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Diapycnal Mixing Induced by Diurnal Tidal Flow in the Aleutian Passes

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Intense diapycnal mixing is considered to be caused by breaking of tide-induced large-amplitude internal waves in the Aleutian Passes. This local mixing modifies water properties and supplies the water mass to the Bering Sea and the North Pacific. The mixing is one of driving forces for bi-decadal variations of the ocean and climate around the North Pacific due to the 18.6-year period modulation of diurnal tides. Although the construction of better parameterization schemes required for ocean general circulation models to be improved needs an understanding of the detailed mixing processes after such breaking of large-amplitude internal waves, the processes are not well known because of their nonlinearity. Therefore, to clarify the diapycnal mixing processes, we investigated numerically the transition from breaking of internal waves to a turbulent state.

We used a two-dimensional non-hydrostatic model with a realistic topography. Stratification was initialized using XCTD data in the Amchitka Pass, and a forcing was the barotropic flow oscillating in the K1 tide period. The grid sizes were horizontally 10m and vertically 1m. A no-slip condition was applied at the bottom.

The results indicated that large-amplitude internal waves were induced by interaction between the tidal flow and the bottom topography, and that convection accompanied with breaking of the waves promoted mixing. Froude number that is an index of hydraulic control was greater than unity when the barotropic current speed was near the maximum. Hydraulic jump thus occur in the downstream region of the sill top. Moreover, we found that Kelvin-Helmholts waves were generated in an unstable shear region under the convection region, and Tollmien-Schlichting waves were generated near the bottom in the downstream region of the sill top. The latter waves grew to form vortexes. The development of the vortexes caused strong vertical currents which had the maximum speed exceeding 100cms-1, and promoted mixing.

In an experiment with a slip condition at the bottom, these vortexes were not generated. In addition, the vertical currents were weaker those in the experiment with no-slip condition at the bottom, which is a necessary condition for Tollmien-Schlichting waves. When a no-slip condition was used, a thick layer with relatively-uniform density was reproduced over the downstream region of the sill top, which was similar to XCTD observation results. When a slip condition was used, this feature was not reproduced well.

These results suggested that the vortex generation, as well as wave breaking, may contribute significantly to the diapycnal mixing.