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GPS-TEC Variation during Low and High Solar Activity Period (2008 and 2014) over the Indian Region

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ABSTRACT:

Accurate Total Electron Content (TEC) measurement is essential to improve the accuracy of GNSS in precise position applications like defence, civil aviation, search and rescue. In this paper measurements of Ionospheric TEC was conducted over the different Indian low latitude stations namely Bangalore(12.97˚N,77.59˚E), Hyderabad(17.45˚N,78.47˚E), Gowhathi(26.14˚N, 91.73˚E) and Delhi (28.61˚N, 77.20˚E) which were established as a part of GAGAN project. The TEC has been measured during low and high solar activity periods (2008 and 2014) and analyzed the variations. From the results it is found that the GPS-TEC values are large in the March, April, September and October i.e. at equinox period. Further, the maximum TEC observed is 148.31 TECu at Delhi Station in the month of April, 2014.

Key Words: Ionosphere,GPS,TEC.

I.INTRODUCTION:

The Global Positioning System (GPS) is a satellite based system that provides users position, navigation and time (PNT) services continuously. The accuracy of the GPS system is affected by several factors like atmospheric delays, satellite clock and orbit errors, multipath, and satellite geometry etc.[1].GPS satellites transmit signals onL1 (1575.42 MHz) and L2 (1227.60 MHz) frequency bands. The positioning accuracy of GPS decreases mainly by ionospheric time delay error. Considering the growing importance of GPS as an underlying foundation for numerous technological, social and economic systems, forecasting and mitigation of the ionospheric effects on GNSS performance have become an essential task in protection of national infrastructure. When the GPS signals propagates through the ionosphere propagation medium, it results delay in signal due to the varying electron density along the line of sight between the receiver and the satellite (i.e. TEC). TEC is significant in determining scintillation and group delay of radio waves through ionosphere medium.

A dual-frequency GPS receiver measures the difference in ionospheric delay between the L1 and L2 signal. The group delay for dual-frequency GPS receiver can be written as:

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$$p_2 - p_1 = 40.3TEC\left(\frac{1}{f_2^{\,2}} - \frac{1}{f_1^{\,2}}\right) \text{.....(1)}$$

Where, p_1 and p_2 are the group path lengths, f_1 and f_2 are the corresponding high and low GPS frequency respectively. From (4), TEC can also be obtained by writing as:

$$TEC = \frac{1}{40.3}\left[\frac{f_1^{\,2} f_2^{\,2}}{f_1^{\,2} - f_2^{\,2}}\right](p_2 - p_1) \text{.....(2)}$$

In this paper TEC was estimated for different Solar activity periods 2008 and 2014 over the four GAGAN TEC stations, and analysed the behaviour. Apart from various locations in globe several researchers have been investigated morphological features of TEC such as the diurnal, monthly, seasonal, latitudinal and solar activity variation using various techniques, e.g. in Africa, [2]in South America,[3][4][5] [6]over China [7] and [8]over North America[9][10] over Japan; [12] [13].

In this Paper we focused on both low Solar Activity and High Solar Activity periods by taking GPS-TEC data for 2008 and 2014 Years. Four different stations across India i.e., Bangalore, Hyderabad, Gowhathi, and Delhi have been considered.

II.DATA ANALYSIS:

The data of 2008 and 2014has been collected from the four GAGAN TEC stations namely Bangalore,(12.97 N, 77.59 E),Hyderabad(17.38 N,78.48 E),Gowhathi(26.14 N,91.73 E),New Delhi(28.61 N,77.20 E).list of stations and data availability is presented in Table1.This data was provided by Space Application Center, ISRO. The data contains following parameters GPS week, GPS seconds of week, PRN number, Elevation Angle, Azimuth angle, $(C/N)_o$, Lock Time, S_4 scintillation Index , 1s-sigma, 3s-sigma ,10s-sigma, 30s-sigma, 60s-sigma, Code-carrier divergence, Sigma divergence, TEC@-45s(TECU), DTEC@-45s(TECU),TEC@-30s(TECU),DTEC@-30s(TECU),TEC@-15(TECU),DTEC@-15s(TECU),TEC@(TECU), DTEC@(TECU).

Out of these 23 parameters GPS week, GPS seconds of the week, Satellite PRN number, Elevation angle, Azimuth angle, TEC have been considered. In order to eliminate the multipath effect, GPS data with elevation angles greater than 30^0 were used for this study. With this data hourly mean over a period of month has calculated for 2008 and 2014 years.

TABLE1Station names data availability

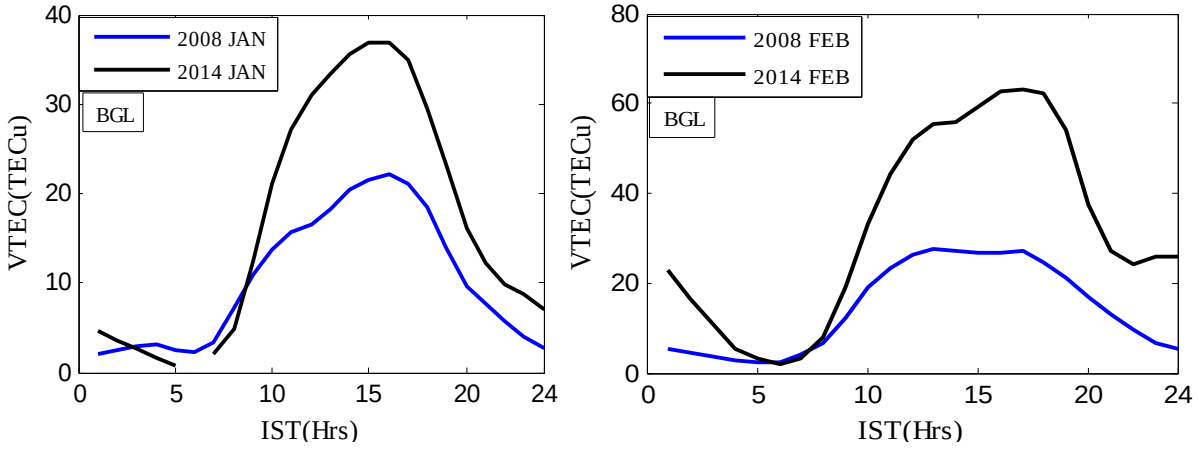
Station Name	Latitude	Longitude	Data available months for the years 2008and 2014
Bangalore	12.97˚N	77.59˚E	January, February, March, April ,May, June, July, August, September, October, December
Hyderabad	17.45˚N	78.47˚E,	January, February, March, April ,May, July, August, September, December
Gowhathi	26.14˚N,	91.73˚E	January, February, March, April ,May, June, July, August, September, October, November, December
Delhi	28.61˚N	77.20˚E	January, February, March, April ,May, June, July, August, September, October,

III.RESULTS AND DISCUSSION:

Monthly variation of GPS-TEC was evaluated for four GAGAN stations in different solar activity periods i.e., 2008 and 2014.Stationwise detailed analysis is presented in the following sections.

3.1 Monthly variation of GPS-TEC for Bangalore Station:

In order to investigate the monthly GPS-TEC variations, data collected from Bangalore station having co-ordinates (12.97˚N,77.59˚E) for the years 2008 and 2014. For this particular station GPS-TEC variations are evaluated for the months January, February, March, April ,May, July, August, September, December . Data is unavailable for the month of November. The hourly mean of GPS-TEC for all days in each month of the years 2008 and 2014 are represented. In the month of January,2014 IST 05:00 to 07:00 hours data is unavailable. The plots of GPS-TEC variations are shown the following Figure 1.in that horizontal axis represents the IST in hours and vertical axis represents the VTEC in TECu.



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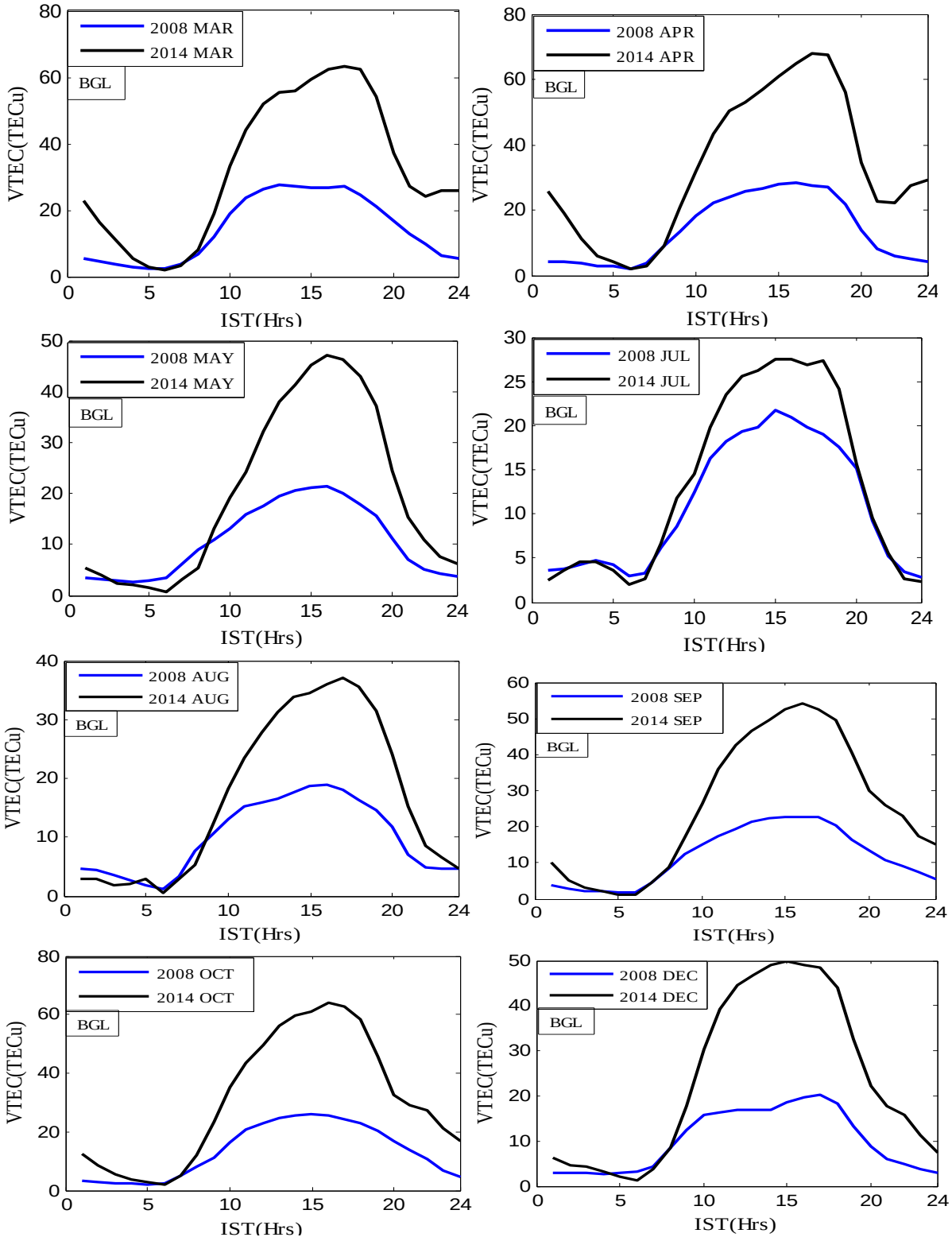

Figure.1. Mean value plots for Bangalore station

From the Fig 1 it is noticed that there is a gradual decrease in GPS-TEC from 00:00 hrs reaching a minimum between 05:00 hrs to IST 06:00 hrs .i.e., predawn to Sun up period. After IST 06:00 hrs , TEC has been increasing with the time and reached the peak at IST 16:00 hrs. However the peak values are not same for all the months. In 2014 largest value of peak is 68.1 TECu at IST 1700 hrs in the month of April. For the year 2008 it is 28.18 TECu at IST 16:00 hrs in the month of April. It is very clear that TEC values are larger in 2014 for all the months because the 2014 is the high solar activity period with large Sun Spot Number, Kp Index and Solar Flux values. The maximum GPS-TEC for this station is 89.83 TECu in the month of March, 2014 and for the year 2008 it is 50.78 TECu in the July (Table 2).

Monthly variation of GPS-TEC for Hyderabad station:

The GPS-TEC variations for Hyderabad station which is located between crest and the equator, data collected for the years 2008 and 2014 has been evaluated. The coordinates of Hyderabad station are 17.45˚N, 78.47˚E. For this station October and November month data is unavailable. The hourly mean of GPS-TEC is evaluated for all 30 days of each month. The TEC variations trend for this particular station is same as the Bangalore station. In 2014 largest value of hourly mean is 89.16 TECu at IST 17:00 hrs in the month of April. For the year 2008 it is 45.23 TECu at IST 16:00 hrs in the month of April. The maximum GPS-TEC for this station is 131.08 TECu in the month of February, 2014 and for the year 2008 it is 58.97 TECu in month of April (Table 2).

Monthly variation of GPS-TEC for Gowhathi Station:

In order to investigate the monthly GPS-TEC variations, data collected from Gowhathi station having co-ordinates26.14˚N, 91.73˚E. This station is having complete 12 months of data for the years 2008 and 2014. The hourly mean GPS-TEC is evaluated for both the years 2008 and 2014.The TEC trend is like other two stations. In 2014 largest hourly mean value is 78.42 TECu at IST 14:00 hrs in the month of April. In the year 2008 it is 35.45TECu at IST 13:00 hrs in the month of March. The maximum GPS-TEC for this station is 128.93 TECu in the month of October, 2014 and for the year 2008 it is 72. 40 TECu in the March(Table 2).

Monthly variation of GPS-TEC for Delhi Station:

For evaluating GPS-TEC variations the data is collected from the Delhi located in 28.61˚N, 77.20˚E coordinates. For this station November and December months data is unavailable. The hourly mean of GPS-TEC for all 30 days in each month of the years 2008 and 2014.In 2014 largest value of peak is 82.63 TECu at IST 16:00 hrs in the month of march. For the year 2008 it is 27.61TECu at IST 13:00 hrs in the month of March. The TEC values are large in the year 2014.The maximum GPS-TEC for this station is 148.31 TECu in the month of April, 2014 and for the year 2008 it is 58.37 TECu in the March(Table 2).

TABLE 2 Maximum GPS-TEC (in TECu) values for years 2008 and 2014

Month	Bangalore Station		Hyderabad Station		Gowhathi Station		Delhi Station	
	2008	2014	2008	2014	2008	2014	2008	2014
January	33.21	60.49	53.01	82.09	38.10	92.37	27.81	98.65
February	30.25	83.46	48.18	131.08	42.24	128.64	36.55	127.00
March	47.63	89.83	57.49	107.31	72.40	125.82	58.37	141.64
Apr	38.54	87.01	58.97	114.23	62.87	131.08	56.69	148.31
May	29.30	69.34	50.09	92.65	50.35	101.60	39.15	120.87
June	26.73	67.25	-	-	39.94	75.88	30.16	92.88
July	50.78	52.30	40.82	70.91	40.74	86.65	34.92	93.65
August	26.78	56.39	44.13	73.92	37.08	86.88	35.98	95.82
September	31.9	73.36	54.27	98.54	42.65	121.47	42.37	139.93
October	37.12	86.72	-	-	42.64	128.93	40.11	143.19
November	-	-	-	-	41.31	124.41	-	-
December	27.23	67.79	43.42	87.20	37.09	118.15	-	-

IV.CONCLUSION:

The GPS-TEC variation during low and high solar activity periods(2008 and 2014) was evaluated for the four stations. From the analysis, it is observed that The TEC values are maximum for all the months in the year 2014 when compared to 2008. The hourly mean GPS-TEC values are maximum at IST 17:00 hrs with 68.1 TECu in the month of April,2014 and 28.18 TECu at IST 16:00hrs in April, 2008 for Bangalore station. Hyderabad station hourly mean values are maximum in April month at IST 17:00 hrs having 89.16 TECu in 2014 and in 2008 it is 45.23 TECu at IST 16:00 hrs. For Gowhathi the values are maximum at IST 14:00 hrs having 78.82 TECu in April, 2014. In 2008 March is having 35.45 TECu at IST 13:00 hrs. For Delhi, the hourly mean peak values are obtained in the month of March for 2014 and 2008 with 82.63 TECu at IST 16:00 hrs , 27.61 TECu at IST 13:00 hrs. For all the stations, the GPS-TEC is high in 2014 when compared with 2008. The maximum GPS-TEC is 148.31 TECu.

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