Stationary wave biases and their effect on upward troposphere-stratosphere coupling in sub-seasonal prediction models - Schwartz et al. 2022

The submitted manuscript evaluates the representation of the stationary wave in the troposphere and the stratosphere during boreal winter in 11 subseasonal forecast models. The stationary wave in all models exhibits wave-1 and wave-2 scale biases in the circulation. By evaluating the relationship between the eddy heat flux and the eddy height amplitudes in the troposphere and the stratosphere, the authors show that stationary wave biases influence stratosphere-troposphere coupling. These biases are more pronounced in models with lower model tops. In an exploratory fashion, tropical convection is considered as a source of the extratropical stationary wave biases. The content of this manuscript will be interesting to readers of Weather and Climate Dynamics.

I appreciate that the authors answered all of my questions in the last review while including additional plots to clarify questions posed during the review. With added specificity in the methods section, figure captions, and with the interpretation of the results, the manuscript feels more polished and is nearing completion in my opinion. However, I think more work is needed. Below will follow a list of a few minor comments and one potentially major comment.

I ask that the authors make a major consideration as it may influence the interpretation of the relationship between the stationary wave and tropical convection. On Figures 4l and 5l, the biases in the wind field are pronounced. In fact, the biases in the NCEP and CMA wind fields appear to be fixed in position and planetary scale (predominantly wave-1). The apparent wave-1 signature in the wind biases is apparent in the winter northern hemisphere, but less so in the southern hemisphere, which will less readily support planetary scale undulations in the circulation during summer. These results are not mentioned in detail (lines 258-260) in the manuscript yet, but it is possible that they should be.

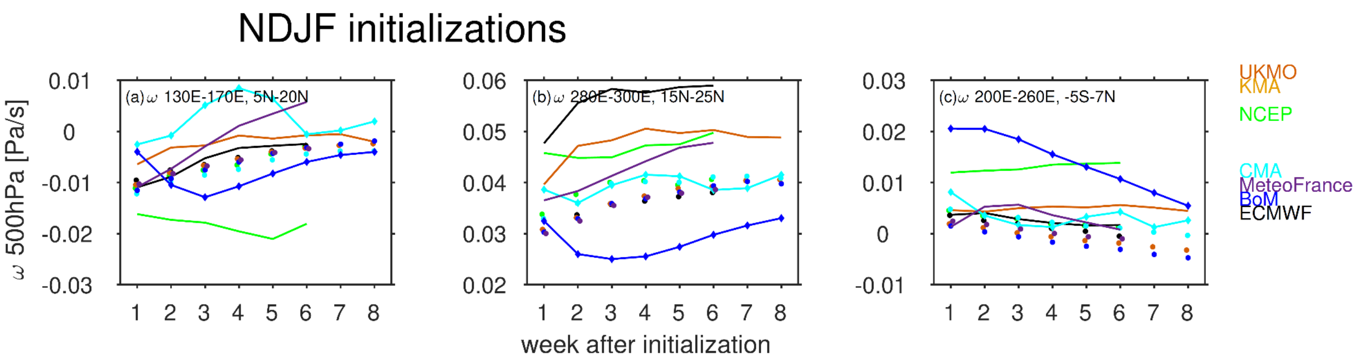
The biases in the zonal wind field on Figures 4l and 5l bear a strong resemblance to the stationary wave itself. The anomalies give the impression of contiguous strips of vorticity rotating cyclonically and anticyclonically between the extratropics and the tropics. In the stratosphere, the stationary wave propagates into the QBO westerlies eliciting a similar tropical wind response (see Hamitlon et al. 2004; Elsbury et al. 2021; Sakazaki and Hamilton 2021). I have not seen this signal in the troposphere before so perhaps Figures 4l and 5l are quite noteworthy. Consider relating the zonally averaged upper tropospheric meridional Eliassen Palm Flux to the tropical wind anomalies in a correlation analysis.

Reviewer 1 asked if it is possible that the stationary wave is causing the tropical convection anomalies rather than the other way around, which is the current interpretation. Reviewer 1's request was not answered and I am not convinced the muddied stationary wave representation is not influencing the tropical ascent/descent. The zonal wind anomalies over the Atlantic in CMA exceed 10 m/s. That is a huge signal, which is not discussed.

The zonal wind anomalies are quite large in CMA (Fig. 5l) compared to NCEP (Fig. 4l), which may stem from the huge underestimation of wave-1 in CMA. Conversely, in NCEP, the zonal wind anomalies are less pronounced because the bias in extratropical wave-1 is weaker, hence the effect of the stationary wave on the tropical circulation is more modest.

Following the above hypothesis, there appears to be a general correlation between westerly tropical zonal wind anomalies and positive tropical omega anomalies. Perhaps anomalous positive du/dz in the upper tropospheric tropics is disruptive to vertical ascent? In an opposite sense, there is a decent amount of evidence in the literature finding a relationship between lower stratospheric QBO easterlies and enhanced convection. If the planetary scale tropical zonal wind anomalies are in fact tied to the underlying omega anomalies, a consideration for this manuscript and subsequent studies is whether or not poor representation of the stationary wave may force biases in tropical circulation and tropical convection, which could subsequently impact tropics-to-extratropics planetary wave propagation. I think the possibility that the stationary wave is modulating the tropical circulation and thereafter, tropical convection, has to be considered before going forward.

Thank you for your detailed comment. Although it is possible that biases in the extratropical stationary waves structure lead to biases in tropical convection, we do not find this behavior to be an important factor in the models. To better demonstrate it, we attach here the time evolution by reforecast week of omega in the three regions discussed in the main text. It is apparent that the biases in omega are evident already in week 1, despite the biases in stationary height in the extratropics still relatively small after the first week (see figure 3).



Specific comments

Figure 5: Consider mentioning that CMA has a "positive-NAO" (North Atlantic Oscillation) like eddy height anomaly, which may be associated with the stronger than average polar vortex (Figure 6). The positive NAO-like bias in figure 5c is shown for week 3. In figure 7e, the vortex strength is not biased during week 1 and slightly positively biased during week 2. Therefore, the stratospheric contribution does not seem to be very significant for the signal in week 3.

Figure 1: Please double check the value of the climatological stationary wave contours. The climatological amplitude of wave-1 at 50 hPa during December should be a few hundred meters. Figure 1 is for the NDJF stationary wave at 500hPa, so are the black and magenta contours for wavenumbers 1 and 2. The peak is indeed much larger than the contours we show for the climatology, however the caption is correct.

Figure 6: Figure 6d shows the relationship between the northwestern North America climatological ridge bias and the wave-2 eddy heat flux bias. Fig. 6g shows the same, but for the other wave-2 ridge. Do the climatological troughs share similarly strong relationships with the wave-2 eddy heat flux? Yes. This is not shown in the main text, but attached here is the correlation between the bias in the Northwest Pacific stationary trough and the bias in stationary wave-2 amplitude. As we can see, the relationship is strong. Now it is also mentioned in the main text.

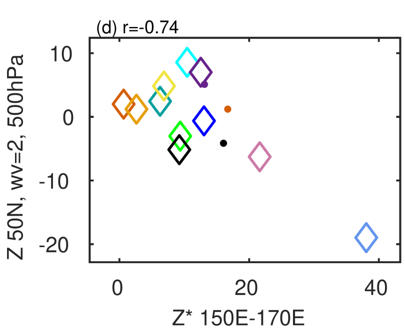


Figure 7 and Lines 233 - 237: Why are the polar stratospheric westerlies systematically decaying over time (Fig. 7e)? Nine of the eleven models exhibit this variability. This does not appear to be linked to the time evolution of the stationary waves (e.g., Fig. 7c,d) as the eddy heat flux biases remain constant or decrease over time.
The decay of the vortex strength over the course of the weeks in figure 7e is due to the seasonal cycle. Only the CMA and ISAC show a weak seasonal cycle.

** See Figures 4, S5, S6: Elsbury, Dillon, Yannick Peings, and Gudrun Magnusdottir. "CMIP6 models underestimate the Holton-Tan effect." Geophysical Research Letters (2021): e2021GL094083.

** See Figure 7: Hamilton, K., Hertzog, A., Vial, F., & Stenchikov, G. (2004). Longitudinal variation of the stratospheric quasi-biennial oscillation. Journal of the atmospheric sciences, 61(4), 383-402.

Sakazaki, T., & Hamilton, K. Discovery of Quasi-stationary Equatorial Waves Trapped in Stratospheric QBO Westerly and Easterly Jets. Journal of Geophysical Research: Atmospheres, e2021JD035670.