Geophysical Research Abstracts
Vol. 16, EGU2014-3229, 2014
EGU General Assembly 2014

On triad nonlinear resonant interactions of deep water waves trapped by jet currents

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We derive an asymptotic description of weakly nonlinear wave interactions between waves trapped by opposing jet currents by extending the asymptotic modal approach developed in Shrira & Slunyaev (2014). It is widely believed that to the leading order the nonlinear interactions between water waves in deep water are always quartic and potential. We show that for waves trapped on the jet currents it is not true: triad resonant interactions between trapped modes are always allowed. Moreover, the nonlinear evolution of the wave field is to the leading order determined by these triad interactions if the current is sufficiently strong or wave field nonlinearity is appropriately weak. To the leading order the corresponding interaction coefficients are controlled by the background vorticity due to the jet. More specifically, we consider waves upon a longitudinally uniform jet current; the current is assumed to be stationary and without vertical shear. The approximate separation of variables allows us to find the two-dimensional mode structure by means of one-dimensional boundary value problem (BVP) for wave Fourier harmonics along the current. The asymptotic weakly nonlinear theory taking into account quadratic nonlinearity for broad but not necessary weak currents is developed. The evolution equations for three interacting modes are written explicitly, the nonlinear interaction coefficients are computed. The three-wave interactions weaken when the current is weak. When the ratio of the current magnitude to wave celerity is of order of wave steepness the effects of 3-wave and 4-wave resonances appear at the same asymptotic order. These regimes, as well as the identified regimes where triad resonant interactions between trapped waves are dominant, lead to a qualitatively new wave dynamics which remains to be explored yet.

V.I. Shrira, A.V. Slunyaev, Trapped waves on jet currents: asymptotic modal approach. J. Fluid Mech. 738, 65-104 (2014).