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Volcanic harmonic tremors during a non-eruptive event, Torfajökull volcano, Iceland

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Harmonic tremor, ground vibrations captured by seismometers oscillating in different frequencies, has been widely identified as a result of distinct physical processes. In volcanic areas, the physical processes to explain the gliding spectral lines are usually identified preceding/accompanying eruptions. Less is known about harmonic tremor that occurs in active volcanic areas but does not end in an eruption.

In this study we analyse a harmonic tremor signal with a spectral behaviour that, to our knowledge, has not previously been observed. We observed the harmonic signal in the vertical component spectrogram of 22 out of the 24 broad-band seismometers placed around and within Torfajökull caldera, in Iceland. The discovery was made while estimating a tomographic image of the volcano using a network of seismometers operating for nearly 3 months in summer 2005. a function of frequency and time, the detected harmonic signal has a parabola structure (or a 'V' shape) with a fundamental frequency and a few overtones exhibiting higher energy. The fundamental mode glides upward from frequencies below 1 Hz up to and above 25 Hz and can take up to 10h from the minimum to the maximum achieved frequency. A few low and high-frequency tremors also occurred during the gliding of the harmonic signal.

In an exploratory phase, we ruled out phenomena of anthropogenic (drilling, helicopters) and natural non-volcanic origins (colliding ice structures, tidal, magnetic field, rain, wind, aurora) due to the time and frequency characteristics of the signal. We then analyzed the temporal and spatial distribution of the harmonic tremors (signal of interest). Automatic detection was leading to a large number of false positives and true negatives, therefore we performed a manual classification of daily spectrograms to detect the 'V' shaped signal. We select the events where the high amplitude spectra were reaching below 2 Hz. The occurrence and strength of the harmonic signal are variable in time and space. The spatial density of signal occurrence does not correlate with the location of the source of subsidence we estimate from InSAR; the detected subsidence of ~13 mm/year is confined to the caldera outline while the harmonic events were registered mostly at seismometers outside the volcano caldera. The detected signal does correlate well with areas of low topography and identified low-velocity S-wave anomalies from the derived ambient noise seismic tomography model using the same seismic network. While the correlation with low topography may indicate preferred water paths, the low S-wave velocity anomalies may indicate the presence of a heat source, leading to a water-magma interaction hypothesis. Finally, we tested for the hypothesis of a resonance set up in magmatic conduits after magma-water interaction and changes in speed flow through conduits assuming the geometries of dykes, tubes and cracks.

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