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Precipitation thresholds and debris flow warning: comparing gauge versus weather radar detection

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Methods relying on rainfall thresholds for debris-flow warning have a long tradition in geomorphology. Usually, the precipitation thresholds are developed based on rain gauge and debris flows data. However, it is well known that extreme rainfall sampling errors over rugged topography may lead to biased precipitation thresholds. At least two reasons contribute to such sampling errors: i) the regions of complex topography have low rain gauge densities; ii) orography may enhance intense precipitation at very localized places.
We studied six storm events that triggered several debris flows each over the Trentino-Alto Adige Region, in the central Italian Alps, between 2005 and 2010. The region is monitored by i) a rain gauge network with an average density of 1/100 km2 and ii) a C-band radar instrument. Radar data have been accurately corrected for errors due to ground clutter contamination, beam blockages, vertical profile of reflectivity, attenuation and wet radome in order to obtain a high quality set of radar-based rainfall fields.
We characterized the variability of each rainfall event using space (horizontal) and time variograms and we investigated the altitude (vertical) distribution of rainfall using hypsometric rainfall moments. We also defined the local severity of the rainfall accumulations over the debris flow areas for different time accumulations. We used the radar precipitation fields to represent space-time rainfall variability and we simulated gauge sampling with a stochastic model accounting for sub-grid variability of precipitation and for gauge measurement errors.
We show that rain gauges systematically underestimate the local severity over the proven debris flow triggering locations. This leads to biased precipitation thresholds. In this respect gauge spatial sampling appears inappropriate both in the horizontal and in the vertical dimensions while the usual gauge time sampling looks appropriate. Moreover, this shows the potential of rainfall estimates based on weather radar for debris flows warning.