This paper presents carbon isotope data of bulk organic matter ($\delta_{13}C_{TOC}$), organic carbon content, and palynomorphs from an Early Eocene study site in Germany. The authors provide a new age model for the section and despite the variability in carbon isotope values, try to make educated interpretations to outline up to six potential negative carbon isotope excursions (CIEs). A full assessment of the intricacies of the lithological interpretations and stratigraphic framework is outside my area of expertise. That said, the paper appears to provide a lengthy description of observations.

We thank the reviewer for the careful and constructive comments and suggestions to improve the paper. In the following each of the comments are specifically addressed.

Reviewer comment 1: *One particular challenge is that there is a lot of variability in the $\delta^{13}C_{TOC}$ values, which is a problem with relying on bulk organic matter to define carbon isotope excursion intervals. The authors do provide some context relative to other sections, especially with regards to the variability in the isotope values. I cannot help but wonder if others looking at the carbon isotope values would draw the same conclusions because of the variability.*
Our response: In conjunction with our age model, which should be very robust, especially due to the occurrence of stratigraphically relevant dinocysts (see also our response to comment 2), we are able to calibrate the isotope curve quite precisely, especially in the lower part. Therefore, the interpretation of our CIE 1 as PETM-CIE is conclusive, especially in comparison to similar curves of other sections at the southern edge of the Proto-North Sea also relying on bulk organic matter. The interpretation of the other post-PETM CIEs has been made more cautiously but is also supported by our age model.

Reviewer comment 2: *It does seem like this paper is a helpful addition to constraining an additional study site of Early Eocene CIEs. This would be constructive for future work analyzing this area and for comparison to study sites in other regions to understand climate in the past. I think it's important to better note the level uncertainty in the results and age correlations to avoid oversimplification though.*
Our response: We will add a new reference (Iakovleva et al. 2021). The authors notice that the dinocyst assemblages from the PETM interval in the Paris and Dieppe-Hampshire basins at the southern edge of the Proto-North Sea contain a significant number of atypical, longer specimens of *Apectodinium parvum*, which could represent an ecological onshore substitute for *Axiodinium augustum,* the open marine marker species of the PETM. Since *A. parvum* is together with *A. homomorphum* the dominant cyst among the dinoflagellate assemblage at the base of interbed 1, this is further evidence that the CIE, which starts in the Main Seam, represents the PETM. We will therefore update the dinocyst photo plate in the supplementary material and the discussion of our age model in the manuscript accordingly.

Reviewer comment 3: *Has any attempt been made to do compound-specific isotopes to help define the carbon isotope excursions? I think it would be worth mentioning this in the paper. For example, Ln 423 refers to work from the Bighorn Basin, where more recent work by Baczynski and others have provided evidence for how bulk organic matter carbon isotopes values can be distorted indicators of CIEs (as a function of a combination of organic matter sources, reworking of organic matter, and degradation). See for example, Baczynski et al. 2016 https://doi.org/10.1130/B31389.1*
Our response: At the moment, we can only present the analysis of bulk organic matter carbon isotopes, which is also the standard method for other records at the southern edge of the Proto-North Sea. We are fully aware of the problem such as reworking of organic matter, differential degrading of organic matter, and the combination of different organic matter sources as already discussed in Methner et al. (2019) (see also our response to comment 4). Therefore, we only interpreted general trends of the curve. We are aware of the mismatch between isotopes values of bulk organic matter and compound-specific isotopes, but this does not affect our interpretation, since the CIEs that we recognised should actually be even more pronounced by using compound-specific isotopes. In that context we will now refer to Baczynski et al. (2016) and add the reference.

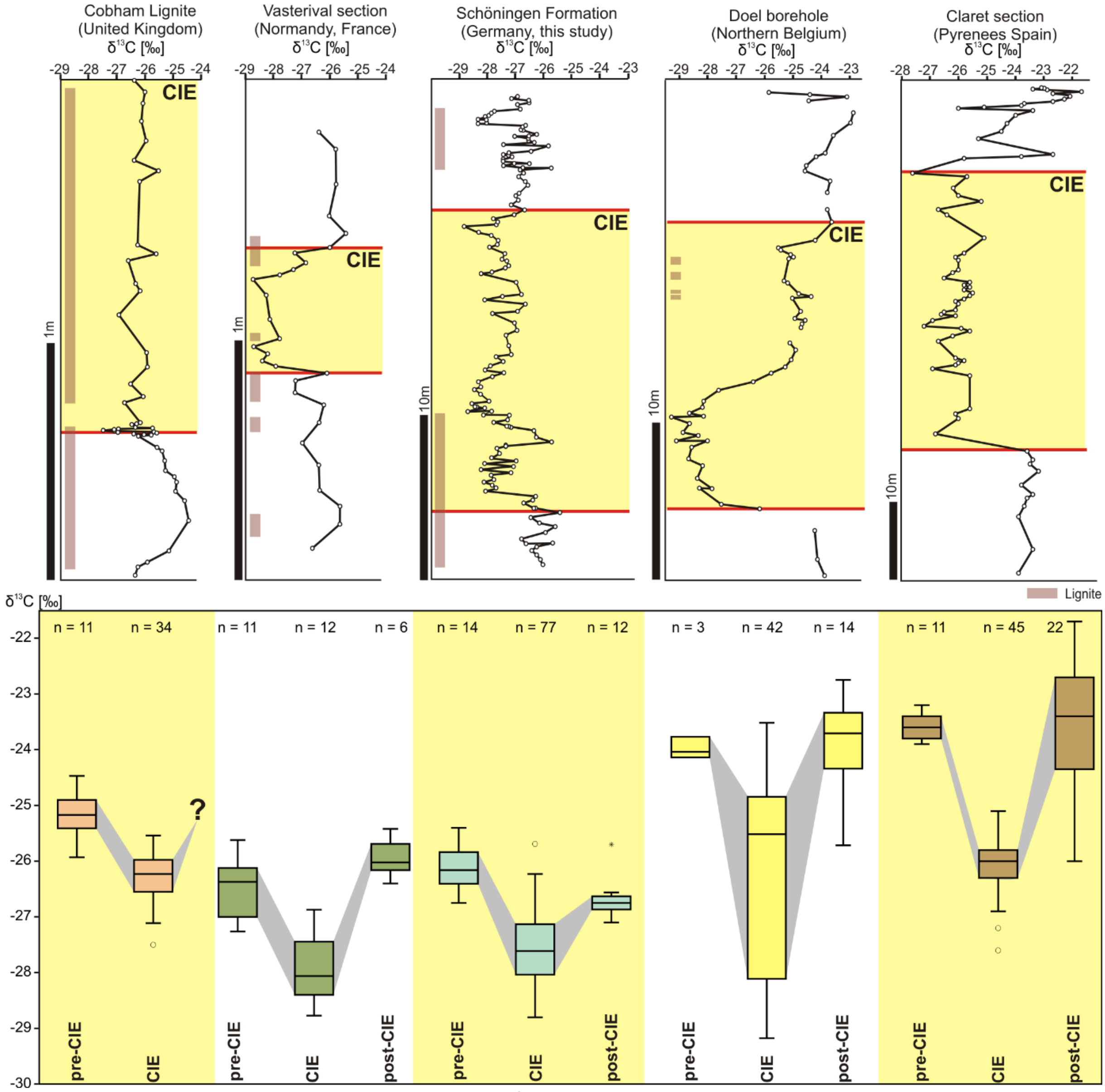
Reviewer comment 4: *Ln 99. The frequent changes between terrestrial and marine conditions and thus changes in TOC input type can be a challenge for sourcing. Mixed inputs would affect the $\delta^{13}C$ of the bulk organic matter.*
Our response: We are fully aware of the problem of mixing of different carbon sources. Therefore, we have already written a paragraph (4.3 - Effects of changes in lithology and mixing of carbon sources on $\delta^{13}C_{TOC}$ values) in which we discuss this problem.

Reviewer comment 5: *Ln 165. The figure number of the diagram needs to be specified.*
Our response: We didn't specify the figure number in Ln. 165, since the pollen diagram should appear as Fig. 7 at the end of the text. Otherwise, because of consecutive numbering of all figures, the pollen diagram would have to be inserted as Fig. 2 at the wrong place in the text. Therefore, we would suggest omitting the reference to the figure number at this point.

Reviewer comment 6: *Ln 276-281. How does the variability compare to other well-constrained CIEs and other sections with similar lithology changes as this section? In Ln 279, "comparatively high standard deviation" – what are the authors comparing to? What is causing the high variability, the "great range of $\delta^{13}C_{TOC}$"?*
Our response: At this point in the text we only present the results of our isotope analyzes and describe the course of the $\delta^{13}C$ curve. The comparison with other well-constrained CIEs in other locations with similar lithology, e.g., the Cobham Lignite (UK) and the Vasterival section (France), is discussed in detail in paragraph 4.4.1.
We will change the sentence in line 279 in "…with the comparatively high standard deviation (SD), compared to other sections of the isotope record (see below),…". Additionally, we will add the reference to Table 2 to present the "great range" of $\delta^{13}C_{TOC}$ values in this part of the record.
Furthermore, we will extend the discussion in paragraph 4.4.1 and add a new figure providing a comparison to other PETM-CIEs from lignite-bearing deposits at the southern margin of the paleo-North Sea such as Cobham, Vasterival and Northern Belgium. In addition, a continental isotope curve from the Pyrenees (Claret section) is also shown for comparison. The $\delta^{13}C$ values from this section, which does not contain any lignites, are clearly higher than those from the wetlands of the North Sea. Only the $\delta^{13}C$ values from the Doel borehole in Belgium are comparable to those from the Pyrenees. However, the section from Belgium includes only few terrestrial sediments, is mainly lagoonal to marine influenced and therefore not fully comparable to the sections from Cobham, Vasterival and Schöningen. Especially in comparison with Vasterival, the variability of the $\delta^{13}C$ values in the pre-, peak-, and post-CIE intervals is almost identical.
We pointed to the similarities between the lignite deposits at Cobham, Vasterival and Schöningen (CIE 2 in our manuscript) already in Methner et al. (2019):

1. Absolute $\delta^{13}C_{TOC}$ values and the range in $\delta^{13}C_{TOC}$ values (-3:2 ‰) are very similar.
2. All three records attain similar minimum $\delta^{13}C_{TOC}$ values during the CIE (-27.5‰ to -28.8‰), averaging 28.05$\pm$0.5‰.
3. At the onset of the CIE the magnitude of changes in $\delta^{13}C_{TOC}$ (calculated as the difference between the last pre-CIE value and the first CIE value) ranges only between -1.4‰ and -1.8‰.
4. Magnitudes of the CIE in bulk organic matter calculated as the difference between the mean pre-CIE and the mean CIE values range from -0.9‰ to -1.6‰. CIEs calculated as the difference between the mean pre- CIE values and the most negative value during the CIE yield magnitudes of -1.1‰ to -2.6‰.

These characteristics now also apply to our CIE 1, which we correlate with the PETM. In summary, the very similar data from the lignite records show that the wetlands at the southern edge of the paleo-North Sea had a uniform behavior during latest Paleocene-early Eocene thermal events. The CIE magnitudes are damped compared to purely continental terrestrial archives such as the Claret section in the Pyrenees but yield a very consistent and robust signal. In Methner et al. (2019) we discuss different possibilities for the dampened magnitude of the CIE in the lignite records such as mixing and dilution of the input signal, occurrence of local signal perturbation (e.g., due to vegetation changes), or the differential degradation and/or preservation of organic matter during the climatic perturbation.



New figure: Comparison of midlatitudinal $\delta^{13}C_{TOC}$ records surrounding the paleo-North Sea: Cobham, UK (Collinson et al., 2003), Vasterival, France (Storme et al., 2012), Schöningen, Germany (this study), Doel borehole, Northern Belgium (Steurbaut et al. 2003). Additionally, a terrestrial $\delta^{13}C_{TOC}$ record from the Pyrenees (Claret section, Domingo et al. 2009) is given that highlights the isotopic differences to the lignite records. Note the different stratigraphic thicknesses due to different sediment accumulation and preservation conditions in the individual depositional environments.

<u>Reviewer comment 7:</u> *Ln 280. "significant decrease". On what statistical basis was this determined to be significant?*
<u>Our response:</u> This statement is not statistically based but relative. Therefore, we will change "significant" in "strong".

<u>Reviewer comment 8</u>*<u>:</u>* *Ln 333. "values increase significantly" As above, are there statistics to attest to the significance?*
<u>Our response</u>: We will delete "significantly" here.

Reviewer comment 9: *Ln 342 "a weak CIE". Weak is a qualitative term, information on the magnitude of the excursion/time or depth interval/number of samples could help clarify the identification of this CIE.*
Our response: We will add "of 0.7 ‰" ("a weak CIE of 0.7 ‰").

Reviewer comment 10: *Ln 389. I think the authors meant 1,000 years (1 kyr), not 1.000 years.*
Our response: Thanks for pointing that out. We will write "1 kyr".

Reviewer comment 11: *Ln 422. Can you provide and clarify the evidence that rules out reworking of organic matter? This is again stated in the conclusions, Ln 489, reworking is almost excluded within our seam. As far as I can tell, the logic may be that the rebound structure is consistent with the pollen and spore record…but that doesn't mean reworking couldn't also be a factor?*
Our response: We will extend the discussion on reworking of organic matter and the rebound structure in our isotope record of the Main Seam and write in paragraph 4.1.1:
"Since within-seam carbon sources are likely to be purely terrestrial, the fluctuations of $\delta^{13}C_{TOC}$ values in the CIE of the Main Seam including a clear rebound to higher values are striking. The PETM reflects injections of large amounts of carbon into the atmosphere-ocean system, but it is uncertain, whether single or multiple episodes of carbon release caused this event (Zhang et al. 2017). Generally, the PETM-related CIE is triangular with a single large decrease in $\delta^{13}C$ values, followed by an exponential recovery as seen in several marine isotope curves (Fig. 6). However, in some records, $\delta^{13}C$ values decrease in several steps indicating complex processes of carbon injection into the atmosphere (Zhang et al. 2017). These steps can be interpreted as a result of multiple phases of carbon release. Bowen et al. (2015) could show in a high-resolution carbon isotope record of terrestrial deposits in the Bighorn Basin (USA) that the beginning of the PETM consists of at least two discrete intervals of decreasing carbon isotope values. The first event had a duration between 2 and 5.5 kyr and the onsets of the two carbon release events lasted not more than 1.5 kyr (Bowen et al. 2015). In our record, the first $\delta^{13}C$ decline was also within less than 1.5 kyr and the first excursion lasted around 4.5 kyr when assuming that one meter of lignite represent about 1 kyr (see above*). Therefore, the data from the Main Seam are consistent with the excursions reported from the Bighorn Basin.
However, the steps in a carbon isotope curve may also be related to sediment reworking or mixing of different carbon sources (e.g., Bralower 2002). Mixing and reworking of organic matter cannot be excluded for the interbeds of the Schöningen succession, since multiple flooding and thus reworking events may have occurred (Methner et al. 2019). However, within the autochthonous lignite seams no mixing of the organic material occurred (Methner et al. 2019). The organic matter of the lignite results in situ from an ombrotrophic (rain-fed) peat mire consisting mostly of mosses, ferns and an associated hardwood mire forest (Riegel et al. 2012, Inglis et al. 2015, Lenz et al. 2021). Therefore, the isotope curve in the Main Seam should indeed reflect a stepwise injection of carbon into the atmosphere."

*According to an average compaction rate of 3:1 (Widera 2015) and an average rate of deposition for tropical peat of 3 mm/year (Stach et al. 1982) as written at the beginning of the paragraph.

Reviewer comment 12: *Table 1. What do the parentheses indicate vs. non-parentheses for the references? Also check for consistent spacing in the table between words.*
Our response: In botanical nomenclature, in cases where a species is no longer in its original generic placement (i.e., a new combination of genus and specific epithet), both the authority for the original genus placement and that for the new combination are given (the former in parentheses). The mistakes regarding spacing between words will be fixed.

Reviewer comment 13: *Table 2. It would be useful to specify what stratigraphic positions (meter levels) were used for each of the identified excursions.*
Our response: We will add a new column "Stratigraphic position (in m above base of the section)" in the table.

Reviewer comment 14: *Figure 1. It looks like there is an extra space in the "Seam 7" label.*
Our response: Thanks for pointing that out. We will fix the bug in the figure.

Reviewer comment 15: *Figure 3. Is there any meaning between the different number of dots in the lines in the legend for global sea level curves?*
Our response: Thanks for pointing that out. We will fix the bug in the figure.

Reviewer comment 16: *Figure 6. I realize the authors may be citing the units used in the other publications, but it's unclear to the reader whether there is any meaningful difference between the types of organic matter. For example, $\delta^{13}C_{org}$ "organic matter" versus $\delta^{13}C_{TOC}$ "bulk organic matter".*
Our response: This is correct. We will change the units in all terrestrial records in "$\delta^{13}C$", since all measurements are based on bulk organic matter. Only the isotope measurements of the Chinese record are based on measurements of black carbon. Therefore, we will add in the figure caption "…; in contrast to standard measurements of $\delta^{13}C$ (bulk organic matter) not only carbonates were removed from the samples prior to $\delta^{13}C_{BC}$ measurements but also silicates by using hydrofluoric acid…". Additionally, a wrong reference was given for the Polecat bench record. We will change Baczynski et al. (2013) in Bataille et al. (2013)

Reviewer comment 17: *Figure 7. Clarify is the carbon isotope data here from bulk organic matter?*
Our response: We will change the sentence in the figure caption "The carbon isotope data are shown for comparison." in "The $\delta^{13}C$ values of bulk organic matter (see Fig. 4 for the complete data set) are shown for comparison."

Reviewer comment 18: *Figure 8. TOC for the carbon isotope record should be subscript.*
Our response: We will change it accordingly.

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