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LARES' contribution to GGOS Assessment after one year in orbit

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Introduction

LARES (LAser RElativity Satellite) is a new geodetic satellite in Earth's orbit since February 13, 2012 (Fig.1). With a diameter of 364 mm and a weight of 386.8 kg, LARES has the smallest area-to-mass ratio of all artificial satellites, i.e., about 2.5 times smaller than the area-to-mass ratio of LAGEOS. LARES' circular orbit at an altitude of 1450 km and inclined by 69.5°, together with a large amount of SLR observations, promises a valuable extension of the standard LAGEOS-Etalon solutions computed within the ILRS.
The contribution of LARES to SLR-derived products is assessed by comparing the standard LAGEOS-Etalon solutions (A) with the combined LAGEOS-Etalon-LARES solutions (B).

LAGEOS-1, LAGEOS-2, Etalon-1, Etalon-2 — **Solution A**

vs.

LAGEOS-1, LAGEOS-2, Etalon-1, Etalon-2, **LARES** — **Solution B**

Solution setup

The following parameters are estimated on a weekly basis: Station coordinates, satellite orbits, Earth rotation parameters (piece-wise linear polar motion and length of day, estimated daily), geocenter coordinates, and range biases (RGB). RGBs for the LAGEOS and Etalon satellites are estimated only for a few sites according to the guidelines of the ILRS Analysis Working Group, whereas station-specific RGBs to LARES are setup for all SLR stations.
The seven-day orbits for each satellite are represented by six initial osculating orbital elements and additional dynamic orbital parameters (one set per 7-day arc), namely a constant and a once-per-revolution acceleration in along-track direction as well as a once-per-revolution acceleration in out-of-plane direction. LARES-specific once-per-revolution pseudo-stochastic pulses in along-track direction are estimated in addition. No-net-rotation and no-net-translation minimum conditions were applied using the SLRF2008 fiducial stations for datum definition.

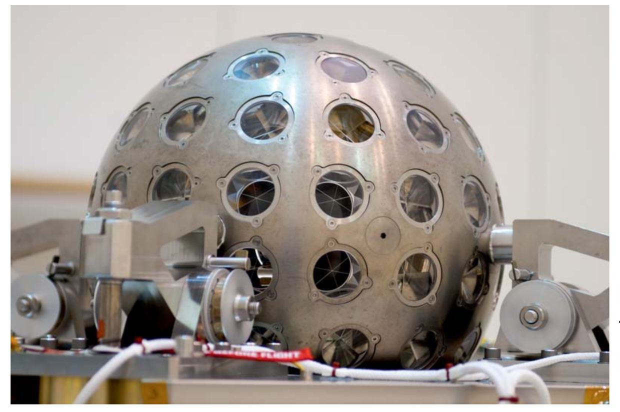

Fig. 1: The LARES laser relativity satellite from Italy's space agency ASI undergoes preparations at Europe's Spaceport in French Guyana (copyright ESA).

Data statistics

57 weeks of SLR observations have been processed, covering the period from February 19, 2012, to March 23, 2013.
Figure 2 shows the weekly number of accepted normal points per satellite group. The critical lack of observations towards the end of 2012 is clearly visible. Due to station outages and seasonal weather conditions on the northern hemisphere the observation performance dropped to about 30% of the average observation number.

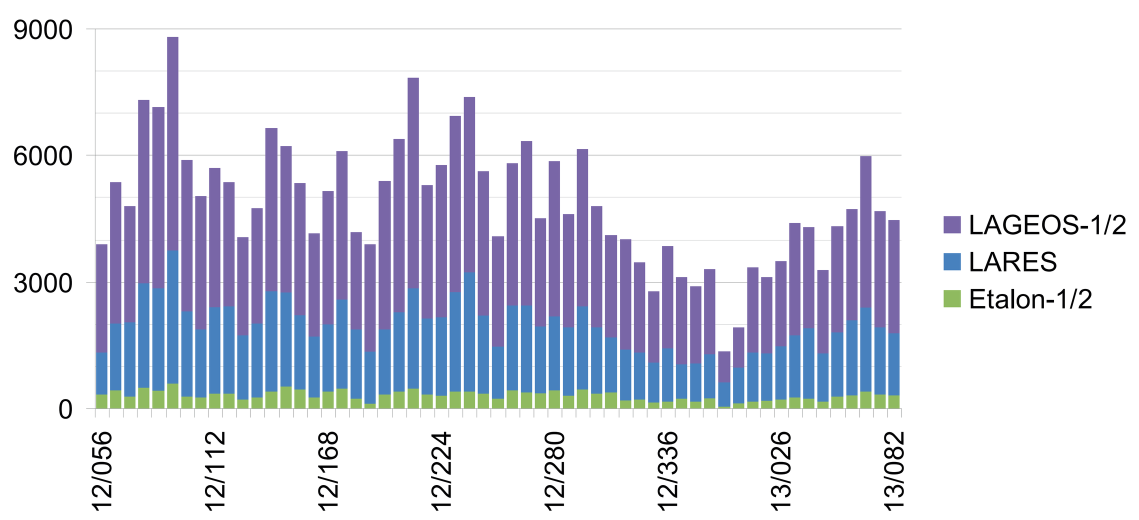

Fig. 2: Weekly number of observations per satellite group. Time axis: YY/DOY.

In Figure 3 the number of observations for LAGEOS and LARES satellite is shown for each station. The most contributing stations provide roughly the same amount of observations to LARES as to one LAGEOS satellite. LARES is apparently the predominant satellite at the stations 7839 (Graz), 7105 (Greenbelt), 7841 (Potsdam), and 8834 (Wettzell).
The spatial distribution of LARES observations (see Fig. 4) reveals bigger gaps compared to LAGEOS due to the lower orbital altitude. The polar coverage is comparable to LAGEOS-1 (inclination 109.9°).

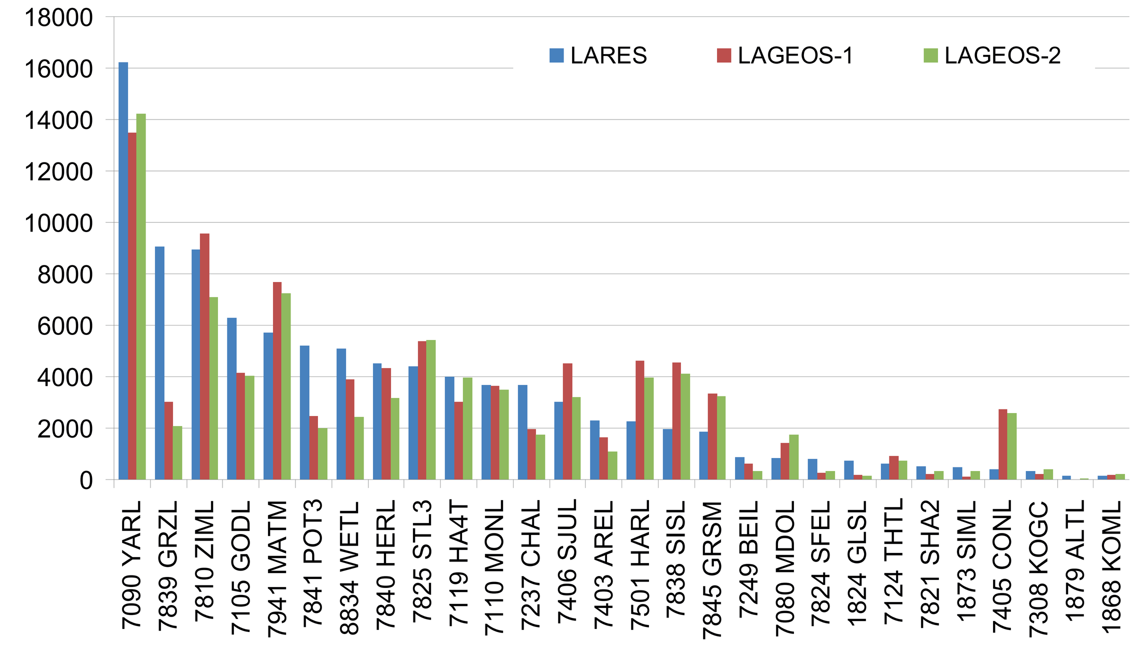

Fig. 3: Total number of observations per satellite over 57 weeks, sorted in descending order of the number of LARES observations.

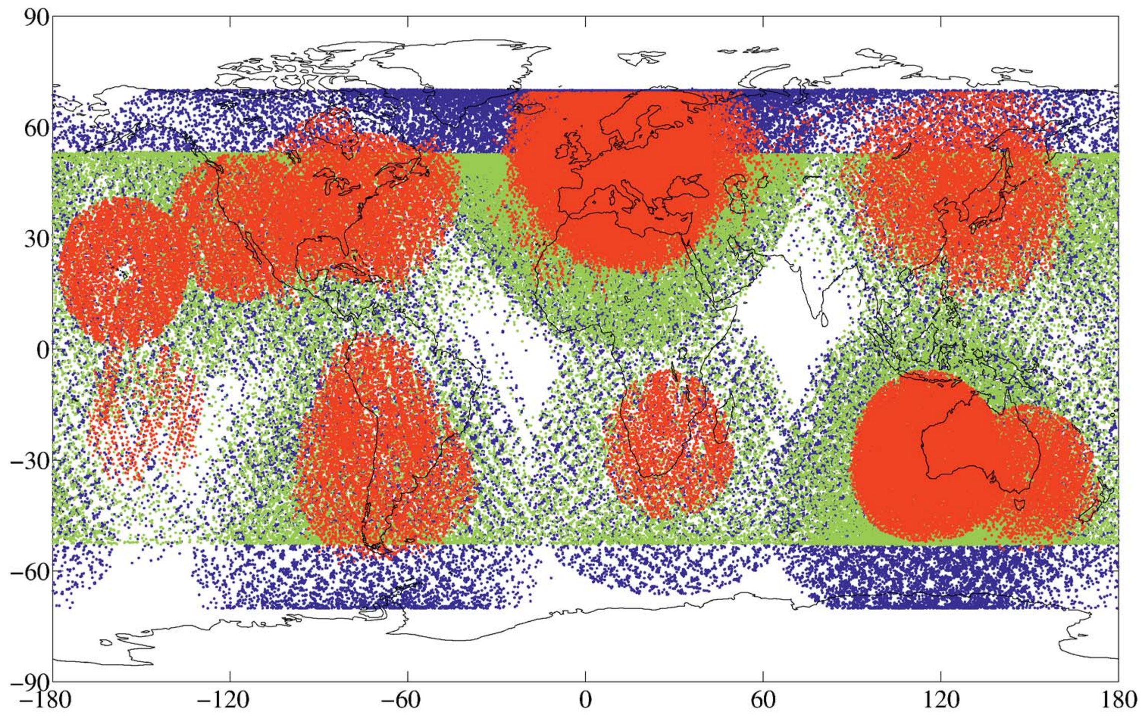

Fig. 4: Spatial observation distribution of LARES (red), LAGEOS-1 (blue), and LAGEOS-2 (green) over 57 weeks.

LARES range biases

The RGBs of all stations tracking LARES were estimated from an accumulated solution covering all 57 weeks (see Tab. 1). The scale of the solution is defined by the LAGEOS and Etalon data, where range biases are only estimated for selected sites. There are no systematic RGBs visible for LARES. This behaviour indicates that the center-of-mass (CoM) correction used for LARES (= 133 mm) is appropriate and fits to the CoM corrections used for LAGEOS and Etalon satellites. The obtained **long-term RGBs have been introduced in to the SLR solution B** in order to stabilize this solution.

Station		Range Bias [mm]	Std.-Dev. [mm]	Station		Range Bias [mm]	Std.-Dev. [mm]
1824	GLSL	-23.9	1.2	7405	CONL	5.5	1.1
1868	**KOML**	**-6.8**	**3.3**	7406	SJUL	2.7	0.5
1873	SIML	-49.5	1.2	7501	HARL	2.7	0.5
1879	ALTL	1.9	2.8	7810	ZIML	1.3	0.3
7080	MDOL	1.7	0.8	7821	SHA2	-2.8	1.1
7090	YARL	2.5	0.3	7824	SFEL	-16.2	0.9
7105	GODL	-0.1	0.4	7825	STL3	-3.9	0.4
7110	**MONL**	**4.2**	**0.6**	7838	SISL	11.1	0.6
7119	HA4T	1.6	0.4	7839	GRZL	-2.6	0.3
7124	THTL	4.3	1.0	7840	HERL	2.1	0.4
7237	CHAL	-0.6	0.5	7841	POT3	-1.5	0.4
7249	**BEIL**	**-23.6**	**1.7**	**7845**	**GRSM**	**-0.3**	**0.7**
7308	**KOGC**	**79.1**	**2.3**	7941	MATM	-5.0	0.4
7403	**AREL**	**16.6**	**1.0**	**8834**	**WETL**	**-10.6**	**0.6**

Tab. 1: Long-term range biases for stations tracking LARES from an accumulated 57-week solution. For the blue-marked stations RGBs were also estimated for LAGEOS satellites.

Terrestrial reference frame

Differences in **geocenter coordinates** between the SLR solutions A and B show systematic offsets (see Fig. 5).

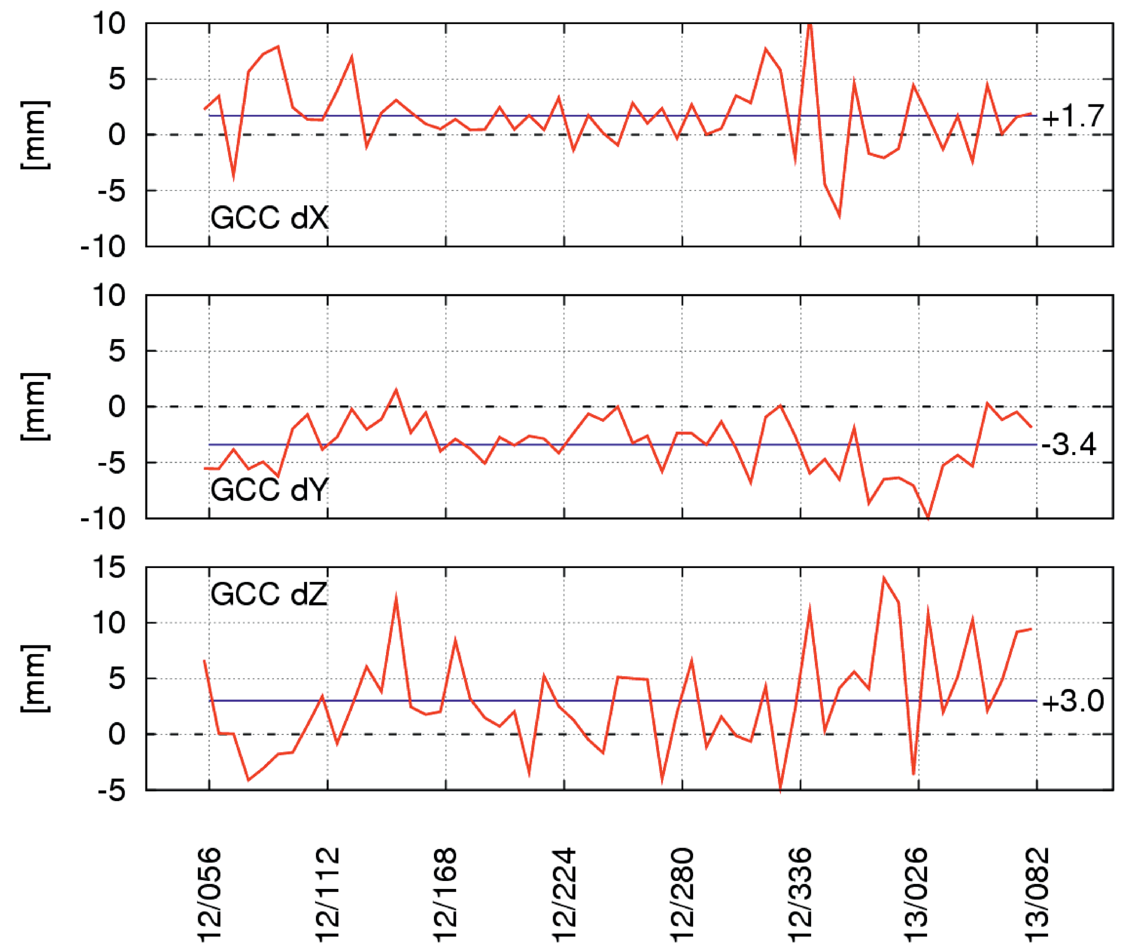

Fig. 5: Differences in geocenter coordinates of both SLR solutions. Solution B minus A (red), mean difference (blue). Time axis: YY/DOY.

The comparison of both SLR solutions by performing a weekly Helmert transformation using the SLRF2008 core sites gives further insight into the impact of LARES (see Fig. 6). The scattering mean North residual (RMS 0.9 mm) is obviously the main **difference between both coordinate sets**. The near-zero Up-component indicates that the range biases are well estimated and the scale is consistent.
The mean RMS of Helmert transformation w.r.t. SLRF2008 yields 8 mm for both SLR-solutions.

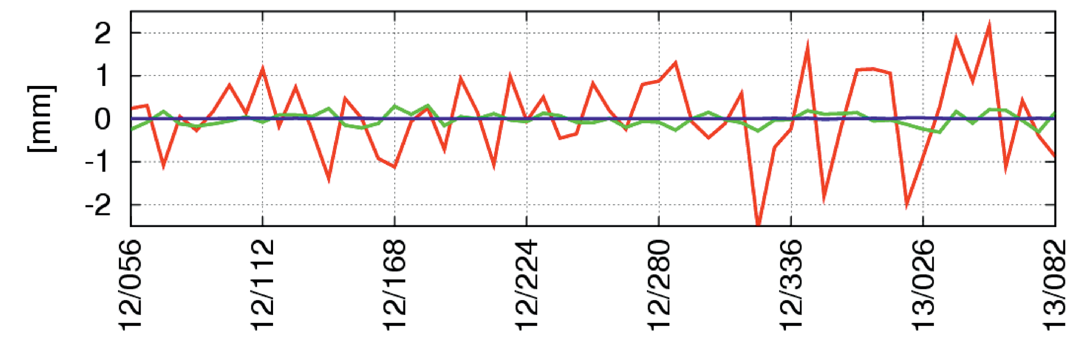

Fig. 6: Differences in mean coordinate residuals of the SLRF2008 core sites in North (red), East (green) and Up (blue) between SLR-derived solutions A and B after performing a Helmert transformation. Time axis: YY/DOY.

Although one could assume from Fig. 3 that stations like Yarragadee (7090) and Graz (7839) profit from the substantial amount of LARES observations, the **coordinate repeatability** is not improved (see Fig. 7). The improvement of the repeatability of Wettzell's Up-component is mostly due to the fact that in solution B all range biases have been fixed to the accumulated 57-week estimates (compare with Tab. 1).

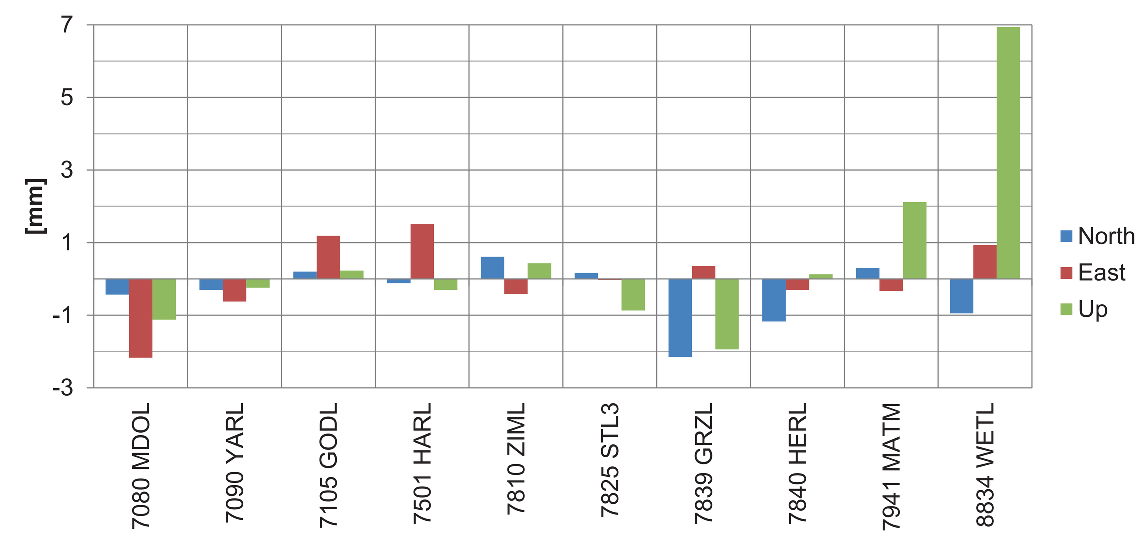

Fig. 7: Differences in coordinate repeatability in N/E/U: Solution A minus Solution B. Positive values denote an improvement for solution B (LARES included). Only SLRF2008 core sites are listed above.

Earth rotation parameters

For evaluating SLR-derived ERPs without and with including LARES, solutions A and B are compared to the IERS-08-C04 of the International Earth Rotation and Reference Systems Service (IERS). The comparisons are shown in Tab. 2 and Fig. 9.

	X-pole [µas]		**Y-pole** [µas]		**LOD** [µs/d]	
	Bias	WRMS	Bias	WRMS	Bias	WRMS
Solution A	39	159	68	178	123	105
Solution B	-119	201	99	214	136	114

Tab. 2: Summary of differences in ERP w.r.t. to the C04 time series.

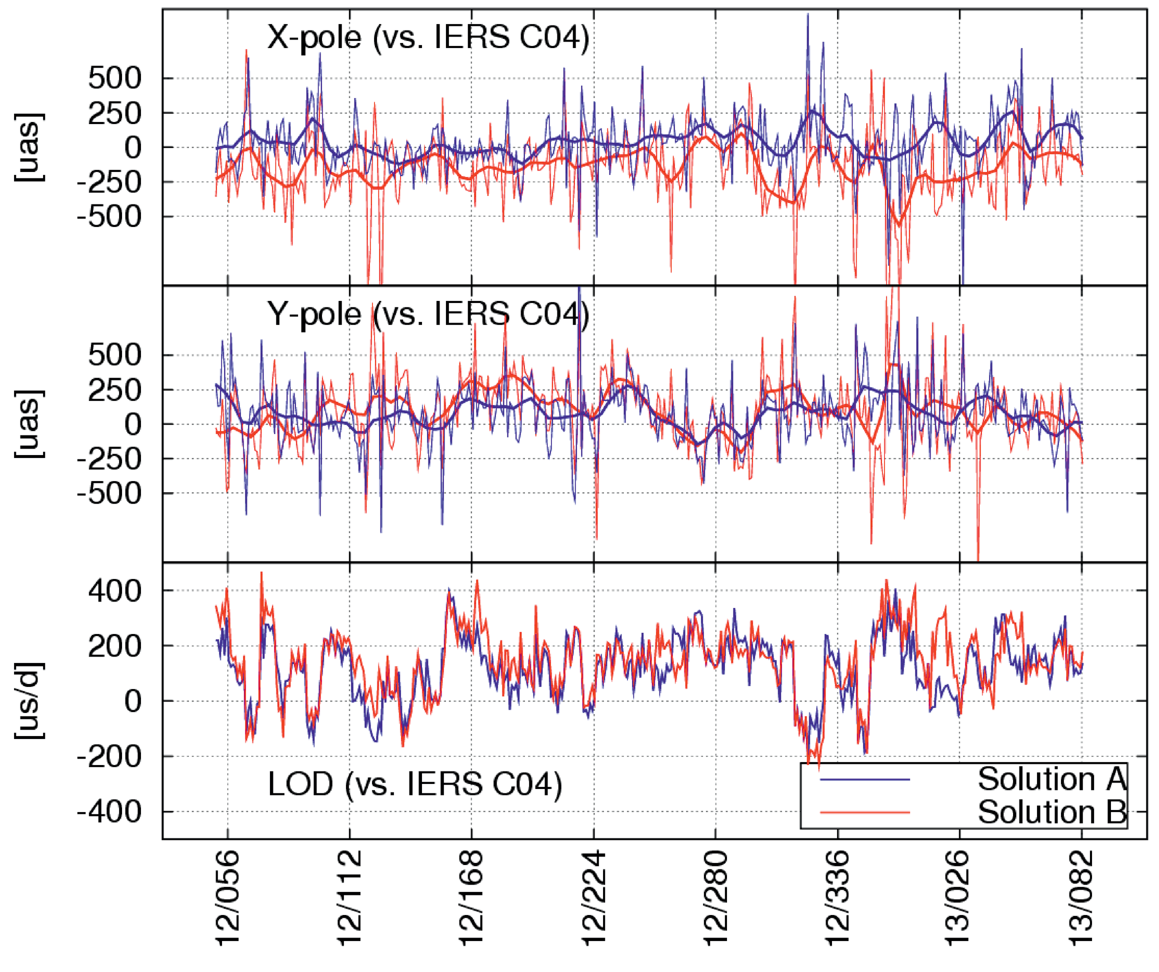

Fig. 9: Polar motion and LOD comparison. Reference: IERS C04. Bold lines in X- and Y-pole are spline-smoothed time series. Time axis: YY/DOY.

Conclusions

No evidence can be given so far that LARES improves the SLR-derived products. Orbit modeling will be revisited to see whether further improvements are possible. Better datum definition strategy for the end of 2012 could improve the results for periods with lack of observations.

LARES' **range biases**:
No systematic RGBs visible for LARES. Indication that the center-of-mass (CoM) correction used for LARES (= 133 mm) is appropriate and fits to the CoM corrections used for LAGEOS and Etalon satellites.

LARES' impact on **geocenter coordinates**:
dX = +1.7 mm, dY = -3.4 mm, dZ = +3.0 mm

LARES' impact on **coordinate sets**:
Mean North residual after Helmert transformation scatters with an RMS of 0.9 mm. A better coordinate repeatability could not be achieved. The mean RMS of Helmert transformation w.r.t. SLRF2008 yields 8 mm for both SLR-solutions.

LARES' impact on **Earth rotation parameters**:
X-pole bias = 152 µas, Y-pole bias = 31 µas, LOD bias = 13µs/d

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