MODELING TOTAL ELECTRON CONTENT AND CRITICAL FREQUENCY AT F1 AND E LAYER BOUNDARY

ABSTRACT

This work investigates the variation of the total electron content TEC and the critical frequency fo in the boundary zone of the F1 and E layers of the low-latitude ionosphere in the African sector during the quiet geomagnetic activity of solar cycle 23. The ionosphere is the upper layer of the Earth's atmosphere ionized mainly by solar X- and UV-rays, extending from around 80km altitude to beyond 1000km [1] [2]. The main source of this ionized environment is ultraviolet light from the sun, which ionizes the atoms and molecules in the Earth's upper atmosphere [3]. For this study, we use the International Reference Ionosphere(IRI)model in its 2016 version, at the Ouagadougou station (12.4°N and 358.5°E), in West Africa. The quiet periods of maximum and minimum phases of solar cycle 23 are considered [4] [5]. From this study, it emerges that at the E and F1 layer boundary zone, TEC and fo increase during the day as solar irradiance increases and decrease as solar irradiance decreases.

Keywords: total electron content, critical frequency, maximum phase, minimum phase, Quiet Days

INTRODUCTION

The molecules and atoms that make up the Earth's atmosphere are not uniformly distributed as a function of altitude, varying according to the ionosphere layer and height [6] [7], but what about the variation of this parameter in the layer boundary zone, particularly between the F1 and E layers? Zones can then be delimited, but in reality, the boundary between two zones is not clear-cut, as there may be variations due to meteorological variations, seasons or even position [8] [9]. We generally distinguish three layers with their properties about wave propagation. The D layer, with an altitude varying between 60-90 km, appears with sunrise and disappears immediately after sunset. The E layer is estimated at between 90 and 150 km. It reflects waves from a few MHz up to a limit frequency that depends on the angle of incidence of the wave on the layer and its density. The F layer, at an altitude of between 150 and 800 km, has a very high level of ionization during the maxima of solar cycle 23 [10].Its altitude fluctuates with solar radiation, and during the day it breaks down into two sub-layers, F1 and F2. These two sub-layers recombine at night, several hours after sunset, but may persist throughout the night at times of maximum solar activity 23. International Reference Ionosphere (IRI) is a semi-empirical model comprising two sub-programs, the Committee on Space Research (CCIR) and the International Union of Radio Science (URSI), whose aims include estimating, developing and improving an international standard for parameters of the terrestrial ionosphere [9] [10]. This work is devoted to the study of the variation of the TEC and fo parameters of the ionosphere at an altitude of about 150 km, which is the boundary zone between the E and F1 layers, using IRI-2016. [11] [12].

MATERIALS AND METHODS

The nature of the cycle phase is determined from the mean annual value of Rz, so the year corresponding to the cycle phase is at a minimum if Rzmoy< 20 and the year corresponding to the maximum cycle phase corresponds to Rzmoy> 100. The months of March, June, September and December of the years 1996 and 2008 [13] during universal time according to the geographical coordinates of the Ouagadougou station are used, under a latitude of 12.5 and a longitude of 358.5 at a height of 150 Km, which is considered to be the lower limit of the F layer and the upper limit of the E layer. The aim is to calculate the monthly hourly averages of the TEC parameter during the quiet periods of solar cycle 23 [14] [15]. The daily average values of the geomagnetic index Aa define the conditions that characterize disturbed, recurrent, fluctuating shock and calm periods. In our study, the Aa index ≤ 20nT corresponds to so-called calm periods [16] [17].

Table 1: Days corresponding to the quietest periods of solar cycle 23[18].

Minimum phase (1996)			
March	June	September	December
4,7,9,18,24	2,9,11,18,29	5,10,13,18,21	5,14,18,22,30
Maximum phase (2008)			
March	June	September	December
8,12,16,25,28	1,7,11,21,28	3,9,13,19,24	6,13,23,26,31

In the study, n is the quiet day in question, so we'll be determining the average value of TEC and fo for the five days during the month that characterize each season of the year and x is an altitude.

$$\lim_{x\to150} TEC = \lim_{x\to150} \frac{1}{n}\sum_{i=1}^{n} TEC^{i}$$
(1)

$$\lim_{x\to150} foF = \lim_{x\to150} \frac{1}{n}\sum_{i=1}^{n} foF^{i}$$
(2)

$$\lim_{x\to150} foE = \lim_{x\to150} \frac{1}{n}\sum_{i=1}^{n} foE^{i}$$
(3)

$$\lim_{x\to150} fo = \lim_{x\to150} \frac{1}{n}\left(\sum_{i=1}^{n} foF^{i} + \sum_{i=1}^{n} foE^{i}\right)$$
(4)

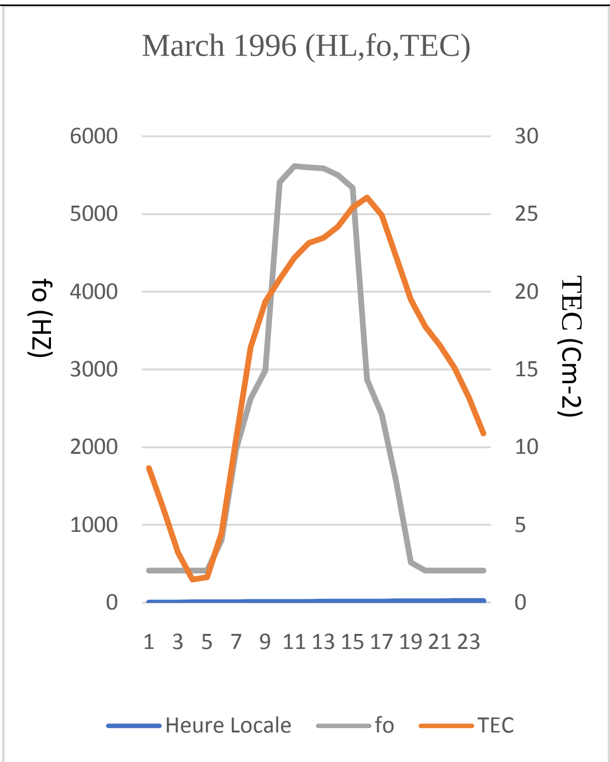
Criticalfrequencyfobeyondwhich a wave crosses the ionospheric layer islinked to itselectrondensity Nm defined by the equation:

$$\lim_{x\to150} fo = 9.\sqrt{\lim_{x\to150} Nm} \quad (5)$$

RESULTS AND DISCUSSION

1. Minimum phase

a. Results



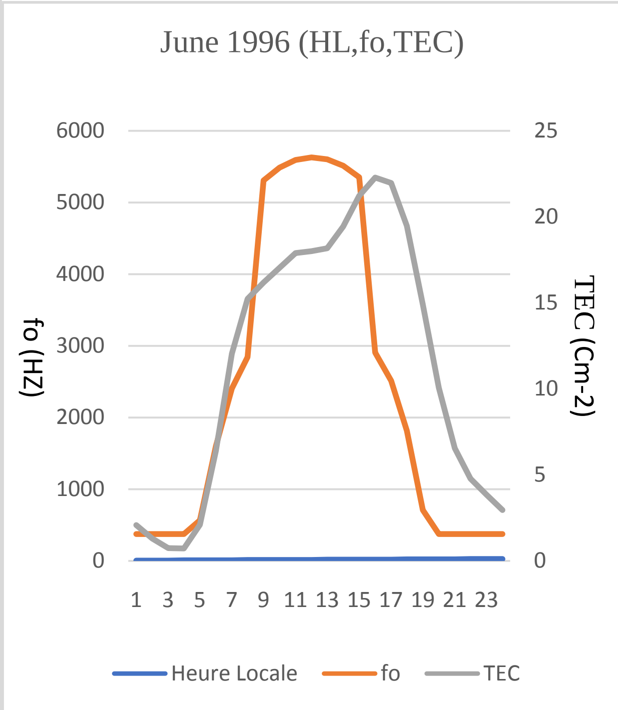


Figure 1.a: variability of fo and TEC in Spring 96 Figure 1.b: variability of fo and TEC in Summer 96

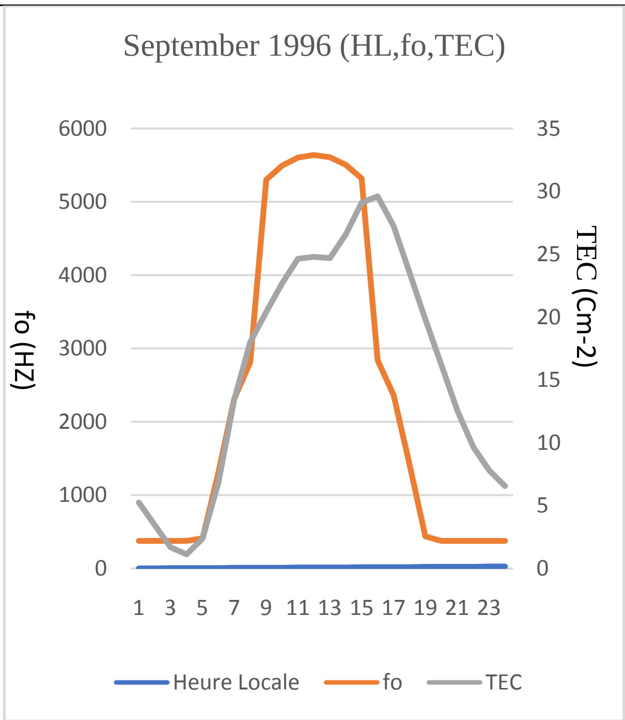


Figure 1.c: variability of fo and TEC in Autumn 96.

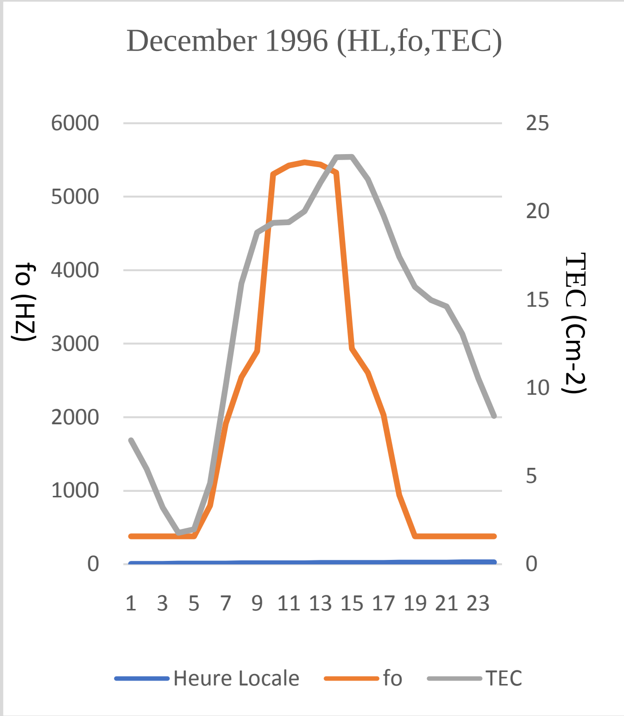


Figure 1.d: variability of fo and TEC in Winter 96.

Figure 1: Profiles of critical frequency and total electron content in spring, summer, autumn and winter at phase minimum of solar cycle 23.

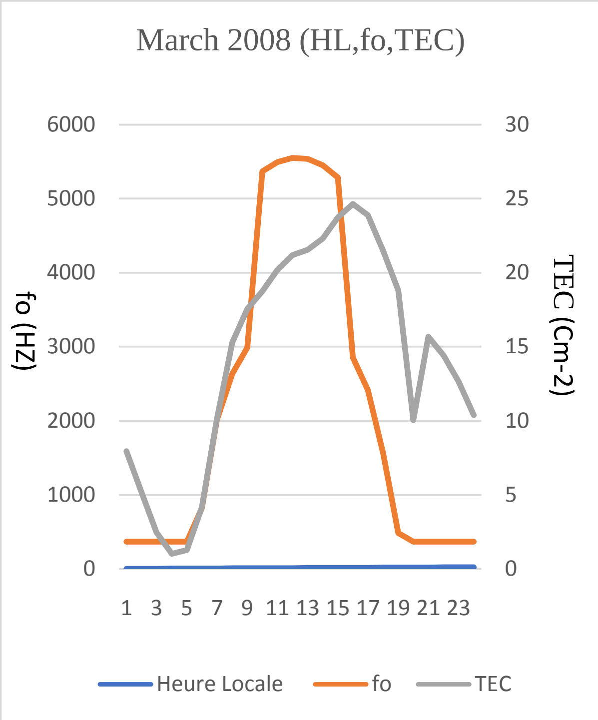
b. Discussion

The profiles in Figure 2 show that the values of critical frequency and TEC are respectively low in the morning, evening and night, between 0:00 and 9:00 and from 1:00 to 24:00. This is because solar irradiation is low at these times, so the ionization of the boundary region between the E and F 1 layers of the ionosphere due to this irradiation experiences a drop in intensitý, so the fo and TEC profiles are decreasing.

In contrast, during the day when solar irradiation begins to increase hencè a rise in ionization of the boundary region of the E and F1 layers of the ionosphere, fo and TEC values begin to increase during the day until reaching their maximum values around peak hours between 12pm and 3pm. This is because solar irradiance is high at these times, so the TEC and fo profiles increase. [19].

2. Maximumphase

a. Results



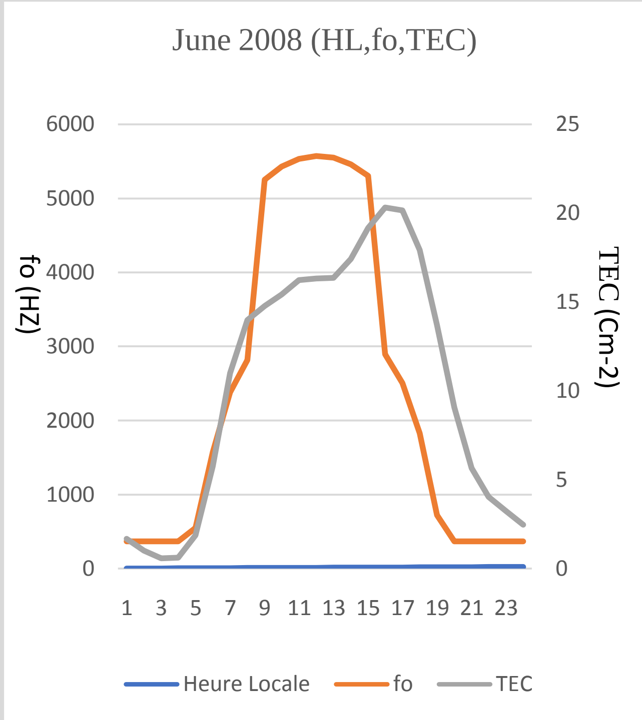
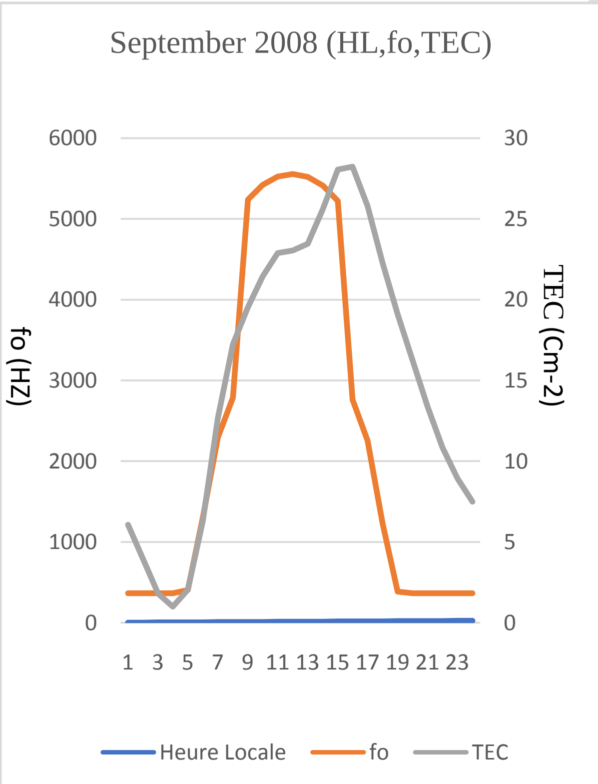


Figure 2.a: variability of fo and TEC in Spring 2008. Figure 2.b: variability of fo and TEC in Summer 2008



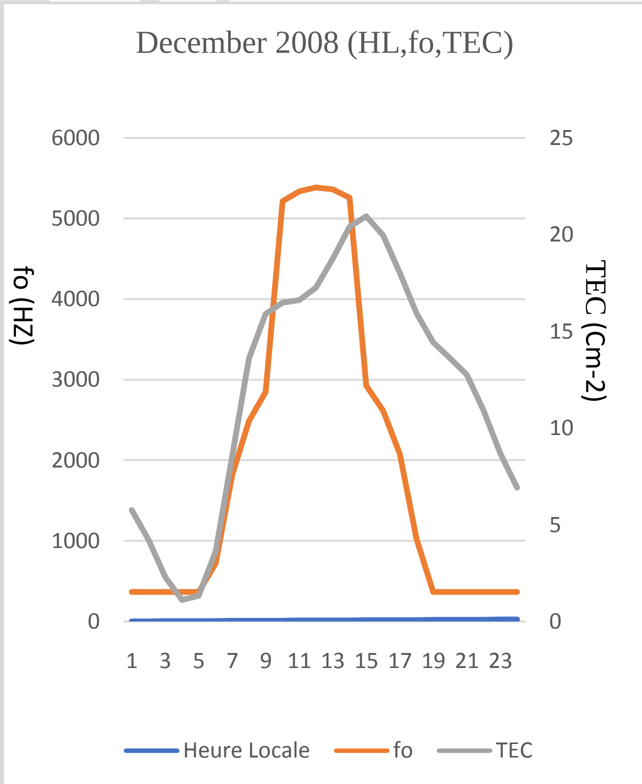


Figure 2.c: fo and TEC variability in Autumn 2008 Figure 2.d: foF2 and TEC variability in Winter 2008

Figure 2: Profiles of critical frequency and total electron content in spring, summer-autumn and winter at phase maximum of solar cycle 23.

b. Discussion

The profiles in Figure 3 show that critical frequency and TEC values are respectively low in the morning, evening and night, from 0 to 5 and from 5 to midnight. Indeed, at these times solar irradiation is low, consequently, ionization of the boundary region between the E and F1 layers of the ionosphere due to this irradiation experiences a decrease in intensitý, thus the fo and TEC profiles are decreasing.

In contrast, during the day when solar irradiation begins to increase, a rise in ionization of the boundary region of the E and F1 layers of the ionosphere, fo and TEC values begin to increase over the day until reaching their maximum values around peak hours between 11am and 3pm. This is because solar irradiation is high at these times, so the TEC and fo profiles increase [20].

CONCLUSION

Our work has focused on studying the morphological variation of the parameters fo and TEC at the boundary zone between the E and F1 layers of the ionosphere at the Ouagadougou station during periods of calm geomagnetic activity. The ionospheric parameters studied are plotted on the same graph, with fo on the main axes and TEC on the secondary axes. Analysis of the curves shows that these parameters decrease during the morning, evening and night hours, and increase during the day when solar irradiance increases. The ionospheric parameters fo and TEC have the highest values during the hours of highest solar irradiation at the boundary of the two layers E and F1.

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