Statistics and Volcanology

EMS Workshop, Bristol, 22-26 March, 2004

When and where will the next large volcano erupt? How large will it be, and where will the lava flow? What will be the associated damage to the environment and will local populations be affected? Is it safe to build in the vicinity of a dormant volcano? In the event of early volcanic activity, should local communities be evacuated?

Since volcanic processes are amongst the most powerful - and therefore most dangerous - natural phenomena on Earth, these are extremely important questions. However, none of these - nor many of the other pertinent questions about volcanic activity and its impact on our environment and our societies - can be answered with certainty. This implies that the various aspects of a volcanic process include components of random behaviour. Recognising and quantifying such randomness provides the key – expressible through probability statements - to obtaining meaningful and usable answers to the various questions that arise in the study of any aspect of volcanic activity.

This was the background to the EMS-funded workshop on Statistics in Volcanology, held at the University of Bristol. Surprisingly, given the potential utility of statistical methodology to volcanological science, this seems to have been the first meeting of its kind. Participants came from 15 different countries (many of which include volcano-sensitive regions) and from both the volcanological and statistical communities. The various aims of the workshop were to share state-of-the-art knowledge and methodologies across these disciplinary boundaries, to look at examples where statistical techniques have been successfully applied to the study of volcanic processes and to generate new lines of cross-disciplinary research.

Much of volcanological science is based around physical models for the various processes that take place before, during and after volcanic eruptions. These include the fragmentation of magma chambers, the formation of conduits, the flow of magma through conduits, the formation (and subsequent failure) of lava domes, and lava and dilute ash flow. The workshop included world-reknowned experts in each of these areas who described the latest models used for each aspect. However, real volcanoes are infinitely more complex than our models of them, and though the models are often successful at capturing general types of behaviour, reality often fails to match expectation.

Statistics has been successful across a wide range of scientific discipline in both helping to develop the determinstic part of a process structure, as well as quantify the variations observed in practice. In essence, statistical models model not just what's expected, but also the potential for surprise. The workshop also included international experts across a wide range of areas within the statistical community, includingtime series analysis, wavelet analysis, Bayesian modelling, geostatistics and extreme value theory. The workshop heard presentations setting out the basic ideas and suggesting how each of these areas might lend itself, with volcanologists' knowledge, to measure the uncertainties that arise within volcanic activity as well as supporting the search for a better understanding of the basic dynamics.

A considerable part of the program of the workshop was also dedicated to current applications of statistics to volcanological science. These included techniques for risk assessment, probability models for tephra dispersion, models for earthquake timing, precursor signal analysis and both the temporal and spatial analysis of various forms of volcanic data. In addition to keynote and contributed lectures, the workshop held two lively poster sessions in which many other interesting, novel and important applications of statistics to volcanology were described. The workshop also heard from one of the principal developers of WOMVOdat, a new online database resource that pools resources from members of the World Organization of Volcano Observatories to combine their various records on all aspects of volcanic activity. Such a resource is likely to provide an essential role in the development of new statistical methodologies for forecasting future volcanic activity.

The meeting closed almost full-circle, with a brief presentation of how recent methodological advances in Bayesian network construction for uncertainty modelling have been successfully applied in the development of a probabilistic risk model for volcanic activity. This provided an important illustration as to how the combined knowledge and expertise of volcanologists and statisticians could be used to assess the risk of a volcanic eruption, and consequently plan to mitigate against its likely effects.

The quality of presentations - both oral and poster - was excellent throughout. The potential for the two separate communities - statistical and volcanological - to talk solely to themselves never materialised. Talks were genuinely informative and at a level that could be understood by non-experts. Discussion following talks was always lively, but never heated. The organisers of the workshop are also aiming to produce for publication a volume, with individual chapters provided by workshop participants, that reflects the tone and general themes of the workshop, but making the arguments available to a wider audience.

Many participants commented both on the timeliness, and the usefulness of the workshop. Knowledge was genuinely shared, with both volcanologists and statisticians having a much greater awareness of the problems in volcanology that need to be tackled, of the scientific knowledge of volcanic processes that is currently available, and of the statistical tools and methodologies that might be useful in taking this knowledge further.