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Probabilistic hazard analysis of dense Pyroclastic Density Currents at Vesuvius (Italy) via parametric uncertainty characterization of TITAN2D numerical simulator

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Probabilistic hazard assessments of Pyroclastic Density Currents (PDCs) are of great interest for decision-making purposes. However, there is a limited number of published works available on this topic. Recent advances in computation and statistical methods are offering new opportunities beyond the classical Monte Carlo (MC) sampling which is known as a simple and robust method but it usually turns out to be slow and computationally intractable.

In this work, Titan2D numerical simulator has been coupled to Polynomial Chaos Quadrature (PCQ) to propagate the simulator parametric uncertainty and compute VEI-based probabilistic hazard maps of dense PDCs formed as a result of column collapse at Vesuvius volcano, Italy.

Due to the lack of knowledge about the exact conditions under which these PDCs will form, Probability Distribution Functions (PDFs) are assigned to the simulator input parameters (Bed Friction Angle and Volume) according to three VEI sizes. Uniform distributions were used for both parameters since there is insufficient information to assume that any value in the range is more likely that any other value. Reasonable (and compatible) ranges for both variables were constrained according to past eruptions at Vesuvius volcanic system. On the basis of reasoning above a number of quadrature points were taken within those ranges, which resulted in one execution of the TITAN2D code at each quadrature point.

With a computational cost several orders of magnitude smaller than MC, exceedance probabilities for a given threshold of flow depth (and conditional to the occurrence of VEI3, VEI4 and VEI5 eruptions) were calculated using PCQ.

Moreover, PCQ can be run at different threshold values of the same output variable (flow depth, speed, kinetic energy, . . .) and, therefore, it can serve to compute Exceedance Probability curves (aka hazard curves) at singular points inside the hazard domain, representing the most important and useful scientific input to quantitative risk assessments and mitigation policies.

Nevertheless, it should be kept in mind that probabilistic hazard assessments for the dilute spectrum of PDCs must be also performed to provide complete hazard assessments that can be efficiently used by decision-makers.