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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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 (1st mode), north-south asymmetric pattern (2nd mode), north-south symmetric pattern (3rd mode) with longer time scales, and north-south symmetric pattern (4th 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 (2nd mode), while the north-south symmetric 1st and 4th 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 1st and 3rd 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.

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.

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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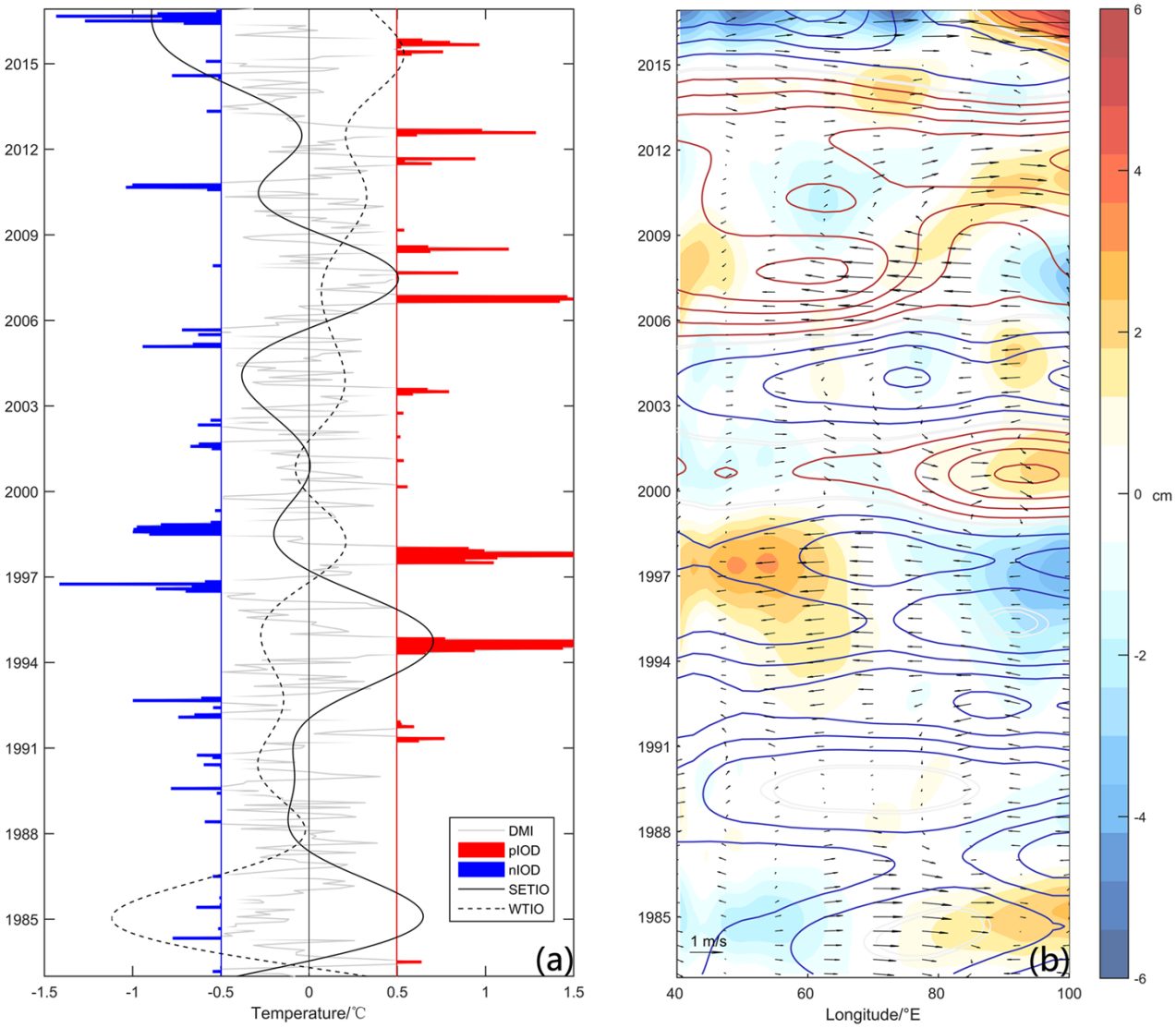
The canonical Indian Ocean Dipole (IOD) event is usually associated with strong sea surface temperature (SST) cooling of eastern pole in the southeastern tropical Indian Ocean (SETIO) and warming of western pole in the western tropical Indian Ocean (WTIO). However, positive IOD in 2015 is western-pole 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.

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 8ºN 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.

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.

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

