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Natural versus anthropogenic subsidence of Venice: investigation of the present occurrence by PSI

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We detected land displacements of Venice by Persistent Scatterer Interferometry (PSI) using ERS and ENVISAT C-band and TerraSAR-X and COSMO-SkyMed X-band acquisitions over the periods 1992–2010 and 2008–2011, respectively. PSI provides the cumulative land displacements (natural plus anthropogenic) of the investigated area independently of the radar band. The natural subsidence rate depends on the reference period and, due to the present elevation of Venice with respect to the sea level, it is much more interesting for the city to evaluate the natural displacement over the last few decades, i.e. the present natural land subsidence, than that averaged over geological periods. Concerning anthropogenic land subsidence the contribution due to activities characterized by large scale and long term effects, e.g., that caused by groundwater withdrawals, ended a few decades ago. Today, the anthropogenic component of the land subsidence is only due to local, short-time interventions such as restoration works and inherent deformations of historical structures. By reason of the larger observation period, the C-band sensors were used to quantify the long-term movements, i.e. the subsidence component primarily ascribed to natural processes. The high resolution, short revisiting time X-band satellites reveal a high effectiveness to monitor short-time movements as those induced by human activities. The statistical analysis of the displacement distributions measured by PSI points out that the average rates, i.e. the natural component of the subsidence, are almost equal with the C-band and X-band satellites. Conversely, the standard deviation with X-band acquisitions (1.6 mm/yr) is characterized by a value significantly larger than that detected with C-band images (0.7 mm/yr). The larger X-band variability superposes to a background velocity similar to that given by ERS/ENVISAT. It is reasonable to assume that the difference between the movements provided by ERS/ENVISAT and TerraSAR-X/COSMO-SkyMed is likely representative of the effects caused by anthropogenic activities. This hypothesis is supported by a proper processing of the two C and X-band measurements. The two datasets are interpolated by the Kriging method on the same regular grid covering the whole city. The grid spacing, fixed at 50 m, has been appropriately tuned to simultaneously i) filter out the outlier values provided by the C-band analysis; and *ii*) keep the heterogeneity of the displacements detected by the X-band investigation. Finally, the quantification of man-induced displacements is obtained by removing the C-band interpolated map from the X-band interpolated solution. The results show that a certain variability characterizes the 1992-2010 natural subsidence (0.9 ± 0.7 mm/yr), mainly because of the heterogeneous nature and age of the lagoon subsoil. The present anthropogenic displacements occur at very local scale and are heterogeneously distributed with values ranging from -10 and 2 mm/yr in 2008. They are caused by conservation and reconstruction processes to preserve the building heritage together with urban maintenance activities such as restoring the embankment walls to guarantee the stability of the canal edges. Moreover, because the sinking zones are generally concentrated along the main channels bounding and crossing the city, waves induced by the intensive boat and ship traffic likely contribute by waking and eroding the fragile masonry canal banks and the building foundations. Geotechnical applications such as micropiles, anchors, jet grouting aimed at improving the subsoil characteristics are likely responsible for the greater stability locally observed in some portions of the city.

References

L. Tosi, P. Teatini, and T. Strozzi, Natural versus anthropogenic subsidence of Venice, Nature Scientific Reports, 3:2710, doi:10.1038/srep02710, 2013.