

Response to Editor: “Publish subject to minor revisions (review by editor)” by Antje Voelker, 29th October 2025.

General comments

Dear Frank W. Jacobsen and co-authors,

Previous reviewer Wolfram Geissler has read your revised manuscript and is asking for some clarifications before the manuscript can be accepted for publication.

I also read the manuscript carefully and am attaching an annotated version of the clean manuscript. I was recently reminded by an expert involved in the Int. Commission on Stratigraphy that we "paleo"-researchers tend to ignore the commission's guidelines when referring to Epochs. When you refer to a specific time period (Epoch), the Late/Middle/Early needs to be capitalized! I tried to mark/correct all instances in the manuscript but please proof-read it carefully before resubmitting.

Dear Antje Voelker,

First of all, thank you for your thorough reading of the manuscript and for bringing these minor issues to our attention. You will find that we have now gone through the manuscript to ensure all subdivided epochs are capitalized. Please, find our response to the comments by you and Wolfram marked in blue below:

You are also all over the place for defining acronyms and then not using them in the subsequent text, especially for the geographical features. I tried to highlight some but also here you need to do some thorough proof-reading. Since you are mainly using full names in the discussion, you might want to skip defining acronyms for some of the local feature's names.

Thank you for bringing this to our attention, we completely agree with you and we have now gone through the manuscript to ensure all acronyms are either removed entirely or used consistently in the text.

Since neither of the previous reviewers is an expert in paleoceanography, I am also pointing

out a few regional studies that could be included in your discussion. Those are suggestions to broaden the scientific base of your discussion and you are not obliged to include them.

Thank you, we really value these suggestions. We have rephrased minor parts of our discussion (mainly section 5.1) to accommodate your suggestions.

Line comments

56 add that numbers 909 and 913 refer to the ODP Sites

Changed accordingly

80 since you defined the acronym here, you need to use it in the subsequent text like on this page in lines 86 and 92.

Thank you, we have decided to remove acronyms for names that are spelled out in the discussion

87 “(SKT)” already defined in line 80

Removed

99 also here you don't mention that 909 and 913 in the map refer to the ODP Sites

Changed accordingly

120 suggested to add “,”

Changed accordingly

132 all three have acronyms defined above. decide if you want to use acronyms that need to be used after being defined, or if spelling out the names might be easier for the reader not so familiar with the geographical names in the study region.

Thank you, we have decided to remove acronyms for these names and rather spell them out as in the discussion.

175 make corrections to reference

Corrected

206 if you refer to a Hole then 909 should be followed by a letter for the Hole, e.g. 909A.

Rephrased to “Site”.

223 see comment above regarding acronym definition and subsequent use

Thank you, we have decided to remove acronyms for these names and rather spell them out as in the discussion.

303 acronym already defined in line 79

Acronym removed

304 add “the” and “the”

Changed accordingly

307 acronyms already defined in line 79-80

Acronym removed

308 here and below: if you define an acronym, you need to use it and not jump between spelling name out and acronyms. Please check the whole manuscript for that.

Thank you, we have decided to remove acronyms for these names and rather spell them out as in the discussion.

424 add “n” = an

Changed accordingly

482 if you want to be age unspecific -not refer to the Epoch itself- you can leave as it; otherwise it should be Late Miocene indicating the you are referring to the epoch starting at 11.63 Ma. This comment also applies to the phrasing in line 485.

Thank you, all sub-epochs are changed accordingly using capitalized names

489 the Late

Changed accordingly

503 acronym already defined

Changed accordingly

506 you could include here also: Lien, Ø. F., Hjelstuen, B. O., Zhang, X., and Sejrup, H. P.: Late Plio-Pleistocene evolution of the Eurasian Ice Sheets inferred from sediment input along the northeastern Atlantic continental margin, Quaternary Science Reviews, 282, 107433, <https://doi.org/10.1016/j.quascirev.2022.107433>, 2022.

Added reference

521 add “there”

Changed accordingly

524 I don't remember reading it: you need to explain the first time it comes up that figure call outs to S.... refer to a figures in the supplementary material.

Added to the first reference to supplementary material in section 3.2.3.

535 this statement needs a reference. It also disagrees with the IRD record shown in figure 2 of Bachem et al. (2017) Clim. Past, 13, 1153–1168, 10.5194/cp-13-1153-2017. It might be worth pointing out the discrepancy between the Fram Strait region and the Norwegian Sea record, some of which might be IRD size fraction related.

Thank you, we have rephrased the paragraph and added the suggested reference as you propose. In addition, we rephrased a sentence and added the reference in section 5.1.3 (line 582).

569 you have a few Early Pliocene related studies for the Nordic Seas that you could include in your discussion:

Bachem, P. E., Risebrobakken, B., De Schepper, S., and McClymont, E. L.: Highly variable Pliocene sea surface conditions in the Norwegian Sea, Clim. Past, 13, 1153–1168, 10.5194/cp-13-1153-2017, 2017.

Risebrobakken, B., Andersson, C., De Schepper, S., and McClymont, E. L.: Low-frequency Pliocene climate variability in the eastern Nordic Seas, Paleoceanography, 31, 1154–1175, 10.1002/2015PA002918, 2016.

De Schepper, S., Schreck, M., Beck, K. M., Matthiessen, J., Fahl, K., and Mangerud, G.: Early Pliocene onset of modern Nordic Seas circulation related to ocean gateway changes, Nat Commun, 6, 10.1038/ncomms9659, 2015.

maybe also look into this review paper: De Schepper, S., Gibbard, P. L., Salzmann, U., and Ehlers, J.: A global synthesis of the marine and terrestrial evidence for glaciation during the Pliocene Epoch, Earth-Science Reviews, 135, 83–102, <http://dx.doi.org/10.1016/j.earscirev.2014.04.003>, 2014.

Thank you, we really value these suggestions. We have rephrased minor parts of our discussion (mainly section 5.1) to accommodate your suggestions.

570 suggested rephrasing to: lower benthic foraminifera oxygen isotope values

Changed accordingly

574 provide reference for that data also in the text; not only the figure caption

Reference added

577 reference for IRD evidence should be provided.

Reference added

600 add “the”

Changed accordingly

614 Piacenzian; with the shift in the lower boundary of the Quaternary that age range is no longer mid-Pliocene.

Changed accordingly

616 Miller et al. (2020) missing in reference list

It is located on line 988 of the submitted manuscript (line 1003 in latest version). We have checked the manuscript for missing references and all references should now be listed under “references”.

649 add “the”

Changed accordingly

670 add Bachem et al. 2017 (with updated age model) or the original Jansen et al. reference

Added reference

690 the Late

Changed accordingly

692 in addition you have Bachem et al. 2017 data/reference

Added reference

700 delete “after”

Changed accordingly

730 you now also have this reference: The Cenozoic CO2 Proxy Integration Project Consortium.: Toward a Cenozoic history of atmospheric CO2, Science, 382, 10.1126/science.adi5177, 2023.

Thank you, we value your suggestion and it is indeed a very interesting and important study that evaluate and compile datasets of atmospheric CO2 and discussed light of global mean surface temperatures and sea levels, although not sea surface temperatures directly. We will keep this reference in mind for future studies, but for now we have decided to slightly rephrase the sentence to make it clear that this is a statement suggested by Herbert et al (2016), which we want to highlight.

736 this snapshot study from the Arctic Ocean support this: Stein, R., Fahl, K., Schreck, M., Knorr, G., Niessen, F., Forwick, M., Gebhardt, C., Jensen, L., Kaminski, M., Kopf, A., Matthiessen, J., Jokat, W., and Lohmann, G.: Evidence for ice-free summers in the late Miocene central Arctic Ocean, Nat Commun, 7, 10.1038/ncomms11148, 2016.

Thank you, we have rephrased this paragraph and added the reference accordingly.

768 use defined acronym

Changed accordingly

770 IRD

Changed accordingly

Figure 8: should say Late Miocene

Changed accordingly in Figure 8 and Figure 2

Response to referee #2 comments: Referee report #1 by Wolfram Geissler, 24th October 2025.

General comments:

Dear authors,

thank you very much for your response to previous reviews and the revisions made accordingly. I think your manuscript is now almost ready, but some minor revisions should be considered.

Dear Wolfram Geissler, thank you very much for your comments and for taking your time to review this manuscript. We believe that your comments have helped to improve this manuscript. Please find our response below:

At first, I am not fully convinced in the new way of presenting the uncertainties. In my opinion the "+-" is better than adding the ranges.

Thank you, we appreciate your comment. The age uncertainties are determined by the vertical uncertainty in tie-depth, which again is determined by the vertical seismic resolution at that depth (given as $\pm m$ Table 2). Since the slope of the age model we apply is not linear (e.g. due to changing sedimentation rates), the corresponding ages at e.g. 20 m above or below the seismic-well tie-depth yield an age variation that is not captured by e.g. $\pm 0,4$ Ma. For example, NEG-1 is tied to ODP Site 909 at 652 ± 31 mbsf. The tie depth at 652 corresponds to an age of 6.4 Ma, whereas the deepest and shallowest possible tie-depth yields an age of 7.0 Ma (683 mbsf) and 6.2 Ma (621 mbsf), i.e. +0,6 Ma and -0,2 Ma. We hope that this clarifies our preference in using a range as uncertainty, rather than $\pm$.

And at second, the probable duration for sedimentation of MU-1 is not clearly presented. There is even a conflict in presented ages on page 20 in the document where changes are highlighted. Maybe it is just not yet phrased in a way that I can understand where the peak of the IRD at about 6.0 Ma belongs to (MU1 or MU2).

Thank you, we have rephrased the paragraphs in 5.1.1 and 5.1.2 in hope that this clarifies any misunderstandings. At this point we do not know the age of NEG-2 which divide MU-1 and MU-2, however, we try to discuss that the age of this boundary likely lies in the Late Miocene and probably corresponds to increased IRDs recorded at ODP Site 909 located in the Fram Strait.

Please check also once again for typos and consistency in the use of southeast/Southeast etc. And I suggest to name the exact names of holes of the ODP expeditions, not just "hole 909", otherwise use "Site 909".

Thank you, we have now checked the manuscript for typos and consistency in the use of capital letters and names.

Line comments:

120 remove s at the end of seaways

Changed accordingly

127 capitalize early in early Miocene

Changed accordingly

155-156 check again: not Canadian Arctic?

Eldrett et al. (2007) and Tripathi et al. (2008) identified IRDs from the Greenland Basin (ODP Site 913) and dated them back to Eocene and Oligocene. They suggested the likely source areas were Southeast and central East Greenland and in addition possibly Svalbard.

166 suggested remove “later”

Changed accordingly

221 Use exact name for the boreholes (e.g. Site 909 not hole 909)

Changed accordingly

228 use “Site 913” not “borehole”

Changed accordingly

539 “the onset of MU-1” ?

Rephrased to “the base of MU-1”

540-541 suggests IRD peak around 6.0 Ma may be correlated to MU-1, and the same peak is suggested to correlate to MU-2 as phrased in lines 564-565.

Thank you, we have rephrased the paragraph

564-565 suggests IRD peak around 6.0 Ma may be correlated to MU-2, and the same peak is suggested to correlate with MU-1 as phrased in lines 540-541.

Thank you, we have rephrased the paragraph

677 capitalize “southeast” and change eastern to “East”.

Changed accordingly