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An interdisciplinary investigation of the Central Valley's aquifer response during recent droughts

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Semi-arid, drought-prone and fast-growing regions like California are experiencing strong pressure on water resources, causing groundwater overdraft and putting at risk future water security. For sustainable management of groundwater, data with sufficient accuracy and resolution are needed to evaluate the impact of human activities and climate extremes on groundwater resources. Recent developments in geodetic remote sensing and modeling have significantly broadened our insights into groundwater resources. Gravity field observations from the GRACE mission in conjunction with hydrological data allows quantifying the overall loss of groundwater in a large aquifer system, and thus providing insight into the severity of groundwater depletion. Moreover, changes in groundwater stocks cause surface deformation associated with regional elastic loading of the Earth's crust and localized poroelastic compaction of the aquifer skeleton, which are detectable by GPS and InSAR. The loading signal is typically much smaller than the land subsidence due to poroelastic compaction and thus masks out the loading signal adjacent to the aquifer system. However, the poroelastic signal can be used to estimate groundwater volume change in confined aquifer units and provides insight into the mechanical properties of the aquifer system.

In this presentation, we perform an integrated multiscale analysis of various data sets to retrieve detailed information on the responses of the Central Valley aquifer system to the drought periods of 2007-2010 (entire Central Valley) and 2012-2015 (focused on the San Joaquin Valley). We use ~300 continuous GPS stations, 620 SAR images acquired by ALOS L-band and Sentinel1-A/B C-band sensors, and ~1600 groundwater level observational wells. GRACE-based estimates of total water storage change are obtained from JPL and converted into groundwater volume loss using hydrological datasets. We estimate maximum subsidence rates in the southern San Joaquin Valley of up to ~25 cm/yr and ~35 cm/yr for the droughts starting in 2007 and in 2012, respectively. Using a 1-D poroelastic calculation based on deformation data, we find a groundwater loss of 21.3 ± 7.2 km^3 for the entire Central Valley during 2007-2010 and of 29.3 ± 8.7 km^3 for the San Joaquin Valley during 2012-2015. The loss estimates are consistent with that of GRACE-based estimates considering uncertainty ranges. We further infer that due to overdraft during both droughts the aquifer system storage capacity permanently reduced by up to 5%. This integrated analysis, allows us to address the question of how well the different geodetic signals agree with one another and what are the possible causes of disagreements. We highlight the need for interdisciplinary efforts to integrate available geodetic and hydrological datasets to improve our understanding of aquifer systems response to drought and human activities.