Geophysical Research Abstracts,
Vol. 11, EGU2009-2011, 2009
EGU General Assembly 2009

Assessing the impact of climate change on snow avalanche activity in France over the last 60 winters using hierarchical Bayesian change point models

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Snow avalanches are mainly ruled by temperature fluctuations, heavy precipitations and wind regimes, so that climate change is likely to modify the frequency and magnitude of both ordinary and extreme events. However, these possible changes are not taken into account in the current engineering practice: reference scenarios and return periods for avalanche hazard management are always computed under the assumption of a stationary process. On a more phenomenological point of view, contrary to other phenomena such as tropical storms, snow avalanches are very rarely used as proxy indicators that point out signals of climate change.

This study focuses on avalanche occurrences and runout altitudes in France over the last 61 winters. A spatio-temporal modelling framework is proposed to quantify the interannual fluctuations of these two critical variables resulting from climate change. The regional annual component is isolated from the total variability using a nonlinear analysis of variance. Moreover, the latent structured time trend is distinguished from the random noise with different time series shifting level sub-models. The hierarchical structure obtained takes into account the uncertainty related to the estimation of the annual component for the quantification of the time trend. Bayesian inference is performed using Monte Carlo simulations.

No strong modifications in mean avalanche frequency or in the number of winters of low or high activity could be found over the last 60 years. This suggests that climate change has recently had little impact on the avalanching rhythm in France. Significant temporal patterns have though occurred, including complex combination of abrupt changes and pseudo-periodic cycles of approximately 15 years.

On the contrary, a change in runout altitude regime has occurred in France around 1977. Between 1946 and 1977, a decrease of 55 m has affected the mean runout altitude, but the probability of a high magnitude event has remained constant. After the change point, the mean runout altitude has regained its initial state, whereas the probability of a high magnitude avalanche has been divided by two. A retreat of avalanche is therefore engaged in France since nearly 30 years, which may be related to climate worming. This especially concerning high magnitude events, even if winters with many high magnitude events remain possible due to the increase of the interannual variability over the same period.