

Reviewer 1: Dr Greg Leonard.

“This is a well-written and important manuscript that represents an in-depth baseline analysis of variability and change in circum-Antarctic fast-ice distribution.”

- We thank Dr Leonard for his careful reading of the manuscript, and constructive comments which will improve it.

Major suggestions:

Line 75: The authors state that the new fast ice regions were grouped manually because an automated selection using a decorrelation length scale minimum-based approach (Raphael and Hobbs, 2014) did not work, and present their partitioning technique in Appendix B. However, sufficient details to determine how the partitioning was done are not provided, other than stating that an investigation of the fast ice anomaly cross-correlation matrix as a function of longitude was undertaken. Can the authors provide more details on how this partitioning was done, particularly as they are introducing a “fundamental new region definition”. Can they also comment on the implications of using a non-conservative region definition (e.g. does not include all of the Antarctic coastline / ice shelf edges) as opposed to the Zwally et al. (1983) oceanic sectors?

- This is a good point - this process could be made clearer. Reviewer 2’s comment number three is also similar.
- We aim to select regions with high correlation within the region and low correlation outside of the region. As with the new region definition in Hobbs and Raphael (2014; hereafter H&R), this was largely a manual process, constrained by the content in Fig. B1. In the case of H&R, their selection was guided by functions of sea ice extent standard deviation and decorrelation length scale, i.e., two quantities whose boundaries did not always match spatially, necessitating a subjective decision. Furthermore, H&R select boundaries based on local minima of these quantities, however the choice of which local minimum should be selected, when more than one option exists (e.g., the boundary between the Ross and Bellingshausen/Amundsen regions in H&R Fig 1), is somewhat subjective. This parallels our selection and the subjective elements within. As with H&R, most section definitions here were quite objective (e.g., the Australia region: Fig B1 shows that this box contains only blue pixels, indicating positive cross-correlation within this region, and is surrounded by red pixels, indicating negative cross-correlation). However, we concede that for more gradually-decorrelating regions (e.g., the demarcation between the Eastern Indian Ocean and Western Indian Ocean regions), the subjective element is higher. We plan to address this in the manuscript by a) more clearly stating how these regions

were defined, and b) including discussion of some of this detailed comparison against H&R's similar region selection process.

- Regarding the reviewer's latter point on the non-conservative nature of this definition: It is worth elaborating on this point. Are there implications of this incomplete region definition for users? It's possible - especially if fast ice forms in the future where there currently is none. Currently, longitudes without regular/extensive fast ice are unable to be assigned a group, since it's not clear which of the two "neighbours" they should be assigned to. Under what scenario might fast ice exist there in the future? Probably only if a change in the distribution of large grounded icebergs was to interfere with the local ice-scape. It's not possible to determine which group those longitudes should be assigned without first seeing how their anomalies cross-correlate. In short, major ice-scape changes may both a) precipitate a need for reassigning these regions, or b) require longitudes currently "between" regions to be assigned a region. We plan to address this comment by emphasizing these points in appendix B where region selection is discussed.

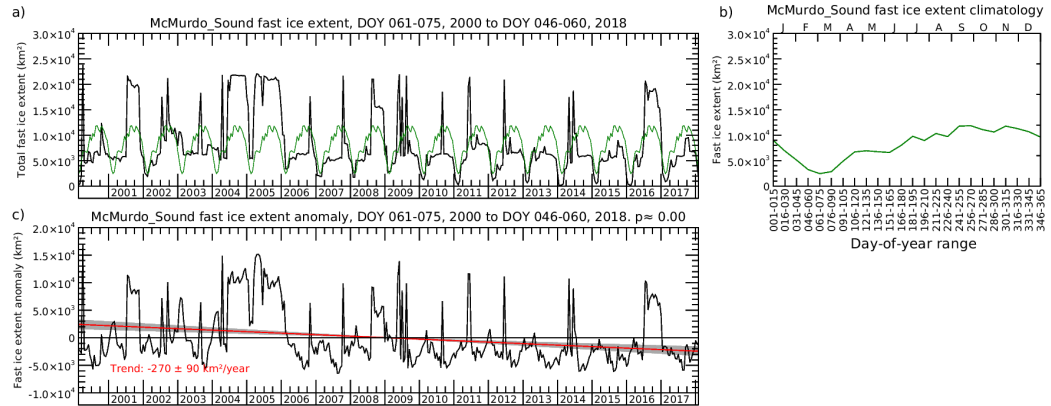
Lines 100–104: Can the authors provide a more indepth description of the technique they used to model the seasonal cycle of sea ice and fast ice. The Handcock and Raphael (2020) paper presents three techniques for modelling annual sea ice extent cycles that are time variant (amplitude only, phase only and amplitude + phase). These models were also only applied to daily sea ice extents, not 15-day interval fast ice extents, although it was noted in the Handcock and Raphael manuscript that this technique could readily be applied to other datasets.

- We agree this is not explained sufficiently, and apologise for that. We used the invariant annual cycle, that is, it is numerically the same year-to-year. This will be made clear around lines 100-104.
- The method can estimate the smooth cyclical spline based on an arbitrary and/or irregular data interval. We treated the fast ice extent value as if it was a point measurement on the day at the midpoint of the 15 day cycle. For example, if the start_doy was 61 and the end_doy was 75, we modeled it as if we had a single measurement at doy $(61+75)/2$. This will also be mentioned around lines 100-104.

Minor comments:

- Lines 22 and 23: The first sentence of this paragraph is not a complete sentence, I suggest rewording by combining it with the next sentence.
 - Good suggestion - will be combined.

- Line 50: There is a missing “a” before “suitable underlying dataset”.
 - Thank you - will accept.
- Lines 76 and 77: “Raphael and Hobbs” is repeated.
 - Thank you - a hangover from a previous version.
- Line 80: “the” is repeated.
 - Will fix
- Line 116: replace “approx” with “approximate”.
 - Will replace
- Line 120: Be consistent with use of hyphenation with “mid” and “late”.
 - A search indicates that, depending on which result I read, “mid” should be hyphenated in places where “early” or “late” isn’t, but I agree it looks a bit silly here. Will be fixed.
- Line 123: I do not understand what is meant by “(as a percentage of average residence time)”. How is average residence time defined? If percentages are relative to an average time, why do they never exceed 100 %? This definition differs to the description in the Fig. 2 caption – the caption definition makes sense to me.
 - I agree it isn’t worded very well. Reworded to match the caption definition.
- Line 143: Capitalise “coast”.
 - Will fix
- Lines 160 + 161 (Comment only): Another area that experienced a large change from multi-year fast ice to seasonal fast ice in the period is the southern reaches of McMurdo Sound. This was due to the presence of large tabular icebergs (B-16 and C-16) (Brunt et al., 2006). I suspect the trend does not appear as strong here as in other regions due to the relative timing of the iceberg affected fast ice cover (2001 - 2011) with reference to the length of the data set (2000 - 2018).
 - Although your “comment only” may not need a detailed reply, I’m also intrigued as to why this region doesn’t show a strong negative trend. If the iceberg-associated positive fast ice anomaly here occurred around the middle of the time series (i.e., around 2009) then I’d expect a minimal trend, but my understanding is this region experienced a positive anomaly much earlier than this (so the trend should be more strongly negative). I prepared a time series subset covering only the Sound (i.e., south of the Drygalski ice tongue):



The extensive fast ice cover throughout the 2016 winter appears to temper this expected negative trend.

- Line 173: Replace reference to Fig. S3 with Fig. C1.
 - Apologies for this oversight - will be fixed.
- Line 176: Suggest moving “only” to before “useful”.
 - Good suggestion
- Line 180: Replace “total sea ice extent” with “total fast ice extent”.
 - Yes - apologies!
- Line 183: Remove duplicate “Fraser et al.”.
 - Will be fixed
- Line 185: Replace Fig. 5b with Fig. 5c.
 - Thank you!
- Line 186: Replace Fig. 5d with Fig. 5e.
 - Thanks again!
- Line 193: Replace “that” with “than”.
 - Will be fixed
- Line 199: replace “than the that of sea ice” with “than that of sea ice”
 - Thank you - will be fixed.
- Line 208: Replace “overall sea ice” with “the overall sea ice maximum”.
 - Will be fixed
- Lines 223 and 226: Replace ref to Fig. S3 with Fig. C1.
 - Thank you - will be fixed.
- Line 231: Replace Massom (2003); Massom et al. (2009) with (Massom, 2003; Massom et al., 2009)
 - Will be fixed.
- Line 293: Suggest insert a comma after “however”.
 - I appreciate this attention to detail! Thanks for picking it up.
- Lines 296 + 297: move $(0.67 \pm 0.55 \text{ %/y})$ to before “sectors”.
 - Good suggestion.
- Line 321: What do the authors mean by “... was re-run using only pre-calving post-calving fast ice anomaly data.”? I assume from the following sentences that the

regional selection algorithm was run twice, once with pre-calving conditions, and a second time with post-calving conditions, 2 but this needs clarification.

- Your interpretation is correct, and sorry this was ambiguous. There's an "and" missing here which wouldn't have helped. This will be rectified and clarified.
- Data availability. The authors need to add a description of how the sea ice concentration from the National Oceanic and Atmospheric Administration/National Snow and Ice Data Center Climate Data Record of Passive Microwave Sea Ice Concentration, Version 3 can be obtained, as well as a citation to Meier, W. N., F. Fetterer, M. Savoie, S. Mallory, R. Duerr, and J. Stroeve. 2017. NOAA/NSIDC Climate Data Record of Passive Microwave Sea Ice Concentration, Version 3. [Indicate subset used]. Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center. doi: <https://doi.org/10.7265/N59P2ZTG>. [Date Accessed]. as described in the dataset's condition of use, reference: <https://nsidc.org/data/G02202/versions/3>.
 - Apologies for this oversight - Reference and description will be added.
- Line 399: I could not find the Kooyman and Burns 1999 manuscript and Kooyman does not appear to list this publication on his website. I did find some other references to a 2009 publication in American Zoologist, so was left wondering if American Zoology should be American Zoologist?
 - Yes - very well spotted! Will change to "American Zoologist".
- Figure 1: I suggest the authors use the same y-axis label for sub-figure a and b. I find it confusing comparing the green line in sub-figure a with the green line in sub-figure b due to the different temporal scales between the two sub-figures, but I appreciate that too much detail might be lost if the width of sub-figure b was reduced.
 - Yes the y-axis labels should be the same - will rectify. We'll try to resist compressing the width of Fig 1b for the reason you stated, but will explain this in the caption.
- Figure 2: "coast" in "Marie Byrd Land coast" needs to be capitalised.
 - Will rectify
- Missing 180° label.
 - Will add
- Figure 5: Caption indicates that p-value of the trend is indicated in the title of each sub-plot, but I could not find this information in the sub-plot titles. To me the need for stating p-values in sub-titles is negated by the last sentence in the caption.
 - Apologies - we replaced the reporting of p-values (in an earlier iteration of the figures) with confidence intervals. As you stated, since all are significant, p-values are redundant. Will amend the caption to refer to confidence intervals only, rather than confidence intervals and p-values.
- Figure A1: The trendline for the Indian Ocean sector is not easily distinguishable from the zero line. I suggest the authors consider using a colour other than black to represent the Indian Ocean anomalies and trend.
 - Good suggestion - we will change the colour.

- Figure B1: The vertical red and blue lines and blue boxes are somewhat difficult to view against the cross-correlation colour scale. I suggest either using thicker lines or choosing colours that do not fall within / near the cross-correlation colour scale. Acronyms for newly defined regions should be spelled out in the figure caption. I find it a bit confusing that the spatial scales on the two axes of a spatial cross-correlation plot are different, and that the coastline on the y-axis is facing the opposite direction relative to the plot than the coastline shown on the x-axis. It would also be useful to distinguish between land and ice shelves in the provided coastal outlines.
 - Thanks for the suggestions. We will use thicker lines for the region boundaries and define the acronyms used in the caption. The spatial scales on the two axes are the same, and the coastline of the y-axis is facing the correct way (at least, it's the intuitive way for me: if one rotates the page 90 degrees clockwise, e.g., to read the y-axis label, then the coastline orientation (on the y-axis) is the same as that on the x-axis without rotation), but happy to discuss further if I've missed something. We will add "Southern Ocean" and "Antarctic Continent" to the y-axis spatial figure to remove any ambiguity (I don't think these will fit onto the x-axis spatial figure).