Implementation of tidal turbines in hydrodynamic models of Pentland Firth & Orkney Waters

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Introduction

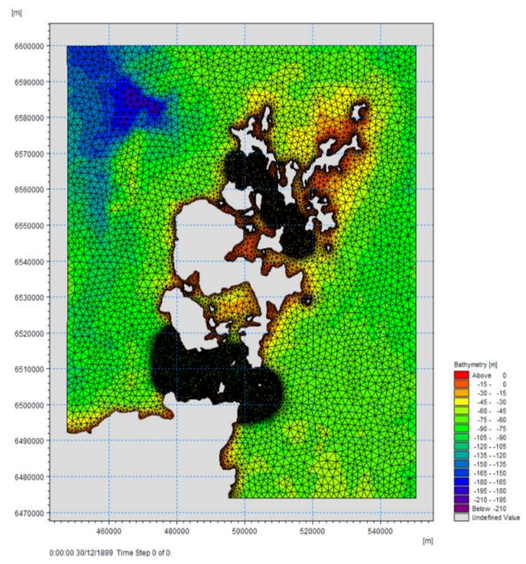
Regional-scale hydrodynamic modelling is an important tool for tidal energy development, both for predicting the performance of arrays and for estimating their environmental impact.

The TeraWatt project focuses on the latter purpose, aiming to demonstrate techniques for a full chain of modelling, from predicting physical changes to effects on sediment and benthos. This poster reports progress on the initial physical part.

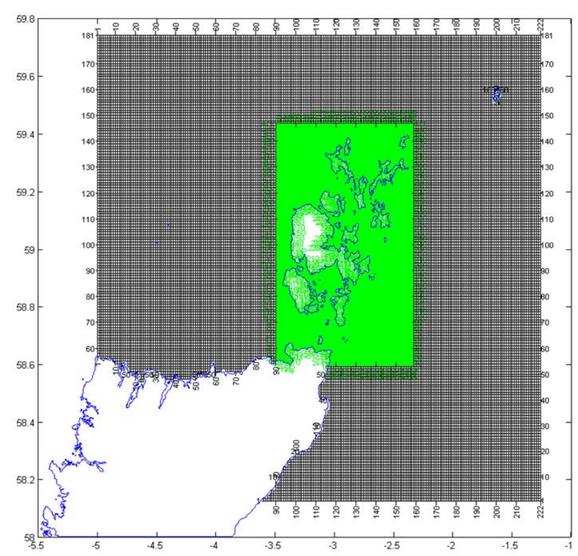
Two commercially-available 3D modelling suites were selected, based on advice from industry stakeholders: MIKE3 by DHI, and Delft3D by Deltares. No modifications were made to these, as the aim was to establish how best to use the existing codes.

The models

Instead of attempting to make the models identical, each was built following best practice to allow exploration of the advantages and disadvantages of each system.



Computational mesh for the MIKE model



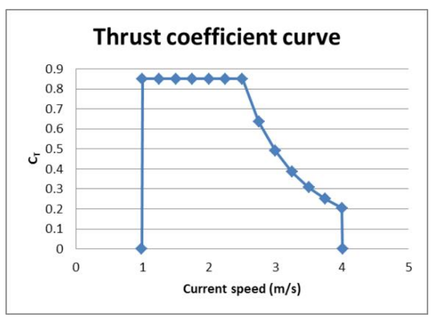
Nested computational grids for the Delft3D model

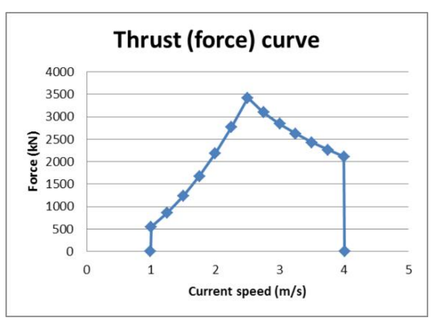
MIKE3 uses an unstructured triangular mesh. The density of points can vary smoothly across the domain, allowing increased resolution in the area of interest. Delft3D uses a regular, structured grid. To achieve high resolution in the area of interest without prohibitive computation time a high resolution grid was nested, fully coupled, inside a lower resolution one.

Turbine specifications

A workshop was held with developers to determine parameters for a generic turbine that was realistic enough to be plausible, while not being so similar to any real device as to raise difficulties with IP. The parameters below, and the thrust curve to the right, were agreed:

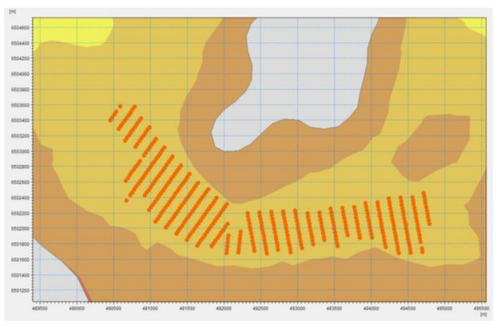
- Rotor diameter: 20m
- Cut-in speed: 1ms^{-1}
- Cut-out speed: 4ms^{-1}
- Rated speed: 2.5ms^{-1}
- Rated capacity: 1 – 1.5MW (approx.)



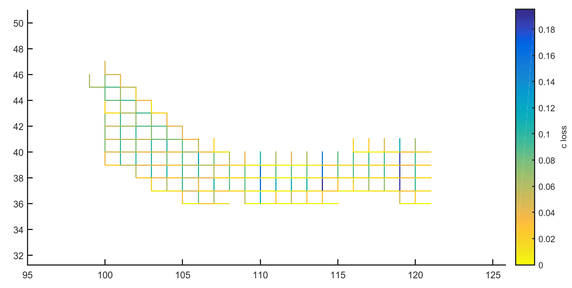


Array layouts

Consortium members at Marine Scotland Science used information from the developers' Environmental Statements to develop layouts for 950 turbines across five arrays[1]. These devices were represented in MIKE as sub-grid 'turbine' objects, and in Delft3D as porous plates specified to remove an equivalent amount of momentum from the cells in question.

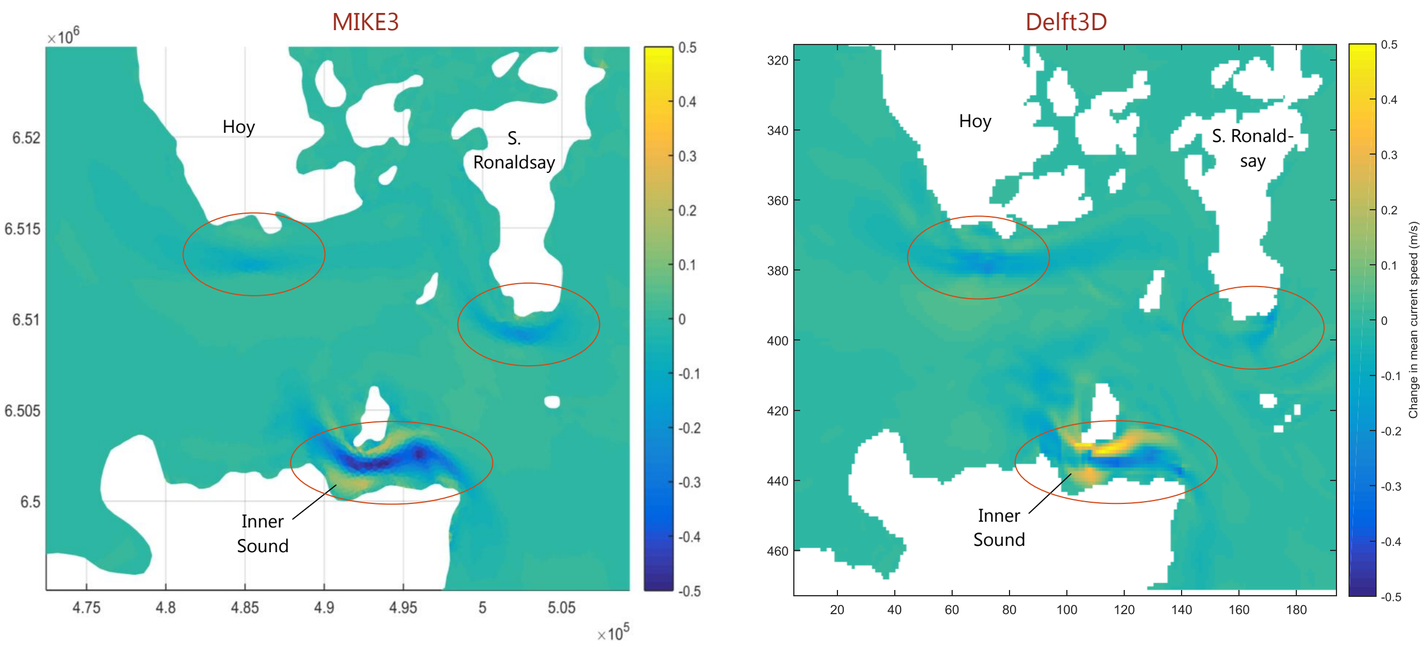


400 tidal turbines in the Inner Sound, represented as subgrid objects in MIKE3.



The same turbines represented as porous plates for Delft3D. Darker colours show lower porosity.

Preliminary results



Plots showing the effects of the introduction of tidal turbines into MIKE3 (left) and Delft3D (right). Each shows the mean difference in the predicted depth-averaged current speed, between runs with and without turbines, for the same 24-hour period. Red ovals indicate the approximate areas containing turbines, but do not represent the extent of the arrays.

As an early view of results, the plots shown here represent the predicted effect of the turbines on mean depth-averaged current speed. Three areas of turbines are present: On the north side of the Pentland Firth are 200MW and 100MW arrays off the southern tips of the isles of Hoy and South Ronaldsay, respectively. Within and east of the Inner Sound, to the south, is a denser area with two further arrays totalling 500MW. In both models we can clearly see areas of reduced current speed in line with the turbines and – especially in the Inner Sound – areas of increased speed where water flows around the impedance of the arrays.

Future work will compare properties of particular interest for environmental impact, such as changes to the magnitude of the seabed stress (for benthic effects), changes to the residual seabed stress (for sediment transport), and surface current speeds (in case of effect on navigation).

References

[1] O'Hara Murray, R., "Pentland Firth and Orkney Waters Round 1 Array Layouts" available at http://www.masts.ac.uk/about/masts-publications/terawatt-publications/

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