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Inner core - mantle gravitational locking and the super-rotation of the inner core

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Seismological observations suggest that the Earth's solid inner core has been rotating faster than the mantle over the past several decades, consistent with the results of some numerical geodynamo models. However, the hemispherical anisotropy structure of the inner core, also seismically observed, may require the inner core to remain at a relatively fixed longitudinal alignment with respect to the mantle, perhaps due to gravitational locking between them. Both of these seismic observations may be compatible if the differential rotation of the inner core is oscillatory in nature, with no mean offset over geologically long time scales. In this work, we investigate the possible rates of rotation of an oscillating inner core and the dynamics of coupling within the core-mantle system from an angular momentum perspective. We show that for an internally generated torque, a long period (longer than 100 yr) oscillation of the inner core with a rate equal to 0.25°/yr, on the high end of the rates inferred from seismic observations, is possible. However, the mantle oscillations entrained by gravitational coupling in such a scenario are only marginally compatible with the observed changes in length of day. We show that, in order to explain the seismically inferred rotation rates, either the gravitational coupling must be lower than previous estimates, or the electromagnetic coupling at the core-mantle boundary must be stronger than typical estimates. Both of these conditions have important implications in terms of lower mantle structure and composition.