Field	Study Information
Title	Impacts of Floating Offshore Wind Subsurface Infrastructure to Hydrodynamics, Biogeochemistry, and Primary Productivity in the Pacific OCS (PC-25-04)
Administered by	Pacific OCS Region
BOEM Contact(s)	Alice Kojima (alice.kojima@boem.gov), Thomas Kilpatrick (thomas.kilpatrick@boem.gov)
Procurement Type(s)	Interagency Agreement or Cooperative Agreement
Performance Period	FY 2025–2027
Final Report Due	TBD
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Problem	Recent and ongoing modeling studies examine the impact of wind wakes (i.e., atmospheric disturbance) from Pacific Outer Continental Shelf (OCS) offshore wind farm development on upwelling and related nutrient availability. However, these studies do not consider fluid-structure interactions between oceanic flow and subsurface wind farm infrastructure (i.e., floating substructures).
Intervention	This study will fill a knowledge gap by modeling interactions between oceanic flow and underwater infrastructure of wind farms to determine how they may influence hydrodynamics (HD), biogeochemistry (BG), and primary productivity (PP).
Comparison	Model simulations that incorporate oceanic flow-floating substructure interactions (ocean wakes) will be compared against a control simulation with no wind farms and available observational data in the region for model validation. There will also be a comparison with a “no-ocean wake” scenario to characterize contribution of ocean wakes to changes in HD, BG, and PP.
Outcome	This study will help provide the full picture of how Pacific OCS offshore wind development may impact HD, BG, and PP via changes in both atmospheric and ocean circulation. Outcomes of this study will be crucial for productive interactions with stakeholders and will inform both the National Environmental Policy Act (NEPA) review process and future construction and operation plans.
Context	The modeling domain will be the Pacific OCS region extending from southern California to Washington, with particular focus on existing lease areas (California) and wind energy areas (Oregon).

BOEM Information Need(s): To support offshore wind (OSW) development in the Pacific OCS region in an environmentally responsible way, BOEM must evaluate the potential impact of OSW infrastructure on the physical upwelling properties of the California Current and associated biogeochemistry (BG). By bringing nutrient-rich waters to the surface, upwelling forms the foundation of the exceptional productivity of the California Current Large Marine Ecosystem (CCLME). Modeling studies to date investigate the potential impact of wind wakes (i.e., reduced wind stress) produced by Pacific OCS wind farm infrastructure on upwelling volume transport and nutrient delivery (Raghukumar et al., 2023) and related BG (NT-23-09). However, these studies do not consider the subsurface interactions between oceanic flow and the floating substructures of the wind farms (i.e., ocean wakes). Environmental impacts of the floating substructure will be considered in the National Environmental Policy Act (NEPA) review process and may inform the designs proposed in construction and operations plans submitted by lessees.

Background: The California Current flows along the Pacific coast of the U.S. and is highly productive due to the upwelling of deep, nutrient-rich waters to the surface. This delivery system of nutrients to the surface allows organisms of all trophic levels to thrive in this region and is thus of primary interest to stakeholders. A recent modeling study funded by the State of California demonstrates a modest impact of OSW infrastructure to patterns of upwelling near the Morro Bay wind energy area (WEA) in central California (Raghukumar et al. 2023). In particular, Raghukumar et al. (2023) observed a slight reduction in upwelling strength on the lee side of the wind farm and a change in the spatial signature. Ever since the results of this study were made public, many stakeholders of the Pacific OCS have expressed concern about the impacts of OSW development on upwelling during the various comment periods of the OSW leasing process (most recently, in response to the Oregon draft WEAs). BOEM has invested in a subsequent modeling study (NT-23-09) to investigate OSW farm impacts more broadly on ocean BG and PP offshore California and Oregon. Both studies represent the presence of floating wind farms as a reduction in wind stress (i.e., wind wake) at the sea surface, but do not include interactions between subsurface infrastructure and oceanic flow (i.e., ocean wakes) as part of their impact.

The dynamics of these ocean wakes produced by floating substructures remain poorly understood in both well-mixed and stratified pelagic waters due to the relatively new expansion of the OSW energy sector into deeper waters (Dorrell et al. 2022). The semi-submersible type of floating substructure is most commonly used in global floating offshore wind farms to date (Musial et al. 2020), and is also the most likely and preferred technology to be used for Pacific floating offshore wind development (Trowbridge et al., 2023). This study will employ the semi-submersible substructure type together with wind wake parameterizations to demonstrate how turbines and substructures together impact HD, BG, and PP.

Objective(s): The objectives of this study are as follows:

- Model interactions between oceanic flow and floating semi-submersible substructures and combine with parameterized wind wake effect to characterize impacts of Pacific OCS wind farms on local HD, BG, and PP.
- Create an engaging communication product (e.g., ArcGIS StoryMap) to share the outcomes of this study with stakeholders and develop related talking points that can be used by BOEM Pacific staff when answering questions about upwelling and public-facing meetings.

Methods: This study will develop a model framework that couples an established general circulation model (e.g., MITgcm) with an ecosystem model (e.g., Darwin package), or use a similar approach. Oceanic flow can be simulated at 10-m resolution (in both x and y) and as high as 3-m resolution (z) using MITgcm (Hughes et al. 2022). The model simulations produced by this framework will be of sufficient resolution to distinguish changes in physical currents beneath and around a semi-submersible floating substructure and the associated HD, BG, and PP impacts. The semi-submersible substructures will have dimensions that support 10- and 15-MW wind turbines.

First, these simulations will be compared against a "no-turbine" control run to determine the full magnitude of impact on HD, BG, and PP. Second, these simulations will be compared against a "no-ocean wake" control to quantify the added influence that the ocean wake has on HD, BG, and PP. The magnitude of change from the "no-ocean wake" control will also be compared against the results of previous modeling studies that incorporated only wind wake effects to demonstrate model differences (e.g., MITgcm vs. ROMS). Relevant observational data (e.g., glider data) will be used to help validate these model simulations. This study will provide a more complete picture of how Pacific OCS offshore wind farm infrastructure will impact HD, BG, and PP of the surrounding area and provide a basis for potential higher trophic level responses.

Specific Research Question(s):

1. How will ocean wake effects from oceanic flow-floating substructure interactions combine with wind wake effects from wind field-turbine interactions of offshore wind farms to impact HD, BG, and PP?
2. How will interactions between oceanic flow and floating substructures influence ocean stratification and thermocline depth in WEAs?
3. How do these changes (ocean stratification and thermocline depth in WEAs, local and regional HD, BG, PP) compare to those that occur due to natural variability (Jacox et al. 2015) and climate change?
4. How do HD and BG changes simulated in MITgcm compare to those simulated in ROMS?
5. How can these modeling results inform a monitoring effort focused on turbine-scale oceanic flow-structure interactions?

Current Status: N/A

Publications Completed: N/A

Affiliated WWW Sites: N/A

References:

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