The Blue-Sky effect

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Introduction

Earth surface displacements caused by tidal and non-tidal loading forces are of crucial importance in high-precision space geodesy. Tidal corrections are widely accepted by the international scientific community and recommended to be applied at the observation level, whereas non-tidal displacement corrections are in general recommended not to be applied at the observation level. We investigate the impact of atmospheric tidal loading (ATL) and atmospheric non-tidal loading (ANTL) corrections on SLR solutions and on the consistency with GNSS results by applying all the corrections at the observation level.

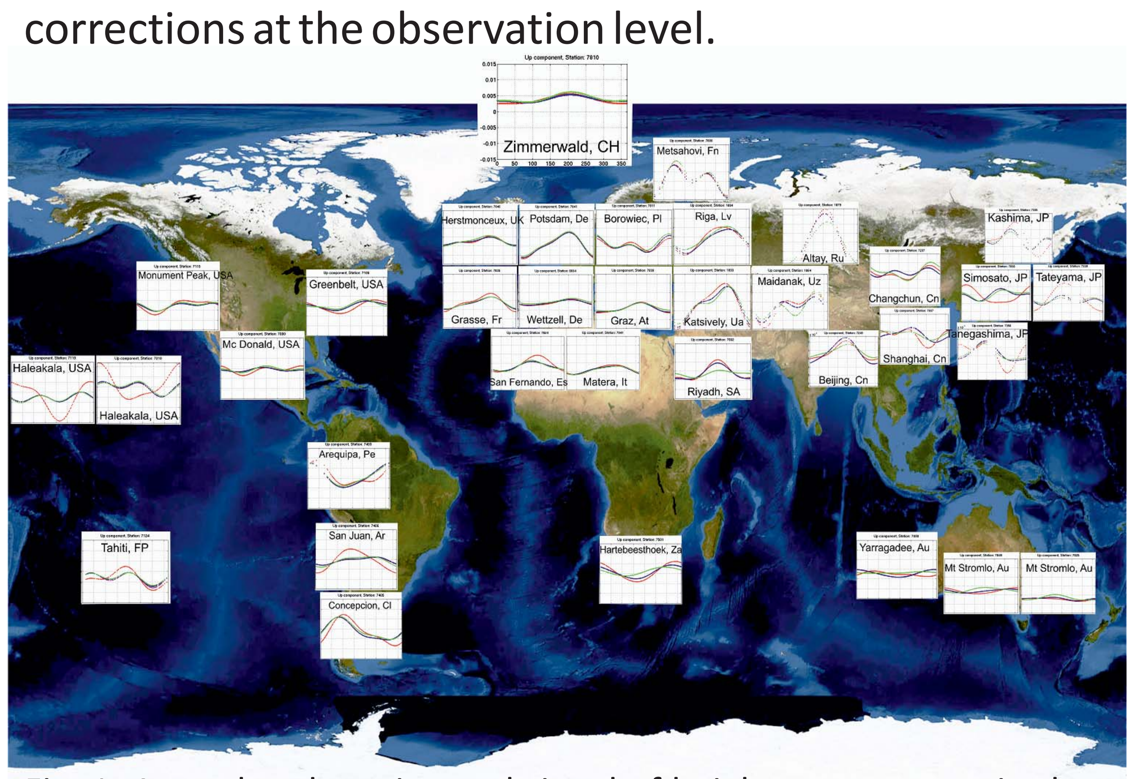

Fig. 1: Annual and semiannual signal of height components in the solutions without loading corrections (red), with ocean tidal loading (OTL, blue), and with OTL, ATL, and ANTL corrections (green).

Impact of ATL and ANTL on SLR results

We assess the impact of ATL and ANTL on SLR-derived parameters by reprocessing eleven years of SLR data (2000-2010). The general reduction of annual amplitudes of SLR station height is 2% and 10%, due to ATL and ANTL corrections, respectively (see Fig. 1). The general improvements of SLR station 3D repeatability when applying ATL and ANTL corrections are: 0.2% and 3.3%, respectively (see Fig. 2).

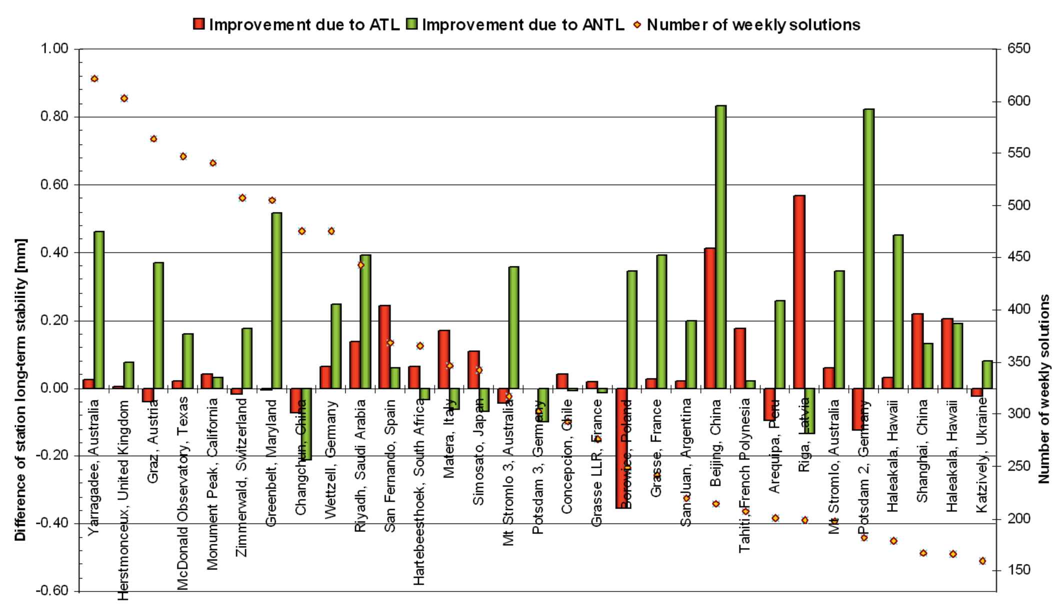

Fig. 2: Differences of SLR station repeatability due to ATL and ANTL. Positive values denote a better repeatability with ATL/ANTL.

A priori impact of APL on geocenter

Due to non-continuous SLR observations and the sparse SLR network, SLR solutions cannot reproduce the full impact of atmosheric pressure loading (APL=ATL+ANTL) on geocenter coordinates. Fig. 3a shows the theoretical impact of APL model on geocenter coordinates, whereas Fig. 3b shows the impact of APL taking into account only APL corrections on SLR stations from epochs, when SLR stations observe (i.e., what the SLR network really ¨sees¨). The resulting network effect is caused by the shortage of regular tracking SLR sites in the regions with the largest impact of APL.

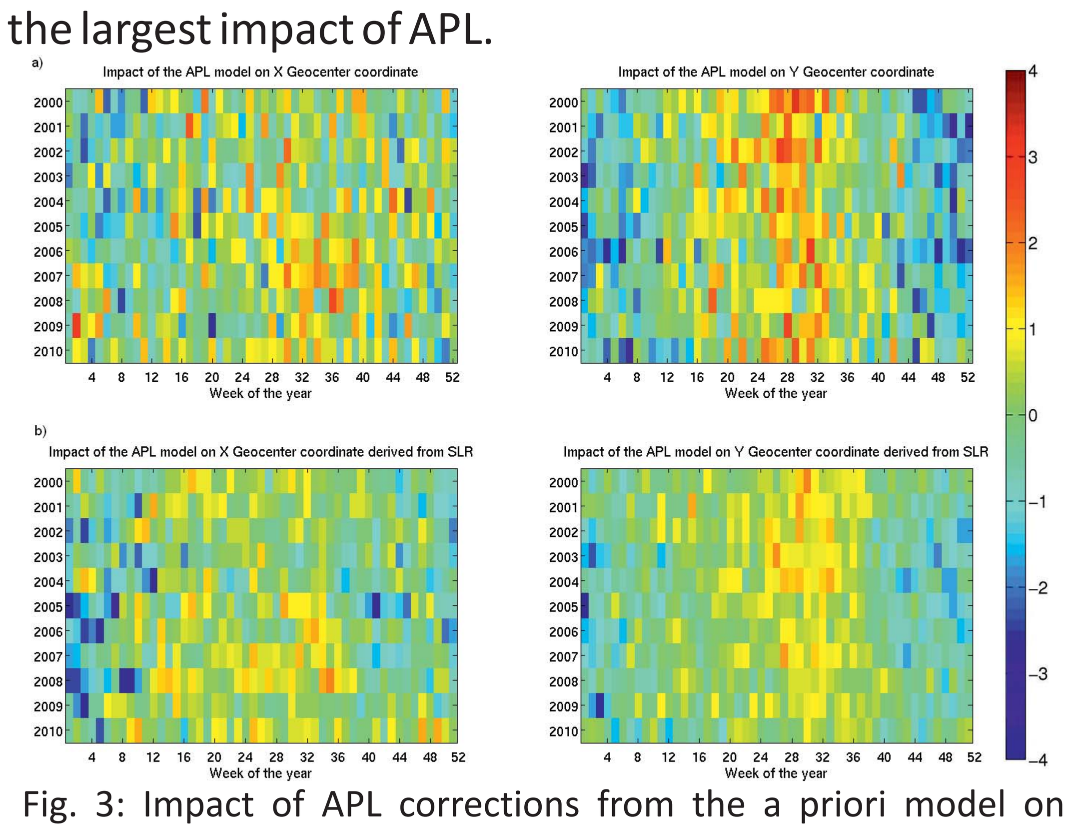

Fig. 3: Impact of APL corrections from the a priori model on geocenter coordinates. Units: mm

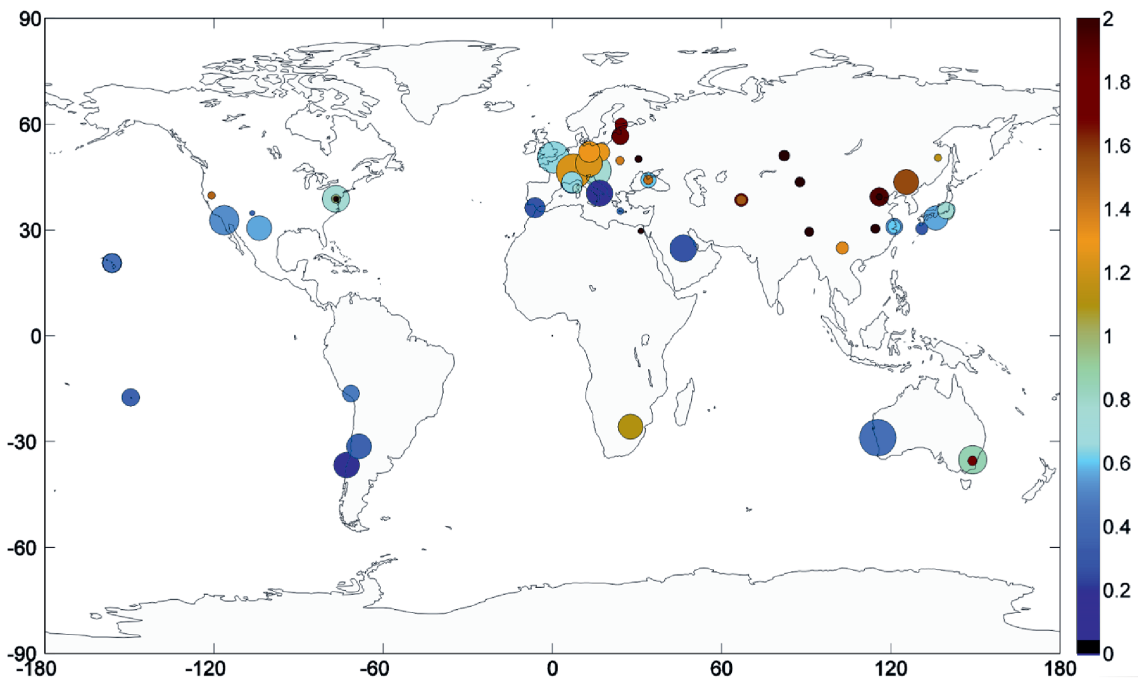

Fig. 4: The Blue-Sky effect on SLR stations as the difference between the mean atmospheric loading correction applied to SLR stations when SLR station observes, and the mean correction to SLR stations for the entire time series. Units: mm

Blue-Sky effect

Atmospheric pressure loading corrections play a crucial role in the combination of optical (SLR) and microwave (GNSS, VLBI, DORIS) space geodetic observation techniques, because of the so-called Blue-Sky effect: SLR measurements can be carried out only under cloudless sky conditions typically during high air pressure conditions, when the Earth crust is deformed most, whereas microwave observations are weather-independent. Thus, applying the loading corrections improves SLR-derived products, as well as, the consistency with microwave-based results.

We assess the impact of the Blue-Sky effect on the SLR stations. The effect assumes a value of 2.5 mm for many in-land stations (see Fig. 4). The Blue-Sky effect reaches even 4.4 mm for one occasionally observing station with APL effect of 6.6 mm (see Tab. 1). Our results agree well with the Blue-Sky effect assessed for six stations by Otsubo et al. (2004).

SLR station	Number of normal points (1999-2010)	Mean impact of Atmospheric Pressure Loading	Blue-Sky effect (this study)	Blue-Sky Effect (Otsubo et al., 2004)
Golosiv, Ukraine	330	6.6	4.4	
Wuhan, China	1052	4.9	3.2	
Beijing-A, China	189	2.7	2.5	
Helwan, Egypt	223	3.2	2.4	
Orroral, Australia	3550	3.0	2.3	
Altay, Russia	1776	6.7	2.3	
Lhasa, China	981	2.5	2.1	
Urumqi, China	1265	3.7	2.0	
Beijing, China	15669	4.1	1.9	
Riga, Latvia	11728	4.2	1.8	
Maidanak 1, Uzbekistan	3914	4.8	1.7	
Metsahovi, Finland	3395	4.5	1.6	
Changchun, China	52808	4.3	1.5	
Zimmerwald, Switzerland	188806	3.2	1.2	0.9
Wettzell, Germany	73215	3.6	1.2	1.3
Hartebeesthoek, South Africa	49550	2.4	1.1	
Mt Stromlo, Australia	82648	2.7	0.8	
Greenbelt, Maryland	71571	2.7	0.7	0.4
Graz, Austria	110888	3.6	0.7	0.7
Herstmonceux, United Kingdom	133739	2.7	0.6	1.0
McDonald Observatory, Texas	50269	2.4	0.5	0.7
Monument Peak, California	105110	1.7	0.5	
Yarragadee, Australia	229063	2.2	0.4	
Riyadh, Saudi Arabia	68631	3.7	0.2	
Haleakala, Hawaii	20890	1.5	0.1	

Tab. 1: The Blue-Sky effect and the mean impact of APL corrections on selected SLR stations. Units: mm

Blue-Sky effect in time

For most of SLR stations the Blue-Sky effect is constant in time. There are, however, few excepction: The SLR stations which are continuously improving their tracking capabilities have the impact of the Blue-Sky effect smaller in time, e.g., the Blue-Sky effect was reduced for Zimmerwald, Switzerland from 1.8 mm in year 1999 to 0.5 mm in 2010, for Greenbelt, Maryland from 0.9 mm in 1999 to 0.3 mm in 2010, and for Katzively, Ukraine from 3.1 mm in 1999 to 1.4 mm in 2010. The reduction of the Blue-Sky effect is especially visible for SLR stations that updated and automatized their laser systems or enabled the daytime tracking capabilities.

References

Otsubo T, Kubo-oka T, Gotoh T, Ichikawa R (2004) Atmospheric Loading "Blue-Sky" Effects on SLR Station Coordinates. Proceedings from the Fourteenth International Workshop on Laser Ranging Instrumentation, San Fernando, Spain June 7-11, 2004

Sośnica K, Thaller D, Dach R, Jäggi A, Beutler G (2012) Impact of Atmospheric Loading Corrections on SLR Solutions and on the Consistency Between GNSS and SLR Results. EGU General Assembly 2012, Vienna, Austria, April 22-27, 2012

Sośnica K, Thaller D, Dach R, Jäggi A, Beutler G (2012) Impact of loading displacements on SLR-derived parameters and on the consistency between GNSS and SLR results. Submitted to Journal of Geodesy

Comparison with local ties

Applying APL corrections improves the inner stability of SLR solutions and reduces the discrepancies between GNSS and SLR solutions. As a result, the estimated GNSS-SLR coordinate differences fit better to the local ties at the co-located stations (see Tab. 2) when applying APL corrections. The intertechnique SLR-GNSS improvements due to APL are, however, small, because the SLR stations providing most of the observations are located close to the coast with a moderate APL effect.

Co-location				Local tie [m]			Difference of position between local tie and the solution [mm]	
Station	GNSS	SLR	Weeks	dX	dY	dZ	Without APL	With APL
Graz, Austria	GRAZ	7839	513	-2.558	8.516	-1.321	12.1	11.9
McDonald, Texas	MDO1	7080	496	22.394	8.467	23.408	9.4	9.4
Monument Peak, California	MONP	7110	482	31.365	-5.456	20.526	9.1	9.7
Zimmerwald, Switzerland	ZIMM	7810	470	13.506	5.986	-6.420	4.2	3.8
Yarragadee, Australia	YAR2	7090	467	-18.612	-12.467	-5.841	4.5	4.9
Greenbelt, Maryland	GODE	7105	456	54.230	97.009	93.863	4.1	3.7
Wettzell, Germany	WTZR	8834	415	3.824	68.202	-15.518	6.7	5.9
Matera, Italy	MATE	7941	346	-29.157	-22.201	37.912	10.2	10.4
Hartebeesthoek, South Africa	HARB	7501	345	-743.471	1994.877	207.587	3.7	3.8
San Fernando, Spain	SFER	7824	345	45.041	-35.273	-89.594	97.8	97.9
Concepcion, Chile	CONZ	7405	286	-25.449	35.349	-74.042	7.2	8.1
Grasse, France	GRAS	7845	233	-1.173	-81.348	5.620	4.8	5.0
Borowiec, Poland	BOR1	7811	217	25.767	-72.908	-0.324	9.0	8.1
Mt Stromlo, Australia	STR1	7825	217	-38.054	4.584	58.108	12.2	11.7
Beijing, China	BJFS	7249	199	16.517	-118.317	146.279	4.0	2.8
Tahiti, French Polynesia	THTI	7124	184	-8.456	24.551	-28.299	23.8	23.8
Riga, Latvia	RIGA	1884	162	3.401	-18.661	6.963	51.7	50.0
Arequipa, Peru	AREQ	7403	153	18.614	-0.547	21.499	3.0	2.7
Potsdam, Germany	POTS	7836	141	50.091	95.219	-40.438	3.9	4.4
	MEAN						**14.8**	**14.6**

Tab. 2: Comparison between GNSS-SLR co-locations from local ties (used in ITRF2008) and station coordinate differences derived from space geodetic solutions (with APL and without APL).

Consistency between SLR and GNSS results

Figure 5 shows the amplitudes of annual signals of the station heights of co-located SLR-GNSS sites. Solutions with APL and w/o APL corrections are presented. In general, SLR stations show smaller amplitudes than GNSS stations. In the solutions with APL the discrepancy of the estimated amplitudes in the vertical components between GNSS and SLR solutions is reduced from 0.8 mm to 0.6 mm, implying a better consistency between SLR and GNSS with APL applied .

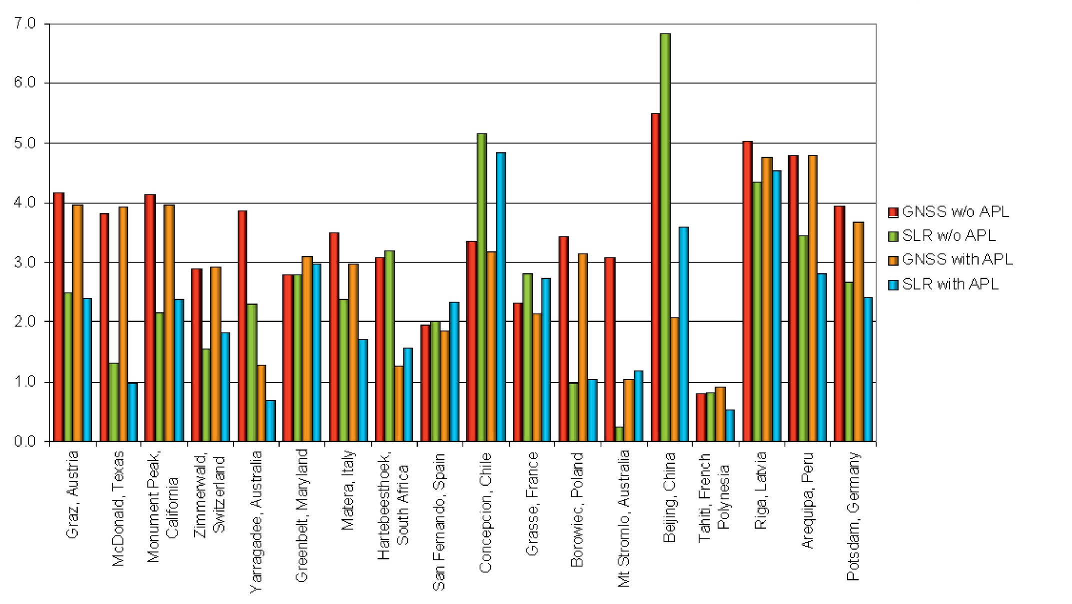

Fig. 5: Amplitudes of annual signals of vertical components for SLR-GNSS co-located stations in solutions with and w/o APL. Units: mm

Impact on geocenter in GNSS and SLR solutions

Figure 6 shows a different impact of APL in the GNSS and SLR solutions for the X and Y geocenter coordinates. The differences are due to correlations with tropospheric parameters in GNSS solutions and due to the unbalanced SLR network. SLR stations located along the Y axis are either coastal stations with minor impact of APL or low performing in-land stations. The GNSS network is to a great extent well balanced. The impact of APL on Y geocenter coordinate can be better reproduced in GNSS solutions in contrary to the X component (compare with the a priori impact of APL in Fig.3).

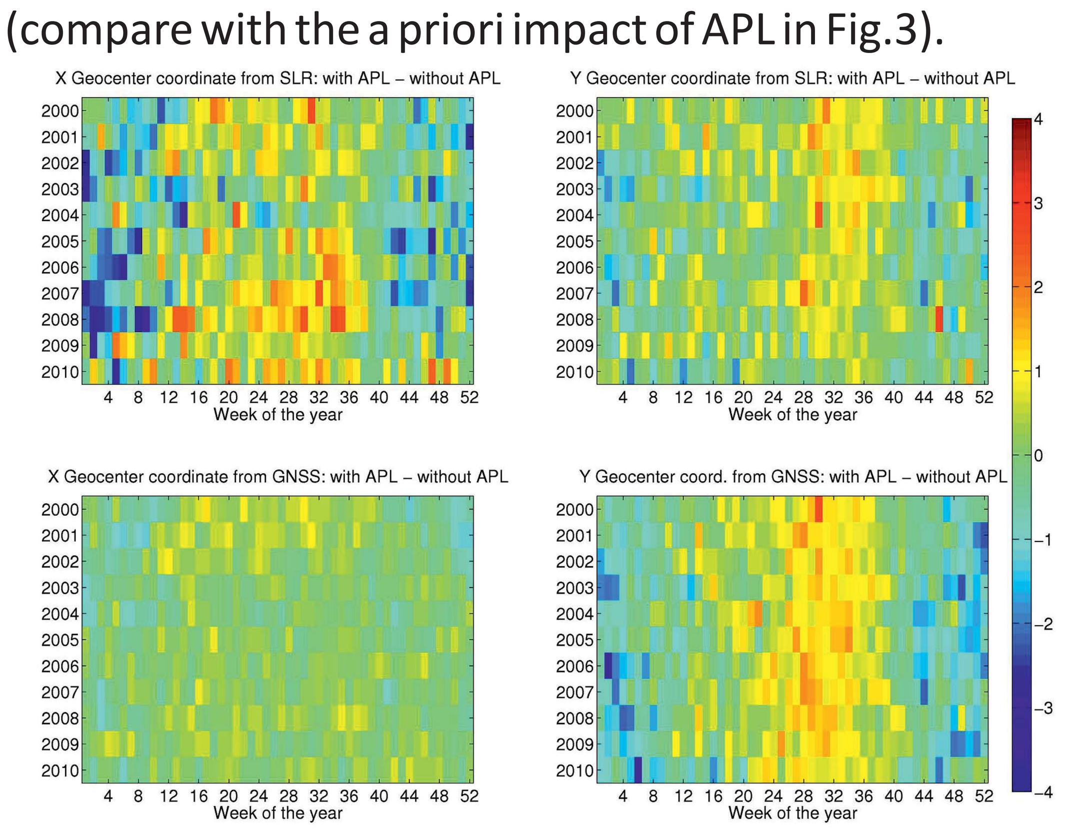

Fig. 6: Differences of geocenter coordinate estimates in SLR and GNSS solution due to APL corrections. Units: mm

Summary

- The Blue-Sky effect reaches up to 4.4 mm,
- Applying the loading corrections at the observation level improves SLR-derived products, as well as, the consistency with microwave-based results.

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