Influence of the distortion of the internal wave field on estimates of turbulent mixing using fine-scale parameterizations

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Although the Southern Ocean is one of the turbulent mixing hotspots, we have not yet clarified quantitatively the turbulent mixing processes in this region, where the Antarctic Circumpolar Current (ACC) coexists with near-inertial internal waves generated by wind forcing and internal lee waves radiated by the impingement of eddy flows on topography.

Fine-scale parameterizations, based on the theory of energy cascade from internal waves to turbulence, are most widely used to estimate the turbulent dissipation rate, ε. It has been reported, however, that these fine-scale parameterizations tend to overestimate ε in the ACC (Waterman et al. 2014). Although Takahashi and Hibiya (2019) have suggested that "the distorted fine-scale shear and strain spectra" caused by the existence of eddies trapping near-inertial waves or upward-propagating internal lee waves might be responsible for the overestimates, the problem remains unresolved.

In this study, we use "eikonal" simulations (Henyey et al. 1986), which trace the propagation, refraction and breaking of test waves within a background internal wave field, to assess the evolution of the energy cascade in vertical wavenumber space. Our objective is to examine how the distortion of the vertical wavenumber spectrum affects the performance of fine-scale parameterizations.

In our simulations, in contrast to high vertical wavenumber test waves that are efficiently Doppler-shifted to their breaking limit, low vertical wavenumber test waves are not subject to dissipation processes. In the existing fine-scale parameterizations, however, the energy flux to dissipation scale is estimated using the integrated vertical wavenumber spectral values. This means that, if the range of this integration includes a spectral bump at the low-wavenumber end of the spectrum, the estimated energy flux and hence the resulting ε might be overestimated by these fine-scale parameterizations.

From the simulation results, it is confirmed that fine-scale parameterizations significantly overestimate ε in spectra with a low-wavenumber bump, in particular as the internal wave energy level becomes large and the shear/strain ratio becomes small. These results are supported by the microstructure and fine-structure dataset from the SOFine experiment carried out in the Kerguelen Plateau.

Keywords: Turbulent Mixing, Fine-scale parameterizations, Antarctic Circumpolar Current region