What can low frequency seismicity tell us about eruption processes at frequently-active subduction zone volcanoes?

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Project Background

The nature of volcanic seismicity is a key indicator of the state of volcanic unrest, and an important piece of information on which eruption forecasts are made. At many volcanoes, the personal experience and insights of monitoring scientists often suggest particular relations between types of seismic signals and likely future changes in volcanic activity. Objective quantification of these signals, and robustly testing empirical relations, can be challenging. However, this process is essential for assessing the reliability of eruption forecasting protocols, and for testing any underlying physical models for the origin of the signals and eruption mechanisms.

Frequently-active subduction zone volcanoes of intermediate composition (andesite to dacite) exhibit a range of different eruption mechanisms. They can pose a significant hazard to surrounding populations, and a considerable challenge to management agencies. Activity at these volcanoes can also generate particularly rich and complex seismic data sets. Notably, this seismicity is often dominated by low-frequency (LF) signals, including long-period (LP) earthquakes, volcanic tremor, and explosion-related signals, with relatively few higher frequency volcano-tectonic earthquakes. Low-frequency signals have been extensively studied at a few 'laboratory' volcanoes, and their occurrence often apparently correlates with changes in eruptive activity. However, these correlations are generally untested statistically, and there remain multiple hypotheses for the source mechanisms of different types of LF signals and their interrelations.

This project will explore the relations between LF seismicity and changes in eruptive activity at frequently-active subduction zone volcanoes, developing a range of new tools for characterizing signals and quantifying correlations, and ultimately providing new insights into seismic source mechanisms and eruption processes.

Key Research Questions

1. What range of LF seismic signal types can be characterized and quantified in earthquake catalogue and seismic waveform data from frequently-active subduction zone volcanoes?
2. To what extent do changes in these seismic signals precede changes in the nature of volcanic activity, and what is their forecasting potential?
3. What do these observations tell us about the likely source mechanisms for LF seismic signals, and about the underlying physical volcanic processes?

Methodology

Initial work will focus on analysis of seismic event catalogues from key study volcanoes. These provide long time-series of 'point-process' data covering many eruptive episodes. Statistical techniques will

be develop and applied to these datasets to identify and test relationships between key metrics and eruptive activity.

Guided by initial findings, and in collaboration with local partners, work will investigate primary seismic waveform data from key eruptive or unrest episodes to characterize the range of LP seismic signals that are recorded. Waveforms will be characterized and their evolution analysed, again using newly developed statistical techniques.

Data will be compared from different episodes, and from different volcanoes, to investigate the factors controlling seismic activity. Conceptual models will then be developed for the origin of these seismic signals and underlying physical processes.

Work is likely to focus on Tungurahua volcano, Ecuador, in collaboration with the Instituto Geofisico de la Escuela Politecnica Nacional, with the possibility of contrasting datasets from volcano, Colombia, in Collaboration with INGEOMINAS

Training

A comprehensive training programme will be provided, comprising both specialist scientific training and generic transferable and professional skills. The student will be trained in fundamental aspects of volcanology and seismology. Within a dynamic and multi-disciplinary research group, they will learn to use high-level coding languages, such as Python, for statistical and time series data analysis. This training will include advanced computing and 'big data' techniques, both of which are highly transferrable skill sets. Research visits to partners in Ecuador and Colombia will provide training in volcano monitoring techniques, data analysis, and the complex reality of volcanic hazard management. There will be the potential for the student to undertake an internship at a relevant volcano observatory.

Requirements

This project would be suitable for a numerate geologist, geophysicist, or physicist with an interest in application to geological problems. Some experience of data analysis using Python, Matlab, R, or a similar language would be useful, but not essential.

30 word project summary

This project will investigate the extent to which changes in low frequency seismicity at intermediate composition subduction zone volcanoes relate to changes in eruptive activity and unrest.