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Seasonal groundwater dynamics in California's Central Valley indicated by GPS-enhanced InSAR

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Recent and persistent droughts in California have stressed regional hydrological systems and driven increased reliance on groundwater resources. Exploitation of these aquifer systems induces changes in surface elevation due to elastic and inelastic compaction associated with reductions in pore pressure within the aquifer matrix. Monitoring dynamic changes in groundwater is complex and has been historically limited to point-wise, in-situ observations, often with poor temporal sampling. With the rise of the satellite age, we have begun to observe broad-scale changes at high resolution using space geodetic tools, particularly using relations between hydrological variations and surface displacements. With the rapidly growing volume of publicly available data for InSAR (Interferometic Synthetic Aperture Radar) studies, sampled as frequently as 6-day repeats, the limits and capabilities of these datasets are continually being pushed and tested.

In this study, we use a dense collection of InSAR observations from the Sentinel 1A/B missions combined with data from a large network of cGPS (continuous Global Positioning System) stations from the Plate Boundary Observatory. From this, we estimated secular velocities and time series of surface deformation with our "GPS-enhanced InSAR" (or GInSAR) algorithm spanning 2015 – 2017 over California's San Joaquin Valley at high spatial resolution (100m). While long-term trends are useful for groundwater monitoring, we focus our attentions here to the seasonal component of deformation in our time series and find complex but spatially coherent patterns in amplitude and seasonal phase, given as the day of year for peak uplift. To determine the drivers of the observed changes, we leverage auxiliary data from topographically driven surface flow routing, precipitation and runoff data, and available groundwater well data to demonstrate the potential of using surface displacements to map groundwater recharge locations and lateral flow paths.

This study reveals a synoptic view of the complexities of groundwater dynamics in the San Joaquin Valley. While many sub-regions behave according to conventional wisdom (e.g. groundwater recharge patterns correlating with precipitation and surface water features), others appear to break this paradigm, exposing previously undocumented hydrogeological structures. This offers crucial insight into our aquifer systems and has the potential to provide critical information for policy relevant decisions and future sustainable planning.