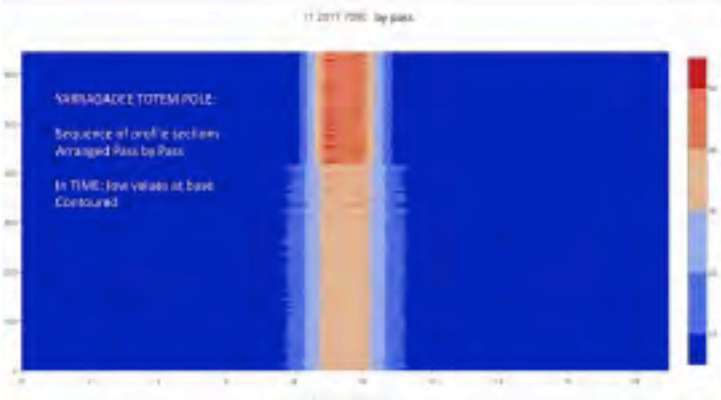
ILRS QCB Meeting

June 25, 2020
9:00 am

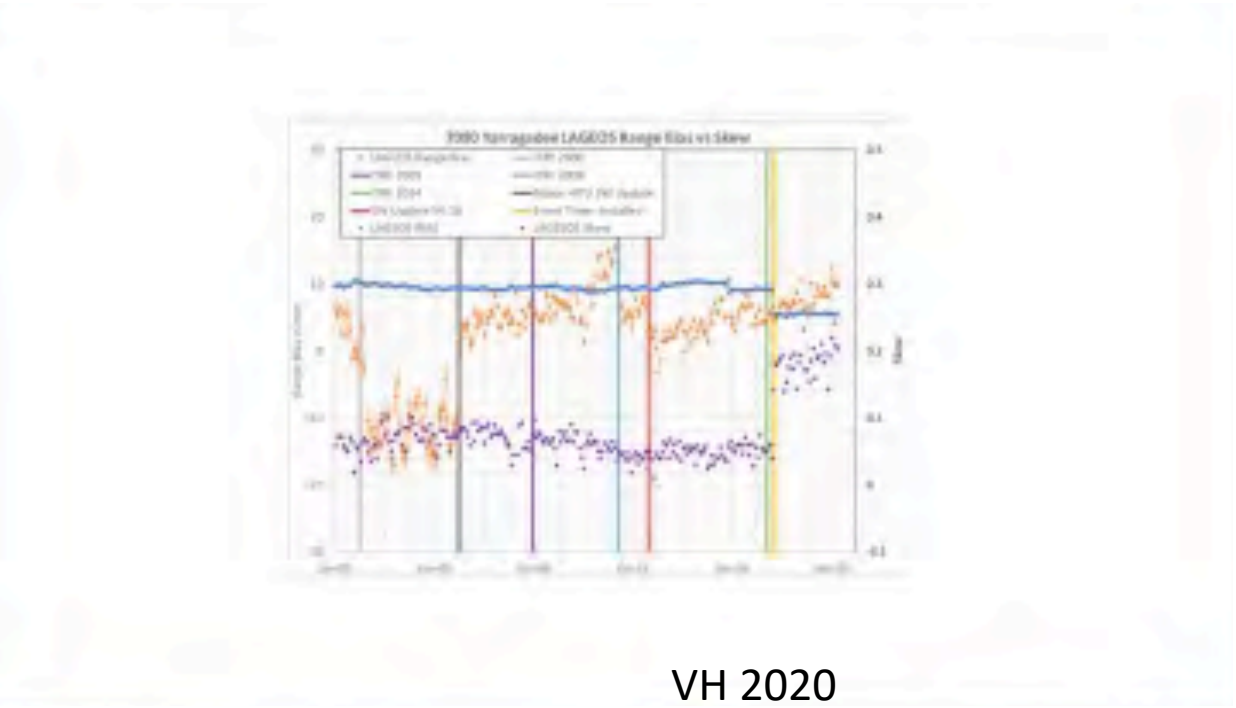
Agenda

- Interpretation of systematics through NP data statistics (10 min) Peter
- Processing data with the Wiener filter (20 min) Stefan
- Some relevant examples from examination of data (30 min) Van
- Discussion



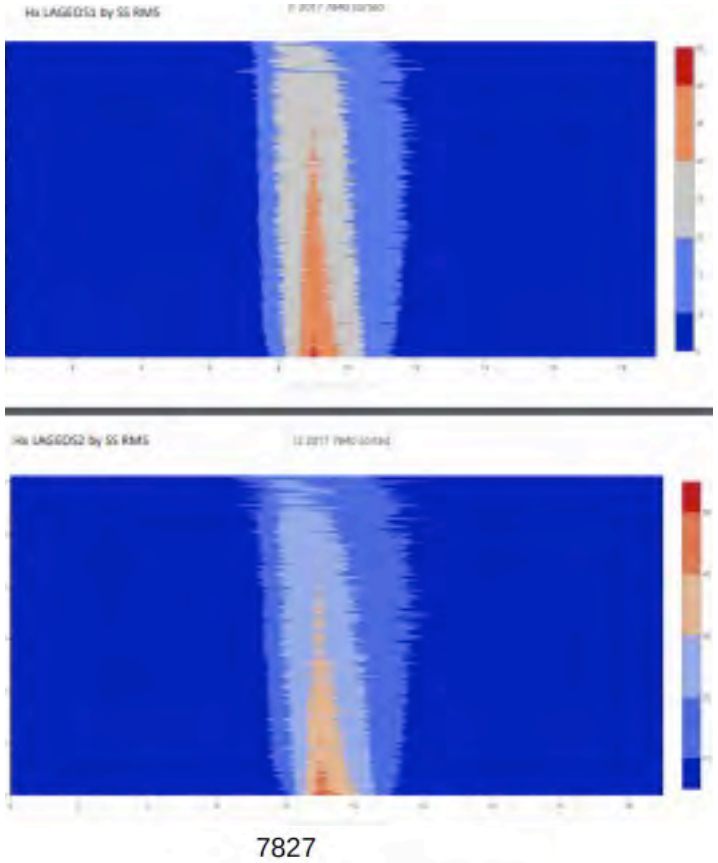
System Transfer Function

Yarragadee ETM shows a characteristic profile different from the HP5370

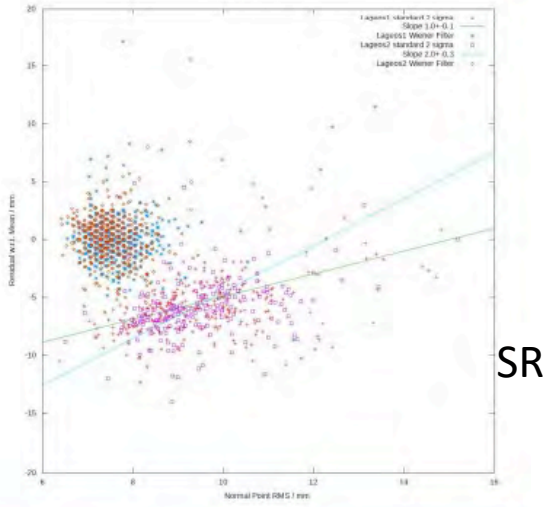


VH 2020

There is potential for pulse width and pulse shape difference as a result of the PMT voltage change.
TV 2020



7827



SR 2020

Satellite Transfer Function

LAGEOS1 shows a characteristic profile different from LAGEOS2

LAGEOS 2 is about 2 mm smaller than LAGEOS1 and this difference varies
PD 2020

Station and Satellite Signature at Core SLR stations

At Yarragadee ,the Rodriguez CoM table entries for LAGEOS1 are

7090 23 03 2015 11 09 2017 532 245.5 HP5370
7090 11 09 2017 01 01 2050 532 246.2 ETM

the Rodriguez CoM table entries for LAGEOS2 are

7090 23 03 2015 11 09 2017 532 244.8 HP45370
7090 11 09 2017 01 01 2050 532 245.7 ETM

The CoM model, based on Hx profile detection, projects a difference between both the satellites and the systems at Yarragadee

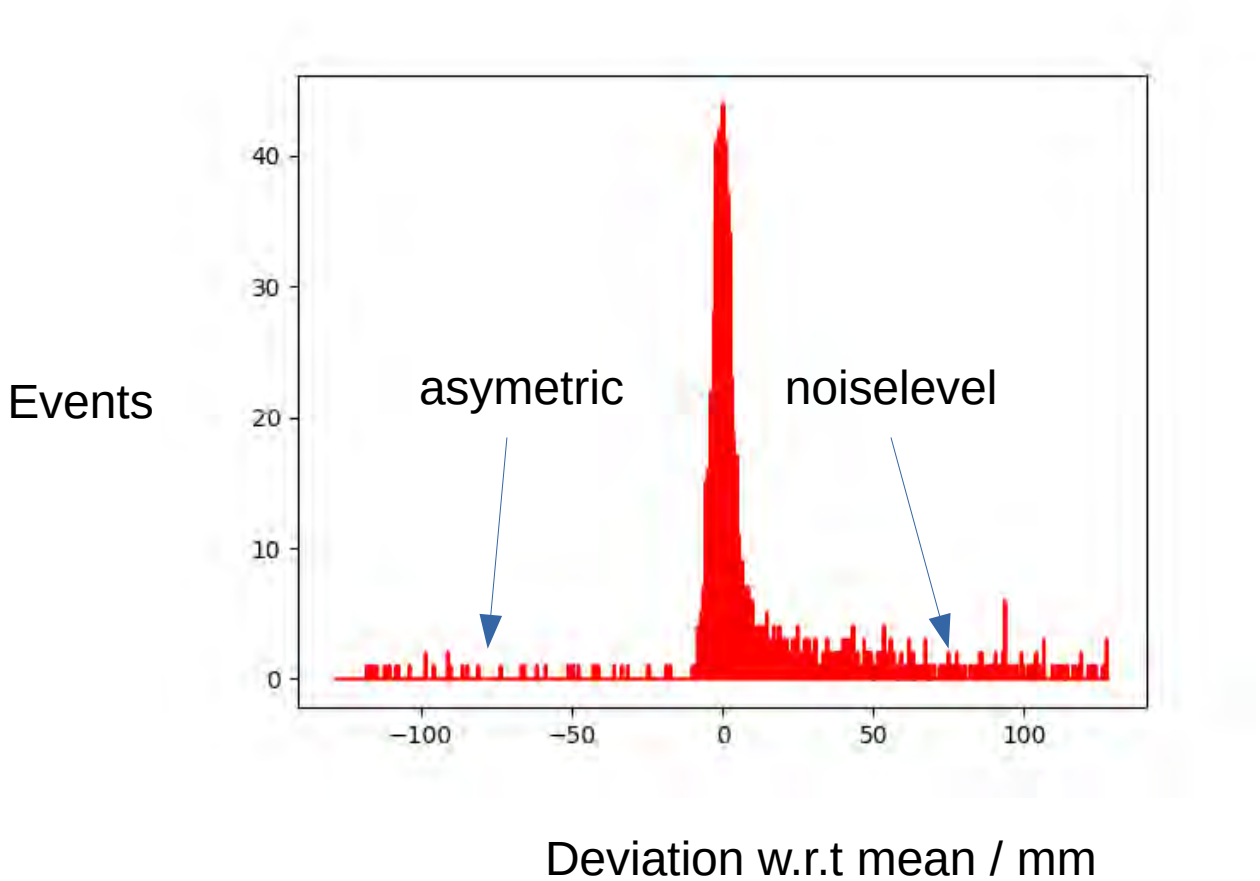
HP5370 L1-L2 = 0.7 mm
ETM L1-L2 = 0.5

L1 ETM-HP5370 = 0.7
L2 ETM-HP5370 = 0.9

The signature differences can bias the analysis of data from some SLR stations tracking some satellites

Optimal Wiener filtered Normal Points from Herstmonceux Data

Instrument Function

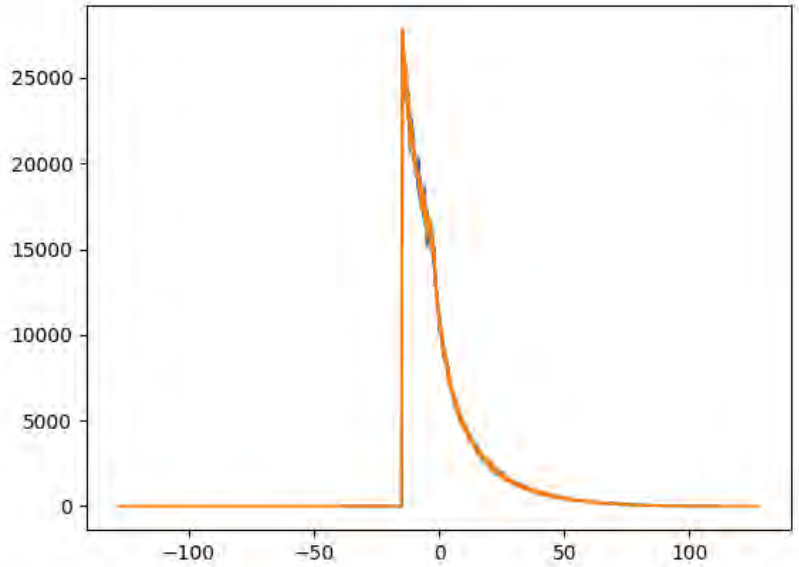


- effect is due to SPAD detector
- same effect visible in TIGO CONL data
- high resolution Hx data allows for 0.125mm bins
- noise is fully accounted for by Wiener Filter Algorithm

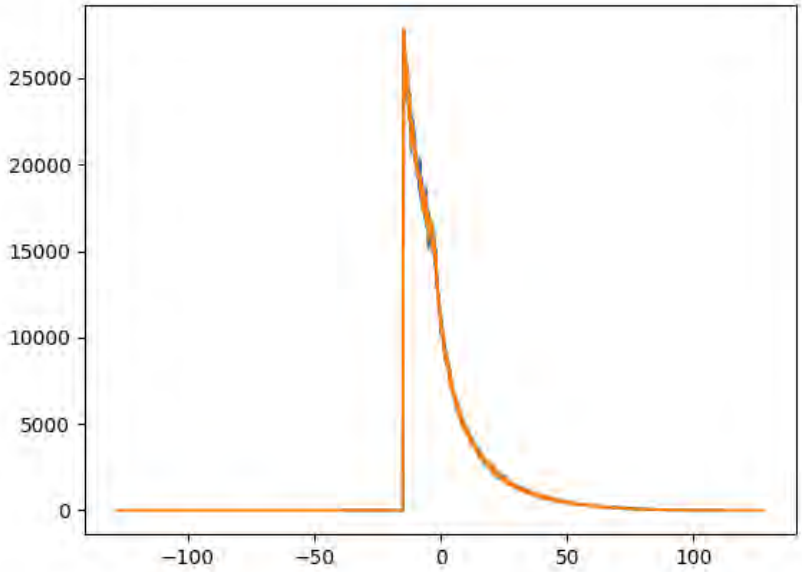
Transfer Function

REFLECTIVITY / a.u.

Lageos1



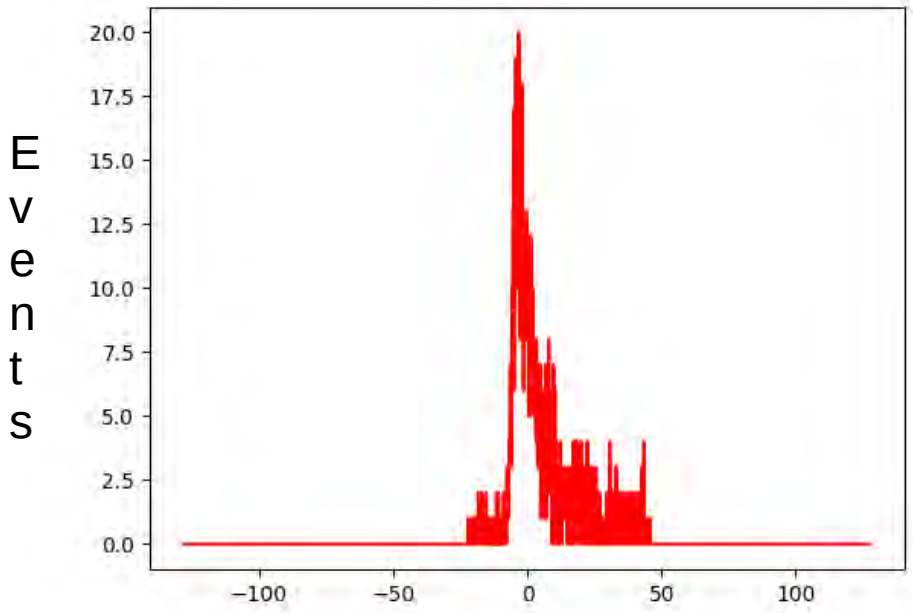
Lageos2



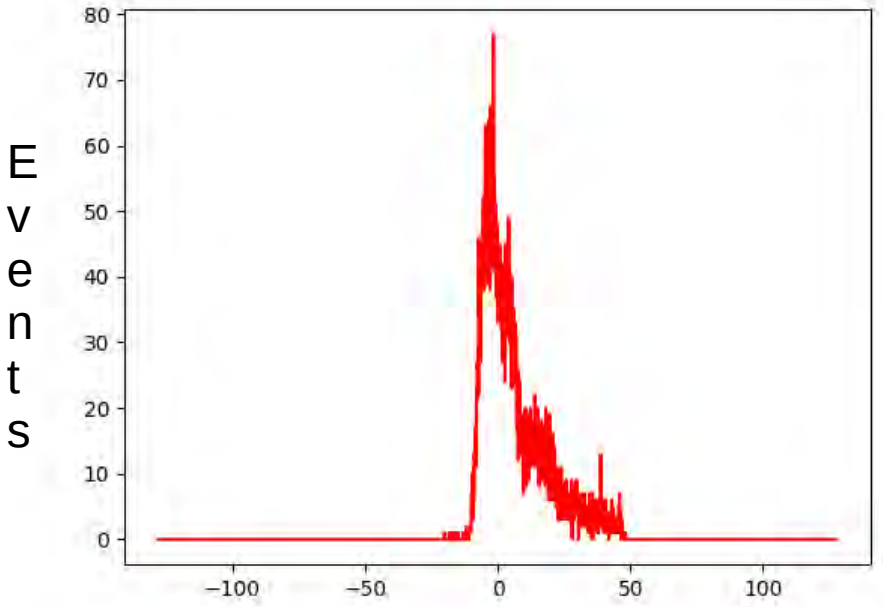
Deviation w.r.t. mean / mm

- kindly provided by J. Rodriguez (exponent 1.25 L1, exponent 1.1 L2)
- high resolution Hx data allows a 0.125 mm grid (Resolution Bandwidth)
- Wiener Filter is used with various cutoff frequencies (Video Bandwidth)

Lageos1 NP-histograms

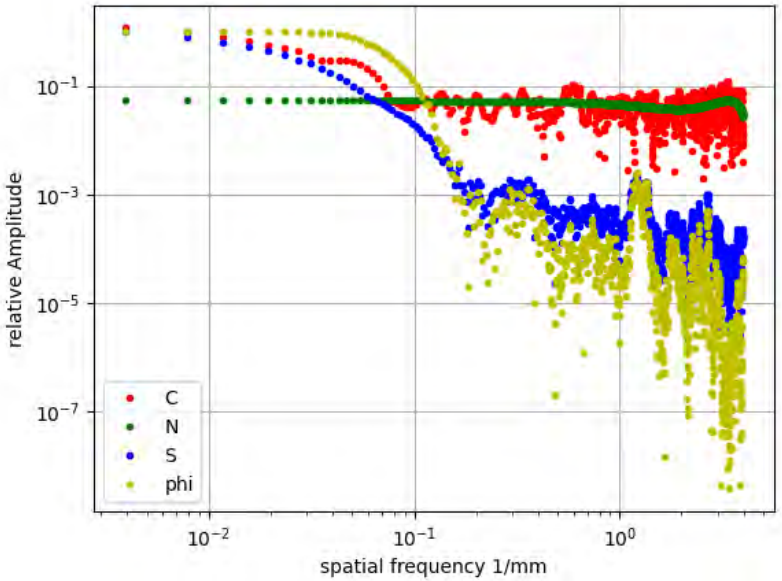


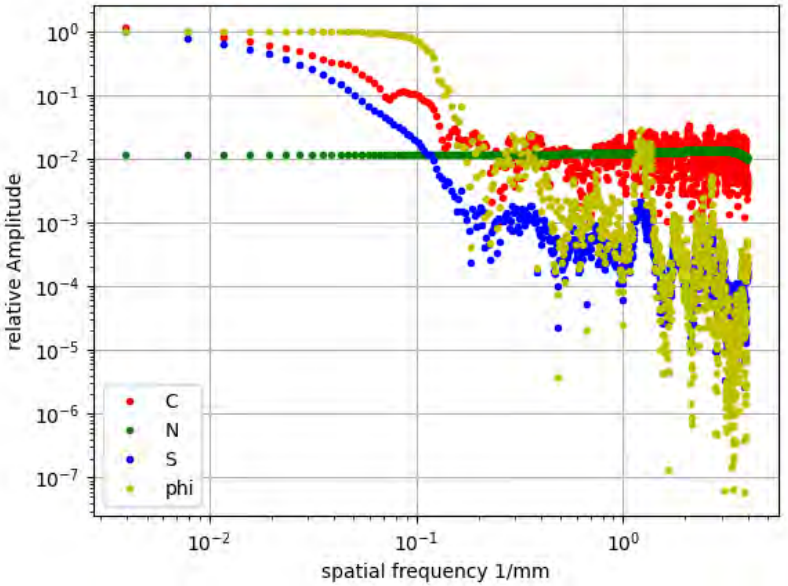
- leptokurtic multiple peaks, the usual case



-platykurtic multiple peaks cause fringes in deconvolution

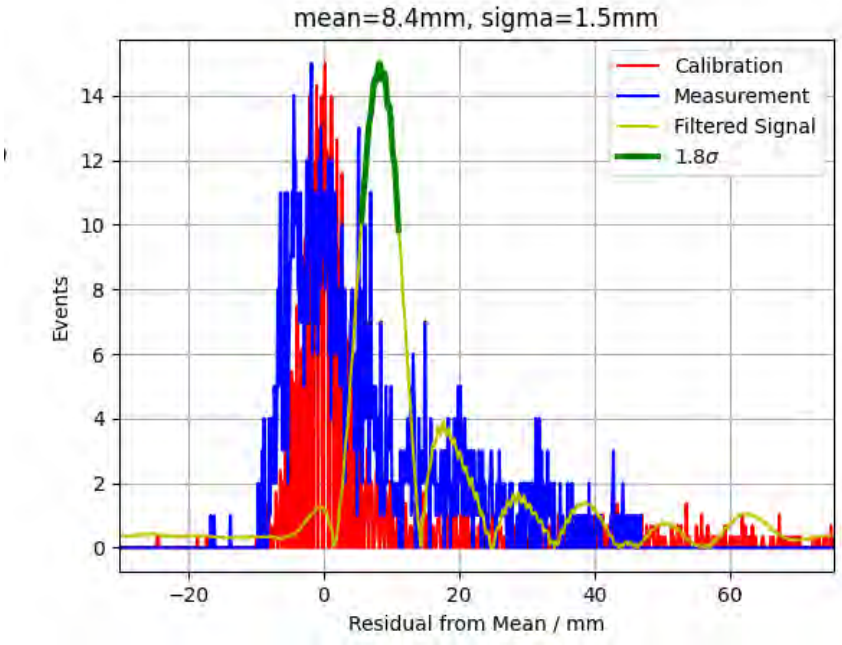
7840 Spectral Data Lageos1

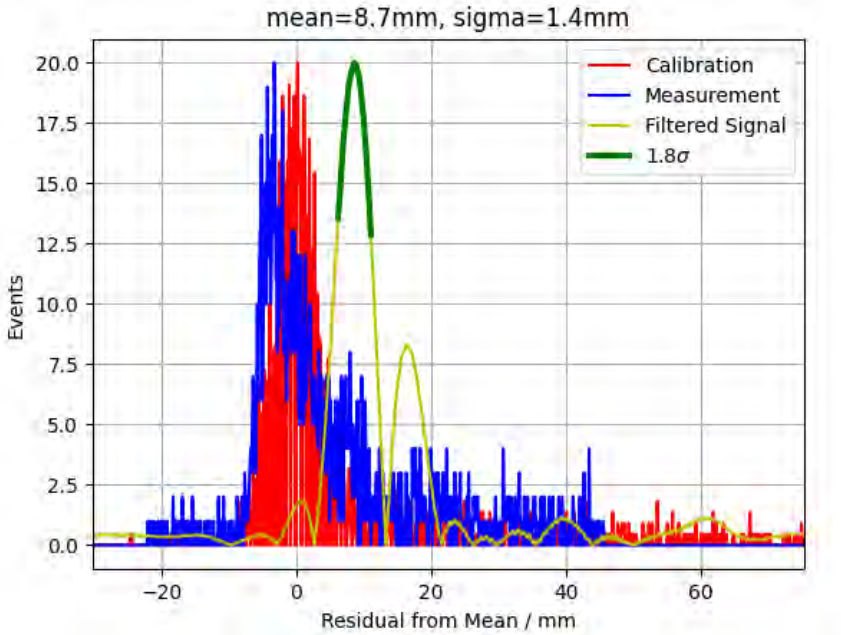




- multiple peaks cause excess in power spectrum w.r.t. incoherent model (left)
- spectral excess is more pronounced for broader leptokurtic peaks (right)
- cutoff frequency is chosen best when measurement spectrum fades into noise, 0.2 cycles/mm seems to be characteristic for Lageos.

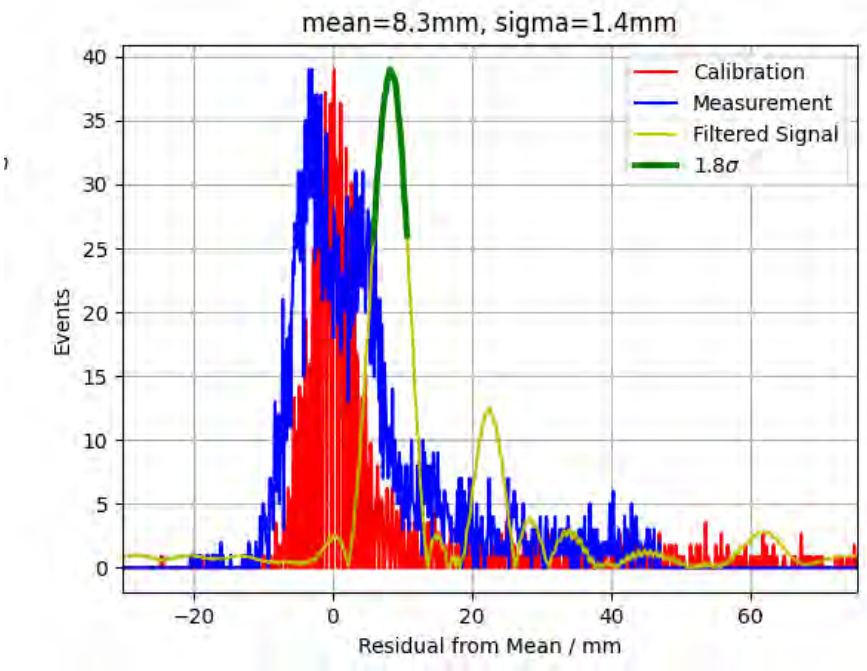
Lageos1 deconvolution

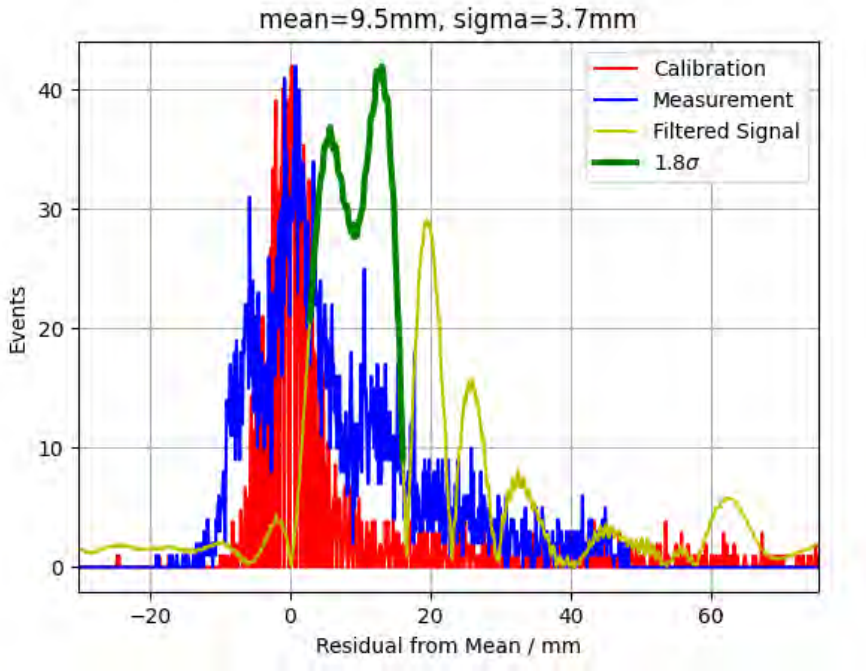




- Wiener Filter works also for sparse data
- in rare cases double peaks cause outliers when editing filtered signal with 2 sigma criterium

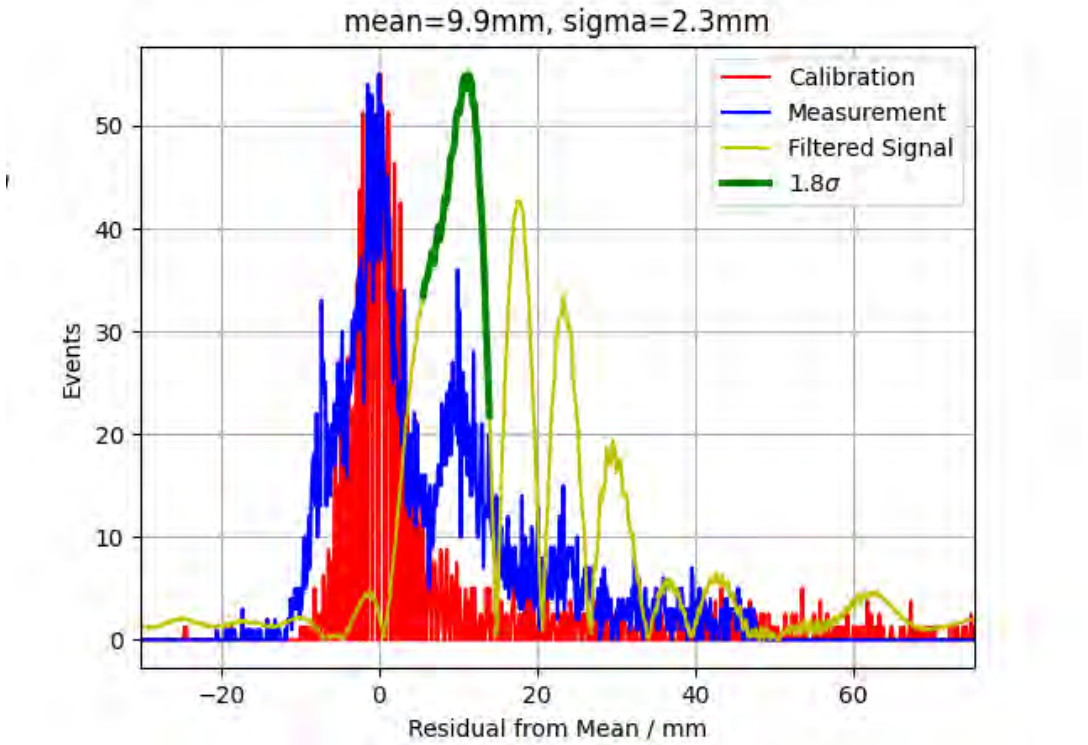
Lageos2 deconvolution





- in general Lageos2 response is more corrupted with multiple peaks than Lageos1 response
-1.8 sigma editing with high cutoff frequency (1.0/mm) of filtered signal is not a general solution

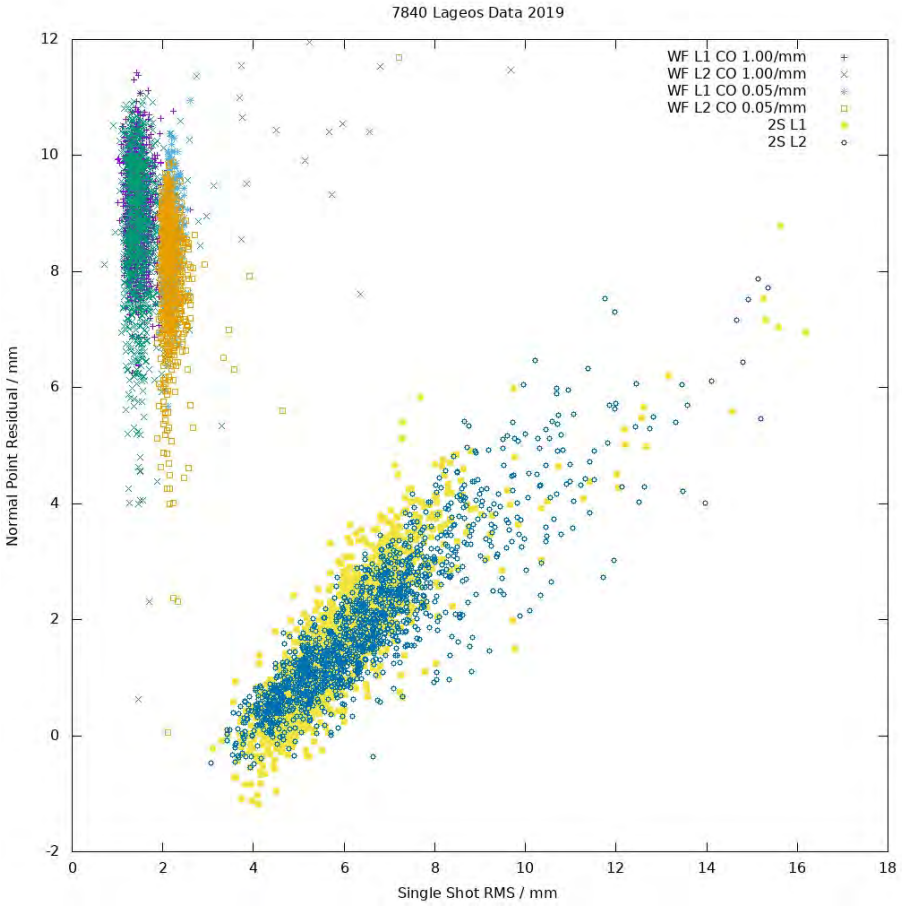
Lageos2 deconvolution co=0.05/mm



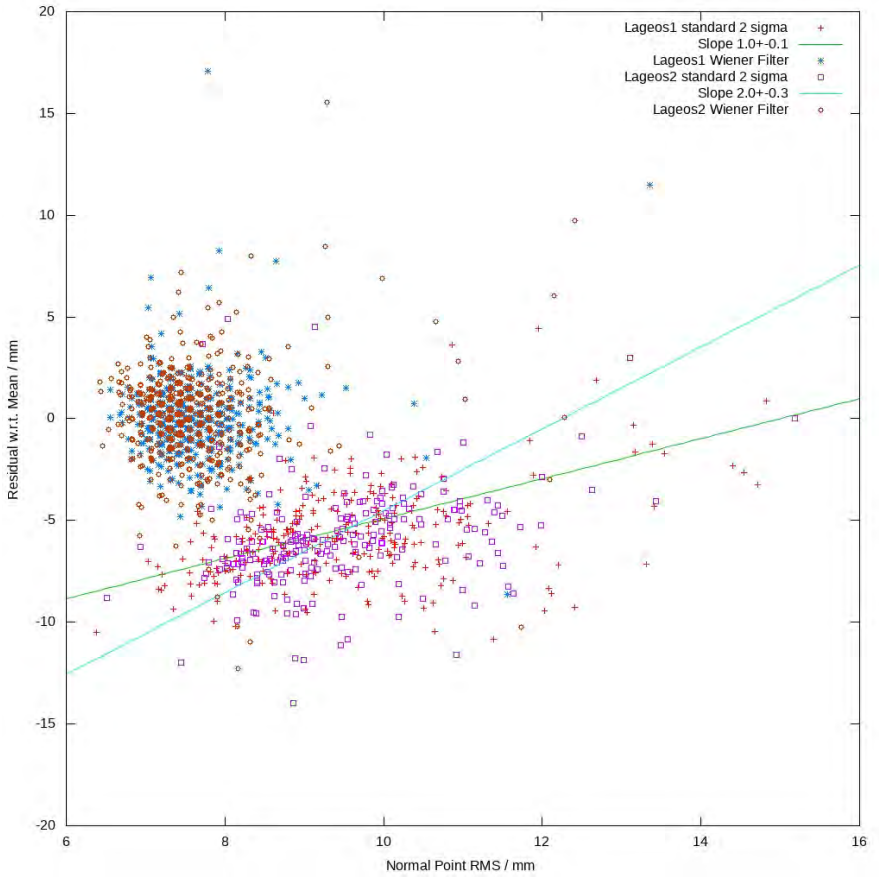
- applying a low pass filter (~ MCP bandwidth) seems to be the best option

NP Residuals vs. SS RMS

7840 Lageos 2019



7827 Lageos 2017



Conclusion

- Herstmonceux 2019 data set for Lageos1 has been processed to form Wiener filtered normal points
- algorithm has been tested on various Linux platforms including a miniconda python installation enabling for portability to other OS's
- Lageos2 data shows in general more details in the response function
- due to the short coherence length of the Hx 10ps laser, interference effects of retro reflectors located within the coherence length show up with more contrast in comparison to systems with longer coherence length
- as long as the incoherent response function is used to define center of mass corrections, the Wiener Filter with cutoff frequency of 0.05/mm seems to be the most convenient option for editing of high resolution data
- scatter of the resulting distribution towards shorter NP residual is apparently caused by interference effects between the partial rays of the contributing retro reflectors
- further improvements rely on the knowledge of the array orientation and the ability to model the instantaneous transfer function for every normal point interval

Case Studies of Systematic Error Detection

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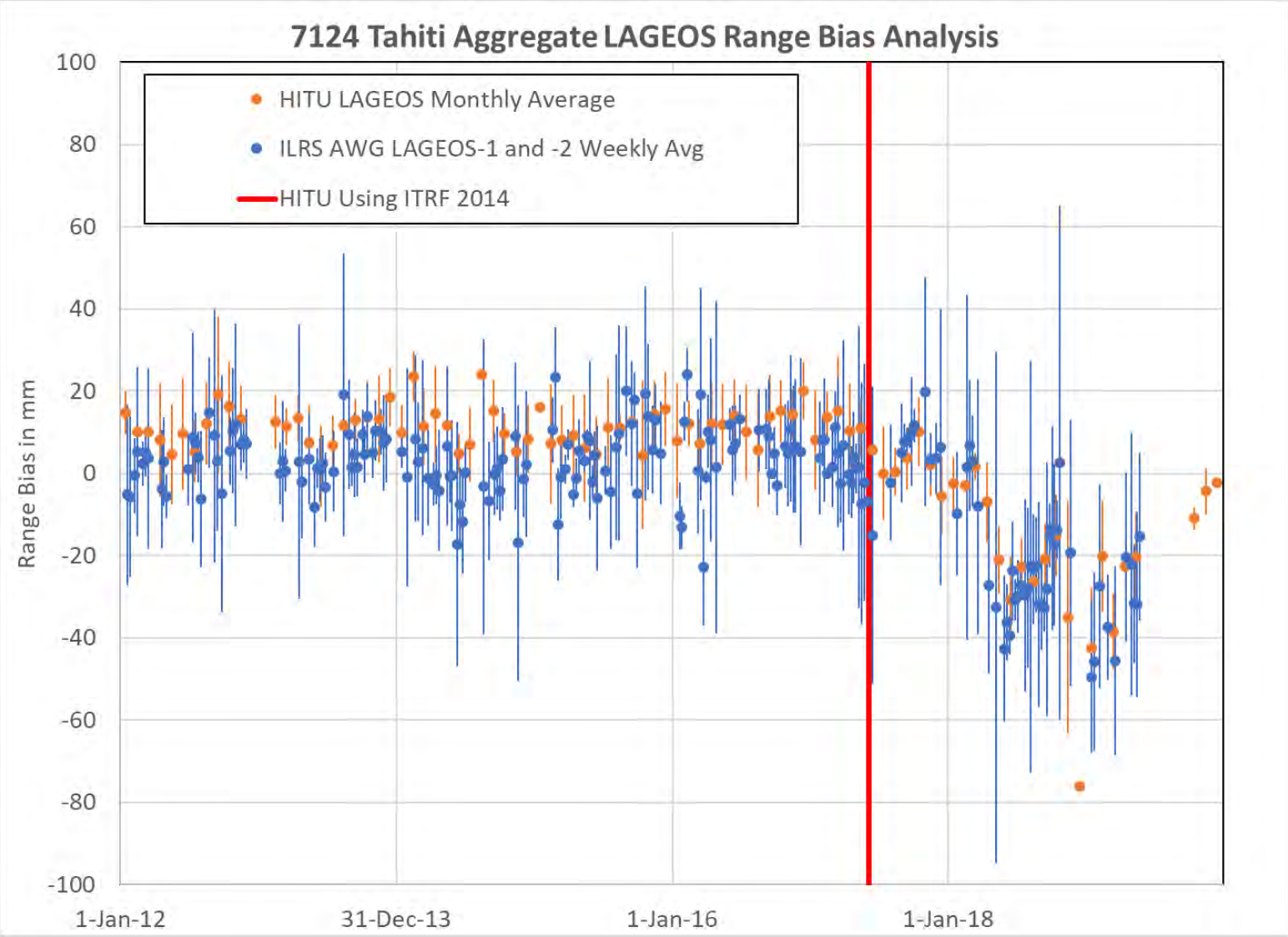
Background

- Toshi's past yearly aggregate analyses of normal points has shown mm level systematics as a function of time of day; signal strength, bin RMS, kurtosis, etc.
- Let's explore what level of biases can be detected using Toshi's 6 hour pass-by-pass analyses. We would like to answer the following question:
  - If there is an abrupt change in a station's range bias, how small a range bias can be detected and how long must it persist to be detected?

	Period of Time					
Satellite/Bias Type	Pass	Day	Week	Month	3 Months	Year
LAGEOS Range Bias (mm)						
LAGEOS Time Bias (μsec)						
Lares Range Bias (mm)						
Lares Time Bias (μsec)						
Stella/Starlette Range Bias (mm)						
Stella/Starlette Time Bias (μsec)						
Ajisai Range Bias (mm)						
Ajisai Time Bias (μsec)						
Etalon Range Bias (mm)						
Etalon Time Bias (μsec)						

7124 TAHITI ANALYSIS

7124 Tahiti LAGEOS Range Bias Analysis



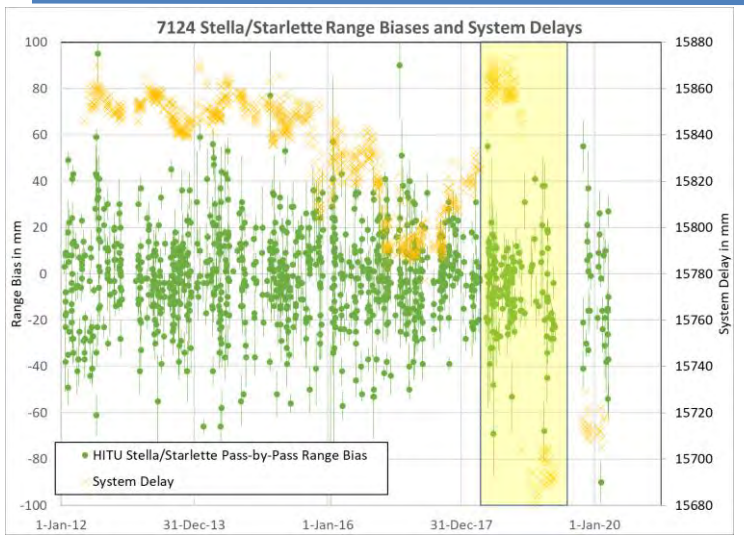
In mid April 2018, there appears to have been a ~30mm change in the 7124 LAGEOS range bias which Erricos identified. Follow-on analysis reveals there was a laser diode change in mid April 2018, which coincides with the apparent change in the bias and change in system delay.

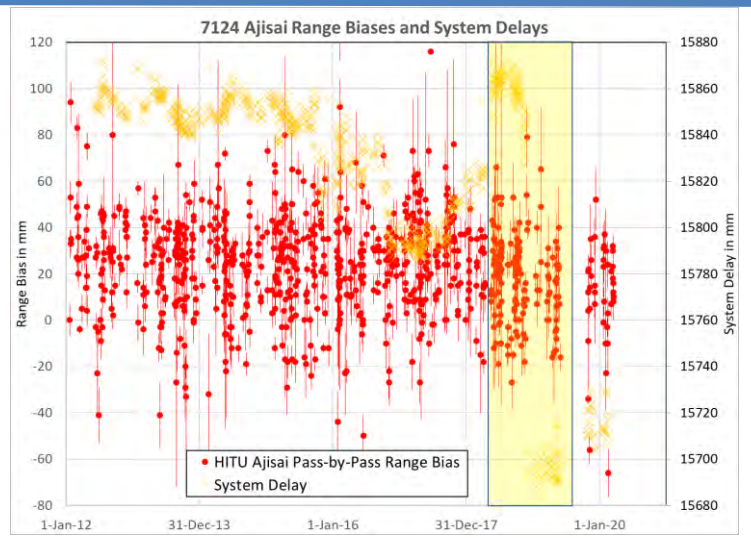
Both Erricos' weekly analysis results along with Toshi's bias results indicate this change.

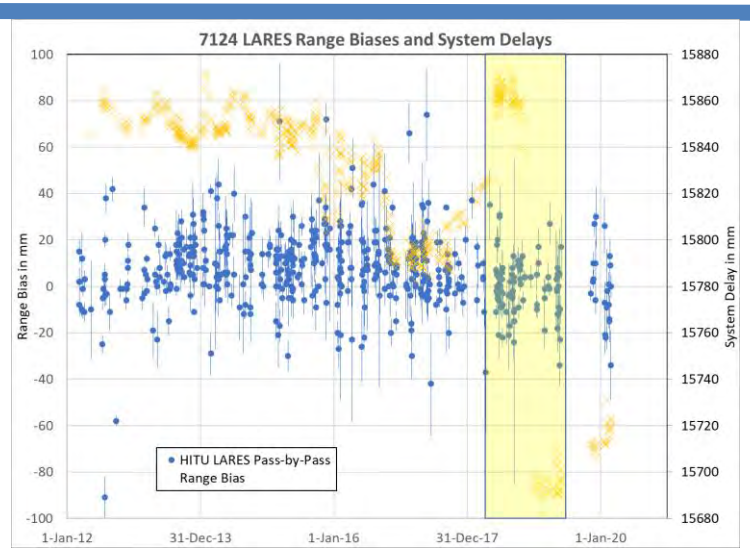
There is some evidence that the LAGEOS bias may have started drifting before the laser diode change (see next slide).

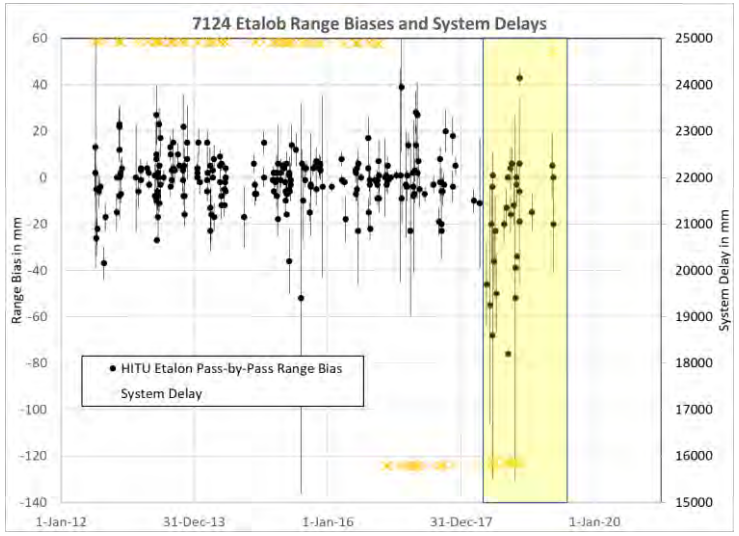
Note: The Event Timer was installed in Nov 2018, but the first ETM pass did occur until March 19, 2019.

7124 Tahiti HITU Goedetic Range Bias Analysis



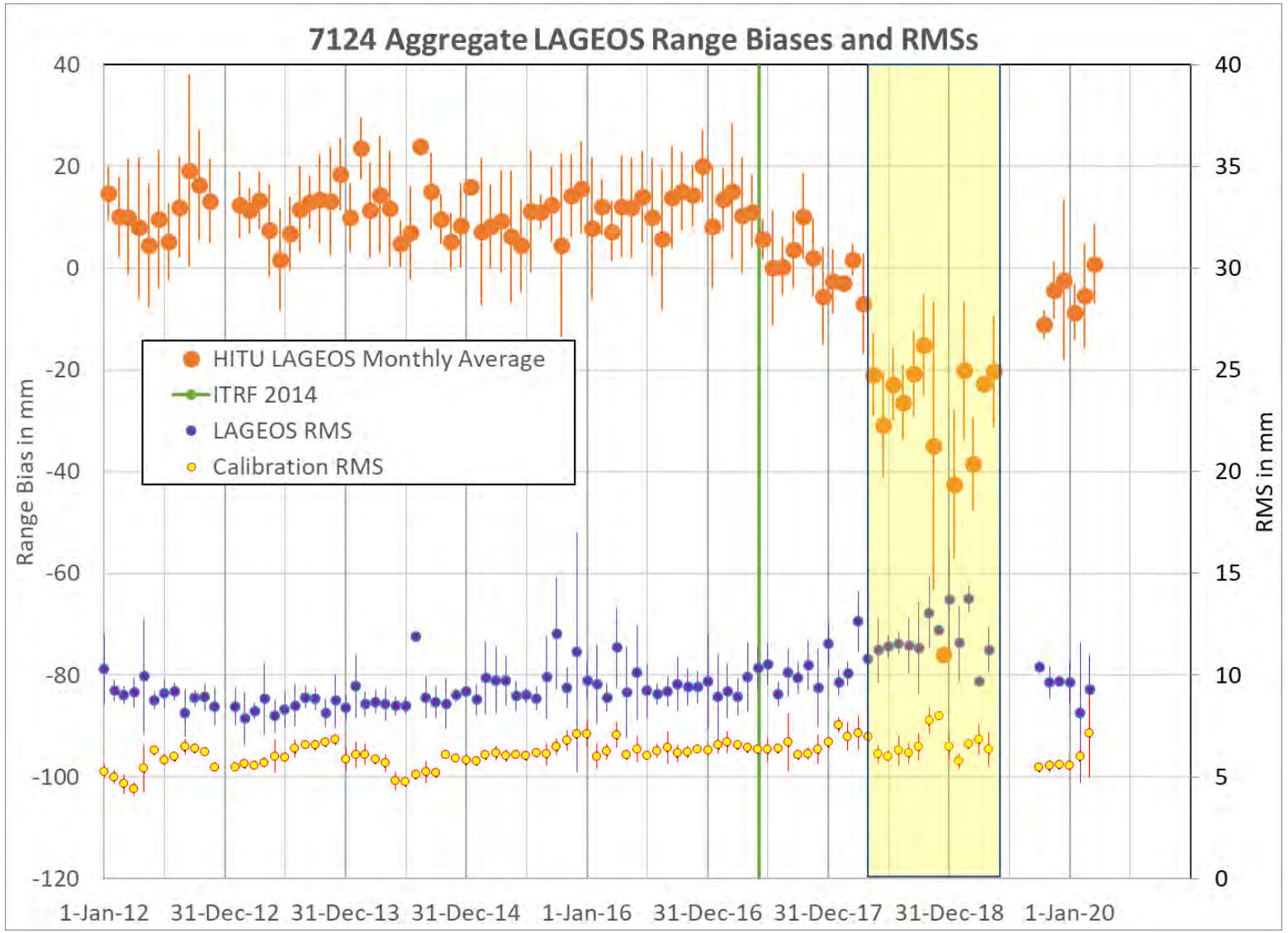






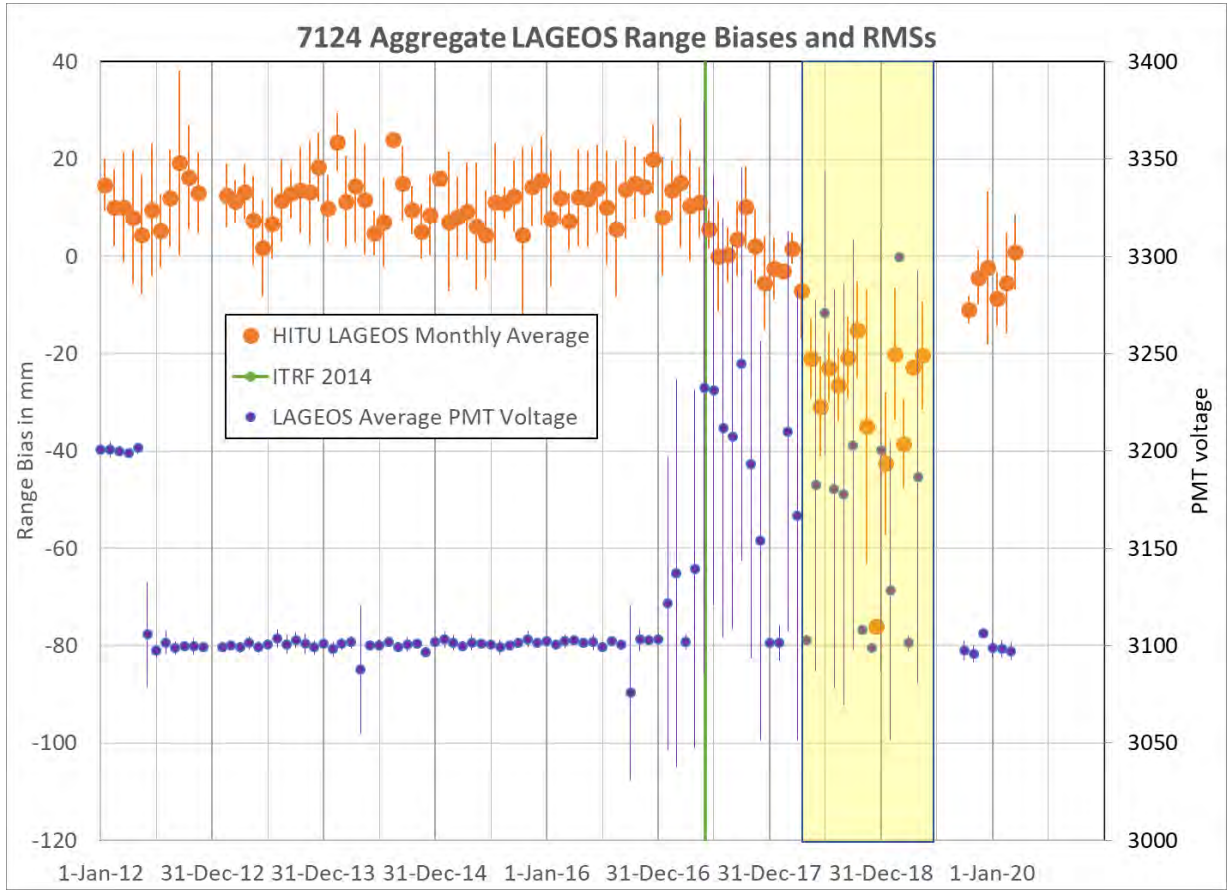
The ~30mm change in the LAGEOS bias does not appear to be as large on the LEO satellites. You can also see an initial change in the Etalon bias.

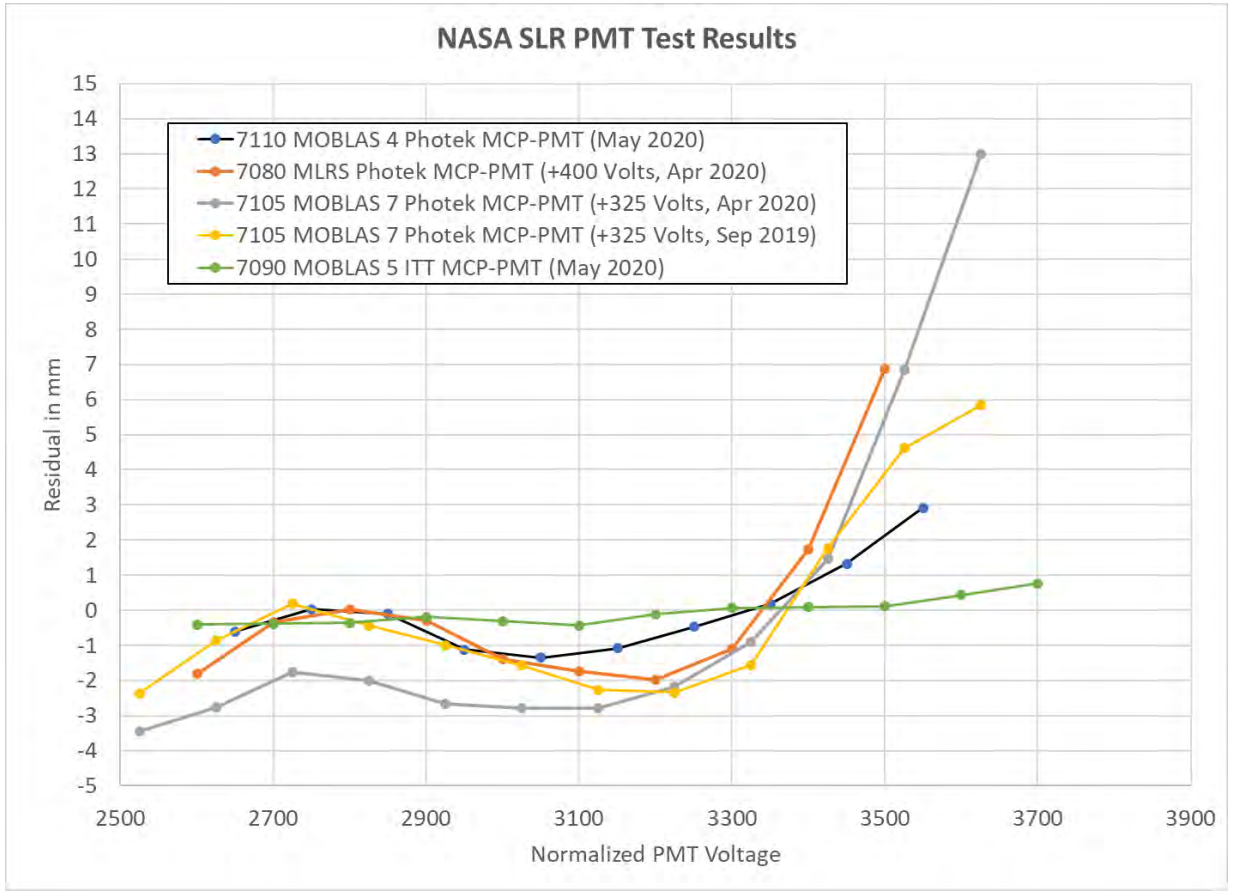
7124 LAGEOS Range Bias and RMSs



The LAGEOS RMs were higher in the highlighted period when the bias was most negative.

7124 LAGEOS Range Bias and RMSs

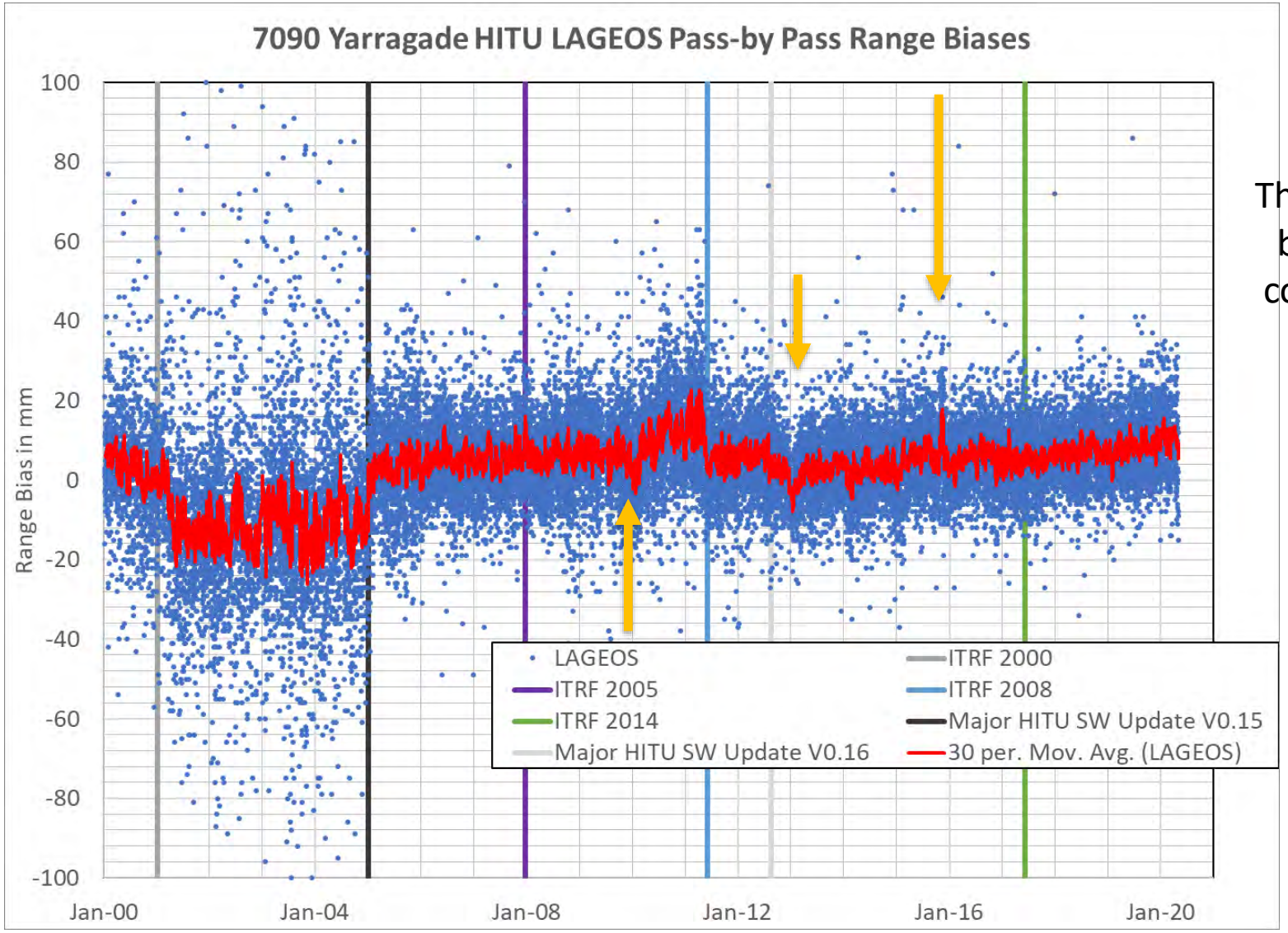




It appears the LAGEOS range bias started starting drifting prior to April 2018. Part of this drift perhaps be explained by a similar drift in LAGEOS PMT voltages. LAGEOS calibrations were taken at 3100 volts since late 2012, but LAGEOS data was taken at higher voltages. We currently don't have a PMT test from MOBLAS 8, but they have a Photek MCP-PMT. As the PMT is operated at higher voltages the RMS increases along with the system delay.

7090 YARRAGADEE ANALYSIS

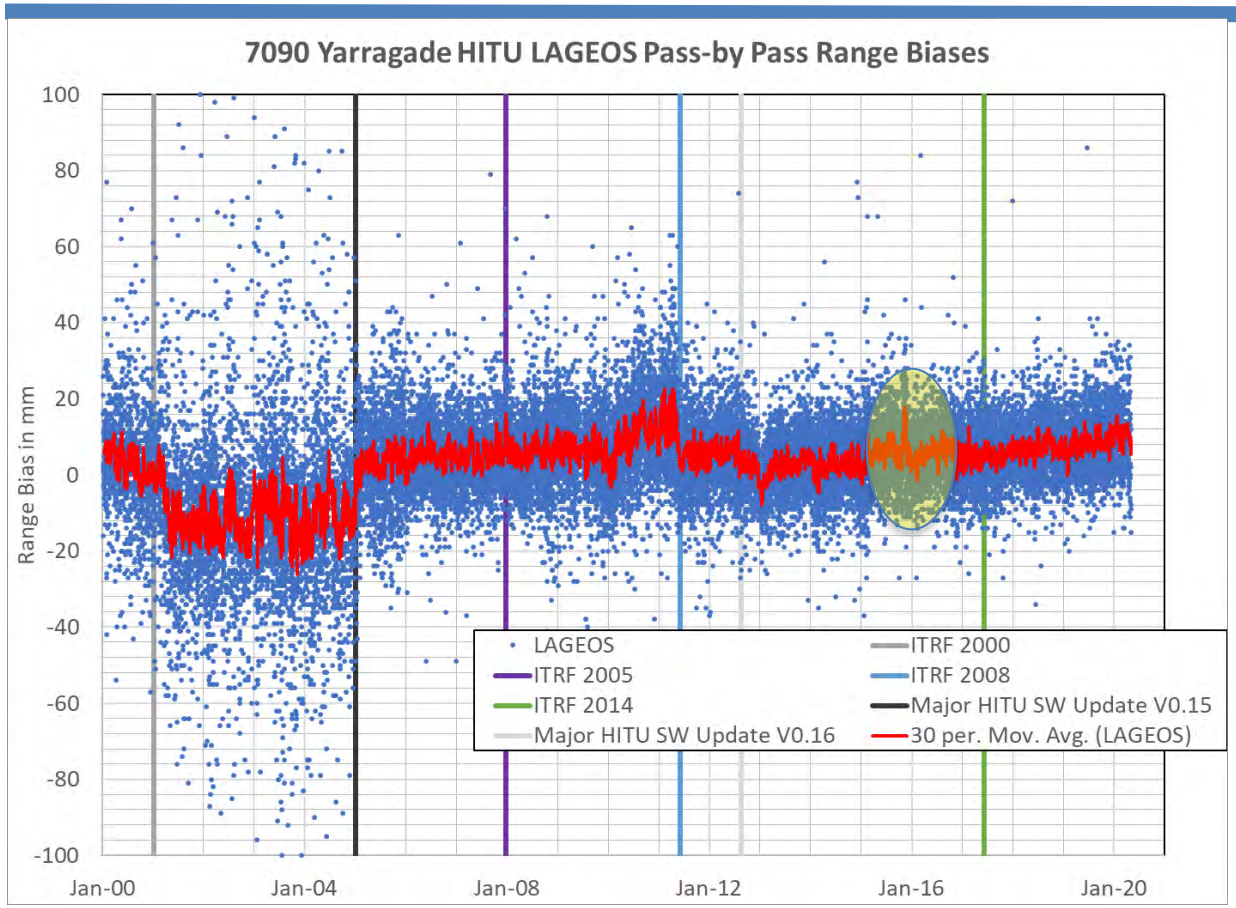
7090 Yarragadee Range Bias Blips

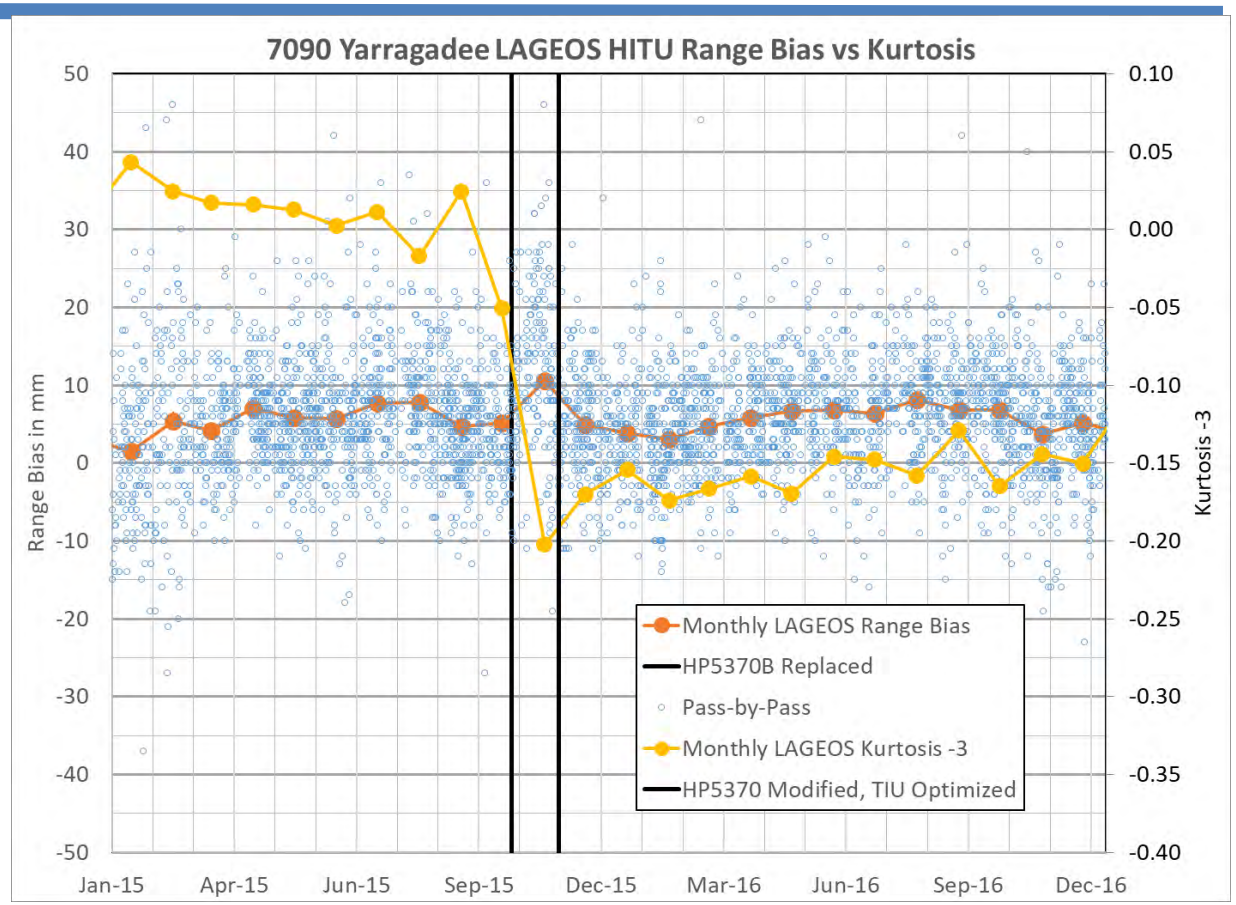


The orange arrows mark some of the strongest blips for further investigation, which are not correlated to coordinate or HITU SW changes.

New

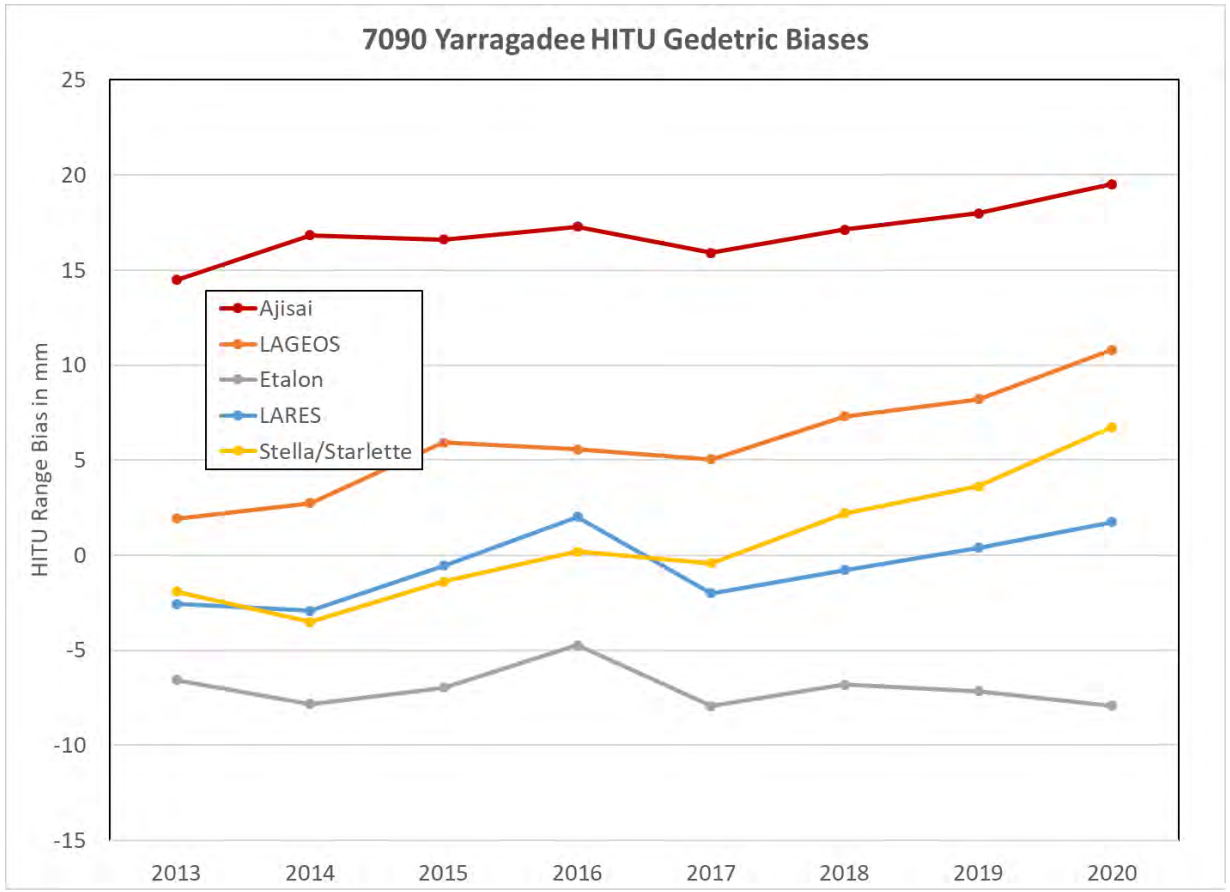
7090 Yarragadee LAGEOS Analysis

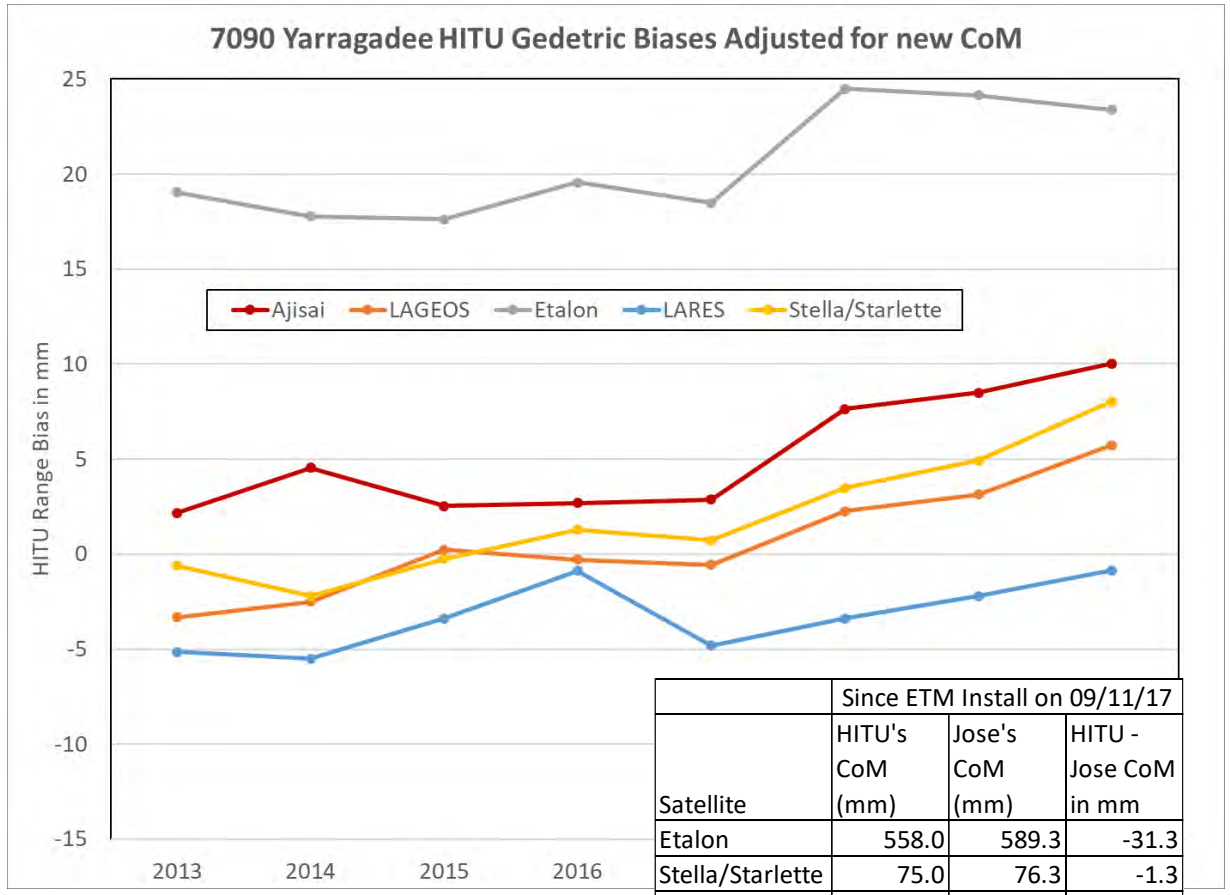




The right chart is a zoom of the left chart, where a blip in range bias appeared. Based on the chart on the right the range bias jumped ~5 mm after the HP5370B was replaced on Oct 22, 2015 with another HP5370 and the bias returned to it previous levels after the HP5370 was modified (input termination resistors soldered in) and a TIU optimization was performed on Nov 26, 2015. Notice the kurtosis appeared to be drifting and then showed A sudden jump was the HP5370 was replaced.

7090 Yarragadee Yearly Geodetic Range Biases





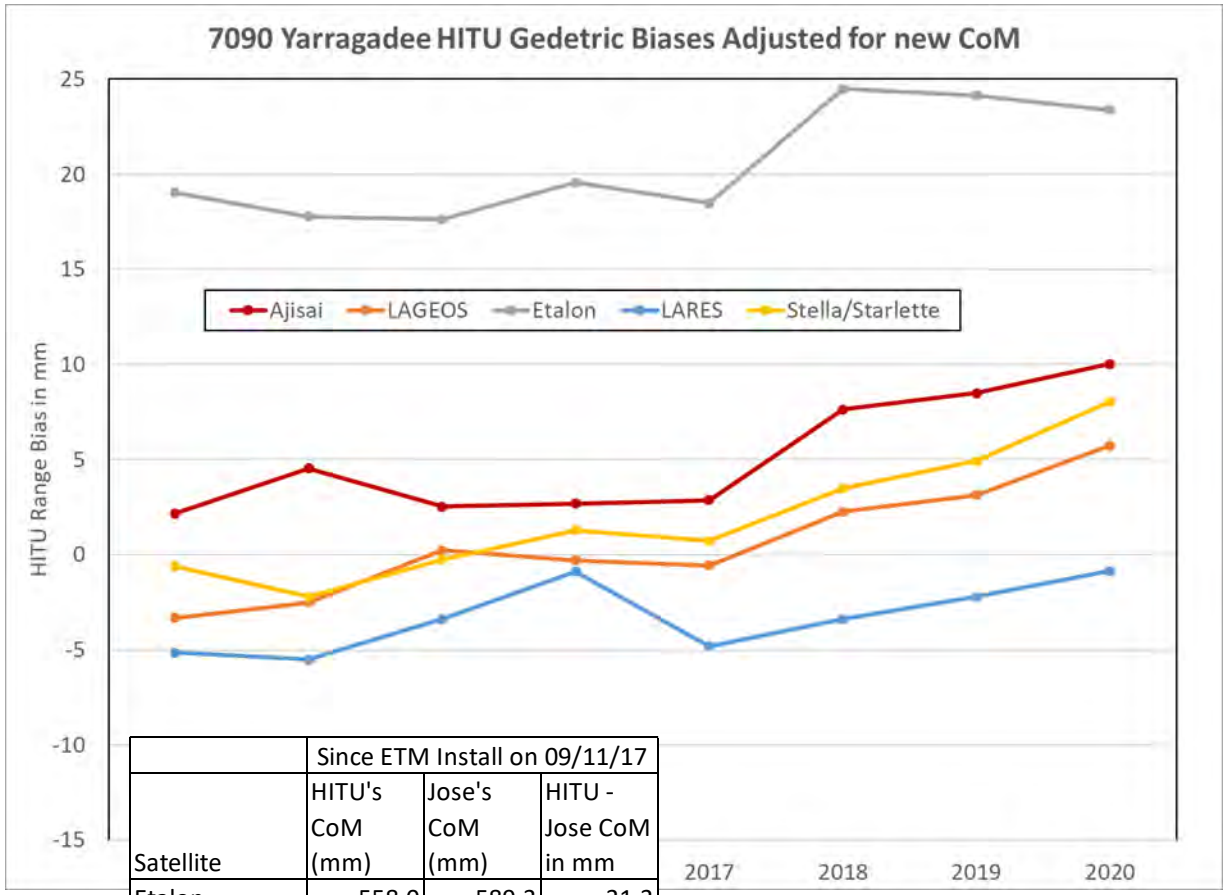
	Since ETM Install on 09/11/17		
Satellite	HITU's CoM (mm)	Jose's CoM (mm)	HITU - Jose CoM in mm
Etalon	558.0	589.3	-31.3
Stella/Starlette	75.0	76.3	-1.3
Lares	133.0	130.4	2.6
LAGEOS-1	251.0	246.2	4.8
LAGEOS-2	251.0	245.7	5.3
Ajisai	1010.0	1000.5	9.5

The right chart is adjusted for Jose's latest CoM corrections.

Are these adjusted biases on Etalon in the HITU analysis, in the new CoM, or in the system?

Starting in 2017, all the biases except Etalon are drifting positive. The several mm bias difference between LARES and LAGEOS is slowly widening over time.

7090 and 7105 Yearly Geodetic Range Biases



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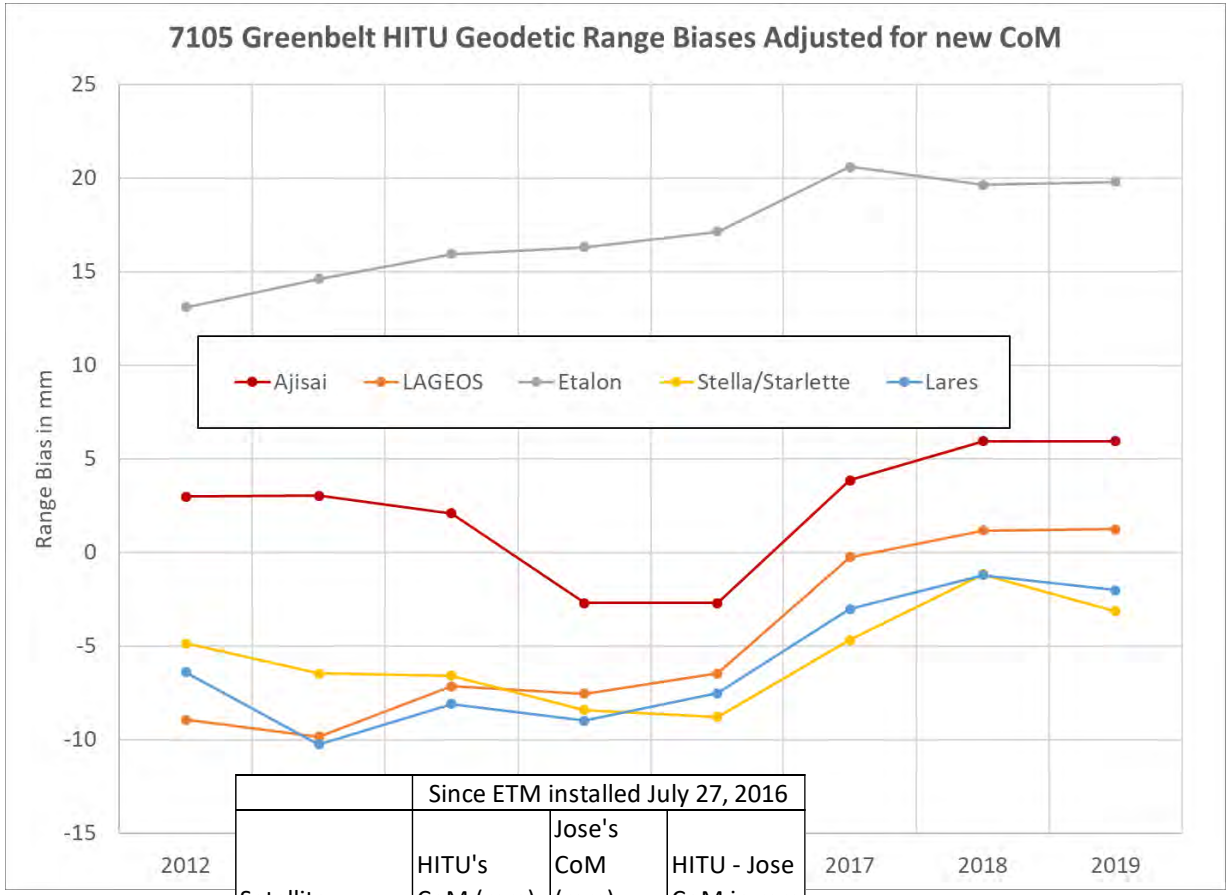
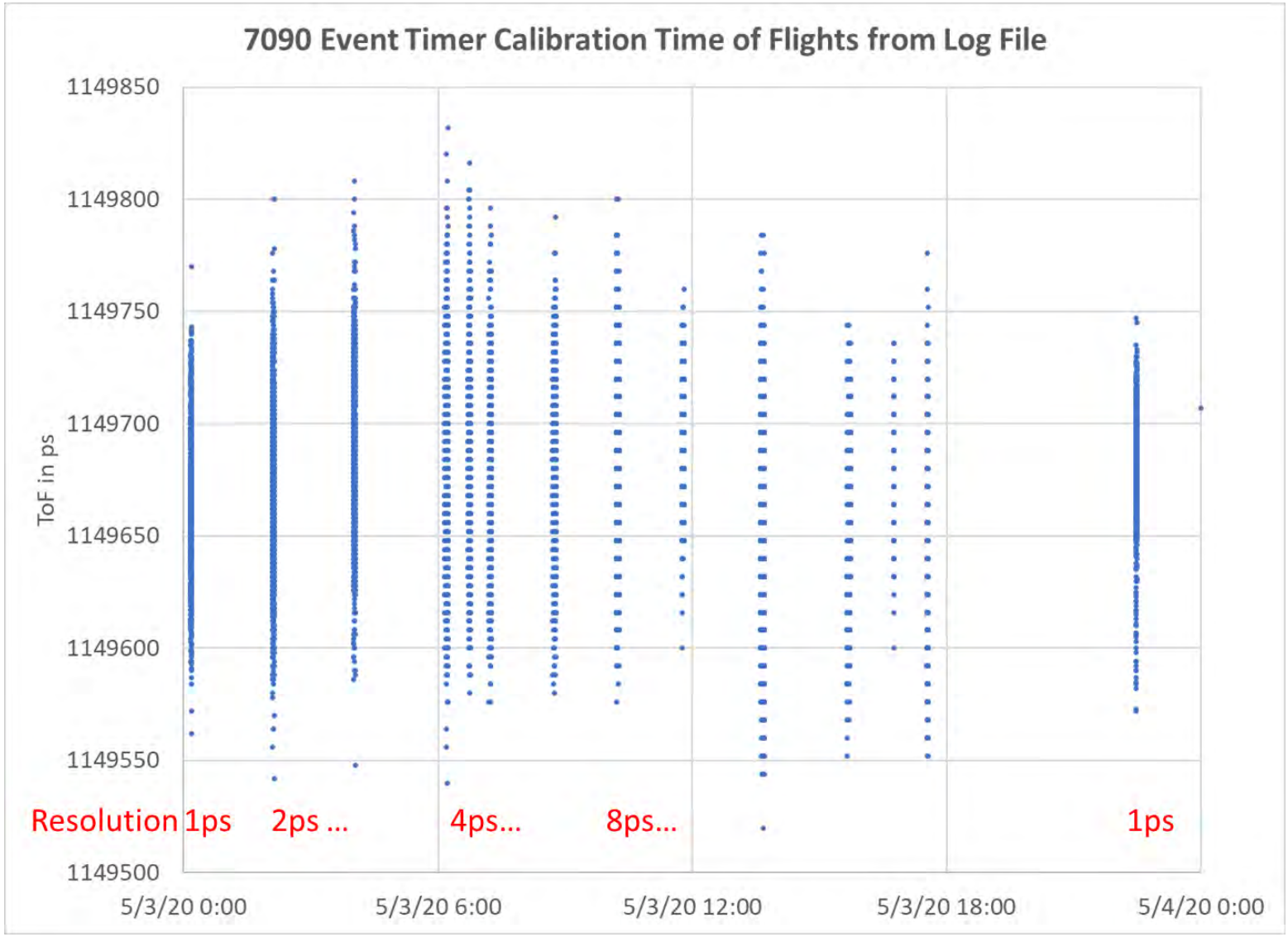


	Since ETM installed July 27, 2016		
Satellite	HITU's CoM (mm)	Jose's CoM (mm)	HITU - Jose CoM in mm
Etalon	558	583.3	-25.3
Stella/Starlette	75	76.1	-1.1
Lares	133	130.1	2.9
LAGEOS-1	251	246	5
LAGEOS-2	251	245.6	5.4
Ajisai	1010	998.5	11.5

7090 Yarragadee Event Timer Resolution Variation



We recently discovered that the resolution of the Yarragadee/MOBLAS-5 Event Timer (ET) can vary through the day from 1 to 8 picoseconds.

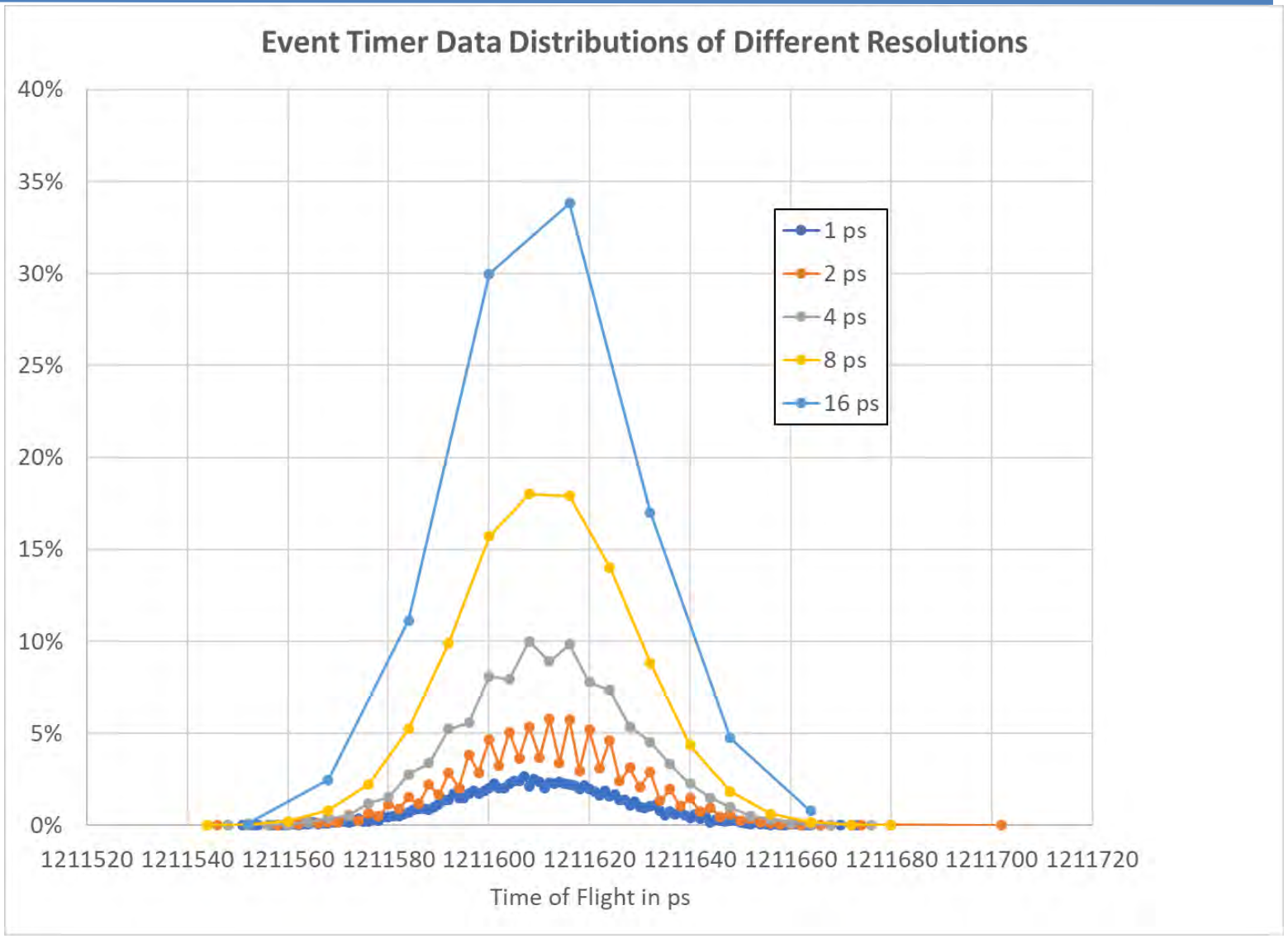
The other NASA systems (MOBLAS & TLRS) reset the ET after each 2 hour tracking scenario, but Yarragadee/MOBLAS-5 was only resetting theirs once per day.

Event Timer Lab Characterization Test

Start Time	Resoluti	Elapsed time from start of test (hh:mm
5/9/20 10:41	1 ps	N/A
5/9/20 12:53	2 ps	2:12
5/9/20 15:23	4 ps	4:42
5/9/20 20:23	8 ps	9:42
5/10/20 6:24	16 ps	19:43
5/10/20 10:19	1 ps	N/A
5/10/20 11:47	2 ps	1:28
5/10/20 14:17	4 ps	3:58
5/10/20 19:18	8 ps	8:58
5/11/20 5:18	16 ps	18:58

Resolution (ps)	Mean ToF (ps)	Std Dev (ps)	Skew	Excel's Kurtosis	Points
1	1211610.48	16.89	0.0387	0.0090	6817
2	1211611.30	17.08	0.0150	0.0633	9004
4	1211611.42	16.92	0.0126	0.0002	18015
8	1211611.07	17.11	0.0091	0.0150	36025
16	1211611.02	18.34	0.0738	0.0203	1411

There was less than 1 ps change in mean ToF for the different resolutions.

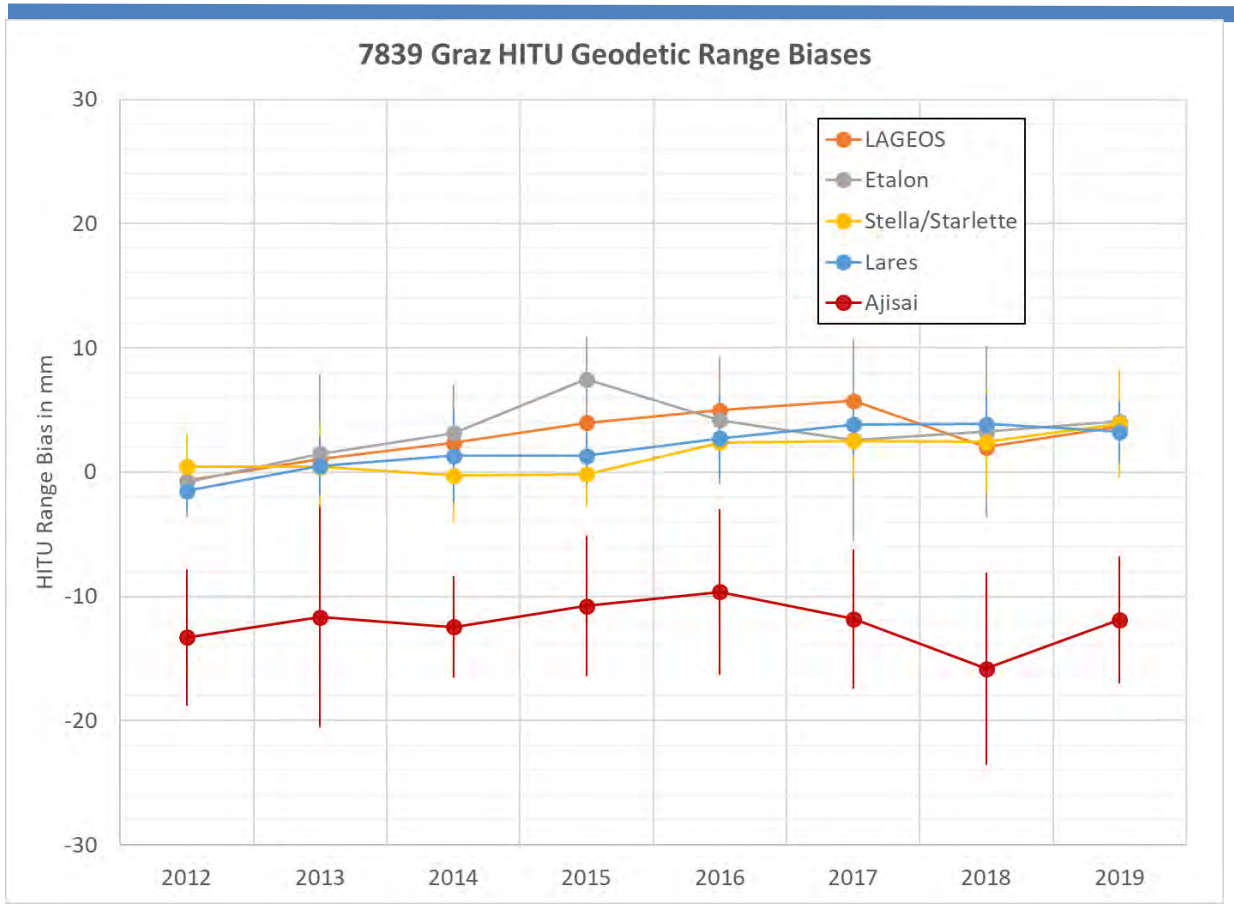


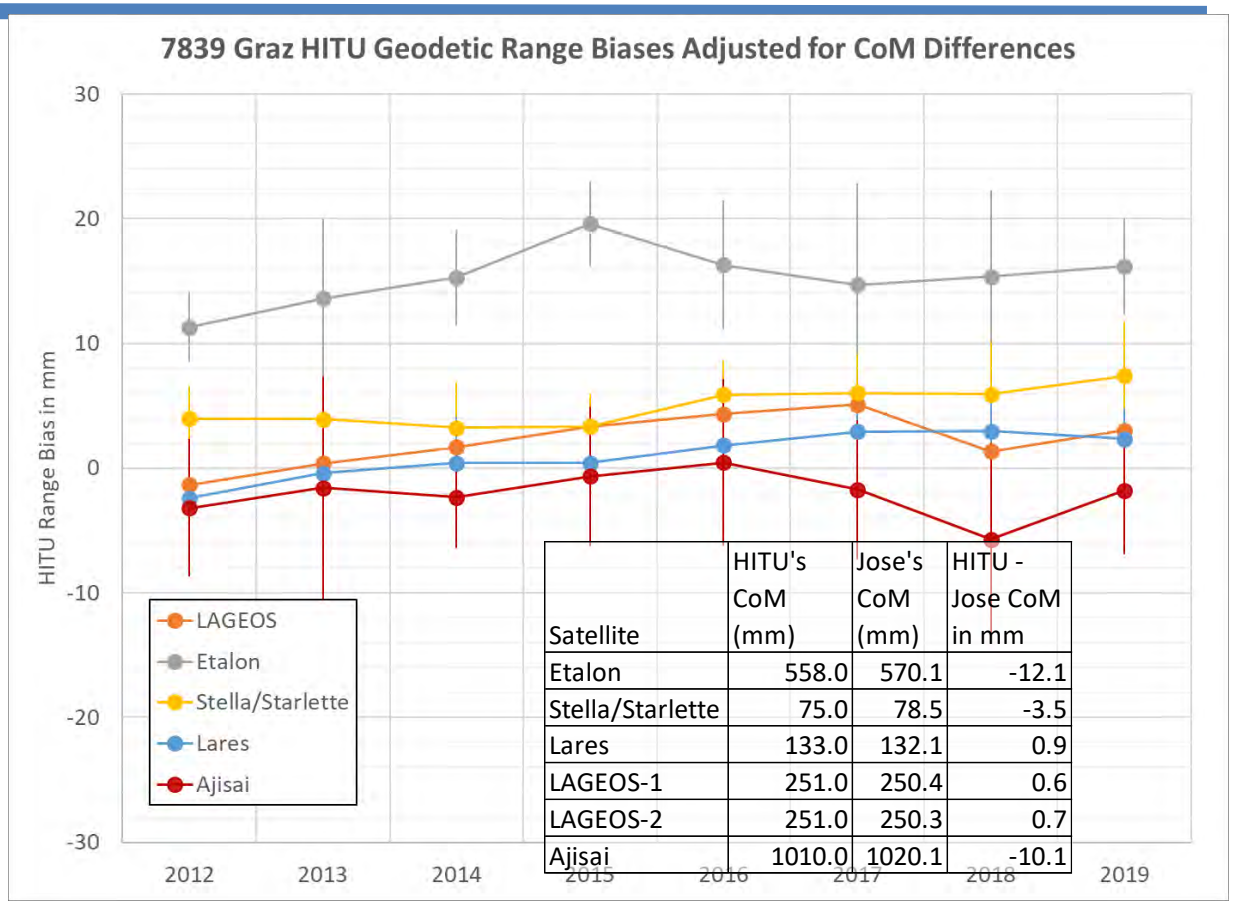
7090 Yarragadee Conclusions

- Based on our findings, 7090 has instituted the following procedural changes:
  - 5-May-2020: Reset the event timer 3-4 times per day versus once to better maintain the event timer resolution.
  - 1-Jun-2020: Standard PMT Voltage is 3200 volts.
- Some of the biases are receive energy related. Better calibration of receive energies of the geodetic satellites is needed. We will work with the station and continue to monitor their progress on this issue.
- Questions that still remain:
  - Is the HITU ~+1 mm/year bias drift in the 4 sets of the geodetic satellites (LARES, Stella/Starlette, LAGEOS, Ajisai) real or is the 7090 ITRF2014 height rate incorrect?
  - What is the real range bias difference between 7090 LAGEOS, Lares and Etalon and how accurately can we determine these offsets?

7839 GRAZ ANALYSIS

7839 Graz Yearly HITU Geodetic Range Biases





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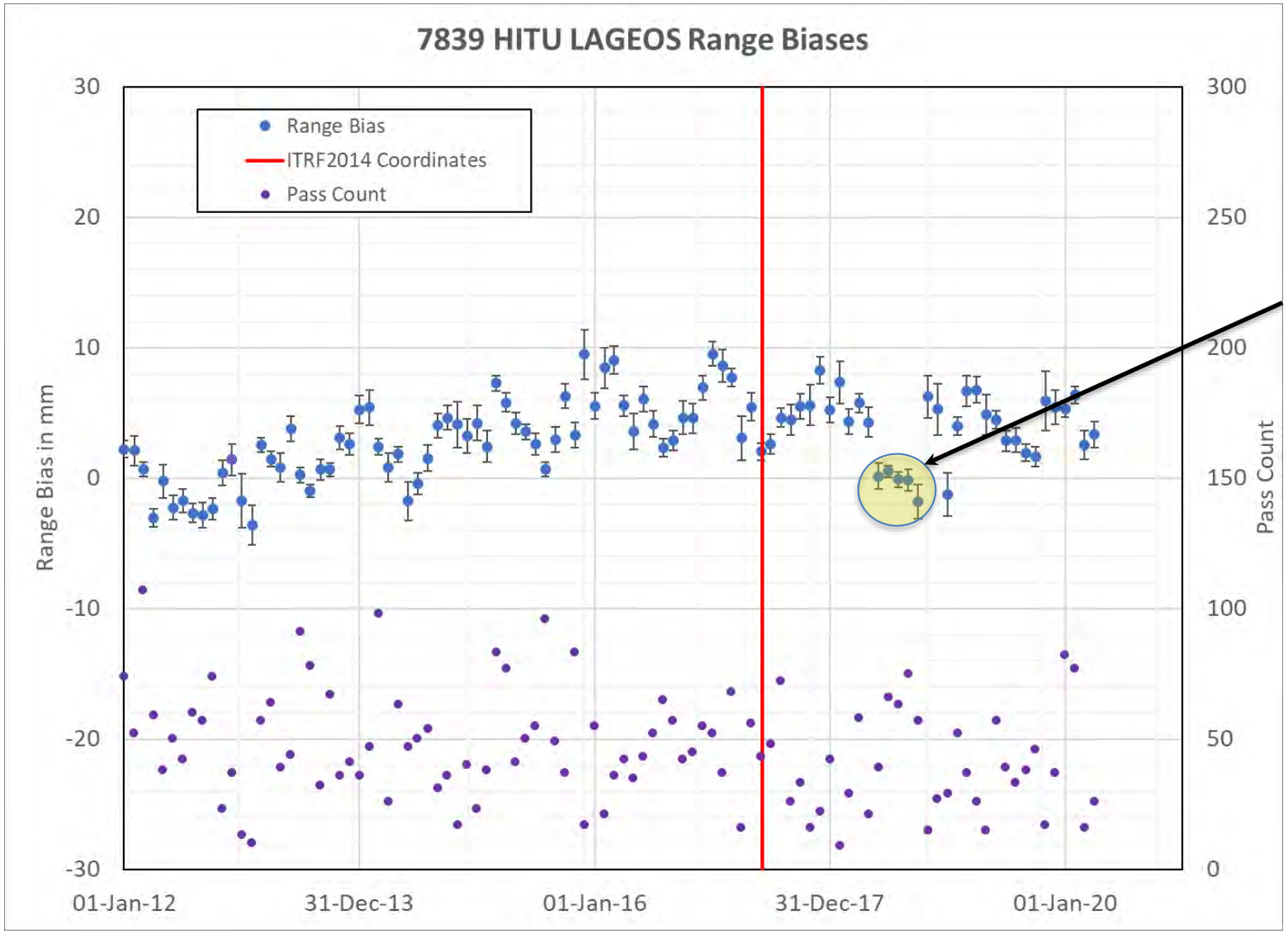
Etalon	558.0	570.1	-12.1
Stella/Starlette	75.0	78.5	-3.5
Lares	133.0	132.1	0.9
LAGEOS-1	251.0	250.4	0.6
LAGEOS-2	251.0	250.3	0.7
Ajisai	1010.0	1020.1	-10.1

Does Graz have a ~+15 mm bias on Etalon?
What is the uncertainty in Jose's Graz Etalon CoM correction?

7839 Graz HITU LAGEOS Range Biases

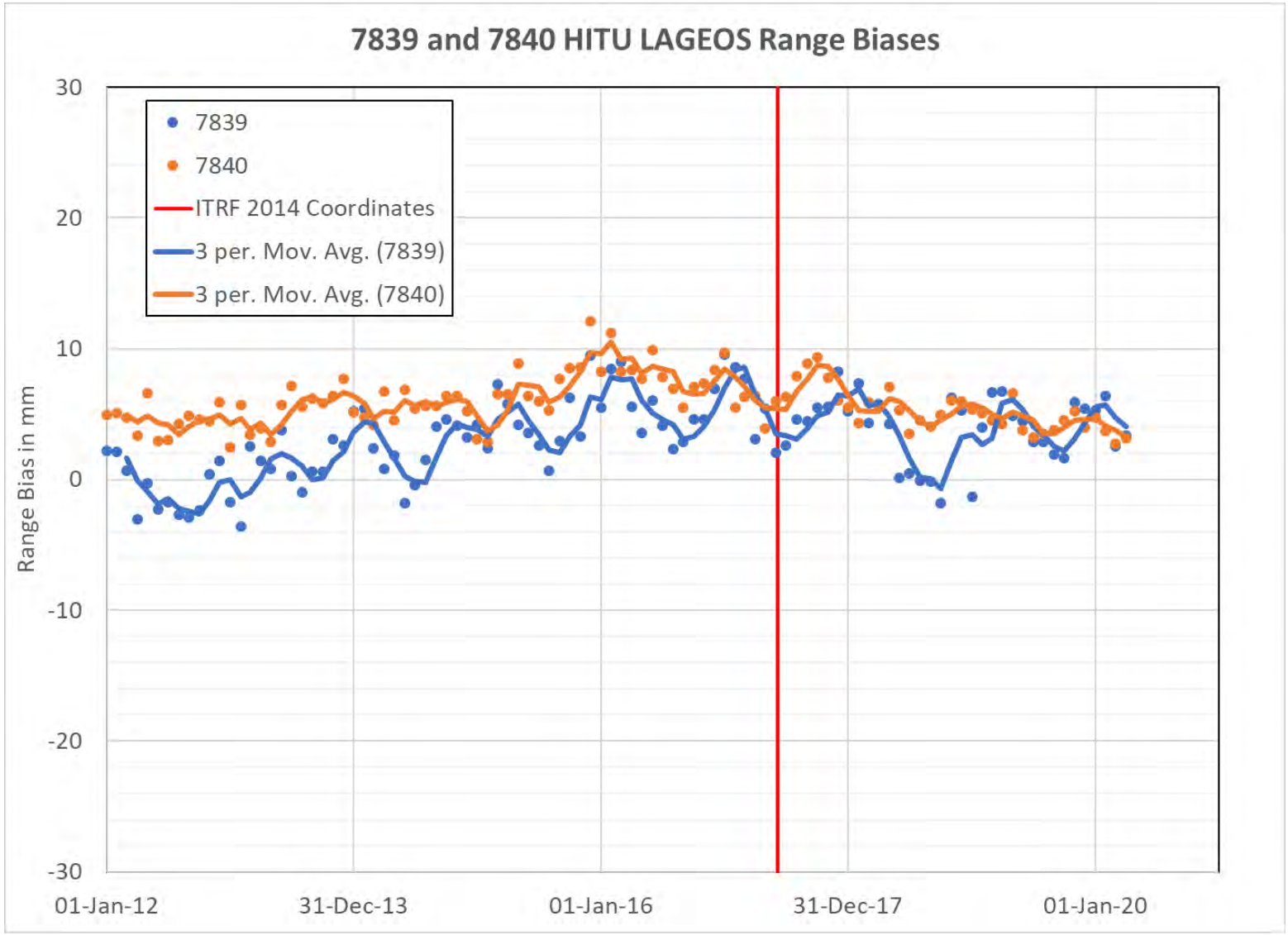


There appears to be several mm level signals in LAGEOS range biases.

Was there an abrupt actual ~5mm change in bias starting May 2018 and then did the bias return to previous levels?

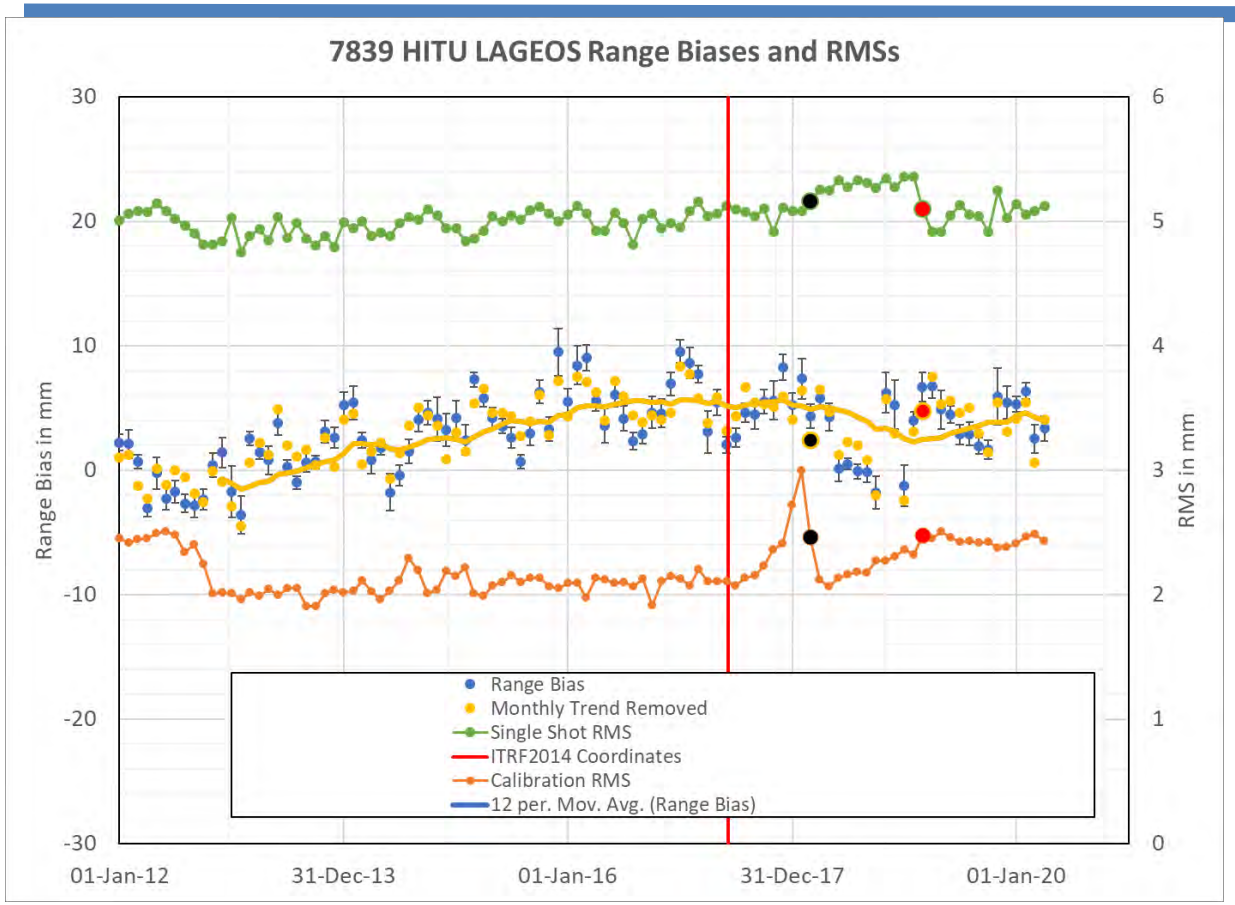
Did the biases on Stella/Starlette and Lares see a similar change?

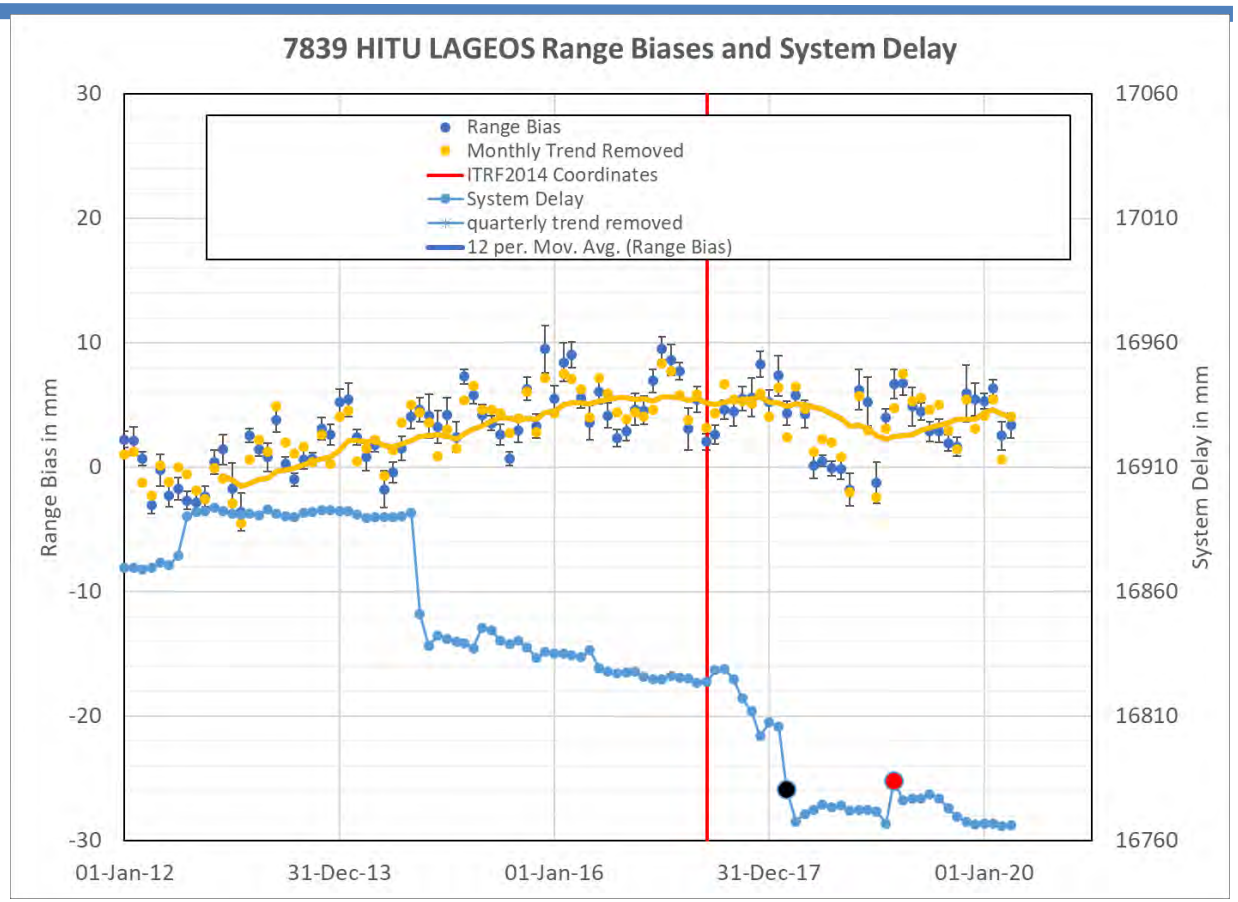
7839 and 7840 Yearly HITU LAGEOS Range Biases



The 7839 and 7840 LAGEOS bias trends are different.

7839 Graz LAGEOS Analysis





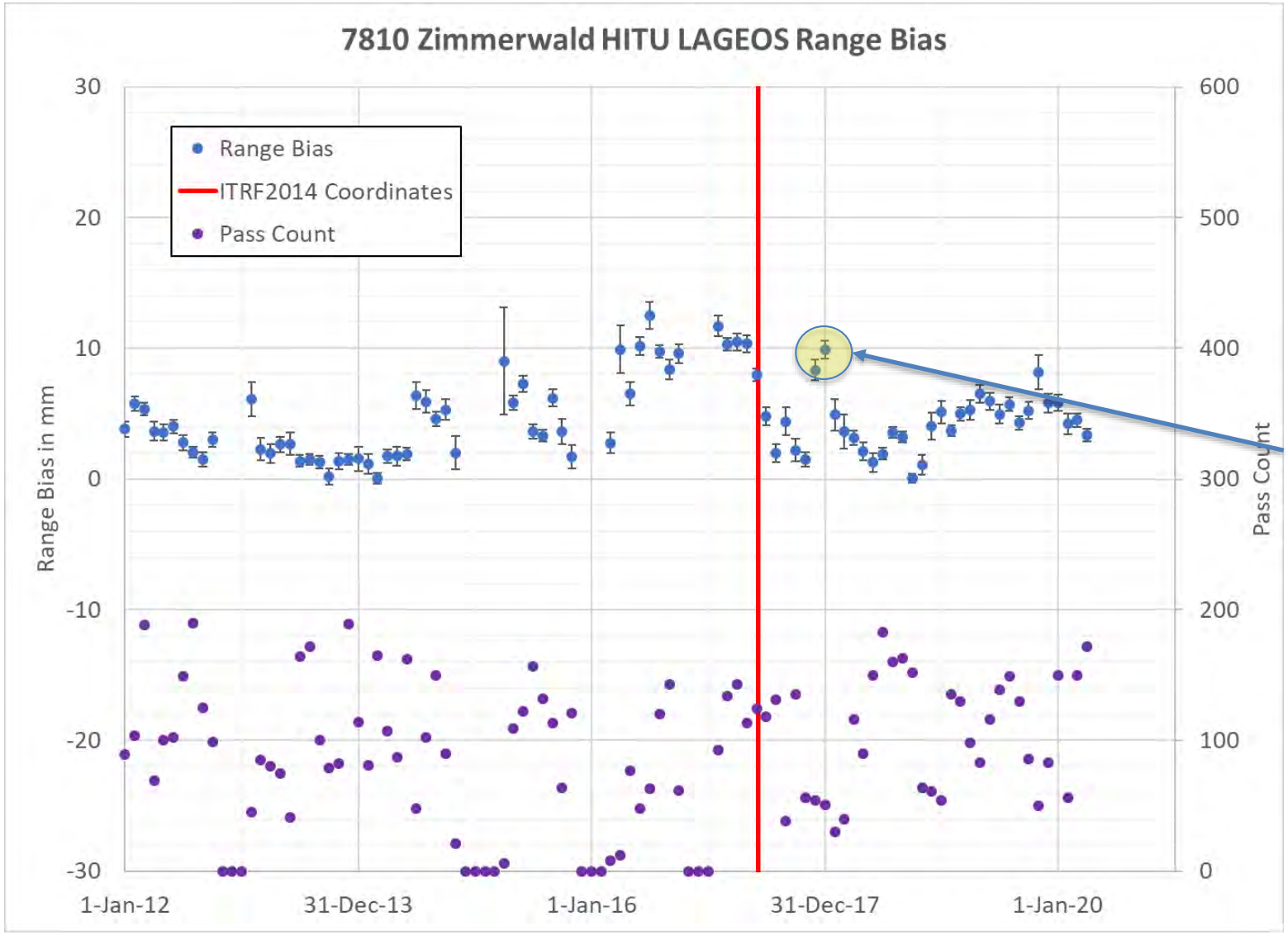
LAGEOS performance statistics (single shot RMS, calibration RMS and system delay) were added to the bias charts.

Sometime between March 12 and 15, 2018, there was a sudden ~50 mm/~330 ps decrease in system delay.

Since March 15, 2018 their system delay stabilized and their calibration RMSs returned to previous levels, but their calibration RMSs started drifting upwards until March 11, 2019 and then stabilized after a repair to their pulse distribution box/power supply and changed cables. There are no entries for 2018 in their system change history .

7810 ZIMMERWALD ANALYSIS

7810 Zimmerwald HITU LAGEOS Range Biases



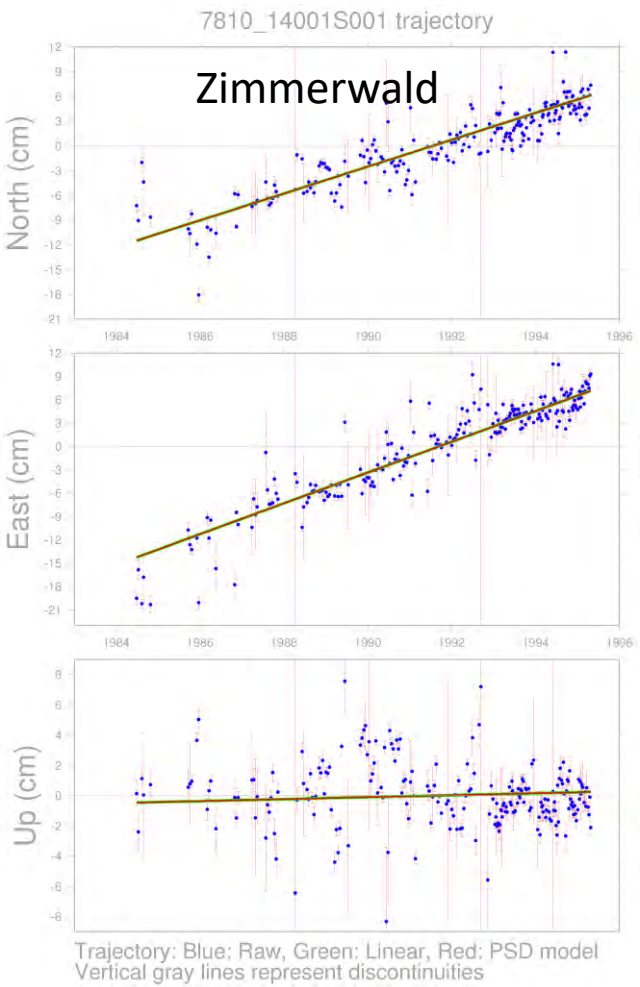
There is no obvious signal in their range bias like there was in Graz, which is a very close neighbor.

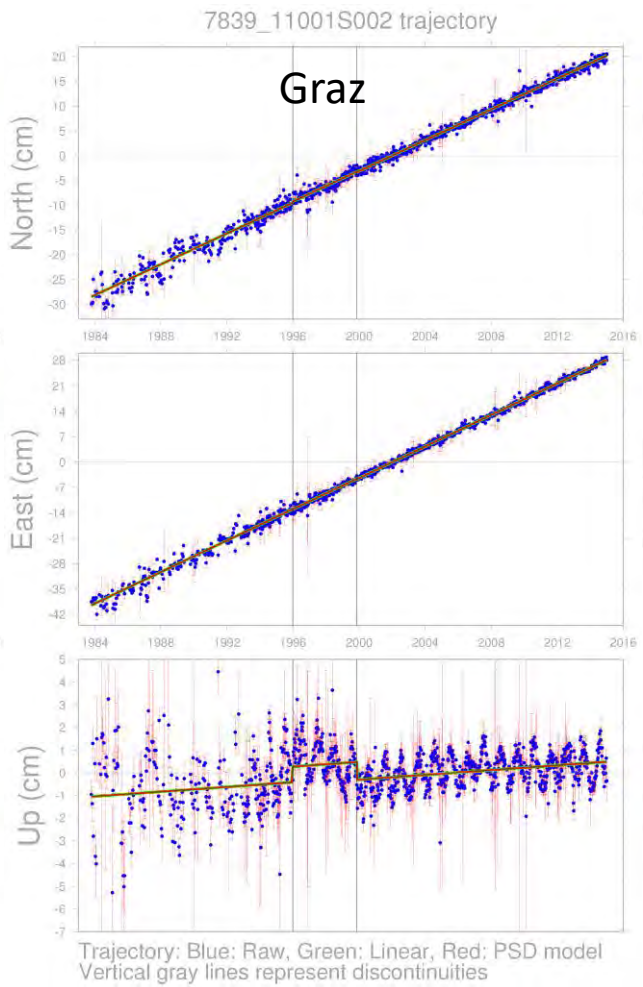
The monthly LAGEOS range bias variations are devoid of structure relative to other stations. This could be indictive of an instability in the system.

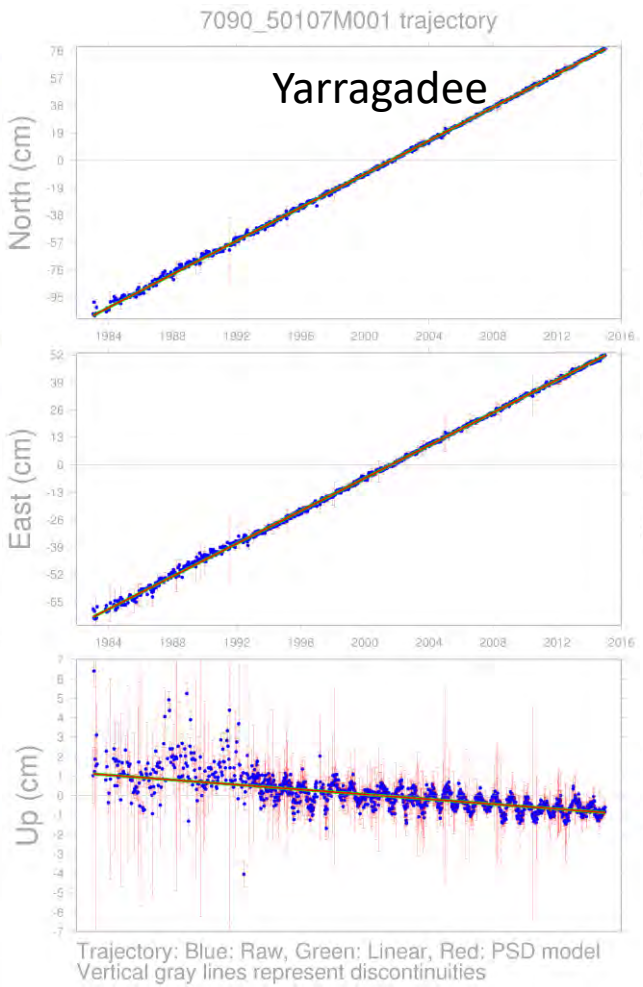
Was there an abrupt actual ~5mm change
In bias starting in Dec 2017 and then did the bias return to previous levels?

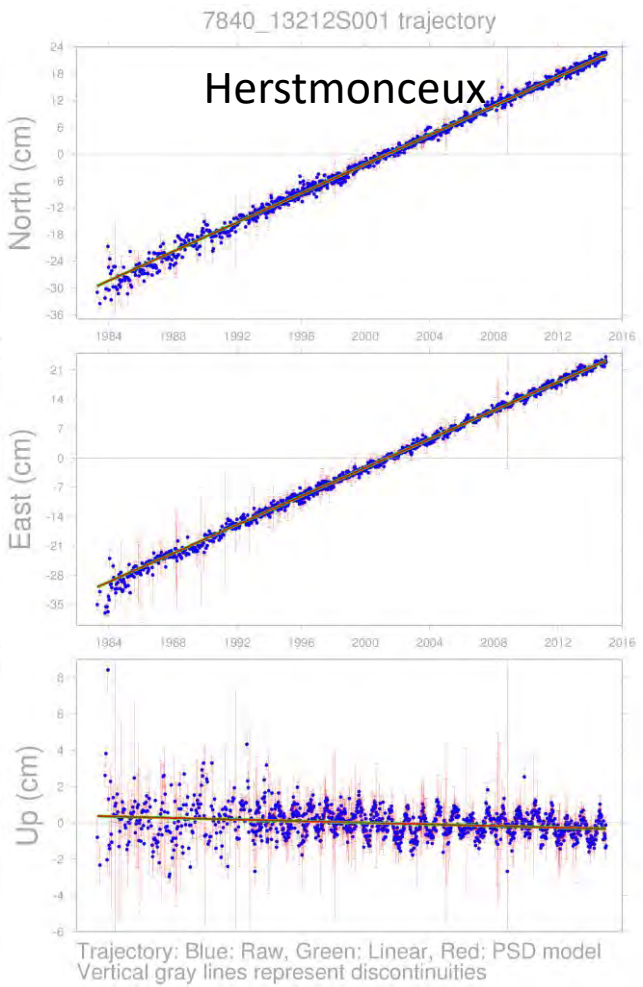
Did the biases on Stella/Starlette and Lares see a similar change?

ITRF2014 Station Result Comparisons



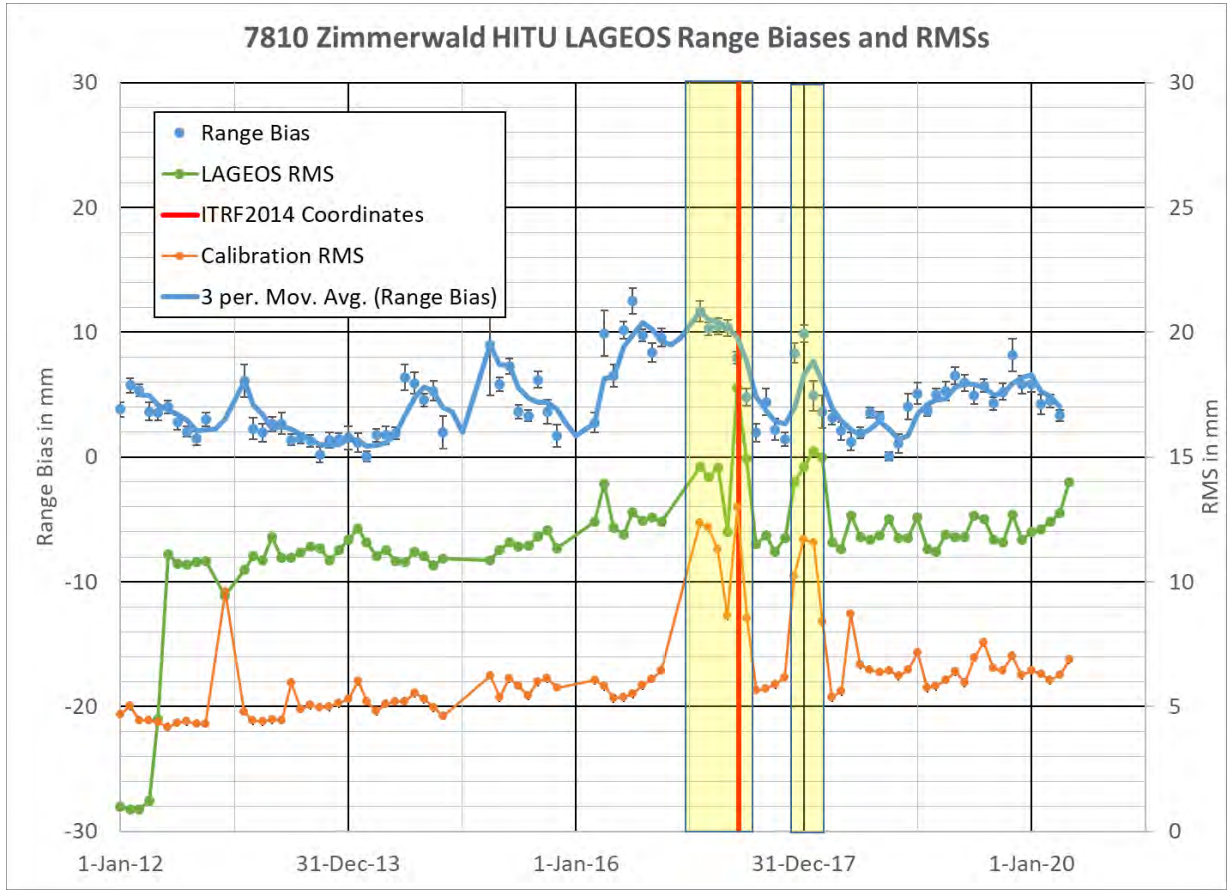


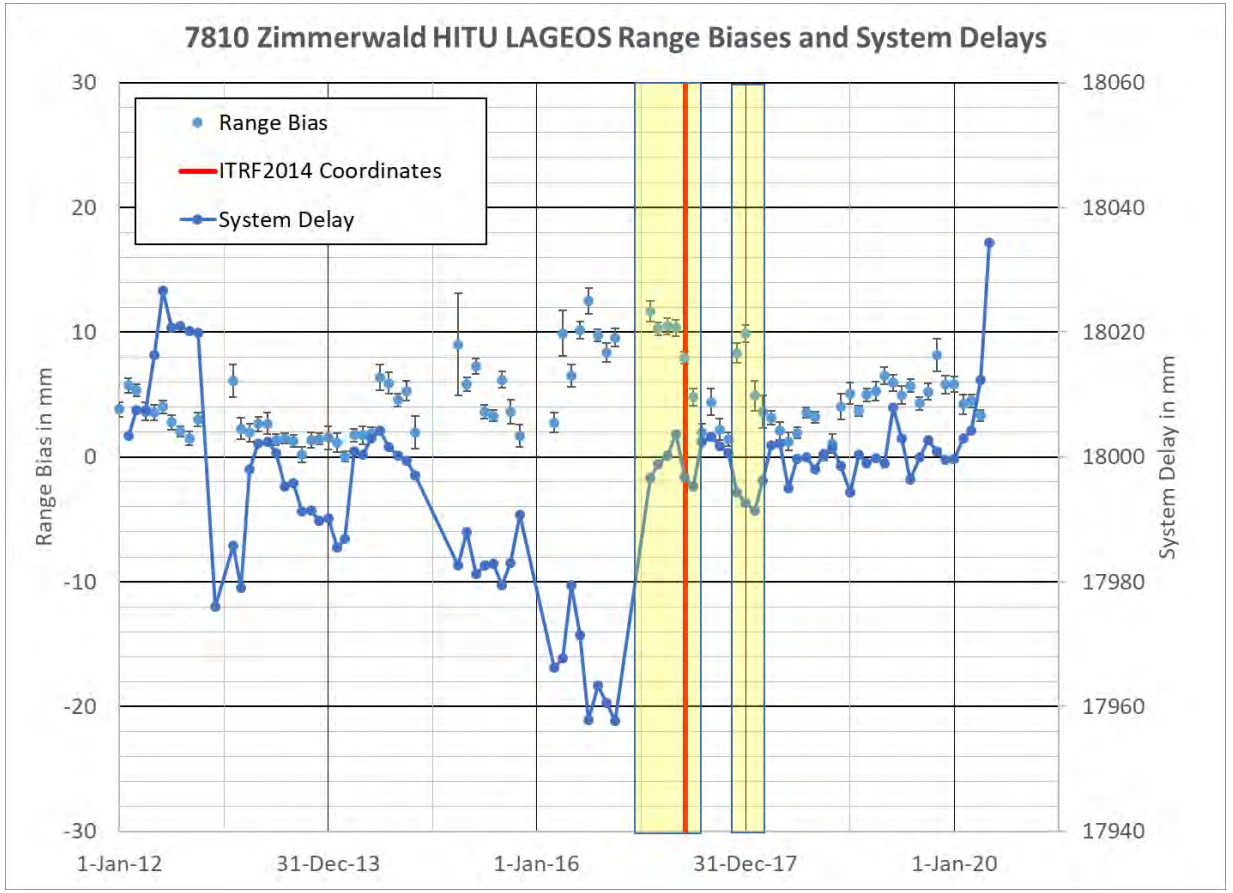




A side by side comparisons of site velocities. Notice that station heights from Graz, Yarragadee, and Herstmonceux have annual signals but Zimmerwald does not. This could be indicate of an instability in the Zimmerwald range bias.

7810 Zimmerwald LAGEOS Analysis





The two areas highlighted in these charts are when there were some instabilities in the Zimmerwald system. The most notable periods are Feb through July 2017 and Dec 2017 through March 2018. In the later period the RMSs went up and the system delay went down, so the range bias change could be real.

Bias Detection Capabilities from Orbital Analysis

	Period of Time					
Satellite/Bias Type	Pass	Day	Week	Month	3 Months	Year
LAGEOS Range Bias (mm)	60-100	30-50	20-40	4-5	2-4	1-2
LAGEOS Time Bias (µsec)	30-60					
Lares Range Bias (mm)	80-120					
Lares Time Bias (µsec)	40-70					
Stella/Starlette Range Bias (mm)	100-200					
Stella/Starlette Time Bias (µsec)	40-70					
Ajisai Range Bias (mm)	120-240					
Ajisai Time Bias (µsec)	50-80					
Etalon Range Bias (mm)	80-120					
Etalon Time Bias (µsec)						

I need to complete this table and review the LAGEOS numbers provided.

Questions/Comments/Conclusions

- Something seems suspect in the Etalon data analysis at the 2 cm level
- We need to develop and then automate if possible, mm level bias detection techniques on very short time scales (e.g. days and weeks) in support of GGOS one mm requirements
- When mm level range bias changes are correlated to system performance; equipment or procedural changes; then chances that the bias is real improve significantly.
- Can Stella, Starlette and/or Ajisai data be considered for use in future ITRF solutions?
- Stations needs to do a better job on maintaining their station change histories and especially documenting issues that were resolved.