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Dissertation

Geostatistical analysis of the conditions of terrain surface subsidence identified using satellite interferometry in the Upper Silesian Coal Basin

Abstract

The aim of the dissertation was to present the different applications of satellite data processed using radar interferometry techniques for the study of surface subsidence in the area of active and closed coal mines.

In the study seven data sets were used, including three sets of raster data, differential interferograms, obtained in the Differential Interferometry Synthetic Aperture Radar (DInSAR) technique, three sets of points data, acquired in Persistent Scatterer Interferometry (PSInSAR) technology and one set of SqueeSAR data. The data included fragments of Upper Silesian Coal Basin (USCB) and were used to perform analyzes on four research areas: "Bytom", "Katowice", "Uskok kłodnicki" and "Bedzin", of which the first three covered the area of the active mines, while the last one area of the closed mines.

The rich set of data allowed to determine the suitability of different types of data, as well as the radar bands used for imaging, to study the vertical surface deformation. The first part of the work shows the analysis of slow ground displacements identified on PSInSAR and SqueeSAR vector point data. They enabled the identification of a range of mining activity influence in the areas "Bytom" and "Katowice". In addition, the example of the area of the closed mines "Bedzin" shows a significant change in the nature of occurring vertical terrain movements. In the period just before the closure a little, a few millimeters per year, subsidence was seen, while after the closure, was visible stable or uplift trend. Slight uplift was associated with a change in the underground water level, which has been proved by comparison with the measurements of the water level in five piezometers.

Analysis of fast, centimeters per month, displacements was carried out in areas "Bytom" and "Katowice" based on the differential interferograms data sets. By summing the values of the subsidence received on individual images maps of total vertical displacements for periods of about one year were obtained. These maps show the subsidence basins caused by mining underground activities. By comparison with data from the precise leveling it was demonstrated that they are useful for the analysis of large displacements of more than 118 mm for the L-band radar images and 60 mm for the X-band radar images.

In the following chapter was presented a combination of two types of information, points of small movements and raster of larger movements. The merger was carried out for areas "Bytom" and "Katowice" through simultaneous interpolation of values obtained, both small and large. Methods of interpolation included the use of Simple Kriging and Gaussian Simulation. The result of geostatistical analysis were comprehensive maps of vertical ground displacements for the two research areas, of full, simple image of total vertical deformation incurred in the period February 2007 - May 2008 in "Katowice" and July 2011 - June 2012 in "Bytom". Geostatistical analysis also allowed the determination of the area most likely for the occurrence of changes in the surface.

In addition, for the area "Bytom", was carried out an analysis of changes on the surface in relation to mining activity in the mine KWK Bobrek-Centrum. In extreme cases, the comparison showed that the subsidence were visible from one month after the start of underground operation, and after the end of the works significant influence up to 1 decimeter persisted even up to half a year.

As an example of using the resulting map of vertical ground deformation was presented an analysis of the impact of changes in the terrain surface on the construction of buildings. The analysis included the calculation of the maximum differential subsidence, and the maximum relative rotation for each of the buildings and assign them to classes of probable occurrence of damage.

For the area "Uskok kłodnicki" an analysis was performed on the location of subsidence basins for data covering 11 years of active mining operations in the context of the faults identified in the carboniferous roof. It did not show a clear correlation between the nature of the fault and the subsidence range and direction. However, it can be concluded that although the settlement is directly related to mining activity, its presence confirms the contemporary nature of the Kłodnicki fault, as well as transverse faults delimiting the zones in its environment.

The presented study allows to conclude that the geostatistical methods help in the interpretation of the acquired interferometric data. Processed PSInSAR, SqueeSAR or DInSAR datasets do not contain direct information about the vertical displacement in particular period. Only their conversion allows for detailed analysis of the changes in the terrain surface. Both interpolation of PS points as well as their join with the data from the differential interferograms provide information of mining damage in a transparent way. It should be also emphasized that the satellite radar data allow to conduct a regional analysis of

changes in the terrains surface in the Upper Silesian Coal Basin since 1991 (launch of ERS-1 satellite) to the present moment, i.e. to a period of 25 years.

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