Clim. Past Discuss.,
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Climate of the Past Discussions

Interactive comment on "The 405 kyr and 2.4 Myr eccentricity components in Cenozoic carbon isotope records" *by* Ilja J. Kocken et al.

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We thank reviewer 2 for his/her constructive and elaborate feedback on the manuscript.

Reply to major comments

1) Our study explores the behaviour of the well-documented LOSCAR model (e.g. Zeebe 2012 GMD) under orbital forcing. This carbon cycle model is rather simple and generates multiple output variables. In our initial paper we showed all the tracers relevant for this study. In the revised version we will add all model output in the digital supplement for completeness: it will allow the reader to evaluate alternatives. Detailing the behaviour of all tracers in the main text would not only dilute the main message, but it would also largely repeat what has been published before.

The model calculates temperature (TCB in the supplementary plot, we shall update the legend) from atmospheric CO_2 from an input temperature sensitivity parameter of 5 °C, resulting in changes of about 3 °C (as estimated by the reviewer). Thus, if we simply translate these into δ^{18}O, this would result in 2.4 Myr cyclicity with a too-high amplitude (~0.75 ‰ when compared to our data-composite.

However, it is important to note that the LOSCAR model is a carbon cycle model and not a climate model. Thus, its simple climate sensitivity equation relates CO_2 and temperature to each other directly, whereas in reality temperature is a function of a number of variables, including but not limited to pCO_2. For instance, insolation directly affects the climate system components (e.g. atmosphere, etc.), which in turn affect temperature. These insolation-driven changes to the climate system are not part of the temperature-response to CO_2, however. This behaviour cannot be captured by the carbon cycle model. The above justifies our initial focus on δ^{13}C in the data–model comparison, rather than δ^{18}O. Therefore it is not surprising that temperature, δ^{18}O, and pCO_2 records show different power spectra, whereas our carbon cycle model output does not. Thus the lack of a strong 2.4 Myr cycle in δ^{18}O (and temperature) records does not necessarily suggest that the 2.4 Myr cycle can not be dominant in pCO_2.

Furthermore, the pCO_2 records that the referee refers to (e.g. Bartoli et al. 2012, Seki et al. 2010) have neither the length nor the resolution to pin down a possible 2.4 Myr cycle. New, long pCO_2 proxy records are required to establish a possible 2.4 Myr cyclicity.

However, because qualitative comparison of model output to δ^{18}O records would be useful to the reader, we shall add the analysis to the model–data comparison in the results and discussion, and further elaborate on the fact that indeed, the model shows strong 2.4 Myr cyclicity, whereas the record shows very weak cyclicity (possibly overshadowed) as well as amplitude modulation (AM). The above possible explanation for this discrepancy will be introduced in the discussion.

2) Comparing the CCD model output changes to those reconstructed by Pälike et al. (2012) would be a great addition to the manuscript. In terms of absolute values this exercise would not be very informative, however, since it is dependent on multiple input parameters of the model. The main aim of this study is not necessarily to get the best agreement between model predictions and data based reconstructions, but rather to study the possible underlying mechanisms.

As to whether strong 2.4 Myr cyclic fluctuations in the CCD are realistic, this is rather hard to estimate from the data. Based on this suggestion by the reviewer we have revisited several $CaCO_3$ datasets, including those published by Pälike et al. (2012). We have attempted to perform spectral analysis on the CCD reconstructions from Pälike et al. (2012), but the highest resolution record (Site U1334) has a sampling resolution of ~85 kyr, meaning that it would barely be able to resolve 425 kyr cyclicity without the risk of aliasing. We find no significant longer periods in their data.

3) We shall add the δ^{18}O of the composite record to the analysis in the supplement, to facilitate model–data comparison. Additionally, we shall comment on the likeliness of the δ^{18}O record being reflective of CO_2 dynamics in the discussion. We thank the referee for bringing the very relevant Paillard (2017) paper to our attention. It is a beautiful extra motivation for our study and we will acknowledge and address it as such revised manuscript.

4) Spectral analysis indeed forms the backbone of this paper, as it is the primary tool by which we assess the presence and impact of the 2.4 Myr and 405 kyr cycles. We deliberately included detailed spectral analysis based on multiple techniques, to inform the reader about, a.o. the spectra of different model (and data) variables, amplitude modulation thereof and cross-correlation between variables.

5) In our simulations, we use white noise as input, which results in red-noise in model output. The goal of adding relatively a lot of white noise to the astronomical forcing (50/50 noise/signal), is to assess how our simulated signal could be perturbed by un-

known/stochastic processes. We agree that creating a nice spectral fit to the data is of a secondary/non-pertinent nature and not the main focus of our study. We will modify the text to articulate this.

Other comments

6) We thank the referee for clarification. We shall rephrase ‘shifting of spectral power’ to low-pass filtering.

7) We agree, we shall adjust our wording in these lines and include separate model runs for eccentricity and precession to the supplement and include discussion of these in the main text discussion. For completeness, runs with 65°N and 30°N insolation curves as forcing will also be added to the supplement (see attached figures for initial drafts of these figures).

8) We shall revise the legend.

9) We shall revise out-of-phase to in anti-phase.

10) We shall revise the wording to more clearly reflect our approach.

11) Exponent -1 will be added.

12) Figures in the supplement.

Figure 1: These are actually not three colours, but two lines with low opacity. We shall choose different colours to improve readability of the figure.

Figure 2: red = temperature, purple = CO_2. We shall change the legend in B.

Figure 3: The purple curve is the data composite δ^{13}C, while the green curve is δ^{13}C model output for the specified run. The legend will be updated.

Figure 6: We shall re-add the δ^{18}O records to the figure.

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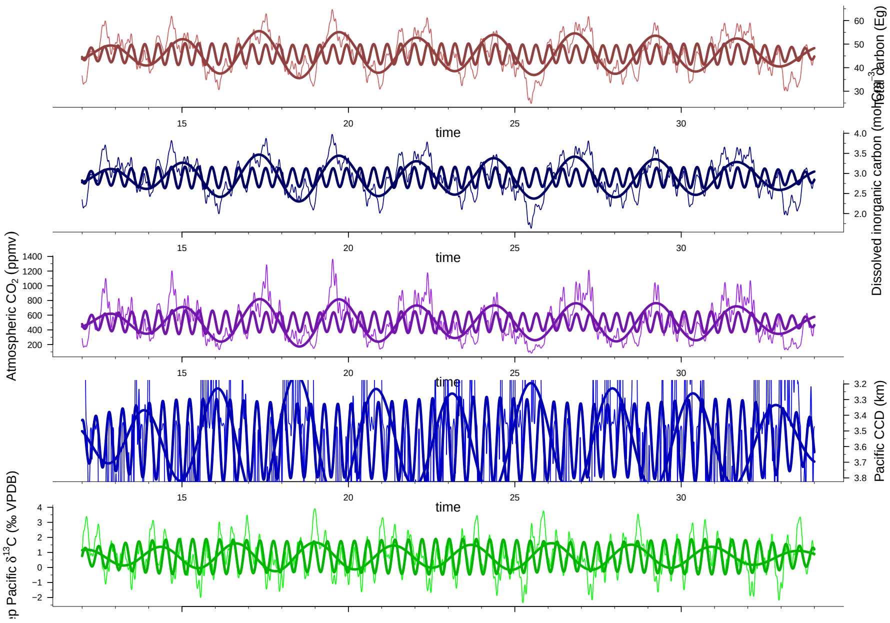

Fig. 1. A time-series with eccentricity as forcing. Thick lines through the tracers represent 405 kyr and 2.4 Myr filters.

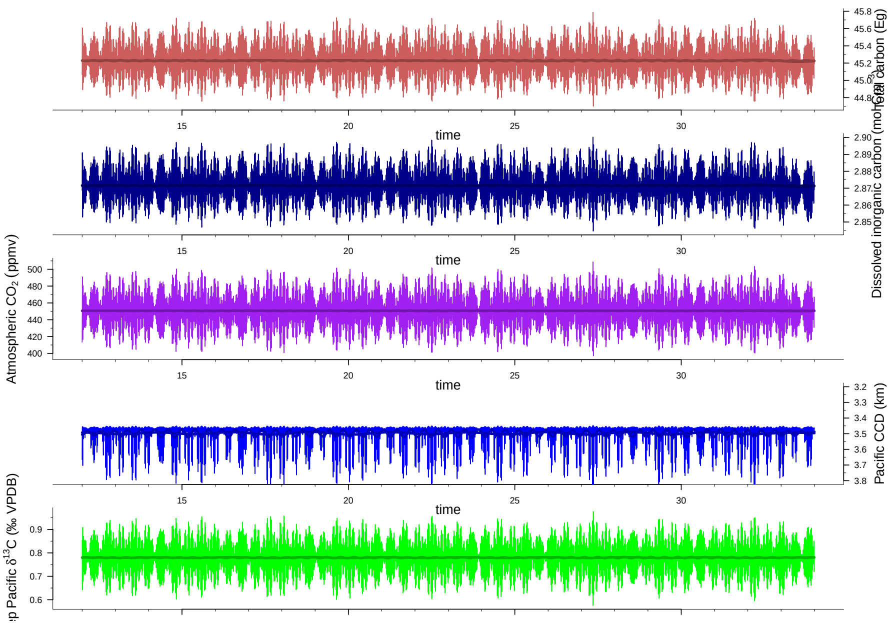

Fig. 2. A time-series with precession as forcing.

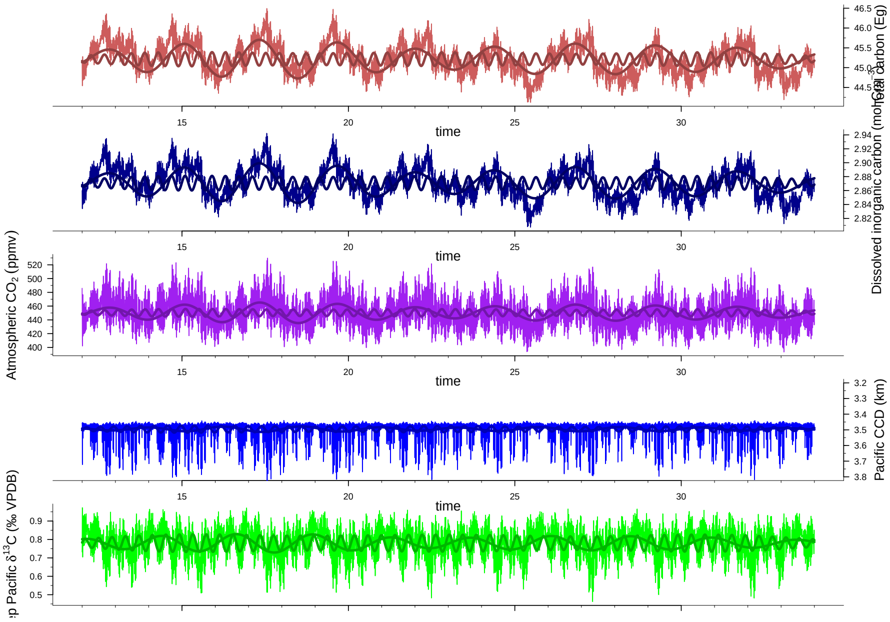

Fig. 3. A time-series with 30°N summer insolation as forcing.

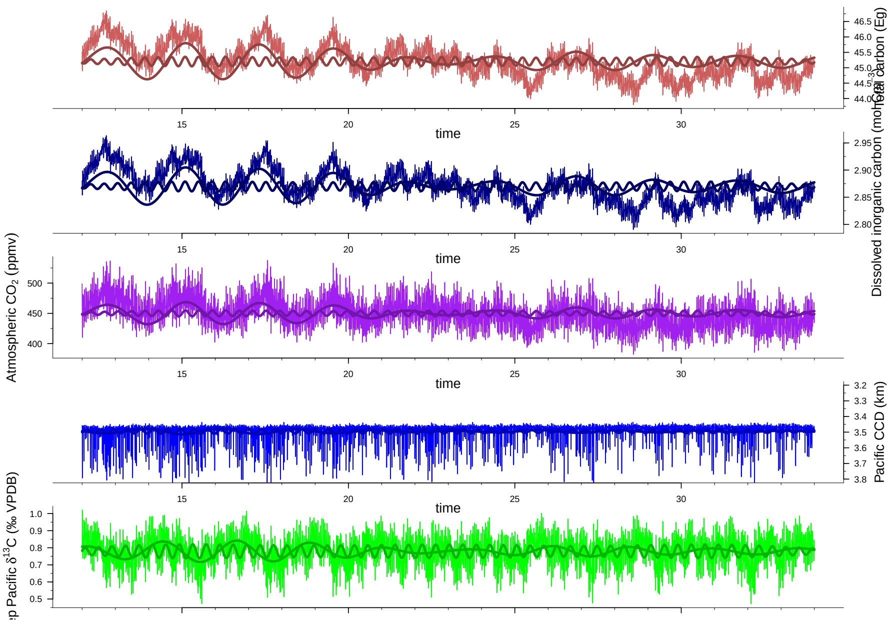

Fig. 4. A time-series with 65°N summer insolation as forcing. Notice that the long-term trend is the result of the long-term trend in obliquity (see Laskar et al. 2004, Science, fig. 14)