Ph.D. Defense Announcement
Kai-Chih Tseng
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THE MADDEN JULIAN OSCILLATION AND TROPICAL-EXTRATROPICAL TELECONNECTIONS

The Madden Julian Oscillation (MJO) excites strong variations in extratropical circulations that have important implications for subseasonal-to-seasonal (S2S) prediction. In particular, certain MJO phases are characterized by a consistent modulation of geopotential height patterns in the North Pacific and North America. Although the MJO's influence in the downstream weather has been widely explored in previous studies, the relationship between robust MJO teleconnection patterns and model prediction skills has received little attention. In this study, the reanalysis data and ensemble hindcasts from numerical weather forecast system are used to quantify the influence of robust MJO teleconnection on model prediction skills.

By calculating the pattern consistency of MJO teleconnection, the ability of MJO convection to modulate extratropical weather is quantified over different time lags and phases. The diagnostic result demonstrates that the robust MJO teleconnection in specific MJO phases/lags are also characterized by excellent agreement in the prediction of geopotential height anomalies across model ensemble members at forecast lead of up to 3 weeks. The mechanisms that lead some MJO phases to have more consistent teleconnections than others are examined by using a linear baroclinic model (LBM). The simulation results show that MJO phases 2, 3, 6 and 7 consistently generate Pacific-North America like (PNA-like) pattern on S2S timescales while other phases do not. By employing a Rossby wave source analysis, the result shows that a dipole-like Rossby wave source patterns on each side of the jet in MJO phase 2, 3, 6 and 7 can increase the pattern consistency of teleconnection due to the constructive interference of similar teleconnection signals. On the other hand, the symmetric patterns of Rossby wave source in other phases can dramatically reduce the pattern consistency due to destructive interference.

The consistency of MJO teleconnections is also characterized by an interannual variability. During the El Niño years, the pattern consistency is dramatically decreased compared to the La Niña years. Employing the numerical experiments in LBM and applying a Rossby wave ray tracing algorithm, we demonstrate two factors largely determine the interannual variability of MJO teleconnection consistency. During El Niño years, the eastward extension of subtropical jet and a less-dipole like Rossby ii wave source pattern on each side of the jet dramatically decrease poleward propagating wave signals. By contrast, the competing effect between these two factors results in modest changes in pattern consistency during LaNiña years. Thus, the observed consistency of MJO teleconnections is much smaller during El Niño years than La Niña years.

The dynamics associated with the pattern consistency of MJO teleconnection are addressed in the first half of this work. What is still unclear, however, is the importance of the accumulated influence of past MJO activity on these results. To examine the importance of past MJO phases in determining future states of extratropical circulations, a LBM and one of the simplest machine learning algorithm: logistic regression are used. By increasing the complexity of logistic regressions with additional informational about past MJO phases, we show that 15 additional lags before lag 0 play a dominant role in determining the future state of MJO teleconnections. This result is supported by the numerical LBM simulations. We further demonstrate that this 15-day span is characterized by a phase/lead time dependent feature, which is relevant to the dynamics of MJO teleconnections and explained in this work.

Ultimately, a particular emphasis is placed on the role of model MJO in influencing the winter climatology of extratropical circulations. The MJO is known for consistently modulating the extratropical weather. In addition, simulating the MJO continues to be a challenge for many state-of-art climate models, and it is unclear the extent to which these biases in the MJO may cause biases in midlatitude variability. By analyzing 22 climate model simulations from the CoupledModel Intercomparison Project Phase 5 (CMIP5) and the reanalysis data, we demonstrate that one of leading variability of daily geopotential height is associated with MJO activity, and can be identified without prior knowledge of MJO in both observations and CMIP5 data. This shows the dominant role of MJO in modulating extratropical circulations. However, due to this strong relationship between MJO and extratropical circulations, the model biases in the MJO convection is also reflected in the wintertime climatology of extratropical circulations.