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Large eddy simulation of stratified mixing

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Mixing in both coastal and deep ocean emerges as one of the important processes that determines the transport of pollutants, sediments and biological species, as well as the details of the global thermohaline circulation. Both the observations, due to their lack in space and time resolution, and most coastal and general circulation models, due to inadequate physics, can only provide partial information about oceanic mixing processes. We propose the use of large eddy simulation (LES) as another tool of investigation to complement observational and large-scale modeling efforts.

LES models, however, have been developed primarily for homogeneous, isotropic flows. Here, four LES models based on Smagorinsky eddy viscosity and diffusivity are tested for stratified flows in the context of 2D dam-break problem in a rectangular enclosed domain. This idealized testbed leads to a number of simplifications about the initial conditions, boundary conditions and geometry, while exhibiting the dynamically complex characteristics of stratified flows involving the interaction of shear-induced mixing and internal waves. High resolution numerical simulations are taken as benchmark solutions. Under-resolved simulations without subgrid-scale (SGS) terms are used to quantify the impact of SGS stresses. The performance of LES is assessed by using the time evolution of the volume fraction of intermediate density water masses generated by mixing. The simulations are conducted using a nonhydrostatic high-order spectral element model Nek5000 developed to exhibit minimal numerical dissipation and dispersion errors, which is advantageous to quantify accurately the impact of SGS stresses.

It is found that all tested SGS models lead to improved results with respect to those from under-resolved numerical simulations. Also, SGS models allow for simulations with coarse resolutions that blow up in under-resolved simulations due to lack of adequate dissipation where needed. The SGS model in which the vertical eddy diffusion

is modulated via a function that depends on the Richardson number Ri shows the most faithful reproduction of mixed water masses at all resolutions tested.

The sensitivity of the results to the tunable parameter of the SGS model are shown. A high Reynolds number 2D LES, and a 3D LES are carried out. Finally, the steps that must be taken towards a full adaptation of LES to study oceanic flows are discussed.