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# Systematic errors between SLR and GNSS due to the omission of atmospheric pressure loading

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Satellite Laser Ranging (SLR) is a precise space geodetic technique that contributes to Global Geodetic Observing System (GGOS) by providing e.g., the origin and the scale of the International Terrestrial Reference Frame, station coordinates, Earth rotation parameters, standard gravitational parameter – GM, and low-degree spherical harmonics of the Earth's gravity field. Currently, all new active navigation satellites are equipped with laser retroreflectors for range measurements. Due to that fact, one can determine SLR-derived parameters based on the range measurements to multi-GNSS constellations: Galileo, GLONASS, BeiDou and QZSS. However, a full consistency between both SLR and GNSS techniques is required to obtain reliable global geodetic parameters.

The current requirement imposed by GGOS demands a precise reference frame that is stable-in-time and accurate at the level of 1 mm. Atmospheric pressure loading (APL) plays an important role in precise space geodesy, due to the fact that it causes displacements of the geodetic stations of magnitude at the level of 1 cm both in vertical and horizontal directions. As a result, APL corrections should be considered if one would like to fulfill requirements imposed by GGOS.

SLR is especially affected by APL due to the fact that range measurements can be performed only during cloudless conditions, which coincide with the high atmospheric pressure that deforms the Earth's crust. This systematic shift of station heights is called the Blue-Sky effect. Although APL corrections affect mostly station coordinates they also act on other geodetic parameters i.e. geocenter coordinates, multi-GNSS orbit parameters and Earth rotation parameters.

The goal of this study is to both determine the Blue-Sky effect for particular laser ranging stations and evaluate the impact of the omission of the APL corrections on the whole SLR network. The highest values of the Blue-Sky effect occur for the inland SLR stations and equal 2.3, 2.0, 2.0, and 1.9 mm for Svetloe, Potsdam, Baikonur, and Altay, respectively. For the first time, we determine the errors of the estimated Blue-Sky effect values and compare the obtained values to previous studies.

APL corrections act not only on estimated station coordinates but also on the multi-GNSS orbit parameters. We performed Helmert transformation on satellite positions which shows an amplitude of the annual signal at the level of 2.7 mm for the Z component. Geocenter coordinates are affected by APL modelling with the amplitude of the annual signal of 1.9 mm for the Z component. Earth rotation parameters are affected as well. The amplitude of the annual signal for the differences between ERPs calculated with and without APL correction equal 8.1 $\mu$as and 21.0 $\mu$as for the X- and Y-Pole, respectively.

As a result, the systematic offsets of estimated SLR station coordinates, related to the Blue-Sky effect, estimates amplitudes of geocenter coordinates and the satellite orbits show the differences exceeding the level of 2 mm when neglecting APL. All of these systematics limit the current consistency between SLR and GNSS and other space geodetic techniques, therefore deteriorate the quality of GGOS products.