QUIET- AND STORM-TIME CORRELATION OF F2-LAYER SLAB THICKNESS AND B0 AT AN EQUATORIAL STATION

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ABSTRACT

Ionosonde data, obtained at an equatorial station, for years of high solar activity [1990(Rz=143), 1991(Rz=146)] and a year of low solar activity [1995 (Rz =18)] were analyzed. The slab thickness of the F2 layer (TF2) was found to exhibit positive correlation with the IRI bottomside thickness parameter (B0), at high and low solar activity. This positive correlation was also observed between these ionospheric parameters during geomagnetic storms, at high and low solar activity.

Keywords: *Equatorial ionosphere, slab thickness, magnetic storms.*

1. INTRODUCTION

The slab thickness is defined as the ratio of the total electron content (TEC) to the maximum electron density of the ionospheric F-region (NmF2). This parameter has not been studied as much as the peak electron density, NmF2. It is known that the ionospheric slab thickness (TF2) influences the shape of the electron density profile, N(h). Studies have shown that the ionospheric slab thickness shows appreciable diurnal, day-to-day, seasonal, as well as solar activity variation. It is also noted that this variation depends considerably on the location of the observation station (Bhuyan et al, 1986 [4]; Rao et al, 1988 [12]; Davies and Liu, 1991 [5]; Bhonsle et al., 1965[3]; Titheridge, 1973 [10]; McNamara and Smith, 1982 [8]; Gulyaeva, 1997[6]). In the daytime, around 1400 – 1600LT, the largest values of slab thickness are observed in spring and autumn. Summer and winter produce the smaller values of slab thickness. The two peaks observed in slab thickness appear around 1000 – 1800LT, especially in summer (Jin et al, 2007 [7]). Occurrence of a pre-sunrise peak in slab thickness has been reported by many workers for low-latitudes (Walker and Ting, 1972 [13]; Bhuyan et al, 1986 [4]; Rao et al., 1988 [12]). This kind of result has not been reported for the equatorial region.

In the international reference ionosphere (IRI), B0 represents the thickness parameter for the bottom side F2 layer profile. This parameter has been studied under magnetically quiet ionospheric conditions. It has been shown that B0 exhibits solar zenith angle dependence during daytime for all seasons. This solar zenith angle dependence is strongest in winter and least in spring. Seasonal effect on B0 is observed to be much more evident during daytime hours between 1000 and 1800LT than for other part of the whole 24 hours of the day. B0 displays the greatest values in spring and the lowest in winter during this period of the day, while the values in autumn and summer are about the same for the same time interval of the day. It has also been observed that B0 has a high value during daytime and a low value during nighttime. The maximum value of B0 occurs around local noontime in spring months and shifts to prenoon hour when time goes from spring toward summer (Adeniyi and Radicella, 1997 [1]; Zhang et al, 2004 [14]). It has been observed that during June solstice and autumnal equinox, B0 seems to be lower near the magnetic equator than further away. The values of B0 at low solar activity are observed to be lower than those at high solar activity (Obrou et al, 1999 [9]).

This study investigated the relationship between the ionospheric slab thickness (TF2) and the IRI bottomside thickness parameter (B0),at high and low solar activity during quiet periods, as well as during geomagnetic storms.

2. DATA USED

Ionosonde data obtained at Ouagadougou, Burkina Faso (12.4^{o}N,1.5^{o} W, dip 5.9^{o}N) were used for this work. Data for 1990 (Rz= 143), 1991(Rz=146) and 1995(Rz=18) were analyzed. The first two years correspond to years of high solar activity while the third year is a year of low solar activity.In order to identify quiet days, the geomagnetic index Ap with values less than 26 were used. Ap values greater than 26 were used to identify the disturbed days (Adeniyi, 1986 [2]). These geomagnetic indices were selected from the geomagnetic planetary indices supplied monthly by the International Association of Geomagnetism and Aeronomy.

3. METHOD OF ANALYSIS

Ionograms were scaled manually by means of the personal computer. Compressed ionogram files were decompressed to obtain the individual ionograms. A software designed for scaling ionograms was used. Through a polynomial analysis programme [POLAN], the scaled data was inverted to obtain the true height (Titheridge, 1995 [11]). Ionograms were scaled for 24 hours of each day. Values of each parameter were extracted from the POLAN output. Five of the most magnetically quiet days of the month (within the month in which a magnetic storm occurred) were chosen and the ionograms scaled. The hourly average of the value each parameter for these five quiet days was calculated. These were then used as reference values and formed a basis for a standard of comparison with the disturbed days. The storm events in each month were identified and the ionograms scaled on hourly basis, covering the 24 hours of the days. These were done for years of low as well as high solar activity.

4. RESULTS

Typical examples of the diurnal variation of slab thickness of the F2 layer is depicted in figures 1 and 2, for low and high solar activity respectively. The bottom side parameter, B0, displayed a diurnal structure that is similar to that of the slab thickness (figures 1 and 2).

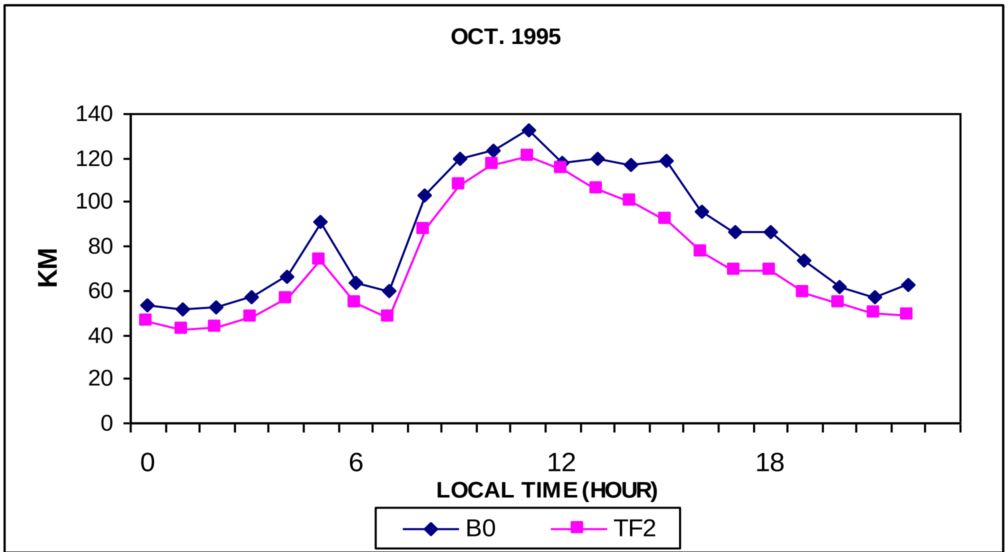

Figure 1: Typical diurnal variation of TF2 and B0 at low solar activity

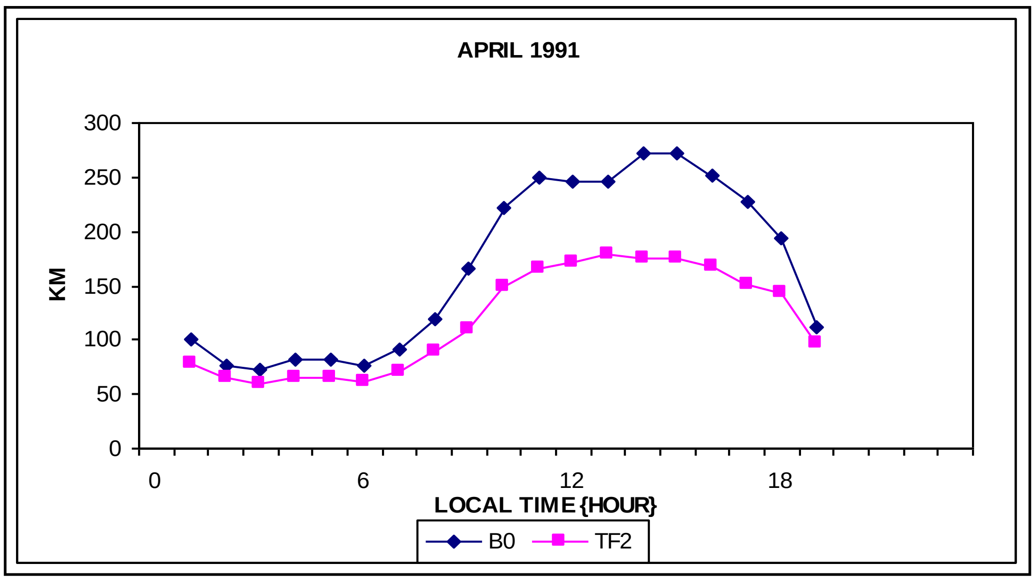

Figure 2: Typical diurnal variation of TF2 and B0 at high solar activity

At both solar epochs, a positive correlation was found between TF2 and the bottom side parameter B0. Tables 1 and 2 show the correlation coefficients obtained between B0 and TF2, at high and low solar activity respectively, during magnetically quiet period.

Table 1: Correlation Coefficient between B0 and TF2 at High Solar Activity

Storm Event	Correlation Coefficient between B0 and TF2
1990 APRIL 8-15	0.972826
1990 APRIL 22-26	0.972826
1990 OCTOBER 9-13	0.954497
1991 APRIL 2-5	0.992186
1991 JUNE 3-9	0.977857
1991 JUNE 22-25	0.977857
1991 OCTOBER 6-9	0.996088
1991 OCTOBER 24-31	0.996088
1990 JULY 27-30	0.991879

Table 2: Correlation Coefficient between B0 and TF2 at Low Solar Activity

Storm Event	Correlation Coefficient between B0 and TF2
1995 JANUARY 16-20	0.951978
1995 JANUARY 28-31	0.951978
1995 APRIL 6-10	0.968107
1995 OCTOBER 1-7	0.983018
1995 OCTOBER 17-21	0.983018

The highest correlation coefficient, with a value of 0.99, occurred at high solar activity. This correlation suggests a linear relationship between the two parameters. Tables 3 and 4 depict the results of the regression analysis for B0 and TF2.

Table 3: Regression Line for B0 and TF2 at High Solar Activity

Storm Event	Regression Line for B0 and TF2
1990 APRIL 8-15	B0=1.454267 (TF2) – 18.2233
1990 APRIL 22-26	B0=1.454267 (TF2) – 18.2233
1990 JULY 27-30	B0=1.56857 (TF2) – 25.7784
1990 OCTOBER 9-13	B0=1.471525 (TF2) – 11.8563
1991 APRIL 2-5	B0=1.638565 (TF2) – 26.7279
1991 JUNE 3-9	B0=1.527151 (TF2) – 19.6747
1991 JUNE 22-25	B0=1.527151 (TF2) – 19.6747
1991 OCTOBER 6-9	B0=1.525882 (TF2) – 13.2239
1991 OCTOBER 24-31	B0=1.525882 (TF2) – 13.2239

Table 4: Regression Line for B0 and TF2 at Low Solar Activity

Storm Event	Regression Line for B0 and TF2
1995 JANUARY 16-20	B0=1.130002 (TF2) + 3.5000302
1995 JANUARY 28-31	B0=1.130002 (TF2) + 3.5000302
1995 APRIL 6-10	B0=8.979645 (TF2) + 1.035025
1995 OCTOBER 1-7	B0=1.027074 (TF2) + 10.43163
1995 OCTOBER 17-21	B0=1.027074 (TF2) + 10.43163

From the results, one could deduce general expressions for B0 and TF2. The linear relationship between B0 and TF2 could be written as:

$$\mathbf{B0} = \mu\,(\mathbf{TF2}) \pm \xi \qquad (1)$$

where the positive intercept was obtained for low solar activity and the negative intercept for high solar activity. Considering the absolute value of the intercepts, greater values were obtained during March equinox than September equinox. Similar comparison for the solstices could not be done due to absence of data for December solstice.

A strong positive correlation was observed between B0 and TF2 during storms. Tables 5 and 6 display the correlation coefficients obtained for these parameters during storms, at high and low solar activity respectively.

Table 5: Storm time correlation coefficient between B0 and TF2 at high solar activity

STORM EVENT	CORRELATION COEFFICIENT
1995 APRIL 6-10	0.948384
1995 JAN 16-20	0.919843
1995 JAN 28-31	0.953861
1995 OCT. 1-7	0.940149
1995 OCT. 17-21	0.944734

Table 6: Storm time correlation coefficient between B0 and TF2 at low solar activity

STORM EVENT	CORRELATION COEFFICIENT
1990 APRIL 8-15	0.943119
1990 APRIL 22-26	0.952354
1990 JULY 27-30	0.901404
1990 OCT.9-13	0.967132
1991 APRIL 2-5	0.936911
1991 OCT. 6--9	0.963086
1991 OCT. 24-31	0.980114
1991 JUNE 3-9	0.922724
1991 JUNE 22-25	0.985529

These results showed that the linear relationship observed between B0 and TF2 during quiet period still exists during geomagnetic storms. Tables 7 and 8 show the results of the regression analysis.

Table 7: Storm time regression line for B0 and TF2 at high solar activity

STORM EVENT	REGRESSION LINE
1990 APRIL 8-15	1.503802(SLAB TF2) – 14.2241
1990 APRIL 22-26	1.626591(SLAB TF2) – 24.3072
1990 JULY 27-30	1.327905(SLAB TF2) – 2.21239
1990 OCT. 9-13	1.450482(SLABTF2) – 8.64547
1991 APRIL 2-5	1.428908(SLAB TF2) – 8.83028
1991 OCT 6-9	1.388778(SLABTF2) – 3.15724
1991 OCT. 24-31	1.488803(SLAB TF2) – 12.2789
1991 JUNE 3-9	1.54451(SLAB TF2) – 23.3792
1991 JUNE 22-25	1.618108(SLAB TF2) – 23.4693

Table 8: Storm time regression line for B0 and TF2 at low solar activity

STORM EVENT	REGRESSION LINE
1995 APRIL 6-10	1.235064(SLABTF2) – 3.2309
1995 JAN. 16-20	1.042772(SLAB TF2) + 7.426989
1995 JAN. 28-31	1.198507(SLAB TF2) – 0.3915
1995 OCT. 1-7	1.12865(SLAB TF2) + 0.030962
1995 OCT. 17-21	1.202703(SLAB TF2) – 2.03356

An expression similar to equation (1) could be written for B0 and TF2 during geomagnetic storms, at low and high solar activity:

$$\mathbf{B0^{*} = \mu\ (TF2)^{*} \pm \xi} \qquad (2)$$

where the asterisk shows that the quantity is for disturbed period; only negative intercept was obtained for high solar activity; low solar activity had both positive and negative intercepts.
Figures 3 and 4 show examples of the plots for the line fit for B0 and TF2, at both high and low solar activity respectively.

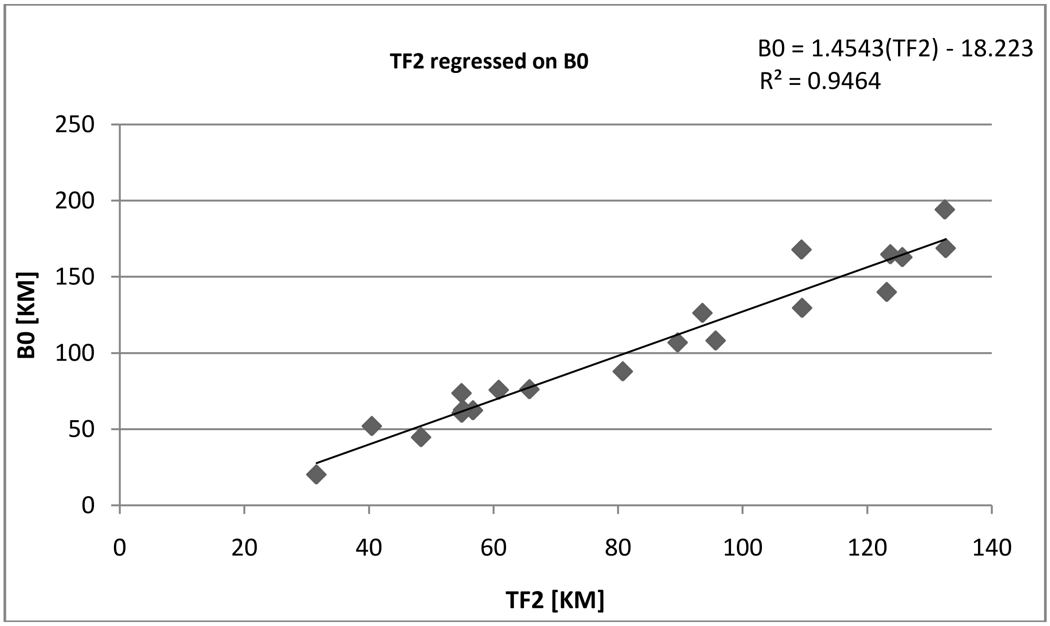

Figure 3: Example of line fit for B0 and TF2 at high solar activity

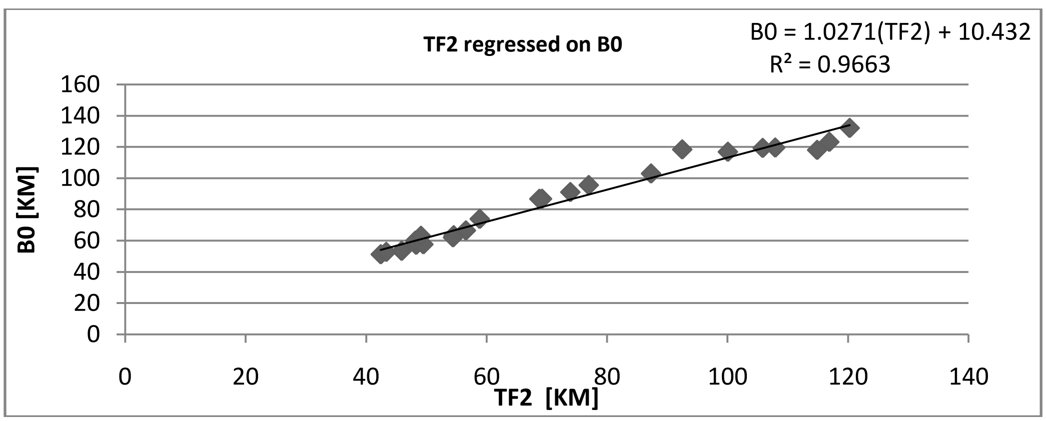

Figure 4: Example of line fit for B0 and TF2 at low solar activity

5. DISCUSSION

The slab thickness of the F2 layer (TF2) featured two noticeable peaks, at both solar epochs. The daytime peak is higher than the presunrise one at both solar epochs. The first peak occurred at between 0500 and 0600LT at both solar epochs while the second peak occurred at about 1100LT at low solar activity and between 1200 and 1300LT at high solar activity. Higher values of the slab thickness were obtained at high solar activity than at low solar activity. Generally, higher values of B0 were obtained at high than at low solar activity.
Observation of a positive correlation between B0 and TF2 showed that there exists a relationship between the two parameters. One of the salient features of this study is the observation of positive correlation between TF2 and B0 even during geomagnetic storms, at high and low solar activity. The observation of the diurnal behavior of these ionospheric parameters at this equatorial station was consistent with the observations made by earlier workers

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