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Simulation of device-scale unsteady turbulent flow in the Fundy Tidal Region

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ABSTRACT

This paper specifically focuses on site-specific CFD modelling in the context of tidal energy development, and presents results for two sites from the Fundy Tidal Region (FTR) situated in Eastern Canada. The FTR is one of the best and most energetic areas in the world for tidal energy development. To efficiently meet the computational demands of modelling unsteady three-dimensional turbulent flow in complex tidal zone terrains, highly parallel GPU hardware are utilized. Strategically deployed Acoustic Doppler Current Profiler (ADCP) measurements at two tidal turbine locations provide validation of the predictions under ebb and flood flows. The processing methodology of ADCP devices is incorporated into the CFD simulation to improve predicted turbulence levels for validation. The simulations use detached eddy simulation (DES) turbulence modelling with engineered inlet boundary conditions and realistic bathymetry. The inlet boundaries use mean horizontal velocity values interpolated from regional tidal simulations and are perturbed by synthetic turbulence to accelerate boundary layer development. Simulations cover tidal developments from ~1.5 to 3 square kilometres with spatial and temporal resolutions of 1–2 m and 0.1 s, respectively.

1. Introduction

Interest in tidal power as a reliable renewable energy resource has grown significantly in recent years, as evidenced by the increasing number of sites under development and strong support from governments worldwide. Manufacturers and developers are however challenged by the highly-variable ocean environment. It is a taxing environment for machines of any type, and designers must carefully account for unique, site-specific conditions in their devices. The growth rate and overall success of the global tidal marine renewable energy industry depends on sustained research and cost reductions in several key areas (Uihlein and Magagna, 2016). These include device installation and foundation costs, prime-mover component costs, and operations & maintenance budgets. It will become increasingly important to address all of these areas and help identify the best potential for cost reduction (on a site-by-site basis) as the industry matures (Uihlein and Magagna, 2016).

Experimental field data is currently the primary source of information used by designers. The rigors of the ocean environment make this data likewise costly (both in terms of expenditure and effort) to obtain. By way of example, the Acoustic Doppler Current Profiler (ADCP) is often used to measure flow velocity at a planned installation site. This device provides vertical mean velocity profile information that is critical to the design and operation of turbines, but it provides limited resolution for only one geographic location. Obtaining additional information requires numerous ADCP measurements and increased experiment costs.

It is possible to improve the return on investment for an experimental program by augmenting it with high-resolution CFD simulations. A small number of strategically placed experimental measurements can be used to validate a CFD solution for a particular region providing detailed, time varying three-dimensional data. The extent of a validated region is difficult to quantify; however, a validated region is inherently greater than point ADCP measurements and naturally increases with the number of measurement devices included in the validation. As always, sound engineering judgement should be applied in considering the limits of any

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Fig. 1. Location of important tidal energy sources in the Nova Scotia Bay of Fundy region, with the Minas Channel (Passage) and Grand Passage locations highlighted.

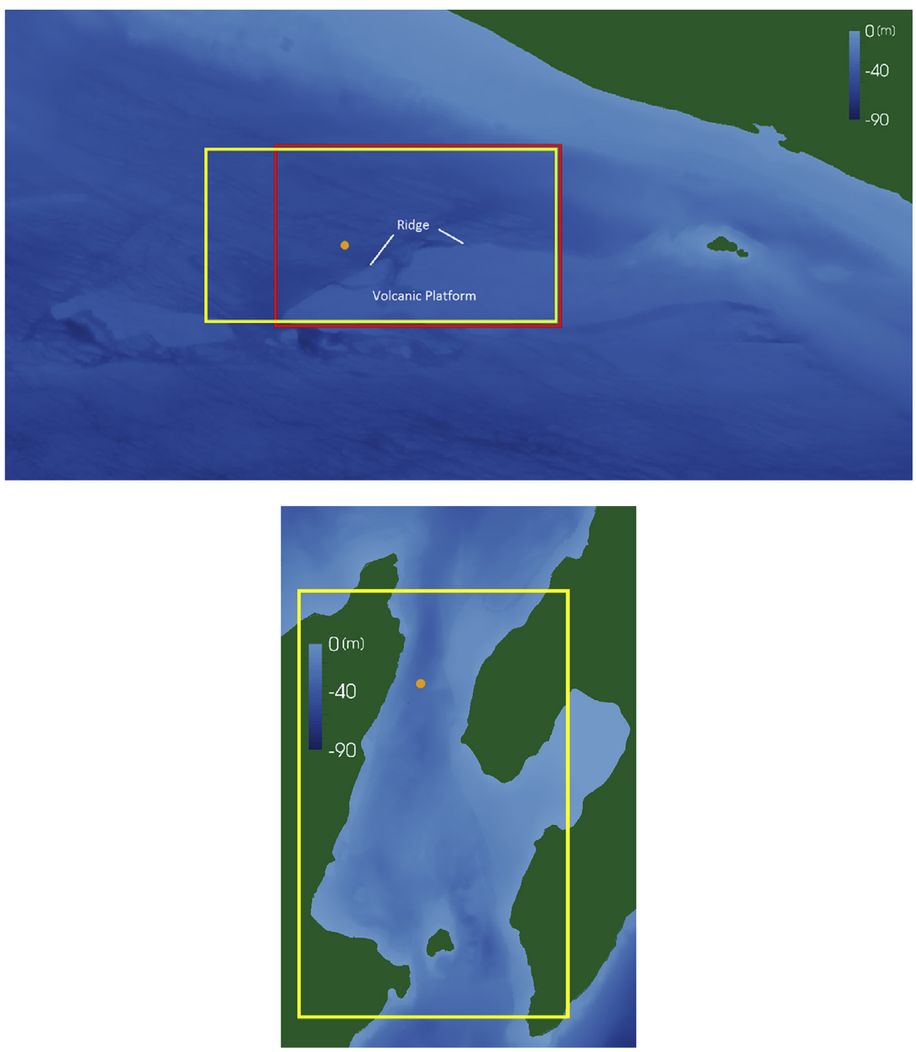

Fig. 2. In the top view color shaded bathymetry of the FORCE region (within the Minas Passage) used to generate the bottom boundary of the CFD domain. The red box denotes the FORCE Crown Lease Area, the yellow box the location of the computational domain. The orange dot indicates the location of the field placed ADCP device used for validation. Ebb tide flow, investigated in this study, comes from the south-east; due north is up. Shading corresponds to depth; areas shaded in green are above mean sea-level. In the bottom view the Grand Passage location with yellow box showing the computational domain and the orange dot the ADCP device location. Ebb flow is from the top (north) and flood from the bottom (south). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)