Project title: Oceanic–Windfarm Interactions in the German Bight

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Allocation Period: 2026 – 07 – 01 to 30 – 06 – 2027

Abstract:

Offshore wind farms (OWFs) are experiencing rapid growth in the German Bight and represent a pivotal element of the European energy transition. While their contribution to renewable energy production is well established, the cumulative impacts of large OWF clusters on hydrodynamics, waves, sediment transport, and biogeochemical processes remain insufficiently quantified. In shallow shelf seas such as the southern North Sea, monopile foundations modify local circulation, wave attenuation, and turbulence, which in turn affect suspended sediment concentrations, light availability, nutrient cycling, and ecosystem functioning. Robust assessment of these processes requires fully coupled, very high-resolution numerical modeling systems and large-scale high-performance computing resources.

This project aims to quantify the cumulative physical and biogeochemical impacts of adjacent offshore wind farms in the German Bight. To this end, a fully coupled SCHISM–WWM and SCHISM–WWM–ICM modeling framework will be employed. Multi-year simulations for 2024–2025 will be conducted on unstructured meshes with meter-scale resolution (~2 m) around monopile foundations, explicitly resolving wave–current–structure interactions. Parallel model configurations with and without monopiles enable direct attribution of OWF-induced effects on currents, wave dynamics, sediment resuspension and transport, and suspended sediment concentrations. The coupled biogeochemical simulations further assess impacts on nutrient dynamics, oxygen conditions, and ecosystem-relevant variables, providing new insight into physical–biogeochemical feedbacks driven by OWF clusters.

High-frequency model outputs during observation-rich periods support detailed validation and process-based analysis, while systematic quality assurance and post-processing ensure delivery of validated, reusable datasets. Due to the combination of ultra-high-resolution unstructured grids, two-way coupling of hydrodynamics, waves, sediment, and biogeochemistry, and the need for multiple comparative simulations, the project is computationally demanding and particularly well suited for execution on the HLRE-4 system. The resulting datasets will directly support environmental impact assessments, offshore multi-use planning such as aquaculture, and future machine-learning applications, contributing to sustainable offshore wind development in the German Bight.