Coupled Physical Processes in the Bay of Bengal and Monsoon Air-Sea Interaction

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The Bay of Bengal (BoB) receives about 4000 km^3 of freshwater every year from summer monsoon rainfall and river discharge. The freshwater persists in the northern BoB for about three seasons, resulting in a near-surface stratified layer (usually less 30 m deep) with warm subsurface water. The meso-scale eddy flow and wind-driven shallow Ekman flow play major role in dispersing the riverwater in the Bay. The pathways of the riverwater can have significant year-to-year changes. The freshwater further strengthens the near-surface currents by squeezing the Ekman layer. As part of the OMM-ASIRI initiative, in the last four years we made intense fine-scale observations of near-surface temperature, salinity and currents in the north BoB from various platforms like moorings, research ships and other autonomous instruments including gliders, Lagragian floats. Our ship-based observations suggest presence of strong submesoscale (order 10 km) fronts, which could set the near-surface stratification by slumping the denser water under the light water. The shallow mixed layer influences the air-sea interaction on diurnal to subseasonal timescales. The monsoon active-break spells modulate the mixed layer depth, winds, air temperature and humidity just above the ocean surface. We discuss the relevence of these processes in observations and model simulations.

Keywords: Salinity, Near-surface stratification, Freshwater dispersal, Air-sea interation

The impact of full 3D ocean coupling to MJO simulations using the global cloud/cloud-system resolving model NICAM.

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The global cloud/cloud-system resolving model NICAM and its new fully-coupled version NICOCO is run on one of the worlds top-tier supercomputers, the K computer. NICOCO couples the full-3D ocean component COCO of the general circulation model MIROC using a general-purpose coupler Jcup. We carried out multiple MJO simulations using NICAM and the new ocean-coupled version NICOCO to examine their extended-range MJO prediction skills and the impact of ocean coupling. NICAM performs well in terms of MJO prediction, maintaining a valid skill up to 27 days after the model is initialized (Miyakawa et al 2014). Here we focus on the initial 100 days to estimate the early drift of the model, and subsequently evaluate MJO prediction skills of NICOCO. Results show that in the initial 100 days, NICOCO forms a La-Nina like SST bias compared to observation, with a warmer Maritime Continent warm pool and a cooler equatorial central Pacific. The enhanced convection over the Maritime Continent associated with this bias project on to the real-time multi-variate MJO indices (RMM, Wheeler and Hendon 2004), and contaminates the MJO skill score. However, the bias does not appear to demolish the MJO signal severely. The model maintains a valid MJO prediction skill up to nearly 4 weeks when evaluated after linearly removing the early drift component estimated from the 54 simulations. Furthermore, NICOCO outperforms NICAM by far if we focus on events associated with large oceanic signals, such as the 1998 MJO event that is suggested to have ended the intense 1997/1998 El Niño.

キーワード：MJO、ENSO、全休雲解像モデル
Keywords: MJO, ENSO, global cloud resolving model

Thermodynamical processes associated with the life-cycle of the Monsoon intraseasonal variability in CFES integrations

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The equatorially trapped convective anomalies associated with the Madden-Julian oscillation (MJO) interacts with the mean monsoon during boreal summer resulting in north-northward migration of convective anomalies over the northern Indian Ocean and tropical west Pacific. First, in climate models, the necessary and sufficient conditions required for realistic simulation of monsoon intraseasonal variability will be summarized. Second, moisture and moist static energy budget diagnostics are applied to free runs of two versions of Coupled model For Earth Simulator (CFES) –difference between the two runs being changes made to cumulus convective schemes, particularly the vertical structure of entrainment. Third, budget diagnostics are applied to an AMIP-type simulation performed with the Atmospheric model For Earth Simulator (AFES). In the model simulations, the leading thermodynamical processes responsible for the monsoon variability will be discussed. Finally, results from CFES and AFES runs will be compared to understand (if any) the role of air-sea interaction in monsoon intraseasonal variability characteristics.

Keywords: CFES, Moist Static energy budget

Origins of biases in the Arabian-Sea climatological state for the CMIP5 models

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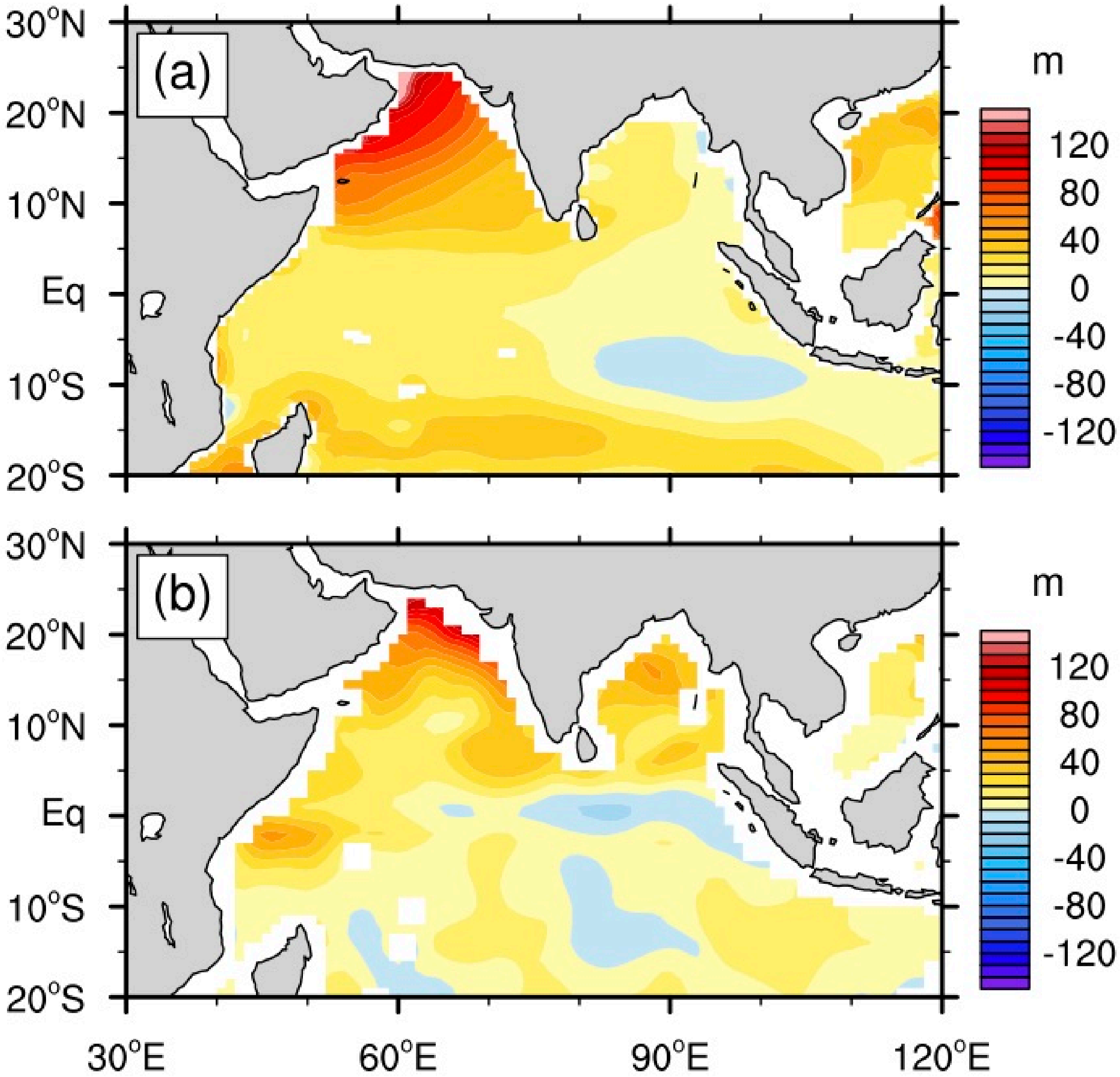
In this study, we investigate biases of a suite of 32 coupled ocean-atmosphere models in representing the climatological mean state of the Arabian Sea, as measured by differences between climatologies of the model fields and observations. The suite consists of 31 models from the Coupled Model Intercomparison Project Phase 5 (CMIP5) and the Coupled model For the Earth Simulator (CFES) developed at the Japan Agency for Marine-Earth Science and Technology (JAMSTEC). In the multi-model-mean fields, errors in the depth of the 20°C isotherm (D20) are largest in the northwestern corner of the Arabian Sea basin (Fig. 1a), suggesting they are linked to errors in the models' simulation of Arabian Sea High Salinity Water (ASHSW), which is a watermass generated along the northern boundary of the Arabian Sea. In addition, the mixed-layer thickness (MLT) increases to unrealistically large values near the northern boundary of the basin during the winter (Fig. 1b). Another prominent bias occurs for sea-surface salinity (SSS) along the west coast of India, which is linked to SSS errors in the Bay of Bengal that are advected into the northern Arabian Sea by the West Indian Coastal Current (WICC). Our analyses suggest the following conclusions. The MLT bias leads to the generation of too much ASHSW and its spread into the interior of the northern Arabian Sea, resulting in the excess volume of upper water and thus the D20 bias. The wintertime MLT bias is most strongly linked to the density stratification (jump) across the bottom of the mixed layer, rather than to errors in the surface buoyancy flux. In turn, the density jump is determined largely by SSS advected by WICC along the west coast of India. Ultimately, then, the stratification errors in the northern Arabian Sea are linked to errors in the freshwater input (rain and river outflow) into the Bay of Bengal.

キーワード：大気海洋結合モデル、CMIP 5、モデルバイアス、インド洋
Keywords: Atmosphere-Ocean coupled models, CMIP 5, model bias, Indian Ocean


(a)
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Interannual and decadal variability of the 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 ten years sea surface salinity (SSS) data from Argo, 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: S-IOD, SST-precipitation-SSS feedback, tropical Indian Ocean, Argo

Present-day zonal wind influences projected Indian Ocean Dipole skewness

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A prominent feature of the Indian Ocean Dipole (IOD) is its positive skewness, where positive phases tend to be stronger in amplitude than the negative phase. Positive IOD events are associated with devastating floods over parts of East Africa and India whilst Australia and Indonesia experience dry conditions. Under greenhouse warming, climate models project a weakening of the positive IOD skewness but their simulation of present-day skewness is too weak. Here we show that this bias and the projected skewness change is related to the simulation of the climatological zonal wind in the central equatorial Indian Ocean. In particular, models with overly weak present-day westerlies, which is a common model bias, generate overly weak present-day skewness and a smaller projected reduction in skewness. Improving the ability of models in simulating stronger westerly winds may lead to stronger present-day simulated skewness and a larger skewness reduction in a warmer climate.

Keywords: Indian Ocean Dipole, CMIP5, Tropical climate, Climate change

Dynamics of the atmospheric boundary layer response to ocean mesoscale sea surface temperatures

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The impact of the mid-latitude ocean on the atmosphere has been a long standing area of research, that was upended with observations of ubiquitous imprints of ocean meso-scale sea surface temperatures on near surface winds. Here, we test a recent theory for the mid-latitude atmospheric response to ocean mesoscale sea surface temperature (SST) in the Southern Ocean. The theory is based on a linearization about a spatially uniform, large-scale Ekman spiral of the steady state, atmospheric boundary-layer dynamics, and yields the atmospheric response as classical Ekman dynamics extended to include advection, and sea surface temperature induced changes of atmospheric mixing and hydrostatic pressure. The theoretical response is governed by spectral transfer functions between sea surface temperature and boundary layer variables. Transfer functions estimated from an extended integration of an atmospheric general circulation model, AFES, are consistent with the theory, and suggest that it faithfully captures the underlying physics. Regressions or 'coupling coefficients' between surface wind stress and sea surface temperatures are explained by SST induced changes of the surface stability, that directly impact surface stress, and changes of the surface winds as described by the theory.

Keywords: air-sea interaction, sea surface temperature, ocean mesoscale

Pacific trade winds accelerated by aerosol forcing over the past two decades

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The Pacific trade winds, coupled with the zonal sea surface temperature (SST) gradient in the equatorial Pacific Ocean, control regional sea levels and thereby their trend is a great concern in the Pacific Rim. Over the past two decades, easterly winds have been accelerated in association with eastern tropical Pacific cooling. They may represent natural interdecadal variability in the Pacific and possibly explain the recent global warming hiatus. However, the intensification of the winds has been the strongest ever observed in the past century, the reason for which is still unclear. Here we show using multiple climate simulations for 1921–2014 by a global climate model that approximately one-third of the trade wind intensification for 1991–2010 can be attributed to changes in sulphate aerosols. The multidecadal SST anomaly induced mostly by volcanic aerosols dominates in the western North Pacific (WNP), and its sign rapidly changed from negative to positive in the 1990s coherently with Atlantic multidecadal variability. The WNP warming resulted in intensification of trade winds to the west of the dateline. These trends have not contributed much to the global warming hiatus, but have greatly impacted rainfall over the western Pacific islands.

Nonlinear ENSO Warming Suppression (NEWS)

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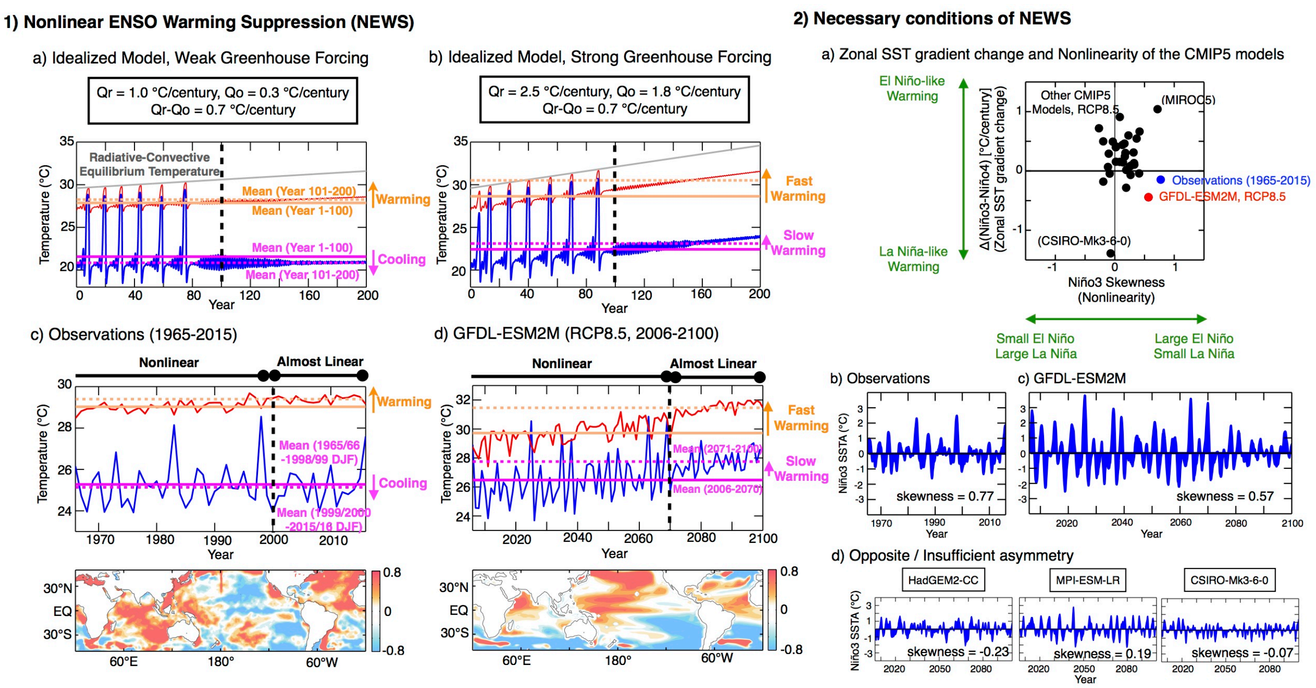
Under global warming, the majority of state-of-the-art global climate models warm faster in the eastern equatorial Pacific than in the west and produce a weakening of the Walker circulation. Recently, however, Kohyama, Hartmann, and Battisti (2016) showed that GFDL-ESM2M is an exception that exhibits a La Niña-like mean-state warming with a strengthening of the Walker circulation. This study explores the cause of this exceptional response and proposes a new mechanism, the Nonlinear ENSO Warming Suppression (NEWS), where the transient heating rate difference between the atmospheric and oceanic reservoirs annihilates extreme El Niños, causing a suppression of the mean-state warming in the east. Heat budget analyses of GFDL-ESM2M robustly show that nonlinear dynamical heating, which is necessary for extremely warm El Niños, becomes negligible under warming. An idealized nonlinear recharge oscillator model suggests that, if the temperature difference between the atmospheric and oceanic reservoirs becomes larger than some threshold value, the upwelling becomes too efficient for the El Niño Southern Oscillation (ENSO) to keep its nonlinearity. Therefore, extreme El Niños dissipate but La Niñas remain almost unchanged, causing a La Niña-like mean-state warming. NEWS is consistent with observations and GFDL-ESM2M but not with the majority of state-of-the-art models, which lack realistic ENSO nonlinearity. NEWS and its opposite response to atmospheric cooling, the Nonlinear ENSO Cooling Suppression (NECS), might contribute to the Pacific multi-decadal natural variability and global warming hiatuses.

キーワード：エルニーニョ南方振動、地球温暖化、平均場の変化
Keywords: ENSO, Global Warming, Mean-state change



Austral summer rainfall in Peru and its dependence on ENSO flavor and interactions with ITCZ and SPCZ

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The El Niño/Southern Oscillation (ENSO) is a coupled ocean-atmosphere phenomenon originating in the tropical Pacific with global impacts. Currently, there are few studies about the change of large-scale weather anomalies associated with the ENSO flavor events around the globe through atmospheric and oceanic teleconnections, with significant impacts on society and natural system. For example, El Niño in the East and Central Pacific have different impacts on the rainfall of Peru and the atmospheric pathways through the SPCZ and Pacific ITCZ are poorly understood yet. Therefore, the goal of this study is describe the impact of ENSO flavors, ITCZ and SPCZ on the interannual variability of Peruvian rainfall during austral summer.
To address this, we performed linear regression of sea surface temperature (SST) E (eastern Pacific) and C (central Pacific) indices, as well as precipitation indices for SPCZ and ITCZ, with gridded precipitation and ERA Interim reanalysis data sets during the austral summer (December-January-February) for the 1980-2016 period.

The results show clearly that many aspects of the ENSO impacts over South America associated with E and C are similar, but there are also significant differences. Positive C induces dry anomalies along tropical Andes (Ecuador, Peru and Bolivia) and northern South America (SA), while wet anomalies prevail over southeastern South America (SESA). Moreover, they produce wet (dry) conditions in northwestern (central and southern) Peruvian Amazon. In contrast, E enhances wet conditions along the coast of Ecuador and northern Peru associated with the southward displacement of the eastern Pacific ITCZ and dry only in the Peruvian Altiplano. Both E and C are associated with upper-level westerly wind anomalies over Peru, but it is more restricted to the central Andes with E. Both the zonal position of the SPCZ and its northward displacement suppresses rainfall over the Peruvian Andes; but the latter also inhibits rainfall over the Bolivian Altiplano. Both are linked to upper-level westerly wind anomalies over all of Peru, but these anomalies do not extend as far south in the former. The southward displacement of the eastern Pacific ITCZ also induces wet anomalies in SESA while induces dry anomalies over northeastern Brazil (NEB) and Altiplano region. In contrast, the southward displacement of the central Pacific ITCZ induces dry anomalies in NEB and along the northern coast of Peru; while wet anomalies occur in eastern Brazil, Paraguay and the Bolivian Altiplano.

Keywords: Rainfall of Peru, atmospheric teleconnections, El Niño-Southern Oscillation (ENSO), South Pacific Convergence Zone (SPCZ), Intertropical Convergence Zone (ITCZ), South America

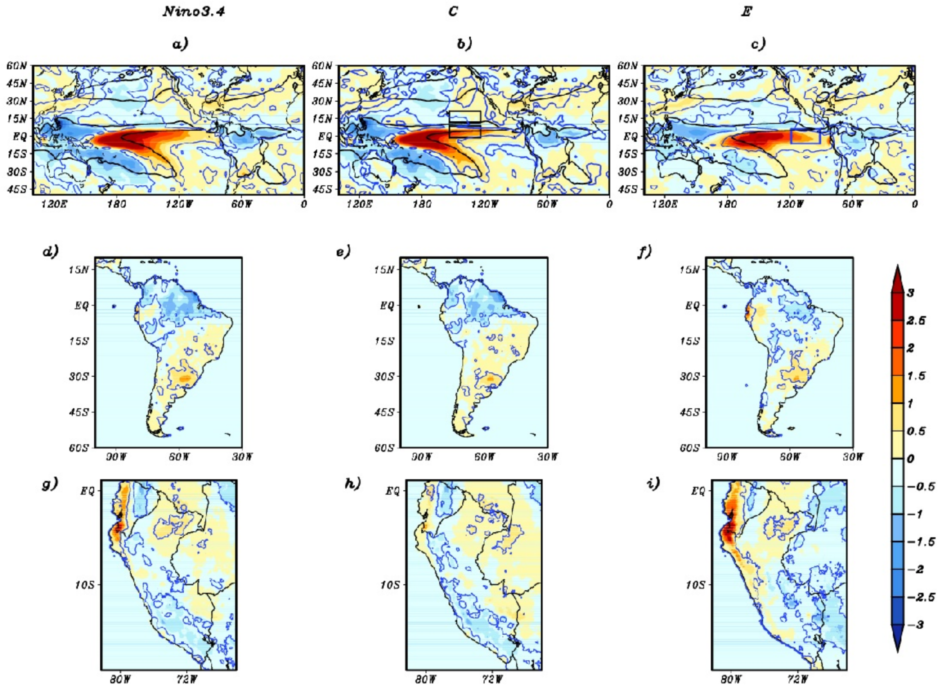

Figure 1. One standard deviation of ENSO indices (Niño 3.4, E and C) regressed upon DJF GPCP precipitation: (a, b and c), Delaware precipitation (d, e and f) and PISCO precipitation (g, h and i). Black contours represent significant correlation at the 95% confidence level. Black boxes are associated with ITCZC index, while the blue box is linked to ITCZE index. Analysis based on the period 1980-2016.

Structure and Variability of the North Equatorial Current/Undercurrent from Mooring Measurements in the Western Pacific

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The mean structure and variability of the North Equatorial Current/Undercurrent (NEC/NEUC) are investigated with 1-year Acoustic Doppler Current Profilers measurements from 4 subsurface moorings deployed at 10.5ºN, 13ºN, 15.5ºN, and 18ºN along 130ºE in the western Pacific. The strong westward flowing NEC ranges from the sea surface down to 400 m, and the mean zonal velocity of the NEC at 10.5ºN is around -30 cm/s at the depth of 60 m. Eastward flowing NEUC jets are detected below the NEC at 10.5ºN and 13ºN, and the depth of the NEUC could reach at least 900 m. The mean velocity of the NEUC is around 4.2 cm/s at 800 m. No eastward undercurrents is observed at 15ºN and 18ºN. The mooring measurements also reveals a strong intraseasonal variability of the currents at all 4 mooring sites, and the period is around 70-120 days. The vertical structure of this intraseasonal variability varies at different latitudes. The variability of the NEUC jets at 10.5ºN and 13ºN appears to be dominated by subthermocline signals, while the variability of the currents at 15.5ºN and 18ºN is dominated by surface-intensified signals.

Atlantic-induced trans-basin teleconnection as a driving factor for the recent enhancement of global monsoon

Atlantic-induced trans-basin teleconnection as a driving factor for the recent enhancement of global monsoon

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Recent decadal trends of sea surface temperature (SST) during the satellite era since 1979 include Atlantic and Indian Ocean warming and Pacific cooling associated with phase shifts of the Atlantic Multidecadal Oscillation and the Pacific Decadal Oscillation. Global monsoon (GM) circulation and rainfall also show remarkable trends during these three decades especially in the Northern Hemisphere. Li et al. (2016) revealed that the Atlantic warming since 1979 can be a trigger for the observed global SST trend (the Indian Ocean and western Pacific warming and eastern Pacific cooling) through trans-basin interactions including Rossby and Kelvin responses to diabatic heating over the tropical Atlantic. Here we evaluate effects of the oceanic changes (Atlantic warming, Indian Ocean warming, and Pacific east-west warming/cooling asymmetry) on the global and regional monsoon trends by partial ocean temperature restoring simulations in a coupled climate model, similar to Li et al. (2016). Via trans-basin interactions, the Atlantic warming favors the Indian Ocean warming and resultant subtropical tropospheric warming over North and South America, Atlantic, and North and South Africa. The tropospheric warming results in a larger temperature gradient between land and ocean that can track variation of monsoon intensity (Kamae et al. 2017). In contrast, the Indian Ocean and Pacific temperature do not result in the observed GM enhancement. The results of this study indicate that the Atlantic multidecadal variability can explain large parts of the observed decadal climate trends including monsoons.

Reference:

Kamae, Y., et al. 2017. Clim. Dyn., doi:10.1007/s00382-017-3522-3.
Li, X., et al. 2016. Nature Clim. Change, 6, 275–279.

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Keywords: Meridional thermal gradient, Global monsoon, AMO, PDO, Trans-basin teleconnection