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The study of the interaction between small-scale turbulence and internal gravity waves by direct numerical simulation

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The interaction between small-scale turbulence and internal gravity waves (IWs) plays an important role in the processes of mixing which have direct impact on the dynamics of seasonal pycnocline in the ocean. Among many interesting and practically important aspects of this interaction are the effects of damping of IWs by turbulence on the one hand, and the possibility of the enhancement of turbulence by IWs on the other hand. Previously these effects were studied mostly in laboratory experiments. The present study presents the results of direct numerical simulation (DNS) of the IW-turbulence interaction.

We perform DNS of the dynamics of small-scale turbulence near a pycnocline in the presence of monochromatic internal gravity wave propagating along a pycnocline. Small-scale turbulence is induced in a horizontal layer at some distance above the pycnocline. The velocity and density fields of IW propagating in the pycnocline are also prescribed as initial condition, and the IW wavelength is considered to be by the order of magnitude larger as compared to the initial turbulence integral length scale. Stratification in the pycnocline is considered to be sufficiently strong so that the effects of turbulent mixing remain negligible.

In order to study the effect of damping of IW by turbulence, we firstly consider a stationary forced turbulence. The DNS results show that the observed IW damping rate is well predicted by a theory based on the semi-empirical approach, but only in the case where turbulence is sufficiently strong to be only weakly perturbed by the internal wave. However, the theory overestimates the damping rate almost by the order of magnitude if IW amplitude is of the order or larger as compared to the turbulence amplitude.

The effect of the IW on the turbulence dynamics is further studied in the case where IW amplitude is of the order of the initial turbulence amplitude. In this case, turbulence is not supported by additional forcing and the effect of damping of IW by turbulence remains negligible. The DNS results show that in the absence of IW turbulence decays, but its decay rate is reduced in the vicinity of the pycnocline where stratification effects are significant. In this case, at sufficiently late times most of turbulent energy is located in a layer close to the pycnocline center. Here turbulent eddies are collapsed in the vertical direction and acquire the “pancake” shape. IW modifies turbulence dynamics, in that the turbulence kinetic energy (TKE) is significantly enhanced as compared to the TKE in the absence of IW. As in the case without IW, most of turbulent energy is localized in the vicinity of the pycnocline center. Here the TKE spectrum is considerably enhanced in the entire wavenumber range as compared to the TKE spectrum in the absence of IW.

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