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Uncertainty and decision making: Volcanic crisis scenarios

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ABSTRACT

The impact of uncertainty on Disaster Risk Reduction decision-making has become a pressing issue for debate over recent years. How do key officials interpret and accommodate uncertainty in science advice, forecasts and warnings into their decision making? Volcanic eruptions present a particularly uncertain hazard environment, and to accommodate this scientists utilize probabilistic techniques to inform decision-making. However, the interpretation of probabilities is influenced by their framing. We investigate how verbal or numerical probabilities affect decisions to evacuate a hypothetical town, and reasons given for that decision, based upon a volcanic eruption forecast. We find fewer evacuations for verbal terms than for equivalent numerical terms, and that the former is viewed as more ambiguous. This difference is greater for scientists, which we suggest is due to their greater familiarity with numerical probabilities and a belief that they are more certain. We also find that many participants have a poor understanding of the relationship between probability and time window stated, resulting in an incorrect assessment of overall likelihood and more evacuations for the lower likelihood version of two scenarios. Further, we find that career sector (scientist or non-scientist) influences evacuation decisions, with scientists tending to reduce the uncertainty by focusing on the quality and volume of information provided, while non-scientists tended to either acknowledge or suppress the uncertainty, focusing on actions to take. These findings demonstrate the importance of identifying communication strategies that mitigate different perceptions of forecasts, to both enhance end-user decision making and to prevent premature, delayed, or unnecessary actions.

1. Introduction

Volcanic crises can create conditions of extreme uncertainty for scientists and key officials managing the crisis. A volcano showing signs of unrest may exhibit changes in geophysical signals (such as seismic and geodetic changes), geochemical signals, cause felt earthquakes and result in visual signs of impending activity (such as increased degassing or bulging flanks). While indicative of changes occurring in the volcanic edifice, they do not always lead to eruptions and may be unreliable as indicators of when an eruption may occur [62,66,72]. They thus present a challenging environment for effective response, emergency management planning, and decision management.

Once an eruptive phase has occurred, volcanoes can also go through cycles of quiescence, followed by periods of unrest, periods of activity and then periods of quiescence

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again. Since 1995, Soufrière Hills Volcano, Montserrat, has gone through at least 3 distinct eruptive periods [23]. Eighteen years after it re-awoke, Soufrière Hills continues to display unrest and activity, presenting challenges for long term management and communication as communities learn to live with the volcano [35,36,67]. The epistemic uncertainty (the unknowns) and the aleatoric uncertainty (the stochastic variability) of the volcanic physical process thus contributes to considerable uncertainty in the crisis management process itself. In addition, an event such as this requires inter-disciplinary interaction, and if relationships and procedures are not well established and practiced before, considerable uncertainty can arise in its management due to problems with inter-agency communications, collaborations, and the understanding of each others' roles, responsibilities, and inter-dependencies [76,77,19], particularly when under high pressure, short time situations characterized by high ensuing risk and stress.

This variation in unrest periods, and the potential for eruption, non-eruption, or continued eruptive cycles, creates extreme challenges for those involved in the response as decision makers balance the issue of life safety and community continuity through the crisis [78,76]. Issues have arisen due to conflicting scientific advice either from internal and external agencies, or due to the presence of a wide range of scientific advisory bodies and individuals (e.g., [51,102,28,12,84,72,101,67]). Based upon experiences from Guadeloupe in 1976 and St. Vincent in 1979, Fiske [28] highlighted that successful volcanic crisis management is not just dependent on improved monitoring techniques but upon the communication between scientists, journalists and the public, and in particular, the need for experienced chief scientists, who "while not suppressing scientific disagreements, would attempt to coordinate the activities of the scientists involved into a single group effort, to increase communication between the scientists, and to help ensure that a single and complete stream of information is made available to civil authorities and journalists" (ibid, p. 176). Over 20 years later, during New Zealand's (NZ) Civil Defence exercise Ruaumoko, which practiced the nationwide response to an eruption in the Auckland Volcanic Field, one of the highlighted recommendations was again the demonstrated importance of having official scientific advice provided by "one trusted source" [65]. This was in the form of the Auckland Volcanic Science Advisory Group, which gathered together the social, geological, economic, geophysical and monitoring groups and communicated this pooled expertise to the decision makers while also responding to direct requests for information from the emergency managers. This process was identified as being of a considerable benefit to the response process as it helped to prevent conflicting or confusing messages [65]. Numerous other volcanic and geophysical events have identified the need for official scientific advice to be the trusted source of advice, that delivers appropriate, accurate advice that meeds the needs of (diverse) decision makers, emergency managers, and the public. This makes it impossible to consider a one-size fits all approach, and makes it important that recipent organizations not only establish a single source of advice, but build strong relationships and trust across agencies via exercises, workshops and meetings prior to an event, to help build individual and team mental models of each other's roles, responsibilities, and their information needs as well as to develop an understanding of other political and legal issues that may play a role in the implementation of advice (see [77,19]). As discussed by Jordan [45, p. 6], in light of the L'Aquila earthquake and trial, it is vital that the different roles of the science advisors and the civil decision makers are understood and kept distinct, as "confusing these roles can lead to trouble". In addition, as stated by McGuire et al. [67, p. 75], it is vital that the "mechanisms that underpin effective communication during a volcanic crisis are in place long before a volcano shows signs of unrest" so that seamless communication between main stakeholder groups can occur in-event. Thus all efforts need to focus on the "building of trust between stakeholders, the maintenance of good working relationships, and the safeguarding of an open and continuous information flow between all key players" (p. 75).

Currently in NZ, advice is communicated by a number of Scientific Advisory Groups across the volcanic regions, established to bring expertise from various scientific agencies together [65,98,19], and who often sit within wider volcanic advisory groups established by the regional authorities. For example, the Central Plateau Volcanic Advisory Group was established by the Horizons Regional Council to ensure that all responding organizations are "working together to increase community resilience to volcanic hazards within the Central Plateau" [14]. This group encompasses a Science Focus Group, a Planning Focus Group, and a Communications Focus Group, all guided by a framework strategy and Contingency Plan, and who meet every six months to report on work programmes, outcomes and future plans, and to help build relationships and inter-agency coordination.

However, while the goal is to have the experts within a SAG familiar with each other and other responding agencies via exercises, training, workshops, planning, and other relationship building activities, the need to call on other experts (e.g., the Ministry of Health for ash fall advice or psychosocial issues), changes of personnel within an agency over time, and changes in agency structure can create a situation where in fact these groups may be relatively unfamiliar with each other and their respective roles and expertise; particularly as the size of an event grows and extends beyond the regional to the national or international level, with the impact and management consequences of these differences being magnified by the high risk, high stress environment in which they would have to interact. Developing more comprehensive inter-agency training and embedding inter-agency operations into the organizational culture is a crucial first step to creating the kind of organizational learning required for "superordinate" organizational response to rapidly escalating, complex volcanic crises [29]. In the absence of such capabilities, the Scientific Advisory Group (SAG), which may thus include individuals familiar or unfamiliar with each other, thus has an important role in soliciting, collecting and pooling together a wide range of expertise into a single source of advice. However, little research has