VTEC BEHAVIOUR IN THE HIGH LATITUDE REGION DURING HIGH SOLAR ACTIVITY

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ABSTRACT

The behaviour of vertical total electron content (VTEC) obtained, from installed Global Positioning System (GPS) during high solar activity year 2001 over three (3) stations of the high latitude region, is reported. The considered stations are KELY, NRIL and YAKT. Median, lower and upper quartiles are used to specify variability, because they are less affected by large deviations that can occur during magnetic storms. The results show that the VTEC values corresponding to December solstice are in most cases greater than those of equinox; least in June solstice and that the highest VTEC values were observed at YAKT. In addition, for most of the considered stations, the variability observed during winter solstice is greater than that observed during equinoxes. The highest VTEC value is observed at YAKT and highest variability occurred at NRIL in December solstice.

Keywords: Ionosphere; Vertical total electron content; Solar activity.

INTRODUCTION

Ionosphere is the upper part of the atmosphere that has sufficient free electrons to affect radiowaves. This layer is basically composed of molecular and atomic Oxygen (*O*) and Nitrogen (*N*) at low pressure, which are partially ionized ($O \Rightarrow O^+$ and $N \Rightarrow N^+$) by the high energy solar ultraviolet UV and X-rays. This process generates free electrons for short periods of time before recombining again with the ions. The ionosphere is generally recognized to have several layers such as D layer (the innermost layer), E layer (the middle layer) and F layer.

The ionosphere produces several effects on trans - ionospheric radiowaves. These effects are proportional to the number of free electrons encountered by the wave on its passage through the ionosphere (total electron content, TEC). The highest TEC values in the world occur at the equatorial anomaly (EA) peaks located at approximately 15^O either side from the magnetic equator (Ezquer et al., 2004). The major factor responsible for this VTEC behaviour is clearly attributed to the solar activity. Generally, VTEC are higher during high solar activity period in all the stations. This is because ionospheric electron content increases with increasing solar activity (Stubbe, 1964; Rishbeth, 1964).

This research work was done to contribute to the study of vertical total electron content (VTEC) variability. Also to compare the VTEC values observed at different high latitudes and seasons. With this in mind, the behaviour of the vertical total electron content, obtained from GPS signals received during equinox and solstice of the high solar activity year 2001 at three (3) stations of the high latitude region, is reported.

It is well known that the ionosphere has a strong dependency with solar radiation. Thus, any variation in the intensity or position of the Sun can cause large variations on the electron density and distribution. These variations are mainly due to:

• Solar cycle variation**:** Due to the fact that the Sun has an activity cycle of about 11 years, the corresponding radiation (or flux) variations of the Sun is translated to ionospheric electron density content variations.

• Diurnal variation**:** As the apparent position of the Sun changes day by day, the ionization follows the footprint of the Sun.

• Latitudinal variation**:** The main feature of the latitude variation is the occurrence of the so-called Appleton-Hartree Anomalies (also known Equatorial Anomalies). This effect is due to the existence of an Eastward electric field combined with an horizontal magnetic field, that causes an upward plasma stream in the equator.

Several models have been developed to predict the behaviour of the ionosphere (Chiu, 1975; Bent et al., 1976; Anderson et al., 1987; Bilitza, 1990, among other). One of the most widely used empirical models is the International Reference Ionosphere (IRI) (Bilitza, 1990, 2001a), which predicts the TEC value. Nevertheless, in general, the models give the average behaviour of the ionosphere.

The development of a model for ionospheric variability is useful for the user of ionospheric models. Many efforts, including those of the IRI, are devoted to get knowledge on the variability of different ionospheric characteristics (Mosert de Gonzalez and Radicella, 1995; Bilitza, 2000; Ezquer et al., 2002, among others). The variability of critical frequencies, electron density and M(3000)F2 factor were discussed at the IRI Task Force Activity meetings held at the International Centre for Theoretical Physics during 2000 and 2001 (Bilitza, 2001b).

DATA AND METHOD OF ANALYSIS

In this work GPS data from UNAVCO were used to study the behaviour of VTEC and ionospheric variability. These data collected in zip files were extracted by software known as GPS – TEC analysis designed by Dr. Gopi Krishna Seemala of the Institute for Scientific Research, Boston, USA. VTEC of three stations, located along the Northern hemisphere, were grouped into four seasons: DECSOLS, MAREQUI, JUNSOLS and SEPEQUI. Table 1.1 shows the considered stations.

Table 1.1 Considered Stations and Geographic Coordinates.

Stations	Latitude	Longitude
YAKT(Yakutsk, Russia)	62^0N	129^0E
KELY(Kangerlnssuaq)	66.9^0N	309.1^0E
NRIL(Norilsk, Russia)	69^0N	88.1^0E

The obtained data was analyzed using Mathlab Software. The variability [V%] was also estimated, by this software, and different graphs were plotted in order to quantify the deviation of the VTEC. The following coefficient was calculated.

$$V = [\ (Qup - Q_{lo})\ /median]\ X\ 100$$

Fig.1.1 – 1.3 show the VTEC behaviour, at three high latitude stations, in December solstice, June solstice, March equinox and September equinox during high solar activity of 2001. It is observed that VTEC values before and afternoon periods are greater than the noon hours.

The peak VTEC values were observed between 4UT and 8UT in all stations except in fig. 1.1 where the peak VTEC values were found at 16UT. The highest VTEC was recorded in 2001 December solstice at YAKT.

The results for variability for the four seasons in each station were shown in figs. 1.4 – 1.6. For YAKT and KELY, in general, the variability is less than 100%, and that observed for night time and pre - noon hours are greater than the indicated percentage, especially at last hours of the night at NRIL in Dec sols. Generally, at high latitude the variability is high at all hours of the day. Comparing the values of coefficient, V[%], for the three stations, the results show that the variability during solstices are greater than that observed during equinox, particularly at night except June solstice.

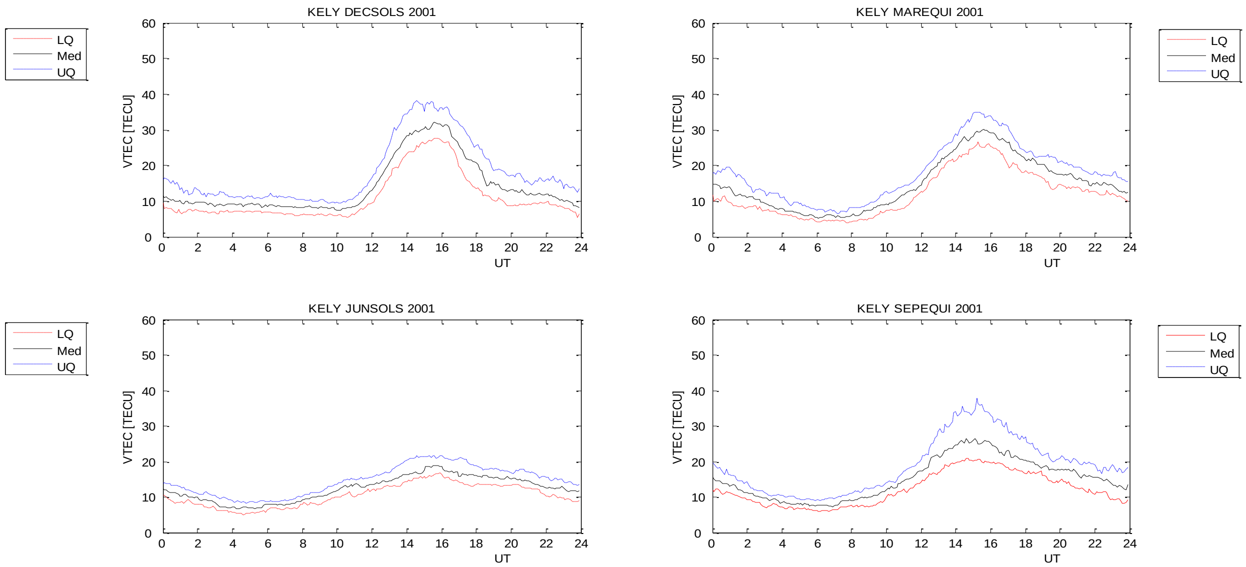

Fig.1.1: VTEC (median, upper quartile, Q_{UP}, lower quartile, Q_{LO}) KELY 2001

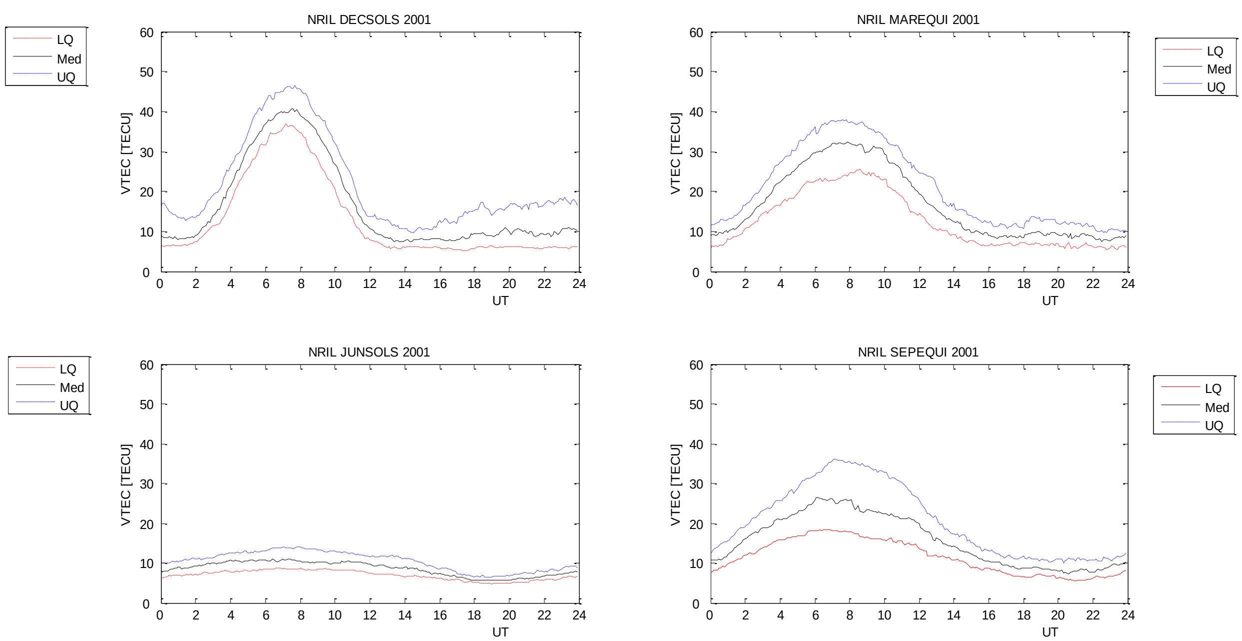

Fig.1.2: VTEC (median, upper quartile, Q_{UP}, lower quartile, Q_{LO}) NRIL 2001

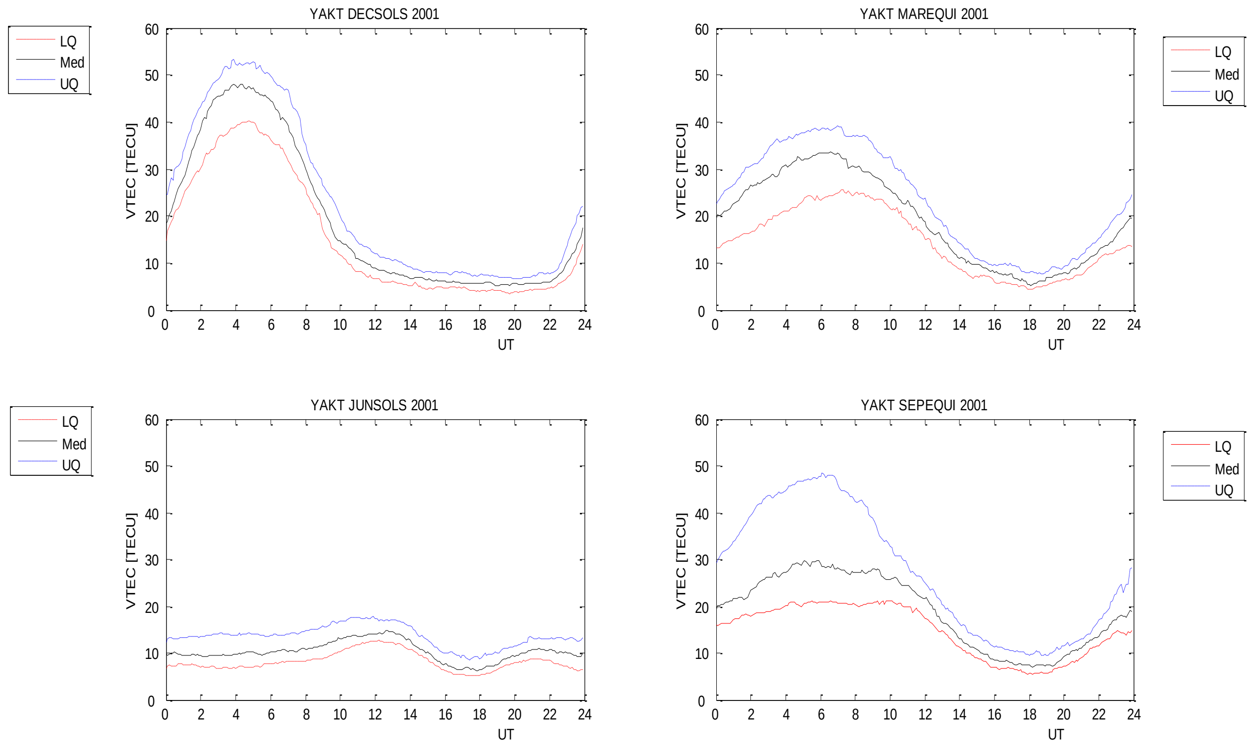

Fig.1.3: VTEC (median, upper quartile, Q_{UP}, lower quartile, Q_{LO}) YAKT 2001

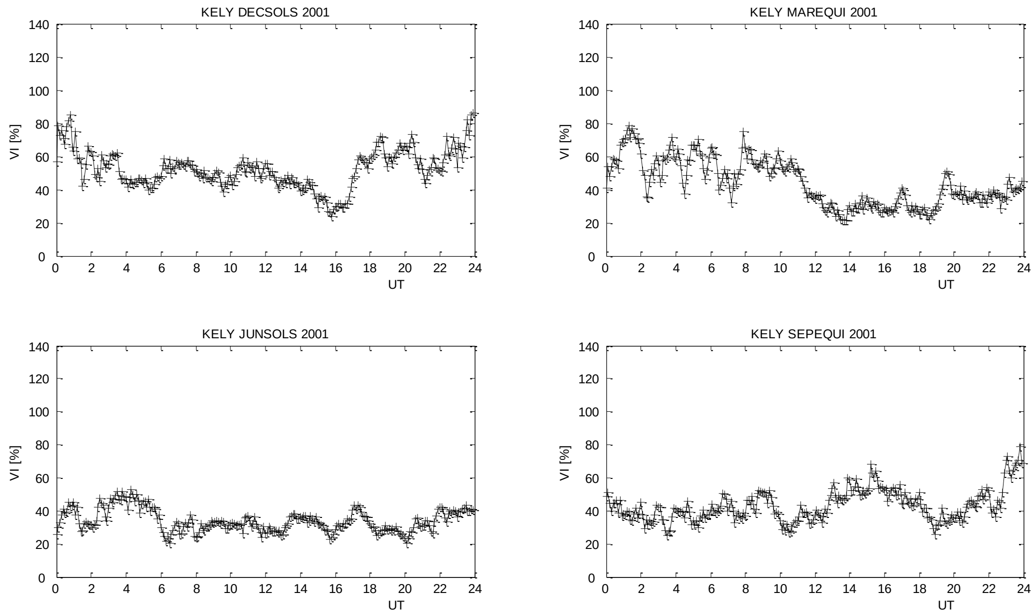

Fig.1.4: Variability of VTEC [%] on KELY in 2001.

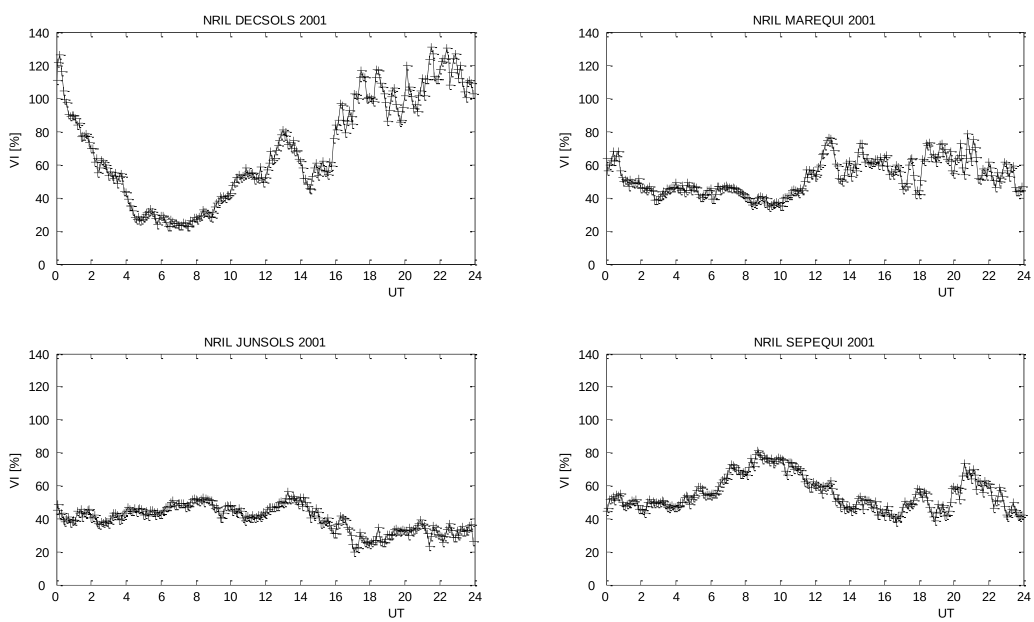

Fig.1.5: Variability of VTEC [%] on NRIL in 2001.

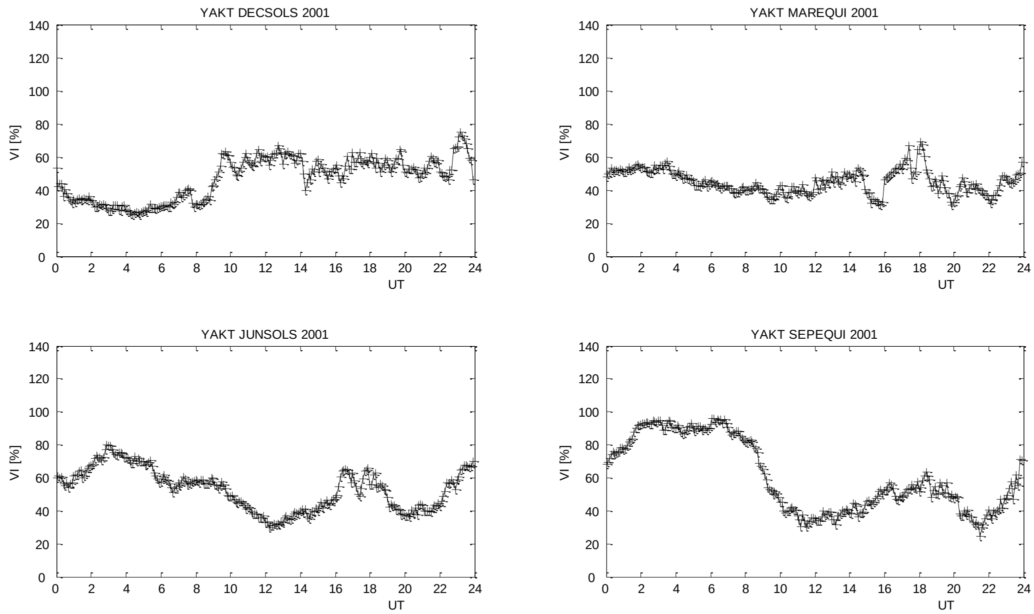

Fig.1.6: Variability of VTEC [%] on YAKT in 2001.

CONCLUSION

The report shows that VTEC has low values in the daytime especially at 12UT (i.e. noon) compared with nighttime values in all the months considered, with maximum value before and afternoon periods. From the result provided, the highest VTEC value occurred during DEC solstice. In addition, VTEC value observed in June solstice have the lowest values throughout the year. Then it is obvious that the variability index depends on solar activity because the diurnal and seasonal variations have irregular behaviour.

RECOMMENDATION

The result of this study shows the need for further validation studies using more stations in order to have a better picture of the variation of VTEC for different seasons in the ionosphere. This research work was restricted to three stations along the Northern hemisphere, thus further studies should be done to cover a wider geographical area and more years should be compared. Additional studies considering other conditions are needed in order to provide useful information for the development of VTEC variability to improve telecommunication.

REFERENCES

Anderson, D.N., Mendillo, M., Hertniter, B. A. (1987). Semi empirical low latitude ionospheric model. Radio Sci. **22:** 292.

Bent, R.B., Llewelyn, S.K., Nesterczuk, G., Schmid, P.E. (1976). The development of highly – successful world – wide total electron content investigations, in: Goodman, J. (Ed.), Effect of the Ionosphere on Space Systems and communications. Springfield, VA, USA, pp. 13–28.

Bilitza, D. (1990). International reference Ionosphere 1990, National Space Center/World Data Center A for Rockets and Satellites, Maryland, USA. 90-22.

Bilitza, D. (2000). Report from 33rd COSPAR Scientific Assembly. Warsaw, Poland, 16–23 July, 2000, IRI News Letter 7, No. 3/4.

Bilitza, D. (2001a). International reference Ionosphere 2000. Radio Sci. 36: 261.

Bilitza, D. (2001b). IRI task force activity 2001, IRI News Letter 8, No. 4.

Chiu, Y.T. (1975). An improved phenomenological model of the ionospheric density. J. Atmos. Terr. Phys. **37:** 1563.

Ezquer, R.G., Mosert, M., Radicella, S.M., Jadur, C.A. (2002). The study of the electron density variability at fixed heights over San Juan and Tucuman. Adv. Space Res. 29 (6): 993–997.

Mosert de Gonzalez, M., Radicella, S.M. (1995). Study of ionospheric variability at fixed heights using data from South America. Adv. Space Res. 15 (2): 61–65.

Rishbeth, H. (1964). A time – varying model of the ionospheric F2 – layer. J. Atmos. Terr. Phys. **26:** 657 – 685.

Stubbe, P. (1964). Temperature variation at the F – layer maximum during a sunspot cycle. J. Atmos. Terr. Phys. **26:** 1055 – 1068.