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Comment on wcd-2021-84

Anonymous Referee #1

Referee comment on "Differences in the sub-seasonal predictability of extreme stratospheric events" by Rachel Wai-Ying Wu et al., Weather Clim. Dynam. Discuss., https://doi.org/10.5194/wcd-2021-84-RC1, 2022

General Comments

The manuscript addresses an important gap in the subseasonal-to-seasonal (S2S) community - an investigation of how predictable rapid acceleration and deceleration polar vortex events are in the ECMWF subseasonal forecasting system. Quantifying this predictability is important, as changes in the strength of the Northern Hemisphere stratospheric polar vortex typically precede changes in winter weather regimes in the troposphere. The authors find that, while the ECMWF performs well in terms of the driving mechanisms for these acceleration/deceleration events, it cannot capture the magnitude of the most extreme events, a finding common to other prediction systems. This discrepancy in magnitude is especially true for the wave fluxes, which are underestimated in the model. Altogether, the analysis of the model and comparisons with reanalysis is done generally well, and the authors have identified a couple of key metrics that could be assessed for these events. These two metrics - meridional heat flux and a proxy for the index of refraction - could be useful in future assessments of subseasonal forecasting systems and their stratosphere-troposphere coupling mechanisms. The statistics shown are valid and comprehensive, though admittedly numerous and could be streamlined. I think that the conclusions follow the analyses conducted, though a bit more on the mechanistic framework and some more spatial-dependent analyses could help the paper. As such, I am suggesting that the work undergo major revisions before acceptance.

Specific Comments

- **Interdependence of Refractive Index and Wave Forcing.** The authors examine mechanisms and drivers that could explain strong acceleration and deceleration events.

To do this, they have examined the index of refraction and meridional heat flux. However, the authors indirectly treat these two metrics as independent and look at their evolution separately. In fact, the authors treat the index of refraction as a measure of the "background state of the stratosphere" (**Line 245**). However, these two variables are a function of each other. While initially the refractive index may facilitate wave propagation, the breaking of waves in the stratosphere and the changes in the zonal winds and heating profiles caused by these breaking waves will alter the refractive index, which in turn influences future wave breaks. So, it is hard to keep the two metrics completely separate. Have the authors considered this interdependence and thought of ways to address it? For example, if a model poorly handles wave fluxes 25-30 days before an observed event, can we actually use the simulated index of refraction to assess its prediction of an event?

- **Spatial Analyses.** The manuscript studies all events and their forcings in a zonal-mean framework. That approach is a classical way to look at stratosphere-troposphere coupling, but emerging evidence points to the importance of polar vortex morphology and tropospheric source regions of waves for understanding circulation anomalies in the troposphere and stratosphere. As such, spatial distributions of meridional heat flux (at a given isobaric level or even as a cross-section) could be very informative to understand whether the models initiate the waves in the right places. For example, climatologically, vertical wave propagation has two major hotspots during boreal winter: (a) Siberia and (b) Scandinavia / Northern Europe. However, other forecasting systems possess biases on where these hotspots are because of their representation of planetary-scale waves. How does the ECMWF perform in this context, and specifically during strong acceleration or deceleration events? Is one region better represented than the other? Also, what about the morphology of the stratospheric polar vortex? How is that different in the lead up to strong and weak acceleration events, and could that be a predictive element? I am offering two suggestions here, but others are possible. My main point is that I would like to see more multi-dimensional analyses in addition to the zonal-mean metrics (which are important!).
- **More Justification for Choice of Events.** The authors provide definitions for their strong and weak magnitude events as being above their respective 60th percentiles. However, I am unsure why this percentile is chosen other than that threshold is used in other works. In fact, I do not consider the 60th percentile as "extreme" as the title of the manuscript indicates. I would like the authors to provide more details on the choice of this threshold and also how sensitive their analyses and conclusions would be if the value was shifted to the 75th or 80th percentiles.
- **Complexity of Figure 7.** I understand the motivation of looking at multiple lead times and ensembles when studying these different events and comparing their features to reanalysis. However, **Figure 7** has seven differently colored lines (six of which are different shades of blue), two different line styles, and six colors of shading *per panel*. I found it difficult to differentiate the different blue colored lines, especially since many of them overlap each other. I think the authors should consider simplifying these figures by, for example, reducing the quantity of lines. Since we already know that the models improve with shorter lead times from the other previous analyses, can the same message come across with just LTG-25, LTG-10, and LTG-5? Are all the shading colors needed? Again, I am thinking of ways of making this figure more accessible and cleaner without losing its meaning.

Technical Corrections

- **Lines 1-2.** The phrase "associated with an anomalously weak or strong polar vortex" is

oddly placed. Please consider removing this phrase.

- **Line 10.** Please add a semicolon after "behaviour."
- **Lines 10-11.** The wording following "that is" reads awkwardly. Please consider revising.
- **Lines 34-35.** How does the strong latitudinal temperature gradient drive radiative cooling in the stratosphere? Isn't the radiative cooling a function of the (lack of) solar insolation during winter months?
- **Line 39.** Please add "Major" before "SSW events."
- **Figure 1.** I suggest that the authors break this figure into two panels: one for the deceleration/SSW events and the other for the acceleration/strong vortex events. As presented, the one plot has a lot of information and is too cluttered to understand fully. Moreover, is **Line 197** correct? When I examine the figure, I see the blue line (median for deceleration events) higher than red line, indicating a higher magnitude error for deceleration events, not the other way around. Maybe it is just hard to see in the figure (for me), but could the authors check this and perhaps explicitly state the values of the medians just to make sure?
- **Line 203.** Please add "wind changes" after "magnitude" to make clear what the magnitude represents.
- **Figure 2.** In the caption, please change "brackets" to "parentheses."
- **Lines 213-216.** I read this sentence several times, and I still do not understand what it is saying about the gray diagonal line. Please consider rewriting.
- **Lines 228-229.** This line starting with "For instance" is a fragment and should be corrected.