Examining the role of land motion in estimating altimeter system drifts

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Outline

- Question: how does the tide gauge comparison depend on the vertical land motion estimates?
- Definitions and previous work: internal vs. external estimates, bias error, scale errors, reference frame errors
- Methods: what’s included, what’s different?
- Results: drifts and statistics
- Discussion/conclusions

Motivation and previous work

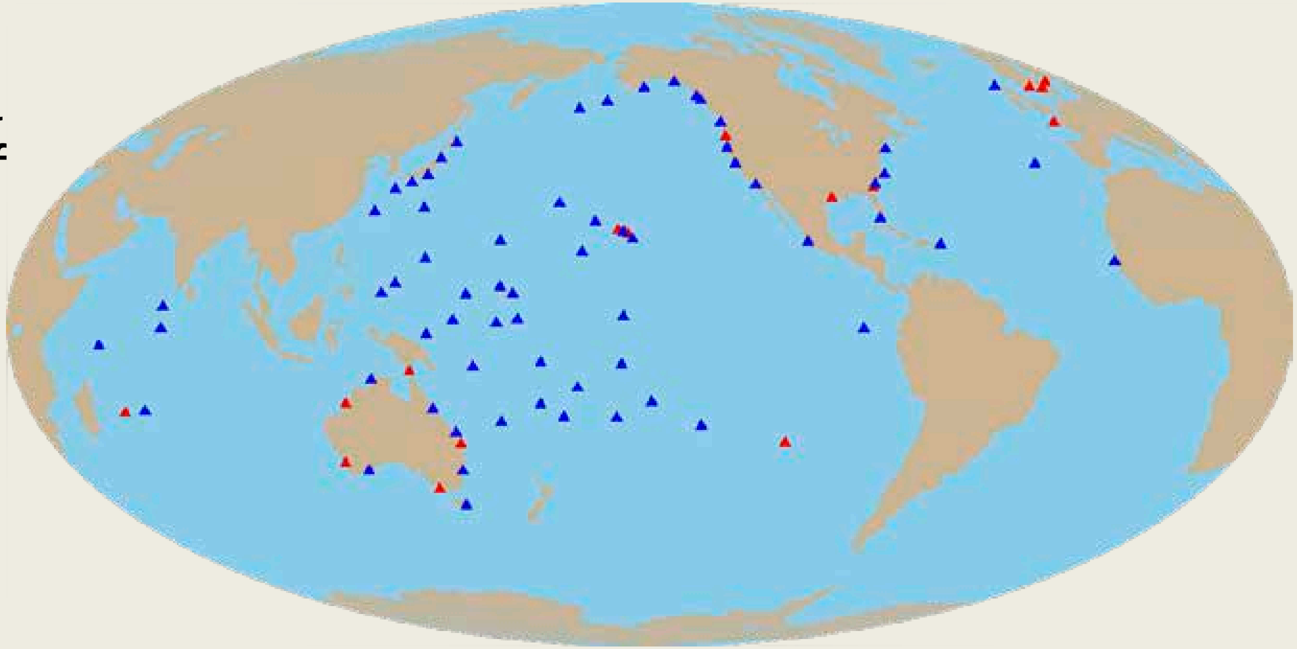
- Previous studies have used tide gauges to determine altimeter bias drift, e.g. Watson et al., 2015, King et al. 2012, Mitchum 2008
  - each incorporated some estimate of vertical land motion (VLM) at the tide gauges
  - VLM rates commonly vary at a given gauge by 1-3 mm/year and can differ as much as 5-10/year mm
  - At some gauges, estimates vary not only in scale but also in direction, with some solutions showing positive land motion and some showing negative
- As Jason-3 and Sentinel-3 extend the record, it becomes ever more important to understand the impact of these differences

Estimates of VLM error

- See Mitchum and Doran talk from 2009 OSTST meeting
- Internal vs external
  - "internal" from the difference between local gauge-based relative sea level and global sea level
  - "external" from GPS/DORIS/etc
- Mitchum estimates land motion error = +0.4 mm/yr
  - Mainly due to using a majority of gauges with internal estimates
- Issues
  - internal: bias due to reliance on global SLR
  - external: scale error and reference frame error
  - these errors cannot be minimized by adding more gauges

Altimetry and Tide Gauge Data

- Altimetry data via current version of RADS
  - TOPEX/Jason-1/Jason-2 (TJM)
  - Envisat
  - Merged Envisat/Altika



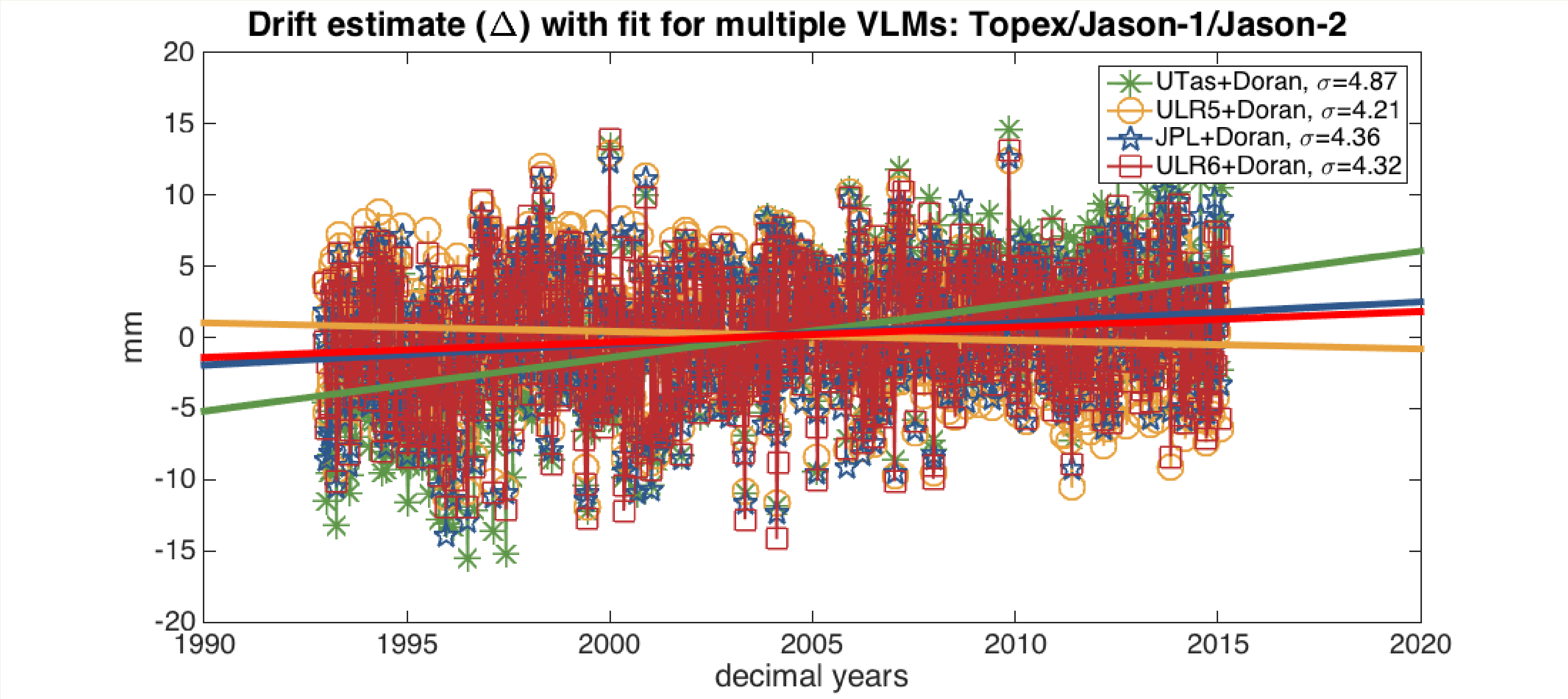
- Tide gauge (TG) data from SOEST
  - 64 gauges used by Mitchum (blue)
  - 19 additional gauges chosen from those used in Watson et al 2015 after controlling for data availability (red)

VLM solutions

- Internal estimates are used when no GPS VLM rates are available (Doran 2010)
- ULR5: solution by Université de La Rochelle, Santamaría-Gómez 2012
- JPL: GPS time series available publicly (see http://sideshow.jpl.nasa.gov/post/series.html)
- UTas: solution used in King et al. 2012 (University of Tasmania), updated 2015
- ULR6: solution by Université de La Rochelle, pre-release (see Santamaría-Gómez OSTST2015)

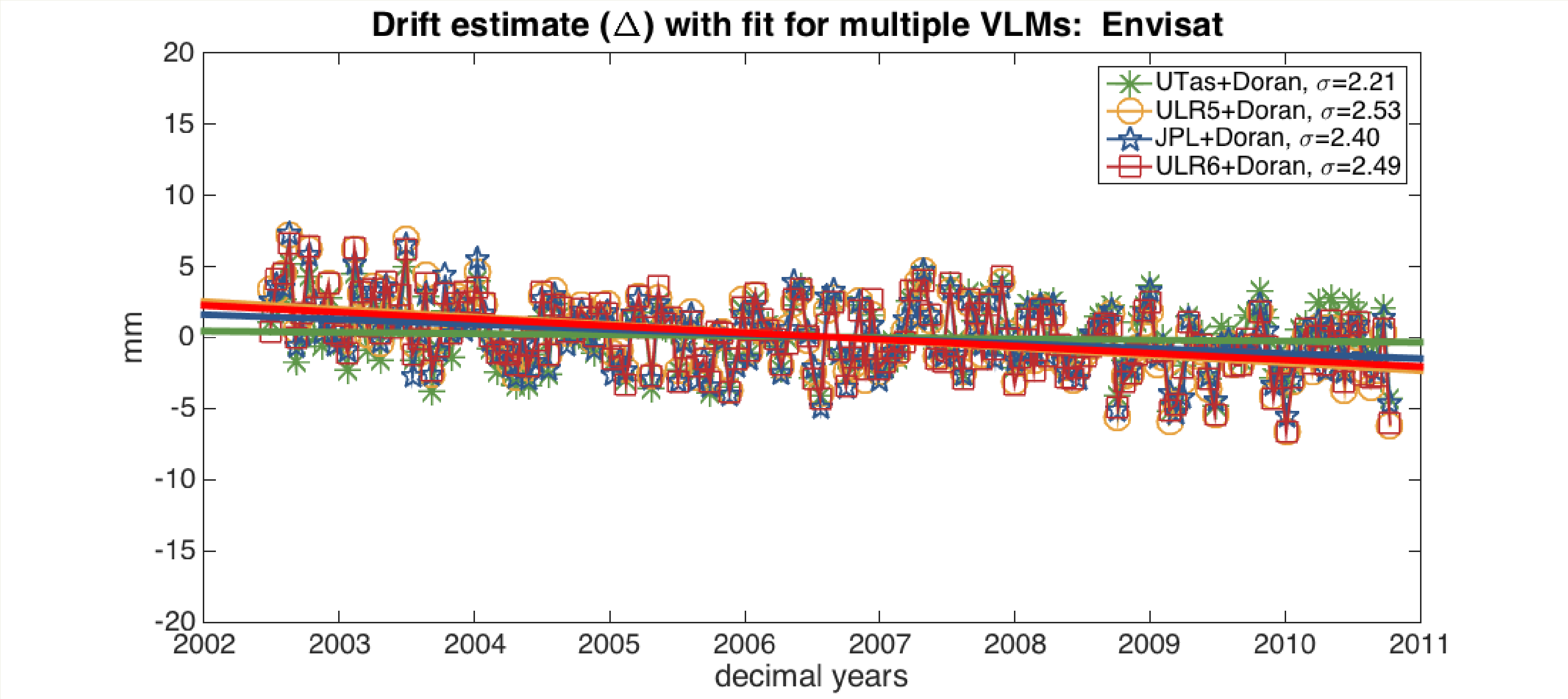
Per TG breakdown	Internal	GPS	Missing
ULR5+Doran	47	29	6
ULR6+Doran	31	46	5
JPL+Doran	25	52	5
UTas+Doran	29	48	5

Results: TOPEX/Jason1-2



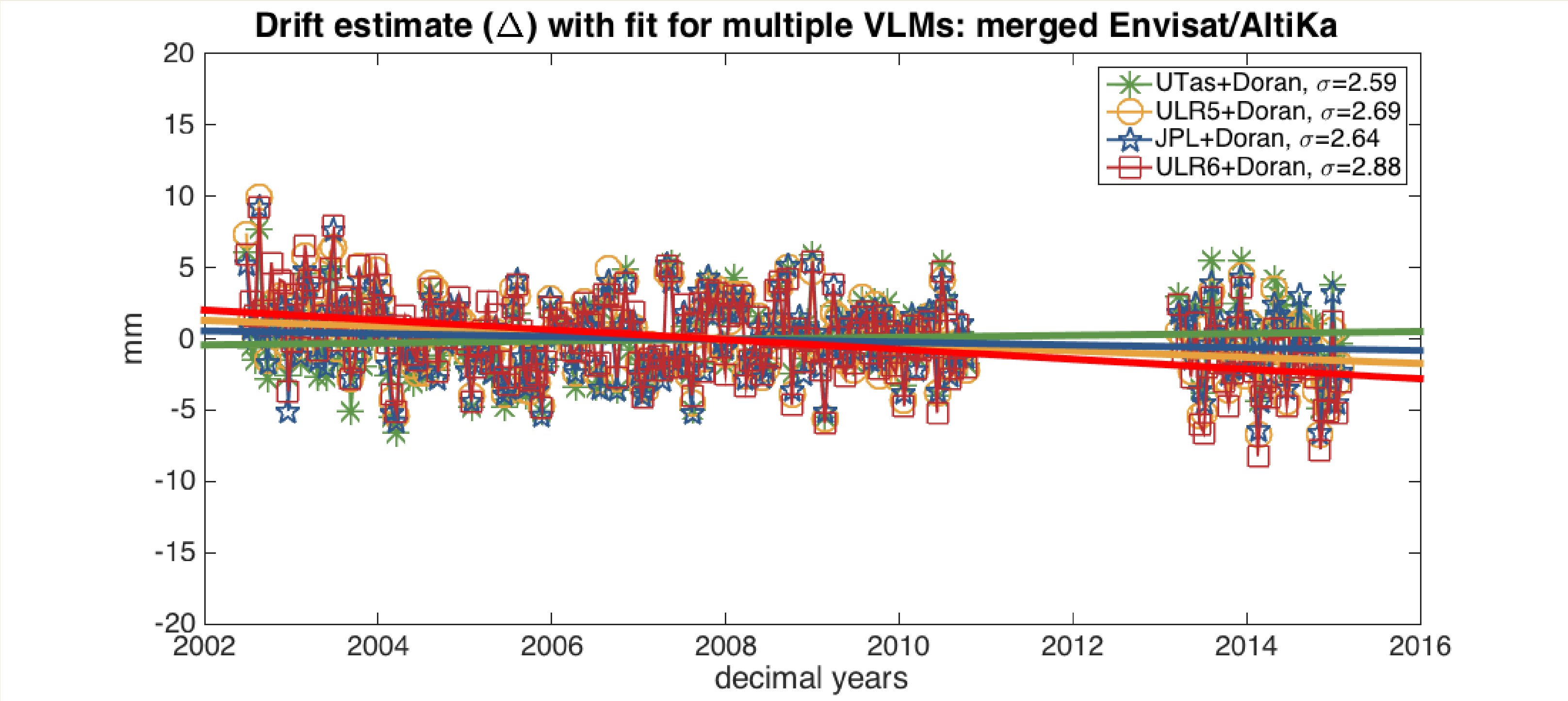
- Drifts range from 0.37 mm/yr (UTas) to –0.06 mm/yr (ULR5)
  - Max difference of 0.43 mm/yr
  - Closest agreement between JPL and ULR6 estimates.

Results: Envisat



- Drifts range from -0.09 mm/yr (UTas) to -0.54 mm/yr (ULR5)
  - Max difference of 0.45 mm/yr
  - Closest agreement between JPL and ULR6 estimates.
  - Less spread than with TJM

Results: Merged Envisat/AltiKa



- Drifts range from 0.07 mm/yr (UTas) to -0.34 mm/yr (ULR6)
  - Max difference of 0.41 mm/yr
  - Closest agreement between JPL and ULR5 estimates.

Results: Summary

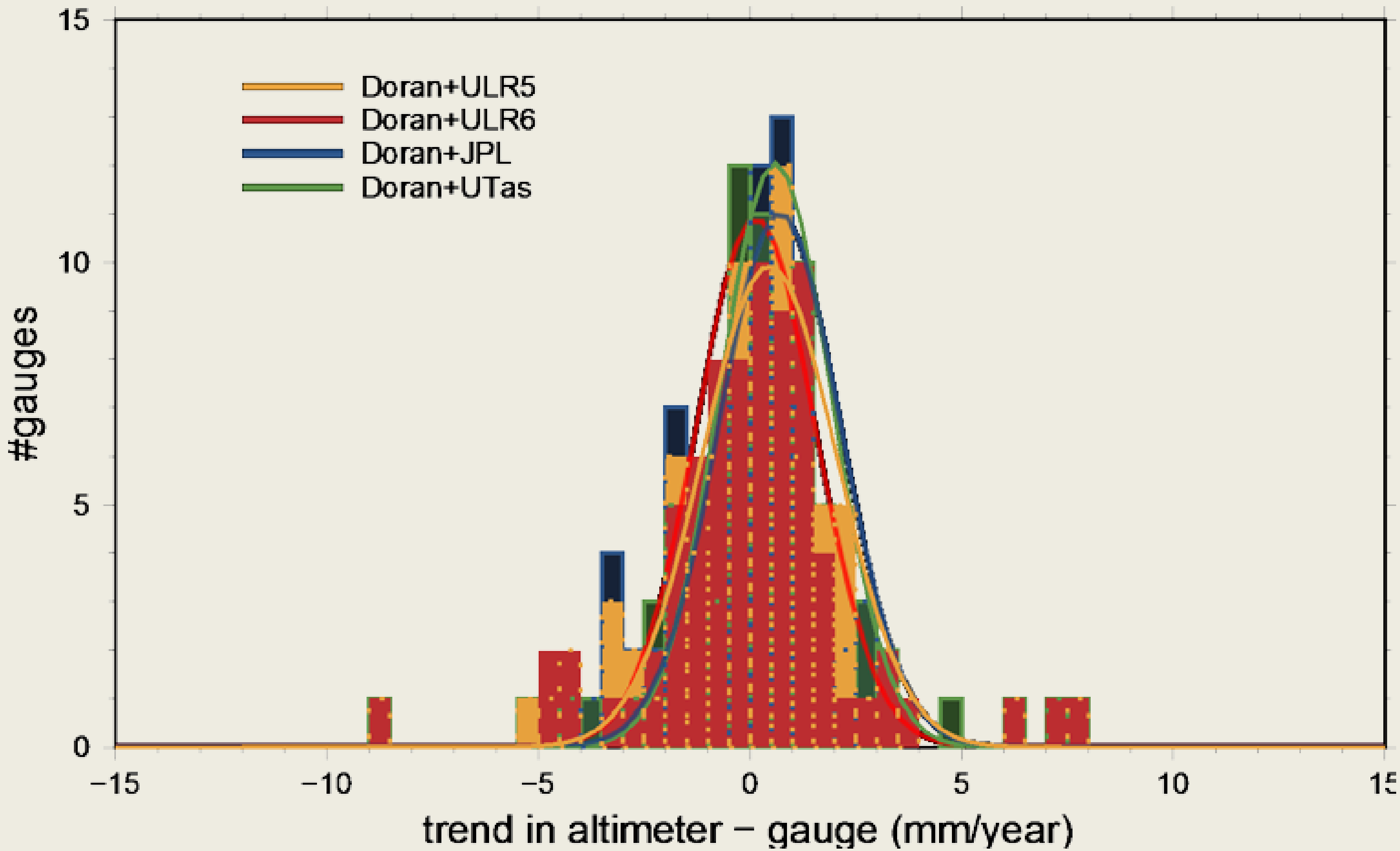
DRIFT FIT (mm/year)	TJM	Envisat	Envisat/AltiKa
ULR5+Doran	-0.06	-0.54	-0.22
ULR6+Doran	0.11	-0.48	-0.34
JPL+Doran	0.15	-0.34	-0.10
UTas+Doran	0.37	-0.09	0.07

St. dev. (mm)	TJM	Envisat	Envisat/AltiKa
ULR5+Doran	4.21	2.53	2.69
ULR6+Doran	4.32	2.49	2.88
JPL+Doran	4.36	2.40	2.64
UTas+Doran	4.87	2.21	2.59

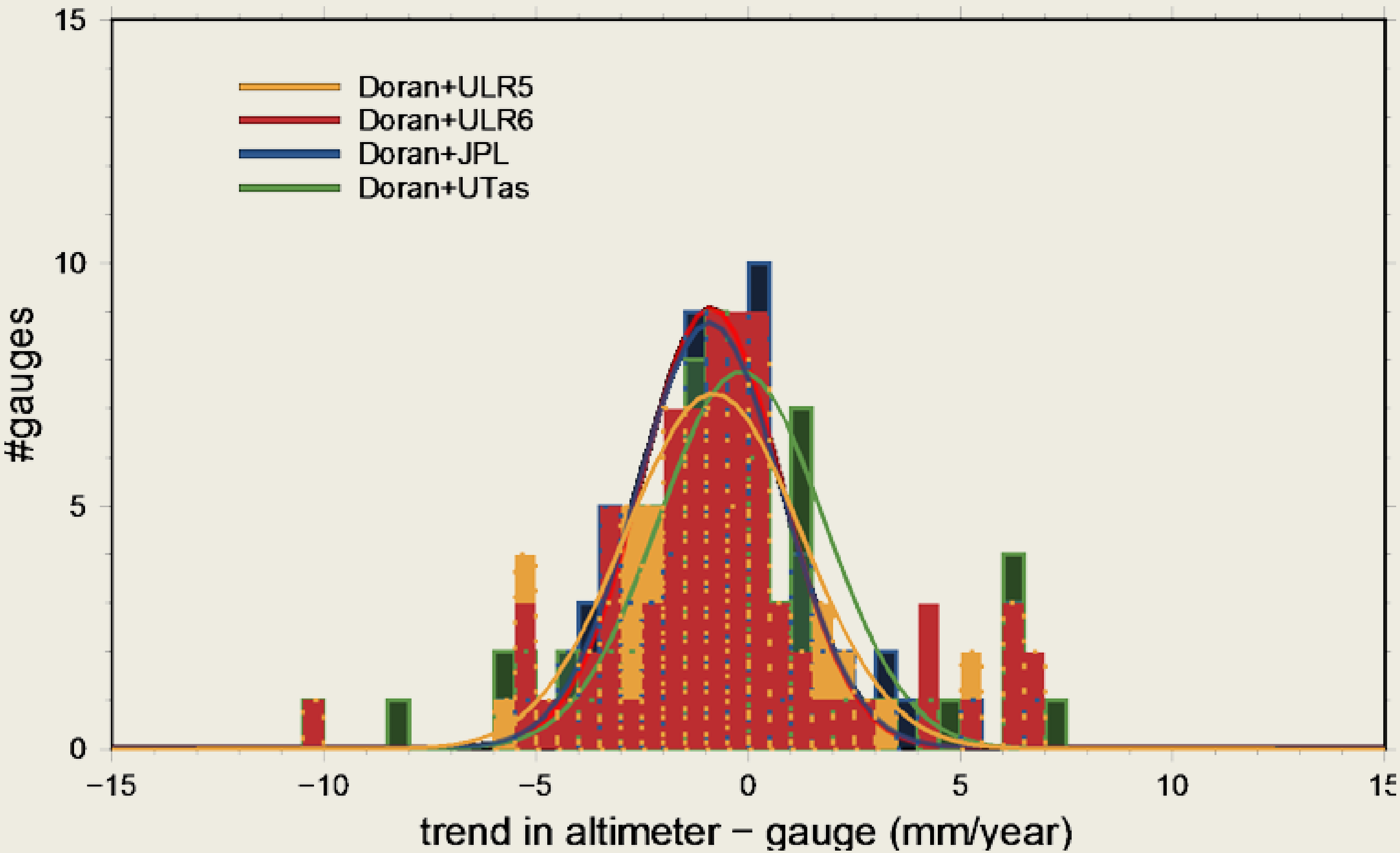
Statistics of altimetry-tide gauge residuals

- 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:
  - Find mode and scale parameter sigma from the least absolute deviation (Rousseeuw) to avoid outliers
  - Overplot the equivalent normal distribution
  - Theory: the smaller the scale, the better the VLM?

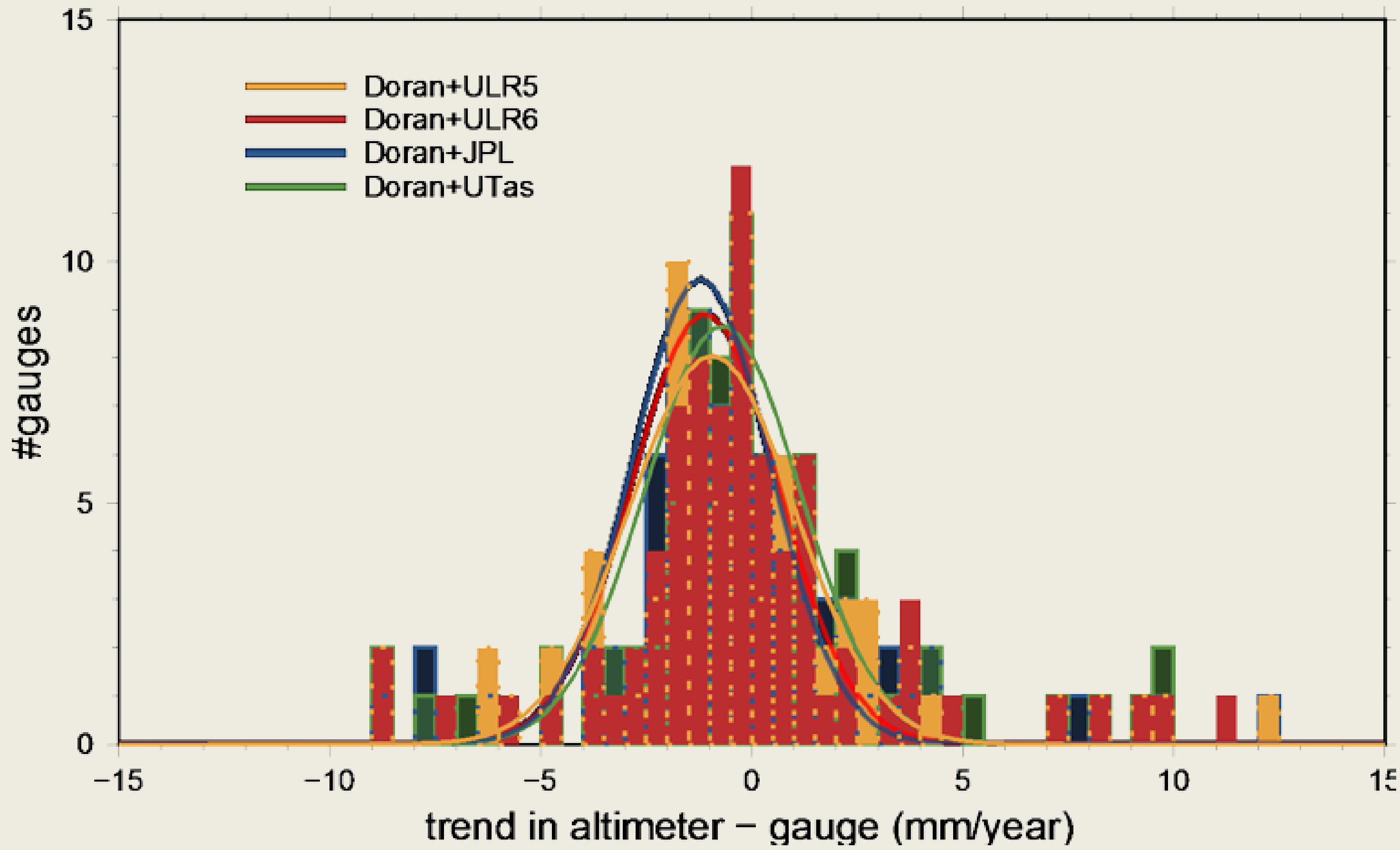
Histogram: Per-TG trends for TOPEX/Jason



Histogram: Per-TG trends for Envisat



Histogram: Per-TG trends for Envisat/AltiKa



Median Absolute Deviation

- TOPEX/Jason has larger peak/smaller scale: why?
- Least absolute deviation scale error for altimetry – gauge residuals (mm/year)
  - (50% of gauges have residuals with a trend < mode ± scale)

	TOPEX/Jason	Enivsat	Envisat/AltiKa
Doran+ULR5	1.59	2.07	1.96
Doran+ULR6	1.41	1.65	1.73
Doran+JPL	1.43	1.71	1.64
Doran+UTas	1.32	1.95	1.84

Discussion and Conclusions

- None of the altimetry time series appear to have significant drifts
- The range of drifts produced from the VLM models is consistent with a land motion error of ±0.4 mm/yr
- Can we conclude which VLM model is better?
  - Generally, using GPS rates at more gauges (and fewer internal estimates) reduces the trends in the altimeter – tide gauge residuals

- Future work:
  - evaluation of algorithms to choose which solution used where multiple GPS stations available (e.g., weighting from Watson et al., 2015)
  - test VLM from GIA rather than internal estimates (again e.g. Watson et al. 2015)