InSAR data to study aquifer-related deformation: Three case studies in Spain

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Résumé

Land subsidence resulting from groundwater extractions is a global phenomenon affecting many regions worldwide that is expected to intensify due to future climatic conditions and population growth. Identifying the areas affected by subsidence and understanding the factors that control aquifer-related deformation is crucial to mitigate or reduce its adverse consequences. Synthetic Aperture Radar (SAR) interferometry is ideally suited to study ground deformation associated with aquifer-system compaction. Here we present three case studies in Spain: 1) The Alto-Guadalentín detritic aquifer (SE Spain) where the continuous pumping of groundwater, mainly for agricultural use, led to a decrease in the piezometric levels of more than 200 m since 1975, resulting in overexploitation of the aquifer and land subsidence. Using 20 years of InSAR data (1992–2012) in combination with groundwater level data and geological information, we characterize the spatio-temporal evolution of ground deformation and found a clear relationship between the thickness of the compressible deposit and the ground deformation. After comparing the temporal evolution of groundwater level and ground deformation, we conclude that the displacements observed from 1992–2012 were triggered by the piezometric drawdown that began in the 1970s, suggesting a long delayed compaction process. 2) The detrital aquifer of the Vega de Granada (SE Spain), one of the largest groundwater reservoirs in Andalusia, which is considered of strategic importance for the economy of this semiarid region. Combining InSAR data from different satellites (ENVISAT 2003–2009, Cosmo-SkyMed 2011–2014 and Sentinel-1A 2015–2016) with piezometric and geological data, we monitor the evolution of ground subsidence and characterize the deformational behaviour of the aquifer. Our study reveals that the most widespread land subsidence occurred during the ENVISAT period (2003–2009), which corresponds to a long, dry period in the region. Regarding the factors controlling the aquifer-related deformation, lithology seems to play a main role in the spatial distribution of ground subsidence, with all the subsiding areas located in areas of higher clay content. 3) The Tertiary detritic aquifer of Madrid (TDAM), in central Spain, that provides water to Madrid during drought periods. Combining ERS and ENVISAT InSAR data, covering the periods 1992-2000 and 2003-2010, and piezometric data from 19 wells we characterize the deformational behaviour of the aquifer and conclude that the aquifer system behaves almost elastically through cycles of groundwater pumping and recovery. We then estimate an average elastic coefficient of storage of the aquifer system and use it to model groundwater levels over the entire extraction fields and groundwater storage changes to identify regions affected by storage loss. These cases illustrate the application of InSAR techniques to detect and monitor aquifer-related deformation, characterize the deformational behaviour of aquifer systems and model water level

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changes and groundwater storage variations. These results can help designing management plans for the sustainable use of aquifers. The historical archive of SAR data suitable for InSAR, acquired since the early 1990s by different satellites along with the new Sentinel-1 satellites, guarantee the availability of InSAR data for virtually studying every aquifer on Earth.