Assessing and forecasting landslide hazards of The Right Bank of the Kanev reservoir based on radar remote sensing data with corner reflectors using

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SUMMARY

The core problem of man-made and natural disasters is human activity. Modern radar materials of space surveys are unique data on the detection of geodynamic processes proceeding of the reservoir coast. Remote sensing and geological data are integrated into geoinformation systems to facilitate analysis and interpretation. The technique can potentially measure millimetre-scale changes in deformation over spans of days to years.

Introduction

The development of civilization in modern conditions is impossible without an anthropogenic impact on nature. The course of dangerous landslide processes is primarily determined by the peculiarities of the geological and geomorphological structure, hydrogeological, climatic, hydrological and seismic factors. The development of the economic complex of Ukraine over the past years has been taking place in the context of increasing technogenic destabilization of the geological environment. Real preconditions are being created for the activation of natural landslide-prone areas.

The territory of the right bank of the Kanev reservoir is located in the zone of the junction of the Ukrainian shield with the Dnieper-Donetsk depression, in the region of the eastern submergence of the shield. Sliding and squeezing block landslides prevail on the territory of the Kanev reservoir. The lithological age of the landslide rocks is associated with brown and variegated clays of the Neogene formation, sandy-clayey deposits of the Jurassic and Cretaceous formations, sandy-clayey and marl-chalk deposits of the Paleogene formation (*Paliienko at al., 2005*). A characteristic feature of landslides is the preservation of contacts between the unshakable base rocks and landslide masses. The period of temporary stabilization is replaced by a period of activity.

The main relief-forming exogenous processes developed in the study area are due to the specific features of the relief and the conditions of its formation. The development of the landslide process in the study area is closely related to the intensity of watering of the coastal slopes and the regime of aquifers. The maximum landslide activity occurs during periods when erosion processes were actively manifested, especially in spring when the snow melts, in summer during heavy rains.

Method

Modern methods of the erosion process dynamics studying are based on the use of remote sensing data and computer data processing facilities, which makes it possible to ensure the high accuracy of research inherent in ground-based methods. Detecting and mapping the high-precision land surface movement dynamics will serve as a very important indicator of potential environmental vulnerability. The technique for time series of land surface small displacements analysis and interpreting are described in Stankevich at alю, 2020. Geological and geophysical data are auxiliary for risk forecasting (*Kozlova at al., 2018*).

The studies of landslide hazard of lands using radar satellite interferometry are considered. Satellite radar interferometry is based on the processing of pairs of radar data images using phase information, the main purpose of which is to determine the value of the heights of points on the earth's surface (*Meisina at al., 2007*). Data acquisition is performed using synthetic aperture radar (SAR).

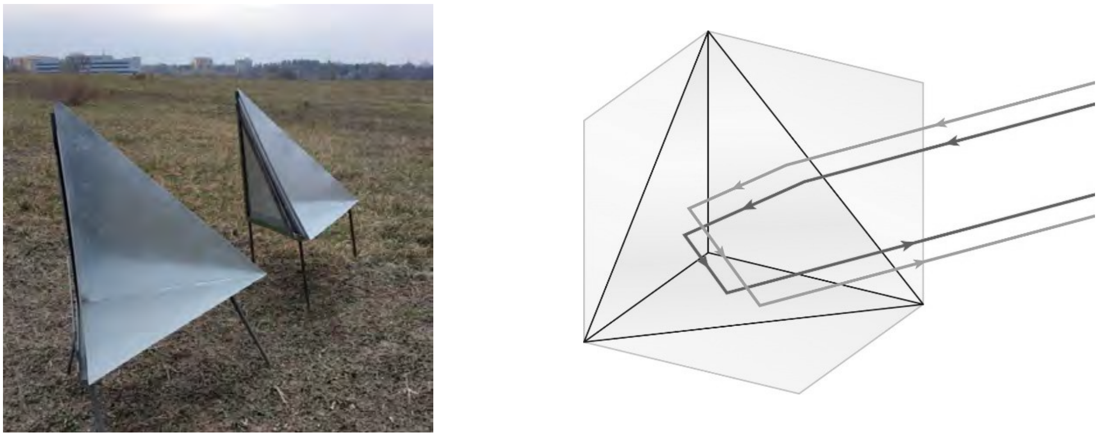
Many operational monitoring tasks require changes to be detected over some time. This can be accomplished using differential radar interferometry, which records the corresponding topographic changes in the DEM that have occurred over some time since the inception of the DEM (*Stankevich at al., 2019b*). When evaluating longer periods and limiting differential interferometry by temporal decorrelation, interferometry based on stable reflectors is used, which are artificial and natural objects coherent for many years and decades. These so-called stable reflectors can be used as reference points for the most sensitive remote sensing of Earth's crust movement (*Ferretti at al., 2001*).

Stable reflectors are generally defined as bright points in an image with a very high signal-to-noise ratio. However, the phase information itself cannot be used to identify stable points, since it contains phase uncertainties caused by unknown height and deformation, but for this, time series of amplitudes are well applied (*Devanthery at al., 2014*). The stable reflector technique uses a sequence of many radar interferograms of the same area of interest over a long period, establishing in the first stage a database of a very large number of radar images. From the observed phase time series of differential interferograms, it is possible to determine the difference in heights and the difference in strain rates in time.

Theoretical and experimental determination of the possibility of detecting corner reflectors in the Sentinel-1 radar images is an important task in the context of further application of the stable reflector method for performing precision radar interferometry.

Results

To verify the materials of the radar survey on the ground, corner reflectors were made of galvanized metal in the form of a triangular angle with mutually perpendicular planes and an edge size $a = 0.6$ m (Fig.1a). A theoretical evaluation of the brightness of the corner reflector was carried out for use in field research. Most often, a triangular corner reflector is used for field research, the diagram of the passage of radar beams in which is shown in Fig. 1b.



a *b*

***Figure 1** a - Experimental corner reflector; b -The signal path through a triangular corner reflector*

For a corner reflector, the specific effective scattering area σ_0 is calculated by the formula:

$$\sigma_0 = \frac{4\pi a^4}{3\lambda^2},$$

where a – is the edge length of the reflector, λ – is the wavelength of the radar radiation. The calculated specific effective scattering area of the corner reflector for the Sentinel-1 radar wavelength $\lambda = 5.547$ cm is $\sigma_0 = 176.39$ m^2.

Within the territory of Kiev, the study sites were selected with various factors that can affect the reflectivity of the reflector. Field work was carried out on selected test sites from February to June 2019. During the field work, data was obtained on the reflectivity of the corner reflector (backscatter coefficient), soil moisture and pH, as well as data on illumination and temperature of the earth's surface. The field work schedule was coordinated with the Sentinel-1A satellite operation calendar. The Sentinel-1 satellites are equipped with a Synthetic Aperture Radar C-band (SAR-C), which surveys at a frequency of 5.405 GHz (corresponds to a wavelength of 5.55 cm). This enables data to be collected in changing weather conditions, day or night. Sentinel-1 Groung Range Detected products are supplied to users with pixel dimensions of 10x10 m with a shooting time interval of 12 days (*https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-1*).

Within the experimental site "Pirogovo", the background brightness of the main types of the earth's surface was calculated for both polarizations of the Sentinel-1 radar data. The results of measurements of the specific reflectance of the predicted test areas with a corner reflector were obtained. The calculations assumed that the brightness of the reflector itself was 50% of the theoretical.

In theory, in most cases, the corner reflector is easily detected on virtually all backgrounds (Roofs, Asphalt, Vegetation and Open Ground). Taking into account the general purpose of the study - determination of landslide processes on the ground - it can be concluded that it is better to place the reflector on the open ground.

After conducting field studies and installing a corner reflector on test sites, the radar images obtained the brightness distributions exposed to it, as shown in Fig. 2.

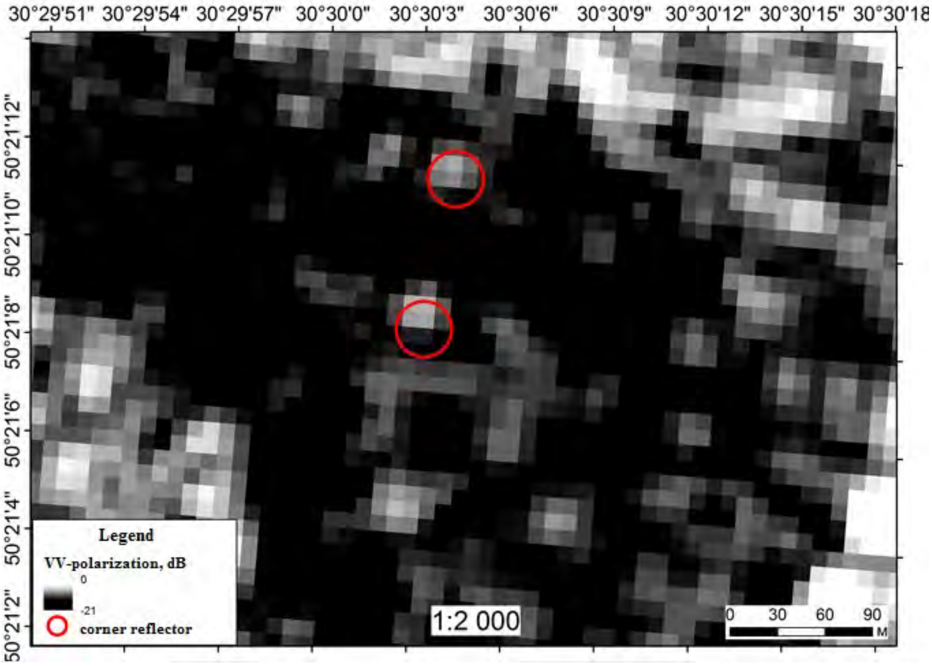


Figure 2 *Location of corner reflectors in the test region "Pirogovo" from 15.05.2019 against the background of satellite radar image Sentinel-1 (VV-polarization)*

The experimentally determined values of the signal-to-noise ratio for test sections with a reflector are given in the Table 1.

Table 1 *Experimental values of the "signal-to-noise" ratio of the test area*

Data	Brightness with corner reflector		Signal-to-noise ratio	
Polarization	VV	VH	VV	VH
04.04.2019	0,3467	0,0146	**19,7**	2,4
21.04.2019	0,049	0,0176	1,8	2,0
03.05.2019	0,1314	0,0176	**2,5**	1,2
15.05.2019	0,1243	0,0217	**2,5**	1,3

Based on the results of field studies, it was determined that the real reflectivity of the used experimental corner reflector differs significantly from the theoretical one. This can be explained by the discrepancy between the reflection characteristics of the reflector material and the mechanical imperfection of its manufacture. However, under favorable conditions even small-sized corner reflectors can be used as stable rappers when performing radar interferometry. Also, one of the solutions to this problem may be to increase the spatial resolution of radar images taking into account their subpixel displacement (*Stankevich at al., 2019a*).

Conclusions

The method of satellite differential radar interferometry, which detects the small land surface displacements with high accuracy, becomes more widely used. The output of the pair of images processing is a precision terrain elevations map. Obtained images describe the recent geodynamic conditions within the study area. Though temporal decorrelation and atmospheric inhomogeneity strongly affect interferogram quality, reliable deformation measurements can be obtained in a multi-image framework on a small subset of image pixels, corresponding to stable areas.

Digital maps enable following the spatial distribution of the selected objects. To conclude our research suggests that the geoinformation systems ensure functioning the system of monitoring of the landslide. Interferometry is one of the most important and difficult procedures in remote sensing.

The solution of different scientific and practical problems, using radar satellite images always includes a procedure of image classification. The performed studies are shown that under the conditions of typical hazardous landslide areas of the Kaniv Dnieper region it is possible to apply the remote radar interferometry aiming to estimate and predict the landslide developments. For this purpose, it is necessary to use the ground angle reflectors for radar signals, when their specific scattering cross-section is equal to the pixel sizes of the radar imagery. The values of these pixels should not exceed the few meters, because the coarseness of spatial resolution will cause an increase of the errors in the estimation of dynamics parameters for the land surface (*Stankevich at al., 2017*).

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