Comparison of GRACE Derived Seasonal Deformation with Hydrology Model and GNSS Measurements in Poland

Global vs Regional GNSS solution

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Abstract. We evaluate usefulness of regional solution in terms of studies of large scale geodynamic phenomena. For this purpose a few GNSS sites in Poland with long history of measurements were selected. Co-ordinate time series were taken from homogeneously reprocessed global network within International Global Navigation Satellite Systems (GNSS) Service (IGS) "repro1" project and from our own regional processing – Warsaw University of Technology (WUT) Local Analysis Center (LAC) contribution to European Permanent Network (EPN) "repro1". This results were compared with modelled crustal deformation due to continental hydrology loading. The hydrology mass variation were taken from Gravity Recovery and Climate Experiment (GRACE) satellite data assessment and WaterGAP Hydrology Model (WGHM) output. For completeness of comparison we took Atmospheric Loading (ATML) into account to give an illustration of importance of this phenomena on seasonal signal for considered sites.

We found good agreement of observed and modelled variation for vertical component. The hydrology loading explain main source of seasonal height variation of GNSS sites in Poland which can reach as much as 1 cm peak to peak. The interpretation for horizontal component variation is ambiguous.

The regional and global solution show good agreement for site co-ordinate time series if homogeneous global products were taken in regional network processing. Some discrepancies shown here favor global solution as a source of more reliable information when global scale effects are considered. Nevertheless our solution are rather consistent with IGS results indicating great potential of regional networks in terms of global geodynamic effects investigation.

Keywords. GNSS time series, Regional Solution, WUT LAC, GRACE, WGHM

1 Introduction

With Global Navigation Satellite Systems (GNSS) measurements we are able to observe subtle geodynamic processes. Among different phenomena loading effects are subject of ongoing discussion whether the conventional models should be included in routine processing scheme (Petit and Luzum, 2010). The most pronounced loading effects are those of atmospheric (van Dam et al., 1994; Dong et al., 2002; Petrov and Boy, 2004; Dach et al., 2011) and hydrologic origin (van Dam et al., 2001; Fritsche et al., 2011; Rajner et al., 2011). We give here a comparison of modelled seasonal crustal deformation due to continental hydrology loading computed on the basis of Gravity Recovery and Climate Experiment (GRACE) (Tapley et al., 2004) satellite data and WaterGAP Hydrology Model (WGHM) (Döll et al., 2003; Güntner et al., 2007) output. To get a proper conclusion the Atmospheric Loading (ATML) was considered as well.

In order to investigate in such small signal and get correct interpretation it is common to use global solution. In this work we compared regional network time series with global ones and obtained comparable results. The exceptional discrepancies on the other hand can be crucial. This problem still need for more comprehensive elaboration.

2 Data

2.1 GNSS

We consider here International GNSS Service (IGS) "repro1" weekly solution (Dow et al., 2009)(herein referred as global solution) and the results of Warsaw University of Technology (WUT) Local Analysis Center (LAC) reprocessed regional European Permanent Network (EPN) (Bruyninx, 2004) subnetwork of 60 sites within "repro1" project (Volksen, 2009)(re-

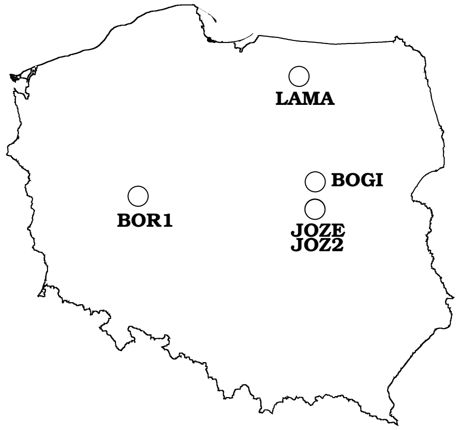

Fig. 1. Selected GNSS sites

ferred as regional solution). The Bernese GNSS software was used along with IGS “repro1” products. The processing details can be found in Liwosz et al. (2010).

We selected five permanent GNSS stations in Poland (Fig. 1) according to their long observation period and availability of results within IGS “repro1” and WUT LAC “repro1” projects. Site co-ordinates were transformed to topocentric reference frame, outliers were removed and trend was subtracted. For better comparison the smoothing procedure was applied using simple smoothing window with length of 60 days.

2.2 Loading

Hydrological loading was computed using Green’s function formalism (Farrell, 1972). The continental water masses distribution were taken from Groupe de Recherche en Géodésie Spatiale (GRGS) solution (Lemoine et al., 2007) and WGHM. This computation follows scheme given in Rajner et al. (2011).

The Petrov and Boy (2004) model of ATML was used in this study to show its importance for site position in seasonal time scale. Note that ATML is removed in processing of GRACE data to avoid aliasing effects (Lemoine et al., 2007). Therefore GRACE observes mainly hydrology mass transport when a few years time scale is considered and removed ATML from GNSS time series seems to be proper way when such comparison is performed.

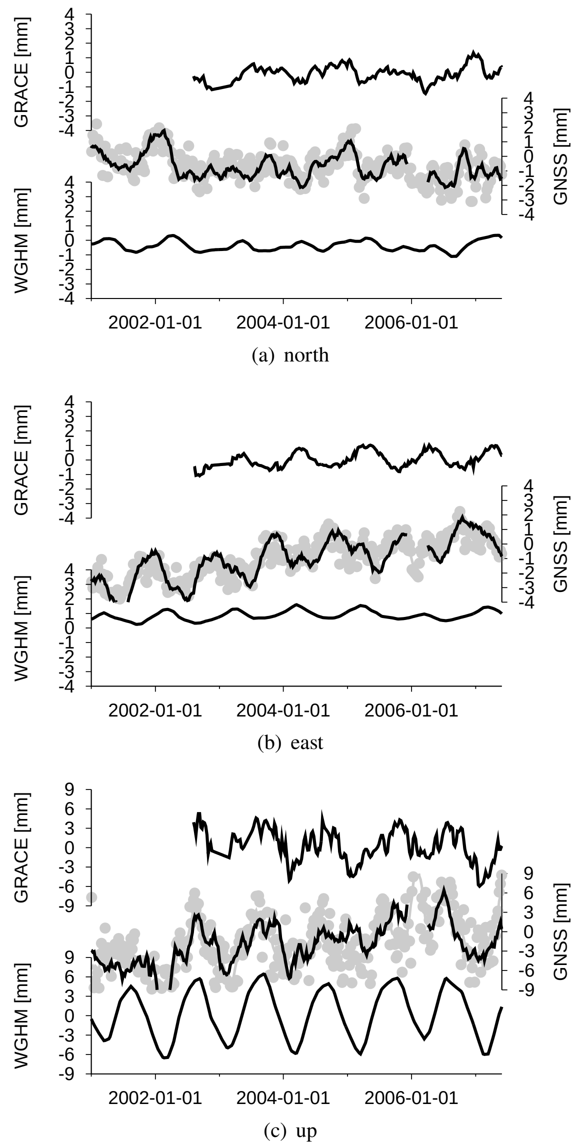

Fig. 2. North, east and vertical component of GNSS solution (from IGS, gray dots) and smoothed time series (gray line, see text) along with modelled deformation from GRACE and WGHM for Lamkówko site (LAMA). The black solid line indicate smooth GNSS solution with ATML subtracted. Note different scale for horizontal and vertical components.

3 GNSS results vs modelled hydrology loading

The one example of comparison of GNSS time series with modelled hydrology deformations for north, east and vertical component are presented in Fig. 2.

The seasonal variation of height is well explained by hydrology loading (with some obvious exceptions

Table 1. Correlation of GNSS results between IGS and WUT solutions for north (n), east (e) and vertical (u) component

Site	n	e	u
BOR1	0.20	0.69	0.73
JOZ2	0.18	0.40	0.73
JOZE	0.41	0.63	0.68
LAMA	0.53	0.83	0.62

due to local effects or processing imperfection). The WGHM gives slightly overestimated results. The good agreement in phase shows typical behaviour of maximum load in spring and the rebound during late summer and early autumn. For horizontal component the interpretation is ambiguous. Moreover we observe different pattern of deformation from GRACE and WGHM model. The periods with reasonable agreement of GNSS results with modelled deformation as well as disagreement period (even with opposite phase) can be recognized. This problem was already reported before (Tregoning et al., 2009) but remains unexplained. The example of LAMA shown in Fig. 2 is representative for other considered sites. We refer to Rajner et al. (2011) for the quantitative evaluation of similar comparison using more sites.

4 Comparison of regional with global time series

In this section we look into similarities of time series between regional and global signals. The regional solution is belived to be not suitable for geodynamic studies. GNSS time series are usually slightly different for global and regional networks.

Fig. 3 shows an example of IGS and WUT LAC results for Borowiec (BOR1) site (the modelled deformation are shown for completeness). Quick look give an impression that this time series are similar but detailed inspection reveal some crucial differences.

In Table 1 we present the correlation coefficients of IGS and WUT solution for topocentric component for different sites (Borowa Góra was excluded due to problematic results in both solution). These results lead to conclusion that investigating in global scale geodynamic process is possible with regional solution but possible misinterpretation should be kept in mind. This problem still need to be carried out more comprehensively in future.

5 Conclusion

In the previous section we showed that the hydrology loading is the main source of seasonal height variation. Modelled deformation on the basis of water mass distribution and crust properties explain well GNSS results. Discrepancies for horizontal components still wait for reasonable explanation, however this ones are of much smaller amplitudes. Presented regional time series for Polish sites possess comparable geophysical signal in height component as global IGS results.

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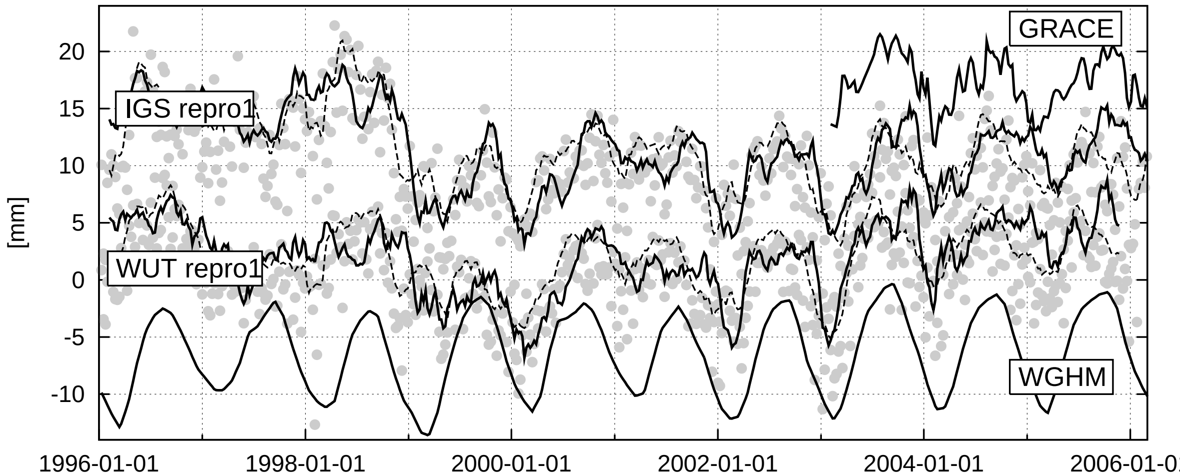

Fig. 3. Comparison of global IGS and regional WUT LAC solution for Borowiec (BOR1) for vertical component along with modelled deformation using GRACE and WGHM. Time series were shifted for clarity.

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