Cloud-Based Tool for Evaluating Offshore Wind Turbine Effects on Seabed Ecosystems: Integrating GOTM, EnKF, and Fine Resolution Calibration

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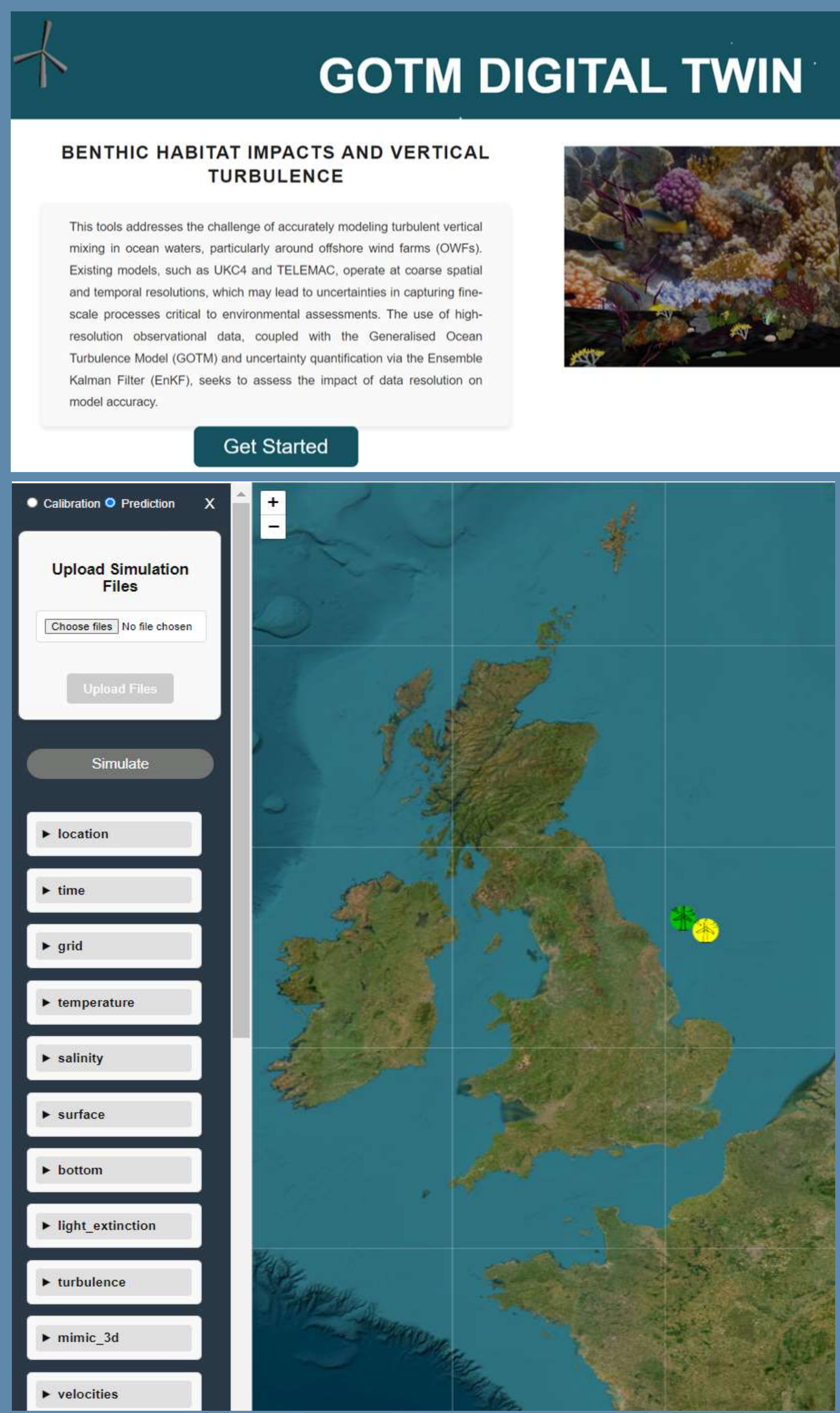
Background

Offshore wind farms (OWFs) are increasingly being developed worldwide to meet renewable energy demands. However, OWFs can influence seabed ecosystems, primarily through changes in bed stress, which affect habitats and the broader marine environment. Understanding these impacts requires an accurate assessment of turbulence and other hydrodynamic parameters near the seabed. We aim to develop a tool that leverages the Generalised Ocean Turbulence Model (GOTM) to estimate bed stress and to quantify the uncertainty in coarser-resolution model predictions. This tool, designed for user accessibility, will allow for precise, site-specific assessments and support sustainable offshore wind energy development.



Methodology

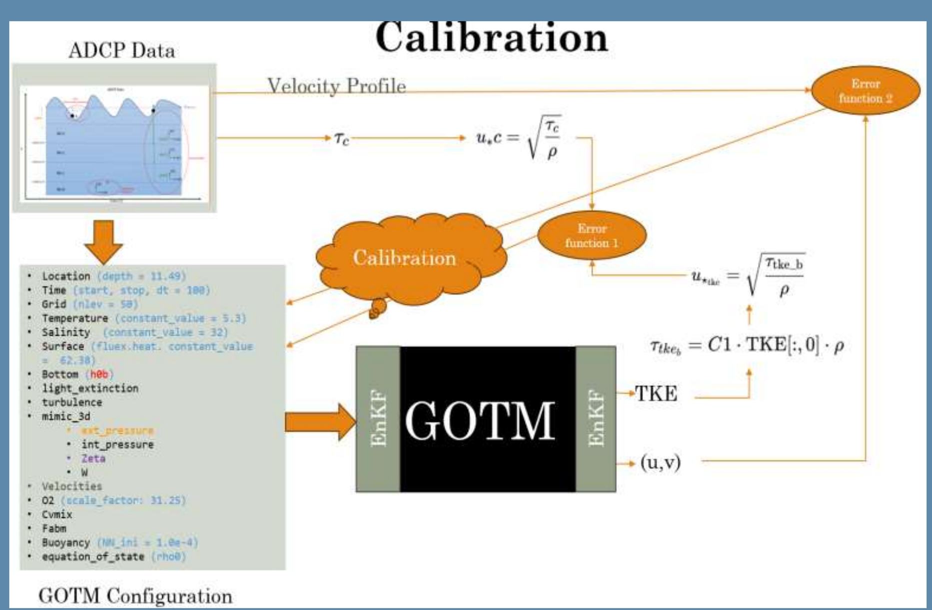
Model Selection: We use the GOTM to simulate vertical turbulence and calculate key parameters like turbulent kinetic energy (TKE), which influence bed stress.

Data Input and Configuration: Users can input high-resolution data, such as from Acoustic Doppler Current Profilers (ADCP), or select from pre-configured model setups for other sites.

Calibration with Ensemble Kalman Filter (EnKF): The EnKF method is employed to calibrate the model, address uncertainties, and optimize data resolution. This ensures accurate predictions while balancing computational cost and time.

Implementation as a Cloud-Hosted API: The tool is integrated as a cloud-hosted API within a web application, providing users with a flexible, accessible platform for environmental assessment.

(a)



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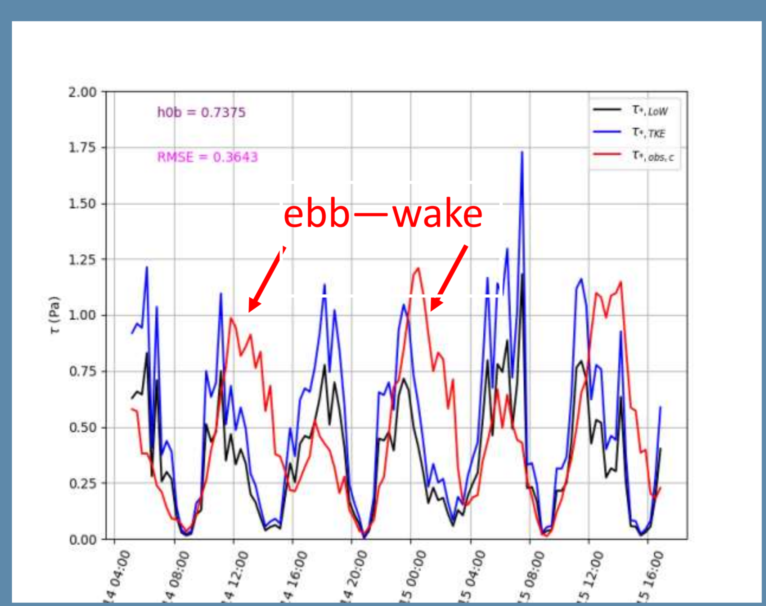

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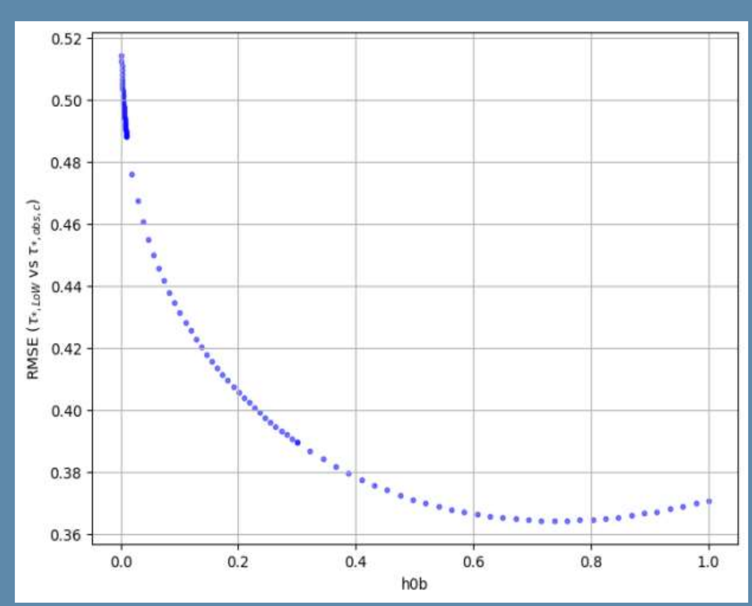

Benefits

- ✓ Sustainable Development
- ✓ Enhanced Decision-Making
- ✓ Cost Efficiency
- ✓ Scalability
- ✓ User-Friendly Access

(a) GOTM Calibration Diagram (b) The figure compares modelled and observed bed stress during flood and ebb tides. The black line and blue line show model predictions for bed stress using two approaches, both accurately representing background (flood tide) flows but underestimating wake-affected flow during the ebb tide. This is expected, as the model doesn't account for the turbine's presence. The red line displays observational data, capturing the real wake effect: a reduction in mean flow (velocity deficit) and an increase in TKE due to the vortex wake behind the turbine (c) Effect of bottom roughness (h0b) on model accuracy: The convex curve shows how RMSE between predicted and observed bed stress varies with h0b. The shape suggests an optimal roughness value where model predictions align best with observations.

We will use the tool to:

1. Quantify the uncertainty in the under-prediction of the Turbulent Kinetic Energy during the turbine wake-effected flows.
2. Explore the sensitivity of bed stress estimates to the resolution of the input forcing (temporal and spatial). We can thus advise industry on the level of uncertainty that they will expect in their large-scale modelling and strategic observations.