Comparisons of Jason-3 and Sentinel-3A and tide gauges

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Outline

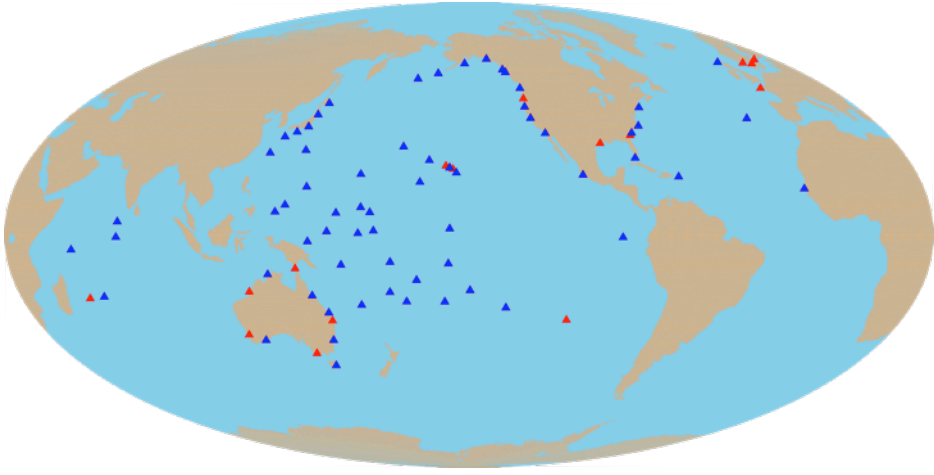
1) Altimeter/tide gauge comparison method
2) Review of our vertical land motion sensitivity study
3) Modifications for Sentinel-3A comparisons
4) Sentinel-3A and Jason-3 results
5) Implications for verifying Jason-CS/Sentinel-6 global mean sea level stability

NOAA Altimeter/tide gauge comparison system

Altimetry data from RADS

"Colinear" merged datasets

- TOPEX/Jason-1/Jason-2/Jason-3
- Merged ERS-2/Envisat/Altika
- Sentinel-3A NTC/STC



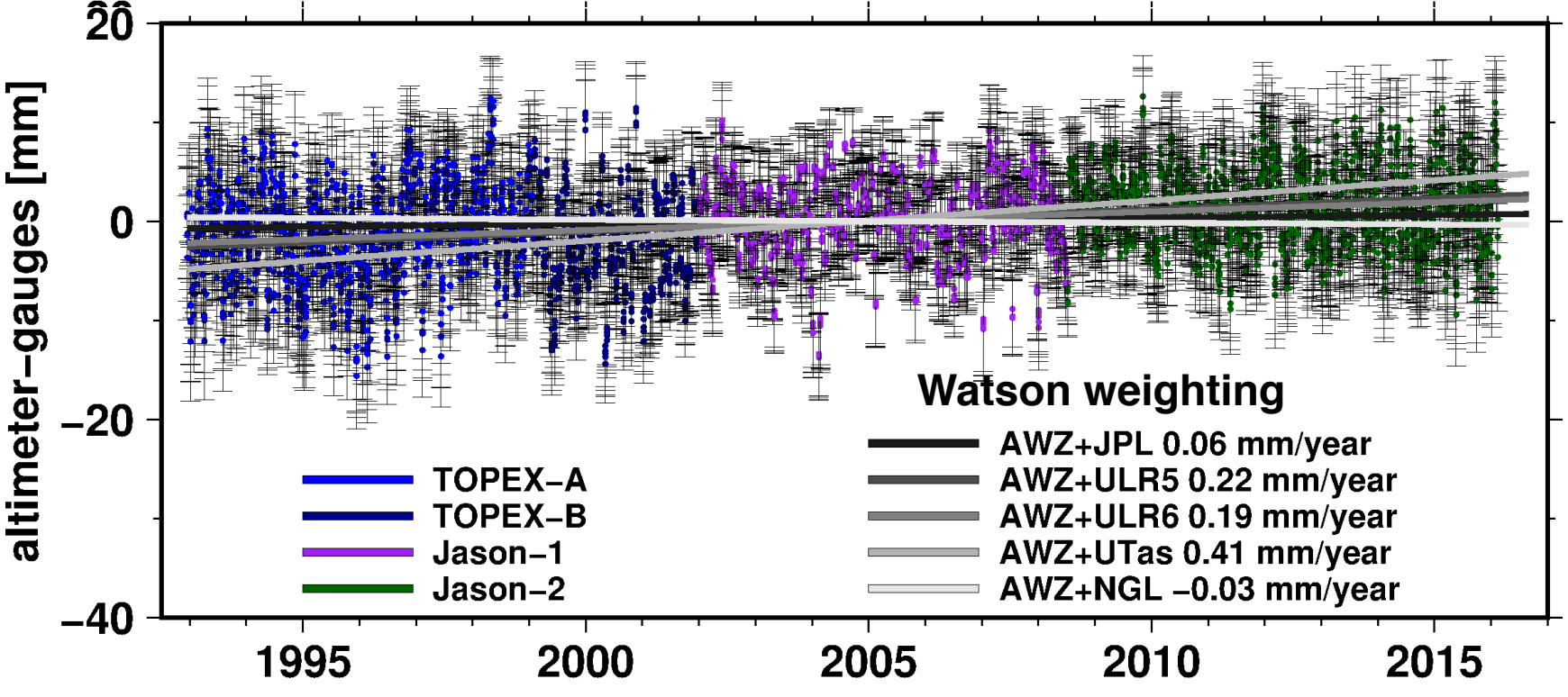
Daily tide gauge (TG) data from UHSLC (75 gauges)

- 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)

Covariance method of combing along-track altimetry – gauge residuals

VLM sensitivity study: TOPEX/Jason1-2

Estimate drift in the TOPEX/Jason-1/Jason-2 using each vertical land motion (VLM) method (GPS estimates + GIA model)



Drift estimates in alt-TG residuals

The range of drifts in TOPEX/Jason-gauge results from VLM strategies is roughly consistent with a ±0.4 mm/year uncertainty.

Drift estimates in in altimeter–TG residuals for TOPEX/Jason-1/Jason-2 (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

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)

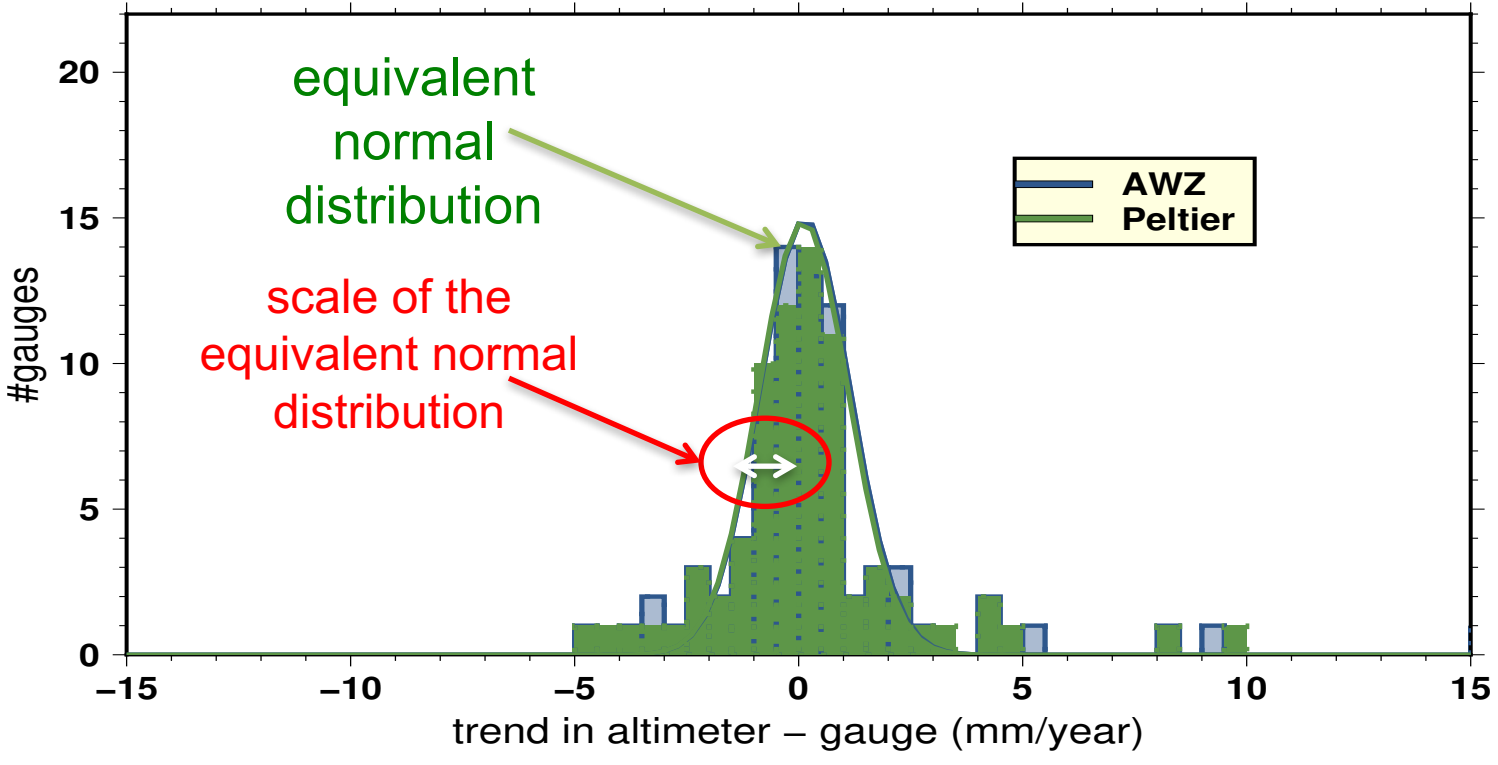
Method:

  - 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?
  - Examine the residuals from both the TOPEX/Jason minus TG and Enivsat/AltiKa minus TG

Distribution of TJ-TG residuals (GIA-only)

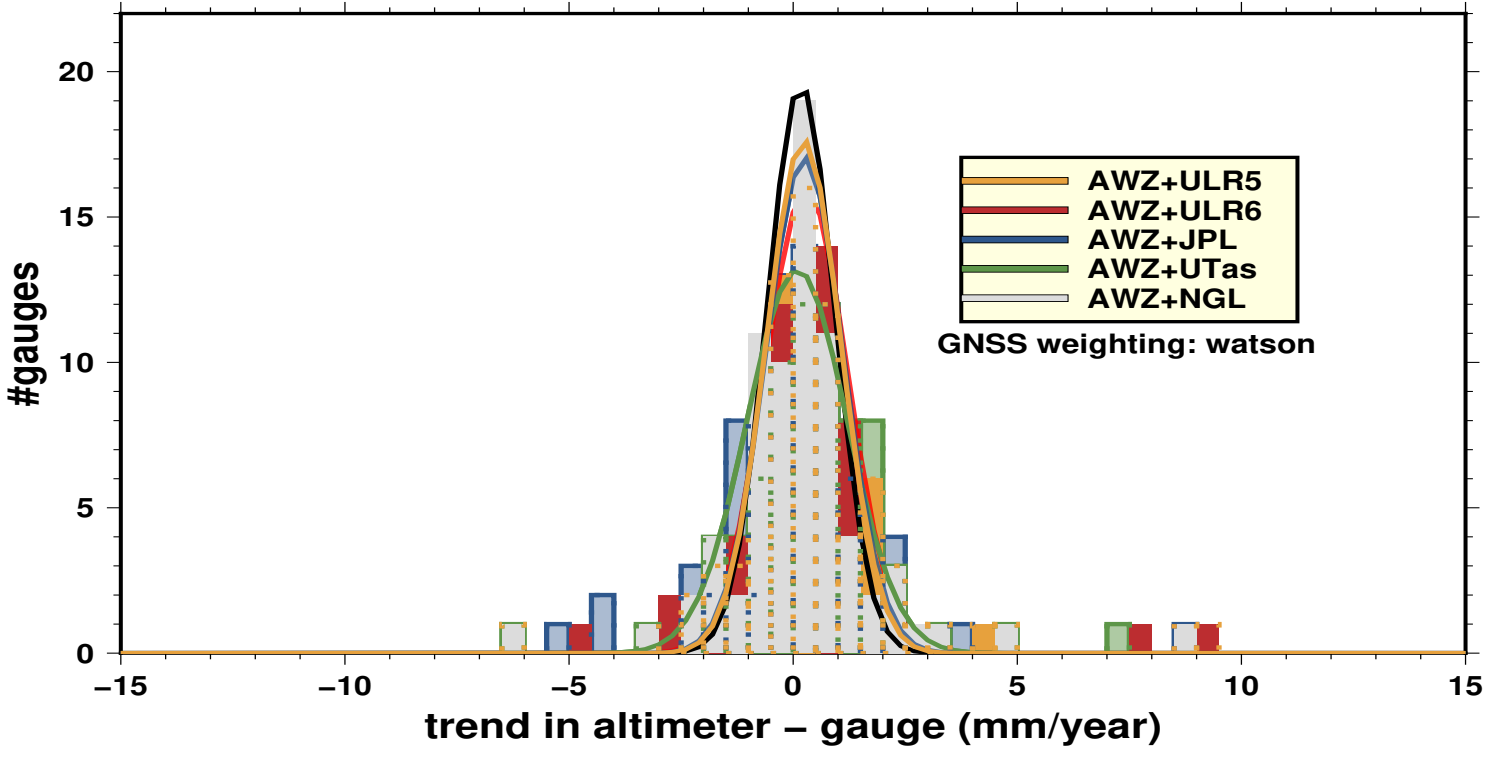
Using only GIA model estimates of VLM produce TOPEX/Jason–TG the distribution of the residuals have scales of 0.84 and 0.82 mm/year

Similar results for AWZ and Peltier.



Distribution of alt-TG residuals (GNSS+GIA)

Equivalent MAD scales found for each of the 30 GNSS+GIA VLM models/selections



Median absolute deviation scales (mm/year)

	GPS lowest error	Closest GPS	Watson weighting
AWZ+ULR5	0.90	0.84	0.84
AWZ+ULR6	0.93	1.00	0.93
AWZ+UTas	1.12	1.25	1.12
AWZ+JPL	0.97	0.90	0.87
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.

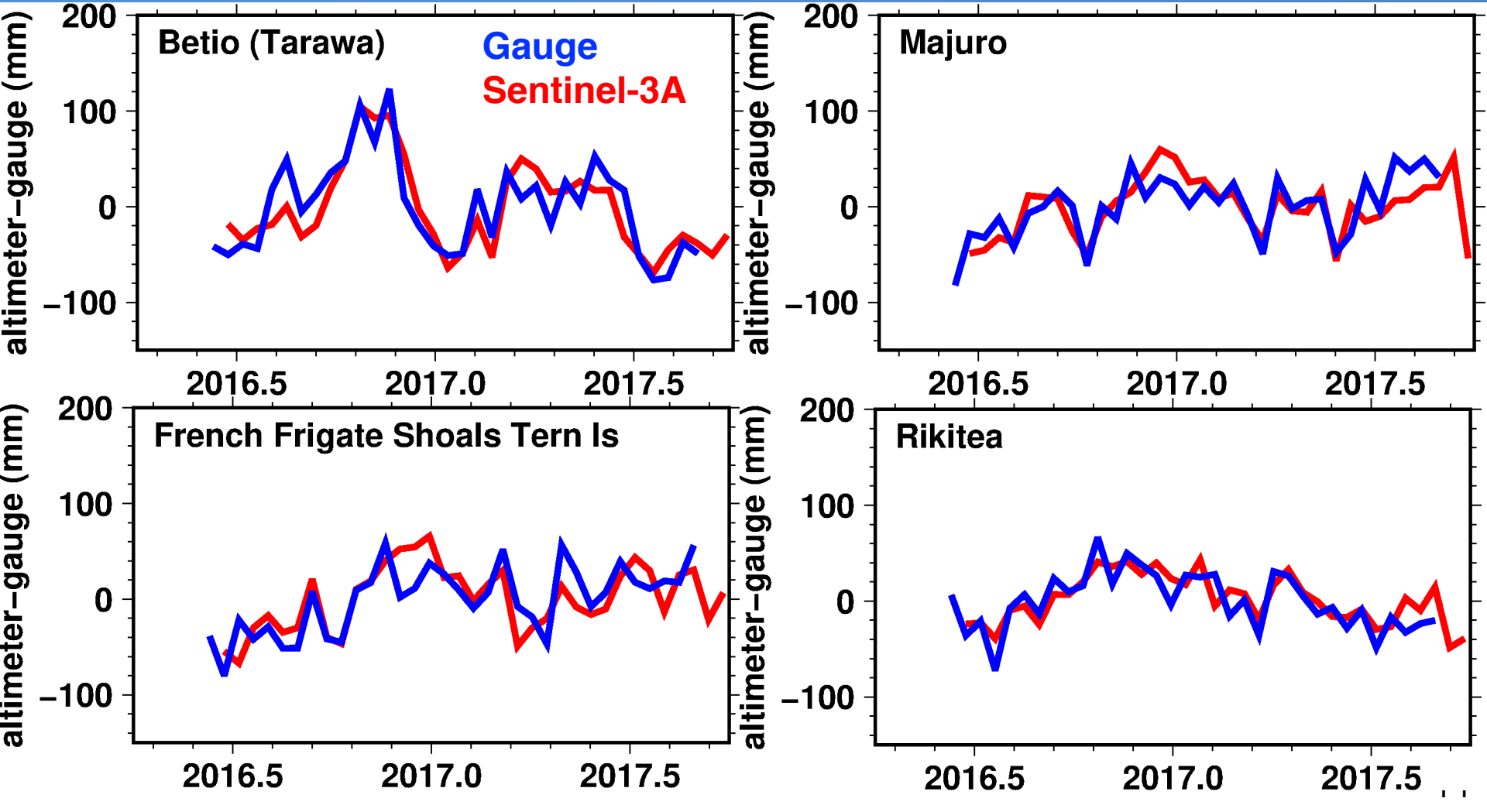
Sentinel-3A methodology

Modifications to the methodology for Sentinel-3A

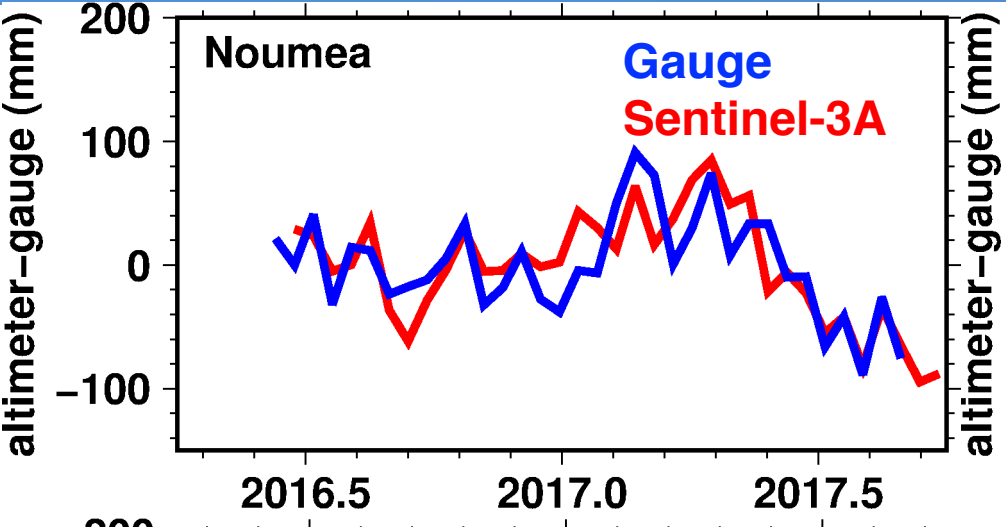
- Time step: half cycle (13.5 days)
- Tidal alias removal
  - Gauge data are daily averages and GOT4.10 removed from S3A
  - Remove variability at tidal aliases from altimeter–gauge residuals, if time series > 2x alias period and periods are separable
  - Because several S3A aliases are much longer than TOPEX/Jason, these aliases aren't yet removed

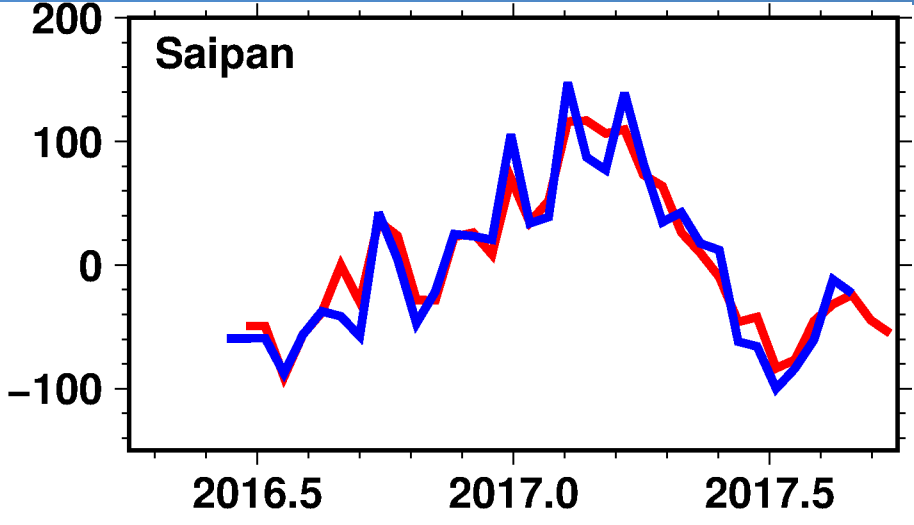
Tidal component	S3A alias period (days)
Sa/K1/P1	365.2
Ssa	182.6
M2/Msf	2171.0
O1	157.5
N2	277.0
Q1	2268.0
Mf	141.0
Mm	1147.0

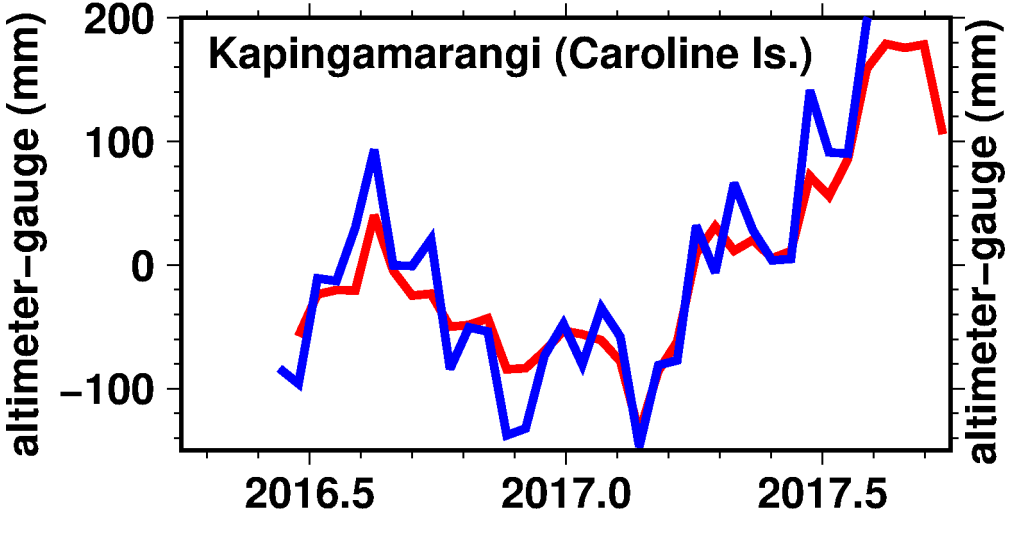
Tide gauge results (Sentinel-3A)

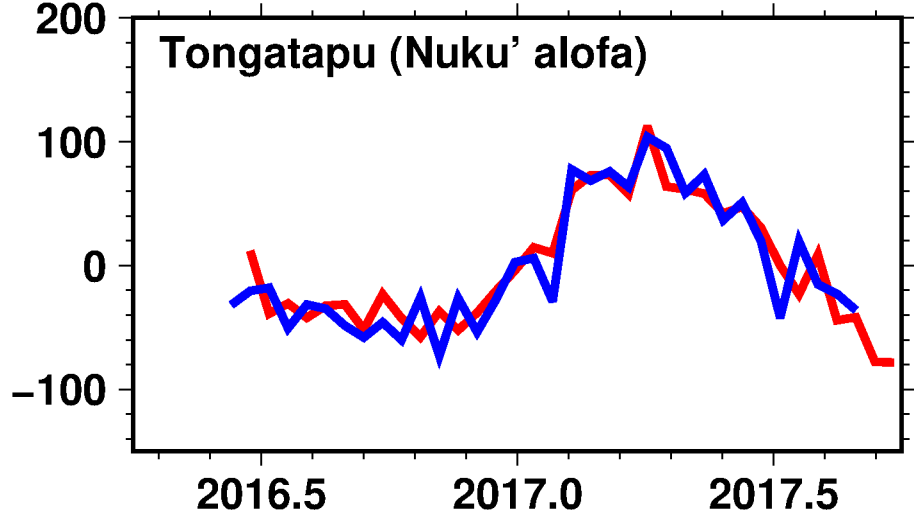


Tide gauge results

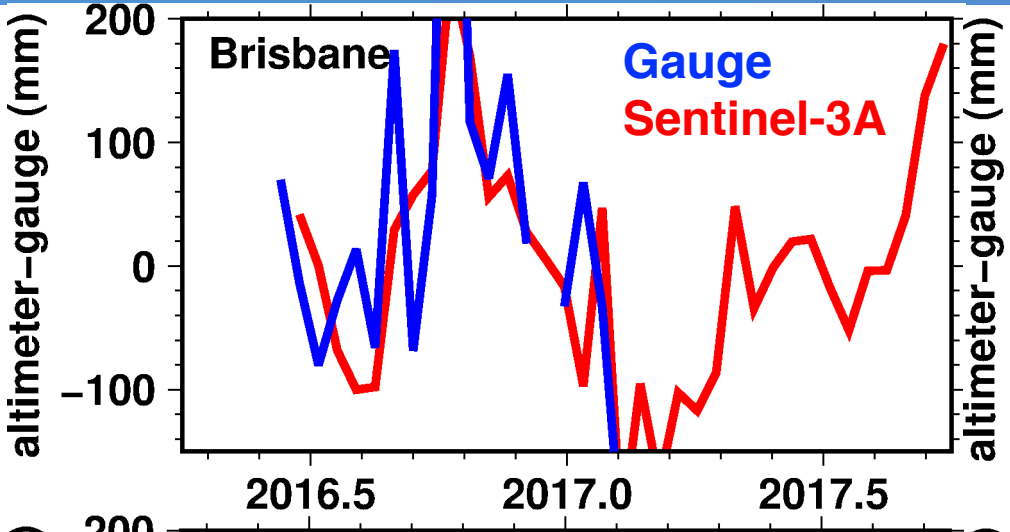


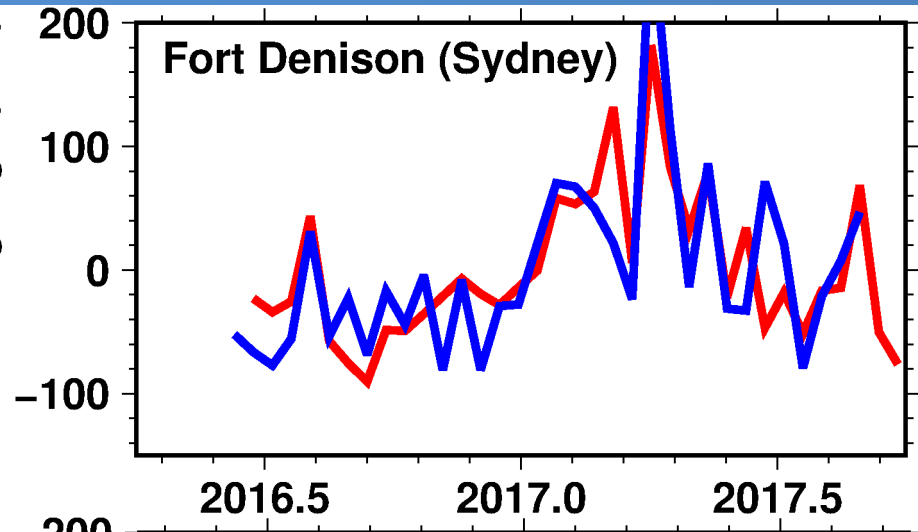


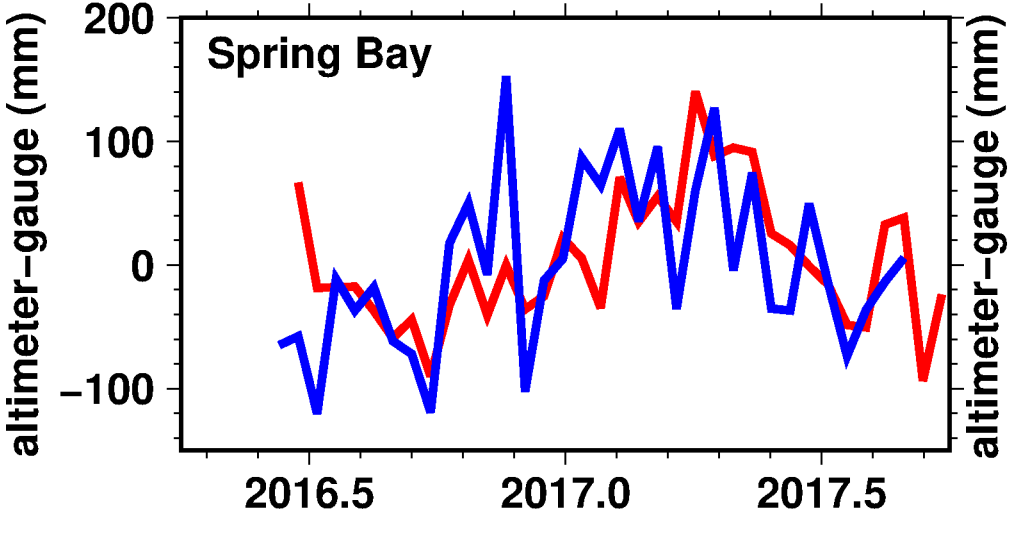


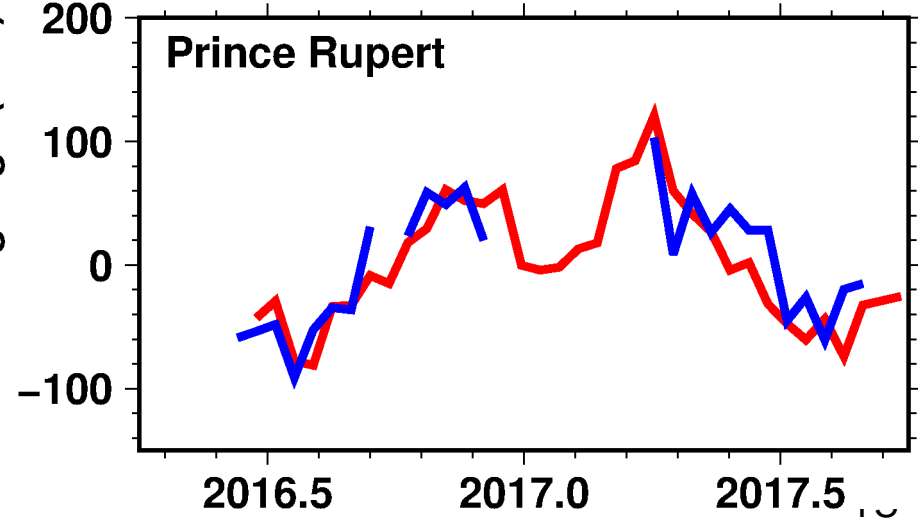


Tide gauge results



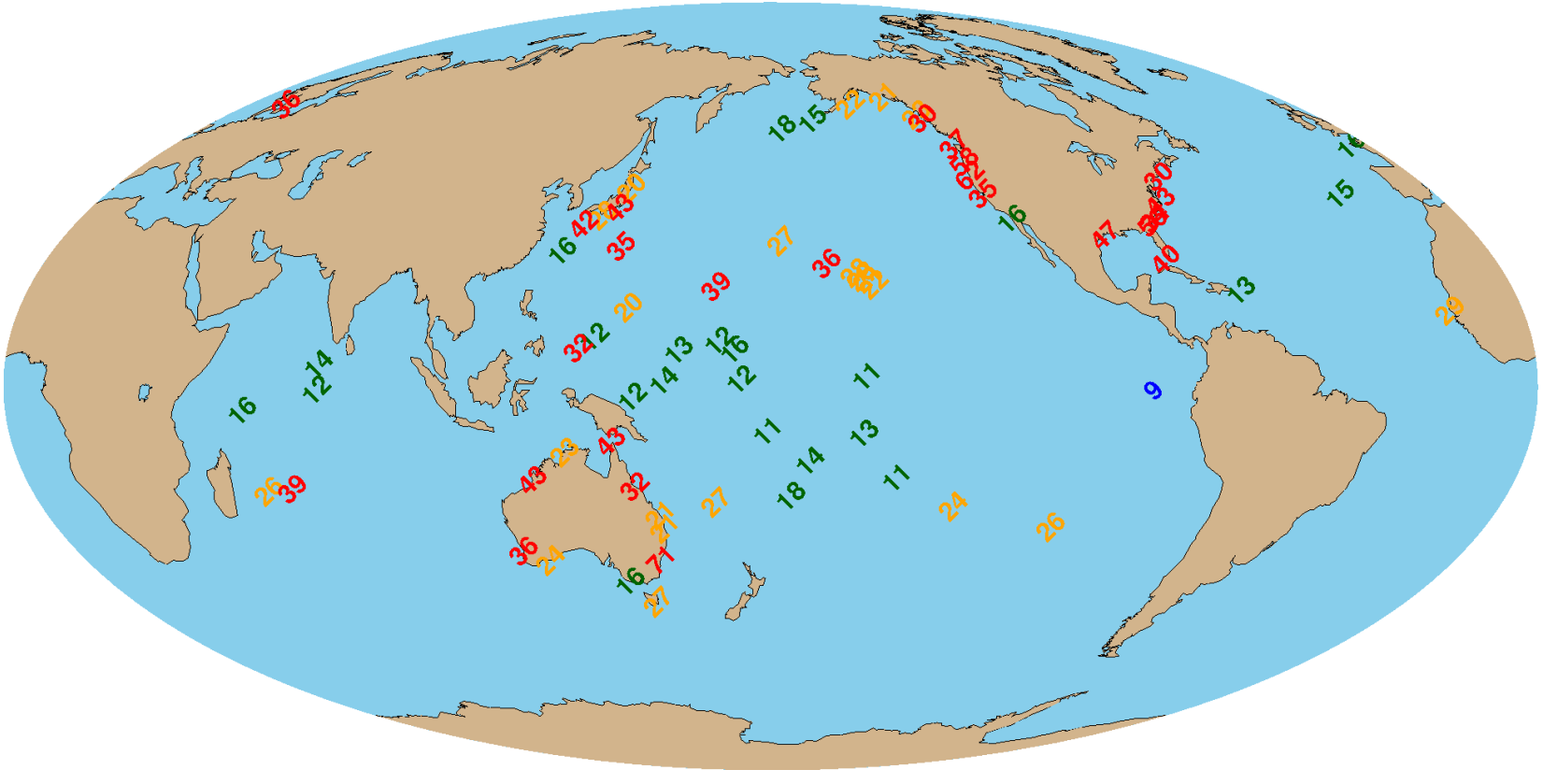






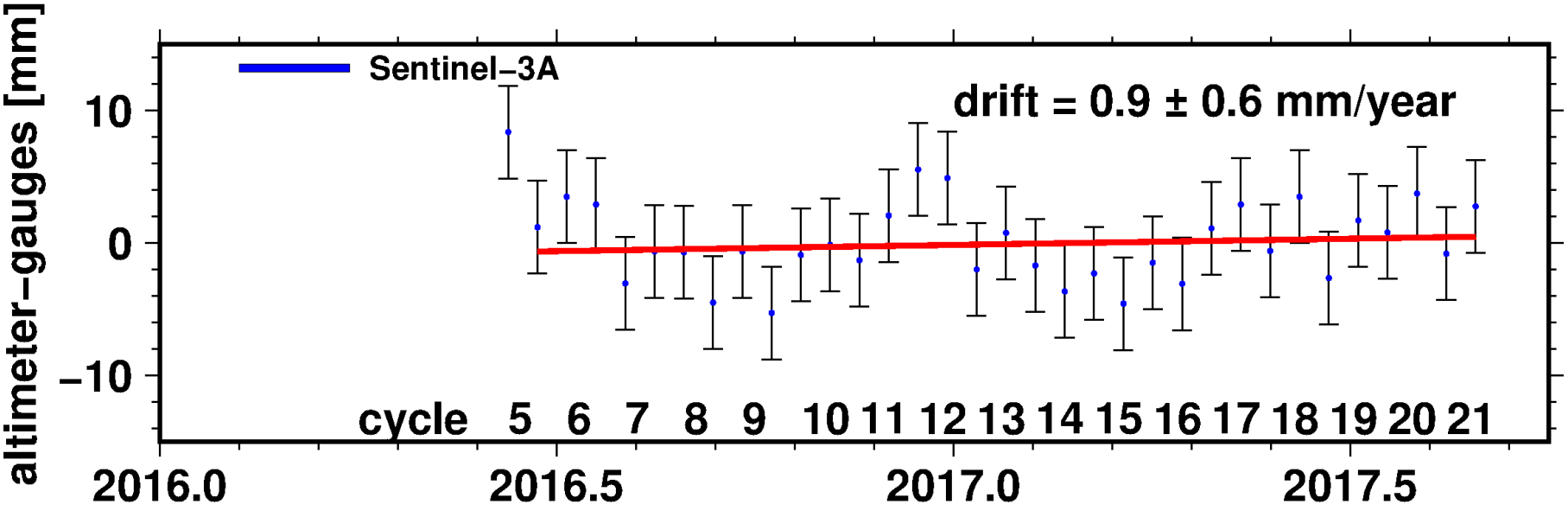
St dev of S3A-gauge residuals (mm)

The lowest variances of S3A-gauge residuals are (blue and green) are at tropical island gauges (blue and green) and highest at coasts (red).



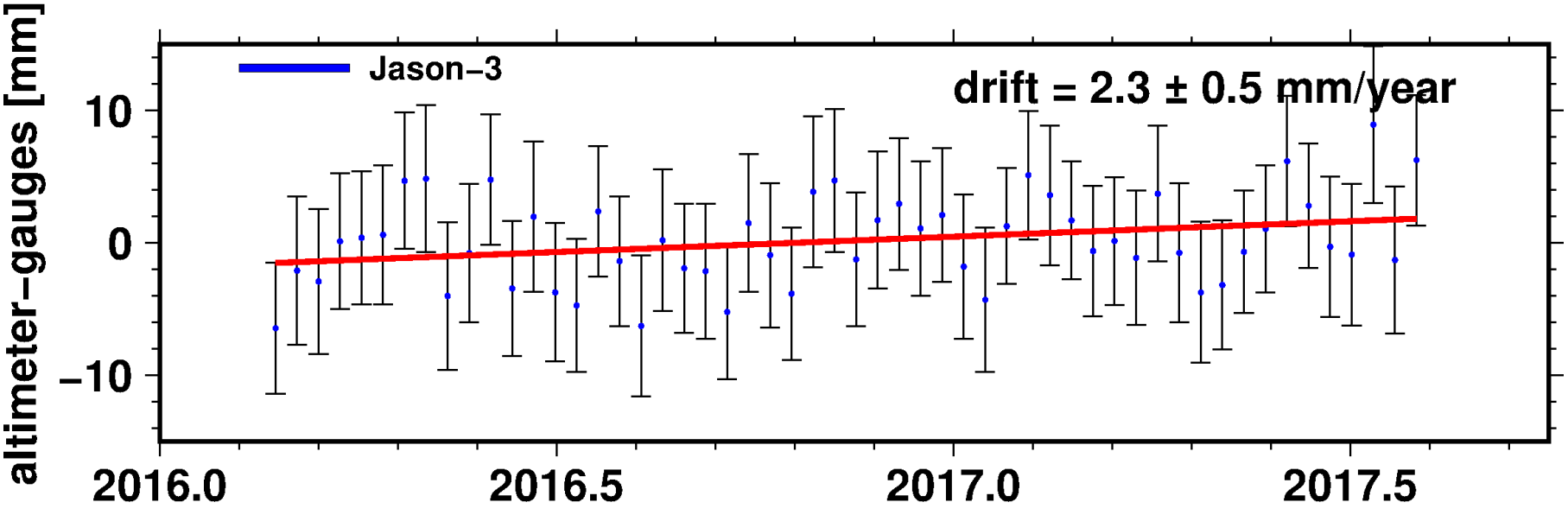
Estimated S3A – gauges drift time series

The residuals in 14 months of Sentinel-3A/tide gauge differences (N=32) have an r.m.s. of 3.1 mm.



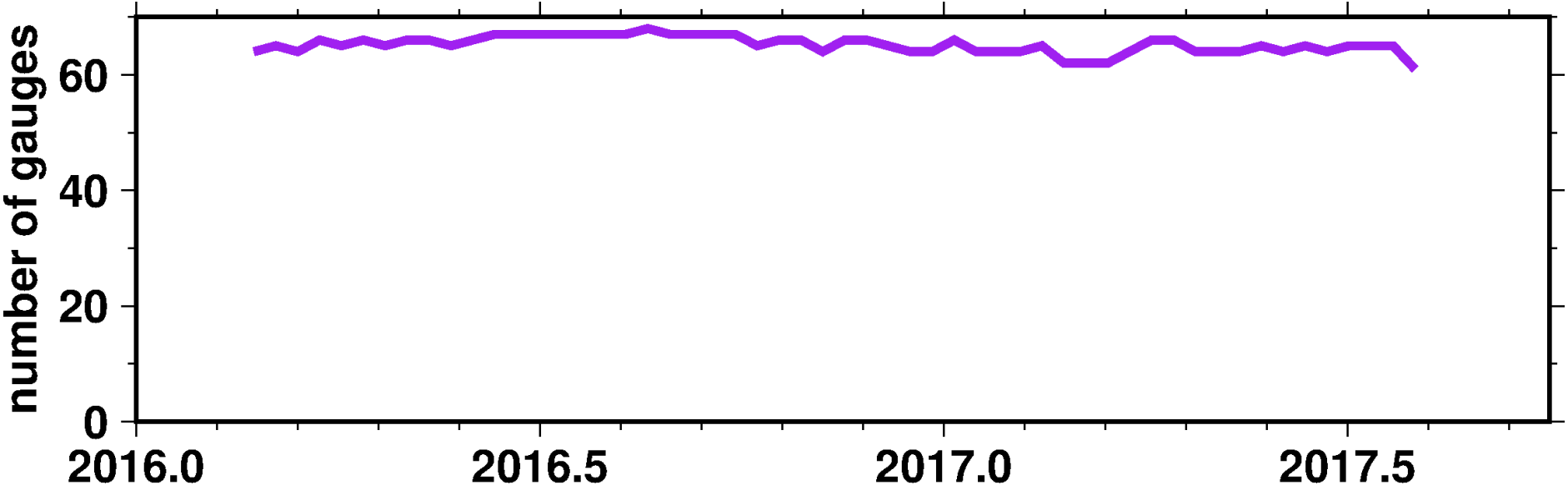
Half-cycle time steps (13.5 days)

Estimated Jason-3 – gauges drift time series



Gauge availability

The number of gauges available usually increases over time as UHSLC research-quality data replaces fast-delivery.



Implication for monitoring stability

$$\text{Mean annual bias error} = \frac{\sigma_{residuals}}{\sqrt{N_{eff}}}$$

Altimeter	St. dev. of residuals (mm)	Autocorr (95% CI)
TOPEX-A	4.65	0.38 (0.13)
TOPEX-B	4.65	0.29 (0.19)
Jason-1	3.92	0.23 (0.13)
Jason-2	3.67	0.29 (0.12)
Jason-3	3.42	0.08 (0.27)
S3A*	3.13	0.24 (0.34)

*(13.5 days)

The standard deviations and the autocorrelations of the residuals imply that the tide gauge network can monitor annual changes in the bias to ±0.8 mm for Jason-2 and ±0.5 mm for Jason-3 (standard error).

However, this assumes that there are no systematic errors, like gauge availability.

Conclusions

- Tide gauge comparisons with Jason-3 and Sentinel-3A suggest that annual bias changes in JCS/S6 global mean sea level can be monitored < 1 mm.
- The impact of systematic errors, like gauge availability and vertical land motion need further study.
- The drift in 15-months of Sentinel-3A (0.9 mm/year) isn't significant (95%), but the Jason-3 drift, 2.3 ± 1.1 mm/year (95%) may be.

Backup slides

TOPEX/Jason residuals