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Reevaluating gravitational coupling in the core-mantle system

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Angular momentum exchange between the mantle and core has long been associated with observed variations in the length of the day (LOD). Decadal variations in LOD have previously been inferred to represent periods of torsional oscillations in the fluid outer core (Braginsky, 1970), rigid rotations of concentric cylindrical surfaces that are coupled by the magnetic field that permeates them. A critical aspect to this explanation is the strength of the component of the magnetic field that provides the restoring force for the motions: stronger field decreases the oscillation period. On shorter timescales, a six-year variation in LOD has been attributed to gravitational coupling due to mass anomalies in the mantle, which deflect equipotential surfaces in the core thus leading to oscillations associated with angular momentum exchange (Buffett, 1996; Mound and Buffett, 2006). Crucial to this mechanism is a sufficiently large viscosity of the inner core, such that deflections of its equilibrium shape relax on timescales longer than the period of oscillation, and the amplitude of the coupling constant, which determines the period of oscillation. The majority of studies since the work of Buffett (1996) use standard values for these parameters that are consistent with gravitational coupling being the cause of the six-year LOD signal. However, recent work has found that the magnetic field strength in the core is much larger than previously thought, with the implication that torsional oscillations can be fast enough to explain the six-year signal in LOD (Gillett et al, 2010). Therefore, we are motivated to reanalyse the gravitational coupling problem in a more general manner without the onus of demonstrating causality for the six-year LOD signal. We use a method similar to that of Buffett (1996) to calculate three-dimensional density and gravitational potential anomalies throughout the mantle from recent models of seismic tomography. We calculate the response of a hydrostatic core to these anomalies and present revised estimates for the gravitational coupling constant, showing its dependence on the assumed tomographic model, radial profile of mantle viscosity, and radial profiles of the scaling factor between mantle density and seismic velocity. Based on these revised models, we report that the value obtained by Buffett (1996) is recovered in many of the cases studies. However, we find some cases that are arguably more analogous to more recent observations of the core-mantle boundary region, which act to decrease the gravitational coupling by more than one order of magnitude. We will discuss the sensitivities of the model to assumptions made for material properties above the core-mantle boundary.