Impacts of offshore wind farm wakes on regional ocean circulation

José Amell, Pharlin Médard and Umberto Ciri*

Department of Mechanical Engineering
University of Puerto Rico at Mayagüez, Mayagüez, PR 00680, US
* umberto.ciri@upr.edu

ABSTRACT

Offshore wind farms have the potential to play a key role in advancing transition to renewable and sustainable energy sources. Nevertheless, during operations, they interact with the atmospheric circulation and the upper ocean through the non-linear feedback of air-sea fluxes, surface waves and wind-driven currents. The resulting hydrodynamic processes may impact transport and distribution of temperature, salinity, nutrients and other biogeochemical components that influence the ocean ecosystem (van Berkel et al., 2020). To date, there remain critical uncertainties on the effects of large offshore wind farms on the marine ecosystem, especially in tropical waters such as the case of Puerto Rico.

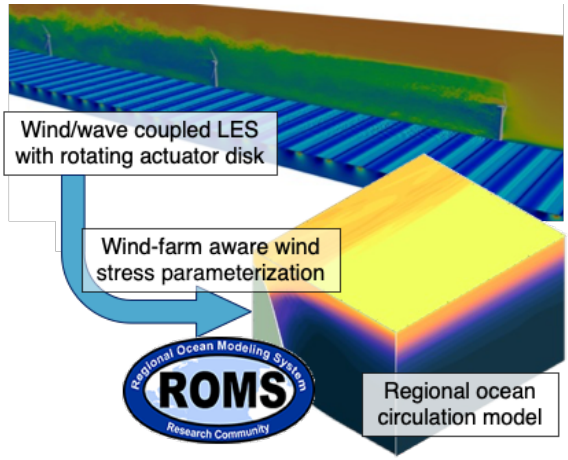

Figure 1: Schematic of the numerical framework.

This work seeks to address this knowledge gap through a hydrodynamic modeling study of offshore wind farms effects in tropical latitudes. Early studies have identified the spatial wind speed variations induced by offshore wind farm wakes on the wind distribution as a key mechanism of wind farms-hydrodynamics interaction (Broström, 2008; Christiansen et al., 2022). The spatial variability within the wake leads to a heterogeneity of the surface wind stress, which induces upwelling and downwelling patterns in the ocean because of link between the wind stress curl and the Ekman transport (Cushman-Roisin and Beckers, 2011). A critical challenge for predicting this effect is the parameterization of the wind stress reduction (and spatial variability) in ocean circulation models. Thus, we propose a multi-scale approach coupling the Regional Ocean Modeling System (ROMS) with high-resolution large-eddy simulation (LES) of offshore wind farm flows (fig. 1). We will use an in-house LES model to resolve, at meter-scale resolution, modulations of air-sea fluxes induced by turbulent wind turbine wakes. LES of minimal wind farm flow unit will be used to develop a wind stress parameterization for ROMS depending on different sea states. ROMS will be run for different wind farm deployment scenarios to assess their hydrodynamic impacts on ocean circulation and scalar distributions.

References

G. Broström. On the influence of large wind farms on the upper ocean circulation. J. Mar. Syst., 74: 585–591, 2008.

N. Christiansen, U. Daewel, B. Djath and C. Schrum. Emergence of large-scale hydrodynamic structures due to atmospheric offshore wind farm wakes. Front. Mar. Sci., 9: 818501, 2022.

B. Cushman-Roisin and J. M. Beckers. Introduction to Geophysical Fluid Dynamics. Academic Press, 2011.

J. van Berkel, H. Burchard, A. Christensen, L. O. Mortensen, O. S. Petersen and F. Thomsen. The effects of offshore wind farms on hydrodynamics and implications for fishes. Oceanography, 33: 108–117, 2020.