Development of a HPC framework to assess the impact of offshore wind turbines on the ocean circulation and mixing

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Miguel A. Guzmán, Federico Bernandoni, and Stefano Leonardi[†]

Department of Mechanical Engineering
University of Texas at Dallas
[†]e-mail: stefano.leonardi@utdallas.edu

ABSTRACT

At over 100 GW of installed capacity, wind is the largest source of renewable energy in the U.S. To reach 35% of the nation's electricity needs, wind capacity needs to quadruple to 400 GW by 2050. By necessity, much of this increase in wind capacity will come from offshore wind energy with farms covering hundreds to hundreds of thousands of square miles. While a few isolated turbines may not significantly affect ocean circulation and the atmosphere, the effects of a major deployment of wind turbines on local to regional physical and biological processes is for the most part unknown. Preliminary idealized numerical simulations of fixed turbine farms suggest that even at light to moderate wind speeds (5-10 m s^{-1}), the spatially variable wind stress in the wake of a turbine can induce significant upwelling and downwelling currents in the upper ocean (1 m day^{-1}; Broström, 2008). These vertical velocities and modified mixing in the wake of the farm will alter the downstream stratification. Consequently, nutrients, such as nitrate, could be mixed into the surface layers and result in enhanced primary production. The turbulence and mixing around wind farms may also reduce settlement of fouling organisms on the seaweed and cultivation system, as well as sediment build-up.

Wind farm simulations have been performed using out in-house Large Eddy Simulation (UTD-WF). The immersed boundary method mimics the floating platform, tower, and nacelle, whereas the turbine blades are modeled with an actuator line model. The angular speed of the turbines is determined by the balance of aerodynamic and generator torque. The code includes yaw, pitch, and torque gain control variables and it is highly scalable on parallel computers.
The code is coupled with the Weather Research and Forecast Model (WRF) and the Regional Ocean Modeling System (ROMS) to assess how the turbine wakes affect the local circulation in the ocean and the mixing. Results of fundamental test cases varying the size of the turbine rotor disk and number of turbines in the farm will be discussed at the conference.

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