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Flows Induced by Internal Gravity Wavepackets of Arbitrary Aspect Ratio

Bruce Sutherland (1) and Ton van den Bremer (2)

(1) University of Alberta, Physics, Edmonton, Canada (bruce.sutherland@ualberta.ca), (2) University of Edinburgh, Edinburgh, UK

Even when small amplitude, internal wavepackets induce a flow as a consequence of the divergence of the momentum flux and pressure corrections that ensure conservation of mass. It has been known since Bretherton (1969) that one-, two- and three-dimensional wave packets induce qualitatively different flows. Whereas the wave-induced mean flow for compact three-dimensional wavepackets consists of a purely horizontal localized circulation that translates with and around the wavepacket known as the Bretherton flow, such a flow is prohibited for a two-dimensional wavepacket of infinite spanwise extent, which instead induces a non-local internal wave response that is long compared with the streamwise-extent of the wavepacket. One-dimensional (horizontally periodic) wavepackets induce a non-divergent unidirectional flow in the main direction of travel of their waves. Through perturbation theory for quasi-monochromatic wavepackets of arbitrary aspect ratio, we predict for which aspect ratios which type of induced mean flow dominates. We compose a regime diagram that delineates whether the induced flow is comparable to that of one-, two- or compact three-dimensional wavepackets. The predictions agree well with the results of fully nonlinear three-dimensional numerical simulations.