CHAPTER: 31

DIURNAL AND SEASONAL EXAMINATION OF GPS BASED TOTAL ELECTRON CONTENT RECORDED AT AGRA STATION IN DIFFERENT SOLAR ACTIVITY PERIODS

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ABSTRACT

In this study we have analyzed GPS-TEC data of the year 2011 when the solar cycle24 is in ascending phase. In this study good correlation is found between vertical total electron content (VTEC) and solar activity (solar flux F10.7 cm). In order to show variation of the data, statistical study employing mean (m) and standard deviation (σ) approach is employed. In the month of October day time TEC has peak value above m+ σ whereas in the months of January, February and April depletion are seen below m- σ. Further we compared results with IRI 2012 and strong correlation with variations during the three seasons are found.

Keywords: *GPS, Activity Periods*

INTRODUCTION

The low latitude ionosphere is significantly influenced by geophysical phenomena such as solar flares, magnetic storms, and human causes such as nuclear explosions, volcanic eruptions, seismic activity, and EIA spread-F and sporadic E (Pullinets and Davidenko, 2014). These cause significant variations in the lower ionosphere's structure and behaviour. Because these causes can induce ionization anomalies, it is challenging to detect the abnormalities caused by seismic events. Therefore, morphological research on the low-latitude ionosphere is necessary in order to distinguish anomalies caused by seismic occurrences. Using GPS-based total electron content measurements, a number of researchers (Akala et al., 2013; Huy et al., 2014 and references cited there in) have examined the morphological aspects of the ionosphere and discovered some significant findings. Due to the existence of EIA, numerous researchers have extensively studied the low latitude ionosphere at the national level. Their findings have been compared with ionospheric IRI models (Karia et al., 2015; Rathor et al., 2015 and references cited therein). Using GPS-TEC observations, researchers were able to anticipate the behaviour of the ionosphere, which was helpful in determining the impact of solar events (Adebiyi et al., 2014 and references cited their in). Rama Rao et al. (2006) looked at the temporal and spatial variations for TEC data from the Indian GPS network during the low solar activity period of 2004–2005. At every observing station from the equator to the EIA crest region, the largest value of the diurnal variation in TEC has been observed between 13:00 and 16:00 LT, while the least value has been observed between 05:00 and 06:00 LT. Seasonal temperature differences are greatest during the equinox months and least throughout the summer. Prasad et al. (2012) examined the TEC variations for the year 2004 at four GPS stations. The summer and equinoctial seasons have lower and higher TEC values, respectively. There have been notable daily differences noted. IRI-2007 model over four Indian GPS stations shows that there are more deviations near anomaly crest and fewer at equatorial stations. The SSN, F10.7, and EUV solar activity indices exhibit strong connections during the equinoctial months, but not during the summer. The outcomes of the 2011 TEC data analysis at the low latitude GPS station in Agra have been examined here. A high association is established when the results are also validated using the Ionospheric Model IRI-2012.

EXPERIMENTAL SETUP

A GPS receiver (Novatel's Euro Pak 3-M), an L1/L2 GPS antenna (Novatel's Model GPS 702), connecting connections imported from GPS Silicon Valley, USA, and Novatel software make up the entire system. Slant-TEC (STEC) is multiplied by the mapping function provided by Mannucci et al. (1993) and then translated into vertical-TEC (VTEC) in the study.

$$S(E) = \frac{1}{\cos z} = \left[1 - \left(\frac{R_{E\times\cos(E)}}{R_E + h_s}\right)^2\right]^{-0.5}$$

Where R_E means radius of earth in km

h_s denotes effective height of ionosphere above earth surface. For determination of IPP locations 350 kms height is used (Rama Rao et al., 2006)

z denotes zenith angle

E denotes elevation angle in degrees

RESULTS AND DISCUSSION

Daily Variation

The contour figure 1. displays fluctuation of TEC data averaging it each month for each period for whole year 2011, at the Agra station. Also other part of the figure states its comparison with IRI-2012 model. During sunrise to afternoon the diurnal pattern of VTEC increases and attains minimum just before sunset. It can be seen in the diurnal variation of TEC-data the value is minimum in the morning and with day time value is maximum and then again it decreases after

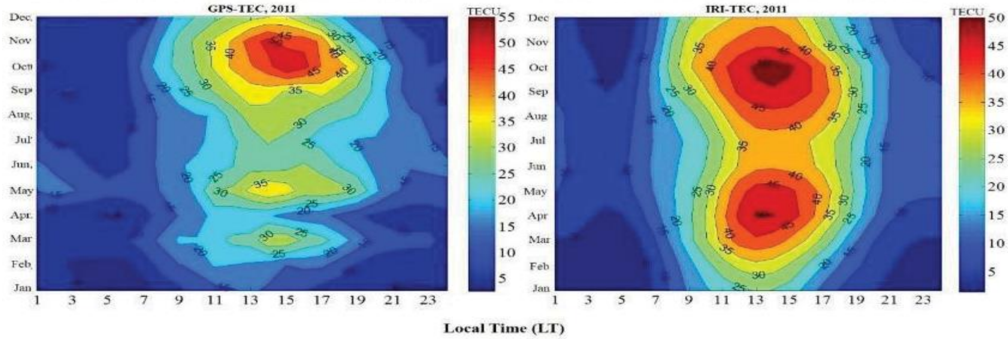

Fig.1: left panel shows the contour plot of average monthly GPS-TEC variations for year 2011 and right panel shows IRI-2012 model TEC data variations over Agra station for same year.

Sunset. Many researchers have reported same result in their monographs (Mukherjee et al.,2010; Kumar et al., 2012; Sharma et al., 2012). VTEC has its peak value between 14:00 and16:00 hours. Monthly variations VTEC has been mostly during morning to Midday hours as depicted from the plots. The variability in the intensity of the arriving solar radiations may be caused by the monthly variations of VTEC at Agra. These variations are helpful in forecasting and navigation (Bhagya et al., 2009; Rama Rao et al., 2006).During the equinoctial months of November and October value of GPS -TEC are the highest and also supported by IRI TEC variations. The IRI models shows the variations similar to GPS -TEC in the equinox periods as well. Hence forth we can say TEC values are escalated in equinox then in winter and summer season.

SEASONAL VARIATIONS

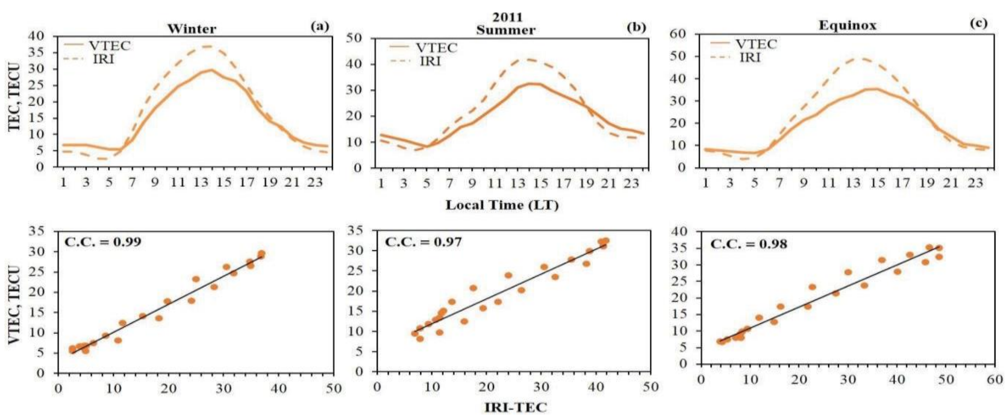

Fig:2 correlation plots between VTEC and IRI-TEC for the year 2011.

In this study whole year is divided in to three season: summer, equinox and winter. In summer month of April, May, June and July are considered. For equinoxes TEC data average is calculated for the months of March, April, September, and October. For winter the month of November and December January and February are counted. In the Fig.2 upper panel shows the variations of VTEC for three seasons by solid lines whereas dotted lines show the comparison with seasonal IRI- TEC. The lower panel displays how the values of GPS-TEC and IRI-TEC are correlated for the two periods. For the entire season, the highest GPS-TEC value is between 25 and 30 TECU. In case of winter and equinox season the peak hour of the IRI model is over estimated whereas in case of morning and afternoon hour the value are underestimated in case of summer season the values are underestimated in the morning and afternoon hours. Strong correlations, with correlation coefficients of approximately 0.98 for each of the three seasons, were found when the GPS-TEC and ionospheric IRI-2012 model were compared for validation. This can be direct effect of solar activity periods. GPS-TEC and IRI have high value during equinoxes and low value in winter which matches very well with the earlier workers (Kumar et al., 2012; Sharma et al., 2012). This work matches with the study of other low latitude stations which are near to Agra station (Sharma et al., (2012)).

SOLAR ACTIVITY DEPENDENCE

Correlation coefficients has been calculated between monthly mean TEC and solar flux F10.7 for every month in year 2011 in order to research how solar activity affected TEC throughout the time period under review as seen in Fig 3. Between the two factors good correlation is found in the months of February, May, September, October, November and December. Except for January maximum correlations are found in winter and equinox season. As TEC is minimum in morning as well as evening and maximum value in the afternoon.

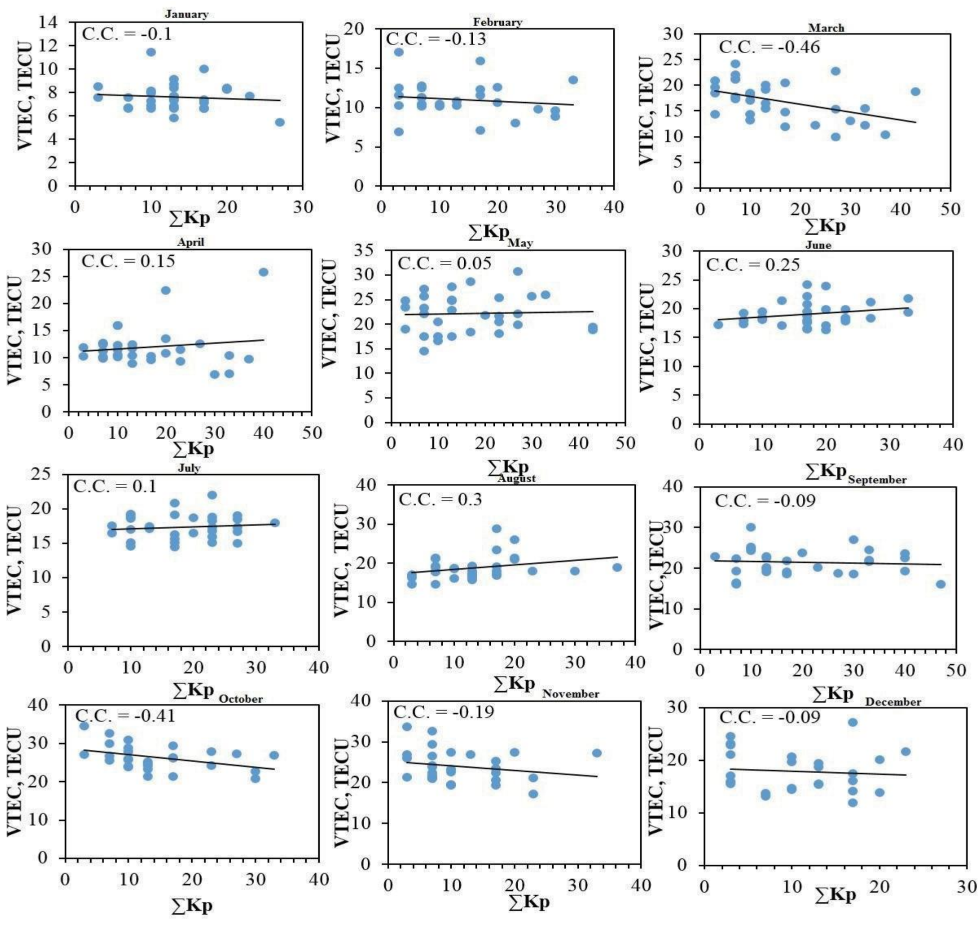

Fig.3: correlation plots between VTEC and geomagnetic activity factor (∑ Kp index) during year 2011.

CONCLUSIONS

At the Agra station, the GPS-TEC data for 2011 during the ascending portion of solar cycle 24 have been studied. Temporal, seasonal, nocturnal, and peak-VTEC changes have all been examined for this time frame. Investigations into the solar and geomagnetic dependency of TEC data have shown a strong association with solar activity. VTEC is found to be maximum during equinox and minimum in winter solstice. The diurnal, seasonal variations of VTEC have been examined and related mechanisms are explained. Strong correlation (≈ 0.98) with IRI-2012 model for each season has been found. TEC values maximizes during equinox and minimizes during winter season and solar activity directly affect the TEC data during the year 2011 may be due to rising phase of solar cycle 24.

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