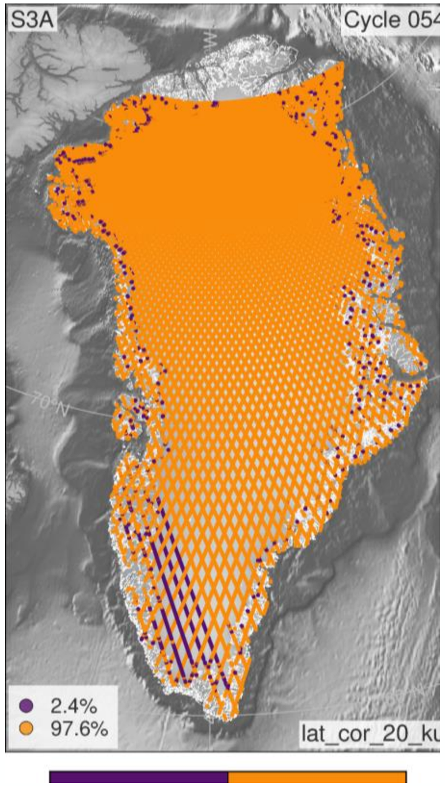
Exemplified close to the grounding line of the Filchner-Ronne Ice Shelf, illustrating the additional data retrieved (yellow arrow) within this glaciologically important region.

"Cyclic report" for the TDS S3A 054 – Slope correction

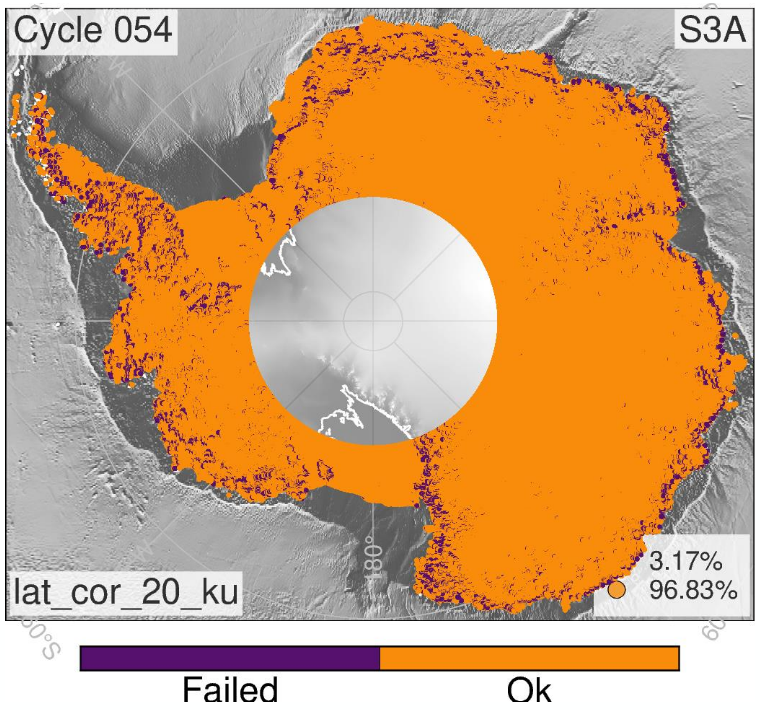
NTC



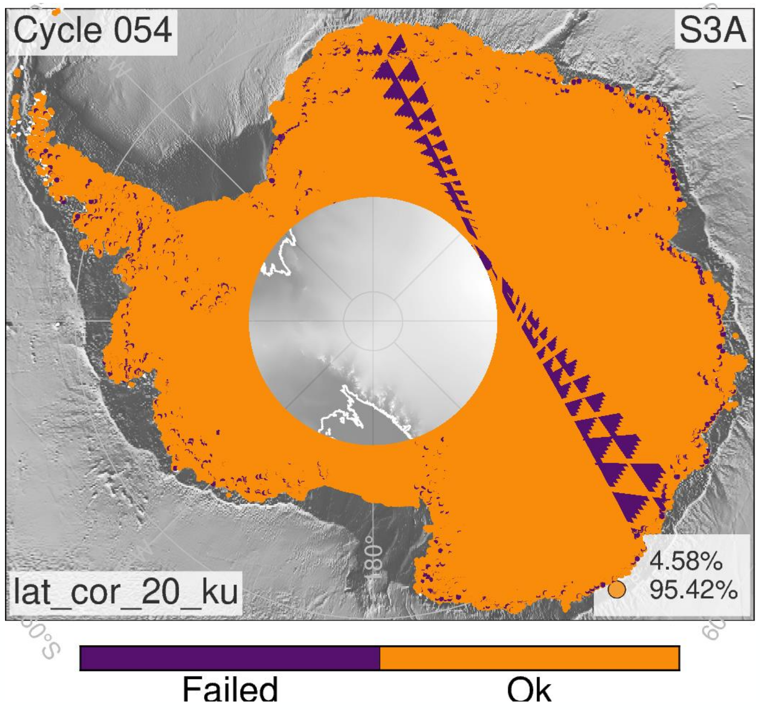
TDS



NTC

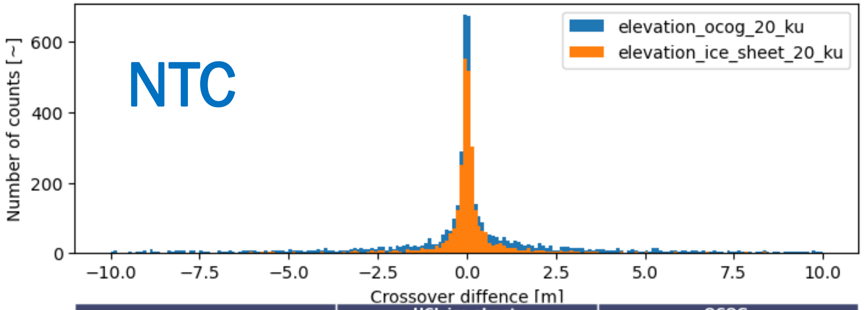


TDS

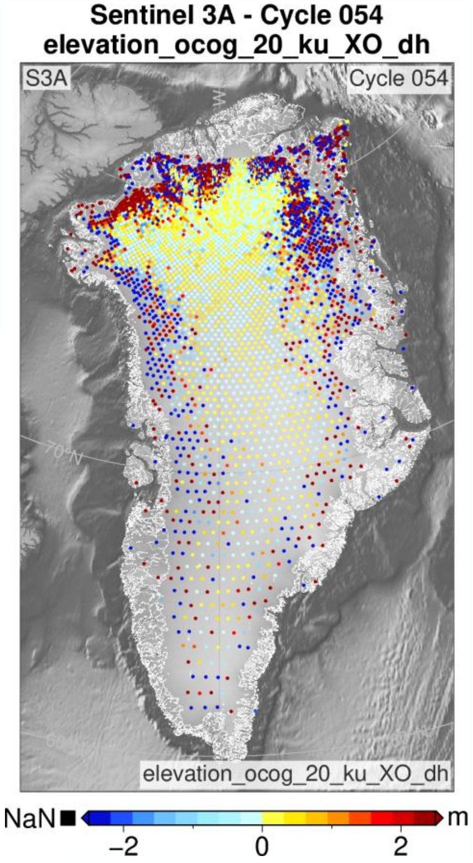


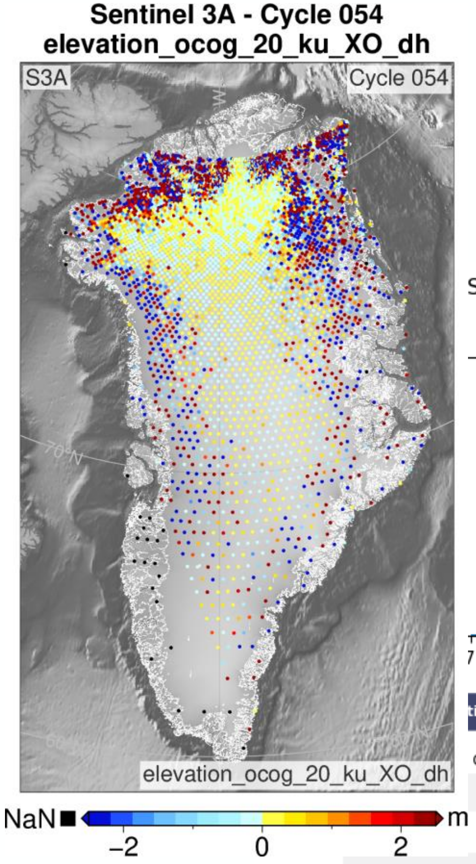
"Cyclic report" for the TDS S3A 054 – Cross-overs Greenland

Sentinel-3A_Cycle054_Greenland_crossovers_stats

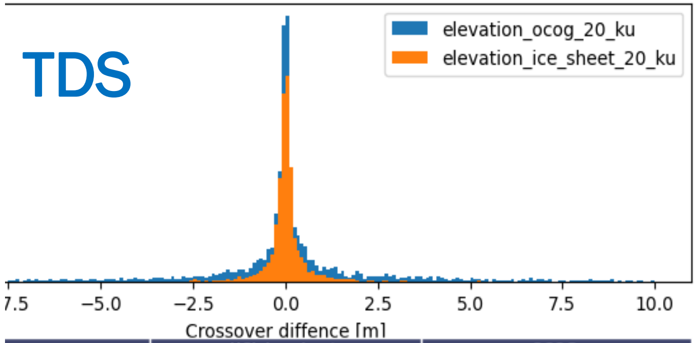


Statistics	UCL ice sheet retracker	OCOG retracker
Total number Observation [#]	3181.0	6800.0
Median [m]	0.02	0.027
Std [m]	146.485	116.82
Observ. [%] (dh < 1 m)	75.731	43.956
Median [m] (dh < 1 m)	0.006	0.004
Std [m] (dh < 1 m)	0.296	0.326





Sentinel-3A_Cycle054_Greenland_crossovers_stats



tistics	UCL ice sheet retracker	OCOG retracker
Total number Observation [#]	2701.0	6004.0
Median [m]	0.007	0.006
Std [m]	169.398	81.377
Observ. [%] (dh < 1 m)	87.079	52.049
Median [m] (dh < 1 m)	0.005	0.002
Std [m] (dh < 1 m)	0.292	0.348

Comparison to nearly co-located ICESAt-2 ATL06 v005 measurements

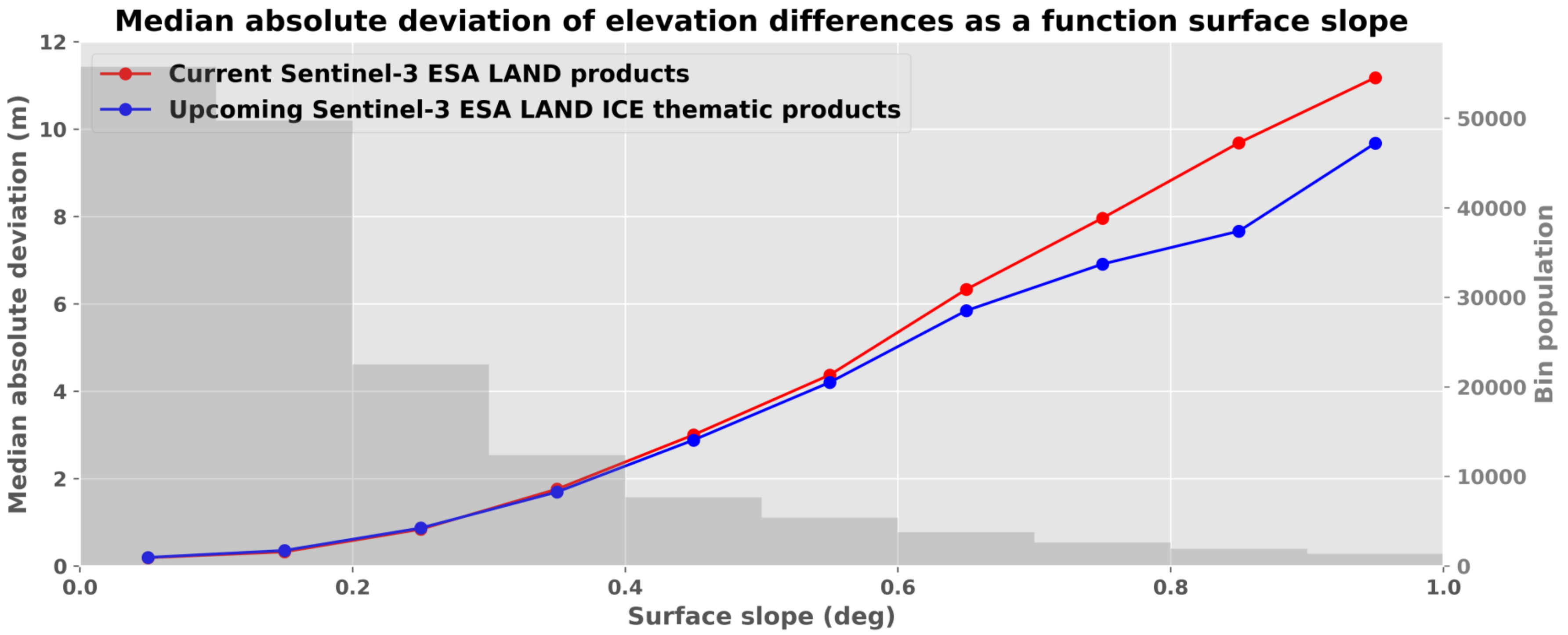
Search radius = 50 m & maximum time span = 46 days

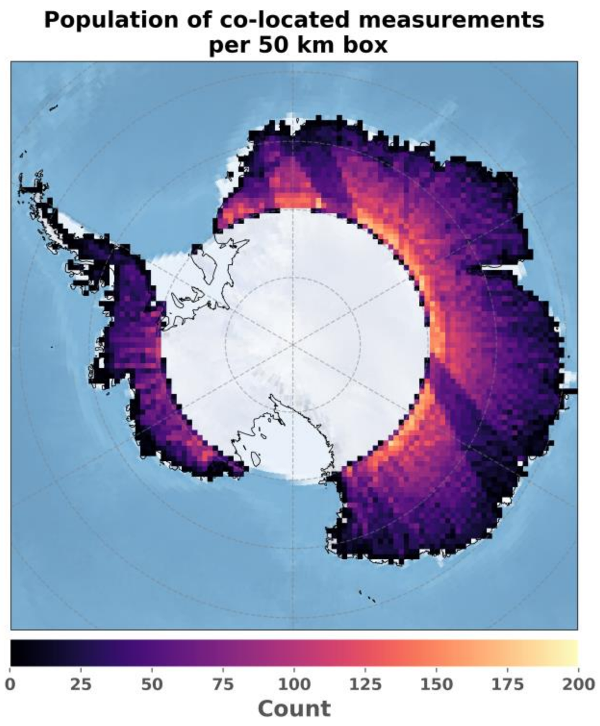
Quality controls performed on S3 data (elevation from ICE-1 RTK)

Sigma-0 > -12 dB, Relocation distance < 15km, waveform_qual_ice_20_ku == 0 | waveform_qual_ice_20_ku == 2

Latitude > -78°, to limit the oversampling of areas close to the poles

Elevation differences > 100m not included in the statistics





1 – Missing measurements: When the on-board tracker of the altimeter loose the signal, and shifts from "measurement" to "acquisition " mode to recover it (no measurements in the products)

2 – Very low SNR: When the Sigma-0 is estimated below -12 dB (a rough estimation based on WF max. amplitude value, to estimate the SNR on **all available** measurements)

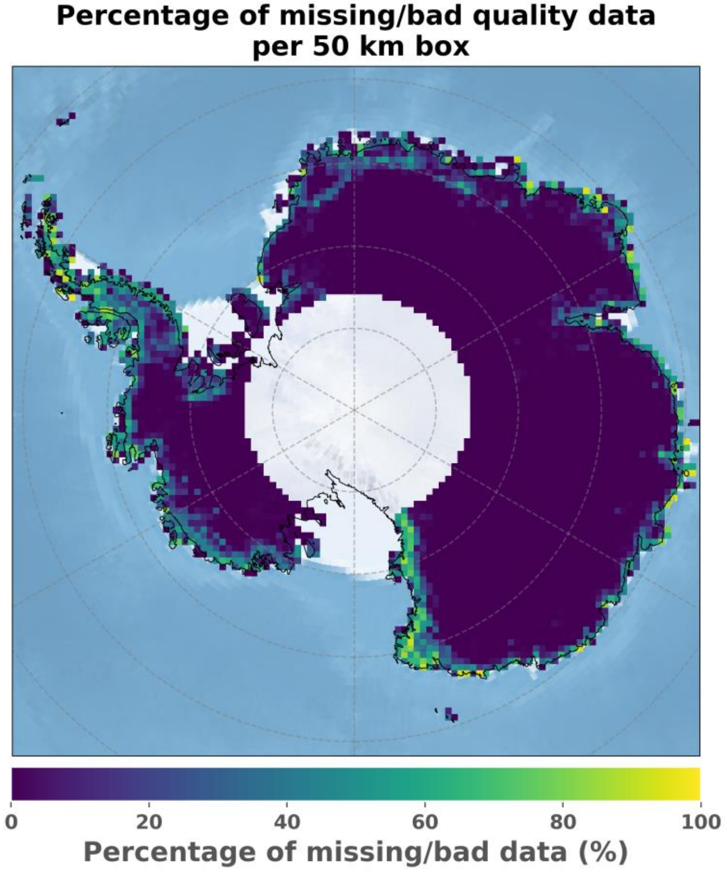
3 – Invalid waveforms: When the waveforms is flagged not valid by the dedicated flag available in the product ("waveform_qual_ice_20_ku")

	1 - Missing data	2 - Very low SNR	3 - Invalid waveforms	SUM
Current LAND products	2.47%	3.22%	6.33%	9.09%
Upcoming land ice thematic products		1.62%	2.05%	4.76%

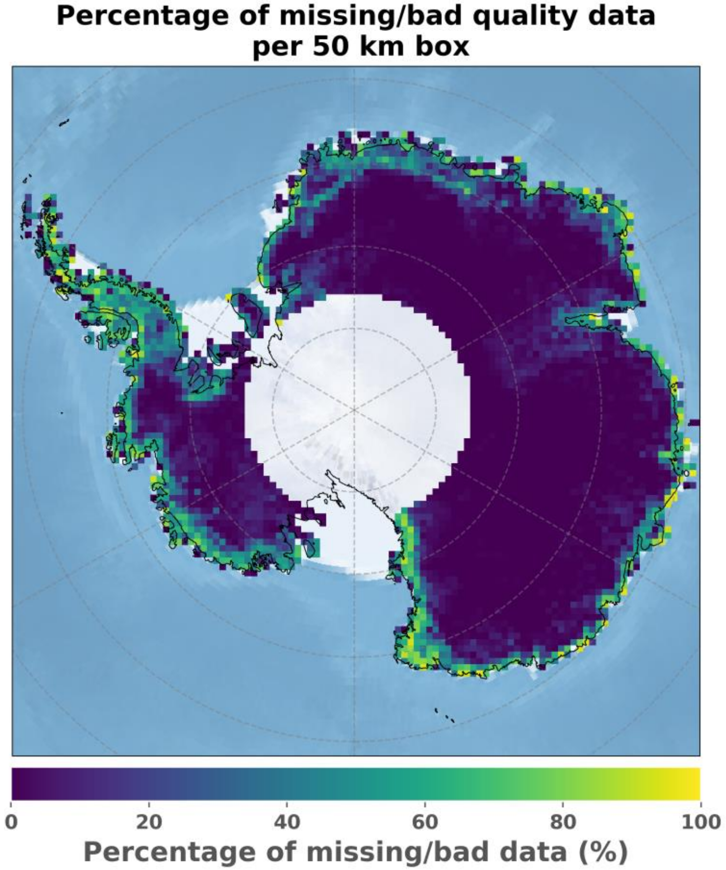
20

Ratio of "bad quality" or "missing" measurements per 50 km box

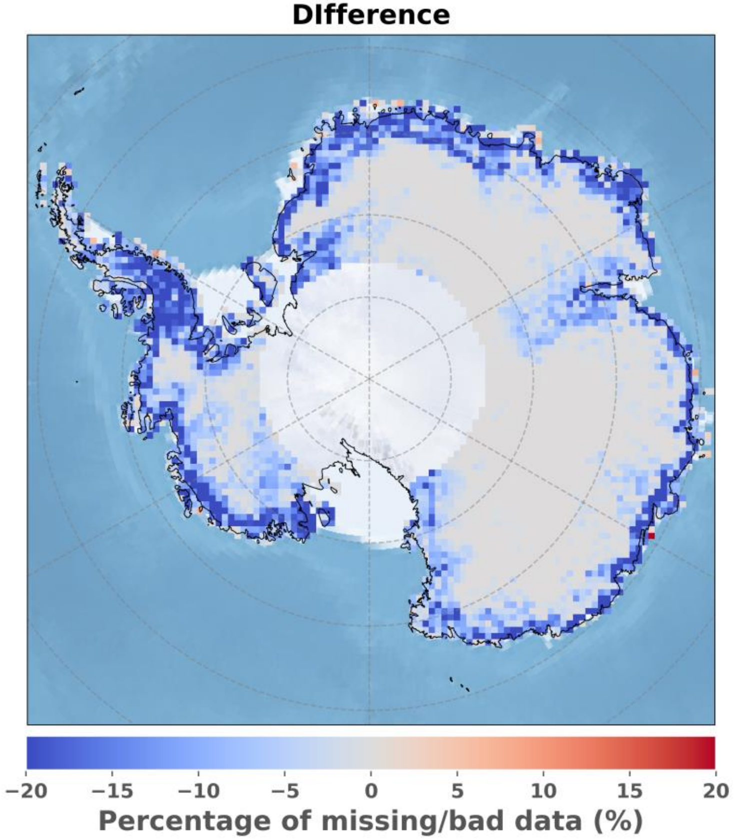
LAND ICE Thematic products



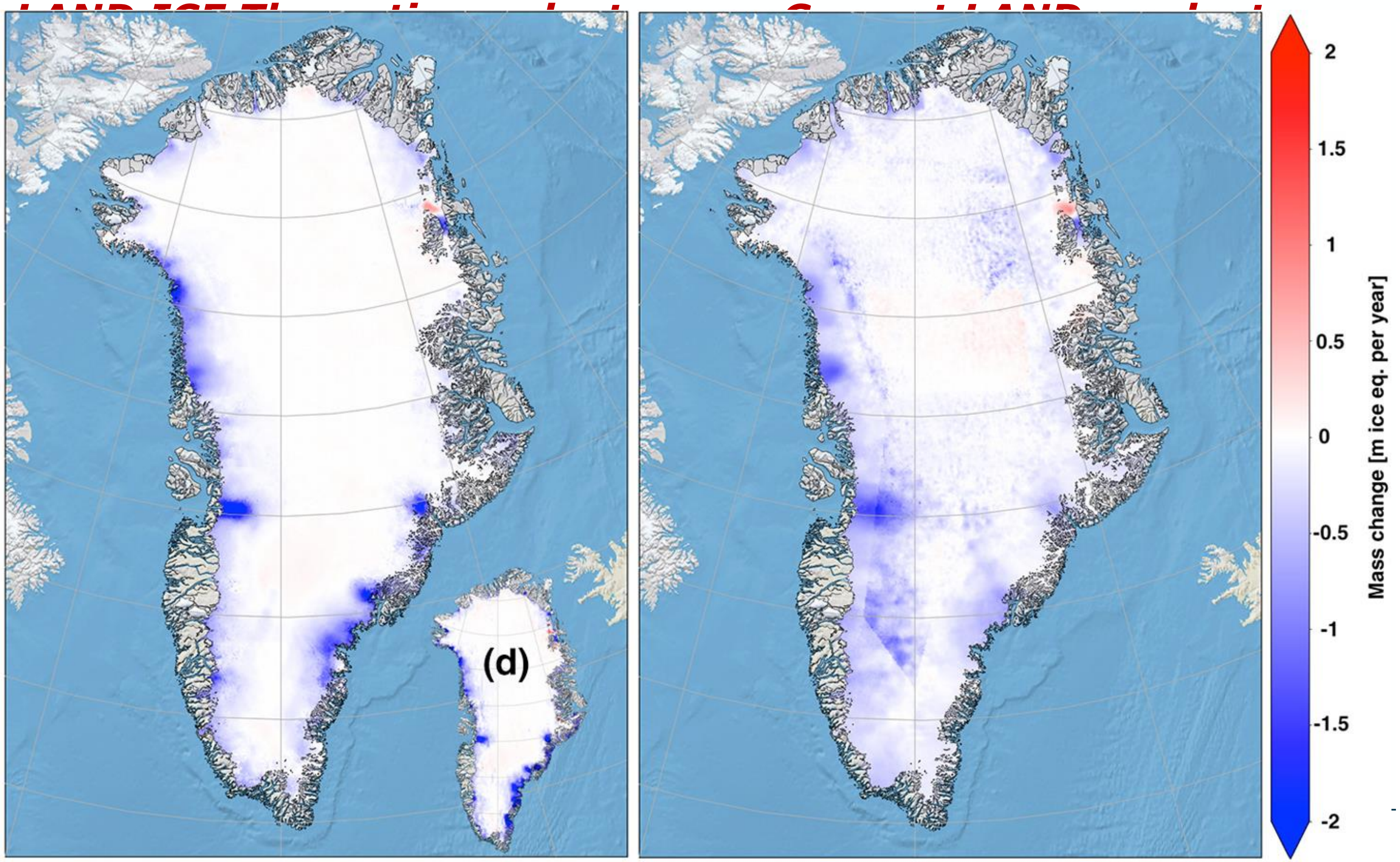
Current LAND products



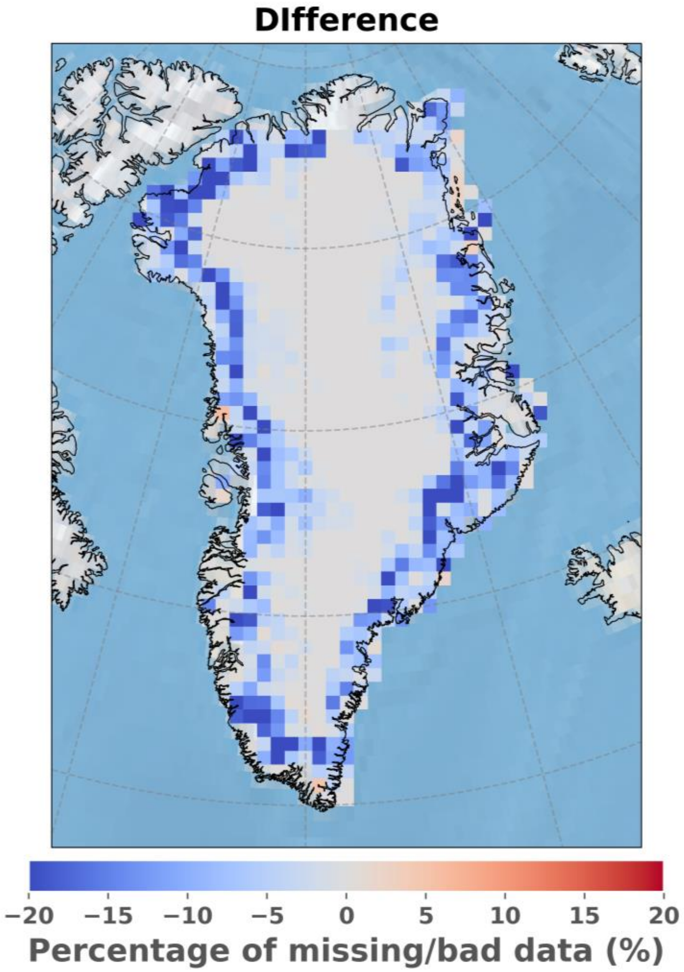
Difference of the two maps



Ratio of “bad quality” or “missing” measurements per 50 km box



Difference of the two maps

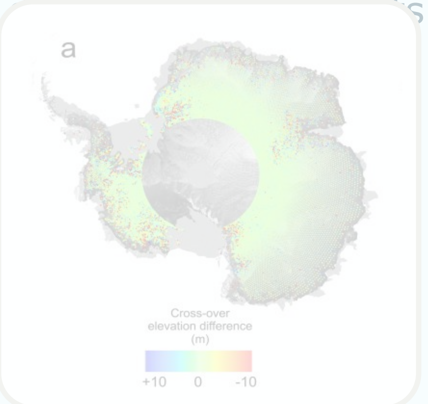


Current evolutions listed in the roadmap over land ice

	Title	Maturity (High/Medium/Low)	Priority (High/Medium/Low)
1	Dedicated ice sheet/ice shelves flag	High	High
2	New DEM information (slope, elevation…)	High	High
3	Waveform Classification using Neural Network	Medium	High
4	Improvement of the measurement location at POCA	Medium	High
5	Tunning of Sigma0 for all retrackers	High	Medium
6	Doppler processing in exact beam forming	High	Medium
7	Waveform shape parameters from retracking	Medium	Low
8	Use of MNT for Doppler processing focussing	Medium	Low
9	Other parameters	Low	Low

Cyclic Activities

- Monthly, per cycle, cadence.
- Internal Evaluation.
- Comparison to satellite



DTU

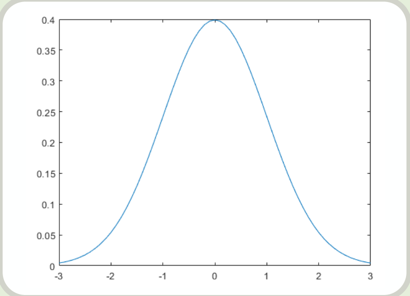
In Depth Analyses

- Annual cadence.
- External validation against airborne & in situ data.
- Benchmarking against other satellite products.

DTU CLS

Error Budget

- Uncertainty assessment and documentation via an 'Error Budget table'.
- Characterisation according to surface type.
- Reviewed and updated annually.



DTU

Land Ice ESL – Error Budget

Source	M	rms	U1	CD [km]	CT	U2
Snow Penetration	50	50	cm	10	1	Year
Asymmetry	50	50	cm	100	1	Year
Re-tracker		25	cm	1		
Radar Speckle	20	20	cm	1		
Terrain gradient		5	cm	1	1	Year
Satellite position		1,5	cm	20000	12	Hour
Ice shelf tides	20	1	cm	300	12	Hour
Dry troposphere	230	0,5	cm	1000	1	Day
Wet troposphere	50	0,5	cm	100	3	Hour
Ionosphere	20	0,3	cm	1000	3	Hour
Datation errors		0,25	cm		1	Year
GIA errors	1	0,1	cm/yr	2000	>100	Year
Range bias	100	0,1	cm		1	Year

Error sources as identified for CryoSat-2 within the CryoVal-LI project.
M indicates the expected magnitude of the effect prior to correction (if relevant)
Rms the standard deviation after a correction method is applied
U1 shows the units that apply to M and rms.
CD is the expected spatial scale in kilometer associated with this effect
CT is the expected time scale, with unit **U2**

Radar altimetry-derived estimates of ice sheet elevation are subject to a wide range of uncertainties; some are common to altimetry measurements across multiple different surface types, and others are specific to ice sheets. These errors differ in their relative importance across different parts of the ice sheet surface and vary in terms of spatial and temporal correlation structures.

For ice sheets, the dominant sources of uncertainty arising from:

1. Retracking
2. Level-2 geophysical corrections (including corrections for ocean tide and atmospheric pressure over floating ice shelves)
3. Radar wave penetration into the snowpack
4. The echo relocation (commonly called the slope correction; which accounts for the fact that over ice sheets the target surface is not orthogonal to the radar boresight vector, meaning that the point of closest approach is upslope of nadir).

Error Budget table is based on a review of the literature

Thank you, for your attention!

Since cycles **078/059**, the cyclic validation of **Land Ice and Sea Ice** is reported in two separated documents. **For Land Ice,** the SR_2_LAN Level 2 STC (Short Time Critical) products generated by the LAND Centre are assessed. The reports focus on the data availability, global performances of the main geophysical parameters recorded in the products (ice sheet elevation, Sigma-0...), and on any detected changes in the data quality.

S3 Land Ice Cyclic Quality Reports										
2022	078/059	079/060	080/061	081/062	082/063	083/064	084/065	085/066	086/067	087/0
	088/069	-								