Impact of terrigenous materials on satellite bio-optical variables in the Bay of Bengal

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Transported by atmospheric deposition and river discharge, the Bay of Bengal (BoB) largely receives terrigenous iron-contained alluvial dust and dissolved inorganic nitrogen, the micro-macro nutrients which fuel phytoplankton growth and ocean primary productivity (e.g., Jutla et al. 2011; Srinivas et al. 2012; Narvekar and Kumar 2014; Sarangi 2016). Besides nutrients, river discharge also supplies the BoB suspended sediment and dissolved organic carbon, the sizable presence of which may be detrimental for phytoplankton growth and primary productivity. To date however, there is no information how the long-term river discharge variability may interannually affect the above-said in-water bio-optical variables in the BoB. In this analysis, by utilizing satellite-retrieved remote sensing reflectance (Rrs), the optical variables of chlorophyll-a concentration (Chl-a, a proxy for ocean primary productivity), total suspended matter concentration (TSM), and colored dissolved organic carbon absorption coefficient (CDOM) were derived within the period from September 1997 to December 2015. In-situ Ganges-Brahmaputra River (GBR) discharge (a proxy for nutrient input), and satellite-derived rain rate (RR) within the same time-span were also analyzed, and their interannual impacts on the ocean color variables were identified. The flood season in the GBR basin is in summer with the peak (in August) approximately lagged RR (in July) by one month. Chl-a, TSM, and CDOM in the BoB had larger non-seasonal component variances than seasonal ones, indicating that they might be sensitive to climate changes. Observing meridional distributions, the coastal water (with high bio-optical variables) can be roughly separated from the open ocean (with low bio-optical variables) approximately at 21°N. In summer of the years 1998, 2007, and 2011 however, it was obvious that bio-optical variables dispersed more southward to occupy the open ocean. In the same periods, RR and GBR discharge were remarkably higher than those during the normal summer season. This might indicate that high GBR discharge caused by high RR during summers 1998, 2007, and 2011 supplied terrigenous nutrients, suspended solid, and dissolved organic carbon into the BoB. In addition, the summers in 1998, 2007, and 2011 were the moderate La Niña periods, and it is well known that summer rainfall in the upstream GBR basin was anomalously high during La Niña years (e.g., Chowdhury 2003; Cai et al. 2015). Even though the aforesaid results showed increments of bio-optical variables through La Niña teleconnections with RR and GBR streamflow, further analysis is required to clarify whether any factors other than GBR discharge may also modulate the bio-optical variables. This is because, strengthened physical factors such as, wind speed, surface current, and vertical mixing, may entrain nutrients, suspended sediment, and dissolved organic carbon from deeper layer. Terrigenous alluvial dust deposition may also fertilize the BoB, thereby may also enhance Chl-a at interannual time-scale. La Niña teleconnections with atmospheric alluvial dust, wind speed, current, and vertical mixing in the BoB also need to be investigated. Therefore, we will analyze other geophysical variables such as, satellite-derived aerosol absorbing index (a proxy for alluvial dust), wind speed, surface ocean current, and reanalyzed mixed layer depth data, and identify whether or not those factors also interannually modulate the BoB bio-optical variables.

Keywords: Remote sensing, Ocean color, River discharge, Aerosols, La Nina

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Intraseasonal coastal upwelling signal along the southern coast of Java observed by Indonesian tidal station data

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Understanding coastal upwelling along the southwestern coasts of Sumatra and Java and their impacts on ocean surface heat and biogeochemical balance in the eastern Indian Ocean are the main target of international research collaboration, the Eastern Indian Ocean Upwelling Research Initiative (EIOURI). In this study, analyzing sea level data along the coasts of Sumatra and Java, we investigated the coastal upwelling signal that is linked to local sea surface temperature (SST) variability. We used Indonesian tidal station data together with satellite SST data and atmospheric reanalysis data. The sea level variations along the southern coast of Java have a significant coherence with remote wind, local wind, and local SST variations, with an intraseasonal time scale of 20–50 days. Assuming that a coastal upwelling signal would appear as a sea level drop (SLD), we focused on intraseasonal-scale SLD events in the data. Significant upwelling signals are frequently observed during both the boreal summer and winter. To evaluate the impact of the coastal upwelling on local SST, we examined statistical relationships between sea level and SST variations. The results demonstrated that events that occurred during April-August were associated with local SST cooling. The horizontal distribution of the SST cooling was analogous with annual-mean SST, suggesting the importance of intraseasonal-scale coastal upwelling in forming the climatic conditions of the southeastern tropical Indian Ocean.

キーワード：東部インド洋、沿岸湧昇、スマトラ・ジャワ島、潮位データ、東部インド洋湧昇イニシアティブ
Keywords: Eastern Indian Ocean, Coastal Upwelling, Sumatra and Java, Tidal Station Data, EIOURI

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Improved prediction of the Indian Ocean Dipole Mode by use of subsurface ocean observations

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The numerical seasonal prediction system using the SINTEX-F ocean-atmosphere coupled model has so far demonstrated good performance of predicting the Indian Ocean Dipole Mode (IOD) despite that the system adopts a relatively simple initialization scheme with nudging only the sea surface temperature (SST). However, it is easily expected that the system is not sufficient to capture the subsurface oceanic precondition. Therefore, we have introduced a new three-dimensional variational ocean data assimilation (3DVAR) method that takes 3D profiles of observed ocean temperature and salinity into account. Since the new system has successfully improved the IOD prediction, the present study has clearly shown that the ocean observational efforts in the tropical Indian Ocean are quite useful for improvement of the IOD prediction and may contribute to rich socio-economic activities, particularly in the Indian Ocean rim countries.

キーワード：インド洋ダイポールモード現象、季節予測、海洋亜表層の観測
Keywords: Indian Ocean Dipole Mode, Seasonal prediction, Subsurface ocean observation

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赤道インド洋中深層での季節内変動により励起された平均鉛直流
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.

キーワード：インド洋、季節内変動
Keywords: Indian Ocean, intraseasonal variability

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On the trigger and interannual variability of the Natal Pulse

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Variability of the Agulhas Current in the southwestern Indian Ocean is characterized by its solitary meander event, known as the Natal Pulse, which may trigger the pinch off of the Agulhas Rings in the Agulhas retroflection region. These turbulent motions may influence inter-ocean water mass exchange between Indian and Atlantic Oceans and thus the global climate system.
In this study, the trigger of the Natal Pulse, and the interannual variability in the occurrence of Natal Pulse events are investigated using satellite altimeter data and outputs from the high-resolution OGCM (OFES) simulation.
It is found that most of the Natal Pulse events are triggered by anticyclonic eddies propagating from the upstream region, most of which originates from the Southeast Madagascar Current (SEMC), although eddies from Mozambique Channel also contribute to the Natal Pulse event.
Futhermore, interannual variations in the Natal Pulse occurrence correlate with eddy kinetic energy off the southern coast of Madagascar, which suggests that the Natal Pulse is controlled by anticyclonic eddies from the SEMC region. An automatic eddy tracking method supports this idea, and shows that possible eddy corridor is mainly from the SEMC region. The connection between the Natal Pulse and western boundary current along the Madagascar coast implies the potential contribution of the basin-scale wind field.

キーワード：アガラス海流、Natal Pulse、渦-平均流相互作用、蛇行、中規模渦
Keywords: Agulhas Current, Natal Pulse, Eddy-Mean Flow Interaction, Meander, Mesoscale Eddies

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Decadal climate prediction in the southern Indian Ocean using SINTEX-F2 coupled GCM

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Decadal climate variation in the southern Indian Ocean plays a crucial role in rainfall variability over southern Africa through changes in moisture transport. The rainfall increase over southern Africa has a strong relation with warm sea surface temperature (SST) and high sea level pressure (SLP) anomalies in the Southwest Indian Ocean. Despite many efforts devoted to understanding the physical mechanisms, few studies have examined the decadal climate predictability in the southern Indian Ocean. This study aims at investigating decadal climate predictability in the southern Indian Ocean using a state-of-the-art coupled general circulation model (GCM), called SINTEX-F2. Here we performed 12 ensemble decadal hindcast experiments using different initial conditions with SST-nudging scheme, starting from Mar 1st in each year of 1982-2005.
On decadal timescale, the observed SST anomalies averaged in the Southwest Indian Ocean show positive peak in late 1990s and negative peak in late 2000s. Both positive and negative peaks are well reproduced in the decadal hindcast runs initiated in 1994 and 1999, respectively. Particularly, the decadal hindcast experiments initiated from 1999 successfully capture a distinct phase change from the positive to negative peak. In addition, the spatial patterns of warm SST and high SLP anomalies observed in late 1990s show a clear eastward propagation from the South Atlantic to the southern Indian Ocean along the Antarctic Circumpolar Current. The decadal hindcast experiments initiated in 1994 successfully capture this observed eastward propagation of SST and SLP anomalies from the South Atlantic, indicating an important role of SST anomalies in the South Atlantic. These results suggest that the SINTEX-F2 decadal hindcast experiments, with simple SST-nudging initialization, have reasonable skills in predicting the decadal climate variability of the southern Indian Ocean, important for the southern African climate.

キーワード：十年規模変動、南インド洋、海面水温
Keywords: Decadal variability, Southern Indian Ocean, Sea surface temperature

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