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Investigation of the Development of Internal Boundary Layers by Means of Large-Eddy Simulation

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Many on- and offshore wind turbines are situated close to the coastline due to expected favourable wind conditions and considerably lower costs for erection and maintenance compared to far-offshore locations. A better understanding of the impact of the coastline on the flow might be a key factor for the improvement of the wind resource assessment in the near-coastal region.

The ERA-NET+ project NEWA aims at an improved accuracy of wind resource estimates in the whole of Europe including near-coastal zones. Here, we present work from the NEWA project in which a number of different large-eddy simulations (LES) were performed to investigate the parameters that have an impact on the development of internal boundary layers (IBL) developing due to the transition of the flow across the coastline.

The simulations were performed with the LES model PALM. For simplification a straight coastline, which was positioned perpendicular to the flow direction, was simulated. A number of different simulations were performed while varying the parameters surface roughness, atmospheric stability, wind speed and surface temperature. Equations with which one can calculate the height of an IBL depending on the distance to the coastline have already existed for years, but have not been compared to measurement data exhaustively. An alternative approach is to compare these equations to LES data. Therefore, the equations that were mostly used in previous studies were compared to the LES results of this work, among others the equations developed by Savelyev and Taylor (*Boundary-Layer Meteorology*, 115:1-25, 2005). To derive the IBL height from the results of the LES the methods described by Bou-Zeid (*Water Resources Research*, 40, 2004) were utilised.

The results suggest that the downstream roughness length only has significant impact on the IBL development when the magnitude of the change is sufficient, i.e. the differences in roughness lengths offshore hardly impact the development of the IBL. The atmospheric stability however has a more significant impact: for an unstable stratification the vertical mixing is higher, therefore the new properties of the flow are transported faster to larger heights compared to a neutral or stable stratification.

Furthermore, the order of the transition, i.e. land to sea or sea to land, influences the shape of the IBL development. A slower wind speed increases the growth of the IBL height as well as an unstable stratification. The formulas of Savelyev and Taylor (*Boundary-Layer Meteorology*, 115:1-25, 2005) provide a good estimate of the IBL height for a change in roughness length. The effect of an additional temperature change however, is not predicted well by the formulas of Savelyev and Taylor (*Boundary-Layer Meteorology*, 115:1-25, 2005).

Although our study showed that LES might be helpful to increase our knowledge on IBLs, a thorough validation of IBLs in LES is still lacking. Future research should therefore focus also on measurement campaigns that can deliver the data required for a validation.