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A Real-time TREmor Analysis Tool for seismic and infrasonic arrays

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The EUROVOLC project aims to promote an integrated and harmonised European volcanological community, with one of its main themes focusing on understanding sub-surface processes. Early identification of magma moving towards the surface is very important for the mitigation of risks from volcanic hazards, and joint research activities within the project aim to develop and improve schemes for detecting pre-eruptive unrest. Volcanic tremor is a sustained seismic signal that is often associated with such volcanic unrest, and has been linked to the movement of magmatic fluids in the subsurface. However, signals with similar spectral content can be generated by other surface processes such as flooding, rockfalls or lahars. Hence, one of the best ways of distinguishing between different possible mechanisms for generating tremor is by tracking the location of its source, which is also important for mitigating volcanic risk. Due to its emergent nature, tremor cannot be located using travel-time based methods, and therefore alternatives such as amplitude-based techniques or array analysis must be used. Dense, small-aperture arrays are particularly suited for analyzing volcanic tremor, yet costs associated with installation and maintenance have meant few long-term or permanent seismic arrays in use for routine monitoring.

Given the potential for wider usage of arrays, this work presents a freely available python-based software tool, developed as part of the EUROVOLC project, that uses array data and array processing techniques to analyze and locate volcanic tremor signals. RETREAT utilizes existing routines from the open-source ObsPy framework to carry out analysis of array data in real-time and performs either f-k (frequency-wavenumber) analysis, or alternatively Least-Squares beamforming, to calculate the backazimuth and slowness in overlapping time windows, which can help track the location of volcanic tremor sources. A graphical, or web-based, interface is used to configure a set of input parameters, before fetching chunks of waveform data and performing the array analysis. On each update the tool returns several plots, including timeseries of the backazimuth and slowness, a polar representation of the relative power and a map of the array with the dominant backazimuth overlaid.

The tool has been tested using real-time seismic data from the small-aperture SPITS array in Spitsbergen, as well as on data from a small aperture seismic array deployed during the 2014 eruption of Bárðarbunga volcano, Iceland. Although designed specifically for seismic array data (with a particular focus on volcanic tremor), RETREAT can also be used with infrasound sensors and has been successfully tested on infrasonic array data of explosive activity recorded at Mt. Etna, Italy, in 2019.

Although RETREAT has been designed for deployment as part of volcano monitoring systems and provides the ability to track tremor sources in real-time, it also has the capability to analyse existing datasets for testing, comparison and research purposes. However, RETREAT is primarily intended for use in real-time monitoring settings and it is hoped that it will facilitate wider use of arrays in tracking volcanic tremor or infrasonic sources in real-time, thereby enhancing monitoring capabilities.