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S1&S2A Presentation

S1&2A-1

The impact of the mean bias on the prediction of the MJO

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The Madden-Julian Oscillation (MJO) is a special type of organized tropical convection which is distinct from other forms of its vast horizontal scale, subseasonal variability, and propagation over the Indo-Pacific basin. Enhanced or suppressed convection associated with the MJO affects global weather and climate, thereby providing a source of subseasonal predictability. In the most recent decade, MJO prediction has benefitted from the significant strides in the ability of models to represent the MJO. Various operational forecast centers are now releasing MJO forecasts and are continuously upgrading their systems. Current operational forecasting systems now show useful MJO prediction skill up to 3-4 weeks. However, this achievement is still below the theoretical estimate of predictability, which may be 6-7 weeks. Thus, there would seem to be room for further enhancing MJO prediction by improving various aspects of the prediction system based on a better understanding the MJO phenomena. In this talk, the current status and the future challenges of MJO prediction will be discussed. Although many recent studies have investigated the MJO prediction in multi-models, analyses have been limited to simple performance-oriented metrics than process-oriented diagnostics which can provide insights for model success or failure at predicting the MJO. A new diagnostic applied to hindcasts will be introduced. Also, detailed analysis of the propagating mechanism related to the mean biases in the ECMWF ensemble prediction system will be presented.

S1&2A-2

MJO prediction skill of the subseasonal-to-seasonal (S2S) models

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The Madden-Julian Oscillation (MJO), the dominant mode of tropical intraseasonal variability, provides the primary source of tropical and extratropical predictability on subseasonal to seasonal timescales. This study conducts quantitative evaluation of MJO prediction skill in the state-of-the-art operational models participating in the subseasonal-to-seasonal (S2S) prediction project. The forecast skill assessment utilizes various skill metrics that are constructed using real-time multivariate MJO index, including a set of new skill metrics that ease tracking the source of the forecast error in between the MJO amplitude and phase errors. The S2S models exhibit MJO prediction skill ranging from 12 to 36 days. These prediction skills are affected by both the MJO amplitude and phase errors, the latter becoming more important with forecast lead times. The MJO events with stronger initial amplitude are typically better predicted, whereas essentially no sensitivity to the initial MJO phase is observed. Overall MJO prediction skill and its inter-model spread are further related with the biases in the mean state and in the longwave cloud-radiation feedback process. In most models, a dry bias quickly builds up in the deep tropics, especially across the Maritime Continent, which could damp MJO organization and propagation via weakened horizontal moisture gradient. Models also tend to underestimate the longwave cloud-radiation feedbacks in the tropics, which may affect the maintenance of the MJO convective envelop. Models with a smaller bias in horizontal moisture gradient and the longwave cloud-radiation feedbacks show a higher MJO prediction skill, suggesting that improving those processes would enhance MJO prediction skill.

S1&2A-3

Past and present Madden-Julian Oscillation

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The Madden-Julian oscillation (MJO) is the most prominent physical mode in tropical intraseasonal variability (Madden and Julian 1994, Zhang 2005). This affects the timing of the onset and modulates the intraseaonal variability of the monsoon systems of the Indian subcontinent (Goswami 2005), southeast Asia (Hsu 2005, Yun et al. 2008), Australia and Indonesia (Wheeler and McBride 2005), America (Mo and Paegle 2005), and Africa (Matthews 2004). Also, it significantly influences on the human life and agriculture in these regions. Hence, it is very important to predict the MJO changes.

The MJO during the pre-industrial period (the nineteenth century) has not been examined due to the scarcity of the observed or assimilated global data and difficulty in realistically simulating the MJO in climate models. According to Hung et al. (2013), CNRM-CM5 is one of the best MJO simulation model in CMIP5. So, this study represents possible MJO changes during the three centuries and to suggest dynamical mechanisms for these changes using CNRM-CM5.

Five simulation output are analyzed: 1) Pre-industrial control simulation (referred to as piControl) is integration with no changes in the external climate forcing set as year 1850 values. This simulation output corresponds to the past climate. 2) “Historical” is run with changes estimated by anthropogenic and natural forcing, and land use changes for the record period. This simulation is considered as the current climate, so it can be used to evaluate the model performance against observation. 3) “RCP8.5” is simulation with highest future emissions scenario. This run indicates the extreme warming climate. 4) “HistoricalNat” is a historical run imposed by only external natural forcing, which is solar and volcanic variability (SI and VI) forcing in CNRM-CM5. 5) “HistoricalGHG” is run forced with a time-evolving historic reconstruction of observed well-mixed greenhouse gases concentration. In this study, 30 years of data are analyzed for piControl during the period of 1870-1899, RCP8.5 during 2071-2100, and for the other simulations during 1976-2005.

The past and present MJO is compared using piControl and historical run. The present MJO is stronger than the past MJO by as much as 33% and it is about 10% more frequent. In particular, the MJO phases 4-7 signifying deep convection located over the Maritime continent and western Pacific are considerably enhanced. Similar results are shown under extreme warming condition. These changes are mainly due to GHG forcing (explaining 75% of changes from total forcing) with the nature forcing producing little impact. A different model in CMIP5 also shows the similar results.

Dynamical mechanisms for an increase in MJO variance over the WP is explained by differences in mean states between the past and present-day climate. This increase arises from the increased SST over the CP and EP regions during the current period compared to the past. In response to the enhanced SST over the CP, precipitation over the WP increases. Meanwhile, the inverted Walker circulation induced by the EP and CP SST increase in the present-day climate generates suppressed convection over the MC and southwestern IO, leading to a pair of anticyclonic Rossby waves straddling the equator and the low-level moisture convergence over the WP.

S1&2A-4

MJO in a warmer climate: Diagnosis and mechanisms

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The processes that lead to changes in the propagation and maintenance of the Madden-Julian oscillation (MJO) as a response to increasing CO2 are examined. On the basis of a moist static energy budget and theoretical considerations that define the MJO as a "moisture mode", it is found changes in MJO propagation is dominated by several key parameters. Horizontal moisture advection, a key process for MJO propagation, is found to enhance predominantly due to an increase in the mean horizontal moisture gradients. The terms that determine the strength of the advecting wind anomalies, the MJO horizontal scale and the dry static stability, are found to exhibit opposing trends that largely cancel out, leading only to a weak amplification. Furthermore, reduced sensitivity of precipitation to changes in column moisture, i.e. a lengthening in the convective moisture adjustment timescale, also opposes enhanced propagation. The sum of all these processes results in enhanced eastward propagation at a rate of ∼ 3.5%K-1, a fraction of the rate that the column moisture anomalies amplify with. When it comes to processes that contribute to MJO maintenance, it is found that damping by vertical MSE advection is reduced due to the increasing vertical moisture gradient. This weakening is balanced by weakening cloud-radiative feedbacks. When other processes that maintain the MJO are also considered, no clear change is found in the maintenance of the MJO.

S1&2A-5

Convective Gravity Waves during the Madden-Julian-Oscillation

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Weather systems in the tropical Indian Ocean region are prominently influenced by the Madden-Julian-Oscillation (MJO) (Madden and Julian, 1972). Once an MJO active cycle is established, it can drive surface weather for several months, forcing heavy rainfall and droughts on the Indian Subcontinent. Although understanding of the MJO has improved over the last decade, MJO still considerably degrades forecasting skill, particularly in the Asian Monsoon region (Kim et al. 2014). This is especially true for seasonal prediction.

The interaction of gravity waves (GW) from convection during MJO active phases is one of the various sources of uncertainties in MJO modeling. We developed a coupled model of convective gravity wave (CGW) forcing and propagation to evaluate the entire lifecycle of GWs from their convective excitation to their dissipation in the upper stratosphere / lower mesosphere region. CGW forcing at source level was calculated using the Song & Chun (2005) model. Simulations were performed for all respective MJO phases for MJO cycles during a 30 years period using CFSR data for the full spectrum of CGWs. Our results show a strong correlation between momentum flux at cloud top height and 850 hPa zonal wind anomalies. Maximum momentum flux is prominently found in the inner tropics at altitudes between 20 km and 45 km. Horizontal and vertical wavelength spectra show maximum momentum flux for rather short wavelengths (～ 15-20 km) - a challenge for limb- and nadir-sounding satellite instruments. Furthermore, GW momentum flux phasespeed spectra show a strong dependence on MJO phase with more prominent eastward directed cloud top momentum flux during MJO wet phases and lower cloud top momentum flux during MJO dry phases. Wavelength spectra show prominent momentum flux exerted by GWs with vertical wavelengths as long as 30 km. Horizontal wavelengths are relatively short and typically around 80 km. Phase-wise analysis of GW wavelength spectra again show a connection to the MJO phase with increasing momentum flux during the first four MJO phases and decreasing momentum flux during phases 5-8. We also calculated GW upward propagation using a column model (Song et al. 2006). Results show maximum average eastward momentum flux between 10°S and 10°N at altitudes from 15 km to 45 km with increasing amplitude from MJO phases 1 to 4 and decreasing amplitude from MJO phase 5 to 8. GW drag maximums are found westward directed at altitudes higher than 45 km. However, between 20 km and 40 km altitude, GW drag is eastward directed and about 0.15 m/s/day and almost independent from the MJO phase.

Time series analysis for 32 years of MJO data also reveal a close relationship to QBO phase indicating that GW momentum flux distributions in the Indian Ocean - Western Pacific region depend on CGW forcing during the MJO and the inner-tropical QBO induced wind-filtering of GWs during their upward propagation. Our GW drag calculations also show the prominent significance of convective GW drag for the overall momentum budget in middle-atmosphere tropical regions and its connection to QBO phase.

S1&2A-6

Temperature variance in Alaska in response to the Madden-Julian Oscillation during boreal winter

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The Madden-Julian oscillation (MJO) is the predominant atmospheric mode at the tropics on intraseasonal time scales of 30-70 days (Madden and Julian 1972), and is well-known as one of triggers of the extratropical circulation disturbances which ultimately affects the weather in midlatitude and even polar regions. Recently, Seo et al. (2016) examined that the intraseasonal temperature variation at the surface of three continents (i.e., East Asia, North America and eastern Europe) is caused by the MJO. According to them, warming over East Asia is attributed to adiabatic heating due to subsidence, a part of local Hadley circulation induced by MJO convection, while warming over North America and cooling over eastern Europe come from horizontal advection in poleward propagating Rossby wave. In addition, Alaska is the region where the surface temperature is strongly influenced by the MJO. Extreme warm and cold anomaly appear over Alaska at MJO phase 8-1 and 4-6, respectively. It is comparable to that over East Asia, North America and eastern Europe but it has the greatest spatial extent. Through thermodynamic budget equation using JRA-55 reanalysis data, we identified that the main contribution of the cold anomaly at lagged day 6-18 of phase 2 and warm anomaly at lagged day 6-18 of phase 7 over the regions are due to the horizontal advection of climatological temperature by intraseasonal wind anomaly. In addition, we tried to understand an asymmetry between opposite MJO phases in the circulation response using a primitive equation model.