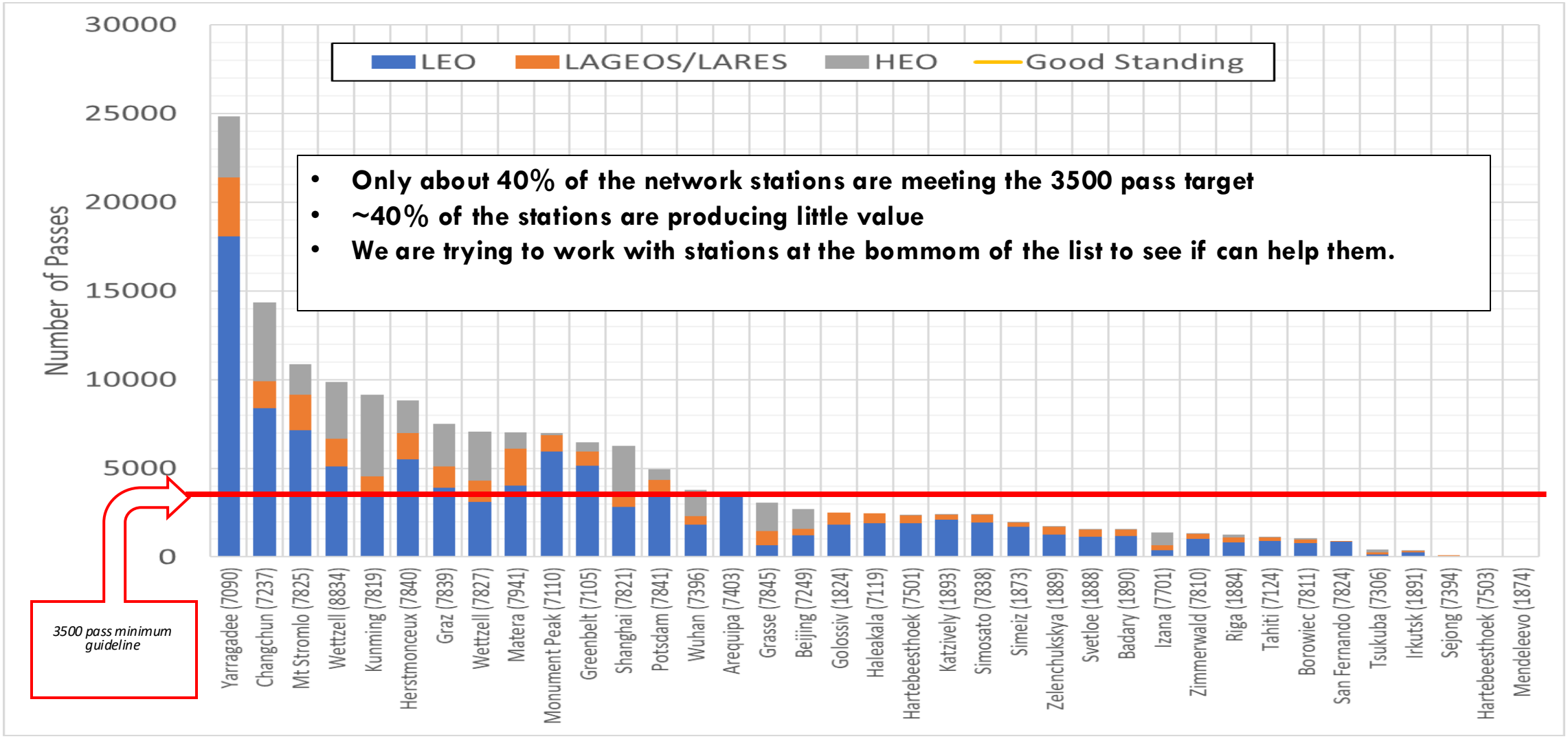
ILRS Survey and Station Plan

Mike Pearlman

10/04/2024

ILRS – Network Performance 2023



Station Survey and Plan

- We started a program with 10 stations at the bottom of the list, or stations whose data yield has fallen off; We also chose a few higher performing stations to broaden out the sample;
- We developed a questionnaire to ask stations some questions about their operations, data, procedures, their modes of failure, etc. to give us some basis for a dialogue with them; questions included are given on the next page;
- This first list of stations included Zelenchukskaya, Irkutsk, Mendeleevo, Svetloe, Badary, Moblas-6, Moblas-8, Borowiez, Metsahovi, Graz, Riga, and Simosato;
- We established a review team including Van Husson, Randall Carman, Matt Wilkinson, Clement Courde, You Zhao, Mike Pearlman, Alexandre Belli, Claudia Carabajal.
- Our plan was to review the responses from the stations, and begin a dialog with them;
- Much to our surprise, all except one station filled out and returned the questionnaire;
- Our team has met, reviewed their answers, and are now preparing our responses back to the stations;
- In general, we think the stations were candid, but we will have to probe deeper to get more detail.

Ground Survey and Station Plan

- The questions asked included:
  - Can your station track the full ILRS target list?
  - Does your station track during day and night?
  - How many days a week does your station operate?
  - How many hours per day does your station operate?
  - Are there additional tracking priorities beyond SLR?
  - How could your station improve its tracking capability?
  - Which targets are difficulty to acquire?
  - Can you track GNSS in day and nigh-time conditions?
  - Do you have lunar ranging capability?
  - Does your station interleave satellites?
  - Are there restrictions on SLR in azimuth and/or elevation?
  - Do temperature changes impact target acquisition rates?
  - What is currently limiting data volume?
  - What would make a significant improvement in your station's tracking capability?
  - Is your station fully supported?
  - Is your station funded to observe continually?
  - How often is the work of your station reviewed?
  - How many full time and part time staff work at your station?
  - Do staff have other duties to make them unavailable to observe?
  - Is your tracking operational pattern likely to change soon?

ILRS Quality Control Board

Van S Husson

5-Oct-2024

Agenda

- Simeiz (1873) Recent Epoch Errors
- Geodetic System Performance Comparison: Yarragadee (7090) versus Mt Stromlo (7825)
- Yarragadee (7090) 2024 Local Survey and MINICO Results
- Summary of Stations using the LE Filter
- LAGEOS Single Shot RMSs from the LE Systems

Simeiz 1873 Recent Epoch Errors

```
#  1873 = SIMEIS
# sat site       date  time dur    rb mm   error       tb us    error    prec bad total  rms   pres  temp hum  sdelay shft  rms cfg r wlen
 AJI1 1873 2024/09/17 23:32   5    -101 (   178 )   -12561.6 (   60.4 )    33   0 /  12   10  971.5 289.1  97   10164     0   21 0 0 0  532
 AJI1 1873 2024/09/18 01:29   6       7 (    36 )   -12531.8 (   10.8 )     7   0 /  14    9  971.0 288.0  96   10164     0   21 0 0 0  532
 LAG2 1873 2024/09/18 22:58   2    9598 ( 27437 )   -------.- ( ----.- ) #####   0 /   2   26  973.3 288.1  94   10164     0   21 0 0 0  532
 AJI1 1873 2024/09/19 00:37   8    -137 (   347 )   -19482.4 (  121.0 )   120   1 /  13   18  973.0 289.0  96   10164     0   21 0 0 0  532
 STEL 1873 2024/09/20 18:21   2  -24625 (    78 )   -------.- ( ----.- )    21   0 /   7   10  974.4 291.9  30   10164     0   21 0 0 0  532
 LARS 1873 2024/09/20 18:56   9   14631 (     0 )   -------.- ( ----.- )     0   2 /   4   39  974.5 292.2  29   10164     0   21 0 0 0  532
 AJI1 1873 2024/09/20 22:53   5     -93 (   231 )    -6588.1 (   60.5 )    21   0 /  11   12  974.3 291.6  28   10164     0   21 0 0 0  532
 AJI1 1873 2024/09/21 00:49   8     -82 (    75 )    -6570.7 (   24.5 )    29   1 /  17   10  974.1 291.6  25   10164     0   21 0 0 0  532
 LARS 1873 2024/09/21 17:58   3    -151 (   176 )    -6525.0 (   55.9 )    11   2 /   7    9  974.1 292.4  30   10164     0   21 0 0 0  532
 AJI1 1873 2024/09/22 23:08   4     -30 (   369 )    -6467.3 (   86.2 )    17   0 /  10    6  969.8 294.7  26   10163     0   38 0 0 0  532
 AJI1 1873 2024/09/23 01:12   3     -85 (  1316 )     -843.5 (  280.6 )    30   0 /   8    7  969.1 293.5  26   10163     0   38 0 0 0  532
 STEL 1873 2024/09/23 17:01   2   -2912 (   104 )   -------.- ( ----.- )    25   1 /   7   13  971.7 292.3  54   10149     0   38 0 0 0  532
 LAG1 1873 2024/09/23 17:11   9     -32 (   126 )    -6455.0 (  147.6 )    19   0 /   5   10  971.7 292.3  54   10149     0   38 0 0 0  532
 LARS 1873 2024/09/23 17:44   7     -34 (   112 )    -6424.2 (   43.5 )    29   0 /   8   10  971.9 291.8  54   10149     0   38 0 0 0  532
 AJI1 1873 2024/09/23 22:15   1   -3735 (    92 )   -------.- ( ----.- )    21   0 /   5    9  972.2 291.9  54   10149     0   38 0 0 0  532
 F217 1873 2024/09/23 23:37  14   -6570 (   100 )   -------.- ( ----.- )    20   0 /   4    9  972.3 292.1  47   10149     0   38 0 0 0  532
 AJI1 1873 2024/09/24 00:11   2   14471 (    93 )   -------.- ( ----.- )    23   0 /   6   10  972.5 291.6  51   10149     0   38 0 0 0  532
 LAG2 1873 2024/09/24 01:21  15      25 (   136 )     -783.4 (   88.1 )    12   0 /   9    7  973.0 290.8  53   10149     0   38 0 0 0  532
 LARS 1873 2024/09/24 01:47   3     -32 (   130 )    -6410.3 (   80.8 )    20   0 /   7   10  973.0 290.8  52   10149     0   38 0 0 0  532
 AJI1 1873 2024/09/24 02:14   2    4282 (    68 )   -------.- ( ----.- )    17   0 /   6    8  973.0 290.8  53   10149     0   38 0 0 0  532
 LARS 1873 2024/09/24 16:42   1    3617 (    41 )   -------.- ( ----.- )     8   0 /   4   12  975.5 291.3  83   10149     0   38 0 0 0  532
 LARS 1873 2024/09/24 18:40   5     -11 (   142 )    -6385.9 (   48.4 )    25   1 /  10    9  975.7 291.4  80   10149     0   38 0 0 0  532
 LAG1 1873 2024/09/24 19:21   8     108 (   162 )    -6317.3 (  198.9 )    23   0 /   6   17  975.6 291.1  81   10149     0   38 0 0 0  532
 LAG2 1873 2024/09/24 19:47   8     149 (   476 )    -6454.7 (  269.3 )    16   0 /   6   11  975.5 291.1  80   10149     0   38 0 0 0  532
 AJI1 1873 2024/09/25 01:16   3     -65 (   239 )     -783.8 (   61.0 )    14   0 /   9    7  975.6 288.4  75   10149     0   38 0 0 0  532
 LARS 1873 2024/09/25 02:39   3      23 (   435 )     -752.3 (  116.8 )    27   0 /   8   10  975.8 287.8  76   10149     0   38 0 0 0  532
 LARS 1873 2024/09/25 17:34   4      50 (    47 )     -731.6 (   21.0 )    15   0 /  10    9  976.9 290.0  97   10149     0   38 0 0 0  532
 STEL 1873 2024/09/25 17:50   1   -4282 (   141 )   -------.- ( ----.- )    28   0 /   4   12  976.9 290.0  98   10149     0   38 0 0 0  532
 AJI1 1873 2024/09/25 18:15   3    -177 (   507 )      205.6 (  129.9 )    18   0 /   7    8  976.7 289.8  97   10149     0   38 0 0 0  532
 LARS 1873 2024/09/25 19:29   9     -63 (    44 )     -746.3 (   20.6 )    13   1 /  12   13  976.9 289.3  83   10149     0   38 0 0 0  532
 AJI1 1873 2024/09/26 00:26   5     -25 (    77 )     -708.2 (   27.8 )    20   0 /   9   10  975.9 289.6  75   10149     0   38 0 0 0  532
 LAG2 1873 2024/09/26 02:01   3    -641 (   788 )   -------.- ( ----.- )   137   0 /   3   14  976.0 288.5  80   10149     0   38 0 0 0  532
 AJI1 1873 2024/09/26 02:24   2    -931 (    66 )   -------.- ( ----.- )    16   0 /   6   10  976.0 288.4  80   10149     0   38 0 0 0  532
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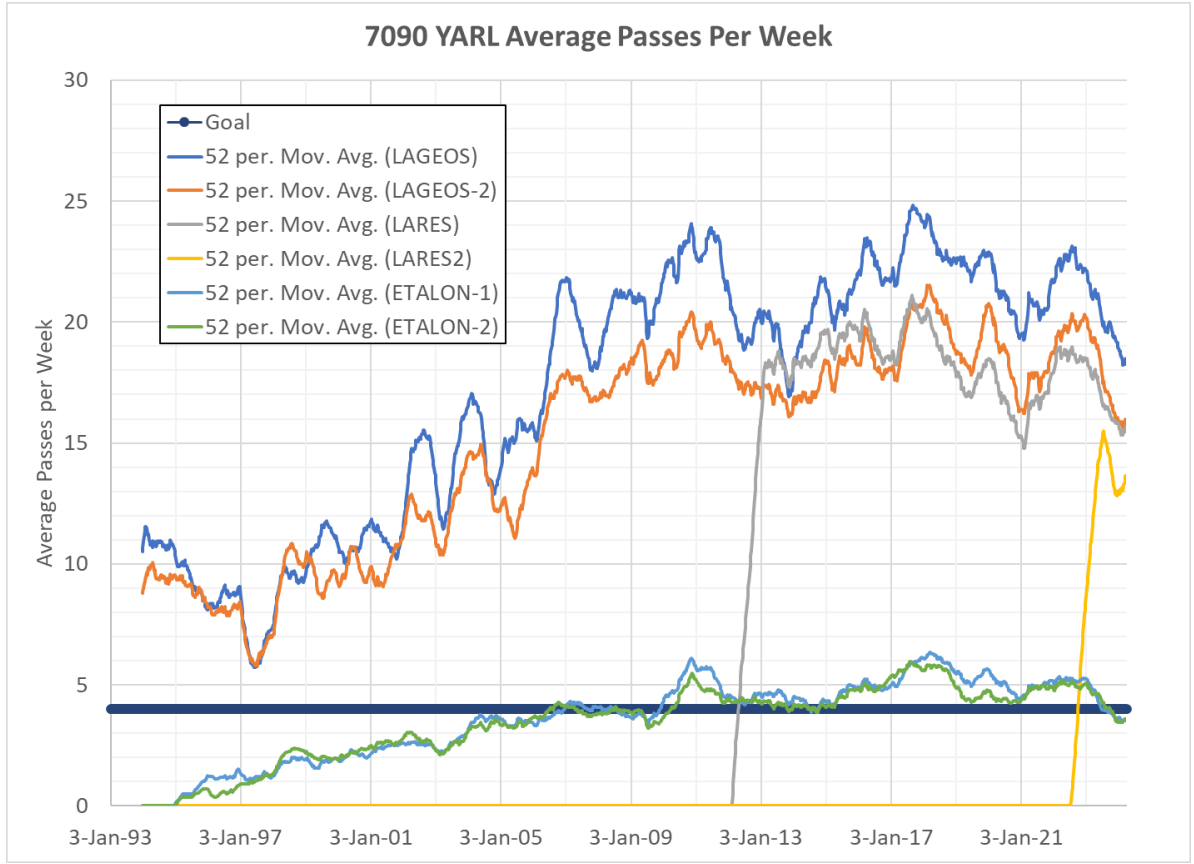
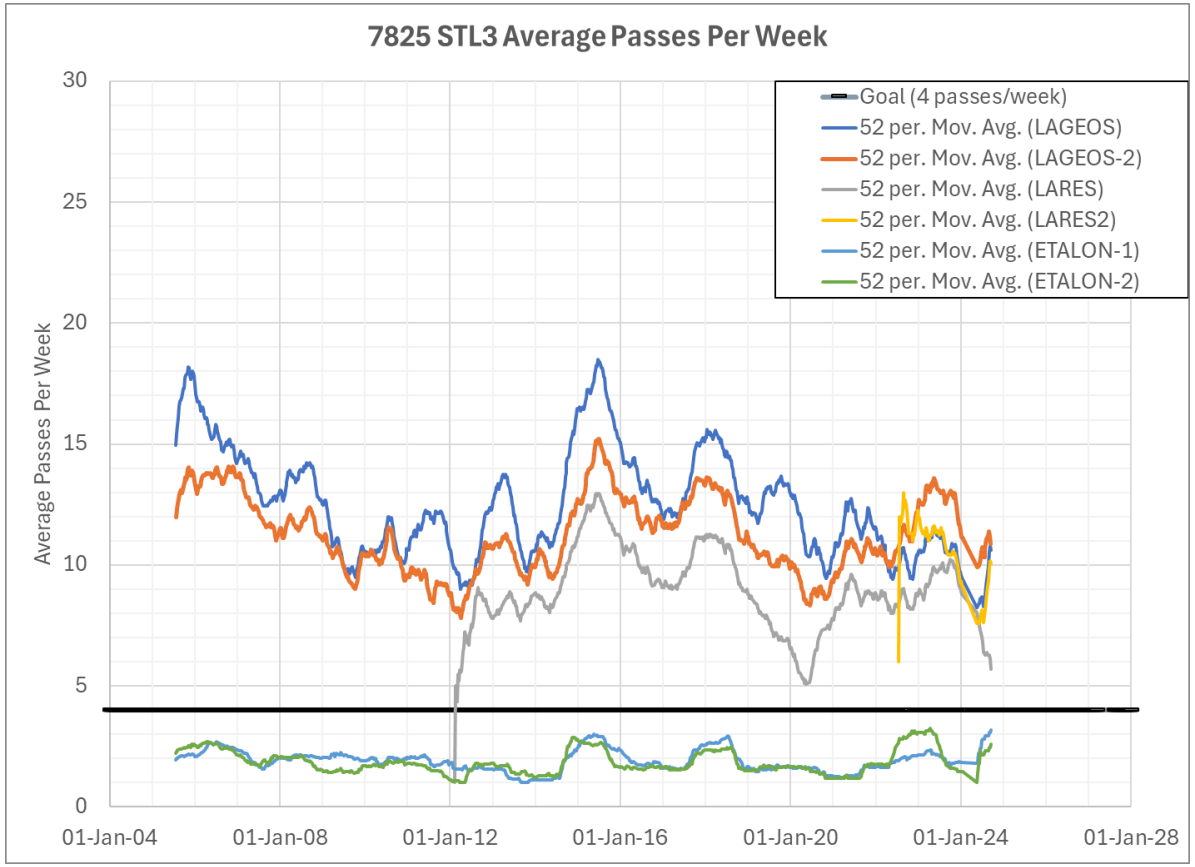
- **What is the best approach to handle and document 'unrecoverable problem' data (e.g. epoch errors, frequency errors, large range biases etc.) so that is doesn't contaminate our science products (e.g. station coordinates)? Is placing an 'X' in the Data Handling File to cover the period in question the best and only approach for all end users?**

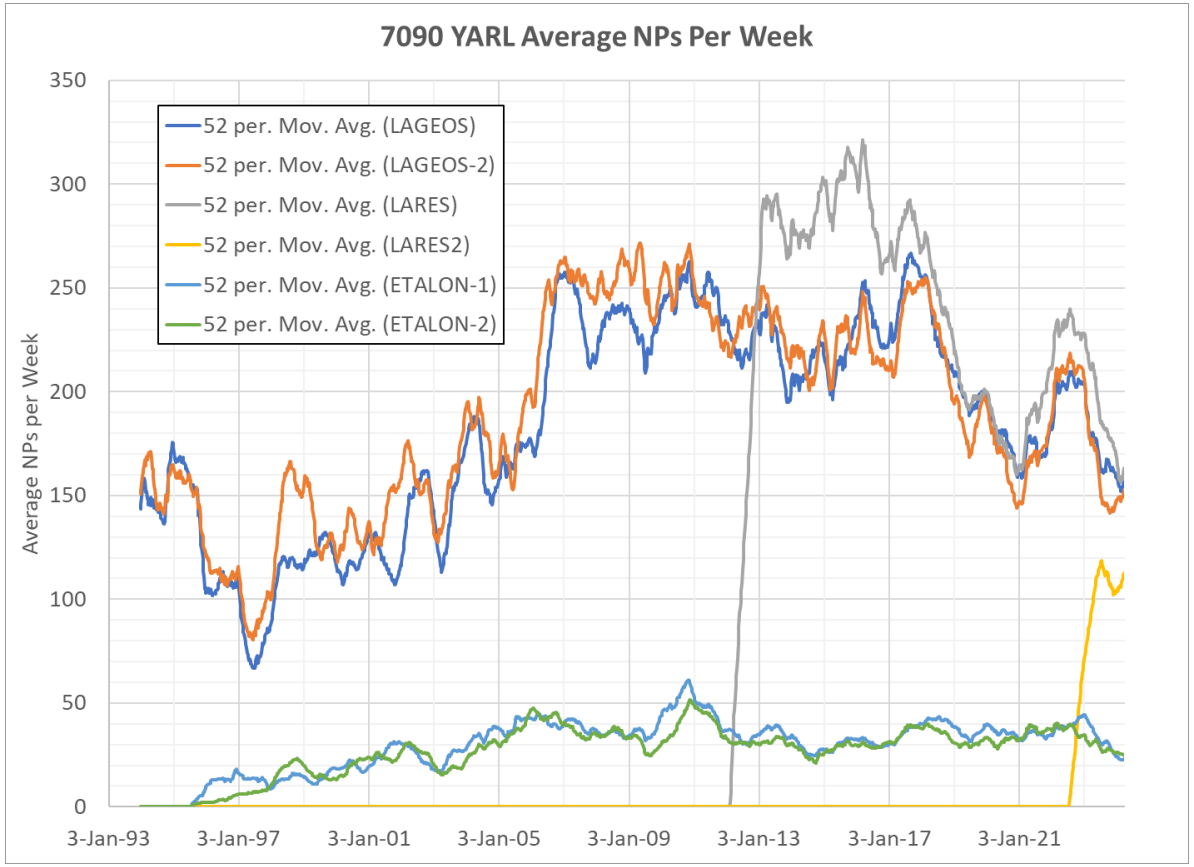
Geodetic System Performance Comparison Yarragadee versus Mt Stromlo (Passes)

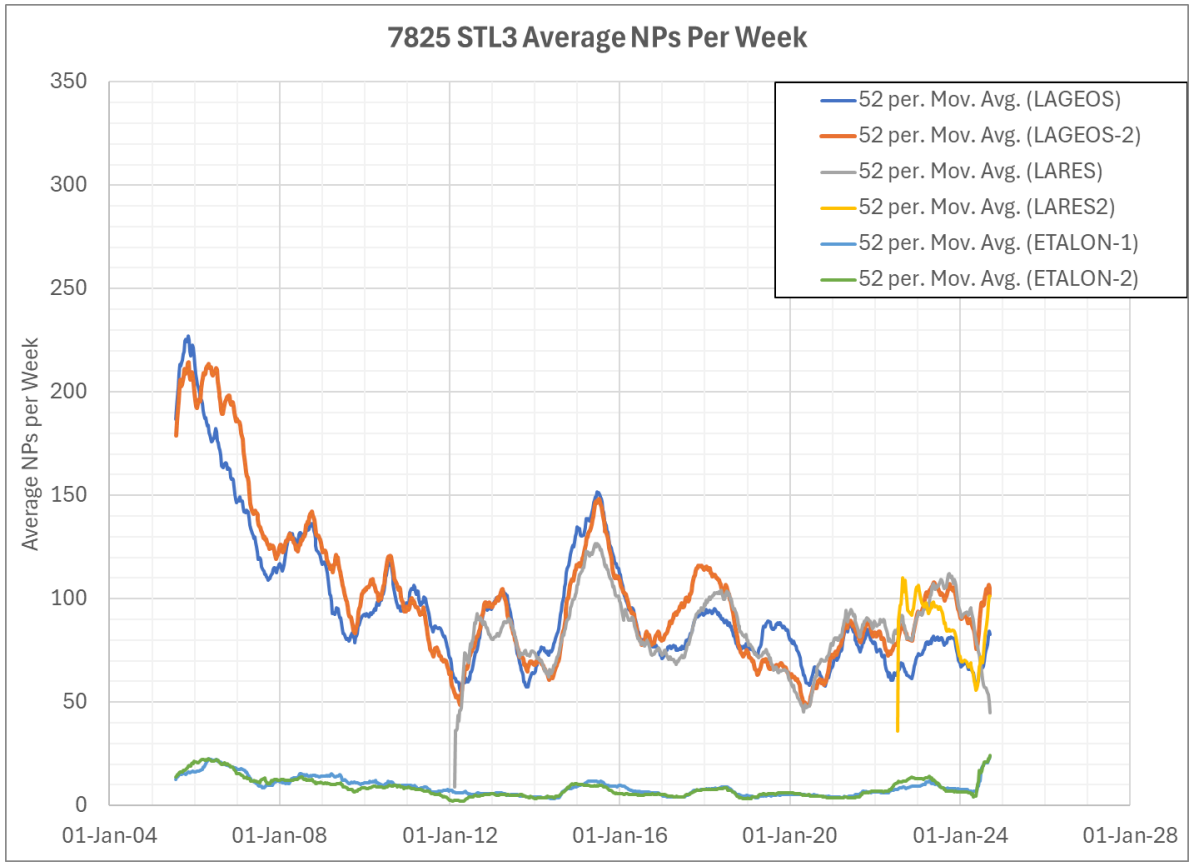




- Yarragadee (non-autonomous) and Mt Stromlo (autonomous) geodetic system performance (passes) on the left and right charts; respectively. Yarragadee does have a weather advantage and is the GOLD standard
- Both systems easily exceed the ILRS ITRF geodetic data quantity requirements for LAGEOS and LARES (i.e. 4 passes per week is slightly greater than ~200 passes per year for each geodetic satellite); while Etalon is challenging.

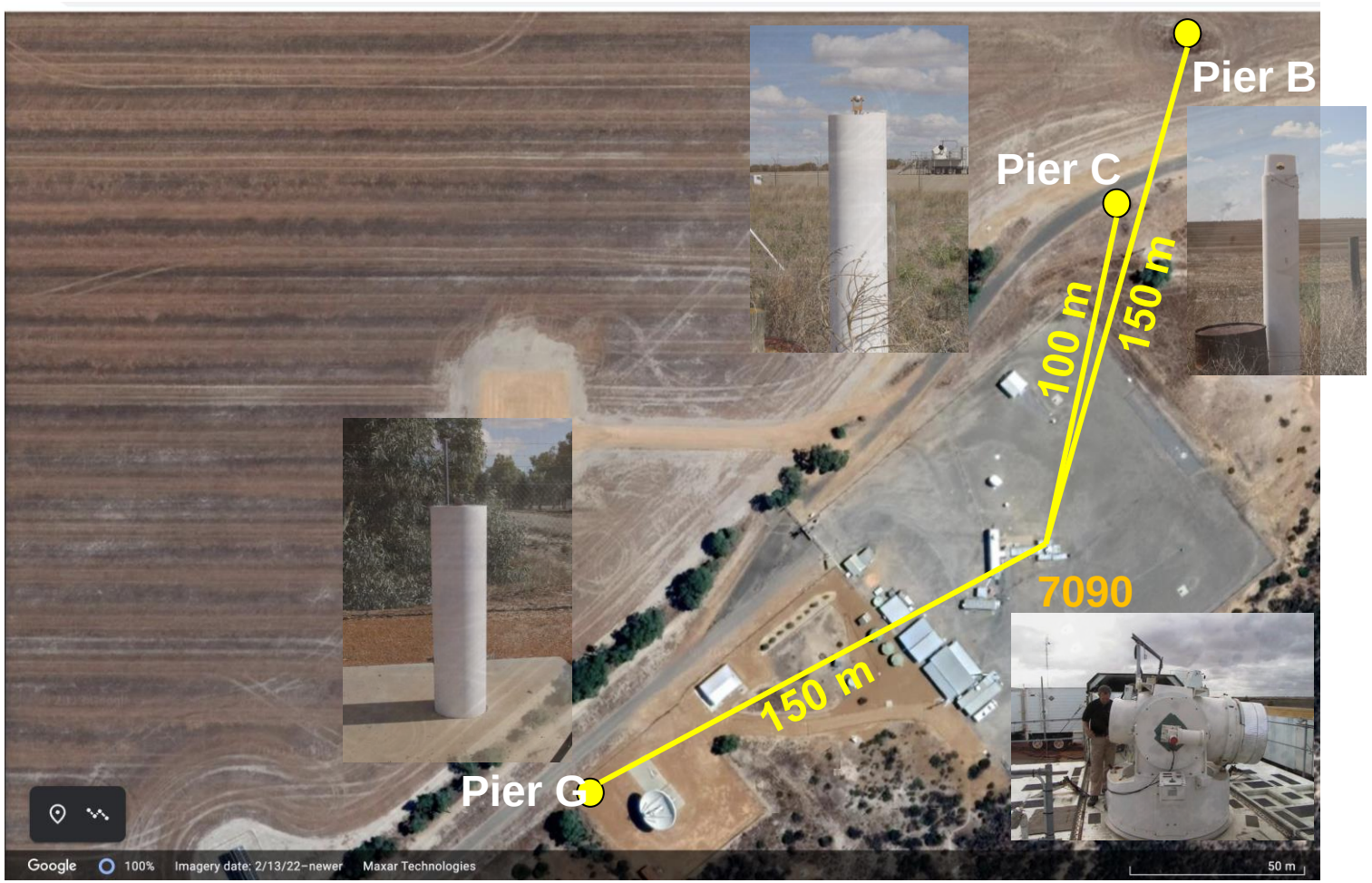
Geodetic System Performance Comparison Yarragadee versus Mt Stromlo (NPs)





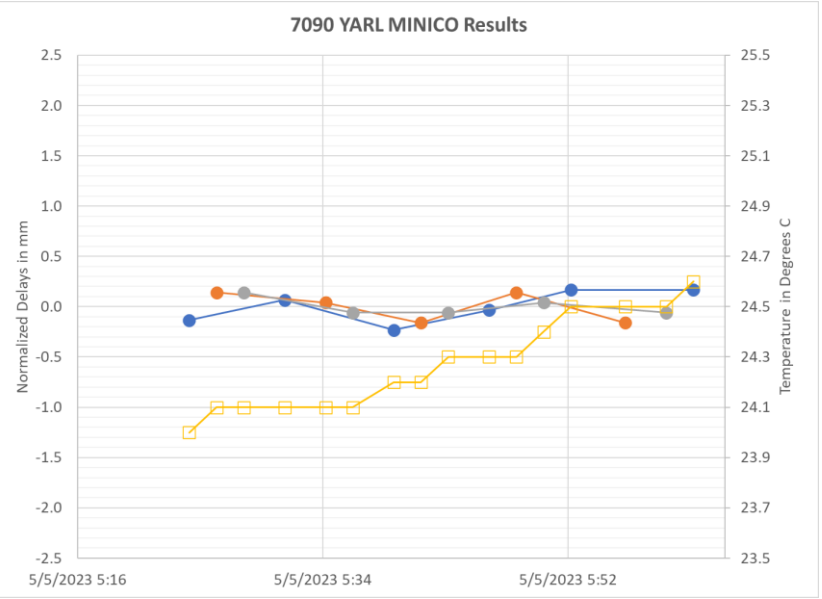
- Yarragadee (non-autonomous) and Mt Stromlo (autonomous) geodetic system performance (normal points) on the left and right charts; respectively. Yarragadee does have a weather advantage
- Should there also be a normal point per pass performance requirement?

MOBLAS-5 at 7090 YARL (Yarragadee)



- MOBLAS-5 has three calibration targets B, C, & G. Target B is prime
- Target G has a concrete pad, but targets B & C do not
- Ranging to Target G, the laser beam must pass between two buildings
- *Pier photos courtesy of MOLBAS-5*

7090 YARL MINICOs in May 2023



- **Potential systematic error sources**
  - Temporal: Will cancel within a Test
  - Laser: Spatial/Wavefront Distortion
  - Detector: Diurnal/Ambient Background Noise
  - Discriminator: Signal Strength
  - Receiver: Range Gate Window
  - Local Survey

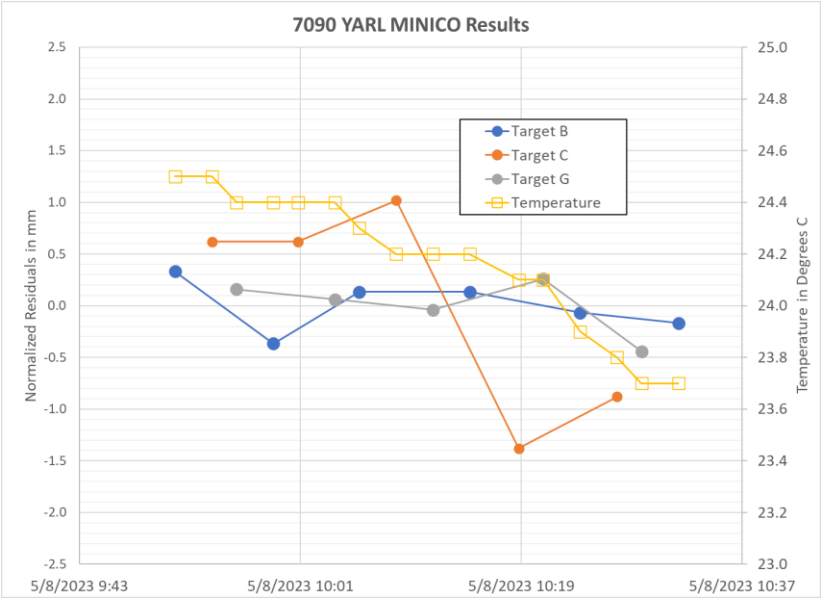


Table 1: MINICO Analysis by Calibration Target (05-May-2023)

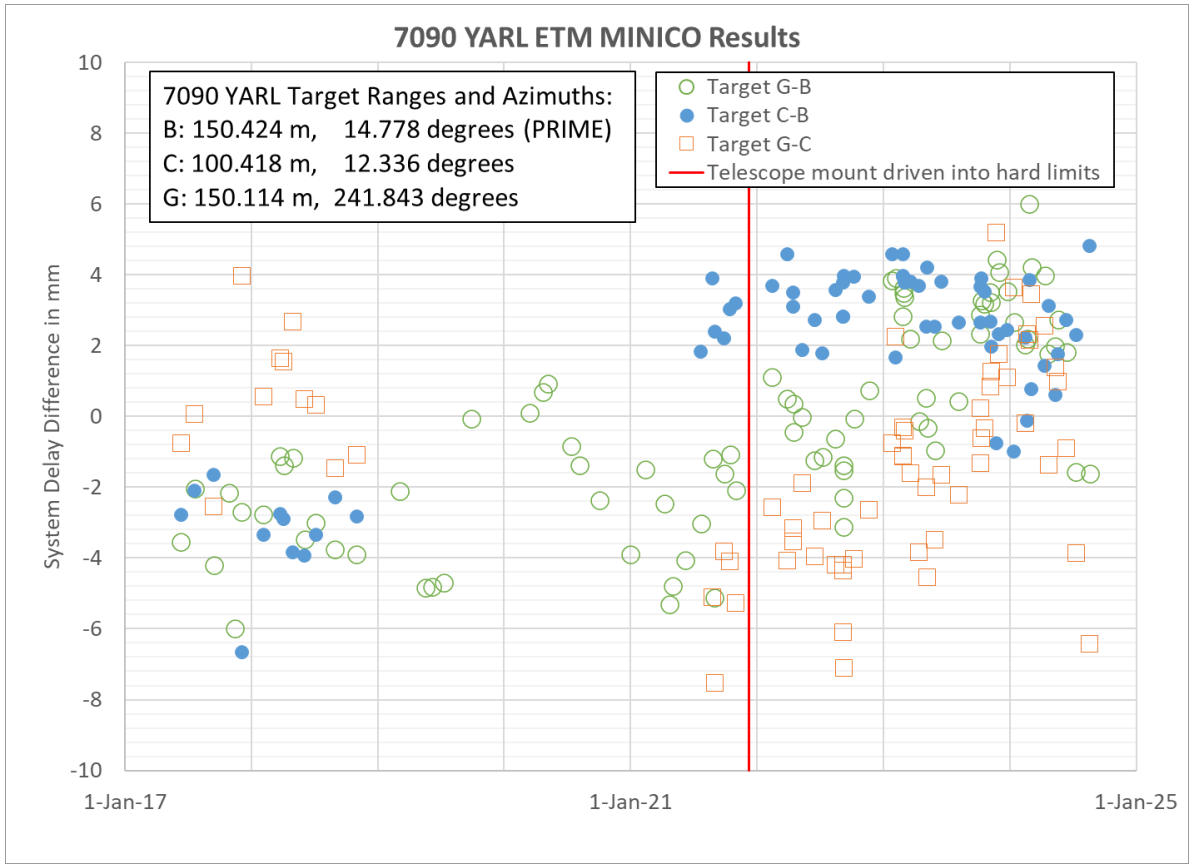
Statistic	Target	System delay in mm	System delay in ns	Temperature in degrees C	RMS in mm	Transmit energy	Receive energy
Average	B	14485.4	96.637	24.3	2.05	892.5	255.8
Peak-to-Peak	B	0.4	0.003	0.6	0.20	74.0	17.0
Correlation with System Delay	B	N/A	N/A	0.70	-0.15	-0.57	0.06
Average	C	14488.0	96.653	24.2	2.12	891.4	290.0
Peak-to-Peak	C	0.3	0.002	0.4	0.20	58.0	14.0
Correlation with System Delay	C	N/A	N/A	-0.51	0.96	0.32	-0.68
Average	G	14486.0	96.640	24.3	1.78	889.2	320.2
Peak-to-Peak	G	0.2	0.001	0.4	0.20	55.0	27.0
Correlation with System Delay	G	N/A	N/A	-0.38	-0.13	0.25	0.45

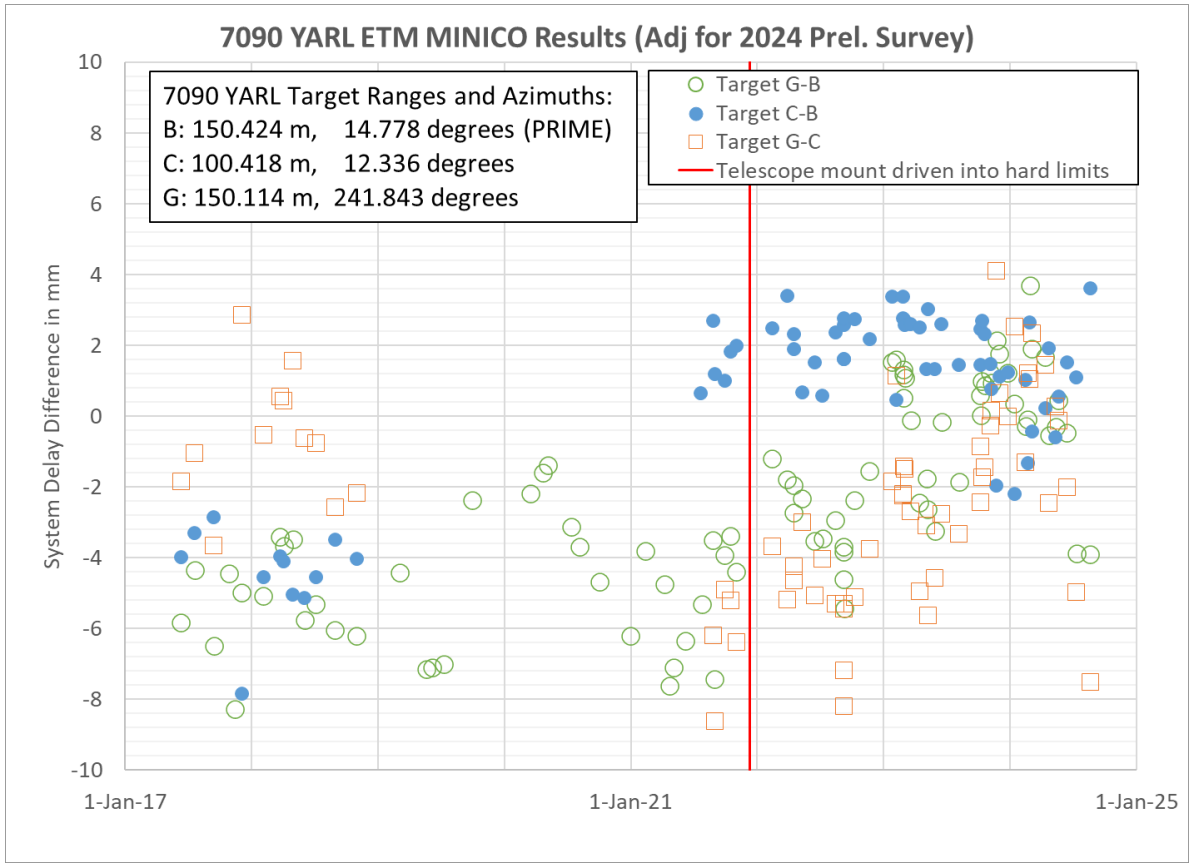
Table 2: MINICO Analysis by Calibration Target (08-May-2023)

Statistic	Target	System delay in mm	System delay in ns	Temperature in degrees C	RMS in mm	Transmit energy	Receive energy
Average	B	14486.3	96.642	24.2	2.22	1030.5	233.5
Peak-to-Peak	B	0.7	0.004	0.8	0.40	53.0	85.0
Correlation with System Delay	B	N/A	N/A	0.37	0.07	-0.47	-0.40
Average	C	14490.5	96.670	24.2	2.48	1021.8	245.8
Peak-to-Peak	C	2.4	0.016	0.7	0.80	25.0	99.0
Correlation with System Delay	C	N/A	N/A	0.69	0.97	-0.14	-1.00
Average	G	14485.9	96.640	24.2	2.24	1033.4	247.8
Peak-to-Peak	G	0.7	0.005	0.7	0.20	26.0	58.0
Correlation with System Delay	G	N/A	N/A	0.76	-0.70	-0.13	0.64

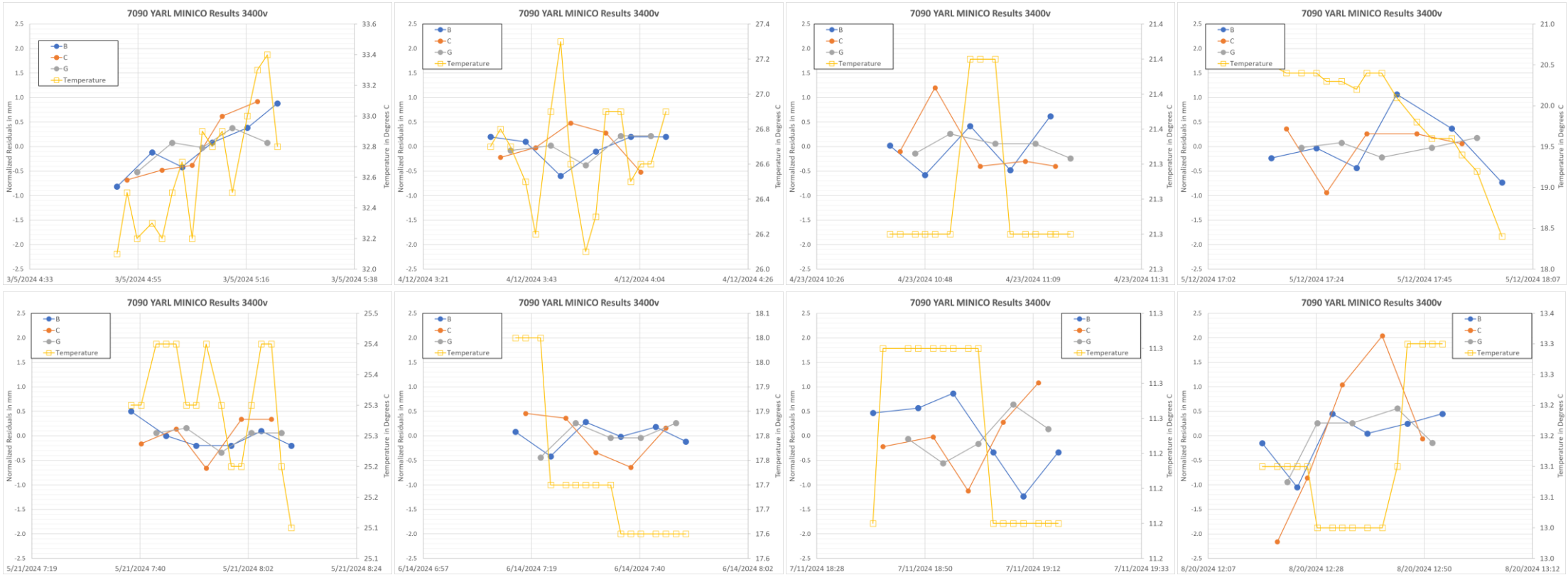
- **These two MINICOs were taken 3 days apart by different operators**

7090 YARL MINICOs Adjusted for Preliminary Results from the 2024 Survey





2024 7090 YARL MINICOs



Date	local time	G-B	C-B	G-C
5-Mar-24	12:51	4.20	0.76	3.44
12-Apr-24	11:35	3.98	1.42	2.56
23-Apr-24	18:41	1.76	3.12	(1.36)
12-May-24	1:15	1.99	0.61	1.38
21-May-24	15:39	2.74	1.76	0.98
14-Jun-24	15:16	1.82	2.72	(0.90)
11-Jul-24	2:40	(1.57)	2.29	(3.86)
20-Aug-24	20:18	(1.61)	4.81	(6.42)
peak-to-peak		5.81	4.20	9.86

Old Survey	G-B	C-B	G-C	peak-to-peak
Day mean	3.19	1.67	1.52	1.67
Night mean	0.14	2.71	(2.57)	5.27
Delta	3.05	(1.04)	4.09	5.12

New Survey	G-B	C-B	G-C	peak-to-peak
Day mean	0.89	0.47	0.42	0.47
Night mean	(2.16)	1.51	(3.67)	5.17
Delta	3.05	(1.04)	4.09	5.12

- **Potential systematic error sources**
  - Temporal: Will cancel within a Test
  - Laser: Spatial/Wavefront Distortion
  - Detector: Diurnal/Ambient Background Noise
  - Discriminator: Signal Strength
  - Receiver: Range Gate Window
  - Local Survey

Stations using a Leading Edge (LE) Filter

Geodetic Satellite Edit Criteria from Site Logs

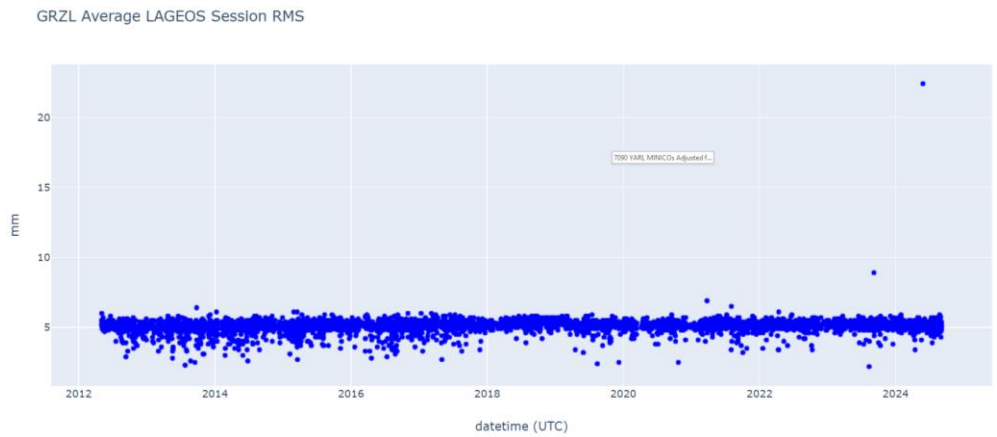
Station	Marker	LAGEOS-1/-2	LARES-2	LARES	Aiisai	Stella/Starlette	Etalon-1/-2
Graz	7839	20 mm LE	20 mm LE	2.2 σ	20 mm LE	2.2 σ	2.2 σ
Shanghai	7821	20 mm LE	2.2 σ	2.2 σ	2.2 σ	2.2 σ	2.2 σ
Changchun	7237	20 mm LE	20 mm LE	20 mm LE	2.5 σ	20 mm LE	2.5 σ
Izana	7701	20 mm LE	2.2 σ	2.2 σ	300 mm LE	2.2 σ	2.2 σ
Tsukuba	7306	20 mm LE	2.2 σ	2.2 σ	300 mm LE	2.2 σ	2.2 σ
Yebes	7817	2.2 σ	2.2 σ	2.2 σ	2.2 σ	2.2 σ	2.2 σ

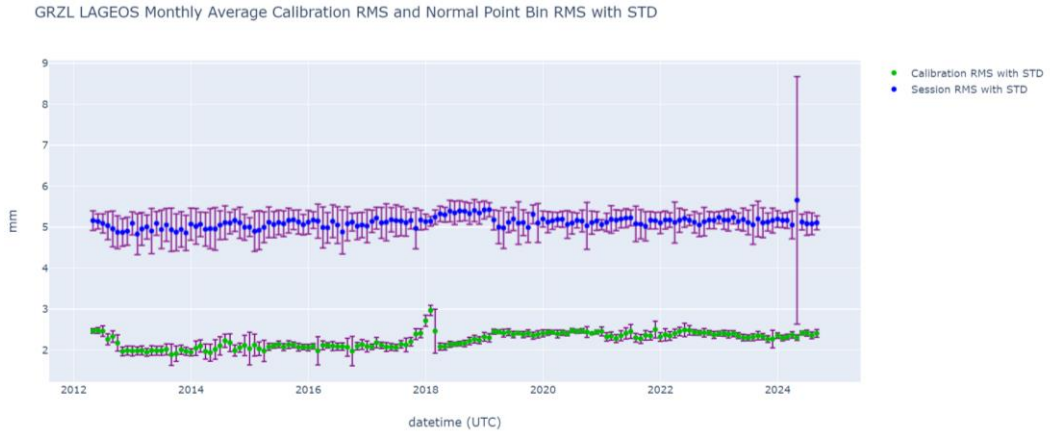
LAGEOS Fullrate Filters and the Filter Flag

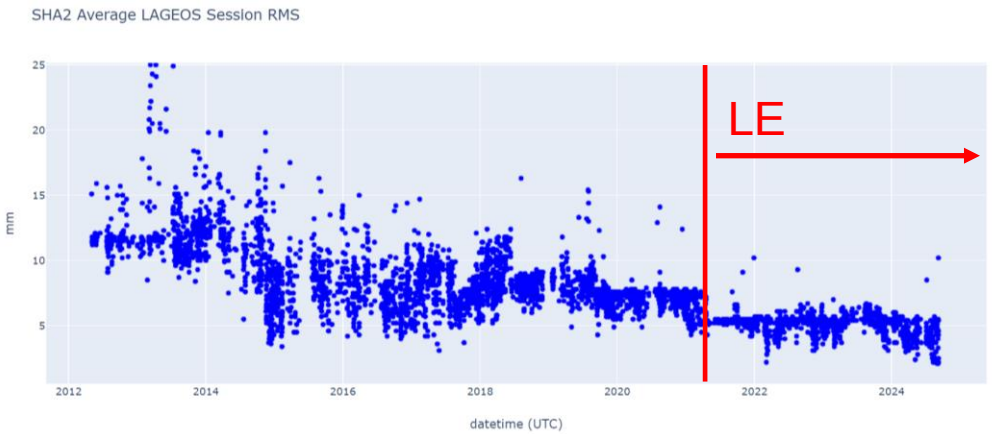
Station	Marker	LAGEOS-1/-2	Fullrate Data Filter	Noise and Excluded Returns
Graz	7839	20 mm LE	20 mm LE	No
Shanghai	7821	20 mm LE	20 mm LE	No
Changchun	7237	20 mm LE	20 mm LE	No
Izana	7701	20 mm LE	2.2 σ	No
Tsukuba	7306	20 mm LE	2.2 σ	No
Yebes	7817	20 mm LE	2.2 σ	Yes

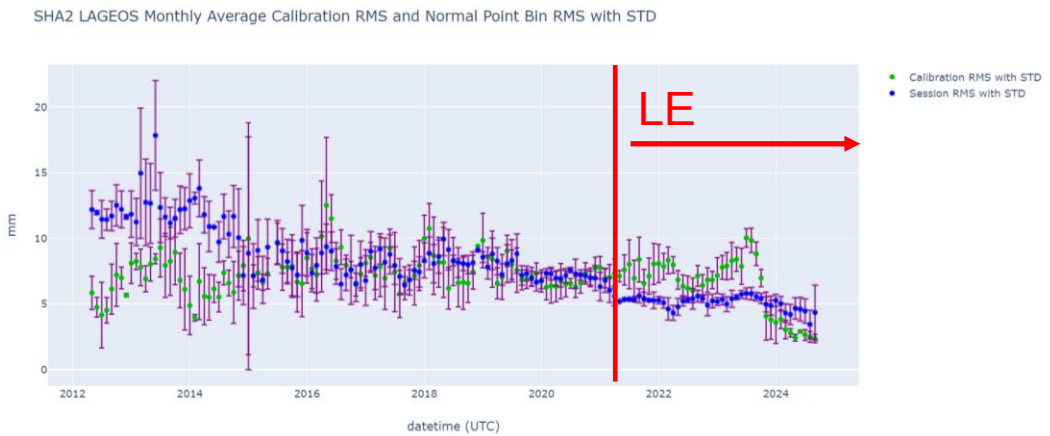
- ❑ **The site log information can't always be trusted**
- ❑ **There is no standardization of the edit criterion; which satellite returns should be included in the FullRate (FR) data; and use of the CRD FR Filter Flag**

LE System LAGEOS and Calibration Single Shot RMSs (Graz and Shanghai)



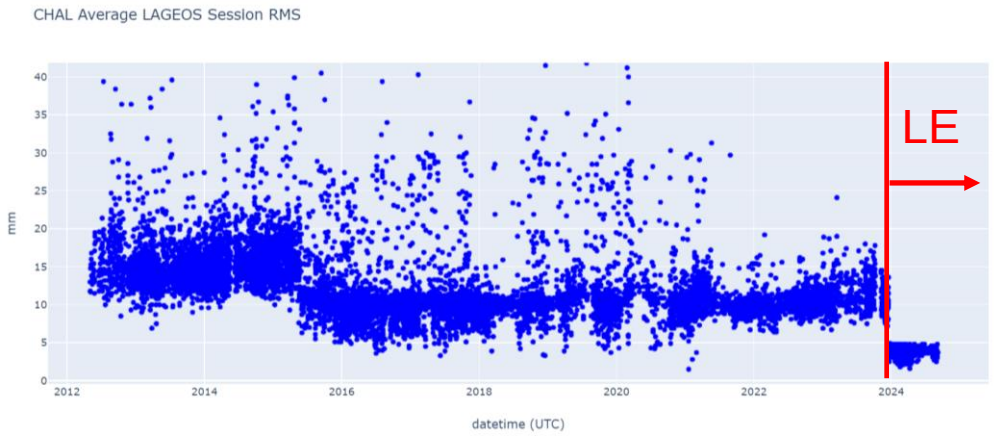


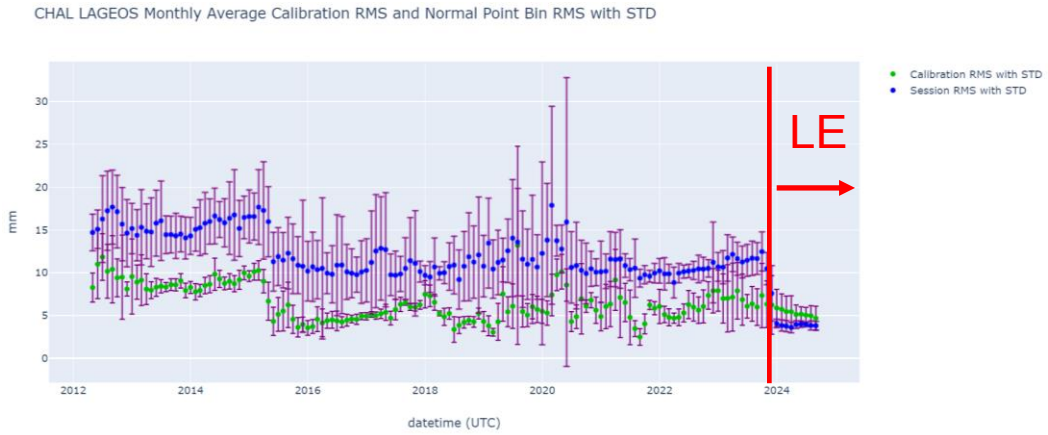




- Charts on the left and right are a time series of LAGEOS (-1, -2) pass segment single shot RMSs and average monthly single shot satellite and calibration RMSs; respectively, from the ILRS website
- Graz (7839) and Shanghai (7821) implemented the 20 mm LE filter in 05-Mar-2008 and 22-Jul-2021; respectively.
- A 20 mm LE filter should result in a single shot RMS of ~5mm (+/- 2 sigma in a Gaussian distribution is 95% of data)

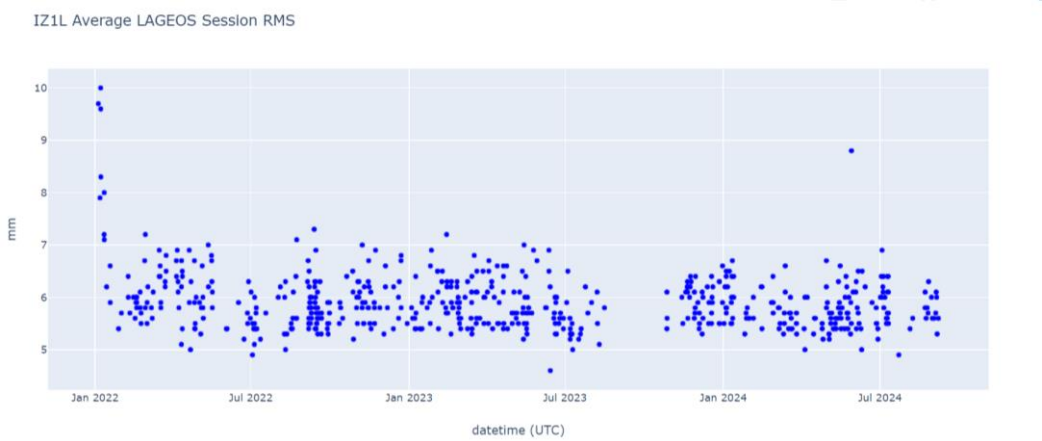
LE System LAGEOS and Calibration Single Shot RMSs (Changchun)

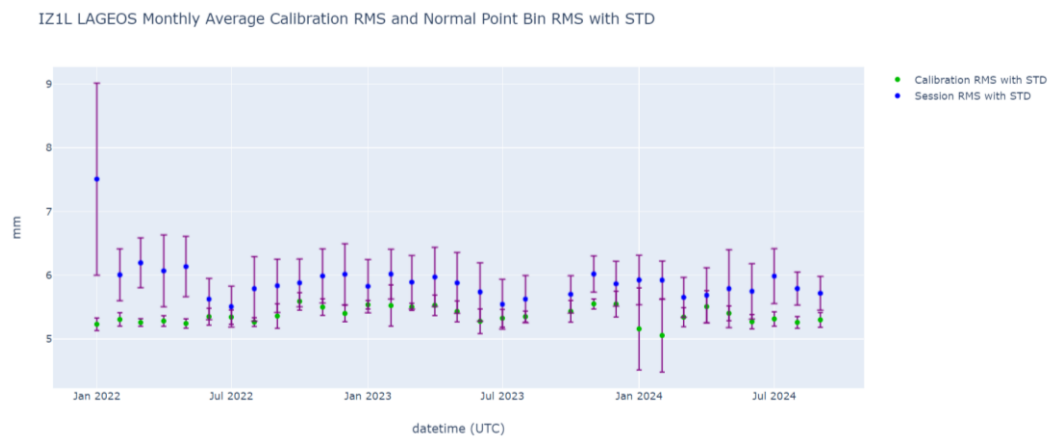


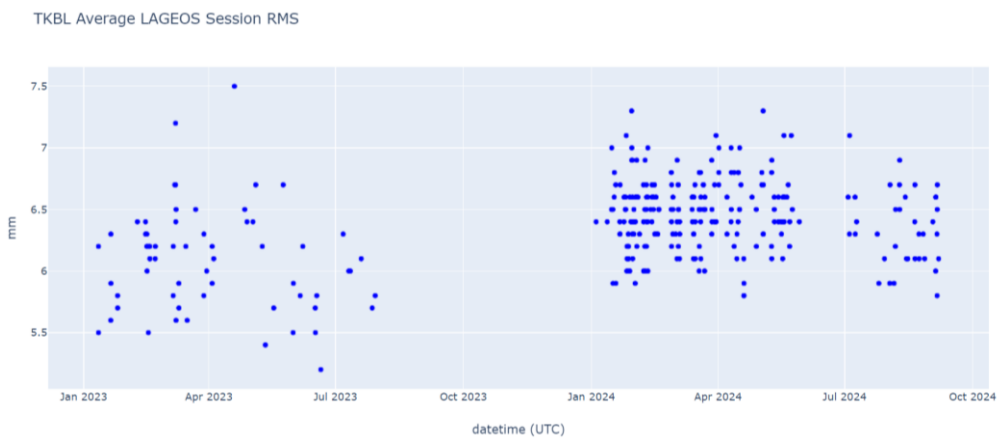


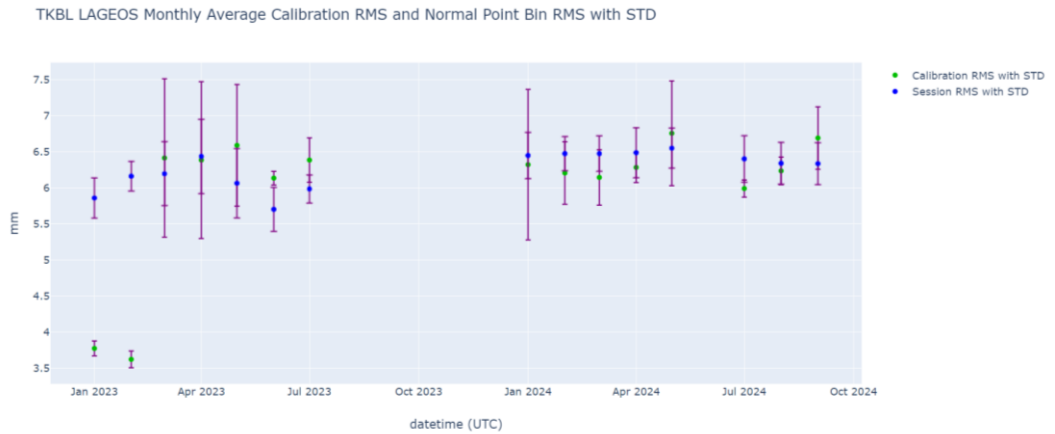
- **Changchun (7237) implemented a LAGEOS 20 mm LE filter on 19-Dec-2023**

LE System LAGEOS and Calibration Single Shot RMSs (Izana and Tsukuba)









- Izana (7701) and Tsukuba (7306) implemented a LAGEOS 20 mm LE filter on day 1 of their operations. Both systems have taken LAGEOS data with their primary and secondary wavelengths. Izana's primary and secondary wavelengths are infra-red (1064 nm) and green (532 nm) (the primary receiver chain listed in the site log is green). Tsukuba's primary and secondary wavelengths are green (532 nm) and infra-red (1064 nm)

ILRS QCB Meeting

10/04/2024

Mike Pearlman & Claudia Carabajal

Agenda

Agenda:

- Mike: ILRS Survey and Station Plans
- Jose: quarantine procedures for stations capable of firing at different wavelengths (Grasse, Yebes, etc.). Updating the quarantine guidelines.
- Van:
  - Yebes data analysis
  - Simeiz (1873) Recent Epoch Errors
  - Geodetic System Performance Comparison: Yarragadee (7090) versus Mt. Stromlo (7825)
  - Yarragadee (7090) 2024 Local Survey and MINICO Results
  - Summary of Stations using the LE Filter
  - LAGEOS Single Shot RMSs from the LE Systems
- Peter: Polynesian Discontinuities* **Moved to next meeting*
- Frank/Magda: Quarantine Stations Updates (will be discussed after official notification is sent)
- Alex: Tracking Priorities List*
- Claudia:
  - Mission Updates/New missions
  - Workshop updates

Agenda, Notes, and materials from the last QCB meeting on July 15th, 2024 will be posted here:
https://ilrs.gsfc.nasa.gov/science/qcb/qcbActivities/index.html

Mission Updates/New Missions

- Received Missions SLR Tracking Reports from the first group of LEO missions contacted are under review by the review committee.
- ALOS-4 restricted tracking campaign to start mid-October, satellite checkout taking longer. The mission will inform us when they would like to start.
- Received MSRF from Hideki Yamada from JAXA, for "QPS-SAR" satellite on September 27, planning to launch on 2025. JAXA requested to have the opportunity to re-examine the contents of the request, and resubmit to ILRS. MSC review on hold until updated version received.

2026 IWLR

- The 24th IWLR in 2026 will be hosted by the Argentinean CONICET and German BKG (AGGO). CONICET offers the venue in the center of Buenos Aires, the Argentine capital. More to come.

International Workshop on Laser Ranging – Kunming 2024

Celebrating 60 Years of SLR (1964-2024), Cooperation in the new era of ILRS

- The Yunnan Observatories and the International Laser Ranging Service (ILRS) are pleased to announce that the 23rd International Workshop on Laser Ranging will be held in Kunming, China during 20-26 October 2024.
- Second announcement sent with change in venue. Workshop website online with the link below (recently updated): https://23rdworkshop.casconf.cn/

  KunmingLOC@outlook.com
- LOC POC:

  Yongzhang Yang

- Deadline for submissions 10/07/2024

[Abstracts and full presentations]

I. Session-chair arrangement:

- Current IPC Members

Information as of 10/02/2024

	Name	Affiliation
	[Chair] Changyin Zhao	PMO, China
	[Chair] Toshimichi Otsubo	Hitotsubashi University, Japan
	[Secretary] Claudia C. Carabajal	ILRS Central Bureau, USA
no reply	Ben Greene	EOS, Australia
	Cinzia Luceri	ASI/CGS Matera, Italy
	Chengzhi Liu	CHO, China
	Clément Courde	INSU, France
online	Evan Hoffmann	NASA, USA
	Hyung-Chul Lim	KASS, Korea
	Johann Eckl	BKG, Germany
	José Rodríguez	IGN, Spain
	Michael Pearlman	CfA, USA

	Name	Affiliation
online	Michael Steindorfer	OEAW, Austria
	Mathis Blossfeld	DGFI-TUM, Germany
	Matthew Wilkinson	NERC Space Geodesy Facility, UK
online	Peiyuan Wang	OEAW, Austria
	Stephen Merkowitz	NASA, USA
online	Tomasz Suchodolski	Space Research Centre of PAS, Poland
no reply	Yue Gao	EOS, Australia
	Yuqiang Li	YNAO, China
	You Zhao	NAO, China
	Zhongping Zhang	SHAO, China

II. Sessions and potential Chairperson

- the intentions of chairing one of the sessions
- * as online

Session Name	Oral reports	In-person	Online
Scientific applications of satellite laser ranging (Interested in chairing: Mathis Blossfeld,)	12	9	3
Development of satellite laser ranging (Interested in chairing:)	14	10	3
Lunar laser ranging and deep space missions (Interested in chairing: Clément Courde,Hyung-Chul Lim, Stephen Merkowitz)	8	4	2
Developments in software and automation (Interested in chairing: Peiyuan Wang*)	2	2	0
Space debris laser ranging (Interested in chairing: Michael Steindorfer*, Hyung-Chul Lim, Tomasz Suchodolski*)	3	2	1
Retro-reflectors (Interested in chairing: Stephen Merkowitz)	1	1	0
TOTAL	**40**		

II. Detailed schedule

- Local time of Kunming is UTC+8:00, the Beijing time zone
- Start time shifted to 9:00 in the morning, and 14:00 in the afternoon
- Splinter meetings put together

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Time(UTC+8)	Oct.20	Oct.21	Oct.22	Oct.23	Oct.24	Oct.25	Oct.26
9:00~10:00		Opening Session	Academical Reports	Academical Reports	Visit Fuxian-Lake Site	Academical Reports	End of the workshop
10:00~10:30		Tea Break	Tea Break	Tea Break		Tea Break	
10:30~12:00		Keynote Reports	Academical Reports	Academical Reports		Academical Reports	
12:00~14:00		Lunch	Lunch	Lunch		Lunch	
14:00~15:00	ILRS GB	Academical Reports	Academical Reports	MSC NESC		Closing Ceremony (GB included)	
15:00~15:30		Tea Break	Tea Break	Tea Break	Visit Kunming Station and Buffet Dinner		
15:30~18:00	ASC	Academical Reports	Academical Reports	NEWG LLR&T			
18:00~19:00	Buffet reception	Dinner					
19:00~20:30							

Presentations

- Presentation topics: Relevant to the SLR workshop themes, maje it informative, engaging and relevant to the audience.
- Oral report length: 20 minutes followed by 5 minutes questions/discussion. PPT, PPTX, and PDF format.
- Poster guidelines: 0.9 m wide x 1.2 m high, portrait orientation. Paper versions presented at the workshop, digital versions will be made available. PPT, PPTX, and PDF format.
- Networking sessions will also be set in October.

7817 YEBL Data Analysis

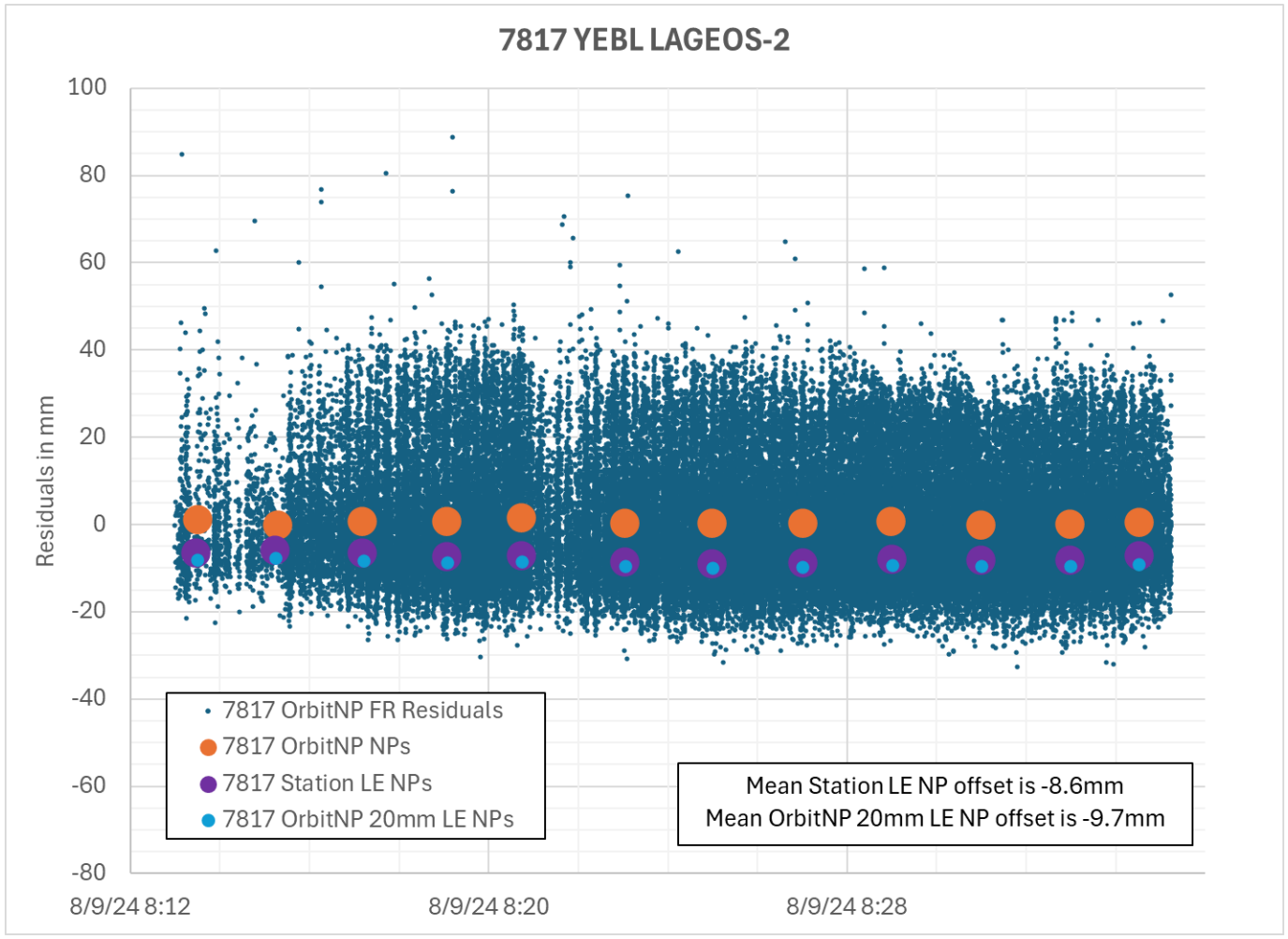
Van Husson

2-Sep-2024

7817 YEBL Fullrate and Normal Point Analysis Process

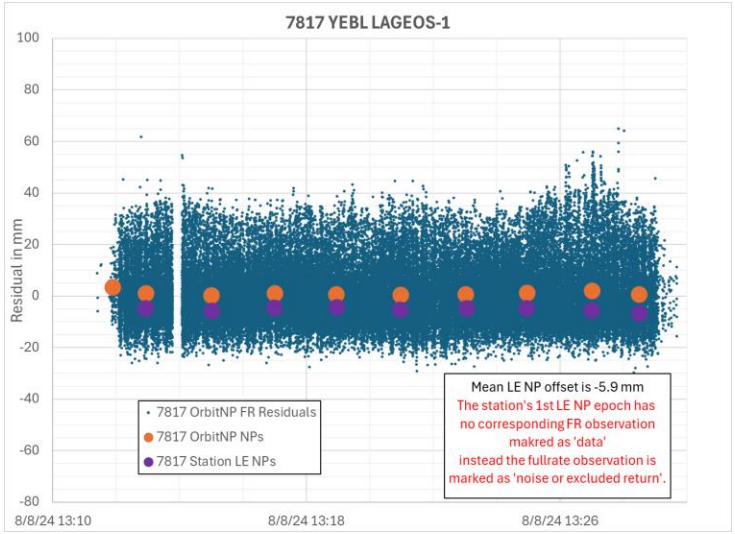
1. **Matt Wilkerson's OrbitNP program was used to analyze 7817 YEBL fullrate data**
   - OrbitNP inputs FullRate (FR) data and generates fullrate residuals and Normal Points (NPs) based on the FR 10-record filter flag, by default; only accepting data with a filter flag of '2' (data). There are other OrbitNP options to accept all FR data irregardless of the filter flag or apply different data filtering techniques (e.g. sigma or leading-edge filter). It plots the FR and NP residuals as a function of time and generates a residual histogram. The FR residuals and generated NPs are written to text files.
2. **Parse the OrbitNP FR residuals; OrbitNP NPs; and station generated NPs into Excel**
3. **Generate a time series of the OrbitNP FR residuals overlaying the OrbitNP NPs and the station generated NPs**
   - If the OrbitNP generated NPs and station generated NPs have the same epochs, the NP time-of-flights can be directly compared. Since the epochs are different this can't be done. However, by using the OrbitNP FR residuals it is possible to compare OrbitNP generated NPs to station generated NPs

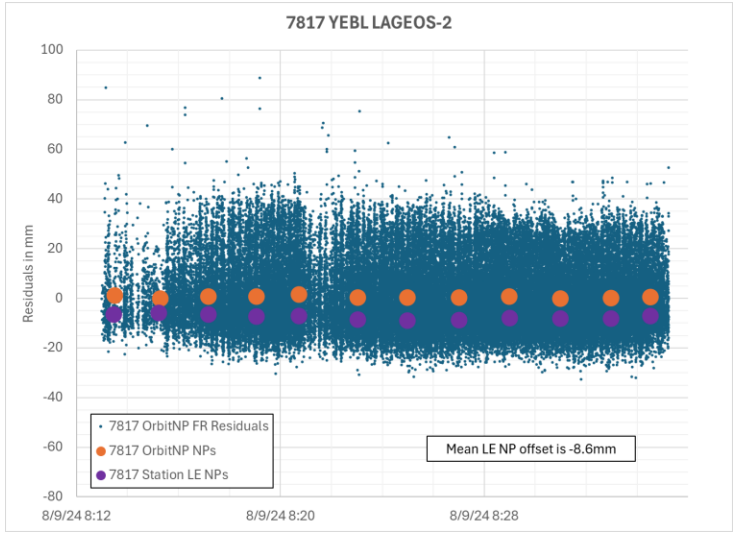
7817 YEBL OrbitNP Analysis Example

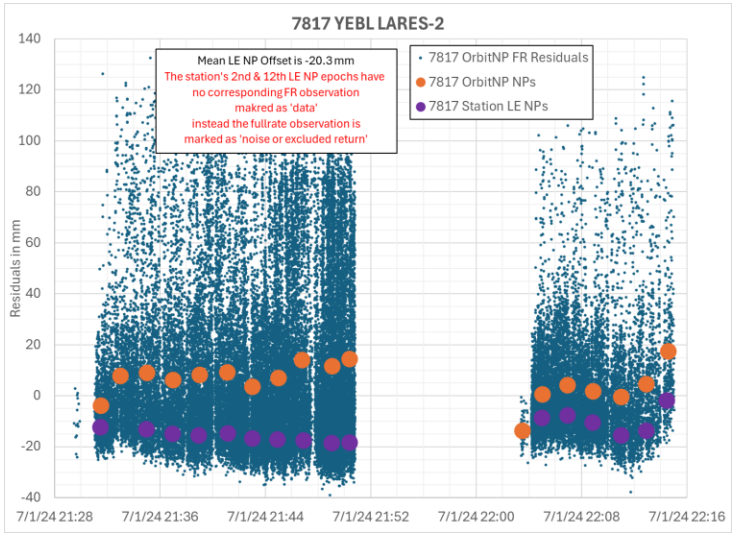


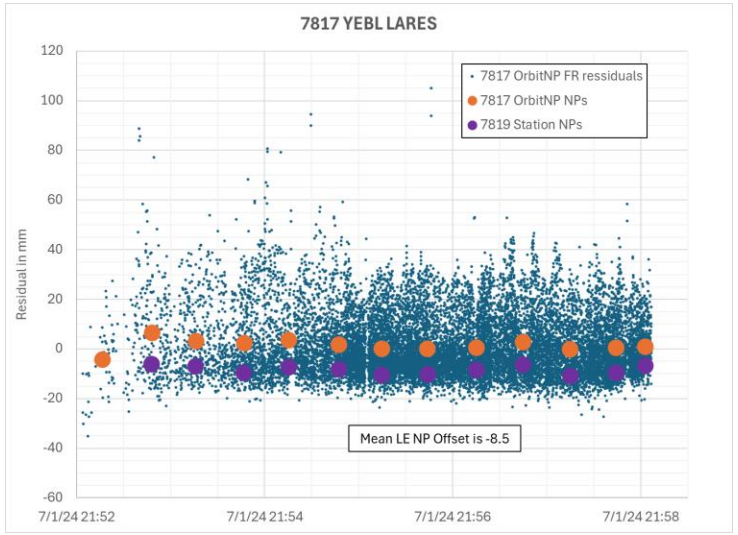
- Here is chart of OrbitNP 7817 FR residuals (small blue dots) based on the 'data' FR filter flag; OrbitNP generated NPs from the same FR (orange circles); the station generated NPs (purple circles); and the OrbitNP generated NPs using a 20 mm Leading-Edge (LE) filter (small light blue circles)
- Based on this analysis we can conclude; the station generated NPs were based on an ~20mm LE filter
- We can also conclude that if a default Center of Mass (CoM) is applied in the range bias analysis; 7817 NPs should appear to be biased short by several mm; assuming no other systematic errors and accurate station coordinates

7817 YEBL NP Analysis Examples from All Four Geodetic Satellites



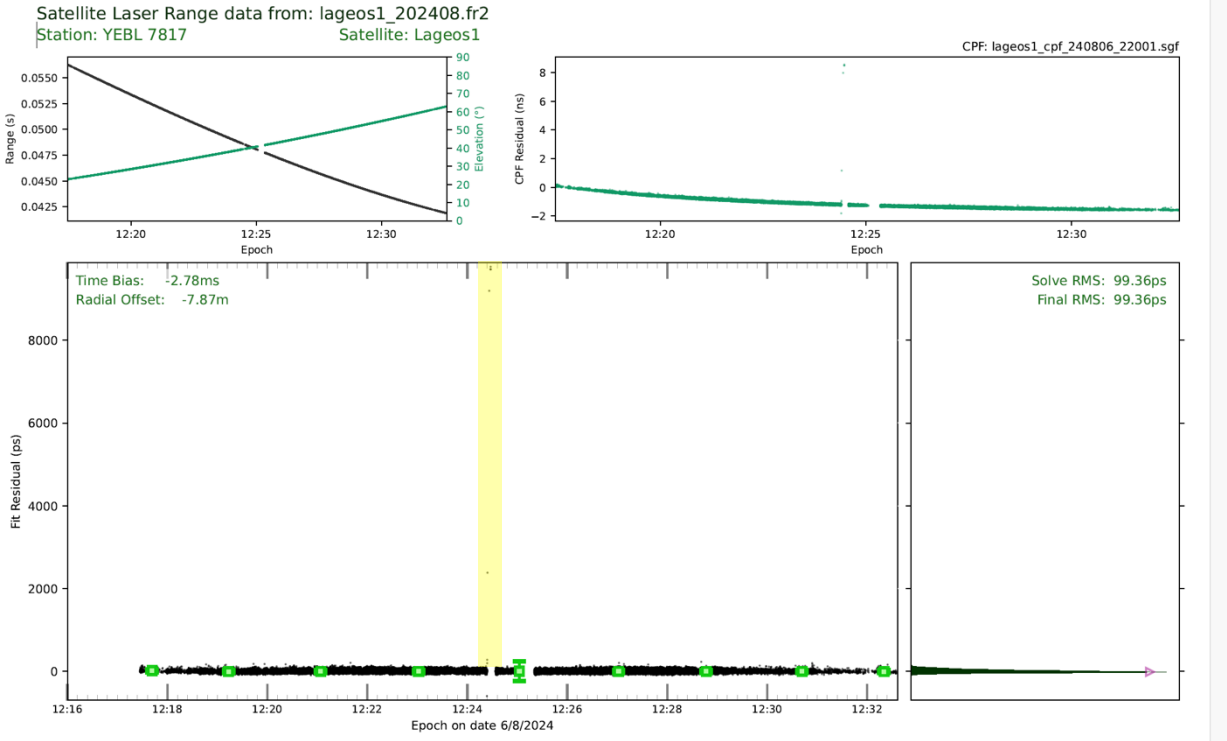


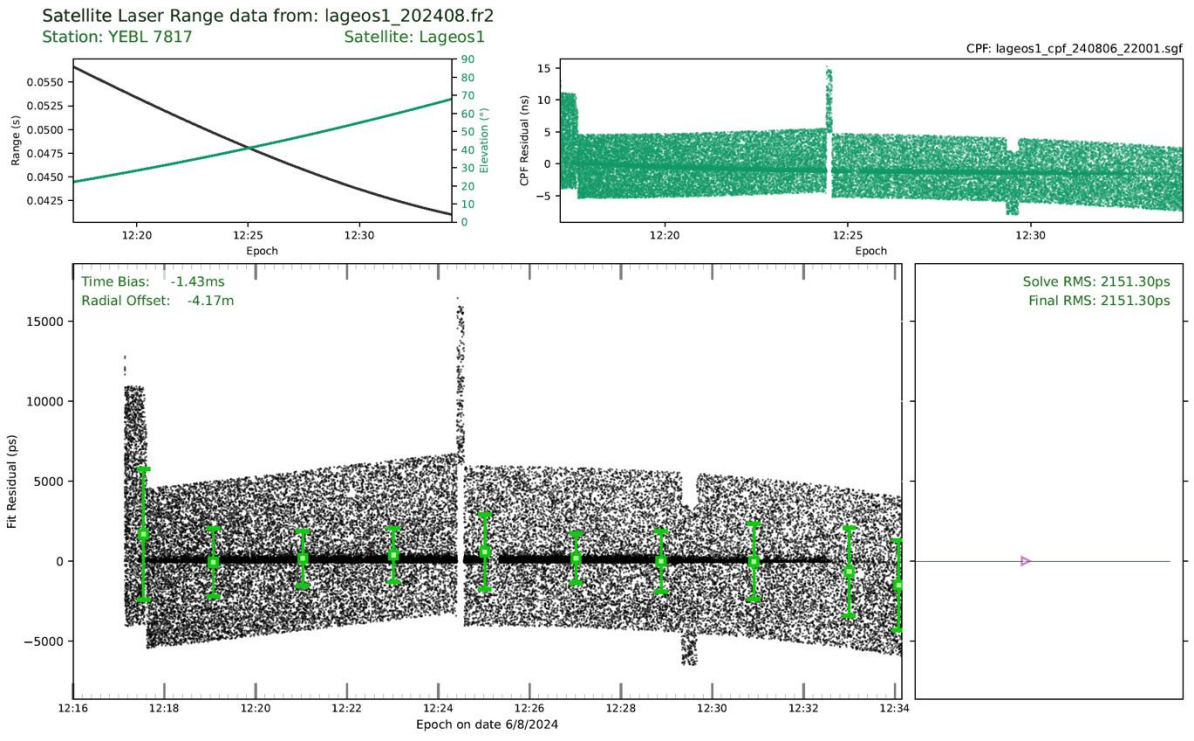




- Here are 4 random samples comparing the station generated NPs to the OrbitNP generated NPs using the station's fullrate data with a filter flag of '2' (i.e. data).
- There are some passes where the Epochs of the station generated NPs do not have a corresponding fullrate observation that is flagged as 'data'. Instead the corresponding fullrate observation is flagged as a '1' (noise or excluded returns). The two passes on the left side are examples of this. This issue could be a software bug, because according to Herstmonceux NP definition, the NP epoch should exactly match an epoch of an 'accepted' fullrate observation

7817 YEBL LAGEOS-1 OrbitNP Screen Shots



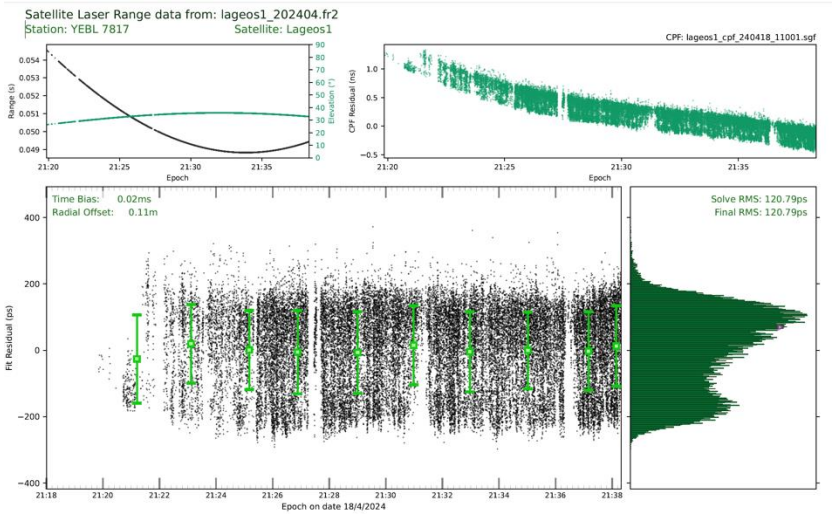


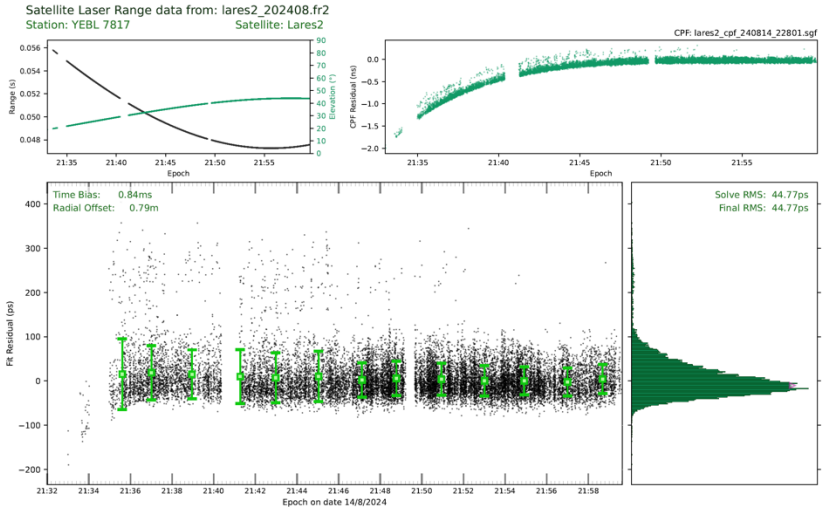
- **The left set of OrbitNP charts only contain fullrate data that is flagged as data (filter flag ‘2’); while the right set of charts contain data plus noise and excluded returns (a filter flag of ‘1’). The left chart indicates some noise in the middle of the pass was erroneously flagged as data and why OrbitNP didn’t converge on just the real data**

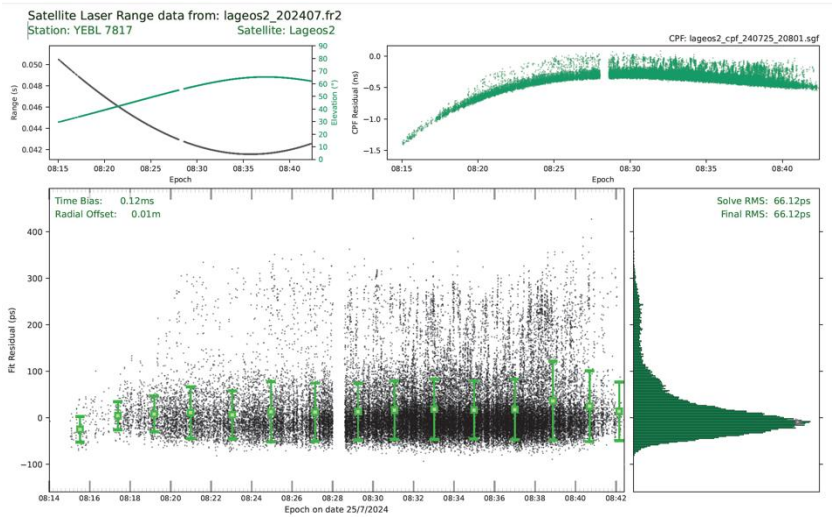
7817 YEBL Findings

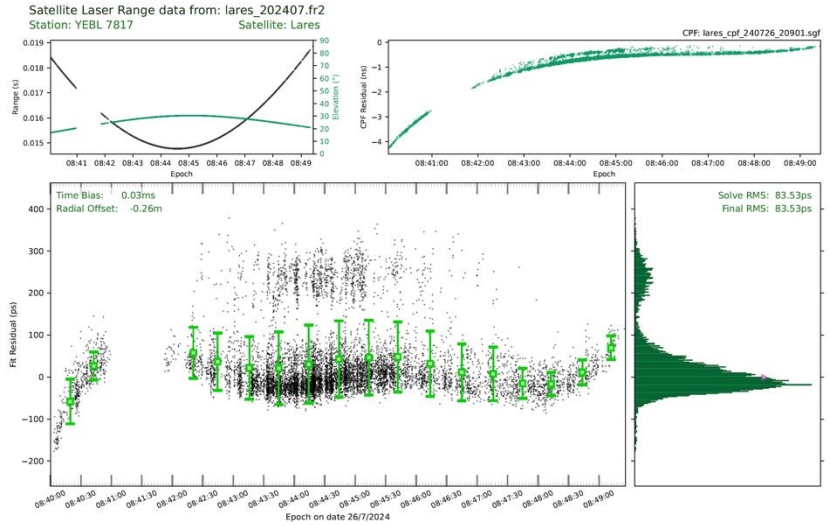
- It appears a LE filter is being applied to all 4 geodetic satellites (LAGEOS-1, LAGEOS-2, LARES, LARES-2). Please update your Site Log Section 10: Preprocessing Information to indicate which satellite(s) has/have a LE filter applied under Additional Comments (See 7306 TKBL's site log at https://ilrs.cddis.eosdis.nasa.gov/network/stations/active/TKBL_station_info.html?log#10.%20%20%20Preprocessing%20Information as an example to update this section)
- In some passes, the filter flag is not properly set (noise/excluded returns are sometimes flagged as data and data is sometimes flagged as noise/excluded returns). Not sure if this is a software and/or operator issue

7817 YEBL OrbitNP Residual Distributions



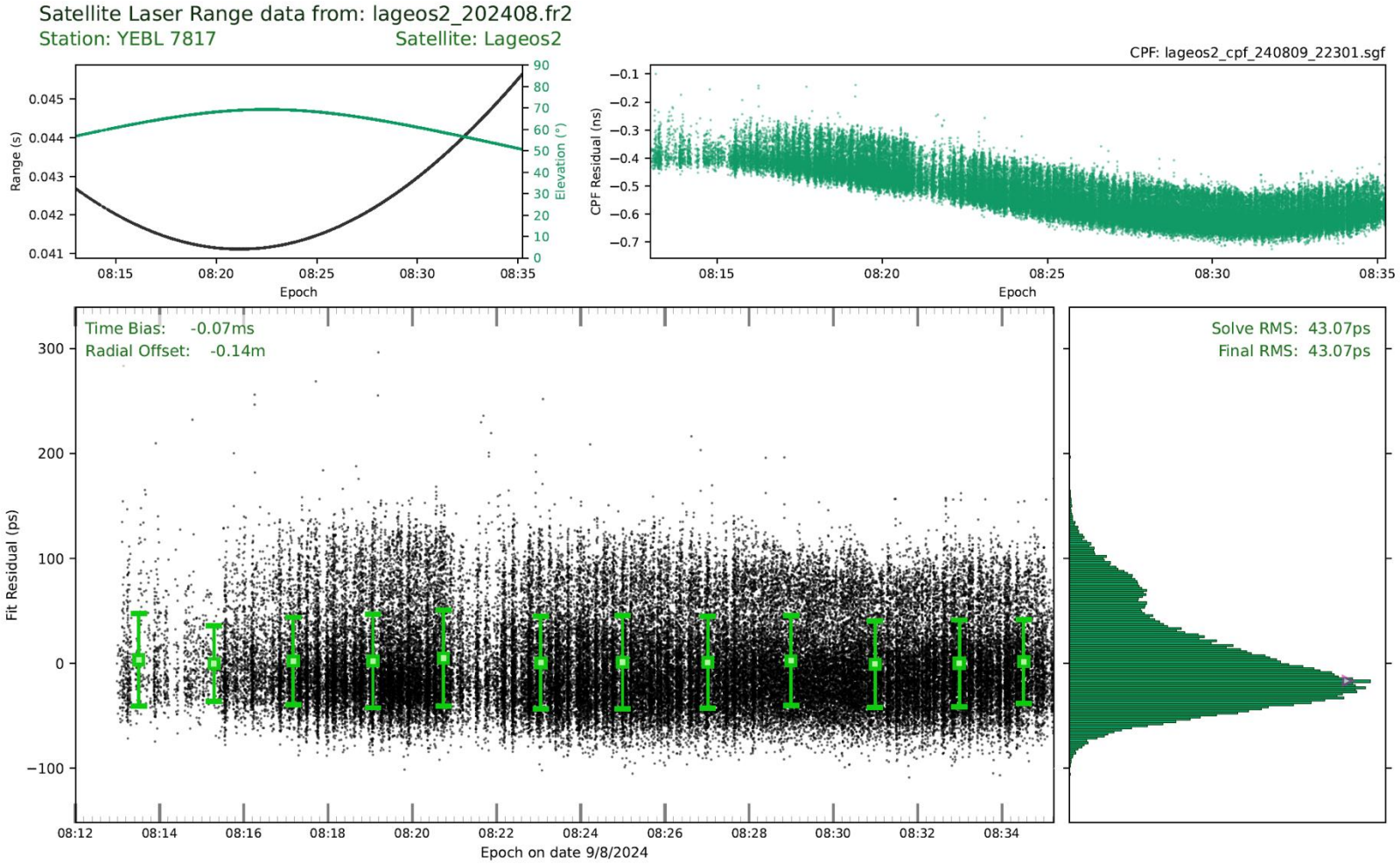






- Here are examples of residuals from the four different geodetic satellites showing some evidence of second distribution of data about +200 ps (+60 mm). On the LAGEOS-1 chart (top left) the distributions are almost 300 ps (90 mm) apart.
- Are all these signatures from the satellites, even on LARES (bottom right)?
- No matter the cause, applying a LE filter probably improves the accuracy of the NP data.

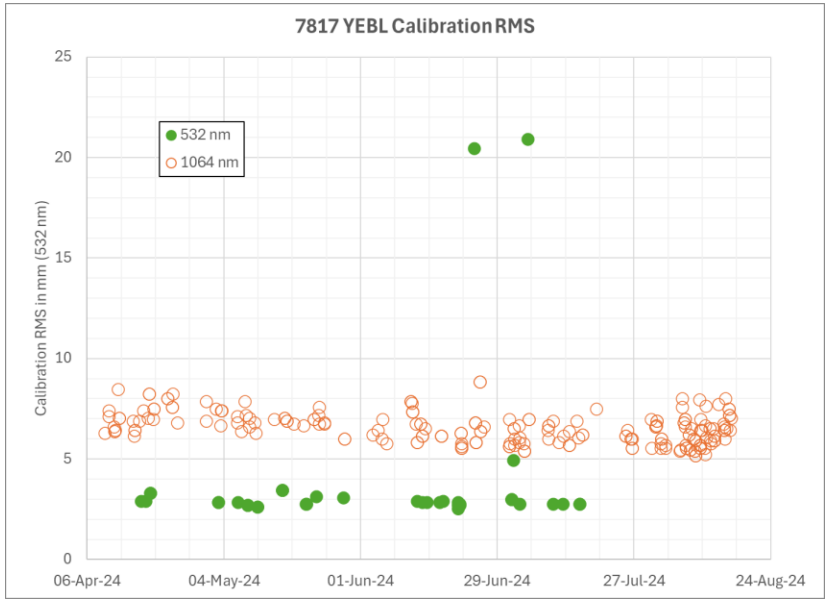
7817 YEBL OrbitNP Residual Distribution

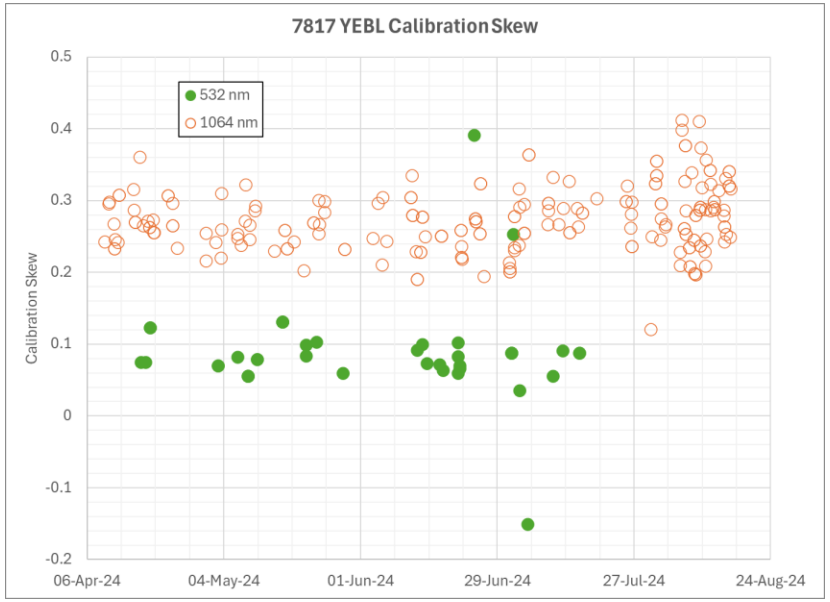


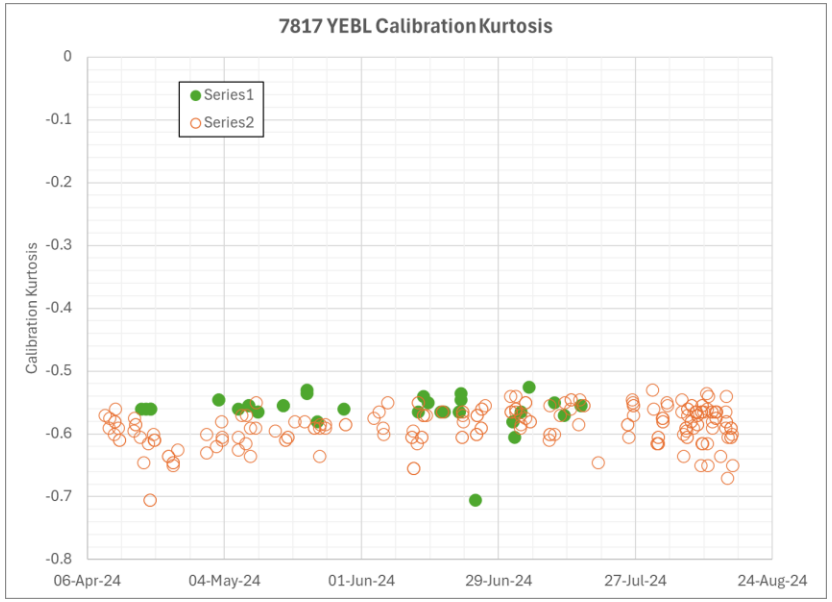
- There appears to be a Zebra pattern in the residuals on this pass. Just curious to the cause of this pattern because other passes seem to exhibit a similar pattern.

7817 YEBL Calibration and Satellite Moment (RMS, skew, kurtosis, peak minus mean) Analysis

7817 YEBL Calibration Moments (RMS, Skew, Kurtosis)

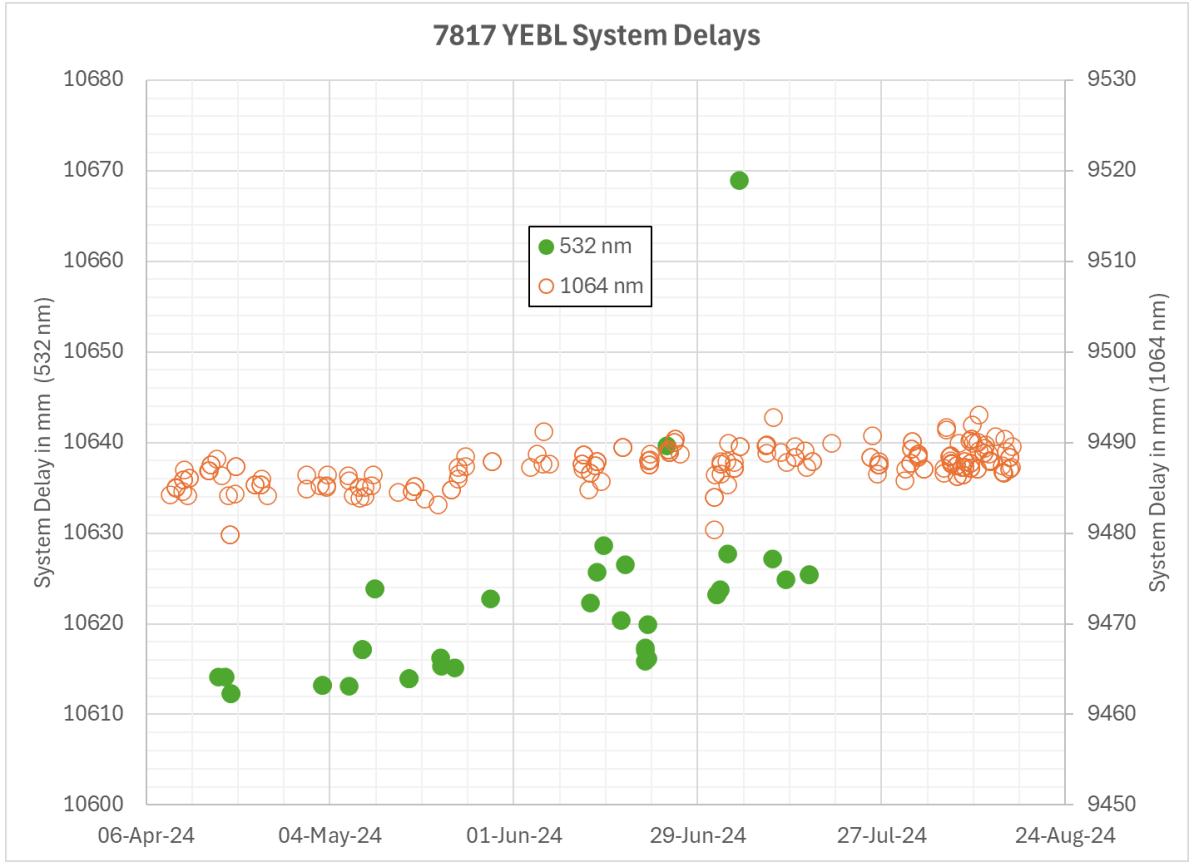


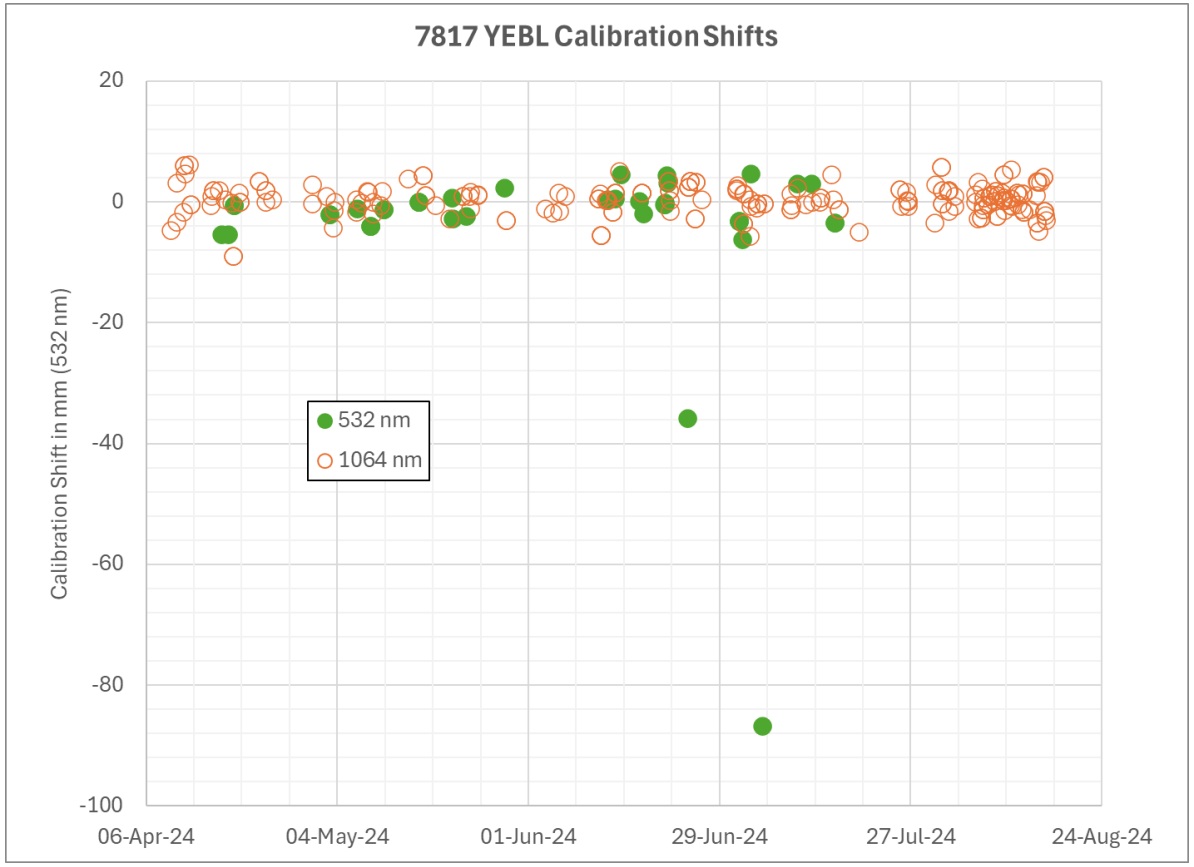




- ❑ According to the site log, an iterative 2.2 sigma filter is being applied to the calibration data
- ❑ The green calibration RMSs tend to be lower but have a few outliers
- ❑ The infrared calibration data is more skewed
- ❑ The calibration kurtosis from both wavelengths are similar

7817 YEBL System Delay Stability





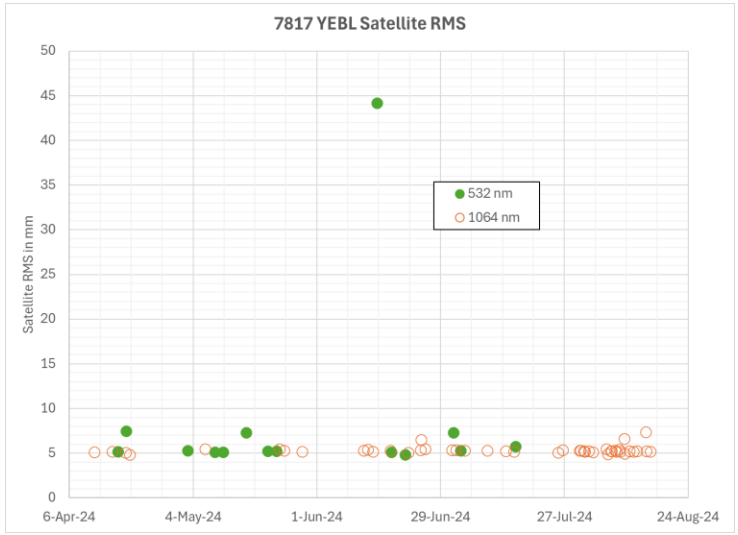
- The infrared system delays are more stable. Two of the green calibrations; LARES-2 on 24-Jun-2024 and LAGEOS-2 on 5-Jul-2024 seemed to be outliers

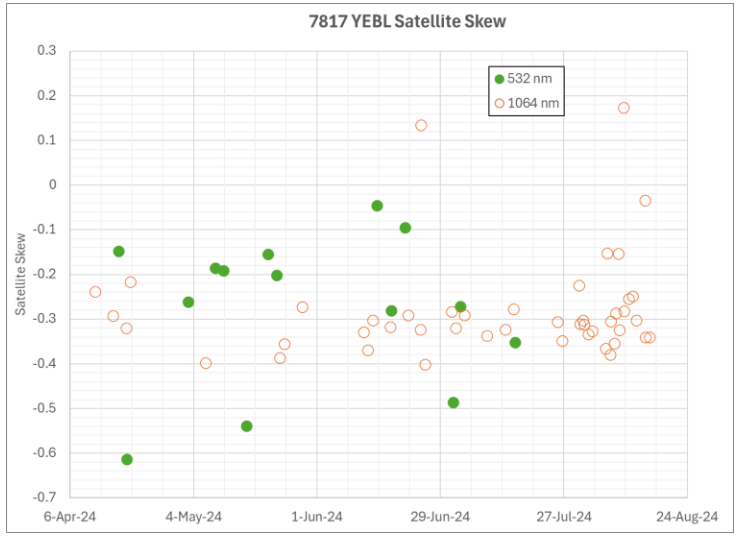
7817 YEBL Satellite Moments and Peak minus Means Summary

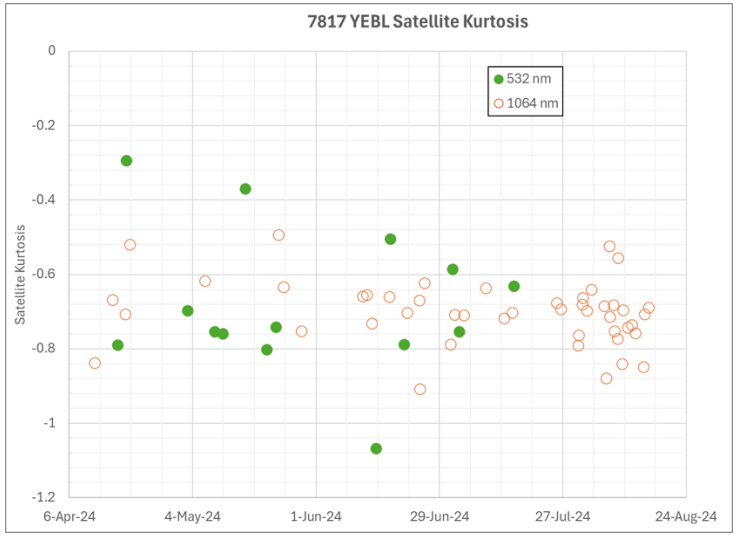
	1064 nm							532 nm						
Satellite	Sat RMS (mm)	Sat RMS Stdev (mm)	Satellite Skew	Skew Stdev	Kurtosis	peak - mean (mm)	Pass Segments	Sat RMS (mm)	Sat RMS Stdev (mm)	Satellite Skew	Skew Stdev	Kurtosis	peak - mean (mm)	Pass Segments
LAGEOS-1	5.34	0.43	-0.28	0.12	-0.70	0.33	46	8.47	10.32	-0.27	0.17	-0.68	0.34	14
LAGEOS-2	5.39	0.39	-0.30	0.10	-0.70	0.39	67	7.63	5.29	-0.31	0.29	-0.60	0.40	12
LARES	7.11	1.23	0.13	0.09	-0.60	0.03	57	6.00	1.34	0.17	0.08	-0.63	-0.02	7
LARES-2	6.72	1.64	0.00	0.21	-0.75	0.18	49	7.39	4.94	-0.02	0.28	-0.74	-0.09	7
Grand Total	6.13	1.30	-0.12	0.23	-0.69	0.24	219	7.60	6.94	-0.16	0.28	-0.66	0.22	40

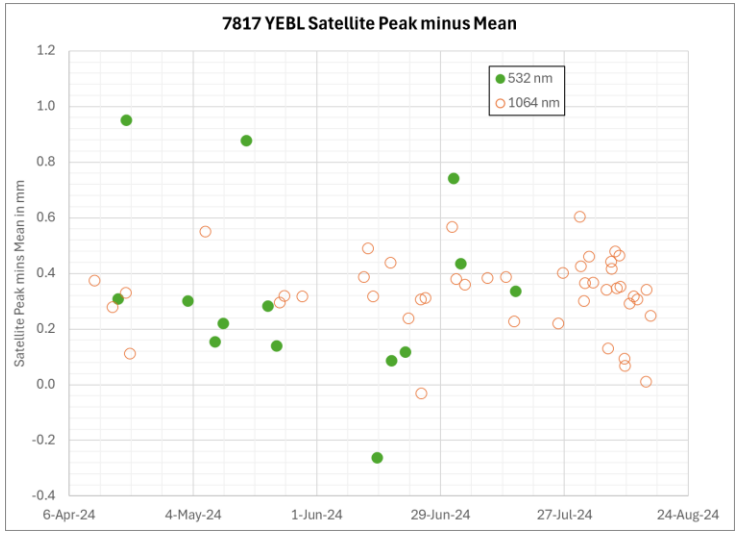
- **The 1064 LAGEOS-1 and LAGEOS-2 moments were the more consistent than 532 LAGEOS-1 and LAGEOS-2 moments and were more consistent than the 1064 and 532 LARES and LARES-2 moments**
- **Since the LARES and LARES-2 RMSs were higher than LAGEOS-1 and LAGEOS-2; is a different LE filter applied to all four satellites (e.g. 20 mm for LAGEOS-1 and LAGEOS-2 and 30 mm for LARES and LARES-2)?**

7817 YEBL LAGEOS-1 Moments and Peak minus Means



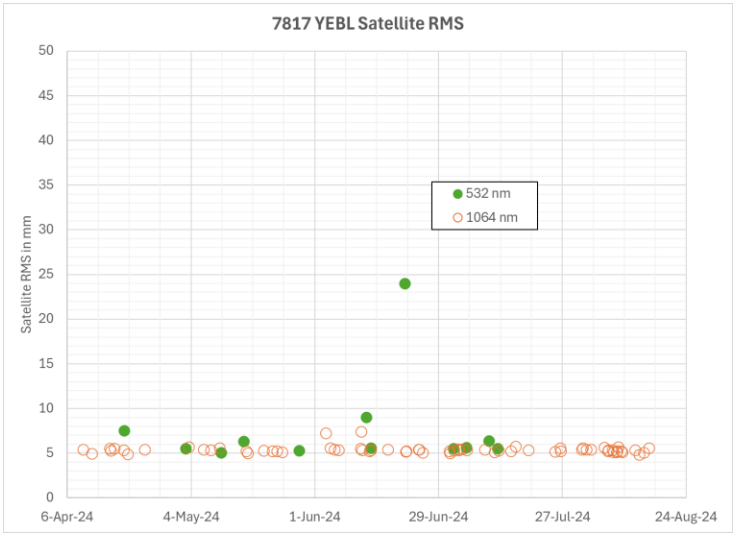


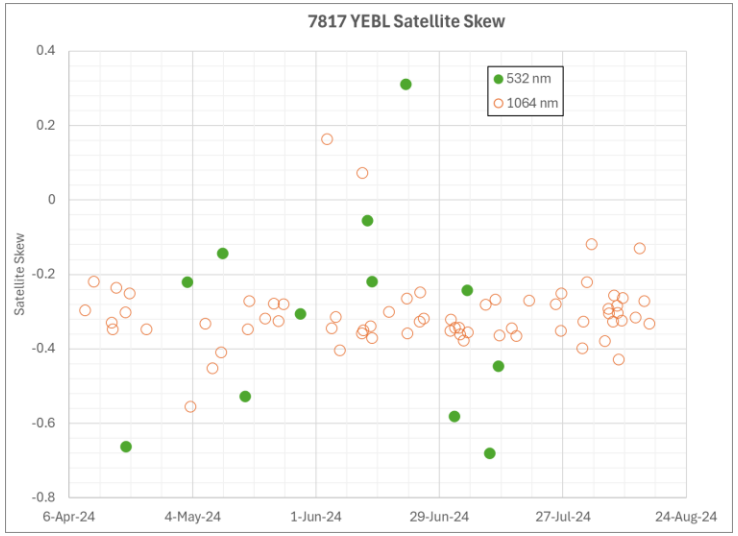


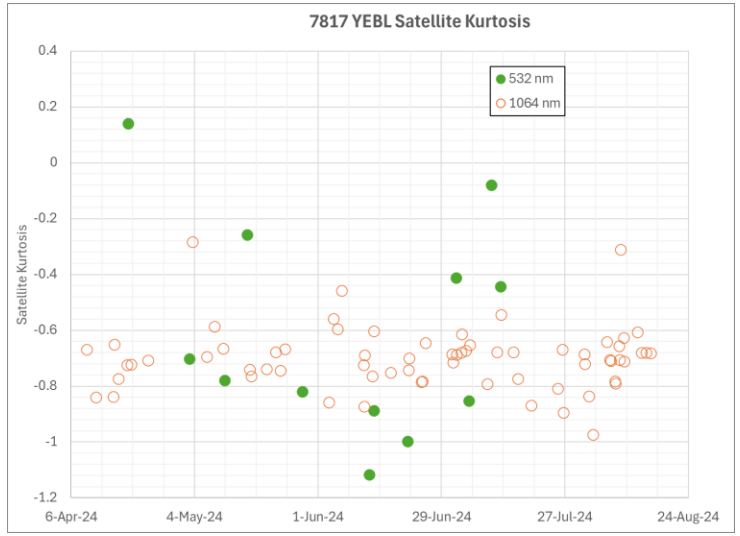


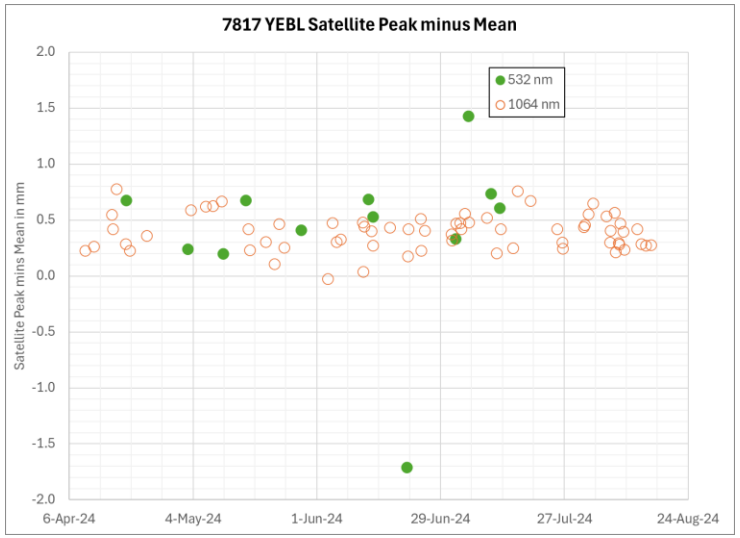
- Based on the satellite RMS, the green LAGEOS-1 pass on 14-Jun-2024 at 14:07 may not have had a LE filter applied.
- In general, the infrared LAGEOS-1 moments were more consistent than the green moments.

7817 YEBL LAGEOS-2 Moments and Peak minus Means



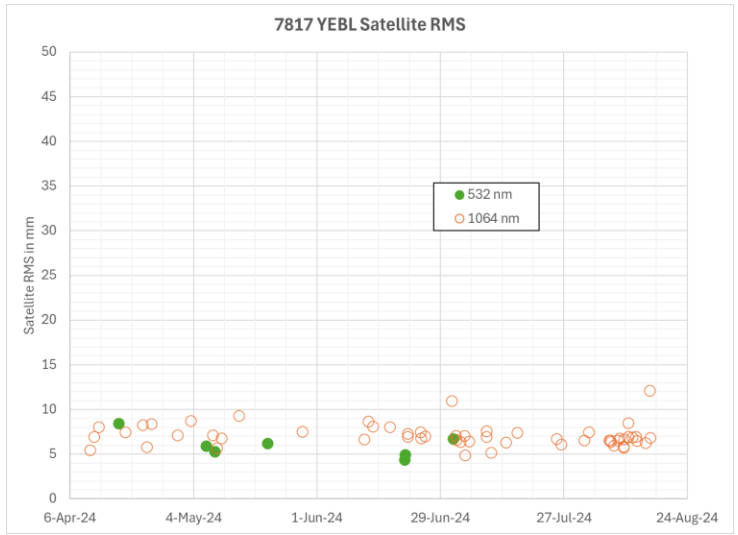


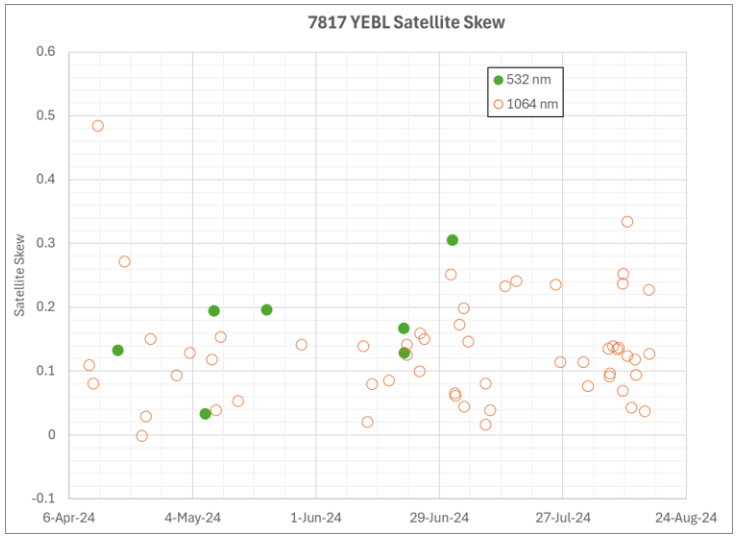


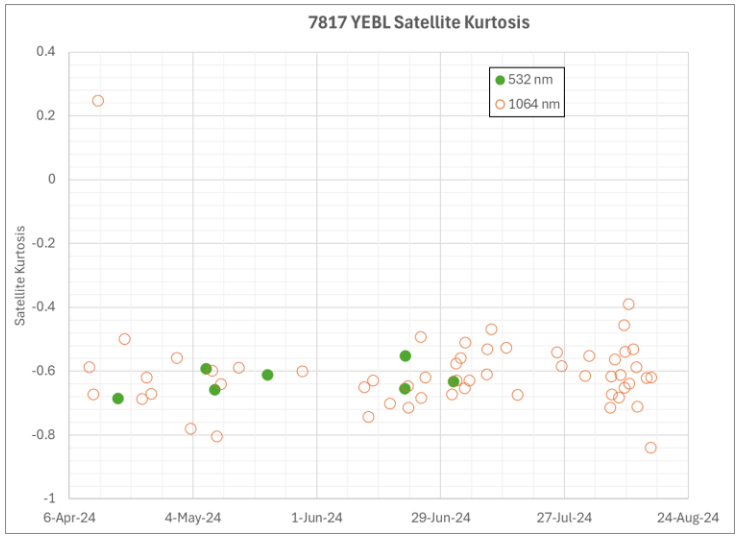


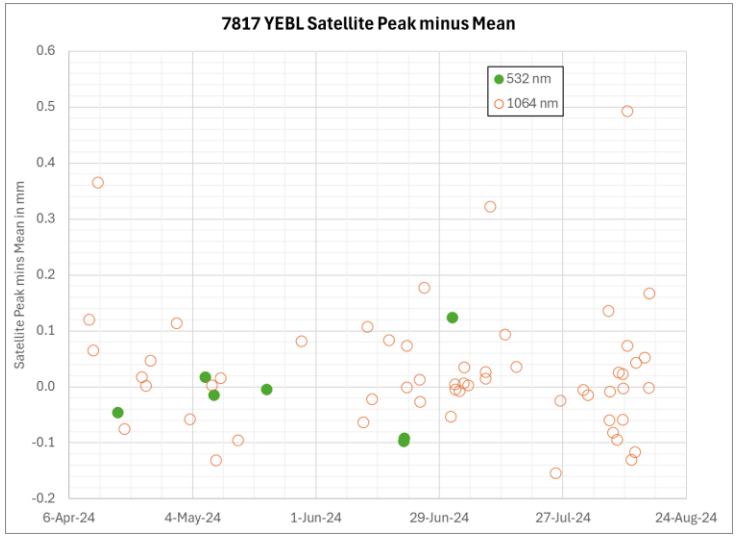
- ❑ **Based on the satellite RMS, skew and peak-mean, the green LAGEOS-2 pass on 21-Jun-2024 at 08:17 may not have had a LE filter applied.**
- ❑ **In general, the infrared LAGEOS-2 moments were more consistent than the green moments.**

7817 YEBL LARES Moments and Peak minus Means



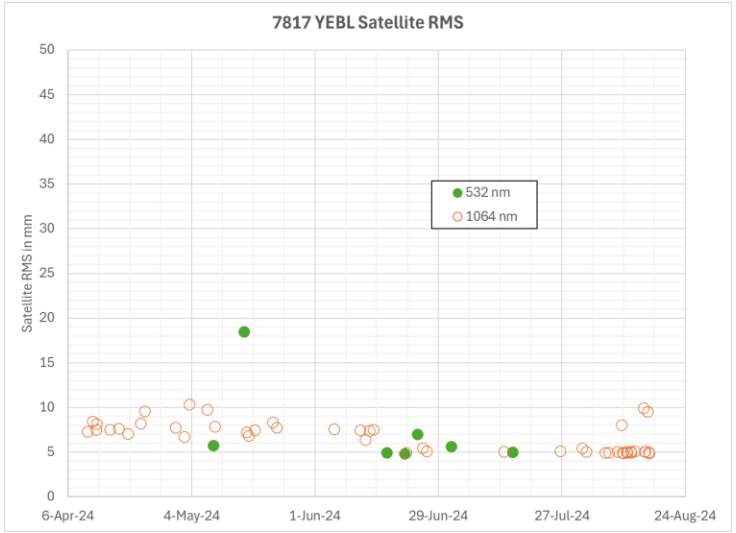


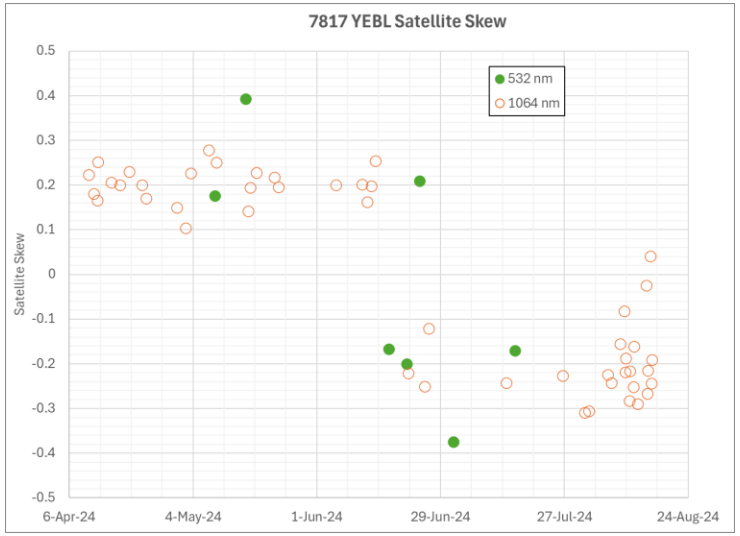


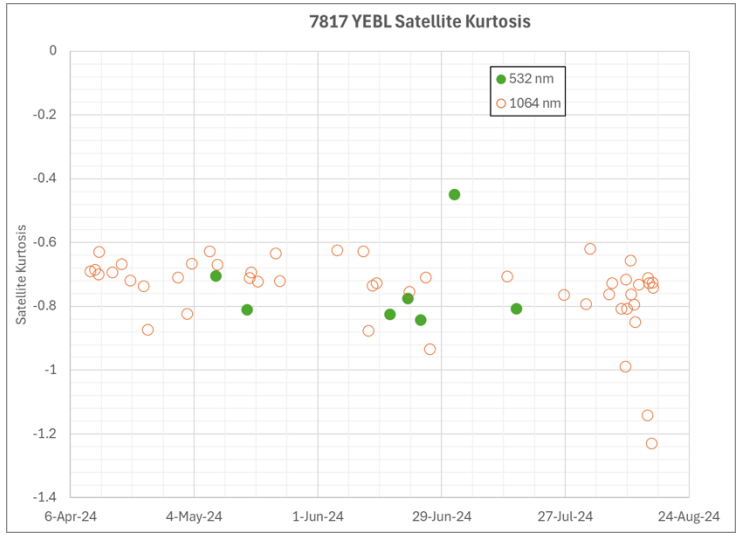


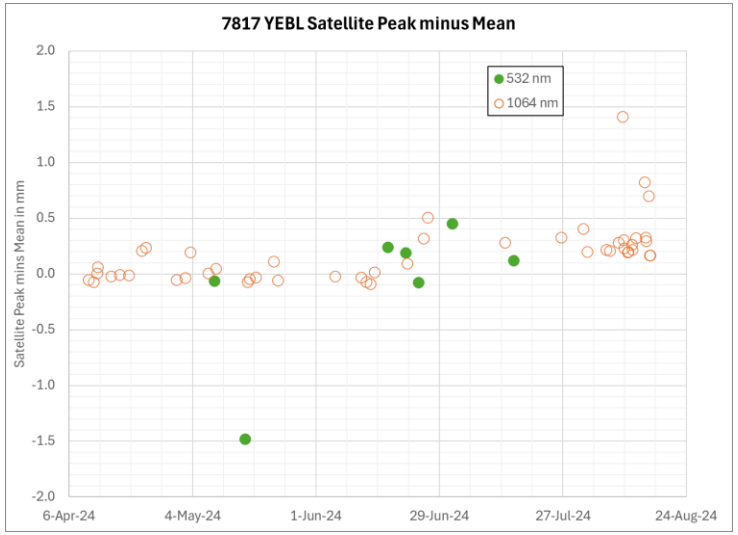
- **Since the LARES RMSs are higher than LAGEOS-1 and LAGEOS-2 is a different LE filter applied?**

7817 YEBL LARES-2 Moments and Peak minus Means

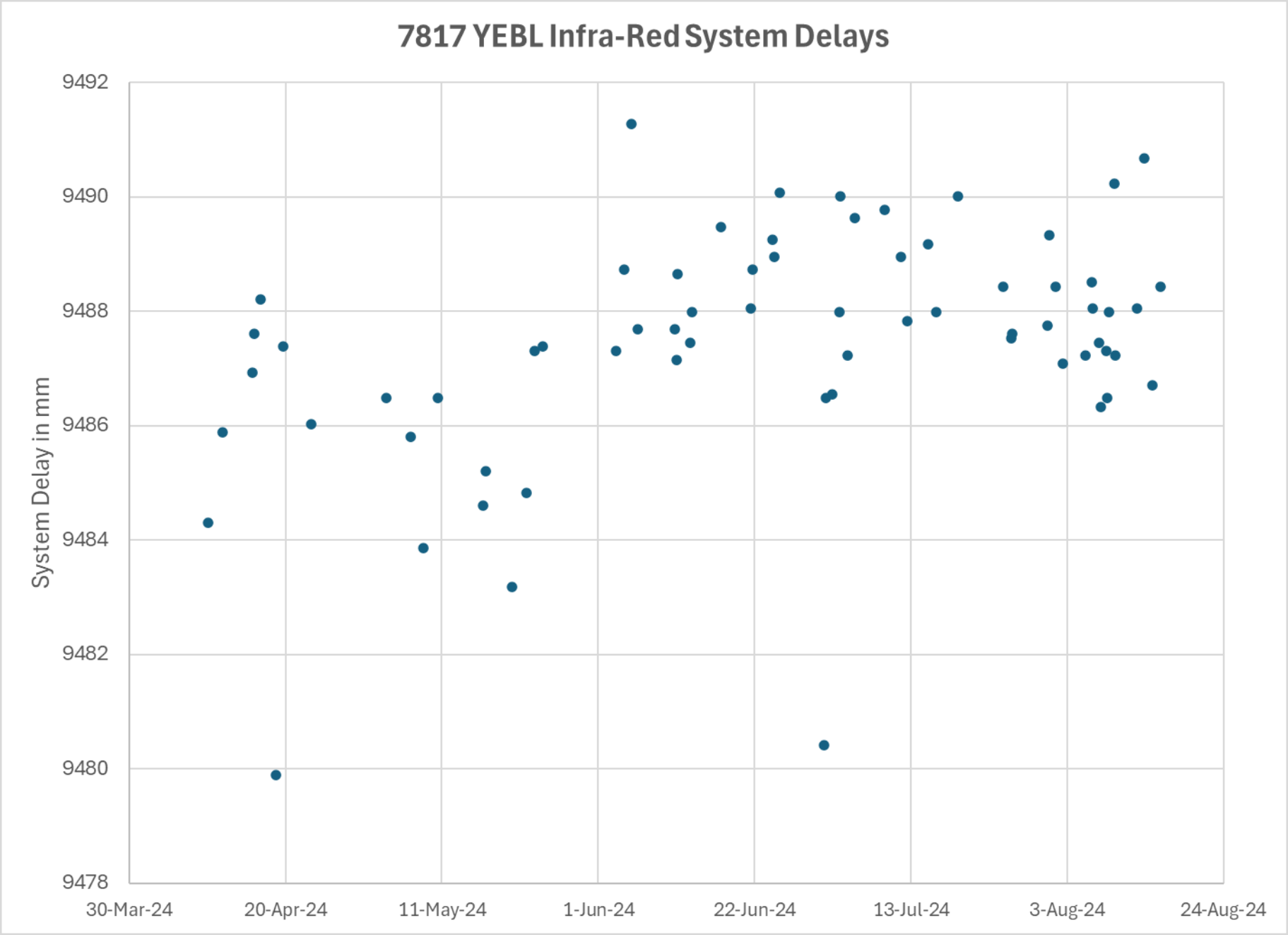








- **There is an obvious change in LARES-2 skew starting on 17-Jun-2024, was the LARES-2 LE filter changed on this date?**


7817 YEBL Infra-Red System Delays
System Delay in mm
9492
9490
9488
9486
9484
9482
9480
9478
30-Mar-24
20-Apr-24
11-May-24
1-Jun-24
22-Jun-24
13-Jul-24
3-Aug-24
24-Aug-24

LAGEOS-1

78176211 L1	PREC EST [mm]	RANGE BIAS [mm]
Mean	2.4	-6.5
STD	1.2	13.5
RMS	2.7	14.9
Passes	40	40

LAGEOS-2

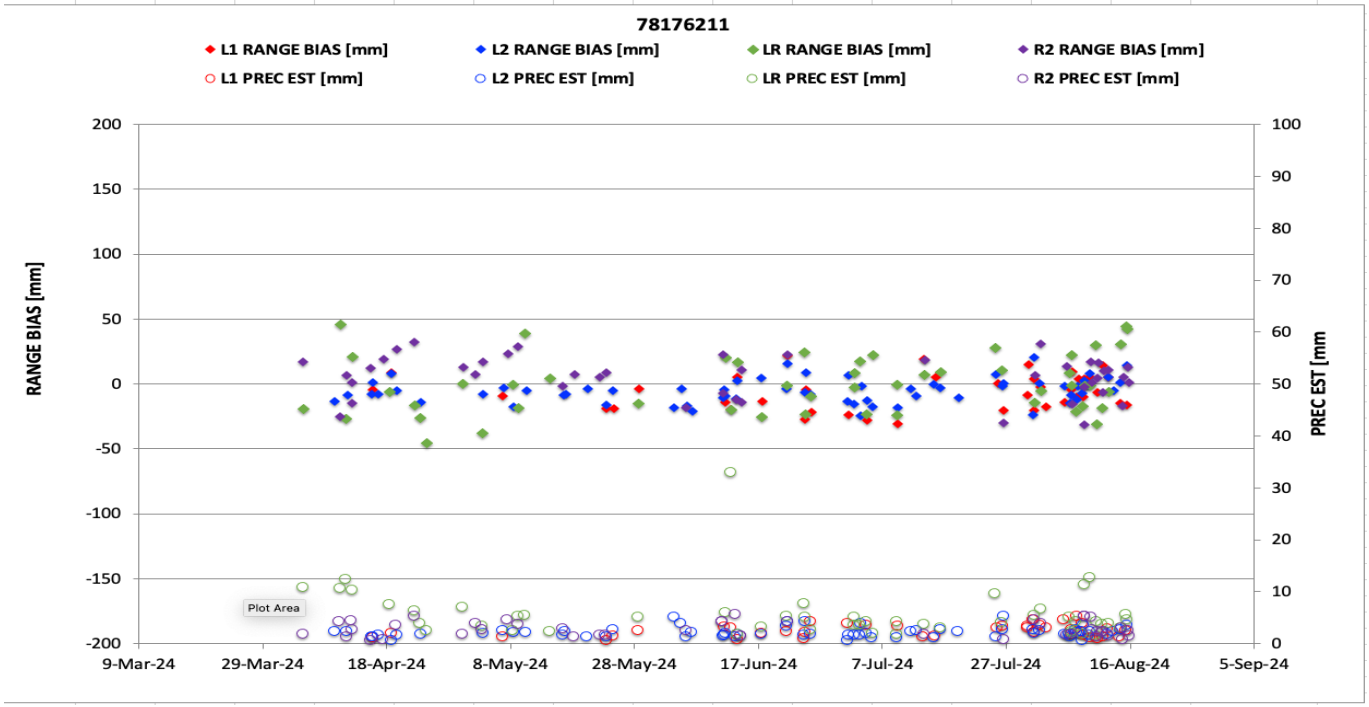
78176211 L2	PREC EST [mm]	RANGE BIAS [mm]
Mean	2.1	-5.3
STD	1.0	9.3
RMS	2.3	10.6
Passes	65	65

LARES-2

78176211 R2	PREC EST [mm]	RANGE BIAS [mm]
Mean	2.7	5.3
STD	1.5	16.0
RMS	3.1	16.7
Passes	44	44

LARES

78176211 LR	PREC EST [mm]	RANGE BIAS [mm]
Mean	5.6	-0.2
STD	4.9	22.4
RMS	7.4	22.2
Passes	50	50



NASA/GSFC & UMBC: M. Kuzmicz-Cieslak, F. G.Lemoine, A. Belli. October 3, 2024

Dear all:

Based on our QC analysis, the Yebes (7817) system has now completed successfully the validation process and we can release it from quarantine.
The system demonstrates a 2.1 to 2.7 mm NP precision on the two LAGEOS and LARES-2 targets, and about 5.6 mm on LARES. The QC results show negligible biases to within the statistical uncertainty of the analyses. The present analyses were conducted with the laser ranging data at 1064 nm, and the default values for the satellite CoM offsets. We used the following number of passes to complete the analysis: L1 (40), L2 (65), LR2 (44), LR1(50). We thank the station for providing more than adequate number of passes at 1064 nm to complete the validation. The ASC will need to monitor the performance at 532 nm as we have had an insufficient number of passes to qualify the performance at this wavelength so far.

We did try adjusting the station coordinates with L1+L2 or L1+L2+LR2 data, while we saw an improvement in the station data precision (1.7 to 1.9 mm on L1 & L2), we saw an increase in the absolute value of the mean biases on the LAGEOS satellites. This seems an undesirable result, and might be tied to the use of the a prior (default) values of station-COM offset for the geodetic satellites. In addition, Van Husson reports (*after tests using Matt Wilkinson's program orbitNP*) that the current data from Yebes seems consistent with normal points being produced by a leading edge filter, rather than a 2.2 sigma edit criterion. Therefore for the time being we recommend using the original coordinates provided by José Rodriguez until the ASC can study these points and provide a Yebes-station-dependent CoM model for the geodetic satellites. The ASC can readjust the coordinates at a later when more months of Yebes data are available and these issues are clarified. In any event, the current coordinates provide excellent performance for the station and its integration in the daily and weekly ILRS reference frame solutions.

STAX 77881177 A 1 15:001:00000 m 2 0.484874726680000E+07 0.50000E+00
STAY 77881177 A 1 15:001:00000 m 2 -.261792742500000E+06 0.50000E+00
STAZ 77881177 A 1 15:001:00000 m 2 0.412306010700000E+07 0.50000E+00
VELX 77881177 A 1 15:001:00000 m/y 2 -.100232390946555E-01 0.10000E-01
VELY 77881177 A 1 15:001:00000 m/y 2 0.196168211104461E-01 0.10000E-01
VELZ 77881177 A 1 15:001:00000 m/y 2 0.121571251674908E-01 0.10000E-01

All of the quarantined data should be placed in the public domain after the station receives the usual congratulatory message from the CB.

A congratulatory message should be sent now to the station from the the ILRS CB, and the station can be welcomed to the network and
the station data can be included in the routine analyses and products.

Frank, Magda & Alex & Van
(On behalf of the ILRS ASC & ILRS CB)