Answers to reviewer #2

Thank you very much for the time and effort you have put into reviewing and improving our work. We would like to thank you for your constructive comments, which we have addressed individually below.

General comments:

- The paper is lengthy and unnecessary repetitions between sections should be avoided (e.g., Introduction and Regional settings).

  Thank you very much for this comment. We have carefully screened the manuscript for repetition and have removed those sections. Further, in accordance with comments by reviewer #3 we have combined section 5.1 and 5.2, where a lot of repetition occurred.

- Neoglacial should be capitalized

  Thank you for noticing this. We have changed this throughout the manuscript.

Figure 1.

- Please precise what the extent of the NOW represents (average between year-a/year-b, and season). It is not necessary to repeat the same sentence twice "The approximate extent of the NOW is indicated with a black dashed line." The red box already indicates the close up.

  Thank you for this comment. We have added the missing information to the caption of Figure 1 and removed the repetition ('*The approximate extent of the NOW polynya (mean extent in May 1954-1968) (Dunbar, 1969) is indicated with a black dashed line.*')

- From the caption, one may interpret that core AMD15-Kane2b was analysed as part of this study. Should add reference to paper.

  This was not our intention. We have added the reference Georgiadis et al. (2020) to the figure caption, to clarify that Kane2b is not part of the new work presented in this manuscript.

Line 107. Since this sentence is already the first of the introduction, it should be left out here. Avoiding repetition will help reduce the length of the paper.

We have removed this sentence while screening the manuscript for repetition.

Lines 150-152. This sentence does not read easily. Please try to reformulate.

Thank you for bringing this to our attention, we have rephrased the sentence to '*Modelling studies suggest that the displacement of water masses in Nares Strait in response to the prevailing sea-ice regime also affects Petermann Fjord, with enhanced inflow of warmer, saltier AAW during times of mobile sea-ice (Shroyer et al., 2017).*'.

Line 205. Should also mention HBI II-producing species. Co-production implies same species, strictly? Please clarify.

> Thank you for this comment. We have added the known species producing HBI II to the text ('*Given its co-production in H. spicula, H. kjellmanii, and Pleurosigma stuxbergii var. rhomboides (Brown et al., 2014), HBI II co-varies with IP_{25} in the Arctic realm. Thus, the typically higher HBI II concentrations can provide additional information during times of low/absent sedimentary IP_{25}.*').

Figure 2.

- Line 166 should be Hal**l**
- "After 2012/2012, the differences increase due (…)" remove "s" in "increase".

> Thank you for both comments, we have corrected the typos.

Lines 222-225. This information does not seem necessary since both sterols are not direct indicators of sea ice conditions. Could only keep the last sentence of this paragraph.

> We have removed the first sentence of this section, but kept '*Depending on the predominant primary producers, high concentrations of brassicasterol and dinosterol are reported from ice-free regions, the MIZ, and under varying concentrations of seasonal sea ice (Xiao et al., 2015). In general sterol concentrations are low under perennial sea ice in the Arctic Ocean, where all primary productivity is impeded due to limited light availability (Xiao et al., 2015).*'. This is to provide the reader with a brief overview of how sterols (via general changes to the primary productivity) are affected by different sea-ice regimes.

Lines 234-236. These sentences seem out of place. This information (storage of research material and subsampling) should be included in the first paragraph of the Method section.

> Thank you for this comment, we agree and have moved this information to the method section.

Line 252. "The $d^{13}C_{org}$ reproducibility **of** non-acid pretreated (…)" add "of"

> We have corrected this typo, thank you for noticing.

Line 284. "Dry bulk densities were calculated (…)" this is repetitive with Line 258. No need to repeat multiple times. If applies to all, could be included in the first paragraph of the method section.

> Thank you, we have removed the repetition and added the information to the first paragraph of the method section, as the reviewer suggests (*'The dried samples were weighed and dry bulk densities (DBD) were determined from the samples respective volume and dry weight.'*).

Line 288. Could rephrase to "A multitude of environmental factors determine the abundance and species composition of benthic and planktonic foraminifer assemblages"

> We have rephrased this sentence, as the reviewer suggests.

Line 294. Replace light conditions by light availability.

Thank you for this comment, we have changed this in the manuscript.

Results section

- Verify significant digits for the foraminifer fluxes.

  In the revised version of the manuscript, we have rounded the foraminiferal fluxes to the nearest whole number.

- Why aren't the results reported against the age rather than depth (or both)? This would make it easier to follow the changes/story in the context of Holocene climate variability.

  The results are reported against depth for two reasons; 1) To show the close connection with the lithology of the core (i.e. sedimentary units). 2) Because the age model does not cover the entire depth interval studied throughout this core. Thus, we have kept the results reported against depth in the revised manuscript, while the data is reported against age in the discussion.

- The same structure (i.e., order) could be maintained between the Method and Result sections.

  Thank you for this comments, we have rearranged the results section accordingly in the revised manuscript.

Line 317. Add "s" to "unit"; same in **Line 342** (please correct throughout)

We have corrected this throughout the manuscript, thank you for noticing this.

Figure 3.

- Should include an age axis.

  As discussed above, we have kept the description of results against depth. Thus, we have not added an age axis to figure 3.

- Remove "s" in foraminifer**s** results
- Turquois**e**

  Thank you we have corrected both typos.

- Should mention in the captions why the fluxes do not extend beyond 400 cm.

  Thank you for this comment. We have added the following statement to the figure caption: '*Fluxes do not extend beyond ~400 cm, as this depth corresponds to the lowermost available radiocarbon date (Reilly et al., 2019).*'.

- Should include HBI concentrations normalized to TOC.

> Our interpretations in the discussion section are not based on the HBI concentrations normalized to TOC; therefore, we have decided to keep those in the supplementary material, to not overcrowd Figure 3.

Line 441. "Sedimentary unit 3 represent**s**" add a "s"

> We have corrected the typo, thank you for noticing.

Lines 447-449. This sentence is not clear.

> Thank you for this comment. In accordance with a comment by reviewer #3 we have combined section 5.1 and 5.2 of the discussion and deleted this particular sentence in the process.

Figure 5. The title of this figure is "Temporal changes in the environmental conditions in Petermann Fjord". Yet, there is no indication of "environmental conditions" in this figure, with the only exception of the ice tongue length from the grounding zone. To make this figure truly distinct from the other figures presented in the results, more interpretive information could be added.

> We are not entirely sure what the reviewer would like us to add to the figure. It is termed 'temporal environmental changes' because an age axis is included for the first time in the manuscript. We would like to refrain from adding interpretative information such as arrows to indicate more/less sea ice, as we want to allow the readers to gain an independent understanding of the data.

Line 600. "In years **when** only the northern (…)" replace were by when.

> We have corrected the typo, thank you for noticing.

What about pelagic productivity?

> In this study we focus on the sea-ice biomarkers and associated phytoplankton biomarkers presented at Kane2b (IP_{25} and HBI III) and at OD15-03TC-41GC-03PC (IP_{25}, sterols). The schematic and its description thus focus on the dynamics of these biomarker groups in response to the predominant position of the spring sea-ice edge. However, we have revised Figure 6 (see below) to account for the difference in phytoplankton biomarker used in this study and in Georgiadis et al. (2020).

Figure 6. Great representation of scenarios.

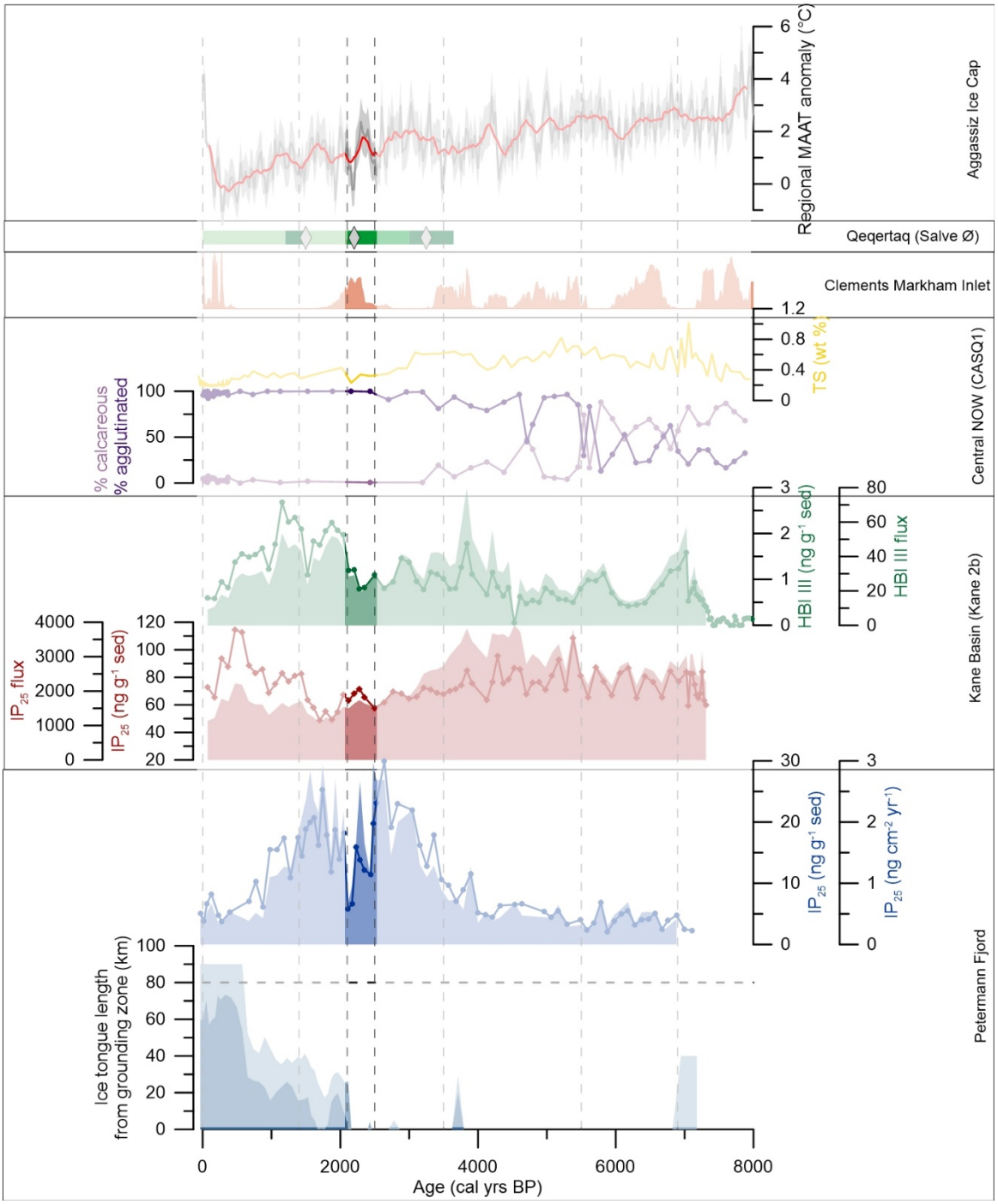
> Thank you very much for this comment.

Lines 695-704. This section as well as the interpretation of the southern/northern ice arch conditions (e.g., Line 738), need to be revisited. The IP_{25} fluxes reported by Georgiadis et al. 2020 are very low around 2,200 cal yrs BP. Authors from this paper indicate that IP_{25} fluxes are at their lowest between 2.2 and 1.1 cal ka BP, which they interpret to result from an unstable southern ice arch in Kane Basin from 3.0 cal years BP. Little auks are present in low numbers at lake Annikitsoq and only one discrete event of

local peak in bird abundance is reported from lake Qeqertaq (Davidson et al. 2018). These data do not point towards a stable spring/summer North Water polynya and return to a southern ice arch dominated regime in Nares Strait, as suggested here.

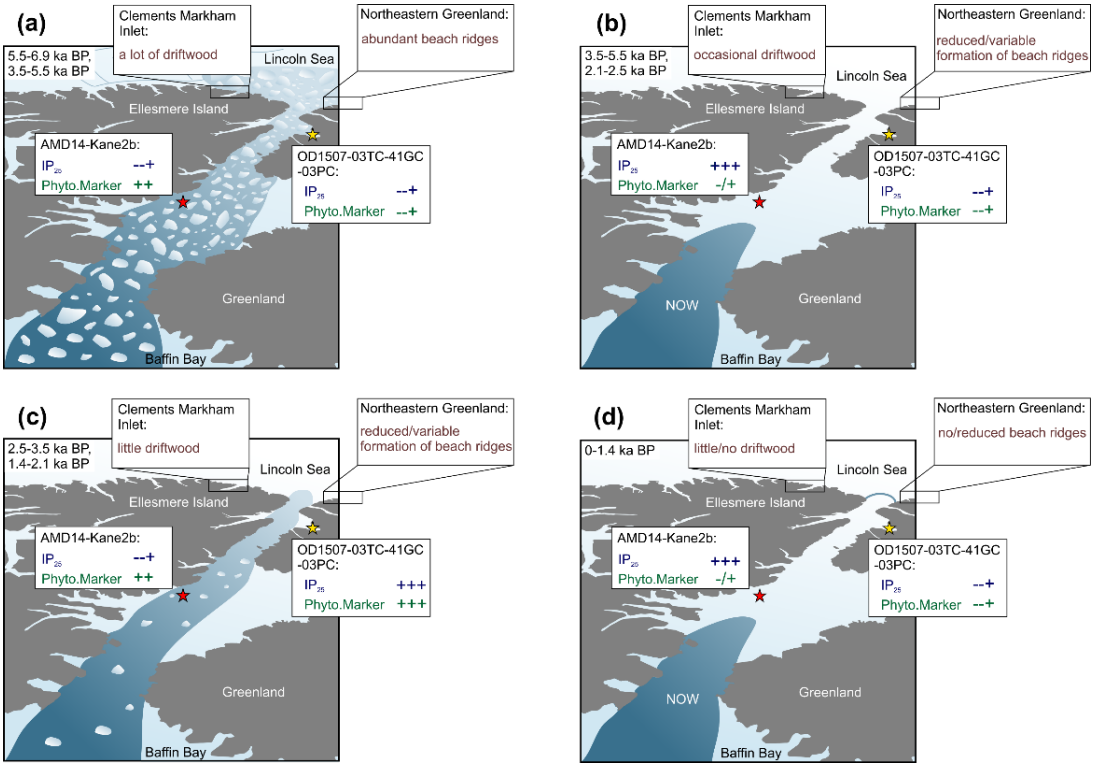
Lines 760-762. See comment above. Perhaps supported for the rapid extension at 600 cal yrs BP and double-arching, but the evidence from Kane Basin is pointing towards less stable southern ice arch from 3.0 to 1.1 cal yrs BP.

> Thank you very much for these comments. We agree with the reviewer that this time period experienced relatively low IP_{25} fluxes in Kane Basin. Nevertheless, a small increase can be observed between ca. 3,000 cal yrs BP and 1,400 cal yrs BP (Rev. Fig. 1). This increase alone is not convincing, however it is associated with a decrease in HBI III fluxes at Kane2b (Rev. Fig. 1). Georgiadis et al. (2020) interpret HBI III to represent ice-laden and fresh surface waters in Nares Strait. This can be a result of either the break-up of the southern ice arch (variable HBI III fluxes depending on the seasonal timing of break-up) or year-round mobile sea ice in Nares Strait (northern ice arch or no ice arch scenario). Thus, a small increase in IP_{25} and a decrease in the HBI III fluxes points towards intermittent formation of a southern ice arch and a longer landfast ice season in Kane Basin. Our interpretations are further supported by a recently published study of foraminiferal assemblages in the central NOW region (Jackson et al. 2021), suggesting strong polynya conditions and CO_2-rich brine formation throughout this interval causing dissolution of calcareous foraminiferal tests but preservation of agglutinated species (Rev. Fig. 1). The foraminiferal assemblage interpretation is supported by measurements of total Sulphur, which decrease throughout this interval, in line with enhanced bottom water ventilation as a result of brine formation (Jackson et al. 2021) (Rev. Fig. 1).



Review Figure 1. Evidence for southern ice arch formation between 2,500 cla yrs BP and 2,100 cal yrs BP from the wider Nares Strait region. From the bottom to the top: Petermann Glacier ice tongue extent (Reilly et al., 2019), outer Petermann Fjord IP_{25} concentration (blue line) and fluxes (blue filled area), Kane Basin IP_{25} concentration (red line) and fluxes (red filled area) and HBI III concentration (green line) and fluxes (green filled area) (Georgiadis et al., 2020), Central NOW agglutinated (deep purple) and calcareous (light purple) foraminiferal abundances and total Sulphur (TS) (Jackson et al., 2021), driftwood occurrence at Clements Markham Inlet (England et al., 2008), Little auk occurrence at Qeqertaq (Salve Ø) (Davidson et al., 2018), regional mean annual air temperature (MAAT) anomaly based on $\delta^{18}O$ at Agassiz ice cap at 25 yr resolution (Lecavalier et al., 2017).

These considerations led us to revise the schematic Fig. 6 to account for the difference in phytoplankton biomarker used at Kane2b and OD15-03TC-41GC-03PC (Revised Fig. 6). Georgiadis et al. (2019) measured HBI III as phytoplankton biomarker, while this study from outer Petermann Fjord measured sterols as phytoplankton biomarkers. HBI III is interpreted to reflect ice-laden surface waters, which can occur during times of mobile sea ice and after the break-up pf the southern ice arch (Georgiadis et al., 2019). For the latter, HBI III fluxes likely depend on the seasonal timing of ice arch break up, thus, the southern ice arch and double ice arch scenario can be associated with variable HBI III concentrations, while no ice arches and a northern ice arch only are likely associated with moderately high HBI III concentrations in Kane Basin. In outer Petermann Fjord marine sterols are significantly positively correlated with IP_{25}, suggesting a close relationship between sterol-producing pelagic productivity and sympagic productivity. Thus, their concentrations are likely to co-vary in response to the prevailing sea-ice state.



Revised Figure 6. Schematic of spring sea-ice conditions and the respective sea-ice biomarker and primary productivity (HBI III at Kane2b, sterols at OD1507-03TC-41GC-03PC) indicator concentration patterns at OD1507-03TC-41GC-03PC (yellow star) and AMD14-Kane2b (red star), as well as driftwood delivery to CMI and beach ridge formation along the coast of north-eastern Greenland, based on different sea-ice and ice-arch scenarios in Nares Strait. In addition to the access to the coast, driftwood delivery also depends on the multiyear ice conditions in the Arctic Ocean, this is not considered in this simplified schematic. (a) No ice arch formation in Nares Strait resulting in year-round mobile sea ice, (b) Recurrent southern ice arch with landfast sea ice in Nares Strait and an open NOW, (c) Recurrent northern ice arch with locally formed sea ice remaining mobile in Nares Strait year-round, (d) Recurrent northern and southern ice arch with landfast sea ice in Nares Strait and a stable NOW. The time periods in the top left corner of each panel correspond to the proposed Holocene interval that experienced the respective conditions.