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Electromagnetic core-mantle coupling and decadal motions of core fluid

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Decadal variations of the observed length of day (LOD) are known to be attributable to angular momentum exchange between the core and mantle. Dynamics of rotating fluid implies that decadal variation of the core angular momentum is likely to result from changes in core fluid motions organized by a rigid circular annulus coaxial with the Earth's rotation axis. In this paper we assume that the angular momentum exchange is due to the electromagnetic core-mantle coupling, effectively caused by poloidal and toroidal advective torques, which are associated respectively with toroidal and poloidal electric current within the weakly conducting mantle induced by the core surface flow. We develop a general expression of these torques acting on a core annulus, in terms of one dimensional profile of the mantle's conductivity, the main field and the core surface flow including their non-axisymmetric components. Based on a time-series of tangentially geostrophic flow model estimated such as to explain both geomagnetic and LOD observations, we find that zonal toroidal flow, varying in accordance with the LOD variations with typical periodicity of ~ 60 years, makes a primary contribution to variation of the advective torque on the annulus with similar periodicity. The advective torque is thus considered as an effective constraint allowing zonal toroidal flow to have higher temporal resolution. Around the equatorial region, even flows generating magnetic signal are constrained by the poloidal advective torque, implying that such flows are relatively less constrained by geomagnetic data. Non-axisymmetric flows are not as variable in time as zonal toroidal flow, and lead to important advective torque only on the annulus near the equator on timescales ($\gtrsim 100$ years) somewhat longer than that of the decadal LOD variations. Explaining the LOD

variations by the advective torque requires that rotation of the annulus should fluctuate with typical periodicity of ~ 30 years, shorter than that of the LOD variations. This cannot be caused by the advective torque in itself, because of its property of the torque as a friction with spin-up time longer than the fluctuation timescale. In light of the decadal core dynamics, whether this rapid fluctuation can be excited continuously is a key to find out the possibility for the advective torque to be predominantly responsible for the decadal LOD observations.