Surface wave response to offshore wind farms off the Coast of New England

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Summary of the work

Offshore wind energy installations are rapidly expanding in U.S. coastal waters to meet the U.S. goal of producing 30GW of offshore wind energy by 2030 and 3000GW by 2050. Offshore wind turbines extract kinetic energy from the atmosphere at wind farm scales, reducing wind speeds and producing downstream wind wakes of enhanced turbulence. The accelerated developments of large-scale offshore wind farm clusters are expected to modify regional wave climates.

Here, we present some preliminary analysis of the summertime wave field response to hypothetical large-scale wind farms in the MA/RI lease areas simulated by high-resolution atmosphere-ocean-wave coupled model simulations. We show that the wind deficit due to wake effects reduces significant wave height, wave-supported momentum flux, and wave-to-ocean energy flux by 10-30%, indicating the reduced wave energy, wind stress, and near-surface turbulent mixing.

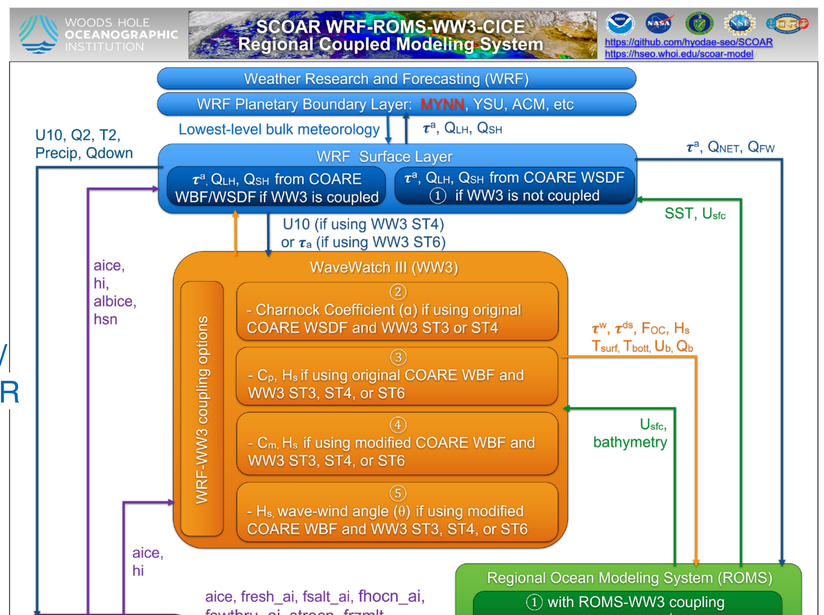
The reduction of wave energy is primarily in the direction of prevailing wind and is consistently in the 20-30% range. Furthermore, wave energy reduction occurs at different periods at different fetches. Close to the wind farms, the wave energy reduction is most pronounced at short periods (<4s), but further away from the wind farms (longer fetch), it occurs at considerably longer periods (~8s or more). A more detailed wave response analysis and a separate investigation of the hydrodynamic responses in the Nantucket Shoals regions are ongoing and will be reported elsewhere.

Modeling approach

SCOAR WRF-ROMS-WW3 fully-coupled modeling system

https://github.com/hyodae-seo/SCOAR

hseo.whoi.edu/SCOAR



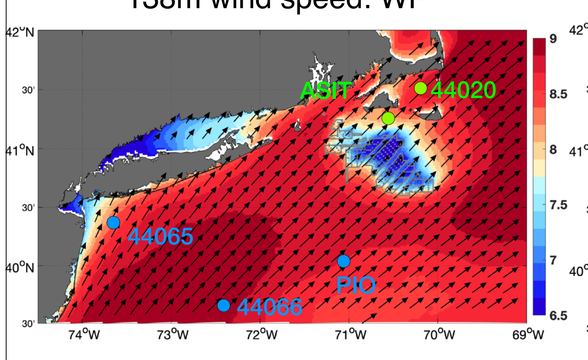
Seo et al. (2007, 2016, 2021); Sauvage et al. (2023)

Exps	WFP	SST determined by	Period
WF	Yes	WRF-ROMS-WW3	JJA, 2017-2019
noWF	No	WRF-ROMS-WW3	JJA, 2017-2019

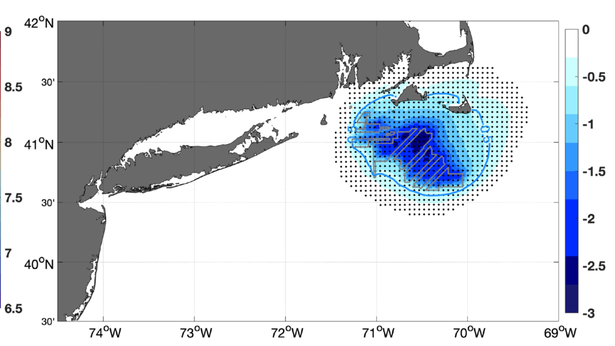
830 12MW turbines in the MA/RI lease areas represented by the "Fitch" parameterization

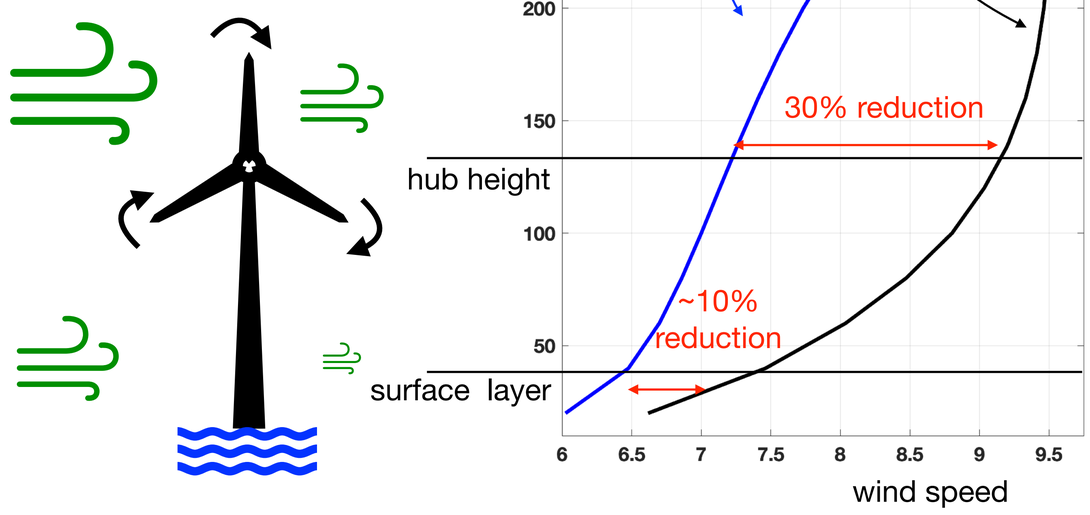
Wind response

138m wind speed: WF



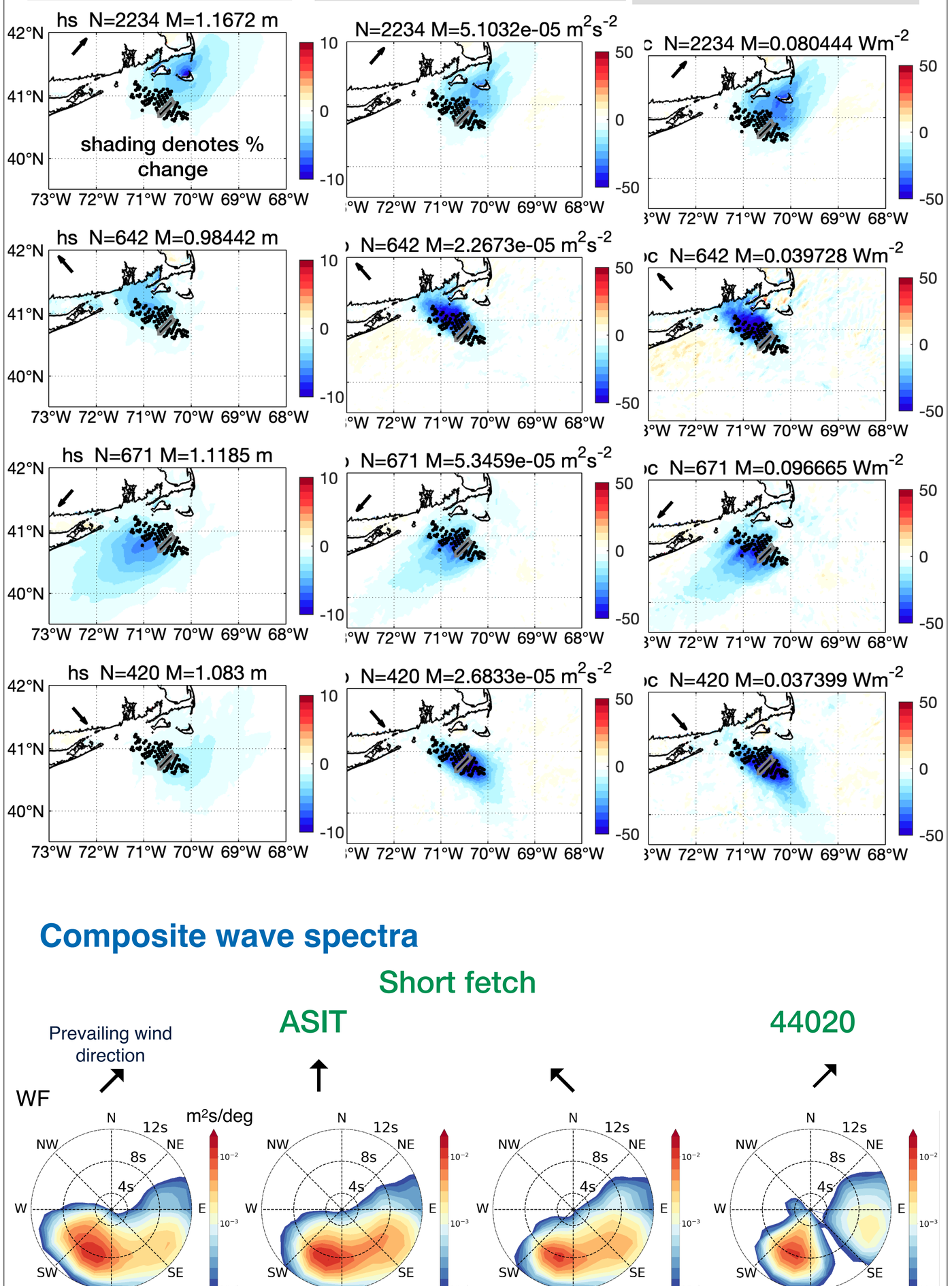
WF - noWF





Composite wave responses

Significant wave height (Hs) | Wave-induced wind stress (taw) | Wave-to-ocean energy flux (foc)



Composite wave spectra

Short fetch

Longer fetch