Update on the activities of the NASA GSFC/JCET ILRS Analysis Center

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Abstract

The NASA GSFC/UMBC JCET ILRS Analysis Center supports the International Laser Ranging Service (ILRS) by operating as an Analysis Center (AC), submitting regular SINEX solutions on a daily and weekly basis, acting as the backup combination center (ILRSB), and conducting validation of ILRS tracking stations. These validations are essential for new stations or stations implementing significant changes. In support of the ILRS Analysis Standing Committee (ASC), the JCET AC processes data to the ILRS "ITRF" satellites (LAGEOS-1, LAGEOS-2, LARES, LARES-2, Etalon-1, and Etalon-2) and submits different SINEX solutions containing Earth orientation parameters and station coordinates daily and weekly. We provide an overview of these analysis activities and present the methods and results of our recent validation efforts, benchmarking the ILRSB results with the results obtained by ILRSA. We summarize the recent contributions of the Analysis Center, including the v85 (ITRF2020 & extension contributions), v80, v180 (LAGEOS1, LAGEOS2, Etalon1-2), as well as v90, v190 (including LARES-2). Additionally, we report on the validation activities that we perform for the ILRS Analysis Standing Committee, where the performance of new stations or stations undergoing system upgrades are evaluated with respect to the quality of their precision of their data and their bias stability. ILRS Stations that have undergone validation in the last six months include Matera (7941), and Yebes (7817).

ILRS Station Qualification & Quarantine

What: When a new station applies to join the ILRS tracking network, or under special circumstances when an existing station has a long lapse in data delivery, or has undergone major changes, the station must undergo a "data validation" process in order to assess the quality of its data and to ensure that the overall performance of the station meets the ILRS Standards.

When: (1) New stations; (2) Stations undergoing major changes to the ranging system; (3) Stations that have not submitted data for more than 90 days.

Why: The purpose is to ensure that the station produces reliable data for users and for inclusion in ILRS products, especially for contribution to the International Terrestrial Reference Frame (ITRF).

How:
→ The stations whose data are being validated are asked to submit **at least** 20 passes of data to each of the following geodetic satellites, **LAGEOS-1, LAGEOS-2, LARES-2 and LARES**, nominally within a 60-day period (*exceptions can be made for special circumstances*). Stations should consider that the QC process might edit out some passes due to editing or removal of spurious data. **So, submitting more than the minimum number (*20 passes per satellite*) is a really good idea.**
→ **Stations should obtain more than five normal points per pass,** in order that the mean data precision and mean bias can be computed and to allow that spurious data might be edited.
→ The station SLR data are held in a special folder at the Eurolas Data Center (EDC) to be retrieved only by the members of the Analysis Standing Committee (ASC).

Who:
(1) **The station must inform the ILRS CB of any major changes, or repairs to the laser ranging system, and send the data it collects to the EDC.**
(2) **ASC-designated analysts**: F. G. Lemoine (*NASA GSFC*); M. Kuzmicz-Cielak (*GESTARII/UMBC*); A. Belli (*SSAI*), V. Husson (*Perraton*) **conduct the qualification analyses**;
(3) **The ILRS secretary** (C. Carabajal, *SSAI*) sends out the official announcements regarding the successful completion of the validation requirements.
(4). **The EDC** (C. Schwatke, *DGFI-TUM*) releases the with-held data to the public repositories and directories at the EDC and the NASA CDDIS.

Background models:
SLRF2020 coordinates if available, **the latest ILRS-approved target-signature model**; Station coordinates may be adjusted if warranted using the available station data.
POD Software:
NASA Precise Orbit Determination and Geodetic Parameter Estimation Program (GEODYN).

Other aspects: We have learned that it is useful to examine other aspects of the data (e.g. system delays vs time; verifying with independent software how the normal points are processed; checking the barometer (pressure) values with independent models such as VMF3o).

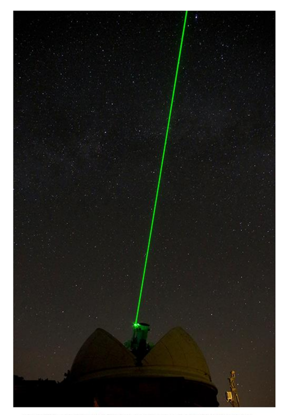
Feedback & Communication: An important aspect is to provide feedback to the station rapidly and regularly. Equally important is for the station to keep the ILRS informed of any station-related or data-related issues, especially while the station undergoes validation.
A reminder: Stations should update the history and site logs as necessary following any changes in the laser ranging system.

For more information:
https://ilrs.gsfc.nasa.gov/network/site_procedures/quarantine_procedure.html

Acknowledgement: E.C. Pavlis (UMBC/JCET, retired) for conducting the station validation process until November 2023.

2025 ILRS Stations Data Validation & Quarantine Analysis

Stations validated so far in 2025


Herstmonceux 7840


Credit: Astronomical Institute of the University of Bern (AIUB)
Zimmerwald 7810

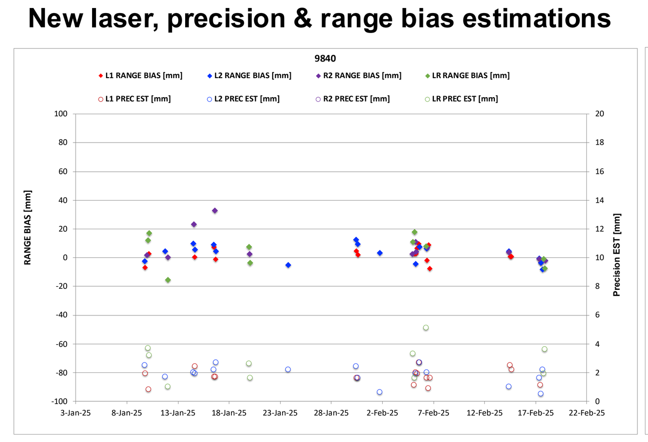

Wettzell 7827

Station	Status
Herstmonceux (HERL, 7840)	✓ Validated @ 532nm, 03/31/2025.
Zimmerwald (ZIML, 7810)	✓ Validated @ 532nm, 04/09/2025.
Wettzell (SOSW, 7827)	✓ Validated @ 850nm 04/14/2025.

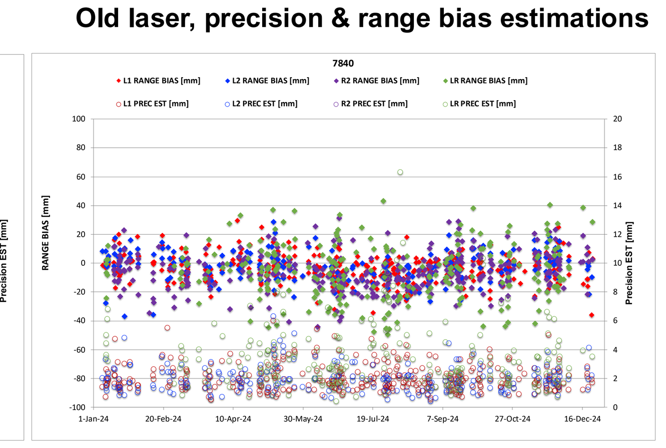
QC Validation for Herstmonceux 7840 New Laser

1. Used data from January – February 2025 provided by R. Sherwood, as well as normal ILRS data submitted by the station. (New station laser data results internally labelled "9840" in charts below)
2. Used normal station validation procedures (see Kunming meeting poster for details), estimating RMS and biases on pass-by-pass basis for passes with >= 5 normal points.
3. Coordinates are from SLRF2020. Target signature model as defined for this station and was not changed for these tests.
4. We analyzed all the data from the year 2024 using the same procedures as applied to the data in Jan/Feb 2025

New laser, precision & range bias estimations



Old laser, precision & range bias estimations



	New Laser 9840 (*data for January & February 2025*)			Old Laser 7840 (*data for 2024*)		
Satellite	Precision	Range bias	N passes	Precision	Range bias	N passes
LAGEOS-1	1.7 ± 0.5	1.5 ± 4.9	17	2.0 ± 0.9	3.7 ± 9.5	382
LAGEOS-2	1.9 ± 0.7	2.9 ± 6.1	17	2.0 ± 0.9	2.7 ± 10.3	236
LARES-2	4.3 ± 1.6	11.3 ± 17.1	12	5.8 ± 1.4	5.8 ± 12.7	341
LARES	2.8 ± 1.3	4.4 ± 11.0	10	3.4 ± 2.2	5.2 ± 18.8	255

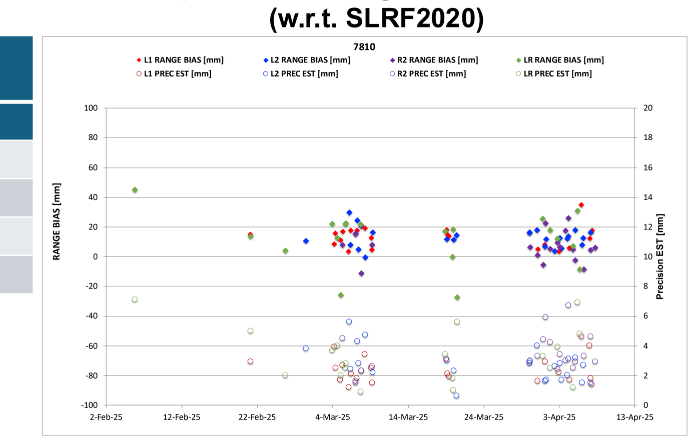
Conclusions:
1. Excellent performance with the new laser. Comparable to or even slightly better than the "old" laser.
2. Both data sets show good precision on L1, and L2 and minimal or no significant range bias (within the given statistical uncertainty).
3. The data precision seems higher on LARES-2, but we need to sort out if this is a processing issue, as we do not see this phenomenon with data from other stations.

QC Validation for Zimmerwald 7810

1. We completed the QC validation by analyzing quarantine data from 7810 for March and April 2025.
2. We find data precision of 2.4 ± 0.9 mm data precision for Lageos-1; 2.7 ± 1.1 Lageos-2; 3.4 ± 1.3 mm data precision for LARES-2, and 3.4 ± 1.8 mm data precision for LARES. We used the standard CoM models for this station. We find slightly positive mean biases for L1, & L2: 13.1 ± 7.1 mm (L1); 12.4 ± 6.6 mm (L2). For LARES-2, we find a mean bias of 7.3 ± 10.1 mm; For LARES, we find 12.0 ± 17.9 mm.

	Station 7810 (*data for March & April 2025*)		
Satellite	Precision	Range bias	N passes
LAGEOS-1	2.4 ± 0.9	13.1 ± 7.1	22
LAGEOS-2	2.7 ± 1.1	12.4 ± 6.6	24
LARES-2	3.4 ± 1.3	7.3 ± 10.1	20
LARES	3.4 ± 1.8	12.0 ± 17.9	19

7810 precision & range bias estimations (w.r.t. SLRF2020)

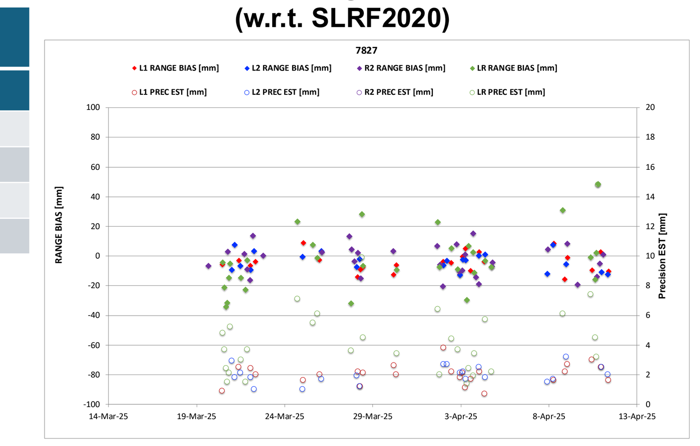


QC Validation for Wettzell 7827

1. We completed the QC validation by analyzing quarantine data from 7827 for March and April 2025. The station has sufficient passes and adequate performance to qualify for "exit from quarantine" after the system changes.
2. We find data precision for of 2.0 ± 0.7 mm data precision for Lageos-1; 2.0 ± 0.6 Lageos-2; 2.9 ± 1.4 mm data precision for LARES-2, and 4.4 ± 2.8 mm data precision for LARES. We used the standard CoM models for this station. Over the test interval for L1, L2, Lares-2, Lares, the average mean bias is statistically consistent with zero.

	Station 7827 (Wettzell) (*data for March & April 2025*)		
Satellite	Precision	Range bias	N passes
LAGEOS-1	2.0 ± 0.7	-4.8 ± 6.6	25
LAGEOS-2	2.0 ± 0.6	-4.1 ± 6.3	21
LARES-2	2.9 ± 1.4	-3.1 ± 10.0	32
LARES	4.4 ± 2.8	-3.6 ± 19.3	31

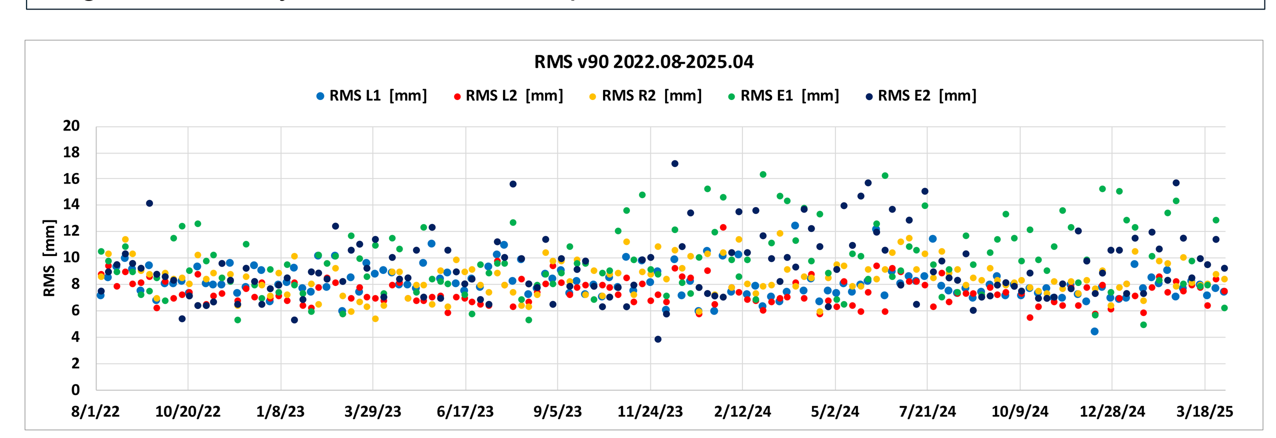
7827 precision & range bias estimations (w.r.t. SLRF2020)



Results of v90 Processing 2022.08-2025.04

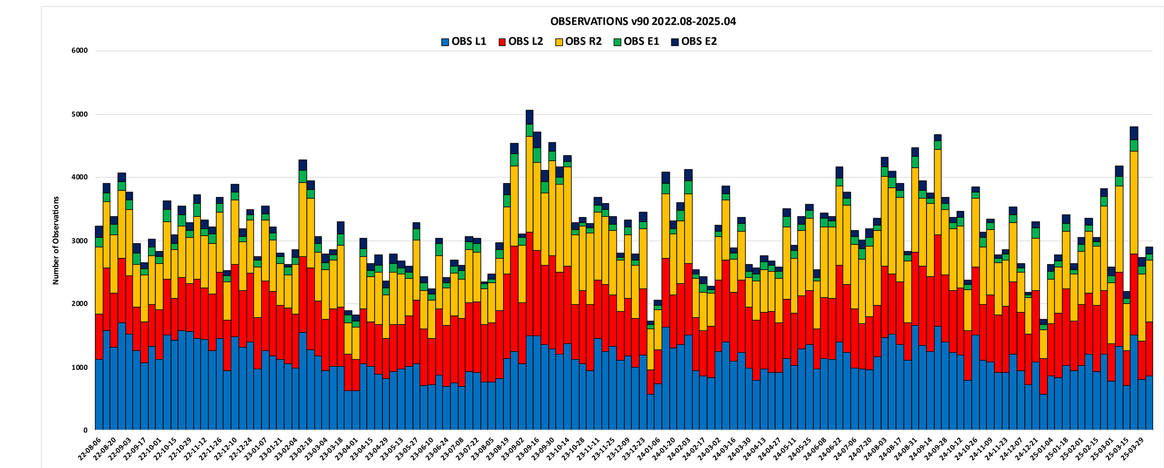
LARES-2 Incorporation into ILRS ASC Operational Products

Although LARES-2 was launched in August 2022, ILRS Analysis Centers began generating and submitting v90-format solutions in April 2025. These solutions follow the structure of the earlier v80 series but incorporate LARES-2 tracking data using the new Data Handling Format (DHF). The v90 series retroactively covers the period from September 2022 through April 2025. Including LARES-2 enhances geodetic coverage and contributes to improved reference frame realization and long-term stability of ILRS and ITRF products.



RMS [mm]	L1	L2	R2	E1	E2
Mean	8.1	7.4	8.5	9.8	9.3
STD	1.2	1.0	1.3	2.5	2.4

NO of OBS	L1	L2	R2	E1	E2
Mean	1120	948	911	120	111
Total	156855	132679	127603	16744	15513



Tsukuba 7306 Coordinate Summary

Iteration	Solutions (Epoch 2015.0)	X (m)	Y (m)	Z (m)	Δ from a priori X (m)	Δ from a priori Y(m)	Δ from a priori Z (m)	Δ from a priori lat (s)	Δ from a priori lon(s)	Δ from a priori h (m)
1	**SLRF2020 a priori, pre-240101**	-3961640.9245	3308774.6771	3734291.4734	-	-	-	-	-	-
1	L1+L2	-3961640.9264	3308774.4967	3734291.4757	-0.0019	-0.1804	0.0023	0.0022	0.0056	-0.0910
1	L1+L2+Lares2	-3961640.9278	3308774.4994	3734291.4753	-0.0033	-0.1777	0.0019	0.0022	0.0055	-0.0889
1	L1+L2+Lares2+Lares	-3961640.9263	3308774.4937	3734291.4746	-0.0018	-0.1834	0.0022	0.0057	0.0056	-0.0932
1	J3+S6A	-3961640.9192	3308774.4694	3734291.4845	0.0053	-0.2077	0.0111	0.0029	0.0062	-0.1044
2	**JAXA2022 a priori**	-3961640.9446	3308774.4052	3734291.4970	-	-	-	-	-	-
2	L1+L2+Lares2	-3961640.9323	3308774.4848	3734291.4914	0.0123	0.0796	-0.0056	-0.0009	-0.0028	0.0304
2	L1+L2+Lares2+Lares	-3961640.9367	3308774.4951	3734291.4960	0.0079	0.0899	-0.0010	-0.0010	-0.0030	0.0411
3	**L1+L2+Lares2+Lares a priori (from Iteration 2)**	**-3961640.9367**	**3308774.4951**	**3734291.4960**	-	-	-	-	-	-
3	L1+L2+Lares2	-3961640.9280	3308774.4992	3734291.4874	0.0087	0.0041	-0.0086	-0.0001	-0.0003	-0.0083
3	L1+L2+Lares2+Lares	-3961640.9252	3308774.5016	3734291.4872	0.0115	0.0065	-0.0088	-0.0001	-0.0005	-0.0090

Iteration	Solutions (Epoch 2015.0)	X (m)	Y (m)	Z (m)	Δ from a priori X (m)	Δ from a priori Y(m)	Δ from a priori Z (m)	Δ from a priori lat (s)	Δ from a priori lon(s)	Δ from a priori h (m)
1	**SLRF2020, post-240101**	**-3961640.9321**	**3308774.3897**	**3734291.5058**	-	-	-	-	-	-
1	L1+L2	-3961640.9275	3308774.4808	3734291.4880	0.0046	0.0911	-0.0178	-0.0015	-0.0029	0.0339
1	L1+L2+Lares2	-3961640.9283	3308774.4808	3734291.4897	0.0038	0.0911	-0.0161	-0.0015	-0.0029	0.0353
1	L1+L2+Lares2+ Lares	-3961640.9275	3308774.4773	3734291.4936	0.0046	0.0877	-0.0122	-0.0013	-0.0028	0.0354
2	**JAXA2022 a priori**	**-3961640.9446**	**3308774.4052**	**3734291.4970**	-	-	-	-	-	-
2	L1+L2+Lares2	-3961640.9323	3308774.4848	3734291.4914	0.0123	0.0796	-0.0056	-0.0009	-0.0028	0.0304
2	L1+L2+Lares2+Lares	-3961640.9367	3308774.4951	3734291.4960	0.0079	0.0899	-0.0010	-0.0010	-0.0030	0.0411
3	**L1+L2+Lares2+ Lares A priori (from Iteration 2)**	**-3961640.9367**	**3308774.4951**	**3734291.4960**	-	-	-	-	-	-

Summary:

We completed several series of adjustments with the Tsukuba SLR data, in order to estimate better coordinates for the station, before and after the Noto Earthquake (240101). In each case, the SLRF2020 velocities were held fixed [SLRF2020 Velocities (not adjusted): Xvel= -0.01054 m/yr; Yvel= -0.00635 m/yr; Zvel = -0.00415 m/yr], and the Epoch of the coordinates was unchanged. In each case, we stacked the normal equations over the designated time interval to obtain the coordinate solution. The data were processed in "multi-arcs" with GEODYN, after cleaning up the data with individual mono-satellite POD.

→ In Iteration 1, we started with SLRF2020 *a priori*, and used only the 2023 data (for the pre240101 estimate) and the 2024 data (for the post-240101 estimate). Range-biases/station/satellite per arc were adjusted in these runs.

→In Iteration 2, we started from the "JAXA2022 a priori" (supplied to E.C. Pavlis). Also, we included data from October 2022 to December 2023 (for the pre-240101 estimate); for the post-240101 estimate, we included data from January 2023 to March 2025. Also in iteration 2, in addition to the range biases, we adjusted troposphere biases and time-biases as global parameters (for TKBL) in the multi-arc run (with all the satellite data).

We tested the final set of coordinates for TKBL (*Iteration 2, L1, L2, LR+LARES-2*) using independent SLR data from weekly SLR+DORIS arcs of Jason-3 & Sentinel-6A from 2023, 2024 and early 2025. We found average TKBL SLR fits by year to be 2.3 to 5.5 mm (*after adjusting for a range bias/arc & other parameters*), showing that the new coordinates provide acceptable POD performance.

Conclusions: (1) The TKBL data are somewhat sparse, so it is best to stack the NEQ over an entire year (or more) to obtain the best solutions; (2) Adding in LARES, seems to benefit the solution estimation, but requires proper modelling (here we used the COST-G FSM gravity model, and substituted in the Loomis et al (NASA-GSFC)-derived values of C20, C21, S21, C30 for each arc (derived from geodetic satellites)). (3) We can try velocity estimation when we have more than 2 ½ years of data; (3) The new estimates are more consistent with the known (minimal) co-seismic displacement of stations in Eastern Japan following the Noto earthquake of 240101.