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The wind speed profile at offshore wind farm sites

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The first large offshore wind farms are in the planning phase in several countries in Europe. Their economic viability depends on the favourable wind conditions compared to sites on land. The higher energy yield has to compensate the additional installation and maintenance cost. For project planning and siting a reliable prediction of the wind resource is therefore crucial. For turbine design the wind shear of the marine surface layer is an important design parameter, especially since the growing rotor diameter makes turbines more vulnerable for spatial wind speed variations.
Compared to land surfaces the roughness of water is very low. It is commonly described either as a constant (as in the wind resource estimation program WAsP) or by means of the Charnock approach, relating sea surface roughness and friction velocity. While this relation works well for the open oceans it has been found inappropriate for coastal areas where waves are not fully developed. Information about the wave field is needed to model the sea surface roughness more accurately (see e.g. Johnson et al. (1998)).
The atmospheric stability differs greatly between land and water areas. It is more important offshore compared to land sites due to the low surface roughness of water. The main influence of the atmospheric stability is on the vertical momentum transport, which is reflected in the vertical wind speed profile. It is usually described with Monin-Obukhov similarity theory.
However, other effects not described by this approach might also play an important role: For offshore flow the flow regime at coastal sites is affected by the land-sea discontinuity (Højstrup, 1999). An internal boundary layer develops at the coastline and an inhomogeneous flow field might develop in the coastal zone, especially in stable stratification (see e.g. (Smedman et al. (1997))
Recent data from the measurement at Rødsand, 10 km off the Danish coast in the Baltic Sea, include simultaneous wind and wave data from a 50 m meteorological mast and an acoustic sea bed mounted wave gauge. Wind speed and turbulence intensity profiles are modelled for the Rødsand site using different approaches for stability and roughness. Results are compared with the measured data. For the sea surface roughness the use of the Charnock equation leads to good results. Improvements from using a wave field dependent roughness description are found to be small.
For stability induced influences on the profiles M-O-theory works well in the case of unstable stratification. For stable stratification large deviations are found. They can be explained qualitatively as flow regimes with a mixed layer close to the surface and a capping inversion. In such a flow the atmospheric stability is strongly dependent on height and Monin-Obukhov similarity theory fails. For the Rødsand measurement this flow regime has been found to have an important influence on the wind climatology of the site. A wind speed at hub height predicted from a lower measurement with conventional theory will be underestimated.

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