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Geoscientific Model Development Discussions

Interactive comment on "Testing the Reliability of Interpretable Neural Networks in Geoscience Using the Madden-Julian Oscillation" *by* Benjamin A. Toms et al.

Anonymous Referee #2

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Recommendation:

Manuscript requires minor revisions

General comments:

The authors develop and apply neural network techniques to identify the phase, associated spatial structure and seasonality of the Madden–Julian Oscillation from a set of fundamental physical quantities (temperature, geopotential height, moisture and

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winds). The authors aim to demonstrate that computational science techniques, such as these neural networks, can not only recover our current physical understanding of an important geophysical phenomenon like the MJO, but can also give us insights into the phenomenon to further that knowledge. This is an admirable, physically motivated application of computational techniques that are too often treated as “black boxes”. The authors demonstrate that their neural network technique outperforms conventional linear regression; can identify the seasonality of the MJO, particularly with regard to the classical distinction between eastward propagation in boreal winter and northward propagation in boreal summer; and can aid understanding of which atmospheric variables are most “relevant” for the MJO in each phase and at each time of year.

This is a well-presented manuscript with clear objectives and sound understanding. I have a few minor comments for the authors to consider in a revised manuscript, detailed below, but otherwise I believe the manuscript should be accepted for publication after a round of minor revisions.

Minor revisions recommended:

1. For a discussion on the current understanding of MJO theory, and the historical evolution of that understanding, the authors may wish to refer to the recently published manuscript of Jiang et al. (2020): http://dx.doi.org/full/10.1029/2019JD030911.

2. Many in the target audience for this manuscript (climate scientists studying the MJO) will not be familiar with neural network techniques. Adding some background information, or references for further information, to section 2.2 would help the community to understand and accept these techniques. In particular, it would help to understand what “hidden layers”, the “ReLu activation function” and the “softmax operator” are. These are probably commonly used terms in computational science, but I believe the authors would agree that they want to

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avoid their audience treating this technique as a black box. A few sentences of explanation or a few references with further information would help guard against this.

3. In Figure 4, the authors show the probabilistic performance as a 2D histogram of predicted phase against target phase. A similar figure for the deterministic performance would be useful, to demonstrate whether the neural network technique performs similarly well for all target phases of the MJO. It is not easy to determine this from Fig. 4a, as the reader has to estimate the density of dots on the phase diagram.

4. Further to the above, from Fig. 4a it seems that the neural network performs better for stronger MJO events, as there seem to be more red dots closer to the unit circle and more blue and grey dots further away from the unit circle. Did the authors examine performance as a function of target MJO amplitude?

5. In Figure 5, the authors show the seasonality of the deterministic performance of the neural network technique, but provide little interpretation of the seasonality of performance. Can we learn anything – either about the MJO or about the neural network technique – from the fact that the neural networks are less successful at predicting MJO phase in boreal summer than in boreal winter? Can these results help to support the authors' conclusions about the seasonality of the MJO itself?

6. Related to the above, are there similar seasonalities in the probabilistic performance of the neural network technique? If so, is there any useful information we can gain from interpreting those seasonalities?

7. In Figure 7, the authors compare classical composite diagrams of OLR anomalies by MJO phase (panels (a) and (b)) against the "interpreted" results from the neural network that highlight the most salient features for identifying the MJO phase. The authors' interpretation is that the neural network identifies a more

focused area of active and suppressed convection as relevant for the MJO, versus the more widespread or diffuse anomalies in the classical composites. The common approach in composite analysis is to show only those anomalies that are statistically significant at some threshold (e.g., 5% significance) based on a t test or similar. Did the authors perform such a test on panels (a) and (b)? If not, I would recommend performing one, as it might result in a more "focused" composite anomaly.

8. The results presented in this manuscript are certainly a useful first step toward using neural network techniques for understanding and predicting the MJO. However, the greatest uncertainty in community understanding of the MJO is not the identification of MJO phase or seasonality, but the mechanisms for MJO genesis, intensification and propagation. For instance, why do some MJO events propagate across the Maritime Continent while others do not? Why are some MJO events stronger than others? The authors hint that their neural network techniques might be useful for addressing these challenges (L315), but I believe a more detailed discussion of this potential would help the community to see the value in these techniques for understanding and predicting the MJO. As I am not an expert in neural network techniques, I cannot see a straightforward way to apply these techniques to understanding the propagation of the MJO or the mechanisms that drive that propagation. Can the authors add to this discussion in a revised manuscript?

9. Throughout section 3.2.2, the authors discuss the atmospheric fields that are most "relevant" to the MJO. Perhaps this word has a precise definition in neural network analysis, but I struggled with the interpretation here. What does "relevant" mean? Does it mean that the atmospheric field controls MJO strength, or determine MJO phase? Is a "relevant" field simply a field that has a structure common to most MJO events in that phase, regardless of intensity?

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