Climate of the Past Discussions

Reply to Interactive comment of J. Backman (Referee) on "Orbitally tuned time scale and astronomical forcing in the middle Eocene to early Oligocene" by T. Westerhold, U. Röhl, H. Pälike, R. Wilkens, P. A. Wilson, and G. Acton.

We are delighted to read that referee J. Backman recommends the chronology to be published after minor polishing and after addressing a few issues.

Please find below our detailed description of the corrections and reply to Referee J. Backman. The original comments are italicized and our responses are in normal font red colored.

This manuscript represents an important contribution to late Paleogene stratigraphy and chronology and should be published after some minor polishing and after addressing a few issues described below.
46 relatively ice-free warm world of the early Eocene: is there any firm proof of early Eocene continental ice? Delete "relatively". - deleted
49 Oberhänsli (you don't use Paelike) - corrected
52 delete extremely - deleted
55 of, not in the - corrected
62-63 clumsy and incorrect. Site 1218 represents one record, not several. – The age model for the Eocene of Site 1218 is based on the correlation to Site 1219 and subsequent transfer of the magnetostratigraphic interpretation from 1219 to 1218. Further, both sites 1218 and 1219 were used to check and consolidate the spliced records (Pälike et al. 2005) that then provided the physical property data used (amongst other data) for the tuning of the Oligocene. Hence, prior to Exp 320/321 there were at least two records key for recent breakthroughs in reconstructing the late Eocene and Oligocene epochs.
68 delete e.g. - deleted
69 low, not lower - corrected
70 sparser biostratigraphic control in the carbonate-poor interval. - corrected
77-78 ... of carbonate in middle to late Eocene ....allows tests and ... - corrected
79 delete e.g. - deleted
83 delete and - deleted
84 chrons, not Chrons - corrected
85 this study, not our - corrected
87 rewrite and delete we generated - corrected
91+93+98+102+ EVERYWHERE: delete "we" and rewrite - corrected
102 what a clumsy way to say it. rmcd is the same as CCCSF-A. Most readers will be confused by "revised CCSF-A". Why don't you just say that you have replaced the shipboard CCCSF-A with "rmcd", in order to avoid the long and awkward "rmcd (revised CCSF-A)"? – rewritten; NOTE: We refrain from correcting "rmcd (revised CCSF-A)" to "rmcd". This will be even more confusing because the depth nomenclature follows the Westerhold et al. 2012a (Expedition Proceedings Volume 320/321) publication, which assembles the splice records. We think it is not a good idea to change this again, but better to keep this distinction.
139 ...1369 freeze-dried powered bulk... – corrected to "freeze-dried powdered bulk";
202 spell out EOT; unclear if the E/O boundary, defined by the top of Hantkenina, has been observed where you place the EOT (cycles 84-85, see line 281). A comment about this

would be useful. – corrected. We added a comment about the E/O boundary position and definition in the discussion chapter 6.1
230-231 al., not al, – corrected.
265 S4, not S3, – corrected.
Figure 4 caption, explain blue line – corrected to "Blue line marks the Eocene/Oligocene boundary (defined as 14% down in C13r - C13r.14)."
288 Interesting to notice that lower bulk 13C corresponds to enhanced Si accumulation/preservation, which to some readers would seem counter-intuitive as lower bulk 13C may suggest lower photic zone productivity. Does lower bulk 13C implies increased carbonate dissolution at depth (causing the Si maxima)? A comment about this would be useful. – The data in this interval show that lower bulk 13C corresponds to higher Si content. Accumulation and/or preservation of Si are not part of this manuscript and thus never mentioned in the text. Investigating if variations in accumulation / preservation of Si or carbonate dissolution caused the Si to bulk $\delta^{13}C$ phase relation is a laborious task and not the objective of our manuscript. We simply utilize the relationship for cyclostratigraphic purposes. Regarding the question: *Does lower bulk 13C implies increased carbonate dissolution at depth (causing the Si maxima)?* If dissolution of carbonate preferentially removes 13C the lower bulk $\delta^{13}C$ values indicate dissolution of carbonate enhancing the Si content. But, unfortunately the picture is much more complicated than this, especially when you look at the 100 and 405 kyr level (see supplementary Figure S11). In the EOT interval on 405 kyr level lower $\delta^{13}C$ values correspond to Si maxima and Ca minima. On the 100 kyr level lower $\delta^{13}C$ values correspond to minima in Si and maxima in Ca. For constructing the cyclostratigraphic framework it is fine to know the phase relationship between $\delta^{13}C$ and Si on the 405 kyr level. The phasing on the 100 kyr level could indicate that higher photic zone productivity might have caused higher Si accumulation. This observation could be an indication different processes operating on 100 and 405 kyr (Productivity/Dissolution) time scales. As mentioned above, this is not the objectives of the manuscript and very speculative.
297 you must mean 88-89, not 85 – corrected.
305 lower bulk 13C corresponds to decreased Si and increased Ca; please address again the productivity/dissolution issue. – as discussed above we refrain from adding a comment on productivity/dissolution because it is speculative, not of major importance for the cyclostratigraphy itself and subject of a subsequent manuscript on accumulation rates.
308 delete m revised CCSF-A – we like to keep this because of consistency in the manuscript and the revised composite records for the PEAT data as in Westerhold et al. 2012.
314 C16n, not C16 – corrected.
317 prominent 2.4 myr long eccentricity cycles (avoid the lazy "very") – corrected.
321 in the 2.4 myr-long – corrected.
366 delete very – deleted.
377 Lourens reference is incorrect, also in the reference list – corrected.
380 in the 2.4 myr-long (avoid the lazy "very") – corrected.
383 spell out ETP; rewrite so as to get rid of "we" – corrected.
386 delete very in both places – deleted.
387-88-90 get rid of we – corrected.
402 Here, the focus... – corrected.
409 This new – corrected.
410-11 Based on the ... confident that the data set (all the personal boasting in this manuscript strongly uglifies the text) – corrected.

413 get rid of us and We (GO THROUGH THE ENTIRE TEXT AND GET RID OF ALL THE US-WE-OUR CRAP) – corrected.
418-22 Important sentence. Would be useful if you explained your 20 kyrs younger age relative to Brown's astronomical tuning from Massignano. Again, it would also be useful, and much appreciated by many, if you could address the Hantkenina issue: "The GSSP is at the base of a grenish grey marl bed 0.5 m thick. At this level, both the planktonic foraminifera Hantkenina and Cribrohantkenina, Eocene genera of the Hantkeninidae, become extinct." Episodes September 1993
So, does the Hantkenina extinction fall precisely at the layer which you have dated to 33.89 Ma in any of the PEAT sites? If so, great, everyone will be happy. And you should add a statement to that effect. If not, you should address/discuss the difference/problem between Massignano and the PEAT sites.
Furthermore, Pearson et al. (Geology 2008) placed the Hantkenina extinction on the 18O plateau from Tanzania (and Site 522), just after 18O step 1. Same 18O position of the E/O boundary in the PEAT sites? - We re-wrote the text here as follows: "The GSSP for the Eocene/Oligocene (E/O) boundary in Massignano is defined at the layer holding the extinction of the Hantkeninidae (Premoli Silva and Jenkins, 1993). This group of planktonic foraminifers is not preserved in the investigated equatorial Pacific sites. Because it is currently unknown whether or not the top of the Hantkeninidae is synchronous between the Massignano section and the equatorial Pacific sites we assume that the E/O boundary occurs 14% down in Chron C13r (as given in Luterbacher et al., 2004). This results in an astronomically tuned absolute age for the E/O boundary of 33.89 Ma, which is ~100 kyr older than the age in Pälike et al. (2006). Pearson et al. (2008) placed the Hantkenina extinction on the δ18O plateau from Tanzania just after δ18O step 1. Based on the correlation between the Tanzania record and ODP Site 1218 (Pearson et al., 2008) we arrive at the same age of 33.89 Ma for the E/O boundary in the PEAT sites. This validates the astronomical tuned age from the Massignano (Italy) global stratotype section and point (GSSP) (Brown et al., 2009)."
472 delete see – deleted.
475-76 delete the crap in front of the reference – deleted.
490 explain 33 in C21n.33, perhaps in a footnote – corrected.
516 with the 2.4 myr-long – corrected.
527 the 2.4 myr-long – corrected.
532 Pearson – corrected.
535 ice buildup at the poles; Arctic ice known is sea-ice. Perhaps: ephemeral ice buildup on Antarctica causing a sea level fall (ref) and cooling and seasonal sea-ice formation in the Arctic. – corrected.
540 A new stratigraphic framework has been assembled based on... – corrected.
551 in the equatorial Pacific. delete second half of sentence. – deleted.
558 middle, not mid – corrected.
559 the 2.4 myr-long eccentricity – corrected.