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## Recent unrest (2002-2015) imaged by space geodesy at the highest risk Chilean volcanoes: Villarrica, Llaima, and Calbuco (Southern Andes)

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Villarrica, Llaima, and Calbuco volcanoes are the most active and dangerous volcanoes in the Southern Andes, and we use Interferometric Synthetic Aperture Radar (InSAR) observations from multiple satellites (ERS-2, ENVISAT, ALOS, RADARSAT-2, COSMO-SkyMed, TerraSAR-X, Sentinel-1A and ALOS-2) to constrain ground deformation that spans episodes of unrest and eruption at all three volcanoes between 2002 and 2015. We find episodes of ground deformation at each volcano, which we invert using analytic elastic half space models to make some of the first geophysical inferences about the source depths of potential magma chambers. At Llaima, we interpret that the VEI 2 April 3 2009 eruption was preceded by ~6-15 cm of precursory ground uplift one month before from a source ~5 km below the surface on the western side of the edifice. The VEI 2 March 3 2015 Villarrica eruption was followed by a short lived uplift of 5 cm in the SE part of the volcano from a source depth of ~6 km. The VEI 4 April 22-23 2015 Calbuco eruption produced 12 cm of coeruptive subsidence from a source depth 8-11 km and offset ~2 km S from the summit. Importantly, we do not find clear evidence that the January 1 2008, the March 3 2015 and April 22 2015 eruptions at Llaima, Villarrica and Calbuco volcanoes were preceded by either transient or continuous ground uplift. There are several possible explanations for the lack of precursory deformation at each volcano – it is possible that any precursory deformation occurred only hours before

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