

Bulging of the salt dome of Lesina Marina (Gargano, Southern Italy) revealed by DInSAR techniques



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Site description & DInSAR processing

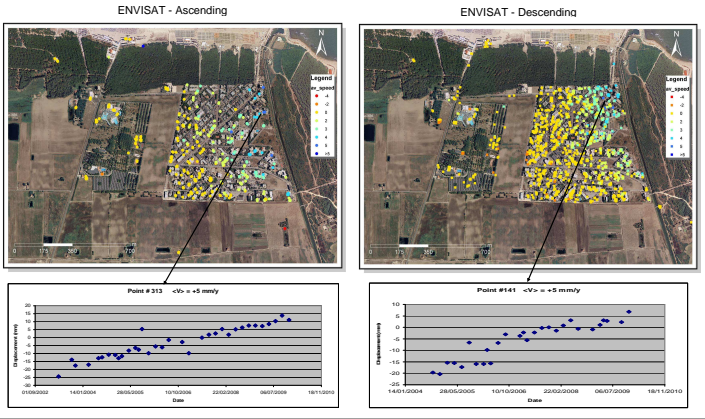
In the Northern part of the Apulia Region, between the Lesina Lagoon and the mouth of the Fortore River, lies the "Pietre Nere" (black stones) Point, a very interesting site and the only outcrop of magmatic rocks in the Puglia region and in the whole Adriatic coast of Italy. The excavation of a canal through this area exposed grey micro- and meso-crystalline gypsum with intercalations of black limestones and marls of Upper Triassic age, mantled by loose sandy Quaternary deposits. The gypsum bedrock shows a high density of cavities, either dissolutional conduits or voids related to gravitational collapse processes. Starting from about 1970, a large touristic settlement has been built over the area. Since about 1990, the area began to suffer for the increasing formation of sinkholes.

Several interpretations have been proposed to explain the outcrops of Triassic evaporites that occur in the Pietre Nere Point area, previously buried by a sequence several kilometres thick of Mesozoic rocks: diapirism; pushing upwards by compressional tectonics; halokinesis and tectonic deformation. The presence of the sinkholes and of the karst reactivation leads to the demand of a monitoring system, for the detection of vertical displacements over a large area.

Thanks to the ability of radar systems to operate in all weather conditions, day or night, and the possibility of accurately measuring small surface deformations (changes in altitude of a few millimeters), SAR (synthetic aperture radar) differential interferometry (DInSAR) is an ideal technique for detecting and monitoring ground deformation phenomena (subsidence, faults, landslides, etc.) over vast areas. As an evolution of DInSAR, persistent scatterers interferometry (PSI) (Ferretti et al., 2001) allows to follow millimetric movements of stable objects (mainly building and man-made features) present on the Earth surface through time, studying the interferometric response of such objects along series of SAR acquisitions.

We used data from the ASAR sensor onboard the European Space Agency's ENVISAT satellite, from both ascending (34 acquisitions) and descending (28 acquisitions) geometry, covering a total time interval from May 2003 to December 2009.

Data were processed with a PS-like algorithm named SPINUA (Bovenga et al., 2004) in order to extract relevant information about mean velocities of stable points located on the Lesina Marina area.



Vertical and horizontal components

We observe PS objects undergoing uplift displacements in both ascending and descending data, with uplift rates decreasing in a roughly W-SW direction from the Acquarotta canal. These data are consistent with other PSI data coming from the European ERS sensor and spanning the interval July 1992 – December 2000.

Relying on the relatively smooth nature of the investigated phenomenon, and assuming negligible north-south movements, as justified by the overall geometry of the site geomorphological units, information coming from ascending and descending geometries was interpolated over a common georeferenced grid, then combined to obtain vertical and horizontal (east-west) velocity components.

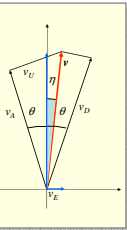
Velocity components retrieval

Assuming velocity is a vector in the Up-East plane (negligible North component) it results:

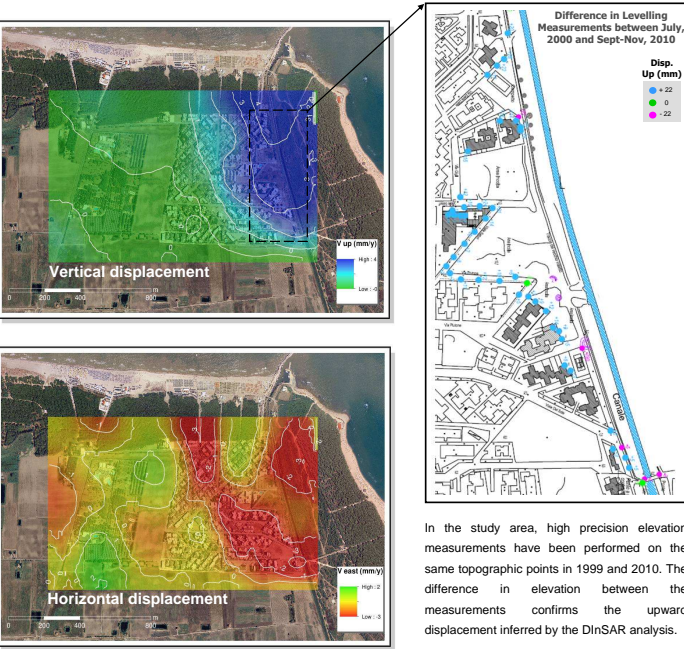
$$\begin{aligned} v_A &\equiv v \cos(\theta + \eta) = v_v \cos \theta - v_e \sin \theta \\ v_D &\equiv v \cos(\theta - \eta) = v_v \cos \theta + v_e \sin \theta \\ v_v &= \frac{v_A + v_D}{2 \cos \theta}; \quad v_e = \frac{v_D - v_A}{2 \sin \theta} \end{aligned}$$

Processing:

- Interpolation of v_A & v_D velocity fields on a regular grid through ordinary Kriging
- Combination of the two fields to obtain v_v & v_e

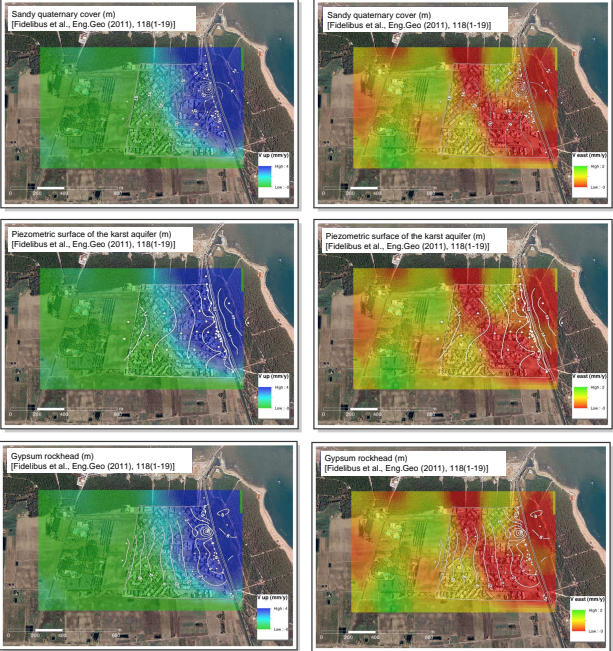


Derived vertical displacement rates exceed 4 mm/y on locations adjacent to the canal, decreasing to zero towards the western end of the built up area (about 600 m width). The east-west velocity component shows an apparent W-SW trend with maximum rates of about 2 mm/y over a sector about 200 m thick, starting at about 200 m from the canal.



In the study area, high precision elevation measurements have been performed on the same topographic points in 1999 and 2010. The difference in elevation between the measurements confirms the upward displacement inferred by the DInSAR analysis.

Preliminary interpretations



The surprising results are not of easy interpretation, because the whole area affected by the vertical displacements has been also affected in the past by important geological phenomena, which could be not completely expired at present, like diapirism. Another possible explanation of the phenomenon is the hydration of the residual anhydrite, in the core of the gypsum mass.

We are trying to analyze the potential effects of these processes, to test them against the PSI-derived displacements, and thus to assess on a quantitative basis the observed phenomena.

In particular, here we show a visual comparison of the derived Up and East PS velocity components with, respectively, maps of the sandy quaternary cover, the piezometric surface of the aquifer, and the gypsum rockhead, coming from in situ observations (Fidelibus et al., 2011). The maps, especially the up velocity component, seem to be correlated to the measured fields.

Future work will be devoted to investigate through modeling the chemical-physical properties of the materials involved, in order to assess the observed displacement rates.

Acknowledgements

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