Observation of the Total Electron Content for 14-GPS stations in Malaysia during the Annular Eclipse of 15th of January 2010

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***Abstract*— The paper examines the Ionospheric response to the annular eclipse of the sun on January 15, 2010 over eastern and western Malaysia using GPS data measurement from 14-ground station in Malaysia. The GPS sensing technique employs two different approaches to verify the TEC depletion occurrence at the 14-stations. The first approach measures the TEC depletion parameters at the 14 GPS stations during the solar event. The second approach compares the TEC value with the quiet day TEC variation at one of the station 3-days before and 3-days after the solar eclipse event. The GPS observation indicates occurrence of TEC depression at 6 stations where the behaviour varying from one station to another. On the basis of the first and second measurement techniques, the range of TEC depletions at the six stations were 9 to 20 %, while for the other 8-stations 0.4 to 12% respectively. The measurement shows that TEC depression at most GPS stations began on the neck of the first contact of the solar eclipse followed by deeper depressions. This effect was as a result of the hiding of the optical rays during the solar eclipse which causes direct reduction in photo ionization; destroy the previous photo-chemical equilibrium and result in the depletion in electron density.**

Keywords— Total Electron Content, GPS stations, Annular Eclipse

I. INTRODUCTION

The partial or total blockage of the solar radiation from the sun reaching the earth called solar eclipse is an event that happens only for a short period of time every year. This short event can induce or cause variations in Ionospheric parameters such as; reduction of Ionospheric Plasma, Total Electron Content (TEC), F-layer maximum [1] profiles of temperature, source-response relation between the ambient rates of production the ions and electrons start to recombine, chemical loss and motion of ionization, photochemistry, an increase of effective reflection heights during the eclipses ([2], [3], [4]). It can also cause variations in the atmospheric parameters ([5], [6], [7]). A lot of work has been done by many researchers in the past and have shown that there is a significant decrease in the TEC during solar eclipse ([8], [9], [10]). For example at Scott Base Antarctica during 23rd November 2003, total solar eclipse the TEC level shows a decrease by about 17% and 30% [11].

In this paper, the TEC measurement recorded by 14 ground-based GPS receiving stations in Malaysia are employed to examine the Vertical Total Electron Content (VTEC) variations during the short period (about 2 hours and 50 minutes) of the solar eclipse.

Geophysical Location And Eclipse Path

Figure 1 shows the path of annular solar eclipse and the coverage area by the eclipse shadow on 15th January 2010 [12]. The eclipse shadow was first seen at the western part of the Central African Republic at 05:14 UT. The Moon's antumbral shadow then move across Chad, Democratic Republic of the Congo, Uganda, Kenya and Somalia. The shadow then moves leaving Africa and crosses the Indian Ocean. The greatest eclipse with magnitude reaches 0.9190 occurs at 07:06:33 UT while the maximum duration of the annularity reaches 11 minutes and 08 seconds. The central path then continues moving into Asia and passes through Bangladesh, India, Sri Lanka, Burma (Myanmar) and China. In its final moments, the antumbra travels down the Shandong peninsula and disappear at 08:59 U [13].

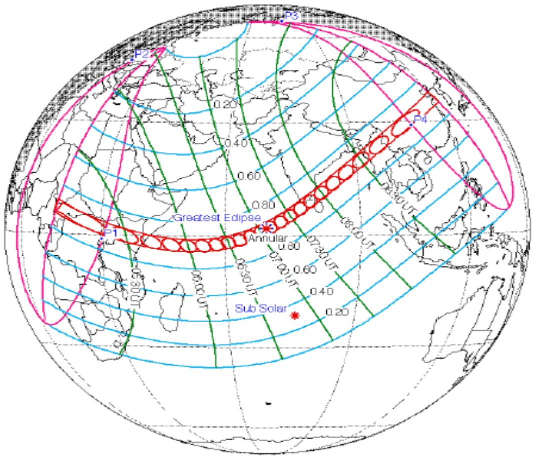

FIGURE 1: THE PATH OF ANNULAR SOLAR ECLIPSE ON 15TH JANUARY 2010 (SOURCE: ESPENAK 2010)

Station Name	Lat deg	Lon deg	Maximum Obscuration	Eclipse begings 1st Contact time	Maximum Magnitude	Max Mag time	Eclipse ends 4th Contact time	Eclipse Local Time	Total Eclipse Time
Alor Setar (SRIJ)	6.13	100.37	38.09	06:56:44.0 UT	0.50	08:28:26.8 UT	09:45:21.1 UT	2:56 to 4:45pm	2hrs 49min
Ipoh (BABH)	4.65	101.05	33.28	06:58:55.7 UT	0.45	08:27:21.8 UT	09:41:55.5 UT	2:58 to 4:41pm	2hrs 43min
UKM (UKM)	2.92	101.77	28.50	07:01:19.4 UT	0.41	08:26:02.9 UT	09:37:55.8 UT	3:01 to 4:37pm	2hrs 36min
Kota Bharu (UMAS)	6.12	102.30	34.46	07:03:32.2 UT	0.47	08:31:01.3 UT	09:44:49.3 UT	3:03 to 4:44pm	2hrs 41min
Kuantan (KRAI)	3.83	103.35	27.32	07:07:23.3 UT	0.40	08:29:19.8 UT	09:39:06.7 UT	3:07 to 4:39pm	2hrs 32min
Johor Bahru (JHJY)	1.48	103.77	21.54	07:09:40.1 UT	0.34	08:26:32.4 UT	09:32:37.3 UT	3:09 to 4:32pm	2hrs 23min
Kuching (UPMS)	1.53	110.30	12.19	07:34:26.6 UT	0.23	08:34:25.4 UT	09:27:31.3 UT	3:34 to 4:27pm	1hrs 43min
Sibu (SIB1)	2.28	111.85	11.67	07:38:53.7 UT	0.22	08:36:54.0 UT	09:28:27.0 UT	3:38 to 4:28pm	1hrs 50min
Sri Aman (AMAN)	1.20	111.58	10.08	07:39:29.5 UT	0.20	08:35:15.9 UT	09:25:02.1 UT	3:39 to 4:25pm	1hrs 47min
Miri (MIRI)	4.43	114.02	13.02	07:43:11.7 UT	0.24	08:41:22.4 UT	09:33:04.9 UT	3:43 to 4:33pm	1hrs 50min
Kota Kinabalu (UMSS)	5.97	116.08	13.52	07:47:19.0 UT	0.24	08:44:35.0 UT	09:35:36.8 UT	3:47 to 4:35pm	1hrs 50min
Sandakan (SAND)	5.87	118.05	11.14	07:52:59.7 UT	0.21	08:45:48.6 UT	09:33:18.2 UT	3:52 to 4:33pm	1hrs 41min
Tawau (MTAW)	4.27	117.90	8.47	07:55:22.0 UT	0.18	08:44:06.0 UT	09:28:15.2 UT	3:55 to 4:28pm	1hrs 33min

II. DATA SOURCES AND METHODOLOGY

Data for January 15 2010 were retrieved from 14 ground-based GPS receiving stations in Malaysia namely, Alor Setar, Ipoh, UKM (Bangi), Kota Bharu, Kuantan, Johor Bahru, Kuching, Sibu, Sri Aman, Miri, Kota Kinabalu, Sandakan, SIK1 and Tawau. For depth analysis of the solar eclipse event, available GPS data from 12th to 18th of January at UKM Bangi station (only) was retrieved. The data covers 3-days before and 3-days after the solar eclipse. The 13th and 17th day data are the most disturbed and quiet days respectively, in the GPS calendar for the month of January 2010. Bernese GPS software version 5.0 was used to model the Vertical Total Electron Content (VTEC) for the 14-stations. The variation of VTEC during the 2hours 49 minutes period of the annular solar eclipse at the 14-stations were investigated. Figure 1: The path of annular solar eclipse on 15th January 2010 (Source: [9]).

III. RESULTS AND DISCUSSION

Table 1 presents the Geo-location and eclipse characteristics for the 14- GPS stations in Malaysia.

Table 2: Comparison of VTEC values during the Solar Eclipse

Name	(A) Max TEC Values Before Eclipse TEC (TECU)	(B) TEC Values When Eclipse begins TEC (TECU)	(C) TEC Values At Max Eclipse Contact TEC (TECU)	(D) TEC Values When Eclipse end TEC (TECU)
AMAN	24.234	24.08	23.29	21.64
MIRI	23.326	22.85	21.75	19.69
SAND	22.932	21.85	20.45	18.31
MTAW	23.322	22.41	21.12	19.15
UMSS	22.89	21.89	20.67	18.37
BABH	23.07	23.06	22.40	21.30
JHJY	24.14	24.14	23.59	22.17
KRAI	23.05	22.94	22.18	20.97
SIB1	23.98	23.77	22.71	20.58
UKM	24.02	23.90	23.50	21.70
SRIJ	23.50	23.50	22.84	21.55
UMAS	24.16	24.04	23.07	21.03
UPMS	23.70	23.70	23.13	21.93

IV. SUMMARRY AND CONCLUSION

The paper examines the Ionospheric response to the annular eclipse of the sun on January 15, 2010 over eastern and western Malaysia using GPS data measurement from 14-ground station in Malaysia. The GPS sensing technique employs two different approaches to verify the TEC depletion occurrence at the 14-stations. The first approach measures the TEC depletion parameters at the 14 GPS stations during the solar event. The second approach compares the TEC value with the quiet day TEC variation at one the station 3-days before and 3-days after the solar eclipse event. The GPS observation indicates occurrence of TEC depression at 6 stations where the behaviour varying from one station to another. On the basis of the first and second measurement techniques, the range of TEC depletions at the six stations were 9 to 20 %, while for the other 8-stations 0.4 to 12% respectively. The measurement shows that TEC depression at most GPS stations began on the neck of the first contact of the solar eclipse followed by deeper depressions.

This effect was as a result of the hiding of the optical rays during the solar eclipse which causes direct reduction in photo ionization; destroy the previous photo-chemical equilibrium and result in the depletion in electron density.

The magnitude of the eclipse and the maximum angle of obscuration varies from 0.18 to 0.50 and 8.47^o to 38.09^o respectively for all the stations. The first eclipse contact time for Malaysia began in Alor Setar at 06:56 Universal Time (UT) around 2:56 pm Local time (LT) and the eclipse fourth contact time also end at Alor Setar at 09:46 UT around 4:46 pm (LT). The total duration of the eclipse for all the stations was between 1hrs 33min at Tawau and 2hrs 49 min at Alor Setar.

Table 2 presents the various values of VTEC before contact with eclipse, at 1st contact time, at maximum magnitude time and the end of eclipse (4th contact time) respectively. The time of contact are shown in Table 1. Six out of the 14-stations namely; UKMG, AMAN, MIRI, SAND, MTAW AND UMSS shows significant drop in VTEC values from 9.6 to 20.2% at the end of the eclipse. There was positive correlation coefficient of about 0.5 between the eclipse magnitude and the depletion of VTEC at the end of eclipse contact. Figure 2a, 2b, 2c and 2d present the VTEC variation at 5-minute and one hour intervals during the 2-hours 49 minutes period of the eclipse for all the 13-station in Malaysia. A gradual drop in values of the VTEC can be seen, but was more higher at five stations in Figures 2a, 2c when compared to Figures 2b and 2d.

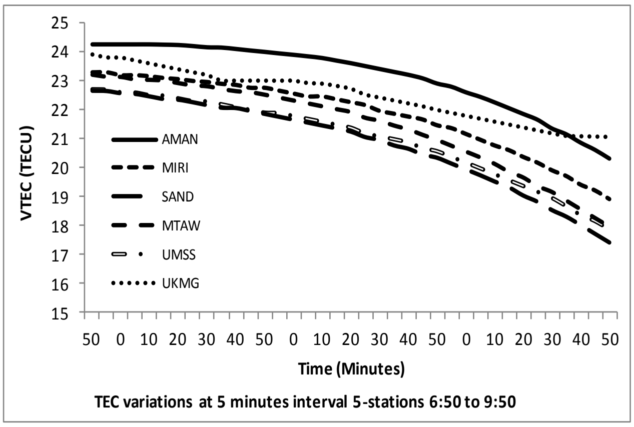

Figure 2a: VTEC variation at 5 minutes Intervals for the 6-stations

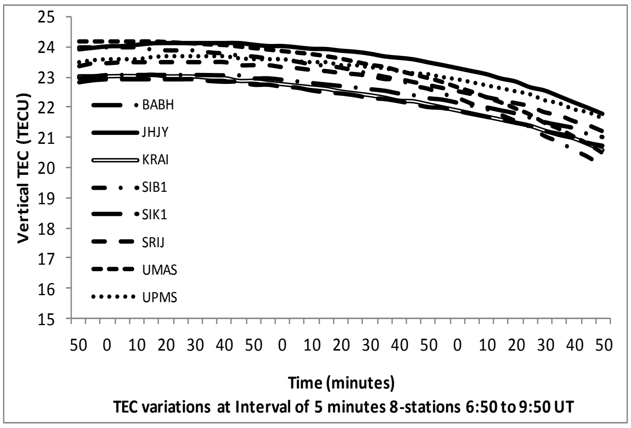

Figure 2b: VTEC variation at 5 minutes Intervals for the other 8-stations

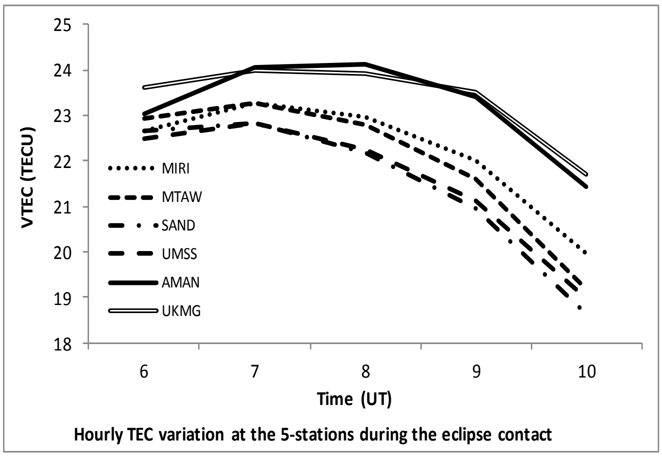

Figure 2c: Hourly VTEC variation at for the 5-stations

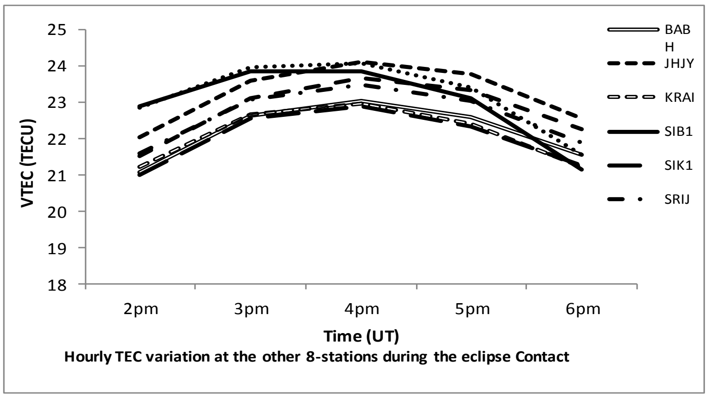

Figure 2d: Hourly VTEC variation at the other 8-stations

Figures 3a, 3b and 3c present the daily variation of VTEC data for UKM Bangi from 12th to 18th and also for 15th January 2010 at the same local time (2pm to 9pm) of the solar eclipse respectively.

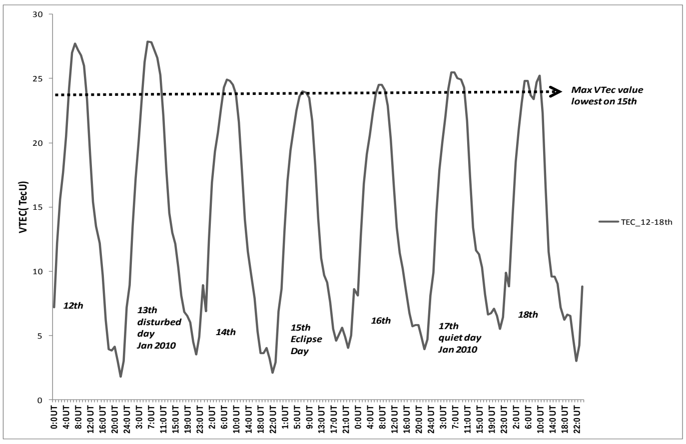

Figure 3a: Daily VTEC variations 3-days before and 3-days after Solar Eclipse at UKM

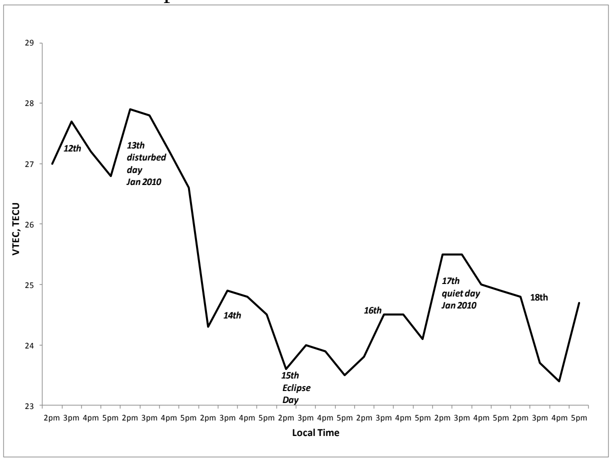

Figure 3b: Total Electron Content from 12th to 18 Jan 2010 between 2-5pm Local Time UKM Bangi.

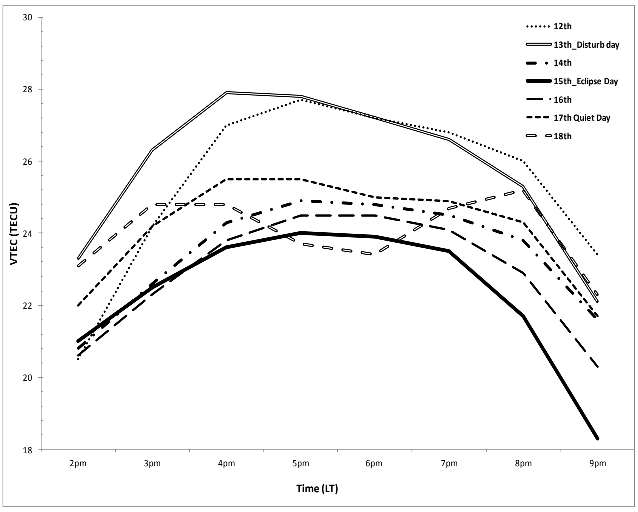

Figure 3c: VTEC values at the station local time (06 to 13 UT) from 15th to 18th January 2010 at UKM Bangi

Figures 3a shows there is a drop in the maximum value of VTEC on 15th when compared to other days of the week. On the basis of local time of the eclipse 2pm to 9pm, Figures 3b and 3c shows that the VTEC maximum was the lowest on the 15th, when compared to same hour of the week. VTEC varies from 18.3 to 23.9 TECU on 15th between 2pm to 9pm, but when compared with the same hours 3-days before and after the eclipse (20.3 to 27.9 TECU) the difference was about 2 to 4 TECU. Figures 4a and 4b present the percentage difference of VTEC when all other days were compared with the quiet day (17th January 2010) and also with the Local time of event 2pm to 9pm respectively.

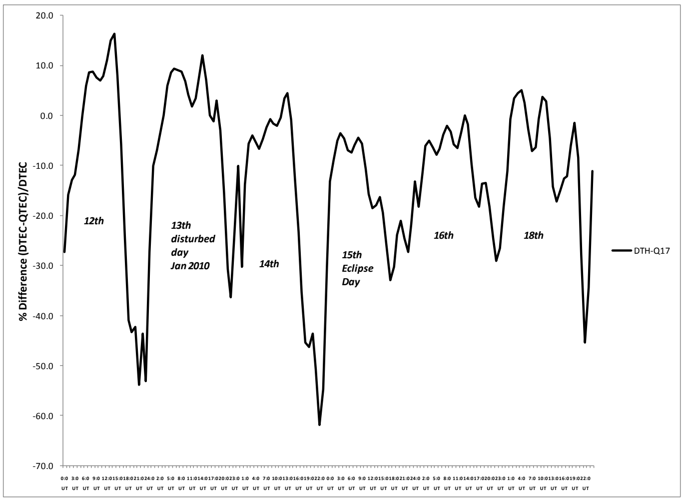

Figure 4a Percentage difference of each Day VTEC compared to quiet day 17th Jan 2010.

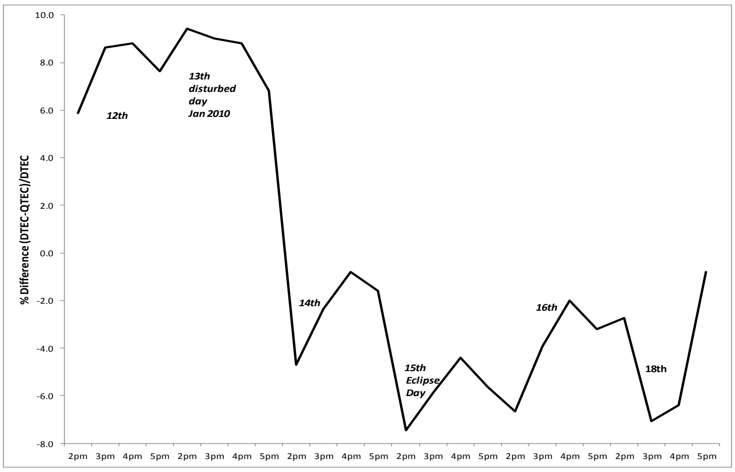

Figure 4b Percentage difference of each Day VTEC compared to quiet day 17th Jan 2010 at the Local Time of event 2pm to 5pm for UKM Bangi.

Comparison of the eclipse day (15th) with the quiet day 17th show a variation up to -7.5% during the local time of event (2pm to 9pm) compared to other days of the week.

Figure 5 present the curve fitting for the solar eclipse event at UKM Bangi.

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