Workshop Title: MJO Predictability: Its Sources and Limits

Overview

The Madden-Julian Oscillation (MJO, Madden and Julian, 1971, 1972) is one of the most dominant phenomena in the tropical atmosphere on the subseasonal-to-seasonal (S2S) timescale (two weeks to three months). It features slow eastward propagation of clusters of deep convection and their closely associated large-scale circulation from the Indian to the Pacific Oceans (Zhang 2005). The MJO affects many high-impact environmental events, including floods, wildfires, heatwaves, tropical cyclones, and tornados (Zhang 2013). Prediction skills of these and other events depend on how numerical models reproduce the MJO (Andrade et al. 2021; Huang et al. 2021; Li and Robertson, 2015), making it a major source of predictability for S2S prediction. Improving the prediction of the MJO has been a main effort for advancing S2S prediction (Vitart 2017). Understanding MJO predictability is thus crucial for improving S2S predictions.

A wide range of the predictability limits of the MJO (20 to 50 days) has been estimated by studies using numerical models (Waliser et al; 2003; Kim et al 2014; Neena et al., 2014), theoretical models (Chen and Majda, 2015), and observations (Lu et al. 2020). The discrepancies in the estimated limit stem from different methodologies and metrics used. Consolidating and refining these results are needed for reliable estimates of the MJO predictability limits

While the MJO is commonly considered a major source of predictability for S2S prediction, the origin or source of predictability for the MJO itself has remained unclear. Studying the predictability source and limit of the MJO in tandem has not been explored. This presents a new avenue of research that potentially can lead to breakthroughs in S2S prediction.

Comprehensively understanding MJO predictability is urgently needed to build theoretical frameworks for advancements in practical prediction of not only the MJO but also other environmental phenomena on S2S timescales. Typical sessions at general scientific conferences often fall short in providing the depth and scope required for thorough discussions on this critical subject. There has not been any specialized workshop on this subject.

An international workshop convening experts across theories, numerical models, observations and AI/ML is thus timely. This specialized forum centered on the fundamental aspects of MJO predictability will enable in-depth exploration and collaboration. Expected outcomes would be to accelerate the progress in advancing the understanding of both sources and limits of the MJO predictability by expanding currently existing tools of numerical modeling to include approaches using observations, dynamical systems, and information theories. Such progress would improve S2S prediction capabilities for the MJO and related phenomena that directly benefit society.

Objectives

The objectives of the proposed workshop are:

(1) Discuss the present state, gaps, and the future direction in research on MJO predictability, including both its sources and limits.

(2) Cultivate collaborative efforts among experts in theories, observations, numerical models, and AI/ML to advance our understanding of both the source and limit of MJO predictability.

(3) Explore how a fundamental understanding of MJO predictability can guide the advancement of practical MJO and S2S predictions to benefit society.

The following tentative questions are designed to foster the discussions at the workshop to help achieve the three objectives:

- How should the predictability limit of the MJO be studied using theoretically based (e.g., information theories) and AI/ML based methods in addition to the conventional numerically based ones (e.g., perfect model experiments)?
- What are the advantages and disadvantages of different methods of estimating the predictability limit of the MJO?
- How can the physical processes responsible for the predictability limit of the MJO be identified?
- What is the predictability source of the MJO? Can the physical mechanisms for the MJO be considered its predictability sources?
- Are the predictability source and limit of the MJO related to each other through common processes? If so, how should their relationship be identified?
- How does MJO predictability depend on its life cycle (e.g., initiation, propagation through the Indo-Pacific Maritime Continent) and its interaction with other climate phenomena (e.g., El Niño, stratospheric Quasi-Biennial Oscillation)?
- How should the advanced understanding of the predictability sources and limits of the MJO guide the improvement of MJO and S2S prediction?

References:

de Andrade, F.M., Young, M.P., MacLeod, D., Hirons, L.C., Woolnough, S.J. and Black, E., 2021. Subseasonal precipitation prediction for Africa: Forecast evaluation and sources of predictability. *Weather and Forecasting*, *36*(1), pp.265-284.
Chen, N. and Majda, A.J., 2015. Predicting the real-time multivariate Madden–Julian oscillation index through a low-order nonlinear stochastic model. *Monthly Weather Review*, *143*(6), pp.2148-2169.

Huang, H., Patricola, C.M., Bercos-Hickey, E., Zhou, Y., Rhoades, A., Risser, M.D. and Collins, W.D., 2021. Sources of subseasonal-to-seasonal predictability of atmospheric rivers and precipitation in the western United States. *Journal of Geophysical Research: Atmospheres*, *126*(6), p.e2020JD034053.

Lu, D, Ding, R, Li, J. The predictability limit of the amplitude and phase of the Madden-Julian oscillation. *Atmos Sci Lett*. 2020; 21:e968. https://doi.org/10.1002/asl.968

Kim, H.M., Webster, P.J., Toma, V.E. and Kim, D., 2014. Predictability and prediction skill of the MJO in two operational forecasting systems. *Journal of Climate*, *27*(14), pp.5364-5378.

Li, S. and Robertson, A.W., 2015. Evaluation of submonthly precipitation forecast skill from global ensemble prediction systems. *Monthly Weather Review*, *143*(7), pp.2871-2889.

Lu, D., Ding, R. and Li, J., 2020. The predictability limit of the amplitude and phase of the Madden-Julian oscillation. *Atmospheric Science Letters*, *21*(6), p.e968.

Madden, R. A., and P. R. Julian, 1971: Detection of a 40-50 day oscillation in the zonal wind in the tropical Pacific. J. Atmos. Sci., 28, 702–708.

—, and —, 1972: Description of global-scale circulation cells in the tropics with a 40-50 day period. J. Atmos. Sci., 29, 1109–1123.

Neena, J.M., Lee, J.Y., Waliser, D., Wang, B. and Jiang, X., 2014. Predictability of the Madden–Julian oscillation in the intraseasonal variability hindcast experiment (ISVHE). *Journal of Climate*, *27*(12), pp.4531-4543.

Vitart, F. , 2017: Madden–Julian oscillation prediction and teleconnections in the S2S database. *Quart. J. Roy. Meteor. Soc.* , 143, 2210–2220.

Waliser, D. E., K. M. Lau, W. Stern, and C. Jones, 2003: Potential pre- dictability of the Madden–Julian oscillation. Bull. Amer. Me- teor. Soc., 84, 33–50, doi:10.1175/BAMS-84-1-33.

Zhang, C., 2005: Madden-Julian Oscillation. Rev. Geophys., 43, RG2003, doi:10.1029/2004RG000158.

Zhang, C., 2013. Madden–Julian oscillation: Bridging weather and climate. *Bulletin of the American Meteorological Society*, *94*(12), pp.1849-1870.