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We have made the minor revisions requested by the anonymous reviewer and have included a response to the reviewers' comments here and highlighted in the tracked change documents that follow where the manuscript and supplement was revised.

Note the datasets are provided only for invited reviewers through the password protected site (we do not want to have the full dataset available for the public until the manuscript is published): Editor/Reviewer only password for Dataset: GriFFWestH198

Best regards,

Dr. Elizabeth M. Griffith

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23 October 2022

Editor decision: Publish subject to minor revisions (review by editor)
by Zhengtang Guo

Dear Drs. Ji-Eun Kim and Thomas Westerhold,

Thank you for submitting the revised version of your work. The reviewers have read it again. They are in overall satisfactory with the revisions you made. Reviewer#2 request adding some further explanations about the roles of the other orbital parameters in modulating the late Cretaceous climate. It would be finer if you can consider this suggestion in an appropriate way. Once you consider this minor point in a further revised version, I'll be happy to accept you work for publication in CP.

Thank you in advance.

With the best wishes

Sincerely,

Zhengtang GUO

Referee comment: The authors thoroughly considered nearly all the comments and suggestions of mine and the other reviewer's and made revisions accordingly. My major comment on the revised manuscript focuses on the discussion on the orbital cycle. As clearly presented in this study, the 405-kyr cycles in all the late Cretaceous proxy records from the tropical Pacific Ocean leave great impression on me. In the revision, however, the authors insisted on taking the precession as the dominant orbital forcing on the XRF-Ba changes (they use it as proxy of export productivity) during the late Cretaceous in the tropical Pacific Ocean, obviously ignoring the eccentricity's role (particularly the 405-kyr long eccentricity cycle) in modulating the hydrological cycle and productivity related carbon cycles. As clearly seen in all the spectral analyses in depth domain (no tuning effects; figure2, figure S11, S12), both the bulk isotopes and XRF-Ba records display significant 5 m cycles that correspond the 405 kyr long eccentricity cycle according to their age model. All the wavelet analyses of the three proxy records show the same spectral features with the 405 kyr as the strongest and the most continuous cycle. Even though this paper focuses on the XRF-Ba derived productivity record, as they stressed in the rebuttal letter, the most abundant and significant spectral peaks that range from 0.025 to 0.06 (cycles/kyr) include the cycles of both the precession and non-precession bands (figure S12; Please check the MTM spectral analyses in b. Is the unit cycles/meter of the X-axis in b as the same as in a?). Thus, what do these non-precession cycles represent? These non-precession cycles are as significant as the 19-23 kyr precession cycles. We have no doubt that the precession plays an important role in modulating the XRF-Ba derived productivity changes. However, the spectral and wavelet analyses also tell us that the other orbital cycles including those near the precession band and the 405-kyr long eccentricity cycle also play significant roles. This is the reason why I commented on the original draft that why do you only concentrate on the precession band? The CENOGRID climate records from the tropical oceans (Westerhold et al., 2020, Science), a great work led by one of the corresponding authors of this manuscript, display dominant 405-kyr cycles in the hydrological and carbon cycles throughout the whole Cenozoic, which is also one of the focuses of this famous paper. Was the 405 kyr cycle not as important as the precession in the late Cretaceous? At least, you should point out its role and clarify its relationship with the precession in the late Cretaceous tropical Pacific Ocean rather than ignore it and made no change in the revision.

The x-axis in figure S12b (MTM spectral analysis) was labeled with the unit cycles/meter but should have been cycles/kyr. This is a typo and we are grateful that the reviewer pointed out this mistake. It has been corrected in the revised supplement.

Section 4.2 "Orbital cyclicity in the tropical Pacific biological pump" describes the relative importance of the various cycles seen in our records of bulk carbon and oxygen isotopic composition and XRF Ba record. As we mentioned in our response previously to the reviewer, "…there is a strong 405-kyr component in both carbon and oxygen bulk isotope data. We are cautious to interpret the oxygen bulk stable isotope data because it will be a mix of calcareous nannofossils from the surface ocean, planktonic foraminifera from the upper ocean layers and, to a lesser extent, the deep sea benthic foraminifera. It is not focus of this manuscript." The CENOGRID record was constructed from deep sea benthic foraminifera – and the 2020 paper was focused on interpreting these global changes. The focus of this manuscript is on the export production record (XRF-Ba) in the tropical Pacific Ocean. We do include initial observations on the bulk record in this section (1st paragraph) "…Because the bulk carbonate $\delta^{13}C$ values closely resemble the lower resolution surface planktic foraminiferal $\delta^{13}C$ record of *Rugoglobigerina rugosa* (Fig. S3) from the same sites reported by Jung et al. (2013), it is possible that it reflects surface conditions potentially related to local surface productivity. However additional high resolution work is needed to confirm this initial observation." In the Section 1. Introduction (2nd paragraph) we state that "…Proxy records that provide evidence of carbon cycle dynamics, such as marine carbon isotope records ($\delta^{13}C$), show dominant variability in the eccentricity (rather than precession) band. This effect could be due to the long residence time of carbon in Earth's exogenic system, which filters out higher resolution fluctuations (e.g., Pälike et al., 2006) or is related to orbitally paced phytoplankton evolution (Beaufort et al., 2022)."

Based on the spectral analysis shown in Figure S12, the XRF Ba record is clearly dominated by short cycles in the order of 20-30 cm (highest peak in the MTM) and a really minor component of a 5 m cycle, which is equivalent to the long eccentricity cycles if the short cycles are precession (~20 precession cycles in one 405-kyr cycle; ~20 25 cm cycles in a 5 m cycle). The one dominating rhythm for the carbon export record is related to precession with very little expression of modulations by eccentricity. This is in spite of the fact that the age model is based on the 405-kyr dominant cycle in bulk carbon isotopes (~ 5 m cycle). So, yes, the 405 kyr cycle is not as important as precession for carbon export in the tropical Pacific in the late Cretaceous. This is the focus of the manuscript, including the title.

The reviewer points to other cycles that might be of significance writing: "Even though this paper focuses on the XRF-Ba derived productivity record, as they stressed in the rebuttal letter, the most abundant and significant spectral peaks that range from 0.025 to 0.06 (cycles/kyr) include the cycles of both the precession and non-precession bands … Thus, what do these non-precession cycles represent? These non-precession cycles are as significant as the 19-23 kyr precession cycles."

The band 0.025 to 0.06 (cycles/kyr) is the range from 40 to 16.7 kyr thus spanning the range from obliquity to precession. The age model is based on a very simple and minimalistic 405-kyr cycle level preventing the introduction of obliquity and precession components into the spectral analysis allowing a clear view to the cycle distribution of the XRF Barium record. The MTM spectral power analysis (Figure S12a) in the depth domain shows a broader high significance interval of cycles ranging from 50 cm to a little less than 20 cm per cycle. The 405-kyr age model allows to identify those cycles as mainly in the precession frequency band. There is no single sharply defined dominant peak for precession because precession has several components (mainly 19 and 23 kyr, and some others) AND the record is affected by changes in sedimentation rate and drilling disturbance. Thus there will be no clear spectrum. The MTM spectrum is a statistical tool to verify what can be seen by the human eye in the record and it should not be overinterpreted in terms of the significance levels. The algorithms behind it are definitely not made for geological data and thus a robust significance level is problematic.

Therefore, we think that the cycles seen in the power spectra are related to orbital cycles, mainly precession, and are not non-precession related cycles as suggested by the reviewer. We thus refrain from changing the basic assumption as this is backed up by the very good correlation to the Zumaia record.

The reviewer reiterates: "We have no doubt that the precession plays an important role in modulating the XRF-Ba derived productivity changes. However, the spectral and wavelet analyses also tell us that the other orbital cycles including those near the precession band and the 405-kyr long eccentricity cycle also play significant roles. This is the reason why I commented on the original draft that why do you only concentrate on the precession band?"

We think that based on the MTM analysis of the XRF Ba data precession is the major component in the cyclicity as explained above. Eccentricity does play a modulating role but is of much less significance and presence in the data. We do not share the opinion of the reviewer here and are not convinced that precession and eccentricity play an equal role in the XRF Ba data. As provided in the first reply to the reviewer we think that for the productivity changes recorded in the Ba record, not the other records, the data speak for themselves showing clearly a clear imprint of precession cycles that is focus of the manuscript, not the minor component of eccentricity.

In addition, the reviewer suggests: "The CENOGRID climate records from the tropical oceans (Westerhold et al., 2020, Science), a great work led by one of the corresponding authors of this manuscript, display dominant 405-kyr cycles in the hydrological and carbon cycles throughout the whole Cenozoic, which is also one of the focuses of this famous paper. Was the 405 kyr cycle not as important as the precession in the late Cretaceous? At least, you should point out its role and clarify its relationship with the precession in the late Cretaceous tropical Pacific Ocean rather than ignore it and made no change in the revision."

We did not ignore the 405 kyr cycle in our data. We used the imprint in the bulk carbon isotope data to develop a simple 405-kyr eccentricity age model. The strong 405-kyr component in bulk d13C data in the Cretaceous is well known. Prominent examples of eccentricity modulated precession cycles in geochemical data is the late Paleocene and early Eocene (see Lourens et al. 2005; Westerhold et al. 2007 and 2008) are published from Walvis Ridge in the South Atlantic. Compared to those records the Maastrichtian Shatsky Rise XRF records show a minor eccentricity component. Because of the modulation of the precession by eccentricity some related variation in amplitude of the data can be expected and is seen, but not to an extent that would lead to the interpretation of major importance on the XRF data. In the manuscript we focus on the cyclicity of XRF Ba data as a proxy for carbon export which we show are very likely related to changes in surface ocean productivity. And because these data are dominated by precession our manuscript focuses on the precessional pacing of tropical ocean carbon export. We think this is justified by the outstanding quality of the data. As the manuscript is aiming to explain the dominant precession component and not in addition the globally seen dominant 405-kyr eccentricity, we would refrain from discussing more in the current manuscript this aspect as asked by the reviewer as it will imply a major expansion of the existing manuscript and distract from the focus of this manuscript. As a side note, the benthic foram data for example only cover the potential precession cycles seen in the XRF Ba and do not extend to reconstruct changes in 405-kyr eccentricity. We are trying to understand these dominant cycles of precession in the XRF Ba record.

We highlight the novel aspect of the focus of this manuscript on the cycles of carbon export in the tropical Pacific during the Maastrichtian using the new composite XRF record at Shatsky Rise - without expanding here in this manuscript (beyond what we have written) on the global 405-kyr eccentricity cycle (which is not dominant in this carbon export record from the tropics). We are excited about the opportunity to share these results with others in this manuscript which we hope is publishable in *Climate of the Past.*

Referee comment – signed by Mingsong Li: I have no further comment. This manuscript can be published as is.

We thank the reviewer (Mingsong Li) for their review and support for publication.