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WKBJ Theory of Triad Interactions of Internal Gravity Waves in Varying Background Flows

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Internal gravity waves are a well known mechanism of energy transport in stratified fluids such as the atmosphere and the ocean. Their abundance and importance for various geophysical processes like ocean mixing and momentum deposition in atmospheric jets are widely accepted. While resonant wave-wave interactions of monochromatic disturbances have received intensive study, little work has been done on resonant interactions between wave trains that are modulated by a variable mean flow to leading order.

We present a Boussinesq WKBJ theory for interacting small amplitude gravity wave trains propagating through a finite amplitude background flow. In such a scenario the local wave numbers and frequencies depend on the variation of the background and are not constant. As a result, the wave trains are allowed to pass through resonance conditions and exchange energy in a small neighborhood around resonance. Our analysis is based on the method of multiple scales and the weak asymptotic theory.

To test the theory we use idealized simulations in which two wave trains generate a third by passing through resonance in a sinusoidal background shear flow. Comparing a corresponding WKBJ ray tracer with wave resolving large eddy simulations we find good agreement. Furthermore we assess the impact of the amplitude of the background flow on the energy exchange between the interacting wave triad.