

Interactive comment on “Late Miocene to Recent High Resolution Eastern Equatorial Pacific Carbonate Records: Stratigraphy linked by dissolution and paleoproductivity” by Mitchell Lyle et al.

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General Comments

I enjoyed reading and reviewing the Lyle et al. manuscript (MS No.: cp-2018-157). For most of the part, it is a well written and structured manuscript, which presents high resolution sediment properties and compositional records from multiple locations of the eastern equatorial Pacific Ocean. The Results and their interpretation represent a fundamental contribution to the effort of understanding how this region and, more in

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general low latitude ocean areas, works as the ocean/climate system evolved to modern conditions. The Discussion mainly focuses on five Plio-Pleistocene intervals of low carbonate content. The causes of low carbonate content in the EEP, dilution by biosilica particles versus dissolution of carbonate particles, are here examined using carbonate content, MAR of different sediment components, sedimentation rates, CaCO₃:BaSO₄ ratios and benthic foraminifera stable isotopes records from multiple locations of the EEP.

The main issues I found in the manuscript mostly concern parts of the Methods and Results and are listed in “Specific comments”. The inaccuracies typical of carbonate content estimations from GRA density have not been discussed. It is not clear how CCD depth was calculated from CaCO₃ MAR and data are missing. In the Results/Discussion it is not always clear how intervals of low carbonate content were interpreted as reflecting dilution by biosilica rather than greater carbonate dissolution or vice versa. The Biogenic bloom interval is improperly defined and its proposed end is imprecise. Given this, my overall evaluation is that this manuscript has the potential to be published in *Climate of the Past*, but I recommend to revise the manuscript according to all the comments presented below before publication.

Specific comments

- Abstract. At the beginning of the Abstract, add a couple of sentences introducing the problem(s) at the base of this study and the reasons for this study. Also, add a reference to the study area. There is no reference of the EEP in the whole Abstract.
- Introduction. As for the Abstract, in the Introduction I couldn't find the unresolved questions that stay at the base of this study. Please add them together with the aims of this study.
- Biogenic bloom. I think it is incorrect to refer to the Biogenic Bloom as “Late Miocene Biogenic Bloom (LMBB)” because this event did not occur only during the Miocene as it ended in the early Pliocene. This is stated in the manuscript several times and is

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reported in the literature. For example, the studies cited on page 7 line 13 (Farrell et al., 1995, Lyle and Baldauf, 2015) refer to the biogenic bloom as “Biogenic Bloom” or as “late Miocene early Pliocene biogenic bloom”. In the paper it is also awkward to read that an early Pliocene interval (e.g. PPLC-5) is part of the LMBB. For example, on page 35 line 4 what is defined as a late Miocene event (LMBB) includes another event from the early Pliocene. It makes little sense to me. I strongly recommend to substitute “late Miocene Biogenic Bloom (LMBB)” with “Biogenic Bloom” or with “late Miocene early Pliocene biogenic bloom” throughout the text, figures, figure captions and tables. Also change all the acronym “LMBB” accordingly, throughout the text, figures, figure captions and tables.

- Data presented. In the text it is not so easy to keep track where the presented data come from (a previous study, this study, etc.) because of the important amount of data. It would make things easier for the reader to add some columns to Table 1 or even adding a new table in which is clearly listed type of data, drill site, data origin and time span of all the data presented in the study.

- CaCO₃ % estimates from GRA density (sections 3.4 and SM 5). There is no mention in the manuscript that carbonate content estimates calculated from GRA measured in EEP sediment have been demonstrated to lead to imprecise carbonate estimations. Reghellin et al. (2013) [Reghellin, D., G. R. Dickens, and J. Backman (2013), The relationship between wet bulk density and carbonate content in sediments from the Eastern Equatorial Pacific, *Marine Geology*, 344, 41-52] have shown that it is not possible to accurately describe the relationship between carbonate content using a single equation, like it was done in this study. The estimation errors are particularly evident at high CaCO₃ content (>60 %; the case of most of the records presented here) because of the wide range of WDB. Fig. SM-4 show that at Site 849 CaCO₃ estimation from GRA, XRF and discrete measurements give similar values but still differences are apparent between GRA and discrete measurements in the figure. On the basis of the results presented by Reghellin et al. (2013), new carbonate content records estimated from

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GRA density cannot be published without fully considering the uncertainties and inaccuracies of the method. In addition, the relationship varies significantly in the EEP from a site to another because of sediment composition differences (carbonate vs biosilica content and, within carbonate components, the type of them) at different locations. In the SM only one power law equation (5) is presented so I have the doubt that it was computed using all discrete CaCO₃ and density data from Sites 848, 849, 850 and 851 together. This can potentially bring to even greater errors in the CaCO₃ estimates than using different power law equations at different sites. If this is the case, I recommend to recalculate CaCO₃ estimates using different power law equations at different sites. Each power law equation should be computed using the data from that particular site only.

- MAR data (section 3.5). I tried to calculate some MAR for a few sediment components using the equation (6), with dry bulk density, sedimentation rates and CaCO₃ % data in the SM tables and the results were different from corresponding MAR data listed in your tables. Please verify if data presented in the tables are correct.

- Biogenic bloom end. On page 7 line 16 is stated “is easily observed by the change in slope of the age-depth curves at about 4400 ka (Fig. 2)”. To me is evident that the most significant and clear change in the age-depth curves of Fig. 2 is a bit to the right of where the grey line is placed, which is at about 4600 ka. This is particularly evident in curves of Site U848, U1338, U851, U850 and U849. I would then strongly recommend to: i. move the end of the biogenic bloom line at 4600 ka in Fig. 2; ii. move green arrow tip to 4600 ka; iii. recalculate average sedimentation rates for the periods 0-4600 ka and 4600-7200 ka in Fig. 2; iv. modify all figures, figure captions and manuscript text according to the above reasoning.

- Sediment focusing (page 10 line 6). “Surprisingly, the sediment. . . .strongly affect the CaCO₃ % profile” isn’t this because of moderate currents strength preferentially removes light-fine sediments as you say on lines 1 and 2? If this is the case it makes sense to me that sedimentation rates increase, CaCO₃ % decreases but leaving the

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CaCO₃ % profiles unaltered. And CaCO₃ MAR would increase because of higher sedimentation rates, even if dry density decreases because of the input of fine sediments. This is not anomalous to me.

- Dilution vs dissolution. In the Results (sections 5.3-5.5) it is often missing a clear explanation of how it was distinguished between carbonate dilution by biosilica and carbonate dissolution. Section 5.3. The first paragraph (page 10 lines 12-19) is difficult to follow and needs rewriting because it is not clear how you interpreted some intervals (i.e. PPLC-5 and PPLC-2) as high production rather than high carbonate dissolution. Is it because carbonate% is low at on equator sites and not as much at off equator sites? or is it because of low carbonate% and relatively high carbonate MAR at on equator sites? The CaCO₃:BaSO₄ used to estimate carbonate dissolution is also very low at PPLC-2 at all sites (Fig. 7). Couldn't it be that high production also generated greater carbonate dissolution? How is it possible to completely exclude carbonate dissolution in this interval? I recommend to clearly state in which way it is possible to distinguish between dilution and dissolution. Section 5.4. Lines 14-15: it is not clear how data at PPLC-4 indicate dissolution rather dilution by biosilica. Provide clear explanation. Section 5.5. Here it is easier to follow your rationale because you introduce the CaCO₃:BaSO₄ proxy. I strongly recommend to add references to this proxy in the interpretation of the other PPLC intervals (so in sections 5.3 and 5.4). It would make your interpretation of low carbonate intervals much stronger and easier to follow by the reader.

- CCD depth estimate from CaCO₃ MAR (section 6.1). It is not clear how MAR CCD were calculated. From reasoning in 6.1 it seems that you have calculated MAR CCD from CaCO₃ MAR using equation (1) in page 13, but in that equation there is no MAR CCD. Clarify this. I could not find the data used to calculate MAR CCD anywhere in the manuscript nor in SM. I strongly suggest to add a table listing all data used to make curves in Fig. 5 panel b. While reading section 6.1 I got the feeling that the estimation of CCD depth from CaCO₃ MAR is a weak approach. This is because you

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state that i) “local sediment anomalies. . . .cause significant noise to this approach”, ii) “weaker signal in the Pliocene and Miocene is harder to distinguish from noise”, iii) the CCD estimate “suffers from the noise resulting from building the trend with records from only 2 sites” and iv) “minor errors in correlation. . . .are magnified in the CCD estimate”. Plus, it is not clear how you calculated CCD depth from CaCO₃ MAR. Also, I see there are significant differences between the CCD depth record (Fig. 5 panel b) and the equatorial Pacific CCD of Pälike et al. (2012). The latter ranges between about 4200 and 4700 mbsl whereas yours mostly between 4300 and 5500 mbsl. How can you explain this difference? It seems to me that all the issues of the method are strongly affecting the CCD estimates. Isn't it enough to speculate on carbonate preservation (dissolution) over time by using the CaCO₃:BaSO₄, CaCO₃ MAR, CaCO₃ % and sedimentation rates? In my opinion the message emerging from this part of the Discussion would be much stronger without the CCD depth estimate.

- Page 17 lines 22-24. Add that evidence of early Pliocene higher SST and lower biogenic production compared to during the biogenic bloom comes also from bulk sediment stable isotopes and sedimentation rates records from Leg 138 on-equator sites and from Site 573 and U1338 (see Shackleton and Hall., 1995 and Reghellin et al., 2015) [Reghellin, D., H. K. Coxall, G. R. Dickens, and J. Backman (2015), Carbon and oxygen isotopes of bulk carbonate in sediment deposited beneath the eastern equatorial Pacific over the last 8 million years, *Paleoceanography*, 30, doi:10.1002/2015PA002825].

- Page 18 lines 5-6. Add explanation of how the “expansion of an Antarctic source. . . .and Pacific” can cause opposite changes in the d¹³C records from the Atlantic and the Pacific

Technical corrections

Page 1 Line 12: define “XRF” Line 13: define “IODP” and “ODP” Line 23: define “DIC”

Page 2 Line 2: add “Reghellin et al., 2013” to references. Line 25: define “DIC” Line

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27: add references Line 28: define “NADW” Line 34: substitute square brackets with round brackets.

Page 3 Lines 4-7: move this sentence to Results or Discussion Lines 13-15: add references Line 26: define “XRF” Line 31: define “IODP”

Line 32: define “ODP” and “GRA”

Page 4 Line 2: change “3°S” to “3.0°S” Line 11: define “ccsf”. Also, “ccsf” is in the text sometimes written as lowercase and sometimes as uppercase. Modify to be consistent

Page 5 Line 11: add explanation of the criteria used to choose the base or master drill site

Page 6 Line 5: define “ICP-MS” Line 14: add “Reghellin et al., 2013” to references

Page 7 Lines 16-17: substitute “4400 ka” with “4600 ka” Line 20: define “DSDP”

Page 8 Line 3: late Miocene carbonate crash here defined from 11 to 8 Ma and on page 7 line 11 from 10 to 8 Ma. Change time periods to be consistent Line 5: in References list there are two Pälike et al., 2010b. To which one do you refer? References list

Page 9 Lines 3-8: the same concept is repeated in these two sentences. Keep one and delete the other. I would also add low carbonate production as a cause for low CaCO₃ intervals.

Page 10 Line 26: add “(Figure 3)” after “at Site U1338”

Page 11 Line 1: define “MIS” Line 14: substitute “lowest record” with “panel b” Lines 15-19: these are speculations. Move to Discussion Line 22: substitute “bottom” with “panel b”

Page 12 Lines 27-30: add references

Page 13 Line 25: is (1) a novel equation? If so state it otherwise provide reference

Page 15 Line 5: how about PPLC-2? I see that also during this time period the

CaCO₃:BaSO₄ is very low at XRF sites Line 32: specify the type of smoothing

Page 16 Line 10: define “AABW”

Page 17 Line 5: substitute “implies” with “would imply” Line 11: define “NCW” Line 15: define “SST”

Page 18 Line 31: add “early Pliocene” after “late Miocene” Line 32: add “Reghellin et al., 2015”

Page 19 Line 34: define “CAS”

Page 27 There are two Pälike et al., 2010b. Fix

Page 31 Table 1: change “length (ka) of dated record” to “length of dated record (ka)”. Can you specify what is meant with “Data available”? See comment in “Specific comments”

Page 32 Specify origin of background map. In the map are present many light grey dots which (drill sites locations?) that are not labelled. Add a label or remove the dots

Page 33 See comment “Biogenic bloom end” in Specific comments section Figure 3: subscript 3 in “CaCO₃” in panel a scales Substitute “4400 ka” with “4600 ka” in figure and figure caption In figure caption, define what is the grey vertical line

Page 35 What are darker curves on panel a? is it a kind of smoothing of actual data record? Clarify in figure caption Line 4: see “biogenic bloom” comment in “Specific comments”

Page 36 Can you reverse y axis scale on panel b? With shallower depths at the top it is difficult to follow lines 5-6: see “CCD depth estimate from CaCO₃ MAR” comment in “Specific comments” line 6: specify which curve is the 50 kyr smoothing (blue line?) and which one is the 750 kyr smoothing (bold blue line?)

Page 37 Please add a sentence in figure caption about alignment of d18O glacial

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intervals and high opal MAR

Page 39 Specify in figure caption what the dark red line on the stack isotope curve is

Page 40 Specify in figure caption what are dark color lines

SM Page 1 Lines 26-27: given what is written here I do not understand why in the captions of Tables SM-1 to SM-4 (ODP sites) you refer to CSF and CCSF depths and in captions of Tables SM-5 to SM-7 (IODP sites) you refer to mbsf and rmcd depths. Please correct depth scales in all supplemental tables or clarify

SM Page 2 Line 16: define "IMPH"

SM page 5 Line 24: substitute "since they have partially..." with "because they have partially..." Line 25: define "APC" Line 26: define "XCB"

SM page 6 Lines 30-31: describe method used to obtain GRA estimates

SM page 7 Lines 8-9: can you state where the "discrete CaCO₃ data" come from? and can you clarify with which data the power law estimate (5) was computed? Line 23: specify the unit of "Xe" Line 24: change "grams" to "g/cm³"

SM page 8 Lines 19-20: Can you provide a possible cause of this sediment accumulation/erosion feature at Site U1337? Lines 22-23: "Site U1337... . . .significantly elevated relative to the CaCO₃ MAR" add reference to Fig. 5

SM page 12 On panel d there are two marks for Site 572 location. Fix

SM page 14 Change "Figure SM-1" to "Figure SM-3"

SM page 15 Change "Figure SM-2" to "Figure SM-4"

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