An Evidence of Hydrological Signal in GPS time series in Poland

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Abstract

CURRENTLY well known influence of continental water loading on surface displacement can be measured by various geodetic methods. Among others satellite positioning is the most robust and easily available technique. In this paper we compare GPS measured position changes with deformations computed on the basis of global water storage models.
We used GPS data from several Polish permanent sites with long-time measurement period available, applying Precise Point Positioning method using consistent IGS products. Results were corrected for other geophysical signals. An overall good agreement (specially for height component) was found.
Paper deals also with possibility of reduction of predominant yearly hydrological signal from positioning results. Simple model appropriate for studied area is introduced and its accuracy is estimated.

Hydrological loading

In this studies we used WaterGAP Hydrology Model (WGHM) monthly storage values with 0.5° spatial resolution. This model includes all kind of water in land cells. The deformations were computed using Green's function formalism with well known equation,

$$\mathbf{L}(\mathbf{r}) = \rho \cdot \iint_{Earth} G(|\mathbf{r} - \mathbf{r}'|) \cdot \mathbf{H}(\mathbf{r}')\,\mathrm{d}A.$$

GPS measurements

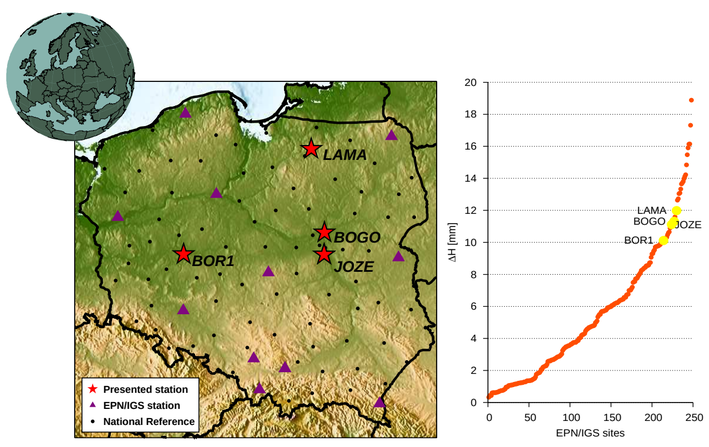

Figure 1. *Permanent GNSS Polish sites (left graph). Range of height change due hydrological loading for permanent GNSS sites from EPN/IGS network in 2002 year (right graph).*

For analysis we used Precise Point Positioning (PPP) technique. Some details concerning computation are given below,
- orbits and EOP from IGS – "repro1" (IGS05 reference frame),
- daily solutions,
- DCB – from CODE,
- absolute antenna phase center model – I05,
- Earth tides model – IERS2000,
- ocean tidal loading – FES2004,
- atmospheric loading removed (Petrov's service),
- outliers rejected, time-series detrended.

Comparison

In Fig. 2 we present time series of height component (daily and smoothed) and computed hydrological induced deformations. An overall good agreement was found confirming predominant annual cycle. Some obvious disagreement are probably PPP technique artefacts.

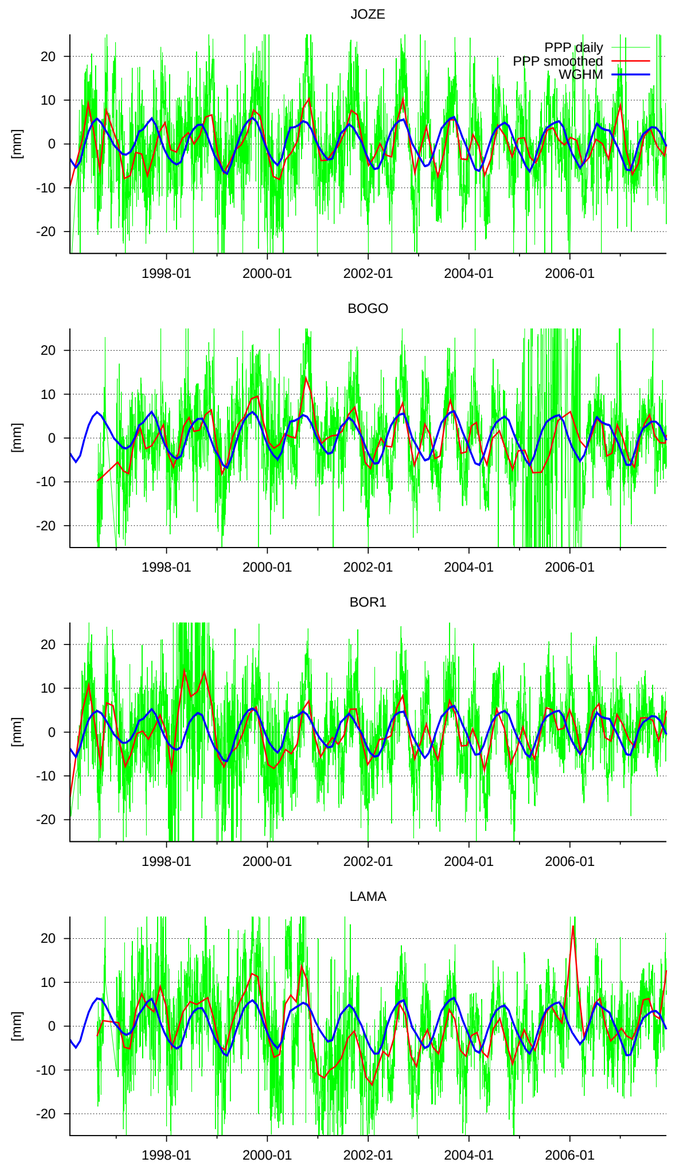

Figure 2. *Comparison of PPP results with computed height deformation from hydrological model*

While PPP technique gives good agreement for up component it is insufficient to detect hydrological induced horizontal deformations. In Fig. 3 we present results for Józefosław site.

Figure 3. *Comparison of PPP results with computed horizontal deformation from hydrological model*

Simple model for Poland

Fig. 4 shows hydrological loading along with annual height variation determined from the global network reprocessing (Tesmer et al.). One can see good agreement. Yearly harmonic is predominant thus we fitted simple cosine model according to equation, $\Delta H = A \cdot cos(\omega t - \varphi)$.

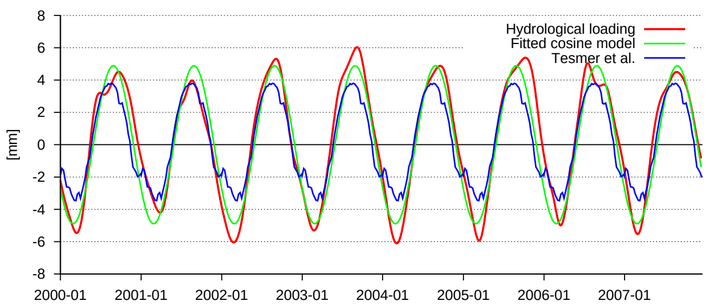

Figure 4. *Comparison of computed height deformation with fitted cosine model for JOZE site. Additionally we present here annual height variation computed by Tesmer et. al (`http://www.iapg.bv.tum.de/mean-annuals`)*

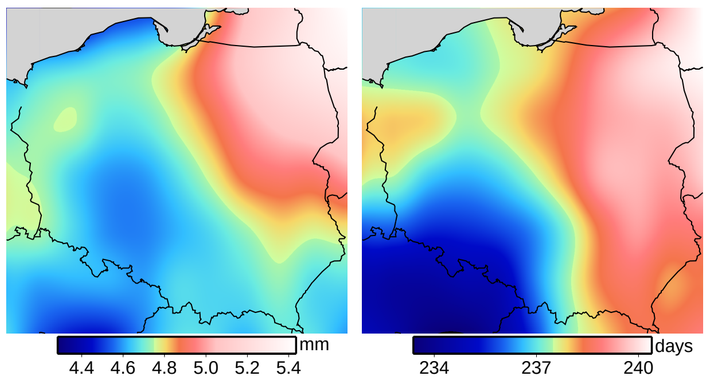

Figure 5. *Fitted amplitudes (left) and phases (right) of hydrological loading (1997-2007)*

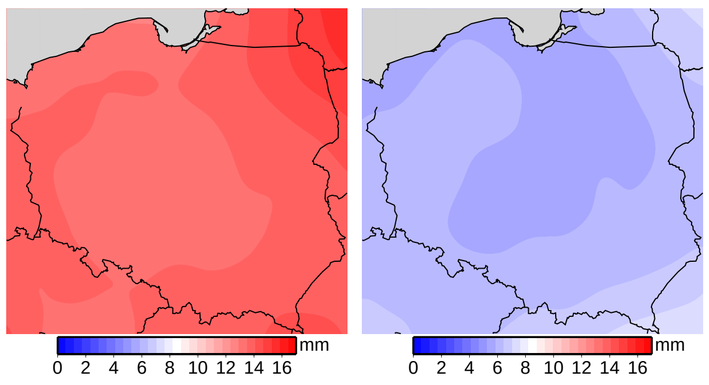

Figure 6. *Range of hydrological loading computed using WGHM model and after subtraction of cosine model (1997-2007)*

Conclusions

PPP technique is able to detect deformation stemming from water storage variation but it is restricted to height component only. Moreover comparison of monthly taken absolute gravity measurements in JOZE (FG5 no.230) show significant influence of global water storage on gravity - in this case it is not so clear probably due local hydrological influence, thus it is not presented here.
Seasonal height changes due to continental water storage do not show secular change. Computed loading, PPP height variation results as well as double differencing results from network reprocessing shows regular annual repeatability. For Polish territory simple cosine model could be applied for reduction of main part of hydrological loading phenomena.

Acknowledgments

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