Dear Referee #2,

Thank you very much for your detailed review of the submitted manuscript.

Below find our reply (red) to your comments (*black*).

Specific comments

1) The definition of the end of CIE-PETM in the Polecat Bench δ13C record

Duration estimates of the PETM and comparison with previous studies depend tightly on how the stratigraphic extent of CIE is defined. While it is easier to define the onset of CIE at both realms, the definition of its end is more problematic, especially in the continental δ13C record.

In the present form of the ms, it is not clear how the authors (or may be by referring to previous papers) set the end of CIE in the δ13C terrestrial record. Based on their figure 5, I can place it appropriately at 60 mcd depth, and largely at 55 mcd depth. This implies respectively 7.5 to 8 precession cycles, yielding respective durations of 157.5 and 168 kyr (21 kyr mean precession period). These durations are close to the 171 kyr estimate inferred from deep-sea records (Röhl et al., 2007).

Definitions for the different phases of the PETM in the deep-sea and the terrestrial realm are given in Zachos et al. 2005, Röhl et al. 2007, Murphy et al. 2010 (all three deep-sea) and Bowen et al. 2015 (Polecat Bench record). We think it is not very helpful to reiterate the definitions again in the manuscript, citation of those seems to be the best way.

The CIE in the BBCP Polecat Bench drill core has been defined and discussed in Bowen et al. 2015. Assuming, as proposed by the referee above, that the PETM CIE lasted from the onset (118.70 mcd – Bowen et al. 2015) and 55 to 60 mcd (~58.20 mcd) at PCB results in a duration (applying the Table 1 age model) of 157 kyr.

But as written on page 9, line 14: "At the Walvis Ridge ODP sites, the top of the clay layer coincides with the top of the initial rapid recovery of the CIE (Recovery phase I in Murphy et al., 2010). To correlate deep-sea and terrestrial records, the onset and the top of the initial rapid recovery of the CIE are commonly used (McInerney and Wing, 2011)". It is important to know, as written in McInerney and Wing, 2011, that the top of the initial rapid recovery (phase I in Röhl et al. 2007) of the CIE is NOT the top of the subsequent gradual recovery (phase II in Röhl et al. 2007) as assumed by the referee. This matter is complex and can be confusing, but using the definitions as given in Röhl et al. 2007, and more deeply discussed by Murphy et al. 2010, the results of this manuscript clearly show that the duration in the deep-sea is about one precession cycle shorter that in the terrestrial Polecat Bench section.

In all figures dealing with CIE's correlation between terrestrial and deep-sea records (Figures 7, S12 and S13), the onset of CIE is clearly shown at the abrupt negative δ13C shift, whereas the end of CIE is not obvious neither at ODP sites nor in PCB terrestrial record. It's even sometimes confused when reading the cyclostratigraphic interpretation against the proposed age model, and what is said in the text. For instance, in figure 7, the duration of the entire CIE is assessed at about 180 kyr (120 kyr for the clay layer indicated by the brown rectangle plus 59 kyr till the end of CIE shown by light blue rectangle). In the text, the authors discuss a longer duration of 200 kyr..

Again, considering a very likely end of CIE in the terrestrial δ13C data at the top (maximum) of precession cycle no. 8 (Fig. 7), a duration of 168 ky (21 kyr x 8 cycles) could be inferred..

We admit that the definition of phases needs clarification. The onset of the PETM CIE is pretty clear. "The termination of the CIE at Site 1263 and the ''reference section'' at Site 690 were defined (Tables 1 and 2), by identifying an inflection point in the bulk d13C curve" (Röhl et al. 2007). The inflection point was labeled "G" in Zachos et al. 2005 and used for correlation to other records. It is located at 167.12 mbsf in ODP 690 (Zachos et al. 2005. Table S4). Using the Röhl et al. 2007 age model this point is 153.5 kyr after the onset of the PETM (Table 2 of Röhl et a, 2007; not 171 kyr as written in Murphy et al. 2010)! Using the updated age model developed in this study we obtain an age of 55.749 Ma for inflection point G which translates into 182 kyr between onset and end CIE. As given in Figure 7 of the manuscript.

Looking at Figure 5 of Röhl et al. 2007 the end of the recovery is between cycle 8 and 9 at ODP 690. Based on the cycle counting the duration of the CIE is 8*21=168 or roughly 170 kyr was determined in that paper. In our revision of the age model we simply added one precession cycle, therefore the duration of the PETM sensu Röhl et al. 2007 will be 9*21=189 kyr or roughly 190 kyr. In addition, the position of the onset of the PETM in our manuscript was placed between two precession cycles adding another 7 kyr to the duration (compare the relative age of precession cycle 2: in Röhl et al. this is 24 kyr after the onset, in our study it is 31 kyr after onset). Summing up, the PETM CIE duration is 189+7=196 kyr or roughly 200 kyr in the manuscript.

In a revised manuscript we will add a paragraph clarifying this matter. We will also add some details on the definition of the inflection point G, that is problematic because it is located in the very top of ODP 690B-19H and difficult to identify in other isotope records.

A focus was also given on the duration of clay-layer interval. The clay layer is characteristic of deep-sea environment. What is the degree of reliability of correlation between terrestrial and deep- sea (using δ13C) data that led to the projection of equivalent clay-layer interval into the terrestrial records? Note that this correlation is crucial for the assessment of duration of the clay layer. Could the authors add uncertainties on their stratigraphic correlation?

This is discussed on page 9, lines 16 to 34 of the submitted manuscript. The onset of the PETM is clearly correlated by the dramatic shift in carbon isotopes. In marine sediments this is the base of the clay layer. The top of the clay layer, in marine sediments of Walvis Ridge, coincides with the top of the initial rapid recovery of the CIE (Recovery phase I in Murphy et al., 2010). The relatively fast rate of carbon exchange between atmosphere and surface (10's of years) and deep (100's of years) ocean reservoirs requires that the rapid recovery in marine and terrestrial records should be recorded at almost the same time. Using the Röhl et al. 2007 age model as time lag of 25 kyr is apparent between the PCB record and marine data. Assuming that this rapid shift should be nearly synchronous, as written in the ms, we concluded that 25 kyr or about one precession cycle could be missing in the marine records due to the severe dissolution at the onset of the PETM.

In summary, the authors should state clearly in the manuscript how they define the stratigraphic extent of the entire CIE (especially its end) and the projected clay-layer into the terrestrial records, and accordingly they could compare duration estimates between the two realms.

We will add a paragraph in the revised version dealing with the above issues.

2) Comparison with previous age models

In the outcrops (Bighorn Basin) in the Polecat Bench section, Abdul-Aziz et al. (2008) arrived to a duration of 157 kyr for the entire CIE-PETM.

Westerhold and co-authors cited Abdul-Aziz et al.'s (2008) study, but they did not explain the 157 kyr shorter duration compared to their longer duration of 200 kyr obtained from Polecat Bench drill cores. Given both studies are based on precession cycle counting from the same basin (and the same Polecat Bench site), I strongly recommend that the authors explicitly discuss the source of such significant difference. Although the authors evoked promptly this difference (Page 7, lines 21-23), but it is still ambiguous how they found a longer duration with regard to a shorter duration provided by Abdul-Aziz et al. (2008) (see also 'Comment 1' above).

Note that Abdul-Aziz et al.'s (2008) duration estimate (i.e., 157 kyr) is close to the 171 kyr duration of Röhl et al. (2007) inferred from deep-sea records.

"The main body of the CIE spans ~5.5 precession cycles, or ~115 k.y., and the recovery tail of the CIE spans 2 precession cycles, or ~42 k.y." (157 kyr) – Abdul-Aziz et al. 2008.

Again, as already discussed above, the issue here is the definition of different phases of the PETM. The duration for the main body of the PETM, as written in the ms, is almost identical to Abdul-Aziz et al. 2008. The recovery phases of the PETM CIE have been defined in deep-sea records (Zachos et al. 2005, Röhl et al. 2007). Rapid recovery from the CIE should be nearly synchronous in both records. But it is rather difficult to identify the end of the recovery phase (the inflection point G mentioned above) in other records (including the PCB records) than ODP 690. In Abdul-Aziz et al. 2008 the recovery is from ~63 to ~77m, a distance of 14 m (their Figure 3) containing two precession cycles. The new higher resolution data for the PETM CIE from Bowen et al. 2014 show that the recovery starts (note that the depth in the core is from top down, in the outcrop from bottom up) at 75m and ends at 55m, a distance of 20m. We do not want to discuss here which definition at Polecat Bench is correct, but rather point to the fact that is comes down to this definition to find out the duration of the PETM at Polecat Bench. Concerning the marine records, and applying the definitions given in Zachos et al. 2005 and Röhl et al 2007, the duration of the PETM determined in our manuscript remains at 196 kyr, roughly 200 kyr.

In a revised manuscript, we will clarify this by pointing to the rather difficult identification of the inflection point G in the Polecat Bench records.

3) Amplitude modulation (AM) of the precession by the eccentricity

The authors outlined 'AM of the precession by the eccentricity' in the text body and they also pointed it out in the abstract and conclusions, however, there is no statistical test (or even an attempt by visual inspection) to show or retrieve such modulation. If the authors would still retain this result, then they should demonstrate it, at least at the short eccentricity band.

The authors stated (Page 7, lines 8 and 9) : "The filter of the precession cycles of ~8.2 m in both data show modulations that are consistent with eccentricity". Filtering is not sufficient to draw such conclusion. Here a Hilbert transform is required to extract such AM envelopes...

We will add a Hilbert transform of the data to figure 5 – see below.

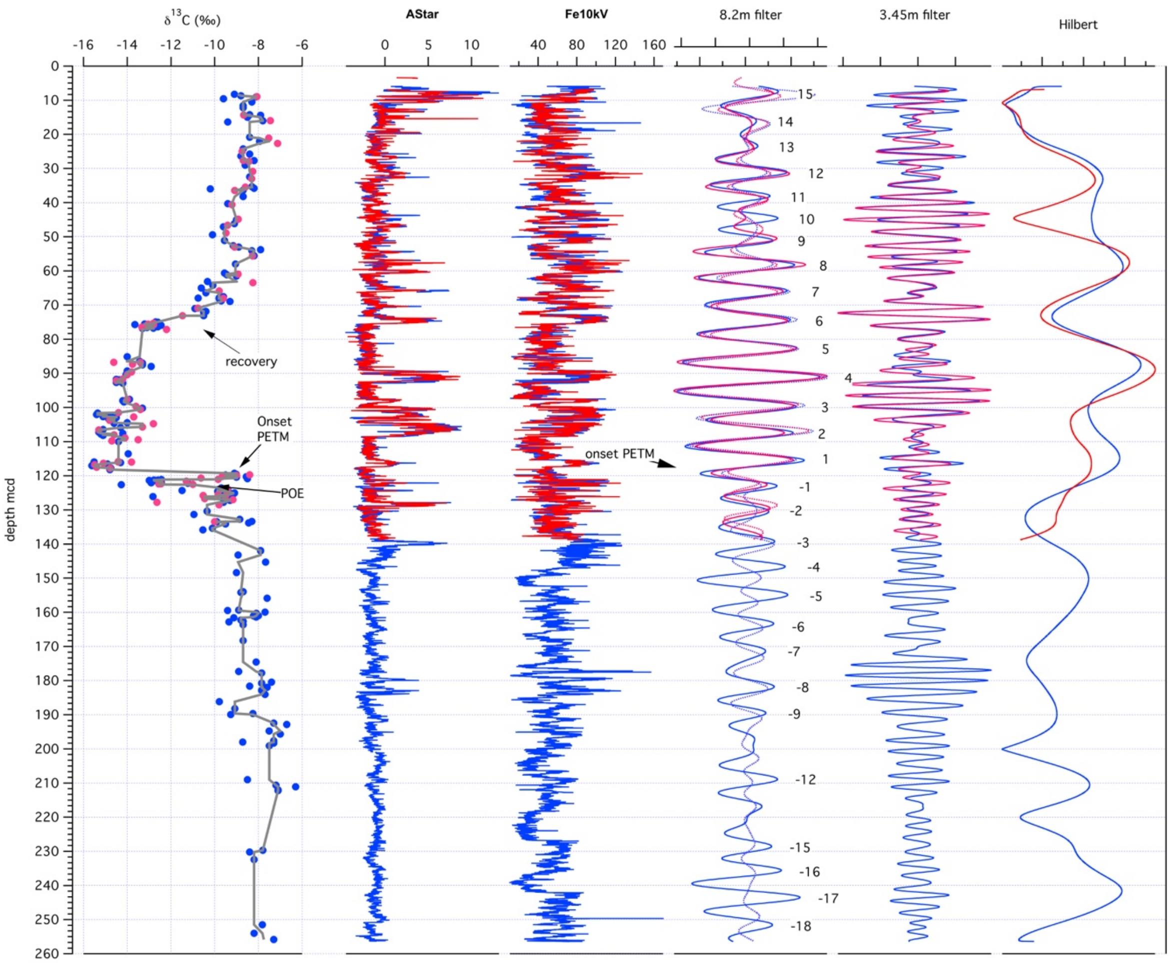

Figure 1 – Modified Figure 5 for the main manuscript: Cyclostratigraphy for Polecat Bench. From left to right: PCB-A(red) and PCB-B (blue) soil nodule carbon isotope data (Bowen et al. 2015), a* data from color scanning, XRF Fe intensity data (in total counts area *1000). Then Gaussian filter of the longer 8.2 m cycle (precession) of the Fe data (lines) and from a* data (dashed lines). Numbers mark the precession cycle counting 5 starting at the PETM, positive numbers is time after PETM, negative numbers before. On the right, Gaussian filter of the 3.5 m cycle (half-precession) and the amplitude modulation of the Fe data extracted by Hilbert transform using the Astrochron software package.

4) Half-precession

Precession vs half-precession ratio is not consistent with the selected bandwidths used for filtering (see for e.g., Fig. 5). Visual inspection in figure 5 indicates that several precession cycles do not match two 'half-precession' cycles, making the hypothesis of 'half-precession' implausible. Also, if the precession central wavelength is 8.2 m, then 'half-precession' central wavelength should be around 4 m (not 3.45 m).

Can the authors resolve this mismatch, by changing the bandwidth for example, or abandon the hypothesis of 'half-precession'.

In addition, the authors stated (Page 5, Lines 28-29) "The two longer cycles around 8 and 3.5 m have been interpreted as precession and half precession cycles also present in Plio-Pleistocene successions (see Abdul-Aziz et al., 2008)."
Abdul-Aziz et al. (2008) did not interpret the 3.5 m cycles as half-precession. Instead, they interpreted them as sub-Milankovitch (or millennial). They even stated in their paper « However, the exact origin of sub-Milankovitch cycles remains enigmatic. ». Sub-Milankovitch (or millennial-scale) cycles do not imply half-precession cycles...

This was mentioned by referee #1 as well. We will correct this in a resubmitted version of the manuscript. However, it is not important for the cyclostratigraphy which is based on the recognition of the precession cycle only.

5) Significance of changes in sediment a* color reflectance and Fe content in terrestrial records

Although the authors evoked very promptly the potential significance of XRF iron intensity in terrestrial sediments by referring to previous studies (Abels et al., 2012), [and this topic is beyond the scope of the present study], I suggest that the authors develope a little bit the significance of such proxies in terms of climate change (astronomically forced climate). Orbitally driven fluctuations in Fe content in deep-sea sedimentary records have generally (and extensively) been attributed to the relative contribution from carbonate deposition versus detrital-clay inputs. However, the origin of cyclic change in Fe content in terrestrial environments is not well addressed in the litterature...

It is not the scope of the manuscript to discuss and explore the nature of Fe variations and its direct links to climate change. This requires detailed geochemical analysis, as already done in Kraus et al. 2015 (Palaeogeography, Palaeoclimatology, Palaeoecology 435 (2015) 177–192; http://dx.doi.org/10.1016/j.palaeo.2015.06.021) at Polecat Bench, on thre PCB drill cores. Our focus is on using the apparent cyclicity for age model construction.

The XRF core scanning method applied provides semi-quantitative information of bulk iron concentrations. It does not allow to distinguish oxidation states of Iron necessary to address imprints of climate change on the sediment Fe composition as done in Kraus et al. 2015. Looking at Fe only it is not possible to speculate about humidity, this can be done by combining elemental information into ,e.g., the chemical index of alteration (CIA) done for Polecat Bench by Kraus and Riggins (2007). We are currently working on exactly this topic towards an additional manuscript dealing with XRF core scanning data from the BBCP drill cores. We would like not to include the discussion of the potential significance of XRF iron intensity in the BBCP records because this will be focus of a subsequent manuscript following the our here presented age model study.

Minor points

We will correct the revised manuscript as pointed out by the referees recommended edits.