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Machine Learning Models Use Large Scale Signals to Forecast the MJO

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The Madden-Julian Oscillation (MJO) is a large-scale tropical phenomenon where fluctuations of clouds, rainfall, winds, and pressure propagate eastward around the globe every 30 to 90 days on average. The MJO has significant impacts on weather and climate both locally and globally. Despite its importance, forecasting the MJO remains challenging due to the limitations of traditional numerical and statistical methods. To address this, machine learning has emerged as a promising avenue for MJO forecasting (Martin et al. 2022, Silini et al. 2021, Delaunay and Christensen 2022). Apart from accurate forecasts emphasized in previous research, our study aims to get more physical insights: we build a predictive and interpretable convolution neural network (CNN) and unravel what tropical waves at which spatial scales are essential for MJO forecasting.

Our CNN model takes tropical reanalysis maps as input and predicts the MJO index, achieving forecast skills comparable to NCEP Climate Forecast System (CFSv2). This level of skill is state-of-art in interpretable neural networks. To understand what information is crucial to our MJO forecast, we decompose the output of each convolution layer into tropical waves at different zonal scales. We find that the CNN focuses on large-scale patterns whose zonal scale is above 2500 km. In fact, even when fed exclusively with large-scale features as input, the CNN achieves MJO forecasts akin to the skill of the original model. Furthermore, the CNN chooses to reconstruct large-scale features from input containing solely small-scale features instead of relying directly on small scales for forecasting. This reconstruction further emphasizes the critical role of large-scale patterns in MJO predictions.

In future research, we plan to perform a systematic analysis to evaluate the contribution of different tropical waves to MJO forecasting. We will also simplify the model architecture to facilitate better understanding. Additionally, we plan to incorporate more previous time steps as input memories to enhance forecast accuracy. This work represents a promising advance towards economic yet precise MJO forecasting.