The Blue-Sky effect

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1. 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 pressure loading (APL) corrections on SLR solutions and on the consistency with microwave results by applying all the corrections at the observation level.

2. Blue-Sky effect

APL 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 loaded and deformed most, whereas microwave observations are weather-independent.
We assess the impact of the Blue-Sky effect on the SLR stations as a difference between the mean atmospheric loading correction applied to SLR stations when SLR station observes LAGEOS-1/2, and the mean correction to SLR stations for the entire time series (Sośnica et al., 2012a). The effect amounts 2.5 mm for many in-land stations (see Tab. 1). 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), even though different methods applied in both studies, i.e., Otsubo et al. (2004) use regression factors and pressure observables from GNSS stations, whereas APL grid files are used in our study. Using regression factor is a less effective way of accounting for APL effect than corrections from loading models including the pressure information from the stations' surrounding areas (Dach et al., 2011). However, both approaches lead to similar results with a mean difference of only 0.2 mm.
The largest APL effect is for in-land stations in central Asia and Eastern Europe (see Fig. 1). It is not astonishing that the largest Blue-Sky effect is for stations with largest magnitude of APL impact. Even if the Blue-Sky effect is at the mm-level, it should be considered in SLR analyses, because all sources of errors leading to bigger discrepancies than 1 mm between space geodetic techniques should be taken into account, as the goal of Global Geodetic Observing System (GGOS) for the precision of station positions is 1 mm. Table 1 shows that the Blue-Sky effect exceeds the goal of GGOS for more than half of all SLR stations.

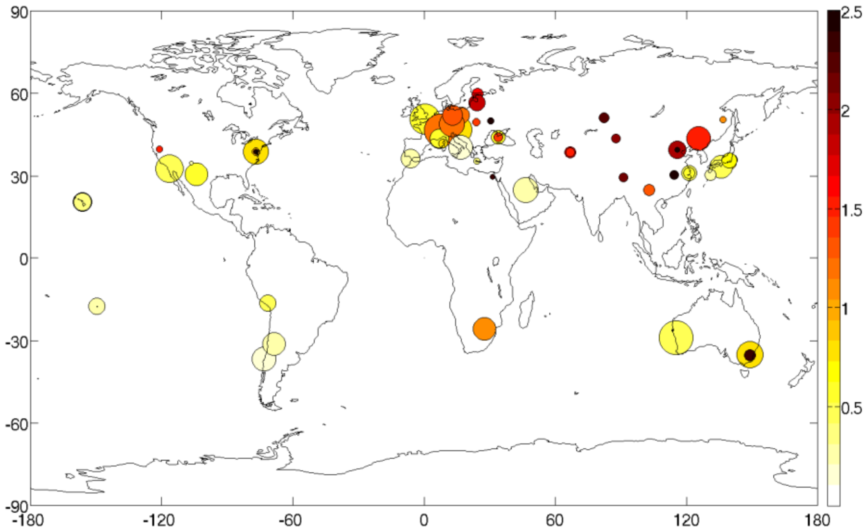

Fig. 1: The Blue-Sky effect on SLR stations in mm. The area of circles is proportional to the number of normal points to LAGEOS-1/2 in 1999-2011.

SLR station	Number of normal points (1999-2010)	Mean impact of Atmospheric Pressure Loading [mm]	Blue-Sky effect (this study) [mm]	Blue-Sky Effect (Otsubo et al., 2004) [mm]
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	
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, after Sośnica et al., (2012c).

3. Summary and recommendations:

- The Blue-Sky effect is largest for in-land stations with maximum value up to 4.4 mm,
- The Blue-Sky effect has to be considered in the SLR analyses in order to meet the GGOS' goal of 1 mm stability of SLR stations,
- Applying atmospheric pressure loading corrections at the observation level eliminates the impact of the Blue-Sky effect and improves the consistency between SLR and GNSS solutions (Sośnica et al., 2012b),
- Applying APL in post-processing cannot fully compensate the Blue-Sky effect, because this method implies a continuous and uniform distribution of measurements in time, what is typically not the case for SLR (Sośnica et al., 2012c).

4. References

- Dach R, Böhm J, Lutz S, Steigenberger P, Beutler G (2011) Evaluation of the impact of atmospheric pressure loading model on GNSS data analysis. J Geod, 85, pp 75-91, doi:10.1007/s00190-010-0417-z
- 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 (2012a) Impact of Atmospheric Loading Corrections on SLR Solutions and on the Consistency Between GNSS and SLR Results. Poster on EGU General Assembly 2012, Vienna, Austria, April 22-27, 2012
- Sośnica, K, Thaller D, Dach R, Ostini L, Jäggi A, et al. (2012b) Time Series Analysis of GNSS-SLR Co-located Stations. Poster on IGS Workshop 2012, Olsztyn, Poland, July 23-27, 2012

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