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"Improving ILRS Performance to Meet Future GGOS Requirements"
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WROCŁAW UNIVERSITY
OF ENVIRONMENTAL
AND LIFE SCIENCES

Combined multi-GNSS+LAGEOS solutions

with the focus on SLR station coordinates, Earth rotation parameters, geocenter and the scale of the reference frame

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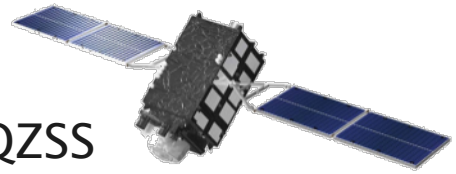
Motivation

Standard SLR solution

LAGEOS-1/2

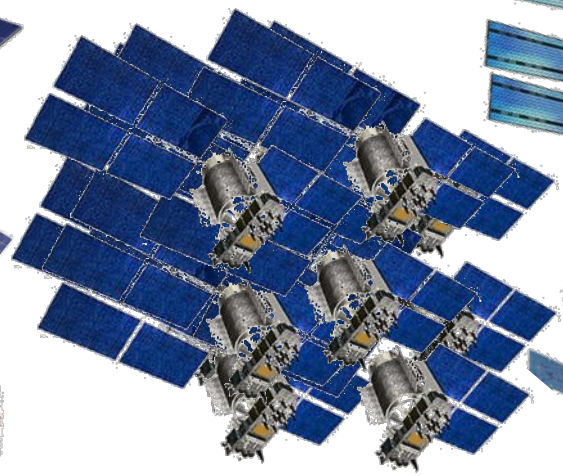
This study



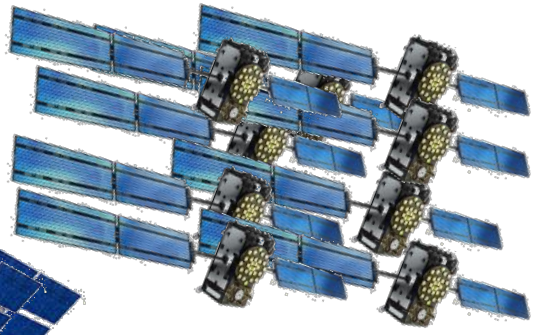
1 QZSS

1 GPS

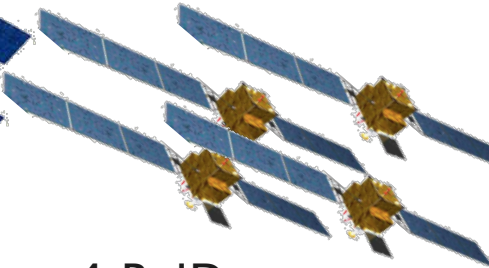
LAGEOS-1/2



31 GLONASS



18 Galileo

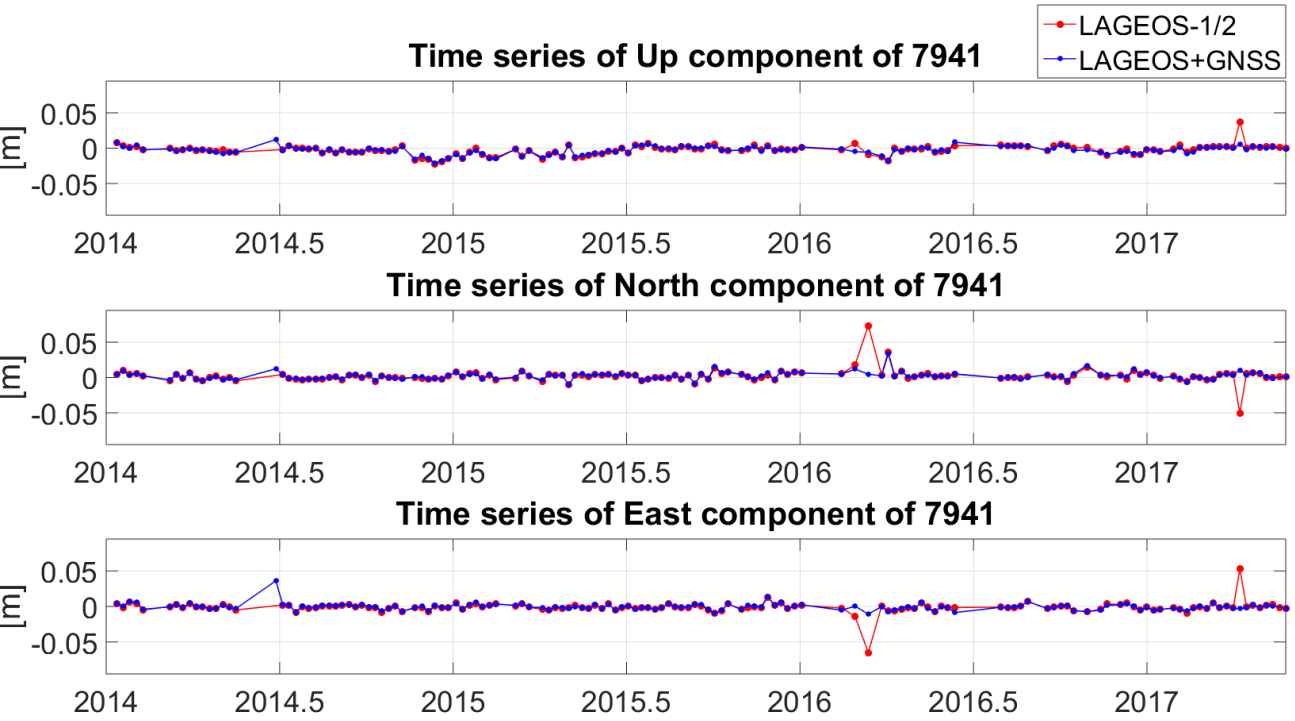


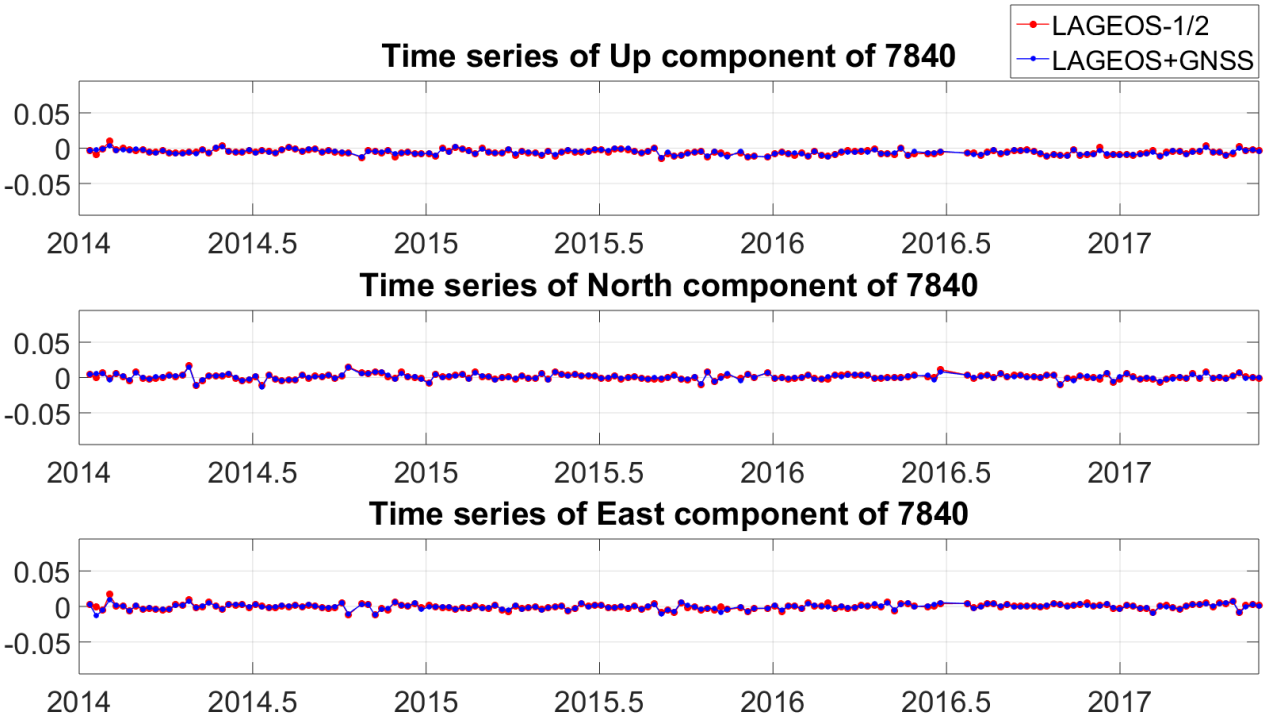
4 BeiDou

- Currently, the SLR reference frame is based on **2 LAGEOS and 2 Etalon** satellites. The contribution of **Etalon is almost negligible**.
- All new GNSS systems are equipped with laser retroreflector arrays.
- **No** active satellites, such as **GNSS, are used for the ITRF definition**, e.g., for the estimation of GNSS station coordinates, geocenter coordinates or Earth rotation parameters.
- **Some stations**, e.g., from the Russian SLR network, **provide much more SLR observations to GNSS** than to LAGEOS.
- Between 2014 and 2017, ILRS conducted a series of **intesive campaings tracking GNSS**.
- Today, there are about **60 active GNSS satellites** tracked by ILRS stations.

Station coordinates - core stations

-> Minor improvement for high-performing SLR stations





Matera (Italy) :

RMS: 9.0 7.9 6.7 mm for North, East, Up, resp. in LAGEOS-1/2

RMS: 5.1 4.8 5.6 mm for North, East, Up, resp. in LAGEOS+GNSS fix

143 solutions in LAGEOS-1/2

144 solutions in LAGEOS+GNSS

Herstmonceux (UK) :

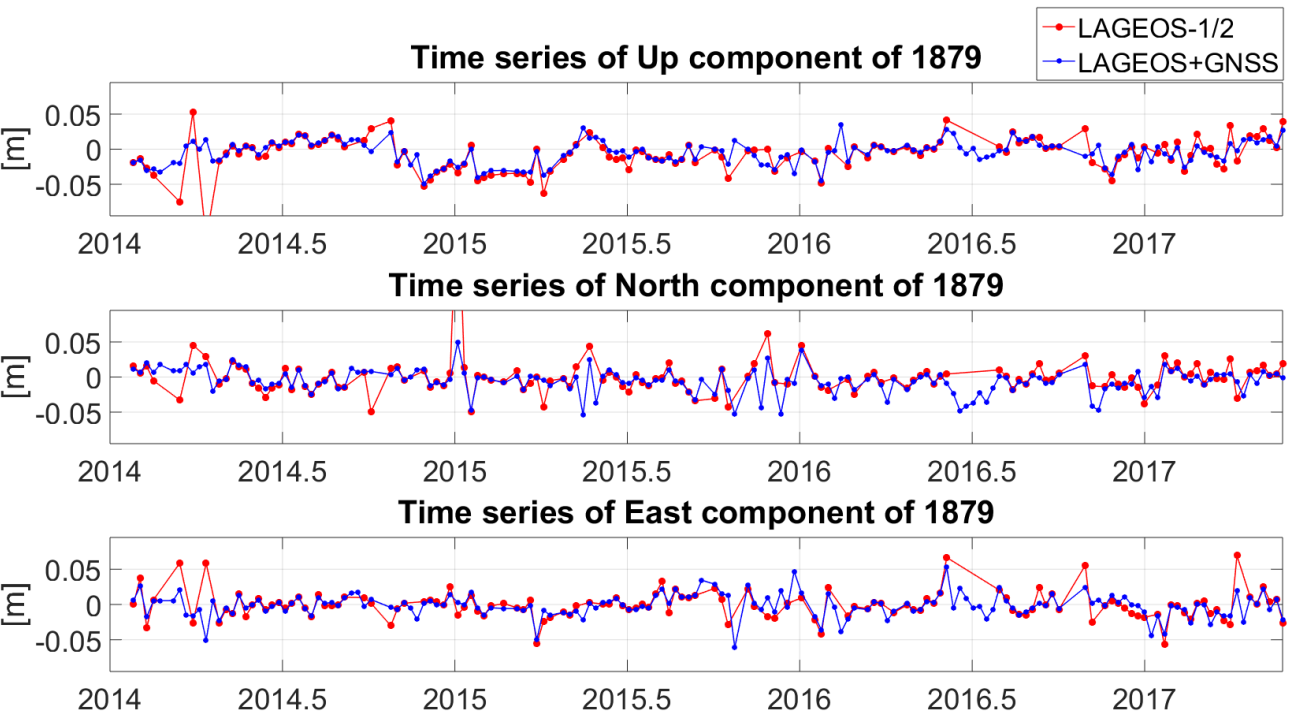
RMS: 4.0 3.8 3.6 mm for North, East, Up, resp. in LAGEOS-1/2

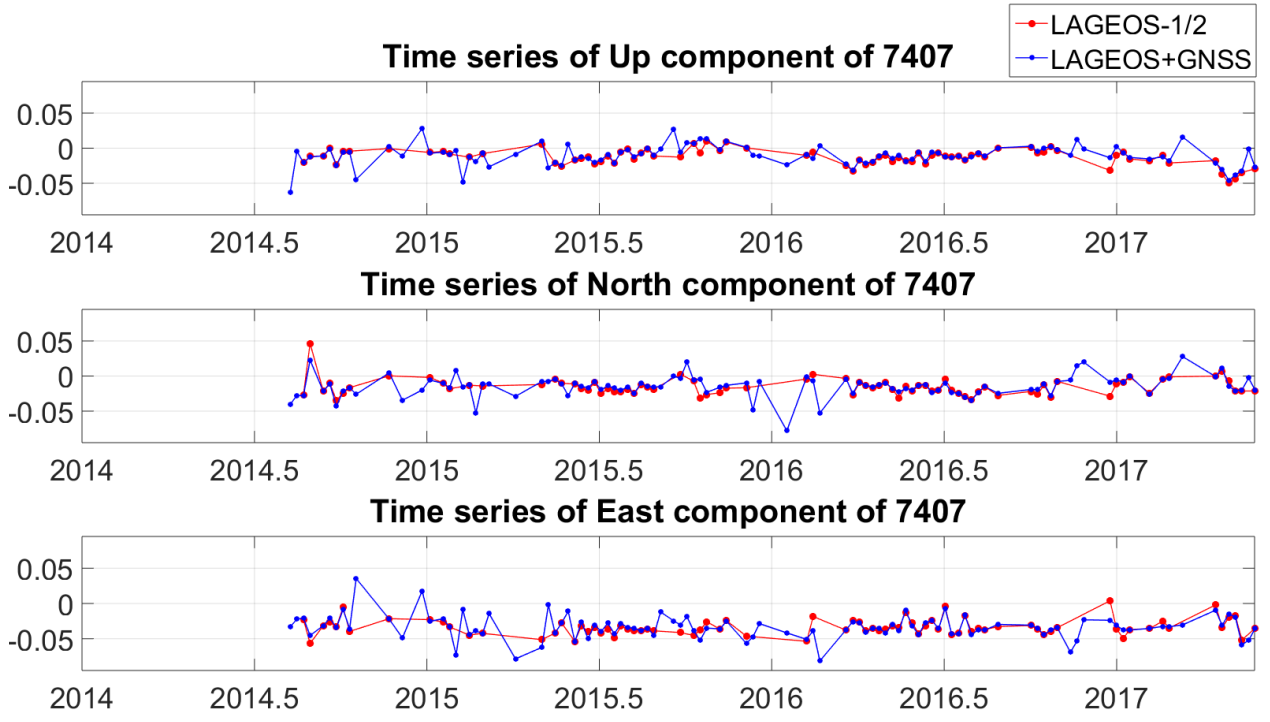
RMS: 3.9 3.7 3.4 mm for North, East, Up, resp. in LAGEOS+GNSS fix

170 solutions in LAGEOS-1/2

170 solutions in LAGEOS+GNSS

Station coordinates - other stations





Altay (Russia) :

RMS: 31.1 19.8 24.3 mm for North, East, Up, resp. in LAGEOS-1/2

RMS: 17.1 16.5 16.6 mm for North, East, Up, resp. in LAGEOS+GNSS fix

132 solutions in LAGEOS-1/2

161 solutions in LAGEOS+GNSS (23% more solutions)

Brasilia (Brazil) :

RMS: 11.6 11.5 11.2 mm for North, East, Up, resp. in LAGEOS-1/2

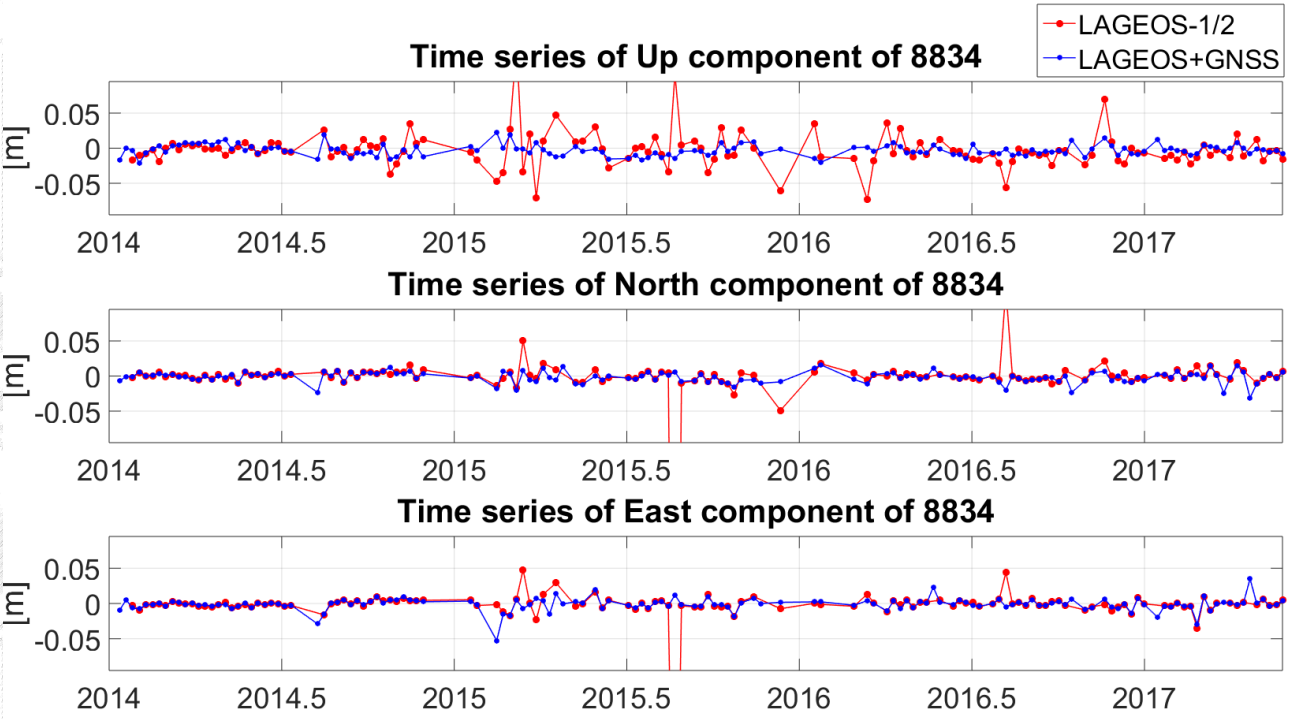
RMS: 15.1 16.8 14.3 mm for North, East, Up, resp. in LAGEOS+GNSS fix

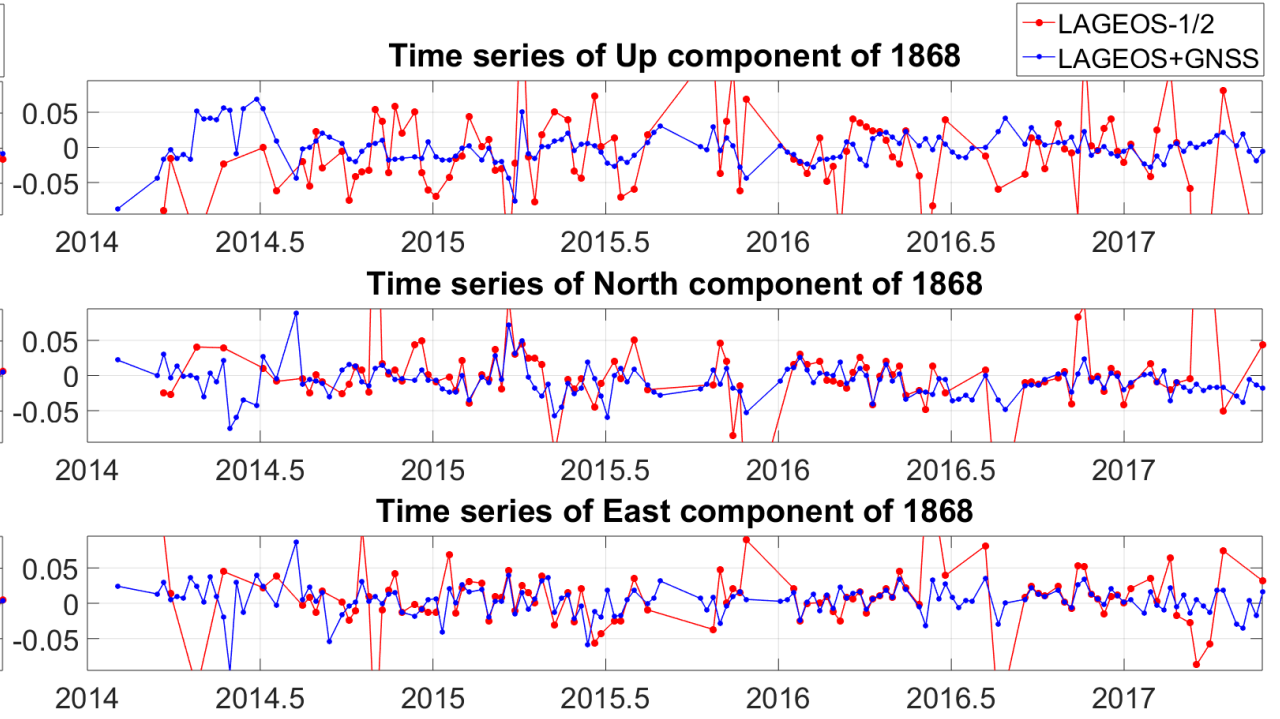
79 solutions in LAGEOS-1/2

103 solutions in LAGEOS+GNSS (30% more solutions)

Station coordinates - other stations

-> Substantial improvement of the number of solutions
-> Substantial improvement of the coordinate repeatability





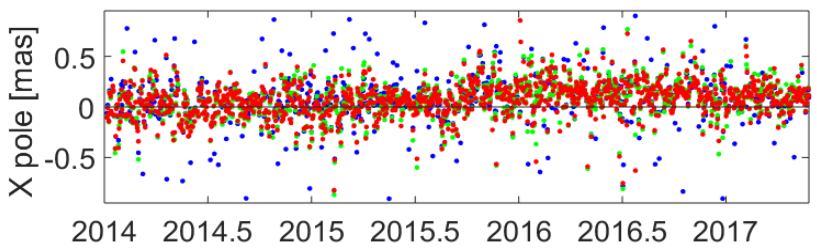
Wettzell (Germany) - range bias to LAGEOS estimated since 2010.8

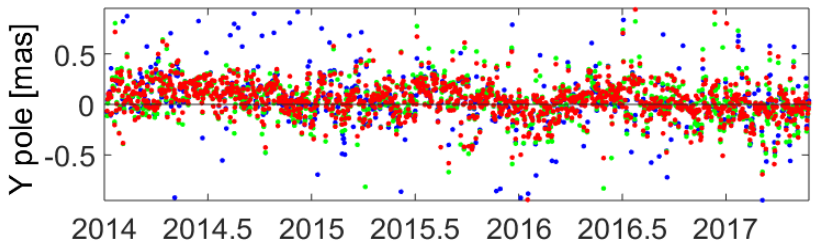
RMS: 42.2 27.3 25.7 mm for North, East, Up, resp. in LAGEOS-1/2
RMS: 7.7 8.8 7.9 mm for North, East, Up, resp. in LAGEOS+GNSS fix
132 solutions in LAGEOS-1/2
143 solutions in LAGEOS+GNSS (8% more solutions)

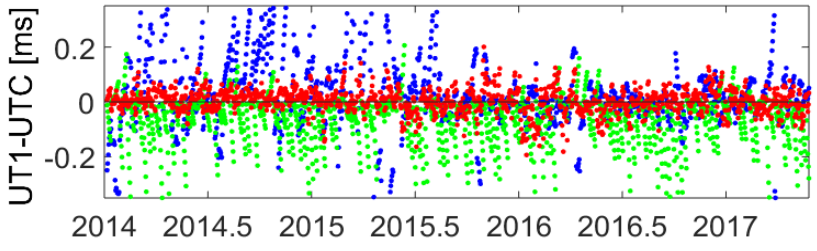
Komsomolsk na Amure (Russia) - range bias to LAGEOS estimated

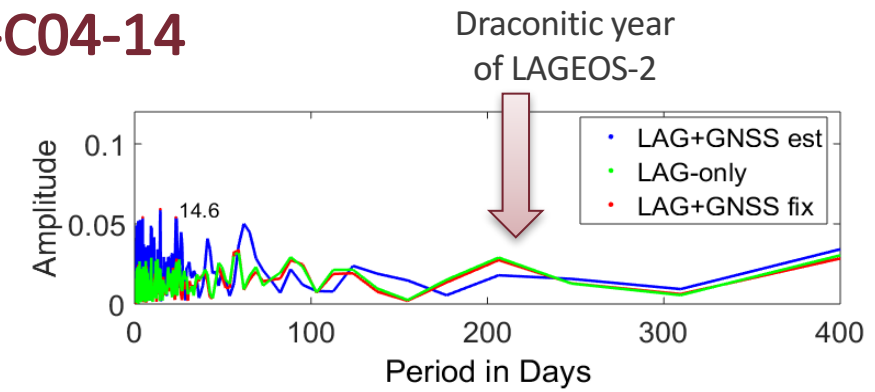
RMS: 69.0 48.6 78.5 mm for North, East, Up, resp. in LAGEOS-1/2
RMS: 22.4 21.2 23.0 mm for North, East, Up, resp. in LAGEOS+GNSS fix
102 solutions in LAGEOS-1/2
144 solutions in LAGEOS+GNSS (41% more solutions)

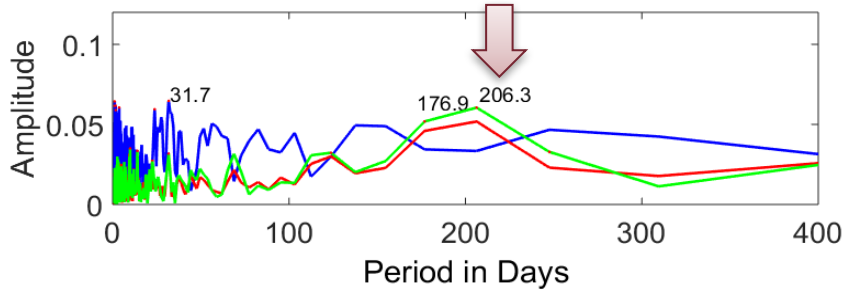
Earth rotation parameters w.r.t. IERS-C04-14

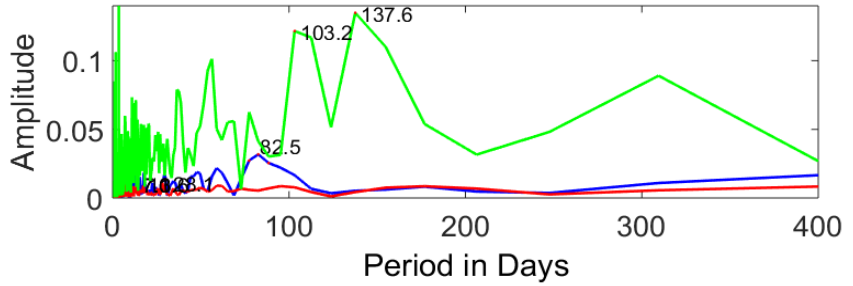












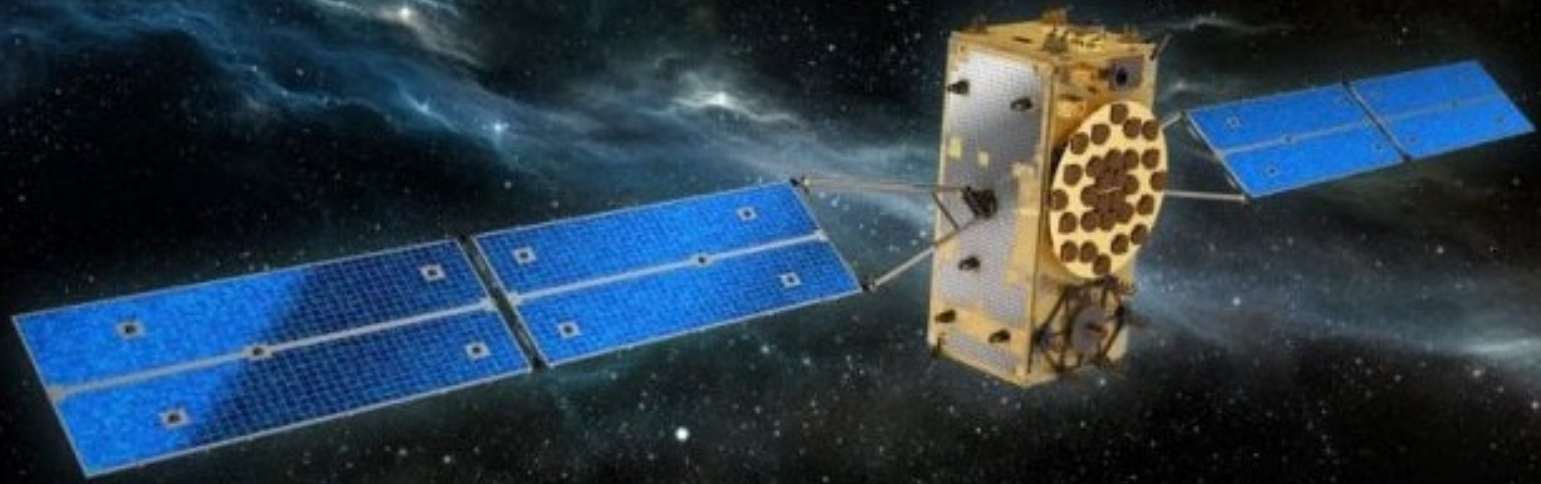
No significant improvement for the X and Y pole coordinates, because in both solutions the no-net-rotation constraint is imposed on the same set of core SLR stations, whose station coordinates improve only slightly in LAG+GNSS.
Pole: 150 μas = 5 mm
LoD: 40 μs = 20 mm.

Such high-quality LoD from SLR could not be earlier obtained without estimating gravity field, especially C_{20}.

	X pole [μas]		Y pole [μas]		LOD [μs]	
Solution	mean	RMS	mean	RMS	mean	RMS
LAGEOS-only	77.8	157.2	52.9	143.2	**-81.6**	**122.5**
LAGEOS+GNSS (GNSS orbits freely estimated)	81.8	153.6	55.1	142.7	**25.5**	**68.7**
LAGEOS+GNSS (orbits fixed to microwave GNSS)	73.5	149.0	51.3	140.7	**0.5**	**43.0**

SLR observations to GNSS allow for the transfer of the network orientation from GNSS to SLR solutions.

Thank you for your attention



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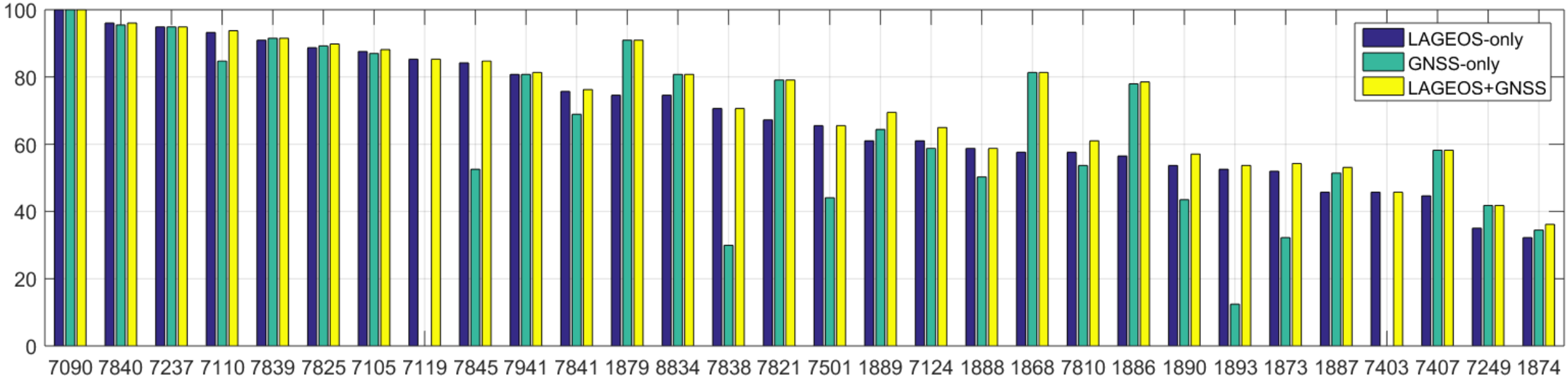
Back-up slides

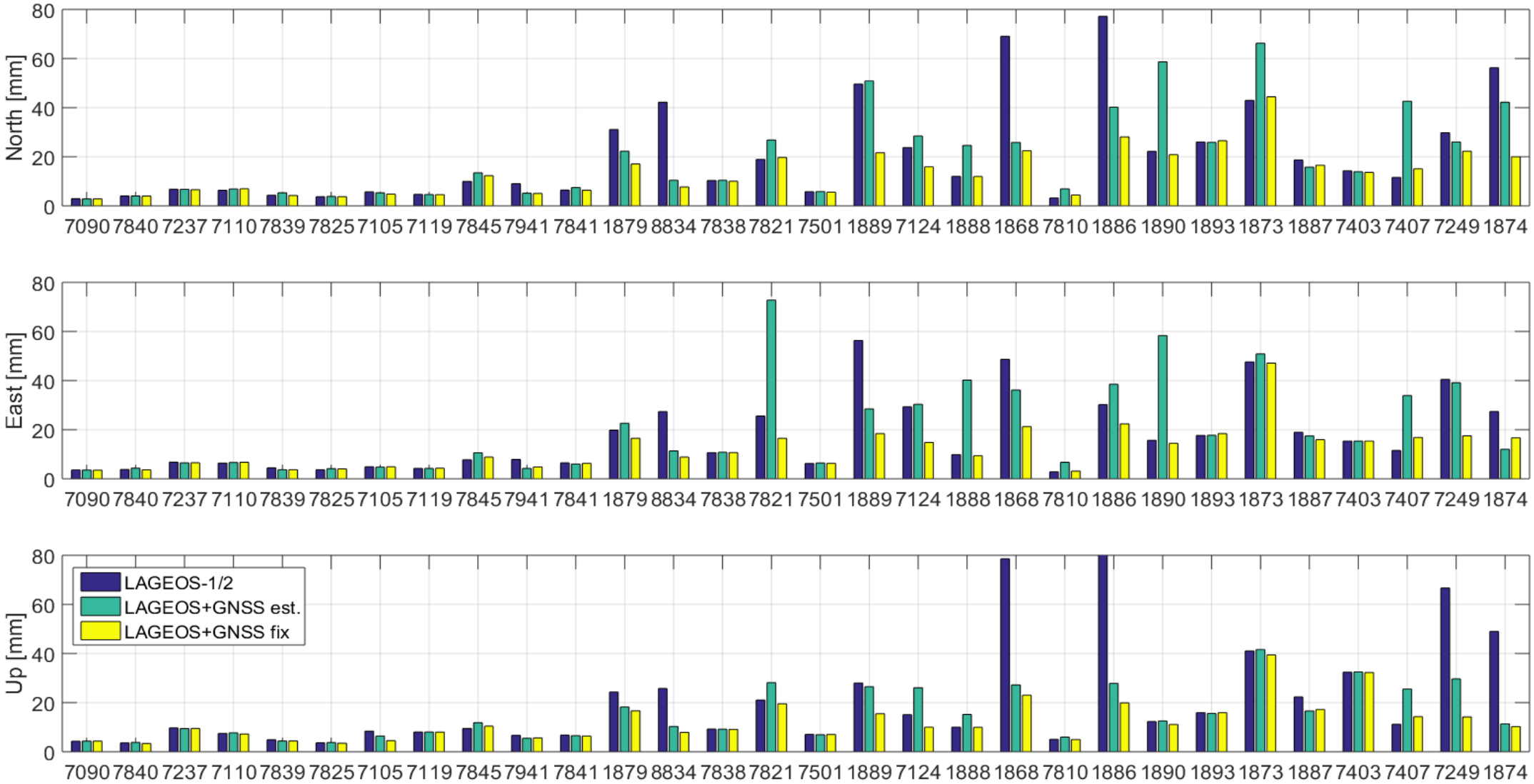
Number of solutions for different SLR stations



The occurence of SLR stations in 7-day solutions for the period 2014.0-2017.5 in %.

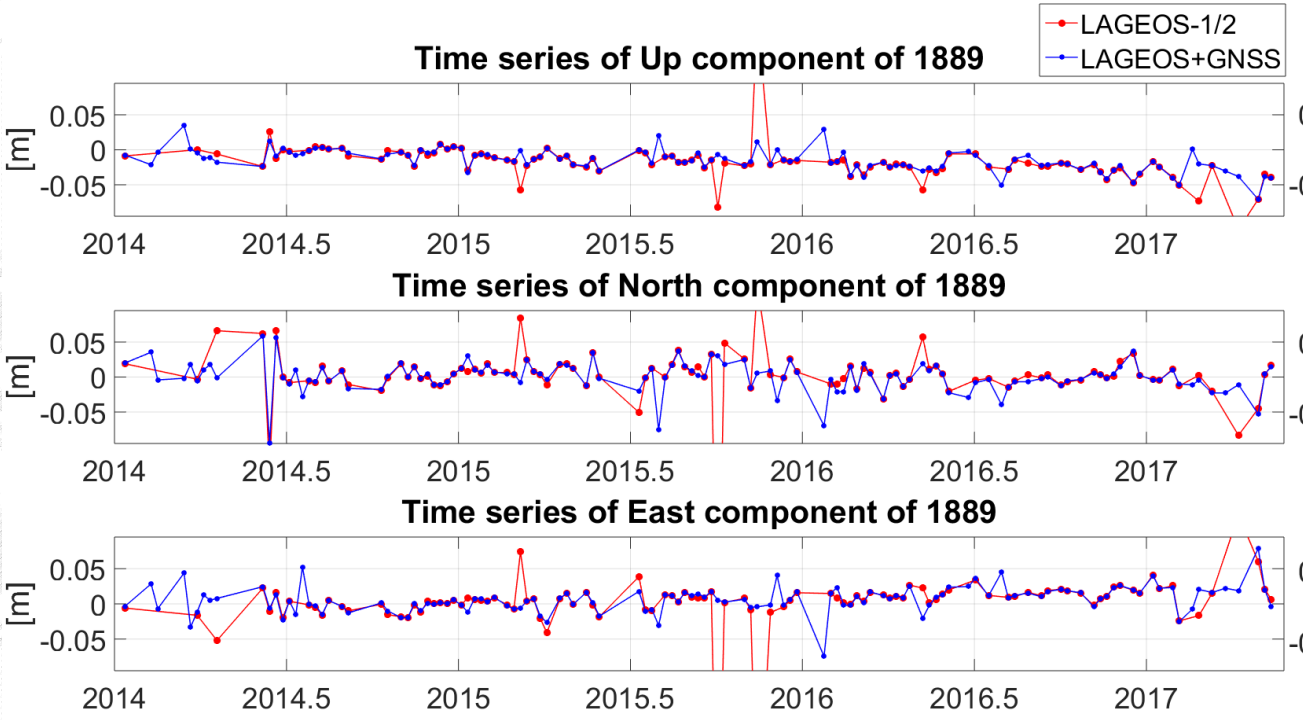
- Number of stations in 7-day solutions is: 3909 (LAGEOS-only), 3476 (GNSS-only), 4170 (LAGEOS+GNSS).
- Some stations (Haleakala, Hawaii, 7119, Arequipa, Peru, 7403) do not observe GNSS satellites. However, most of the SLR stations observe GNSS on the regular basis (7090, 7840, 7237, 7825, 7105, 7941, 8834).
- Some stations provide by far more observations to GNSS than to LAGEOS (Altay, Russia, 1879, Shanghai, China, 7821, Komsomolsk, Russia 1868, Arkhyz, Russia, 1886, Brasilia, Brazil, 7407, Beijing, China, 7249, Mendeleevo, Russia, 1874, Wettzell, Germany, 7827).

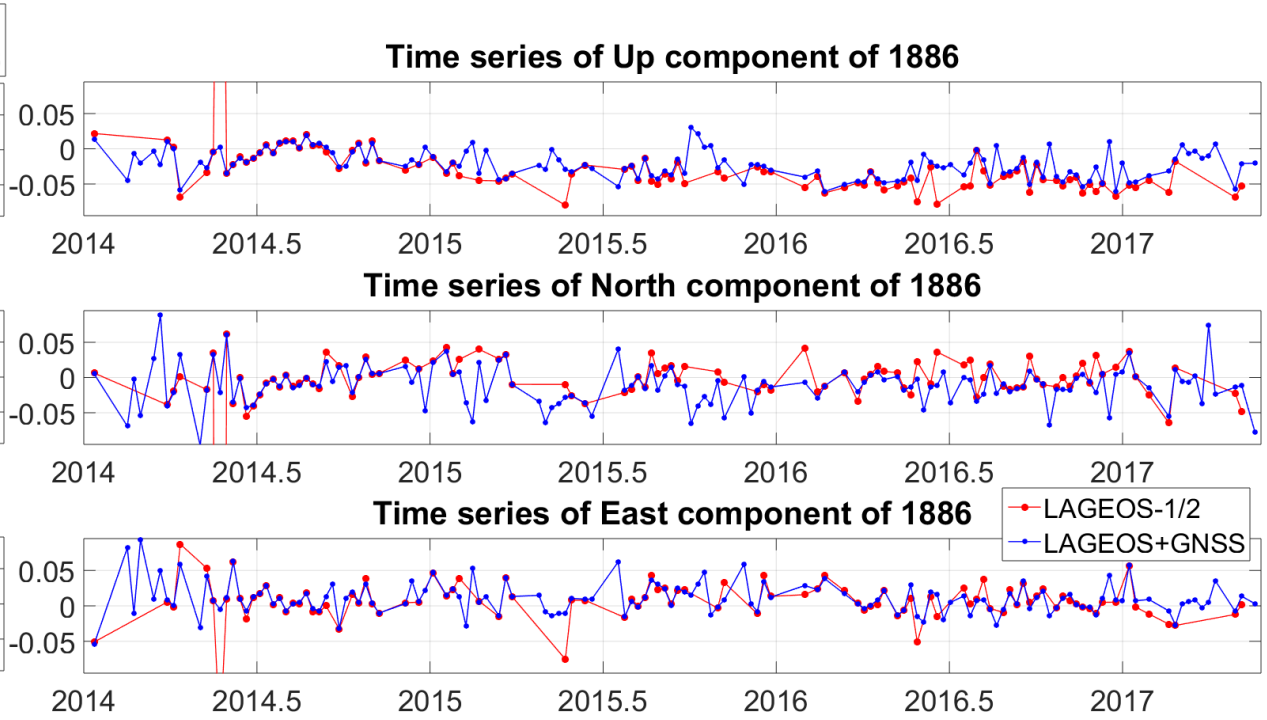
Station coordinate repeatability



Mean improvement of LAGEOS+GNSS fix wrt LAGEOS-1/2: 6.9, 6.4, 15.7%, for N, E, U, resp.

Station coordinates- other stations





Zelenchuksakya (Russia) :

RMS: 49.6 56.3 27.9 mm for North, East, Up, resp. in LAGEOS-1/2

RMS: 21.6 18.4 15.4 mm for North, East, Up, resp. in LAGEOS+GNSS fix

108 solutions in LAGEOS-1/2

123 solutions in LAGEOS+GNSS (14% more solutions)

Arkhyz (Russia) :

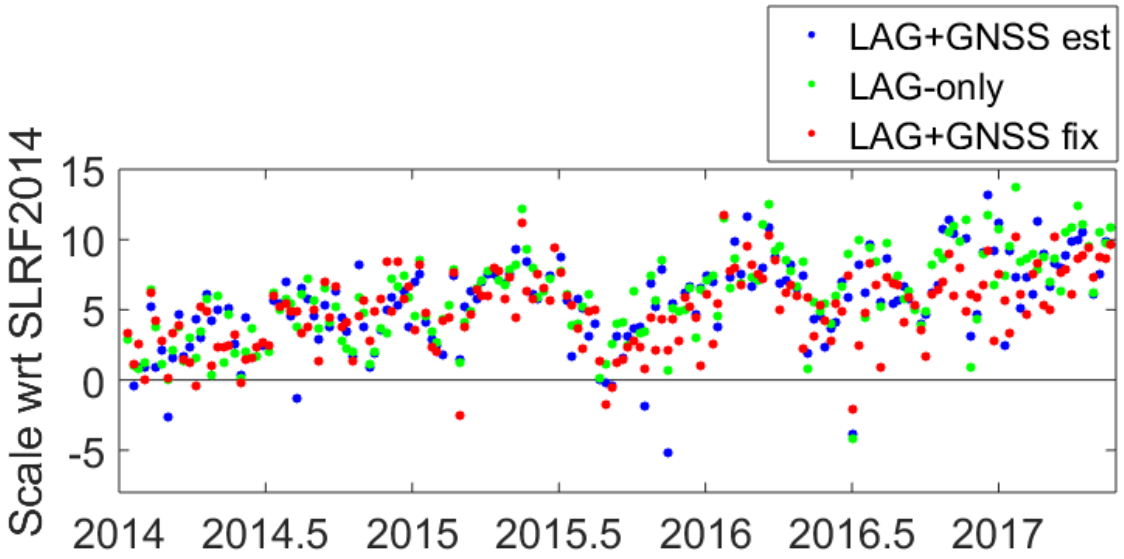
RMS: 77.2 30.2 94.7 mm for North, East, Up, resp. in LAGEOS-1/2

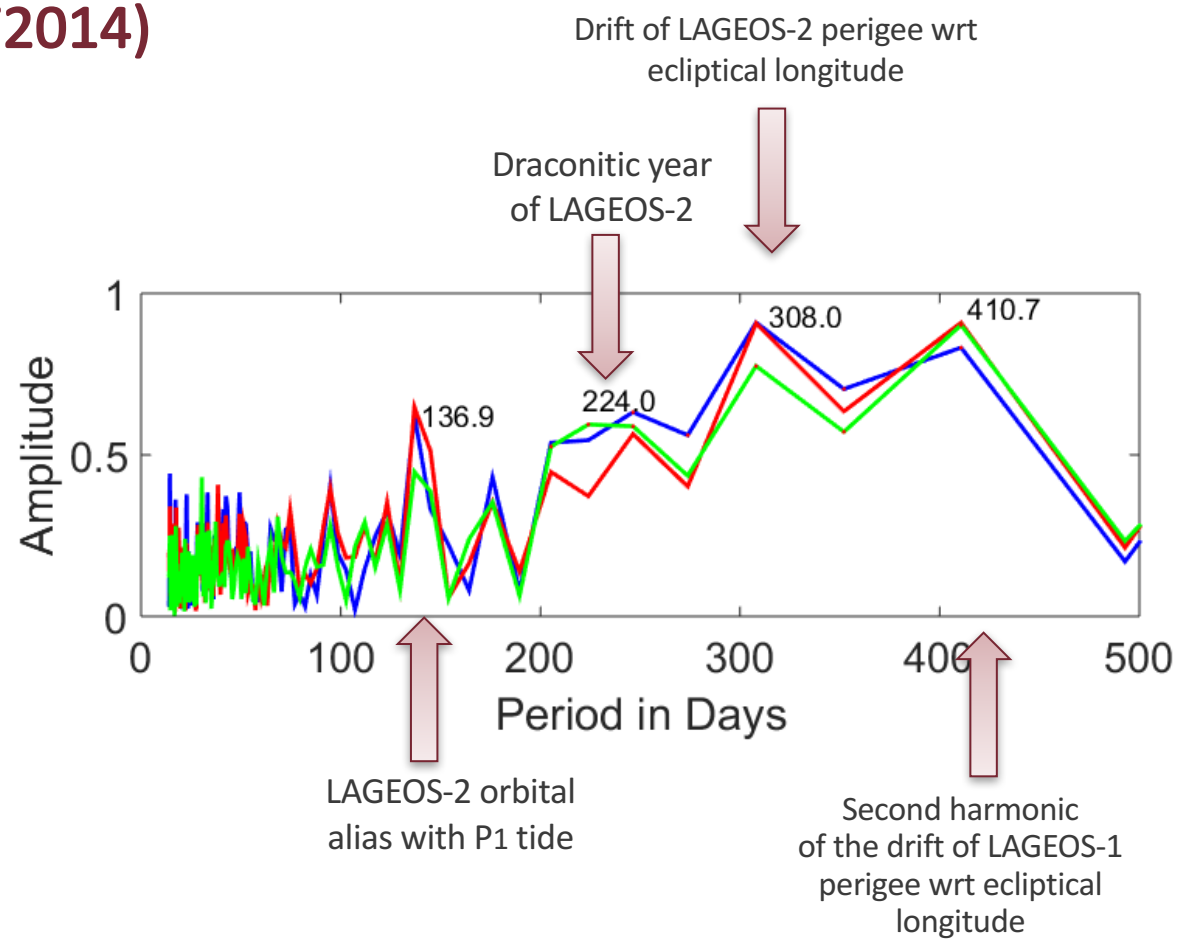
RMS: 28.0 22.3 19.9 mm for North, East, Up, resp. in LAGEOS+GNSS fix

100 solutions in LAGEOS-1/2

139 solutions in LAGEOS+GNSS (39% more solutions)

Scale of the reference frame w.r.t. ITRF2014 (SLRF2014)





Scale difference w.r.t. ITRF2014 :

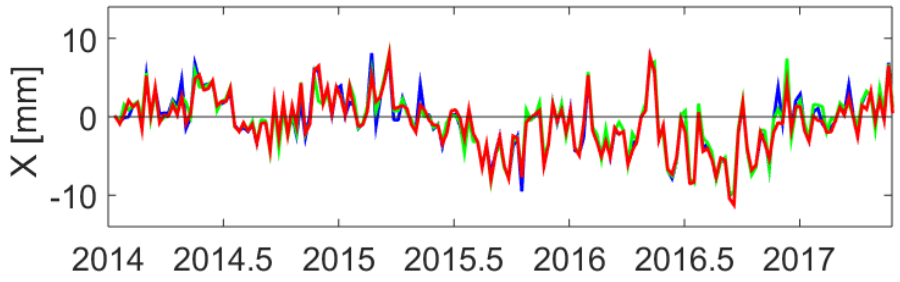
6.05 ± 3.14 mm for LAGEOS-1/2

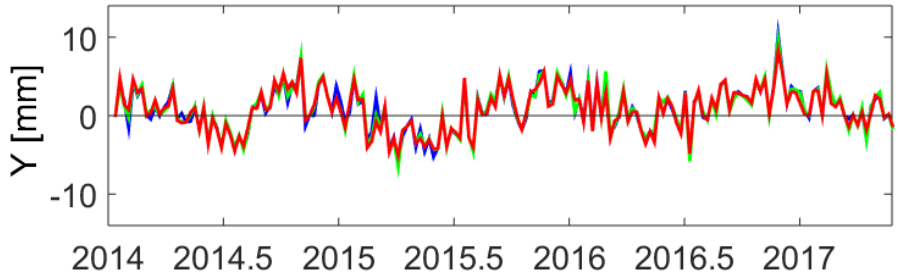
5.73 ± 3.22 mm for LAGEOS+GNSS est

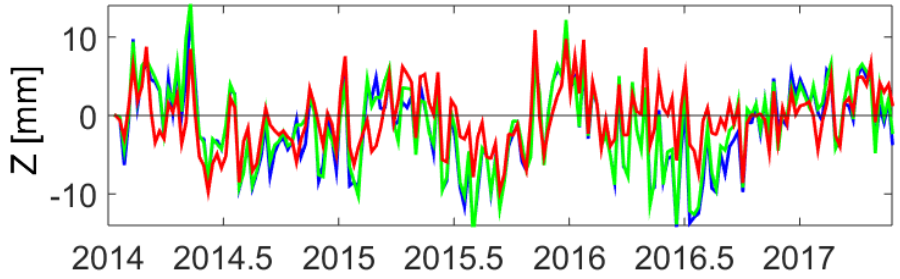
5.16 ± 2.71 mm for LAGEOS+GNSS fix

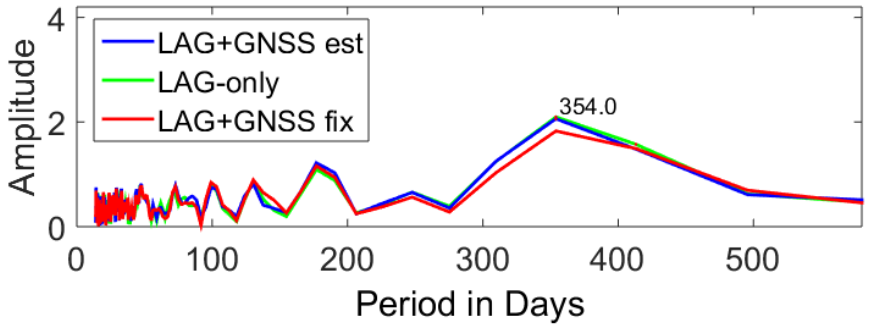
Fixing GNSS orbits aligns better the scale to ITRF2008, because GNSS solutions are not affected by the blue-sky effect (in this solution atmospheric pressure loading corrections are not applied)

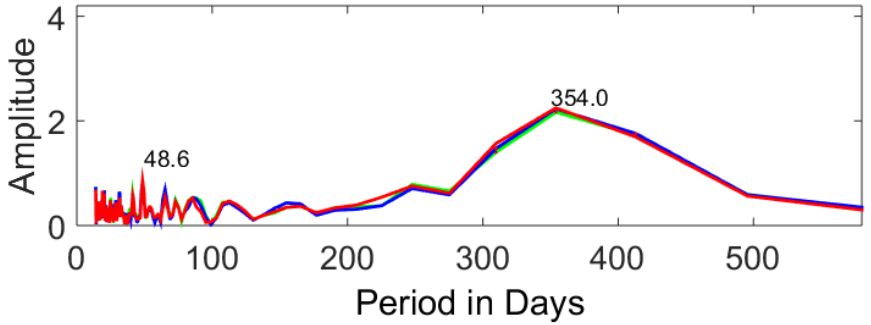
Geocenter coordinates

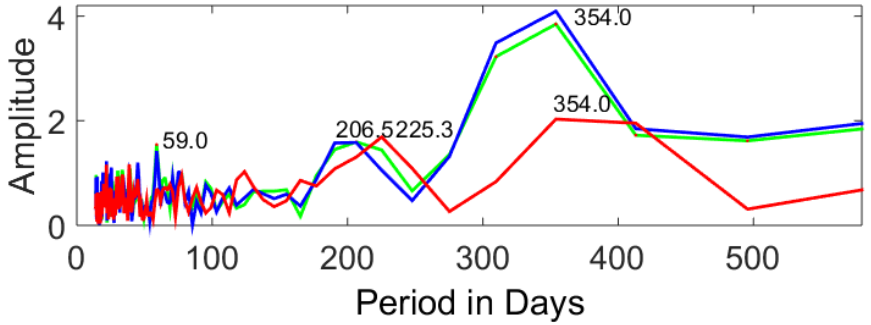








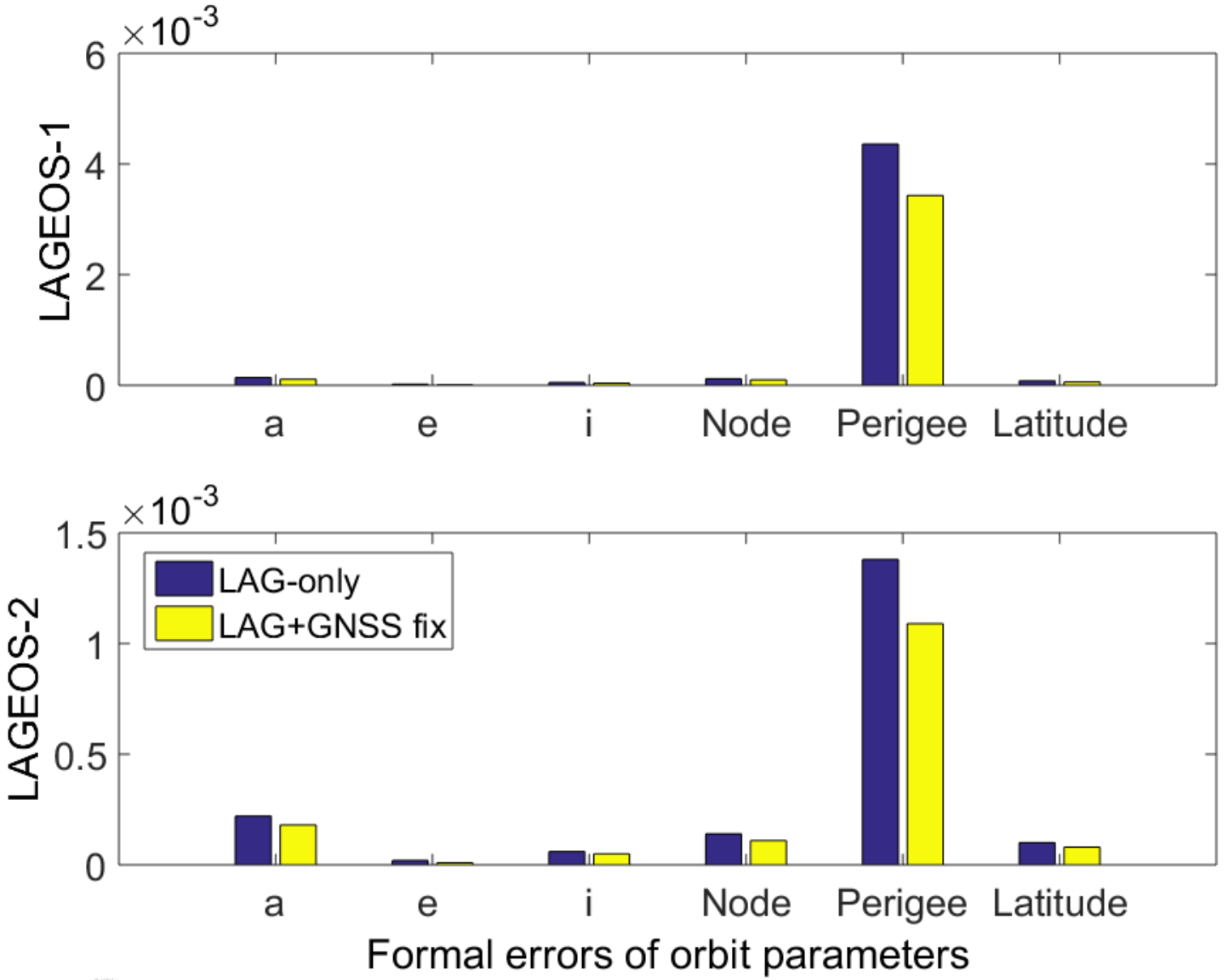




The no-net-translation constraint is imposed on the same set of core SLR stations.

No significant change for the X and Y components. A different signal for the Z component when fixing GNSS orbits to a priori values.

LAGEOS orbits



SLR observations to GNSS satellites can also indirectly improve the LAGEOS orbits thanks to providing a better orientation of the network. As a result, especially the orientation parameters, inclination, node, perigee, are improved in the LAGEOS+GNSS solutions.