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Hydrological control on the triggering of debris flows in alpine catchments: storm analysis and basin response variability

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Three storm events, occurred in 2006, 2007 and 2009 in the upper Adige River basin (Eastern Alps, northern Italy) have been analyzed. The first storm system (4 October 2006) generated a flash flood with almost no debris flows and landslides, the second (21 June 2007) triggered a large number of debris flows and was characterized by a relatively minor runoff response, and the third (4 September 2009) resulted in both a relevant flash flood response and debris flows in minor streams. A strong interest both for civil protection and research purposes has been devoted by local authorities and researchers to such events. The study methods include radar rainfall analysis, hydrological modeling and GIS processing of spatial rainfall data and debris-flow locations. Precise information on debris-flow location and related volumes were derived from a geo-spatial database of instability phenomena implemented and managed by the Autonomous Province of Bolzano.
Patterns of rainfall distribution and relations between the main hydrological variables (cumulative rainfall, intensity and antecedent moisture) have been analyzed to explain differences in catchments responses between the three studied events. Radar rainfall data have permitted to analyze rainfall fields with high spatial resolution, taking into account also the elevation variability of rainfall rates. The striking responses' contrast among the three events is related to differences in antecedent moisture, space-time structure of the rainstorms, cumulative rainfall and intensity distributions and temperature regime. The frequency analysis of the main hydrological variables revealed to be a powerful tool capable of distinguishing, within a synoptic framework, the space-time-magnitude variability of the events, so as to highlight the differences in flood and debris-flow response.