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On the use of the elastic lattice method to model nonlinear ground response at Mt. Etna, Italy

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Ground response (GR) refers to the ability of a field site to naturally amplify and damp seismic wavefield components under linear and/or nonlinear conditions. While seismic waves are typically the main triggers of GR, explosions and strong acoustic waves can also induce it through air-to-ground coupling. As both explosive sources and unconsolidated near-surface materials are common to find in volcanic environments, understanding GR becomes a critical task in volcanic hazard monitoring.

Previous studies have characterised the interaction between volcanic explosions and the loose granular scoria at Pizzi Deneri (PDC), an observatory site located 2.1 km northeast of Mt Etna's summit craters. Infrasound sensors recorded high-frequency components (10–50 Hz) embedded in low-frequency explosion signals (0.7–4 Hz), which, upon coupling with the near-surface, were amplified as captured by broadband seismometers and Distributed Dynamic Strain Sensing data (DDSS). A nonlinear elastic model for the near-surface was derived from pressure rate vs. strain rate observations. However, the physical mechanism behind the observed high-frequency amplification remains unclear.

To investigate this, we employ the Elastic Lattice Method (ELM) to simulate wave propagation in the shallow scoria layer, modelled either as a linear or nonlinear medium using parameters derived from the nonlinear elastic model. Two source-time functions are tested: 1) a modified Shannon wavelet to test theoretical amplifications due to resonance, and 2) a real explosion waveform recorded in 2018 to replicate the observed GR events.

Our results indicate that horizontal-layer resonance cannot explain the observed GR behaviour. Instead, a nonlinear mechanical expression the layer might be required to reproduce the amplification. We discuss further in the potential variables to include in ELM to sharpen the nonlinear media modelling. These findings highlight the potential of ELM to model complex mechanical and wavefield responses in geomaterials and underscore the need to integrate GR and nonlinear effects into volcanic hazard assessments.

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