

Using the LAGEOS Satellites to Assess the Accuracy of ILRS Stations' Observations During the Last Decade

Graham Appleby

Jose Rodriguez

SGF Herstmonceux ILRS Analysis Centre

Outline

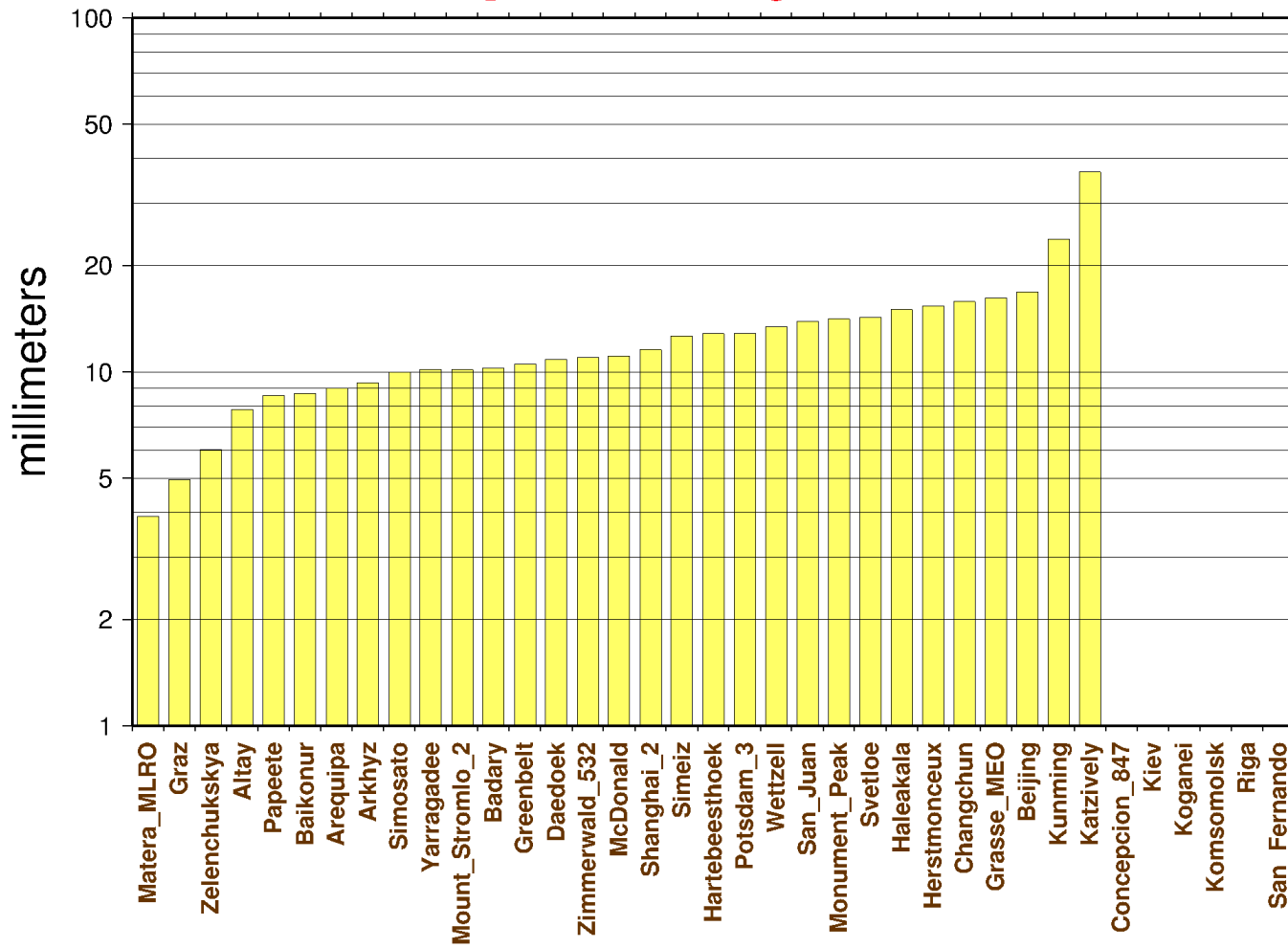
- In this presentation we:
- Attempt to determine laser range accuracy through whole-system bias determinations;
- Test the effects of range bias on the scale of the reference frame;
- Use the results to comment on the standard value of GM

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 coords
 - e.g., using ITRF2008

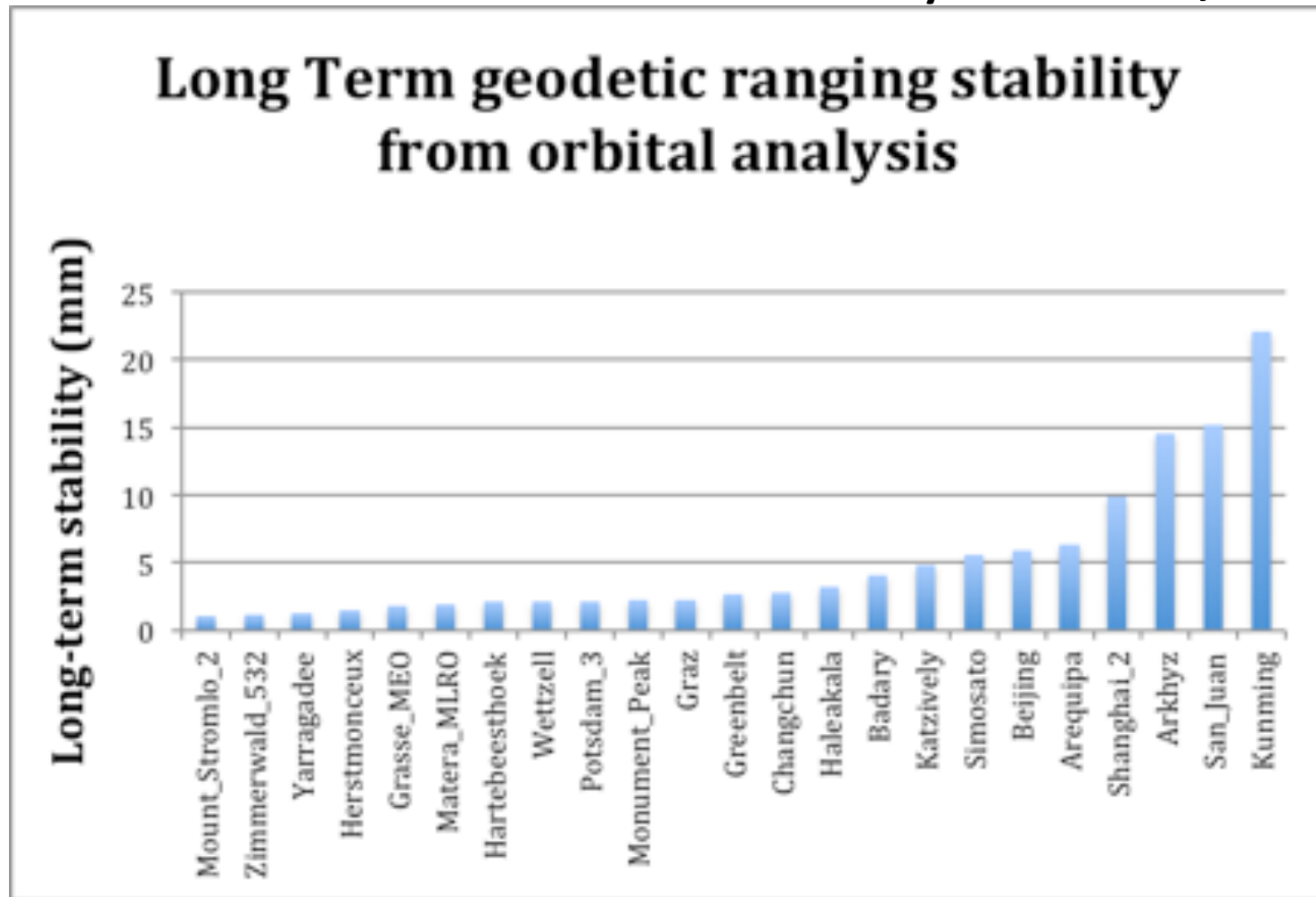
e.g., Single-shot precision on LAGEOS (ILRS)

LAGEOS RMS
from April 1, 2014 through June 30, 2014



20140701

e.g., Long Term geodetic ranging stability (mm)
from ILRS AC QC orbital analysis 2013/14



Regular Operations

- Operational reference frame products from ILRS Combination Centres (Pavlis, Luceri)
- **Apply** data corrections as per ‘handling file’ developed through work by Analysis Working Group (AWG)
- **Solve for** range biases for the few ‘known bias’ stations;
- all AC’s use same set of ‘RB’ stations.

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

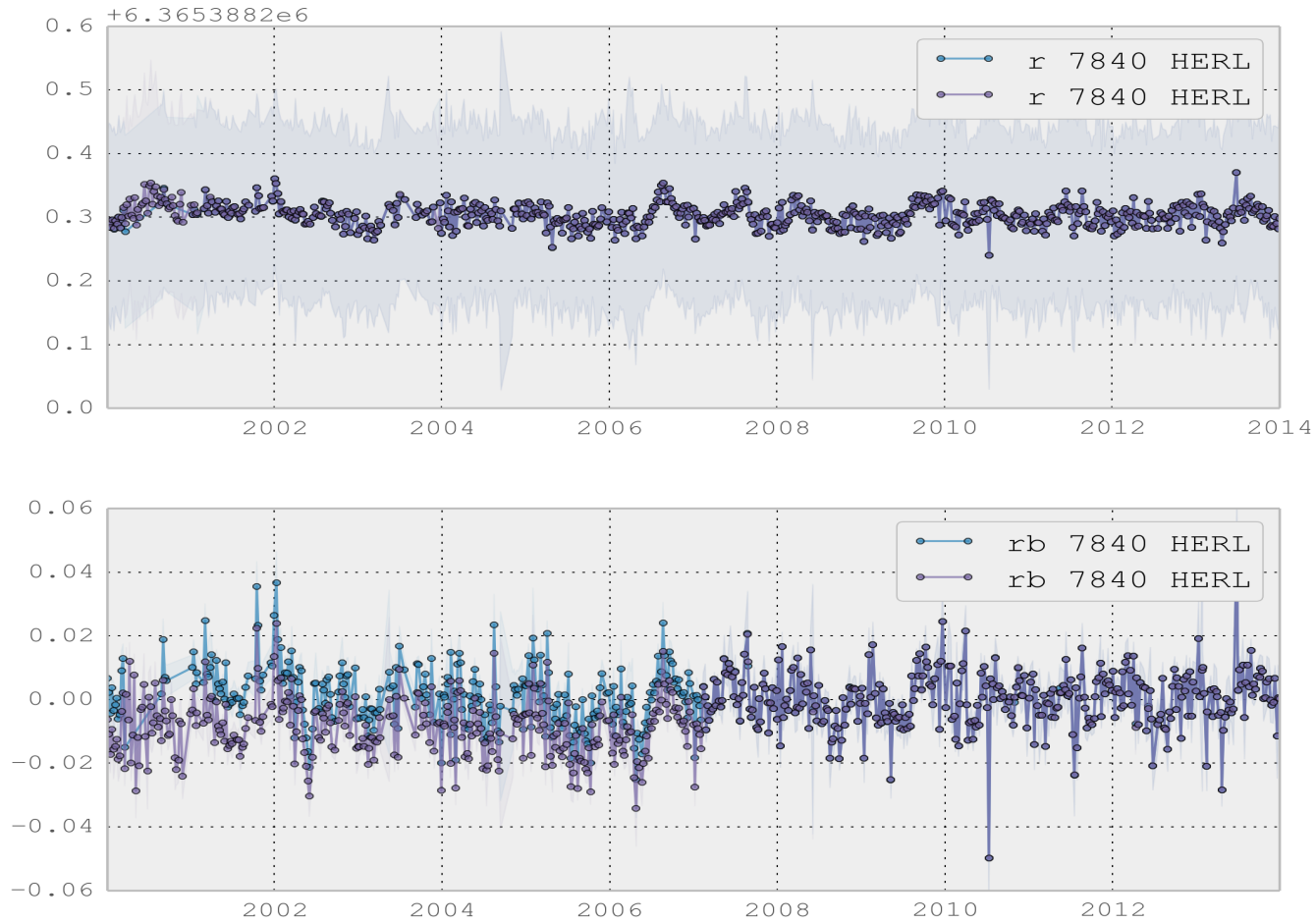
Consequence

- Such small bias, if not **explicitly** solved-for:
- Will be absorbed into station coordinates, primarily the station height
 - In the Zenith, height and RB partials are identical
- 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?

Procedure

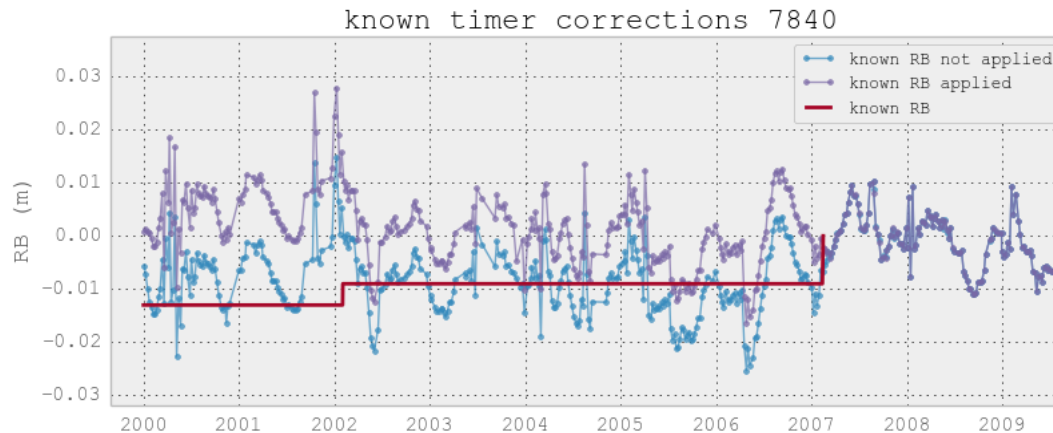
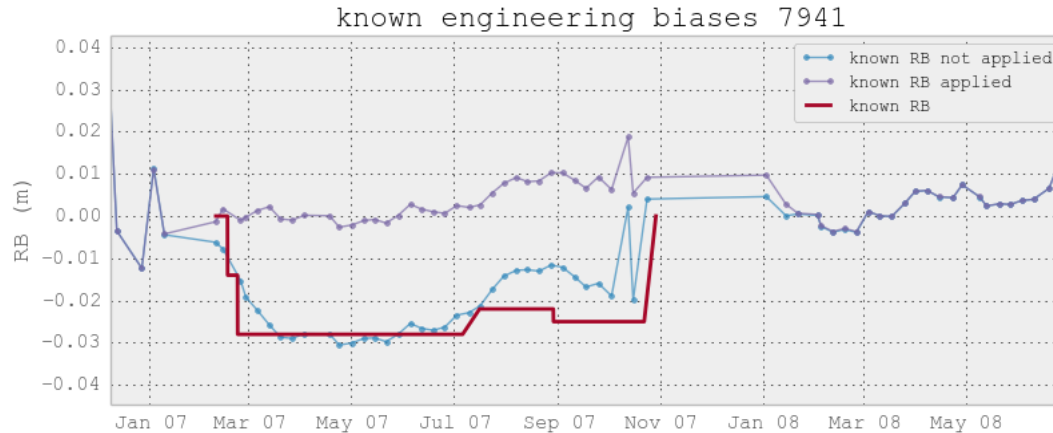
- Carry out full reference frame solutions using weekly LAGEOS and LAGEOS-2 arcs
- Solved for station coordinates, orbits, EOPs and L1+L2 **combined** range bias for ALL stations ('v50' solutions) using SATAN
- For comparison, as above but RB only for the AWG-approved RB stations ('v55' solutions)
- Weekly solutions for 2000-2013.9
 - Applied CoM from tables plus data corrections from ILRS handling file

Test – apply a RB and then solve for it



Test: comparison of solved-for RB with that in data handling file ('known') – two examples

RB estimation correctly identifying known biases

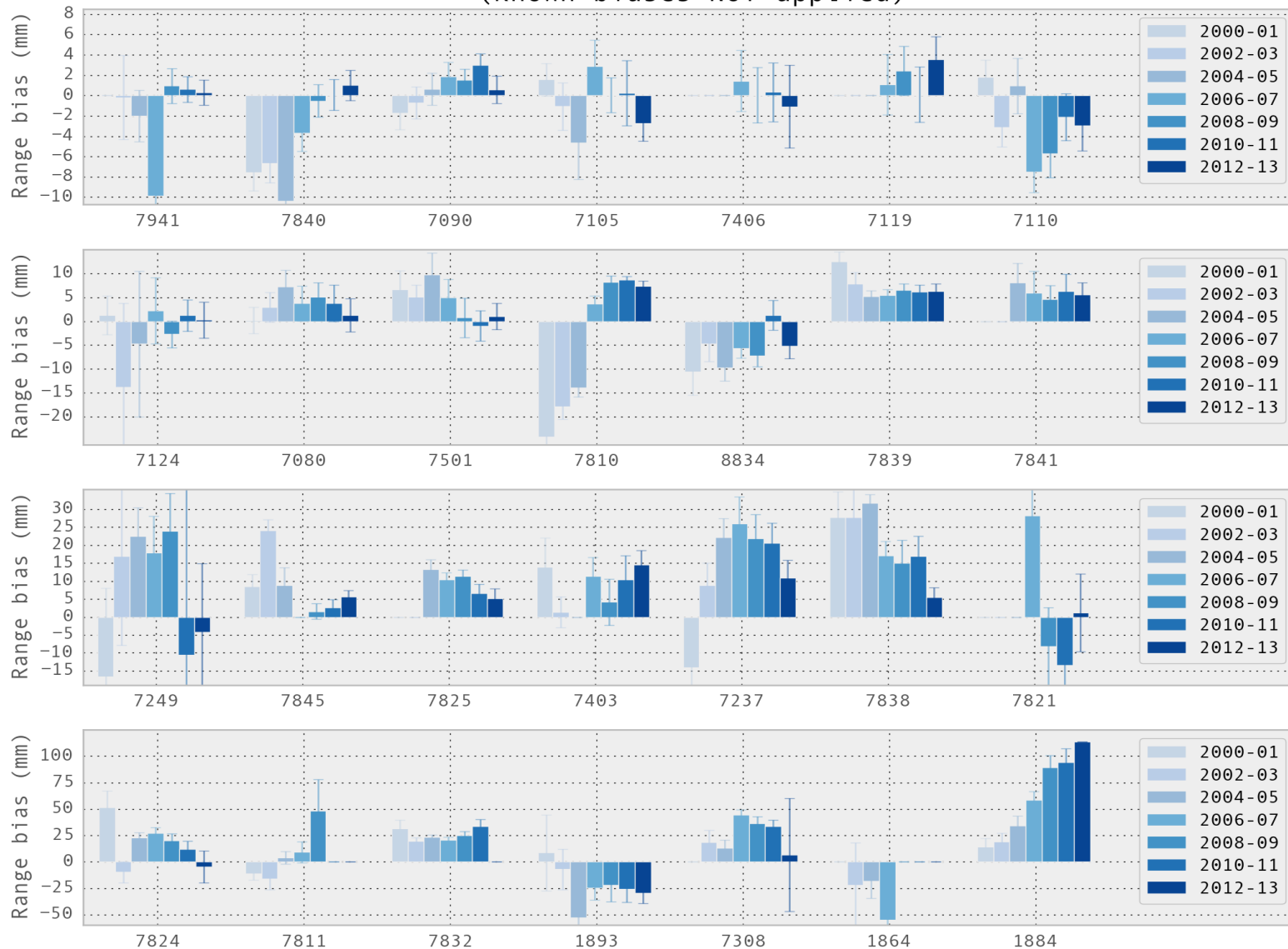


Results

- The following plots:
- Show mean RB averaged over two year intervals for 2000-2013.9
- Shown with and without applying a-priori data corrections from the 'handling' file
- Further plot with RB for most productive stations in period 2006-2013.9 (two-year averages)

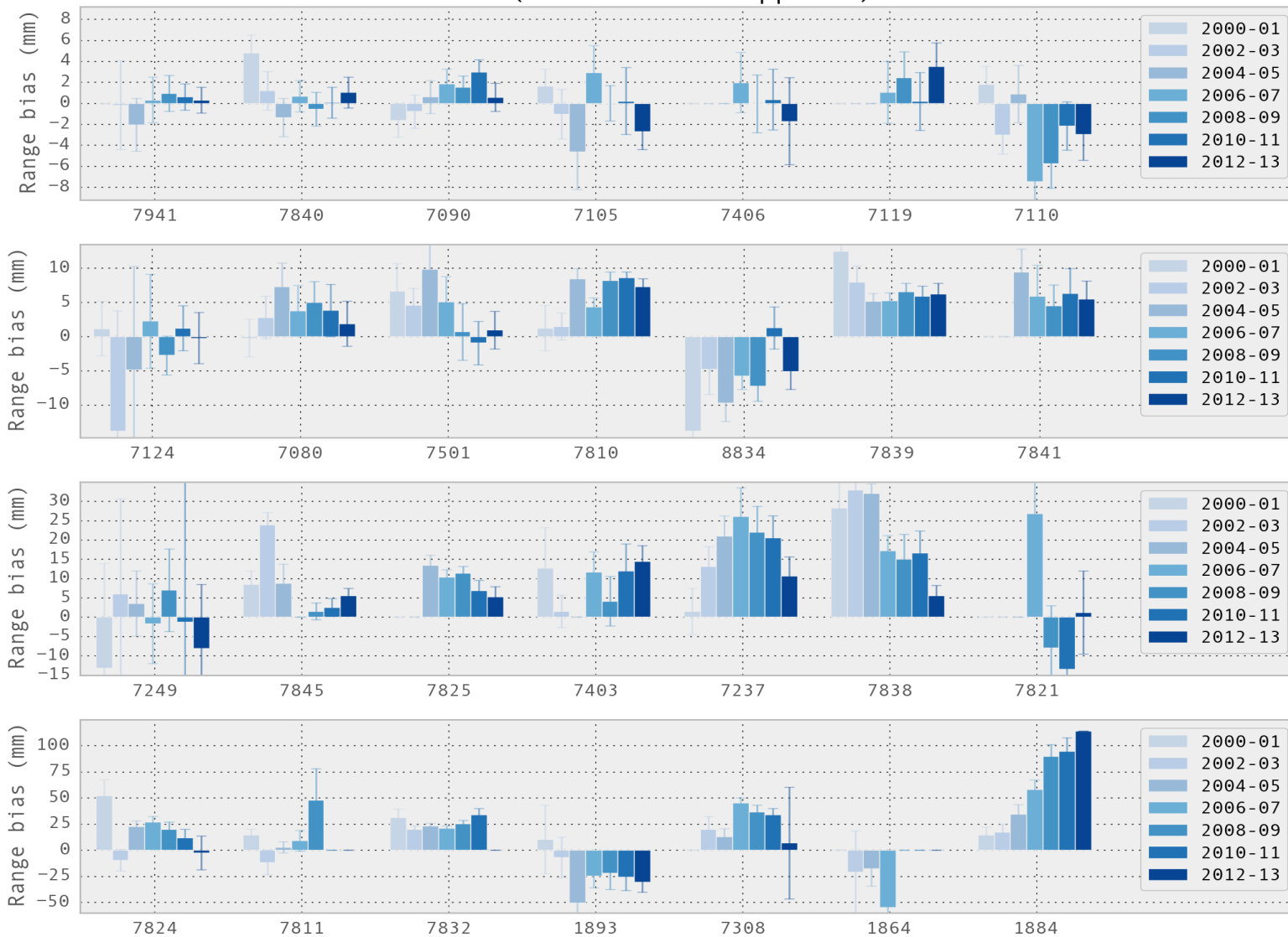
Two-year RB averages of most productive ILRS stations 2000-2013

(known biases NOT applied)



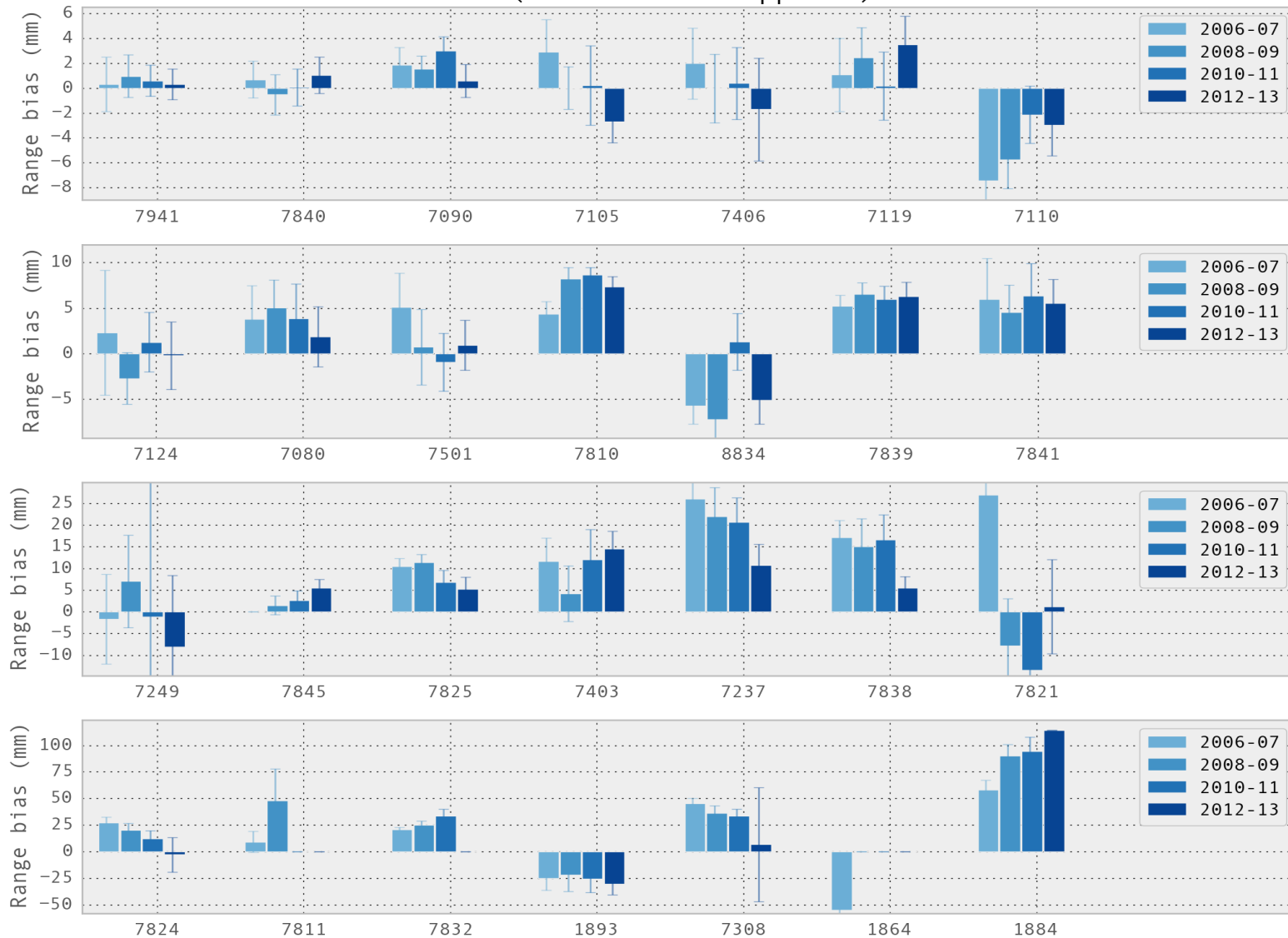
Two-year RB averages of most productive ILRS stations 2000-2013

(known biases applied)



Two-year RB averages of most productive ILRS stations 2006-2013

(known biases applied)



Comparison of weekly solutions with SLRF2008

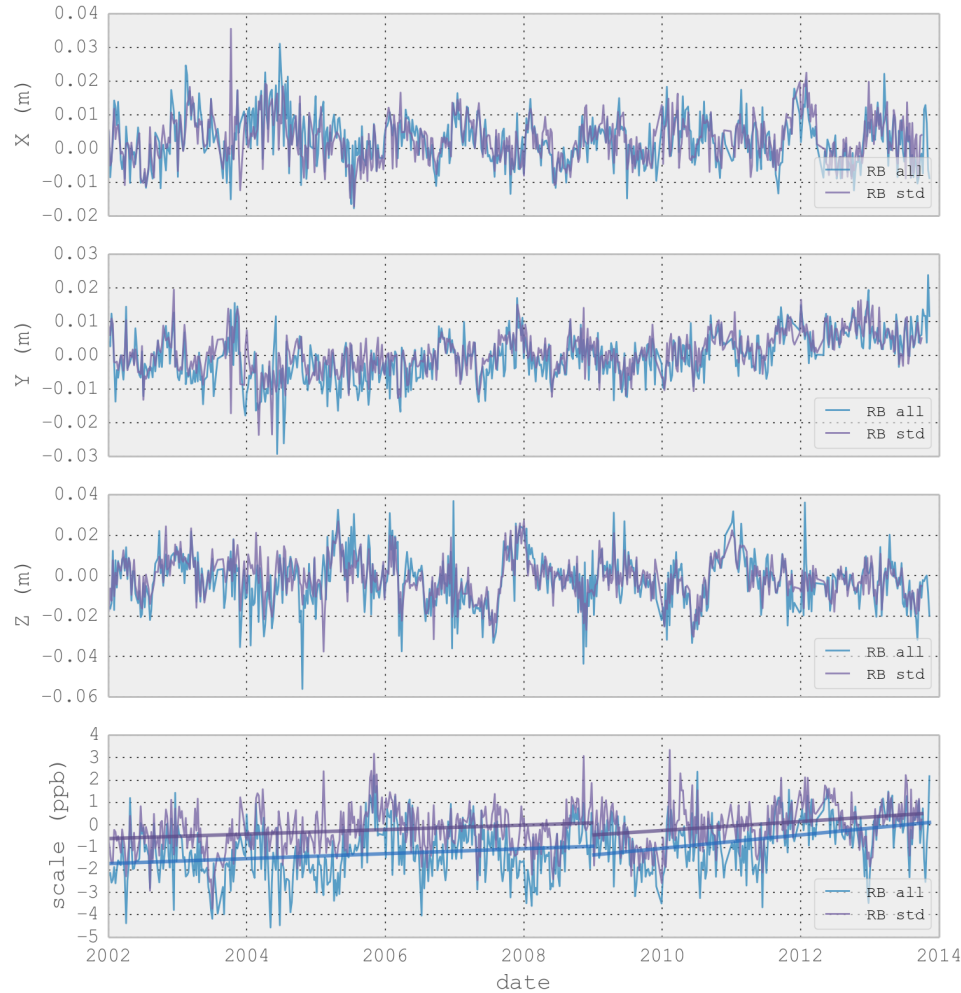
- We compared both our ‘standard’ (limited RB, v55) and ‘experimental’ (all-RB, v50) solutions to SLRF2008 (ITRF2008)
- Helmert 7-parameter solutions for translation, **scale** (and rotations) each week, 2002-2013.9
- O-C is (SLRF2008 – SGF v50/55 solutions), station-by station

Results - Scale

- For the standard (v55) solutions, scale difference is very small ($\sim 0.2 \pm 0.2$ ppb), as expected
- For the 'all RB' (v50) solutions, mean scale difference is -0.90 ppb
- Implies ITRF2008 scale **too small** by 0.90ppb
 - **Sense and magnitude** of this correction is independently confirmed from SGF SINEXs (Altamimi, personal communication, 2014)
- NB ITRF2008 (Altamimi): SLR scale 1.0ppb **smaller than VLBI**

Helmert solutions w.r.t. ITRF2008

Helmert parameters ITRF2008 - SLR



TRF scale change implied by solving for all RB is ~ 1ppb

Outcome/suggestions

- Scale slope same for both solutions –
- Translations (geocentre): not a major increase in noise for the all-bias solutions
- Next steps – increase stations for which RB should be solved operationally?
 - As suggested as an ILRS AWG pilot project
- Revisit some stations' LAGEOS CoM values
 - e.g. (poster) by P Dunn & T Otsubo Etalon/Aji
- Rationalise the issues at station level

Check on IERS standard GM

- This work also leads to a simple test for GM, using the LAGEOS satellites alone
- If just a single station is truly bias-free
 - Perfect counters, accurate CoM, accurate ground-target survey
- The value of GM that returned on average a zero bias for that station would be ‘correct’
- We tested for four years and GM increments of 0.1ppb from ..4412 to ..4419
- Full geodetic solution, RB for all stations:-

Range bias solutions (mm) for different GM values



Results - GM

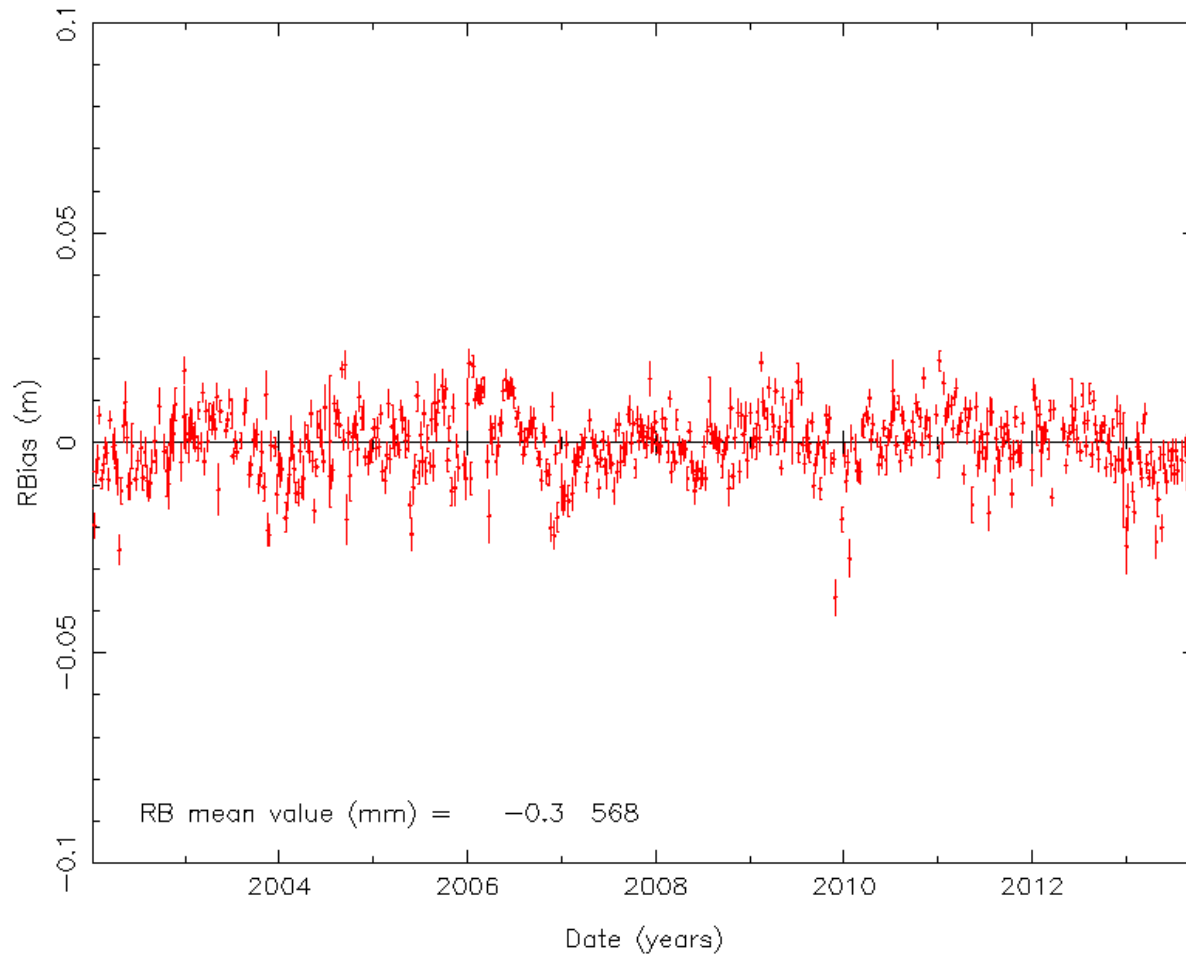
- Each station tends to have a different 'preferred' value of GM
 - where RB goes through zero
- Plausible values are from ..4413 to **..4415** to ..4419
- Preliminary work, needs longer timespan
- Challenge is to be the 'zero-bias' station
- Note: Standard GM is $0.3986004415E^{15} \text{ km}^3\text{s}^{-2}$
- Most recent determination (Smith et al, 2000) $..44187 \pm 00020$

Conclusion

- Significant systematic range error at level of $\sim 5\text{mm}$ appears to exist at many stations
- Likely caused by **combination** of shortcomings of technology and of data processing (CoM corrections)
- Can be mitigated in terms of TRF scale by using the LAGEOS' to determine range error
- Better understanding of station parameters needed in order to improve CoM values:
 - See poster by Peter Dunn and Toshi Otsubo
- Stations also to check systematics, incl. target survey
- Potential then to improve on determination of GM

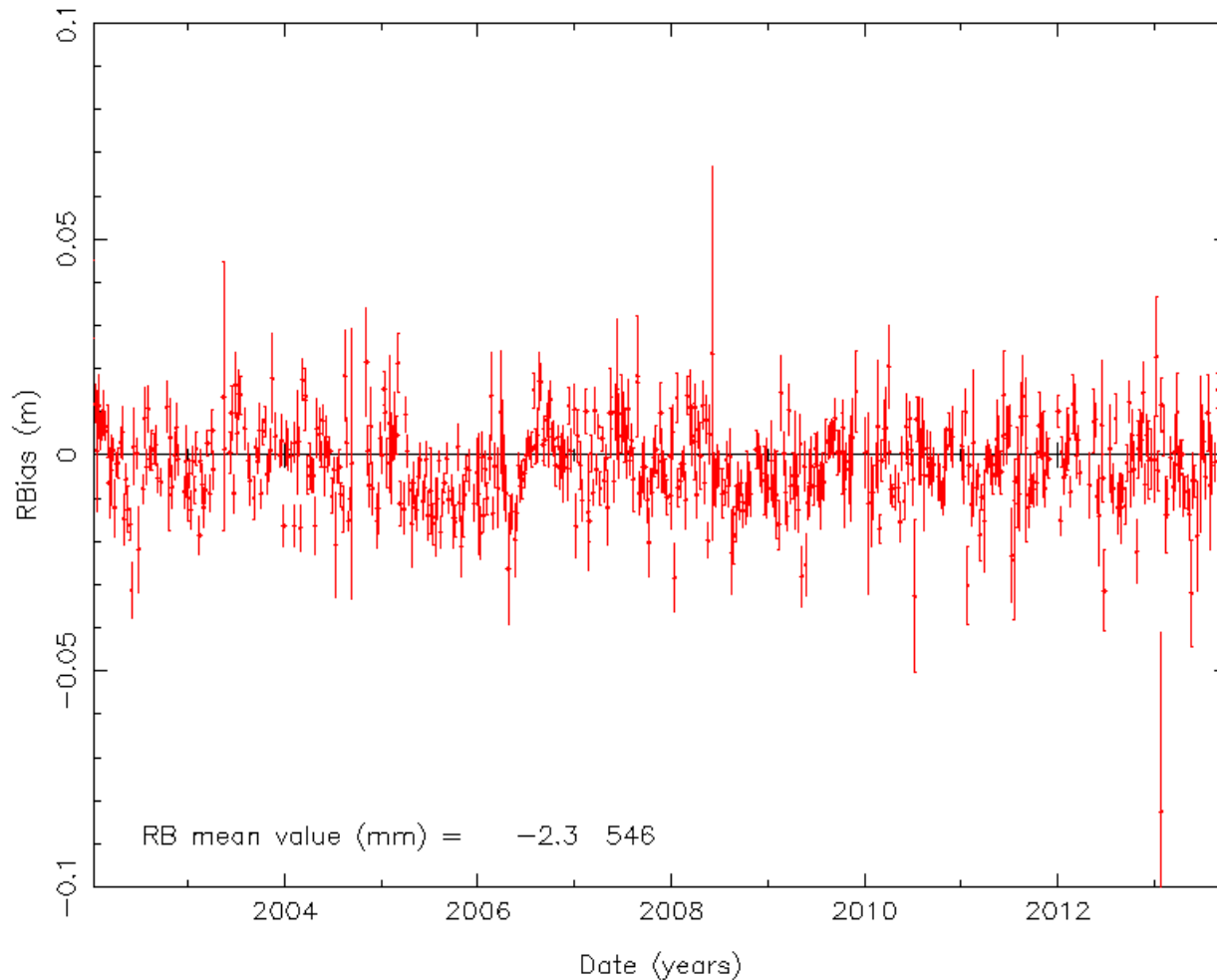
Some RB time series

7-day LAGEOS RB solutions for station 7090



Some RB time series

7-day LAGEOS RB solutions for station 7840



Some RB time series

7-day LAGEOS RB solutions for station 7810

