Monitoring groundwater depletion in Iran from space: results from gravity and InSAR observations

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Iran is located in a semi-arid to arid environment and is highly dependent on its groundwater resources for development in its agricultural and industrial sectors. In many aquifers across the country, unsustainable groundwater extraction in the past few decades caused severe groundwater level decline, at locations exceeding 20 m. The country is divided into six major basins. However, neither the water consumption nor renewable water resources are distributed evenly. Quantitative assessment of the groundwater situation in different basins is a piece of crucial information for improving management practices. In this study, we use satellite observations to assess the groundwater situation across Iran.

We observe the terrestrial water storage (TWS) from Satellite gravimetry measurements of Gravity Recovery And Climate Experiment (GRACE). These observations provide a country-scale picture of groundwater variations at a coarse spatial resolution of 500 km. In all six basins, TWS declines during the 15 year lifetime of GRACE from 2002 until 2017. In total, the Equivalent Water Height (EWH) declines as much as approximately 10 cm during this period. Although part of this decline is caused by other components such as surface water or soil moisture, groundwater decline is responsible for the major part.

The compaction of aquifers resulted from the over-extraction of groundwater can be observed as land subsidence on the surface. We analyze ground subsidence for the whole Iran using Interferometric Synthetic Aperture Radar (InSAR) observations of the Copernicus Sentinel-1 satellite and present the first detailed map of compacting aquifers across the country at a high spatial resolution of 100 m. The average rate of displacement, exceeding 30 cm/yr in some areas, reveals hundreds of aquifers across the country are suffering unsustainable groundwater consumption. The distribution of subsidence basins is significantly correlated with the distribution of agricultural regions.

To obtain information on the sustainability of groundwater consumption, we separate the time series of land subsidence into two parts: the short term part as elastic/recoverable component and the long-term part as inelastic/irrecoverable. The ratio between elastic and inelastic elements provides quantitative measurements of aquifer health. Combining the Sentinel-1 subsidence measurements with GRACE observations of groundwater variations gives us new details on how the groundwater is consumed across different basins in the country. The results can have
essential implications on the more sustainable management of groundwater resources.