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Using cluster analysis to understand patterns of volcano-tectonic seismicity in active continental rifts

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In Ethiopia there are 65 volcanoes and 45 of these are of the highest risk level of uncertainty. These 45 are therefore unmonitored and could potentially pose a greater hazard than currently known. We aim to develop methods for reliable forecasting, improving probabilistic forecasts of eruption likelihood and time. Although the reliability and accuracy of forecasts using volcanic earthquakes has improved considerably in the last 20 years in many parts of the world, existing models are difficult to apply for volcanoes situated in active continental rifts. The seismicity is far more complex; it has mixed origins with tectonic processes and the migration of non-magmatic fluids leading to less-systematic swarms that can occur synchronously with accelerating sequences and/or mainshock-aftershock sequences. Therefore, here, we investigate methods to identify discrete clusters of earthquakes in volcano-tectonic regions by separating clusters into their respective volcanic or tectonic origins.

Firstly, we separate the independent, background earthquakes and the dependent, triggered earthquakes in an earthquake catalogue. By comparing to the Epidemic-Type Aftershock Sequence (ETAS) model, we are currently using measures of the interevent time and interevent distance and their 2D distribution to separate independent and triggered events. It has been found that, using synthetic data from an ETAS simulation, spatially nearest-neighbour events divide clearly into two groups, provided the background rate is low (Touati et al. 2011). For the real data in Southern California catalogue this split is still seen, although with more overlap between the events. Here we extend this work beyond the nearest neighbours, with the aim of sorting the entire earthquake catalogue into cluster families. A cluster family is defined as a group of related earthquakes that have been triggered by another in the same family, e.g. in mainshock-aftershock sequences, or those triggered by a similar underlying process such as a dyke intrusion. We are interested in investigating the statistics and trends of the individual families in order to identify the underlying processes.

Applied to datasets from Iceland and Ethiopia, initial results show the different cluster families have separated the tectonic and volcanic events. Statistical analysis currently being conducted on the individual families further supports this. Future work will involve the refinement of this technique and a comparison to other methods of identifying the discrete clusters. Finally, with the help of additional geophysical constraints, such as geodesy data, we aim to elucidate the nature of the underlying triggering processes. For a volcano-tectonic region, this will be important to discriminate between tectonic or volcanic hypotheses for the origin of triggering in the area. Should they relate to volcanic activity, from there, probabilistic forecasts of the likelihood and timing of the eruption may be made.