Mean subsurface upwelling induced by intraseasonal variability over the equatorial Indian Ocean

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A possible formation mechanism of mean subsurface upwelling along the equator in the Indian Ocean is investigated using a series of hierarchical setting of ocean general circulation model (OGCM) integrations and analytical considerations. In an eddy-resolving OGCM with realistic forcing, mean vertical velocity in the tropical Indian Ocean shows rather strong upwelling, with its maximum on the equator in subsurface layer below the thermocline. Heat budget analysis exhibits that horizontal and vertical heat advection due to currents and temperature deviations from the mean balances with vertical advection due to mean equatorial upwelling. Horizontal heat advection is mostly associated with intraseasonal variability with a period from 3- to 91-day, while contribution from longer period (> 91 days) are small. Sensitivity experiments with a coarse-resolution OGCM further demonstrate that such mean equatorial upwelling cannot be reproduced by seasonal forcing only. Adding the intraseasonal wind forcing, especially meridional wind variability with a period of 15 days, generates significant mean subsurface upwelling on the equator. Further experiments with idealized settings confirm the importance of intraseasonal mixed Rossby-gravity (MRG) waves to generate mean upwelling, which appears along the energy “beam” of the MRG wave. An analytical solution of the MRG indicates that wave-induced temperature advection caused by the MRG waves with upward (downward) phase propagation results in warming (cooling) on the equator. This wave-induced warming (cooling) is shown to balance with the mean equatorial upwelling (downwelling), which is consistent with simulated characteristics in the OGCM experiments.

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