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

*Jin-Yi Yu[1]

1.University of California Irvine

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

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

*Ruihuang Xie[1,2], Fei-Fei Jin[3], Mu Mu[1,2]

1.Key Laboratory of Ocean Circulation and Waves, Institute of Oceanology, Chinese Academy of Sciences, Qingdao 266071, China, 2.Laboratory for Ocean and Climate Dynamics, Qingdao National Laboratory for Marine Science and Technology, Qingdao 266237, China, 3.Department of Atmospheric Sciences, School of Ocean and Earth Science and Technology, University of Hawaii at Manoa, HI 96822, USA

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

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ENSO diversity generated by the state dependence of westerly wind events

*Michiya Hayashi[1], Masahiro Watanabe[1]

1.Atmosphere and Ocean Research Institute, the University of Tokyo

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

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

*Yuxing Yang[1], Ruihuang Xie[1], Faming Wang[1], Fei Huang[2]

1.Key Laboratory of Ocean Circulation and Wave, Institute of Oceanology, Chinese Academy of Science, 2.Ocean University of China

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

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

*Dachao Jin[1,2], Liwei Huo[2], Saji Hameed[1], Pinwen Guo[2]

1.University of Aizu, 2.Nanjing university of Information Science & Technology

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

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

*Yu Kosaka[1], Shang-Ping Xie[2], Hisayuki Kubota[3], Yan Du[4], Kaiming Hu[5], Jasti S Chowdary[6], Gang Huang[5]

1.Research Center for Advanced Science and Technology, University of Tokyo, 2.Scripps Institution of Oceanography, University of California San Diego, 3.JAMSTEC, 4.South China Sea Institute of Oceanography, Chinese Academy of Sciences, 5.Institute of Atmospheric Physics, Chinese Academy of Sciences, 6.Indian Institute of Tropical Meteorology

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

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A sea surface salinity dipole mode in the tropical Indian Ocean

*Yan DU[1], Yuhong Zhang[1], Tangdong Qu

1.South China Sea Institute of Oceanology, Chinese Academy of Sciences

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

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

*Takanori Horii[1], Wenju Cai[2], Kanako Sato[1], Kentaro Ando[1]

1.Research and Development Center for Global Change (RCGC), Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 2.Commonwealth Scientific and Industrial Research Organisation (CSIRO)

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

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

*Tomoki Tozuka[1], Satoru Endo[1]

1.Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo

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

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On semiannual equatorial undercurrents in the eastern Indian Ocean

*Motoki Nagura[1], Michael J. McPhaden[2]

1.Japan Agency for Marine-Earth Science and Technology, 2.National Oceanic and Atmospheric Administration

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

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

*Tomoe Nasuno[1], Kunio Yoneyama[1], Masaki Katsumata[1], Shuichi Mori[1], Junko Suzuki[1]

1.Japan Agency for Marine-Earth Science and Technology

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

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

*Pascal Oettli[1], Yushi Morioka[1], Toshio Yamagata[1]

1.Japan Agency for Marine-Earth Science and Technology

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".

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