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Monitoring for volcano-hydrothermal activity using continuous gravity and local ground acceleration measurements: New deployments at Inferno Crater, Waimangu and White Island, New Zealand

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Volcanoes with crater lakes are often characterised by shallow hydrothermal systems which display cyclic behaviour (temperature, lake level, chemistry, etc.) and shallow seismic tremor. Present monitoring programmes in New Zealand include routine collection of these observables, but the associated shallow sub-surface processes are still inadequately modelled and poorly understood. Models would be better constrained with the incorporation of additional geophysical parameters. To this end, we have established a new test programme to continuously monitor for micro-gravity variations at New Zealand volcanoes. We utilise a Micro-g-LaCoste gPhone relative gravity meter having 1 Hz sample rate and a measurement precision of 1 microgal to test the viability of gravity monitoring for volcano-hydrothermal systems. We have initially tested the new sensor in a short term deployment ($\sim$2 months) at Inferno Crater, Waimangu, New Zealand. Inferno shows dramatic variations in crater lake level ($>$ 7 m range), temperature ($>40^o$ C range) and hydrothermally derived tremor, all over a period of $\sim$5 weeks. The amplitude and period of these observables are ideal for testing gravity variations associated with a cycling hydrothermal system because several cycles can be obtained in a relatively short campaign. We have deployed the gravity sensor into a buried vault having a stable concrete base to minimise local environmental influences. This vault is located $\sim$20 meters from Inferno Lake edge (at high stand) and offers sufficient noise reduction to measure the gravitational effects associated with lake level changes. We will show results for the new gravity meter including raw relative gravity measurements and first order corrections (earth-tide, ocean loading, sensor level, temperature, and barometric pressure) to obtain both residual gravity and overprinted local ground accelerations (earthquakes and local tremor). To examine the effects of local ground vibrations on the gravity meter, we have co-located a broadband seismometer (100 Hz sample rate). Of particular interest in this analysis is the separation of any microgravity changes from the hydrothermal tremor signature. Future modelling of the Inferno Crater lake will incorporate gravity, lake level and temperature changes into a multi-phase spatio-temporal model of the subsurface. We anticipate that separation of the gravity and seismic signals may allow future constraint of the sub-surface hydrothermal processes which control cyclic behaviour. We also will show results of a planned deployment of the new gravity meter to White Island volcano, New Zealand which will occur in March 2010. Lessons learned from the Waimangu deployment will be incorporated to understand the long-term variations of White Islands' hydrothermal and magmatic system.