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Ionospheric plasma variability using GPS Total Electron Content (TEC) over Equatorial-, Low- and Mid-latitude stations during the low and high solar activity period

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Abstract

Ionosphere is a part of upper atmosphere having existence of charged particles and neutrals. Ionospheric perturbations are well known to affect radio wave communication and navigation system and hence, knowledge of ionospheric plasma variabilities at different geographical locations under different climatic conditions is quite significant to improve such radio-based system. The presented paper is an attempt to understand the variability of ionospheric plasma over different latitude regions. The ionospheric total electron content derived from Global Positioning System (GPS) at **Bangalore, India (low-latitude station) – latitude- 12.9716, longitude- 77.5946, Varanasi, India (EIA station) – latitude- 25.3176, longitude- 82.9739 and Bishkek, Kyrgyzstan (mid-latitude station) – latitude-42.680, longitude-74.694** have been used to study the seasonal and annual variations during the solar minimum period 2008 and solar maximum period 2013. We have found that the winter anomaly is absent at all the 3 stations in both the years. The yearly comparison of TEC shows that there is direct control of solar activity over GPS-TEC.

1. Introduction

The ionosphere is the ionized part of the Earth's upper atmosphere which affects the propagation of radio waves passing through it. There is equal number of free electrons and free ions present in the ionosphere i.e., ionosphere as a whole is electrically neutral. Since, the charged particles are in minority relative to the neutral particles still they have a great influence on the properties and behavior of the medium [Hargreaves, 1979]. The plasma density of ionosphere changes with latitude. This change is due to the different configuration of geomagnetic field lines over the high, mid, and low latitudes. In higher latitudes, the magnetic field lines are vertical and open. The electron density of this region depends upon the solar zenith angle and particle precipitation. In mid-latitudes, the magnetic field lines are inclined. The ionosphere of this region is the most well behaved and predictable. In low-latitudes and equatorial regions, the magnetic field lines are almost horizontal and due to this special alignment, the ionosphere of this region is more complex [Rastogi et.al., 1959]. The knowledge about the ionospheric variabilities and irregularities over different latitude regions is essential to improve the efficiency of satellite communication system [Dandekar, 1995]. In present study our aim is to study the ionospheric plasma variability over different equatorial-, low- and mid-latitudes using GPS based TEC measurements.

2. Data and methodology

To study the ionospheric variabilities TEC is the key variable. Total Electron Content (TEC) is defined as the total number of electrons in a unit cross-section along the satellite to receiver ray path. The unit of TEC is electron/m^2, but mostly expressed in TEC units (TECu), 1 TECu = 10^{16} electron/m^2. The estimation of total electron content is done by using dual frequency GPS receiver data. The slant total electron content (STEC) data obtained from the GPS receiver is in the RINEX FORMAT [Hofmann-Wellenhof et. al., 1994]. The STEC is converted into vertical total electron content (VTEC) using the method described by [Smith et al., 2008].

In this paper the analysis of seasonal variation of GPS-TEC at low-latitude station - Bangalore, EIA station - Varanasi and mid-latitude station - Bishkek has been done for the solar minimum year 2008 and solar maximum year 2013.

3. Results and Discussions

Here, we have divided a year into three different seasons, Summer season (May, June, July and August), Equinox season (March, April, September and October) and Winter season (January, February, November and December). The seasonal variation of GPS-TEC at Bangalore, Varanasi and Bishkek for the year 2008 and 2013 are presented in figure. 1 and in figure. 2 respectively. The seasonal TEC is obtained by taking the average of 10 quietest days of each month belongs to particular season. The red, green and blue curves represents the summer, equinox and winter season respectively. The yearly variation of GPS-TEC is represented by the figure 3 and figure 4 at the 3 stations Bangalore, Varanasi and Bishkek for the year 2008 and 2013 respectively. The yearly TEC is obtained by taking the average of 10 quietest day of each month of the particular year.

The fig. 1 and fig. 2 shows that the GPS-TEC of Bangalore (equinox season GPS-TEC is ~26 TECu in year 2008 and ~54 TECu in year 2013) and Varanasi (equinox season GPS-TEC is ~24 TECu in year 2008 and ~64 TECu) in year 2013 is highest for the equinox season for both the years 2008 and 2013, while at Bishkek (summer season GPS-TEC is ~8 TECu in year 2008 and ~24 TECu in year 2013) summer season have highest GPS-TEC. The winter anomaly, i.e. the higher value of GPS-TEC in winter season than in the summer season is absent at all the 3 stations in both the years 2008 and 2013. The GPS-TEC of all the three seasons- summer, equinox and winter of station Bishkek (ranging from ~1 TECu to ~8 TECu for year 2008 and from ~2 TECu to 24 TECu for year 2013) is comparatively attain much smaller than the other two stations, Bangalore (ranging from ~1.5 TECu to ~26 TECu for year 2008 and from ~2 TECu to 49 TECu for year 2013) and Varanasi (ranging from ~2 TECu to ~17 TECu for year 2008 and from ~3 TECu to 53 TECu for year 2013).

From this we can say that the GPS-TEC at mid-latitudes have comparatively smaller values than the GPS-TEC at low-latitude and EIA station.

It can be seen clearly from the figure 3 and figure 4 that the GPS-TEC is comparatively much larger in the year 2013 for all the three stations as compared to the year 2008. The data chosen fall in the solar cycle 24. The year 2008 is the minimum peak year of solar cycle 24 and the year 2013 is the maximum peak year. Here, we can conclude that the GPS-TEC is higher in solar maximum year 2013 and its value are comparatively smaller in solar minimum year 2008.

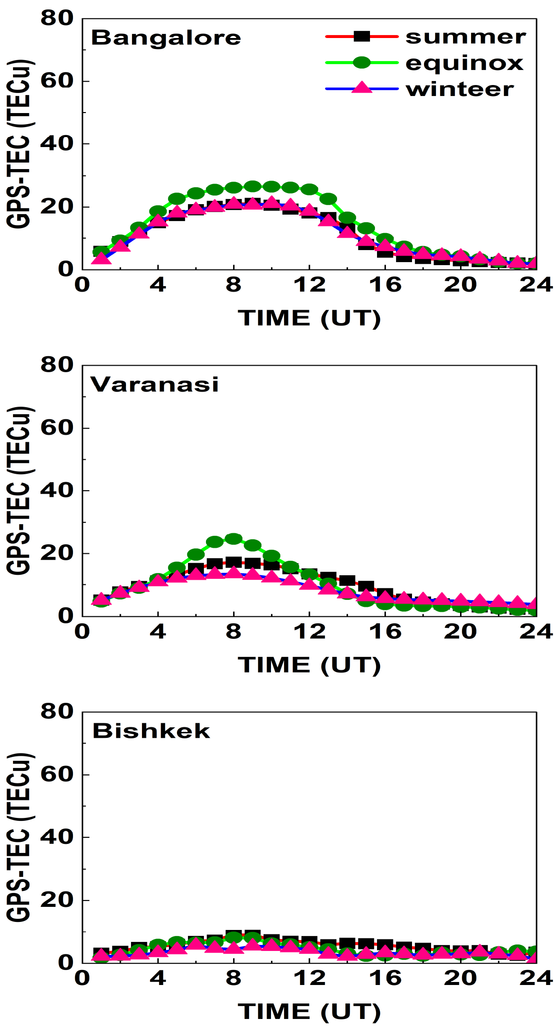

Fig. 1 Seasonal variation of GPS-TEC for the year 2008

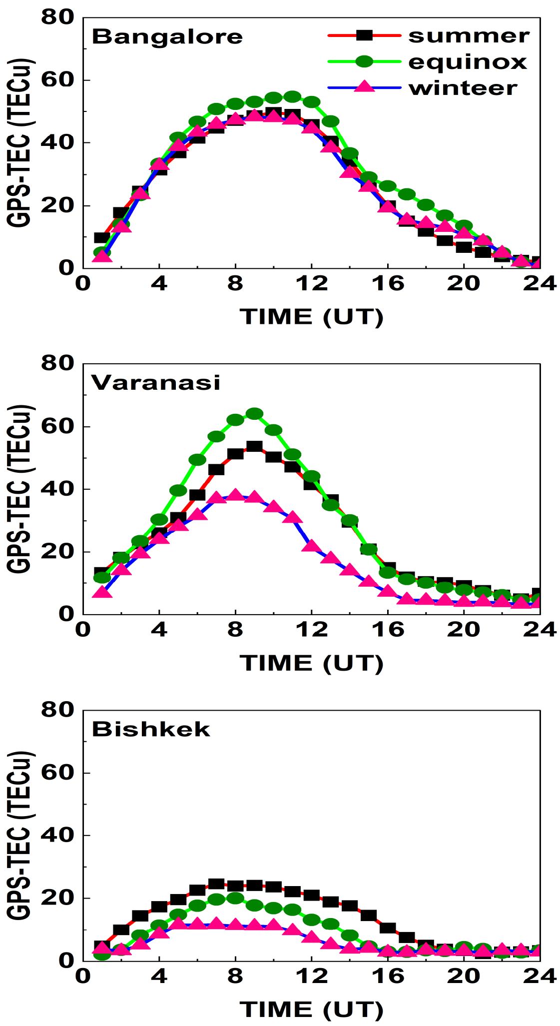

Fig. 2 Seasonal variation of GPS-TEC for the year 2013

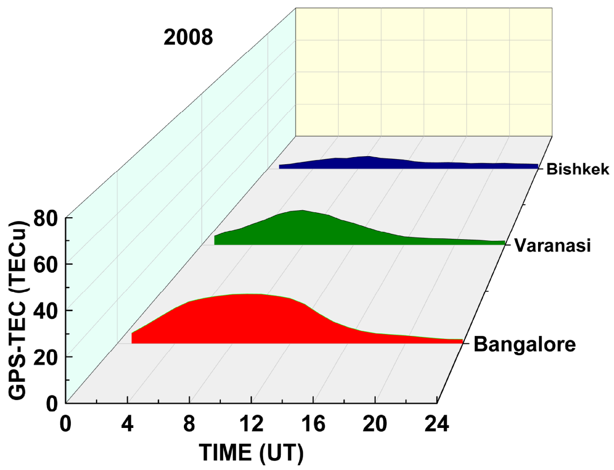

Fig. 3 GPS-TEC yearly variation of year 2008

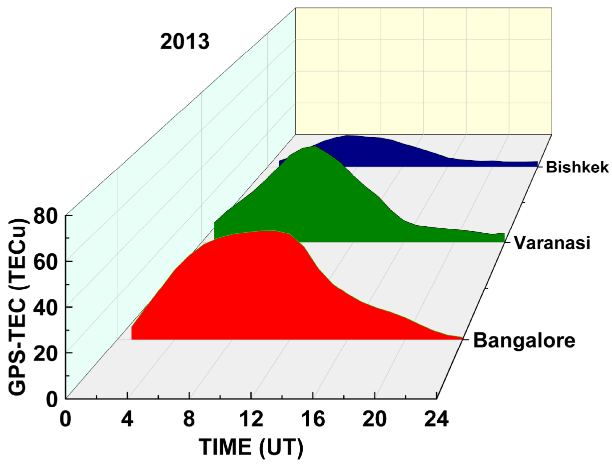

Fig. 4 GPS-TEC yearly variation of year 2013

5. Conclusion

(1) The winter anomaly is absent in both the year 2008 and 2013 for all the three stations.
(2) There is a direct control of solar activity on the plasma density of ionosphere. The magnitude of TEC is higher in the year 2013 (solar maximum year) and lower in the year 2008 (solar minimum year).
(3) There is a latitudinal variation in GPS-TEC. The TEC of low-latitude and EIA station is higher in comparison to the TEC of mid-latitude station.

6. References

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7. Acknowledgements

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