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IONOSPHERIC EFFECTS DURING THE EVENT OF SOLAR ECLIPSE (22ND JULY 2009) ON GPS NAVIGATION SOLUTION IN THE CONTEXT OF INDIAN SUBCONTINENT

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1 INTRODUCTION

The Global Positioning System (GPS) navigation accuracy is severely affected due to Ionosphere, which is a function of Total Electron Content (TEC). The TEC, which is defined as the number of electrons encountered along the ray path between a transmitter and a receiver, is strongly affected by solar activity, earthquakes, Tsunami and geomagnetic activity. In this paper, an attempt is made to analyze the TEC variations along the satellite propagation path in the upper atmospheric layers during the total solar eclipse on 22nd July, 2009. The GPS receiver data from IISc, Bangalore is collected on the day of the eclipse and the entire month of July for analysis. Data is sampled at a sampling rate of 30 seconds for analysis. TEC is estimated for the day long data of the corresponding days and response of total TEC to the eclipse was analyzed. The results show that: 1) Eclipse led to depression of TEC mounted to 2-6TECU 2) maximum TEC depression (6TECU) occurred during eclipse maximum.

This particular investigation of ionospheric effects on navigation solution during the solar eclipses is very much useful during the Landing of CAT-I aircrafts.

2 GEOMETRY AND GENERAL INFORMATION OF THE SOLAR ECLIPSE, 22nd JULY, 2009

Solar eclipses provide unique opportunities to study the behavior of the ionosphere. During a solar eclipse, the Moon's shadow decreases the ionizing radiation from the Sun, causing changes in electron concentration and temperature, and neutral compositions and temperature. During the past decades, the responses of the ionosphere to solar eclipses have been studied extensively with various methods, such as the Faraday rotation measurement, ionosonde network, incoherent scatter radar (ISR), Global Positioning System (GPS), and satellite measurements .Ionospheric response to the solar eclipse of 22nd July 2009, found an enhancement, a depression, followed by an enhancement and depression in Total Electron Content (TEC). During the same eclipse event, there might be different ionospheric responses in different locations because of the differences in background parameters.

The Solar eclipse began on the 22nd of July 2009 at around 5:30 AM IST in India and spent almost two hours for passing the subcontinent. The path of totality will pass through central India passing over Surat, Ujjain, Baroda, Bhopal, Patna, Darjeeling, and Dibrugarh in the far east. Global visibility chart of the Solar eclipse is shown in Fig.1. The eclipse began at sunrise on the left (India), and ended at sunset on the right (Pacific ocean).

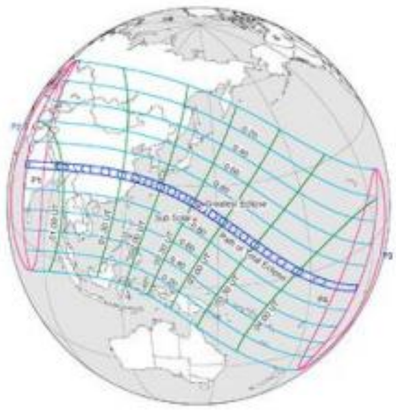

Fig.1: Global visibility chart of the Solar Eclipse

In this paper, we present the numerical calculation results of ionosphere effects of the solar eclipse. We obtained the behavior of various parameters such as Total Electron content (TEC), dTec/dt of the ionosphere during solar eclipse by means of numerical calculations.

3 IONOSPHERIC RESPONSE TO THE SOLAR ECLIPSE

The dual frequency GPS receiver data of Indian station, IISc, Bangalore (IGS Station Lat/Lon: 13.02º/77.57º) is collected corresponding to July 22nd 2009(Solar eclipse) .The data is sampled at a sampling rate of 30 seconds for the analysis. The Converter software tool of Novatel make is used to convert receiver specific data format into Receiver Independent Exchange (RINEX) format**.** Eclipse starts at 6:05:21 Hrs of the local time, reaches its maximum at 6:20:38Hrs and lasts up to 7:17:00Hrs. It is observed that the TEC drops drastically at eclipse maximum (6:20:38hrs) and Variation in TEC is also minimum at eclipse maximum. TEC variations on the day of solar eclipse is represented in Fig.2.

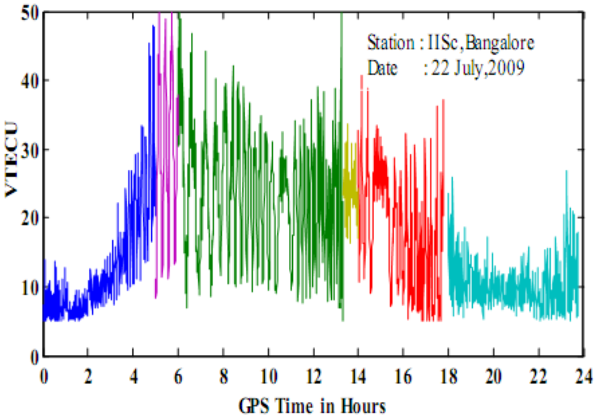

Fig.2: Variations of the VTEC on July 22, 2009(Solar eclipse)

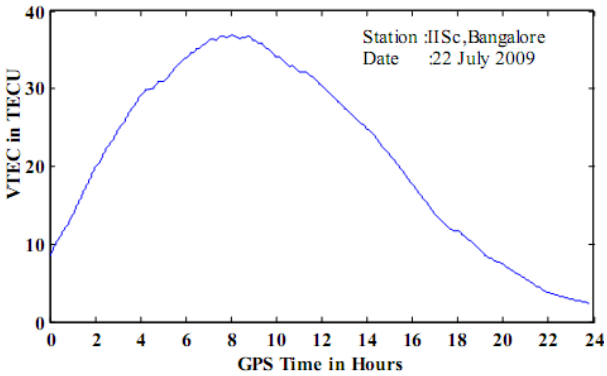

Fig.3: Smoothed VTEC on 22nd July, 2009(Solar eclipse)

Fig.3 represents the plot of smoothed code-TEC on 22nd July, 2009. Smoothing of TEC is done by convolution technique[1].

TEC plot of SVPRN 14 for three consecutive days (July 20, July21, July22) during the eclipse time is shown in Fig.4. It can be observed form the plot that TEC is minimum (7.24TECU) at the eclipse maximum (00:50:38 Hrs GPS Time). Comparison of TEC of the Eclipse day during the eclipse time with the monthly average shows that the TEC is minimum (7.24TECU) on the day of the eclipse than the monthly average. Fig.5. represents the TEC of SVPRN 14 on eclipse day and the monthly average.

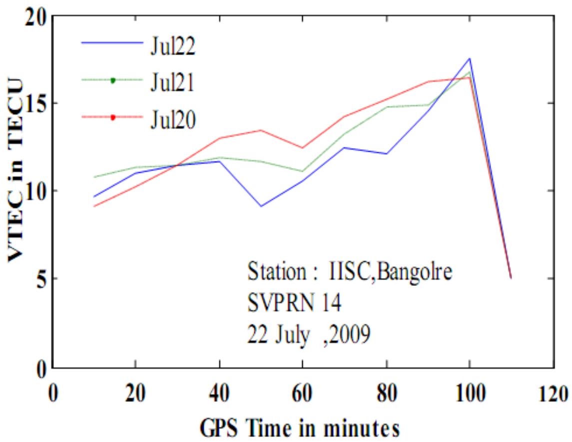

Fig.4: TEC for SVPRN14 on 20th July, 21st July, 22nd July 2009

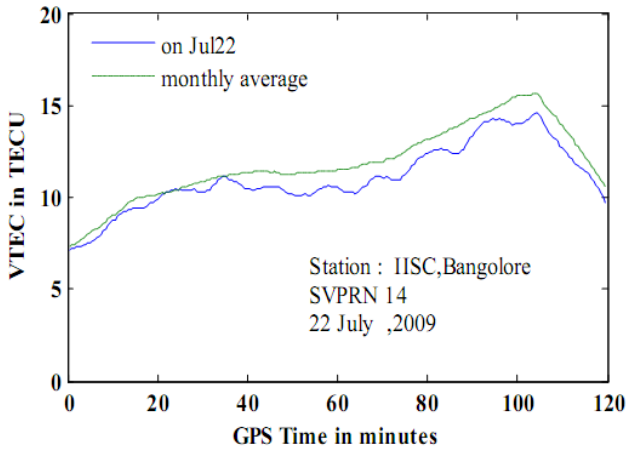

Fig.5: TEC for SVPRN14 on 22nd July 2009 and Monthly average

Rate of change of TEC is estimated for three consecutive days (July 20, July21, July 22) for SVPRN 14 and it is observed that the rate of change in TEC is minimum on the eclipse day i.e. 22nd July 2009. Fig.6 represents the rate of change of TEC for the three consecutive days (20th July ,21st July, 22nd July) for SVPRN 14.

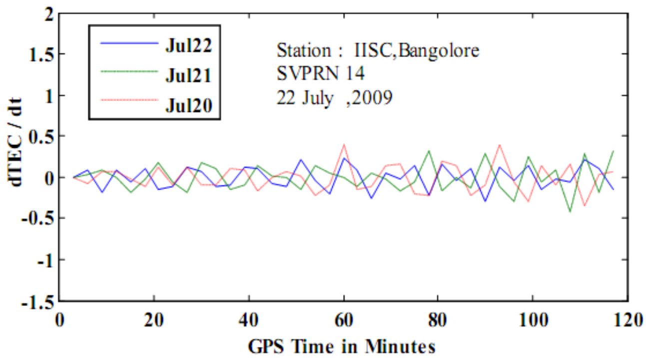

Fig.6: Rate of change of TEC for SVPRN 31(July 20,July21, July22)

Navigation solution during the eclipse is computed using the measurements of the satellites: SVPRN 14, SVPRN 18, SVPRN 31, SVPRN 22. Due to the reduction of ionospheric delay during the eclipse time, position errors are lessened and navigation solution approaches the true value(x=1337936.4550m, y=6070317.1261m, z=1427876.7852m). Variations of Ionospheric delay and Navigation solution during the time of eclipse is illustrated for few epochs in Table.1.

Time (GPS) in Hours	Ionospheric Delay in meters	Navigation solution			Position Error in meters		
		X Position in meters	Y Position in meters	Z Position in meters	X	Y	Z
00:35:20 (start ofEclipse)	2.4616	1337932.0674	6070312.4119	1427880.7478	4.2200	4.7064	3.822
00:50:38 (Max .of Eclipse)	1.4630	1337931.8794	6070313.8313	1427881.5148	4.408	3.287	4.589
01:47:00 (End .of Eclipse)	2.7253	1337934.7094	6070313.8965	1427882.7258	6.862	4.191	5.80
3:00	3.0041	1337926.1750	6070312.9740	1427880.1194	10.112	4.1442	3.1936
4:00	4.5269	1337926.7891	6070310.1981	1427880.6070	9.498	6.9201	3.6813
5:00	4.8999	1337922.9269	6070313.5653	1427878.0329	13.36	3.5529	1.1072

Table.1: Details of the Ionospheric delay and navigation solution for few epochs.

CONCLUSIONS

- From the data collected on 22nd July, 2009, it is found that a significant variation in the TEC along the satellite propagation path. This variation observed is mainly due to Eclipse totality (66%) at the observed station (IISc, Bangalore). TEC observed is minimum during the maximum of the eclipse time i.e. at 6:20:38Hrs (LT) and is due to the obstruction of solar ultraviolet rays by the moon.
- With significant reduction in TEC during the eclipse time, ionospheric delay is reduced significantly (1.76m), hence a better navigation solution is obtained.

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REFERENCES

[1] Hofmann-Wellenhof, B., H. Lichtenegger and J. Collins, "GPS Theory and Practice", Spriner-Verlag Wien, New York, 5th edition, 2001.