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Comprehensive processing of InSAR radar images and GNSS measurements to determine deformations of the Kaniv HPP dam

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INTRODUCTION

Military aggression in Ukraine and military actions led to numerous technogenically loaded and ecological disasters in a third of the territory. Buildings and structures of various purposes were damaged, partially or completely destroyed, including roads, railways, water and sewage systems, oil and gas pipelines, etc. There are constant technogenically loaded threats to critical and military infrastructure, including energy facilities and hydraulic structures. In this regard, monitoring of HPP dams, in particular by geodetic and geotechnical methods, is relevant. In the conditions of war, remote methods are especially relevant. To date, systems for continuous monitoring of their displacements and deformations have been installed on some dams of Ukrainian hydropower plants. At the Kaniv HPP, monitoring of spatial displacements and deformations of dams is performed periodically by traditional geodetic methods (high-precision leveling, GNSS surveying, linear-angular measurements). The periodicity of these measurements ranges from 3 to 12 months. This approach to determining displacements and deformations of dams does not provide continuous spatial information about dams and a satisfactory frequency of measurements over time. One of the ways to eliminate these shortcomings is the complex processing of the results of automated systems for monitoring displacements and deformations of the dam with remote sensing of these processes using interferometric synthetic aperture radar (InSAR). **The aim** of the study is to comprehensively process InSAR radar images and GNSS measurements to determine the vertical deformations of the Kaniv HPP dam. **The object** of study is the monitoring of the Kaniv HPP dam using satellite radar data and GNSS data from the network of the stationary system for monitoring the spatial movements of the Kaniv HPP structures.

SELECTED TEST RESULTS

In order to control the displacements and deformations of the Kaniv HPP dam, a stationary system for monitoring spatial displacements of structures was implemented, which is a hardware and software complex designed to perform periodic measurements by GNSS receivers and robotic electronic total stations (TPS) to determine the coordinate-time location of specially fixed on the surface of the dam geodetic points (Fig. 1). A detailed analysis of the time series of the results of GNSS and TPS measurements revealed seasonal horizontal and vertical fluctuations of all control points. Extreme values of displacements occur almost every year in the first decade of February (which corresponds to 0.1 year from the beginning of the year) and the first decade of August (which corresponds to 0.6 years from the beginning of the year) (Fig. 2). The study of surface deformations of the Kanivskaya HPP dam using satellite radar based on DInSAR technology was carried out in the freely available SNAP software on the Linux platform using radar images taken by the Sentinel-1 satellite and uploaded to the Copernicus Open Access Hub web platform (Fig. 3). 30 satellite images received by the Sentinel-1 satellite from August 10, 2020 to August 5, 2021, received every 12 days, were subject to processing (Fig. 4). In Fig. 5, 6 present histograms of the distribution of reduced differences.

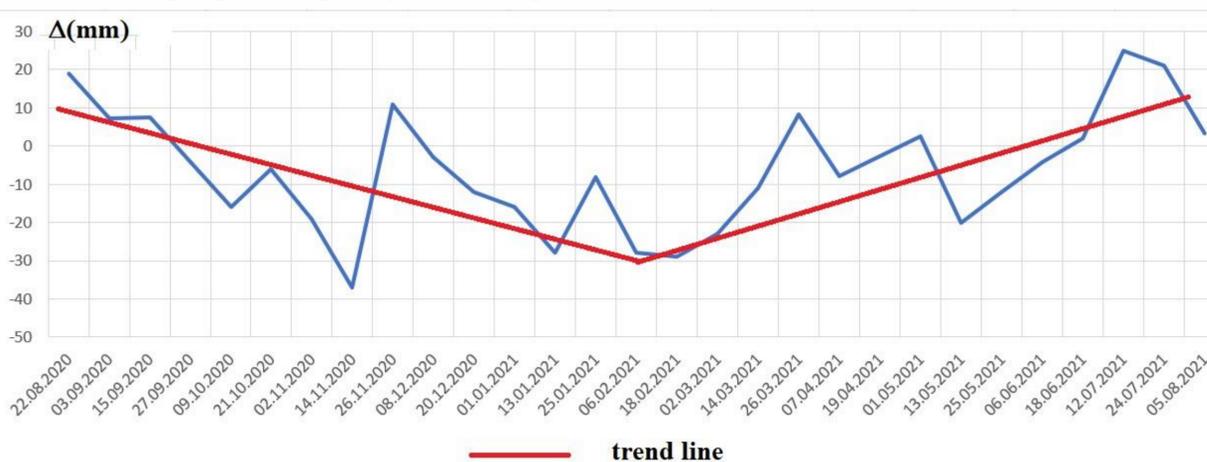**Figure 1. The network of geodetic points of the SSMPZS of Kaniv HPP**

Figure 4. The time series of the vertical displacements of one of the points located near the GNSS point MP2 determined by radar interferometry data
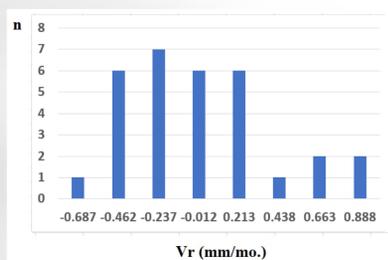

Figure 2. Time series of height displacements of the reference GNSS point MP1

Figure 5. Histogram of the distribution of reduced differences for the measurement period (2020.6 – 2021.1)
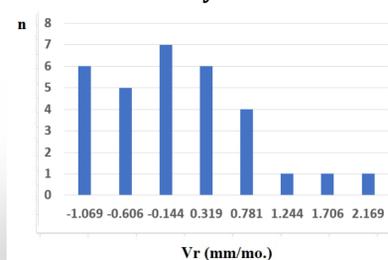

Figure 6. Histogram of the distribution of reduced differences for the measurement period (2021.1 – 2021.6)

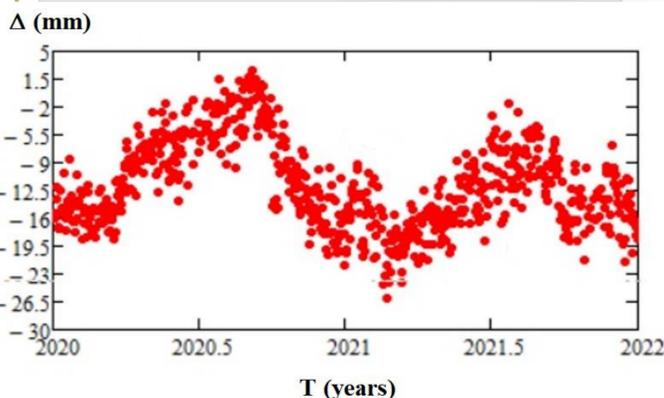**Figure 3. Map of vertical displacements for the period 10.08.20 - 14.11.20**

CONCLUSIONS

Research at the Kaniv hydroelectric power station was carried out at geodetic control points of the Stationary System for Monitoring Spatial Displacement of Structures. To compare the results of the surface vertical displacements of the Kaniv HPP dam, double processing of radar images was performed for a period of one year, from August 2020 to August 2021, with a frequency of 12 days. Data obtained by terrestrial and satellite methods demonstrate similar temporal and spatial displacement patterns. With the help of joint processing of radar images and instrumental GNSS and TPS data, the spatial distribution of velocities of vertical displacements of the Kanivskaya HPP dam was obtained and a zone of anomalous velocities was identified, where there are no GNSS points and reflectors for linear-angular measurements.

Summary: Research at the Kaniv hydroelectric power station was carried out at geodetic control points of the Stationary System for Monitoring Spatial Displacement of Structures. To compare the results of the surface vertical displacements of the Kaniv HPP dam, double processing of radar images was performed for a period of one year, from August 2020 to August 2021, with a frequency of 12 days. Data obtained by terrestrial and satellite methods demonstrate similar temporal and spatial displacement patterns. With the help of joint processing of radar images and instrumental GNSS and TPS data, the spatial distribution of velocities of vertical displacements of the Kaniv HPP dam was obtained and a zone of anomalous velocities was identified, where there are no GNSS points and reflectors for linear-angular measurements.

Keywords: satellite radar system, InSAR, GNSS-measurements, geodetic monitoring, surface deformations.