Migration of the dip equator in the Indian region

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Abstract. The position of the dip equator (DE) is worked out in the Indian region based on fairly close geomagnetic measurements made during a survey in the year 1981. The DE is located about 24 km south of its 1971 position along the 77°5'E meridian. Also, the DE positions for the epochs 1971 and 1981 show closeness on the east coast of India when compared to its west coast positions. The DE positions inferred from the repeat observations since 1909 are used for estimating the pattern of migration and the results are discussed.

Keywords. Dip-equator; migration; geomagnetic measurements.

1. Introduction

The geographic setting of India is unique in that the northern focus of the Sq current system and the magnetic dip equator, which are manifestations of the geomagnetic field of external and internal origins respectively, are located in the sub-continent. Seasonal movement of the Sq-focus is known to affect the geomagnetic field variations at low latitudes (Tarpley 1973).

The equatorial ionospheric currents during daytime are concentrated over the magnetic dip equator and the associated geomagnetic phenomena are enhanced near the dip equator (Sugiura 1953; Yacob 1966; Sastri and Jayakar 1970 etc.). Also, the causes for other related phenomena like counter electrojet (Rastogi 1974), generation and enhancement of the negative impulse before a positive sudden commencement SSC (— +) at stations near the magnetic equator (Rastogi and Sastri 1974), etc., are sought for in the equatorial ionospheric region. Thus it becomes essential that the position of the dip equator be determined precisely from time to time.

The long-term shifts of the dip equator in the Indian region have been studied earlier, among others, by Chatterjee (1970), Sanker Narayan and Ramanujachary (1971), IIG, NGRI and SOI (1972) and Srivastava and Habiba Abbas (1977). These studies were based on either magnetic charts, data from a few repeat stations, or on magnetic recordings at a few equatorial stations in selected longitudinal zones. For the first time magnetic field measurements at about 30 stations with near-zero dip values over different longitudinal zones have been used by us in determining the latest position of the dip equator, the details of which are presented here.

2. Data and analysis

A magnetic survey was conducted in south India during early 1981 for delineation of subsurface geological structures and for accurate determination of the position of the

dip equator. Absolute values of the total field (F) and its vertical component (Z) were measured, using a proton precession magnetometer (PPM) and a digital fluxgate magnetometer respectively at 520 stations with a spacing of 8 to 10 km. The stations were so chosen as to attain even distribution over different longitudinal zones, as far as possible, over an area of about 42000 km² lying to the south of 10°N geographical latitude. Care was taken to avoid observations on disturbed days.

From the F and Z observations at each station the horizontal component (H) values were computed. The H and Z data were then corrected for the diurnal magnetic variation, using the hourly values at the magnetic observatories at Trivandrum, Etaiyapuram and Annamalaiagar. The abbreviations and geographic coordinates of the observatories and other places mentioned in this note are given in table 1. The hourly values on each day of the field work were harmonically analysed and values for each minute of the day were computed. While correcting the H -data, the H -ranges at the time of observation at each of the field stations were computed at ANR and TRD, with respect to the pre-dawn field level. The diurnal ranges at the latitudes of each station were obtained by interpolating between the corresponding H -ranges at ANR and TRD, for stations in between the two observatory latitudes. With the availability of Z -data from ETP, the Z -ranges at each of the station latitudes were obtained by interpolating between the Z -ranges at the respective observation times at TRV and ETP for the stations located between the two; and between the corresponding Z -ranges at ETP and ANR for the stations north of ETP. For stations lying to the south of TRD, the diurnal H and Z ranges at the respective observation times at TRV were assumed to be valid in view of the earlier comparative studies of the diurnal characteristics at TRD and Kanyakumari by Murty *et al* (1975). The station values thus corrected for diurnal variations, now represent the main magnetic field, essentially of internal origin, at the station locations.

From these corrected H and Z values the magnetic inclination (dip) at each station was computed. The field stations with dip angles between -0.1° and $+0.1^\circ$ are marked on the map and a line drawn joining the stations with near-zero dip values (figure 1).

3. Results and discussion

Based on isomagnetic charts and repeat magnetic observations at field stations Chatterjee (1970) pointed out that the magnetic equator in the Indian region had shifted towards south from the year 1909 to 1920 and from then on it steadily shifted

Table 1. Coordinates of the observatories and other places mentioned in the text.

Observatory	Abbreviation	Geog. latitude (N)		Geog. longitude (E)	
Trivandrum	TRD	8°	29'	76°	57'
Etaiyapuram	ETP	9°	09'	78°	00'
Kodaikanal	KOD	10°	14'	77°	28'
Annamalaiagar	ANR	11°	22'	79°	41'
Alibag	ABG	18°	38'	72°	52'
Tirunelveli		8°	44'	77°	43'
Sankerankovil		9°	10'	77°	31'
Mandapam		9°	17'	79°	08'

Figure 1. Positions of DE for the epochs, 1971 by IIG, NGRI and SOI, 1980 as computed from MAGSAT spherical harmonic coefficients, and 1981 survey results reported in this communication.

northward and in 1965 the dip equator passed very near Tirunelveli. Sanker Narayan and Ramanujachary (1971) showed that the dip equator was located to the north of Tirunelveli during 1970, based on a vertical magnetic survey, along 4 N-S profiles. Based on IGRF model, Cain (1969) showed that for the epoch 1970, the dip equator in India passed further north, *viz.* north of Sankerankovil. Later, the results of a joint geomagnetic survey during 1971, by IIG, Bombay, NGRI, Hyderabad and SOI, Dehradun (1972) showed that the dip equator passed very close to 9°N (geog. lat.) on the longitude 77.5°E for the epoch 1971. The recent study, by Srivastava and Habiba Abbas (1977), of the secular variation of Z at the Indian equatorial stations *viz.*, ANR, TRD and KOD suggests that the dip equator migrated to the south from 1968 onwards, though the actual estimates for 1970 and 1971 mentioned earlier, indicate a northward movement up to 1971. The latest position determined for the epoch 1981 based on at least 30 equatorial stations with near-zero dip values, distributed over different longitudinal zones, is about 24 km to the south of the 1971 position along the 77.5°E longitude. Also, the inclination of the present dip equator to the 9° parallel is at variance with that of the 1971 dip equator, the values being 13° and 7° respectively. Thus, the two dip equators are closer on the east coast as compared to the west coast (figure 1). The position of the dip equator since 1909, as determined by various workers, is shown in figure 2, which includes the present estimate. The repeat observations of magnetic inclination made by Chatterjee (1970) at the equatorial stations of Mandapam and Tirunelveli are plotted in figure 3. The sense of movement of the dip equator as per figures 2 and 3 is in accordance with the secular variation of Z at equatorial stations.

Cain (1969) estimated the northward movement of the dip equator in the Indian region to be 2.2 to 3.3 km/year, whereas the later estimate (Report 1972) put it at 5 km/year. The present rate of southward migration works out to be 2.4 km/year. The dip values are also estimated at the survey stations by substituting the coefficients in the spherical harmonic expansion. The thirteenth degree and order spherical harmonic coefficients derived using MAGSAT data (Langel *et al* 1980) are used for calculation. The

Figure 2. Position of DE at 77.5° longitude since 1910.

Figure 3. DE migration inferred from the repeat observations of inclination at Mandapam and at Tirunelveli since 1909.

calculated equator lies close to the observed dip equator and both intersect at 8° 42.5' N lat. and 77° 15' E long.

The station locations with near-zero dip values (figure 1) are spread over a region of about 10' in latitude (18 km approximately) signifying that, in India there appears to be a dip-equatorial belt, rather than a single linear dip equator; though a straight line representation is shown in figure 1, as a first approximation.

However, one has to bear in mind that part of the scatter observed could have been caused by (a) the observational errors and (b) the errors involved in correcting the data for diurnal variation, in spite of the best possible care taken to minimize these errors.

Also, there could be a contribution by the different subsurface geological setting at different station locations.

Further, it is noteworthy that if the present trend of southward migration (figure 2) of the dip equator continues, it would reach its 1909 latitude by the year 1990, apparently representing one full cycle of migration in the Indian region with its mean position approximately at $8^{\circ} 35' \text{ N. Lat.}$ with a periodicity of about 80 yr as pointed out by Srivastava and Habiba Abbas (1977). This coincides with the known 80 yr spectral peak in the secular variation of the geomagnetic field at Alibag (Bhargava and Yacob 1970).

Thus, presently the dip equator is migrating southward as a direct consequence of the secular variation of the magnetic field components observed at the surface of the earth, which is believed to be related to the core dynamics.

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