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# Geomorphological controls on seismic recordings in volcanic areas

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In volcanoes, topography, shallow heterogeneity, and even shallow morphology can substantially modify seismic coda signals. Coda waves are an essential tool to monitor eruption dynamics and model volcanic structures jointly and independently from velocity anomalies: it is thus fundamental to test their spatial sensitivity to seismic path effects. Here, we apply the Multiple Lapse Time Window Analysis (MLTWA) to measure the relative importance of scattering attenuation vs absorption at Mount St. Helens volcano (MSH) before its 2004 eruption. The results show the typical dominance of scattering attenuation in volcanoes at lower frequencies (3 - 6 Hz), while absorption is the primary attenuation mechanism at 12 Hz and 18 Hz. Still, the seismic albedo (measuring the ratio between seismic energy emitted and received from the area) is anomalously-high (0.95) at 3 Hz.

A radiative-transfer forward model of far- and near-field envelopes confirms this is due to strong near-receiver scattering enhancing anomalous phases in the intermediate and late coda across the 1980 debris avalanche and central crater. Only above this frequency and in the far-field, diffusion onsets at late lapse times. We also implemented a layered model with a shallower layer with increased scattering properties to model late coda envelopes. While the broadening of late coda phases improves, this model cannot explain the phases of the intermediate coda with higher amplitude than the direct waves.

The scattering and absorption parameters derived from MLTWA are used as inputs to construct 2D frequency-dependent bulk sensitivity kernels for the S-wave coda in the multiple-scattering (using the Energy Transport Equations - ETE) and diffusive (AD, independent of MLTWA results) regimes. At 12 Hz, high coda-attenuation anomalies characterise the eastern side of the volcano using both kernels, in spatial correlation with low-velocity anomalies from literature. At 3 Hz, the anomalous albedo, the forward modelling, and the results of the tomographic imaging confirm that shallow heterogeneity beneath the extended 1980 debris-avalanche and crater enhance anomalous intermediate and late coda phases, mapping shallow geological contrasts.

The geomorphological map of MSH highlights extremely rough landforms (hummocky structures) of the already complex morphology of the debris avalanche. The comparison with the attenuation tomography reveals several matches, not only with the debris avalanche itself but also with other areas in the south flank of MSH, like the volcanoclastic plane, affected by intense eruptions in the

past (e.g. Cougar stage, 28-18 ka).

We remark the effect those may have on coda-dependent source inversion and tomography, currently used across the world to image and monitor volcanoes.