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Probabilistic analysis of rain-triggered lahar initiation at Tungurahua volcano

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Abstract

Semi-continuous production of pyroclastic material by intermittent strombolian, vulcanian and sub-plinian eruptions at Volcán Tungurahua, Ecuador has created a persistent rain-triggered lahar hazard during the 1999–present eruptive episode. Lahars threaten the city of Baños, which lies approximately 8 km from the crater, as well as other villages and vital infrastructure situated in close proximity to the dense radial drainage network of the volcano. This study analyses the initiation of rain-triggered lahars and the influence of antecedent rainfall on this process in two northern instrumented drainages, La Pampa and the Vazcun. Analysis of lahar-triggering rainfall intensity and duration between March 2012 and June 2013 yields a power-law relationship, whilst receiver operating characteristic (ROC) analysis indicates that peak rainfall intensity (10, 30 and 60 min) is the most effective single predictor of lahar occurrence. The probability of a lahar exceeding a pre-defined magnitude increases with peak rainfall intensity. Incorporation of antecedent rainfall (24 h and 3, 5 and 7 days) as a secondary variable significantly impacts lahar probabilities, particularly during moderate–high-intensity rainfall events. The resultant two- and three-dimensional lahar probability matrices are applied to rainfall data between 1st July and 31st December 2013 with the aim of predicting lahar occurrence. Composite lahar indicators comprised from the mean lahar probability estimates of individual matrices are shown to perform this task most effectively. ROC analysis indicates a probability > 80 % that these composite indicators will generate a higher estimated lahar probability for a randomly selected lahar event than a randomly selected non-lahar event. This method provides an average of 24 min of additional warning time compared with the current acoustic flow monitors (AFMs) used for lahar detection, effectively doubling warning times for key downstream infrastructure in the two drainages. Ultimately, this method of lahar analysis could be used to construct real-time probabilistic rain-triggered lahar forecasts as an aid to current lahar hazard mitigation techniques at any location with a significant rain-triggered lahar hazard and a basic instrumental setup.

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