Parameter sweep experiments on gravity wave radiation from unsteady rotational flows in f-plane shallow water system

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Using forced dissipative system, gravity wave radiation from unsteady rotational flows is investigated numerically in f-plane shallow water system for a wide range of Rossby number (Ro) and Froude number (Fr). Unlike classical Rossby adjustment problem which supposes the initial unbalanced states, gravity waves are continuously radiated from nearly balanced rotational flows, where Fr is so small that balance dynamics is thought to be good approximation for the full system. Though time evolution of flow field is qualitatively the same for different parameter values, gravity wave radiation for each experiment has several different features. In this study, we focus on gravity wave flux which depends on nondimensional parameters Ro and Fr.

For large Ro where the effect of the earth rotation is negligible, the gravity wave flux is proportional to Fr, which is consistent with the aero-acoustic radiation theory. However, this power law is not valid for relatively small Ro, where the effect of earth rotation is important. This is because the deformation radius is smaller for large Fr so that the interaction between vortices is inhibited and the unsteadiness of vortex is weakened. In addition, for much smaller Ro, the gravity wave flux decreases suddenly. Since the inertial frequency exceeds the frequency of the unsteady rotational flow for very small Ro, gravity waves cannot propagate. On the other hand, for intermediate Ro, the gravity wave flux is larger than that for large Ro. This is because a source term which is related to the inertial frequency increases with Ro. This result suggests that the effect of the earth rotation can intensify gravity wave radiation.

Balanced dynamics which is introduced by formal scaling analysis assuming small Ro supposes no gravity wave radiation from balanced rotational flows. In contrast to the general understanding, gravity wave radiation is not always weakened by decreasing Ro.