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A comparison of active seismic source data to seismic excitations from the 2012 Tongariro volcanic eruptions, New Zealand

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The 6 August 2012 eruption from Tongariro volcano's Te Maari vent comprised a complex sequence of events including at least 4 eruption jets, a large chasm collapse, and a debris avalanche (volume of $\sim$7x10^5 m^3) that propagated $\sim$2 km beyond the eruptive vent. The eruption was poorly observed, being obscured by night time darkness, and the eruption chronology must be unravelled instead from a complex seismic record that includes discrete volcanic earthquakes, a sequence of low to moderate level spasmodic tremor and an intense burst of seismic and infrasound activity starting at 11:52:18 UTC that marked the eruption onset. We have discriminated the timing of the complex surface activity by comparing active seismic source data to the eruptive sequence. We dropped 11 high impact masses from helicopter to generate a range of active seismic sources in the vicinity of the eruption vent, chasm, and debris avalanche areas. We obtained 8 successful drops having an impact energy ranging from 3 to 9x10^6 joules producing seismic signals to a distance of 5 to 10 km and having good signal to noise characteristics in the 3-12 Hz range. For the 8 drops, we picked first-P arrival times and calculated amplitude spectra for a uniform set of four 3-component stations. From these, we obtained a distribution of amplitudes across the network for each drop position which varied systematically from the eruption vent and avalanche scar to the debris avalanche toe. We then compared these proxy source excitations to the natural eruption and pre-eruption data using a moving window cross-correlation approach. From the correlation processing, we found evidence for the debris avalanche a few minutes prior to the eruption in both the broad spectrum and narrow frequency (5-10 Hz) analysis. The total seismic energy release calculated from the new method is $\sim$8x10^{11} joules, similar to an independently estimated calculation based on the radiated seismic energy. The inferred seismic energy release for the debris avalanche ($\sim$$10^9$ Nm) is several orders of magnitude smaller than the available potential energy, a result that suggests that these surface excitations are inefficiently coupled into seismic waves. We conclude that active source seismic mass drops are suitable proxies for seismic surface processes, offering an easy and effective method to estimate the location and energy release for a wide range of energetic surface mass movements.