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MODELLING OFFSHORE WIND FARMS OFF THE EAST COAST OF SCOTLAND USING THE FINITE-VOLUME COASTAL OCEAN MODEL (FVCOM)

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ABSTRACT

There is considerable interest in Scotland in the expansion of renewable energy production. In particular, significant offshore wind energy developments are already planned in coastal waters to the east of the Forth and Tay estuaries. It is important to understand the local and cumulative environmental impact of such developments within this region, to aid licensing decisions but also to inform marine spatial planning in general. Offshore wind farms have the potential to interact with physical marine and coastal process in numerous ways, such as tidal, wind, and wave driven circulation, as well as coastal sediment transport and estuarine dynamics. These interactions can provide further feedbacks with ecological systems, which could ultimately have socio-economic consequences. The Firth of Forth and Tay areas both exhibit complex estuarine characteristics due to fresh water input, intricate bathymetry and coastline, and tidal mixing. An unstructured grid hydrodynamic model of the Firth of Forth and Tay region is being developed using the Finite-Volume Coastal Ocean Model. Our goal is to resolve the estuarine hydrography of the area, and simulate the presence of wind farms by considering the potential wind speed deficit due to the wind farms and by representing the wind turbine foundations within the model. In this study the potential for large wind farms to influence the physical processes in the area is investigated. It is anticipated that this work will help provide an accurate baseline of the hydrography in this region, and the means for the assessment of the potential consequences of multiple wind farm development scenarios.

INTRODUCTION

There are currently substantial plans in place for wind farm developments east of the Firth of Forth and Tay. This area has a diverse number of stakeholders and includes a number of environmentally sensitive areas. There is some concern as to whether such developments will cause changes to the physical environment including the regional tide and wave driven processes, such as stratification and sediment transport pathways.

The aim of this study is to represent wind turbines within an unstructured grid hydrodynamic model of the Firth of Forth and Tay region and to examine the potential for offshore wind farms to alter physical processes within the region.

METHODOLOGY

The Finite Volume Coastal Ocean Model (FVCOM) [1] was used to create an unstructured grid tidal model of the Firth of Forth and Tay region. The model was validated using current meter and water elevation data from four locations around St Andrews Bay, and tide gauge data from Leith. A tidal analysis was performed on modelled and measured water elevation data. This showed that the differences in the amplitude of the most dominant tidal constituents (M2, S2, O1) were between 7 – 13% and that the differences in phase were around 5°. The model was forced with 8 tidal constituents from a tidal model based on the Oregon State University tidal inversion of TOPEX/POSEIDON altimeter data [2]. For this study the atmospheric forcing of the model was limited to wind forcing from the European Centre for Medium-Range Weather Forecasts (ECMWF) ERA-Interim reanalysis archive [3].

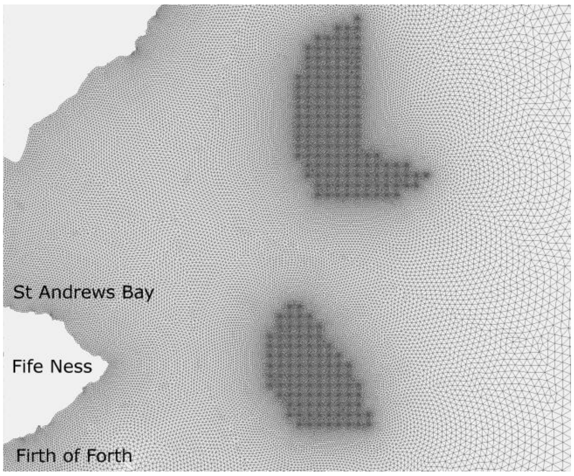

Figure 1: A section of the unstructured grid with enhanced resolution within the wind farms.

The *validated model grid* was refined to make the *wind farm model grid* which included the two Scottish territorial waters wind farm sites in the area, Inch Cape and Neart ne Gaoithe. The Environmental Statements submitted to the licensing authority as part of the offshore renewables licensing process were examined to decide on a realistic wind farm scenario. The Environmental Statements included a range of potential scenarios, with the foundation type, wind turbine spacing and power output of each

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individual turbine being constrained within fixed ranges. The scenario of 1 km spaced gravity bases for the turbine foundations was selected as this was within the envelope of potential options for each of the two wind farms. Each wind turbine foundation was represented by a triangular object with 100 m sides, and they were arranged in a regular grid pattern within the wind farm zones. Figure 1 shows a section of the model grid around Fife Ness and the wind farm sites. In the wind farm zones the mesh resolution goes down to around 100 m.

In addition to the wind farm model grid, a *baseline model grid* was also constructed. This was exactly the same as the wind farm model grid but with the addition of an extra model element replacing each wind turbine foundation.

In order to validate the baseline model grid, a comparison was made between model output from this model and the validated model. The two models were found to agree well, confirming the validity of the new model grids.

In addition to including the individual wind turbine foundations within the model, the wind speed deficit within the wind farm sites was also taken into account. Satellite observations have suggested that the local wind field within North Sea wind farms is typically reduced by around 8 – 9% [4]. Modelling of the wind field through wind farms has also shown that the wind field can drop by 5 – 14% [5]. Following these results, the wind forcing for this study was reduced by 10% within the wind farm areas. The model was run twice; once with the wind farm model grid and the reduced wind speeds, and once with the baseline model grid and the unaltered wind speeds.

RESULTS

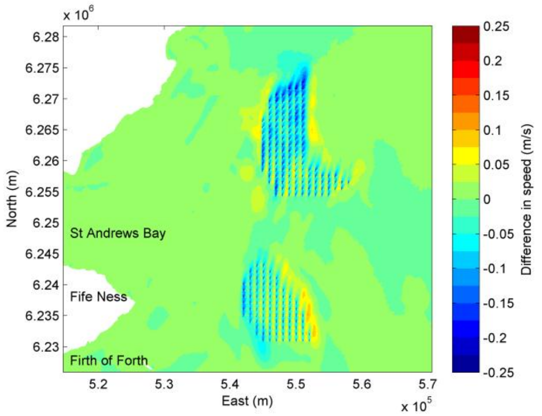

Figure 2: The difference in peak surface current speeds between the baseline model run and the model run with wind turbines included.

Figure 2 shows the baseline model results subtracted from the wind farm model results, around the time of peak current speeds during a spring tide. The results indicate that the surface current speeds are reduced by approximately 0.25 m/s in the immediate vicinity of the foundations. The results also show that the surface current speeds can increase by approximately 0.25 m/s between the rows of foundations, and around the outside of the wind farm sites. There are also some changes in the current speed further afield, of around 5 cm/s, but these differences are patchy and reduce with distance from the wind farms.

CONCLUSIONS

These results indicate that offshore wind farms have the potential to change current speeds both within and outwith wind farm zones at times of peak current speeds. Such changes have the potential to alter other physical processes such as mixing, stratification and sediment transport, which we plan to quantify in the future.

It is acknowledged that the representation of the wind turbine foundations can only realistically represent the largest gravity bases likely to be used. The use of these structures was considered for this study as a worst case scenario, when considering potential change to current speeds. It is most likely that, in addition to large gravity bases, the wind farms will utilise smaller gravity base structures, jacket or piles. These alternative foundations are likely to have different effects on the currents. Representing these foundation types within FVCOM is an area of future research.

This work is limited to an analysis of the surface current speeds around spring tides. There is a great deal of scope for the analysis of other physical processes as this work is ongoing.

ACKNOWLEDGEMENTS

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