Comments Anonymous Referee #3:

The study by Maier et al., "Spatial and temporal variability of sea surface temperatures and monsoon dynamics in the northwestern Arabian Sea during the last 43kyr" would be a significant contribution based on Alkenone proxy in the Arabian Sea.

There are only few studies based on Alkenone proxy in the study area and the present study with high resolution, long SST record is interesting work in the complex region and is accepted subject to minor modifications. There are few suggestions which authors need to address prior its acceptance.

Major comments

Gulf of Oman is a complex region and specifically influenced by SW monsoon due to its location and regional factors. Studying the region where seasonality is less pronounced due to the upwelling induced cooling during the summer season. Can the present study mark the variations in the seasonality of the two monsoon periods. Please elaborate on this aspect.

It is assumed that the alkenone proxy used in the study provides an Annual Mean SST. Does it not bias the study, can this give a true measure of the seasonality in the study area?

Response: First, we would like to thank the anonymous referee for her/his comments, which have helped us improve our manuscript.
We agree that while our SST data reflect an annual mean, the variations observed within the record still provide insight into seasonal changes. This is primarily due to the distinct influence of both the SW and NE monsoons on SST in our study area, particularly during their respective seasons.
Generally, we observe that stronger SW monsoon conditions prevail during interglacial periods, while glacial periods are marked by stronger NE monsoon conditions (Clemens et al., 1991; Prell and Kutzbach, 1992; Prell and van Campo, 1986). Other core locations in the Arabian Sea show a tendency to be more directly impacted by either the SW monsoon (e.g., MD00-2354) or the NE monsoon (93 KL, 136 KL). The unique location of our sediment core allows us to capture a more balanced view of these influences, where seasonal SST signals emerge based on glacial or interglacial periods. For instance, a warmer SST signal aligns with stronger SW monsoon conditions (as seen in D-O interstadials), while cooler SSTs are consistent with stronger NE monsoon activity (as during Heinrich event 4) or strong influence by the Oman Upwelling. We recognize that not every cold or warm event is captured in our record due to the complex interplay of other factors such as mesoscale eddies, SST gradients, northward expansion of the Oman Upwelling and NW winds. Nonetheless, the core's highly sensitive SST fluctuations, relative to other Arabian Sea locations, underlines its dependency to monsoon variability.

Annual SST variations are combination of different temperature signals such as Solar insolation and evaporative cooling, Strong NE winds, intensity of Upwelling, thus overcoming the bias by each signal would be difficult to estimate.

Response: We totally agree with the reviewer. This makes the core location very complex and difficult to interpret in terms of the individual drivers of SST changes. In combination with other proxies ($\delta^{15}N$) and other regional cores we tried to estimate what are the potential drivers behind the SST changes. However, given the complexity of the region, more research is needed to unravel the unsolved patterns.

Past studies based on alkenones and other proxies from Arabian Sea reveals cooling during the LGM which varied regionally.

"The Unusual SST pattern at LGM" is not explained properly, majorly all the records in the Arabian Sea suggest cooling of at least 2°C at LGM. There are several reasons as discussed in this section which prompts towards reduced SST contrary to what has been given as justification for warm SST at LGM, for example

1. (i) When there is an intensified NE monsoon effect the associated SST would be lowered
2. (ii) Reduced solar insolation compared to Holocene
3. (iii) Weakened SW monsoon during the entire glacial period cited references such as Boll et al., 2015; Naidu and Malmgren, 2005; Schulte and Müller, 2001, also suggest reduced SST at LGM.
4. (iv) Elevated dust levels could lower the SST then why there is a warm SST at the core site?

Infact, at the YD the low SST was explained with these reasons, compared to LGM's warm SST anomaly. All these points indicate towards lower SST's. Please provide proper justifications of warm SST at LGM.

Response: We agree with the reviewer that typical SST patterns in the Arabian Sea during the LGM generally show cooling and all 4 remarks (i – iv) promote the cooling. In this chapter, we outline the key factors that typically led to SST drops during the LGM and then provide insights into why these factors may not have had the same impact in the Gulf of Oman:

As already mentioned in the chapter, do we need to keep in mind the unique, semi-enclosed location of Gulf of Oman. This may have retained heat more effectively compared to open Arabian Sea. Also, mesoscale eddy circulation and a shift of the SST gradient may also have retained heat more effectively in the Gulf of Oman, so that these processes probably outweighed the effects of the other four processes. Further, having a look at the absolute SSTs the differences between the northern Arabian Sea and the Oman Upwelling is quite low (between 0 and 0.5°C (Gaye et al. (2018)) but was a bit higher at the beginning and the end of the LGM (Gaye et al. 2018). Our record shows similar SSTs (around 26°C) at the beginning of the LGM as the 93KL in the northern Arabian Sea to drop down to almost 24°C around 19 ka with a smooth increase afterwards (Figure 4). The difference to other records from the Arabian Sea are the faster increasing SSTs right after its minima compared to other records. We will also clarify this point at the corresponding position in the manuscript.

Is there any time lag similar to what has been discussed by Naidu and Malmgren, 2005 or the chronology of the sediment core needs to tested for its robustness. Since in few studies the increase in sedimentation rate has been reported at LGM for various reasons in the basin.

Response: The chronology of the sediment core (covering the past 22 ka) studied by Naidu and Malmgren (2005) is based on thirteen AMS radiocarbon dates vs. twenty-one AMS radiocarbon dates (with sixteen in the similar time range of the studied by Naidu & Malmgren) of our sediment record (see Burdanowitz et al. 2024). We developed the age-depth model with the Bayesian model package BACON (v. 2.5.6) within R and using the Marine20 calibration curve and a deltaR of about 93+-61 years. Therefore, we are convinced that our age-model is robust. Further, in terms of solar insolation, we question the assumption that there is a SST time lag response of about 6 ka within the Holocene time period (around 12 ka duration so far). The sedimentation rates in core SL167 were relatively low during the LGM compared to the Pleistocene and Holocene (Burdanowitz et a. 2024).

The chronology part is discussed in Burdanowitz paper, however there should be an age model in the present study.

Response: Response: We agree with the referee (and the other two referees) that we need to discuss our age model in more detail. Therefore, we will add a paragraph and the figure of the age-depth model by Burdanowitz et al. 2024 into the material and methods section. We will also add the measured ages including their uncertainties as diamonds to figure 4.

Minor Comments
Line no. 62, d13O needs to be corrected to “d18O”

Response: We agree with the reviewer’s comment and have revised the point accordingly and we will also check the manuscript thoroughly for more typos.

References should be in chronological order (for eg., line no. 72-75), this needs to be corrected throughout the manuscript. At several instances similar correction has to be made.

Response: We agree with the reviewer’s comment and ensure that any additional errors in the chronological order of references are corrected.

Line no. 90, “500 -1500m”, add space between the no. number and units. Similar comment for the line 96, 98, 99, then at 120 and at several other. This need to be corrected throughout the manuscript.

Response: We agree with the reviewer’s comments and will check the hole manuscript for the correct spelling of number and units.

The initial sampling was done at 2 cm interval. However, the alkenone analysis has been done only for 219 samples. The reason stated behind this the concentration of organic matter. However, is there any difference in terms of resolution of the study at later half of the core?

Response: Analyses were conducted at 2 cm intervals down to a depth of 162 cm, and at 4 cm intervals below this depth due to lower organic carbon content (approximately <1.5%) and limited lipid material. This approach provides higher resolution data in the Holocene compared to the Pleistocene, while still maintaining a high level of resolution throughout the entire sediment core.

At line no. 199 “Enhanced SW monsoon conditions can also strongly impact the SST” If the SST is Annual average then how to distinguish the seasonality?

Response: While we assume that our SST data reflects an annual mean, variations within the record can still be indicative of seasonality due to the influence of the SW monsoon (and also the NE), which has a pronounced effect on SST, particularly in the summer month (or winter month for the NE monsoon). For example, stronger NE monsoon conditions during the LGM reflecting in general lower SST in northern Arabian Sea (e.g. 93 KL and 136 KL) and also in the Oman Upwelling Area (MD00-2354). Conversely, stronger SW monsoon winds after the LGM lead to a continuous warming in SST in the northern Arabian Sea (93 KL and 136 KL).

Why there isn’t any trend in increase in SST at DO 2 and DO3?, Please provide justification for these two interstadials.

In general, for DO Interstadials strong NW monsoon was predicted, however the authors didn’t mention about the effect of upwelling induced cooling on the SST in these time periods. Specifically looking at DO2 the low SST justification provided is due to intrusion of RSW or AIW in the Oman margin, with stronger mixing forced by NW/NE winds. However, at large at all the interstadials the SW monsoon winds were prevalent then what led to the change in contrasting wind conditions at DO2 interstadial? Please elaborate.

Is there any specific reason behind the increase in SST after DO2 and at the onset of LGM at 23 Ka.

Response: Our SST record demonstrate that the Gulf of Oman is highly sensitive to climate variations, responding readily to shift in both oceanographic and atmospheric conditions. However, these varying conditions can also retain or damp a pronounced SST signal. Since so many factors can influence the SST, individual warm or cold events may not be represented. This includes D-O 2 and and D-O 3 but also the LGM.

We also noted that the temperature increase around 23 ka may be attributed to the D-O 2 interstadial (following Böll et al., 2015), but our marking of the interstadial is a little earlier (ca 23-24 ka). However, we consider an increased influence from upwelling unlikely during this event, as a strongly pronounced OMZ is absent in our data (Figure 4f).

Instead, we observe an oxygen-depleted signal (Figure 4g), suggesting a more plausible influence from the intrusion of RSW or AIW rather than upwelling (following Burdanowitz et al., 2024).

At line no. 246, Moreover, during the LGM it has been postulated that there was an increased transport of warm water into GOM. The authors didn't provide any justification for the statement.

Response: Thank you for the suggestion. We intended to explain the transport of warmer water masses into the Gulf of Oman through mesoscale eddies. We will revise the sentence to clarify this point.

Global Factors influencing the SST variations at Gulf of Oman
In this section, the present dataset compared with records of other regions show similar variations. However, at LGM variation doesn't match with global records and the authors suggest influence if regional processes. What significant factors change this trend when comparing the records at other time periods such as Heinrich events, DO and BA cycles, early Holocene etc. which doesn't apply compared to LGM?

Response: The observed discrepancy in SST variations during the LGM compared to other global records is indeed one of the key findings of our study. We hypothesize that regional processes such as a stronger NE monsoon conditions, intense NW winds and a shift in the SST gradient likely explain this discrepancy. However, we acknowledge that these conclusions are based on the current data set and further studies in the Gulf of Oman are needed to fully understand the underlying mechanisms and confirm these results. We will express this in our manuscript.

The spectral analysis periodicities of 7200 in the SST data which is attributed to Heinrich Events due to changes in Laurentide ice sheet. However, the authors may look at Naidu et al., 2019 wherein changes in the cyclicity is attributed to precision.

Response: The reviewer is right, that the 7200 year cycle can be also attributed to (subharmonic) the precession cycle as also mentioned by another reviewer. We will add and discuss this in our discussion.

Conclusion

The significant points of the present study should be elaborated rather just mere stating the results of the study.

In general the dataset is very interesting but the discussion lacks proper reasoning and interpretation and the authors are encouraged to touch upon the comments to provide a better insights on their study.

Response: Thank you again for your time and effort. Your comments and suggestions helped us to improve our manuscript.

On behalf of all co-authors,

Jan Maier