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Orbital variations in atmospheric CO2, astronomical solutions, and Solar System chaos

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Geologic records across the globe show prominent variations on orbital time scales during numerous epochs going back hundreds of millions of years. The origin of the Milankovic cycles are variations in orbital parameters of the bodies of the Solar System. On long time scales, the orbital variations can not be computed analytically because of the chaotic nature of the Solar System. Thus, numerical solutions are used to estimate changes in, e.g., Earth's orbital parameters in the past. The orbital solutions represent the backbone of cyclostratigraphy and astrochronology, now widely used in geology and paleoclimatology. Hitherto only two solutions for Earth's eccentricity appear to be used in paleoclimate studies, provided by two different groups that integrated the full Solar System equations over the past >100 Myr. In this presentation, I will touch on the basic physics behind, and present new results of, accurate Solar System integrations for Earth's eccentricity over the past hundred million years. I will discuss various limitations within the framework of the present simulations and compare the results to existing solutions. Furthermore, I will present new results from practical applications of such orbital solutions, including effects of orbital forcing on coupled climate- and carbon cycle variations. For instance, we have recently revealed a mechanism for a large lag between changes in carbon isotope ratios and eccentricity at the 400-kyr period, which has been observed in Paleocene, Oligocene, and Miocene sections. Finally, I will present the first estimates of orbital-scale variations in atmospheric CO2 during the early Paleogene.