Reviewer 2 – Florence Fetterer

I read the article from the standpoint of someone familiar with sea ice data sets, but not at all familiar with biomarkers for sea ice. The authors state that the outcomes "support the reliability of biomarkers for sea-ice reconstruction in this region". They present biomarker evidence that a "polynya-like feature" may have been forming in the westernmost Belgica Trough sometime before mid-century. This is an interesting finding, and it illustrates how these proxy data can be used when other sources fall short. The work contributes to understanding the history of sea ice area and extent off NE Greenland, and this, as the authors note, contributes to understanding the dynamics of two important glaciers that are buttressed by sea ice.

We are happy that the reviewer believes this work is of importance in understanding the history of sea ice in Northeast Greenland

The historical sea ice data set that biomarker data are compared with (Walsh et al., 2019) has large uncertainties, but I think it is used appropriately here. The authors are not correlating sea ice concentration percent values from the historical data with bioindicator values, rather, they are considering only relative amounts of sea ice cover and adding strength to their interpretation with change-point analysis.

Overall, the paper is well constructed and well written. Terminology needs clarifying in places, if only to help cross-discipline readers. I've called out those places below.

We have responded to the comments below with plans of how this will be corrected in the manuscript.

Specific comments

In the Introduction, it would be helpful to give a few descriptive words when IP25 and PIP25 first appear. This would be a kindness to those of us who know nothing of biological proxies for sea ice but want to learn how they can be used along with the satellite and other observational records we're familiar with.

We will define these descriptive words more clearly in the text.

Ln 28. Please define sea-ice cover here. "Sea-ice cover" can be confused with sea ice extent, when what I think you mean is sea ice concentration or area. (NSIDC has a short piece on "What is the difference between sea ice area and extent?", by the way.) "Sea-ice cover" is fine to use if how it is being used is made clear.

This is a good point. When we are referring to the observational record we are referring to sea-ice concentration data. Therefore, we will change the terminology when referring to the observational record. However, as sea-ice biomarkers (specifically the PIP_{25} index) produce a semi-quantitative estimate of sea ice we believe that sea-ice concentration is not the best term to use for this. Sea-ice cover or sea-ice conditions are widely used to describe sea-ice biomarker data. Therefore, when we refer to sea-ice biomarker data we will use those terms accordingly.

Beginning line 59 is: “Northeast Greenland is an area characterised by several sea ice types and features; it is thus a region of interest to understand the impact of climate changes on sea-ice extent. These features include land-fast sea ice (hereafter ‘fast ice’), seasonal sea ice and the Northeast Water (NEW) polynya.”

I’d like to better understand how the authors are using “seasonal sea ice”. Usually, the term refers to broad expanses of ice that form in the winter months but are ice free in the summer; that is, the region between the ice edge in winter and the ice edge in summer. The Belgica Bank area has not typically experienced this type of seasonal ice. Looking quickly at the monthly extents in passive microwave satellite data, August and September of 2021 are the only times I see the sea ice extent retreat north of the Belgica Bank, although ice retreats well to the west in 2017.

In typical usage, “seasonal” means ice is there in the winter but not in the summer. But ice off the NE coast of Greenland is always there (except, notably, in summer 2021). If the authors are thinking of seasonal ice as ice cover interrupted over time by polynyas, or just by variable areas of open water between pack ice floes moving south as shown in Figure 1, I recommend using a different term.

We agree with the reviewer that this terminology should be changed and will do so.

Ln 57. It’s not necessary to include this but I want to note that the Divine and Dick data are available at NSIDC:

D.V. Divine, C. Dick. March through August Ice Edge Positions in the Nordic Seas, 1750-2002, Version 1 NSIDC: National Snow and Ice Data Center, Boulder, Colorado USA (2007), 10.7265/N59884X1

Around Line 90, suggest you reference Fig 1(b) in the same sentence that first mentions the two marine-terminating glaciers. Why is one glacier labeled NG when first introduced, and labeled “79NG” on the figure and in the text in later mentions?

This was a mistake and will be changed in the manuscript accordingly to 79NG.

Ln 126-129 Curious as to why this X-ray fluorescence step was not carried out for the other cores. Consider adding a sentence as to why. Also for the grain size analysis step. Were these steps done just to check the match between Rumohr core and gravity core results for roughly the same location?

We will add information to explain that XRF and grain size analysis was carried out on core 90R for the purpose of correlation with 92G. This was undertaken for the purpose of age constraint and was not undertaken on 109R and 134R for this reason. We will explain this in the text.

Ln 209. Please reference Fig. 7, where the sea ice cover (a.k.a. concentration in this instance, for Walsh et al.) data are used.

We will reference Fig. 7 as suggested.

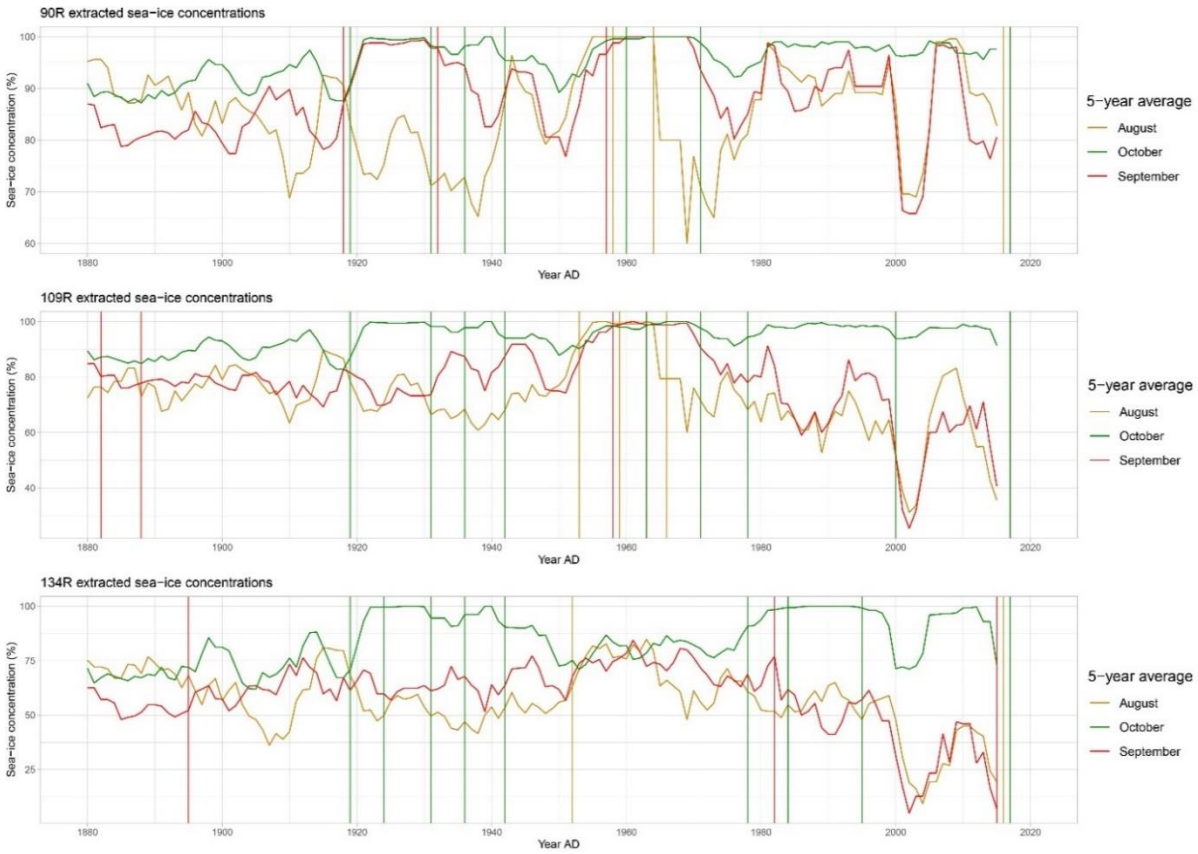
Section 4.5 beginning Ln 293 on “Sea ice cover observational record”:

Given the uncertainty in the Walsh et al. record, it might be good to run the change detect routines for Aug and Oct just to see if there is a material change in results, although perhaps this is unnecessary given that 5-yr running means are used.

It is important to note that the models were run on the annual data, not the 5-year averages. We have presented the 5-year data sea-ice data for better comparison to the biomarker data, however we acknowledge that this is not clear in the methodology. We will update this accordingly to make it clearer for the reader.

We have examined the Aug and Oct sea-ice concentration data and run the change point analysis, comparing the results to the September data currently used in the manuscript. The results are shown in the figure below, together with the various change points (vertical lines) associated with each station and month.

The long-term average observational sea-ice dataset from August, October and September shows that sea-ice concentrations in August and September are similar at all three sites. The October data is different from the trends in sea-ice concentration that we see in September and August for the sites, and this makes sense as we expect the sea-ice to begin to grow from this point.



Results of the change point analysis on the same observational sea-ice dataset is shown in the table below. There is a consistent change-point seen around 1970, but the shift at 1984 is less widespread across the different stations and months, as is evident from the September change-point analysis alone. It is only visible at 134R in September and October but not in August and is not distinguished when the averaged area or inner stations are examined.

However, we believe that using the 1984 change is still valid based on the changes in mean and trend, and the consistency in the major changes no matter which of August, September or October were used.

Core	Month of sea-ice data	Year of change	Type of change (model best fit – AIC)
DA17-NG-ST08-090R	August	1958	Mean cpt
		1964	
		2016	
	September	1918	Mean cpt
		1932	
		1957	
		1971	
		2017	
	October	1919	Mean cpt
		1931	
		1936	
		1942	
		1960	
		1971	
		2017	
DA17-NG-ST10-109R	August	1953	Mean cpt
		1959	
		1966	
		2017	
	September	1882	Mean cpt
		1888	
		1958	
		1963	
		1971	
		2017	
	October	1919	Mean cpt
		1931	
		1936	
		1942	
		1963	
		1971	
		1978	
		2000	
		2017	
DA17-NG-ST12-134R	August	1952	Trend AR (1)
		2016	
	September	1895	Mean + AR (2)
		1984	
		2015	
	October	1919	Mean cpt
		1924	
		1931	
		1936	
		1942	
		1978	
		1984	
		1995	
		2017	

As the September sea-ice data reflects the sea-ice minima it is arguably the best dataset to compare with biomarker data. Furthermore, the changes in August and September are very similar (see table above), again reflecting the sea-ice melt which is recorded in the biomarker data. The trends in the October sea-ice concentration do not match well with the biomarker data, likely because it marks the beginning of sea-ice accumulation. The change-point analyses for different months reveals little shift in the timing of changes in sea-ice concentration, especially when the five-year averages are considered, as the minor variations in the timing of key changes are within the five-year averages.

Thus, we will continue to use the September sea-ice data for this study as we believe it best reflects the biomarker data. This justification will be outlined in the methods.

Paragraph beginning Ln 390:

Please rewrite this sentence: "The positive correlations between IP25 and brassicasterol, and IP25 and dinosterol at all three sites (Fig. 5) can best be explained by the fact that under more extreme sea-ice conditions, both biomarkers show low values but with decreasing sea-ice, indicating more open-water and ice-edge conditions. "

Here is what I think is meant, but I am not sure about it:

"…can best be explained by the fact that when sea ice is preset more of the time, both biomarkers show low values. When open water conditions prevail, because the concentration of sea ice is low, or the ice edge moves shoreward of the location, both biomarkers show higher values. "

We will change the wording accordingly to reflect the reviewers' comments and improve the clarity of this statement:

"The positive correlations between IP_{25} and brassicasterol, and IP_{25} and dinosterol at all three sites (Fig. 5) can best be explained by the fact that when more extensive sea ice is present both biomarkers show low values. When more open water conditions prevail, because the concentration of sea ice is low, or the ice edge moves shoreward of the location, both biomarkers show higher values."

Ln 396. Suggest referring to Fig 4 here.

We will refer to this in the text

Ln 415. Consider replacing "seasonal sea ice has" with "areas of open water have" in this sentence: "The presence of IP25 in most of the samples in 90R and 109R suggests that seasonal sea ice has been present for the last ~120 years in the coastal and mid part of the Belgica Trough.

Seasonal sea ice generally refers to broad expanses where ice forms in the winter and melts or moves out in the summer, "an area of ocean that extends from the permanent ice zone to the boundary where winter sea ice extent is at a maximum; here, sea ice is present only part of the year; this zone primarily consists of first-year ice." (from the NSIDC glossary). Here, I believe you're referring to what biomarkers are indicating could be a fairly regular occurrence of polynyas in an area that is more often thought of as ice-covered.

Ln 419. Same comment as for ln 415, although in this sentence, could you replace “absence of seasonal ice” with “presence of sea ice” or “absence of periods of open water”?

We agree with the reviewer about the changes to this terminology in the above two sentences. This will be changed in the manuscript.

The sea ice edge in this region, as defined using satellite passive microwave data, retreated north of the Belgica Bank area in 2021 (see https://nsidc.org/arcticseaicenews/2021/09/) but I believe that may have been only time that has happened in the satellite record.

Technical corrections

All of the technical corrections outlined below will be corrected accordingly.

In Table 1, the longitude in the last row is missing a minus sign.

Ln 375 There is a missing “are”.