Development of an Eastern Irish Sea TELEMAC model to predict changes to seabed habitats for future OWF and climate scenarios

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ECOWind-ACCELERATE aim and objectives

Understand the combined impacts of climate change and OWFs on accelerated ecologically-relevant seafloor change (Fig. 1).

- How will future climate driven changes to wind, waves, tides and sea-level influence flow and bed stress across the UK continental shelf?
- How will changing hydrodynamic forces around OWFs combine with those due to the climate crisis to drive seabed change the Eastern Irish Sea?

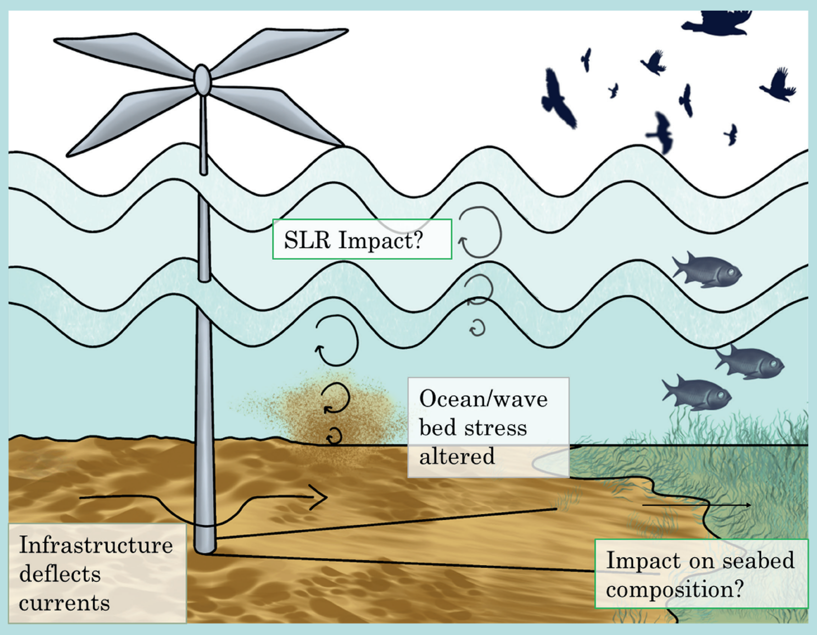

Fig. 1: Schematic of the drivers of ecologically-relevant seafloor change

What is ecologically-relevant seafloor change?

- Seabed sediment composition can influence the benthic communities it supports and as a result seabird prey, and the seabirds which feed on them.
- Currents and wave-generated bed shear-stresses mobilise and transport sediment, thus changing sediment composition.

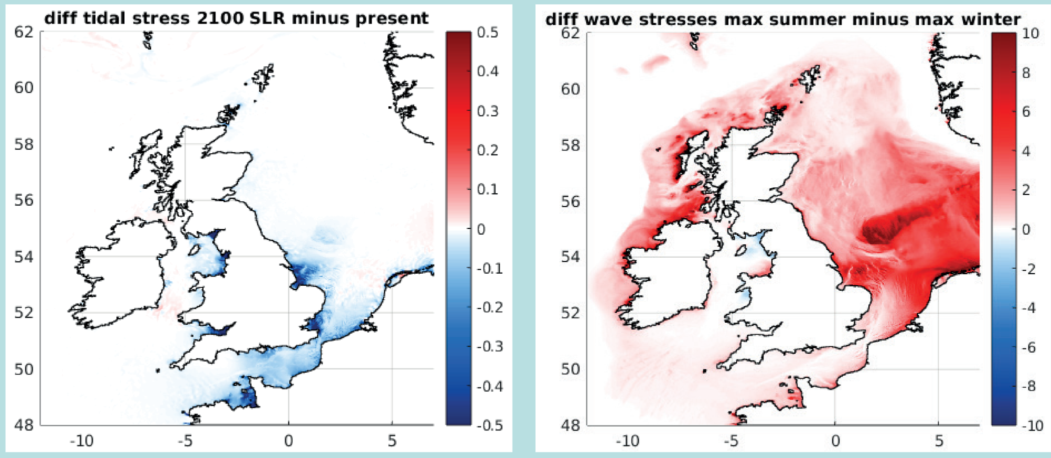

Fig. 2: Change in bed shear-stress (N/m2) between present day and 2100 (left); difference in peak bed shear-stress between peak winter and peak summer (left)

- In the future we predict that SLR alone will reduce bed shear-stress by end-century, but the monthly variability of storms (less frequent, very unpredictable) will dominate the SLR signal (Fig. 2)
- How will the presence of OWF infrastructure enhance the combined effect of SLR and storms?
- What impact will this have for seafloor change and the benthic/seabird communities the seabed supports?

How do we predict this?

- Develop a high-resolution model including the presence of existing and proposed OWF infrastructure
- Force the model with tides and waves from a 1.5 km resolution UK Shelf model (without OWF infrastructure) (Fig. 3). Developed as part of Task 1.1.1 of the ECOWind-ACCELERATE Project

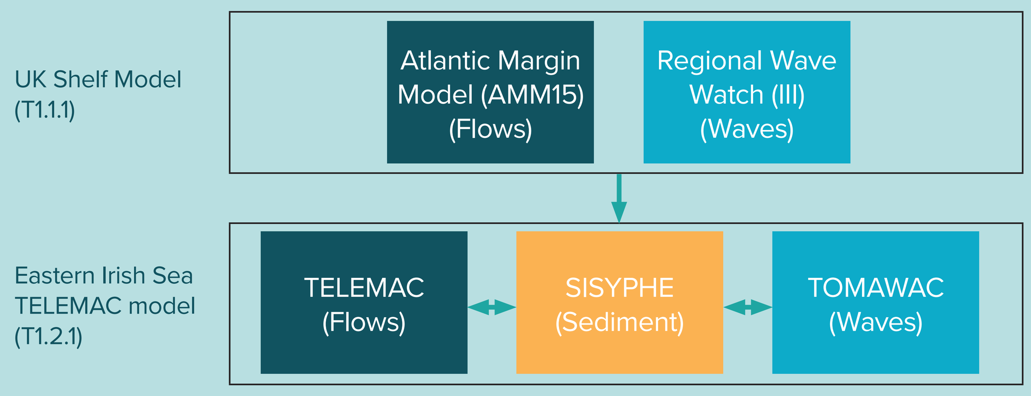

Fig. 3: Coupling between UK shelf scale model and high-resolution Eastern Irish Sea model

- Predict changes to flows, sediment transport and bed composition, with and without OWF infrastructure for past, present and future climate scenarios (Table 1).

Table. 1: Climate scenarios

Climate Scenario	Winter	Summer
Past	Jan 1996	Jun 1992
Present	Jan 2017	Jun 2018
Future (Mid-Century)	Jan 2050	Jun 2053
Future (End-Century)	Jan 2090	Jun 2093

Eastern Irish Sea model

- A TELEMAC model was developed for the Eastern Irish Sea with approx. 390,000 nodes and 780,000 elements (Fig. 4).
- Existing (689) and proposed (136) OWF monopiles are represented by hexagonal islands in the mesh.
- The mesh resolution ranges from 1.5 km offshore to > 1 m in vicinity of monopiles.
- The model bathymetry is EMODnet 2022 MSL bathymetry (1/16', ca. 115 m), supplemented with UKHO bathymetry data.

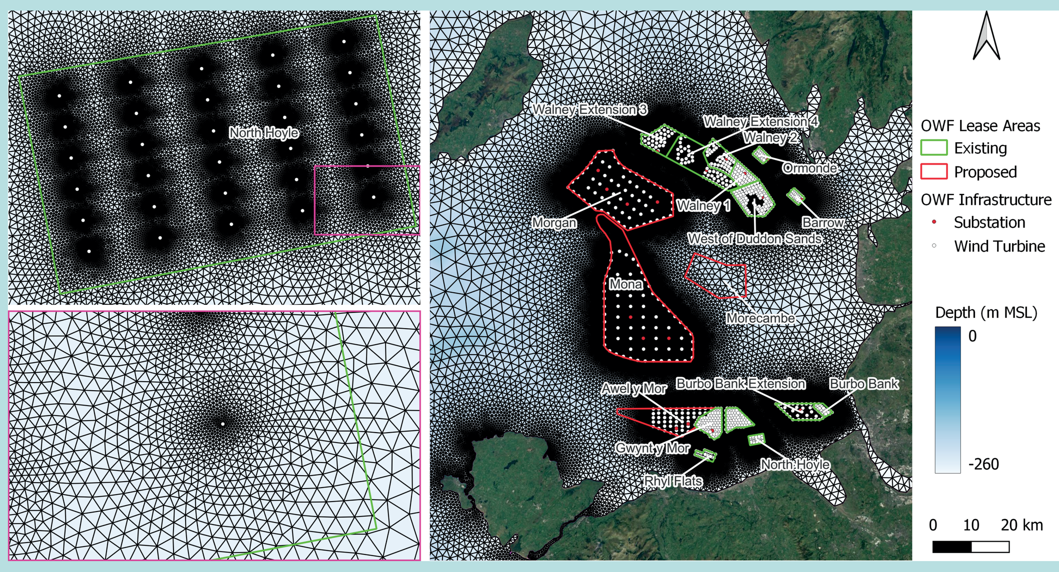

Fig. 4: Eastern Irish Sea TELEMAC model mesh (right), zoomed in on North Hoyle OWF (top left) and an individual monopile (bottom left)

- A sediment map was produced from analysis of 3,504 sediment samples (Fig. 5):
  - 2,355 OneBenthic
  - 659 British Geological Survey
  - 490 Miscellaneous
- Bedrock and hard substrates were defined using BGS 250K Offshore Bedrock and Hard Substrate layers
- The model represents 6 sediment classes (Table 2, Fig. 6)

Table. 2: Model sediment fractions

Description	Size Classes
Fines*	< 0.063 mm
VF-F Sand	0.063 mm - 0.25 mm
M Sand	0.25 mm - 0.5 mm
C-VC Sand	0.5 mm - 2.0 mm
Gravel	2.0 mm - 64.0 mm
Cobbles	> 64.0 mm

*Note, we do not plan to model cohesive sediment transport

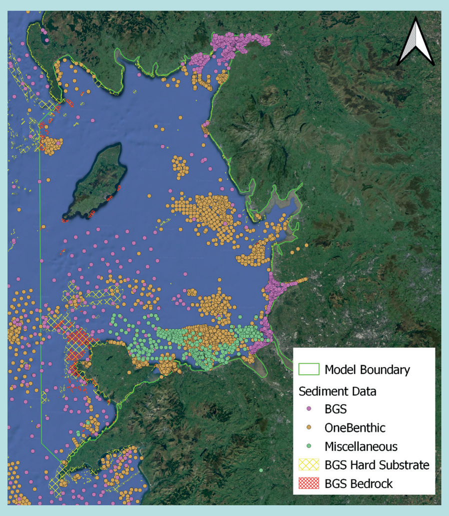

Fig. 5: Available Eastern Irish Sea sediment samples

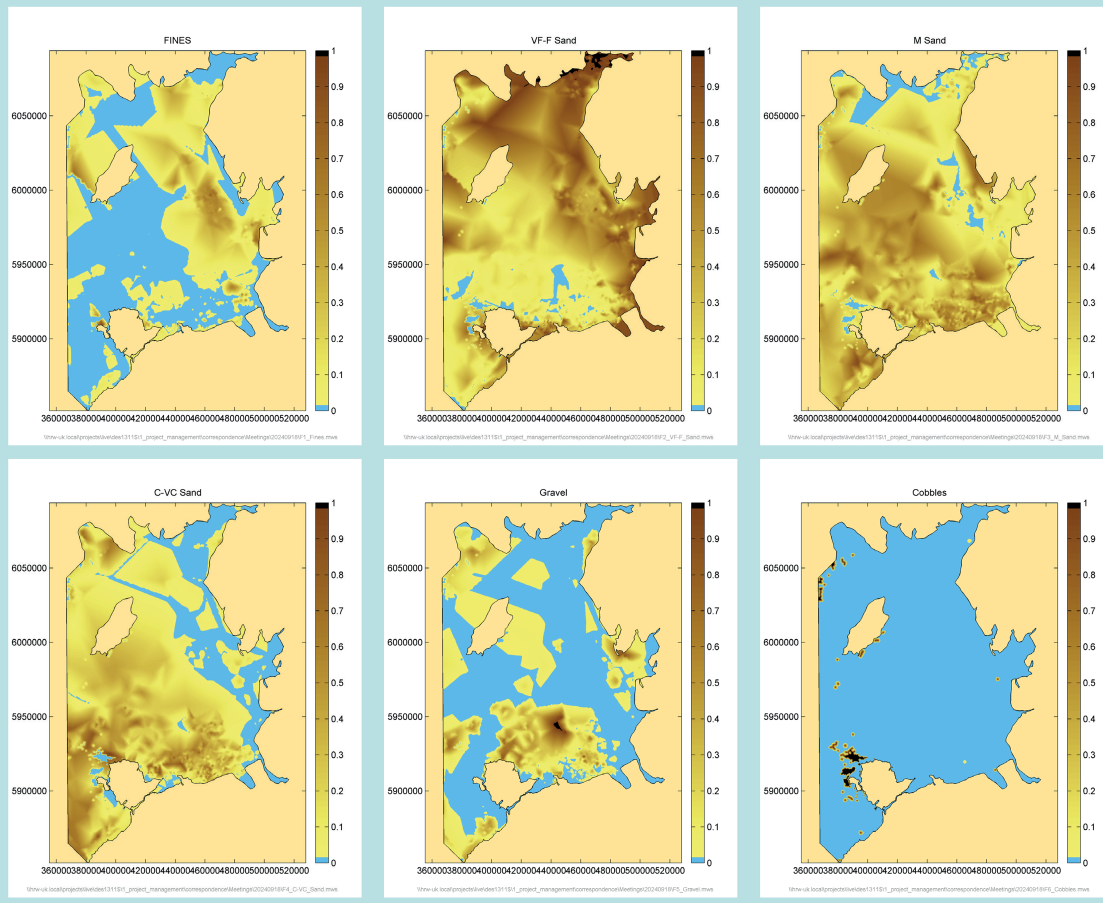

Fig. 6: Proportions of the 6 sediment classes represented by the model

Model calibration and verification

- The hydrodynamic performance of the model is verified against observations of tidal levels, waves, and tidal currents during August 2011. The observation locations are shown in Fig. 7
- The error between predictions and observations is quantified by the mean error (ME or bias); the mean absolute error (MAE); and the root mean square error (RMSE)
- The Willmott (1981) Skill Score (WSS) is used to assess the skill of the model (WSS = 1 for a perfect fit).
- The WSS can be categorised as adequate (0.55-0.65); sufficient (0.65-0.75); good (0.75-0.85); and very good (>0.85).

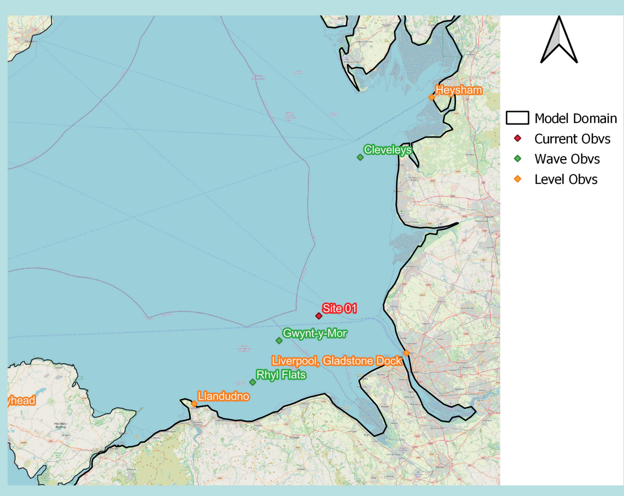

Fig. 7: Locations of tidal level, waves, and tidal current observations

Tidal levels

- The skill of the model for tidal levels is very good at all tide gauges with WSS > 0.99 (Table 3).
- The model predicts the magnitude and phase of the tidal levels well (Fig. 8) with MAE values ranging between 0.13 and 0.31 m (Table 3).
- The largest errors between observation and prediction occur at neap tides (Fig. 8)

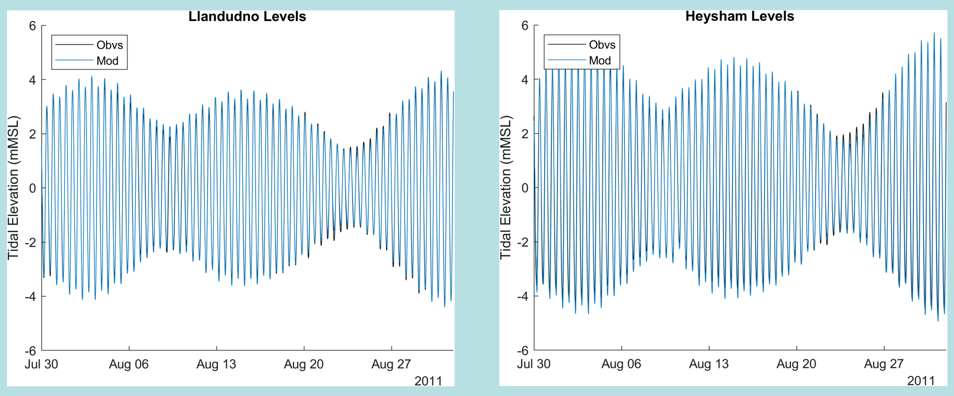

Fig. 8: Predicted (blue) and observed (black) tidal levels

Table. 3: Tidal level error stats

Tidal Level (m)	ME	MAE	RMSE	R2	WSS
Heysham	-0.10	0.31	0.40	0.98	0.994
Holyhead	-0.01	0.15	0.26	0.97	0.991
Liverpool	-0.15	0.23	0.28	0.99	0.997
Llandudno	0.05	0.13	0.16	0.99	0.999

Tidal currents

- The skill of the model is very good for both current speeds and directions with WSS > 0.96 (Table 4).
- The model accurately predicts peak tidal current speeds and corresponding directions well (Fig. 9) with MAE values of 0.05 m/s and 15.05°, respectively (Table 4).
- The largest errors occur at neap tides when current speeds are weak resulting in uncertainty in direction.

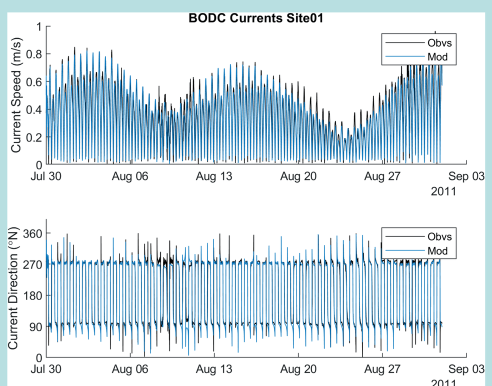

Fig. 9: Predicted (blue) and observed (black) tidal currents

Table. 4: Tidal currents error stats

Site 01	ME	MAE	RMSE	R2	WSS
Speed (m/s)	-0.01	0.05	0.07	0.89	0.97
Direction (°)	-4.36	15.05	34.39	0.86	0.96

Waves

- The model appropriately predicts the timing and magnitude of wave events (Fig. 9) represented by WSS values ≥ 0.97 (Table 5)
- The model overpredicts the sig. wave height of peak events reflected in MAE values of between 0.10 and 0.14 m (Tab. 5).
- The model skill for wave directions is good. Uncertainty during periods of changing wave direction (Fig. 9) increases the MAE resulting in lower WSS values (Table 5).

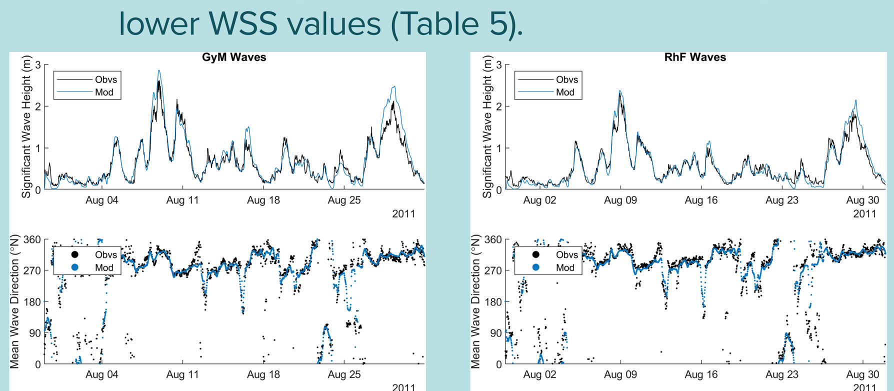

Fig. 9: Predicted (blue) and observed (black) wave heights and directions

Table. 5: Wave error stats

Sig. Wave Height (m)	ME	MAE	RMSE	R2	WSS
Cleveleys (Clv)	0.09	0.14	0.19	0.94	0.97
Gwynt-y-Mor (GyM)	0.04	0.13	0.19	0.93	0.97
Rhyl Flats (RhF)	0.01	0.10	0.14	0.94	0.98
Wave Direction (°)					
Cleveleys (Clv)	1.18	22.39	44.02	0.36	0.75
Gwynt-y-Mor (GyM)	6.01	32.68	71.61	0.33	0.76
Rhyl Flats (RhF)	8.96	35.36	76.00	0.37	0.78

Conclusions

- The model has been validated against observations of tidal levels, waves and tidal currents.
- The skill of the model provides confidence in ability of the model to accurately predict prevailing hydrodynamics. This instills confidence in applying the model to predict morphodynamics.
- The calibrated and validated hydrodynamic model will be coupled with a sediment transport model to predict changes to seabed composition, without and with OWF infrastructure (existing and proposed), for future climate scenarios (Table 1).

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