論文の内容の要旨

Mechanisms and impacts of salinity anomalies associated with the positive Indian Ocean Dipole
(正のインド洋ダイポールモード現象に伴う塩分変動のメカニズムおよびインパクト)

氏名 木戸　晶一郎

Accompanied by the anomalous atmospheric circulation and precipitation pattern, surface and subsurface salinity in the tropical Indian Ocean is known to undergo significant variations associated with the Indian Ocean Dipole (IOD), which is a dominant climate mode in the tropical Indian Ocean. Though recent advances in salinity observation have revealed many interesting features of salinity variations in the tropical oceans, comprehensive descriptions of underlying physical processes and their impacts on the upper ocean fields, such as sea surface temperature (SST) and currents are yet to be established. Thus, this thesis is devoted to quantitatively elucidate the mechanisms and impacts of salinity variations in the tropical Indian Ocean, with a particular emphasis on their link with the IOD.

Through analyses of observational datasets, it is found that negative (positive) sea surface salinity (SSS) anomalies appear in the central-eastern equatorial Indian Ocean (southeastern tropical Indian Ocean) during the mature phase of the positive IOD (pIOD) events. In addition to these SSS anomalies, significant subsurface salinity anomalies, with positive (negative) anomalies in the eastern equatorial Indian Ocean (southern tropical Indian Ocean), are also detected. The main driver of these surface and subsurface salinity variation is the IOD, rather than the remote influences from the El Niño-Southern Oscillation (ENSO).

Mechanisms of salinity anomalies associated with the pIOD are then investigated through a series of sensitivity experiments and an online budget analysis using a regional ocean model. The results from sensitivity experiments show that positive SSS anomalies in the southeastern tropical Indian Ocean are primarily caused by reduction in precipitation and partly by enhanced evaporation due to increased wind speed, while negative SSS anomalies in the central-eastern equatorial Indian Ocean are generated by zonal advection anomalies induced by anomalous wind stress, consistent with previous studies. Completely new results are that the modulation of nonlinear salinity advection associated with mesoscale eddies also plays an important role in determining the spatial pattern of SSS anomalies, especially in the southeastern tropical Indian Ocean. On the other hand, subsurface salinity anomalies are almost entirely caused by wind stress effects mediated by ocean dynamical processes. Further decomposition of advective anomalies suggests that they are mainly explained by the pIOD-related current anomalies governed by equatorial wave dynamics. However, a vertical shift of nonlinear freshening due to high-frequency variability also substantially contributes to the generation of positive subsurface salinity anomalies in the eastern equatorial Indian Ocean. The significance of low-frequency modulation of the rectified effects due to high-frequency variability is further justified by an additional set of sensitivity experiments using a linear continuously stratified ocean model (LCSM), which isolates the essential physics under a simple framework. It is shown that large-scale oceanic changes in response to the pIOD-related atmospheric anomalies are the key drivers of the observed salinity anomalies, while some nonlinear effects also seem to be at work.

Impacts of salinity anomalies associated with the pIOD-related salinity anomalies are assessed through observational data analysis. It turns out that density stratification in the eastern equatorial Indian Ocean is enhanced due to anomalous surface freshening and subsurface saltening during the pIOD. On the other hand, surface saltening and subsurface freshening in the southeastern tropical Indian Ocean leads to weakening of density stratification there. By decomposing observed densities into contribution from temperature and salinity anomalies, it is shown that the contribution from anomalous salinity stratification mentioned above is comparable to that from anomalous thermal stratification. Furthermore, a regression analysis of SST evolution against salinity anomalies, as well as an SVD analysis between them, implies that enhanced stratification in the eastern equatorial Indian Ocean may lead to SST warming there.

To quantify the impacts of these pIOD-related salinity anomalies, we have carried out novel sensitivity experiments using a ROMS and detailed diagnostics of heat and momentum budget. During the pIOD, the enhanced stratification in the eastern equatorial Indian Ocean causes momentum inputs from the wind forcing to be more strongly trapped in the surface layer, and zonal and vertical current anomalies to be more confined to the upper layer. As a result, upward transports of cold water from below the thermocline to the surface layer are significantly suppressed, and the cooling in the eastern-equatorial Indian Ocean is suppressed by as much as 1.0°C. The above arguments are further corroborated by a set of sensitivity experiments using a linear continuously stratified ocean model, which can isolate the effect of stratification change caused by salinity anomalies associated with the pIOD in the ROMS simulation. Our results suggest that salinity does play an active role in the evolution of the pIOD, rather than being passively affected by large-scale

anomalous atmospheric and oceanic conditions.