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The Effects of Hydrologically-Related Processes on Long Valley Caldera and Adjacent Sierra Nevada at Different Temporal and Spatial Scales

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Long Valley Caldera (LVC, California) is well-known for its complex geophysical signals that result from an active magmatic system featuring recent episodic inflation, long-term tectonic motion, and associated seismicity. Located at the eastern edge of the Sierra Nevada block, this region is also influenced by hydrological forcing associated with large amounts of precipitation (average annual of ~100 cm/yr) in the Sierra Nevada and its spatiotemporal variability. The instruments measuring deformation in this area, such as Global Navigation Satellite System (GNSS), are therefore recording the effects of superimposed tectonic and non-tectonic processes.

Combining displacement data from permanent GNSS networks with different hydrological records, we analyze the non-tectonic deformation affecting the LVC region and the adjacent Sierra Nevada range. The vertical and horizontal components of GNSS displacement vectors show a clear correlation with hydrological trends at both multiyear and seasonal time scales.

At the seasonal timescale, deformation is largely controlled by the response to hydrological surface loading. However, we detect several GNSS sites mainly clustered in the south/south-western rim of the LVC showing anomalous horizontal deformation that cannot be explained as elastic response to surface load. This is also the area where most of the water recharging the LVC hydrothermal system occurs and where a runoff-induced seismicity has been recently identified. Based on the location of the GNSS sites, the shape and timing of transient seasonal deformation, and its temporal correlation with spring/summer discharge and shallow seismicity rates, we hypothesize that this signal reflects poroelastic deformation in response to surface water recharge into Sierra Nevada slopes.

At the multi-year scale, recent inflation episodes at LVC show a temporal correlation with periods of severe droughts affecting a larger region (Western US). Using numerical modeling (COMSOL software), we investigate the influence of surface water load variation on the LVC magmatic system. Furthermore, we evaluate the effect of geometrical and structural complexities of the area on the deformation pattern related to inflation episodes.

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