Structures of vortices in underwater hill wakes

Jinyuan J. Liu[a,*], Pranav Puthan[b], Sutanu Sarkar[a,b,†]
[a] *University of California San Diego, La Jolla, CA*
[b] *Scripps Institution of Oceanography, La Jolla, CA*

Underwater hills are stirring rods in the ocean which lead to turbulent mixing of stratified water that crucially impacts the interior ocean state. Besides, the associated vortical flows impact marine flow, morphology of underwater features and offshore marine structures.

This study focuses on vortical structures in the wake of a three-dimensional submerged conical hill in a strongly stratified, weakly rotating, and tidally modulated environment at $Re = U_\mathrm{c}D/\nu \sim 10^4$. The spatio-temporal coherent structures of the vertical vorticity (ω_z) are characterized by Spectral Proper Orthogonal Decomposition (SPOD).

For weak rotation and no tide, the vortex shedding exhibit vertical coherence, in spite of strong stratification. The temporal modes of the vortex shedding present a low-order behavior and the leading mode at different vertical planes are at the same frequency $St = fU_\mathrm{c}/D = 0.26$ as for cylinder wakes. The SPOD eigenmodes have a spatio-temporal symmetry, which is reminiscent of the von Kármán vortex street.

In the case of weak rotation and periodic tidal modulation, the signal of ω_z is decomposed into a phase-coherent part and the residual. It is the tide which dominates the near wake so that the vortices are synchronized to shed at the tidal frequency f_t. The residual vorticity in the near wake presents universality in the SPOD eigenspectra, reflecting the homogenizing effect of the tide, which is spatially invariant. In the far wake, the leading frequency is altered to $f_\mathrm{t}/4$ (Puthan et al., Geophys. Res. Lett, 48 (2021)), which is neither the tidal nor the natural shedding frequency, and is regarded as an indirect effect of the tide.

[*] jinyuanliu@ucsd.edu, presenter
[†] sarkar@ucsd.edu