APPLICATION OF TERRASAR-X DATA TO THE MONITORING OF URBAN SUBSIDENCE IN THE CITY OF MURCIA

Daniel Monells[(1)], Giuseppe Centolanza[(1)], Jordi J. Mallorqui[(1)], Sergi Duque[(1)], Paco López-Dekker[(1,4)], Roberto Tomás[(2)], Gerardo Herrera[(3)], Juan M. López-Sánchez[(2)], Fernando Vicente[(2)], Victor D. Navarro-Sanchez[(2)], Joaquín Mulas[(3)]

(1) Remote Sensing Lab.-UPC, Spain; (2) Universidad de Alicante (UA), Spain; (3) Instituto Geológico y Minero (IGME), Spain; (4) DLR, Germany

1. INTRODUCTION

This abstract presents an analysis of the performance of TerraSAR-X for urban subsidence monitoring in urban areas. The city of Murcia has been selected as a test-site due to its high deformation rate and the set of extensometers deployed along the city that provide validation data. The obtained results have been compared with those obtained from ERS/ENVISAT data belonging to the same period and validated with the in-situ measurements. The long dataset of TerraSAR-X images, which will be longer when the final version of the paper is presented, allows study the behavior of the temporal evolution of coherence.

2. THE COHERENT PIXELS TECHNIQUE (CPT)

Orbital DInSAR is a technique widely used to survey the surface of the Earth and monitor hazards due to natural and human agents, such as earthquakes or mining [1][2][3]. Nowadays, there are a large number of satellites in orbit carrying SAR instruments able to perform this monitoring. Among then, ERS/ENVISAT and TerraSAR-X are widely used for this application.

The Coherent Pixels Technique (CPT) has been used for monitoring urban subsidence [3]. The algorithm can work with both coherence and amplitude stability criteria to perform pixels selection. The former is more suited for detecting stable distributed targets and the latter for detecting the so-called Permanent Scatters (PS). The retrieval of the deformation time-series is done in two steps. Firstly, a linear model adjustment to data provides the linear velocity of deformation, the DEM error and the azimuth position of the PS (only for amplitude-based processing). Secondly, the non-linear processing that retrieves the remaining deformation and the atmospheric phase screen for each image.

3. THE CITY OF MURCIA TEST-SITE

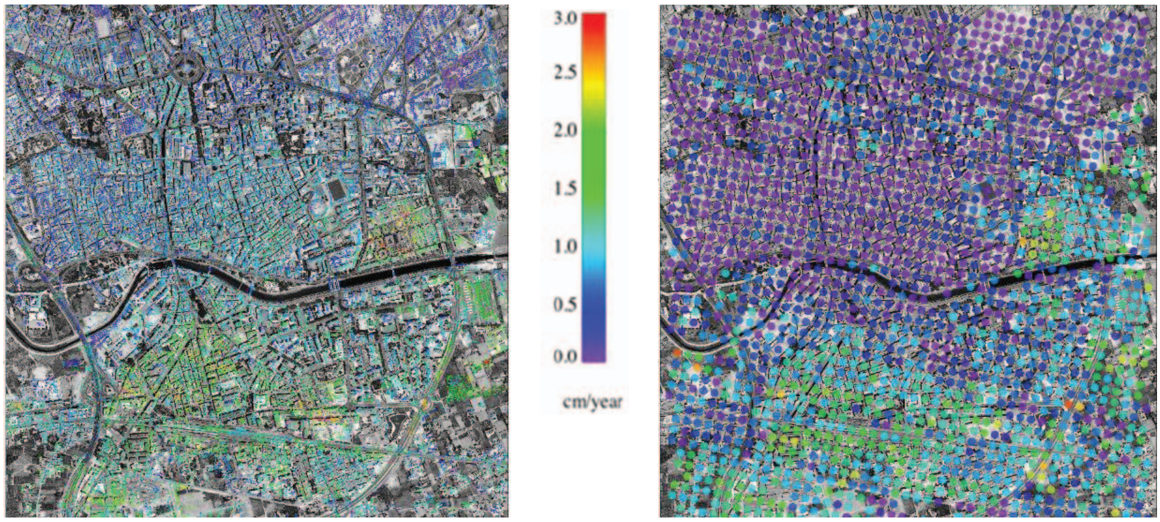
The area selected for this purpose is the city of Murcia (SE Spain). Certain zones are affected by subsidence since the 90's due to the presence of aquifers in the subsoil, mainly related to the Segura River, which crosses the city. The subsidence has caused from moderate to severe damages in more than 150 buildings and other structures. In order to measure the temporal evolution of the deformation in depth, 22 extensometer boreholes were installed, in four suburban areas of in the South and East of the city. An extensometer consists of a device for measuring the deformation of the ground along a borehole. They provide valuable data for the validation of the DInSAR results [4].

4. TERRASAR-X AND ERS/ENVISAT DATASETS

From one side, the results presented in this abstract have been obtained with 39 TerraSAR-X images acquired during the temporal interval comprised from 7/18/2008 until 11/25/2009. From the other side, 24 ERS/ENVISAT images covering a similar period have been used for comparison purposes. The reduced number of images for the latter case does not allow retrieve a very reliable non-linear deformation pattern and thus comparison between the two datasets has been limited to the linear velocity of deformation. The data sets used come from the Project GEO0389 for the TerraSAR-X data and the ESA Project Cat.1-2494 of the EO program, for the ERS/ENVISAT images.

5. PROCESSING RESULTS

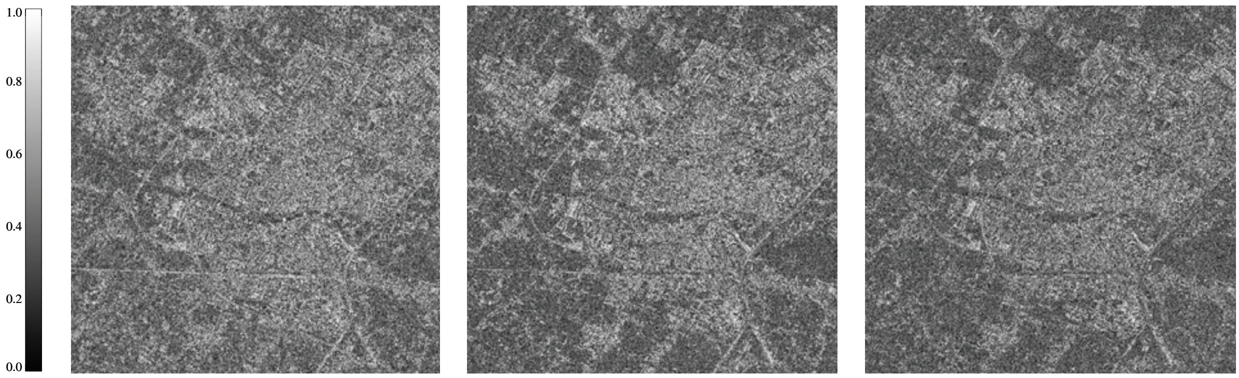
The deformation results are very similar for both sensors, i.e. subsidence areas are found in the same places and with similar rates, as it can be seen in Figure 1. The main differences are highlighted on particular deformations that can be detected with TerraSAR-X, thanks to its better resolution, but cannot be seen with ERS/ENVISAT data. For instance some buildings or infrastructures that were hardly identifiable in the ERS/ENVISAT results are clearly seen with TerraSAR-X. The good resolution of TerraSAR-X that reduces the speckle allows to work under the coherence approach with lower multilooks, for instance 3x3 or 5x5. Pixel selection is an interesting topic as each technique can retrieve a particular type of scattering mechanisms. Coherence is better suited for distributed targets while amplitude detects point scatters, the well-known Permanent Scatters. A comparative study of the selection performed with each technique highlights that both are complementary and its combination will allow an improved performance of the DInSAR algorithms. Taking advantage of the large dataset of TerraSAR images, one acquisition is programmed each 11 days until July 2010, a temporal study of the coherence and amplitude stability is also being performed. A temporal model, assuming that for most of the pixels the coherence and the amplitude stability decrease with the temporal baseline, is being evaluated and adjusted to the available data. What it can be observed from the preliminary results some of the pixels decorrelate very fast, mostly on non-



(a) (b)

Figure 1 Linear velocity retrieved for Murcia test-site using (a) TerraSAR-X and (b) ERS/ENVISAT data.

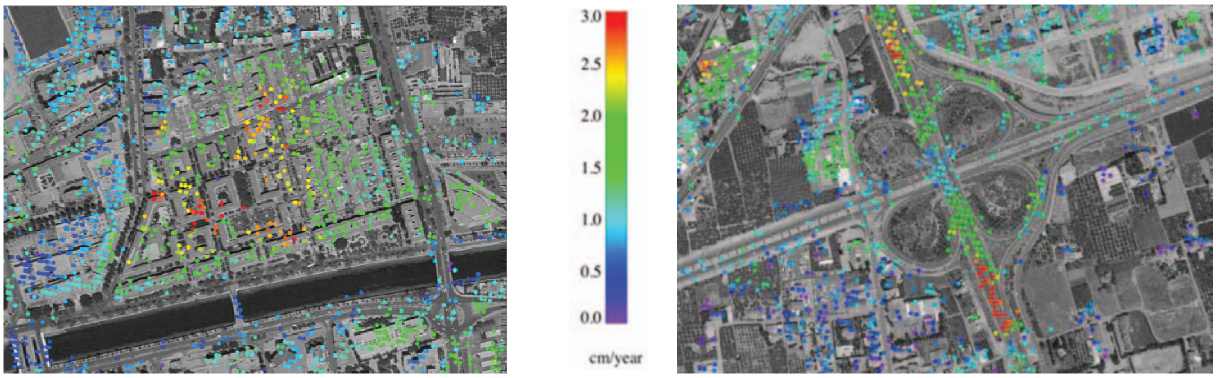
urbanized areas, while others, in urbanized ones, preserve a very good stability along time. The model when working under a coherence approach considers the bias of the estimator. Figure 2 shows the temporal evolution of the coherence for different temporal baselines.



22 days 220 days 385 days

Figure 2 Evolution of the coherence as a function of the temporal baseline.

Figure 3(a) shows the deformation of a group of buildings near Segura River, which are dramatically affected by strong gradients of subsidence. Another example of the excellent performance of TerraSAR-X for monitoring civil infrastructures can be seen in Figure 3(b). The access ramps to a highway high pass are subsiding at a high rate while the bridge itself, with deep foundations, is more stable.



(a) (b)

Figure 3 Deformation in a group of buildings near Segura River (a). Non-uniform deformation of a bridge over a high-way, the access ramps are subsiding at a faster rate than the elevated pass (b).

6. RESULTS VALIDATION

The results of deformation measurements retrieved from TerraSAR-X data analysis are being compared with the lithological units that domain the flood plain of Segura River, as well with the spatial distribution of the most important factors that control subsidence phenomenon in Murcia such as the thickness of the compressible layer, the presence of drought wells or ground water table evolution in time. Additionally the temporal evolution of the estimated displacements is compared with data available from and extensometer network located in the urban area of Murcia. Finally the effects of subsidence on some particular buildings and human infrastructures will be discussed with respect to measured ground surface radar deformations. Since the validation has not been finished at the moment of writing the abstract they will be included on the final version.

7. CONCLUSIONS

The paper has demonstrated the excellent performances of TerraSAR-X for urban monitoring and it has characterized the behavior of the coherence and amplitude stability along time. The deformation time-series has been validated with in-situ data coming from the extensometers deployed in the city.

8. REFERENCES

[1] Ferretti, A., C. Prati, Rocca, F. (2000). Nonlinear subsidence rate estimation using permanent scatterers in differential SAR interferometry. IEEE Transactions on Geoscience and Remote Sensing 38, 2202-2212.

[2] Berardino, P., Fornaro, G., Lanari, R., Sansosti, E. (2002). A new algorithm for surface deformation monitoring based on small baseline differential SAR interferograms, IEEE Transactions on Geoscience and Remote Sensing 40, 2375-2383.

[3] Blanco, P., Mallorquí, J.J., Duque, S., Monells, D. (2008). The Coherent Pixels Technique (CPT): an Advanced DInSAR Technique for Non-linear Deformation Monitoring, Pure and Applied Geophysics 165, 1167-1193

[4] T. Roberto, Y. Márquez, J.M. López Sánchez, J. Delgado, P. Blanco, J.J. Mallorquí, M. Martínez, G. Herrera, J. Mulas, Mapping ground subsidence induced by aquifer overexploitation using advanced Differential SAR Interferometry: Vega Media of the Segura River (SE Spain) case study, Elsevier Remote Sensing of Environment, Vol. 98, pp. 269-283, August 2005.