Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

ACG37-01 Room:423 Time:April 28 11:00-11:25

What the recent international field campaign in and around the Indian Ocean has advanced our knowledge of the MJO?

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A coordinated international field experiment with special focus on the convective initiation mechanism study of the Madden-Julian Oscillation (MJO) took place in and around the central equatorial Indian Ocean from October 2011 through January 2012. This campaign consisted of several projects including CINDY2011 (Cooperative Indian Ocean experiment on intraseasonal variability in the Year 2011), DYNAMO (Dynamics of the MJO), AMIE (Atmospheric Radiation Measurement program - MJO Investigating Experiment), and LASP (Littoral Air-Sea Process). More than 70 institutes/universities from 16 countries joined the campaign. During a four-month intensive observing period from October through January, three MJO events were observed. It is worth noting that while it is clear to identify three events (late October, late November, and late December) from the time-longitude cross section of outgoing long-wave radiation data along the equator, the most popular MJO identification method - Real-time multivariate MJO Index introduced by Wheeler and Hendon (2004) - could not capture the December event.

While the vertical stepwise moistening which was trapped around trade inversion and 0degC level were confirmed from the equatorial sounding data as previously reported, it was emphasized that lateral transport of moisture and dry air from the Southern Hemisphere as well as westward-propagating disturbances from the Indonesian Maritime Continent were also keys. Several topics from published works during past 2 years after the campaign will also be introduced to indicate what we expected and what are not.

Keywords: Madden-Julian Oscillation, CINDY2011

ACG37-02 Room:423 Time:April 28 11:25-11:40

Mesoscale Convective Complex Activities over Indian Ocean and Their Effects on Convections Over Sumatera Island

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Effects of Mesoscale Convective Complexes (MCC) over Indian Ocean on convections over Sumatera Island have been investigated using Multi-functional Transport SATellite (MTSAT) infrared (IR1) imageries, Tropical Rainfall Measuring Mission (TRMM) rainfall data and Cross-Calibrated Multi-Platform (CCMP) surface wind data of 10-year period (2000-2009). Occurrences of MCC were identified using an algorithm that combines criteria of cloud coverage, eccentricity, and cloud lifetime. This study begins with a case study on 16 to 17 August 2005 and 27 to 28 October 2007 to show the evolution of MCC, we found the development phase of MCC was accompanied by surface wind convergence, while wind divergence was clearly seen below decaying MCC. Following the decay of MCC, convective activities were observed in the surrounding regions by the presence of a new convective cell around the MCC, indicating the role of cold pool mechanism. The new convective cell was generated from cold pool affect convective clouds in the surrounding area and propagate to over Sumatra Island so causing extreme rainfall over Sumatra.

The correlation between MCC and convection over Sumatera was further investigated by performing composite analysis using more samples of MCC events. During the 10-year period, about a number of 553 MCC events have been identified over Indian Ocean. However, it is of interest to that MCC events tend to occur with significantly higher frequency during the monsoon transition season of March- April-May (MAM) period. Available data suggest that the life cycle of MCC over Indian Ocean is about 12 to 15 hours. Results of composite analyses confirmed that the MCC have significant influence on the development of cloud convection over Sumatera Island by means of cold pool propagation mechanism. This seems to imply that weather observations over the western Indian Ocean are crucial for rainfall prediction in Sumatera regions.

Keywords: Cold Pool, MCC, Convection, Rainfall

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

ACG37-03 Room:423 Time:April 28 11:40-11:55

Observed moisture variations associated with shallow convection

BELLENGER, Hugo[1*] ; KATSUMATA, Masaki[1] ; YONEYAMA, Kunio[1] ; NISHIZAWA, Tomoaki[2] ; YASUNAGA, Kazuaki[3] ; SHIROOKA, Ryuichi[1]

[1]JAMSTEC, [2]NIES, [3]University of Toyama

The variability of tropospheric moisture is a key feature of tropical climate. In particular, the importance of moisture variations due to convective transport is still to be quantified on a variety of spatial and temporal scales. For instance, there is a debate on the importance of moisture convective transport in preconditioning the atmosphere prior to deep convection development associated with the Madden–Julian Oscillation (MJO). We use here high frequency observations of humidity and convection in the Indian Ocean by lidars and radars on board the R/V Mirai during the CINDY/DYNAMO campaign. Significant moisture variations on the scale of few hours are observed within the first first kilometers of the atmosphere in association with shallow convective and congestus clouds. We then compare these local tendencies with large–scale ones and discuss the potential importance of convective transport by convection in the moisture budget during the transition from convectively suppressed to convectively active periods.

Keywords: Convection, moisture, MJO, CINDY/DYNAMO, preconditionning, observation

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

ACG37-04 Room:423 Time:April 28 11:55-12:10

In-situ observed detailed temperature profile in surface 10-meter layer over the tropical western Pacific

KATSUMATA, Masaki[1*] ; BELLENGER, Hugo[1] ; YONEYAMA, Kunio[1]

[1]JAMSTEC

The oceanic thermal stratification in the first meters impacts significantly the energy exchanges between the atmosphere and the ocean by modulating the skin Sea Surface Temperature (SST). A thermistor chain was deployed from a research vessel to continuously measure the temperature profile in the ocean first 10 meters during 17 days in June 2013 in the tropical western Pacific (12N-135E). A clear diurnal cycle was captured with daytime warming in the first meters of the ocean that gradually decrease and deepened during the evening. In addition, a 0.5K-cooling event of the first meter with duration of about 3 hours was also captured during the passage of precipitating cloud system. By utilizing meteorological data from on-board instruments, we asses the relative importance of precipitation and accompanying cold pool in this cooling event.

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

ACG37-05 Room:423 Time:April 28 12:10-12:25

Abrupt cooling associated with the oceanic Rossby wave and lateral advection during CINDY2011

SEIKI, Ayako[1*] ; KATSUMATA, Masaki[1] ; HORII, Takanori[1] ; HASEGAWA, Takuya[1] ; RICHARDS, Kelvin J.[2] ; YONEYAMA, Kunio[1] ; SHIROOKA, Ryuichi[1]

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The cooperative Indian Ocean experiment on intraseasonal variability in the Year 2011 (CINDY2011) was conducted to capture atmospheric and oceanic characteristics of the Madden-Julian Oscillation (MJO) in the central Indian Ocean from late 2011 to early 2012. During CINDY2011, the research vessel (R/V) MIRAI stayed at 8 ^{o} S, 80.5 ^{o} E for two months during the special observing period (SOP). Intraseasonal convection associated with the MJO was organized in the central Indian Ocean in late October and late November during the SOP. In the middle of November, both sea surface temperature (SST) and mixed layer temperature decreased suddenly when cold low salinity water intruded into the upper layer around the R/V MIRAI. This intrusion was accompanied by a surface current change from southwestward to westward/west-northwestward associated with the passage of the annual oceanic downwelling Rossby wave. The mixed layer heat budget analysis shows that horizontal advection plays an important role in the abrupt cooling whereas the net surface heat flux cannot account for the cooling. This is an interesting result because the associated downwelling Rossby wave is usually considered to increase SST through a reduction of entrainment cooling. In addition, for the second MJO event convection was activated around 20 November over the central north and equatorial Indian Ocean but not in the south. It is suggested that the cooler surface waters (as seen at the location of the R/V MIRAI) tended to suppress the initial atmospheric convection, resulting in the lagged convective onset in the end of November over the central south Indian Ocean.

Keywords: CINDY2011, abrupt cooling, Indian Ocean

ACG37-06 Room:423 Time:April 28 14:15-14:30

Modulation of Equatorial Turbulence by Tropical Instability Waves

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[1]JAMSTEC, [2]University of Washington, [3]Oregon State University, [4]University of Miami

Strong modulation of turbulent mixing by a westward propagating Tropical Instability Wave (TIW) was observed during October and November 2008 on the equator at 140^{o}W in the stratified shear layer between the equatorial undercurrent (EUC) and the surface mixed layer. At these depths, the unique deep diurnal-cycle mixing in the stratified layer under the equatorial cold tongue was observed with nighttime turbulent mixing a factor of 10 greater than during daytime. The turbulent kinetic energy dissipation rate, ϵ, was O(10^{-6})Wkg^{-1}, and the turbulent heat flux was ~500 Wm^{-2}, at least 5-10 times greater than previously observed at the central equatorial Pacific. Turbulence mixing varied significantly during the four distinct phases of the meridional flow associated with the TIW: steady northward (~0.6 ms^{-1}), northward-to-southward transition, steady southward (~-0.6 ms^{-1}), and southward-to-northward transition. During the northward-to-southward transition, we observed the largest values of reduced shear squared (Sh^2?4N^2), where Sh^2 is the total shear squared and N^2 the buoyancy frequency squared, the thickest nighttime surface mixed layer, the deepest penetration of the deep-cycle turbulence, and the largest turbulent heat flux and largest integrated ϵ in the deep-cycle layer. During steady southward flow, the depth of the bases of the nighttime surface mixed layer and of the deep-cycle layer were shallowest. For the first time, a 50-m-thick layer of strong turbulence was observed immediately above the EUC core during the northward-to-southward and steady southward phases. The average ϵ exceeded 10-^{6} Wkg^{-1}, the eddy diffusivity was ~10^{-3} m^{2}s^{-1}, and the turbulent heat flux was ~500 Wm^{-2}. It is likely that to accurately parameterize mixing in the central equatorial Pacific, numerical models must properly simulate not only the enhancement of mixing associated with TIWs but also the variability of mixing within individual TIWs. In this talk, some results from the extensive (from November 2008 to February 2009) mooring data set, comparisons with a general circulation model, and details of mixing events will also be shown.

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

ACG37-07 Room:423 Time:April 28 14:30-14:45

Air-sea interaction over the northern edge of the Pacific wam pool

HASEGAWA, Takuya[1*] ; NAGANO, Akira[1] ; HATTORI, Miki[1] ; INOUE, Tomoshige[1] ; KUBOTA, Hisayuki[1]

[1]JAMSTEC

Abstract is written in Japanese.

Keywords: norhtern edege of the Pacific warm pool, air-sea interaction, multi-scale temporal-spatial variability

ACG37-08 Room:423 Time:April 28 14:45-15:00

Why is initialization of heat content anomalies in the tropical Indian Ocean difficult in a CGCM with SST-nudging?

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We have evaluated oceanic initial conditions in the tropical Indian and Pacific Oceans prepared by a coupled general circulation model (CGCM) with a sea surface temperature (SST)-nudging scheme. It is shown that the heat content anomalies in the upper 150 m are generated extremely well in the Pacific even though only the SST data is incorporated. In contrast, the upper ocean heat content anomalies produced by the model have negative correlation coefficients over vast areas of the tropical Indian Ocean. We propose that this is due to a difference in the SST-outgoing longwave radiation (OLR) relationship between the Indian and Pacific Oceans; the use of SST-nudging generally assumes that correlation coefficients between SST and OLR are negative, but this is not necessarily true. The correlation coefficients between SST and OLR anomalies are negative in the central to eastern equatorial Pacific, and this feature is well reproduced in the model. As a result, equatorial zonal wind anomalies are well captured by the model, and forced equatorial Kelvin and Rossby waves are accurately reproduced. On the other hand, the model cannot capture the observed positive correlation coefficients in the eastern equatorial Indian Ocean, particularly from January to April. As a result, equatorial zonal wind anomalies tend to have an opposite sign and induce equatorial Kelvin and Rossby waves with a wrong sign. The positive correlation between SST and OLR is an outcome of remote influence, but this is more difficult to simulate in an atmospheric general circulation model (AGCM) and a CGCM with strong SST nudging, in which local air-sea interaction is not explicitly allowed. Since the results presented in this study is based on a single model, it will be interesting to check skills of other models in initializing the upper ocean heat content with an SST-nudging scheme.

Keywords: Tropical Indian Ocean, Ocean-atmosphere coupled model, SST-OLR relationship, Upper ocean heat content, SST-nudging

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

ACG37-09 Room:423 Time:April 28 15:00-15:15

Two flavors of the Indian Ocean Dipole

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The Indian Ocean Dipole (IOD) is known as a climate mode in the tropical Indian Ocean accompanied by negative (positive) sea surface temperature (SST) anomalies over the eastern (western) pole and easterly wind anomalies along the equator during its positive phase. However, the western pole of the IOD is not always covered by positive SST anomalies throughout the region. For this reason, the IOD is further classified into two types in this study based on SST anomalies in the western pole. The first type is close to the canonical IOD with negative (positive) SST anomalies in the eastern (central to western) tropical Indian Ocean. The second type, on the other hand, is associated with negative SST anomalies in the eastern and western tropical Indian Ocean and positive SST anomalies in the central tropical Indian Ocean. Based on a composite analysis, it is found that easterly wind anomalies reach the east coast of Africa in the first type, and as a result, positive rainfall anomalies are observed over East Africa. Also, due to the basin-wide easterly wind anomalies, the first type is accompanied by strong sea surface height (SSH) and thermocline depth anomalies. In contrast, zonal wind anomalies converge in the central tropical Indian Ocean in the second type, and no significant precipitation anomalies are found over East Africa. Also, only weak SSH and thermocline depth anomalies are seen during the second type, because equatorial downwelling anomalies induced by westerly wind anomalies in the west are counteracted by equatorial upwelling anomalies caused by easterly wind anomalies in the east. Due to the above difference in oceanic anomalies, the first type is stronger and lasts longer than the second type.

ACG37-10 Room:423 Time:April 28 15:15-15:30

Evolution and mechanism of the positive Indian Ocean Dipole event in 2012

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Evolution and mechanism of a peculiar positive Indian Ocean Dipole (IOD) event that occurred in 2012 are examined. In contrast to the normal IOD event, which starts to develop in late boreal spring, peaks in fall, and decays in winter, the 2012 IOD event was initiated in July, peaked in August, and decayed quickly in fall. Although the normal IOD event is associated with shallower thermocline in the eastern equatorial Indian Ocean, it was deeper than normal in 2012 and this may have delayed the onset of the IOD in this year. For quantitative discussions, mixed layer temperature balance of the eastern pole of the IOD is calculated using outputs from an ocean general circulation model. In agreement with past studies, negative sea surface temperature anomalies in the eastern pole are generated mainly owing to anomalous cooling by the vertical terms (i.e. entrainment and turbulent vertical diffusion) during the normal IOD. However, anomalous cooling by the surface heat flux term played the dominant role in the development of the eastern pole in 2012, and the vertical terms opposed the anomalous cooling. The anomalous cooling by the surface heat flux term is due to stronger cooling by latent heat flux. Also, warming of the surface mixed layer by the climatological shortwave radiation was suppressed owing to deeper mixed layer.

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

ACG37-11 Room:423 Time:April 28 15:30-15:45

Interannual Variability in SST off Bangladesh

NAGURA, Motoki[1*] ; TERAO, Toru[2] ; HASHIZUME, Masahiro[3]

[1]JAMSTEC, [2]Kagawa University, [3]Nagasaki University

Oceanic variability off Bangladesh is one of the environmental factors which can impact on the local community. For example, Hashizume et al. (2011) pointed out that the number of cholera patients increases in Dhaka, which is populated by 15 million people and the largest city in Bangladesh, when sea surface temperature (SST) off Bangladesh rises. This study examines interannual SST variability in the coastal regions off Bangladesh, which has not attracted much attention in climate sciences so far. We detect a significant interannual SST variability off Bangladesh in two different satellite datasets (NOAA OI SST and TMI SST) and a high-resolution ocean general circulation model driven by a reanalysis dataset. The SST variability is trapped near the coast, amounts to 0.5 to 1.0 degrees Celsius in magnitude, and peaks in the boreal winter. The two observational datasets and the model results show consistency in the spatial and temporal patterns of SST variability, which gives credibility to the detected phenomenon. A statistical analysis shows that SST off Bangladesh tends to be high in the year next to El Nino and in the year of negative Indian Ocean Dipole events, suggesting those climate modes as possible drivers. We are conducting a mixed layer heat budget analysis using the model output, a preliminary result of which shows that a thick barrier layer caused by the freshwater supply from the Ganges plays a role in the generation of the SST variability. Details of the mixed layer heat budget analysis will be reported in the meeting.

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

ACG37-12 Room:423 Time:April 28 15:45-16:00

A drastic change in predictability of precipitation off the west coast of Australia after late 1990s

DOI, Takeshi[1*] ; BEHERA, Swadhin[1] ; YAMAGATA, Toshio[1]

[1]JAMSTEC APL

Global warming and natural decadal variability after late 1990s strongly warm the coastal ocean off West Australia, which drastically changed climate dynamics there. The warm ocean drives precipitation locally there after the late 1990s, while the local atmospheric variability or the remotely forced atmospheric bridges mainly controlled the local precipitaiton variability before that. By virtue of that, precipitation predictability off West Australia on a seasonal time scale is also drastically changed after late 1990s; austral summer precipitation off West Australia is significantly predictable 5 months ahead after late 1990s, while there is no predictability of that in 1980s and early 1990s. Although the high prediction skill of precipitation off West Australia is useful for its early warning to extreme events and reducing their damages, the extreme event itself might increase due to global warming and decadal climate variability through a local air-sea feedback.

Keywords: Seasonal prediction, Precipitation, Ningaloo Nino

ACG37-13 Room:423 Time:April 28 16:15-16:35

Interdecadal Amplitude Modulation of ENSO and its Impacts on TPDV

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ENSO is a major climate mode in the tropical Pacific, and its interdecadal variabilities in ENSO characteristics (e.g. amplitude, propagation, period) are investigated as responses to background mean state change. On the other hand, tropical Pacific decadal variability (TPDV) is known as a major decadal-interdecadal variability, and coupled-GCM has revealed that ENSO also acts to TPDV. This study shows that the GFDL coupled-GCM (GFDL-CM2.1) also captures significant relationship between ENSO amplitude modulation and TPDV in interdecadal timescale. Furthermore, importance of ENSO rectification on TPDV is investigated by OGCM sensitivity experiments.

Keywords: air-sea interaction, tropical ocean, ENSO

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

ACG37-14 Room:423 Time:April 28 16:35-16:50

The role of interaction between the Pacific and the north Atlantic Oceans in the prediction of ENSO

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Observational and climate modelling studies indicate a close link between the north tropical Atlantic (NTA) sea surface temperature anomalies (SSTA) and the El Nino-Southern Oscillation (ENSO). An El Nino peak in boreal winter is followed by a warming of the NTA SSTA in the subsequent spring, which in turn leads to a La Nina in the following autumn/winter. Using the seasonal prediction system based on the atmosphere and ocean general circulation model (AOGCM) MIROC5, we conducted an ensemble of hindcast experiments from 1979 to present, in which the transition from El Nino to La Nina in 1997-1998 was successfully predicted. We also conducted a series of accompanying sensitivity experiments targeted at the transition event in 1997-1998, in which the NTA or equatorial Pacific air-sea interactions were decoupled. We found that NTA SSTA plays an important role in increasing the skill in predicting the following La Nina event. We also found that the preceding particularly-large El Nino SSTA and the associated atmospheric bridge are essential for the generation of NTA SSTA of the observed magnitude.

References

Ham, Y.-G., J.-S. Kug, J.-Y. Park, and F.-F. Jin, 2013: Sea surface temperature in the north tropical Atlantic as a trigger for El Nino/Sourthern Oscillation events, Nature Geoscience, 6, 112-116.

Keywords: ENSO, the north tropical Atlantic climate variability, seasonal prediction, atmosphere and ocean general circulation model

ACG37-15 Room:423 Time:April 28 16:50-17:05

Important factors for long-term change in ENSO transitivity

OHBA, Masamichi[1*]

[1]CRIEPI

El Nino and La Nina exhibit significant asymmetry in their duration. El Nino tends to turn rapidly into La Nina after the mature, while La Nina tends to persist for up to 2 years. Reconstructed historical sea surface temperatures (SST) show a significantly increase in the intensity of El Nino-Southern Oscillation (ENSO) asymmetry, particularly El Nino transitivity, during the last six decades. Atmospheric observational data have shown that the relationship between El Nino and surface zonal wind anomalies over the equatorial Western Pacific (WP) has strengthened, and anomalous WP easterlies have appeared after the 1970s climate regime shift. To investigate the dependency of ENSO transitivity on its amplitude, a suite of idealized experiments using an atmospheric general circulation model (AGCM) is performed by imposing historical SST and 12 different ENSO-related SST anomalies exhibiting equal spatiotemporal distribution but different amplitude. Our AGCM experiments show strong nonlinearity in the WP zonal wind against the amplitude of the warm phase.

Keywords: Sea surface temperature, Pacific Ocean, El Nino/Southern Oscillation, Indian Ocean

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

ACG37-16 Room:423 Time:April 28 17:05-17:20

Temporal variations of Mascarene High in austral summer and their causes, and influences on the SST field

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Changes in intensity and longitudinal/latitudinal position of Mascarene High (MH) in austral summer (November-January) from 1951 to 2012 are investigated using NCEP-NCAR reanalysis dataset. We define the MH intensity and longitudinal/latitudinal position as sea level pressure (SLP) maximum within a region of [40E-120E, 50S-10S]. The intensity has an interannual variation on a dominant timescale of 3-4 years. The pressure variations associated with the intensity show annular and equivalent barotropic structures throughout the troposphere, which are similar to Southern Annular Mode (SAM). The intensity time series shows a significant correlation with the SAM index. Therefore, it is suggested that the MH intensity variation results from the SAM. The MH longitudinal position also shows an interannual variation on a dominant timescale of 5-6 years and the time series has no significant correlation with the intensity time series. The SLP anomalies associated with the longitudinal variation represent a dipole pattern, whose centers of action are located off the western Australia (WA) and off the south-eastern Madagascar Island (SEMI). The geopotential height anomalies in these regions have different vertical structures; those off the WA are confined from the sea surface to the middle troposphere, while those off the SEMI are distributed throughout the troposphere. In addition, the SLP anomalies averaged within these regions show no significant correlation. It is indicated that the SLP variations off WA are associated with El Nino Southern Oscillation (ENSO). On the other hand, the SLP changes off the SEMI have no relationship with the large-scale atmospheric variations such as SAM and ENSO.

The MH intensity variation forms southwest-northeast dipole pattern of sea surface temperature (SST) field, which resembles the Indian Ocean Subtropical Dipole (IOSD) pattern. In addition, the MH longitudinal changes also show the dipole pattern, which is shifted westward by 10 degrees in longitude compared to the SST pattern associated with the intensity variation. The correlations between the MH variations and IOSD index show significant values (0.39 for intensity and -0.57 for longitudinal position). Therefore, it is suggested that both the changes in the intensity and the longitudinal position cause the IOSD.

Keywords: Mascarene High, Indian Ocean Subtropical Dipole, El Nino Southern Oscillation, Southern Annular Mode

ACG37-17 Room:423 Time:April 28 17:20-17:35

Role of tropical SST variability in the generation of subtropical dipoles

MORIOKA, Yushi[1*] ; MASSON, Sebastien[2] ; TERRAY, Pascal[2] ; PRODHOMME, Chloe[2] ; BEHERA, Swadhin[3] ; MASUMOTO, Yukio[4]

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Interannual variations of Sea Surface Temperature (SST) in the midlatitudes of the Southern Hemisphere play an important role in the rainfall variability over the surrounding countries by modulating synoptic-scale atmospheric disturbances. These are frequently associated with a northeast-southwest oriented dipole of positive and negative SST anomalies in each oceanic basin, referred to as a subtropical dipole. This study investigates the role of tropical SST variability on the generation of subtropical dipoles by conducting SST-nudging experiments using a coupled general circulation model. In the experiments where the simulated SST in each tropical basin is nudged to the climatology of the observed SST, the subtropical dipoles tend to occur as frequently as the case in which the simulated SST is allowed to freely interact with the atmosphere. It is found that without the tropical SST variability, the zonally elongated atmospheric mode in the mid-high latitudes, called the Antarctic Oscillation (AAO), becomes dominant and the stationary Rossby waves related to the AAO induce the SLP anomalies in the midlatitudes, which, in turn, generate the subtropical dipoles. These results suggest that the tropical SST variability may not be necessary for generating the subtropical dipoles, and hence provide a useful insight into the important role of the AAO in the midlatitude climate variability.

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

ACG37-18 Room:423 Time:April 28 17:35-17:50

Mechanism of long-term change in the Indian Ocean subtropical dipole mode

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The Indian Ocean subtropical dipole (IOSD) is a climate mode in the Southern Indian Ocean associated with negative sea surface temperature (SST) anomalies in the southeastern tropical Indian Ocean and positive SST anomalies in the southwestern part of the southern Indian Ocean during its positive phase. In this study, the long-term change in the IOSD is investigated for the first time using observational data and outputs from an ocean general circulation model. It is found that the frequency of the IOSD has become higher in the recent decade because of a decreasing trend in the mixed layer depth (MLD) over the southwestern pole in January and February. Positive (Negative) SST anomalies associated with the IOSD are generated when the mixed layer becomes anomalously shallow (deep) and the warming of the mixed layer by the climatological shortwave radiation is enhanced (suppressed). The thinner mixed layer in the recent decade amplifies this effect and even weak atmospheric forcing may trigger the IOSD. Based on a diagnosis of the Monin-Obukhov depth, we show that an increasing trend of surface heat flux is the cause of the decreasing trend in the MLD. On the other hand, it is found that the amplitude of the IOSD has become smaller. This is because the IOSD generally starts to develop in December, but the thicker mixed layer in December in the recent decade is unfavorable for its development. Also, the thinner mixed layer in January and February amplifies the negative feedback processes that damp the SST anomalies, as well as the positive effect on generating the SST anomalies. Since no long-term change in atmospheric forcing corresponding to that in the IOSD is observed, the long-term change in the MLD is essential in that of the IOSD.