TOTAL ELECTRON CONTENT IN THE ASIAN MID-LATITUDE REGION AND ITS EFFECTS ON EARTH-SPACE PROPAGATION

H.Minakoshi and K.Sinno

Radio Research Laboratories, Koganei-shi, Tokyo 184,Japan

1. Introduction

Total electron content (TEC) is one of the most significant parameters responsible for the effects of the earth's ionosphere on radio waves which pass through it. Some of these effects may be important for satellite engineering purposes such as communication, navigation, ranging and precise time comparison,depending on the system operating frequency and the state of the ionoshere at the time. A knowledge of the TEC thus enables many important ionospheric effects to be estimated quantitatively.

The TEC has been observed along with ionospheric scintillations at Radio Research Laboratories in Japan since Spring 1977, using 136 MHz signal transmitted from the Engineering Test Satellitte Type II (ETS-II) geostationed at 130° E.

In this paper we will describe results of the TEC observations made at Koganei, Tokyo throughout the period April 1977 - December 1984 which covers almost the whole current solar cycle and estimate TEC effects on Earth - space propagation on the basis of these results.

2. The Observational Data Base

The TEC data has been obtained from measurements of Faraday rotation of 136 MHz telemetry signal transmitted from ETS-II. The mesurement data given in this paper were taken at Koganei, Tokyo, 35.71° N, 139.49° E for the period April 1977 - December 1984. The sub-ionospheric point at a height of 300 km was located at 33.5°N, 138.7° E. The corresponding geomagnetic latitude is 23.1° N, so these data are considered to represent characteristics of TEC in the Asian northern mid-latitude region. An essentially continuous record of the Faraday rotation angles was obtained throughout the observational period. However, there were about 40 days gaps in the record due to the satellite transmitter being switched off in every equinox since March 1980. Values of measured Faraday rotation were scaled at 15 minute intervals and converted to equivalent vertical TEC using the standard method. Data for the observational period has been compiled and statistical values such as monthly median, upper quartile and lower quartile values are represented here to see the average TEC behavior and the variability from it.

3. Results

Figure 1 shows the sunspot numbers for the period 1977 - 1984 which covers almost the whole current solar cycle. The

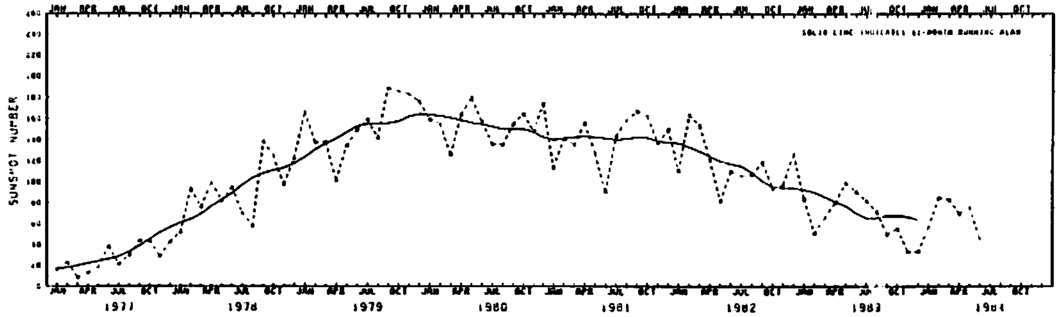

Figure 1. Sunspot numbers

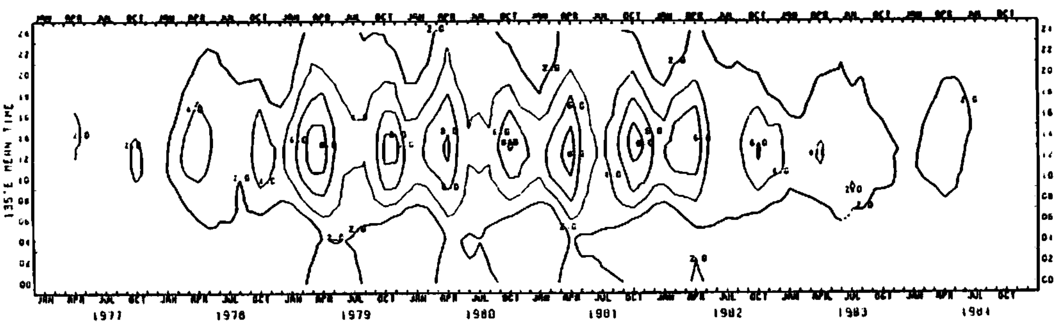

Figure 2. Contour plot of median values of TEC (x 10^{17} elec./m^2)

average TEC behavior for the complete observation period is illustrated in the contour plot of Fig. 2, which is based on monthly median values. Missing data have been interpolated where necessary. This contour plot contains plenty of information on average TEC behavior. The solar cycle and seasonal variations at a particular hour are given by slicing the contours parallel to the abscissa while the diurnal variation for any month is given by slicing the contour parallel to the ordinate.

3.1. Solar cycle and seasonal variations

The diurnal maximum and minimum values of monthly medians of TEC for the whole data interval April 1977 - December 1984 (dashed line) are plotted in Fig. 3, with the 12-month running mean superimposed (solid line) on the plot.

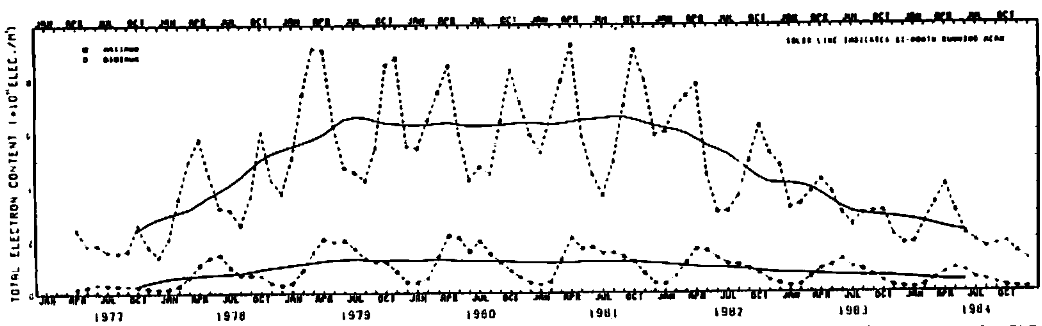

Figure 3. Diurnal maximum and minimum of monthly medians of TEC

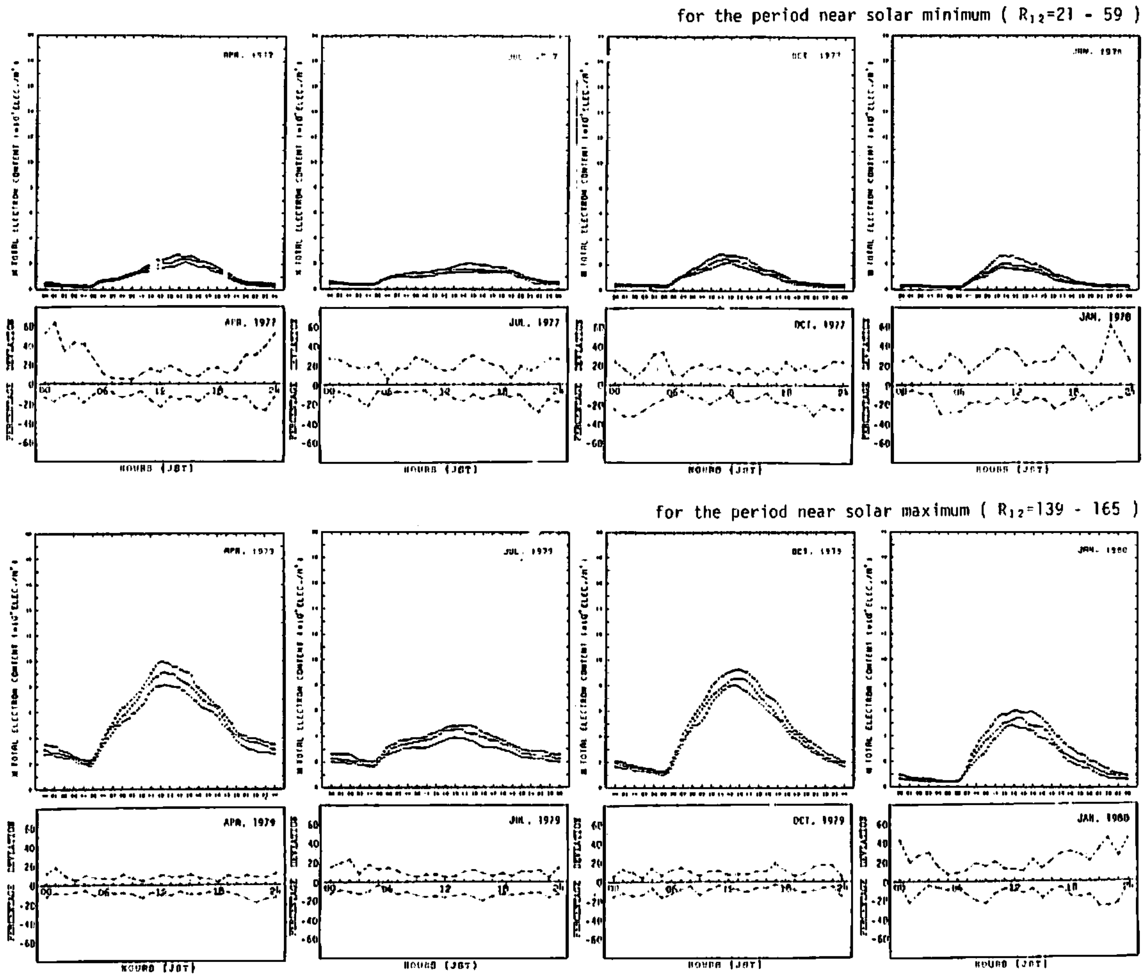
for the period near solar minimum (R12=21 - 59)
APR. 1977
JUL. 1977
OCT. 1977
JAN. 1978
for the period near solar maximum (R12=139 - 165)
APR. 1979
JUL. 1979
OCT. 1979
JAN. 1980
HOURS (JST)
PERCENTAGE DEVIATION

Figure 4

3.2. Diurnal variations and day-to-day variations

Figure 4 shows the diurnal variation of monthly median and quartile values of TEC for four months representative of the season during the period near solar minimum and near solar maximum. The percentage deviation of quartile TEC values from the monthly median values is also shown in Fig. 4. This deviation can be regarded as a measure of the day-to-day variability.

4. Ionospheric Effects on Earth-space Radio Propagation

The amount of various ionospheric effects is not only proportional to TEC but also an inverse function of frequency of a radio wave. It is important for satellite system design and operation to know the extreme limits of ionospheric effects and the variability on the basis of actual values of TEC. Table 1 shows the frequency dependence of typical ionospheric propagation effects and the extreme limits of these effects estimated at 1 GHz on the basis of the diurnal maximum of monthly median values obtained for four months during the current solar maximum period. The values given are calculated for the one-way traversal of the wave and vertical ray path angle of about 40 through the ionosphere.

Table 1 Maximum magnitude of ionospheric propagation effects estimated at 1GHz for vertical ray path angle of about 40° on the basisof monthly median values obtained for four months during the current solar maximum period (R_{12}=139-165)

Effect	Frequency dependence	Apr	Jul	Oct	Jan
Propagation delay (nsec)	f^{-2}	158	79	149	94
Range error (m)	f^{-2}	47.5	23.8	44.6	28.3
Carrier phase advance (rad)	f^{-1}	992	496	931	591
Faraday rotation (rad)	f^{-2}	0.98	0.49	0.92	0.59

5. Conclusions

For the Asian northern mid-latitude region for almost the whole solar cycle we have presented the average behavior of TEC, which is propotional to a number of ionospheric effects. The monthly median values of TEC range from 10^{16} to 10^{18}(elec./m^2). It has a close correlation with the solar activity, the seasonal variation of equinox maximum and the diurnal variation of midday maximum. The deviations from monthly median values are approximately 10 - 20 percent during the daytime periods for solar maximum conditions when absolute values of TEC effectd are greatest. Therefore a satellite system which has severe error requirements needs some corrections for the effects of the earth' ionosphere. The main ionospheric effect on the system can be eliminated by the use of average TEC values such as TEC model, but still it must tolerate the approximately 10 - 20 percent variability of TEC effect.

The next step of our studies is to test a couple of present TEC models including the International Reference Ionosphere by comparing with observed values of TEC and to modify the best model to agree more closely with the actual values in the Asian mid-latitude region if necessary.