ILRS QCB Meeting

February 23, 2021

Agenda

- Update on the ILRS contribution to the ITRF - Erricos
- Simosato Performance
  - Quick Comments on Simosato and CoG updates. Jose
  - Review on Simosato data - Van and Pater
- Discussion
- Recommendation on minimum NP content
- Discussion on replacing NP rms with stability.

Quick comments on Shimosato
&
CoG updates

IGN/Yebes ASC

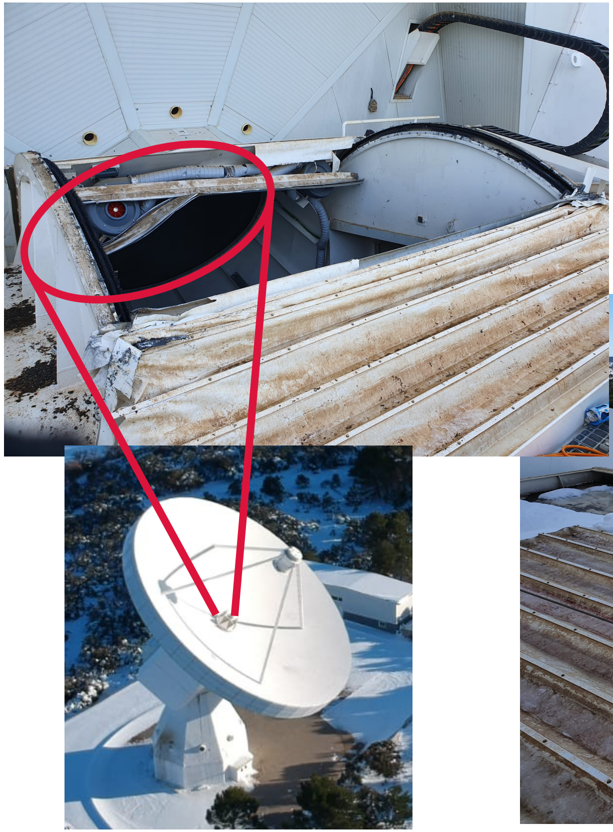
José Rodríguez

ILRS QCB 2021-01-19

But first: beautiful snow

More beautiful snow

Some nasty snow too

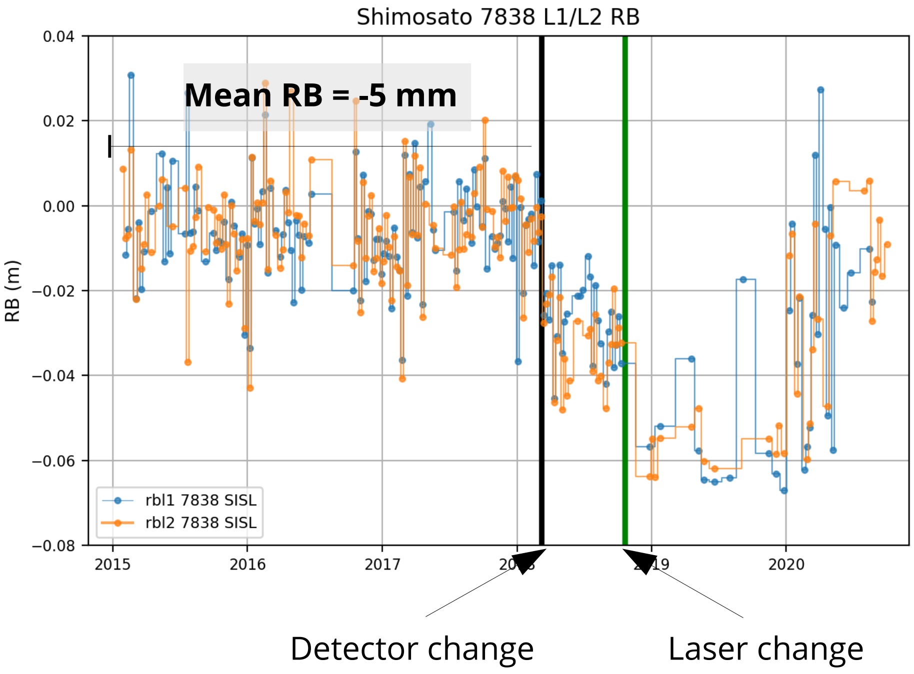


Blinds covering detector cabin through EL movement wrecked

Anyway, just a few comments inspired by the more detailed slides from Van Husson, from the CoG modelling perspective…

Shimosato biases

No CoM value change since 2009. Some breaks coincide with changes detailed in system log



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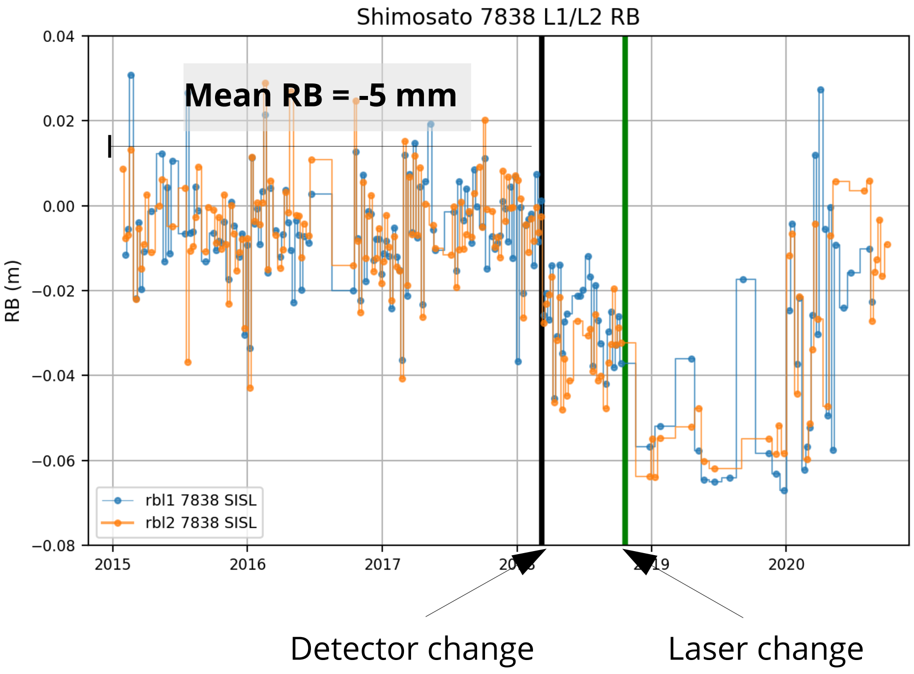


BUT, in terms of CoM modelling:

-New **detector** can not explain over 2 cm drop

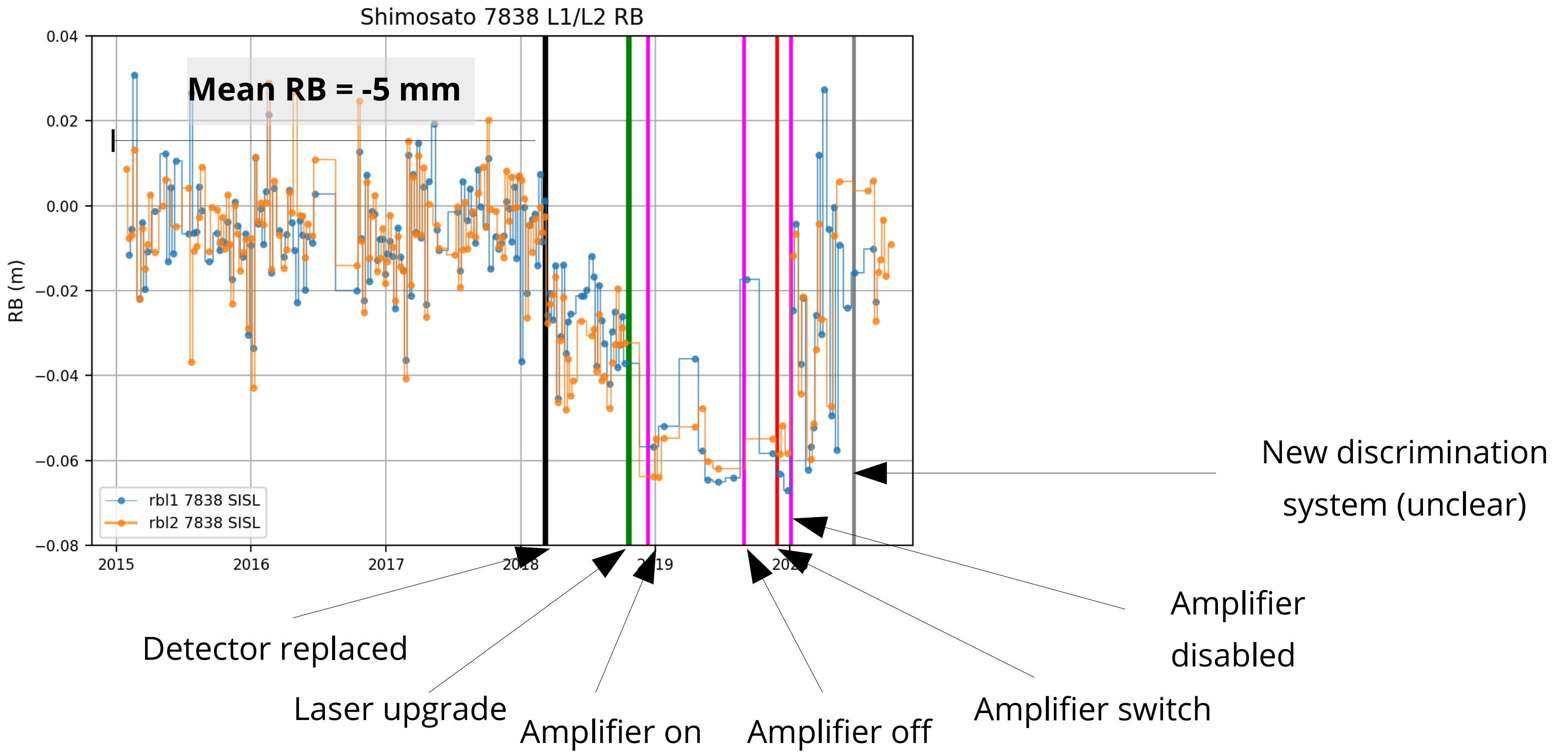
They have the same features according to log, and in any case 2 cm is too big.

-New **laser** can not, on its own, explain over 2 cm drop

Essentially, 10 ps increase in pulse with, from 20 to 30 ps: very small change

Shimosato biases detected

More information in the history log, some of which likely have an impact on the measured ranges



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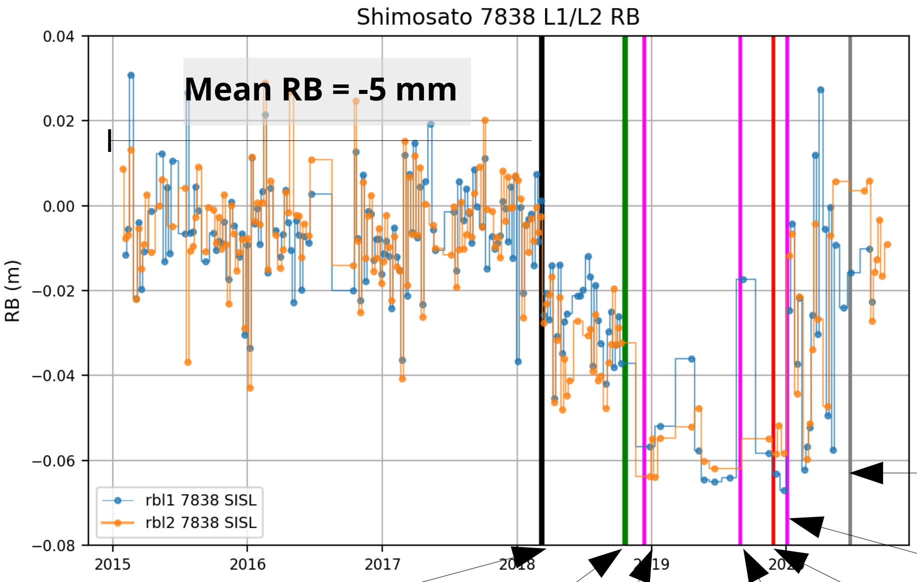


What causes what??

New discrimination system (unclear)

Amplifier disabled

Detector replaced

Laser upgrade

Amplifier on

Amplifier off

Amplifier switch

Notes

- For CoM modelling nominal operation always assumed. Also, other system changes are irrelevant
- Possibility: station engineers are still tuning the laser performance: very low intensity could indeed contribute to the jump observed (V.Husson's slides relevant)
- CoM model takes into account return rate *under normal operation* (still to do for Shimosato)
- Amplifiers are *not* modelled at the moment
- I commend Shimosato staff for their detailed records and recent quick response to update the logs

- This is a perfect example of why the new ASC analysis strategy is in place. What we can't currently model, we estimate
- Reviewing **7124 Tahiti**: similar problems with multiple concurrent configurations arise (amplified chain)
- Reviewing **7396 JiuFeng**: pending minor update to most recent value (2020-09-01)

Instituto Geográfico Nacional
Centro Nacional de Información Geográfica

Some answers regarding CoM tables

IGN/Yebes ASC

José Rodríguez

2021-02-23

Things *included* for CoM modelling

- Cube corner retroreflector physical characteristics (material, size, recess depth)
- Retroreflector array geometry (individual CCR positions and orientations)
- Laser pulse length and frequency
- Photodetector type and characteristics (jitter, and rise time if multi-photon)
- Timing device precision
- Operation policy (single-photon/everything else)
- Average return rates

Things *adjusted* for CoM modelling

- Average **optical properties** of retroreflector array
  - Includes aberration and thermal effects and deviations from perfect geometry (or CCR spoiling)
  - How? → from millions of strictly single-photon data points from Herstmonceux
  - Does it work? → YES

- **Discriminator settings** for multi-photon operation and PMT/MCP detectors
  - How? → Manually, on the basis of best agreement between simulated and empirical width of detection distributions
  - Nobody knows these values, and they change if station engineers tweak settings
  - Does it work? → I wouldn’t bet my mortgage on this (but confident things are good for LAGEOS)

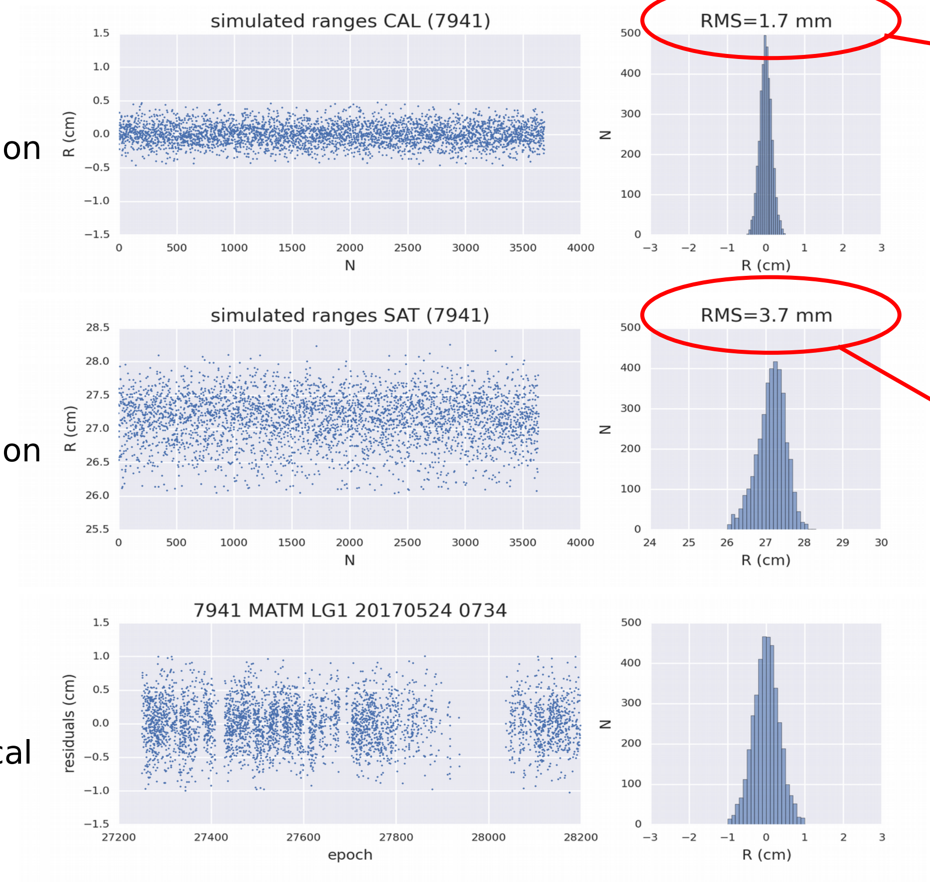
From Rodríguez et al. Updated CoM tables […], Canberra, 2018

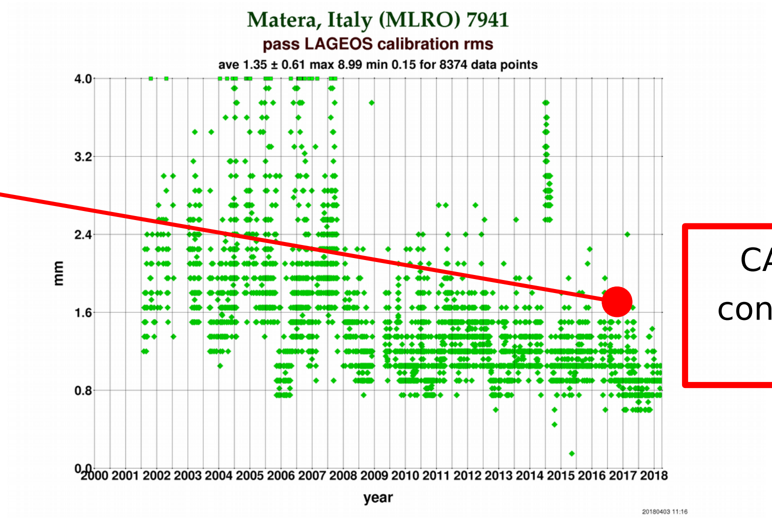
3. CoM computation

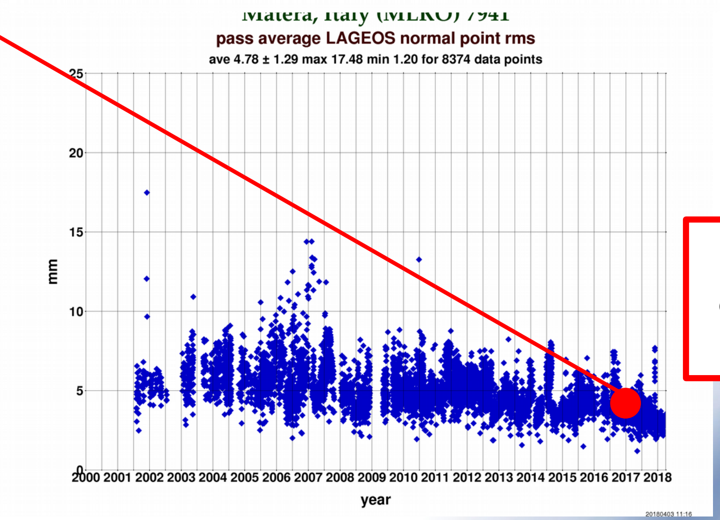
CAL simulation

SAT simulation

SAT empirical







CAL RMS consistency ?

SAT RMS consistency ?

Things *not included* for CoM modelling

- Laser polarisation
- Presence of other devices in the detection chain, like amplifiers
- Contribution to electrical signals spread caused by e.g. cabling
- Effects of not calibrating with identical setups to those used for satellite ranging
- Gross deviations from stated operational policy
- Any divergence from nominal operation (as detailed in system logs)
- Any deviation from stated data reduction policy
- Any other undocumented shenanigans

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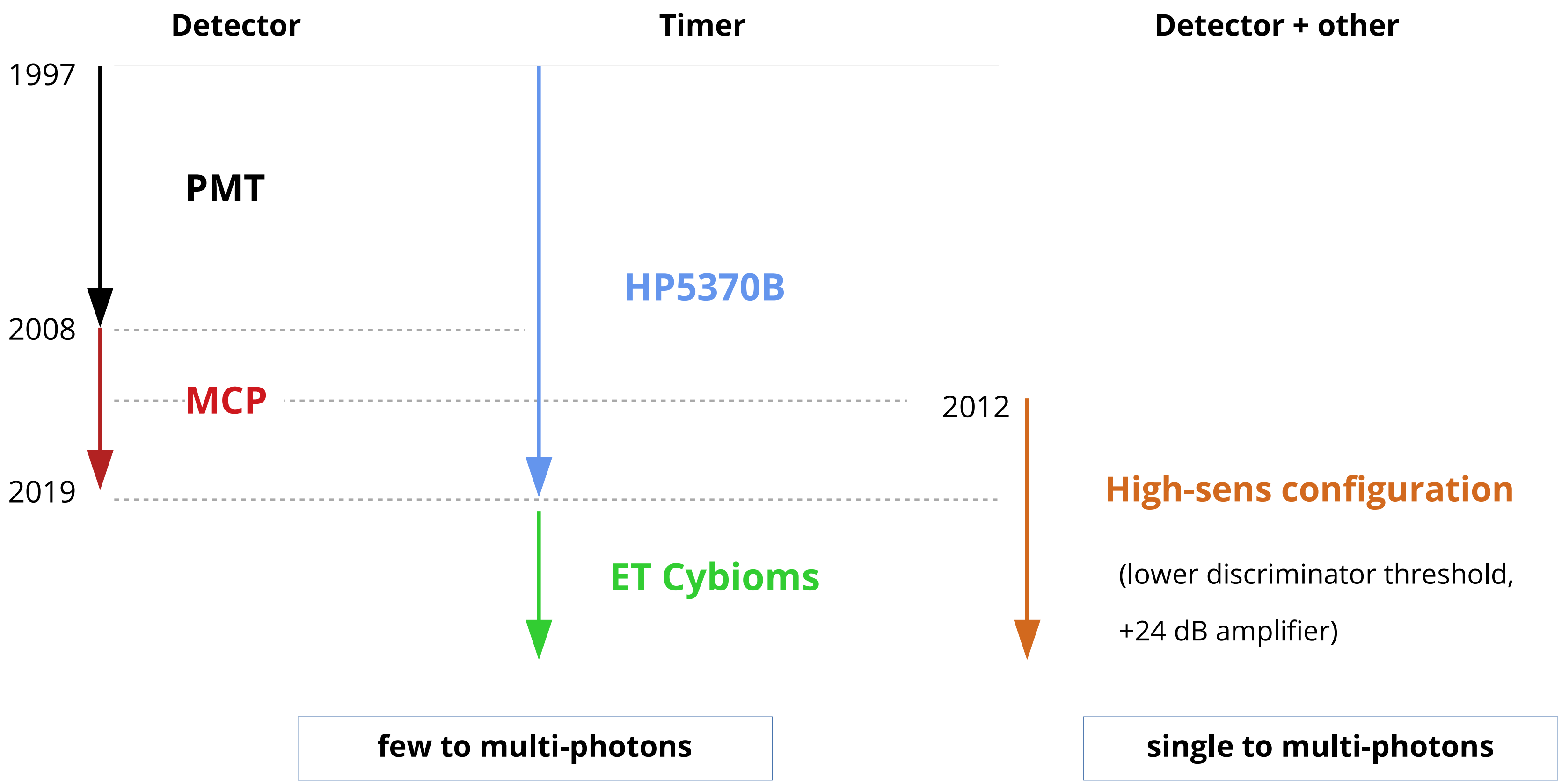
All these fascinating phenomena have been observed in the wild

An example of tricky situations: Tahiti 7124



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- Not possible (as far as I know) to tell which configuration was in use (let alone calibration):

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h1 CRD  1 2021  2  5 12
h2 THTL       7124  8  2 3
h3 cryosat2     1001301 8006       -1 0 1
h4  1 2021  2  5 11 23 43 2021  2  5 11 29 14  0 0 0 0 1 0 2 0
c0 0  532.000 std la1 mcp til
c1 0 la1 Nd:Yag      532.00      10.00     100.00  150.0 15.00    1
c2 0 mcp MCP-PMT     532.000  12.0 2800.0  31.0 analog 400.0  1.00  80.0 30.00 none
c3 0 til Truetime_XLDC Truetime_XLDC Cybi_ETM na   -1.0
60  std 7 1
```

```
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h3 glonass129  1106402 9129       -1 0 1
h4  1 2021  2  5 10 44 48 2021  2  5 11  1 40  0 0 0 0 1 0 2 0
c0 0  532.000 std la1 mcp til
c1 0 la1 Nd:Yag      532.00       4.00     100.00  150.0 15.00    1
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60  std 7 1
```

Detector configuration ID is useless: not implemented in the site log.

Therefore, not possible to match CoM values on its basis.

Plus, it is used inconsistently by stations.

Additional questions to consider

- Before the plethora of system configurations, the CoM tables have been generated focusing on LAGEOS and LAGEOS-2
- Modelling tweaks are possible, but unclear how to put into practice (e.g. how was *this* NP collected?)
- Only some of these potential issues were considered to assess the uncertainty of the values provided

Additional questions to consider

- Before the plethora of system configurations, the CoM tables have been generated focusing on LAGEOS and LAGEOS-2
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Sensitivity analysis

Total range:

	LAG	ETA	LAS	STR	AJI
STA1	2.3	7.2	2.4	3.5	35.2
STA2	3.0	5.0	1.5	1.6	9.0
STA3	1.4	4.8	1.0	1.5	4.0

Max error pessimistic case: 1-3 mm small targets and LAGEOS
5-10 mm Etalon
10-30 mm Ajisai

Comparison of computed and empirical distributions indicates situation is much better

None of this informs us about whether models are fundamentally flawed somewhere

Rodríguez. CoM accuracy and sources of errors, UAW Paris, 2019

Thank you

LAGEOS-2 and LAGEOS-1 Range and Time Biases Differences

Van S Husson
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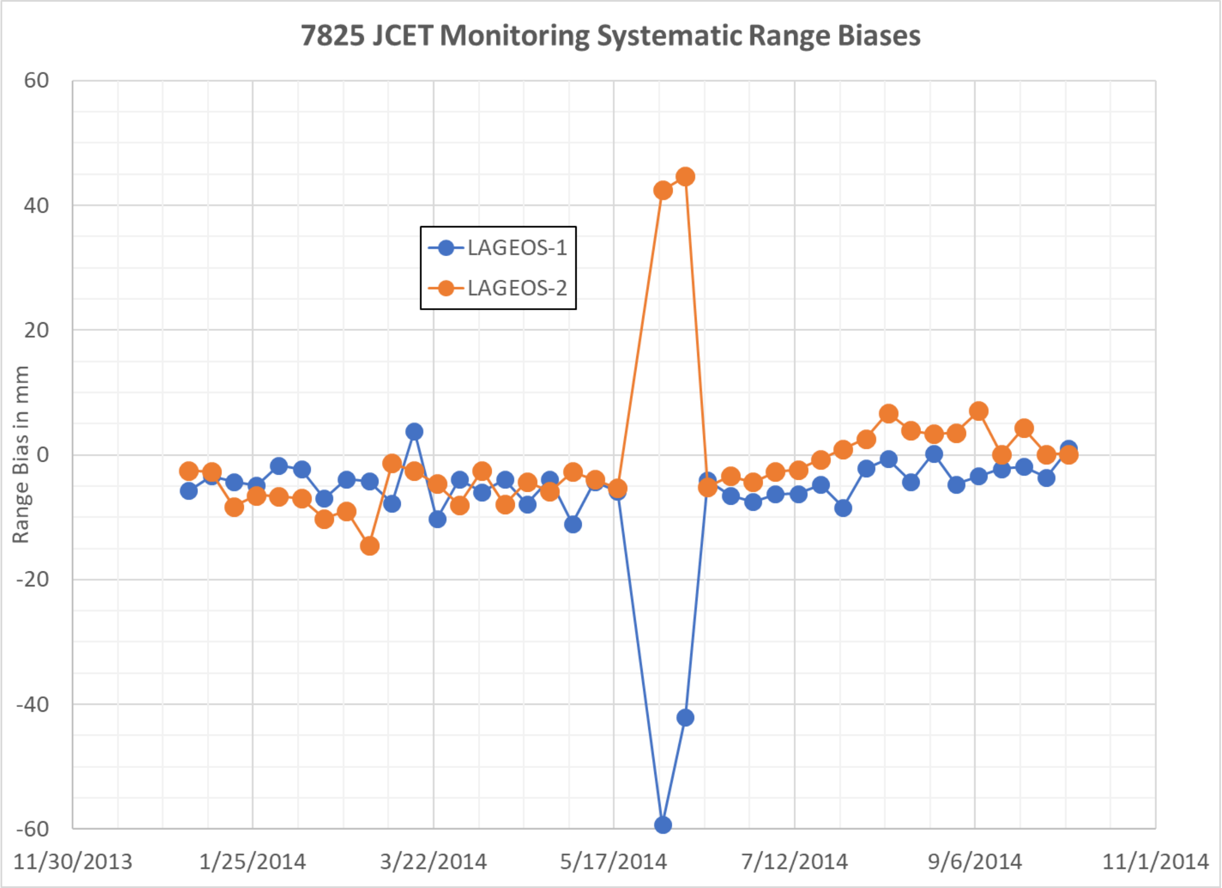
ILRS Quality Control Board

LAGEOS-1 and -2 Range Bias Differences

- From orbital analysis, LAGEOS-2 range biases estimates are typically a few mm longer relative to LAGEOS-1 from the best performing stations
- Analysis of 7840 Herstmonceux full-rate data has shown the residual trends are different between the two LAGEOSs (i.e. Peter Dunn's totem pole analysis)
- Stations have been reporting that LAGEOS-2 returns are weaker than LAGEOS-1 returns, but the reverse use to be true
- Jose's new Center of Mass corrections account for some of this difference (see sample table below)
- Where is the rest of the difference coming from?
  - Is this a station calibration issue;
  - Is this in the modeling of the orbits;
  - Is this a combination of effects; or
  - Is this something else?

Station	Jose CoM (L1-L2) Differences in mm
7840	0.7
7839	0.1
7105	0.4
7501	0.6
7090	0.9
7825	0.8

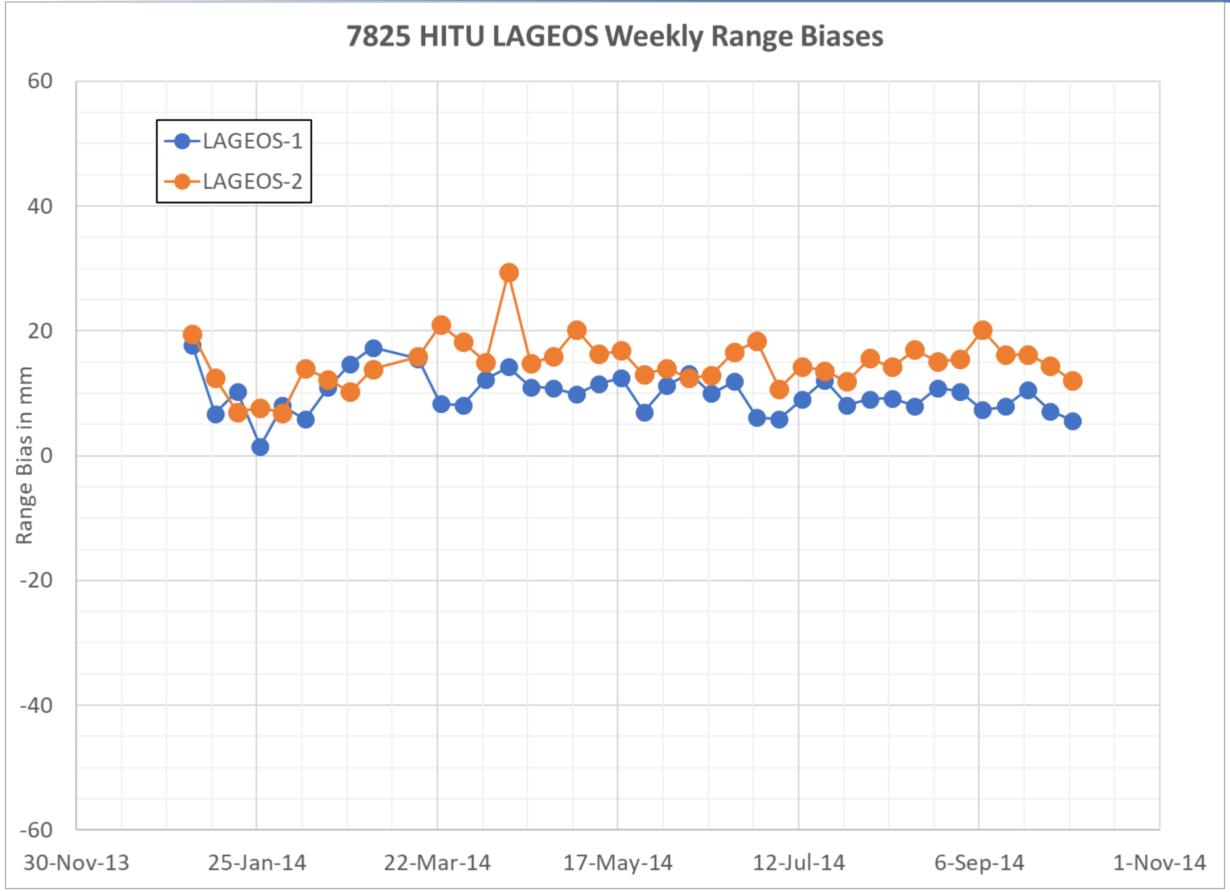
7825 2014 JCET Weekly LAGEOS Range Biases

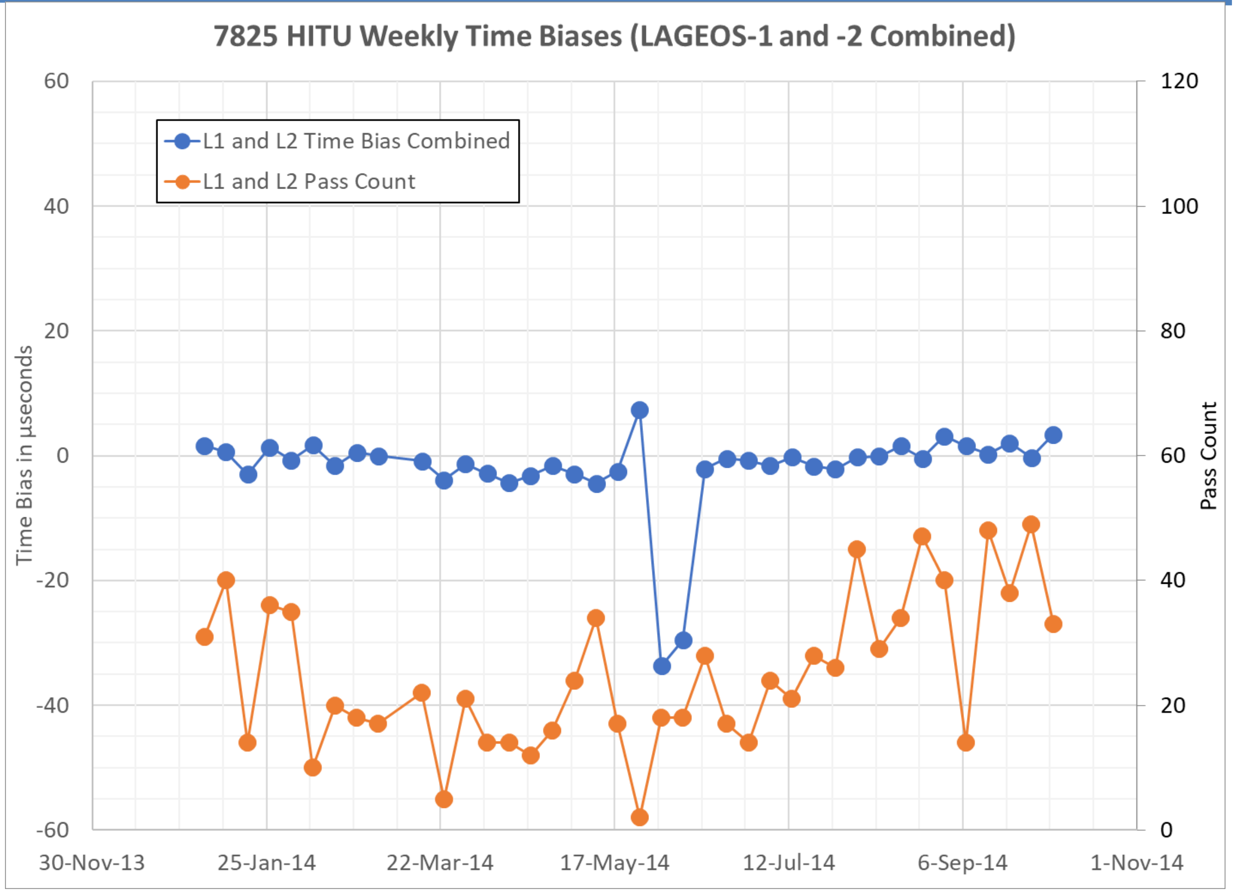


- Between June 3 and 15, 2014; Mt Stromlo (7825) had a 31 μsecond time bias based on HITU bias analysis (see next slide)
- The7825 data was in quarantine during this period, so it was not in the T2L2 analysis, and it was NOT documented in the ILRS Data Handling File
- This unmodeled time bias induced an apparent 93 mm delta range bias between LAGEOS-1 and LAGEOS-2
- The LAGEOS range rate is 3 mm per μsecond which is identical to this ratio (93 mm / 31 μsecond, i.e. 3:1)

Reference: JCET weekly biases from http://geodesy.jcet.umbc.edu/BIAS_W_SLRF2014_JCETDB/configuration.php

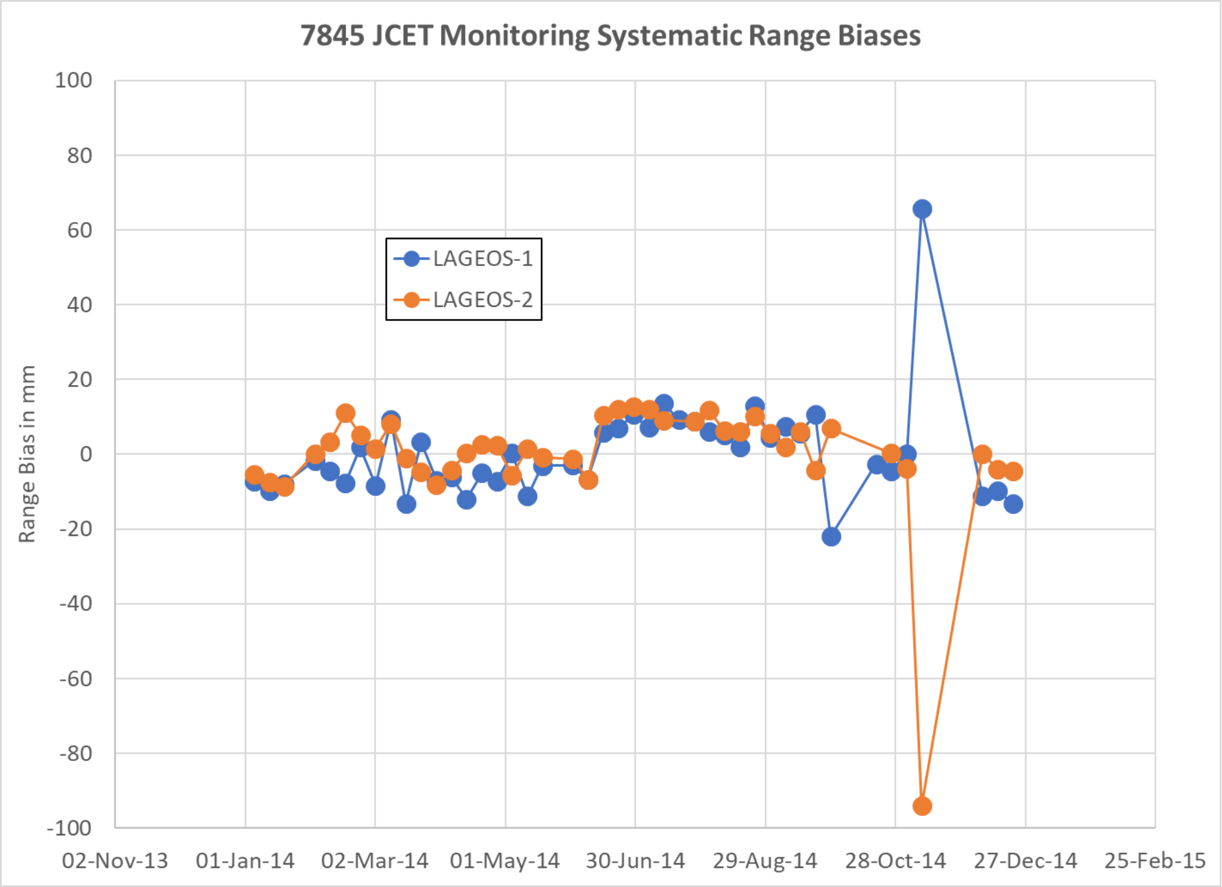
7825 HITU LAGEOS Weekly Range & Time Biases





- Reference: HITU pass-by-pass biases from http://geo.science.hit-u.ac.jp/slr/bias/
- HITU pass-by-pass results aggregated weekly. In pass-by-pass analysis, a range bias is computed for each pass after an along track error (i.e. time bias) has been estimated. This is why there is no apparent change in HITU range biases in the presence of the real 31 μsec time bias.

7845 2014 JCET Weekly LAGEOS Range Biases



- 7845 had a -61 μsecond time bias from 13-Nov-2014 to 22-Nov-2014 based on pass-by-pass results and confirmed by T2L2 analysis. This time bias is the reason why the weekly LAGEOS-1 and -2 range biases diverge on the chart on the left, since only a range bias is estimated.

Station Time Biases and Along Track Errors

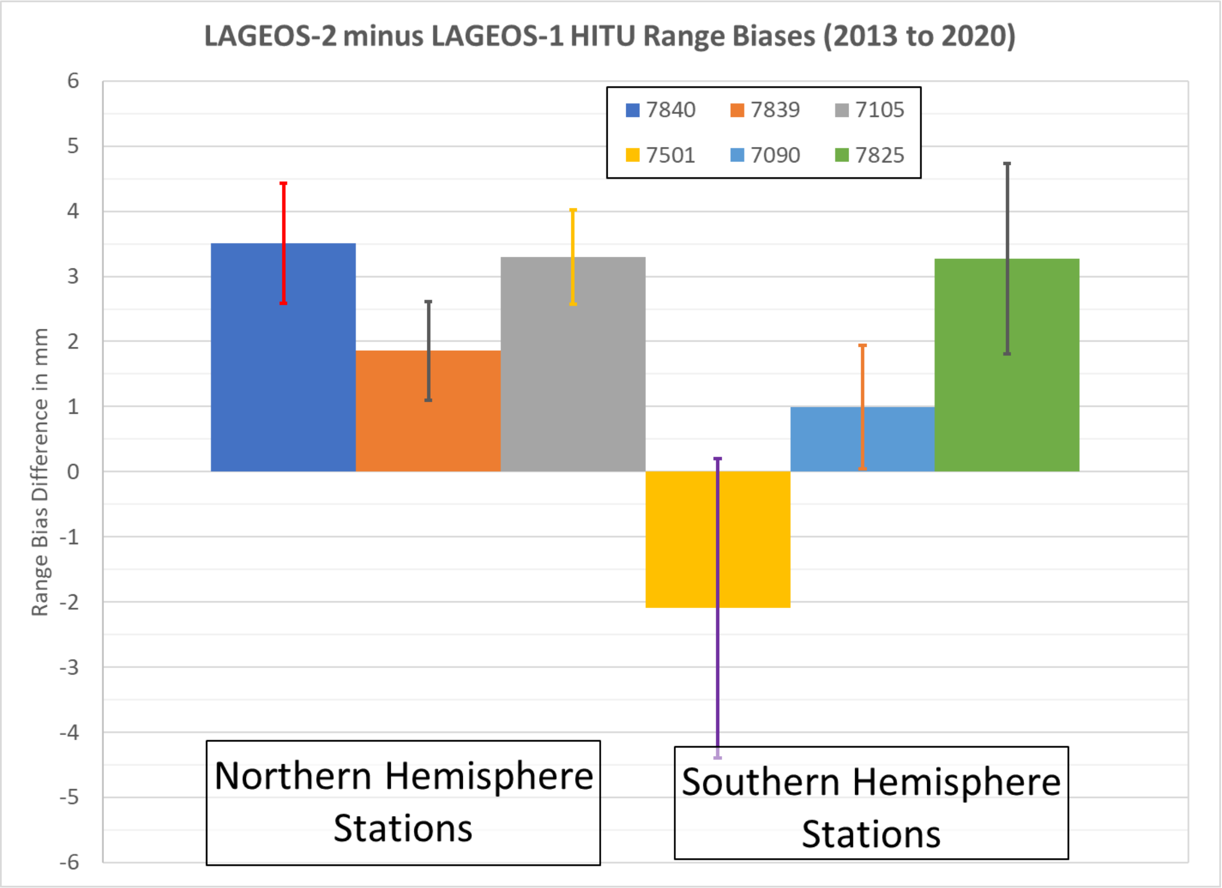
- Real station time biases can cause 'apparent' LAGEOS-1 and -2 range biases differences when only range biases are estimated.
- Hypothetically in the weekly coordinate solutions, if every ILRS station had a constant +0.5 μsecond time bias, it could explain a 1.5 mm difference between LAGEOS-1 and -2 range bias estimates, with LAGEOS-2 range biases more positive.
- Now let's investigate LAGEOS-1 and -2 range bias and along track error estimate differences from pass-by-pass results from six of the higher performing stations, three from each hemisphere.

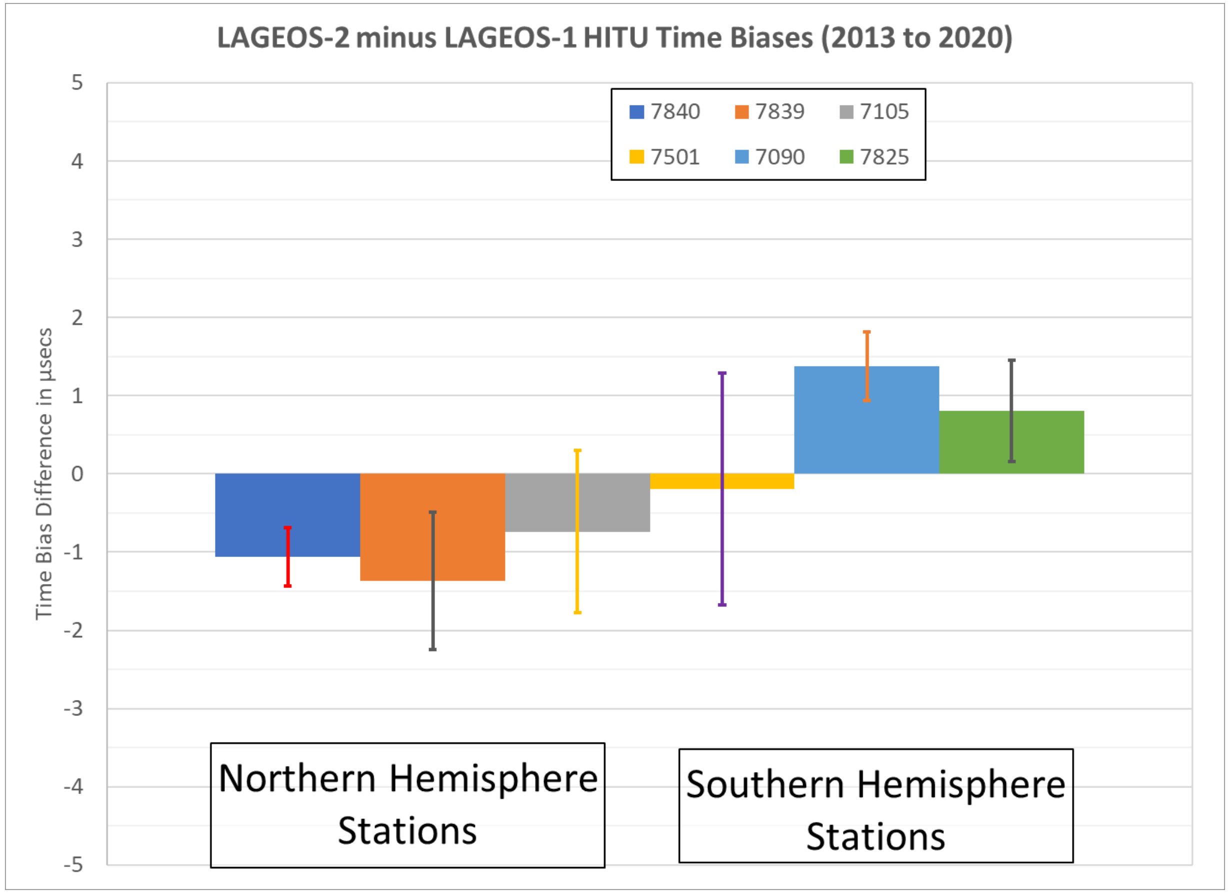
LAGEOS HITU Range and Time Bias Differences

- Analyzed HITU LAGEOS-1 and LAGEOS-2 pass-by-pass range and time bias results from 2013 to 2020 (8 years).
- Two different HITU coordinate sets were used
  - ITRF2008: used on CRD data between Jan 2013 to Jun 2017
  - ITRF2014: used on CRD data after Jun 2017
- For each year and system, a mean range and time bias for each LAGEOS was computed and then differenced. Then the yearly results were aggregated over the 8 years: Below is a table of the aggregated yearly results:
- See next slide for a chart of results

Hemisphere	Station	L2-L1 RB (mm)	L2-L1 RB Std(mm)	L2-L1 TB (µs)	L2-L1 TB Std(µs)
North	7840	3.5	0.9	-1.1	0.4
North	7839	1.9	0.8	-1.4	0.9
North	7105	3.3	0.7	-0.7	1.0
South	7501	-2.1	2.3	-0.2	1.5
South	7090	1.0	0.9	1.4	0.4
South	7825	3.3	1.5	0.8	0.6

HITU Aggregate LAGEOS Range & Time Bias Results





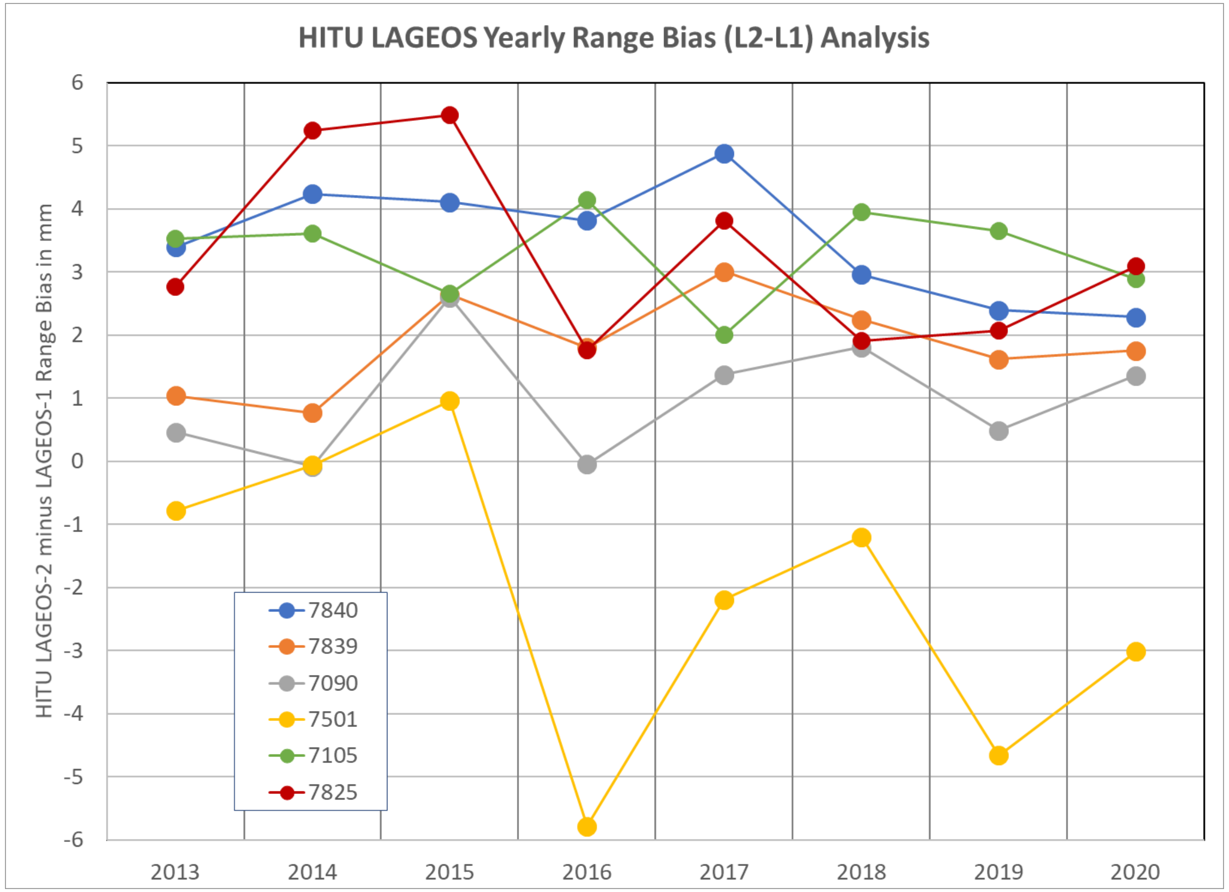
- Note: In the HITU analysis, LAGEOS-1 and -2 CoM corrections are identical for a given system
- There appears to be a systematic difference in the along track error between sites in the two hemispheres

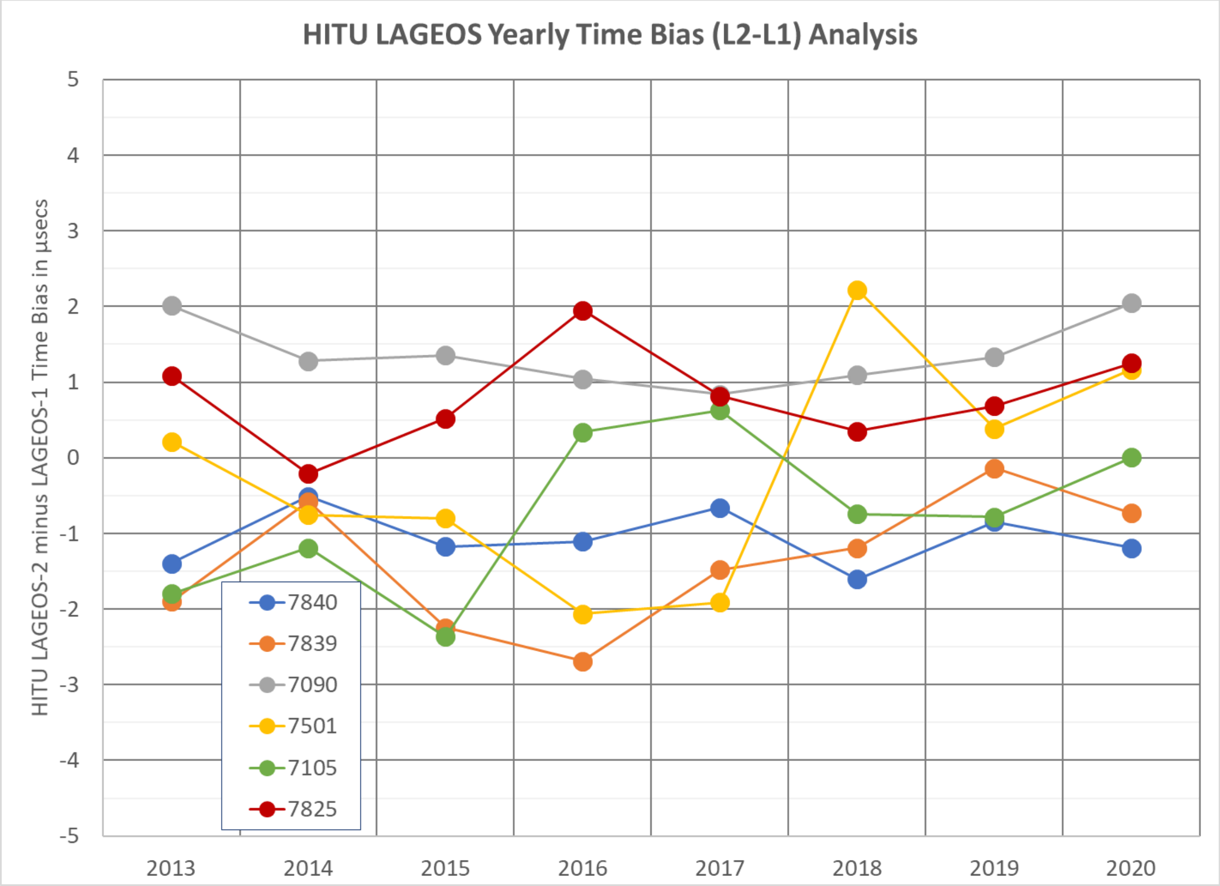
Conclusions/Summary/Questions

- Action: Add a +31.4 μsecond time bias for 7825 to the ILRS Data Handling File.
- Prochazka has recommended reducing all systematics errors to less than 1 mm in order to achieve 1 mm absolute accuracy.
  - Less than 100 nanosecond epoch error would induce an apparent range bias difference of less than 0.3 mm between LAGEOS -1 and -2.
- If there is a less than or equal to a 1 μsec systematic error in the along track error between the LAGEOS satellites, which is not estimated in the weekly coordinate solutions, can a systematic range bias be induced at the mm level?

BACKUP Material

HITU Aggregate LAGEOS Range & Time Bias Results





Yarragadee Aggregate Analysis by Hour