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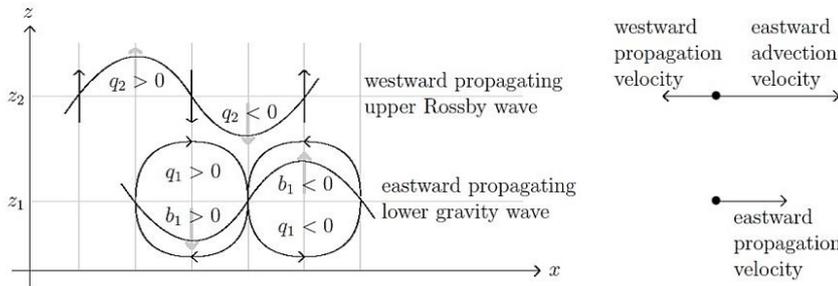
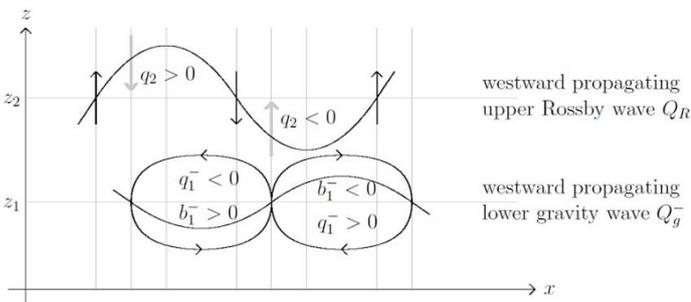


Figure1. Interaction between the upper Rossby wave and the lower gravity wave. Figure2. Schematic diagram illustrating the effect of the westward-propagating lower gravity wave.



The sinusoidal line at $z = z_2$ represents the iso- q line. The sinusoidal line at $z = z_1$ represents the iso- b line. The arrowed circles at $z = z_1$ represent the vorticity there. q_2 is the vorticity disturbance of the westward-propagating upper Rossby wave. q_1 (q_1^-) and b_1 (b_1^-) are the vorticity and buoyancy disturbances of the eastward-(westward-)propagating lower gravity wave, respectively. The gray arrows at $z = z_2$ represent the circulation induced by q_1 or q_1^- . The gray arrows at $z = z_1$ represent the circulation induced by q_2 .

- The interaction between westward-propagating upper Rossby and westward- and eastward-propagating lower gravity waves is examined in a simple vertical-zonal two-dimensional model. We analytically solve the initial value problem for the buoyancy and vorticity disturbances.

- For the parameter values for exponential instability, the upper Rossby wave and the lower gravity waves are phase locked and grows as an exponential function of time(Fig 1). For the parameter values for marginal instability, the solution grows as a linear function of time and asymptotically approaches an in-phase or anti-phase configuration between the upper and lower disturbances. For the parameter values for stability, the upper and lower waves are not phase-locked but pass away from each other, just like free waves.

- Although the resonant interaction occurs between the westward-propagating upper Rossby wave and the eastward-propagating lower gravity wave, the westward-propagating lower gravity wave also plays a role in the resonance. The westward-propagating gravity wave regulates the westward propagation velocity of the Rossby wave, helping the Rossby and eastward-propagating gravity waves to become phase-locked(Fig.2). By the presence of the westward-propagating gravity wave, the unstable region in the parameter space is enlarged.