Computational studies on coupled triads in the dynamics of oceanic internal waves under the effects of density stratification

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Abstract. Triad resonance involving three wave modes occurs when the frequency and wave number of one mode match the sums of those quantities of the other two modes. Coupled triads refer to two sets of triad resonance with one common member, i.e. five distinct waves are involved. For the dynamics of oceanic waves with density stratification and shear current, coupled triads can arise where all five waves travel in the same direction. Nonlinear evolution equations for slowly varying wave packets are derived by the method of multiple scales. Numerical simulations are conducted to highlight the spontaneous generation of modes due to coupling. Such information and trends will be beneficial in understanding the energy transfer among internal wave modes in a stratified ocean.

Introduction

Wave interaction can serve as a mechanism in conveying information as well as energy, and as such constitutes a significant factor in the dynamics of oceanic surface and internal waves. Triad resonances among three waves constitute crucial examples of spontaneous mode generation. Triad resonance for internal waves has been studied from the perspective of physical oceanography, as a possible explanation for the cascade of energy from large scale internal tides to motions of a smaller scale [1]. Coupled triads, two sets of triads with a common member, might cause ‘explosive’ growth for marginally unstable modes from the perspective of plasma physics and atmospheric science [2, 3].

The goal here is to highlight the existence of new coupled triads for oceanic internal waves arising from density stratification. For simplicity we assume a constant buoyancy frequency. The evolution equations for slowly varying envelopes are derived by the method of multiple scales. To simplify the nonlinear dynamics, we focus on a reduced system by considering only the temporal evolution. Numerical simulations are performed to trace the evolution of the amplitudes. Energy exchange mechanisms and spontaneous generation of signals are demonstrated. Some representative scenarios are found: i) The common member of the two coupled triads can excite all the participating modes; ii) Energy can flow from one triad to another through a common member; iii) Dynamical phase factors drastically influence the temporal development of the wave profiles; iv) The evolution of wave profiles critically depend on the magnitude of the interaction coefficients; v) Energy present initially in the common mode can be transmitted to the other two members of one triad, while other two members of the second triad remain effectively at zero amplitude.

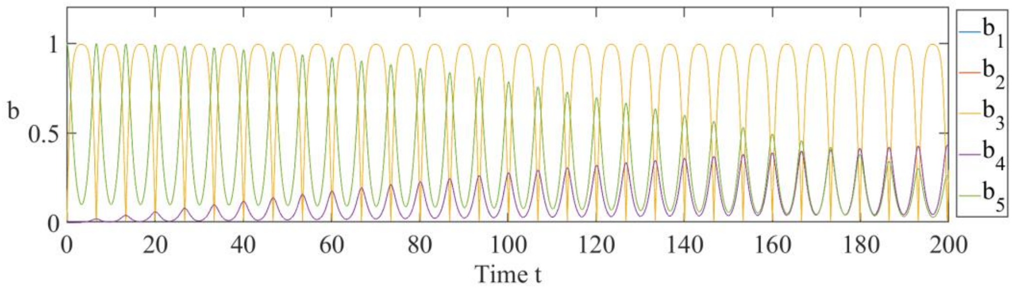

Figure 1: Energy transfer arising from the coupling of triads through the common member. b_1, b_3, b_5 and b_2, b_3, b_4 are two sets of triad, amplitude of wave mode b_5 of the first triad is decreasing while amplitude of wave mode b_4 of the second triad is increasing.

Results and discussion

The numerical simulations serve to illustrate the spontaneous generation of modes in one triad by wave trains from the other triad. The temporal developments of the wave profiles will depend critically on the magnitudes and sign patterns of the interaction coefficients. Hence, the precise fluid mechanics input for wave resonance is crucially important.

References

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