



Rapid groundwater-related land subsidence in Yemen observed by multi-temporal InSAR

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Several basins in Yemen are suffering from a rapid drawdown of groundwater, which is the most important water source for agricultural irrigation, industry and domestic use. However, detailed geodetic measurements in the region have been lacking and the extent and magnitude of groundwater-related land subsidence has been poorly known. We used 13 ascending ALOS and 15 descending Envisat images to study land subsidence of several basins in Yemen, with a special focus on the Sana'a and Mabar basins. From multitemporal synthetic aperture radar interferometric analysis (persistent scatterers (PS) and small baseline subsets (SBAS)) we examined the spatio-temporal behavior of the subsidence induced by depletion of groundwater aquifer systems from November 2003 to February 2011. In the interferometric data processing, we carefully chose interferogram pairs to minimize spatial and temporal decorrelation, because of high subsidence rates and the type of land cover. Our results show that the spatial pattern of subsidence remained quite stable during the observation period in both the Sana'a and Mabar basins. In the Sana'a basin, the maximum subsidence rate exceeded 14 cm/year in the radar line-of-sight (LOS) direction between 2003 and 2008 in an agricultural area just north of Sana'a city, where water wells have been drying up according to the well data. The subsidence rate was lower in the urban areas, or approximately 1 cm/year, exhibiting annual variations. The main subsidence was found in the center and southern parts of the city, while deformation in the northern part is less obvious. For the Mabar basin, the subsidence rate exceeded 30 cm/year in the agricultural area north of the town of Mabar during 2007 – 2011. The southern part of the Mabar basin also experienced high subsidence rates, although somewhat lower than to the north. Excessive water pumping is the main cause of the ground subsidence and it has already led to extensive ground fracturing at the edge of some of the basins. Our results highlight the usefulness of InSAR in monitoring land subsidence in areas where limited or no conventional geodetic observations are carried out. Future work will focus on obtaining more InSAR and well pressure data and on analyzing further the subsidence and its connection with the groundwater reservoir pressure distribution.