Near-shore wind resource estimation using lidar measurements and modelling

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Abstract
The atmospheric flow in the coastal zone is investigated using (scanning) lidars, mast measurements and the mesoscale WRF model. The WRF model is set up in 12 different configurations using 2 planetary boundary-layer schemes, 3 horizontal grid spacings and varied sources of land use, and initial and lower boundary conditions.

Objectives
- Describe the impact of boundary layer scheme, resolution, land use data and atmospheric forcing on the WRF modelled wind speed
- Estimate the wind resource using scanning and vertically profiling lidars

Methods
The WRF model was set up to cover northwestern Europe.

Horizontal transects
The horizontal gradient in mean wind speed across the experimental site from 5 km offshore up to 2 km inland is shown above. Data were filtered based on the CNR ratio (measurement quality) and availability in the whole transect, leaving 731 transects at 50, 100 and 150 m. The model output from all simulations was extracted during the same 10-min intervals.

Generally the model prediction shows slightly higher wind speeds offshore. Over land at 50 m the observed wind speed is much lower than the modelled wind. The WRF model cannot capture the effect of the cliff well, partly due to its coarser resolution.

Both scanning lidar systems agree well offshore. The vertical profiling lidars show a lower mean wind speed.

Vertical profiles
The WRF modelled wind speed was close to scanning lidar observations in a transect across the coastline, although all simulations showed wind speeds that were slightly higher than observed. Inland at 50 m, the model did not capture the strong decrease in mean wind speed resulting from the surface roughness change when moving eastward from the coastline. Using ERA-interim data as boundary conditions improved the model skill scores. Using a finer horizontal grid spacing deteriorated the model performance. Modelled and observed spectra were compared and showed that the horizontal grid spacing had a large impact on the ability of the different setups to capture high frequency atmospheric motions.

Conclusions
The WRF modelled wind speed was close to scanning lidar observations in a transect across the coastline, although all simulations showed wind speeds that were slightly higher than observed. Inland at 50 m, the model did not capture the strong decrease in mean wind speed resulting from the surface roughness change when moving eastward from the coastline. Using ERA-interim data as boundary conditions improved the model skill scores. Using a finer horizontal grid spacing deteriorated the model performance. Modelled and observed spectra were compared and showed that the horizontal grid spacing had a large impact on the ability of the different setups to capture high frequency atmospheric motions. Combining the WRF model with lidar measurements can be useful to describe and understand the flow in the coastal zone.

Velocity spectra and error metrics
Velocity spectra are often used to gain insight in the ability of models or observations to represent atmospheric motions. Below the spectral energy from the cup anemometer at 100 m at the Høvsøre mast is shown as a function of frequency. At low frequencies (left) the model and observations compare well, showing the model resolves the energy at these scales. At high frequencies, the model set-ups with fine horizontal grid spacing have more energy than the observations. This has an impact on the model performance (see below).

The table below shows a summary of different metrics during the whole campaign for all sites, for example the root-mean-square error (RMSE) and Pearson correlation coefficient (R). There were 237493 10-minute mean measurements available. The simulations with the MYJ scheme and the ERA-interim boundary conditions have the lowest RMSE and mean absolute error. It can be seen that using a higher resolution leads to worse error metrics.

Conclusions
The WRF modelled wind speed was close to scanning lidar observations in a transect across the coastline, although all simulations showed wind speeds that were slightly higher than observed. Inland at 50 m, the model did not capture the strong decrease in mean wind speed resulting from the surface roughness change when moving eastward from the coastline. Using ERA-interim data as boundary conditions improved the model skill scores. Using a finer horizontal grid spacing deteriorated the model performance. Modelled and observed spectra were compared and showed that the horizontal grid spacing had a large impact on the ability of the different setups to capture high frequency atmospheric motions. Combining the WRF model with lidar measurements can be useful to describe and understand the flow in the coastal zone.

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