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Lagrangian Transport by Horizontally Modulated Internal Modes

Using perturbation theory for quasi-monochromatic internal gravity wavepackets, we consider flows induced by horizontally modulated vertical modes. In uniform stratification, a mode-n wavepacket induces a mode-2n flow whose amplitude varies spatially on the scale of horizontal modulations of the wavepacket. The flow is a combination of the Stokes drift and the Eulerian induced flow, which combined give the Lagrangian flow induced by the waves, as determined previously by McIntyre (J. Fluid Mech., 1973) through consideration of the conservation of the wave impulse. In particular, horizontally long waves in a wavepacket induce a Stokes drift and Eulerian flow of comparable magnitude. For horizontally modulated vertical modes in non-uniform stratification, the induced flow is significantly more complicated. Both the Stokes drift and Eulerian induced flows exhibit strong shear where the stratification varies rapidly in the vertical. Superharmonic disturbances are also excited. In constructing of the Lagrangian flow, the Stokes drift and Eulerian flows can superimpose constructively or destructively depending upon the horizontal wavenumber of waves in the wavepacket relative to the characteristic length scale of the stratification.