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Fluctuating lava lake density revealed by changes in deformation, gravity, and lava lake elevation at Kilauea Volcano, Hawaii

Daniele Carbone (1), Michael Poland (2), and Matthew Patrick Patrick (2)

(1) INGV - Osservatorio Etneo - Sezione di Catania, Catania, Italy (carbone@ct.ingv.it), (2) USGS - HVO, Hawaii National Park, USA

Changes in lava level within the summit eruptive vent at Kilauea Volcano, Hawaii, observed during 2011–2012 are strongly correlated with changes in ground deformation in the vicinity of the vent. This relation suggests that the lava level is a good indicator of changing pressure within the shallow magma reservoir that is feeding the lava lake. Indeed, pressure changes influence both deformation and lava level, but those two parameters are related to pressure through different mechanical properties. The ratio between pressure in the shallow magma chamber and lava level is a function of the density of the lava filling the vent—the level rise will be greater for a low-density lava lake than for a higher-density lake given the same pressure increase, for instance. The ratio between changes in magma chamber pressure and deformation depends on the size and position of the reservoir and on the elastic parameters of the host rock. Over the short timescales considered in this study ($\sim$2 years), we do not expect that the host rock properties or magma reservoir location will vary. Lava lake density, on the other hand, may not be constant, which could impact the relation between lava level and deformation over time.
Preliminary analyses in the time and frequency domains of lava level (determined from thermal camera imagery of the lava lake) and tilt (measured on a borehole instrument located $\sim$2 km from the summit vent) demonstrate that there is a good correlation throughout February 2011-December 2012), and that the highest correlation occurs over periods ranging between 1 and 20 days. We found an average ratio between lava level and tilt during 2011–2012 of 5-6 meters of lava level change per microradian of tilt, but this ratio is not constant over time. Using a 15-day-long sliding window with 50% overlap between steps, we found variations in the ratio between changes in lava level and tilt during 2011–2012, with high and low ratios of 4 and 20 meters per microradian, respectively. Using data from a continuously recording gravimeter located near the rim of the summit eruptive vent, we calculated the density of the upper few hundred meters of the lava lake over time during 2011–2012. Variations in density correlate with changes in the ratio between lava level and tilt, indicating the primary control that lava density exerts on the ratio. These density variations are important since they may impact the degree of outgassing, emission of tephra, and potential for small explosions from the vent.