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Interactions of oceanic surface waves and offshore wind farm wakes

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The heat and momentum fluxes between ocean and atmosphere are influenced by the local wind and wave conditions. Offshore wind farms influence those conditions, because they extract kinetic energy from the wind to produce electricity and thereby reduce the wind speed in their wakes. The wind deficits also reduces the source for wind-generated waves in the wake and thus changes the wave field. In turn, the changed wave field alters the momentum flux and thus the local wind and thereby impact the power production of neighboring wind farms. A better understanding of this complex interrelation of wind farm wakes and waves is needed both for improved resource modelling of wind farms as well as for the assessment of their environmental impacts. Thus, in this study we investigate, how strongly wind farms affect waves and how far this impact reaches.

To achieve this goal, mesoscale numerical model simulations are performed with a fully coupled ocean-wave-atmosphere modeling system, which is part of the Coupled-Ocean-Atmosphere-Wave-Sediment Transport modeling system (COAWST, Warner et al. 2008, 2010). The modelling system consists of the Regional Ocean Modeling System (ROMS, Shchepetkin and McWilliams 2005), the Simulating WAves Nearshore model (SWAN, Booij et al 1999) and the Weather and Researching Forecast model (WRF, Skamarock et al. 2008). SWAN and WRF are linked with the Wave Boundary Layer Model (WBLM, Du et al. 2017, 2019) to ensure that the momentum fluxes to and from the wave model are consistent in both models. Wind farm wakes are parameterised with two different methods: the Explicit Wake Parameterisation (EWP, Volker 2014) and the WRF Wind Farm Scheme (WRF-WF, Fitch 2012). Two different methods are used to determine the possible range of wind farm wakes effects.

The coupled modeling system is applied to the offshore area to the west of Jutland with the wind farms of HornsRev 1, 2, 3, DanTysk and Sandbank. For this area wind and wave measurements are available from FINO 3 as well as measurements from DanTysk and Sandbank, which can be used for validation. To determine the interactions of wind farm wakes and waves, simulations of different complexity are performed: WRF-ROMS-WAKE (EWP, WF), WRF-SWAN-ROMS, WRF-SWAN-ROMS-WAKE (EWP, WF). Differences between those simulations are used to detect the effect of wind farm wakes on waves (WRF-SWAN-ROMS – WRF-SWAN-ROMS-WAKE) and of waves on wakes (WRF-ROMS-WAKE – WRF-SWAN-ROMS-WAKE). From SAR data, meteorological conditions with strong wakes are identified. Starting from those cases, the large scale atmospheric stability as well as the large scale wave field is varied to investigate, how those parameters affect the interactions between wind farm wakes and waves. Based on the results, offshore wind farms impacts on waves and implications of waves for offshore wind resource modeling are indicated.