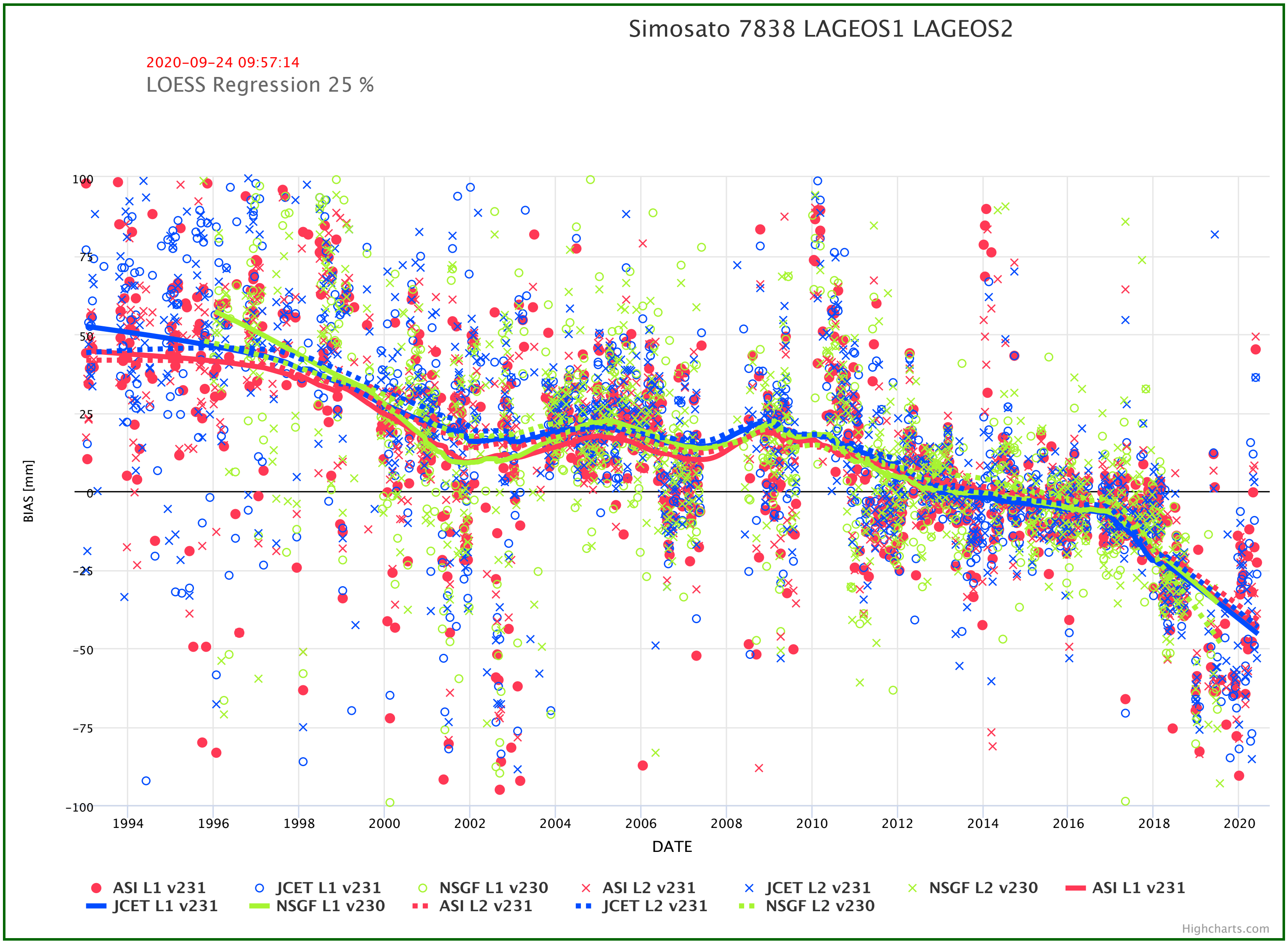
ILRS QCB Meeting

September 24, 2020
13:00 UTC

Agenda

• Brief on ILRS preparations for ITRF2020 submission	Erricos (10 min)
• Continued diagnostic work (some focus on Russian stations)	Van (40 min)
• Update on NP studies	Randy (15 min)
• Analysis of NPTs not following ILRS guidelines	John R. (15 min)
• Questions and discussion	All (30 min)

SYSTEMATIC ERRORS AT ILRS STATIONS FROM the SSEM PP



ASI LAGEOS1 v231	Mean/Std. Dev.:9.72±32.89 Count:863
JCET LAGEOS1 v231	Mean/Std. Dev.:11.39±33.92 Count:864
NSGF LAGEOS1 v231	Mean/Std. Dev.:10.27±31.58 Count:720
ASI LAGEOS2 v231	Mean/Std. Dev.:11.51±30.47 Count:838
JCET LAGEOS2 v231	Mean/Std. Dev.:13.1±32.63 Count:845
NSGF LAGEOS2 v231	Mean/Std. Dev.:11.31±30.27 Count:694

Data Analysis

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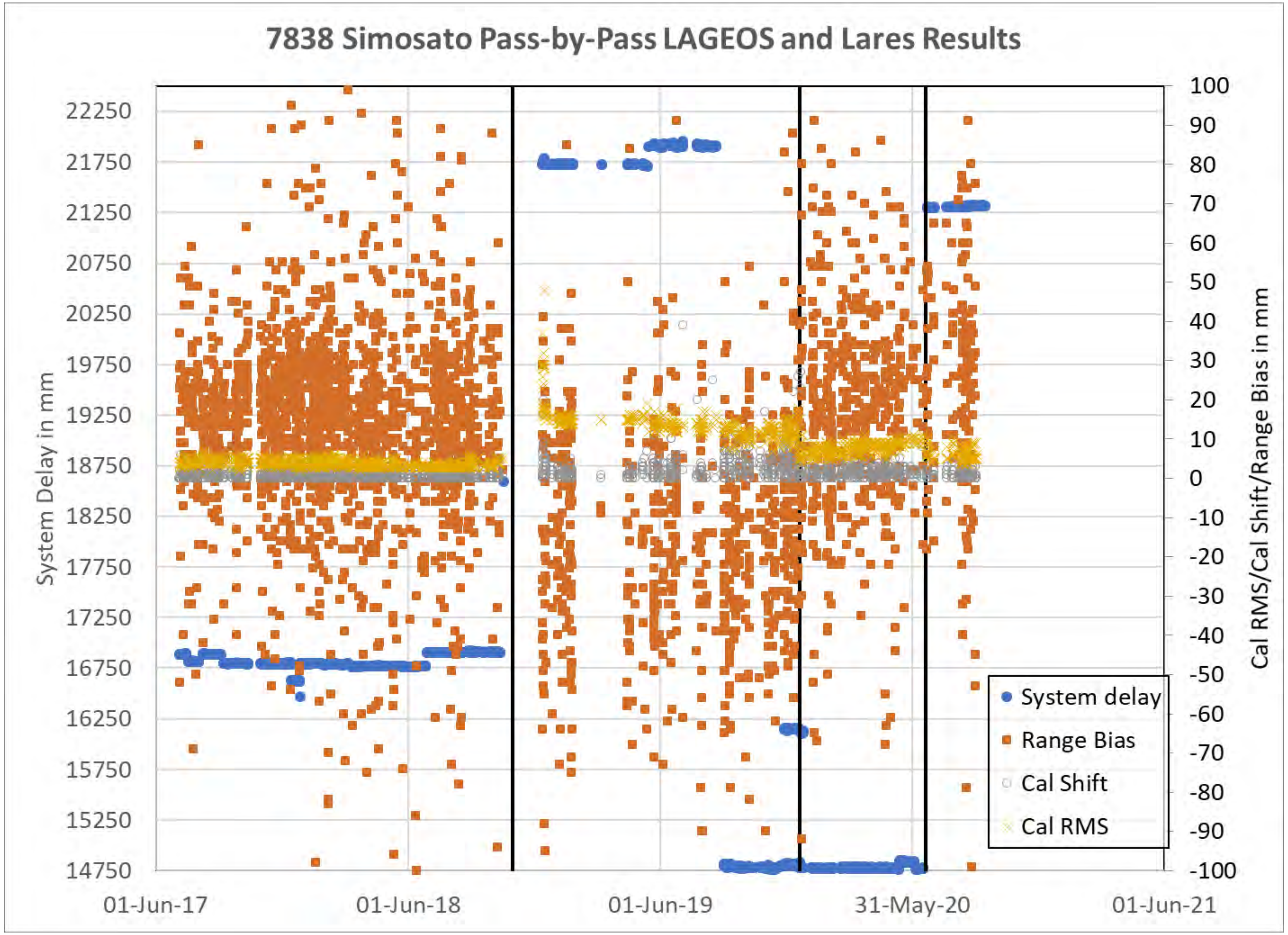
Agenda

- Simosato (7838) Data Analysis
- Recap and Update of 7105 Greenbelt Analysis
- Analysis of 7090 Yarragadee, 7825 Mt Sromlo, and 7110 Monument Peak
- Analysis of NASA SLR MOBLAS Center of Mass (CoM) changes
- Summary

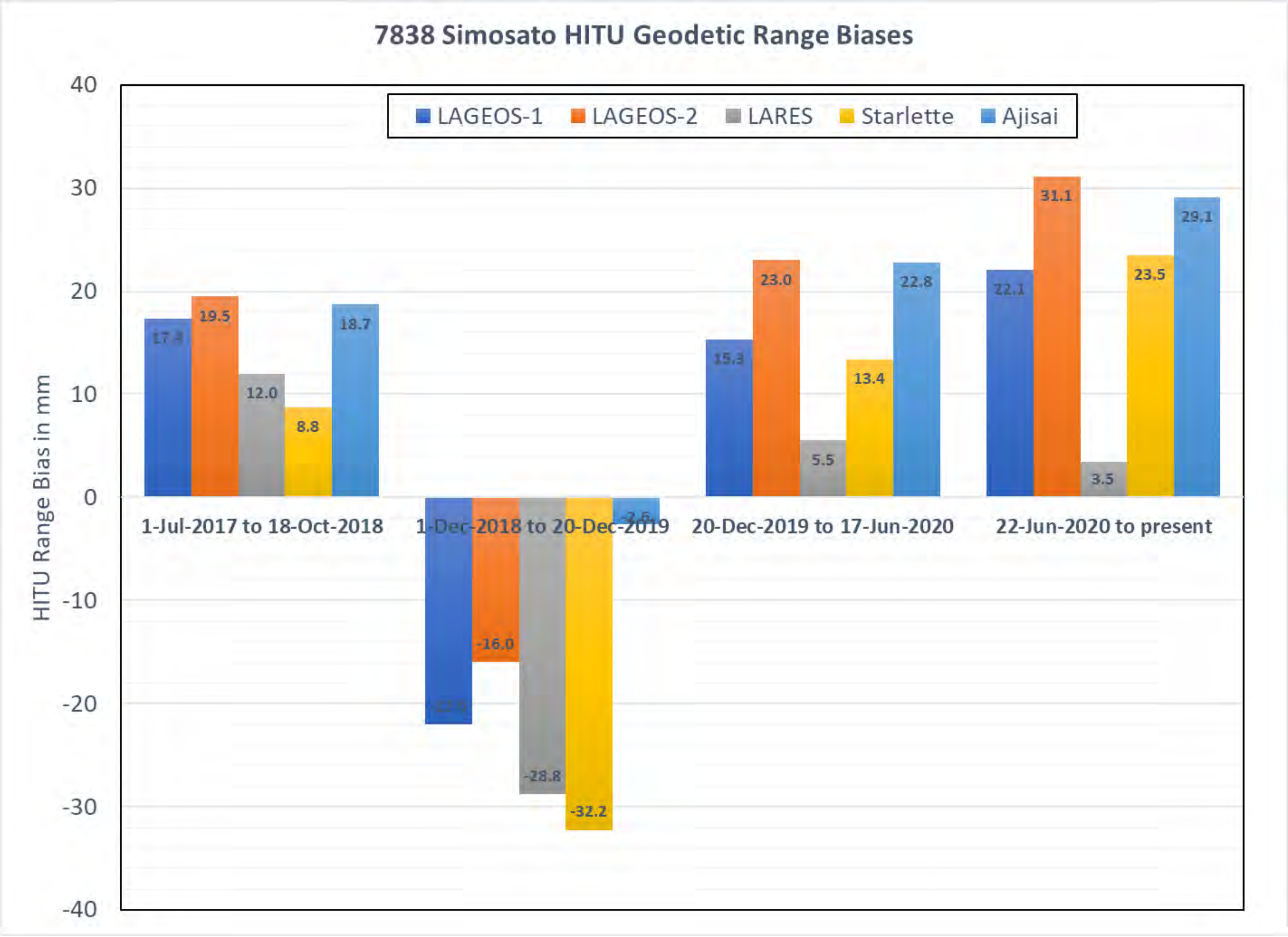
7838 Simosato Data Analysis

- Simosato has no station history log, but on 22-Oct-2018, they upgraded their laser from 5 to 1000 Hz (ref: site log), the pulse width changed from 20 to 30 ps and the max energy changed from 60 to 3 mJ
- 13-Dec-2018 was their 1st CRD post laser upgrade. The following performance changes were observed:
  - A ~5 meter increase in system delay
  - Increased calibration and satellite RMSs (all satellites)
  - >40% rejection rate of calibration obs;
  - calibration skew and kurtosis were set to 999.999
  - ~40 mm bias change on LAGEOS
- Since June 2017, there are 4 distinct periods of performance (See chart)
- Note: Their calibration target is mounted on the end of their telescope pre and post upgrade.



7838 Simosato Data Analysis (con't)

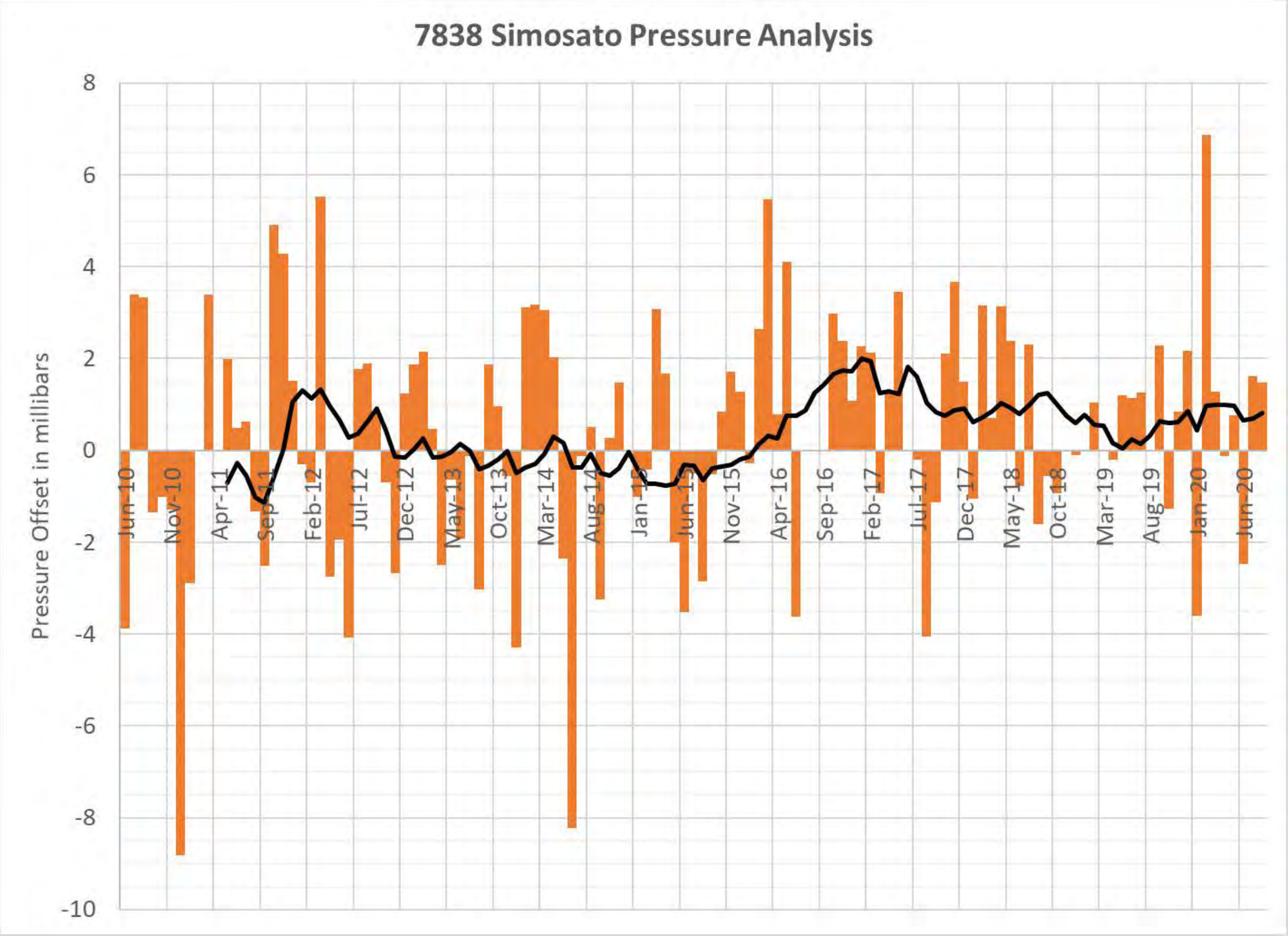
- The chart indicates the different range biases for the 4 different periods of performance.
- The 1st and 3rd periods have similar biases
- The Ajisai bias change (~20mm) in Period 2 relative to Period 1 was less than the other geodetic satellites. Perhaps signal strength related, but they don't measure signal strength.
- There was a ~6.5 meter system delay change between Periods 3 and 4 and there appears to mm level changes in the range bias (for each satellite).
- Should there be a new set of CoM corrections for the new laser?



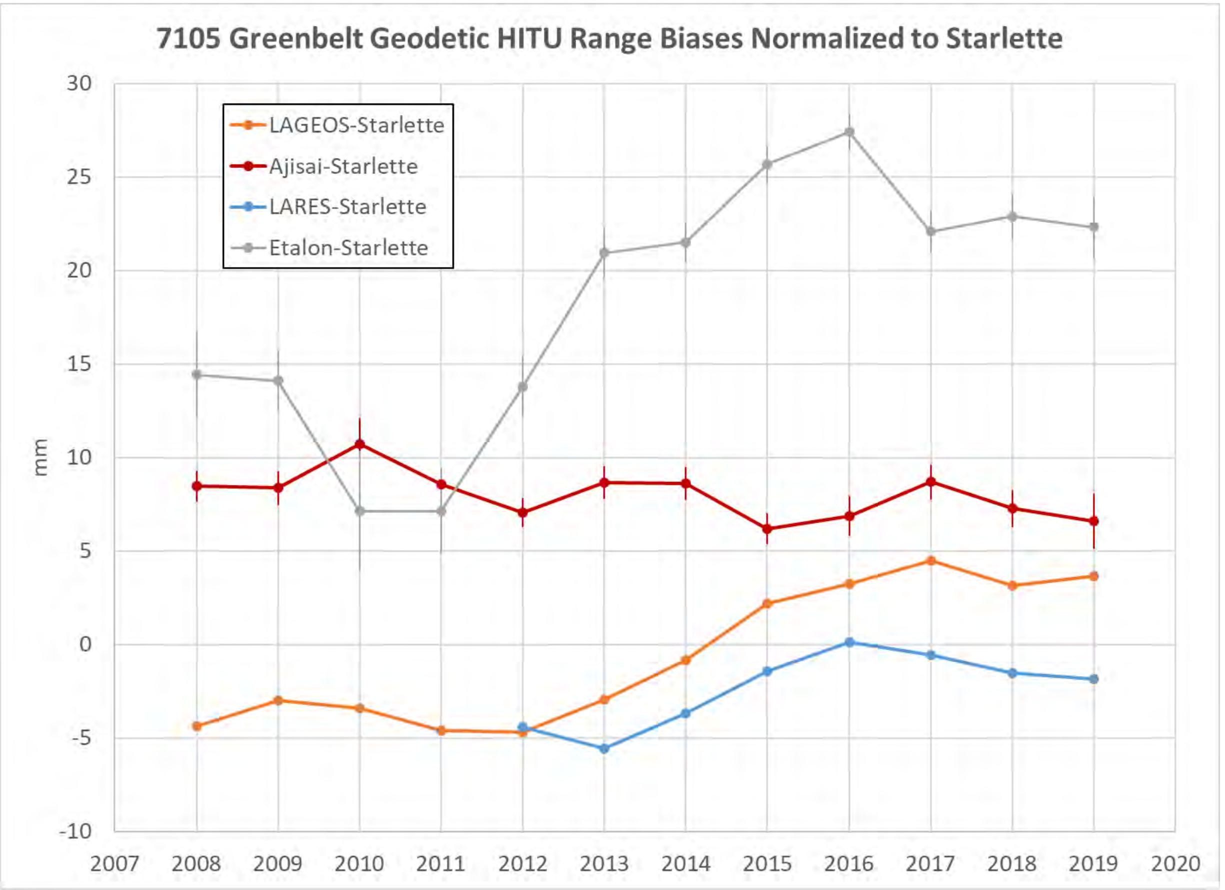
-3.3hPa to the observed values
-3.3hPa to the observed values

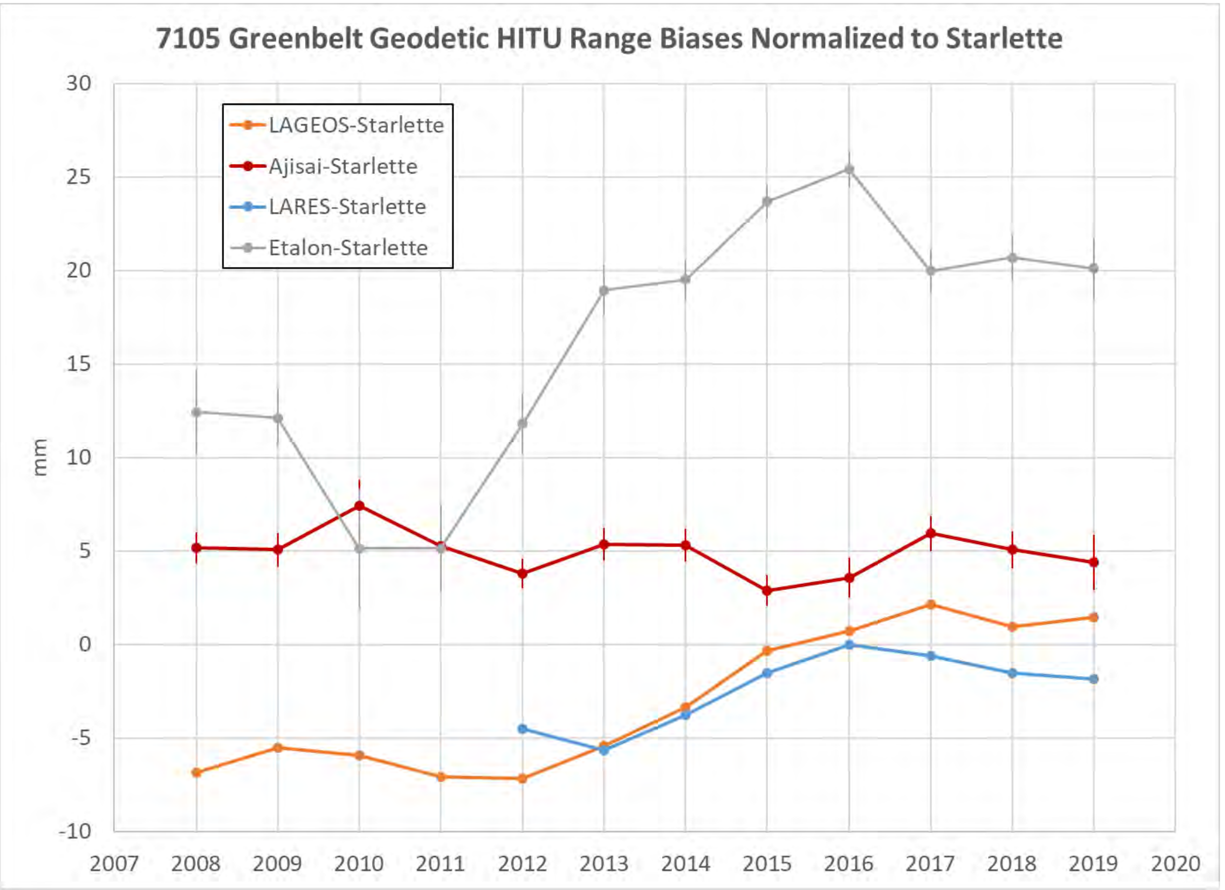
7838 Simosato Barometric Pressure Analysis

- The chart shows the monthly pressure offsets after removing long term seasonal trends with a 12- month running average applied
- Has the barometric pressure drifted positive the past few years?
- According to their site log:
  - Their barometer is only calibrated every 5 years.
  - The height difference between the barometer and system reference point is 0.3 meters. Is this difference accounted for in their onsite data processing?
  - Since 7-Oct-2003, -3.3 hPa have been added to the measurements based on a sensor calibration.
- A unmodeled drift in barometric pressure is one of the worst kinds of systematic errors.
  - For a station at sea level, a 1 mbar error is a 3mm and 7mm tropospheric error at 20 and 90 degrees; respectively
- When was the last barometric calibration and what were the results?



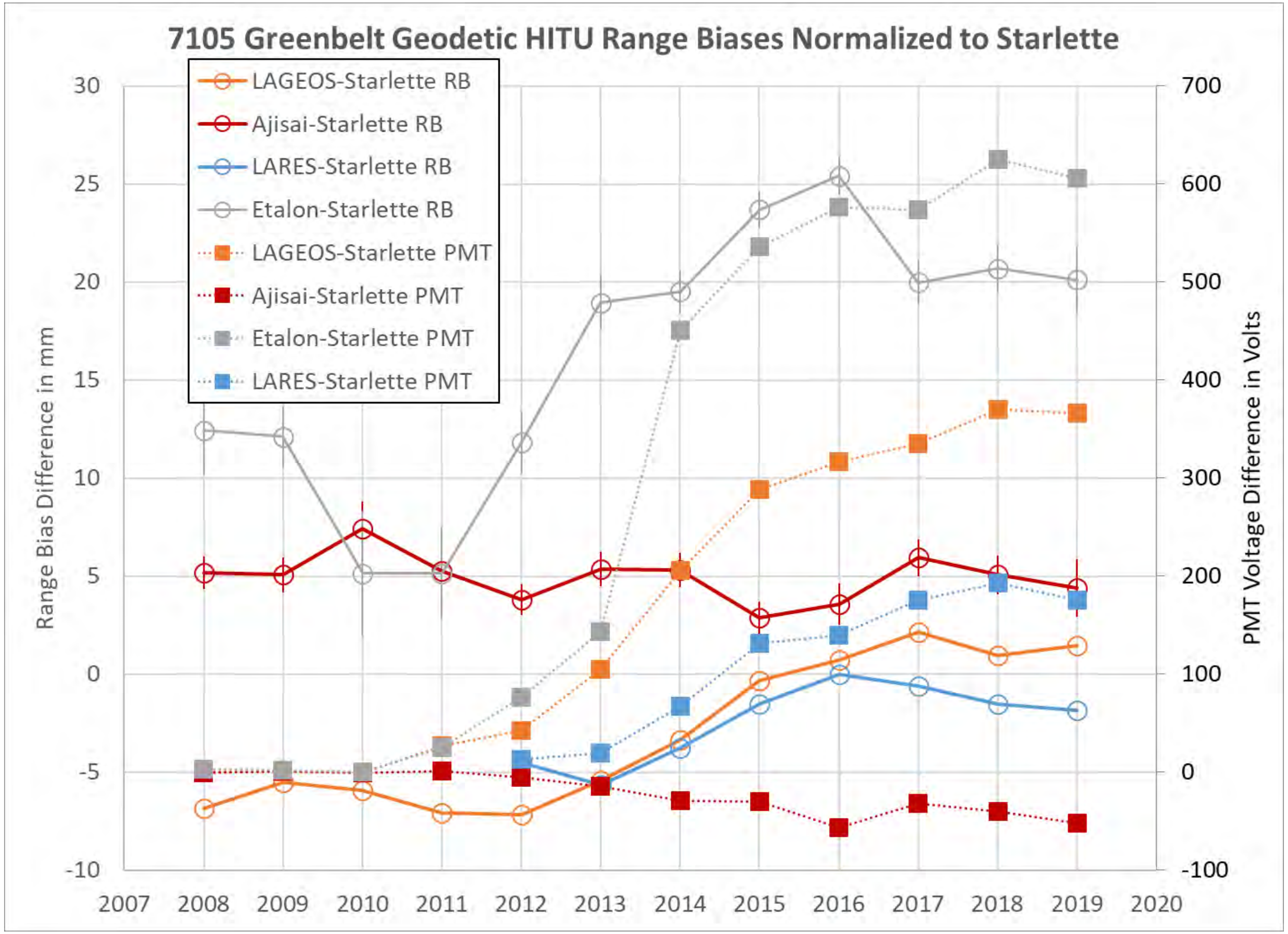
HITU 7105 Geodetic Range Biases (RB) Normalized





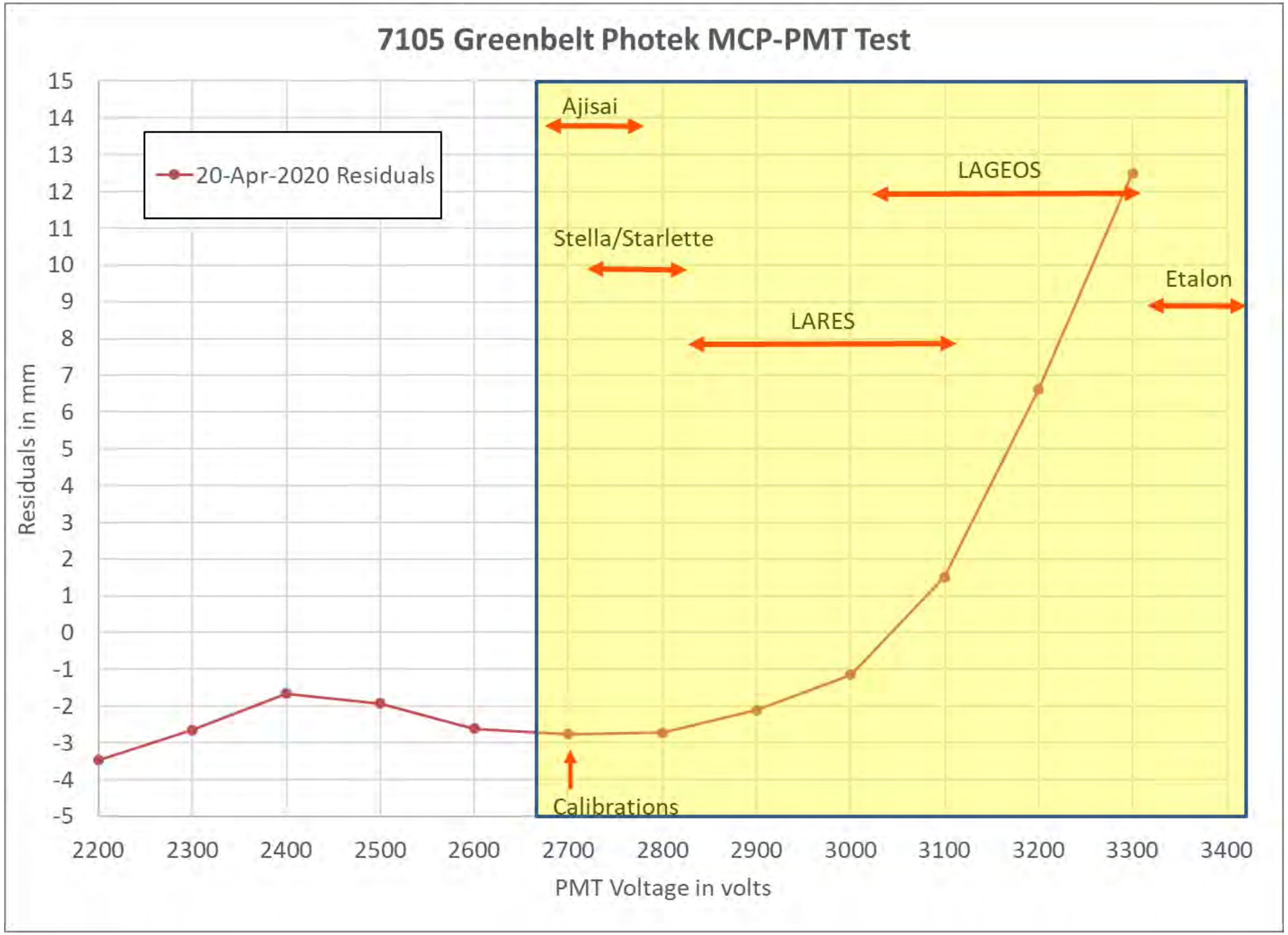
When I was preparing this presentation, I realized the chart on the left that I presented on July 15, 2020 I did not account for different CoMs before the 7105 ETM installation in 2016. Also on the chart on the left I included Stella with the Starlette data. The chart on the right accounts for CoMs changes prior to the ETM installation and only compares data relative to Starlette (Stella data not used).

7105 Yearly RB and PMT Voltages Differences



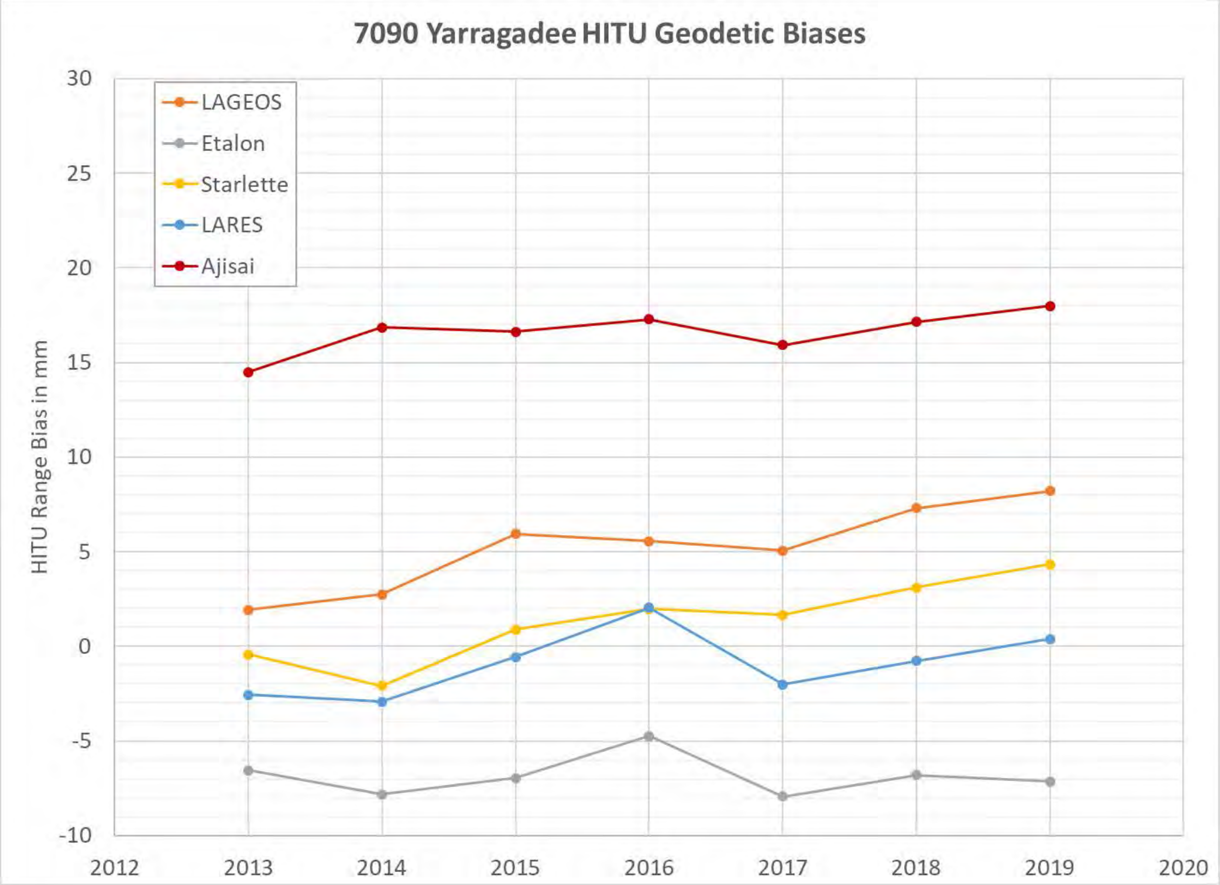
- ❑ The open circles and the solid squares are the range bias and PMT voltage differences relative to Starlette; respectively.
- ❑ Etalon voltages differences from Starlette increased to 600 volts and as a result the relative Etalon range bias increased by ~12mm.
- ❑ LAGEOS voltages differences from Starlette increased to 375 volts and as a result the relative LAGEOS range bias increased by ~7mm.
- ❑ LARES voltages differences from Starlette increased to 175 volts and as a result the relative LARES range bias increased by ~3mm.
- ❑ Ajisai voltages were always within 50 volts of Starlette and the reason there is little drift in the relative Ajisai range bias.

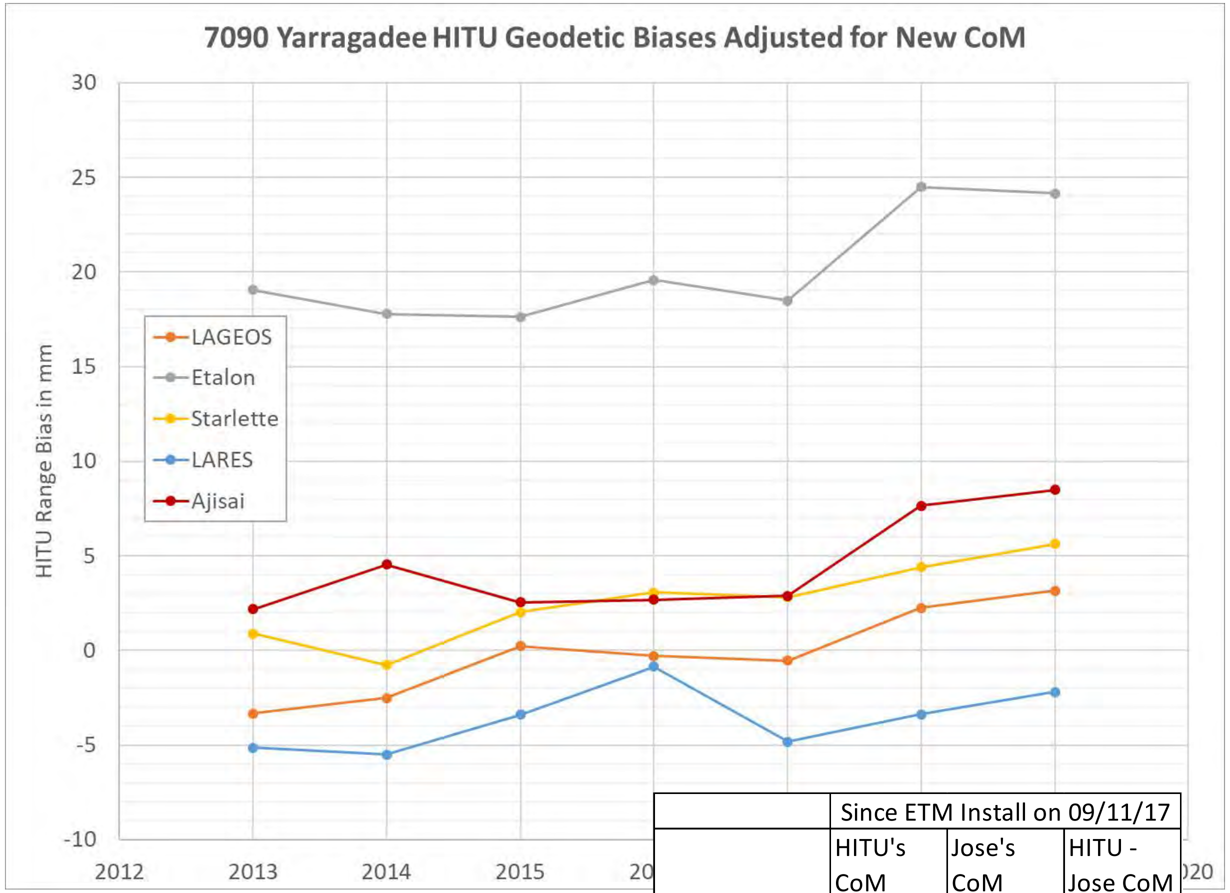
7105 Greenbelt PMT Voltage Tests



- PMT voltages differences between calibrations and satellite voltages can explain most of the following range bias changes.
  - Etalon voltages differences increased to 600 volts and as a result the relative Etalon range bias increased by ~12mm.
  - LAGEOS voltages differences increased to 375 volts and as a result the relative LAGEOS range bias increased by ~7mm.
  - LARES voltages differences increased to 175 volts and as a result the relative LARES range bias increased by ~3mm.
- *Starting on August 14, 2020, at 03:14 GMT, 7105 starting using one voltage for all satellites and calibration. Their change history was updated to reflect this.*

7090 Yarragadee Yearly Geodetic Range Biases

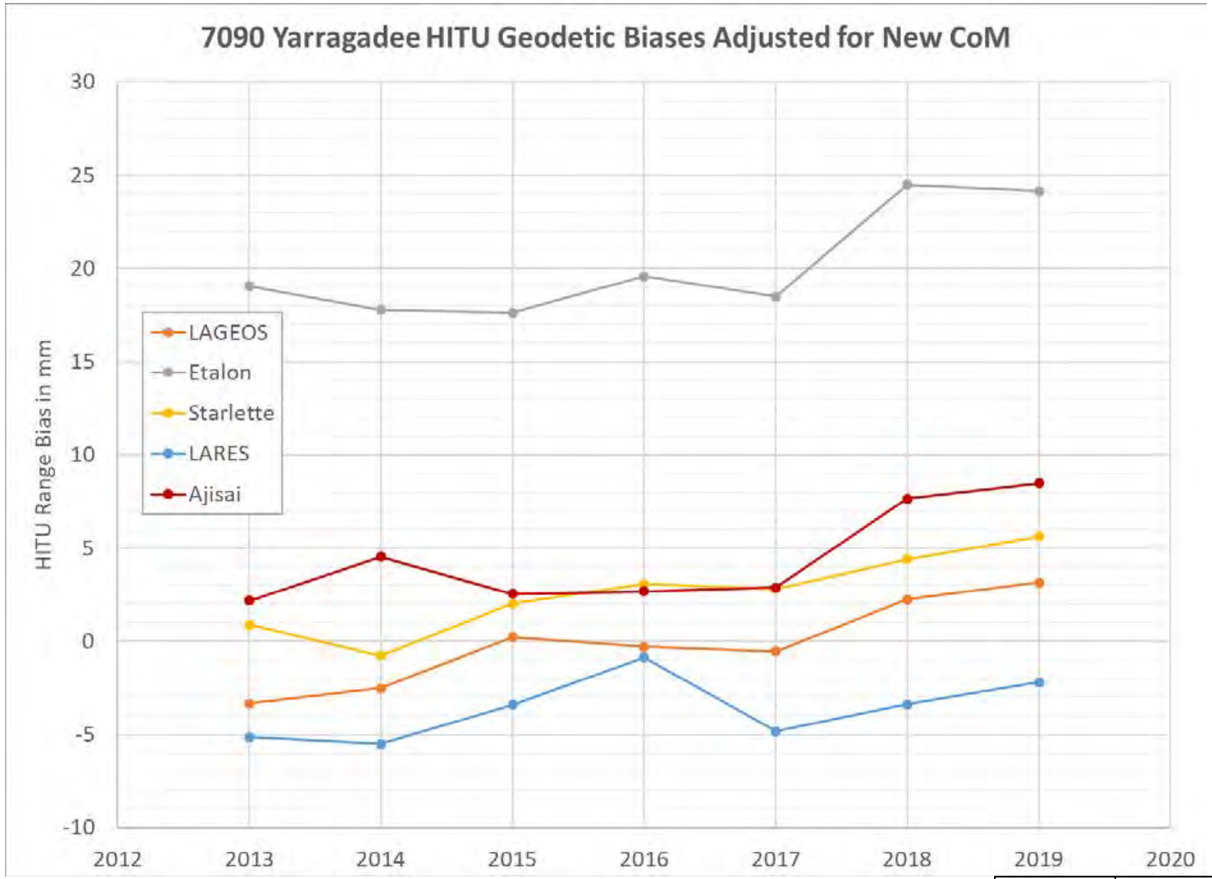




Satellite	Since ETM Install on 09/11/17 HITU's CoM (mm)	Jose's CoM (mm)	HITU - Jose CoM in mm
Etalon	558.0	589.3	-31.3
Stella/Starlette	75.0	76.3	-1.3
Lares	133.0	130.4	2.6
LAGEOS-1	251.0	246.2	4.8
LAGEOS-2	251.0	245.7	5.3
Ajisai	1010.0	1000.5	9.5

The right chart is adjusted for Jose's latest CoM corrections which tightened up the RBs except for Etalon. This trend holds true for all the NASA Systems, except for 7110 Ajisai. Starting in 2018, all the 7090 biases appear to be drifting positive.

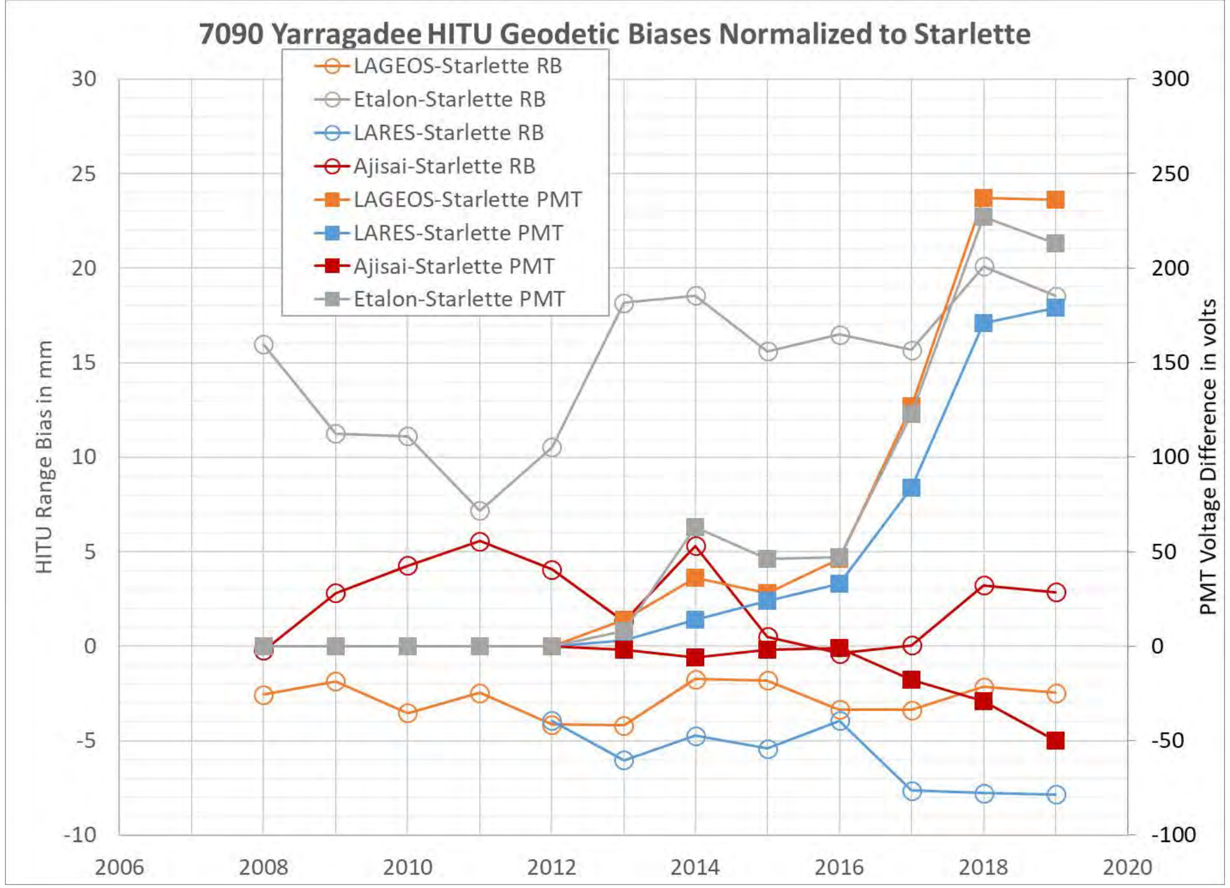
7090 Yarragadee Yearly Geodetic Range Biases

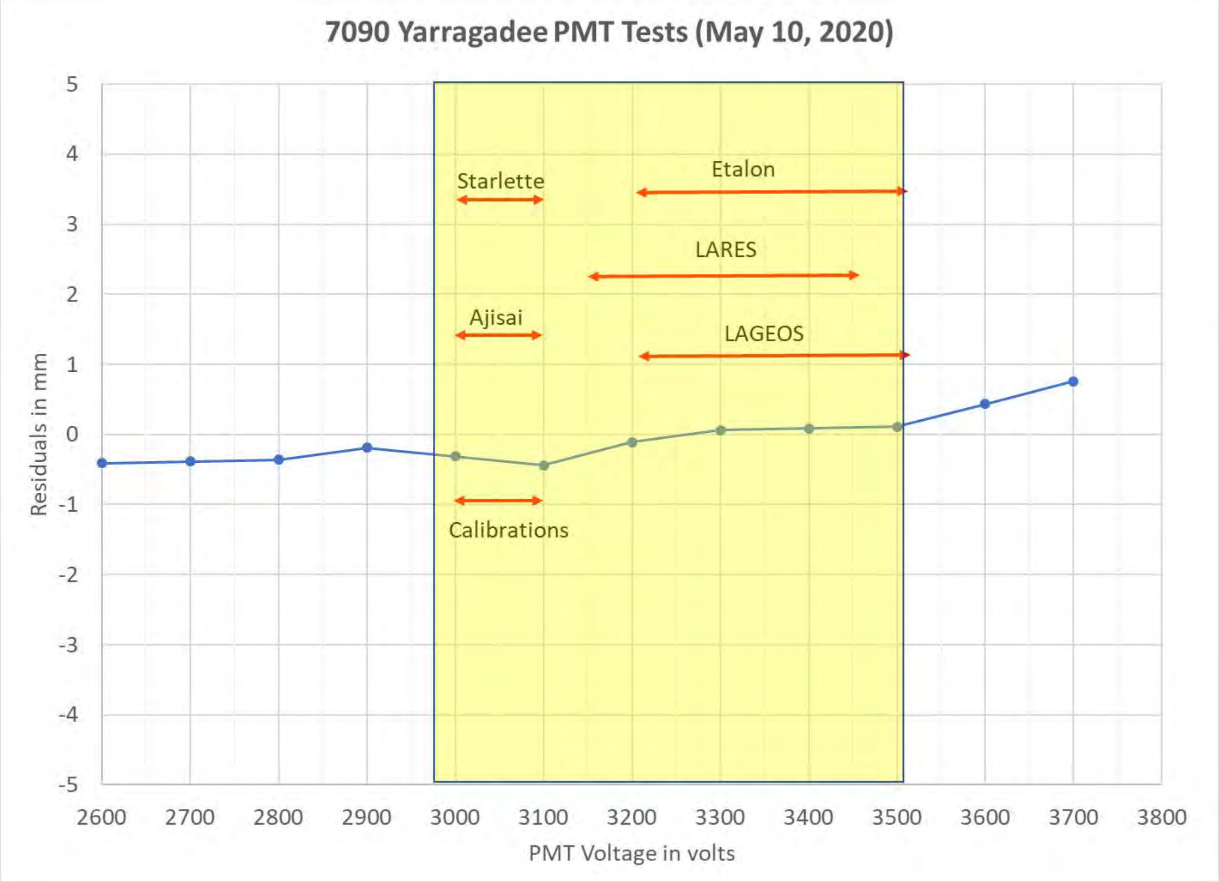


Satellite	Pre ETM CoM in mm	Post ETM CoM in mm	Difference Post-Pre ETM CoM in mm
Etalon	582.3	589.3	7.0
LAGEOS-1	245.5	246.2	0.7
LAGEOS-2	244.8	245.7	0.9
Lares	130.1	130.4	0.3
Starlette	76.1	76.3	0.2
Ajisai	995.4	1000.5	5.1

- The apparent uptick in RBs in 2018 and 2019 may have multiple causes.
- In June 2017, HITU updated coordinates to ITRF2014 which has a 7090 station height rate of ~0.5 mm/year. Is this height rate correct?
- On Sep 11, 2017, the ETM was installed and new CoMs were computed (see CoM table) with large changes in Etalon and Ajisai CoMs. If the 7090 HP5370 and ETM data compared favorably on all satellites, does these several mm level CoMs changes make sense?
- Does 7090 PMT Voltage variations have any influence on these range biases?

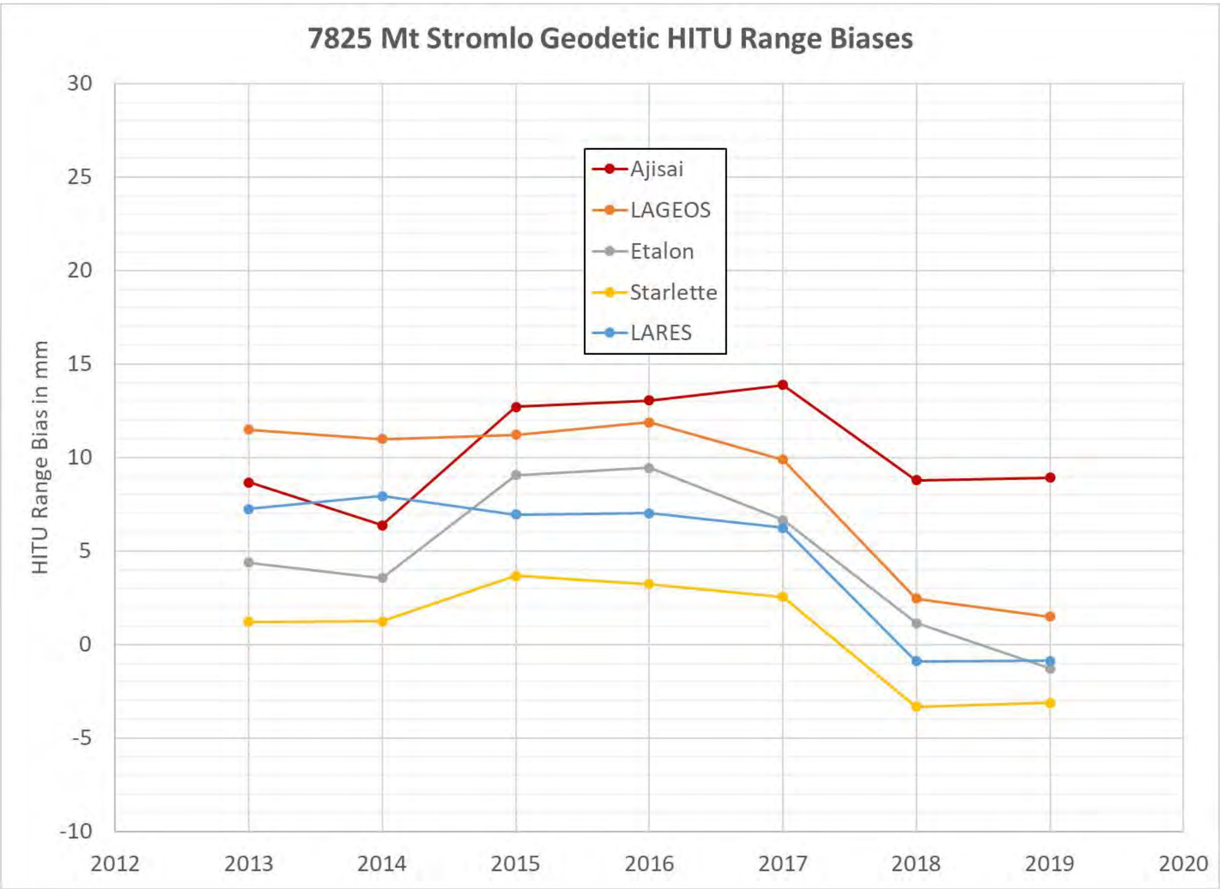
7090 Yarragadee RBs Normalized and PMT Results

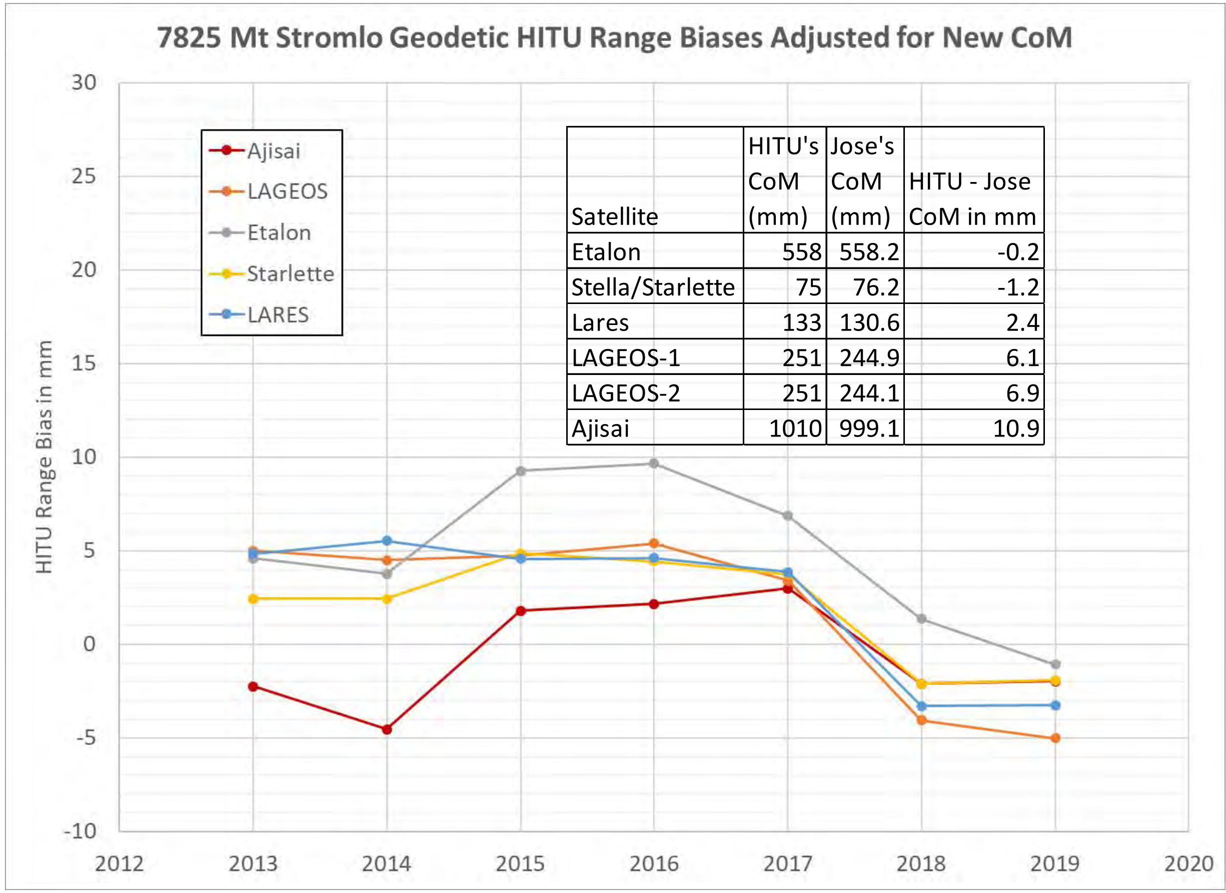




The left chart is the same analysis that we did for 7105. Based on the 7090 PMT test results on the right increasing, PMT voltage changes have less than 1mm impact on range bias changes. On June 1, 2020, 7090 uses one voltage for all satellites and calibrations.

7825 Mt Stromlo Yearly Geodetic Range Biases

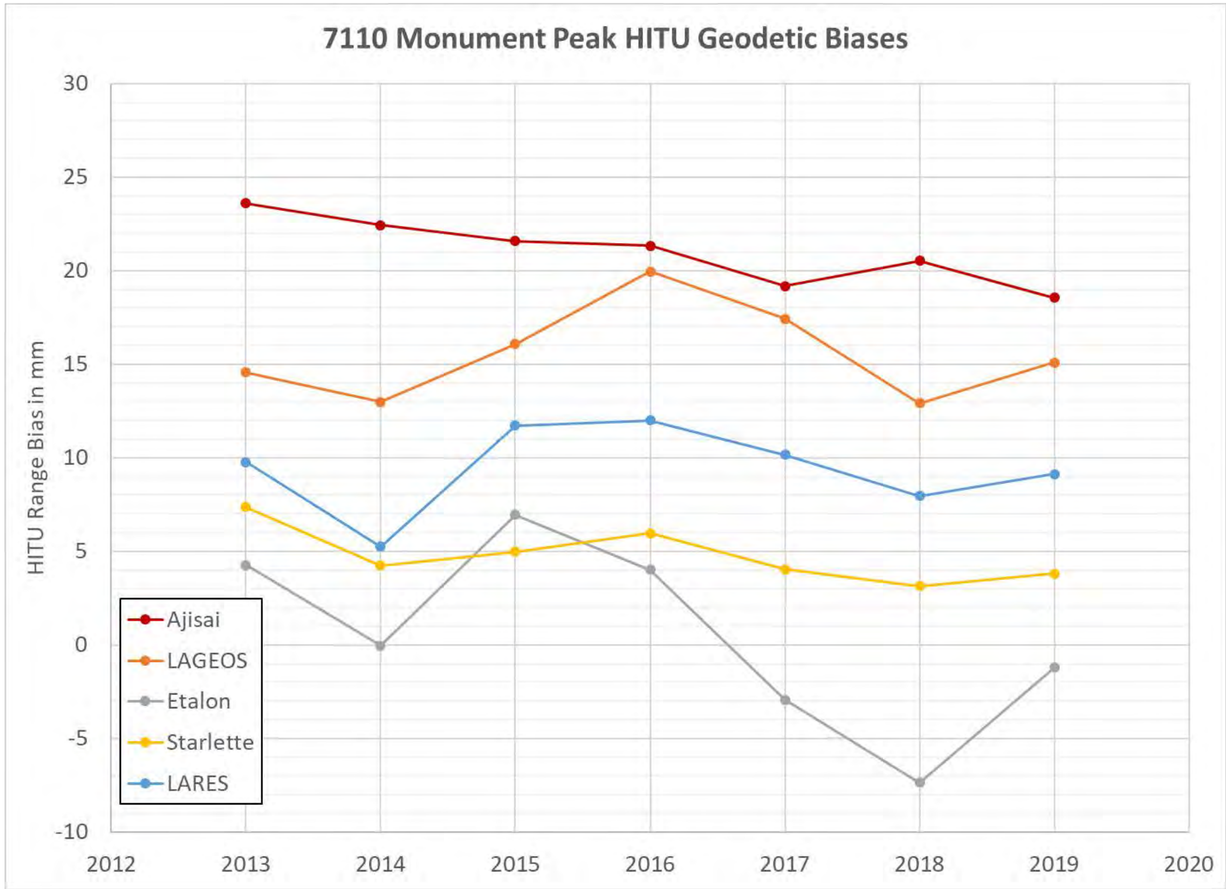


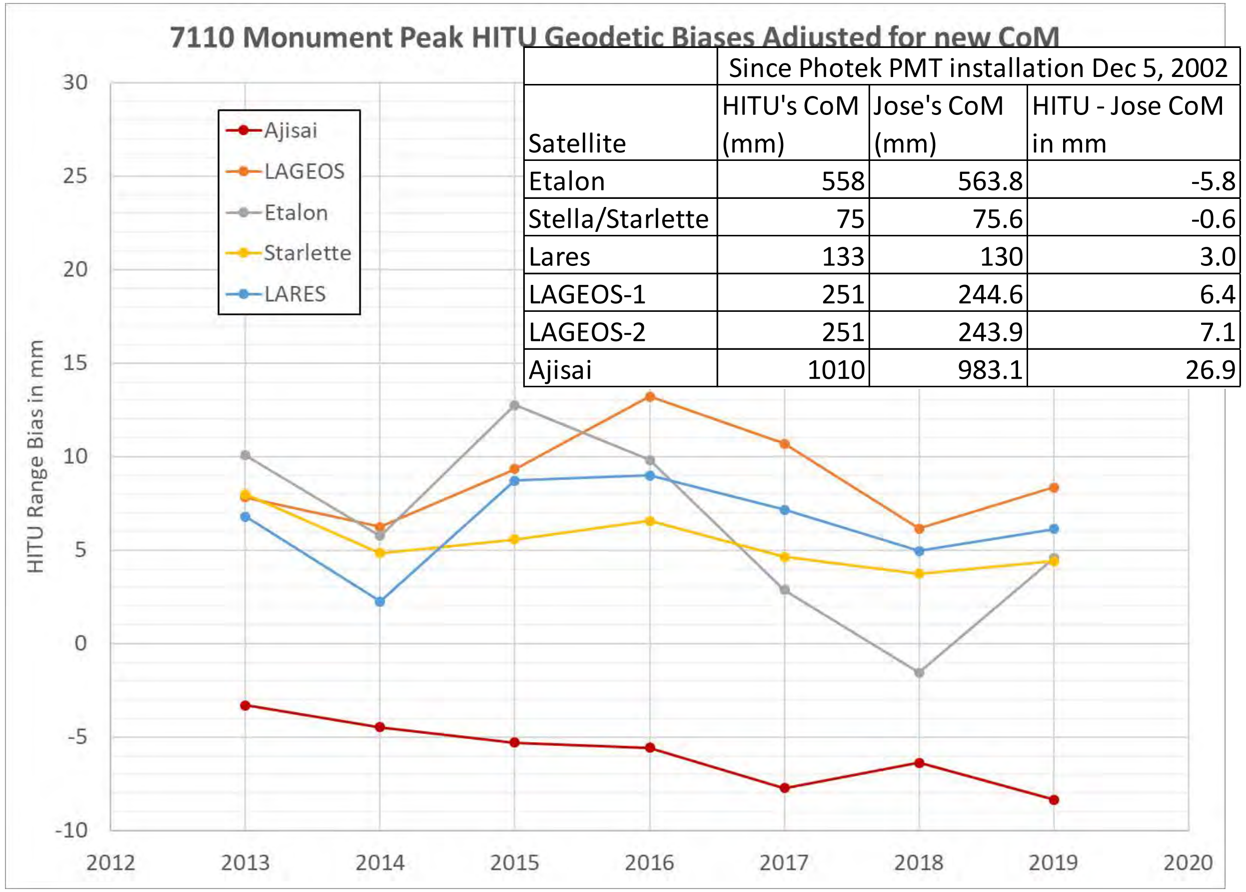


Satellite	HITU's CoM (mm)	Jose's CoM (mm)	HITU - Jose CoM in mm
Etalon	558	558.2	-0.2
Stella/Starlette	75	76.2	-1.2
Lares	133	130.6	2.4
LAGEOS-1	251	244.9	6.1
LAGEOS-2	251	244.1	6.9
Ajisai	1010	999.1	10.9

Mt Stromlo biases on LARES, LAGEOS and Starlette tighten up quite nicely with the new CoM corrections and Ajisai since 2015. All biases show a downward trend the past 2 years, where Yarragadee biases trend upwards.

7110 Monument Peak Yearly Geodetic Range Biases

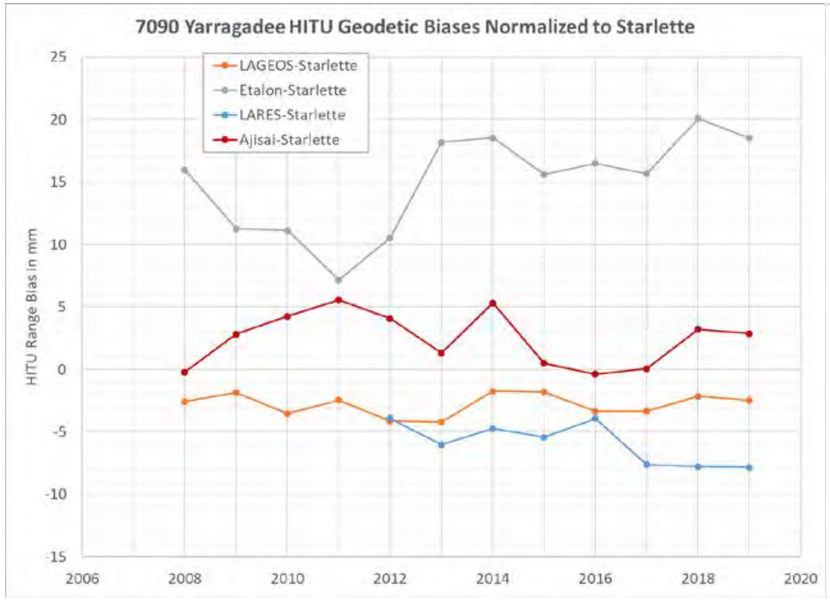


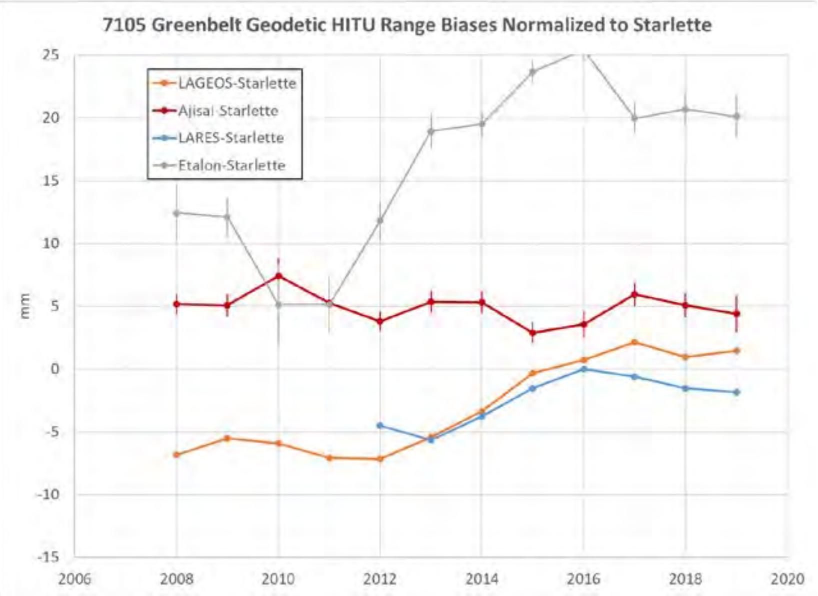


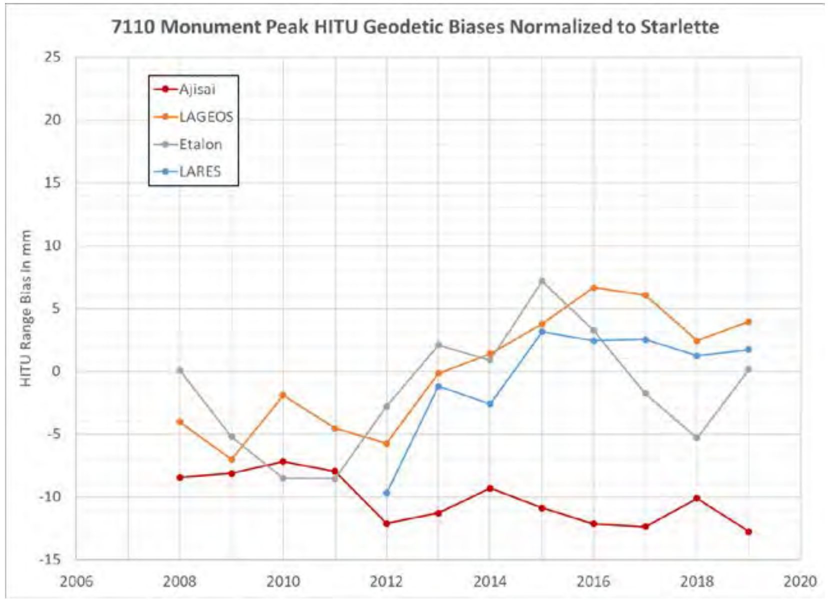
	Since Photek PMT installation Dec 5, 2002		
Satellite	HITU's CoM (mm)	Jose's CoM (mm)	HITU - Jose CoM in mm
Etalon	558	563.8	-5.8
Stella/Starlette	75	75.6	-0.6
Lares	133	130	3.0
LAGEOS-1	251	244.6	6.4
LAGEOS-2	251	243.9	7.1
Ajisai	1010	983.1	26.9

The right chart is adjusted for Jose's latest CoM corrections. The range biases have a tighter grouping with the new CoM applied except for Ajisai. Also, not that Etalon is not an outlier like it was for 7090 and 7105.

HITU Geodetic Range Biases Normalized







NASA SLR Center of Mass Differences						
Satellite	7090 CoM (mm)	7105 CoM (mm)	7110 CoM (mm)	7105-7090	7110-7090	7110-7105
Etalon	589.3	583.3	563.8	-6.0	-25.5	-19.5
Stella/Starlette	76.3	76.1	75.6	-0.2	-0.7	-0.5
Lares	130.4	130.1	130.0	-0.3	-0.4	-0.1
LAGEOS-1	246.2	246.0	244.6	-0.2	-1.6	-1.4
LAGEOS-2	245.7	245.6	243.9	-0.1	-1.8	-1.7
Ajisai	1000.5	998.5	983.1	-2.0	-17.4	-15.4

Range Bias Differences and new CoMs						
Satellite	7090 RB Diff (mm)	7105 RB Diff (mm)	7110 RB Diff (mm)	7105-7090	7110-7090	7110-7105
Etalon-Starlette	14.9	16.2	-1.5	1.3	-16.5	-17.8
LARES-Starlette	-5.9	-2.4	-0.3	3.5	5.6	2.1
LAGEOS-Starlette	-2.8	-3.0	0.1	-0.2	2.9	3.1
Ajisai-Starlette	2.4	4.9	-10.2	2.5	-12.7	-15.2

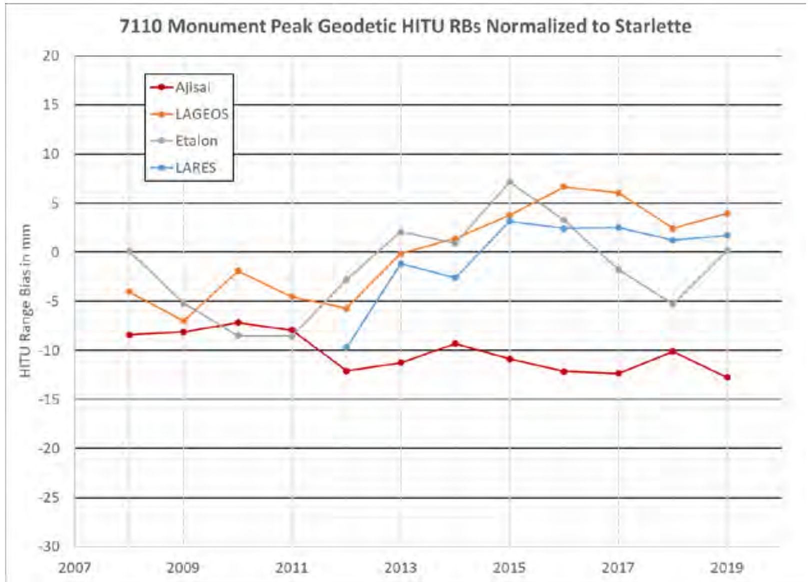
The Etalon and Ajisai CoM corrections are quite different between these 3 systems which have essentially the same configuration except for the detector. The differences in CoM show up in the relative differences of the range biases.

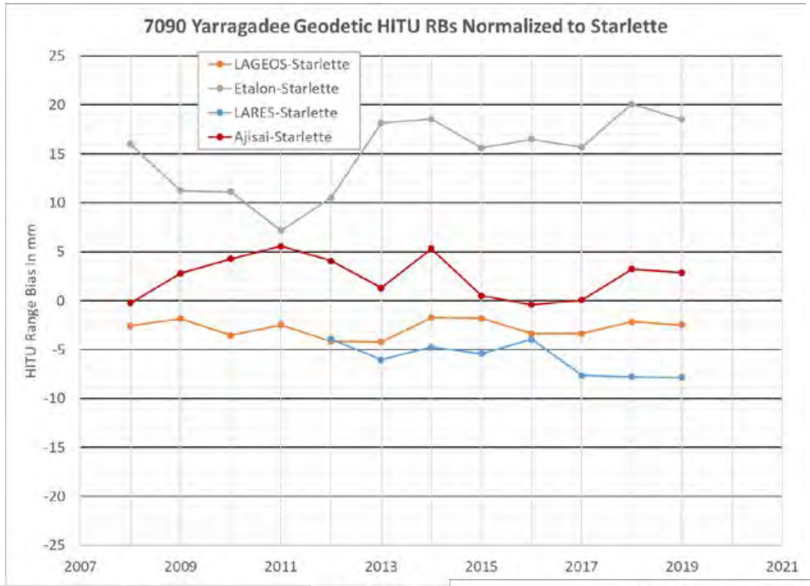
Summary/Questions and Next Steps

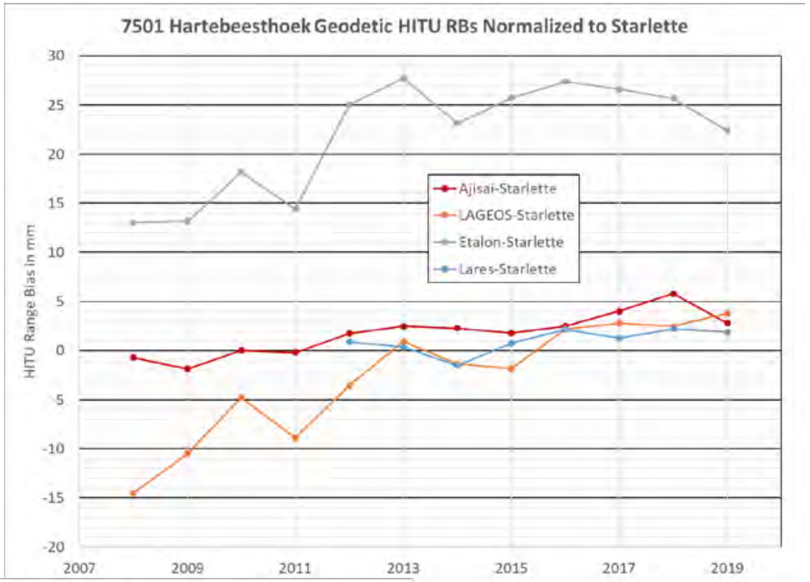
- Simosato range biases and calibrations are not as stable post 1 kHz laser upgrade
- Excluding Etalon and 7110 Ajisai results, updated CoM corrections improve the HITU NASA MOBLAS range bias stability on the geodetic satellites
- There appears to be a few to several mm 7090, 7105 and 7110 LAGEOS and Lares range biases differences relative to Starlette. Are these differences in the orbit; the station; the CoM corrections; or a combination?
  - Is there something in the NASA SLR systems that effect receive pulse shape that should be modeled in the CoM corrections, but currently is not.
- Are the 12-25 mm variations between the NASA SLR MOBLAS Etalon and Ajisai CoM corrections real?
- Is there a process in place to track system configuration changes and then update the CoMs accordingly?
  - Do we need some updated CoMs for ETM installations at 7110, 7124 and 7403.
  - Do we need updated CoMs for the 1 kHz Simosato laser?

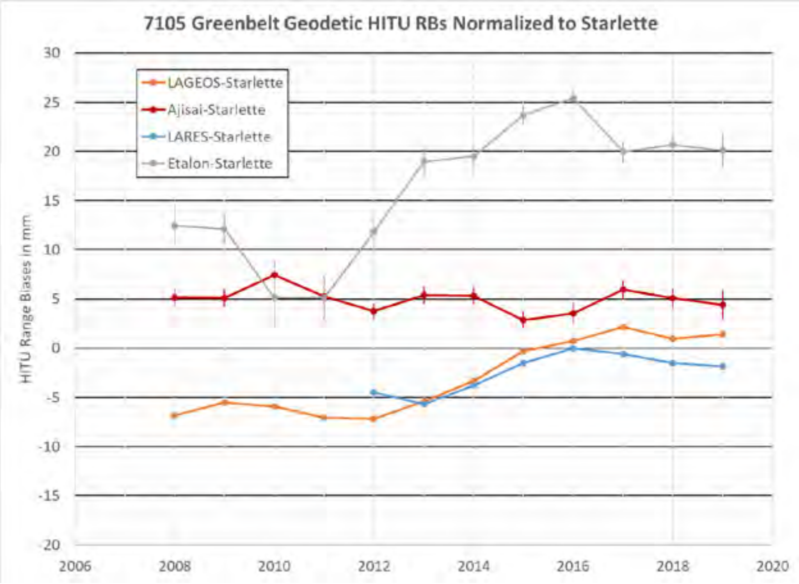
BACKUP SLIDES

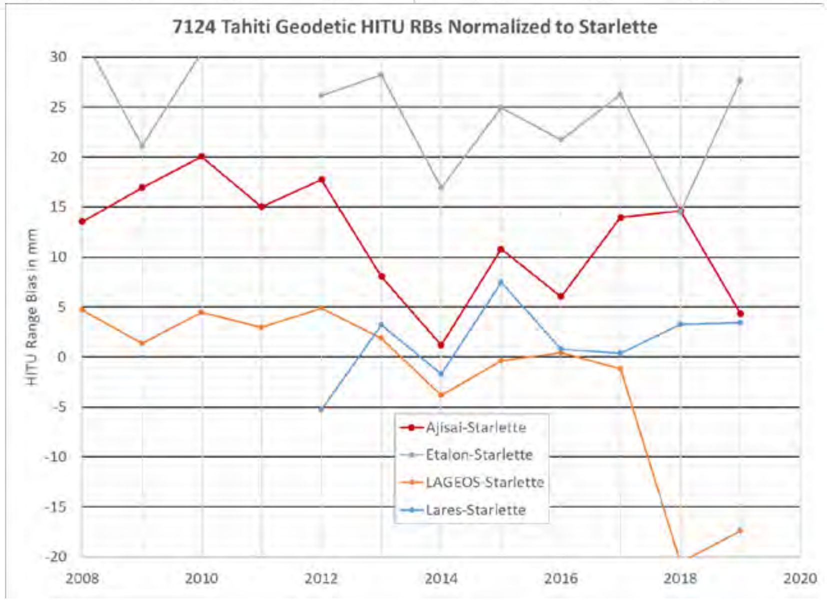
NASA MOBLAS HITU Range Bias Analysis



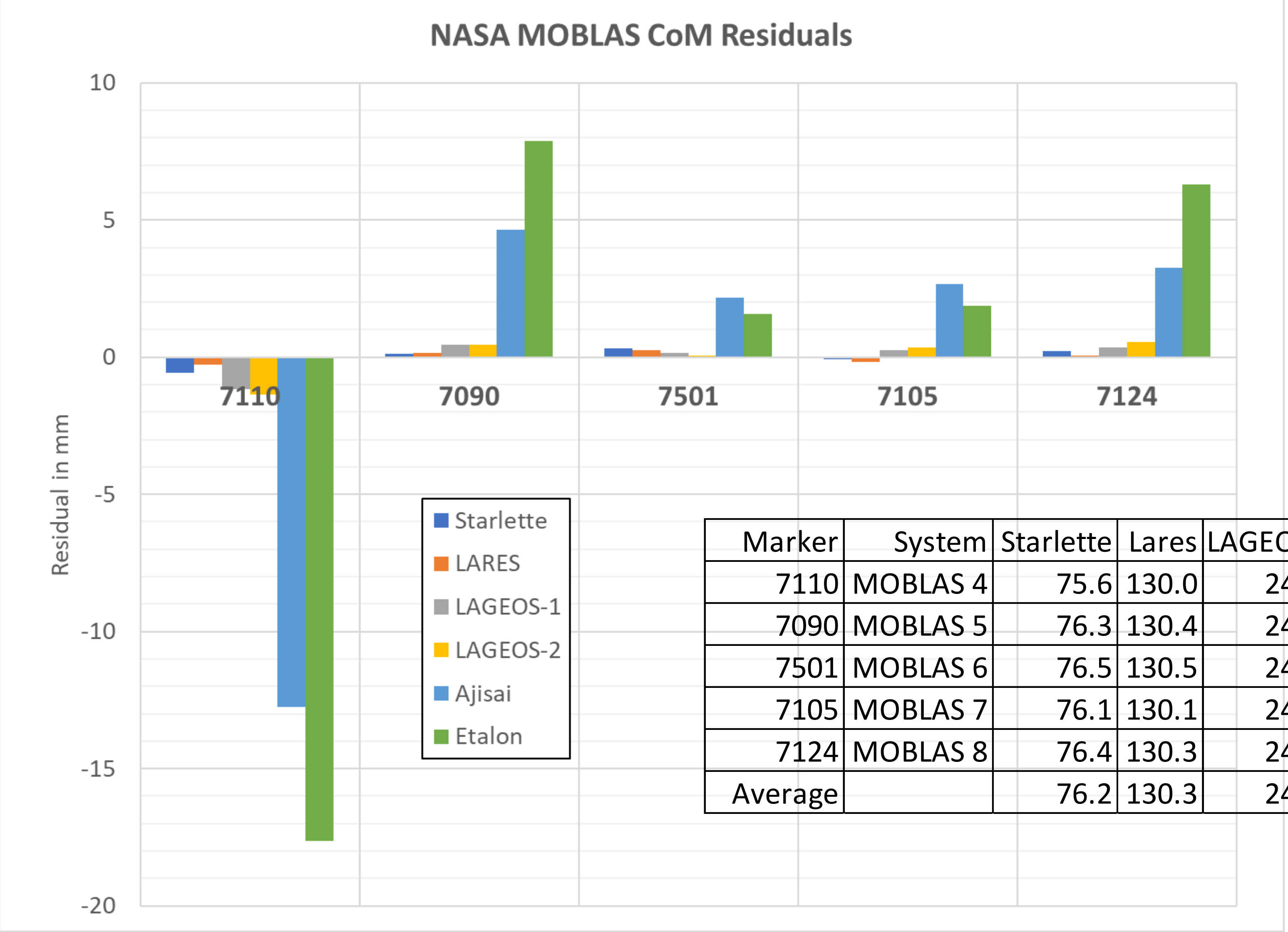








NASA MOBLAS CoM Correction Analysis



Marker	System	Starlette	Lares	LAGEOS-1	LAGEOS-2	Etalon	Ajisai
7110	MOBLAS 4	75.6	130.0	244.6	243.9	563.8	983.1
7090	MOBLAS 5	76.3	130.4	246.2	245.7	589.3	1000.5
7501	MOBLAS 6	76.5	130.5	245.9	245.3	583.0	998.0
7105	MOBLAS 7	76.1	130.1	246.0	245.6	583.3	998.5
7124	MOBLAS 8	76.4	130.3	246.1	245.8	587.7	999.1
Average		76.2	130.3	245.8	245.3	581.4	995.8

Skew, Kurtosis, and P-M Python library vs DISTRIB

Revisiting a Point From Our Last Meeting

R. Ricklefs

24 September 2020

ILRS QCB

The Issue

- Use python library routines to calculate skew, kurtosis, and peak-mean rather than ILRS standard DISTRIB routine converted to Python?
- It looked like we had different results from these options, and the python library routine results looked closer to the stations' results
- It's nice to use native library routines, or so I thought.

The Failings

- The python routines don’t do a 3 or any other sigma filtering, so the skew and kurtosis don’t reflect the data used.
- Computing the peak and the 1-sigma has been painful and unsuccessful using python routines. Someone more adept at python may have had better results.

The Good News

- The FORTRAN and python DISTRIB routines give the same results for even large normal points
- The python routines and DISTRIB converted to python compute the same skew and kurtosis *as long as there have been no observations filtered out.*
- This was missed earlier because the program using distrib wrote in the normal points the total number of observations rather than the number after filtering.

Comparison of Pass 7840_lageos1_crd_200118_2118_0

```
 -- Normal Points using python library routines
11 76769.624198946243    0.052199019455   KS 2  120.0  1494      80.6  0.787 -0.082   0.000   2.3 0
11 76814.508383945547    0.051398211603   KS 2  120.0   690      81.6  0.676 -0.305   0.000   3.2 0
11 77036.591549955250    0.047687283425   KS 2  120.0   549      92.9  0.279 -0.947   0.000   7.1 0
11 77064.171549953709    0.047260048456   KS 2  120.0  1501      89.4  0.235 -0.769   0.000   3.3 0
11 77502.422220250068    0.041802667026   KS 2  120.0  1839      90.7  0.618 -0.567   0.000   2.8 0
11 77534.998505953015    0.041515724835   KS 2  120.0  1121      92.9  0.625 -0.603   0.000   4.4 0
11 77977.276069956177    0.039637223571   KS 2  120.0  2066      82.2  0.493 -0.380 264.967   3.6 0
11 78007.989069945092    0.039654708710   KS 2  120.0   976      83.3  0.388 -0.757   0.000   5.5 0
11 78211.901872947739    0.040262014160   KS 2  120.0  3024      81.8  0.740 -0.096 463.718   5.5 0
 -- Normal Points using distrib.py
11 76769.624198946243    0.052199019445   KS 2  120.0  1415      68.6  0.650 -0.365  12.832   2.1 0
11 76814.508383945547    0.051398211598   KS 2  120.0   675      76.8  0.607 -0.403  15.270   3.1 0
11 77036.591549955250    0.047687283425   KS 2  120.0   549      92.9  0.279 -0.947  20.196   7.1 0
11 77064.171549953709    0.047260048457   KS 2  120.0  1499      89.0  0.253 -0.800  16.131   3.2 0
11 77502.422220250068    0.041802667026   KS 2  120.0  1838      90.6  0.627 -0.579  13.882   2.8 0
11 77534.998505953015    0.041515724835   KS 2  120.0  1121      92.9  0.625 -0.603  13.651   4.4 0
11 77977.276069956177    0.039637223572   KS 2  120.0  2064      81.9  0.512 -0.410  11.435   3.6 0
11 78007.989069945092    0.039654708710   KS 2  120.0   976      83.3  0.388 -0.757  19.639   5.5 0
11 78211.901872947739    0.040262014150   KS 2  120.0  2880      70.7  0.549 -0.407  12.150   5.2 0
```

“DISTRIB vs Python Functions III”

Imperfect match

7810_lageos1_crd_200107_1515_0.npt – Zimmerwald

Native Python Functions

							RMS	SKEW	KURT	P-M		
11	55023.332522335077	0.054587345161	KS	2	120.0	861	77.4	0.395	-0.613	0.0	7.2	0
11	55136.981252328987	0.052815484071	KS	2	120.0	952	72.0	0.420	-0.527	0.0	8.0	0
11	55258.065992333133	0.051075100427	KS	2	120.0	1193	71.8	0.433	-0.441	0.0	10.0	0
11	55378.161752328364	0.049521359979	KS	2	120.0	1257	65.9	0.454	-0.473	0.0	10.5	0
11	55500.562022333921	0.048138108828	KS	2	120.0	1255	67.1	0.521	-0.143	0.0	10.5	0

DISTRIB.f converted to Python (and showing correct number of points)

							RMS	SKEW	KURT	P-M		
11	55023.332522335077	0.054587345161	KS	2	120.0	861	77.4	0.395	-0.613	12.317	7.2	0
11	55136.981252328987	0.052815484071	KS	2	120.0	952	72.0	0.420	-0.527	12.261	8.0	0
11	55258.065992333133	0.051075100427	KS	2	120.0	1192	71.6	0.429	-0.447	10.134	10.0	0
11	55378.161752328364	0.049521359979	KS	2	120.0	1256	65.8	0.449	-0.481	9.922	10.5	0
11	55500.562022333921	0.048138108823	KS	2	120.0	1224	62.2	0.361	-0.388	7.724	10.2	0

Station Normal Point Records

							RMS	SKEW	KURT	P-M		
11	55023.332522335077	0.054587345155	sys1	2	120	860	78.0	0.368	-0.629	181.3	-1.00	0
11	55136.887952329431	0.052816886466	sys1	2	120	953	71.7	0.409	-0.524	176.2	-1.00	0
11	55258.065992333133	0.051075100430	sys1	2	120	1193	71.9	0.421	-0.495	174.5	-1.00	0
11	55378.161752328364	0.049521359982	sys1	2	120	1257	66.1	0.436	-0.509	161.5	-1.00	0
11	55500.487382326137	0.048138885940	sys1	2	120	1254	67.0	0.527	-0.121	184.1	-1.00	0

Conclusion

derived python statistical routine rather than python libraries for statistics

Analysis of SLR normal points from Herstnomceux opne-source normal pointing software

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Open-Source NPT Software Summary

- Concerning the new NP software, it seemed to me that the software worked fine and sometimes produced a more consistent set of normal points than the original software.
  - However, for some of the poorer performing stations, the new software sometimes made quite bad NPTs, but even the NPTs generated by the 'native' software were generally quite poor. This seemed to be limited to a few Russian and Ukrainian stations.
  - The original analysis was muddled by operating the new NPT software with settings that allowed low-return NPTs.
- Regarding the question about how many returns the ILRS should require to make a NPT, it turns out that generally, most stations only occasionally have NPTs with less than 6 returns.
- The following discussions tries to give a little more insight into the impact of using 'low-return' NPTs.

ILRS NPT Guidelines

- *Daytime normal points - minimum 6 data points*
- *Night time normal points - minimum 3 data points*
- *Fewer data points would be acceptable on lower satellites (5-second normal points) from those ranging systems with lower pulse repetition rates where these minimum requirements are not practical.*

- Question: what is the impact of ignoring these guidelines and making NPTS with as few as 1 return (particularly for LAGEOS)?
  - Look at affects for 7090 specifically (including position estimates) but also overall performance.
  - In the following, ‘low-return NPTs’ refers to NPTs with less than 3 returns

Breakdown of NPTS by number of returns
(January 2020 for LAGEOS)

STATION	1SHOT	2SHOTS	3SHOTS	4SHOTS	5SHOTS	6+SHOTS
1873	4	5	5	4	2	28
1884	0	0	0	0	1	27
1888	0	0	0	0	0	45
1890	0	0	0	0	0	129
1893	5	6	4	5	4	47
7090	64	62	44	44	42	703
7105	3	4	4	6	6	268
7110	15	8	5	10	4	282
7119	7	7	4	3	3	101
7237	0	0	0	0	0	301
7249	0	0	0	0	0	17
7501	4	3	1	1	0	94
7810	0	0	0	1	5	1036
7811	0	0	0	0	1	97
7821	0	0	0	0	0	90
7825	0	0	0	0	0	44
7827	0	0	0	0	0	218
7838	3	2	5	7	8	216
7839	0	0	0	0	0	307
7840	0	0	0	0	0	478
7841	0	0	0	0	0	144
7845	0	0	0	0	0	392
7941	7	4	6	2	2	479
8834	0	0	0	0	0	230

Several stations are clearly not adhering to ILRS guidelines

Original data set used since new NPT program testing included a number of low-return NPTs not normally released.

Look at Yarragadee to test impact of successively removing NPTS with only 1 shot, then 2 shots,...up to 5 shots, since it has the most low-return NPTs.

Fit and NPT precision statistics (in cm)
(only a small number of orbit parameters are estimated)

CASE	TOTAL OBS	FIT RMS	B/TB RMS	POLY RMS
test1 (7090 only)	959	0.76	0.29	0.24
test2 "	895	0.74	0.24	0.20
test3 "	833	0.72	0.24	0.18
test4 "	789	0.72	0.24	0.18
test5 "	745	0.72	0.23	0.16
test6 "	703	0.65	0.19	0.16

Moving from bottom to top, as NPTs with fewer and fewer returns are included, the FIT RMS degrades. The POLY RMS (the estimated NPT precision) also degrades, indicating that the scatter is significantly worse for NPTs with only 1 or 2 returns.

A few passes are lost if low-return NPTs are excluded, but these are going to be unreliable in any case.

However, the impact on the position estimates for 7090 was minor; no difference larger than 0.6 mm was observed for any component (ENU) for all cases.

Not shown, the overall FIT RMS (for all stations) increases from 7.6 to 8.5 mm (a variance increase of 6.9 mm^2). Also, the 3-D orbit difference RMS could reach 8 mm (mostly along-track).

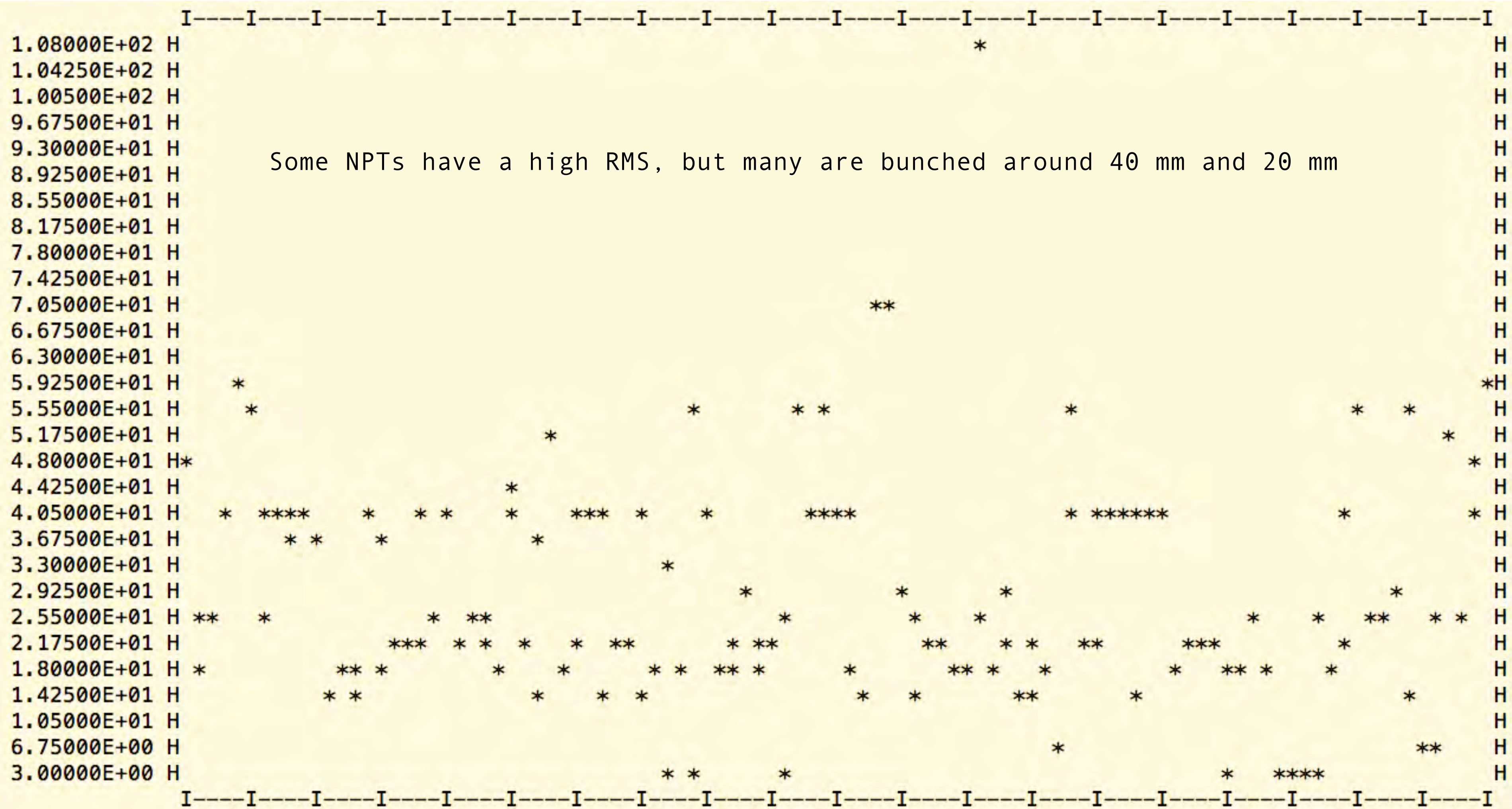
test1 contains all NPTS (from all stations) but the results for 7090 are shown

test2 uses NPTs with at least 2 returns

test3 uses NPTs with at least 3 returns

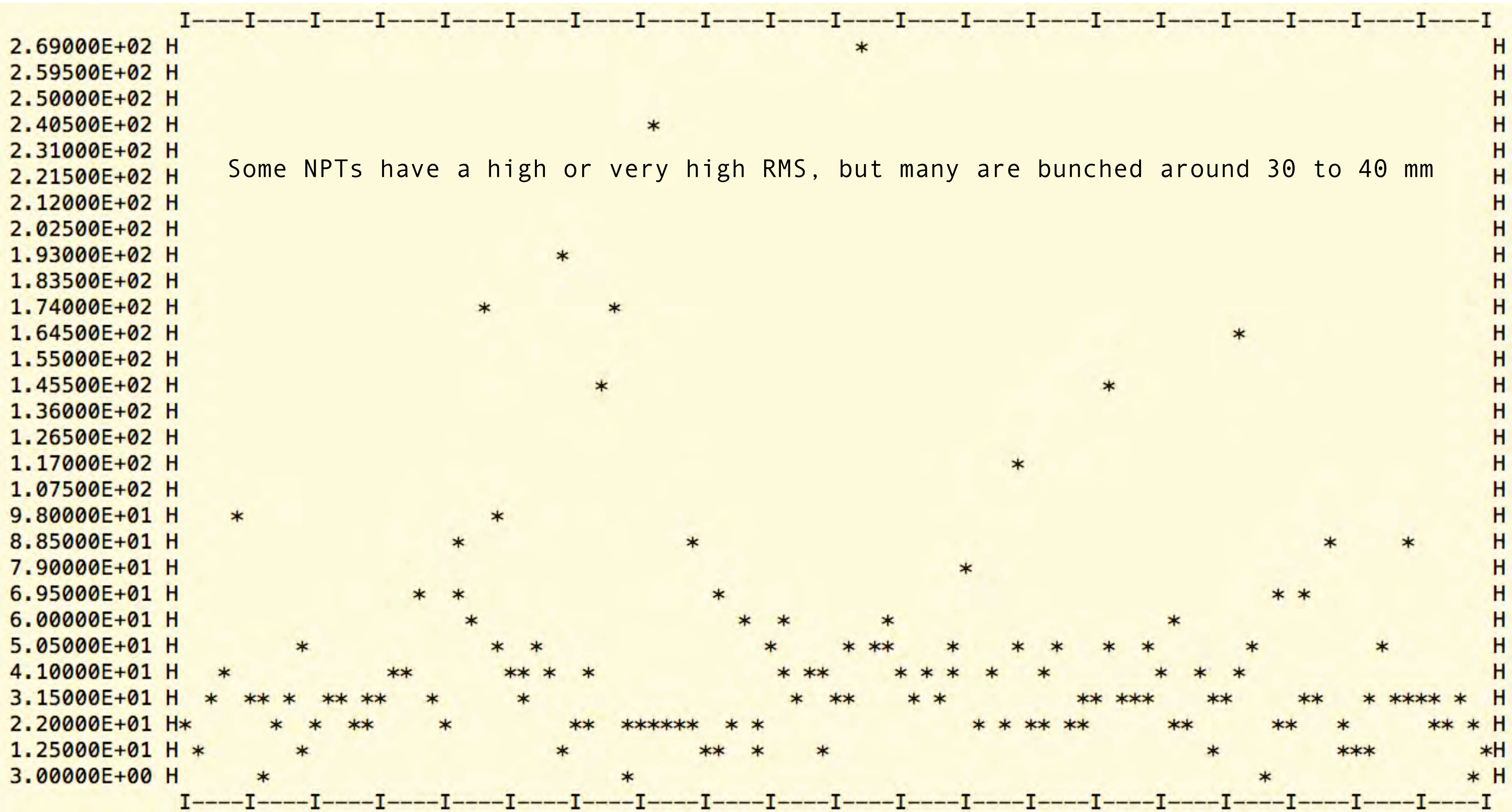
Similarly up to test6, which includes only NPTs with at least 6 returns

If a 1-return NPT is released, how is the RMS computed?



Horizontal axis is simply the count; the ‘ith’ NPT based on 1 return

Same question for 2-return NPTs



Horizontal axis is simply the count; the ‘ith’ NPT based on 2 returns

Conclusions

- There seems to be little consistency in the assigned RMS for low-return NPTs.
  - How exactly ***is*** the RMS assigned for a single or two-return NPT?
  - Since the uncertainty of a low-return NPT is large, surely the assigned RMS should be correspondingly large.
- The FIT RMS increases from 6.5 to 7.6 mm for 7090, and from 7.6 to 8.5 mm for all stations (an increase in variance of 6.9 mm^2) when low-return NPTs are used.
  - The orbit difference RMS reaches 8 mm (mostly along-track).
  - The low-return NPTs are clearly worse than NPTs with at least 6 (or even 3) returns.
- While the geodetic impact of the low-return NPTs is small, there seems to be good reason to not deliver or use them due to their effect on the orbits.
  - The assigned RMS is unreliable and the analysts do not use it to inform their data weighting in any case. *This is a little worrisome.*
  - If stations continue to deliver low-return NPTs, analysts should consider editing NPTs with only 1 or 2 returns (only a few passes would be lost and these are clearly among the worst ones). *I would strongly recommend adhering to ILRS guidelines for LAGEOS-1/2.*
  - This should become less of a problem with time as high-rep-rate stations come on line (7840, for example, had only a single NPT with less than 6 returns even when the test NPT software was run to allow for NPTs from as few as a single return).