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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.

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Authors' response to anonymous referee 1; GMD 2020-152

We appreciate the quick review from the first anonymous referee. It seems the referee misunderstood our methodology, and so we seek to clarify this misunderstanding below.

The reviewer's comment originates from our usage of the term "linear regression", which the reviewer seems to have interpreted differently than how we implement the method in our paper. In the paragraph starting on Line 165, we begin a discussion

of how we approach a comparison between a nonlinear neural network and a linear regression-like approach. In this paragraph, we state "the linear regression models have no hidden nodes and no nonlinearities, but are otherwise identical to the neural networks in that the regression model assigns a normalized likelihood that the input is associated with a particular MJO phase by using a softmax operator before the final output". While this is a fairly wordy sentence, the key point here is that we use eight linear regression models, each connected from the input values to an output node associated with a particular phase of the MJO. We then identify the maximum value across these eight output nodes and accept the corresponding phase as the predicted phase. This type of model is effectively similar to a neural network, except that the neural network has no hidden layers and so is not permitted to use any nonlinearities. The method we use is a more complex version of linear regression than the rather simple approach that the reviewer suggests we used. Our approach is described schematically in the attached Response Figure 1 (the associated caption is pasted at the end of this response).

Given this misunderstanding, the reviewer's proposed method of using only PC1 and PC2 to identify the phase of the MJO using a conventional linear regression technique is an over-simplification of the method that we use. We therefore agree with the reviewer that their proposed method will not work well, and we therefore used a more complex form of linear regression in our original manuscript. To address this misunderstanding, we propose the following changes to the wording within our manuscript, which we will implement once the discussion period has closed:

1) Throughout the manuscript, our usage of the phrase "linear regression" will be changed to "multi-output linear regression"

2) The rather complicated sentence explaining how we implement multi-output linear regression will be changed from (as written in Lines 168 through 171) "the linear regression models have no hidden nodes and no nonlinearities, but are otherwise identical to the neural networks in that the regression model assigns a normalized likelihood that

the input is associated with a particular MJO phase by using a softmax operator before the final output" to read as the following: "The multi-output linear regression models have no hidden nodes and no nonlinearities, but are otherwise identical to the neural networks. These models therefore receive atmospheric state variables as inputs, which are then connected to eight output nodes, after which a softmax operator is applied to transform the output into a normalized likelihood. This method therefore does not allow nonlinearities, but does still permit the model to identify patterns unique to each phase of the MJO."

With that said, we finally address the reviewer's suggestion that the reduced accuracy in the multi-output linear regression approach is caused by low accuracies only for phases 1 and 8 of the MJO. The accuracies for each phase using the neural network and multi-output linear regression approaches averaged throughout the year are as follows:

Phase 1:

Neural network: 47.5

Multi-output linear regression: 30.2

Phase 2:

Neural network: 74.7

Multi-output linear regression: 40.3

Phase 3:

Neural network: 76.1

Multi-output linear regression: 32.6

Phase 4:

Neural network: 39.8

Multi-output linear regression: 27.1

Phase 5:

Neural network: 38.1

Multi-output linear regression: 25.3

Phase 6:

Neural network: 79.1

Multi-output linear regression: 36.3

Phase 7: Neural network: 71.4Multi-output linear regression: 35.8

Phase 8:

Neural network: 56.4

Multi-output linear regression: 20.6

The accuracy of the multi-output linear regression approach is lower than that of the neural network for all phases, not just in phases 1 and 8. We also note that the minimum accuracies for both the multi-output linear regression and neural network approaches both occur during phases 4 and 5. The Maritime Continent has been shown to disrupt the spatial and temporal evolution of the MJO (e.g. Chen et al., 2020; Demott et al., 2018; Zhang and Ling, 2017), which likely makes it more difficult to identify its phase in spatial fields of atmospheric state variables during these phases. The reduced accuracy during phases 1 and 8 may be caused by these phases being associated with the initiation and demise of an MJO event, for which the atmospheric signature of the MJO may be weakest. These hypotheses extend beyond the scope of our paper, and we are interested to see if further studies use our proposed method to test such hypotheses more directly.

We again thank the reviewer for their quick response, and we hope our clarification and proposed changes to wording address their comments.

References:

Chen, G., Ling, J., Li, C., Zhang, Y., Zhang, C. (2020). Barrier Effect of the Indo-Pacific Maritime Continent on MJO Propagation in Observations and CMIP5 Models. Journal of Climate, 33(12), 5173-5193.

DeMott, C. A., Wolding, B. O., Maloney, E. D., Randall, D. A. (2018). Atmospheric mechanisms for MJO decay over the Maritime Continent. Journal of Geophysical Research: Atmospheres, 123(10), 5188-5204.

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Figure for Response Caption 1:

Schematic for the multi-output linear regression method used in this study. The first layer ingests vectorized input images and transfers this information to an output layer of 8 nodes that correspond to the eight phases of the MJO. A separate multi-output linear regression model is trained for each calendar week of the year

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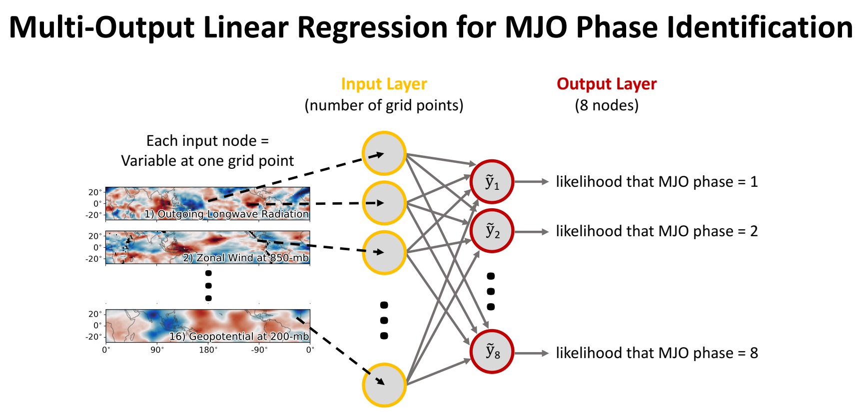

Fig. 1.