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THE MODELLING OF TIDAL TURBINE FARMS USING MULTI-SCALE, UNSTRUCTURED MESH MODELS

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In the ongoing quest for renewable energy sources, tidal energy generation may provide a substantial, and reliable contribution to a sustainable power supply in coastal regions. In addition to tidal barrages which significantly influence the natural flow conditions in a tidal basin, a number of projects are underway to harvest energy using submerged turbines in places with high tidal currents, e.g. in the channel between a headland and an island. Numerical modelling of the tidal flow and the influence of turbines on this are a key part of the development of new projects, in particular where large numbers of turbines are placed together in a farm. Typical questions that can be answered through hydrodynamic models are: How much energy is available, what is the optimal configuration of a farm and what is its impact on the environment? Because of the often complicated geometry of high tidal-current environments, and the large range of length scales, from large-scale tidal flow down to the turbine scale, unstructured mesh models are a natural candidate in efficiently answering these kinds of modelling questions.

A particular challenge is the representation of turbines in the model. The flow through and around the turbines is a complex, fully three-dimensional phenomenon. For a tidal model that may have to stretch out to 100s of kms to avoid boundary effects, and needs to be run for a significant time to capture the full tidal cycle, a two-dimensional, depth-averaged approximation is often the only feasible approach. The parameterisation of turbines in such a model is not straightforward. Often the full 3D dynamics of the flow around a single turbine are studied with high resolution CFD models combined with measurements, and the results of that are summarised in a single total drag force as a function of some upstream velocity. The challenge then is to incorporate this drag force in a consistent and mesh-independent way. In addition, a correct representation of the turbine wake and parameterisation of the turbulence is essential, especially for farm configuration optimisation studies.

In this contribution a number of test cases will be presented, modelled using Fluidity, that range from simple configurations in idealised tidal basins to large scale turbine farms in realistic domains. Fluidity is an open source, mesh adaptive, finite element modelling framework that has a wide range of applications from CFD problems to large scale oceanographic simulations. It allows us to simulate the turbine scale flow and the large scale tidal flow within the same modelling framework and thus to better study the effects of the interaction between the two. Our results are validated using tidal gauge data and ADCP measurements, and by comparison with other models, a.o. MIKE, a model widely used in the tidal renewable industry, developed by DHI. We will highlight the shortcomings of turbine parameterisations in two-dimensional, depth-averaged models and investigate a number of ways to improve these. In particular, we will look at ways to locally increase the number of layers, to fully incorporate the 3D dynamics of the flow in and around the turbine, embedded in a large scale depth-averaged tidal model.

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