DECREASE OF SNOW AVALANCHES ACTIVITY AND PROLIFERATION OF WET SNOW AVALANCHES IN FRENCH ALPS UNDER CLIMATE WARMING

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ABSTRACT: The processing of the data, including cross analysis, of two well documented databases of snow and avalanches in France Alps (namely EPA avalanches chronicle and ERA40 reanalyzes of snow mantle properties) allowed highlighting several trends of avalanche activity as a response to climate warming. Although the avalanche activity has a significant variability, it was shown that, on average, avalanche run-outs and frequencies has decreased over the past thirty years. In addition substantial increase of the annual number and proportion of wet snow avalanches has been highlighted. These trends are concomitant with climate warming. On the one hand, the proven decrease regarding both the frequency and the run-out distances with the expected changes in terms of amount and quality of snow for the next century will tend to reduce the long-term avalanche hazard. On the other hand, the proliferation of wet snow avalanches characterized by long run-outs and strong impact pressures advocate for an increase in avalanche hazard. These two competing trends bring up questions about how to adapt prevention guidelines.

KEYWORDS: snow avalanche, climate change, natural hazard, risk.

1. INTRODUCTION

In recent winters the French Alps have experienced several periods of high activity of wet snow avalanches. Dramatic consequences for infrastructure were observed. Among the most remarkable events, the destruction of the ski lift station at Saint François Long-champ (Savoie, France) in 2/3/2012 by a wet snow avalanche (Figure 1). The process that led to the release of the entire thickness of the snow pack has been very slow. The fracture at the top of the starting area has evolved over almost a month. This behavior made the forecast very difficult. The avalanche has propagated with a high depth (5m) at very low speed (~1m.s^{-1}) and developed strong pressures.

The stakeholder's concerned or involved in the assessment and the mitigation of snow avalanche risk, demand a better clarification and quantification of the relationship between the proliferation of wet avalanches and the global warming. In this context, they are highly concerned about the future long-term evolution of the avalanche hazard so as to anticipate and adapt the regulations and practices.

Figure 1: Wet snow avalanche of 2 March 2012 at Saint François Longchamp (Photos DAG Modane / data-avalanche.org) (with courtesy of Alain Duclos).

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The National Office of Forest (ONF), Irstea and Metéo France has built up a unique set of well documented databases related to snow and avalanches EPA and ERA40 (described hereafter). Several studies using these data allowed evidencing several trends of the avalanche activity as a response to the proven climate warming in the French Alps. The purpose of this short paper is to summarize several proven tendencies notably the number, the type and the extensions of snow avalanches in the French Alps over the period 1959-2009.

2. EPA DATABASE

The EPA (Enquête Permanente sur les Avalanches) is a chronicle describing the avalanche events on approximately 3800 determined paths in the French massif. Avalanche counts have been registered since the beginning of the last century, along with different quantitative and qualitative data. This database is highly valuable for two reasons. First, the data series are unusually long, so that they are now used for local predetermination using physical modeling combined statistical–dynamical approaches (Eckert et al. 2010). Second, the EPA database's is as comprehensive as possible on chosen set of paths. It gives a relatively accurate view of the spatiotemporal fluctuations of avalanche activity in France over the last century. Eckert et al. (2013) have thus highlighted coherent spatial patterns in the northern French Alps. It can therefore be assumed that EPA offers a good opportunity to investigate large-scale temporal fluctuations related to climate change.

3. ERA 40 REANALYSIS DATABASE

The SAFRAN-CROCUS-MEPRA model chain has been used for retrospective snow and weather climate analyses. Using 44 years of newly analyzed atmospheric model data from the European Centre for Medium Range Weather Forecast reanalysis project, and supplemented by datasets from operational databases, the model chain has been run over the period 1959-2009. The simulation setup and the validation of the system are presented in Durand et al. (2009). Various outputs related to snow quantities and properties (derived from the CROCUS model) are available for each of the 23 alpine massifs over the period 1959-2009 for several elevations and four aspects (Casbrunet et al. 2012).

4. MAIN RESULTS

The processing of the data from EPA or the crossing of data issued from the EPA and ERA40 allowed to draw up a diagnostic of the recent evolution of the avalanche activity in the French Alps where since the late 1970s significant changes have been noted. The average number of avalanche per path and per year decreased. The run-out altitudes increased and the proportion of avalanches with aerosol decreased (Eckert et al. 2013) (Figure 3). The proportion of wet avalanches has increased in Chamonix Valley since the mid 1970s (Figure 2).

These changes are concomitant with the increase in the average temperature in the Alps during the same period. Over this period the correlations between the snow friction and the snow properties has been studied in the upper valley of the Arve Chamonix, France. First, it was established that the friction coefficient increases quasi linearly with average temperature. This trend is perfectly consistent with the trends observed in the evolution of run-out altitudes. Second, the friction coefficient decreases sharply when the average liquid water content reaches the threshold of 30 $kg.m^{-3}$. A significant increase of run outs is therefore expected. This last result confirms the recent observed events of very wet avalanches.

5. PERSPECTIVES

A set of matching facts suggests that, due to the increase in temperature in the Alps since 1980, several proven trends of avalanche activity has been established. Except, perhaps, at high altitude and in winter, climate projections for the next century indicate that in the French Alps, on one hand the overall avalanche activity will tend to reduce and on the other hand the proportion of wet avalanches will increase.

In terms of risks, increased humidity of snow will lead to dangerous avalanches for two reasons: increased distances due to a low dynamic friction coefficient at low velocity, and an impact pressure significantly higher than those predicted for flows of dry snow. Current knowledge of wet snow is too limited to accurately quantify these trends. A research effort must now be focused on space-time statistical analysis on a larger scale explicitly dedicated to wet snow avalanches and on the rheology of wet snow in the quasi-static (release) and dynamic (propagation) regimes.

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REFERENCES

Durand, Y., Giraud, G., Laternser, M., Etchevers, P., Mérindol, L., Lesaffre, B., 2009, Reanalysis of 47 Years of Climate in the French Alps (1958—2005), Climatology and Trends for Snow Cover, J. Appl. Meteor. Climat., 48, 2487-2512

Eckert, N., Baya, H., Deschatres, M., 2010. Assessing the Response of Snow Avalanche Runout Altitudes to Climate Fluctuations Us-ing Hierarchical Modeling: Application to 61 Winters of Data in France. Journal of Climate, vol. 23, p. 3157 – 3180.

Eckert, N., Naaim, M., Parent, E., 2010, Long-term avalanche hazard assessment with a Bayesian depth-averaged propagation model, Journal of Glaciology, Vol. 56,198., pp 563-586.

Eckert, N., Keylock, C. J., Castebrunet, H., Lavigne. A., Naaim, M., 2013. Temporal trends in avalanche activity in the French Alps and subregions: from occurrences and runout altitudes to un-steady return periods. Journal of Glaciology. 59, issue 213, pp. 93-114.

Naaim, M., Durand, Y., Eckert, N., Chambon, G. (2013). Dense avalanche friction coefficients : influence of physical properties of snow. Journal of Glaciology. Vol. 59, No. 216. pp 771-782.

Castebrunet, H, Eckert, N., Giraud, G., 2012, Snow and weather climatic control on snow avalanche occurrence fluctuations over 50 year in the French Alps, Clim. Past, 8, 855–875, 2012.

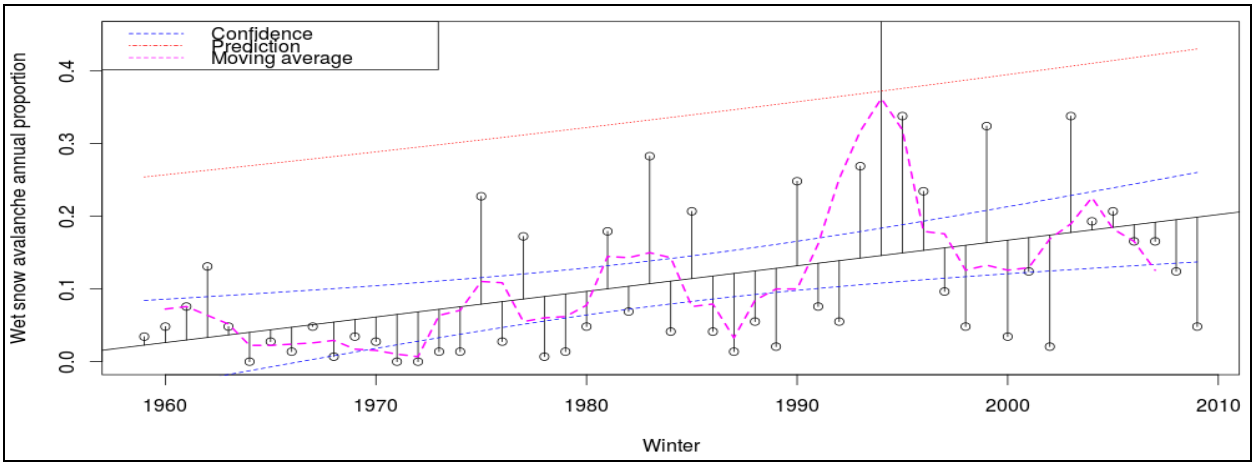

Figure 2 : Wet snow avalanche annual proportion at Chamonix valley, France, over the period 1959-2009 (result obtained by crossing EPA and ERA40 databases, an avalanche is considered wet if its total water content is higher than 10 $kg.m^{-3}$)

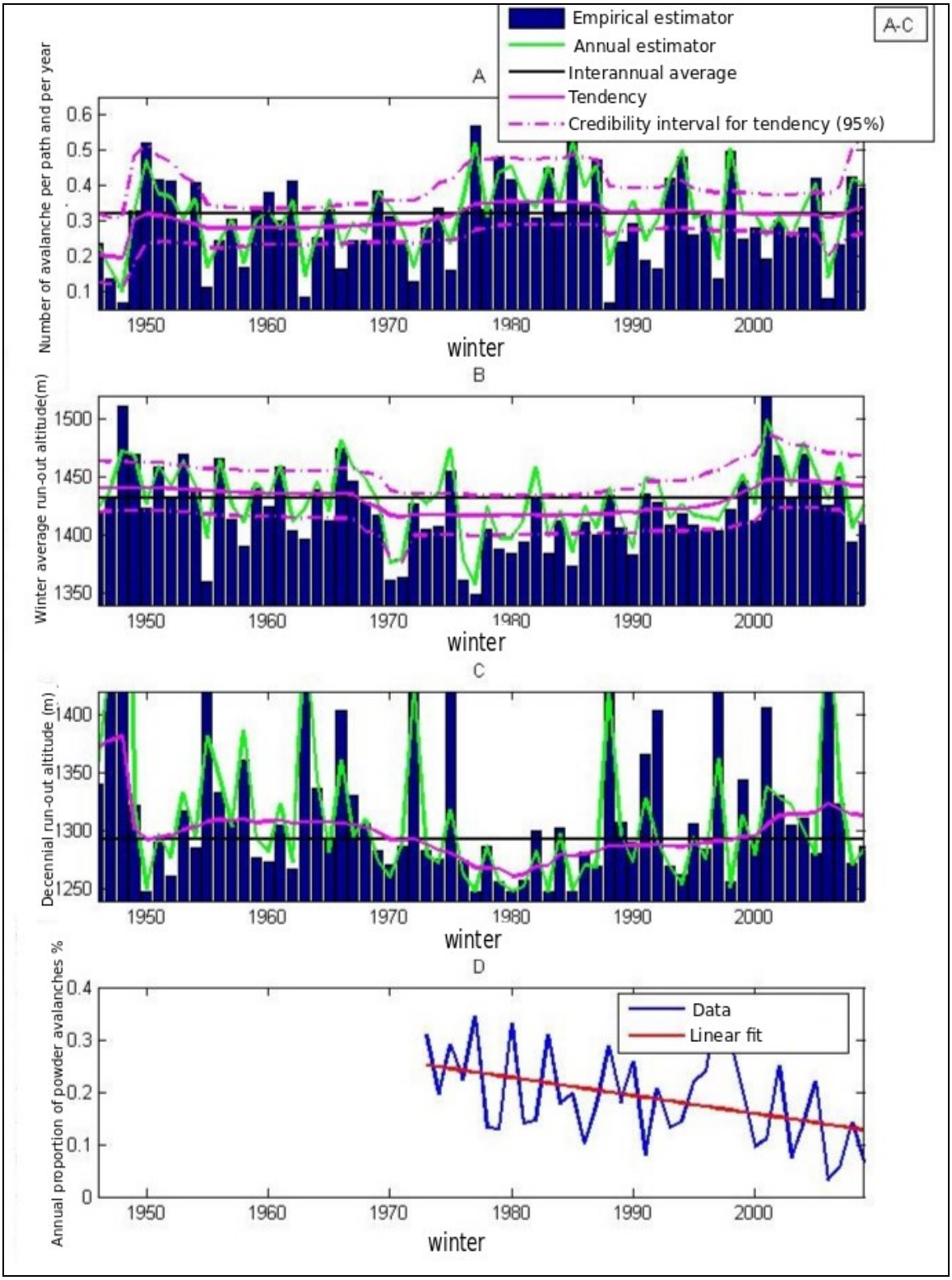

Figure 3: Recent evolutions of avalanche activity in the French Alps (from Eckert *et al.* [2013]), A) Number of avalanche per path and per year, B) Average annual run-out, C) decennial run-out altitude, D) Proportion of avalanches with powder component.