7839 Graz Data Analysis
“The importance of strict adherence to the CRD format. Is Peak-Mean (P-M) useful???”

Van S Husson
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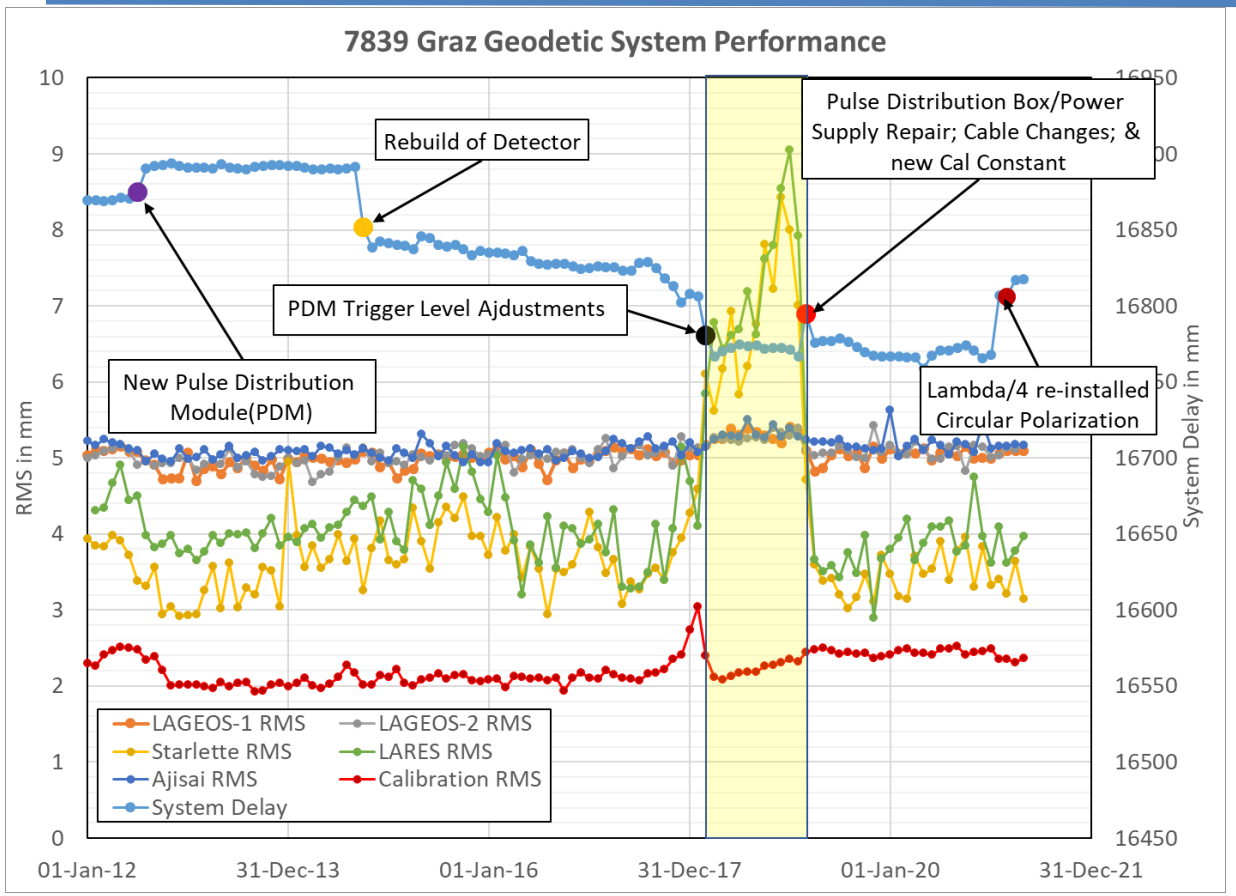
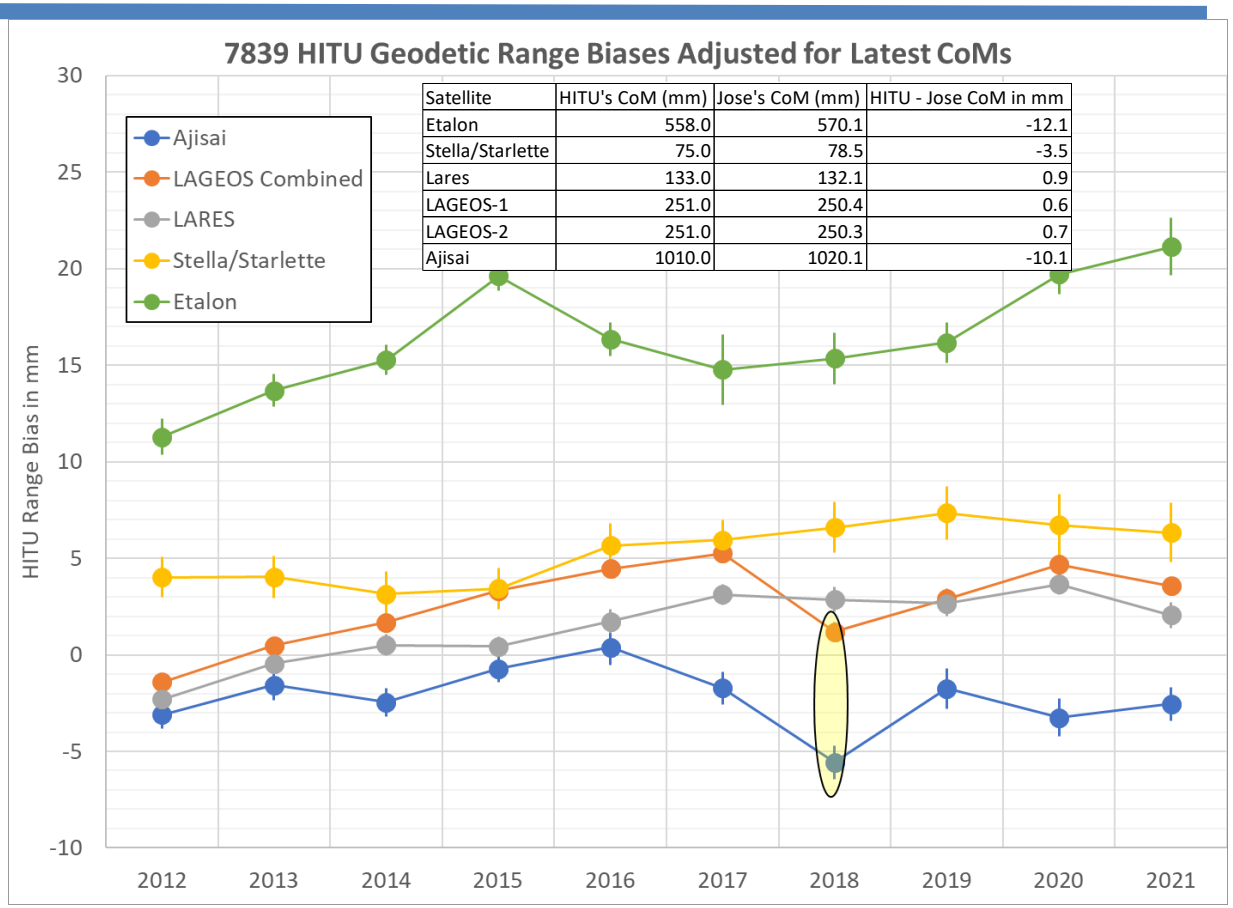
ILRS Central Bureau (CB)
ILRS Quality Control Board (QCB)
Networks and Engineering Standing Committee (NESC)

7839 Graz System Performance



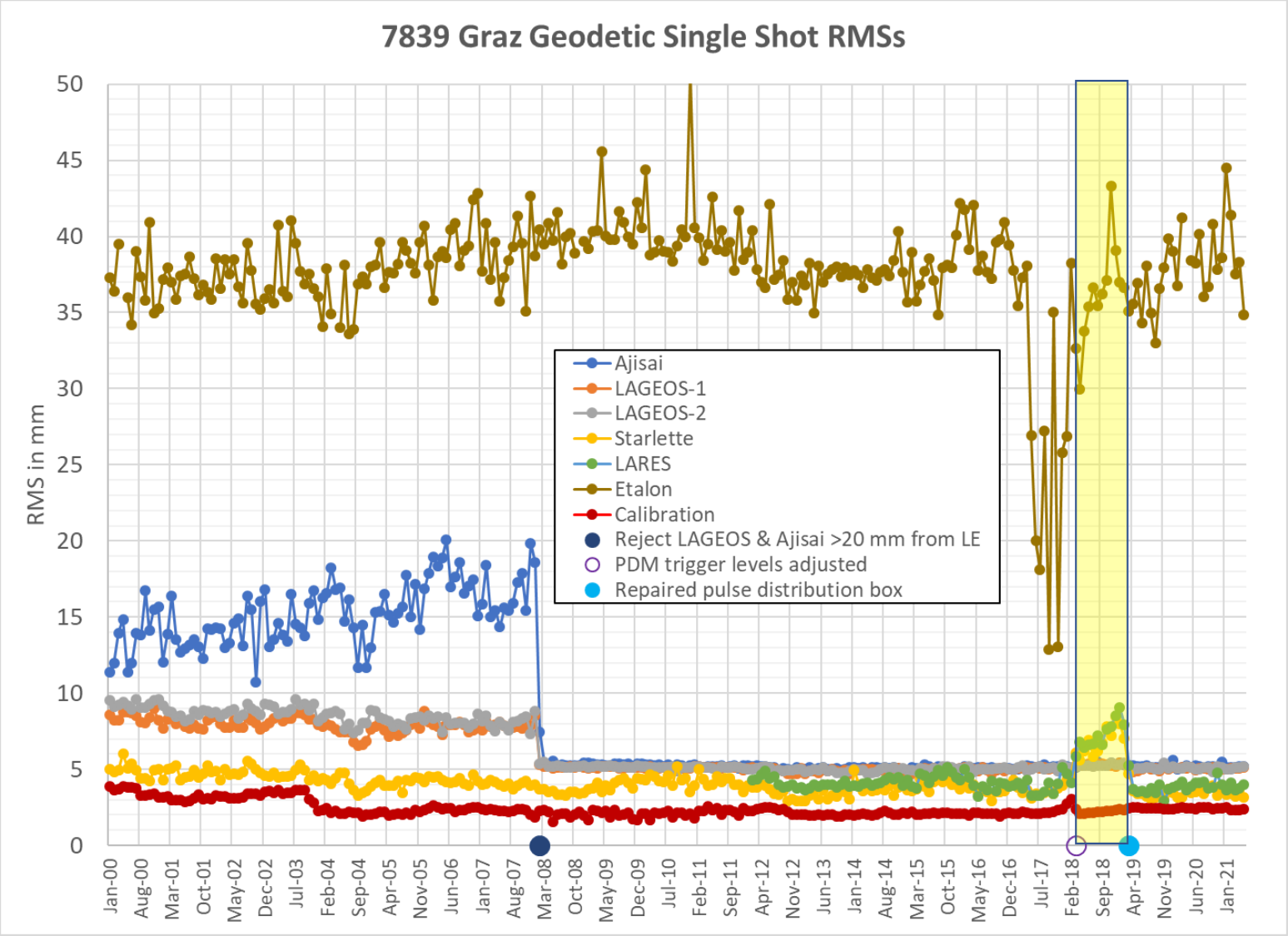


Satellite	HITU's CoM (mm)	Jose's CoM (mm)	HITU - Jose CoM in mm
Etalon	558.0	570.1	-12.1
Stella/Starlette	75.0	78.5	-3.5
Lares	133.0	132.1	0.9
LAGEOS-1	251.0	250.4	0.6
LAGEOS-2	251.0	250.3	0.7
Ajisai	1010.0	1020.1	-10.1

Left chart: Monthly Graz single shot RMSs (satellites & calibration) and system delays along with system changes. The PDM trigger level changes in March 2018 were originally undocumented. This change returned calibration RMSs to previous levels and stabilized the system delay, but the single shot RMSs began to drift until the next system change 12 months later. Why were the RMS trends satellite dependent and did the 'relative' geodetic range biases change during this highlighted period?

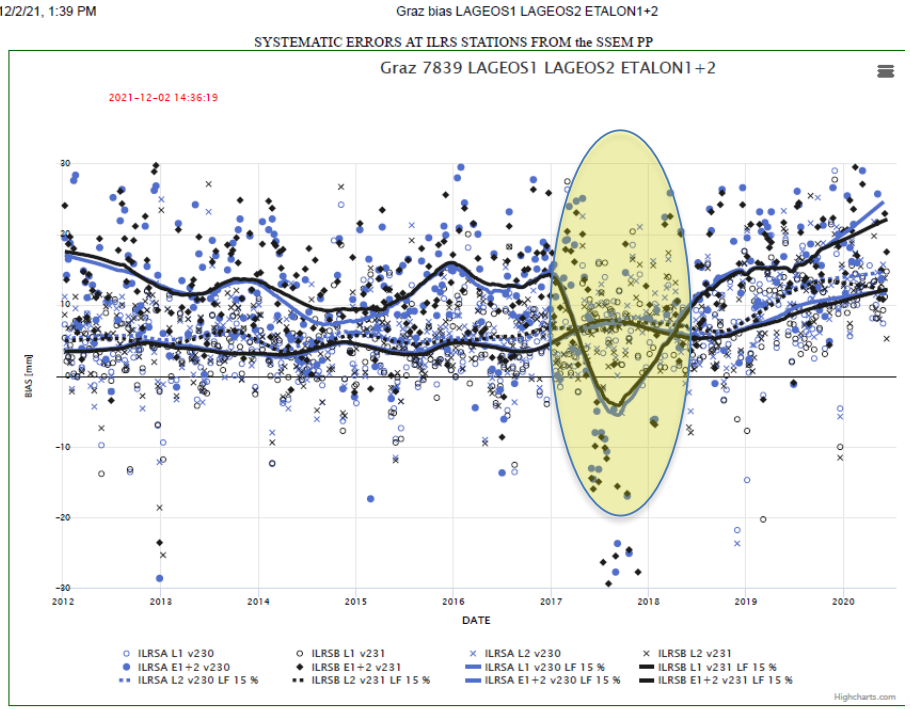
Right chart: The HITU yearly geodetic range biases answers the later question. *Note: HITU switched to ITRF2014 coordinates in June 2017 which changed the Graz height by ~5mm which impacts the long-term trends, but each satellite would be impacted the same*. In 2018, there is **3 to 4mm drop** in LAGEOS and Ajisai biases relative to Etalon, Stella/Starlette, and LARES. Based on the left chart, the LAGEOS and Ajisai RMSs were less impacted than the other satellites. Next slide will address this question.

7839 Graz Geodetic Satellite Performance

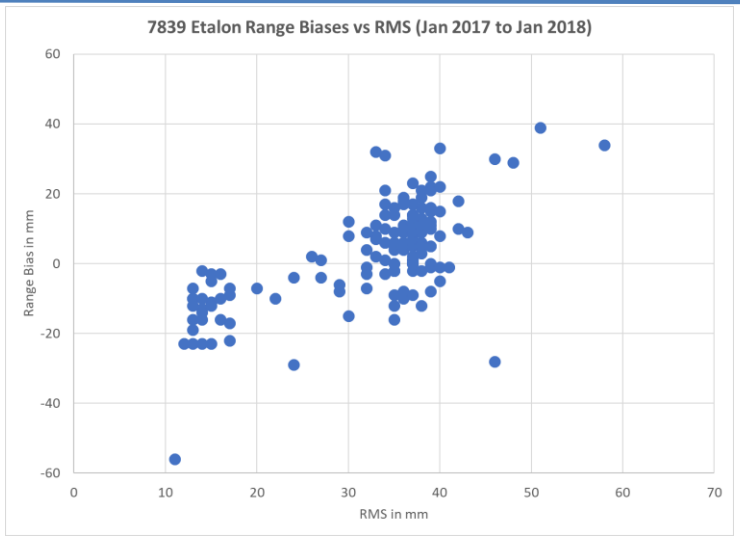


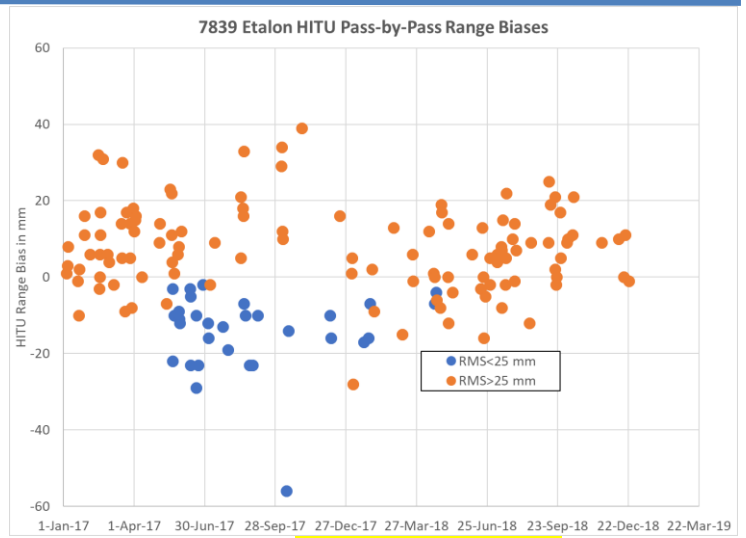
- On 5-Feb-2008, Graz implemented a new data rejection criterion where returns > 20 mm from the Leading Edge (LE) were rejected for LAGEOS-1, -2 and Ajisai [Kirchner et al, 2008]. This configuration change was added to the site log in October 2021. Graz LAGEOS-1, -2 and Ajisai CoM corrections were adjusted by 3.1, 3.4, and 27 mm; respectively.
- In May 2017, Etalon RMSs dropped and were very erratic before the March 2018 PDM trigger level change. What caused this and was there an Etalon range bias change?

7839 Etalon Range Bias Analysis



ILRSA LAGEOS1	Mean/Std. Dev.:5.42±6.41 Count:395
ILRSB LAGEOS1 v231	Mean/Std. Dev.:5.3±6.32 Count:398
ILRSA LAGEOS2	Mean/Std. Dev.:6.85±7.26 Count:387
ILRSB LAGEOS2 v231	Mean/Std. Dev.:6.64±7.31 Count:392
ILRSA ETALON1+2	Mean/Std. Dev.:11.76±12.05 Count:336
ILRSB ETALON1+2 v231	Mean/Std. Dev.:12.12±11.66 Count:340





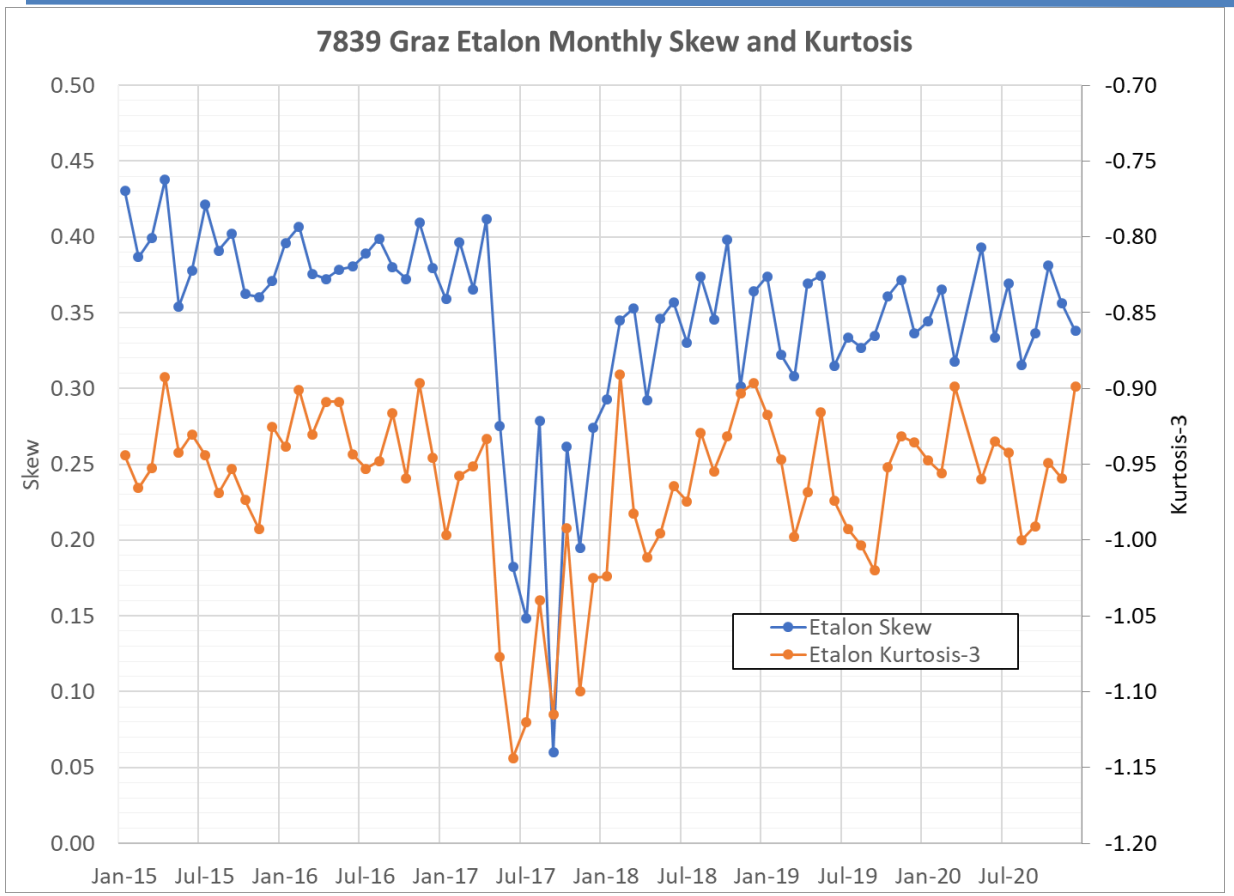
Left chart: SSEM 7839 results *Note: The big highlighted* ***20 mm*** *dip in the Etalon bias in mid-2017.*

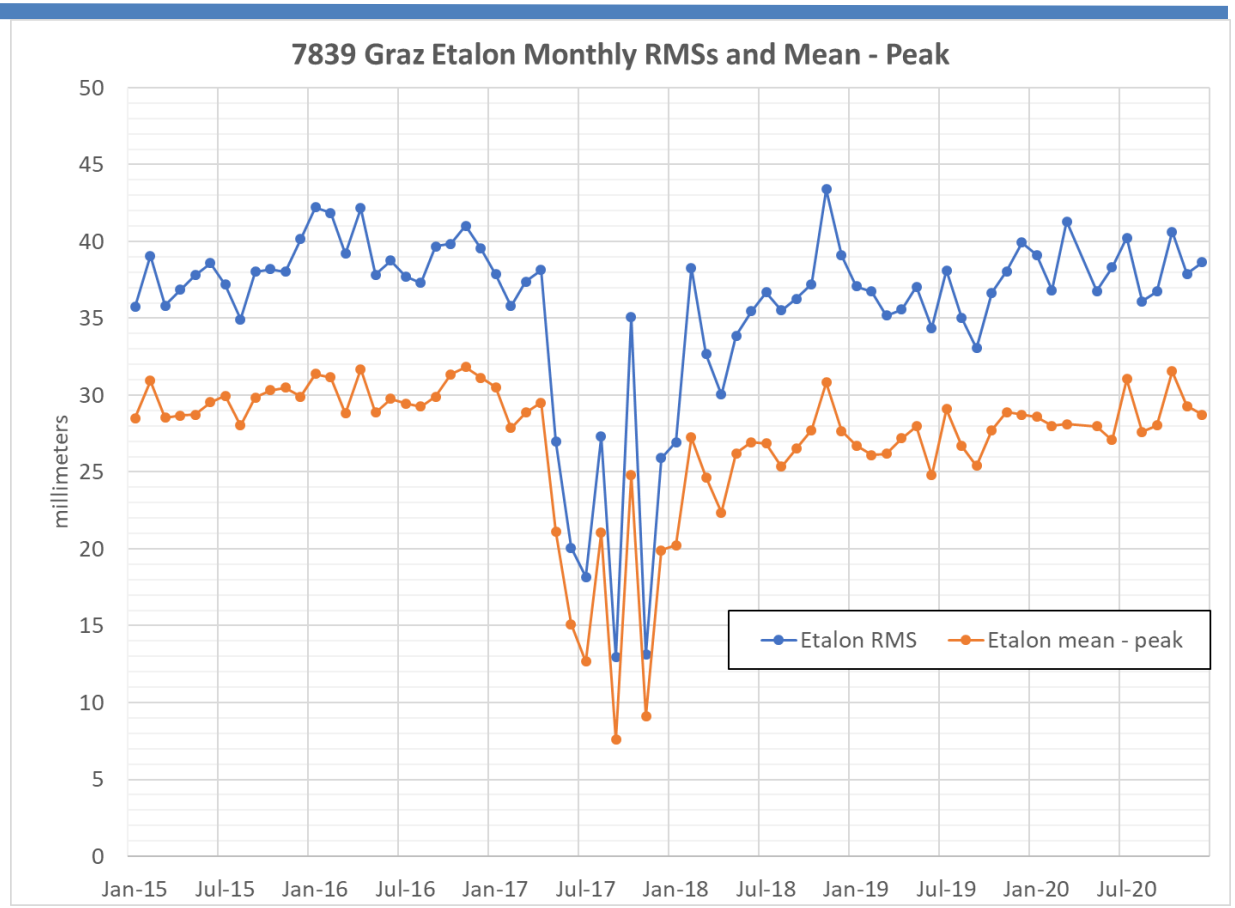
Middle chart: HITU Etalon pass-by-pass range bias vs RMS. *Note: At RMSs > 25 mm, there appear to be a linear trend (i.e. bias increases as RMS increases).*

Right chart: Time Series of HITU Etalon pass-by-pass range biases.

Questions: Was a new Etalon data reduction algorithm **intermittently** implemented? Can a bias model be developed?

7839 Graz Etalon Moment Analysis

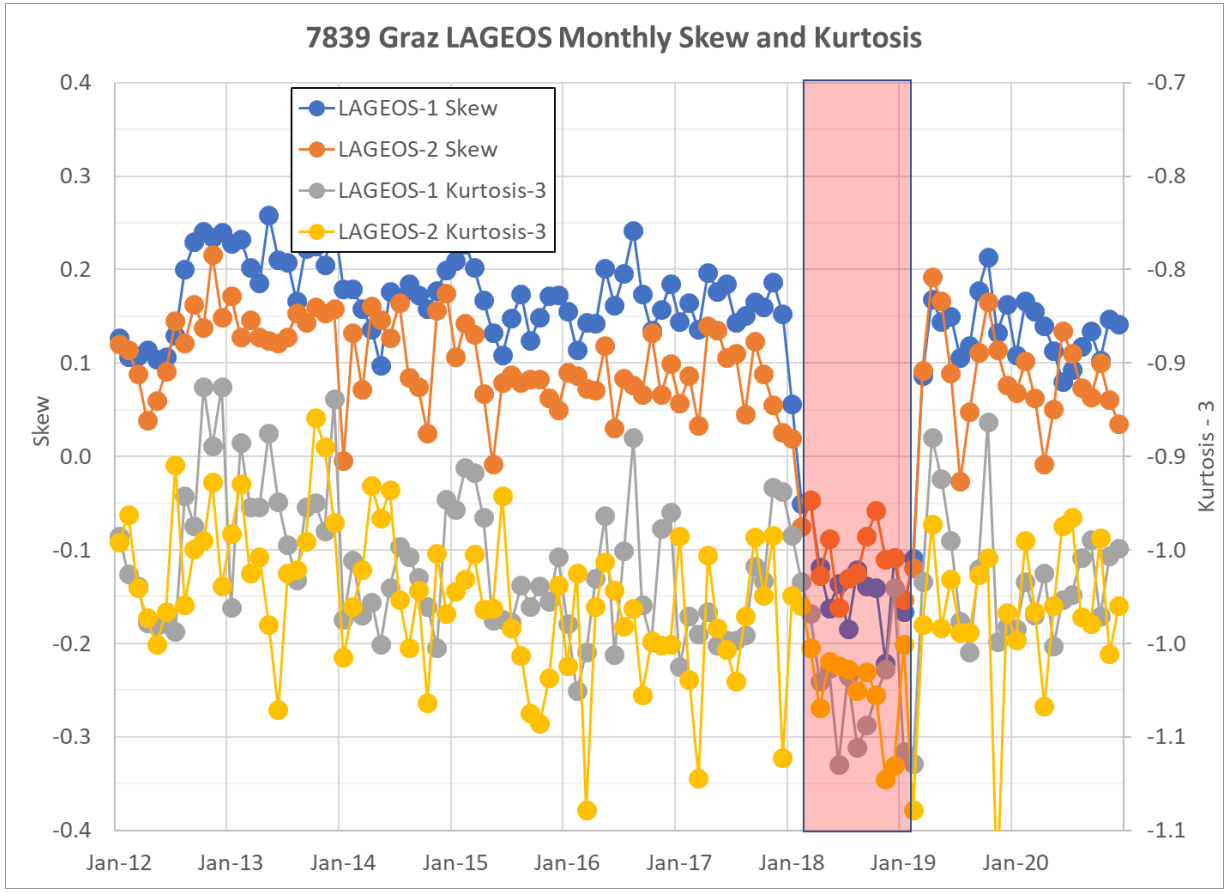


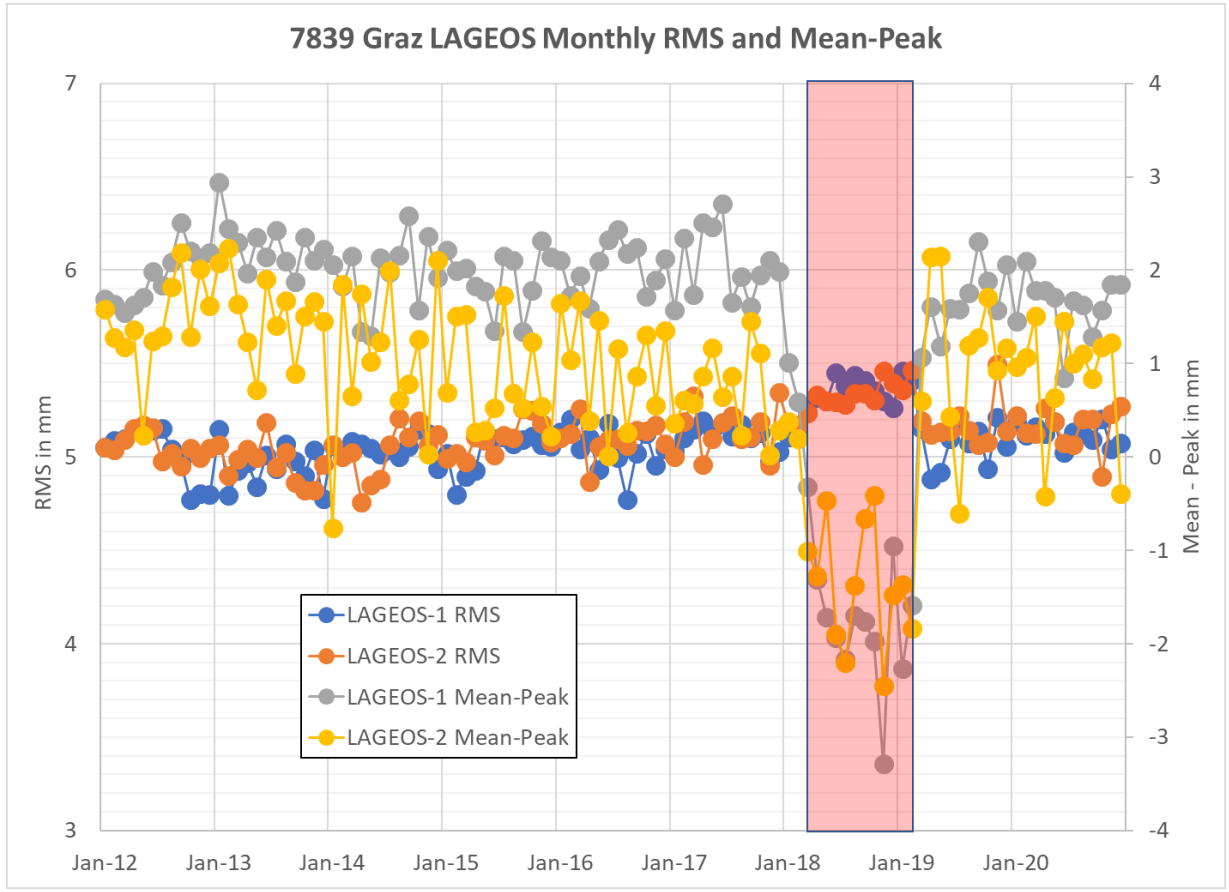


Left chart: 7839 Etalon (1,2) monthly skew and kurtosis (*Note: 2.2 sigma editing except for LAGEOS and Ajisai*)

Right chart: 7839 Etalon (1,2) monthly RMS and mean minus peak. The higher moments all indicate a change in system performance starting in May 2017, but **most importantly the P-M can accurately model the Etalon bias change in 2017** ☺ (Peter Dunn is buying the 1st round of drinks when the pandemic ends)

7839 Graz LAGEOS Moment Analysis

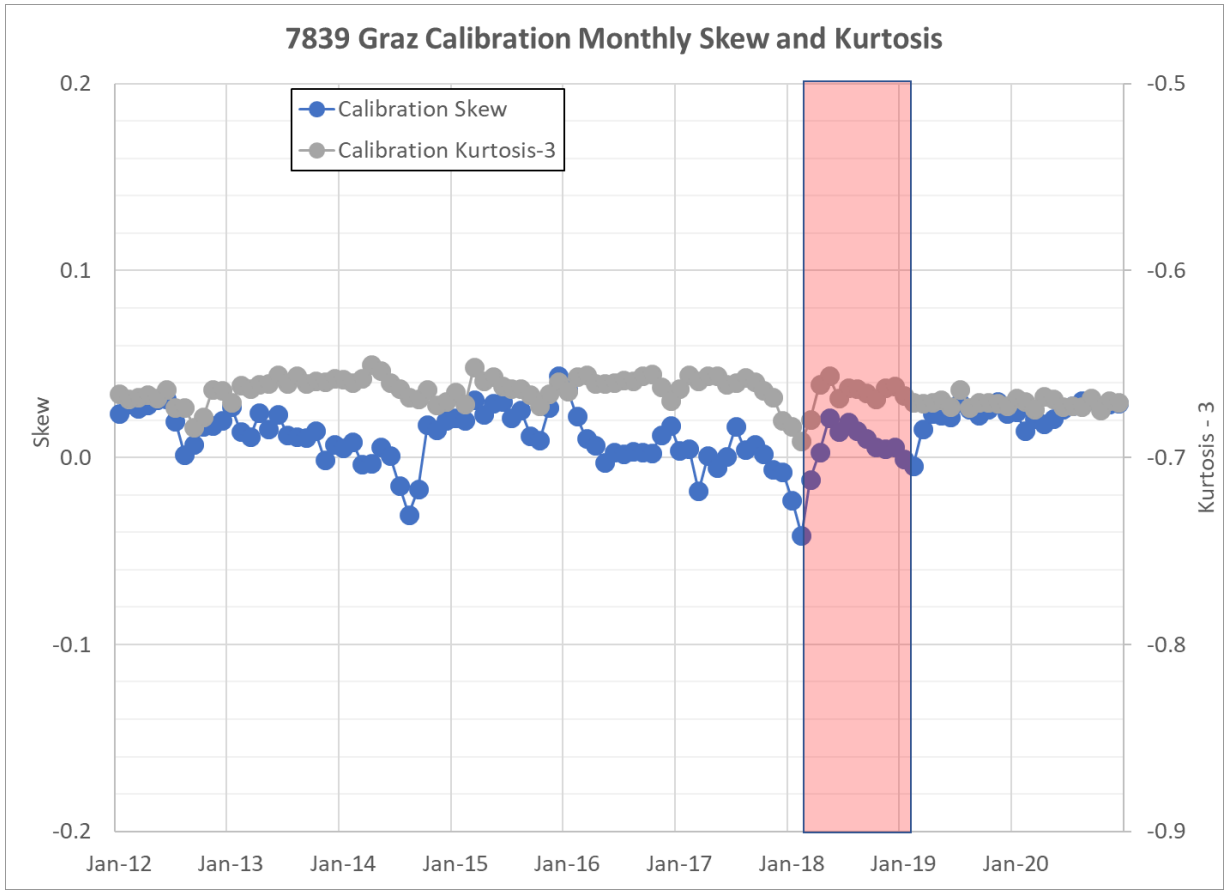


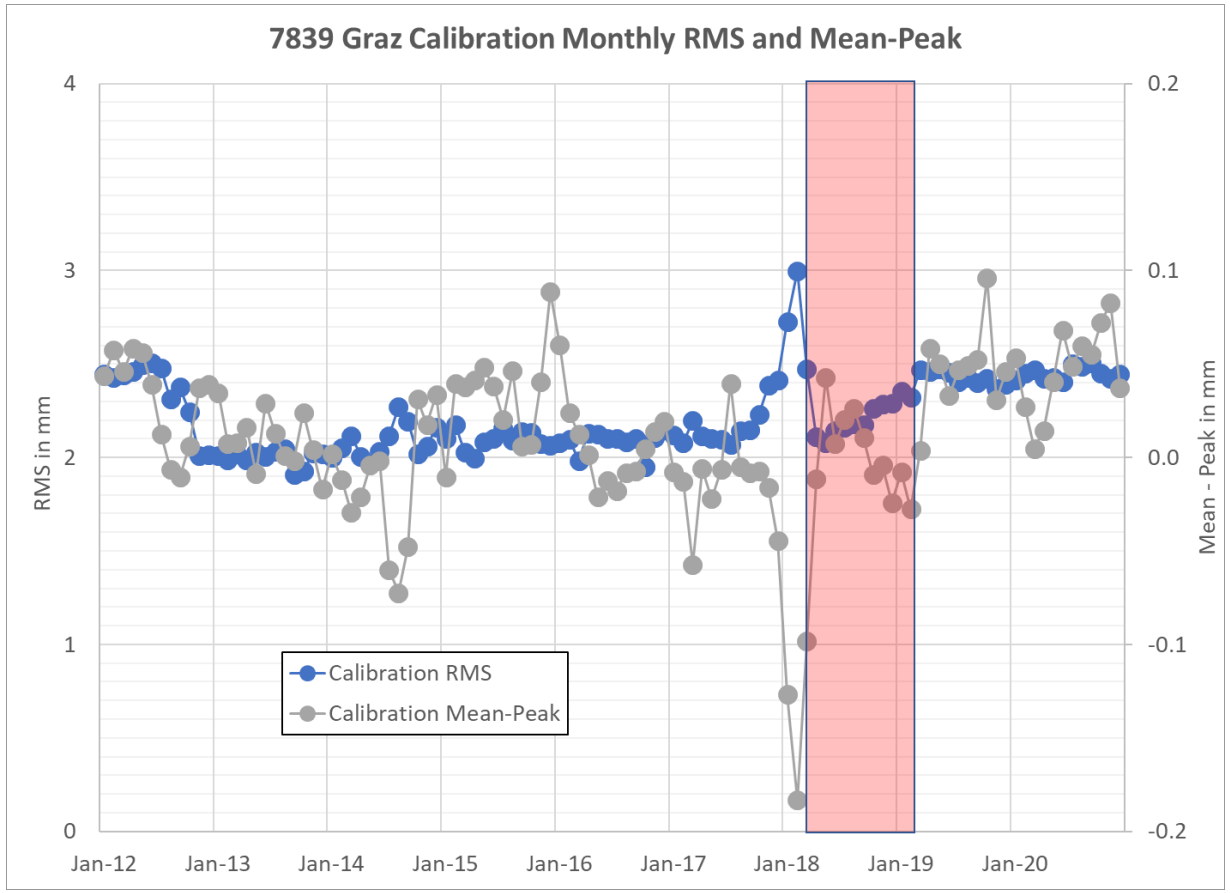


Left chart: 7839 LAGEOS-1, -2 monthly skew and kurtosis (*Note: For LAGEOS, the 20 mm leading edge rejection criteria*)

Right chart: 7839 LAGEOS-1, -2 monthly RMS and mean minus peak. The higher moments all indicate a change in system performance in the highlighted area, but **most importantly the P-M can model the 3 to 4mm change in the LAGEOS range bias during this period** ☺ (Peter is also buying the 2nd round of drinks when the pandemic ends)

7839 Graz Calibration Moment Analysis



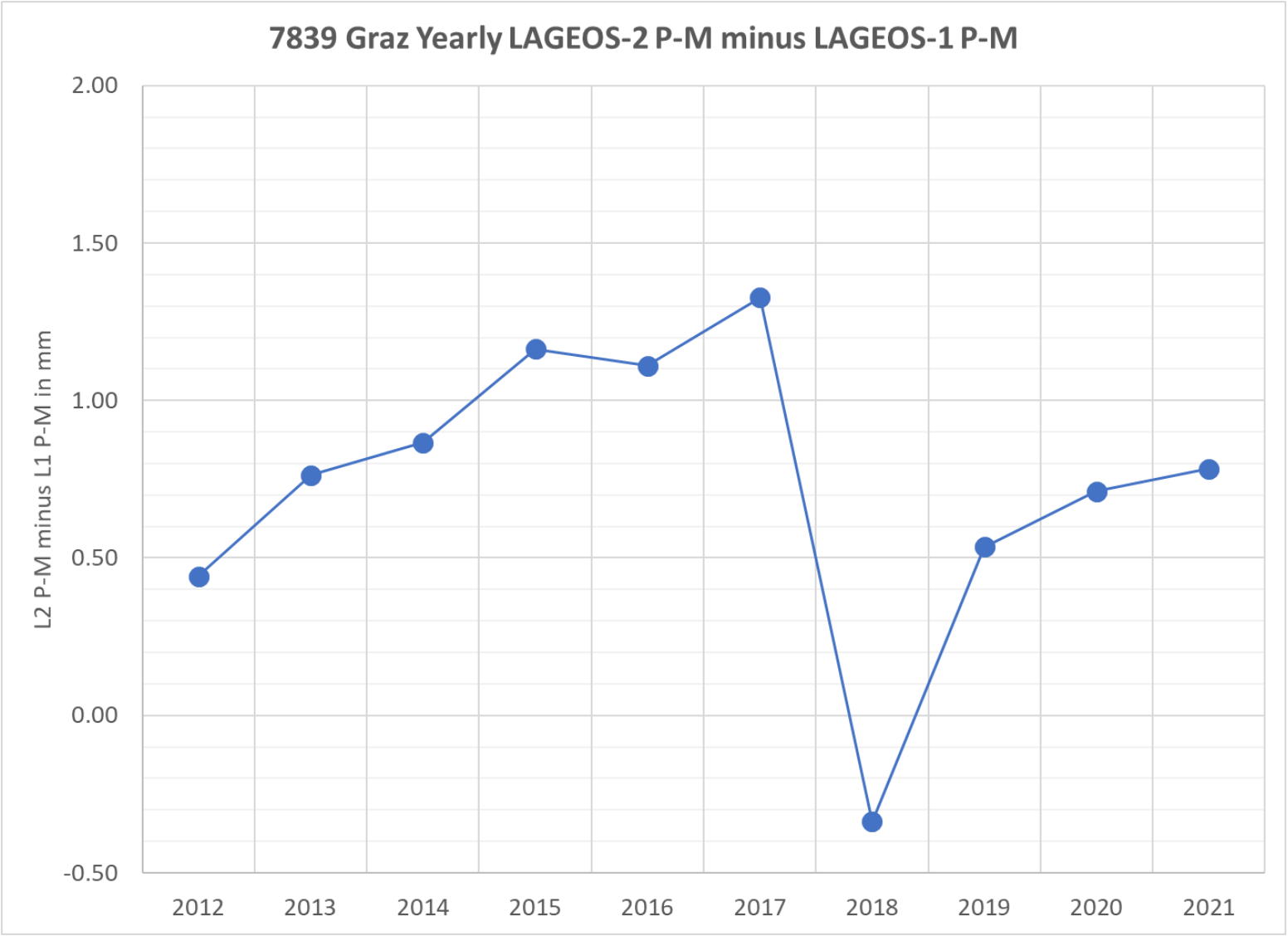


Left chart: 7839 calibration monthly skew and kurtosis (*Note: 2.2 sigma editing criteria for calibration*)

Right chart: 7839 calibration monthly RMS and mean minus peak.

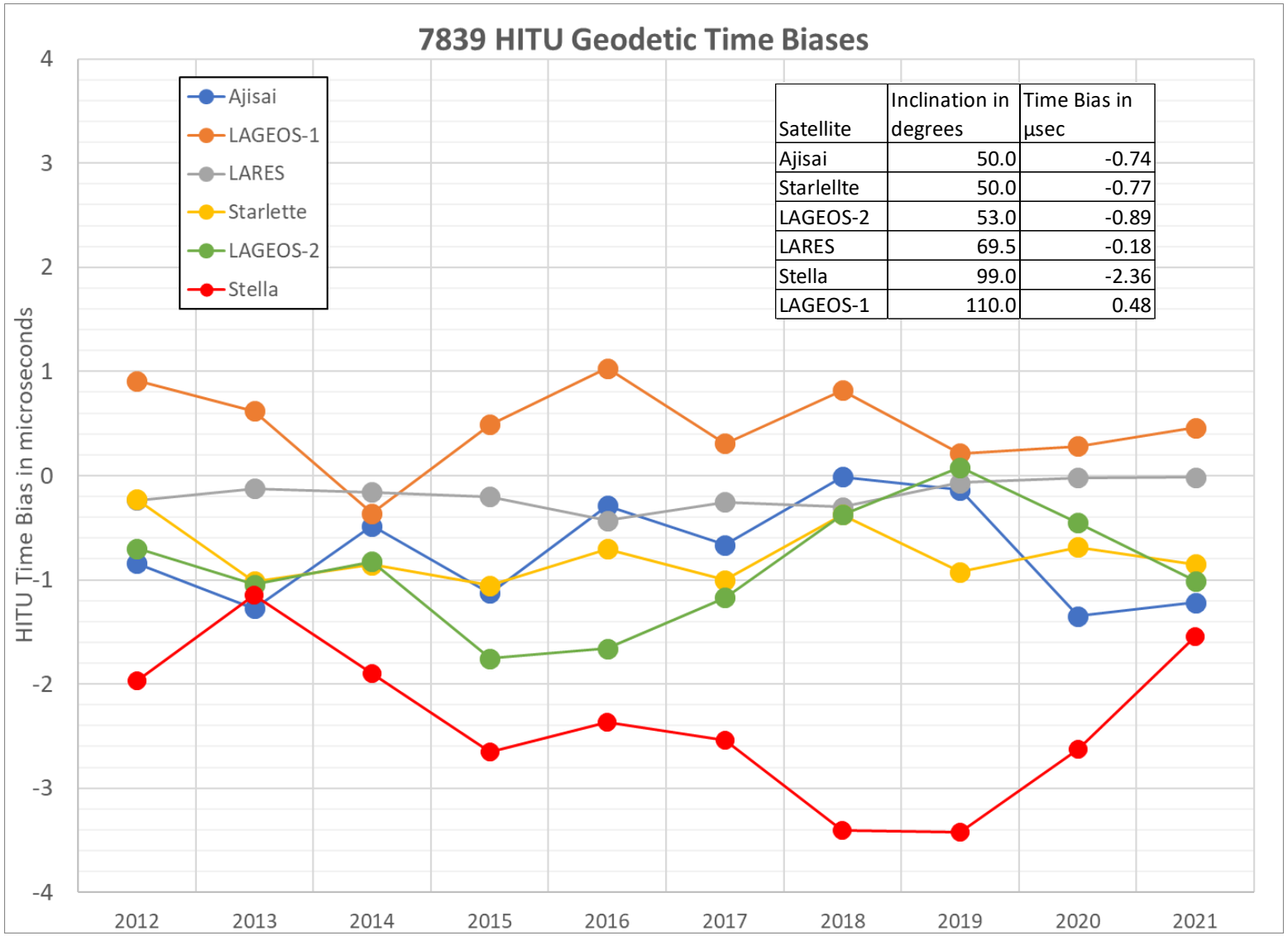
The calibration higher moments and peak-mean all indicate a change in system performance before the PSD trigger levels were adjusted in March 2018.

7839 Graz Peak-Mean Analysis



- LAGEOS-2 P-M minus LAGEOS-1 P-M
- The current 7839 CoM difference between LAGEOS-1 and LAGEOS-2 is 0.1 mm
- The mean SSEM ILRSA and ILRSB differences (LAGEOS-2 – LAGEOS-1) are 1.43 and 1.34 mm; respectively, the average peak-mean is 0.73 mm, which can explain half of this difference
- On Nov 19, 2012, the laser polarization was changed from circular to linear and on Mar 19, 2021 it was changed back to circular

7839 Graz HITU Time Bias Analysis



Satellite	Inclination in degrees	Time Bias in µsec
Ajisai	50.0	-0.74
Starlellte	50.0	-0.77
LAGEOS-2	53.0	-0.89
LARES	69.5	-0.18
Stella	99.0	-2.36
LAGEOS-1	110.0	0.48

- The time bias estimates are dependent upon the satellite inclination angle
- Also note that the LAGEOS-1 and -2 along track errors have opposite signs. This trend exists in other stations.

Summary/Recommendations/Questions

- Graz is the only station that strictly adhered to the new CRD V1 format from the onset (i.e. 2012) and their peak minus mean (P-M) calculations can be used in recovering mm level biases in Etalon and LAGEOS
  - Recommendation: Adopt the Graz P-M algorithm as the ILRS standard?
  - Recommendation: OrbitNP, if not already equipped with the Graz P-M algorithm, could be a valuable tool in diagnosing biases in SPAD systems
  - Is performing Graz Moment analysis on LARES and Ajisai worth the effort?
- Did Graz laser polarization changes impact the range bias at the mm level?
- Changes in system performance parameters (i.e. satellite and calibration moments, P-M, system delays,) can identify system changes. This analysis can be used to identify gaps in site and/or station history logs
  - RMS and/or system delay stability can be a leading indicator of an impending component failure
- Time bias/along track estimates are dependent on satellite inclination angles. Do along track errors impact range biases at the mm level?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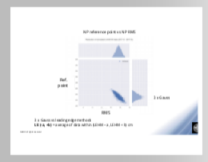
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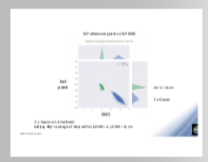
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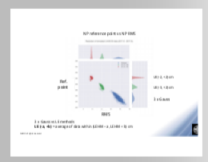
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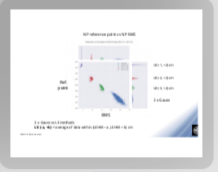
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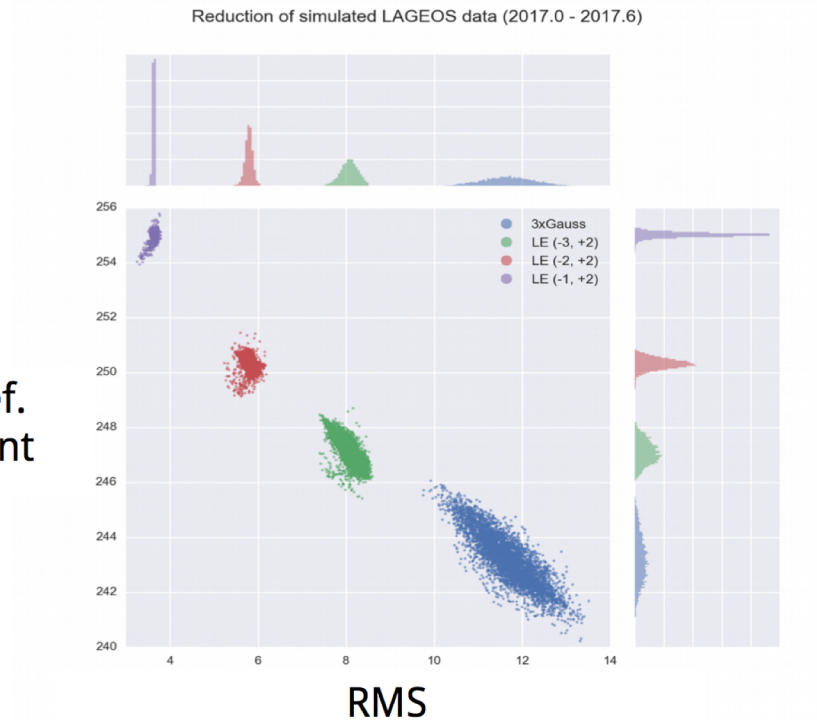
NP reference point vs NP RMS



Ref. point

RMS

LE (-1, +2) cm

LE (-2, +2) cm

LE (-3, +2) cm

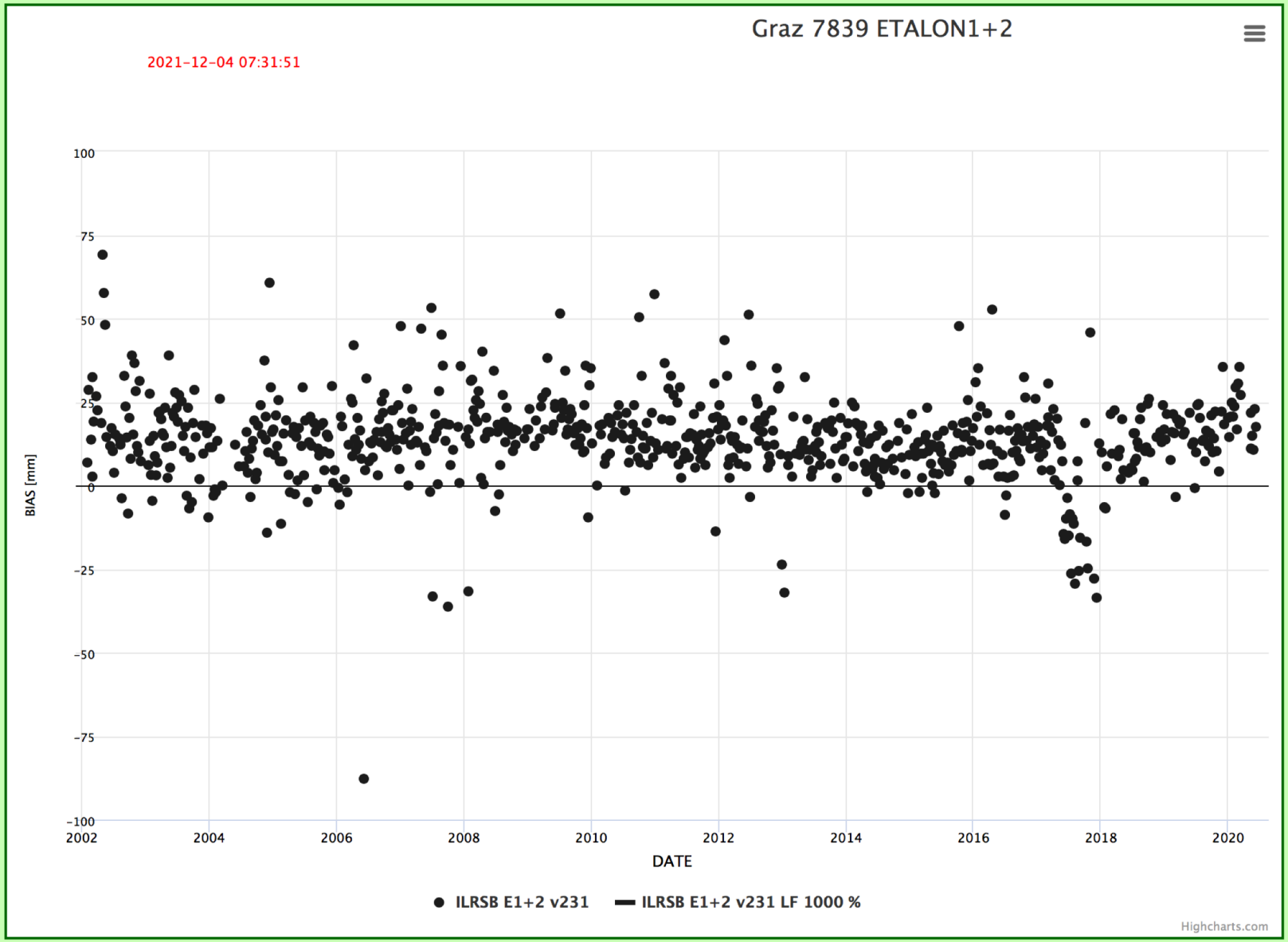
3 x Gauss

3 x Gauss vs LE methods

LE (-a, +b) = average of data within (LEHM – a, LEHM + b) cm

SSEM for E12 GRAZ shows a RB dip in 2017

SSEM for L12 HERL shows a RB dip in 2002/2007



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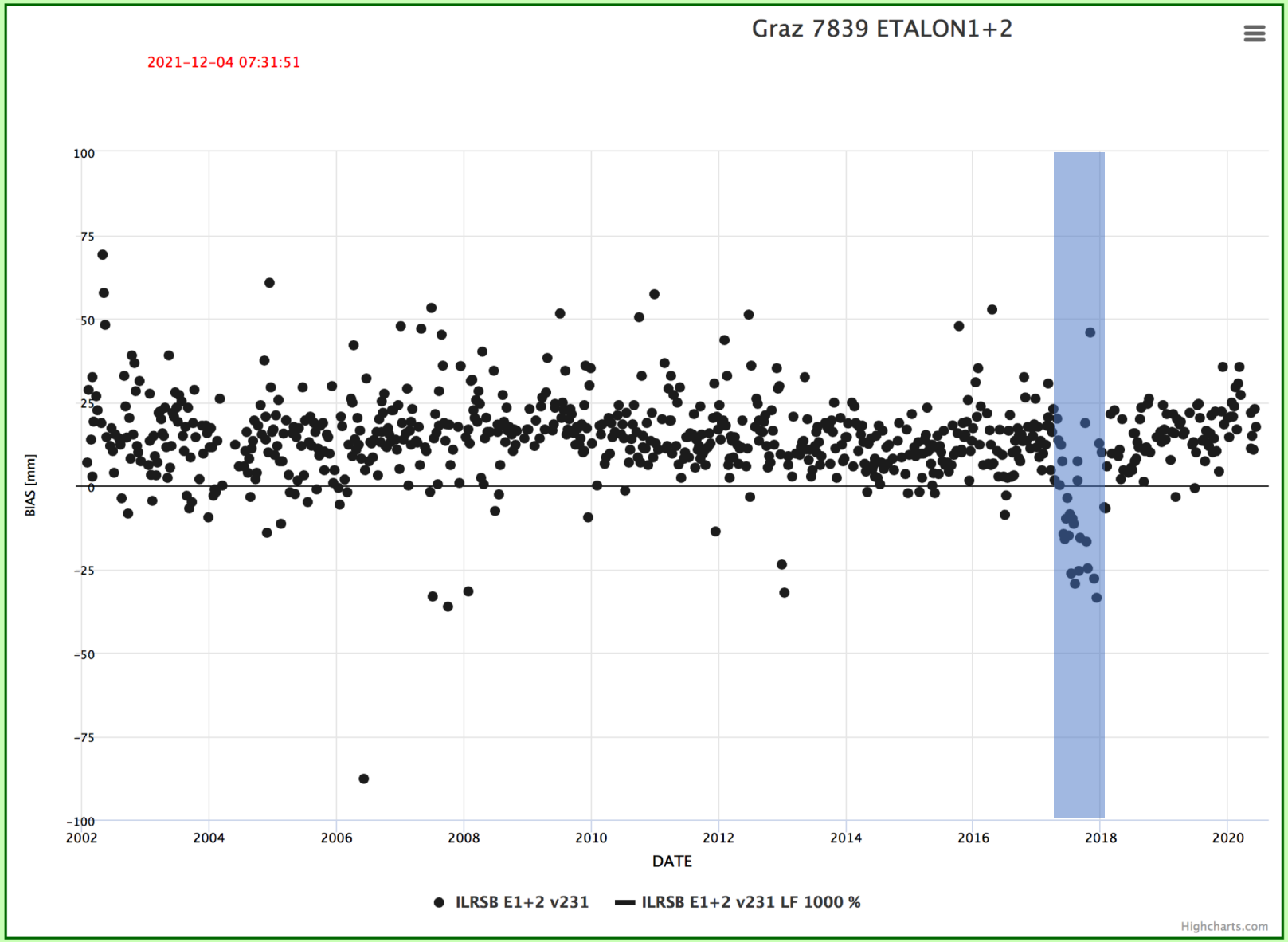
ILRSB ETALON1+2 v231 Mean/Std. Dev.:13.88±12.67 Count:737



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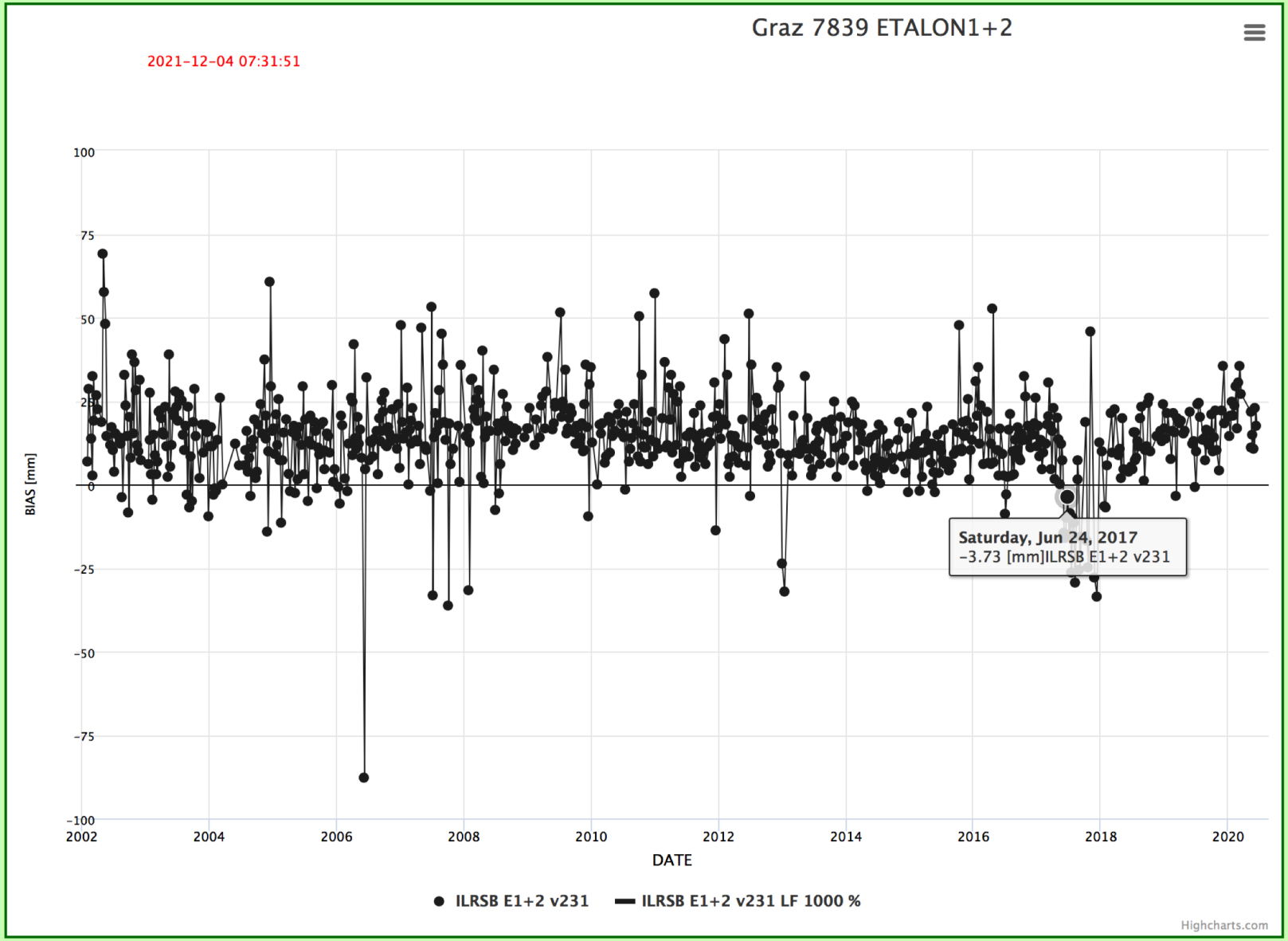

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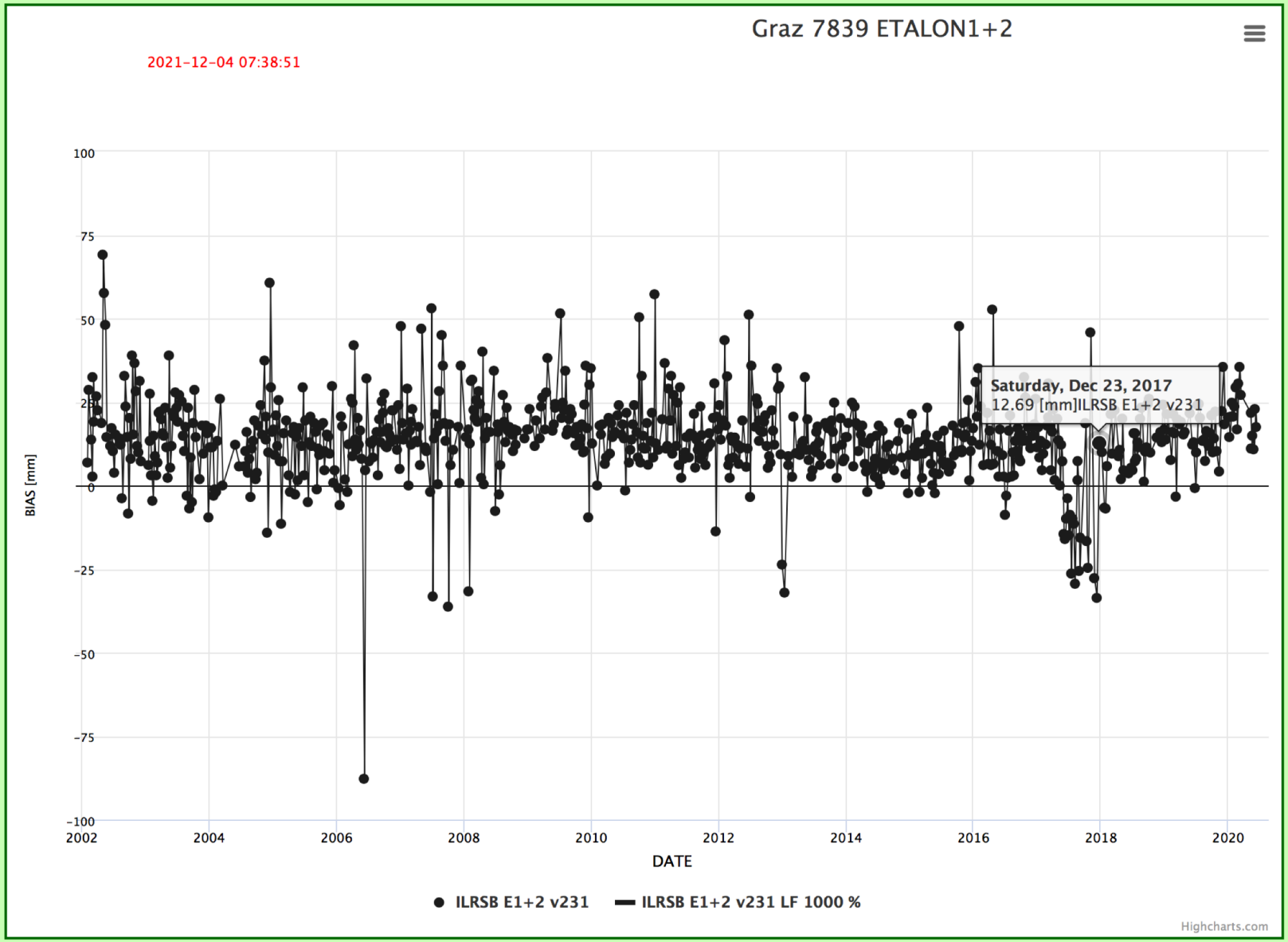

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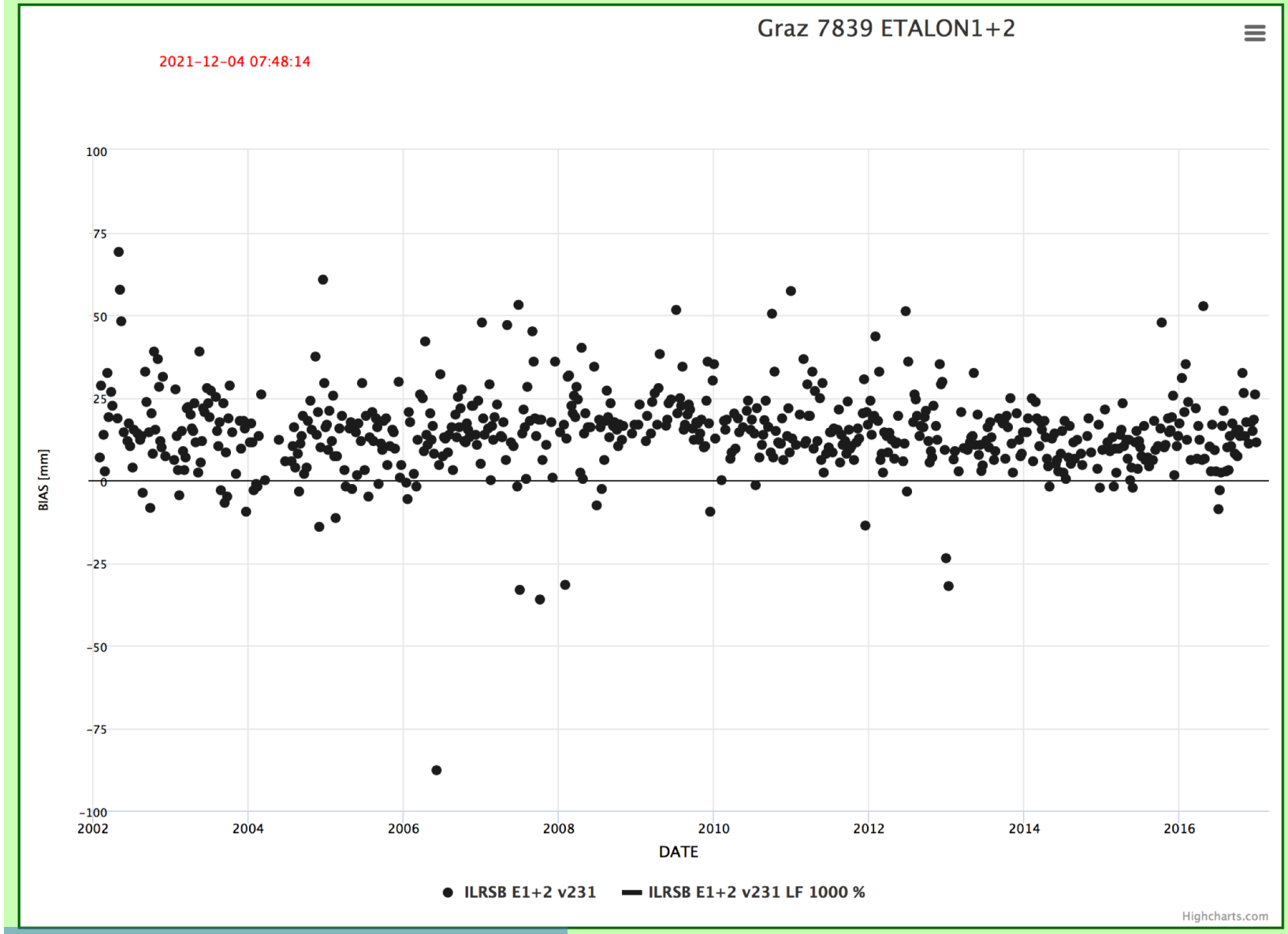

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ILRSB ETALON1+2 v231 Mean/Std. Dev.:14.53±12.3 Count:609

The E12 GRAZ 20 mm dip was between
2017-6-24 and 2017-12-23

Since 2002 GRAZ is 15mm long +/- 1 mm
(standard error)

Subject: [ilrs-qcb] my QCB presentation
Date: Friday, December 3, 2021 at 11:48:49 AM Eastern Standard Time
From: Husson, Van (PERATON) via ilrs-qcb
To: ilrs-qcb@lists.nasa.gov
Attachments: Graz Data analysis.pdf

FYI… see attached. Happy holidays and stay safe everyone! Van

This is a continuation of my in-depth analysis of Graz data which began in the spring of 2020. Based on monthly aggregate analysis of HITU LAGEOS pass-by-pass biases, there appeared to be a few mm LAGEOS bias change in mid-2018. Based on monthly aggregate analysis of their calibration RMSs, system delays and LAGEOS RMSs, there appeared to be an undocumented system change in March 2018. Back then there was a 4-year gap (2015 to 2019) in their station history log.

In May 2020, I sent a few plots to Georg for his input. He reviewed their onsite station logbook which revealed there was system change in March 2018. They adjusted the trigger levels in their laser Pulse Distribution Module (PDM). Georg at the time didn't thing this change impacted their data quality and why they didn't add it to their change history. A few months ago, I learned that in Feb 2008, they implemented a data rejection scheme based on the leading edge. For Ajisai and LAGEOS, returns greater than 20 mm were edited. This change was noted in their change history, but since it was a configuration change to their data processing it should have also been noted in their site log, but it wasn't. Graz has since updated their change history for adjusting PDM trigger levels and their site log for the LE data rejection scheme.

The most significant findings in this presentation are based on the contents of their onsite data processing statistics embedded in their CRD normal point 50 session records and 40 calibration records. Therefore, I have subtitled this presentation the importance of strict adherence to the CRD format and ask the question is peak-mean useful since this has been a discussion topic for at least a few decades.

Recalibration of Herstmonceux ranges since February 2002

SSEM for HERL shows a RB shift on 2007-02-11
SSEM for HERL shows a RB shift on 2002-01-30

On 2007-02-11 the HeXT event timer was introduced
Between 1999-06-30 and 2007-02-11 SR620d was used

Before 2002-01-30 SR620d data was affected by SLRMail0891 bias removal

Recalibration of SR620d after 2002-01-30 aligns the RB series within a millimeter

International Laser Ranging Service
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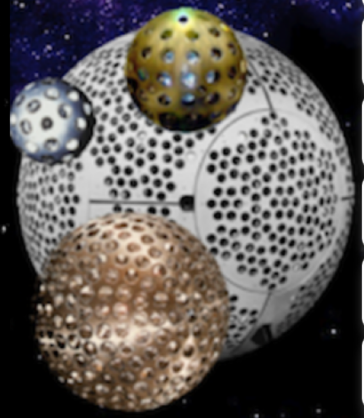
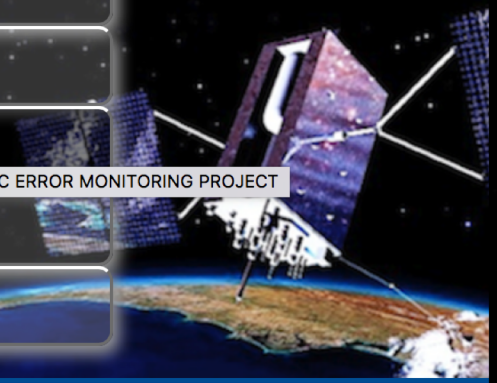


- WEEKLY STATION POSITIONS & DAILY EOP SERIES
- JCET DAILY NETWORK PERFORMANCE REPORT
- EVALUATION OF WEEKLY ASC PRODUCTS
- MONITORING SYSTEMATIC ERRORS AT ILRS STATIONS
- QC REPORT
- ILRS REPORT CARD
- NETWORK PERFORMANCE ON LAGEOS AND LAGEOS2
- SYSTEMATIC ERROR MONITORING PROJECT
- NORMAL POINT DATA MONITORING (CDDIS)
- Obs. & Stations Used in ILRS Products

SYSTEMATIC ERROR MONITORING PROJECT



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Station Systematic Errors Estimated from SLR DATA

2019 Reanalysis Project Results since 1993

EDITED ±100 mm SUBMISSIONS

LAGEOS ESTIMATE	LAGEOS-2 ESTIMATE	COMBINED ESTIMATE ETALON1&2
☐ **ASI v231**	☐ **ASI v231**	☐ **ASI v231**
☐ **BKG v231**	☐ **BKG v231**	☐ **BKG v231**
☐ **DGFI v232**	☐ **DGFI v232**	☐ **DGFI v232**
☐ **ESA v231**	☐ **ESA v231**	☐ **ESA v231**
☐ **GFZ v231**	☐ **GFZ v231**	☐ **GFZ v231**
☐ **JCET v231**	☐ **JCET v231**	☐ **JCET v231**
☐ **NSGF v231**	☐ **NSGF v231**	☐ **NSGF v231**
☐ **ILRSA v230**	☐ **ILRSA v230**	☐ **ILRSA v230**
☑ **ILRSB v231**	☐ **ILRSB v231**	☐ **ILRSB v231**

Start (MM-DD-YYYY): 01-01-1993

End Date (MM-DD-YYYY) 01-01-2021

Station 7840 Herstmonceux

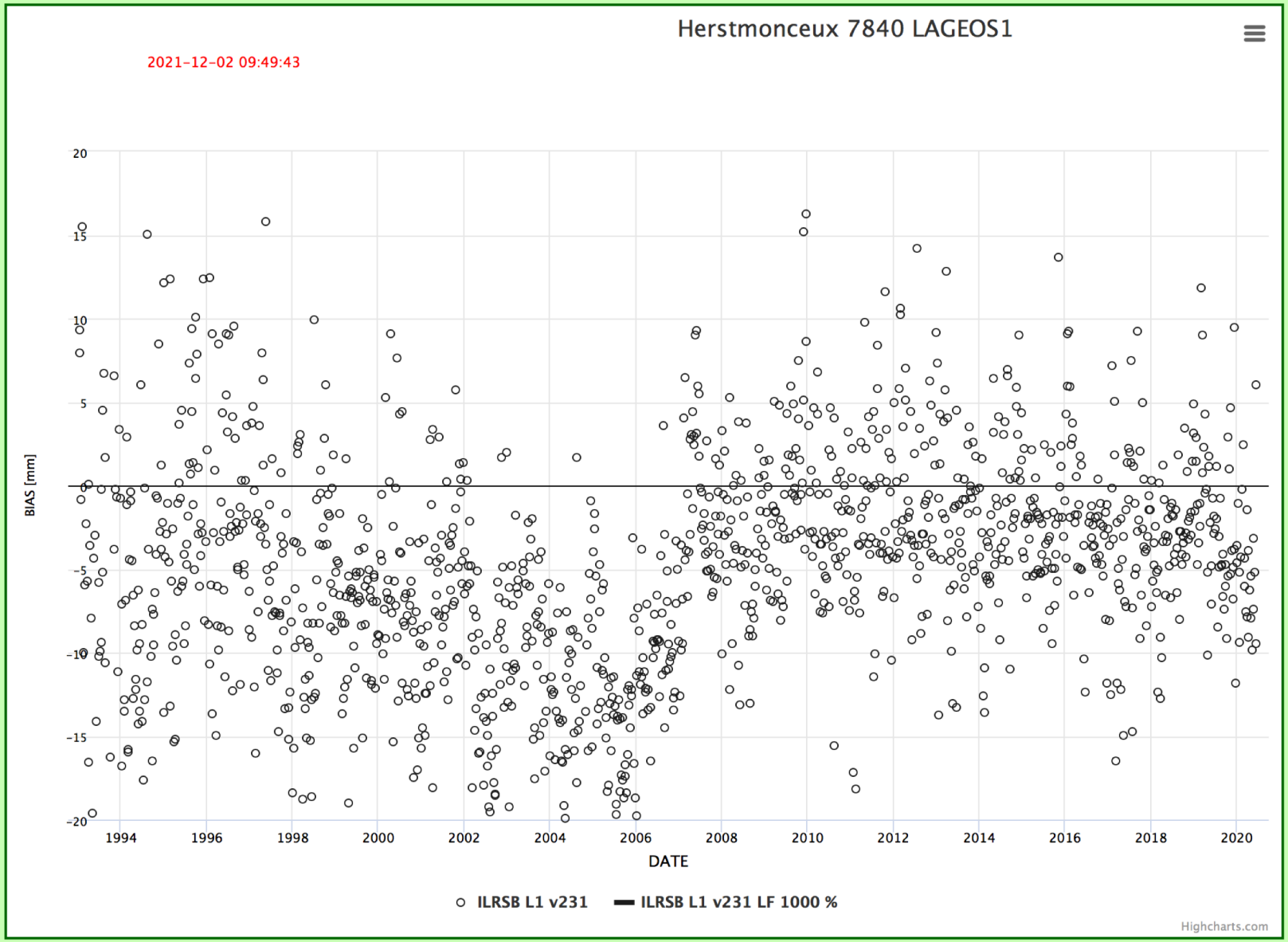
Plot Size	Minimum	Maximum
Y axis	-20	20

LOESS regression 1000 %

☐ SHOW STATION EVENTS

SHOW STATION EVENTS EQUAL TO (SELECT BETWEEN 0-3) 0

Submit Reset form



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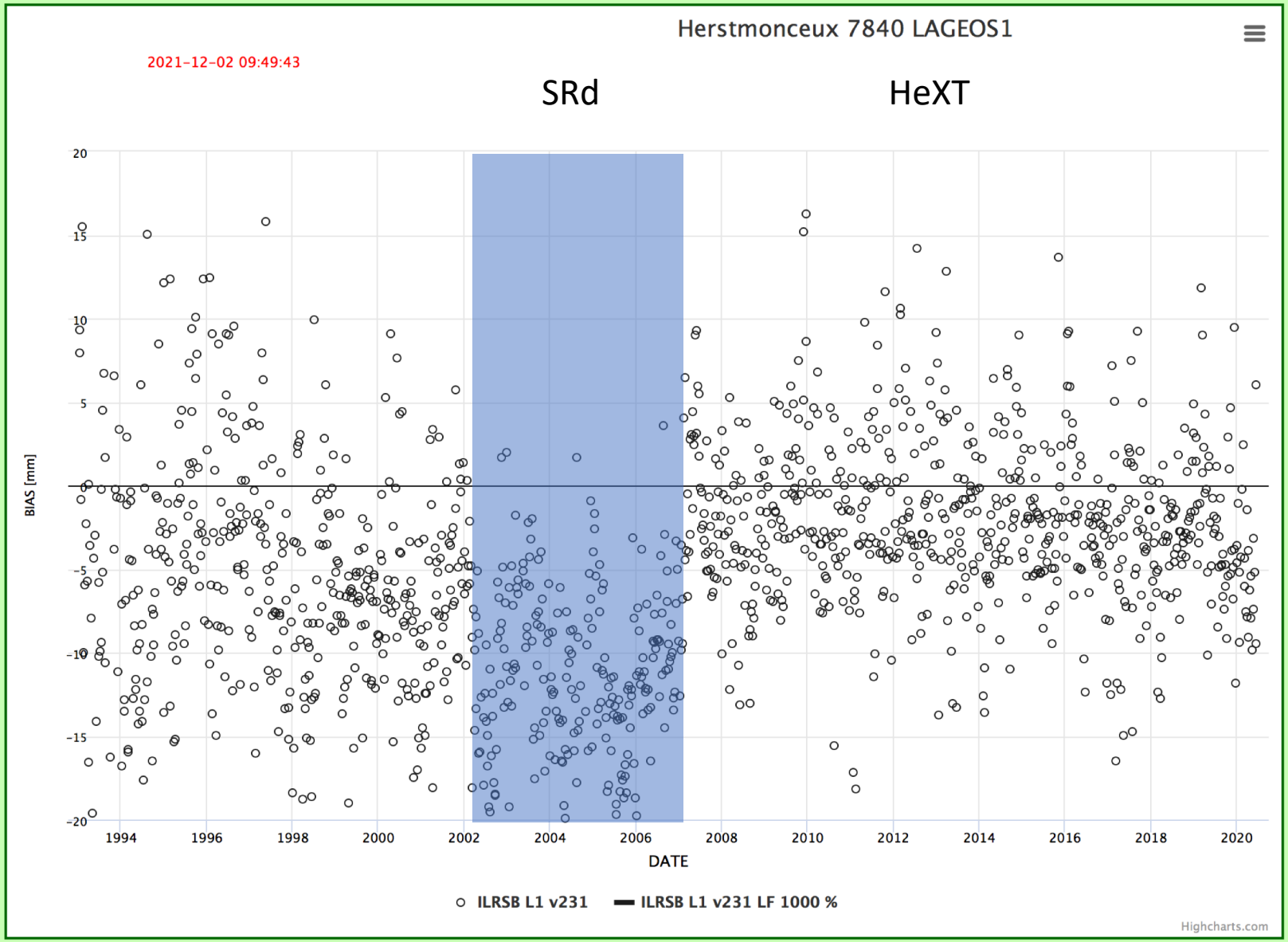
ILRSB LAGEOS1 v231 Mean/Std. Dev.:-5.01±8.12 Count:1395



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ILRSB LAGEOS1 v231 Mean/Std. Dev.:-5.01±8.12 Count:1395

A reassessment of laser ranging accuracy at SGF Herstmonceux, UK

Philip Gibbs, Graham Appleby and Christopher Potter

October 2006

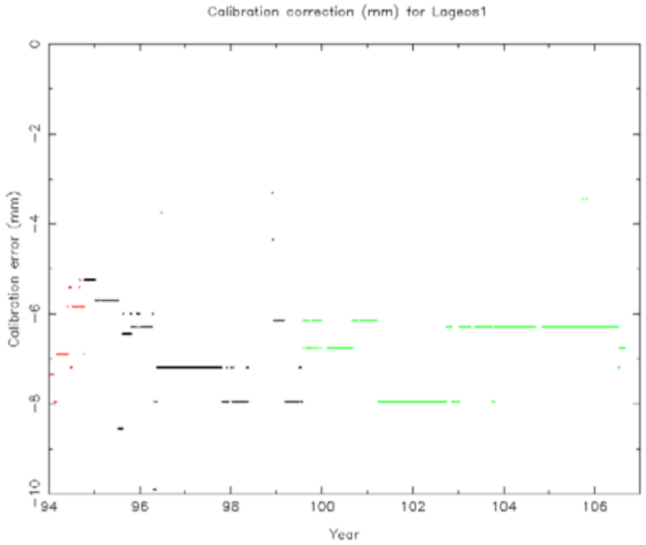

Figure 5 *Correction to calibration values used for LAGEOS during 1994-2006*

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.

Assuming that the corrections presented in SLRMail 0891 have been made to the Herstmonceux ranges, it is interesting to look at the implications for and evidence in geodetic solutions of this newly-discovered correction of 8.5±2 mm. The centre-of-

Hx site log

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B599 | 2007-02-01

	A	B	C	D	E	F	G	H	I	J	K	L	M
562	Date Installed	1995-01-01											
563	Date Removed	2007-02-01											
564	Additional Information	Four Stanford counters of varying											
565		ages were used historically -											
566		for details of usage see SCH and SCI											
567		files. The telescope has a field of											
568		view of 10 arc minutes. However this is											
569		reduced to a maximum of 250 arcsecs											
570		by an iris in the light path.											
571		For normal daytime observing											
572		the iris size is reduced to 50 arcsecs.											
573		For normal night observing a 100 arcsecs											
574		iris is used.											
575		Whichever iris is used, the light is											
576		focused onto the detector via a field lens.											
577													
578	6.01.06 Primary Chain												
579	Wavelength [nm]	532											
580	Detector Type	CSPAD											
581	Manufacturer	PESO Consulting											
582	Model												
583	Quantum Efficiency [%]	20											
584	Nominal Gain												
585	Rise Time [ps]	1500											
586	Jitter (Single PE)[ps]	30											
587	Field of View Diam ["]	20 - 250											
588	Date Installed	2002-10-16											
589	Date Removed	2009-02-01											
590	Return-Rate Controlled	YES											
591	Mode of Operation	Single Photon											
592	Additional Information												
593	Time of Flight Observ.	Event Timer											
594	Manufacturer	Home Build around 3 Thales Modules											
595	Model	2x timing modules 2396-201-000 No.s 12 & 13											
596		1x clock module 3396-211-000 No. 6											
597	Resolution [ps]	1											
598	Precision [ps]	5											
599	Date Installed	2007-02-01											
600	Date Removed												
601	Additional Information												
602													
603	6.01.07 Primary Chain												

Sheet1 +

Ready

100%

Subject: [SLR-Mail] No. 891: Removal of systematic bias in Herstmonceux SLR range data
From: Graham Appleby & Philip Gibbs <slr@slrb.rgo.ac.uk (SLR Herstmonceux)>

****
SLR Electronic Mail 2002-01-30 08:34:00 UTC Message No. 891
****

$Author: Graham Appleby & Philip Gibbs
Subject: Removal of systematic bias in Herstmonceux SLR range data

NERC Space Geodesy Facility
REMOVAL OF SYSTEMATIC BIAS IN HERSTMONCEUX SLR RANGE DATA

REASON FOR CHANGE
We are now confident that we understand the characteristics of a range-dependent range bias that has been in our SLR measurements since 1994 October 1. It is caused by subtle non-linear effects in the Stanford SR620 counters that we use to make the range measurements; the range bias values (amounting for example to some 8-10mm at the distance of LAGEOS) continue to be stable and predictable at a level of uncertainty of about 20ps (3mm in 1-way range).

DATE OF CHANGE
From 2002 February 1 00:00 UT we will apply range corrections to our data before they are submitted to EDC and CDDIS and no further corrections will be required by users.

CONSISTENCY WITH PREVIOUS DATA
For maximum accuracy in interpretation of Herstmonceux (7840) data obtained in the period 1994 October 1 until 2002 January 31 inclusive, the following table should be used to determine the appropriate range-dependent correction that must be ADDED TO the time-of-flight given in the normal point data.

Range (ms)	Correction (ps) to 2-way time-of flight
0	0
2	35
4	48
6	52
8	73
10	77
12	91
14	92
16	100
18	120
20	109
22	120
24	111
26	115
28	112
30	97
32	100
34	87
36	82
38	75
40	72
42	73
44	62
46	61
48	50
50	54
52	48

Station Systematic Errors Estimated from SLR DATA

2019 Reanalysis Project Results since 1993

EDITED ±100 mm SUBMISSIONS

LAGEOS ESTIMATE	LAGEOS-2 ESTIMATE	COMBINED ESTIMATE ETALON1&2
☐ **ASI v231**	☐ **ASI v231**	☐ **ASI v231**
☐ **BKG v231**	☐ **BKG v231**	☐ **BKG v231**
☐ **DGFI v232**	☐ **DGFI v232**	☐ **DGFI v232**
☐ **ESA v231**	☐ **ESA v231**	☐ **ESA v231**
☐ **GFZ v231**	☐ **GFZ v231**	☐ **GFZ v231**
☐ **JCET v231**	☐ **JCET v231**	☐ **JCET v231**
☐ **NSGF v231**	☐ **NSGF v231**	☐ **NSGF v231**
☐ **ILRSA v230**	☐ **ILRSA v230**	☐ **ILRSA v230**
☑ **ILRSB v231**	☐ **ILRSB v231**	☐ **ILRSB v231**

Start (MM-DD-YYYY): 01-30-2002

End Date (MM-DD-YYYY) 02-11-2007

Station 7840 Herstmonceux

Plot Size Minimum Maximum

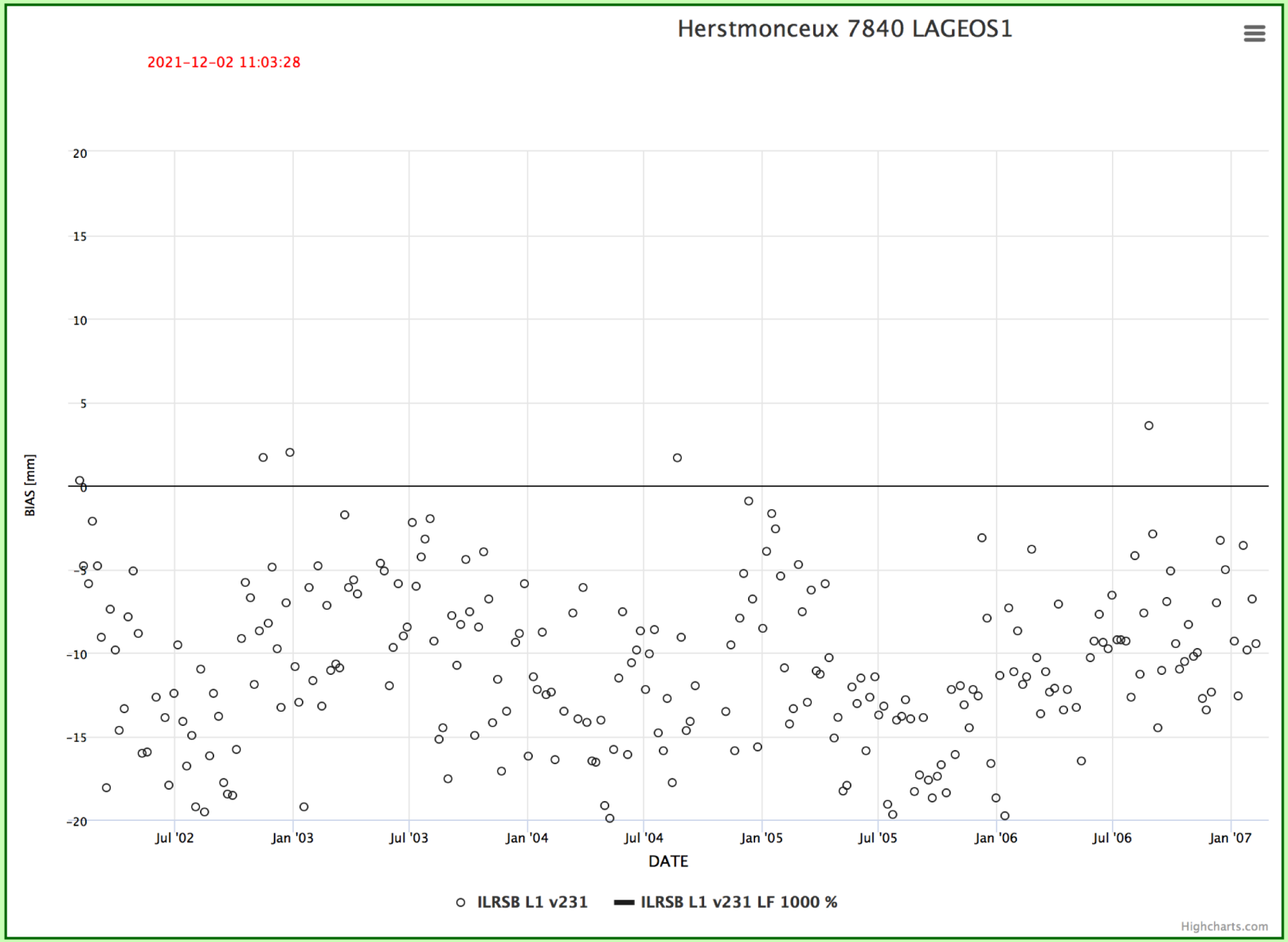
Y axis -20 20

LOESS regression 1000 %

☐ SHOW STATION EVENTS

SHOW STATION EVENTS EQUAL TO (SELECT BETWEEN 0-3) 0

Submit Reset form



HOME

New Plot

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

Station Systematic Errors Estimated from SLR DATA

2019 Reanalysis Project Results since 1993

EDITED ±100 mm SUBMISSIONS

LAGEOS ESTIMATE	LAGEOS-2 ESTIMATE	COMBINED ESTIMATE ETALON1&2
☐ **ASI v231**	☐ **ASI v231**	☐ **ASI v231**
☐ **BKG v231**	☐ **BKG v231**	☐ **BKG v231**
☐ **DGFI v232**	☐ **DGFI v232**	☐ **DGFI v232**
☐ **ESA v231**	☐ **ESA v231**	☐ **ESA v231**
☐ **GFZ v231**	☐ **GFZ v231**	☐ **GFZ v231**
☐ **JCET v231**	☐ **JCET v231**	☐ **JCET v231**
☐ **NSGF v231**	☐ **NSGF v231**	☐ **NSGF v231**
☐ **ILRSA v230**	☐ **ILRSA v230**	☐ **ILRSA v230**
☑ **ILRSB v231**	☐ **ILRSB v231**	☐ **ILRSB v231**

Start (MM-DD-YYYY): 02-11-2007

End Date (MM-DD-YYYY) 01-01-2021

Station 7840 Herstmonceux

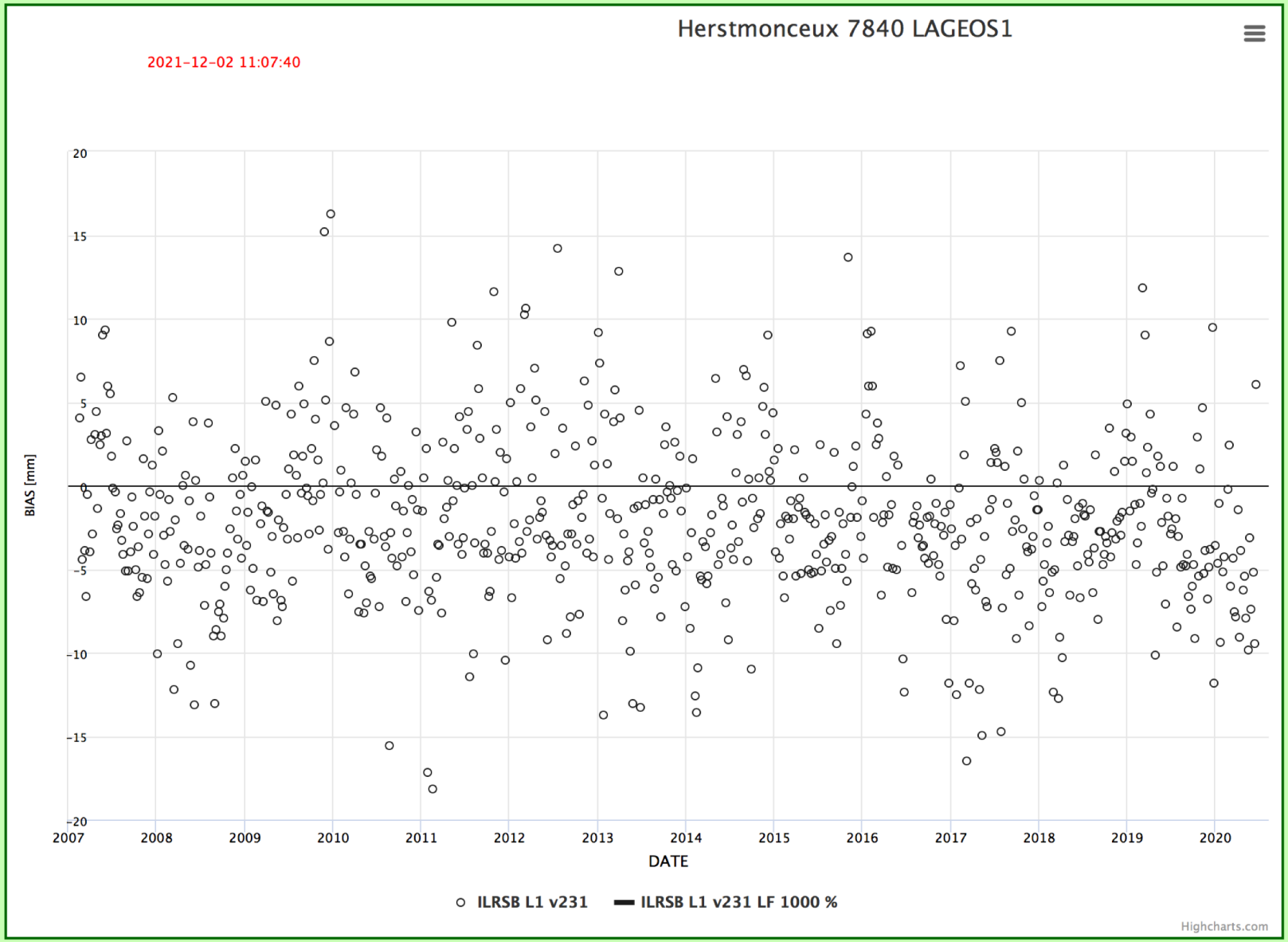
Plot Size	Minimum	Maximum
Y axis	-20	20

LOESS regression 1000 %

☐ SHOW STATION EVENTS

SHOW STATION EVENTS EQUAL TO (SELECT BETWEEN 0-3) 0

Submit Reset form



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

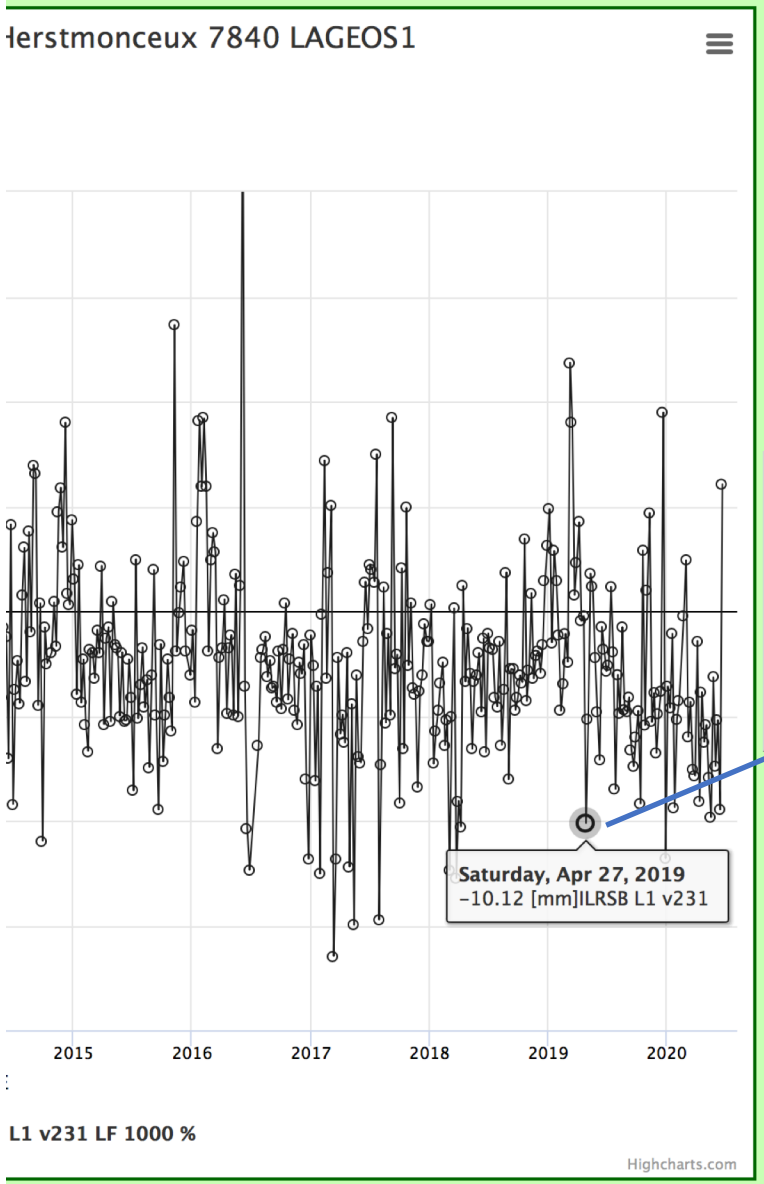
Conclusions

Between February 2002 and and February 2007 Hx reads short on LAGEOS1
by (-11.2+8.5 =)
-2.7 +/- 1 mm standard error

Between February 2007 and and June 2020 Hx reads short on LAGEOS1
by
-2.1 +/- 1 mm standard error

Safari File Edit View History Bookmarks Develop Window Help 100% Fri 8:11 AM Peter Dunn

Not Secure — geodesy.jcet.umbc.edu



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Station History Log | Herstmonceux, United Kingdom (7840) | Stations | EUROLAS

Zoom Share Highlight

Station History Log - Herstmonceux, United Kingdom (7840

SOD	Year	Day of Year	Time of Day	Data Impact	System	Description
78403501	2020	269	10:00	1	5.01	Switched to kHz laser for SLR operations
78403501	2020	240	09:00	0	5.01	12Hz laser service
78403501	2020	211	19:00	1	5.01	Switched to older 12Hz laser for SLR operations
78403501	2020	198	18:00	1	06.01.07	New SPAD cable fitted
78403501	2020	049	18:00	0	7.02	New Ranging PC installation complete
78403501	2020	041	21:00	0	7.02	PC fatal crash. Motherboard stopped working.
78403501	2019	136	08:30	1	05.02	New kHz freq-doubler crystal fitted
78403501	2019	098	08:30	1	05.02	kHz chiller water changed and flow cleaned
78403501	2018	339	08:30	1	9.01.02	GPS reference replaced with new S650 GPS rece
78403501	2018	275	08:30	1	06.01.07	New SPAD cable fitted
78403501	2018	268	08:30	0	99	correction to rms in CRD record 50 pass statistics
78403501	2018	254	08:30	0	04.01	Narrow spectral filter fitted with oven. Tilted
78403501	2018	141	08:30	1	05	Coude mirrors cleaned
78403501	2018	120	08:30	0	04.01	New narrow spectral filter fitted
78403501	2018	116	08:30	0	99	Mains electrical provided by power grid
78403501	2018	099	08:30	0	99	Mains electrical provided by generator

s://edc.dgfi.tum.de/en/stations/7840/station_history_log/

ion History Log | Herstmonceux, United Kingdom (7840) | Stations | EUROLAS Data Center (EDC)

78403501	2018	074	08:30	0	04.01	New daytime narrow filter assemby fitted
78403501	2018	036	08:30	1	08.02	New external target adopted as primary calibratior

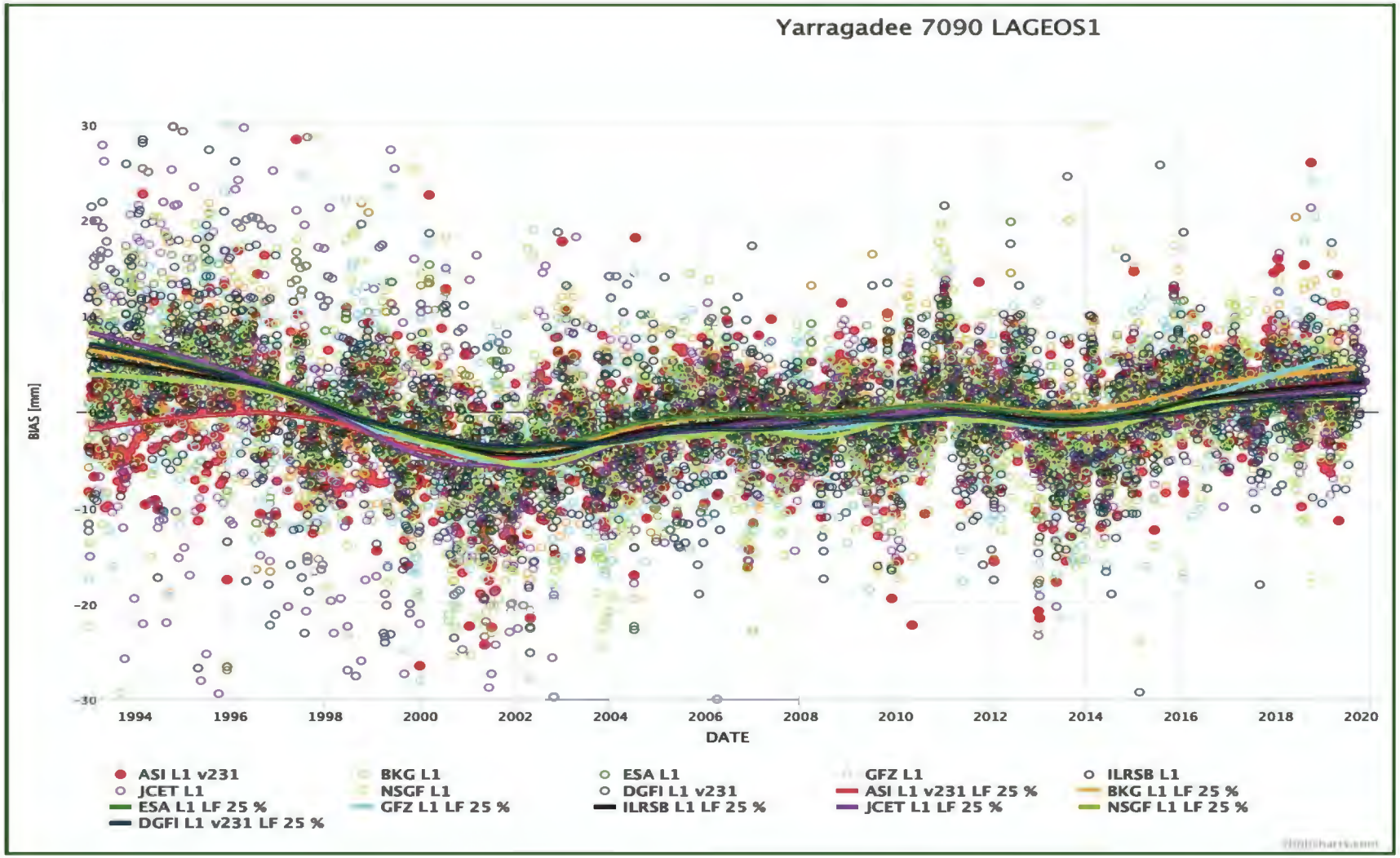
Interpretation of ITRF2020 SSEM Results

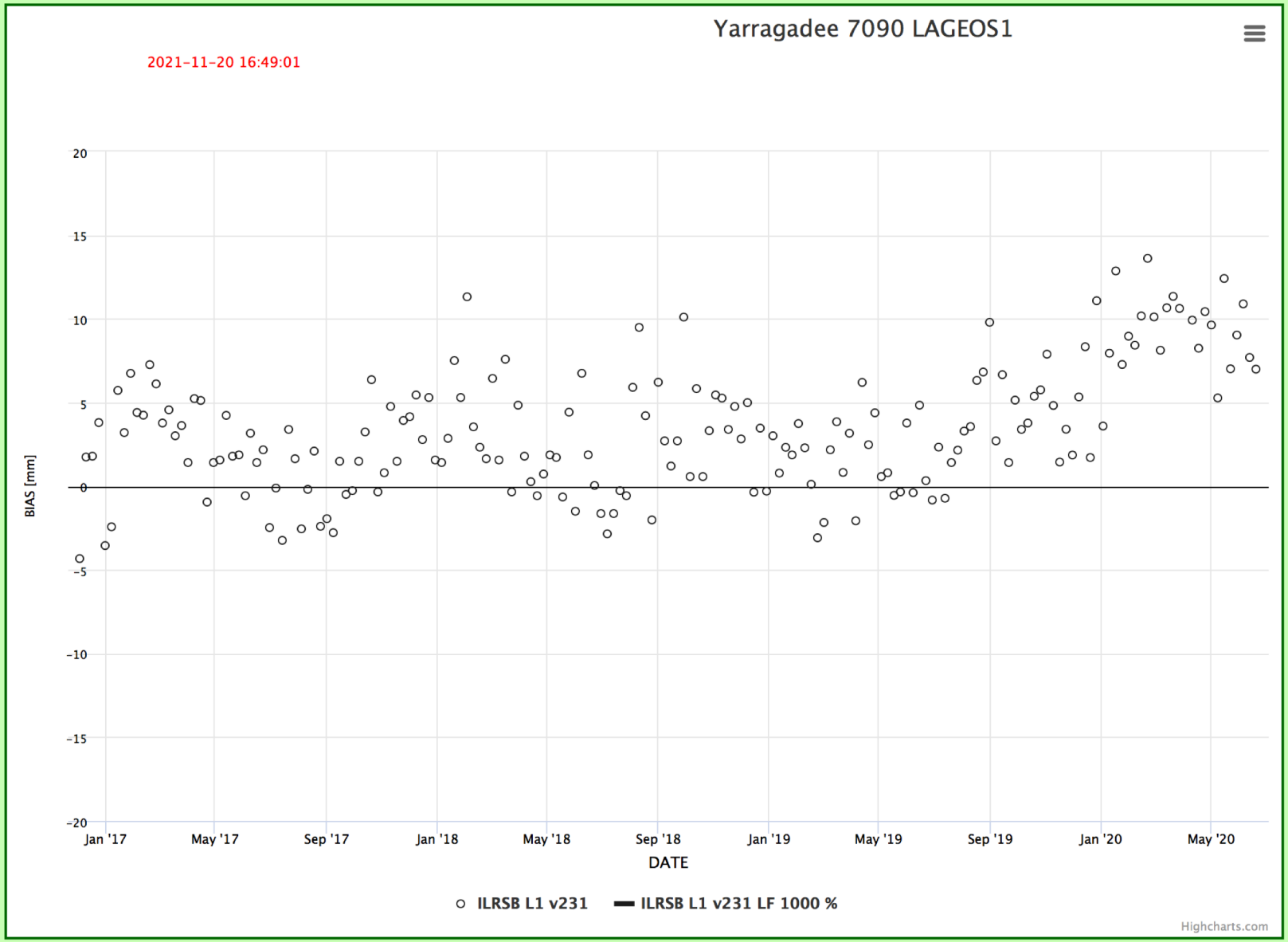
Consider YARL from 1992 to 2020

Dive deeper into 2017 to 2020

Can we rationalize the observed SSEM RB behavior?

Yarragadee, 7090, SSEM Results





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New Plot

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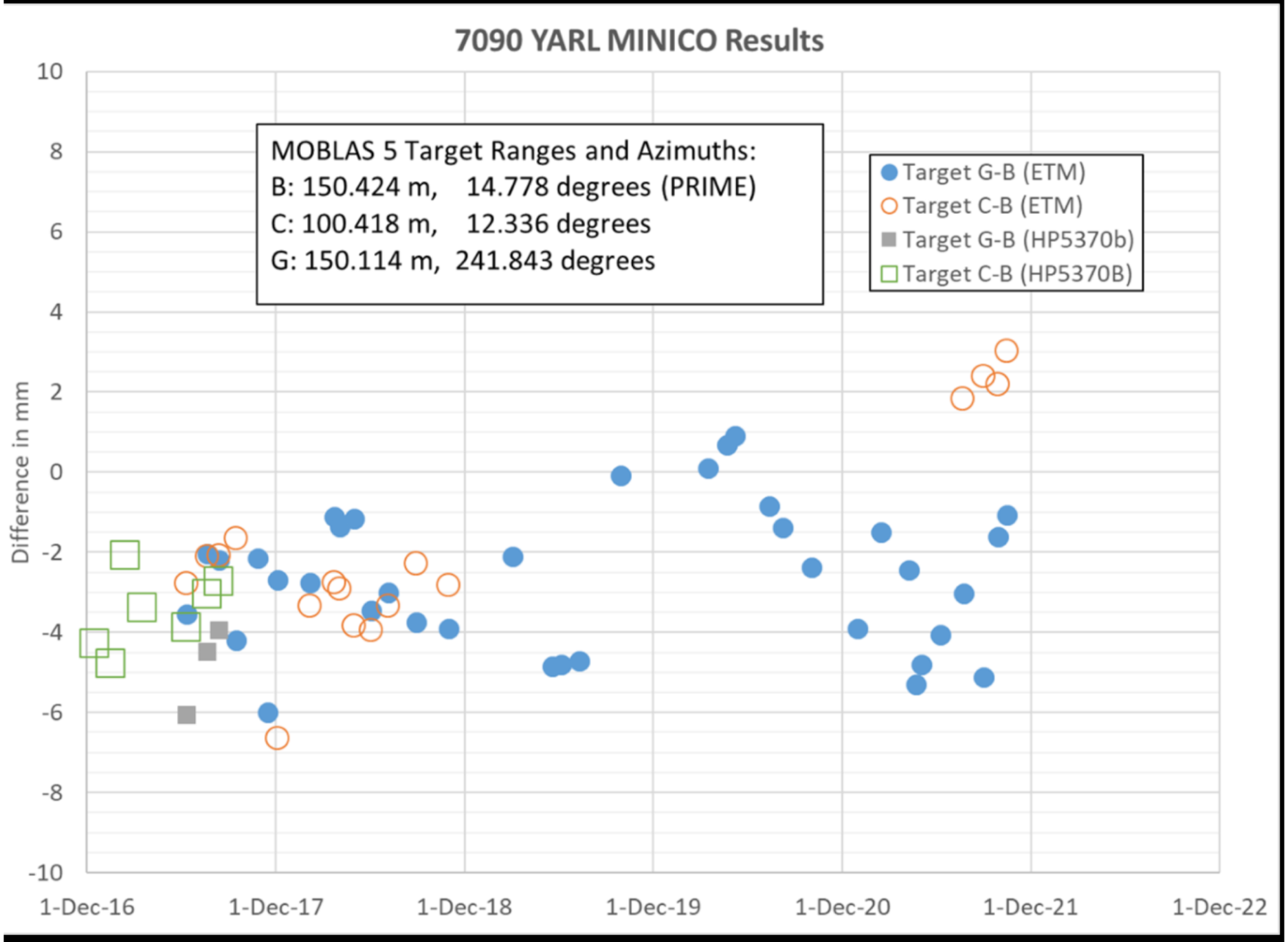
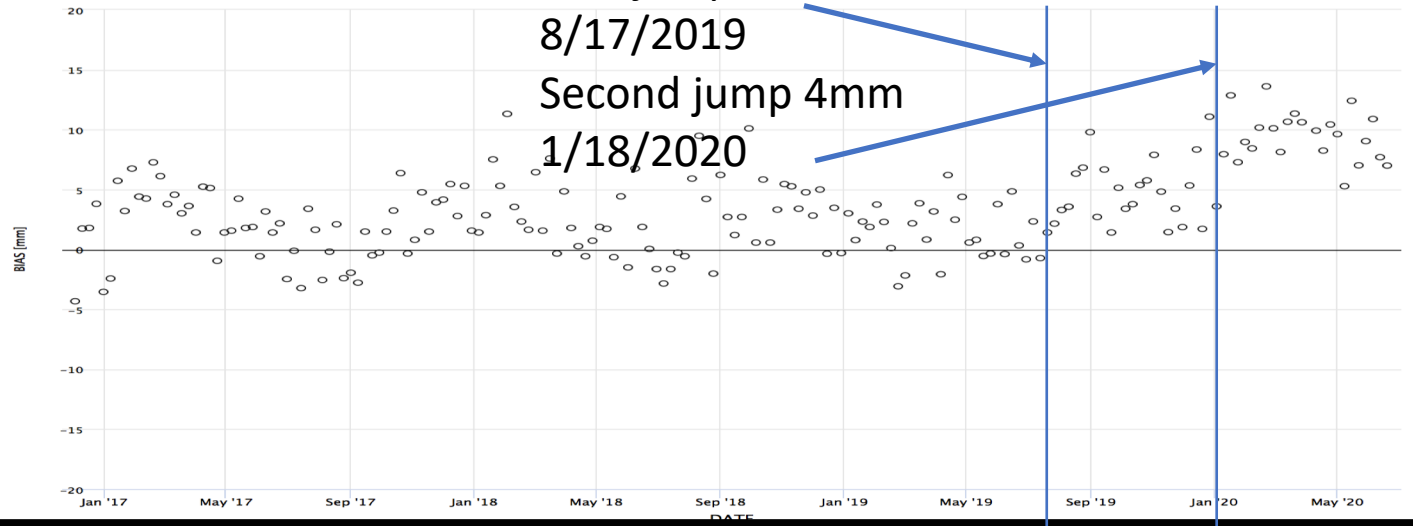
ILRSB LAGEOS1 v231 Mean/Std. Dev.:3.41±3.71 Count:185


7090 YARL MINICO Results
MOBLAS 5 Target Ranges and Azimuths:
B: 150.424 m, 14.778 degrees (PRIME)
C: 100.418 m, 12.336 degrees
G: 150.114 m, 241.843 degrees
Target G-B (ETM)
Target C-B (ETM)
Target G-B (HP5370b)
Target C-B (HP5370B)
Difference in mm
10
8
6
4
2
0
-2
-4
-6
-8
-10
1-Dec-16
1-Dec-17
1-Dec-18
1-Dec-19
1-Dec-20
1-Dec-21
1-Dec-22

First jump 4mm
8/17/2019
Second jump 4mm
1/18/2020



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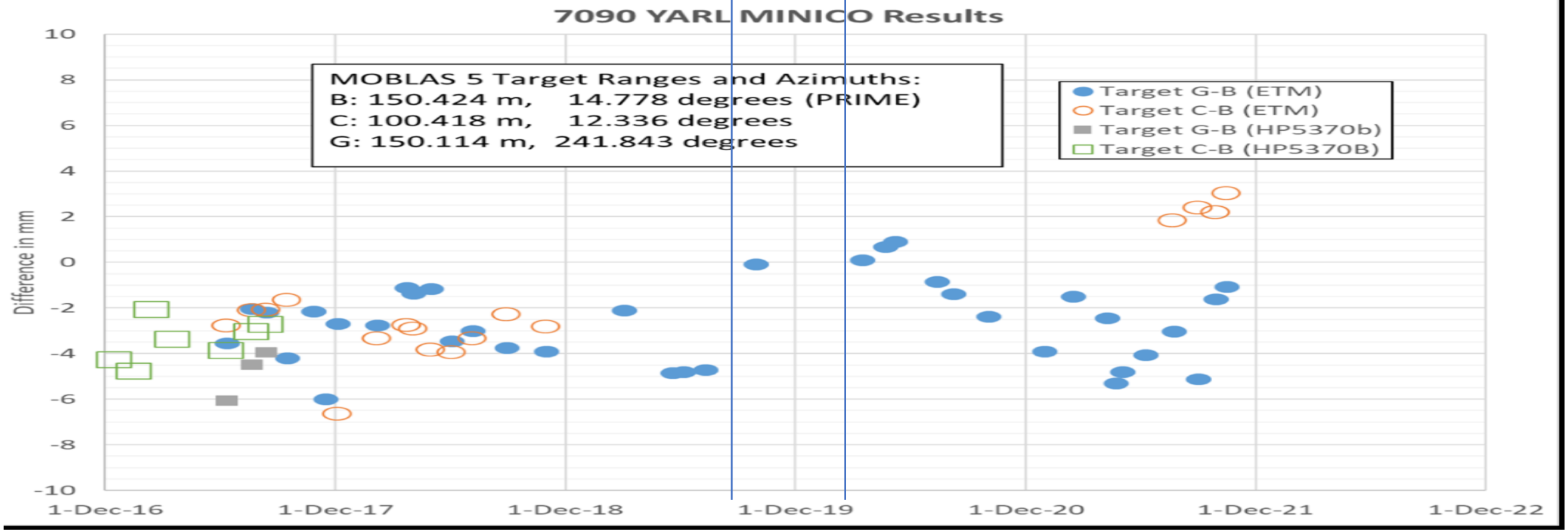


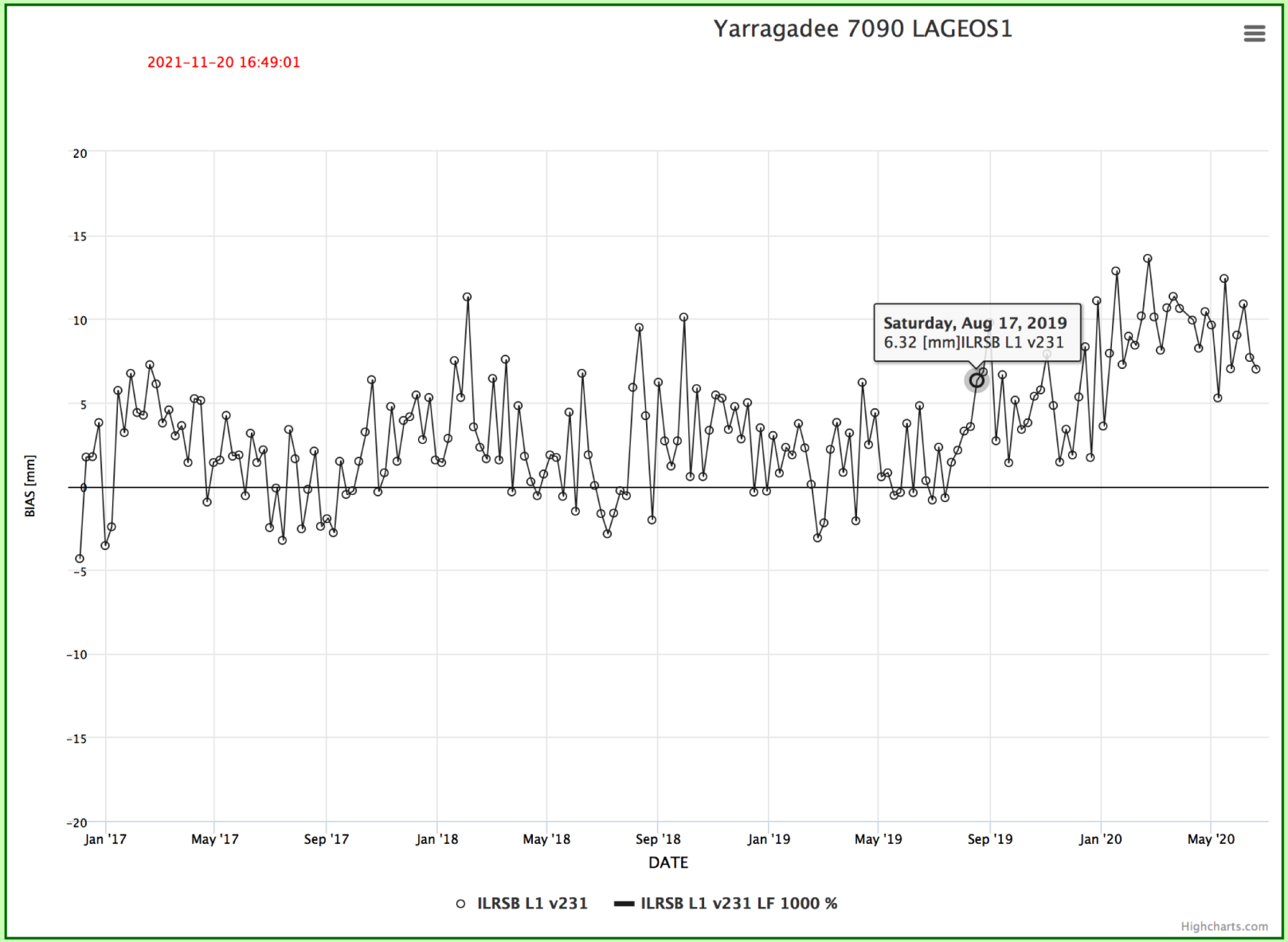
Conclusions

An 8mm RB shift at YARL between 2017 and 2021
corresponds to a 6mm Minico measurement.

The prime target moved umm 7mm.

1.this can be confirmed by completing a survey.
Or
2. can be considered as the survey

So
Subtract 3mm from ranges after 8/17/2019
Subtract another 4mm from ranges after 1/18/2020



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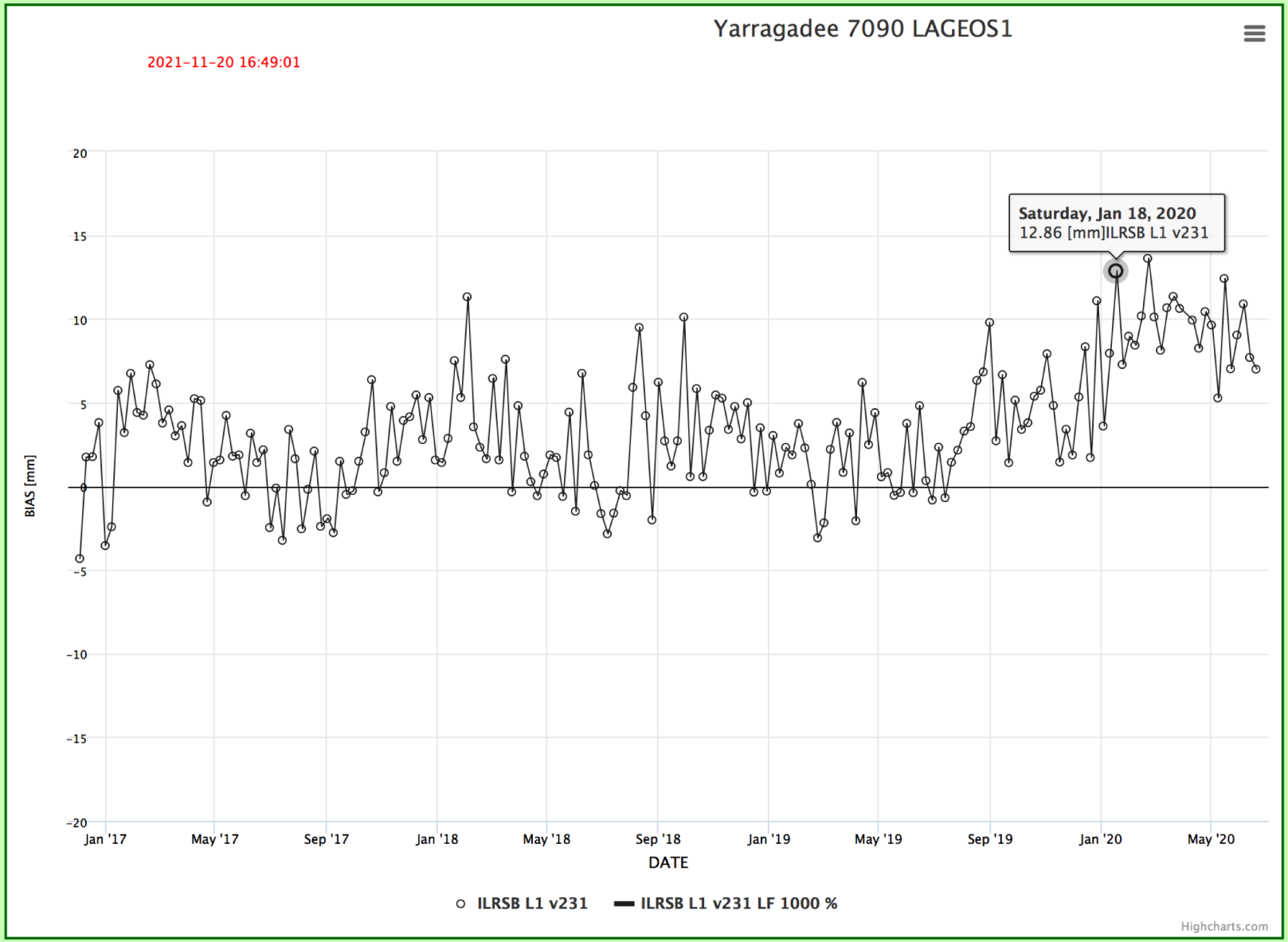
ILRSB LAGEOS1 v231 Mean/Std. Dev.:3.41±3.71 Count:185



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New Plot

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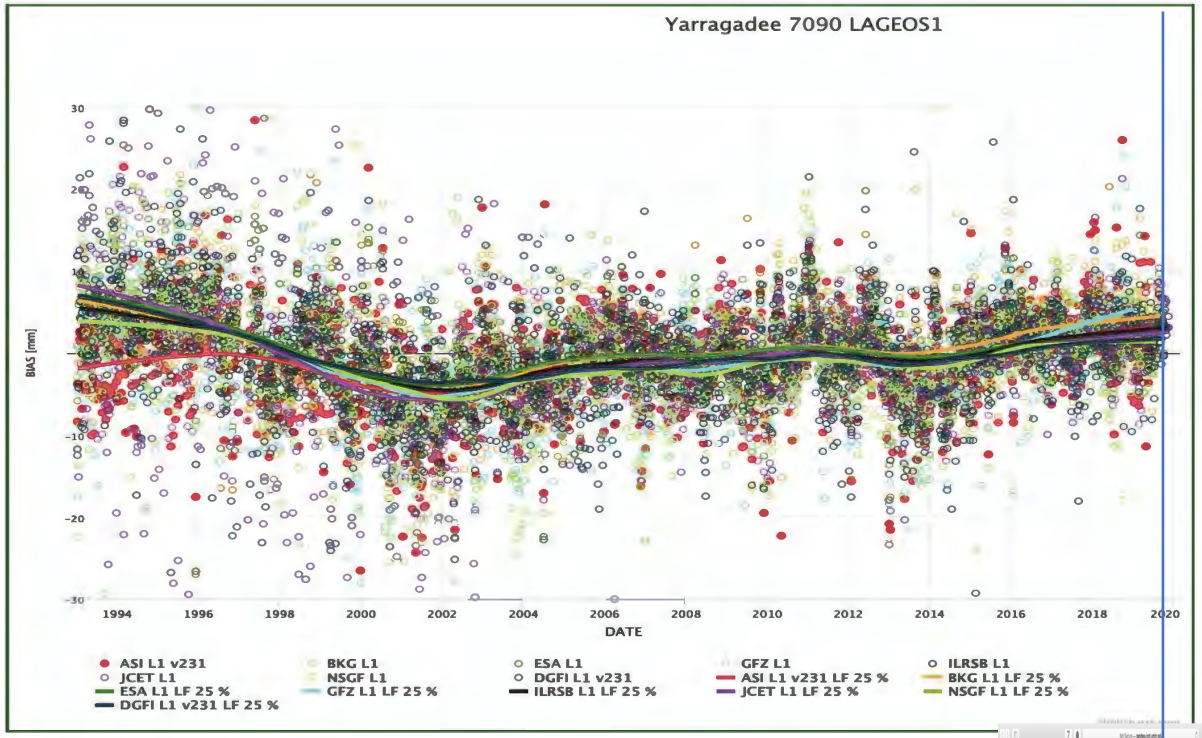
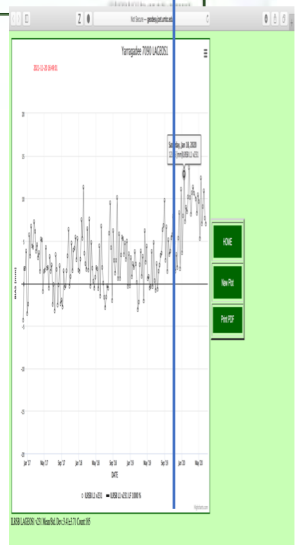
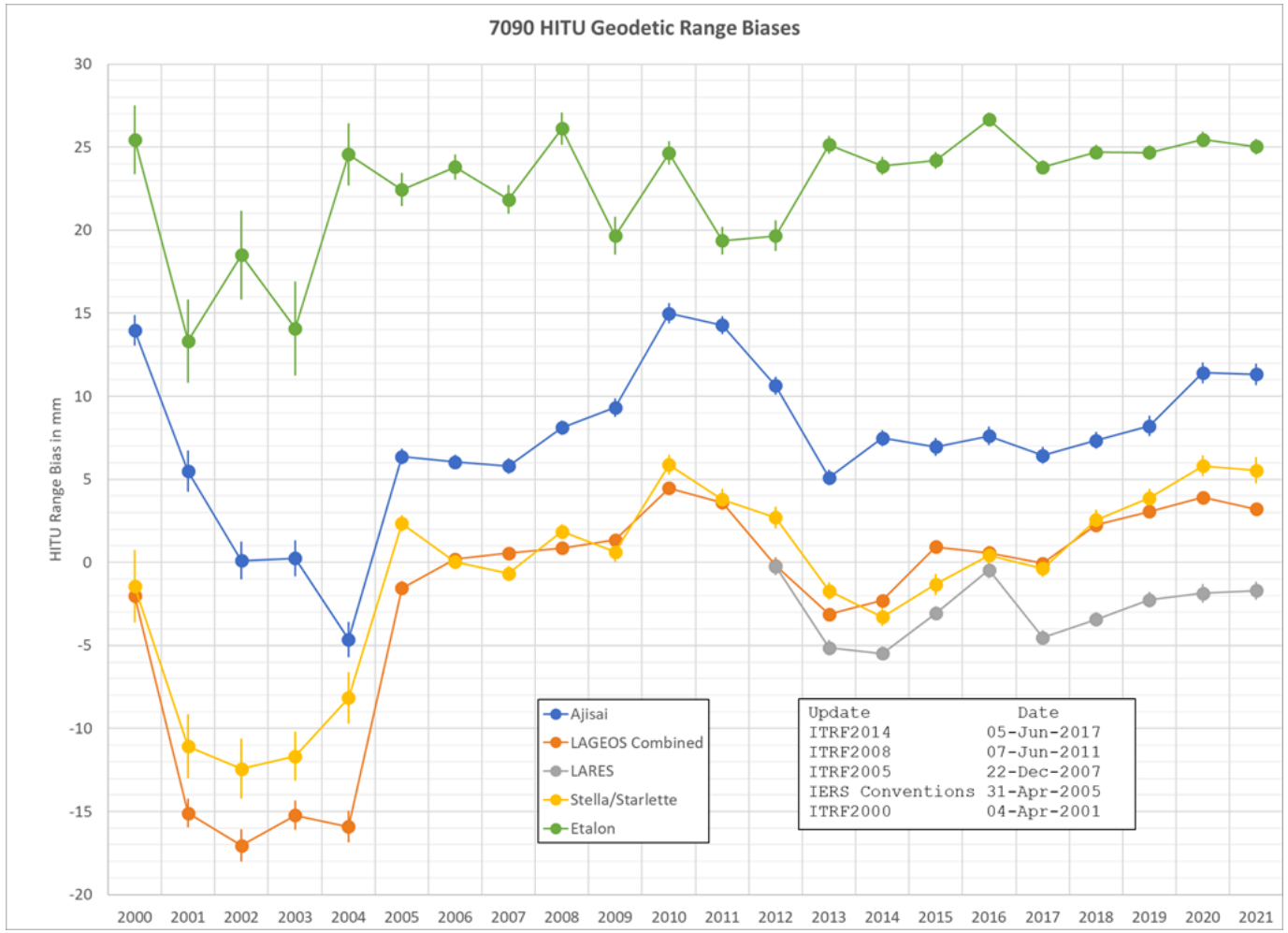
ILRSB LAGEOS1 v231 Mean/Std. Dev.:3.41±3.71 Count:185

Yarragadee, 7090, SSEM Results






7090 HITU Geodetic Range Biases
HITU Range Bias in mm
30
25
20
15
10
5
0
-5
-10
-15
-20
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Ajisai
LAGEOS Combined
LARES
Stella/Starlette
Etalon
Update Date
ITRF2014 05-Jun-2017
ITRF2008 07-Jun-2011
ITRF2005 22-Dec-2007
IERS Conventions 31-Apr-2005
ITRF2000 04-Apr-2001