REGIONAL VOLCANIC HAZARD ASSESSMENT

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Volcanic ash is one of the farthest-reaching volcanic hazards. Communities in volcanically active areas may therefore be threatened by ash falls from any one of a number of active volcanoes. To assess regional volcanic ash hazard thus requires generic principles, or rules, that can consider the likely magnitude, style and occurrence of future events at a large number of volcanoes. We use a knowledge engineering approach to incorporate qualitative volcano descriptions into a quantitative numerical model. While our approach simplifies certain attributes that may be known for a few well-studied volcanoes, it nonetheless imposes a consistent methodology on the quantification of ash fall hazard across a large region, in a way that has not been attempted previously.

Keywords: Quantitative volcanic hazard and risk assessment, Probabilistic modelling, Regional hazard assessment.

The relative rarity of volcanic eruptions, and the variety and complexity of processes involved, means that quantification of volcanic hazard and risk can be more complicated than for other natural hazards such as floods or hurricanes. In particular, volcanic ash - tiny fragments of rock produced by explosive eruptions - can travel hundreds, or even thousands, of kilometres from source affecting large numbers of people and disrupting air travel. Therefore, many communities

in volcanically active areas are exposed to a number of volcanoes so that traditional volcano- or event-specific hazard studies do not fully capture the total hazard.

Quantifying the hazard from volcanic ash is problematic, in part because of data limitations that make eruption characteristics uncertain but also because, given an eruption, the distribution of ash is then controlled by the properties of erupted material and by time- and altitude-varying wind conditions. To address these uncertainties, we have developed a probabilistic framework for assessing ash fall hazard on a regional scale (Jenkins et al., 2012a; Jenkins et al., 2012b). Previous probabilistic assessments of volcanic ash hazard have explored the likely dispersion of ash from a single volcano, conditional upon an eruption having taken place (e.g. Bonadonna et al., 2005; Jenkins et al., 2008). Hazard is then estimated independently of the probability that the eruption will occur. For our study, such an approach would be invalid as, at any given location, the ash fall hazard may be an accumulation of the hazard from many volcanoes, all of which are likely to have different eruption probabilities, styles and magnitudes. For our purposes, it was therefore necessary to develop a framework that employs knowledge engineering methods in incorporating qualitative data into a robust quantitative hazard assessment (Pshenichny and Kanzheleva, 2011). In this way, broad rules could be used to estimate the individual annual eruption probability for any volcano. The assessment is deliberately based upon generic principles that could be applied to any area, but are here applied to the Asia-Pacific region.

With the purpose of inferring averaged eruptive behaviour across analogous volcanoes, we follow the Smithsonian Institution classification of volcanoes (Siebert et al., 2010) by type and assign each volcano to a broad type category based upon its physical characteristics. The volcano type category implicitly relates to previous eruption styles and magnitudes at the volcano and is indicative of magma composition, i.e. shields and small cones tend to be less silicic, and therefore produce less explosive eruptions, than large cones, lava domes and calderas. Average recurrence intervals for eruptions greater than or equal to Volcanic Explosivity Index 4 were thus established for 190 volcanoes in the Asia-Pacific region, based upon the eruption history of each volcano and, where data were lacking, the averaged eruptive behaviour of global analogous volcanoes. Stochastic simulation techniques were used with ash dispersal for each of 190,000 plausible eruption scenarios determined using an advection–diffusion model and local wind conditions. Key uncertainties are described by probability distributions. Modelled results include ash hazard footprints and corresponding probabilities for each of 190 volcanoes. By summing ash accumulation over all modelled scenarios and all volcanoes, and weighting each by their probability of occurrence, our modelling produces Average Recurrence Intervals (ARIs) for damaging thresholds of ash fall across more than 1 million km2 of urban area.

Within the Asia-Pacific region, urban areas in Indonesia are found to have the highest levels of hazard and risk, and Australia the lowest. Countries with no volcanoes, such as North Korea and Malaysia, also face ash falls from volcanoes in neighbouring countries. Modelling for the study region also shows that ashfalls exceeding 1 mm (from any volcano) affect more than one million people living in urban areas on average less than every 40 years in Indonesia, Japan and the Philippines. The 1 mm threshold exceeds the depth of ash at which road markings become obscured and represents a threshold where, for an urban area, significant clean-up operations would be required. Clearly much greater depths are possible. Some areas in Japan, where ash accumulation is expected to exceed 1 mm on average every 300 to 400 years, are concentrated in the Greater Tokyo area. The study region contains at least six urban agglomerates of over 10 million people. Of these six, Tokyo, Manila and Jakarta are at greatest risk from volcanic ash.

Our methodology is adaptable and can provide estimates of ash accumulation for given ARIs, which allows comparison with other natural perils. The work can easily be expanded to

other regions, and by including exposure and quantitative and qualitative estimates of vulnerability, used to estimate loss. While our approach simplifies certain attributes that may be known for a few well-studied volcanoes, it nonetheless imposes a consistent methodology on the quantification of ash fall hazard across the region and provides a regional view of the ash fall hazard in a way that has not been attempted previously.

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