

Circulation and mixing in a tidal channel connecting the Kuroshio region and an inland sea (Bungo Channel, Japan): a coastal-offshore transition zone

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The Bungo Channel (BC) is a waterway with an average depth of about 70 m located between Kyushu and Shikoku Islands, Japan. The circulation and hydrography in the BC are influenced by the water masses of both the Seto Inland Sea, which is a semi-enclosed sea with a large terrestrial influence, and the Kuroshio region in the Shikoku Basin, which has a character as open ocean. Therefore, the BC can be regarded as a transition zone between coastal and offshore areas. It is known that the circulation and environment of the BC is affected by “Kyucho”, which is a sporadic intrusion of the surface Kuroshio water, and a bottom intrusion of the Kuroshio sub-surface water. Tidal mixing is considered to be responsible for the occurrence of the Kyucho and bottom intrusion. However, there have been very few field observations and evaluations of turbulent mixing in the BC, and its strength and dynamics are not still fully understood. To unravel the variability of turbulent mixing in the BC and to better understand the tidal mixing and exchange processes in the coastal-offshore transition zone, we conducted surveys of microstructure turbulence, hydrography, and current at various locations in the channel in July–September 2012, August 2016, August 2017, and July 2021. In most of the surveys, we also carried out measurements of nitrate concentration. These surveys revealed a large spatial variability in the mixing strength in the BC. Large vertical eddy diffusivities of 10^{-3} – $10^{-1} \text{ m}^2 \text{ s}^{-1}$ were obtained in the Hoyo Strait (HS) in northern BC and 10^{-4} – $10^{-2} \text{ m}^2 \text{ s}^{-1}$ in the slopes around the HS. The eddy diffusivity was similarly large at 10^{-4} – $10^{-2} \text{ m}^2 \text{ s}^{-1}$ in the lee side of Hiburi Island (HI) in east-central BC. In the central southern part of the BC and the northeastern part (Uwa Sea), where turbulent mixing occurred in limited layers within the bottom boundary layer and the upper pycnocline, the eddy diffusivity was 10^{-5} – $10^{-3} \text{ m}^2 \text{ s}^{-1}$. In the HS and HI areas, elevated turbulent diffusivity was accompanied by density overturns in thick mid-column layers. In the tidal front area formed in the southern part of the HS, we also found vertical diffusivity of $\sim 10^{-3} \text{ m}^2 \text{ s}^{-1}$ with density overturns in the surface layer. These observations suggest that, in addition to conventionally considered bottom boundary layer turbulence, instabilities generated from the internal waves and tidal fronts in the HS region and topographic eddies at the HI region may be responsible for the elevated eddy diffusivity in the BC.

Keywords: turbulent mixing , internal wave, topographic eddy, Bungo Channel, coastal-offshore transition zone