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Correcting Bias in Tephra Fallout Hazard Estimates Using Numerical Simulations

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Tephra dispersal and fallout is a major hazard associated with pyroclastic eruptions because of the vast areas that may be impacted by this fallout. One means of estimating the hazard of tephra fallout is with an empirical survivor function estimated from tephrastratigraphy. The survivor function is the complement of the distribution function and is frequently used to determine if the frequency of a random variable T exceeds some value,t: S(t) = P[T>t] . Often we are concerned with the probability that the repose interval between eruptions, T, will exceed a specific time period of interest, t. While very useful, geologic observations of tephra fallout events are incomplete and therefore produce biased empirical survivor functions. For example, the Large Magnitude Explosive Eruptions Database for Japan includes 696 eruptions VEI 4 or greater and occurring within the last 1.8 my. Half of the eruptions in this database are < 65 ka. Statistical models of the of preservation of tephra, based on these known eruptions, suggests that 97 percent of VEI 4 eruptions are missing from the geologic record after 100 ka, whereas 40 percent of VEI 5-7 events are missing after this time period, with the likelihood of an eruption being preserved in the geologic record following an exponential trend. This means that empirical survivor functions based on the geologic record of past events will be biased to long repose intervals and larger magnitude eruptions, creating a substantial problem for hazard assessment of the world's numerous long dormant volcanoes.

Numerical models of tephra fallout provide one mechanism of addressing this potential bias provided model characteristics can be well-documented. Advection-diffusion models are generally used to model tephra fallout, using well-known assumptions for eruption total grainsize distribution, column characteristics, and particle settling velocities. We tested these assumptions for the 1992 (VEI 3) deposit of Cerro Negro volcano using near-vent to medial deposit information collected from sample pit data and high resolution ground penetrating radar (GPR). Horizons identified in proximal GPR profiles exhibit Gaussian distributions and downwind exponential thinning trends with a high degree of confidence. Numerical inversion of these combined GPR and sample pit data reproduce the observed characteristics of the eruption (total mass, column height, granulometry). Inversion results, especially using specific particle sizes, are equally successful in modeling characteristics of the most recent Ooshima (Japan) eruption, and have been used to infer characteristics of numerous recent eruptions (e.g., Chaiten (Chile), Colima (Mexico)). This experience in model validation suggests that numerical simulations of tephra fallout can be used to create ensemble forecasts. These forecasts appear to have low epistemic uncertainty, but have substantial aleatory uncertainty associated with the uncertain frequency-magnitude distribution of tephra fallout events from individual volcanoes.