Geophysical Research Abstracts, Vol. 9, 04165, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-04165

Optimal design of a small dam for mitigation against dense snow avalanches: classical and Bayesian computations

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Mitigation against snow avalanches generally involves considering high return period avalanches for hazard mapping and dam designing. This approach is however problematic as soon as different variables such as runout distance, pressure or velocity are considered because there is a one to one mapping between a return period and a probability quantile only for univariate variables. This theoretical difficulty can be avoided by minimizing the expected loss using the combination of the hazard model with a cost function.

This study applies such an economical approach to the design of a small vertical dam for the protection of one or several buildings against dry dense snow avalanches. The avalanche model combines a propagation operator with a Voellmy constitutive law and an adapted probabilistic formalism. It is calibrated on the studied site using the available data, so as to obtain the joint probability distribution of the local characteristics of dense snow avalanches. The dam effect is quantified in terms of runout distance and velocity reduction with a simple empirical relation. The cost corresponding to each couple dam height-hazard value is roughly quantified with a construction and amortizing term and the evaluation of the corresponding damage. The loss function compares for a given hazard value the cost of choosing a certain height for the dam and the cost without any dam. The risk function is then obtained by considering the mathematical expectation of the loss function. Computations are provided in both a classical and a Bayesian set-up and illustrated with a real case study. The Bayesian framework avoids choosing a punctual estimator for the unknown quantities of the hazard model, but computation times are increased due to the averaging over the posterior distribution. It appears that the Bayesian optimum is more pessimistic than the classical because of the increasing effect of parameter uncertainty. Sensitivity to the cost ratio and to the position of the exposed buildings is discussed.