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Determination of snow avalanche return periods using a tree-ring based reconstruction in the French Alps: cross validation with the predictions of a statistical-dynamical model

Romain Schläppy (1), Nicolas Eckert (2), Vincent Jomelli (1), Delphine Grancher (1), Daniel Brunstein (1), Markus Stoffel (3,4), and Mohamed Naaim (2)

(1) Laboratoire de Géographie Physique, UMR 8591 CNRS, France, (2) IRSTEA, UR ETGR, France, (3) Laboratory of Dendrogeomorphology, University of Berne, Switzerland, (4) Climatic Change and Climate Impacts, University of Geneva, Switzerland

Documenting past avalanche activity represents an indispensable step in avalanche hazard assessment. Nevertheless, (i) archival records of past avalanche events do not normally yield data with satisfying spatial and temporal resolution and (ii) precision concerning runout distance is generally poorly defined. In addition, historic documentation is most often (iii) biased toward events that caused damage to structure or loss of life on the one hand and (iv) undersampled in unpopulated areas on the other hand. On forested paths dendrogeomorphology has been demonstrated to represent a powerful tool to reconstruct past activity of avalanches with annual resolution and for periods covering the past decades to centuries. This method is based on the fact that living trees may be affected by snow avalanches during their flow and deposition phases. Affected trees will react upon these disturbances with a certain growth response. An analysis of the responses recorded in tree rings coupled with an evaluation of the position of reacting trees within the path allows the dendrogeomorphic expert to identify past snow avalanche events and deduced their minimum runout distance.

The objective of the work presented here is firstly to dendrochronogically -reconstruct snow avalanche activity in the Château Jouan path located near Montgenèvre in the French Alps. Minimal runout distances are then determined for each reconstructed event by considering the point of further reach along the topographic profile. Related empirical return intervals are evaluated, combining the extent of each event with the average local frequency of the dendrological record. In a second step, the runout distance distribution derived from dendrochronological reconstruction is compared to the one derived from historical archives and to high return period avalanches predicted by an up-to-date locally calibrated statistical-numerical model. It appears that dendrochronological reconstructions correspond mostly to rare events, i.e. to the tail of the local runout distance distribution. Furthermore, a good agreement exists with the statistical-numerical model's prediction, i.e. a 10-40 m difference for return periods ranging between 10 and 300 years, which is rather small with regards to the uncertainty levels to be considered in avalanche probabilistic modeling and dendrochronological reconstructions.

It is important to note that such a cross validation on independent extreme predictions has never been undertaken before. It suggest that i) dendrochronological reconstruction can provide valuable information for anticipating future extreme avalanche events in the context of risk management, and, in turn, that ii) the statistical-numerical model, while properly calibrated, can be used with reasonable confidence to refine these predictions, with for instance evaluation of pressure and flow depth distributions at each position of the runout zone. A strong sensitivity to the determination of local avalanche and dendrological record frequencies is however highlighted, indicating that this step is an essential step for an accurate probabilistic characterization of large-extent events.