We would like to thank the reviewer for the careful evaluation of our work and for the constructive comments. In the following, the reviewer's points are in italics, our response in plain text.

General Comments

This article is an interesting and valuable contribution to our ability to determine the frequency of large, multi-year open-ocean polynyas in the Weddell Sea. The authors use a combination of continental observations and atmospheric model simulations to identify the potential signature from these open-ocean polynyas in continental ice cores located between 50°W and 0°E. The authors then use a series of high-resolution ice core records to estimate when large Weddell Sea open-ocean polynyas have occurred during the 800 yrs prior to the satellite era. There are substantial uncertainties associated with the reconstruction methods utilised here, which are clearly stated and discussed throughout the paper.

The paper presents novel techniques for identifying past open-ocean polynyas which are worth publishing. However, the uncertainties result in the majority of the conclusions being largely speculative. Therefore, this paper would benefit from a refocused discussion on the possible wider implications of the predicted polynya occurrence frequency, as these implications would help guide future work into corroborating or disproving the polynya frequency predicted by the authors.

We agree with the reviewer that the uncertainties are large. This will be expanded in the revised version, in particular by presenting the reconstructions differently (see below) and by discussing more explicitly the perspective to reduce the uncertainties, as suggested, in new paragraphs of the final section (Discussion and Conclusions)

Specific Comments

=> The introduction is very long, with substantial detail on polynya formation that seems superfluous to the focus and aims of the paper. If more discussion were to be added on the link between the formation mechanisms and the predicted occurrences in Figure 6 then this detail would become more relevant to the scope of the paper.

As suggested by the reviewer, we will add in the final section (Discussion and Conclusions) new paragraphs to discuss the link between the mechanisms of formation and the predicted occurrence of open ocean polynya, making the connection to the material described in the introduction. Specifically, this final section will include a discussion of the wind changes, in particular how a connection between our reconstructions of polynya activity can be made with available reconstructions of the Southern Annular Mode (SAM; related to the intensity and the position of the Westerlies) for the past millennium. This will justify the discussion of the hypotheses related to the role of SAM in polynya formation in the introduction. The link to oceanic processes mentioned in the introduction is a bit more difficult to develop in the final section because of the small number of high resolution data available, but we will add an explanation of the potential impact of the reconstructed changes on the ocean state and how new information about past ocean changes could support, or refute some of the changes in polynya occurrence estimated from our reconstruction. Additionally, we propose to shorten the introduction by about 20%, to focus on the elements specifically relevant to the other sections of the manuscript.

=> In both Figures 3a and 4 there are anomalies across large parts of the West Antarctic Peninsula and Amundsen-Bellingshausen Seas regions. The authors indicate in line 274 that these anomalies are not related to the Weddell Sea polynya. However, there is no further discussion of what is causing these anomalies. It is important to at least speculate as to what is causing these anomalies and, crucially, whether it is also responsible for the anomalies closer to the polynya that are currently being interpreted as a signal from the polynya itself.

We agree that the sentence line 274 was a bit too short and that the topic deserves a more detailed explanation. We propose to change this line from 'it is unlikely that they are all related to the great Weddell Sea polynya formation' to ' it is unclear if they are all related to the great Weddell Sea polynya formation' and discuss further this point in section 4. We propose to add, in the section devoted to the description of the fingerprint of the polynya, a justification as to why we consider that the higher accumulation in the section roughly between 50°W and 0° is a more robust signature of the open ocean polynya formation compared to other areas of the ice sheet.

=> Concerning the Hadley Centre data set used to drive the ECHAM5-wiso atmospheric model, it is not clear which years have been used in this study. Lines 189-190 suggest that data from 1871-2011 has been used whereas Figure 4 only seems to have the years 1958-2000. For either option there needs to be an appreciation of the limitations in using the Antarctic sea ice data from Rayner et al. (2003) to run the model. For example, the Antarctic sea-ice extents for the years 1871-1927 are all duplications of the 1927 climatology.

The Rayner et al. (2003 and updates) estimate of the Antarctic sea ice concentration has indeed clear limitations, with could potentially lead to large uncertainties in the ECHAM5-wiso results. The simulation covers the period 1871-2011, as mentioned in section 2.2. However, we only use the period 1958-2000 here to obtain a climatology of the model results that we compare with the years 1974-1976 corresponding to the great Weddell polynya existence. For clarity, this will be specified in the revised version when we describe the simulation itself. We do not use the earlier period, in particular the years 1871-1927 mentioned by the referee when the uncertainties on the sea ice extent are particularly large. The uncertainties are already large before 1973 as no satellite-based imagery is directly included and the reconstruction is derived from various climatologies. We have chosen the years 1958-2000 as a reference to have a common period for all the datasets in Figures 2, 3 and 4. Nevertheless, our results for the region of the ice sheet close to the Weddell Sea, and therefore more directly influenced by the polynya formation, are not very sensitive to the reference period chosen. This is illustrated in the figure below (Figure R2.1) where the reference period is 1979-2011 (when satellite information is available and the uncertainties on the Rainer et al. (2003) data set are lowest).

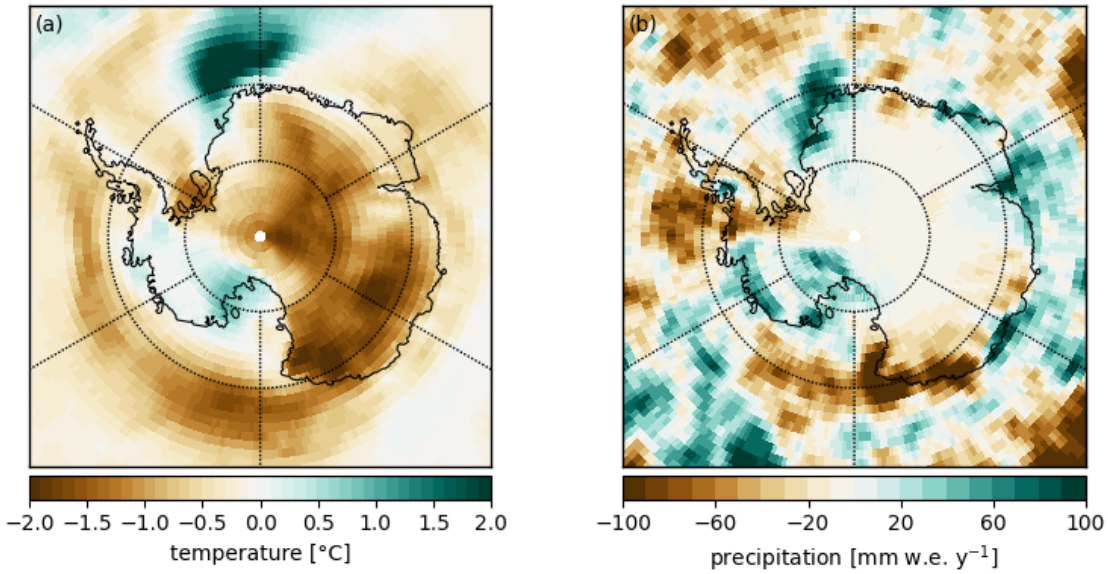

Figure R2.1: Anomaly of (a) annual mean temperature (°C), (b) precipitation (mm w.e./y), averaged over 1974-1976 compared to the period 1979-2011 in a simulation performed with ECHAM5-wiso. This figure is similar to Figure 4 of the main manuscript but with a different reference period.

=> There should be some discussion of how changes in wind direction could influence the variability seen in Figures 6 and 7 as well as possible explanations for the hypothesised centennial-scale variability in line 432.

As suggested, we will include a discussion of the possible role of wind changes, in particular related to the Southern Annular Mode, in the variability seen in our reconstruction. See also the response to the main comment above.

Technical Corrections

Lines 55-57: statements on the ocean preconditioning should be referenced.

References will be added.

Line 229: replace "averages is" with "averages are".

Corrected.

Line 357: presumably should be 50°W not 50°E, as in line 368.

Thank you for pointing out this mistake. It will be corrected in the revised version.

Line 399: should be Figure 5 not Figure 4.

This will be corrected.

Lines 425-428: it is unclear whether this is referring to years when any single index is greater than 0.8/1 or when the average of all the indices is greater than 0.8/1.

The discussion is written for any individual reconstruction. This will be specified in the revised version.

Figure 6: the use of "complete" and "all" to identify different time ranges is confusing for the reader.

Instead of the reconstructions based on the 6 ice core records ('all') or only on the records that cover the entire studied period (i.e. 1250-now); 'complete'), we propose to estimate the uncertainties of the reconstructions by showing the reconstructions obtained when selecting five out of the 6 records in turn for the assimilation. This is a more comprehensive and objective way to measure the uncertainties (e.g. Hakim et al., 2016). The word 'complete' and 'all" will thus not be used anymore in the revised version.

Figure 6: all the overlapping coloured records make it difficult to identify years with high values in all the indices, especially in Figure 6a. The addition of arrows to indicate which years had an average index value greater than 0.8 or 1 would be beneficial for analysing the changes in polynya frequency during the last millennium.

We propose to modify the way the reconstructions are presented and their uncertainty estimated by showing for the three methods (simple average and data assimilation using SPEAR_AM2 and SPEAR_LO) only one curve, that uses all six ice core records. For those three reconstructions, the uncertainties will be estimated by the range in the results from assimilating only 5 out of the 6 ice core records using the same methodology (a different record is excluded each time). This will have the advantage of reducing the number of curves per panel and thus providing clearer figures. We will also add horizontal lines for values of 0.8 and 1.0 to clearly see when each threshold is crossed (the other horizontal bars will be removed).

References

Hakim, G. J., J. Emile-Geay, E. J. Steig, D. Noone, D. M. Anderson, R. Tardif, N. Steiger, and W. A. Perkins (2016), The last millennium climate reanalysis project: Framework and first results, J. Geophys. Res. Atmos., 121, 6745–6764, doi:10.1002/2016JD024751