Anisotropic energy-flux vector in stratified turbulence

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In broad-band stratified turbulence, anisotropic weak turbulence of internal gravity waves and isotropic Kolmogorov turbulence of eddies as well as vertically sheared horizontal flows coexist. The weak turbulence theory accounts for the nonlinear energy transfer among internal waves due to resonant interactions, and the Kolmogorov theory describes the energy transfer among eddies. The breaking of internal waves in the real space generates the energy transfer from the large-scale waves to the small-scale eddies, but such energy transfer between the different kinds of turbulence in the wavenumber space is only qualitatively predicted by the critical balance[1].

The energy-flux vector in anisotropic turbulence can be uniquely defined by assuming net locality and efficiency of the nonlinear energy transfer, resulting in the conservative vector field of the energy flux in the wavenumber space. The anisotropic energy fluxes in weak turbulence of rotating turbulence were successfully reproduced by the irrotational energy vector[2]. Similarly, in quasi-geostrophic turbulence, the irrotational flux vectors of energy, enstrophy and zonostrophy among different kinds of turbulence are consistent with qualitative prediction in earlier studies[3].

In this work, the anisotropic energy flux in the stratified turbulence is quantitatively evaluated by the irrotational vector (Fig. 1). Most energy is transferred to the vertically sheared horizontal flows, and the dissipation of the horizontal flows is remarkable. Such energy flux is not necessarily consistent with the critical balance, and the isotropization process at large wavenumbers will be discussed.

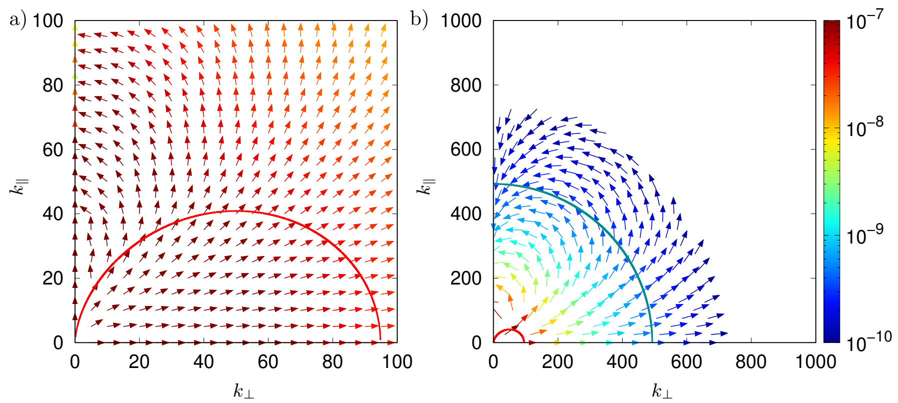

Figure 1: Energy-flux vectors (a) in the small-wavenumber range and (b) in the whole computational domain. The weak turbulence and the Kolmogorov turbulence are predicted to appear inside of the red curve and outside of the cyan curve, respectively.

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