The Early-1990s Climate Shift in the Pacific and the ENSO Diversity

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There is substantial evidence that significant changes occurred in broad areas of the Pacific in the early 1990s, including the shift of the location of El Niño events from the eastern Pacific to the central Pacific (CP). Observational analysis and coupled model experiments are conducted to show that the early-1990s climate shift is linked to a phase change of the Atlantic Multi-decadal Oscillation (AMO) that occurred at about the same time. The recent emergence of the CP El Niño can be attributed to this AMO phase change via the following chain of events: a switch in the AMO to its positive phase in the early 1990s led to an intensification of the Pacific Subtropical High. The intensified High resulted in stronger-than-average background trade winds that enhanced the Wind-Evaporation-SST feedback mechanism, strengthening the subtropical Pacific coupling between the atmosphere and ocean, making the subtropical Pacific precursors more capable of penetrating into the deep tropics, and ultimately leading to increased occurrence of the CP El Niño events. Associated with the change of the El Nino type, the El Nino teleconnection is found to become different after the early-1990s. A changing relationship between El Nino and Southern Hemisphere climate will be presented in the talk. Evidence is also found that the typical drought pattern in Eastern China diminished after the early-1990s climate shift and is replaced by a new pattern that is produced by the AMO via a Eurasian wave train emanating from North Atlantic to China. This study indicates that the early 1990s is a time when the Atlantic began to exert a stronger influence on climate over East Asia and a large part of the Pacific.

Keywords: early-1990s climate shift, ENSO diversity, Atlantic Multi-decadal Oscillation

ENSO diversity caused by mean state-dependent ENSO modes resulting from an intermediate coupled model

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ENSO diversity is referred to the event-to-event differences in the amplitude, longitudinal location of maximum sea surface temperature (SST) anomalies and evolutional mechanisms, as manifested in both observation data and climate model simulations. Previous studies argued that ENSO diversity is associated with westerly wind burst (WWB) or subtropical forcing in the northeastern Pacific. Here, we bring evidences, from a modified intermediate complexity Zebiak-Cane (MZC) coupled model, to illustrate that the ENSO diversity is also determined by the mean states. Stabilities of the linearized MZC model reveal that the mean state with weak (strong) wind stress and deep (shallow) thermocline prefers ENSO variation in the equitorial eastern (central) Pacific with a four-year (two-year) period. Weak wind stress and deep thermocline make the thermocline (TH) feedback the dominant contribution to the growth of ENSO SST anomalies, whereas the opposite mean state favors the zonal advective (ZA) feedback as the key one. Different leading dynamical contributor and pacemaker make ENSO display its diversity in spatial pattern and period. In a mean state that resembles the tropical Pacific climate after 2000, the four-year and two-year ENSO variations coexist with similar growth rate. Even without WWB forcing, the nonlinear integration results with adjusted parameters in this special mean state also present at least two types of El Niño, in which the maximum warming rates are contributed by either TH or ZA feedback. The consistency between linear and nonlinear model results indicates that the ENSO diversity depends on the mean state.

Keywords: ENSO diversity, ENSO modes, mean states, favorable feedbacks

ENSO diversity generated by the state dependence of westerly wind events

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A coupled dynamics between westerly wind events (WWEs) and El Niño-Southern Oscillation (ENSO) is examined using an atmosphere-ocean coupled model with an intermediate complexity. WWEs are short-lived surface westerly wind anomalies over the western-central equatorial Pacific and observed frequently at the eastern edge of the warm pool when the sea surface temperature (SST) anomaly at the Niño4 region (160 °E-150 °W, 5 °S-5 °N) is positively large. These features of WWEs are parameterized as a state-dependent stochastic noise to wind stresses in the model. Without the noise (experiment NO), the model produces a periodic ENSO-like oscillation with a period of 6 years and its variance increases with respect to a parameter that controls efficiency of the positive thermocline feedback, γ. When additive (purely stochastic) noise is given to the model over the western Pacific (experiment AD), oscillations become irregular with the dominant period of about 5 years and the increase of its variance relative to NO depends on γ. When the state-dependent noise is adopted (experiment SD), the oscillatory solution is also irregular besides its variance and asymmetry increase irrespective the value of γ.
Both the additive and state-dependent noises help to produce two types of oscillation, corresponding to the eastern-Pacific (EP) and central-Pacific (CP) El Niños, although there is no such diversity in NO. EP El Niño is magnified in SD due to the eastward shift of the noise location caused by the warm pool expansion. CP El Niño is even favored by the state-dependent stochastic noise, which enhances the zonal advection to warm the central Pacific, and in turn the warmer Niño4 SST increases the probability of occurrence of the noise. This positive feedback ensures the existence of CP El Niño regardless of γin SD, while the number of CP El Niño declines with larger γ in AD. The above results thereby suggest that the state dependence of WWEs may play a crucial role on the asymmetry and diversity of ENSO in nature.

Keywords: Westerly wind event, ENSO, State dependence

Impacts of decaying eastern and central Pacific El Niños on tropical cyclone activities over the western North Pacific in summer

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We investigate the influences of the decaying eastern Pacific El Niño (EP - El Niño) and central Pacific El Niño (CP - El Niño) on tropical cyclone (TC) activities in the western North Pacific (WNP) during July, August and September (JAS). During this period, TC geneses and tracks are reduced in the central and eastern WNP. However, TC tracks reaching the Philippines increase, and more TC geneses appear west of 145°E during EP - El Niño. During CP - El Niño, tracks reaching the South China Sea (SCS) and southeast coast of China increase, and positive anomalies of TC genesis are found in the southern part of the central WNP and southern SCS. It is possible that the different variation of the anomalous anticyclone over east of the Philippines in the WNP induced by El Niños are instrumental to different TC variations in the two types of decaying El Niños during JAS. Compared with EP - El Niño, strengthening and northward expansion of the anomalous anticyclone during CP - El Niño cause a westward shift of the western Pacific subtropical high in summer, which is responsible for more westward TC tracks over the SCS and southeast coast of China. This northward expansion can cause the center of suppressed TC geneses in the central WNP to migrate further north during CP - El Niño. A decreased magnitude of vertical shear dominates the southern part of the central WNP and southern SCS, which enhances TC formation in these regions during CP - El Niño.

Keywords: two types of El Niños, tropical cyclone, decaying summer

The role of tropical Atlantic SST anomalies in modulating western North Pacific tropical cyclone genesis

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The connection between north tropical Atlantic (NTA) sea surface temperature (SST) anomalies and tropical cyclone (TC) genesis over the western North Pacific (WNP) and associated physical mechanisms are investigated in this study.We demonstrate a remarkable negative correlation ofWNP TC genesis frequency with the (preceding) boreal spring NTA SST anomalies. Our analysis suggests that major factors for TC genesis including distributions of large-scale vorticity and midtropospheric humidity are rendered unfavorable by remote teleconnections while barotropic energy conversion from the large-scale flow is suppressed. As shown in recent studies, the remote teleconnection from the Atlantic is sustained and enhanced throughout the typhoon season through local air-sea interactions. These results suggest that boreal spring NTA SST anomaly could be a new predictor for the seasonal WNP TC activity.

Keywords: Climate, tropical Atlantic SSTA, western North Pacific, tropical cyclone genesis

The Indo-western Pacific Ocean capacitor mode and coherent climate anomalies in post-ENSO summer

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El Niño typically peaks in boreal winter, and the associated equatorial Pacific sea surface temperature (SST) signal dissipates before subsequent summer. Its impact, however, outlasts until boreal summer in the Indo-western Pacific, featuring basin-wide Indian Ocean warming and tropical Northwestern Pacific cooling accompanied by the Pacific-Japan (PJ) teleconnection pattern with an surface anomalous anticyclone (AAC) extending from the Philippine Sea to the northern Indian Ocean. Two formation mechanisms have been proposed for these climate anomalies in post-El Niño-Southern Oscillation (ENSO) summer. One hypothesis invokes the wind-evaporation-SST (WES) feedback in the tropical Northwestern Pacific, while the other points to inter-basin feedback between the Indian Ocean and tropical Northwestern Pacific. Based on a coupled model experiment, we propose an ocean-atmosphere coupled mode that synthesizes the two mechanisms. This Indo-western Pacific Ocean capacitor (IPOC) mode evolves seasonally from spring to summer under seasonal migration of background state. In spring, the WES feedback is operative in association with the tropical Northwestern Pacific cooling, while in summer the Indian Ocean warming and the inter-basin interaction maintains the AAC. While the IPOC mode is independent of ENSO in mechanism, ENSO can drive this mode in its decay phase. This excitation, however, has undergone substantial interdecadal modulations, depending on ENSO amplitude and persistence of Indian Ocean warming. The ENSO-IPOC correlation is high after the mid-1970s and at the beginning of the 20th century, but low in between.

Keywords: Air-sea interaction, Teleconnection, East Asian summer monsoon

A sea surface salinity dipole mode in the tropical Indian Ocean

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Ocean salinity is a natural freshwater tracer in the global hydrological cycle and its changes represent large-scale ocean-atmosphere coupled climate signals such as the El Ni?o/Southern Oscillation (ENSO). Studies of ocean salinity are much less than those of temperature since salinity observations are more sparse. Based on the sea surface salinity (SSS) data from Argo and reanalysis dataset, we identified a salinity dipole mode in the tropical Indian Ocean, termed S-IOD: a pattern of interannual SSS variability with anomalously low-salinity in the central equatorial and high-salinity in the southeastern tropical Indian Ocean (IO). The S-IOD matures in November-December, lagging the Indian Ocean dipole (IOD) mode derived from sea surface temperature (SST) by two months. For the period of observations, the S-IOD persists longer than the IOD, until the following September-October. Oscillations of the two S-IOD poles are governed by different processes. Ocean advection associated with equatorial current variability dominates the SSS anomalies of the northern pole, while surface freshwater flux variability plays a key role in the SSS anomalies of the southern pole, where anomalous precipitation is sustained by preformed sea surface temperature anomalies. The S-IOD concurs with the strong IOD, reflecting an ocean-atmosphere coupling through the SST-precipitation-SSS feedback.

Keywords: Salinity, S-IOD, tropical Indian Ocean

Low salinity signal on the high salinity subsurface water during negative Indian Ocean Dipole

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The Indian Ocean Dipole (IOD) is a seasonal to interannual ocean-atmosphere phenomenon occurring in the tropical Indian Ocean. During the negative phase of the IOD (nIOD), the eastern Indian Ocean is characterized by warmer-than-normal sea surface temperature (SST), enhanced atmospheric convection, and high-salinity anomalies advected from the west. In this study, we investigated ocean temperature and salinity data in the south eastern Indian Ocean to understand a possible role of the salinity variation on the development of nIOD. We used ocean temperature and salinity data from Argo floats and mooring buoy. We also used satellite SST and precipitation data from the Tropical Rainfall Measuring Mission satellite. During the development phase of the 2010 nIOD (July-August-September), eastward surface currents induced by westerly wind anomalies produced high salinity anomalies in the central-eastern equatorial Indian Ocean. Observation data also showed relatively low salinity signal around 0-10m depth together with relatively shallow mixed layer in the south-eastern Indian Ocean. Our analysis indicated that the low salinity signal was associated with enhanced local precipitation that eventually formed vertical salinity gradient on the high salinity anomalies. The upper-layer stratification due to the salinity variation could affect ocean-atmosphere interaction during the nIOD by changing the mixed layer depth. A possible contribution of the salinity variation to the mixed layer heat balance and hence an effect on SST will be discussed.

Keywords: Indian Ocean Dipole, Precipitation, Barrier Layer

Anomalous Walker Circulation Associated with Two Types of the Indian Ocean Dipole

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The Indian Ocean Dipole (IOD), an air-sea coupled phenomenon in the tropical Indian Ocean, can be classified into two types based on sea surface temperature (SST) anomaly patterns. One type is referred to as the canonical IOD; positive (negative) sea surface temperature (SST) anomalies cover the eastern (central to western) tropical Indian Ocean. The other is named the IOD Modoki; it is associated with positive (negative) SST anomalies cover the central (eastern and western) tropical Indian Ocean. It is shown that the canonical IOD is associated with a single cell anomalous Walker Circulation, while the IOD Modoki is accompanied by a double-cell anomalous Walker Circulation. Implications of differences in the anomalous Walker Circulation cell will also be discussed.

Keywords: Indian Ocean Dipole, Walker Circulation, Tropical Indian Ocean

On semiannual equatorial undercurrents in the eastern Indian Ocean

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Unlike those in the Pacific and Atlantic, the equatorial undercurrents (EUCs) in the Indian Ocean are transient and eastward only in early boreal spring and fall. Their dynamics is investigated in this study using observations obtained from four acoustic Doppler current profilers (ADCPs) deployed along the equator in the eastern Indian Ocean (78^{o}E, 80.5^{o}E, 83^{o}E and 90^{o}E). The harmonic analysis is applied to observed zonal velocity and reveals that annual and semiannual variability contributes to zonal velocity at the depth of the EUCs (about 100 m). Whereas the annual harmonic does not show any consistent tendency of zonal phase propagation, the semiannual harmonic shows eastward propagation at the depth of the EUCs. Owing to data gaps in ADCP records, the analysis is repeatedly applied to several two-year segments, and the phase speed is estimated using results obtained from various pairs of ADCPs. The results show that eastward phase propagation of the semiannual harmonic is a statistically robust feature. For a further confirmation, zonal velocity and its divergence are calculated using ADCP records. Zonal velocity leads zonal divergence, which is another evidence for eastward phase propagation. These results suggest that the semiannual transient EUCs in the Indian Ocean are Kelvin beams radiated from the surface to the east and to the depth.

Keywords: Equatorial undercurrents, Indian Ocean, Kelvin beams

Global non-hydrostatic simulation of the Pre-YMC field campaign in 2015

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In order to deepen our understanding of multi-scale multi-process interactions over the Maritime Continent, a field campaign Pre-YMC was conducted during November-December 2015 in the southwest Sumatra by JAMSTEC. Near real-time forecasts using a global non-hydrostatic model (Nonhydrostatic Icosahedral Atmospheric Model, NICAM) had been operated throughout the observation period at cloud-system-resolving resolutions. This approach is useful for investigating relationship between mesoscale convective systems and large-scale disturbances, such as the Madden-Julian Oscillation (MJO), equatorial waves, and monsoon activities. The forecasts were initialized at 0000 UTC each day using NCEP Final analysis, and integrated for 7 (30) days using the 7 (14) km mesh sizes. Two member ensemble was made by different setups of sea surface temperature. We will discuss the model performance in simulating the observed large-scale variabilities and the processes in them.During the first half of the observation period, lower tropospheric westerlies and convective center persisted over the central Indian Ocean. Over the Maritime Continent, diurnal variation of precipitation was pronounced, with passages of westward propagating synoptic-scale vorticity disturbances at 4-5 periodicity. After 12 December 2015, the peak of equatorial westerlies rapidly moved eastward, with southward shift of westerly axis over the broad warm pool domain. These correspond to intensification of MJO amplitude and eastward propagation. The 30-day forecasts generally capture these large scale variations at the lead time of approximately two weeks. The abrupt change in the low-level winds were accompanied with marked variation in convective organization. The 7-km mesh simulations show that the westerly intensification started on 10-11 December as a part of a vorticity disturbance around the northwest Sumatra, followed by further acceleration within eastward propagating Kelvin-wave like convective disturbances. In the latter phase, convective activity was significantly enhanced, which masked diurnal variation in precipitation. These results suggest that mesoscale convective organization was not totally passive to the dynamical modulations, but drove the large-scale change in some ways. Possible scenarios are being searched.

Keywords: Global high-resolution model, Maritime Continent, Madden-Julian Oscillation, equatorial waves, diurnal cycle

A Regional Climate Mode Discovered in the North Atlantic: Dakar Niño/Niña

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The interrannual variability of coastal sea surface temperature (SST) anomalies confined off Senegal is explored from a new viewpoint of the ocean-land-atmosphere interaction. The phenomenon may be classified into "coastal Niño/Niña" in the North Atlantic as discussed recently in the Northeastern Pacific and Southeastern Indian Oceans. The interannual variability of the regional mixed-layer temperature anomaly that evolves in boreal late fall and peaks in spring is associated with the alongshore wind anomaly, mixed-layer depth anomaly and cross-shore atmospheric pressure gradient anomaly, suggesting the existence of ocean-land-atmosphere coupled processes.
The coupled warm (cold) event is named Dakar Niño (Niña). The oceanic aspect of the Dakar Niño (Niña) may be basically explained by anomalous warming (cooling) of the anomalously thin (thick) mixed-layer, which absorbs shortwave surface heat flux. In the case of Dakar Niña, however, enhancement of the entrainment at the bottom of the mixed-layer is not negligible.
The atmospheric aspect is a warming (cooling) of the lower atmosphere, in response to the warming (cooling) of the upper ocean. Locally, this modifies the cross-shore pressure gradient and helps to maintain weaker (stronger) than normal wind along the coast. This can be viewed as a "coastal Bjerknes feedback".

The lack of westerly wind bursts in 2014 and its relation to background wind states

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The strong El Niño in late 2014 was predicted by many climate scientists based on high warm water volume and successive equatorial westerly wind bursts (WWBs) in early 2014. However, it turned out to be a weak El Niño and developed again in 2015. Several studies have been devoted to elucidate the reasons of the unmatured El Niño in 2014. One of the reasons addressed is the lack of WWBs after boreal spring. In this study, we examine what caused the lack of WWBs in 2014 focusing on background wind states.

The successive WWBs from January to March 2014 excited strong oceanic Kelvin waves, resulting in a large increase in the eastern Pacific sea surface temperature (SST). However, there are no successive WWBs or the Kelvin waves after April, resulting in a decrease in the SST.

Our previous studies have shown that WWBs occur frequently when tropical intraseasonal convection, so-called the Madden-Julian Oscillation (MJO), propagates over the Pacific under the equatorial westerly background states, which contribute to develop eddy disturbances via background zonal wind convergence near the equator. In 2014, there were several MJO events throughout the year. However, few WWBs accompanied the MJO convection.

Focusing on the background states after the WWB occurrences in early 2014, zonal wind convergence was retracted and did not reach the equatorial central Pacific. In boreal summer, climatologically, convectively active and westerly regions shift north of the equator. Because this environmental condition is not favorable for the WWB occurrences, the WWB frequency in boreal summer is statistically low. In 2014, unchanged background states can be a reason for the lack of WWBs even with several MJO events.

Keywords: El Niño, westerly wind bursts, Madden Julian Oscillation

Long-term modulation of the quasi-decadal scale variation in the tropical Pacific during the 1990s and 2000s

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To explore a low-frequency-modulation of ENSO-like quasi-decadal (QD)-scale variation in the tropical Pacific, relationship between QD-scale modulation and inter-annual scale variation (i.e., El Nino, El Nino modoki, La Nina, and La Nina modoki) is compared between the 1990s and 2000s. QD-scale sea surface temperature (SST) anomaly averaged in the central equatorial Pacific (i.e., Nino-3.4 region) is used for the index of the QD-scale variation. Periods of the positive values of the index are defined as the “QD positive period” in this study. QD-scale SST anomalies averaged over QD positive period in the 2000s show stronger positive and weaker negative values in the central equatorial Pacific and Philippine Sea than the 1990s, respectively. The spatial pattern is similar to the El Nino modoki, as pointed out in previous studies. To explore a relationship between such QD-scale modulation and inter-annual scale variation, composite analyses are conducted. A composite map for inter-annual SST anomalies during El Nino and El Nino modoki periods within the QD positive period of the 1990s shows stronger positive SST anomalies in the central equatorial Pacific and stronger negative SST anomalies in the Philippine Sea than the 2000s. A composite map for La Nina and La Nina modoki during QD positive period of the 1990s shows negative SST anomalies both in the central equatorial Pacific and Philippine Sea. On the oher hand, a composite map for LA Nina and La Nina modoki during QD positive period of the 2000s shows weak negative SST anomalies in the central equatorial Pacific and positive SST anomalies in the Philippine Sea, in contrast to the 1990s. Such differences in SST anomalies of El Nino/El Nino modoki and La Nina/La Nina modoki between the 1990s and 2000s may lead the QD-scale modulation of SST anomalies during the 1990s and 2000s. In addition to those results, analyses results of temperature profiles obtained along 137E repeated line conducted by JMA and atmospheric reanalysis data will be showed in the presentation.

Keywords: quasi-decadal scale variation, El Nino/Southern Oscilaltion, tropical Pacific

The Pilot Aeroclipper Campaign in North Pacific Cyclones (PACNPaC)

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Tropical Cyclones (TCs) are a major threat for many tropical and subtropical coasts. Their monitoring and forecasting are thus of great importance to deliver accurate early warnings. Most of the real time data available for operational centers is however coming from satellite observations. For example, the Dvorak technique gives an indirect estimate of the wind intensity based on the structure of the cyclone cloudiness. Yet, there is no device able to measure continuously the surface pressure in the eye of the TC that is critical to follow the evolution of its intensity. The Aeroclipper developed by the French Space Agency (Centre National d’Études Spatiales, CNES) is a quasi-lagrangian device (small streamlined balloon) drifting with surface wind at about 20-30m above the ocean surface. It is a new and original device for real-time and continuous observation of air-sea surface parameters in open ocean remote regions. This device enables the sampling of the variability of surface parameters in particular under convective systems toward which it is attracted. The Aeroclipper is therefore an ideal instrument to monitor TCs in which they are likely to converge and provide original observations to evaluate and improve our current understanding and diagnostics of TCs as well as their representation in numerical models.
We will present the challenges of the test Aeroclipper flight during the Pilot Aeroclipper Campaign in North Pacific Cyclones (PACNPaC) that will take place from Palau, an archipelago situated in the most cyclonic region on Earth, during next northern hemisphere cyclonic season. This campaign aims at obtaining the first continuous observation of surface parameters in a TC It should provide a crucial first step toward an operational use of Aeroclippers in real-time operations to improve the reliability of TCs forecasts and warning procedures.

Keywords: Aeroclippers, Tropical Cyclones, Observation campaign

Variation of North Pacific subtropical gyre heat transport caused by the interior flow change

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The subtropical gyre of the North Pacific consists of the northward flowing Kuroshio and the southward interior return flow. The variation of the net heat transport of the gyre is caused by the changes of the volume transport distribution with respect to temperature in the Kuroshio and the interior flow in addition to the gyre volume transport change. In this study, we focused on the volume transport distribution change in the interior flow, which can be taken into accounted by the volume transport-weighted temperature. By applying the altimeter-derived gravest empirical mode method to hydrographic and altimetric data from San Francisco to 30N, 145E via Honolulu, we estimated the geostrophic interior flow of the subtropical gyre between 1993 and 2012. Anomaly of the volume transport-weighted temperature from the seasonal mean cycle is caused by the change of the volume transport in a layer just above the isopycnal of 25.5sigma-theta. Peaks in a quasi-decadal variation of the volume transport-weighted temperature are found approximately one year before peaks of sea surface temperature in the tropical western Pacific warm pool region.

Keywords: North Pacific subtropical gyre, quasi-decadal variation, Tropical western Pacific warm pool

Methods to evaluate prediction skill in the Madden-Julian oscillation phase space

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Indices of prediction skill over the Madden-Julian oscillation (MJO) phase space are examined with reanalysis and forecast data provided by the Japan Meteorological Agency (JMA). In addition to the bivariate root-mean-square error (RMSE) and the bivariate anomaly correlation coefficient (ACC), the mean-error vector is assessed. Conventionally, the ACC and RMSE has been used, although this approach misses information on the model bias for MJO events. Moreover, the ACC is not suitable for models in which the MJO signal tends to damp in some phases, because the ACC strongly depends on the MJO amplitude. The mean-error vector compensates for this drawback by associating a model’s erroneous mean tendency with RMSE. For example, the JMA forecast produces a leftward mean error vector field uniformly distributed over the MJO phase space with its amplitude related to RMSE. RMSE should be then used with the mean error vector for evaluating MJO prediction skill.

Keywords: Madden-Julian oscillation, predictability

Subsurface salinity anomalies in the eastern equatorial Indian Ocean during positive IOD events

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The Indian Ocean Dipole (IOD) is known as an important climate mode in the tropical Indian Ocean. Previous studies have reported that not only sea surface temperature (SST), but also subsurface oceanic temperature and sea surface salinity (SSS) undergo significant variations owing to the anomalous oceanic circulation during IOD years. However, influences of the IOD on subsurface salinity are not fully understood due to the scarcity of observations. In this study, using an ocean reanalysis product, subsurface salinity variability in the eastern equatorial Indian Ocean (95°-100°E, 3°S-3°N) associated with the IOD and its influence on the upper-ocean stratification have been investigated. It is found that salinity near the pycnocline becomes anomalously high off Sumatra in boreal fall-winter of positive IOD (pIOD) years. Anomalies with an opposite sign but smaller amplitude were observed in negative IOD years. Enhanced upwelling and eastward transport of high salinity water seem to be the main causes of those positive salinity anomalies. By decomposing density anomalies into contributions from temperature and salinity anomalies, it is demonstrated that positive density anomalies associated with high salinity anomalies lead to stronger density stratification in the upper-ocean and shoaling of the mixed layer during the mature phase of pIOD events. Our results suggest that subsurface salinity anomalies have a potential to influence the air-sea interaction by modifying the upper-ocean stratification and mixed layer processes.

Keywords: The Indian Ocean Dipole, salinity variation, upper-ocean stratification, mixed layer depth

Phase locking of equatorial Atlantic variability through the seasonal migration of the ITCZ

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The equatorial Atlantic is marked by significant interannual variability in sea-surface temperature (SST) that is phase-locked to late boreal spring and early summer. The role of the atmosphere in this phase locking is examined using observations, reanalysis data, and model output. The results show that equatorial zonal surface wind anomalies, which are a main driver of warm and cold events, typically start decreasing in June, despite SST and sea-level pressure gradient anomalies being at their peak during this month. This counterintuitive behavior is explained by the seasonal northward migration of the intertropical convergence zone (ITCZ) in early summer. The north-equatorial position of the Atlantic ITCZ contributes to the decay of wind anomalies in three ways: 1) Horizontal advection associated with the cross-equatorial winds transports air masses of comparatively low zonal momentum anomalies from the southeast toward the equator. 2) The absence of deep convection leads to changes in vertical momentum transport that reduce the equatorial surface wind anomalies. 3) The cross-equatorial flow is associated with increased total wind speed, which increases surface drag and deposit of momentum into the ocean.
Previous studies have shown that convection enhances the surface wind response to SST anomalies. The present study indicates that convection also amplifies the surface zonal wind response to sea-level pressure gradients in the western equatorial Atlantic, where SST anomalies are small. This introduces a new element into coupled air-sea interaction of the tropical Atlantic.

Keywords: equatorial Atlantic, phase locking, ITCZ

Development of a Coupled Atmosphere-Ocean Model in JMA/MRI

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A coupled atmosphere-ocean data assimilation (DA) system is a system in which atmospheric and oceanic observation data are assimilated into a coupled atmosphere-ocean model. Many researchers consider a coupled DA system as an indispensable tool for seamless forecasting of daily weather to interannual climate variations. Using a coupled DA system is also considered to be effective to improve the skill of ENSO forecasting. For example, JAMSTEC developed a coupled DA system based on a four-dimensional variational (4DVAR) method, and confirmed its potential for improving ENSO forecasts (e.g. Sugiura et al. 2008; Masuda et al. 2015). JMA/MRI has also been developing a quasi-coupled DA system in which only ocean data are assimilated into a coupled model (atmospheric data is not assimilated) since 2006, and confirmed that the system improved key atmospheric climate features such as the Walker Circulation, the Monsoon Trough, and the Typhoon activities in the Philippine Sea over simulation of an uncoupled atmospheric model forced by observed SST data, that is, AMIP-Run (Fujii et al. 2009, 2011).

Recently, operational agencies such as NCEP, ECMWF, and UKMO, have started to develop or to use coupled DA systems in order to realize the seamless forecasting and to improve climate predictions (Saha et al. 2010, Laloyaux et al. 2015, Lea et al. 2015). Those systems are, however, so-called weakly-coupled data assimilation systems; atmospheric and ocean analyses are generated independently by separated atmosphere and ocean data assimilation systems. First-Guess fields for next analysis time-windows are given by the simulation of a coupled model from the ocean and atmospheric analysis fields. Although a weakly-coupled data assimilation system is not sufficient for generating balanced analyses fields of atmosphere and ocean due to the lack of explicit evaluation of the balance, development of the system is relatively easy because existing atmosphere and ocean data assimilation systems can be exploited.

JMA/MRI have also started to develop a weakly-coupled DA system by coupling the 4DVAR global atmosphere DA system, MRI-NAPEX, the global ocean data assimilation system, MOVE-G2, and the coupled atmosphere-ocean model for seasonal forecasting, JMA/MRI-CGCM2. In the plan, the system will use assimilation time-windows of 6 hours for the atmosphere and 10 days for the ocean. The system simulates time-evolution of the atmosphere and ocean from the atmospheric analyses fields generated by MRI-NAPEX and ocean fields at the end of the previous simulation using JMA/MRI-CGCM2. In the simulation, the ocean fields are continuously modified by adding oceanic analysis increments estimated by MOVE-G2. Atmospheric first-guess fields for the next assimilation time-window are prepared by the simulation. Thus, the system uses the uncoupled atmospheric model for the inner loop and the coupled model (JMA/MRI-CGCM2) for the outer loop in the 4DVAR DA system. Here, it should be noted that MOVE-G2 and JMA/MRI-CGCM2 have been used in the operational seasonal forecast in JMA since June 2015.

We have also developed a new quasi-coupled DA system using MOVE-G2 and JMA/MRI-CGCM2, and performed a reanalysis experiment for the period after 2000. In the presentation, we will introduce results of the reanalysis experiment as well as the features of the weakly-coupled DA system which we are developing now.

Keywords: Data Assimilation, Seamless Forecasting, Seasonal Forecasting