A theoretical and observational study of the vertical decay scale of tidal mixing over rough seafloor topography

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There are much limited studies for tidal mixing enhanced over abyssal rough seafloor, compared with that in the surface mixed layer and/or in the interior ocean. Part of the reason is that direct observation of abyssal turbulent mixing requires special instrument as well as enormous time and cost, leaving the most universal method to estimate abyssal turbulent mixing in terms of finescale parameters. The most widely used parameterization for tidal mixing over abyssal seafloor is the one proposed by Jayne and St. Laurent (2001). However, this parameterization contains several ambiguities; in particular, although the vertical decay scale of tidal mixing over rough seafloor topography is usually assumed to be constant at 500 meters, recent field observations show that it varies depending on the roughness of the seafloor topography and the amplitude of tidal flow.

In the present study, using a microstructure profiler called VMP-X, we conducted detailed field observations at two locations (Station 1 and Station 2) with different seafloor topography of the Izu-Ogasawara Ridge to examine the spatial and temporal variations of the vertical profile of turbulent dissipation rates off the seafloor. At the same time, we carried out numerical simulations using high-resolution vertical two-dimensional numerical model incorporating the realistic seafloor topography and the spatial and temporal variations of tidal velocity to clarify the physical mechanism behind the observed results.

The vertical decay scales of turbulent dissipation rates off the seafloor at both stations were observed to vary with the amplitude of tidal flow. The decay scale of turbulent dissipation rates at Station 1 was observed to increase with the increase of the tidal flow amplitude, whereas the decay scale of turbulent dissipation rates at Station 2 was observed to decrease with the increase of the tidal flow amplitude.

We next investigate the generation of internal waves at each station using the results of the numerical simulations. At Station 1, the vertical decay scale extending higher up off the seafloor is attributed to the continuous generation of upward propagating internal lee waves with harmonic frequencies of M_2 tidal forcing, consistent with the theoretical prediction by Bell (1975). At Station 2, on the other hand, the dominant process of turbulent mixing is density overturning just over the steep sloping bottom that occurs as the amplitude of tidal flow increases, so that the vertical decay scale of turbulent mixing shows the dependence on the amplitude of tidal flow, quite contrary to that at Station 1.

These results indicate that microstructure observations combined with the information of roughness of the seafloor topography and the amplitude of tidal flow are absolutely necessary to improve the parameterization of tidal mixing over rough seafloor topography.

Keywords: Parameterization, Energy dissipation rates, Vertical decay scale, Tidal flow, Abyssal rough seafloor, Internal lee waves