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: Monsoon Intraseasonal variability, CFES simulations, Entrainment

夏季北西太平洋で卓越する2つの変動モードとそれらの十年規模変調

Two dominant modes over the summertime western North Pacific and their interdecadal modulations

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Structures and dynamics of two dominant meridional teleconnection patterns over the summertime western North Pacific (WNP) in intraseasonal to interannual time scales are examined. One of them features a positive correlation between convective activity around the northern Philippines and lower-tropospheric circulation centered near Japan, and called the Pacific-Japan (PJ) teleconnection pattern. Preceding studies argued that this pattern could be regarded as a dynamical mode, which efficiently gain energy from background state. The PJ pattern is significantly correlated with El Niño-Southern Oscillation (ENSO) peaked in preceding winter. Through an empirical orthogonal function (EOF) analysis for over half a century of Japanese 55-year reanalysis (JRA-55), the PJ pattern outstands as the leading mode of lower-tropospheric vorticity. The second EOF mode features a positive correlation between convective activity centered at Guam of the Mariana Islands and lower-tropospheric circulation around the Bonin Islands. We therefore call it the Mariana-Bonin (MB) pattern. This pattern also gains energy from background state through barotropic and baroclinic energy conversion as efficiently as energy generation due to anomalous diabatic heating, and thus bears dynamical mode features. The efficiency, however, is less than in the PJ pattern, consistent with the dominance of the PJ over MB patterns. In addition, the MB pattern is highly correlated with ENSO in developing stage.
The two patterns have undergone significant interdecadal modulations. The PJ pattern amplified from the 1950s to 1980s, and then weakened until the 2000s. It is suggested that interdecadal changes of ENSO forcing of the PJ pattern via Indian Ocean and tropical WNP sea surface temperature anomalies are responsible for these modulations. The MB variance also shows interdecadal modulations but the changes are weaker than in the PJ pattern. As a result, the PJ pattern has degraded to the second EOF mode since the late 1990s, while the MB pattern has been promoted to the leading EOF mode instead.

キーワード：ENSO、遠隔影響
Keywords: ENSO, Teleconnections

北半球冬季海洋大陸における対流活動変動にともなう南北遠隔影響

Wintertime meridional teleconnection associated with convective activity over the Maritime Continent

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Anomalous convective activity forced by tropical SST variability associated, for example, with ENSO influences the climate and weather in the extratropics. It has been known that El Niño (La Niña) tends to bring milder (colder) winter to East Asia, providing a statistical basis for wintertime seasonal predictions. However, ENSO variability is found to account only for nearly 60% of the interannual variance of convective activity around the maritime continent, and a significant fraction of the convective variability may therefore be uncorrelated with tropical SST variability. Through analysis of observational data for 1979/80-2011/12, the present study attempts to identify the tropical region where the interannual variability in seasonal-mean activity of SST-uncorrelated convection tend to be strongest and how effectively the variability can force atmospheric teleconnections into the extratropics if compared to ENSO-forced anomalous convection. At each location SST-correlated OLR variability was first identified by regressing seasonal-mean OLR anomalies linearly on the five leading PC time series of tropical SST variability. Defined locally as the residual, seasonal-mean anomalies in SST-uncorrelated OLR variability include no direct contribution from MJO. The leading EOF of the SST-uncorrelated OLR variability in boreal winter over the entire tropics accompanies the largest local variance around the maritime continent, where the variability reaches as much as a third of the ENSO-forced OLR variance. The associated atmospheric anomaly pattern differs considerably from that forced by ENSO, especially in the midlatitude north Pacific. The SST-uncorrelated convective variability around the maritime continent is found to exert remote influence on wintertime East Asian climate, which tends to be even slightly stronger than the ENSO influence. Our analysis thus suggests that the anomalous convective activity around the maritime continent uncorrelated with SST variability significantly limits the wintertime seasonal predictability over East Asia.

キーワード：冬季東アジアモンスーン、ENSO、季節予測可能性
Keywords: East Asian winter monsoon, ENSO, seasonal predictability

Effects of the North Pacific subtropical SST front on the Baiu precipitation

Effects of the North Pacific subtropical SST front on the Baiu precipitation

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The Baiu/Meiyu front is manifested as a rain band and is one of the most remarkable features in the East Asia summer monsoon. It appears over the subtropical western North Pacific around late May and then subsequently migrates northward. Focusing on the subtropical SST front that extends almost zonally about 25°N in the western subtropical gyre, the present study examines its effect on the Baiu precipitation in late May using satellite observations and ERA-interim reanalysis data from 2002 to 2014.
The subtropical SST front has a clear seasonal cycle and becomes strong in May. The strong SST front enhances atmospheric baroclinicity and anchors cyclonic surface wind curls that occur intermittently at intervals of a few days. The wind curls are associated with subsynoptic low pressure systems embedded in larger, synoptic highs in the main storm track to the north (Kobashi et al. 2008). The climatology of the precipitation in late May reveals the two rain bands separated by the minimum in precipitation along the SST front. The moisture budget analysis shows that the observed two rain bands correspond well to the horizontal convergence of moisture flux. Dividing the moisture flux into a slowly-varying component and a high-frequency disturbance component, we find that disturbances cause the moisture flux divergence along the SST front and split the slowly-varying large-scale Baiu rain band into the two rain bands. Northerly winds from synoptic highs are locally enhanced behind the subsynoptic lows and carry dry air to the north of the SST front, causing the moisture flux divergence along the front. The subsynoptic lows along the subtropical front are each accompanied by convective rain, but their contribution to the climatological precipitation is outweighed by the effect of the northerly wind-induced moisture divergence.

キーワード：亜熱帯海面水温前線、梅雨前線、降水
Keywords: Subtropical SST front, Baiu front, precipitation

Quantifying the Intra-Regional Precipitation Variability in Northwestern China over the Past 1,400 Years

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There has been a surge of paleo-climatic/environmental studies of Northwestern China (NW China), a region characterized by a diverse assortment of hydro-climatic systems. Their common approach, however, focuses on “deducing regional resemblance” rather than “exploring regional variance.” To date, efforts to produce a quantitative assessment of long-term intra-regional precipitation variability (IRPV) in NW China has been inadequate. In the present study, we base on historical flood/drought records to compile a decadal IRPV index for NW China spanned AD580–1979 and to find its major determinants via wavelet analysis. Results show that our IRPV index captures the footprints of internal hydro-climatic disparity in NW China. In addition, we find distinct ~120–200 year periodicities in the IRPV index over the Little Ice Age, which are attributable to the change of hydro-climatic influence of ocean-atmospheric modes during the period. Also, we offer statistical evidence of El Niño Southern Oscillation (Indo-Pacific warm pool sea surface temperature and China-wide land surface temperature) as the prominent multi-decadal to centennial (centennial to multi-centennial) determinant of the IRPV in NW China. The present study contributes to the quantitative validation of the long-term IRPV in NW China and its driving forces, covering the periods with and without instrumental records. It may help to comprehend the complex hydro-climatic regimes in the region.

Keywords: Precipitation variability, Asian Summer Monsoon, El Niño Southern Oscillation, Indo-Pacific warm pool, Temperature, Northwestern China

北太平洋における固有の月平均大規模大気偏差の予測可能性

Predictability of the specific monthly-mean large-scale atmospheric anomalies over the North Pacific

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The North Pacific shows the specific monthly-mean large-scale atmospheric anomalies, even after removing the components of the northern annular mode (NAM) and the El Niño/Southern Oscillation (ENSO). This work examines the spatial structures, precursors, and development of the residual anomalies using global objective reanalysis data. The rotated empirical orthogonal function (REOF) analysis extracts the prevailing anomalies in upper tropospheric geopotential height in the northern hemisphere (NH). The first REOF mode (REOF1) is featured by a monopole in the North Pacific, while a dipole characterizes the second REOF mode (REOF2), both of which have large month to month variability. The equivalent barotropic structure characterizes the two modes, and the stationary Rossby waves form the anomalous circulations downstream. The blocking and the transient eddy (TE) are effective to maintain the two modes over the North Pacific. The precursors for REOF1 and REOF2 are detected in one month earlier; that is, there appear systematic zonal bands over Eurasia and North America in the anomaly fields of surface temperature and baroclinic instability in the lower troposphere. The later extends into the central North Pacific at different latitudes with the convergence of thermal fluxes. The anomalous zonal bands are also identified in the anomaly field of upper tropospheric geopotential height. Such systematic organization of anomalous zonal bands over the two continents reflects the ovalization of polar vortex in the upper troposphere and of polar high in the lower troposphere with the continent-ward shift of longer axis. The latitudinal difference determines which of REOF1 and REOF2 develops in the following month with the zonally guided activation of TEs over the North Pacific. The anomalies of the two REOF modes disappear by the further following month with the change of surface temperature over the two continents, while the anomalies of sea surface temperature retain in the North Pacific.

キーワード：北太平洋、大規模大気循環、予測可能性
Keywords: the North Pacific, large-scale atmospheric circulations, predictability

Testing frontal air-sea interaction dynamics using spectral transfer functions

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We test a linear model for the response of the atmospheric boundary layer to variations the sea surface temperature associate with the ocean mesoscale. The model includes the impact of sea surface temperature fronts on vertical mixing and on pressure gradients, and includes advection by a background Ekman spiral. Model dynamics are governed by transfer function in wave-number space between sea surface temperature, and frontally boundary layer variables. Using output from the atmospheric general circulation model AFES, we evaluate the spectral transfer functions for frontally induced wind speed and direction. For the Southern Ocean results show encouraging agreements and suggest that the linear model captures the underlying physics. In contrast, the Kuroshio region is more challenging.

Keywords: atmosphere, air-sea interaction, sea surface temperature

The roles of latent and sensible heat fluxes in the atmospheric response to the Kuroshio/Kuroshio Extension

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It has been known that heat fluxes from extratropical SST fronts play important role for modifying the stormtrack activity and its position. (e.g. Nakamura et al. 2008; Taguchi et al. 2009). The heat flux consists of the latent and the sensible heat flux, which are released in different altitudes. To investigate their contribution for the stormtrack response, we have conducted a series of experiments for simulating the western North Pacific, using a regional atmospheric model. High-resolution SSTs are used for calculating both the latent and sensible heat fluxes in Experiment A. Low-resolution SST is used for calculating the latent heat flux in the Experiment B and for the sensible heat flux in the Experiment C. The difference between the Experiments A-B indicates the response induced by the latent heat flux from the SST front and A-C that by the sensible heat flux.
It is found that precipitation enhancement along the SST front is mostly caused by the response to the latent heat flux. The sensible heat flux induces near surface moisture convergence, but it does not contribute to the precipitation. Only the response to the latent heat flux significantly increase the storm track activity defined as high-frequency SLP fluctuation along the Kuroshio/Kuroshio Extension. Paths of cyclones are tended to be shifted by the latent heat flux toward north a few degrees. Meridional eddy heat transports due to the latent and sensible heat flux averaged along the Kuroshio Extension region take the maximum at 850 hPa and 1000 hPa, respectively. The vertically integrated heat transport due to the latent heat flux is three times larger than that due to the sensible heat flux.

Keywords: Stormtrack, SST front, Kuroshio

北西太平洋と北西大西洋における爆弾低気圧の気候学的な月頻度
Climatological Monthly Frequency of the Explosive Cyclones in the Northwestern Parts of the Pacific and the Atlantic

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This study examines the climatological monthly frequency distribution of the explosive cyclones over northwestern parts of the Pacific (NWP) and the Atlantic (NWA) in the boreal cold season (October to April) from 1979/80 to 2012/13, using the long-term reanalysis data. The distributions show the different patterns between the NWP and the NWA, i.e., trapezoid in the NWP and triangle in the NWA. The difference is particularly large in March. This study reveals the physical mechanisms that yield the difference in the monthly frequency distributions, especially around March. The low-level meridional temperature gradient well explains the monthly frequencies in the two regions. The large frequencies in the NWP are maintained from February to March, and this feature can be explained by the gradient. The gradient to the east of Japan is maintained until March, because the cold air advection with the northwesterly winter monsoon is largely decreased in March, and the warmed area largely spreads from north to south of the gradient. However, in the NWA, the northerly winds are relatively weak in winter, and the cold air advection to the south of the gradient is weak. As a result, the monthly changes of the gradient fit the triangle following the simple temperature change to the north. The large-scale land-sea distribution and mountains control the strength of winter northerly winds in the NWP and the NWA, and the difference in cold air advection yields the different temperature change to the east of the two continents. This difference further forms the specific monthly changes in the low-level meridional temperature gradient, which results in the difference of the climatological monthly frequency distributions of the explosive cyclones between the NWP and the NWA.

キーワード：爆弾低気圧、南北温度勾配、冬季モンスーン
Keywords: explosive cyclone, meridional temperature gradient, winter monsoon

2013-2015年に持続した北太平洋東部の表層昇温に伴う水温偏差の温度躍層への潜り込み
Subduction of temperature anomalies of the 2013-2015 North Eastern Pacific warm “blob”

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Northeastern Pacific sea surface temperature (SST) off the west coast of North America has been extremely warm since late 2013, a record SST warming sometimes called “blob”. This study investigates subsurface oceanic changes associated with the blob using a gridded objective analysis dataset based on Argo profiling floats (MOAA-GPV) for the period 2005-2015. The MOAA-GPV data show that the warming is not confined at the surface mixed layer (ML) but penetrates into thermocline around the depth of 100-200m since the development of the blob. Decomposition of the temperature anomalies into parts associated with density anomalies and parts that are density-compensated with salinity reveals that the subsurface penetration of the temperature anomalies into the thermocline takes pace in the form of density-compensated anomalies (a.k.a. spiciness) while the density-associated anomalies are only confined in the ML. A possible explanation of this subsurface spiciness generation is a previously proposed mechanism where a temperature anomaly at the surface shifts isopycnal outcrops across mean temperature and salinity gradients and thereby alters the temperature-salinity properties on isopycnal surfaces. We will discuss how this local spiciness generation process as well as large-scale spiciness advection in the thermocline contribute to the subsurface heat penetration beneath the blob. Even after the surface blob decays, it is likely going to leave a longer-lived signature in the subsurface thermocline.

キーワード：表層昇温、warm blob 、密度補償した水温偏差、熱吸収
Keywords: surface warming , warm blob , spiciness , heat uptake

カリフォルニアニーニョ/ニーニャ現象の予測可能性
Predictability of the California Nino/Nina

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Predictability of a recently discovered regional coupled climate mode called the California Nino (Nina) off Baja California and California is explored using a seasonal prediction system based on the Scale Interaction Experiment-Frontier, version 1 (SINTEX-F1) coupled ocean–atmosphere general circulation model. Because of the skillful prediction of basin-scale El Nino (La Nina), the California Nino (Nina) that co-occurs with El Nino (La Nina) with a peak in boreal winter is found to be predictable at least a couple of seasons ahead. On the other hand, the regional coupled phenomenon peaking in boreal summer without co-occurrence with El Nino (La Nina) is difficult to predict. The difficulty in predicting such an intrinsic regional climate phenomenon may be due to model deficiency in resolving the regional air–sea–land positive feedback processes. The model may also underestimate coastal Kelvin waves with a small offshore scale, which may play an important role in the generation of the California Nino/Nina. It may be improved by increasing horizontal resolution of the ocean component of the coupled model. The present study may provide a guideline to improve seasonal prediction of regional climate modes for important industrial as well as social applications.

キーワード：カリフォルニアニーニョ/ニーニャ現象、季節予測
Keywords: California Nino/Nina, Seasonal prediction

Variability of South Pacific Subtropical Gyre

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Taking advantage of the decade-long Argo data, this study investigates the variability of South Pacific subtropical gyre. Both sea level and steric height exhibit a linear increasing trend in the subtropical South Pacific, with its maximum value taking place in the western part of the basin. The increase north of 30ºS is primarily caused by variability in the upper 500 m, while the increase south of 30ºS is driven by variability in the whole water depth from the sea surface to 2000 m, with contributions from below 1000 m accounting for about 50% of the total variance. Most of this linear trend is due to thermal expansion, except in the deep ocean where haline contraction is of equal importance. A spin-up of the South Pacific subtropical gyre is seen during the Argo period, and the spin-down during 2002-04 reported by previous studies is merely an interannual perturbation. Atmospheric forcing of this variability is discussed.

