HYDROLOGICAL EFFECT ON ABSOLUTE GRAVITY MEASUREMENTS USING THE MODEL GLDAS

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1. INTRODUCTION

Time series of gravity measurements can be used to characterize geodynamic processes. However, these measurements can be strongly influenced by hydrological processes, especially water mass variation. Therefore, the influence of hydrological effects should be modeled so that the observed gravity can be appropriately corrected. In the present-time the absolute gravity measurements have very high accuracy (<1 µGal). Often, due to the lack of measurements, an accurate local hydrological model is not available and the gravity corrections are affected by an unknown error. The purpose of this paper is to analyze the possibility to calculate the hydrological correction from freely available data, namely global hydrological model The Global Land Data Assimilation System at spatial resolution 0.25° x 0.25°. The hydrological corrections obtained in this study were tested with FG5 absolute gravity measurements. This methodology could be used for data-processing in the National Centre for Diagnostic of the Earth Surface Deformation in the Area of Slovakia. The paper presents theoretical and numerical results of the test.

2. GLOBAL LAND DATA ASSIMILATION SYSTEM

The hydrological model Global Land Data Assimilation System (GLDAS) provides information about the state of hydrology at a global scale (Rodell et al., 2004). This model is freely available (see Bibliography). Model GLDAS NOAH provides information at the space resolution of 0.25 degrees (approximately 27 km) and time resolution of tree hours in several layers. Only six layers are essential for the calculation of the hydrological correction. The soil moisture (Average Layer Soil Moisture) is indicated in four levels according to depth from surface up to a depth of two meters. It is also possible to use the information about the amount of accumulated snow (Snow Water Equivalent) as well as the information about the amount of water which is stored in the vegetation (Total Canopy Water Storage). Fig. 1. shows the coverage of the model GLDAS.

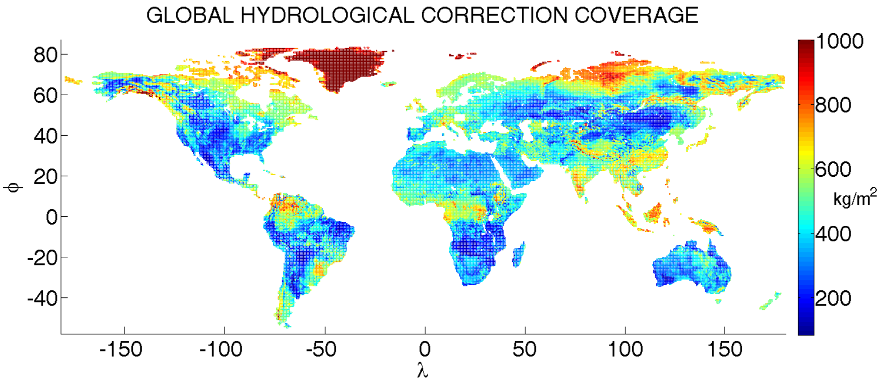

Fig. 1. Model GLDAS coverage.

3. STATION CHARACTERISTICS

For the purpose of this paper were used five absolute gravity (AG) points in Slovakia i.e., stations Gánovce (699 m about sea level) , Liesek (691.6 m), Modra (532.9 m), Skalnaté Pleso (1773.3 m) and Telgárt (904 m). All absolute gravity measurements were realized by VUGTK, Czech Republic, absolute gravimeter Micro-g FG5#215 and corrected for tides, atmospheric pressure and polar motion effects (dash-dot line in Fig. 3.-7.). The FG5 measurements in Slovakia started in 2003, with the last observation in 2010.

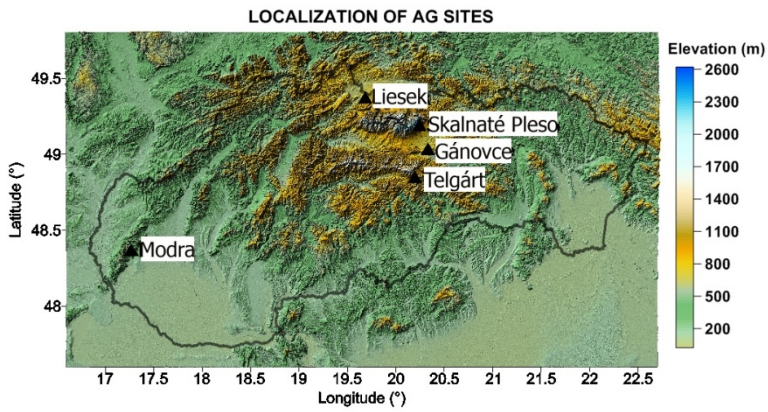

Fig. 2. Localization of AG sites in Slovakia.

4. HYDROLOGICAL CORRECTION

Hydrological mass variation causes the changes of the gravity in the form of direct attraction and in the form of surface-deformation due to the loading. It is appropriate to use Green's functions (Farrell, 1972) with Love's numbers given by (Guo et al., 2004) for the calculation of the indirect effect (1). The calculation of the direct effect depends on the distance between hydrological mass and the point of observation. This is the reason for dividing the hydrological correction into global, regional and local correction. The global correction was computed for the spherical distance greater than 1.75° (195 km) from observation point. The equitation (2), which was used for global

correction, represents the gravitational effect of water mass concentrated in the point at the spherical distance θ (Farrell, 1972). The regional correction represents the water mass variation from 0.00045° (5 km) to 1.75° (195 km) and is using the same equation as the global correction (2). Local hydrological correction is calculated with help of digital terrain model up to a distance of 5 km. In this case is the direct effect calculated as gravitational effect of 3D prism (3) (Sorokin, 1951).

$$g^E = \frac{g}{M_e}\sum_{n=0}^{\infty}[2h_n - (n+1)k_n]P_n(cos\theta), \quad \textbf{(1)}$$

$$g_z(\theta) = -\frac{g}{4M_e \sin(\frac{\theta}{2})}, \quad \textbf{(2)}$$

$$g_z = -G\rho[Xln(Y+R) + Yln(X+R) + Zarctg\frac{ZR}{XY}]. \quad \textbf{(3)}$$

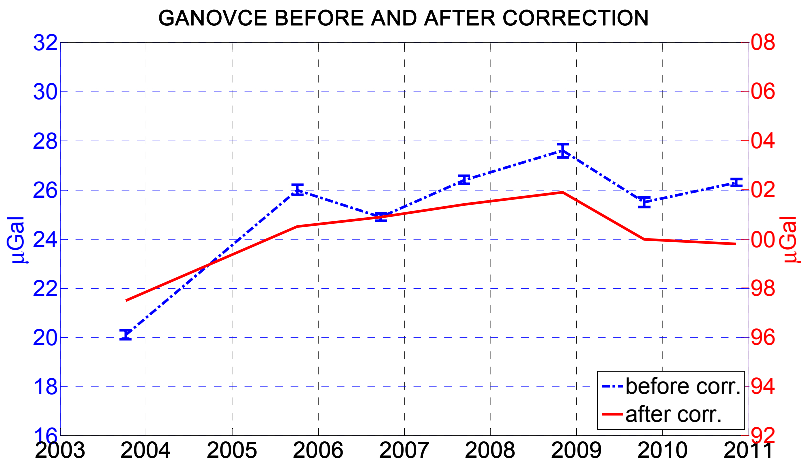

Fig. 3. Absolute gravity on site Gánovce before and after applying hydrological correction.

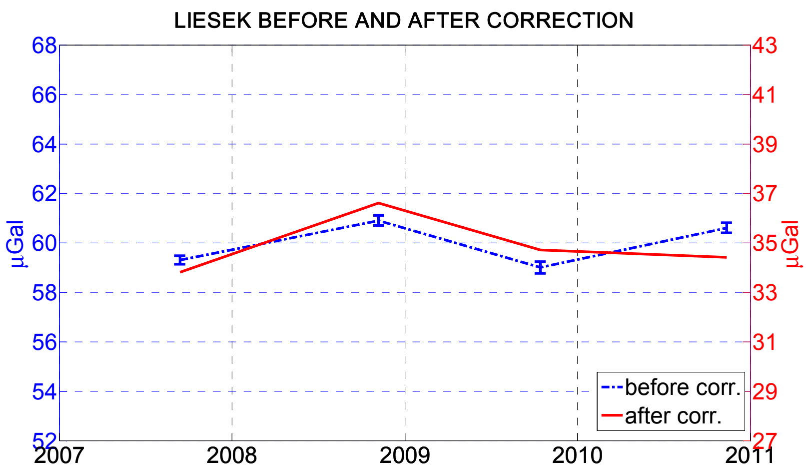

Fig. 4. Absolute gravity on site Liesek before and after applying hydrological correction.

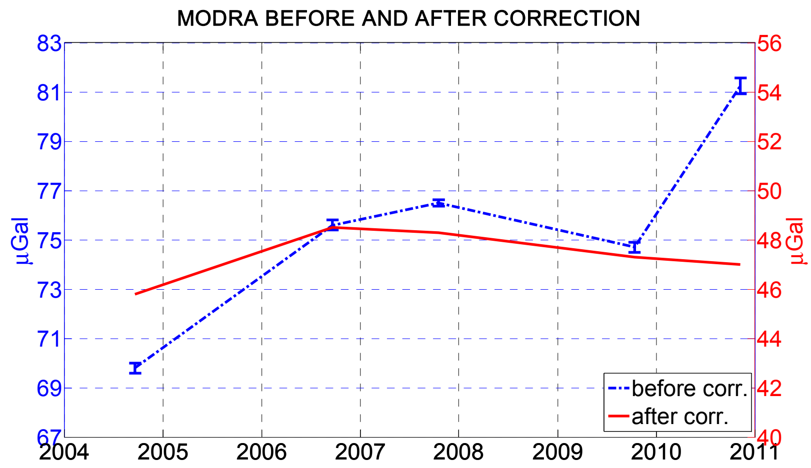

Fig. 5. Absolute gravity on site Modra before and after applying hydrological correction.

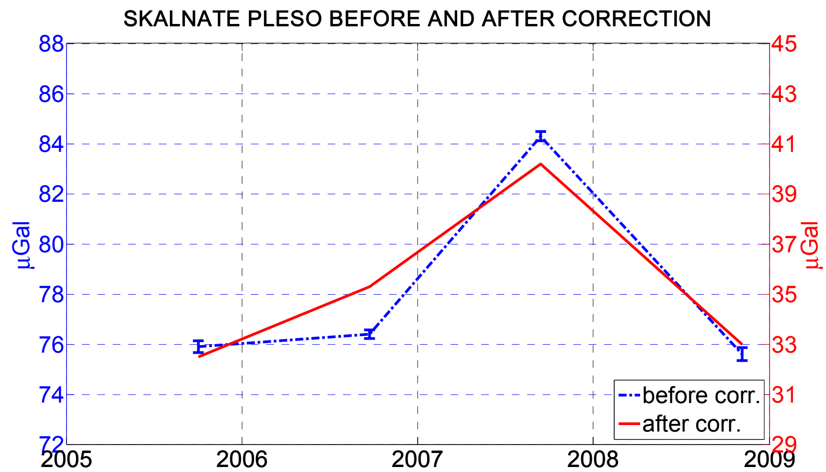

Fig. 6. Absolute gravity on site Skalnaté Pleso before and after applying hydrological correction.

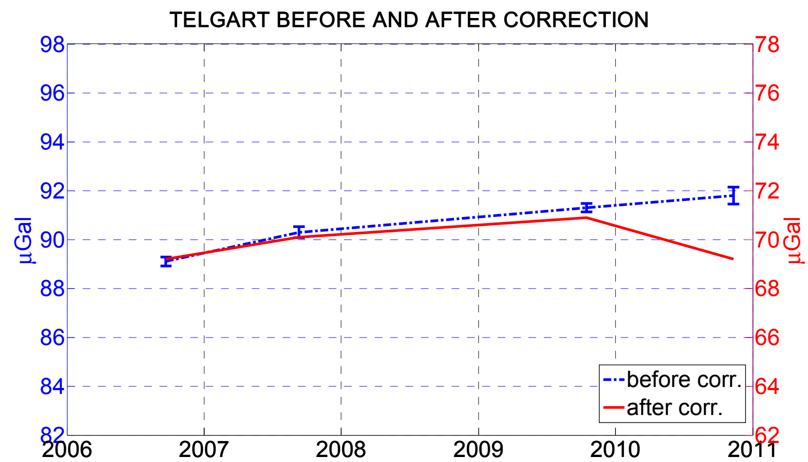

Fig. 7. Absolute gravity on site Telgárt before and after applying hydrological correction.

Table 1. Results of the test

Site	Before hydrological correction (µGal)			After applying hydrological corr. (µGal)		
	max - min	Standard deviation	annual trend	max-min	Standard deviation	annual trend
Gánovce	7,50	2,42	0,72	4,40	1,43	0,27
Liesek	1,90	0,94	0,21	2,80	1,21	0,02
Modra	11,45	4,10	1,40	2,70	1,09	0,10
Skalnaté Pleso	8,70	4,18	0,57	7,70	3,52	0,52
Telgárt	2,70	1,19	0,61	1,70	0,82	0,07

5. CONCLUSIONS

Overall, the numerical experiment based on the model GLDAS shows an improvement in standard deviation and trend (see Table 1. and Fig. 3.-7.). This is the case in Gánovce, Telgárt and especially in Modra, where the last observation in 2010 shows significant improvement after applying hydrological correction (Fig. 5.). At the same time the correction does not degrade the measurements with a small dispersion (Liesek, Fig. 4.). This method is not suitable for the alpine environment (Skalnaté Pleso, Fig. 6.). Model GLDAS is suitable for the calculation of hydrological correction for distance greater than 300 m from observation point approximately. To successfully eliminate the impact of water mass variation on gravity measurements, it is necessary to monitor local hydrological characteristics such as the soil moisture and the groundwater level. It is also necessary to dispose of precise digital terrain model. The experimental results could be used for choosing the optimal site for intercomparison of absolute gravimeters.

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