短期滞在型共同研究
2023LS-07

京都大学　防災研究所
Disaster Prevention Research Institute
Kyoto University

衛星搭載 SAR 干渉法を用いた日本とスロバキアの都市部における地すべり活動評価の高度化

Advanced methods of spaceborne SAR interferometry in landslide activity assessment of urbanized areas in Japan and Slovakia

May 28, 2024

Coordinator: GREIF Vladimir

Final Report for

Short-term Research Visit
Disaster Prevention Research Institute, Kyoto University

Project No.: 2023LS-07

To the Director of Disaster Prevention Research Institute, Kyoto University

Applicant (Principal Investigator)
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Project Title:

Advanced methods of spaceborne SAR interferometry in landslide activity assessment of urbanized areas in Japan and Slovakia

Principal Investigator : GREIF Vladimir
Affiliation : Dept. of Engineering Geology, Hydrogeology and Applied Geophysics
Comenius University in Bratislava, Slovakia
Contact Person at DPRI : WANG Gonghui
Research Period : August 21th, 2023 ~ September 8th, 2023
Research Location : Research Center for Landslide Disaster Risk Cognition and Reduction, DPRI, Kyoto University; Some landslide potential sites in Japan
Number of the Participants in the Project: 8 (DPRI: 4 / non-DPRI: 4)

Anticipated Impact on Research and Education:

A seminar was held on the premises of LCR on August 23, 2023, where Dr. Greif presented possible applications of PSInSAR and the availability of Sentinel1 satellite radar data for Japan, and Prof. Wang presented the outcomes of his field investigation of landslides triggered by the 2023 Turkey–Syria earthquake to the Ph.D. students.

Research Report

1. Research objectives and significance

The purpose of the short-term visit is to prepare joint collaborative research between the Research Centre on Landslides, DPRI of Kyoto University, and the Department of Engineering Geology, Hydrogeology and Applied Geophysics, Comenius University in Bratislava focused on the advanced methods of spaceborne SAR interferometry in landslide activity assessment of urbanized areas in Japan and Slovakia.

In recent years, with climate change or frequent occurrences of earthquakes, a huge number of landslides occurred in Japan almost every year, resulting in great damage to the properties and a large number of casualties. Among them, these landslides occurring in urbanized areas were the most catastrophic. Therefore, it is essential to identify, study and monitor those slopes with landslide risk. In recent years a considerable effort was put forward in the development of new algorithms and services in the field of earth surface deformation monitoring employing new satellite-born sensors by the European Space Agency. In the future collaborative research, we plan to employ the Synthetic Aperture Radar Interferometry (InSAR) on images taken by radar sensor onboard Sentinel 1 satellite to study deformation and monitor selected urbanized areas in Japan and Slovakia in order to understand the activity and assess the potential of these areas to failure before the catastrophic failure actually occurred. This will be achieved by processing archived data using PSInSAR techniques. The significance of this research is in the application of new technology in the study of landslides, which could contribute to the reduction of life and property loss due to catastrophic landslide events. This research could be also beneficial to the local community governments in recognition of potentially unstable residential areas and help in better management of land.

2. Description of research project

The main aim of the short-term visit is to have discussions between collaborators and prepare the application for the collaborative research project focused on the study of landslide activity affecting urban areas, which makes use of state-of-the-art methods of satellite radar imagery. One of the latest methods used for this purpose is applying the interference of electromagnetic waves for scanning the Earth. Images of the Earth from radar with the synthetic aperture will be analyzed by PSInSAR (Permanent Scatterer InSAR) and SBAS (Small Baseline Subset Algorithm) algorithms. The results enable precise monitoring of landslide deformation and for the first time in history can detect deformations prior to the catastrophic event, therefore we can see its deformations, thanks to the availability of archive radar images, practically backward in time. In October 2014 data from a completely new sensor carried onboard the SENTINEL-1 satellite were given to the scientific community for utilization by the European Space Agency (ESA) and we plan to incorporate these valuable new data into our project in order to process the radar images to produce deformation outputs for selected landslide sites.

The project will focus on the possibility of joining remote sensing techniques with on-site data provided by RCL of DPRI and possibly Tokushima landslide observatory from local landslide sites in Japan, with a long history of monitoring such as Zentoku landslide (Tokushima prefecture), Takahashi (Bitchu-Matsuyama Castle landslide) in Okayama prefecture, and other sites.

In the framework of the short-term visit stay a joint visit to potential field landslide sites will be vital to evaluate the applicability of the remote sensing methods to some particular sites and assess the availability of permanent

scatterers (buildings, walls, roofs, rocks, and other good signal scatterers) inside the landslide body, degree of foliage and forestation which hinders the radar signal etc. Some ring shear tests will also be conducted on the samples taken from these landslides for the prediction of their sliding phenomena, and also for the check of the analyzed results of PSInSAR.

3. Summary of Research Progress and results

The project was focused on the possibility of joining remote sensing techniques with on-site data provided by LCR of DPRI and possibly Tokushima landslide observatory from local landslide sites in Japan, with a long history of monitoring such as the Zentoku landslide in Tokushima prefecture or other possible new investigation sites. In the framework of the short-term stay, a seminar was held on the premises of LCR on August 23rd, 2023 (Fig. 1) where Dr. Greif presented the possible application of PSInSAR and availability of Sentinel1 satellite radar data for Japan and Prof. Wang presented the outcomes of his field investigation of landslides triggered by the 2023 Turkey - Syria earthquake to the Ph.D. students. Further, short field trips to potential investigation sites were conducted by Dr. Greif in the following days including Noto peninsula hit by an earthquake on 5.5.2023 (and subsequently another stronger one M_w = 7.5 on January 1st, 2024), Matsushima Bay (Sendai) where famous islands of Matsushima composed of Miocene tuffs are considered a product of a large coastal Holocene mega-landslide and could be a possible target of PSInSAR measurements. Further, a volcanic site near Noboribetsu (Hokkaido) was identified as a potential site for PSInSAR application in the study of ground deformations due to the lack of vegetation in the Jigokudani valley.

Fig. 1 Photo from a seminar was held on the premises of LCR on August 23th, 2023

The possible application of PSInSAR to landslide monitoring has been exampled by two case studies that had been conducted by Dr. Greif and colleagues. The details are listed below.

(1) Vladimir Greif, Jaroslav Busa, and Martin Mala (2021): Landslide Activity Classification Based on Sentinel-1 Satellite Radar Interferometry Data. Pp: 111-118, In Understanding and Reducing Landslide Disaster Risk, Springer (eds/ Guzzetti et al).

Abstract: "*Kosice basin located in the Eastern part of Slovakia heavily affected by landslides was studied using radar data from Sentinel-1A satellite. Existing landslide inventory activity map was reassessed using processed data from Sentinel-1A radar mission acquired between December 2014 and May 2017. PS InSAR technique was used for generation of landslide displacement permanent scatterers inside the landslide area, where average LOS velocity was applied for assessment of landslide activity in the form of thematic map. Using alternative method a LOS deformation velocity vectors were transformed into the slope direction generated from DEM resulting in kSLOPE velocity data used for alternative classification map. This was possible thanks to availability of radar data from both acquisitions (ascending and descending) on the studied AOI. Comparison of both methods showed increase in number of landslides classified as active on behalf on medium active class when kSLOPE transformed data were used, resulting in more comprehensive activity classification map. The transformation of velocity vector vLOS must be, however, used with caution, due to variable sensitivity of radar data in different directions with regard to the satellite path.*"

(2) Vladimir Greif, Jan Vlcko (2012): Monitoring of post-failure landslide deformation by the PS-InSAR technique at Lubietova in Central Slovakia. Environ Earth Sci (2012) 66:1585–1595

Abstract: "*Interferometric synthetic aperture radar data from ERS and ENVISAT sensors were utilized in the analysis of the post-failure deformations in the area of Lubietova town in Central Slovakia. The catastrophic landslide of 1977 together with surrounding landslides in the Lubietova area were analysed with the help of persistent scatterers (PS) technique in order to evaluate recent and past deformations of the unstable slopes. Although long-term precise geodetic monitoring of the 1977 landslide revealed differential deformations inside the sliding mass, due to the lack of the PS located inside the landside caused by temporal decorrelation, unfortunately, these records could not be directly compared. The adjacent landslides with sufficient number of PS were analysed by transformation of the line of sight displacements recorded by the sensors to the slope vector direction. This procedure allowed identification of the precise boundaries of the actively moving landslide parts and the updating of the landslide inventory for the Lubietova area."*

As stated above the main purpose of the short-term visit was to have discussions between collaborators and prepare the application for the collaborative research project focused on the study of landslide activity affecting urban areas. It was concluded that the Noto peninsula as recently affected by several damaging earthquakes could be the focus of the future joint collaborative research between the Research Centre on Landslides, DPRI of Kyoto University, and the Department of Engineering Geology, Hydrogeology and Applied Geophysics, Comenius University in Bratislava. Regarding the Sentinel1 data availability, there were together 18 acquisitions available for relative orbit 119 between 1.1.2023 and 8.8.2023 for the Noto peninsula area, although only in descending orientation. This

number should be in meantime higher which is promising for obtaining positive results in future research.

4. Other contributors to this Research

Martin Mal'a: Dept. of Engineering Geology, Hydrogeology and Applied Geophysics, Faculty of Natural Sciences, Comenius University in Bratislava
Gen Furuya: Professor, Toyama Prefectural University
Gonghui Wang: Professor, DPRI, Kyoto University
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