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Interactive comment on "Subseasonal Midlatitude Prediction Skill Following QBO-MJO Activity" *by* Kirsten J. Mayer and Elizabeth A. Barnes

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1. Section 2.3: I suggest the authors revise the method section to make it more accessible to a broader audience. The authors also jump into explaining the details of each analysis technique (i.e., STRIPES and ACC). Before jumping into the details, it would be helpful to the readers if the authors could first outline what they attempt to quantify and how it relates to the objective of this study. More specifically, I suggest the following points.

a. For readers who are unfamiliar with Jenney et al. 2019, it would be difficult to understand the STRIPES index. I suggest to move the Supplemental Figure S1 to the main manuscript and include further visual illustrations on how the STRIPES index is

calculated.

Response: We agree that the STRIPES index is new and may not be familiar to the reader. Therefore, as suggested, we have added supplemental Figure 1 to the main paper in Section 2.3: Methods. We have additionally added two panels of spatial z500 anomalies at lead 12 days following phase 6 and phase 2 of the MJO to additionally aid the reader in understanding STRIPES. We have also included additional text: "Midlatitude circulations can be modified by quasi-stationary rossby waves initiated by MJO convective heating. In a phase-lead diagram (e.g. Figure 1a), these are apparent as slowly alternating-sign z500 anomalies with lead following a specific phase of the MJO. In addition, the MJO is a propagating phenomenon with a phase speed of about 5-8 days/phase. Therefore, if there is a teleconnection signal 10 days following phase 2, this signal is likely also present 5 days following phase 3 in the same region, in a composite sense. On a phase-lead diagram, this is apparent as a diagonal line or 'stripe' slanted at the phase speed of the MJO (Figure 1a). Therefore, if a region is sensitive to the MJO, we expect alternating z500 anomaly stripes approximately sloped at the average phase speed of the MJO, as in Figure 1a, which we refer to as the 'stripey-ness'. For further intuition of the phase-lead diagram, Figure 1a and 1b show composite z500 anomalies for the domain around 45\degree N and 5\degree W (marked by the white X) 12 days following phase 6 and phase 2, respectively. The value of the box in the phase-lead diagram is the same as the value plotted at the X in Figure 1b,c."

b. I suggest the authors add more discussion on the novelty and benefits of STRIPES analysis. Why do the authors choose to use the STRIPES index to quantify the model's ability to represent MJO teleconnection instead of using some other simpler techniques (e.g., averaging absolute values of z500 anomaly composites based on RMM phases)?

Response: The STRIPES index was used over more common techniques because it allows us to regionally quantify the strength, consistency and propagation of the MJO impact on the extratropics using only one metric. This has been added to the text: "Therefore, the STRIPES index allows us to regionally quantify the strength, consistency and propagation of the MJO impact on the extratropics and thus, allows us to quantify the ability of hindcast models to capture tropical-extratropical teleconnections on one to four week timescales in a single metric."

c. Discussion on potential caveats of STRIPES analysis should also be included. For example, as discussed by the authors, the propagation speed of the MJO can change with the QBO. In such a case, using the same phase speed to calculate the STRIPES index could be problematic. Is the sensitivity to choosing different phase speeds tested?

Response: As the reviewer suggests, the changes in phase speed of MJO under different phases of the QBO may impact the STRIPES values. This is also discussed in Jenney et al. (2019) if the reviewer is interested in further discussion. Specific to this work, we conducted a sensitivity analysis and found that our STRIPES analysis and conclusions are not sensitive to the exact value of the phase speed over the range of observed phase speeds of 5-8 days/phase. This analysis of the sensitivity of the STRIPES index to the phase speed of the MJO is now included in the text: "It should be noted that the westerly phase of the QBO reduces the propagation speed of the MJO (Nishimoto and Yoden 2017), however, we find that our results are robust to changes in phase speed of +/- 2 days/phase."

d. Line 108: Please clarify what "the resultant vector" means.

Response: We have removed the term 'resultant vector', and replaced the sentence with a more detailed description. "Averages along the slopes corresponding to the MJO phase speed are calculated, and if there are alternating stripes (i.e. sensitivity to the MJO), the resulting averages concatenated into a vector will look like a sine wave, for which the amplitude can be calculated.The amplitude of this oscillatory vector is the STRIPES index (Jenney et al. 2019)."

2. Section 3.1: I was a bit confused about how to interpret the results in this section. The authors explain that Figures 1 and 2 represent the sensitivity of z500 anomaly to

the MJO and QBO states. However, when the authors apply the normalization, the maps appeared noisier and no regions stood out to be "sensitive" to the MJO and QBO states (in Fig. 3). Does this mean that the regions of high values in Figs. 1-2 are just regions of greater variance in z500 and do not necessarily represent the high sensitivity to the MJO and QBO? I suggest the authors recreate Figs. 1 and 2 using normalized z500 anomalies (e.g., by the standard deviation of z500), which I think would be a more proper way to show the sensitivity of z500 to the MJO and QBO states.

Response: We do not standardize the z500 anomalies in Figure 1, 2 and 3 because the variance of z500 has greater variability in the midlatitudes compared to the tropics and therefore, may mute the extratropical signal. In section 2.3, we state: "Since our application focuses on extratropical sensitivity in z500, we do not standardize our data for STRIPES as in Jenney et al. (2019). Standardization may mute the extratropical signal due to the greater variability of z500 in the midlatitudes, which is of main interest here. In addition, we wish to retain any differences in z500 anomaly amplitudes between the QBO phases." Furthermore, differences in composite anomaly amplitude between EQBO and WQBO are also of interest for this work. If we normalize the EQBO and WQBO by their respective maximum anomaly amplitudes in the original Figure 1 and 2 (results shown in the original Figure 3), we ignore this potential difference between the two QBO phases (i.e. one phase could lead to stronger anomalies, in a mean or event-by-event sense, than the other). The fact that the normalized plots look different compared to the non-normalized plots suggests that this anomaly amplitude difference may be appreciable between the two QBO phases, and thus, we choose not to normalize here. In regards to the standardization technique used for Figure 3 (now Figure S2), the reviewer mentions the noisiness of the figure and lack of specific regions 'sensitive' to the MJO. Since we divided by the absolute max of the z500 anomalies to normalize, the noisiness suggests the importance of the combined influence of the magnitude of the z500 anomaly as well as the stripy-ness to determine regions of sensitivity. Furthermore, the maximum is itself a noisy value. Due to the extensive confusion from this figure, and the fact that it is not a main part of this paper's focus, we have moved it to supplemental material.

a. And please clarify what “distinct stripes” on line 176 and “stripey-ness” on line 181 mean. Response: We have added a more detailed description of distinct stripes and stripey-ness: “In addition, the MJO is a propagating phenomenon with a phase speed of approximately 5-8 days/phase. Therefore, if there is a teleconnection signal 10 days following phase 2, this signal is likely also present 5 days following phase 3 in the same region, in a composite sense. On a phase-lead diagram, this is apparent as a diagonal line or ‘stripe’ slanted at the phase speed of the MJO (Figure 1a). Therefore, if a region is sensitive to the MJO, we expect alternating z500 anomaly stripes approximately sloped at the average phase speed of the MJO, as in Figure 1a, which we refer to as the ‘stripey-ness’.”

3. Section 3.2: There were many interesting results presented in this section, but some interpretations of the results must be done more carefully. One of the conclusions that the authors make is that the prediction skills increase during MJO active states when combined with WQBO more than with EQBO states (section 3.2.4). This could be because there is a greater difference in the MJO amplitude between its active and inactive periods during WQBO then EQBO. I suggest the authors check the average amplitude of the RMM index during the different combination states of the QBO and MJO. Another point to check is if the similar samples of different RMM phases are included in each combination of QBO and MJO states. If there are any skewness in the samples of RMM phases, that should be considered for the interpretation of the Results.

Response: The reviewer suggests that the more prevalent enhanced prediction skill following active MJOs during WQBO over EQBO may be due to the differences in MJO amplitude, and suggest that the authors look at the RMM index. This is a great suggestion, and a few recent studies have found that the amplitude of the MJO is enhanced during EQBO compared to WQBO (e.g. Son et al. 2017, Nishimoto and Yoden 2017, Densmoore et al. 2019) while another says that EQBO has a greater

number of strong MJOs than WQBO (Zhang and Zhang 2018). Neither findings explain why WQBO-MJO appears to impact the midlatitude prediction skill more than EQBO-MJO. The reviewer also suggests that we check the skewness of samples of MJO phases within the analysis. This has also been calculated in Zhang and Zhang (2018), where they found that the MJO tends to propagate further into the Pacific Ocean during EQBO. However, this also does not explain why WQBO-MJO appears to impact the midlatitude prediction skill more than EQBO-MJO. With all of this said, this paper is specifically about the resulting changes in prediction skill under different QBO-MJO states, rather than a dynamical explanation behind the changes in prediction skill. This is an important next step for this work.

4. Section 3.2.5: The authors could consider eliminating this section. I am not sure how much value is added by including this section. The general finding that is summarized in this section (i.e., no relationship between z500 sensitivity and prediction skill) could be summarized in a few sentences in the summary or conclusion section.

Response: Thank you for this comment. The other reviewer had similar concerns and so we have decided to remove Section 3.2.5: Northern Hemisphere Prediction Skill and Sensitivity.

5. Lines 336-338: I think it would be nice to add more information/discussion on the dynamics behind the importance of WQBO state to the NAO and AR associated with the MJO

Response: The dynamics behind the importance of WQBO-MJO connection on the NAO and ARs is on going research. We agree this would be an interesting discussion, and an important next step. In the introduction, we hypothesize that the QBO may impact ARs through “its modulation of MJO-induced Rossby waves, and consequently, changes in the steering and frequency of atmospheric rivers.” However, the paper specifically focuses on the resulting changes in prediction skill rather than the dynamical explanation behind these changes in prediction skill, and therefore, is beyond the scope of the paper.

Please also note the supplement to this comment:
http://www.weather-clim-dynam-discuss.net/wcd-2019-13/wcd-2019-13-AC2-supplement.pdf

Interactive comment on Weather Clim. Dynam. Discuss., https://doi.org/10.5194/wcd-2019-13, 2019.

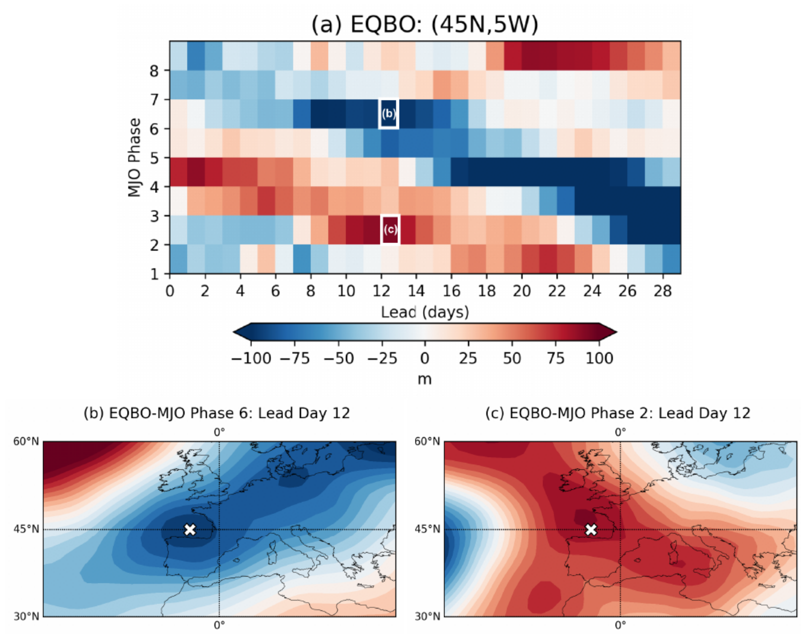

Figure 1. (a) Boreal winter (DJF) composite ERA-I z500 anomalies subsampled to ECMWF initialization dates (1995-2016) for each MJO phase during EQBO vs lead at 45N and 5W. White boxes and text denote corresponding figure in bottom panel. The bottom panel includes composite ERA-I z500 anomalies subsampled to ECMWF initialization dates (DJF, 1995-2016) over Europe for (b) Phase 6 and (c) Phase 2 at lead day 12. The white X denotes 45°N and 5°W.

Fig. 1.