Weather Clim. Dynam. Discuss., author comment AC2
https://doi.org/10.5194/wcd-2021-58-AC2, 2021

Reply on RC2

Chen Schwartz et al.

Author comment on "Stationary wave biases and their effect on upward troposphere–stratosphere coupling in sub-seasonal prediction models" by Chen Schwartz et al., Weather Clim. Dynam. Discuss., https://doi.org/10.5194/wcd-2021-58-AC2, 2021

1) *Use and choice of small regions for bias characterization*

The discussion around l125 suggests that the largest biases arise near the peaks and troughs of the observed stationary wave. In comparing Fig. 2a and b don't see this at all. In particular, I worry that focusing the discussion on these quite narrow (10 degree by 10 degree) regions can give quite an incomplete view of the nature of the biases across the S2S models. I worry that Figs. 3, 6, and 9 may be quite sensitive to these choices. At a minimum there should be some demonstration that the inferred connections between biases are not sensitive to these choices, and this should be in the manuscript, not just in the response to reviewers. It would also be very helpful to see maps of intermodel correlations in some cases (more on this below). I also wondered if the analysis might be more powerful if the focus was on amplitude and phase of the leading wavenumber components of the anomalies.

Thank you for this comment. We now consider wider areas of 20 degrees by 20 degrees, and the results remained unchanged. If anything, the correlations are even stronger.

In general the phases of wv1 and wv2 are well captured by essentially all models, however the amplitude is more of a mixed bag. The amplitudes of wv1 and wv2 are already shown on figure 6, which connects these amplitudes to regional biases in Z*.

2) *Connection to tropical convection*

It is certainly very reasonable to hypothesize that these biases could be related to biases in tropical convection. But I again find the evidence presented to be pretty weak: I am not at all convinced that the first place a modeling group should turn to to correct these errors is the tropical mean convection. In part the correlations are relatively weak. Moreover, this is again based on correlations of very small regions. One way to make this connection more convincing may be to show inter-model correlation maps of omega versus geopotential height biases. This would indicate whether the biases have a teleconnection pattern.

We have made figures of the correlation between omega biases across models and Z biases across models as requested. See supplemental Figure S13 in the revised paper.

The results from this figure support the paper. More generally, we have lowered the degree of confidence implied when we discuss the role of convection for stationary wave biases, as we cannot demonstrate causality.

3) *Connection between stratospheric bias and stratospheric resolution*

This is a simple request (hopefully), but it takes a lot of effort to determine which symbol in a given plot corresponds to which model, and in particular, which symbol corresponds to a high resolution vs low resolution model. It would help to have a different kind of symbol for models in these categories; in particular this seems more useful than distinguishing model versions from individual models.

Old model versions have been removed from figure 2 and similar spaghetti plots. We also added diamonds to low-top models.

A closely related question: Is the wave two component of low-resolution models in better agreement with observations than those of high-resolution models, or is it just that the wave one biases dominate in these cases?

For wave-2, biases in low-top models are comparable in magnitude to those of high-top models, especially in the troposphere (ISAC is an exception). For wave-1, biases in low-top models are more pronounced, therefore it is indeed wave-1 that dominates the biased mean state in the stratosphere.

4) *Importance of outliers*

In many of the inter-model correlation plots there are one or two models that are to some extent outliers and in some cases seem to be determining the overall correlation (at a quick glance: Fig 6d,e,g; 9b). Some discussion should be included about the sensitivity of these correlations to such outliers.

In figure 6, the outliers have been removed and the correlation coefficient has increased in most panels. Please see figure 6 without the outliers in the attached pdf file.

Note that the outliers in the originally submitted version of figure 9 were for models where we had a bug in the initial calculation. This bug has been fixed.

Further questions/comments

1) *The authors choose to stratify forecasts by model version in some cases as a result of updates the forecast model over the course of the S2S project. Is there any evidence that these biases depend on model version and not just on sampling errors due to the different time periods? My impression from some single model studies was that the difference was fairly small (I could not easily find a reference for this). In any case, if this is clear it should be presented to justify the extra stratification; if not I would think it better not to stratify the results in this way (?)*

Older model versions have been removed from figure 2 and other spaghetti plots. We choose to keep them for the correlation plots (figures 6 and 9), but the reviewer is indeed correct that biases are not substantially changed across model generations.

2) *Figure 7 is quite interesting in that it suggests some connection between the stationary wave biases and the zonal mean state. One point of clarification - are the heat fluxes from the stationary component alone?*

The heat fluxes are computed using daily data, and then we average over many initializations to get the time mean heat flux. So this isn't a true stationary wave heat flux (where one would generally take the time mean v and time mean T). However in the Northern Hemisphere the difference between the time mean of the daily heat flux and the heat flux computed using time mean v and time mean T is small. (See e.g. the ERA-40 atlas, though we have reproduced this result using other reanalyses. In the Southern Hemisphere this is not the case.)

This is important in that it provides a connection between these biases and other mean-state biases that could be of strong important for accurately capturing the impact of the stratosphere on forecast skill, for instance. There are some interesting relationships - for instance, the heat flux forecasts of JMA seem to be about right, whereas the zonal mean wind speeds seem to systematically decay. Also, heat flux biases in the CMA forecasts are larger than those in the ISAC model, but the zonal mean state of the latter seems to diverge more quickly.

The JMA zonal mean winds at 10hPa decay as in reanalysis, so that agrees with the simulated eddy meridional heat flux in the lower stratosphere. As for the CMA and ISAC, for wave-1 the CMA indeed has larger biases, but for wave-2 the biases in ISAC are larger. In fact, ISAC is biased in both wave-1 and wave-2, so it somewhat agrees with its biased 10hPa zonal mean winds. For ECCC on the other hand, there doesn't seem to be a relationship between heat flux biases and U10hPa60N biases

Can the authors comment on the relative role of dynamical and radiative processes in determining the mean bias?

Given the present work, we can only comment on dynamical processes that may contribute to the mean bias. The SNAP subproject of SPARC is currently organizing a comprehensive overview of biases in the stratosphere in the S2S models, and this will include a discussion of the relative role of dynamical vs radiative processes. We have added "Radiative processes can also contribute to mean-state biases in the stratosphere, and future work should consider the relative role of radiative vs. dynamical processes for mean-state biases."

3) *Can the authors comment in the consequences of these biases? Do they correlate with forecast skill in any way?* We added 1-2 sentences to the conclusions regarding predictability skill. However, this is not the focus of this work, and is discussed in Domeisen et al. 2020a, and will be further analyzed as part of the SNAP papers on stratospheric biases in S2S models.

Domeisen, D. I. V., Butler, A. H., Charlton-Perez, A. J., Ayarzagüena, B., Baldwin, M. P., Dunn-Sigouin, E., et al (2020). The role of the stratosphere in subseasonal to seasonal prediction: 1. Predictability of the stratosphere. *Journal of Geophysical Research: Atmospheres*, 125, e2019JD030920. https://doi.org/10.1029/2019JD030920

Please also note the supplement to this comment:
https://wcd.copernicus.org/preprints/wcd-2021-58/wcd-2021-58-AC2-supplement.pdf