Development of a Western European continental shelf model for simulating large arrays

D. S. Coles, A. S. Bahaj, L. S. Blunden – (www.energy.soton.ac.uk)

Arrays, wakes and Near Field Effects

1. Introduction

Many sites around the UK coastlines exhibit high potential to inhabit large marine current energy converter arrays for electricity generation. This is predominantly dependant on high average flow speeds and suitable depths, with environmental impact, grid infrastructure and many other features all requiring significant consideration. One such site is the Alderney Race, situated in the Channel Islands off the coast of Normandy, where it has been estimated that an annual generation of 1340 GW h with an array capacity of 1.5GW could be achieved [1].

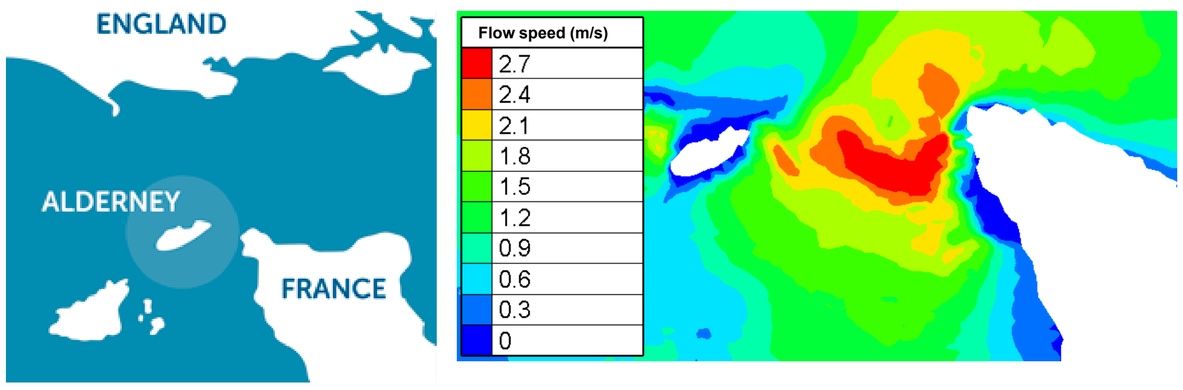

Figure 1 – Location and typical flow speeds at Alderney Race, a high potential site for marine current development

A numerical model of the Western European continental shelf is being developed using Telemac 2D. The primary aim of this work is to model large arrays in high potential locations to understand their potential for electricity generation by quantifying energy extraction and their effect on the surrounding flow field.

2. Model setup

2.1 Domain

Tidal wave propagation onto the continental shelf can be complex, with the abrupt change in geometry partially transmitting and partially reflecting incident long waves. Conversely for waves travelling from the continental shelf to the deep ocean, the wave is almost completely reflected. This is beneficial for energy extraction as the majority of the energy remains in the shallow waters until it is dissipated. To simulate this phenomenon the domain spans to the West and South of the continental shelf into the deep Atlantic Ocean, as shown by figure 2.

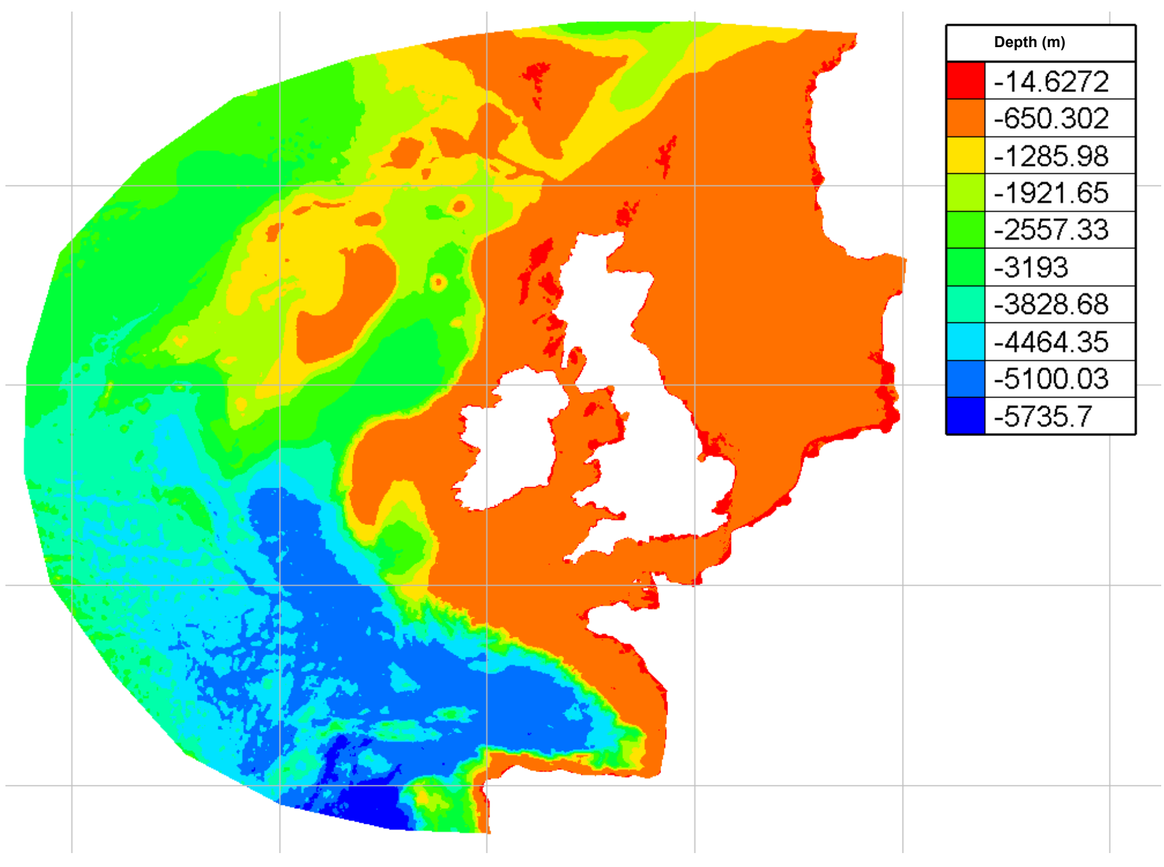

Figure 2 – Western European continental shelf domain, showing water depth in metres.

2.2 Boundary conditions

Tidal harmonic elevation code was developed to define the tidal elevation at each node on the liquid boundary, from the coast of Portugal up to Norway. Amplitudes and phases of nine tidal constituents (M_2, S_2, N_2, K_2, K_1, O_1, P_1, Q_1 and M_4) were extracted from the Tide Model Driver (TMD) Matlab package (https://www.esr.org/polar_tide_models/README_TMD.pdf) to define the elevation at each node on the liquid boundary using tidal harmonic analysis.

Bathymetry data was obtained from the General Bathymetric Chart of the Oceans (GEBCO) at 30 arc second resolution, with higher resolution data in areas of interest for marine current development.

Definition of bed friction is ongoing to tune the model during the validation process.

4. Results

4.1 Amplitude and phase analysis at ports

M_2 and S_2 amplitudes and phases where extracted from the tidal signal given by the model and compared with data at 14 ports using the T-Tide matlab package (http://www.eos.ubc.ca/~rich/#T_Tide) and the Tidal Analysis Software Kit 2000(TASK). Results were within ±10% accuracy for six M_2 amplitudes and three S_2 amplitudes. The same accuracy was obtained for four M_2 phases and nine S_2 phases.

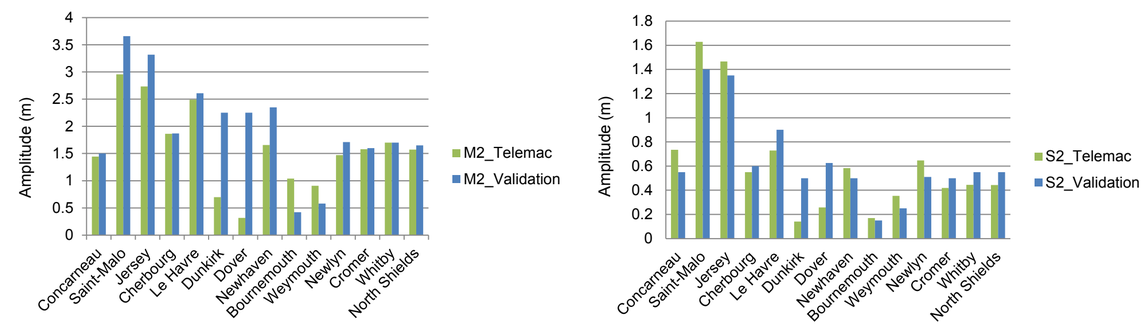

Figure 3 – Comparison of M_2 and S_2 amplitudes at fourteen ports over a period of 16 days

4.2 Tidal elevation analysis at ports

Tidal elevation data was compared with real data obtained from Easytide (http://www.ukho.gov.uk/easytide/EasyTide/SelectPort.aspx) at the fourteen ports. In general a reasonable correlation was found with the results from the model using nine tidal constituents over a one week period, as demonstrated at Newlyn and Jersey in figure 4.

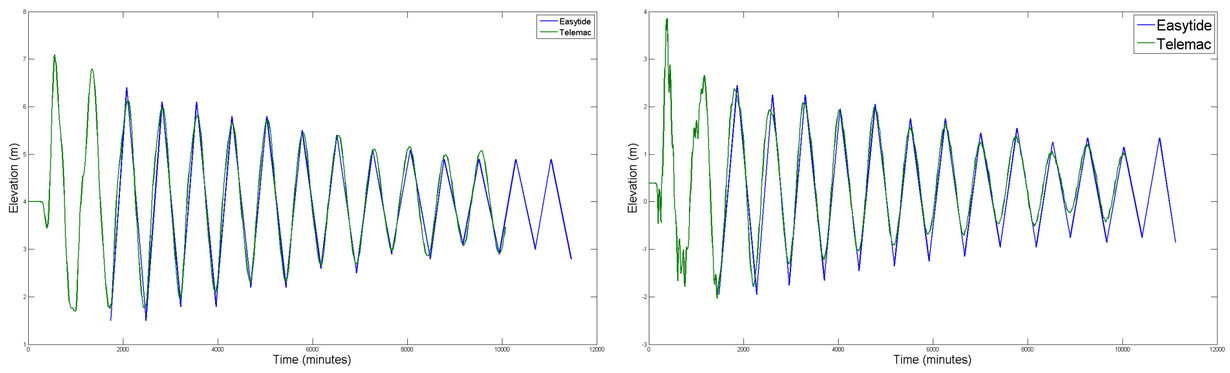

Figure 4– Comparison of tidal elevation over a one week period at (a) Newlyn and (b) Jersey

5. Conclusions

Initial amplitude, phase and tidal elevation analysis shows reasonable agreement with real data, however there are several ways in which the model can be further improved. This includes undertaking mesh independence studies, bed friction definition and Acoustic Doppler Current Profiler (ADCP) data analysis of flow speeds in areas of interest .

Consideration of energy extraction quantification for large arrays and their effects on the surrounding flow field can then be considered.

References

1.Myers L.E. and Bahaj A.S. (2005) Simulated electrical power potential harnessed by marine current turbine arrays in the Alderney Race, Renewable Energy, Volume 30, pp 1713 – 1731.