GNSS orbit validation using SLR observations at CODE

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INTRODUCTION

SLR observations to GNSS satellites provide an independent validation of the orbits determined from microwave observations, thus, allowing us to assess the quality of the GNSS orbits. We have GPS orbits for the time span 1996-2012 and GLONASS orbits for the time span 2003-2012 at hand which were generated with the latest models (e.g., IERS Conventions 2010, IGS08 reference frame and antenna modelling).

Both GPS satellites carrying Laser Reflector Arrays (LRAs) are tracked by the SLR sites, but only 3-6 selected GLONASS satellites are tracked at the same time. Fig. 1 shows the timescale for those GLONASS satellites included in the official ILRS tracking scheme.

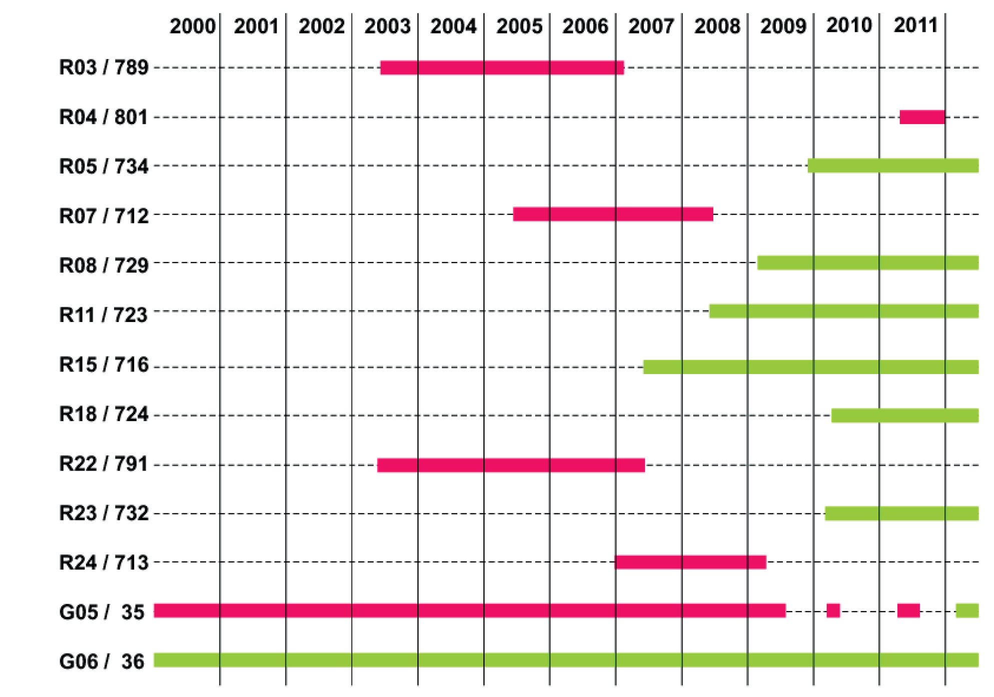

Fig: 1: Timescale for official ILRS tracking of GPS and GLONASS satellites. Before 2000 only the GPS satellites are tracked (omitted in the plot). Red: Satellites not active anymore.

SLR RESIDUALS FOR LONG TIME SERIES

SLR residuals to the microwave-based GNSS orbits were computed for all satellites. The CODE orbits (including ERPs) were kept fixed and the SLR station coordinates were introduced from SLRF2008. No additional parameters were estimated. Fig. 2 shows the time series of SLR residuals for selected satellites, and Tab. 1 summarizes the statistics of the analysis. The mean biases for GPS and GLONASS are quite different, i.e., 25 mm and about 3-30 mm, respectively. The scatter is about 20 mm and 25-40 mm for GPS and GLONASS, respectively.

The characteristics of the SLR residuals (bias, RMS) are different between the stations. Fig. 3 shows examples for well-performing SLR stations. Especially the scatter is smaller, e.g., the RMS of the best SLR stations for R15 is only about 25-30 mm (overall RMS: 40 mm).

However, Fig. 3 reveals as well some signals in the station-specific residuals. Possible reasons might be:

- Orbit modelling (e.g., solar radiation pressure)
- SLR tracking issues (e.g., day- /night-time tracking)

The first topic is discussed since many years, and correlations with the beta angle have been demonstrated. Butthe residuals for R11 and R15 (Fig. 3) show a different signature, although they belong to the same orbital plane. Therefore, we want to focus on the second aspect (see next column).

SIGNALS IN SLR RESIDUALS

In Fig. 3 it appears that the signal contained in the residuals of the European sites (7810, 7839, 7840, 7845, 7941, 8834) is shifted compared to that of the Australian sites (7090, 7825). Therefore, we looked at the residuals depending on the tracking time (Fig. 4+5): A dependency on the tracking time is present, and in most cases the daylight data shows a larger bias than the night-time data. This dependency is, however, not pronounced in the same way for all stations and for all satellites: For R15-716 the residuals show a clearly different bias for the daylight data than for the night-time data for all stations. For R11-723 the dependency is not as obvious.

From Fig. 4 we see that the bias between day- and night-time data is more pronounced for Zimmerwald (7810) than for Yarragadee (7090).

Only the six mentioned European sites and Yarragadee (Australia) perform daylight tracking regularly, thus, a detailed study of this aspect is difficult. Nevertheless, we conclude that the impact of day-/night-time tracking should be further studied together with the correlation with orbit modelling issues.

SVN	PRN	Num. Obs.	Bias [mm]	RMS [mm]
36	G06	49182	-31.59	24.59
35	G05/30	45343	-29.52	22.16
716	R15	36222	-8.04	40.18
791	R22	30047	-18.42	38.86
729	R08	29708	-33.93	33.12
789	R03	29059	-17.79	41.89
723	R11	27835	-30.68	40.49
712	R07	22004	-12.35	38.36
713	R24	17626	-19.72	43.59
734	R05	10093	-14.07	33.17
724	R18	9100	-16.58	33.19
801	R03/04	2658	3.54	52.01
714	R17/23	1448	-11.55	54.59
746	R17	1391	-25.94	41.82

SVN	PRN	Num. Obs.	Bias [mm]	RMS [mm]
716	R15	19490	-9.75	40.15
729	R08	16204	-34.65	31.15
723	R11	15571	-31.74	35.58
732	R23	6276	-20.10	28.13
724	R18	5093	-19.64	25.26
737	R12	2902	-23.75	28.84
738	R16	2542	-22.10	28.81
736	R09	2450	-20.73	29.46
720	R19	2262	-12.53	23.12
721	R13	2237	-21.41	24.90
728	R02	2216	-31.29	23.35
719	R20	2159	-10.19	28.39
715	R03/14	2060	-22.46	28.59
717	R10	2017	-10.07	35.01
730	R01	1779	-2.52	28.43
731	R22	1608	-20.19	28.41
725	R21	1598	-12.41	27.98
733	R04/06	1592	-16.12	24.09
735	R24	1570	-12.20	30.79
742	R04	1216	-16.66	24.05
744	R03	1149	-14.96	23.49
746	R17	1020	-29.07	45.21
745	R07	894	-14.20	24.60

Tab. 1: Statistics on SLR residuals (sorted by descending number of SLR data). Satellites with un-coated corner cubes are marked in green. The satellites currently tracked are labelled **red**. **Top:** Satellites officially tracked between 1996 and 2012. **Bottom:** All satellites tracked since Dec. 2009.

TRACKING THE FULL GLONASS CONSTELLATION

Herstmonceux (7840) started in Dec. 2009 to track the full GLONASS constellation, and a few other SLR stations followed since mid of 2011. The statistics on SLR residuals starting Dec. 2009 is given in Tab. 1 (bottom). We can see that the RMS for the newer satellites decreased, which must be attributed to the denser GNSS network for orbit determination and an improved analysis strategy for GLONASS data.

Another point of interest is the comparison of coated and un-coated corner cubes of the laser reflector arrays (LRA): The un-coated LRAs are marked green in Tab. 1. It seems that the mean bias becomes larger for un-coated cubes (i.e., a similar order of magnitude as for GPS), but the RMS decreases. As soon as longer series are available, this aspect can be studied in more details, as well as issues related to the orbital plane.

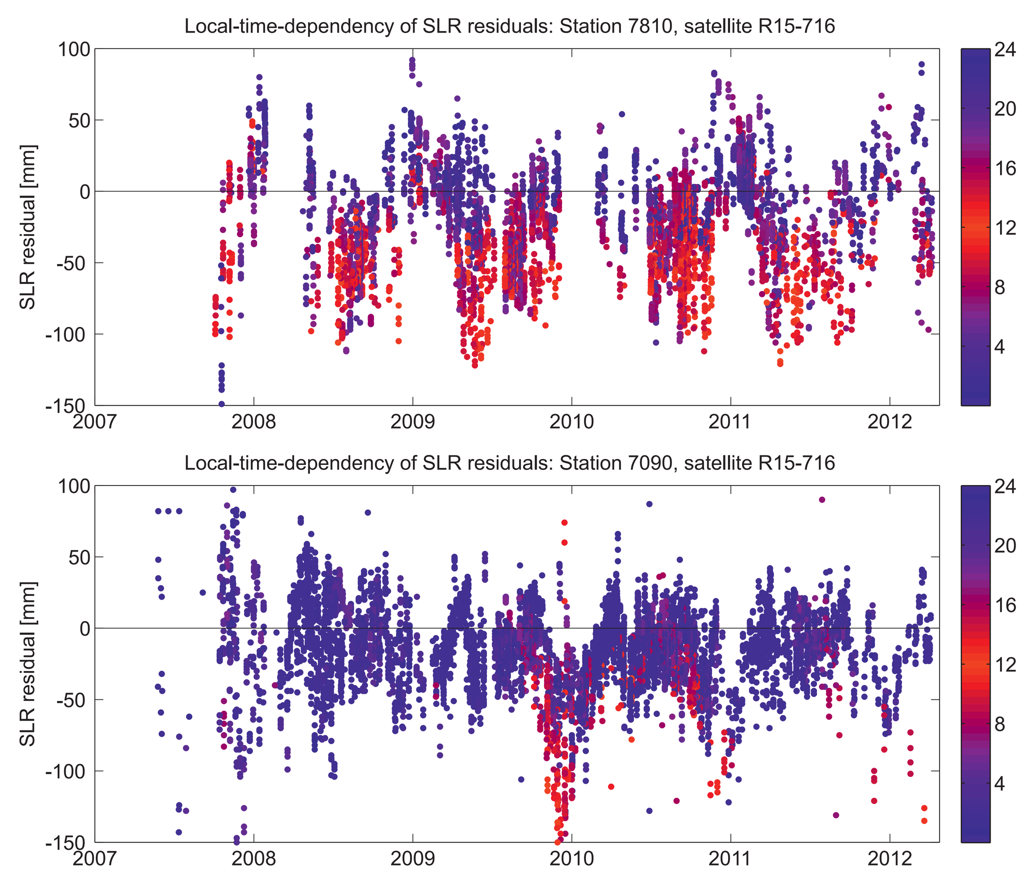

Fig. 4: SLR residuals depending on the tracking time for a European (7810, Zimmerwald) and an Australian (7090, Yarragadee) station. Color code = Local time.

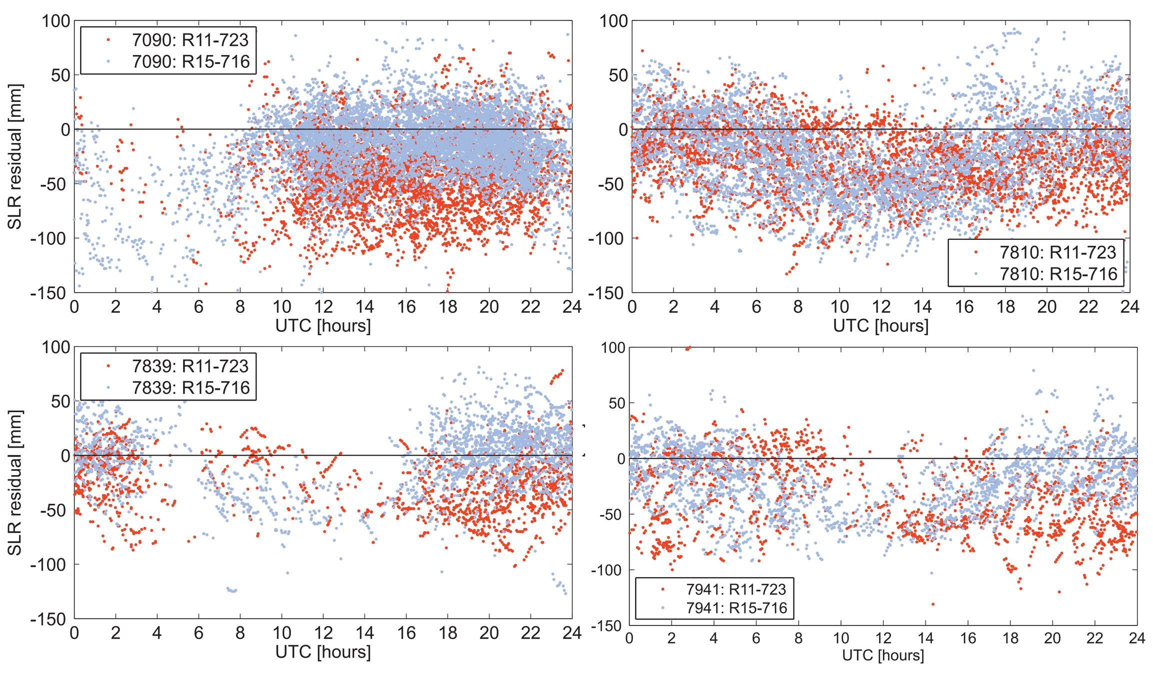

Fig. 5: SLR residuals depending on the tracking time (UTC) for two satellites of the same orbital plane.

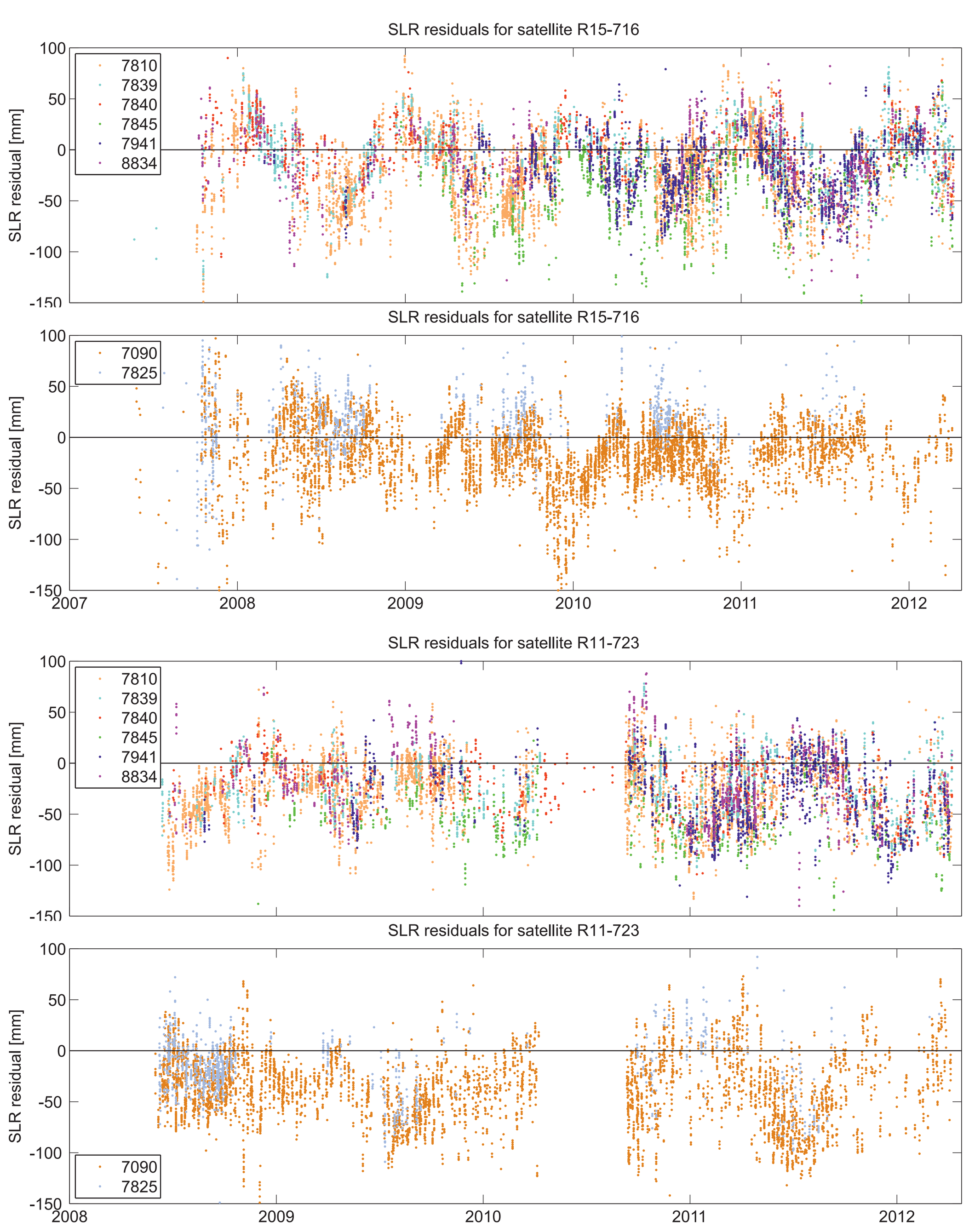

Fig. 3: Distinction between European and Australian sites for two GLONASS satellites of the same orbital plane.

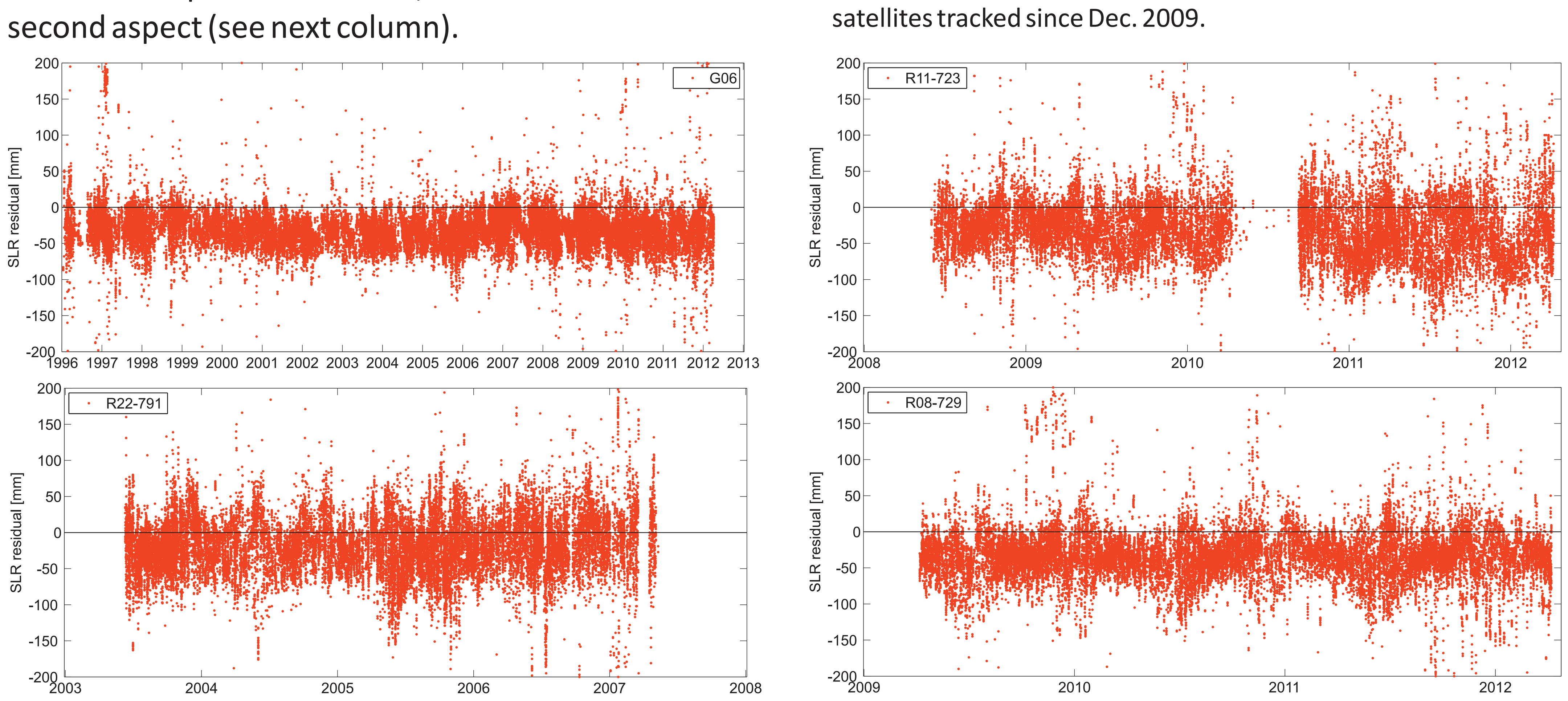

Fig: 2: SLR residuals to microwave-based orbits and SLRF2008 station coordinates for selected satellites.

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