Subsurface IOD revisited:Contribution from nonlinear rectification of high-frequency variability

Subsurface IOD revisited:Contribution from nonlinear rectification of high-frequency variability

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The Indian Ocean Dipole (IOD) is a coupled ocean-atmosphere mode in the tropical Indian Ocean, and its positive phase is characterized by positive (negative) sea surface temperature (SST) anomalies in the west (east). In addition to SST, subsurface temperature undergoes significant variation during the IOD. Since the coupling between surface and subsurface plays an important role in generating SST anomalies, understanding the mechanism of subsurface temperature anomalies is of great importance. Although previous studies have argued that the vertical heaving of thermocline, induced by a baroclinic response to anomalous wind, is the key process for the generation of the subsurface anomalies. No studies have assessed the importance of these processes in a quantitative manner. To this end, we carried out an ocean model simulation and performed an on-line heat budget analysis.

In agreement with previous studies, anomalous warming (cooling) in the west (east) is mainly explained by positive (negative) vertical advection anomalies associated with anomalous downwelling (upwelling). However, in the eastern equatorial Indian Ocean (EEIO), meridional advection, which exhibits positive (negative) anomalies above (below) the thermocline, also plays an important role in determining the vertical structure of negative temperature anomalies. By decomposing these anomalies, it is found that they are mainly due to low-frequency modulation of high-frequency-related nonlinear rectification, rather than low-frequency anomalies of current and temperature. Climatologically, high-frequency variability associated with mixed Rossby gravity waves generates nonlinear heating near the thermocline along the equator. During the positive IOD, strengthening of vertical stratification in the EEIO leads to upward shift of nonlinear heating there, and gives rise to enhanced (reduced) warming above (below) the climatological thermocline. Sensitivity experiments using a linear continuously stratified ocean model also support this hypothesis. Our results suggest that the nonlinear interaction between intraseasonal and interannual variability plays a crucial role in the evolution of the IOD.

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