

Clim. Past Discuss., referee comment RC2  
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## Comment on cp-2021-10

Anonymous Referee #2

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Referee comment on "A Modified Milankovitch theory that reconciles contradictions with the paleoclimate record" by Robert E. Wong, *Clim. Past Discuss.*,  
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This manuscript attempts to provide a new point of view on the question of Quaternary glaciations and the 100-kyr cyclicity. It is based on rather obvious facts : indeed the Earth receives (globally) less energy when far from the Sun at the aphelion. But it also receives (globally) more energy six months later. Overall the argumentation is confused, to say the least. It seems that the author is « cherry-picking » the processes that corresponds to the desired effect : when at the aphelion, the Earth being far from the Sun we have cold winters (in the winter hemisphere) and cool summers (in the summer hemisphere) therefore a glaciation... But obviously the opposite holds true six months later.

More fundamentally, it appears that the author attempts to give answers to problems that do not even exist. For instance, he states (line 308) that « An issue with the Milankovitch summer insolation curves is that glaciation is asynchronous between hemispheres ». This is not true. The main forcing in the Milankovitch theory (in contrast to Croll's one) is obliquity, at 41 kyr. Obliquity changes have a symmetric impact on both hemispheres : both are cooled due to low obliquity. This was actually a major difference with previous theories based mostly on precession (on the false premise that Antarctica is currently in a glacial state). Besides, ice-sheets are too cold in winter to allow for any significant precipitations, and there is never « mild rainy winters » over there. This is the key argument of Milankovitch to focus on the summer season, something already strongly discussed in the 19th century.

But at the end, on Figure 4, the author mentions (line 279) that « The precession cycles are responsible for the oscillation of insolation for summer and winter bounded by the ap- and peri-insolation ». Indeed, this is the well-known amplitude modulation of insolation at the basis of most of classical theories explaining the 100-kyr cycles. Nothing new.

Overall, this manuscript is flawed (and very confused) in its climatic mechanisms. I do not recommend its publication.

Detailed comments :

Lines 73-74 :

« to attribute the dominant cycle to multiples of precession or obliquity cycles »

This is certainly not the « standard » explanation. The most common explanation involves the amplitude modulation of the effect of precession on climate (which is precisely eccentricity). A non-linear system will in general extract the envelop of the forcing and produce a 100ky oscillation, even for very simplified models. The difficulty is not to identify the origin of the 100-kyr cycles (ie. the amplitude modulation of precession) but to identify the non-linearity of ice-sheets that can extract this envelop. Many possibilities have been put forward.

Line 80 :

« eccentricity does provide necessary solar energy conditions for global glaciation »

Obliquity is symmetric and explains very easily globally synchronous glaciations. This is in fact one of the main argument for the Milankovitch theory. It could also be argued that teleconnections are also critical : The Quaternary is characterized by northern glaciations (since in Antarctica, the ice-sheet is always close to its maximum extent, the continent being ice-covered today) therefore, concerning ice-sheets, we can neglect Antarctica. Concerning climate, the main (ice) changes are occurring in the North and will probably have global consequences. CO2 can also have a global impact.

Line 160 :

« Which theory is valid has been a long running debate (Imbrie and Imbrie, 1989). »

This is not true for at least a century. Nobody would claim today (except maybe in this current paper) that winter insolation has any consequence on ice sheets. In polar regions, winter is extremely cold and without significant precipitation. The mass balance of the ice sheet does not depend at all of insolation changes. The rôle of summer insolation is widely recognized, and is also consistent with simulations of ice-sheets using detailed numerical models. Since Milankovitch at the beginning of the 20th century, there is no more debate on this point. And again, Milankovitch already has glaciations synchronous in both hemispheres, since the main forcing is obliquity.

Line 163 :

« Annual snow growth for building ice sheets would result from more snow created in the colder winter of one hemisphere and less snowmelt in a cool summer of the other hemisphere ».

No. Winter is irrelevant : there is almost no snow in winter, since there is almost no water vapor in the winter atmosphere.

Line 185 :

« The eccentricity ... shown in Fig. 2a reveal three discernable cycle periods of approximately 65 kyr, 100 kyr and 400 kyr »

65 ky does not clearly show up in the spectral analysis.... The vocabulary « cycle period » is not quite relevant, « duration of specific events » would be more appropriate.

Figure 2

In other words, Earth receives less energy per day (less power) when far from the Sun. This seems quite obvious to me.

Line 200 :

« Conditions for glaciation occur during increasing eccentricity resulting in increasing ap-season cooling (more negative) and increasing peri-season warming while conditions for deglaciation occur during diminishing eccentricity »

Why ? I do not understand... ap-season = cold winters (in the winter hemisphere) and cool summers (in the summer hemisphere) but just the opposite 6 months later during the peri-season. So why should « cooling during the ap-season » dominate ?

The reasoning seems basically flawed to me...

Line 205 :

« Global temperature variations are not directly derived from eccentricity deviations indirectly by Earth system responses to solar energy variations including the contraction and expansion of the cryosphere, the corresponding albedo variations and the carbon cycle »

So why do we need to define ap-seasons and peri-seasons if this does not explain anything after all ?

Line 244 :

« For this analysis, vernal equinox is defined as the middle of the spring season quartile rather than the start of spring. The other seasons follow suit. »

I do not think « equinox » should be redefined.

Line 262 :

« traditional seasons participating as cooling in the ap season would provide either conditions for snow where rain would have occurred »

It is too cold in winter to rain or snow... This is fully irrelevant for ice-sheet dynamics. The rain/snow is certainly not a simple linear response to insolation forcing.

Line 284 :

« This alternation of glaciation types also explains »

Actually, I do not see any explanation here...

Line 292 :

« Obliquity is prominent when eccentricity approaches zero »

Again, obliquity is dominant in the Milankovitch theory. This probably explains why climate variability was dominated by a 41k periodicity before the MPT (with smaller ice-sheets having a more linear behavior).

Line 308 :

« An issue with the Milankovitch summer insolation curves is that glaciation is asynchronous between hemispheres »

No. This is not true. You should have a look at the « caloric seasons » as defined by Milankovitch at high latitude in both hemispheres, which are closely in phase.