

Validation of Sentinel-3A/B baseline collection BC_005 over ocean

F. Nencioli¹, L. Rinchuso¹, P. Prandi¹, C. Durnad¹,
B. Lucas², S. Dinardo² and C. Nogueira-Loddo²

¹ Collecte Localisation Satellites, ² EUMETSAT

2023 OSTST, 2023-11-09



fnencioli@groupcls.com



The COPAS project

- COPernicus ALTImetry Service for the Sentinel-3 mission



- Started on May 2022
- Regular monitoring of Sentinel-3 Surface Topography Mission (STM) performance over the oceans

The COPAS project

- COPernicus ALTimetry Service for the Sentinel-3 mission



- Started on May 2022
- Regular monitoring of Sentinel-3 Surface Topography Mission (STM) performance over the oceans

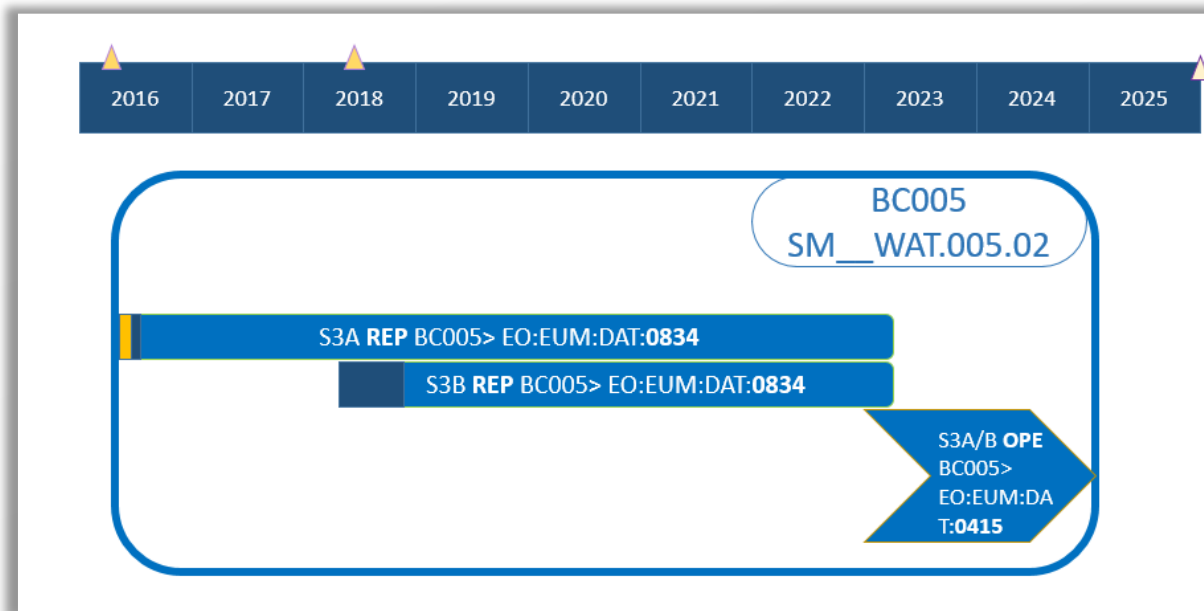
Monitoring activities presented today:

- Validation of the ground processing and final products
- Assessment of the overall mission performance
- Support for the continuous improvement of the S-3 STM performance



Baseline Collection BC_005

- Processing baseline (PB) SM__WAT.005.02 deployed operationally on 9 March 2023
<https://www.eumetsat.int/new-evolution-sentinel-3-altimetry-products>
- Full mission reprocessing released on 31 July 2023
<https://www.eumetsat.int/release-sentinel-3-altimetry-marine-bc005-reprocessed-dataset>



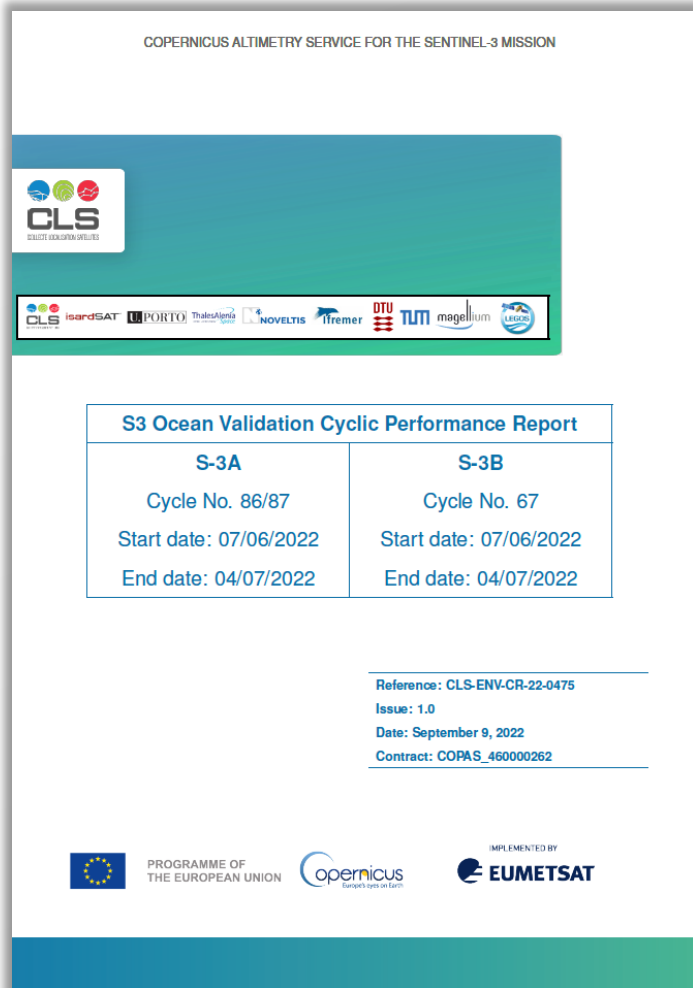
- SM__WAT.005.02.00 (SRAL/MWR L2 Marine)
- SR__L1M.005.01.00 (SRAL L1 Marine)
- MW__L1_.005.01.00 (MWR L1 Global)

Release notes document her:

<https://www.eumetsat.int/media/51161>

Replaces Baseline Collection 004 to correct limitations identified from monitoring activities

BC_004 limitations: Cyclic reports



Available from Sentinel-3 Knowledge Base site:

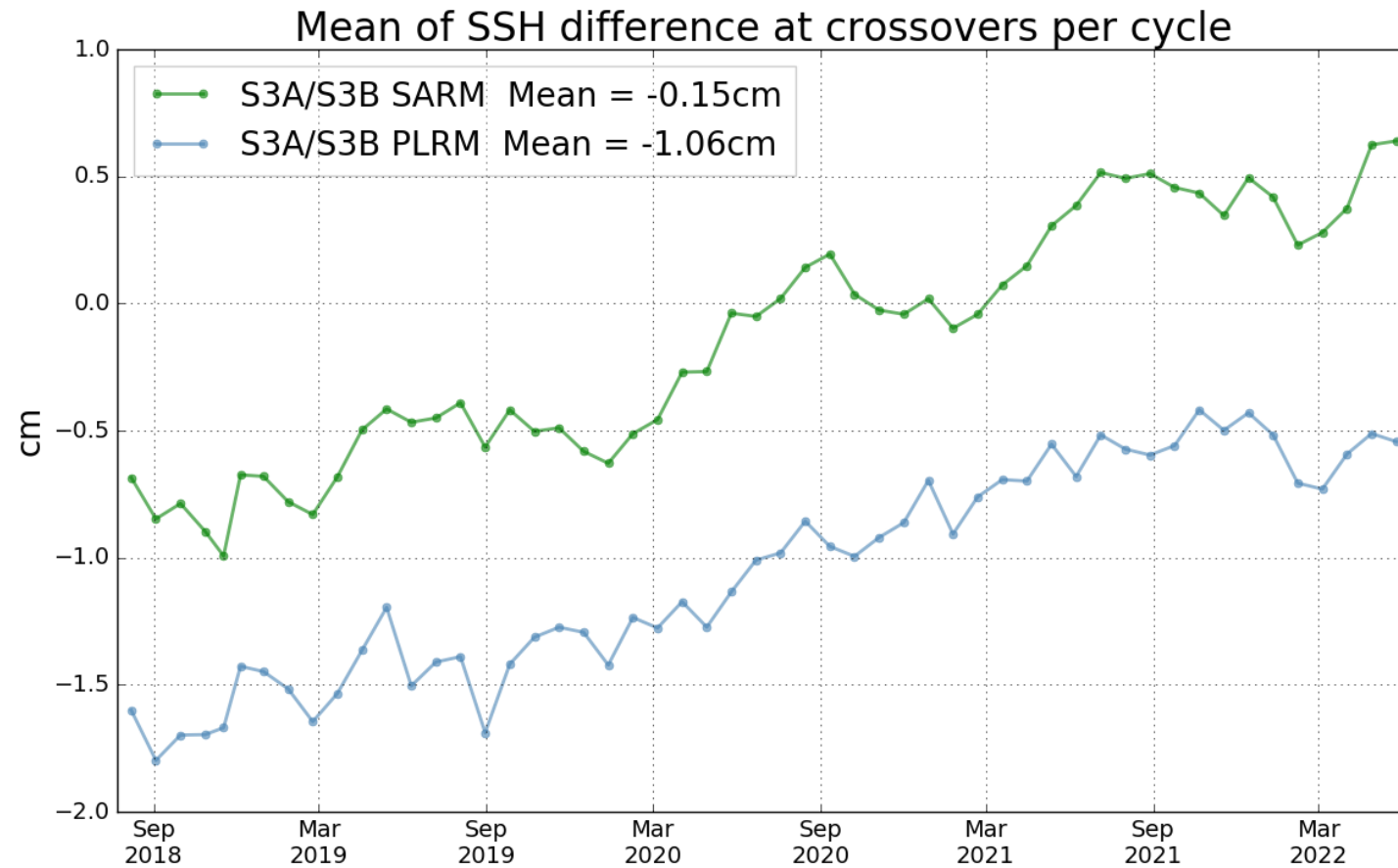
<https://eumetsatspace.atlassian.net/wiki/spaces/PQ/pages/1828126721/Sentinel-3+cyclic+reports>

The Sentinel-3 ocean validation cyclic performance reports for altimetry contain information on data quality for each orbital cycle for Sentinel-3A and B satellites. This includes information on: missing measurements, analysis of the geophysical parameters provided (significant wave height, backscattering coefficients, and wind speed); as well as crossover analysis between the two missions. The detailed information in these reports would be useful for users seeking to understand missing or anomalous data, or using the products to create longer term records.

Cyclic Performance Reports before Sentinel-3A cycle 78 and Sentinel-3B cycle 59 are available on the Mission Performance Centre pages in the [ESA Sentinel Online website](#).

Year	Sentinel-3 Ocean Validation Cyclic Performance Reports (Altimetry)										
2022	Cycle 82/83 (S3A) & 63 (S3B)	Cycle 83/84 (S3A) & 64 (S3B)	Cycle 84/85 (S3A) & 65 (S3B)	Cycle 85/86 (S3A) & 66 (S3B)	Cycle 86/87 (S3A) & 67 (S3B)	Cycle 87/88 (S3A) & 68 (S3B)	Cycle 88/89 (S3A) & 69 (S3B)	Cycle 89/90 (S3A) & 70 (S3B)	Cycle 90/91 (S3A) & 71 (S3B)	Cycle 91/92 (S3A) & 72 (S3B)	Cycle 92/93 (S3A) & 73 (S3B)
	Cycle 93/94 (S3A) & 74 (S3B)	Cycle 94/95 (S3A) & 75 (S3B)	Cycle 95/96 (S3A) & 76 (S3B)	Cycle 96/97 (S3A) & 77 (S3B)	Cycle 97/98 (S3A) & 78 (S3B)	Cycle 98/99 (S3A) & 79 (S3B)	Cycle 99/100 (S3A) & 80 (S3B)	Cycle 100/101 (S3A) & 81 (S3B)	Cycle 101/102 (S3A) & 82 (S3B)	Cycle 102/103 (S3A) & 83 (S3B)	

BC_004 limitations: Cyclic reports X-over analysis

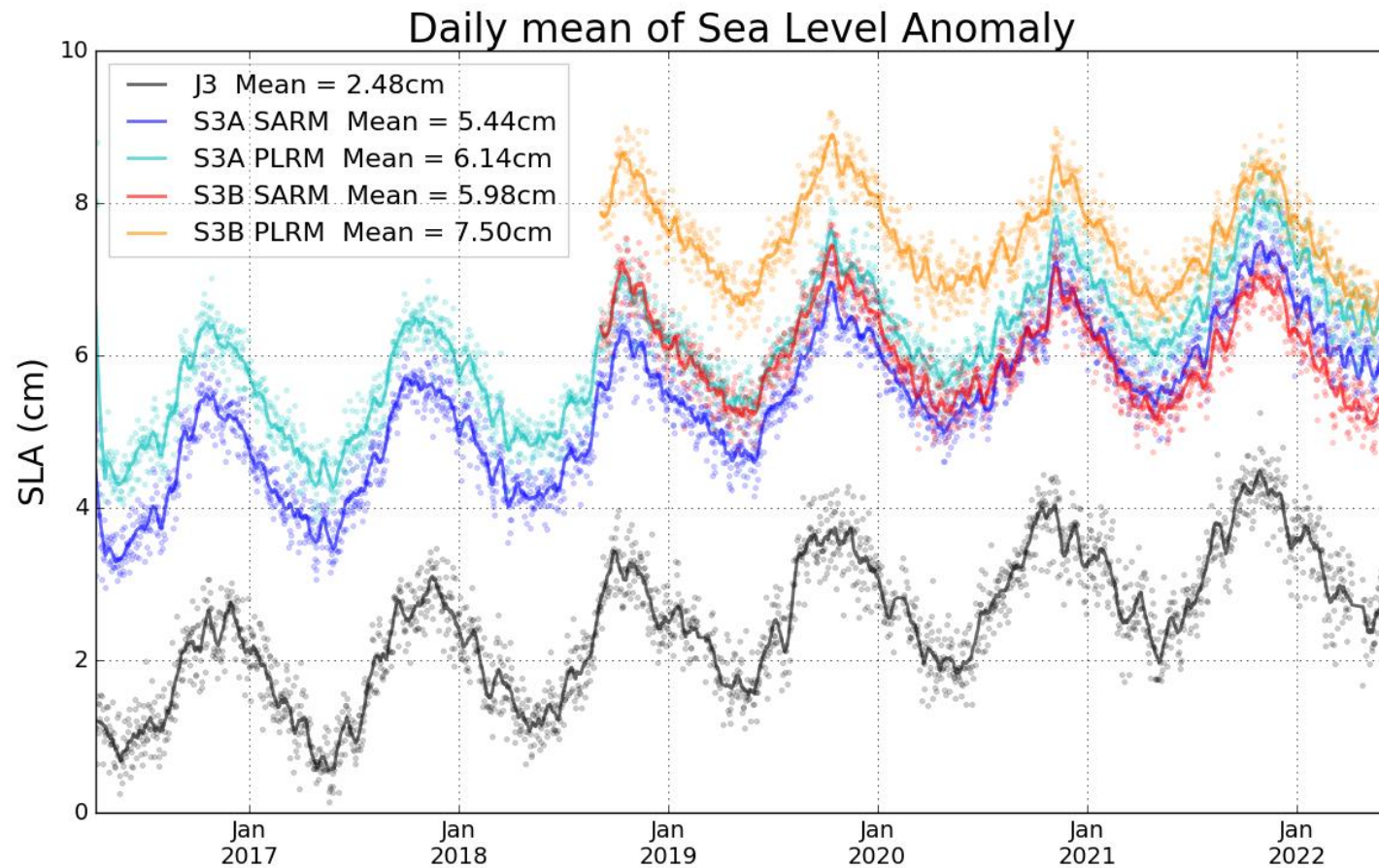


S3A-S3B SSH differences

- Slope in both SAR and PLRM time series
- Issues with long-term stability of one (or both missions)

From cyclic report:
Cycle 85/86 (S3A) & 66 (S3B)

BC_004 limitations: Cyclic reports Long term trends

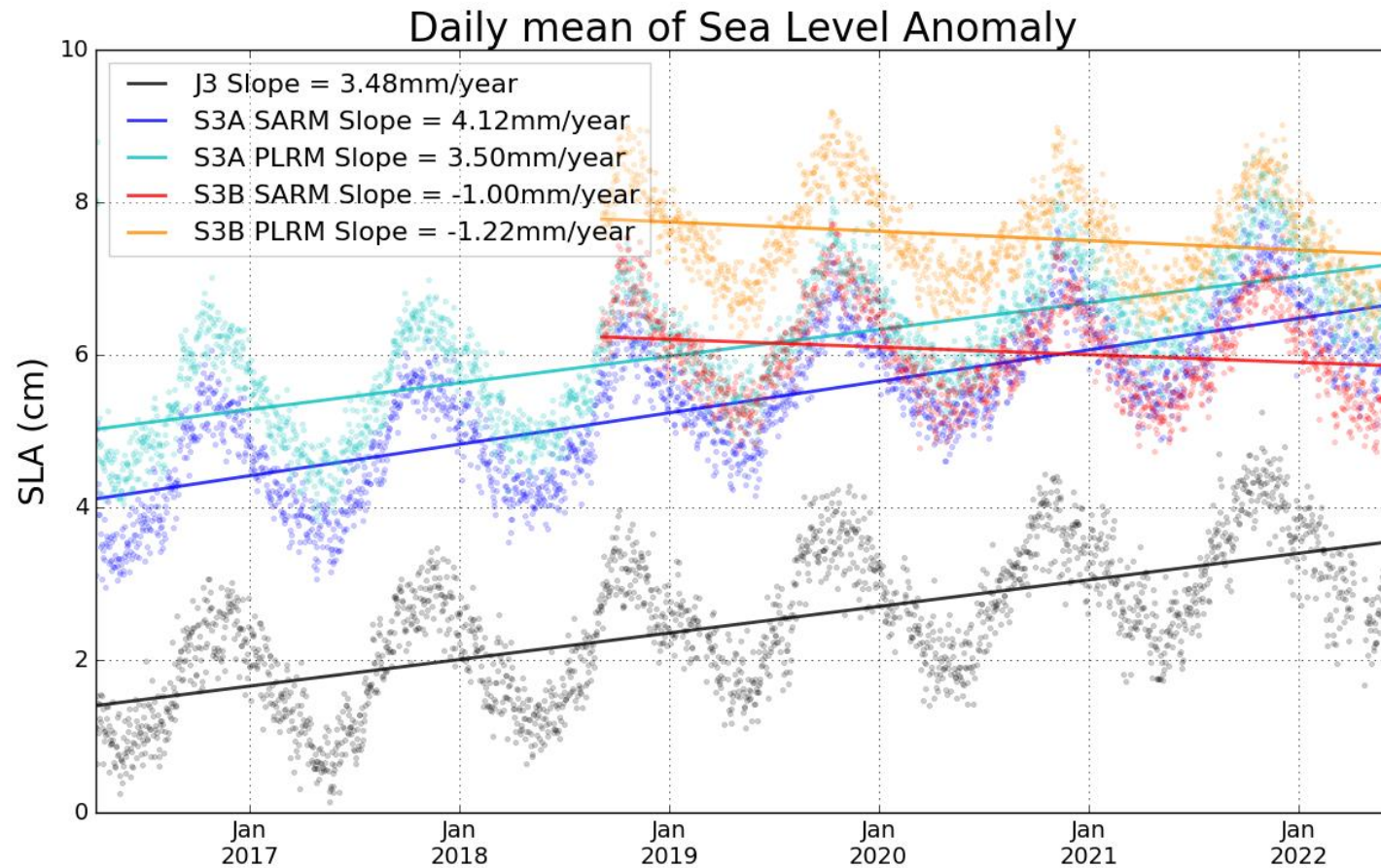


Multi-mission comparison

- Bias between modes
- Bias between satellites
- Bias wrt Jason-3

From cyclic report:
Cycle 85/86 (S3A) & 66 (S3B)

BC_004 limitations: Cyclic reports Long term trends



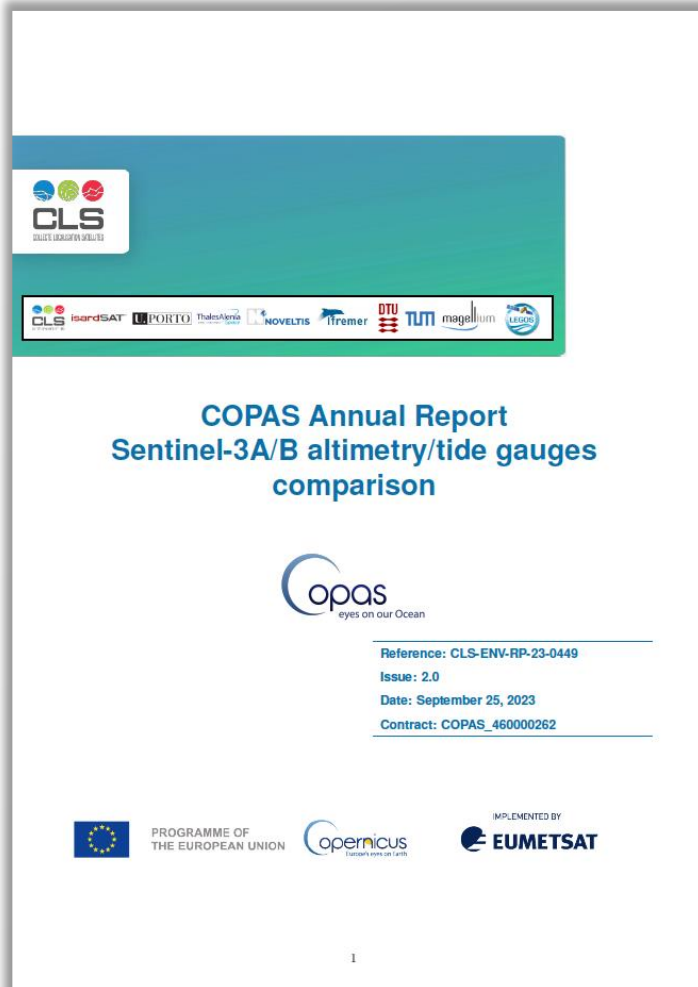
Multi-mission comparison

- Bias between modes
- Bias between satellites
- Bias wrt Jason-3

- No positive trend for S3B
- S3A SAR trend steeper than Jason-3 (by ~1.2 mm/year)

From cyclic report:
Cycle 85/86 (S3A) & 66 (S3B)

BC_004 limitations: Annual reports



From BC_005 full mission reprocessing dataset release news:
<https://www.eumetsat.int/release-sentinel-3-altimetry-marine-bc005-reprocessed-dataset>

EUMETSAT IMAGES SATELLITES ABOUT US NEWS & EVENTS

More details about the BC005.

The data can be accessed from the [Data Store](#), the same source to obtain Operational data, but on dedicated collections for the BC005 datasets:

Reprocessed dataset (BC005)	Collection ID	Data Store direct link (available from 31 July 2023)
SRAL/MWR Level 2 (SR_2_WAT_...)	EO:EUM:DAT:0834	https://data.eumetsat.int/product/EO:EUM:DAT:0834
SRAL Level 1B (SR_1_SRA_...)	EO:EUM:DAT:0833	https://data.eumetsat.int/product/EO:EUM:DAT:0833
SRAL Level 1A (SR_1_SRA_A_...)	EO:EUM:DAT:0836	https://data.eumetsat.int/product/EO:EUM:DAT:0836
SRAL Level 1B-S (SR_1_SRA_BS)	EO:EUM:DAT:0835	https://data.eumetsat.int/product/EO:EUM:DAT:0835

This [release note](#) for this reprocessing provides detailed information about the reprocessed dataset.

The following COPAS reports provide an assessment of the reprocessed dataset:

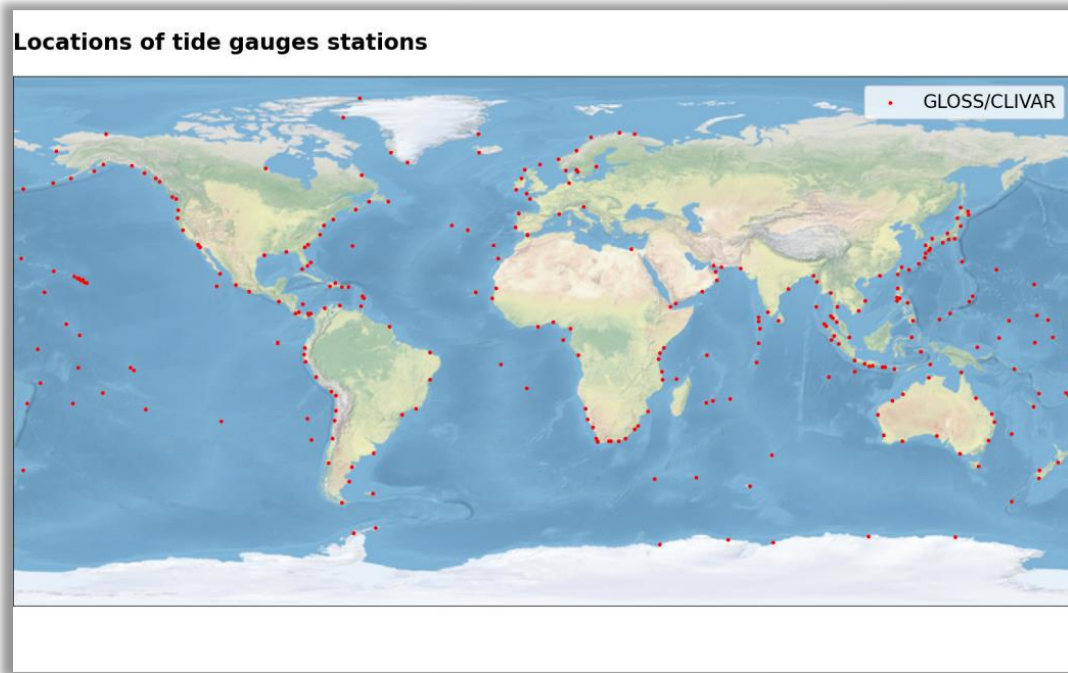
- [S3 Altimetry comparison with tide gauges](#)
- [S3 Altimetry Wind & Waves performance](#)
- [S3 Altimetry high-latitude performance](#)
- [S3 MWR assessment and comparison with in-situ](#)

For more information, contact our [User Service Helpdesk](#).

<https://www.eumetsat.int/media/51601>

BC_004 limitations: Annual reports TG-Alti analysis

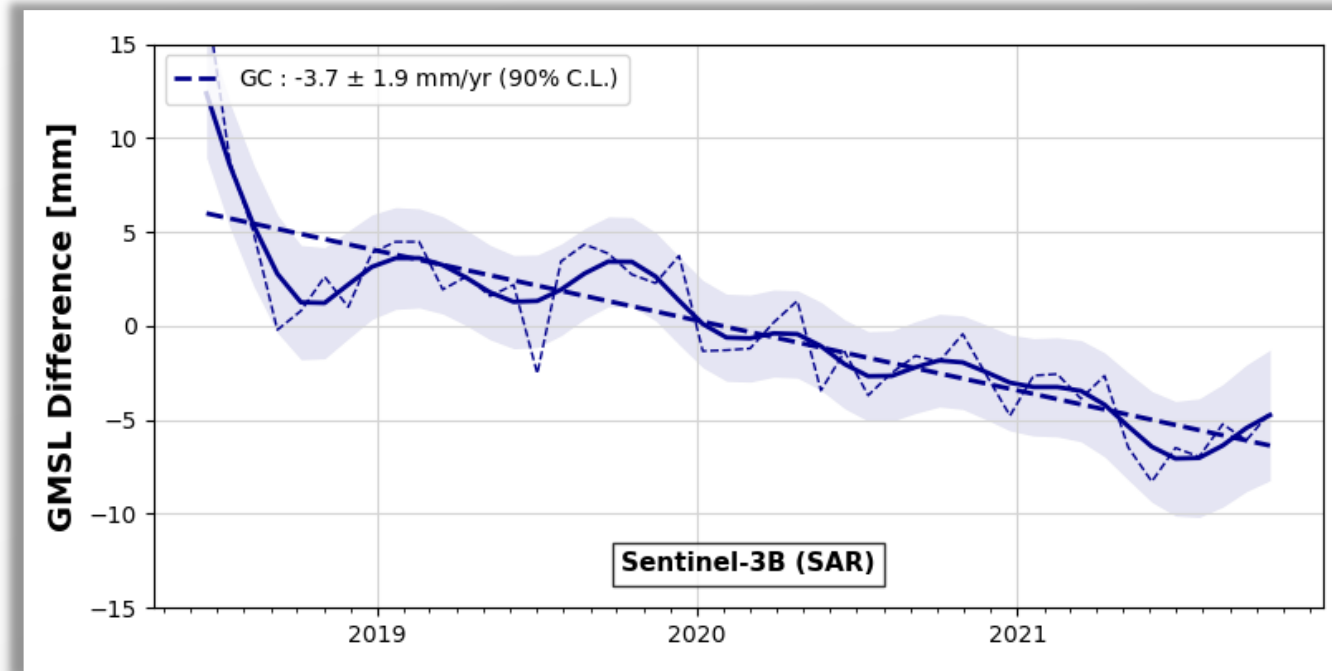
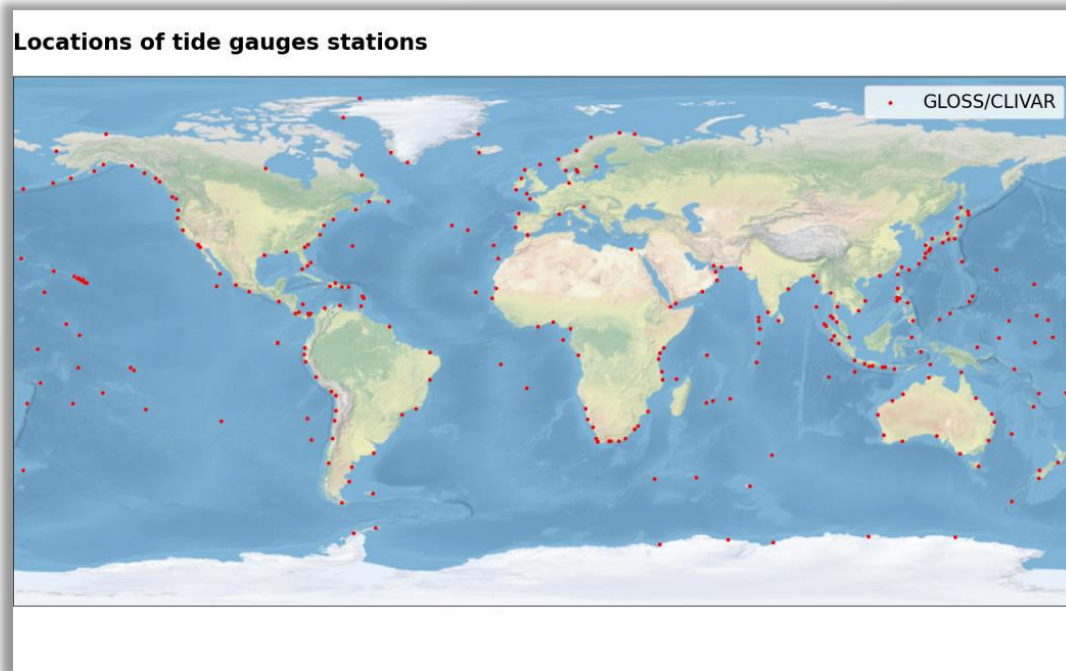
Comparison with GLOSS/CLIVAR Tide Gauges observations



- High frequency sampling (hourly)
- North hemisphere biases as limited as possible
- "Fast Delivery" (couple of months)

BC_004 limitations: Annual reports TG-Alti analysis

Comparison with GLOSS/CLIVAR Tide Gauges observations



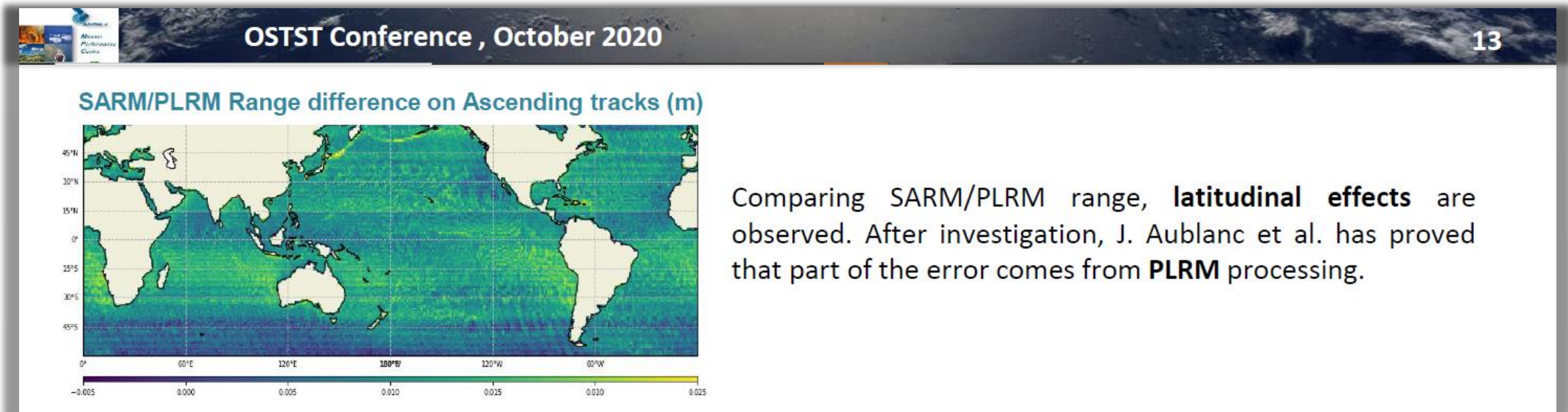
- High frequency sampling (hourly)
- North hemisphere biases as limited as possible
- "Fast Delivery" (couple of months)

t-series of global mean SSHA difference: S3B - TG

- Negative slope => No positive trend for S3B

BC_004 limitations: Previous OSTST results

Slide from OSTST 2020 presentation by E. Cadier et al.



- Latitudinal bands = > due to PLRM echo centering
- Geographical patterns (OLTC vs MMS differences) => SAR echo centering sensitivity
- Similar patterns also in SWH (not shown)
- Differences of few mm only (!!!)....but still to be corrected

From BC_004 to BC_005: Full change list

- Update from BC_004 to BC_005 in two successive steps
 - BC_005.01 deployed on 7 July 2022

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

SRAL/MWR L2 (v7.01)

- Updates to the SSHA
 - New Mean Sea Surfaces
 - Combined MSS, CNES/CLS15, SIO, DUT15 (new default MSS)
 - DTU21 (including accuracies information)
 - New Pole Tide solution (Desai 2017).
 - Internal tides and long tide non-equilibrium now applied to calculate SSHA.
 - Dynamic Atmospheric Correction (DAC/MOG2D) available in NRT and applied to the SSHA.
 - New Sea State Bias (Tran 2021) derived from S3A SAR/PLRM for Ku-band.
 - Real Zero Masking from L1B data applied at SAR L2 (all timeliness).
 - Range Walk (applied at SAR L1, only NTC).
- GPD+ Wet Tropospheric Correction available for NTC timeliness (not yet applied to the SSHA).
- More information to the user:
 - Processing Baseline; All system bias; etc.
- No-more (land-)ice variables being generated by Marine products.
- 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

SRAL L1 (v6.23)

- Correction of USO reading (relevant for all S3B data).
- Removal of CAL2 application to CAL1.
- CAL1 range correction generated using CoG (centre of gravity) method.
- New CAL2 normalization, by plateau instead of max
- Range Walk correction is now applied to SAR mode (NTC only currently).

- BC_005.02 deployed on 9 March 2023

<https://www.eumetsat.int/new-evolution-sentinel-3-altimetry-products>

SRAL/MWR L2 (v7.03)

- Update of mean values for SSHA (and its corrections) and SWH and Wind Speed.
- Application of GPD+ Wet Tropospheric Correction (WTC) to SSHA (NTC only).
- Addition of Wind Speed calculated from Sigma0 and SWH (like Sentinel-6).
- Addition of quality flags for SSHA, SWH, Wind (at 1Hz measurement level)
- Update of the 1Hz data generation method, to include strict MQE screening – preventing bad 20Hz data to be used on 1Hz
- Addition of information (in the netCDFs) about the bias applied in the L2 products.
- Addition of sea ice concentration information at 1Hz.
- Addition of SRAL acquisition mode at 1Hz.
- Addition of information regarding the WTC applied to build the SSHA.
- Correction of the geoid (EGM2008) since the version used previously on the product had an error.
- Elevation from sea-ice/ocog retrackerers now uses high frequency dynamic atmospheric pressure correction.
- Correction of S3B cycle number on the first pass of the cycle – netCDF only.
- Improved radiometer quality flag, especially during lunar calibration events.

- Full mission reprocessing based on BC_005.02
- Full info in the Product Notice

<https://www.eumetsat.int/media/50766>



From BC_004 to BC_005: Specific changes

Corrections

- Range Walk (applied at SAR L1, only NTC)
- Correction of USO reading (relevant for all S3B data)
- Real Zero Masking from L1B data applied at SAR L2 (all timeliness).

- PLRM pulse alignment

- Internal tides and long tide non-equilibrium now applied to calculate SSHA.
- New Sea State Bias (Tran 2021) derived from S3A SAR/PLRM for Ku-band
- Application of GPD+ Wet Tropospheric Correction (WTC) to SSHA
- New mean sea surface
-

Goals

- Direct impact on range
- Improve stability of GMSL t-series

- Correct mm scale geographical patterns

- Improve overall SSHA performance

Dataset used for the analysis

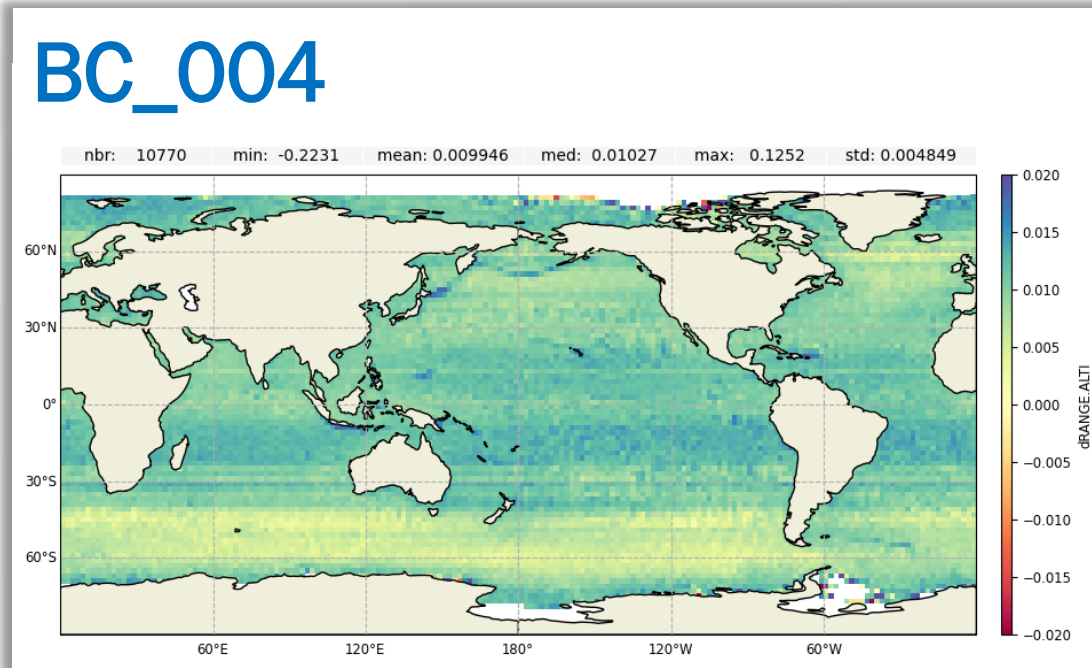
- Full mission reprocessing covers (with some holes)
 - For S3A: from 05/05/2016 to 09/03/2023
 - For S3B: from 08/05/2018 to 09/03/2023
- FMR validation until 11/06/2022 (when the new baseline BC_005.01 was implemented in NTC)
 - For S3A: from 05/05/2016 to 11/06/2022 (C004P002 - C086P395)
 - For S3B: from 01/06/2018 to 11/06/2022 (C008P004 - C067P110)

[Note: May 2018 for S3B is not in dataset because of drift + some doubled pass numbers]

- Focus on next slides on S3A (S3B shows similar results)

BC_005 improvements: Geographical patterns

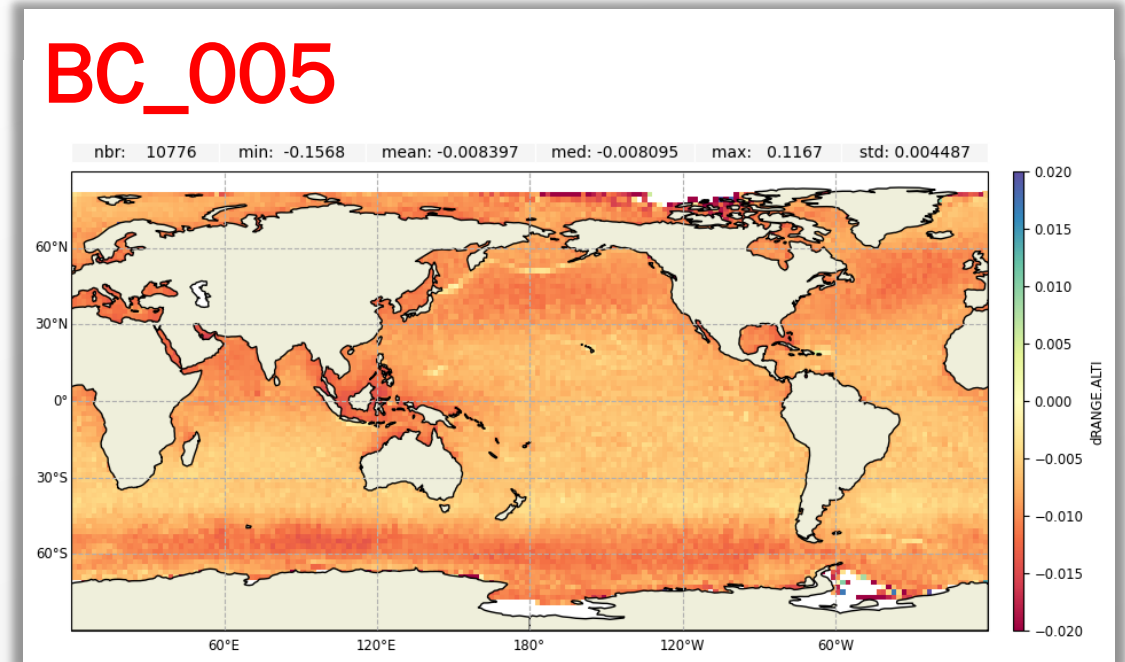
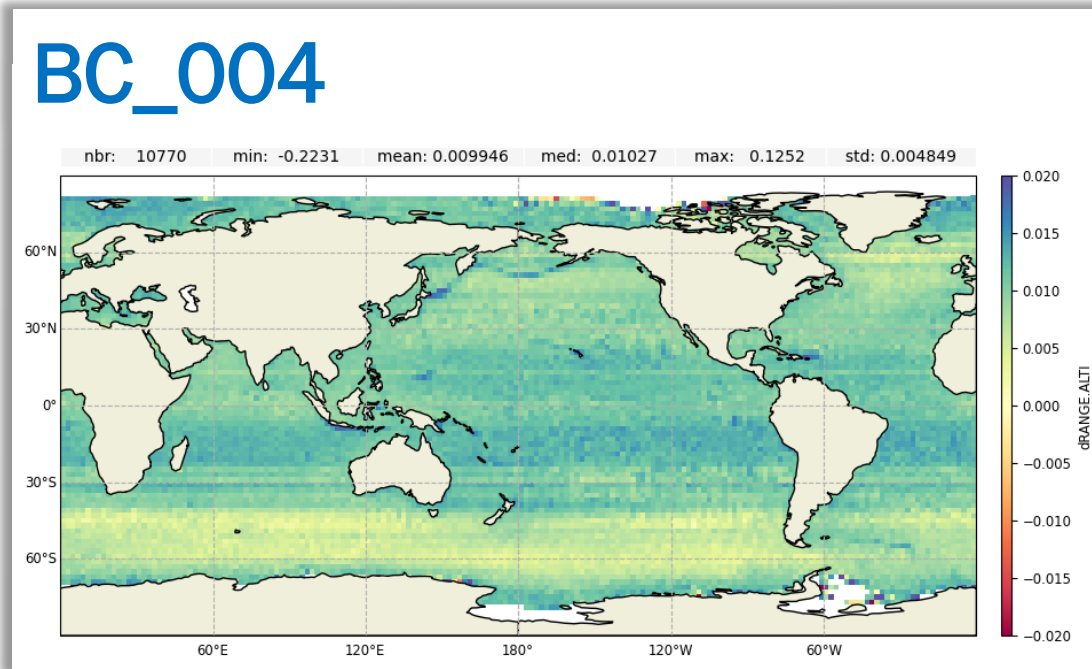
- Binned maps ($2^\circ \times 2^\circ$) of mean SARM – PLRM range differences



- Same latitudinal bands as seen in Cadier et al. 2020 OSTST presentation
- Impact visible on other variables (sigma0, wind, swh, iono correction, SSHA)

BC_005 improvements: Geographical patterns

Binned maps (2° x 2°) of mean SARM – PLRM range differences



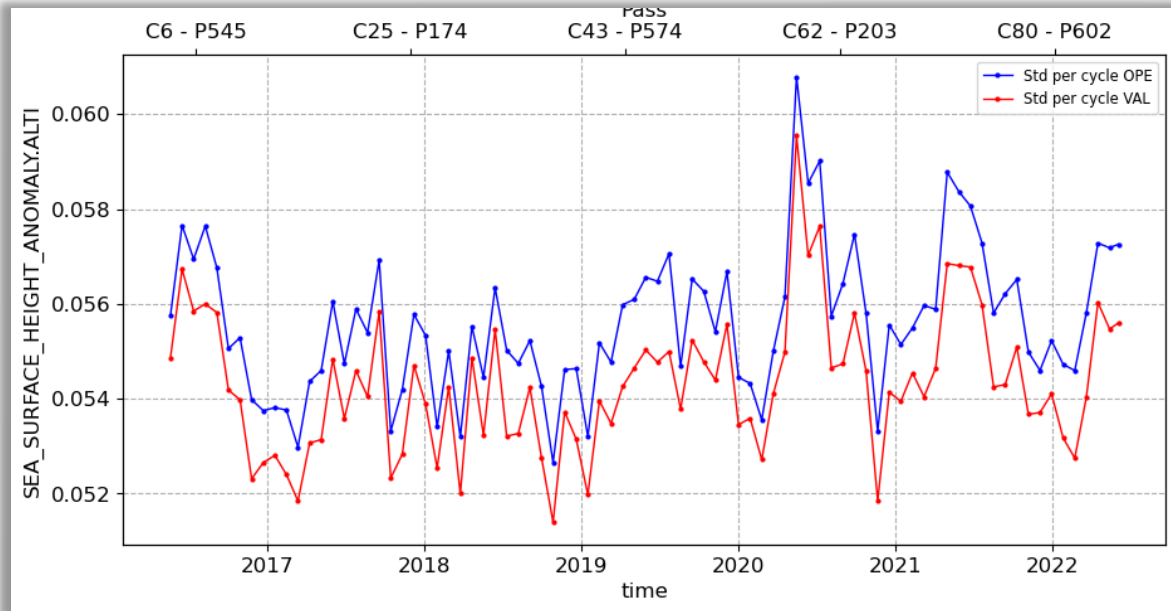
- Same latitudinal bands as seen in Cadier et al. 2020 OSTST presentation
- Impact visible on other variables (sigma0, wind, swh, iono correction, SSHA)

Corrected in BC_005 (mainly by PLRM pulse alignment)

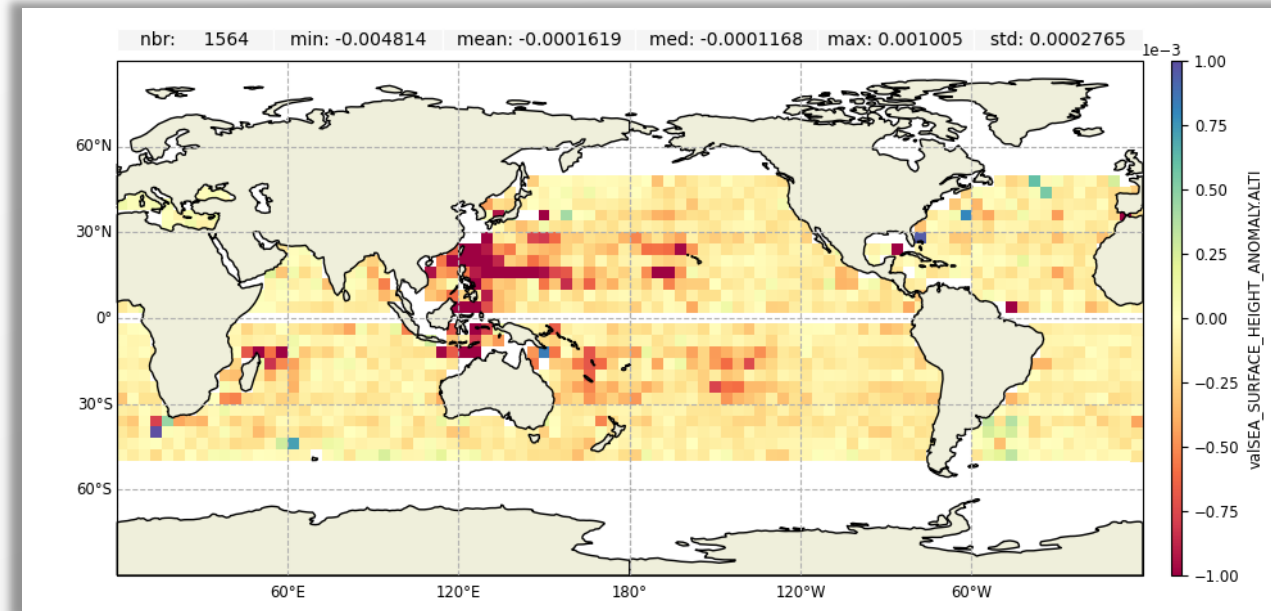
BC_005 improvements: Overall SSHA performance

SARM SSHA mono-mission differences at X-overs (10-days max)

- Time-series of std per cycle
- **BC_004** and **BC_005**



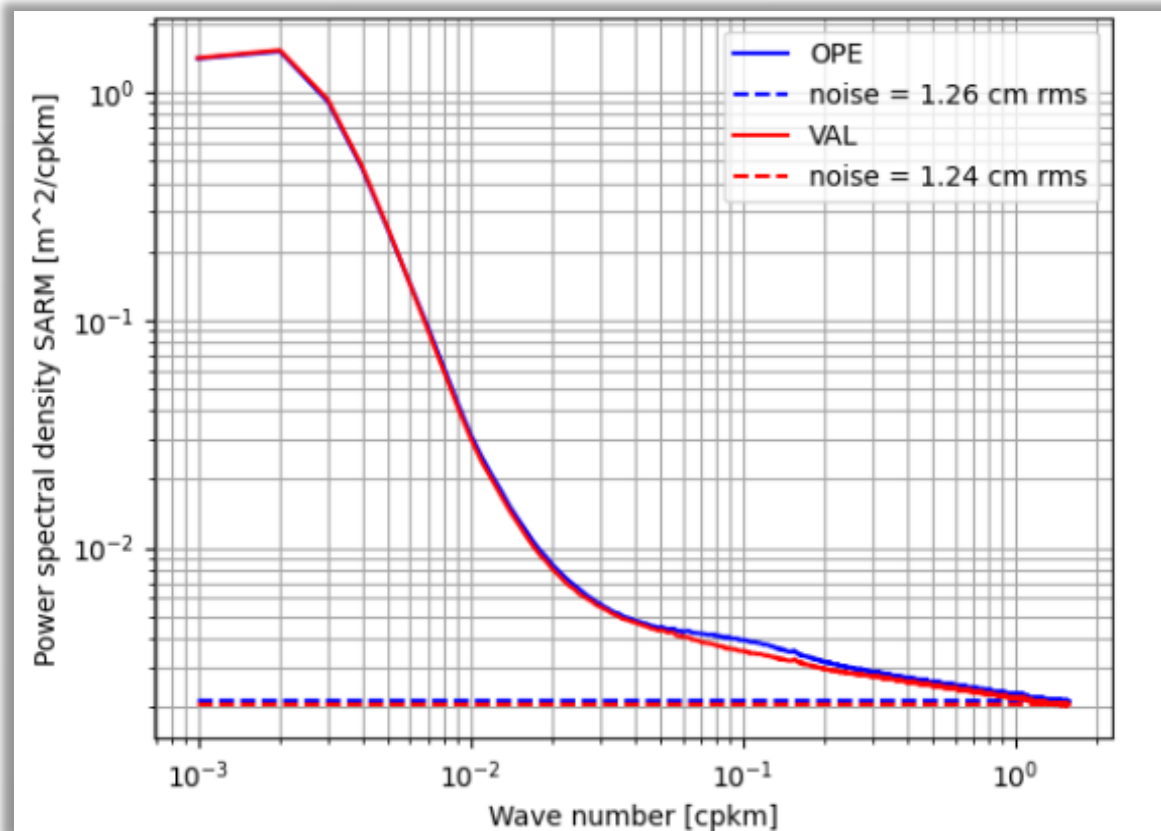
- Binned maps of std of BC_004 BC_005 difference
- Red is good (reduced noise)



Reduction on 1 mm on average (mostly due to internal tide correction)

BC_005 improvements: Overall SSHA performance

Spectra of SARM SSHA



- **BC_004** and **BC_005**
 - Computed for 2019
 - Computed over segment of 1000 km

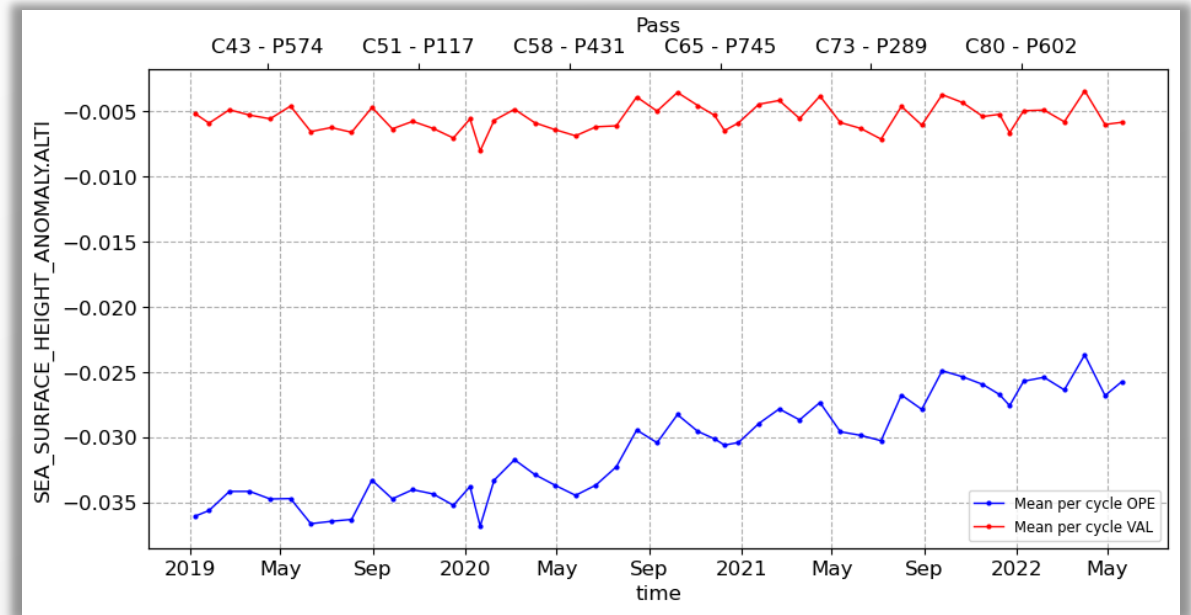
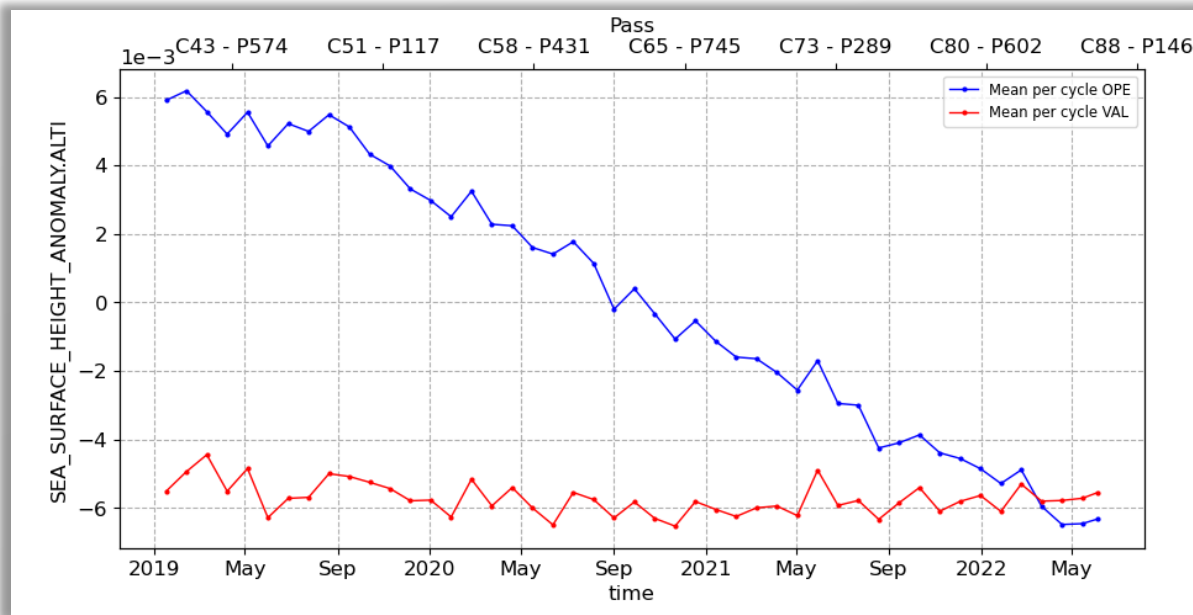
 - Little "bump" at $\sim 10\text{km}$ in **BC_004**
 - Not observed in "orbit-range-mss" spectra (usually used to assess instrument performance from spectral analysis)
- Bump largely removed in **BC_005**
 - Largest contribution from SSB correction...
 - ...but further analysis required

BC_005 improvements: Long-term SSHA stability

SARM SSHA multi-mission differences at X-overs (10-days max)

- Time-series of mean per cycle: S3B – S3A
- **BC_004** and **BC_005**

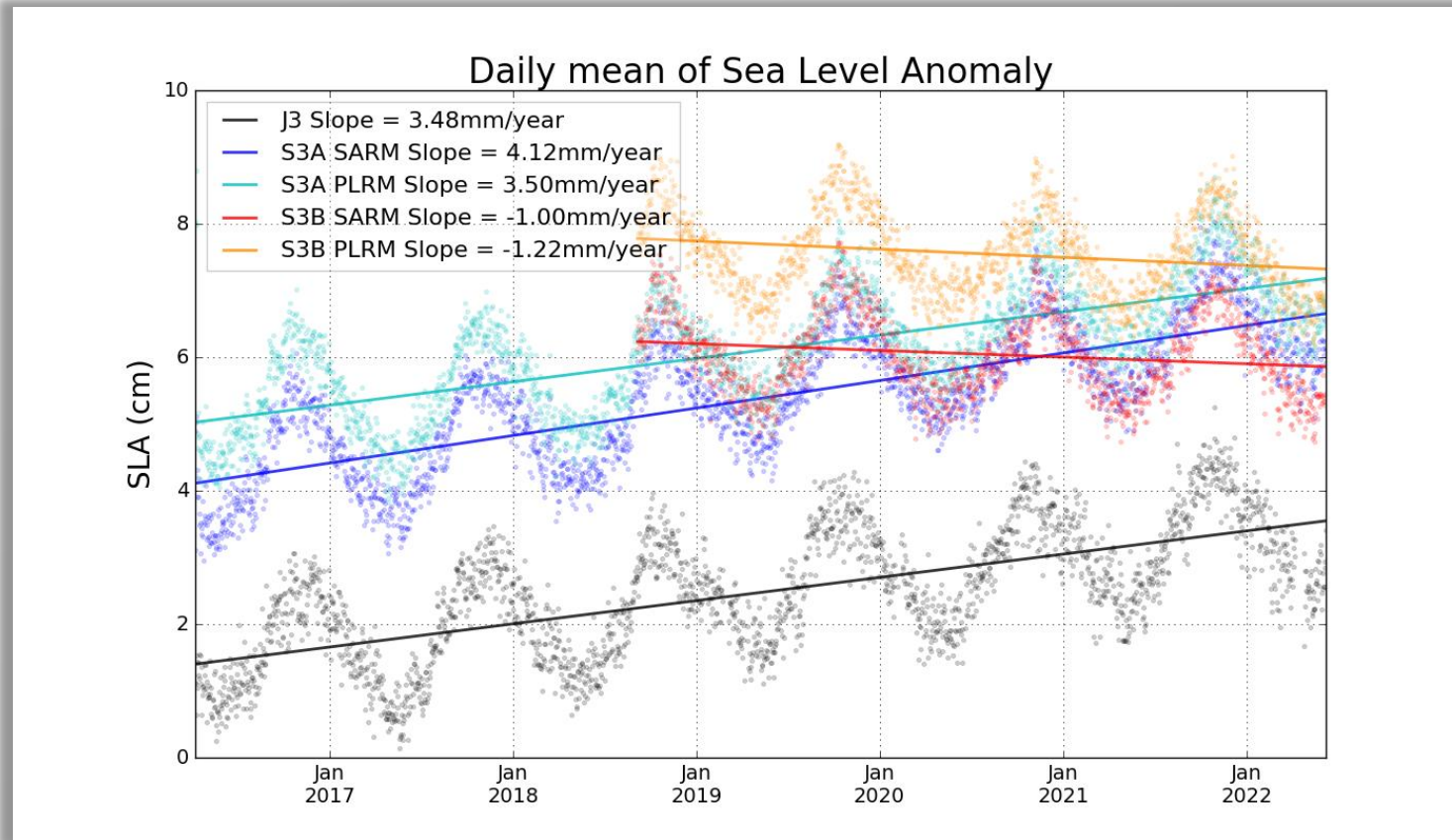
- Time-series of mean per cycle: J3 – S3B
- **BC_004** and **BC_005**



- Consistency between all missions (S3A, S3B, J3)
- Mainly due to Range Walk and USO Correction (for S3B)

BC_005 improvements: Long-term SSHA stability

BC_004

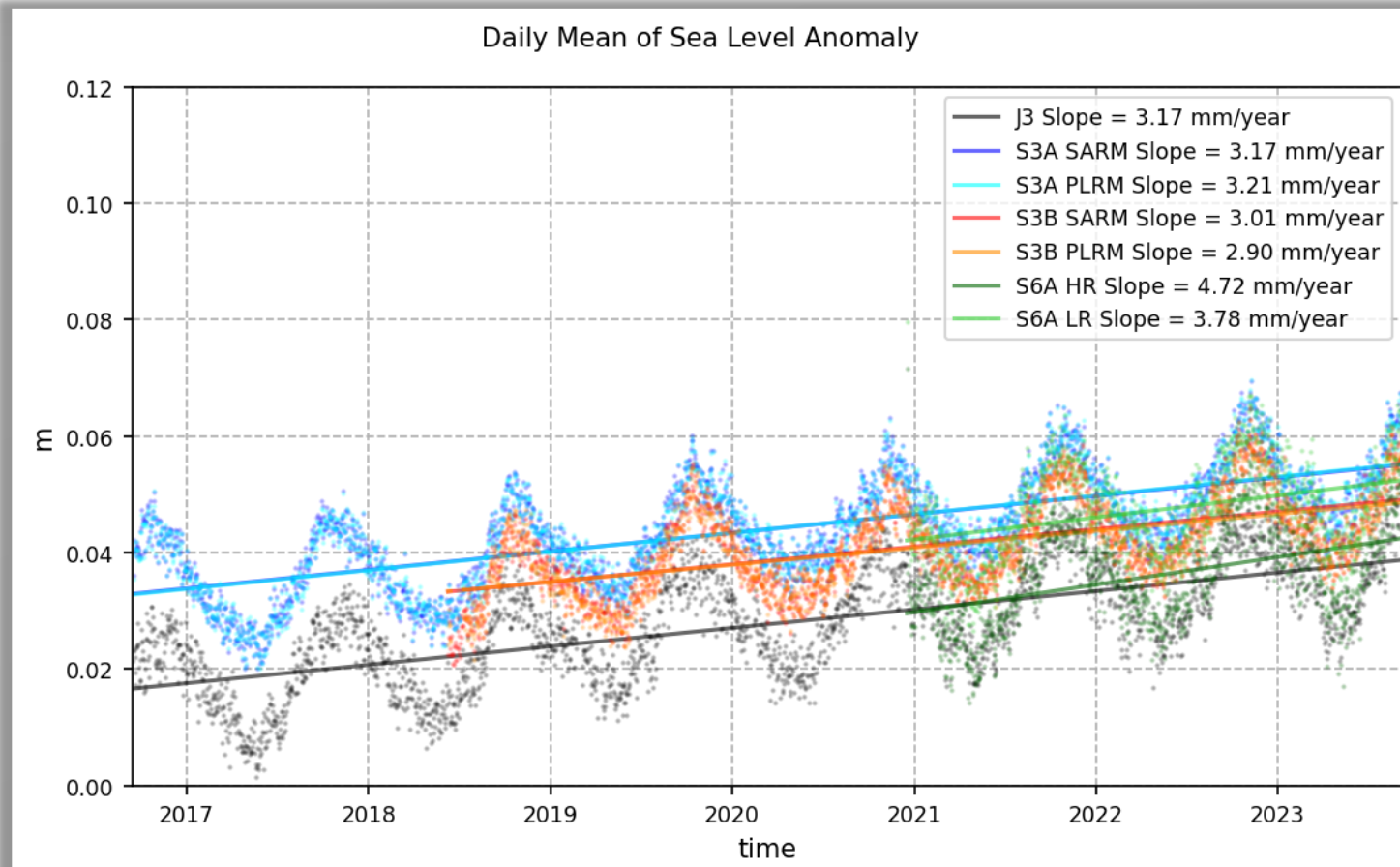


multi-mission
comparison

- Consistency between all missions (S3A, S3B, J3)
- Mainly due to Range Walk and USO Correction (for S3B)

BC_005 improvements: Long-term SSHA stability

BC_005



multi-mission comparison

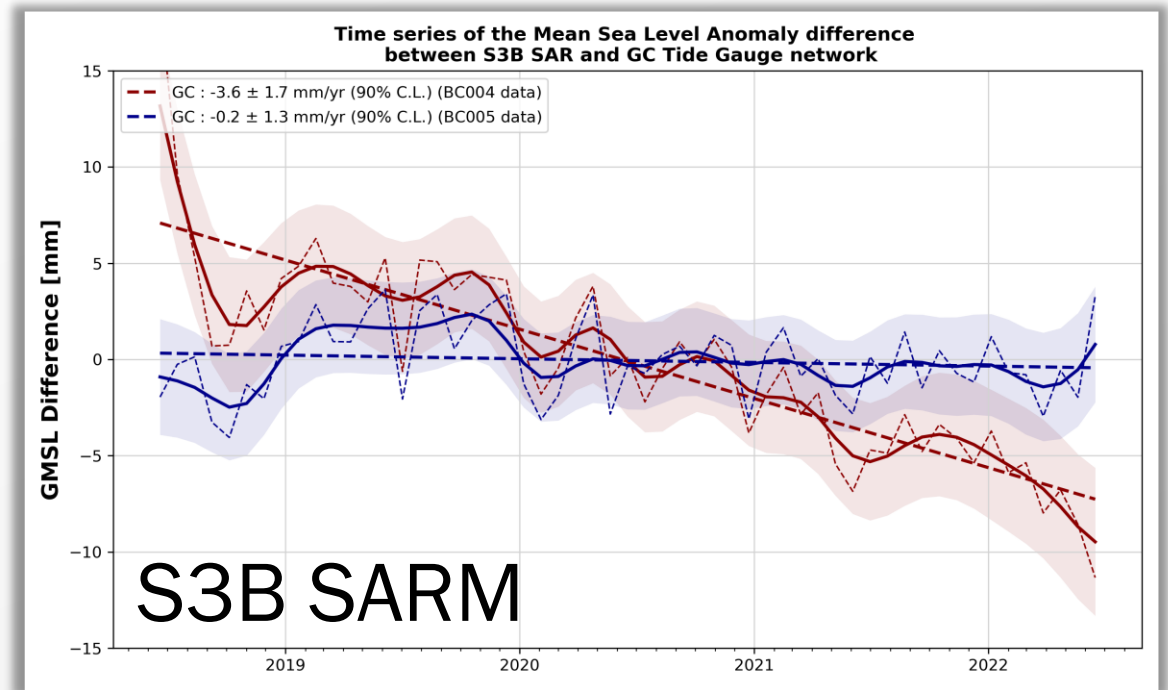
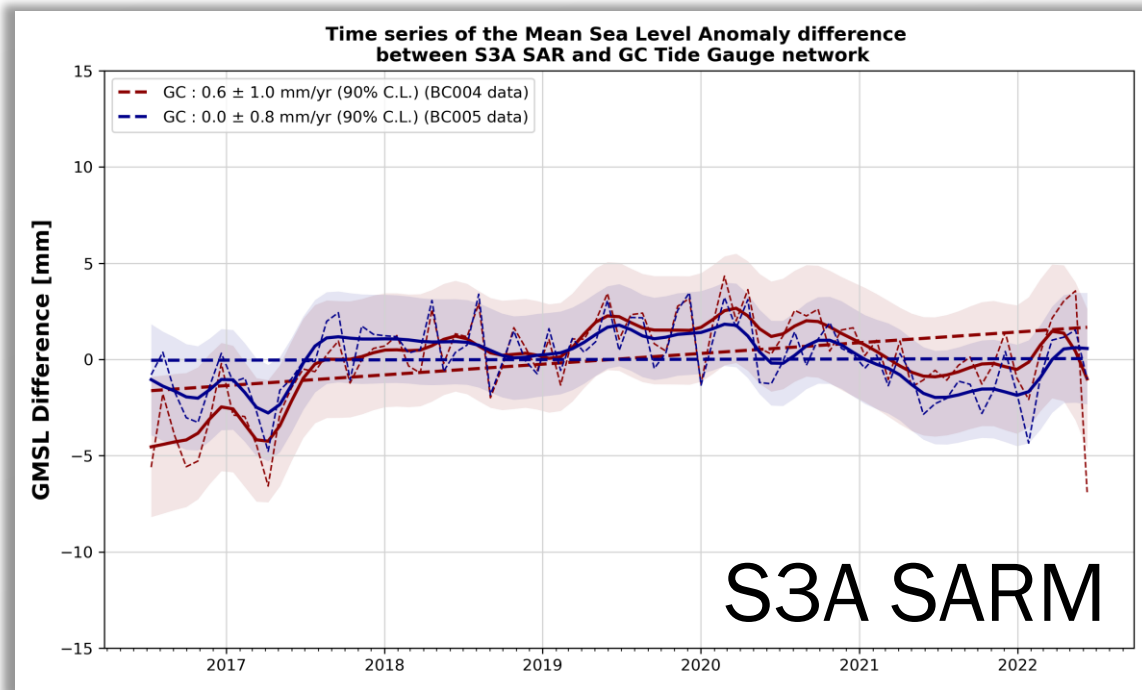
- All missions aligned to ~3 mm/y
- Further improvements with implementation of numerical retracker

- Consistency between all missions (S3A, S3B, J3)
- Mainly due to Range Walk and USO Correction (for S3B)

BC_005 improvements: Long-term SSHA stability

Global mean SSH differences: Tide gauges – Sentinel-3

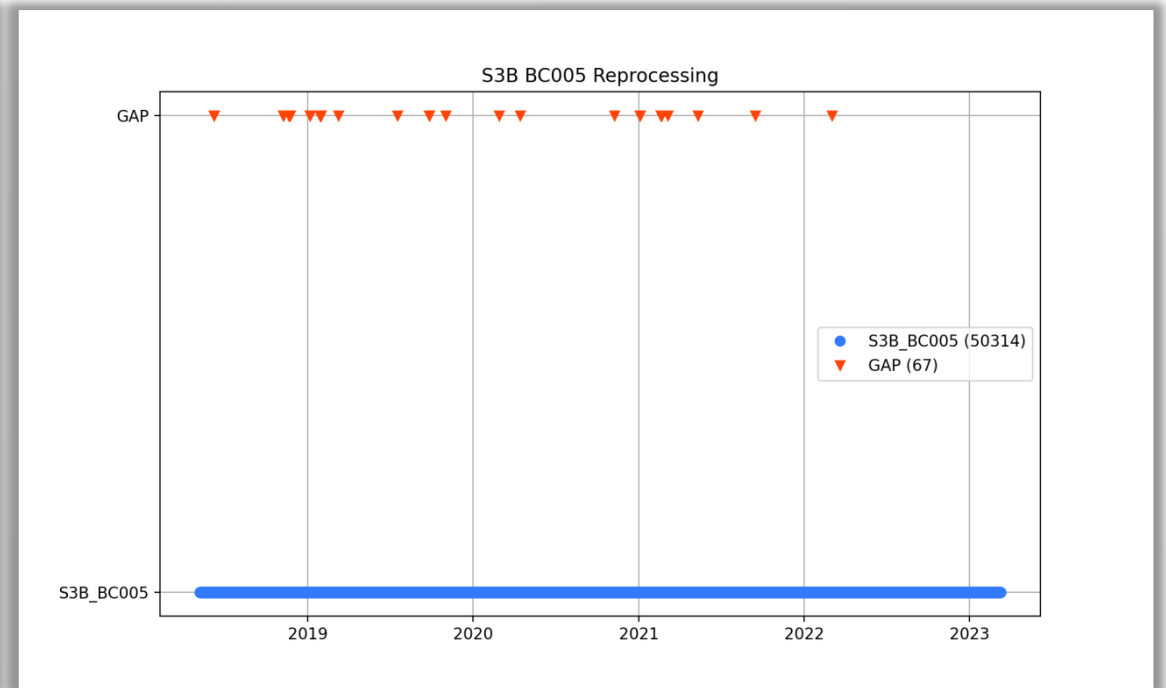
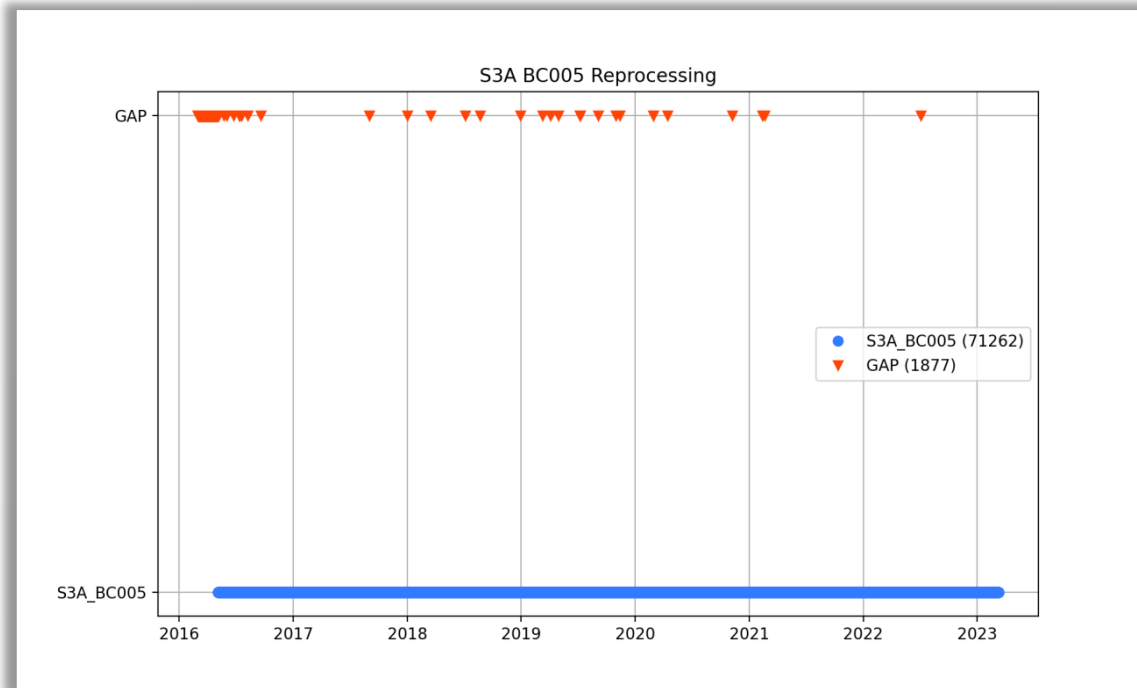
- **BC_004** and **BC_005** (sorry about that!!!)



Sentinel-3A and 3B trend consistent with in-situ observations

BC_005 remaining issues: Missing observations

- Some passes without any observation available
- Due to multiple causes

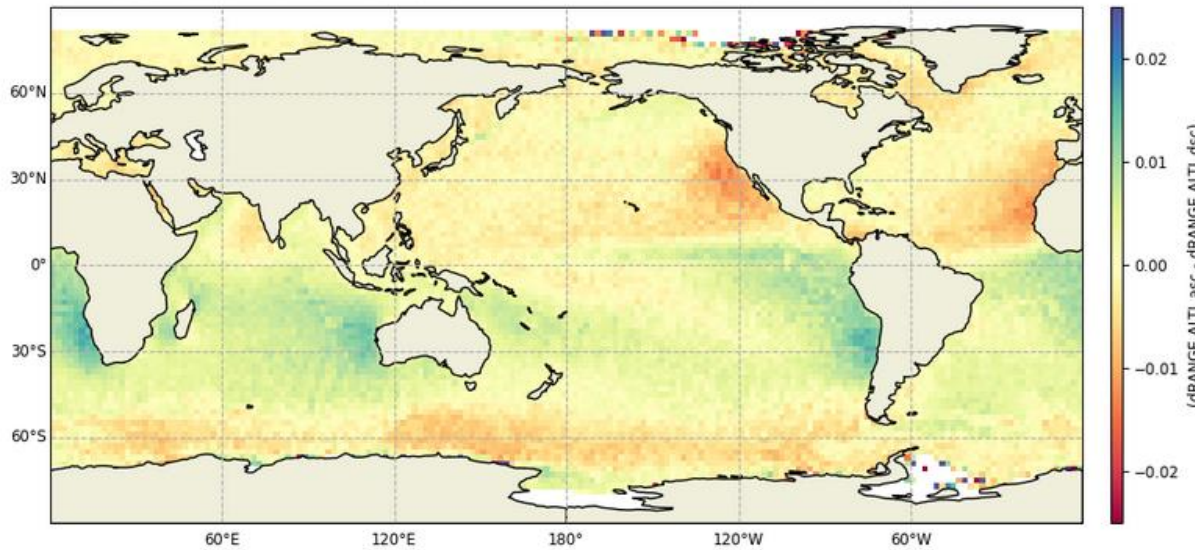


Will be recovered (wherever possible) for future reprocessing campaigns

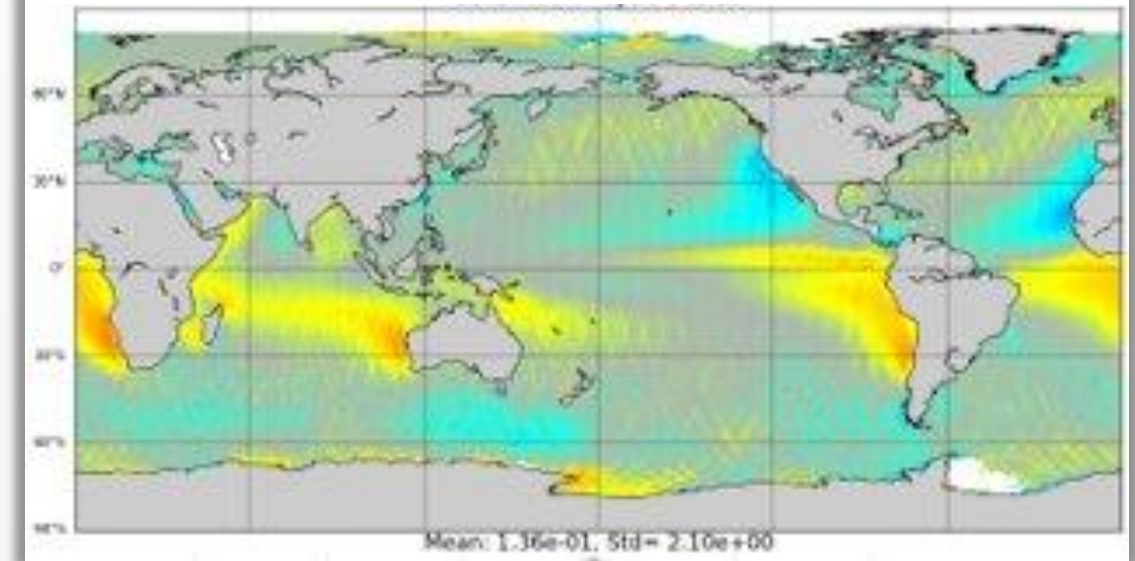
BC_005 remaining issues: Geographical dependencies

- Binned maps ($2^\circ \times 2^\circ$) of asc – dsc differences of mean SARM – PLRM range differences

BC_005



Meridional wind



- High values appear in regions with strong along track winds (Eastern Boundary of all Ocean Basins)
- To be corrected in future BC

Conclusions

B005_02 improvements

- Geographically correlated errors (mm-scale) further mitigated
- Improved overall SSHA performance:
 - Reduced x-over SSHA std
 - Removed small spectral bump
- Greatly improved long-term SSHA stability
 - S3A and S3B long-term slopes aligned with reference missions (J3 and S6)
 - S3A and S3B long-term slopes aligned with in-situ tide-gauge observations

Due to the recent full mission reprocessing, there is consistency from the beginning of the mission with the data currently being produced operationally

COPAS S3 Monitoring Reports

- Full BC_005 mission reprocessing report to be released soon

Many reports already available from EUMETSAT

➤ Cyclic reports:

- Overall S3 Ocean Surface Topography performance

<https://eumetsatspace.atlassian.net/wiki/spaces/PQ/pages/1828126721/Sentinel-3+altimetry+cyclic+reports>

➤ Quarterly reports:

- SRAL
- MWR

<https://eumetsatspace.atlassian.net/wiki/spaces/PQ/pages/1994489857/Sentinel-3+altimetry+quarterly+reports>

➤ Annual reports (comparison with in-situ observations):

- MWR <https://www.eumetsat.int/media/51603>
- SWH & Wind <https://www.eumetsat.int/media/51604>
- High latitude performance <https://www.eumetsat.int/media/51602>
- TG/Alti comparison <https://www.eumetsat.int/media/51601>

