Reply to the comments of Reviewer 1:

This study uses a new methodology based on Functional Data Analysis (FDA) to analyze changes in the annual cycle of temperature for different regions of the globe. Changes are examined for the second half of the 20th century and projections into the end of the 21st century. Two reanalysis products (CERA20C and ERA5) and five CMIP6 earths system models are analyzed. Specific diagnostics of the annual cycle documented are the changes in absolute temperature, shifts in the maximum temperature, absolute velocity, and changes in the amplitude of the seasonal cycle.
The study is interesting and presents valuable diagnostics for understanding past and future changes in the annual cycle. I feel this paper is a valuable contribution to the literature. A few comments are listed below.

Line 193-194: Can you expand here on why there may be disagreement between the reanalyses in these situations, and if one may be more believable?
The sentence in question is: "Larger disagreement between the reanalyses also occurs over the southern ocean and in some regions near the equator (e.g., SAH and ARP)".
The discrepancies are caused by large observational uncertainty and large internal variability in southern high latitudes, in our opinion.
Due to the large observational uncertainty, it is really hard to assess which of the reanalyses should be considered more reliable, and it is beyond the scope of our study to hypothesize in this regard. Brunner et al. (2025) emphasize that the discrepancies between different reanalyses are larger in the southern ocean than in other ocean basins, not only for ERA5 and CERA, but also for other 8 reanalyses. Casado et al. (2023) even mention the possibility that the polar amplification, so far generally considered larger in the northern hemisphere than in the southern hemisphere, might be (or become in the near future) more pronounced in the southern hemisphere.

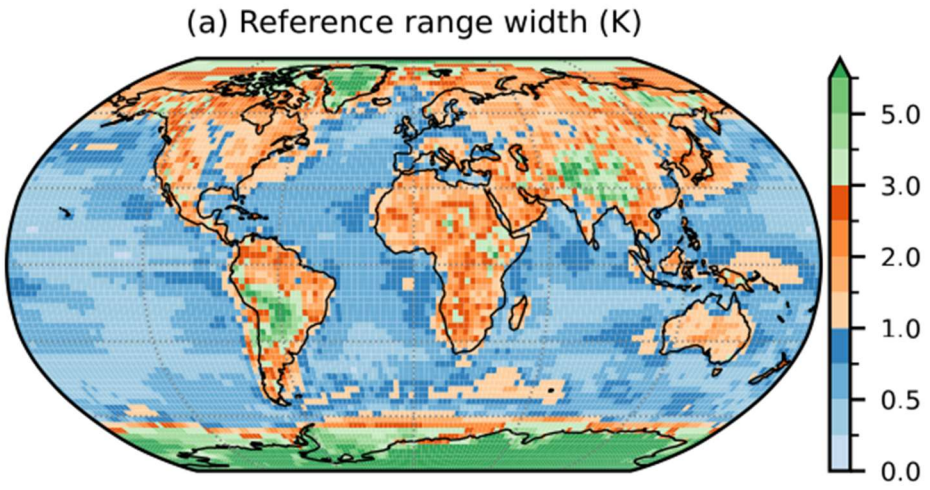


Figure: Width of the 20-year (1980-1999) temperature climatology from 10 observation-based datasets calculated as the maximum minus the minimum value at each grid cell. Note the different step sizes for each of the three shadings, used to roughly highlight the three regimes of uncertainty (ocean, land, high latitudes). The 10 datasets used are: 20CR, Berkeley Earth, ERA40, ERA-Interim, ERA5, JRA55, JRA3Q, MERRA, MERRA2, and NCAR-NCEP. Figure reprinted from Brunner et al. (2025).

Recent studies (e.g., Xin et al., 2023; Turner et al., 2020) described that during the second half of the 20th century, there was warming in the west and slight cooling in the east. This feature probably reversed after 2000, but we do not see any difference between the regions in terms of warming. The lack of this feature in our results is probably related to the Southern Annual Mode. Interestingly, we do not see any difference in the warming rates between West Antarctica (which includes the Antarctic Peninsula) and Eastern Antarctica. Maybe in our case, it is masked by the long-term averaging, but it might also be the result of uncertainty in both used reanalyses.

Moreover, the big difference between CERA and ERA5 in southern high latitudes, unlike in northern high latitudes, points to the importance of the coupling between the atmosphere ocean for the southern high latitudes. As demonstrated by, e.g., Kang et al. (2023), there is a strong relationship between tropical and subtropical Pacific and temperature changes in the southern ocean, and the simulation of these features is expected to be different in ERA5 (atmosphere only) than CERA (coupled simulation). The coupling does not automatically guarantee a better simulation, naturally.

We suggest that we will add the following text (a shorter version of the above discussion) into the first paragraph of the Discussion section, where we already discuss the observational uncertainty in high latitudes:

"Brunner et al. (2025) emphasize that the discrepancies between different reanalyses are rather larger in the southern ocean than in other ocean basins, not only for ERA5 and CERA20, but also for other 8 reanalyses. Moreover, the big difference between CERA20 and ERA5 in southern high latitudes, unlike in northern high latitudes, points to the importance of the coupling between the atmosphere ocean for the southern high latitudes. As demonstrated by, e.g., Kang et al. (2023), there is a strong relationship between tropical and subtropical Pacific and temperature changes in the southern ocean, and the simulation of these features is expected to be different in ERA5 (atmosphere only) than CERA (coupled simulation). The coupling does not automatically guarantee a better simulation, naturally."

New references:

Brunner, L., Ghosh, R., Haimberger, L., Hohenegger, C., Putrasahan, D., Rackow, T., Knutti R., Voigt, A.: Three decades of simulating global temperatures with coupled global climate models, submitted to communications Earth & Environment, 2025.

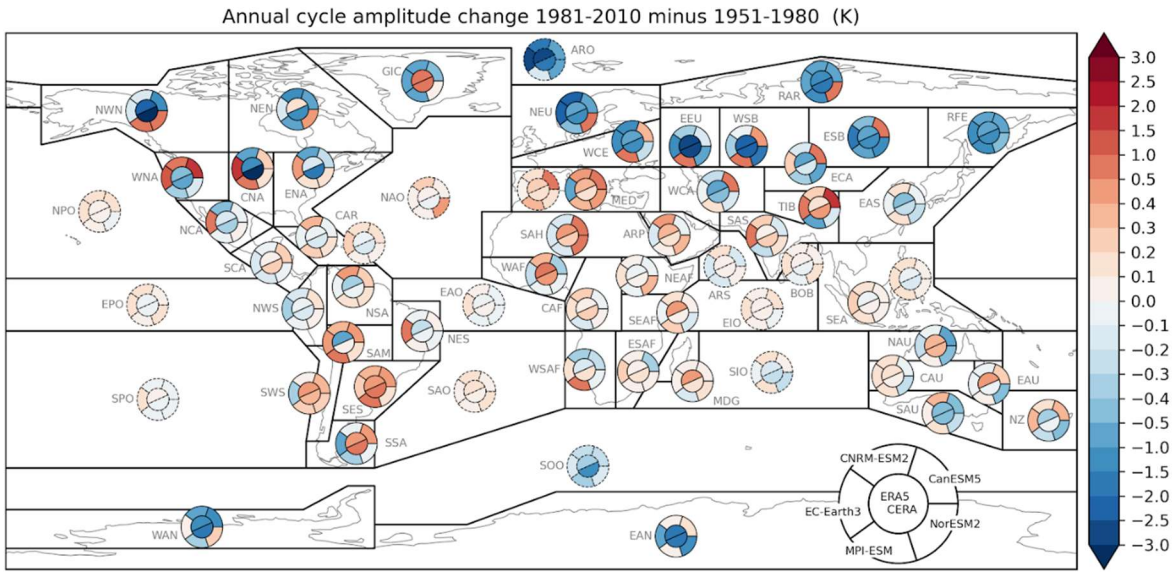
Kang, S.M., Ceppi, P., Yu, Y. *et al.* Recent global climate feedback controlled by Southern Ocean cooling. *Nat. Geosci.* **16**, 775–780 (2023). https://doi.org/10.1038/s41561-023-01256-6

Turner, J., Marshall, G. J., Clem, K., Colwell, S., Phillips, T., & Lu, H. (2020). Antarctic temperature variability and change from station data. *International Journal of Climatology*, *40*(6), 2986-3007.

Xin, M., Clem, K. R., Turner, J., Stammerjohn, S. E., Zhu, J., Cai, W., & Li, X. (2023). West-warming East-cooling trend over Antarctica reversed since early 21st century driven by large-scale circulation variation. *Environmental Research Letters*, *18*(6), 064034.

Line 277-278: In Figure 9, it appears to me that the EEU and NWN have experienced an increase in amplitude. Please clarify.

We are sorry for this; we accidentally inserted an old version of the plot with erroneous results. We have updated the plot, see below, we will also update it in the revised version of the paper. The results in the supplementary plots are correct and show more details about the shift in temperature and the amplitude change.



Discussion: I think it should also be considered how the number of assimilated observations in the reanalysis products changes between the 2 observed periods (1951-1980 and 1981-2010), and what effect this may have on the results.

Thank you for pointing this out. We will add this comment into the revised text, into the first paragraph of the Discussion, when discussing the observational uncetainty:

"Moreover, the number of observations in both CERA20 and ERA5 were increasing during the study period, which might have influenced the results. In case of CERA, in which only variables measured over the ocean are assimilated, the data inputs from ships more than doubled, and data from buoys started to be assimilated after 1970 (Laloyaux et al., 2018). For ERA5, the number of assimilated observations increased from 53 000 to 570 000 between 1950 and 1970 (Bell et al., 2021)."

new reference:

Bell, B., Hersbach, H., Simmons, A., Berrisford, P., Dahlgren, P., Horányi, A., ... & Thépaut, J. N. (2021). The ERA5 global reanalysis: Preliminary extension to 1950. *Quarterly Journal of the Royal Meteorological Society*, *147*(741), 4186-4227.