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Climate of the Past Discussions

# *Interactive comment on* "Bispectra of climate cycles show how ice ages are fuelled" *by* Diederik Liebrand and Anouk T. M. de Bakker

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1. General comments

Drs. Liebrand and de Bakker provided here new, original statistical analyses of the LR04 d18O stacking to document the non linear interactions between the Milankovitch cycles which lead to the generation of new cycles in the palaeoclimatic data and lead to power transfer from the precession band (dominant in the insolation series) to the obliquity and to the 100-kyr eccentricity cycles. In particular, bispectra are used to observe non-linearities between the insolation forcing and the d18O series, which is an excellent and original idea in palaeoclimatology. However, I find section 3 of the manuscript hard to read to someone who is not familiar with the reading the interpre-



tation of bispectra despite I could see the authors made many efforts to make their paper accessible. In section 3.2., I do not understand what is reference to calculate the gains and the losses of energy and I do not understand how the authors can find this information in the bispectra. This step must be clear for any reader to then completely follow the result description in section 3.4.

I can see that bispectra document the energy (or power) transfers and the evolutive spectral analyses seem to document these power transfers very clearly. However, I do not understand how the bispectra contribute in understanding the mechanisms of non linearities in the d18O already evoked in prior publications and this needs to be clarified.

In summary, much clarification is needed to allow a larger community to access this enthusiasming way to observe cycles in sedimentary series and observe their interactions. I thus suggest this manuscript deserves to be published after revisions will be done.

The authors can find more specific comments below:

2. Specific comments

Throughout the manuscript, the term "energy transfer" is used. What do the authors refer to when they use this terminology? This must be more clearly stated, unless I missed it in the manuscript.

In page 3, line 26, the author mention they used SiZer to resample every 1 kyr. What is the method used by SiZer to resample? Is it a linear resampling? Is it another method of resampling? Can the authors write exactly the method of resampling because it can impact the spectrum at high frequencies.

In page 4, line 13, what do the authors call "time averaging operator"?

Section 3.2. ("Bispectra of Pliocene and Pleistocene climate cycles") is hard to follow in my point of view at least for the following reasons:

The authors mention gain or loss of eneregy. Gain or loss should be a difference compared to a reference. What is the reference used to calculate these gains and losses? The authors mention positive or negative interactions, e.g. (page 8, lines 24-25): "negative interactions are concentrated at and between triads along the from ðİŘţ (40âĘŚ, ∞âĘŚ, 40âĘŞ) to ðİŘţ(40âĘŚ, 40âĘŚ, 20âĘŞ)". I do not know where to observe this in Figure 4. Can the authors either explain this with a theoretical example easy to understand prior to the real data or at least show where to observe this in Figure 4?

From these two examples, I think much effort have to be made to guide step-by-step a reader who is not familiar in the use and interpretation of bispectra. Otherwise section 3.4., which describes the results of bispectra, will remain unacessible for many readers. So, I suggest more step by step explanation to make easier the observation and the interpretation of the bispectra.

In Figure 5, I do not understand what the authors refer to by writing "Input –> “black box” climate –> output". What do the authors mean by "black box" here?

Still in Figure 5, I would clarly state what conservative net energy transfer means

In Figures 5 and 6, I would label the freqencies on which energy transfers occur

In section 5.2.1. "Based on the bispectral results, we infer that during the Pliocene and Early Pleistocene this predominantly monsoonally-driven precession motor fuels the 40-kyr obliquity-paced ice age cycles, aided by more linear climatic-cryospheric responses resulting from variability in insolation at this periodicity, especially at higher latitudes" » I do not really understand how the authors can deduce that from bispectral analyses. The authors can of course observe transfers of power from the precession to the obliquity band, but how can they link that to the moisture and heat transfer at low latitude? There is a step I do not understand. Comparatively, the interlatitudinal insolation gradient evoked by Bosmans et al. (2015) appears much more intuitive and easy to understand.



I experience the same feeling with section 5.2.2.: how the power transfer observd in the bispectra can help in linking the transfer from the obliquity to the eccentricity with crustal sinking and delayed rebound? I think the authors need to clarify how the bispectra can contribute to the debate

3. Technical corrections

In Figure S3, labels a, b, c in the caption do not correspond with the panels in the figure. Can the author correct that?

4. References

Bosmans, J.H.C, Hilgen, F.J., Tuenter, E., Lourens, L.J., 2015. Obliquity forcing of low-latitude climate. Clim. Past, 11, 1335-1346.

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