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A first order regional model of IEC derived from ionosonde measurements for application in radio astronomy

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Abstract A regional model of ionospheric total electron content (IEC) over the Indian low latitude region is presented. Applying a set of diurnal and seasonal coefficients to observe data, maps of critical frequency of the F2 layer (foF2) are first prepared for low, medium and high solar activity periods. These maps are then converted into maps of IEC by deriving vertical height profiles of electron density. The simulated maps compare well with observed data

Keywords IEC, foF2, regional model

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In radio astronomy, ionospheric Faraday rotation may affect polarisation observations carried out with single dish instruments. The ionospheric refraction effect is visible as a position shift of the celestial radio source and a change in its structure. For high quality astrometry and imaging, knowledge of the probability and severity of these effects is desirable. A climatological knowledge of ionospheric electron density variations is, therefore, essential. To derive correction factors from ionospheric observational parameters, some models are generally used. Using the voluminous ionospheric data available from ionosonde stations in the Indian zone, a regional model of foF2 was developed and reported earlier by Bhuyan and Baruah [1]. In this communication, we present a method to convert the foF2 to IEC at any location from equatorial to low mid-latitudes under all levels of solar activity.

The foF2 data collected at the near equatorial station Tiruchirapally (10.8°N, 78.7°E; mag.dip 4.8°N), low latitude station Hyderabad (17.3°N, 78.5°E; mag.dip 19.4°N), anomaly crest location Ahmedabad (23.0°N, 72.6°E, mag.dip 34°N) and the low mid-latitude station Delhi (28.6°N, 77.2°E; mag.dip 42.4°N) during the period 1960 to 1984 form the database. Monthly mean foF2 for all months having average $F_{10.7}$ solar flux value of less than 200 and for all stations are subjected to a harmonic analysis to derive latitudinal contours of foF2 for low ($F_{10.7} = 75$), moderate ($F_{10.7} = 150$) and high ($F_{10.7} = 200$) solar activity periods. Details of the procedure adopted are given in Bhuyan and Baruah [1]. The foF2 data are then converted to IEC by assuming a Chapman layer electron density profile from an altitude of a scale height below hmF2 to the top of the ionosphere :

$$N(z) = Nm\mathrm{F2}.\exp.\,[1-z-\exp(-z)] \quad (1)$$

$$z = (h-hm\mathrm{F2})/H \quad (2)$$

NmF2 is the maximum density of the F2 region; H is a scale factor assumed independent of latitude and altitude in the topside F-region and hmF2 the height of maximum electron density obtained following [2] as

$$hm\mathrm{F2} = [1346.92 - 526.4 \times M(3000)\mathrm{F2} + 59.825 \times \{M(3000)\mathrm{F2}\}^2] \times 10^3 \text{ metre}, \quad (3)$$

where M (3000)F2 = MUF(3000)F2/foF2 [ref. 3] and

$$Nm\mathrm{F2} = 1.24 \times (\mathrm{foF2})^2. \quad (4)$$

Following the procedure adopted by [3], the electron density around the E region is modelled as

$$N = NmE \exp.\,[h-110)/s], \quad (5)$$

where NmE and s are functions of local time, latitude and solar activity. From the analysis of past data from several ionosonde stations, the value of Nm and s can be predicted for a given set of conditions.

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The M (3000) F2 factor was obtained from published ionospheric data sources. Figure 1 shows the scheme of building the vertical electron density profile. The vertical electron density profile is then integrated using numerical procedure to obtain IEC.

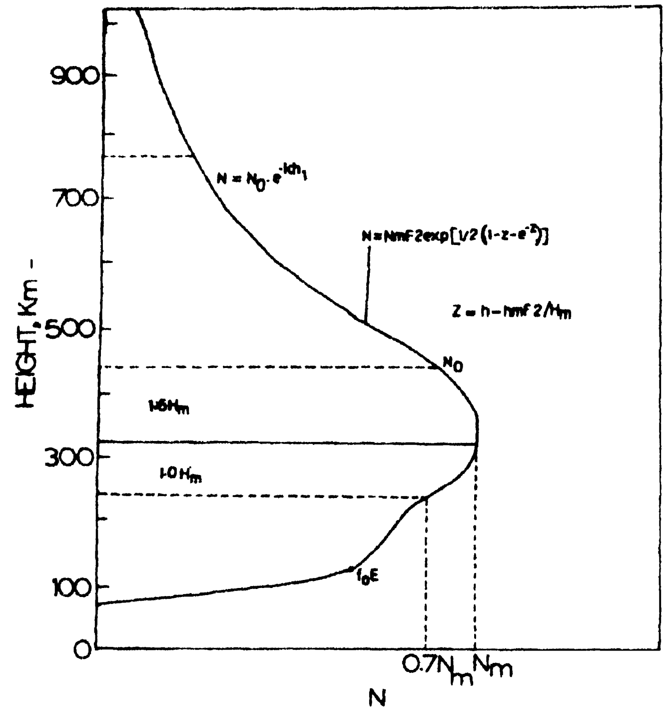

Figure 1. Scheme of building the vertical electron density profile

Figures 2–4 are the 3-D contours of IEC over the Indian zone computed for solar minimum, moderate solar activity

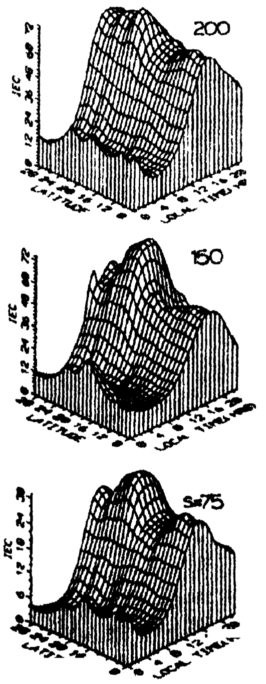

Figure 2. 3-D plot of IEC under three level of solar activity for winter

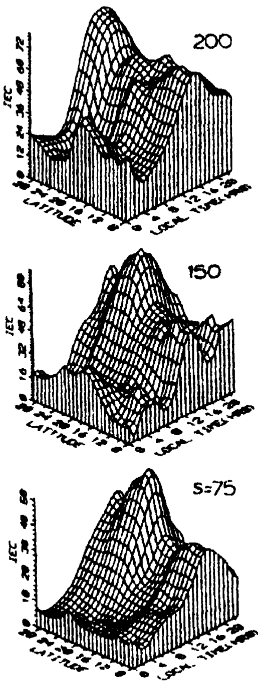

Figure 3. 3-D plot of IEC under three level of solar activity for Equinox

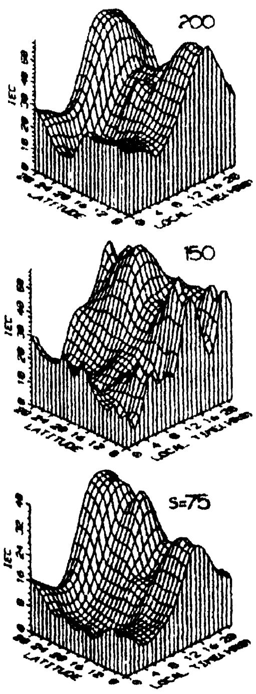

Figure 4. 3-D plot of IEC under three level of solar activity for Summer

and solar maximum. The relationship between the $F_{10.7}$ cm solar flux and ionospheric parameters such as NmF2 and IEC are reported to be non-linear under intense solar activity conditions [4,5]. Balan *et al* [6] observed that the ionosphere responds linearly to the solar EUV (and UV) inputs and nonlinearly to $F_{10.7}$ because the expected relationship between

EUV (and UV) fluxes and $F_{10.7}$ breaks down during intense solar activity conditions. Since $F_{10.7}$ was used in the present model as the solar activity indicator, mapping has been restricted to periods of solar activity corresponding to $F_{10.7}$ < 200. For periods of $F_{10.7}$ > 200, the maps for $F_{10.7}$ = 200 can be used as *Nm*F2 and IEC saturates at very high solar activity levels [4]. In Figure 5, the observed IEC in the Indian zone obtained from co-ordinated Faraday rotation measurements during ATS-6 campaign (October, 1975-August, 1976) is plotted for compariso with modelled IEC The comparisons for this low solar activity period show good agreement. However, as the model is based on foF2 data, it does not reproduce the pre-reversal enhancement observed in IEC. Viability of the model will be further tested by comparing the modelled IEC with observed data for all levels of solar activity from Delhi, Calcutta, Waltair and Bombay.

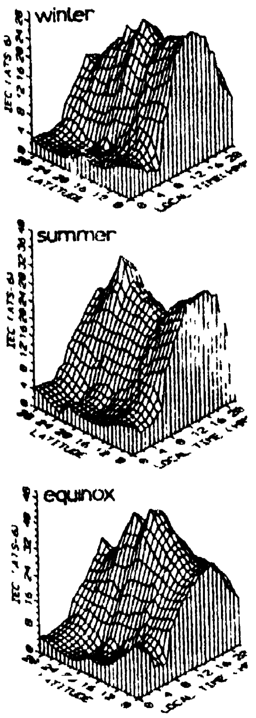

Figure 5. The observed TEC in the Indian zone obtained from co-ordinated Faraday rotation measurement during ATS-6 campaign

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