GeoTerrace-2021-013

On the impact of non-tidal atmospheric loading on the GNSS stations of regional networks and engineering facilities

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SUMMARY

The research analyses the impact of non-tidal atmospheric loading (NTAL) on the GNSS stations of GeoTerrace network (Ukraine) and Dnister hydro power plant (HPP) in December 2019. Based on the data of 32 stations in the Western region of Ukraine authors divide them into two groups. One of the groups shows two times fewer dynamics of vertical subsidence comparing with vertical displacements due to NTAL models. The analysis of modeled NTAL with dense GNSS network of Dnister HPP-1 is also provided. The time series of up, east, north position changes of GNSS stations and NTAL models does not fully correlate. It leads us to the need for the regionalization of NTAL models and the need to calculate special corrections for engineering facilities.

Keywords: GNSS time series, non-tidal atmospheric loading, Dnister HPP, GeoTerrace GNSS network

Introduction

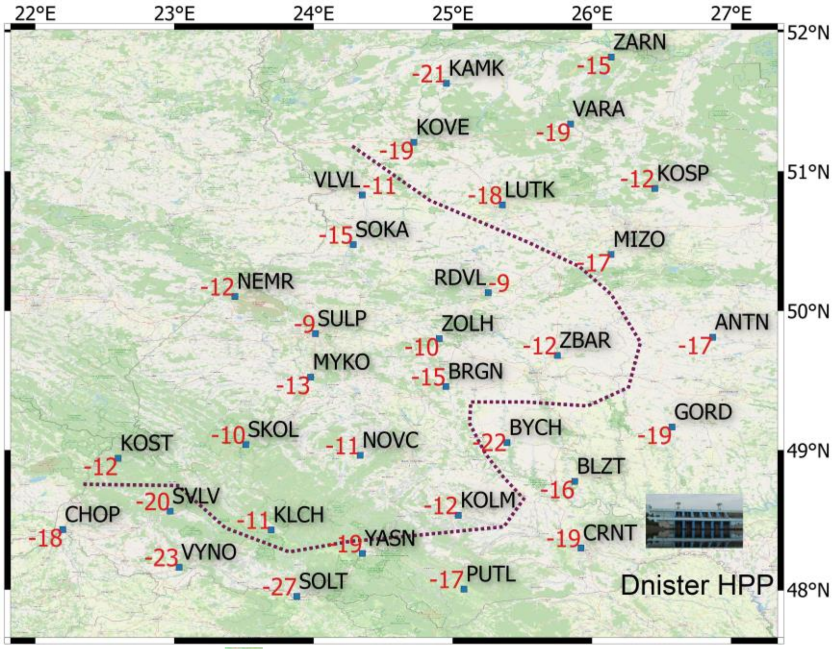
Nowadays, geodynamic interpretation of the results of GNSS time series should take into account plenty of factors and additional parameters for their correct interpretation when precision better 1 cm is required. On the one hand, deformations of the Earth's crust observed by GNSS data may be the result of such groups of factors as exogenous, endogenous and instrumental (Tretyak et al., 2012). The last one includes geometry of the satellite constellation, tropospheric and ionospheric delay, multipath exposure, and errors of hardware or software processing and for now, can be correctly eliminated. The exogenous group includes rotational motion of the Earth, tidal effects, atmospheric factor, post-glacial return, the balance of glacial and snow masses, thermal expansion of the Earth's surface. Plate tectonics, seismic activity, changes in the Earth's gravitational field, changes in continental water, and ocean loading are the endogenous factors. On the other hand, there are four mass loading parameters should be taken for the processing GNSS data such as variations of air mass that results in a change of surface air pressure; variations in ocean level due to lunar and solar tides; variations in ocean level due to wind and atmospheric pressure; variations in soil moisture (Petrov, 2015).

This research began with an attempt to interpret the phenomenon of short-term vertical subsidence of GNSS stations in continental Europe in December 2019 (Brusak & Tretyak, 2020). Now it is a standard to subtract loading models before geodynamical analyses upon GNSS time series. As Petrov, 2015 states: «these variations on average have the rms of 2.6 mm for the vertical component and 0.6 mm for the horizontal component, but peak to peak variations can reach 40 mm for the vertical component and 7 mm for the horizontal one». We process measurements of the GeoTerrace Ukrainian network using Bernese GNSS software (Dach et al., 2015). The result is network solutions with a double-difference strategy. Calculations are based on the automatic Bernese Processing Engine module, RNX2SNX strategy, and IGS stations as reference stations. For detailed information, the following link can be used https://geoterrace.lpnu.ua. It is known that this approach (Dach et al., 2015) takes into account different models of tidal loadings, but does not take into account ocean and atmospheric non-tidal loadings. The research shows the analyses of the impact of non-tidal atmospheric loadings (NTAL) on the GNSS stations of GeoTerrace network and Dnister hydro power plant in December 2019 for further geodynamic interpretation.

Methods and theory

To assess the regional impact of NTAL we analyzed subsidence of 32 stations in the Western region of Ukraine according to the data GeoTerrace network (Fig.1). In the research used the NTAL grid data downloaded from German GeoForschungs Zentrum provided for International Earth Rotation and Reference System Service. The data is public available on http://esmdata.gfz-potsdam.de. It should be noted that NTAL vertical deformation on this period is more than 20 mm for all of the stations of the region.

According to the dynamics of subsidence, the stations are divided into 2 groups. The first group includes stations with larger values of vertical displacements taking into account their location. This group includes GNSS stations such as ANTN, BLZT, BYCH, CHOP, CRNT, GORD, KAMK, KOSP, KOVE, LUTK, MIZO, PUTL, SOLT, SVLV, VARA, VYNO, YASN, ZARN. The second group includes the Lviv region and adjacent territories and shows other dynamics of vertical subsidence comparing with NTAL in December 2019. The group has vertical displacements about 10 mm, but NTAL displacements are over 20 mm in return. The group include GNSS stations such as BRGN, KLCH, KOLM, KOST, MYKO, NEMR, NOVC, RDVL, SKOL, SOKA, SULP, VLVL, ZBAR, ZOLH.



- GNSS station -21 - short-term vertical subsidence, mm (Brusak & Tretyak, 2020)
- location of Dnister HPP - the line dividing stations into 2 groups

***Figure 1** Analysis of the dynamics of vertical displacements of GeoTerrace network in December 2019*

Due to the research, there is a need for special regionalization of the NTAL displacements for their adequate correction. The next part of the research is the analysis of NTAL special displacements with the dense GNSS network of Dnister hydro power station (HPP).

Figure 2 shows the location of permanent GNSS stations of Dnister HPP-1 that operates throw the studied period from 15.12.2019 to 10.01.2020. The data from other stations is not included in the study, as the solutions for these days have data gaps.

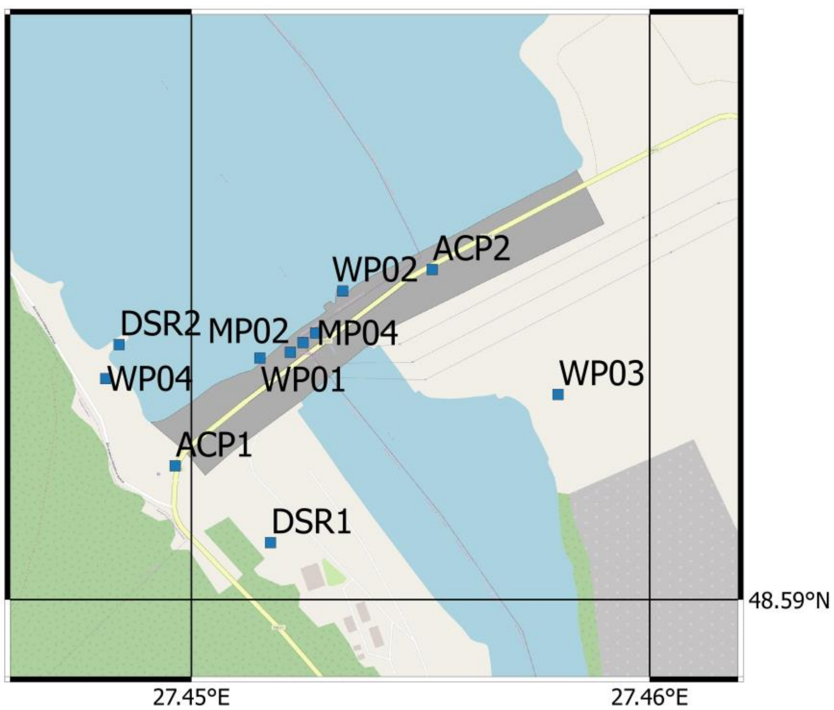


***Figure 2** Location of permanent GNSS stations of Dnister HPP-1*

Figure 3 shows the time series of up, east, north position changes of GNSS stations of Dnister HPP and modeled NTAL during the short-term subsidence in Europe (Brusak & Tretyak, 2020). It can be seen, that the dynamics of GNSS stations of the dam MP02-MP04 and some other base points are a bit different, but they do not correlate with NTAL displacements, especially for Up series.

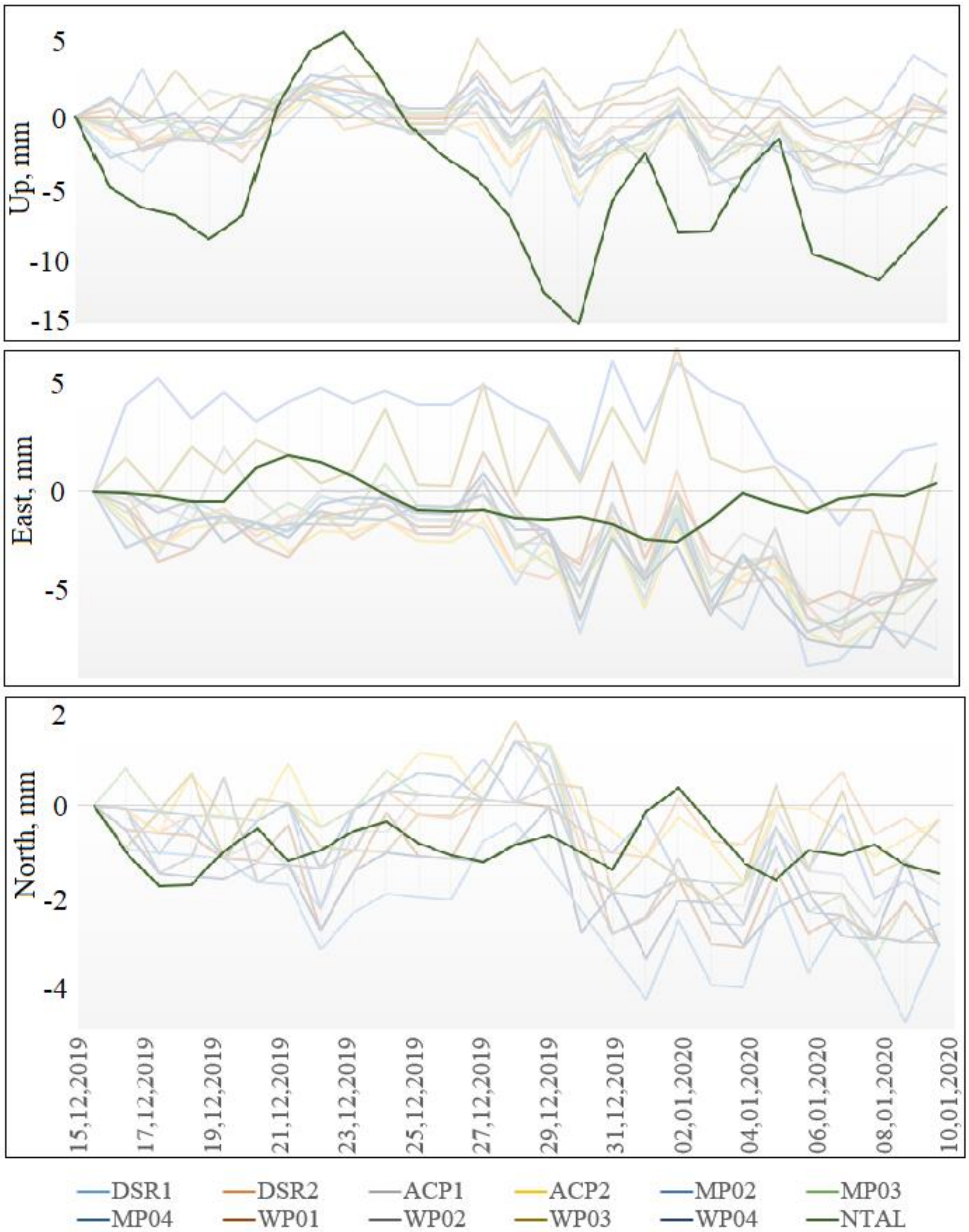


Figure 3 *Time series of up, east, north position changes of GNSS stations of Dnister HPP and modeled NTAL loading during the short-term subsidence in Europe (Brusak & Tretyak, 2020)*

Conclusions and discussion

In the research based on the data of 32 stations in the Western region of Ukraine, GeoTerrace network is divided into two groups. One of the groups (14 stations) includes Lviv region and adjacent territories shows two times fewer dynamics of vertical subsidence comparing with NTAL model in December 2019 (Brusak & Tretyak, 2020). This phenomenon needs further analysis and confirmation in GNSS time series in 2020-2021. The analysis of modeled NTAL during the short-term subsidence in Europe and up, east, north position changes of GNSS stations of Dnister HPP-1 is also provided. It can be seen in Figure 3, that the dynamics of GNSS stations and NTAL has no correlation. It leads us to the need for the regionalization of NTAL models.

We also can admit that there is a need to test NTAL vertical displacements with other very precise measurements of the region of Dnister Hydro Power Complex (Savchyn & Zyhar, 2020) or for the modernization of the Ukrainian height system (Dzhuman, & Zablotskyi, 2020) in general. Because the Earth as a whole respond to external forces as an elastic body and some corrections can possibly correct the results of precise leveling. Such models can be also tested for monitoring and compared by geodetic and geotechnical methods on technogenic disaster territories (Savchyn et al., 2019).

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