Bayesian methods for eruption and hazard forecasting during volcanic crises

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Project Background
During volcanic crises, volcano monitoring institutions are required to make critical decisions regarding the state of unrest and the potential for hazardous events. The difference between a good and bad decision can mean saving or losing hundreds or thousands of lives, or minimizing potentially huge economic and social impacts. However, these decisions are usually based on uncertain, partial, and incomplete data and models, and with severely limited time and resources. Modern statistical approaches can provide new methods for more reliable and quantitative data analysis and modelling, resulting in better estimates of uncertainty, and a clearer basis for decision-making. Recent advances in time-series analysis of monitoring data, eruption forecasting, and hazard mapping incorporate Bayesian techniques, and use a suite of cutting-edge statistical methods, such as a new generation of ‘quasi-periodic’ point process models, Markov chain Monte Carlo, and statistical emulators. Although these developments promise significant improvements over existing techniques, they remain relatively untested, and require further work before operational deployment.

Key Research Questions
1. How can Bayesian methods be best employed to identify changes in volcanic unrest based on multi-parametric time-series monitoring data?
2. How reliable are quasi-periodic point-process models for eruption forecasting based on low-frequency volcanic earthquakes, and how can these methods be operationalised?
3. How can time-dependency based on monitoring data time-series be incorporated into hazard maps and forecasts?

Methodology
Initial work will focus on time-series analysis of multi-parametric monitoring data from key study volcanoes. Methods will be developed to identify and characterise step-wise and progressive changes in data and derived metrics, such as earthquake rate. Different time-series models will be applied to the data, and their performance evaluated. Available data span many eruptive episodes, and provide scope for application and testing of a wide variety of statistical and computational techniques, including machine-learning.

Guided by initial findings, and in collaboration with local partners, work will focus on developing operationally applicable tools for use by monitoring institutions to aid decision making. This work will become increasingly data intensive (in terms of volumes, rates, and complexity of data), and so effort will be required to apply new methods in real-time, rather than retrospective analysis.
Data will be compared from different episodes, and from different volcanoes, to explore the generality of methods and models.

Work is likely to focus on Tungurahua and Reventador volcanoes in 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 statistician or mathematician with an interest in application to volcanological problems. Experience of Bayesian data analysis with MCMC, using Python, Matlab, R, or a similar language, is essential.

30 word project summary
This project will develop and apply new Bayesian statistical methods for analysing and modelling volcano monitoring data during crises in order to support better operational decision making.