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Effective expansion of satellite laser ranging network to improve global geodetic parameters

Toshimichi Otsubo[1*], Koji Matsuo[2], Yuichi Aoyama[3], Keiko Yamamoto[4], Thomas Hobiger[5], Toshihiro Kubo-oka[6] and Mamoru Sekido[6]

Abstract

The aim of this study is to find an effective way to expand the ground tracking network of satellite laser ranging on the assumption that a new station is added to the existing network. Realistic numbers of observations for a new station are numerically simulated, based on the actual data acquisition statistics of the existing stations. The estimated errors are compared between the cases with and without a new station after the covariance matrices are created from a simulation run that contains six-satellite-combined orbit determination. While a station placed in the southern hemisphere is found to be useful in general, it is revealed that the most effective place differs according to the geodetic parameter. The X and Y components of the geocenter and the sectoral terms of the Earth's gravity field are largely improved by a station in the polar regions. A middle latitude station best contributes to the tesseral gravity terms, and, to a lesser extent, a low latitude station best performs for the Z component of the geocenter and the zonal gravity terms.

Keywords: Space geodesy, Satellite laser ranging, Geodetic satellites, Terrestrial reference frame, Earth gravity field, Global geodetic observing system

Introduction

Satellite laser ranging (SLR) is a high-precision measurement technique for the two-way distance between a ground station and an artificial satellite, and it has been regarded as one of the key elements of global-scale geodesy (Pearlman et al. 2002). SLR data have been used to determine satellite orbits and retrieve global-scale geodetic products. In particular, it has provided the origin (three components) and the scale (one component) of the latest International Terrestrial Reference Frames (e.g., Altamimi et al. 2011; IGN 2016) and also gravity coefficients of the Earth (e.g., Reigber 1989).

The origin of terrestrial reference frames has been defined as a long-term average of the geocenter, that is, the gravity center of the Earth, but annual and interannual variations of the geocenter have also been observed from SLR data (e.g., Chen et al. 1999; König et al. 2015). The gravity field also varies in time, and SLR has played an important role in long-term monitoring of low-degree terms (e.g., Cox and Chao 2002; Sośnica et al. 2015). These global-scale geodetic products have helped to understand global-scale mass transfers such as ice mass depletion in the polar regions (Nerem and Wahr 2011; Matsuo et al. 2013).

SLR is composed of its satellite segment and its ground segment. In space, dozens of artificial satellites equipped with retroreflectors have been launched into various types of orbits. Among them spherical-shaped geodetic satellites are often used for the determination of terrestrial reference frames and Earth gravity fields. As for the ground segment, about 40 laser-tracking stations all over the world are routinely operational (ILRS 2016a) where the majority of them has now attained sub-centimeter precision (Otsubo et al. 2015).

Realizing the importance of uniform global station coverage, the SLR community has been extending the

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network during the last decade by building stations, especially in the southern hemisphere and recently in Russian territory, but there are still some gaps remaining on the globe. Pavlis and Kuzmicz-Cieslak (2008) showed that geodetic products such as the origin and the scale of a terrestrial reference frame can be improved by 50 % or more when the number of laser ranging stations increases from 8 to 32, assuming reasonably uniform station distributions and perfect collocation with four techniques, i.e., SLR, VLBI (Very Long Baseline Interferometry), GNSS (Global Navigation Satellite Systems) and DORIS (Doppler Orbitography and Radiopositioning Integrated by Satellite).

In this paper, we focus on the SLR ground segment and, through a numerical simulation study, discuss what the best way is to reinforce the existing SLR ground network. We look at several geodetic parameters in this study, and the best position for a new SLR station may depend on a geodetic parameter. The simulation analysis in this study is composed of two parts. First, a set of virtual SLR data is generated for any position on the Earth. Then, the data set, combined with the actual SLR data, is processed by our orbit determination software so that we can compare the estimated formal errors.

Data acquisition simulation

In this section, the planning of the simulated observations is outlined. The inclination angle of a satellite orbit, combined with the altitude, significantly affects its observability, which depends on the latitude of a ground station. This is shown in Fig. 1 where the number of all fly-over normal points during a 1-year span is plotted for the six geodetic satellites, LAser GEOdynamics Satellite (LAGEOS)-1, LAGEOS-2, Ajisai, LAser RElativity Satellite (LARES), Starlette and Stella, with the sky coverage being defined above 20 degrees of elevation. Visibility of low-orbit satellites is heavily dependent on their inclination angles. For instance, Ajisai and Starlette cannot be seen from the polar regions at all due to their inclination angles of 50 degrees. Even the LARES satellite whose inclination is about 70 degrees is not observable from the poles, whereas Stella, with its highly inclined orbit, can be seen more often from the polar regions. On the other hand, despite the similar inclination angles, the two LAGEOS satellites can be seen from any point on the Earth due to their higher altitudes around 6000 km. What is notable is that a station in a higher latitude has more chances to observe the highly inclined LAGEOS-1 satellite because the satellite flies over the polar regions every revolution.

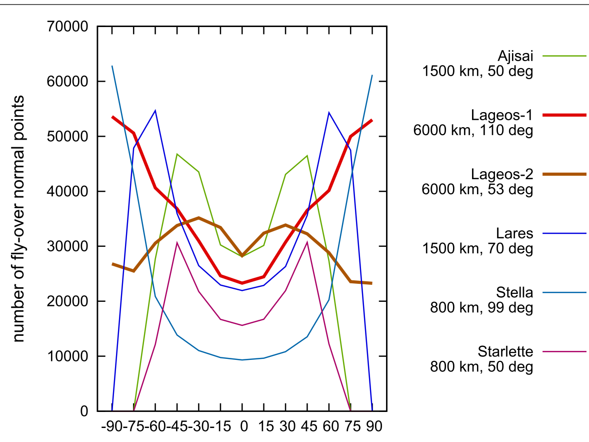

Fig. 1 Number of fly-over normal points with respect to the latitude (in degrees) of a ground station, for six geodetic satellites during a 1-year period from July 2014 to June 2015. The distance (km) and the angle (degrees) in the legend are the altitude and the inclination of satellite orbits

A normal point is a compressed form of a ranging observation made from a number of actual shot-by-shot measurements per a certain duration, 2 min for the LAGEOS satellites and 30 s for Ajisai, LARES, Starlette and Stella (ILRS 2016b). The six-satellite-combined number of fly-over normal points is maximized at around 45 degrees of latitude, and it does not vary much (10 % or less) in regions from 30 to 75 degrees. However, it drops by 18 % at the poles and 30 % around the equator. Due to the difference in the normal-point bin size, 2 min and 30 s, the total duration of the observable time for the two LAGEOS satellites is much longer than the other low-orbit satellites.

Unlike other space geodetic techniques based on microwave bands and automatic data acquisition, the operation of SLR is dependent on weather conditions and often relies on human resources at a ground station. In addition, even if conditions are met, only one satellite can be tracked at one time whereas a large number of SLR satellites orbit above a station these days. Hence, it is too optimistic to expect horizon-to-horizon coverage of all possible passes.

We collect all SLR observations made during a 1-year period from July 2014 to June 2015 to see the ratio of successful ranging observations with respect to all possible observations. Figure 2 illustrates the success rates of the most productive 15 stations in two ways: a pass-based ratio (solid) and a normal-point ratio (gray). The former is the number of observed passes divided by that of fly-over passes. The latter is the number of normal-point observations divided by that of all fly-over normal-point chances, setting the lowest limit of the elevation angle at 20 degrees. We see from Fig. 2 that full coverage cannot be expected as only the top three stations, Yarragadee (station code 7090), Changchun (7237) and Mt Stromlo

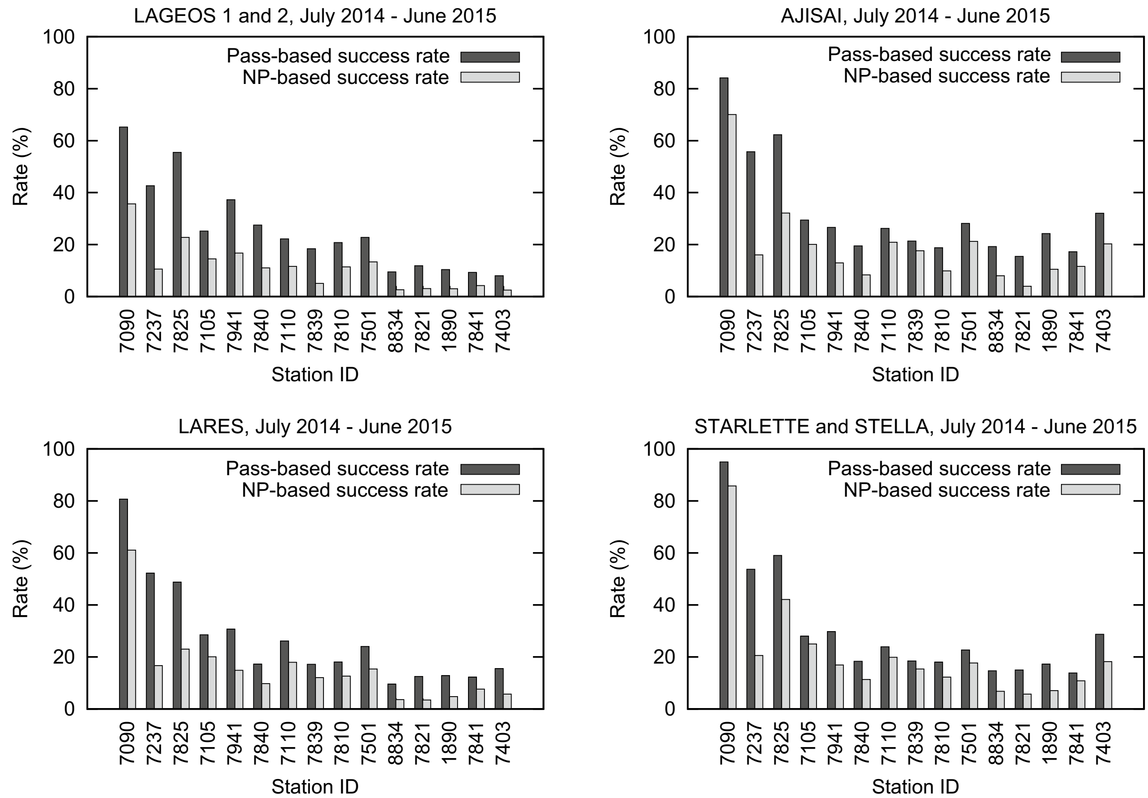

Fig. 2 Pass-based success rates and normal-point-based success rates for four types of satellites during a 1-year period from July 2014 to June 2015. Fifteen highly productive stations are shown where the four-digit station IDs are the NASA CDDIS Codes

(7825), exceed or come close to 50 %. In order to generate simulation data, we assume, for all types of satellites, 25 % for a pass-based rate and 15 % for a normal-point-based rate so that the data productivity correspond to a station between the 5th and the 10th in the rankings, assuming that this new station will be among the top-ranked. This means 60 % (=15 %/25 %) of possible normal points are observed among the observed 25 % passes. Practically, in the simulation data generating procedure, after calculating all fly-over passes and normal points for a certain virtual station, we randomly take 25 % of possible passes and then, for each pass, take a segment that covers 20–100 % (average 60 %) of possible normal points. The lowest elevation angle is set to 20 degrees. A segment is chosen so that it starts at the beginning of a pass, it ends at the end of a pass, or its center is aligned to the center of a pass, randomly at a rate of one-third each. This procedure for generating simulation data is repeated for the six satellites (LAGEOS-1, LAGEOS-2, Ajisai, LARES, Starlette and Stella) and for 134 virtual station points placed at intervals of 15 degrees in latitude and 30 degrees in longitude.

Orbit determination simulation

In this study, software "c5++," cooperatively developed and maintained by institutes in Japan and Sweden (Hobiger et al. 2014), is operated in a simulation mode in which a covariance matrix is created and actual observation values are not used. We look at estimated errors that are the square root of the diagonal elements of the covariance matrix. We focus on not the absolute values of estimated errors, but the relative change of them. The covariance matrix is first generated without including a new station (to be referred to as the baseline case and as C^0), and the result is then compared with that generated by adding one of the virtual stations to the existing ground network (to be referred as C^i for the i-th virtual station).

Assuming that a parameter in the n-th row/column in the case of the i-th virtual station is to be investigated in comparison with the baseline case, we define the improvement rate of the estimated error as:

$$\text{Improvement rate (\%)} = \left(1 - \sqrt{\frac{C^i_{nn}}{C^0_{nn}}}\right) \times 100.$$

The number of observations of a virtual station corresponds to 4–6 % of that of the entire existing network. If the existing stations uniformly increased their observations by 4–6 %, the estimation error of every parameter would be reduced from the baseline case by its square root, 2–3 %. If the improvement rate is significantly better than that, we can conclude that the virtual station will effectively work together with the existing network.

The actual SLR data in March and April 2015 are merged with the simulation data set that is generated for each virtual station placed at a grid point. Software c5++ is used to simulate the orbit determination and the parameter estimation.

The analysis procedure for examining the effect of a new station is as follows. The whole span is 60 days, and the orbits are chopped into 5-day arcs for the LAGEOS satellites and 3-day arcs for the other four satellites. Based on a fact that the post-fit residual scatter of LAGEOS data is about half of that of the low-orbit satellites, the LAGEOS normal-point data are assigned a weight double that of the other satellites' data. On the other hand, all stations' data are treated equally. In addition to the six orbital elements, five empirical parameters, i.e., one along-track offset coefficient, two along-track once-per-revolution coefficients and two cross-track once-per-revolution coefficients, are estimated per arc. The Earth gravity field coefficients up to degree and order of 4 are estimated as common parameters. A range bias as a constant for the 60-day span is estimated for each station and for each type of satellite, i.e., LAGEOS-1 and 2 combined, Ajisai only, LARES only, and Starlette and Stella combined, so that they can absorb station-dependent, satellite-dependent biases primarily caused by target signature effects (Otsubo and Appleby 2003; Otsubo et al. 2015; Kucharski et al. 2015). Earth orientation parameters are also solved for per day. While the positions of all stations are fixed to an a priori set of coordinates, three transformation parameters and a scale parameter of the whole network with respect to the a priori set are solved for in the same batch estimation as other parameters.

Results and discussion

The improvement rates for geodetic parameters are presented in this section. We begin with the translation and scale parameters of a terrestrial reference frame. In Fig. 3, the triangles are the positions of existing laser

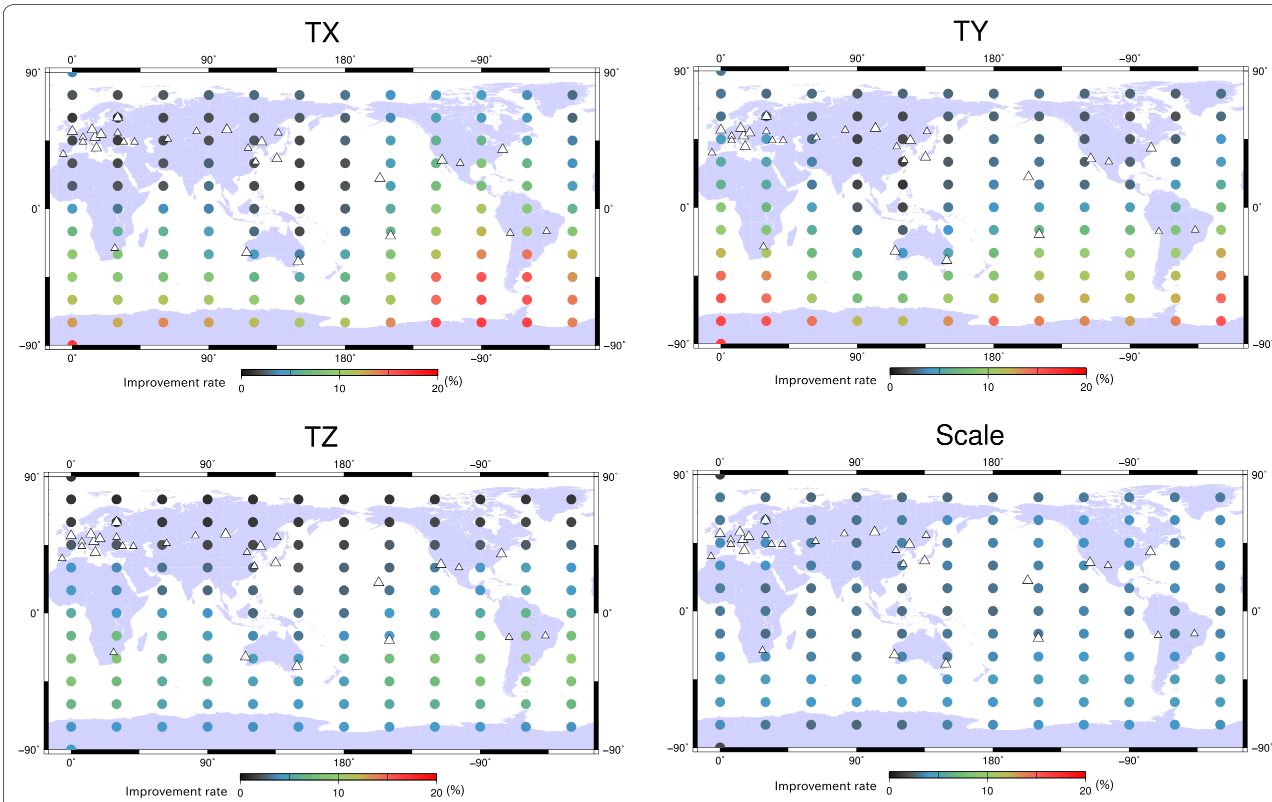

Fig. 3 Simulated improvement rate of three translation parameters and a scale parameter of a terrestrial reference frame when one laser-tracking station (one of the *colored circles*) is added to the existing laser-tracking network (*white triangles*; large ones are high productive stations with >2000 normal points during the March–April 2015 period)

ranging stations where large ones represent stations with high productivity that yielded more than 2000 normal points to the six satellites during the 2-month period. For the case when a virtual station at one of the circles aligned on the grid is added to the station network, the improvement rate with respect to the baseline setup is illustrated in color for each parameter. We can read from the graphs that the X and Y components can be significantly improved by adding a station in the southern hemisphere, especially in the high-latitude region. The best position was the South Pole, which drastically improves the two components by about 17 %. The Z component, on the other hand, is not benefitted so much by a high-latitude station but is most effectively determined by adding a station in a lower latitude, 15S–30S. Different outcomes are observed in the scale parameter case where the improvement rate is not so high at 2–5 %, no matter where a new station is placed.

Turning now to low-degree gravity coefficients, among all the coefficients up to degree and order 4 treated as solved-for parameters, the five cases of the degree-2 coefficients are plotted in Fig. 4 in the same way as in

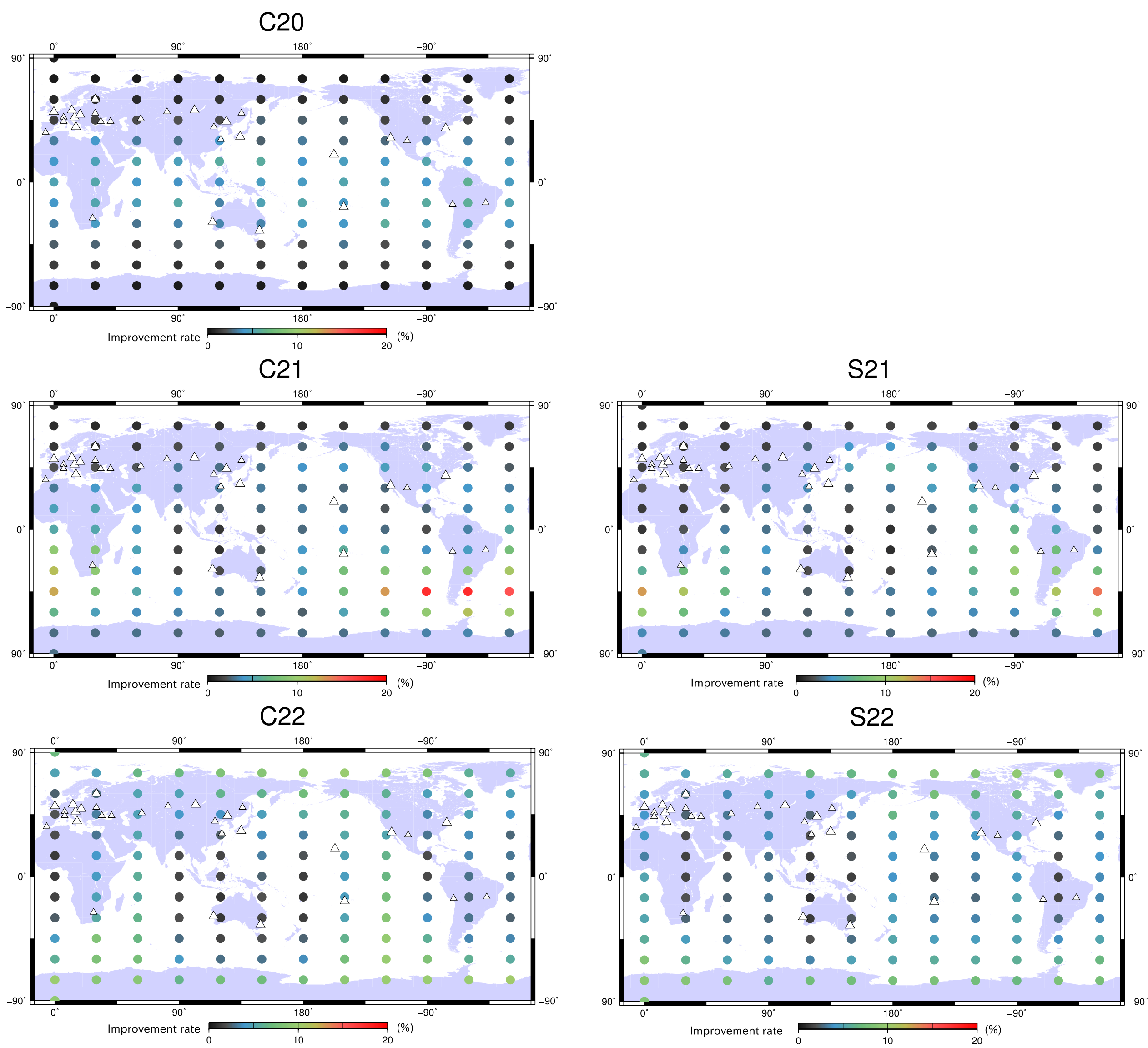

Fig. 4 Simulated improvement rate of degree-2 Earth gravity parameters when one laser-tracking station (one of the *colored circles*) is added to the existing laser-tracking network (*white triangles*; large ones are high productive stations with >2000 normal points during the March–April 2015 period)

Fig. 3. It is clearly seen that the station's latitude plays an important role again. For the zonal term C_{20}, a station at a low latitude has the largest impact while the improvement rate is not so high, up to 6 %, as other coefficients below. A new station placed in a middle latitude or a high latitude has a larger effect on the order 1 terms C_{21} and S_{21} by 18 % at maximum, and the order 2 terms C_{22} and S_{22} by 10 % at maximum, respectively. Similar patterns have been observed for the degree 3 and 4 coefficients although these are not shown graphically: A station near the equator is the most effective for the zonal terms, whereas a station near the poles best performs for the sectoral terms and a station in a middle latitude best performs for the tesseral terms.

In the end, it should be noted that the productivity of a new station has been modeled in a simplified way, and the actual improvement rate depends on the quantity and also the quality of the station's SLR data.

Conclusions

Under a realistic assumption that a laser ranging station can be added to the existing network, our set goal is to find the best position on Earth for a new station, but it is concluded that the best position depends on a geodetic parameter.

Filling the network gaps, especially in the southern hemisphere, has the expected efficacy on the whole, but our study also revealed that the effect largely depends on station latitude and target parameters. The most remarkable impact is expected for the X and Y components of the geocenter and the sectoral gravity terms such as C_{22} and S_{22} by adding a station near the South Pole. A station in a middle latitude also significantly improves the tesseral gravity terms such as C_{21} and S_{21}. A station in a low latitude is shown to be effective for the geocenter's Z component and the zonal gravity terms where the improvement rates do not match the above cases.

This study focused on the best-performing cases and areas, but considering the fact that the derived improvement rates, in most cases, exceed those predicted by the square root of the number of observations, adding more stations to the SLR network should be strongly encouraged.

This simulation study has assumed a very simple error model and compared relative changes of formal errors, but that various error sources and the measurement correlations should be taken into account when we handle an actual observation data set.

We hope this study will be used to seek a strategic expansion of the geodetic network, which the global geodetic observing system component (Plag and Pearlman 2009) under the International Association of Geodesy has been formed to discuss. Further, comparison and combination with different geodetic techniques should be targeted as proposed by Schuh et al. (2016).

Abbreviations

CDDIS: crustal dynamics data information system; LAGEOS: LAser GEOdynamics Satellite; LARES: LAser Relativity Satellite; NASA: National Aeronautics and Space Administration; SLR: Satellite laser ranging.

Authors' contributions

TO led the whole study and drafted the manuscript. KM was involved with the SLR data analysis, and YA and KY interpreted the outcome of the simulation analysis. TH, TK and SM developed key components of the c5++ software. All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

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References

Altamimi Z, Collilieux X, Métivier L (2011) ITRF2008: an improved solution of the international terrestrial reference frame. J Geod 85(8):457–473. doi:10.1007/s00190-011-0444-4

Chen JL, Wilson CR, Eanes RJ, Nerem RS (1999) Geophysical interpretation of observed geocenter variations. J Geophys Res 104:2683–2690. doi:10.1029/1998JB900019

Cox CM, Chao BF (2002) Detection of a large-scale mass redistribution in the terrestrial system since 1998. Science 297:831–833

Hobiger T, Otsubo T, Sekido M (2014) Observation level combination of SLR and VLBI with c5 ++: a case study for TIGO. Adv Space Res 53(1):119–129

IGN (2016) ITRF2014. http://itrf.ign.fr/ITRF_solutions/2014/. Accessed 10 Feb 2016

ILRS (2016a) The global ILRS network. http://ilrs.gsfc.nasa.gov/network/. Accessed 22 Mar 2016

ILRS (2016b) Normal point data. http://ilrs.gsfc.nasa.gov/data_and_products/data/npt/. Accessed 22 Mar 2016

König R, Flechtner F, Raimondo J-C, Vei M (2015) Atmospheric loading and mass variation effects on the SLR-defined geocenter. In: Part of the Series International Association of Geodesy symposia. doi:10.1007/1345_2015_60

Kucharski D, Kirchner G, Otsubo T, Koidl F (2015) A method to calculate zero-signature satellite laser ranging normal points for millimeter geodesy—a case study with Ajisai. Earth Planets Space 67:34. doi:10.1186/s40623-015-0204-4

Matsuo K, Chao BF, Otsubo T, Heki K (2013) Accelerated ice mass depletion revealed by low-degree gravity field from satellite laser ranging: Greenland, 1991–2011. Geophys Res Lett 40:4662–4667. doi:10.1002/grl.50900

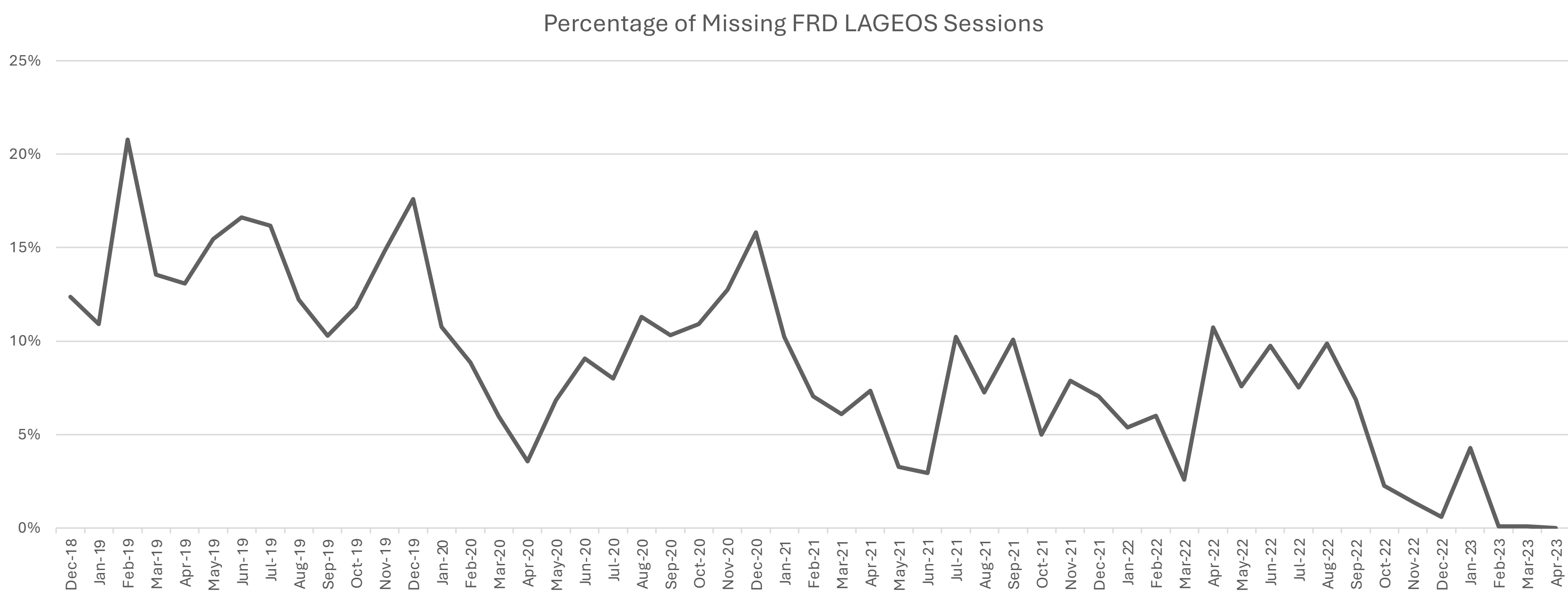
Nerem RS, Wahr J (2011) Recent changes in the Earth's oblateness driven by Greenland and Antarctic ice mass loss. Geophys Res Lett 38:L13501. doi:10.1029/2011GL047879

Otsubo T, Appleby GM (2003) System-dependent centre-of-mass correction for spherical geodetic satellites. J Geophys Res 108:2201. doi:10.1029/2002JB002209
Otsubo T, Sherwood RA, Appleby GM, Neubert R (2015) Center-of-mass corrections for sub-cm-precision laser-ranging targets: Starlette, Stella and LARES. J Geod 89:303–312. doi:10.1007/s00190-014-0776-y
Pavlis E, Kuzmicz-Cieslak M (2008) SLR and the next generation global geodetic networks of low satellites. In: Schilliak S (Ed) The 16th international workshop on laser ranging, Poznan, 13–17 October 2008
Pearlman MR, Degnan JJ, Bosworth JM (2002) The international laser ranging service. Adv Space Res 30(2):135–143. doi:10.1016/S0273-1177(02)00277-6
Plag HP, Pearlman M (eds) (2009) Global geodetic observing system. Springer, Berlin
Reigber C (1989) Gravity field recovery from satellite tracking data. Theory of satellite geodesy and gravity field determination, volume 25 of the series lecture notes in earth sciences, pp 197–234
Schuh H, König R, Ampatzidis D, Glaser S, Flechtner F, Heinkelmann R, Nilsson T (2016) GGOS-SIM: Simulation of the reference frame for the global geodetic observing system. In: International Association of Geodesy symposia. Springer, Berlin. doi:10.1007/1345_2015_217
Sośnica K, Jäggi A, Meyer U, Thaller D, Beutler G, Arnold D, Dach R (2015) Time variable Earth's gravity field from SLR satellites. J Geod 89:945–960. doi:10.1007/s00190-015-0825-1

Context

- Conversion of CRD V1 → CRD V2
  - After 08/2022, some passes were still sent in as CRD V1 but not V2
    - This has been addressed
- Some NP2 passes were being received but not FR2
- Problem extends from December 2018 to March 2023
- Reasons:
  - NPT passes OC QC but not FRD
  - Not all stations consistently sent their FRD
  - Others?

Is it an issue that we have NP2 without a corresponding FR2? Most users use NPT



Subject: Re: [ilrs-qcb] Re: [EXTERNAL] Re: Quarantine Station procedure - possible updates needed
Date: Wednesday, March 13, 2024 at 10:46:18 AM Eastern Daylight Time
From: Pearlman, Michael R. (Mike)
To: Alexandre Belli
CC: Graham Appleby - BGS, mathis.blossfeld@tum.de, Toshimichi Otsubo, Carabajal, Claudia C. (GSFC-61A.0)[SCIENCE SYSTEMS AND APPLICATIONS INC], ILRS QCB QCB

Alex,

You have obviously given this a lot of thought. I suggest that we may not want to make this too complicated. But I do agree that we add some flexibility. We have already received lots of thoughts.

If you have not already sent in your "paragragh" for the QCB notes, please do.

Thanks, Mike

On Tue, Mar 12, 2024 at 11:52AM Alexandre Belli via ilrs-qcb <ilrs-qcb@lists.nasa.gov> wrote:

> Dear Team,
>
> The ongoing discussion has proven to be engaging, prompting me to suggest a dedicated meeting focused solely on the quarantine process.
>
> Mathis has presented compelling arguments regarding the necessity of multiple targets and an adequate number of passes for achieving optimal TRF and EOP outcomes. Additionally, I value the perspectives shared by Graham and Toshi.
>
> Consider this scenario: a station engages in heavy observation activities, albeit solely focusing on Lageos 1, Earth's observation satellites, or GNSS. Should such a station be subject to quarantine? Conversely, another station meets only the minimum requirements, yet remains unaffected by quarantine. What message does this convey?
>
> The aspect of funding and grants cannot be overlooked. Seeking financial support while a station is under quarantine by the ILRS could potentially convey the wrong message, jeopardizing the participation of valuable stations and observers, which runs counter to our objectives.
>
> While striving for the highest standards to deliver superior products to the IERS, we must also consider the message conveyed to stations when they are placed under quarantine and the potential repercussions thereof.

Therefore, I propose an open-ended question for consideration (as I continue to refine my thoughts): What if we introduce additional "labels" (distinct from ranks to avoid fostering competition)? This approach aims to comprehensively categorize stations, facilitating efficient communication and providing clarity regarding their roles within the network. Here's a preliminary outline:

- Quarantine should be reserved for significant issues such as non-observance or substantial biases.
- Engineering stations, as previously described.
- TRF stations capable of providing 20 passes on four geodetic satellites over 60 days.
- Core Stations, fulfilling TRF station criteria.
- LLR stations.
- Actively Contributing stations, characterized by frequent observations, albeit not exclusively of the four geodetic satellites.
- High/low Latitude or geographically constrained stations.
- And so forth...

These labels are not mutually exclusive. Regarding the categorization of "Actively Contributing" and "High/low Latitude" stations into the TRF, the decision rests with analysts.

Furthermore, let's remain mindful that observers on call at stations may not necessarily grasp the specific significance of each observation/target.

I find this topic immensely stimulating and am delighted to be back, sharing my thoughts with the team.

Thanks!

Best,
Alex

From: Graham Appleby - BGS <gapp@bgs.ac.uk>
Sent: Tuesday, March 12, 2024 8:18 AM
To: Toshimichi Otsubo <t.otsubo@r.hit-u.ac.jp>; Alexandre Belli <alexandre.belli@ssaihq.com>
Cc: Carabajal, Claudia C. (GSFC-61A.0)[SCIENCE SYSTEMS AND APPLICATIONS INC] <Claudia.C.Carabajal@nasa.gov>; ILRS QCB QCB <ilrs-qcb@lists.nasa.gov>
Subject: Re: [ilrs-qcb] Re: [EXTERNAL] Re: Quarantine Station procedure - possible updates needed

Dear all

I too am of the view that for the process of testing that a station is ready to be included as an ILRS operational station a total of about 60 passes of the primary geodetic spheres is sufficient. The purpose of the testing surely is to determine that no gross errors are being committed, such as reasonable NP/FR precision and accuracy, application of the target-board calibration with the wrong sign, error in time-tagging, etc.

Getting over this hurdle for a station will be a great help and incentive in its operational funding bids, and just the start of the process to ensure that it reaches the ILRS goals in terms of passes/year, etc., for all the satellites.

Graham

From: Toshimichi Otsubo via ilrs-qcb <ilrs-qcb@lists.nasa.gov>
Date: Tuesday, 12 March 2024 at 08:24
To: Alexandre Belli <alexandre.belli@ssaihq.com>
Cc: Carabajal, Claudia C. (GSFC-61A.0)[SCIENCE SYSTEMS AND APPLICATIONS INC] <claudia.c.carabajal@nasa.gov>, ILRS QCB QCB <ilrs-qcb@lists.nasa.gov>
Subject: [ilrs-qcb] Re: [EXTERNAL] Re: Quarantine Station procedure - possible updates needed

Dear all,

Welcome back Alex to the ILRS community. I feel more or less the same as you about the impression of the word (also in its Japanese translation).

I am the person who asked about the possibility of a combined total number of passes, knowing the current rules.

I thought (still think) that the combined count is preferable because:

- The ILRS products are multi-satellite combined solutions anyway.
- Quarantine-passing does not mean the station's quality/stability is at the mm level (where the target signature matters).
- The latitude dependence of fly-over chances is significant. See Fig 1 of our 2016 paper. https://earth-planets-space.springeropen.com/articles/10.1186/s40623-016-0447-8 The current constellation is not so kind for low latitude, for instance. The LAGEOS-2 skymap won't be uniform at high latitude.

but I do not insist too much if my view is in the minority.

Toshi

Toshimichi Otsubo <t.otsubo@r.hit-u.ac.jp>

2024年3月12日(火) 5:22 Alexandre Belli via ilrs-qcb <ilrs-qcb@lists.nasa.gov>:
>
> Dear Team,
>
> I would like to contribute my perspective on the quarantine aspect of our recent discussions. I welcome open dialogue and constructive feedback to ensure clarity and alignment.
>
> Reflecting on our meeting, it's apparent that the term "quarantine" has generated some concern due to its negative connotations. I acknowledge the importance of incorporating all four targets for comprehensive statistical analysis. However, I recognize the challenge posed when a station, diligently observing one target, risks being labeled solely as a "quarantine station."
>
> I found particular resonance in the statement from Ecp regarding the need to adapt rules dynamically to uphold ILRS Network standards while accommodating system nuances. This raises the need for a clearer delineation between two forms of quarantine: Qualitative Quarantine, which addresses biased or noisy data, and Quantitative Quarantine, solely based on pass frequency per target over a given period.
>
> Introducing this distinction could alleviate concerns and foster motivation among stations, ensuring they understand the purpose and value of their contributions without feeling marginalized.
>
> I welcome your insights and feedback on this proposal.
>
> Best
> Alex
> ________________________________
> From: epavlis@umbc via ilrs-qcb <ilrs-qcb@lists.nasa.gov>
> Sent: Monday, March 11, 2024 3:52 PM
> To: Carabajal, Claudia C. (GSFC-61A.0)[SCIENCE SYSTEMS AND APPLICATIONS INC] <Claudia.C.Carabajal@nasa.gov>
> Cc: ILRS QCB QCB <ilrs-qcb@lists.nasa.gov>
> Subject: [EXTERNAL] [ilrs-qcb] Re: Quarantine Station procedure - possible updates needed
>
> Dear all,
>
> I was not part of today's discussion but I heard through the grapevine that there is a proposal to change the criteria to 60 passes in total (which means that one or more targets can have ZERO contribution in these 60 passes!). I find this a very bad idea and I do not see the reasoning behind it helping ILRS maintain the quality of stations that want (need) for the future GGOS products.
>
> When a station applies to join the ILRS network they sign off on the following pledge:
>
> All stations in the ILRS network must routinely track LAGEOS-1, LAGEOS-2, and LARES.
>
>
> Look up page 2 of the ILRS Network Application Form. By the way, the form is dated "20170614" and needs to be updated ASAP to include LARES-2 explicitly!

>
> @Claudia: the application is linked to the "Station" choice on the "Join ILRS" side-bar link:
>
> https://ilrs.gsfc.nasa.gov/about/joinilrs.html
>
> We need to have a reliable sample of data on each target in order to characterize each station's performance, and even 20 passes is marginally sufficient for robust statistics. If we have no data or very few passes on target, we cannot make a reliable estimate of the station's quality. The two LARES targets have very much improved metrology, with the target signature correction being very well defined and far better than the older LAGEOS targets. This assures that the estimated biases will reflect station problems and NOT target related deficiencies, providing clean estimates of the bias.
>
> If any station cannot meet these requirements it should expect to be moved to the group of "Engineering Stations" which we do not necessarily validate for acceptance, unless they request it and provide the data.
>
> For what it's worth, in my opinion not having at a minimum 20 acceptable passes on each of the four targets is unacceptable for operational sites, especially for the Core network. When we were doing the QC validation we looked for 25 passes on each target, to make sure that the statistics were stable. Even if you accept to request all four targets, dropping the required passes to 15 per target seems a few steps backwards. Two months should be enough time for any station to collect these passes, and if there special circumstances (e.g. Arequipa's rainy season, Golosiiv, etc.), we always modified the rules on the fly in order to accommodate the system without compromising the ILRS Network standards.
>
> My 5¢
>
> ecp
>
>
>
>
> On Mar 11, 2024, at 11:15 AM, <claudia.c.carabajal--- via ilrs-qcb <ilrs-qcb@lists.nasa.gov> wrote:
>
> Dear ILRS QCB colleagues,
> Attached is the latest version with comments for the Quarantine Station Procedure.
> Based on our discussion from the March 11th, 2024 meeting, there may be a reason to revise it.
>
> I have dated the file '03112024' so I can keep track of the latest, and update it on the ILRS website as well.
>
> Please add comments with tracked changes, and append your initials to the filename before sending it back to the group.
>
> If changes need to be made, we should probably send a message to stations to make them aware of it.
>
> Regards,
> Claudia.

>
>
>
>
> --
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> Secretary, ILRS Central Bureau
> Research Scientist SME/HBG Geodesy & Geophysics Group Lead
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>

The Leading Edge (LE) Filter

Pros and Cons

11-March-2024

The LE Filter (Background)

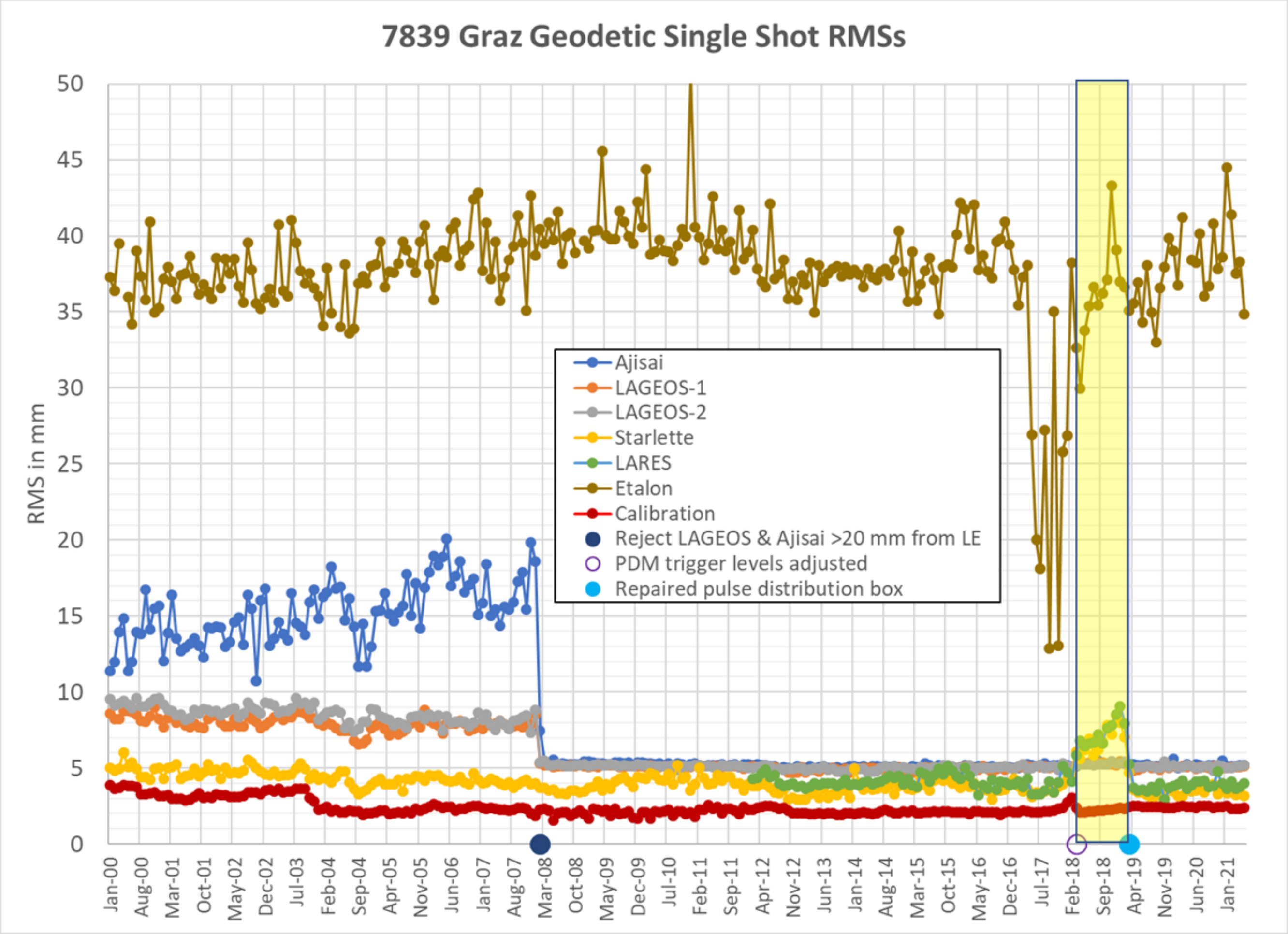
- **In 2008, Georg Kirchner presented "Millimeter Accuracy from Centimeter Targets" at the 16th International Workshop https://ilrs.cddis.eosdis.nasa.gov/lw16/docs/presentations/rep_4_Kirchner.pdf**
- **The Concept:**
  - Only accept returns from the nearest retroreflector for LAGEOS and Ajisai
  - Reducing the reflective depth to 20 mm
- **The Process:**
  - Fit a polynomial to the LE returns to flatten the LE residuals to avoid inducing systematic errors in the normal point generation process
  - Reject all returns > 20 mm from the LE
- **The Pros:**
  - Reduces the variation in the normal point distance to the LE to < 1 mm
  - No hardware changes required
  - No real time adjustment to keep return energy constant
  - No observer training
  - Center of Mass (CoM) Correction is constant for every NP

Questions to be Answered

- **Can the use of the LE filter introduce mm/cm level systematic and/or random errors?**
  - If the ‘true’ single shot RMSs are time varying
  - If the LE filter has difficulty identifying the LE due to time gaps and/or sparse data
  - If the LE filter is not properly documented in the site log
  - If the station operators are not properly trained

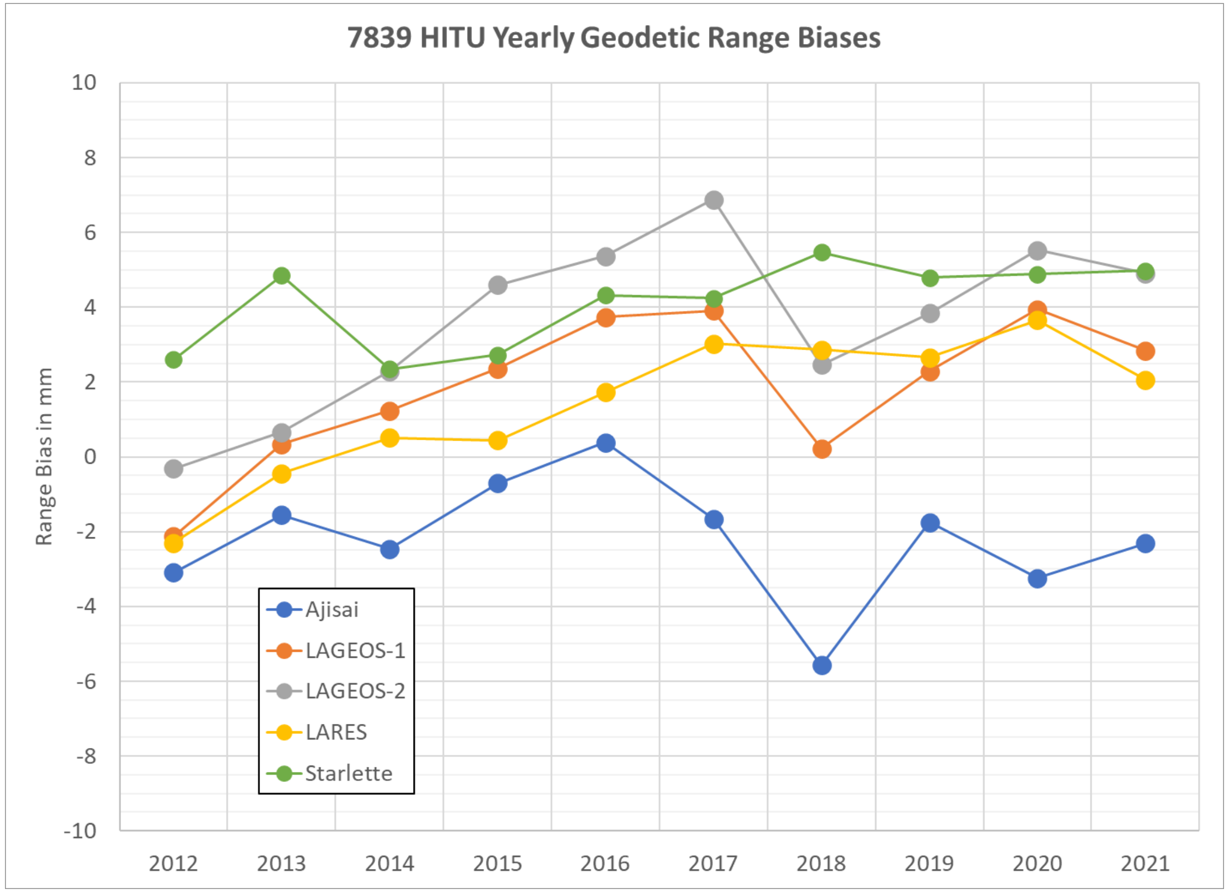
7839 Graz System Performance Analysis

7839 Graz System Performance Analysis (Monthly Single Shot RMSs)



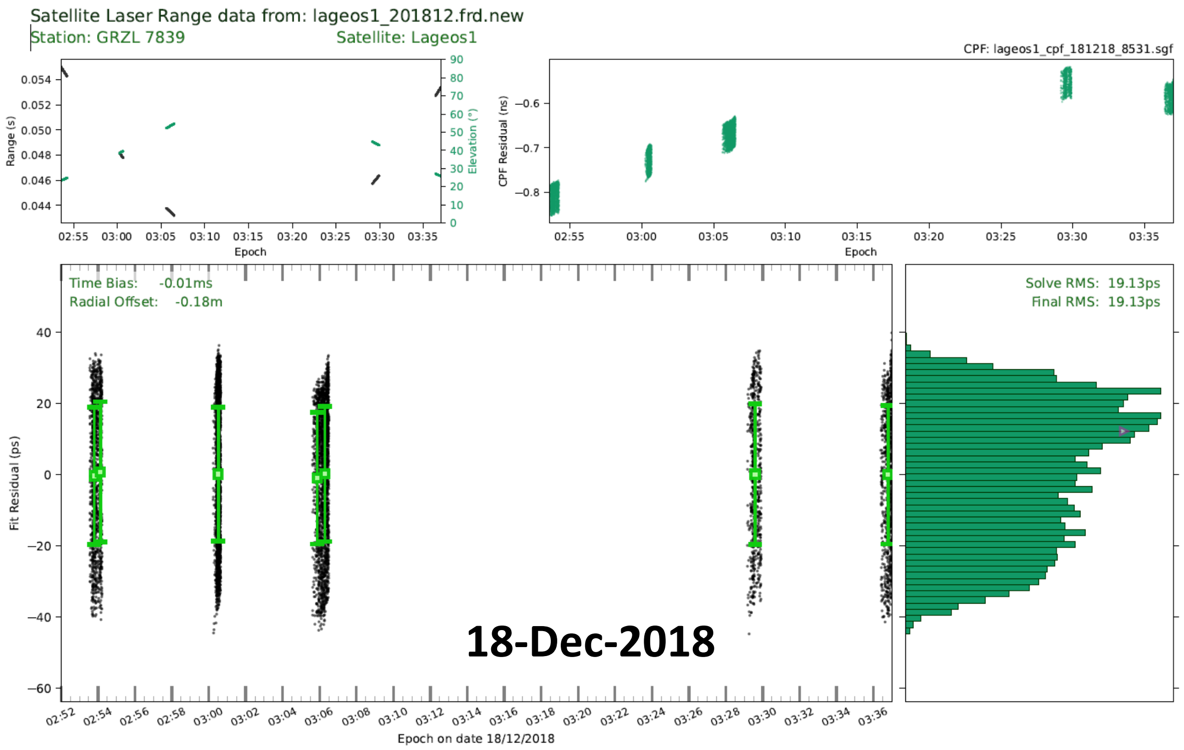
- Significant drop in LAGEOS-1, -2 and Ajisai RMSs on 6-Feb-2008 when the LE filter was implemented. LAGEOS-1, -2, & Ajisai, CoM corrections were increased by 3.1, 3.4, & 27mm; respectively
- In early 2017, there were significant reductions in the Etalon RMSs. Was there a change in the Etalon range bias?
- On 15-Mar-2018, the pulse distribution module trigger levels were adjusted resulting in a ~50 mm decrease in system delay and calibration RMSs returned to nominal levels. However; LARES and Starlette RMSs started trending upward
- On 11-Mar-2019 there was a repair to the pulse distribution box/power supply; plus a cable & calibration constant change
- The LE filter constrained LAGEOS and Ajisai RMS increases in 2018 & early 2019, but was a range bias introduced?

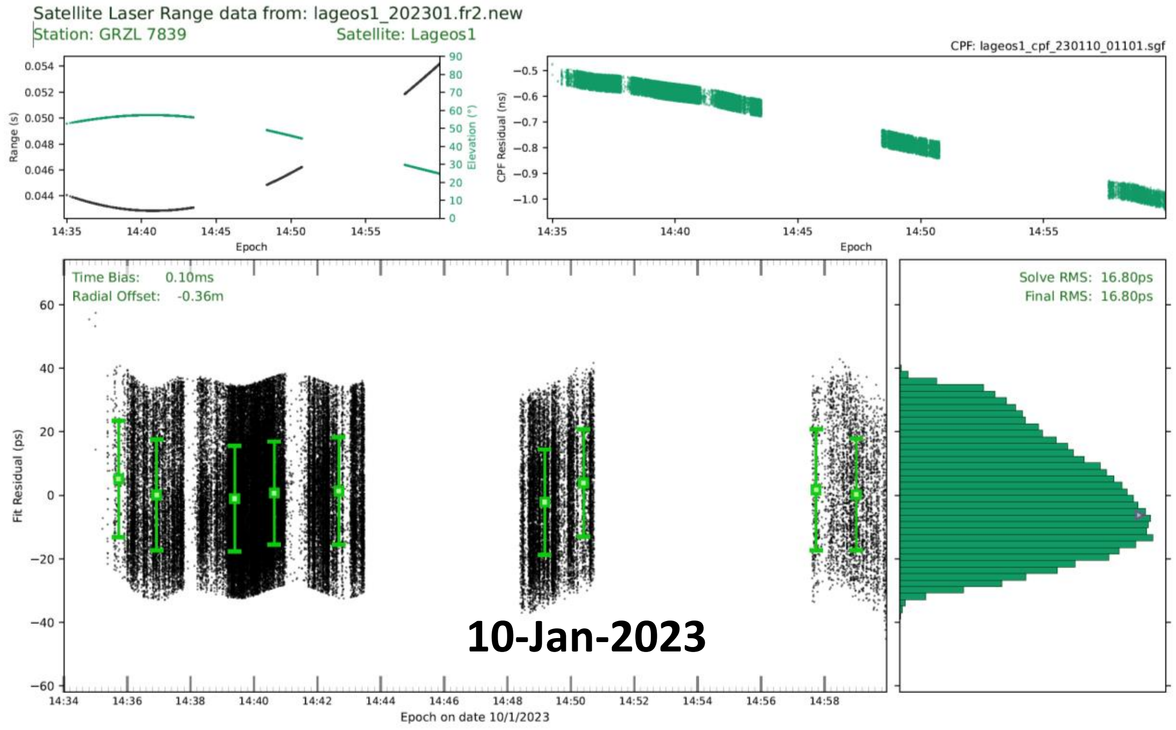
7839 Graz HITU Yearly Geodetic Range Biases



- In 2018, there was a few mm drop in the 7839 LAGEOS-1, LAGEOS-2 and Ajisai HITU range biases while LARES and Starlette biases remained relatively stable
- CON: a key component in the laser subsystem began to degrade in March 2018, but the LE filter constrained any Ajisai or LAGEOS RMS increases inducing a few mm of range bias

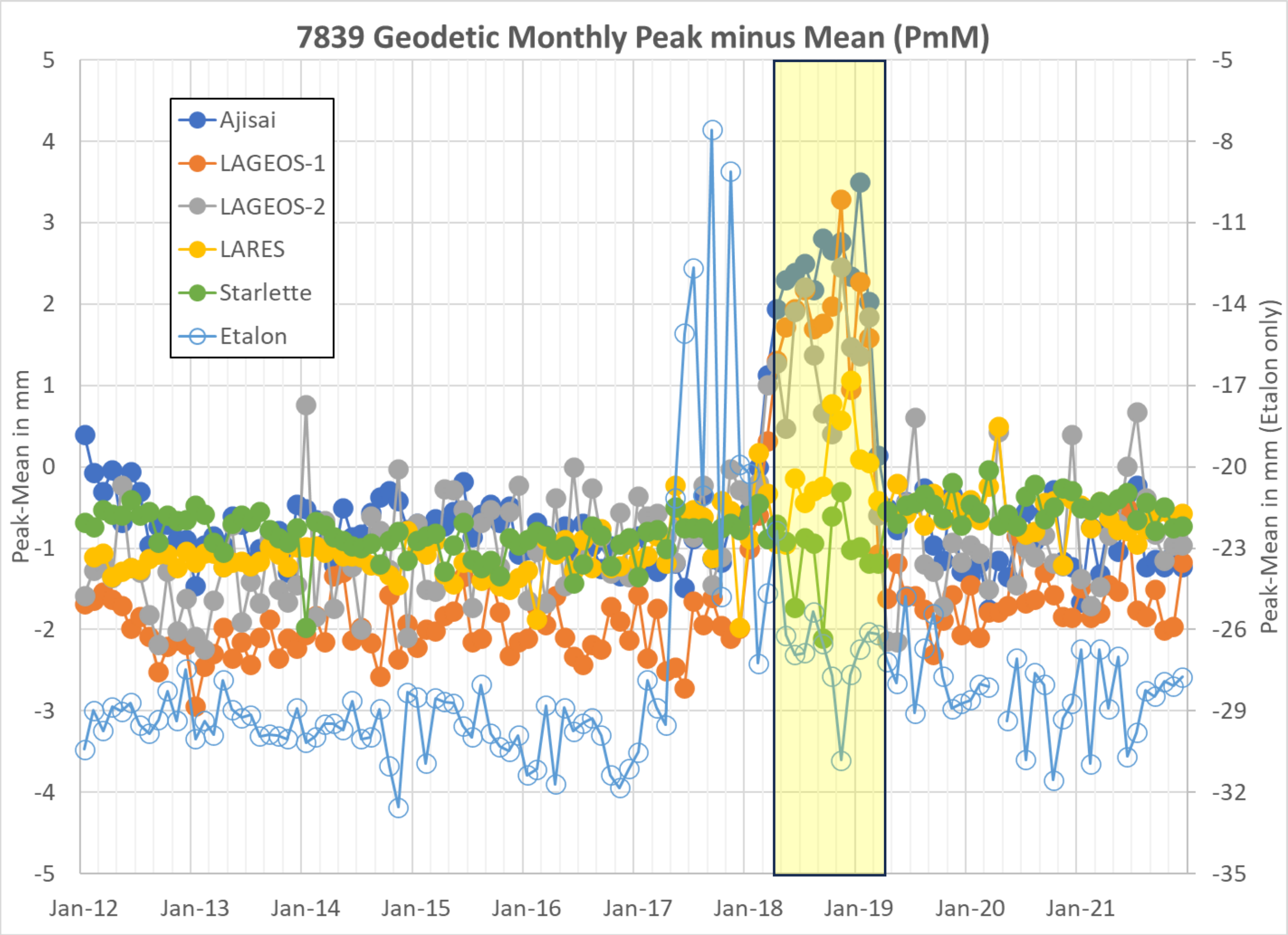
7839 GRZL LAGEOS-1 OrbitNP Fullrate Analysis (2018 vs 2023)





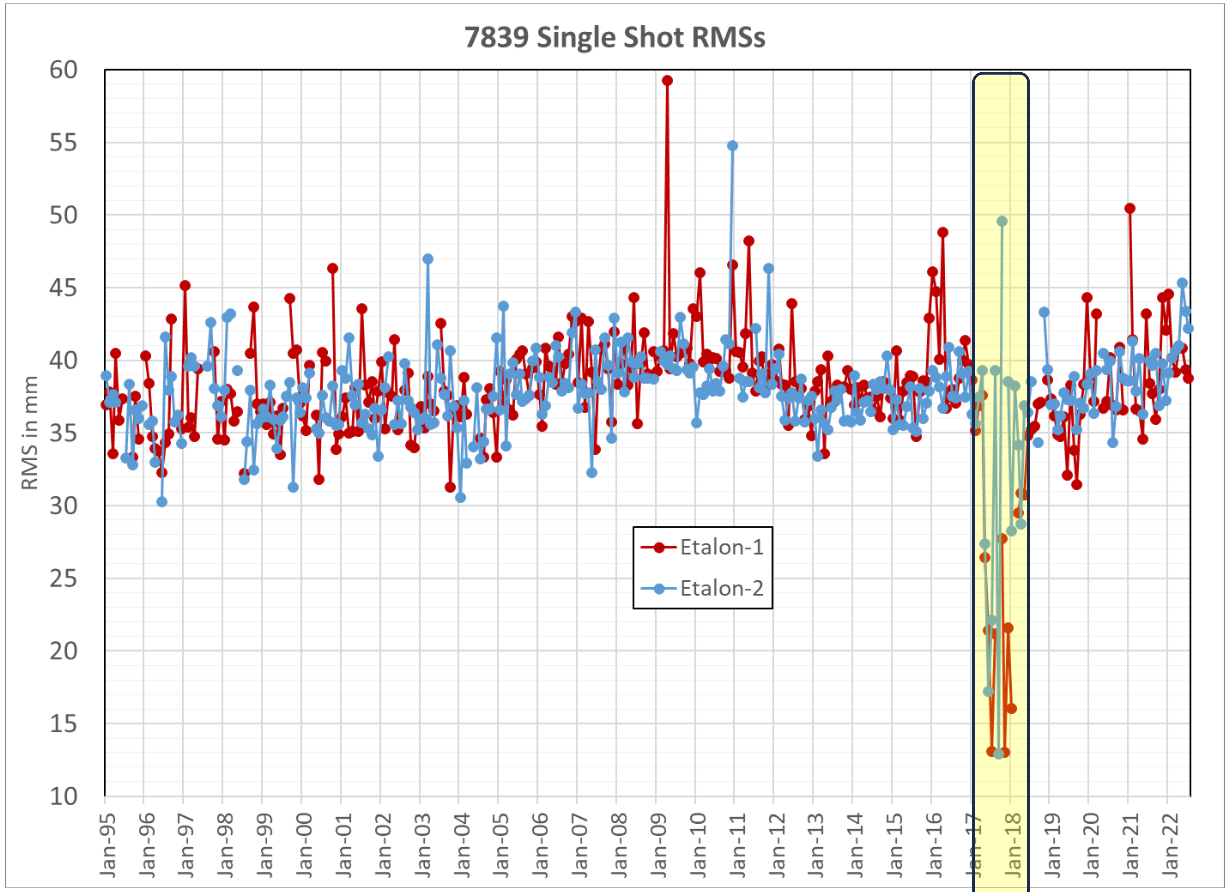
- **Notice the difference in the shape of the two LAGEOS-1 distributions between the left chart and the right chart. Data on the left is when the pulse distribution module/power supply was experiencing performance issues, and the normal points were biased toward the LE because the RMS was constrained by the 20 mm LE filter. The change in the bias was captured by the change in the peak minus mean.**

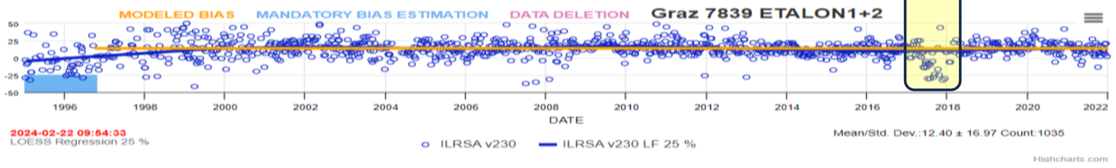
7839 Graz System Performance (Monthly Peak minus Means [P-Ms])



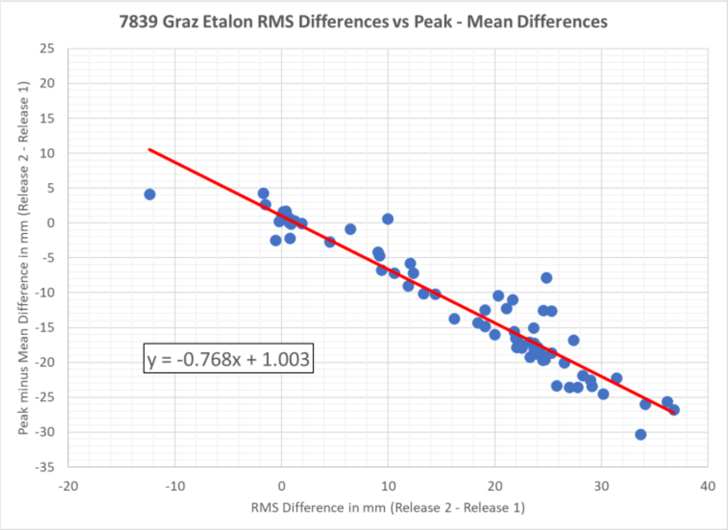
- ❑ **Graz Ajisai, LAGEOS-1, LAGEOS-2, LARES and Starlette P-Ms are on the left axes (+/- 5mm, 10 peak-to-peak) while Etalon P-Ms are on the right axes (-5 to -35mm, 30 mm peak-to-peak)**
- ❑ **Between March 2018 and March 2019, the Ajisai and the LAGEOS-1 P-Ms increased by up 4 to 5 mm during that period. An increase in P-M values indicates the returns are more biased towards the LE resulting in a more negative range bias or a larger CoM correction.**
- ❑ **Changes in the Ajisai, LAGEOS-1, and LAGEOS-2 P-Ms can recover most if not all of the range bias change**
- ❑ **Also notice the increase in Etalon P-Ms in 2017 and before the highlighted period. What caused this change?**

7839 Graz Etalon-1, -2 Single Shot RMSs





- In early 2017, a new Graz operator mistakenly processed Etalon data with a LE filter causing a noticeable drop in the Etalon single shot RMS inducing a negative range bias up to a few cm
- In February 2022, Graz was able to reprocess the affected Etalon data and updated the release flag to a "2". The Etalon RMSs returned to previous levels



- CON: An operator could mistakenly apply a LE filter to a satellite. Changes in Etalon P-Ms could recover most if not all the range bias change. Graz reprocessed the data without applying a LE filter

LE System Configurations; Implementation Dates; RMS, Skew, & Kurtosis

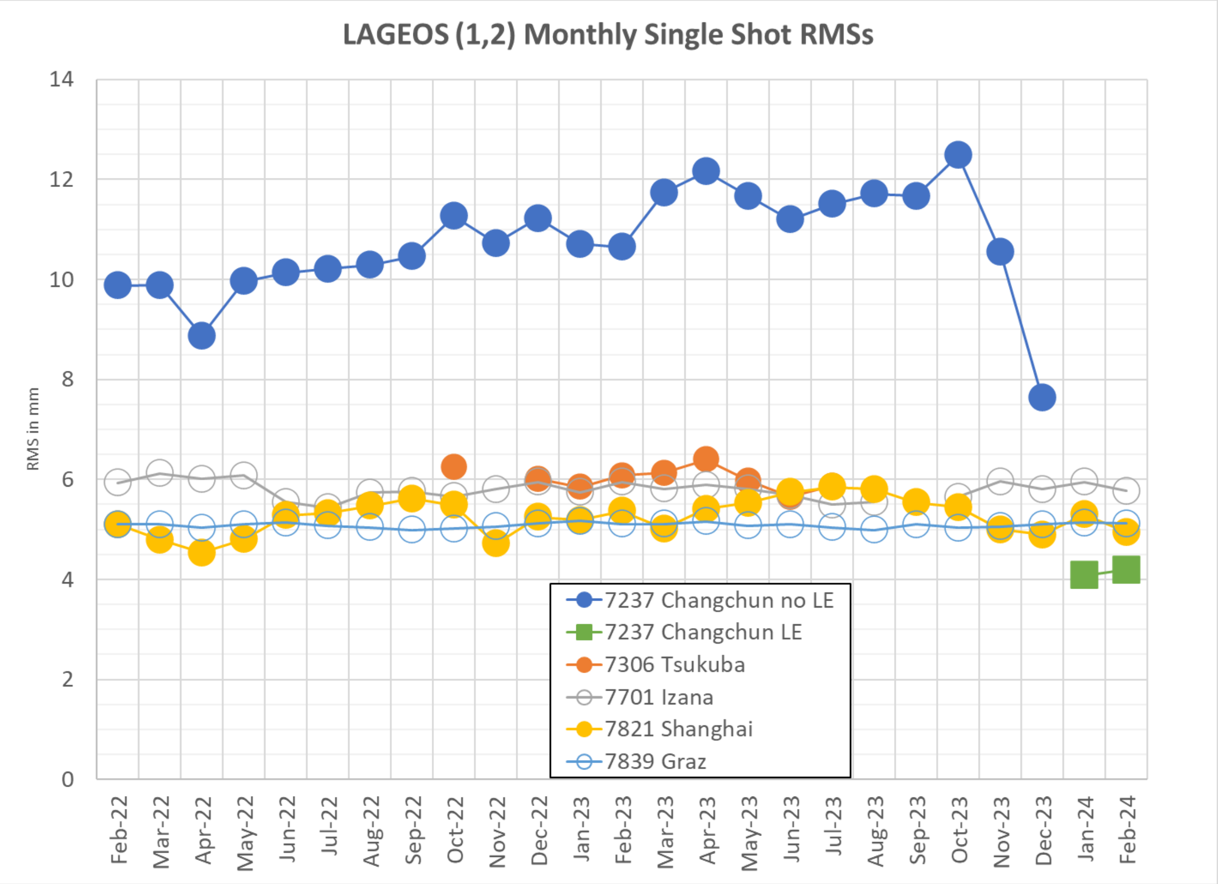
LE System Configurations

Station	Wavelength(s) (nm)	Pulse Width (ps)	Repetition Rate	Detector	Operational Mode (photons)	LAGEOS Fullrate Data Filter
7839 Graz	532	10	2 kHz	CSPAD	multi	20 mm LE, filter flag=2 data only, no excluded returns
7821 Shanghai	532	45	2 kHz	APD	single	20 mm LE, filter flag=2 data only, no excluded returns
7701 Izaña	532 & 1064 (prime)	10	400 Hz	CSPAD & SPAD (prime)	single	2.2σ, filter flag=2 data, excluded returns not flagged
7306 Tsukuba	532 (prime) & 1064	7	1 kHz	CSPAD (prime) & SPAD	single	2.2σ, filter flag=2 data, excluded returns not flagged
7237 Changchun	532	50	1 kHz	CSPAD	single to multi	20 mm LE, filter flag=2 data only, no excluded returns

- **The LE system configurations and mode of operation are not the same. Does this impact the higher moments (Skew and Kurtosis)?**
- **Based on the 7821 station change history, they upgraded their laser to 5 kHz with a 20 ps pulse-width on 13-Nov-2023. The CRD laser configuration record does not indicate this change, nor does their site log.**

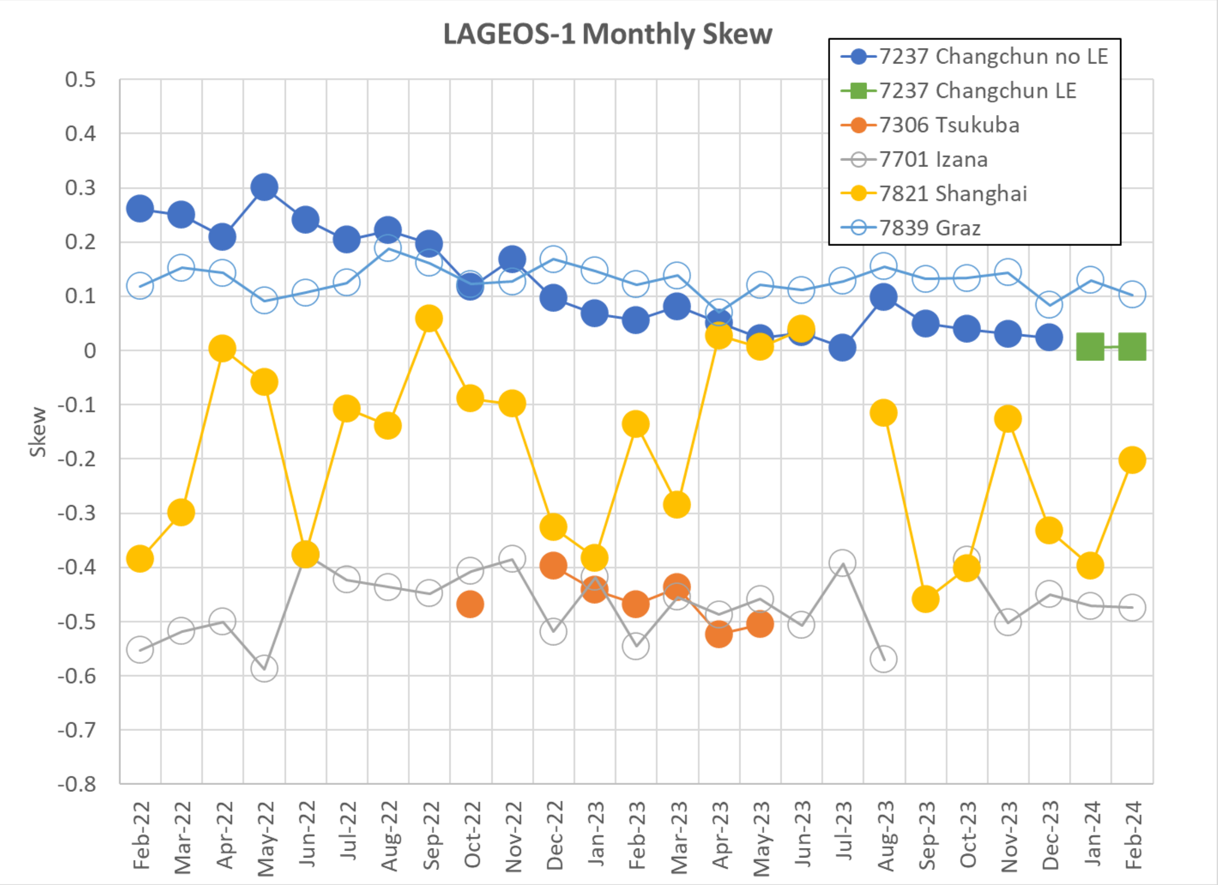
ILRS Network LE Implementation and RMSs

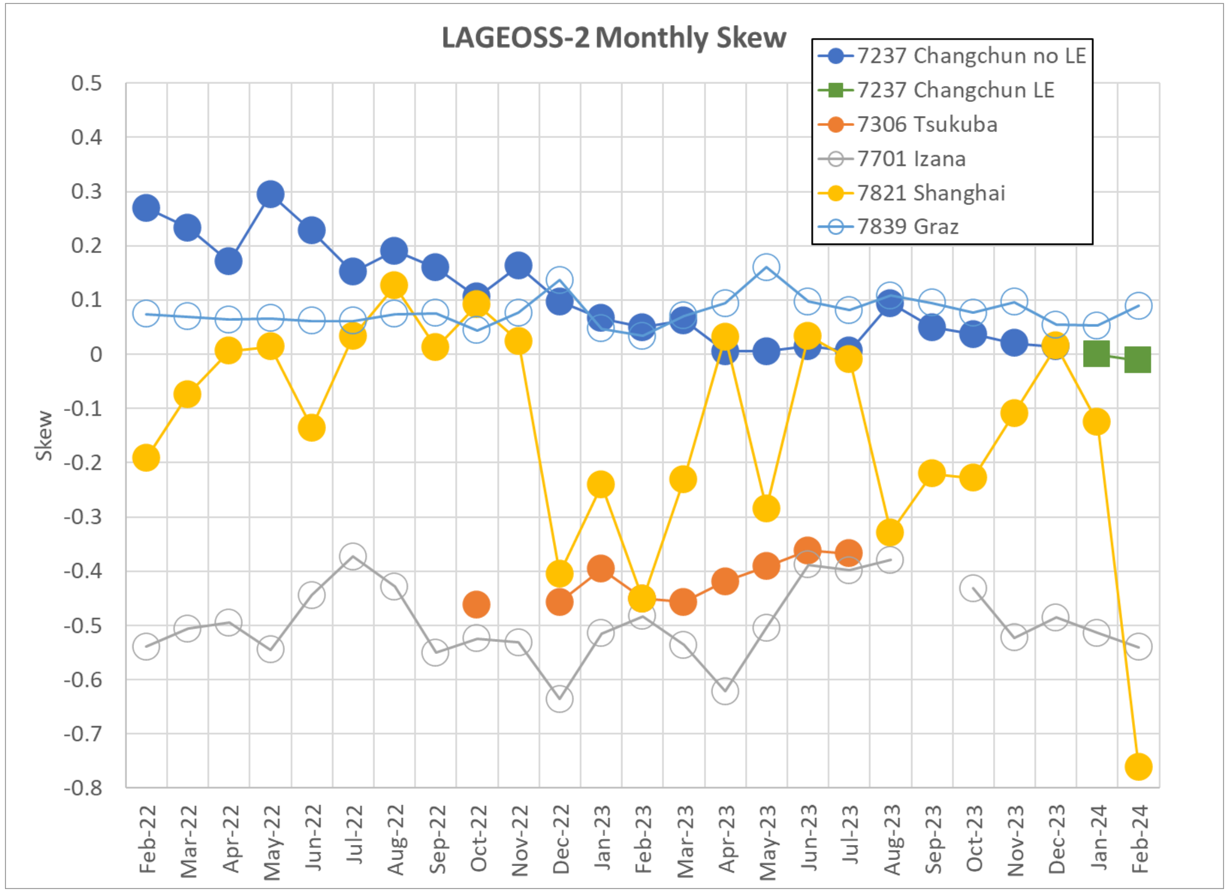
Station	LAGEOS-1 & 2	Ajisai	When
7839 Graz	20 mm	20 mm	05-Feb-2008
7821 Shanghai	20 mm	n/a	20-Jul-2021
7701 Izaña	20 mm	30 mm	29-Nov-2021
7306 Tsukuba	20 mm	30 mm	19-Oct-2022
7237 Changchun[1]	20 mm	n/a	19-Dec-2023



- **7839 Graz has the most consistent LAGEOS RMSs**
- **7237 Changchun has the lowest LAGEOS RMSs**
- ***Footnote #1: On 28-Jan-2024, Changchun implemented a LE filter on LARES, LARES-2, Stella, and Starlette***

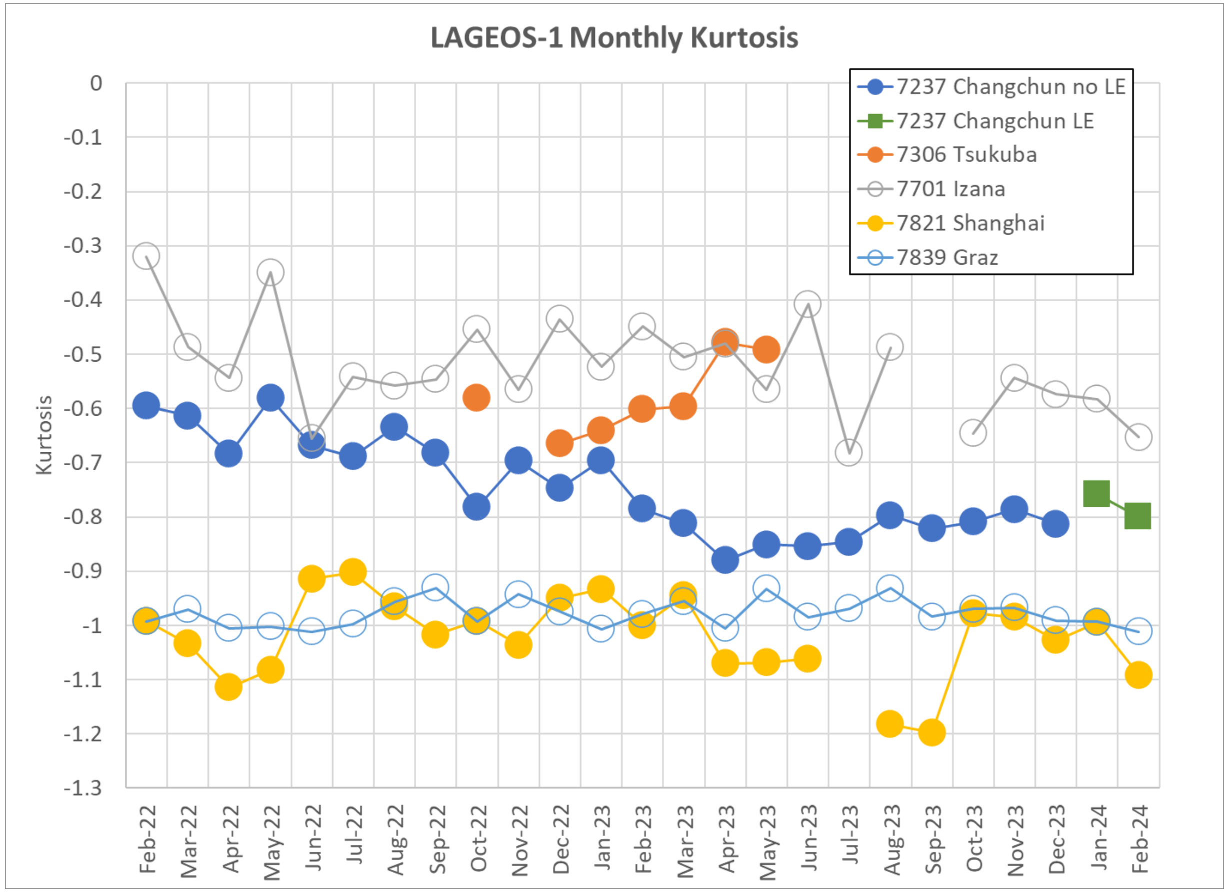
LAGEOS-1 and LAGEOS-2 Skew

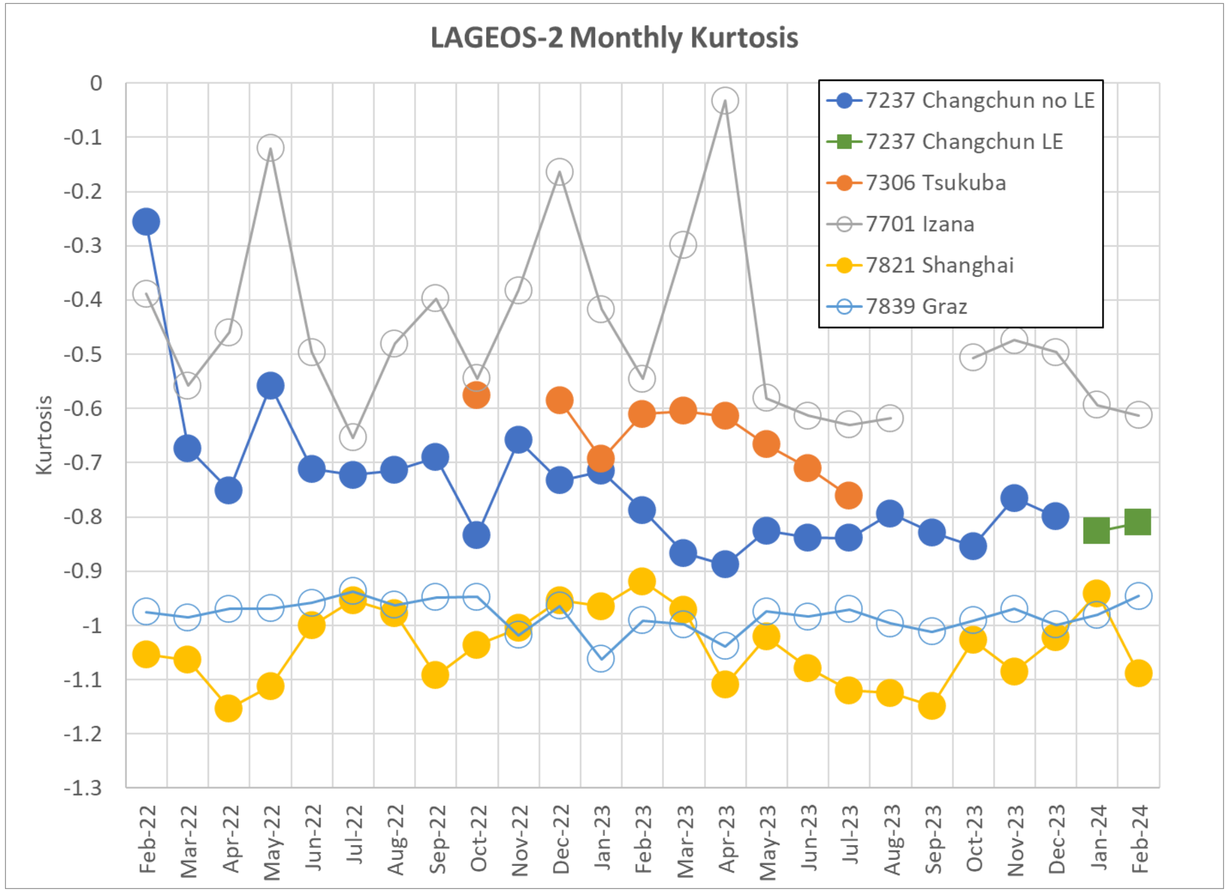




- ❑ **The skew values and their sign (positive or negative) vary by system with 7839 Graz having the most consistent skew. 7839 LAGEOS-1 skew > 7839 LAGEOS-2 skew**

LAGEOS-1 and LAGEOS-2 Kurtosis

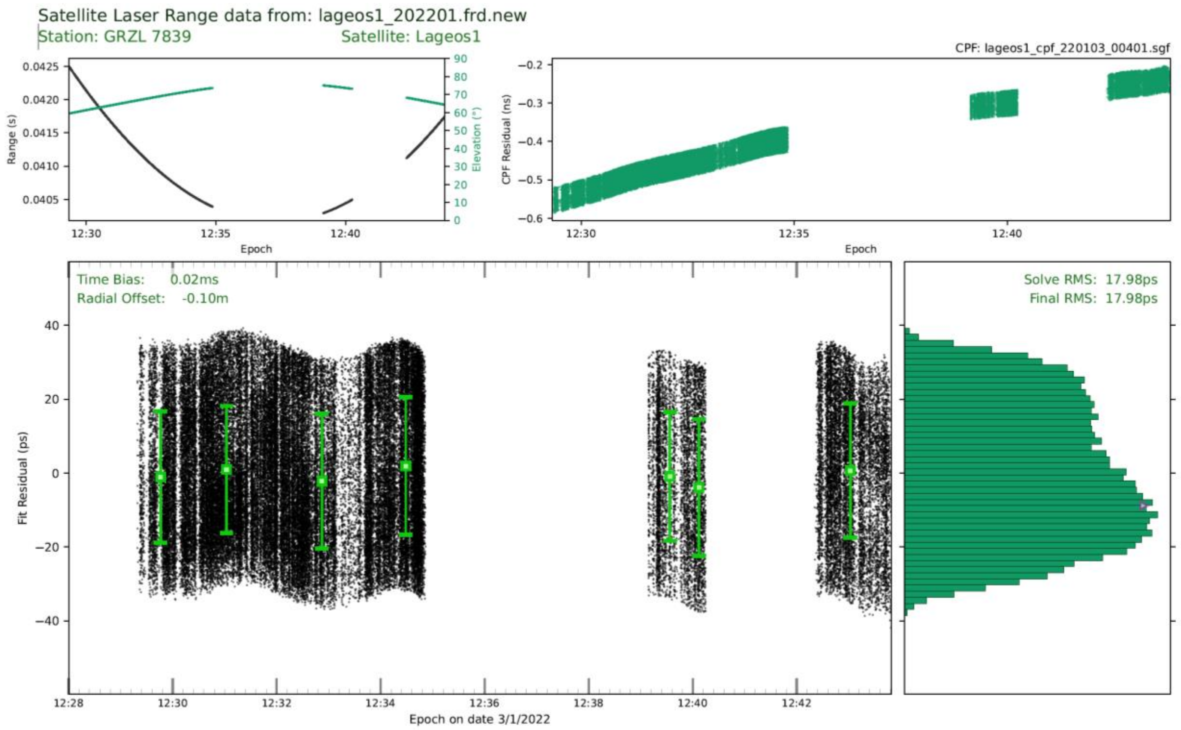


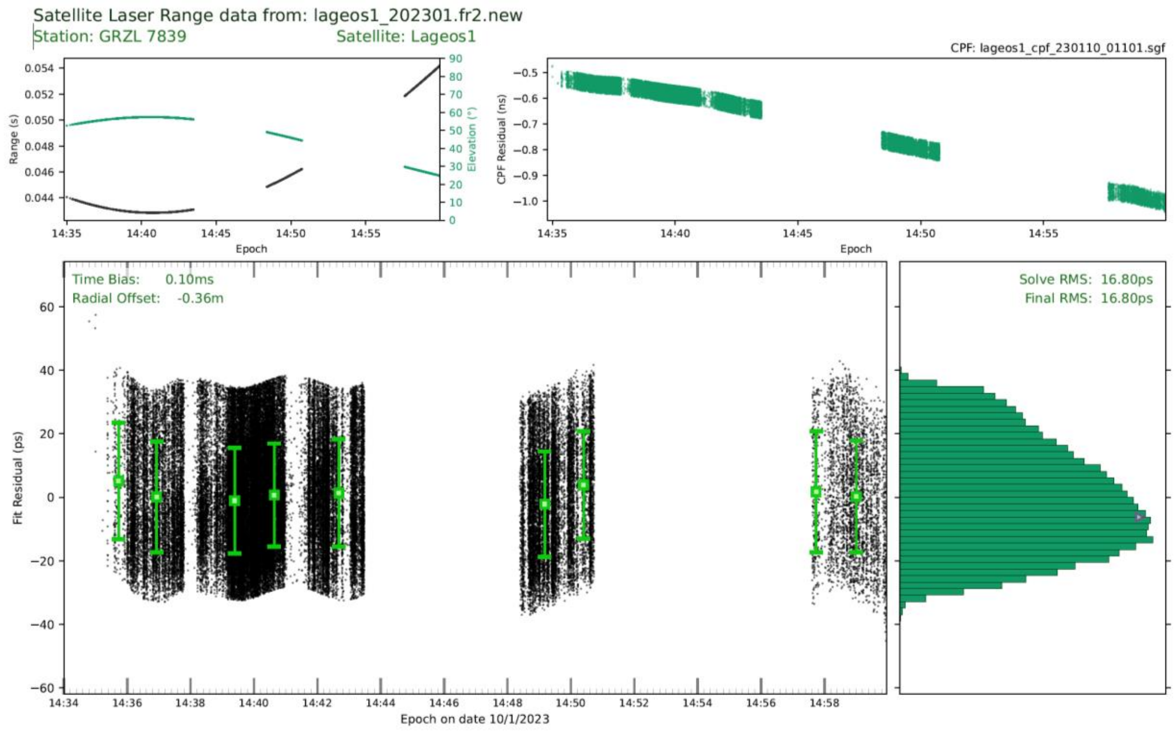


- ❑ **The kurtosis values vary by system with 7839 Graz having the most consistent kurtosis**

OrbitNP Analysis of Fullrate Data from the LE Systems

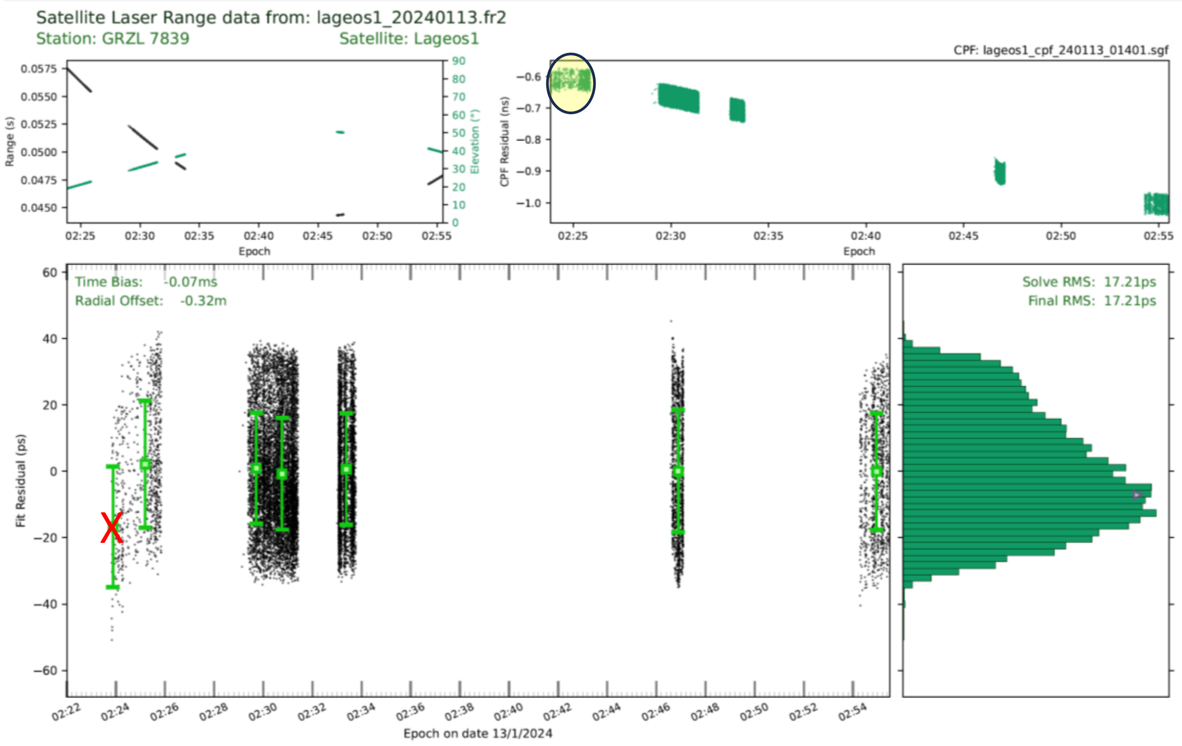
7839 GRZL LAGEOS-1 OrbitNP Fullrate Analysis (2022)

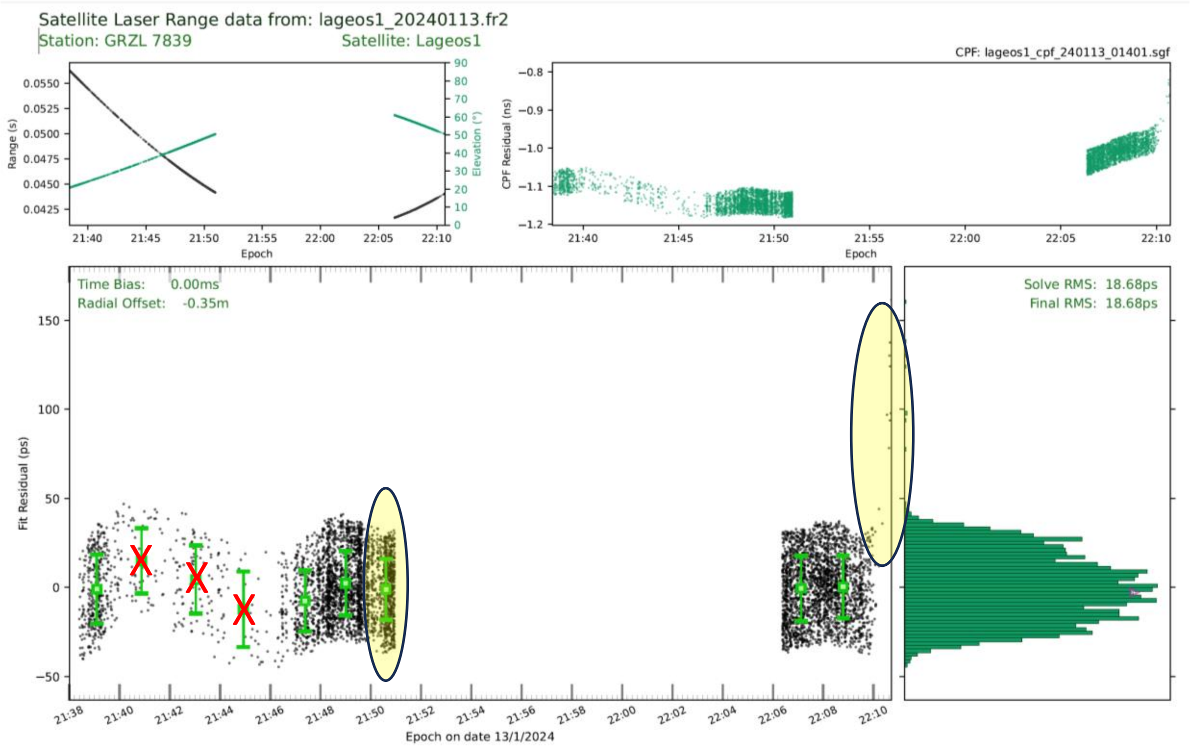




- **7839 fullrate data has already been clipped by the 20 mm LE filter. The RMS scatter after applying the LE filter is ~5 mm.**

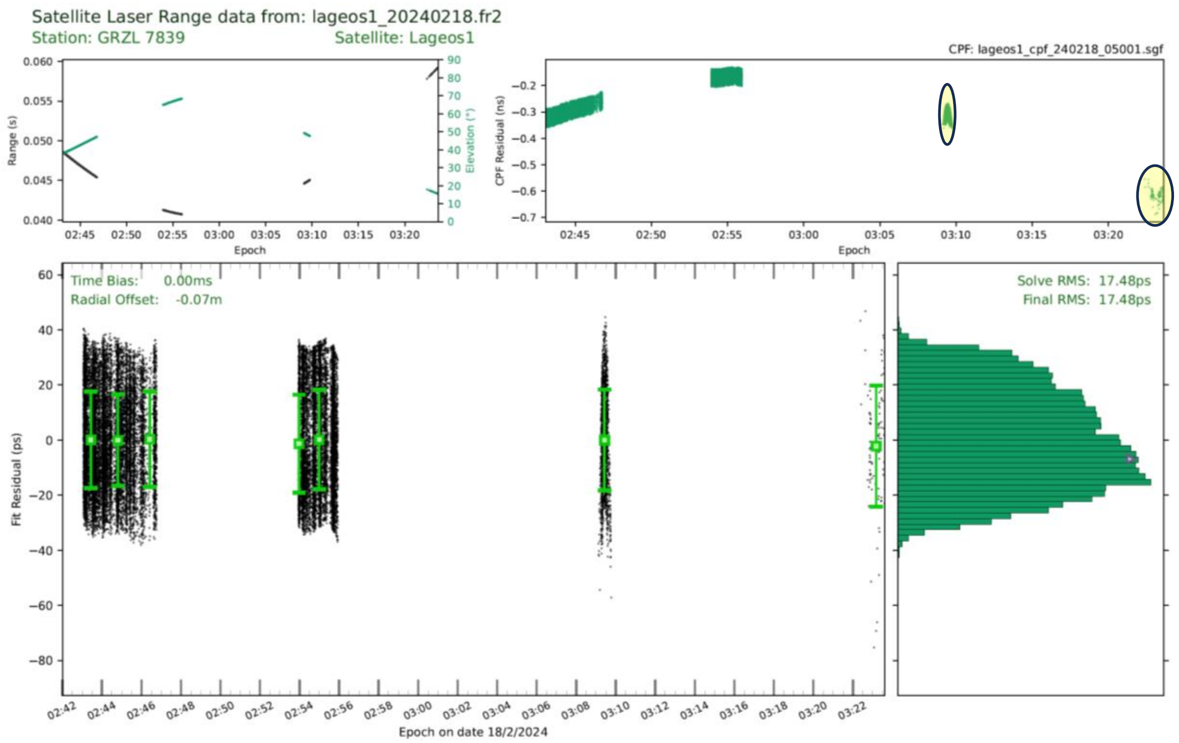
7839 GRZL LAGEOS-1 OrbitNP Fullrate Analysis (2024)





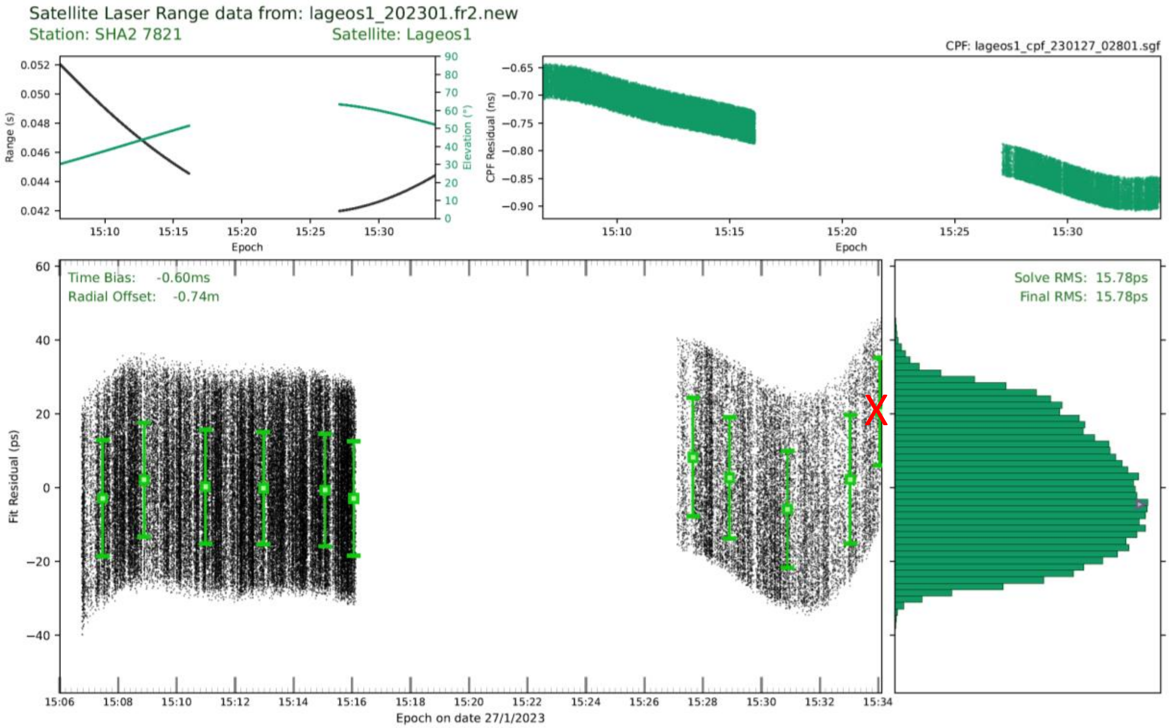
- 7839 does not generate NPs if there is insufficient fullrate data in a bin, see the red Xs on both charts where Graz didn't generate any NPs
- Does the LE filter have trouble identifying the LE when the data is sparse coupled with time gaps?

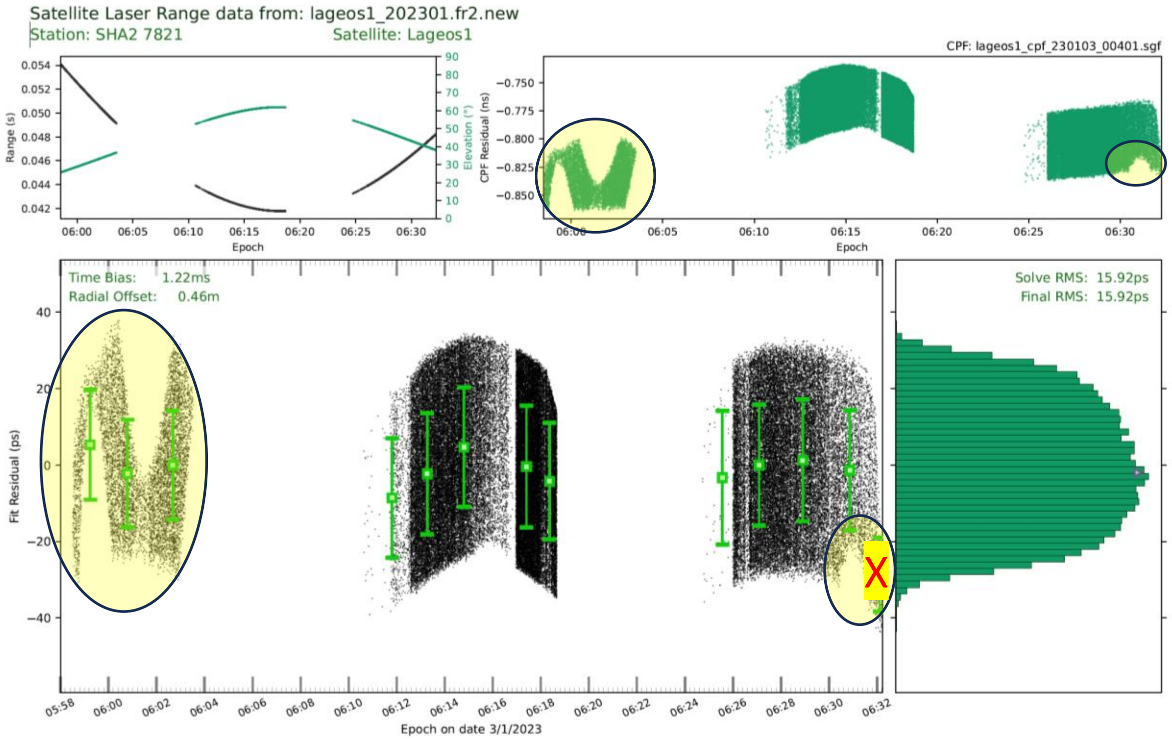
7839 GRZL LAGEOS-1 OrbitNP Fullrate Analysis (2024)



- It appears in 2024, 7839 is switching more frequently between satellites when tracking LAGEOS
- Single shot RMS is 5mm
- Seven NPs were created
- HITU NP RMS was 8 mm on the 7 NPs, larger than the single shot RMS
- JCET NP RMS was 3.1 mm after editing 1 of the 7 NPs
- CON: Quickly switching between satellites to maximize data yield can cause poor quality NPs

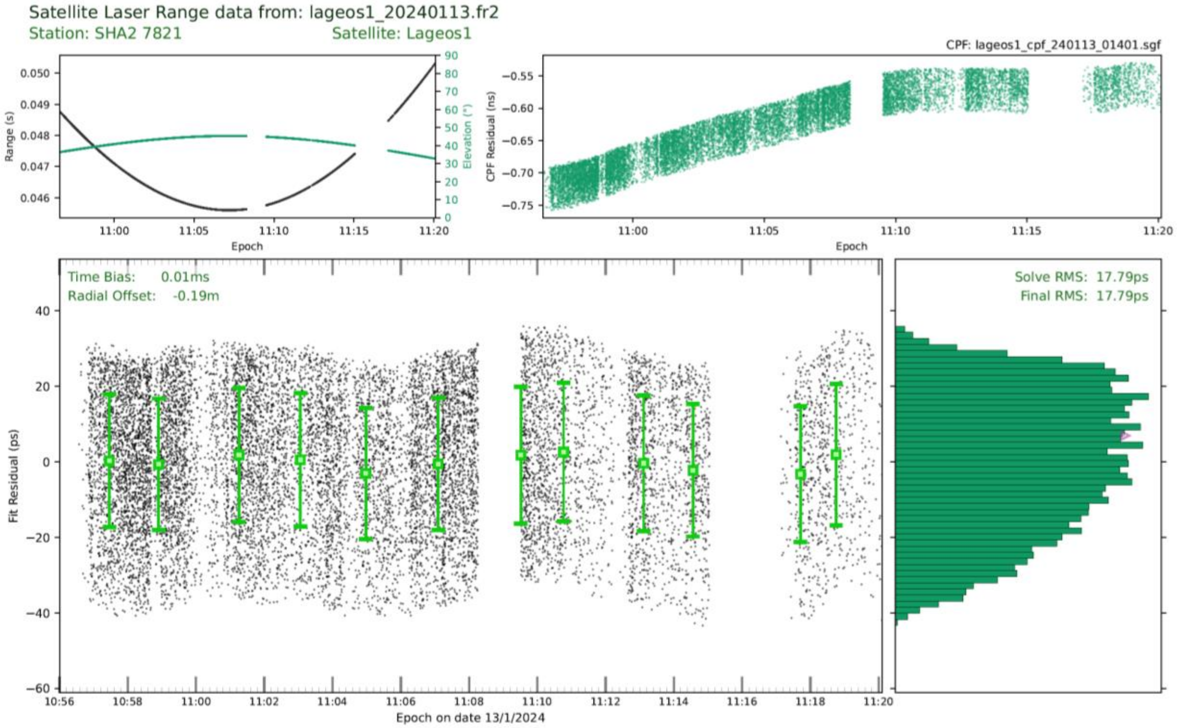
7821 SHA2 LAGEOS-1 OrbitNP Fullrate Analysis





- 7821 fullrate data has already been clipped by the 20 mm LE filter. The RMS scatter after applying the LE filter is ~4.8 mm. The HITU and JCET NP precision of the left and right LAGEOS-1 passes were 1&3 mm and 2.3&4.2 mm; respectively. The beginning and ending residuals on the right chart, highlighted in yellow, have some strange structure
- CON: polynomial fits to the LE may degrade when there are gaps in the tracking data

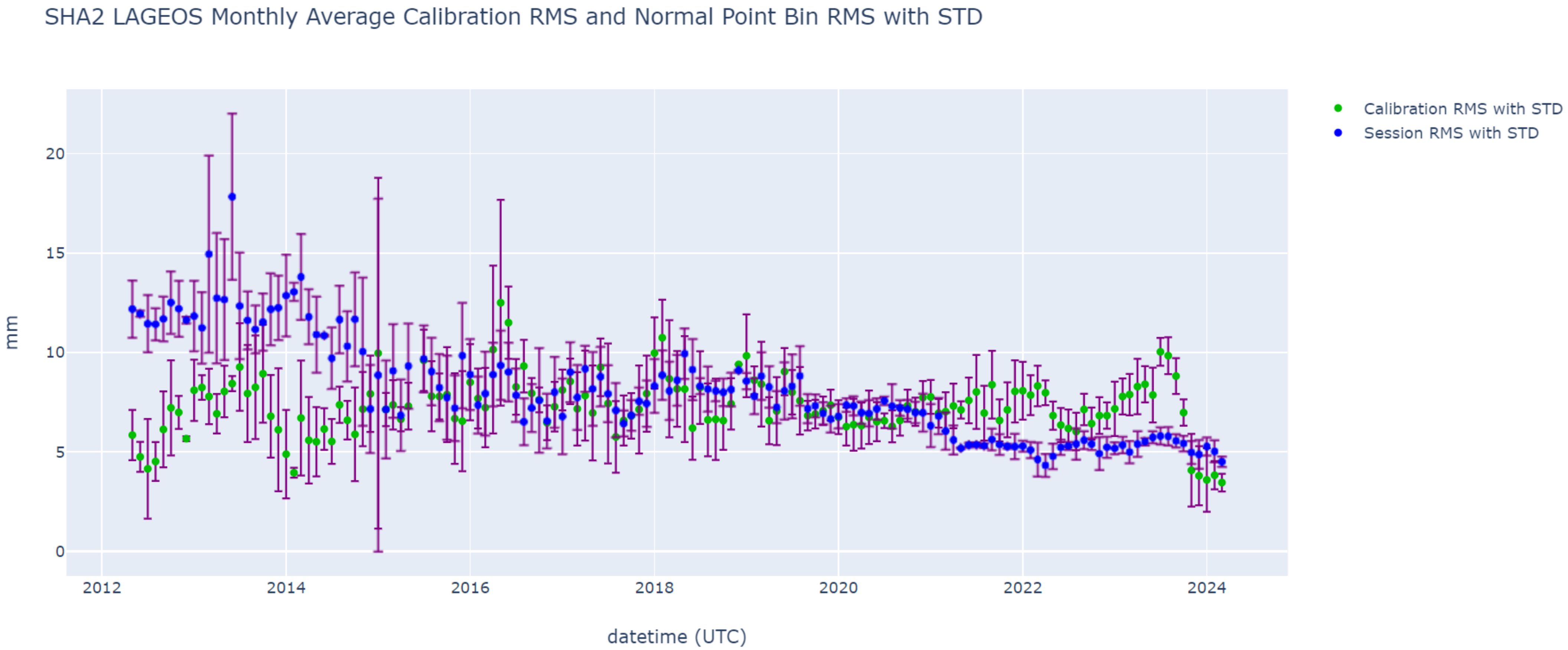
7821 SHA2 versus OrbitNP Comparisons



Epoch (Secs)	ToF (secs)	Obs	RMS (ps)	Skew	Kurtosis	Peak-Mean (ps)	Source	ToF Diff (mm)	Skew Diff	P-M Diff (mm)
39447.778002	0.048288450519	1370	35	-0.09	-0.91	8.9	7821	0.45	0.19	-0.94
39447.778002	0.048288450516	1370	35	-0.28	-0.91	15.2	OrbitNP			
39534.266802	0.047572092939	2468	35	-0.05	-0.92	3.4	7821	0.15	0.17	-0.36
39534.266802	0.047572092938	2468	35	-0.22	-0.90	5.8	OrbitNP			
39675.680202	0.046623935157	1570	35	-0.07	-0.99	10.2	7821	-0.15	0.20	-1.71
39675.680202	0.046623935158	1570	35	-0.27	-0.98	21.6	OrbitNP			
39783.490602	0.046100054846	1527	35	-0.07	-0.95	8.3	7821	0.00	0.20	-0.88
39783.490602	0.046100054846	1527	35	-0.27	-0.93	14.2	OrbitNP			
39898.466402	0.045741985458	1303	35	-0.06	-0.94	7.3	7821	0.30	0.18	-0.96
39898.466402	0.045741985456	1303	35	-0.24	-0.94	13.7	OrbitNP			
40025.749802	0.045595857376	1990	35	-0.07	-0.92	7.6	7821	0.15	0.18	-1.35
40025.749802	0.045595857375	1990	35	-0.25	-0.93	16.6	OrbitNP			
40171.005002	0.045756306388	859	37	0.00	-1.12	0.7	7821	0.60	0.05	0.09
40171.005002	0.045756306384	859	36	-0.05	-1.09	0.1	OrbitNP			
40246.204802	0.045976179980	966	37	0.00	-1.14	-6.0	7821	0.00	-0.01	0.49
40246.204802	0.045976179980	966	37	0.01	-1.12	-9.3	OrbitNP			
40386.847802	0.046632674000	907	36	-0.07	-1.00	8.9	7821	0.00	0.19	-1.98
40386.847802	0.046632674000	907	36	-0.26	-1.01	22.1	OrbitNP			
40473.536602	0.047191490301	537	35	-0.14	-0.76	8.4	7821	0.15	0.22	0.27
40473.536602	0.047191490300	537	35	-0.36	-0.77	6.6	OrbitNP			
40662.561202	0.048791975931	261	36	-0.08	-0.93	9.6	7821	0.00	0.17	-1.29
40662.561202	0.048791975931	261	36	-0.25	-0.91	18.2	OrbitNP			
40725.204002	0.049430239522	576	37	-0.04	-1.05	8.5	7821	0.30	0.15	0.78
40725.204002	0.049430239520	576	38	-0.19	-0.98	3.3	OrbitNP			
							Average	0.16	0.16	-0.65

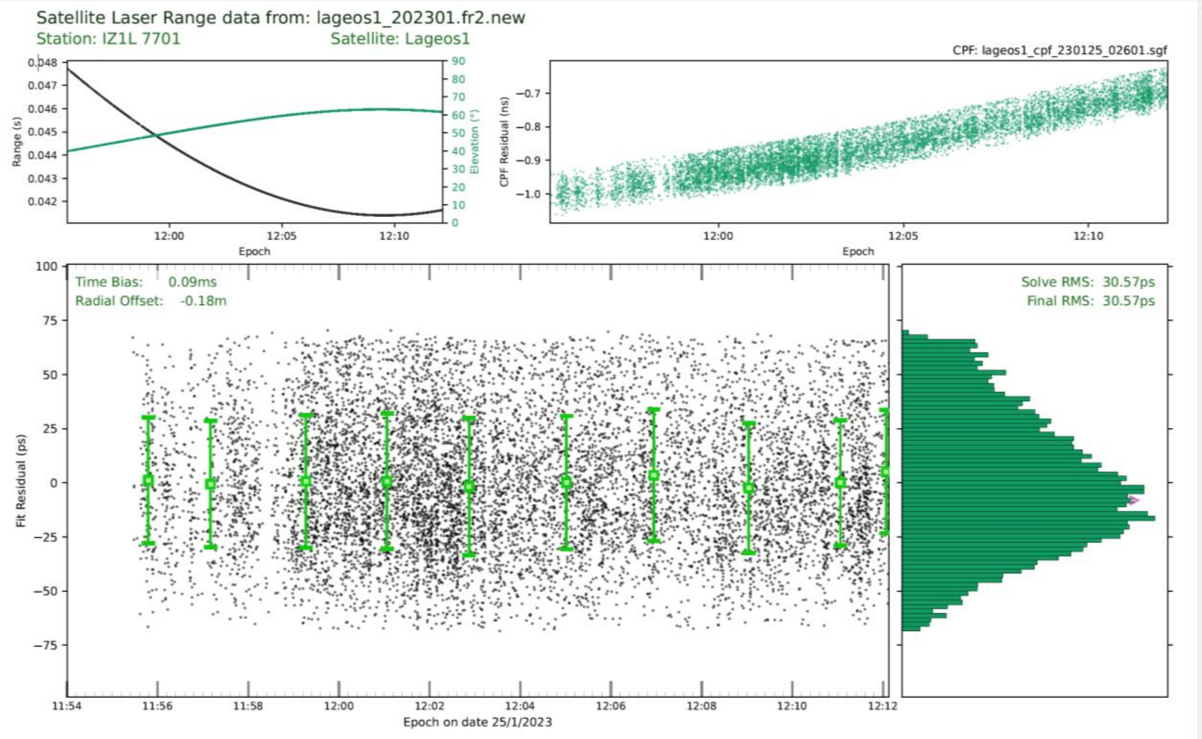
- **Conclusions: NP epochs agree; NP ToFs agreement to sub-mm; Observation counts, bin RMSs and kurtosis's agree; skews are quite different and there are variations in the P-Ms. Based on the OrbitNP histogram on the left, the data does appear to have a negative skew but the onsite generated skew is quite different.**

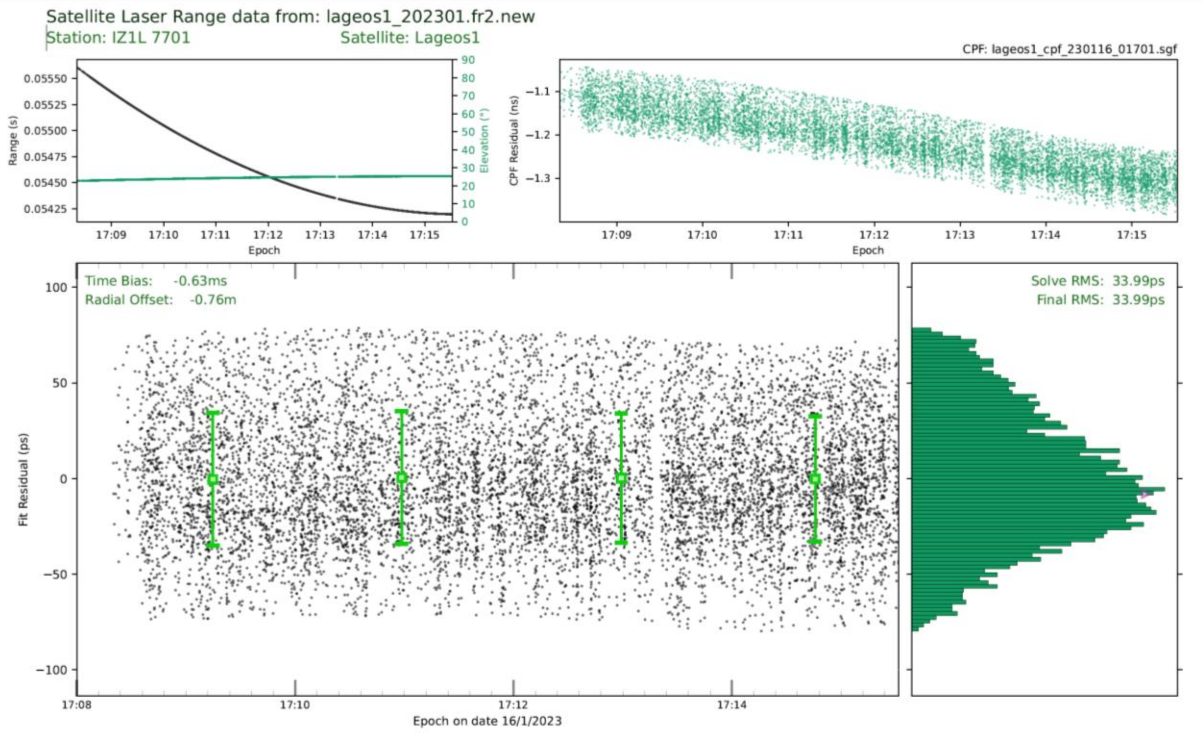
7821 Shanghai LAGEOS and Calibration RMSs



- The calibration RMSs are from a single cube mounted inside the building. Calibration RMSs should be less than LAGEOS even if the LAGEOS LE filter is applied. The calibration RMSs were reduced when the new shorter pulse-width laser was installed with a higher repetition rate in November 2023.

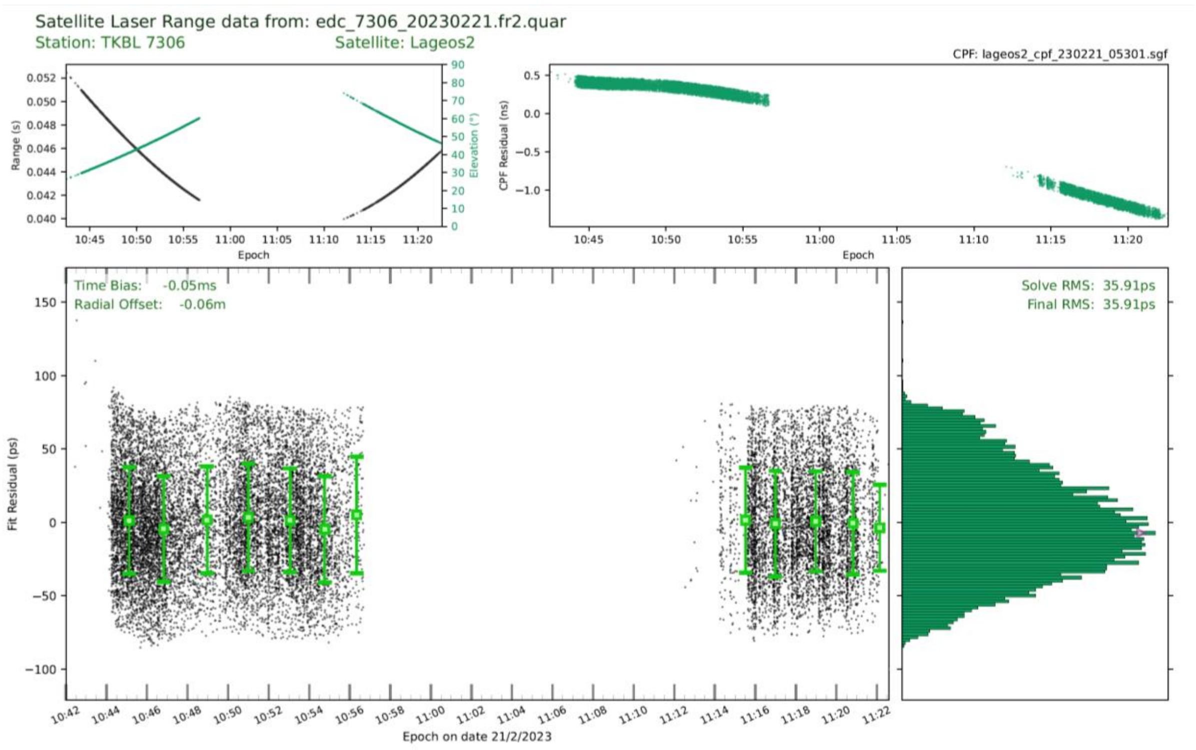
7701 IZ1L LAGEOS-1 OrbitNP Fullrate Analysis

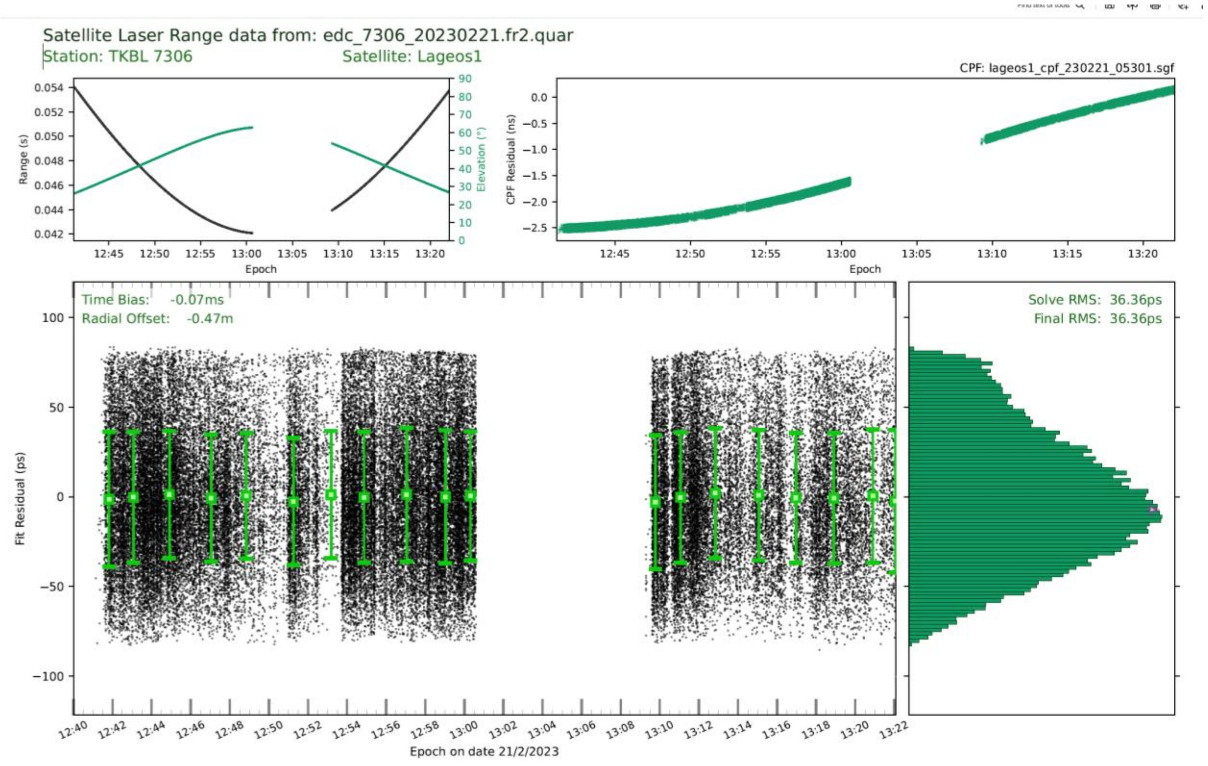




- 7701 fullrate data is clipped with a 2.2 sigma filter. All data is flagged as data (filter flag=2), excluded returns due to the 20 mm LE filter are not properly annotated
- CON: The fullrate data filter flag needs to be properly set to avoid any confusion and should be properly documented in the Site Log Section 10 Preprocessing Information
- The RMS scatter using a 2.2 sigma filter is 9 to 10 mm. Normal Points are formed based on a 20 mm LE filter. 7701 data with a 400 Hz infra-red laser is more sparse relative to 7839 and 7821 data which both have a 2 kHz green lasers

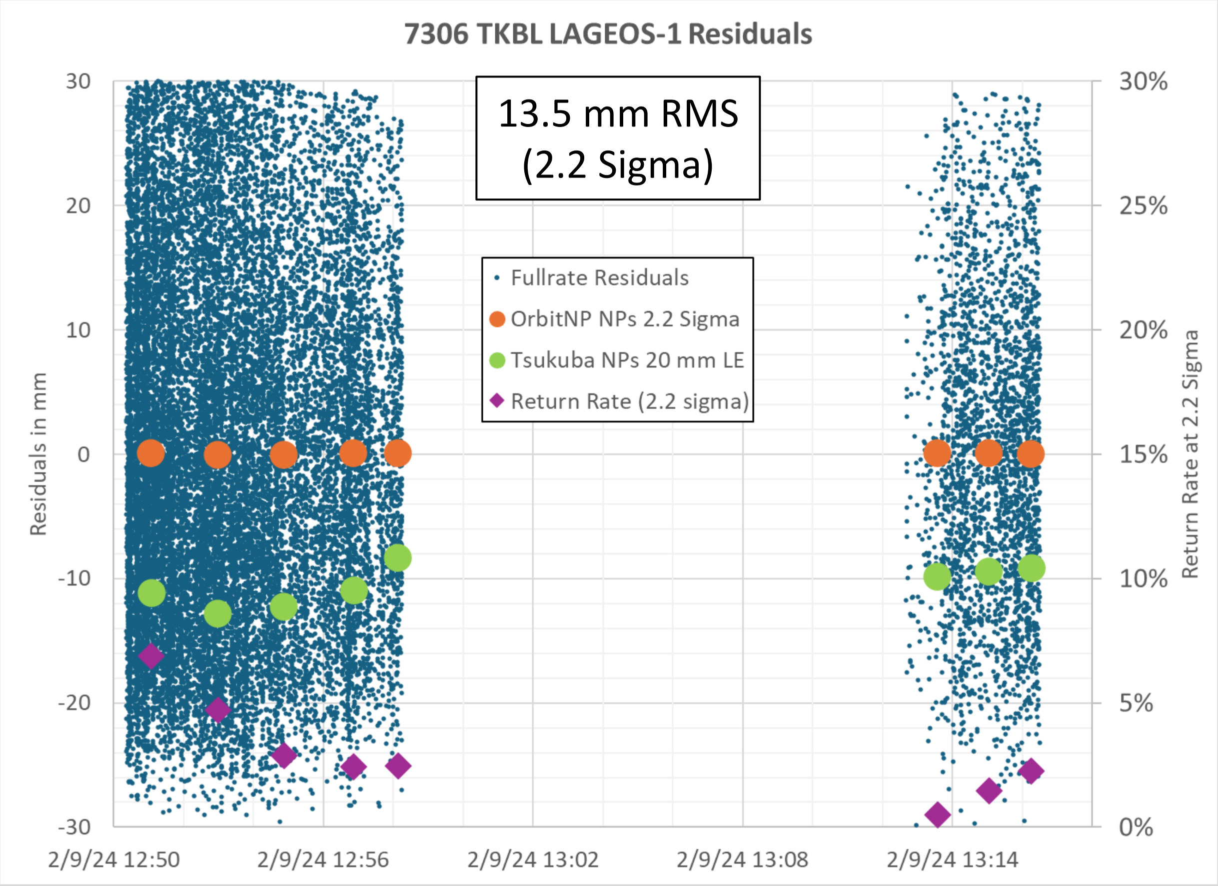
7306 TKBL LAGEOS-1 OrbitNP Fullrate Analysis

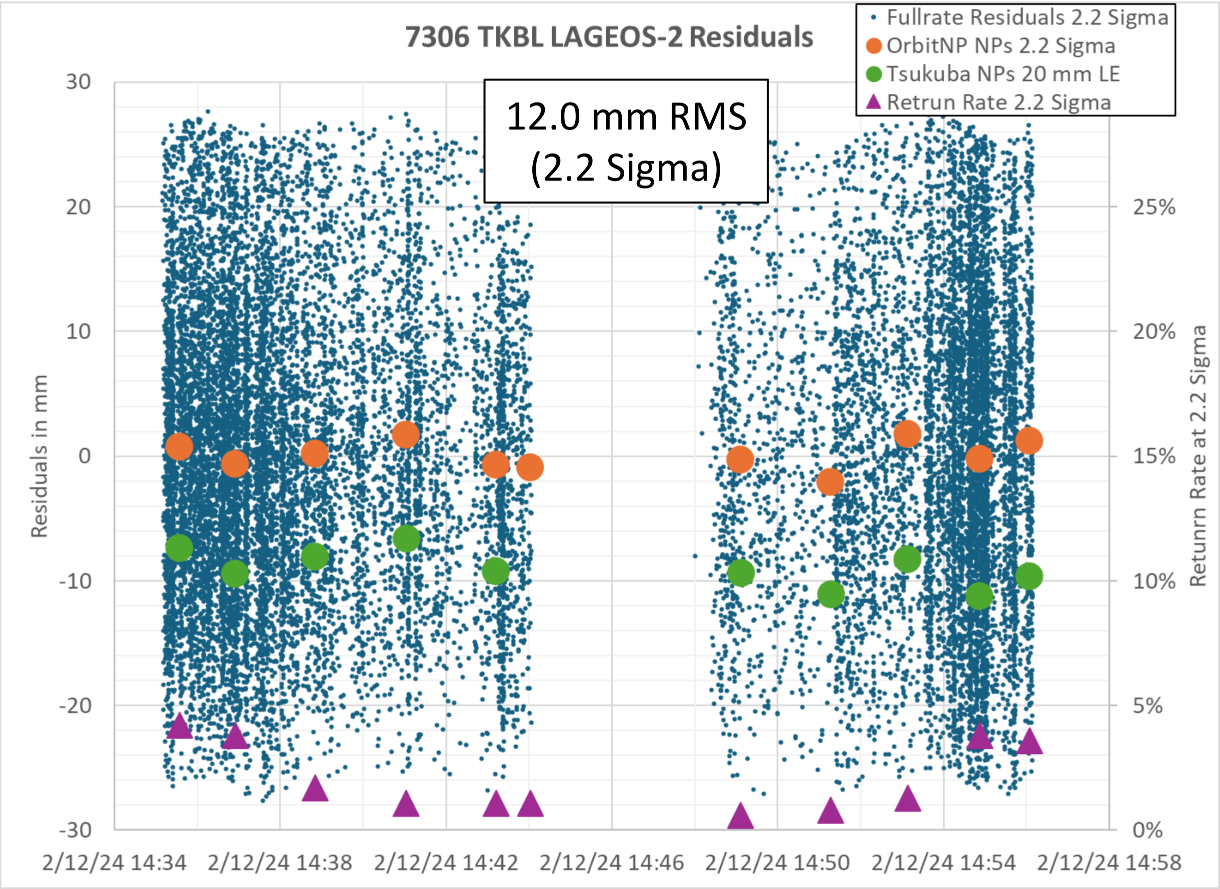




- **7306 fullrate data is clipped with a 2.2 sigma filter. All data is flagged as data (filter flag=2). The RMS scatter using a 2.2 sigma filter is 10 to 11 mm. Normal Points are formed based on a 20 mm LE filter**

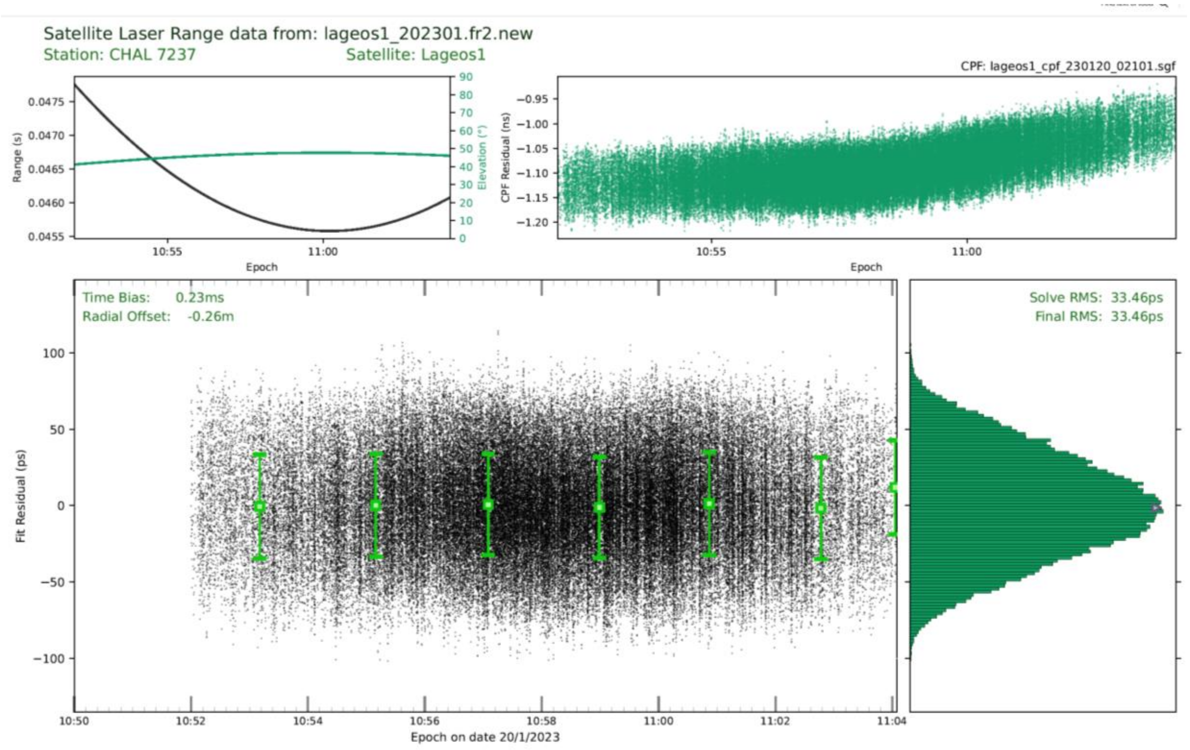
7306 TKBL LAGEOS-1 OrbitNP Fullrate Analysis

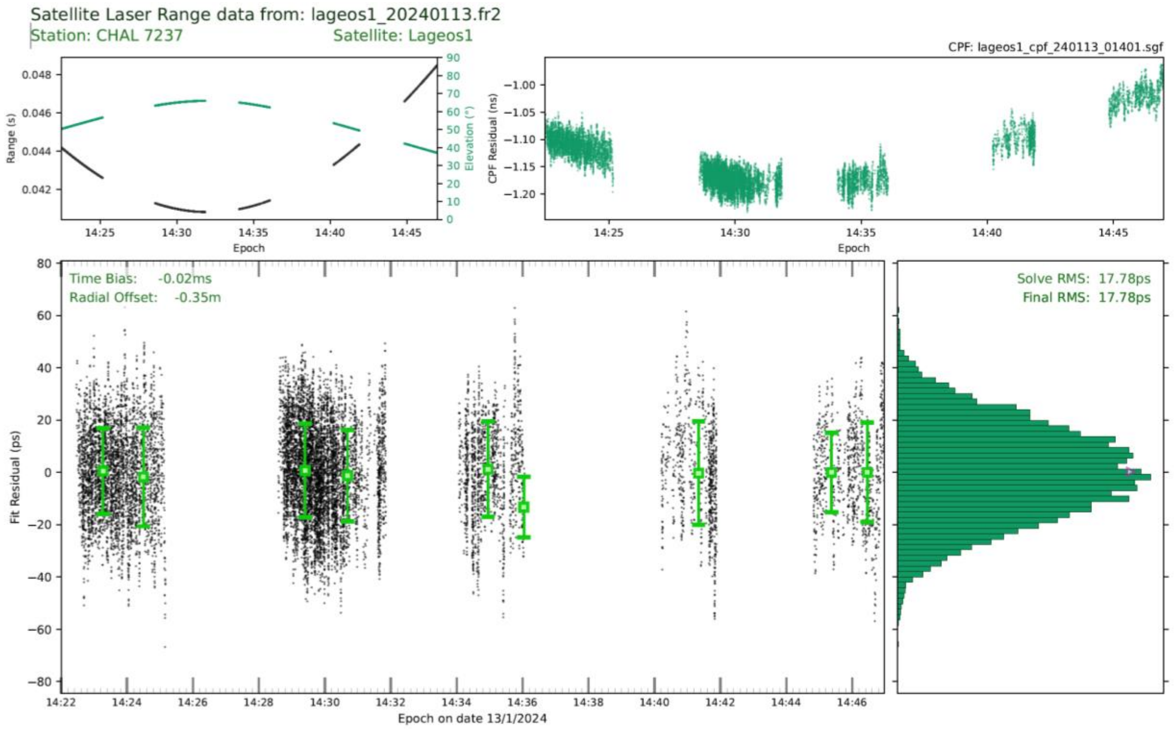




- **Here are comparisons of the OrbitNP generated NPs based on the 2.2 sigma edited fullrate data versus the site generated NPs based on the LE filter.**
- **The 7306 LAGEOS-1 pass has a larger RMS than the LAGEOS-2 pass and the LE NPs are biased more negative (-10.5 vs -9.0 mm)**

7237 CHAL LAGEOS-1 OrbitNP Fullrate Analysis





- **OrbitNP 7237 LAGEOS-1 residuals before and after 19-Dec-2023 implementation of the LE filter: Left chart 10 mm OrbitNP RMS and right chart 5 mm OrbitNP RMS. There is no clear sign of a LE relative to the other stations**

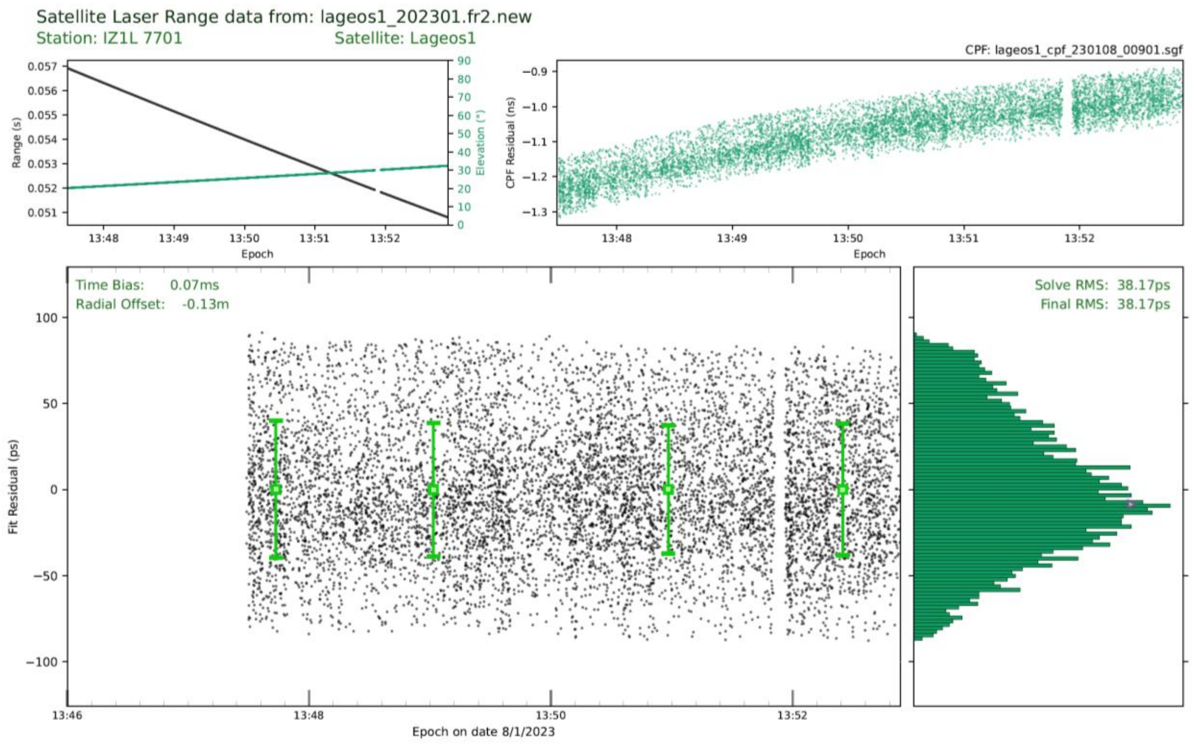
Summary

- **7839 GRZL was the 1st system to develop and implement a LE filter; since then, four other systems (7821, 7701, 7306, 7237) have implemented a LE filter. Will 7817 Yebes be next?**
- **The five systems that have implemented the LE filter have slightly different configurations (laser and receiver) and mode of operation**
- **7839 GRZL has the most consistent moments and their P-Ms can be used to model changes in their range biases**
- **When the LE filter is applied, changes in the 'true' single shot RMS result in range bias changes**
- **Discussion**
  - Does Graz possess the most robust LE algorithm and/or the optimum LE filter system configuration?
  - What is the best approach for the LE systems to provide their fullrate data so the inherent 'true' single shot RMS can be determined?
  - Is the LE filter reducing or increasing systematic errors?
  - Should Systems who implemented a LE filter be placed in quarantine and/or seek ILRS approval?
  - Should the LE filter be abolished?

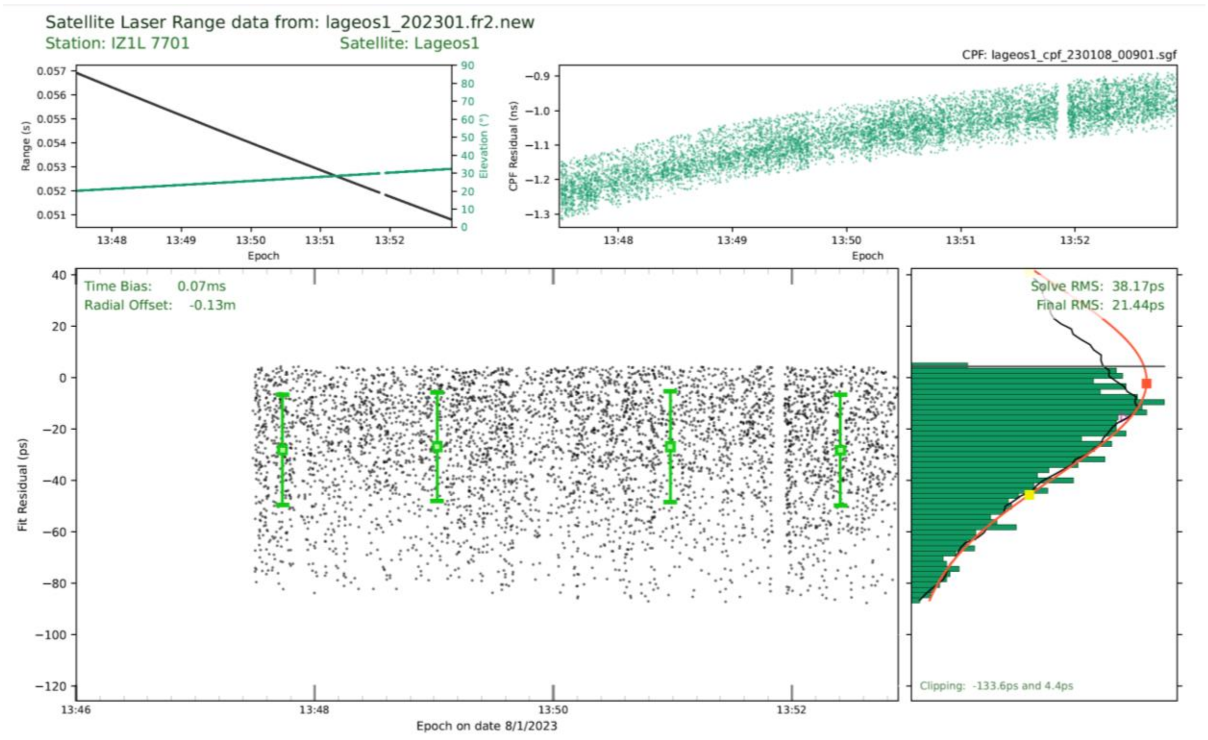
OrbitNP Analysis of a 7701 LAGEOS-1 fullrate data using different editing techniques

OrbitNP Different Editing Criteria Example using 7701 fullrate data

7701 Fullrate data (+/- 2.2σ)
No Additional OrbitNP Edit Criteria



7701 Fullrate data (+/- 2.2σ)
OrbitNP 2cm LE Filter applied

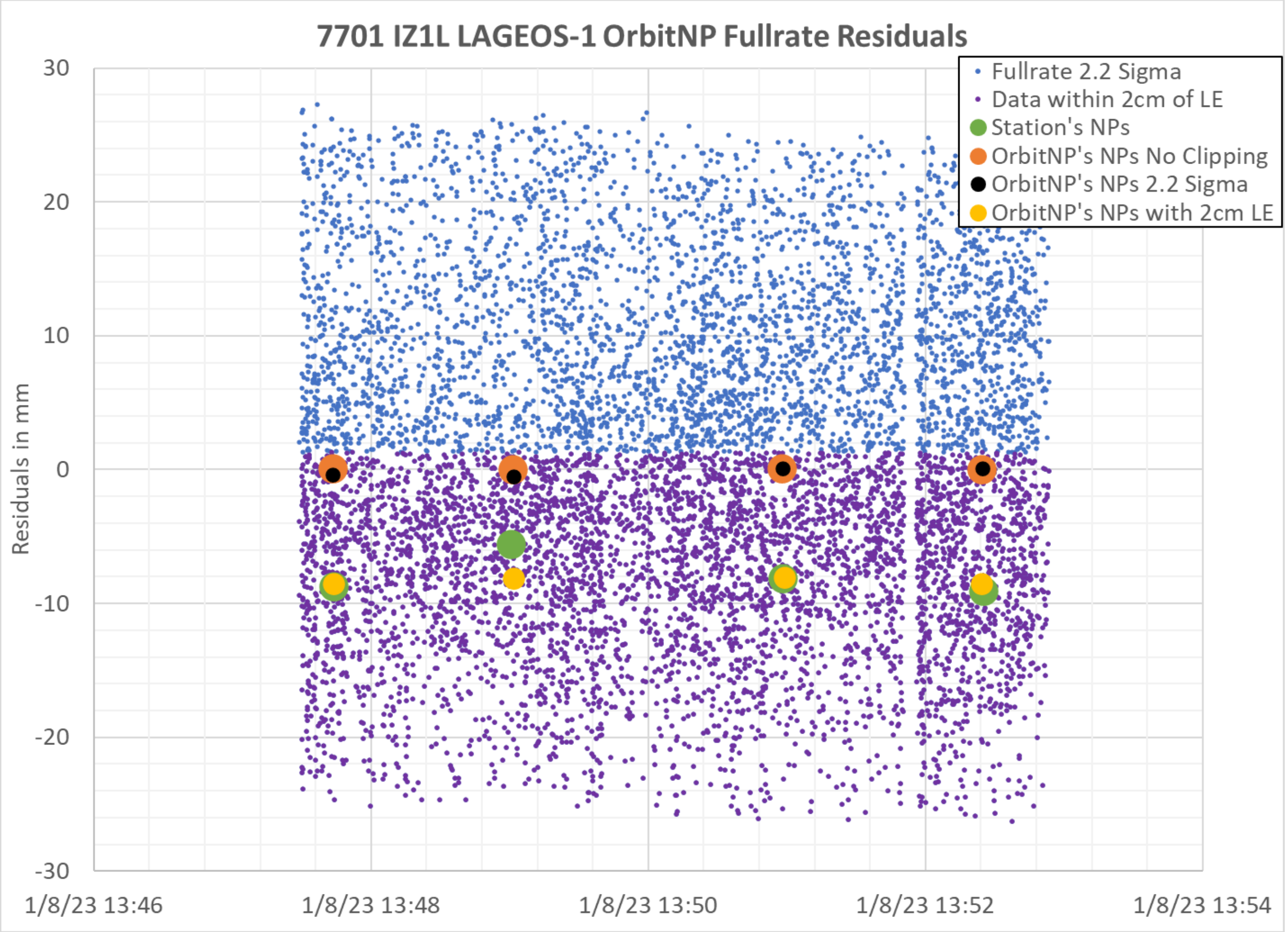


7701 IZ1L LAGEOS-1 (8-Jan-2023 at 13:47) NP Comparisons

Source	Seconds of Day	Range in seconds	Obs in Bin	Bin RMS (ps)	Bin RMS (mm)	Skew	Kurtosis	Peak - Mean (ps)	Peak - Mean (mm)	Return Rate (%)
OrbitNP	49663.520411523	0.056626979491	926	79.5	11.9	0.27	-0.60	-15.8	-2.4	7.5
OrbitNP	49741.698016615	0.055106421324	2962	77.5	11.6	0.27	-0.54	-19.6	-2.9	6.2
OrbitNP	49858.288061567	0.052898849868	3279	74.4	11.2	0.07	-0.59	-9.1	-1.4	6.8
OrbitNP	49944.785411640	0.051316672625	1604	76.4	11.5	0.06	-0.77	-21.8	-3.3	7.5
OrbitNP 2.2	49663.490411476	0.056627568422	912	77.2	11.6	0.24	-0.61	-11.3	-1.7	7.4
OrbitNP 2.2	49741.740561586	0.055105601959	2909	74.7	11.2	0.22	-0.56	-16.9	-2.5	6.1
OrbitNP 2.2	49858.288061567	0.052898849868	3252	73.1	11.0	0.10	-0.64	-10.5	-1.6	6.8
OrbitNP 2.2	49944.822911561	0.051315998268	1591	75.2	11.3	0.09	-0.81	-22.6	-3.4	7.4
OrbitNP 2cm LE	49663.827911486	0.056620943174	529	43.0	6.4	-0.51	-0.65	24.3	3.6	4.3
OrbitNP 2cm LE	49741.565561458	0.055108972279	1730	42.3	6.3	-0.63	-0.44	23.2	3.5	3.6
OrbitNP 2cm LE	49858.835561541	0.052888675556	1842	43.2	6.5	-0.67	-0.31	22.9	3.4	3.8
OrbitNP 2cm LE	49944.372911547	0.051324091301	899	43.2	6.5	-0.58	-0.38	24.7	3.7	4.2
Station	49664.095411509	0.056615692446	512	41.9	6.3	-0.52	-0.62	7.2	1.1	4.1
Station	49741.020411501	0.055119472519	1728	42.1	6.3	-0.60	-0.43	6.9	1.0	3.6
Station	49858.465561600	0.052895551095	1876	43.6	6.5	-0.66	-0.30	7.3	1.1	3.9
Station	49945.477911552	0.051304220965	884	42.7	6.4	-0.52	-0.42	7.9	1.2	4.1

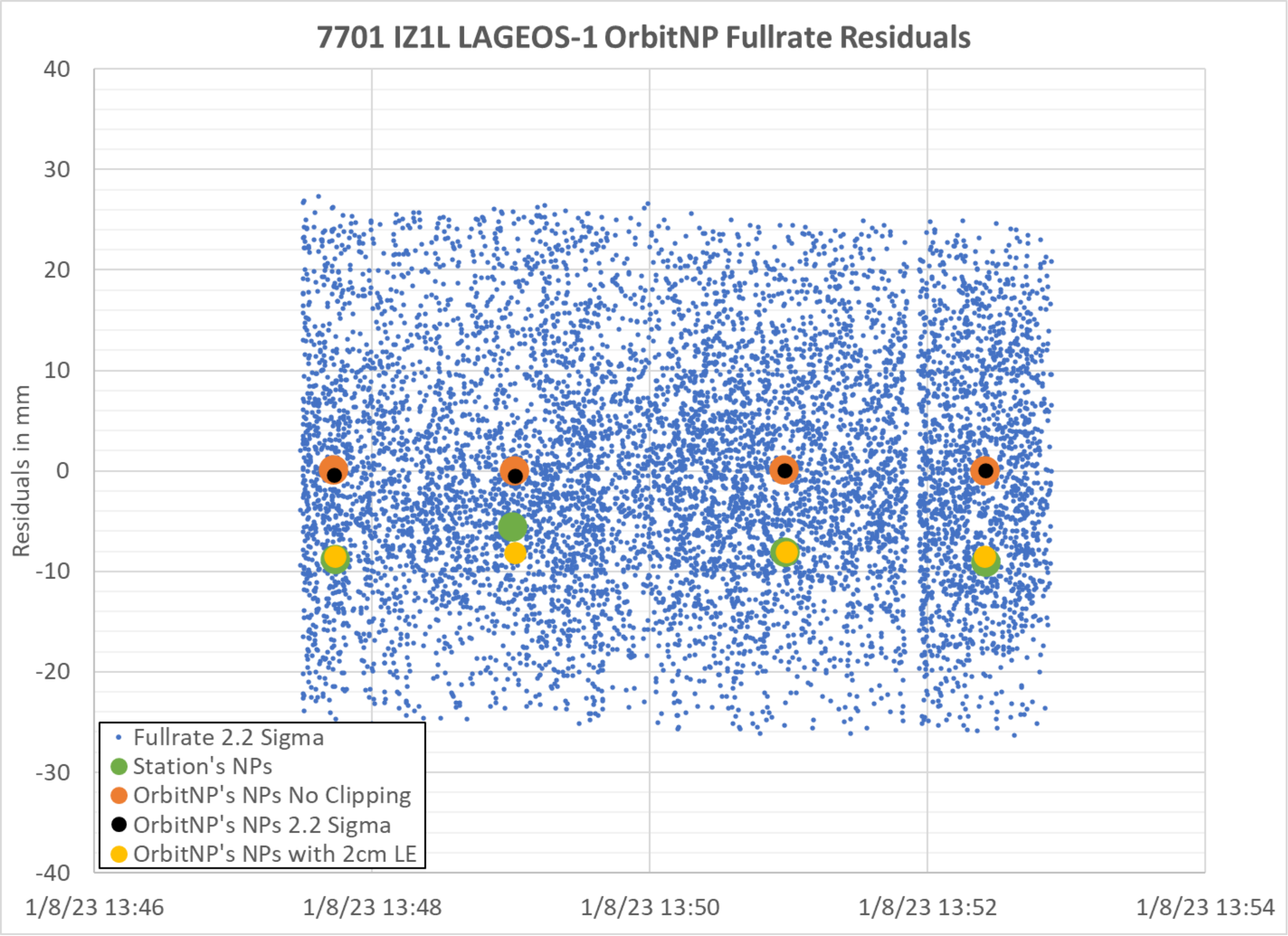
- **7701 CRD fullrate data includes all observations based on a 2.2 sigma filter, no observations are flagged as excluded. This table was presented during the March 2023 QCB meeting showing a comparison of OrbitNP generated NPs with different edit criteria along with the station generated NPs.**
- **Post March 2023 QCB meeting, DiGOS confirmed a 2cm LE filter edit criterion was being used for LAGEOS-1 and LAGEOS-2 for both DiGOS developed systems (7306 Tsukuba and 7701 Izana), and their site logs now reflect this**

7701 IZ1L LAGEOS-1 OrbitNP Fullrate Residuals & NP Comparisons



- Blue and purple dots represent all the fullrate residuals. The purple dots are the fullrate observations within 2cm of the LE determined by OrbitNP
- The mean offset between the Orange NPs (no editing) and the Green NPs (Station generated NPs using a 2cm LE filter) is 7.9 mm
- The mean offset between the Orange NPs (no editing) and the Yellow NPs (OrbitNP generated NPs using a 2cm LE filter) is 8.3 mm

7701 IZ1L LAGEOS-1 (8-Jan-2023 at 13:47)
Normal Point Comparisons



- ❑ **As it turns out, a precise orbit is NOT needed to compare the NP ranges when the NP epochs are NOT the same**
- ❑ **The FullRate (FR) residuals from OrbitNP can be used to compare the NP time-of-flights (ToF) by**
  1. Take the normal point epoch and find the corresponding FR ToF and residual
  2. For each normal point epoch take the NP ToF minus (the corresponding FR ToF from the CRD minus the OrbitNP FR residual)
- ❑ **The station generated NPs average offset is -8 mm which seems to indicate an ~2 cm LE filter has been applied**

Subject: [ilrs-qcb] Re: [EXTERNAL] Re: Quarantine Station procedure - possible updates needed
Date: Tuesday, March 12, 2024 at 8:27:10 AM Eastern Daylight Time
From: Mathis Bloßfeld via ilrs-qcb
To: ilrs-qcb@lists.nasa.gov

Dear Erricos, Alex, Toshi and Graham,

thank you very much for all your thoughts on the ILRS quarantine status. I also have a personal opinion which I want to share here...

1) As I stated in the QCB meeting yesterday and in agreement with what Erricos is writing, I recommend to keep a minimum of 20 passes per satellite (LA-1/-2, LRS, LR2, i.e. the primary geodetic spheres) as absolute requirement in order to pass the validation process to be released from the quarantine status. We want well performing stations with a reasonable data quality in our network. To ensure this a robust estimation of the arnge biases etc. is mandatory.

2) I see Toshi's point that for some stations, it might be hard to aquire enough passes to meet these requirements but I think we have to stress them to do whatever they can to get these passes. The above mentioned 4 satellites will build the basis for the future ILRS TRF, EOP, etc. products

3) Erricos is right in saying that we need to do the validation process for more than 1 satellite in order to see if the station observations are not corrupted by satellite target signatures, etc. Therefore, at least two satellites are necessary for the validation. I personally prefer the 4-satellite solution.

4) The ILRS quarantine status and validation procedure is a well established strategy to ensure data quality within the ILRS network. wWe are curently facing so many other problems with the TS model, the DHF and the NP generation at the stations (which are all correlated and dependent on each other) that I perosnally think we should keep the strategy as it is (I think this is the same as Magda was saying yesterday in the QCB).

5) **To be precise, the ASC needs 20 passes for each of the 4 satellites (LA-1/-2, LRS, LR2) with at least 5 NPs per pass over a time period of 60 days!** I really think this is achievable by all stations. If individual circumstances make it hard to reach these goals, I can also live with individual other qualification steps, e.g., observations to other geodetic spheres...

Bye, Mathis

PS: with the 7306 validation I ran into the problem that the NPs of Tsukuba once they are released are stored twice at EDC, in the common observation folder and the quarantine folder... this might be sth. we want to change in the future;-)
--
Dr.-Ing. Mathis Blossfeld

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Von: Alexandre Belli via ilrs-qcb <ilrs-qcb@lists.nasa.gov>
Gesendet: Montag, 11. März 2024 21:22
An: Carabajal, Claudia C. (GSFC-61A.0)[SCIENCE SYSTEMS AND APPLICATIONS INC]; epavlis@umbc
Cc: ILRS QCB QCB
Betreff: [ilrs-qcb] Re: [EXTERNAL] Re: Quarantine Station procedure - possible updates needed

Dear Team,

I would like to contribute my perspective on the quarantine aspect of our recent discussions. I welcome open dialogue and constructive feedback to ensure clarity and alignment.

Reflecting on our meeting, it's apparent that the term "quarantine" has generated some concern due to its negative connotations. I acknowledge the importance of incorporating all four targets for comprehensive statistical analysis. However, I recognize the challenge posed when a station, diligently observing one target, risks being labeled solely as a "quarantine station."

I found particular resonance in the statement from Ecp regarding the need to adapt rules dynamically to uphold ILRS Network standards while accommodating system nuances. This raises the need for a clearer delineation between two forms of quarantine: Qualitative Quarantine, which addresses biased or noisy data, and Quantitative Quarantine, solely based on pass frequency per target over a given period.

Introducing this distinction could alleviate concerns and foster motivation among stations, ensuring they understand the purpose and value of their contributions without feeling marginalized.

I welcome your insights and feedback on this proposal.

Best
Alex

From: epavlis@umbc via ilrs-qcb <ilrs-qcb@lists.nasa.gov>
Sent: Monday, March 11, 2024 3:52 PM
To: Carabajal, Claudia C. (GSFC-61A.0)[SCIENCE SYSTEMS AND APPLICATIONS INC] <Claudia.C.Carabajal@nasa.gov>
Cc: ILRS QCB QCB <ilrs-qcb@lists.nasa.gov>
Subject: [EXTERNAL] [ilrs-qcb] Re: Quarantine Station procedure - possible updates needed

Dear all,

I was not part of today's discussion but I heard through the grapevine that there is a proposal to change the criteria to 60 passes in total (which means that one or more targets can have ZERO contribution in these 60 passes!). I find this a very bad idea and I do not see the reasoning behind it helping ILRS maintain the quality of stations that want (need) for the future GGOS products.

When a station applies to join the ILRS network they sign off on the following pledge:

All stations in the ILRS network must routinely track LAGEOS-1, LAGEOS-2, and LARES.

Look up page 2 of the **ILRS Network Application Form.** By the way, the form is dated "20170614" and needs to be updated ASAP to include LARES-2 explicitly!

@Claudia: the application is linked to the "Station" choice on the "Join ILRS" side-bar link:

https://ilrs.gsfc.nasa.gov/about/joinilrs.html

We need to have a reliable sample of data on each target in order to characterize each station's performance, and even 20 passes is marginally sufficient for robust statistics. If we have no data or very few passes on target, we cannot make a reliable estimate of the station's quality. The two LARES targets have very much improved metrology, with the target signature correction being very well defined and far better than the older LAGEOS targets. This assures that the estimated biases will reflect station problems and NOT target related deficiencies, providing clean estimates of the bias.

If any station cannot meet these requirements it should expect to be moved to the group of "*Engineering Stations*" which we do not necessarily validate for acceptance, unless they request it and provide the data.

For what it's worth, in my opinion not having at a minimum 20 acceptable passes on each of the four targets is unacceptable for operational sites, especially for the Core network. When we were doing the QC validation we looked for 25 passes on each target, to make sure that the statistics were stable. Even if you accept to request all four targets, dropping the required passes to 15 per target seems a few steps backwards. Two months should be enough time for any station to collect these passes, and if there special circumstances (e.g. Arequipa’s rainy season, Golosiiv, etc.), we always modified the rules on the fly in order to accommodate the system without compromising the ILRS Network standards.

My 5¢

ecp

> On Mar 11, 2024, at 11:15 AM, <claudia.c.carabajal--- via ilrs-qcb <ilrs-qcb@lists.nasa.gov> wrote:
>
> Dear ILRS QCB colleagues,
> Attached is the latest version with comments for the Quarantine Station Procedure. Based on our discussion from the March 11th, 2024 meeting, there may be a reason to revise it.
>
> I have dated the file ‘03112024’ so I can keep track of the latest, and update it on the ILRS website as well.
>
> Please add comments with tracked changes, and append your initials to the filename before sending it back to the group.
>
> If changes need to be made, we should probably send a message to stations to make them aware of it.
>
> Regards,
> Claudia.
>
> --

> Claudia C. Carabajal
> Secretary, ILRS Central Bureau
> Research Scientist SME/HBG Geodesy & Geophysics Group Lead
> Mail Code 61A – Geodesy and Geophysics Laboratory
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