Initial comparisons of Jason-3 and Sentinel-3A and tide gauges

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Outline

Three issues concerning the drift of the TOPEX/Jason GMSL time series with respect to a global network of tide gauges:

Past
- Evaluating the TOPEX A/B bias with ERS-2

Present
- Vertical land motion selections at tide gauges and drift estimates of the 23-year TOPEX/Jason-1/Jason-2 record

Future
- Initial results comparing Jason-3 GDR & tide gauges

Bias between TOPEX-A and -B

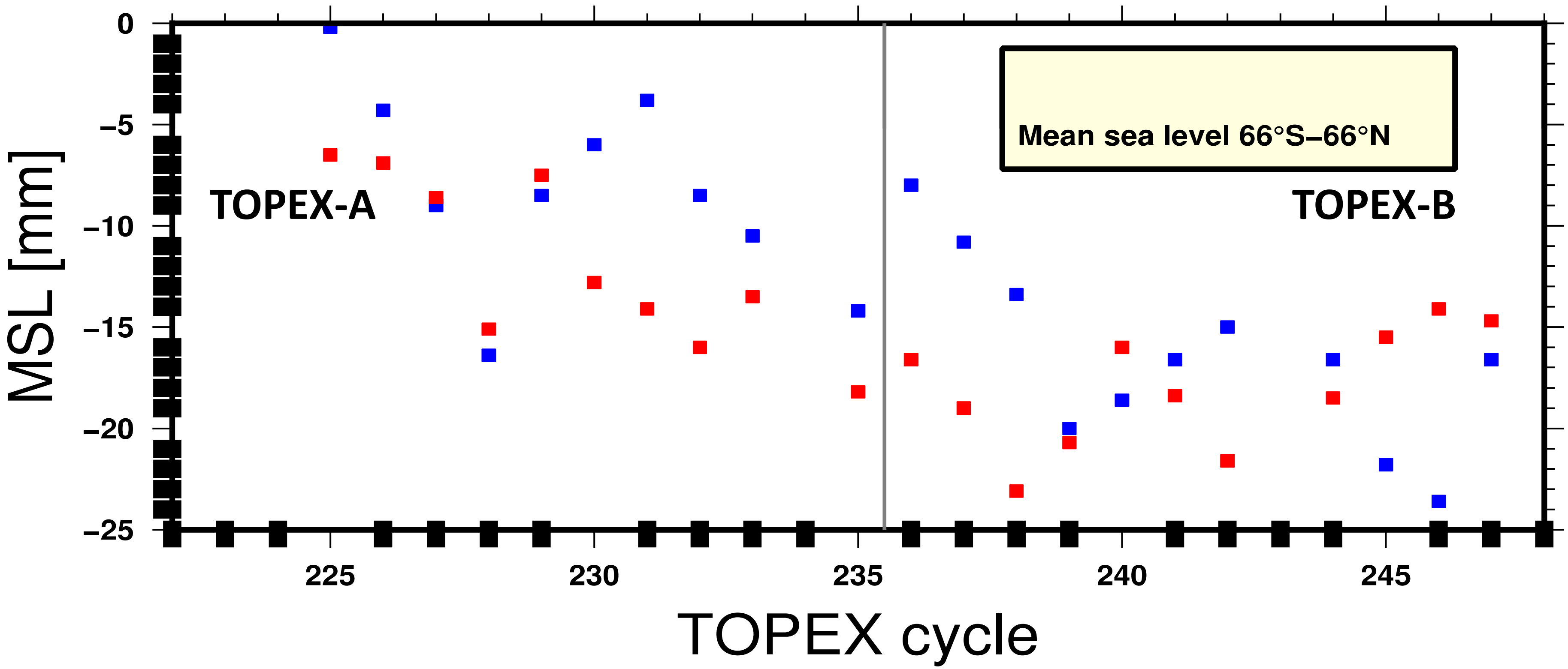
The uncertainty in the bias in linking TOPEX A and TOPEX B in February 1999 is one of the key uncertainties in the 24 year altimetry record in global mean sea level.

- Albain et al. 2008 estimated that the uncertainty in intermission biases contributed 0.1 to 0.25 mm/yr to the uncertainty in GMSL.
- To estimate an acceleration in GMSL in the 24-year record, the uncertainty in the A/B bias will need to be bound.
- Choice of sea state bias model can affect the A/B bias (Gaspar et al. 2002; Chambers et al. 2003; Tran et al. 2010)

Because ERS-2 was the only other altimeter operating during the A/B transition, only it and the tide gauges are independent measures of any bias.

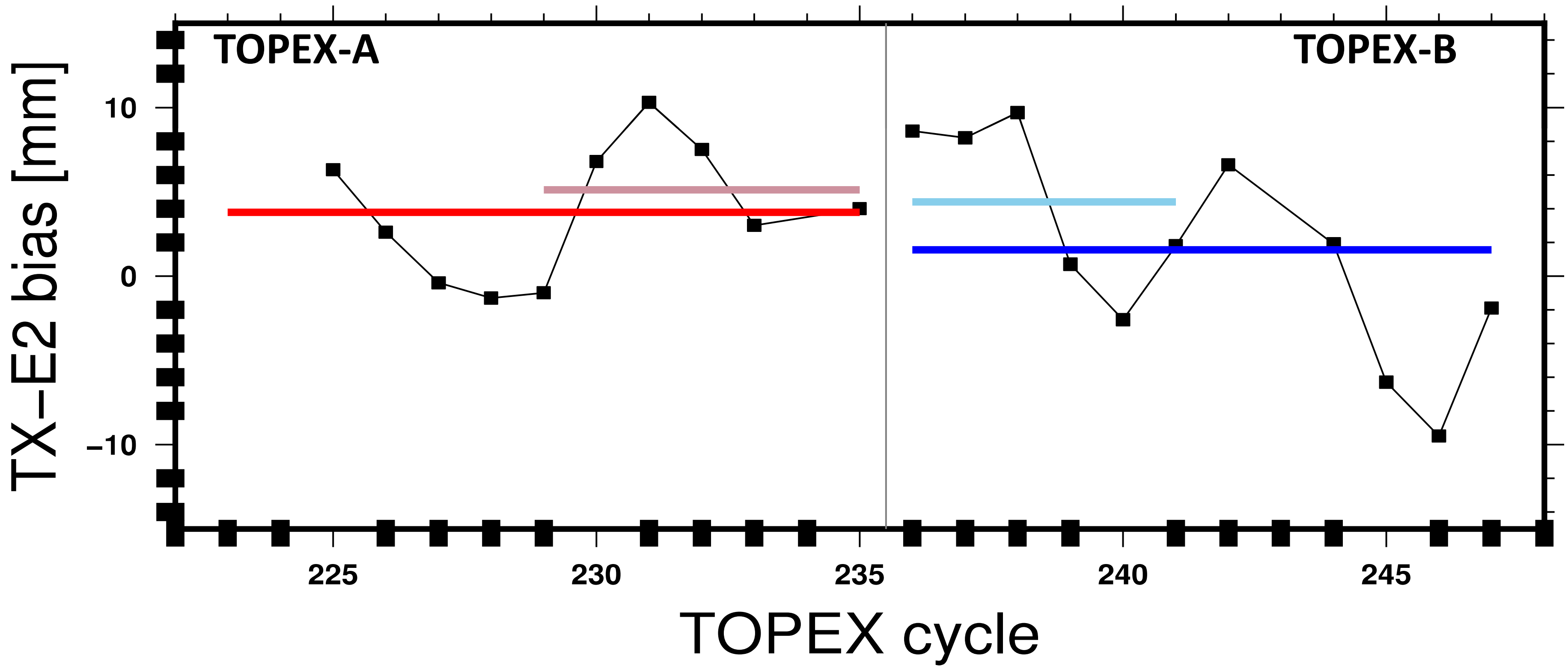
GMSL from TOPEX and ERS-2

When ERS-2 is sampled to match TOPEX's time and latitude sampling, the 10-day GMSL appears to be too noisy to compute biases.



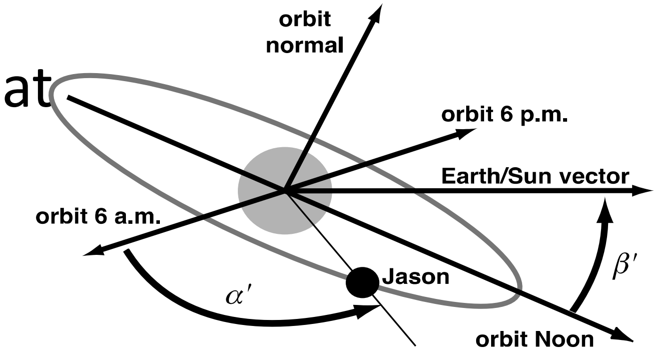
GMSL from TOPEX and ERS-2

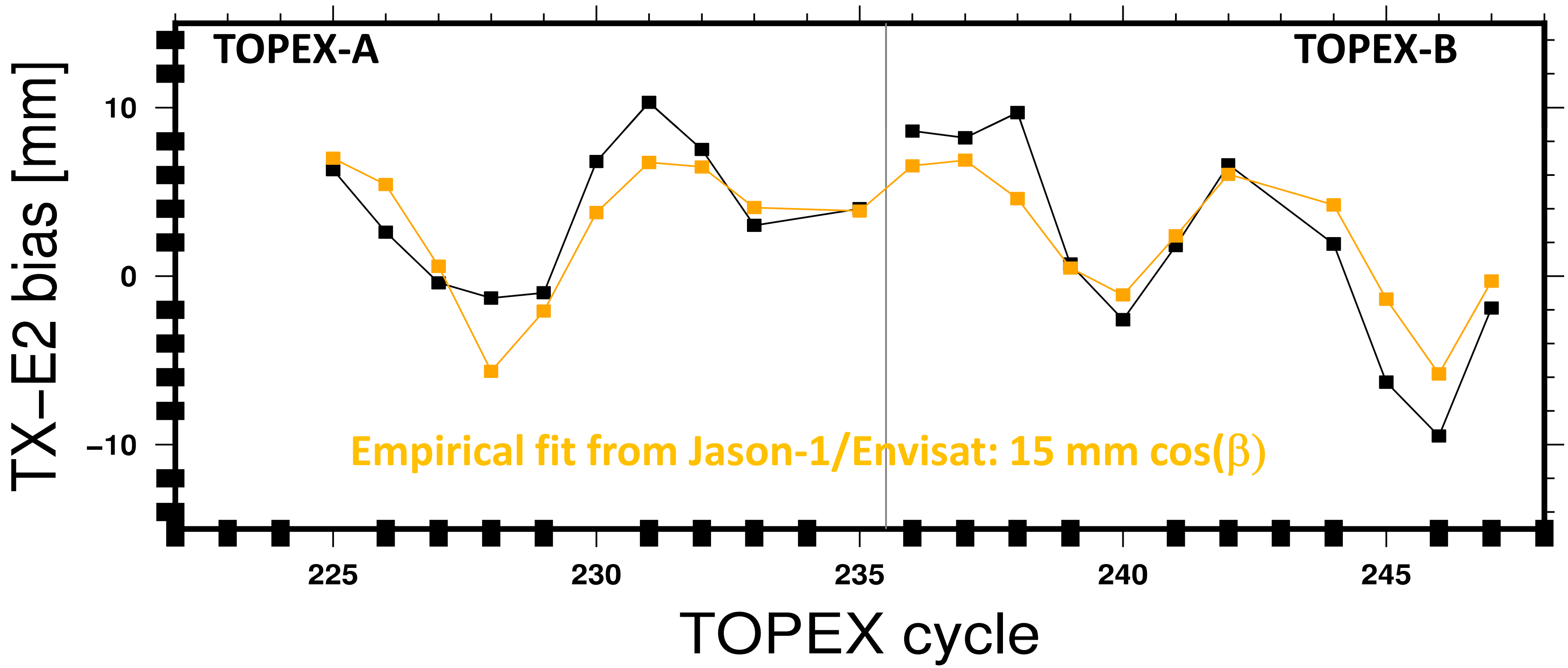
Because of the variability in TX-E2 differences, estimates of the A/B bias depend on the length of time and the method used to model a bias. Averaging over 60 or 120 produces a 1 mm bias or a 3 mm bias, respectively.



TOPEX has a β' dependence

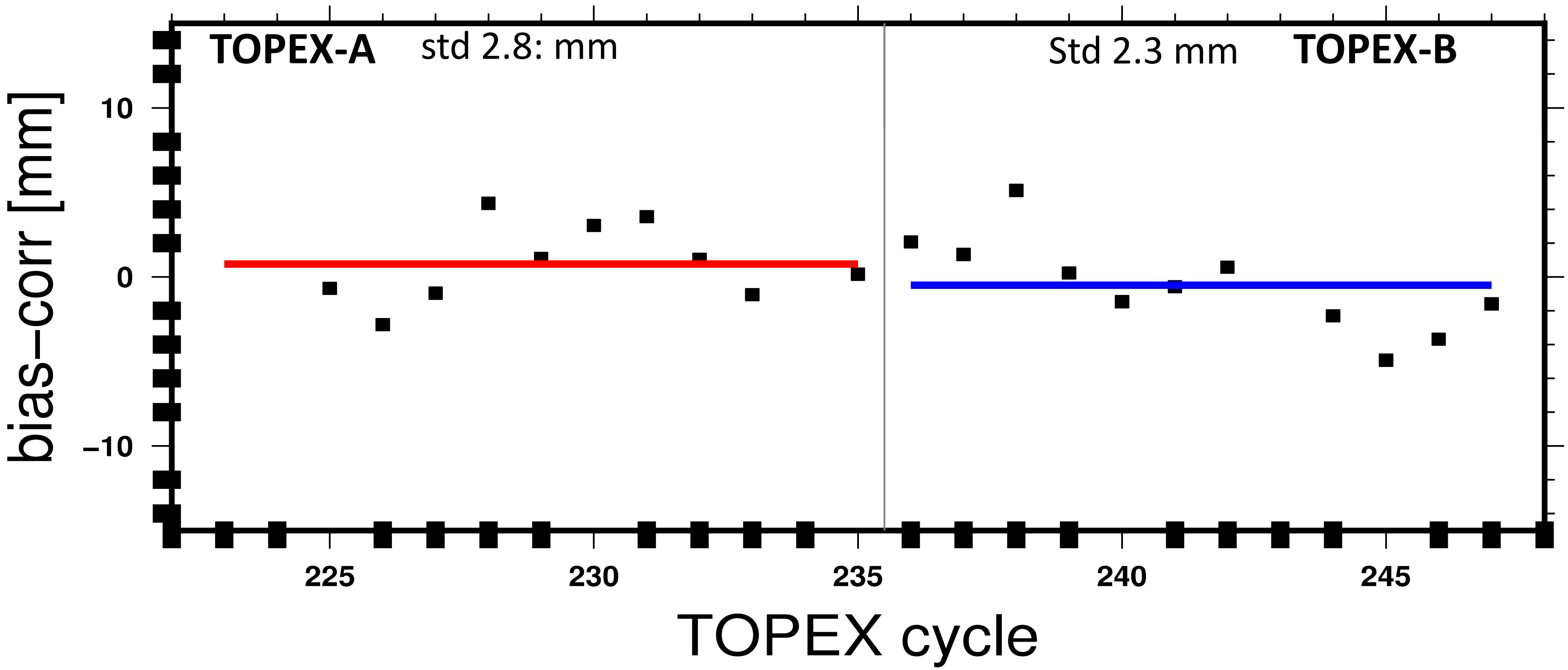
TOPEX MSL differences with Jason-1 and Envisat are correlated with β', which varies at 58.77 days <u>AND</u> ½ year. (It's not just a 59-day/S_2 problem!)





Correcting TOPEX for β' dependence

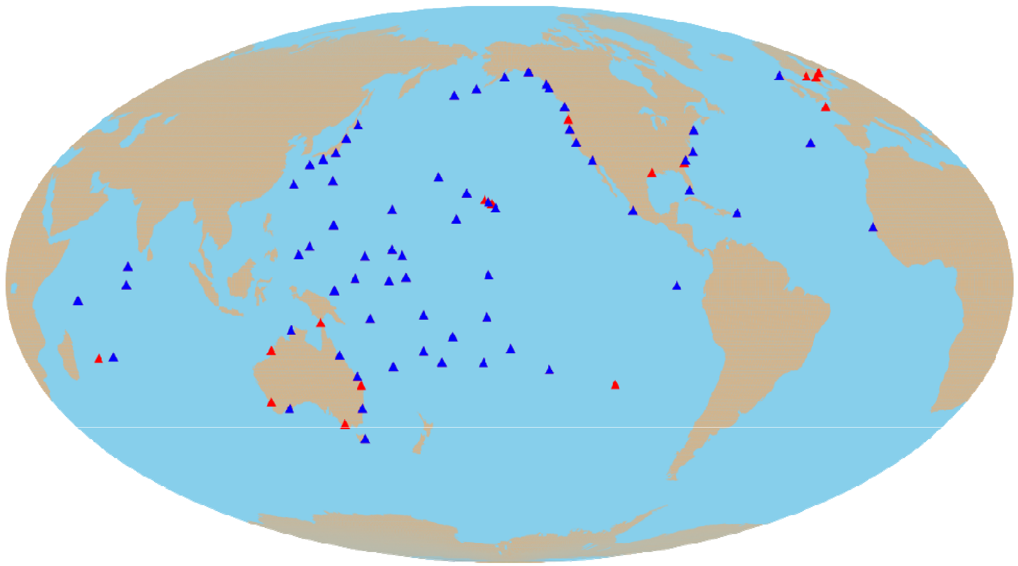
After removing the empirical β' dependence from TOPEX, the bias between 120-day averages of TXB-E2 TX—E2 differences is 0.7 mm. The std of the residuals is 2.8 and 2.3 mm, smaller than the drift series from the tide gauges. F-test says that there's only an 11% that we need change the A/B bias.



Altimetry and tide gauge data

Altimetry data from RADS

- TOPEX/Jason-1/Jason-2 (TJM)
- TOPEX/Jason-1/Jason-2/Jason-3 (GDR cycles 1 to 19)
- Merged Envisat/Altika
- Sentinel-3A NRT



- Tide gauge (TG) data from UHSLC/SOEST
  - 61 of 64 gauges used by Mitchum 2000 (blue)
  - 14 additional gauges chosen from those used in Watson et al 2015 after controlling for data availability (red)

Estimates of VLM

Vertical land motion (VLM) must be removed from tide gauges before comparing with altimetry

- Mitchum estimates uncertainty in drift series = ±0.4 mm/yr
  - Some errors cannot be minimized by adding more gauges
- Some VLM estimates that have been used:
  - direct measurements from GNSS/DORIS/etc.
    - GNSS is not always colocated with the gauge
    - scale error and reference frame error
    - extrapolation errors
  - the difference between multidecadal local gauge-based relative sea level and global or regional sea level
    - bias error due to reliance on global or regional sea level rise
  - Glacial Isostatic Adjustment models of crustal vertical motion at the tide gauge
    - GIA VLM vulnerable to “omission” errors because other land motion (e.g. tectonic motion, subsidence from resource extraction

VLM solutions

GNSS vertical velocity solutions

- ULR5 and ULR6: Université de La Rochelle,
- JPL: GPS Time Series http://sideshow.jpl.nasa.gov/post/tables/table2.html
- UTas (University of Tasmania): updated from King et al. 2012
- NGL: Nevada Geodetic Laboratory MIDAS velocity fields (Blewitt et al. 2016)

When a GNSS solution is not available, we use GIA estimates from Peltier or A, Wahr, and Zhong

	GIA	GNSS
ULR5	47	28
ULR6	28	47
JPL	26	49
UTas	28	47
NGL	12	63

GNSS station selections

Evaluated three different methods for selecting the VLM at each gauge from the available GNSS stations when multiple (2-3) colocated stations are available:

1. Use only the VLM closest in distance co-located receiver
2. Use only the VLM with the lowest estimated uncertainty
3. Use the weighting of Watson et al. [2014]: W=W1*W2

$$W_1 = 0.5\cos(2\pi\, d/400) + 0.5$$

$$W_2 = \begin{cases} 1 & if\ \sigma \leq 0.2 \\ -1.25\sigma + 1.25 & if\ 0.2 < \sigma < 1 \\ 0 & if\ \sigma \geq 1 \end{cases}$$

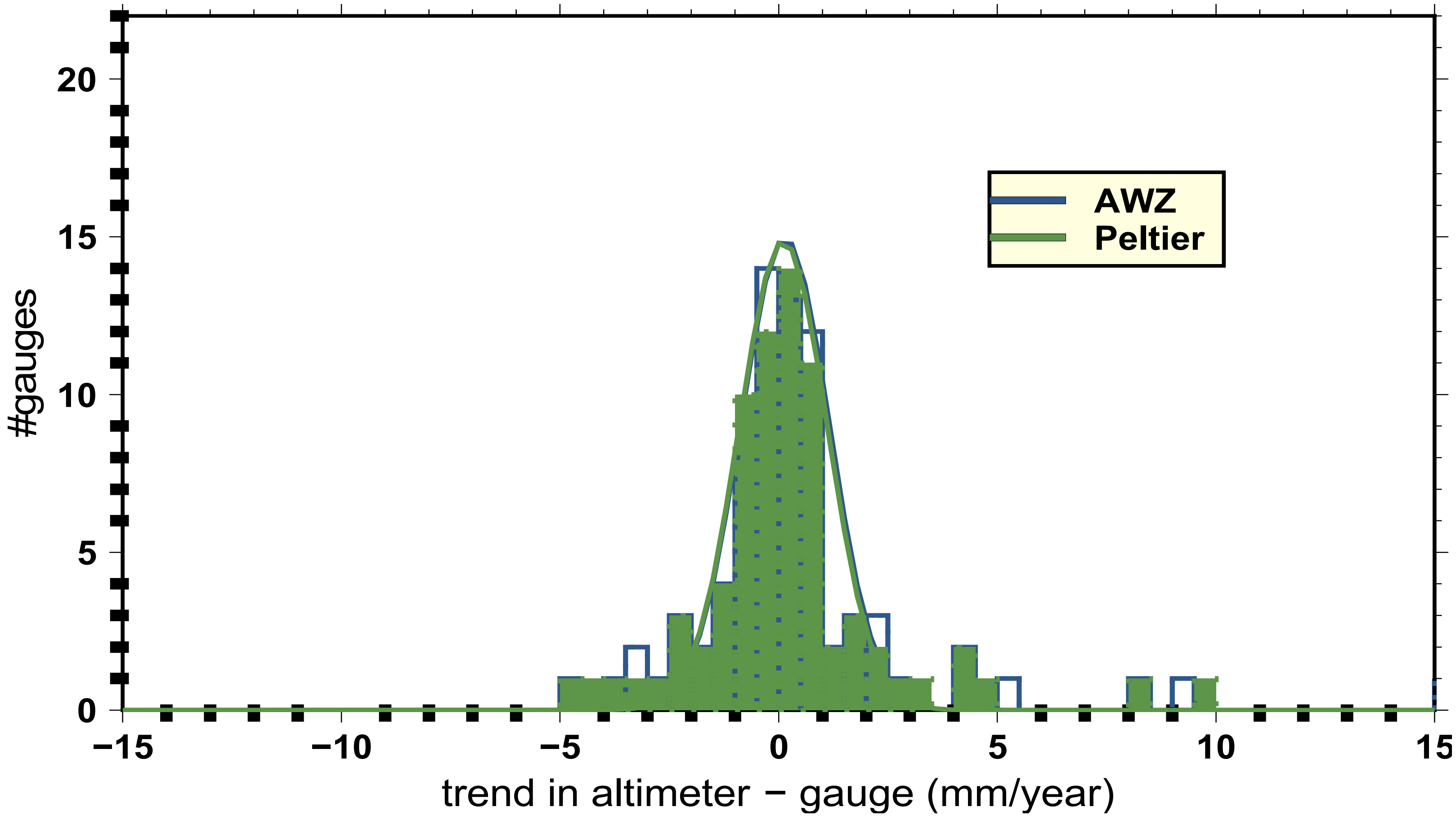
Evaluated the alt–TG drift estimates for 30 different VLM models/selections:
5 GNSS * 3 colocated selections methods * 2 GIA models

Statistics of altimetry – tide gauge residuals

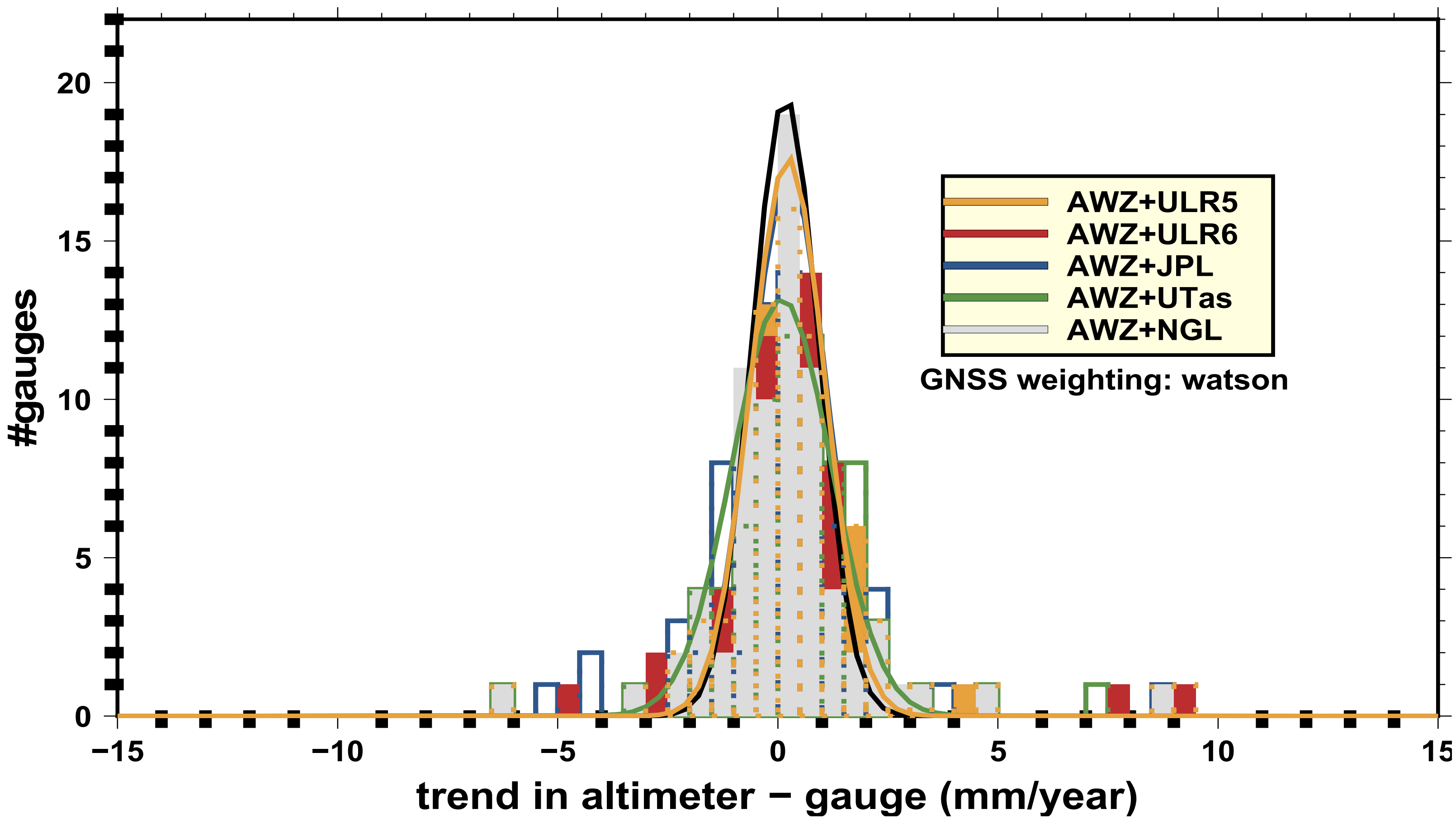
- Assumption: if we are able to completely remove the VLM from the gauge data, then the trends in the *individual* altimeter-TG residuals will have a Gaussian distribution
- If they aren't Gaussian, then either we still have VLM or there are other systematic errors (like geophysically-correlated errors in the altimetry)
- Method:
  - To avoid outliers find mode and scale parameter (sigma) from the least absolute deviation of the distribution of residuals
  - Find the scale of the equivalent normal distribution
  - The smaller the scale, the better the VLM?

Distribution of alt-TG residuals (GIA-only)

Using GIA model estimates of VLM produce alt-TG distributions with a scale of 0.84 and 0.82 mm with similar results for AWZ and Peltier.



Distribution of alt-TG residuals (GNSS+GIA)



Median absolute deviation scales (mm)

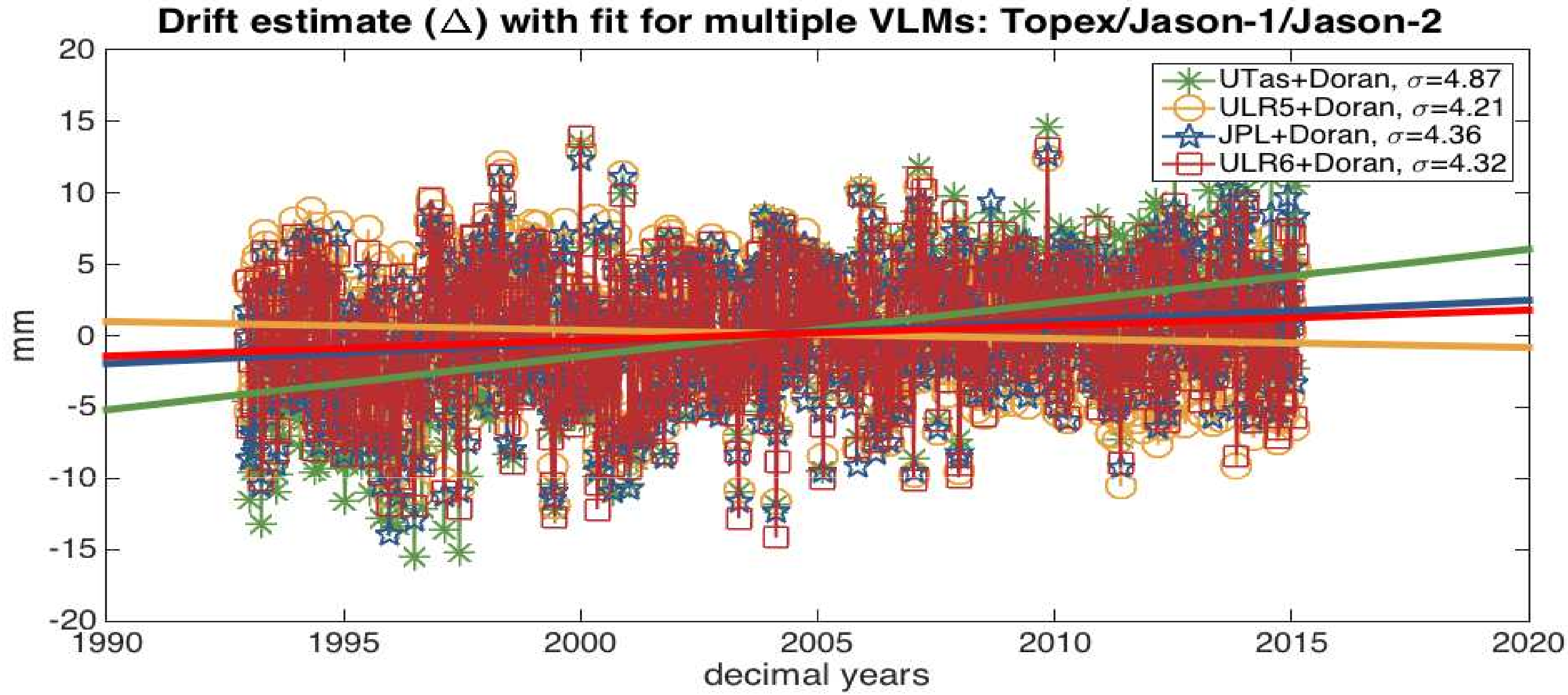
	GPS lowest error	Closest GPS	Watson weighting by dist/err
AWZ+JPL	0.97	0.90	0.87
AWZ+UTas	1.12	1.25	1.12
AWZ+ULR5	0.90	0.84	0.84
AWZ+ULR6	0.93	1.00	0.93
AWZ+NGL	1.10	1.07	0.75
Peltier+JPL	0.99	0.92	0.90
Peltier+UTas	1.15	1.28	1.15
Peltier+ULR5	0.90	0.88	0.86
Peltier+ULR6	0.94	1.01	0.98
Peltier+NGL	1.11	1.07	0.79

Median absolute deviation scales (mm)

	GPS lowest error	Closest GPS	Watson weighting by dist/err
AWZ+JPL	0.97	0.90	0.87
AWZ+UTas	1.12	1.25	1.12
AWZ+ULR5	0.90	0.84	0.84
AWZ+ULR6	0.93	1.00	0.93
AWZ+NGL	1.10	1.07	0.75

- The Watson weighting criteria of sigma < 1 mm/year reduces the number of NGL VLMs used from 63 to 46, similar to the other VLM selections.

Results: TOPEX/Jason1-2



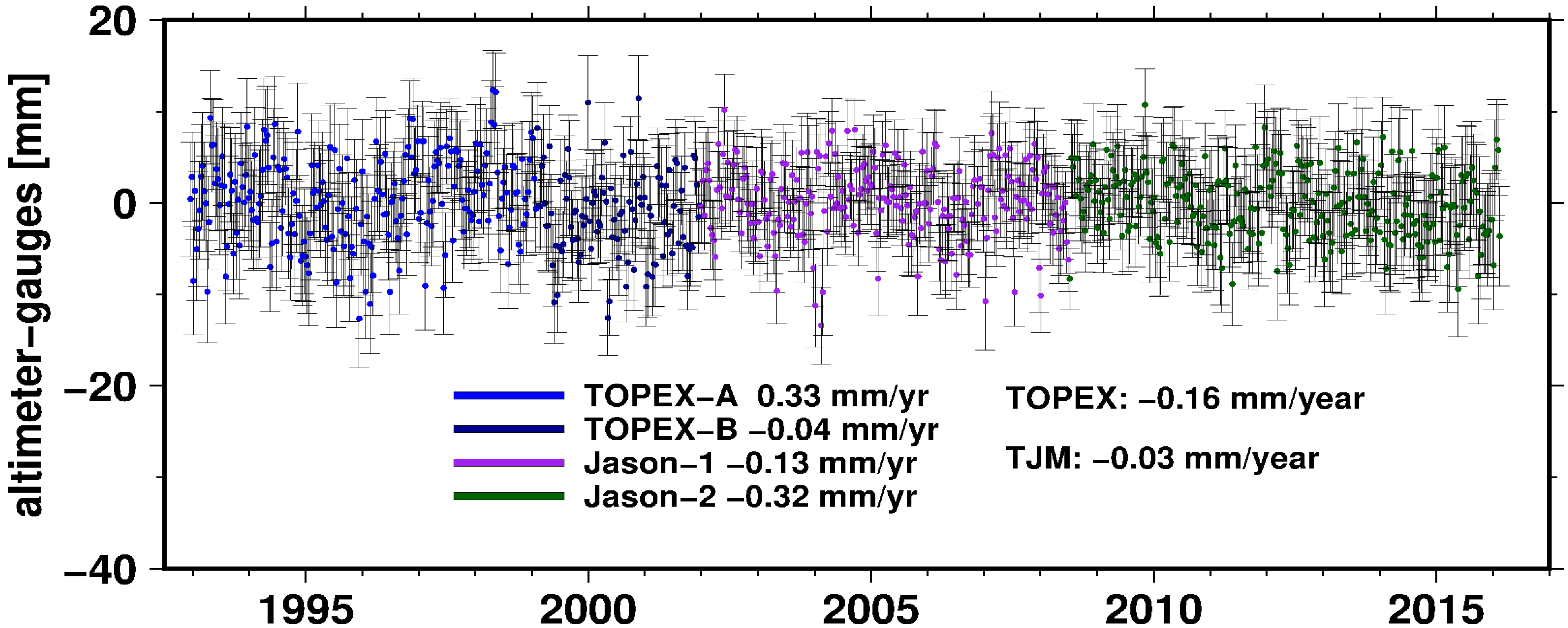
- Estimate drift in the TOPEX/Jason-1/Jason-2 using each VLM method

Drift estimates in in alt-TG residuals (mm/year)

	GPS lowest error	Closest GPS	Watson weighting by dist/err
AWZ+ULR5	0.25	0.28	0.22
AWZ+ULR6	0.16	0.21	0.19
AWZ+UTas	0.45	0.90	0.41
AWZ+JPL	0.27	0.34	0.06
AWZ+NGL	–0.27	–0.38	–0.03

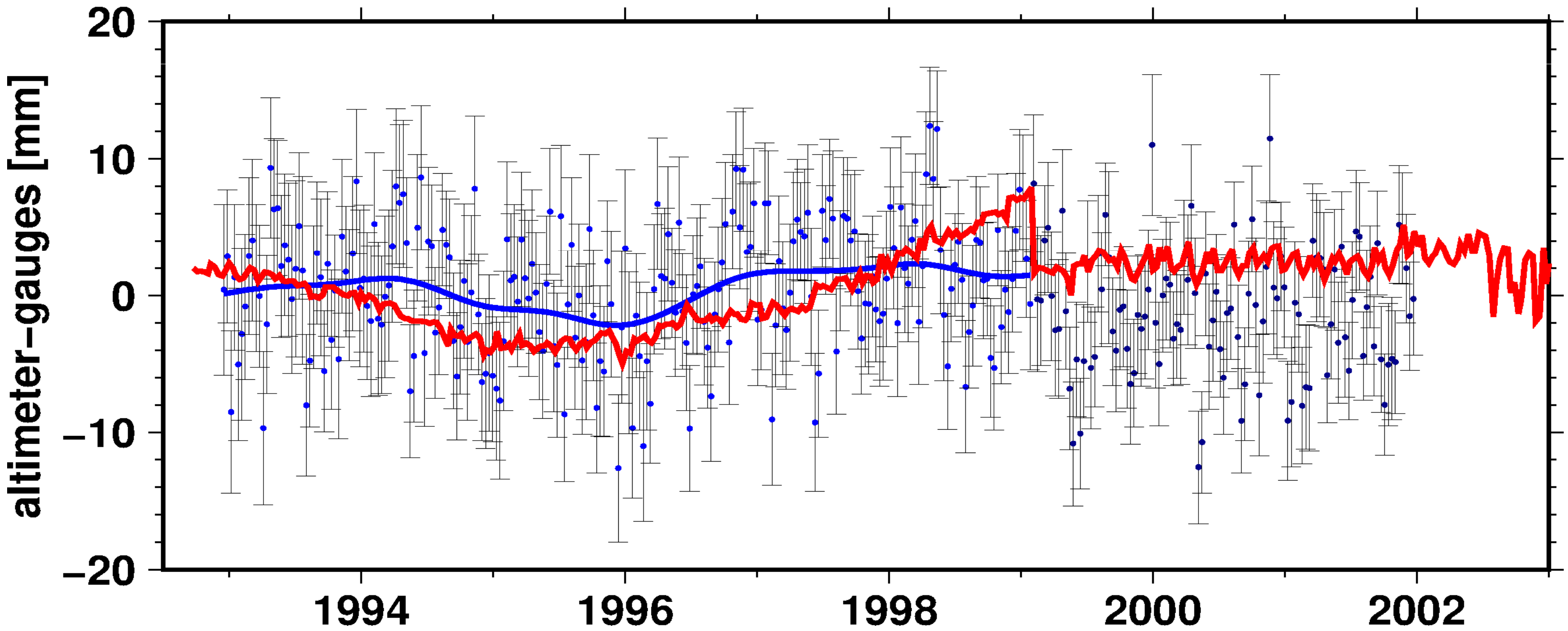
TOPEX/Jason-1/Jason-2 drift series

Using NGL+AWS with Watson weighting, the combined TX/J1/J2 does not have a significant drift.



TOPEX and WFF Cal-1 range correction

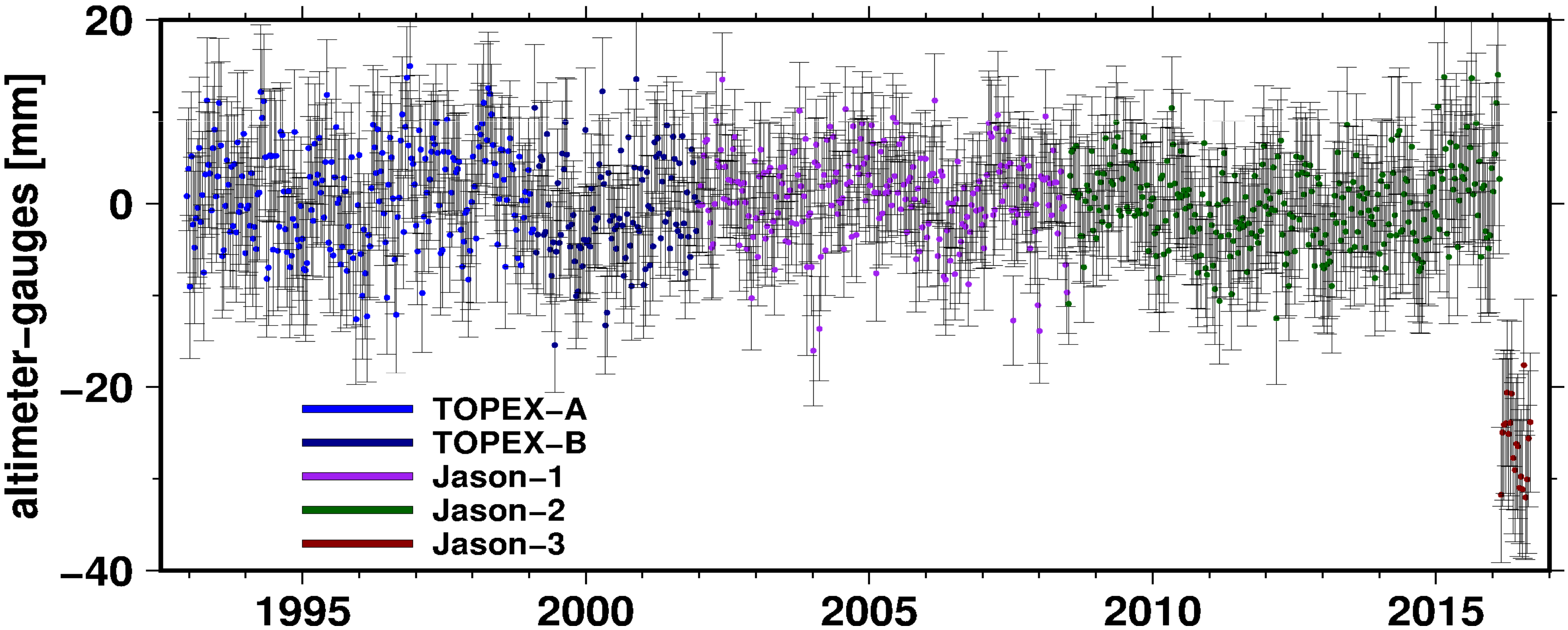
In RADS the Cal-1 range correction is applied to TOPEX. Cal-1 and the 1-year smoothed altimeter–gauge residuals is not significantly correlated.



Jason-3 (GDR) bias estimate

Cycles 1–19 Jason-3 GDR-T: –26.0 ± 0.9 mm (std err.)

Cycles 5–19: –26.7 ± 1.1 mm (std err.)



Conclusions

- Estimates of the TOPEX A/B bias should take in to account the β‘ dependence in TOPEX MSL.
  - Differences between TOPEX-ERS-2 are reduced when the β‘ dependence is removed.
- The range of drifts in TOPEX/Jason-gauge results from VLM strategies is consistent with a ±0.4 mm/year uncertainty.
- The Jason-3 bias with respect to the 24 year GMSL time series is –26.7 ± 1 mm. The combined TOPEX/Jason time series may need to start with Jason-3 cycle 5.

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