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

西風イベントの環境場依存性がもたらすENSOの多様性
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.

キーワード：西風イベント、エルニーニョ・南方振動、環境場依存性
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

インド洋-西太平洋キャパシターモードとENSO衰退年夏季の異常気象

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.

キーワード：大気海洋相互作用、遠隔影響、東アジア夏季モンスーン
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

負のインド洋ダイポール現象発生時における表層の低塩分シグナルと亜表層の高塩分水
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.

キーワード：インド洋ダイポール現象、降水、バリアレイヤー
Keywords: Indian Ocean Dipole, Precipitation, Barrier Layer

二種類のインド洋ダイポールモード現象に伴うウォーカー循環偏差

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.

キーワード：インド洋ダイポールモード現象、ウォーカー循環、インド洋熱帯域
Keywords: Indian Ocean Dipole, Walker Circulation, Tropical Indian Ocean

赤道インド洋東部の半年周期の潜流について
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°E, 80.5°E, 83°E and 90°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.

キーワード：赤道潜流、インド洋、ケルビン波のビーム
Keywords: Equatorial undercurrents, Indian Ocean, Kelvin beams

Pre-YMC集中観測(2015)を対象とする全球非静力学数値実験
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.

キーワード：全球非静力学モデル、海大陸、マッデン・ジュリアン振動、赤道波、日周期
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

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.

キーワード：エルニーニョ、西風バースト、マッデンジュリアン振動
Keywords: El Niño, westerly wind bursts, Madden Julian Oscillation

1990年代と2000年代における熱帯太平洋準10年スケール変動の長周期変調
Long-term modulation of the quasi-decadal scale variation in the tropical Pacific during the 1990s and 2000s

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熱帯太平洋に存在する準10年変動(QD変動)とエルニーニョ・エルニーニョモドキおよびラニーニャ・ラニーニャモドキ（経年スケール変動）の関係について、1990年代と2000年代の比較を行い、赤道太平洋からフィリピン海を含む熱帯太平洋の大気海洋に関する長周期変調に関する知見を得た。まず、中部赤道太平洋(Nino-3.4 region）の海面水温偏差のQDスケール成分を指数として、その正偏差が持続する期間をQD変動のQD positive periodと定義した。1990年代と2000年代において、QD positive period期間におけるQDスケールの海面水温偏差の合成図をそれぞれ作成した。1990年代および2000年代の合成図はともに過去の研究で指摘されたように、エルニーニョモドキに似た分布（すなわち、中部赤道太平洋で正の海面水温偏差、フィリピン海で負の海面水温偏差）を示した。QDスケールの海面水温偏差の振幅を1990年代と2000年代で比較すると、中部赤道太平洋の正偏差は2000年代の方が大きく、フィリピン海の負偏差は1990年代の方が大きいという違いが見られた。このQDスケールにおける相違と経年スケール変動との関係を探るために、経年スケールの海面水温偏差に関して、エルニーニョ・エルニーニョモドキの合成図解析を1990年代と2000年代のQD positive periodにおいてそれぞれ行った。その結果、1990年代の方が2000年代と比べて、中部赤道太平洋の正偏差とフィリピン海の負偏差の両方において振幅が大きいエルニーニョモドキ的なパターンが見られた。一方、ラニーニャ・ラニーニャモドキに関しては、1990年代では中部赤道域およびフィリピン海で負偏差が見られ、2000年代では中部赤道太平洋で1990年代よりも弱い負偏差、フィリピン海では1990年代とは異なり正偏差となっていた。以上のことから、1990年代は経年スケールのエルニーニョ・エルニーニョモドキに関係する中部赤道太平洋の正偏差およびフィリピン海の負偏差が2000年代よりも大きかったが、ラニーニャ・ラニーニャモドキに関しては1990年代ではフィリピン海および中部赤道太平洋において負偏差の値が大きかったために、QDスケールでは2000年代はフィリピン海の負偏差が1990年代よりも弱く、中部赤道太平洋の正偏差が1990年代よりも強くなったと考えられる。講演では、気象庁が長期間にわたり実施している東経137度沿いの観測ラインで得られた水温データや大気再解析データなどの解析結果を示し、さらに議論を行う予定である。

キーワード：準10年スケール変動、エルニーニョ/南方振動、熱帯太平洋
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

北太平洋亜熱帯循環内部領域の南下流変動に起因する熱輸送量変化

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.

キーワード：北太平洋亜熱帯循環、準10年変動、西部熱帯太平洋暖水プール
Keywords: North Pacific subtropical gyre, quasi-decadal variation, Tropical western Pacific warm pool

マッデン・ジュリアン振動相空間上における予報精度の評価手法

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

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気象庁の再解析データと予報データを用いて，マッデン・ジュリアン振動(MJO)相空間上での予報精度の指標を調査した．二変数二乗平均平方誤差(RMSE)と二変数アノマリ相関係数(ACC)に加えて，平均誤差ベクトルも評価する．これまでRMSEとACCの組み合わせが慣例的に使われてきたが，これらの評価方法はMJOイベントに関するモデルバイアスを評価できない．それだけでなく，ACCはMJOの振幅に強く依存するので，あるフェーズでMJOのシグナルが減衰する傾向にあるモデルにおいてACCを使うことは適切ではない．平均誤差ベクトルはモデルの平均テンデンシー誤差とRMSEを結びつけることでこの問題を解決する．たとえば気象庁の予報モデルは，MJO相空間上で一様な左向きベクトルであらわされる平均誤差を持ち，その振幅はRMSEと関係づけられる．この場合，MJOの予報精度の評価においては，RMSEと平均誤差の組み合わせを用いるべきである．

キーワード：マッデン・ジュリアン振動、予測可能性
Keywords: Madden-Julian oscillation, predictability

赤道インド洋東部において正のIOD時に現れる亜表層の塩分偏差

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.

キーワード：インド洋ダイポールモード、塩分変動、海洋上部成層、混合層厚
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

気象研究所における大気・海洋結合同化システムの開発
Development of a Coupled Atmosphere-Ocean Model in JMA/MRI

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大気海洋結合モデルに大気・海洋観測データを直接同化するシステムを大気海洋結合同化システムと呼び、これまで、数日先の気象を予測するいわゆる天気予報と数週間から数ヶ月先の気候予測を同一のモデルで行うシームレス予測の実現や、エルニーニョなどの予測のさらなる高精度化への有効性が指摘されている。例えばJAMSTECは、世界に先がけて４次元変分法による結合同化システムを開発し、エルニーニョ予測の改善の可能性を示している（e.g. Sugiura et al. 2008; Masuda et al. 2015）。また、気象研では、2006年より、結合モデルに海洋観測データのみを同化する（大気観測データは同化しない）準結合同化システムを開発し、大気モデルを観測海面水温データで駆動したAMIPランと比べて、ウォーカー循環やモンスーントラフ、フィリピン沖の熱帯低気圧の活動などが改善されることを確認している（Fujii et al. 2009, 2011）。
そのため近年NCEP、ECMWF、UKMOなどの現業機関が、シームレス予測や気候予測の高精度化に向けて、結合同化システムの開発、運用を開始している（Saha et al. 2010, Laloyaux et al. 2015, Lea et al. 2015）。ただし、現在開発されているのは、大気解析値は大気データ同化システム、海洋解析値は海洋データ同化システムで別々に作成し、これらの解析値から結合モデルで予測を行い次の解析時刻の第一推定値を作成するいわゆる弱結合同化システムである。弱結合同化システムでは、解析値を計算するときに大気と海洋のバランスを陽に評価していないという点で不十分であるが、既存の大気及び海洋の同化システムをそのまま利用できるので開発が比較的容易である。
気象研でも将来の気象庁現業での利用に向けて、４次元変分法全球大気同化システム（MRI-NAPEX）、全球海洋データ同化システム（MOVE-G2）、季節予報用大気海洋結合モデル（JMA/MRI-CGCM2）を組み合わせた弱結合データ同化システムの開発を行っている。このシステムでは、大気の同化ウィンドウは６時間、海洋の同化ウィンドウは１０日とし、MRI-NAPEXで計算された大気解析値を初期値とし、MOVE-G2で計算された海洋の解析インクリメントを与えながら、JMA/MRI-CGCM2を駆動することで、次の大気同化ウィンドウにおける大気初期推定値を算出する予定である。これは、4次元変分法同化システムにおいて大気モデルをいわゆるインナーループ、大気海洋結合モデルをいわゆるアウターループとして利用することに相当する。なお、本システムで利用するMOVE-G2およびJMA/MRI-CGCM2は、2015年6月より気象庁現業季節予報で使われている海洋データ同化システムおよび大気海洋結合モデルである。
気象研では、上記の弱結合同化システムの開発に先がけて、MOVE-G2およびJMA/MRI-CGCM2を用いた準結合同化システムを完成させ、準結合同化システムを用いた2000年以降の再解析実験を実施した。発表では、開発中の弱結合同化システムの仕様や特徴などについての紹介と共に、準結合同化システムの再解析実験の結果についても示す予定である。

キーワード：データ同化、シームレス予報、季節予報
Keywords: Data Assimilation, Seamless Forecasting, Seasonal Forecasting

