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Seasonal variation in water storage, vertical land motion and well levels: Implications for groundwater storage change in Central Valley

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The establishment of the Inter-Commission Committee on "Geodesy for Climate Research" (ICCC) of the International Association of Geodesy (IAG) emphasizes on the usefulness of geodetic sensors for estimating high-resolution water mass variation, which is due to broad applications of geodetic tools ranging from water cycle studies to water resources management. As such, data from both GRACE missions continue to provide insight into the alarming rates of groundwater depletion in large aquifers worldwide. Observations of vertical land motion (VLM) from GPS and InSAR may reflect elastic responses of the Earth's crust to changes in mass load, including those in aquifers. However, above confined aquifers, VLM observations are dominated by poroelastic deformation processes. In previous works, Ojha et al. 2018 and 2019 show that GRACE-based estimates of groundwater storage change in the Central Valley, California, are consistent with those obtained by utilizing measurements of surface deformation. These studies also show that annual variations in VLM correlate well in time with groundwater levels.

Here, we investigate seasonal variations in groundwater storage by identifying how their effect is manifested in geodetic and hydrological datasets. Groundwater well observations in the Central Valley indicate maximum groundwater levels at the beginning of the year between February to April and lowest water levels in the middle of the year about July to October. Meanwhile, GRACE groundwater storage estimates peak about four months later. To get insight into the mechanisms leading to this discrepancy, we perform a Wavelet multi-resolution analysis of GRACE TWS variations and complementary groundwater, snowcap, soil moisture, and reservoir level variations. We show that the majority of the differences between wavelet spectrums at seasonal frequencies occur during drought periods when there is no supply of precipitation in the high elevations. We employ a 1D diffusion model to demonstrate that the variations in groundwater levels across the Central Valley are due to the propagation of the pressure front at recharge sites due to gradual snowmelt. Such a model could explain the different timing of peaks in groundwater time series based on satellite gravimetry compared to deformation and well observations. We also discuss that winter rains are not able to directly contribute to recharging deep aquifers in the Central Valley, whereas most of the recharge must source from lateral flow caused by differential pressure at the sites of snow-melt in the Sierra Nevada as well as from agricultural return flows.

This analysis addresses the question of how well the different geodetic signals that reflect groundwater discharge and recharge processes agree with one another and what are the possible causes of disagreements. We emphasize the need for interdisciplinary efforts for the successful integration of available geodetic and hydrological datasets to improve our ability to utilizing geodetic sensors for climate research and water resources management.

References:

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