**Present ground surface dynamics in the North Adriatic coastland**

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**INTRODUCTION**

Land subsidence represents one of the most geologic hazards threading the low-lying coastal areas worldwide. The Lag one of Venice, Italy, is emblematic of a coastal area prone to progressive submersion by the rising sea. Indeed, relative sea level rise (RSLR), i.e. the interaction between eustatic rise and land subsidence, has produced 25 cm of elevation loss in Venice over the 20th century (CARBOGNIN and TOSI, 2002; CARBOGNIN et alii, 2004; CARBOGNIN et alii 2006; CARBOGNIN et alii, 2009) that significantly increased the flood frequency with severe damages to the urban heritage and to the lagoon morphology.

Geodetic surveys have been periodically carried out to monitor land subsidence in the Venice ice coastal area since the end of the 19th century. Starting from the 1980s, space-based geodetic techniques such as the Global Positioning System (GPS) have been adopted to monitor vertical movements, and mostly from the late 1990s because GPS measurements reached a point where millimeter-level positioning became achievable (TOSI et alii, 2000; TOSI et alii, 2007a).

The land subsidence monitoring in the Venice ice coastal area has been significantly improved over the last few years by space borne earth observation techniques based on Synthetic Aperture Radar (SAR) -based interferometry. SAR interferometry has been used to complement the ground-based methods. Firstly, Differential InSAR (DInSAR) and afterward Interferometric Po int Target Analysis (IPTA) have been applied (TOSI et alii, 2002; TEATINI et alii, 2005; TEATINI et alii, 2007; STROZZI et alii, 2009).

This work describes the map of annual subsidence rates achieved by the ISMAR, DMMMSA, and DGG AMMA REMO TES SENSING Working Group in recent research activities that have allowed to produce high-resolution maps of the present ground vertical movements in the Veneto coastal area (Italy) both at “regional” (100×100 km²) and “local” (few km²) scales.

**GROUND VERTICAL MOVEMENTS OF THE VENETO COASTLAND**

The mapping refers to the three periods 1992-2005, 2003-2007, and 2008-2009 and is based on images acquired by the
ERS-1/2 and ENVISAT satellites of the European Space Agency and the new TerraSAR-X launched by the German Space Agency, respectively. Figure 1 shows the total displacements occurred from 1992 to 2007 and obtained by the integration of ERS-1/2 and ENVISAT acquisitions. The calibration and validation of the SAR data using high precision spirit levelling (Figure 2) and differential and continuous Global Positioning System (GPS) allowed to verify the high accuracy of the (SAR)-based interferometric analyses.

The investigation on the Veneto coastland pointed out a significant spatial variability of the ground vertical movements, both at regional and local scales, and displacement rates ranging from a slight (1-2 mm/yr) uplift to a serious subsidence of more than 10 mm/yr.

Tectonics, differential consolidation of the Pleistocene and Holocene deposits, and human activities, such as groundwater withdrawals, land reclamation of marshes and swamps areas, and farmland conversion into urban areas, superimpose to produce the observed displacements. According to Tosi et alii, 2009, the displacement components have been distinguished on the basis of the depth of their occurrence.

In a 10-15 km wide coastal strip the thickness, texture, and sedimentation environment of the Holocene deposits (Tosi et alii, 2007b; Tosi et alii, 2007c; Zecchin et alii, 2008; Zecchin et alii, 2009), the displacement factors located in the medium depth interval, i.e. between 400-600 m below m.s.l., are of both natural and anthropogenic origin. The former refers to the Medium-Late Pleistocene deposits that exhibit a larger cumulative thickness of clayey compressible layers at the lagoon extremities with respect to the central lagoon area where stiffer sandy formations prevail. Land subsidence due to aquifer exploitation mainly occurs in the north-eastern sector of the coastland where thousands of active wells are located.

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Deep causes, acting at a depth generally greater than 400-600 m below m.s.l., refer to downward movements of the pre-Quaternary basement and land uplift (up to 2 m/yr) most likely related to co-tectonic activity connected with the Alpine thrust belts and a NW-SE fault system.

Fig. 1 – Map of the 1992-2007 ground vertical movements (cm) obtained by the integration of ERS-1/2 and ENVISAT IPTA results. Green dots: position of the IGM34 (IRMA54) leveling line benchmarks used for the comparison between IPTA and leveling results.

Fig. 2 – Comparison between leveling and IPTA results along the IGM34 (IRMA54) line.
RIZZETTO et alii, 2009; TOSI et alii, 2009; ZECCHIN et alii, 2009) play a significant role in controlling shallow causes of land subsidence. Other factors that contribute to increasing land sinking at a smaller areal extent are the salinization of clay deposits due to saltwater intrusion and biochemical oxidation of outcropping peat soils (GAMBOLATI et alii, 2005; CARBOGNIN et alii, 2006). Even the load of buildings and nd structures after the conversion of farmland into urbanized areas causes local shallow compaction.

REFERENCES


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