RS31

Study of Road Deformations in the Area of Dabrowski Basin using Satellite Radar Interferometry

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SUMMARY

In the presented paper the PSInSAR data were used to analyse the small, long-period road deformations in Dabrowskie Basin area in Upper Silesia Mining Region (Poland). It is the area of intensive coal exploitation since XIX century. The seven coal mines are located in the basin. Only the one of them is the active mine. The others were closed in 1995-2004 period. The dense faults network with throws ranging from several dozens to over three hundred meters crosses the road network so they also can be the reason of subsidence. Based on PSInSAR data, the interpolation of average annual motion rates were performed for all studied region. The interpolation was done using kriging method. The analysis of PSInSAR data revealed that main roads in the Dabrowski Basin are located in the region with different values of average annual motion rates. The largest values of subsidence rates were revealed for part of road number 86 and part of Eastern GOP Ring Road. In both cases the average annual motion rates rapidly increase up to 20 mm/year and then also very fast decrease to 0 mm/year.
Introduction

Surface land deformations that appear in different regions of Poland have natural or anthropogenic nature. They differ in amplitudes and rates and often cause damages in surface and subsurface infrastructure. One of the key components of surface infrastructure are roads. They are especially exposed on destructive influence of land lifting or subsidence. Land deformations are reasons of roads’ surface damages and can limit or even hinder their usage. For reasons of road protection and development of existing roads network the permanent monitoring of deformations on risk-exposed areas has to be performed.

Monitoring of deformations on large areas can be performed using satellite SAR (Synthetic Aperture Radar) data. Two techniques are most widely used – the radar interferometry (InSAR) and Permanent Scatterer InSAR (PSInSAR). The InSAR method compares two SAR images of the particular area taken in different moments of time to evaluate the relative differences between phases of the reflected electromagnetic signal. These differences can be converted to relative changes of surface elevation and provide priceless information about vertical land deformations. The method is widely used in landslides monitoring (Mirek, 2006), post mining area subsidence (Perski et al., 2003) or road deformations (Krawczyk et al., 2007). The PSInSAR technique uses several dozens of SAR images to monitor very small, long-period deformations of permanent scatterers e.a. separated points of surface that coherently reflect the radar signal. Theoretical aspects of the PSInSAR method were severally discussed and described (Ferretti et al., 2001, Perski et al., 2007, Porzycka et al., 2007). In the presented paper the PSInSAR data were used to analyse the small, long-period road deformations in Dabrowskie Basin area in Upper Silesia Mining Region (Poland).

Characteristic of studied area and exploited data set

The analysis of deformations of main roads in Dabrowskie Basin mining area is presented in the following sections (Fig.1). The total length of analyzed roads is almost 40 km. The Dabrowskie Coal Basin is faced to intensive deformations of different origins. It is the area of intensive coal exploitation since XIX century. The seven coal mines are located in the basin, e.a. mines „Jowisz”, „Grodziec”, „Saturn”, „Paryz”, „Sosnowiec”, „Porabka-Klimontow” oraz „Kazimierz-Juliusz” (Fig.1). Only the last one is the active. The others were closed in 1995-2004 period.

Not only past and present mining activity can be a source of road surface deformations. The discussed area has complex geological structure. The dense faults network with throws ranging from several dozens to over three hundred meters crosses the road network. The main dislocation in this area is Bedzinski fault (Fig.1) with general strike direction from NW-SE. The fault throw changes from 50 m in SE part up to 200 m in NW part of the fault. The Bedzinski fault is crossed by several smaller faults oriented in perpendicular direction e.a. in with approximately longitudinal strike.

In the measurement area there were 24887 permanent scatterers identified. They were obtained as a result of processing of almost 80 images from ESA satellites ERS-2 and ENVISAT. It was verified that the PS points are mainly related to roofs of buildings and pylons. The location of permanent scatterer points is very irregular. For each permanent scatterer the average annual deformation velocity was evaluated for years 1992-2003.

PSInSAR data analysis

In the first step of the analysis, based on PSInSAR data, the interpolation of average annual motion rates were performed for all studied region. This task was done using kriging interpolation method. The obtained results were shown in the figure 2. It can be seen that regions with the large values of velocities are located along the line of Bedzinski fault.
In the described work the charts of average annual motions rate along main roads were prepared. Firstly the chart was done for the part of road marked in the figure 1 as AB, which corresponds with Eastern GOP Ring Road. This part of road crosses the mining area of “Porabka-Klimontow” coal mine, which in studied period of time performed the coal exploitation. It can be seen in the figure 3 that almost whole analyzed AB part of road is located in the areas for which subsidence phenomenon is characteristic. The increase of subsidence rates occurred in place where the described road the crosses line of Bedzinski fault. Near 5 km from point A the values of subsidence velocities start to decrease to 0 mm/year value.
Figure 3 Average annual motion rates along part of Eastern GOP Ring Road (AB segment).

The second chart was prepared for the part of road marked in the figure 1 as a CF, which correspond with the roads with numbers 4 and 94. These roads cross the mining areas of “Saturn” and “Sosnowiec” coal mines. It can be seen in the figure 4 that the CF part of road is located on the areas for which subsidence phenomenon is characteristic. However the changes in the average annual motion rates are not so large as in case of AB part of road. The stabilization of the ground starts in the place where CF part of road crosses the line of Bedzinski fault.

Figure 4 Average annual motion rates along part of roads number 4 and 94 (CF segment).

The third chart was prepared for ED part of road (Fig. 1) which correspond with roads number 94 and 910. These roads cross the mining areas of “Saturn” and “Paryż” coal mines. The maximum values of average annual subsidence rates were revealed for the areas located 3.8 km and 5 km form point E. The stabilization of the ground starts, like in previous example, in place where CF part of road crosses the line of Bedzinski fault.

Figure 5 Average annual motion rates along part of roads number 94 and 910 (ED segment).
The last chart was prepared for JH part of road (Fig. 1) that correspond with road number 86. For this part of the road the largest values of subsidence rates were revealed. This part of road crosses “Saturn” and “Grodziec” coal mines. The significant increase of subsidence velocity was revealed 3.5 km form point J. The decrease of subsidence starts 3.9 km from point J. The stabilization of ground is characteristic for this JH part of road that is located in the upthrow block of Bedzinski fault.

**Figure 6** Average annual motion rates along part of roads number 86 (JH segment).

The analysis of prepared charts revealed that the values of average annual subsidence rates are different for upthrow and downthrow blocks of Bedzinski fault. In the downthrow block there are larger values of subsidence velocity than in upthrow block.

**Conclusions**

The analysis of PSInSAR data revealed that main roads in the Dabrowski Basin are located in the region with different values of average annual motion rates. The largest values of subsidence rates were revealed for part of road number 86 and part of Eastern GOP Ring Road. In both cases the average annual motion rates rapidly increase and then also very fast decrease to 0 mm/year. The largest values of subsidence velocities were revealed in downthrow block of Bedzinski fault. The values of deformations rates in the upthrow block of this fault are close to 0 mm/year.

**References**


