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Assessment of hyperconcentrated-flow hazard with methodological examples in Calabria (southern Italy)

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In Calabria, events of slope instability (soil erosion and shallow landslides) are quite frequent as a result of severe rainstorms that induce flash floods. These latter mobilize volumes of debris accumulated in the floodplains, usually experiencing dry conditions for long periods. The flows, enriched by significant amounts of solid materials, commonly impact against obstacles along their paths. The volumetric concentration, C, of the flows makes it necessary to model them as intermediate types between river currents (C < 5%) and debris-flow (C > 60%).
To properly assess hyperconcentrated-flow hazard requires a combination of different disciplinary skills, ranging from geology to hydrology, hydraulic, and mathematical modelling. The main issues to be addressed include: (i) defining the design storm, characterized in probabilistic terms; (ii) defining the corresponding hydrogram and sedimentogram; (iii) understanding the hydraulic geometry of the riverbed; (iv) delimiting the computational domain and characterizing its physical properties; (v) characterizing the fluid based on rheological assumptions.
In this study, a methodological proposal and the results obtained for two case studies in Calabria are described. In particular, the Esaro of Crotone river and the Mercaudo stream have been selected as study areas. In the first study case, a recent geo-hydrological disaster was caused by the invasion of hyperconcentrated-flows in the urbanized area of Crotone, resulting in 6 victims and notable damage. For this event, the return period of the daily rainfall was known (63 years); the recorded rainfall and the instantaneous unitary hydrogram were available, together with other data (e.g., hydric levels at selected cross sections, flooded areas). Nevertheless, a parametric analysis had to be performed on some of the physical parameters (e.g., C in function of the liquid discharge, the duration of each simulation, the roughness coefficient, the size of the elementary cell, etc.), aiming at obtaining reasonable results that could be compared to the real cases. For the Mercaudo study case, the analysis resulted to be even more complex, as the design storm and the related hydrogram and sedimentogram had to be computed for different return periods.
By considering a set of different scenarios, hyperconcentrated-flow hazard maps could be obtained by applying the sedimentograms for different return periods (from 25 to 200 years). Such flows are assumed to be originated by erosion and progressive enrichment in solid fraction of hydraulic flows, being available sufficient amounts of debris along the slopes and the channels. The triggering factors of such erosive events are represented by severe storms, characterized by a range of cumulated rains, maximum intensities and return periods. Based on performed simulations, useful insights on risk mitigation countermeasures can be obtained. In addition, by considering maximum flow velocities and depths, some considerations on the destructive power of the simulated hyperconcentrated flows are also presented.