**How do I apply variable astronomical forcing over time?**

For model simulations over long timescales (longer than 104 year) you might want to consider the effects of time-varying astronomical forcing. In this case, the amount of daily mean insolation at each latitude can vary as a function of eccentricity, obliquity and (climatic) precession, as opposed to a fixed insolation pattern. Such transient forcing can be applied in cGENIE with the following set of parameters that can be added to the user-configuration file:

# Call orbit\_radfor: Applies astronomical forcing

ea\_38 = "y"

# Specify the type of orbital forcing default (0), time-varying (1), alternative config (2)

ea\_39 = 1

# Number of data points in orbits file

ea\_40 = 1001

# Interval between data points in goldstein time steps

ea\_41 = 96000

# filename for orbital parameters (must be in genie-embm/data/input)

ea\_42 = "orbits\_La2004\_1Myr.dat"

In addition to these settings, a textfile (.dat) needs to be added to genie-embm/data/input that specifies the values for eccentricity, obliquity and precession over time. In the example described above, the filename is “orbits\_La2004\_1Myr.dat” which provides the astronomical solution for the past 1 million year based on the astronomical solution of Laskar (2004) in timesteps of 1,000 years, meaning that 1,000,000 / 1,000 = 1,000 data points (+ 1 for year zero) = 1,001 data points are available in file (ea\_40).

The value for parameter ea\_41 depends on the resolution of the model that is used. By default, cGENIE.muffin employs 96 goldstein time-steps per year for a 16-level ocean circulation model. When the astronomical solution is provided in time steps of 1,000 year, this equates to 1,000 × 96 = 96,000 goldstein time steps. For lower resolution configurations of cGENIE.muffin, goldstein may be operating on 48 time steps per year, which means that ea\_41 need to be changed to 48,000 when the astronomical solution is provided in 1,000 year time steps.