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# Emergence of large-scale hydrodynamic structures due to atmospheric offshore wind farm wakes

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The aerodynamic drag of wind turbine rotors creates downstream wake structures in the atmosphere, which represent decreasing wind speed and increasing turbulence behind wind turbines. In the marine environment, these atmospheric wakes entail attenuated wind forcing at the sea surface boundary and thus imply consequences for wind-driven processes in the ocean dynamics. Based on the unstructured-grid model SCHISM, this study presents a new cross-scale hydrodynamic model setup for the southern North Sea, which enables to simulate wake effects in the marine environment at high resolution. We introduce an observational-based empirical approach to parameterize the atmospheric wakes in the hydrodynamic model and simulate the seasonal cycle of the summer stratification in consideration of the current state of European offshore wind farm development. The simulations show the emergence of large-scale structural changes in local hydro- and thermodynamics due to the wind speed reductions caused by offshore wind farms. The wake effects lead to spatial variability of the mean horizontal currents and, in particular, affect the stratification strength during the summer season. Our results aim to advance understanding of how coastal systems adapt to anthropogenic stressors such as offshore wind farms and raise awareness of potential changes to the future ocean. In particular, large-scale changes in stratification suggest potential consequences for biogeochemical processes and marine ecosystem dynamics.