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Developing International Guidelines on Volcanic Hazard Assessments for Nuclear Facilities

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Worldwide, tremendous progress has been made in recent decades in forecasting volcanic events, such as episodes of volcanic unrest, eruptions, and the potential impacts of eruptions. Generally these forecasts are divided into two categories. Short-term forecasts are prepared in response to unrest at volcanoes, rely on geophysical monitoring and related observations, and have the goal of forecasting events on timescales of hours to weeks to provide time for evacuation of people, shutdown of facilities, and implementation of related safety measures. Long-term forecasts are prepared to better understand the potential impacts of volcanism in the future and to plan for potential volcanic activity. Long-term forecasts are particularly useful to better understand and communicate the potential consequences of volcanic events for populated areas around volcanoes and for siting critical infrastructure, such as nuclear facilities. Recent work by an international team, through the auspices of the International Atomic Energy Agency, has focused on developing guidelines for long-term volcanic hazard assessments. These guidelines have now been implemented for hazard assessment for nuclear facilities in nations including Indonesia, the Philippines, Armenia, Chile, and the United States.

One any time scale, all volcanic hazard assessments rely on a geologically reasonable conceptual model of volcanism. Such conceptual models are usually built upon years or decades of geological studies of specific volcanic systems, analogous systems, and development of a process-level understanding of volcanic activity. Conceptual models are used to bound potential rates of volcanic activity, potential magnitudes of eruptions, and to understand temporal and spatial trends in volcanic activity. It is these conceptual models that provide essential justification for assumptions made in statistical model development and the application of numerical models to generate quantitative forecasts. It is a tremendous challenge in quantitative volcanic hazard assessments to encompass alternative conceptual models, and to create models that are robust to evolving understanding of specific volcanic systems by the scientific community.

A central question in volcanic hazards forecasts is quantifying rates of volcanic activity. Especially for long-dormant volcanic systems, data from the geologic record may be sparse, individual events may be missing or unrecognized in the geologic record, patterns of activity may be episodic or otherwise nonstationary. This leads to uncertainty in forecasting long-term rates of activity. Hazard assessments strive to quantify such uncertainty, for example by comparing observed rates of activity with alternative parametric and nonparametric models.
Numerical models are presented that characterize the spatial distribution of potential volcanic events. These spatial density models serve as the basis for application of numerical models of specific phenomena such as development of lava flow, tephra fallout, and a host of other volcanic phenomena. Monte Carlo techniques (random sampling, stratified sampling, importance sampling) are methods used to sample vent location and other key eruption parameters, such as eruption volume, magma rheology, and eruption column height for probabilistic models. The development of coupled scenarios (e.g., the probability of tephra accumulation on a slope resulting in subsequent debris flows) is also assessed through these methods, usually with the aid of event trees.

The primary products of long-term forecasts are a statistical model of the conditional probability of the potential effects of volcanism, should an eruption occur, and the probability of such activity occurring. It is emphasized that hazard forecasting is an iterative process, and board consideration must be given to alternative conceptual models of volcanism, weighting of volcanological data in the analyses, and alternative statistical and numerical models. This structure is amenable to expert elicitation in order to weight alternative models and to explore alternative scenarios.