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Depth of the Non-Conducting Layer in Central-Africa

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The geomagnetic daily variations in Central Africa are separated into their parts of external and internal origin and from these parts the depth of the non-conducting layer in that zone is found using methods previously discussed by the authors. A sharp latitudinal gradient in this depth is found in the interval (−400 km, 600 km) around the dip equator.

1. Introduction

The analysis of the geomagnetic daily variations (g.d.v.) at equatorial latitudes makes it possible to infer the depth of the non-conducting layer, (e.g. FORBUSH and CASAVERDE, 1961; ONWUMECHILLI, 1967; SAMPATH and SASTRY, 1979; OSELLA and DUHAU, 1982). To do so it is necessary to separate those variations into their parts of external (ionospheric) and internal (induced) origins.

As is well known, at the dip equator the g.d.v. can be represented by a localized part, the electrojet field, and an extended one, the planetary field. To separate the total field into its external and internal parts it is usual to assume that the internal part of the planetary field is a fraction of 0.4 and −0.4 for the horizontal and vertical components, respectively, of the external part. Using this assumption, the total planetary field is removed from the total field and the electrojet field is obtained. From the analysis of this field the depth of the non-conducting layer is estimated.

The above mentioned assumption on the internal part of the planetary field is not valid when it is applied to a localized zone as the assumed fractions are the global averages of the first three coefficients of the spherical harmonic analysis of the g.d.v. In a previous work the authors removed this assumption, yet they could obtain the external and internal fields of the total g.d.v. at the Peruvian dip equator (DUHAU and OSELLA, 1982). From the external part they found the total external current system and then they compared the internal part with the field induced by this current system in a two-layered model of the earth conductivity, to find the depth of the non-conducting layer (OSELLA and DUHAU, 1982).

Such a procedure was found to be adequate for investigating the presence of anomalies in the earth's conductivity and in the present paper it will be applied to

Central Africa, where FAMBITAKOYE (1973) measured the g.d.v. in a broad latitudinal chain around the dip equator.

2. The Data

The g.d.v. at Central Africa were measured by FAMBITAKOYE (1973) in a chain of nine stations covering the latitudinal interval of (22° 48′ N, 0.4° 23′ S) around the dip equator. In the present work all the data have been normalized to give a horizontal field of 100 nT at a location 140 km distant from the dip equator. The validity of this procedure has been discussed by several authors (e.g. MAYNARD *et al.*, 1967, and DUHAU and ROMANELLI, 1979). The resulting profiles are shown in Fig. 1.

3. Analysis of the Geomagnetic Daily Variations

To separate the g.d.v. into their parts of external and internal origin without making any assumption about the induced field, the method introduced by SIEBERT and KERTZ (1957) can be used; that is, the external and internal parts of one of the

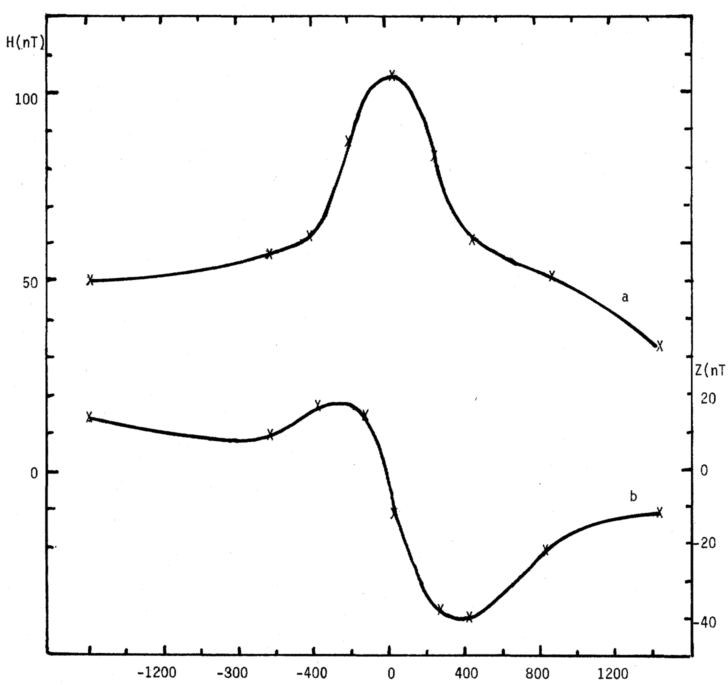

Fig. 1. a) The horizontal and b) the vertical components of the geomagnetic daily variations as measured by FAMBITAKOYE (1973). All the data are normalized to give a horizontal field of 100 nT at a location 140 km distant from the dip equator.

components of the total field may be computed, provided the Hilbert transform of the other component can be accurately calculated. This problem was analyzed by the authors in the previous work (DUHAU and OSELLA, 1982) and it was proved that, in equatorial zones, the accuracy of the Hilbert transform can be guaranteed only for the vertical component.

Therefore, in the present paper, this method is applied only to separate the horizontal component.

3.1 The horizontal component

3.1.1 Separation into the external and internal parts

The external, H^e, and internal, H^i, parts of the horizontal component, H, are obtained using the Kertz method, as described in the previous work (DUHAU and OSELLA, 1982). The results are shown in Fig. 2.

3.1.2 The external part

The ionospheric current system is represented by a localized part, the electrojet contribution, and an extended one, the planetary system.

The electrojet can be described by (CHAPMAN, 1951, DUHAU and OSELLA, 1982)

$$J_e^j(x,z) = \begin{cases} J_0^j(1 - x^2/D^2)\delta(z+h)\hat{y} & -D \leqslant x \leqslant D \\ 0 & x \geqslant D,\, x \leqslant -D \end{cases} \tag{1}$$

where J_0^j, the amplitude of the electrojet current density and D, the width of the electrojet, are the parameters to be determined, δ is the Dirac delta function, $h = 107$ km (DAVIS *et al.*, 1967) the height at which the current is flowing, x, y, z the

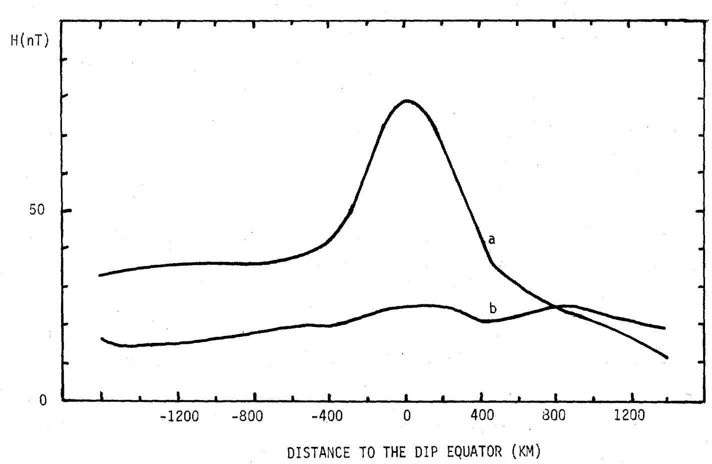

Fig. 2. a) The external and b) the internal parts of the horizontal component separated from the total horizontal field.

cartesian coordinates, northward, eastward and vertical (positive down) respectively and $\hat{y}$ denotes a unit vector for the eastward coordinate.

For the planetary part, an adequate representation is (OSELLA and DUHAU, 1982)

$$J_e^p = \frac{2}{\mu_0}\{C e^{-kz} \cos[k(x - x_0)] + B\}\,\delta(z + h)\,\hat{y} \tag{2}$$

with the wave number k and the constants B, C and x_0 to be determined. The horizontal component of the magnetic field produced by the current system given by Eqs. (1) and (2) is given by

$$H_e(x) = \frac{\mu_0}{2} J_0^j F_H(x_1 h) + C\cos[k(x - x_0)] + B \tag{3}$$

with

$$F_H(x,h) = \frac{1}{\pi}\left\{\left(1 - \frac{x^2}{D^2} + \frac{h^2}{D^2}\right)\left(\operatorname{arctn}\frac{x + D}{h} - \operatorname{arctn}\frac{x - D}{h}\right) - \frac{2h}{D} + \frac{xh}{D^2}\ln\frac{(x + D)^2 + h^2}{(x - D)^2 + h^2}\right\}. \tag{4}$$

The parameters are obtained by fitting Eq. (3) to the external part of the horizontal component (see Fig. 2a). It was found that a good fit is attained only if the electrojet centre is displaced from the dip equator by a distance x_j; therefore in Eq. (4), x is replaced by $(x - x_j)$ and x_j is now another parameter to be determined. Using the least squares method the parameters are found to be

$$C = 19\ \text{nT},\ B = 15\ \text{nT},\ x_0 = -700\ \text{km},\ k = 7.6 \times 10^{-4}\ km^{-1}$$
$$H_0^j = \frac{\mu_0}{2} J_0^j F_H(0,h) = 47.5\ \text{nT},\ D = 350\ \text{km},\ x_j = 40\ \text{km}$$

with a correlation factor $\rho = 0.998$.

In Fig. 3, the horizontal component computed for these parameters is compared with the external part of this component found in the previous section (see Fig. 2a).

3.1.3 The internal part

The external part of the horizontal component of the g.d.v. is almost twice the internal part in the south of the measured profile while in the north this part is larger than the external one (see Fig. 2). This latitude dependence of the relation between both parts of the horizontal component could indicate (OSELLA and DUHAU, 1983) either a deeper non-conducting layer in the south of the dip equator or an electrojet internal field still appreciable near the northern end, whereas the electrojet external field is already negligible there.

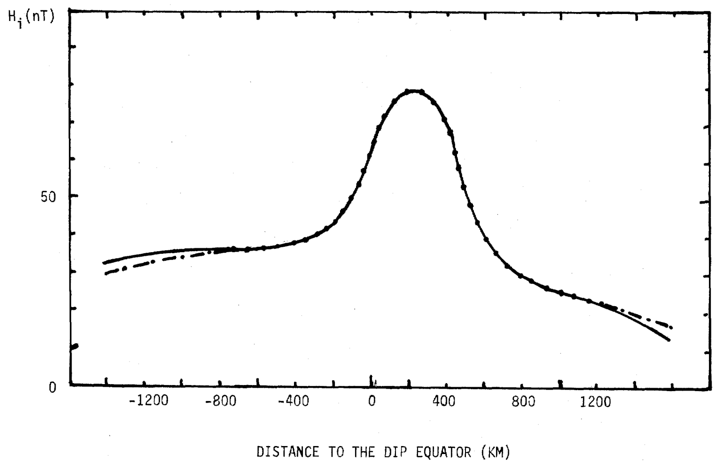

Fig. 3. The external part of the horizontal components. Solid curve: obtained from the total field (Fig. 2a). Dot-dashed curve: computed for the current density model proposed in the text (see Eqs. 1 and 2).

The depth of the non-conducting layer seems to be constant in the intervals (-1200 km, -400 km) and (600 km, 1300 km) from the dip equator. Therefore, in these zones, a simple model of the earth's conductivity will be assumed, as several authors did before (e.g., ONWUMECHILLI, 1967; OSELLA and DUHAU, 1982), consisting of a non-conducting layer up to a depth p and a perfectly conducting half-space below it. Then, using this model, the horizontal field induced by the current system given by Eqs. (1) and (2) is given as (OSELLA and DUHAU, 1982)

$$H_i = \frac{\mu_0}{2} J_0^j F_H(x - x_j, h + 2p) + B + Ce^{-2kp} \cos [k(x - x_0)]. \qquad (5)$$

Using the parameters found in the previous section, p is estimated by fitting Eq. (5) to the internal part (see Fig. 2b) by the least squares method. The depth of the non-conducting layer is found to be 500 km in the northern interval and 1000 km in the southern one. The result is shown in Fig. 4a.

3.2 *The vertical component*

3.2.1 *The external and internal parts*

From Eqs. (1) and (2), the external part of the vertical component is derived as

$$Z_e(x) = \frac{\mu_0}{2} J_0^j F_z(x - x_j, h) + C \sin [k(x - x_0)] \qquad (6)$$

with

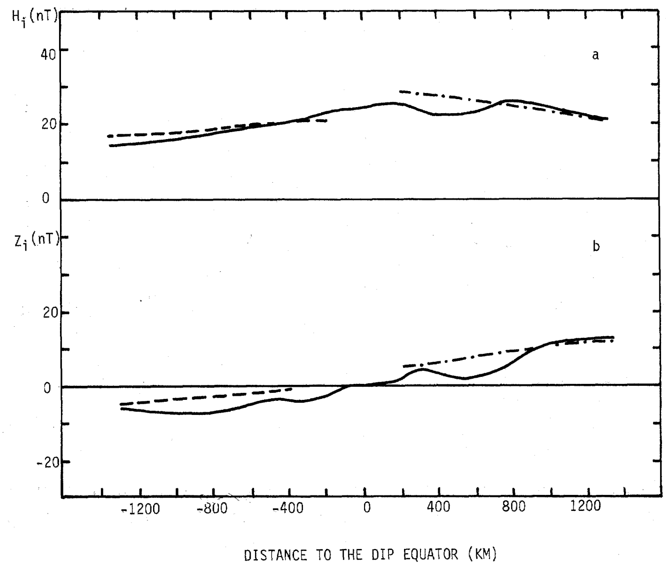

Fig. 4. a) The horizontal and b) the vertical component of the internal part. Solid curve: obtained from the measured total field. Dashed curve: computed for $p = 1000$ km. Dot-dashed curve: computed for $p = 500$ km.

$$F_z(x - x_j, h) = -\frac{1}{\pi}\left\{\frac{1}{2}\left(1 - \frac{x^2}{D^2} + \frac{h^2}{D^2}\right)\ln\frac{(x - x_j + D)^2 + h^2}{(x - x_j - D)^2 + h^2} + \frac{2(x - x_j)}{D} - \frac{h(x - x_j)}{D^2}\left(\operatorname{arctn}\frac{x - x_j + D}{h} - \operatorname{arctn}\frac{x - x_j - D}{h}\right)\right\}. \quad (7)$$

Z_e is obtained from Eq. 6 with the values of the parameters found in the previous section. By substracting this part from the total vertical component (Fig. 1b) the internal part, Z_i, is obtained (Fig. 4b).

3.2.2 Analysis of the internal part

Using the two-layer conductivity model, the vertical component of the magnetic field induced by the current system given by Eqs. (1) and (2), is obtained as

$$Z_i(x) = -\frac{\mu_0}{2} J_0^j F_z(x - x_j, h + 2p) - Ce^{-2kp}\sin[k(x - x_0)] \quad (8)$$

with F_z given by Eq. 7.

The field computed using this equation and the value of p found in the previous section is shown in Fig. 4b.

4. Discussion

A good agreement between the horizontal component of the computed induced field (with $p = 500$ km) and of the internal part of the g.d.v. in the interval (600 km, 1300 km) north of the dip equator is clearly seen in Fig. 4a. In the southern interval (-1200 km, -400 km) the agreement is not so good and it seems that within this interval the depth of the non-conducting layer increases slightly to the south, having an average depth at least twice as large as that in the northern interval. Therefore a sharp latitudinal gradient in p is localized in the interval (-400 km, 600 km) around the dip equator.

The agreement for the internal part of the vertical component (see Fig. 4b) is also better in the northern than in the southern interval, which confirms the existence of such discontinuity in the depth of the non-conducting layer in Central Africa.

This result is similar to the one found in the Peruvian zone (OSELLA and DUHAU, 1982) where the discontinuity in the depth was found to be localized in the interval (-700 km, 800 km) around the dip equator, although there p is larger to the north (450 km) than to the south (150 km).

The model used here is very simple; nevertheless, since the upper layers of the mantle would have much lower conductivity than the deeper ones, the contribution to the total field due to the currents induced in the upper layers is unlikely to be

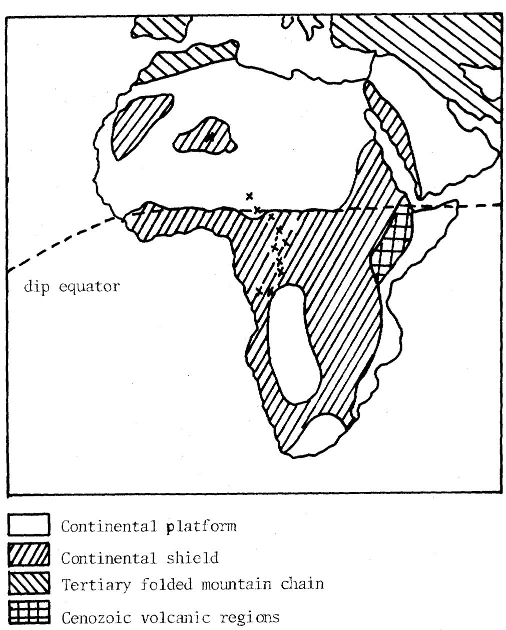

Fig. 5. Simple tectonic map of Africa (from WYLLIE, 1971). The crosses indicate the position of the geomagnetic stations.

remarkable for low frequencies with which we are concerned (DUHAU and ROMANELLI, 1980), and so the present model will be a reasonable one.

Figure 5 shows a simple tectonic map of the African equatorial zone, in which the position of the geomagnetic chain is indicated. The discontinuity in p may be associated with the presence of a transition between the continental platform to the north of the dip equator and the continental shield to the south. Moreover, the fact that a good agreement is not found at the south may be due to the proximity of a zone of continental platform there.

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