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DETECTION OF LAND SUBSIDENCE DUE TO MINING ACTIVITIES IN NORTHERN MORAVIA REGION USING SATELLITE RADAR INTERFEROMETRY

Summary. The progression of landscape character of Northern Moravia, Czech republic, is strongly affected by the black coal mining since the 18th century. The land around mining locations is subsiding especially in the Karvina region where the subsidence velocity is more than one meter per year. Subsidence is monitored geodetically, but this solution is not very effective – quite a new method of radar interferometry can help. It uses satellite radar images for detection of topography changes in time. The VSB-TU University in Ostrava got, within an ESA project, more than 100 radar images of ERS and Envisat satellites that describe the regional progression since 1995. These images were processed by basic and advanced radar interferometry methods and compared with land measurements.

WYKRYWANIE OBNIŻEŃ TERENU WYWOŁANYCH DZIAŁALNOŚCIĄ GÓRNICZĄ W PÓŁNOCNYCH MORAWACH METODĄ INTERFEROMETRII SATELITARNEJ

Streszczenie. Charakter rzeźby terenu północnych Moraw jest silnie uwarunkowany wpływami górnictwa węgla kamiennego, którego początki datują się na tym terenie na XVIII wiek. Wpływy te widoczne są zwłaszcza w rejonie karwińskim, gdzie obniżenia sięgają ponad 1 m/rok. Technika interferometrii radarowej oparta jest na wykorzystaniu zdjęć radarowych, dokumentujących zmiany powierzchni w czasie. W ramach projektu ESA Uczelnia VŠB-TU w Ostrawie zakupiła ponad 100 zdjęć radarowych ERS i Envista, dokumentujących zmiany topografii począwszy od 1995 roku. Zdjęcia te przeanalizowano za pomocą podstawowych i zaawansowanych metod interpretacji interferometrii radarowej, a rezultaty porównano z wynikami pomiarów geodezyjnych.

1. Introduction

The land subsidence is one of the most common and sometimes dangerous effects of the mining industry that affects our environment. Even with the most sophisticated mining techniques used, the subsidence still occur and provide damage to buildings, roads and other human structures on the land surface. In the area of Northern Moravia region (Czech republic), there are several mines – active or in a non-active state. All of them can denote a threat for citizens in the region, especially in Karvina region. For a long period of time, the subsidence has been monitored using geodetical attempts that resulted in maps of subsidence. Now we know the average velocities of progression of subsidence in several cities that can achieve even more than a metre per year. Unfortunately, this form of detection and monitoring is a very expensive solution and sometimes even not very dependable because of the need of more precise measurements.

In the last years, another usable methods have been developed for detection of land subsidence. The images from satellites with a radar sensor onboard are used in this science branch called the radar interferometry. The radar interferometry techniques were successfully used in many situations similar to the one in this region. For example, Dr. Zbigniew Perski [1] has worked for many years on the monitoring of land subsidence due to the mining activities in Southern Poland and proved that it is possible to detect subsidence effectively this way, with some limitations, nevertheless. After the fashion of his work, the VSB-TU University in Ostrava has arranged an ESA project that uses radar interferometry to detect and monitor the subsidence in Northern Moravia.

2. The methodology

The main principle of the radar interferometry techniques, is a creation of differential interferograms from two images of the exactly same area taken in a temporal difference that match the probable velocity of subsidence - to be able to detect some land movement during the time between these two acquisitions. Advanced techniques can describe the subsiding trend in a longer time period using a stack with many more images. The advantages of the radar interferometry is its cost effectiveness and very precise measurement of land deformation (in the areas with a good radar scattering characteristics, it is theoretically possible to detect even mm sized land movement). On the other hand, the method has its weaknesses – it is very dependable on the quality of the images acquisitions – on the atmospheric conditions during scanning, geometrical characteristics of the scanned land (e.g. orientation of hill slopes and the direction of subsidence itself), seasonal characteristics etc.

The advanced techniques that were used in the project, are so-called Small baselines subset technique (SBAS) and Persistent Scatterers technique (PS). Both of them are searching for stable scattering points in time series of images – the PS technique uses the difference between all images in a stack (slaves) and one single image (master), while in the SBAS technique combinations of images with small temporal and geometrical baselines of their acquisitions are used. Because the land subsidence is not stable at one place (it is moving according to the mining progress direction), it is not possible to monitor it pointwise in a longer time period. Therefore only a relatively short time period can be used to get some reasonable results. Also, a very fast subsidence evokes problems with so-called phase unwrapping that results in getting (much) lower amount of subsidence than it is in reality.

For the creation of single interferograms, an InSAR (Interferometric Synthetic Aperture Radar) processor Doris, a tool created by TU Delft Netherlands, was used to create combinations between all the available images. For PS the TU Delft implemetation of this method was tested, the testing will continue to achieve some rational result. PS and SBAS techniques results presented in this work were created using StaMPS [2].

3. Application of interferometry and comparison with geodetical measurements

There are two main regions where the geodetical measurements were available – a subsiding road Lazecka nearby Mine Lazy, Orlova and an area between several mines in Karvina/Stonava. The interferograms processing was focused mostly on these places.

The Lazecka road has sinked for about 7 metres between years 1999 and 2009 – this number is a maximum value measured on one of 40 points on this road. The area was investigated using interferograms – only several pairs of radar images could show some interpretable signs of subsidence (fringes). The Figure 1 on the left shows the measurement points (green circles) together with an interferogram created from ERS-2 data with 70 days temporal baseline (30.10.2000 and 4.12.2000). It is possible to see the subsidence centers that correspond to the locations of the mining paths. On the right side of the Figure 1, the results of PS+SBAS techniques (detected stable points found by these methods are merged togethes) are shown – for this processing only 22 ERS-2 images from 1999-2001 were chosen – during this period the ERS-2 satellite was flying very stable, the perpendicular and so-called Doppler centroid baselines were small enough and all the images with a 35 days temporal step could be used to achieve the most reasonable processing results. On the same picture, two points are marked as A and B. The difference between these scatterer points and the nearest geodeticaly measured point is described in the Table 1.

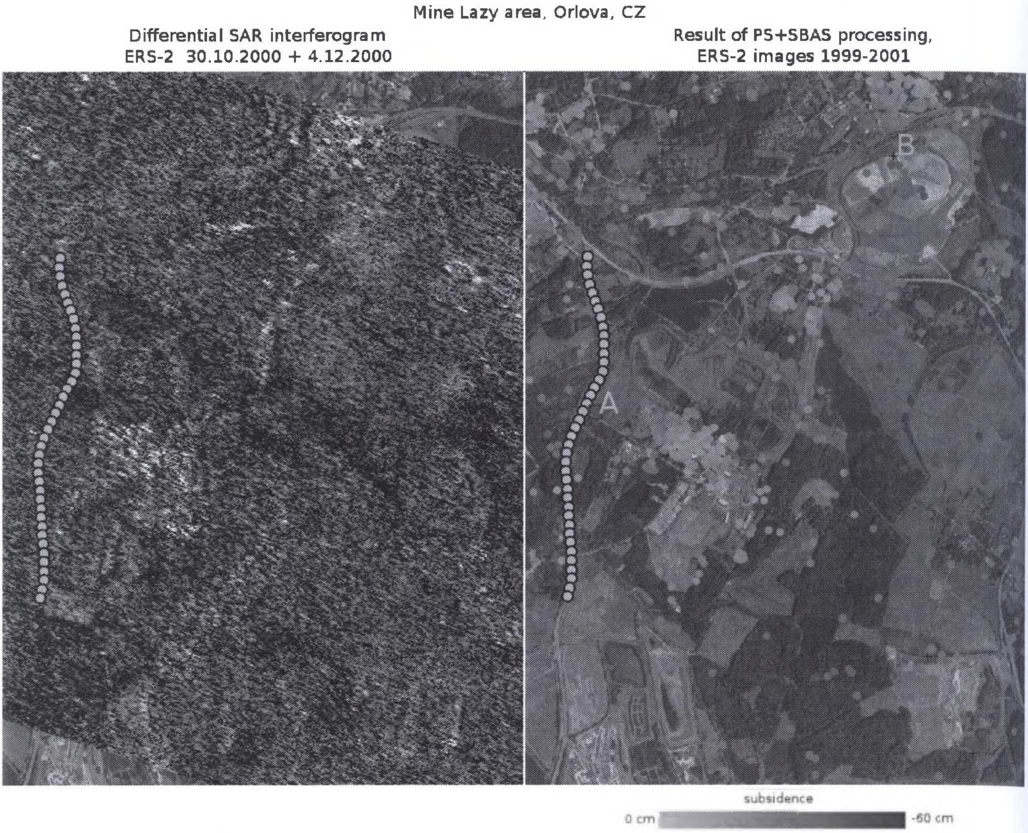

Fig. 1. Processing of Mine Lazy area, Orlova, CZ
Rys. 1. Interpretacja na obszarze kopalni Lazy, Orlova, CZ

Table 1

Comparison of methods applied on 2 near points

Scatterer point	Computed value (PS+SBAS) of subsidence 1999-2001	Measured subsidence of the nearest meas. point, 1999-2001
A	17.7 cm	13 cm
B	32.7 cm	0 cm

From the Table 1 it is possible to see that although the results look very promising, it cannot be ever fully trusted – there is a lot of possible error sources, this one (point B) was caused probably by wrong phase unwrapping (the unwrapping processor was expecting a phase shift in images with included atmosphere artefacts that passed to the final result because it seemed probable – the coherence between these images was very good thanks to the strong reflection from the ground). Anyway, the coarse view at subsidence places gives at least a map of suspicious places to check.

Another investigated place was Karvina region. Several subsiding places were detected in interferograms that correspond with real subsidence near the mines, mostly from newer acquisitions (year 2008) – this shows that the subsidence is still active, concretely in the Mine CSM surroundings in Stonava city – and Mine CSA in Karvina. Unfortunately, the PS and SBAS methods again resulted in false subsidence detection.

4. Conclusions

Several smaller areas were targeted for creation of interferograms that should show the progress of land changes from 1995 to 2008. Anyway, a lot of radar images combinations resulted in loss of coherence due to various factors (too much of atmosphere influence on the radar waves phase changes, too large baselines between acquisitions, the regional characteristics), so only several combinations contain some interpretable information. In Ostrava area, no subsidence was detected at all. In the Karvina area it was possible to monitor land subsidence in the Mine Lazy surroundings and nearby the Mine CSM and others between the Karvina and Stonava cities.

The results of StaMPS processing are describing the land subsidence more or less according to the in-situ measurements in the years 1999-2001 in the Karvina region. It will be applied for more datasets in order to achieve a better view for subsiding trends in the area.

As a conclusion, it is indeed possible to monitor land subsidence due to the mining activities with existing techniques of radar interferometry, but because of its many processing limitations and because of the nature of the subsidence itself (its high velocity that makes it wrongly computed due to achieved phase unwrapping errors, and position changes in time due to the mining progressions that makes it more difficult to monitor it pointwise), it is still recommended to be used only as a complementary technique to the in-situ measurements that are supposed to be the most veritable.

This project will continue with attempts to eliminate the errors in the PS and SBAS processing.

BIBLIOGRAPHY

1. Perski Z.: The Inerpretation of ERS-1 and ERS-2 InSAR Data for the Mining Subsidence Monitoring in Upper Silesian Coal Basin, Poland, International Archives of Photogrametry and Remote Sensing, vol. XXXIII, 2000.
2. Hooper A.: A multi-temporal InSAR method incorporating both persistent scatterer and small baseline approaches, Geophys. Res. Letters, doi:10.1029/2008GL034654, 2008.
3. Kampes B. M., Hanssen R. F., Perski Z.: Radar interferometry with public domain tools, in Third International Workshop on ERS SAR Interferometry, 'FRINGE03', Frascati, Italy, 1-5 Dec 2003, p. 6.

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