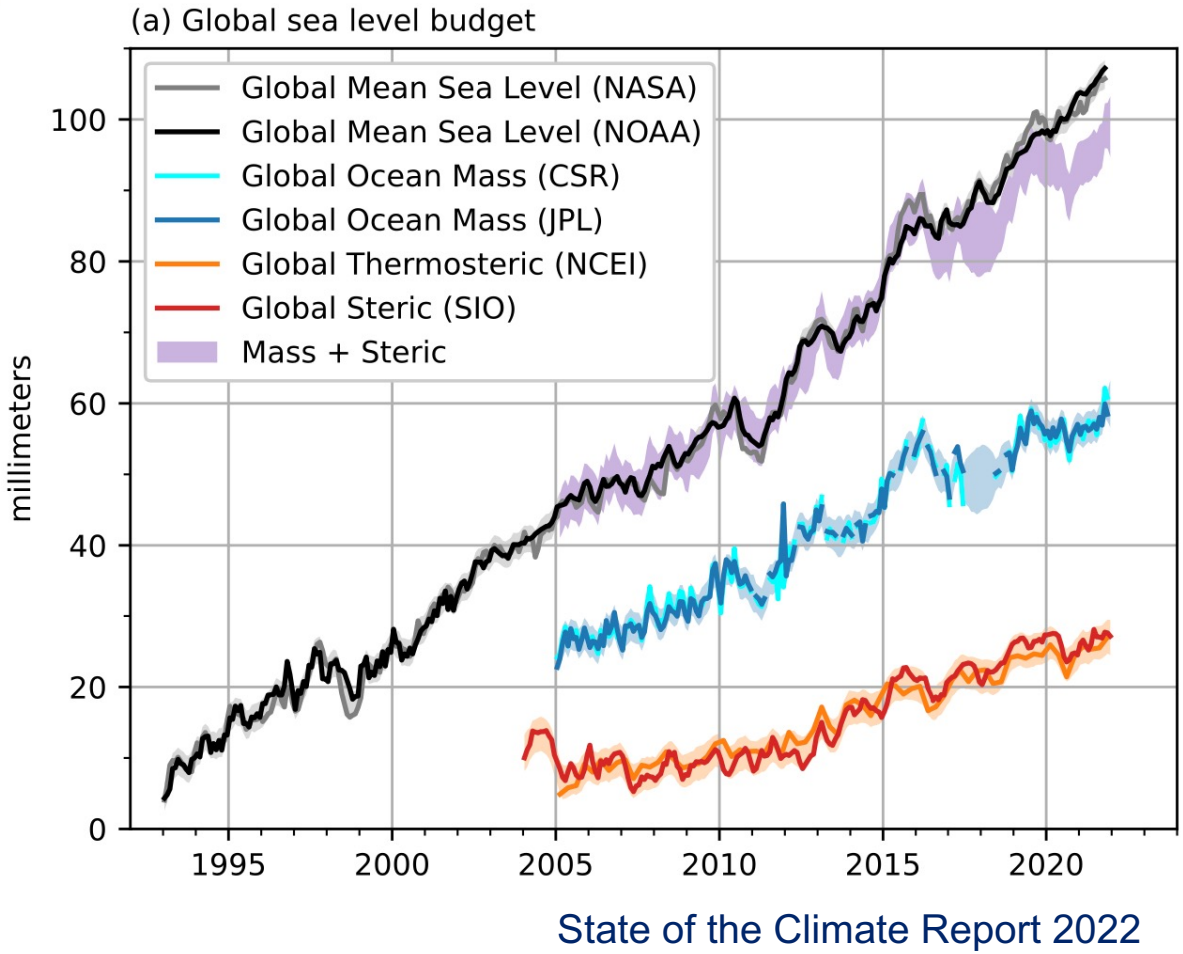
Tide gauge comparisons for Jason-3, Sentinel-3, and Sentinel-6MF

Eric Leuliette[1], Amanda Plagge[2], and Bin Zhang[2]
1. NOAA/NESDIS/STAR Laboratory for Satellite Altimetry
2. Global Science and Technology, Inc.

Sea level budget closure

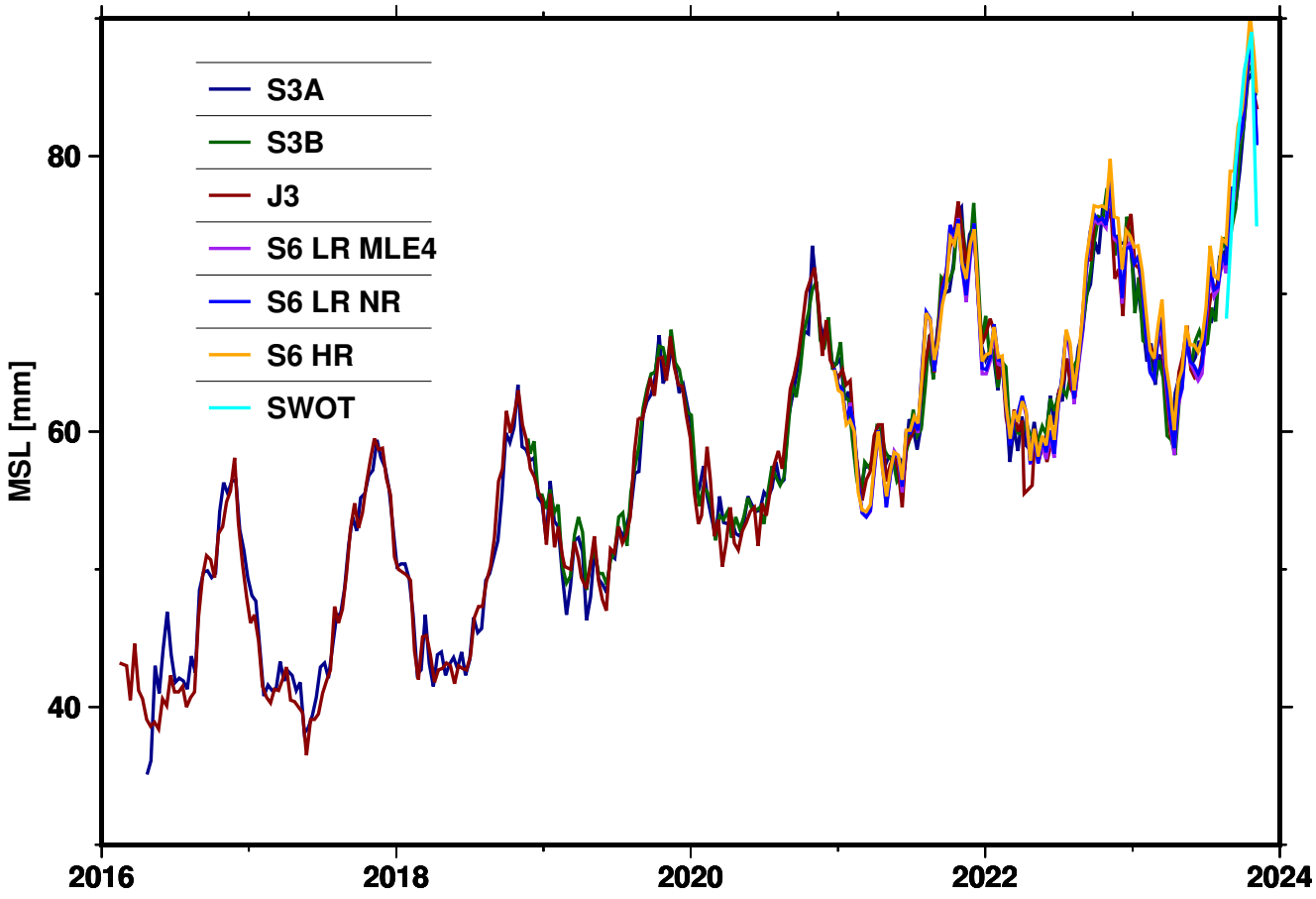


The global sea level budget from altimetry, Argo, and GRACE has not been able to be closed since ~2016.

Global mean sea level from the altimetry constellation

There is excellent agreement in 10-day global (< 66°) mean sea level estimates from the current constellation of operational altimetry missions.

Intermission biases and system drifts need to be validated with independent measurements (gauges).

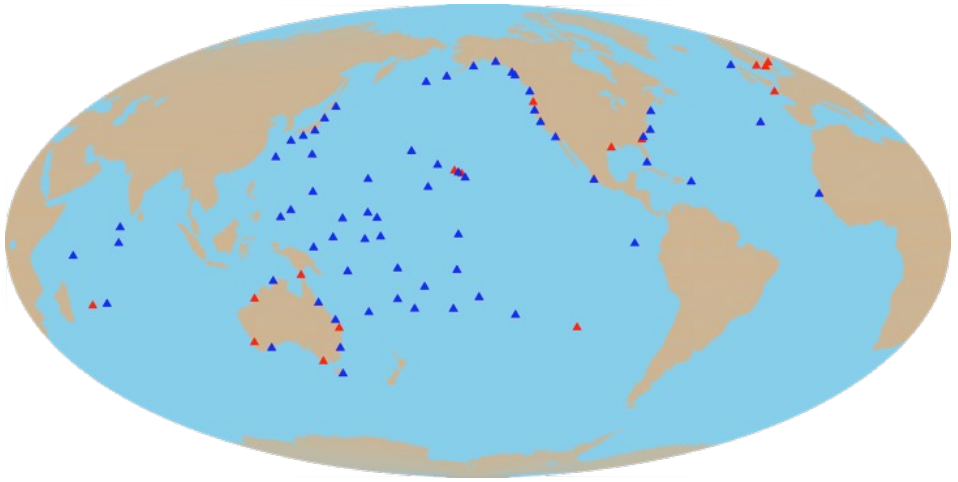


Tide gauge comparisons

NOAA Altimeter/tide gauge comparison system

Methodology

- Modified method of Mitchum [2000]
- Use multiple passes near each gauge, adjust for time/space lags and combine with a covariance weighted least squares
- Vertical land motion estimates from GNSS (NGL) and GIA (A, Wahr, Zhong 2013)
- Updated gauge selection



(blue gauges were selected by Mitchum 2000; red gauges were included in Watson et al. 2015)

Tide gauge comparisons

Gauge data from University of Hawaii Sea Level Center (UHSLC)

Up to 69 gauges; research + fast delivery

Altimeter data from the Radar Altimeter Database System (RADS)

Reference series

Estimate a drift using combination of TOPEX/J1/J2/J3 (GDR-F)/S6MF (RL08)

Sentinel-3A/B

Comparisons by ½ cycle (13.5 days)

Baseline Collection 5

UNIVERSITY OF HAWAII SEA LEVEL CENTER

RADAR ALTIMETER DATABASE SYSTEM

Reference missions
Jason-3

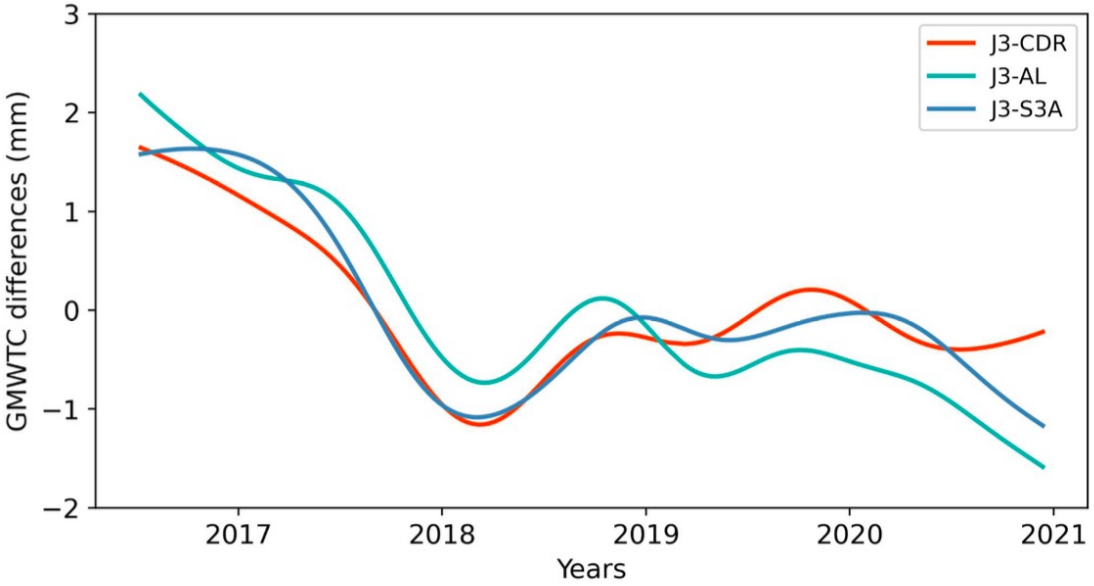
Wet troposphere correction validation

The Jason-3 GDR-F wet troposphere correction (WTC) has been identified as a source of error in global mean sea level.

We routinely validate WTC with the SNPP Advanced Technology Microwave Sounder (ATMS).

NOAA radiometer monitoring site: https://www.star.nesdis.noaa.gov/socd/lsa/AMR/realtime.php

(For more details, see Bin Zhang's talk at S6VT splinter)

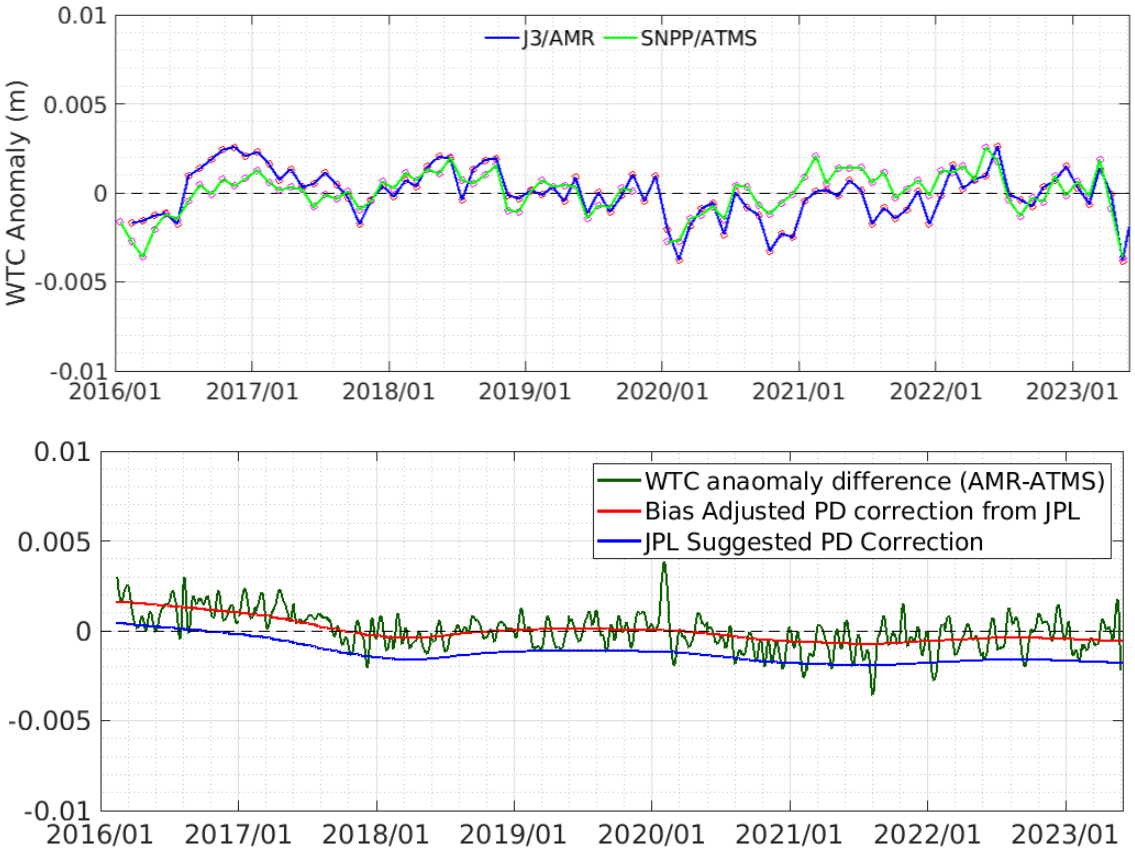


Barnoud et al. 2022

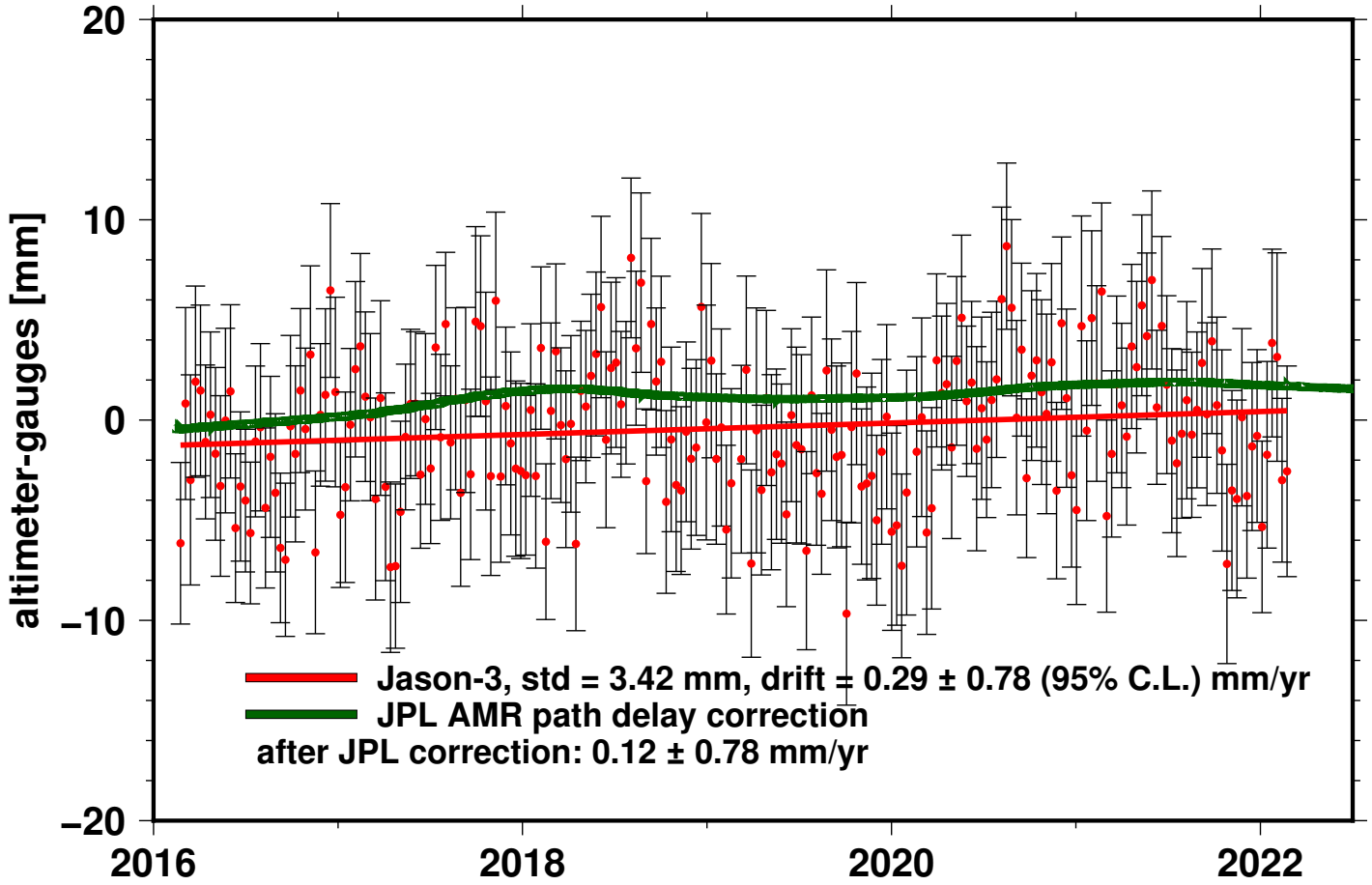
Jason-3 Global mean ATMS WTC comparison with AMR WTC

Global monthly WTC anomaly

- Calculated global (< 66°) mean over monthly, removes monthly mean (Bias (2.5mm) and seasonal difference exists) between Jason-3 AMR and ATMS WTC.
- Global monthly anomaly difference time series shows a clear negative trend.
- The trend agrees with recent JPL WTC correction (from Shannon Brown).



Jason-3 Tide gauge comparison



Reference missions
S6MF

RADS intermission biases

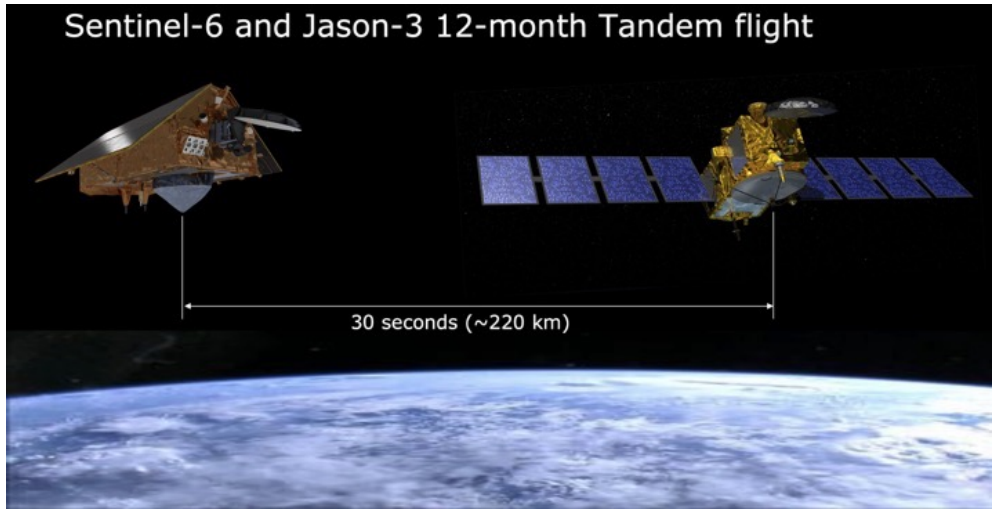
For OSTST2022 we estimated S6MF-J3 biases with 1-Hz colinear differences:
LR MLE4: –12.5 ± 0.5 mm and HR: –24.4 ±0.5 mm with no significant side-A/B differences.
The latest version of RADS introduced S6MF intermission biases using F08 and slightly revised the Jason-3 bias.

RADS intermission biases (mm) w.r.t. TOPEX

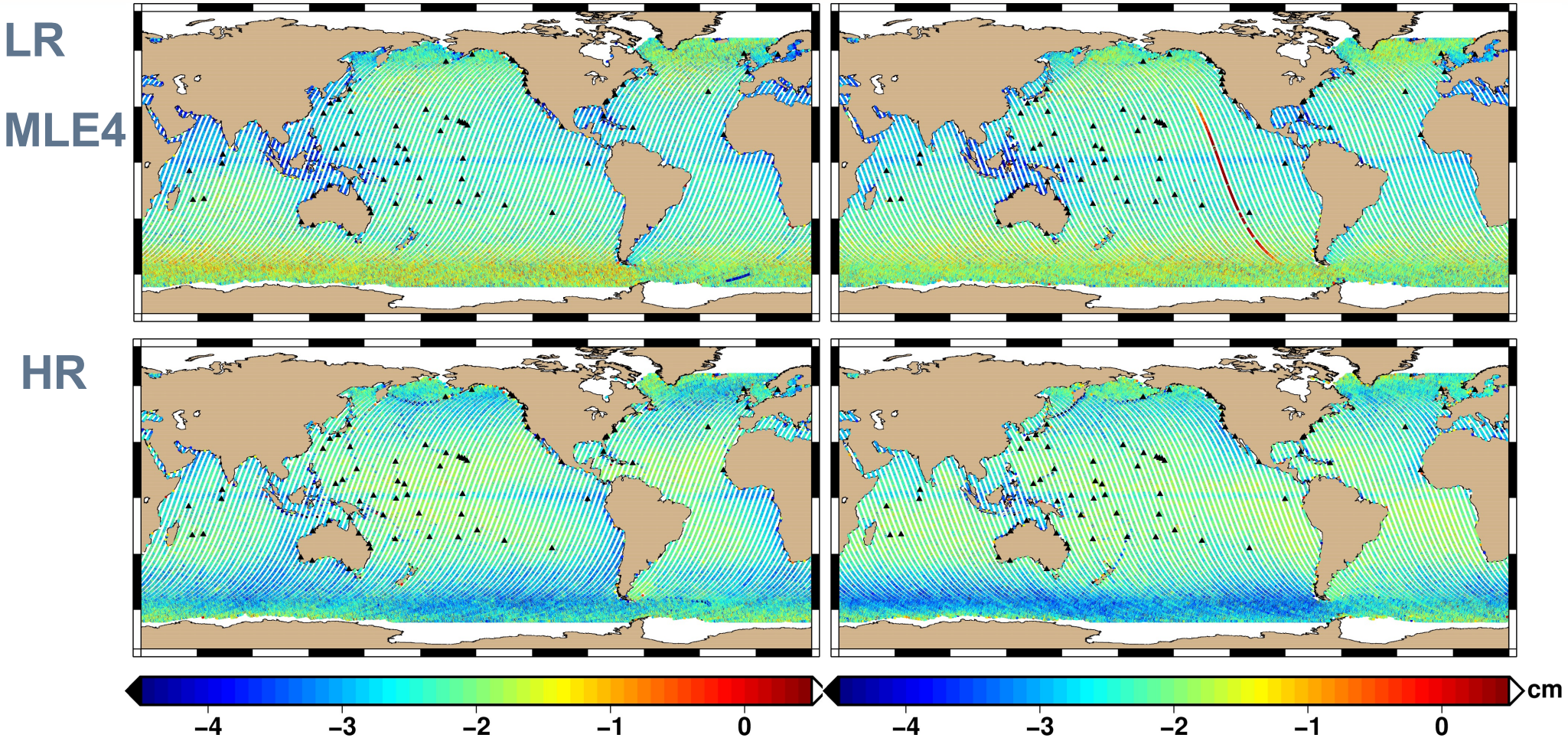
Retracker RADS version	JA3 4.4	JA3 4.5	S6A 4.4	S6A Side A 4.5	S6A Side B 4.5
LR MLE4	-23.0	-22.6	0.0	-13.2	-11.9
LR MLE3	-9.0	-8.9	0.0	-17.5	-15.8
LR adaptive/NR	-48.0	-47.7	0.0	-19.6	-17.2
HR			0.0	-23.5	-21.5

Sentinel-6MF to Jason-3 intermission bias

- The global S6MF/Jason-3 biases were within requirements and stable during the tandem phase, particularly for S6MF side-B.
- However, uncorrected geographically-correlated biases could produce an apparent drift in global tide gauge comparison of the reference series.



Sentinel-6MF – Jason-3 bias during the tandem phase

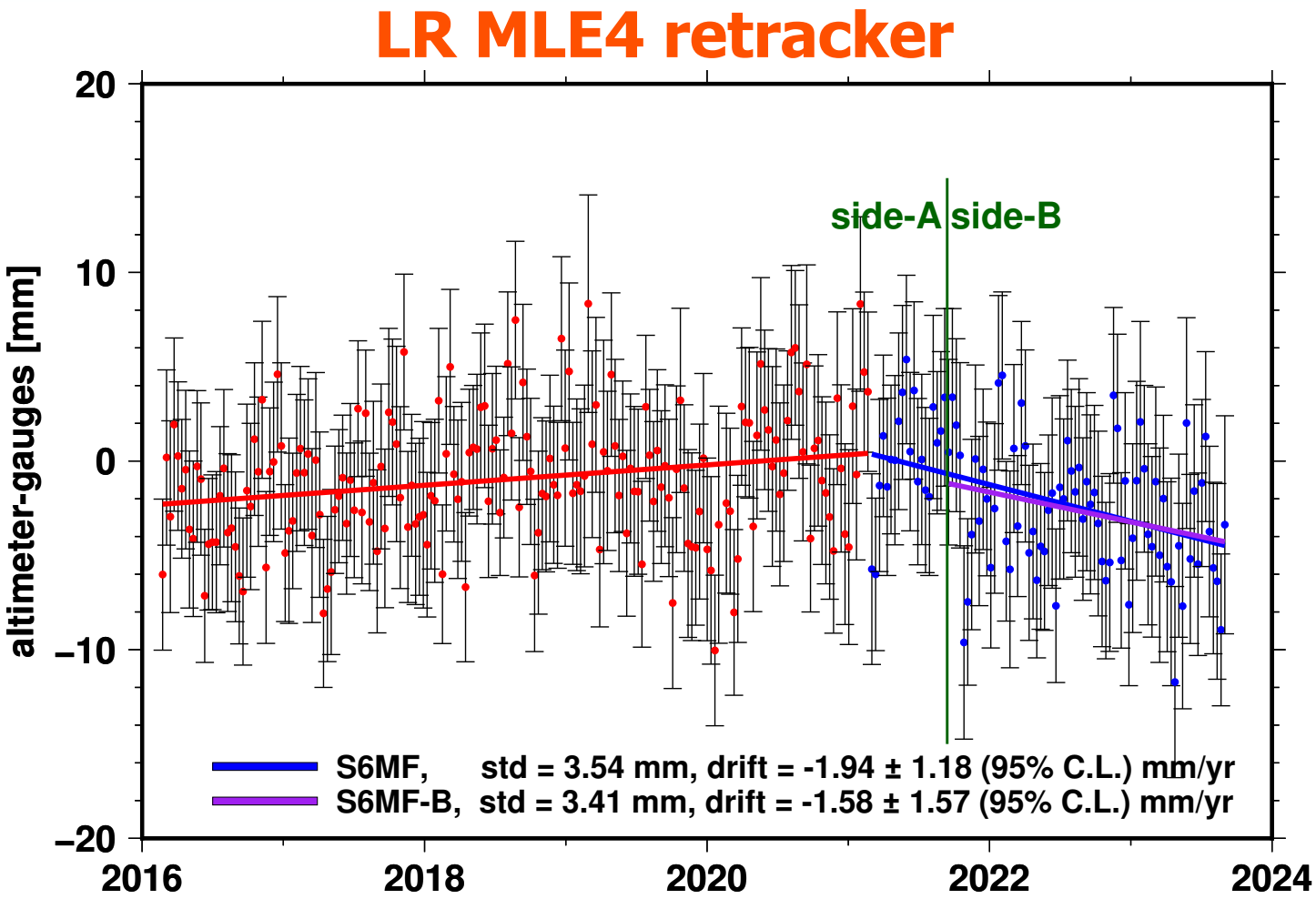


Tide gauge comparison: Sentinel-6MF (LR MLE4)

Default sea level from the S6MF MLE4 retracker does not account for shape evolutions in time of POSEIDON4 altimeter point-target-response.

The tide gauge results confirm this significant drift.

The Numerical Retracker (LR NR) was introduced in the F08 baseline to address this.



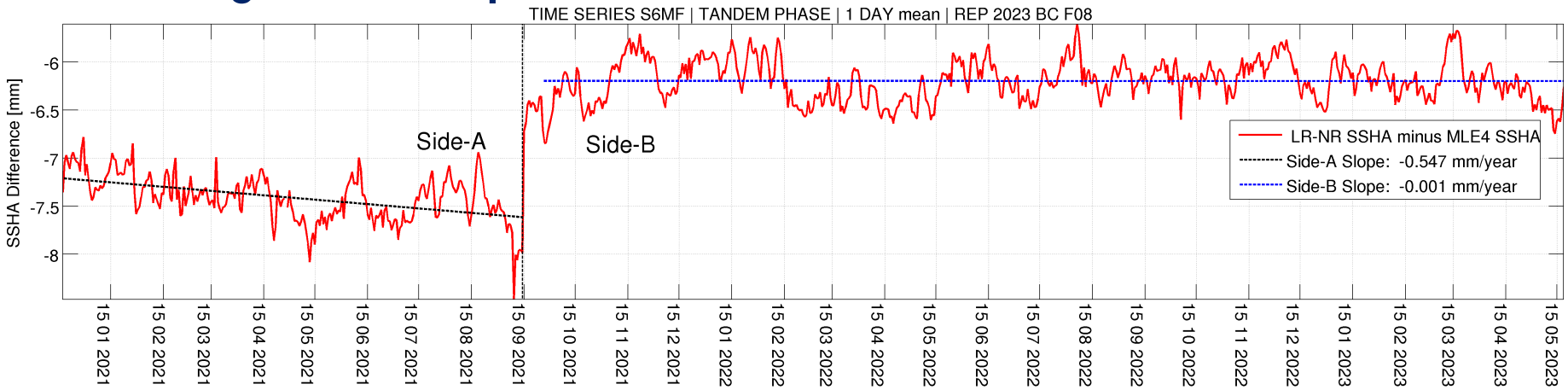
Tide gauge comparison: Sentinel-6MF (LR MLE4)

Default sea level from the S6MF MLE4 retracker does not account for shape changes in time of altimeter point-target-response.

Numerical Retracker (LR NR) was introduced in the F08 baseline to address this.

The trend in SSH differences between MLE4 and NR are significant on side-A
On side-B SWH/sigma0 drifts mitigate the effect on SSH.

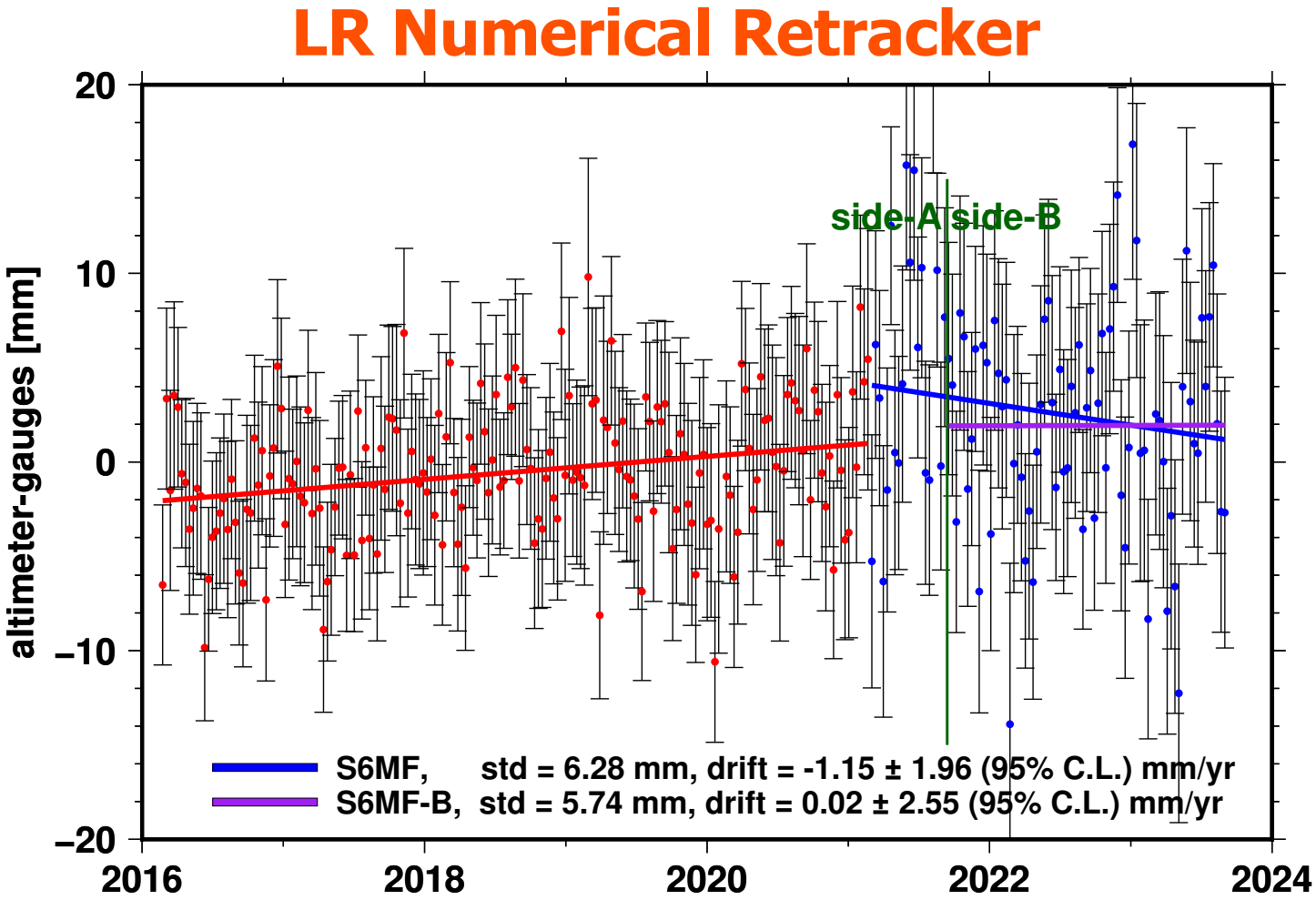
SSH "straight from the products"



Tide gauge comparison: Sentinel-6MF (LR NR)

No significant drift in Sentinel-6 LR NR, but the record is short.

The LR NR data near most gauges has higher variability, increasing the uncertainty and lengthening the data span needed to determine the stability to within the S6 requirements for LR.



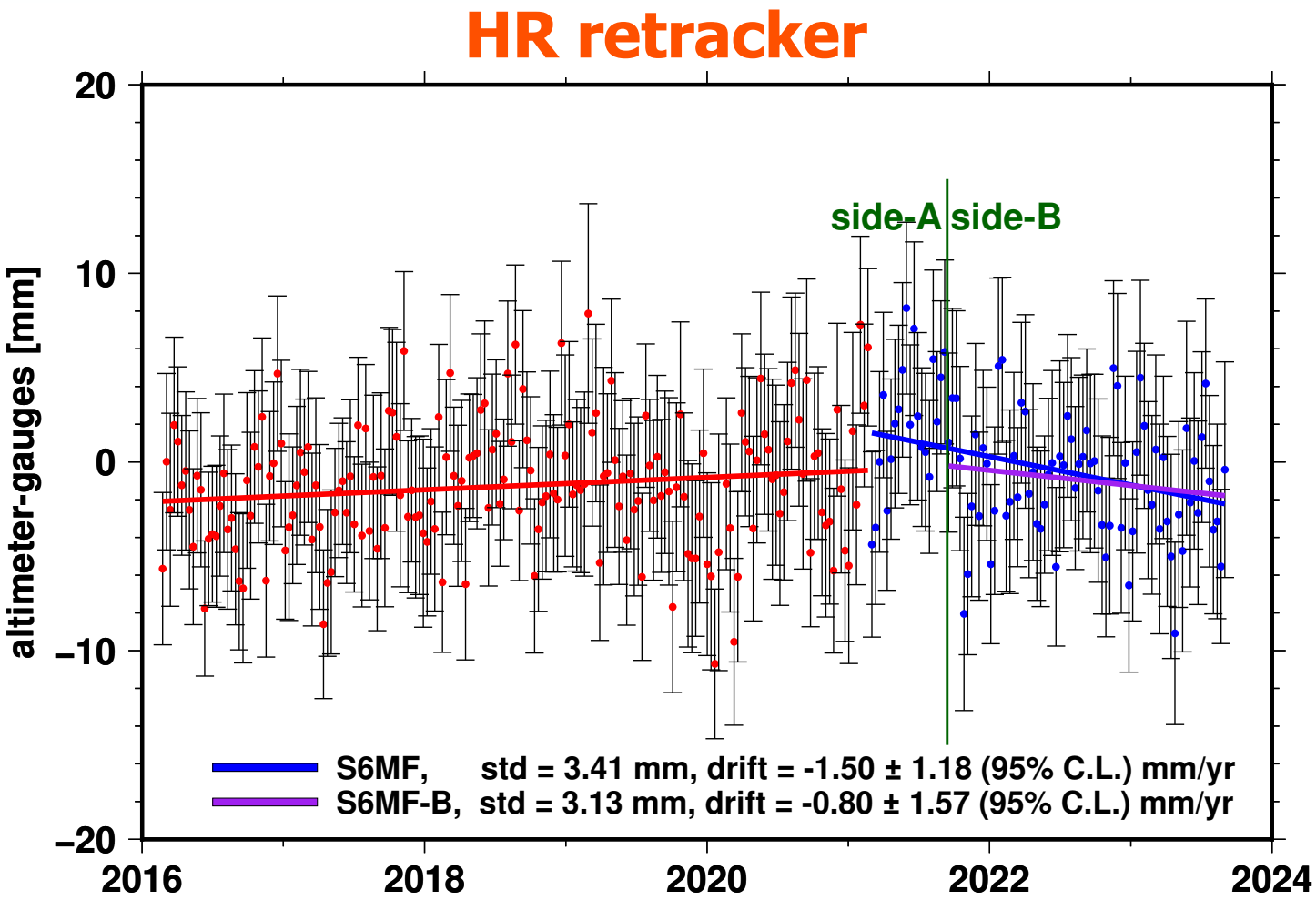
Tide gauge comparison: Sentinel-6MF (HR)

The HR/SAR data show a significant drift for the full mission.

The drift for side-B only is smaller and not significant and st dev is low (3.1 mm).

Possible side-A/side-B bias different from the global bias.

Will need to revisit HR when NR is included in baseline F09.



Tide gauge comparison: Sentinel-6MF LR MLE4 versus LR NR

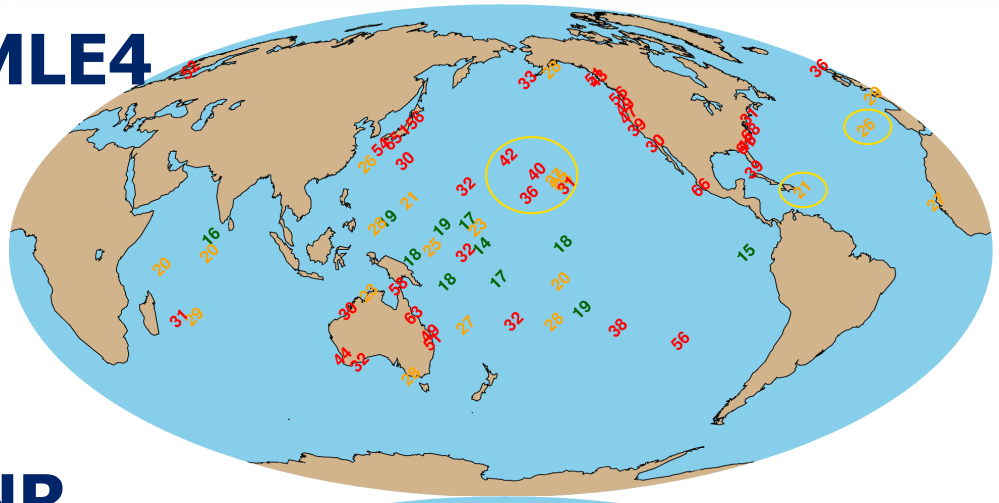
St. dev. in mm S6MF minus tide-gauge sea level.

Highest variance increases in harbor gauges:

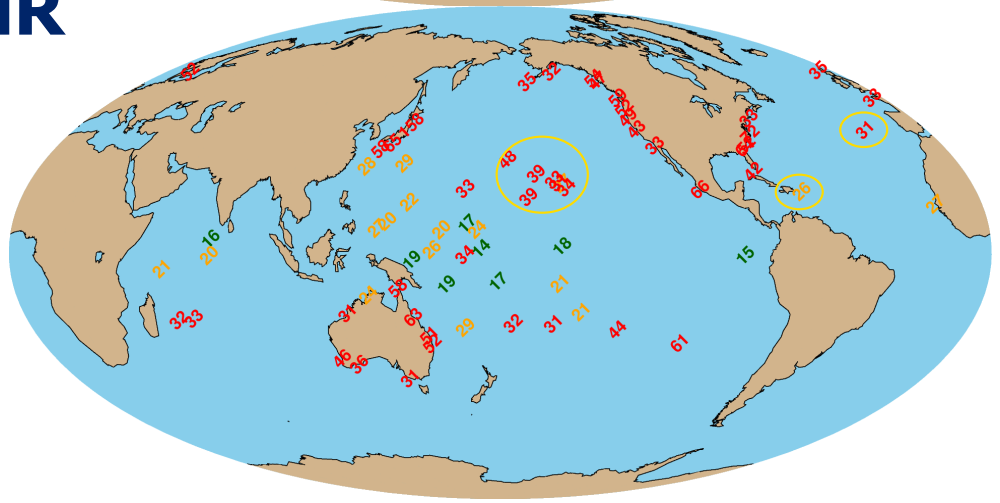
- Honolulu
- San Juan
- Kauai
- Ponta Delgada

LR NR in F08 has a known error at very low SWH and SWH is lower near gauges.

LR MLE4

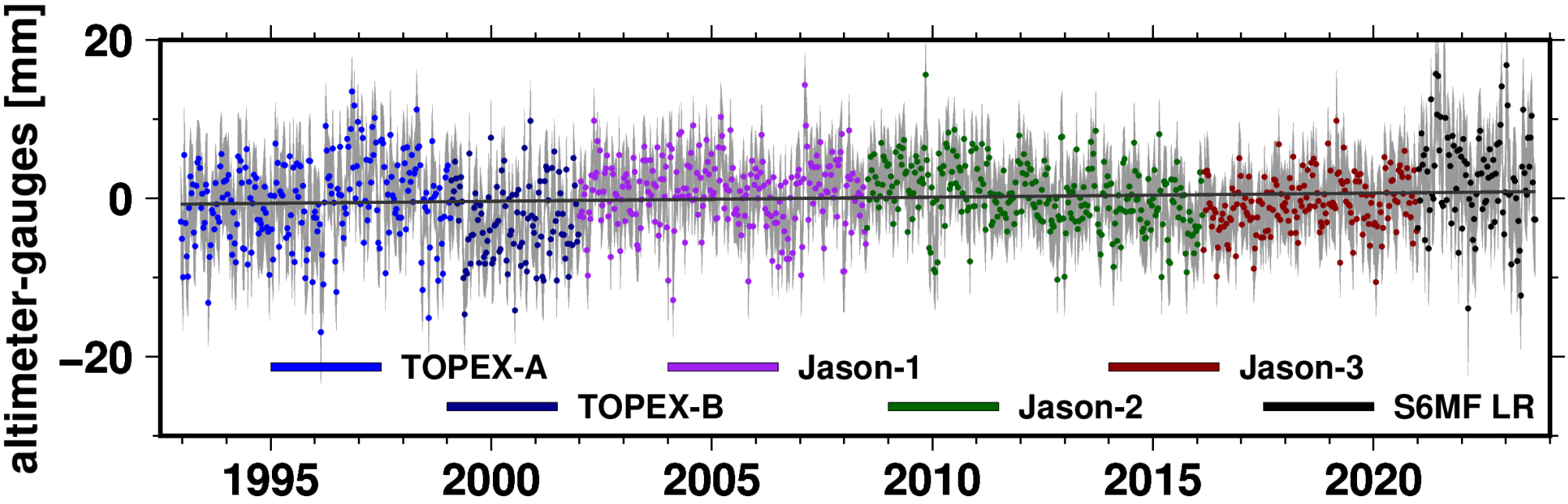


LR NR



30-year reference mission/tide gauge comparison

The residuals from the 30-year reference series record are consistent with no drift (0.05 ± 0.8 mm/year, 95% CI)

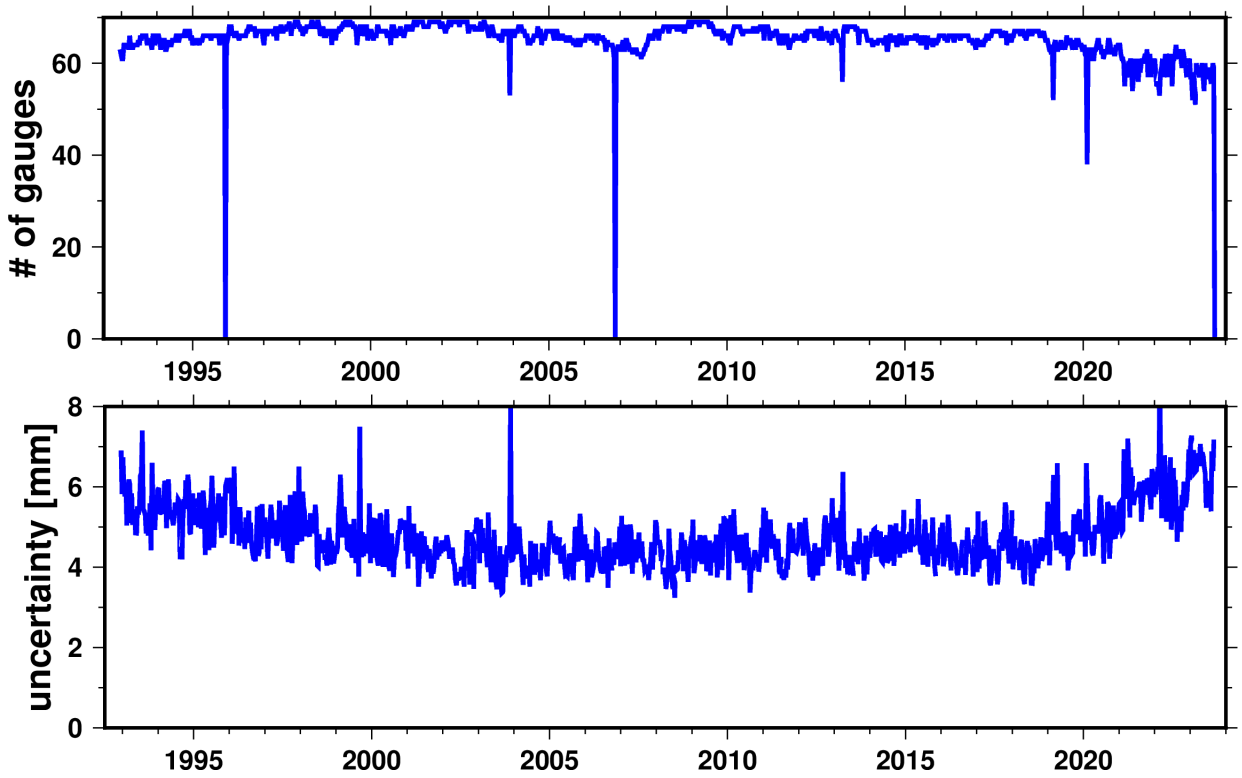


Gauge availability and comparison errors

The number of our selected gauges with available data has been dropping since the 2010 with a decline in 2019.

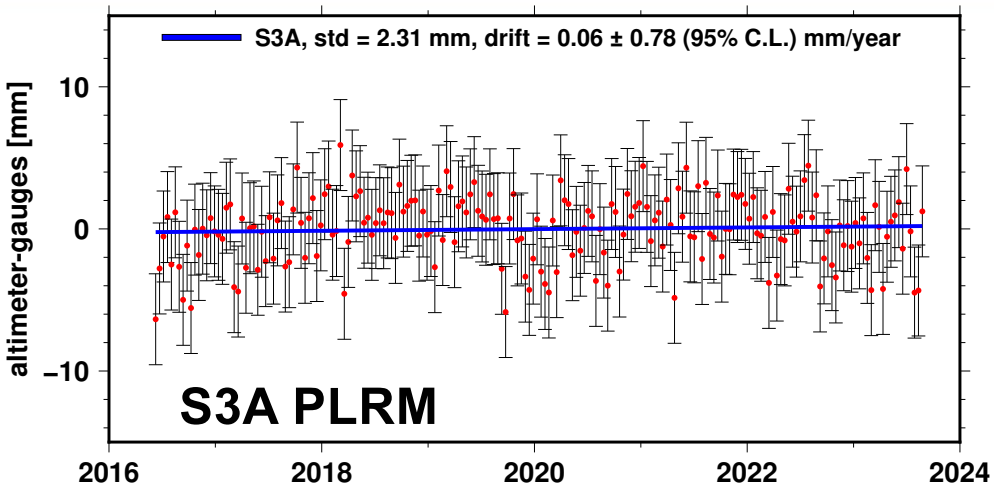
For Jason-1 through Jason-3 the per cycle uncertainty in the altimeter-gauge bias is ~4 mm.

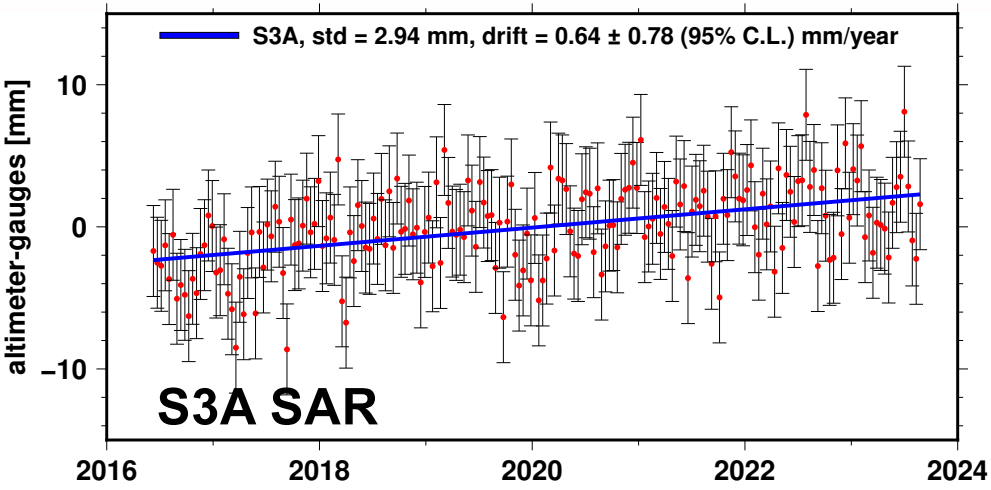
Errors have increased with fewer gauges available and a higher variance from LR NR.

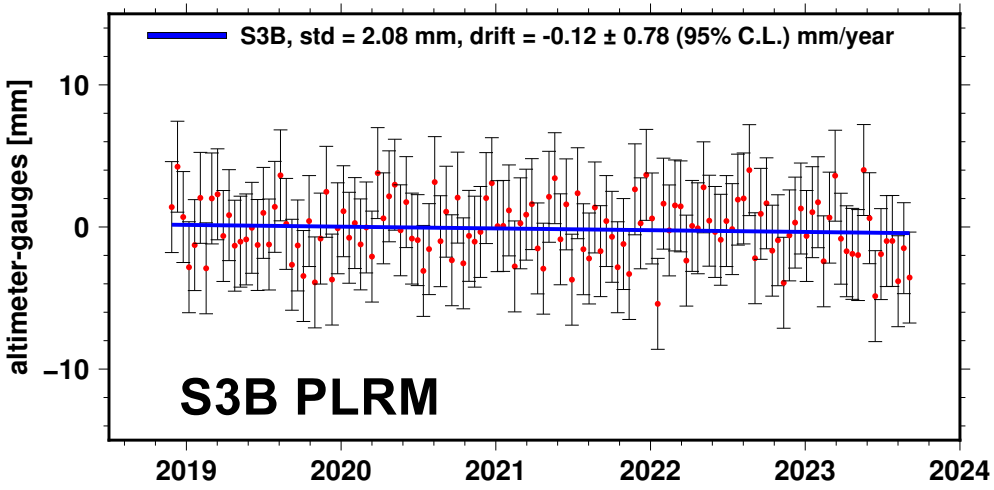


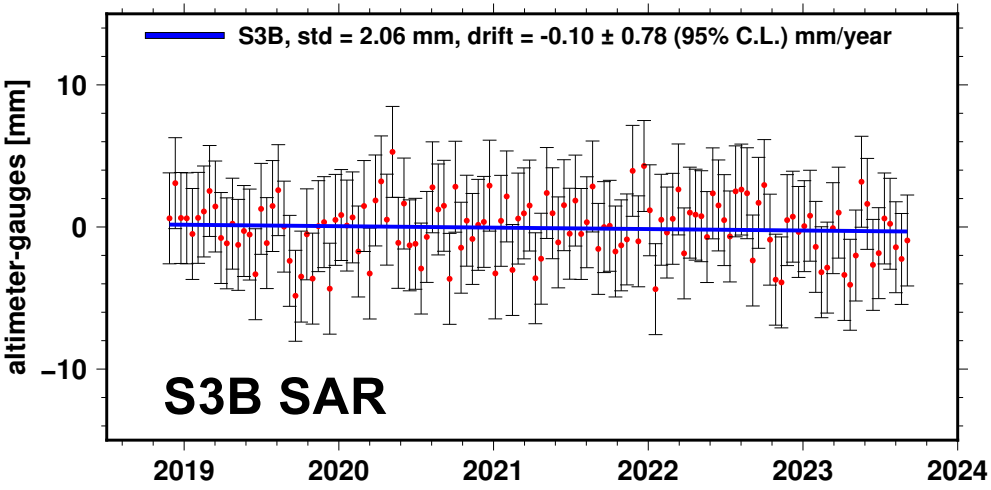
Sentinel-3
Baseline Collection 5

Tide gauge comparisons S3A/B (Baseline Collection 5)









Summary

- **Jason-3: Verified JPL AMR path delay correction**
- **Sentinel-6MF: No significant drifts in LR NR**

  The higher variance of NR near the gauges presents a challenge for validation of the stability requirement
- **Sentinel-3: No significant drifts; S3A SAR drift reduced from BC4**
- **Future plans**
  - Adopt Ray et al. 2023 tide gauge datum fixes
  - Implement the J3 path delay correction in RADS
  - Reprocessed TOPEX/POSEIDON
  - Re-evaluate S6 HR from baseline reprocessing F09 (numerical retracking)
  - Test GPD+ for Sentinel-3