

# 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<sup>3</sup> 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, Lagrangian 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 relevance of these processes in observations and model simulations.

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

## 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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\*Motoki Nagura<sup>1</sup>, H Annamalai<sup>2</sup>, Julian P. McCreary<sup>2</sup>

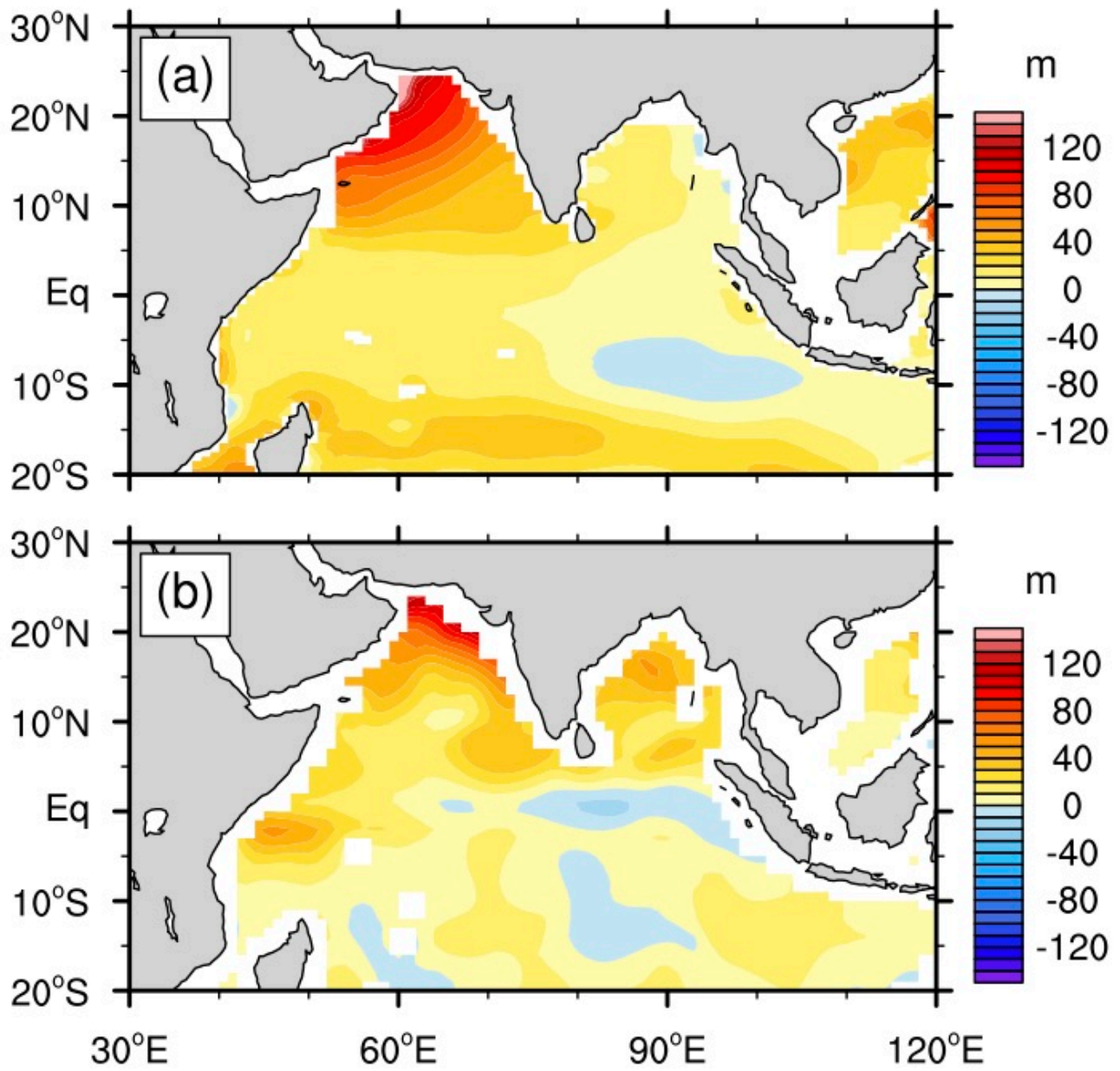
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In this study, we investigate biases of a suite of 32 coupled ocean-atmosphere models in representing the climatological mean state of the Arabian Sea, as measured by differences between climatologies of the model fields and observations. The suite 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. 1 a), 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. 1 b). 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



# 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 Niño/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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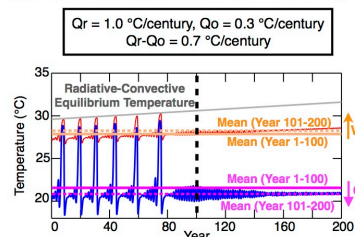
Under global warming, the majority of state-of-the-art global climate models warm faster in the eastern equatorial Pacific than in the west and produce a weakening of the Walker circulation. Recently, however, Kohyama, Hartmann, and Battisti (2016) showed that GFDL-ESM2M is an exception that exhibits 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

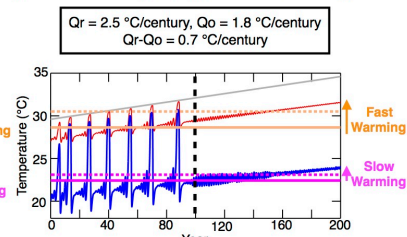
Keywords: ENSO, Global Warming, Mean-state change

## 1) Nonlinear ENSO Warming Suppression (NEWS)

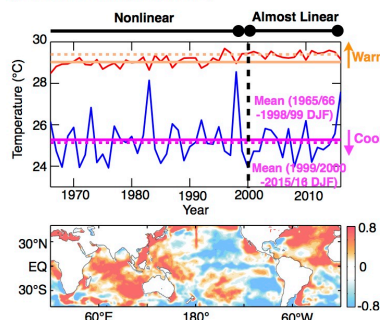
a) Idealized Model, Weak Greenhouse Forcing



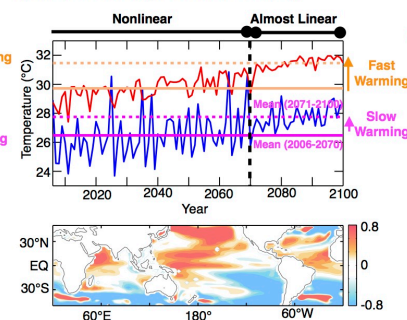
b) Idealized Model, Strong Greenhouse Forcing



c) Observations (1965-2015)

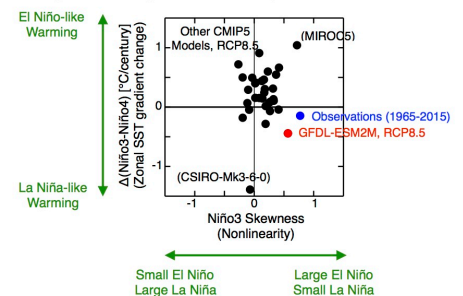


d) GFDL-ESM2M (RCP8.5, 2006-2100)

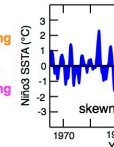


## 2) Necessary conditions of NEWS

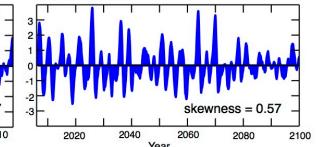
a) Zonal SST gradient change and Nonlinearity of the CIMP5 models



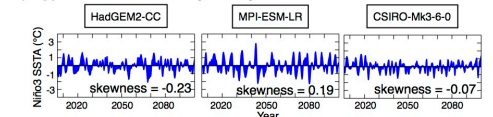
b) Observations



c) GFDL-ESM2M



d) Opposite / Insufficient asymmetry



## 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

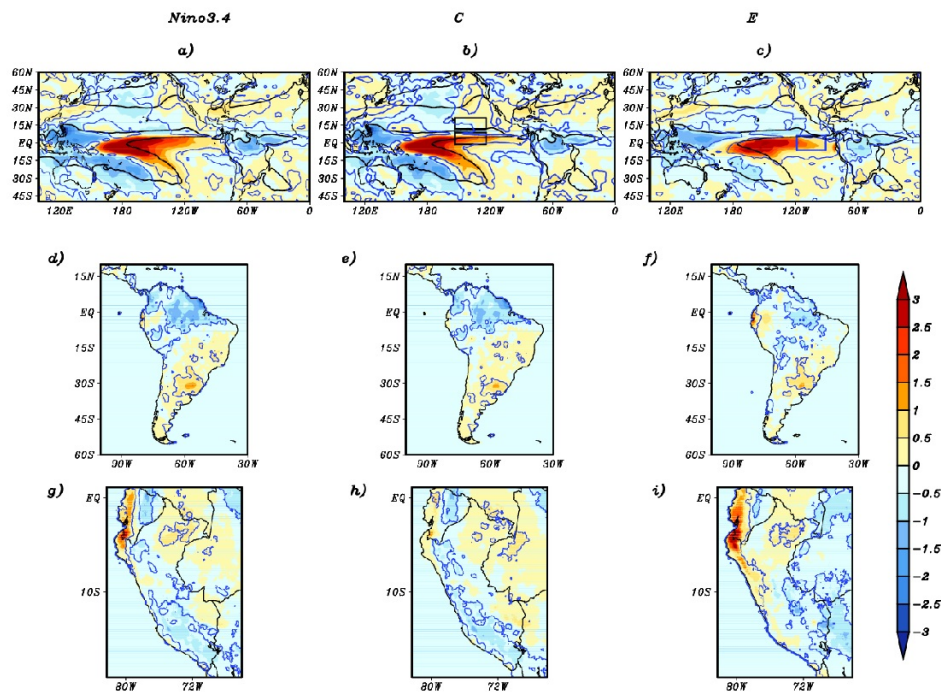


Figure 1. One standard deviation of ENSO indices (Niño 3.4, E and C) regressed upon DJF GPCP precipitation: (a, b and c), Delaware precipitation (d, e and f) and PISCO precipitation (g, h and i). Black contours represent significant correlation at the 95% confidence level. Black boxes are associated 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 10.5°N, 13°N, 15.5°N, and 18°N along 130°E 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 10.5°N is around -30 cm/s at the depth of 60 m. Eastward flowing NEUC jets are detected below the NEC at 10.5°N and 13°N, 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 15°N and 18°N. 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 10.5°N and 13°N appears to be dominated by subthermocline signals, while the variability of the currents at 15.5°N and 18°N 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.

キーワード : Meridional thermal gradient, Global monsoon, AMO, PDO, Trans-basin teleconnection  
Keywords: Meridional thermal gradient, Global monsoon, AMO, PDO, Trans-basin teleconnection

## Extension of the prognostic model of sea surface temperature to rain-induced cool and fresh lenses

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The Zeng and Beljaars (2005) sea surface temperature prognostic scheme, developed to represent diurnal warming, is extended to represent rain-induced freshening and cooling. Effects of rain on salinity and temperature in the molecular skin layer (first few hundred micrometers) and the near-surface turbulent layer (first few meters) are separately parameterized by taking into account rain-induced fluxes of sensible heat and freshwater, surface stress, and mixing induced by droplets penetrating the water surface. Numerical results from this scheme are compared to observational data from two field studies of near-surface ocean stratifications caused by rain, to surface drifter observations and to previous computations with an idealized ocean mixed layer model, demonstrating that the scheme produces temperature variations consistent with in situ observations and model results. It reproduces the dependency of salinity on wind and rainfall rate and the lifetime of fresh lenses. In addition, the scheme reproduces the observed lag between temperature and salinity minimum at low wind speed and is sensitive to the peak rain rate for a given amount of rain. Finally, a first assessment of the impact of these fresh lenses on ocean surface variability is given for the near-equatorial western Pacific. In particular, the variability due to the mean rain-induced cooling is comparable to the variability due to the diurnal warming so that they both impact large-scale horizontal surface temperature gradients. The present parameterization can be used in a variety of models to study the impact of rain-induced fresh and cool lenses at different spatial and temporal scales.

**Keywords:** A prognostic scheme to represent rain-induced cooling and freshening (near surface and skin layer), The simple scheme reproduces many aspects of the rain-induced surface lenses, Preliminary results on the impact of the rain-induced lenses on climate and its variability

## Decadal variations in the tropical Indo-Pacific sea surface height based on a historical OGCM simulation

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\*Goro Yamanaka<sup>1</sup>, Hiroyuki Tsujino<sup>1</sup>, Hideyuki Nakano<sup>1</sup>, Shogo Urakawa<sup>1</sup>, Kei Sakamoto<sup>1</sup>

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We examine long-term sea surface height (SSH) variations in the tropical Indo-Pacific Oceans, using a historical OGCM simulation (1948-2006). It is known that the SSH pattern in the tropical Pacific is not a mirror image on decadal timescales. For example, it is north-south asymmetric during the positive phase (1977-1987), while it is north-south symmetric during the negative phase (1996-2006). EOF analysis of tropical Pacific SSH anomalies indicates four dominant modes: east-west seesaw pattern (1<sup>st</sup> mode), north-south asymmetric pattern (2<sup>nd</sup> mode), north-south symmetric pattern (3<sup>rd</sup> mode) with longer time scales, and north-south symmetric pattern (4<sup>th</sup> mode) with ENSO timescales. The SSH pattern during the positive phase is largely explained by the combination of the four modes including a north-south asymmetric pattern (2<sup>nd</sup> mode), while the north-south symmetric 1<sup>st</sup> and 4<sup>th</sup> modes are dominant during the negative phase. This answers the question why the tropical Pacific SSH pattern is not a mirror image on decadal timescales. Overall, the tropical Indo-Pacific SSH decadal variability is correlated with the wind stress curl. The 1<sup>st</sup> and 3<sup>rd</sup> modes are associated with the tropical Indian Ocean SSH variability through the atmospheric bridge. We also discuss a possible reason for the enhancement of the trade winds over the tropical Pacific after the late 1990s, which leads to the enhanced negative phase hereafter.

キーワード：十年規模変動、海面水位、海洋大循環モデル、インド洋—太平洋

Keywords: decadal variability, sea surface height, ocean general circulation model, Indo-Pacific



## Intraseasonal coastal upwelling and heat balance in the mixed layer along the southeastern coasts of Sumatra and Java

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Coastal upwelling along the southwestern coasts of Sumatra and Java brings cool and nutrient-rich water to the coastal region, and plays an important role in the ocean surface heat and biogeochemical balance in the eastern Indian Ocean. In this study, to understand the coastal upwelling system, we investigated intraseasonal-scale thermodynamic balance in the mixed layer of the coastal region. We used satellite-based observational datasets of surface heat flux, SST, sea level, and ocean surface currents. Ocean mixed layer depth was estimated by Argo floats. During summer monsoon, intraseasonal-scale anomalous cold SST south of Java developed with anomalous southeasterly winds in the southeastern tropical Indian Ocean. The wind anomalies enhanced climatological southeasterly winds and hence latent heat loss. The anomalous latent heat loss was partly canceled by enhanced shortwave radiation, and the SST cooling could not fully explained by the net air-sea flux variations. Local sea level anomalies were lowering at this phase, suggesting that coastal upwelling played a role in the SST cooling. On the other hand, anomalous SST variations off of Sumatra were mainly controlled by anomalous surface heat flux variations. The implications of these results for regional and basin-scale air-sea interaction will be discussed.

キーワード：東部インド洋、スマトラ・ジャワ島、沿岸湧昇、海洋混合層、海面熱フラックス

Keywords: Eastern Indian Ocean, Sumatra and Java, Coastal Upwelling, Mixed Layer, Surface Heat Flux

## Onset of the Bay of Bengal summer monsoon and the seasonal timing of ENSO' s decay phase

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Based on multiple sources of atmospheric and oceanic data, this study demonstrates a close relationship between the onset of the Bay of Bengal (BOB) summer monsoon (BOBSM) and the seasonal timing of ENSO' s decay phase. Through distinguishing 'later-decay' and 'normal-decay' ENSO events, it is found that a later/earlier onset of the BOBSM following El Niño/La Niña is mainly caused by later-decay ENSO events, while no significant changes in BOBSM onset can be identified between normal-decay El Niño and normal-decay La Niña events. Diagnosis of the related dynamic and thermodynamic processes further confirms that, for later-decay ENSO events that remain active until mid-April, persistent ENSO-induced 'atmospheric-bridge' processes can significantly modulate the lower tropospheric barotropic instability over the northern BOB by inducing a remarkable anomalous zonal SST gradient between the Indian Ocean and the western Pacific. Meanwhile, these processes alter the position of the South Asian high and the upper atmospheric divergence-pumping through the anomalous Walker circulation. A stronger vertical coupling between the upper and lower troposphere, which is crucial for BOBSM onset, thus appears anomalously earlier (later) following a later-decay La Niña (El Niño). In contrast, due to the earlier damping of normal-decay ENSO, the BOBSM onset processes are barely modulated.

Keywords: Bay of Bengal, Summer monsoon onset, Seasonal timing of ENSO's decay phase

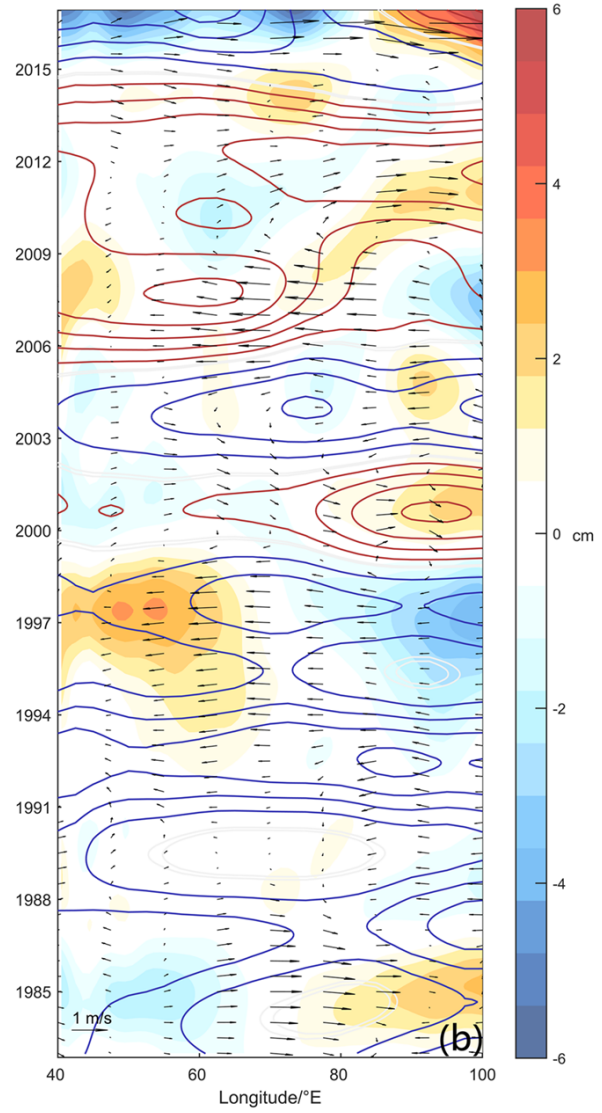
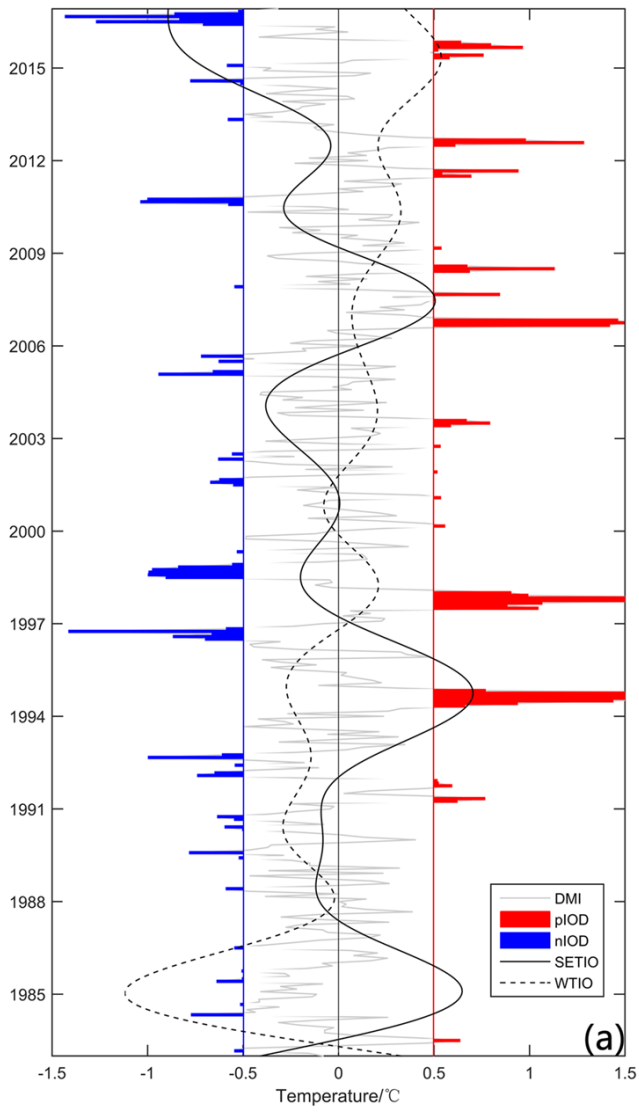
## A western-pole controlled Indian Ocean Dipole event in 2015 modulated by long-term variability

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The canonical Indian Ocean Dipole (IOD) event is usually associated with strong sea surface temperature (SST) cooling of eastern pole in the southeastern tropical Indian Ocean (SETIO) and warming of western pole in the western tropical Indian Ocean (WTIO). However, positive IOD in 2015 is western-pole controlled event, with little SST change off Sumatra-Java. The coastal upwelling in the SETIO was suppressed in 2015, causing the weakened SST cooling in the region. Empirical mode decompositions of SETIO and WTIO SST index show that the decadal variability and long-term trend modulate the strength of IOD. That implies the background state in the Indian Ocean is unfavorable for the eastern-pole controlled IOD in 2015. It also can be observed by the low-frequency oscillation of sea surface height, sea level pressure and surface wind, all of them following the Bjerknes feedback. In short, anomalous strong SST warming in the WTIO and unfavorable ocean state in the SETIO induced by long-term variability along the equator are the reasons for the western-pole controlled IOD in 2015.

Keywords: IOD, western-pole controlled, long-term variability



## The lack of westerly wind bursts in unmaterialized El Niño years

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The lack of westerly wind bursts (WWBs) when the intraseasonal variability (ISV) such as the Madden-Julian Oscillation is observed from boreal spring to autumn is investigated by comparing two types of El Niño and unmaterialized El Niño (UEN) years both with high ocean heat content buildup. Whereas there were several intraseasonal convective events propagating eastward throughout the focused seasons in all years, few WWBs accompanied them in UEN years. The eddy kinetic energy budget analysis based on the ISV shows that background zonal wind convergence in the lower troposphere, which facilitates the development of eddy disturbances including WWBs, is retracted northwestward and does not reach the equatorial central Pacific in UEN years. In addition, positive sea surface temperature (SST) anomalies, which are conducive to active convection, lie from the equatorial western-central Pacific to the off-equatorial region. The northwestward-retracted convergence and off-equatorial warming both enhance off-equatorial eddies, which resulting in the reduced ability of equatorial eddy developments such as WWBs. These characteristics found in UEN years are significantly different from those in the eastern Pacific El Niño years (EP-EN), which are characterized by anomalous cooling (warming) and suppressed (enhanced) convective eddies in the off-equatorial (equatorial) western Pacific. Mixed features of the EP-EN and UEN years in the background states are found in the central Pacific El Niño years. Different background states not only in the equatorial but also off-equatorial region can be a reason for the lack of WWBs even with several ISV events in UEN years.

キーワード：西風バースト、エルニーニョ、季節内変動

Keywords: westerly wind bursts, El Niño, atmospheric intraseasonal variability

## Structure and dynamics of decadal variability of the meridional geostrophic transport in the tropical North Pacific Ocean in observations and in CMIP5 climate models

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The meridional geostrophic transports in the interior tropical and subtropical gyres of the North Pacific Ocean are estimated based on the hydrographic data of the Global Ocean Heat and Salt Content Data. The decadal to inter-decadal variations of the observed meridional geostrophic transports along 8°N across the Pacific basin are found to precede the Pacific Decadal Oscillation (PDO) or the Inter-Pacific Decadal Oscillation (IPO) at the lead time of 3 to 5 years above the 95% significance level. This result suggests that the decadal variability of the Pacific is predictable if the meridional transport of the tropical gyre is used as a precursor. However, this predictability is not found in the CMIP5 coupled simulations and in the OFES ocean simulation, suggesting significant deficiencies of these oceanic and climate system models in simulating and predicting the decadal variability of the Pacific Ocean. The dynamics of the meridional transports are investigated using the Sverdrup theory. The simulated meridional transport anomalies in the CMIP5 and the OFES models are consistent with the Sverdrup theory at the decadal time scales, suggesting linear dynamics of the variability, whereas the observed meridional geostrophic transport anomalies differ from the Sverdrup theory significantly in the tropical North Pacific Ocean. The comparison suggests that the model deficiencies in simulating and predicting the Pacific decadal variability are primarily due to the neglect of the nonlinear processes in the tropical ocean.

Keywords: meridional geostrophic transport, Sverdrup Balance, Decadal variability

## Analysis of Mid-latitude System effect on ENSO Evolution over the Tropical Pacific

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Recently, El Nino/Southern Oscillation (ENSO) has irregular characteristic, including its period and strength. Due to the Variation of sea temperature is an important factor in the diagnosis of ENSO. Our study analyzed 1951-2010 NOAA sea surface temperature, which found that interannual Pacific SST has obvious characteristics of the Pacific decadal oscillation (PDO). Therefore, in accordance with the time section of PDO to distinguish cold (warm) epoch, the analysis showed that the ENSO event features of 1975-2000 (warm epoch) is stronger than 1951-1975 (cold epoch), while the ENSO event features of 2000 (cold epoch 2) is weaker than warm epoch. In addition, our analysis found that most of ENSO events after 1970 in spring have common features that before the ENSO occurs there are warming SST in the central Pacific. Many studies have pointed out that this phenomenon resulted from westerly wind bursts in the spring in the tropical western Pacific.

Westerly wind bursts in the tropical Pacific often occurred during the early spring in most ENSO events and which is a key factor triggering an ENSO event. Past studies have pointed out that the source of the westerly wind burst is tropical cyclone, Madden-Julian Oscillation and mid-latitude cold-air outbreak. This study would like to know more about the mid-latitude system.

In this study, a simple hybrid coupled model was used to examine the effects of cold-air outbreak on ENSO evolution. The experiment results show that the mid-latitude cold-air outbreak causes SST become cooler in the tropical western Pacific, and there is a divergence over the cold SST. Furthermore, the divergent effect not only enhances the surface westerly wind component in the tropical western Pacific, but also causes SST in the tropical central Pacific become warmer. The downdraft over the tropical western Pacific cold SST and the updraft over the tropical central Pacific warm SST combine into a vertical circulation, which may cause westerly wind bursts over the western Pacific in the subsequent early spring, and the associated anomalous westerlies then induce an ENSO event in the coming winter.

Keywords: El Nino/Southern Oscillation, westerly wind burst, cold-air outbreak

## Variability of Western Pacific Equatorial Currents Associated with 2014-2015 El Niño

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Direct current measurements by ADCP moorings are used to investigate intraseasonal-to-annual variability of Western Pacific Equatorial Currents during the fickle 2014 El Niño and the strong 2015 El Niño. The results show that Equatorial Undercurrent (EUC) around 142°E weakened during both 2014 and 2015 El Niño events. The South Equatorial Current (SEC) and EUC are closely correlated with developing phase of El Niño, leading NINO3 index by 4-6 months. The Equatorial Intermediate Current (EIC) has less relationship with ENSO, but its intraseasonal variability is strongly influence by local and remote atmospheric forcing.

Combined with HYCOM analysis sea water velocity fields and ERA-Interim 10m wind velocity fields, roles of surface and subsurface Western Pacific Equatorial currents in ENSO cycle are further discussed.

Keywords: ENSO, Western Pacific, South Equatorial Current, Equatorial Undercurrent, Equatorial Intermediate Current



## Large ensemble high-resolution climate simulations –Application to Event Attribution study

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Recently, an unprecedentedly large ensemble of climate simulations with a 60 km atmospheric general circulation model and dynamical downscaling with a 20 km regional climate model have been released in Japan (the “Database for Policy Decision making for Future climate change [d4PDF]” ) to assess probabilistic change in localized severe events that have large uncertainty from internal variability. Internal variability includes decadal variations in the ocean, inter-annual variability in the extratropical atmosphere, intra-seasonal variation in the tropics, and so on. Two sets of ensemble for past climate with and without historical trends associated with the anthropogenic effect, respectively, and an ensemble for 4 K warmer future climate are simulated more than 5000 years in d4PDF. Here, we will introduce our recent works using large ensemble simulations focusing on how much the inter-annual and decadal variability in the Pacific Ocean contributed to increased occurrence of heatwaves around the globe when compared to anthropogenic global warming.

キーワード：気候の大規模アンサンブルシミュレーション、大気大循環モデル、異常気象、熱波、太平洋10年規模変動、地球温暖化

Keywords: Large ensemble climate simulation, AGCM, Extreme event, Heatwaves, Pacific decadal variability, Global warming

## Experimental seasonal climate prediction using CFES: Preliminary results

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An experimental seasonal climate prediction system has been developed based on the Coupled atmosphere-ocean general circulation model for the Earth Simulator (CFES). Following the well-established system based on the SINTEX-F model, initial conditions for seasonal climate prediction are constructed by strongly nudging sea surface temperature (SST) to observed one.

The atmospheric component of CFES has the resolution of T119 in the horizontal and 48 sigma-layers in the vertical with the top level placed at about 3 hPa. The oceanic component has the resolution of 1/2 degree in the directions of both longitude and latitude and 54 levels in the vertical. They are coupled every hour.

At this stage, 2-member ensemble 6-month predictions from the 1st day of March, June, September, and December have been conducted from 1983 through 2016, after 32-years of coupled spin-up integration with SST-nudging to the observed climatology. The experimental system exhibits skill in predicting SST variability in the tropical Pacific. Detailed analysis of the prediction skill, including comparison with the SINTEX-F system, will be shown in the presentation.

キーワード：季節予測、大気海洋結合モデル

Keywords: Seasonal climate prediction, Coupled atmosphere-ocean general circulation model