Generation Mechanism of Tropical Instability Waves in the Equatorial Pacific Ocean

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Tropical instability waves (TIWs) are prominent features observed in the eastern to central equatorial Pacific, which typically have a wavelength of ~1000 km and a period of ~25 days, propagating westward at a speed of ~0.5 m/s. Although TIWs are thought to be generated by meridional shear between the westward-flowing South Equatorial Current (SEC) and the eastward-flowing North Equatorial Countercurrent (NECC), the decisive parameter responsible for the occurrence of the instability has not yet been fully understood. Because the meridional and vertical momentum and heat transfer by TIWs are essential to drive the equatorial ocean circulation and affect the air-sea interactions related to the global climate, a better understanding of the generation mechanism of the TIWs is prerequisite for improving models' capability to predict climate variations.

In this study, we show that a linear stability analysis using a 1.5-layer shallow water model with a zonal mean flow on the equatorial beta plane can successfully predict an unstable mode whose phase speed and meridional structure are both very similar to those of the TIWs simulated in an eddy-resolving ocean general circulation model (OGCM), although the wavelength and the growth rate are somewhat larger and smaller, respectively. This unstable mode can be interpreted as resulting from a coupling between a Rossby wave propagating eastward in the negative potential vorticity (PV) gradient just north of the equator (~1°–3.5°N) while advected westward by the SEC, and a Rossby wave propagating westward in the positive PV gradient further north (~3.5°–8°N) while weakly advected eastward by the NECC. The unstable mode tends to have smaller growth rate as the negative PV gradient becomes weaker, and even disappears when it is completely absent.

The negative PV gradient just north of the equator thus plays an essential role in forming the unstable mode. Actually, the seasonal and interannual variability of the TIWs simulated in the OGCM is shown to be significantly controlled by the strength of the negative PV gradient, suggesting the possibility that it can serve as a key parameter for a dynamically based parameterization of the heat and momentum transfer associated with TIWs in coarse-resolution OGCMs.

Keywords: Tropical Instability Wave, Equatorial Pacific Ocean, Potential Vorticity Gradient, Rossby Wave, 1.5-Layer Shallow Water Model, Linear Stability Analysis

