Empirical GNSS-derived terrestrial water storage-streamflow relationship in the Sierra Nevada mountain range, California

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One of the most dynamic components of Earth surface mass variability is the constant global redistribution of terrestrial water storage (TWS) across temporal scales of hours to decades. Mass loading and unloading from TWS changes induce instantaneous elastic deformation of the solid earth, producing predominantly vertical transient displacements that are observable by geodetic methods. While contemporary GNSS studies have demonstrated the ability to map regional-scale water storage variabilities, incorporating these geodetic estimates with in-situ hydrologic measurements can provide further insights on physical mechanisms underlying the terrestrial water cycle.

In this study, we investigate the potential of using GNSS-derived TWS estimates to infer individual watershed condition along the Sierra Nevada mountains, a major water source for urban and agricultural use in California. Utilizing the dense GNSS coverage in the western United States, we invert for TWS change at sub-regional spatial resolution. We show that network-wide common mode components in GNSS positions must be corrected for understanding short-period loading events. Joint hysteresis analysis with stream gauges shows contrasting seasonal behaviours in the northern and southern Sierra Nevada: the snow-dominated southern section exhibits significant time lag between maximum storage and maximum baseflow during precipitation season, suggesting a decoupled connection between surface storage and ground reservoirs; on the other hand, the northern section exhibits little to no lag, suggesting a more coupled connection with its higher rain-to-snow ratio. Continued development of GNSS-based water storage estimates and future assimilation with hydrologic models can provide additional understanding on the terrestrial water budget, as well as the increasingly intense wet and dry seasons due to the changing climate.

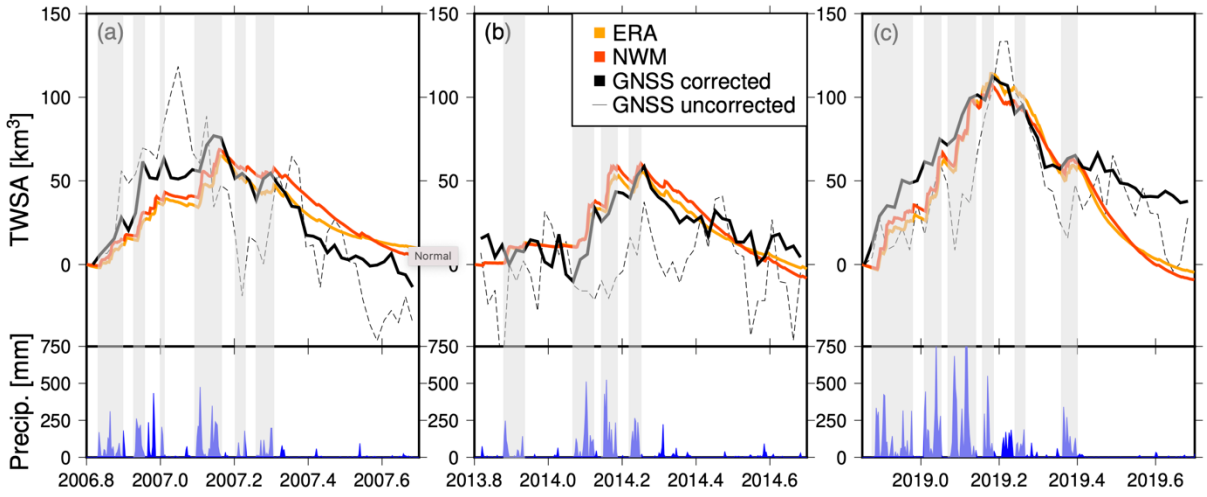

Figure: California (HUC-2 level) weekly GNSS-inverted water storage (black lines) compared to hydrologic model output (NWM and ERA5) and precipitation data.