Direct numerical simulation of stratified turbulence generated by local instability of internal gravity waves

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Turbulent mixing in the deep ocean is thought to be caused by the dissipation of internal gravity waves, but the mechanisms of wave breaking and how much it contributes to mixing remain open questions. In this study, we develop a new technique for direct numerical simulation of wave-driven turbulent mixing. Since the spatial scale of internal waves is typically much larger than the scales of turbulence, fully incorporating both the waves and turbulence in a model requires high computational cost, and thereby out of our scope. Alternatively, we cut out a small domain periodically distorted by an unresolved large-scale internal wave, and simulate the generation, evolution, and dissipation of turbulence within it. This method enables us to evaluate the conversion of both kinetic and potential energy from a wave to turbulence, unlike many previous studies that considered mixing caused by a vertically-sheared horizontal flow.

This time, we demonstrate a particular case, turbulence generation in a small-amplitude internal wave. Even though this wave does not cause any overturn or shear instabilities, a striped pattern of disturbance is exponentially amplified due to parametric instability. When the amplitude of this disturbance reaches a threshold level, secondary instability arises to produce much smaller-scale random fluctuations. Passing through these two stages, wave energy is transferred into turbulence energy and will be eventually dissipated. Different from the classical Kelvin-Helmholtz instability, a large part of the turbulent potential energy is supplied from the outer wave component and is directly used for mixing to raise the background potential energy. The resulting mixing efficiency is higher than the typical value in the ocean by several factors, a finding to be explored further in future studies.

Keywords: internal waves, turbulence, direct numerical simulation