Temporal Analysis of Small, Long-period Ground Deformations within Selected Mining Areas in South Poland

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SUMMARY

In the paper the results of temporal analysis of small, long period ground deformations are presented. The analysis concerns mining areas of two coal mines located in Southern Poland. The first one is still working “Kazimierz-Juliusz” coal mine and the second is “Grodziec” coal mine where the coal exploitation was conducted up to 1998. The analysis of small, long period ground deformations was performed for time period between years 1993 and 2000 based on the set of PSInSAR (Permanent Scatterer Interferometry Synthetic Aperture Radar) data.

The analysis performed for these coal mines confirm hypothesis that these trend changes can be related to coal exploitation. In “Kazimierz-Juliusz” coal mine the increase of subsidence velocity is characteristic for all analysed time period. For areas located near exploitation field in “Grodziec” coal mine the increase of subsidence velocity was found for period 1994-1995. In the mentioned time period the coal exploitation was carried on in “Grodziec” coal mine. For time period between March 1999 and April 2000 when it had finished exploitation the decrease of subsidence velocity was characteristic. Such a situation may indicate that the coal exploitation can affect the values of small, long period ground deformations.
Introduction

In the presented paper the results of temporal analysis of small, long period ground deformations are presented. The analysis concerns mining areas of two coal mines located in Southern Poland. First of them is the mining area of still working “Kazimierz-Juliusz” coal mine located in Sosnowiec city. The second one is the mining area of “Grodziec” coal mine located near Bedzin city where the coal exploitation was conducted up to 1998. The analysis of small, long period ground deformations was performed for time period between years 1993 and 2000 based on the set of PSInSAR (Permanent Scatterer Interferometry Synthetic Aperture Radar) data.

PSInSAR data

The PSInSAR technique is one of dynamically developing methods of satellite SAR (Synthetic Aperture Radar) data processing. In this method set of several dozen satellite SAR images are exploited (Ferretti et al. 2001). The images are acquired at different times but cover the same studied area. The PSInSAR technique derives information about small, long period ground deformations, with millimetre accuracy (Porzycka et al. 2007). In this method the values of ground deformations rates are determined only for these pixels of SAR images (called PS points) that are characterised by high values of coherence (the values of signal phase are stable in time for all radar images). The PS points correspond mostly with man-made features like buildings, bridges, viaducts etc. The PSInSAR technique allows determining only small ground deformations, not larger than several centimetres per year.

The PSInSAR data used in this work were obtained by processing 79 SAR images acquired form ERS-2 and ENVISAT satellites. For selected mining areas 799 PS points were identified - 263 for “Kazimierz-Juliusz” coal mine (Fig.1) and 536 for “Grodziec” coal mine (Fig.2). The location of PS points within mining areas is very irregular. There are regions without stable radar targets. These regions correspond mainly with undeveloped areas or/and with areas were large values of subsidence are characteristic. For each PS point the average annual motion and value of coherence were determined. The values of deformations that occurred between the acquisition of each exploited SAR image and reference image were also determined. The satellite radar images that were used in the PSInSAR procedure where acquired mostly with 35 day temporal baseline.

Figure 1 Mining area of “Kazimierz-Juliusz” coal mine with location of PS points, main shafts and exploitation fields.
Temporal analysis of PSInSAR data

The values of ground deformations obtained using PSInSAR technique depend on many local factors that affect the particular stable radar targets. In many cases the approximation of deformation values at PS points that utilize linear model (as it is done in standard PSInSAR algorithm) results in loss of important information. Such a case may lead to wrong interpretation of the deformations measurements. On the other hand the over-interpretation may lead to amplification of irrelevant factors. The aim of temporal analysis of PSInSAR data performed in this work was to study how the temporal ground deformation trend changes for each PS point. In order to perform this task the special algorithm was developed. The algorithm was prepared in R, e.a. an open source environment for advanced statistical analysis. Developed algorithm allows to reveal maximum one, the most significant, ground deformation trend change for each PS point. In this work trend changes were divided into four categories: (1) increase of subsidence velocity, (2) decrease of subsidence velocity, (3) increase of ground lifting velocity, (4) decrease of ground lifting velocity.

Performed analysis revealed that for 46.7% of PS points from “Kazimierz-Juliusz” coal mine and for 45.3% of PS points from “Grodziec” coal mine the ground deformation trend changes occurred in studied period of time. For both coal mines the most trend changes occurred at the beginning (between December 1993 and November 1995) and at the end (between March 1999 and April 2000) of analysed time period. For the first time period the increase of subsidence velocity is characteristic (category (1)) and for the last part of considered time period the trend changes indicated the decrease of subsidence velocity (category (2)). In order to study the spatial distribution of PS points, for which the ground deformation trend changes were revealed, the maps of relative density were prepared. The values of relative density of PS points were determined using two-dimensional kernel density estimator (KDE) (Waller et al. 2008). In the presented work a Gaussian function was used as a kernel function.

In the figure 3 the values of relative density of PS points, within mining areas of “Kazimierz-Juliusz” coal mine were shown. The values of relative density concern these stable radar targets for which the decrease of subsidence velocity were revealed. The separate maps were prepared for time periods between December 1993 and November 1995 and between March 1999 and April 2000. For the first mentioned time period the increase of subsidence velocity is characteristic for larger part of mining area, especially for regions located on the west and south of the exploitation fields. For the time
period between March 1999 and April 2000 the area for which decrease of subsidence is characteristic is larger than between years 1993 and 1995. However, character of ground deformation trend changes in the region on the west and south of the exploitation fields did not changed. Such situation can be caused by coal exploitation that has been performed continuously in the “Kazimierz-Juliusz” coal mine.

Figure 3 The relative density of PS points, within mining area of “Kazimierz-Juliusz” coal mine, for which the increase of subsidence velocity was revealed.

In the figure 4 the relative densities of PS points, within mining areas of “Grodziec” coal mine were shown. Similarly as in the case of “Kazimierz-Juliusz” coal mine the values of relative density concern these stable radar targets for which the decrease of subsidence velocity were revealed. It can be seen that in the time period between December 1993 and November 1995 for large part of mining area the increase of subsidence velocity is characteristic (category (1)). It is clearly visible especially near exploitation field, located in the SW part of the studied region. In this time period the coal exploitation was carried on in the “Grodziec” coal mine. The situation has changed for the second analysed time period (III.1999 – IV.2000) for which the decrease of subsidence velocity is characteristic for larger part of mining area (category (2)). It has to be mentioned that coal exploitation was finished in the “Grodziec” coal mine at the end of 1998. The decrease of subsidence velocity is very clearly visible near the exploitation field.
Conclusions

The performed temporal analysis of PSInSAR data from mining areas of “Kazimierz-Juliusz” and “Grodziec” coal mines revealed that for 45.8% of analysed PS points the ground deformations trend changes occurred in time between December 1993 and April 2000. Most of the trend changes occurred between December 1993 and November 1995 and between March 1999 and April 2000. The analysis performed for two coal mines confirm hypothesis that these trend changes can be related to coal exploitation. In still working “Kazimierz-Juliusz” coal mine the increase of subsidence velocity is characteristic for the region located near exploitation parcels for all analysed time period. For areas located near exploitation field in “Grodziec” coal mine the increase of subsidence velocity was found for period between December 1993 and November 1995. In the mentioned time period the coal exploitation was carried on in “Grodziec” coal mine. For time period between March 1999 and April 2000 when the “Grodziec” coal mined finished exploitation the decrease of subsidence velocity was characteristic almost for all mining area. Such a situation may indicate that the coal exploitation can affect the values of small, long period ground deformations that were previously explained mostly by neotectonic movements (Leśniak et al. 2007).

References


