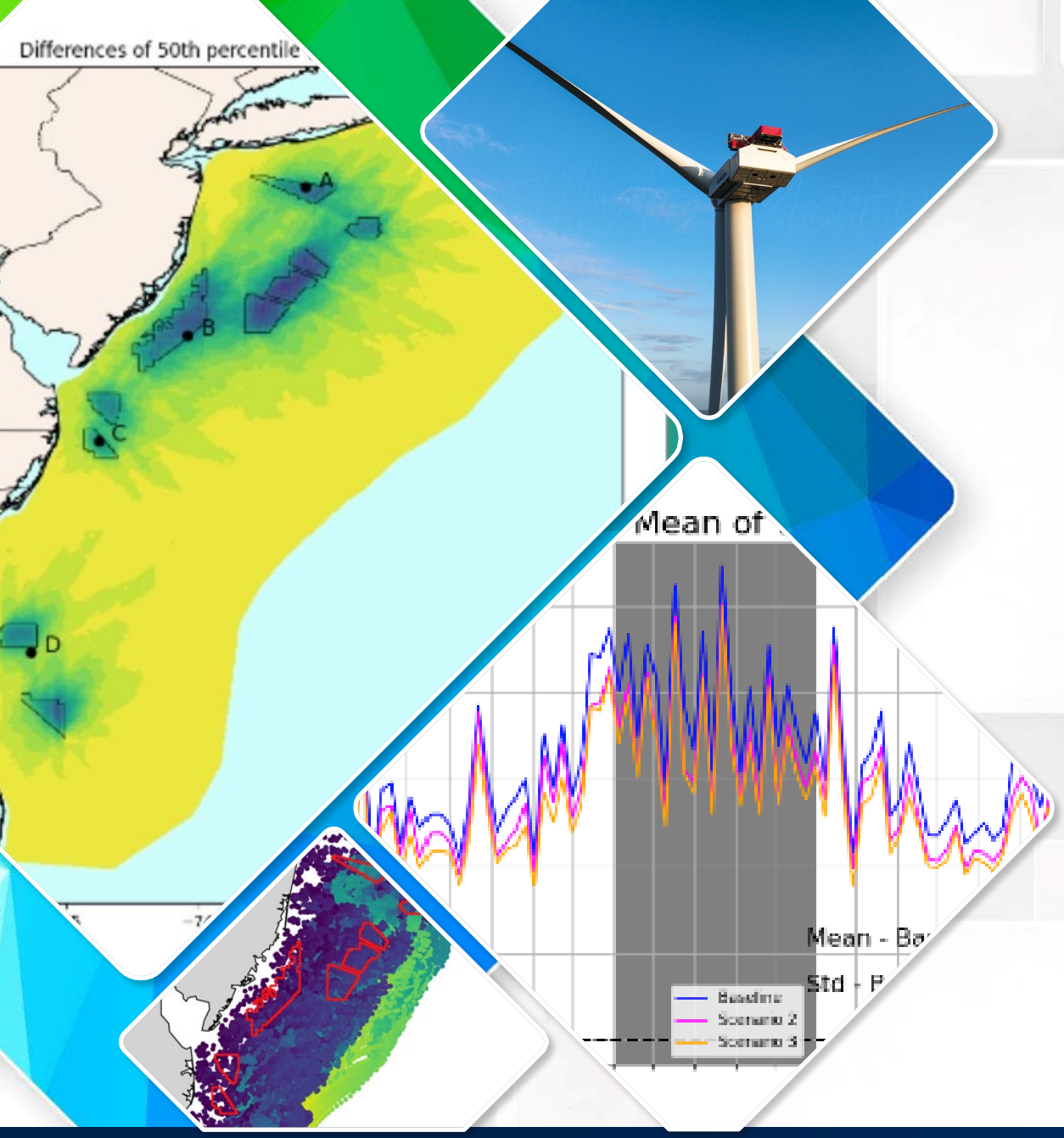

Study concept, oversight, and funding were provided by the U.S. Department of the Interior, Bureau of Ocean Energy Management, Environmental Studies Program, Washington, D.C. under Contract Number 140M0123C0001

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Offshore Wind Impact on Oceanographic Processes: Cape Hatteras to Long Island

Mahmud Monim, Emily Day, Dan Codiga, Nickitas Georgas, Lily Engel, Lenaïg Hemery, and Lysel Garavelli

NASEM Committee on Offshore Wind and Fisheries

December 18, 2024

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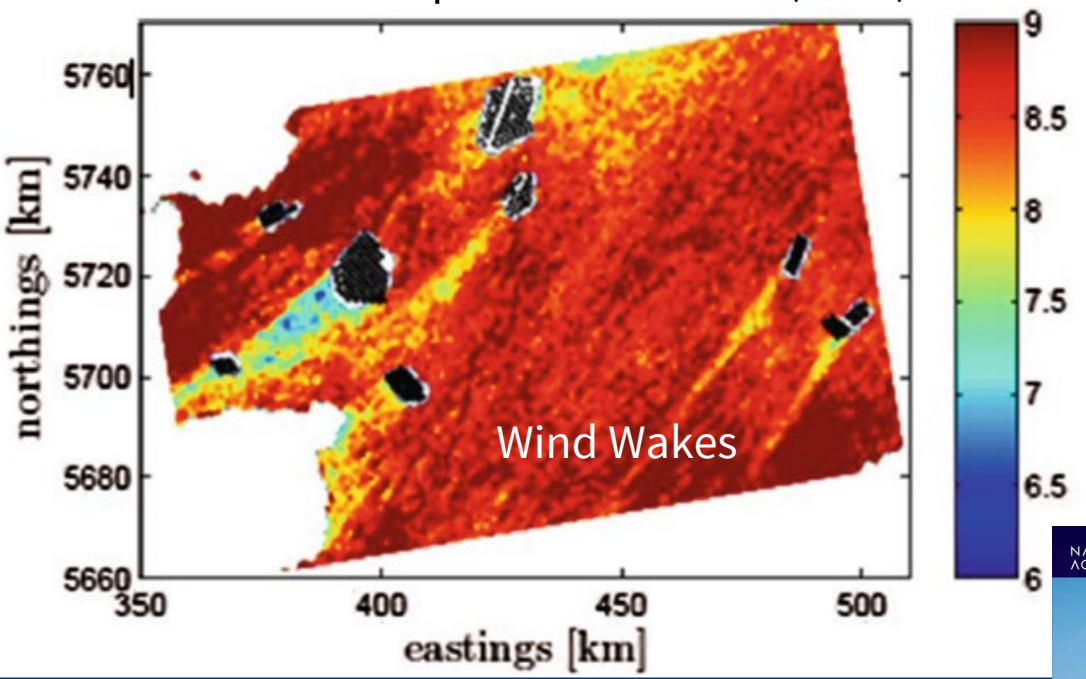
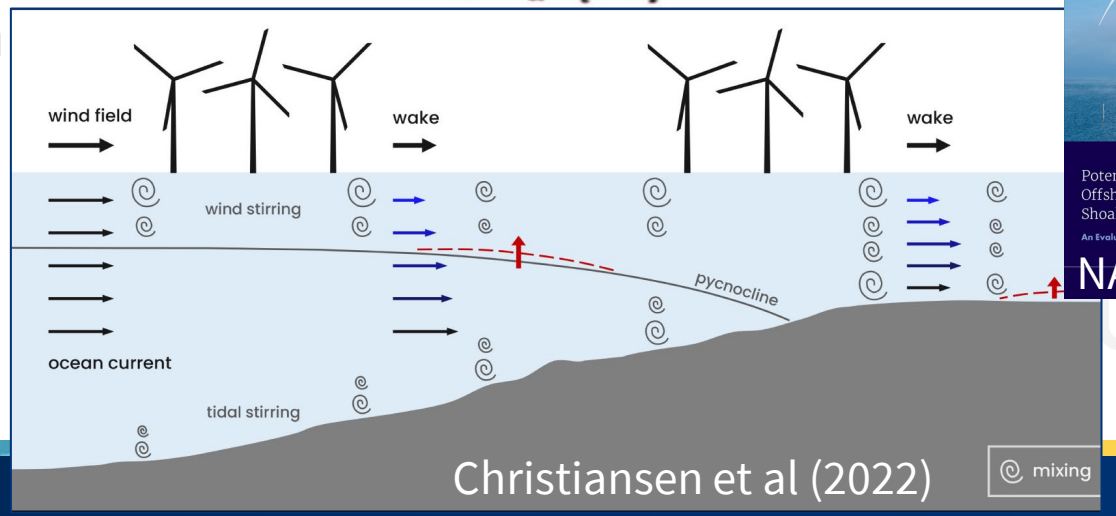
Some potential impacts of Offshore Wind Development

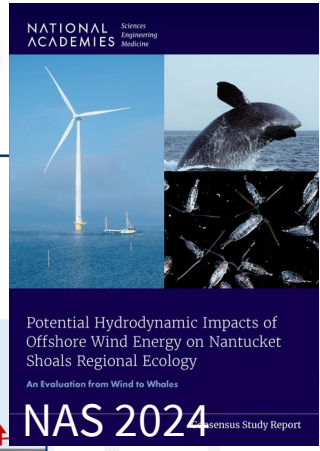
- Surface wind through wind wakes (downstream deficits)
- Surface waves through wind stress reduction
- Currents through wind stress reduction, foundation resistance and flow separation
- Air-sea heat flux, ocean temperature, mixing, stratification (Pycnocline)
- Sediment mobility
- Thus, may affect larval transport and fisheries

Dörenkämper and Steinfeld (2022)





Christiansen et al (2022)

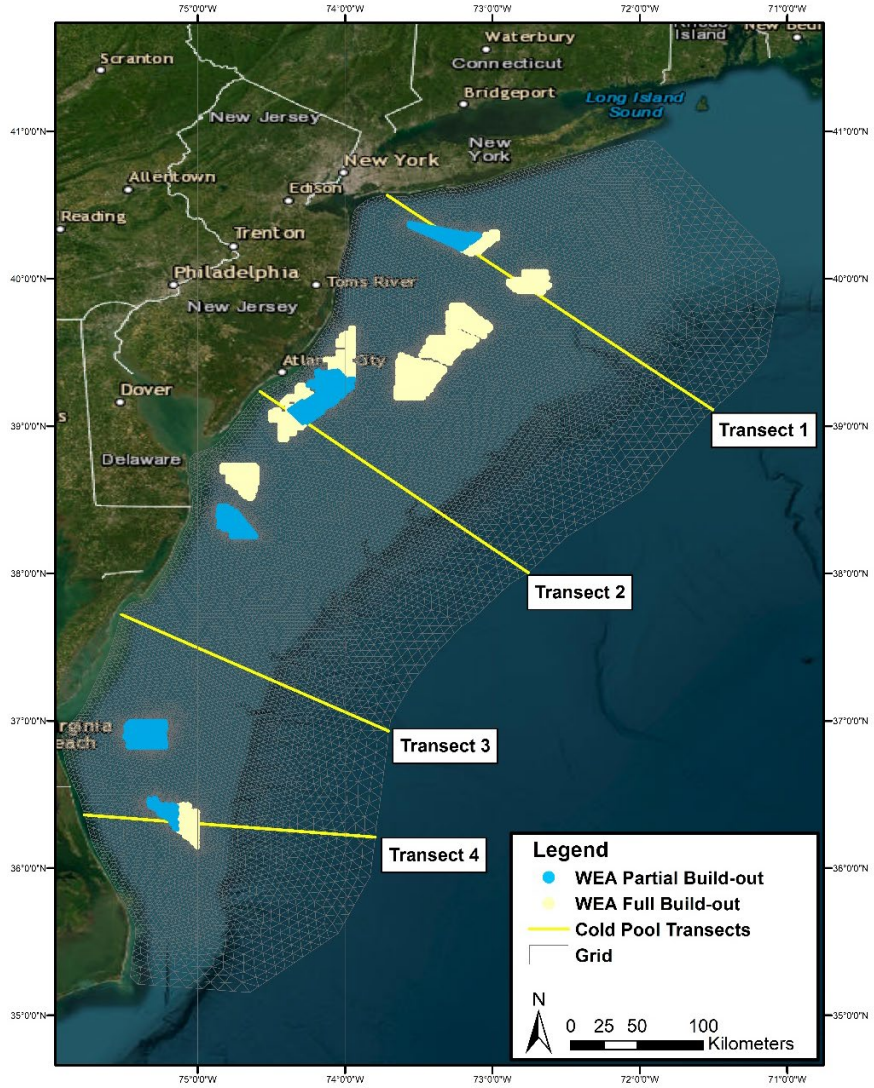


NAS 2024

Offshore Wind Development over MAB

- 15MW NREL Wind Turbine:
  - 150m hub, 240m rotor diameter
  - 10m monopile diameter
  - 3-25m/s cut-in cut-off speed

- Three scenarios:
  1. Baseline, no wind turbines
  2. Partial / Limited 27.8GW
     1852 WTGs, all publicly available
  3. Full build-out 95.3GW
     6353 WTGs, provided by BOEM

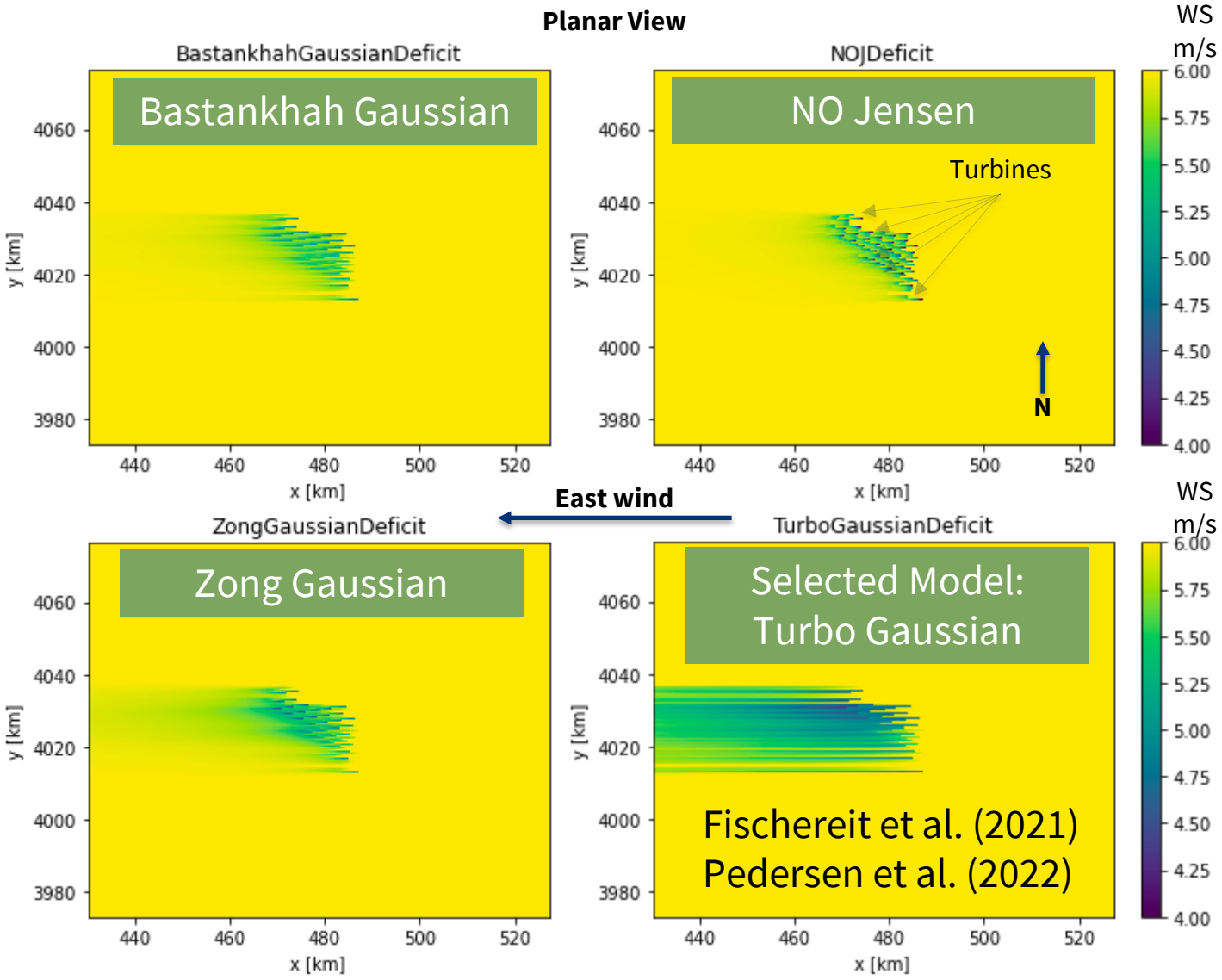


PyWake: Engineering Models for Wind Wake Deficit

- Based on turbine design specs
  - Physical dimensions
  - Power and Thrust curves

  And on wind farm design
  - Individual turbine orientation and placement within a wind farm

- Calculate wind wake
  - Downstream wind deficit
  - Accounting for turbine to turbine and farm to farm interactions
  - Based on Engineering models



Delft3D-FM & SWAN Hydrodynamic and Wave model

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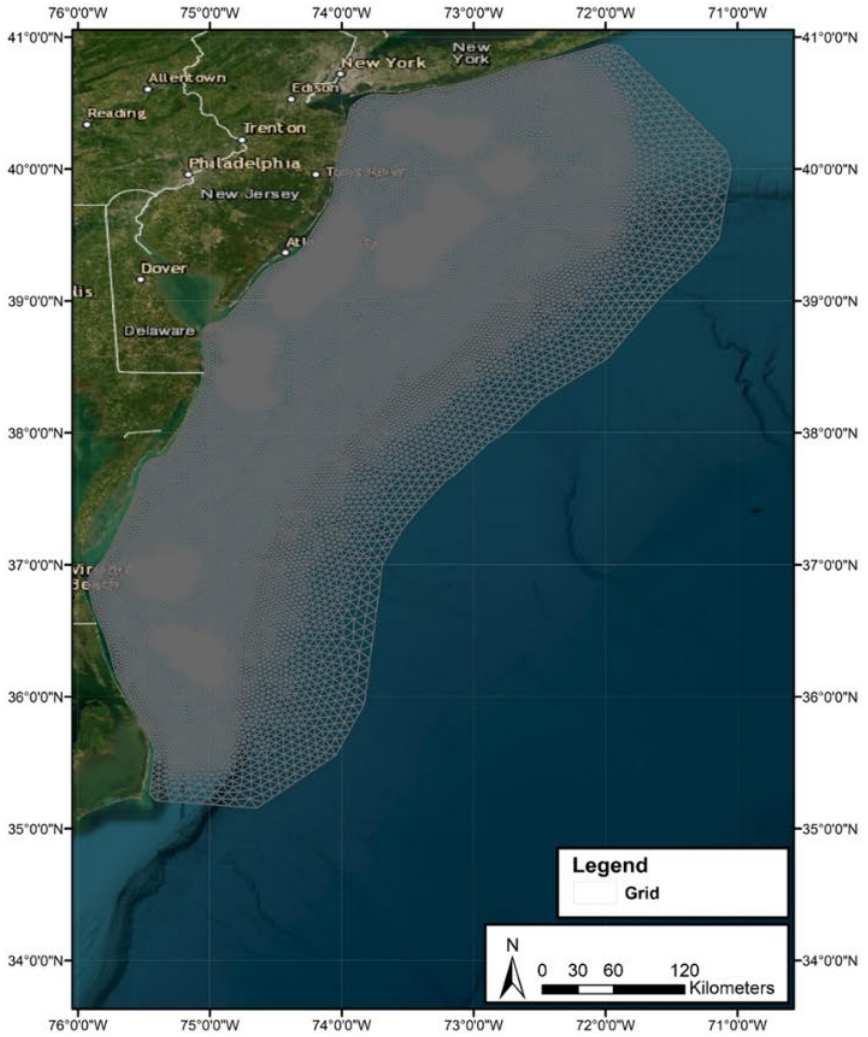
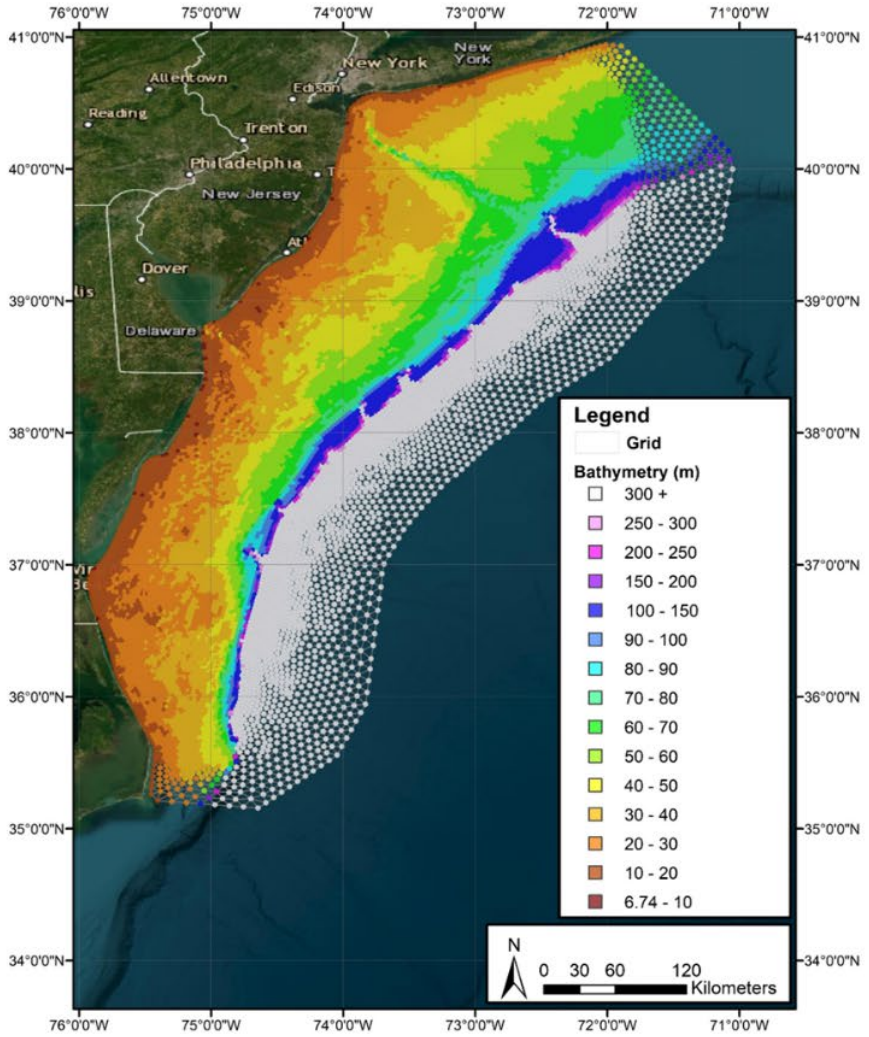
- Common Grid
  - Highest resolution in the farms
  - 40 vertical layers
- Nested within data-assimilative Doppio (10km) and ERA5 waves
- ERA5 winds and heat fluxes (with PyWake deficits)
- Monopile hydrodynamic drag
- Feb 2018-Jan 2020 simulation period





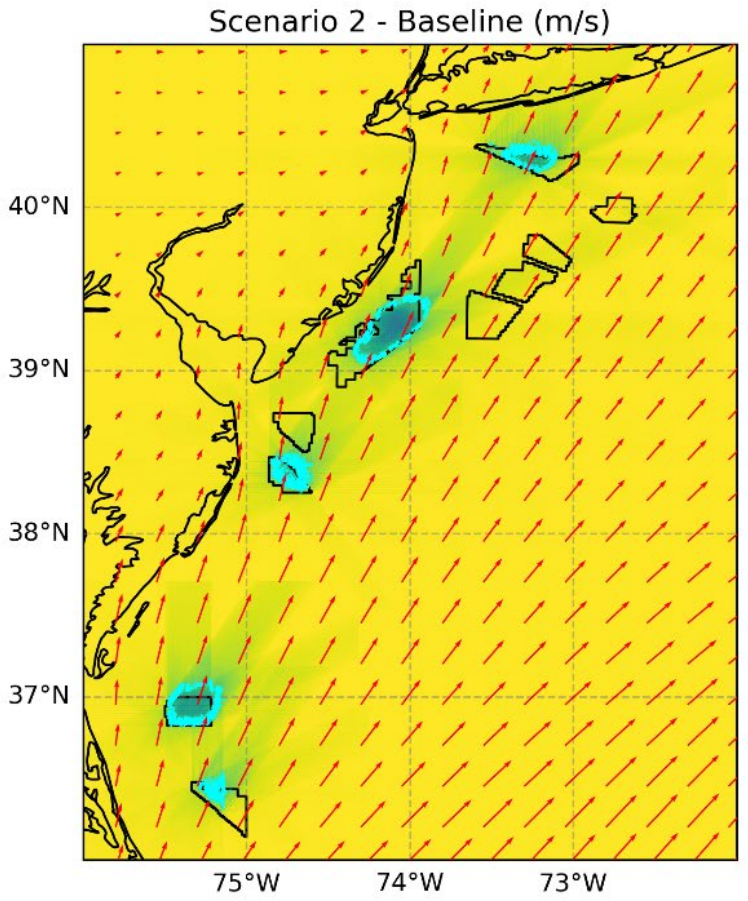
Effect on 10m Winds

- Max deficits within farms aligned with prevailing winds
  - ~20% reduction, climatological
  - Up to 30-50%, 1% of the time
- Wakes extend 50 to 200km
- Farm to farm interactions
- Full buildout (Scenario 3) has highest reductions

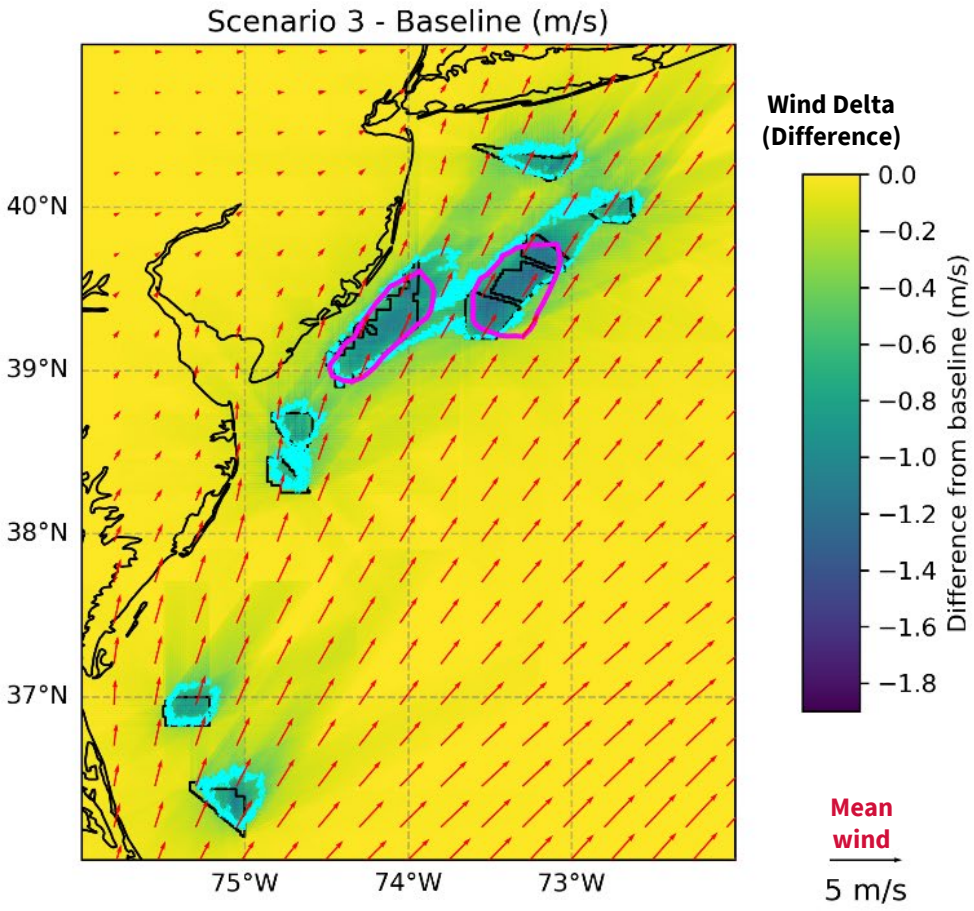
* Reductions more pronounced than Golbazi et al. (2022)

Colormap:
Delta for Mean Summertime Winds

Scenario 2 - Baseline



Scenario 3 - Baseline

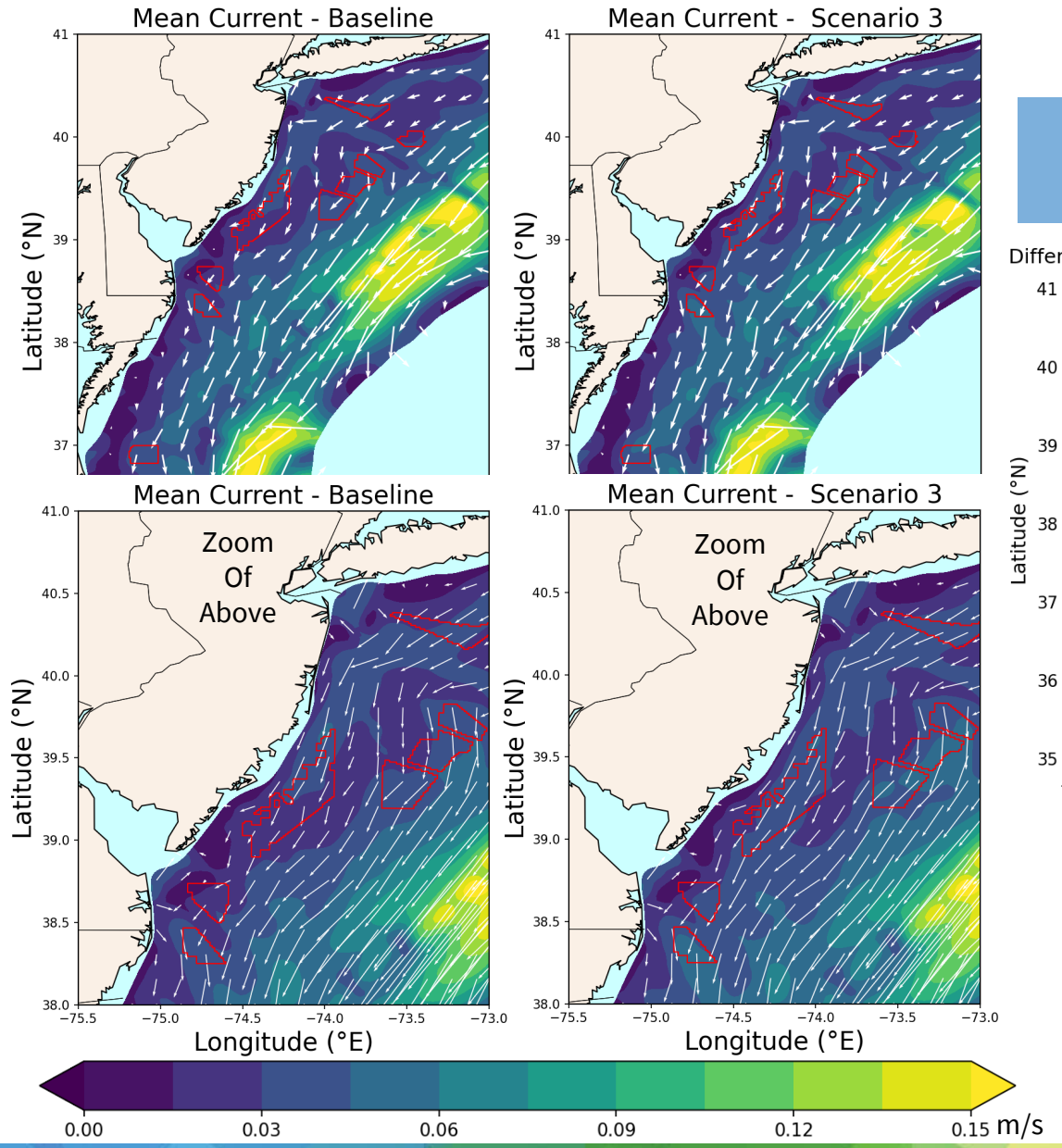


Effect on Tidal Residual Currents

- Along-shelf **tidal residual** currents increase along the wind farms.
- Consistent with some other studies.
- Shear production.
- Doming of thermocline on the lee side of farms (see report).

Baseline Mean

Scenario 3 Mean



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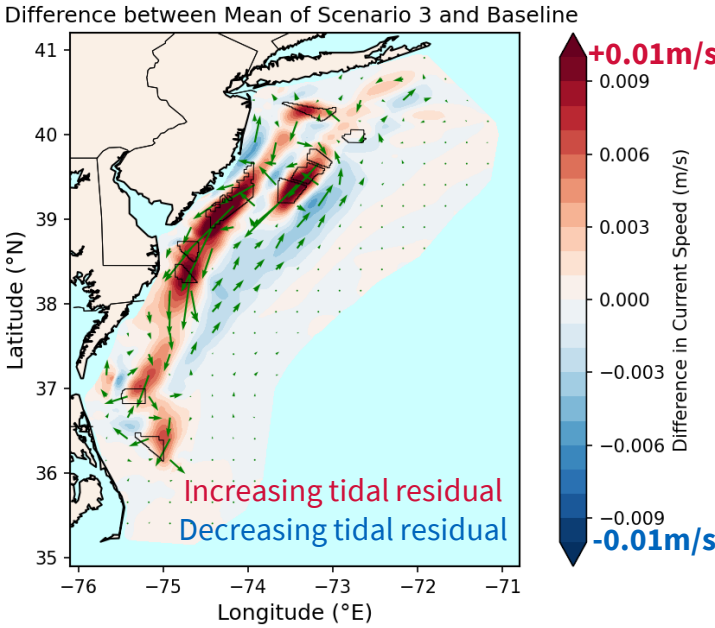
Scenario 3 delta of Tidal Residual Current



Effect on Summer Stratification (Delta-T, surface-bottom)

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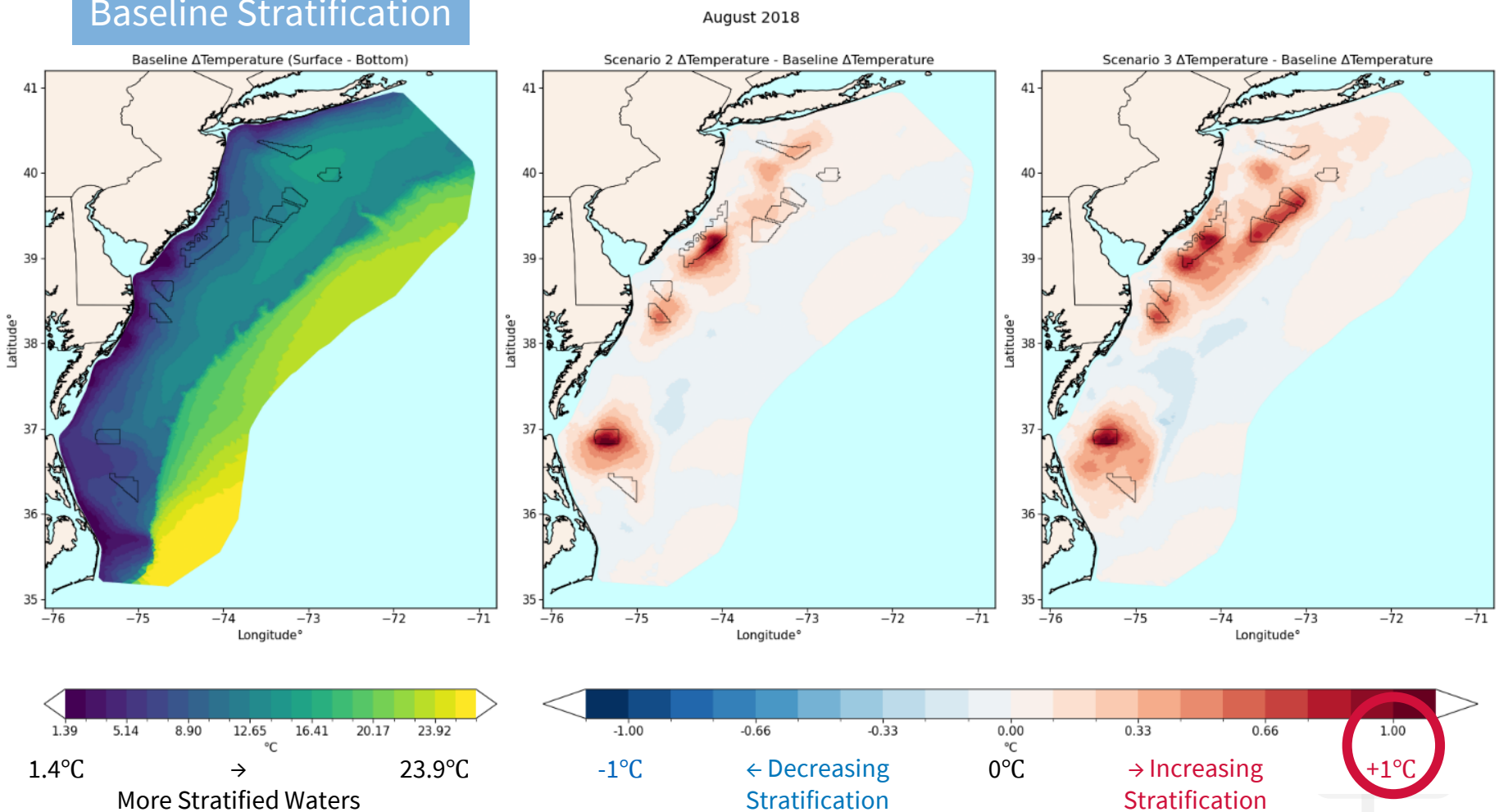
- Dominant loss of surface wind stress ->
- Less mixing (TKE, Richardson #)->
- More stratification->
- Possible changes in upwelling

August 2018
Baseline Stratification

Scenario 2 delta

Scenario 3 delta



1.4°C → 23.9°C
More Stratified Waters

-1°C ← Decreasing Stratification 0°C → Increasing Stratification +1°C

Summary of Results for Oceanographic Processes

- Wind turbines cause wind wake deficits, esp. for windspeeds ~3 to ~11 m/s
  - Within farms, and tens of km downwind; detectable to 200 km
  - Up to 20% reduction of average winds at 10m height
  - Max 30-50% reduction (1% of the time)
- Resulting surface wave changes (mainly wind waves, not swell) relatively minor
  - Local to farms, strongest for farms aligned with wind
  - Heights reduced (~0.17 m, < ~5%), periods lengthened (~0.16s)
- Changes to the typical 2-12 cm/s southward alongshore tidal residual currents
  - Wind deficit causes up to ~1 cm/s increase in southward alongshore residual flow along WEAs
  - Changes wind balancing regional southward alongshore pressure gradient
- Reduced wind-driven vertical mixing affects water column
  - Doming of thermocline; summer stratification increase up to +1°C (Aug 18)
  - ~ 0.25°C seasonal surface warming in summer within WEAs
  - Possible changes in upwelling / downwelling
- Cold pool seasonal evolution not modified. We also looked at heat fluxes.

Biophysical Larval Dispersal Model

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Hydrodynamic model

Current velocities
Current direction
Temperature

Per location and time

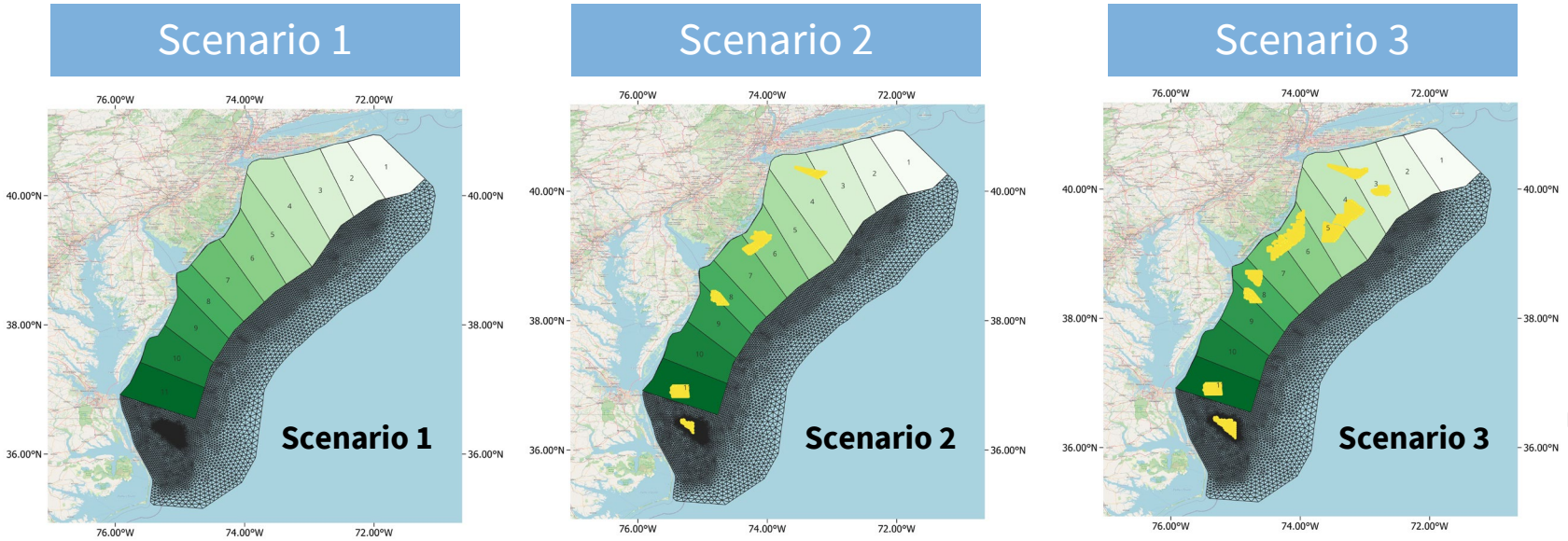
ICHTHYOP

Individual-based model

Transport Growth
Behavior Mortality
[Lett et al. 2008]

Larvae position at each timestep

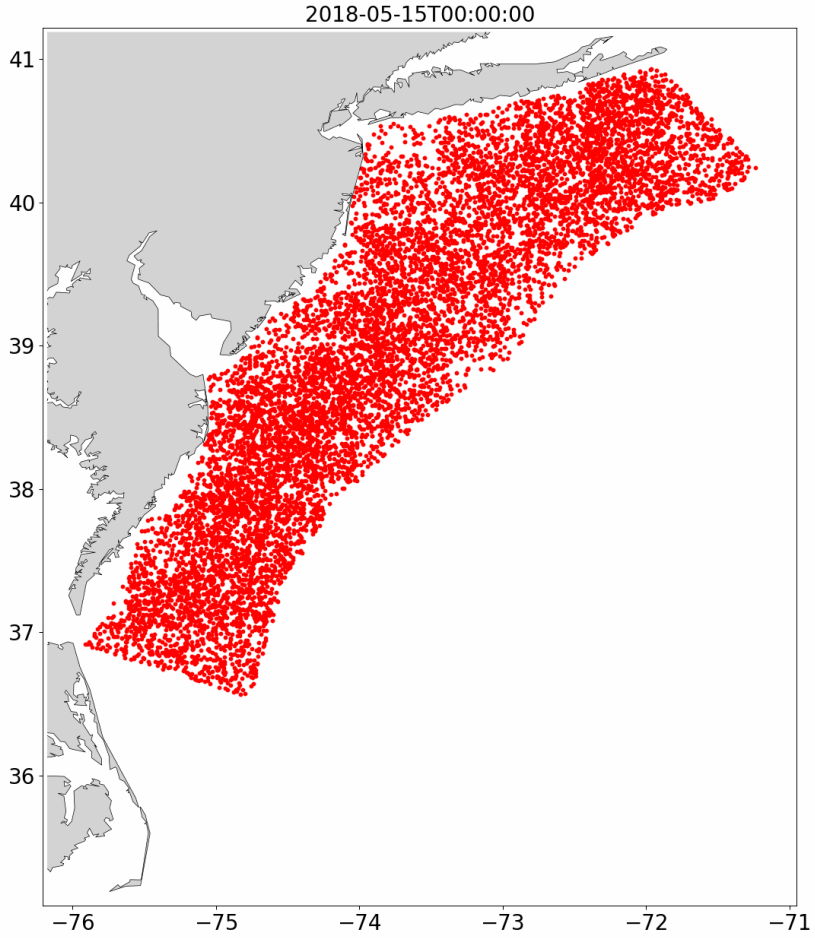
Atlantic sea scallop
Placopecten magellanicus



Spawning and settlement zones

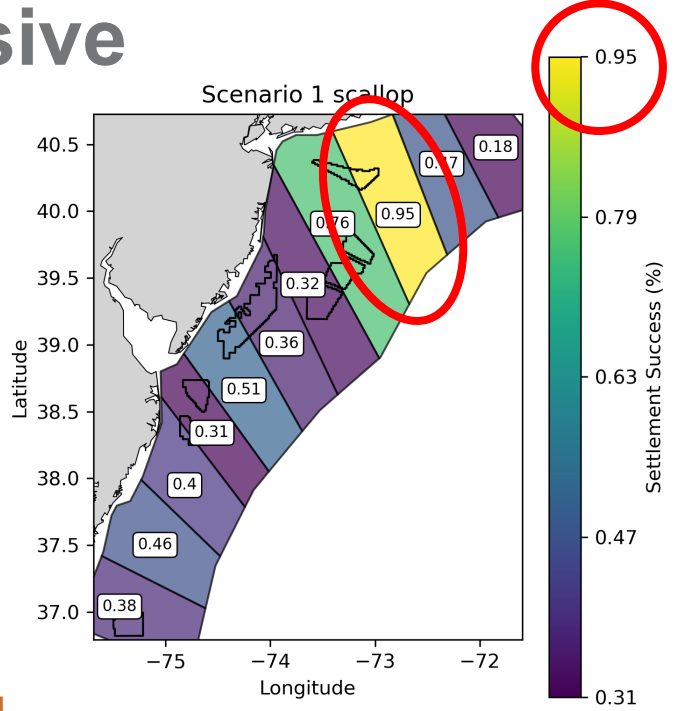
Atlantic scallop larval transport

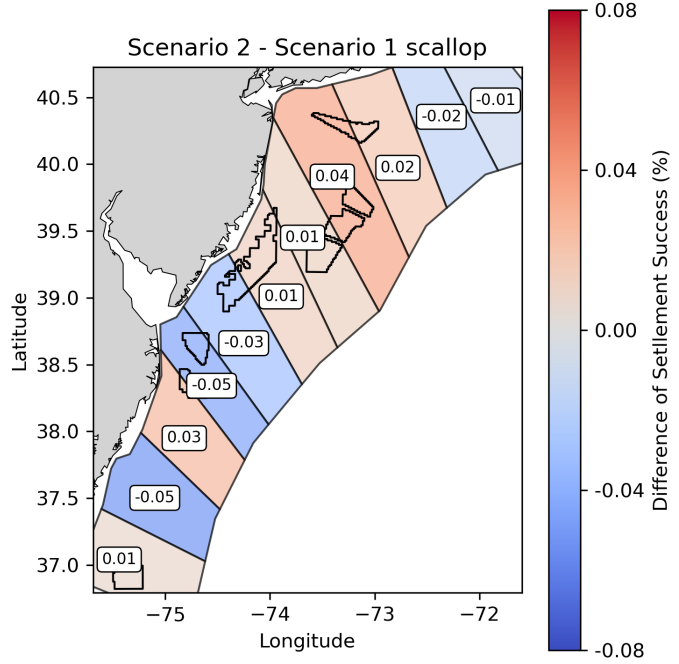
- Release May 14, 2018
- 1,000 larvae
- Dispersal duration: 45 days
- Pre-competency period: 28 days
- No diel vertical migration (DVM) behavior (passive in initial simulations)
- If larvae exit from the model boundary, they are considered lost (disappear from video)
- Successfully settled larvae stop moving in video

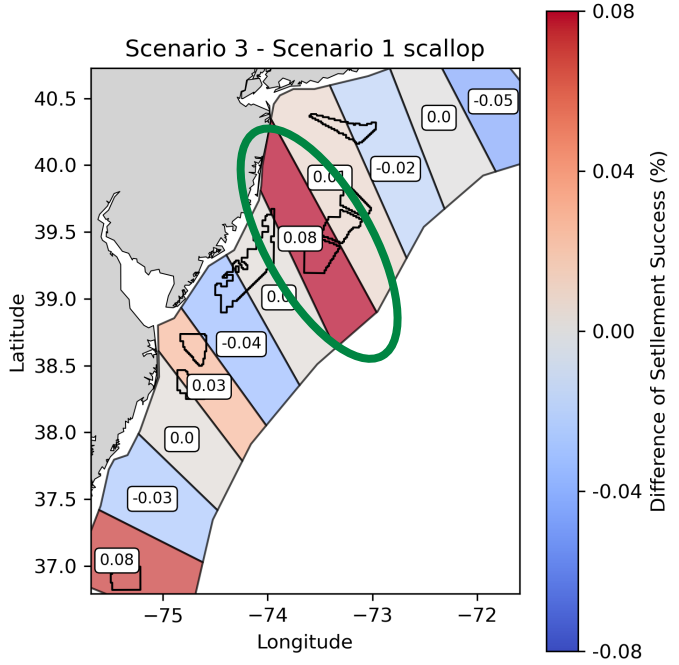


First settlement occurs at day 28

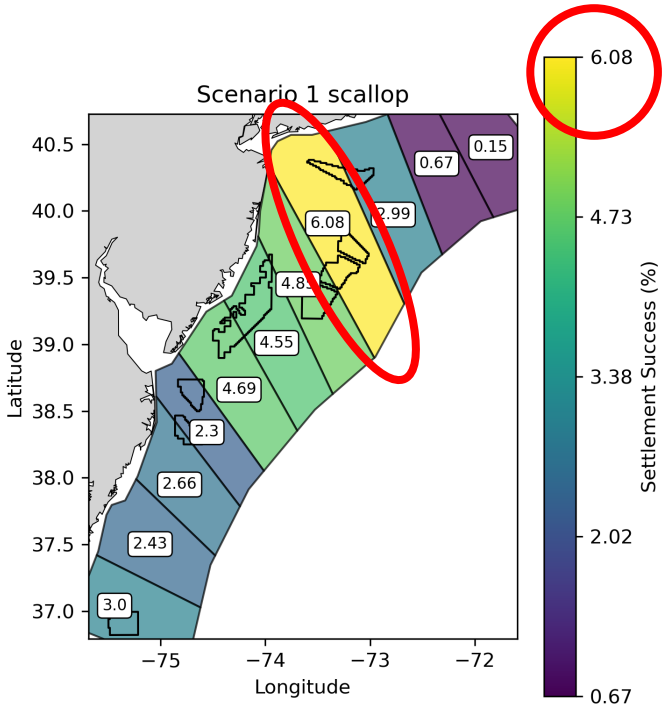
Passive

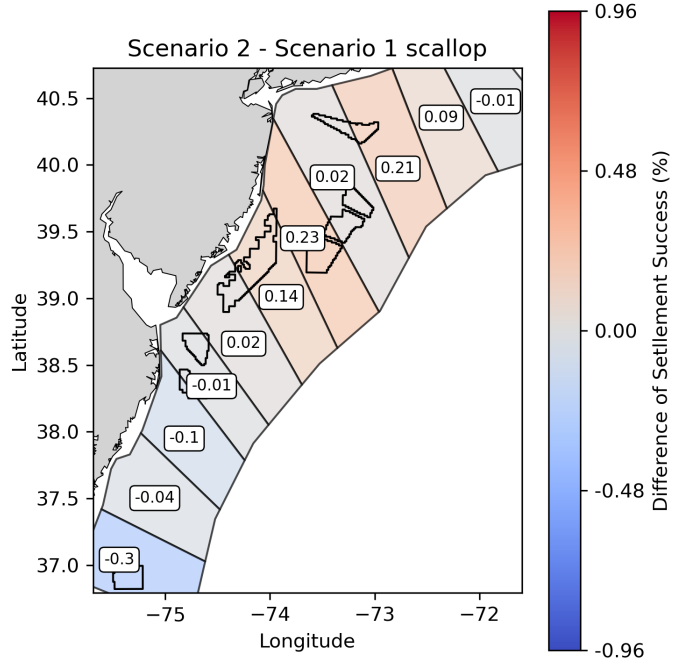


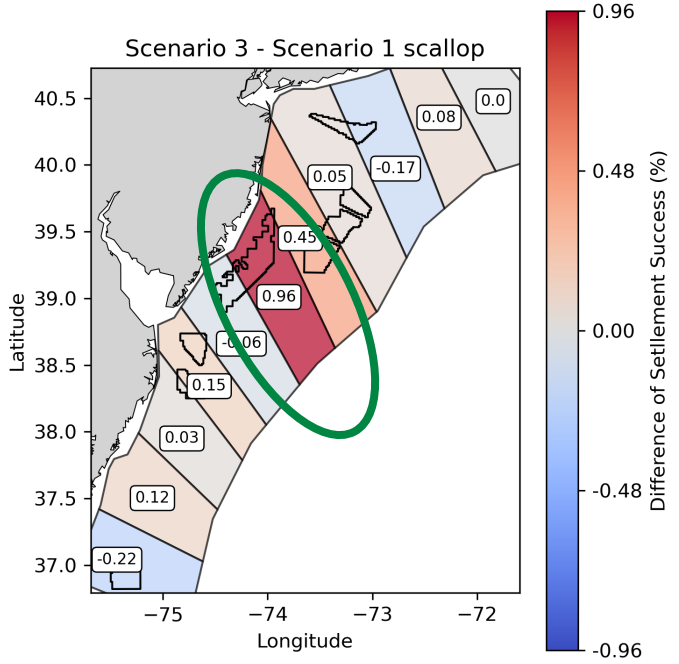




DVM







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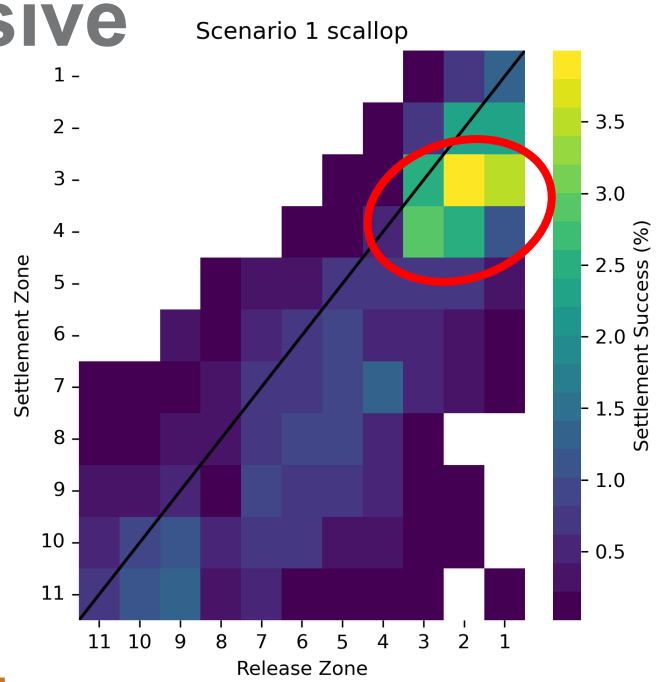
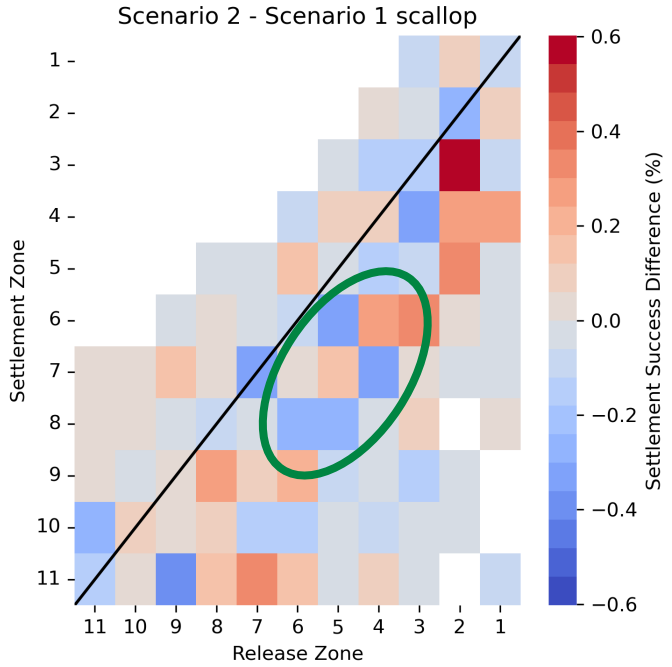
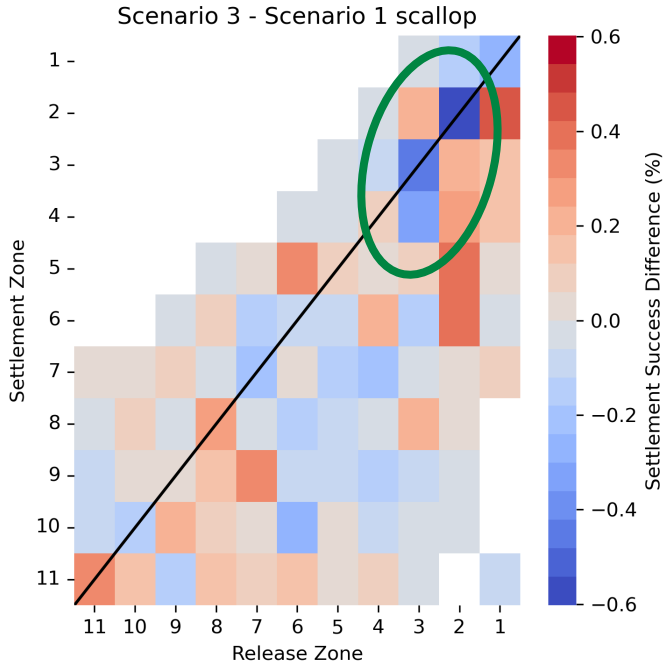
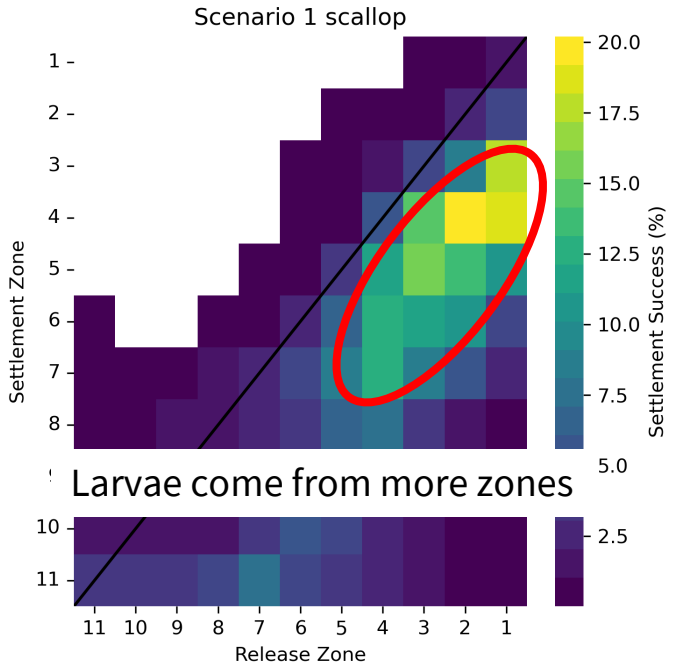
Passive

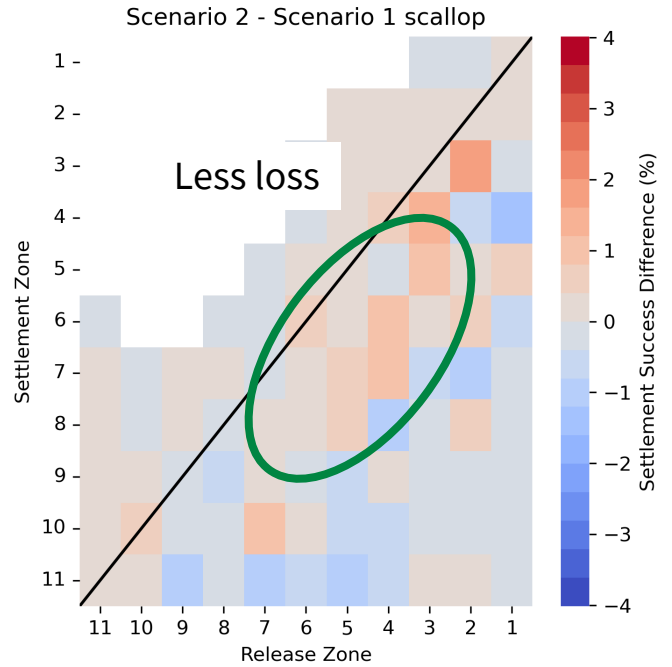


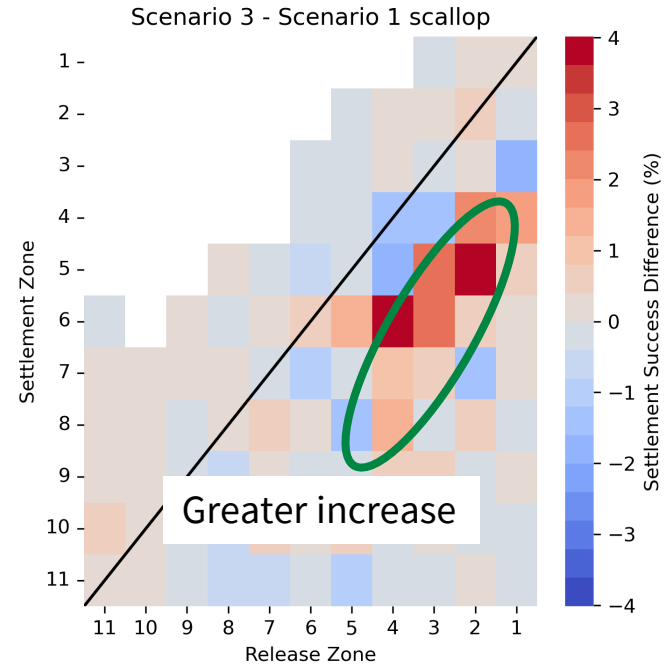




DVM







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Summary of Results for Larvae

- General trends on the effects of WEAs:
  - **Decrease local retention** (north)
  - **Increase larval dispersal distances**
  - **Not statistically different**
- Connectivity hotspot in northern region **persists with WEAs**
- Effects of WEAs are location dependent
- **Larval behavior** influences larval dynamics with and without WEAs
- The other species (Atlantic surfclam and black sea bass) see similarly **mixed responses** to WEAs.

Source: ACP

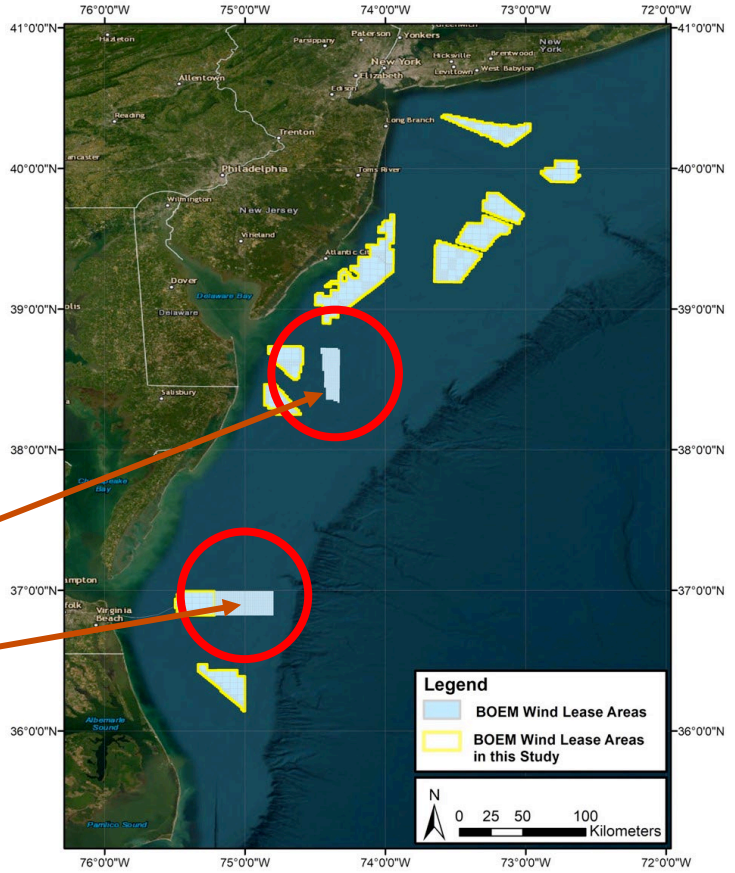
Possible Next Steps

- More years, interannual variability, different species.

- Improve understanding of upwelling / downwelling zones; Dipoles; Vorticity dynamics (convergence / divergence, Persistent Lagrangian Coherent Structures - LCS).

- Refining biological parameters such as larval behavior and growth.

- Two new lease areas in the MAB.



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