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Ground deformation monitoring of Gardanne coal mine (France) exploiting eleven years of ERS-SAR data

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This paper describes the results of eleven years (30 June, 1993 – 26 June, 2004) of land subsidence analysis for Gardanne coal mine located in southern France. Synthetic Aperture Radar (SAR) images acquired by European satellites ERS-1 and ERS-2 have been exploited for generating the non-linear surface deformation time series using differential SAR interferometry. Gardanne coal mine is located between Aix-en-Provence and Marseille, and was mainly associated with underground coal mining based on the long wall mining technique. The mine was exploited since the 17th century and was closed down in 2003. From 1993 – 2003, the mining panels were located at a depth of 600 – 1100 m, with a width of about 250 m. The thickness of the coal layers ranged between 2 - 3 m. Levelling values during this period show cumulated deformation values varying from zero (in stable areas) to a few decimetres.

Differential interferometry has been used in recent years for very precise surface deformation monitoring over large areas in radar's line of sight. With the availability of large stacks of SAR images acquired over the same area, long time series can be analyzed using advanced techniques such as Persistent Scatterer Interferometry (PSI) and Small Baseline Subset Algorithm (SBAS). However, it has been shown in the study conducted by the European Space Agency (ESA) for PSIC4 (PSI Codes Cross-Comparison and Certification for Long-Term Differential Interferometry) project that PSI has limitations in the C-band (6 cm wavelength of ERS) for monitoring strong and fast non-linear deformations, as is the case for this mine. Also, the density of Persistent Scatterers (PSs) is very low in the mine area.

We have used the SBAS algorithm for generating the deformation time series for Gardanne coal mine. SBAS makes use of small baseline differential interferograms to limit spatial decorrelation, and then applying singular value decomposition (SVD) to link independent subsets in time, thus increasing temporal sampling. This technique works well even in areas where coherence is low. Non-linear deformation can be estimated without any modeling and prior knowledge.

The results obtained for surface deformation show two subsidence bowls (one having a larger deformation than the other and also covering a larger area). The cumulated deformation is largest in the center of the bowls and gradually decreases as we go away from the center. A maximum of 250 mm of cumulated deformation over 11 years has been measured. We have also calculated variance values for the deformation results, which show the accuracy of our approach. The deformation time series results have been geocoded and visualized in Google Earth for the considered time period. The results compare well with the geodetic leveling results used in PSIC4 project. It can be concluded that SBAS is a good technique for monitoring mining subsidence and similar applications, and the results can be used for further geological and risk analysis.