TOTAL ELECTRON CONTENT OF THE IONOSPHERE OVER THE MAGNETIC EQUATOR*

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Abstract

Total electron content of the ionosphere (N_t) at Kodaikanal (dip 3·4° N, Geogr. longitude 77° E) is measured using the faraday rotation of the 40 MHz signals from the low orbiting beacon satellites explorer 22 and 27 during the period November 1964 to December 1966. The diurnal variation of N_t is compared with the diurnal variation of the maximum electron density in the F region, N_m. The noon bite-out which is present in N_m is not seen in N_t. The latitudinal variation of N_t, obtained by combining the observations at Kodaikanal and Ahmedabad indicate the presence of the equatorial anomaly in N_t with peak around 15° dip latitude. The results are discussed in relation to the observations at other equatorial stations in African and American sectors. The latitudinal anomaly in neutral density is suggested to play a role in the latitudinal variation of N_t.

Introduction

THE equatorial ionosphere is characterised by the well-known F_2 anomaly, *i.e.*, the latitudinal variation of the midday value of f_0F_2 shows a bite-out at the dip equator and the daily variation of f_0F_2 at equatorial station shows a bite-out around noon. The wide network of the ionospheric sounding stations has provided understanding of both the latitudinal as well as the diurnal anomaly of the F_2 region under different geophysical conditions. The radio beacons on-board satellites have provided a useful method of computing total columnar electron content in the ionosphere (TEC). The measurements of TEC at Huancayo by Blumle (1962), and at Ibadan by Olatunji (1967), showed no noon bite-out. Rufenach *et al.* (1968) analysing faraday rotation records of the 54 MHz signals from the Transil 4–A satellite at Bangkok showed that TEC increased monotonically from the morning till noon or early afternoon hours while the peak electron density (N_mF_2) showed the midday dip and late afternoon maximum (for the low sunspot considered). Combining the observations at Hong Kong, Bangkok and Singapore, they found that latitudinal variation of TEC during the daytime showed distinct trough over the equator with peaks at about ± 30° magnetic dip. Rastogi *et al.* (1973), combining the observations at Thumba and Ahmedabad, showed distinct development of the latitudinal anomaly in TEC with time after 06 hr and its vanishing after 20 hr, but no diurnal anomaly in TEC was evident over Thumba. It may be mentioned that other authors have suggested the midday bite-out to be present in TEC at equatorial stations, *viz.*, Skinner (1966) for Zaria (dip 2° N), Yeboah Amankwah and Koster (1972) for Legon (dip 9·4° N). However, Bandyopadhyay (1970) showed a dip in TEC at Huancayo at about 14 hr and Onwukve (1974) found a dip in TEC at Ibadan around 15 hr. With these varied data of TEC at equatorial stations, it was felt necessary to examine the faraday rotation observations at Kodaikanal (dip 3·4° N) for the low sunspot years 1964–66.

Data and Results

The recording equipment consisted of E–W oriented dipoles fed to Hammerlund communication receivers through a HF converter and the output was recorded by strip chart pen recorder. Only 40 MHz records are analyzed for the present study. Total electron contents were calculated for every minute during the pass using the total rotation method ($\Omega = K\ M\ N_T/f^2$) where the symbols have the usual meanings. Near the QT region the differential formula ($d\Omega = K\ N_T\ dM/f^2$ over short interval of time) was used. Regular ionospheric sounding records are obtained at Kodaikanal every fifteen minutes. The ionogram taken at time nearest to the time of the satellite transit at Kodaikanal was analyzed for the electron density profile using Budden's matrix method (1954) and therefrom the height of peak F_2 ionization (h_mF_2) and the peak electron density (N_mF_2) and semi-thickness (Y_mF_2) of the F_2 region were computed. Horizontal drift velocity (V_x) at ionospheric F_2 region was measured at Thumba using spaced receiver technique

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(Misra *et al.*, 1971) and these data are also used for comparison with other data here.

Figure 1 shows the average diurnal variation over the period 1964–66 of the parameters N_T, N_mF_2, h_mF_2, Y_mF_2 and V_h (F). The number of observations of N_T measurements for any particular hour are also indicated at the top of the diagram. The observations around midnight are very few but for the daytime hours there are sufficient observations for any of the hours.

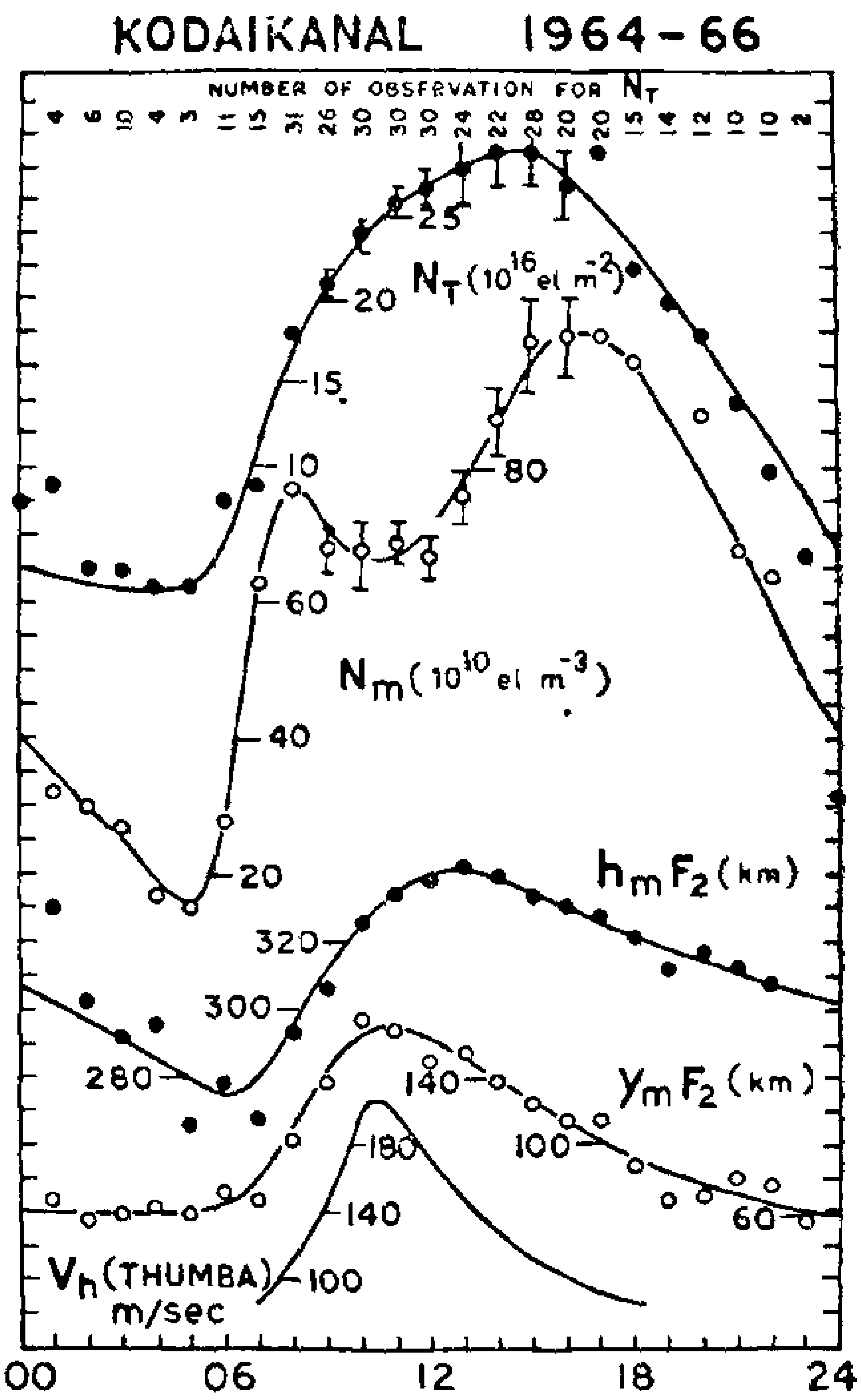

FIG. 1. Diurnal variation of total electron content (N_T), peak electron density in F_2 region (N_m), height of peak F_2 ionization h_mF_2 and semithickness Y_mF_2 of the ionosphere at Kodaikanal. Also shown is the F region horizontal drift velocity, V_h, at Thumba. Note that the maxima in V_h, Y_mF_2 and h_mF_2 and the minimum in N_m coincide fairly well in time.

The mean value of N_T shows a minimum value around 04 hr, increases sharply after sunrise reaching a peak around 15 hr, thereafter decreasing steadily till 04 hr. The diurnal ratio of N_T is about 10. There is no evidence of the midday bite-out in N_T. The N_m curve shows minimum value around 05 hr, and two maxima at 08 hr and around 16–17 hr with a bite-out around 11 hr, the diurnal ratio is about 6. The height of peak ionization h_mF_2 is minimum around 06 hr and maximum around 13 hr. The semi-thickness Y_mF_2 is maximum around 11 hr. The F region ionospheric drift velocity V_h is also maximum around 11 hr. The maxima of V_h, Y_m and minimum of N_mF_2 show clearly that the decrease of N_mF_2 is due to the electrodynamic uplift of the ionization over the magnetic equator during the midday hours.

In Fig. 2 are shown the diurnal variation of N_T at the equatorial station Kodaikanal (dip 3° N) and at tropical peak ionization region, Ahmedabad (dip 34° N) for comparison. The diurnal variation of N_T is very similar at both the stations the maximum being around 14–15 hr. local. However, the values of N_T are reasonably larger at Ahmedabad than at Kodaikanal between 11 and 16 hr.

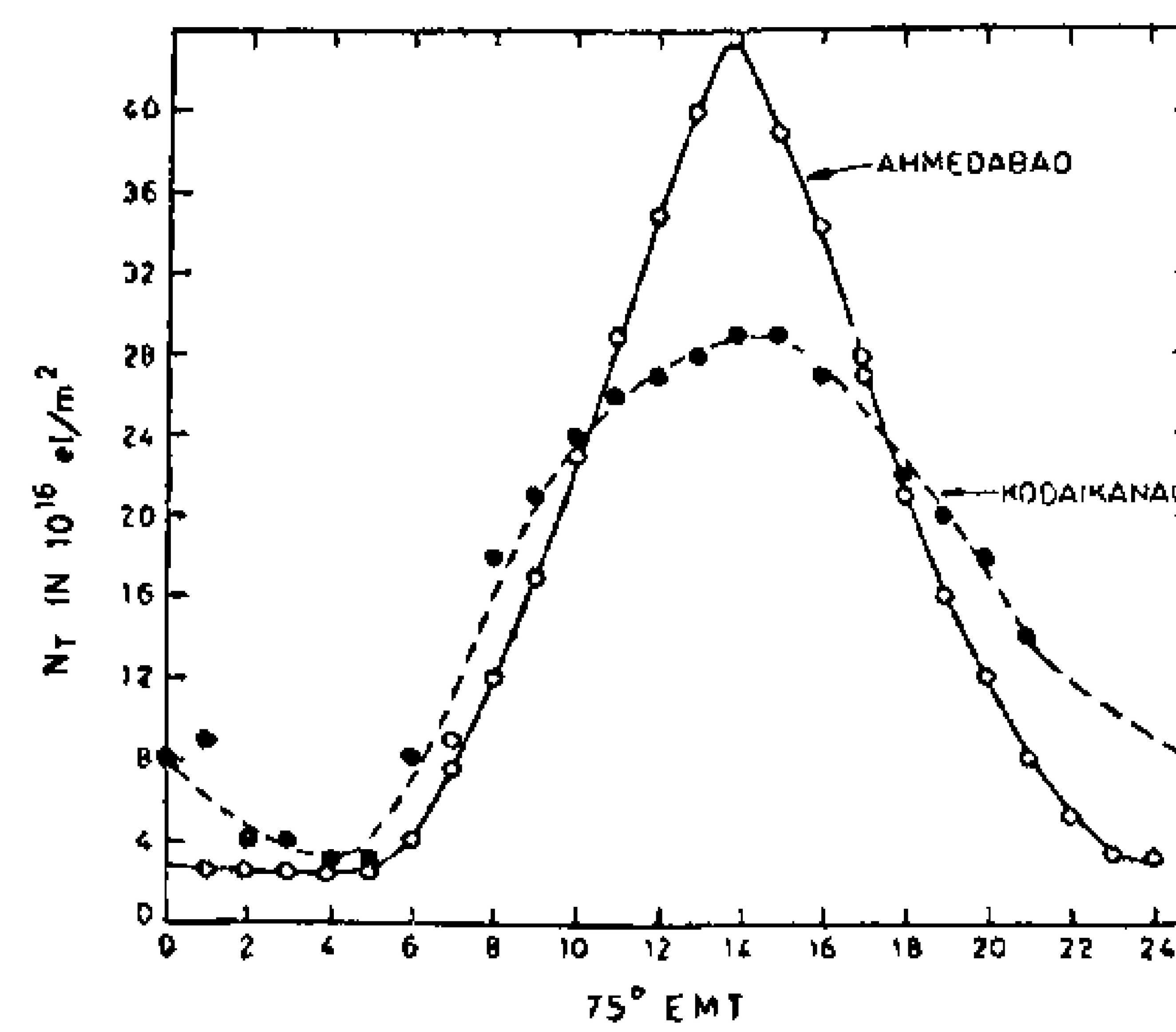

FIG. 2. Comparison of diurnal variation of N_T at Kodaikanal (closed circles and broken line) with that at Ahmedabad (open circles and continuous line), indicating the depletion of ionization at Kodaikanal around noon relative to Ahmedabad.

From a particular station the satellite goes through about 15° latitude during the useful recording period and so by combining the results of the same passes at the two stations one can get the latitudinal variation of N_T from the geographic equator to 30° N latitude. The latitudinal variation of TEC derived from some such satellite passes common to Kodaikanal and Ahmedabad are shown in Fig. 3. We have chosen the passes around midday hours only. It is clearly seen that the value of TEC is minimum around the dip equator and is maximum between 15° and 20° dip latitude, very similar to the latitudinal behaviour of N_mF_2.

Thus it is confirmed that at least in the Indian zone during low sunspot years the N_T does show the latitudinal anomaly but the diurnal anomaly is not evident over the magnetic equator.

The diurnal as well as the latitudinal anomaly in $N_m F_2$ is supposed to be the consequence of the so-called "fountain effect" ; the ionization over the magnetic equator is lifted up by the $\vec{E} = \vec{B}$ force during the daytime and later the ionization diffuses to tropical latitudes along the magnetic lines of force. If it is wholly true then the daily and latitudinal variations of both N_T and N_m should be very similar to each other. The absence of the daily anomaly of N_T at the equator but the presence of latitudinal anomaly of N_T during midday hours suggests some modifications of the classical theory. First the excess ionization around dip ± 30° may be due to the accumulation of ionization over a large volume of the equatorial ionosphere ; at a particular station in the equatorial zone the transport of ionization away from the region is too small to produce a midday bite-out in N_T.

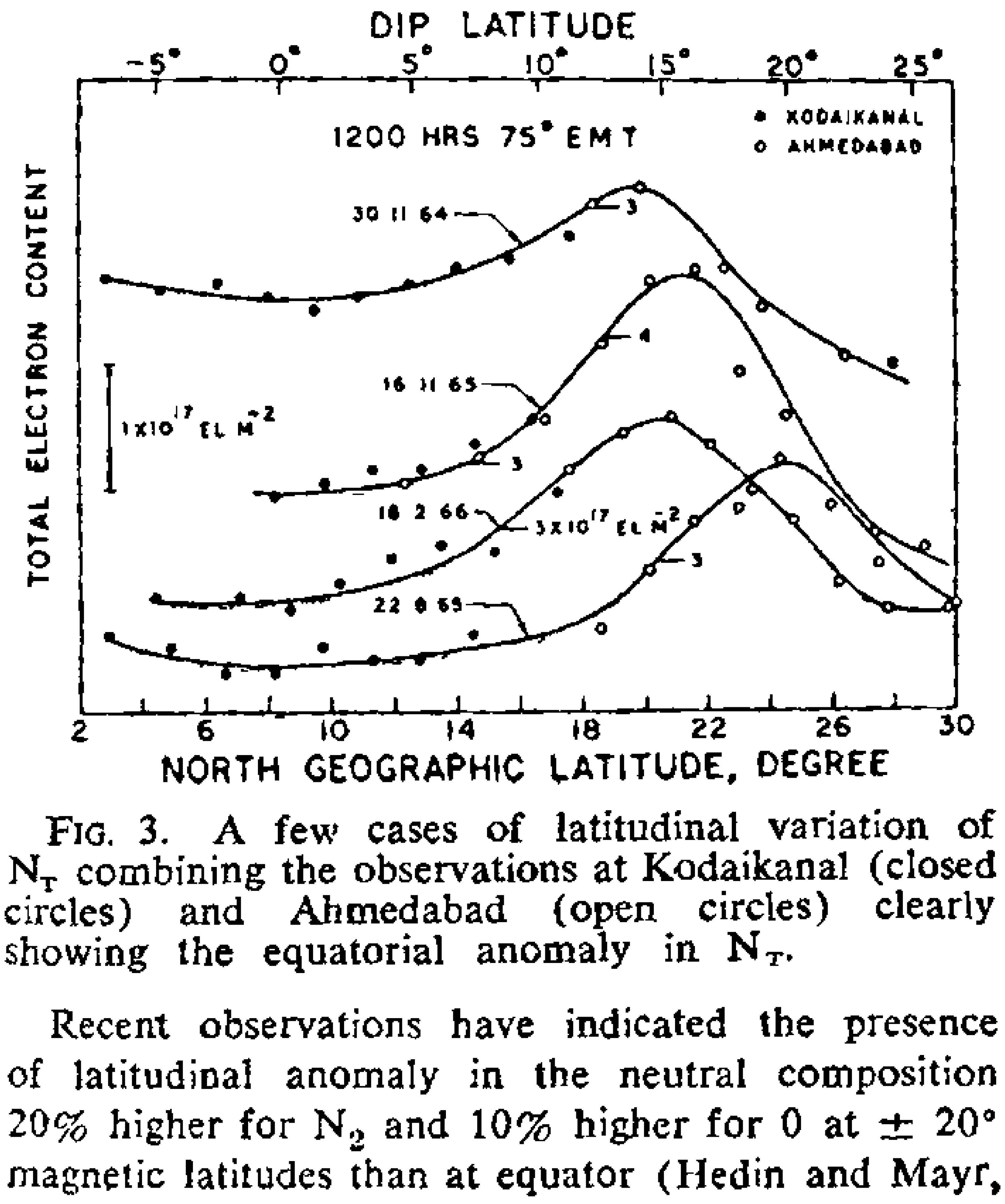

FIG. 3. A few cases of latitudinal variation of N_T combining the observations at Kodaikanal (closed circles) and Ahmedabad (open circles) clearly showing the equatorial anomaly in N_T.

Recent observations have indicated the presence of latitudinal anomaly in the neutral composition 20% higher for N_2 and 10% higher for 0 at ± 20° magnetic latitudes than at equator (Hedin and Mayr, 1973 ; Newton and Pelz, 1969 ; Anderson, 1966). Chandra and Goldberg (1964) had theoretically indicated the geomagnetic control of neutral density in the lower F-region when the ion-neutral interaction is dominant. This brings to question if the ionization anomaly is wholly due to the transport and diffusion of ionization or the neutral anomaly has a major share in the equatorial anomaly of the ionization. It is also felt that the daily variation of N_T at the equator may have large day-to-day and seasonal variation such that the daytime bite-out in N_T is not evident on averaging. The measurement of N_T at a number of equatorial stations using the beacon signals from a geostationary satellite would greatly help solving the problem of the equatorial anomaly. The forthcoming positioning of the ATS-6 satellite at 35° east longitude would provide a unique opportunity to Indian scientists. It may be mentioned that the recording of the faraday rotation of 137 MHz beacon signals from Syncom III Satellite at Trichy (dip 4·8° N) have shown to us that this method is not very useful at these latitudes (Deshpande, 1975—private communication). It is therefore stressed that the measurements of N_T at low latitude should be done using group delay method rather than by the Faraday rotation method.

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