CoM and SSEM Range Bias Analysis

Van S Husson

vhusson@peraton.com

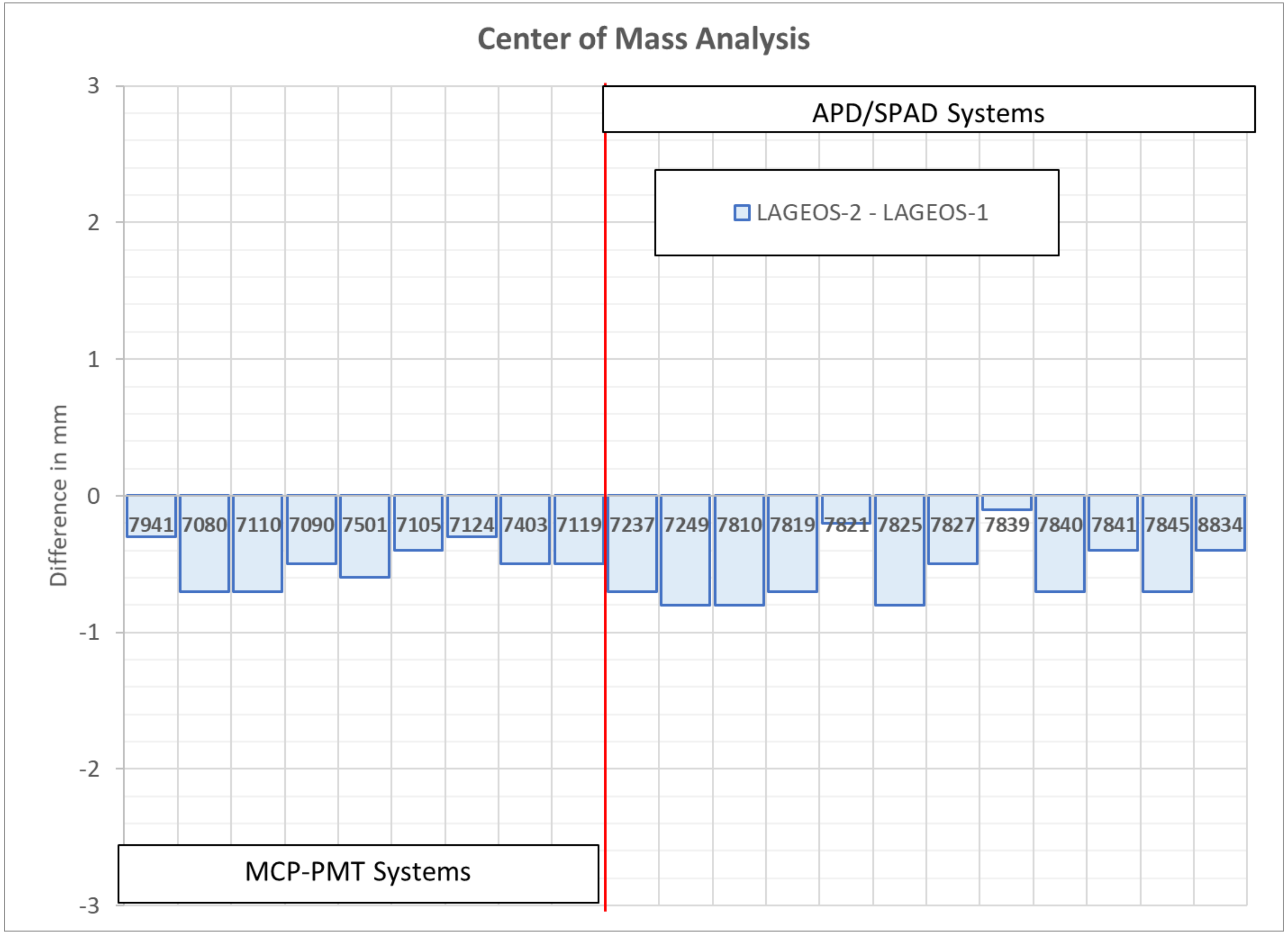
ILRS Central Bureau (CB)

ILRS Quality Control Board (QCB)

Networks and Engineering Standing Committee (NESC)

Peraton

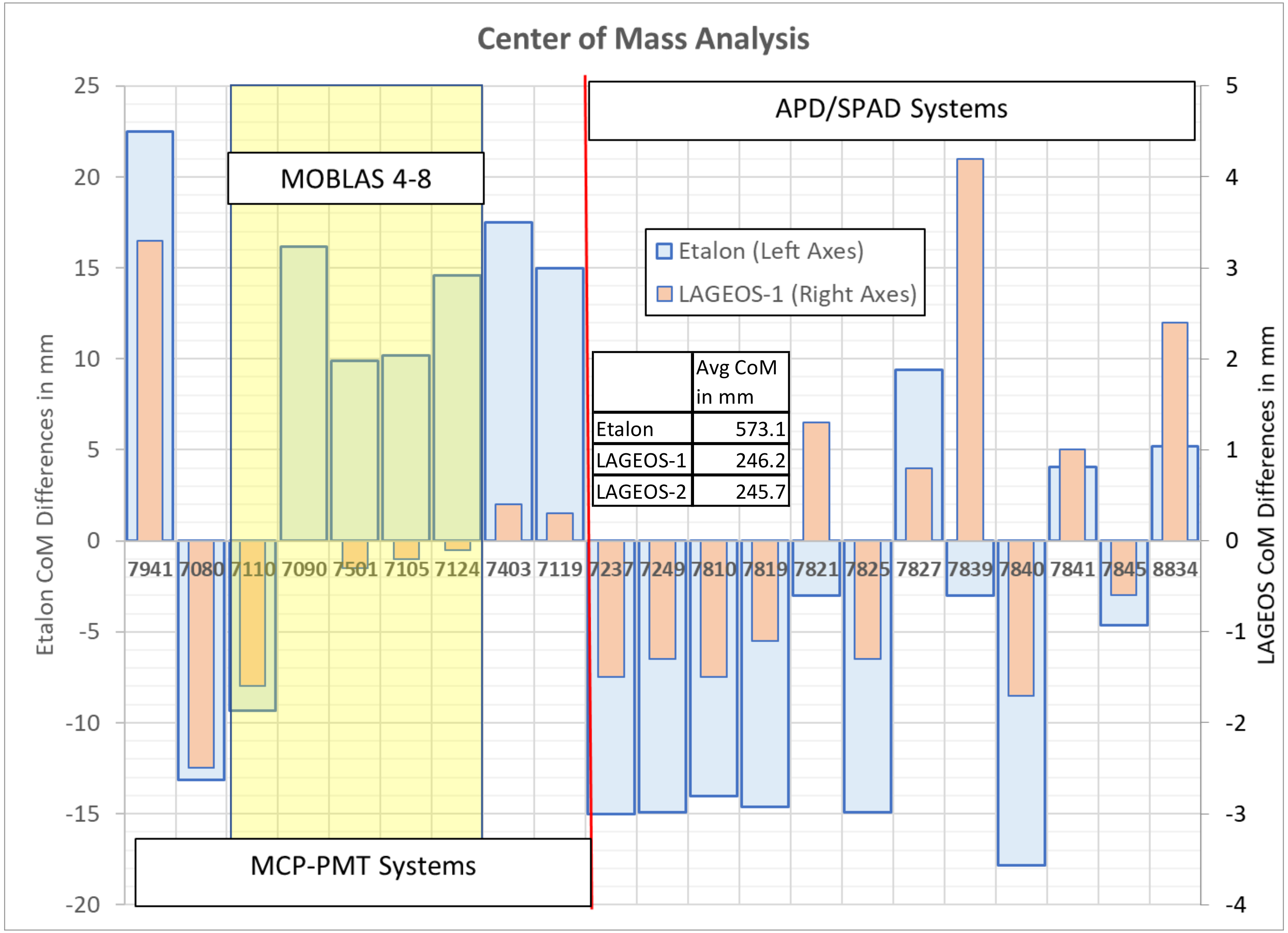
LAGEOS-1 and -2 Center of Mass Differences



- LAGEOS-2 minus LAGEOS-1 CoM corrections are sub-mm for all systems with a mean offset of -0.54 mm
- MCP-PMT and APD/SPAD systems are left and right of the red line; respectively.

System	Location	System Acronym	Wave
7941	Matera	MLRO	532
7080	McDonald	MLRS	532
7110	Monument Peak	MOBLAS-4	532
7090	Yarragadee	MOBLAS-5	532
7501	Hartebeesthoek	MOBLAS-6	532
7105	Greenbelt	MOBLAS-7	532
7124	Tahiti	MOBLAS-8	532
7403	Arequipa	TLRS-3	532
7119	Haleakala	TLRS-4	532
7237	Changchun		532
7249	Beijing		532
7810	Zimmerwald		532
7819	Kunming		532
7821	Shanghai		532
7825	Mt Stromlo		532
7827	Wettzell	SOSW	850
7839	Graz		532
7840	Herstmonceux		532
7841	Potsdam		532
7845	Grasse		532
8834	Wettzell	WLRS	1064

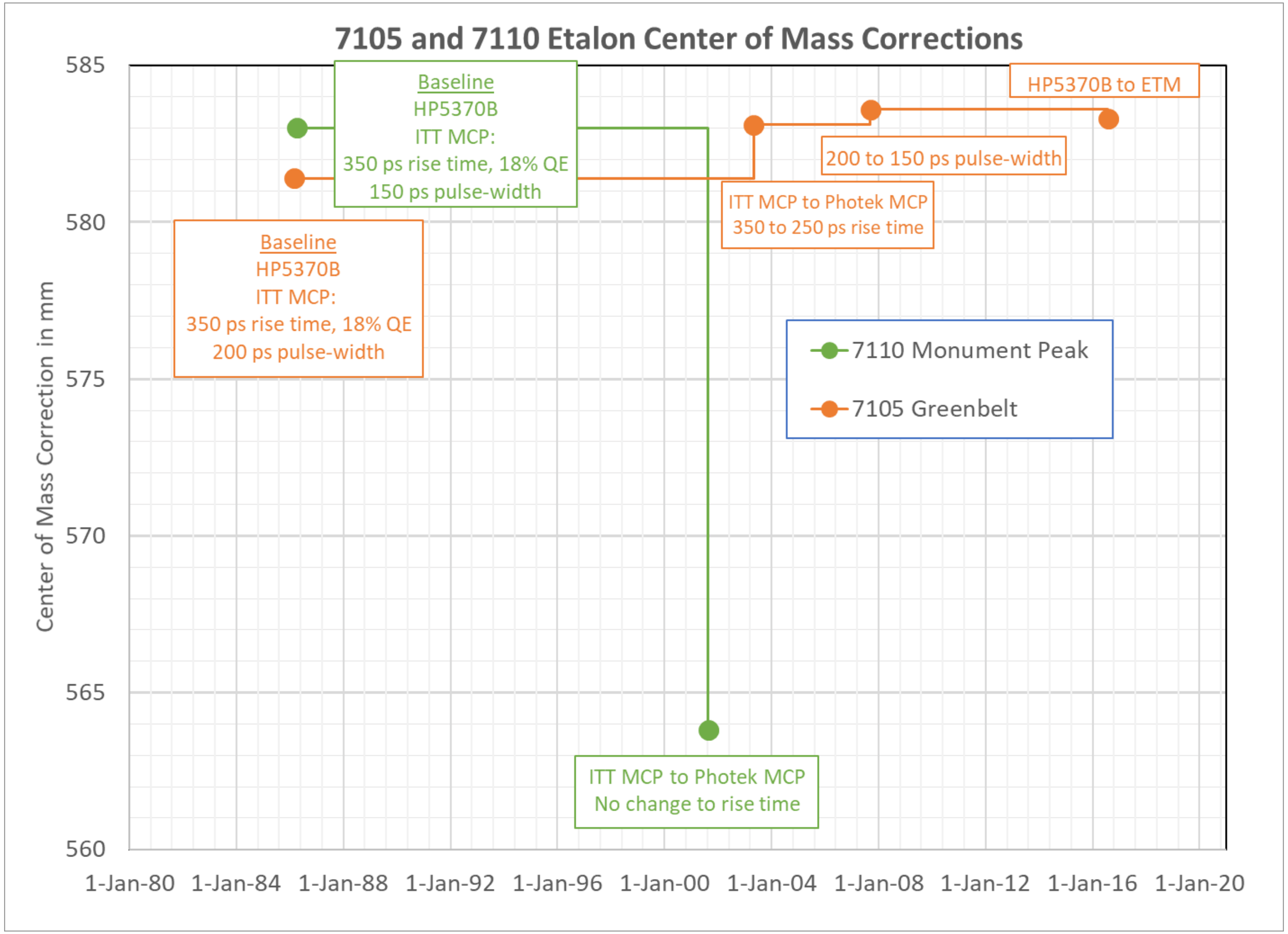
Etalon and LAGEOS-1 CoM Analysis



	Avg CoM in mm
Etalon	573.1
LAGEOS-1	246.2
LAGEOS-2	245.7

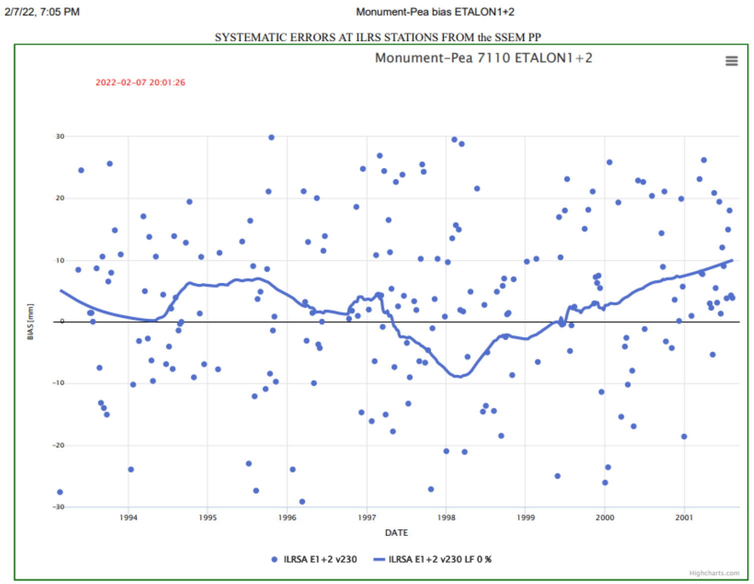
- The center line is the average CoM correction from the best performing stations. MCP-PMT and APD/SPAD systems are left and right of the red line; respectively
- Current Etalon and LAGEOS offsets on the left and right axes are from the mean CoM values in the table; respectively. *Note: The 5:1 scale differences on the left and right axes.*
- MCP-PMT systems and Graz are considered leading edge detection systems. *Note: TLRS systems (7403, 7119) are slightly more leading-edge than the MOBLAS*
- There are ~30 mm CoM differences in Etalon between these 2 types of SLR systems
- The 7110 (MOLBAS-4) CoMs are much different than its other MOBLAS peers
- The CoMs for 7841 are much different than its other SPAD 532 nm peers.

7110 and 7105 Etalon CoMs

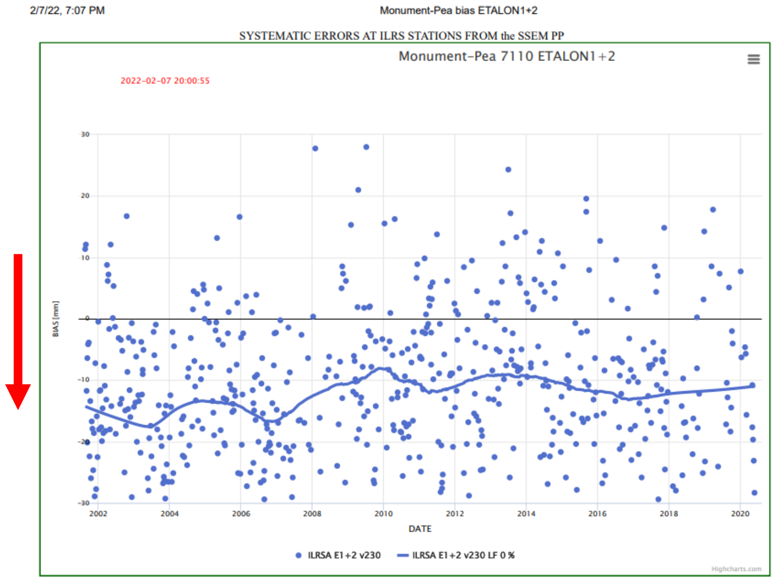


- This is a time series of 7110 (MOBLAS-4) and 7105 (MOBLAS-7) Etalon CoM corrections. The system configuration changes are annotated inside the boxes. Based on the 7110 MCP-PMT change there was a 20 mm drop in the MOBLAS-4 CoM correction on 19-August-2001
- 7110 and 7105 currently have the same system configuration, but the CoM corrections are quite different
- Did the 20 mm drop in the 7110 Etalon CoM impact the estimated range bias?
- If the CoM correction is in error by ‘z’, it will induce an apparent range bias = ‘z’. For example, if the CoM is too small by 1 mm, it will induce an apparent -1 mm range bias.

7110 (MOBLAS-4) SSEM Range Bias Estimates



7110 Etalon SSEM Bias Estimates
before 19-Aug-2001



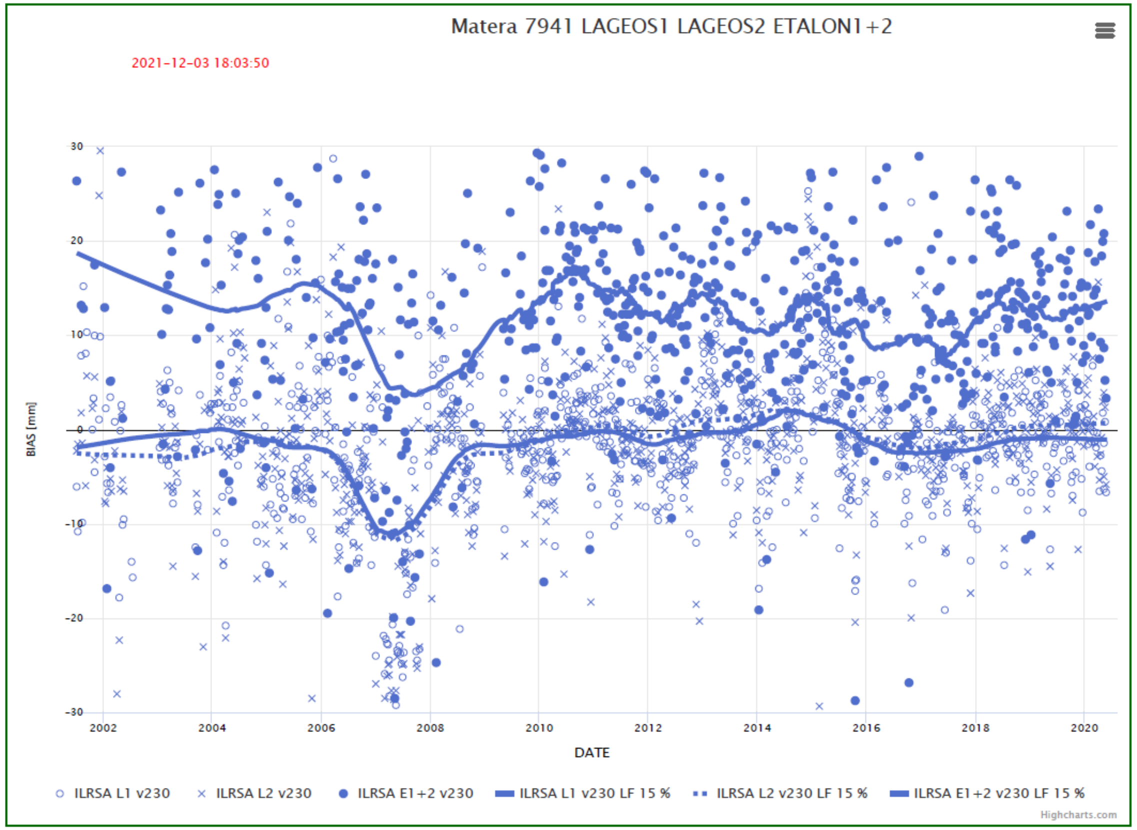
7110 Etalon SSEM Bias Estimates
after 19-Aug-2001

- ❑ 7110 Etalon and LAGEOS CoM corrections were updated on 19-Aug-2001 based on a MCP-PMT detector change. The change from the previous 7110 Etalon CoM was 20 mm
- ❑ The -20 mm 7110 Etalon CoM change on 19-Aug-2019 instantaneously induced a ~24 mm drop in Etalon range bias indicated by the red arrow

7941 Matera SSEM Range Bias Estimates

12/3/21, 5:03 PM Matera bias LAGEOS1 LAGEOS2 ETALON1+2

SYSTEMATIC ERRORS AT ILRS STATIONS FROM the SSEM PP

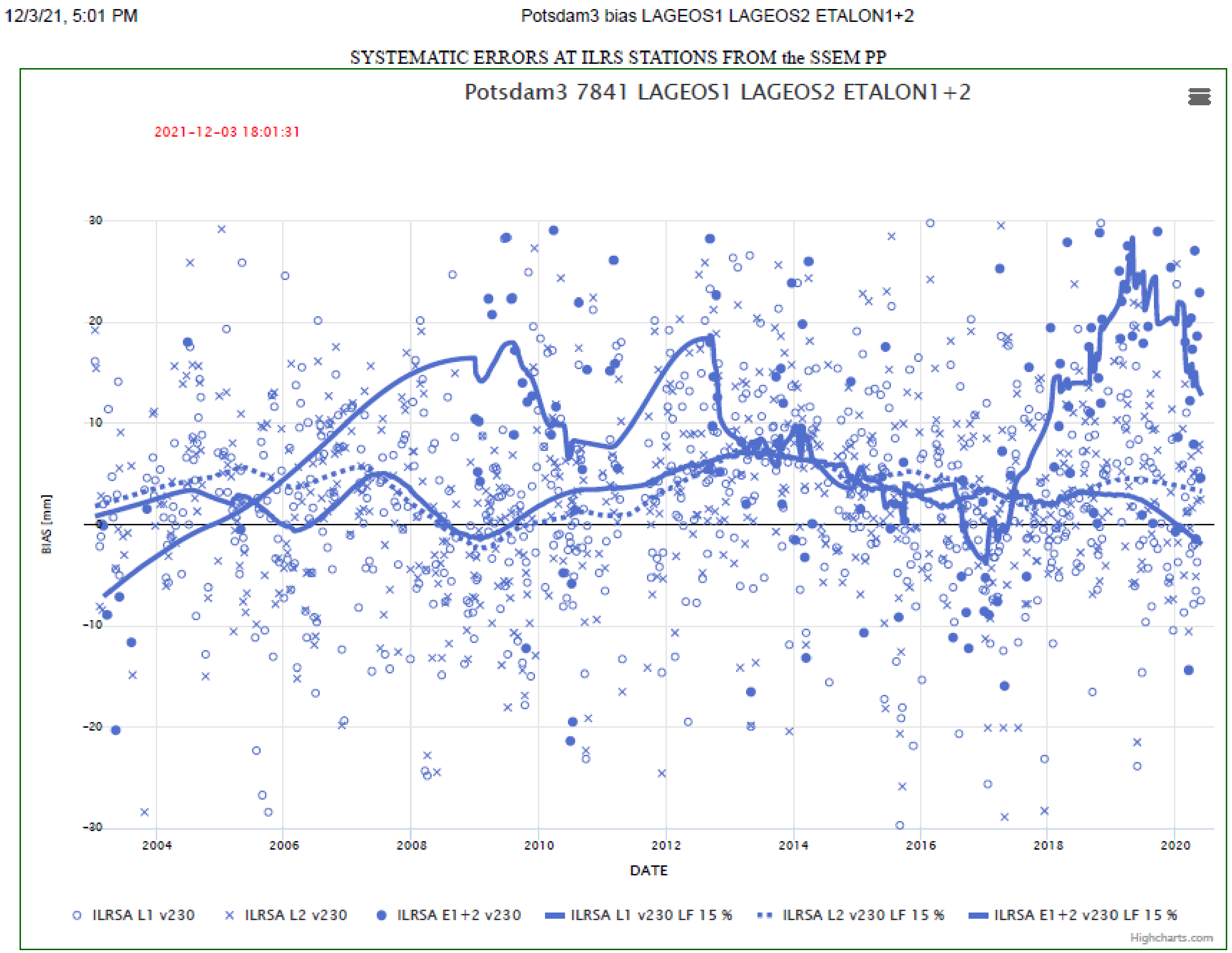


ILRSA LAGEOS1	Mean/Std. Dev.:-1.8±10.35 Count:807
ILRSA LAGEOS2	Mean/Std. Dev.:-1.61±9.39 Count:800
ILRSA ETALON1+2	Mean/Std. Dev.:11.94±14.21 Count:675

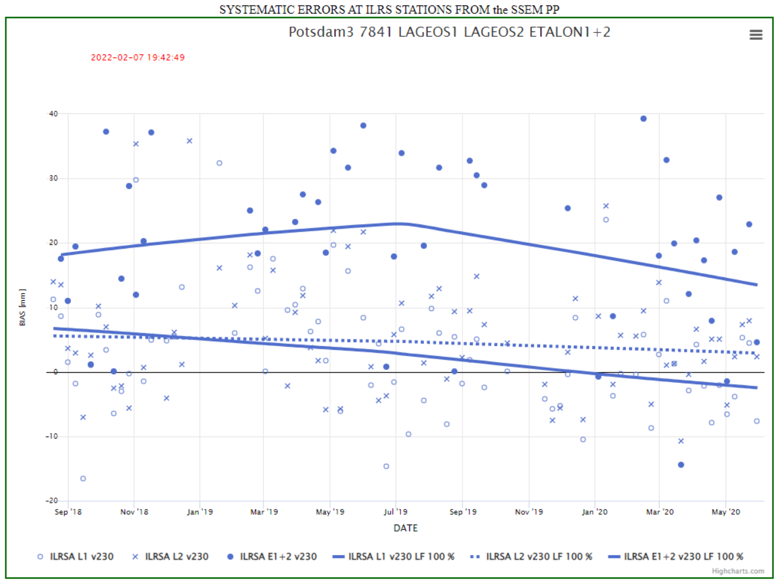
- 7941 Etalon range bias estimates are longer by 13 mm versus their LAGEOS-1 and -2 range bias estimates
- The 7941 Etalon CoM correction is 12 mm longer on average then the MOBLAS and TLRS MCP-PMT systems

7841 Potsdam SSEM Range Bias Estimates

- Potsdam has used two different detectors, a PMT and a SPAD. On 15-Aug-2018, 7841 switched from a PMT to a SPAD as its prime detector
- Current 7841 Potsdam Etalon and LAGEOS CoM corrections are longer than 7840 Herstmonceux CoM by 22mm and 2.7 mm, respectively.



7841 SSEM Bias Estimates 2003 to 2020



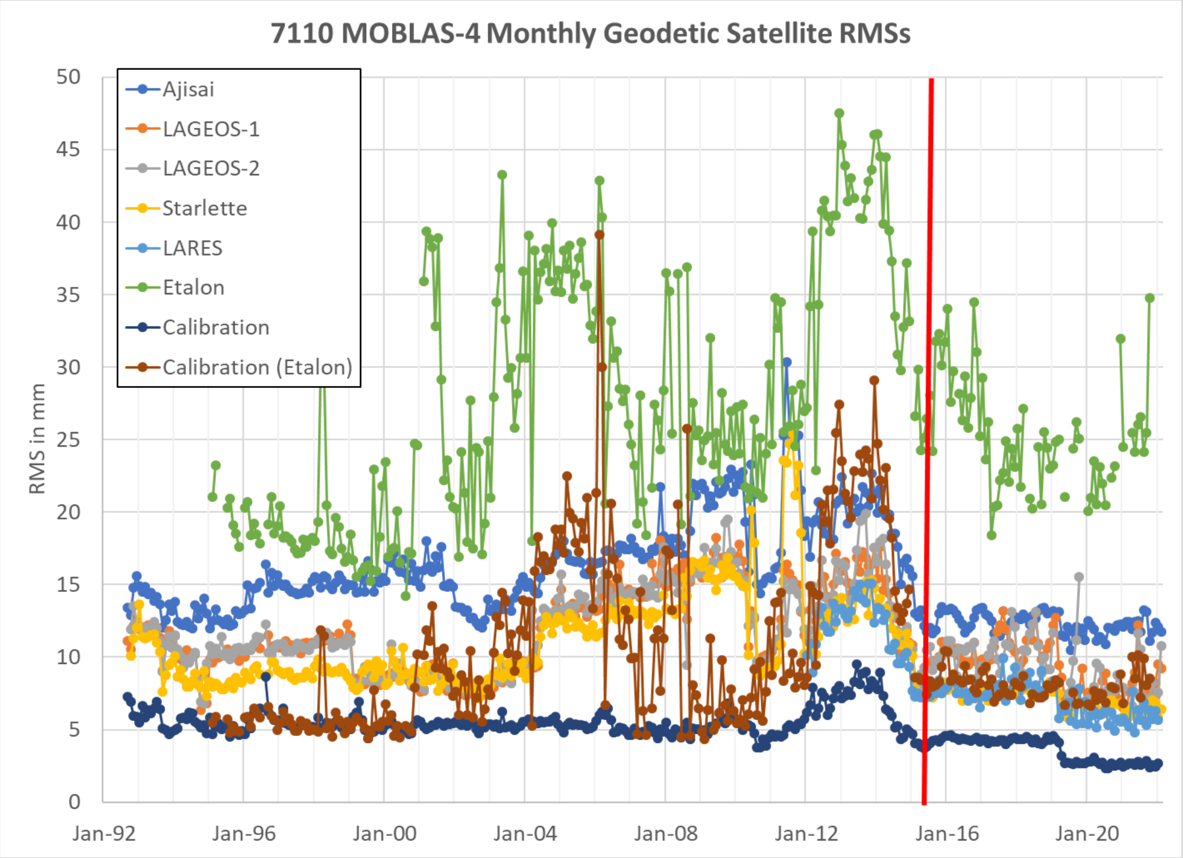
ILRSA LAGEOS1	Mean/Std. Dev.:2.42±11.98 Count:79
ILRSA LAGEOS2	Mean/Std. Dev.:4.49±11.52 Count:77
ILRSA ETALON1+2	Mean/Std. Dev.:19.55±12.47 Count:47

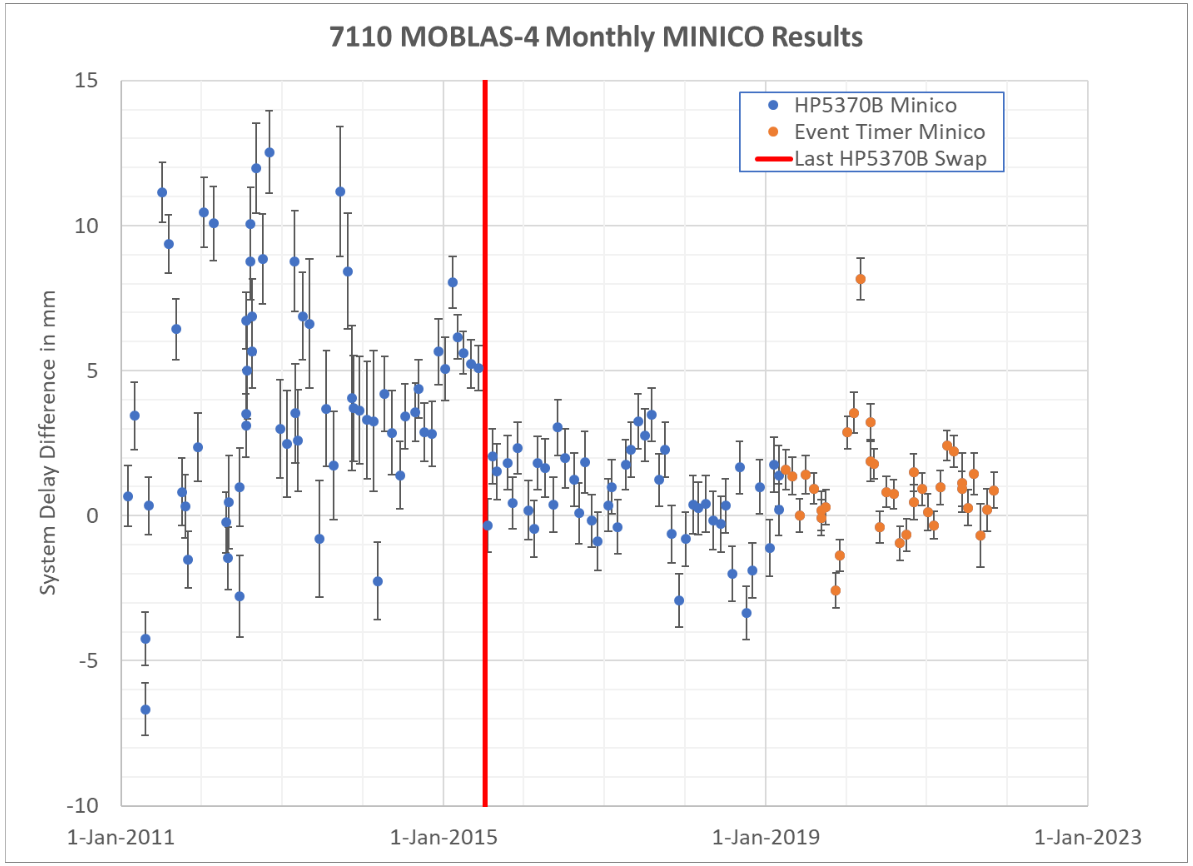
7841 SSEM Bias Estimates since 15-Aug-2018

Comments from Jose

- "I think it's not the first time we discuss potential glitches in the Etalon CoM. I'm pretty sure you are right in attributing some of those to model error."
- "One thing to keep in mind about the computed CoM values is that I tried not to pay much attention to the estimated RBs. The reason is that if I knew the result I wanted I might be myself biased when it came to making certain choices. We're talking small stuff here---I could not just tweak something and change the values by 20 mm---but I still wanted to follow a more or less blind process. The range biases are not part of the model at all anyway, so there was no need for me to look at them carefully."
- "The second thing is that certain parameters, such as calibrations, are common for both LAGEOS and Etalon. We now know that this doesn't hold, as the return intensity for both doesn't necessarily coincide (certainly true for MOBLAS). Additionally, the results are optimized for modelling LAGEOS, so if a parameter used for the calibrations needed adjustment to get a better match between the empirical and modelled distribution of returns, I chose to tweak it for LAGEOS. I could see when I was doing all this that the Etalons were less well modelled indeed."
- "Finally, there are a few fundamental reasons why those results are poorer (bigger targets, bigger uncertainties, lower return rates, less observations). I would say that the greatest value brought in by the new Etalon CoM modelling isn't as much absolute accuracy for individual stations, but the fact that with it the estimated biases are not as lopsided as they used to be. If you wish, now we're wrong with a closer-to-zero average (although grouping the differences by detector type reveals very obvious systematics)."
- "This kind of analysis is what I envisaged should be done---not necessarily by me indeed. I think you are uncovering some things that justify taking a magnifier glass and have a look at some individual stations. I do have some ideas that might improve the model performance, but that will have to wait a bit. As a quick explanation about the suspect drop in 7110 is that the model takes as inputs the average RMS and return rates of the NPs collected. It may well happen that for a particular station and time period the Etalon data is just not very good and they drive the whole thing off. Alternatively, there is a parameter that I tweak almost manually that tries to model the discriminator level. This is not *that* critical for LAGEOS, and in any case it is optimized for it, but I've seen it throwing off the Etalon values. I have not found a good way of dealing with this. It is related to the stuff you guys discussed some months ago about discriminator calibration, difference between calibrations and satellite ranging, and the essential impossibility of getting this right for both flat terrestrial targets and satellites of different sizes."

7110 (MOBLAS-4) Monthly RMSs and MINICO Results





- ❑ The PMT voltage; the timing device (e.g. HP5370 or Event Timer); the receiver configuration (non-amplifier, amplifier); the receive discriminator timewalk and distribution of receive amplitudes; and the receive system state of health have the most influence on the NASA MOBLAS and TLRS single shot RMSs. *Note: 7110 Etalon data was sometimes taken with and without an amplifier. RMSs (satellite and calibration) increase when the amplifier is used.*
- ❑ The 7110 performance (RMSs & MINICO results) stabilized after 8-Jul-2015 when the HP5370B was swapped for the last time (the red line on the charts). Based on SSEM results the 7110 LAGEOS range bias moved more positive by several mm on this date. A future topic for the QCB.

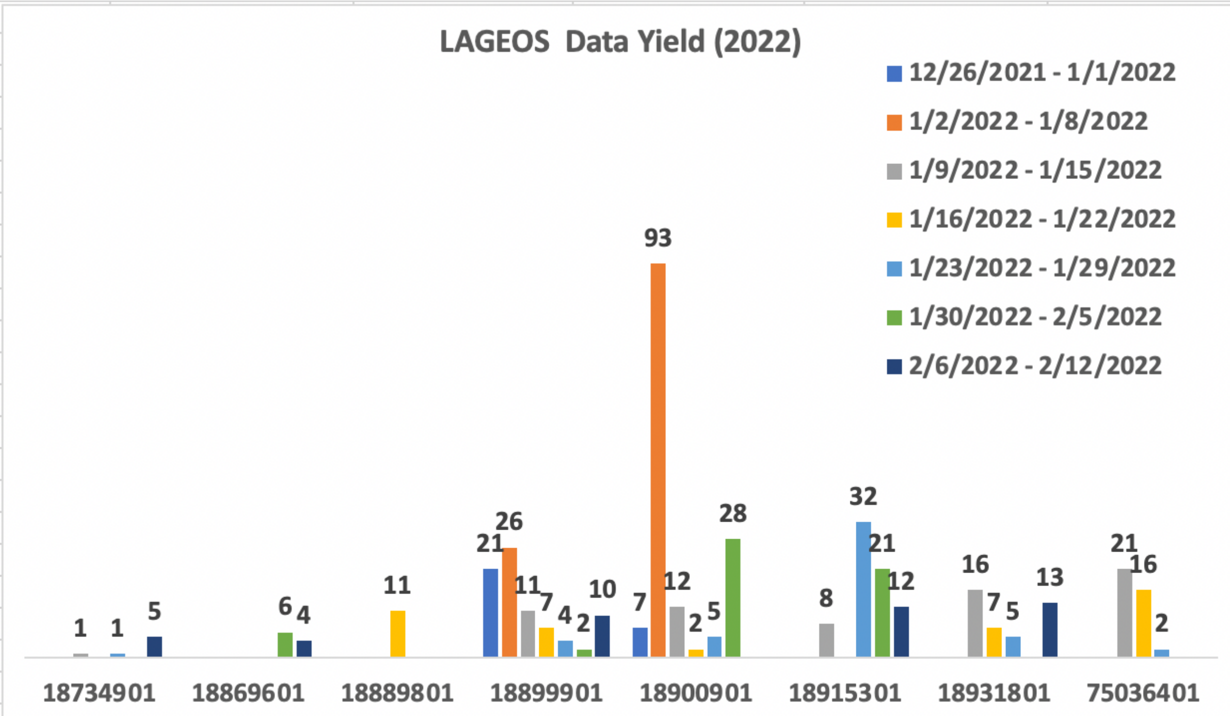
Erricos Pavlis - Re. missing stations in analysis. Monday, February 14th, 2022.

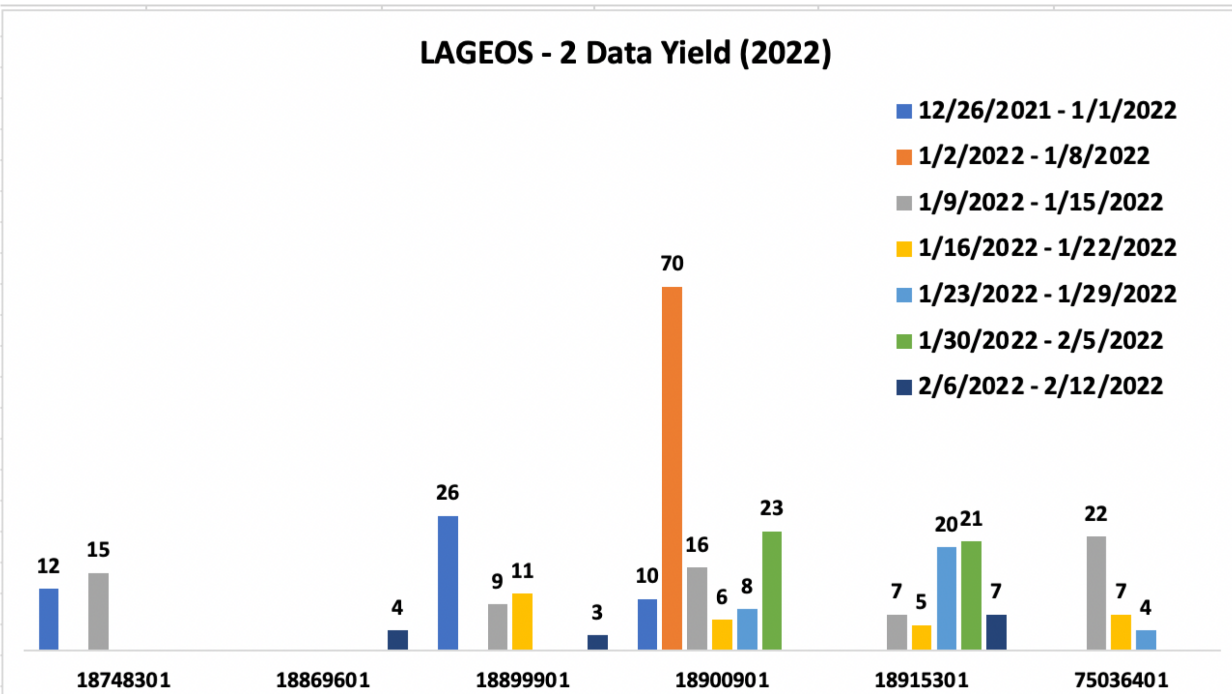
The ILRS ASC has a rule that states: eliminate stations from an arc if they have not collected over the week at least 10 valid ranges on each LAGEOS and at a minimum over two passes. When we consider that rule and convolve it with the tracking yield of the Russian sites in the recent weeks, the result is that most of them do not appear in our solutions.

Of all sites, only the ones in BOLD delivered data in 2022 and of these, only the three in RED had significant contributions (they happen to be IAA & VNIIFTRI sites):

Komsomolsk 1868
Simeiz 1873
Mendeleevo 1874
Altay 1879
Arkhyz 1886
Baikonur 1887
Svetloe 1888
Zelenchukskaya 1889
Badary 1890
Irkutsk 1891
Katzively 1893
Brasilia 7407
Hart/hoek_HRTL 7503

The bar charts show for each of the past seven weeks which Russian stations tracked and how many acceptable NPTs they collected for each LAGEOS. Those single digit entries are as if they did not exist!

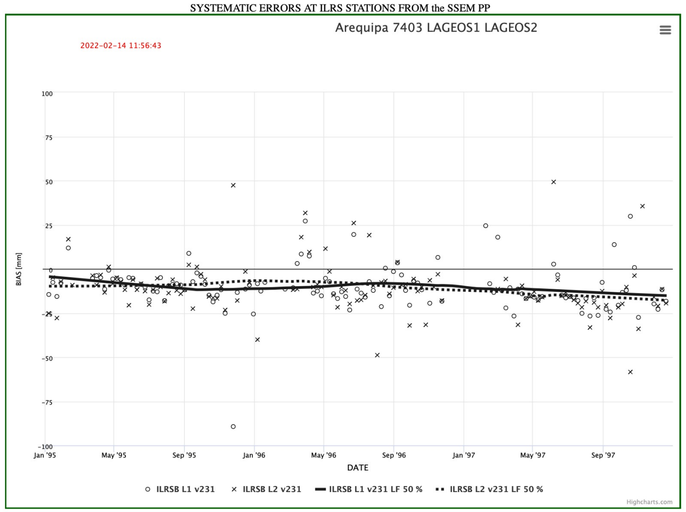

LAGEOS Data Yield (2022)
12/26/2021 - 1/1/2022
1/2/2022 - 1/8/2022
1/9/2022 - 1/15/2022
1/16/2022 - 1/22/2022
1/23/2022 - 1/29/2022
1/30/2022 - 2/5/2022
2/6/2022 - 2/12/2022
1
1
5
6
4
11
21
26
11
7
4
2
10
7
93
12
2
5
28
8
32
21
12
16
7
5
13
21
16
2
18734901
18869601
18889801
18899901
18900901
18915301
18931801
75036401


LAGEOS - 2 Data Yield (2022)
12/26/2021 - 1/1/2022
1/2/2022 - 1/8/2022
1/9/2022 - 1/15/2022
1/16/2022 - 1/22/2022
1/23/2022 - 1/29/2022
1/30/2022 - 2/5/2022
2/6/2022 - 2/12/2022
12
15
4
26
9
11
3
10
70
16
6
8
23
7
5
20
21
7
22
7
4
18748301
18869601
18899901
18900901
18915301
75036401

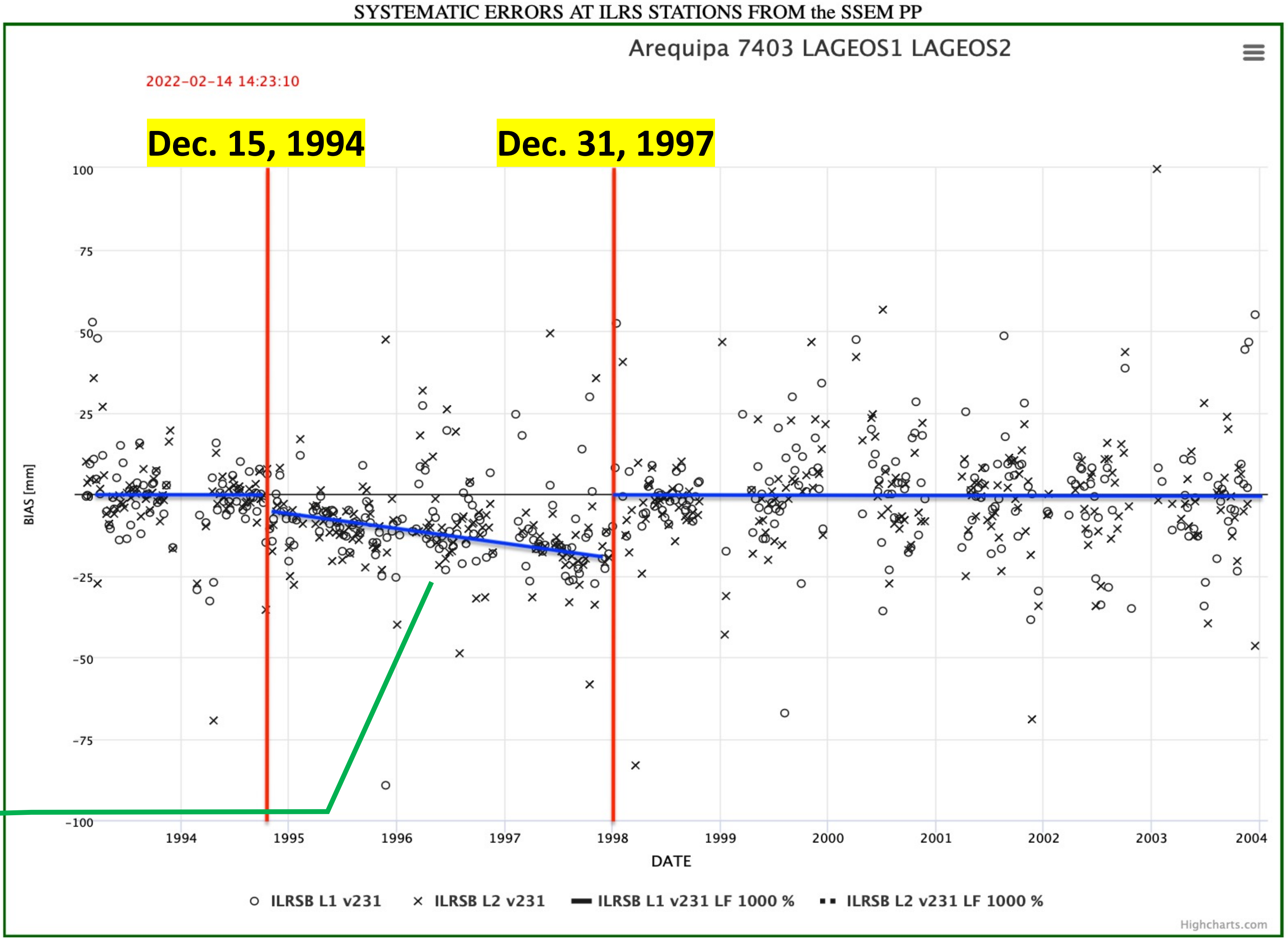
SSEM Estimated Biases

Arequipa 7403

0 to -20 mm over 3 years ➔
~ -6. 7 mm/y



ILRSB LAGEOS1 v231	Mean/Std. Dev.:-10.56±12.83 Count:124
ILRSB LAGEOS2 v231	Mean/Std. Dev.:-10.79±15.25 Count:118



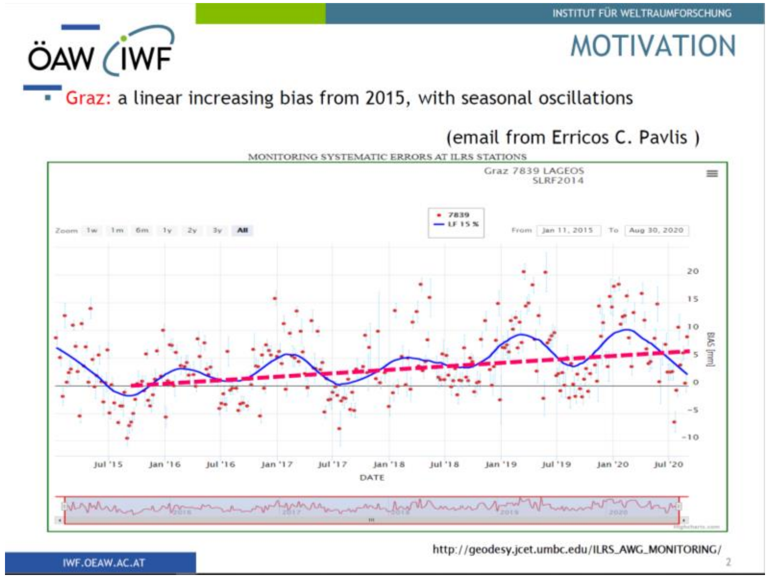
ILRSB LAGEOS1 v231	Mean/Std. Dev.:-3.47±15.2 Count:389
ILRSB LAGEOS2 v231	Mean/Std. Dev.:-4.09±17.08 Count:382

7839 Graz Data Analysis Update

Van S Husson
vhusson@peraton.com
ILRS Central Bureau (CB)
ILRS Quality Control Board (QCB)
14-Feb-2022

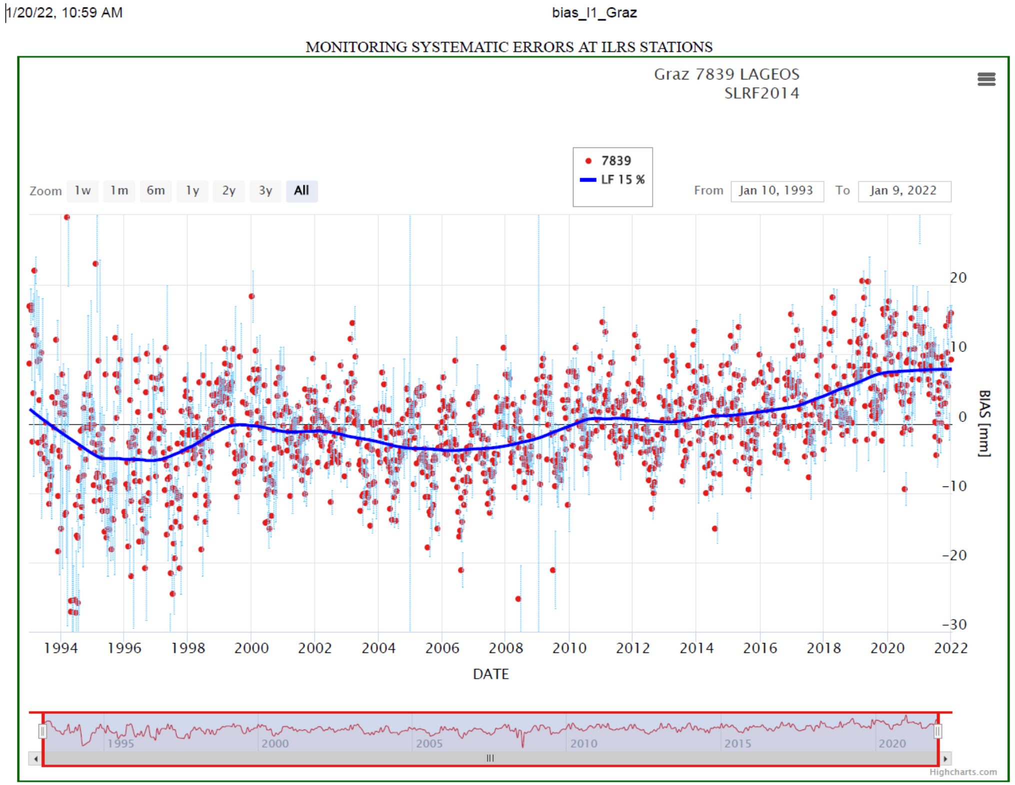
Unanswered Questions from Previous Meetings

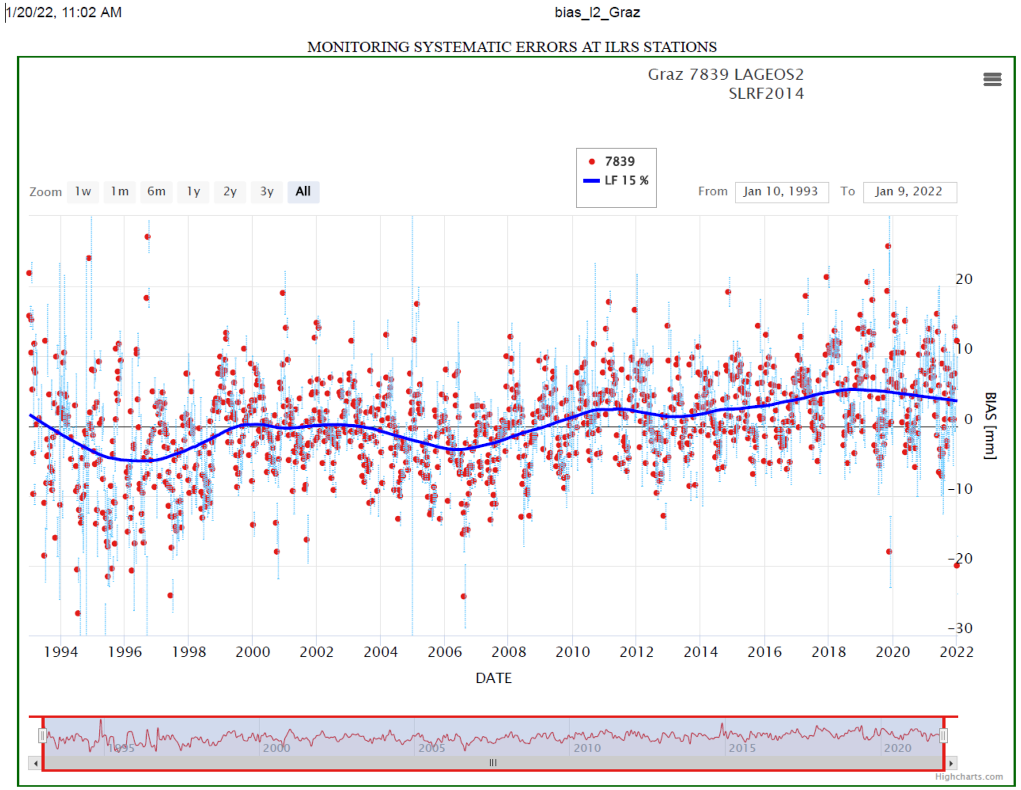
- ❑ What caused a significant reduction in Graz Etalon RMSs starting in May 2017?
  - ➢ Graz had a staff change in 2017 and inadvertently the Etalon editing criteria was modified. This change was not documented in the station change history but will be added.
- ❑ What Peak minus Mean (P-M) algorithm did Graz implement?
  - ➢ Still unknown. Georg is retired now but based on some preliminary checking of the code, he is not sure which algorithm was implemented.



- ❑ Since the beginning of 2015, the Graz Paroscientific barometer was drifting lower by slightly more than 0.1 mBar/year and by December 2020 it was off by -0.8 mBar. As a result, the range bias was drifting higher (See chart above). In 2021, did Graz range biases return to previous 2014 range bias levels?
- ❑ Graz wanted to know if changing their laser polarization in March 2021 from linear back to circular impacted their bias?

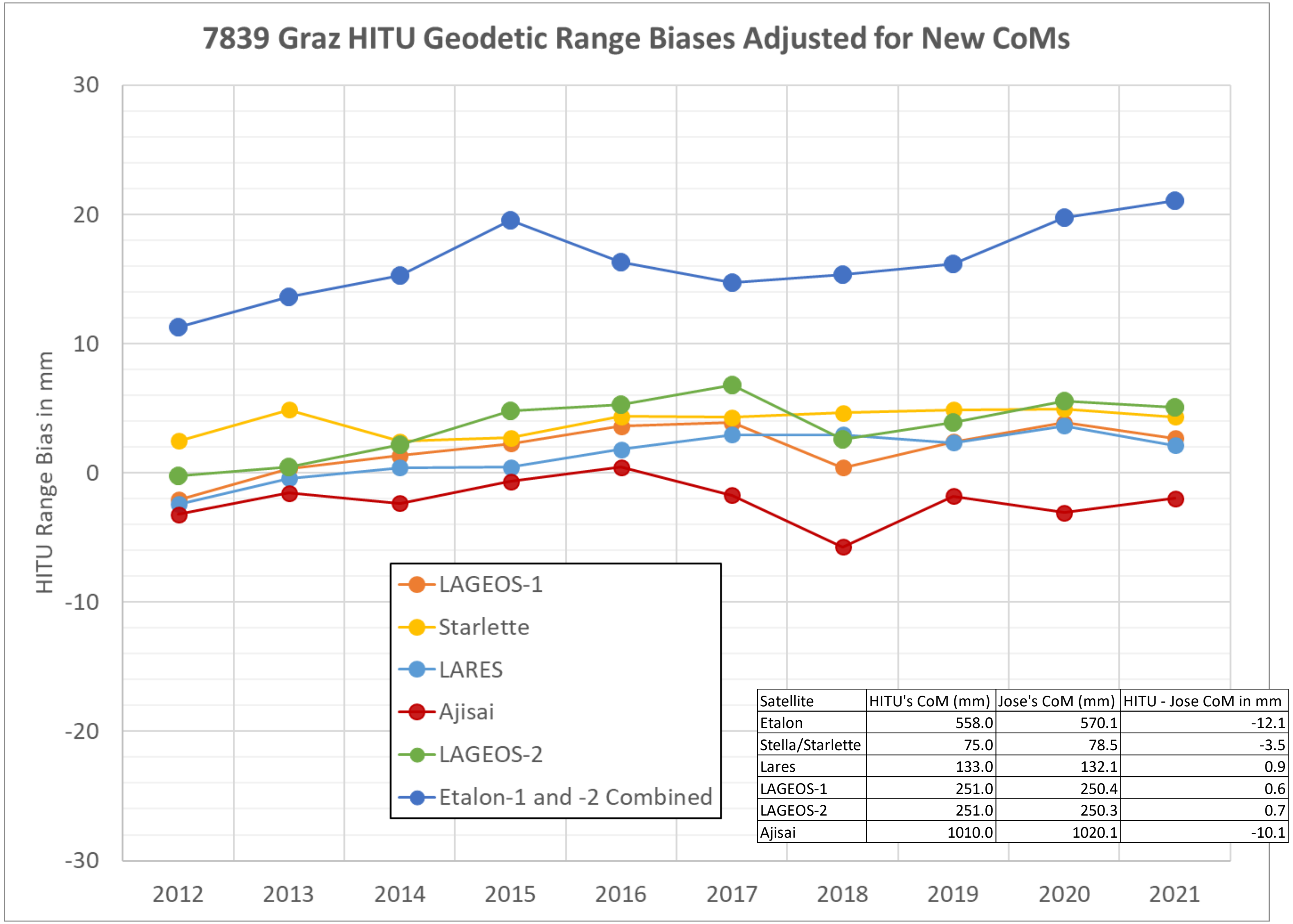
JCET Graz 7839 LAGEOS Range Biases





- JCET Graz 7839 LAGEOS-1 (left chart) and LAGEOS-2 (right chart) weekly range bias estimates through early Jan 2022 using ITRF2014 coordinates.
- There appears to be very little change in Graz LAGEOS biases between 2020 and 2021. Can we conclude the 2021 range biases did not return to pre 2015 range bias levels? Let’s see if Toshi’s yearly geodetic range biases show any reduction in range bias in 2021.

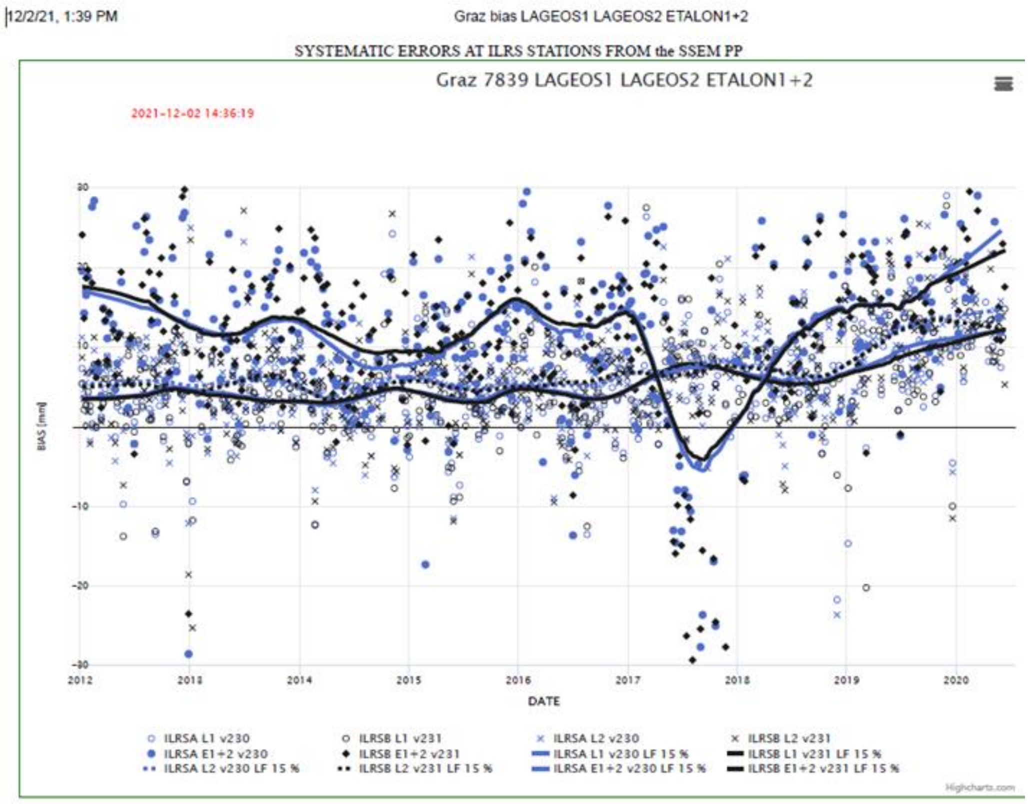
HITU Yearly Graz Geodetic Range Biases



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

- The HITU results are based on yearly aggregation of pass-by-pass geodetic range biases and adjusting for the current Center of Mass models. In June 2017, HITU updated the ILRS station coordinates from ITRF2008 to ITRF2014. Graz’s height changed by 4 mm between these two ITRF solutions.
- In 2021, there was between a 0.5 to 1.5 mm drop in LAGEOS-1, LAGEOS-2, LARES and Starlette range biases, but a 1 mm increase in Etalon and Ajisai range biases.
- Conclusion: Both JCET and HITU results see little change in the Graz range biases in 2021.
- Question: Did the polarization change or some other system change counteract the Dec 2020 barometric change?
- Question: Why is the Etalon range bias out of family with the LAGEOS and LARES Biases?

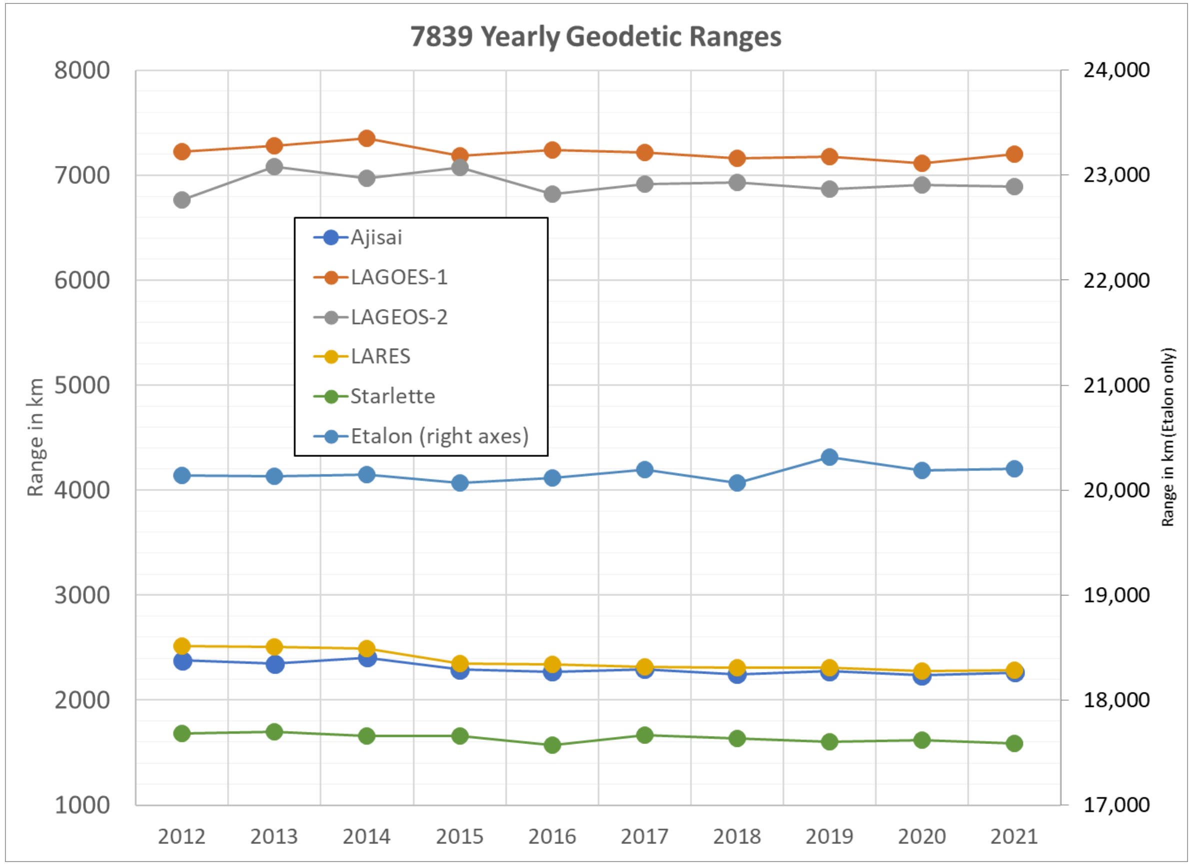
SSEM Graz 7839 Range Bias Results

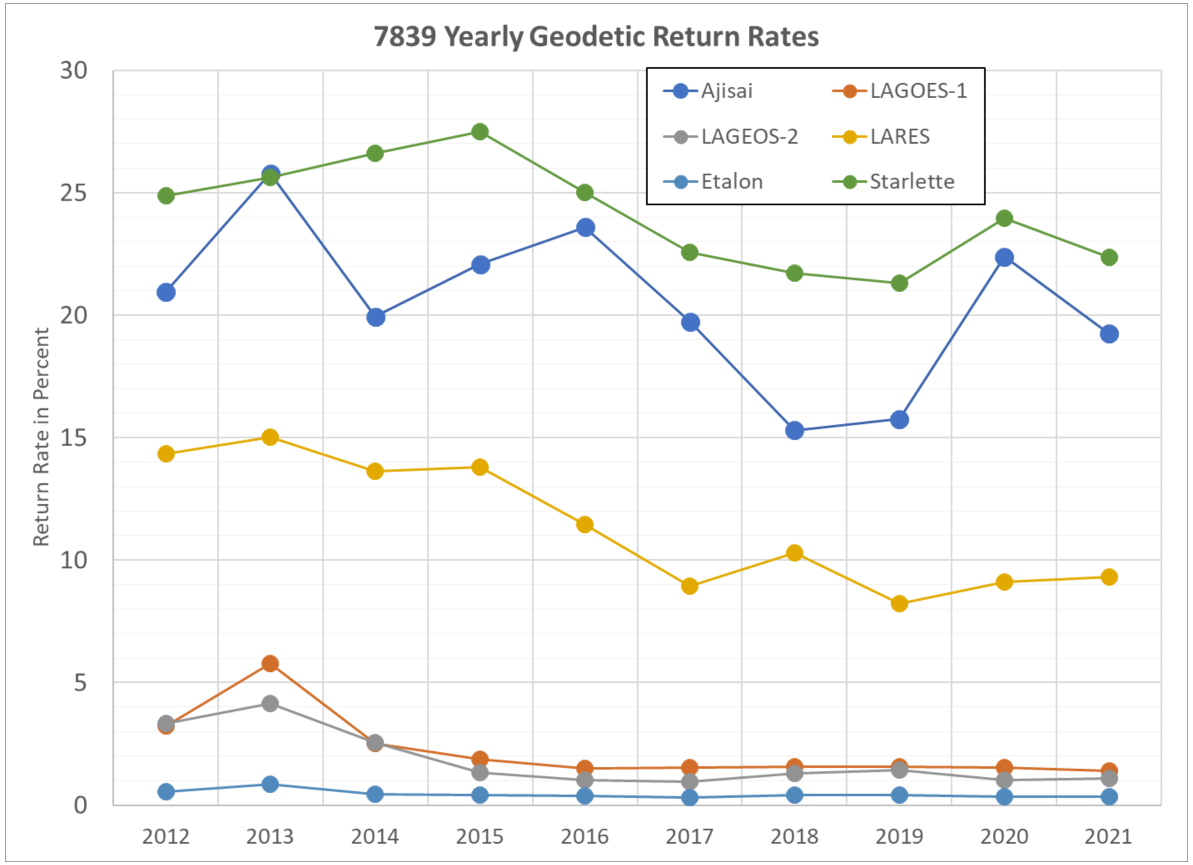


ILRSA LAGEOS1	Mean/Std. Dev.:5.42±6.41 Count:395
ILRSB LAGEOS1 v231	Mean/Std. Dev.:5.3±6.32 Count:398
ILRSA LAGEOS2	Mean/Std. Dev.:6.85±7.26 Count:387
ILRSB LAGEOS2 v231	Mean/Std. Dev.:6.64±7.31 Count:392
ILRSA ETALON1+2	Mean/Std. Dev.:11.76±12.05 Count:336
ILRSB ETALON1+2 v231	Mean/Std. Dev.:12.12±11.66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

- Ignoring 2017 when Graz made a change to its Etalon data editing technique, there is more than 5 mm offset between Etalon and LAGEOS Range Biases.
- Also, prior to the barometric drift, there is a +3 to +4 mm range bias on LAGEOS-1 and LAGEOS-2
- Question: Are these range biases real (i.e. in the station); in the modeling (e.g. Center of Mass correction); something else; or some combination.

Graz 7839 Geodetic Yearly Average Ranges and Return Rates based on CRD 11 Records





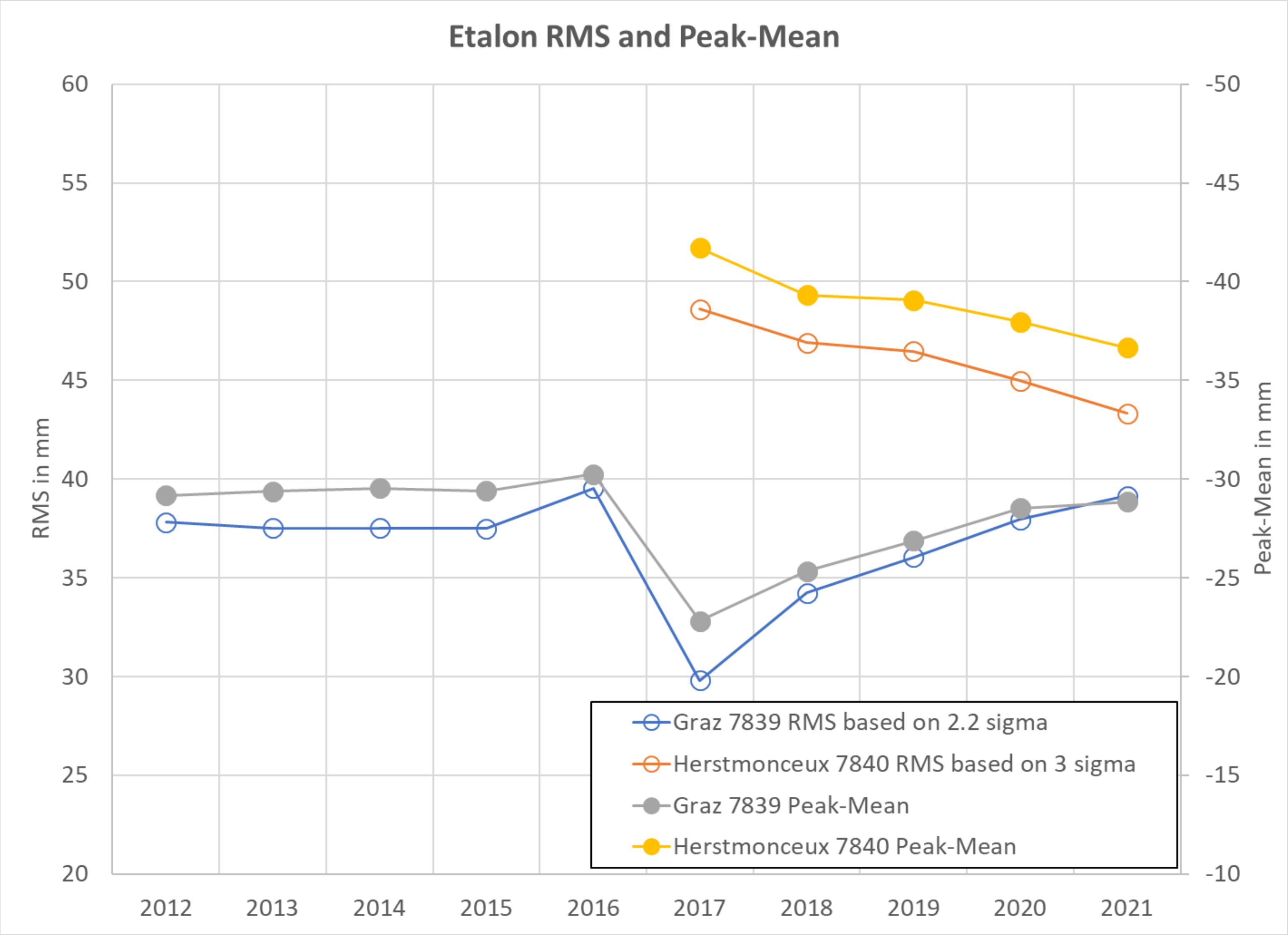
- ❑ Graz return rates are a function of the station to satellite link; the frequency of satellite interleaving and the data rejection criteria. Graz return rates are trending lower which could be due to increases in satellite interleaving.
- ❑ For Etalon, Starlette and LARES a 2.2 sigma edit is applied. For LAGEOS and Ajisai a 20 mm Leading Edge (LE) data rejection criteria is applied reducing the returns by ~30%. Since 2015 LAGEOS and Etalon return rates are well below 10%.
- ❑ Return rates based on fullrate data would be more accurate.

ILRS LAGEOS-1 Return Rate Analysis from January 2020 CRD (NP and Fullrate)

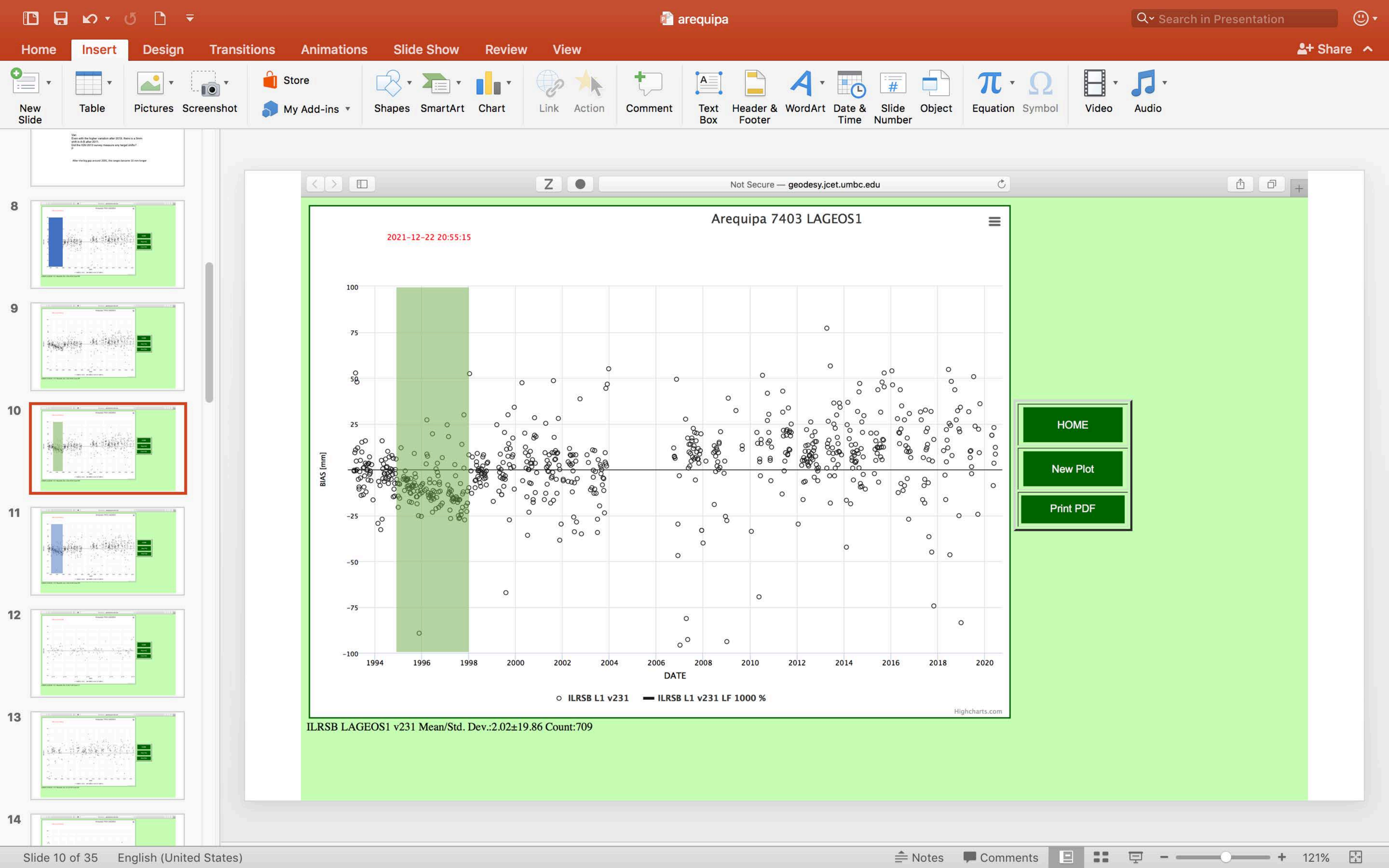
	OrbitNP		Station				
Pad	Average return rate in %	StdDev return rate in %	Average return rate in %	StdDev return rate in %	# of NPs	Return Rate Differences in %	Comments
1824	1.0	0.9	0	0	3	N/A	Station provides a zero vs -1
1873	1.7	1.7	0	0	33	N/A	Station provides a zero vs -1
1874	20.6	26.9	-1	0	11	N/A	Station does not compute peak-mean
1884	31.8	10.8	87.0	7.6	10	N/A	Station provides signal to noise ratio vs return rate
1888	1.8	2.7	-1	0	39	N/A	Station does not compute peak-mean
1890	0.7	0.7	-1	0	123	N/A	Station does not compute peak-mean
1891	48.2	35.5	-1	0	33	N/A	Station does not compute peak-mean
1893	2.1	1.6	-1	0	49	N/A	Station does not compute peak-mean
7090	8.5	9.4	5.2	6.2	688	-3.3	
7105	28.8	27.5	23.9	23.8	284	-5.0	
7110	11.9	10.6	9.9	9.7	264	-2.0	
7119	14.6	16.7	10.3	9.4	108	-4.3	
7237	9.1	8.5	6.4	6.8	229	-2.6	
7249	22.7	13.8	-1	0	17	N/A	Station does not compute peak-mean
7501	34.4	26.9	25.2	24.3	79	-9.2	
7810	6.3	3.3	-1	0	945	N/A	Station does not compute peak-mean
7811	11.9	6.4	10.8	6.6	87	-1.1	
7821	1.3	1.2	1.3	1.2	67	0.0	
7824	12.1	6.3	0	0	6	N/A	Station provides a zero vs -1
7825	0.4	0.2	3.0	4.1	44	2.6	
7827	3.3	2.3	8.2	5.9	81	4.9	
7838	4.6	3.8	0	0	213	N/A	Station provides a zero vs -1
7839	3.1	3.0	1.2	1.2	237	-1.9	
7840	4.2	2.1	2.0	1.7	415	-2.2	
7841	1.2	1.5	50.7	17.0	103	N/A	Station provides signal to noise ratio vs return rate
7845	7.4	7.0	6.0	4.6	312	-1.4	
7941	43.8	25.1	35.3	25.4	374	-8.5	
8834	1.9	1.2	0	0	207	N/A	Station provides a zero vs -1

- This Table is the analysis of comparing OrbitNP return rates based on January 2020 fullrate data vs return rates based on the Normal Points provided by the station. Graz 7839 return rates are highlighted in light blue.
- OrbitNP's return rate algorithm is based on the first and last fullrate observation and why OrbitNP's return rates tend to be higher than the return rates computed by the stations
- Graz 7839 LAGEOS-1 return rates based on OrbitNP are 3.1% which is significantly higher than the 1.2% computed by the station.
- Since ~30% of Graz LAGEOS returns are rejected due the 20 mm LE filter, Graz's real average return rate would be 4.4% which is interestingly very close to Herstmonceux 7840 LAGEOS-1 return rate in this table.

Graz 7839 and Herstmonceux 7840 Etalon RMS and Peak Minus Mean Analysis based on 50 Records



- The chart displays the yearly Etalon RMSs and Peak – Mean (P-M) values from Graz and Herstmonceux based on the CRD 50 session records. RMSs and P-M are highly correlated.
- Based on Etalon return rates Graz appears to be at the single photon level
- If you ignore 2017 and 2018, when Graz implemented tighter Etalon data rejection criteria, the differences between 7839 and 7840 P-Ms are in the range 7 to 10 mm. The difference in CoMs between 7839 and 7840 is 14.8 mm.
- Question: Is the Graz CoM in error by 5 to 6 mm causing the apparent SSEM range bias offset between Graz Etalon and LAGEOS range biases?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Search in Presentation
Home
Insert
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Transitions
Animations
Slide Show
Review
View
Share
New Slide
Table
Pictures
Screenshot
Store
My Add-ins
Shapes
SmartArt
Chart
Link
Action
Comment
Text Box
Header & Footer
WordArt
Date & Time
Slide Number
Object
Equation
Symbol
Video
Audio
Not Secure — geodesy.jcet.umbc.edu
Arequipa 7403 LAGEOS1
2021-12-22 20:55:15
BIAS [mm]
100
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DATE
ILRSB L1 v231
ILRSB L1 v231 LF 1000 %
Highcharts.com
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New Plot
Print PDF
ILRSB LAGEOS1 v231 Mean/Std. Dev.:2.02±19.86 Count:709
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English (United States)
Notes
Comments
121%