Variations in Sediment Concentration caused by Modified Waves and Currents in an Offshore Wind Farm

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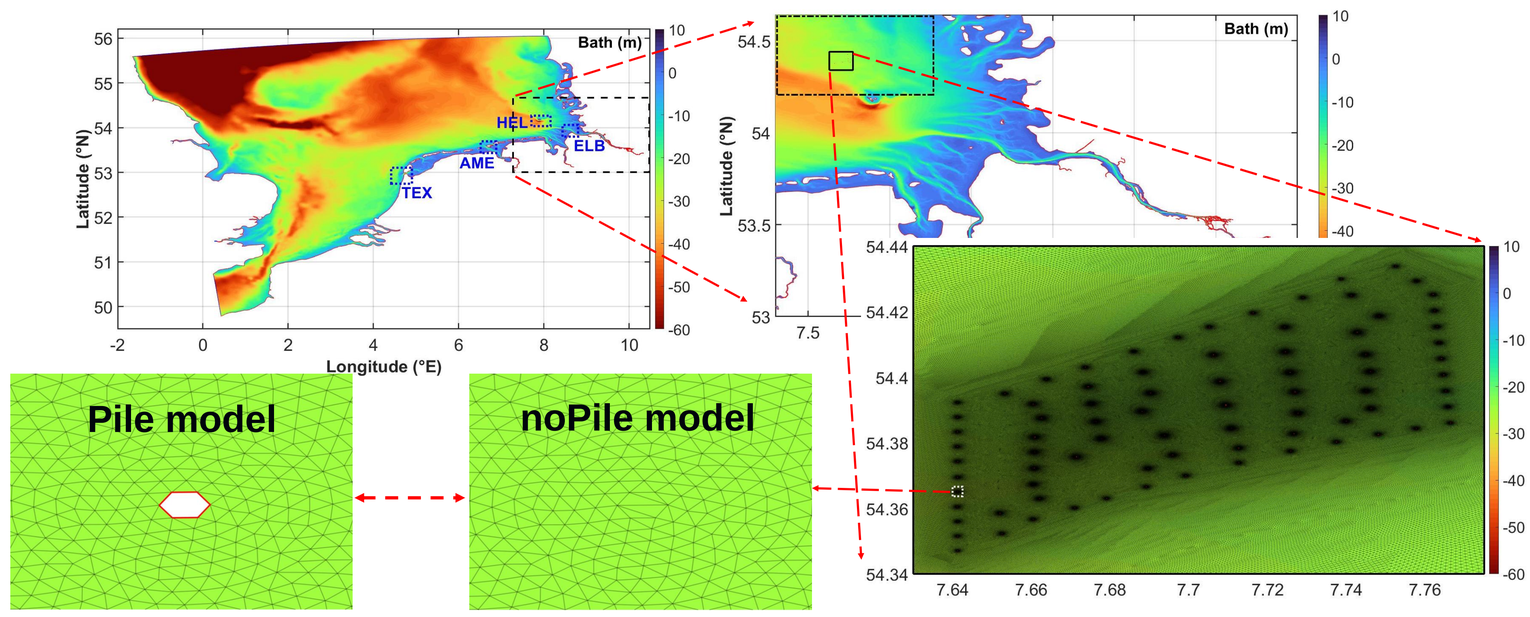
Motivation

This study adopts a multi-use resource strategy to advance the blue economy under the EU Green Deal, with particular focus on the potential of multi-use offshore wind farm (OWF) energy and low-trophic-level aquaculture. It constitutes a foundational step in our efforts to simulate suspended sediment concentration (SSC) under realistic conditions involving current–wind wave–OWF monopile interactions at the Meerwind-OWF site (German Bight, North Sea).



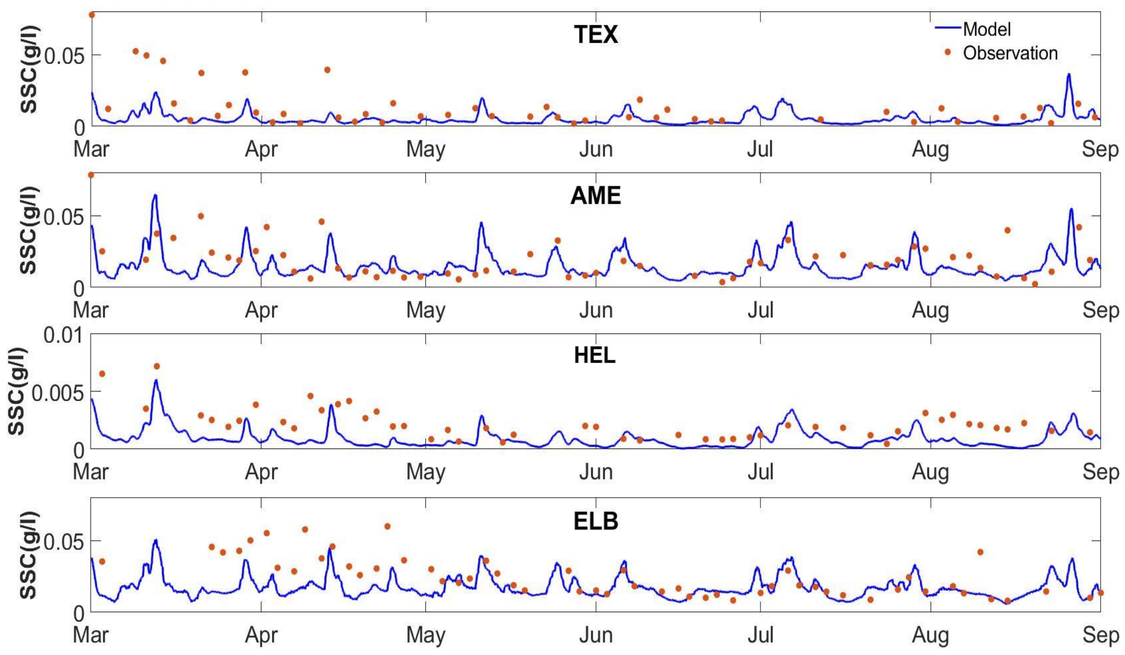
Numerical modeling

- 3D fully coupled model (**SCHISM-WWM**) integrating hydrodynamics, wind wave dynamics, and sediment transport
- High-resolution unstructured grids: **2 km** (marine open boundaries) **to 2 m** (near the OWF piles)
- Sediment inputs: "**EasyGSH-DB**" dataset (Sievers et al., 2020).
- Horizontal grid: ~**589k nodes**
- 21 vertical **LSC²**-layers
- Open ocean boundary: **CMEMS AMM15** (SSH,Vel, T, S)
- Atmospheric forcing: hourly **DWD** data
- Wave boundary: **WaveWatch III** data
- Four different numerical experiments (**Pile, noPile, PileNW, noPileNW**)

Experiment	Activated "Hydro" + "Sed" modules	Activated "Wave" module	Including OWF piles
Pile	Yes	Yes	Yes
noPile	Yes	Yes	No
PileNW	Yes	No	Yes
noPileNW	Yes	No	No

Model Results

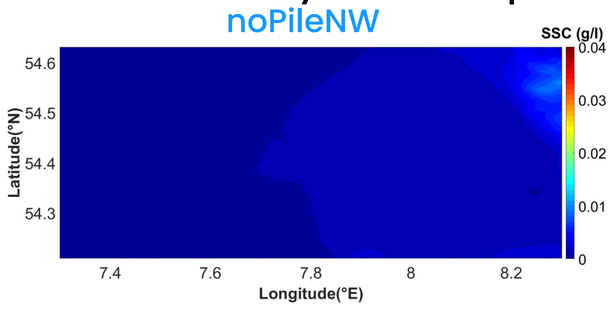
❑ Validation



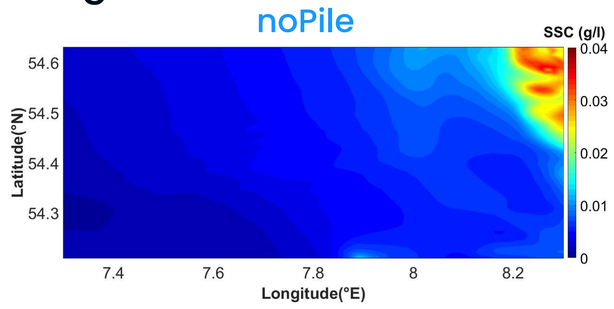
Site	Model skill (-)	RMSE (g/l)
TEX	0.728	0.008
AME	0.603	0.013
HEL	0.601	0.001
ELB	0.714	0.013

❑ Monthly mean depth-averaged SSC in March 2020

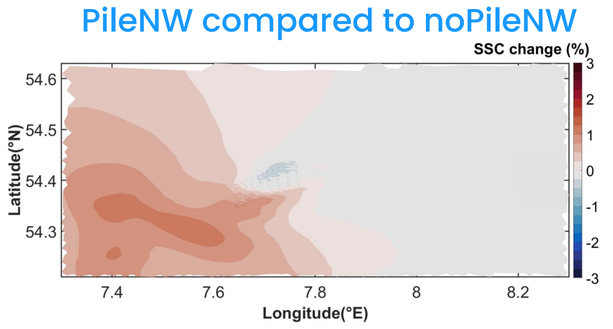
noPileNW



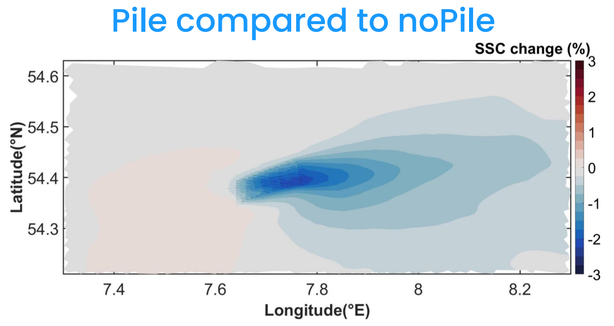
noPile



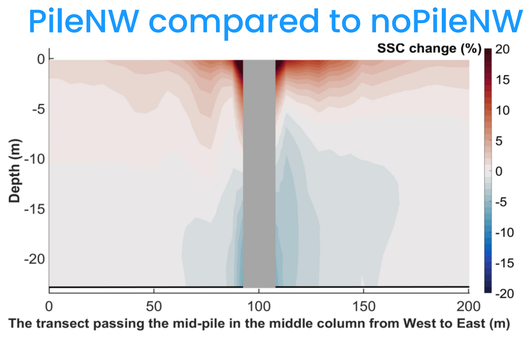
PileNW compared to noPileNW



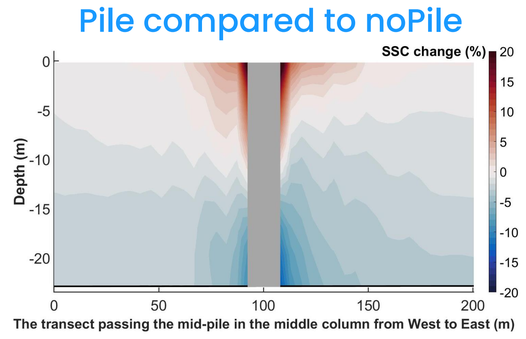
Pile compared to noPile



PileNW compared to noPileNW

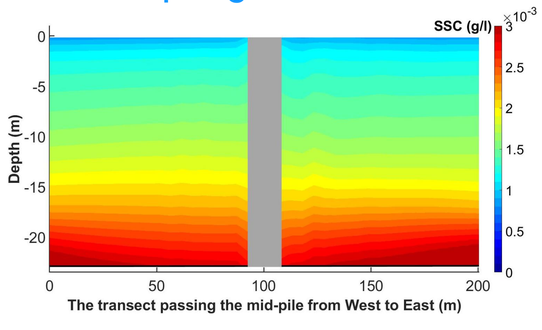


Pile compared to noPile

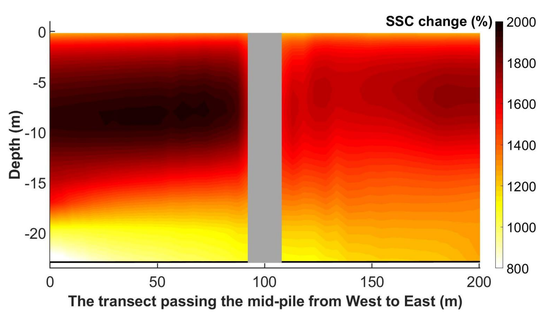


❑ SSC in the neap-spring transition

Spring tide



Spring tide compared to neap tide



Summary

- Current-pile interactions enhance SSC promoting southwestward deposition.
- Wave-current-pile interactions result in erosion downstream of the dominant westerly and southwesterly waves.
- SSC exhibits substantial variation (~ 20-fold) across neap-spring tidal cycles.
- Tidal asymmetry in turbulent wakes on either side of the piles induces a corresponding asymmetry in SSC.

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