The Astronomical Theory of Climate: A Review

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The astronomical theory of paleoclimates aims to explain climatic variations occurring with quasi-periodicities between 20,000 – 100,000 years. Such variations are recorded in deep-sea sediments, ice sheets and continental archives. The quasi-cycles originate in the astronomically driven changes in latitudinal and seasonal distribution of energy that the Earth receives from the Sun. These changes are amplified by feedback mechanisms involving the temperature relationships between albedo, water vapor, and vegetation. Climate models of different complexities provide an understanding of the chain of processes that finally link the long-term variations in eccentricity, obliquity and precession to long-term climatic variations.

To understand our current interglacial climate and its future better, we have studied the response of the climate system to insolation and greenhouse gases (GHG) at the peaks of interglacials over the past 800,000 years. Our simulations show that the interglacials after 430 ka BP (the Mid-Brunhes Event) are warmer than those before, in agreement with proxy records. The proportional role of insolation and greenhouse gases was also analyzed to explain the differences in global-scale and high-latitude air temperatures, and in sea ice, precipitation and vegetation among the interglacials.

The best analogues to our present interglacial stage are the marine isotope stages (MIS) 11 and 19, which show similar latitudinal and seasonal distribution of the incoming solar radiation because of their similarity in obliquity and eccentricity (precession). Having the same low CO2 concentration, MIS-19 can be considered as a good analogue of the Holocene interglacial. Regarding our future climate, the next eccentricity minimum at 400-ka time scale is approaching. Even without our exceptionally high CO2, this future low eccentricity means that our interglacial was expected to last exceptionally long, as long as MIS-11 in the EPICA record. Given the important role of insolation forcing at the seasonal time scale, we recommend that in order to understand the future of our Holocene interglacial, attention should be paid to MIS-11 and mainly to MIS-19.