ILRS QCB Meeting
July 15, 2024
9:00 – 11:00 AM EST

Next QCB Meeting: Friday October 4th, 2024, 09:00-11:00 AM EDT (13:00 UTC)

Participants: Van Husson, Peter Dunn, Mike Pearlman, José Rodríguez, Alexandre Belli, Stefan Riepl, Matthew Wilkinson, Andreja Susnik, Magdalena Kuzmicz-Cieslak, David Sarrocco, Randy Ricklefs, Frank Lemoine, Austin Garrety, Claudia Carabajal.

The charts from the meeting will be available at (when posted):
https://ilrs.gsfc.nasa.gov/science/qcb/qcbActivities/index.html

Agenda:

- Stations udpates: Claudia/Mike
  - ILRS Survey and Station Plan – Claudia/Mike
  - San Fernando station updates
- Missions updates: Mike/Claudia
  . Missions SLR Tracking Report Template
  . New Galileo Satellites
- Van inputs:
  - Analysis of Full Rate Data (Peiyuan) Graz
  - Greenbelt Surveys and Calibration Issues
- Peter inputs:
  - Discontinuities
- Frank:
  - Station Quarantine Procedure Updates
  - Update on the COM models for the Geodetic Satellites
- Justine inputs from last meeting (not present at the meeting):
  - Do we want to maintain FR files; How do we keep track of FR - NP voids?
  - Notification of FR or NP voids?
- Graham and Andreja: Stanford historical problems (will report at a later date).

Stations Updates:

- **ILRS Survey and Station Plan:**
  - As a first cut, the Station Survey and Plan was sent to the following stations: Borowiec, Tahiti, Riga, Svetloe, Metsahovi, Simosato, Hartebeesthoek, Beijing, Mendeleevo, and San Juan. Received responses from several stations, and sent a reminder to those that did not respond. Responses received: Irkusk, Mendelevo2, Metsahovi, Badari, Svetloe, Zelenchukskaya, Borowiec, MOBLAS-6 and MOBLAS-8 (and Graz).

- Reviewers include: Van Husson, Randall Carman, Alexandre Belli, Mathew Wilkinson, Clément Courde, You Zhao, and Mike Pearlman. Reports received will be sent to the Review committee for their inputs.

- **San Fernando (SFEL, 7824) Station Upgrade (see slides):**
  The San Fernando station upgrade is underway with a new mount/telescope, and there was considerable discussion on how we should accommodate the change in the system reference point. In 1999 the station moved the laser without a survey to connect the old and new location of the mount, so Zuheir introduced the concept of a "second" occupation "B" in order not to lose the continuity in estimating a common velocity with "A". Without a new super survey to tie the new with the old locations of the mount and use of a new DOMES and the introduction of occupation "C" was introduced. We would expect that whatever was done to handle occupations A & B for 7824, we would need to expand this process, with a new SOD to accommodate the new third occupation C.

  However, with all the ITRS realizations nowadays, velocity constraints (even between the techniques) have been introduced. The IDS changes DOMES number quite often, when a DORIS beacon is replaced. As Mathis and Erricos have both cited, in the last SLRF2020 solution, a new DOMES number is introduced and the point code is changed from "A" to "B".

  Mathis and Erricos recommend (calling the TRF letter code "solution codes" instead of "occupations") that in the San Fernando case we: (1) increase the solution code to C, (2) change the DOMES number (must be requested at (https://itrf.ign.fr/en/network/domes/request<https://itrf.ign.fr/en/network/domes/request>) and (3) increase the system ID to 03 (like 78244503).

  From the ITRS CC point of view, a station is uniquely identified by the 4 character-ID, DOMES number and solution number (related to the number of discontinuities introduced). The latter one is usually checked by the ITRS CCs on their own since the interface between the techniques (e.g., SLR) and the ITRS CCs is not that strong.

  José Rodriguez pointed out that there will be a meeting with the Station and IGN to discuss this the following week. We will get an update at the next QCB meeting and we will discuss the system acceptance testing for the mount at that time.

  Van pointed out that we should have a survey to measure the new local ties between the new mount/telescope to the other space geodetic techniques at their sites (i.e. GNSS, DORIS). It would be great if the survey could be done by IGN. Maybe we should talk with Zuheir. CDDIS also needs to update its tables (more specific).

Missions Updates (Claudia/Mike):

- **Missions SLR Tracking Report Template**
  Template (version 1.6) was sent out to the active LEO satellites to start. Missions contacted were: Cryosat-2, Geo-IK-2, GRACE-FO-1 and GRACE-FO-2, HY-2B, HY-2C, HY-2D, ICESat-2, Jason-3, PAZ, SARAL, Sentinel-3A, Sentinel-3B, Sentinel-6A/Jason-CSA, Swarm-A, Swarm-B, Swarm-C, SWOT, TanDEM-X, TerraSAR-X.

  We received responses from: Sentinel-3/-6, GFO, PAZ and HY-2. We sent reminders to the other listed missions, extending the deadline to July 31st, 2024.

  Reviewers are: Rob Sherwood, Nils Bartels, Alex Belli, Van Husson, Mike Pearlman and Graham Appleby. Reports received have been sent to reviewers.

- **New Galileo Satellites**

  Two new Galileo satellites (-225 and -227) are active missions. The missions were contacted to verify parameters and assigned SIC. CPFs are flowing into CDDIS. The Priority List has been changed replacing Galileo 210 with Galileo-211 at priority #44. Galileo-210 will be decommissioned; CPFs are still going to be issued until then. Tracking reports from Van continue to be posted on the ILRS website for the Galileo for Science campaign:
  https://ilrs.gsfc.nasa.gov/science/SLR_science_campaigns/galileo_for_science.html

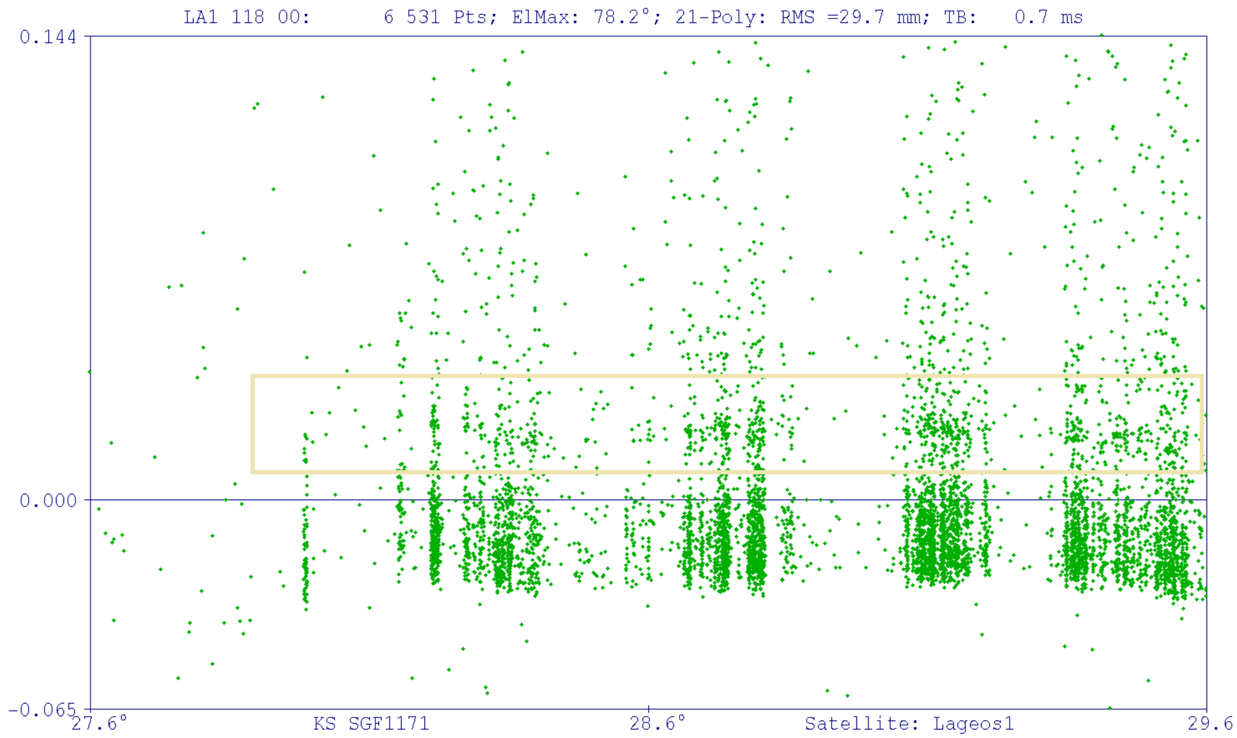
- **Contributions from Van Husson:**

  - **Analysis of Full Rate Data (**Peiyuan) **Graz**
    Communication with the station:
    - I completed my analysis of your full-rate data and normal point data. I think the LE algorithm that was implemented by your colleagues in 2008 coupled with your mode of operation (multi photon) is superior to that at the other stations (Shanghai, Changchun, Izana, Tsukuba) that have since implemented a Leading Edge (LE) algorithm. Here is description of what I did in my analysis. See attached presentation.

    - OrbitNP was used to generate residuals and normal points on all three versions of the Graz full-rate data. The raw Graz full-rate residual histograms from both LAGEOS-1 and LAGEOS-2 indicate some early ambient background noise; followed by a skewed distribution with a long tail (300+ps) and a clear LE. The LAGEOS-2 residual histograms exhibited some additional smaller peaks after the LE. Is some of the long residual tail due to 'ringing' of the CSPAD?

    - We believe this early ambient background noise and long tail come from the impulse response of the C-SPAD. Then this is related to true signal photons but not the corresponding to the true range. I've also just learned from one paper, and its "chapter 2" explains the same issue. https://opg.optica.org/oe/fulltext.cfm?uri=oe-19-11-10735&id=214120

- Regarding the small peaks of La2, first it comes very likely from the satellite signature. Although with the same CCRs distribution, why we do not see that from La1? We guess when choosing 5+5 Lageos passes, I was more in favourite to higher return rate – more in multi-photon mode. From different people we hear that La1 normally has higher return rate than La2 – if that is true (??) – The more in multi-photon mode, the more returns from the further CCRs (small peak) are "swallowed" by the closer CCRs. Below I show you a low return rate pass from La1, and you see the small peak is also appearing there.



- Microsoft Excel was used to overlay the 2.2σ and LE observations on the full-rate raw residuals to illustrate which 2.2σ and LE data was kept.

- Microsoft Excel was also used to directly compare the OrbitNP generated normal points (NPs) Time-of-Flights (ToFs) from the Graz 2.2σ fullr-ate data to the station's 2.2σ generated NPs since the NP epochs and the number of points in a bin matched exactly. The Bin RMSs varied slightly by a few tenths of a ps; the mean NP ToF differences for a pass were less than 0.2 mm, and individual NP ToF differences could approach 2 mm. Some of the variation between the two NP datasets might be caused by trends in OrbitNP full-rate residuals i.e. the residuals are not always 'flat' within the NP bin.

- The station's generated LE NPs can't be compared directly to either of the OrbitNP or the station's 2.2σ generated NPs, because the LE NP epochs will not match the 2.2σ generated NPs since there are less observations in the LE NP bins. However, based on the Herstmonceux normal point ToF equation, it is possible to compute the ToF offsets from the station generated LE NPs to the OrbitNP 2.2σ fullrate residuals. Below are the equations used to compute these LE NP ToF offsets:

- For each NP Bin_i
- $LE\_NP\_ToF\_Offset_i = LE\_NP_i - 2.2\sigma\_NP\_Simulated_i$ where
- $2.2\sigma\_NP\_simulated_i = 2.2\sigma\_O_i - 2.2\sigma\_Fit\_Residual_i + 2.2\sigma\_Mean\_Fit\_Residual_i$ where
- $2.2\sigma\_O_i$ is the Observation's ToF from the station provided 2.2σ edited fullrate data that has the same epoch as the LE_NP_i
- $2.2\sigma\_Fit\_Residual_i$ is the OrbitNP's fit residual for O_i
- $2.2\sigma\_Mean\_Fit\_Residual_i$ is OrbitNP's mean fit residual for Bin i

- The mean LE NP ToF offsets from the ten Graz LAGEOS 2.2σ fullrate passes along with several LE NP ToF offsets from Tsukuba (7306) and Izana (7701) were plotted versus their corresponding 2.2σ single shot RMSs revealing a linear trend. Graz (7839) had the most stable single shot 2.2σ RMSs and ToF offsets. The root cause of this linear trend is still undetermined and poses several questions:
- If the inherent single shot RMSs based on a 2.2σ edit criterion change, does applying a 20 mm LE filter induce a systematic error?

- We believe that is a good point in favour of LE. During real-time tracking, either stay always in single photon mode (not very simple: pointing offset, adjust divergence, switch filters….train observers accordingly, then loose the benefits of kHz), or only keep maximum return rate – like us, much less affords. The only thing is our observation might switch back and forth between single and multi-mode -- RMSs based on a 2.2σ changes also. LE is an efficient way to kick-out this trouble, because our "results" always from leading-edge to 20 (-3/+17) mm without introducing any systematic error – independent on mode.

- Are LAGEOS single shot RMS variations from pass-to-pass due to the retroflector array? Wilkerson's comment "The pass-to-pass variations of LAGEOS single shot RMS are due to both the retro-reflector array response and the signal to noise level. More noise means a larger sigma, which means wider N*sigma clipping, which results in a larger single shot RMS."

- He is somehow right. The retroflector array/the satellite signature can vary from pass-to-pass (bin-to-bin of NP) and depends on rotation/attitude/incidence angle….. The return rate, relating to single/multi-mode, decides the data distribution. Both will influence the final RMS.

1. Since applying a 20 mm filter, LAGEOS RMSs are constrained to a narrow band of 4 to 6mm. Does any degradation in the inherent station performance over the long-term induce a systematic error?

Yes or no. It depends on the station performance, to be more specific, the RMS after 2.2σ must be good enough (like Graz 😊). Otherwise if a station has Lageos 2.2σ RMS > 30 mm but applying 20mm LE filter, a systematic error is inevitable. In this case increasing LE filter width might be a solution to get a stable value – anyway RMS issue should be fixed first.

- **Center of Mass ILRS webpage updates (Frank):**
  - Updates to the CoM pages are out of date; they were done in April/May.

- **LAGEOS Center of Mass**

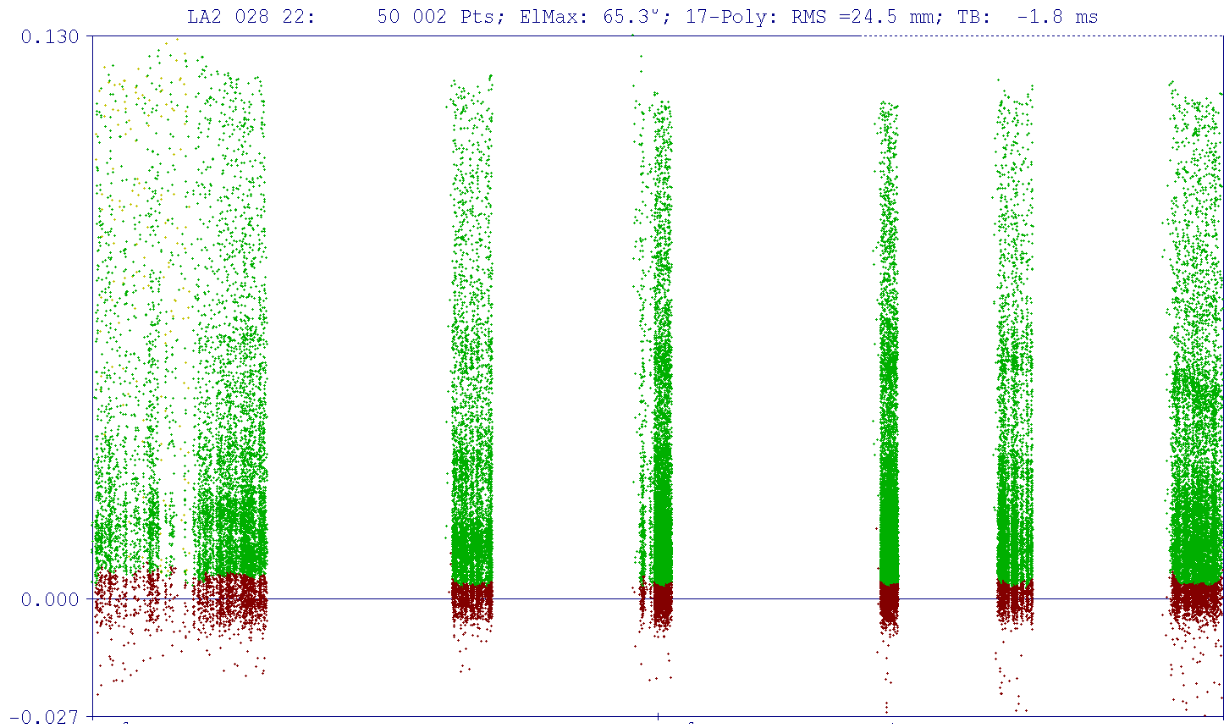
LAGEOS Center of Mass (CoM) corrections are dependent upon the NP formation edit criterion and will increase in magnitude from a 2.2σ to a 20 mm LE edit criterion. In Table 1 below are the Graz (7839) and Tsukuba (7306) average ToF offsets (LE - 2.2σ) and their standard deviations along with CoM differences (LE - 2.2σ): Note: Tsukuba CoM corrections based on LE filtering are still in progress. The mean Graz (7839) ToF offsets (LE - 2.2σ) are within ~1 mm of the CoM corrections.

Table 1: ToF Offsets (LE - 2.2σ)

	LAGEOS-1			LAGEOS-2		
Station	Avg Offset (mm)	Std Dev (mm)	CoM Diff (LE-2.2σ in mm)	Avg Offset (mm)	Std Dev (mm)	CoM Diff (LE-2.2σ in mm)
7306 TKBL	-9.0	1.0	TBD	-9.9	2.3	TBD
7839 GRZL	-2.0	0.7	-3.1	-2.2	1.1	-3.4

If a station switches from a sigma edit criteria to a LE filter, can this technique be used to estimate the CoMs differences between the different NP formation techniques?

Don’t know exactly how TKBL and IZ1L find their LE, we mark the leading 20% of all points of each NP bin (red dots in the picture below), then keep (-3/+17 mm). 20 mm LE defines a rather stable offset from CoM, however in case of using 2.2σ clipping, the bigger RMS (the broader distribution) the bigger offset to CoM. Therefore, we see that as the 2.2σ RMS increases the LE NPs will be biased more negative.



- Discussion:
  There were a few discussions during the review of Graz's comments:
  In the past few years, two Chinese systems (7237 CHAL, 7821 SHA2) and three DiGOS systems (7817 YEBL, 7701 IZ1L, 7306 TKBL) have implemented a LE filter and there was concern that their LE algorithms may not be identical to Graz's plus these other systems may operate at the different signal strength levels than Graz. Stations use one method that seems best for their data.

- Mike expressed concern that there is no ILRS standard algorithm used in filtering LAGEOS data prior to normal point production including no standard filtering approach for calibration data reductions.

- **Greenbelt Surveys and Calibration Issues (see slides from Greenbelt Surveys and 7105 Calibration Distances.pdf presentation)**

  - Pictures of the three 7105 GODL (MOBLAS-7) calibration piers were presented. Pier C is the prime 7105 calibration target while Pier A is the prime Space Geodesy (SG) SLR calibration target. The tops of both Piers A and C show "signs of deterioration", which doesn't imply the concrete pier is unstable.

  - There have been five Greenbelt local surveys since the late 1990's, three by NASA SLR surveyors (1999, 2007 and November 2012) and two by the NOAA National Geodetic Survey (NGS) (July 2012 and March 2024). The NGS survey reports provide a table of the geocentric (i.e. X, Y, Z) coordinates of reference marks including the 7105 System

Reference Point (SRP); the 7105 brass monument; and the 7105 Calibration Piers A, B and C. The algorithm to compute the 7105 Calibration target distances was presented and requires two additional pieces of information that are not included in these reports, the prism height and its depth at a wavelength of 532 nm. Prism heights are constant, but prism depths can vary by millimeters.

- Based on the 2024 and 2012 NGS geocentric coordinates and the computed distance between the different reference marks, there appears to be an ~+0.000064 scale error in the 2024 coordinates. This is further supported by 7105 MINICO ground test results. An email has been sent to Kevin Jordan of NGS presenting this evidence, but his reply is pending. It was also mentioned the NGS Monument Peak Survey performed in 2018, may exhibit the same issue.

Contributions from Peter (ITRF2020 HartRAO height rates from SLR, VLBI, GNSS and DORIS presentation):

- 'Ideally, any "signal" being detected is seen in all three* major geodetic systems, and they have sufficiently different sensitives to systematic errors that a common signal is likely to be real'. Tom Herring (p.c. EGU2024)
- The VLBI and DORIS systems show flat long-term height for HRAO in ITRF2020.
- The long-term height series for GNSS HRAO is compromised by several discontinuities.
- 'IGS station operators are way too cavalier about their antennas, causing so many discontinuities that the induced velocity errors across the network will never get down to the stated GGOS levels'. Jake Griffiths (p.c. 2024)
- HARL exhibits small but significant (and questionable) uplift in ITRF2020.
- A discontinuity applied to the HARL height series has also compromised the SLR results.

Frank Lemoine's follow-up to the ILRS QCB after Peter's presentation:

1. A couple of comments on the DORIS solutions:

(a) The early part of the time series (before 2002) will be noisier for two reasons
(i) The DORIS satellite. receivers could track only one station beacon at a time;
Only 2-3 satellites were in orbit.
(ii) Starting in 2002 we had multiple satellites, Jason-1, Envisat, SPOT-5
that had dual-channel DORIS receivers
(iii) Starting in 2008, all new satellites included DGXX (7-channel) DORIS
receivers.
(iv) Hervé Fagard of IGN; with the support of the IGN & CNES implemented
a station monumentation improvement program (1990's to mid-2000's) -- which
increased the stability of the monuments.
(v) so for above reasons - to reiterate. the latter part of the DORIS position time
series are better determined than the early part of the DORIS time series.

(b) The IDS Combination Center, Toulouse, Guilhem Moreaux, produces quarterly solutions, extending the DORIS contribution to ITRF2020, but w.r.t.ITRF2020.

He archives "STCD" files (station coordiante displacement series) at the NASA CDDIS:

https://cddis.nasa.gov/archive/doris/products/stcd/ids24wd01/

Accessible using a NASA Earthdata account.

I attach a tar file of the ids24 data files and plot (png) files for colocated SLR+DORIS stations.

(c) It might be useful to look at alternate GNSS solutions either from JPL or from the Nevada Geodetic Laboratory (unfortunately apparently still in IGS14). The latter from UNR is courtesy of Geoffrey Blewitt and colleagues.

JPL:
https://sideshow.jpl.nasa.gov/post/series.html

UNR:
https://gcc02.safelinks.protection.outlook.com/?url=http%3A%2F%2Fgeodesy.unr.edu%2FNGLStationPages%2Fstations%2FGODE.sta&data=05%7C02%7Cclaudia.c.carabajal%40nasa.gov%7Cec1ce91ee3d7418ae05f08dca50e9561%7C7005d45845be48ae8140d43da96dd17b%7C0%7C0%7C638566729968060533%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C0%7C%7C%7C&sdata=xSkpxRMMc1xiM7hs7kXMV%2FvL3gxOrqr14bp73ioptcM%3D&reserved=0

Attached is a tar file of the ids24 data files for co-located SLR+DORIS sites.
If you have questions about the combination, Guilhem is the person to interrogate.

I should add that when DORIS instruments are changed, there typically is a ground survey, and therefore to construct the long-term solutions in the ITRF DORIS-DORIS site ties are applied. The file of these tie vectors is available somewhere on the IDS website.

To learn more about particular DORIS sites and their history, please look at the site logs:

https://gcc02.safelinks.protection.outlook.com/?url=https%3A%2F%2Fids-doris.org%2Fnetwork%2Fsitelogs%2Fstation.html%3Fcode%3DHARTEBEESTHOEK&data=05%7C02%7Cclaudia.c.carabajal%40nasa.gov%7Cec1ce91ee3d7418ae05f08dca50e9561%7C7005d45845be48ae8140d43da96dd17b%7C0%7C0%7C638566729968068993%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C0%7C%7C%7C&sdata=ALWwouq2zTj9kuVZoeHcbgbCh3UX2iSmuxIXKqSUiac%3D&reserved=0

- **International Workshop on Laser Ranging – Kunming 2024 (Claudia)**

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
- NASA approvals for participation may be difficult, needed two months in advance.
- Splinter meetings possible, schedule unknown.

Next QCB Meeting: Friday October 4th, 2024, 09:00-11:00 AM EDT (13:00 UTC)

Table 1. History Log Voids by Station (2024.07.05)

Station Location	CDP #	Time Gap(s)*				Last entry
Kiev	1824	000120-080302	080402-110515			141410
Komsomolsk	1868	NO DATA				
Simeiz	1873	NO DATA				
Mendeleevo	1874	NO DATA				
Altay	1879	NO DATA				
Riga	1884					240705
Arkhyz	1886	NO DATA				
Baikonur	1887	NO DATA				
Svetloe	1888	NO DATA				
Zelenchukskaya	1889	NO DATA				
Badary	1890	NO DATA				
Irkutsk	1891	NO DATA				
Katzively	1893	NO DATA				
Yarragadee	7090					240530
Greenbelt	7105					240418
Monument_Peak	7110					240614
Haleakala	7119					240304
Tahiti	7124	020825-080414	130321-191022			230520
Changchun	7237	950101-970802	020714-051002	180410-210106		240417
Beijing	7249	881101-940301	940301-981116	981116-211013		230425
Tsukuba	7306					231108
Sejong	7394	NO DATA				
Wuhan	7396	NO DATA				
Arequipa	7403	920718-951023	951023-981130	981130-010523		200629
San Juan, Argentina	7406	NO DATA				
Brasilia	7407	NO DATA				
Hartebeesthoek_HARL	7501	020409-081105				240530
Hartebeesthoek_HRTL	7503	NO DATA				
Izana	7701					230406
Zimmerwald_532	7810	030905-060203	080715-100901			231019
Borowiec	7811	030329-071227	080205-131218			211005
Kunming	7819					240306
Shanghai_2	7821	140222-170315	170720-190811			231113
San_Fernando	7824	900703-930222	971216-010124	090302-110601	180801-210518	231121
Mount_Stromlo_2	7825					210901
Wettzell_SOSW	7827	140501-160511	160511-190528	200424-230607		240119
Simosato	7838	900701-950810	950810-991007	991019-040701	080401-181212	211209
Graz	7839	150504-190311				240117
Herstmonceux	7840					230427
Potsdam_3	7841	040906-081026	081026-110501	170303-200303		240305
Grasse_MEO	7845	010601-200818				240517
Matera_MLRO	7941	140902-171204	171206-210629			240612
Wettzell	8834	980720-001012	001012-090324	090324-131021	170407-190604	240605

* Assuming at least 2 year data gap

Status 2024.07.09