Current state of the contribution of ESA's Izana-1 station to the ILRS

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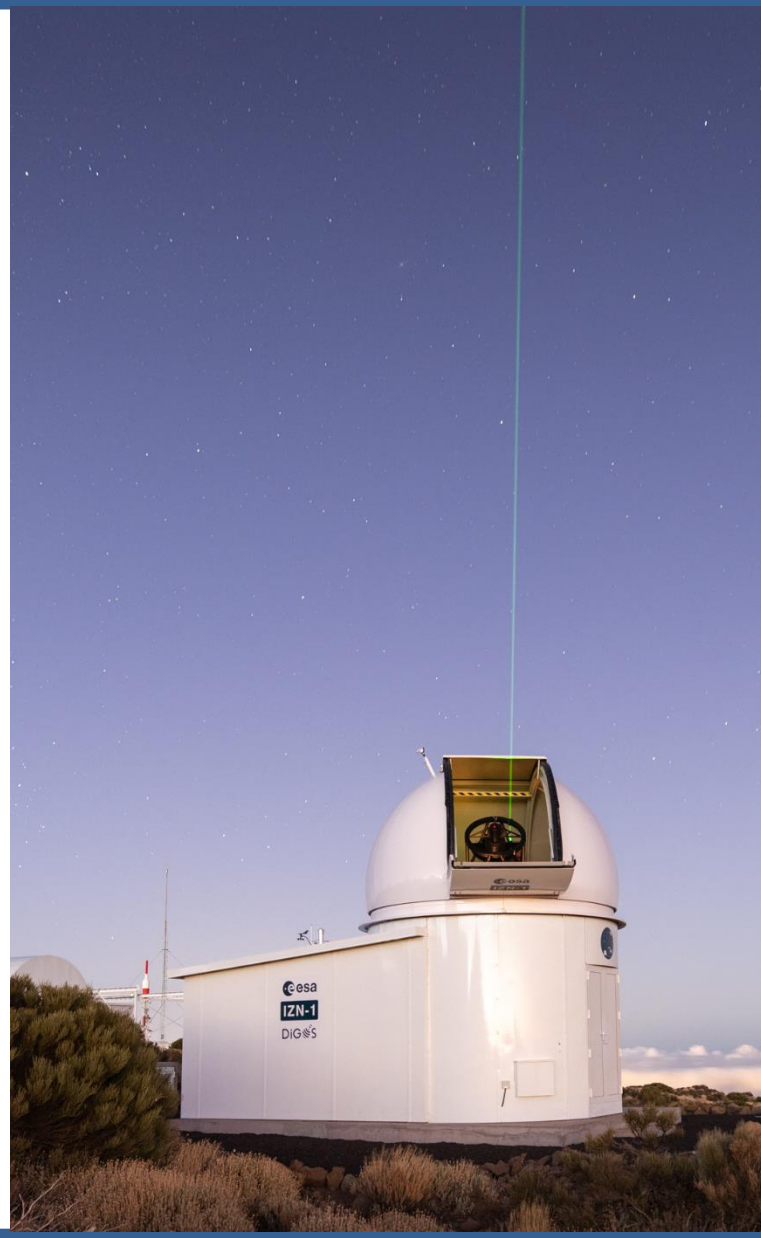
22nd ILRS workshop, Nov 10th 2022, Guadalajara, Spain.

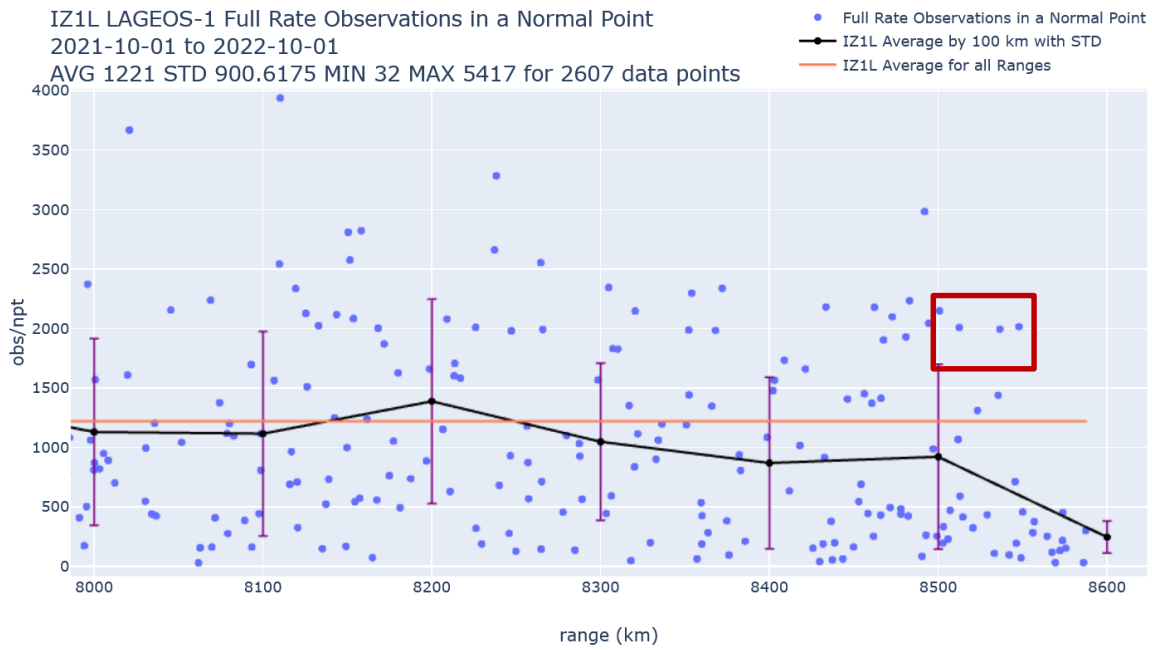
Content

- Station performance and conditions
- Station data amount and distribution
- Station data precision
- Station data accuracy
- Station calibration experiments
- Further station experiments

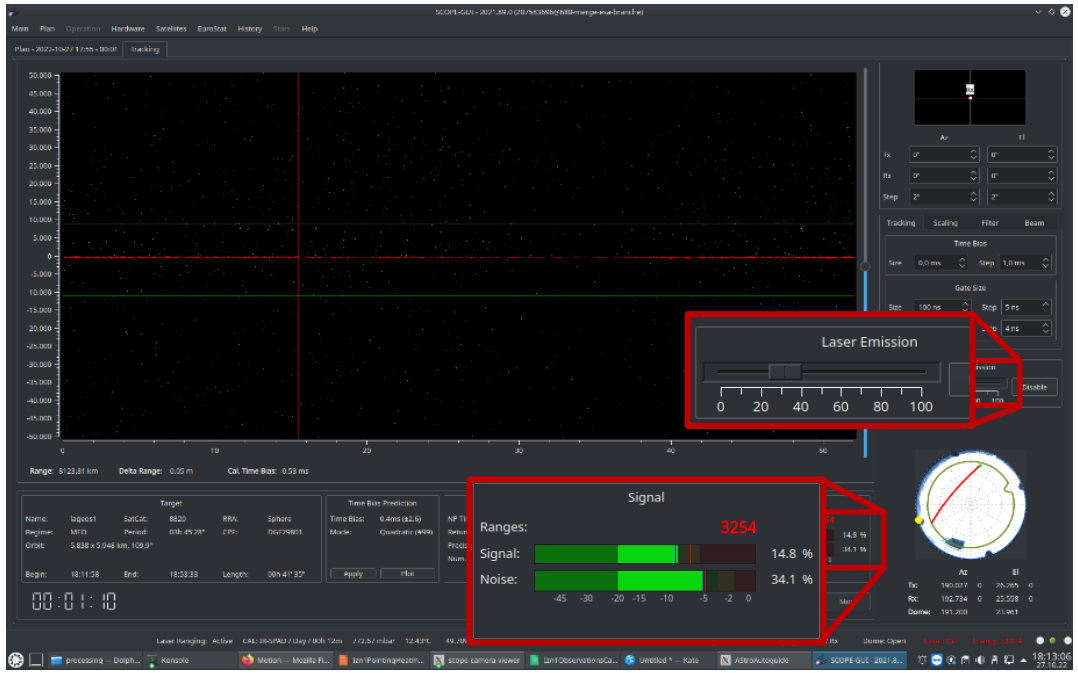


Station performance and conditions

- Currently operational baseline is 1064 nm with 550 µJ pulses @ 400 Hz (piggyback)
  - Other optical/astronomic observatories
  - Less noise
- Good performance e.g. for Lageos
  - Up to 4% return rate per NPT almost down to the horizon
  - Up to 15% FR data return rate at 30% of the energy



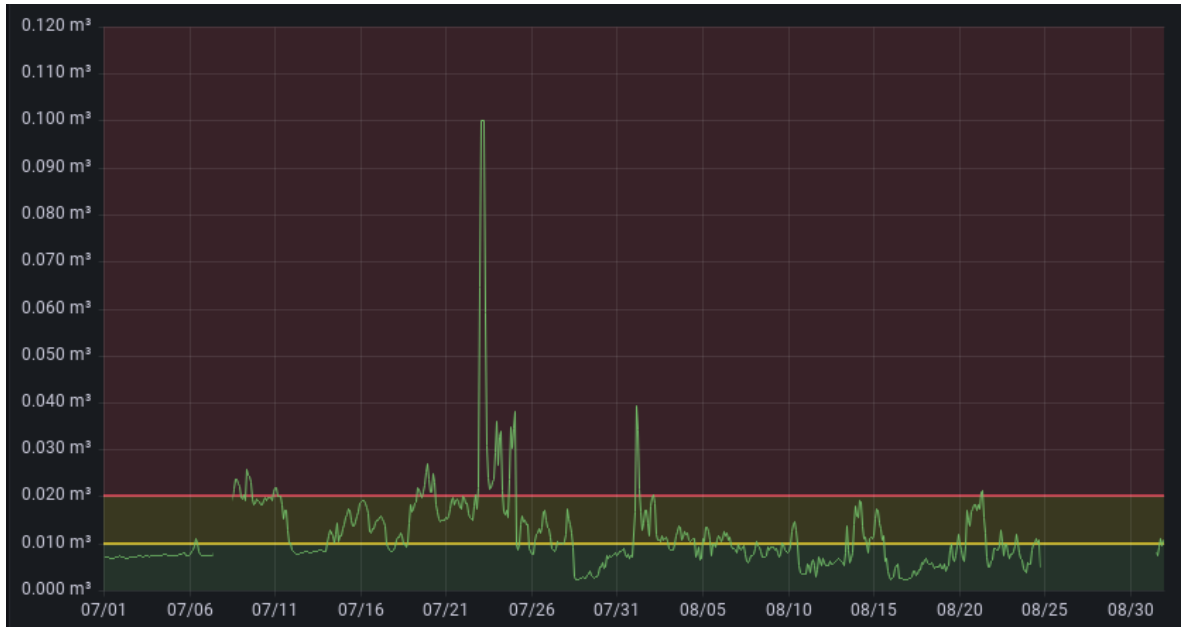
IZ1L Lageos-1 FR Obs per NPT over range (ILRS website/Station Satellite Data Info).



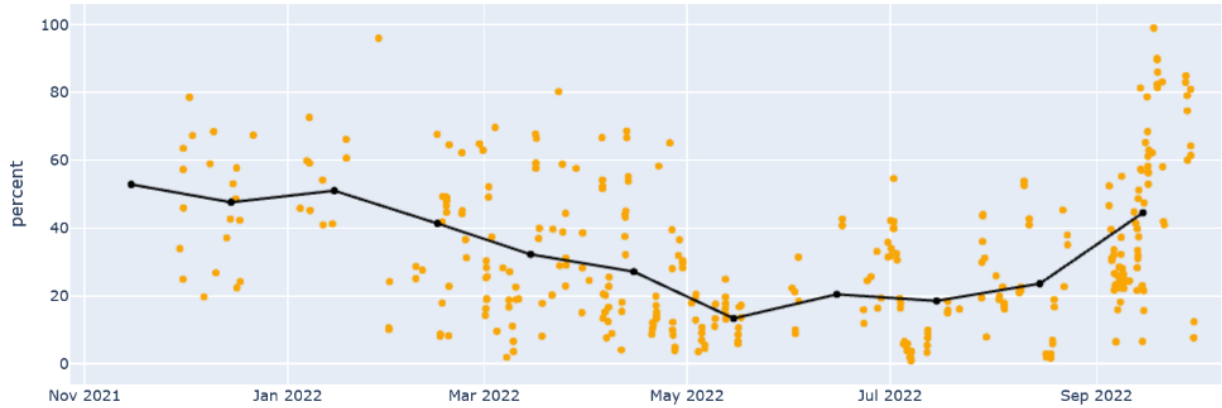
IZ1L station tracking Lageos-1 at 26° elevation at 14.8% return rate with a laser energy reduced to approx. 33%.

Station performance and conditions

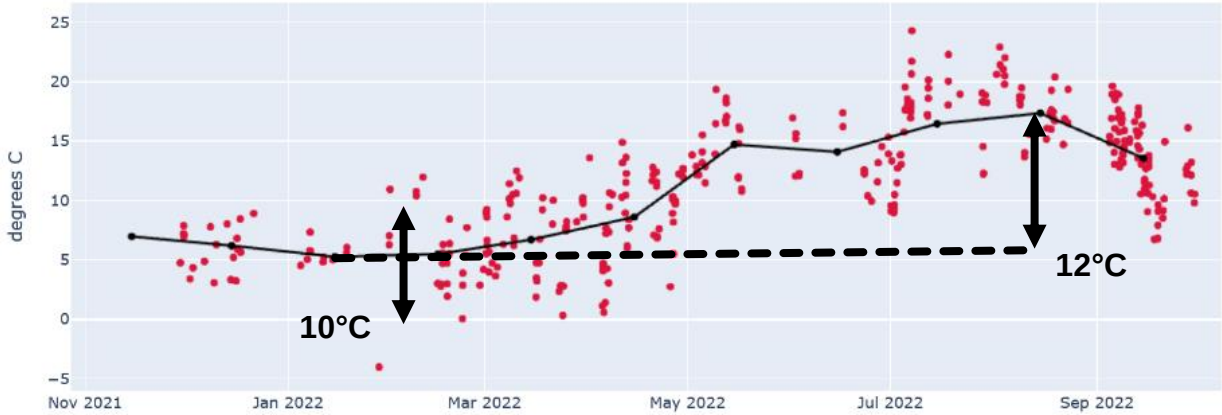
- Good meteo conditions
  - Low humidity (winter < 60%, summer < 20% on average)
  - Small temp changes per day (< 10°C)
  - Small temp changes per year (on average 12°C)
  - Pressure is 760 … 775 hPA due to 2400 m elevation
- No flight zone … almost no aircraft
- High dust concentration due to Calima from the Sahara



IZ1L dust level during July and August 2022.



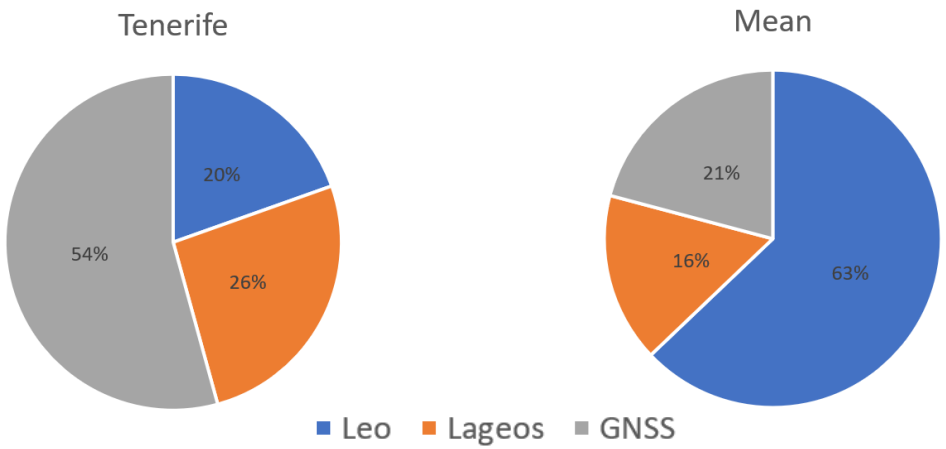
IZ1L reported humidity
(ILRS website/Station Meteo info).



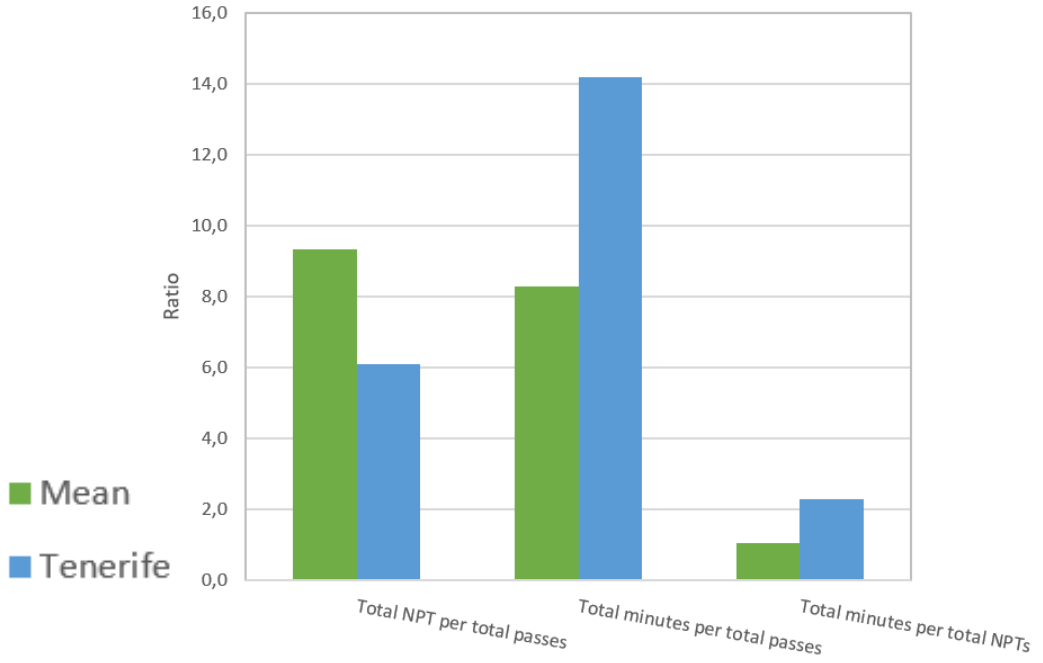
IZ1L reported temperature
(ILRS website/Station Meteo info).

Station data amount and distribution

- ILRS website/System performance, Table 1: 211001 – 220930
  - 879 passes in total, 172 LEO, 230 Lageos, 477 GNSS
- Facts
  - Not the average station/data distribution
  - GNSS and Lageos share is much higher than for average station
  - ESA focus is Galileo, ILRS contribution (Lageos/Etalon)
  - Consequently, compared to average station (mean ILRS)
    - Less NPTs per pass
    - More minutes of data per pass
    - More minutes of data per NPT
- Perspective
  - GNSS, Lageos and data shares will stay similar
  - Output is already increasing with new observers
  - Output will further increase with employed automation
  - Ranking will improve from currently 30th spot
  - Good for ESA and ILRS



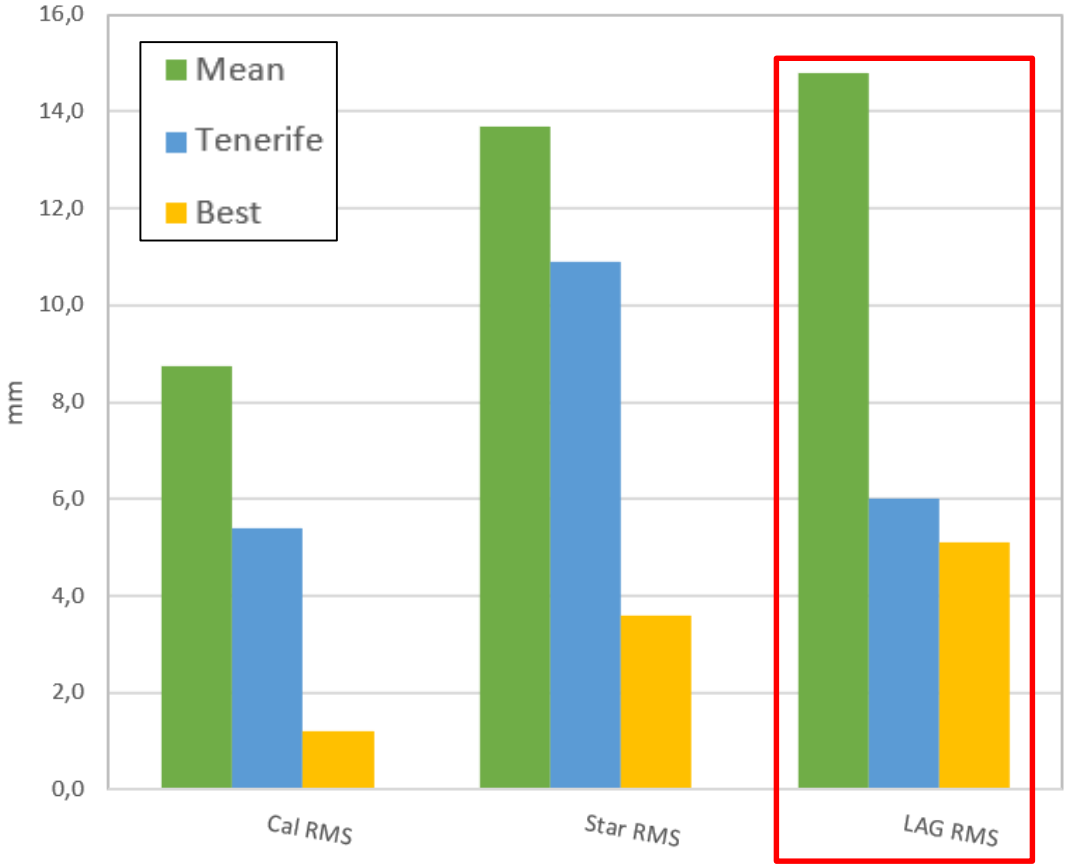
Up: data distribution for SLR stations (ILRS mean vs. Tenerife).
Down: Various data distribution ratios (ILRS mean vs. Tenerife).



Station data precision

- System precision
  - Green:
    - Laser pulse length 7.0 ps,
    - Detector RMS 22 ps / Std 27 ps
  - IR:
    - Laser pulse length 8.5 ps,
    - Detector RMS 29 ps / Std 35 ps

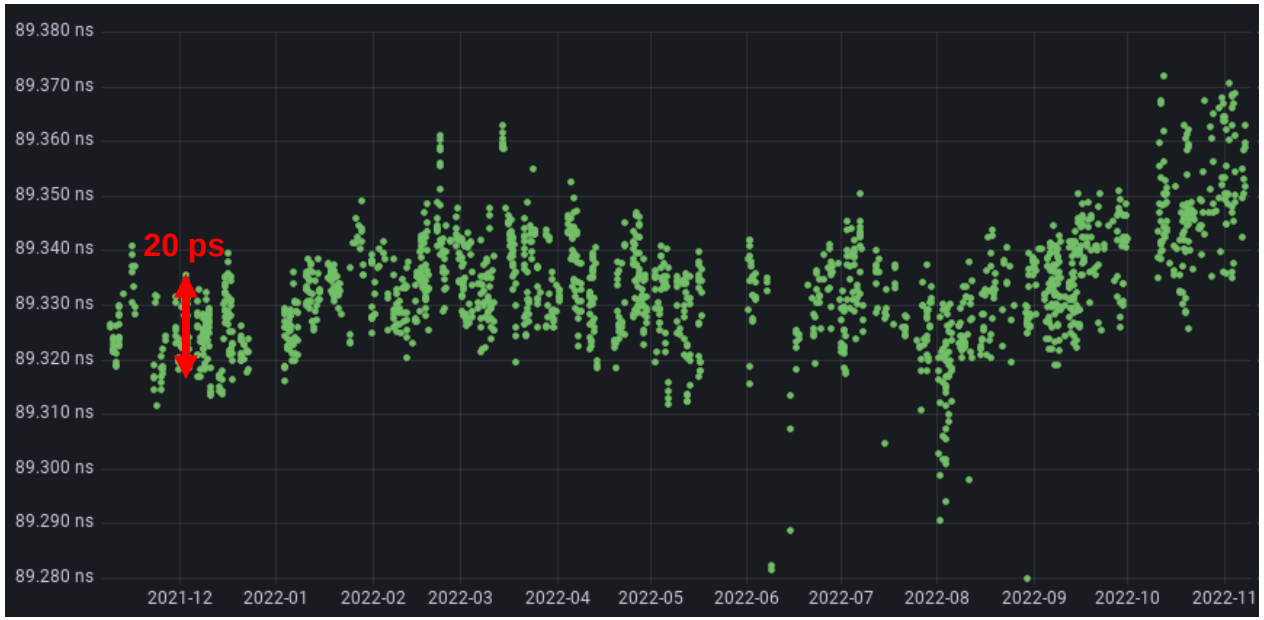
- ILRS website/System performance, Table 1: 211001 – 220930
  - Cal and Starlette RMS are better then average
  - Lageos RMS is close to best



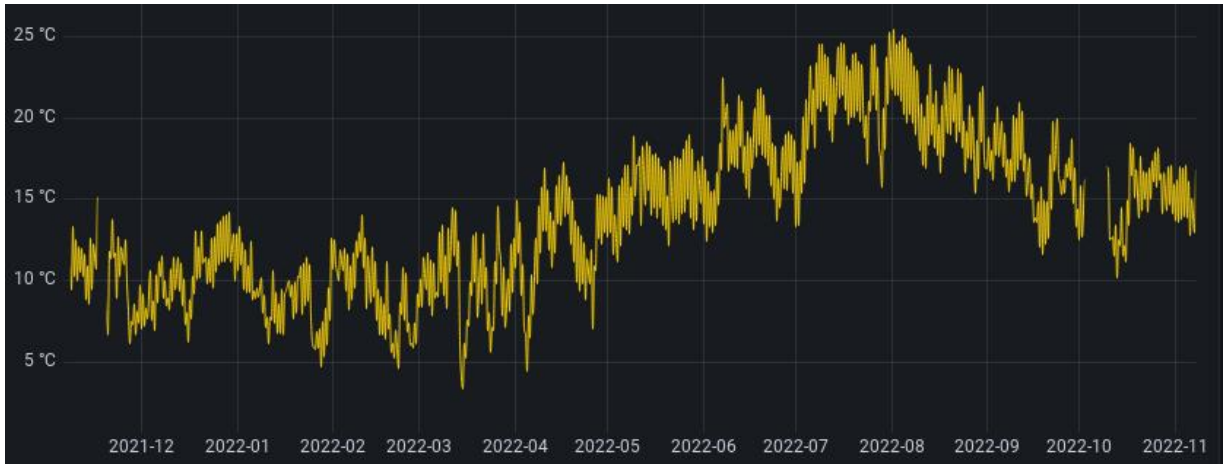
Comparison of various RMS values
(ILRS website/System performance, Table 1).

Station data accuracy

- Calibrated system delay long term development
  - Last year of data (2111 until 2211)
  - Seasonal trend
  - Daily change
    - approx. 20 ps
    - stable except for outliers
  - Recent trend matches temperature change
  - Of course: check on the outliers in 2208



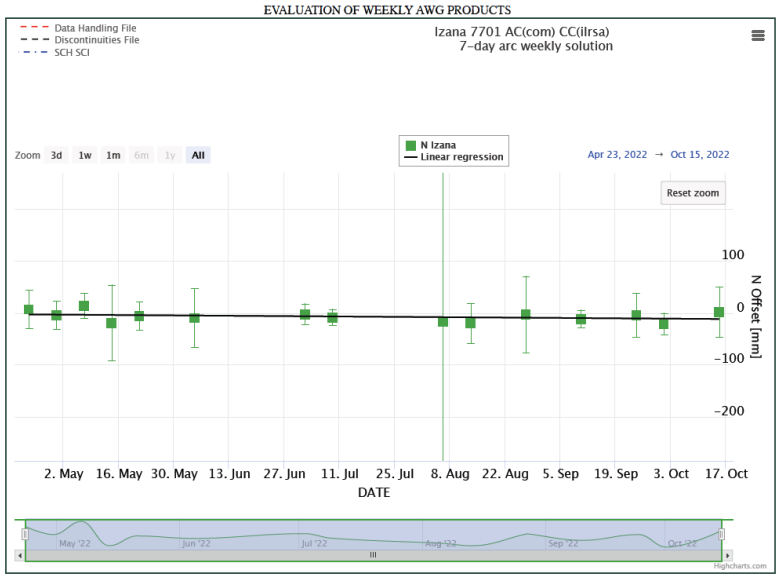
IZ1L long term calibrated system delay.



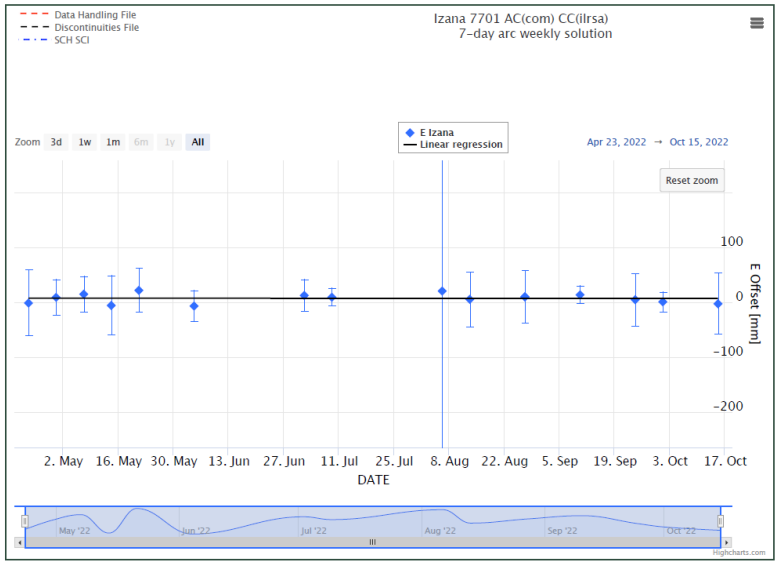
IZ1L long term dome temperature.

Station data accuracy

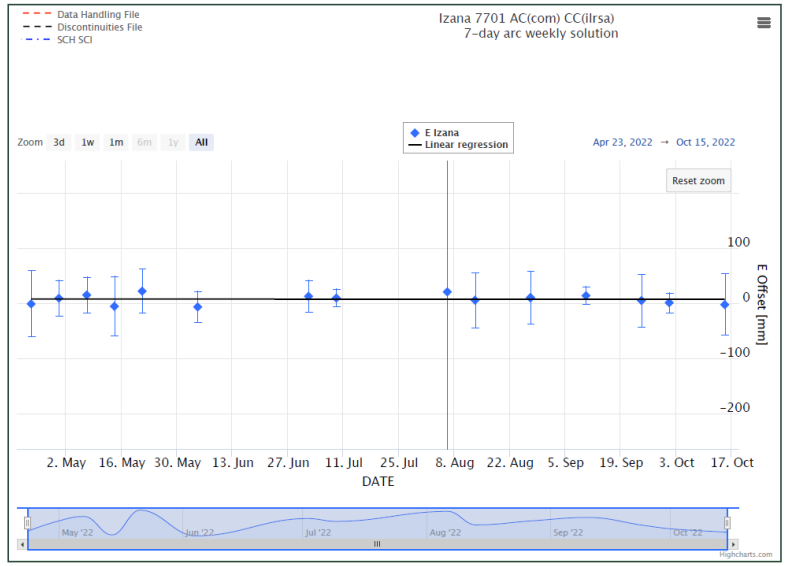
- Station position from ILRSA weekly combination (Thanks to Erricos!)
  - Offsets at mm level, STDs almost as well
  - Almost No drifts
  - Large STD in 2208 to be checked



N component.



E component.



Up component.

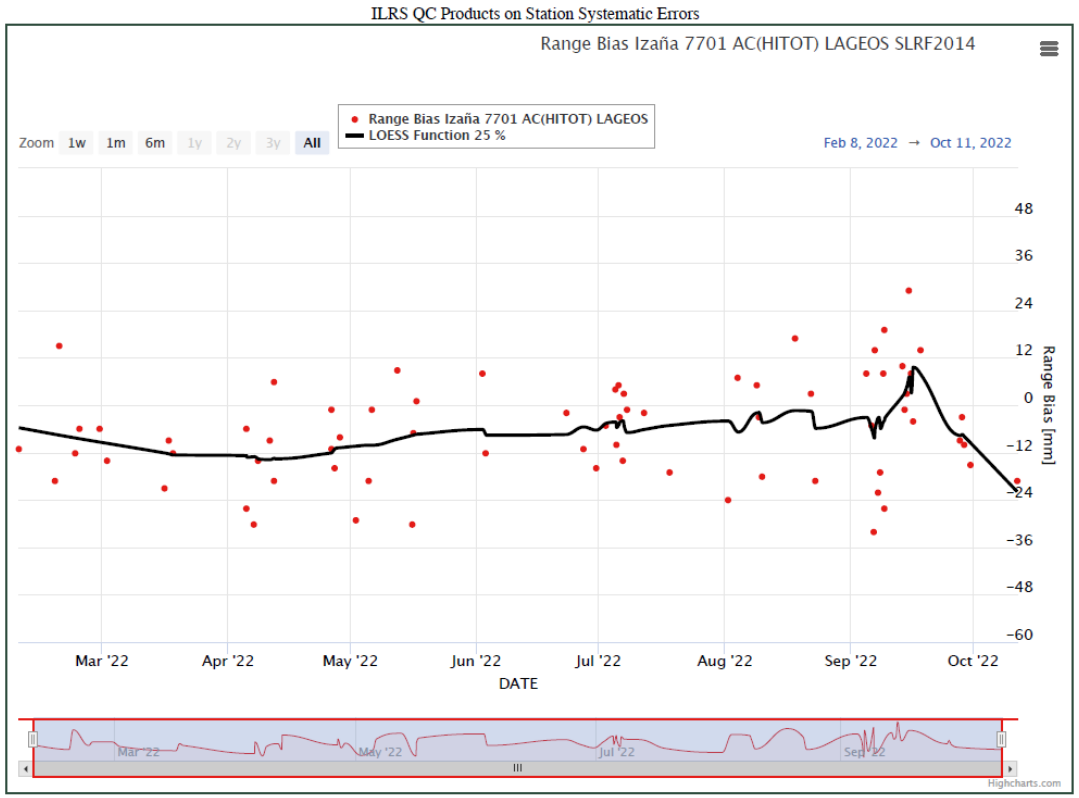
N Offset [mm] Izana 7701 AC(com) CC(ilrsa)	E Offset [mm] Izana 7701 AC(com) CC(ilrsa)	U Offset [mm] Izana 7701 AC(com) CC(ilrsa)
Mean/Std. Dev.: -7.05 ± 9.44 Count:16	Mean/Std. Dev.: 7.30 ± 8.38 Count:16	Mean/Std. Dev.: 1.00 ± 10.99 Count:16

Station position result summary.

Station data accuracy

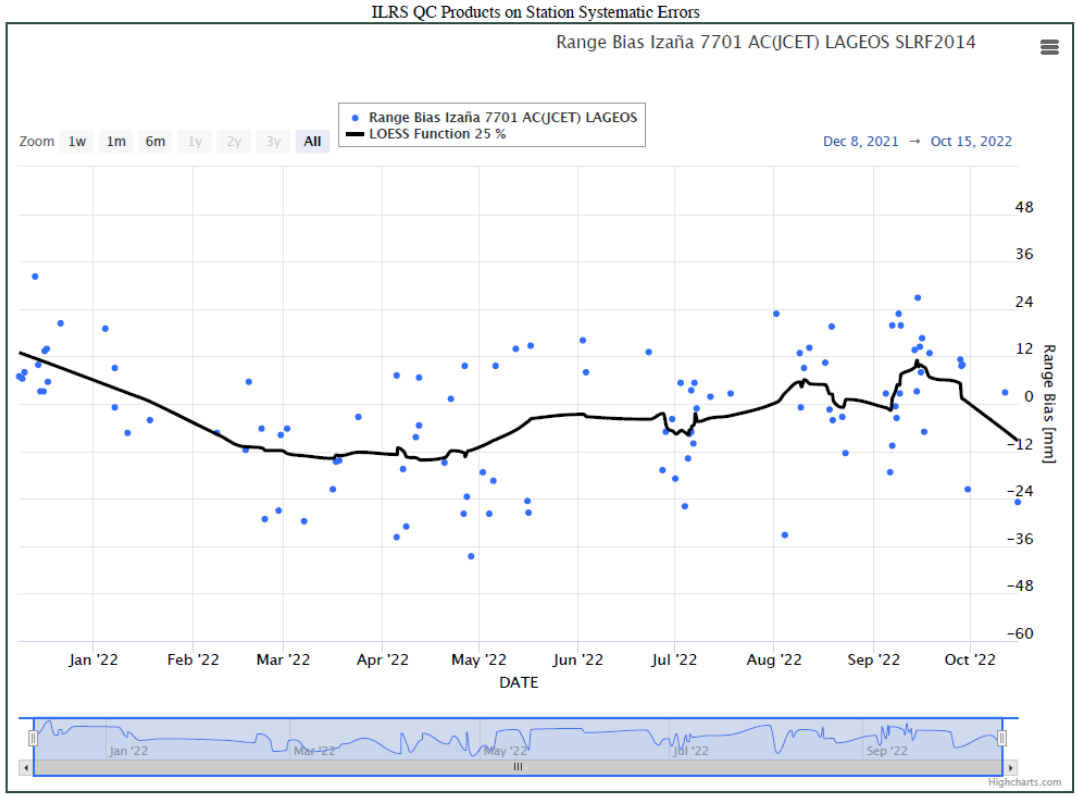
- Range biases from HIT and JCET (Thanks to Erricos!)
  - Lageos 1 shown here cause most data available, values in agreement
  - Outlier in 2208 not present

7701 Range Bias Izaña 7701 AC(HITOT) LAGEOS
Mean/Std. Dev.: -6.39 ± 12.95 Count: 72



HIT RB results for IZ1L Lageos 1 passes.

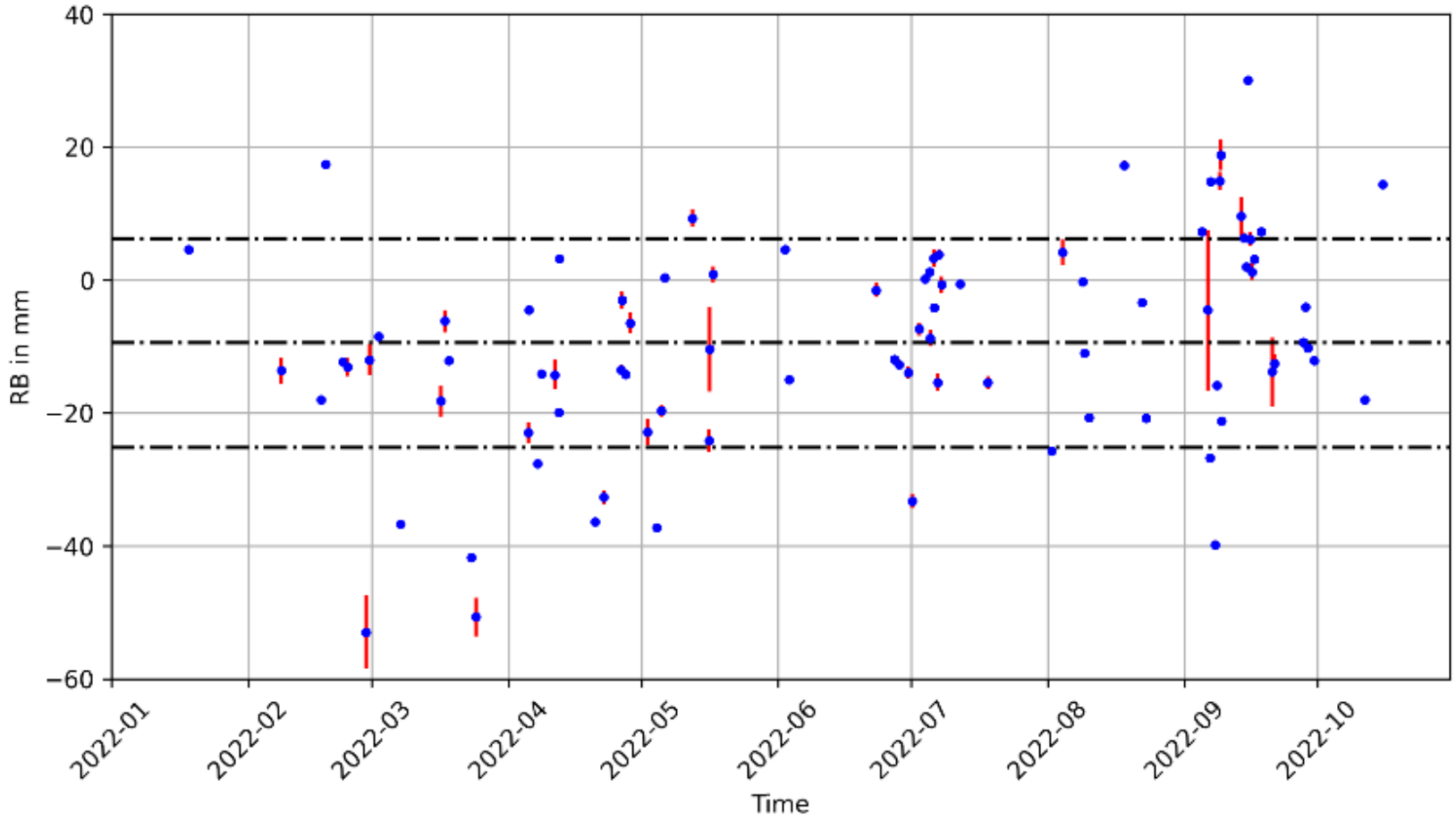
7701 Range Bias Izaña 7701 AC(JCET) LAGEOS
Mean/Std. Dev.: -1.86 ± 15.63 Count: 103



JCET RB results for IZ1L Lageos 1 passes.

Station data accuracy

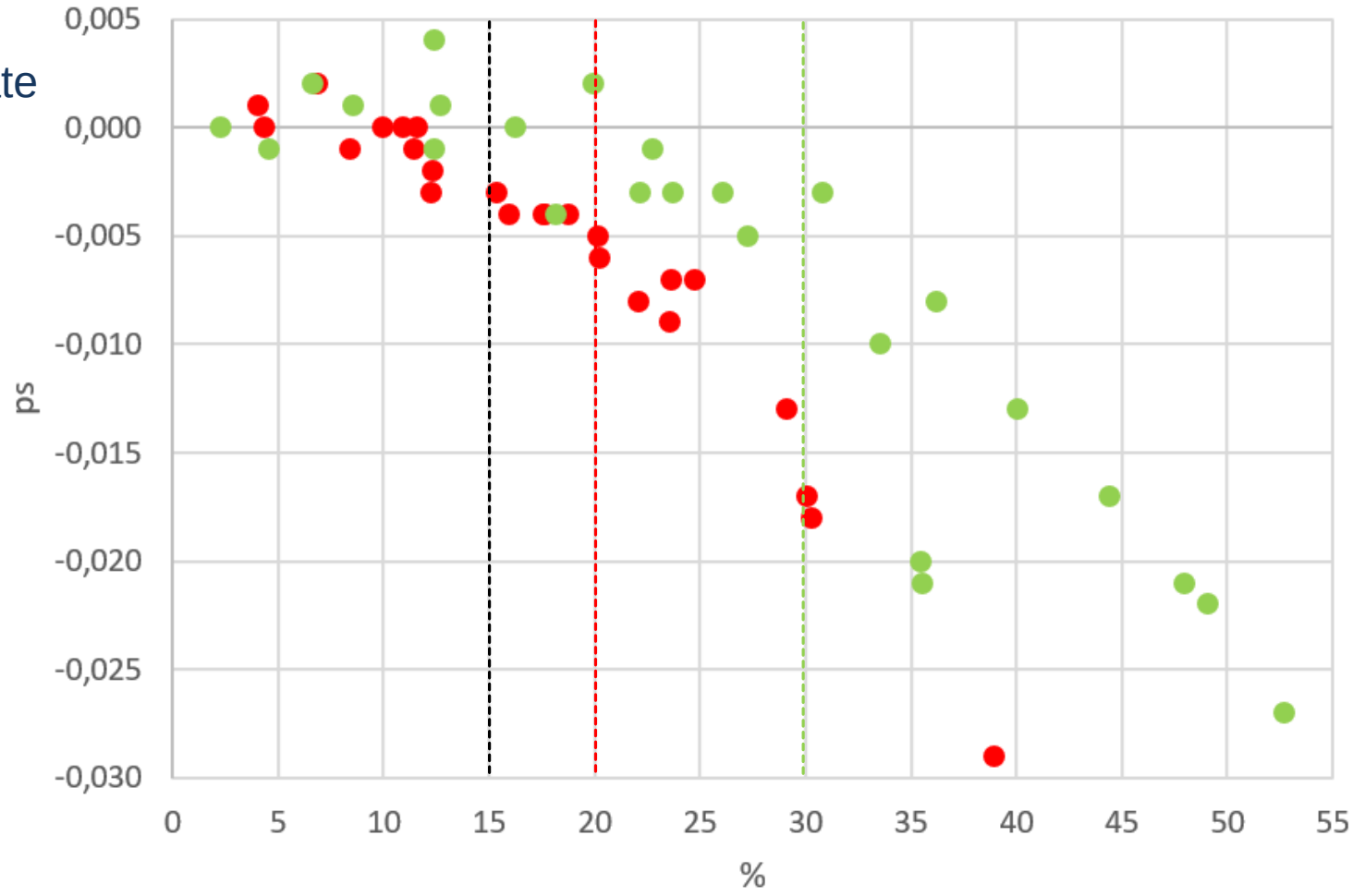
- Toshis pass by pass range bias analysis (http://geo.science.hit-u.ac.jp/slr/bias/)
  - Good tool for pass monitoring (Thanks to Toshi!)
  - Pass by pass average and std for Lageos in 22
  - L1 average RB is -9+/-16 mm, in agreement with the ILRSA HIT results, bit larger
  - 2208 outlier not existent here



L1 averaged pass by pass biases with a mean of -9 mm and an std of +/-16 mm.

Station calibration experiments

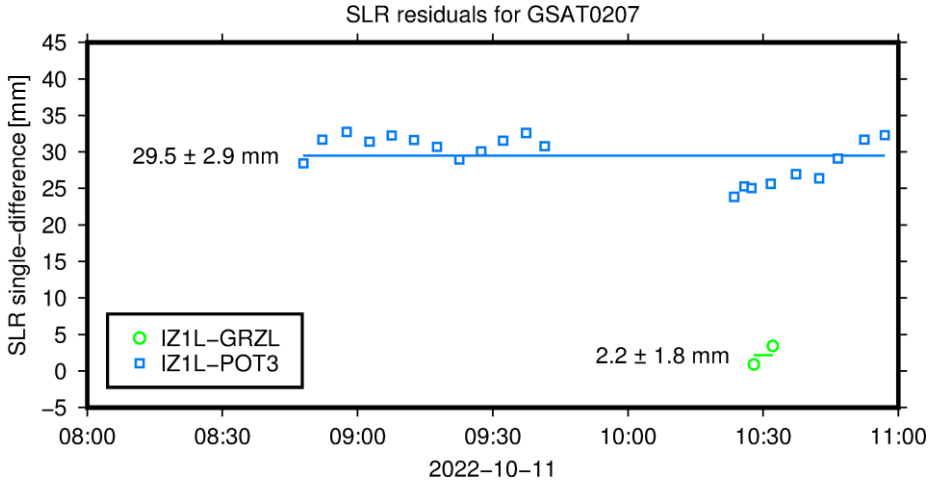
- Fiber calibration runs over 10000 echos
- Variation of laser energy / return rate
- Calibrate system delay change over return rate
  - C-Spad at 532 nm
  - IR-Spad at 1064 nm
- Almost no change (< 6 ps / 2 mm) up to
  - 30 % for the C-Spad
  - 20 % for the IR-Spad
- During operation
  - Automatic energy adjustment
  - Keeps the return rate < 15 %
- Perspective
  - Allow up to 30 % for the C-Spad
  - Good for LEO observations



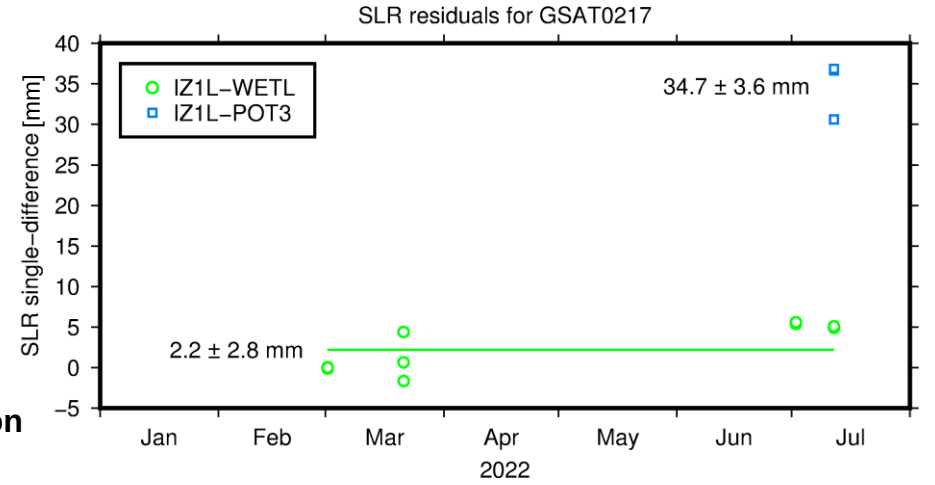
Normalized system delay over return rate for the C-Spad at 532 nm (green) and the IR-Spad at 1064 nm (red). The various max. rates are highglighted with the dashed lines for 532 nm (green), 1064 nm (red) and operational (black).

Further station experiments

- Dedicated simultaneous GNSS tracking from IZ1L and POT3
  - 221011
    - 08:15 - Gal207 (120 min) – also GRZL and BEIL, max. 3 stations simultaneously
  - 221012
    - 09:55 - Gal221 (18 min)
    - 10:28 - Beidou3M3 (16 min)
    - 11:00 - Gal212 (49 min)
    - 22:01 - Gal210 (34 min) – also WETL, 3 stations simultaneously
- Potential application
  - Station systematics analysis from single differencing
  - Orbit error cancels out
- Station monitoring
  - Potentially valuable data/information for stations
  - Should that be done frequently? E.g. once a month?
  - Initiate an experiment within the EUROLAS network?
  - Europe good place with its high station density



Singe-differences for IZ1L, GRZL and POT3 for one Gal207 pass.

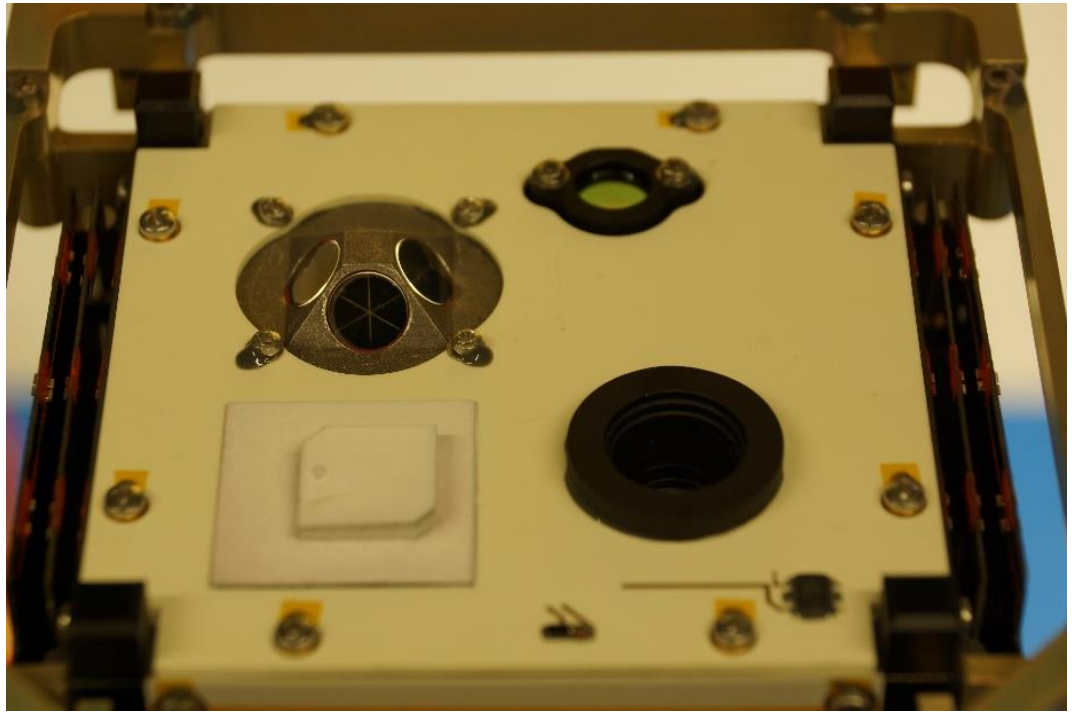


Singe-differences for IZ1L, WETL and POT3 from March to July 2022.

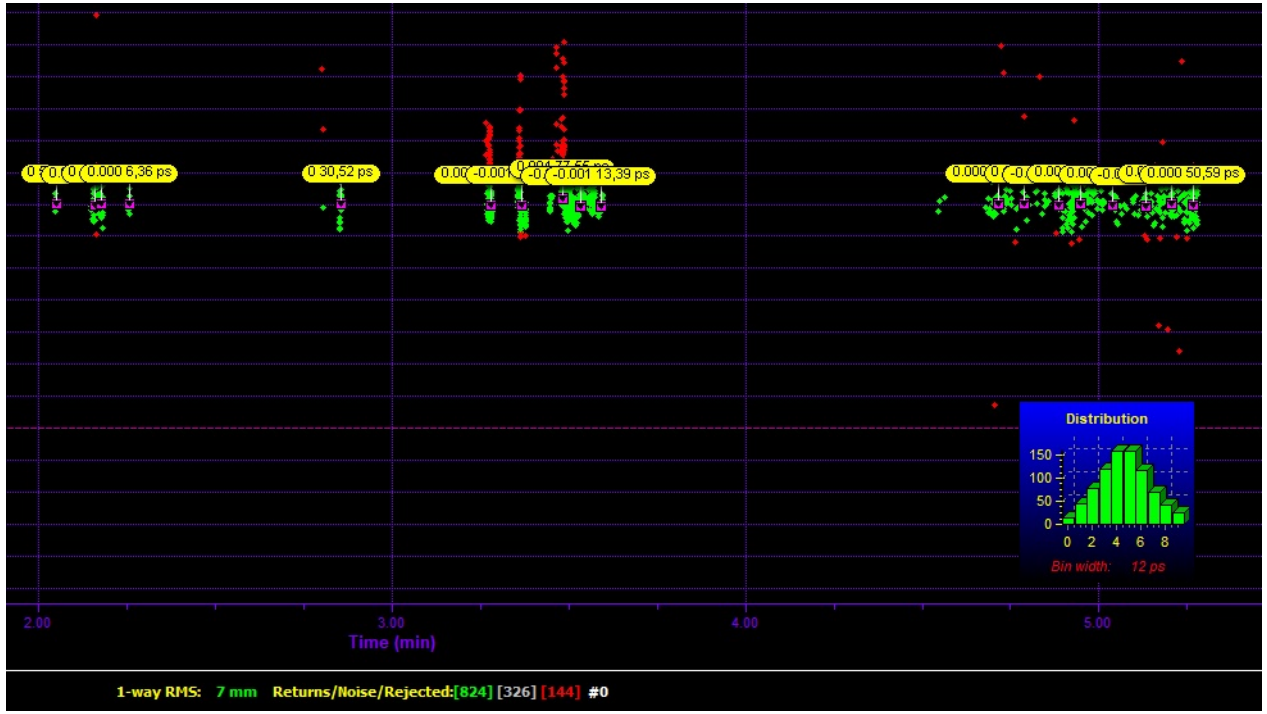
Analysis results from Francisco Gonzalez et al. presentation

Further station experiments

- Request from ESA to track Cubesat OPS-SAT
  - Features 10 mm CCR in a 3D metal printed array from Graz
- Successful pass
  - 221028 at 06:47 UTC
- Statistic
  - Approx. 3.5 minutes, 824 FR data points, 7 mm one-way RMS, 18 NPTs @ 5 s bin size



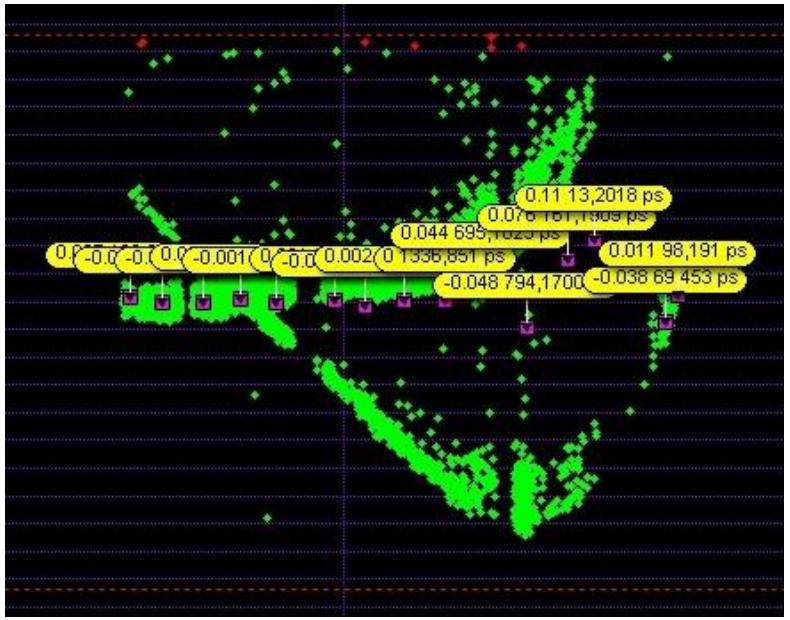
OPS-SAT 3D printed metal LRR array with 10 mm CCR (ESA/OPS-SAT mission).



Residuals of the OPS-SAT pass from 221028 at 06:47 UTC.

Further station experiments

- Debris observations as preparation for the Space Debris Laser Upgrade (see presentation of M. Ploner et al.)
  - Laser used: 1064 nm, 550 µJ, 400 Hz
  - Overall 22 passes, 16 in a 2 weeks timeframe
  - Does 22830 have an LRR? Probably not?
    - If not, this is the 1st uncooperative pass for IZ1L
  - Challenging targets
    - Rotating -> LRR visibility -> Acquisition
    - Multiple LRR -> NPT formation



Residuals of the CZ-2C/28240 pass from 20220914. The formed NPTs are also shown.

A40 H10 SPOT3 launcher.

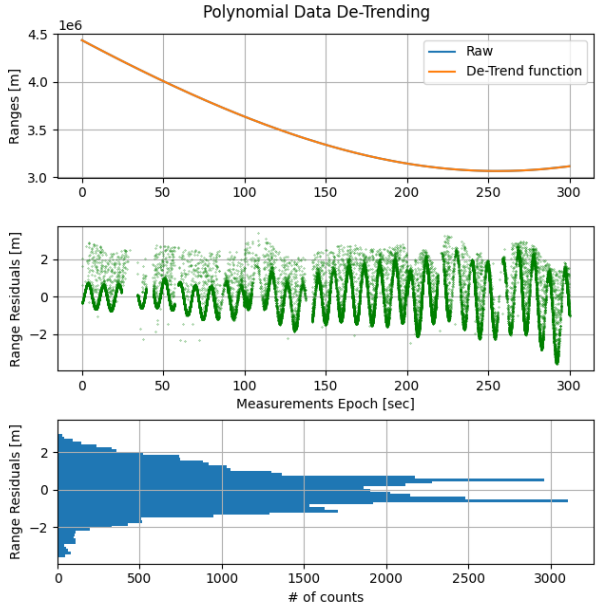
Date	Time	Name	NORAD	#FR	1-way RMS	#NPTs	Bin size
20220904	20:24:41	Topex	22076	18334	569	20	15
20220905	20:50:34	Topex	22076	17880	694	21	15
20220906	05:56:03	Envisat	27386	128	3	1	15
20220908	05:38:20	CZ-2C	28480	9599	11	59	5
20220908	19:57:40	Topex	22076	49537	544	27	15
20220909	05:12:06	CZ-2C	28480	6856	25	30	5
20220909	05:31:31	CZ-2C	31114	2391	6	14	5
20220909	05:41:55	Envisat	27386	2275	5	3	15
20220912	19:57:40	Topex	22076	77	32	2	15
20220914	05:38:02	CZ-2C	31114	1084	46	10	5
20220914	06:27:31	CZ-2C	28480	10820	114	15	5
20220915	05:18:10	Envisat	27386	689	11	3	15
20220915	06:01:45	CZ-2C	28480	10780	17	33	5
20220916	05:36:44	CZ-2C	28480	32164	17	74	5
20220919	05:45:15	CZ-2C	31114	3504	8	31	5
20220921	05:07:58	CZ-2C	31114	306	5	7	5
20220927	22:00:27	Spot3 Ariane RB	22830	143	305	10	5
20220929	06:16:51	Topex	22076	6669	264	3	15
20220930	06:39:24	Topex	22076	47497	652	28	15
20221011	17:59:58	CZ-2C	31114	358	8	4	5
20221012	13:28:05	Topex	22076	9653	757	9	15
20221020	05:03:07	ERS-1	21574	103	5	2	15

List of Debris targets observed by IZ1N station during the given timeframe.

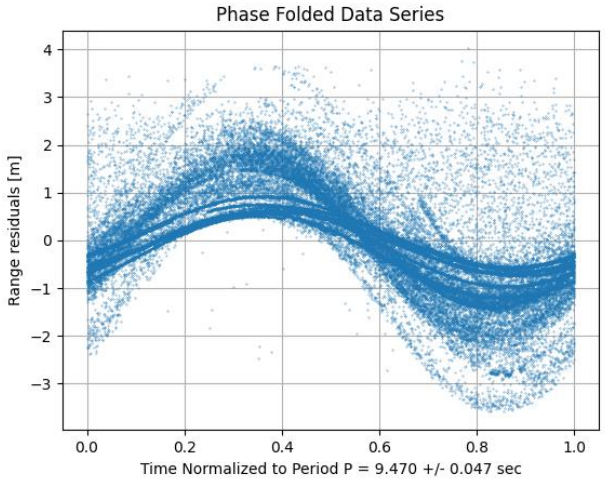
Further station experiments

- SLR residuals: Spin period estimation for Topex (220908-19:57UTC - approx. 9.5 s)

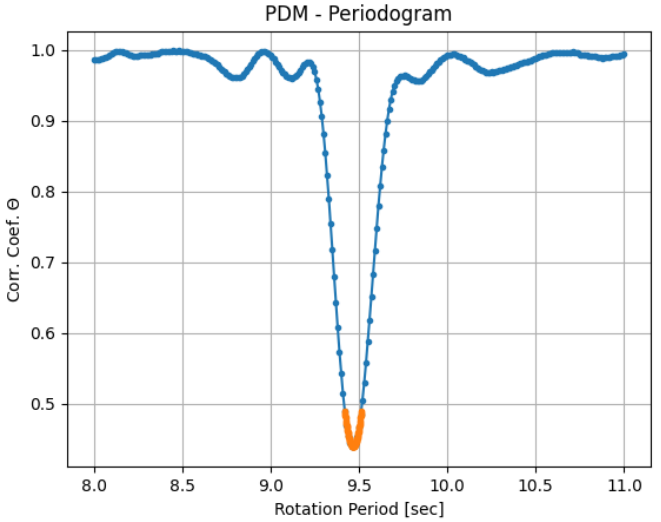
Topex pass residuals (Raw, Detrended and histogram). The residuals amplitude change might be helpful to estimate the spin axis orientation.



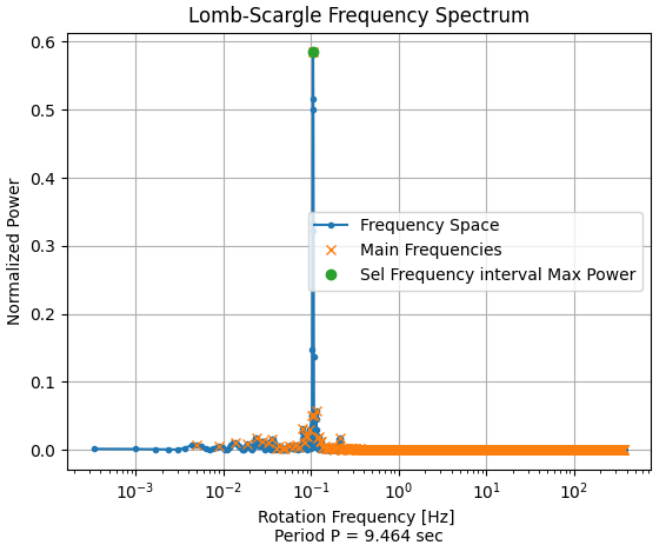
Topex pass phase folded residuals.



Topex pass phase periodogram with the estimated spin period highlighted.

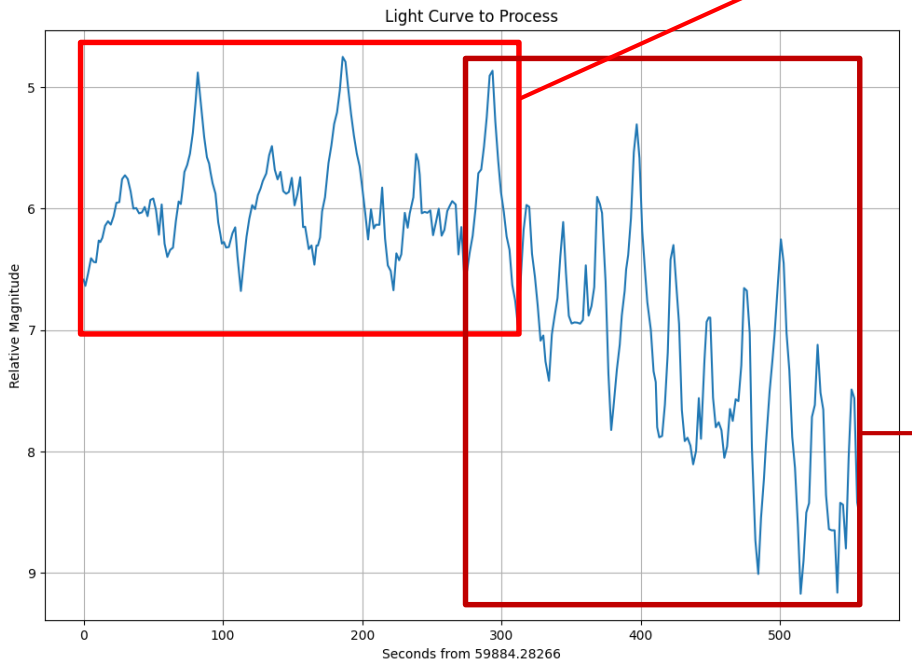


Topex pass Lomb-Scargle Frequency Spectrum.

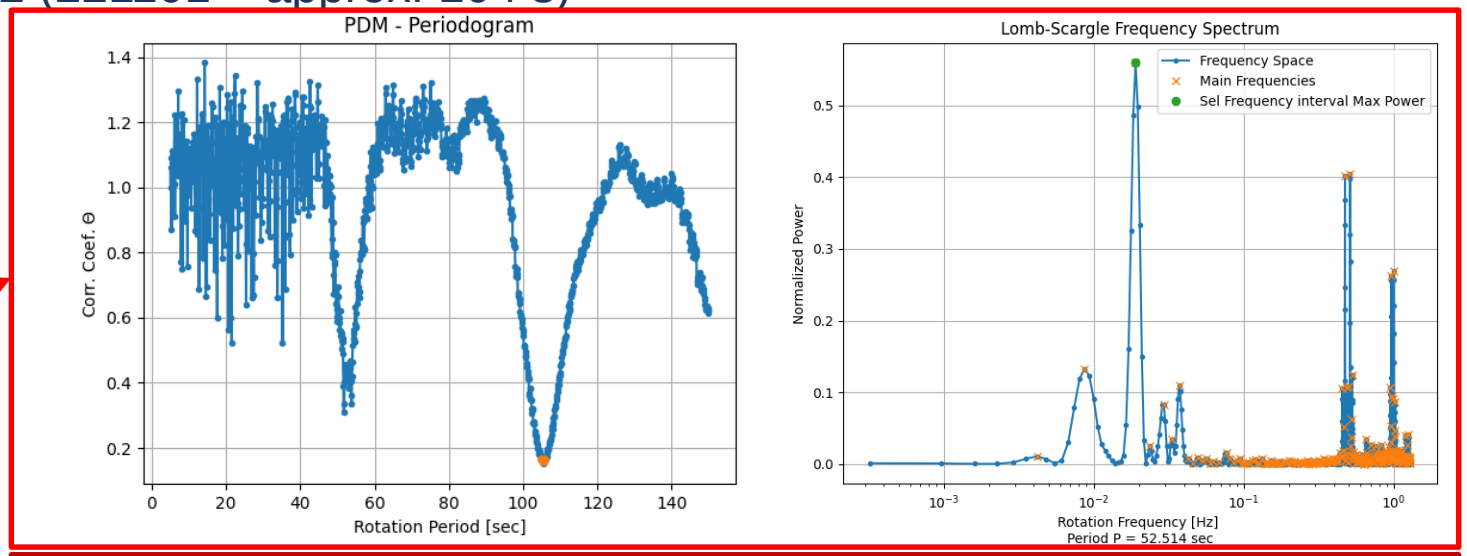


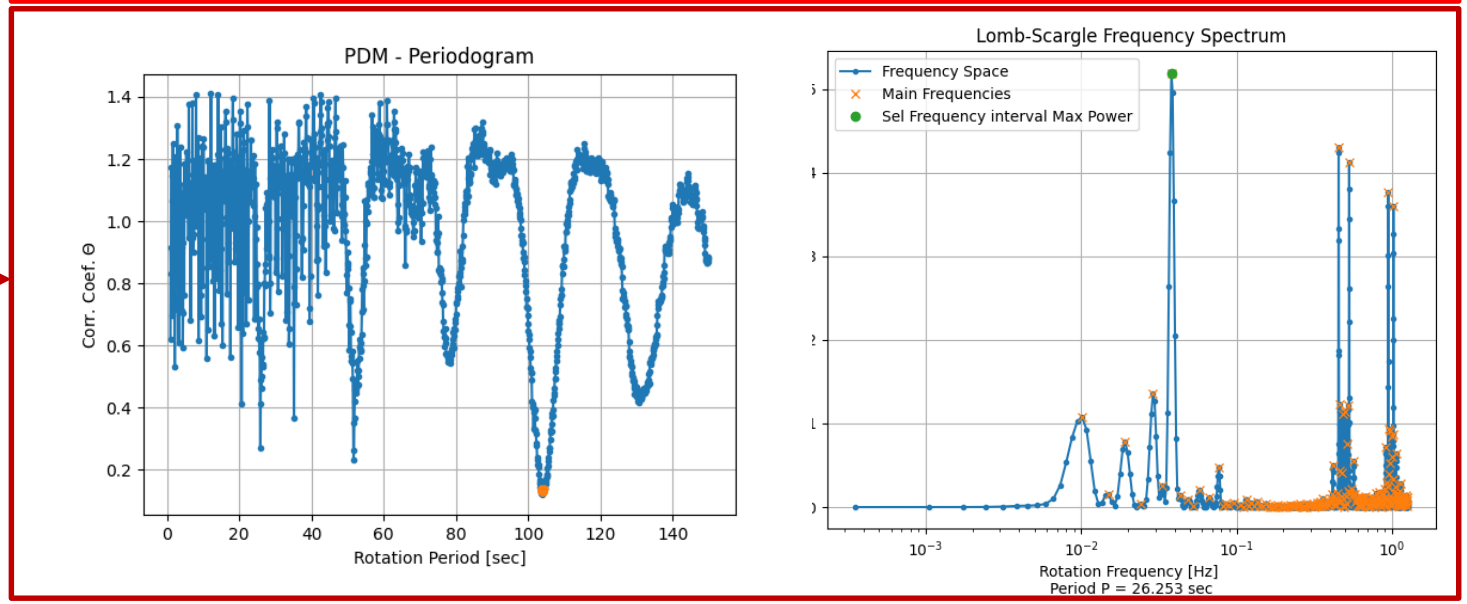
Further station experiments

- Light curve: Spin period estimation for Jason-2 (221101 – approx. 104 s)
  - Amplitude is changing over the pass
  - 1st part: 2 peaks (52,104 s)
  - 2nd part: 5 peaks (26, 52, 78, 104, 130 s)
  - Observation geometry change?
  - Rotation only around one axis?
  - Spin axis knowledge could help



Jason-2 light curve (left), split for the 1st and 2nd:
Lomb-Scargle (middle) and periodogram (right)



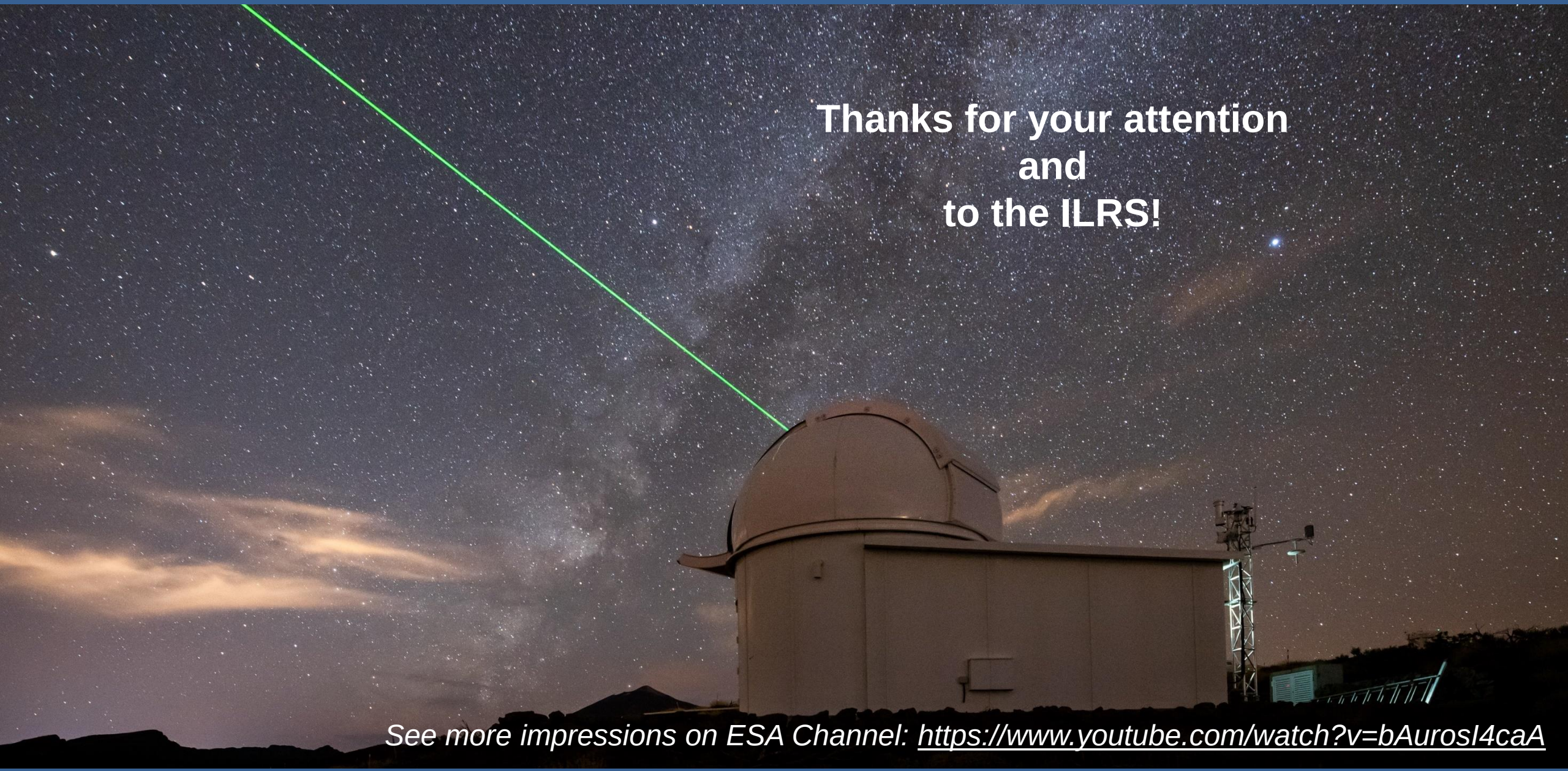


Summary

- ESA‘s IZ1L station actively contributes data to the ILRS
  - Large GNSS and Lageos share due to focus on Galileo and ILRS contribution (Ref. Frame)
  - Station data precision and accuracy (position and range biases) is looking good
  - Return rate calibration experiments and automatic energy control ensure good data quality

- Station is also ESA‘s testbed, so a variety of experiments
  - Simultaneous Galileo observations with potential for station monitoring (EUROLAS campaign?)
  - OPS-SAT observations upon request
  - Space debris observations in preparation for the station upgrade to
    - Cooperative targets such as Topex, Envisat, … and various Rocket Bodies
    - Potentially one uncooperative target (SPOT3 Ariane 4 RB)
  - Spin period estimation from SLR residuals (Topex) and Light curves (Jason2, GPS36)

- IZ1L contribution to ILRS is beneficial for both parties (data & monitoring)


Thanks for your attention
and
to the ILRS!
See more impressions on ESA Channel: https://www.youtube.com/watch?v=bAurosI4caA

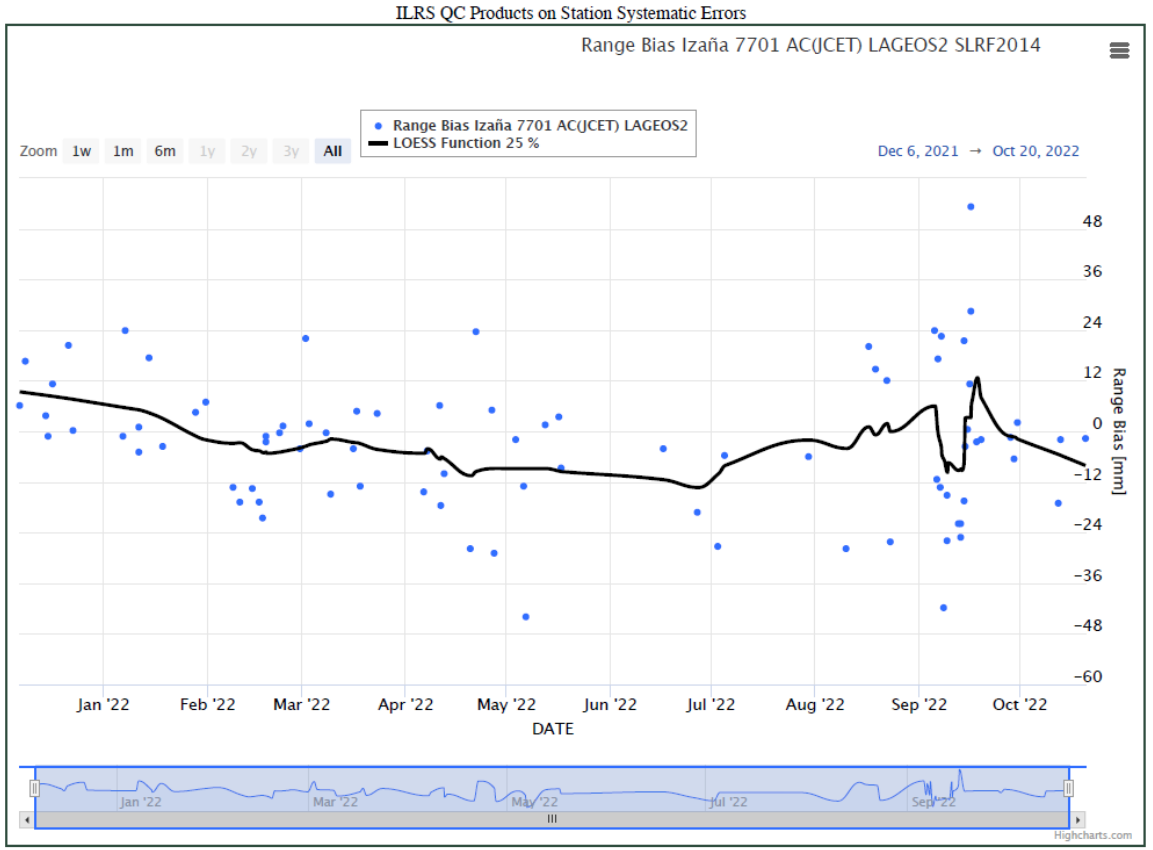
Station data accuracy

- Range bias comparison for HIT and JCET (Thanks Erricos!)
  - Lageos 2 shown here

7701 Range Bias Izaña 7701 AC(HITOT) LAGEOS2
Mean/Std. Dev.: -0.95 ± 5.80 Count: 21

HIT RB results for IZ1L Lageos 2 passes.

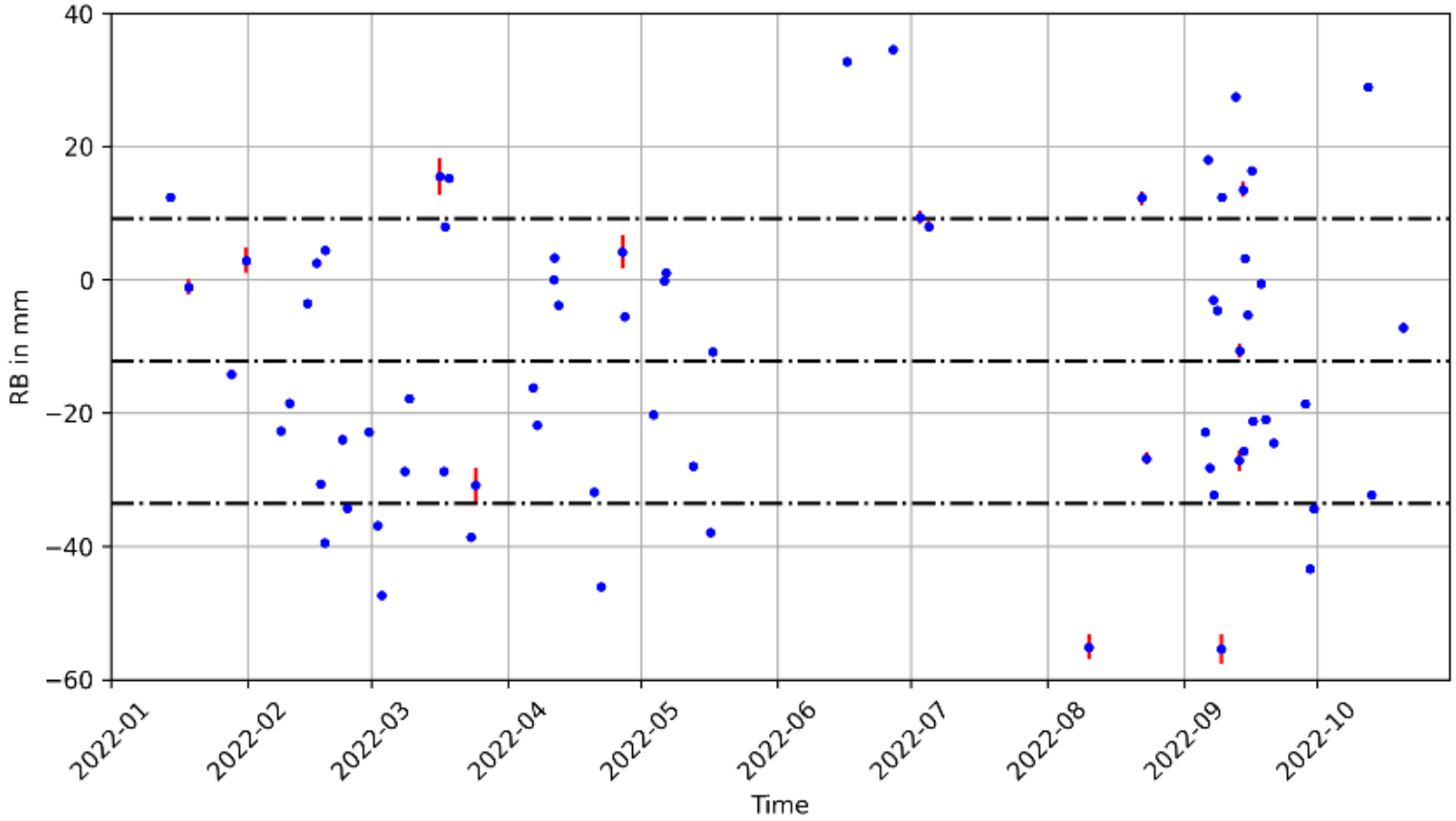
7701 Range Bias Izaña 7701 AC(JCET) LAGEOS2
Mean/Std. Dev.: -2.74 ± 16.56 Count: 84



JCET RB results for IZ1L Lageos 2 passes.

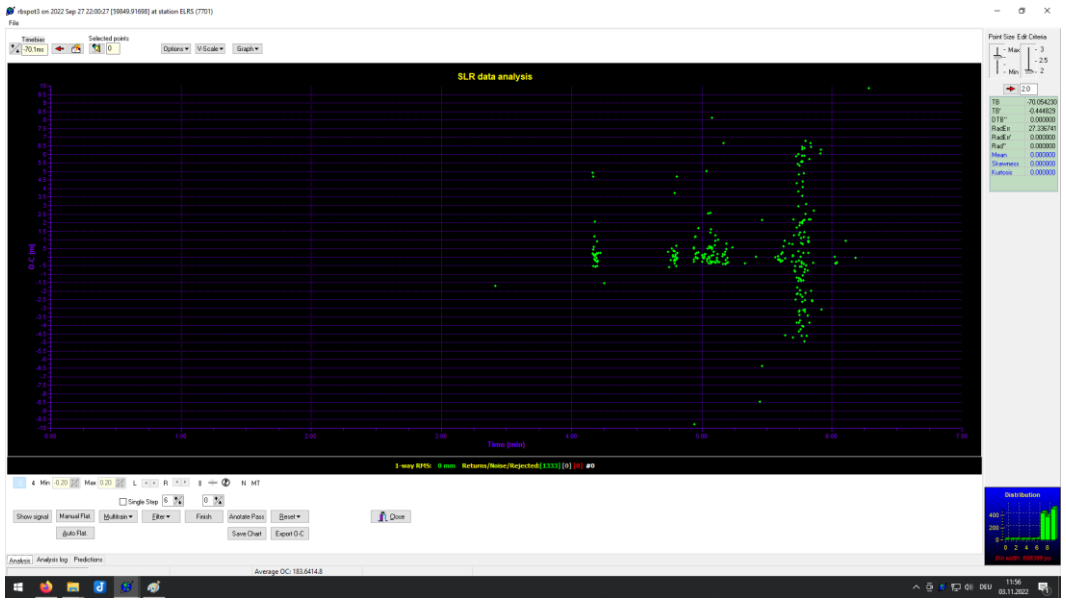
Station data accuracy

- Toshis pass by pass analysis
  - Pass by pass average and std for Lageos in 2022
  - L2 average RB is -12+/-21 mm for L2



L2 averaged pass by pass biases with a mean of -12 mm and an std of +/-21 mm.

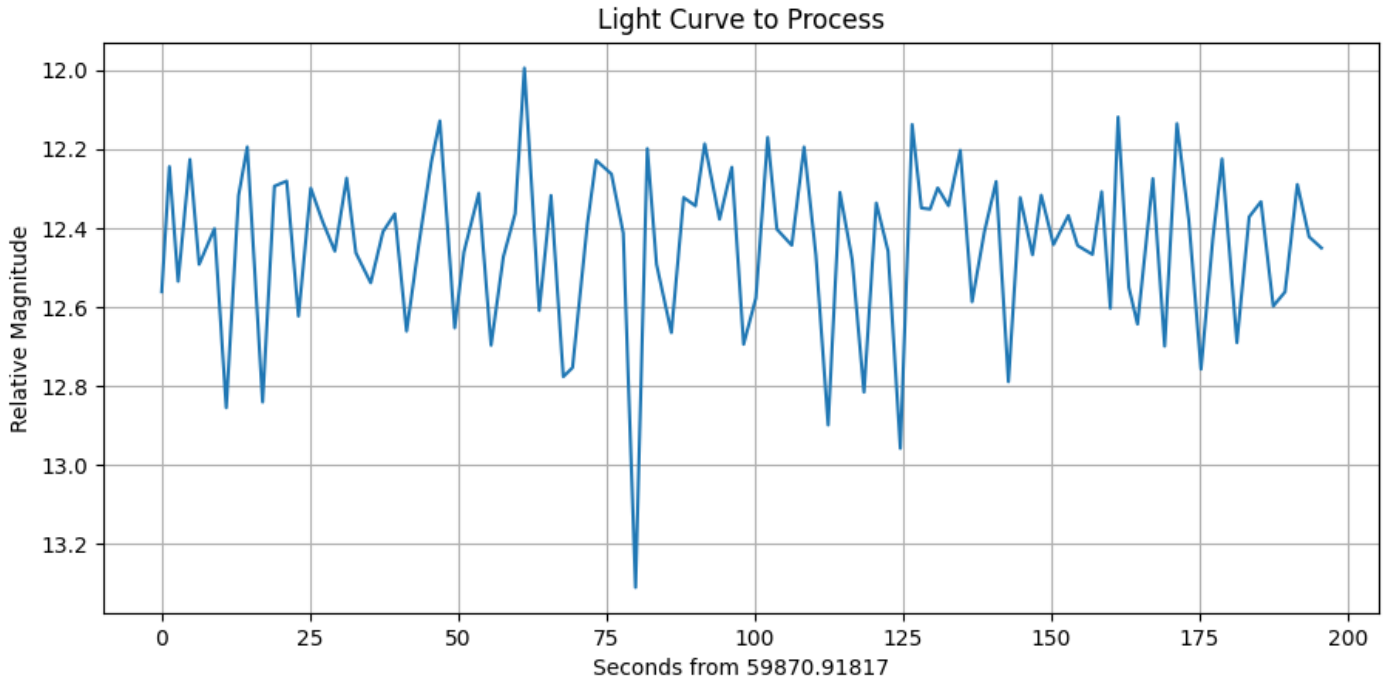
Spot3 RB Ariane pass 22830



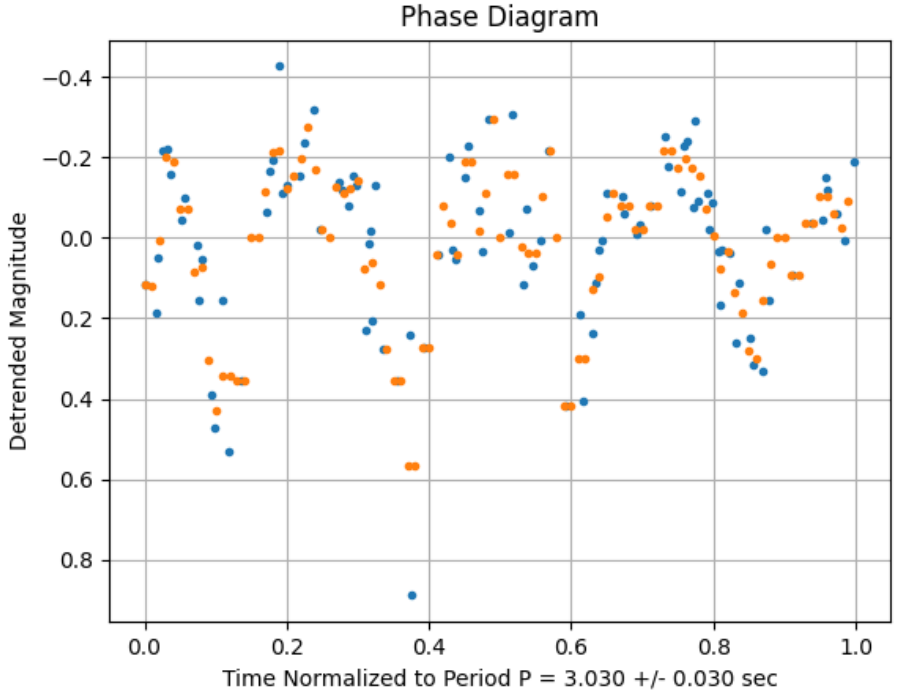
RB A40 SPOT3 pass residuals from 20221027-22:00UTC.
2 minutes of data, 143 FR data points, 305 mm one-way RMS, 10 NPTs.

Further station experiments

- Light curve: spin period estimation for GPS36 (20221028 – approx 3.0 s)



GPS36 Light Curve.



GPS36 phase folded residuals.