Natural and anthropogenic origin of subsidence of the Northern Adriatic coast (Italy) from satellite data and modelling

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Subsidence can be caused by multiple natural or anthropogenic factors. Natural factors account for compaction of recent sedimentary deposits, oxidation and shrinkage of organic soils. Anthropogenic factors include the pumping of groundwater for human use and the exploitation of hydrocarbon reservoir, both inland and off-shore. The area of Ravenna (Northern Italy) is affected by both anthropogenic and natural subsidence. Natural contribution is due to the compaction of the deposits of the Po plain, of approximately 2 mm/yr. This phenomenon has dramatically increased since the 1950s because of shallow groundwater pumping and deep gas production from several on-shore and off-shore reservoirs in the Upper Adriatic Sea basin.

In this work, we used SAR, GPS and levelling data to investigate the deformation detected at Lido Di Dante, located along the coastal area of Ravenna. This area is subject to gas pumping of the Angela-Angelina gas field, a gas reservoir exploited since 1973, with platform located very close to the coast, at approximately 2 km from the shoreline. We analysed SAR data from multiple missions from 1992 to 2018. In particular, the ESA’s archives were exploited considering ERS data (ascending and descending orbits, spanning 1992-2000), ENVISAT data (ascending and descending orbits, 2003-2010) and Sentinel-1 satellites (ascending and descending orbits, 2015-2018) and ASI’s images acquired by Cosmo-SkyMed (ascending orbit, 2011-2017). The GPS data are provided by Eni S.p.A. In particular, we consider the GPS ANGA, located offshore on the Angela-Angelina platform, and the GPS FIUN, located near Lido Di Dante. The levelling data are from Eni S.p.A. archives, span 1983-2017.

The subsidence detected by InSAR (Interferometric SAR) time series at Lido Di Dante from 1992 to 2018 is approximately 250 mm. The ERS time series show a change in the slope between 1997 and 1998, when the Angela-Angelina platform came into operation. There is a general correlation between gas extraction and surface deformation, indeed the subsidence increases when the gas production increases. Therefore, to better analyze the correlation between gas extraction and observed deformation, the exploited reservoir is modelled as a closing crack (dislocation tensile fault), whose contraction rate is constrained by data inversions. The results indicate that the subsidence in the area of Lido di Dante is the sum of natural contribution due to soil compaction and of hydrocarbon extraction activities during the periods of massive extraction.

In order to better discriminate the factors affecting subsidence we build a Finite Element Model, by
means of the software Comsol Multiphysics. The geometry of reservoir has been deduced by literature, while the pressure inside the reservoir is modulated by the GPS signals at ANGA between 1998 and 2018. The results show that the contraction of reservoir due to gas pumping produces measurable deformation along the coastline. The vertical and horizontal cumulative displacements between 1998 and 2018 reach the maximum values of 28 cm and 15-20 cm, respectively.