ABSTRACT

Quantifying the Effect of OWF Monopile on Vortex Induced-mixing in a Stably Stratified Environment using High-fidelity Turbulence Simulations

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New technological and scientific innovations have pushed offshore wind farming as sustainable and low carbon energy. Stably stratified flows are often present in the regions where offshore wind farms (OWFs) are installed [1]. The impact OWFs have on the local oceanic ecology is an open question. It is expected that a single monopile will likely not have a large impact but, if large OWFs are installed the impact could be much greater. It is understood that the presence of OWFs enhances turbulent mixing within and around an array of monopiles. Figure 1 illustrates how mixing occurs in flow around OWFs. As the stratified flow moves across a monopile, flow behind the it is enhanced by the vortices in the wake. The wake formed sometimes takes on the shape of a stable von Karman vortex street, but at other times is unstable and changing in shape and frequency.

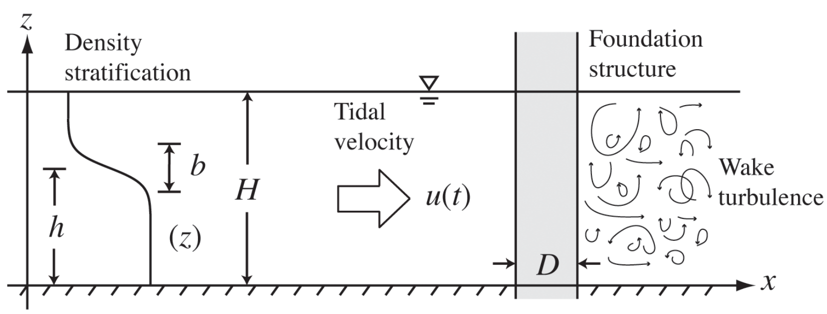

Figure 1: Schematic representation of stratified flow past a monopile. Vortices generated in the wake of the flow results in turbulent mixing (figure taken from [2]).

In the current research we quantify the effect a singular idealized monopile has on mixing downstream from it. Unidirectional stably stratified flow past a cylinder is simulated using the spectral-element based high-order code Nek5000 [5]. These simulations aim to capture and categorize the different flow structures induced by a cylinder in a stably-stratified flow. 2D simulations are first conducted for a wide range of Densimetric Froude numbers and Reynolds numbers (Re calculated using diameter as the length scale). Simulated Fr ranges between 0.01 to 1000 and simulated Re ranges between 10 to 180. Boyer et al. discussed structures from experiments for a range of Fr and Re, however, the study did not quantify drag or mixing [3]. In current study we provide insight into these processes across the parameter space (e.g. figure 2). 3D simulations have been conducted for Re = 300, for range of Fr ~ 0.1 – 100. The effect of increasing stratification on the vortex shedding was quantified, including how the stratification changes the coherent structures downstream of the idealized cylinder.

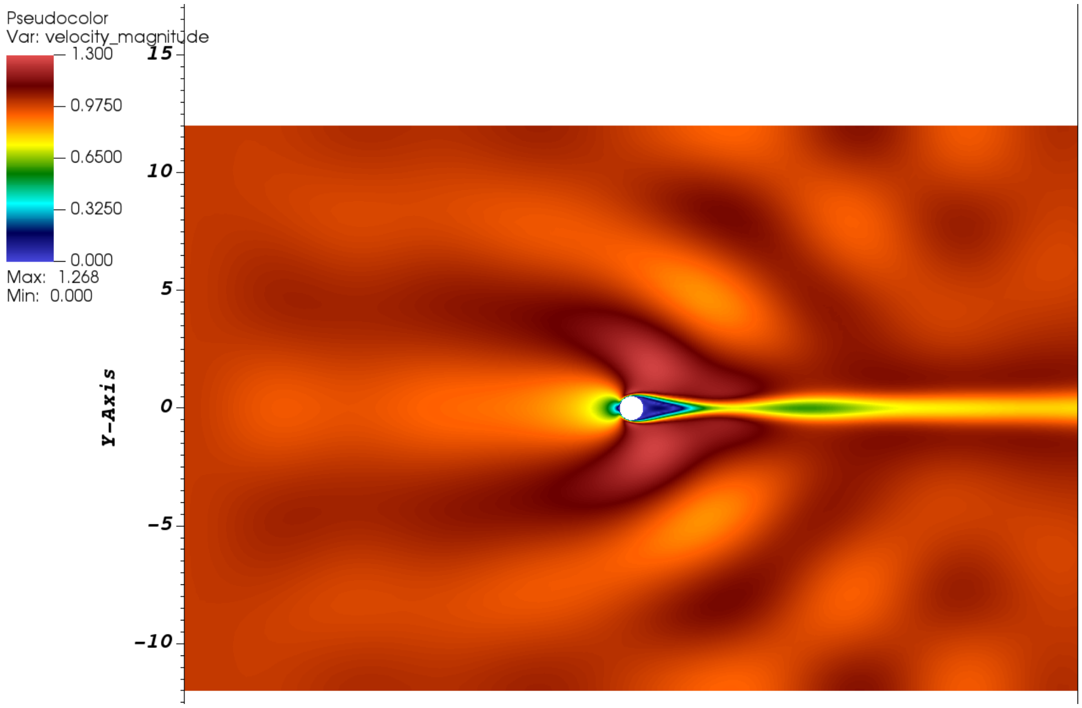

Figure 2: 2D instantaneous velocity field of flow past a cylinder at Reynolds number 180, and Froude number of 1.

[1] *Dorrell, R., Lloyd, C., Lincoln, B., Rippeth, T., Taylor, J., Caulfield, C. C., ... & Simpson, J.* (2021). Anthropogenic Mixing of Seasonally Stratified Shelf Seas by Offshore Wind Farm Infrastructure. Frontiers in Marine Sciences.
[2] *Carpenter JR, Merckelbach L, Callies U, Clark S, Gaslikova L, Baschek B* (2016) Potential Impacts of Offshore Wind Farms on North Sea Stratification. PLOS ONE, 11(8), 1-28.
[3] *Boyer, D. L., Zhang, X., Davies, P. A., &, Fernando, H. J. S.* (1989). Linearly stratified flow past a horizontal circular cylinder. Philosophical Transactions of the Royal Society of London. Series A, Mathematical and Physical Sciences, 328(1601), 501–528.
[5] https://nek5000.mcs.anl.gov/