

The Cryosphere Discuss., referee comment RC2  
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## **Comment on tc-2022-151**

Anonymous Referee #2

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Referee comment on "Antarctic sea ice regime shift associated with decreasing zonal symmetry in the Southern Annular Mode" by Serena Schroeter et al., The Cryosphere Discuss., <https://doi.org/10.5194/tc-2022-151-RC2>, 2022

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Review of 'Antarctic sea ice regime shift associated with decreasing zonal symmetry in the Southern Annular Mode' by Schroeter et al.

Overview: This paper uses smaller temporal subsets of the Southern Hemisphere sea ice observations to demonstrate that there are changes in sea ice variations (anomalies and trends) through time that occur since 1979. Importantly, the trends weaken in time, and the earlier part of the satellite record (with the exception of record low years in 2017 and 2022) contain the majority of low sea ice extent / area anomalies. The study relates these changes to changes in the structure of the Southern Annular Mode by analyzing EOFs of SLP and how these change in time, and using a gradient of these anomalies to connect changes in the meridional winds to sea ice concentration.

The paper is interesting, and provides new insight on sea ice variability and its connections to atmospheric (and to some extent, SST) variability. However, it is sometimes unclear what is exactly being shown in the paper, and (from what I can tell) it often masks important seasonal variations as well as discussing relationships that are not likely statistically significant due to the smaller sample size. I recommend a minor revision to add in these details to improve the paper substantially.

## Main comments:

- More detail is needed throughout – particularly if the analysis is done on annual means or monthly anomalies, or something else (Fig 3, Fig 5-7). More details are needed on the calculation of the SAM gradient, as well as some demonstration of the relationship with the meridional wind and its changes through time. Important seasonal deviations from the annual mean or annual cycle (the latter for sea ice especially) are needed throughout. (some details are provided in the listed minor comments below)
- While the shorter time period helps to understand changes in anomalies or trends, there is essentially nothing done in the manuscript to discuss any statistical significance. I suspect as the time period / sample size decreases, the relationships are not statistically significant. In my view, this needs to be discussed – and changes that are statistically significant need to be emphasized. While I realize the paper is about the large variability – it needs to be made clear that this large variability dampens the ability to detect meaningful relationships beyond noise, especially at smaller temporal scales (smaller sample sizes).

## Minor comments

L25: A recent paper by Turner et al. (2022) may be worth citing here as well (<https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2022GL098904>)

L69. 72: change 'data is' to 'data are'

Fig 1a – I think you have the SIA and SIE lines labeled incorrectly, SIA should be larger than SIE

Fig1b-e, and discussion on lines 79-83: Perhaps it is better to call these 'anomalies' rather than deviations, since from the word deviation I immediately think of standard deviation (a measure of variance – which is clearly not what you are showing), rather than a difference from the mean

L83: again, from statistical standpoint, suggest changing to: '...the long-term mean of

both SIA and SIE is more reflective of conditions during the earliest years of the satellite observations' as you are not showing the statistical measure of skew

Fig. 2 – again, SIA should be greater than SIE (SIE does not include ice with less than 15% concentration), so something is off in the labeling here

Fig 2b- It doesn't appear that the trends in sea ice variability are statistically significant, and indeed, if there is any decrease it is because the higher variability at the beginning and lower variability at the end of the timeseries – much of the timeseries shows relatively consistent (at least for such a highly-variant sea ice!) year to year variation.

Fig 3 – are these EOFs based on all monthly anomalies, or for the annual mean? Either way, it masks the important seasonal cycle in sea ice and therefore makes it difficult to interpret. In the same way your paper argues that the climatological (time) mean is biased toward the earlier part, these EOFs represent conditions of sea ice that are only observed for a small portion of the annual cycle. They don't appear to be a robust representation of the dataset. It would be better to look at conditions perhaps at sea ice max / min, or seasonal averages instead.

Fig 3 – the correlation has shifted perhaps, but again due to the very small sample size there is not a statistically significant shift in the correlation magnitude.

Fig 4 – the challenge in interpreting the changes in these long term trends (again masking the annual cycle) is that a lot of the sea ice is gone in the Bellingshausen and King Hakon seas in recent years – which naturally would decrease the variance and weaken the spatial heterogeneity. I'm not entirely convinced from these figures that it is a sea ice regime shift rather than just a complete (or near complete) removal of much of the summer sea ice in these regions and a lengthened ice-free season. The pattern seems to be preserved in the Ross Sea and Weddell Seas, areas with the most ice (even in recent years) in the austral summer seasons.

Fig 5 – is this for annual means? If so, you are masking the role of ozone depletion that has a strong seasonal footprint on the SLP anomalies (which aren't really reliable over Antarctica, but I suspect you'd have a similar depiction in surface pressure anomalies) – this should be noted

Fig 5 – the caption needs redone as it does not describe the paneling in the actual figure – there's no 5e in the caption (it is incorrectly described as 5d)

L157 – the SAM structure may be more zonally asymmetric in the annual mean, but it is more symmetric in the summer according to Fogt et al. (2012) – likely due to the role of ozone depletion mentioned above

Fig 5e – can you confirm that the zonal anomalies sum up to zero for each 15 year period? The integration almost looks negative for the later part (red lines), but it could be my eyes tricking me.

Fig 6 – how is this gradient calculated exactly and it is smoothed in some way spatially?

Fig 6, lines 170-176: Is there any way to show these relationships differently, and to demonstrate some of level of statistical significance? Correlations of SIE anomalies with meridional winds or something similar? You talk about things being in agreement (with meridional winds in particular), but none of this is directly shown other than the difficulty to interpret connections with the SAM gradient.

L220-229: Worth adding into the discussion here the recent paper by Fogt et al (2022) who also discuss a regime shift in Antarctic sea ice in the 20<sup>th</sup> century – consistent with the lower SIE in the mid 20<sup>th</sup> century near the start of the satellite observations (<https://www.nature.com/articles/s41558-021-01254-9>)