Understanding the subsidence process of a quaternary plain by combining geological and hydrogeological modelling with satellite InSAR data: The Acque Albule Plain case study

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A B S T R A C T

This paper focuses on a multidisciplinary study carried out in an urban area affected by subsidence and related structural damages. The study area is located about 20 km east of Rome (Italy) and is characterised by relevant groundwater exploitation for various purposes as well as by the presence of compressible soils immediately below the ground level. Extensive processing at different scales of SAR satellite images (ERS and ENVISAT provided by ESA in the frame of a CAT-1 project) by means of A-DInSAR technique was performed. The time histories of ground displacements, have been analysed in combination with a detailed geological setting of the study area and with the hydrogeological changes occurred in the last decades (as the response to the anthropic stress) based on a large piezometric dataset. This comprehensive dataset allowed us to describe the space and time distributions of the subsidence process. The spatial pattern and deformation rate change is attributed to the following causes: i) the changes in the groundwater levels due to the intensification of mine exploitation (requiring dewatering operations) and ii) the distribution and thickness of recent compressible deposits. Specifically, it is derived that the groundwater level variations drive the timing of subsidence triggering over the area, whereas the local geological conditions control the magnitude of the deformation process.

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1. Introduction

Ground subsidence is a common process occurring on the ground surface. Subsidence can be controlled by natural processes, such as volcanic activities (Lu, Masterlark, Power, Dzurisin, & Wicks, 2002), but quite often it can be triggered or accelerated by human activities. Underground excavations (e.g., mining and tunnelling) and new settlements on the ground surface are likely the most common anthropogenic factors causing local scale subsidence (Guéguen et al., 2009; Jung, Kim, Jung, Min, & Won, 2007; Samsonov, d’Oreye, & Smets, 2013). However, fluid and gas exploitation are most commonly associated with regional scale subsidence involving square kilometre areas (Dixon et al., 2006; Meckel, ten Brink, & Williams, 2006; Teatini et al., 2011). Groundwater exploitation is likely the most challenging process as it generally affects large cities that require huge quantities of water for human activities. These processes have been extensively reported worldwide for several important cities, such México City (Cabral-Cano et al., 2008; Chaussard, Wdowinski, Cabral-Cano, & Amelung, 2014; Osmanoğlu, Dixon, Wdowinski, Cabral-Cano, & Jiang, 2011), Bangkok (Phien-wiej, Gao, & Nutalaya, 2006), Shanghai, Tianjin, Beijing, China (Xue, Zhang, Ye, Wu, & Li, 2005), Lhokseumawe, Medan, Jakarta, Bandung, Blanakan, Bekalongan, Bungbulang, and Semarang, Indonesia (Chaussard, Amelung, Abidin, & Hong, 2013), Taipei, Taiwan (Hung et al., 2011), Florence (Colombo, Farina, Moretti, Nico, & Prati, 2003), Prato (Raucoules, Le Mouélic, Carnec, Maisons, & King, 2003), and Bologna (Modoni et al., 2013).

In some cases, subsidence can be on the order of some metres with velocities of some decimetres per year, thus quite often causing damage to buildings and infrastructures. In other cases, more minor displacements can be revealed only by instrumental analyses.

Among the ground displacement measurement techniques, satellite differential InSAR (Berardino, Fornaro, Lanari, & Sansosti, 2002; Bürgmann et al., 2000, Ferretti, Prati, & Rocca, 2000, 2001, Ferretti et al., 2011, 2000, 2001; Gabriel, Goldstein, & Zebker, 1989; Hooper, Zebker, Segall, & Kampes, 2004, Kampes, 2006; Massonnet, Briole, &