WHAT DO WE KNOW ABOUT THE IMPACT ON THE SNOWPACK IN A CHANGING CLIMATE – A WORK IN PROCESS

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ABSTRACT: This contributions aims at giving an overview of studies on the impact of a changing climate on the snowpack and avalanche activity. Most studies on climate change impacts are local studies and are not directly comparable. The reason for this is due to the geographical settings and due to the different statistical methods used. Besides a visualisation of locations, where studies were performed we summarize the different purposes and statistical methods used in the different studies.

KEYWORDS: climate change, avalanches, statistical methods

1. INTRODUCTION

This contribution shall give on overview of the existing studies on the impact of a changing climate on the snowpack and avalanche activity. Most studies on climate change impacts are local studies and are not directly comparable. This is due to the geographical settings and also due to the different statistical methods used. Keeping in mind the critical discussion on the misuse of statistical analysis in climate research by e.g. Storch (1999) we try to consider his concerns for the evaluation of the studies in the specific field of the impact of a changing climate on the snowpack and avalanches activity.

2. STATEMENTS ON AVALANCHE TRENDS AND FUTURE PROJECTIONS

Most of the studies dealing with avalanche activity and climate change state that it is difficult to quantify a trend, no matter which purpose the study had (e.g. run-out height, frequency of avalanches, magnitude).
The following statements are a summary of these studies (see Section 6 – Literature for references):

- Wet snow avalanches will increase due to more frequent and intense melting periods and an elevated snow/rain limit – depending on location
- Decrease of avalanche activity at low and middle altitudes, because of reduced snow-depth, while it may increase at higher altitudes
- Increase of snow stability because of an increase of temperature
- Avalanches stop at higher elevations suggesting that this is an indicator for more wet snow avalanches
- A climate sensitive elevation level is around 1800 m in Austria, which may impact the avalanche activity
- As snow avalanches are mainly caused by temperature fluctuations, heavy precipitation and wind, climate change is likely to modify the frequency and magnitude of both ordinary and extreme events.
- No trends have been observed regarding the frequency and the location of avalanches in the Alps
- Climate change will only affect the lower altitudes
- There is a shift of the avalanche activity between different month

All hypothesis have not yet been verified to a satisfactory degree. Nonetheless, significant associations between temperature and precipitations are observed when comparing dry and wet snow avalanches, despite the incomplete dataset.
Most studies deal with datasets from the past, but do not perform a projection into the future.

3. CHALLENGES USING STATISTICS IN CLIMATE/AVALANCHE RESEARCH

The difficulties to quantify a long-term trend of avalanche activity are, as stated in the publications (see Section 6), due to the following reasons:

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- daily values are important rather than the knowledge of monthly trends
- differences in avalanche activity between winters overlap the general trend of the climatic trend
- there is only one observational record which is analysed again and again so that the processes of building hypotheses and testing hypothesis are hardly separable
- the researcher is not a statistic expert
- almost all data in climate research are interrelated both in space and time
- incomplete datasets hinder a solid interpretation of the avalanche dataset, e.g. only larger events are recorded or only those that caused some damages
- quality of the dataset (e.g. due to different observers)
- Time lags in recordings (e.g. due to poor visibility)
- lack of verification options
- uncertainties in data acquisition
- local peculiarities make it difficult to compare datasets
- once an avalanche released a second in the same position may be less likely
- data from elevation levels that differ from the elevation levels of the release area of the avalanche is used in the analysis
- due to the structural avalanche mitigation in Europe a “natural” dataset is not available
- meteorological factors that are important for wet snow avalanche initiation have not been observed in a climatic relevant period
- the process of wet snow avalanche is not well understood
- stationarity – handling non-stationarity
- treating inhomogeneity caused by non-climatic influences

4. STATISTICS AND PARAMETERS STUDIED

Parameters: Snow depth, Frequency of avalanches, magnitude of avalanches, Snow cover, Snowfall days, Snow line, Extremes, Snow stability during rain, Warm periods, rain-on-snow events, snow level, snow water equivalent, snow density, precipitation type, runout altitudes

Statistical Methods: Binary logistic regression, Descriptive statistics, Box-plots to show significantly different, binomial distributed counts, Monte Carlo simulations, trend analysis (e.g. Kendall’s tau), ordinary least squares regression, extreme value analysis, time series analysis, Bayesian change-point analysis, ARMA, spectral analysis, fluctuation analysis, expert systems, Bayesian probabilistic framework, hierarchical modeling

5. OUTLOOK

This paper only summarizes the ideas for the intended quantitative analysis. A systematic literature review and an objective evaluation of the statistical methods are the next steps.

6. SELECTED LITERATURE

Bellaire, S., B. Jamieson, G. Statham 2013: The avalanche climate of Glacier National Park. Proceedings of the ISSW 2013. 1256-1263.

Castebrunet, H., Eckert, N., Giraud, G., Durand, Y. and Morin, S. 2014: Projected changes of snow conditions and avalanche activity in a warming climate: a case study in the French Alps over the 2020-2050 and 2070-2100 periods. The Cryosphere Discuss., 8, 581-640.

Chimani, B. Böhm, R. Matulla, C. and M. Ganekind 2011: Development of a longterm dataset of solid/liquid precipitation. Adv. Sci. Res., 6, 39-43.

ClimChAlp, 2008: Climate change in the Alps: impacts and natural hazards. ONERC Technical Report No 1.

Dobler, C., Bürger, G. and J. Stötter 2013: Simulating future precipitation extremes in a complex Alpine catchment. Nat. Hazards Earth Syst. Sci., 13, 263-277.

Hug, D. 2012: Uncertainties in natural hazard risk assessment. Master Thesis. Julius-Maximilians-Universität Würzburg.

Laternser, M. and M. Schneebeli, 2002: Temporal trend and spatial distribution of avalanche activity during the last 50 years in Switzerland. Natural Hazards, 27(3), 201-230.

Martin, E., G. Giraud, Y. Lejeune and G. Boudart, 2001: Impact of a climate change on avalanche hazard. Annals of Glaciology, 32(1), 163-167.

Nemec, J., Gruber, C., Chimani, B. and I. Auer 2013: Trends in extreme temperature indices in Austria based on a new homogenised dataset. International Journal of Climatology 33: 1538-1550.

Schneebeli, M., M. Laternser, W. Ammann, 1997: Destructive snow avalanches and climate change in the Swiss Alps. Eclogae Geologicae Helvetiae, 90(3), 457-461.

Stoll, E. 2016: Influences of a warming climate on wet snow avalanche activity. Master Thesis. University of Innsbruck.

Storch, H. 1999: Misuses of statistical analysis in climate research. In: Analysis of climate variability. Applications of statistical techniques; Ed. H. Storch, A. Navarra.

Umbricht, A., S. Fukutome, Liniger, M., Frei, C. and Appenzeller, C. 2013: Seasonal variation of daily extreme precipitation in Switzerland. Scientific Report MeteoSwiss No. 97.