Dear Bjørg Risebrobakken

Thank you for your valuable comments. Our replies are marked below in blue

- We have added a new figure in the Supplementary Information file (Fig. S5 – scatter plot comparison of model annual mean sea surface temperatures with the proxy data)
- Few new relevant references are added (highlighted in red)
- The dataset with all new data will be included in the FAIR database (dataverse.geus.dk). When referring to the dataset in the manuscript text, we write "Supplements", but I am not entirely certain that this is the proper way to do. Once I have the doi for the dataset, it will be possible to include it in the reference list.

Comments to the author:
Dear Kasia Sliwiska and co-authors,

Thanks for sending the revised manuscript and your responses to the reviewers' comments. I have now gone through the manuscript and the responses. There are still some issues that I would like you to address before accepting the paper (see comments bellow). I will invite you to submit your new version in a clean and a track changes version, as well as your replies to my comments.

Best regards,
Bjørg Risebrobakken
Editor, Climate of the Past

All my comments refer to the track changes version of your resubmitted manuscript.

One thing that stoke me when reading the paper again is that it is unclear exactly what part of your record you refer to at different times, and which of your datasets you refer to. Your data cover 38-26.5 Ma, however, mostly you only discuss the interval 37-32 Ma. Hence, a lot of the new data is not really discussed in detail.

This is a valid point. We focused on the interval between 37 and 32 Ma because this was the maximum time span with SST data coverage across the EOT. Secondly, the age model for the interval 32 to 26.5 Ma is rather poorly constrained. But we recognise that this should be addressed better, so we have now modified a part of section 4.1 as follows "Overall, both paleothermometers suggest Oligocene SST (interval from 34.4 Ma to ~26.5 Ma) below 26°C (Figs 2 and S2), with two temperature minima. However, with the existing uncertainties in the age model for this interval (i.e. depth from 190 to 130 mbsf; Firth et al., 2013) it is challenging to link the SST minima with the cooling episodes from the Oligocene (e.g. Wade and Pälike, 2004). This could potentially be improved by a more detailed analysis of dinocysts (e.g. Śliwińska et al., 2010; Śliwińska, 2019), but it is outside the scope of the present study. Notably, at the older SST minimum (depth ca. 183 mbsf, Fig. S2) $U_{37}^{K'}$- derived SST becomes significantly colder than TEX_{86}-derived SST. Potentially this may be due to the fact that the surface conditions, reflected by the $U_{37}^{K'}$-, changed more substantially than subsurface temperatures,

which will affect TEX_{86}-derived to a larger extend. Alternatively, it could indicate that there were shifts in seasonal impacts on the proxies."

We have now also addressed the absolute ages for the Oligocene better in section 2 (lines 127-132): "The absolute ages for the studied succession are calculated up to the depth of 214.19 mbsf, where the highest occurrence of *Reticulofenestra umbilicus* (with diameter >14 µm) is observed, which provides an absolute age of 32.02 Ma at that depth (Firth et al., 2013). The uppermost part of the studied succession belongs to the NP24 (Firth, 1989) and the normal polarity magnetochron (Firth et al., 2013), suggesting that it is probably not younger than 26.5 Ma.".

Furthermore, the SST evolution across the EOT is complex enough, so we did not want to diffuse the focus of our discussion too much.

When you zoom into the 37-32 ma interval, only a fraction of your alkenone data is included **The alkenones appear only around 33 Ma, as we mention in lines 280-282**

When you compare your data to other North Atlantic records you do only for a selected time interval (37-32 Ma), not the full reconstructed time interval. Why? **Due to all the data and model uncertainty, it is already challenging to convincingly couple the signals found to processes. So, a lot of carefully writing was needed not to mislead the reader. If we include more and even more uncertain data, the manuscript could become dominated with what we don't know and loose its power**

I would very much like you to g carefully through the text and specify what proxy and time interval you refer to at different times. Some places you use Eocene and Oligocene, but it's not clear if you refer to the 37-32 Ma interval or your full records. Similar when you use pre and post 43.5 Ma – does this always refer to 37-34.5 and 34.5-32 Ma? Make sure that it is clear throughout the paper what time interval you refer to. **We have followed this suggestion and carefully checked across the entire text, see (track changes version) lines 287, 298-299, 343, 368, 463, and figure captions.**

The first reviewer asked you to do a careful language check of the text. There are still quite some places where the sentences can be hard to follow, or where words should be deleted or added (e.g. line 324 … the where the…); as reviewer 1 mentioned this may have emerged through the revisions, but should still be taken care of. **The language is checked now**

Line 174: suggested rephrasing: .. and is commonly used to estimate Uk`37-derived SSTs of the… **rephrased as suggested**

Line 234: I agree with reviewer 2 that it's not clear from the way it's written that this statement refers to the early Oligocene only (even if you have the statement earlier in the same paragraph). Suggested rephrasing: … the similarity of both records during the earliest Oligocene (x-y Ma) suggests that at this time the temperatures recorded… **This is a valid point, and the suggestion is followed. However, we are not able to provide absolute ages as suggested, since it is not possible in this depth interval. We have addressed this issue in section 2.**

Line 285/Fig. S1: The statement that the data are in the same range; yes, it is true for the early Oligocene, but not above ca 270(?) m. However, it's not true for the younger interval/when you look at your full record. In the younger end, your alkenone SSTs are much colder than the TEX SSTs. There is a clear transition in the alkenone data; maybe I missed it, but I cannot see that this divergence between the proxies is discussed anywhere **This is addressed by our new text:** "Overall, both paleothermometers suggest Oligocene SST (interval from ~34 Ma to ~26.5 Ma) below 26°C (Figs 2 and S2), with two temperature minima. However, with the existing uncertainties in the age model for this interval (i.e. depth from 190 to 130 mbsf; Firth et al., 2013) it is challenging to link the SST minima with the cooling episodes from the Oligocene (e.g. Wade and Pälike, 2004). This could potentially be improved by a detailed analysis of dinocysts (e.g. Śliwińska et al., 2010; Śliwińska, 2019; Śliwińska and Heilmann-Clausen, 2011), but it is outside the scope of the present study. Notably, at the older SST minimum (depth ca. 183 mbsf, Fig. S2) U_37^K'- derived SST becomes significantly colder than TEX86-derived SST. Potentially, this may be because the surface conditions, reflected by the U_37^K', changed more substantially than subsurface temperatures, which will affect TEX86-derived to a larger extend. Alternatively, it could indicate that there were shifts in seasonal impacts on the proxies." **Since the data on this is limited at the moment, we would not like to dive into this in details. However, we think that it is important to show all the data span we have produced and hope that when more data appears we could have a better idea how to explain this.**

L288: Cn you specify the ages off the intervals you compare? The statement that its <25°C after the transition is true for TEX, but not really for the early Oligocene alkenone data. If you take into account the uncertainty (that you use to say that the proxies show the same (S1) both proxies are potentially above 25°. **This is a good point. We have specified these, by modifying the text in lines 297-299 as follows: "**Overall, TEX_{86}^{H} - derived SST shows a distinctive cooling step of ~3-4 ºC at Site 647, when comparing the warmer Eocene (SST between 29 °C and 25.5 °C, interval from ~38 to 35.5 Ma) with the colder Oligocene (SST below 25 °C, interval from 33.5 to ~26 Ma) "

Line 289: You refer to Table 1 - where is this table? I cannot find it anywhere. **This is an error on our side, the data are shown in the excel file as one of the supplementary information files. All references to Tables are checked and corrected now.**

Line 322: Be clear that pre and post 34.5 Ma does not include your full record. Rather be specific and use the exact time intervals you refer to. Also, it is not totally clear why you set the change point at 34.5 Ma **We explained it in line 334-335:** "The threshold of 34.5 Ma is chosen, because that is where the clear shift towards colder temperatures in Site 647 is recorded. " Please be more specific on the reasoning behind this choice. Is it the midpoint of the transition as seen in your data? . **We have modified lines 343-346 as follows: "**Here we compare the late Eocene (37 to 34.5 Ma) and early Oligocene (34.5 to 32 Ma) SST at the five North Atlantic core sites to the four combinations of an open and closed Arctic, and 400 and 800 ppm atmospheric CO2 concentrations as described in Hutchinson et al. (2018, 2019). The selected time frame from 37 to 32 Ma covers the most complete data-derived SST evolution from all selected sites (Fig. 3). "

IF so, how do you define the start/end? **We have focused on the 5 million year bracket around the EOT, where the SST data coverage from all sites is the most complete.** Or is it the the starting/end point (does not look like it)? Would it make a

difference to your results if you looked at the pre and post transition intervals instead of including the transition in the SST estimates that you compare with the model results? **Skipping the SST transition interval in our data-driven ΔSST would probably show slightly larger Eocene SST in site 647, but we would lose many data points in site 1404, and few in some other sites. All the existing records, compared to our 647 SST record, are of very low resolution, so we had to compromise in order to get the most optimal view on the SST transition.** In your figures you visualize EOT, however, your transition point is not set at the same time. Please visualize your transition point in the figures as well as the general EOT. **The cooling/transition point coincides with the Late Eocene cooling. We have the Late Eocene event marked on all figures with the SST data, including the absolute ages. However, we now made it clearer (line 302) that the cooling relates with the Late Eocene cooling, so it should be easier to follow for readers.**

You refer to Table S2 here, however, there is no table in your supplement (neither a Table S1 nor S2). **It was error on our side. The data referred here to Table S2 are now incorporated in Figure 6.**

Line 430: Suggested rephrasing: The position and strength of the gyres, as well as the strength of the AMOC, is model dependent … **it is rephrased**

Line 447: before the 34.5 Ma cooling step? **Yes, it is corrected now**

Line 573: Is there room for being more specific on your recommendations here? SST data in general? Preferentially multi proxy reconstructions from the same sites, or preferentially larger spatial spread from one proxy? Pros and cons with both approaches? What about other proxies that can help characterise the climate system before, during and after the transition? **Our work focus on the marine records, so we have added more specific recommendations in lines 487-495 regarding marine proxies:** "This calls for more proxy records SST data to increase the spatial coverage and resolution of regional temperature trends across the North Atlantic in order to identify possible thermohaline fingerprints of the AMOC start-up at the EOT. For areas located south from site 647 and Kysing-4 this could include construction of east-west Atlantic surface and deep water δ18O and temperature gradients using multiple palaeotemperature proxy methods (e.g. clumped isotopes, foraminiferal Mg/Ca, or TEX86). For the higher northern latitudes, where calcareous microfossils fossils are very limited in this time interval, this could include higher resolution SST proxy reconstruction based on TEX86 and/or $U37K'$. Despite the existing hiatuses at the EOB interval in the North Atlantic region, increasing sampling resolution in the existing sites in the interval from 37 to 32 Ma would be beneficial. ". **The added information reflects well in the state of the art outlined in the Introduction (lines 69-75)**

Figure 4: Please be more specific in the caption: 1) zonal average - global of for the Atlantic sector? 2) Specify that WOA is shown as a reference, and for what it is considered a reference. 3) In the captions you use >34.5 and <34.5, while in the figure you are more specific (37-34.5 and 34.5-32. Please be consistent and use the exact time interval also in the caption. 4) specify that its TEX data presented - or is the mean calculated based on a mix of proxies for the younger interval? It should be clearly

specified what is included where. Also be clear on why you make the choice to integrate the proxies if that is what you have done. **We have clarified these issues in the figure caption and other relevant places (e.g. caption to Fig 6 and 7).**

Figure 6: I agree that the added changes contribute to visualise the differences between the reconstructed SST of the pre and post 34.5 Ma intervals. However, it does not solve the problem of seeing clearly how these temperatures relate to the modelled temperatures of the different scenarios. Maybe it is one option to show the modelled SSTs at the core sites in a similar way as you do now with the proxy data, for each scenario? Make an additional panel or add to the legend one line where you place the relevant information where it should be relative to the legend for each model scenario as well as the now added pre/post symbols. Would also be a cleaner presentation if all the squares were at one line, the circles at one line, and then similar for each model scenario. **We agree with this comment, but when these suggestions are applied, the figure becomes messier, in our opinion. For more detailed proxy and model data the reader can follow Fig.4, where all site-specific simulated SST are shown as triangles. We have added a reference in the figure caption, the raw data are included in the excel spreadsheet (online dataset) and a new figure S5.**

Figure 7: TEX data only? Please specify. **It is specified now**

Figure S4: For Figure 6 you argue for the use off a colour scheme fitted for colour blindness. Why do you not follow the same line of logic here? **We have now applied the same colour palette as in Figure 6.**

My best regards

Kasia K. Śliwińska