Variability of Ionospheric TEC at Low Latitude Station, Hyderabad During Medium Solar Activity

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Introduction

- The ionosphere is the most important region of the atmosphere not only from application point of view but also because it protects and shields the human life on the planet from the harmful effects of very intense and hazardous solar radiations.

- The state and behaviour of ionosphere changes from place to place as well as from time to time. These changes in the ionosphere are due to the level of solar and geomagnetic activity.

- The solar cycle is the periodic variation of solar activity about eleven years period. During this phase of solar activity, several kinds of transient phenomena take place on the sun and huge release of energy occurs from sun which reaches ionosphere and makes it highly turbulent and inducing large scale irregularities.

- The highly complex variability of ionosphere makes it very difficult to develop global models which will predict the behavior of the global ionosphere. However, models specific for particular regions and for specific solar activity conditions have been developed which are quite helpful in predicting the ionospheric variability at those places.
Total Electron Content (TEC)

- The TEC is an important parameter that can be used to study the variability of ionosphere as it determines the amount of ionization in the ionosphere and its changes.

- The total number of electrons present in the signal path from satellite to receiver is called as the Total Electron Content and abbreviated as TEC. It is defined as the total number of electrons present in cylinder column of one square meter area of cross-section from satellite to receiver.

- TEC is the integral electron density. It is measured in TEC units (TECU). One TECU = \(1 \times 10^{16}\) el/m\(^2\)

- The slant TEC is converted to an equivalent vertical TEC by using a proper mapping function as:

\[
VTEC = \text{STEC} \times \cos\chi
\]

Where

\[
\chi = \arcsin\left(\frac{R_E}{R_E - h_m}\right) \times \sin\delta
\]

- Where \(R_E\) is the radius of Earth in Kilometres and \(h_m\) is the mean height of ionosphere and \(\delta\) is the zenith angle at receiver position.
The Sun is a highly active star and continuously emits energy in the form of radiations. However, sometimes there occurs dramatic increase in the energy output. During such time there occurs catastrophic release of energy from sun, in the form of huge radiation fluxes, clouds of solar plasma and highly energetic particles etc. Such solar phenomena during which huge energy is released in a short time are called as solar transients. The changes on the sun take place on different time scales. Some changes in the state of sun take years and tens of years to take place while some other changes occur within minutes or hours. The three main and important solar transients are Solar Flares, Coronal Mass Ejection (CMEs) and Solar Energetic Particles (SEPs).
SOLAR FLARES
A solar flare is defined as a sudden and intense brightening on the Sun, usually observed near its surface. These are observed as sharp and intense flashes of light on the solar disc.

CORONAL MASS EJECTIONS (CMEs)
A coronal mass ejection (CME) is a significant release of plasma from the solar corona. Coronal Mass Ejections occurs on a time scale of a few minutes and several hours and involves the appearance of a new, discrete, bright, white light feature in the coronagraph.

SOLAR ENERGETIC PARTICLES (SEPs)
The solar flares and Coronal Mass Ejections can accelerate the ambient charged particles to very high energies. Such energetic particles observed in relatively short burst are called as Solar Energetic Particles (SEPs).
- **Sunspot Number (Rz):** Sunspots are temporary phenomena on the photosphere of the Sun that appear as dark spots compared to surrounding regions.

- **Solar radio flux (F10.7 cm):** Flux means the flow of some property through a given area in a given amount of time. *The 10.7 solar radio flux is a measure of the solar flux density* (amount of solar energy per unit area per unit time) at the 10.7cm wavelength observed at the Earth by radio telescopes called flux monitors.

- **Flare Index:** The sudden release of energy stored in magnetic fields. The flare index is of value as a measure of this short-lived activity on the Sun.
Event Selection

- To investigate the ionospheric variability at low latitude during the medium level of solar activity, we have first selected a low latitude IGS station namely Hyderabad (17.41°N, 78.55°E) of India. Then to study the variability of ionosphere at Hyderabad, we have chosen year 2014 of solar cycle 24, which was in declining phase and the solar activity was medium. Moreover, the selection of year 2014 was also on the basis of a very good coverage of data for the full year.

- To investigate the ionospheric variability we have used the GPS derived **Total Electron Content (TEC)** as the parameter quantifying ionospheric variations.

- We have compared the variability of observed values of TEC at Hyderabad with the corresponding values as predicted by **IRI-2016 model** for Hyderabad.
Data Sets and Sources

- **Data for TEC**
The Hyderabad station is an International GPS Service (IGS) station, hence the data for TEC at Hyderabad station taken from IGS data server at:
  
  Source: [http://sopac.ucsd.edu/dataArchive/](http://sopac.ucsd.edu/dataArchive/)

- **Data for IRI Model**
The IRI modelled values were obtained by using the interactive database tool accessed at:
  

- **Data for Solar Activity Indices**
Solar activity indices namely sunspot number, solar radio flux F10.7 cm, number of CMEs per day and flare index data taken from following data server:
  
  Source: [https://omniweb.gsfc.nasa.gov/form/dx1.html](https://omniweb.gsfc.nasa.gov/form/dx1.html)
  Source: [https://www.ngdc.noaa.gov/stp/solar/solarflares.html](https://www.ngdc.noaa.gov/stp/solar/solarflares.html)
The Behavior of Solar Activity

Figure 1: Temporal variability of four solar activity indices during the year 2014.
Figure 2: The hourly averaged diurnal variability of the TEC during the all the days of months of January to December of year 2014, at Hyderabad.
Figure 3: The day to day variability of the daily averaged values of TEC at Hyderabad during 2014.
Figure 4: The comparison of daily averaged values of TEC during the different months of 2014 at Hyderabad.
Figure 5: The month to month variability of hourly values of TEC at Hyderabad during the year 2014.
Figure 6: The variability of the monthly averaged values of TEC at Hyderabad during 2014.
Figure 8: The hourly variability of the TEC during three different seasons of the year 2014.
Figure 9: The seasonal variability of the monthly averaged values of TEC at Hyderabad during 2014.
Figure 10: The comparison of mean hourly variability of TEC with the mean hourly variability of IRI-2016 modeled TEC during the year 2014 at Hyderabad.
Figure 11: The comparison of daily variability of TEC with the daily variability of IRI-2016 modeled TEC during 365 days of year 2014 at Hyderabad.
Figure 12: Correlation of hourly and daily values between the IRI-2016 model predicted values and the observed values of TEC at Hyderabad.
Conclusions

- All types of temporal variations of TEC at Hyderabad are regular, systematic and similar.
- The diurnal variation of TEC follows a Gaussian type curve, achieving a diurnal peak around the afternoon around 09:00 hrs UT. The hourly variability is same on all days of all months. The peak values or the height of diurnal peak has significant variations. In addition, on some days deviations from this regular behavior were also observed.
- The average peak value of TEC at Hyderabad during the year 2014 is about 68 TECU.
- The day to day variability of TEC is not only regular but also periodic following, semi-annual type of variability.
- The monthly variability of TEC also follows semi-annual type of variability. The first peak is higher than the second peak. The peaks are observed in the months of March and October while minima are observed in the months of January, June and December.
- The seasonal variability is such that the highest value is observed during the equinox season followed by winter season and the lowest values are observed in summer season.
- The comparison with IRI-2016 model, shows that mean hourly values are in a good agreement with the observed values, while as some departures and deviation are observed for the daily values.


THANKS