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Snowfall and avalanche synchronization: beyond observational statistics

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We present a methodology for quantifying the synchronization between snowfall and avalanches in relation to slope and terrain properties at the detachment zone. Focusing on a particular field situation (SLF study site, Vallée de la Sionne, Valais, Switzerland), we present a dataset consisting of 549 avalanche events and use a stochastic framework (Perona et al., Proceedings of the Royal Society A, 2012) for capturing the avalanche statistics with a minimal number of ingredients. Over the observation period (7 years), meteorological data was collected and pictures of the slope were taken every 30 minutes. For the avalanche events, slope, aspect, coordinates and altitude of the detachment zone are available from georeferenced images, and the timing of the events can be obtained from selecting the images before and after avalanche events.

All model parameters can directly be computed from meteorological data (snow depth evolution), except for one parameter: the state-dependent avalanche release rate, which aggregates the influence of slope and terrain properties. From the timing distribution of the precipitation events and of the avalanche events, we calibrate the model and fix the value of the missing parameter by maximizing the likelihood of the field observations, conditional to the value of the model parameter. We carefully discuss confidence intervals for our parameter estimation.

The calibrated model allows us to obtain statistical properties of the avalanches in our study site, beyond observational statistics. We compute the synchronization between snowfall and avalanches for low and high slopes, which in turn allows us to derive the return period of avalanche events (dependent and independent on the release depth). We obtain the critical event magnitude above which the return period of avalanche events with release depth h* is shorter than the return period of snowfall with equal deposited snow depth h*. Finally, using the concept of information entropy, we quantify the uncertainty in predicting the occurrence of an avalanche from the observation of snowfall.