SAR INTERFEROMETRY FOR GROUND VERTICAL DISPLACEMENT OF SMALL ISLANDS IN THE VENICE LAGOON: THE CASE OF MURANO ISLAND

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Riassunto.

La conoscenza della dinamica dei movimenti verticali del suolo assume un ruolo fondamentale nello studio dei processi geomorfologici ed in particolare nella valutazione delle cause dell'erosione o dell'accumulo dei sedimenti. La sopravvivenza di strutture morfologiche lagunari, quali le barene e le velme, oltre che ai fenomeni di erosione imputabili al moto ondoso e alle correnti, è subordinata alla loro altimetria rispetto al livello del mare che, per periodi brevi, risente principalmente del processo di subsidenza e secondariamente dell'eustatismo. Variazioni di quota del piano campagna rispetto al livello del mare, anche piccole, possono innescare i processi di erosione o accumulo di sedimenti.

Con lo scopo di determinare i tassi dei movimenti verticali del suolo in aree insulari della Laguna di Venezia non coperte dai rilievi topografici tradizionali (livellazioni e GPS differenziale), è stata effettuata l'analisi di immagini SAR, acquisite dai satelliti ERS-1 e ERS-2, attraverso interferometria differenziale (INSAR) e l'analisi dei riflettori puntuali (IPTA). In questo lavoro è riportato l'esempio dell'Isola di Murano.

Abstract.

Our knowledge of the dynamics of vertical ground movements plays a fundamental role in the study of the geomorphological processes, particularly for determining sediment deposition and erosion causes. The conservation of lagoon morphological structures such as salt marshes and tidal flats, besides erosion due to waves and currents, depends on their surface height with respect to the sea level that, for short periods, is primarily related to the land subsidence process and secondarily to eustasy. Ground vertical variations with respect to the sea level, even if small, can, in fact, trigger sediment erosion and deposition processes.

To determine land displacement rates in small islands of the Venice Lagoon not covered by traditional surveys (levelling and differential GPS), SAR-based monitoring techniques, i.e. differential SAR interferometry (INSAR) and interferometric point target analysis (IPTA) from ERS-1 and ERS-2 satellites, were performed. We will use the Murano Island for our example in this contribution.

1. Introduction.

Repeat-pass spaceborne Synthetic Aperture Radar (SAR) interferometry is a powerful technique for the observation of land surface deformation at mm resolution, as demonstrated in the Venice area by Tosi *et al.* [2002] and Strozzi *et al.* [2003]. In the SAR interferometric approach two satellite radar images are combined to exploit the phase difference of the signals. The interferometric phase is sensitive to both surface topography and coherent displacement along the look vector occurring between the acquisitions of the interferometric image pair. The basic idea of differential SAR interferometry (INSAR) [Strozzi *et al.*, 2001a] is to subtract the topography related phase from the interferogram to derive a displacement map. Important problems for SAR interferometry are decorrelation and heterogeneity of atmospheric path delay. Temporal decorrelation occurs from changes in the scatterer characteristics, for instance over vegetation, and leads to incomplete spatial coverage. Spatial decorrelation prevents interpretation of the interferometric phase for extended targets in pairs with long baselines. Techniques for overcoming these problems have been developed and can be applied for a specific case depending on the availability of a Digital Elevation Model (DEM), on the characteristics of the SAR data with respect to spatial baseline, acquisition time difference and coherence, on the displacement rates and shapes, on the land cover, and on the topography. Interferometric Point Target Analysis (IPTA) [Werner *et al.*, 2003] makes interpretation of the phase values only on reflectors with a scattering behavior corresponding to that of a point target, to avoid geometric decorrelation, and that are persistent over the whole observation time period, to avoid temporal decorrelation. In this way more acquisitions may be included in the analysis to increase accuracy, temporal sampling, and spatial coverage.

2. The application of SAR interferometry in the Venice Lagoon.

In this project we used SAR interferometry to measure the ground vertical displacement of areas of the Venice Lagoon not covered by traditional surveys (levelling and differential GPS) i.e. small islands. The validation of the SAR interferometric displacement rates performed in the framework of the ISES and VENEZIA Projects [Carbognin and Tosi, 2003; Carbognin *et al.*, 2004] through levelling and differential GPS surveys in areas where data from all techniques are available demonstrated a mm/year accuracy of the vertical displacement rates.

First, a time series of six interferometric radar images of the European Remote Sensing Satellites ERS-1 and ERS-2 from 1993 to 2000 was considered. In order to generate a displacement map with reduced errors, the six INSAR images were combined [Strozzi *et al.*, 2001b]. The map presented in Fig. 1 shows information over the major urban areas, with a few scattered points in other regions. Then, IPTA has been applied with 59 ERS-1/2 SAR images between 1992 and 2000. Point targets with valuable information are scattered over villages, suburban areas, and isolated structures (Fig. 2a). Deformation time series, as indicated for one point in Fig. 2b, are available from IPTA. This analysis of ground vertical displacement with SAR interferometry demonstrated a general land stability of Murano Island.

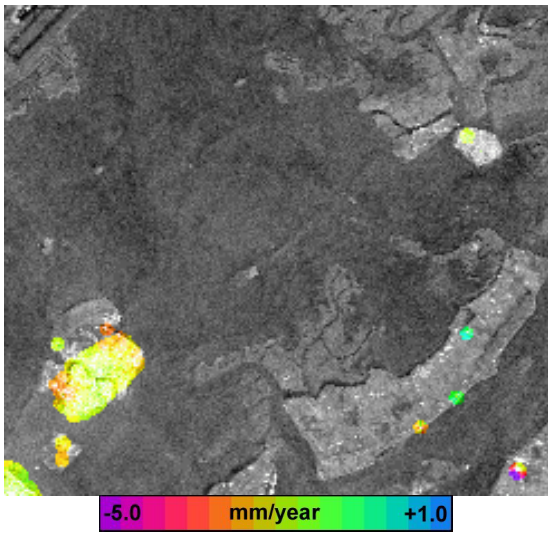

Fig. 1 – Land subsidence map for the Lagoon area in the north-east of Venezia (Murano Island) over the time period 1993-2000 from INSAR. Background is an averaged ERS backscattering intensity image.

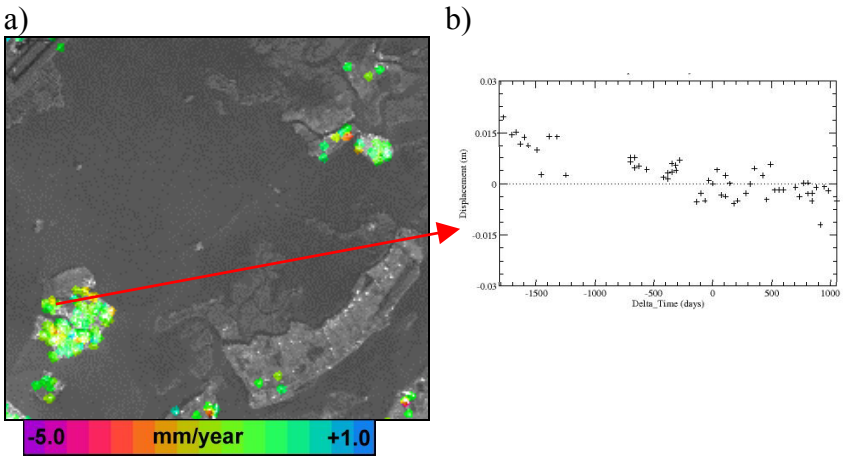

Fig. 2 – a) Land subsidence map for the Lagoon area in the north-east of Venezia (Murano Island) over the time period 1992-2000 from IPTA. Background is an averaged ERS backscattering intensity image. b) Deformation time series from IPTA for the indicated point target for the time period from 1992 to 2000.

Conclusions.

The application of differential SAR interferometry (INSAR) and Interferometric Point Target Analysis (IPTA) in small island of the Venice Lagoon provided new data regarding the ground vertical movements of areas never investigated in the past. In particular, in the case of Murano Island, the analysis of ground vertical displacement with SAR interferometry shown a general land stability with maximum sinking rates of less than 2 mm per year. The application of SAR-based monitoring techniques appears as an important tool capable of providing data for the morphodynamics study of the lagoon setting.

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