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Long-Term Trends in Annual Ground Snow Maxima for the Carpathian Region

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Abstract: The current structural design provisions are prevalently based on experience and on the assumption of stationary meteorological conditions. However, the observations of past decades and advanced climate models show that this assumption is debatable. Therefore, this paper examines the long-term trends in ground snow load maxima, and their impact on structural reliability. For this purpose, the Carpathian region is selected, and data from a joint research effort of nine countries of the region are used. According to our knowledge, the long-term trends in extreme snow loads, i.e. annual maxima, for this region has not been sufficiently studied yet.

Methodology and results

Stationary and five non-stationary generalized extreme value (GEV) distributions are fitted to the snow water equivalents (SWE) utilizing the maximum likelihood method. First, a linear line is fitted to the annual snow maxima at every grid point by the least-square method, while the snow-free years are discarded from the analysis. The associated slope parameters are illustrated in Fig. **1**, where the negative values are referring to decreasing trend in time. At 97% of 5895 locations negative trend is detected, whereas a mild increase is observed in the northern part of the region, Slovakia, Czech Republic, and Poland.

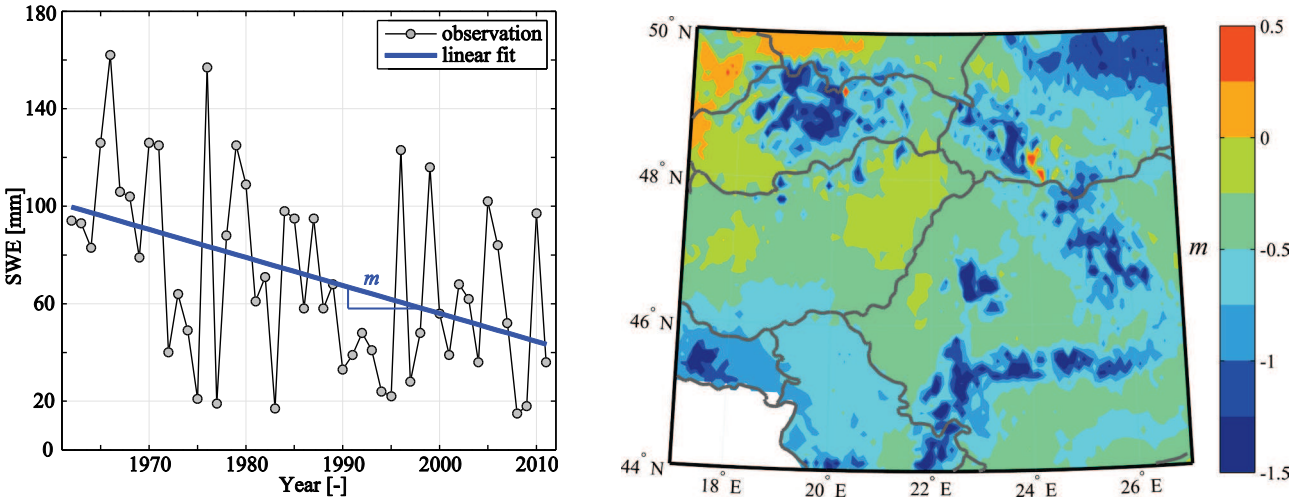

Fig. 1: A representative location with decreasing trend (left), and map of the linear trend line's slope parameter *m* in mm/year (right).

Then statistical and information theory based approaches, likelihood ratio (LR) test and Akaike weights respectively, are used to compare the models and to identify trends. Both approaches reveal that the trend in the annual maxima is better captured by allowing trend in the location parameter

than in the scale parameter of GEV. Hence, the non-stationary model with linear trend in the location parameter (μ1) is used for further study. The characteristic values and confidence intervals are calculated for year 1962 and 2011, for six selected locations. The time trend is deemed practically significant if the stationary estimate is outside of the non-stationary confidence interval. Based on this criterion, only two of the selected locations exhibit practically significant negative trend.

Additionally, reliability analyses are performed for a simple structure to explore the practical significance of the trends. Two locations are examined, one from Hungary with moderate decreasing trend (statistically significant by the LR test), the other one from Ukraine with strong decreasing trend. Reliability is analysed considering a reference period of one year. The location parameter is obtained from the non-stationary model for each of the selected years - 1962, 2011 and 2062. Fig. 2 indicates reliability indices and confidence intervals illustrating effect of parameter estimation uncertainty.

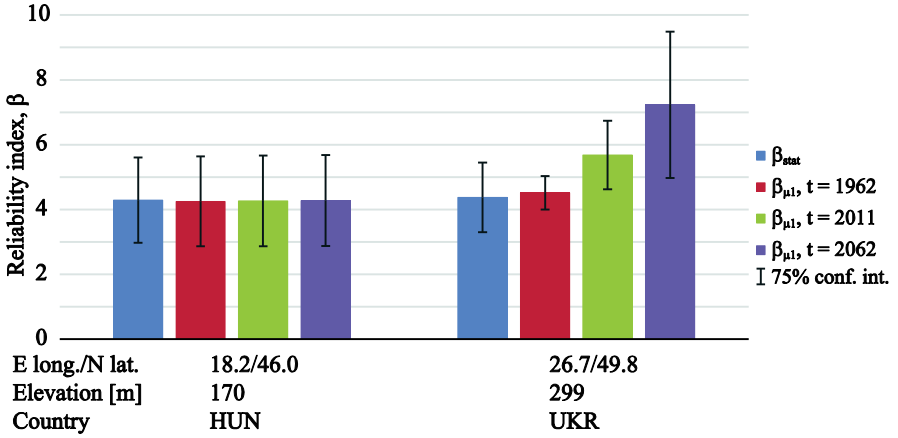

Fig. 2: Reliability indices with 0.75 confidence intervals from ground snow parameter estimation uncertainty.

Conclusions

The main conclusions of the study can be summarized as follows:

- A decreasing trend in annual snow maxima is found for 97% of the studied region.
- The reliability analyses show that the practical significance of time trends not necessary follows the statistical significance. This is largely due to the substantial uncertainty in parameter estimation.
- The simple, limited reliability analyses indicate that for most locations in the region, which are characterized by Fréchet distribution, the negative trend in annual snow maxima has a minor effect on structural reliability, the uncertainty in parameter estimation rules.
- For locations with strong, decreasing trend and Weibull distribution, the impact on structural reliability is practically significant, although the change is favourable from a safety point of view.

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