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Investigation of subsidence in the Manfredonia Gulf (Southern Italy) through multitemporal DInSAR techniques

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We present results of an experiment aimed at detecting possible displacements due to subsidence in the coastal area of the Tavoliere plain, Puglia Region, in Southern Italy, through analysis of remotely sensed data.

The Tavoliere is the second largest Italian plain. Its coastal area, between the urban centers of Manfredonia and Barletta, is composed of a 50 km long sandy beach (Manfredonia gulf), linking the Gargano massif at north with the Murge plateau in the south-east. Both areas belong to the carbonate Mesozoic Apulian platform.

The current configuration of the Gulf was reached recently, as a consequence of the Holocene sea level rise. During the Neolithic age the plain was occupied by an elongated lagoon (Salpi Lagoon) [1]. During the 2nd century B.C., alluvial deposition caused the lagoon to be separated into two basins: the so-called Salpi lake at south and the Salso lake at north. To cope with the increasing demand of arable lands and with the necessity to make unhealthy areas accessible to humans, some reclaims were accomplished by diverting and channelling the rivers crossing the Tavoliere plain, and by levelling dune belts. At present, the beach is separated by low artificial dunes from the areas already reclaimed and intensely cultivated or exploited as evaporation basin for salt production.

In the last decades, the coastal area has been retreating due to a reduction in sediment input necessary for coastal equilibrium. The levelling of dunes and the decrease of fluvial turbid discharge due to dam constructions are probably the cause of this deficit in sediment supply.

During highly intense hydrodynamic and meteorological events, sea waters often penetrate deeply inland, flooding intensively cultivated areas. These events are occurring with growing frequency and rates. They are an indication of the possibility that those areas are subject to subsidence at a faster rate in comparison to the surroundings.

An example is the salt marsh located inland of the tourist sea village "Ippocampo". Here, unpublished studies based on ground data indicate average subsidence rates of the order of 0.20 mm/y in the last 125 ka for the inland area next to the village.

More recently, height maps issued by the Italian Military Geographic Institute (IGM) in the 1950s report heights a.s.l. of the order of a few m. Observing that today the area is practically at sea level, an average subsidence of the order of tens of mm/y can be inferred for the last 50 years.

To gain insight into the recent evolution of these phenomena, we investigate vertical movements on the coastal Tavoliere area through multitemporal differential Interferometric synthetic aperture radar (DInSAR) techniques. We use a persistent scatterers interferometry (PSI) processing methodology [2] to estimate subsidence displacement rates from long temporal series of SAR acquisitions. PSI techniques, first developed at POLIMI [3], allow to retrieve phase information from stacks of co-registered SAR interferograms spanning many years and taken from different directions with large baselines, by restricting the analysis to selected image pixels containing single objects with strong radar backscatter returns. Exploiting the high temporal stability of radar returns from these targets, it is possible to correct the images from spurious phase contributions such as atmospheric phase artefacts and errors in the digital elevation models used to account for topographic InSAR phase. Such stable objects typically coincide with man-made features, so successful applications of PSI techniques are mainly reported over urban centers.

We processed a total of 105 SAR images acquired from the ERS-1/2 and ENVISAT satellites, organized in 3 stacks related to both descending (50 ERS-1/2 scenes) and ascending (25 ERS-1/2 and 30 ENVISAT scenes) acquisition geometries. The acquisitions refer to the temporal periods from 1995 to 2000 (ERS) and 2003 to 2008 (ENVISAT), respectively, with a temporal repetition frequency of roughly 1 acquisition every 35 days.

The 3 stacks, covering approximately the same ground area centred on the Tavoliere coastal plain, were processed independently. Reliable phase measurements were obtained over small urban centers and anthropogenic features scattered along the coast.

Results from all 3 stacks indicate the presence of displacements occurring through the entire temporal interval of observation. In particular, displacements appear spatially organized as a subsidence "bowl" centered approximately around the area of Zapponeta, with maximum subsidence rates exceeding 20 mm/y.

The detected displacements appear consistent with the average rates deduced heuristically from analysis of the environmental settings as exposed above. Moreover, they also qualitatively agree with other investigations performed using analogous techniques and data over the region (e.g. [4]).

Possible interpretation of these results can be attempted by considering that the area has been repeatedly subject to reclaiming through filling, and that the deposited sediments are most exposed to compaction. Moreover, the area is subject to intense water extraction, which further enhances the effects of sediment compaction.

Validation of the obtained measurements is in progress through extended data analysis and in situ activities. However, these preliminary analyses and comparisons between InSAR and ground data hint to the possible presence of two co-existing subsidence phenomena in the area: a natural subsidence due to tectonics or isostatic rebound, with slow subsidence effects occurring over geologic time scales, with an additional, more pronounced subsidence phenomenon on the recent sediment deposits due to sediment compaction under lithostatic loading, and an anthropogenic local, accelerated subsidence on the lowest areas, due to intensive draining mostly for irrigation purposes, which adds to recent land remediation actions to cause a worrisome lowering of the water table in the area.

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