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Exploring the full natural variability of eruption sizes within probabilistic hazard assessment of tephra dispersal

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The intrinsic uncertainty and variability associated to the size of next eruption strongly affects short to long-term tephra hazard assessment. Often, emergency plans are established accounting for the effects of one or a few representative scenarios (meant as a specific combination of eruptive size and vent position), selected with subjective criteria. On the other hand, probabilistic hazard assessments (PHA) consistently explore the natural variability of such scenarios. PHA for tephra dispersal needs the definition of eruptive scenarios (usually by grouping possible eruption sizes and vent positions in classes) with associated probabilities, a meteorological dataset covering a representative time period, and a tephra dispersal model. PHA results from combining simulations considering different volcanological and meteorological conditions through a weight given by their specific probability of occurrence. However, volcanological parameters, such as erupted mass, eruption column height and duration, bulk granulometry, fraction of aggregates, typically encompass a wide range of values. Because of such a variability, single representative scenarios or size classes cannot be adequately defined using single values for the volcanological inputs.
Here we propose a method that accounts for this within-size-class variability in the framework of Event Trees. The variability of each parameter is modeled with specific Probability Density Functions, and meteorological and volcanological inputs are chosen by using a stratified sampling method. This procedure allows avoiding the bias introduced by selecting single representative scenarios and thus neglecting most of the intrinsic eruptive variability. When considering within-size-class variability, attention must be paid to appropriately weight events falling within the same size class. While a uniform weight to all the events belonging to a size class is the most straightforward idea, this implies a strong dependence on the thresholds dividing classes: under this choice, the largest event of a size class has a much larger weight than the smallest event of the subsequent size class. In order to overcome this problem, in this study, we propose an innovative solution able to smoothly link the weight variability within each size class to the variability among the size classes through a common power law, and, simultaneously, respect the probability of different size classes conditional to the occurrence of an eruption. Embedding this procedure into the Bayesian Event Tree scheme enables for tephra fall PHA, quantified through hazard curves and maps representing readable results applicable in planning risk mitigation actions, and for the quantification of its epistemic uncertainties. As examples, we analyze long-term tephra fall PHA at Vesuvius and Campi Flegrei. We integrate two tephra dispersal models (the analytical HAZMAP and the numerical FALL3D) into BET_VH. The ECMWF reanalysis dataset are used for exploring different meteorological conditions. The results obtained clearly show that PHA accounting for the whole natural variability significantly differs from that based on a representative scenarios, as in volcanic hazard common practice.