Rationale

- Volcanoes exhibit a very broad range of seismic source types
- In a crisis we want to know/track the source type & source location
- This is difficult to achieve with a sparse seismic network as volcano signals are emergent – particularly for continuous signals such as volcanic tremor
- A seismic ‘array’ is a cluster of stations lying outside the seismic source area
- An array can ‘point’ to the source location (by measuring the back azimuth)
- An array can be used to estimate lateral and vertical migration of the source
- Arrays are often used for research, but not often as an operational tool

EUROVOLC Project – how this work fits in

EUROVOLC project: aims to harmonise volcanological infrastructure and communities in Europe.

Theme 3: Sub-surface processes

WP9: Pre-Eruptive Unrest Detection Schemes

D9.1: Seismic changes as an unrest detection tool

Task 9.1: Using seismic tremor as a real-time unrest indicator

Seismic arrays – how they work

- Plane-wave assumption
- Slowness = inverse of apparent velocity across array
- Determining delay times (via beamforming) gives direction from which waves are arriving

- Perform beamforming in frequency/spectral domain
- Form beams with different slowness vectors (grid search over horizontal slowness values)
- Compare the amplitudes or the power of the beams and identify which gives the highest energy
- Derive the slowness and back azimuth from the magnitude and angle/phase of the wavenumber vector

GUI interface

- Update/refesh interval
- Array processing parameters
- Output options – choice of figures

Example screenshots of RETREAT GUI and web interfaces

Example Output 1 – Real-time data

Real-time data sources implemented so far:

- obspy FDSN client
- obspy seedlink client

Example of output produced by analyzing real-time data from the SPITS array using the RETREAT tool:

- Timeseries of backazimuth & slowness
- Envelope, seismogram and spectrogram
- Polar representation of power from F-K results
- Backazimuth projected onto map

Example Output 2 – Archive data

- ‘Replace’ mode using existing archive seismic array data has also been implemented to allow analysis of non-real-time datasets
- Uses customisable Seiscomp Directory Structure (SDS) and accepts all common data formats supported by obspy

Example results from analysis of data on 03 September 2014 using the RETREAT software (right):

Corresponds to part of the same time period analyzed in Eibl et al., (2017b) in FUTUREVOLC

Results using RETREAT show an excellent match with the previous analysis

Summary

- Volcanoes can display pre-, syn- and post-eruptive tremor. One important means of better understanding processes driving tremor is to track the spatio-temporal evolution of its 3D field and aid detection.
- RETREAT - a python-based software tool has been successfully developed for operational use that uses seismic array data and array processing techniques to help detect, quantify and locate volcanic tremor signals in real-time.
- The tool has been tested on both real-time and archived data and is ready for testing and implementation in a volcano monitoring setting at observatories.

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Download link: https://git.dias.ie/paddy/retreat

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