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Interactive comment on "Orbital forcings of the Earth's climate in wavelet domain" *by* A. V. Glushkov et al.

Anonymous Referee #1

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The purpose of the paper is to apply wavelet technique to extract the components at the eccentricity, obliquity and precession frequencies from paleoclimatic records. More precisely, the paper shows that the non-decimated wavelet transform can be used to extract components from climatic records. The paper starts with a large reviews of the periodicities recorded by climatic proxies at different timescales. Then it reviews methods of spectral analysis (Fourier, wavelet) already applied to such records. The next section is a long review of the orbital parameters, their fundamental periodicities and their role in the astronomically driven insolation. Section 3 mostly described the method used in the analysis, i.e. non-decimated wavelet transform. It also mentions, without description, the data that will be analysed in the next section (i.e. reconstructed temperature from Vostok ice core and a composite oxygen isotope record). Unfortunately the authors do no explain how the composite record was built. The title and the summary are reflecting the major lines of the paper. The references are very unevenly distributed in the paper. Some parts contain very accurate references of previous work while major references are missing in other parts of the paper.

I am sorry to say that the English is so poor, in particular in some key sections, that it prevents the fully and correct understanding of the points raised by the authors. Therefore I am unable to fairly assess the quality of the paper. Thus my recommendation is to reject the paper in its present form. But I suggest the authors to make their paper edited for English and maybe to take this opportunity to improve it.

Nevertheless, I would like to try to give some constructive comments.

1. Introduction

Solar energy received by the Earth is indeed varying at different time scales and there are several causes for these variations. Amongst them, there is the solar energy emitted from the Sun. As pointed out by the authors, only short cycles (Schwabe, Gleissberg) are identified up to now, as well as period of minimum of solar activity (Maunder minimum). The Maunder Minimum is actually defined according to the solar activity. It was later related with the climate anomaly recorded at the same time. Changes in the Earth orbital parameters also induce insolation change. At the very long timescale, it is often refer to it as “Milankovitch theory”. Instead of the melting of the ice sheet, it is rather the glacial inception that Milankovith characterised in his theory. According to him ‘cold summers must be the cause of glaciation and they are to be considered responsible for the formation of inland-ice’. The strongest component in the daily insolation arises from climatic precession, i.e. ˜21 kyr period, except for high northern latitudes in winter. The obliquity component (˜41 kyr) is stronger in winter than in summer; it is also stronger in the high latitudes than in low latitudes. The eccentricity component (400 and 100 kyr) is always small (at least in daily insolation). This has raised the question of the 100-kyr cycle, a so prominent features in many paleoclimatic data. Moreover, the 400-kyr cycle is also recognised as a feature of long records (see e.g. Philosophical Transaction of the Royal Society, 1999, vol 357, number 1757, pages

1731-2007, including papers from Olsen and Kent, Gale et al., Herbert).

A reference for the 'causality problem' would be welcome.

2. Change in orbital parameters

The planets in the solar system move in almost perfectly elliptical orbits about the Sun, according to their mutual attraction and the Sun's attraction upon them. Six elements for each of the planets allow identifying their position in the solar system. For example, the inclination of the ecliptic is the angle between the orbital plane and the reference plane. The eccentricity is characterising the shape of the orbit. All the elements are varying through time, including the inclination. Thus the instantaneous ecliptic is not invariable. There is only one element, the semi-major axis of the Earth orbit, that is constant at the second order. The major periodicities of these elements were published for the Earth (e.g. Berger, 1978) and for other planets. For the Earth, they are 95, 125 and 413 kyr for the eccentricity, 41 and 54 kyr for the obliquity, and 19, 22 and 24 kyr for the climatic precession (Berger, 1978). It is not clear why the values given by the authors for the eccentricity are slightly different. In global annual mean the total solar energy received by the Earth varies indeed very slightly between two extreme cases, i.e. nearly circular orbit and maxima of eccentricity. Moreover, the eccentricity is the only parameter that affects this total insolation. However, it is not so much the total energy that is responsible for climatic changes, rather it is the distribution during the year and in latitude that affects climate. This distribution is strongly dependent on precession and also on obliquity. Of course, as climatic precession is indicating the position of the Earth at the beginning of the different season, it is also strongly related to the length of the season. The climatic precession is playing an opposite role in both hemispheres. To any insolation change in one hemisphere due to precession change corresponds an insolation change of opposite sign in the other hemisphere six months later. On the other hand, obliquity is playing an opposite role in both hemispheres, e.g. any increase in obliquity increases the insolation received in the high latitude during the local warm season. I assumed that it is what the authors meant. Some references would be welcome

3.1 The data

There is no reference for each of the series taking part of the composite record of oxygen isotope ratios. Moreover there is no explanation on how this composite record was built. The relationship between oxygen isotope ratio and climate is clearly explained, at least for a non-specialist. I am not sure whether a geochemist would agree with me.

3.2 The non-decimated wavelet transform

I do not know enough in this field to give relevant comments. Sj is not defined in the equation after equation (2).

4 Decomposition of paleoparameters

As far as I understand the authors used the NWT to extract some component of the paleorecords. It is interesting to perform a similar analysis using the orbital parameters instead of the extracted components. Indeed in doing so it is actually the forcing and the response that are compared. Going a step further, the extracted components could be compared with the orbital parameters. Comparing the signal and an extracted part of this signal might be misleading. It seems 'natural' that they compare well because they have the same origin. Moreover doing so does not provide any evidence for orbital forcing. Drawing a figure similar to figure 2 with the deuterium in EPICA DC and the orbital parameters (eccentricity, obliquity and climatic precession) leads to very similar conclusion. The interglacial peaks recorded in EPICA coincide with large relative values of eccentricity. Eccentricity is not yet at its maximum when the 'climatic optimum' is reached. Obliquity is large, either still increasing or already decreasing and climatic precession is almost minimum, which means June solstice at perihelion. However, as it was the case for the data analysed by the authors, MIS7 is an exception. Should it be possible that ˜240 kyr BP is not the 'real' interglacial but rather that it coincides with a 'kind of' abrupt event not directly related with insolation forcing? A reference for the definition of Mid-Pleistocene Transition would be welcome, e.g. Mudelsee and Schulz, 1997. Several papers were already published dealing with the transition from a dominant 40-kyr to a dominant 100-kyr in climatic records, as well as in models. References to some of these papers are missing (e.g. Berger et al., 1999; Jun Tian et al., 2002). I understand (but I am not sure that my understanding is correct) that the authors pointed out that the power or amplitude of the 400-kyr period is stronger that the 100-kyr before 780 kyr and that it is the reverse after 780 kyr. Wavelet analysis of the eccentricity time series is showing a reverse pattern, with the 100 kyr being the strongest before ˜500 kyr BP and the 400 kyr being the strongest after 500 kyr BP (Berger et al., 1998). Is there any explanation for such behaviour? Many time series of oxygen isotope ratios show a decreasing trend over the last 4 Myr. However the different components obtained from the NWT does not show any trend. But they are showing strong changes in their amplitude. Why is it so? Has the time series been detrended before the wavelet analysis? Or does the wavelet analysis perform a 'kind of' detrending? Do the authors think that the trend is not related to orbital forcing? It would be interesting to have the authors' comments on that matter.

Specific comments

The periods recognised by Fourier power spectrum should be labelled within figure 1 and figure 3. Otherwise, it is difficult to identify them. The caption of figure 4 is not correct. X-axis is not kyr but Myr.

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