Evaluation of the 2013 NGSLR and MOBLAS-7 Co-location Dataset at GGAO

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International Laser Ranging Service

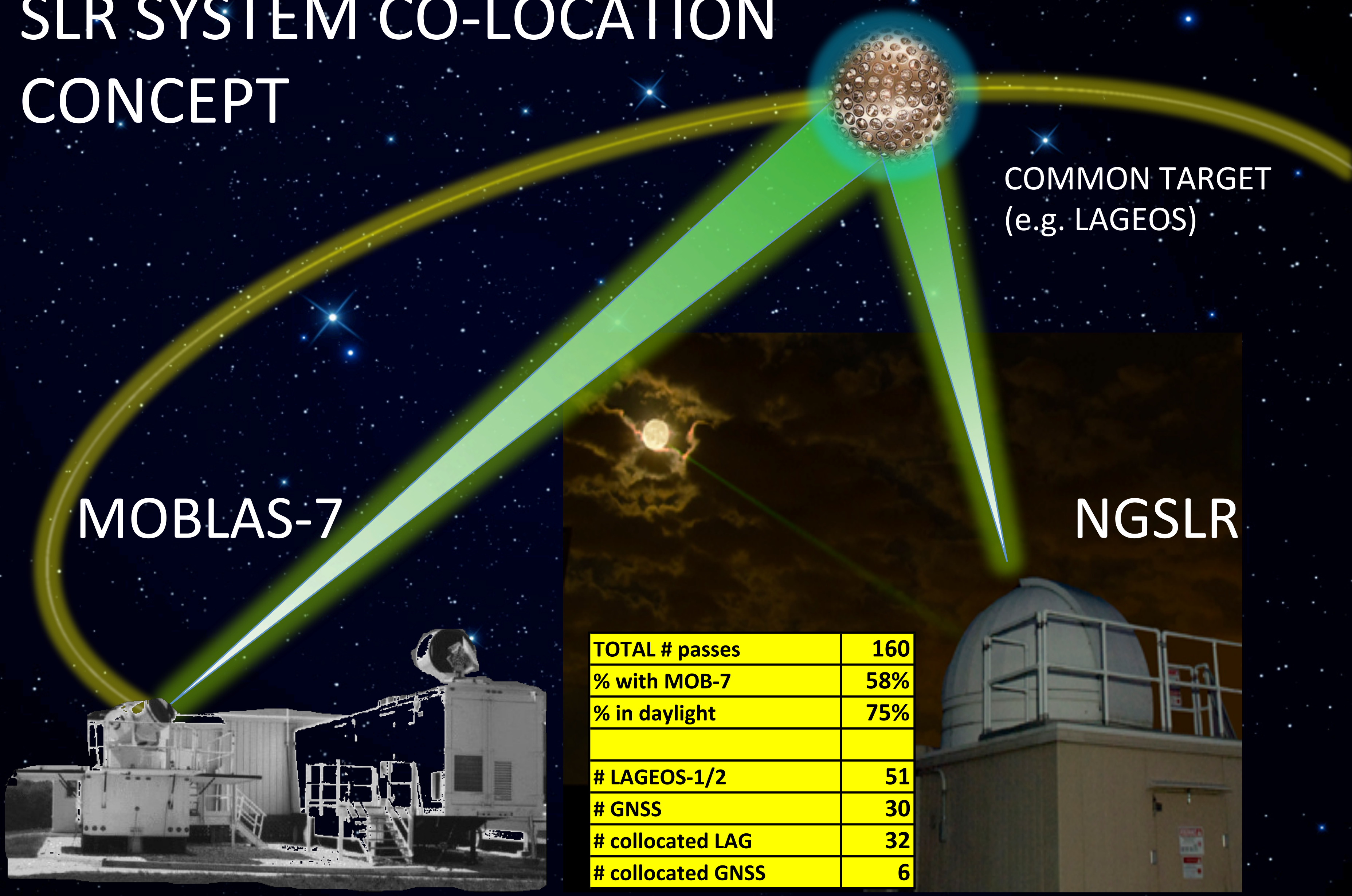
Introduction

- After years of development at the Goddard Geophysical and Astronomical Observatory (GGAO) campus, NASA's prototype Next Generation Satellite Ranging System (NGSLR) was completed earlier this year
- Part of the acceptance process was a co-location campaign with the legacy SLR system at GGAO, the MOBLAS-7 system
- The successful co-location campaign lasted five weeks
  - NGSLR tracked a variety of satellite targets day and night, from very low altitude all the way to GNSS altitude
- The main purpose of the campaign was to demonstrate the capabilities of NGSLR and to validate its design
  - NGSLR is the prototype on the basis of which future NASA systems will be built as (a) NASA's contribution to GGOS and (b) the long overdue modernization of its SLR tracking network

GGAO Campus

- Legacy systems SLR, VLBI, GNSS, DORIS
- GGOS-class Systems:
  - NGSLR
  - VLBI2010
  - Multi-constellation GNSS receivers
- VTS System to monitor the vector ties between all of the deployed systems

SLR SYSTEM CO-LOCATION CONCEPT



TOTAL # passes	160
% with MOB-7	58%
% in daylight	75%
# LAGEOS-1/2	51
# GNSS	30
# collocated LAG	32
# collocated GNSS	6

Data Validation Process

- The NGSLR data were processed along with the rest of the data collected contemporarily by the entire ILRS network using our standard QC analysis procedure
- A precise orbital fit to the data, allowing for orbit estimation along with systematic errors for each station (e.g. measurement and timing errors), on a pass-by-pass basis
- The analysis is based on a model that includes our best knowledge for geophysical processes, the dynamics of the satellite targets, and their optical signature
  - As far as the latter ("CoM" offset), we only have a general and preliminary result for LARES (LAGEOS CoM is MOBLAS-7 specific)
  - This process is the same one which feeds data into the "Global Performance Report Card" generation (on a monthly basis now)
  - Due to the limited length of the campaign, only short-term performance assessed, long-term results after we have more than 1 year of tracking analyzed

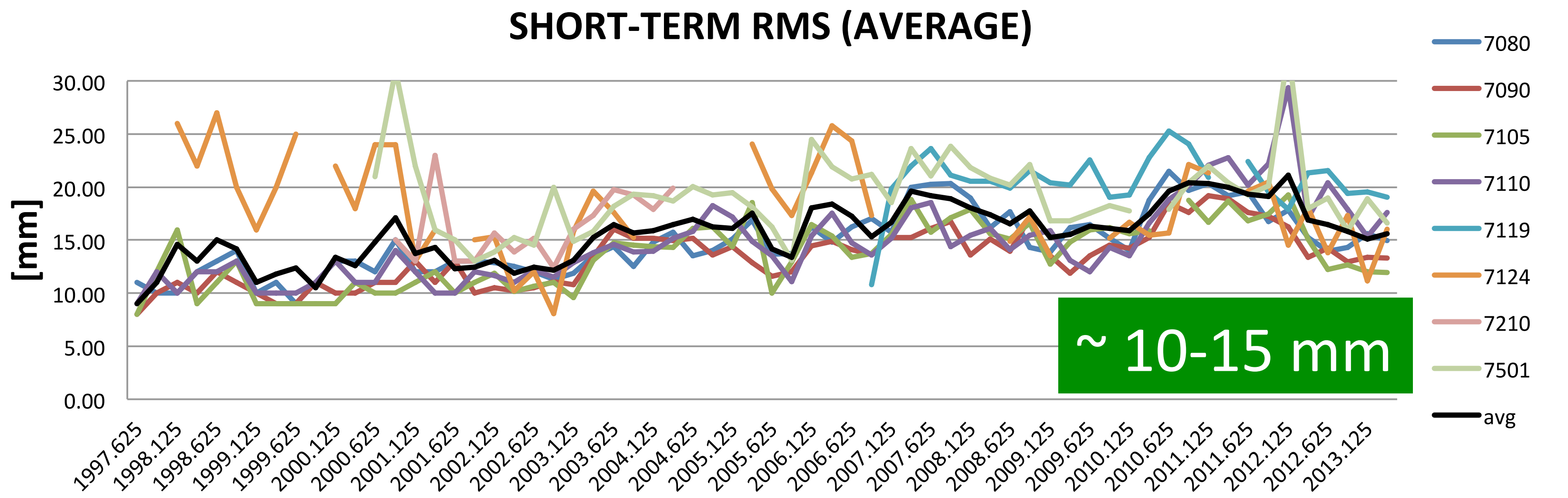
SLR Global Performance Report Card

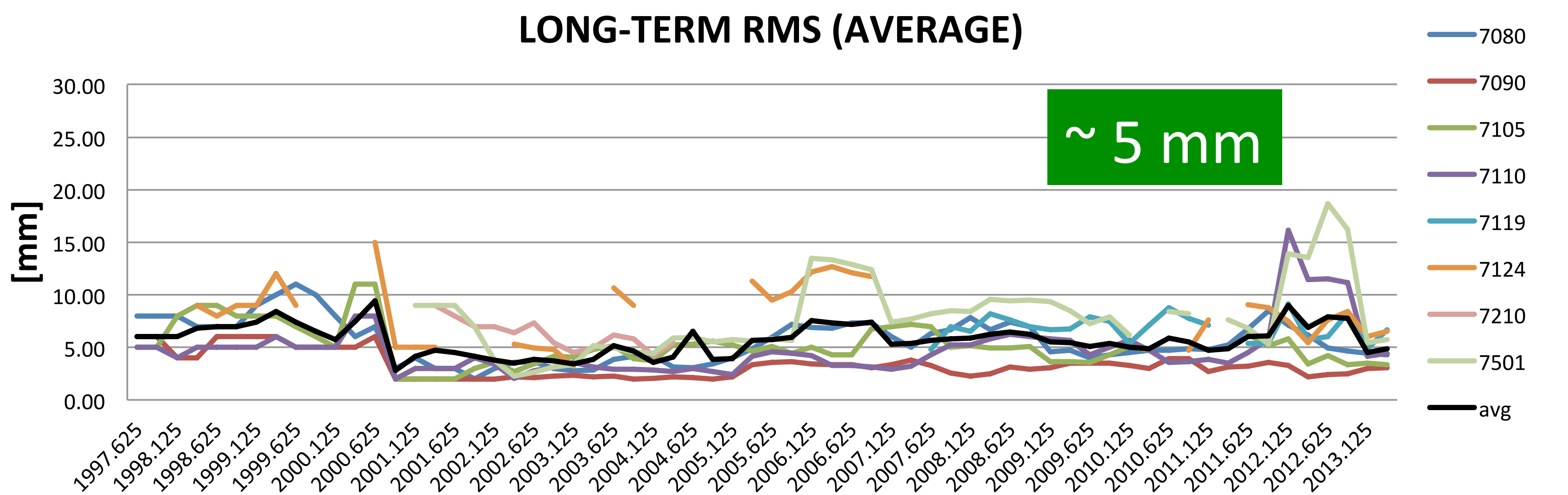
http://ilrs.gsfc.nasa.gov/network/system_performance/global_report_cards/monthly/

DGFI **HITO UNI.** **JCET** **MCC** **SHAO**

Site Information		DGFI Orbital Analysis				Hitotsubashi Univ. Orbital Analysis				JCET Orbital Analysis				MCC Orbital Analysis				SHAO Orbital Analysis			
Station Location	Station Number	LAG NP RMS (mm)	short term (mm)	long term (mm)	% good LAG. NP	LAG NP RMS (mm)	short term (mm)	long term (mm)	% good LAG. NP	LAG NP RMS (mm)	short term (mm)	long term (mm)	% good LAG. NP	LAG NP RMS (mm)	short term (mm)	long term (mm)	% good LAG. NP	LAG NP RMS (mm)	short term (mm)	long term (mm)	% good LAG. NP
Baseline		10.0	20.0	10.0	95	10.0	20.0	10.0	95	10.0	20.0	10.0	95	10.0	20.0	10.0	95	10.0	20.0	10.0	95
Yarragadee	7090	3.7	15.6	1.8	100.0	2.0	7.5	1.9	100.0	3.2	14.8	2.8	99.8	2.4	16.6	2.9	98.3	1.7	15.2	2.0	91.9
Changchun	7237	4.2	26.7	4.7	99.1	3.1	25.2	2.8	99.7	3.1	28.6	3.5	96.8	4.1	30.9	10.5	96.4	3.1	32.3	10.0	90.3
Mount_Stromlo_2	7825	4.2	14.1	4.1	100.0	3.1	8.1	2.0	100.0	3.5	15.2	3.7	99.9	4.1	12.9	3.3	95.4	2.7	12.9	3.1	95.1
Zimmerwald_532	7810	3.1	11.6	7.8	99.9	1.4	5.4	3.1	99.8	2.1	13.0	7.8	99.9	2.6	13.6	3.2	98.3	1.5	11.2	3.7	95.0
Wettzell	8834	3.7	13.1	3.8	100.0	2.5	8.6	2.2	100.0	3.1	12.4	3.9	99.4	2.6	11.5	4.2	96.2	1.5	12.3	5.2	94.2
Graz	7839	2.5	11.2	3.8	100.0	0.8	4.4	1.8	100.0	1.9	11.7	4.9	98.5	1.9	12.0	4.5	98.0	0.7	9.3	2.5	95.5
Matera_MLRO	7941	2.6	12.0	4.7	99.9	1.2	6.0	2.6	100.0	2.1	12.4	4.4	100.0	1.8	14.3	3.7	99.5	2.1	32.0	3.6	97.6
Greenbelt	7105	4.5	12.9	4.2	99.9	2.2	6.6	1.7	99.8	3.3	11.5	2.8	99.2	2.5	16.6	5.5	97.0	2.3	13.5	3.3	91.0
Herstmonceux	7840	2.7	9.8	3.5	100.0	1.4	5.4	1.5	100.0	1.7	11.6	2.9	100.0	2.6	8.9	2.7	96.9	1.7	11.4	2.5	97.2
Monument_Peak	7110	5.8	17.2	5.3	99.7	3.8	12.3	2.0	99.7	5.7	20.5	4.9	98.0	3.9	20.5	3.9	94.4	3.5	14.6	6.2	91.0
Hartebeesthoek	7501	4.8	18.6	5.0	99.9	2.8	8.4	3.2	99.9	3.8	18.7	5.4	98.8	3.3	23.5	4.6	96.3	2.5	19.0	6.2	92.0
San_Juan	7406	15.9	44.1	9.5	97.5	5.6	33.0	10.7	96.0	7.2	33.0	8.3	79.2	7.4	30.5	9.0	91.5	8.7	32.3	11.9	90.4
Potsdam_3	7841	3.9	10.7	4.2	100.0	1.7	7.7	2.7	99.6	2.7	10.9	5.0	99.4	2.1	7.4	2.9	98.2				
Grasse_MEO	7845	4.2	14.1	3.1	100.0	2.6	9.6	3.1	100.0	3.5	13.3	2.6	100.0	3.1	12.9	3.3	97.5	2.1	14.0	2.9	94.3
Arequipa	7403	5.6	22.6	11.8	99.5	2.4	22.6	18.4	99.2	5.0	25.8	21.5	97.4	3.6	16.6	6.8	96.0	4.2	18.7	6.7	89.5
Shanghai_2	7821	8.0	44.8	19.7	99.4	3.8	43.9	18.8	100.0	4.1	46.2	24.6	94.1	5.0	46.6	21.5	97.5	2.6	31.5	19.6	95.0
Haleakala	7119	7.0	22.3	9.0	98.3	3.6	11.3	2.7	98.1	5.3	15.1	4.8	96.7	5.8	27.0	14.3	96.6	5.0	43.1	20.1	92.5
Simosato	7838	6.5	27.7	11.3	100.0	3.1	17.7	6.8	99.8	6.1	19.0	8.0	97.1	4.5	19.1	9.9	98.9	6.1	18.4	6.2	90.6
McDonald	7080	5.2	14.9	5.3	99.7	2.9	7.8	3.5	99.7	4.2	14.1	3.6	99.3	3.4	15.9	6.2	93.2	2.5	15.1	4.2	96.5
Kiev	1824	18.3	42.8	26.5	84.1	12.6	49.7	28.3	89.1	4.9	30.1	16.7	47.8	1271.8	44.6	33.8	87.8				
Katzively	1893	15.8	15.7	6.4	98.9	9.8	17.8	3.5	97.9	7.0	20.5	6.5	79.9	12.1	18.8	10.4	86.3	9.8	18.6	13.0	92.8

NASA Supported Stations



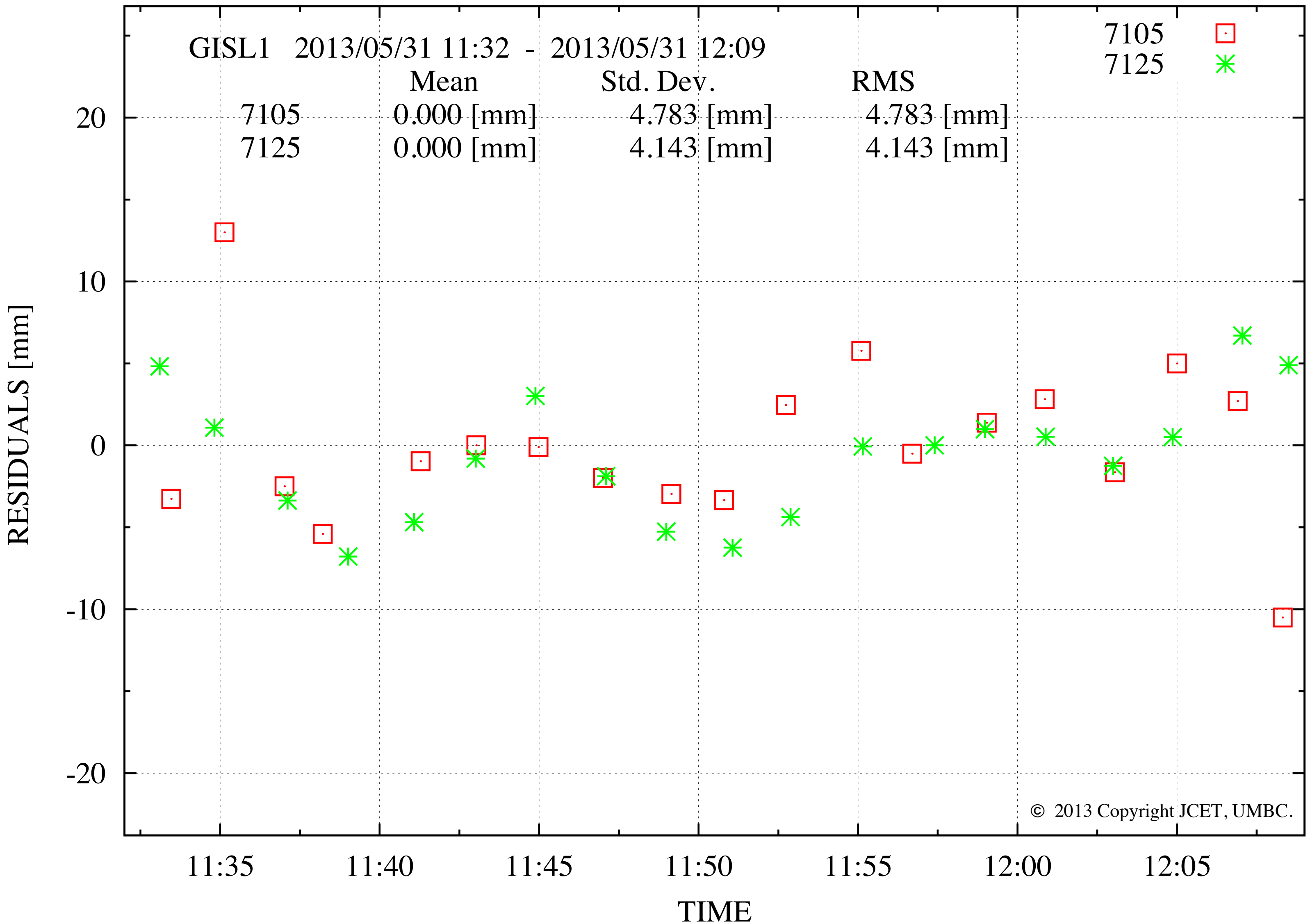


Data Validation Process (cont.)

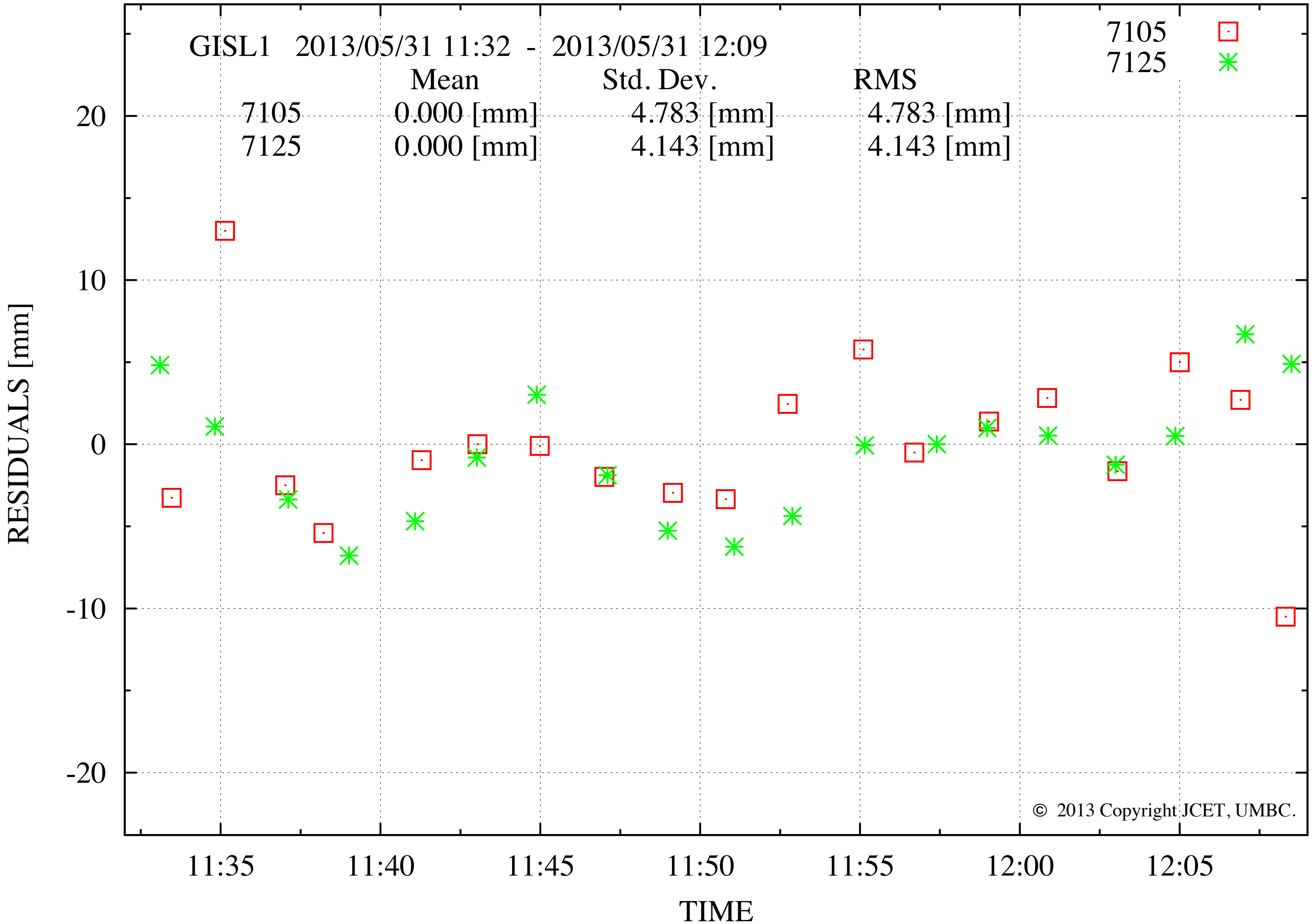
- The range residuals from NGSLR and MOBLAS-7 data on the same target and for passes which were co-observed, were compared
- Statistics for each group of residuals and for every co-observed pass were formed and compared
- We are looking for similar trends in the residuals and lower noise in the NGSLR case, reflected in their RMS about the mean
  - Theory predicts that there should be a systematic difference between NGSLR and MOBLAS-7 (see talks by the NGSLR team)
  - Higher stability of the NGSLR system should result in a significantly higher precision of that data set compared to MOABLS-7

- In the following we show a few examples of residual comparisons for LAGEOS, LAGEOS 2 and LARES passes tracked by NGSLR ★ and MOBLAS-7 □

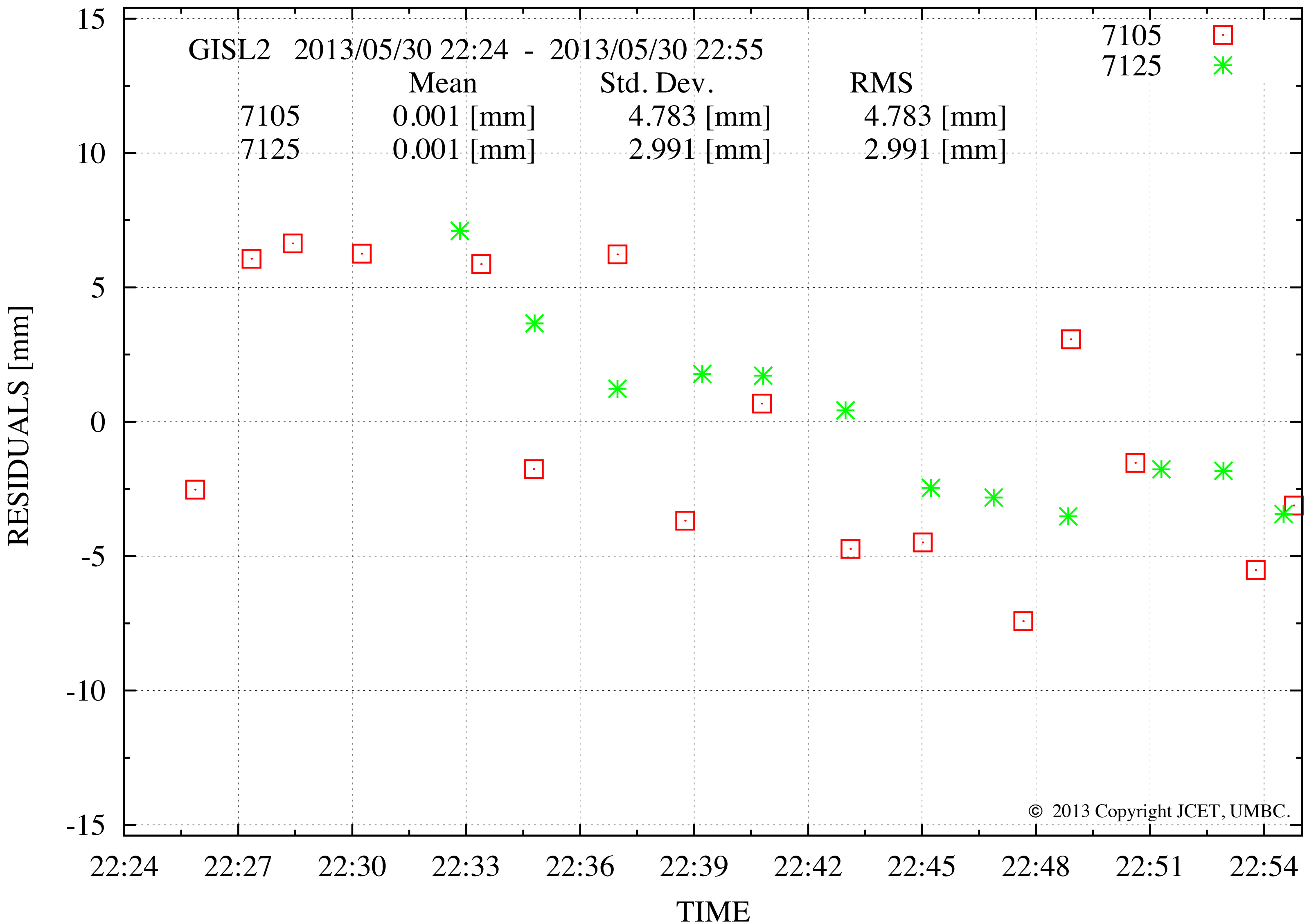
Residual Comparisons NGSLR – MOBLAS-7 LAGEOS 1



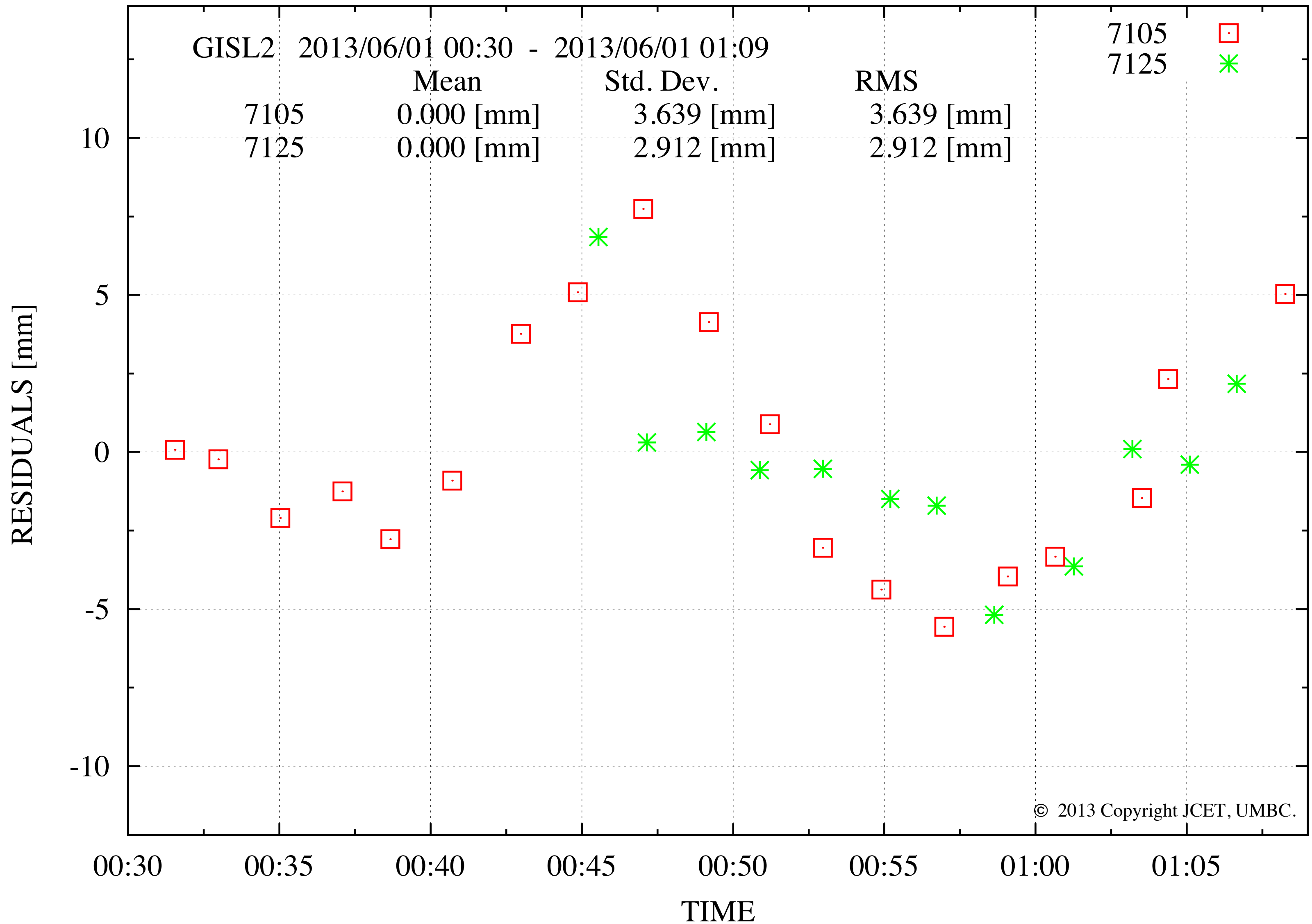
Residual Comparisons NGSLR – MOBLAS-7 LAGEOS 1



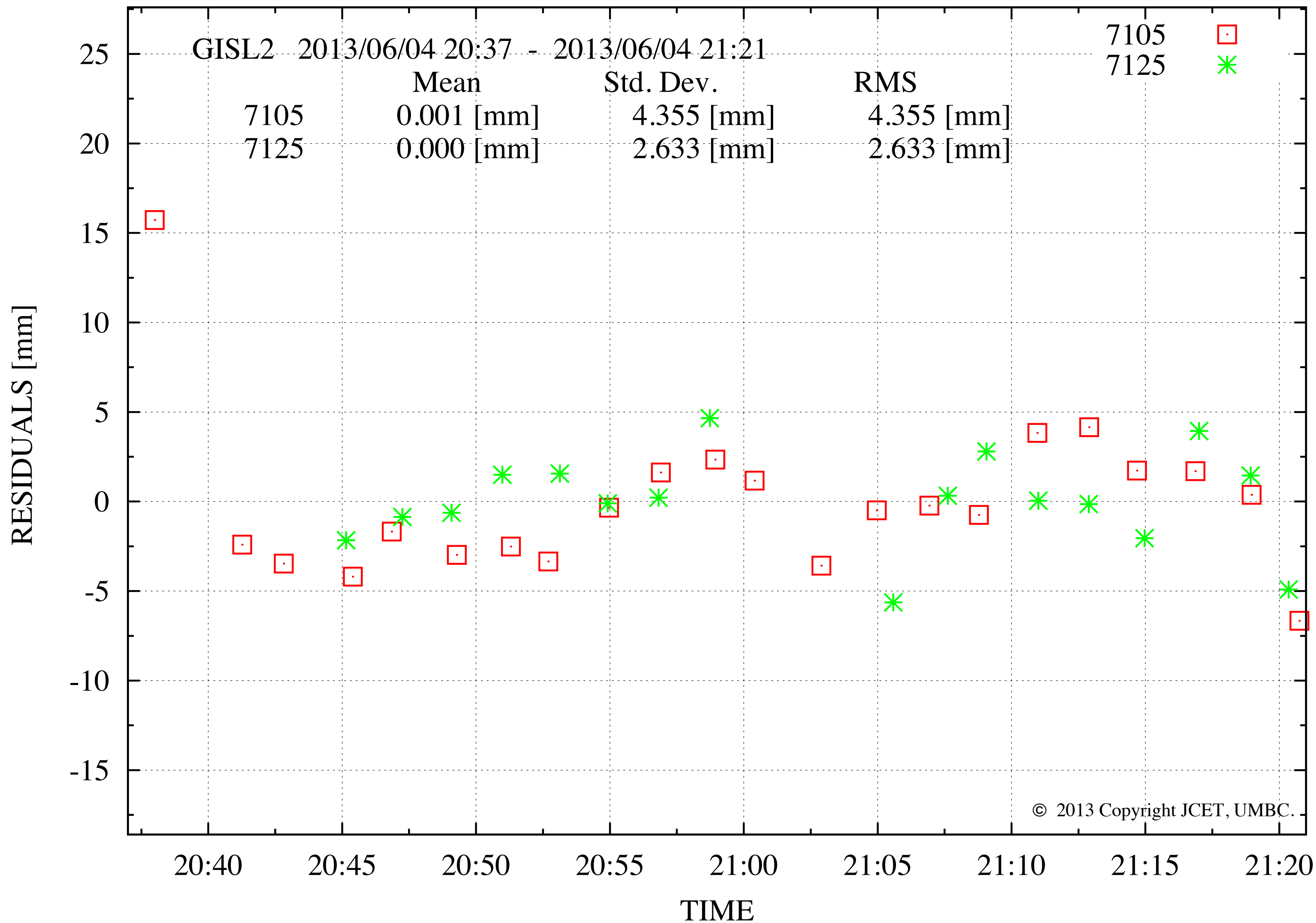
Residual Comparisons NGSLR – MOBLAS-7 LAGEOS 2



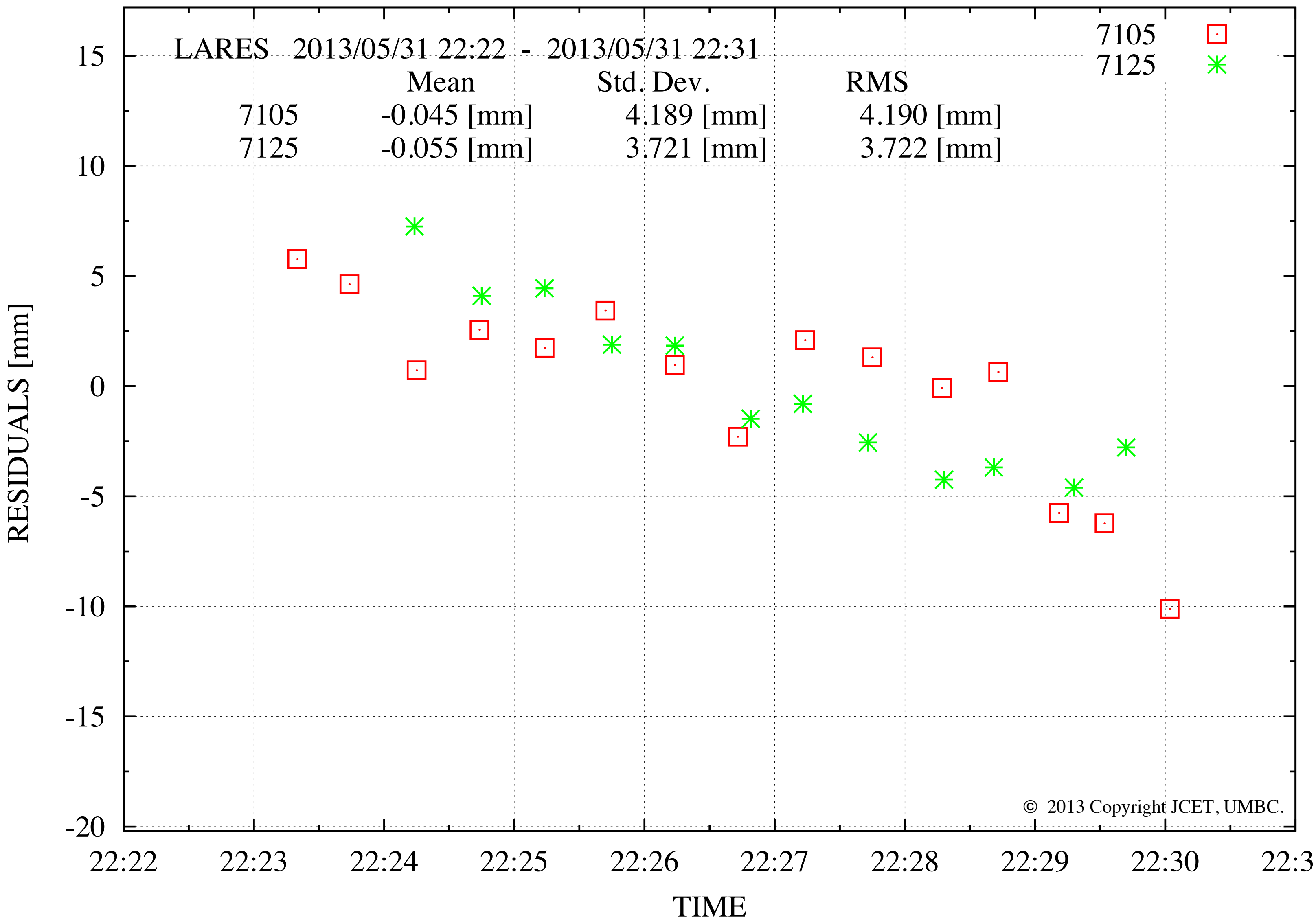
Residual Comparisons NGSLR – MOBLAS-7 LAGEOS 2



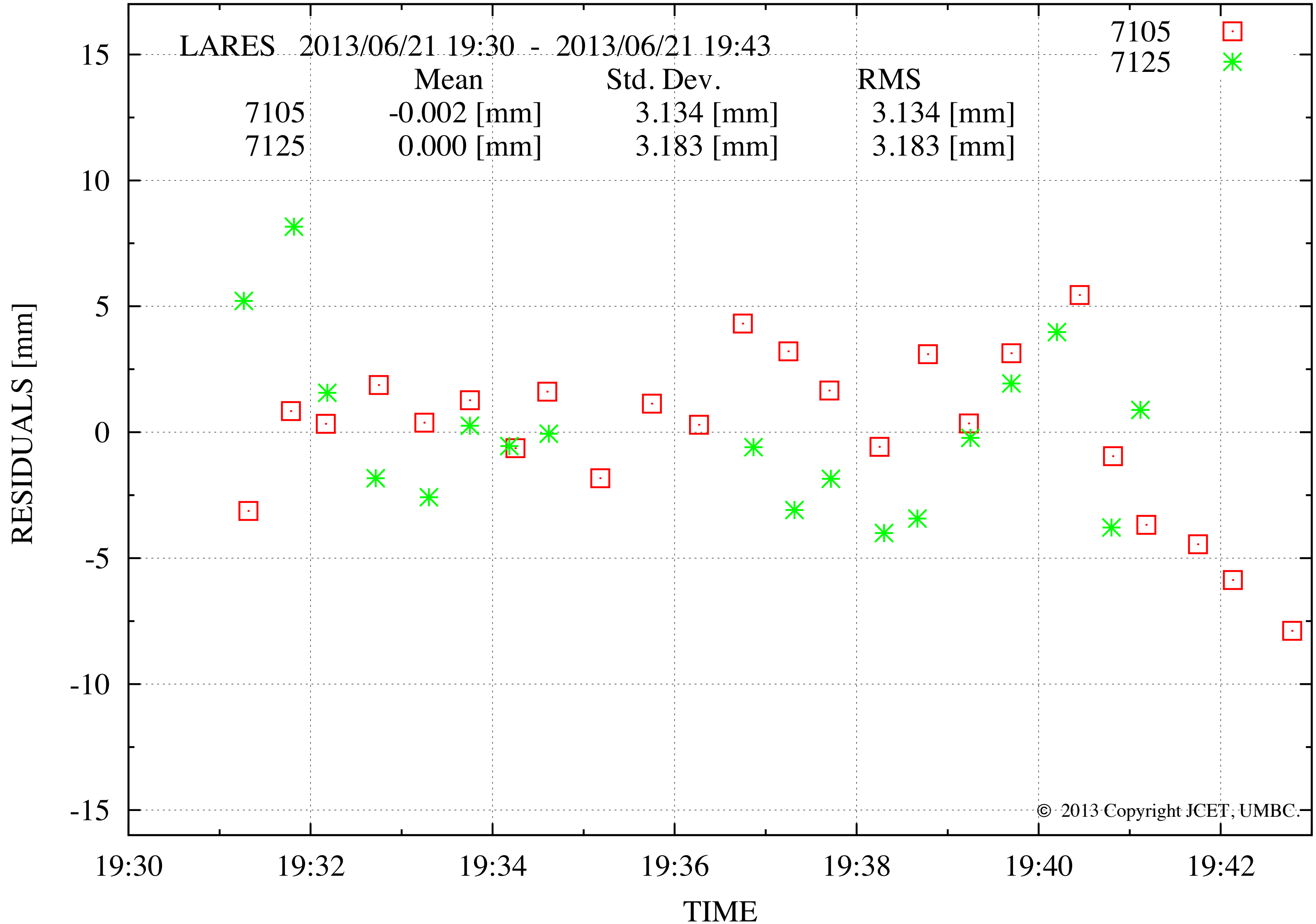
Residual Comparisons NGSLR – MOBLAS-7 LAGEOS 2



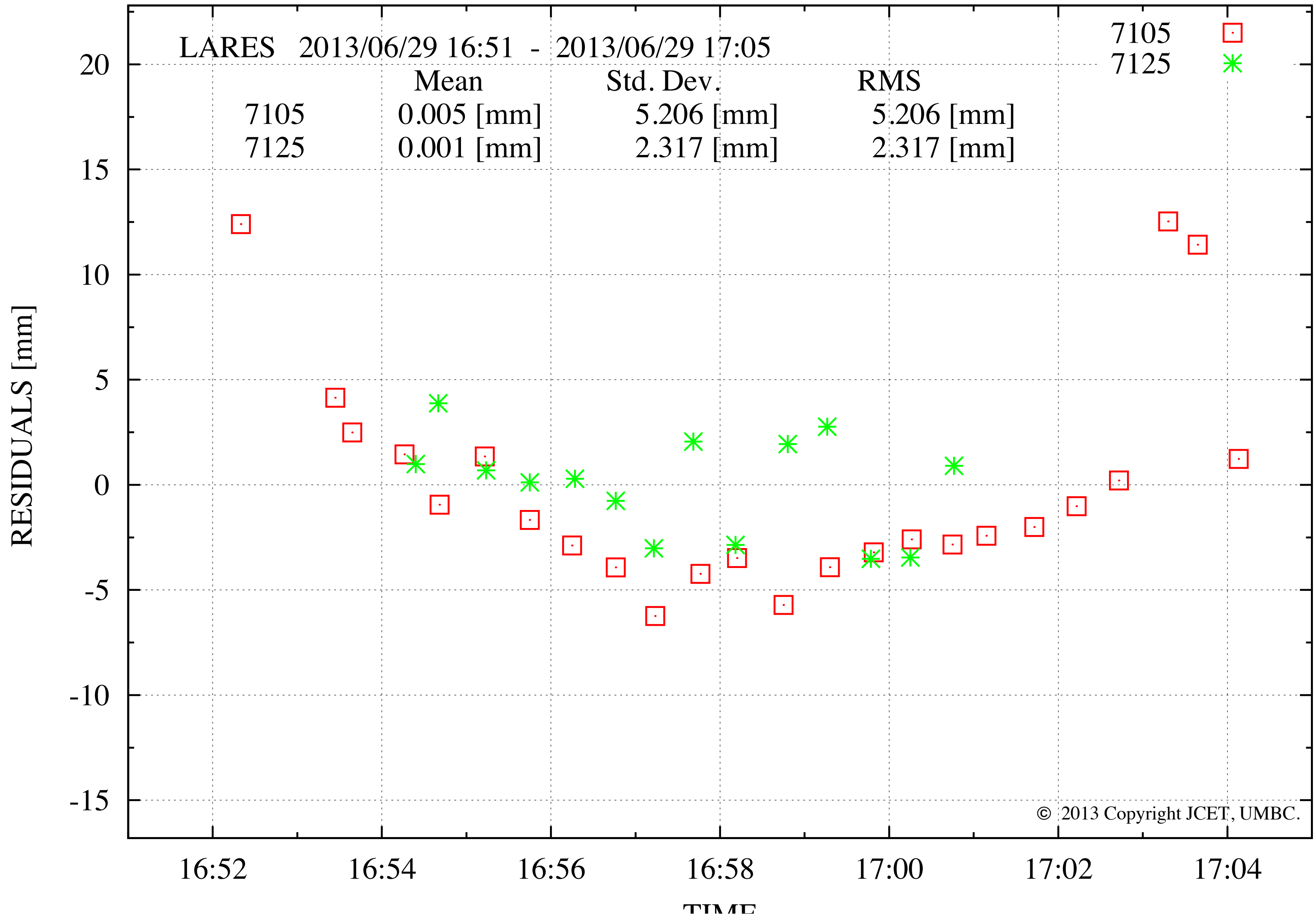
Residual Comparisons NGSLR – MOBLAS-7 LARES



Residual Comparisons NGSLR – MOBLAS-7 LARES



Residual Comparisons NGSLR – MOBLAS-7 LARES



Residual Statistics MOBLAS-7 vs. NGSLR

LAGEOS 1

MOB7 7105	Precision [mm]	Rb [mm]	Sig_Rb [mm]
Points	16	16	16
Median	2.95	-3.80	3.50
Std Deviation	2.35	14.15	2.42

NGSLR 7125	Precision [mm]	Rb [mm]	Sig_Rb [mm]
Points	18	18	18
Median	2.8	15.6	3.85
Std Deviation	1.87	10.30	1.86

Commonly observed passes

RELATIVE BIAS: ~18 mm

Residual Statistics MOBLAS-7 vs. NGSLR

LAGEOS 2

MOB7 7105	Precision [mm]	Rb [mm]	Sig_Rb [mm]
Points	21	21	21
Median	4.10	-0.30	2.50
Std Deviation	1.92	5.99	1.06

NGSLR 7125	Precision [mm]	Rb [mm]	Sig_Rb [mm]
Points	13	13	13
Median	3	16.1	2.7
Std Deviation	0.91	9.32	0.99

Commonly observed passes

RELATIVE BIAS: ~16 mm

Residual Statistics MOBLAS-7 vs. NGSLR

LARES

MOB7 7105	Precision [mm]	Rb [mm]	Sig_Rb [mm]
Points	6	6	6
Median	3.20	-10.75	5.40
Std Deviation	1.24	14.49	7.97

NGSLR 7125	Precision [mm]	Rb [mm]	Sig_Rb [mm]
Points	7	7	7
Median	3.70	2.30	6.30
Std Deviation	2.10	17.95	1.81

Commonly observed passes

RELATIVE BIAS: ~13 mm

ILRS Global Network vs. NGSLR

Statistics from all of tracked data

Target	Global Network			NGSLR		
	Precision [mm]	R_b [mm]	σ_{Rb} [mm]	Precision [mm]	R_b [mm]	σ_{Rb} [mm]
LAGEOS 1	4.6	0.1	16	3.4	14.6	1.6
LAGEOS 2	4.4	7.2	14	3.3	15.2	1.5
LARES	7.1	-3.9	12	4.1	-5.1	0.6

Statistics of ~24 stations that tracked over the period of the co-location campaign

Summary

- A very successful five week co-location campaign produced a good set of SLR data on various targets (from LEO to HEO) tracked by the permanent GGAO system (MOBLAS-7) and the recently completed NGSLR system, many tracked simultaneously
- We compared the data on LAGEOS 1 & 2 and LARES via our standard QC process, for the entire network and NGSLR
- Comparison on a pass-by-pass basis revealed a good agreement between the two systems, with a relative systematic range difference that is theoretically expected between the two systems
- We will continue the comparison focusing on data from LEO & HEO missions (e.g. Starlette, GLONASS)