Intensifying precipitation over the Southern Ocean challenges reanalysis-based climate estimates – Insights from Macquarie Island's 45-year record

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General Comments

This paper presents an interesting study on the discrepancy between the precipitation observations over Macquarie Island and the ERA5 reanalysis based climate estimate. They link this discrepancy to the limited representation of atmospheric moisture transport and increasing evaporation in ERA5.

The authors identify five different synoptic regimes for characterising the progression of mid-latitude cyclones and associated fronts along the SO storm track: zonal flow, warm air advection, low pressure, cold air advection and high pressure. Among these, only the warm air advection regime has a statistically significant trend in frequency of occurrence over the 45-year period (1979-2023), increasing from 63.2 days per year in 1979 to 78.5 days in 2023.

Over the same period, the intensity of the daily MAC precipitation increases 28.1% (2.6 to 3.3 mm day-1), while ERA5 only increases 8.5%, both statistically significant increases. The authors decomposed the increase in accumulated precipitation into the components arising from changes in frequency of occurrence and changes in mean daily intensity. They found that the shift in frequencies over the different regimes has a small impact on the overall increase in accumulated precipitation for both MAC and ERA5. Instead, the results suggest that it is the increase in the mean daily intensity of the different synoptic patterns that drives the increase in accumulated MAC precipitation.

Overall, the paper is very well written, and the results are clearly presented. Before recommending publication, I would like the authors to address some comments.

1 Representativeness error

The findings of this analysis are indeed interesting and very useful, but I believe the authors should emphasize the limitations of this work due to the usage of a single rain gauge. A single point measurement might not be representative of the ERA5 output which represents an average over a grid cell with a resolution of roughly 31km. The differences observed could stem from ERA5 model bias but also from mismatch bias (point vs cell-mean). A discussion on representativeness errors should be included.

2 Risk of over-interpreting the results

Considering that the study is based on a single measurement site, the authors should be very careful about drawing conclusions that are too broad. The discussion on the changes across the full SO track, starting line 335 feels a little bit too broad. This study is a step towards evaluation and understanding the changes across the full SO storm track, but a much broader evaluation will be required to fully understand the long-term dynamics in this area.

In the abstract,

This precipitation discrepancy reveals moisture and energy budget biases in reanalysis over the SO ...

In my opinion, there is not enough data to support this, and it's not clear how representativeness errors affect this study. The authors should use a more suggestive tone rather than a definitive statement.

3 Line 326. ERA5 captures these trends in the synoptic meteorology, as MAC soundings are assimilated into the reanalysis and are heavily weighted given the remoteness of the location.

This is a little bit misleading, since this statement seems to imply that it is only due to the MAC readings that ERA5 captures these trends. MAC soundings are surely important, but ERA5 heavily relies on satellite data also. Therefore, the authors should rewrite this phrase in a more suggestive tone.

4 Line 266. For ERA5, only the trend in the daily intensity of the low pressure regime is statistically significant. Notably, the trend is negative for both zonal flow and high pressure regimes.

The trends for zonal flow and high pressure regimes are not statistically significant. Therefore, the authors should not use the word *notably*. It could be argued that this should not be mentioned at all (trend being negative). The same applies for line 253

This increase in warm air advection days largely comes at the expense of low pressure days, which decrease from 60.9 to 50.5 days, followed by cold air advection days, which decrease from 85.4 to 80.4

The increase in warm advection is statistically significant, while the decrease in low pressure and cold air advection regimes is not. We lack statistical support to state that the increase in warm air advection comes at the expense of the other two regimes.

5 IMERG

Have the authors considered exploring different global precipitation products, such as IMERG, to check whether similar differences in trends are observed? One potential

issue is that IMERG is calibrated using measurements from Macquarie Island, but an IMERG–ERA5 comparison would still be interesting for this region. I am not suggesting that the authors undertake this analysis for the present paper, but a discussion on the topic could be interesting.