Expert Judgement and the Montserrat Volcano Eruption

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Abstract

A structured procedure for eliciting expert judgement has been used for the first time in a volcanic crisis for hazard assessment and risk management.

1 Introduction

In July 1995, the Soufrière Hills volcano on the West Indies island of Montserrat came to life with several steam-venting explosions, after 400 years of quiescence. Activity then grew gradually more and more violent with the generation of lethal pyroclastic flows (turbulent avalanches of superheated gas and ash) and explosive outbursts of incandescent ash, gas and steam. The volcano occupies the southern one-third of the island, a British dependent territory with an area of only 80 sq km. Before the crisis, Montserrat had a population of 11,000 people; each time activity escalated more people left, so that less than 4,000 remain. The authorities first evacuated villages on the flanks of the volcano and eventually were forced to evacuate the capital, Plymouth, but on 25 June 1997, after nearly two years of activity, the volcano claimed its first fatalities: 19 people who had ventured into the evacuated zone were engulfed by a large pyroclastic flow that travelled down one of the valleys of the mountain at a speed in excess of 100km per hour, spilling on to slopes where farmers were working and others were looking after their homes. Until then, the volcano was considered by many to be a diverting spectacle, but not necessarily a personal threat. Restrictions on access to prime farming land and to the facilities of the main town were seen by some as an unwarranted reaction, engendered by alarmist scientists.

When a potentially deadly volcano becomes restless, civil authorities invariably turn to scientific specialists to seek to anticipate what the volcano will do next, and to help them judge the danger. Although it is usually possible to discern the earliest signs of unrest, forecasting the course and precise timing of eruptions still remains awkwardly inexact. Volcanology began to evolve into a modern, multidisciplinary science at the beginning of the 20th century with fatal explosions at two other volcanoes in the Eastern Caribbean: on St. Vincent and on Martinique, and a third in Guatemala, all three erupting within 6 months of one another in 1902. In a matter of only minutes at each, pyroclastic flows killed about 36,000 people in total, thus giving rise to the grave anxiety which now attends any significant volcanic activity in the region. In particular, the devastation by Mont Pelée of the tropical city of St. Pierre, Martinique, the Pompeii

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of modern times, convinced scientists of the time of the need to understand the processes of these glowing avalanches which could kill thousands of people with so little warning, a phenomenon until then unrecognized and inexplicable. More recently, in 1976, the French sister island of Gaudeloupe was the scene of a new challenge for modern volcanologists. In the wake of acrimonious and unresolved public debate over interpretations of uncertain scientific evidence, the authorities felt obliged to call a major evacuation for an episode which turned out to be of only minor volcanic intensity. This led to disputatious exchanges amongst volcanologists as to their role and responsibilities in decision-making and advice during such crises [1]. Since then, the role of the scientist has become even more fraught; in one recent incident, an official geologist was threatened with criminal action for failure to predict a small but fatal eruption [2]. Finding the most appropriate ways of formulating and articulating scientific opinion in volcanic emergencies has thus become an important concern for volcanologists.

Since the onset of the present activity in Montserrat, the volcano has been one of the most closely monitored in the world: the Montserrat Volcano Observatory (MVO) was established with staff drawn from the University of the West Indies, from citizens of Montserrat itself, and from the international volcanological community. Even though armed with arrays of sophisticated monitoring equipment, the scientists working on the problem have a wide range of opinions about what the volcano might or might not do next, and even the “best” experts cannot say with any assurance whether a coming eruption will be large or small, whether it will occur within a few days or not for many months. In attempting to furnish good advice to the decision-makers, ideally in the form of consensus, all these intrinsic scientific difficulties are compounded by the diversity of specialisms and experiences and, as time passed, the fluctuating levels of involvement of individual members of the monitoring team. Thus, the protracted Montserrat crisis has exemplified all the challenges of forecasting volcanic hazards in the face of scientific uncertainty and under safety-critical conditions. In order to systematize this important aspect of the team’s work, a formalized procedure for eliciting expert judgements has been adopted for the first time in a live volcanic crisis.

2 Expert Elicitations at the Volcano

The main focus of the monitoring operation at the observatory comprises visual observations and instrumental monitoring of seismicity, ground deformation and gas output, with helicopter support providing access to critical locations on the volcano. A modern volcanic hazard evaluation of the island, drawn up in 1988, was the initial basis for risk zoning the island during the present crisis, but needed revising to meet new developments at the volcano as they occurred. For instance, it was necessary to provide daily advice to the authorities on critical issues for prioritizing and timing appropriate civil protection response, e.g. “What is the chance the volcano could explode within 24 hours?”, “Which villages will be affected?”, and so on. In the event, striving for scientific consensus in committee was taking an increasing amount of time each day (at the expense of field observation and data analysis), divergences of opinion developed as the crisis deepened, and the authorities became frustrated with the perceived indecision of the
At that stage, a formalized procedure was introduced, following the suggestion, first made [3] at the International Symposium on Large Explosive Eruptions in Rome in 1993, to consider using the "Classical Model" for structured expert judgement [4] for just such an eventuality. This immediately alleviated some, but not all, the headaches of producing a collective scientific opinion. The method performs weighted combinations of expert judgments, where weights are determined by 'calibration' and 'information' performance on questions for which the true values are known, or become known post hoc [4]. However, in application, the procedure had to be adapted to the exigencies of real time crisis management. In open meetings, some preferred to hold their counsel, while others were very forceful in giving their opinions so, from the outset, it was felt better to focus the procedure on quantifying the informativeness/conservatism of each individual's views, rather than rely too heavily on a hurried and questionable calibration score. (The problems of calibrating a group of volcanologists are non-trivial at the best of times, let alone with an eruption going on outside the window!). This emphasis on informativeness meant there was an implicit assumption that approximately equal expertise attached to each member of the team, a reasonable supposition for the initial group which assembled in Montserrat. In fact, when the concepts of this approach were being introduced to the administrators and scientists it was novel to most, and several pressed for the scheme to be administered in such a way that no single participant was ever zero-weighted: all views would be used with some weight in the decision process. However, in order to bring an element of calibration into play, a preliminary set of five suitable seed questions was hastily prepared. While this set was aimed primarily at measuring the individual's informativeness factor, it was also used to provide a rudimentary measure of how well each person might make quick judgements on issues related to safety and hazard mitigation in an emergency. The latter element of the exercise was undertaken, with general agreement, as an initial exploration of the method in application. Therefore, the emphasis in the seed questions was placed on judgement of generic hazard-related variables and factors - such as percentage casualties from different sorts of volcanic action; durations of eruptions, and so on - rather than on the science of volcanology itself. Devising a comprehensive range of fair technical questions to encompass geologists of all kinds, geodesists, geochemists and seismologists, for full implementation of the procedure, was impracticable under the circumstances.

As the emergency progressed month by month, three shortcomings with the adopted approach emerged. First, having once used the initial set of seed questions, for uniformity these had to be repeated for scientists subsequently joining or replacing others in the team (but, to everyone's credit, the answers were not leaked to new arrivals at the observatory); over the course of three years activity, the total number of individual scientists and technical specialists participating in the different elicitations eventually exceeded 55, although there were generally only between five and twenty at any one time. Secondly, an experienced technical facilitator was not always available in Montserrat to supervise elicitations; and thirdly, there was a fluctuating mandate to undertake formal elicitations as conditions and levels of anxiety varied.
Notwithstanding these slight weaknesses, the approach was very successful in handling key on-going issues, such as regular assessments of the scientific team’s “comfort” with the current alert level. In a volcanic emergency, it is common to use previously published criteria (often just borrowed from other, not necessarily apposite, eruptions) for defining different status (or colour) levels. However, these a priori written criteria are generally too inflexible to allow scope for learning (Bayesian updating?), or for adjustment to the circumstances of the particular crisis. In deciding mitigation actions, civilian administrators often respond directly only to changes in an alert level, so setting the level always becomes especially critical or contentious when a decision may be needed to switch from one level to another. It is at these times that the formalized elicitation approach comes into its own and, at the MVO, a semi-quantitative weighted voting scheme was devised and used to good effect in 64 separate reappraisals. This scheme provided the decision-makers with both the central (optimal) value from the poll and a measure of the spread of views (see Fig. 1), allowing them to select their own level of conservatism in accepting the recommendation. A time-line sample of results from some of the reappraisals, together with the associated alert level, are shown on Figure 1. More often than not, the distributions of scientific opinion were skewed, with a longer tail to the cautious end of the range.

At the MVO, the other use of the structured elicitation methodology has been for occasional re-assessments of the future long-term outlook at the volcano, providing

![Figure 1. Repeat appraisals of volcanic Alert Level using expert judgement elicitation.](image-url)
In the case of the Montserrat eruption, summary probability trees have been updated as circumstances demanded (e.g. Fig. 2) and, in turn, the associated underlying probability distributions ascribed to the branches have been used as input to Monte Carlo simulations of population scenario impact estimations as part of overarching risk assessments for the civil authorities. As the eruption progressed, and its behavioural patterns changed, these trees have become increasingly detailed and complex to maintain; handling the elicitation data and presenting outcomes has been made easier by recourse to a specialist spreadsheet add-in package [5]. However helpful, probability trees do not necessarily add precision to forecasts: the success of such trees [6] in showing the imminent danger from the Mount Pinatubo volcano in the Philippines just weeks before its violent eruption in June 1991, was aided by the fact that the volcano went ahead and erupted before people became inured to the warnings. In Montserrat, on the other hand, the protracted nature of the eruption led to many people becoming de-sensitized to the risks, a danger for civilian, administrator and scientist alike, as made evident by the incurring of casualties.
3. Discussion and Conclusions

In Montserrat, the use of the “Classical Model” structured elicitation procedure [4] to assess current volcanic alert level has worked well, giving continuity across a changing team and providing a detailed record of views on the movements of the alert, up or down, in more than sixty appraisals. The same elicitation procedure has also been extensively used, in concert with traditional decision-conferencing and numerical modelling, to obtain probability estimates for hazard event trees. The procedure is found to be efficient to implement and, by forcing clarity of thought on key issues within its structured nature, a considerable assistance to group decision-making. The participating volcanologists have been on a steep learning curve with this methodology, as it has never been used in a live volcanic crisis before, so it is not surprising that there were some initial concerns about its basis and application. However, it became generally accepted that the elicitation outcomes were giving a satisfactory collective expression to the whole group’s views - as one eminent American volcanologist put it: “Those aren’t exactly the probability values I would have chosen but, for our present purposes, I can’t object to any of them” - and it was recognized that one strength of the method is that serious discrepancies or illogicalities in views can be detected and registered, and then analyzed and rationally addressed. In addition, the formalised basis to the method also offers flexibility in use. In a recent instance, the opinions of several scientists involved with the eruption of the Soufrière Hills volcano, by now familiar with the concepts and principles of the method, were simultaneously elicited at the observatory in Montserrat and, over the Internet, from as far away as the USA, the UK, Hawai’i and Kamchatka - a form of “tele-elicitation” which could be used in other disciplines. But perhaps the most important attribute of the structured expert judgement approach for the Montserrat emergency has been that it provided an appropriate means to accommodate in the decision-making process the participation of local technical people involved long-term in the volcano monitoring: those most directly affected by and concerned about the eruption in their home land.

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References

2. Hadfield P. Mount Mayon blows without warning. New Scientist 1993; 1860, 8