The ~~long-term~~ effect of OWF on the wave field in the North Sea using a spectral wave model – a sensitivity study

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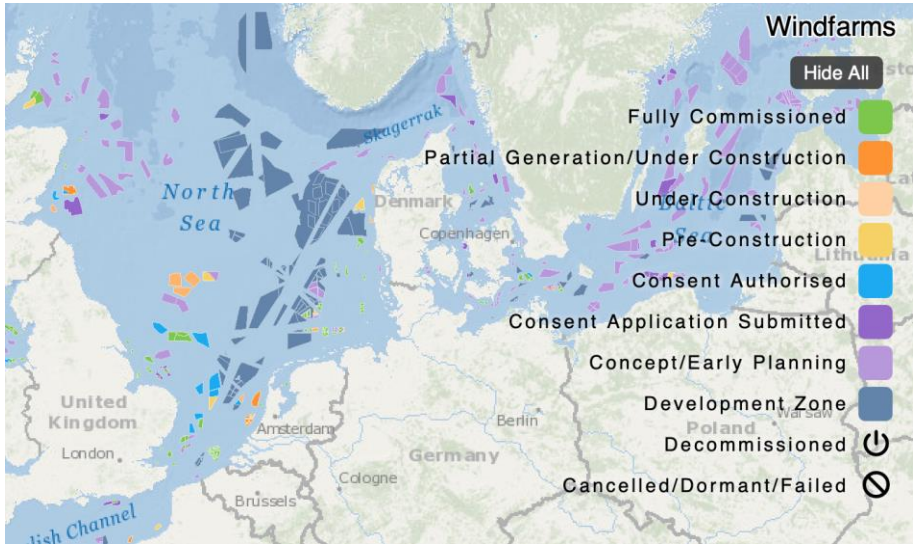
Motivation

- ".., the nine NSEC (North Sea Energy Cooperation) countries agreed in a Joint Statement to reach at least 260 GW of offshore wind energy by 2050, which will represent more than 85% of the EU-wide ambition of reaching at least 300 GW by 2050. The 2050 NSEC ambitions are complemented with intermediate targets of at least 76 GW by 2030 and 193 GW by 2040" (https://www.bmwk.de/Redaktion/EN/Downloads/M-O/nsec-joint-statement.pdf?__blob=publicationFile&v=2)
- The German Government plans to increase the power outcome of the Offshore Wind Farms (OWF) from today 8GW to 30GW by 2030 (and 40GW by 2035)
  https://www.bmwk.de/Redaktion/DE/Pressemitteilungen/2023/01/20230120-30-gigawatt-bis-2030-bsh-veroeffentlicht-flaechen-entwicklungsplan-zum-ausbau-der-offshore-windenergie.html
- Have the usage of large areas for OWF an effect on the atmospheric flow and to what extent?
- And can this impact other parameters like the sea state?



https://map.4coffshore.com/offshorewind/


Vattenfall, 2010 - licence CC BY-ND 2.0

Experimental setup

Atmospheric forcing:

The COSMO-CLM regional atmosphere model is run with a wind farm parametrisation after Fitch et al. 2012.

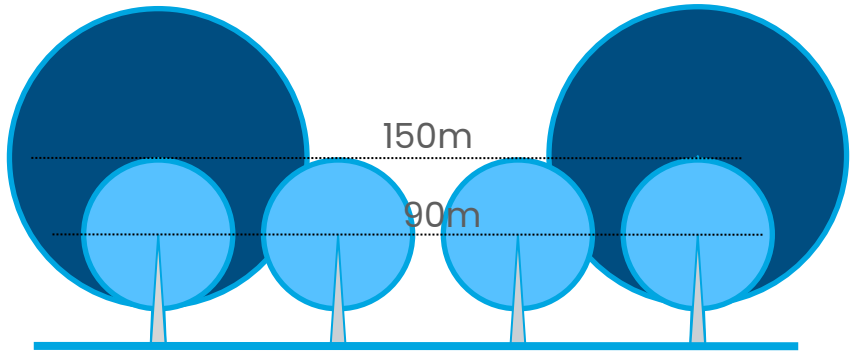
Wind farms are represented as elevated sink of momentum and source of turbulent of kinetic energy depending on wind speed, turbine type

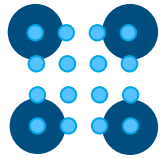
sensitivity experiment with three one year (2008) simulation :

1. reference simulation with no OWF
2. all OWF with 3.6MW turbines
3. all OWF with 15MW turbines

each OWF has approximately the same total energy power outcome

power (MW)	hub height (m)	rotor diameter (m)
3.6	90	120
15	150	240



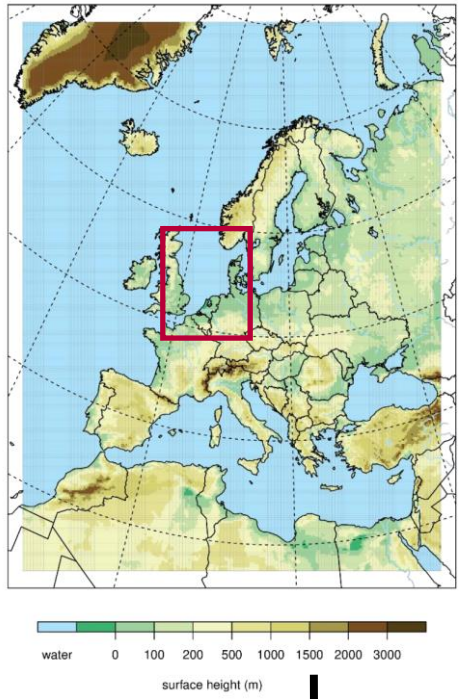


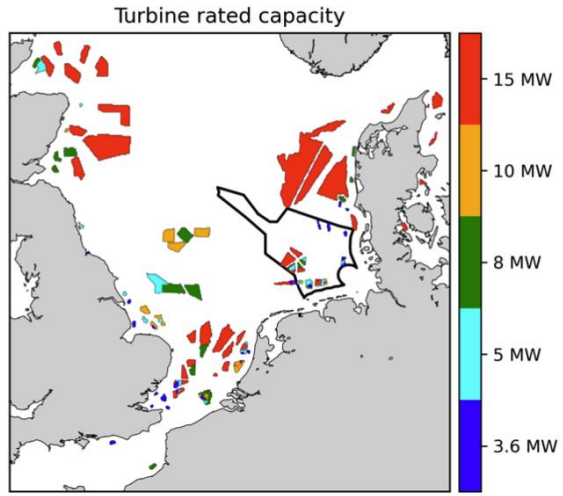
16 x 3,6MW = 57,6MW

4x 15MW = 60MW

Model chain

COSMO-CLMsn (ERAi)
11 x 11 km



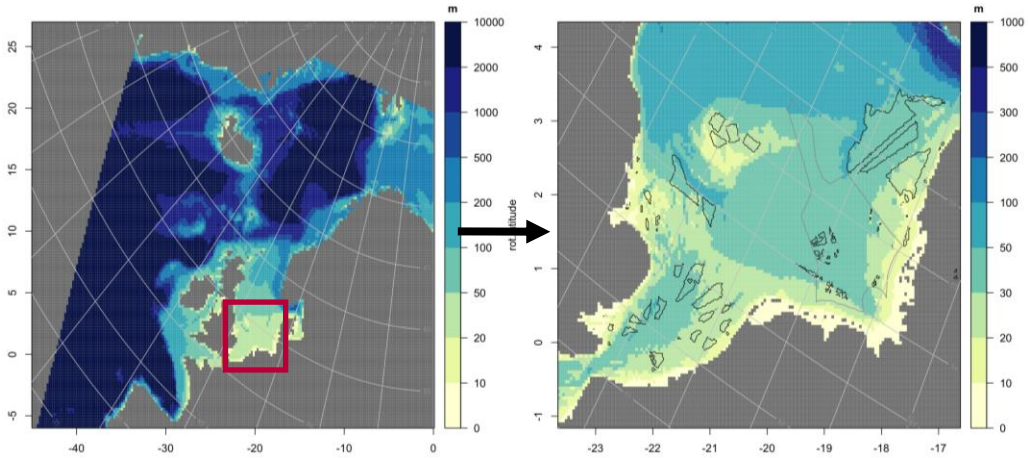


COSMO-CLM WF
2.2 x 2.2km

atmosphere

sea state

WAM cycle 6
25 x 25km



WAM cycle 6
2.5 x 2.5km

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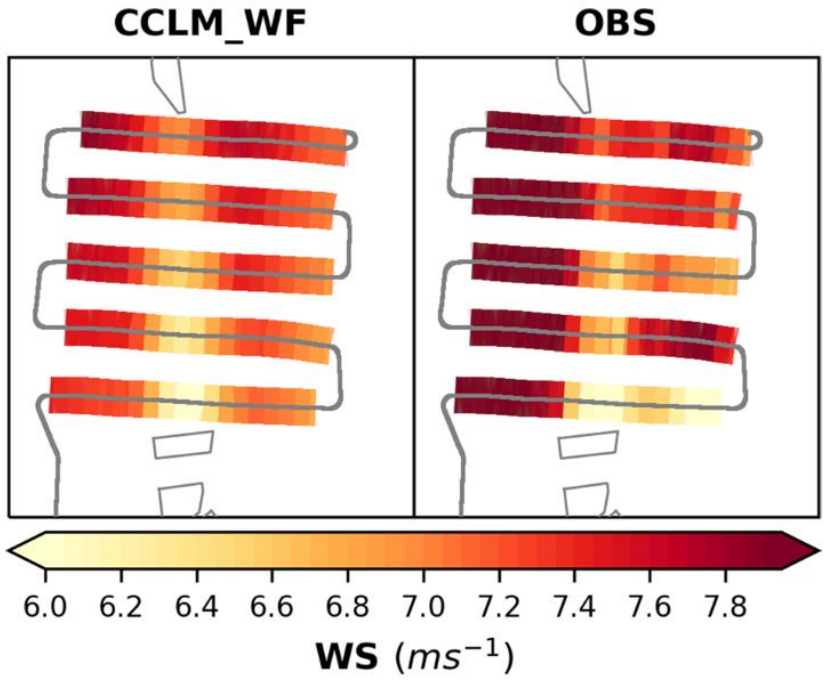
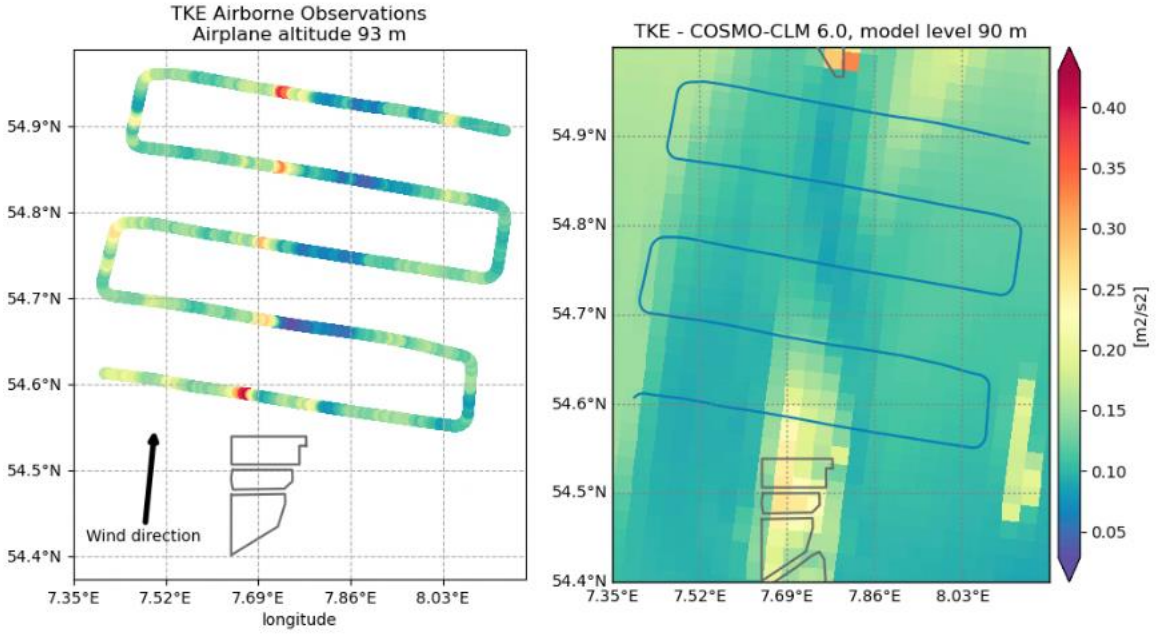
Comparison of OWF parametrisation with observation

wind speed at 90m (hub height)



Ahktar et al. Sci Rep 11, 11826 (2021)

turbulent kinetic energy at 90m (hub height)



A. Elizalde pers comm.

Airborne observations a taken within the WIPAFF project Bärfuss et al. 2019

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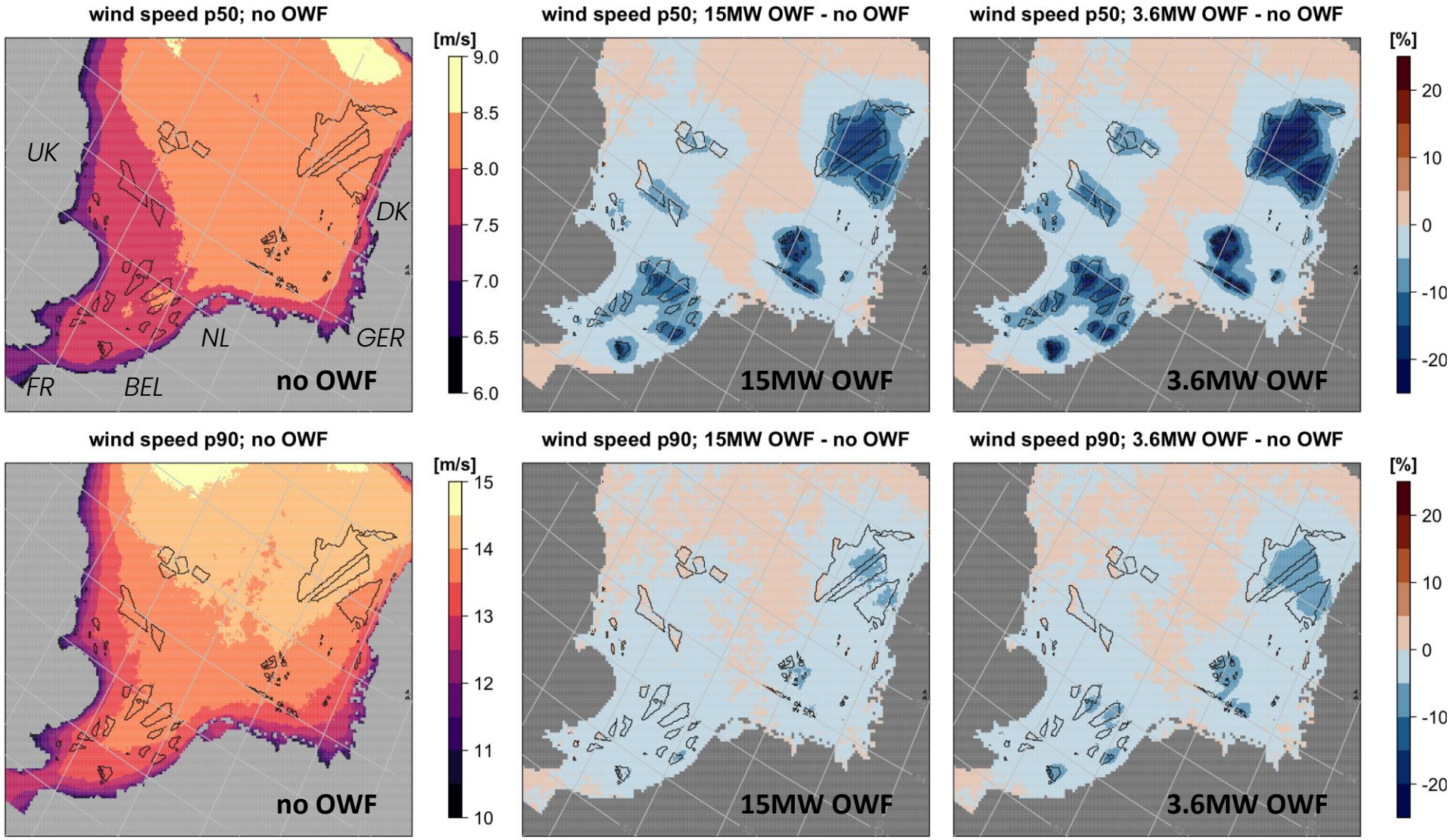
10m wind speed – p50 & p90

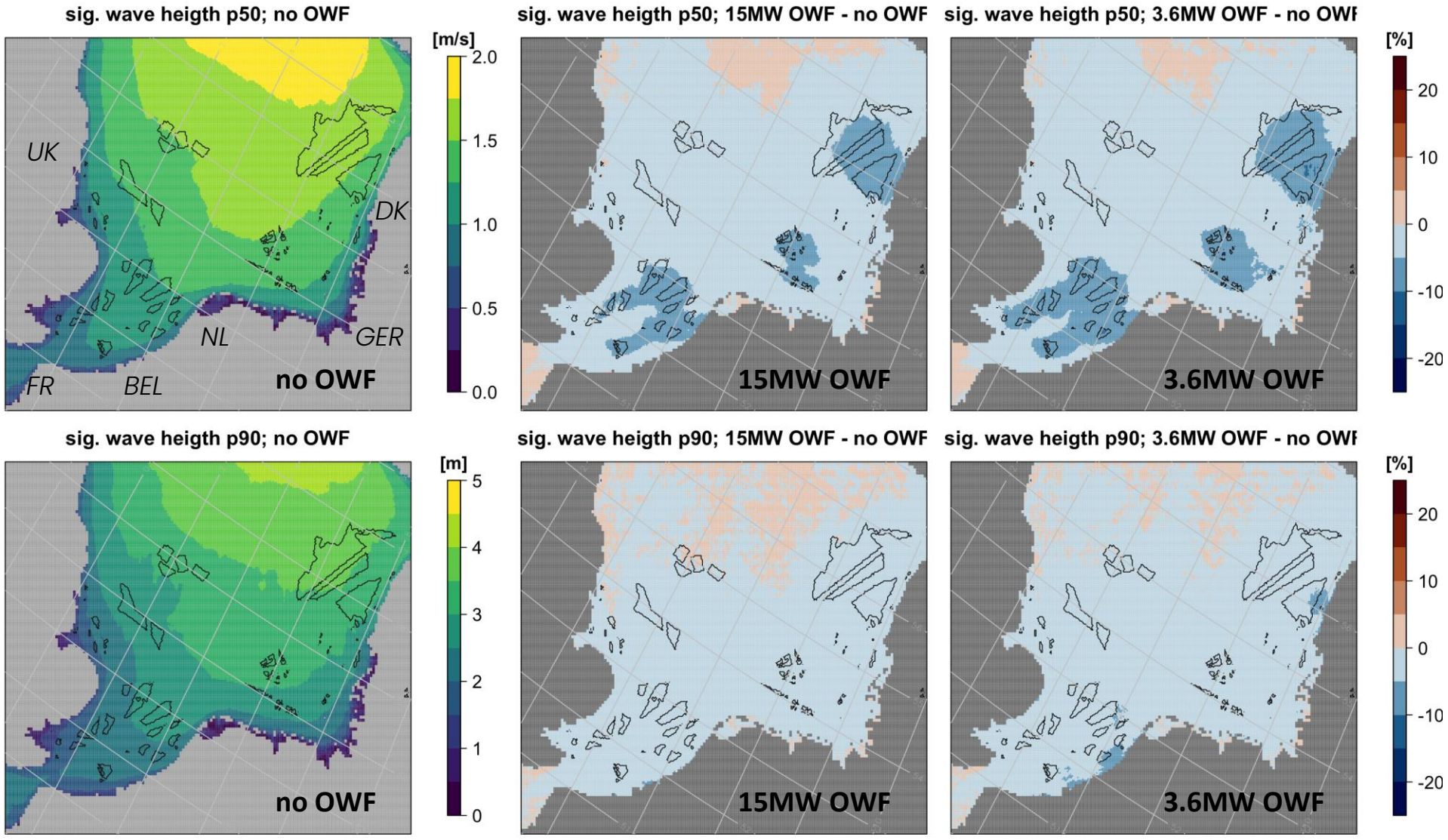


reduction up to 1-2 m/s

->20% within the OWF

small changes for high percentiles (p90) -> cut-off at high wind speeds

sig. wave height – p50 & p90

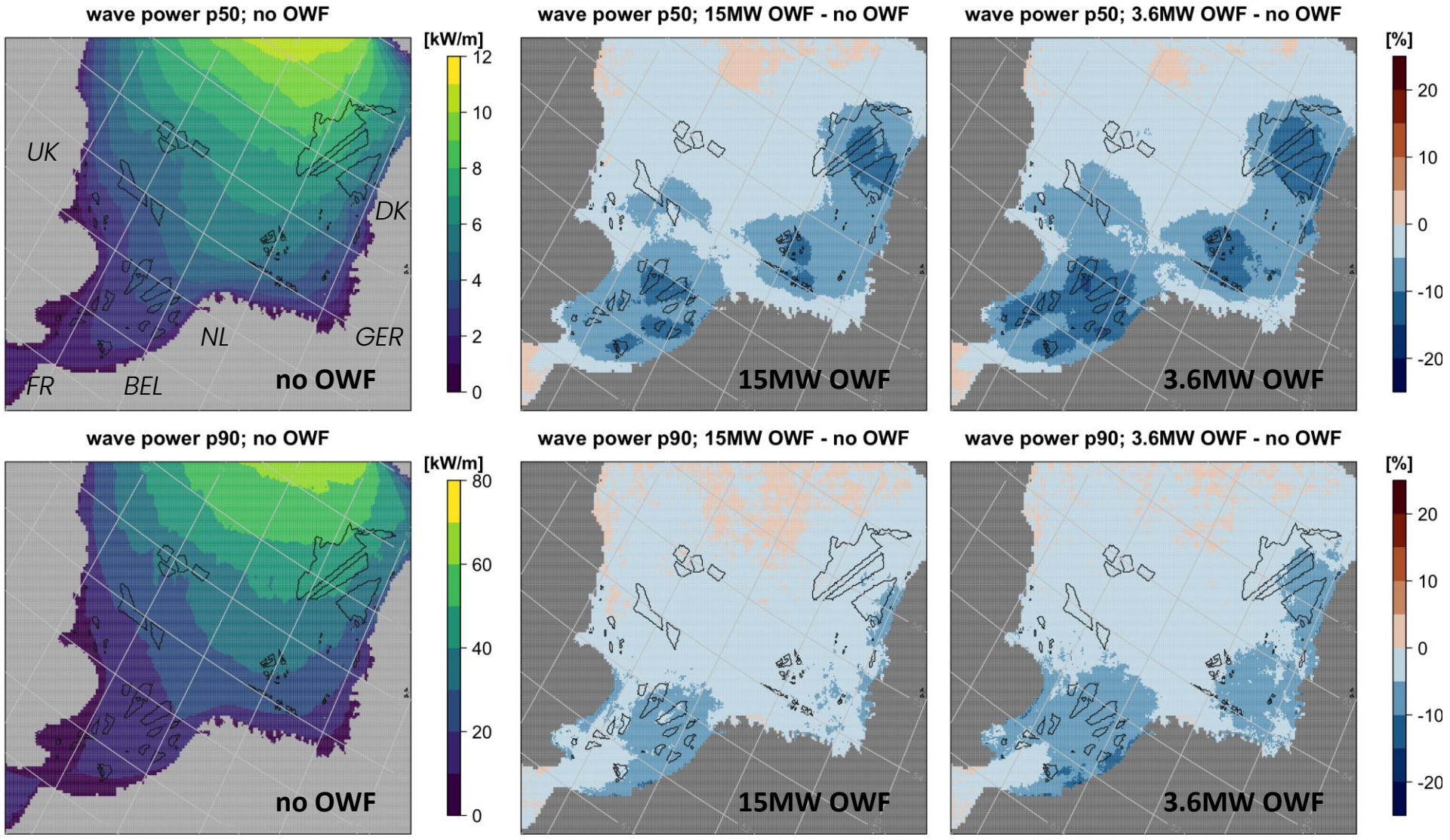


reduction of 5cm -10cm

> 5% for p50

smaller turbines -> larger effect

wave power - p50 & p90

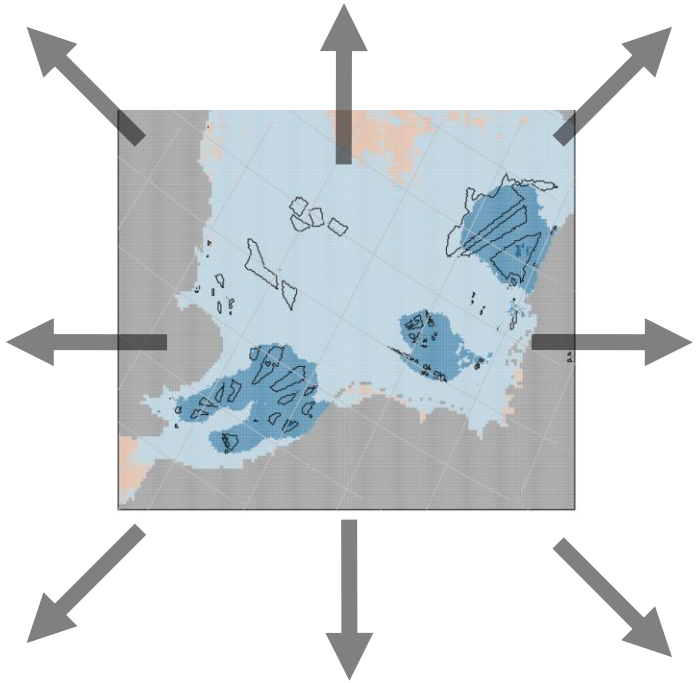


$$P = \frac{\rho_w g^2}{64\pi} T_{m-1} H_s^2$$

reduction of more then 10% for p50 and also larger areas outside the OWF are effected

smaller turbines -> larger effect

directional analysis
sig. wave height p50
per wind direction
no OWF - 3.6MW



[%]

-20 -10 0 10 20

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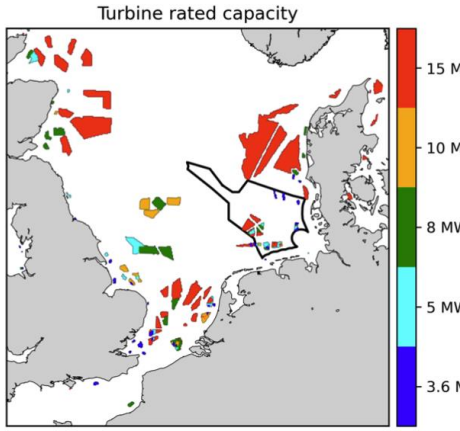
Summary

- shown difference does not include any possible direct effect (e.g. damping, refraction) of the offshore structures on the wave field
- OWF parametrisation in the atmosphere model, is capable of represent the basic features of the changes in the wind field

- reduction of surface wind is restricted to the vicinity of the OWF
- reduction of wave height and wave power is also visible further downstream, in particular for specific wind directions.
- in general the reduction is around 5% outside the OWF, higher for wave power
- the cut-off of the wind turbines at higher wind speed leads to less changes at upper percentiles
- changes for 3.6MW turbines are larger than for 15MW turbines -> lower hub height

- simulation with a more realistic distribution of wind turbine power
- 10 year simulation
- Hindcast with the actually temporal development of OWF (sites and the according turbine power) in the North Sea



Source: EMODnet

Thank You

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