Study the Growth and Decay of Equatorial Ionization Anomaly over Indian sector by using Coherent Radio Beacon Experiment (CRABEX): A Preliminary results

***Rupesh M. Das*[1], *R. S. Dabas*[2], *Arun K. Upadhayaya*[3], *Sudha Ravidaran*[4] and *Rajneesh Sharma*[5]**

1. Radio and Atmospheric Sciences Division, National Physical Laboratory,
Dr. K. S. Krishnan Marg, New Delhi-110012, India
E-mail: rupesh@mail.nplindia.org

2. Radio and Atmospheric Sciences Division, National Physical Laboratory,
Dr. K. S. Krishnan Marg, New Delhi-110012, India
E-mail: rajdabas@mail.nplindia.org

3. Radio and Atmospheric Sciences Division, National Physical Laboratory,
Dr. K. S. Krishnan Marg, New Delhi-110012, India
E-mail: upadhayayaak@mail.nplindia.org

4. Space Physics Laboratory, Vikram Sarabhai Space Centre,
Trivandrum 695 022, India
E-mail: sudha_ravindran@vssc.gov.in

5. Master Control Facility, Indian Space Research Organization,
Bhopal, India
E-mail: sharmarajnish_23@rediffmail.com

Abstract

The trans-ionospheric communications and navigations needs to realize the dynamics of low and equatorial region ionosphere on real time basis. For this purpose a chain of three coherent radio beacon (CRABEX) receivers, for ionospheric tomography, are installed over the Indian sector along a common meridian. In the present study data from above network of stations is used to study the latitudinal variations of ionospheric TEC (Total Electron Content) over the region. The result shows day-to-day variability in the growth and decay of equatorial anomaly including the nighttime enhancement of electron density over low latitude region. The observed results are also compared with TEC value derived from the PIM and IRI-2001 models. CRABEX receivers measure the differential Doppler phase and amplitudes of 150 and 400 MHz signals from Naval Ionospheric Measuring System (NIMS) satellites. The ionospheric TEC estimation depends on the measured phase difference and initial phase offset of two coherent signals. The phase offset is evaluated by using Lietinger two-station method. The estimated TEC is then used to study its day-to-day variation over the Indian zone and the association of between the occurrence of spread-F and development of post sunset hours ionization anomaly. The result gives a clear picture of latitudinal distribution of TEC over Indian zone with time and shows that the value derived from the PIM and IRI-2001 model are over estimating from the actual observed TEC value during the day time as well as during night time. The crest of EIA (equatorial ionization anomaly) derived from the models is also differed from actual observed one.

1. Introduction

The Indian Coherent Radio Beacon Experiment (CRABEX) has been initiated for ionospheric tomography and to study the development and decay of equatorial ionization anomaly (EIA) and its latitudinal variations with local time, seasons and solar and magnetic activity changes over Indian zone. The CRABEX chain consists of five radio beacon receivers along a common meridian extend from geomagnetic equatorial station Trivandrum (8.5° N, 76.9° E) to low-mid latitude station New Delhi (28.67° N, 77.22° E) with other stations like Bhopal (23.29° N, 77.46° E), Hyderabad (17.2°N, 78.3° E) and Bangalore (12.59° N, 77.4° E) in the EIA crest region as shown in figure-1. These receivers are capable to receive 150 and 400 MHz beacon transmission from the Low Earth Orbital Satellites

(LEOS). It is known that the day-to-day variability of EIA mainly dependent upon the various parameters like intensity of ExB drift [1], geomagnetic activity level and direction of meridonal wind [2]. The CRABEX can also be useful for occurrence prediction of Equatorial Spread-F (ESF) irregularity, because the latitudinal occurrence of ESF is controlled by ExB drift and post sunset enhancement of ionization [3]. Moreover, the knowledge of latitudinal variations of TEC is useful to determine the ionospheric time delay of a radio wave in the Trans-Ionospheric communication.

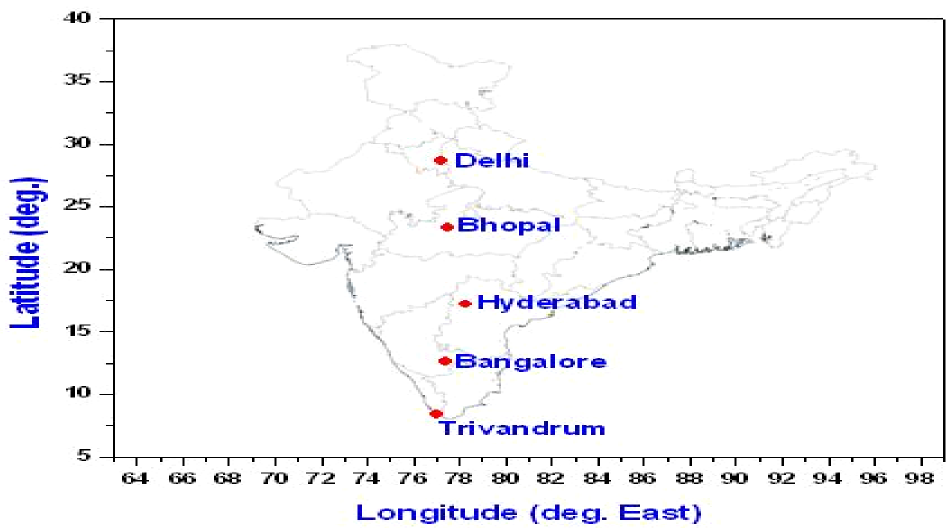

Figure-1: CRABEX receiver location over Indian Zone.

The objective of this paper is to presents the preliminary results of latitudinal variation of TEC along with growth and decay of EIA crest on day-to-day basis over Indian region. In this paper three station (i.e. Trivandrum, Bhopal and Delhi) data observed during the months of May to November 2007 are analyzed. The results are also compared with International Reference Ionosphere (IRI)-2001 model and PIM model results.

2. Data Analysis Methodology

The differential Doppler signals of 150 and 400 MHz are measured with the help of CRABEX receivers located at different locations along the 77° E meridian (±1°) to avoid the time difference. The measured value is then converted into Slant TEC value by using the equation

$$STEC = \Phi / 1.6132 \times 10^{-15} \ m^{-2} \qquad (1)$$

The value 1.6132×10^{-15} is a constant factor for NNSS satellites derived by Leitinger et al. [4] and Φ is the cumulative phase value in radians. The absolute Slant TEC is estimated by using two-station method as suggested by Leitinger [5]. This absolute slant TEC is then converted into vertical TEC (VTEC) at the ionospheric pierce point using the expression:

$$VTEC = ASTEC \times \sqrt{(1- (R_E \times \cos(E))/(R_E + hpp)} \qquad (2)$$

Where VTEC is vertical TEC, ASTEC is absolute slant TEC, R_E is the radius of earth, E is the elevation angle of satellite and hpp is height of ionospheric pierce point. Since the experiment is conducted over equatorial and low latitude region, the hpp value is considered as 300 km.

3. Results and Discussion

For better study the observed results are divided into two parts. The first part deals with the day-to-day variation of TEC and movement of EIA crest over Indian zone. The second part deals with the night-time TEC distribution over Indian region during the Spread-F and no Spread-F condition.

3.1 Day-to-day TEC variation and movement of EIA crest

Figure-2(a) and (b) shows the day time TEC variation and movement of EIA crest over the Indian latitude region from 0° N to approximately 40° N. Figure-2 (a) shows the latitudinal variations of TEC over the Indian zone under normal geophysical condition (Ap < 10) while figure-2 (b) shows the latitudinal TEC distribution over the Indian zone when the Ap > 10. Under normal geophysical condition the observed day-to-day TEC variation is almost ±5 TECU (TEC Unit) beyond the latitude 10° north which might be due to the difference in satellite pass-path. While the TEC variation is more than ±12 TECU below the latitude 10° north. It is also observed that the occurrence of EIA crest fluctuates between the latitude 12° to 15° as shown in figure-2(a) & (b) and fully developed after 10:30 Indian Standard time (IST). It is quite evident from figure-2(b) that the latitudinal TEC distribution shows the dependence of EEJ Strength and the direction of neutral wind. From figure- 2(a) and (b) it is clearly visible that the variation of TEC value and occurrence of EIA crest is different from those days when Ap<10. This might be due to variation of EEJ strength during the active geophysical parameters.

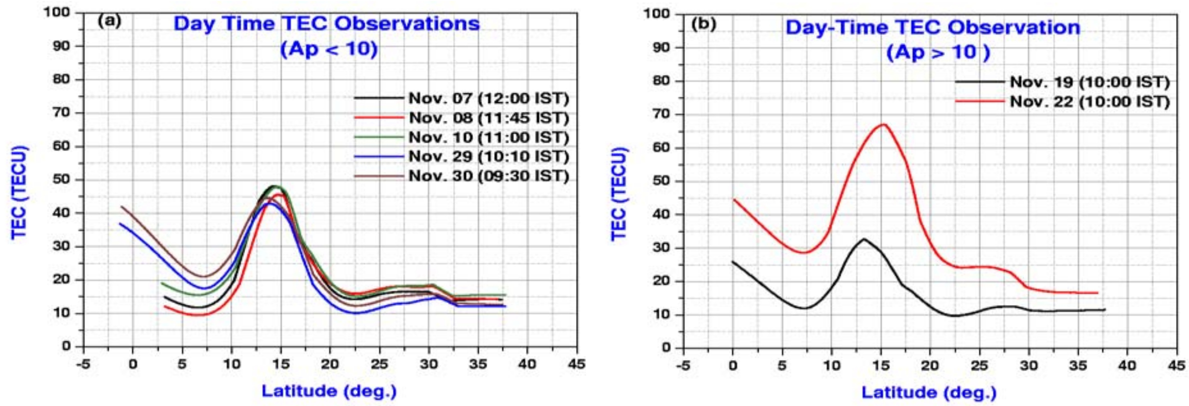

Figure-2:- Day-to-day latitudinal TEC distribution and movement of EIA crest over the Indian latitude zone. **(a)** During Ap < 10 , **(b)** During Ap > 10.

3.2 Night-time TEC distribution over Indian region during the Spread-F and no Spread-F condition.

Figure 3 (a) and (b) shows the night time TEC distribution during the Spread-F and no Spread-F conditions. From the figures it is clearly observed that the occurrence of Spread-F at different latitude is dependent on the night time TEC distribution. As shown in figure-3 (a) when the Spread-F is extended far off from the equatorial region i.e. over all the three observing station (Trivandrum, Bhopal and Delhi), a strong night-time EIA is generated (shown in red color) while the extension of Spread-F is confined over very limited i.e. up to the anomaly crest region when the night time enhancement is less intense. The figure-3(b) shows that during the no Spread-F condition the night time enhancement over low latitude region is negligible. The results clearly indicate that the irregularities are generated at equatorial region is transported to low latitude region during certain favorable conditions as explained by Dabas et. al. [3].

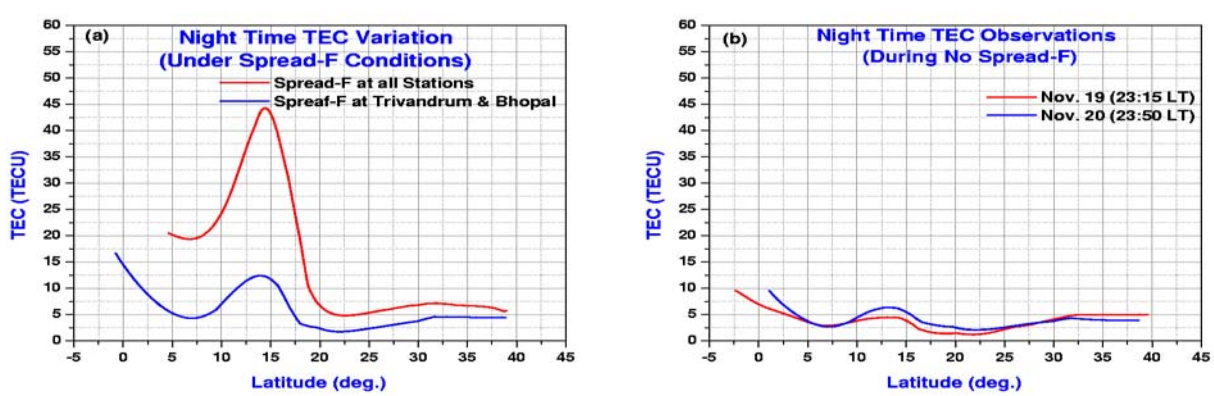

Figure: 3:- (a) TEC distribution during Spread-F conditions. **(b)** TEC distribution during no Spread-F condition.

3.3 Comparison of observed results with IRI-2001 and PIM model derived values.

Figure 4 (a) and (b) shows the comparison between observed and TEC value derived from the PIM model and IRI-2001 model. Figure-4 (a) shows the day time comparison of observed TEC value with PIM and IRI model value whereas figure- 4 (b) shows the comparison during the local midnight hours. The result shows that the actual crest of EIA is observed at 15° N latitude while it is beyond 20° N from in PIM and IRI models. This indicates that the TEC value given by PIM and IRI-2001 is over estimated.

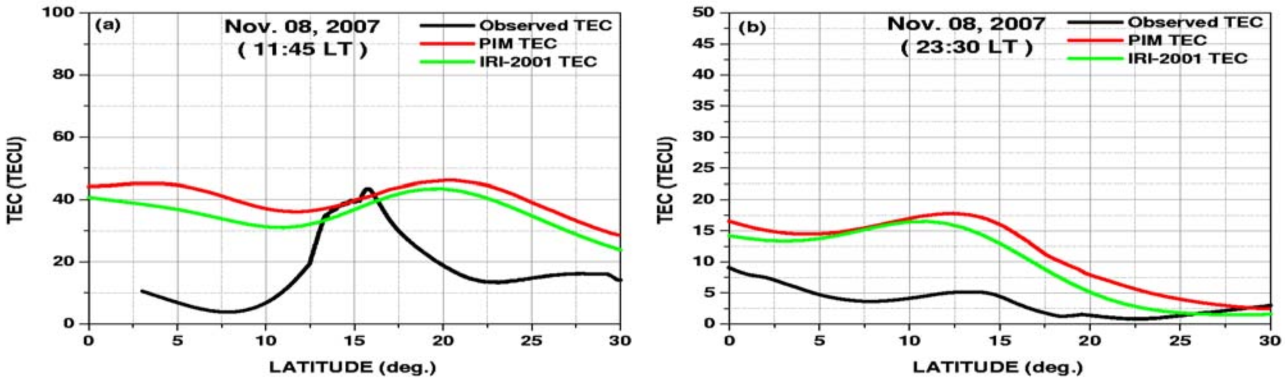

Figure: 4:- Comparison of observed TEC and occurrence of EIA crest with IRI-2001 and PIM model derived value.

4. Conclusion

The study shows that during the EIA crest appears around latitude 12° to 15°N over Indian zone and variability of TEC beyond the 10° latitude is very less but higher at equatorial belt under low solar activity and normal geophysical conditions. The result also shows that the Spread-F is only occurred at low latitude region when there is nighttime enhancement along with moderate geophysical condition. Further the observed TEC is not in accordance with the TEC values derived from PIM and IRI model. These models need modification for better accuracy during low solar activity period.

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5. References

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