Assessment of changes in extreme wind speeds from Regional Climate Models

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overview

Severe winter storms and related destructive near-surface wind speeds pose a significant threat to modern societies and their assets. In Central Europe, winter storms are responsible for more than 50% of the total economic loss due to natural hazards. In light of global warming it is an important and still open question to what extent the frequency and/or intensity of severe winter storms may change by greenhouse gas forcing conditions (IPCC, 2007).

Within the projekt „RESTER“, frequency and intensity of gust wind speeds from winter storms over Germany are estimated by applying extreme value statistics to data sets from different Regional Climate Models (RCM). For Northern Germany the RCMs suggest an increase in extreme wind speed for a 10-year return period between +2 and +8%, whereas for Southern Germany a decrease between 0 and -4% is expected.

from gcm to rcm

- Ensemble of different Regional Climate Models (Table 1)
- Gust wind speed at 10 m asl
- Control period **C20**: 1971-2000
- Projection period **PRO**: 2021-2050

Tab. 1: *RCM model runs used in this study.*

	REMO-UBA	CCLM-KL	CCLM-IMK
version	REMO 5.8	CLM 2.4.11	COSMO-CLM 4.2
driving GCM / realization	ECHAM5/MPI-OM Run1	ECHAM5/MPI-OM Run1 + 2	ECHAM5/MPI-OM Run1 + 3
emission scenario (SRES)	A1B, B1, A2	A1B, B1	A1B
horiz. resol.	0.088° ~10 km	0.167° ~18 km	0.065° ~7 km

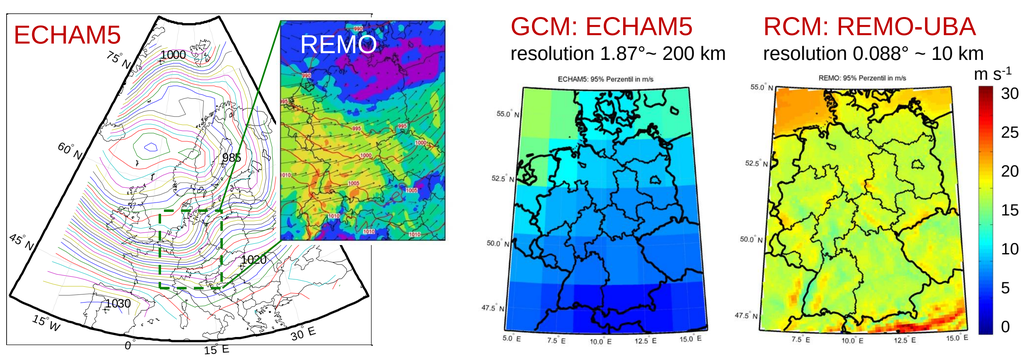

Fig. 1: *Storm cyclone in the global climate model (GCM) of ECHAM5 and the RCM of REMO (left); fields of gust wind speed for a 10-year return period during C20 (centre and right).*

expected changes in extreme wind speed

- The results of the RCMs differ from each other. The change signal is dominated by the realization of the GCM, whereas the choice of the RCM seems to be of minor importance.
- Relative changes in gust wind speeds show a north-south and west-east gradient almost consistent in most of the models. Maximum changes between +5 and +15% are expected over the northwest.
- Minor changes in gust speeds are statistically not significant.

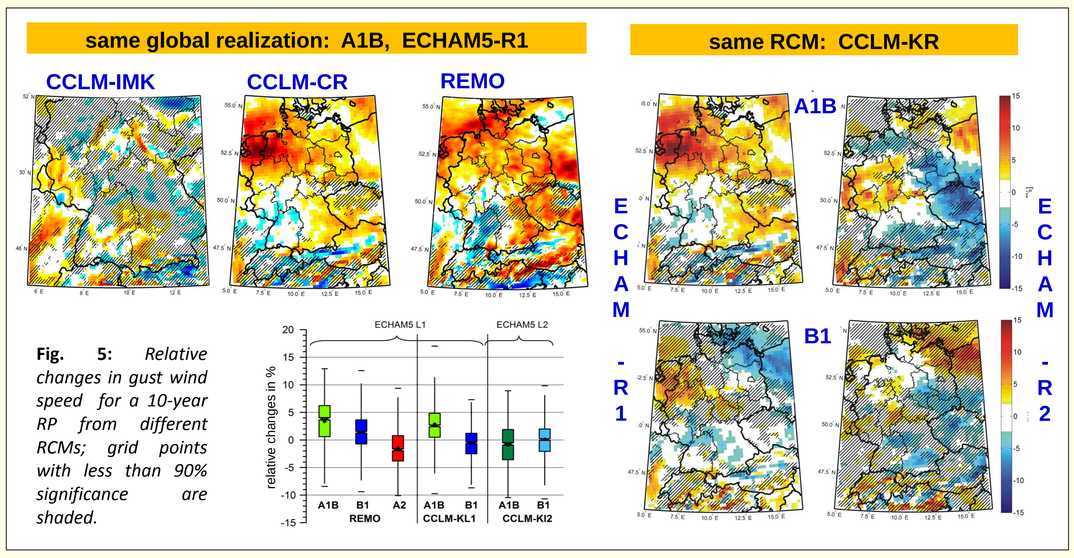

Fig. 5: *Relative changes in gust wind speed for a 10-year RP from different RCMs; grid points with less than 90% significance are shaded.*

statistical modelling

- **Data filtering**: method of independent storms with a minimum time lag of 48 h (Fig. 2a)
- Samples: 100 strongest events at each grid point
- Generalized Pareto Distribution (GPD) & Maximum Likelihood (ML) estimator
- Uncertainty estimation: Wilcoxon rank-sum test, bootstrap method
- **Change signal**: relative differences of gust wind speed between PRO and C20, $\Delta V'$ (Fig. 2b)

GPD $X_T = \zeta + \frac{\alpha}{k}[1-(\lambda T)^{-k}]$

ML $L(\alpha,k) = \prod f(\alpha,k,x_i)$

$$\frac{\partial \log[L(\alpha,k)]}{\partial(\alpha,k)} = 0.$$

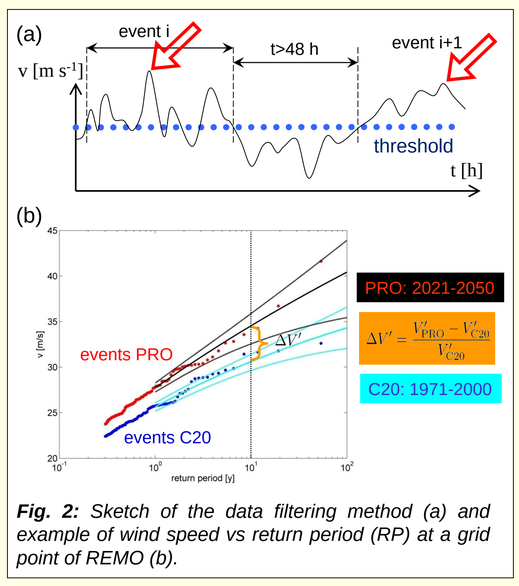

Fig. 2: *Sketch of the data filtering method (a) and example of wind speed vs return period (RP) at a grid point of REMO (b).*

rcm ensemble

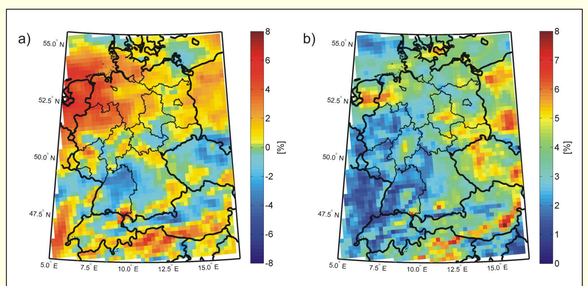

Fig. 6: *Relative changes in gust wind speed for a 10-year RP of the ensemble of 7 RCMs with mean (a) and standard deviation (b)*

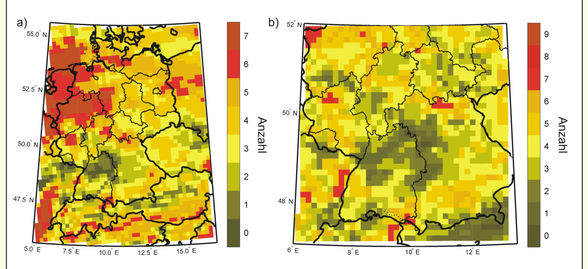

Fig. 7: *Number of RCM runs indicating an increase in gust wind speed based on a 7 (a) and 9 (b) member ensemble.*

According to the ensemble mean, wind gusts over Northern Germany are expected to increase between 2 and 8%, whereas they slightly decrease (0-4%) over Southern Germany in the future (Figs. 6 and 8). These results are confirmed by the majority of RCM runs(Fig. 7)

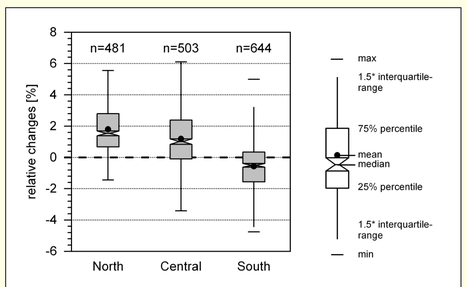

Fig. 8: *Ensemble mean for three different regions of Germany: North (>52.5°N), Central (>50°N and ≤52.5° N) and South (≤ 50° N).*

evaluation in C20

All RCMs basically are able to reproduce reliable extreme wind fields (Fig. 3). In general, the spatial distribution of storm climatology is well reproduced, but the magnitude of the gusts is significantly underestimated compared to observation data (SYNOP) and the CEDIM storm hazard map (Fig. 4 and Table 2). It is assumed that the systematic errors will vanish when relative differences as climate change signal are considered.

Tab. 2: *Statistical parameters (m s^{-1}) for a 10-year RP.*

	SYNOP	CEDIM	REMO	CCLM1	CCLM2
Mean	35.2	33.9	29.7	25.5	25.5
Median	34.2	33.4	28.7	24.5	24.6
q25	32.3	31.8	27.5	23.5	23.5
q75	37.2	35.1	30.6	25.7	25.7

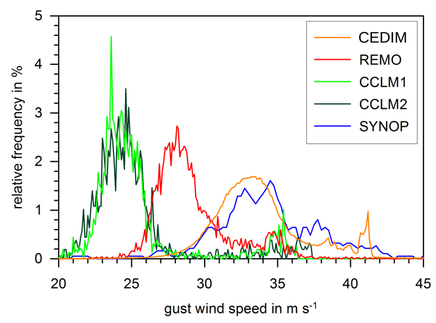

Fig. 4: *Relative number of grid points as a function of gust wind speeds for a 10-year RP .*

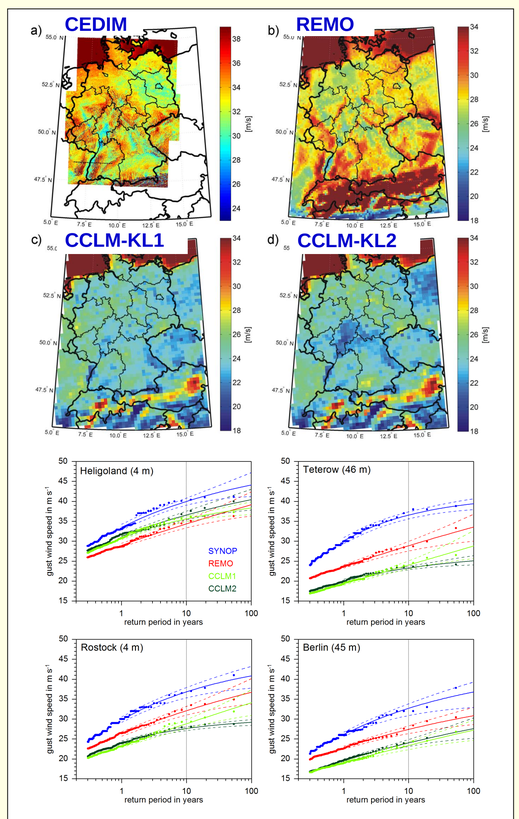

Fig. 3: *Top: Maximum gust wind speeds for a 10-year RP from CEDIM (a), REMO (b), CCLM-R1 (c) und CCLM-R2 (d). Bottom: Gust wind speed vs RP with 90% confidence intervals at observations sites.*

conclusions

- High-resolution RCMs basically are able to reproduce reliable extremes which occur only infrequently. This is a prerequisite when applying extreme value analysis techniques.
- In general, the spatial distribution of storm climatology is well reproduced by the RCMs. Depending on the terrain, simulated gusts, are systematically underestimated by 10 to 30% for a 10-year RP.
- Relative changes in gust wind speed in the future are dominated by the GCM realization. The choice of the RCM (REMO/CCLM) is of minor importance. This conclusion is valid only for the ensemble presented.
- Most of the RCM scenarios and the ensemble mean show a north-south and a west-east gradient. Gusts over the northern parts are expected to increase (2-8%), whereas they slightly decrease (0-4%) over Southern Germany. Note that damage by extreme wind speeds are approx.~ v^3.
- An ensemble comprising different GCMs, RCMs and emission scenarios is essential for the assessment of future changes in extreme wind speeds (or other quantities).
- In order to obtain more realistic wind speeds, it is essential to introduce comprehensive and physically-based parameterization schemes for the near-surface wind fields and the gusts.

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