Anonymous Referee #2

The authors present an interesting and sound analysis of the influence of cold biases in CMIP6 models/AGCM and its influence on the atmospheric state across east Asia and the North Pacific. The results presented by the authors is of interest and relevant to the journal, however I believe it could be improved by expanding on some results further and exploring model sensitivity. Furthermore, a greater explanation of the results from the SPEEDY model would be welcome. I list my several major points below as well as some more minor comments. Once these are addressed I see no reason why this manuscript should not be accepted for publication.

Major Comments

1.1 It would be beneficial to show some of the model spread in the cold bias. Several things that would improve the analysis are: is it only the cold models that have the downstream response in heat fluxes, wind biases, Eady growth rate, etc. A comparison of warm and cold models would be useful. Furthermore, all changes are expressed relative to the model mean, but are the models already biased relative to the observations/reanalysis? Do these cold models amplify an existing model mean bias or how much of the bias can be associated with the colder models? Do the coldest models have the largest biases in heat fluxes etc? I suggest plotting a scatter plot of temperature bias in the TP/MP region against average heat flux (or wind bias) downstream to test this.

The role of the CMIP6 TP cold bias has been further expanded in the new version of the manuscript. A new figure (Figure 1 in the revised manuscript, see below) now shows the bias in near-surface temperature, completing the information on the inter-model spread (Figure 1a in the former version of the manuscript). We have corrected the text in order to avoid confusion between the terms bias, spread and anomaly from the multi-model mean.

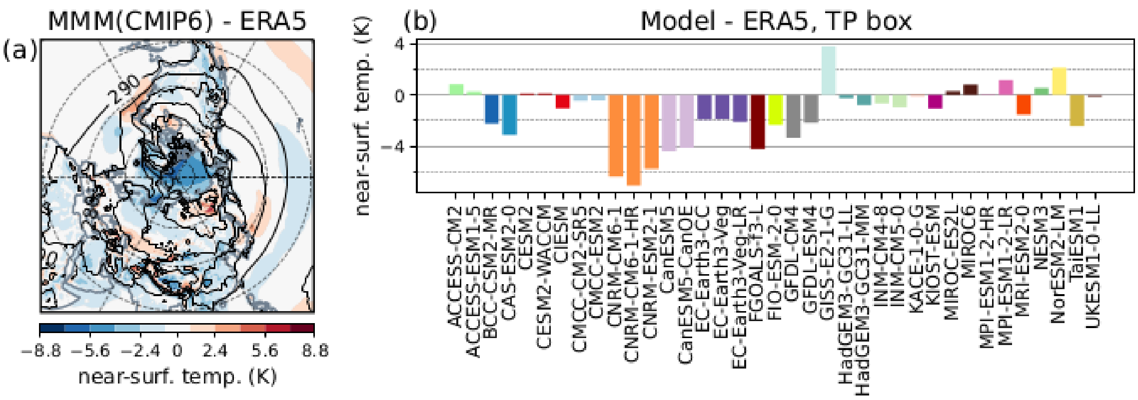

Figure 1. (a) The multi-model mean bias with respect to ERA5 in the Jan-Feb near-surface temperature climatology 1979–2008, with the ERA5 climatology in contours, and (b) the individual model biases over the TP box [25-40 N, 70-105 E] (see black box in panel (b) of Figure 2)

Furthermore, in Figure R4 (below) we report a scatter plot of TP near-surface temperature against surface sensible heat flux in a lon-lat box to the south of Japan. It shows a rather linear relation between the near-surface temperature on the Tibetan Plateau and the downstream sensible heat flux (uw.) - with correlation coefficient of -.0.85, confirming that the TP temperature plays a role in the downstream conditions generally among CMIP6 models, not only in the “cold TP composite”. We report this new result in the manuscript as in the following. Note that the figure numbers refer to the revised version of the manuscript (to be submitted).

“The strong surface heat flux anomalies present over the Pacific basin in the “cold TP composite” (Figure 3(b,c)) are related to the strengthening of the Pacific jet over and downstream of the East China Sea (Figure 4(c)), which extend down to the near-surface level (green arrows in Figure 3(c)) and intensify the advection of cold air masses over the ocean (Figure 6(a)). Indeed, cold air temperatures and strong winds in the boundary layer reinforce the surface turbulent heat fluxes by the warmer sea surface. We note that the relation between (i) cold TP temperatures, (ii) strong low-level winds entering the Pacific basin south of Japan and (iii) strong sensible heat fluxes from the ocean surface over the South China Sea, shows a linear tendency across the CMIP6 models (e.g. the correlation coefficient between (i) and (iii) is -0.85, where (i) is the near-surface temperature in the TP box (black box in Figure 3(b)) and (iii) is the surface sensible heat flux in a [25-40 N, 120-135 E] box). This confirms that the impact of the TP thermal state on the dynamical features over East Asia is not just a peculiarity of the “cold TP composite”, but rather extends to the whole CMIP6 ensemble. ”

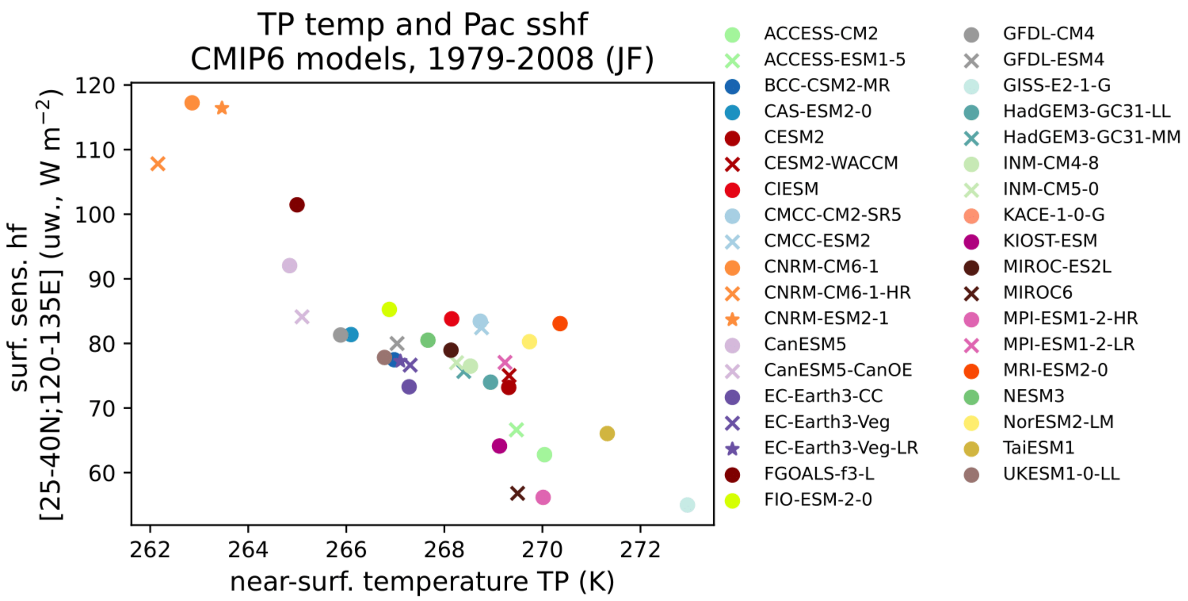

Figure R4: Scatter plot between TP near surface temperature (area-weighted average over lat-lon box [25-40N,70-105N]) and Pacific surface sensible heat fluxes south of Japan (area-weighted average over lat-lon box [25-40N,120-135N]).

1.2 What is the spread in response in the SPEEDY simulations? No stippling is shown in Fig. 5. I suggest something similar as above to investigate the variability in AGCM response.

The significance of the variables in SPEEDY has been computed and stippling has been added to Figure 5 (will correspond to Figure 7 in the revised manuscript).

1.3 You have performed a TP+MP and MP cold experiments and come to the conclusion that most of the downstream response is a result of the TP forcing. Surely running experiments of just the TP cold bias would answer this question. I suggest the authors address this in some way.

We are grateful to the reviewer for this suggestion, which elucidates further how the temperature in the TP region leads to a southward shift in the downstream circulation. We added the results in the figures (new figures 4,7) and expanded the corresponding discussion in the Results and Conclusions sections.

Minor Comments

2.1 L37-38: I suggest adding a reference to Fig. 1b here.

The reference has been included.

2.2 L150: hyphen required in years.

The typo has been corrected.

2.3 L151 and Fig. 1a: how do you determine spread? Is this just the standard deviation of the temperature at each grid point?

We thank the reviewer for pointing out the missing information. In the Results section and in the caption it is added that the spread is the standard deviation of the models' climatologies.

2.4 L154: incorrect colour labelling and figure reference – please correct.

Correction applied.

2.5 L167: 'land' not required.

Correction applied.

2.6 L180-185: suggest adding more explanation here on the mechanism as to how the cold TP bias influences the flow downstream. This will just need to add some discussion from the introduction I believe.

Some more detailed perspectives on the reasons for jet strengthening are given in the paragraph following, that will be part of the new Results section. Please note that the Figures will have modified numbering in the new manuscript.

"The advection of cold air downstream of the TP (Figure 6(a), see Methods for details on the computation) is supported both by the negative temperature anomaly on the orography and, to the east, by the reinforcement of the north-westerly wind (Figure 4(b,d)). These conditions are responsible for intensified meridional temperature gradients east of the TP and along the Pacific coast which enhance the baroclinicity (see positive anomalies in the Eady growth rate west and east of the chinese coastline at latitudes 20–40 N, Figure 6(b)). Given that the Eady growth rate (definition in Methods) measures the environmental conditions favourable to atmospheric baroclinic instability, we would expect the strengthening of the jet at the entrance of the Pacific basin (Figure 4(c)): this should be induced by increased synoptic

activity east of the TP and over the East China Sea, a region where cyclogenesis is climatologically high in mid winter (Priestley et al., 2020; Schemm et al., 2021). However, an analysis of the eddy feedback on the zonal flow for the idealised "TP+MP experiment" - generally coherent with the results of the CMIP6 composite analysis - supports the hypothesis that the jet strengthening is induced by a decline in the synoptic activity to the north of the jet maximum, rather than by an increased activity to its south, as prospected by the Eady growth rate east of the Chinese coast. This will be discussed in more detail in the description of the idealised experiments."

2.7 L188-189: suggest adding some lat/lon co-ordinates to reference which part of the Chinese coast line you are referring to – it's slightly confusing.

Latitude reference has been included.

2.8 Is there anything particular about the models that have the largest cold bias? Are they of lowest horizontal or vertical resolution?

Information about models' resolution has been included in Table 1, but no evident correlation exists between cold TP and resolution, suggesting that this might be part of the land-surface scheme.