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Reaction of Ethiopia Ionosphere to Sun based Movement and Geomagnetic Storm

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Abstract: The ionosphere is the shell of Electrons encompasses the Earth, extending from the stature of around 50km to more than 1000km. The sun powered radiation goes through the environment is assimilated and causes ionization. Ionization is the procedure of making absolutely or adversely charged particles or atoms by including or striping one or more electrons. The data collected by the ground based GPS receiver located at Adama (8.57° N and 39.29° E) have been analyzed to study the temporal variations of the ionosphere in the region. We have investigated the effects of sunspot and geomagnetic storm on the characteristics of the total electron content (TEC) values. We observed that the TEC values are minimum at pre-down throughout the year, followed by a steep increase in its value in the intervals 1000UT-1400UT. This may be due to the variation of the strength of solar radiation that reaches the atmosphere. Larger TEC values were observed in autumn and spring seasons, minimum and the intermediate TEC values in summer and winter seasons respectively. During the autumn and spring the Sun is overhead at Adama station the intensity of radiation that comes from the Sun is maximum. During summer and winter the Sun is not overhead at Adama and this means minimum Sun's radiation reaches to the atmosphere. The TEC values increase when the sunspot number increases. The observed TEC values are correlated with sunspot numbers as there are more radiation (X-ray and UV) from the Sun during large number of sunspots. The effects of the geomagnetic storm on TEC values have been found negative and positive correlation with geomagnetic storm.

Keywords: Ethiopia, Ionosphere, Geomagnetic Storm and Environment

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1. Introduction

The ionosphere is the shell of Electrons and electrically charged, uncharged atoms, molecules that surround the Earth, stretching from the height of about 50km to more than 1000km. The solar radiation passes through the atmosphere is absorbed and causes ionization. Ionization is the process of making positively or negatively charged atoms or molecules by adding or striping one or more electrons. In Earth's upper environment it is regular to make emphatically charged particles by uprooting an electron than it is to make adversely charged particles by including an electron. Ionization is expert when electrons are thumped free of their host particle by either sun based high vitality photons (generally UV and X-beams) or enthusiastic molecule that accelerates into environment and crash into encompassing gas. All molecules and particles in Earth's lower environment are impartial, implying that there are equivalent number of protons and electrons in every particle, in the upper atmosphere number of charged (particles and electrons) gets the opportunity to be self-evident.

The generation of the fundamental piece of the ionosphere is fundamentally because of sun powered electromagnetic radiation through a procedure called photograph ionization, and in this way the top thickness of the ionosphere is found on the day-side. The ionosphere fluctuates in efficient ways in light of the fact that the primary wellspring of ionization (sunlight based UV and X-beam power) relies on upon the position of the Sun in the sky at specific area on Earth and on the Sun's total yield. At the point when the sun is straightforwardly over head, the force of the Sun light coming to the upper air is most prominent. To the day-night terminal, the force diminishes on the grounds that the edge the sun makes with upper climate is more sideways. As the spectator moves a dull or night side half of the globe of the Earth, the measure of Sun light goes to zero and creation because of photograph ionization is disposed of. The pivot and bend of Earth in this way offer ascent to varieties in the ionosphere structure. Notwithstanding the Sun's yield of vitality is not consistent in time. It changes quickly (particularly at the high vitality end of electromagnetic range) because of sun based flares and over the sun powered cycle. Amid sun powered least there is little X-beam discharge, while at sunlight based most extreme the Sun's environment radiates a lot of X-beams. These offers ascend to a sun based cycle variety in the power of ionization of ionosphere. Amid sun based tempest, the ionosphere structure can be definitely changed by vitality data from the sun. There are a few analysts that working the impacts of the sun and geomagnetic tempest on central climate. TEC variations have been studied extensively by, A. Yamamoto [1], Jaris portegeis zwart[2], Y.Zhang[3], Jakowski, N., M.M. Hoque, and C. Mayer [4] and Komjathy, A., Langley, R.B.[5] . All of these studies have shown the characteristics features of TEC.

In this study, we want to show the diurnal and seasonal variation of Ethiopian ionosphere and its response of the solar activity. Solar flux and solar terrestrial indices using ground based GPS receiver located at Adama, Ethiopia.

2. Materials and method

The earth's ionosphere which causes problems in radio applications, especially for navigation, is now the subject of active research. Solar activity such as flares and Coronal Mass Ejections (CMEs) often produces large variations in the particle and electromagnetic radiation above the earth Bergeot N, Tsagouri I, Bruyninx C, Legrand J, Chevalier J, et al [6]. The perturbations cause large disturbances in Total Electron Content (TEC) and ionospheric current system. The TEC measurements obtained from dual frequency GPS receivers are one of the most important methods of investigating the earth's ionosphere.

GPS can be used to measure the TEC by utilizing dual frequency data forming the linear combination, L4 (geometry-free LC) Bergeot N, Tsagouri I, Bruyninx C, Legrand J, Chevalier J, et al [7]. In the case of code observation, the TEC is proportional to the difference of the ionospheric time delay on two frequencies. For the phase observations, the method is influenced by an unknown differential ambiguity term. This ambiguity can be estimated together with ionospheric model parameters or scaled to the code pseudo-range but multipath effects must also be taken into account.

To simulate actual measurements of TEC observed at ground GPS stations in Ethiopia, we use an Adama ground GPS station. To calculate the value of this TEC we used SENDA software. By using this software we analysis the data what we gate from Adama ground GPS data. After that we use MATLAB software and we plot our data. Generally for this research we got our TEC data from Adama ground based GPS and solar radio flux and sunspot number from website [8-10].

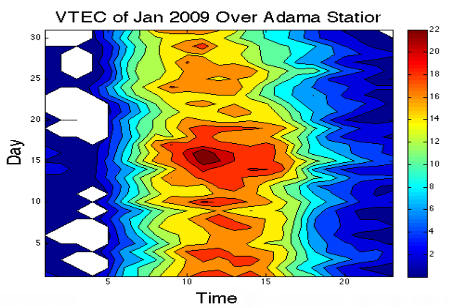
3. Results and discussion

Diurnal variations of TEC

The diurnal patterns of TEC exhibits a steady increases starting about sunrise to an afternoon maximum and the falls to attain a minimum just before sunrise. The diurnal characteristic of TEC has seasonal, solar activity, geomagnetic activity and latitudinal dependence.

In Figures (1 to 6) show the diurnal and hourly variation of TEC over Adama station. In all these plots the diurnal variations show a maximum occurring 1000UT-1400UT and short-lived minimum in TEC occurring around 0000UT-0900UT and 1500UT-2400UT. Generally this temporal variation depending on intensity of radiation coming from the Sun, since the intensity increase start from sunrise and will be maximum when Sun is overhead and comes to zero when sunset. Since the hourly TEC value is dipped on intensity of radiation coming from the Sun has good correlation with it. Figure 1 show the TEC value during January and February are shown respectively. In these two figures the maximum value of TEC is formed in the in terval of 1000UT-1400UT. Similarly Figure 2 – 5 shows the maximum value record on interval of 10000UT-1400UT.

In all above figures from Figure 1 - 6 the TEC value of one day difference from the TEC value of another day of the same month. These day to day variations TEC may be attribute to the change in activity of the Sun itself. This means that, sunspot number, geomagnetic activity and differ particle coming from the Sun is different from day to day the TEC values which varies daily. At the last the diurnal variation of TEC value is affected by daily variation of sunspot number and space weather event and also seasonally. These all activities are described in the following sections.



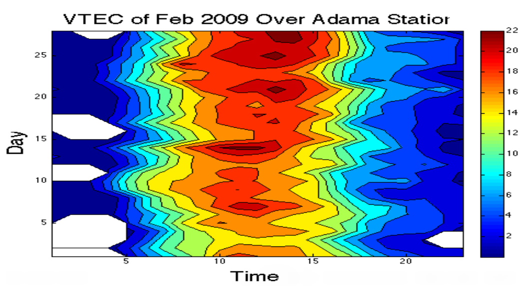


Figure 1: VTEC value in January and February 2009 over Adama station.

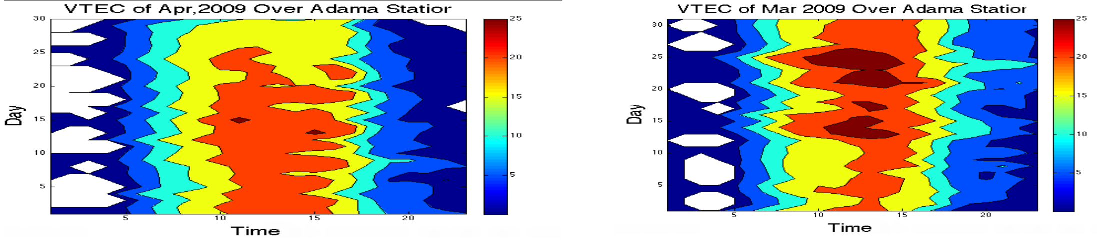


Figure 2: VTEC value in March and April 2009 over Adama station.

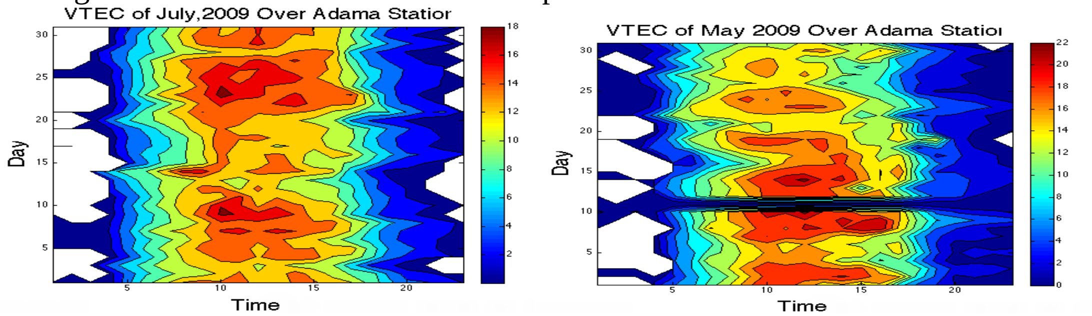


Figure 3: VTEC value in July and May 2009 over Adama station.

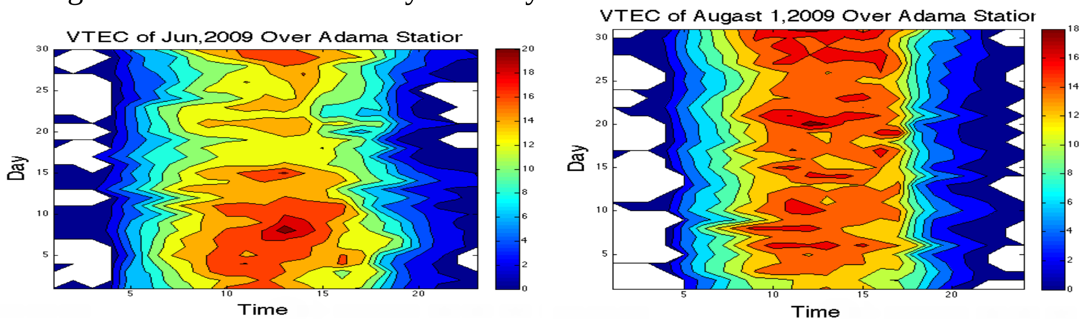


Figure 4: VTEC value in Jun and August 2009 over Adama station.

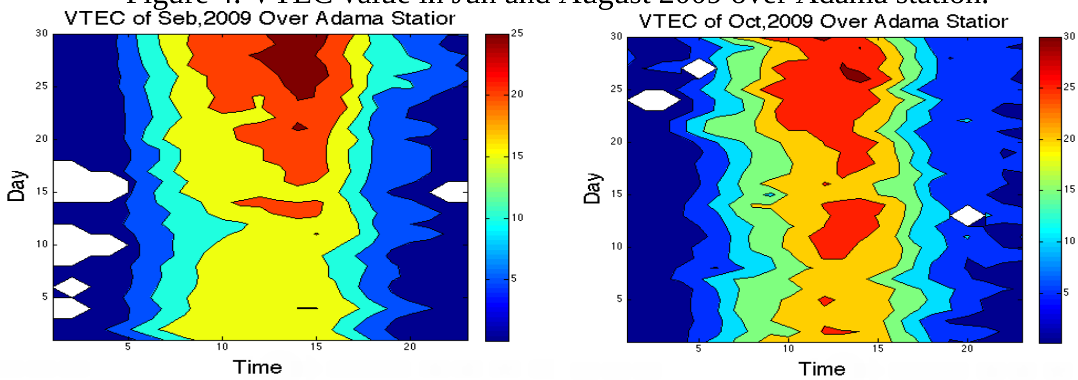


Figure 5: VTEC value in September and October 2009 over Adama station.

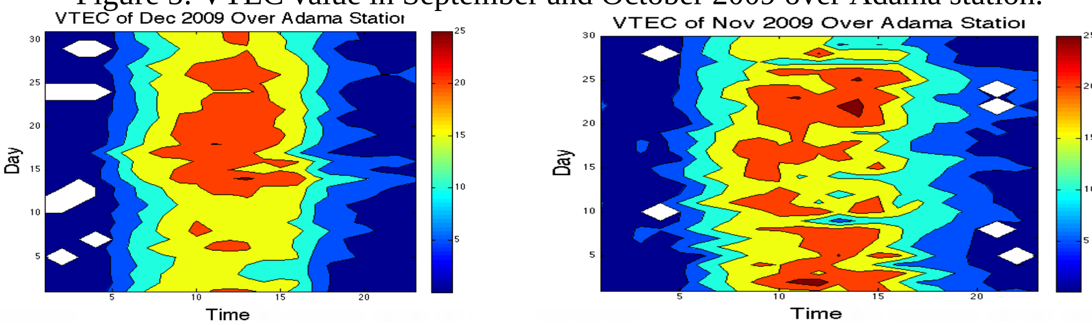


Figure 6: VTEC value in November and December 2009 over Adama station.

Seasonal Variation of TEC

The median diurnal variation during different seasons recorded at Adama GPS station for the year of 2009 is shown on Figure 7. Thermospheric neutral composition has a direct control on the seasonal variation of TEC Mark Moldw [11], Camargo, P.O., Monico, J.F.G., Ferreira, L.D.D., [12]. During the day time, the equatorial is hotter than the pole there for meridional wind flows toward the pole from the equator. This flow of meridional wind changes the neutral composition and ratio of O/N_2 decreases at equatorial and low latitude station 350km altitude (F_2 layer) dissociation is the major process which removes ambient electrons. Hence, the decrease in O/N_2 ratio will results in higher electron density and therefore in equinox TEC will be highest (i.e during spring and autumn). In other way, seasonal variation of TEC comes due to the orientation of the Sun and our planet Earth. When the Zenith angle is more or less overhead of the ionosphere of the Earth, we will get maximum TEC value because of the maximum intensity of radiation from the Sun. Intensity of the radiation of the Sun liberates energetic photons and determines the variation of TEC throughout the month. Liberated photons (energetic particles) are very important for the production of free electrons in the ionosphere by process of photochemistry. Consequently the TEC value remains high in autumn and spring season. Similarly during summer and winter seasons is less TEC value is produced as we observed from Figure 7.

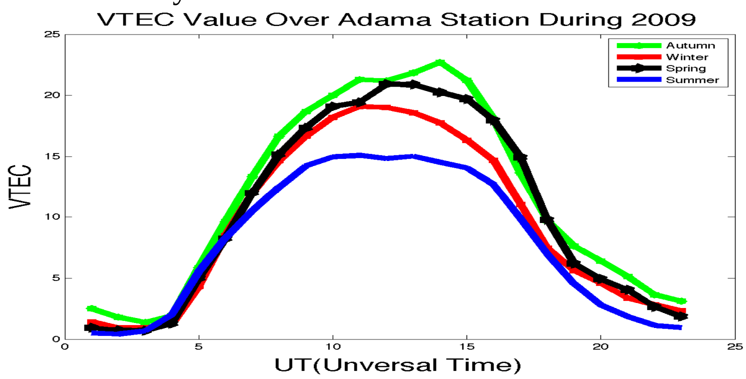


Figure 8: Median value of VTEC different season over Adama station during 2009.

Maximum TEC is observed during autumn (Tseday) and spring (Belg) seasons (as see in Figure 8). During this season the Sun is at the equator since Adama ground based GPS station is located at 8.6° latitude and 39.26° longitude and near to the equator. While maximum radiation reaches on its atmosphere, maximum TEC value is produced. The maximum median TEC value during these seasons respectively is about 24TECU and 21TECU. On the other hand, the minimum and intermediate value of TEC around 15TECU and 19TECU observed during summer (Kiremit) and winter (Bega) season, respectively. During summer, the Sun changes its position to Northern hemisphere since Adama found in Northern hemisphere maximum solar radiation intensity reaches on its atmosphere. During this time the neutral wind flow from north to South Pole, for this reason minimum TEC value is recorded at Adama. During winter season the Sun changes its position to Southern hemisphere while Adama found in Northern hemisphere and near to equator. During this time medium radiation reach on its atmosphere and TEC value recorded during this time is also medium.

Sunspot and solar radio flux dependence of TEC

The Sun emits a wide spectrum of radiation along with high energy particles. Along with the sunspot number, the flux of the Sun's radio emission at a wavelength of 10.7 cm (2.8GHz) is a useful indicator of solar activity relevant for ionospheric effect. Although the range of solar flux variation observed is very small.

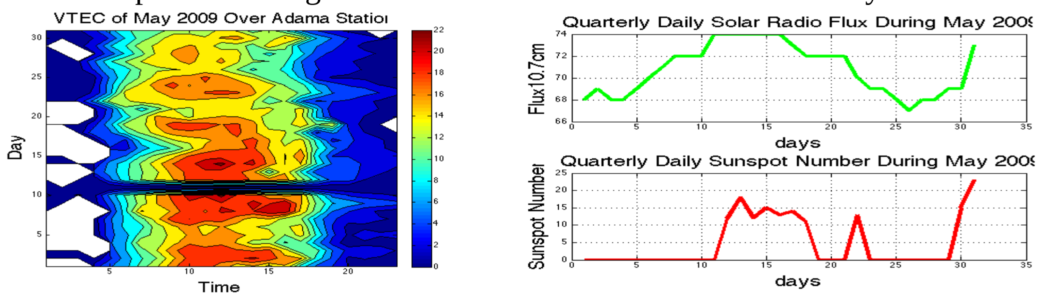


Figure 9: VTEC value during May and daily radio flux and sunspot number During May of 2009.

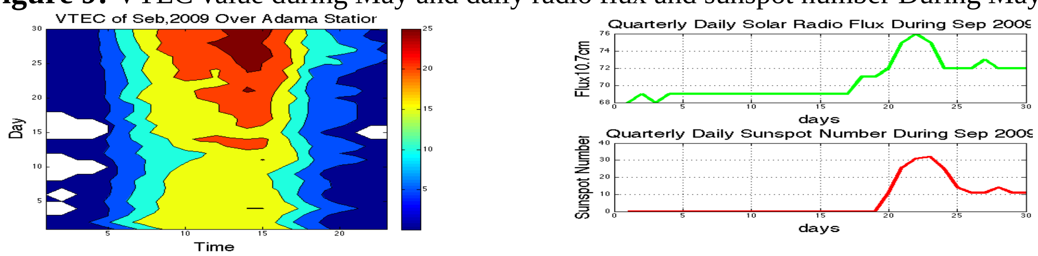


Figure 10: VTEC value during September and daily radio flux and sunspot number during September of 2009.

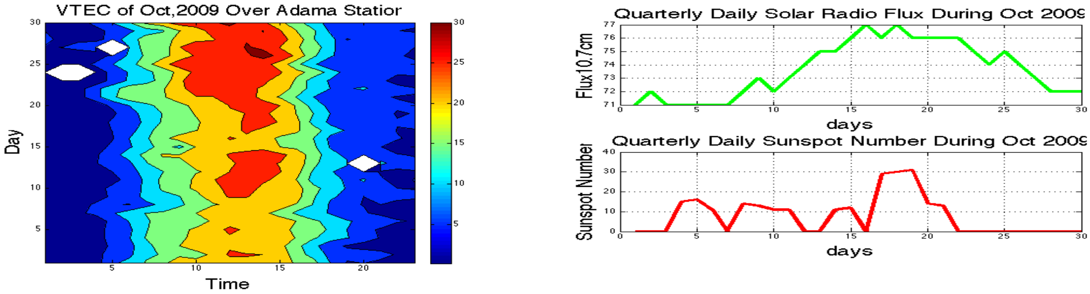


Figure 11: VTEC value during October and daily radio flux and sunspot number during October of 2009.

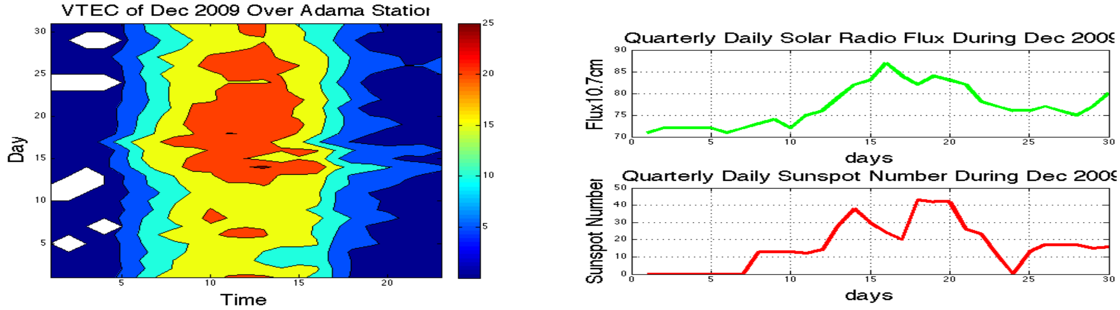


Figure 12: VTEC value during December and daily radio flux and sunspot number during December of 2009.

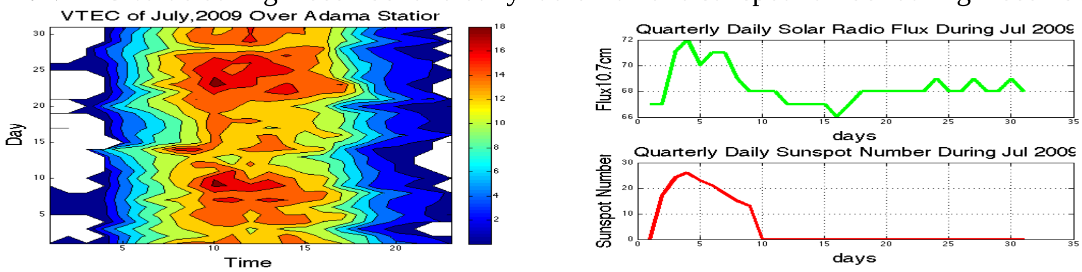


Figure 13: VTEC value during December and daily radio flux and sunspot number during December of 2009.

The Sunspot is different from year to year, month to month, and day to day. Figure 9 to 13 show daily average sunspot numbers and Sun's radio emission at a wave length 10.7cm (2.8GHz). This two condition controls the solar activity on the ionization level, with higher value during a high solar activity and low value during low solar activity. Since the sunspot numbers in 2009 varies daily as shown in the Figure (9 to 13). This solar activity has its own effects on the total electron content (TEC). The effect of this solar activity on ionospheric TEC as shown in Figures 9 to 13. From the all Figures (9 to13) the value of TEC during spotless day is less than during spot day. All these figures show the difference between the spotless day TEC value and spot day TEC value. Maximum TEC value is formed during spot day while minimum TEC value during spot less days. In Figure (9 to 13) we see when maximum sunspot numbers and solar radio flux the TEC value is also maximum. For example on Figure 9 during May 8-24, 2009 there is the maximum solar radio flux on these days the TEC value is also maximum and during May 25, 2009 the solar radio flux and sunspot number is minimum value and the TEC value is also minimum. The same to this on Figure 10 September 16-30 of 2009 there is maximum sunspot number and solar radio flux in the corresponding day the TEC value of these days is maximum and September 1-16, 2000 there is minimum solar radio flux and sunspot number during these days the TEC value is also minimum. Compared to figure 8 and 9 figure 10 and 11 shows maximum TEC is formed during spot days while minimum TEC value is formed during spotless days. But on Figure 13 we observed unexpected value which is different from other result. In Figure 13 there is maximum TEC value seen during July 22, 2009, during this time the sunspot number and solar radio flux is minimum but there is geomagnetic storm during this time. We have seen effects of this geomagnetic storm on the section and other similar geomagnetic storm days. Generally the TEC values of our ionosphere are affected by sunspot and solar radio flux. Because, during spot day there are many radiation and glue of gas released from the sun. For example corona mass ejection (CME), solar flare, X-ray, UV and etc.

Variation of TEC during a Space Weather Event

Geomagnetic storm can be classified according to different Dst index levels as follow,

i. Weak -50nT6Dst6-30nT,
ii. Moderate -100nT6Dst6-50nT and
iii. Intense Dst6-100nT by Bergeot N, Tsagouri I, Bruyninx C, Legrand J, Chevalier J, et al [7] and Basu,S. [13].

But during 2009 only two kinds of storm have occurred that is weak during October 23, February 4 and April 9 and Moderate during July 22. The effect of a geomagnetic storm on the ionospheric electron content has been studied by many workers. The geomagnetic activities have both negative and positive storm effect. The TEC response to the storm depends on the universal time of storm sudden commencement (SSC).

In the case of a day time SSC storm, a prompt penetration electric field directed east ward raises low latitude plasma upward due to the E × B drift where the recombination rate is slow. An increase in the electrodynamics drift will lift more plasma from equatorial region which diffuses down along the field lines to higher latitude and result in the increase of the TEC at stations under the anomaly crest region.

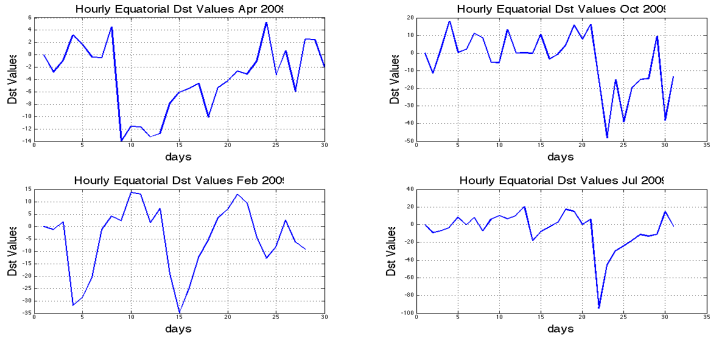


Figure 14: Average hourly Dst index during April, October, September and February 2009.

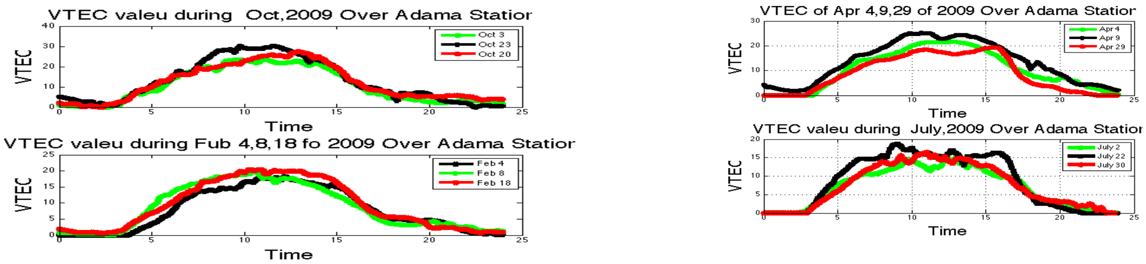


Figure 15: The VTEC value of 2009 over adama station during geomagnetic storm.

As shown on Figure 14 there are different kinds of Sudan storm commencement of geomagnetic storm. From this different Sudan storm commencement we took some days at which strong geomagnetic storm is formed depending on D_{st} indices. Diurnal and disturbance-dependent change in the ionospheric total electron content (TEC) depends on space weather. Therefore, there is strong relationship between geomagnetic storm and variation in the ionospheric total electron content (TEC). Geomagnetic storm can be monitored by the D_{st} indices. It can be seen from Figure 15 the several geomagnetic storms occurred and minor geomagnetic storm level for the corresponding days.

Figure 15 shows the TEC values for the Adama station. In these figures X-axes shows hours universal Time (UT) and Y-axes shows TEC values in TECU. The black line in the figure depicts TEC values obtained during disturbed day. TEC changes irregularly for disturbed days compared with undisturbed days. The TEC value during October 23, greater than value of October 3 and October 20.The maximum values in TEC during October 23, is 30TECU but during October 3 and 20 is 21TECU and 24TECU respectively. Similarly to October during July and April the TEC value during storm day is greater than the TEC value during undisturbed day. But during February the TEC value during storm day is less than the TEC value during undisturbed day. The maximum value during undisturbed day of February 8, 18 is 20TECU and the maximum TEC value of disturbed day of February 4 is 15TECU. This shows the storm occurred during February 4 is negative storm. Since negative storm is decreasing the value of TEC.

4. Conclusions

The TEC variations (diurnal, seasonal, and sunspot dependent and under disturbed geomagnetic conditions) for the low solar activity period (2009) at Adama station is described. Typically, the diurnal profile of TEC maximum around 1400UT, with a minimum in the predawn period. The maximum TEC observed during this span of observation is on the October 26, 2009 with diurnal peak value 30TECU. In this day the solar radio flux 82 and sunspot number 32. The results presented shown a good positive correlation between solar activity and TEC values. During the geomagnetic Storm of October 23, April 9 and July 22, 2009 the TEC variation shows typical low latitude characteristic being highest on storm day and low on quiet day. The SCC occurred during the day time, therefore, TEC increased on the storm day. TEC depletion on February 4 may be due to thermosphere composition changes.

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