Special Program in Applied Mathematics and Applied Mechanics

Oceanic vortex wake behind an island: field observations and modeling

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Oceanic vortex evolution behind Green Island (~7 km in diameter) off Taiwan, where the Kuroshio flows at a speed of 1-1.5 ms-1, is observationally and numerically examined and compared with theory and preceding results of laboratory experiments. The island acts as a stick stirring the Kuroshio water, resulting in nutrient (or other biochemical parameters) pumping and turbulent mixing. In the near wake, the recirculation having relative vorticity ζ ~ 20f, where f is the planetary vorticity, was formed and subsequently sheds at a period of either M2 or M4 tidal cycle. Our analyses suggest the island standing at the Kuroshio having the periodic and cross-stream tidal excursion is analogous to the scenario of a cross-stream oscillating cylinder. As a result, the shedding period of the vortex is synchronized to a tidal period adjacent to its intrinsic period. The free shear layer, characterized by a ~30f relative vorticity band (2 km in width) and a zigzag thermal front, develops between the Kuroshio and the recirculation. The frontal wave at a time scale of 1-3 hour resembles to the Kelvin-Helmholtz instability relevant to high Re. In the far wake, the repeated cross-wake surveys suggest the cyclonic and anti-cyclonic eddies alternatively presents at a period close to M2 tide, in agreement with near-wake measurement. The repeated along-wake surveys depicted that a cyclonic eddy shed downstream at a speed of 0.35 m s-1, 1/3 of the upstream current speed, from the near wake. By examining our observations with the previous results in water tank experiment, we infer that the value of Re in the submesoscale wake regime is O(103), which has long been underestimated in those previous wake studies. By using MITgcm model, we successfully simulate the 3-D variability of the Green Island wake, which is validated by field

observations as well. Analysis suggests the von Kármán vortex street is the dominant process in the wake. However, the vortex street features are adapted by inertial and barotropic instabilities, which act as the secondary processes. Otherwise, the model suggests the hotspot of the turbulent mixing in the wake is located at the plane free shear layer as a result of the tilting of the vertical vorticity.