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Constraints on core-mantle electromagnetic coupling from torsional oscillation normal modes

M. Dumberry (1), J. E. Mound (2)

(1) Department of Physics, University of Alberta, Edmonton, Canada (dumberry@phys.ualberta.ca), (2) School of Earth & Environment, University of Leeds, Leeds, UK (j.mound@see.leeds.ac.uk)

Decadal axial angular momentum variations in the Earth's core are believed to be carried by the normal modes of torsional oscillations. Coupling with the mantle transfers angular momentum to the latter, leading to changes in length of day (LOD). Electromagnetic stresses at the core-mantle boundary (CMB) may be an important coupling mechanism as well as a source of dissipation for torsional oscillations. In this work, we investigate whether the observed spectra of fluid core velocities and LOD variations can be both explained in terms of the normal modes of torsional oscillations when the only coupling with the mantle is through electromagnetic stresses. We show that this explanation may be true when the magnetic field at the CMB is based on a downward continuation of surface observations, provided the conductance at the bottom of the mantle does not greatly exceed 10^8 S and small wavelength field features do not contribute more than approximately 25% of the total radial field at the CMB. A larger conductance or a higher amplitude radial magnetic field results in a damping of the normal modes of torsional oscillation that is sufficiently large that they should not be detectable. In particular, we show that this is the case for the conductance and radial magnetic field that are inferred from the Earth's forced nutations. If these constraints are correct, the decadal periodicities in the fluid velocity and LOD must then represent the preferred frequencies of the excitation mechanism of torsional oscillations rather than the signature of the free modes.