Mesoscale resolving high-resolution simulation of wind farms

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Motivation

The rapid development of offshore wind farms has raised concerns about the local environment and ecosystem. Wind farms influence the local meteorology by extracting kinetic energy from the wind field and by generating a large wake. The rapid increase in renewable energy generation from wind has increased concerns about the impacts that wind farms have on the marine environment.

Atmospheric Model

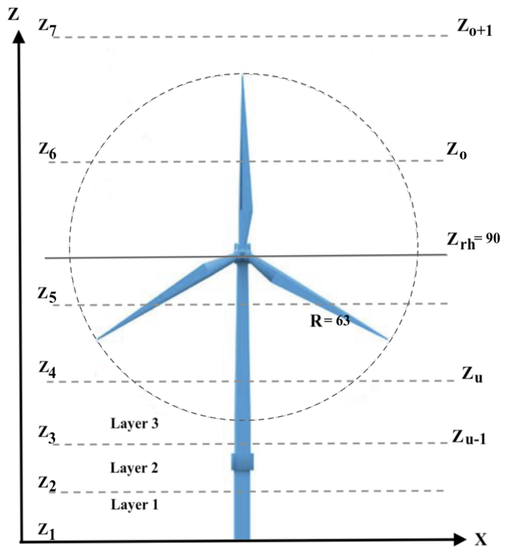
The atmospheric model **COSMO5-CLM15** (Rockel et al. 2008) with the wind farm parametrization (Fitch et al. 2012) is used in the experiment. ERA-Interim reanalysis data is used for the lateral and lower boundary conditions for 0.11^o simulation which is then used to drive 0.02^o simulation using double nesting technique.

- Horizontal Resolution: 0.11^o ($\sim$12.5 km) $\Longrightarrow$ 0.02^o($\sim$2 km)
- Vertical Resolution: 40 σ levels
- Time Step: 12 sec

Methods

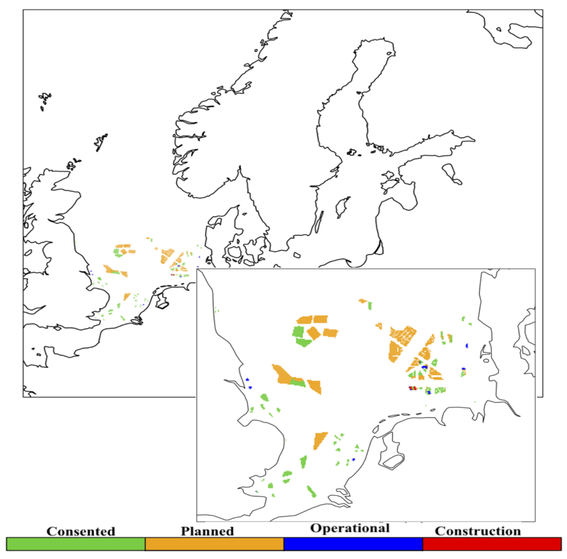
The parametrization for wind turbine driven by Fitch et al. (2012) and Blahak et al. (2010), previously implemented in **COSMO4-CLM8** at KU-Leuven (Chatterjee et al. 2016), has been implemented in the latest **COSMO5-CLM15**.

The parameterization is developed for the typical situation where several of the wind turbines of a large wind farm are contained within one vertical column of model grid boxes of the atmospheric model, but in the vertical, several model layers intersect the rotor area.



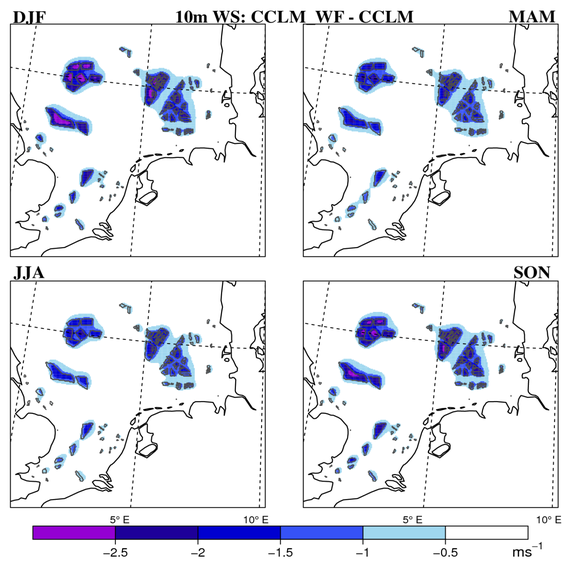
Schematic depiction of a wind turbine and a typical vertical grid configuration of a mesoscale model. The indexing of the layers is from bottom to top, Z_{rh} = 90 is the rotor hub height, R = 63 is the rotor raduis.

Study area

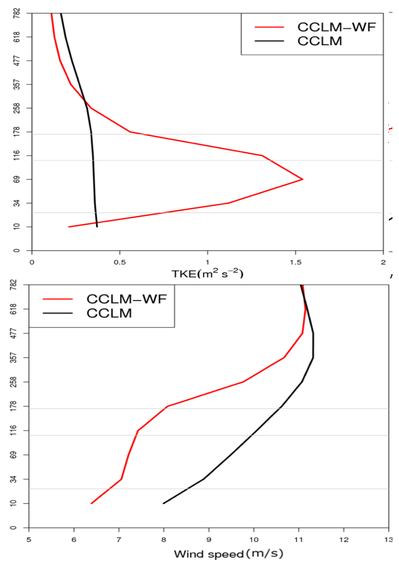


The North Sea is one of the main regions of the world where the growth of offshore wind farms is rapidly increasing.
Figure shows the model domain and distrubtion of offshore wind farms in the southern North Sea (data provided by Slavik et al. 2018). Color indicates the planning status of each offshore wind farm as of september 2015.

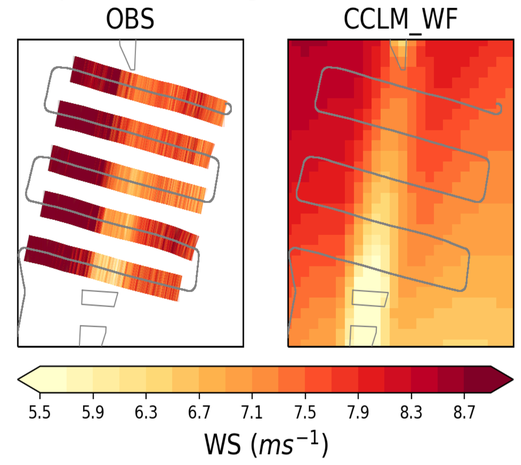
First Results

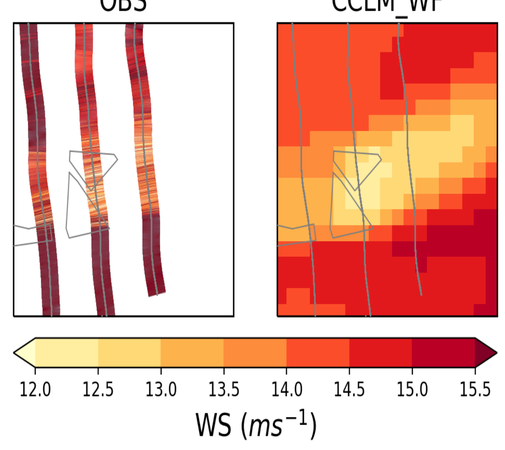


Wind speed at 100 height at 2016-09-10T0900



Wind speed at 250m height at 2017-10-14T1500





Conclusions

- Seasonal mean values show a reduction 2-3 ms^{-1} over the wind farms that reaches up to 258 m height
- Turbulent kinetic energy is increased by approx. 1 m^{2}s^{-2}
- The model simulations show good agreement with the aircraft campaign data (Platis et al 2018)

Outlook

- Implementation of wind farms in an ocean-atmosphere regional coupled model to analyse the impact of offshore wind farms on physical processes of the North Sea
- Coupling to the Ecosystem model (ECOSMO) to analyse the impact of offshore wind farms on the biological system of North Sea

Acknowledgments

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References

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