# ORE Modelling
## Tidal Stream & Offshore Wind

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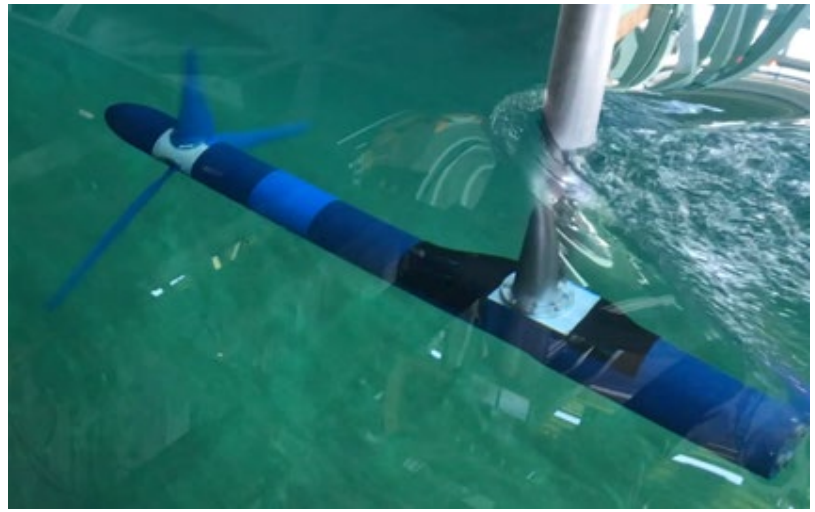
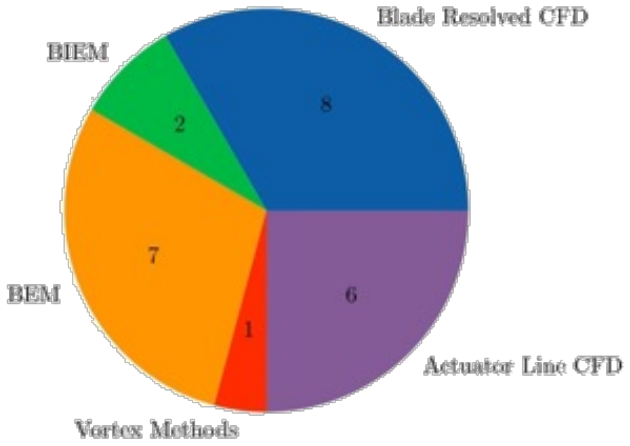
# Tidal: Supergen ORE Phase 1 Benchmark Turbine

- 1.6 m Diameter Turbine
- Designed to facilitate comparison of wide-range of models
  – **23 model submissions from 14 groups**
- Including:

- Blade Element Momentum Methods
- Actuator Line Methods
- Blade Resolved Methods
- Boundary Integral Equation
- Vortex Methods



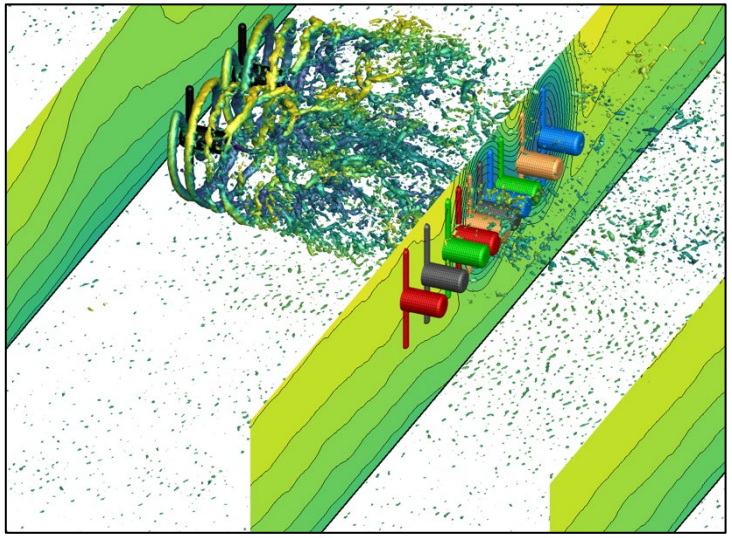



UNIVERSITY OF PLYMOUTH
UNIVERSITY OF ABERDEEN
UNIVERSITY OF HULL
THE UNIVERSITY OF EDINBURGH
UNIVERSITY OF Southampton
MANCHESTER 1824 The University of Manchester
UNIVERSITY OF EXETER
THE UNIVERSITY OF WARWICK
UNIVERSITY OF OXFORD
University of Strathclyde

MANCHESTER 1824
The University of Manchester

# Unsteady loading & wakes in arrays

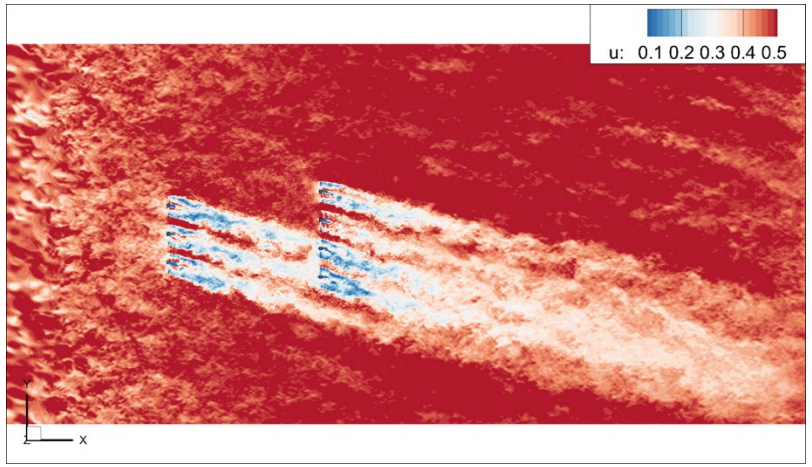
## Complex inflow to BEMT by LES

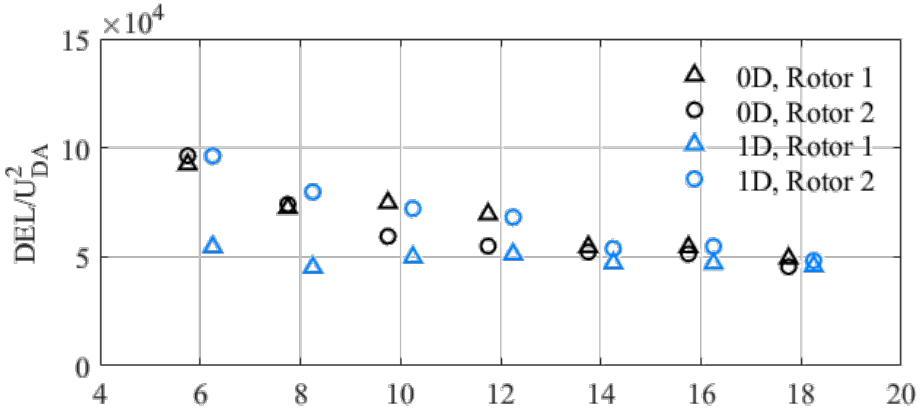


Velocity shear
&
Wake shear
&
Turbulence.

**14,400 CPU hours.**
***reduced to***
**0.33 CPU hours**

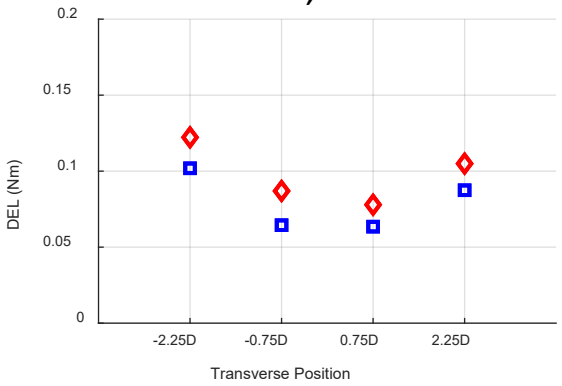
## Synthesis of complex inflow

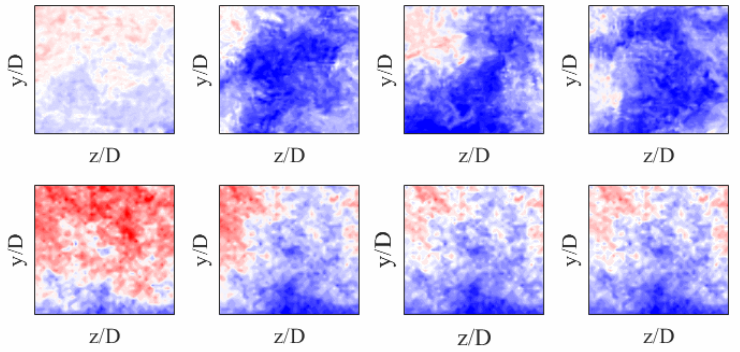



## Fatigue load prediction

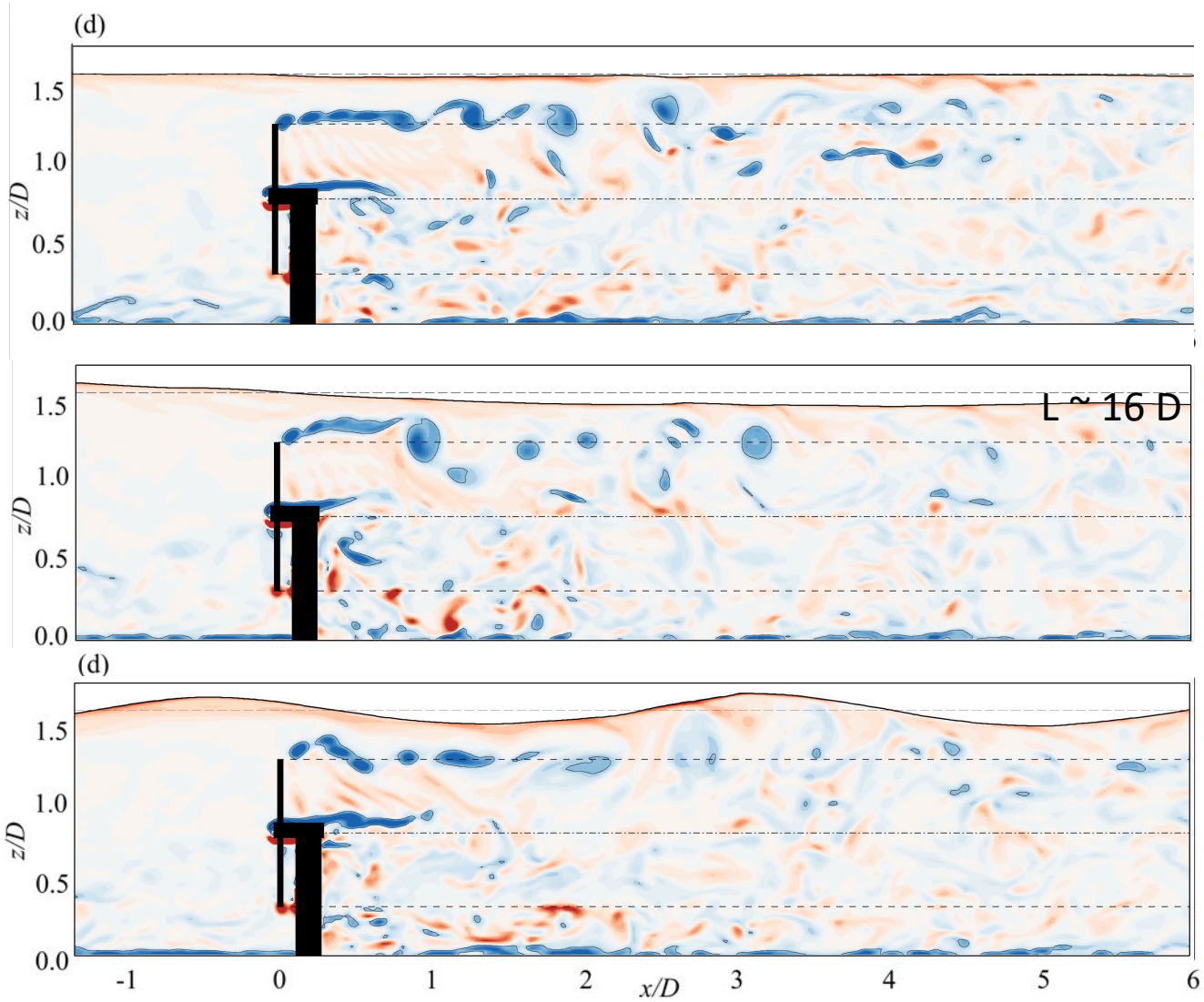
Same trend, conservative

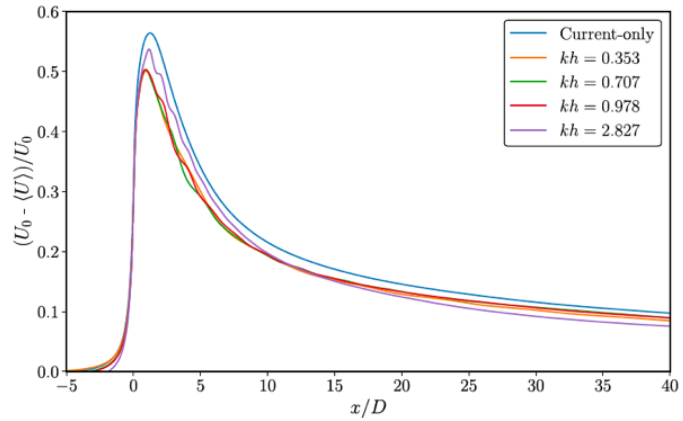


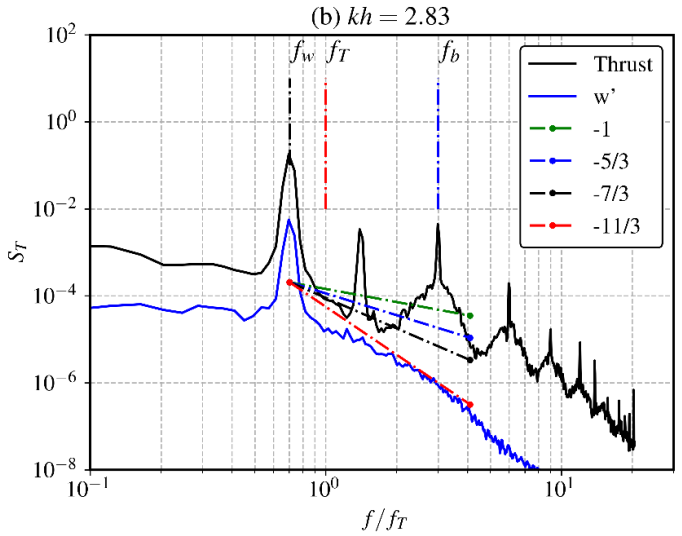

Ouro et al. RENEW 2022, and Mullings et al. JOEME 2024 (in press).

# Unsteady loading & wakes in turbulence and waves




Wake recovery Rate increased

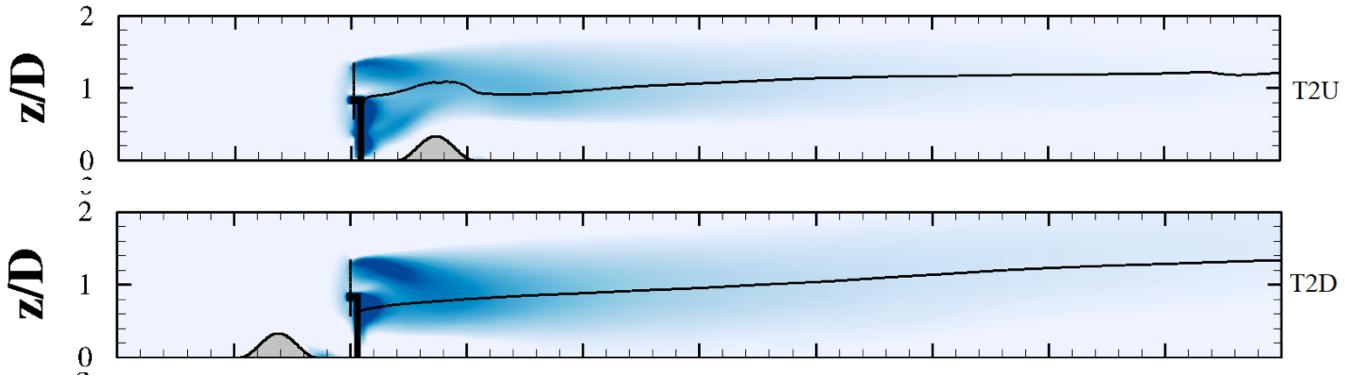



Thrust spectra (approaching deep-water waves)

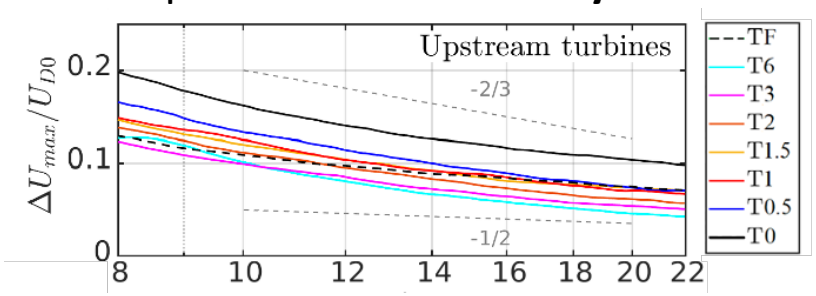
Ouro et al. PRF 2024, Stallard et al. EWTEC 2023.

# Unsteady loading & wakes due to bathymetry

## *Idealised* bed-forms: 2D ridge

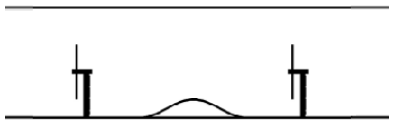



Impact on **wake recovery**



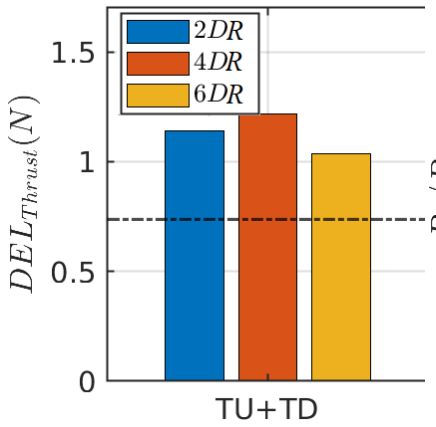

**Turbine siting**:

2 turbines

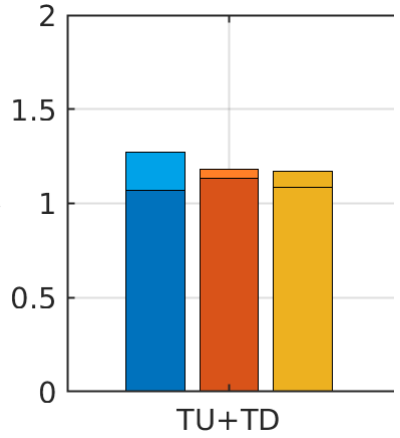


10 D spacing
Bi-directional flow

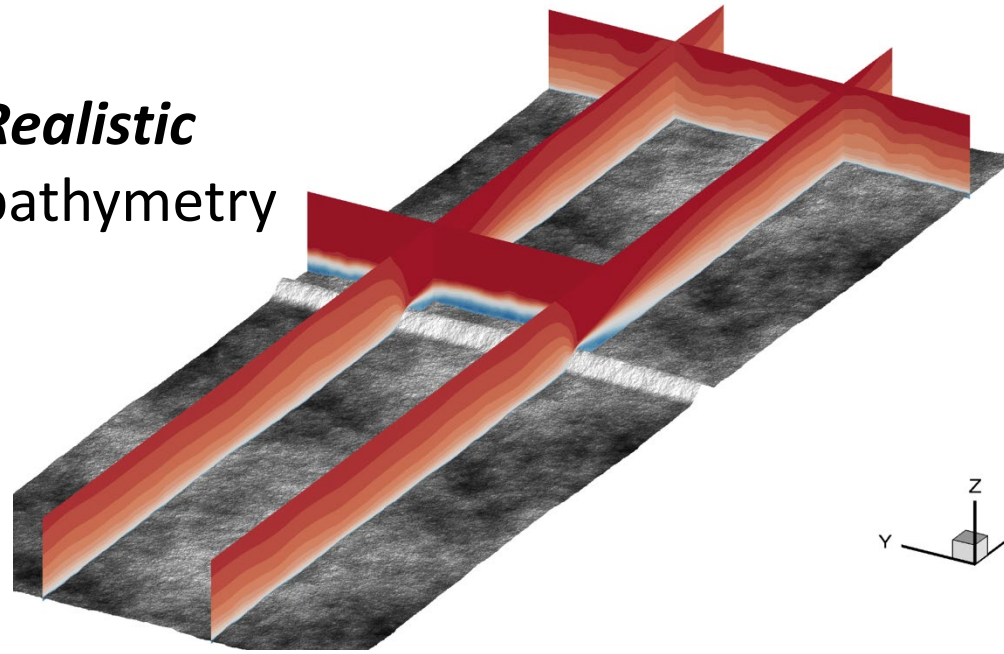
**Fatigue**




**Yield**




***Realistic*** bathymetry




Hurubi et al. EWTEC 2023, and Hurubi et al. (in review)

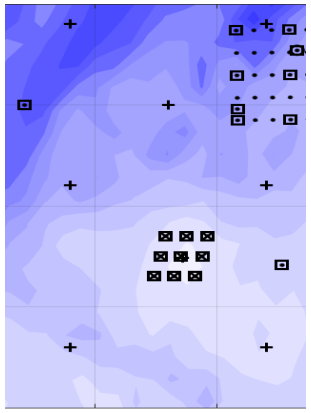
# Models for arrays: fatigue and farm yield

**Fatigue**

Model predictions of flow, shear, turbulence & DEL across site compared to **ADCP at Raz Blanchard.**

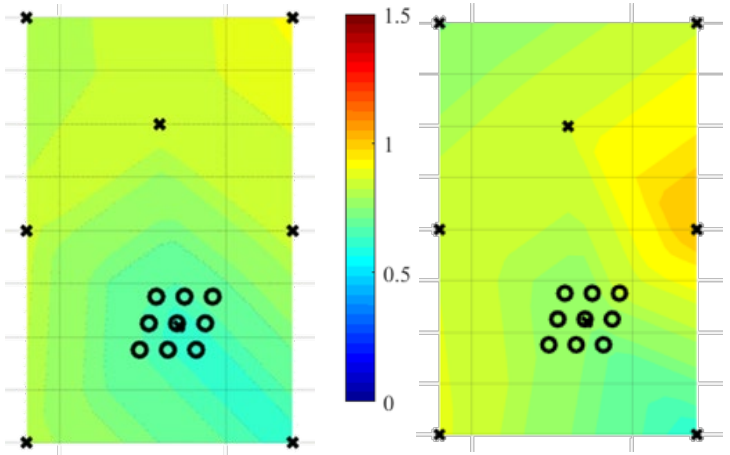
Variation between four models

Bathymetry



TELEMAC RANS

TELEMAC LES




Also with **LBM-LES** & waves **DELFT3D.**

Mullings et al. *Energies* 2023

**Site Models**

Scale

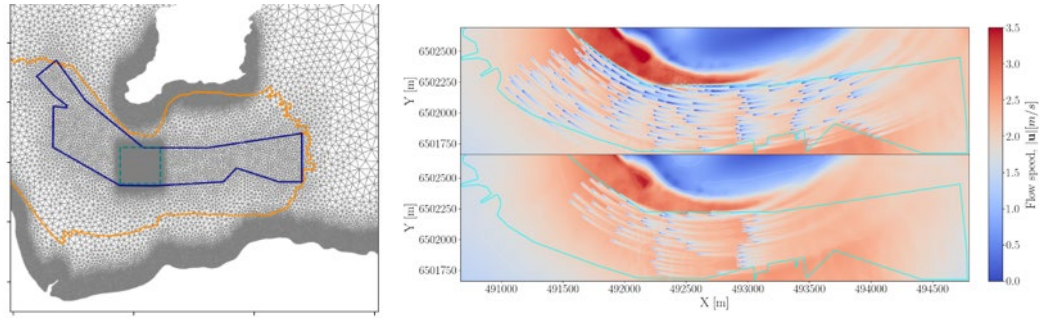
POLCOMS
HYCOM3D
ROMS3D
FVCOM
ADCIRC
Mike21/3
Telemac2D
Telemac3D
LBM-LES
DOFAS

Fidelity

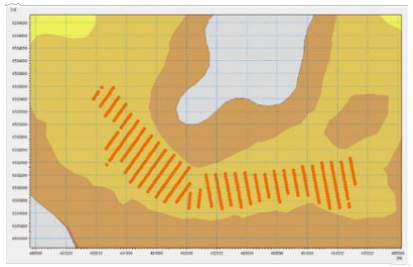
**Yield prediction**

Various options for each calculation stage:

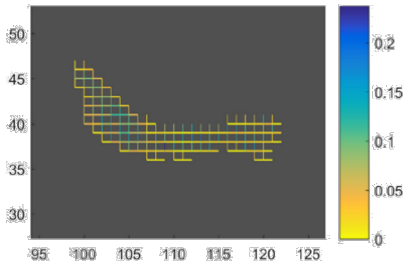
- Flow data – models or measurements
- Turbine representation
- Wake-wake mixing and recovery
- Inter-farm blockage, diverting flow



Jordan et al. 2023 - Thetis

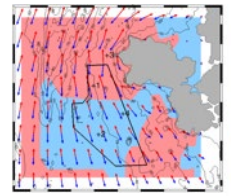
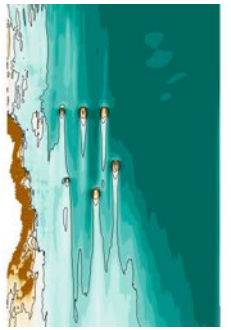
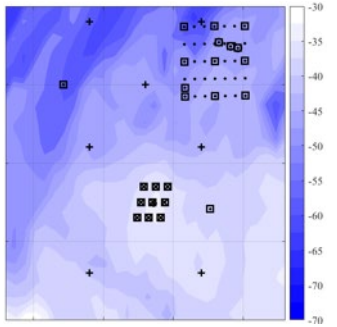


Waldman et al. 2017
MIKE 3



Waldman et al. 2017
DELFT3D

# Supergen ORE Hub Phase 2: ORE Modelling

Piano et al. 2015

## *Unsteady load prediction for tidal turbine design*

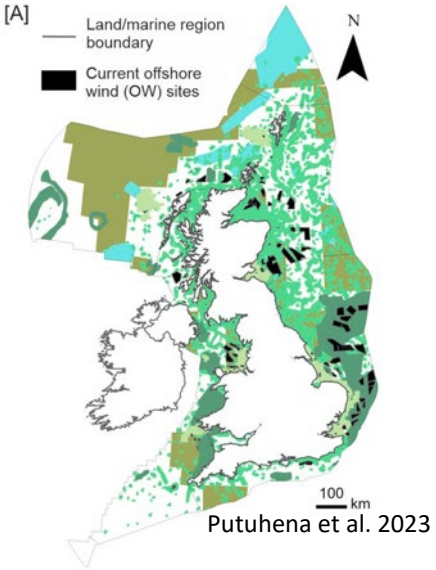
- *Accelerating cost reduction* by *improving confidence in load prediction*.
- Extension of tidal turbine benchmark to unsteady flow conditions
- Staged data release and workshops to undertake model inter-comparison

## ***Array energy yield** predictions and array-siting*

- *Enabling array planning for scale-up* by *improving confidence in yield prediction*
- Wake interaction in spatially varying flow conditions typical of candidate sites
- High-fidelity modelling of representative sites to inform an array-wake benchmark study

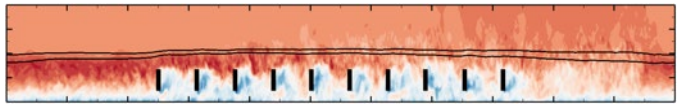
## ***Physical processes affecting ecosystems***

- *Accelerating consenting for large-scale deployment and Net-Zero targets*
- Advance intra-array wake models in resource models (FVCOM + ERSEM).
- Yield, resource & ecological predictions for large-scale deployment scenarios
- Developments to sub-grid parameterisations for floating wind in WRF



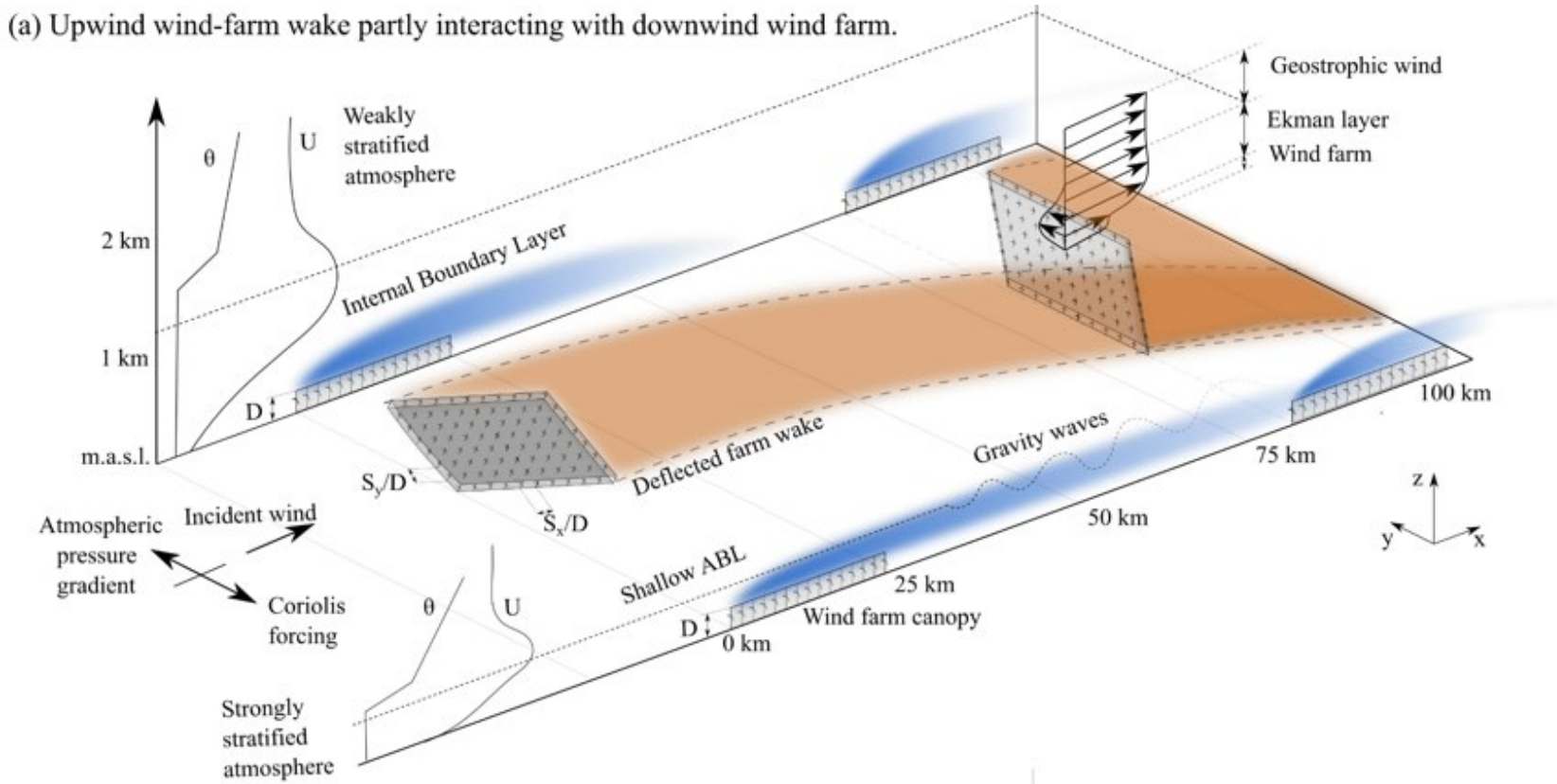

Putuhena et al. 2023

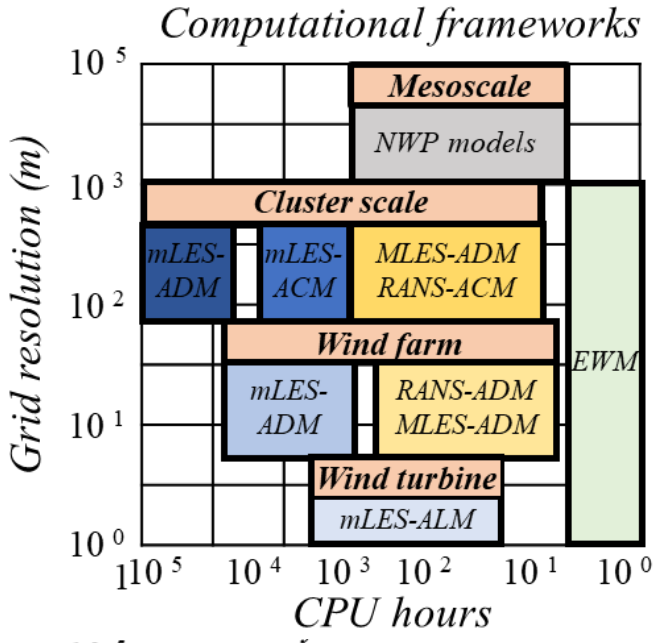
Floating farm density, configuration

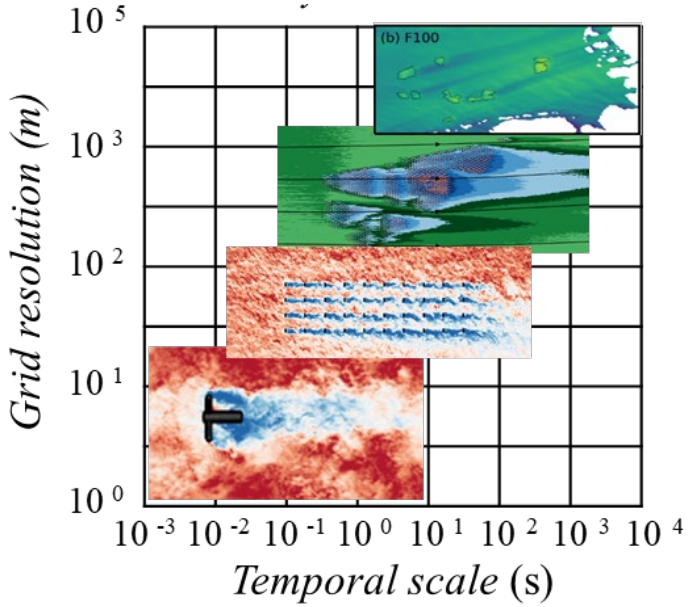


Surface heat flux, surface waves

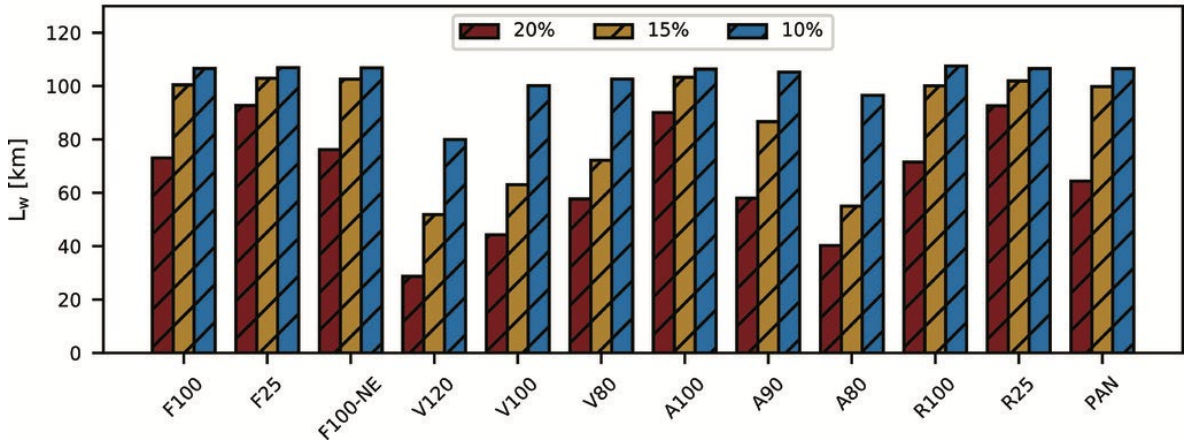
# Wind farm wakes and farm interactions



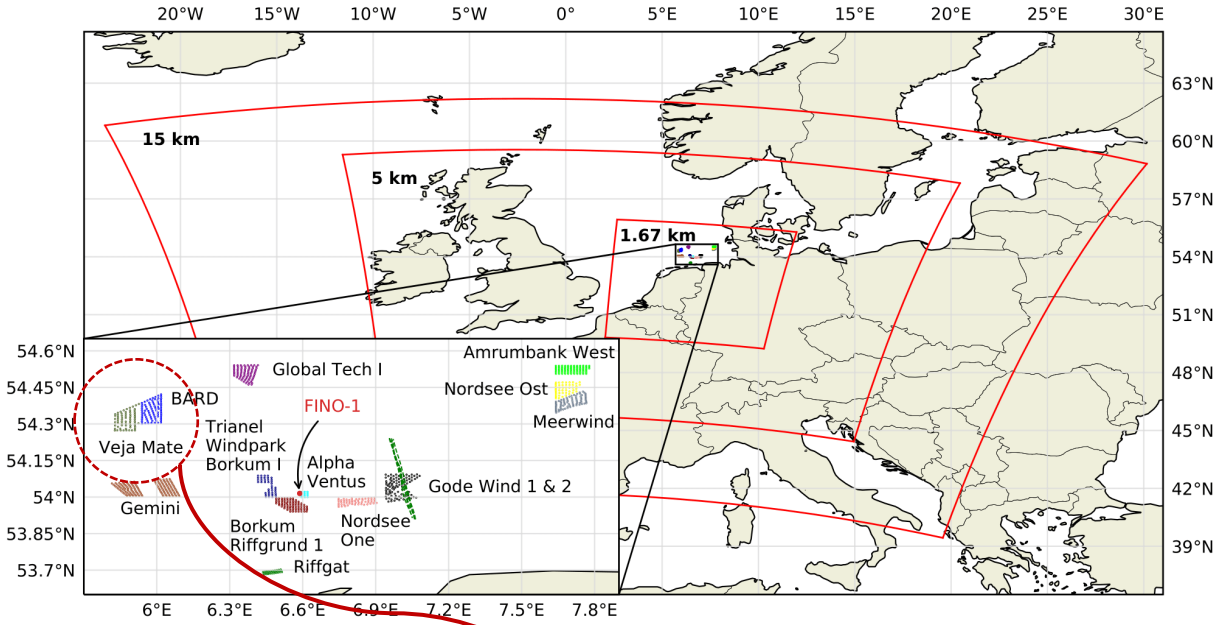



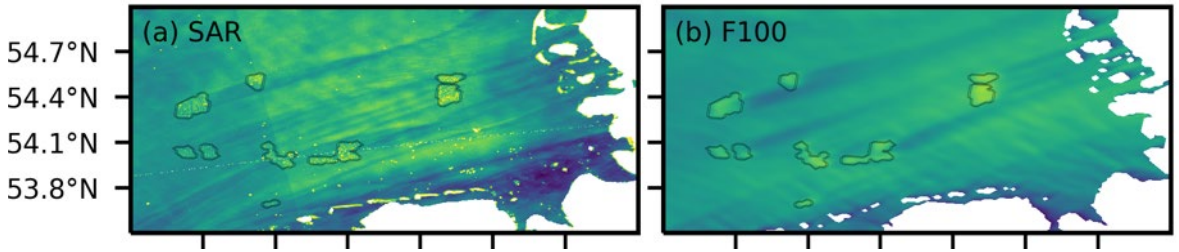
# North Sea case study – Parameterisation in WRF




Wake length ($L_w$) of the Gode Wind farms, 90 m height, 12 h interval




10-m wind speed: SAR vs simulation of the North Sea



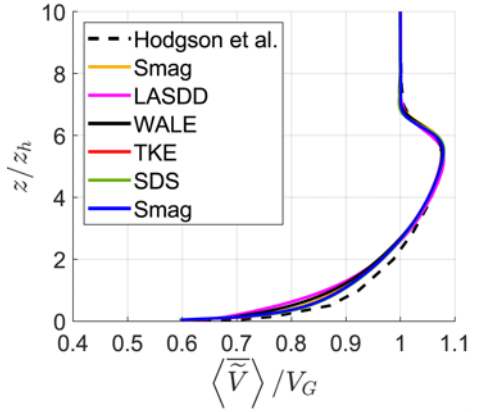

**Bard lost approx. 14% of its rated power** due to the wakes of Veja Mate under stable atmospheric conditions and at rated wind speed.

Ali et al., 2023: Assessment of five wind-farm parameterizations in the Weather Research and Forecasting model. https://doi.org/10.13140/RG.2.2.10497.53601

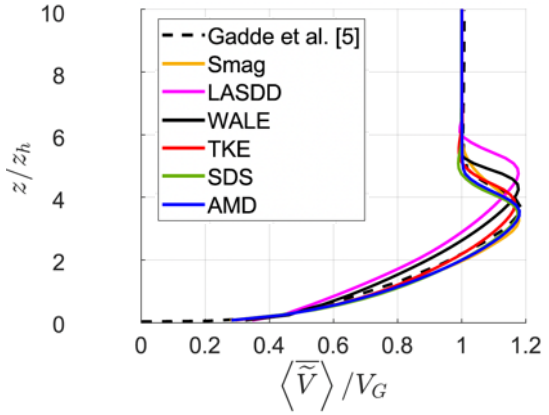
# Farm wakes in differing stability conditions

Evaluation of sensitivity to choice of sub-grid scale (SGS) model in LES (preliminary)

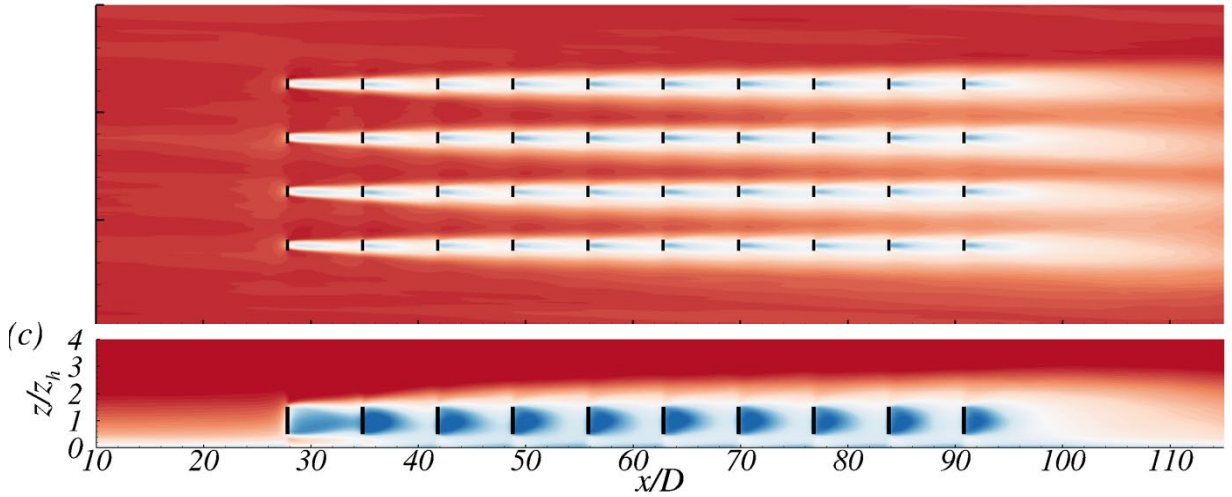
**Boundary layer development**

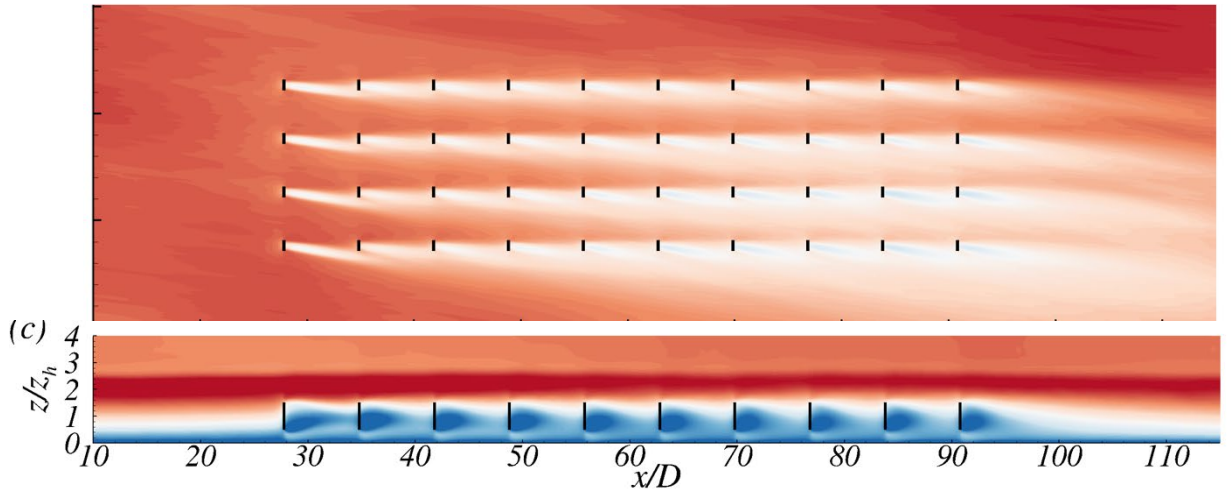



**Conventionally Neutral BL**




**Stable BL**

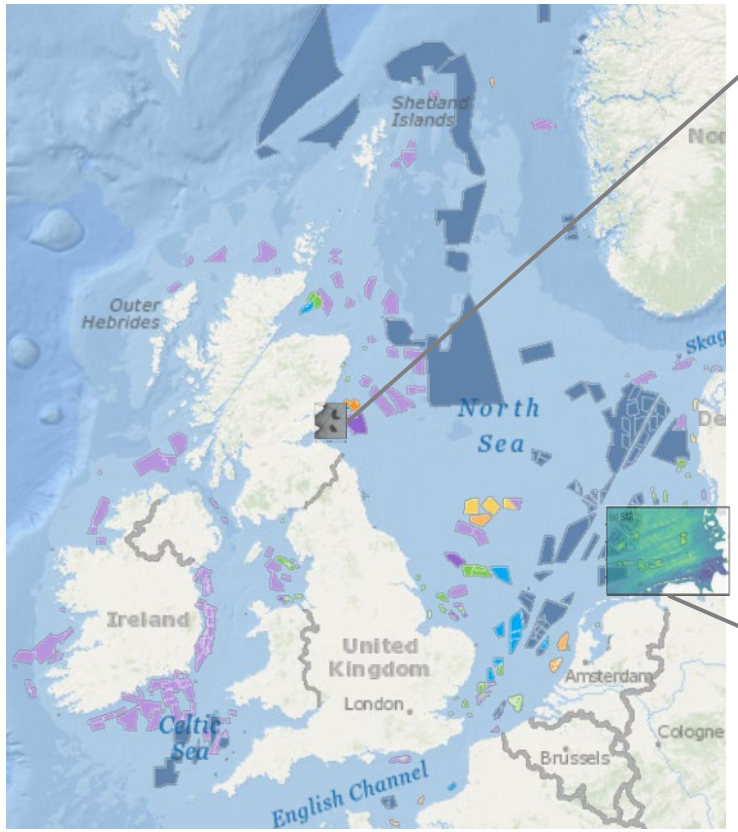


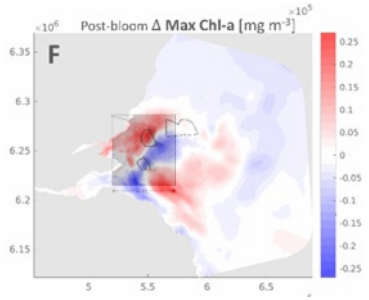

Ghobrial, Ouro, Stallard & Schultz, TORQUE 2024 and Ghobrial et al. (in preparation)

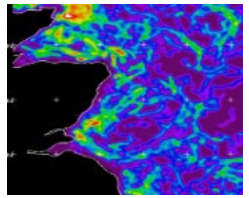
# Offshore wind arrays – interactions and siting

Reference **datasets** – multiple data *types* during *equivalent* intervals or conditions for same *'system'* (?)




**Population modelling & ecological monitoring**

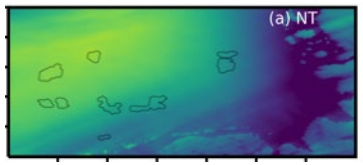


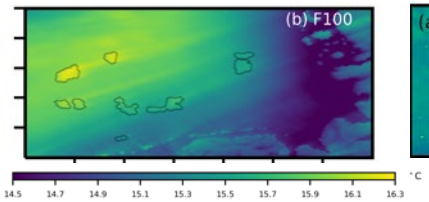
Predator-prey

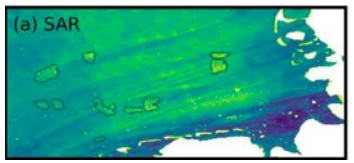
Foraging

***Small* changes to physical processes** – turbulent mixing, internal waves, temperature - at local *and* regional scales




2-m temperature




**Extent of wakes - Intra array- and inter-array.**

***Dependent on farm & turbine operating point***

**Farm performance** and **in-farm design conditions** – shear, turbulence, waves