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Numerical analysis of internal solitary wave generation around a Island in Kuroshio Current using MITgcm.

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We have conducted ADCP and CTD measurements from 31/8/2010 to 2/9/2010 at the Miyake Island, located approximately 180 km south of Tokyo. The Kuroshio Current approached the island in this period, and the PALSAR image showed parabolic bright line upstream of the island. This bright line may be a surface signature of large amplitude internal solitary wave. Although our measurements did not explicitly show evidence of the internal solitary wave, critical condition might have been satisfied because of the Kuroshio Current and strong seasonal thermocline. To discover the generation mechanism of the large amplitude internal solitary wave at the Miyake Island, we have conducted non-hydrostatic numerical simulation with the MITgcm.

A simple box domain, with open boundaries at all sides, is used. The island is simplified to circular cylinder or Gaussian Bell whose radius is 3km at ocean surface level. The size of the domain is 40kmx40kmx500m for circular cylinder cases and 80kmx80kmx500m for Gaussian bell cases. By looking at our CTD data, we have chosen for initial and boundary conditions a tanh function for vertical temperature profile. Salinity was kept constant for simplicity. Vertical density profile is also described by tanh function because we adopt linear type of equation of state. Vertical velocity profile is constant or linearly changed with depth; the vertical mean speed corresponds to the linear phase speed of the first baroclinic mode obtained by solving the eigen-value problem. With these configurations, we have conducted two series of simulations: shear flow through cylinder and uniform flow going through Gaussian Bell topography.

Internal solitary waves were generated in front of the cylinder for the first series of simulations with shear flow. The generated internal waves almost purely consisted of 1st baroclinic component. Their intensities were linearly related with upstream vertical shear strength. As the internal solitary wave became larger, its width became wider compared to the KdV solution described by Grimshaw (2002). This is predicted because higher order analytical solution for 2-layer fluids, i.e. the eKdV solution, gives broader solitary wave shape than that of the KdV solution because of the cubic nonlinear term. When we look at the surface velocity distribution, a parabolic shape corresponding to internal solitary wave is clearly seen.

According to the fully nonlinear theoretical model for internal wave between two fluids having background linear shear flow profiles (Choi and Camassa1999), the shape of internal wave is influenced by the velocity shear as well. However, we could not clarify the effect of vertical shear because there is no fully nonlinear analytical solution for large amplitude internal wave in continuously stratified fluid.

Second series of simulations with uniform flow going through Gaussian Bell topography show that internal solitary wave shows up from sides of the topography. This generation is similar to the one developed in lee side of sill topography by tidal flow. With broader bell topography, generated internal waves become larger. This makes sense because forcing region is wider. A horizontal shape of the internal solitary wave is not parabolic but the two bending line forms from the sides of the island. However, no solitary wave in front of the island develops.

Our results imply that vertical shear profile is needed for the formation of the depression type internal solitary, and explains the parabolic bright line observed in the SAR image