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A probabilistic model for snow avalanche occurrence

P. Perona (1), A. Miescher (1), A. Porporato (2,3)

(1) Institute of Environmental Engineering, ETH Zurich, Zurich, CH (perona@ifu.baug.ethz.ch), (2) Duke University, Durham, NC, USA (amilcare@duke.edu), (3) Visiting Professor at ENAC, EPF Lausanne, Lausanne, CH

Avalanche hazard forecasting is an important issue in relation to the protection of urbanized environments, ski resorts and of ski-touring alpinists. A critical point is to predict the conditions that trigger the snow mass instability determining the onset and the size of avalanches. On steep terrains the risk of avalanches is known to be related to preceding consistent snowfall events and to subsequent changes in the local climatic conditions. Regression analysis has shown that avalanche occurrence indeed correlates to the amount of snow fallen in consecutive three snowing days and to the state of the settled snow at the ground. Moreover, since different type of avalanches may occur as a result of the interactions of different factors, the process of snow avalanche formation is inherently complex and with some degree of unpredictability. For this reason, although several models assess the risk of avalanche by accounting for all the involved processes with a great detail, a high margin of uncertainty invariably remains.

In this work, we explicitly describe such an unpredictable behaviour with an intrinsic noise affecting the processes leading snow instability. Eventually, this sets the basis for a minimalist stochastic model, which allows us to investigate the avalanche dynamics and its statistical properties. We employ a continuous time process with stochastic jumps (snowfalls), deterministic decay (snowmelt and compaction) and state dependent avalanche occurrence (renewals) as a minimalist model for the determination of avalanche size and related intertime occurrence. The physics leading to avalanches is simplified to the extent where only meteorological data and terrain data are necessary to estimate avalanche danger. We explore the analytical formulation of the process and the properties of the probability density function of the avalanche process variables. We also discuss what is the probabilistic link between avalanche size and preceding snowfall event and how this correlates to the local terrain slope. The expected intertime statistics between avalanche events and the related size distributions are obtained and discussed. This allows us to assess the likelihood of overestimating or underestimating the avalanche risk by assuming a direct correlation with preceding snowfall events.