Winter storms with high loss potential in a changing climate: a regional perspective

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1 Introduction

In the recent publications of the IPCC changes of the global climate are unequivocal (IPCC, 2007). Increasing changes in the global climate systems are very likely in the following decades and centuries. But changes of strength and/or occurrence of extreme natural hazards on the regional scale are more or less unknown. Due to the low resolution of current global climate models, regional effects can be hardly estimated – especially for parameters like wind speed and precipitation, which are strongly amplified by local scale conditions and orographic effects.
In the project RESTER (Strategien zur Reduzierung des Sturmschadensrisikos für Wälder), various institutions from different research fields investigate the effects and impacts of storms on forests. RESTER is part of the programme “Herausforderung Klimawandel”, which is funded by the federal state of Baden-Württemberg. The principal aim of our part of the project is to characterise the changes in winter storm climate in Germany with a focus on the region of Baden-Württemberg in the southwest of Germany.

2 Data and Methods

This study is based on different data sets from regional climate models. Besides the output of REMO also that of CLM is used. These regional climate models are both forced by the global circulation model ECHAM5. The Max-Planck-Institute for Meteorology in Hamburg model has conducted the runs of ECHAM5 and REMO. In contrast to ECHAM5 with a horizontal resolution of about 210 km, REMO and CLM have a resolution of about 10 and 18 km, respectively. The REMO simulations are commissioned by the Federal Ministry of the Environment. The CLM simulations are a part of the so-called “Konsortialläufe”. The methods described in the next paragraph are applied to the control period (1971–2000) and to the projection period (2021–2050). For the projection period the calculations are generally based on the medium emission scenario A1B, but also one model run with A2 scenario and one with B1 scenario are investigated.
To estimate the reliability of the regional climate data, they are evaluated for the control period against point measurements and results of the so-called storm hazard map from CEDIM (Center of Disaster Management and Risk Reduction Technology) which is presented by Hofherr and Kunz (2008) and Heneka et al (2006).

Extreme value statistics are applied to quantify the storm climate. The analyses are based on the time series of wind gusts at each grid point. The strongest events of every time series are selected with the peaks over threshold-method (POT). To separate the storm events from each other, the minimum time lag between two events has to be 48 h (Palutikof et al., 1999). This method of independent storms (MIS) ensures the independency of the events, which is important for the statistical analysis. From these selected storms the 100 strongest events are picked out and their maximum gusts are fitted with a statistical distribution. The generalized Pareto distribution (GPD) gives the best description of the data (Hosking and Wallis, 1987; Palutikof et al., 1999). From the fitted probability distribution, the strength of storms of a specific return period is estimated. This analysis is applied to every single grid point for both the control and the projection period. The difference of guest wind speed for a specific return period yields the change of storm climate.

3 Results

In previous studies of results from global climate models, an enhancement especially of severe cyclones over Europe is found (see review by Ulbrich et al., 2008 and references therein), but the regional impacts are more or less unknown. Therefore, gust wind speeds of regional climate models are investigated in the following to characterise the storm climate on a regional scale.

3.1 Evaluation of the regional climate models

To evaluate the results of regional climate models, the results of the control period (1971–2000) are compared with observations. In Figure 1 the wind speed of gusts of 10-year return period is shown. Beside the results of REMO (middle) and CEDIM (right) the ECHAM5 data are presented (left). First, ECHAM5 results are compared to REMO results. In the ECHAM5 data small scale conditions and orographic effects are not resolved, e.g. the strong differences in guest wind speeds between the Rhine valley and the Black Forest are only clearly visible in the regional data. This comparison demonstrates nicely why the regional climate modelling is necessary. The maps of REMO and CEDIM agree qualitatively well besides the different resolution, which is a factor 10 higher in CEDIM (1 km) than in REMO (10 km). But the gust wind speeds are up to 15% lower in REMO than in the storm hazard map of CEDIM. Similar results are found for the CLM data.

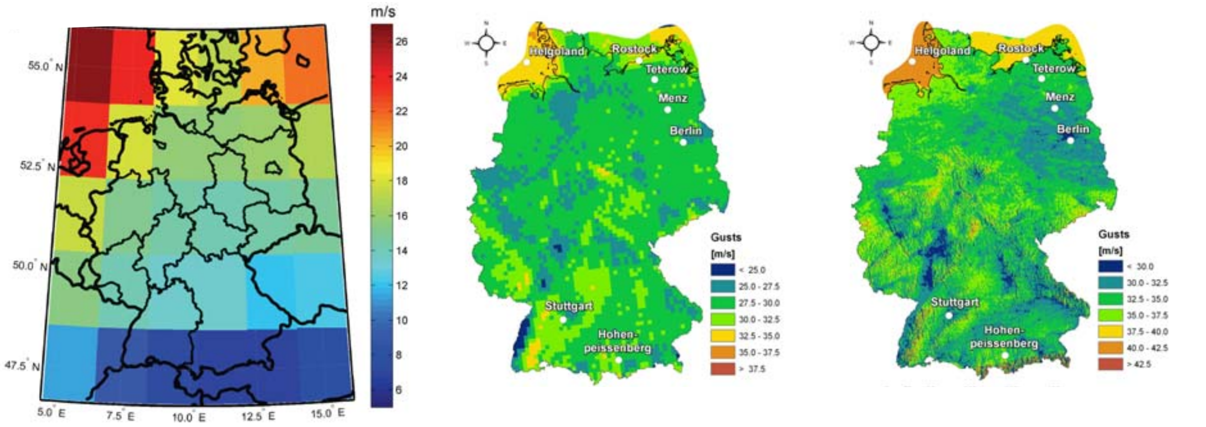

Figure 1: Gust wind speeds of a 10-year return period from ECHAM-5 (left), REMO (middle) and CEDIM (right). CEDIM is a storm hazard map from the Center of Disaster Management and Risk Reduction Technology (Hofherr and Kunz, 2008). Note the different colour scales.

These results are also confirmed by observations at SYNOP stations (Fig. 2). Apart from the underestimation by the model, a dependency on the elevation above sea level is clearly visible. Stations at higher elevations show larger differences between observations and REMO data than those at lower elevations (cf. Rostock at 4 m a.s.l. and Hohenpeissenberg at 977 m a.s.l.). As can be seen in the results for Stuttgart (419 m a.s.l.), the effect exists only if the elevation is significant.

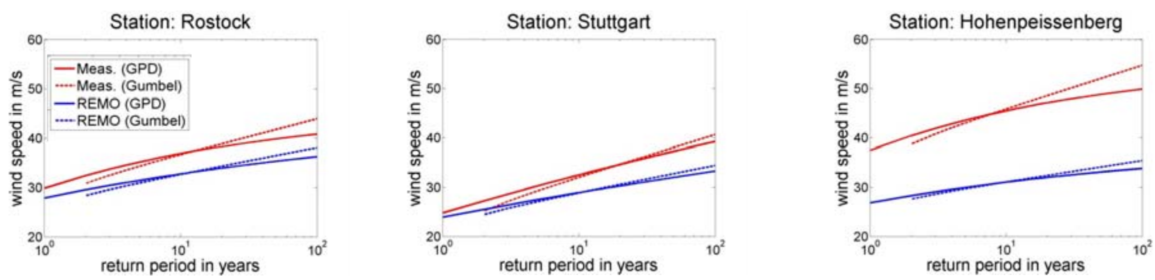

Figure 2: The gusts wind speed depending on the return period. Comparisons of REMO data and observations at selected SYNOP stations using two different distributions: the Gumbel and the generalised Pareto distribution.

Altogether, the underestimations of the gust wind speeds are systematic because of the following weaknesses of the regional model: Orography and land use are only resolved as it is possible by the grid (10 km). Furthermore, the gust parameterisation bears some uncertainties. But these constraints will not change in the future. However, the spatial pattern of the storm climate is well reproduced in the regional climate models. Since relative climate change signals are quantified in the following, the underestimation of the absolute gust wind speeds in the simulations is not relevant.

3.2 Changes of the storm climate in the future

As mentioned above, regional models are able to reproduce qualitatively the storm climate of the past. Figure 3 shows the relative changes between the projection (2021–2050) and the control period (1971–2000) in the REMO data for three parts of Germany. The projection period is forced with the A1B scenario. The future changes of the storm climate vary in the different parts of Germany. In Northern Germany (left panel of Fig. 3) the changes are generally positive, i.e. the storm activity will increase in the future. The results for Central Germany (middle panel of Fig. 3) are similar in these data. In contrast to the growing storm activity in Germany northward of 50°N there is no clear trend in Southern Germany (right panel of Fig. 3) what means that in Southern Germany no changes of storm climate has to be expected. It has to be noted that the distribution is broader and more centred than in the other parts of Germany.

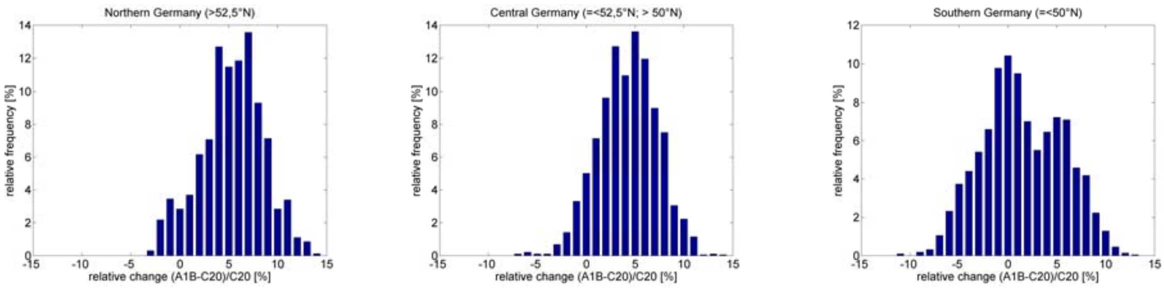

Figure 3: Histograms of relative changes of gust wind speeds between projection and control period relative to the control period for three parts of Germany. Data base is the REMO model with the A1B scenario.

The results for the northern and southern part of Germany are generally in agreement with the results of the REMO data for the B1 and A2 scenarios and also with those of CLM with A1B scenario, i.e. more or less no changes in Southern Germany and an increase of storm activity in the north. In Central Germany between 50°N and 52°N the results are indifferent: the changes are positive as well as negative. But only due to the regional climate models such a differentiation between the regions of Germany is possible. It has to be noted that the changes of the storm climate in regional models are greatly determined by the changes of the global model.

3.3 First results of the storm index

The analyses presented in the previous sections take into account, however, only the strength of the storms in terms of gust wind speed. But the horizontal extension of the storms is also an important factor for the loss potential. To combine the two parameters strength and extension of the storms, the following storm index adapted from Della-Marta et al. (2008) is used:

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

with $v(i)$ representing the gusts at each single grid point i, N all grid points of the examined region and $q95(i)$ and $q99(i)$ the 95% and 99% quantile of the probability distribution, respectively. The index considers only storms with gusts above the 95% quantile. The number of grid points used can be adapted to the region investigated. Moreover, the index is normalised by the tail of the distribution.

To check the storm index, CLM-ERA40 data with a resolution of about 7 km are used. The CLM is forced by ERA40 reanalysis data giving that the data comprise real storm events. A detail of the time series is shown in Figure 4. The region investigated is Baden-Württemberg. As indicated by the names, the large values of the index are related to known extra-tropical cyclones. The storm index is not only applicable to a global model as shown by Della-Marta et al. (2008) but also to a regional model. First calculations with REMO data produce similar results as the analysis based on the grid points presented in Figure 3.

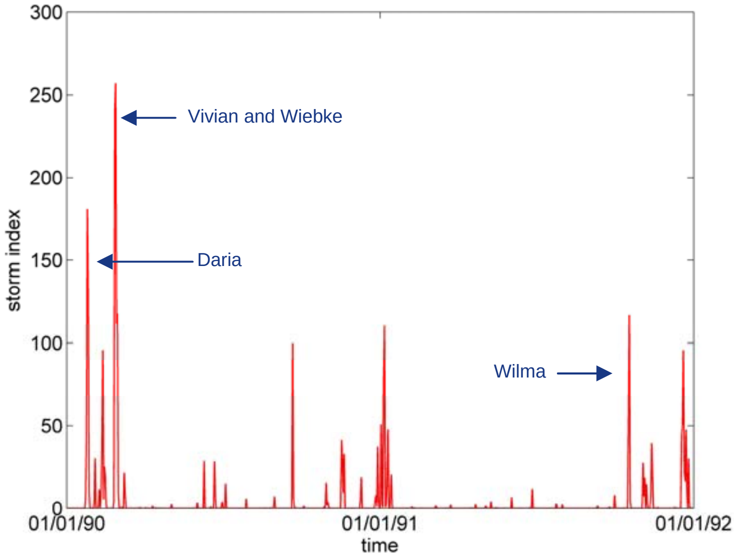

Figure 4: Storm index for the years 1990 and 1991 calculated from the CLM-ERA40 data. Prominent storms are labelled.

4 Conclusion and Outlook

Regional climate modelling is important for the investigation of extreme weather events because they are not well represented by global models. Despite the underestimation of the gust wind speeds the spatial pattern is well reproduced in the regional model data. The future changes of the storm climate in Southern and Central Germany are not significant, while in Northern Germany an increase of the storm activity seems to be likely. These results are confirmed by a storm index which includes the strength of the storm and its horizontal extension.
Because of the first promising results the index will be developed concerning the financial and other losses caused by the storms. Furthermore, an ensemble of global and regional models is necessary to consolidate the results because of model uncertainties and the influence of the global model on the regional model.

Literature

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