ILRS Stations' range biases revealed by a 15-year analysis of LAGEOS observations 2000-2014

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Outline

- In this presentation we:
- Give a brief account of our efforts to determine laser range ***accuracy*** through bias determinations from LAGEOS orbital analysis
- Look in detail at some of the individual station results
- Consider why this is an issue that matters
- Aim to prompt discussion on causes and solutions

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Motivation

- It is relatively straightforward to assess the ***precision*** of laser range measurements made by the global ILRS stations
  - Single-shot precision of calibration board ranges
  - Single-shot precision of LAGEOS ranging
  - Leads to mm-precision normal point data via $\sqrt{n}$
- Daily/weekly QC also monitors **change** in range bias **relative** to current ITRF coordinates
  - e.g., using ITRF2008

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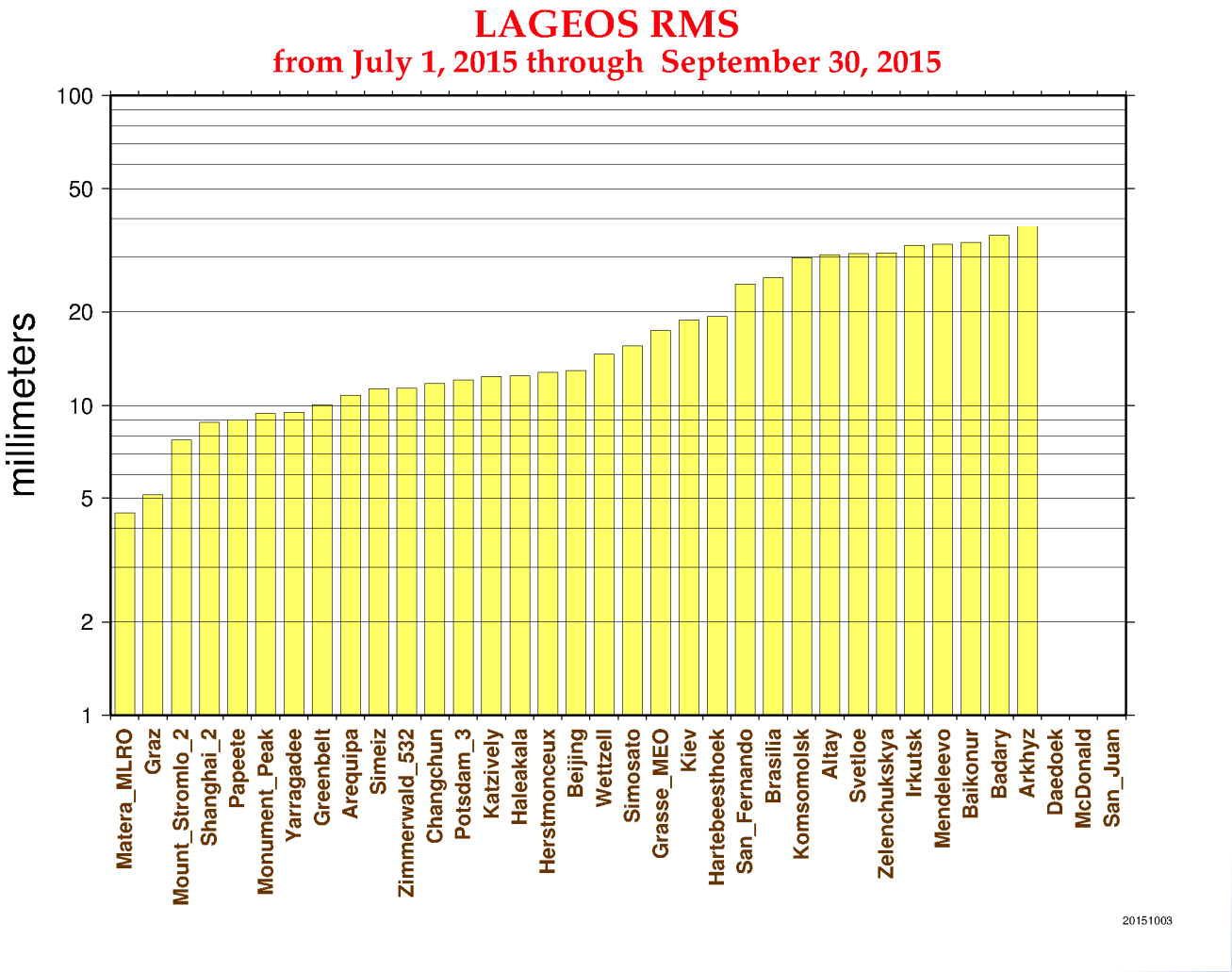
e.g., Single-shot precision on LAGEOS (ILRS)



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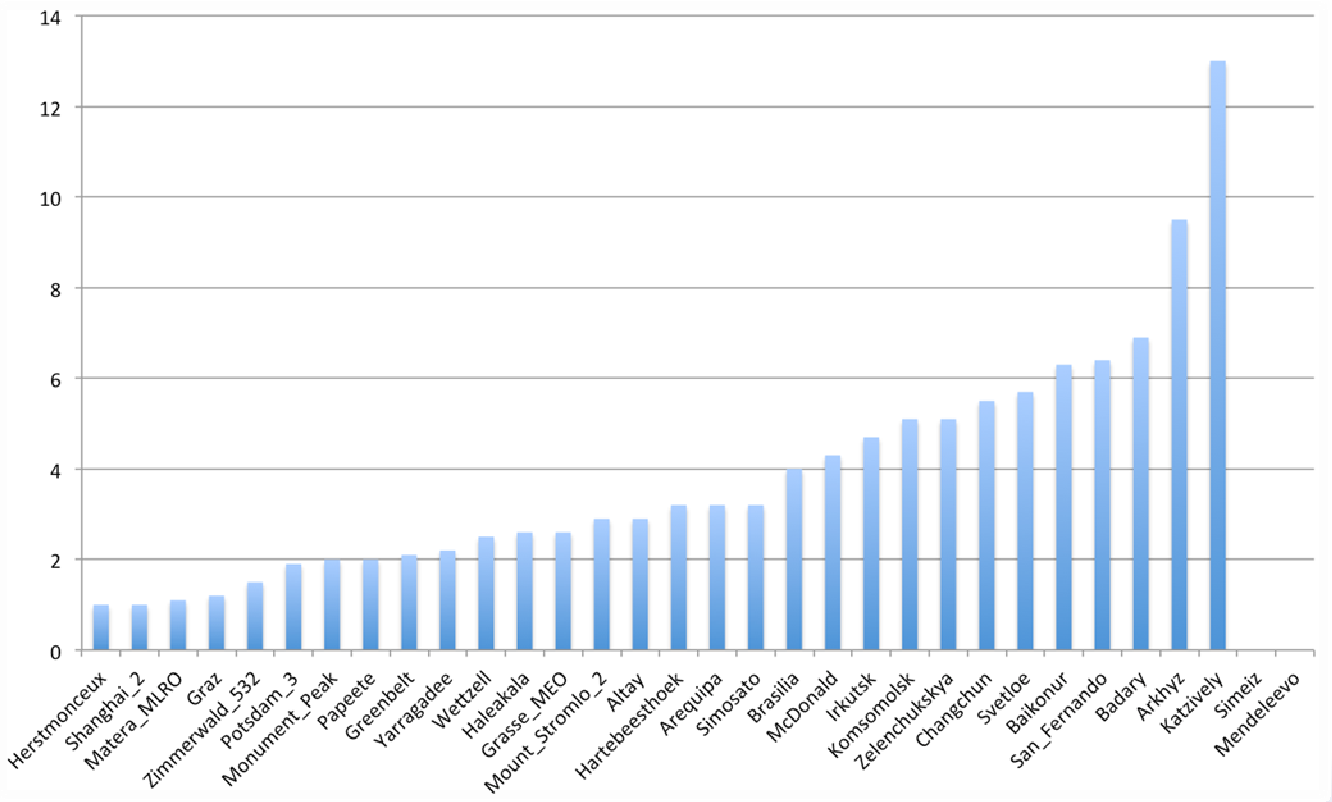
e.g., Long Term geodetic ranging stability (mm) from ILRS AC QC orbital analysis 2014/15



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Towards an accuracy assessment

Following bias issues with station Herstmonceux prior to 2007:

- Effect of non-linearity in time-of-flight counters revealed by introduction of ps-level event timer

We considered the possibility that other prolific stations may have small biases

- Perhaps induced by hardware (counters, signal-strength bias, calibration target distance error, etc.)
- Perhaps induced by post-processing, such as non-perfect CoM correction for LAGEOS, Etalon

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Consequence

Such small bias, if not **explicitly** solved-for:

- Will be absorbed into station coordinates, primarily station height,
- so later attempts to monitor RB will be ***relative*** only to that already absorbed in ITRF

Can we solve for RB for all stations simultaneously with orbits and TRF?

Will the TRF scale be changed?

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Procedure

- Carry out full reference frame solutions using 7-day LAGEOS and LAGEOS-2 arcs
- Solved for station coordinates, orbits, EOPs and L1+L2 ***combined*** range bias for ALL stations (software: SATAN)
- Weekly solutions for 2000-2014
- Applied system-dependent CoM (e.g., ~250mm for MCP, 245mm for single photon SPAD)

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Results

The following plots:

- Show ***mean RB*** averaged over one year intervals for 2000-2014
- Shown (in mm) ***without applying any*** a-priori data corrections

Note this exercise is to inform and learn what needs to be done to the whole technique to achieve the 1mm accuracy goal

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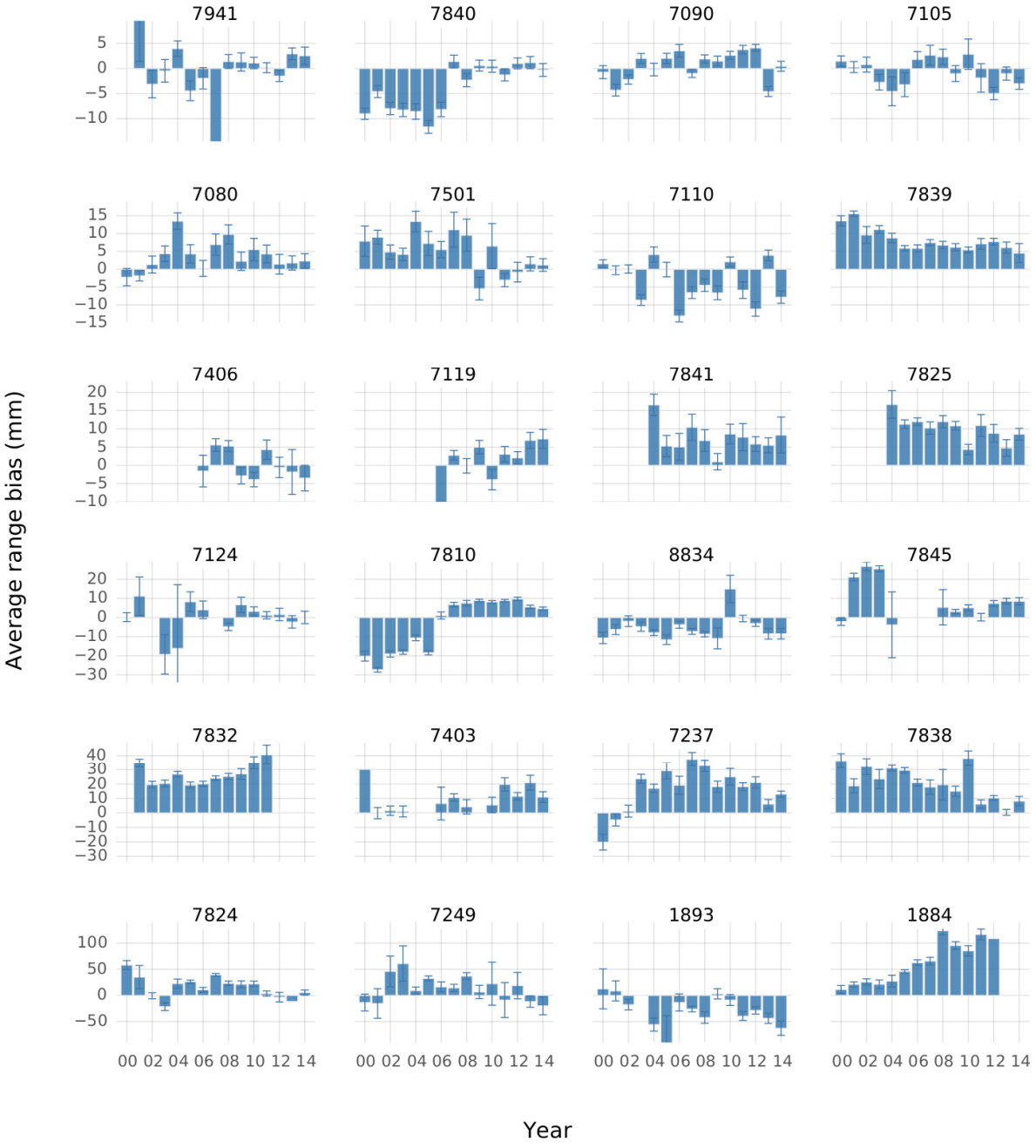

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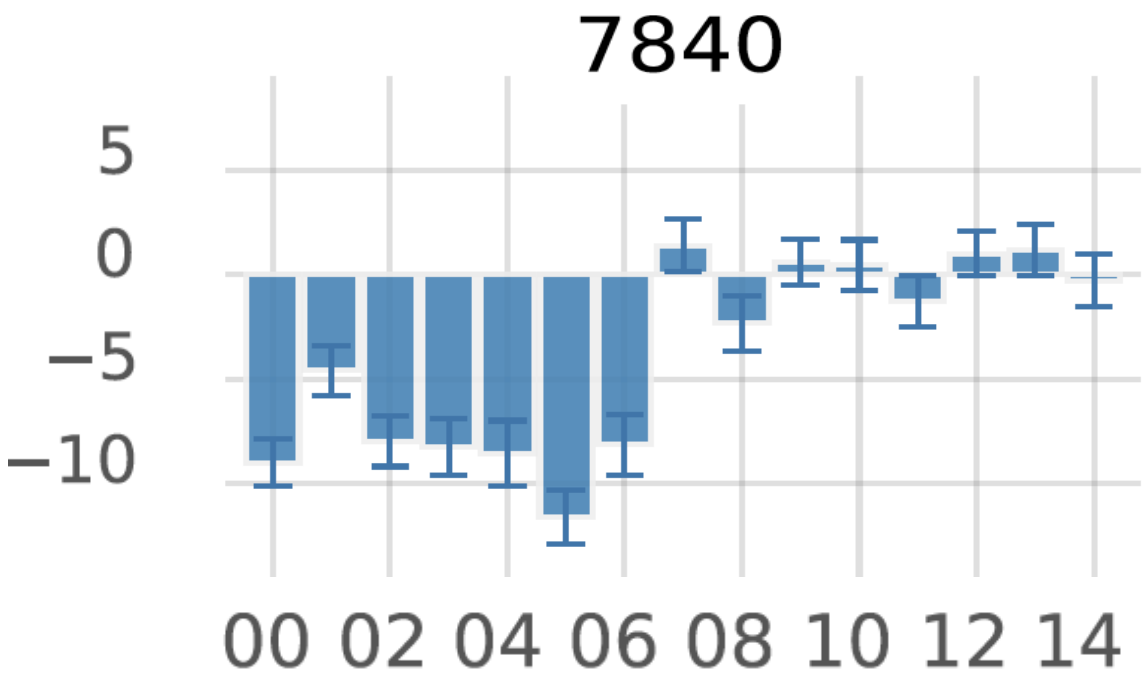
HERL



Stanford counter -> Event timer 2007

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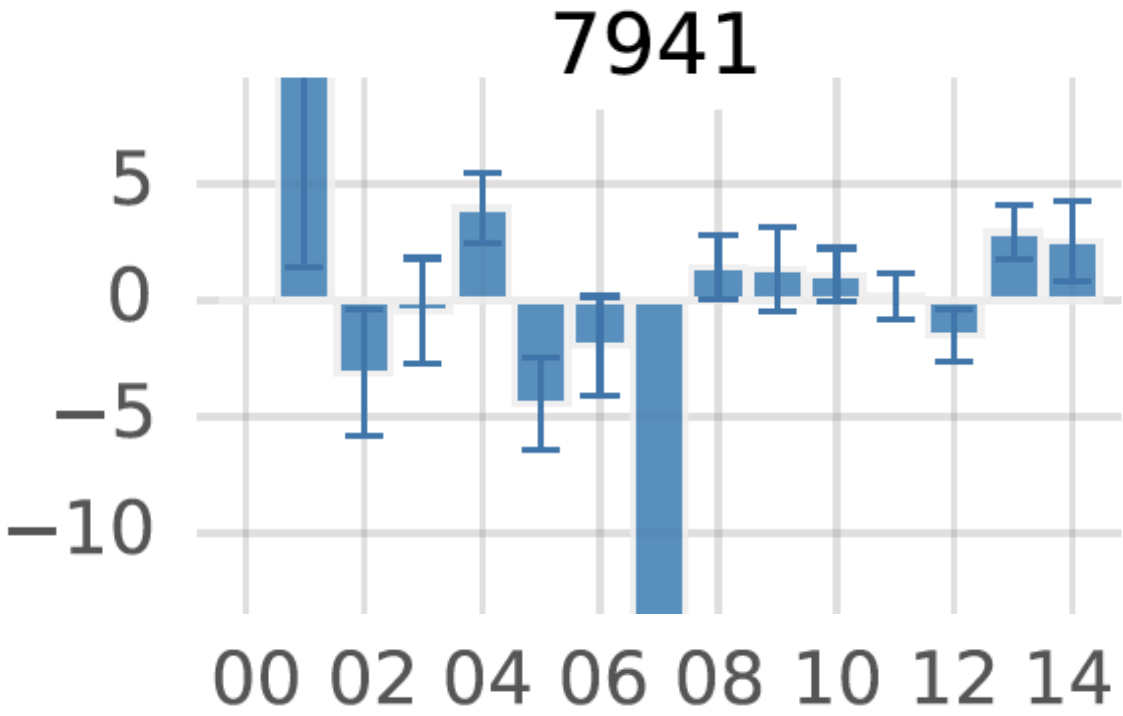
MATM



Known hardware problem in 2007

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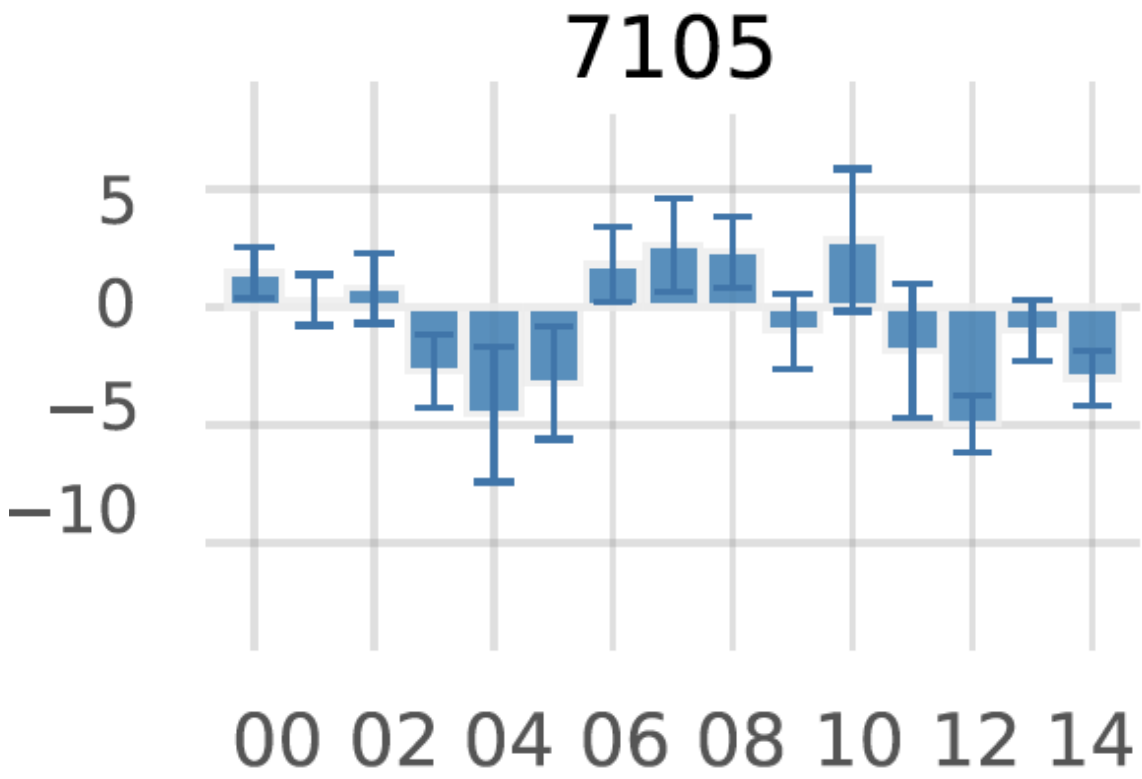
GODL



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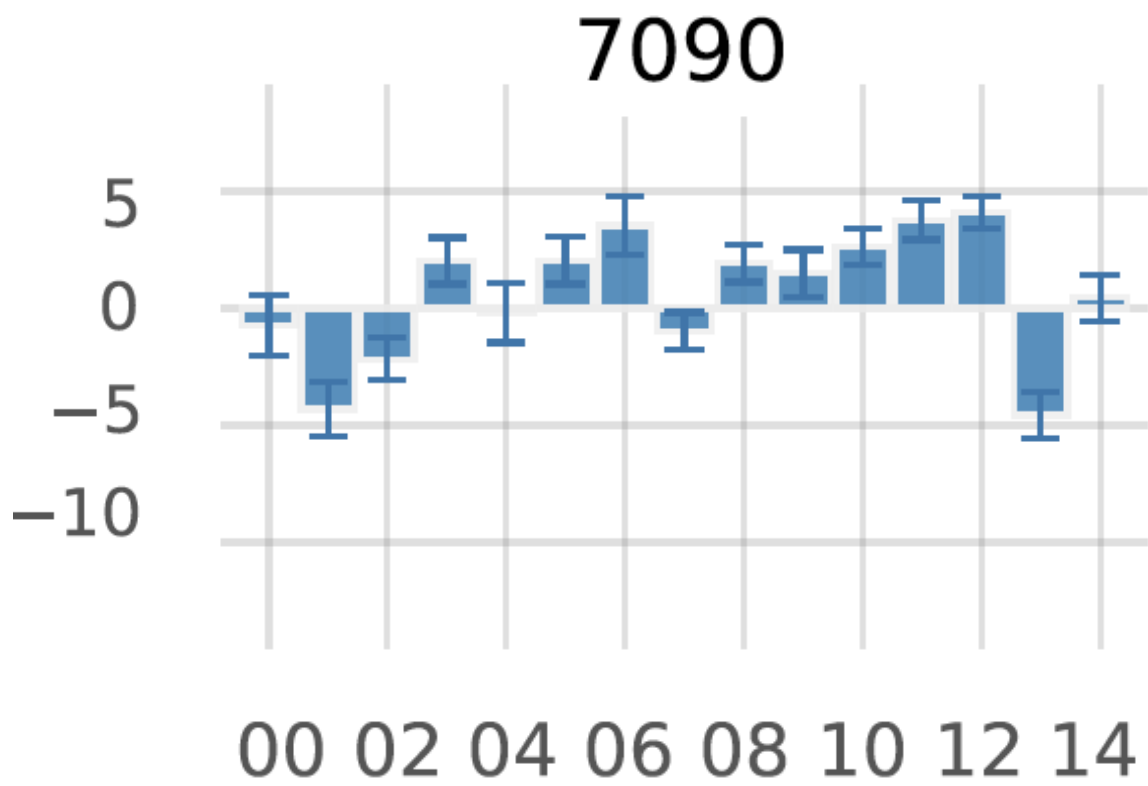
YARL



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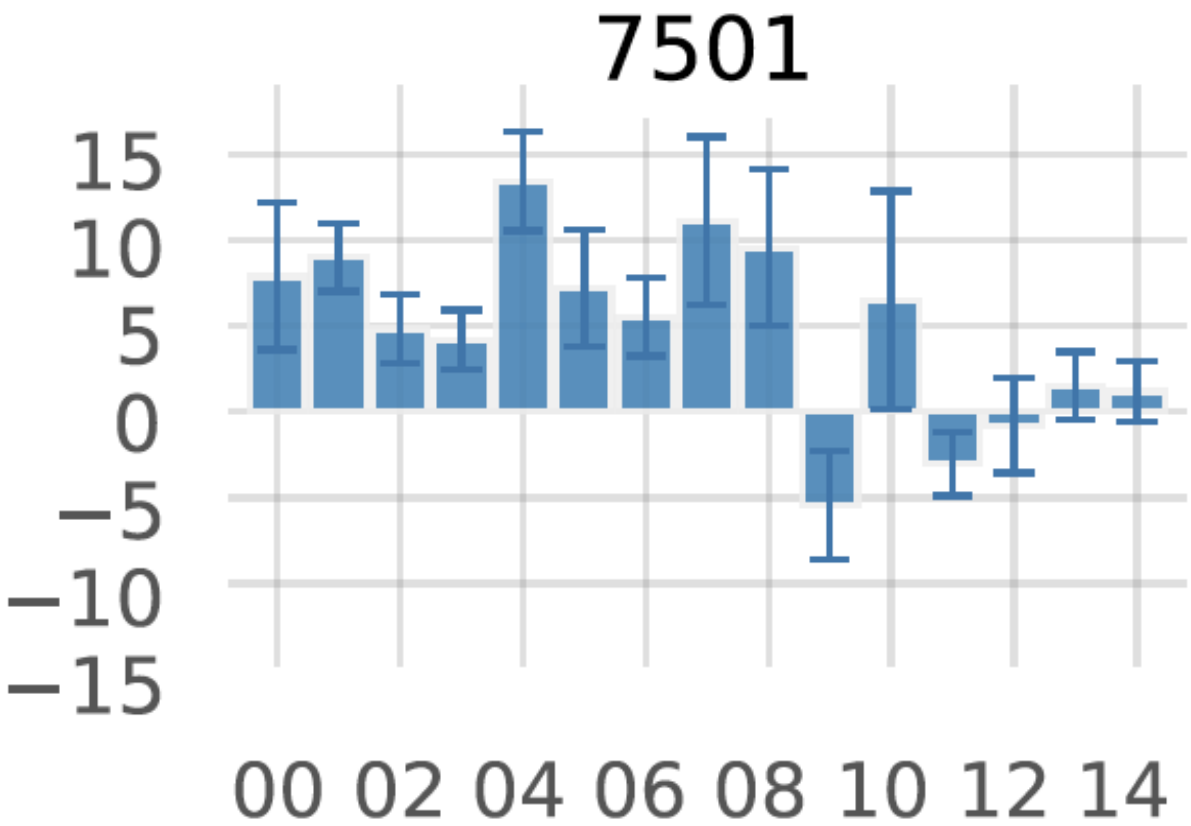
HARL



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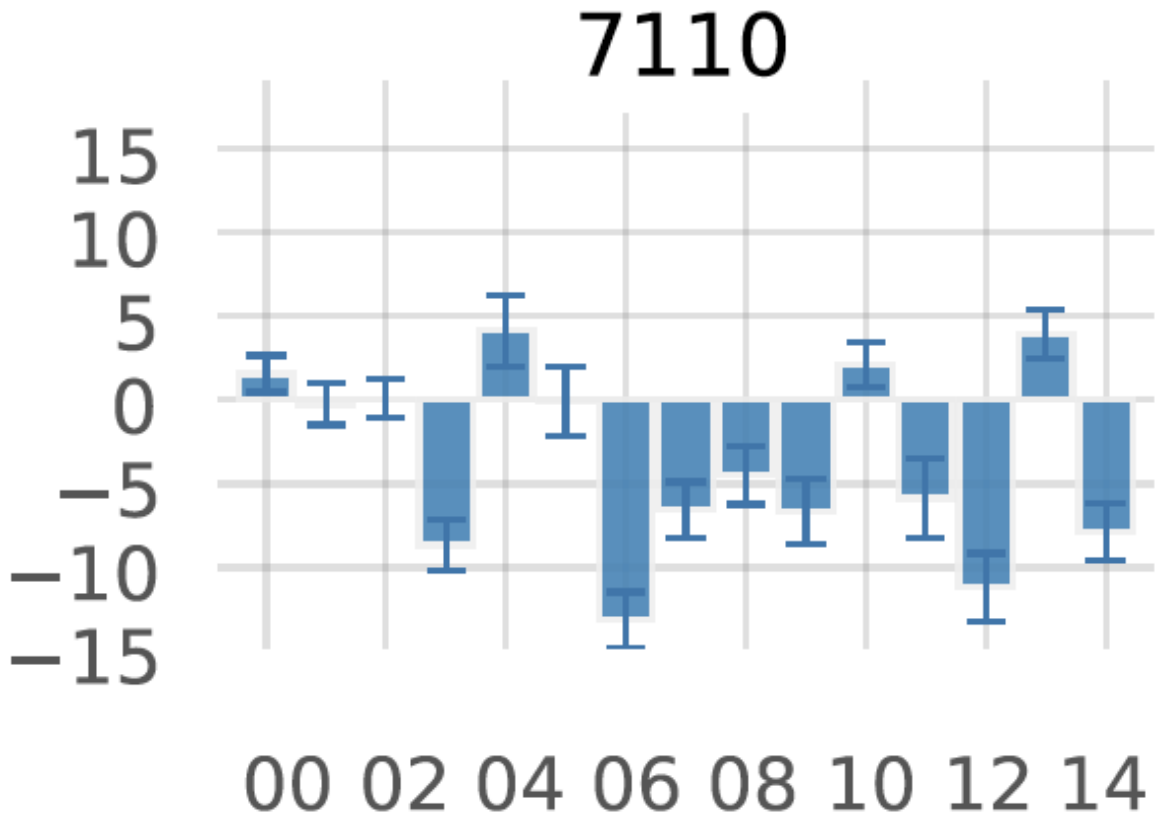
MONL



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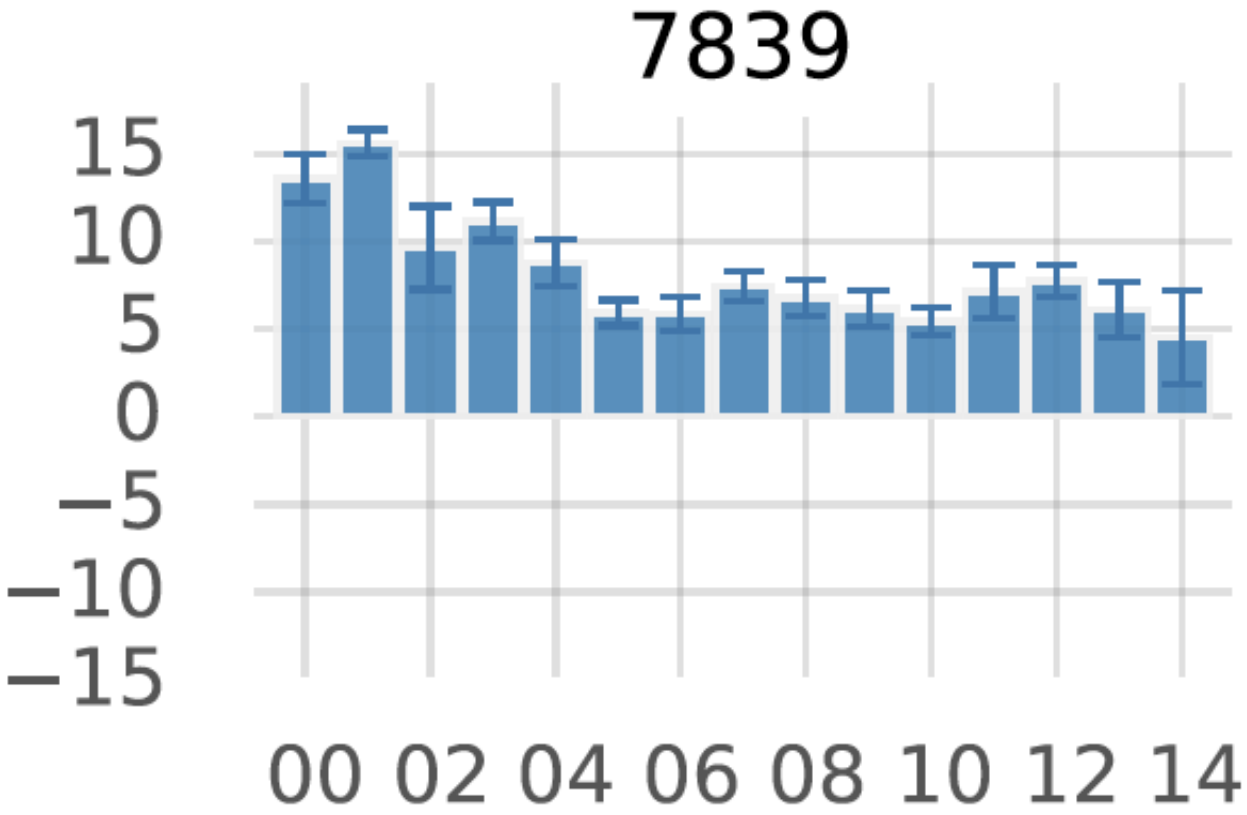
GRZL



Bias remains positive through laser upgrade to KHz in 2002

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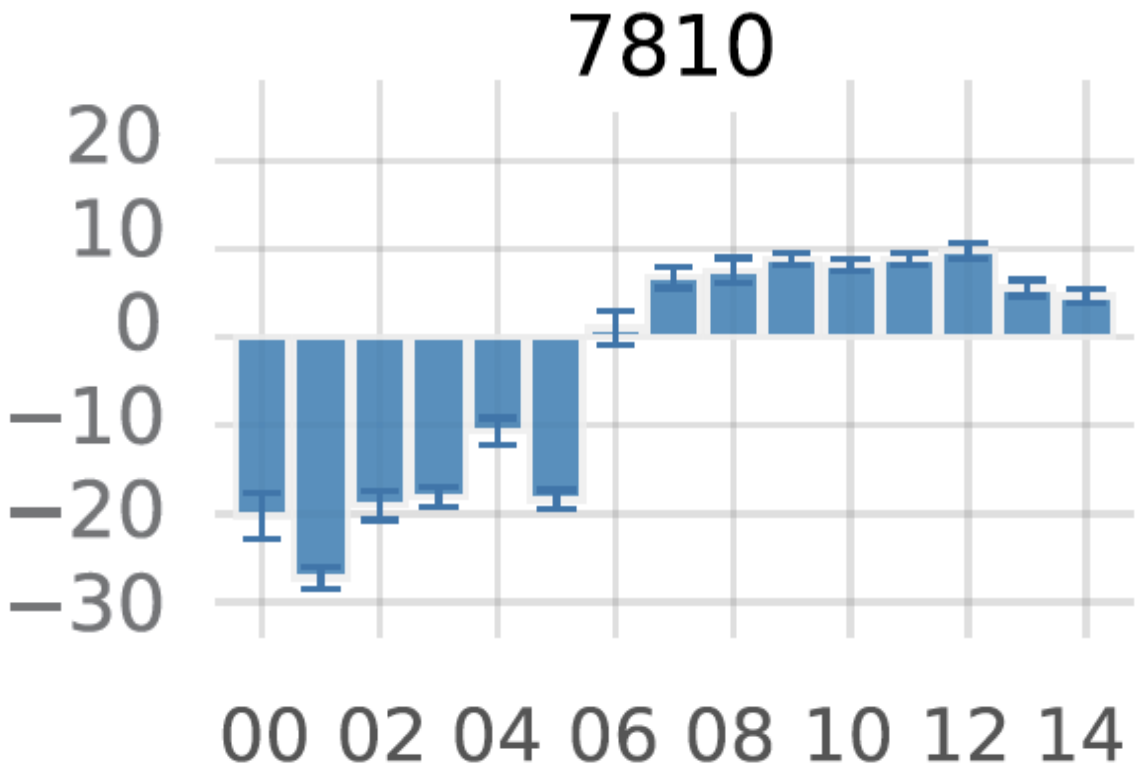
ZIML



Known biases pre-2006
Stanford counter -> Riga ET 2006

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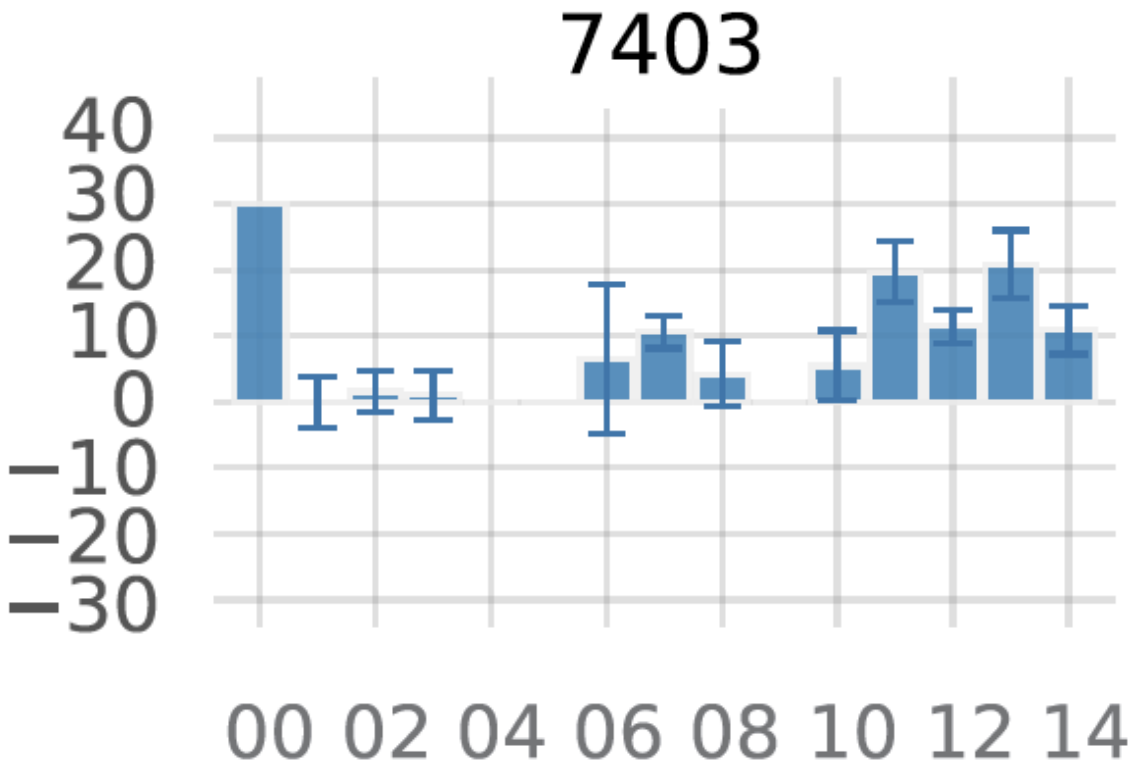
AREL



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Summary

- Significant systematic range error at level of ~5mm and more appears to exist at many stations
- Likely caused by ***combination*** of shortcomings of technology and of data processing (CoM corrections)
- Can be determined/mitigated by using the LAGEOS' to determine range error
- **BUT** stations *must* check systematics, incl. target survey
- **Finally - Does it matter?**

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Test of impact on ITRF Scale

- Laser ranging solutions from 2000 to 2015.0 computed using both ILRS-recommended RB and **all-station RB estimation**

- Weekly SINEX solutions mapped onto ITRF2008
  - 7-parameter iterative solutions
  - comparing each week each station XYZ with that computed at weekly epoch from ITRF2008

- Plots of translations and scale for ILRS-RB and ALL-RB comparisons:

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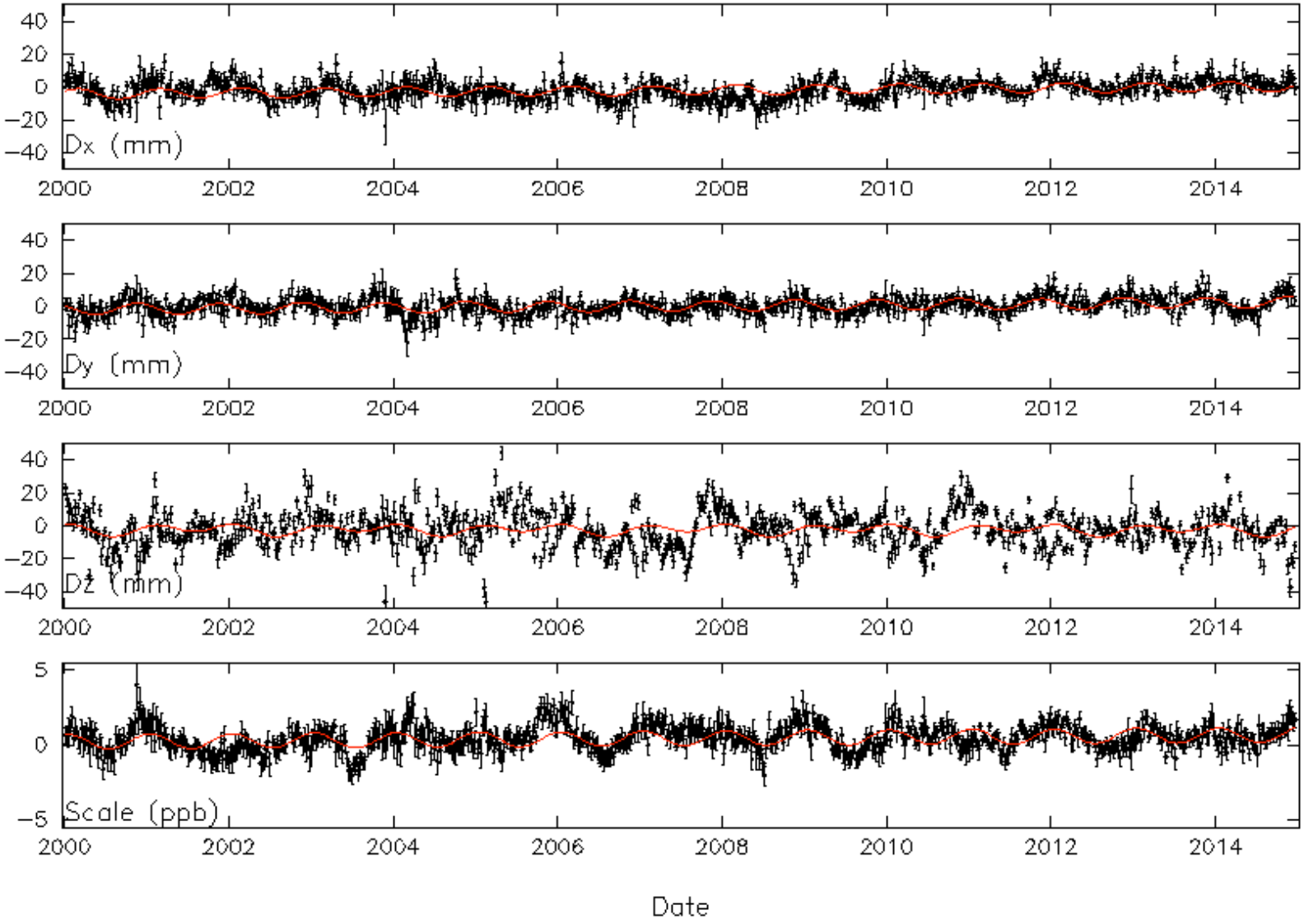
Translations and scale wrt ITRF2008: ILRS RB standard' solutions



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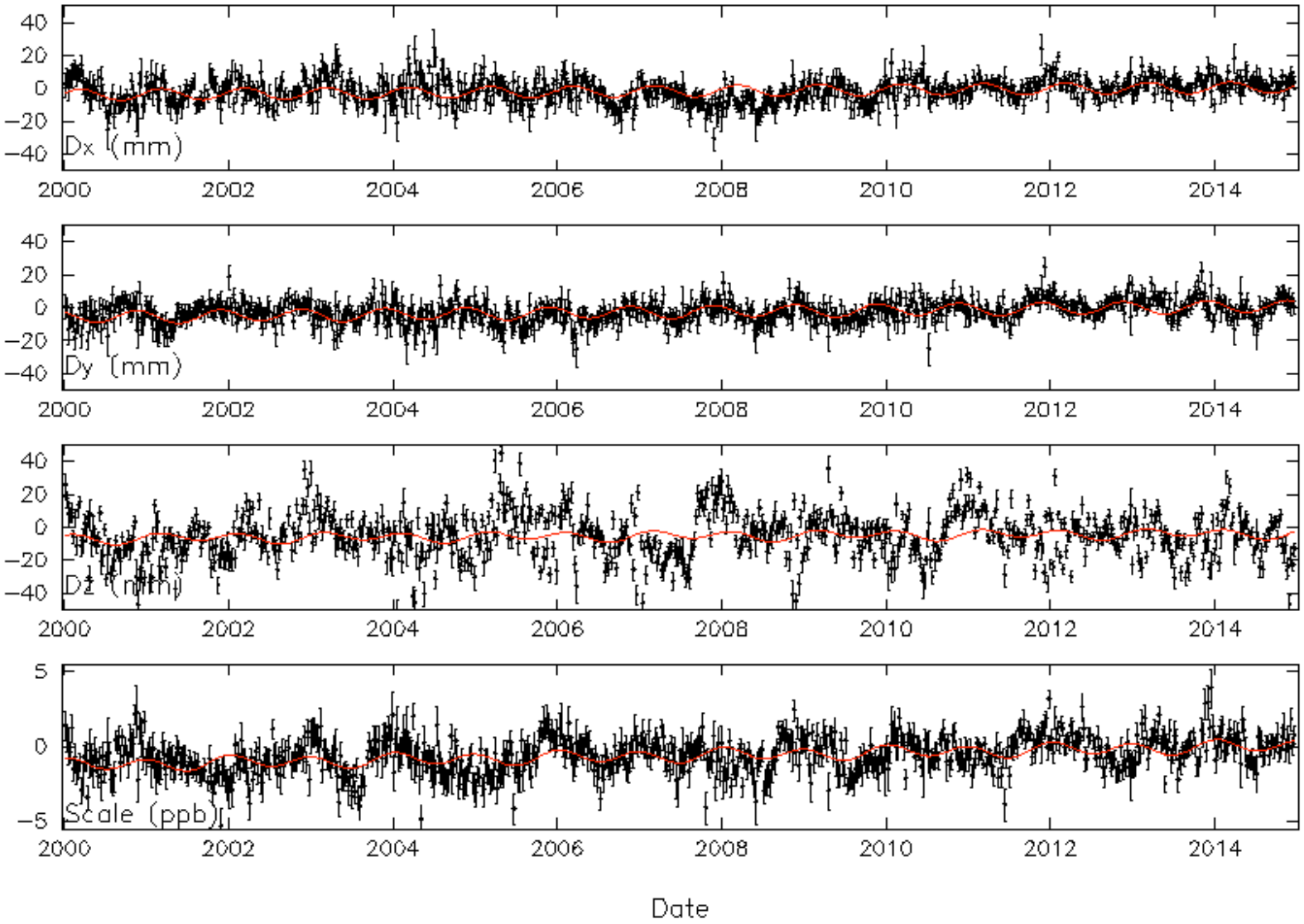
Translations and scale wrt ITRF2008: ‘RB all’ solutions



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Numerical results on scale (ppb)

(constant, linear, annual and semi-annual terms fitted to time series)

	ILRS RB		ALL RB	
Scale	**+0.22**	**0.05**	**-1.21**	**0.08**
Scale rate	+0.03	0.006	+0.09	0.009

RB has significant impact on ITRF scale, but not on scale-rate

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Conclusion

Computing weekly L1 & L2 Solutions for 2000-2015.0 reveals that:

- ‘standard’ ILRS RB solutions scale agrees with ITRF2008 (0.2ppb diff)
- ‘all RB’ solutions scale: 1.2 ppb difference => ITRF2008 ‘too small’

•Likely very similar results will be found when performing this comparison with ITRF2014

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Thank you

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