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## Comment on cp-2021-81

Anonymous Referee #2

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Referee comment on "Early Eocene carbon isotope excursions in a lignite-bearing succession at the southern edge of the proto-North Sea (Schöningen, Germany)" by Olaf Klaus Lenz et al., *Clim. Past Discuss.*, <https://doi.org/10.5194/cp-2021-81-RC2>, 2022

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The study by Lenz and colleagues provides a high-resolution terrestrial organic carbon isotope curve covering the Late Paleocene – Early Eocene. The new  $\delta^{13}\text{C}_{\text{org}}$  curve is embedded into a detailed stratigraphic framework based on new dinoflagellate biostratigraphy coupled with sequence-stratigraphic considerations. The new age constraints enable comparison (and tentative correlation) of pronounced carbon isotope anomalies (CIE 1 to 6) observed in the lignite-bearing record with marine carbon isotope trends and associated hyperthermals including the PETM, ETM2 (questionable) and EECO. The core of the study is a high-resolution  $\delta^{13}\text{C}_{\text{org}}$  curve based on >320 measurements, part of which (~120 data points) has already been published by Methner et al. (2019) in *Climate of the Past*.

The manuscript represents a well written scientific study of very good quality, presenting new and important findings. The data-set is well presented in a number of high-quality figures and diagrams. Stratigraphically well constrained land-sea correlations during times of exceptional global warmth are of paramount importance to better understand the coupled response of the marine and continental biosphere during such hyperthermal events. In this respect, the study is clearly well suited for publication in *Climate of the Past*. However, some aspects remain critical and need revision, as outlined below.

### Major points

My main criticism is the absence of an in-depth discussion on the controls of the carbon isotopic composition of the mire-derived OM, which is interpreted here to record a global atmospheric carbon isotope signal. In my view, several aspects should be considered in order to better distinguish between potential global and local carbon isotope signatures. Firstly, the overall composition of the predominantly land plant-derived OM is rather negative ( -25.5 to -28.5 ‰) which deserves some discussion. Gröcke (2002) gives an average of -23 to -27 ‰ for C<sub>3</sub> land plant-derived OM. Comparison with time-equivalent

plant derived carbon isotope values would help to get an idea of the background level expected during the Late Paleocene – Early Eocene. In addition, data from other near-shore mire deposits would provide a range for the carbon isotope composition variability in such environments.

In chapter 4.3, the authors refer to the general difference in the  $\delta^{13}\text{C}$  composition of land- and marine-derived OM. In consequence, mixing of marine and terrestrial organic carbon is used to explain certain variations in the Schöninggen stratigraphic record (line 321 ff.). However, when comparing the  $\delta^{13}\text{C}$  signature of isolated marine particles (dinoflagellate cysts) analyzed from before and throughout the PETM (Sluijs et al. 2017, *Geology*), it becomes clear that the dinoflagellate-derived  $\delta^{13}\text{C}$  composition covers a similar range compared to the OM from the Schöninggen record. During the Early Paleogene, the  $\delta^{13}\text{C}_{\text{org}}$  composition of marine OM is not depleted compared to the values obtained from Schöninggen, which hampers any source assignment of the OM based on the  $\delta^{13}\text{C}$  signature. To better distinguish between different sources, RockEval pyrolysis and/or palynofacies data would certainly help.

At the beginning of chapter 4.3 (line 309-310), the authors state that when comparing the new CIEs with known CIEs, a differentiation between shifts at lithological boundaries and shifts occurring within the same lithology is necessary. This statement seems to indicate that CIEs associated with lithological boundaries are more prone to be caused by local changes (e.g. OM composition) compared to within-facies shifts, which are - in consequence - interpreted as super-regional (global) phenomena. The authors do not refer to potential processes, which may cause the high-amplitude shifts in  $\delta^{13}\text{C}_{\text{org}}$  within individual coal seams. Their data shows that pronounced changes do occur within many of the studied coal seams, which may be controlled by various environmental processes and not necessarily reflect changes in the global  $\delta^{13}\text{C}$  signature. Mires do evolve with time and mire-producing plant successions change with mire growth, which is expected to cause stratigraphic changes in the bulk  $\delta^{13}\text{C}$  signature of the peat/lignite. Interestingly, the detailed pollen record from the main seam (Fig. 7) does show pronounced changes in the pollen assemblage, which does occur time-equivalent to a major shift in the  $\delta^{13}\text{C}$  record (e.g. pronounced increase of Myricaceae associated with a strong negative CIE). This negative CIE is considered to represent the onset of the PETM negative CIE and therefore, the co-occurrence of negative CIE and vegetation shift needs to be explained in more detail. In lines 411 ff. the authors refer to this coincidence as intra-PETM fluctuations, but a more in-depth discussion is lacking. The authors need to explain, on which basis local environmental drivers (incl. vegetation and/or humidity changes) can be excluded to explain the onset of the negative CIE 1. In general, potential environmental processes affecting the  $\delta^{13}\text{C}$  composition of the OM need to be considered in more depth and need to be included in the interpretation of the stratigraphic trend obtained from Schöninggen.

Chapter 4.4.1 deals with the CIE associated with the PETM. The authors provide compelling evidence for a correlation of the Schöninggen CIE1 with the globally recognized PETM CIE. What is less clear is the basis for the base and top boundaries shown in Fig. 6, which constrain the PETM CIE. Why is the basal boundary placed at the data point showing the least negative value in this part of the curve (and not slightly higher at the data point just before the negative shift)? This has implications for the total amplitude of the anomaly (see table 2). Similarly, the positioning of the upper limit (red line in Fig. 6) of the CIE is hard to follow given that another interval with comparatively negative values is

following above. A more plausible termination of the CIE would be at the transition towards less negative values (~23 m height). Are there any stratigraphic constraints for the positioning of those boundaries?

Line 351 – here, the authors refer to the previous study by Methner et al. (2019, CP), which – according to the authors - already did suggest a position of both, the PETM and the P/E boundary below seam 1. However, when reading the study by Methner et al. (2019), one does get another impression. In this previous work, a pronounced negative anomaly (the interval entitled CIE2 in the submitted paper) is suggested to tentatively correspond to the PETM negative anomaly and comparison and correlation with PETM-equivalent anomalies (Cobham lignite, Vasterival) is given. This view is now significantly revised and the part considered to correspond to the PETM by Methner et al. (2019) is now placed in the post-PETM part of the Schöningen record. This is not in itself problematic since new stratigraphic data does results in a re-interpretation of the previous data set. But this re-interpretation needs to be made clear and the statement above (line 351) should be rephrased to better represent the suggestions of Methner et al. (2019).

Minor points

Line 22: The abbreviation EECO is not explained in the abstract.

Line 40: Please include “to 27 to 35°C in the earliest Eocene (Inglis et al. 2020)”

Line 49: The author refers to “kilo year to millennial scale”. To me (and maybe to other readers) the difference between the 2 time intervals is not clear? Please explain or rephrase.

Line 76 ff. There is a new published terrestrial  $\delta^{13}\text{C}_{\text{org}}$  record and associated palynology across the PETM published by Xie et al. (2022, Paleo3) entitled “Abrupt collapse of a swamp ecosystem in northeast China during the Paleocene–Eocene Thermal Maximum” which should be referred to.

Line 272: The heading refers to the “basal Schöningen Formation” but the interval studied does represent more than half of the Schöningen Formation. Hence, the phrase “lower”

might be better suited here...

Line 421: Change to "observed in the terrestrial records".