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Refining calibration and predictions of a Bayesian statistical-dynamical model for long term avalanche forecasting using dendrochronological reconstructions

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A crucial step for proposing relevant long-term mitigation measures in long term avalanche forecasting is the accurate definition of high return period avalanches. Recently, "statistical-dynamical" approach combining a numerical model with stochastic operators describing the variability of its inputs-outputs have emerged. Their main interests is to take into account the topographic dependency of snow avalanche runout distances, and to constrain the correlation structure between model's variables by physical rules, so as to simulate the different marginal distributions of interest (pressure, flow depth, etc.) with a reasonable realism. Bayesian methods have been shown to be well adapted to achieve model inference, getting rid of identifiability problems thanks to prior information.

An important problem which has virtually never been considered before is the validation of the predictions resulting from a statistical-dynamical approach (or from any other engineering method for computing extreme avalanches). In hydrology, independent "fossil" data such as flood deposits in caves are sometimes confronted to design discharges corresponding to high return periods. Hence, the aim of this work is to implement a similar comparison between high return period avalanches obtained with a statistical-dynamical approach and independent validation data resulting from careful dendrogeomorphological reconstructions.

To do so, an up-to-date statistical model based on the depth-averaged equations and the classical Voellmy friction law is used on a well-documented case study. First, parameter values resulting from another path are applied, and the dendrological validation sample shows that this approach fails in providing realistic prediction for the case study. This may be due to the strongly bounded behaviour of runouts in this case (the extreme of their distribution is identified as belonging to the Weibull attraction domain).

Second, local calibration on the available avalanche chronicle is performed with various prior distributions resulting from expert knowledge and/or other paths. For all calibrations, a very successful convergence is obtained, which confirms the robustness of the used Metropolis-Hastings estimation algorithm. This also demonstrates the interest of the Bayesian framework for aggregating information by sequential assimilation in the frequently encountered case of limited data quantity. Confrontation with the dendrological sample stresses the predominant role of the Coulombian friction coefficient distribution's variance on predicted high magnitude runouts. The optimal fit is obtained for a strong prior reflecting the local bounded behavior, and results in a 10-40 m difference for return periods ranging between 10 and 300 years. Implementing predictive simulations shows that this is largely within the range of magnitude of uncertainties to be taken into account. On the other hand, the different priors tested for the turbulent friction coefficient influence predictive performances only slightly, but have a large influence on predicted velocity and flow depth distributions. This all may be of high interest to refine calibration and predictive use of the statistical-dynamical model for any engineering application.