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Celestial Mechanics and Estimating the Termination of the Holocene Warm Period

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Summary of conference speech

This paper addresses several issues concerning Milankovitch Theory and its relationship to paleoclimate data over the last 800,000 years. The insolation is described physically as a time-dependent wave. It is analogous to an AM radio wave. Its wave-like nature is produced by the "beating" of the earth's celestial motions on the solar irradiance (about 1,368 W/m^2) resulting in its complex time-dependent distribution over the earth's surface. Each of the three celestial motions, precession, eccentricity, and obliquity, contributes a wave component to the insolation. Like ordinary waves, they can produce a beat-like structure through constructive and destructive interference. This description begs several questions. How large in magnitude is each of these wave components, and how do they interfere? Does the interference manifest itself in the paleoclimate data, and if so, how? Does the description of the insolation as a wave and its components have any predictive power for determining the reoccurrence and duration of interglacial and glacial periods? The objective of this paper is to answer these questions.

The results are presented in temporal space as opposed to typical frequency space analyses for two reasons. First, paleoclimate data is commonly represented as a time series. The goal of this paper is to present a model that accounts for the features in the data as a function of time. Second, the three basic celestial parameters, the precession, eccentricity, and obliquity, are all quasiperiodic functions of time. They have no fixed period. Their quasi-periodic behaviour is fundamental to understanding the time series paleoclimate data.

The shortest cycle of the three celestial parameters is that of the precession, which, over the last 800,000 years, on average, has been about 21,000 years. That of the obliquity has been about 41,000 years and the eccentricity about 94,000 years. However, the variation in these cycles and their half-cycles is quite large. For example, precession half-cycles vary from 7,000 to 15,000 years, the obliquity half-cycles from 18,000 to 23,000 years, and the eccentricity half-cycles from 30,000 to 70,000 years. In terms of timescales, the precession sets the scale for the time-dependent behaviour of the insolation.

In terms of physical effects, the obliquity primarily affects the angular distribution of the insolation over the earth. In a half-cycle, it shifts the sun's rays south to north and vice versa by about 2.4 degrees in latitude or roughly 267 km. This shift changes the angle the sun's rays make with the vertical at each illuminated point on the earth's surface resulting in a comparatively small overall effect on the insolation amplitude.

The most significant effect on the insolation amplitude comes from the combination of the precession and eccentricity, the precession index (sometimes referred to as the climate precession.) It is defined as the precession modulated by the eccentricity and physically accounts for insolation minima and maxima. For example, when the earth is at perihelion (the closest distance to the sun), and the earth's axis points toward the sun, the insolation approaches a maximum for the northern hemisphere. Fast forward about 11,000 years, an average precession half-cycle, the earth's axis points toward the sun at aphelion (the farthest distance from the sun) the insolation approaches a minimum for the northern hemisphere. The change from maximum to minimum and vice versa can be quite significant (more than 100 W/m^2) at northern latitudes during the summer solstice and is driven by changes in the eccentricity over a precession half-cycle. This qualitative analysis suggests, and is demonstrated in this paper, that the insolation can be approximated by the effects produced by just two parameters, the precession index, and the obliquity at insolation maxima and minima.

Over the last 800,000 years, the insolation has transitioned from maxima to minima and vice versa a total of 74 times. These transitions range in percentage from about +28 % to -19 % with half-cycle durations (the average is about 11,000 years) that range from 4,200 to 16,900 years. However, the number of prominent temperature excursions indicated in the EPICA Dome C paleoclimate data is at best 13. Reconciling the 74 transitions in terms of timing and amplitude with the prominent temperature excursions is a formidable theoretical challenge. These features are affected by eccentricity, precession, and obliquity cyclical behaviours, which have been computed from -250 million to +250 million years. According to the Milankovitch hypothesis, their determination provides a consistent temporal calibration that should correlate insolation changes with features in the paleoclimate data.

These cursory observations raise several questions. What, if any, relationship is there between insolation changes and prominent features in the paleoclimate data? Are there specific insolation changes that are special, or are there trends in the insolation over time that correlate with significant changes in the paleoclimate data? To gain some insight into correlations, one might consider the largest changes in insolation from successive minima to maxima, and vice versa to see if these influenced the paleoclimate data more than other insolation changes. Such an approach would also capture insolation trends (as opposed to just individual changes) that could explain certain reoccurring features in the paleoclimate data over time.

Since the obliquity primarily affects the angular distribution of the solar irradiance over the earth's surface with a comparatively small effect on its amplitude over long cycles and the precession index is the primary driver of the insolation amplitude over shorter cycles, the product of the two contributions should well approximate the insolation at maxima and minima. This approximation partitions these two effects over time and allows for their time series comparison with the paleoclimate data that implicitly includes the quasiperiodic nature of the three celestial parameters.

A partition model is presented that does not include any aspect of the earth's climate. It is a parameter-free kinematic model based on the three celestial motions of the earth and the sun's rays.

The model provides a set of points in time for the obliquity and precession index contributions that represent the percentage change between successive mean-daily-insolation extrema at 65N in June. Its predictions for the insolation are compared with the corresponding theoretical calculations of J. Laskar et al. (2004) showing excellent agreement. An interpolation is made between the set of points for the obliquity and precession index contributions that enables a wave description of these separate contributions to the insolation.

The primary conclusion is the precession index wave dominates the insolation compared to the obliquity wave, which is evident from the following graphical comparison, Figure 1.

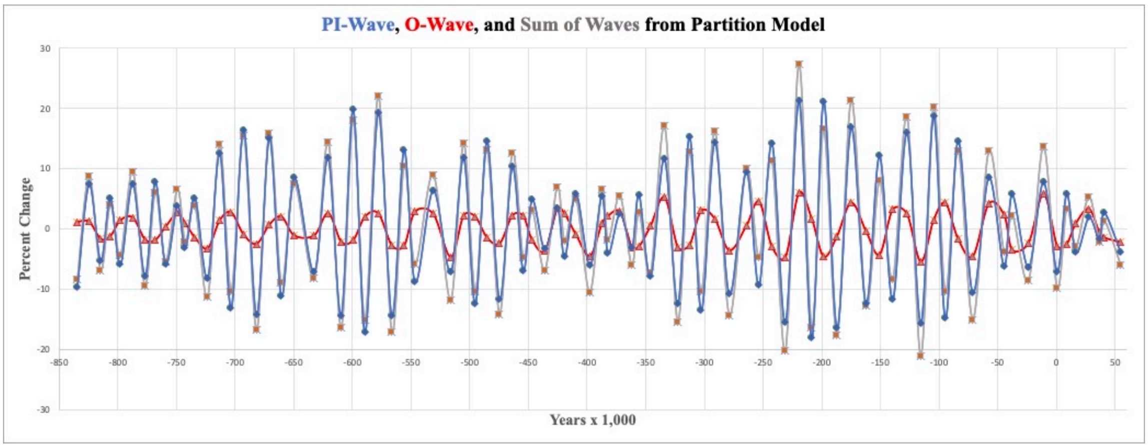

Figure 1: Partition model estimates for the precession index wave (blue curve), obliquity wave (red curve), and their sum (grey curve with red dots) associated with the percentage change between successive mean-daily-insolation maxima and minima at 65N latitude during June from -844,200 to +53,500 years.

The dominance of the precession index wave is also evident from a comparison of its behaviour with the EPICA Dome C ice core data as indicated in the following graph, Figure 2.

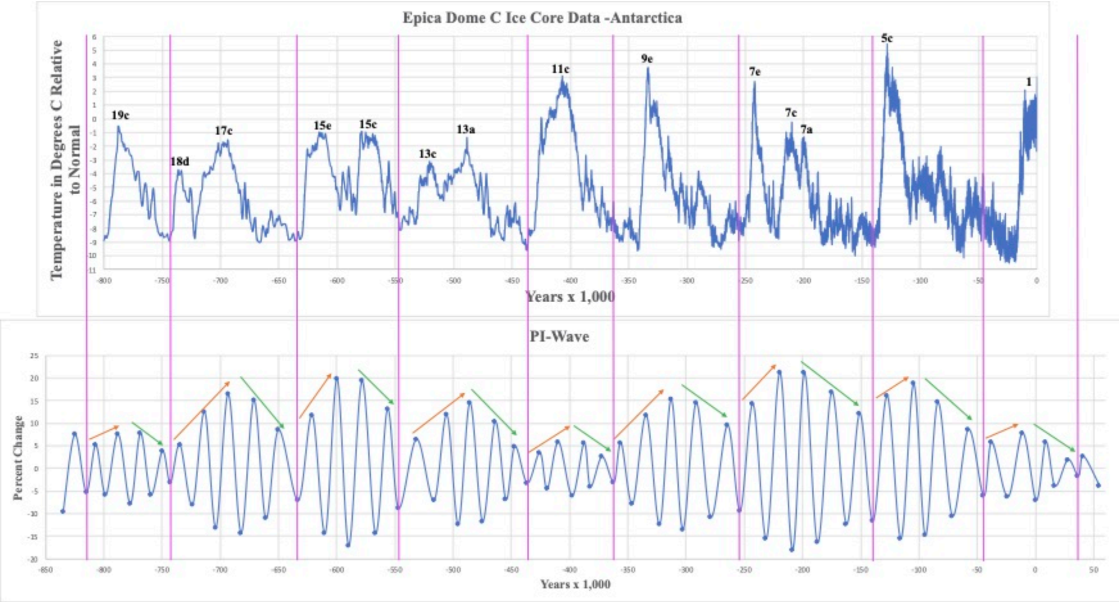

Figure 2: Precession index recurring wave packets (judiciously defined by purple vertical lines) approximately correlate with interglacial and glacial periods over the last 800,000 years. Precession carrier wave maxima trends qualitatively correlate with increasing temperature trends (red arrows) and decreasing maxima trends (green arrows) with decreasing temperature.

Visually, the quasiperiodic precession index wave packets, which are specified by the vertical purple lines, roughly correlate with recurring interglacial and glacial periods indicated by marine isotope stages. To determine occurrences of interglacial and glacial periods, simply follow the recurring precession index wave packets. However, the relationship between the timing of prominent temperature excursions and the partition model predictions also depends on the obliquity wave contributions. As a new timing result from the model, interglacial inceptions and terminations coincide with rare synchronizations (constructive interference) between the precession index and obliquity waves.

The model also predicts that the temperature descent into the next ice age is likely to occur within the next 500 years. Finally, the partition model provides support for the Milankovitch Hypothesis, however, the primary driver for the prominent features in the paleoclimate data over the last 800,000 years is the precession index and not the obliquity.

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References

Laskar, J., Robutel, P., Joutel, F., Gastineau' M., Correia, A.C.M., and Levrard, B. 2004, *A Long-Term Numerical Solution for the Insolation Quantities of the Earth*, Astron. Astrophys., Vol. 428, pp. 261-285. https://www.aanda.org/articles/aa/full/2004/46/aa1335/aa1335.html, 2004.

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