Variations in Sediment Concentration caused by Modified Waves and Currents in an Offshore Wind Farm

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Abstract

The European Green Deal's objective of transforming the EU into a modern, resource-efficient and competitive economy hinges on the establishment of a sustainable blue economy. This study pursues a multi-use of resources strategy to advance the blue economy under the EU Green Deal, with a particular focus on the potential of multi-use offshore wind energy and low trophic level aquaculture. The multi-use of offshore wind farms (OWFs) for the dual purpose of energy and food production exemplifies the advantages of multi-use of ocean space such as promotion of restoration and regeneration, nutrient and carbon capture or improving quarter quality. This study constitutes a foundational step in our endeavors to simulate realistic hydrodynamical conditions at the Meerwind-OWF site (German Bight, North Sea).

A high-resolution, 3D coupled circulation-wave-sediment model based on unstructured grids was employed to simulate the interactions between monopiles and wave-current interactions. The model effectively captures detailed hydrodynamic processes, transitioning from open boundary scales (~2 km) to near-foundation resolutions (~2 m). The presence of OWF monopiles induces complex changes in local and regional hydro- and sediment dynamics, altering current velocities and wave characteristics. The OWF monopiles cause varying local and regional changes in the monthly mean velocity at mid-depth: a reduction of around 5% near the piles and an increase of about 1% in the surrounding region. Consequently, the monthly potential energy anomaly rises by about 5% outside the OWF, while it drops by 40% within it. Prevailing westerly waves influence tidal asymmetry, especially on the eastern side of the piles, leading to asymmetric turbulent wakes on either side of the piles over both monthly and tidal timescales. However, wave intensification can disrupt the periodic tidal pattern of the wake. An extreme event with Hs > 4 m generates a peak wake during slack water that surpasses those during maximum tidal currents in spring tides. These hydrodynamic changes, influenced by wave-structure interactions, can significantly affect sediment transport, nutrient dynamics, and habitat conditions. Suspended sediment concentration is subject to modification by changes in tidal asymmetry and wind-driven waves caused by the OWF foundations. Building on these findings, we designed a series of "What-If" scenarios to evaluate the environmental impact of potential of OWFs.