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Analysis of the hydrological triggering and propagation mechanisms of debris flows in the Cardoso basin (Apuan Alps, Italy), using a numerical GIS based mass flow model

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On June 19^{th}, 1996 an extremely heavy rainstorm (about 500 mm within 12 hours) hit some restricted areas in NW Tuscany (Italy), involving a few basins of the Versilia and Garfagnana areas. The storm induced various effects on the slopes, causing landslides, soil slips, debris flows, mostly hitting the Cardoso Torrent basin (Upper Versilia).

A Detailed survey and study provided the characterization of the main factors (pluviometric, hydrogeological, geological, geomorphological and geotechnical), which contributed to the landslide triggering. In particular, some factors were recurrent in the landslide sites: bedrock features (impermeable bedrock, discontinuity dipping downslope), slope morphology (hollow shape), geotechnical characteristics (fine, scarcely permeable cover material). Considering the large number of data available, a GIS based mass flow model was used to simulate the debris flow triggering and evolution. The hydrological module in this model describes the infiltration capacity, the percolation of water in the unsaturated zone and the water fluxes in the saturated zone. Slope stability is described by means of the infinite slope model. It is assumed that unstable

cells during the simulation liquefy and turn into debris flows. The propagation and deposition of these debris flows is simulated according to several rheological propagation models. There is an option to simulate erosion in the channel by debris flows using the concept of undrained loading. Scouring of in situ material by the debris flow is considered and calibrated using a mass balance analysis of the source material and the deposited material.

With this model we tried to give an answer to the hydrological triggering mechanism of the soil slips and to the factors, which determine the run-out distances of the debris flows.

The hydrological triggering can occur in two ways:

- Advancement of a waterfront of infiltrating water in the unsaturated zone until a critical depth.

- Building up of pore pressure in the saturated zone until a critical value.

Concluding, this model allowed to analyse the most sensitive parameters, which determine propagation and deposition of debris flows by testing different rheological models.