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Using InSAR to investigate long term caldera unrest: case studies from Yellowstone and Long Valley

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Interpreting geodetic measurements can be particularly difficult in the case of slow, years-to-decades deformation, such as that commonly observed at large Quaternary silicic calderas.

For example, Yellowstone caldera has shown a complex behavior over recent decades: uplift of resurgent domes within the caldera started sometime after 1923, reaching a total of 90 cm, but in 1984 the deformation reversed to subsidence at a rate of 1–2 cm/yr until 1992. Starting in 1992, the deformation began migrating from one resurgent dome to the other, and deformation was also detected along the caldera boundary – the so-called Northern Caldera Rim - starting in the mid-1990s. Evidence from geodetic surveys suggests that magma intrusion and/or pressurization of hydrothermal fluids may both drive uplift at Yellowstone.

Geodetic measurements at Long Valley caldera have also revealed multiple episodes of caldera uplift, but in contrast to Yellowstone, deformation is largely restricted to the caldera's single resurgent dome. The fact that the energy released during the resurgent dome uplift is much larger than that which can be explained by seismic activity within and around the caldera, together with the observation that the onset of accelerated deformation precedes increases in earthquake activity by several weeks, suggests that the major source of caldera unrest is probably magma intrusion beneath the resurgent dome.

Here we present time series of surface deformation for Yellowstone and Long Valley retrieved by applying the SBAS InSAR technique. We estimate the average regional deformation signal by using the mean velocity values derived from coherent SAR pixels belonging to areas outside the caldera. This tectonic signal is removed from the InSAR displacement and we modeled the InSAR, leveling, and gravity measurements to retrieve the best fitting source parameters.

For Yellowstone caldera, different distinct sources, either hydrothermal or magmatic, have been intermittently active during the last three decades. For example, the joint inversion of gravity and deformation measurements indicates that hydrothermal fluids were the driving force behind the 1977–1983 uplift of the Sour Creek dome; the same data reveal that since 1983–1993 the deformation source deepened and included a higher proportion of magma. On the other hand, gravity and deformation data suggest that the deformation source beneath Mallard Lake dome has been magmatic for the entirety of the investigated period. Uplift of the Northern Caldera Rim is probably due to magma accumulation, while subsidence of that area could either be the result of fluid migration outside the caldera or the gravitational adjustment of the source from a spherical to a sill-like geometry.

The activity in Yellowstone contrasts with that of Long Valley caldera, where deformation is driven by a single magmatic source beneath the resurgent dome that has been active for the past 35-40 years.