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Modelling potential changes in marine biogeochemistry due to large-scale offshore wind farms

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Large-scale renewable energy generation by offshore wind farms may lead to changes in marine ecosystem processes through the following mechanism: 1) wind-energy extraction leads to a reduction in local surface wind speeds; 2) these lead to a reduction in the local wind wave height; 3) as a consequence there's a reduction in SPM resuspension and concentrations; 4) this results in an improvement in under-water light regime, which 5) may lead to increased primary production, which subsequently 6) cascades through the ecosystem. A three-dimensional coupled hydrodynamics-biogeochemistry model (GETM_ERSEM) was used to investigate this process for a hypothetical wind farm in the central North Sea, by running a reference scenario and a scenario with a 10% reduction (as was found in a case study of a small farm in Danish waters) in surface wind velocities in the area of the wind farm. The ERSEM model included both pelagic and benthic processes. The results showed that, within the farm area, the physical mechanisms were as expected, but with variations in the magnitude of the response depending on the ecosystem variable or exchange rate between two ecosystem variables (3-28%, depending on variable/rate). Benthic variables tended to be more sensitive to the changes than pelagic variables. Reduced, but noticeable changes also occurred for some variables in a region of up to two farm diameters surrounding the wind farm. An additional model run in which the 10% reduction in surface wind speed was applied only for wind speeds below the generally used threshold of 25 m/s for operational shut-down showed only minor differences from the run in which all wind speeds were reduced. These first results indicate that there is potential for measurable effects of large-scale offshore wind farms on the marine ecosystem, mainly within the farm but for some variables up to two farm diameters away. However, the wave and SPM parameterisations currently used in the model are crude and need to be further tested and refined. Also, potential counter-acting processes such as possible increases in SPM concentrations due to turbulence generated by the wind-turbine foundations may need to be included for more accurate simulations. Moreover, it is unclear to what extent these results would be valid for areas where different hydrodynamic characteristics may predominate, e.g. with summer stratification or strong tidal currents. Finally, an assessment would need to be carried out of how beneficial or detrimental these potential changes might be from various social-economic and ecosystem-management points of view.