Effect of electrojet on the total electron content of the ionosphere over the Indian subcontinent

THE radio beacon method of measuring TEC along a chain of optimally spaced stations near the equatorial anomaly has been used to monitor continuously the latitudinal extent of the anomaly. Comparisons with the magnitude of the electrojet show a clear dependence of anomaly strength upon the electrojet intensity with an approximate two-hour time delay.

Anomalous latitudinal distribution of electron density in the F2 region, often referred to as the equatorial anomaly, was found by Appleton[1]. The diurnal development of the equatorial anomaly has been studied by Rastogi[2]. Dunford[3] showed that the equatorial anomaly in the topside ionosphere is correlated with the E region current system near the magnetic equator. With the development of the satellite radio beacon technique numerous workers[4-9] studied the Appleton anomaly in total electron content (TEC) of the ionosphere with greater spatial resolution, but with poor temporal resolution, as only a few passes per day of the low orbit satellite could be received. Iyer *et al.*[10] showed that the equatorial anomaly in TEC over India is positively correlated with the electrojet strength. The diurnal development of the equatorial anomaly in TEC is presented here for the first time; and, along with magnetometer records which indicate the strength of the equatorial electrojet, the TEC anomaly is shown for three days in May 1976. The equatorial anomaly in TEC was continuously monitored over the Indian subcontinent using radio beacon signals from the geostationary satellite ATS-6, received at many locations in India, namely: Bombay (19.8°N, 69.8°E), Rajkot (20.8°N, 67.7°E), Ahmedabad (21.5°N, 69.4°E), Udaipur (22.9°N, 70.2°E), Jaipur (25.1°N, 71.9°E), and Patiala (28.2°N, 72.1°E). Coordinates given are 350-km intersections along the ray path to the ATS-6 satellite. Details of the stations in the Indian subcontinent measuring TEC using ATS-6 beacon transmissions have been given by Iyer *et al.*[11].

The diurnal development of the equatorial anomaly in TEC and its association with electrojet strength are clearly shown in Fig. 1. Three typical cases are chosen: (1) a normal electrojet day, 18 May 1976, $A_p=3$; (2) a counter electrojet day, where the counter electrojet occurred in early afternoon, 12 May 1976, $A_p=7$, and (3) a geomagnetically disturbed day, 3 May 1976, $A_p=94$. For all three days the horizontal component of the magnetic field (*H*) for an equatorial station, Kodaikanal, dip 3.4°N, are also shown. The magnetic field during daytime is a representative indication of the electrojet strength. In addition TEC plots against latitude are shown for different local times of the day. On a normal electrojet day the magnetic field shows a flat minimum night value (Fig. 1*a*). After sunrise the electron density in the E region increases and the *H* field shows a steady increase until around 1100 h, after which it starts decreasing. Such behaviour of the magnetic field is due to the eastward electric field (*E*) during daytime. Owing to this electric field and the north–south magnetic field at the equator **E** × **B** drifts are produced and the electrons are lifted to higher altitudes. The lifting of electrons takes place up to a few scale heights above the F2 region peak, beyond which they diffuse along the lines of force and are deposited in the latitude regions of about 15° to 20° dip latitude. This process takes approximately 2 h (ref. 10) and any effects in electric fields at E region heights at the equator are seen at latitudes of 15° to 20° after an approximate two-hour delay. At 1000 h, the latitudinal profile of TEC is showing a normal behaviour with high equatorial values (Fig. 1*a*). As time progresses, at 1200 h, a weak anomaly develops with maximum TEC at Udaipur. By 1400 h more electrons have flowed along field lines to Udaipur and the anomaly is well developed. The process continues until evening and a clear maximum is still seen at 1730 h at Udaipur on this normal electrojet day.

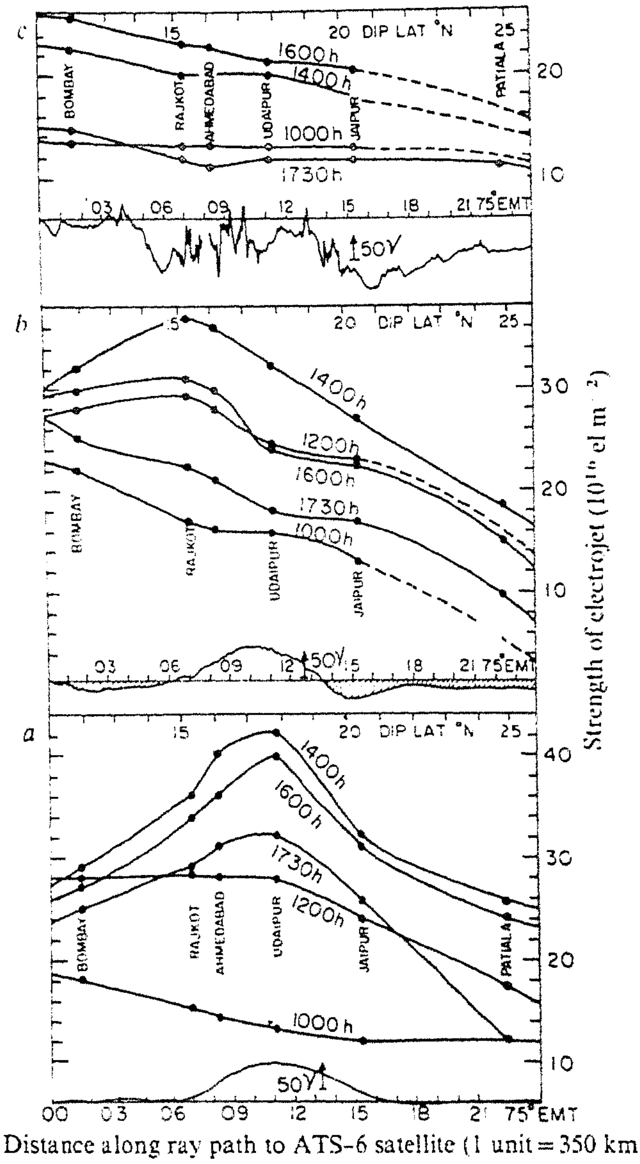

Fig. 1 Diurnal development of equatorial anomaly and strength of electrojet. *a*, Normal electrojet day. Note that the anomaly is fully developed during afternoon hours. *b*, Counter-electrojet day, where anomaly is reduced during afternoon hours. *c*, Disturbed day, where anomaly is not at all developed.

The *H* component of the equatorial magnetic field shows the start of a normal electrojet in the forenoon hours (Fig. 1*b*). However, at approximately 1340 h the direction of the *H* component reverses and a counter electrojet has begun. The latitudinal profiles of TEC for several times on 12 May show a small latitudinal anomaly at 1200 h, reaching a maximum at 1400 h, at the Rajkot ionospheric intersection point (Fig. 1*b*). But, by 1600 h, and later at 1730 h, there is little, if any, trace of the anomalous latitudinal behaviour in TEC, due to the counter electrojet which developed in early afternoon. The reversal of the electric field causes downward drift motion at the equator and the movement of ionisation to the latitude range of 15-20 becomes ineffective. The approximate two-hour delay between the start of the counter electrojet and the near-end of the latitudinal TEC anomaly is clearly seen in Fig. 1*b*.

Data for a highly geomagnetically disturbed day, 3 May 1976, are also shown (Fig. 1*c*). On this day the electrojet does not occur and the transfer of ionisation from the equator to higher latitudes does not take place to any noticeable extent.

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[1] Appleton, E. V. *J. atmos. terr. Phys.* 5, 348 (1954).
[2] Rastogi, R. G. *J. geophys. Res.* 64, 727 (1959).
[3] Dunford, E. *J. atmos. terr. Phys.* 29, 1489 (1967).
[4] Basu, S. & Das Gupta, A. *J. Geophys. Res.* 73, 5599 (1968).
[5] Titheridge, J. E. & Smith, W. D. *Planet. Space Sci.* 17, 1667 (1969).
[6] Mendonca, F. de, Cantor, I. J. & Clemesha, B. *Low Latitude Ionospheric Electron Content Measurements During Half a Solar Cycle Relat. Cient*, LAFE-84 Lab de Fiscica, Espacial Sao Jose dos Campos, Brazil (1969).
[7] Golton, E. & Walker, G. O. *J. atmos. terr. Phys.* 33, 1 (1971).
[8] Rastogi, R. G., Sharma, R. P. & Shodhan, V. *Planet. Space Sci.* 21, 713 (1973).
[9] Rastogi, R. G. & Rajaram, G. *Ind. J. Pure appl. Phys.* 9, 531 (1971).
[10] Iyer, K. N., Deshpande, M. R. & Rastogi, R. G. *Proc. Ind. Acad. Sci.* 84, 129 (1976).
[11] Iyer, K. N., Deshpande, M. R., Sethia, G. & Rastogi, R. G. *Proceedings of the Workshop on Beacon Satellite Studies*, Physical Research Laboratory, Ahmedabad, pp. 64-86, Dec. 1976.