Impact of mesoscale recirculation of the Kuroshio on asymmetric oceanic structure around Okinawa Island in the East China Sea

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Okinawa Island is located in the subtropical region of Japan, hosting ecologically abundant coral reefs even though they lie at the northernmost extreme of the habitable region. The coral ecosystem in the west coast of the island is maintained by persistent intrusions of the Kuroshio warm water through eddy-induced lateral mixing (Kamidaira *et al.*, 2016), while the Ryukyu Under Current is a major source of warm water from the lower latitude on the east coast. The island is situated on a ridge of the Ryukyu Arc that separates the shallow East China Sea (ECS) and the deep Ryukyu Trench (RT) to the Pacific Ocean, preconditioning oceanic asymmetry between the both sides of the island. In the present study, asymmetric oceanic responses around the island are investigated with a synoptic, triple nested downscaling ocean model based on ROMS. The model is forced by the JCOPE2 reanalysis as the outermost lateral boundary conditions and by the JMA GPV-GSM/MSM atmospheric reanalysis as the surface momentum boundary conditions. The horizontal grid spacing is decreased from 3 km in the outermost ROMS-L1 model, to 1 km in the intermediate ROMS-L2 model, and further down to 250 m in the innermost ROMS-L3 model. The L3 model has a 152 x 416 km domain and ten principal tidal constituents based on the TPXO 7.0 reanalysis is newly introduced to account for tides for more realistic reanalysis.

The harmonic analysis of the L3 model result highlights that semi-diurnal and diurnal tides propagate differently on the both sides of the island, yielding the asymmetric distributions in tidal amplitudes and phases. The tides are rather uniform with neither noticeable phase lags nor amplification on the RT side, whereas bidirectional propagation occurs on the ECS side originated from the northern- and southern-most tips of the island with prominent changes in amplitude near the shore. Similarly, the baroclinic energy flux demonstrates that the diurnal internal tides are not trapped topographically. Therefore the resultant clockwise circular propagation, which has been observed in several islands such as Izu Oshima and Sadogashima Islands where the local inertial period is shorter than the diurnal period, is interfered at the southernmost area off Okinawa Island. In addition, these two tips are areas of generation of the most energetic eddy kinetic energy (EKE). In particular, the upstream southernmost area sheds eddies that affect the nearshore area around the island. Remarkable enhancement of EKE is found around the shallow channel lying between Okinawa Island and Tokashiki Island (viz., Tokashiki Channel). These analyses clearly suggest that the southernmost area of the island around Tokashiki Channel plays substantial roles in controlling the asymmetric oceanic responses. The evaluated meridional volume flux normal to the channel indicates seasonal variability with prominent ECS to RT transport in spring, although RT to ESC transport is comparable to ESC to RT transport for the rest of the year. The transport along the channel is highly correlated with the volume transport of the northeastward drifting Kuroshio centered at 150 –200 km west of Okinawa. In spring, opposing southwestward transport is generated between the Kuroshio and the island, often referred to as the Kuroshio Counter Current (KCC). Surface vorticity indicates that the KCC is composed of clockwise-rotating, anti-cyclonic mesoscale eddies. Wavenumber kinetic energy spectra clearly shows seasonal transition from submesoscale-eddy dominance in winter to mesoscale-eddy dominance in spring. Relaxation of surface cooling and mixed layer deepening from winter to spring lead to this transition that is responsible for seasonal exchange between the ECS and the RT.

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