***Interactive comment on* "Pliocene expansion of C_4 vegetation in the core monsoon zone on the Indian Peninsula" *by* Ann G. Dunlea et al.**

Anonymous Referee #2

Dunlea et al. evaluate new organic geochemical data from the Bay of Bengal (Indian Ocean) in order to investigate changes in terrestrial biomes over the past 6 Ma. Specifically, the carry out: (i) geochemical analyses of major, trace and rare elements on sediments samples from IODP Site U1445 to determine the sediment provenance; (ii) 13C and D analysis on leaf-wax fatty acids (C30) to reconstruct the evolution of C4 plants since the late Miocene. The authors suggest that the sediment originates from the Mahanadi River in core monsoon area of the Indian Peninsula, and hence the biomarker data allow to better understand the timing of the C4 plant expansion during the Late Cenozoic in this region. They conclude that although C4 plants have been growing on the Indian Peninsula already during the late Miocene, they expanded strongly from the mid-Pliocene (at c. 3.5 Ma) onwards in agreement with previous observations from East Africa and NW Australia.

The authors have produced a nice dataset that merits publication in Climate of the Past in principle. In its current form, however, the manuscript is poorly structured with most of the important information provided in the supplementary files. It also lacks an in-depth discussion of the results, particularly comparisons with other existing records from both marine and terrestrial settings and an assessment of the potential mechanisms behind the expansion of C4 plants during the Pliocene. These are dealt with in such a superficial detail that an interested reader from the broad audience of Climate of the Past who knows little about C4 plants and their expansion in the Late Cenozoic, would struggle to follow the arguments. If the authors are interested in greatly expanding the manuscript then I would support acceptance after rewriting.

- We thank the reviewer for their comments and suggested revisions. Substantial portions of the discussion have been re-written.

When revising their manuscript, the authors should carefully address the following points:

1. More information on the age model development is needed. How reliable are the magneto- and biostratigraphic tie points used? Were the turbidite layers removed be- fore developing the age model? What are the sedimentation rates, and how do they change through time? It is difficult to imagine that the sedimentation rates stay 'fairly constant' for a such a long time as the authors argue in line 68.

- We added the average sedimentation rate with uncertainty to the main text. We agree that the age model is a critical part of any paleoceanographic study, but the age points we use are published and improving them is not the focus of this study. The line we fit to the previously published age constraints was merely to interpolate the ages to our samples specifically. While we agree that there may have been shorter-term changes in sedimentation rates, Supplemental Figure S1

demonstrates that there are no major or abrupt changes in sedimentation rate over the million year timescales of interest to this study.

2. Please explain what you mean with higher latitudes and elevations in line 152. Reconstructions of C3/C4 vegetation in the Chinese Loess Plateau (An et al. 2005) and palynological records from the Tibetan Plateau (Koutsodendris et al. 2019) – which are arguably from higher latitudes and elevations than the study area – show expansion of C4 plants and arid semi-desert biomes, respectively, during the mid-Pliocene; hence the argument that ecosystems at higher latitudes and elevations remained stable is not correct. By extension, the interpretation that tropical ecosystems adjacent to the Indian Ocean are more sensitive and the CO2 change is likely not the primary driver of the Pliocene C4 expansion is not fully substantiated.

- Yes, we have clarified this point. We were saying that the Indian Peninsula is more sensitive to monsoon changes than the relatively close records in the India, Pakistan, and the Himalayan regions. We added the Pliocene C4 patterns in Asia to the discussion.

3. The early Pleistocene interval (c. 2 - 1 Ma) is characterized by lower 13C values suggesting contraction of C4 vegetation in the study area. Please elaborate on this issue in a revised manuscript. Is a similar pattern also observed in other records? What kind of mechanism could be responsible?

- We added a paragraph discussing the change in the early Pleistocene.

4. The discussion on the global patterns of C4 expansion should be substantially expanded. Please also consider including recently published biomarker data from the western Indian Ocean (e.g., Pollisar et al., 2019) and also comparing the data from Site U1445 with palynological records from adjacent regions to the Indian Ocean (e.g., Miao et al., 2017; Koutsodendris et al., 2019) that also span the time interval from the mid-Miocene to Pleistocene.

- Thank you for these additional references. We included them in the expanded discussion.

5. The influence of precipitation as a trigger for the C4 expansion during the mid-Pliocene is also poorly explained (lines 154-155). The authors simply list several climate components affecting the precipitation variability in the Indian Ocean today without however explaining how they may have influenced the hydroclimate during the mid-Pliocene. They should at least elaborate on whether these climate systems were active during this time interval based on proxy records and model studies, and suggest specific mechanisms responsible for the hydroclimate, and in turn, vegetation dynamics in the study region.

- The explanation of the climate system and possible mechanisms has been expanded.

6. The quality of plots is generally poor and it is difficult to evaluate the proxy records (a prime example is the 13C record from Site 231 in Fig. 3c). Please redraw the figures to increase clarity.

- We have revised the plots to increase aesthetic value and clarity.

References: An, Z., Huang, Y., Liu, W., Guo, Z., Clemens, S., Li, L., Prell, W., Ning, Y., Cai, Y., Zhou, W., Lin, B., Zhang, Q., Cao, Y., Qiang, X., Chang, H., Wu, Z., 2005. Multiple expansions of C4 plant biomass in East Asia since 7 Ma coupled with strengthened monsoon circulation. Geology 33, 705.

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