MODEL TIDAL POWER IN A TURBULENT OCEAN

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Turbulence Makes a Difference

The Large Eddy Simulations (LES) performed in this project make it possible to study how the actual tidal turbulence affects a tidal power plant, e.g., the control system and dynamical loads and how the power plant in turn affects the flow. First the flow and turbulence fields are studied in a undisturbed tidal flow. These simulations are run during several tidal cycles in order to both spin up the flow and to get representative statistics. The results show, e.g., that the turbulence intensity differ between the acceleration and the deceleration phase of a tidal cycle for the same depth averaged mean flow.

Secondly the tidal power plant Deep Green is added to the simulations. This is done using a model that works according to the principles of an Actuator Line Method (ALM). Here the tidal power plant(s), however, can move in an arbitrary path as can be seen in the figures to the right. This newly developed model makes it possible to see how the Deep Green affects the environment and other power plants in eventual arrays. Preliminary results show, e.g., that the width of the trajectory can be used as a measure to estimate how far the wake propagates downstream of the power plant (Fredriksson et.al, 2016).

Optimize Array Design

The first Deep Green will be deployed west off Holy Island along the north west coast of Wales during 2018. A natural step in the development is then to create arrays of power plants in order to increase the power output from a site. Experience from wind power farm development give that Computational Fluid Dynamic (CFD) analysis are crucial in order to find the optimum distribution of power plants and for power estimations. This project makes it possible to use CFD to perform power estimations and optimizations of the tidal power arrays with the Deep Green power plant in a similar way.

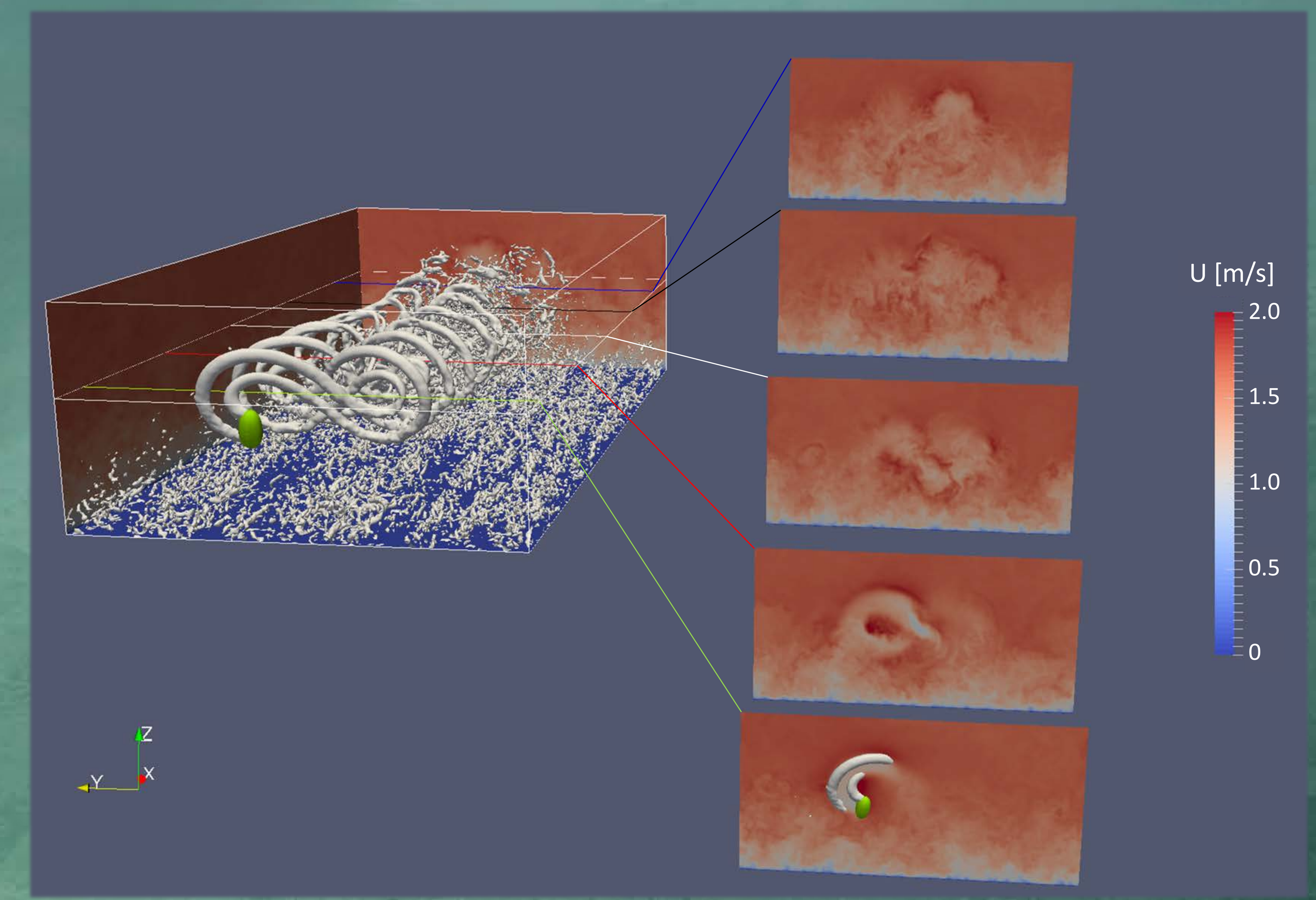
Deep Green – Power From Low-Flow Streams

The Deep Green power plant is a novel marine energy technology that produces electricity from tidal streams and ocean currents. The main components of the Deep Green are the wing, the axial turbine, the nacelle that comprises the generator and power electronics, and the rudders. The Deep Green is attached to a foundation on the seabed via three struts and a long tether. The control system steers the power plant in a predefined trajectory. In its current design, the wing span is 12 m and the rated power of the generator is 500 kW. Multiple Deep Green devices can be placed together to form an array.

The Deep Green technology has the same working principle as a wind kite. The wing hydrodynamics enables the power plant to move several times the speed of the flow, moving almost perpendicular to the tidal flow. Accordingly, the Deep Green power plant can operate in low tidal flow and use less material in construction compared to other similar technologies, in relation to the installed capacity.

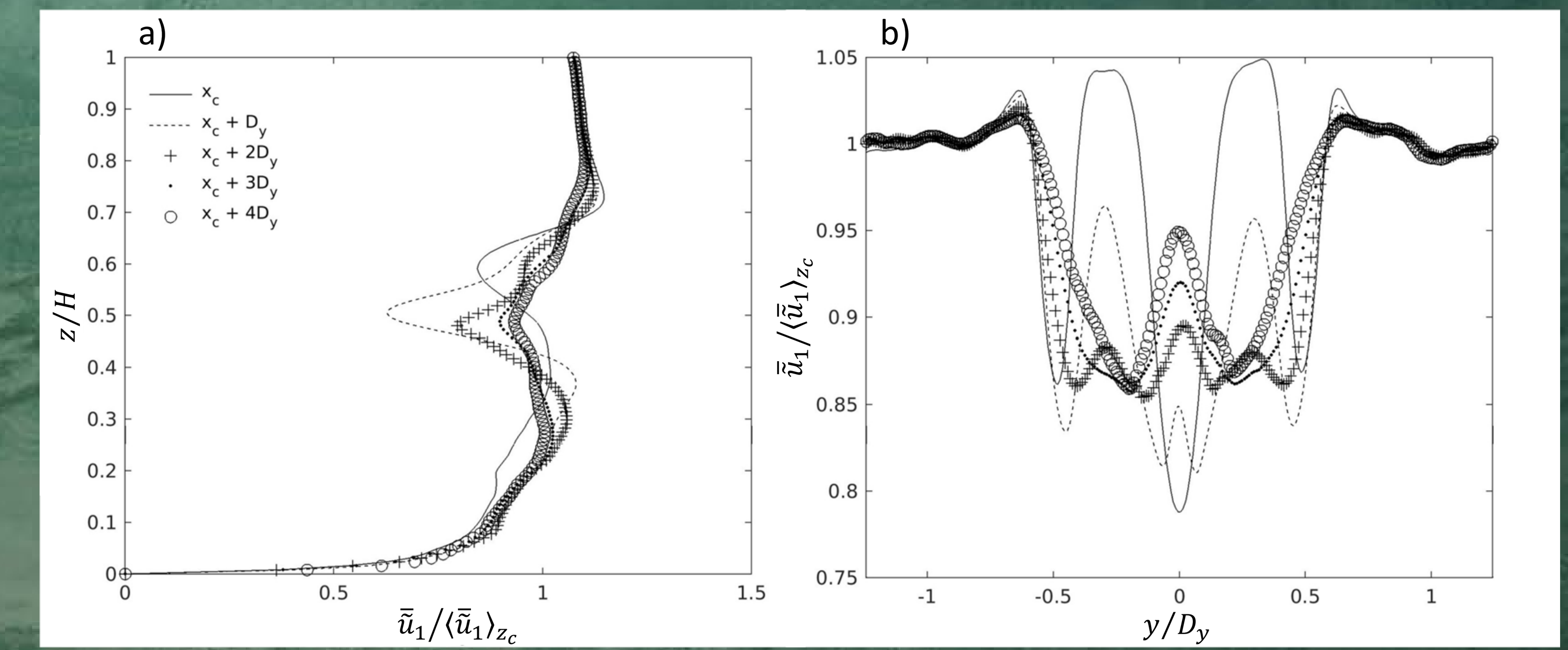
Velocity Field and Vortices

The instantaneous velocity fields after approximately 15 trajectories have been run. Velocities given at domain boundaries and at yz-planes at $x = x_c$, $x_c + D_y$, $x_c + 2D_y$, $x_c + 3D_y$, and $x_c + 4D_y$ where x_c is the center and D_y is the width of the trajectory, respectively. The grey isosurfaces mark a positive value of the second invariant of the velocity-gradient tensor which indicate vortices. The position of the Deep Green is visualized by the green isosurface of the force field.



Velocity Deficit

Comparison of mean flow velocities at locations downstream of the Deep Green trajectory center (x_c, y_c, z_c). a) Vertical profiles along the xz-plane at $y = y_c$. b) Horizontal profiles along the yz-plane at $x = x_c$.



Reference: Fredriksson et.al(2016). http://iopscience.iop.org/article/10.1088/1757-899X/276/1/012014

Acknowledgement: This project is financed by the Swedish Energy Agency.