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On the limits of numerical astronomical solutions used in paleoclimate studies

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Numerical solutions of the equations of the Solar System estimate Earth's orbital parameters in the past and represent the backbone of cyclostratigraphy and astrochronology, now widely applied in geology and paleoclimatology. Given one numerical realization of a Solar System model (i.e. obtained using one code or integrator package), various parameters determine the properties of the solution and usually limit its validity to a certain time period. Such limitations are denoted here as "internal" and include limitations due to (i) the underlying physics/physical model and (ii) numerics. The physics include initial coordinates and velocities of Solar System bodies, treatment of the Moon and asteroids, the Sun's quadrupole moment, and the intrinsic dynamics of the Solar System itself, i.e. its chaotic nature. Numerical issues include solver algorithm, numerical accuracy (e.g., time step), and round-off errors. At present, internal limitations seem to restrict the validity of astronomical solutions to perhaps the past 50 or 60 myr. However, little is currently known about "external" limitations, that is, how do different numerical realizations compare, say, between different investigators using different codes and integrators? 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 (Laskar and coworkers and Varadi et al. 2003). In this contribution, I will present results from new Solar System integrations for Earth's eccentricity obtained using the integrator package HNBody (Rauch and Hamilton 2002). I will discuss the various internal limitations listed above within the framework of the present simulations. I will also compare the results to the existing solutions, the details of which are still being sorted out as several simulations are still running at the time of writing.