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A ground subsidence study based on DInSAR data: Calibration of soil parameters and subsidence prediction in Murcia City (Spain)

R. Tomás [a,*], G. Herrera [b], J. Delgado [a], J.M. Lopez-Sanchez [c], J.J. Mallorquí [d], J. Mulas [b]

[a] Departamento de Ingeniería de la Construcción, Obras Públicas e Infraestructura Urbana, Escuela Politécnica Superior, Universidad de Alicante P.O. Box 99, E-03080 Alicante, Spain
[b] Área de Investigación en Peligrosidad y Riesgos Geológicos, Departamento de Investigación y Prospectiva Geocientífica, Instituto Geológico y Minero de España (IGME), Ministerio de Ciencia y Tecnología, c/ Alenza 1, E-28003 Madrid, Spain
[c] Departamento de Física, Ingeniería de Sistemas y Teoría de la Señal (DFISTS), Escuela Politécnica Superior, Universidad de Alicante, P.O. Box 99, E-03080 Alicante, Spain
[d] Remote Sensing Lab., Departamento de Teoria del Senyal i Comunicacions, Universitat Politècnica de Catalunya, Campus Nord, Ed. D3, c/ Jordi Girona, 1-3, 08034 Barcelona, Spain

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ABSTRACT

Subsidence is a hazard that affects wide areas in the world causing important economic costs annually. The City of Murcia (SE Spain) is affected by this phenomenon since the 90s. In this work, ground subsidence caused by aquifer overexploitation is remotely monitored with Persistent Scatterer Interferometry (PSI). In particular, the so-called Coherent Pixels Technique (CPT) has been applied to SAR images from ERS and ENVISAT satellites. The CPT displacement time series corresponding to the 1993–1995 period have been used to calibrate a proposed one-dimensional subsidence model. Hence, the CPT time series have been successfully used to retrieve physical parameters of the soil. Then the model has been used to predict the deformations for the period 1993–2007. The comparison between the predictions of the model and the actual subsidence time series for the 1995–2007 period provides an average absolute difference of 3.2 ± 2.5 mm. Despite the simplicity of the adopted 1D model, these results show the usefulness of the CPT derived displacement information to calibrate and validate numerical models of ground subsidence due to aquifer overexploitation, which can be used to predict the aquifer's response for future piezometric falls.

1. Introduction

Ground subsidence induced by excessive exploitation of aquifers is a hazard affecting our society. This phenomenon is manifested at ground surface as millimetric to metric vertical displacements during periods that may last years, usually over wide areas. The problem of settlement is a critical issue for urban areas as it can lead to damages in human infrastructures causing important economic losses. It is estimated that there are over 150 cities in the world with serious problems of subsidence due to excessive groundwater withdrawal (Hu et al., 2004). Some well-known examples of subsidence around the world include the Po Valley (Italy), Mexico DC, Antelope, Santa Clara and San Joaquin Valleys (USA), Bangkok (Thailand) or Shanghai (China). In the metropolitan area of Murcia City (SE Spain) subsidence has occurred as a result of excessive pumping of groundwater, generating damages over 50 million euros and a significant social impact after the 1992–1995 drought period (Martínez et al., 2004).

Over the last decades Differential SAR Interferometry (DInSAR) has become an important remote sensing tool for detecting and monitoring ground surface displacements at a low cost with a millimetric precision. The simplest DInSAR technique was based on a single interferogram generated from a pair of SAR images (Rosen et al., 2000) and was applied to analyze subsidence due to ground water extraction in Galloway et al. (1998), Hoffmann et al. (2003) and Hoffman (2003). A remarkable improvement in the quality of the DInSAR results is given by a family of algorithms named Persistent Scatterer Interferometry (PSI) that are based on the simultaneous processing of multiple interferograms derived from a large set of SAR images (Ferretti et al., 2000; Berardino et al., 2002; Mora et al., 2003; Arnaud et al., 2003; Werner et al., 2003; Hooper et al., 2004). Subsidence monitoring applications of PSI can be found, for instance, in Ferretti et al. (2004), Tomás et al. (2005), Casu et al. (2006), Zerbini et al. (2007), Bell et al. (2008) and Herrera et al. (2009).

Diverse approaches have been proposed in the literature to predict land subsidence in order to care for societies affected by this phenomenon. These approaches can be classified following the Xu et al. (2008) criterion that divides subsidence prediction approaches into five categories: (a) Statistical method, as influence function, Gray theory and regression analysis; (b) one-dimensional numerical model; (c) quasi three-dimensional seepage model; (d) three-dimensional seepage, and (e) three-dimensional fully coupled models.

* Corresponding author.
E-mail addresses: roberto.tomas@ua.es (R. Tomás), g.herrera@igme.es (G. Herrera), jose.delgado@ua.es (J. Delgado), juanma.lopez@ua.es (J.M. Lopez-Sanchez), mallorqui@tsc.upc.edu (J.J. Mallorquí), j.mulas@igme.es (J. Mulas).

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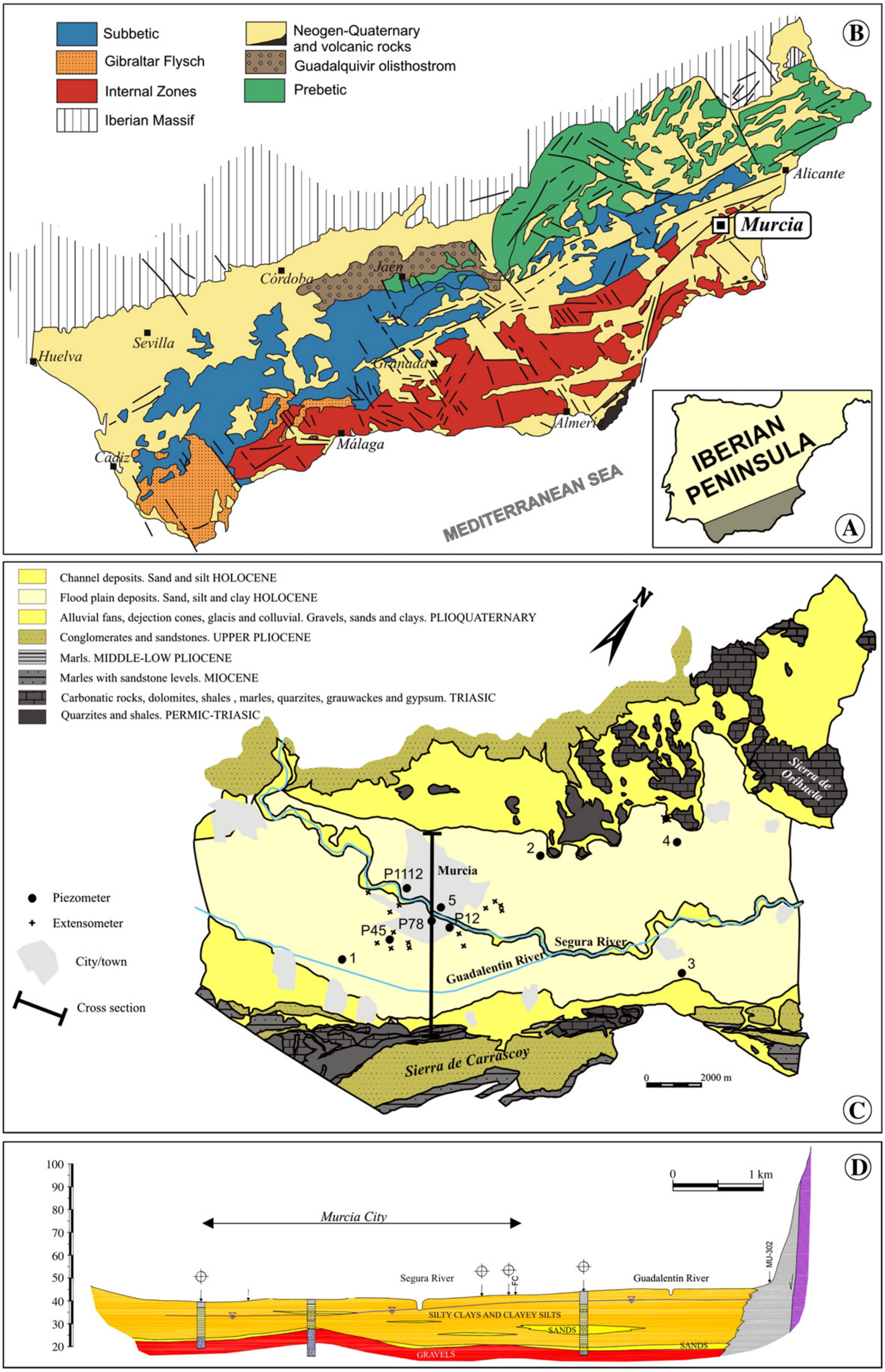

Fig. 1. Geological setting of the study area (based on Montenat (1977) and Aragón et al. (2004)). Piezometric levels for boreholes (1 to 5) and multipiezometers are shown in Figs. 2 and 3 respectively.