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Considerations on rockfall hazard mapping based on trajectory modelling

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The paper presents first considerations about methodologies for local hazard mapping related to rockfalls. This work is being currently carried out at the Swiss Federal Institute of Technology of Lausanne (EPFL), and it concerns the ESR8 research position within the framework of the Mountain Risks project (Marie Curie Research Training Network, funded by EC). The main aim of the research is to collect and use the most recent approaches and results in hazard analyses in order to develop an improved methodology for a detailed rockfall hazard mapping at local scale (and for risk mapping as well, likely at catchment scale). The resulting hazard maps will provide important informations for land-use planning and for the design and location of protective measures (together with appropriate risk considerations).

The basis of the hazard mapping procedure that is going to be used in this research project is constituted by the methodology CADANAV, developed at EPFL's Rock Mechanics Laboratory for the Canton of Vaud in Switzerland. It takes into account the temporal frequency of rockfall events, the number of blocks released together with their intensity, to define three different degrees of danger (high, moderate and low), which will allow to obtain the rockfall related hazard zoning. To apply the method, a probability of failure of the unstable rock mass has to be known. Then, the probability of propagation of the detached blocks must be evaluated, that is the probability that a block reaches a selected area with a given intensity. By means of rockfall simulations, the energy profiles and the trajectories of the blocks can be analyzed to evaluate the magnitude of the rockfall, as well as the spatial extent of the process. By analyzing the trajectory results, probability curves for fixed energy thresholds can be drawn, know-

ing the cumulative frequency of the blocks that reach a particular abscisse along the profile with a given energy value. Then, considering assigned failure return periods, the frequency-intensity informations can be crossed to obtain the extension (limits) of areas characterized by high, moderate and low danger. This step is completed by calculating the probability of propagation for each fixed "intensity-return period" couple (according to a diagram proposed by the Swiss Federal Guidelines) and by determining the abscisses (danger zone limits) beyond which the probability of propagation is lower than the calculated value.

After the presentation of the CADANAV methodology, the paper will evaluate the influence on hazard mapping of three modelling scenarios: i) a change in the temporal probability of failure, ii) the longer propagation of an "extreme" block, iii) the number of runs performed in the trajectory modelling.

(i) Since the CADANAV methodology takes into account the temporal probability of failure of a rock mass, it can describe the evolution of the hazard level due to changes in triggering factors. For instance, if the number of events per unit of time is increasing, the areas at higher hazard levels will be larger i.e. the limits of the danger zones move downslope.

(ii) Compared to other methods, the CADANAV methodology is not very sensitive to eventual "extreme events" obtained from the computer simulations, i.e. the limits defined by the procedure are hardly influenced by the long propagation of an extreme block.

(iii) Moreover, the hazard mapping obtained by CADANAV is also not highly dependent on the number of runs performed in rockfall simulations. If one simulation is constituted by (e.g.) 300 runs and another one by 10'000 runs, the limits of the high, moderate and low danger zones will not be affected by significant changes. So it is, if one compares the hazard mapping obtained by several simulations of (e.g.) 300 runs.

The approach developed for the CADANAV methodology is consistent with the Swiss Federal Guidelines (intensity-frequency diagram characterized by its own energy and return period values), but it could be applied as well for different combinations of rockfall intensity thresholds and return period values, according to the laws and guidelines of other countries.