Chapter 15

The role of volcano observatories in risk reduction

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Volcanic risk reduction is a partnership between science, responding agencies and the affected communities. A critical organisation in the volcanic risk reduction cycle is a volcano observatory (VO), which is an institute or group of institutes whose role it is to monitor active volcanoes and provide early warnings of future activity to the authorities. For each country, the exact constitution of a VO may differ, dependent on the legislative framework for disaster risk reduction and scientific advice to government. For example, in the USA, the Alaska Volcano Observatory is a joint programme of the United States Geological Survey (USGS), the Geophysical Institute of the University of Alaska Fairbanks (UAFGI), and the State of Alaska Division of Geological and Geophysical Surveys (ADGGS), whereas in New Zealand, GNS Science has sole responsibility under the country's Civil Defence Emergency Management Act to provide warnings on volcanic activity and hence provides the function of a volcano observatory.

The responsibilities of a VO also differ from country to country. In some nations, a volcano monitoring organisation may be responsible only for maintaining equipment and ensuring a steady flow of scientific data to an academic or civil protection institution, who then interpret the data or make decisions. In other jurisdictions, the VO may provide interpretations of those data and undertake cutting edge research on volcanic processes. In most cases a VO will provide volcanic hazards information such as setting Volcanic Alert Levels and issuing forecasts of future activity, and in some instances, a VO may even provide advice on when civil actions should take place such as the timing of evacuation. Some of the VOs have responsibility for multiple volcanoes, whereas others may only monitor and provide advice on a single volcano. In some countries an academic institute may fulfil both the monitoring and research function for a volcano.

This wide range of potential roles and responsibilities demonstrates the importance of a VO function, but also shows that there is no single template for the constitution of a VO. However, it is critically important that governments recognise the need for volcano monitoring, provide adequate resourcing and have clear definitions of roles for VOs, academic institutions, civil protection agencies and other key players for the pathway for issuing warnings.

A critical VO role is to provide information to Volcanic Ash Advisory Centres (VAACs). It is stated under regulations of the International Civil Aviation Organisation that states should maintain VOs that monitor pre-eruptive activity and eruptions themselves and provide

Jolly, G. (2015) The role of volcano observatories in risk reduction. In: S.C. Loughlin, R.S.J. Sparks, S.K. Brown, S.F. Jenkins & C. Vye-Brown (eds) *Global Volcanic Hazards and Risk,* Cambridge: Cambridge University Press.

information on the activity to VAACs, Meteorological Watch Offices and air traffic control authorities.

There are over 100 VOs around the world to monitor ca. 1551 volcanoes considered to be active or potentially active. Many of the VOs are members of the World Organisation of Volcano Observatories (WOVO; www.wovo.org). WOVO is a commission of the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI) that aims to co-ordinate communication between VOs and to advocate enhancing volcano monitoring around the globe. WOVO is an organisation of and for VOs of the world and has three co-leaders for each of the following regions: Asia-Pacific, Americas, Europe/Africa. WOVO organises or co-sponsors meetings, workshops and conference sessions that focus on issues of importance for VOs. It also co-ordinates information exchange between the VOs. One of the main recent roles of WOVO has been to enhance communication between VOs and Volcanic Ash Advisory Centres.

To be able to monitor their volcanoes effectively, VOs potentially have a very wide suite of tools available to them. However, the range of the capability and capacity of VOs globally is enormous. Many active volcanoes have no monitoring whatsoever, whereas some VOs in developed countries may have hundreds of sensors on a single volcano [see Chapter 19]. This leads to major gaps in provision of warnings of volcanic activity, particularly in developing countries.

Monitoring programmes typically include: tracking the location and type of earthquake activity under a volcano; measuring the deformation of the ground surface as magma intrudes a volcano; sampling and analysing gases and water being emitted from the summit and flanks of a volcano; observing volcanic activity using webcams and thermal imagery; measurements of other geophysical properties such as electrical conductivity, magnetism or gravity. VOs may have ground-based sensors measuring these data in real-time or they may have staff undertaking campaigns to collect data on a regular basis (e.g. weekly, monthly, annually). Some VOs may also the capability to collect and analyse satellite data.

Volcano seismicity is the fundamental backbone for early warnings of eruption. Magma and fluid movement inside volcanoes create a variety of seismic signals. A typical progression of seismicity preceding and eruption starts with rock-breaking earthquakes or volcano-tectonic signals as magma starts to move upwards inside the volcano. As magma, gases or hydrothermal fluids get forced through cracks, the earthquakes change their character reflecting resonance or repetitiveness of the source of the signals. Eruptions and their products (pyroclastic density currents or lahars) also produce diagnostic signals.

There are many different ways of measuring the shape of the earth; traditional surveying methods such as levelling or electronic distance measurement can be used on a campaign basis, although most VOs now use continuous data collection using Global Navigation Satellite Systems or electronic tilt to provide real-time or near real-time sub-millimetre measurements of the location of points around a volcano. Satellite measurements [Chapter 17], particularly Synthetic Aperture Radar, also allow wide spatial coverage of a deforming volcano although this imagery normally has a return period of weeks to months.

Volcanoes emit many different gas species as the magma rises from depth; the magma also interacts with hydrothermal systems, groundwater or surface water and can change the chemistry and physical properties of existing water bodies. Measuring these changes can provide early warning of magma on the move.

The main gas species that are associated with magma are water, sulfur dioxide and carbon dioxide, although many other gases can be measured, especially halogens, and other carbon and sulfur species. Scientists have devised a wide range of techniques to measure these gases, especially sulfur dioxide and carbon dioxide. Water vapour is very difficult to measure as there is already an abundance in the atmosphere. Very few gas monitoring techniques provide real-time data at a comparable rate to measurements of seismicity or ground deformation, although this is a rapidly developing field and over the next 5-10 years, it is likely that such instrumentation will exist.

Changes in water chemistry and properties are relatively simple to measure in real-time, such as the temperature of a crater lake or the pH of a hot spring, although volcanic environments are commonly highly acidic and/or hot and thus it is difficult to maintain sensors for extended periods as they can be destroyed very easily.

Satellite observations can help with both gas emissions and physical properties of water bodies. For example, the Ozone Monitoring Instrument (OMI) onboard the NASA Aura satellite has the ability to monitor large emissions of sulfur dioxide; a variety of satellite platforms provide thermal monitoring with varying degrees of temporal or spatial resolution. However, not all VOs have either the capability or capacity to access or interpret satellite information.

Observations of volcanic activity are critical during eruptive activity to provide information to the VO on how an eruption is progressing. For example, observations of ash cloud heights are vital for VAACs so they can accurately model the dispersion of ash for aviation. Oftentimes, VOs have web cameras at various points around a volcano to provide visual or thermal imagery back to the monitoring scientists. In some cases, ground-based radar can image eruption clouds. Remote imagery is especially important if the VO is located at some distance from a volcano.

Definition of what constitutes an appropriate level of monitoring has received some attention over the last few years (Ewert et al., 2005, Miller & Jolly, 2014). One approach that has been used is to assess broadly the risk associated with each volcano [see Chapter 23], and allocate more resources to those volcanoes that pose a higher risk. This approach has been extended in this submission to GAR15. In some countries, it may be difficult to provide monitoring for all the volcanoes in its jurisdiction; however, consideration should be made of maintaining at least some minimal monitoring for the high-risk volcanoes through all periods of quiescence. Volcanoes exhibit fluctuations in their background levels of activity and it is difficult to recognise what constitutes unrest that may lead to an eruption if the VO does not understand the long-term behaviour of the volcano fully.

One aspect of VOs that is often underestimated is ensuring that a VO has sufficient human resource to develop and maintain monitoring expertise. Oftentimes, VOs have the ability to purchase capital items, or equipment is provided in an emergency situation through aid donors, but if there is insufficient staffing and/or an ongoing operational budget, the monitoring can quickly fall into disrepair in the recovery period after an eruption. It is important that VOs are resourced sustainably, so that they can maintain at least a minimum level of monitoring through periods with little or no activity, and that they have the ability to call on additional support during crises to bolster a long-term core capability. This can be achieved by partnerships with other organisations either in-country, for example, academic institutions that may be able to provide students for routine monitoring tasks such as collecting ash, or overseas, for example, GNS Science has a long-term partnership with Vanuatu Meteorology and Geohazards Department. In both cases, there has to be clear understanding of the responsibilities of the VO and any other organisations assisting the VO or undertaking research on the volcano (Newhall et al., 1999).

The process for mitigating risk differs from country to country, but in essence, communities need to understand their risk and take action to mitigate risk (by avoiding, minimising or accepting the risks). This is commonly illustrated through a series of steps in a risk management cycle, such as risk reduction (e.g. using planning legislation to prevent people from living in high risk areas), readiness (e.g. having contingency plans in place so that different parts of the community know what they should do in a crisis), response (e.g. reacting to increased activity by evacuating areas) and recovery (e.g. cleaning up after ashfall). VOs play a role in all aspects of risk management.

VOs are often involved in outreach activities in times of volcanic quiet so that the authorities and the communities can better understand the potential risk from their volcano(es); this may also involve regular exercising with civil protection agencies to test planning for eruption responses.

During the lead up to an eruption, VOs may provide regular updates on activity which inform decisions on evacuations or mitigation actions to reduce risk to people or to critical infrastructure. For example, power transmission companies may choose to shut off high voltage lines if there is a high probability of ashfall. They may also assist organisations in developing contingency plans by providing possible eruption scenarios.

During an eruption, VOs will then provide up-to-date information about the progression of activity. For an explosive eruption, information might include the duration, the height that ash reaches in the atmosphere and areas being impacted on the ground. This can inform decisions such as search and rescue attempts or provide input to ash dispersion forecasts for aviation.

After an eruption has ceased, VOs can aid recovery through advice about ongoing hazards such as remobilisation of ash deposits during heavy rainfall. They can also assist or undertake valuable research on the eruption through collection of time-perishable data. This can lead to better understanding of the volcano so that future responses can be fine-tuned.

The role of VOs is critical in reducing risk from volcanoes, both on the ground and in the air. Volcanic risk reduction can only improve if VOs are adequately resourced by national government. If adequate volcano monitoring is established ahead of a volcanic crisis, the VO can provide a wide range of information to responding agencies and to the potentially affected communities, both in quiescence and during response; ultimately, this results in better preparedness and enhanced safety of people and infrastructure.

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https://doi.org/10.1017/CBO9781316276273.017 Published online by Cambridge University Press