Mapping and analyzing land subsidence for Tehran using Sentinel-1 SAR and GPS and geological data

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Tehran, as a megacity in Iran, is exposed to a high rate of land deformation. Recent research shows average land deformation speed is up to 39.9 mm/year in southeast plain (from 2014 to 2017) and groundwater extraction in Tehran plain for agricultural and industrial demands is the most probable driving mechanism. It is undisputed that infrastructure and structure in Tehran are continuously under threat by such rapid land subsidence, and this subsidence may also lead to significant economic losses such as structural damage and high maintenance costs for roads, railways, dikes, pipelines, and buildings. Therefore, when, where and why the subsidence did/does occur has to be closely monitored and analysed considering future planning and the importance of infrastructure and structure damage, which has a profound effect on human activities. This study attempts to use Sentinel 1 SAR data to map land subsidence in Tehran and validate the results by using GPS data.

We implemented the standard persistent scatterer interferometry (PSI) approach with the customized parameter configuration, for Tehran with an area of about 1600 km$^2$. 52 Sentinel 1A (C-band) dataset acquired between 2018 and 2019 were collected. There were 1,746,317 PS measurement points generated. The PSI results illustrate that the maximum loss of elevation over the time period did amount to 11.7 cm/year.

We used the GPS observations between 1/1/2018 and 27/10/2019, from the two GPS stations GPS-m020 (35.64 N, 51.29 E), GPS-m020 (35.58 N, 51.42 E) to evaluate the PSI deformation results. We found that the maximum and minimum double difference between GPSs and PSs were 0.0536 m, 0.0015 m respectively; moreover, the corresponding histogram shows that most of the double-difference values are in the interval of [-0.01 0.01] m, and the RMSE is 0.011 m. Besides, we also applied the velocity comparison of double-differenced GPS and PS, which shows that the PS measurements matched well with the GPS observations.

By comparing the water table variations and PSI-derived land deformation, we found that the groundwater withdraw could be a major driving mechanism but the variation in soil type also plays an important role. For instance, although the groundwater levels (Xutm = 503498, Yutm = 3948916) has decreased by approximately 13m from 2012 to 2017 at the place of Andisheh-Jadid, no subsidence was detected possibly due to the presence of well grade layers at that location.