Dear Dr. Bromwich,

We would like to sincerely thank you for your constructive and insightful comments on the initial version of our manuscript. Below, we provide detailed point-by-point responses to each of your comments. The Referees' remarks are shown in italics, and our responses are provided in plain blue font.

Overview Comments

The authors set out to explain the cold bias in ERA5 temperatures over Antarctica prior to 1979 reported by Bromwich et al. (2024) and Dalaiden et al. (2025). The uncertainty in the SST and sea ice conditions (SSC) over the Southern Ocean during this period is explored to determine the SSC contribution to the cold bias in ERA5. About 30% of the ERA5 cold bias is attributed to Southern Ocean SSC uncertainty. The desire for a reliable SSC prior to 1979 is well justified. This is a valuable study that just needs some more contextual content.

We thank the referee for their positive assessment of our study.

Specific Comments:

Line 30: It is not strictly accurate to call the period prior to 1979 pre-satellite. There were a few primitive satellite sensors in orbit back to the 1960s, as described by Hersbach et al. (2020). It is true that satellite observations became much more extensive starting in late 1978.

We thank the referee for this valuable comment on our use of the term "pre-satellite period". We acknowledge that satellite observations were already available prior to 1979. However, as noted by the referee, continuous and comprehensive satellite coverage began only later, in 1979. We apologize for this simplification and we will revise the manuscript to explicitly acknowledge the existence of earlier satellite observations (e.g., the Electrically Scanning Microwave Radiometer; https://doi.org/10.5194/essd-16-1247-2024), while noting that these observations contain temporal gaps and substantial uncertainties in Antarctic sea-ice retrievals (albeit recent improvements are ongoing to reduce those uncertainties; https://doi.org/10.5194/essd-2025-660).

The reconstruction by Fogt et al. (2022) https://doi.org/10.1038/s41558-021-01254-9 produced a much smaller sea-ice decrease across 1979 than shown by ANT-REC. The seasonal sea ice extent reconstructions were primarily based on monthly mean pressure and temperature records across the Southern Hemisphere extratropics and midlatitudes from 1905 to 2020, similar to ANT-REC. ANT-REC does provide a much more comprehensive analysis, Fig. 5 for example.

We thank the referee for highlighting the differences between ANT-REC and the reconstruction of Fogt et al. (2022). As noted by the referee, the reconstruction of Fogt et al. (2022) shows a weaker decrease in sea-ice extent prior to 1979 (0.18×10^6 km^2 between 1959–1968 and 1981–2000, compared with 0.49×10^6 km^2 for ANT-REC), underscoring the substantial uncertainties in Antarctic sea-ice variability for the period before 1979. As discussed in Goosse et al. (2024) and Dalaiden et al. (2025), the reconstruction of Fogt et al.

(2022) is primarily based on statistical relationships linking large-scale mid-latitude atmospheric variability to Antarctic sea ice, whereas ANT-REC relies on Earth System Model simulations constrained by atmospheric pressure and temperature observations from Antarctic and sub-Antarctic stations through a data assimilation framework. Furthermore, this assimilation-based atmospheric reconstruction is used to force an ocean–sea-ice model, allowing the contribution of oceanic processes to be explicitly represented. These methodological differences may explain the discrepancies between the two reconstructions. In particular, the approach of Fogt et al. (2022), which is primarily atmosphere-based, may underestimate the role of oceanic processes in driving sea-ice changes. This might lead to an underestimation of the long-term changes. In addition, the stronger sea-ice decrease in ANT-REC is broadly consistent with independent paleo-based estimates (Thomas et al., 2019; Dalaiden, Rezsohazy et al., 2023). We will revise the manuscript to discuss these differences and their possible explanations (as mentioned here in the response), emphasizing the complementary nature of the two approaches and the remaining uncertainties in historical sea-ice reconstructions.

Some more discussion of the results of Bromwich et al. (2024) is desirable. Their estimate of the cold bias in ERA5 was ~1C for all of Antarctica, compared to 0.7C here based on station observations. Also those authors discussed the widespread Southern Hemisphere issues with assimilation of satellite (atmospheric) observations prior to 1979 and the jump in performance of the Southern Hemisphere forecasts across 1979 (Fig. 8(e) in Soci et al. (2024) https://doi.org/10.1002/qj.4803).

We thank the referee for this valuable comment regarding the comparison with the results of Bromwich et al. (2024). As noted by the referee, their estimate of the cold bias (~1°C) is based on Antarctic-wide averages, whereas our estimate (~0.7°C) is derived solely from the locations of available weather stations. In addition, the two studies consider different reference periods: Bromwich et al. (2024) estimate the bias over 1940–1978 relative to the post-1979 period, while our analysis focuses on 1959–1968 relative to 1981–2010. These methodological differences likely contribute to the discrepancy in magnitude, and we will clarify them in the revised manuscript. However, the main conclusion remains unchanged, as both Bromwich et al. (2024) and our study conclude in a cold bias in ERA5 for the pre-1979 period.

We also thank the referee for drawing our attention to Soci et al. (2024), in particular their Figure 8, which provides valuable insight into the widespread Southern Hemisphere assimilation issues prior to 1979 related to increased temporal observational constraints and the associated improvement in forecast skill thereafter. In the original manuscript, we noted that the uncertainties in the sea surface conditions alone cannot fully explain the pre-1979 cold bias in ERA5. In the revised version, we will further discuss the role of time evolving observational constraints, especially following the late 1970s, by explicitly referencing Bromwich et al. (2024) and Soci et al. (2024).