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Discussion

K. Lambeck (*Laboratoire de Géophysique et Géodynamique Interne, Université Paris-Sud, France*). The excitation function corresponding to the electromagnetic core–mantle coupling model may be written as

$$\psi = \Delta\psi H(t)\, e^{-at},$$

where $H(t)$ is the Heaviside function and a is the decay constant. The motion $m(t)$ of the rotation axis, relative to Earth-fixed axes, is of the form (Lambeck 1980; p. 59)

$$m(t) = j\sigma_0/(a+j\sigma_0)\, \Delta\psi(e^{-at} - e^{-j\sigma_0 t}),$$

where $j = (-1)^{\frac{1}{2}}$ and σ_0 is the Chandler frequency. At time $t = 0$ the excitation pole jumps to a new position, e.g. from $\psi = 0$ to $\psi = j\sigma_0/(a+j\sigma_0)$, and then drifts back to its original position with a time constant a^{-1}. This model differs from that of Runcorn, who considers a delta function excitation which would seem to imply a time constant a^{-1} that is very short compared with the period of the Chandler wobble. If the formalism of Rochester (1968) and Rochester & Smylie (1965) is used, the requisite lower-mantle conductivity would have to approach that of the core (Lambeck 1980, p. 265).

It should also be noted that Sasao *et al.* (1977) point out that if such delta-like torque operate, the nearly diurnal nutations of the Earth would be excited very efficiently.

My second point is that some insight into the core–mantle coupling required to explain the decade changes in length of day may be obtained through an examination of the time series of the length of day in the spatial domain. Are changes in length of day gradual, taking place over several years, or are they abrupt, over a few months? It has not been possible to examine this previously because zonal wind contributions mask these effects. We have therefore attempted to 'correct' the astronomical data for the atmospheric contribution (Lambeck & Hopgood 1982). The 'corrected' time series points to a rather substantial change in the proportional change in length of day in 1972, although it is premature to say that the latter event marks a substantial change comparable with that observed around 1900–05. It is perhaps tempting to associate it with the change in magnetic field parameters discussed by Le Mouël *et al.* (1981).

The low-frequency part of the spectrum of the length of day may throw some light on the nature of coupling. If the applied torques occur over short intervals of time, less than a year, say, then the spectrum of the first derivative of the change in length of day will be relatively devoid of power at low frequencies, whereas if the changes occur over long intervals the power at low frequencies will be enhanced. The data suggest the former (Lambeck 1980). There may therefore be an argument, albeit tenuous, that changes in the magnetic field at the core–mantle boundary may take place with a very short time constant.

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Discussion

K. Lambeck (*Laboratoire de Géophysique et Géodynamique Interne, Université Paris-Sud, France*). Malin & Hide postulate that the low-degree harmonics in the gravity field originate from an irregularly shaped core–mantle boundary. This can at best be only approximately true because seismic studies suggest that (i) the length scale of lateral variations in the mantle may be much less than the $2\pi R/l$ suggested by the spherical harmonic expansion (R is the radius of the Earth and l the degree of the harmonic), (ii) such variations occur throughout the mantle (see, for example, Julian & Sengupta 1973; Dziewonski *et al.* 1977), and (iii) there is some evidence to suggest that density anomalies tend to be compensated for by anomalies of opposite sign at some greater depth.

These observations lead to the conclusion that at least part of the low-degree harmonics in the gravitational potential is a consequence of much shorter-wavelength density anomalies in the upper mantle. A simple approach is to consider a model in which the mantle density anomalies are of short wavelength and are distributed both with depth and lateral position. If such anomalies occur throughout the mantle then the theoretical spectrum approximates quite closely the observed spectrum (Lambeck 1976). In particular, more than 50% of the power in the low-degree harmonics ($2 \leqslant l \leqslant 5$) originates from density anomalies above about 400 km depth. Gravity anomalies originating from long-wavelength topographic bumps on the core–mantle boundary will therefore be partly masked by the contributions from these shorter-wavelength density anomalies above the interface.

Another model is one in which gravity anomalies are attributed to a specific mantle structure. Subduction zones provide one example. Two recent attempts at evaluating the gravity due to the density anomalies in the subducted lithosphere are by Crough & Jurdy (1980) and McAdoo (1981), and both studies indicate that there may be significant contributions to the low-degree harmonics in the geopotential.

It has been recognized by Hide and his colleagues that the bumps on the interface imply some form of dynamic support and that they are therefore associated with convection in the lower mantle. Hence whether gravity anomalies above the bump should be positive or negative is not immediately obvious: a positive bump (where the core intrudes into the mantle) will be associated with a rising branch of the convection cell and the gravitational attraction of the mass deficit nearer the surface may partly or wholly cancel out the bump effect. Any deformation of the upper surface – or of the 650 km discontinuity if there is no convection across it – will further complicate the gravity anomaly, and it is not obvious whether the final anomaly over the bump will be positive, negative or worse, insignificant.

While these various models are unlikely to reflect the real situation very closely they do all lead to a similar conclusion: that a simple one-to-one relation between the low-degree harmonics of the gravity and magnetic fields should not be expected. Yet the results of Malin & Hide are most suggestive. Perhaps the Earth is, for once, actually simpler than our models.

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