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Leveraging the MJO for Predicting Envelopes of Tropical Wave and Synoptic Activity at Multi-Week Lead Times

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LONG-TERM GOALS

The Madden-Julian Oscillation (MJO) is the dominant mode of tropical intraseasonal variability, and it extensively interacts with other components of the climate and weather systems. In this project, we will focus on its interactions with important higher-frequency tropical modes. The long-term goals are 1) to explore the relationships between the MJO and the tropical synoptic variablility, mainly the convectively coupled equtorial waves (CCEWs) that include Kelvin, equatorial Rossby, mixed Rossby-gravity, Inertio-gravity waves, and tropical depressions; 2) to investigate the physical mechanisms behind these relationships; 3) to explore the predictability and prediction skill of the envelopes of these tropical synoptic waves associated with the MJO, thus contributing to forming a seamless bridge between weather and climate prediction.

OBJECTIVES

The main objectives of this project are listed below.

A. Characterize the representation of MJO-MC interactions in present-day weather/climate models, with particularly attention on their representations of the diurnal cycle, air-sea interaction and synoptic wave interactions across the MC and relate these, where possible, to the ability of the models to simulate the successful passage of the MJO over the MC region.

B. Perform a detailed characterization and analysis of the multi-scale interactions between the MJO, CCKWs, and the local diurnal cycle of precipitation over MC using observation-based data sets and numerical simulations.

APPROACH

In order to achieve the goals listed above, we will be analyzing various datasets including satellite observations such as the TRMM rainfall, reanalysis datasets such as the ERA-Interim reanalysis and NCEP's new Climate Forecast System Reanalysis, surface fluxes data such as TropFlux and OAFlux and a state-of-the-art multi-model 20-year climate simulation experiment from MJO Task Force GEWEX GASS MJO Diabatic Heating Experiment. We will compare the results based on the

observatons and reanalysis with the model simulations to assess the current model performance in capturing the observed relationships between mean precipitation patterns and spatial variability of the diurnal cycle of convection over the Maritime Continent region, and its seasonal and intraseasonal variability. The cross model differences in representation of the local processes over the MC relevant to the MJO propagation will be analyzed on the basis of the model set up (spatial resolution, air-sea coupling, orography representation) and process based metrics (quality of the surface fluxes, convective to large scale precipitation ratio, representation of multiscale interaction). Finally, we will conduct some specific sensitivity tests using the 2-day hindcast experiment dataset from GASS and NAVGEM (weather forecast) GCMs to better understand the results we will get from the observations and multi-model simulations.

The project is led by D. Waliser (UCLA/JPL: PI) and X. Jiang (UCLA/JPL: co-PI). Waliser and Jiang have had a very productive collaboration over the last five years, resulting in at least 10 publications, on topics of tropical climate variability, multi-scale interactions and physical process understanding. In addition, the team and project will benefit greatly from the involvement/leadership of Waliser and Jiang in the establishment of the two sets of model experiments described in the OBJECTIVES. Additional core team members include D. Baranowski (UCLA/JPL postdoc) who will carry out a significant fraction of the analyses. Key partners include M. Flatau and J. Ridout (NRL). Flatau and Ridout are responsible for NAVGEM contribution to the MJO multi-model diabatic heating experiment.

WORK COMPLETED

During the first year, we have downloaded the relevant datasets to carry out the observational component of the analysis listed in OBJECTIVE A, including satellite observations (e.g., TRMM3B42 rainfall), and reanalysis datasets (e.g., ERA-Interim dynamical and thermodynamic parameters). We have analyzed potential capabilities of the observations and numerical models to represent spatial and temporal variability of the diurnal cycle of precipitation over the Maritime Continent region. We have also identified key metrics that can serve as a basis for multi model assessment. Precipitation data from 20-year climate simulation from all participating models have been utilized and prepared for the analysis of the diurnal cycle of precipitation and its seasonal to intraseasonal variability.

RESULTS

Firstly, the mean precipitation pattern and mean diurnal cycle over the Maritime Continent was calculated using 15 years of TRMM 3B42 data. The original data have 3h temporal and 0.25 deg spatial resolution. They are considered high-resolution observations. Further, the high-resolution observational data were downscaled to 2.5deg spatial and 6h temporal resolution to create lo resolution observational data. This resolution is the same as resolution of the modeling experiment's outputs. The low-resolution observational data a target for how well performing models should represent the diurnal cycle of precipitation over the Maritime Continent. It has been established, that despite relatively course resolution, the low-resolution observations are able to well represent key features of the diurnal cycle of precipitation over the Maritime Continent region, namely, the contrast between nighttime precipitation maxima over ocean and daytime precipitation maxima over land is clear and the relative magnitude of the diurnal cycle of precipitation reflects the fine scale differences related to orography. The key metrics identified are the hour of the local precipitation minima and maxima, and the magnitude of the diurnal cycle of precipitation relative to the mean precipitation. Figure 1 shows the

mean precipitation patterns for all available UTC hours of the day for both high and low resolution observational data together with the spatial distribution of the key metrics.

Further, 8 areas have been identified for further detailed studies. Those areas include land masses (the islands of Sumatra, Borneo and New Guinea, and south east Asia) and ocean surface regions (region directly west of Sumatra, eastern Indian Ocean, Banda Sea and south China sea linked with Java sea). Selection of areas was based on the high magnitude of the diurnal cycle of precipitation, land sea contrast, coherence of the phase of the diurnal cycle and potential influences of large scale circulation that can be linked to the representation of the processes such as propagation of the MJO and other equatorial waves, seasonal cycle, etc, in the cross model comparison. Figure 2 shows the Maritime Continent region map of the low-resolution mean diurnal cycle relative amplitude. The areas of interest are also marked.

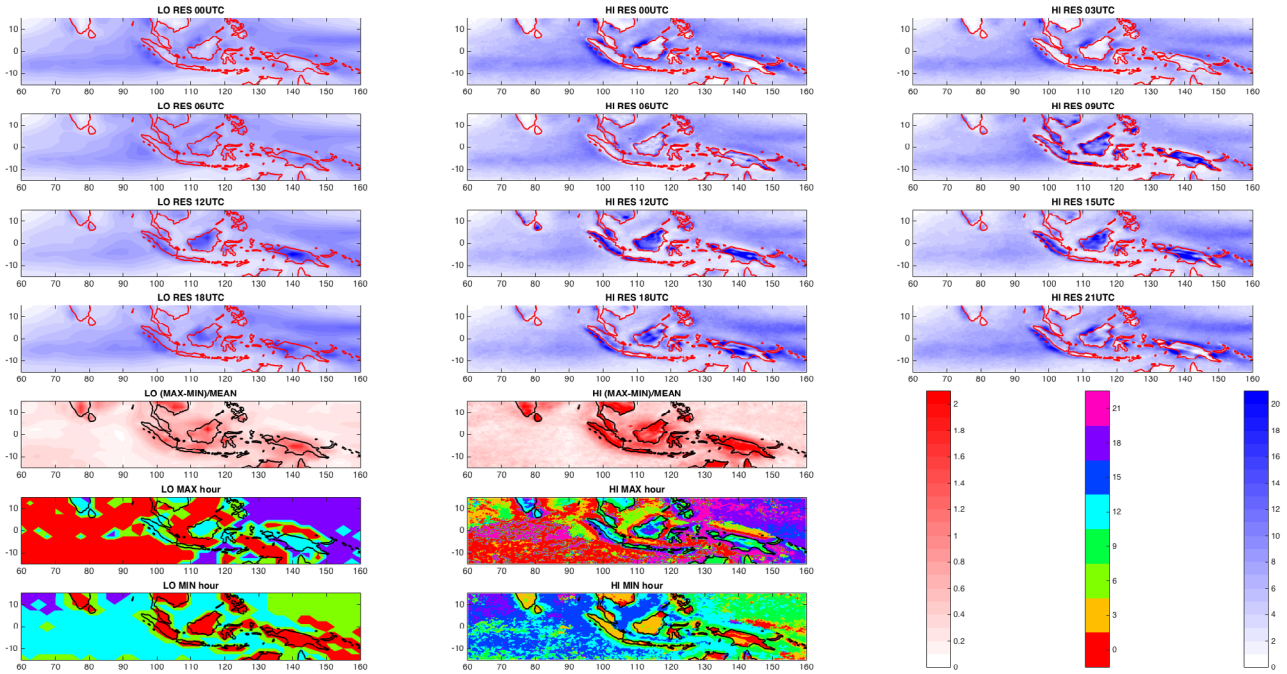

Figure 1 Low resolution (left column) and high resolution (middle and right column) TRMM 3B42 precipitation data in mm/day. Rows 1 to 4 (from the top) represent mean precipitation patterns for specific UTC hours of the day (see titles above plots). Rows 5 to 7 represent relative amplitude of the diurnal cycle of precipitation, hour of the diurnal maximum of precipitation and hour of diurnal minimum of precipitation respectively.

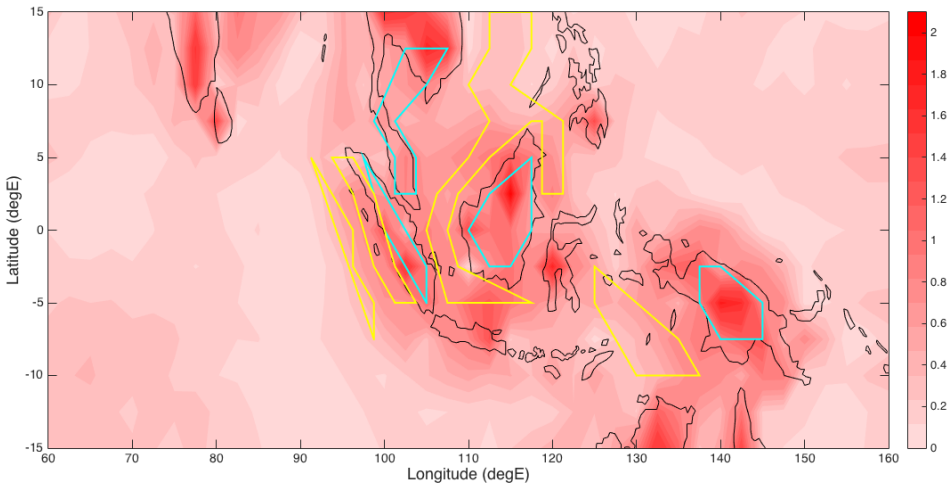

Figure 2 Low resolution TRMM amplitude of the diurnal cycle of precipitation relative to the daily mean precipitation. Black line indicates coastline. Magenta and yellow lines indicate land and ocean areas of interest at model output resolution.

FURTHER PLANS

Based on mean precipitation and amplitude, and phase of the diurnal cycle, the metric for model assessment is being constructed. Preliminary results (not presented here) show that there is spread in the way that numerical models are able to represent the features of the diurnal cycle over the Maritime Continent. We will quantify differences in the representation and relate them to the ability of models to represent seasonal and intraseasonal variability. To that end we will use wavenumber – frequency filtering to isolate model based spectra of the tropical waves and compare them with the observed spectra. We will also assess diurnal cycle seasonal and intraseasonal variability associated with monsoon circulation and MJO, and validate model performance against observation. That analysis will create a basis of the publication on the benchmark assessment of the model representation of the diurnal cycle of precipitation over the Maritime Continent and its variability.

IMPACT/APPLICATIONS

The examination of the relationship between the MJO and the diurnal cycle of convection over the Maritime Continent is an important topic for our understanding of the possible interactions across scales between the planetary scale MJO envelope and the local processes. A key challenge that remains to be overcome to fully exploit the predictability of the MJO is the so called “predictability barrier” of the Maritime Continent. Although skill of numerical models forecasts of MJO initiation and eastward propagation over tropical Indian Ocean has improves, the accurate forecast of the propagation over MC still constitutes a challenge. One of the important characteristics of the Maritime Continent convection is the very strong diurnal variability that could interfere with convective heating of the approaching MJO. It became possible to resolve the diurnal variability of precipitation over the region with the availability of the TRMM data. This research utilizes that knowledge to assess state-of-the-art numerical models performance in the representation of the diurnal cycle of precipitaiton and its links to the MJO via multi-scale interactions.

RELATED PROJECTS

Two very closely related efforts are worth mentioning, each involving one of the community modeling activitites mentioned above in WORK COMPLETED and highlitghted in the proposal. Each of these benefits from the study and discussions associated with the above results and vice versa. This occurs through the joint supervision of these projects by Dr. Waliser and Dr. Jiang and through weekly group meetings where these topics are jointly discussed.

The first is analysis already being carried out on the ISV Hindcast Experiment (ISVHE). Under the guidance of co-PIs Waliser and Jiang, our colleague/postdoc Dr. Neena Mani has carried out a predictability study on eastern Pacific ISV using ISVHE (Mani et al. 2014a). Figure 4 highlights a summary of the results, illustraing a comparison between E.Pac ISV model hindcast skill (model compared to obervations) for single hindcast members (black bars), the improvement when using the model ensemble (hatched), then the estimate of predictability (twin idealized predictions, i.e. model compared to model) for single members (tan bars), and the predictability when using the ensemble compared to a member (gray bars). This illustrates that for the most part there is significant room for improvement in our forecast models of the E.Pac ISV and that ISV in this region is not as predictable as the MJO (cf. Mani et al. 2014b). The results of this study will be submitted for publication in the coming month.

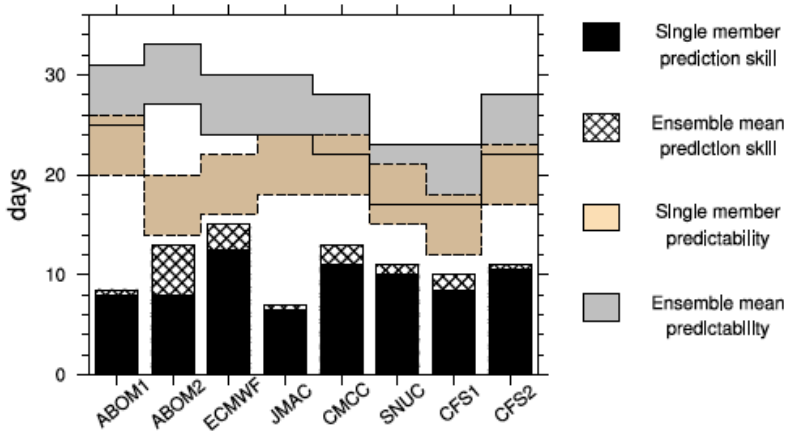

Figure 4 : Average prediction skill (black bar) and ensemble mean prediction skill (hatched bar) estimates for eastern Pacific ISV for the eight models are shown along with the respective, deterministic (wheat shaded area) and ensemble (grey shaded area) estimates of MJO predictability (+/-5 range).

The second is the analyses being carried out on the MJO TF and GEWEX GASS MJO Diabatic Heating Experiment – or more generally the Multi-model Physics Experiment. This work is being led by Dr. Waliser and Dr. Jiang, with the analysis being mainly carried out by Dr. Jiang and our colleague Dr. Guan. The results of this study, along with 3 others, form the initial foundational results from this international community activity (Jiang et al. 2015, Klingaman et al. 2015a, Klingaman et al 2015b, Xavier et al. 2015). Note NRL provided simulations for this activity. Figure 5 highlights a one model performance metric – related to the relationship between mid tropospheric moistening and the suppression/development of strong precipitation - that was discussed in the synthesis paper (Klingaman et al 2015b), which is just one comparison and analysis in a wide spectrum of analyses that includes analyses of 2-day and 20-day hindcasts, and 20 year simulations.

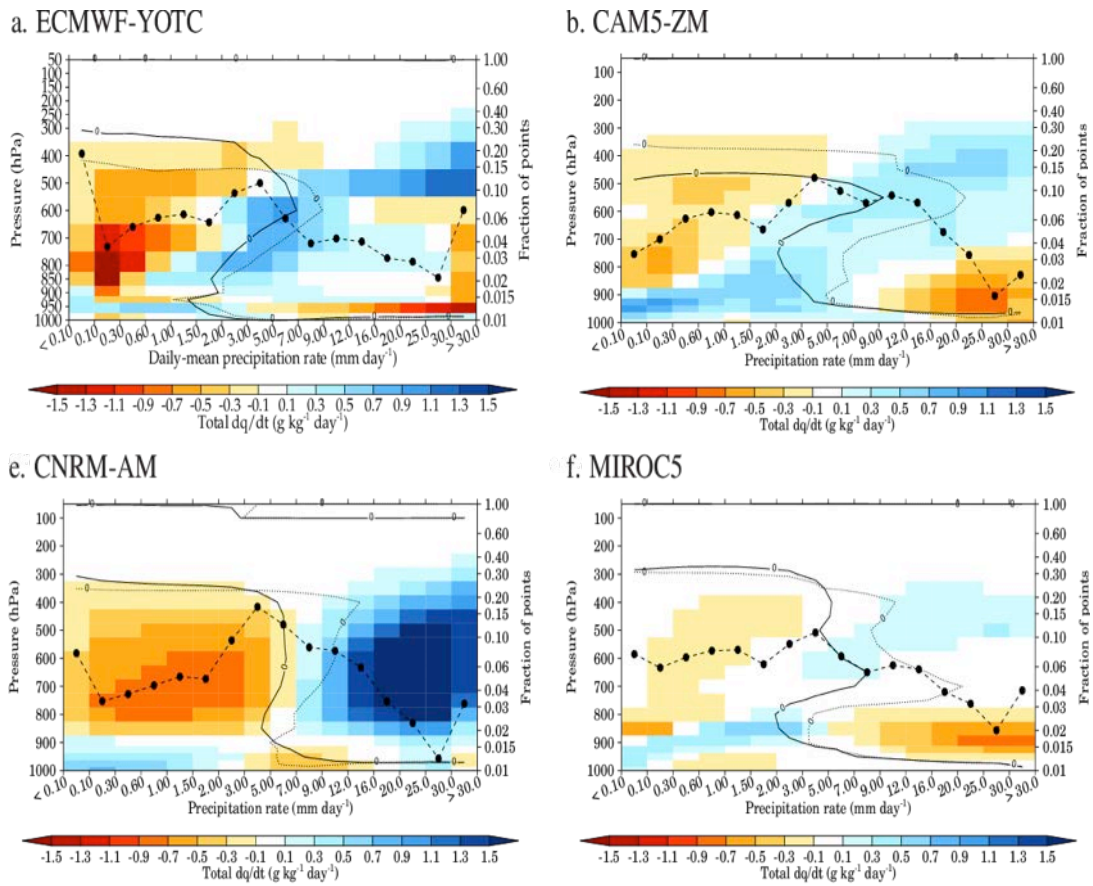

Figure 5 : Shading shows the mean vertical profiles of the rate of change of specifc humidity (dq/dt; g kg day^{-1}) for each range of rain rates on the horizontal axis. Solid (dotted) lines are zero contours of the dq/dt from GCM dynamics (physics). Dynamics tendencies are positive (moistening) above and to the right of the solid line; physics tendencies are positive below and to the left of the dotted line. Dashed lines show PDFs of rain rates, using the right-hand vertical axis. Composites are computed from 3-hr data for 20-day hindcasts. This figure only shows a subset of the figure from Klingaman et al. (2015b)

PUBLICATIONS

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