

Reviewer 1.

We thank the reviewer for their comments and provide our response below in blue.

This paper shows that there is no trend in the areal extent of the marginal ice zone (MIZ), an increase in the fractional area that the MIZ covers in the total sea ice extent, and that the CICE-CPOM model fails to reproduce these observations. I think the observation that the total areal extent of the MIZ hasn't changed is an interesting way to reconsider the dramatic changes in Arctic sea ice, but this isn't really a new insight. For example, Strong and Rigor (2013) and other studies have shown that the MIZ moved northward and its width has increased.

It is true that Strong and Rigor (2013) showed that the width of the MIZ was increasing and moving north. However, our manuscript shows, for the first time and within the bounds of observation error, that there is no trend in the MIZ extent. This is a new insight, as noted by the other reviewers, including the first author of the Strong and Rigor paper.

Rolph et al. is simply arguing that the glass is half full (no change in MIZ extent), rather than half empty (MIZ width is increasing). While I think this is an interesting way to look at the changes in Arctic sea ice, does this different perspective provide any new scientific advances?

Our analysis indicates that the MIZ extent is both not changing in extent *and* is increasing in width, in contrast to the reviewer's description of our results. It is not our intention to speak in sweeping terms about a 'glass half-full' or 'half-empty' situation in relation to climate change and sea ice, but rather to present the first historical analysis of the marginal ice zone extent, which is a vital part of the Arctic climate and biology, e.g. Barber et al. (2015).

The authors also need to consider that the sea ice concentration data has larger errors during summer than they assume. As this paper currently stands, I don't think it provides enough compelling reason to warrant publication.

Naturally, the error in summer sea ice concentration is larger than the 10% error bar we applied. This is evident from the fact that the different observation products do not agree within 10%. We have now made this point more explicitly (see below). However, the true error associated with each observation product is not a known quantity. There are complexities in the processing chain for each observation product produced and, while errors may be quoted for each step in the analysis chain, the true error in representation of sea ice concentration may be subject to systematic or random errors that are not fully accounted for. It is for this reason that we followed precedent and used the 10% error previously introduced in Spreen et al (2008). Increasing the uncertainty of the sea ice concentration datasets would not lead to a known trend, given that the lower uncertainty we used does not show significant trends in MIZ extent.

Major Comments:

1) Why is it important to consider that the areal extent of the MIZ hasn't changed? The authors need to beef up their case that it is important to think of the changes in the MIZ this way. Can the authors show how this perspective provides new insights that the many physical process studies of changes in the fractional area of young ice versus old ice do not? Or new insight into some biological process?

- The Arctic sea ice area is declining with the strongest rate during summer. This can be described by either of the following two extreme scenarios: 1) sea ice concentration is reducing everywhere, so the whole Arctic will become MIZ before it will be free of ice, or 2) the sea ice concentration remains between 80-100% (our definition of pack ice), but the total sea ice extent is reducing until all of the ice is gone. There is no MIZ in the second scenario. We have shown that reality is somewhere in the middle. This is important to know because both of these extreme scenarios are physically very different. In the second scenario, sea ice thickness is homogenous within a grid cell, but in the first scenario, there is a wide sub-grid cell ice thickness distribution, with the thinner ice melting and thicker ice surviving. The changes to the extent of the MIZ depend strongly on the sea ice thickness distribution and provide insights to how sea ice can be expected to melt in the future. We have added a statement to the Discussion section 5.2, at line 324: ‘The lack of trend in the MIZ extent gives an indication about how the sea ice is melting. Given that the sea ice area is declining, it could be (and is often assumed) that the sea ice concentration is declining everywhere.’
- The Arctic MIZ extent is an indicator for the extent of habitat for extremely important biological activity in the Arctic. This is the first study that provides this metric/indicator. While width might be a proxy for extent, it becomes an indirect indicator of extent due to the retracting northward movement of the MIZ.
- Examples of biological activity dependent on the extent of the marginal ice zone have been added in Section 5.3, starting at line 355. Please see also the response to Specific Comment #1 from Reviewer #3.
- Because the MIZ has been shown to be important also in the physical Arctic climate, the timeseries of the extent metric for the MIZ is interesting for a wide variety of Arctic fields of study.

2) The errors in the sea ice concentration retrievals from passive microwave satellites during summer are large. For example, in their figure 3 they show wildly varying estimates of where the northern edge of the MIZ is. Some (Walt Meier and/or others at NSIDC or NASA may have a paper on this) have estimated the summer SIC error to be higher than 40% during summer, and most of this error and differences between the retrieval methods is related to how they filter weather. Rolph et al. need to provide a more thorough error analysis than assuming an overall 10% error estimate since the errors in the SIC retrievals affect how robust their conclusions are.

- We agree and show in our results that the generally applied 10% error is for retrieval of sea ice concentration is not valid for the summer period. Indeed, our analysis demonstrates that MIZ quantities based on current sea ice concentration retrievals are not accurate enough to constrain model results. To avoid misinterpretation, we have added to the manuscript in the Discussion Section 5.5 at lines 381-382: ‘It is clear from the differences in the observations that the uncertainty varies seasonally and often exceeds 10%, with the greatest uncertainty in August (Figures 2 and 3).’
- Increasing the uncertainty of the sea ice concentration will not change the main result of the paper that the MIZ is not exhibiting a significant trend in extent. For this reason, the robustness of the conclusion still stands without increasing the error in summer to 40% for example.

- Spreen et al (2008) gave an error between 10-12% between the sea ice concentration observations from a summer expedition with the German icebreaker Polarstern and three separate algorithms used to process AMSR-E satellite data.

3) The fact that models don't reproduce these observations isn't surprising. There are already many papers that show that various models don't reproduce some observation. But as with any tool, does simply showing that a tool doesn't work for this job warrant publication? If Rolph et al. could pin down what needs to be improved in the models, that would advance science and the inclusion of the model study would be interesting.

- We included the model experiment in order to understand how the MIZ extent, as calculated from satellite-derived sea ice concentrations, compares with the range of MIZ extent as calculated from the model results. We found that modelled MIZ extent does lie within the range/uncertainty of the observations (please see dashed lines in Figure 1).
- Please note we do not conclude that the model does not reproduce observations, but that the observations of the MIZ are not accurate enough to constrain model results.

Minor Suggestions:

4) Be consistent in your use of units. E.g. in lines 194-195 you switch between meters squared to kilometers squared. I suggest sticking with kilometers squared.

Yes, this has been changed now to kilometers squared.

5) Need to note 10^7 in the label for the Y axes in Fig. 1 rather than "1e7" on the top corner of the plots.

Yes, thanks, this has been changed to 10^7 in Figure 1.

6) Provide a short section 3.3 discussing how statistical significance was estimated. Maybe just move this from caption of table 1.

We have moved this from the caption of Table 1 to the end of Section 3.2.

7) Caption of Fig. 1: Change "...is defined at..." to "...is defined as...".

Thanks, changed.