



Intra-eruptive lahars on an active volcano: a combination of earthquake and rainfall effects

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Lahars represent one of the most dangerous phenomena that may occur on active volcanoes, during or just after a main eruptive phase (syn-eruptive or post eruptive) but also during period of volcanic quiescence (intra-eruptive). Popocatepetl is the one of the most active volcanos in Mexico. The largest lahars recorded at this volcano are directly associate with the Plinian eruptions occurred during the late Pleistocene and Holocene that inundated the surrounding basins. In historic time, only the events recorded in 1997 and 2001 were associated to an eruptive phase. Rain-triggered soil slips are common processes during the rainy season, which in most of the cases transform to lahars along main ravines. The M7.1 earthquake that occurred on 19 September 2017, with its epicenter at ~ 70 km SW from Popocatepetl volcano, produced the most intense ground shaking ever felt in Mexico City and drastically affected the center of Mexico. The earthquake triggered several landslides on the volcano slope that consist of saturated soils containing sensitive clays highly susceptible to earthquake-induced landslides. Two weeks later, on 4 October, 35 mm of rains had fallen over 10 hr, with 24 mm accumulated in only 40 minutes. This rainfall event triggered two main lahars on the western slope of the volcano and one on its eastern side. The source material corresponds with the ash flow deposits removed by the landslides induced by the earthquake. The lahars where highly viscous mud flows, containing abundant tree trunks (i.e. woody debris flow), type of flow directly observed at this volcano for the first time. This peculiar rheology is here described based on granulometric analysis of samples and laboratory measurements conducted with a rheometer. The seismic records from two broadband stations located at ~ 2 km from the source are also analyzed and compared with signals produced by no-cohesive debris flows. This event represents a unique opportunity to perform a multi-hazard risk assessment at Popocatepetl volcano, and to investigate how to set up a warning system for events not directly associated to the eruptive activity.