Will the large-scale utilization of wind energy in the North Sea region change the weather?

Multiscale Modelling of European Wind Energy Wake Effects - Investigation of the budgets of higher order turbulent quantities for derivation of improved wind farm parameterizations with large-eddy simulations

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In Short

- With an installed capacity of 260 GW of offshore wind by 2050, the North Sea will be the region with the highest capacity density of wind turbines worldwide.
- Further improvement of flow models is required for allowing e.g. for an optimization of wake effects or weather and power forecasts in the North Sea region.
- The CETP project EuroWindWakes aims at developing, validating and benchmarking various multi-scale wake modelling techniques that originate from applied science as well as current industry standards.
- The goal of the sub-project of ForWind is to provide LES reference data for the interaction of wind farm clusters with a wide variety of atmospheric boundary layer flows for the development and verification of computationally cheaper model.
- In collaboration with the project partner Deutscher Wetterdienst a wind farm parametrization adopted for the turbulence parametrization used in its weather forecasting model ICON will be developed.

The North Seas Energy Cooperation - a collaboration between EU member-states and Norway to create an integrated offshore energy grid - agreed in September 2022 to have installed at least 260 GW of offshore wind energy by 2050 [1]. As such, the North Sea is often referred to as Europe's future powerhouse and will see the world's densest installation of offshore wind farms according to current expansion plans that are developed by the planning authorities, (e.g. Netherlands Enterprise Agency, Danish Energy Agency, BSH). One key aspect that impacts the development of offshore wind energy are large-scale wind farm effects and the associated uncertainty in the modelling of wind energy yields in dense wind farm clusters. Underestimating these effects could result in lower-than-expected power generation on a national or even European scale, impacting economic projections. It could also lead to overly optimistic bids in tenders, rendering wind farm assets unprofitable from a business perspective. The main objective of EuroWindWakes (EWW) is to develop, enhance, validate and benchmark various multi-scale wake modelling techniques that originate from applied science as well as current industry standards. The project's core outcome is the improvement of models, accompanied by guidelines indicating when the use of a particular model is appropriate, considering its associated uncertainties. These advancements will facilitate collaborative international maritime spatial planning efforts and mitigate risks in the development of new offshore wind energy assets. For this purpose, an international consortium of universities, research institutes, consultants, and wind farm operators from North Sea neighboring countries (Netherlands, Germany and Denmark) joins forces to tackle this challenge. Incorporating major wind farm operators and globally active consultants as full- or associated partners ensures the direct implementation of findings and guarantees dissemination to all stakeholders, industrial applications, policymaking and scientific communities. International and neighborly coordination is essential for effectively managing shared offshore resources. To achieve the objectives of the overall project, specific scientific and technical goals must be accomplished by the individual project partners. The subproject "Investigation of budgets of higher-order turbulent quantities for the derivation of improved wind farm parameterizations using large-Eddy simulations" conducted by ForWind at Carl von Ossietzky Universität Oldenburg within the collaborative research project EuroWindWakes pursues i.a. the following scientific and technical objectives: Improvement of the wind turbine parameterization "Actuator Disk Model with Rotation" (ADMR) in the LES model PALM: ForWind aims at improving the ADMR in PALM by implementing an induction correction similar to the smearing correction that has originally been suggested by [2] for the actuator line approach. The recent implementation of a similar correction in the actuator sector model of the LES model PALM by ForWind led to significantly improved power and thrust values obtained from simulations with PALM. While without correction deviations on the order of more than 10 percent from tabulated

power values were recorded the deviations could be reduced to the order of 1 percent with correction. As the actuator sector approach is computationally more expensive than the ADMR we aim at achieving a similar improvement also for simulations with the ADMR. The improved ADMR should then be used to generate LES reference data for the development and verification of computationally cheaper flow models for the calculation of wake effects of wind farms and wind farm clusters. Specifically, we aim at providing the project partners in TU Delft with LES data for the development of a canopy model that parametrise the wind farm in a RANS modelling approach and the project partners in Fraunhofer IWES with LES data for the verification of wind farm simulations with the mesoscale model WRF. A major objective is the analysis of the budgets of higher-order turbulent quantities within and outside wind farm wakes from simulations with PALM. These budgets are crucial for deriving wind farm parametrization in the high-order turbulence closure in the mesoscale model ICON used by the project partner Deutscher Wetterdienst for the operational weather forecast. Specifically, we aim at isolating the quota of these turbulent statistics budgets that remains unresolved by the mesoscale type models, and hence necessitate to be modelled. In work package 3 of EuroWind-Wakes ForWind aims at preparing existing lidar data from previous off- shore measurement campaigns for the derivation of validation exercises i.a. for wind farm simulations with the LES model PALM. The validation itself will also be part of work package 3 of the CETP project. The further developed wind turbine models in PALM will be added to the PALM default code in the framework of the project. Thus, all PALM users will benefit from the developments in the EuroWind- Wakes project

WWW

https://forwind.de/en/project/eurowindwakes-research-project/

More Information

[1] European Commission https://energy.ec.europa.eu/news/north-seas-energy-cooperation-and-uk-\establish-cooperation-framework-\facilitate-development-offshore-2022-12-18_en

[2] A. R. Meyer-Forsting, G. R. Pirrung, N. Ramos-Garcia *Wind Energ. Sci.* **4**, 369-383 (2019). doi:10.5194/wes-4-369-2019

Project Partners

National project partners in the related BMWK project: Fraunhofer IWES, Deutscher Wetterdienst; International partners in the related CETP project: Pondera Consult, Delft University of Technology, Technical University of Denmark, Dansk Kydraulisk Institut, EMD International

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