Assessment of the Accuracy of the Global SLR observations – Multi-Satellite Treatment

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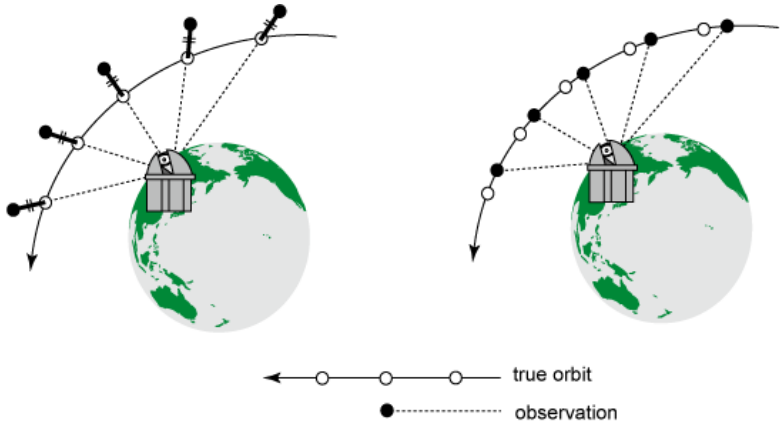
- SLR plays a fundamental role in space geodesy (origin, scale)
- The technique is unsurpassed in terms of simplicity and elegance
- BUT: no such a thing as a flawless realization, the real world is messy and treacherous
- Any systematics inherent in the measurements or modeling will compromise the final product
- Aim is to reach GGOS goal of 1 mm accuracy and 0.1 mm/yr stability

In the pursue for ultimate accuracy many things can go wrong:

- Timers
- Detectors
- Start diode devices
- Inconsistent laser energies
- Inaccurate local surveys
- Power supplies
- Signal discriminators
- Temperature conditioning of sensitive equipment
- Metereologial devices
- Cabling
- CoM models
- Inconsistent operations

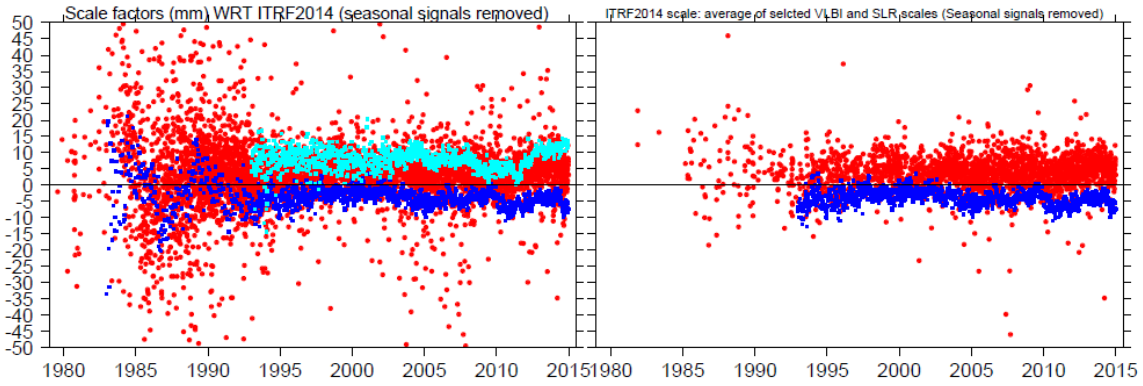
...

- Most of the time these potential problems are kept checked and under control by dedicated station staff
- But things can and do go wrong
- Identification (let alone recovery) of the specific causes behind flawed data is a daunting task
- For historic data, it is nearly impossible

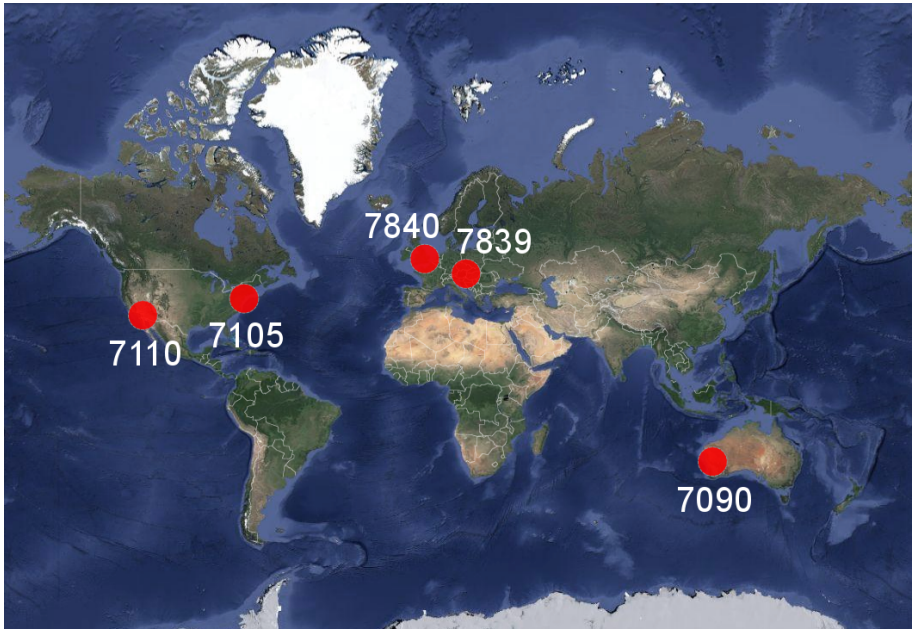


- Range bias is a catch-all parameter that captures any and all range errors, on average, over the estimation period
- RB parameters do not inform us about the causes of the errors
- Experience and knowledge outside the purely numerical solution required
- RB estimation done routinely by other groups in the past for ITRF contributions (e.g. U. Texas ITRF2000) and recovery of known errors (e.g. ASI for ILRS), albeit using longer arcs
- Also routinely estimated on a pass-by-pass basis for QC (e.g. Hitotshubashi U.)

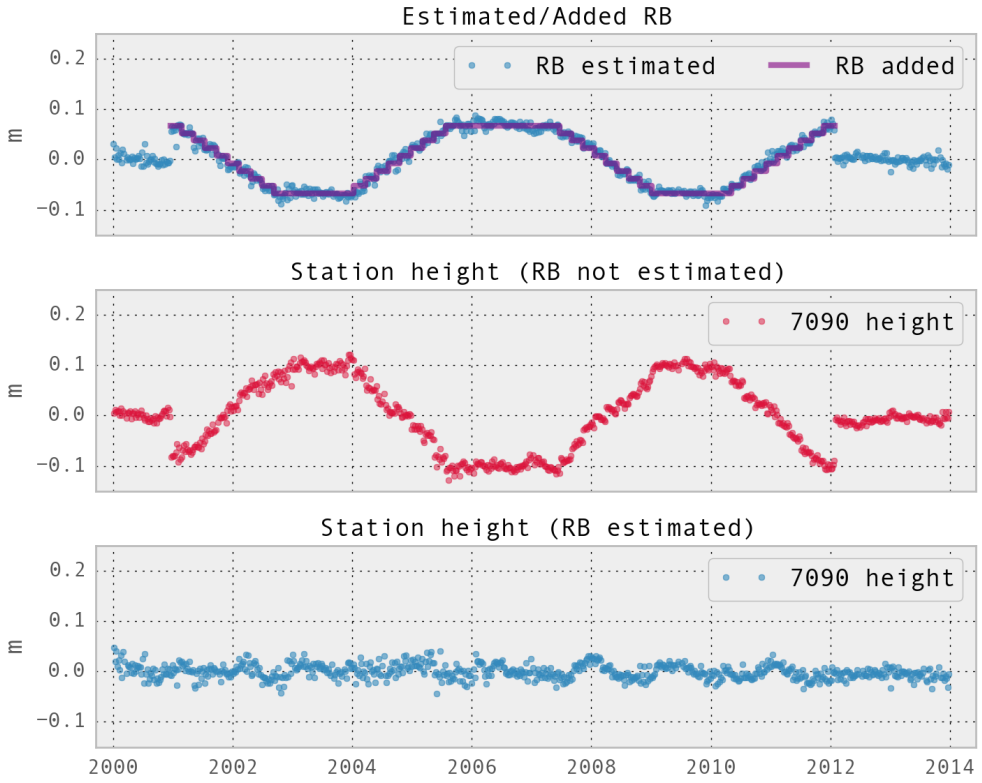
- In view of the infamous scale difference between SLR and VLBI, we abandoned previous assumptions about perfect measurements and flawless stations
- Attempted to estimate RB parameters per station per arc (7-days)
- Multiple tests performed to ensure goodness of the solutions and estimates



(plots courtesy of Z. Altamimi)



- Introduction of artificial biases in the observations of a set of stations
- Computed effect on station heights
- Attempted to recover introduced biases



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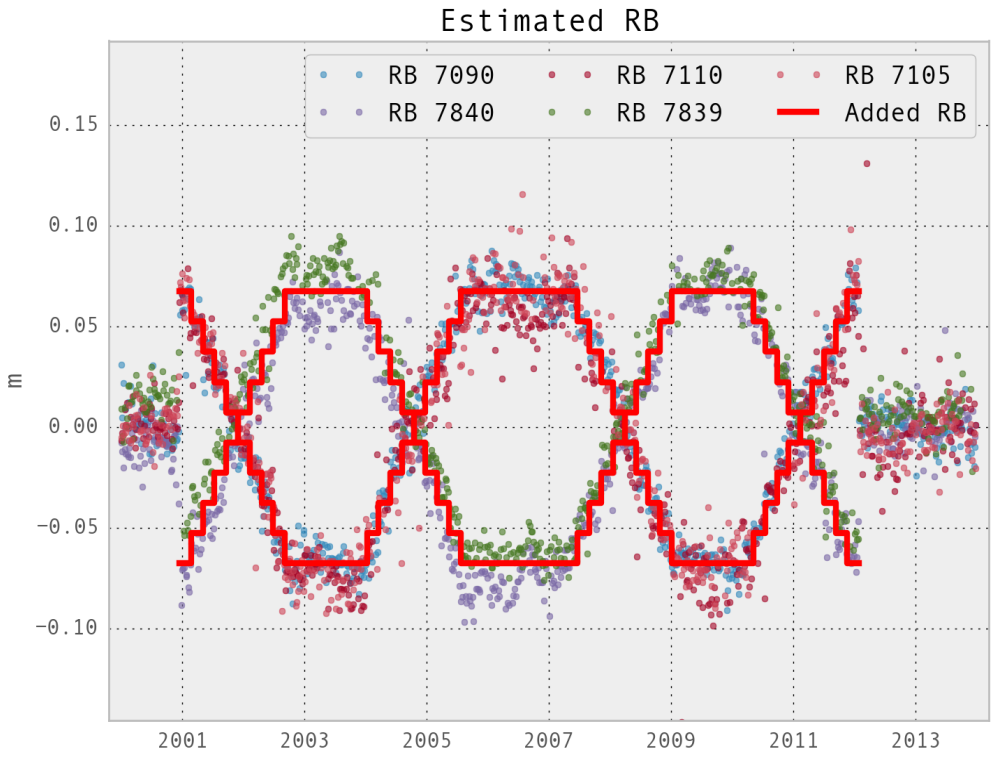

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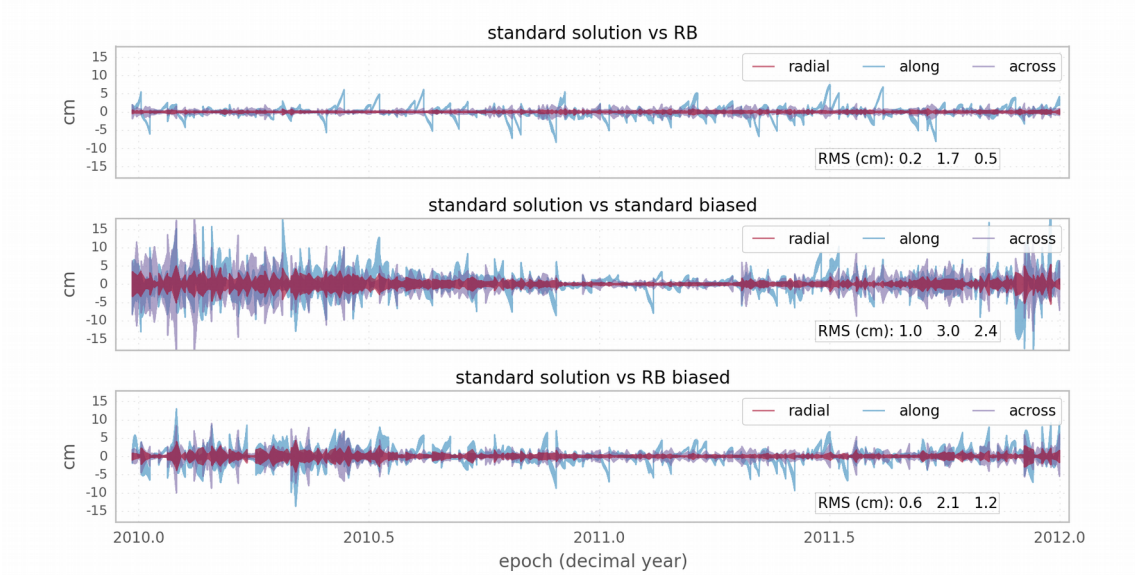
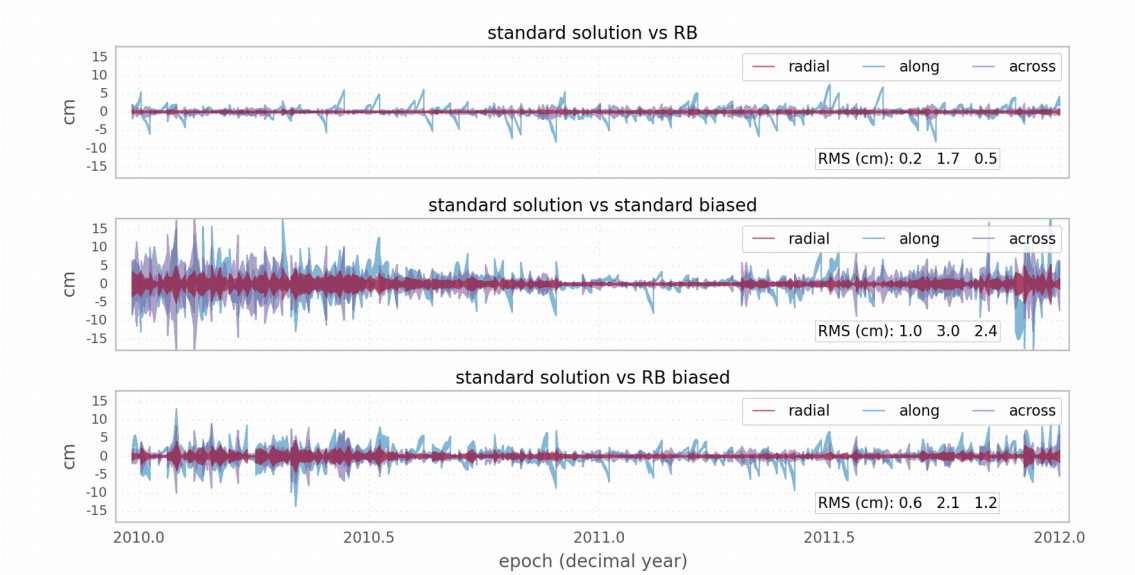


- Orbit comparisons show degradation in the solutions with artificial RB added, proportional to magnitude of bias
- Degradation is reduced when biases are estimated



- RB successfully recovered
- Satisfactory simultaneous estimation of station coordinates (although noisier)
- Orbit improvement over solution with no RB estimation

Satisfied estimation worked, what did results tell us?

- Systematic range errors present, at some level, in most stations of the network
- Mean systematic error stable when averaged over a sufficiently long period
- Some, but by no means all, of the errors attributable to CoM mismodeling
- Implication: scale of SLR determined frame ~0.7 ppb too low due to the presence of these RBs
- Little to no effect on XYZ translations

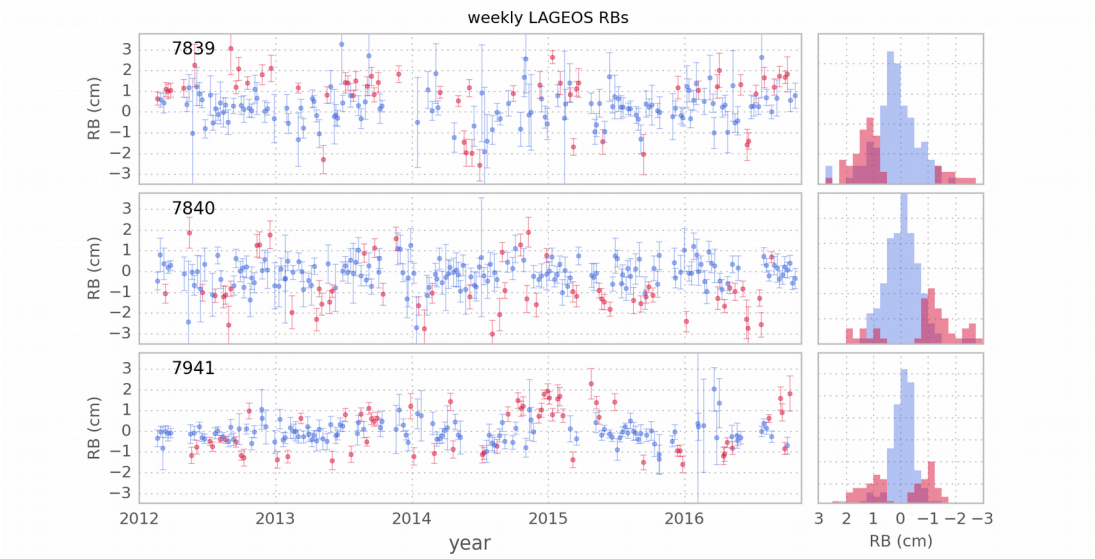
Appleby, Rodriguez, Altamimi. Assessment … JoG 2016

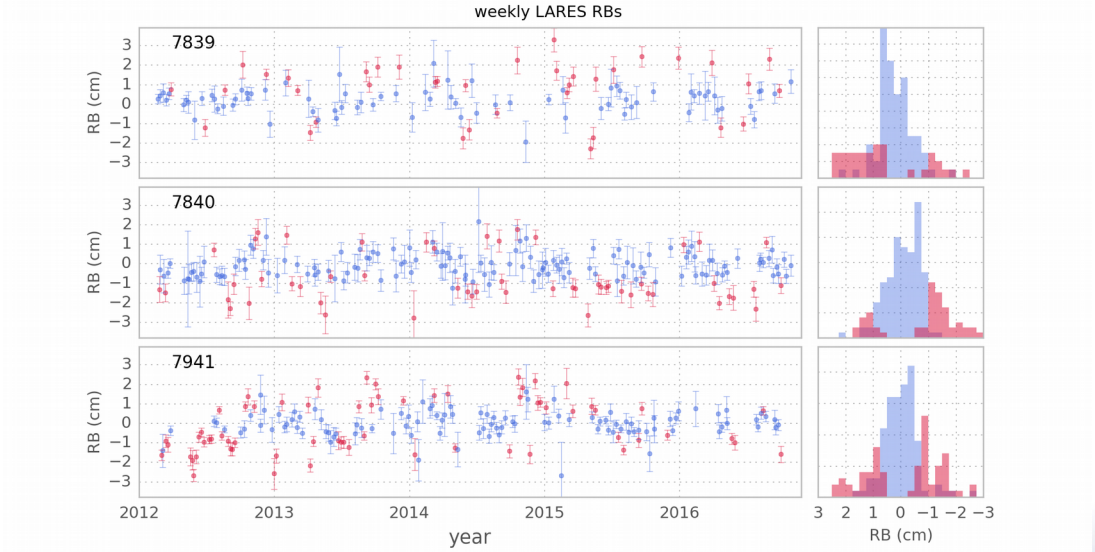
- New solutions using up to date data plus LARES
- TRF type solutions solving for coordinates and RB (weekly), EOPs (daily) and orbits (2xdrags + 2 OPR parameters for LAGEOS-1/2, 3xdrags + 3 OPR parameters for LARES)
- IERS Conventions 2010 plus:
  - EIGEN-6s4 geopotential
  - Up to date interpolated mean pole from IERS (?)
  - FES2014 ocean loading for site displacements and gravity
  - New LARES CoM tables (station, system and time dependent) (*)

- Period: 2012.2 – 2016.9 (since LARES launch)
- Focus on biases estimation and impact on TRF scale

(*) New and updated CoM tables available from EDC and CDDIS!

Examples of weekly estimated RB





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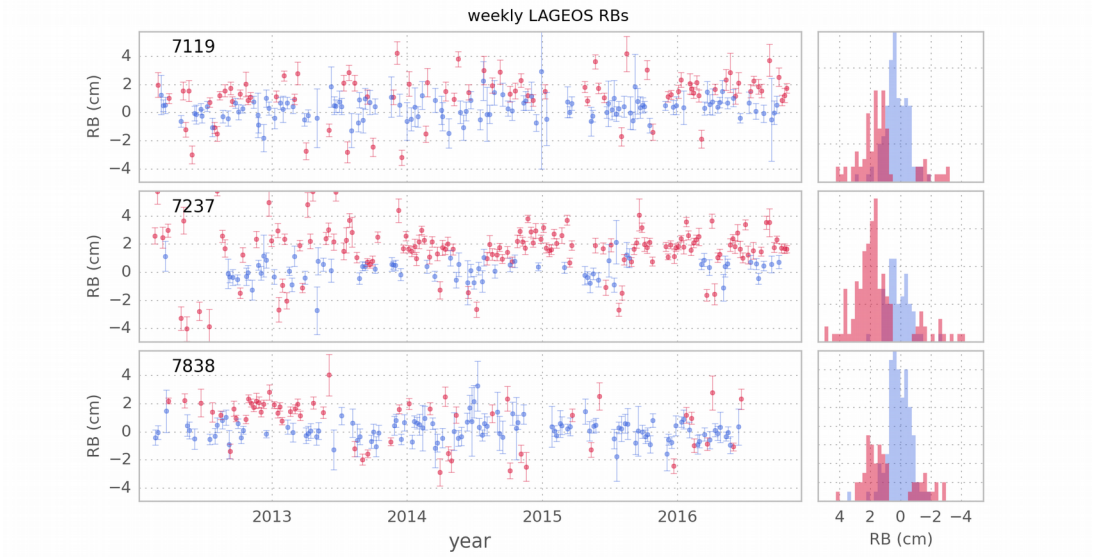
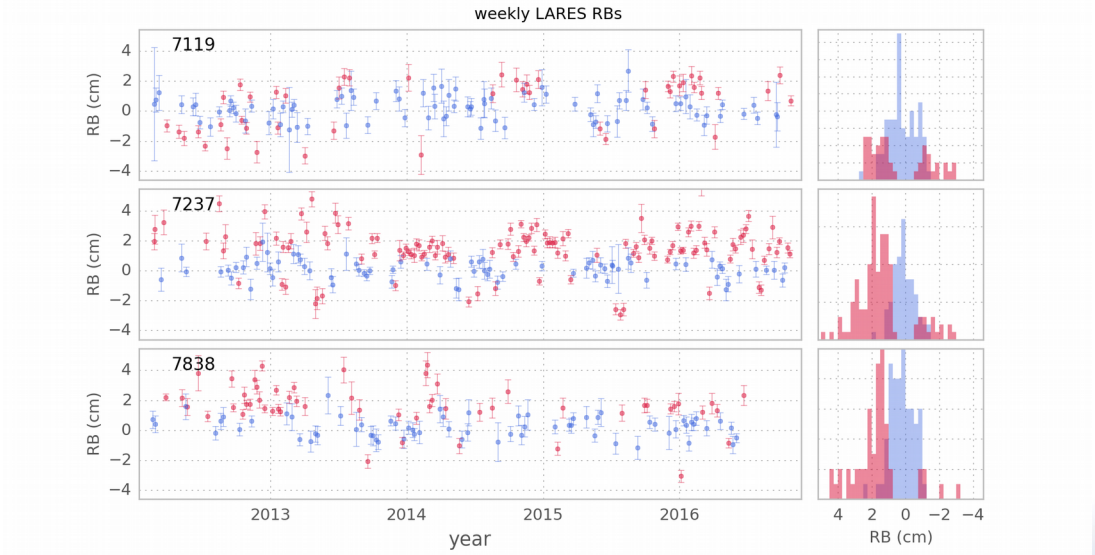
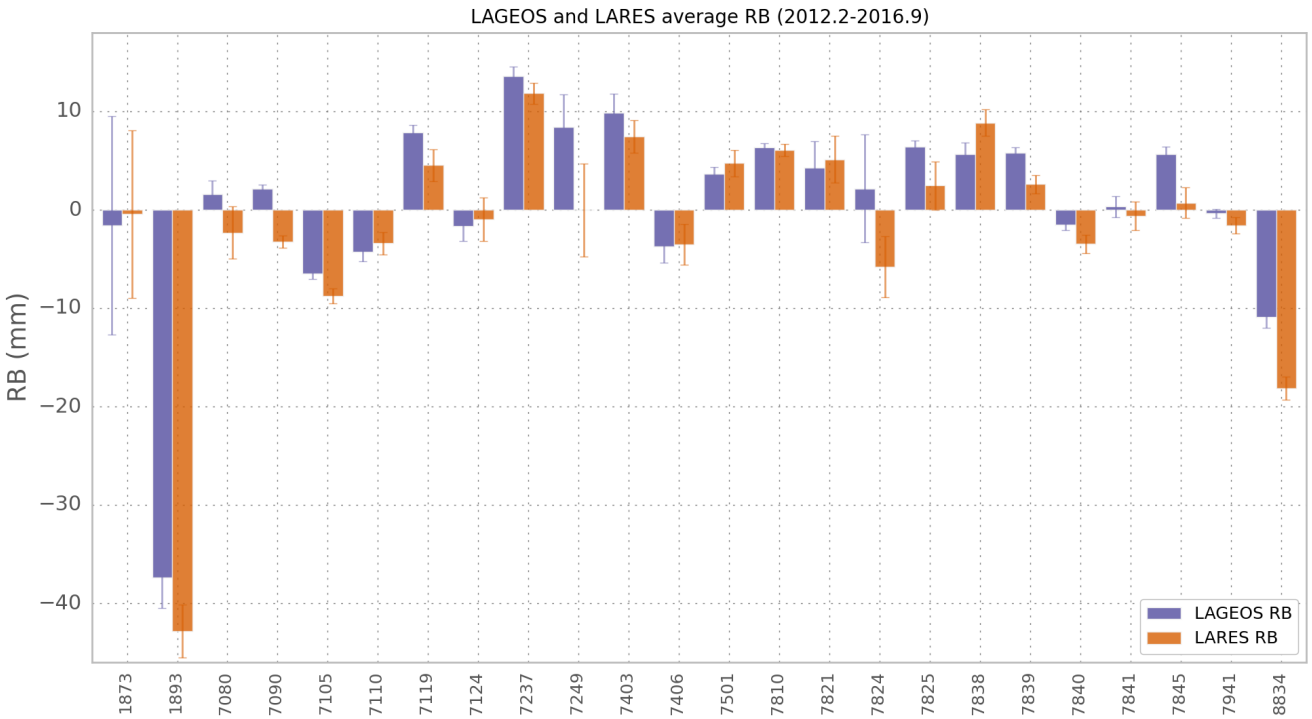
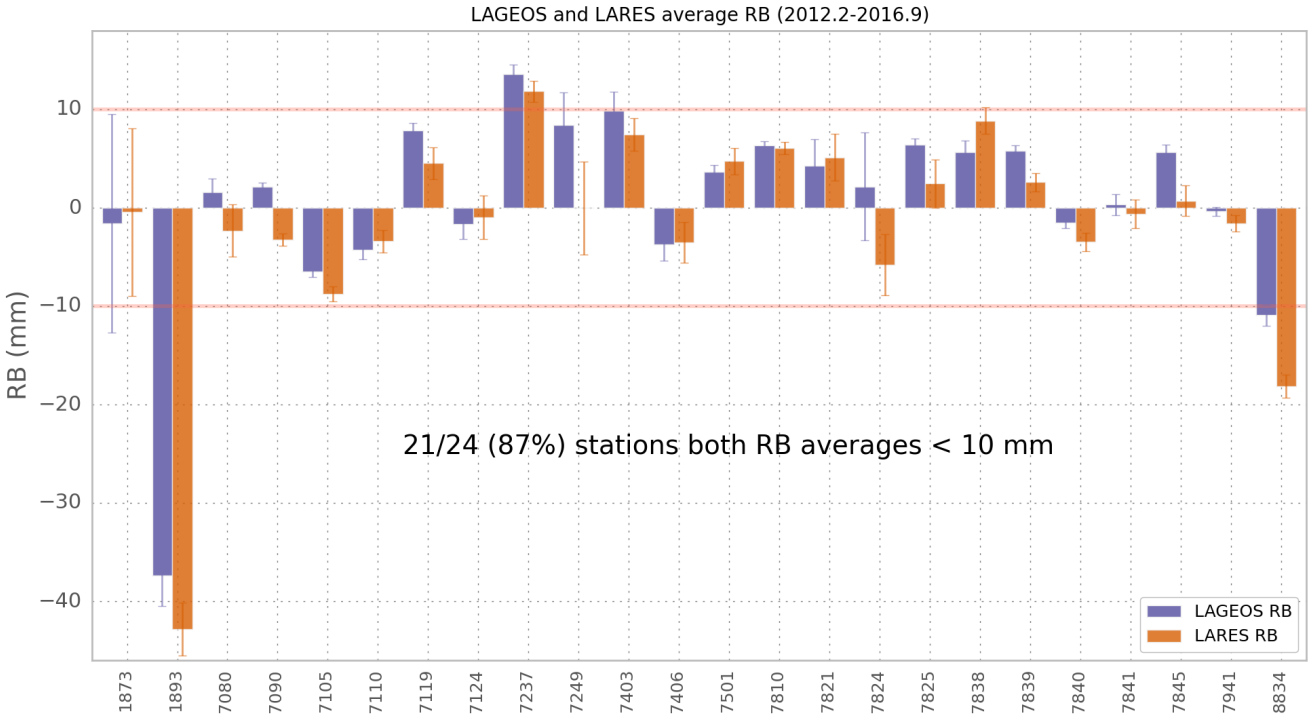






Weighted averages of LAGEOS and LARES RB over the whole period



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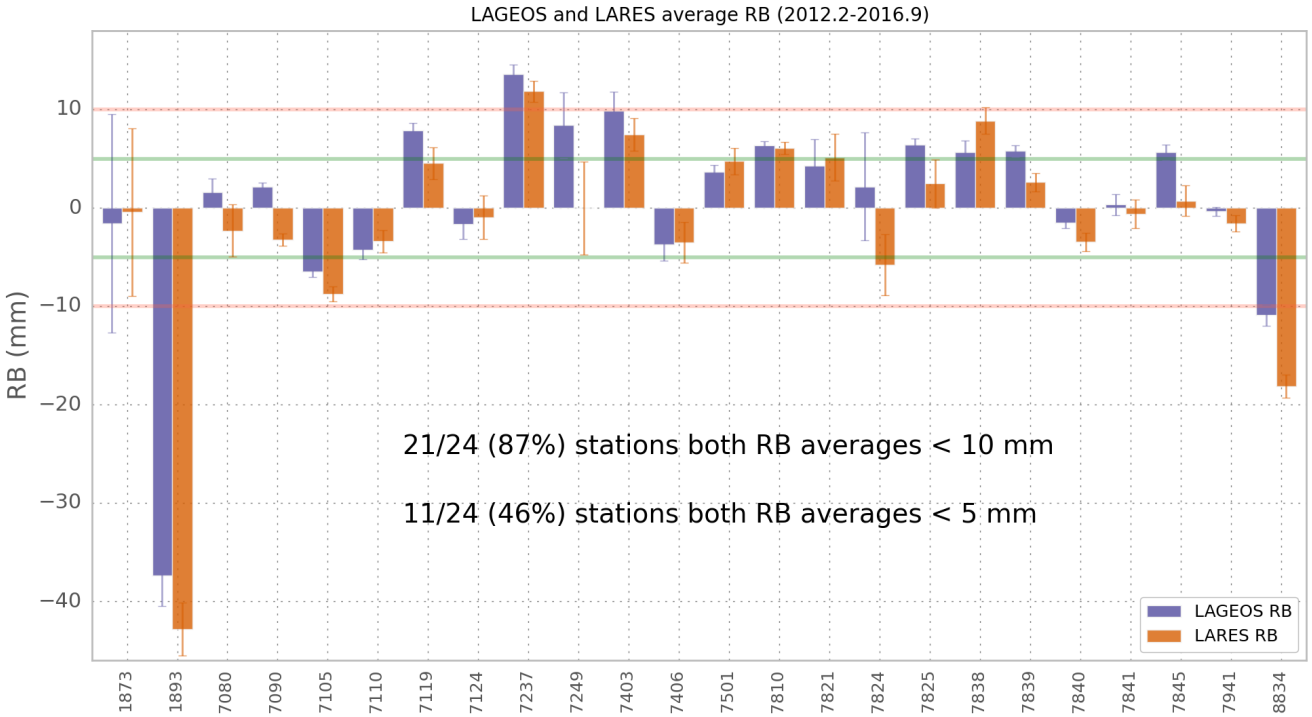

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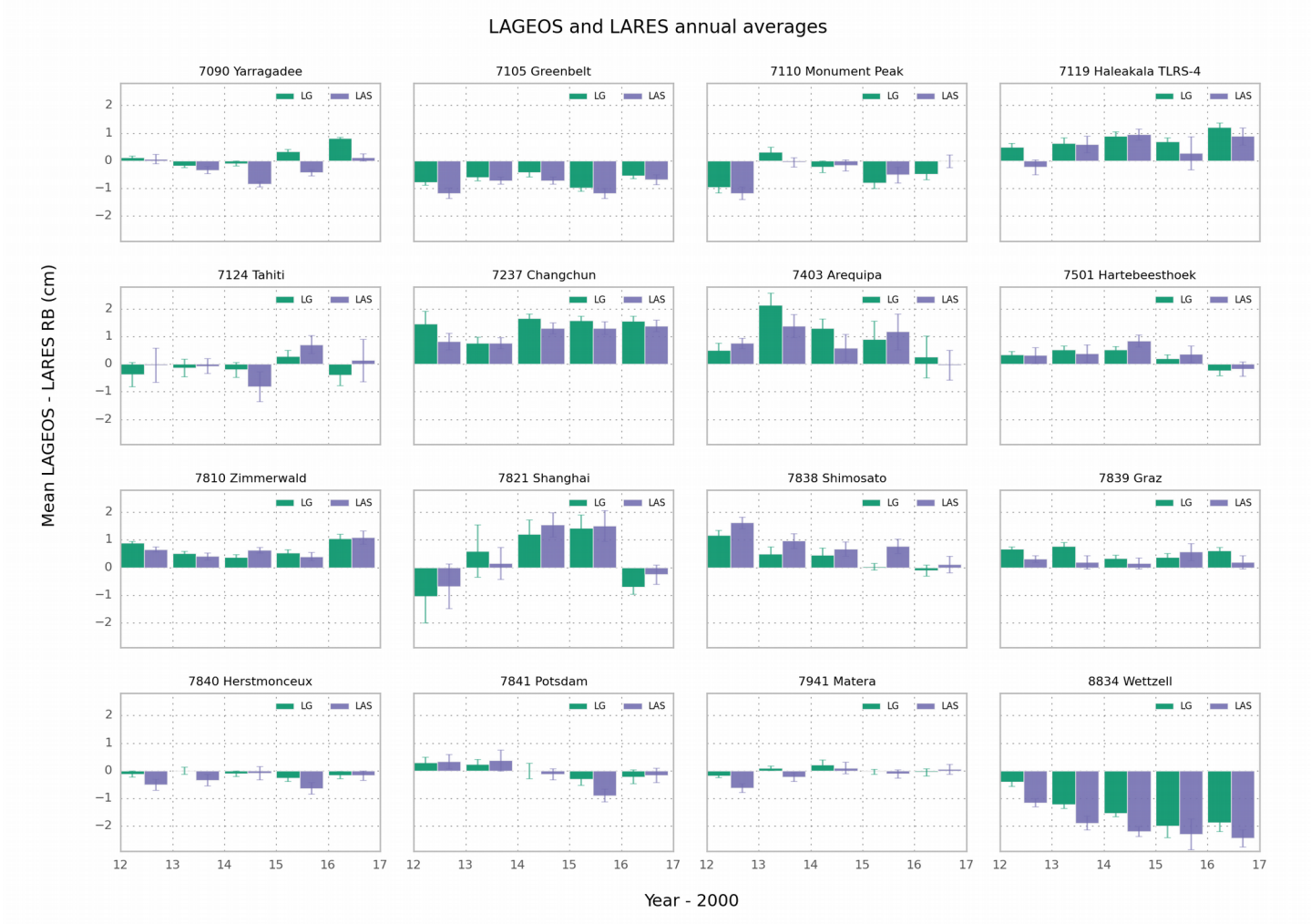
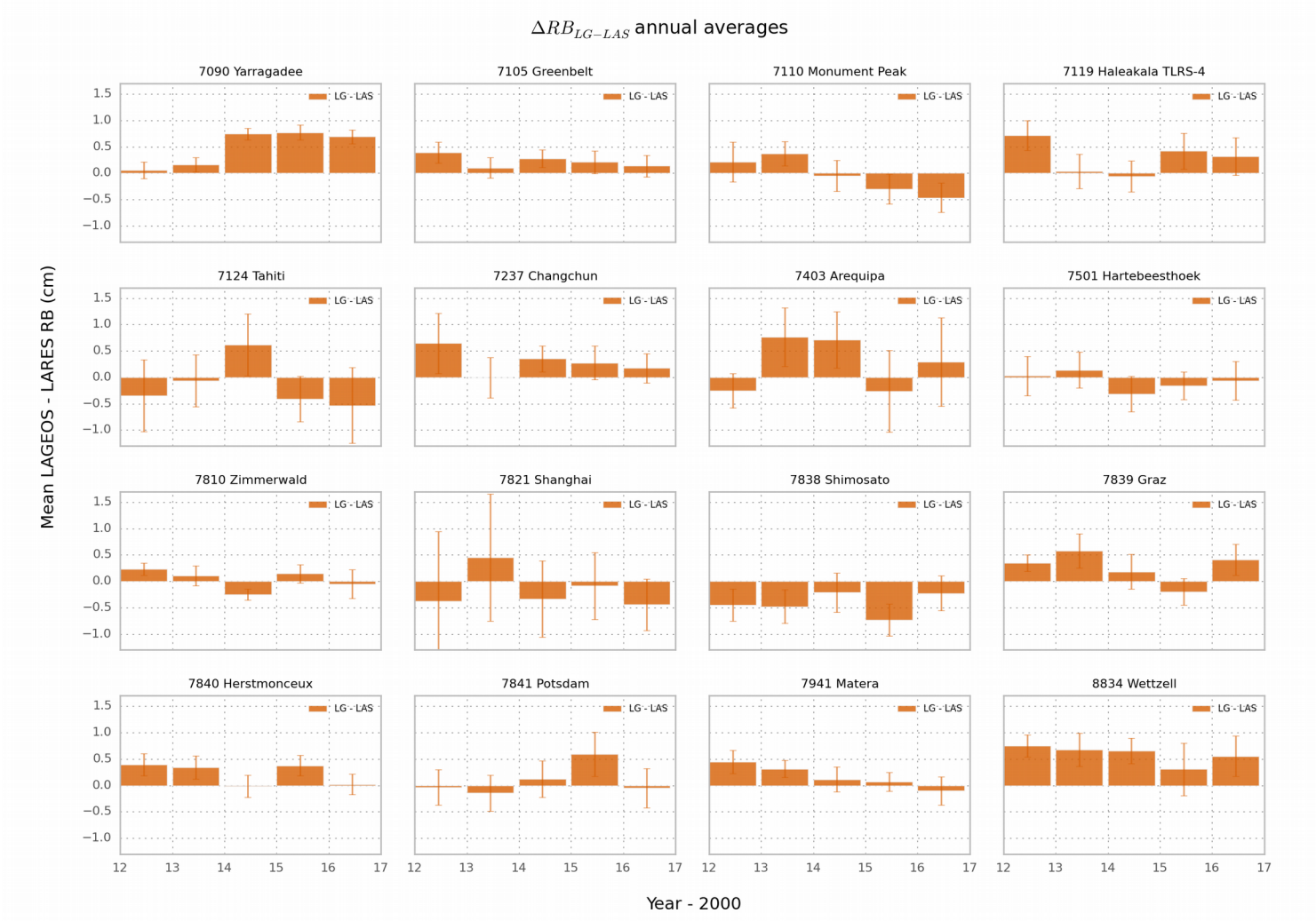
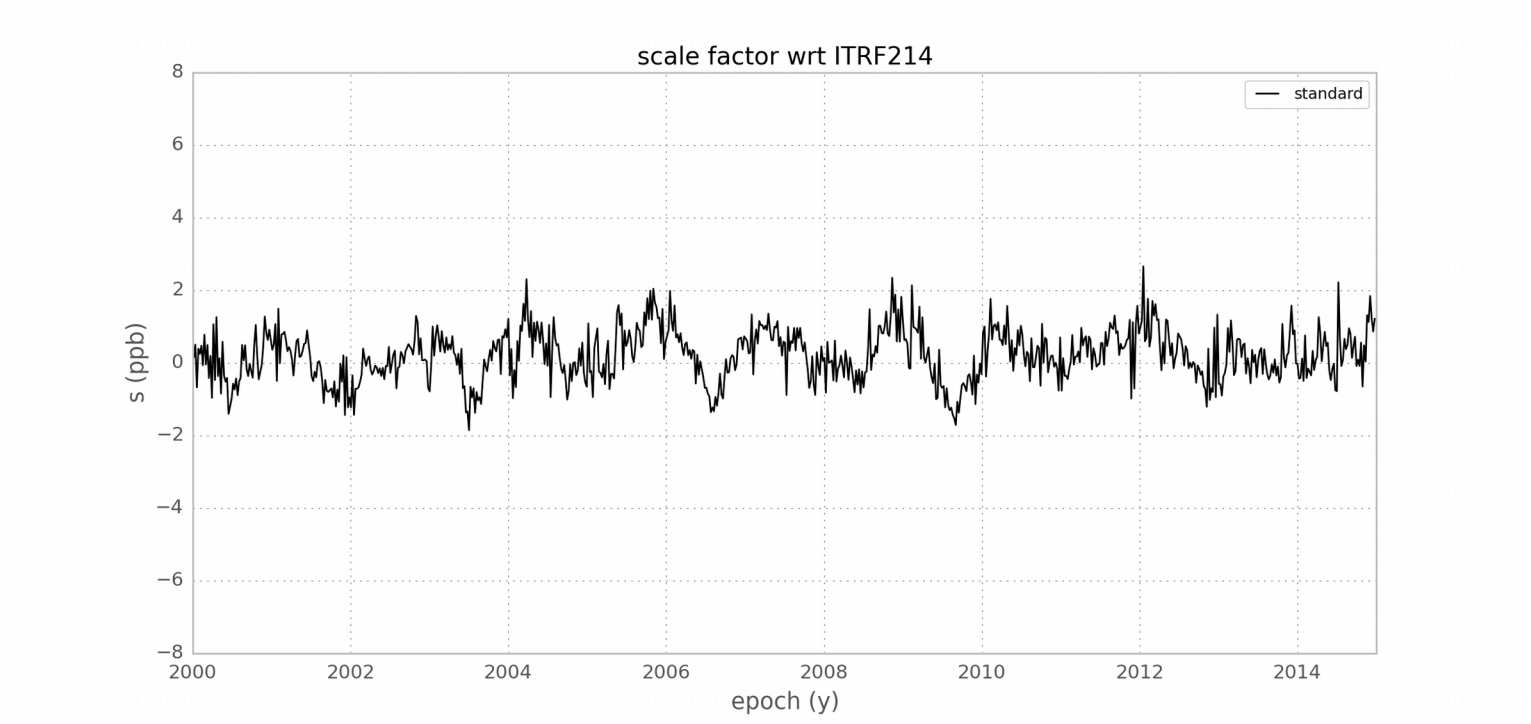


Yearly weighted averages of LAGEOS and LARES RBs



Consistent RB differences for many stations

Consequence: frame scale change



Scale factor time series of previously computed solutions (L1 + L2)

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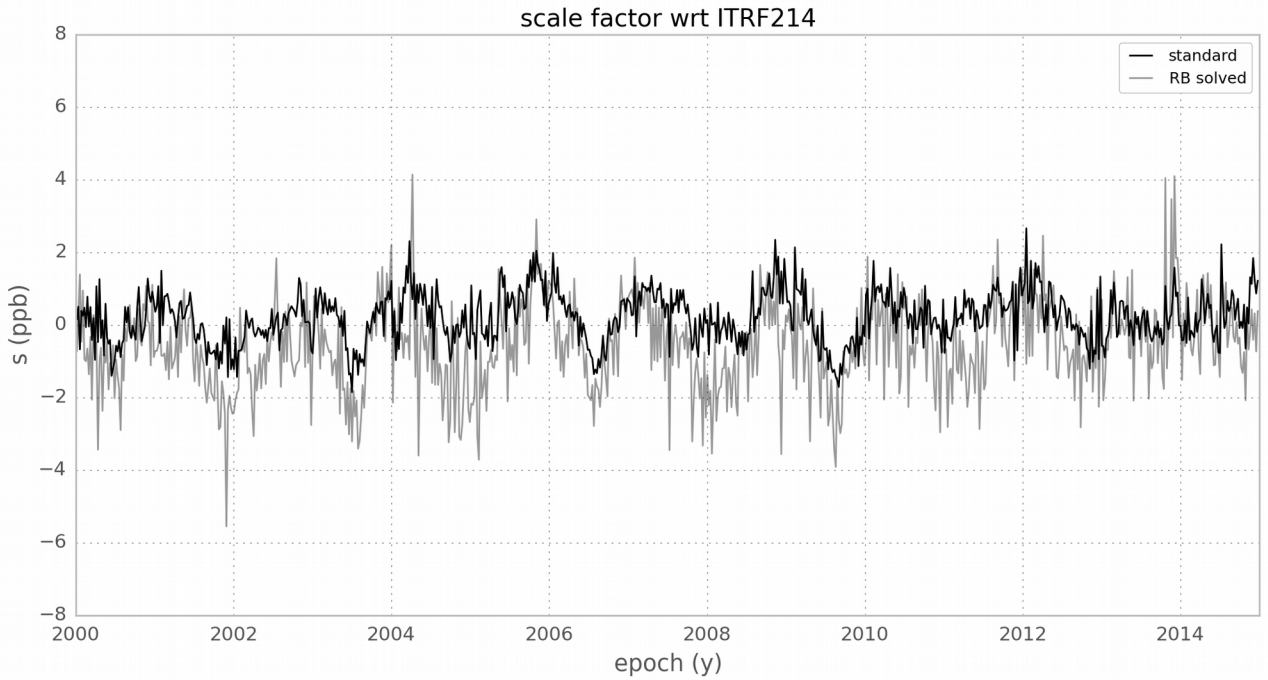

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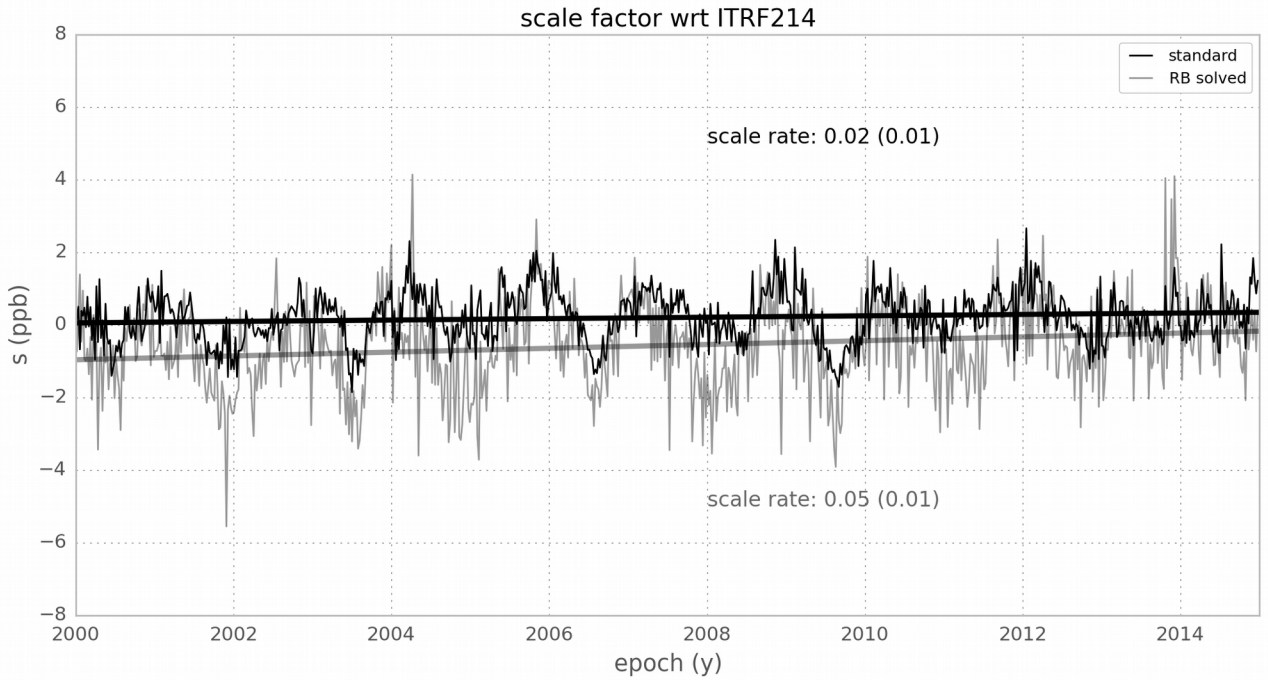
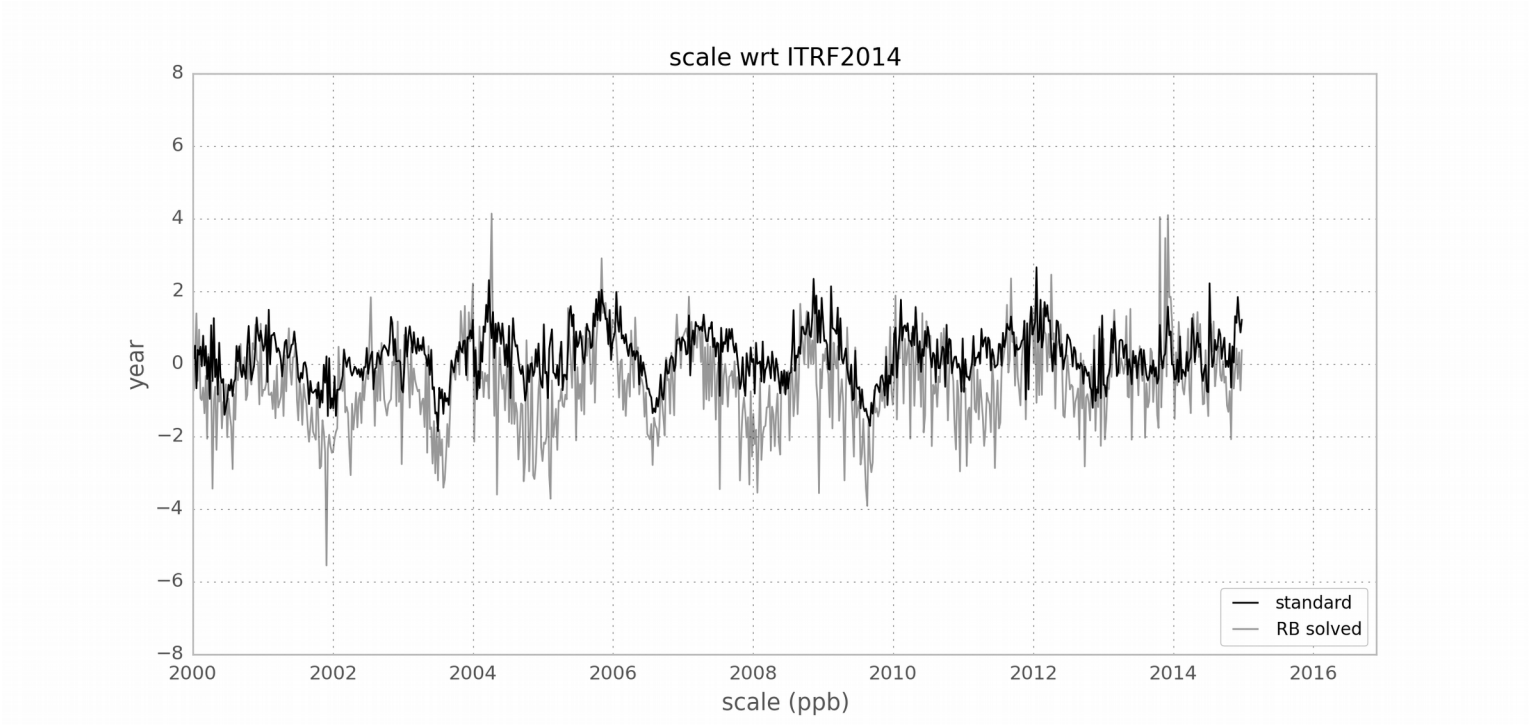
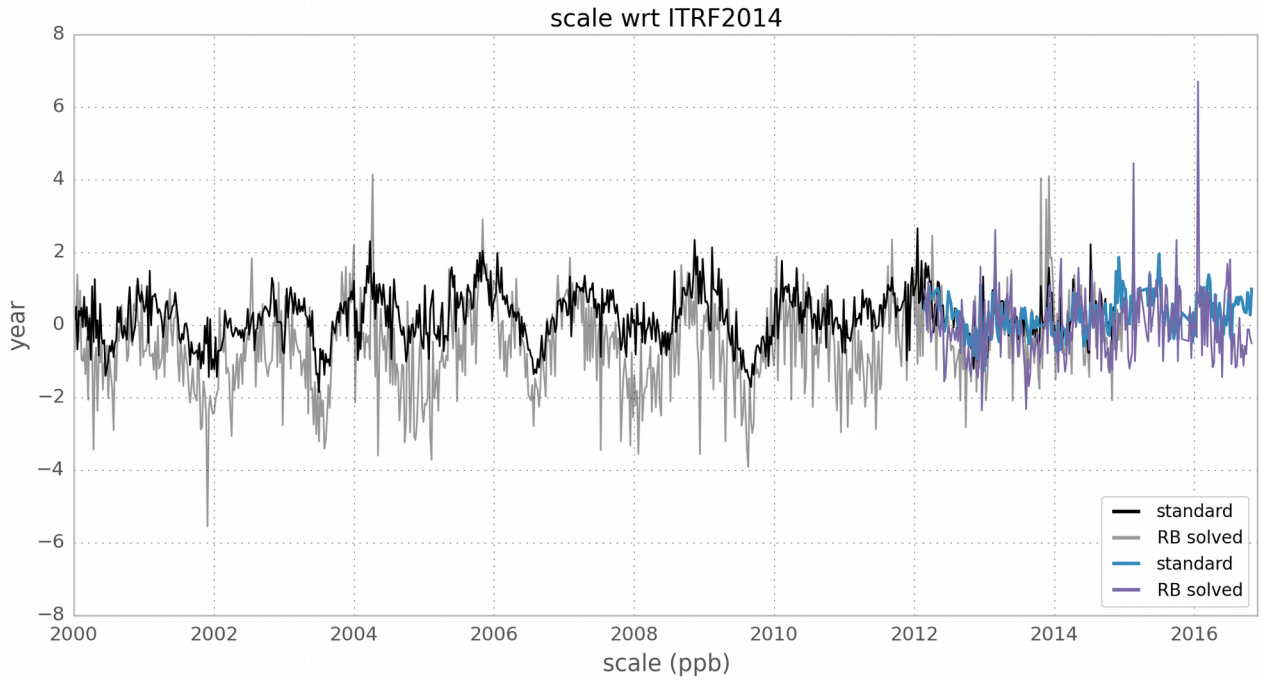


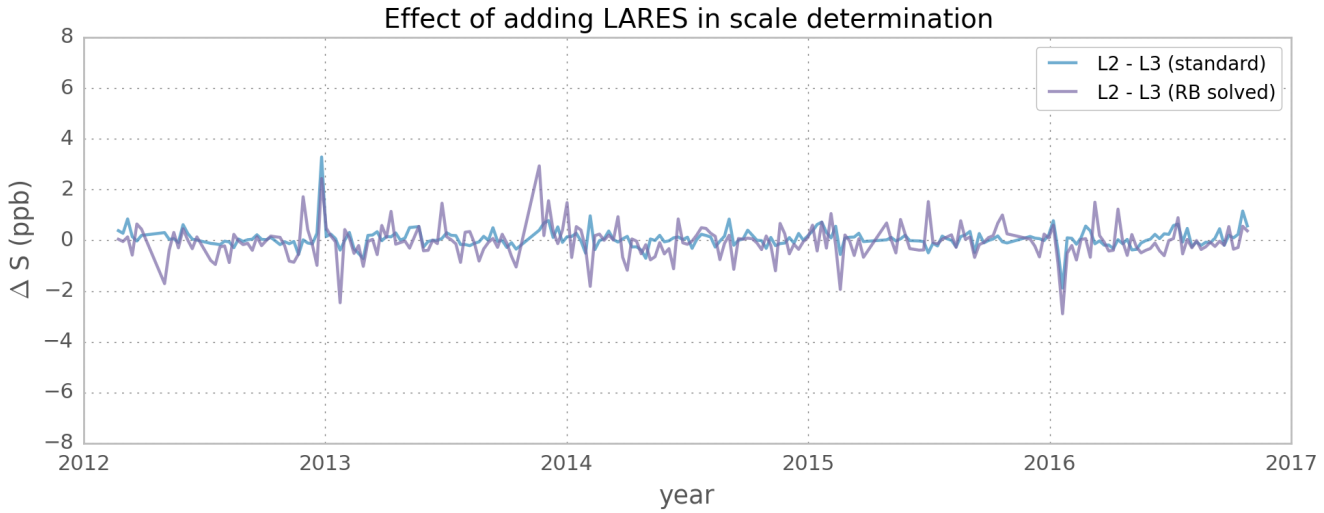
- Approximate scale difference between standard and RB solutions = 0.75 ppb
- Possible convergence of series towards end of the time period?



- What does the new data suggest?



- What does the new data suggest?
- Different solution types agree better in the later years: less biases in the network



- Negligible difference between L2 (LAGEOS 1+2) and L3 solutions (+LARES), both for standard and RB solutions: no scale discontinuities expected upon addition of LARES in the operational products

Conclusions

- Lack of accomodation of systematics in reference frame solutions impacts the SLR-determined scale
- RB can explain up to half of this long-standing discrepancy between SLR and VLBI (1.37 ppb in ITRF2014
- At the station level several factors can be at work:

  - technology based

  - model based (correction from laser reflection on geodetic sphere to centre of mass of satellite
- Study of multiple satellites helpful to reveal causes underlying errors
- Adding LARES to dynamical solutions confirms previous results
- Results for many stations suggest a) presence of errors at a few mm level not attributable to hardware issues; b) consistent CoM differences indicating possible CoM mismodeling (also seen in Etalon results)

Thank you