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BET_VH probabilistic assessment of pyroclastic flows hazard at El Misti volcano, South Peru, based on geological record and numerical simulations with TITAN2D

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Pyroclastic density currents, which include pyroclastic surges and pyroclastic flows (PFs), are among the most dangerous volcanic phenomena. We present a probabilistic hazard assessment of the PFs generated from eruptive column collapse at El Misti volcano (5822 m) in South Peru. The high relief of the cone, the location of the city of Arequipa ($\sim$1,000,000 people) on two large volcanoclastic fans and the H (3.5 km)/L (17 km) ratio (0.2) between the summit and the city center, make PFs a direct threat. We consider three eruption scenario sizes: small Vulcanian/Phreatomagmatic (VEI 2), medium Sub-Plinian (VEI 3-4), and large Plinian (VEI 4+). We use the Event-Tree approach in a Bayesian scheme with BET_VH (Bayesian Event Tree for Volcanic Hazard) software. Quantitative data that stem from numerical simulations from TITAN2D (termed prior models) and from stratigraphic record (termed past data) are input to BET_VH, which enables us to compute the probabilities (in a 1-year time window) of (i) having an eruption (ii) in a selected location/vent (iii) of a specific size, (iv) and that this eruption will produce PFs (v) that will reach a location of interest around El Misti.

TITAN2D simulation runs, expressed as color-coded thicknesses of PDC deposits, fit well the extent of past PFs deposits, including thick confined deposits (0.5-7 m) in the Rio Chili canyon and its tributary ravines (Quebradas San Lazaro, Huarangal and Agua Salada).The unconfined, thinner ($\leq$10cm) deposits, as displayed by simulation runs on the interfluves, is attributed to ash-cloud surges. Such thin, fine ash deposits have not been emphasized in geological maps either because they have been removed away or remain yet unrecognized. The simulated Vulcanian flows, restricted to the upper part of the cone, become confined (0.1-1m thick) in the ravines which converge towards each of the three Quebradas. The simulated Subplinian PF deposits reach 0.1 to 1 m thick in the Quebradas and 1-4 m WNW of El Misti summit in the Rio Chili canyon. The simulation runs suggest that the Subplinian flows will reach a 9 to 12 km distance, i.e. close to the city suburbs on the lower W, SW and S flanks of El Misti. Large Plinian events with volumes exceeding $10^9 m^3$ produce simulated flows that would reach 15 km distance, i.e $\sim$ 3 km beyond the extent of existing similar deposits. On the steep NW flank of El Misti summit, the Subplinian and Plinian PFs run up 500-700 m on the opposite slope of the 2 km-wide canyon and bounce back to the channel to form deposits 1 to 7 m thick. Simulations show that PFs from large Subplinian and Plinian events will deposit after running up and swinging between the walls of the narrow Rio Chili canyon, and also in the upper reach of the Quebradas. In contrast, similar Sub-Plinian and Plinian PFs tend to spread out at the apex of the San Lazaro and Huarangal fans. However, such spreading may also be due to the low-spatial resolution of the DEM (30 m).

The BET_VH results are illustrated through probability maps which show the probability of PFs to reach a selected location given any of the selected eruption sizes (for example the probability that PFs generated by a Plinian eruption to reach the city suburbs upstream of Quebradas Huarangal and San Lazaro is $>$0.6) or through an absolute probability map that provides the probability of different parts of the city of being reached by PFs in the next year.

Keywords: El Misti, Arequipa, PDCs, Bayesian Event Tree, Titan2D, hazard, probabilistic assessment.