Dear Editor and Reviewers,

Thank you very much for your letter and for the constructive and insightful comments concerning our manuscript, entitled **"Nascent Eocene Indian Monsoons recorded in oyster shells from the western Indian margin"** (Manuscript ID: **egusphere-2026-1393**).

We sincerely appreciate the time and effort you have dedicated to reviewing our work. Your thoughtful comments and suggestions have been extremely valuable in improving the clarity, scientific rigor, and overall quality of the manuscript. We have carefully considered all comments and have revised the manuscript accordingly.

We have addressed the three main concerns raised by the reviewers in the revised manuscript:

1. Definition of threshold criteria for identifying pristine and potentially diagenetically altered shell zones
We have added a dedicated section to the Methodology that defines the threshold values used to distinguish pristine shell material from zones that may have been affected by diagenetic alteration. This provides a clearer and more objective basis for the screening of the shell material.

2. Absence of a chronological age model and reliance on climate-model-based seasonal assignments

We have incorporated ShellChron-derived ontogenetic age models for both shells. This provides an independent chronological framework for the shell records and allows the seasonal interpretations to be evaluated within a shell-based temporal context, rather than relying solely on climate-model simulations.

3. Reliance on a single shell and potentially overambitious climatic interpretations

We have revised the analysis to include both pristine shells in the climatic reconstruction. Furthermore, we have substantially refined the interpretations and now base our conclusions primarily on the proxy-derived evidence, with the climate-model simulations used as supporting evidence rather than as the primary basis for interpretation. This has allowed us to moderate the interpretations and ensure that the conclusions remain consistent with the available proxy data.

Based on the interpretations in the revised manuscript, we have modified the title of the manuscript also. In the revised manuscript, the title is: "**Sustained high temperatures and seasonal hydroclimate variability recorded in the middle Eocene oyster shells from the tropical western Indian margin"**

In the detailed response document (attached), we have addressed the reviewers' concerns through additional clarification, revision of the text and figures, and improvements to the presentation and interpretation of our results. We believe that these revisions have substantially strengthened the manuscript.

Please find below our detailed, point-by-point responses to all comments.

For clarity,

Reviewers' comments are presented in blue

Authors' responses are presented in black

Changes made in the revised manuscript are presented in red.

We sincerely thank the Editor and Reviewers again for their constructive feedback and for the opportunity to improve our manuscript. We hope that the revised version satisfactorily addresses all of the concerns raised and will be suitable for publication.

Sincerely,
Aniket Mitra
On behalf of the authors.

Community Comments:

General comments

Good research on paleoclimate. Please, follow my specific comments to improve your manuscript.

Response: Thank you very much for your kind and constructive feedback. We have carefully considered your suggestions and revised the manuscript accordingly. We hope that these revisions have addressed your comments and improved the clarity and quality of the manuscript.

Specific comments

Line 32. I would not start an introduction from "Asia". However, I would start with a global scale sentence. The introduction is very general at the beginning, and then it becomes progressively more specific.

Response: We have modified the opening statement.

The Eocene witnessed a progressive transition from greenhouse to cooler climate conditions, driven in part by declining atmospheric pCO_2, but punctuated by transient warming episodes such as the Middle Eocene Climatic Optimum (MECO; ~40 Ma), when a rise in pCO_2 temporarily reversed the long-term cooling trend (CenCO$_2$PIP Consortium, 2023; Westerhold et al., 2020).

Lines 32-91. Insert further and recent literature on the Cenozoic climate changes registered in the sedimentary record that incorporates the Eocene:

- Medici, G., Marianelli, D., Gori, F., Cornacchia, I., Brandano, M. 2026. Multi-disciplinary approach to paleokarst occurrence in the Eocene–Oligocene succession of the Apulia Carbonate Platform (Salento, Italy). Facies, doi: 10.1007/s10347-026-00729-5

- Jaramillo-Vogel D, Strasser A, Frijia G, Spezzaferri S 2013. Neritic isotope and sedimentary records of the Eocene-Oligocene greenhouse–icehouse transition: the Calcare di Nago Formation (northern Italy) in a global context. Palaeogeogr Palaeoclimatol Palaeoecol 369:361–376

Response: Thank you for these valuable references. Following the feedback from all reviewers, we have substantially revised and streamlined the manuscript, including its discussion of Cenozoic climate change. After carefully considering the suggested studies, we found that their specific focus on the Eocene–Oligocene transition and paleokarst development does not directly align with the scope and objectives of our revised manuscript. We therefore decided not to incorporate these references, in order to maintain a focused discussion of the climatic aspects most directly relevant to our study.

Line 75. "The Fulra Limestone". Is it a geological formation or a group from a lithostratigraphic point of view?

Response: Fulra Limestone is a geological formation. We have provided detailed information, in the scope of this manuscript in lines 69-74.

The pericratonic Kutch Basin belongs to the circum-Tethyan carbonate ramp that evolved in response to the Eocene tectonic reorganization associated with the India-Asia collision (Mutti and Hallock, 2003; Höntzsch et al., 2011; Martín-Martín et al., 2024). The easternmost extension of the carbonate ramp, represented by a very thick limestone deposition (the Fulra Limestone), formed in the late Bartonian tropics (Biswas, 1992; van Hinsbergen et al., 2015; Banerjee et al., 2018; Fig. 1a-d). This formation postdates the MECO (~40 Ma; Khanolkar et al., 2017) characterised by high temperatures of 32-35 °C (Mitra et al., 2025), and predates the late Oligocene cooling (Sarkar et al., 2003).

Lines 105-111:

The Fulra Limestone, characterised by a carbonate platform deposition (Shallow Benthic Zone: SBZ17; Planktic Foraminiferal Zone E12; Fig. 1d; Khanolkar and Saraswati, 2019), is part of the Eocene circum-Tethys carbonate ramp system (Racey, 2001; Banerjee et al., 2018). It was deposited in environments ranging from shallow lagoons to deeper open marine settings, as evidenced by orthophragminid mudstone, nummulitic grainstone, and *Alveolina* wackestone (Fig. 1d-j; Banerjee et al., 2018). *P. kachchhensis* specimens for this study are sampled from the lower part of the Fulra Limestone, ~5-7 meters above the Harudi-Fulra boundary and coinciding with the first appearance of LBF species *Alveolina elliptica* (Fig. 1d,g-h; SBZ17, E12: Banerjee et al., 2018).

Line 91. Clarify the general goal of your research at the end of your introduction.

Line 91. Describe the 3 to 4 specific objectives of your research at the end of your introduction.

Response: We have defined our goal of the study in by pointing to the knowledge gap in the opening lines of the introduction and end of the introduction we told how we achieved our goal to address that.

Lines 38-48:

The Eocene witnessed a progressive transition from greenhouse to cooler climate conditions, driven in part by declining atmospheric pCO_2, but punctuated by transient warming episodes such as the Middle Eocene Climatic Optimum (MECO; ~40 Ma), when a rise in pCO_2 temporarily reversed the long-term cooling trend (CenCO$_2$PIP Consortium, 2023; Westerhold et al., 2020). Against this backdrop of global climatic change, the South Asian summer monsoon (SAM) system was developing during the middle to late Eocene, influenced by Significant tectonic and palaeogeographic changes in Asia (Huber and Goldner, 2012; Dimri et al., 2016; Tardif et al., 2020, 2023; Mitra and Halder, 2024; Abhik et al., 2026 and references therein). However, its timing and character remain debated, with evidence ranging from a fully developed monsoon by the late Eocene to an arid northern India with seasonal variability driven by Intertropical Convergence Zone (ITCZ) migration during 42-38 Ma (Huber and Goldner, 2012; Licht et al., 2014; Tada et al., 2016; Tardif et al., 2020, 2023). Understanding the evolution of seasonality in South Asia under these rapidly changing climatic and ongoing monsoon development therefore remains an important question.

Lines 88-96:

We present here climate proxy results from these ideal fossil targets. We first assessed the stratigraphic position of the studied oyster species in relation to global warming and cooling events using stable carbon isotope ($\delta^{13}C_{org}$) chemostratigraphy from bulk sediment samples of the Bartonian Kutch. Seasonally resolved temperatures were then estimated through clumped isotope (Δ_{47}) thermometry from the calcitic shell of the oyster species. The $d^{18}O_w$ of the water inhabited by the oysters, which is influenced by the precipitation-evaporation cycle and surrounding environmental factors, was estimated from the combination of clumped and oxygen ($\delta^{18}O_{cc}$) isotope values (see e.g. Caldarescu et al., 2021). Proxy-based reconstructions of sub-annual temperature and hydrological variability were compared with Community Earth System Model (CESM) simulations (Baatsen et al., 2020), yielding insights into seasonality dynamics during this critical period.

Lines 92-110. Insert information on tectonics and structural geology.

Response: The Kachchh Basin has been extensively investigated from structural, tectonic, and stratigraphic perspectives. We have therefore kept the description of its tectonic framework concise to avoid duplicating well-established information. For the Eocene interval considered here, the sedimentary succession largely reflects a relatively stable depositional setting, with stratigraphic boundaries showing limited evidence of significant tectonically driven disruption. We have clarified this point in the revised manuscript and added the appropriate reference.

The studied successions of the Kutch (or Kachchh) Basin in a stable depositional setting comprise the Harudi Formation and the Fulra Limestone (Biswas, 1992; Catuneanu and Dave, 2017; Fig. 1d).

Lines 581-596. You can expand the conclusion adding a “take home message”.

Response: We have refined the conclusion. This last paragraph of conclusion is the take home message.

Proxy-based reconstruction from the multi-year archive of the pycnodont shells, supported by climate model simulations, reveal small seasonal temperature difference (ΔSST: ~5 °C: 31-36 °C) comparable to modern north India (ΔSST: ~7 °C: 23-30 °C). The region likely maintained generally more extreme sea-surface temperatures than the present Gulf of Kutch, with rainfall-driven cooling events associated with typical reduced evaporation for at least twice a year with a gap of ~7-8 months. Rainfall occurring ~8-9 months after peak summer had been facilitated by the advection of moisture from the open Tethys Seaway between India and Eurasia. Although the limited sampling points with large material requirements for robust Δ_{47}-temperature estimates do not permit reconstruction of the complete seasonal and the monsoon structure, but represent minimum seasonality. However, the identification of lower $\delta^{18}O_w$ during ~1-2 and ~8-9 months after peak summer provides evidence for a seasonally structured hydrological cycle in the late Bartonian India, different in character from modern four month confined summer monsoon of north India.

Response:

Figures and tables

Figure 1. The outcrop images can go in a separate figure.

Response: Thank you for the suggestion. We considered presenting the outcrop photographs as a separate figure. However, the revised manuscript already contains 10 figures, and we aimed to avoid further increasing the number of figures. We have therefore retained the outcrop images within the existing figure to maintain a concise presentation of the field and geological context.

Figure 4. Increase the graphic resolution to make the graphs more visible.

Response: We have revised the figure to improve its graphical resolution and legibility. Following the deletion of the former Figure 3, all of its components have been moved to the Supplementary Material, and the subsequent figures have been renumbered accordingly. Thus, the figure referred to as Figure 4 in the original manuscript is now Figure 3 in the revised manuscript. We hope that the revised figure is now clearer and more legible.

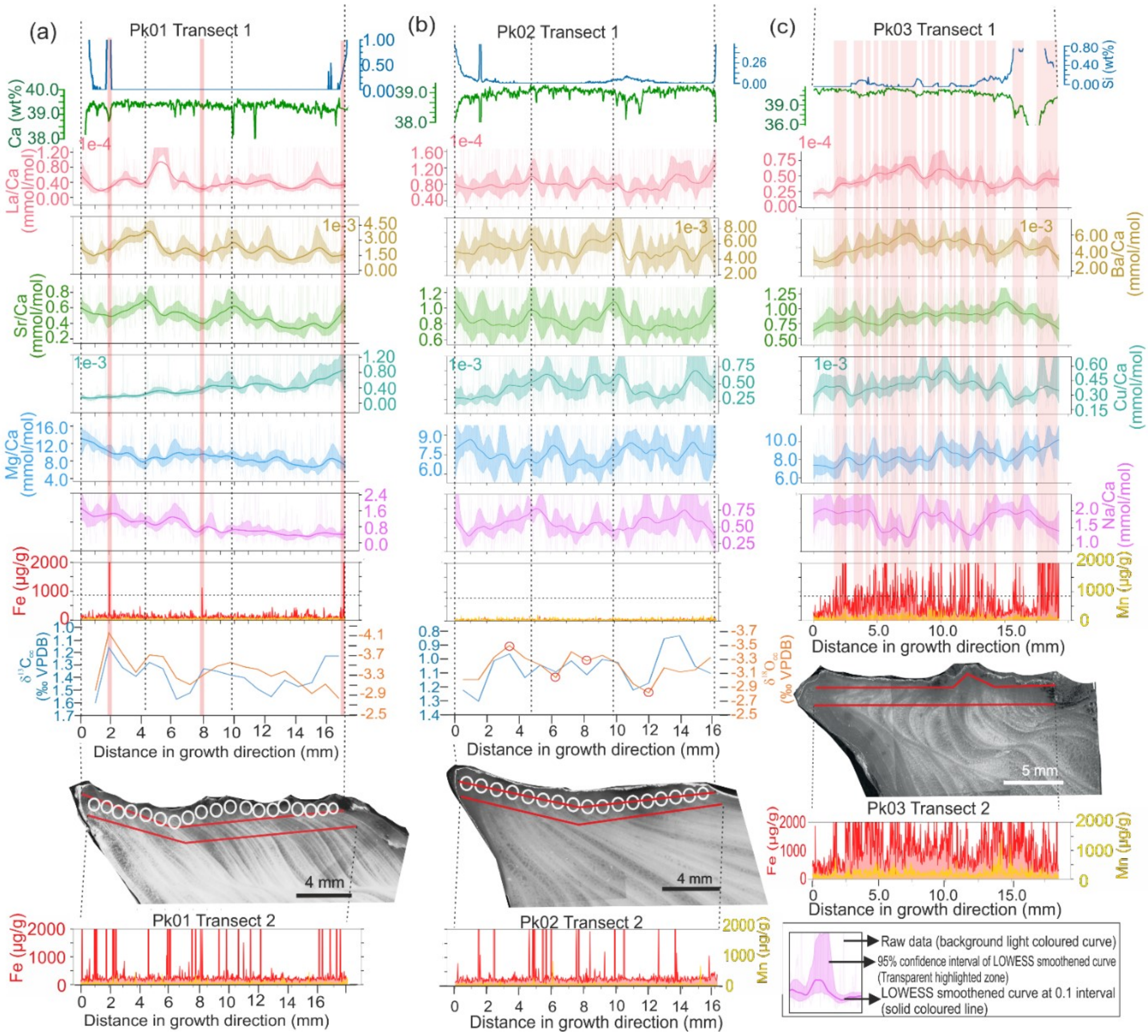

Figure 3. Plots of Ca and Si wt%, manganese (Mn) and iron (Fe) concentrations along with trace element-to-calcium ratios, measured along the growth axes of the resilifers in *P. kachchhensis* shells from resilifer edge transects of (a) K/PK/01 (b) K/PK/02 and (c) K/PK/03; and Mn, Fe concentrations from transects 2mm away from the resilifer edges at the bottom of the respective specimens. Red circles on $\delta^{18}O_{cc}$ profile of K/PK/02 indicate clumped isotope analyses points. Dotted vertical lines are indicative of probable year-markers. The line scan profiles are plotted on the cross-section image by red lines; white circles indicate stable isotope sampling points. Representative trace element-to-calcium ratio profiles from each element category (light metal, large ion lithophile elements, transition metals and rare earth elements) are shown. All trace element-to-calcium profiles is shown in supplementary file Fig. S4.

Figure 6. The spatial scale is a bit unclear. Consider applying changes in the figure or in the caption.

Response: We have revised the caption of the figure.

Figure 6. (a) Comparing Δ_{47}-T and $\delta^{18}O_w$ from the Ypresian (after Evans et al., 2018), the early Bartonian (after Mitra et al., 2025) to the late Bartonian of the Kutch Basin. Temperature (Δ_{47}-T) is plotted against $\delta^{18}O_{cc.}$ (b) PCA plots based on trace element to Ca ratios from the analysed specimens of *P. kachchhensis* (K/PK/02) from lagoonal setting of Fulra Limestone and *F. pseudoflemingi* from shallow shelf setting of Harudi Formation. PCA plots with all the specimens are incorporated in the supplementary file. (c) Environmental model of the late Bartonian *P. kachchhensis* habitat in the lagoonal setting of the Fulra Limestone: (c1) evaporative conditions during the warmest months increased $\delta^{18}O_w$ values in a semi-restricted lagoon; (c2) seasonal rainfall triggered seawater influx into the lagoon, leading to reduced temperature and evaporation and a consequent decrease in $\delta^{18}O_w$ values.

Figure 9. Important figure. Please, increase the graphic resolution in terms of dpi.

Response: We have revised figure and included a white box to denote the study area.

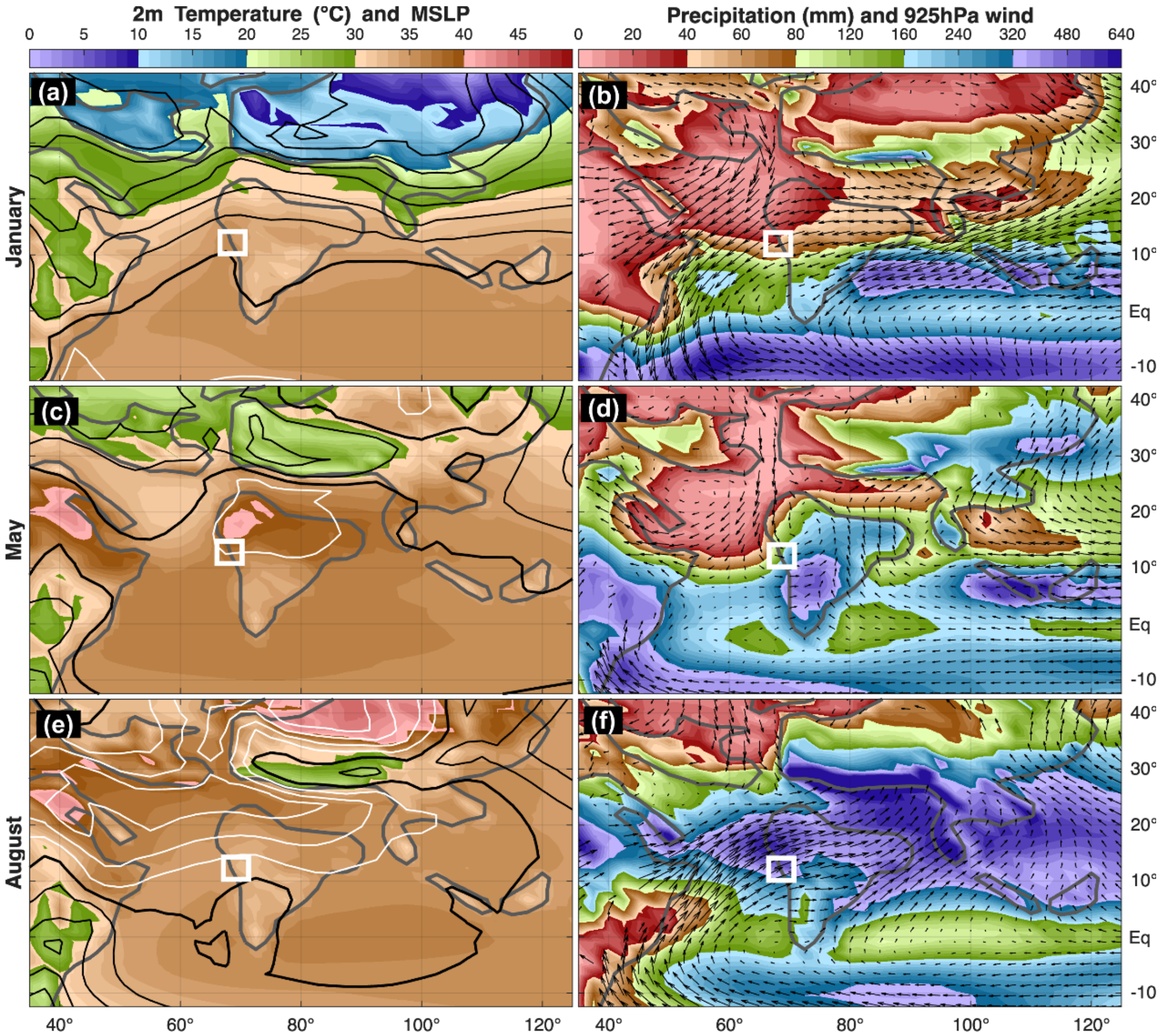

Figure 9. CESM outputs for the south Asian region at ~38 Ma under 2×PIC conditions in the months of January (post-monsoon rainfall month), May (peak summer) and August (monsoon): Left panels (a,c,e) show surface atmospheric air temperature at 2 m (shading) and mean sea level pressure (MSLP at 2.5 hPa intervals, white if <1000 hPa, thick black line at 1000 and 1020 hPa); Right panels (b,d,f) indicate precipitation (shading) and wind speed (length of arrows) and direction at 925 hPa. Study site is marked by white-boundary rectangle.

We have included all the new references in the revised manuscript following the in-text citations.