Model of the flow around offshore wind turbine foundations based on a one-way nesting technique

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Introduction

Understanding and predicting flow around offshore wind turbine foundations is an important part of the planning and maintenance of offshore wind farms. Oceanographic models such as NEMO (Nucleus for European Modeling of the Ocean) are often used for large-scale simulations of ocean and coastal processes. In contrast, OpenFOAM is used for highly detailed, 3D small-scale simulations to model complex geometries with high numerical precision. Therefore, this research proposes a one-way nesting of the detailed numerical model created in OpenFOAM into the oceanographic model. The mentioned procedure can provide valuable insight during foundation installations and maintenance, which is vital for ensuring precision, safety, stability, and environmental protection while minimizing delays and costs.

Methodology

The procedure for one-way nesting data from NEMO to OpenFOAM model is presented in Figure 1. Results from the NEMO model were obtained from Copernicus Marine Service [1,2] for the Mediterranean Sea. The great advantage of using data from the Copernicus Marine Service is freely available results for a long period. Used 3D models have a temporal resolution of up to 1 hour with a spatial resolution of around 4 km. Such models use a global coordinate system, so the first step is the conversion to a local rectangular Cartesian coordinate system applied for detailed numerical simulations in OpenFOAM. After that, velocities interpolation is required to set initial and boundary conditions for OpenFOAM simulation. For other types of problems, different variables such as salinity, temperature and pressure can also be used as previously done in research [3]. From the Mediterranean Sea Physics Analysis and Forecast model [1], hourly and averaged monthly velocities are used, while yearly averaged data was used from the Mediterranean Sea Physics Reanalysis model [2].

Numerical simulations were done using a pimpleFoam transient solver in OpenFOAM and represent 1 hour of flow conditions. For modeling open sea boundaries inlet - outlet boundary conditions were used.

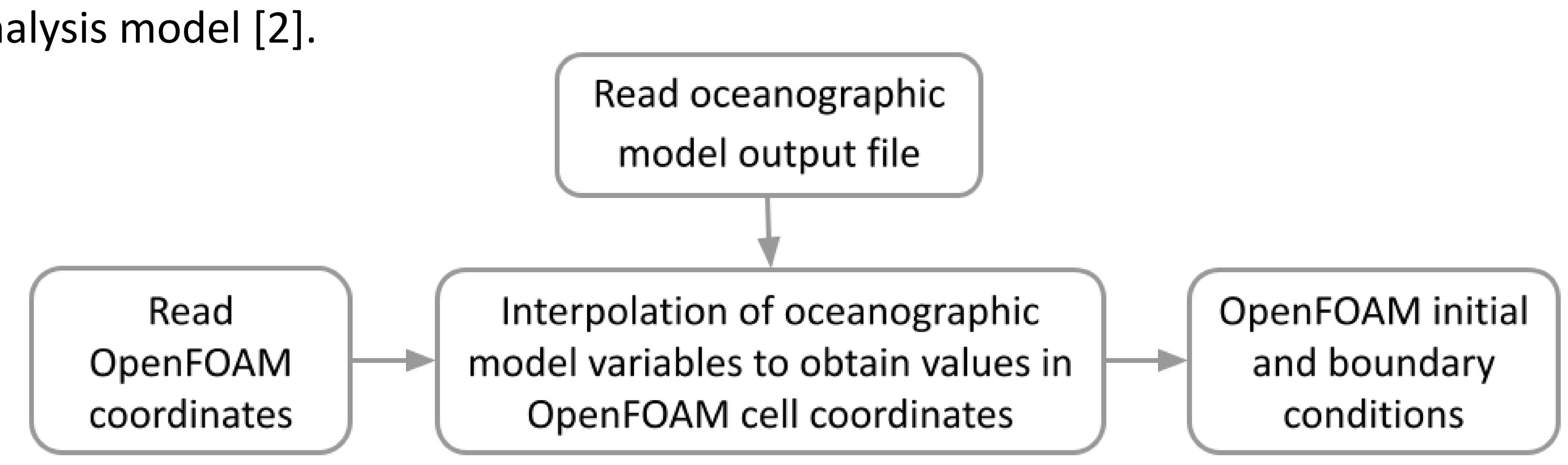

Figure 1. Flow diagram of the one-way nesting technique.

Results

Different pilot locations

Offshore wind potential for 4 pilot regions in the Adriatic Sea has been investigated.

Figure 2. Pilot locations are marked with circles. Purple represents Veneto region (Italy), orange Istria region (Croatia), yellow Dalmatia region (Croatia), and green Puglia region (Italy).

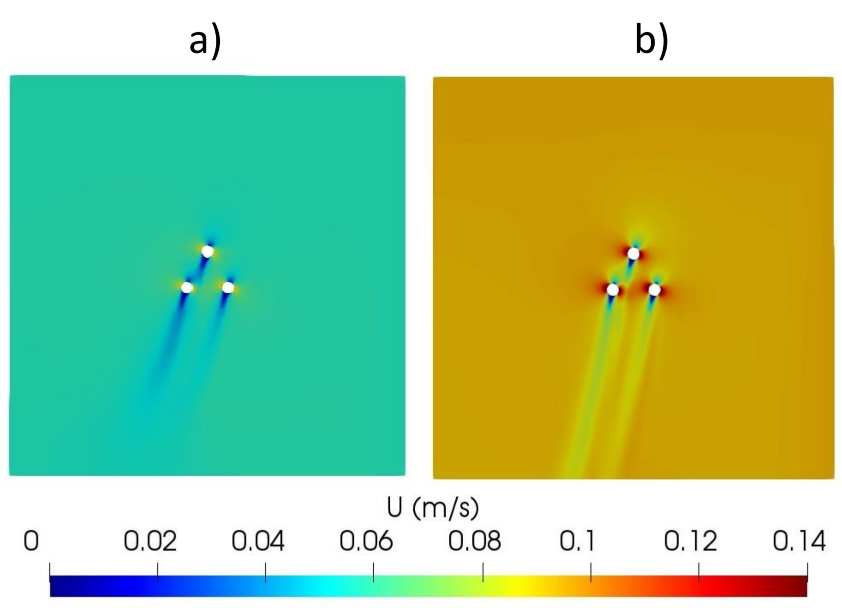

Figure 3. Results for pilot location in Puglia region a) 40 m depth, b) on the surface.

Different types of foundations

For comparison of velocities, numerical models are done for 5 types of foundations in the Veneto pilot location, based on annual (2020.) averaged values of velocities.

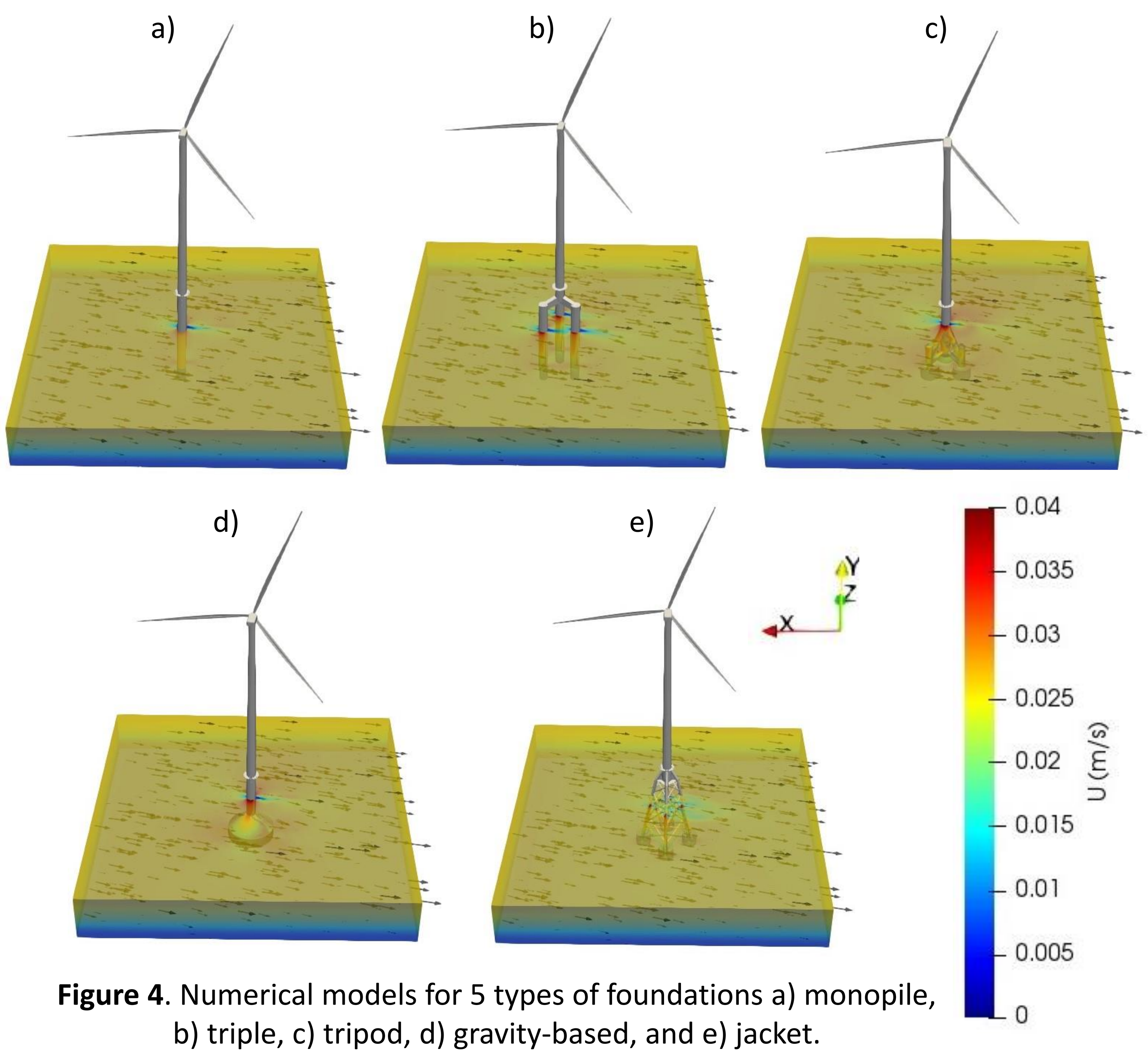

Figure 4. Numerical models for 5 types of foundations a) monopile, b) triple, c) tripod, d) gravity-based, and e) jacket.

Different temporal resolutions

Results are calculated for the pilot location in Istria based on three different temporal resolutions.

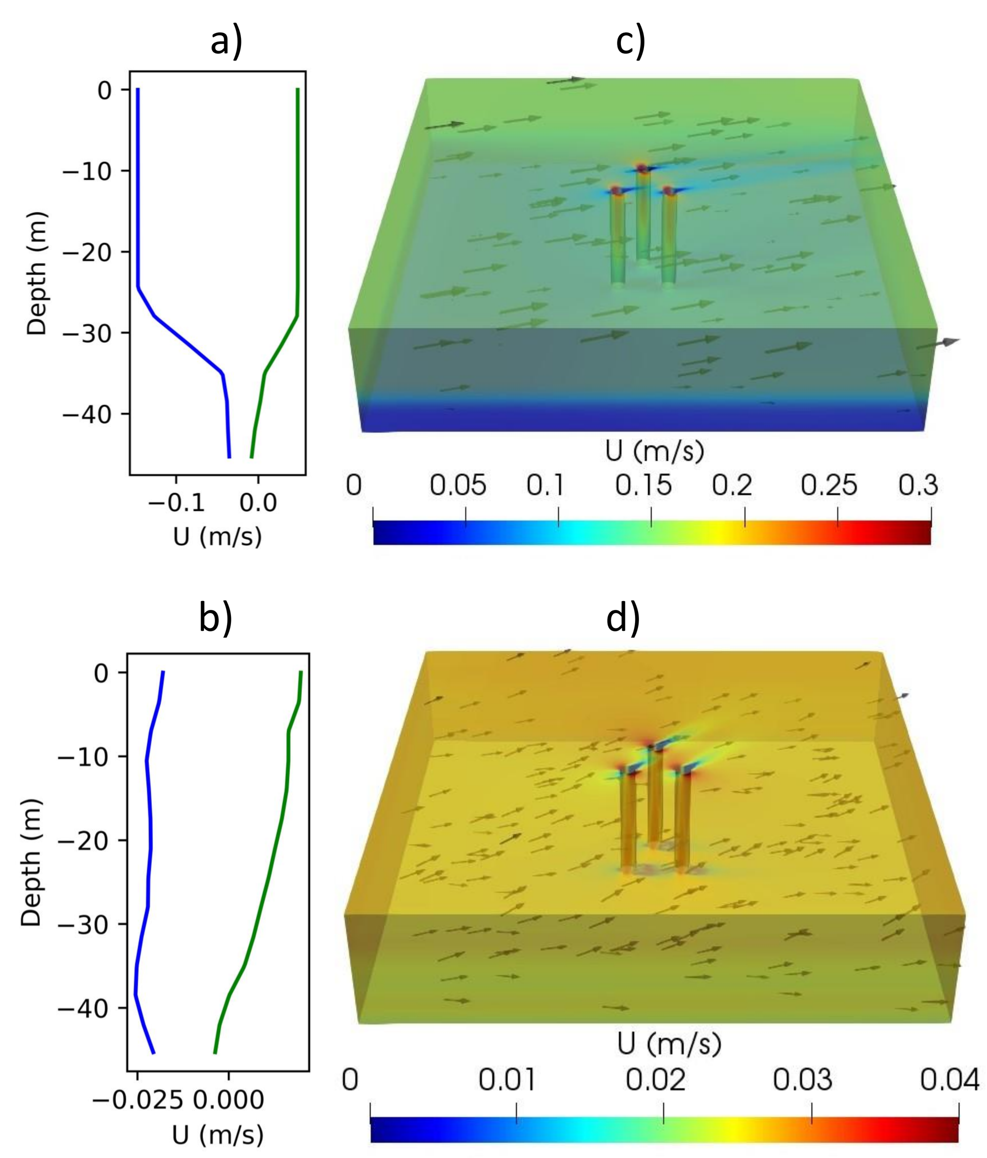

Figure 5. Initial velocities from oceanographic models for a) hourly (20.10.2024. at 9 AM) and b) averaged monthly (April 2024.) values; results of simulation for c) hourly and d) averaged monthly values. The blue and green lines represent velocities in the x direction (east) and y direction (north).

Conclusion

The procedure for one-way nesting of detailed numerical models in oceanographic models has been applied to several different models including 5 types of offshore wind turbine foundations, 4 pilot locations, and 3 temporal resolutions. The results of sea flow models showed that the mentioned technique can be successfully applied and used to compare different scenarios which can help engineers to evaluate different designs and to select the optimal one. Additionally, such models can be used for determining velocities and forces created by currents and waves around foundations that alter local water circulation patterns which can potentially be hazardous to marine ecosystems causing turbulences and disrupting habitats for marine species as well as nutrient cycling. Future research should include the impact of waves on foundations, the interaction of sand, and structural stability.

References

[1] Clementi, Emanuela, et al. Mediterranean Sea physics Analysis and Forecast (CMEMS MED-Currents 2015-2017). 2017.

[2] Escudier, Romain, et al. A high resolution reanalysis for the Mediterranean Sea. Frontiers in Earth Science, 2021, 9: 702285.

[3] Alvir, Marta, et al. OpenFOAM-ROMS nested model for coastal flow and outfall assessment. Ocean engineering, 2022, 264: 112535.

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