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Climate of the Past Discussions

Interactive comment on "Equatorial insolation: from precession harmonics to eccentricity frequencies" *by* A. Berger et al.

A. Berger et al.

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Referee #1

We agree with the referee that climate changes at the geological time scale cannot be understood by looking at orbital forcing only. Instead, as already stated by Milankovitch, insolation forcing is only one step in an astronomical theory of paleoclimate. How forcing is transferred to climate (i.e. climate modelling, including climate feedbacks, land-sea distribution as mentioned by referee #2 and many other processes); how past climates evolved (i.e. data compiling) and how modelled and reconstructed past climate compare are other fundamental steps of climate studies. However, in this paper, we want to focus only on one of these point, i.e. the insolation forcing. More precisely, we want to insist, once again, that in addition to the well-known daily insolation, many other types of insolation might be candidates for explaining climatic records. The daily insolation at 65N at the June solstices is often used as a guideline for climate studies, both geological records and simulated records of climate changes. However climate models-including the Louvain-la-Neuve Earth models of intermediate complexity-, are forced by the latitude and time distribution of insolation and many reconstructed records of past climate variations reflect insolation forcing at other latitudes or time in the year. Moreover, other types of insolation, such as seasonal insolation (Loutre et al., 2004), might have had a significant influence on the climate records (see our introduction). We agree that only a close analysis and confrontation between data and model results will allow to assess precisely the exact role played by the equatorial insolation, and in particular the amplitude of seasonal change in insolation at the equator. This is the topic of a research by itself and certainly of other papers to publish. In the mean time, we have extended our comments about what might be the link between the low latitudes insolation and climate variations from different papers published on the subject.

Minor comments have been taken into account in the manuscript

Referee #2

1. *One of my main problems which the manuscript is it refers to the 100 kyr cycle.*

- 100-kyr period : We agree with the reviewer that the 100-kyr period identified in the insolation signal is indeed split in several periods, according to the orbital solution. This has been modified accordingly.
- In figure 5 (middle and bottom), we labelled somewhat empirically the y-axis (period axis) with the main periods observed in astronomical parameters i.e. precession (19 and 23 kyr), obliquity (41 kyr) and eccentricity (95, 123 and 413 kyr). We also put 5 and 10 kyr in the y-axis.
- The three main peaks with periods of 95, 123, and 413 kyr, which are labelled in the multi-taper spectrum (Figure 5 bottom) are very close to the theoretical

CPD

2, S431–S435, 2006

Interactive Comment

periods obtained i.e. 96, 124 and 409 kyr. Theses periods are clearly related to the eccentricity parameter which explains 93.35% of the variance of the signal max(SE,FE) - min(SS,WS) for the time period from 100 kyr to -1000 kyr. We would obtain the exact 95, 123 and 413 periods if the multi-taper analysis was performed on a longer time series.

- From the wavelet image of Figure 5 (middle) it can be observed that the period of the "∼100 kyr cycle" varies in time. For instance around -250 kyr and -630 kyr the ∼100 kyr cycle has one component with a period centered at 100 kyr whereas around -400 kyr and -850 kyr the ∼100 cycle is splitted in two components with periods at 87 and 127 kyr.

2. *In the conclusion the authors attempt to find support for their 11 kyr and 5.5 kyr cycles in the palaeoclimate records.*

- we draw the attention of the reviewer that the instability of the 100kyr found in geological data is also a characteristic of the eccentricity periods, including the average of about 100 kyr, (see Fig 5 and Berger et al. 1998, Paleoclimates 2 (4), 239-280.).

3. *What I suggest would be more important is for the authors to discuss why at the moment there is very little evidence for the 11 kyr and 5.5. kyr.*

- We have introduced some discussions about the possible mechanisms that might relate low latitude insolation to climate in our conclusions. See also comment to referee #1.

Referee #3 - Peeters

CPD

2, S431–S435, 2006

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Discussion Paper

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1. *To further discuss and clarify if their "orbital seasonality proxy" (Delta) is indeed representing the maximum seasonal insolation contrast for the entire tropical realm (and not only at the equator)*

As the title clearly states, our paper is focusing on the equatorial insolation. However some features characterising the insolation in the equatorial region are also valid for the whole tropical belt. This is the reason why our introduction is broader that the equator only. According to the reviewer's comment, we again check the paper to avoid any misunderstanding.

2. *To discuss in more detail how the "seasonal origin" of their Delta parameter may relate to the low latitude African and Asian monsoon systems, which are known to primarily respond to the difference in the cross-equatorial summer insolation gradient.*

Our Δ index is indeed a measure of the largest seasonal contrast at the equator. The way it is constructed gives the explanation of its origin. The relative intensity of the amplitude is related to eccentricity. The 400000 year cycle explains why some minima may be larger than maxima at the 100000 yr time scale. Mathematically speaking the largest difference is the most significant. However as far as the response of the climate system is concern we cannot neglect that it can be sensitive to the seasonal origin. Nevertheless, if it is the case, it would probably not be to the month of minimum and maximum but rather to the rate of change of the insolation. Moreover, we must keep in mind that insolation distribution over the whole Earth during the year might interact with insolation in the equatorial region.

Some features of the Δ index have been included :"This high frequency signal has an amplitude of the order of a few Wm^{-2}. However, it is carried by a signal of much large amplitude (a few tens Wm^{-2}). Moreover, it must also be noted that local minima of this index (e.g. 86 Wm^{-2} at 198 kyr BP) might be much larger than local maxima (e.g. 66 Wm^{-2} at 154 kyr BP)."

Minor comments

CPD

2, S431–S435, 2006

Interactive Comment

- The suggestion related to the text have been taken into account in the revised manuscript.
- About the solar constant, We have made a comment in our paper. It is taken to be 1368 Wm^{-2}. in our calculation, although it is slightly changing through time (for a recent review, see Bard and Frank, 2006).

Interactive comment on Clim. Past Discuss., 2, 519, 2006.