Nonlinear Transport by Gravity Waves Inside the Ocean

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Abstract. Because the ocean is stratified, meaning that its density increases with depth due changing temperature and salinity, waves can propagate below the surface being driven by buoyancy forces. These provide an important mechanism through which energy is transported from boundaries into the ocean interior where they drive mixing. Recently oceanographers have come to realize that momentum and mass transport by internal waves may also be important, not just for climatology but also for predicting the motion and redistribution of inert biological or other floating particles such as microplastics. In this work we use perturbation theory for quasi-monochromatic wave packets consisting of vertically bounded, horizontally propagating internal modes in order to predict the vertical variations of their horizontal transport composed of the Stokes drift and the Eulerian induced flow which, combined, result in the net Lagrangian transport of fluid. The magnitude of both flows vary as the squared amplitude of the waves. However, their vertical structure can change significantly depending upon the background density variations and the horizontal wavelength of the modes. In particular, if the stratification is vertically symmetric, then mode-1 waves induce a Stokes drift and an Eulerian flow with a mode-2 structure. However, with even small departures from vertical symmetry, the Eulerian flow is dominantly mode-1 and, as well as having finite wavenumber singularities, it also exhibits an "infrared catastrophe" in which the Eulerian induced flow associated with long waves can be larger than the flow due to the waves themselves.