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Prediction reliability and return times of natural snow avalanche occurrence

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The process of snow avalanche formation is inherently complex and different type of avalanches may occur as a result of the interactions of different factors, resulting in some degree of both space and time unpredictability. We model the occurrence of natural snow avalanches by means of the state-dependent stochastic point process in continuous time formerly presented by Perona et al. (2009), the full analytical solution of which has now been obtained. The time dynamics of snow depth h is mathematically described as marked Poisson snowfall events, after which h decreases deterministically because of snowmelt and compaction. Avalanches are also treated as a stochastic Poisson process, whose frequency depends on the state of the variable h, and acts as a renewal event for the entire process, i.e resetting the variable h to zero for the sake of mathematical tractability.
In this paper, we show the statistical distributions for the snow depth, the avalanche size and intertime of occurrence, as a function of snowfall, slope aspect and compaction rate parameters. By using classic Peak over Threshold theory we also compute the Return Time (RT) of both snowfalls and avalanche sizes. We then use such results in order to inquire the origin of the different RT that are often observed between avalanches and preceding intense snowfalls. We find that a gradual decorrelation occurs between size and RT of avalanche events from that of intense snowfalls as the terrain slope decreases within the range of instability (i.e. slopes > 25°). This is due to the important role played by the snow compaction dynamics, which is on the contrary less influent on high slopes where the load increase due to new snow alone drives the detachment. Hence, we discuss how the spatial variability of hydroclimatic conditions (i.e. precipitation and compaction rate), and topographic characteristics (i.e. slope) influence our ability of predicting the statistics of detachment catchmentwise.
Although simplified, this modeling framework is useful both to forecast avalanche hazards to people and the built environment, and to model snow redistribution mechanisms affecting glaciers recharge and freshwater availability.