Comparison of Structure and Evolution Characteristics of Boreal Summer and Winter Intraseasonal Oscillations Derived from Reanalysis Products and Satellite Observations

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Progress Report: Final report

2. Results and accomplishments:

The following summarizes main findings that we have achieved during the one year period of this project.

1. Analysis of vertical heating structures of the Madden-Julian Oscillation (MJO) as a function of rain rate based on reanalyses and TRMM estimates

Given the central role of the diabatic heating for the MJO physics and demand for reducing the model deficiencies in simulating the MJO, it is of great interest and urgent need to explore the observed vertical heating structure of the MJO. Our previous analysis (Jiang et al. 2011), however, illustrated that the MJO vertical heating structure exhibits considerable difference between three recent re-analyses (NCEP-CFS, ERA-Interim, MERRA) and three TRMM-based estimates (TRAIN, CSH, SLH). With support from this project, and built upon our previous study, we have taken a further step to examine composite vertical diabatic heating structure as a function of rain rate, and how it changes during different MJO phases, based on three reanalyses and three TRMM estimates.

This analysis will not only provide insight into MJO physics and help to understand differences in vertical heating structure of the MJO in several datasets as illustrated in Jiang et al (2011), it will also provide an excellent diagnostic/metric to evaluate the multi-model output from the WCRP-WWRP/THORPEX YOTC/MJO Task Force - GEWEX GASS MJO model inter-comparison project, for which the PI (X. Jiang) is a member of the organizing team.

Result: It is illustrated that a clear transit from a shallow heating component with maximum heating anomalies between 600 and 800hPa to a deep heating mode is evident in three reanalysis datasets from the MJO phase 3 to phase 6 (see Fig. 1a-c). Meanwhile, in these three reanalysis datasets, the rain-rate corresponding to the maximum heating anomalies shifts from 15 mm/day at MJO phase 3 to about 30mm/day at phase 6 over the western Pacific. In contrast, the uplifting in the anomalous heating maxima from the MJO phase 3 to 6 is not clearly discerned in all three TRMM-based estimates. The rain-rate corresponding to maximum anomalous heating also does not significantly change based on three TRMM retrievals. This explains why a transition from a shallow to deep heating structure associated with the MJO is clearly evident over the western Pacific in three reanalysis datasets, while it is weakly defined in three TRMM dataset as discussed in Jiang et al. (2011). These differences between reanalyses and TRMM estimates may be related to TRMM retrieval algorithms as well as TRMM sensitivity to detect light rains during suppressed MJO phases (e.g., MJO phase 3 over the western Pacific). Nevertheless, the MJO heating profiles based on reanalyses as shown in Fig. 1a-c need to be further validated by observations, such as in-situ observations from DYNAMO experiment. A similar analysis of composite anomalous heating as a function of rain rate will also be performed based on multi-model output from the MJO Task Force / GEWEX GASS MJO model inter-comparison project. Moreover, moisture and cloud structures in associated with the vertical MJO heating structures will also be explored based on reanalyses and satellite observations. The analyses obtained from this project will provide a critical benchmark for model evaluations. A manuscript contains these analyses is under preparation.

2. Assessment of model fidelity of CMIP5 GCMs in simulating the intraseasonal variability (ISV) over the Eastern North Pacific (ENP) and Intra-America Seas (IAS)

As the intraseasonal variability (ISV) over the eastern north Pacific (ENP) exerts pronounced influences on regional weather and climate. While GCMs are essential tools for prediction and projection of future climate, current model deficiencies in representing this important variability leave us greatly disadvantaged in studies and prediction of climate change. Partly supported by this project, we comprehensively assessed model fidelity in simulating the ISV over the EPAC and Intra-America Sea (IAS) based on simulations from CMIP5 GCMs at 20th century condition and under future projection scenarios (see Fig. 2). A manuscript on this part of work has been submitted to J. Climate (Jiang et al. 2012). Additionally, the PI (X. Jiang) also contributed to the other two overview papers led by NOAA CMIP5 Task Force (i.e., Justin et al. 2012b; Maloney et al. 2012).

Result: Only seven out of the 16 CMIP5 GCMs analyzed in this study capture the spatial pattern of the leading ENP ISV mode relatively well, although even these several GCMs exhibit biases in simulating ISV amplitude. It is indicated that model fidelity in representing ENP ISV is closely associated with ability to simulate a realistic summer mean low-level circulation. The presence of westerly or weak mean easterly winds over the ENP could be conducive for more realistic simulations of the ISV. Results also suggest that, in a future climate, the amplitude of ISV could be enhanced over the southern part of the ENP, while reduced over the northern ENP off the coast of Mexico/Central America and the Caribbean.

3. Highlights of Accomplishments:

- Built upon our previous study on the bulk vertical heating structure associated with the MJO, supported by this project, we further analyzed composite vertical heating structure as a function of rain rate based on three reanalyses and three TRMM estimates. This analysis provide important insight into physical processes of moist convection during the MJO evolution, and thus can be served as important metrics to evaluate GCM capability in simulating the MJO.
- As a coordinated effort by NOAA MAPP Program CMIP5 Task Force, we contributed to

advance knowledge of the long-term climate outlooks for North America by comprehensively assessing model fidelity in representing the ISV over the EPAC and IAS based on CMIP5 simulations, which will provide guidance for the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5).

4. Publications from the Project:

1. Jiang, X., and coauthors, 2012: Moist convection processes associated with the Madden-Julian Oscillation based on re-analyses and satellite observations, under preparation.
2. Jiang, X., E. Maloney, and coauthors, 2012: Simulations of the Intraseasonal Variability over the Eastern Pacific and Intra-America Seas in CMIP5 modes, J. Climate, submitted.
3. Sheffield, J., S. J. Camargo, R. Fu, Q. Hu, X. Jiang, N. Johnson, K. B. Karnauskas, J. Kinter, S. Kumar, B. Langenbrunner, E. Maloney, A. Mariotti, J. E. Meyerson, D. Neelin, Z. Pan, A. Ruiz-Barradas, R. Seager, Y. L. Serra, D.-Z. Sun, C. Wang, S.-P. Xie, J.-Y. Yu, T. Zhang, M. Zhao, 2012: North American Climate in CMIP5 Experiments. Part II: Evaluation of 20th Century Intra-Seasonal to Decadal Variability, J. Climate, submitted.
4. Maloney, E., S. J. Camargo, E. Chang, B. Colle, R. Fu, K. Geil, Q. Hu, X. Jiang, N. Johnson, K. Karnauskas, J. Kinter, B. Kirtman, S. Kumar, B. Langenbrunner, K. Lombardo, L. Long, A. Mariotti, J. Meyerson, K. Mo, D. Neelin, Z. Pan, R. Seager, Y. Serra, A. Seth, J. Sheffield, J. Stroeve, J. Thibeault, S.-P. Xie, C. Wang, B. Wyman, M. Zhao, 2012: North American Climate in CMIP5 Experiments: Part III: Assessment of 21st Century Projections, J. Climate, submitted.

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6. Budget for Coming Year

None.

7. Future Work

The diagnostic metrics for moist convection processes of the MJO developed from this project will be applied to evaluate multi-model simulations from the MJOTF/GEWEX GASS MJO inter-model comparison project. This future work will be supported by PI (X. Jiang)'s other current projects.

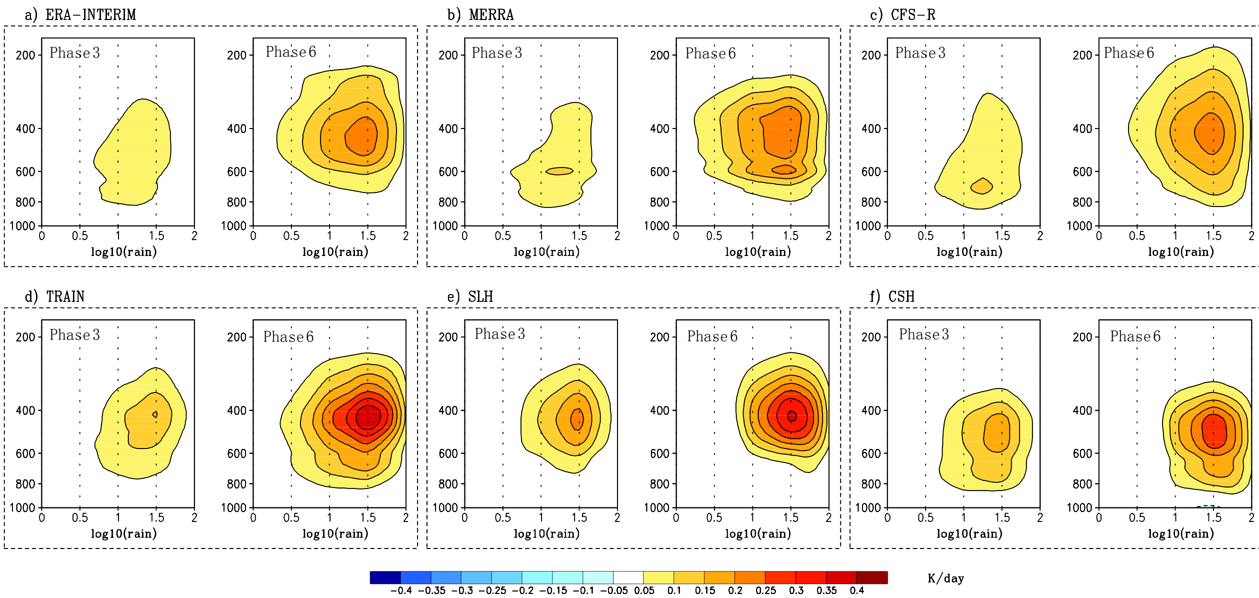

Fig. 1 Composite vertical profiles of anomalous diabatic heating structure associated with the MJO at Phases 3 and 6 (left and right sides in each panel, respectively) as a function of rain rate based on three reanalyses: (a) ERA-Interim; (b) MERRA; (c) CFS-R, and three TRMM estimates: (d) TRAIN; (e) SLH; (f) CSH. The rain rate is plotted on a log scale on the x axis. The analysis was conducted over the western Pacific (15^{o}S-15^{o}N, 120^{o}E-140^{o}E) during boreal winter (Nov-Apr).

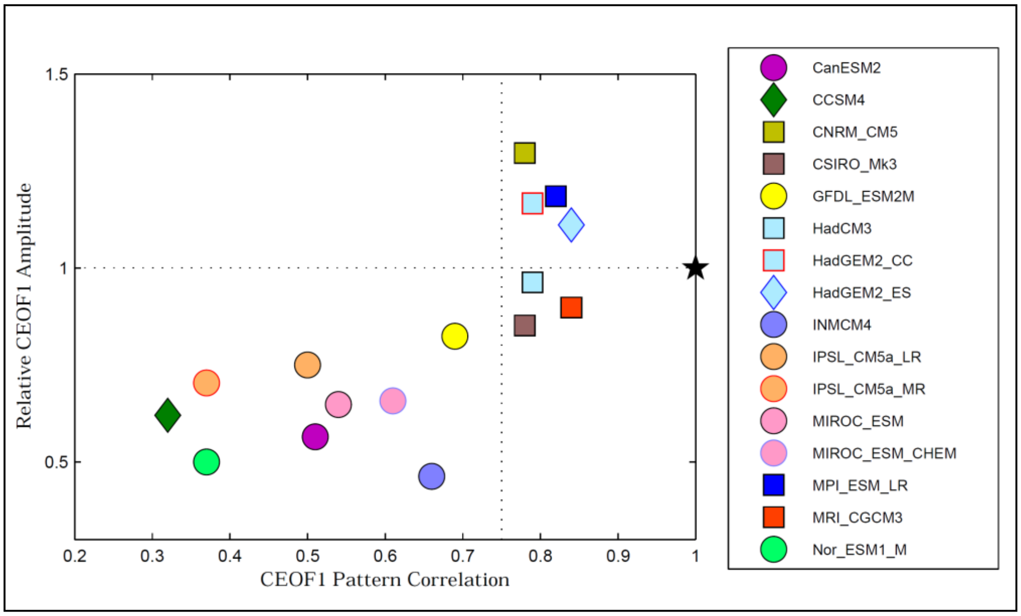

Fig. 2 *(X-axis)* Pattern correlation coefficients of the 1st Complex Empirical Orthogonal Function mode (CEOF1) of the intraseasonal variability over the eastern north Pacific (ENP) between TRMM observations and CMIP5 GCM simulations. *(Y-axis)* Relative amplitudes of CEOF1 in model simulations to the observed counterpart. Both pattern correlations and amplitudes are derived by averaging over the ENP domain (5°N-25°N, 140°W-80°W) where the active ISV is observed during boreal summer. The black “star” mark represents the TRMM observations. Models with “square” marks display westerly or weak easterly (<1.5 m s^{-1}) summer mean wind at 850hPa, while strong easterly winds (> 4 m s^{-1}) are noted in models with “circle” marks. Wind fields are not available in the data portal at the time of this analysis from the two GCMs with “diamond” marks.