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Improvement of snow avalanche hazard and vulnerability assessment in the French Alps using a combination of dendrogeomorphic and statistical approaches

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Snow avalanches constitute major threats for human activities, settlements and infrastructure in mountain environments. In a context of constant demographic growth, populations tend to build infrastructure closer to areas influenced by natural hazards. In the Chamonix region (France), for instance, twelve persons were killed by an extreme snow avalanche in 1999. Such high-magnitude snow avalanches are relatively rare but of interest for research and administration since they correspond to those events which can potentially affect human infrastructure and their residents. Probabilistic models have been used in the past to determine snow avalanche extent of extreme events based on e.g., release and run-out altitudes or topographical characteristics. In France, such data is compiled by the Cemagref in a database called EPA (Enquête Permanente sur les Avalanches) which contains information on $\sim$70,000 events from 4400 avalanche sites since AD 1900. The database contains a huge number of historical accounts on avalanche events but lacks accuracy as one goes back in time. In fact, stringent rules for a complete recording of event characteristics have only been implemented in 2001. A real need for empirical data therefore exists to compare and complement archival records with additional quantitative information. Dendrogeomorphology appears to be an appropriate tool to close the data gap and to provide field evidence for past avalanches and consecutively for the spatio-temporal reconstruction of high-magnitude, low-frequency snow avalanche events. As part of the French research project MOPERA aiming at the improvement of snow avalanche and vulnerability assessment in France, we use dendrogeomorphic techniques to analyze avalanche paths in the French Alps. Results of this study will yield additional details to existing historical data on run-out distance, extent and return periods of extreme avalanche events. One of the main objectives is to compare currently used indices to date avalanche events and to develop new statistical methods based on the number, intensity and position of tree disturbances. Furthermore the results will be confronted with outcomes of the statistical dynamical simulations performed by the Cemagref.