Mapping of vortex and internal waves interaction-induced mixing in the North Pacific from OFES30 output

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Breaking of internal waves are a major source of mixing that contributes to upwelling of nutrients, driving force of thermohaline circulation, water mass formation. The breaking of internal waves have been studied in the context of quiet ocean without a background flow. Recently, some studies have pointed that the interaction between a vortex and internal gravity waves affects the mixing. Those previous researches handle the interaction problem with WKB like methods which assume a scale separation between a large vortex and small waves. However, in the ocean, there are many small, strong vortices like submeso-scale ones are ubiquitous. These vortices violate the scale separation assumption, so that a WKB like approach is invalid. The interaction in this range is never covered in the past studies. We numerically investigated the interaction in a wide parameter range including submeso-scale vortices and long internal waves. Then, the result is applied to the output of a high resolution ocean general circulation model, and the energetic interaction-induced mixing region is mapped. Model settings, datasets and results are described below. MODEL SETTINGS: A three dimensional non-hydrostatic model named “kinaco” is used to simulate the interaction of a vortex and waves. As initial conditions, Barotropic cyclone is put on the center of the model region and internal gravity waves that propagate toward the vortex are put on near an end of the model region. The experiments are controlled by a parameter which scales advection by a vortex, arises from our non-dimensional analysis of the shallow-water system. DATA SETS: The output of OFES30 (Masumoto et al., 2004; Sasaki et al., 2012) is used to estimate the distribution and structure of vortices in the North Pacific Ocean. Interaction-induced mixing is estimated for each vortex for internal waves of M2 tidal frequency. Results: From numerical experiments, dynamics of the interaction is classified to three regimes; First, Incident waves are scattered in two particular directions and vortex only works as catalyst. Second, a part of the incident waves are trapped into the vortex core, residual are scattered to various directions. Third, in strong non-linear vortex case, almost all incident waves are trapped, forming spiral shape, then shrinking rapidly in the radial direction, resulting in increase of vertical wavenumber. The vortex is also affected by shrinked waves through divergence of wave activity flux. As the overall tendency, both increasing rate of vertical wave number and trapped rate of the incident waves energy show monotonic increase with increasing value of the non-dimensional parameter. This suggests that the parameter should be an indicator of interaction-induced mixing. This indicator is estimated using OFES30 output. Remarkably, an extent of regions with large interaction-induced mixing is considerable in the North Pacific Ocean.

Keywords: internal wave, submeso-scale vortex, mixing