Chapter 24

Scientific communication of uncertainty during volcanic emergencies

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24.1 Summary

Forecasting potential outcomes of volcanic unrest and activity is usually associated with high levels of scientific uncertainty. Knowing whether particular volcanic unrest will end with an eruption or not implies reliance on scientific knowledge on how the volcano has behaved in the past and on how monitoring signals can be interpreted in terms of magma movement. This may be relatively straightforward in volcanoes that erupt frequently, but may be much more challenging in volcanoes with long eruptive recurrence intervals or even more in those without historical records. The dramatic consequences that wrong interpretation of volcanic unrest signals may have should persuade volcanologists to understand that communication among them during an emergency is crucial. Consensus to quantify scientific uncertainty must be reached, in order to provide the decision maker with a simple and clear forecast of the possible outcome of the volcano reactivation. Unfortunately scientific communication during volcanic emergencies is not an easy task and there is not a general agreement on how such communication should be conducted, not only among scientists, but also between scientists and other stakeholders (e.g. decision makers, media, local population). The critical questions here, as occurs with other natural hazards, are how to quantify the uncertainty that accompanies any scientific forecast and how to communicate this understanding to policy-makers, the media and the public. In addition to scientific advance in eruption forecasting, future actions in volcanology should also address improving management of uncertainty and communication of this uncertainty.

24.2 Rationale

One of the most challenging aspects in the management of volcanic emergencies is scientific communication. Volcanology is by its nature an inexact science, such that appropriate scientific communication should convey information not only on the volcanic activity itself, but also on the uncertainties that always accompany any estimate or forecast. Deciphering the nature of unrest signals (volcanic reactivation) and determining whether or not an unrest episode may be precursory to a new eruption requires knowledge of the volcano's past and current behaviour to help establish future behaviour. In order to achieve such a complex objective it is necessary

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to have different groups of individuals involved in information exchange, including those from disciplines such as geology, volcano monitoring, experimentation, modelling and probabilistic forecasting. Communication is required on a level that caters for needs and expectations of all disciplines; i.e. there is a need to share a common technical language. This is particularly relevant when volcano monitoring is carried out on a systematic survey basis without continuous scientific scrutiny of monitoring protocols or interpretation of data. In an emerging unrest situation, difficulties may arise with communication among scientists and between scientists and Civil Protection officers, decision makers, media or the public, due to the different skills and degree of knowledge of volcanic phenomena.

Of particular importance is the communication link between scientists with Civil Protection agents and decision makers during evolving volcanic crises. In this case, it is necessary to translate the scientific understanding of volcanic activity into a series of clearly explained scenarios that are accessible to the decision-making authorities. Also, direct interaction between scientists and the general public is inevitable both during times of quiescence and activity. Information coming directly from the scientific community has a special influence on risk perception and on public confidence in this information. Therefore, effective volcanic emergency management requires identification of feasible actions to improve communication strategies at different levels including: scientists-to-scientists, scientists-to-technicians, scientists-to-Civil Protection, scientists-to-decision makers, and scientists-to-general public.

The main goal of eruption forecasting seeks to respond to how, where, and when an eruption will occur. To answer these questions there is an emerging recognition that probabilities should be used for characterisation of associated uncertainties. However, communicating probabilities and, in particular, uncertainty, is not an easy task, and may require a very different approach depending on who is the receptor of such information. Making forecasts on future volcanic activity follows basically the same approach as in other natural hazards (e.g. storms, landslides, earthquakes, tsunamis). However, this approach does not necessarily require the same level of understanding by the population and decision-makers. Compared to meteorologists who have much more data and observations, volcanologists have to deal with a higher degree of uncertainty, mainly derived from this lack of observational data. It is also important to consider that all volcanoes behave in a different way, so a universal model to understand behaviour of volcanoes does not exist. Each volcano has its own particularities depending on magma composition and physics, rock rheology, stress field, geodynamic environment, local geology, etc., which make them unique, so that what is indicative in one volcano may be not relevant in another. All this makes volcano forecasting very challenging and even more difficult to communicate this high degree of uncertainty to the population and decision makers.

24.3 How to communicate volcano forecast?

Significant work has been done during last years to improve communication in natural hazards (Atman et al., 1994, Morgan et al., 2002, Karelitz and Budescu, 2004, Visschers et al., 2009, Stein and Geller, 2012). In a similar way, several studies on communication during volcanic emergencies have been carried out (Newhall et al., 1999, McGuire et al., 2009, Aspinall, 2010, Donovan et al., 2012a, Donovan et al., 2012b, Marzocchi and Bebbington, 2012, Doyle et al., 2014). The common factor in all these studies is the need to communicate the uncertainty that accompanies any forecast on the future behaviour of a natural system. Most of these studies agree that probabilities are the best way to communicate scientific forecasts and, consequently, its associated uncertainties. In this sense the use of probability theory is common in natural hazards (Cooke, 1991, Colyvan, 2008, Stein and Stein, 2013) and also in volcano forecasting (Aspinall and Cooke, 1998, Marzocchi et al., 2004, Aspinall, 2006, Sobradelo and Martí, 2010, Marzocchi and Bebbington, 2012, Donovan et al., 2012c).

Probability can be defined as one measure of uncertainty. The way in which probabilities are understood depends on the degree of numeracy we have. However, during our life we are everyday confronted with situations that require making decisions, and in many cases, even if we are not aware of doing this, we use probabilities (commonly known as 'common sense') to evaluate the degree of uncertainty in a decision. A common situation were we to use probabilities, even if they are not expressed mathematically, is when making decisions based on weather forecasts (e.g. do we take an umbrella? Do we go to an outdoor festival? etc.) that we see everyday in newspapers or on TV. We do not have problems with understanding and accepting a forecast that says the probability of having rain tomorrow is high. It is not necessary for the meteorologists to indicate this in a more precise way (e.g. the probability of rain for tomorrow is of 80%); although in some countries this is communicated. The accuracy of contemporary weather forecasts is typically quite high for periods of a few days in advance. But still there may be incorrect forecasts that may cause serious trouble, for example when bad weather is predicted people may change their plans and important economic losses may result.

Making predictions on the future behaviour of a volcano basically follows the same reasoning that is behind weather forecasts (analysis of past data, monitoring of the current situation and identification of possible future scenarios). However, typically there is less familiarity about the behaviour of volcanoes than about the weather. Thus volcano forecasts are not so easily understood by the population and decision makers. Although there are some scientists who are highly experienced communicators in well established volcano observatories and teams, there is still need for taking this practise to a higher extent as meteorologists have done. This is in part due to lack of observational data and, consequently, to the limitations that volcanologists have to obtain precise probability estimates. This makes it difficult to communicate volcano forecasts in a simple language, difficulty that usually increases because population and decision-makers are not as used to listening to volcano forecasts as they are with weather forecasts. Therefore, scientific communication of volcano forecasts needs to reduce the considerable distance that today still separates the proper scientific language from its understanding by a non-scientific audience.

The uncertainty that accompanies the identification and interpretation of eruption precursors, derives from the unpredictably of the volcano as a natural system (aleatory uncertainties) and from our lack of knowledge on the behaviour of the system (epistemic uncertainties). These uncertainties can be redefined as shallow or deep (Cox Jnr, 2012, Stein and Stein, 2013) depending on the eruption frequency of the volcano. Highly active volcanoes with high eruption frequencies can be more easily predicted (i.e. they are reasonably well known) than those characterised by low eruption frequencies, respectively.

There are different ways in which probabilities (and uncertainties) can be described. These include words, numbers, or graphics. The use of words to explain probabilities seeks to offer a language that appeals to people's intuition and emotions (Lipkus, 2007). However, it usually lacks precision as it tends to introduce significant ambiguity by the use of words such as 'probable', 'likely', 'doubtful', etc, which lack precision or clear definitions. Probabilities are defined mathematically, but such descriptions may fail when the audience has a low numeracy. In the last years it has been increasingly common to use graphics to represent probabilities in natural hazards (Kunz et al., 2011, Spiegelhalter et al., 2011, Stein and Geller, 2012). The advantage of communicating uncertainties (or probabilities) visually is that we are everyday better prepared and trained to use and understand infographics. A graphic can be adapted to the aims of the communicator, stressing the importance of the context of the communication exercise and the needs and capabilities of the audience (Spiegelhalter et al., 2011). Volcanologists can adapt these modern methodologies to their needs, in order to make volcano forecasts and their intrinsic uncertainty clear enough to any potential receptor of this information.

In addition to these 'formal' or 'academic' ways to describe and communicate probabilities (and uncertainties) there are other important aspects (namely odds, regulations and culture) related to each particular society, that volcanologists should take into account for communication purposes. 'Odds' is an expression of relative probabilities that is well understood by many communities (e.g. gambling, games of chance) and can also be effective to communicate volcano forecasting if it is correctly adapted to such a goal. Regulations are not a direct communication tool but are frequently used to manage environmental and natural hazards. Some regulations are widely understood or at least accepted by the public even if they don't understand the science behind them. Regulations are not widely used in volcanic crisis management but can be useful in communication. An example is in Case Study 18 where occupational risk regulations were used to explain risk to workers. Finally, culture is of key importance in communication. The cultural diversity of societies facing volcanic threat determines that some communication approaches may work in one country or culture but not in another. Therefore, it is important to analyse and understand the particular cultural aspects of each society in order to define the best communication procedures and languages in each case.

24.4 What should be communicated?

Forecasting the future behaviour of a volcano requires good knowledge of its past behaviour, based on the analysis of the geological record and/or historical eruptive records, and a precise understanding of its current activity through monitoring systems. Will the eruption occur? What style of eruption will it be? When the eruption will occur? Where the eruption will occur? What is the size of the problem?, are the basic questions that the decision makers will surely pose to the scientist once an alert has been declared and the process of managing a volcanic emergency has begun. Usually, scientists can answer these questions with approximations (with probabilities in some cases) based on knowledge of previous cases from the same volcano, or from other volcanoes of similar characteristics, knowledge of the past eruptive history of the volcano, the degree of accuracy in the detection of warning signals (geophysical and geochemical monitoring), and knowledge about the significance of these warning signs. Giving probabilities as outcomes of volcano forecasts may be relatively easy for the scientist depending on the degree of information available, but it may be not fully understood by the decision-maker or any other receptor of such information. It is necessary to find clear and precise ways to transfer this information from scientist to decision-maker, to avoid misunderstandings and misinterpretations that could lead to incorrect management of the volcanic crisis and, consequently, to a disaster.

Volcano forecasts should be focussed on the science, just communicating precise and clear scientific advice on the potential evolution of volcanic phenomena in the most appropriate terms, in order to make it understandable to all potential receptors. Scientists may also recommend safe behaviour directly to the public, providing advice that saves people's lives (e.g. go up a hill if a lahar threatens). However, this should not imply or be confused with making decisions on how to manage a volcanic emergency (e.g. evacuation), as this belongs strictly to the decision maker.

24.5 When volcano forecasts should be communicated?

Scientific communication in active volcanic areas should be always present. This means that there should be a permanent flow of information from scientists to the population and policy-makers on the eruptive characteristics of the volcano, its current state of activity, or its associated hazards, even when volcanoes do not show signs for alarm. This is crucial preparation for when an emergency starts and things need to move much faster. However, in many cases scientific communication in hazard assessment and volcano forecasting is just restricted to volcanic emergencies. This may reduce considerably the understanding of the scientific information and its reliability due to the previous lack of knowledge on these subjects by the population and decision-makers.

When volcanic unrest starts and escalates, the origin of this unrest needs to be investigated to assess the likelihood of evolving into an eruption. As previously mentioned, the calculation of probabilities will be subjected to considerable uncertainties, as most of the data will be obtained from monitoring systems, so they will constitute indirect evidence of what could be happening inside the volcanic system. In volcanoes with a high eruption frequency comparison with previous unrest episodes will assist understanding unrest.

Past experience shows that good detection and interpretation of precursors allows prediction of what will happen with a considerable degree of confidence. This implies that scientific communication during volcanic crises needs to be constant and permanently updated with the arrival of new data. The longer is taken in making a decision the higher could be the costs incurred, as reaction time decreases and vulnerability increases. This constitutes the main worry in managing volcanic crises, WHEN to make a decision, which in most cases could be to order an evacuation. In essence, the relationship between the decrease of uncertainty in the interpretation of the warning signs of pre-eruptive processes to acceptable (reliable) levels, and the time required to make a correct decision, is a function of the degree of scientific knowledge of the volcanic process and the effectiveness of scientific communication. Therefore, scientific communication during volcanic emergencies needs to be effective from the beginning of the process, but would be significantly improved if this communication channel has already been established when the level of activity of the volcano did not represent a cause of concern.

24.6 What needs to be done?

In order to improve scientific communication during volcanic crises comparisons between communication protocols and procedures adopted by different volcano observatories and scientific advisory committees is recommended, in order to identify difficulties and best practice at all levels of communication: scientist to scientist, scientist to technician, scientist to Civil Protection, scientist to general public. Experience from the management and communication of other natural hazards should be brought in and common communication protocols should be defined based on clear and effective ways of showing probabilities and associated uncertainties. Although each cultural and socio-economic situation will have different communication requirements, comparison between different experiences will help to improve each particular communication approach, thus reducing uncertainty in communicating eruption forecasts.

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