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Rotation of a moonless Earth

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We numerically explore the obliquity (axial tilt) variations of a hypothetical moonless Earth. Previous work has shown that the Earth's Moon stabilizes Earth's obliquity such that it remains within a narrow range, between 22.1° and 24.5°. Without lunar influence, a frequency-map analysis by Laskar et al. (Laskar, J., Joutel, F., Robutel, P. [1993]. Nature 361, 615–617) showed that the obliquity could vary between 0° and 85°. This has left an impression in the astrobiology community that a large moon is necessary to maintain a habitable climate on an Earth-like planet. Using a modified version of the orbital integrator mercury, we calculate the obliquity evolution for moonless Earths with various initial conditions for up to 4 Gyr. We find that while obliquity varies significantly more than that of the actual Earth over 100,000 year timescales, the obliquity remains within a constrained range, typically 20–25° in extent, for timescales of hundreds of millions of years. None of our Solar System integrations in which planetary orbits behave in a typical manner show obliquity accessing more than 65% of the full range allowed by frequency-map analysis. The obliquities of moonless Earths that rotate in the retrograde direction are more stable than those of pro-grade rotators. The total obliquity range explored for moonless Earths with rotation periods shorter than 12 h is much less than that for slower-rotating moonless Earths. A large moon thus does not seem to be needed to stabilize the obliquity of an Earth-like planet on timescales relevant to the development of advanced life.