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Transient ground deformation in silicic volcanoes imaged with InSAR: evidence for episodic magma injection at Cordon Caulle and Yellowstone volcanoes

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One of the most outstanding discoveries of InSAR geodesy in the realm of volcanology is that large silicic volcanoes like Yellowstone, Long Valley and Campi Flegrei undergo transient pulses or cycles of ground uplift followed by periods of either quiescence or ground subsidence. These uplift events have velocities of ∼1-10 cm/yr, but can reach rates up to 20 - 45 cm/yr, and spatial and time scales that vary from ∼15 km to more than 100 km, and from ∼6 months up to at least half a century, respectively. These signals have been interpreted as being produced by either magma intrusion, volatile exsolution, hydrothermal fluid flow, or a combination of these processes. However, inherent ambiguities in the geodetic data interpretation and the lack of other independent data sets have not allowed to unravel the physical mechanism of ground uplift for most of them. In this study we focus on two of these silicic systems with outstanding ground deformation signals, Cordon Caulle (southern Chile) and Yellowstone (western US). Our objective is to constrain the driving mechanism of ground deformation that we relate to episodic pulses of magma injection into reservoirs in the upper and middle and crust respectively.

At Cordon Caulle InSAR data show a sequence of three pulses of ground uplift during 2012 and 2018, immediately after the VEI 4 2011-2012 rhyolitic eruption. These three pulses can be modeled by the same source, a sub-horizontal sill at a depth of ∼ 6 km, but their time evolution is significantly different, ranging from exponential to linear, and with rates between 5 and 45 cm/yr. Finite element models show that viscoelastic effects are negligible, hence we interpret these uplift signals as being produced by episodic pulses of magma injection that provide the heat to remobilize the crystal mush that likely underlies the volcano. These magma batches have injection rates one order of magnitude higher than the geologically averaged rates of pluton growth, and can occur on timescales of just a few months.

At Yellowstone volcano InSAR data has shown that the caldera floor undergoes episodic uplift, followed by either magma or hydrothermal fluids migration towards other zones. The caldera floor uplift shifts to subsidence when the pressurization reaches a threshold that results in fluid migration outside of the caldera. To understand these coupled patterns of magma injection and fluid flow, we will present new ascending and descending ENVISAT and ALOS-1 time series spanning 2003-2011, with a focus on the extraordinary episode of uplift in 2004-2010. We will also present first attempts to model the pattern of inflation and deflation with models of magma injection from a conduit into several reservoirs.