5A.1 SENSITIVITY STUDY OF SIMULATED WIND PROFILES TO MODEL RESOLUTION, LAND COVER AND CLIMATE FORCING DATA

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1. Introduction

The objective of the study was to see if limited area models are able to simulate boundary layer wind fields over different land cover and terrain structures and if necessary which changes in initial conditions lead to an improvement in the simulation. The main point of this study is the investigation of the influence of the forcing data and the land use data on the mean wind profile and especially the investigation of the existence of an added value for increasing spatial resolution. Two different models are used for a comparison with observation data from five measurement towers in different regions of Germany and the Netherlands. Differences in terrain height and land cover structures of the towers due to the regional conditions allow a closer analysis of the influence of the model grid environment. The models chosen for this study are the regional climate model CLM (dynamical downscaling) and the Canadian Wind Energy Toolkit WEST (dynamical/statistical downscaling), whose statistical approach affords a flexible application due to much less computation time.

2. Data

Analysis of measurements from synoptic stations (with measuring heights ~10m) showed that they are hardly useful as representatives for a larger area and for comparisons with winds in grid boxes of low spatial resolution. To reduce the influence of the disturbances due to changes in the environment, measurements from high meteorological towers were used. The towers are located over different terrain and land cover. For a better understanding short information about the towers is given in Table 2.1.

Station	ASL:	Owner:	Environment
Hamburg	0.7m	University of Hamburg	Suburban, flat industrial area, influence of the city still strong
Cabauw	-0.3m	KNMI	Consists of arable fields and small villages
Linden-berg	53m	Richard-Aßmann-Obser-vatory, German Weather Service	Complex structure with mixed land cover consisting of arable fields and small forests
Juelich	91m	Research Center Juelich	Located in a small clearing in a broadleaf forest, surrounded by research Center facilities in a densely populated area
Karlsruhe	110m	Research Center Karlsruhe	Located in a needle-leaf forest, surrounded by research Center facilities

Table 2.1: Observation data

The data were corrected regarding the influence of the tower to keep the measuring error as small as possible. Either the tower has two measuring arms or the data were removed in cases in which the wind comes from the mast direction.

CLM:

The regional climate model CLM is the climate version of the non-hydrostatic model Local Model (LM) from the German Weather Service (DWD). Further details about the physical parameterizations, dynamics and numerics of the model can be found in Doms et al. 2005 and Doms and Schättler 2002. A spectral nudging technique described by Feser and von Storch (2005) is used for the simulation. The simulation area covers Europe and uses a rotated grid with a spatial resolution of 0.44°x0.44° (~50km). The forcing data is the NCEP/NCAR-reanalysis (Kalnay et al. 1996).

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WEST:

The Wind Energy Simulation Toolkit uses a statistical-dynamical downscaling approach (Frey-Buness et al., 1995). A classification of wind data from a forcing data set is conducted. Mean wind and temperature profiles for each class are calculated and used as initial conditions at the center of the chosen domain (Yu et al. 2006). A mesoscale model simulation based on the Canadian Mesoscale Compressible Community Model (Tanguay et al., 1990, Thomas et al.,1998) is generated for each class. The results are weighted by the frequency of the occurrence of the class in the forcing period. A statistical module calculates mean statistical fields which can be seen as representatives for the mean wind fields over the whole forcing period. The low computational effort allows a flexible application of the model and a detailed investigation of the influences of the general settings. In the default version of the model the USGS data base is used for terrain elevation and land use and the model is driven by the NCEP/NCAR-reanalysis (Kalnay et al. 1996) (Yu et al. 2006).

Mean wind profiles over the time period 2001-2005 were calculated for all towers. These profiles were assumed to be representatives for the true mean condition of the wind fields in the lowest 100 meter of the boundary layer. Simulated wind profiles over the same time period are taken from the output of both models. A bilinear interpolation of the four tower surrounding grid boxes is used.

3. Results

a) Influence of the roughness length

At first wind profiles are calculated from the 50km simulations of the models. As figure 3.1 shows the profiles for the northern stations in flat terrain and relatively simple land cover are better than the results for the stations over higher terrain which are located in forests. Depending on the station smaller and larger deviations between both modeled wind profiles can be detected. The largest deviations between modeled and measured profiles for the stations with more complex land cover are possible indications for problems with the roughness structures in the models.

To evaluate the influence of the roughness length to the deviation of the model results, the roughness fields were adjusted after interpolating the roughness lengths used by CLM to the WEST 50km grid. The 50km simulation of WEST was repeated with the adjusted z0. This led to quite similar results of the models and a general improvement for all stations except Cabauw where the profile was already very similar to the measured before z0 was replaced (see Fig. 3.2).

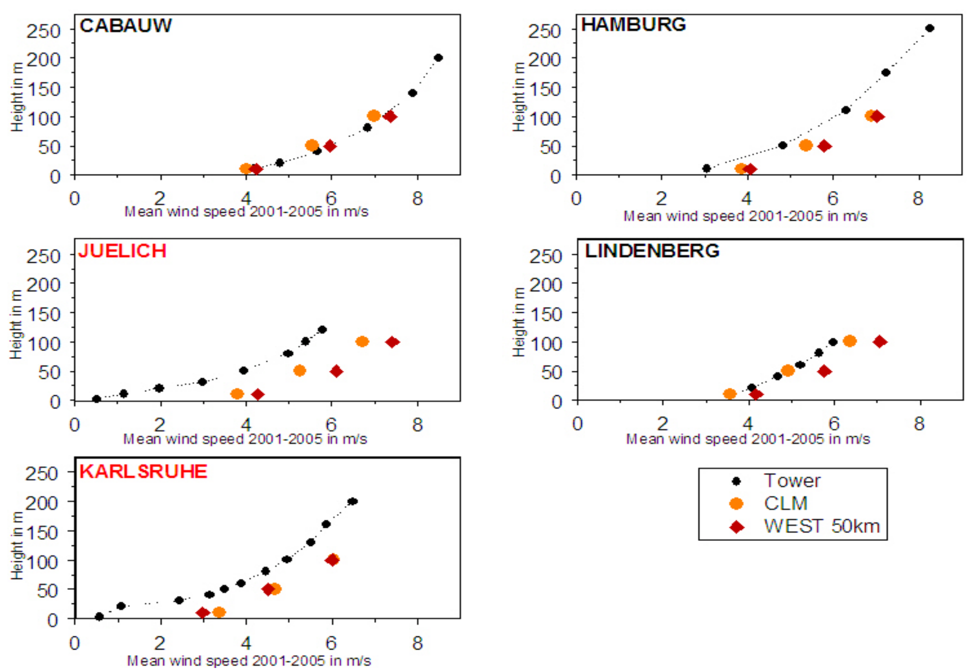

Fig. 3.1 Mean wind speed 2001-2005 in m/s: Observation data from high towers (black), mean wind profile from CLM (orange) and mean wind profile from WEST (50km) (red). Stations in forests are marked with red names.

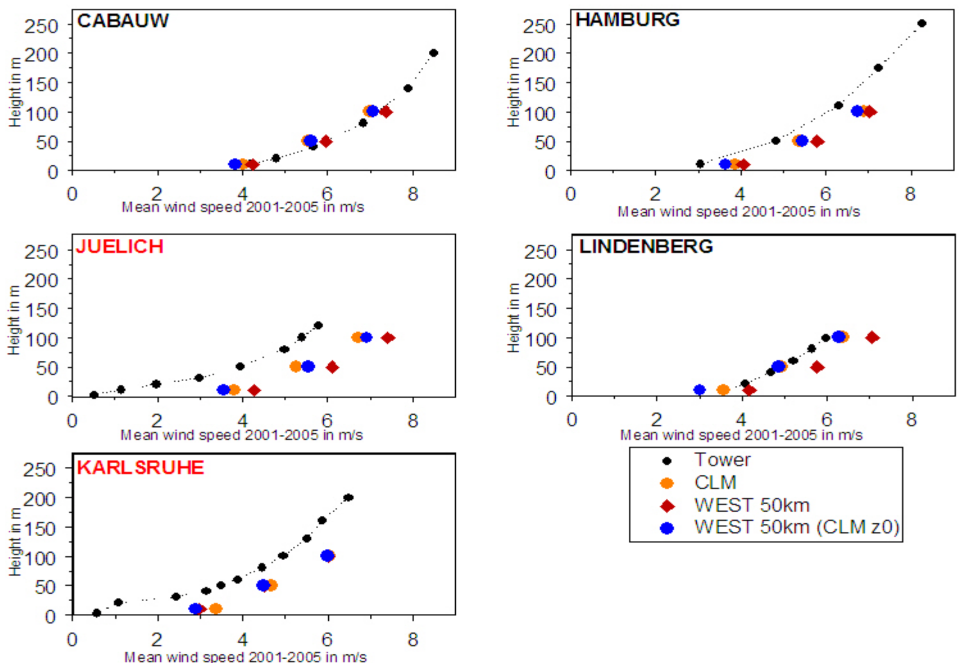

Fig. 3.2 Mean wind speed 2001-2005 in m/s: Observation data from high towers (black), mean wind profile from CLM (orange), mean wind profile from WEST (50km) with USGS z0 (red) and mean wind profile from WEST (50km) with CLM z0 (blue). Stations in forests are marked with red names.

This shows the strong influence of the roughness length on the mean wind profile simulation. However, the mean wind speeds for the stations over complex terrain (forests) are still strongly overestimated. Therefore, further investigations are necessary.

b) Influence of the external forcing

The sensitivity of the Canadian model to changes in the forcing data set is investigated by repeating the simulation with another forcing data set. The classification of wind speed data from NCEP-NCAR is replaced by a classification of the Japanese Reanalysis data set JRA (Japanese 25-year Reanalysis Project JRA-25, (Onigi et al. (2007))) over the same time period. Only small differences occur in the resultant climate data base tables (Fig. 3.3).

Apparently the frequencies of high wind speed classes are higher in NCEP than in JRA. This conforms to the behavior of the simulated wind profiles (Fig. 3.4). The mean wind speed forced with JRA is smaller than the one forced with NCEP for all stations. This results in no general improvement of the wind speed profiles. For Cabauw and Lindenberg the profile is worse after the replacement of the forcing data. Additionally the deviations between the simulated profiles are quite small.

An interesting point would be to see if climate data from a data set with a high spatial resolution would be more representative for the modeled area and would lead to an exacter simulation. Unfortunately, no reanalysis data set with a high spatial resolution was available for the measured time period. For this reason the analysis and its results are limited to small changes in the forcing data base.

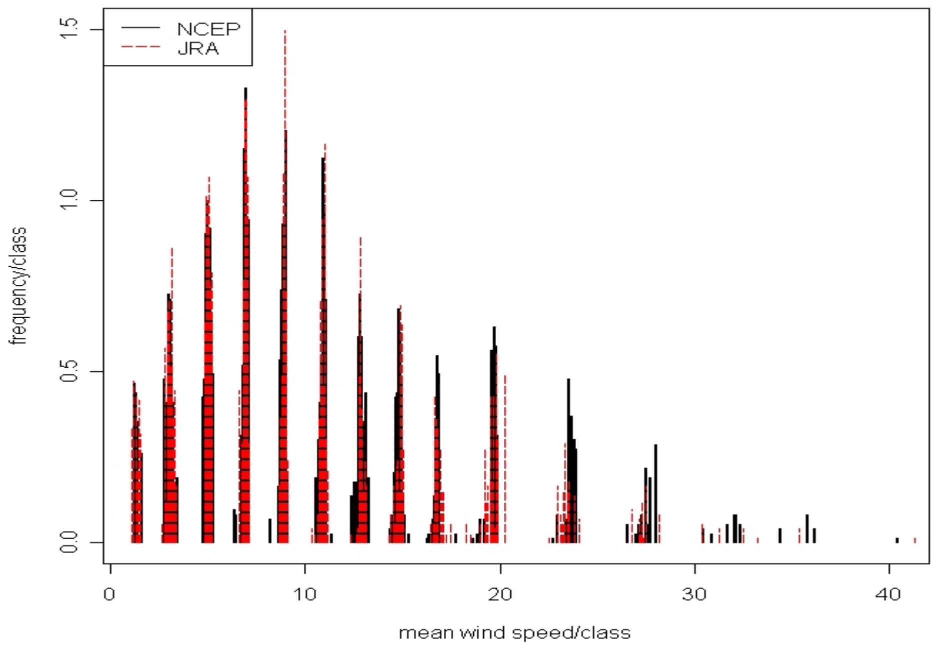

Fig. 3.3 Occurrence frequency of the wind speed classes and their mean wind speed after the classification of the forcing data sets NCEP/NCAR Reanalysis (black) and JRA Reanalysis (red).

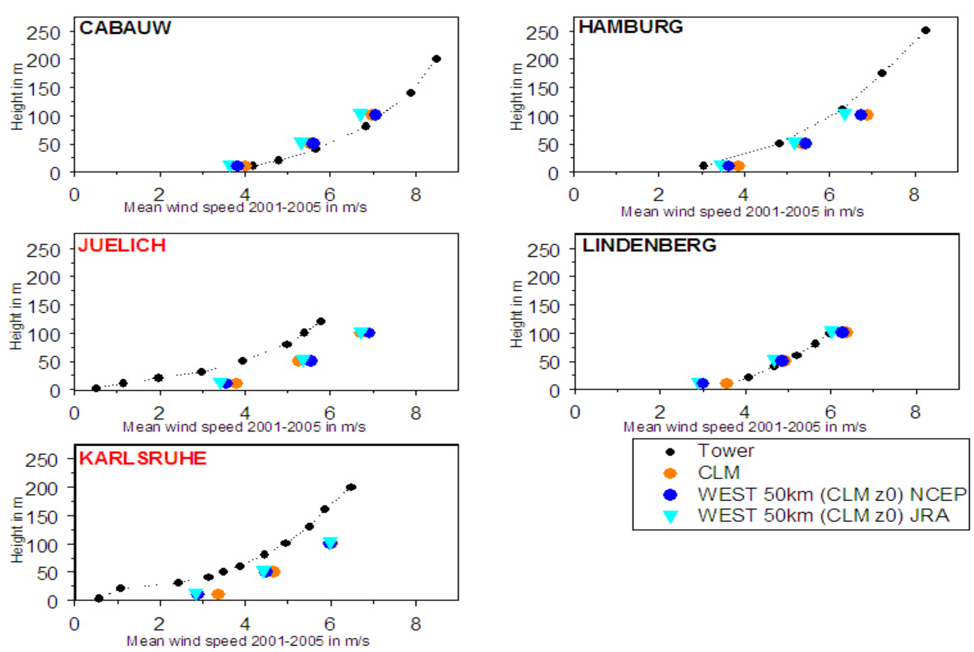

Fig. 3.4 Mean wind speed 2001-2005 in m/s: Observation data from high towers (black), mean wind profile from CLM (orange), mean wind profile from WEST (50km) with CLM z0 driven by NCEP/NCAR (blue) and mean wind profile from WEST (50km) with CLM z0 driven by JRA (light blue). Stations in forests are marked with red names.

c) Influence of the resolution

The flexibility of the Canadian model WEST allows a closer look on the influence of the initial conditions. Due to the low computational efforts simulations with higher spatial resolution could be conducted. The investigation of section 3 a) showed the strong influence of the model roughness length on the mean wind profile. Therefore, a land cover database with a higher resolution is chosen. The Corine Land Cover 2000 database (Copyright EEA, Copenhagen, 2007) consists of 44 different land use classes and is available for Europe with a resolution of 100m. By means of especially generated correspondence tables these land use classes are assigned to the 26 land use classes of WEST. The generation of the correspondence tables required the consideration of differences between Canadian and European Land use definitions. WEST simulations with the spatial resolutions of 50, 20 and 10 km are conducted with new roughness fields based on Corine.

An increasing spatial resolution leads to an improvement of the simulated wind profile in most of the cases (Fig. 3.5). However, the differences between the simulated wind profiles are relatively small. And the wind speed over the forest is still overestimated. For Karlsruhe it seems that the model detects the complex land structure with the 10 km resolution but it is still not able to fully dissolve it.

To consider this complexity, high resolution runs of WEST with a resolution of 1km were conducted, which led to a reasonable agreement of modelled and measured wind profiles for four of the stations (Fig 3.6). However, the systematic overestimation of the wind profile for one station over more complex land cover remains.

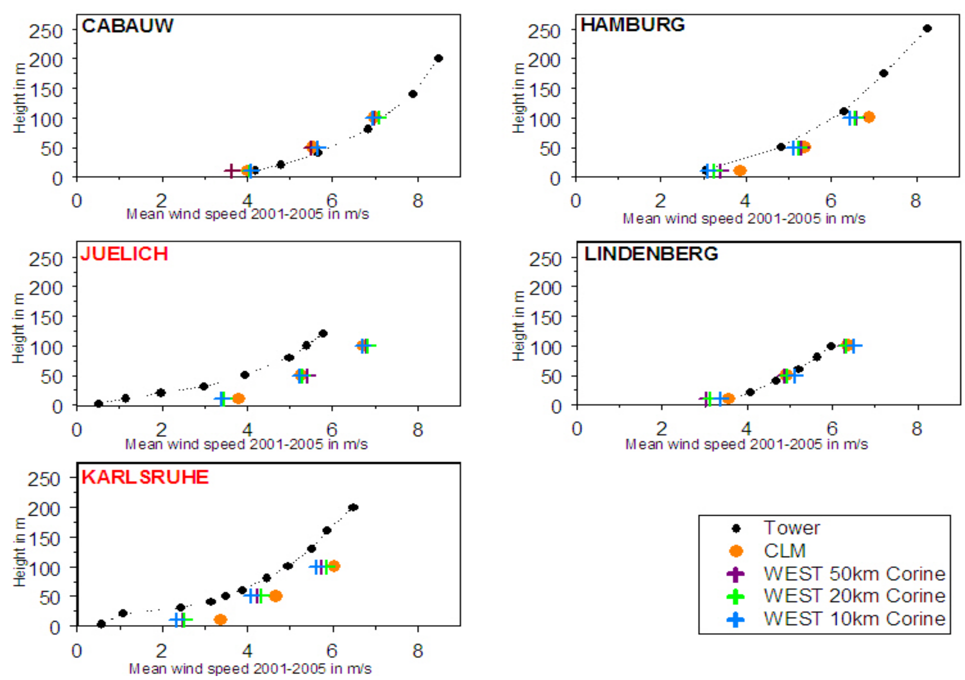

Fig. 3.5 Mean wind speed 2001-2005 in m/s: Observation data from high towers (black), mean wind profile from CLM (orange), mean wind profile from WEST (50km) with Corine z0 driven by NCEP/NCAR (violet), mean wind profile from WEST (20km) with Corine z0 driven by NCEP/NCAR (green) and mean wind profile from WEST (10km) with Corine z0 driven by NCEP/NCAR (blue). Stations in forests are marked with red names.

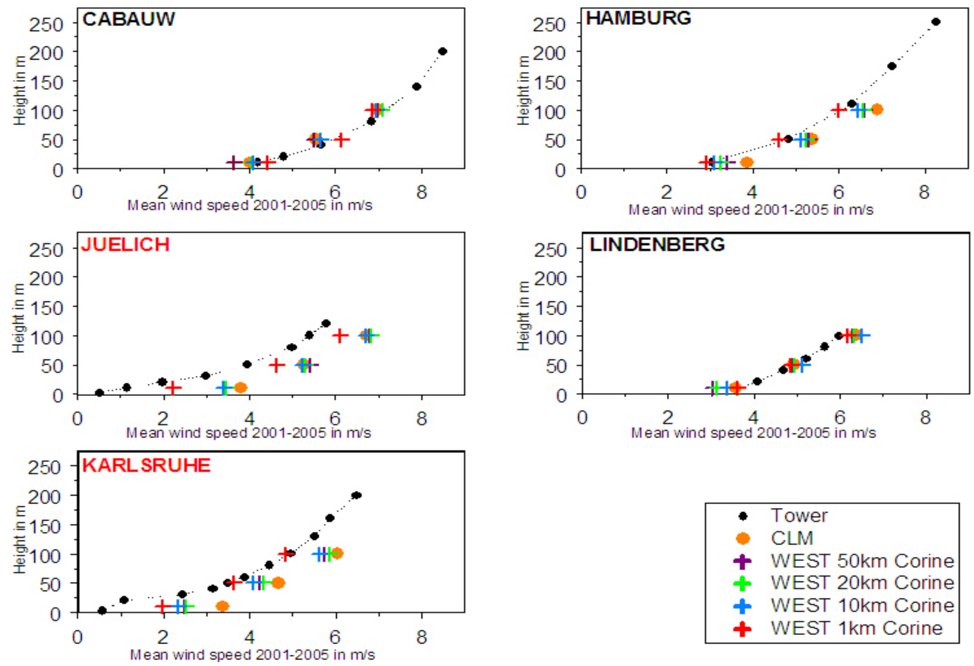

Fig. 3.6 Mean wind speed 2001-2005 in m/s: Observation data from high towers (black), mean wind profile from CLM (orange),
mean wind profile from WEST (50km) with Corine z0 driven by NCEP/NCAR (violet), mean wind profile from WEST (20km) with Corine z0 driven by NCEP/NCAR (green), mean wind profile from WEST (10km) with Corine z0 driven by NCEP/NCAR (blue) and mean wind profile from WEST (1km) with Corine z0 driven by NCEP/NCAR (red). Stations in forests are marked with red names.

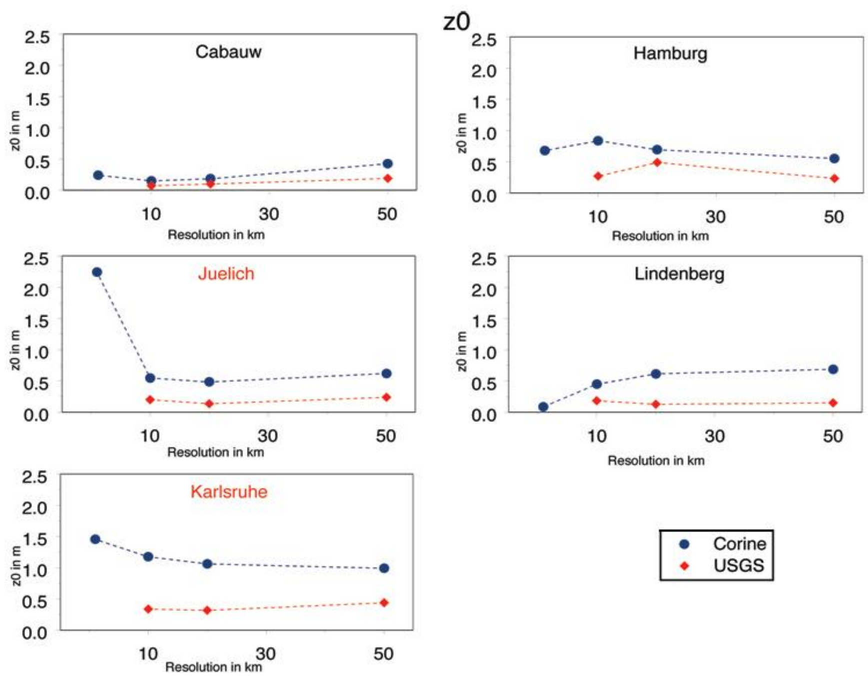

Fig 3.7 WEST roughness length in m based on Corine (blue) and USGS (red) for different resolutions. Forest stations are marked with red names.

The development of the model roughness lengths of WEST with increasing spatial resolution is shown in Fig. 3.7.
The roughness length based on USGS is smaller than the one based on Corine in all cases for all resolutions. The increasing roughness over the forests could be detected but does not seem strong enough especially for Juelich.

4. Conclusions and Outlook

The improvement after replacing the roughness length showed the strong influence of the land cover on the mean wind profile. Therefore, a correct land cover data set is very important for modeling of near surface wind fields. Due to differences between international land cover definitions a correct assignment of land cover classes is necessary and a verification of the validation of the used roughness data is strongly recommended.

Restricted to this case and grid point the deviations between the two Reanalysis data bases are small and have only small effects on the mean wind profile. A further analysis especially the investigation of an added value for higher resolved forcing data is pending.

Wind fields over flat terrain and not complex land cover can already be simulated with a low resolution. The resolution should be aligned to the complexity of the environment otherwise an increasing of the resolution (from 50 to 20 to 10km) leads not necessarily to an improvement of the mean wind profile. For very complex land cover structures it is difficult to simulate the mean wind profiles, a high resolution is necessary.

Acknowledgements

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