Accuracy Improvement to SLR Network Stations from Reference Frame Analysis

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The ITRF2020 Reference Frame Analysis includes estimates of non-geodetic signals in the SLR observations.

Interpretation of these signals and the resulting data handling refinements yield improved orbit and station positioning.

It has been established in recent work (Appleby, Rodriguez and Altamimi, JG 2016) that most stations in the ILRS network exhibit millimeter-level systematic errors.

Each of the three types of SLR sites (Microchannel Plate (MCP), Single Photon (SP), and Compensated SP Avalanche Diode (C-SPAD)) exhibit different characteristics (Couhert et al., JG 2020).

ILRS requirements to maintain high quality SLR data include the ability to perform extensive tests on-site (Otsubo and Genba, 13th. Int. Laser Ranging Workshop, 2002).

Core ITRF SLR stations, including the NASA Mobile and Transportable MCP Systems, regularly monitor electronic characteristics for each satellite pass.

Data features exceeding error specifications can be defined with close consideration of known engineering variables.

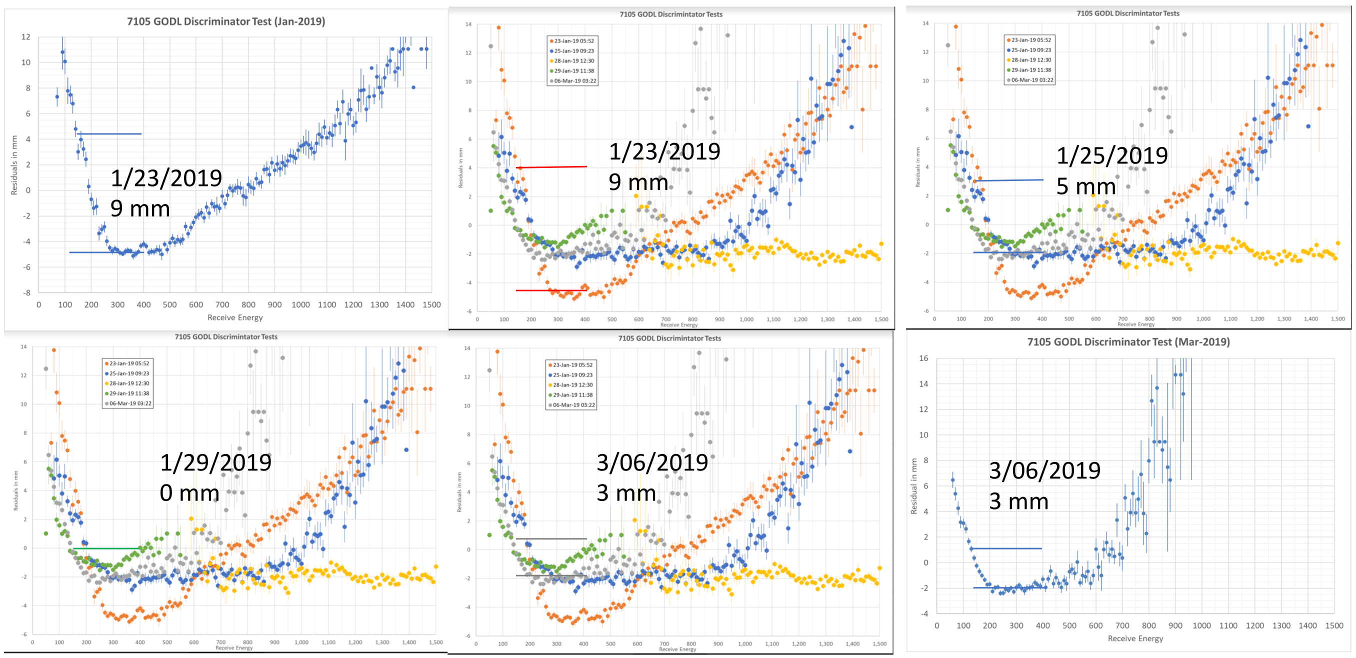
This paper will discuss current accuracy for core stations and system development in the ILRS Network to maintain the millimeter requirement for geodynamic measurements.

Non-geodetic Signals which affect Orbit and Station Positioning

- **Microchannel Plate (MCP): GGAO (GREENBELT, MD)**
  - Discriminator time walk
- **Compensated SP Avalanche Diode (C-SPAD):GRAZ AUSTRIA**
  - Profile Clipping
- **Single Photon: HERSTMONCEUX UK**
  - Return signal profile
  - Time Interval Unit (TIU) non-linearities
- **Common to each system:**
  - Horizontal target survey error
  - Optical path filter delay

Discriminator time walk at GGAO, Maryland(MOB7)

1/23/2019 to 3/06/2019

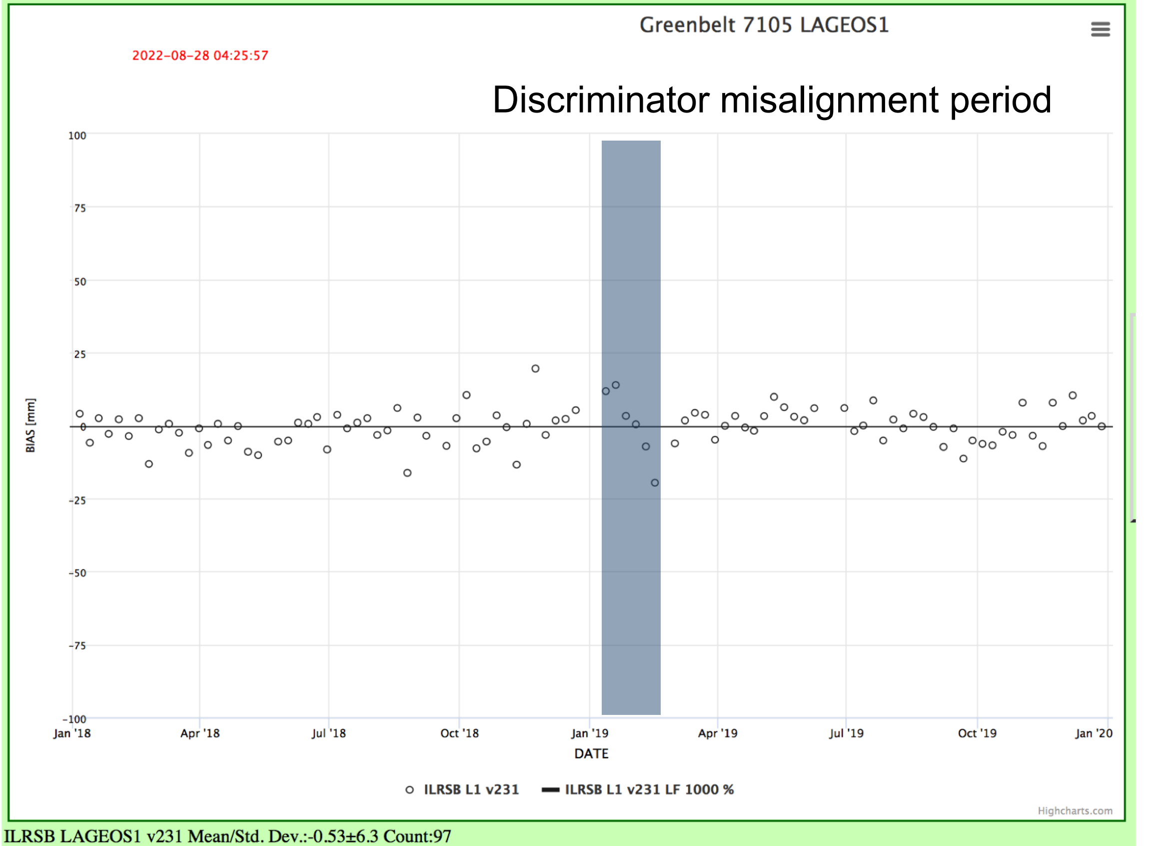


- **Time walk affects satellite receive energies lower than calibration target (400 units)**
  - range-dependent range biases at MOB7 in February 2019 vary from 0 to 9 mm

ITRF2020 SSEM Range Bias Estimates

- ITRF2020 SSEM Range Bias(RB) results can be found on the JCET website

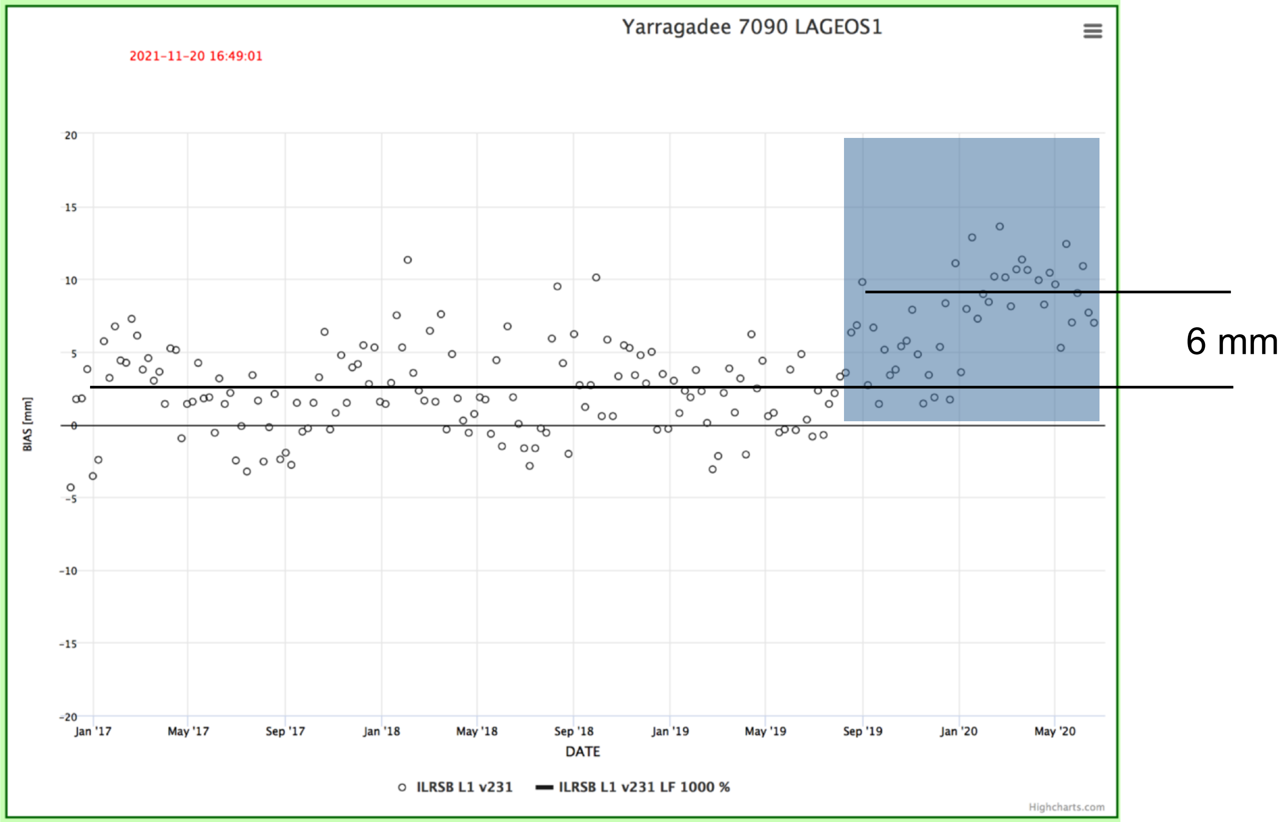
Observed discriminator time walk at GGAO



ILRSB LAGEOS1 v231 Mean/Std. Dev.:-0.53±6.3 Count:97

- ❑ **Occasional discriminator misalignment shows some short term RB variation**

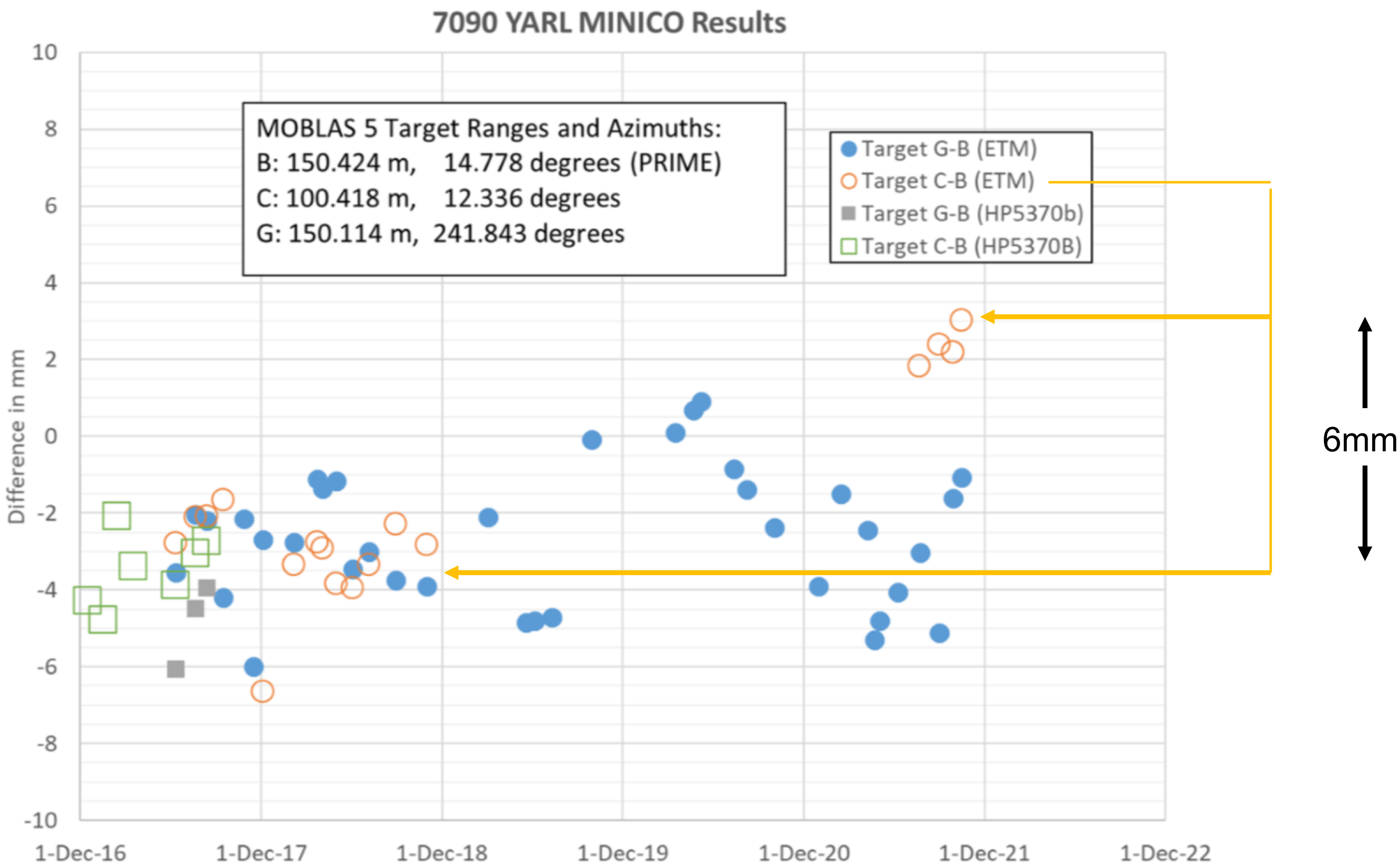
ITRF2020 Range Biases at Yarragadee, Australia (MOB5)



ILRSB LAGEOS1 v231 Mean/Std. Dev.:3.41±3.71 Count:185

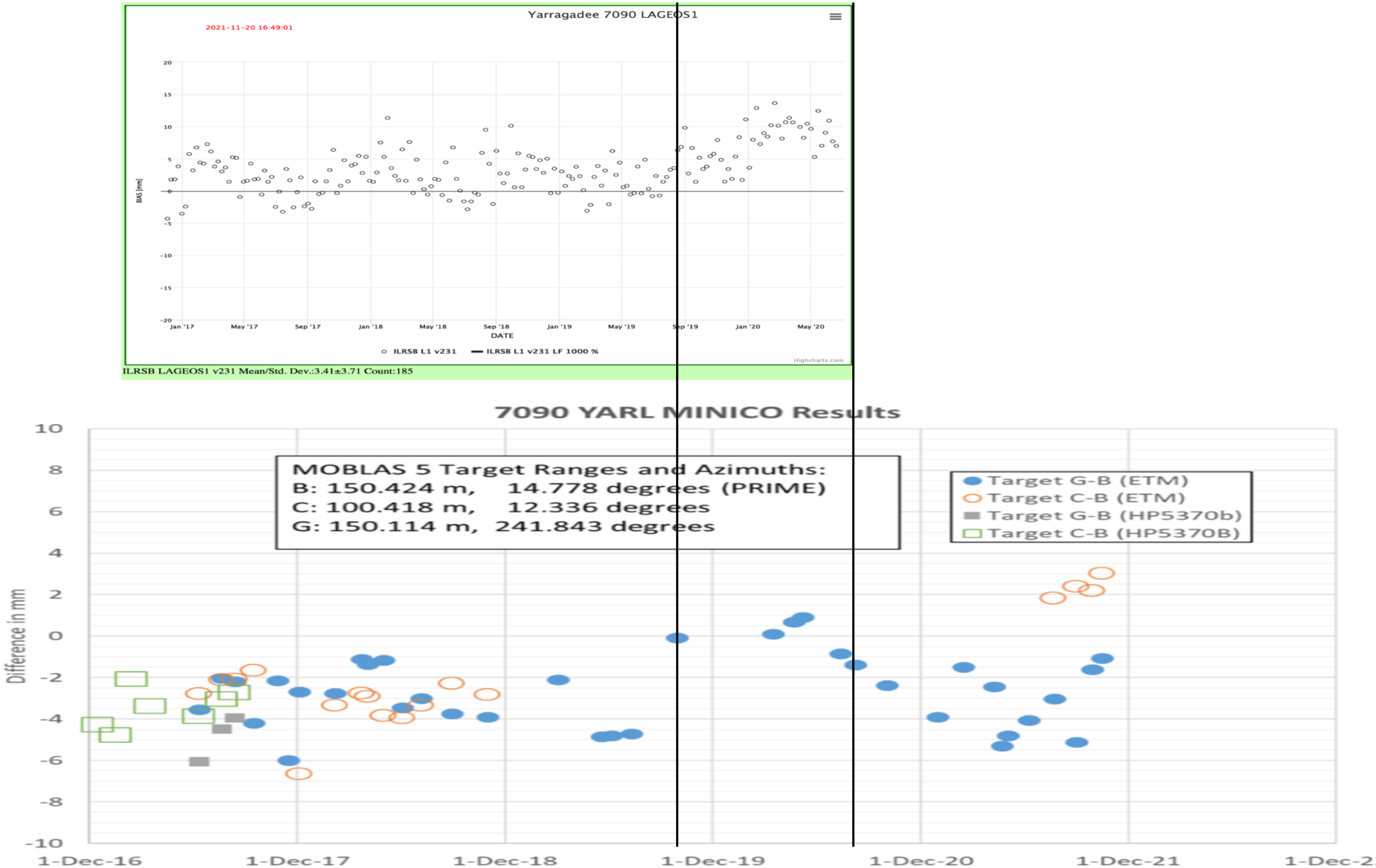
- **SSEM RBs show > 5mm offset in 2019**

Minico Results at Yarragadee, Australia (MOB5)



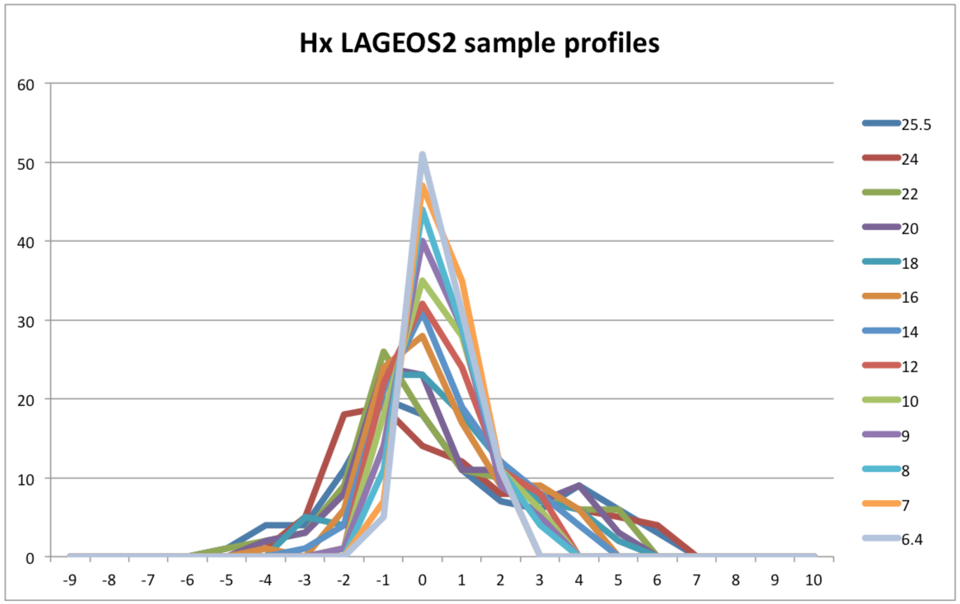
- ❑ **Multiple Target Ranging shows Target B moved 6 mm between 2018 and 2021**

SSEM Results at Yarragadee match Minico



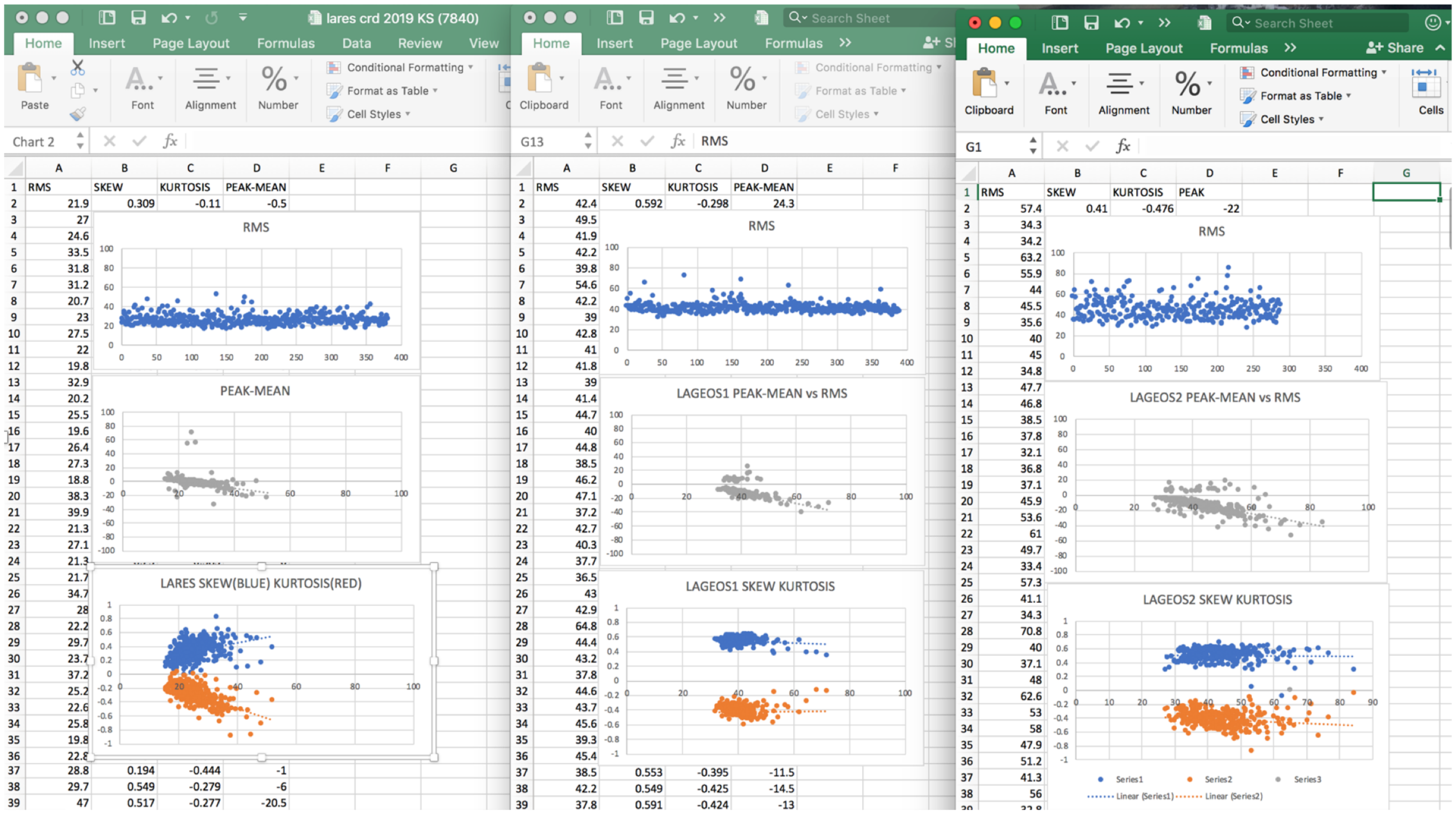
- Two 3 mm target B shifts between 2018 and 2021 are seen in the SSEM RB signal

Return Signal Profile at Herstmonceux



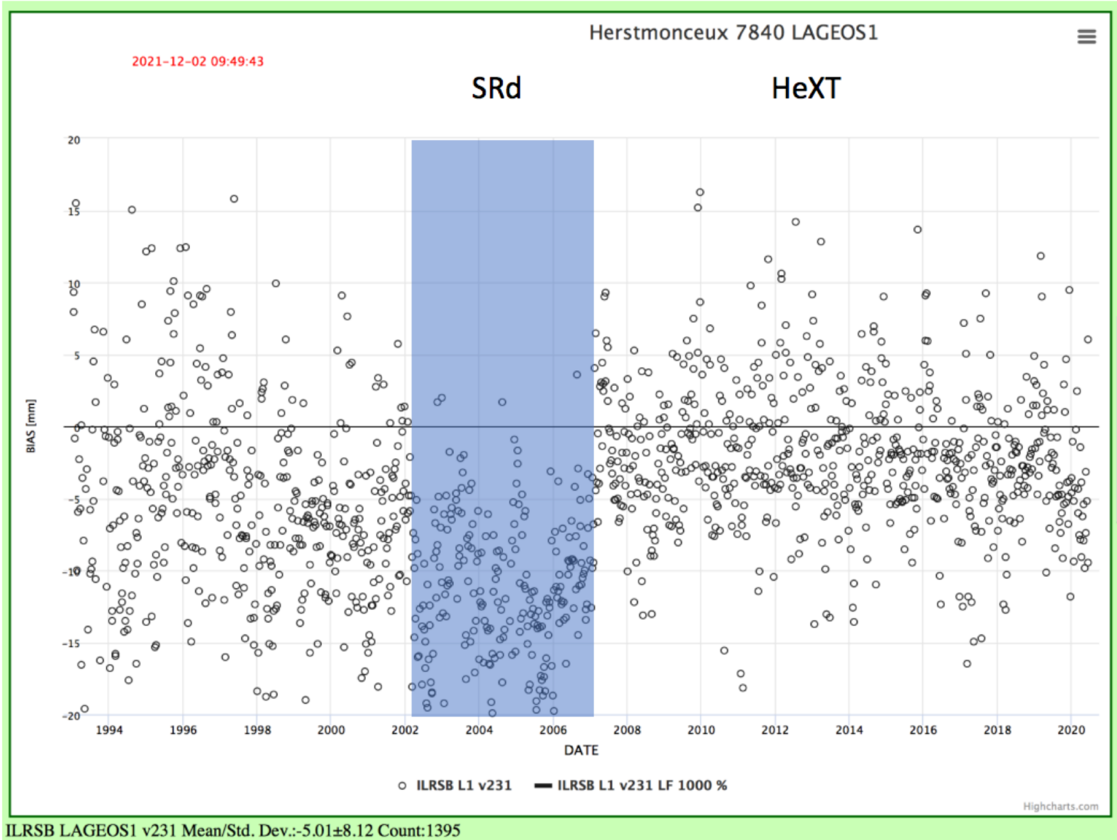
- ❑ **Return profile gives single shot RMS between 6 and 25mm**
  - ➢ Differs from the leading edge detection in multi-photon MCP systems

Return Profile Statistics for a Single Photon System



- ❑ **The return profile for the Hx Single Photon(SP) system is satellite dependent**
  - ➢ Peak displacement from the normal point mean changes the effective satellite reference point (CoM)
  - ➢ Center of Mass(CoM) error produces a small range bias

ITRF2020 Range Biases at Herstmonceux,UK



- **Stanford Counters upgraded to Event Timer in 2007**
  - > 5mm offset seen in SSEM RBs when the Event Timer was installed

A consistent calibration correction to the Stanford Timers was found

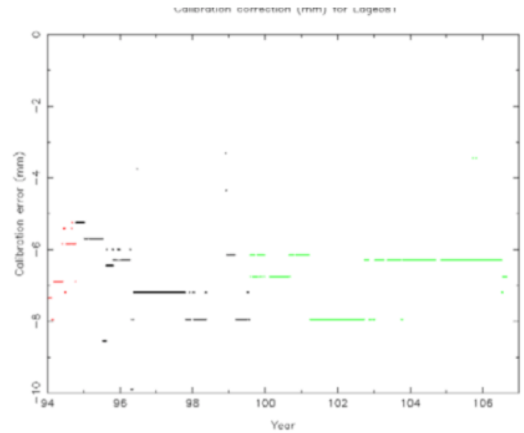


Figure 5 *Correction to calibration values used for LAGEOS during 1994-2006*

SGF LAGEOS data for the period 1994-2006. From these values we have estimated the corrections in mm to be applied to our calibrations taken over that period.The results are displayed in Figure 5, where it is apparent that errors of between 5 and 8mm have been made to the calibration values. However, given our estimate of the uncertainty of these average values, we finally derive an average calibration error of 7±2 mm, and in the sense that the calibration correction is too large by that amount. During this re-assessment we also discovered that no account had been taken for the effect on total delay of a glass neutral density filter that is placed in the optical path during calibration but not during satellite ranging. This correction amounts to 1.5mm, again in the sense that the calibration correction derived from target-board ranging is too long. Therefore our calibration corrections in the period 1994-date are too long by 8.5±2 mm and thus calibrated satellite ranges short by the same amount. This correction, which affects all satellite data equally, is of course in addition to the range-dependent correction discussed under ‘previous calibrations’ above and announced for the period 1994 October to 2002 January in SLRMail 0891 in 2002 January.

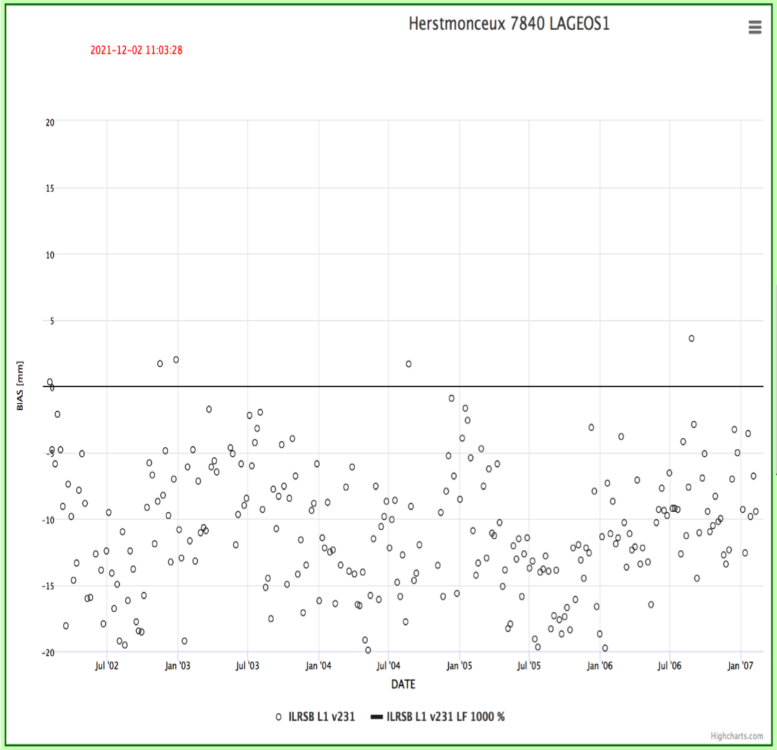
A reassessment of laser ranging accuracy at SGF Herstmonceux, UK

Philip Gibbs, Graham Appleby and Christopher Potter

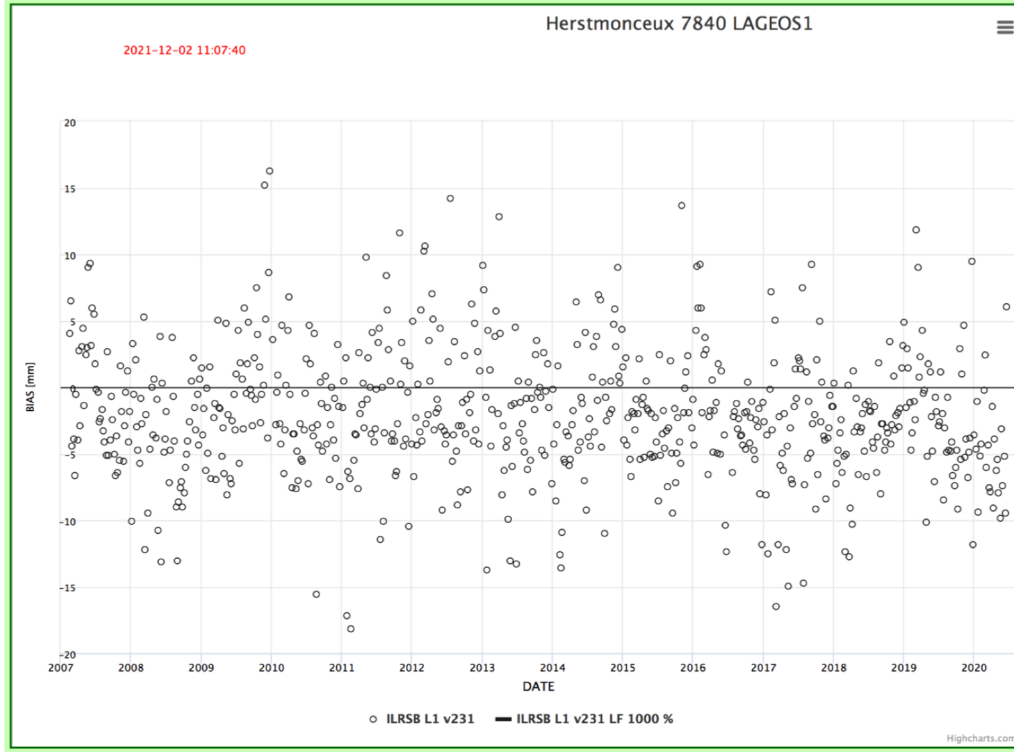
October 2006

- **8.5 mm RB is expected from this calibration correction**

Observed SSEM Range Bias Change at Herstmonceux



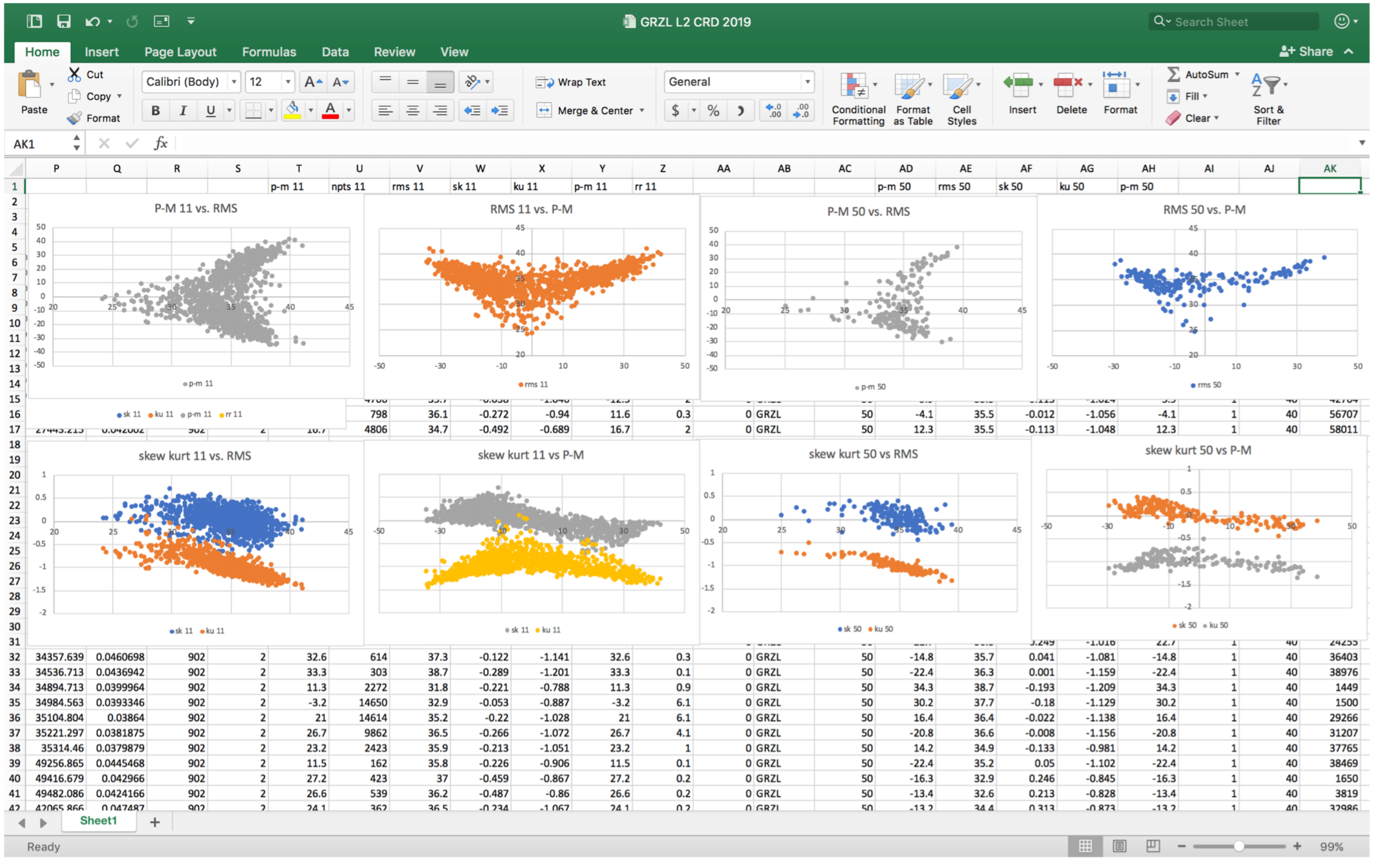
ILRSB LAGEOS1 v231 Mean/Std. Dev.:-11.2±5.41 Count:251



ILRSB LAGEOS1 v231 Mean/Std. Dev.:-2.1±5.29 Count:682

- The average RB for the HxD timer was -11.2 mm: for Event Timer -2.1 mm
- 9 mm difference: expected 8.5 mm
- Remaining -2 mm may be CoM error

Return Profile Statistics for a multi-photon C-spad System



- **The satellite return profile for the Graz multi-photon C-spad is complex**
  - Clipping strategy affects the effective satellite reference point and resulting range bias

Observed non-geodetic signals affecting Orbit and Station Positioning

Microchannel Plate (MCP)

- Discriminator time walk produces occasional Range Bias (RB) errors > 5 mm
- Long term Systematic Error Monitoring(SSEM) RB is seen due to target survey error

Compensated SP Avalanche Diode (C-SPAD)

- Profile Clipping can be accommodated in Satellite Center-of-Mass(CoM) models

Single Photon

- Return signal profile variations have long-term RB effects < 5 mm
- RB from TIU non-linearities > 5mm are detected in the ITRF2020 SSEM Analysis
- The remaining SSEM RB signal might improve the CoM model

Signals common to each system:

- Unmodeled horizontal target change is a significant error source (> 5mm)
- It can be calibrated with routine tests (Minicos)
- The SSEM RB estimates can actually improve the time resolution of the target models