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APPLICATION OF PERSISTENT SCATTERERS INTERFEROMETRY FOR LANDSLIDE MONITORING IN THE VICINITY OF ROZNOW LAKE IN POLAND

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ABSTRACT

The paper presents the preliminary results of the analysis of two archival SAR datasets acquired by ERS-1/2 satellites of the same area of Roznow Lake in Southern Poland. Both datasets cover the same period of 8 years (1992 – 2000) and refers to the same area by the 50% of overlap between the neighbouring satellite tracks. The main purpose of this analysis was to derive the overlapping data about deformation velocity calculated using PSI (Persistent Scatterers Interferometry). The presented PSI results refer to PS (Persistent Scatterers) located on active landslides and therefore representing landslide movement. In Polish Carpathians, due to sparse urbanization, vegetation and rough relief the obtained PS density is usually not very high and generally difficult to interpret. The application of two overlapping datasets, where both of them observe the same phenomena, allow to cross-validate the data by identification of common PS points. For two datasets acquired from different tracks, usually many PS are not common and occur at different locations. Such situation could be explained by the difference between the incidence angles for both acquisitions. In a case of two tracks and therefore different terrain objects might act as PS. By joining the PS point sets from such neighbouring tracks the density of PS could be significantly increased.

In order to perform a PSI analysis of Roznow Lake the data acquired from 179 and 408 tracks have been used and a few hundred of PS were obtained from PSI processing. For both tracks similar deformations velocity were obtained within a range of +/- 6 mm/yr. The PS points on active landslides are usually related to the buildings (walls, roofs) and roads affected usually by high risk.

KEYWORDS: landslides, Persistent Scatterer Interferometry, SAR interferometry, LIDAR, Carpathians

1. INTRODUCTION

Carpathian Mountains are subjected to high landslide geohazards. It is the area where more than 95% of the total number of landslides in Poland is located. Landside occurrence is here caused by the specific combination of the geological, geo-morphological and hydrogeological conditions. Landsliding activity is however controlled by hydrological factors like heavy rains and melting thick snow cover. Such events resulting acceleration and reactivations of landslides causing costly damages to built up areas and communication system. In last decades such situations occur in 1997, 2001, 2003 followed by catastrophic activity in summer 2010.

Learning lesson from past landslide events the Polish Ministry of Environment together with Polish Geological Institute has initiated in 2006 the national project named "Landslide Counteracting System" (SOPO). The purpose of SOPO project is to create detailed maps and the digital database of all recently active and inactive landslide prone areas in Poland (Grabowski, 2008). The main part of the work is detailed field mapping in scale of 1: 10 000 and is currently carried out mostly in the Carpathians. Another important goal of SOPO project is to establish monitoring systems on the particular landslides dangerous to infrastructure.

Traditionally, to support geological and geomorphological analysis stereo-pairs of aerial photographs are applied. Recently analogue stereo pairs were replaced by digital photogrammetry and digital ortophotomaps with associated Digital Terrain Models (DTMs). Within a framework of SOPO project some advanced remote sensing techniques that might support landslide mapping and monitoring are currently tested.

One of these techniques is Synthetic Aperture Radar (SAR) interferometry (InSAR) that utilizes phase information derived from satellite SAR images. InSAR has been already recognized as a very effective low-cost technique for landslide deformation detection and monitoring (Colesanti and Wasowski, 2006). The application of various SAR Interferometric (InSAR) techniques like Differential InSAR (DInSAR) (Achache et al., 1995), Persistent Scatterers Interferometry (PSI) (Colesanti and Wasowski, 2006)

(Hilley et al., 2004), and Small Baseline Subsets (SBAS) (Lanari, 2003) proved their high reliability and usefulness. Moreover, large data archives (since 1992) allowing to perform deformation analyses also for the areas that never has been measured with terrestrial geodetic techniques. However, it should be noted that InSAR is an opportunistic technique (Hanssen, 2001) and it is difficult to predict its performance for a specific area prior to data processing. The InSAR study success rate depends on factors degrading the temporal and geometrical correlation of radar signals. In the case of the Carpathian landslides InSAR applications are limited due to mostly environmental factors (Perski et al., 2010):

- very rough topography,
- lack of rock outcrops,
- dense vegetation cover (forests in the higher parts of the slopes and meadows and fields in the lower parts)
- bad weather conditions with high precipitation,
- long season with thick snow cover,
- very sparse urbanization concentrated in the valleys and along the roads.

2. LIDAR FOR PSI

In order to overcome some of listed above limitations point wise InSAR techniques have been developed as the Permanent Scatterers technique (Ferretti et al., 2000; Ferretti et al., 2001). This method and its modifications, the so called Persistent Scatterers techniques (PSI, see e.g. (Crosetto et al., 2002; Hooper, 2006)) utilizes the identification and the exploitation of stable natural radar reflectors. The dimensions of the reflectors are usually smaller than the resolution cell and their coherence remain high for large temporal and geometrical baselines. The PSI technique is expanding now towards the decorrelated areas with low PS density and a small deformation signal (Ketelaar et al., 2004). PSI has already been partially successfully used for studying Carpathian landslides (Perski et al., 2009; Perski et al., 2010). However the interpretation of PSI results is difficult and complex task due to low density of obtained PS points set and non uniform spatio-temporal pattern of deformation. In some cases the phase signal might be wrongly decomposed due to very high elevation differences. In order to improve PSI results the precise and up-to-date elevation information should be used. However, since the radar signal is backscattered from all objects present on terrain surface, the applied elevation data should include all terrain objects. Required DSM (Digital Surface Model) might be derived from various sources. However, recently DSM data are usually acquired using Airborne Laser Scanning – LiDAR technique.

A supportive use of LiDAR data for terrain deformation estimation with help of PSI technique is presented on the scheme in Figure 1. Application of precise DSM is required on following stages of PSI processing:

(a) during processing of interferograms (classical InSAR processing) to remove topographic contribution on large baseline interferograms,

(b) during PSI processing: DSM might be used to contribute/verify PS phase decomposition into atmospheric, height and deformation components,

(c) during PSI postprocessing: to correctly geolocate obtained PS points.

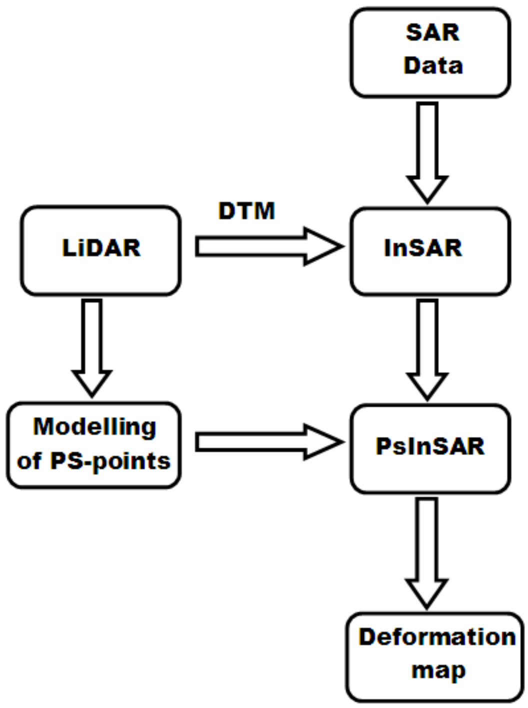

Fig. 1 Author's conceptual scheme of precise LiDAR data application in order to improve PSI processing.

3. THE STUDY AREA AND DATA USED

The InSAR/LiDAR study was performed on the area of Zbyszyce Landslide located on the Eastern coast of Roznow water reservoir. The Zbyszyce landslide is a large, active and complex landslide being monitored by Polish Geological Institute since 1997 and other research groups (Wojciechowski, 2007).

The interferometric processing for the study area was performed based 113 SAR scenes acquired from two parallel and overlapping satellite descending tracks (179 and 408) by European ERS-1 and ERS-2satellites over the period of 8 years from 18 June 1992 to 17 December 2000 (Fig. 2). For the project purposes new acquisitions from high resolution

TerraSAR-X satellite from ascending orbit were ordered.

4. DATA PROCESSING

DInSAR part of the processing was completed using DORIS: Delft Object Oriented Interferometric Software (Kampes et al., 2003) and for PSI processing the TUDelft implementation (Leijen et al., 2005) of the original Persistent Scatteres algorithm was applied.

In order to precisely coregister the image pairs for InSAR processing the optimization of window distribution based on SAR amplitude procedure was used followed by the optimization of the computation of coregistration polynomial. This method ensures correct coregistration even on areas lacking of urbanisation and was successfully applied before (Perski et al., 2008; Perski et al., 2010).

Thanks to a common overlap between the satellite tracks (40-50%) the study area is covered by two datasets. Both datasets: track 178 and 409 were processed independently applying the same processing settings and parameters. As the result two independent PS sets from the same area were obtained that allows to cross-compare and cross-verify the PS measurements. However, the comparison and verification was possible only in situation where the same terrain objects appears as PS for both datasets. In our case the study area is located in different parts of the scenes (*far range, near range*) where incidence angles are different significantly (Fig, 2, Fig. 3).

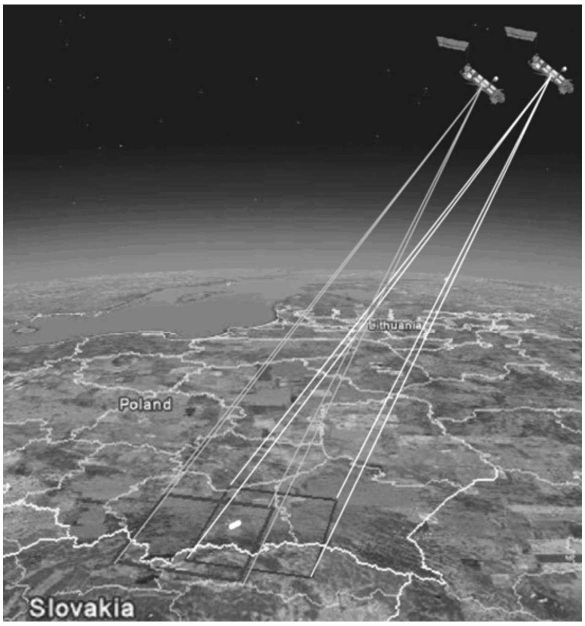

Fig. 3 Schematic view of the difference in acquisition geometry for the study area. (3D terrain view was generated with GoogleEarth).

During the PSI processing of all available images it was found that only a small number of PS could be obtained (Fig. 4). Unfortunately PS points were located in the densely urbanised areas along the valleys. To increase the number of PS, different processing strategies were tested and the best results were obtained with only 29 (track 179) and 30 (track 408) SAR images acquired under no snow conditions. In most cases PS are not sensible to atmospheric conditions but thick snow cover may simply mask many of them.

The final analysis of the geocoded PSI data requires a GIS environment which allows combining all the interferometric results and external data into one common reference system. For this purpose the open-source GRASS (Geographic Resources Analysis Support System) was applied (GRASS-Development-Team, 2006).

Unfortunately during the time of data processing a LiDAR DSM was not yet prepared. However, LiDAR DTM (Digital Terrain Model) representing terrain surface excluding features such as vegetation, buildings was already available. The PSI processing area was larger than LiDAR dataset (Fig. 2) and therefore for the topographic correction LiDAR DTM was merged with the DTM processed from the available DTED (Digital terrain Elevation Data) level 2, a NATO standard one arc second (~30 meters) resolution.

At the present stage of the Project only a small fraction of PS were obtained for Zbyszyce landslide. For both tracks similar deformations velocity were detected within a range of +/- 6 mm/yr. The PS points on active landslides are usually related to the buildings (walls, roofs) and roads affected usually by high risk. Unfortunately, no common points on both datasets that allows cross-comparison were identified.

5. CONCLUSIONS AND FUTURE WORK

The presented preliminary results PSI processing show that PS results obtained for a common coverage for two neighbouring tracks are difficult to analyse. Small number of obtained PS points is probably resulted from high activity of the landslide and errors due to not accurate DEM correction. Another reason of small number of detected PS might be related to SAR acquisition geometry: the SAR data were acquired from descending orbits and therefore “seeing” the terrain from the east. Zbyszyce landslide is located on south-western slope and therefore the SAR signal propagation is almost parallel to the slope. New TerraSAR-X acquisitions for the project purposes were designed to be done from ascending orbit which is perpendicular to the slope direction (Fig. 1). However, the number of already acquired scenes is too small to be used for PSI processing. For the testing purposes TerraSAR-X data have been processed with standard InSAR technique and a promising result was archived for study area.

Figure 5 shows the interferogram revealing the deformation associated with the Klodne landslide. Klodne landslide was activated in April 2010 causing severe damage to a number of houses.

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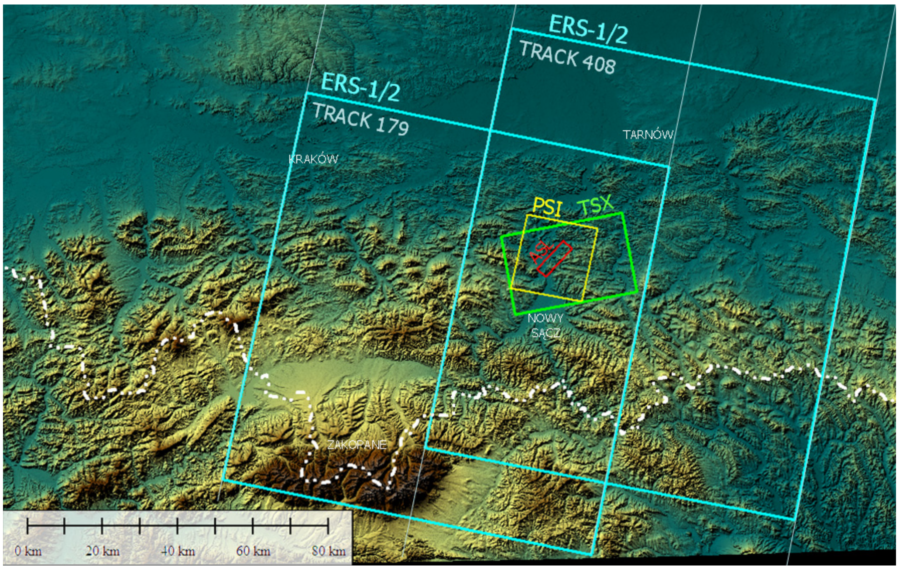

Fig. 2 Location of the Study area and the extent of ERS-1/2 data. TSX – extent of TerraSAR-X data, ASL-extent precise DTM derived from LiDAR data, PSI – extent of PSI processing.

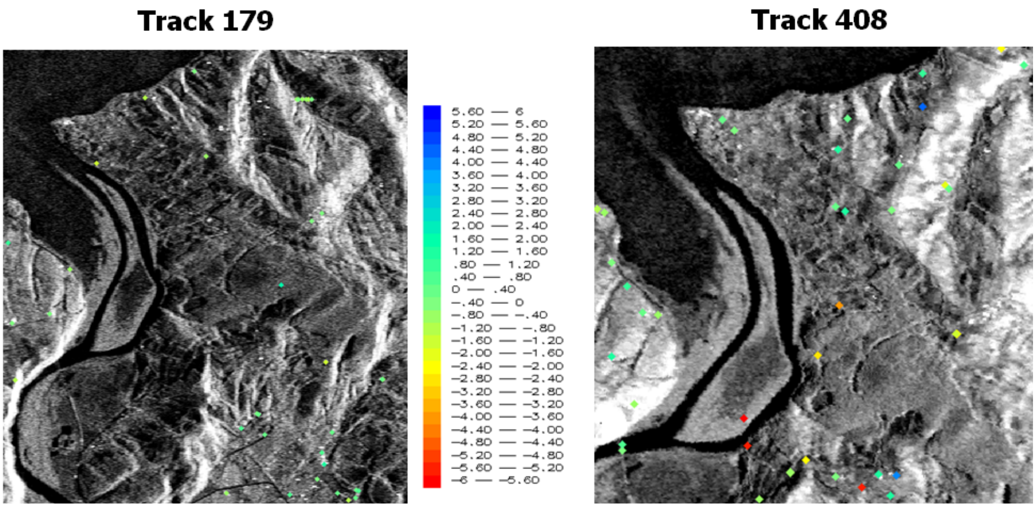

Fig. 4 Preliminary PSI results of of Zbyszyce landslide (zoomed fragment of full PSI set).

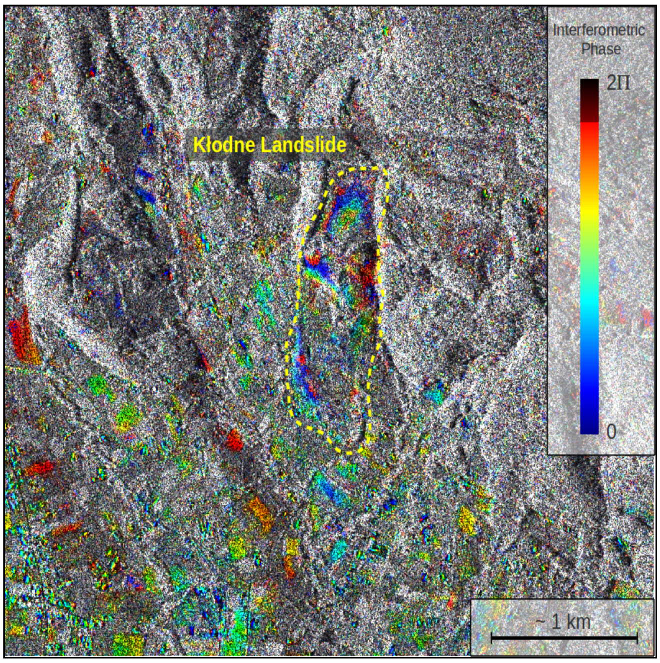

Fig. 5 TerraSAR-X interferogram processed from the SAR scenes acquired on 2010.10.06 and 2010.10.28 showing terrain deformation associated with Klodne landslide. Interferometric phase change of 2Π corresponds to approximately 15 mm of vertical displacement.