Winter storms with high loss potential in a changing climate

STRATEGIEN ZUR REDUZIERUNG DES STURMSCHADENRISIKOS FÜR WÄLDER (RESTER)

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Introduction

According to the recent publications of the IPCC, global climate changes are unequivocal and changes in the global climate system will increase in the following decades (IPCC, 2007). But changes of strength and/or occurrence of extreme natural hazards on the regional scale are relatively unknown. Due to the high loss potential of winter storms the knowledge about changes of the storm climate on the regional scales is very important (see Fig. 1).

In the RESTER project the impacts of extreme storm events on the forests are analysed. The investigations are conducted in the framework of the cooperative research project "Herausforderung Klimawandel" funded by the federal state of Baden-Württemberg. Within the RESTER project changes of the winter storm climate in Germany with a special focus on the region of Baden-Württemberg in the southwest of Germany will be characterised.

Figure 1: Losses after the winter storm 'Lothar' (1999) in the Black Forest near Oberkirch in Baden-Württemberg (Photo: Georg Müller).

Data & Methods

The study is based on two regional climate models (REMO and CLM), which are both forced by the global model ECHAM-5. The different model runs have different resolutions and are driven by different emission scenarios. More details can be found in Table 1. Extreme gust speeds for a control (1971-2000) and a projection period (2021-2050) are investigated with the aim to estimate the extreme value distributions at each grid point.

Statistical basis:

- Method of independent storms with a minimum distance of 48 h in the case of hourly values (see Fig. 2).
- 100 strongest events in 30 years (peak over threshold method).
- Generalised Paretro distribution with maximum likelihood method to estimate the free parameters.

	REMO	CLM-KL-run 1	CLM-KL-run 2
Forcing	ECHAM-5 run 1	ECHAM-5 run 1	ECHAM-5 run 2
Emission scenario	A1B, A2, B1	A1B	A1B
Resolution	0,088° ~10 km	0,167° ~18 km	0,167° ~18 km

Table 1: Details of the regional climate model simulations used in this study. Note that run 1 and run 2 are created by different realisations of the global model.

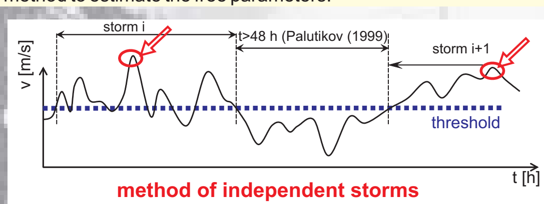

Figure 2: Part of a time series to demonstrate the method of independent storms and the peak over threshold method.

Validation of the control period (C20)

The results of the control period (C20: 1971-2000) are compared with observations to evaluate the climate models (Fig. 3):

- Regional scale effects (e.g. orography or land use) not resolved in ECHAM-5.
- Qualitatively agreement between REMO and CEDIM, but up to 15 % lower gust speeds in REMO than in the storm hazard map.
- Underestimation also confirmed by the SYNOP- stations (Fig. 4).
- Strength of underestimation depends on elevation above sea level, i.e. increase of the differences with elevation.

→ Regional climate modelling is necessary to take into account regional effects, which are especially important for parameters like wind speed or precipitation.

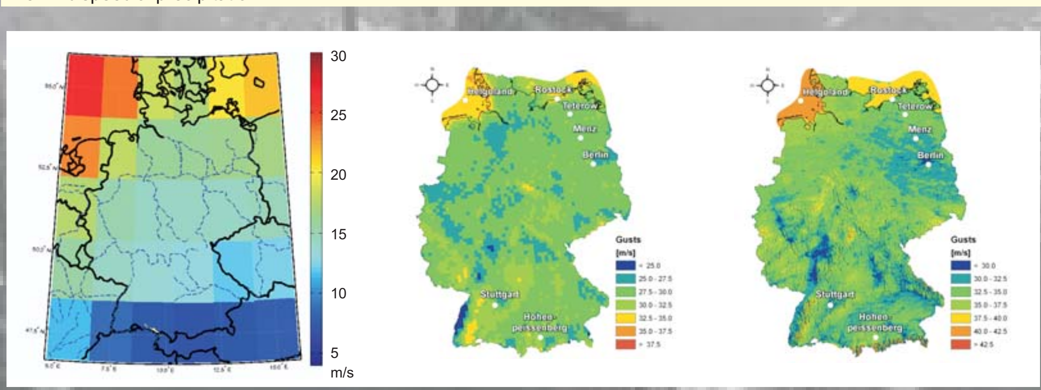

Figure 3: Gust wind speed for a 10-year return period from ECHAM-5 (left, ~280 km), REMO (middle, ~10 km) and CEDIM (right, ~1 km). CEDIM is a storm hazard map from the Center of Disaster management and Risk Reduction Technology (Hofherr and Kunz, 2009). Note the different colour scales.

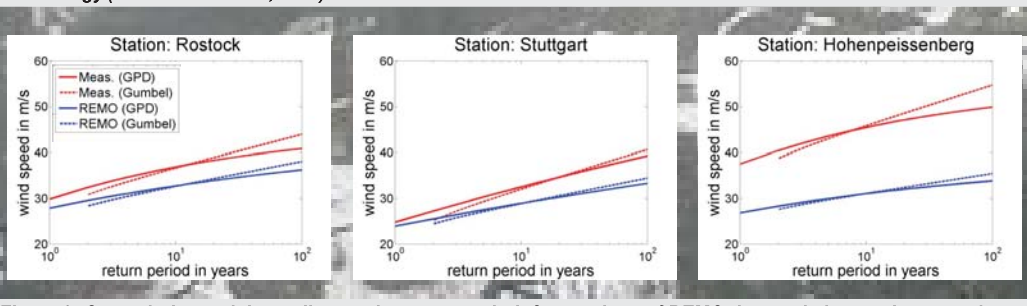

Figure 3: Gust wind speed depending on the return period. Comparison of REMO data and observations at selected SYNOP stations (Rostock, 4 m a.s.l., Stuttgart, 419 m a.s.l. and Hohenpeissenberg, 977 m a.s.l.) using two different distributions: the Gumbel and generalised Paretro distribution.

The systematic underestimation of the gust wind speeds is due to model weakness:

- limited resolution (→ orography, land use) and
- uncertainties in the gust parameterisation.

→ The constraints will not change in the future. Spatial pattern is well reproduced. Since relative climate change signals are quantified, the underestimation of the gust wind speeds in the simulations is not relevant.

References

Della-Marta, P., H. Mathis, C. Frei, M. A. Liniger, J. Kleinn and C. Appenzeller: The return period of winter storms over Europe, Int. J. of Climatology, published online, doi: 10.1002/joc.1794.

Heneka, P., T. Hofherr, B. Ruck und Ch. Kottmeier, 2006: Winter storm risk of residential structures - model development and application to the German state of Baden-Württemberg, Nat. Hazards Earth Syst. Sci., 6, 721-733.

Hofherr, T. und M. Kunz, 2009: Assessment and mapping of extreme wind speeds related to winter storms in Germany, Int. J. of Climatology,submitted.

IPCC, 2007 The Physical Basis: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change edited by Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor and H.L. Miller, Cambridge University Press, Cambridge, United Kingdom and New York, USA, 996p.

Palutikof, J.P., B.B. Brabson, D.H. Lister und S.T. Adcock, 1999: A review of methods to calculate extreme wind speeds, Meteorol. Appl., 6, 119-132, doi:10.1017/S1350482799001103.

Rauthe, M., M. Kunz und S. Mohr, 2008: Winter storms with high loss potential in a changing climate: a regional perspective. 9. Forum Katastrophenvorsorge des DKKVs, 20.-21. November 2008, Offenbach am Main. http://213.23.39.218/download/Forum/9/Rauthe_EA.pdf.

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Changes of the storm climate

REMO results for the A1B emission scenario

In the REMO data for the A1B scenario, in the storm climate locally different signals are found in Germany (Fig. 5):

- Increase as well as decrease of the storm activity.
- Clear influence of the orography.

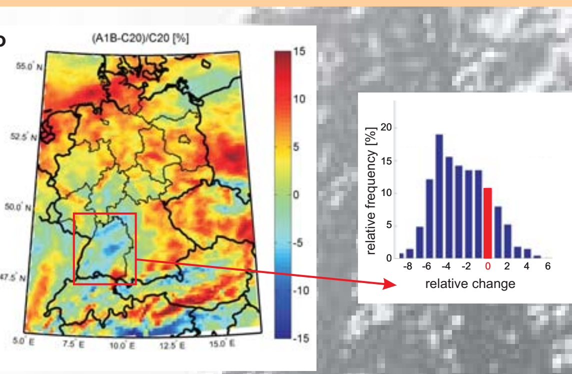


Figure 5: Relative changes of the gust speeds ((A1B-C20)/C20) for a 10-year return period (left). Histogramm of the grid points in Baden-Württemberg (top).

Results of all regional climate projections

The various model calculations can be summarised as follows (Fig. 6):

- In Northern Germany (> 52.5° N) the increase of the storm activity proves true. This increase is statistically significant according to the Wilcoxon rank-sum test (95 % level).
- In Central Germany there are indifferent results: the changes are positive as well as negative.
- In Southern Germany more or less no changes in the storm strength are found.
- The changes of the storm climate seem to be greatly determined by the changes in the global model.

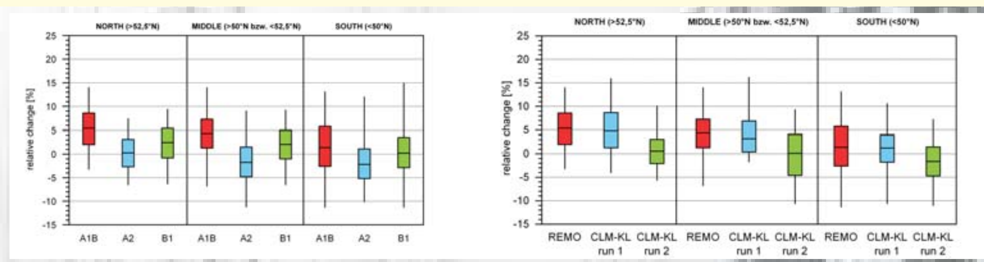


Figure 6: Relative changes of the gust speeds (A1B-C20/C20) for a 10-year return period for different climate model projections. Germany is divided in three parts. The data are from REMO model and the projection period is calculated with three different emission scenarios: A1B, A2 and B1 (left). The other data are from three different model runs of REMO and CLM with the same emission scenario A1B (right).

Ensemble results

An ensemble of the five runs is created on a common grid determined by the model with the lowest resolution to get a better estimation of the reability of the results. The ensemble composite shows which changes of the storm climate are most likely (Fig. 7):

- In Northern Germany the increase of gusts is supported by a high probability.
- In Central and Southern Germany the trends are indifferent
- In the southwest a decrease of the storm activity seems to be possible.

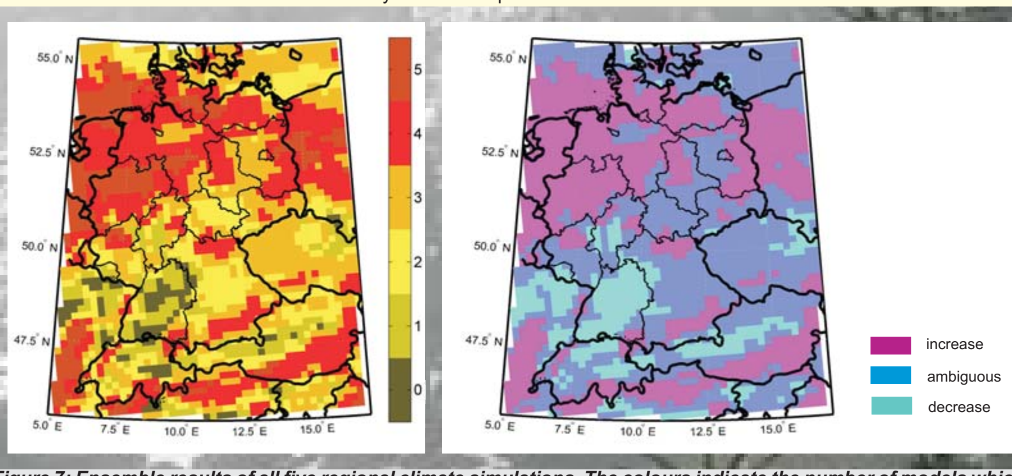


Figure 7: Ensemble results of all five regional climate simulations. The colours indicate the number of models which projects an increase of the storm activity, i.e. a positive change of the gust wind speed in comparison between projection and control period (left). In the right part of the Figure the regions with increase, decrease or no trend are coloured to interpret the results more easily.

Storm index

Besides the strength of the storms, their horizontal extension is an important factor for the loss potential. To combine both, the following storm index is used (Della-Marta et al., 2008):

$$\frac{1}{N}\sum_{i=1}^{N} a \cdot \frac{v(i) - q95(i)}{q99(i) - q95(i)} \quad \text{with } a = \begin{cases} 1 & : \; v(i) - q95(i) > 0 \\ 0 & : \; other \end{cases}$$

- i: grid point
- N: number of used grid points
- v(i): gust at each grid point
- q95: 95% quantile at each grid point
- q99: 99% quantile at each grid point

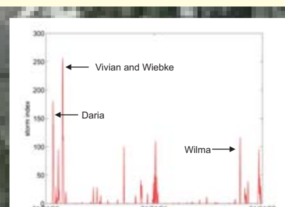
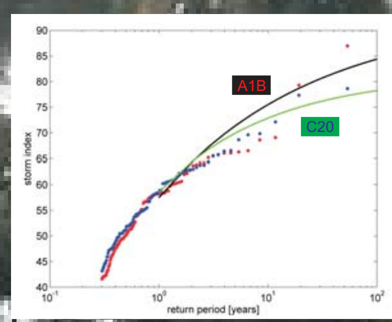


Figure 8: Storm index of Baden-Württemberg for the years 1990 and 1991 calculated from CLM-ERA40 data. Prominent storms are labelled. Note that the regional climate model is forced by the reanalysis data ERA40.



Storm index results:

- Large values of the index related to known storms (Fig. 8)
- Index applicable to regional climate data
- Similar results as for the other method presented above: slight decrease, but not statistically significant in Baden-Württemberg (Fig. 9).

Figure 9: Storm index depending on the return period calculated from REMO data for Baden-Württemberg. The calculations are done for the C20 and the A1B period. The points represent the original data and the lines are the results of the distribution fit.

Conclusions & Outlook

The results can be summarised:

- The spatial pattern of gust wind speeds are well reproduced in regional climate models , but the underestimation is sytematic.
- Only in Northern Germany the changes of the storm climate are significant; an increase of gust speed is predicted.
- The storm index reproduces the results of the gust analysis.

In the future we have the following plans:

- Extension of the ensemble to consolidate the results.
- The storm index should be developed concerning financial and other losses.