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Paper

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3 October 2019

Studying the coastal landslides processes by InSAR

Mila Atanasova, Hristo Nikolov

Author Affiliations +

Proceedings Volume 11156, Earth Resources and Environmental Remote Sensing/GIS Applications X; 1115619 (2019) <https://doi.org/10.1117/12.2532799>

Event: SPIE Remote Sensing, 2019, Strasbourg, France

ARTICLE FIGURES & TABLES REFERENCES CITED BY

Abstract

The landslides are one of the well-known natural hazards occurring on the North East Black Sea coast of Bulgaria. The previous researches that take into account the geological and meteorological peculiarities of this region confirmed that the geomorphological conditions in this region are extremely favorable for landslide formation. Two are the main drivers that are being responsible for activation of the landslide processes in the area investigated. The first one is the sea erosion and the other is the increasing groundwater level. The influence of those is highly aggravated by the construction activities that took place in the last decades and the lack of sewerage networks. Those findings are based on information provided by the national authority responsible for monitoring and filing the landslides in Bulgaria. This was the motivation for developing and implementing reliable and accurate method for operational monitoring of the landslide processes in the said area. For development of such method data from SAR instruments were used. In this specific study data from Sentinel-1 SAR mission were processed by the freely provided by ESA SNAP software. Final results are interferometric images (IFIs) providing information about the ground movements. In this paper we present results reflecting the subsidence in the area of a landslide located some 20km north of the Albena resort. In the last decade two events have caused damages to the infrastructure in the area - one occurred in January 2015 which was attributed to the heavy rains the previous summer and the other took place in mid of August 2018. Both have been studied by processing SAR data for the periods mentioned. The results obtained are considered reliable since they have been reaffirmed by geodetic surveys and other terrain measurements. The outcomes of this research will contribute to better understanding the ongoing slow movements of the Earth's crust, and for forecasting and early warning of geological hazards.

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Rainfalls and groundwater influences on landslides in Northeast Bulgaria

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 Authors Y. Chapanov¹, M. Atanasova², T. Orehova¹, H. Nikolov³
[View Affiliations](#)

Publisher: European Association of Geoscientists & Engineers

Source: Conference Proceedings, 10th Congress of the Balkan Geophysical Society, Sep 2019, Volume 2019, p.1 - 5

 DOI: <https://doi.org/10.3997/2214-4609.201902610>
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Summary

The main reason of landslide activation is rising of groundwater, saturation by rain, water infiltration and snow melting. One part of landslides in Northeast Bulgaria starts after heavy rainfalls, as was evident during the last 20-year wet period. The interconnection between the landslides in Northeast Bulgaria, rainfalls and groundwater maxima is investigated by variations of discharge for spring near Kotel and groundwater levels in two dug wells near Balchik, precipitation from meteorological stations Sofia, Varna, Veliko Tarnovo and Kazanlak, and Palmer Drought Severity Index (PDSI). The periods of maxima of precipitation, PDSI and groundwater time series are compared with the registered occurrence of landslides. Some part of landslides occurs after groundwater maxima, other part – after intensive short-time rainfalls without significant change of groundwater levels. It is necessary to analyze time series of precipitation and PDSI in order to provide comprehensive landslide forecast. The groundwater levels follow almost exactly the PDSI variations, while the short time intensive rainfalls are presented as significant spikes in precipitation time series. The hazard risk of landslides on the territory of Bulgaria should be estimated by the maxima of PDSI, real meteorological data from stations located near the Black Sea coast and inside the territory.

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STUDY ON THE GEODYNAMIC PROCESSES FOR THE AREA OF THE SOUTHWEST BULGARIA USING INSAR DATA

Atanasova, M.; Dimitrov, N.; Nikolov, H.

Abstract:

Geodynamic processes and seismic activity are considered to be the prime driver of horizontal and vertical movements of the Earth's crust in the Balkan Peninsula. One proven method for continuous monitoring of ground deformations is the use of data from active radar remote sensing. These data are the basis for the creation of interferometric images (IFIs) for quantitatively assessment the recorded ground movements of the Earths' surface within a fixed time interval. For this research a set of IFIs were created for areas surrounding the city of Sofia. The main objective of this research is monitoring of the ongoing geodynamic processes by complementary use of SAR and GNSS data. GNSS data from permanent and local geodetic networks are used for validation of the SAR derived information concerning the study area. The study will give reliable data for ongoing risky geo-processes for the region of the Southwest Bulgaria. Landslides are one of the main geological hazards that can cause critical damage to the infrastructure in an area and can result in serious risks to the people's safety there. Maps of active, stabilized and potential landslides in Southwest Bulgaria provided by the national landslide register part of the GIS maintained by Ministry of Regional Development and Public Works (MRDPW) are used. For mapping the deformations in the studied region interferometric images were produced at 4 months intervals. The results obtained from this study are used for the further development of the methodology for monitoring the risk of geo-processes by combining data from different sources.

SGEM Research areas:

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20 September 2020

Integrative use of GNSS and InSAR data: a case study of landslide on the Thracian rocks coastal slope

Mila Atanasova, Hristo Nikolov

[Author Affiliations +](#)

Proceedings Volume 11534, Earth Resources and Environmental Remote Sensing/GIS Applications XI; 1153405 (2020) <https://doi.org/10.1117/12.2573641>

Event: [SPIE Remote Sensing, 2020, Online Only](#)

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Abstract

The main objective of this research is monitoring of landslide areas by integrating results from interferometric images, and GNSS data from permanent and local geodetic networks. This study is providing reliable information with regard to the hazard geo-processes taking place in the region of the landslide area Thracian Rocks. To accomplish the aforesaid first step was to create a local archive of about 400 SLC images from ESA operated mission Sentinel-1 starting from the beginning of 2015. In this archive data from ascending and descending satellite orbits were included in order to increase the reliability of the information derived from SAR data. Due to considerable occurrence of vegetation in the studied area, which is recognized as one of the factors increasing the decorrelation during DInSAR processing, the authors processed mainly scenes with minimum availability of leaves on the trees and shrubs – autumn and spring. The geological setting of the landslide region reveals a narrow strip formed by old landslides that have an average width of 400–500 m and steep slopes of 40–50 m at certain locations. From this setting it was established that the landslide bodies have been formed by 3–4 visible linearly oriented steps and landslide packages with different heights creating negative ground forms with permanent or temporary swamps. Besides the ancient landslides a recent active local landslide processes occur forming recent landslides. In the framework of this study a control geodynamic network covering the landslide area located in the surroundings of Thracian Cliffs golf club was established. In it included are 10 points stabilized with metal pipes which are used to monitor deformations in this area. An advantage of the approach should be pointed out the possibility to map areas that are inaccessible by other means.

Conference Presentation

**MONITORING OF THE LANDSLIDE PROCESSES AT THE
"DALGIYA YAR" LANDSLIDE**

Assoc. Prof. Dr. Nikolay Dimitrov

Prof. Ds. Ivan Georgiev

Assoc. Prof. Dr. Mila Atanasova

Dr. Anton Ivanov

National Institute of Geophysics Geodesy and Geography, Bulgarian Academy of Sciences,
Bulgaria

ABSTRACT

The study of landslides is of particular importance because they can lead to great material damage. The region of the Bulgarian northern Black Sea coast is affected by many landslides and it is important to monitor motions of the major landslides in this area. The paper outline deformation analysis of the landslide processes in the area of "Dalgiya yar". It is a landslide circus from the Varna landslide region that covers several active landslides, whose boundaries are overlapping and for that reason are difficult to differentiate. For some of the landslides located in this area, a smaller landslide could be delineated inside them. For this study we used data from two epochs measurements - in 2013 by classical and in 2018 by GNSS, provided by Ministry of Regional Development and Public Works and new GNSS measurements performed in 2019 year of the geodetic network in the "Dalgiya Yar" landslide. The coordinates obtained by processing of the last GNSS measurements along with coordinates from first two epochs are processed together to solve for point's velocities of the established geodetic control network. Strain rates, crustal dynamic parameters and point's velocities of the network are obtained. The horizontal motions of the landslide vary from 13 mm/y to 46 mm/y. Separately, the landslide movements are estimated by D-iNsar technics using images produced by Sentinel-1. Comparison of the results from both methods shows a good agreement. The results contribute to obtain reliable information about the origin and dynamics of the landslide movement process as well as the assessment of the resulting hazards for the population and the infrastructure. As a whole, the results unambiguously show the necessity to permanently monitor the landslide and the same is valid for most of the North Black Sea landslides.

Keywords: Landslide monitoring, GNSS, crustal dynamic parameters

B.4.6.

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26 August 2020

Study of the contemporary state of the landslides in the northern Bulgarian Black Sea coast

Hristo Nikolov, Mila Atanasova, Keranka Vassileva, Rosen Nankin, Plamen Ivanov, Nikolay Dimitrov

[Author Affiliations +](#)

[Proceedings Volume 11524, Eighth International Conference on Remote Sensing and Geoinformation of the Environment \(RSCy2020\); 115241C \(2020\) <https://doi.org/10.1117/12.2570678>](#)

Event: Eighth International Conference on Remote Sensing and Geoinformation of the Environment (RSCy2020), 2020, Paphos, Cyprus

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Abstract

The territorial distribution of landslides along the Northern Bulgarian Black Sea coast has been evaluated by analyzing the results of field surveys for 2018 and 2019 based on geological surveys and processing of interferometric images from synthesized aperture radars (SAR). A local image archive of Sentinel-1A/B was created for the period 2015 - 2019 for this region and interferograms were produced every 4 months, 8 months, 1 year and in case of registering an event, led to the activation of landslide processes. A raster map of the concentration of deformations of the Earth's crust was created based on data from the obtained interferograms. Areas with active landslide movements along the Northern Bulgarian Black Sea coast have been identified for monitoring with the Global Navigation Satellite Systems (GNSS). A geodynamic network of 30 points covering the landslide circus "Dalgiya Yar" and landslide "Thracian Cliffs" was established and the first measurement cycle was carried out.

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Hristo Nikolov, Mila Atanasova, Keranka Vassileva, Rosen Nankin, Plamen Ivanov, and Nikolay Dimitrov "Study of the contemporary state of the landslides in the northern Bulgarian Black Sea coast", Proc. SPIE 11524, Eighth International Conference on Remote Sensing and Geoinformation of the Environment (RSCy2020), 115241C (26 August 2020); <https://doi.org/10.1117/12.2570678>

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20 September 2020

Studying the slope deformations in a Bulgarian mountain by multitemporal DInSAR data processing

Hristo Nikolov, Mila Atanasova, Plamen Ivanov, Boyko Berov

[Author Affiliations +](#)

Proceedings Volume 11533, Image and Signal Processing for Remote Sensing XXVI; 1153319 (2020)

<https://doi.org/10.1117/12.2573945>

Event: SPIE Remote Sensing, 2020, Online Only

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Abstract



This research is focused on registering the movements along the slope of the several slopes located on south-west of the mountain Stara Planina and establishing their average annual values. Currently at national level there are a low number of studies targeted at operational monitoring of the investigated slopes. These objects are quite specific for research since those kind of natural phenomena are inaccessible by other means or are quite dangerous to be investigated. On the other hand, the moving slopes are causing damages to infrastructural objects such as roads, bridges or power lines. Their behavior is difficult to forecast and for this reason they can be considered as natural hazards. Obtaining precise data for the single slope movements is done by in-situ investigations such as geodetic acquisitions, terrestrial laser scanning, and geological observations, which all require financial resources and human effort. For this reason, we used remotely sensed data from satellite based SAR instruments processed using the DInSAR method in order to analyze the motions of single slope and to establish a technique for the investigation of mountain slopes. An advantage of the selected method is the possibility to register the vertical movements of the whole slope with centimeter accuracy. This approach is based on the free access to the SAR data and tools for their thematic processing provided by ESA. In this study an emphasis is put on the manner how the obstacles encountered during the interferometric processing (e.g. presence of vegetation or topography) have been overcome. From the downloaded set of SAR images covering the region created were two multitemporal InSAR data series from ascending and descending orbits of the satellite. The results from the autumn-winter pairs exhibited good correlation with the expected displacements along the studied slope having a magnitude of 0.8 m.

Conference Presentation

B.4.8.

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26 August 2020

Studying seismic events via satellite interferometry

Hristo Nikolov, Valentina Protopopova, Mila Atanasova

[Author Affiliations +](#)

Proceedings Volume 11524, Eighth International Conference on Remote Sensing and Geoinformation of the Environment (RSCy2020); 115241B (2020) <https://doi.org/10.1117/12.2570676>

Event: Eighth International Conference on Remote Sensing and Geoinformation of the Environment (RSCy2020), 2020, Paphos, Cyprus

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Abstract

Satellite radar instruments deliver SAR data that are able to provide information on the magnitude of ground motions in range of centimeters. Such information is of extreme importance in assessing the consequences of natural or man-made disasters. Since earthquakes are occurring constantly and are not possible to predict it is recognized that any information on the size of these events is important for the local and national authorities responsible for mitigation of the post-event damages. In this research presented are the results obtained after processing two sets of SAR data along with other supplementary data in order to produce two interferometric images that provide information on the deformation processes after several earthquakes that took place on the Ionian shore of Albania in the second half of November 2019. The resulting deformation maps from ascending and descending orbits of the Sentinel1 satellite mission were compared to increase the reliability of the conclusions made upon them. The outcomes reported suggest that it would be possible to deliver to the national authorities details on deformation in regions that are problematical to inspect directly.

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Hristo Nikolov, Valentina Protopopova, and Mila Atanasova "Studying seismic events via satellite interferometry", Proc. SPIE 11524, Eighth International Conference on Remote Sensing and Geoinformation of the Environment (RSCy2020), 115241B (26 August 2020); <https://doi.org/10.1117/12.2570676>

B.4.9.

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12 September 2021

Surface displacements determinations at "Fish-Fish" landslide area based on UAV photogrammetric surveys and remotely sensed SAR data

Mila Atanasova, Hristo Nikolov

[Author Affiliations +](#)

Proceedings Volume 11863, Earth Resources and Environmental Remote Sensing/GIS Applications XII; 1186317 (2021) <https://doi.org/10.1117/12.2599416>
Event: SPIE Remote Sensing, 2021, Online Only

Abstract

Landslide occurrences are result of natural or human activities, but regardless of the origin they change the landscape, destroy infrastructure and in some cases even leads to loss of human lives. In order to assess the hazard of this phenomenon remotely sensed data from aerial and satellite instruments are widely used to monitor the ground motions at regular intervals. Those methods are less expensive and less time consuming than terrain inspections and measurements and the other hand the size of the studied areas is larger. This was the rationale to initiate a study on the surface deformations in the area of "Fish-Fish" landslide located on the north part of the Black Sea coast of Bulgaria. Two sources of data were used to create a map of recent surface displacements in the said area – photogrammetric surveys with UAV and remotely sensed images from synthetic aperture radar from satellite instruments. The area of the landslide was investigated by photogrammetry in years 2019 and 2020 and as result created were two digital elevation models. The accuracy allowed registration of the surface motions at centimeter scale using ground control points located inside and outside the perimeter of the landslide. The satellite SAR data are provided at no cost by ESA originating from the twin constellation of Sentinel-1 mission. The authors downloaded SAR data for the same periods when the UAV surveys were made. Due to peculiarities of the local terrain it was possible only SAR images from descending orbit to be used. The processing of those data was done by verified interferometric processing method implemented in the SNAP software. Finally the results from control points for both sources were compared and good correlation between them was established. A map of the landslide area depicting the registered ground displacements was produced.



СПИСАНИЕ НА БЪЛГАРСКОТО ГЕОЛОГИЧЕСКО ДРУЖЕСТВО,
год. 82, кн. 3, 2021, с. 159–161

REVIEW OF THE BULGARIAN GEOLOGICAL SOCIETY,
vol. 82, part 3, 2021, p. 159–161



Национална конференция с международно участие „ГЕОНАУКИ 2021“
National Conference with International Participation “GEOSCIENCES 2021”

Use of two contemporary remote sensing technologies for mapping the Thracian Cliffs landslide (Northern Bulgarian Black Sea Coast)

Два съвременни метода за картографиране на свлачище „Тракийски скали“ чрез дистанционни изследвания (Северно Черноморие на България)

Mila Atanasova¹, Hristo Nikolov²

Мила Атанасова¹, Христо Николов²

¹ National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences, 1113 Sofia;
E-mail: mila_at_zl@abv.bg,

² Space Research and Technology Institute, Bulgarian Academy of Sciences, 1113 Sofia; E-mail: hristo@stil.bas.bg

Abstract. In this paper are presented the results from the investigations of the active landslide, located in front of the Thracian Cliffs golf club (Northern Bulgarian Black Sea Coast) for the period 2019–2021. Extensive research by means of *in-situ* and remote sensing has been carried out on the latest landslide activations. As part of the study, a control GNSS geodynamic network was established. This network was used as benchmark for the results obtained from satellite SAR data processing and UAV surveys targeted at monitoring the modern landslide developments.

Keywords: landslides, UAS technology, GNSS RTK data, InSAR.

Creating a thematic geodatabase for monitoring the landslide processes of the landslide circus “Dalgia yar”

Mila Atanasova¹, Hristo Nikolov², Ivan Georgiev¹, Keranka Vassileva¹, Nikolay Dimitrov¹, Anton Ivanov¹

¹National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences, Acad. G. Bonchev Street, Bl. 3, 1113 Sofia, Bulgaria

²Space Research and Technology Institute, Bulgarian Academy of Sciences, Acad. G. Bonchev Street, Bl. 1, 1113 Sofia, Bulgaria

m.atanasova@geophys.bas.bg

Abstract. Impact on the process of landslide origin and activation is result of many factors both endogenous and exogenous. The purpose of this study is to provide possibility for analysis and assessment of the geo-processes in the “Dalgia yar” landslide located at Northern Black Sea coast of Bulgaria in order to prevent risks and disasters of natural and anthropogenic origin. An important stage was to seamlessly include data from different sources such as geodetic measurements, satellite SAR (Synthetic-aperture radar) data as well as geological and geophysical data. The established geodatabase structures the collected information on dangerous geo-processes in the mentioned area and introduces them into the GIS (Geographic information system) environment. Its purpose is to facilitate the analysis of the available geological data for this landslide and to integrate them with results of measurements from regular monitoring. Interferometric images (IFIs), data from permanent GNSS (Global Navigation Satellite Systems) stations and from local geodynamic GNSS network, geological, seismic and geophysical data, updated geological maps and maps of the risk of landslide processes are included in the database. The IFIs have been produced using well established procedure for processing large number of Sentinel-1 SAR data of the purposely created local archive. Other key element used to improve the final results of SAR data processing and important part of the geodatabase is the precise Digital Elevation Model (DEM), which is much better in terms of horizontal and vertical resolutions than the open accessed ones (SRTM). The coordinates and velocities of the GNSS points are obtained from adjustment and analysis of two epoch measurements of the geodynamic control network of landslides “Dalgia yar”. Since the area has complex geological structure, small scale maps reflecting the geological and geophysical hazards are integral part of the geodatabase. Having all this information the analysis concerning the ongoing geodynamical processes in the study area is significantly improved and more reliable information is produced for better regional planning by the local authorities and residents.

B.4.12.



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CO-SEISMIC SURFACE DISPLACEMENTS AFTER THE EARTHQUAKES IN LARISSA, 3 MARCH 2021, DERIVED BY DINSAR

Atanasova-Zlatareva, M.; Nikolov, H.; Oynakov, E.

Abstract:

The focus of this study is detection of the deformations of the Earth's surface caused by March 3 2021 earthquake using Differential Interferometric Radar Synthetic Aperture technique. This method takes advantage of the remotely sensed SAR data provided at no cost by ESAs' Sentinel-1 mission which are often used for creation of topographic maps as well as for detection of ground motions. The final results of this processing deliver reliable information about the displacements caused by the mentioned events with centimeter accuracy. The DInSAR approach is based on precise measurements of the phase of the backscattered from the surface radar signal at different dates of acquisition. Based on the differences registered in both signals conclusions on the relative motions are drawn from the created interferometric image (IFI). In the course of the IFI formation a measure of its quality, named coherence, is created too. It needs to be emphasized that the registered ground displacements are in the line-of-sight of the radar and after additional calculations can be transformed into subsidence values. For this research produced were IFIs from two ascending (south-north) and two descending (north-south) orbits of the satellite which provided more details on the occurred ground motions after all earthquake events. The time period covered by the IFIs is from February 25th 2021 to March 20th 2021. The results obtained exhibited high values in the coherence images which guarantee reliability of the final information. All geocoded IFIs were co-registered to the first one which is produced. After that several profile lines reflecting the surface displacements resulting from the events were produced.

SGEM Research areas:

B.4.13.

Bulgarian Academy of Sciences. Space Research and Technology Institute.
Aerospace Research in Bulgaria. 33, 2021, Sofia

DOI: <https://doi.org/10.3897/arb.v33.e07>

APPLICATION OF GNSS AND SAR DATA IN LANDSLIDE MONITORING ALONG THE BLACK SEA COAST OF BULGARIA

Mila Atanasova¹, Hristo Nikolov², Keranka Vassileva³

¹*National Institute of Geophysics, Geodesy and Geography – Bulgarian Academy of
Sciences*

²*Space Research and Technology Institute – Bulgarian Academy of Sciences*

³*Faculty of Physics, Sofia University “St. Kliment Ohridski”,
e-mail: mila_at_zl@abv.bg*

Keywords: *GNSS Data, SAR Data, Black Sea Coast, Landslide Processes*

Abstract

Landslide processes are considered the major part of the natural hazards occurring on the northern part of the Bulgarian sea side. Their monitoring can be done with high precision using GNSS data. The objective of this study is to provide solid grounds for monitoring of the landslide processes using GNSS and SAR data. This goal will be achieved by the implementation of the following: 1) establishment a verified methodology for extracting high-quality information from SAR images aimed at continuous monitoring of landslide areas integrating Interferometric Images (IFI) and GNSS data and 2) creation of a working prototype of an information system for monitoring and prevention of the effects of earth crust movements (landslides, falls, etc.) based on freely accessible data provided by ESA and national sources. One of the scientific tasks to be solved includes the development of methodological approaches for comparison of the results from combined processing of interferometric images from SAR, measurements at permanent GNSS stations of the national NIGGG network in the area of study and geodetic measurements of a newly established test network covering a specific area on the Northern Black Sea coast of Bulgaria with active landslide processes.

B.4.14.



Euro-Mediterranean Conference for Environmental Integration

↳ EMCEI 2019: **Recent Advances in Environmental Science from the Euro-Mediterranean and Surrounding Regions (2nd Edition)** pp 2063–2067 | [Cite as](#)

Adding New Information Content to GNSS Measurements by SAR Data Processing in Studying a Landslide

[Mila Atanasova](#)  & [Hristo Nikolov](#)

Conference paper | [First Online: 10 April 2021](#)

19 Accesses

Part of the [Environmental Science and Engineering](#) book series (ENVSCIENCE)

Abstract

The availability of verified information concerning hazardous geo-processes is of prime importance in monitoring active or potential landslides since they largely affect human lives, infrastructure, and ecological status. Based on data from the Bulgarian national authority in charge of inventories, the landslides number has been constantly increasing since the past decade due to natural phenomena and human activities. Hence, it is necessary to establish a reliable procedure for operational monitoring. In this paper, a procedure is proposed for tracking landslide dynamics based on combining the advantages offered by Global Navigation Satellite System (GNSS) measurements and the information derived from interferometric images produced from Synthesized Aperture Radar (SAR) processing. The latter provides the possibility to register the earth's crust deformations with a magnitude of centimeters. This study covers the landslide area named Trifon Zarezan situated at the Bulgarian Northeast Black Sea Coast. The obtained results can be used as an additional source of information on ground deformations in active ground zones by a large number of local stakeholders, e.g. construction or utility companies.

Keywords

Landslide

GNSS data

DInSAR

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Application of Contemporary Technologies for Monitoring Landslides „Thracian Cliff“

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Authors M. Atanasova-Zlatareva¹, H. Nikolov², I. Georgiev¹, A. Ivanov¹

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Summary

The area of research interest is an activated landslide located near the village of Topola, Kaliakra municipality and it is manifested in the front of an ancient stabilized landslide "Kalkan tepe". The combined GNSS and InSAR applications for landslide monitoring in the north of the Black Sea coast, Bulgaria conducted in the past 3 years aimed to contribute to the complex geodetic and geological research. Due to their high precision GNSS are very appropriate for investigating geodynamic processes. The InSAR technique is a remote sensing technique mostly applied for the detection and monitoring of earth surface deformations with wide spatial coverage. In November 2020, an aerial drone survey of the Thracian Cliff landslide was performed using UAS technology to mapping surface models of the study area. The ability to observe many points (pixels), including the whole object, as well as their behavior over time, allows the development of models of the deformation process and facilitates the solution of a number of tasks on forecasting and geohazard. The application of contemporary technologies for monitoring greatly facilitates the monitoring of landslide deformation processes.

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PROCESSING AND ANALYSIS OF CORS GNSS DATA FOR THE STUDY OF LANDSLIDES IN THE NORTHERN BLACK SEA COAST

Dimitrov, N.; Atanasova-Zlatareva, M.; Georgiev, I.

Abstract:

The Bulgarian northern Black Sea coast is affected by many landslides. Several geodynamic networks have been built to study landslide processes in the northern Black Sea coast. Landslide research is important, as these phenomena can lead to great material damage. Their destructive impact on buildings, engineering structures and disturbances in the resilience of the earth's crust causes enormous economic, environmental, social and other damage, and often takes human lives. A modern tool for monitoring landslides is the application of GNSS measurements, which has an advantage over conventional measurement methods. GNSS data from six continuously operating reference stations from National GNSS network for three years and a half period are processed and analyzed. Time series with coordinates and mean square errors (north, east and up) are obtained. Time series with the residuals from multi-year solution are obtained too. The time series show the very good quality of the solution (the values of nrms are between 0.60 and 0.80). In this study long-term processing of data from continuously operating reference stations (CORS) is performed, to obtain the coordinates and velocities of the stations, because this also affects the local networks built for the study of landslides. The velocities of the points from the National GNSS network in the northern Black Sea region are relatively small, less than 1 mm/year. To obtain the movements of the points from the local geodynamic networks, it is necessary to process their GNSS measurements together with the GNSS measurements from the continuously operating reference stations from National GNSS network but the velocities of the station must be taken in to account, as done in this study. This allows to determine whether the measured points are located in the landslide or outside it and thus to accurately determine landslide boundaries.

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Paper



Study on Ground Motions in Southwest Bulgaria based on in-Situ and Satellite Data

Topics: Big Data and GIS; Disaster Management; Geodesy; Image Processing and Pattern Recognition; RADAR and LiDAR

In Proceedings of the 7th International Conference on Geographical Information Systems Theory, Applications and Management - GISTAM, 157-164, 2021

Study on Ground Motions in Southwest Bulgaria based on in-Situ and Satellite Data

Mila Atanasova-Zlateva¹, Hristo Nikolov² and Nikolay Dimitrov¹
Department of Geodesy, National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences, Bulgaria
 Institute of Space Research and Technology, Bulgarian Academy of Sciences, Bulgaria

Keywords: Ground Movements, SAR Data, GNSS, Crustal Deformation

Abstract: In the last decades the new satellites are being used more frequently to study the ground movements. This fact is evidenced by the increased number of research papers and projects using freely provided data by space agencies such as ESA (European Space Agency) and JAXA (Japan Aerospace Exploration Agency) and increased revisiting time of the new instruments on-board satellites. Other reason for this increase are the latest developments in processing methods such as PSI (Persistent Scatterer Interferometry) and even increasing number of cloud processing options provided by universities and research centres. Nevertheless the information obtained by this manner has some drawbacks for example moderate spatial resolution. This is why in-situ data from precise GNSS (Global Navigation Satellite System) measurements are essential. In this study the authors used both kinds of data to study one of the regions of Bulgaria which is recognized to be highly prone to seismic and geological hazards.

1 INTRODUCTION

The main objective of this research is monitoring of the ongoing geodynamic processes by complementary use of SAR and GNSS data. GNSS data they provided the local precise movements around the study area. The study will provide reliable data for mapping the geoprocesses for the region of the Southwest Bulgaria. Geodynamic processes and seismic activity are considered to be the main drivers of horizontal and vertical movements of the Earth's crust in the last decades. One proven method for continuous monitoring of geodynamic deformations is the use of data from satellite remote sensing. These data are the basis for the creation of interdisciplinary research.

2 PREVIOUS GPS MEASUREMENTS, RESULTS AND ANALYSIS

In 1993 a GPS geodynamic network for accurate monitoring of the crustal movements is established in the region within a part project with the Ministry of Education and Science of Bulgaria.

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Authors: Mila Atanasova-Zlateva¹; Hristo Nikolov² and Nikolay Dimitrov¹

Affiliations: ¹ Department of Geodesy, National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences, Sofia, Bulgaria; ² Institute of Space Research and Technology, Bulgarian Academy of Sciences, Sofia, Bulgaria

Keyword(s): Ground Movements, SAR Data, GNSS, Crustal Deformation.

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Applying the DInSAR Method for Surface Deformations Detection in Pernik Valley

[Buy this Content](#)Authors M. Atanasova-Zlatareva¹, H. Nikolov²[View Affiliations](#)

Publisher: European Association of Geoscientists & Engineers

Source: Conference Proceedings, 11th Congress of the Balkan Geophysical Society, Oct 2021, Volume 2021, p.1 - 5

DOI: <https://doi.org/10.3997/2214-4609.202149BGS12>[« Previous article](#) | [Table of Contents](#) | [Next article »](#)[Abstract](#)[Full-Text](#)[Figures & Tables](#)[References \(6\)](#)[Cited By](#)[Supplements](#)[Metrics](#)[Related Content](#)

Summary

The need for regular monitoring of the ongoing surface displacements is highly recognized by local, national, and international authorities since they are responsible for losses of human lives and cause significant damages to homes, infrastructure, and industrial objects. In this research, the DInSAR method was applied to investigate the ground deformations in a highly populated and industrialized area of the Pernik valley. Outlined in it are the advantages of the technique used and the possibilities offered by processing freely available SAR data to produce reliable results concerning the Earth's motions in the researched area.

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12 September 2021

Obtaining ground deformations by multitemporal DInSAR processing in vicinity of archaeological site “Solnitsata-Provadia”

Hristo Nikolov, Mila Atanasova

[Author Affiliations +](#)

Proceedings Volume 11861, Microwave Remote Sensing: Data Processing and Applications, 118610C (2021) <https://doi.org/10.1117/12.2599762>

Event: SPIE Remote Sensing, 2021, Online Only

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Abstract

The Differential Radar Interferometry (DInSAR) technique provides fast and accurate means for detecting small displacements of the Earth’s surface having a magnitude in centimeters range. Applying this method monitoring of ground movements of natural or anthropogenic origin are reliably registered. The information is produced from the interferograms resulting from purposely processing the phase signal present in two SAR images from different dates over the one and the same area. The motivation behind this research was to study the crustal deformations that pose treat to the archaeological site “Solnitsa-Provadia” located in the area Mirovo salt deposit near the town Provadia, NE Bulgaria. It needs to be mentioned that the said monument is dated back to VI-V millennium BC and includes the remnants of an ancient city near Provadia. The registered deformations in the region are due to natural and anthropogenic factors. The mentioned factors have undisputable negative impact on the preservation of this historical site and justify the necessity of regular monitoring of the ongoing geodynamic processes. In this research the authors provide results based on multitemporal processing of freely accessible SAR data from Sentinel-1 mission by ESA. The information concerning the detected surface deformations was obtained by the DInSAR method. The multitemporal processing included creation of set of interferometric images from several periods with time span of four months. This interval was selected since it was needed to decrease the decorrelation of the phase signal caused by the vegetation and noise introduced by the atmosphere. In order to increase the reliability of the output information SAR data from ascending and descending orbits were processed which provided two different stereoscopic-like views to the investigated area. The results also have been compared with the trends of ground motions using data from repeated multi-year results geodetic measurements made at Mirovo geodynamic network.

F.7.3.



Establishing Surface Displacements along a Railway Route near Mirovo Salt Deposit, NE Bulgaria

Topics: Earth Observation and Satellite Data; RADAR and LIDAR

In Proceedings of the 8th International Conference on Geographical Information Systems Theory, Applications and Management - GISTAM, 155-162, 2022

Authors: Mila Atanasova-Zlateva¹ and Hristo Nikolov²

Affiliations: ¹ Department of Geodesy, National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences, Sofia, Bulgaria; ² Remote Sensing Systems Department, Space Research and Technology Institute, Bulgarian Academy of Sciences, Sofia, Bulgaria

Keyword(s): Ground Movements, SAR Data, GNSS Networks, Railway Line Deformations.

Abstract: Studying Earth's surface motions using data acquired by active instruments such as satellite Synthetic Aperture Radar (SAR) have become ubiquitous in the last years. This trend could be attributed to large extent to the open data policy of ESA that provides such type data from Sentinel-1 mission at no cost from several online repositories. On the other hand the results produced after processing them need to be validated by data from other sources. In this paper a framework for SAR data processing is presented, whose results are compared and analysed with results from GNSS networks. In order to increase the reliability of the information provided by the radar data used in this research ascending and descending orbits of the satellite were used in order to decrease the effect of the topography. Part of railway line which passes through the town of Pravdia and industrial area near it was selected as test site. This object was chosen since surface deformations often occur in it caused by [\(More\)](#)



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- Harvard
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- EndNote

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GROUND DISPLACEMENTS DETECTION IN TRIFON ZAREZAN LANDSLIDE BASED ON GNSS AND SAR DATA

Mila ATANASOVA¹ and Hristo NIKOLOV²

UDC: 551.311.24:[528.8:629.783(497.2)

ABSTRACT

The Trifon Zarezan landslide is one of the well-studied areas north of Varna. It has been registered in 1998 and monitored since then, but due to expansion of construction activities and lack of sewerage facilities in 2005 it exhibited strong activation seriously damaging the panoramic coastal road remaining closed up to nowadays. One important issue in mitigating the effect of this phenomenon is its continuous monitoring and one promising solution of this problem is the usage of differential Synthetic Aperture Radar interferometry. In the framework of this study two sources of data have been used – three geodetic surveys and SAR data from C-SAR instrument onboard Sentinel-1. The main research objective was to combine the advantages offered by both data sources in order to produce regularly updated information about the whole site. The GNSS data are precise, but does not originate from dense geodetic network, while SAR data cover the whole area, but they lack of high spatial resolution which is disadvantage in case of exploring small areas such as this one. Based on the results achieved it can be concluded that both sources of data provide complementary information confirming the overall behavior of the studied phenomena for the time period analyzed.

Key words: landslide, GPS data, DInSAR

**XXVIII INTERNATIONAL SYMPOSIUM ON
MODERN TECHNOLOGIES, EDUCATION AND PROFESSIONAL PRACTICE
IN GEODESY AND RELATED FIELDS**

Sofia, 08 - 09 November 2018

**STUDY ON THE CORRELATION BETWEEN SOIL MOISTURE AND
ACTIVE LANDSLIDE PROCESSES IN NORTHWEST BULGARIA BASED
ON SAR DATA**

Mila Atanasova, Hristo Nikolov (BG)

ABSTRACT

The influence of the water level of the Danube River and its tributaries is one of the key factors for the development of landslide processes in the northwestern part of Bulgaria. Beginning with the assessment of the specific geological situation for the region in which the study was carried out, namely from Vidin to Nikopol, where a large number of landslides were located, the perimeter of their distribution was specified. Most of these landslides are active and stabilized, forming an almost continuous line. A characteristic feature of this type of objects in the area is that they are in a fragile balance, which is often lost when increasing the amount of surface and groundwater which is considered the main reason for their activation. Within this study, free-access data from the SAR apparatus on the Sentinel-1 satellite was used to monitor the shape of the water bodies and determine the amount of soil moisture. This information was used as an indicator for the initiation and subsequent monitoring of potential landslide activities. For some of the landslides in the region (Lom, Oryahovo), interferometric maps were created to assess the surface deformation, and for the same period the areas of the water bodies and the soil humidity were evaluated. The complex approach applied in this study required the use of data from different sources that were integrated and processed in GIS environments.

Keywords: InSAR, landslide processes, mapping of water bodies, soil moisture content

Г.8.3.



IX Национална конференция по геофизика, 30 Ноември 2018
IX National Geophysical Conference, 30th November 2018

Determination of deformations of the Earth's crust after an earthquake by DInSAR

Mila Atanasova^{1}, Hristo Nikolov², Valentina Protopopova¹*

¹ National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences, Sofia 1113, Bulgaria, mila_at_zl@abv.bg

² Space Research and Technology Institute, Bulgarian Academy of Sciences, Sofia 1113, Bulgaria

Key words: DinSAR, deformations of the Earth's crust, earthquake

Abstract

Earthquakes are a natural disaster causing damage that is measured by human lives and destruction of natural and infrastructural sites. The direct consequences of their occurrence are tsunamis, landslides activation, earth ruptures and ground vibrations. An important task after the occurrence of such event is preparation of a plan to manage them, based on the current status of the territory. A valuable source of data about the current state of earth surface is the EU Copernicus program. One of its components is the two-satellite Sentinel-1 mission that provides data from synthesized aperture radar (SAR). Thanks to these data it is possible to determine deformations of the Earth's crust. In this study SAR data were used to determine the deformation parameters of the Aegean earthquake affecting the Greek island of Kos and the town of Bodrum located in the southwest of Turkey on 20 July 2017, the magnitude of which was determined by NOA and KOERI to be Mw6.6. SAR data was used to register the Earth's crust movements creating set interferometric images. Based those images information on subsidence caused by the earthquake was obtained.

Detection of ground motions in coastal area

Mila Atanasova ¹, Hristo Nikolov ²

¹National Institute of Geophysics, Geodesy and Geography-BAS, Bulgaria
Phone: +359 2 979 33 54, E-mail: mila_at_zl@abv.bg

²Space Research and Technology Institute – Bulgarian Academy of Sciences, Bulgaria
Phone: +359 2 979 2458, E-mail: hristo@stil.bas.bg

ABSTRACT

Landslide processes are considered to be the major part of the natural hazards occurring on the northern part of the Bulgarian sea side. Their monitoring can be done by direct measurements in dedicated GNSS networks, which is the most accurate method. The objective of this study is to provide solid grounds for monitoring of the landslide processes using innovative methods by combining GNSS and SAR data. This goal will be achieved by implementation the following two sub-objectives: first, establishment a verified methodology for extracting high-quality information from SAR images aimed at continuous monitoring of landslide areas integrating interferometric images (IFI) and in-situ GNSS data and second, based of freely accessible data provided by ESA and national sources to create a working prototype of an information system for monitoring and preventing the effects of earth crust movements (landslides, falls, etc.). One of the scientific tasks to be solved includes the development of methodological approaches to compare the results of the combined processing of interferometric images from SAR, in-situ measurements by permanent GNSS stations from the national NIGGG network in the area of study and geodetic measurements of a newly built test network a specific area on the Northern Black Sea coast of Bulgaria subject to landslide processes. After the primary processing of the data from three sources, their reconciliation which will form a geodatabase for subsequent spatial analysis envisaged in GIS environment.

KEYWORDS: ground motion, GNSS, InSAR, landslide monitoring

Г.8.5.

XXX МЕЖДУНАРОДЕН СИМПОЗИУМ
“СЪВРЕМЕННИТЕ ТЕХНОЛОГИИ, ОБРАЗОВАНИЕТО И ПРОФЕСИОНАЛНАТА ПРАКТИКА В
ГЕОДЕЗИЯТА И СВЪРЗАНИТЕ С НЕЯ ОБЛАСТИ”

София, 04 – 06 ноември 2020 г.

XXX INTERNATIONAL SYMPOSIUM ON
MODERN TECHNOLOGIES, EDUCATION AND PROFESSIONAL PRACTICE IN
GEODESY AND RELATED FIELDS

Sofia, 04 – 06 November 2020

INVESTIGATION OF “THRACIAN CLIFFS” LANDSLIDE BY RADAR INTERFEROMETRY

Mila Atanasova, Hristo Nikolov

ABSTRACT

The main objective of this research is monitoring the recent and ongoing ground instabilities based on exploiting the benefits of combining geological, SAR and GNSS data. This objective will be achieved by producing information concerning a single landslide area implementing proved methodology for multitemporal monitoring of landslide areas by integrating results from interferometric images, and GNSS data from permanent and local geodetic networks. This study is providing reliable information with regard to the hazard geo-processes taking place in the region of the landslide area “Thracian Cliffs”. The produced output is important for understanding the source and the consequences of current landslide processes in assessing the possible hazards.

KEYWORDS: MONITORING OF LANDSLIDE AREAS, DINSAR, INTERFEROMETRIC IMAGES, GNSS DATA,

Studying the of Landslide Processes at the "Dalgiya Yar" - a Landslide Circus by joint use of GNSS and InSAR

Mila ATANASOVA, Hristo NKOLOV, Ivan GEORGIEV, Nikolay DIMITROV, Anton IVANOV, Bulgaria

Key words: Earth movements, GNSS, SAR, Landslide monitoring

SUMMARY

The main objective of this research is monitoring the ongoing landslide processes by complementary use of SAR and GNSS data. It will be achieved by means of proved methodology for continuous monitoring of landslide areas by integrating information from interferometric images and GNSS data from permanent and local geodetic networks. The study will give reliable data for ongoing risky geo-processes for the region of the Northeastern Bulgaria, known with several large active landslides.

These results are important for understanding the origin and dynamics of landslide processes as well as assessing the resulting hazards. Local archive with Sentinel-1A/B images for this region is created and interferograms are produced. Raster heat map based on displacement values from interferograms was made. The area of interest of this study is "Dalgiya yar" - a landslide circus in which concentration of ground deformations has been observed.

When geodynamic networks are used to study landslide processes several types of surveying points are used – ones fixed on geologically stable terrain, others located inside the landslide. For stable points located in the non-deformable zone of the landslide used were stations of permanent GNSS network NIGGG. New established network in and around the landslide area "Dalgiya yar" – "Fara" consists of a total of 30 stabilized points.

In the geodynamic network "Dalgiya yar" are included all old 6 points that were discovered on the ground from the network used to track deformations along the road. A preliminary study, based on data provided by Ministry of Regional Development and Public Works of the landslide processes in the road I-9. Analysis of horizontal and vertical deformations for the period 2013 - 2018 along the road I-9 the last cycle of June 2019yr.

ФОТОГРАМЕТРИЯ, ЛАЗЕРНО СКАНИРАНЕ, ДИСТАНЦИОННИ ИЗСЛЕДВАНИЯ

ИЗУЧАВАНЕ НА СВЛАЧИЩНИ ПРОЦЕСИ ЧРЕЗ СЪВМЕСТНО ИЗПОЛЗВАНЕ НА ДАННИ ОТ INSAR И GNSS

Доц. д-р. Мила Атанасова, гл. ас. д-р. Христо Николов, БАН

SUMMARY

The main objective of this research is monitoring the ongoing landslide processes by complementary use of SAR and GNSS data. It will be achieved by means of proved methodology for continuous monitoring of landslide areas by integrating information from interferometric images and GNSS data from permanent and local geodetic networks. The study will give reliable information for ongoing risky geo-processes for the region of the Northeastern Bulgaria known with several large active landslides. These results are important for understanding the origin and dynamics of landslide processes as well as assessing the resulting hazards. To achieve the set objective a local archive with Sentinel-1A/B images for this region was created and a large set of interferograms was produced.

Key words: Earth movements, GNSS, SAR, landslide monitoring

РЕЗЮМЕ

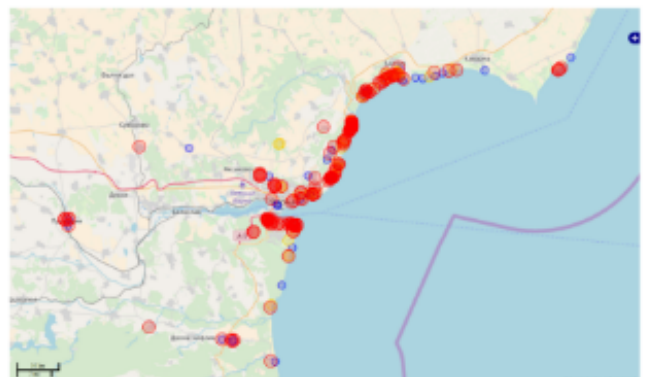
Основната цел на това изследване е мониторинг на процесите, протичащи в свлачищен район чрез допълващо използване на данни от SAR (радар с синтезирана апертура - PCA) и GNSS (глобални навигационни спътникови системи). Тя ще бъде постигната чрез прилагане на доказана методология за непрекъснат мониторинг на свлачищните зони посредством интегриране на информация от интерферометрични изображения и данни от GNSS. Това проучване предоставя надеждни данни за продължаващи рискови геопроцеси за региона на Североизточна България, който е известен с няколко големи активни свлачища. В рамките на изследването е създаден локален архив с изображения от Sentinel-1A/B за този регион, от който беше получен набор от интерферограми, показващи развитието на геодинамичните процеси. Получените от тях резултати са важни за разбирането на произхода и динамиката на свлачищните процеси, както и за оценка на произтичащите от тях опасности.

Ключови думи: GNSS, SAR, мониторинг на свлачища

съоръжения, както и щети на земеделска земя чрез прекъсване на дренажни и поливни съоръжения, както и промяна на наклона на терена. Проследяването и анализът на пространственото разпределение на деформирането на земната повърхност може да бъде полезен при защита на населението и предотвратяване на големи икономически щети. Изследването на движенията на свлачища с помощта на класически геодезически методи като оптични извервания и нивелация или проучвания, базирани на GNSS, може да разкрие деформации с точност милиметър за локализиращи зони, но е скъпоструващ и трудоемък метод, за да покрие големи площи.

2. РАЙОН НА ИЗСЛЕДВАНЕ

Целта на това проучване е да се идентифицират райони с активно движение на свлачища по Северното Черноморие на България и да се осъществи мониторингът им чрез комбиниране на данни от GNSS и интерферометрични изображения от радари със синтезирана апертура (SAR). За тази цел се анализират резултати от проведените от авторите теренни проучвания през 2019 г. и резултати от обработка на SAR данни. Също така са използвани и данни от годишните отчети на „Геозащита“ ЕООД Варна [1], [2] за проведените превантивни дейности през 2017 и 2018 г., свързани с регистрирането и мониторинга на свлачища и райони с абразивни процеси по Черноморието за нуждите на МРРБ фиг. 1 [3].



Г.8.8.

Applications on SAR and GNSS data used in studying a landslide “Trifon Zarezan” - Bulgaria (10922)

Mila Atanasova, Hristo Nikolov (Bulgaria)

Key words: landslide, GNSS data, DInSAR

SUMMARY

This paper focuses on studying landslide processes based on the use of differential interferometric Synthetic Aperture Radar techniques (DInSAR) that make use of data acquired by spaceborne SAR sensors. Landslide activation may cause moderate to severe damage to concrete foundations, houses, buildings, and underground infrastructure, as well as damage to agricultural parcels and land occupied by natural vegetation through disruption of drainage and alteration of ground gradient. Monitoring and analyzing the spatial distribution of the deformed surface may be helpful for population protection and prevention of major economic damages as well as in preserving the natural environment in the national parks and other protected areas.

In this research the DInSAR technique was employed to detect the ground-surface deformation in a single area of Trifon Zarezan landslide located on Northern Bulgarian Black Sea coast. The monitoring of the landslide movements was complemented by Global Navigation Satellite System (GNSS) surveys that can reveal deformations with sub-millimeter to sub-centimeter precision for small areas.

SUMMARY (Bulgarian language)

В настоящата статия се изследват свлачищни процеси, като се използват данни, получени от космически базирани радари със синтезирана апертура и обработени по метода на диференциалната интерферометрия (DInSAR). Активирането на конкретно свлачище може да причини умерени до тежки повреди на основи, къщи, сгради и подземна инфраструктура, както и увреждане на земеделски парцели и площи заети от естествена растителност, поради нарушаване на естественото отводняване при промяна на наклона на терена. Наблюдението и анализирането на деформираните площи от повърхността на Земята може да бъде полезно за защита на населението и предотвратяване на големи икономически щети, както и за опазване на природната среда в националните паркове и други защитени територии

В това изследване е използвана подхода DInSAR за откриване на деформации на земната повърхност в зоната на свлачище „Трифон Зарезан“, което е разположено на българското Северното Черноморие. Мониторингът на движенията на свлачището беше допълнен от измервания с Глобалната навигационна спътникова система (ГНСС), които могат да разкрият деформации с точност под сантиметър за малки площи.

Applications on SAR and GNSS Data Used in Studying a Landslide “Trifon Zarezan” - Bulgaria (10922) (10922)
Mila Atanasova-Zlatareva and Hristo Nikolov (Bulgaria)

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Application of InSAR satellite method for mapping of active landslides in Bulgaria – opportunities and perspectives

Mila Atanasova¹, Hristo Nikolov², and Lyubka Pashova¹

¹National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences, Bulgaria

²Space Research and Technology Institute, Bulgarian Academy of Sciences, Bulgaria

Keywords: InSAR, mapping landslides, landslide hazard

Abstract. Landslides are geological phenomena that are spread on Bulgarian territory mainly along the northern Black Sea coast and on the right banks of the Danube in the western part of the country. Mitigation of the negative effects of these destructive geological phenomena is the compilation of inventory maps of their distribution and registers with the main characteristics of the individual landslides. Conventional methods for making such maps are time-consuming and resource-intensive. Modern satellite, air and ground-based remote sensing technologies facilitate the production of landslide maps, reducing the time and resources required to compile and systematically update them. In this paper, we demonstrate the applicability of Differential Sentinel-1A satellite SAR interferometry (DInSAR) to assess the movement activity and use the information for further updating the national landslide inventories in Bulgaria. We perform several analyses based on multi-temporal InSAR techniques of Sentinel-1A data over selected areas prone to landslides. The use of new opportunities for free access to satellite images, which can be applied in conjunction with other methods, greatly facilitates the processes of inventory, mapping and study of landslides.

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ПРИЛОЖЕНИЕ НА ДИСТАНЦИОННИ ИЗСЛЕДВАНИЯ ЗА МОНИТОРИНГ НА СВЛАЧИЩА

Мила Атанасова, Христо Николов, Иван Калчев

APPLICATION OF REMOTE SENSING FOR LANDSLIDE MONITORING

Mila Atanasova, Hristo Nikolov, Ivan Kaltchev

РЕЗЮМЕ

Появата на свлачища е резултат от естествени или човешка дейност, но независимо от техния произход те променят ландшафта, разрушават инфраструктурата и в някои случаи дори водят до загуба на човешки животи. За да се оцени опасността от това явление данните от дистанционно изследвания от аеро и сателитни апаратурни комплекси се използват широко за наблюдение на движенията на земната повърхност през редовни интервали. Тези методи са по-евтини и отнемат по-малко време от теренните измерванията, а от друга страна и размерът на изследваните площи е по-голям. Това са причините за инициране проучване на повърхностните деформации в района на свлачище „Фиш-Фиш“, разположено в северната част на Българското Черноморие. За създаване на карта на настъпилите в последните години премествания на земната повърхност в споменатата област бяха използвани два източника на данни - фотограметрични проучвания с безпилотна летателна система (БЛС) и изображения от сателитнобазиран радар със синтезирана апертура (РСА). Свлачището е заснето чрез фотограметричен метод през юни 2019 и ноември 2020 г. и в резултат бяха създадени два цифрови модела на терена. Точността им позволи регистриране на повърхностните движения с висока пространствена разделителна способност, използвайки контролни точки разположени както вътре така и извън периметъра на свлачището. Сателитните данни от РСА са получени от двата сателита А и В от мисията Sentinel-1 и се предоставят безплатно от Европейската космическа агенция (ЕКА). Авторите обработиха РСА данни за същите периоди по метода на диференциалната интерферометрия, в които бяха направени проучванията с БЛС. Поради особеностите на конкретния терен беше възможно да се използват само РСА изображения от низходяща орбита. Резултатите от контролните точки за двата източника (БЛС и РСА) бяха сравнени и беше установена добра корелация между тях. Като окончателен продукт беше изготвена карта на свлачищната зона, изобразяваща регистрираните премествания на земята за изследвания период.

ключови думи: свлачище „Фиш-Фиш“, БЛС, РСА

Application of UAS for the purposes of landslide mapping in Bulgaria - a case study of the Thracian Cliff landslide, northern Bulgarian coastal zone

Lyubka Pashova^a *, Mila Atanasova-Zlatareva^a, Hristo Nikolov^b, Grigor Nikolov^a

^a National Institute of Geophysics, Geodesy and Geography - Bulgarian Academy of Sciences, lpashova.niggg@geophys.bas.bg, mila_at_zl@abv.bg, etgeonik@abv.bg

^b Space Research and Technology Institute - Bulgarian Academy of Sciences, hristo@stil.bas.bg

* Corresponding author

Keywords: Landslide mapping, Geospatial technologies, UAS, Coastal area, Northern Bulgarian Black Sea coast

Abstract:

We present a preliminary analysis of DSM/DTM from a UAS survey conducted in 2020 of the recently activated Thracian Cliff landslide located in the northern Bulgarian coastal zone. The 3D models have been generated by Pix4D mapper software using the Structure-from-motion (SfM) method. The resulting high-resolution digital models can be used to map and inventory landslides and, in addition, to compile digital maps of the hazards and risks of such events across the country.

Advanced geospatial and remote sensing technologies provide opportunities for faster and higher spatial-temporal resolution of mapping reducing the time and the cost of labour-intensive field measurements. Unmanned aerial systems (UAVs) are a widely used for rapid spatial data collection that can facilitate the natural hazards mapping. This technology has quickly become a practice and is increasingly used to map and inventory landslides, in emergencies in hard-to-reach areas and at various stages of landslide risk management. Recently, in Bulgaria, this technology is used to quickly acquire spatial data and generate high-precision 3D models of the earth surface.

At a national level, a methodology for assessing the geological risk in Bulgaria was created in 2017 by the Geological Institute at the Bulgarian Academy of Science. Destructive geological processes were analysed, assessed and mapped. Maintaining and managing the national landslide databases is a responsibility of the Ministry of Regional Development and Public Works (MRDPW) and its regional centres in Pleven, Pernik and Varna. MRDPW provides public access to the produced maps of the geological hazard and risk at a scale of 1: 25,000 through the GIS web portal: <http://gis.mrrb.government.bg/KGR/>.

Recently, landslides on Bulgarian territory have increased due to existing geological conditions, improper land use, and anthropogenic activities. Many landslide zoning studies assume that past and present landslides are the keys to predicting future landslides. Detailed information on the location, type, date and size of past landslides and the damage caused is necessary for the proper mapping of landslides and further assessment of the hazard and risk of these natural phenomena. In particular, multidisciplinary studies are needed to monitor and reduce the adverse effects of new or activated old landslides in the Bulgarian coastal zone due to building of new infrastructure objects and tourism activities over the last three decades.

Landslide susceptibility maps for the northern Black Sea coast using the Mora and Vahrson method within the GIS environment have been compiled by Berov et al. (2020). One example of the recently activated landslide in 2014 is that, which is located near the village of Topola, Kaliakra municipality. The landslide is developed along the coastal slope, just before the entrance of the Thracian Cliffs Golf & Beach Resort. The Thracian Cliff landslide is manifested in the front of an ancient stabilized landslide "Kalkan tepe" located SE from the village of Bozhurets, according to Geozastita Varna Ltd (2018). It is ~ 550 m wide and ~280 m long in the eastern part and about 150 m in the western part (Fig. 1a). The main landslide is 12-15 m high. It entered the national register of landslides with № DOB 17.05009-01-03. The main reasons for the activation of the landslide processes are the over-wetting of the earth masses by waters of unclear origin (possibly underground), leaks from the degraded sewerage built in the golf complex and the marine abrasion.

In 2020, an aerial drone survey of the Thracian Cliff landslide was performed using UAS technology to create high-precision 3D DSM/DTM models of the study area. The test aerial mapping method of the landslide aims to contribute to the complex geodetic and geological research conducted in the past 3 years (Atanasova et al., 2019; Nankin & Ivanov, 2019; Atanasova and Nikolov, 2020). Two flight plans were set with the specialized Autel Explorer software with 80% frontal and side overlap between adjacent photos to cover the whole area of the landslide. Autel EVO II 8k UAV equipped with a digital camera with 1/2 " 48MP CMOS sensor, f/ 1.8 range angle, and a focal length equivalent to 25.6mm. Two flights at 120m and 140 m altitudes with a speed of 22-25 m/sec were done to achieve a pre-calculated resolution of GSD digital products of 1.5-1.8

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Home > Journals > X National Geophysical Conference, 4th June 2021 > I

Determination of deformations of the Earth's crust by DInSAR occurred after the earthquake in the Larissa region on March 3 2021

Mila Atanasova, Hristo Nikolov

Abstract:

Earthquakes are a natural disaster, causing damage that is measured by human lives and destruction of natural and infrastructural sites. Direct consequences of their occurrence cause activation of landslides, ruptures and vibrations of the Earth's surface, tsunamis, etc. In this study, we focused on determining the surface deformation that occurred after the Mw 6.0 earthquake as registered by NOAA and USGS /, which occurred on March 3, 2021 at 20 km northwest of the Greek city of Larissa. A valuable source of data on the current state of large land areas of the ground surface is the EU's Copernicus program. One of its components is the two-satellite Sentinel-1 mission, which provides synthesized aperture radar (SAR) data. Based on their data it is possible to determine the deformations of the Earth's crust. In this study, they were used to determine the parameters of deformations caused by a series of earthquakes. SAR data were used to produce information regarding the ground displacements that have occurred after the earthquakes by creating interferometric images from them.

Keywords:

DInSAR, deformations of the Earth's crust, earthquake

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Author information:

Author: Mila Atanasova

E-mail: mila_at_zl@abv.bg

Affiliation: National Institute of Geophysics, Geodesy and Geography – BAS, str. Acad. G. Bonchev, bl. 3, Sofia 1113, Bulgaria

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Using Information Obtained from SAR Data to Assess Flood Affected Areas in the Area of Bregovo, Bulgaria

Hristo NIKOLOV and Mila ATANASOVA, Bulgaria

Key words: monitoring, flood, Sentinel-1, SAR data GRDH

SUMMARY

Flash flood events are type events that are difficult to predict, can develop rapidly and last for a short period of time. In the last years this type of incidents was observed in several areas of Bulgaria affecting human lives as well as infrastructure and landscape. This proves the need to have operational information about the extent of the damages caused by them delivered to the local authorities that could be used to mitigate the consequences and improve the decision making. In order to produce this information several prerequisites are needed such as updated data concerning the state of the impacted territories before and after the flood, a good DTM, the amount of the rain, etc. At present large share of this data are obtained routinely by the instruments onboard the satellites of the Copernicus program e.g. Sentinel 1 and 2, and are being freely distributed by ESA. Based on the said data the real situation of the land cover/land use, the soil moisture, the area of the water reservoirs is produced.

In this paper we present results evidencing the flood event that took place during the first and second decade of March 2018. The flooding started on March 5th caused by fast snow melting in the mountainous region close to the Bregovo village located in the Northwest part of Bulgaria. The results are based on SAR data from Sentinel-1 mission having VV polarization and distributed in GRD format. During the processing additional data for elevation and land cover have been used as well. After classification of the resulting data we obtained information regarding the observed area before and few days after the peak of the event. The total inundated area was estimated to be about 700 ha.



Assessment of the ground displacements in urban and industrial areas using DInSAR time series

Hristo Nikolov¹, Mila Atanasova²

¹ Space Research and Technology Institute (SRTI) - Bulgarian Academy of Science, e-mail: hristo@stil.bas.bg.

² National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences, Sofia 1113, Bulgaria, e-mail: mila_at_zl@abv.bg

Keywords: ground deformations, DInSAR, time series, technogenic activities

Abstract

The terrain deformations in urban and industrial areas pose serious risk to human lives and cause significant economic losses. One modern method to register them is to use information produced by processing data acquired by satellite borne synthetic aperture radar (SAR). In order to produce this information large time series of SAR data processed by DInSAR method should be available. Thanks to the open data policy of ESA from continuous and regular SAR data acquisitions it was made possible to assess the ongoing surface displacements in the region of the town of Pernik, Bulgaria. In this region a large number of mining and industrial plants are located mainly dealing with coal and steel production and processing serviced by a railways and highways. Also the density of the population in the area is high and for this reason to have large residential and utility areas as well. All mentioned industrial, infrastructural and urban sites could be heavily affected by slow ground movements in case those are not properly and timely monitored. This is the reason the authors created short time series with information produced from ascending and descending orbits of Sentinel-1 mission to assess the ongoing geodynamic processes in this region. Those results could be used by the local authorities to prepare plans for mitigation of those unfavourable impacts.

Оценка на земните премествания в урбанизирани и промишлени райони посредством DInSAR времева серия

Христо Николов¹, Мила Атанасова²

¹ Институт за космически изследвания и технологии; ул. "Акад. Георги Бончев" бл. 1, София 1113; e-mail: hristo@stil.bas.bg

² Национален институт по геофизика, геодезия и география; Българска академия на науките, София 1113, ул. "Акад. Георги Бончев" бл. 3, София 1113, България; e-mail: mila_at_zl@abv.bg

Ключови думи: деформации на земната кора, DInSAR, времева серия, техногенни дейности

Резюме

Текст на резюмето до половин страница.

Деформациите на терена в градски и индустриални зони представляват сериозен риск за човешкия живот и причиняват значителни икономически загуби. Един съвременен метод за тяхното регистриране е използването на информация, получена чрез обработка на данни получени от сателитенбазиран радар със синтезирана апертура (РСА). За да се получи тази информация е необходимо да са има големи времеви редове от тези данни, обработени по метод DInSAR. Благодарение на политиката за отворени данни на ESA от непрекъснато и регулярно регистриране на данни от РСА стана възможно да се направят оценки на текущите премествания на земната повърхност в района на град Перник. В този регион са разположени голям брой минни и промишлени предприятия, занимаващи се главно с производство и преработка на въглища и стомана, които са обслужвани от железопътни линии и магистрали. Също така плътността на населението в района е висока и поради тази причина там има и големи жилищни площи и обслужващата ги инфраструктура. Всички споменати промишлени, инфраструктурни и градски обекти могат да бъдат силно засегнати от бавни движения на земната кора, ако те не са правилно проследени във времето. Това е причината авторите да създадат кратки времеви редове с информация за тях получена от възходящи и низходящи орбити на мисията Sentinel-1 за да оценят протичащите геодинамични процеси в този регион. Тези резултати могат да бъдат използвани от местните власти за изготвяне на планове за смекчаване на тези неблагоприятни въздействия.

СЪЗДАВАНЕ НА НОВ АЕРОКОСМИЧЕСКИ ПОЛИГОН В БЪЛГАРИЯ ЗА МОНИТОРИНГ И ОЦЕНКА НА ТЕХНОГЕННОТО ВЪЗДЕЙСТВИЕ ВЪРХУ ОКОЛНАТА СРЕДА – ПАНАГЮРСКИ РУДЕН РАЙОН

Христо Николов¹, Мила Атанасова², Деница Борисова¹

¹*Институт за космически изследвания и технологии – Българска академия на науките*

²*Национален Институт по Геофизика, Геодезия и География – Българска академия на науките*
 e-mail: hristo@stil.bas.bg

Ключови думи: аерокосмически полигон, сателитни и БЛС данни, антропогенно въздействие

Резюме: В този доклад са обобщени извършените дейности за създаване на нов тестов аерокосмически полигон в България насочен към проследяване динамиката на промените в ландшафта на Панагюрския руден район, като се използват най-новите постижения на технологиите за дистанционни и полеви изследвания. По принцип полигонами и тестовите участъци в тях са относително големи площи от земната повърхност съставени от обекти, които лесно се идентифицират в изображенията получавани от сателитни и/или самолетни апаратурни комплекси. В разглеждания район е очевидно техногенното въздействие причинено от предходни (обхващащи последните 40 години) и съвременни минни дейности в няколко открити рудници разположени в него. В това изследване са представени резултатите, получени от авторите при изучаване на промяната в земеползването на районите, където все още функционират минно-добивни комплекси, състоящи се от открит рудник и флотационна фабрика. Друга важна тема, която беше изследвана, са дейностите по възстановяване на качествата на почвата в зоните изложени на висок риск от замърсяване и трансформацията на бивши насипища и хвостохранилища в няколко вече затворени минни обекта в същия регион. Друг резултат от проведеното изследване е редовното наблюдение на текущите минни дейности в изследваната зона, които се считат за основен фактор за местното (река Тополница), както и за трансгранично замърсяване на посредством река Марица. От изследванията, проведени до този момент, беше създадена обширна геобазаданни, която се състои от растерни и векторни слоеве, които са готови да бъдат използвани от местните власти за по-добро регионално планиране.

INITIATING A NEW AEROSPACE TEST SITE IN BULGARIA FOR MONITORING AND ASSESSMENT THE TECHOGENIC IMPACT ON THE ENVIRONMENT – THE PANAGYURISHTE ORE REGION

Hristo Nikolov¹, Mila Atanasova², Denitsa Borisova¹

¹*Space Research and Technology Institute – Bulgarian Academy of Sciences*

²*National Institute of Geophysics, Geodesy and Geography – Bulgarian Academy of Sciences*
 e-mail: spsbyte@space.bas.bg; lusy_t@yahoo.com

Keywords: aerospace test site, satellite and UAS data, anthropogenic impact

Abstract: In this paper summarized is the effort made to establish a new test site in Bulgaria to track the ongoing processes in landscape changes using the latest achievements of the satellite and UAS remote sensing and in-situ technologies. Principally the test sites are relatively large areas of the Earth's surface comprised of objects that are easily identified in the images acquired by satellite and/or UAV based instruments. The uniqueness of the area in focus is the obvious technogenic impact caused by the past (covering the last 40 years) and modern mining activities in several open pit mines located in it. In this study presented are the results obtained by the authors in studying the land use change in the areas where mining complexes consisting of open pit mine and a processing plant are still in operation.

Мониторинг на свлачищни процеси по Северното Черноморие на България, използвайки данни от програма Коперник

Мила Атанасова, Христо Николов

*Национален институт по геофизика, геодезия и география – Българска академия на науките
Институт за космически изследвания и технологии – Българска академия на науките
e-mail: mila_at_zl@abv.bg, hristo@stil.bas.bg*

Ключови думи: *GNSS, InSAR, мониторинг на свлачища*

Резюме: Основната цел на това изследване е мониторинг на процесите протичащи в свлачищен район чрез допълващо използване на данни от SAR (радар с синтезирана апертура - PCA) и GNSS (глобални навигационни спътникови системи). Резултатите от изследването предоставят надеждни данни за протичащи рискови геопроцеси за региона на Североизточна България известен с няколко големи активни свлачища. Получените резултати са важни за разбирането на произхода и динамиката на свлачищните процеси, както и за оценка на произтичащите от тях опасности.

В настоящото изследване е използван метод DInSAR за установяване на деформации на земната повърхност в района на Северното Черноморие на България с цел определяне на райони с регистрирани деформации на земната повърхност и идентифициране на протичащи свлачищни процеси. Локализираните свлачища, както вече регистрираните, така и потенциални могат да бъдат изследвани с помощта на изградена локална геодинамична GNSS мрежа за тяхното прецизно наблюдение. За целта съвместно се анализират резултати от проведените от авторите през 2019г. и 2020г. теренни проучвания и резултати от обработка на набор от SAR данни. Въз основа на получените резултати може да се заключи, че и двата използвани източника от данни водят до подобни резултати (преместванията са в диапазона на сантиметри) и те потвърждават цялостното поведение на изследваните свлачища. Разликите между тях могат да бъдат обяснени с големия брой външни фактори, влияещи върху данните за SAR, като растителност и времева декорелация. При съпоставяне на двата метода трябва да се вземе предвид, че стойностите на елементите на интерферометричните изображения (IFI) съответстват на много по-голяма площ (14 м. на 14 м. размер на пиксел), докато GNSS се отнася до отделни точки.

Monitoring of landslide processes on the Northern Black Sea of Bulgaria using data from the Copernicus program

Mila Atanasova, Hristo Nikolov

*National Institute of Geophysics, Geodesy and Geography – Bulgarian Academy of Sciences
Space Research and Technology Institute – Bulgarian Academy of Sciences
e-mail: mila_at_zl@abv.bg, hristo@stil.bas.bg*

Keywords: *GNSS, InSAR, landslide monitoring*

Abstract: The main purpose of this study is to monitor the processes occurring in a landslide area through the additional use of data from SAR (Synthetic Aperture Radars) and GNSS (Global Navigation Satellite Systems). The results of the study provide reliable data on ongoing hazardous geoprocesses for the region of Northeastern Bulgaria known for several large active landslides. The obtained results are important for understanding the origin and dynamics of landslide processes, as well as for assessing the dangers arising from them.

In the present study, the DInSAR method was used to establish deformations of the Earth's surface in the region of the Northern Black Sea coast of Bulgaria in order to determine areas with registered deformations of the earth's surface and identify ongoing landslides. The localized landslides, both already registered and potential, will be able to be studied with the help of a local geodynamic GNSS network for their precise monitoring. For this

Приложение на сателитни SAR данни за установяване деформации на земната кора след земетресения

Христо Николов¹, Мила Атанасова², Валентина Протопопова²

¹Институт за космически изследвания и технологии – Българска академия на науките

²Национален институт по геофизика, геодезия и география – Българска академия на науките
 e-mail: mila_at_zl@abv.bg, hristo@stil.bas.bg

Ключови думи: DInSAR, природни бедствия, земетресения

Резюме: Сателитнобазираните радарни апартурни комплекси предоставят данни, на базата на които е възможно да се получи информация за размера на настъпили движения на земната повърхност от порядъка на сантиметри. Подобна информация е от изключително значение за оценка на последиците от природни бедствия или такива с антропогенен произход. Тъй като земетресения се случват постоянно и не е възможно да бъдат предсказани всяка допълнителна информация относно обхвата на конкретни сеизмично събитие е от изключителна важност за местните и национални власти, които са отговорни за отстраняване на щетите причинени на населението, инфраструктурата и ландшафта след такива събития. В това изследване са представени резултатите получени след съвместна обработка на два набора SAR данни, допълнени и с данни от други източници, на чиято основа се формират две интерферометрични изображения, които предоставят информация за настъпилите деформационни процеси в райони от земната повърхност след поредица от земетресения, станали на три различни места на Балканския полуостров - едният в близост до остров Кос и град Бодрум, другият близо до остров Закинтос и третият на Йонийското крайбрежие на Албания. Получените карти, отразяващи деформациите на земната кора след споменатите събития, се основават на данни от възходяща и низходяща орбита на спътника Sentinel-1, който е част от програма „Коперник“ на ЕС за наблюдение на Земята. Получените резултати за трите изследвани събития включени в това проучване доказаха своята надеждност тъй като бяха сравнени с in-situ измервания. Тази констатация дава основание да се твърди, че на базата на получените резултати е възможно на компетентните национални органи да се предостави надеждна информация относно настъпилите деформации на земната кора в региони, които са проблематични за директни теренни проверки, които имат за задача да установят настъпилите деформации.

Application of satellite SAR data to detect deformations of the Earth's crust after earthquakes

Hristo Nikolov¹, Mila Atanasova², Valentina Protopopova²

¹Space Research and Technology Institute – Bulgarian Academy of Sciences

²National Institute of Geophysics, Geodesy and Geography – Bulgarian Academy of Sciences
 e-mail: mila_at_zl@abv.bg, hristo@stil.bas.bg

Keywords: DInSAR, natural disasters, earthquakes

Abstract: The data provided by satellite-based active radar instruments after appropriate thematic processing are transformed into information that reflects the amount of movements on the Earth's surface of the order of centimeters. Such information is of crucial importance for assessing the consequences of natural or anthropogenic disasters. Because earthquakes occur constantly and it is not possible to predict them any additional information about the scope of a particular seismic event is essential for local and national authorities who are responsible for mitigating the damages caused to the population, to the infrastructure and to the landscape following such events. This study presents the results obtained by jointly processing two sets of SAR data with other additional data to obtain two interferometric images that provide information on the deformation processes after a series of earthquakes that occurred on three different locations at the Balkan peninsula – one close to island of Kos and Bodrum town, the other close to the island of Zakynthos and the third on Ionian coast of Albania. The obtained maps reflecting the deformations of the Earth's crust after the mentioned events are based

CREATION OF GLACIERS VELOCITY MAPS IN LIVINGSTON ISLAND USING SENTINEL-1 DATA

Mila Atanasova-Zlatareva, Hristo Nikolov

Mila Atanasova-Zlatareva
Assoc. Prof. PhD
National Institute of Geophysics, Geodesy and Geography (NIGGG),
Bulgarian Academy of Sciences
1113 Sofia, Bulgaria
Acad. Georgi Bonchev str., bl. 3
Tel.: +359 2 979 3354
E-mail: mila_at_zl@abv.bg

Hristo Nikolov
Assoc. Prof. PhD
Space Research and Technology Institute (SRTI) - Bulgarian Academy of Sciences
1113 Sofia, Bulgaria
Acad. Georgi Bonchev str., bl. 1
Tel.: +359 2 979 2458
E-mail: hristo@stil.bas.bg

Abstract

Livingston Island is an Antarctic island in the Southern Ocean, part of the South Shetlands Archipelago. The Bulgarian base "St. Kliment Ohridski" is located on the Hurd Peninsula some 130 m from the shores of the inner bay Emona. In this study we use data from the Sentinel-1 satellite constellation to produce velocity maps, covering few key outlet glaciers. During this research used were Sentinel-1 data in GRD format with HH polarisation. We followed the processing workflow described by international scientific community to derive ice velocity maps from pairs of SAR images using the SNAP software. In this paper are presented results for glaciers found in Livingston Island and the ice velocity extracted along the two flow line transects/longitudinal and transverse profiles. This study provides a first demonstration by authors of the operational radar satellites capacity to map and thus providing frequent and timely monitoring of the ice sheet flow as well as to monitor the dynamic evolution of the glaciers around the Bulgarian base "St. Kliment Ohridski"

Keywords: glaciers velocity, Livingston Island, SAR

CREATING A LOCAL GEODATABASE FOR INVENTORY MAPPING AND RISK MONITORING THE LANDSLIDE PROCESSES OF THE LANDSLIDE “FISH-FISH”

Hristo Nikolov, Mila Atanasova

Assoc. Prof. PhD Hristo Nikolov
Space Research and Technology Institute - Bulgarian Academy of Sciences
Acad. G. Bonchev Street, Bl. 1, 1113 Sofia, Bulgaria
hristo@stil.bas.bg

Assoc. Prof. PhD Mila Atanasova
National Institute of Geophysics, Geodesy and Geography - Bulgarian Academy of Sciences
Acad. G. Bonchev Street, Bl. 3, 1113 Sofia, Bulgaria
mila_at_zl@abv.bg

Abstract

The purpose of this study is to provide new means for analysis and assessment of current geo processes in the active landslide located in “Fish-Fish” residential area, northern Black Sea coast of Bulgaria in order to mitigate the risks of natural and anthropogenic origin. In recent decades, starting in 2002, the study region has been subject of several calamity events such as landslides, earth masses collapse, etc. To this end, it is essential to prepare risk management plans using information of high quality and regularly monitor the most vulnerable areas in this zone in advance. In this paper presented is the developed local geodatabase for the investigated site consisting of several layers all of them related to the modelling of the processes such as erosion, sea abrasion, etc.. This modelling is based on large variety of sources - terrain investigations, remotely sensed data from satellites and unmanned aerial systems (UAS).