DInSAR TECHNIQUES VERSUS HIGH TOPOGRAPHIC LEVELING SURVEYS: THE SUBSIDENCE PHENOMENA IN SALLENT

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ABSTRACT

The Estacio quarter of Sallent is being affected by a subsidence process caused by an abandoned mine. The phenomena has been studied and measured during the last years using different techniques. The RISCMASS project has allowed validating the use of new DInSAR techniques to detect and measure terrain movements.

ANTECEDENTS

The *Conca Potàssica Catalana* (Potassic Salt Catalan Basin) is located in the so called Central Catalan Depression, within the Ebre river Depression (Figure 1). This basin is made of a great saline unit, composed by an alternation of potash salts (sylvinita and carnalita mainly) layers. The potash salts have been traditionally exploited since ancient times, being still the most important mining activity in Catalonia. Balsareny, Cardona, Sallent and Súria are the main towns in the Bagues area with mining activities.

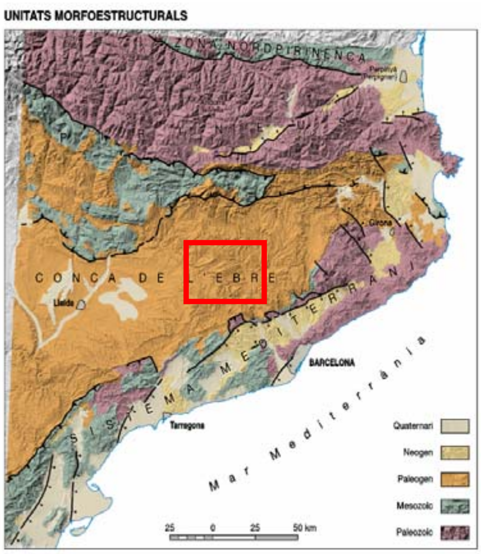


Figure 1 - Situation of the Conca Potàssica on a Geological sketch of Catalonia.

The Enrique Mine, located in Sallent, was opened during the period of 1932 to 1974. This mine has a maximum depth of 260 meters. In 1954 a cavity of approximately 120 meters high and 40 meters wide partially filled up with some ceiling materials, was found while some mining works were being done. This cavity had been caused by water circulation and it is located under the south-east sector of the present Estacio quarter of Sallent.

During the time the mine was active, water floods from Llobregat River occurred twice; in 1957 and 1962, just under the area located under the present Rampiña quarter, close to Estacio quarter.

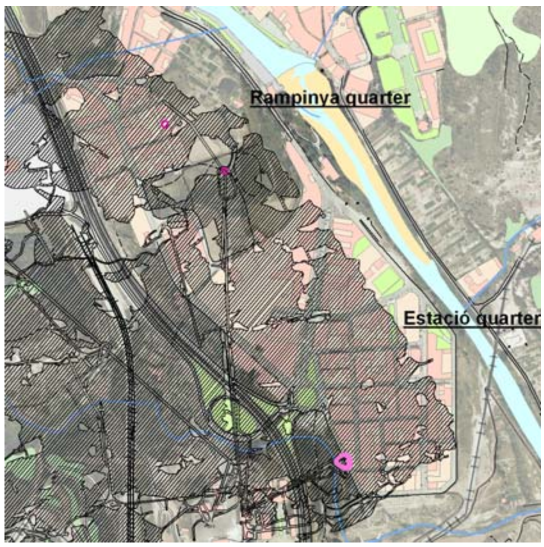


Figure 2 - This map shows the situation of Enrique Mine under Sallent Area. The pink circles represent floods entrances during mine activity.

The great difficulties to control these water floods led to the closure of Enrique Mine in year 1973. During the abandoning process the mine was filled up with saturated salty water.

During the 90s heavy damages appeared in building structures. As a response the Catalan Administration started an investigation program to identify, quantify and model the phenomena subsidence in this area (ICC, 2003).

Within this program a multiple set of techniques has been applied: high precision topographic levelling, geological mapping, geophysic prospection, extensometric measurements, drilling, etc. in order to know the risk caused by the phenomena.

The above works have been supported with the RISCMASS project: "Méthodologies pour la gestion des Risques d'Éboulement et des Mouvements du sol avec Scénarios de Politique d'Assurance" financed by the INTERREG III B – 2003 MEDOCC program. This project has the objective to determine hazard terrain movements and develop risk management methodologies to support insurance policies. It allowed applying DInSAR satellite image techniques to the whole basin, but more in concrete in the Sallent area. The great volume of subsoil information throughout continuous time has made of Sallent an excellent testing area to check reliability and precision on the Differential Interferometry (DInSAR) techniques in hazard subsoil movement calculations. At the same time a Geographic Information System was developed to help on risk management, integrating both whole colleted data and analytical tools.

METHODOLOGY

The methodology used has the aim to validate how precise the DInSAR techniques are. The idea was to compare a set of DInSAR values with real subsidence measurements obtained by high precision topographic levelling surveys.

The high topographic levelling works are obtained by measuring the topographic difference between various control points distributed in the area. These control points are monitored using other points located outside the zone affected by subsidence, which are linked with the geodetic network that permits to know the real initial height. The field measurements have been calculated obtaining the difference between the control points and its reliability.

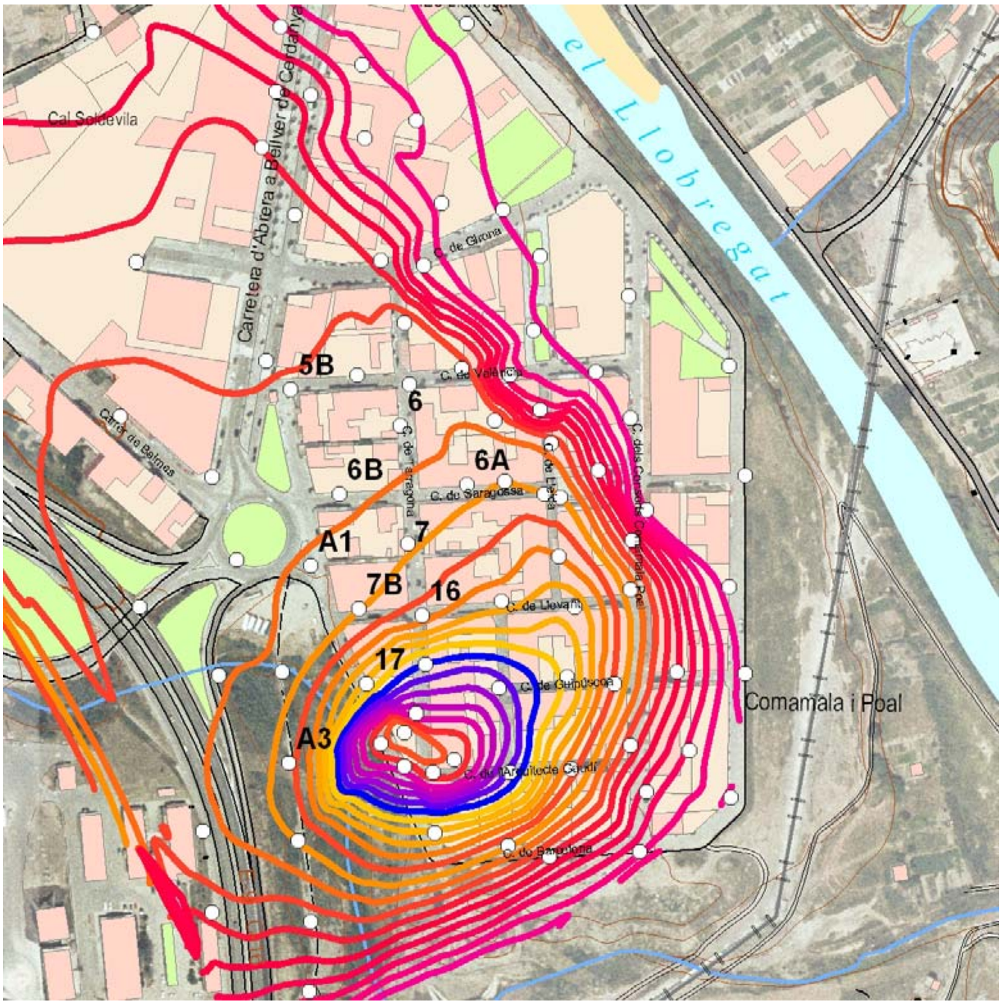


Figure 3 - Subsidence measurements calculated by high topographic levelling.

The measurement surveys in Sallent started in 1997, first of all in the Estació quarter and later on, in 2001, they were extended to the Rampinya neighbourhood. The surveys were carried out with a month's periodicity, having a total of over 70 surveys at present, see Figure 3. The obtained results allow evaluating the dimensions of the possible vertical movements of the control points and comparing the results with the measures carried out with other techniques.

DInSAR techniques consist of the combination of two SAR images of the same area obtained from slightly different positions. The result of this combination is a new image known as interferogram, whose main phase component, after topographic removal, is the terrain displacement. The advanced DInSAR processing developed at ICC is based on the study of a stack of SAR acquisitions to minimize topographical errors and atmospheric artifacts and obtain precise measurements of subsidence (MORA, 2003) (LANARI, 2004). The SAR images used for this study have been acquired by ERS1/2 and ENVISAT satellites. These orbital platforms have been equipped with several sensors, being one of them the Synthetic Aperture Radar. Nowadays ERS satellites are out of order for interferometric processing, but ENVISAT is acquiring data with a re-visit period of 35 days. The number of images used for the generation of the deformation maps of Sallent has been 32 with a pixel size of approximately 30 meters, which allows obtaining the encouraging results of this work, see Figure 4.

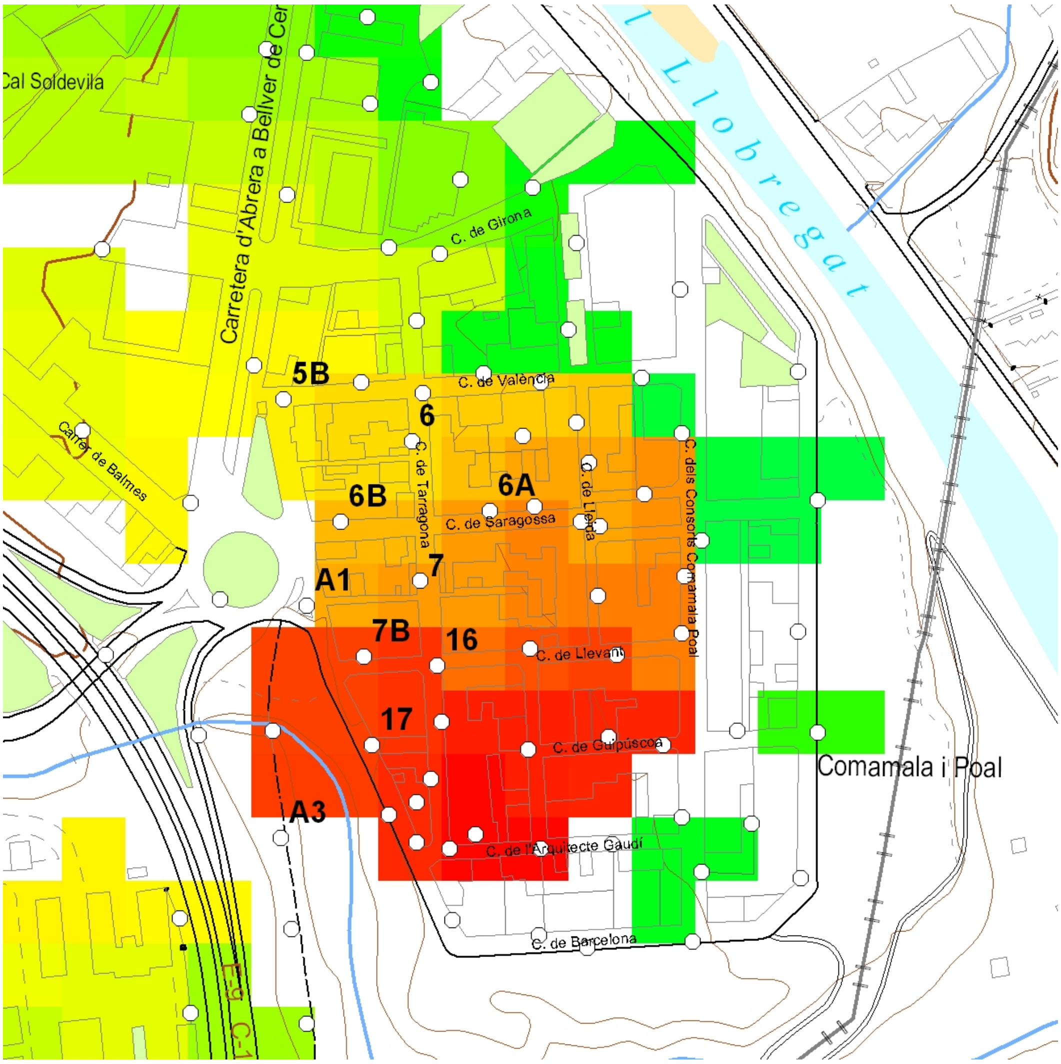


Figure 4 - Subsidence measurements calculated by DInSAR techniques.

In order to establish the correlation between the topographic levelling data and that obtained by DInSAR techniques, subsidence velocity has been used in those points with a high lineal deformation component. There are two main reasons for working with the subsidence velocity:

The time period covered by the levelling campaign and the data obtained by processing satellite images overlap in time, but do not cover exactly the same period of time. The levelling campaigns were carried out between 1997 and 2005, whereas the interferometric from 1992 to 2004.

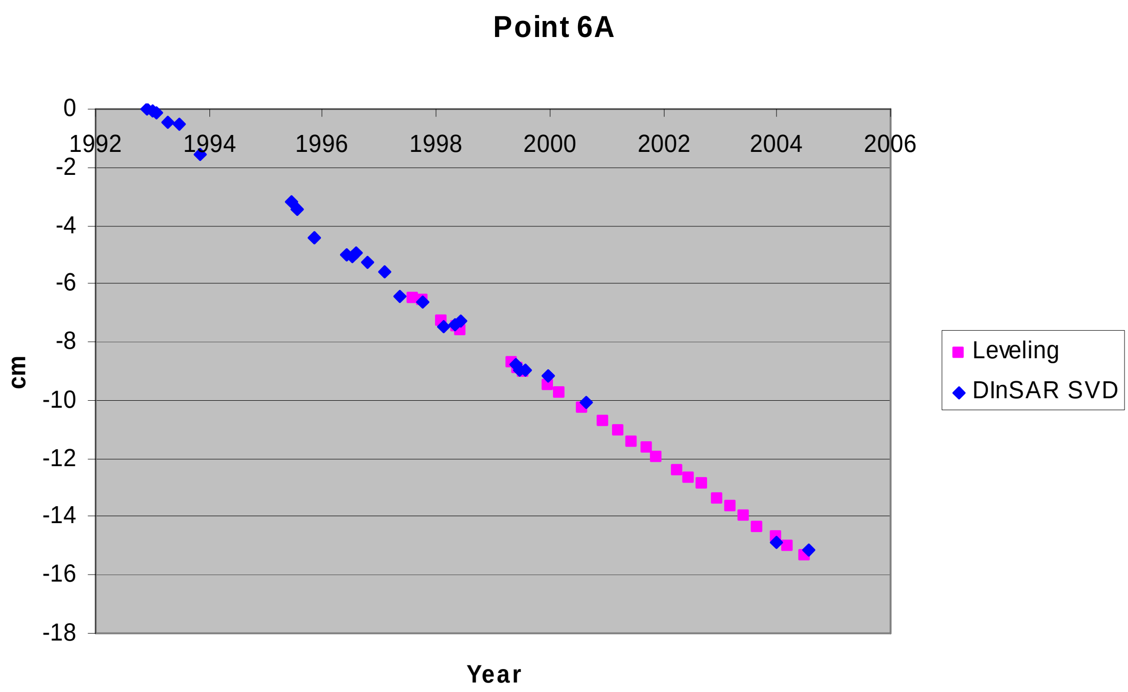
The DInSAR techniques obtain the deformation velocity as a first and most precise result of its statistic process. At the same time, the deformation velocity data for the wanted time period can be calculated from the levelling data.

RESULTS

Table 1 shows the comparison between DInSAR and levelling speed measurements over several points in the area affected by subsidence. Note that differences between both techniques are bellow 2 mm/year, demonstrating the accurate precision of advanced DInSAR techniques. On the other hand, graphic comparisons of the measurement points with subsidence values can be built in order to help understanding the phenomena, see Figure 5.

Point	*DInSAR*	*Leveling*	*Difference*
5B	-1,14	-1,07	0,07
6	-1,18	-1,14	0,04
6A	-1,29	-1,27	0,01
6B	-1,19	-1,15	0,04
7	-1,37	-1,30	0,07
7B	-1,39	-1,32	0,06
16	-1,53	-1,55	-0,02
17	-1,75	-1,88	-0,12
A1	-1,21	-1,22	-0,01
A3	-1,54	-1,41	0,12

Table1 - This table shows the comparison between DInSAR and levelling speed (cm/year) measurements in the Sallent area.



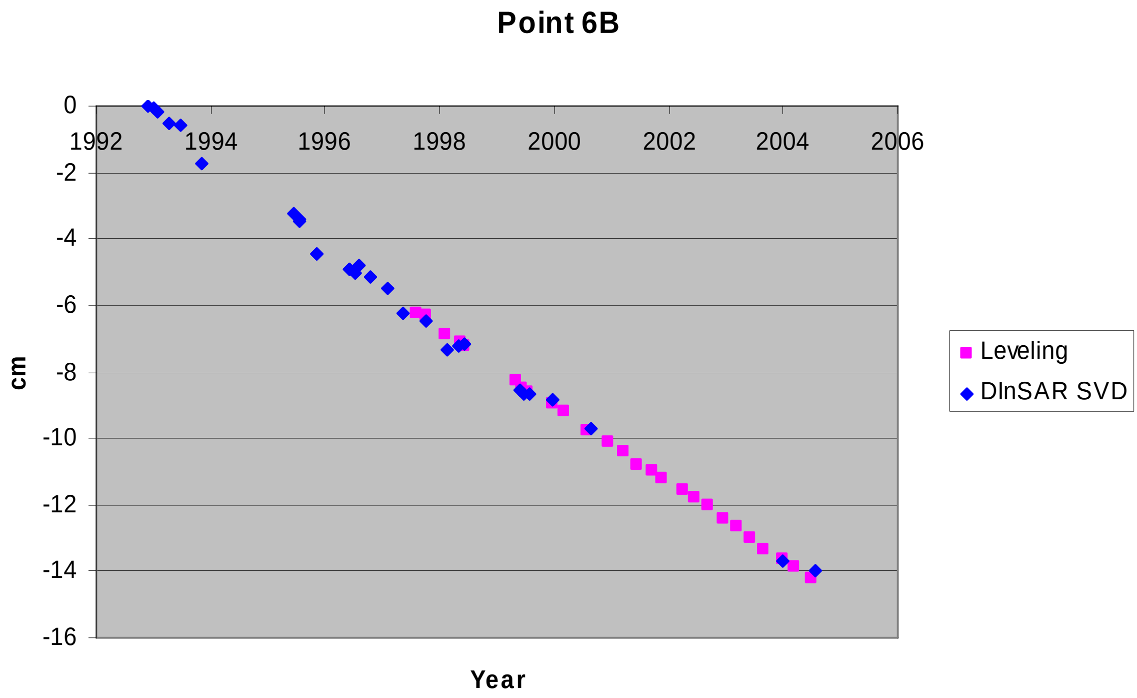


Figure 5 - shows the temporal evolution of 6A and 6B points.

CONCLUSIONS

DInSAR techniques have proved to be an effective tool to quickly detect subsidence affected zones and mass movements.

In the present state of methods and image satellite resolution, it is not only an efficient tool to discriminate problematic areas, but it can also calculate a draft subsidence quantification.

Together with other criteria like the geological context and the territorial knowledge, this tool allows the setting of priorities in actions and optimises resources.

It allows identifying and quantifying deformations in the past, before the implementation of control measures (concretely, ERS images are available since 1992).

This technique allows covering vast extensions with a reduced cost: each 100x100 km ERS/ENVISAT image costs approximately 400 Euro.

This technique requires coherence in the signal quality, that is, the signal response should be continuous in time. This occurs more in urban zones than in vegetated areas. That is why the DInSAR deformation maps show zones without information, where the signal quality is very low.

The technique depends on the ENVISAT radar image availability (one image each 35 days). With the new satellites, the frequency of images will be increased to few days and the image resolution will be also improved (1 to 3 meters of spatial resolution).

ACKNOWLEDGEMENTS

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