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Large variance of the topographic torque due to core surface flow obtained by using geomagnetic data

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Geodetic observations show that the length of day (LOD) or the angular velocity of the Earth's rotation changes with time. LOD variations of decadal time scale are reasonably ascribed to the exchange of angular momentum between the core and the mantle. Past studies also found the presence of polar motion of the same time scale, which can be excited by core-mantle coupling, though its existence is still unreliable. The exact mechanism of core-mantle coupling is not well understood so far, whereas several candidate mechanisms have been proposed. We will focus on the topographic coupling among those mechanisms.

The torque due to topographic coupling originates in the fluid pressure acting on non-spherical core-mantle boundary. The pressure is a dynamical quantity which is related to the flow in the core. Therefore, to obtain reliable flow just below the core-mantle boundary is essential to study the topographic coupling. Core surface flow can be found using geomagnetic field and its time variation, though non-uniqueness to determine the flow only from geomagnetic data is unavoidable. Also, assumptions for the dynamics of the flow in the region are necessary to evaluate pressure, and this could be another set back for evaluation of the topographic torque. Tangential geostrophy is assumed in previous studies such as Jault & Le Mouel (1989).

A simple dimension analysis indicates that the magnitude of the topographic torque might be very large. Exact integration of local forcing over entire core surface is necessary for quantitative discussion of the torque balance. The torque will be canceled each other in large part. It is believed that only small portion remains as net torque. To constrain the possible size of the topographic torque observationally as well as to understand the ambiguity of the estimated torque is important to discuss the importance of the topographic torque for the core-mantle coupling in a systematic way.

We calculate core surface flow using geomagnetic model DGRF80 and the CMB topography model recently obtained by Boschi & Dziewonski (2000). The equatorial torque, which has not been paid much attention, as well as the axial torque is calculated.

Under frozen-flux hypothesis and zero mantle conductivity, a least squares method is applied to deduce core surface flow with dampings on both its roughness and energy. The assumption of tangential geostrophy helps to reduce null space of non-uniqueness to find the flow. Large pressure anomaly tends to appear in high latitude and only small pressure gradient exists around geographic equator. Axial and equatorial torque can have typical magnitude and variation of order 10^{18} Nm and 10^{19} Nm, respectively. The value of the axial torque associated with flow with a certain roughness and energy agrees the value of torque necessary to explain decadal LOD variation.

In order to examine how such variations are caused, distribution of local torque about each axis is investigated. Positive and negative local torques of the scale comparable to the wavelength of degree four or five of spherical harmonics are eminent. Local torque distribution about equatorial axes shows that their anomaly around high latitude causes much larger local torque than those for axial component. Especially local torque corresponding to pressure anomaly in southern hemisphere between 0 degree and 90 degree E longitudes is most influential on the determination of equatorial topographic torque. Perturbations within the estimated error are given to the flow to examine the variation of the torque about three axes. The torque shows a large variance amount to 10^{19} and 10^{20} Nm for axial and equatorial components, respectively, with no correlation to the small change in the flow. This implies that a large range of the topographic torque can be caused even with flows with such slight difference as the can explain the geomagnetic data almost equally.