Verification of simulated near surface wind speeds by a multi model ensemble with focus on coastal regions

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1. Introduction

The knowledge of the wind climate at specific locations is of vital importance for risk assessment, engineering, and wind power assessment. Results from regional climate models (RCM) are getting more and more important to enlarge the investigation from local to regional scale.

With help of GCM- and RCM-simulations *Leckebusch and Ulbrich (1994)* investigate the relationship between cyclones and extreme windstorm events over Europe. It is clearly visible that with the higher temporal and spatial resolution, especially in coastal areas the RCM lead to an improvement in simulating the extreme wind speeds compared to the GCM. For open ocean areas *Winterfeld (2008)* shows no adding value for RCM modeling compared to reanalysis forcing in the wind speed frequency distributions, whereas in coastal regions RCM results - especially for higher wind speed percentiles - are closer to the observations than the forcing data. *Rockel and Woth (2007)* focused on near-surface wind speed over Europe and identified that most of the RCMs have not been able to simulate wind velocities above 8 Bft.

In this study we investigate the simulated near surface wind speed by a multi model ensemble carried out in the EU funded project ENSEMBLES. The special focus is on the coastal regions of the Netherlands and Germany. The Southern North Sea and the German Bight are Luvcoasts, that means the winds blow onshore or parallel to the coast. The main wind direction in this area is West to Southwest.

Figure 1. Locations of all measurements available for the time period 1971-1983

2. Observation Data and their Homogeneity

The German Weather Service (DWD) provided measurements for 31 stations across the German coastal area. The data contains the mean speed and the mean direction of the wind in 10m height as a mean over the preceding hour. Beside these values the daily maximum of the wind speed is available. Until the end of the year 1974 the wind direction measured in degree was transformed into the 32-scale wind classes. From 1.1.1975 the number of these classes has been changed to 36.

The wind measurements network of the Netherlands Meteorological Institute (KNMI) contains more than 50 stations across the Netherlands. For these stations hourly values are available for the mean speed and the mean direction of the wind over the last 10 minute period in the preceding hour, the hourly mean of the wind speed and the maximum wind speed in the preceding hour.

Wind measurements are very strongly influenced by changes in e.g. surface roughness and by shadowing effects from trees and buildings, but also changes in the instrument, the measuring height or the location are reasons for the inhomogeneity of the data.

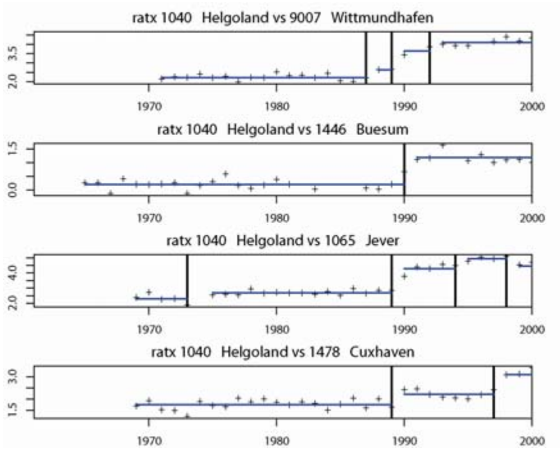

Figure 2. Example for breaks detected in difference in wind speed series (in m/s) from Helgoland vs. Wittmundhafen, Buesum, Jever and Cuxhaven.

A homogenization of wind measurement is critical due the measurements are influenced by local wind effects. Stations history is often incomplete and changes in the stations surrounding (growing trees, new buildings in the neighbourhood) are rarely documented.

In this investigation we used an algorithm for detecting breaks in the time series (*Caussinus and Mestre, 2004)*) based on monthly mean wind speed in the time period from 1961 to 2000. Figure 2 shows the breaks in difference series from Helgoland compared to the closest stations around. The change in the location of the measuring site at the island in 1989 is clearly visible. Together with the provided stations histories we defined two time windows where as many as possible of the measurements are less disturbed. For the Netherlands we choose observation data of 10 stations for the time periods 1971-1983 and 5 stations from 1971 to 2000, for the German coast it is 13 and 10 stations respectively (cf. Figure 1).

3. The Multi Model Ensemble

Within the ENSEMBLES project 14 participating European institutions and one Canadian Research Institute run their RCMs for the same European domain (including the Mediterranean and Island) with the same grid size of 0.44° (~50km) and in a second simulation 0.22° (~25km). For these simulations the ERA40 reanalysis (*Uppala et al. 2005*) were used as forcing data. The simulations cover at least the time period from 1961 to 2000. As far as provided from RCMs daily means of the simulated 10-m wind speed are analysed in this study.

4. Verification of the Simulated Wind Speed

For each station the covering gridcell of each model as well as the driving ERA40 reanalysis data was used for bias, root mean squared error (RMSE), and quantiles assessment.

The bias is small and most of the year at all stations positive with values between -0.5 and 2.5 m/s. At few stations directly located at the coastline for almost all models the bias is negative over the whole year with values down to -2.5 m/s.

All models perform standard deviation quite well and are well correlated with station data. Correlation values are between 0.7 and 0.8. Results from one model using the spectral nudging technique is higher correlated (0.85 to 0.9) with the station data.

The RMSE, combining correlation and bias, gives values between 0.5 and 2 m/s for sites away the coast and higher values up to 3 m/s for the stations at the coastline. For the RMSE there is no distinct additional gain for the simulated wind speeds from grid boxes with the 25km resolution compared to the 50km.

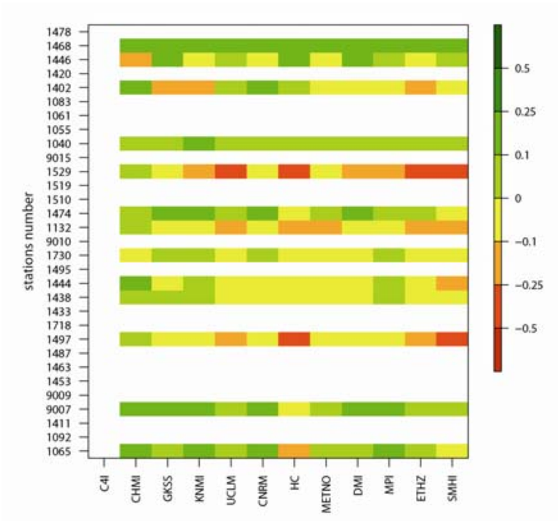

Figure 3. Differences in Perkins Score for the RCMs (50km) and ERA40 reanalysis from 1971 to 1983. (Negative values indicate an added value for the ERA40 reanalysis, positive values for the RCMs.; white: no data available for observation and/or model output.)

The results in the quantiles of the models and the observation are varying for most of the locations with no clear behavior. At stations more than 50km off the coast where in general smaller wind speeds are observed, the RCM´s quantiles fir very well with the observed ones. For the Helgoland (No. 1040) island ERA40 reanalysis data underestimate the wind speed over all quantiles. We can see a clear added value from all RCMs in the quantiles assessment compared to the ERA40 forcing data. All models define the corresponding gridbox as water.

With the help of Skill Scores it is possible to quantify models performance in simulating the surface wind speed compared to the ERA40 reanalysis forcing. We applied the Brier Skill Score (BSS) and a score described by *Perkins et al. (2007)* in a modified way. While the BSS is a relation of the RMSE from the RCMs compared to the RMSE from ERA40 forcing, the Perkins Score is a very simple measure to estimate the relative similarity between simulated and observed Probability Density Functions (PDF). For the available observations in the time period from 1971 to 1983 Figure 3 shows the Perkins Score from each RCMs in relation to the Score for the ERA40 reanalysis as the difference between both scores. The value -1 is full agreement in the PDFs from ERA40 and the observations and no similarity between the PDF from RCM and that one from the observations. The value 1 is the opposite and indicates the gain due to considering the RCM. For many stations we identified a a strong similarity between the PDFs derived from simulated surface wind speed from RCMs and ERA40 reanalysis compared to the observed PDFs. At few sites an added value for the RCMs was detected.

5. Conclusion

Here, we test the performance of 14 RCMs concerning the simulated surface wind speed in coastal regions, especially the North Sea area. We applied several measures and skill scores to analyse the RCMs performance compared to the driving field and to evaluate accuracy gain by including higher spatial resolution of the grid cell Results for bias, RMSE, standard deviation but also for Brier Skill Score and Perkins adapted skill score don't show strong seasonal dependence. The differences can be addressed to the calm summer periods and the stormy autumn and winter month where large scale events are more important than local effects.

At few stations e.g. Helgoland RCMs show an added value concerning the quantiles assessment of daily mean surface wind speed compared to the driving field.

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