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Geo-statistical and GIS-photogrammetric debris flow modeling: a contribution to the geological hazard evaluation

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The geologic and tectonic environment, climatic conditions, and Quaternary glacial events have given rise to a complex geomorphological framework that, in the Val Ferret (Aosta Valley – NW Italy), is expressed through frequent and various types of gravitational flows. Inside this valley, engraved at the foot of Mont Blanc, the most imposing mountain massif in Europe, different phenomena are responsible for a considerable degree of geological hazard: debris flows, glacial floods (glacial routes), rock and ice avalanches and fluvial floods. The most devastating torrent processes that affect this valley, both in terms of social and economic losses, are undoubtedly debris flows. This area of 128,000 residents and numerous year-round tourists has experienced at least 52 known landslide events between 1929 and 2018. Torrent Rochefort, Val Ferret is the seat of some of the most disastrous events recorded in the valley.

A multidisciplinary approach with modern technologies was used to study and model the dynamics of the Torrent Rochefort September 17, 2015 debris flow. In addition to utilizing a 2 m digital elevation model (DTM) data set created in 2008 (DTM2008), an aerial photogrammetric survey by drone was carried out during this project to create a DTM with 7 cm ground resolution and 8 cm vertical precision (DTM2018). The drone data and ground control points were processed utilizing Agisoft Photoscan. Based on field study and historical information, it was determined that the 2015 event was the only event between 2008 and 2018, a critically important assumption for this project. This assumption allowed us to calculate the volume of material left in the riverbed by the debris flow by subtracting the elevations of the DTM2008 from those of the DTM2018. The total volume of material mobilized during the event was then calculated by summing these volumes to those which were removed during the post-debris flow cleanup and material removal operations. Thus, the total mobilized volume was calculated to about 100,000 m3.

Dynamic numerical simulations were created utilizing RASH3D incorporating various rheological parameters to reflect the conditions that occurred during the 2015 debris flow. By determining those parameters which create the best fit for deposition thickness along the run-out path, and range and volume of the deposition, a model and analysis can be constructed for mitigation of human and economic risks associated with future events.

Ultimately, in spite of high-quality elevation data before and after the event, and numerous simulations, it was not possible to closely simulate the 2015 event. This may be due to inaccurate initial assumptions, such as the 2015 event being the only event between 2008 and 2018; the presence of a man-made bridge in the flow path, which is not factored into the terrain surface modeling; use of a single-phase rheology approach, not distinguishing the solid phase from the liquid phase; volumetric errors associated with calculations between two DTMs of differing resolutions; and insufficient calibration and comparison of “absolute orientation” (altitude) of a flat and recognizable point with each DTM.