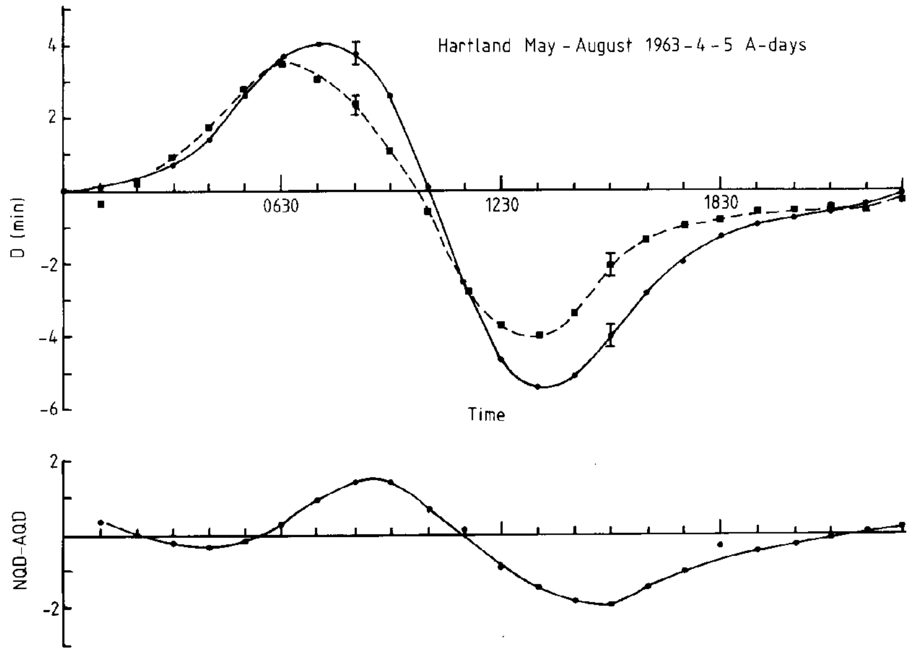

Fig 2 The variation throughout the day of the magnetic declination (*D*) at Hartland, for NQD (—) AQD (---), and (lower graph) their difference.

(Fig. 2). It is evident that on AQD on A-days there is a poleward current in the morning and an equatorward current in the afternoon, the opposite to that predicted by Takeda. The effect does not appear to be present on T-days. Possible sources for this current will be discussed.

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The geomagnetic field and Sq

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The process of conductivity modelling using results for internal and external components of daily magnetic variations and their seasonal changes gives consistently poor results from Sq at 1 c per day and from L at both 1 and 2 c per day. One possible way of proceeding is to assume that there are small terms of internal origin at these frequencies that are not part of the induction process, and to use conductivity models based on other daily variation terms to provide estimates of their amplitude and phase. Studies of local midnight values that extend the work of Malin (1977) on lunar magnetic variation midnight values should also help to determine the extent of magnetic variations of internal origin generated directly by the ocean dynamo. Work by Ashour and Price (1965) on night-time earth currents associated with the daily magnetic variations needs to be included in such studies.

Interpretation of the physics of the standard theory of induction as set down by Chapman and Whitehead (1922), and Lahiri and Price (1939) can also be improved, using, for example, the poloidal and toroidal vector field representation used so successfully by Bullard and Gellman (1954) in their studies of the main field. The induction equation can be written:

$$\nabla^2 \boldsymbol{B}_o + \mu_o \sigma \alpha \boldsymbol{B}_o = -\mu_o(\nabla\sigma) \times \boldsymbol{E}_o + \alpha \nabla \times \boldsymbol{P}_o$$

where the time dependence of magnetic, electric and electric polarization fields is specified by:

$$\boldsymbol{B} = \boldsymbol{B}_0 e^{\alpha t}, \ \boldsymbol{E} = \boldsymbol{E}_0 e^{\alpha t}, \ \boldsymbol{P} = \boldsymbol{P}_0 e^{\alpha t}$$

The equation, together with the boundary conditions, can be considered in terms of poloidal and toroidal representations of the vector fields. When the conductivity (σ) depends upon the radius only, the inducing poloidal magnetic variation gives rise to a purely poloidal magnetic field in the conducting sphere; the inducing and induced fields are associated with toroidal current systems. However, when σ is not uniform over a spherical surface, then the induction equation for $\boldsymbol{B}$ includes a toroidal component of $\nabla\sigma \times \boldsymbol{E}_0$, which will be balanced by the toroidal form of $\alpha\nabla \times \boldsymbol{P}_0$ associated with a poloidal polarization electric field.

The special functions $j_n(\sqrt{ikr})$ required to represent the radial dependence on the induced fields can be set down exactly in terms of trigonometric and exponential functions. Real and imaginary parts of the ratios j_n/j_{n-1} for $n = 1,2,3,4$, can also be set down exactly. These expressions will be compared with the power series and asymptotic series used by Chapman-Whitehead and Lahiri-Price.

Attention is drawn to the use of equator-symmetric seasonal variation terms in induction studies, and also to the mathematical form of magnetic disturbance used by Chapman and Whitehead, as a means of providing further electromagnetic response functions for modelling the electrical conductivity of the earth.

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Solar and lunar magnetic tides at midnight

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Solar tides

The method of Winch (1981) is used to extract the annual and semi-annual components in the magnetic elements starting with hourly values. A series of coefficients of the form:

$$A_{kn}\sin(nt + kh + \lambda_{kn})$$

are obtained for $n = 1$ to 4 and $k = -2$ to $+2$. Here t is the local time and h is the longitude of the mean sun (giving variation with season). These 20 coefficients can then be used to reconstitute the daily variation curve for any season h. This study investigates the variation of the midnight ($t = 0$) values with season.

The data used to derive the coefficients are hourly values for 1964 and 1965 with the five disturbed days of each month omitted. At sunspot minimum this will correspond to relatively quiet conditions.

In Fig. 1 the variation with season of the midnight values of the horizontal component of the magnetic field H is plotted for selected stations. The main point to notice is the large enhancement of this variation at the dip equator (equatorial electrojet stations). The variation at Huancayo is more than 3 times that at Tatuoca or Fuquene, and that at Trivandrum is more than 2.5 times that at Alibag. Addis Ababa also shows a large variation.

The form of the variation, with maxima at solstices and minima at equinoxes, is similar to that obtained by Campbell (1981). But the analysis of Campbell does not yield the large enhancement at the dip equator. He finds a more gradual decrease in amplitude of this variation with latitude, and so is able to explain it in terms of the latitudinal movement of a ring current on the tail side of the magnetosphere at a distance of about two earth's radii ($2r_e$).

While this mechanism may be responsible for some of the observed semi-annual variations at midnight, the dip equator enhancement suggests that there must also be a contribution from a westward equatorial electrojet. Note also that, as the dayside electrojet is stronger at Huancayo than at Trivandrum, so also it appears the night electrojet is similarly stronger (a seasonal change of 15.0 nT at Huancayo and 8.9 nT at Trivandrum).