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Comparative study of TEC for different solar activity

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Abstract:
The total electron content (TEC) is a vital and most dominant ionospheric parameter that can cause Global Positioning System (GPS) signal delays, signal degradation and in extreme cases loss of lock. This results into inefficient operations of ground and space based Global Navigation Satellite System (GNSS) applications. The study of TEC variability is, therefore useful for GNSS users in order to minimize errors where high levels of accuracy in measurements are required. In this study, we describe the diurnal and seasonal variations of TEC, solar activity dependence of TEC at the Tokyo (geographic coordinates: latitude 33.5°N, longitude 138.7°E).

Keywords: *Ionospheric total electron content (TEC), GPS, solar activity, IRI*

1. Introduction

Total electron content (TEC) is broadly defined as the number of free electrons in a column of unit cross-section extending through the ionosphere and above. The various ionosopheric parameters play dominant role in Communication in general and to HF Communication in particular. Various national agencies forecast the communication map, using this parameter; for this type of forecasting the modles are developed which predict the most probable value of given parameter for a given condition. The total electron content (TEC) is one such parameter which is used to predict the ionospheric condition. This study is useful to understand the basic science to modern system like G.P.S.(Global Position Satellites) technique. For this purpose the internationally recommended empirical model of the ionosphere is developed which is known as IRI (International Reference Ionosphere). The latest version of this model is published by D. Bililtza (1990) and his group. The primary aim of this model is to map critical frequency and to predict the electron density using the international network of ionosonde and other ground base techniques. A spherical harmonic analysis is performed on each set of monthly mean critical frequency over 24 hour of the day and for a sunspot number. The IRI also includes the vertical profiles of electron density, electron temperature, ion-temperature and ion-composition. The required input parameters are altitude, location, time, day, month, and solar activity. The IRI is an important contribution in ionospheric science and is adopted by the CCIR (International Consultative Radio Committee) as the basis of prediction of HF Radio propagation. The values provided by IRI are mean values and they do not include any disturbed condition or day-to-day variation.

In the present study the IRI model is used to derive the vertical profile of electron density from which the TEC is derived and compared with the observed value for a given location.

2. Data and Method of Analysis

The TEC data collected at Tokyo (35.5^0 N 138.7^0 E) Published by Minakoshi and Sinno for the years 1978, 1979, and 1980 are used. IRI (1990) model is used to derive the electron density profile for a given location, time, day, month and sunspot number. This electron density values are converted into the electron content using trapezoidal integration formula. These integrated values are then compared with the observed value. For comparison, only the international quite days are selected, because the IRI model is not suitable for the predicting the disturbed condition.

To study the solar activity dependence and its variation in observed and modeled values, the published data for the years 1978, 1979, and 1980 for Tokyo are used.IRI is based on all the important ionospheric data sources including ground-based (ionsonde, absorption, incoherent scatter) and spacecraft(Alouette,ISIS,AE, AEROS, DE, rockets) measurements. IRI provides monthly mean values for magnetically quiet condition at noon-auroral latitudes in the altitude range 50km, to 2000km.

IRI-90 differs from IRI-86 by offering several new options: (i) URSI-1989 f_0F_2 model, (ii) Gulyaeva-1987 model for F_2 bottom side thickness, (iii) Analytical LAY-representation of E-F region, (iv)Danilov-Yaichnilkov-1985 model for ion composition. IRI-90 includes also an improved representation of the f_0 Enight time variation and several technical improvements of the computer code. For more details see Bilitza (1990). In this version if IRI the neutral temperature is obtained with the CIRA-86 model replacing the CIRA-72 used in earlier versions. **Discussion and conclusion:** For comparison with IRI model, the representive international quiet day for a given month was selected. For this day the corresponding input to IRI model like latitude, longitude, mean sunspot number Rz, time and day of the month, etc., are considered and the TEC derived. To bring out the seasonal effect, January, February, November, December, are grouped as winter; May, June, July, August, are grouped as summer; March, April, September, and October are grouped as equinox months. These comparisons are shown in figure (a) through figure (c) for different season. The solid line represent the observed TEC and dashed line represent the IRI derived values, for the years 1978, 1979,and 1980. Figure (a) shows the comparison for the winter months. In general the observed and

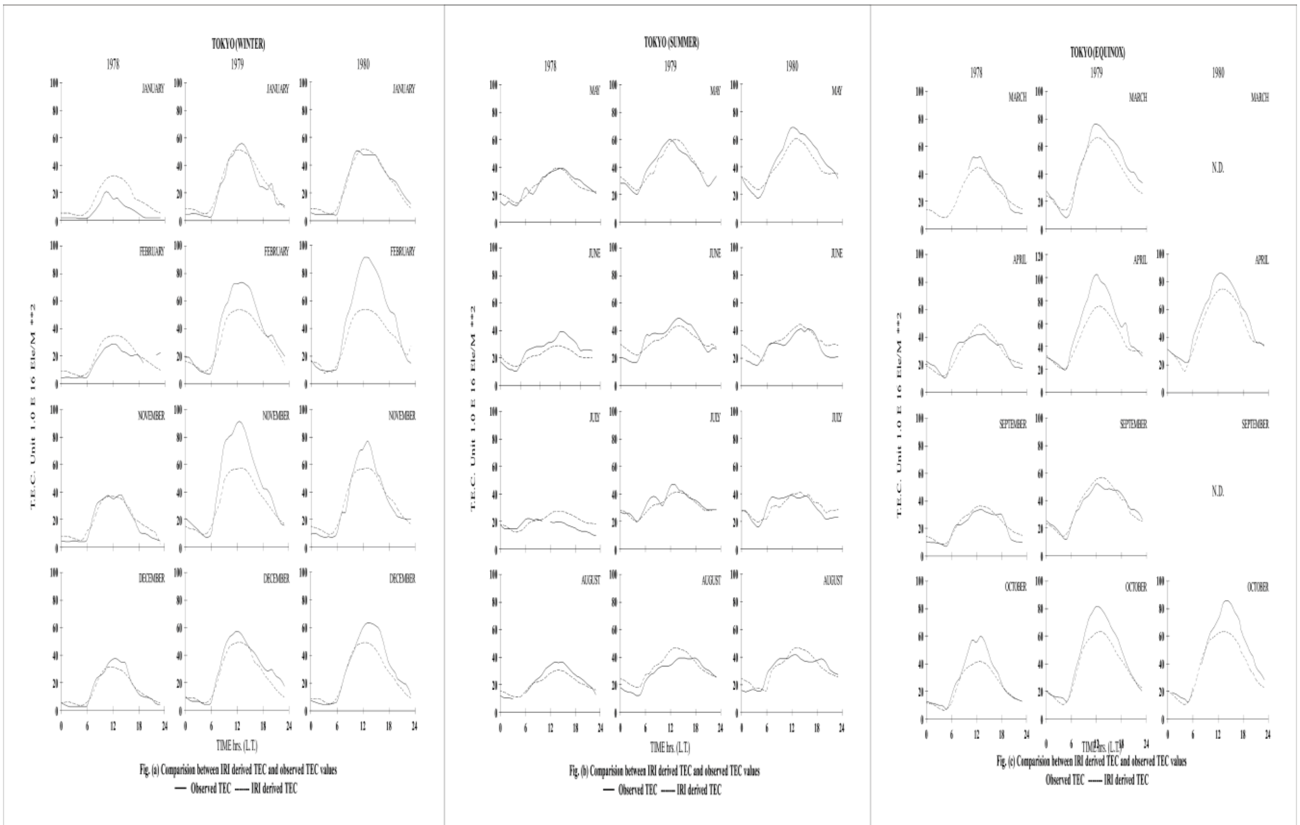

Fig. (a) Comparision between IRI derived TEC and observed TEC values
— Observed TEC — IRI derived TEC

Fig. (b) Comparision between IRI derived TEC and observed TEC values
— Observed TEC — IRI derived TEC

Fig. (c) Comparision between IRI derived TEC and observed TEC values
Observed TEC — IRI derived TEC

IRI derived values match very well from 2100 hour to 0600 hour during all the three years of observation. For daytime peak it is observed that for most of the months the model values under estimates the TEC. This error becomes large as the solar activity increases. The mean sunspot number for the year 1978 is 92.5 where as the same for 1980 is 154.6. The overall picture shows that for a lower solar activity during winter month the model values agree reasonably well with observed TEC.

Figure (b) shows the comparison between modelled values and observed values for summer months. Where as figure (c) shows the same for equinox. A very good agreement is observed between models and observed TEC values for the summer and equinox seasons.

Table No. (a) to Table No.(c) shows □TEC between the observed and model values at different hours of the day for three different season for Tokyo. It is observed that during daytime particularly around the day time peak 1400 hour, the □TEC is as high as 22 TEC unit (i.e. 1 unit=10^{16} ele/m^2). The large

Table No. (a) ⁞ TEC (10^{16} ele/m^2) for Winter

TOKYO-1978				
L.T. (Hour)	0000	0600	1400	2000
January	-3.1	-4.2	-17.4	-8.7
February	-4.7	-3.2	-10.4	N.D.
November	-3.9	-6.4	+2.9	-4.9
December	+0.2	-2.4	+5.8	-0.7
TOKYO-1979				
L.T. (Hour)	0000	0600	1400	2000
January	-3.9	-5.7	+3.9	+4.9
February	+3.2	-4.4	+19.5	+5.0
November	+5.9	-4.3	+27.6	-8.5
December	+1.4	-2.7	+2.4	+10.2
TOKYO-1980				
L.T. (Hour)	0000	0600	1400	2000
January	-2.9	-4.1	-2.0	+3.7
February	+0.9	-3.0	+34.4	+8.4
November	-5.8	-4.6	+13.1	-5.2
December	-1.3	-2.7	+14.9	+3.7

Table No. (b) ⁞ TEC (10^{16} ele/m^2) for Summer

TOKYO-1978				
L.T. (Hour)	0000	0600	1400	2000
May	-5.5	+6.1	-0.3	+4.0
June	-5.0	+4.8	+6.0	+4.9
July	-0.5	+5.6	-7.2	-6.8
August	-3.0	-1.2	+5.5	+3.3
TOKYO-1979				
L.T. (Hour)	0000	0600	1400	2000
May	+4.3	+5.7	-7.0	-4.6
June	-2.6	+8.6	+6.2	-0.6
July	-1.1	+4.4	+1.3	-2.0
August	-6.5	-4.4	-7.4	+2.1
TOKYO-1980				
L.T. (Hour)	0000	0600	1400	2000
May	+0.8	-0.4	+5.5	+6.9
June	N.D.	+0.1	-3.4	-7.3
July	-0.3	+9.2	-4.1	-4.4
August	-8.1	+10.8	-7.7	+6.5

Table No. (c) ⁞ TEC (10^{16} ele/m^2) for Equinox

TOKYO-1978				
L.T. (Hour)	0000	0600	1400	2000
March	-4.1	-3.3	+3.4	-4.3
April	+3.9	+7.6	-5.4	-0.7
September	-3.9	+1.3	-3.6	+6.5
October	-0.9	+4.7	+15.2	-0.8
TOKYO-1979				
L.T. (Hour)	0000	0600	1400	2000
March	+3.2	-6.5	+7.4	+7.7
April	-1.0	+8.2	+21.5	+5.2
September	+2.4	-0.5	-8.0	+3.2
October	+0.4	+3.2	+14.5	+2.1
TOKYO-1980				
L.T. (Hour)	0000	0600	1400	2000
March	N.D.	N.D.	N.D.	N.D.
April	-0.5	+8.5	+8.6	+4.4
September	N.D.	N.D.	N.D.	N.D.
October	-0.5	+2.6	+22.6	+12.0

values of □TEC at day time peak is observed during all the three season. It is also observed that there is no significant variation in □TEC with respect to the solar activity. This is also confirmed by Barman et al (1997). Their analysis also shows that at Delhi (28.6^{0}N) no solar activity variation was detected in the model prediction. The seasonal variation in □TEC shows that there is minimum discrepancy during summer month while comparatively large for winter and equinox months. These results are in general agreement with those of Iyer et al (1996) and Mc Namara (1985) for another law latitude station. The earlier comparison done by several worker has shown that the differences particularly during daytime may even reach to 50% Bilitza (1985) showed that at law latitude, the model electron density decreases with altitude much more rapidly than observed in the measurement made using the Incoherent Scatter data of Jicamarka (11.9^{0}S 283.1^{0}E). The IRI model was accordingly modified and the latest version is known as IRI 90. With this modification, it is observed that for a midlatitude station like Tokyo, the difference never exceeds 50% in summer month regardless of solar activity. At the same time for the winter and equinox months the discrepancy in percentage is observed as high as 134 during daytime. Which suggest that still some modifications are requiring removing the discrepancy during daytime for winter and equinox months. One of the reasons may be the well known winter anomaly.

In general the IRI model for midlatitude station like Tokyo can be used for prediction without any ambiguities for summer months and with about 30% discrepancy for other seasons for any given solar activity. This conclusion is in good agreement with earlier similar exercise done by Mc Namara (1983), Mc Namara et al (1983), Barman et al 1997. The conclusion can be summarized as follows.

- The IRI predicted and observed TEC values agree reasonably well during summer and equinox months. The discrepancy is higher in winter months.
- There is no significant variation observed in □TEC during different solar activity for Tokyo (33.5^{0}N 138.7^{0}E)
- The overall statistics shows that IRI under estimates the TEC for this mid latitude station.

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