MODELLING OF HYDROLOGICAL MASS VARIATION ON THE SITE MODRA-PIESOK

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1. INTRODUCTION

Time series of gravity measurements can be used to characterize dynamic changes of subsurface system. However, these measurements can be strongly influenced by hydrological processes especially water mass variations. Therefore, the influence of hydrological effects on gravity needs to be modelled so that the observed gravity can be appropriately corrected. 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. In the present-time the absolute gravity (AG) measurements have very high accuracy (<1 microgal = 0.3 mm in vertical change of equipotential surface). The hydrological mass variation is very often modelled by global, regional and local hydrological effects. For computation of hydrological effects were used global hydrological model WGHM with 0.5° x 0.5° grid and model GLDAS at spatial resolution 1° x 1°. All hydrological effects were tested by absolute gravity measurements performed on the site Modra-Piesok. The paper presents theoretical and numerical results of the test.

2. HYDROLOGICAL EFFECTS

The hydrological mass variation causes the changes of the gravity in the form of direct attraction (eq. 2) and in the form of deformation due to the loading (eq. 3). The hydrological effect can be divided into:

2.1. Global Hydrological effects

For the computation of global effect it is appropriate to use elastic Green's functions (Farrell, 1972) with Love's coefficients given by (Pagiatakis, 1988). The global effect was computed for the spherical distance (θ) greater than 1° from the observation point, using two hydrological models:

1. **The Global Land Data Assimilation System (GLDAS)**

   It provides 1° x 1° grid of integrated total water content (TWC), obtained by summing five GLDAS layers (one Accumulative Snow layer and four soil moisture layers) provided by NASA with time resolution of one month from 2003 to 2009 (Rodell et al., 2004).

2. WaterGAP Global Hydrology Model (WGHM)

It provides continental total water storage (TWS) at spatial resolution 0.5° x 0.5° every month from 2003 to 2007 (Döll et. al., 2003).

$$\Delta g(\theta) = \frac{g}{M_e}\sum_{n=0}^{\infty}[n + 2h_n - (n+1)k_n]P_n(\cos\theta) \qquad \text{(eq. 1)}$$

$$g^N(\theta) = -\frac{g}{4M_e \sin\left(\frac{\theta}{2}\right)} \qquad \text{(eq. 2)}$$

$$g^E(\theta) = \Delta g(\theta) - g^N(\theta) \qquad \text{(eq. 3)}$$

In equations (1, 2, 3) g is the measured gravity, h_n and k_n are Love's numbers and M_e is the mass of the Earth.

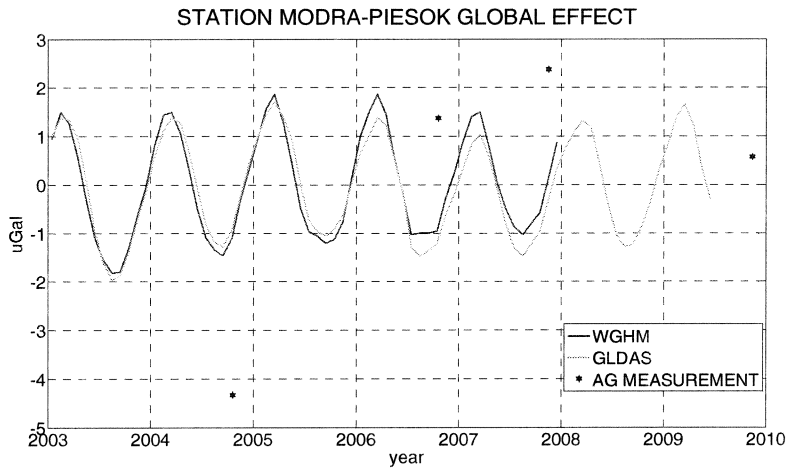

Fig. 1. Global hydrological effect.

2.2. Local and regional effects

The local and regional effects were computed as a terrain correction using the software GRAVSOFT. The software enables to calculate the residual terrain model (RTM) effects, i.e., the effects of the topographic irregularities (hydrological mass in the form of TWS in centimeters) with respect to a reference surface, which was chosen to be a zero (Forsberg, 2005). Gravity disturbance was computed for both, the WHGM model and GLDAS model up to a radial distance of 1°. The deformation effect was computed using elastic Green's functions.

Model for local and regional effects (ρ is the density, G is gravitational constant):

$$\Delta g_{local} = G\rho \iint \int_{z=0}^{z=H_{TWS}} \frac{z - z_P}{\left((x - x_P)^2 + (y - y_P)^2 + (z - z_P)^2\right)^{3/2}}\, dx\,dy\,dz \qquad \text{(eq. 4)}$$

The strongest impact comes from the local zone because the gravimetric measurements are sensitive only to the vertical component of the attraction. Examples of the gravity change caused by planar cylinder with changing radius resp. volume soil moisture can be seen in Fig. 2.

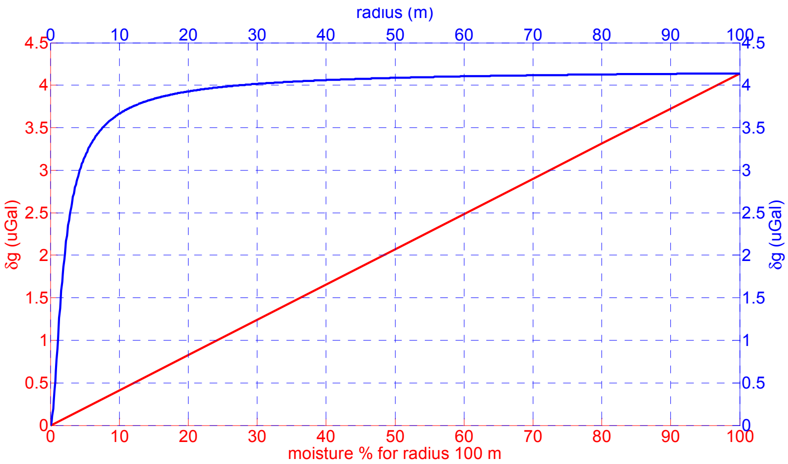

Fig. 2. Gravitational effect of 0,1m high cylinder full of water with changing radius (blue) and gravity change caused by cylinder with changing soil moisture (red). Both for effective height 1.22 m.

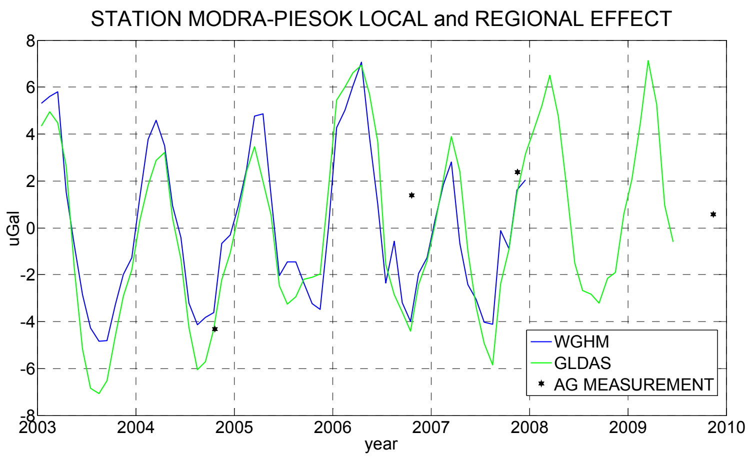

Fig. 3. Local and regional hydrological effect.

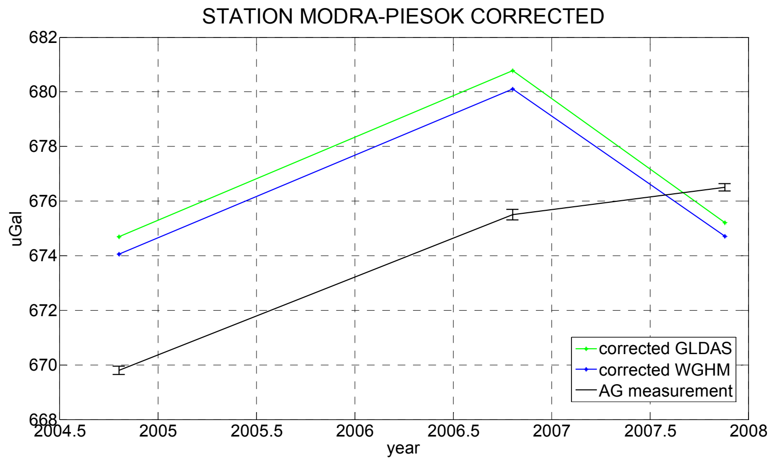

Fig. 4. The absolute gravity measurements before (black, with precision 1σ after applying standard corrections) and after global, regional and local hydrological corrections (blue and green).

3. THE STATION MODRA-PIESOK

The Modra-Piesok is an UNIGRACE (Project for Unification of Gravity System in Central and Eastern Europe) station used for absolute gravity measurements with permanent meteorological and hydrological parameter observations. Modra-Piesok is a GNSS permanent EPN station used for investigation of dynamical effects. Absolute gravity measurements were realized by VUGTK, FG5#215. The absolute gravity measurements were processed using standard correction models for tide, polar motion and atmosphere effects. We decide to create a local micro-gravity monitoring network with monthly observations of relative gravity and hydrological parameters (see Fig. 5.).

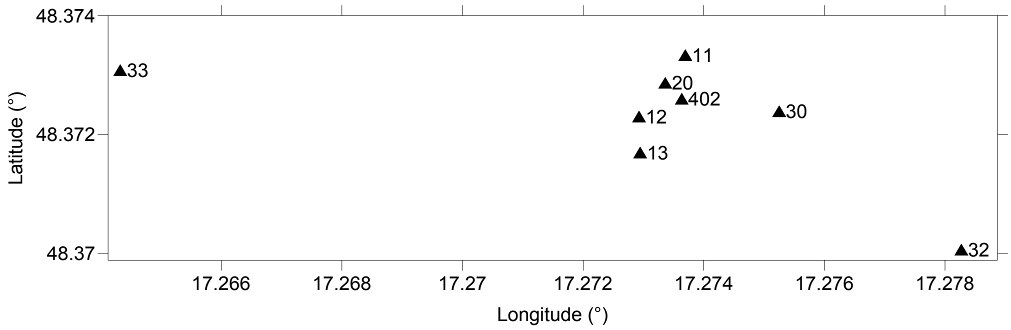

Fig. 5. Micro-gravity network configuration at Modra-Piesok site (402-absolute gravity point).

4. CONCLUSIONS

The hydrological mass variation shows constant period (one year) with variable amplitude. The biggest contribution to the gravity variation comes from local hydrological mass variations and the global effect is very stabile. To improve the results, we need a hydrological model with higher spatial resolution and more meteorological and hydrological observations like soil moisture sensors, groundwater depth measurements etc., in the near area of the station. We also need geological information

about the subsurface in the near area of the station. For validation of the hydrological effects, it is necessary to measure the absolute gravity.

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