**Analysis of seasonal variation of densities electronic : NmE and NmF boundary of E and F layers of ionosphere in low latitudes, Ouagadougou station.**

**Abstract**

This work was undertaken to contribute to a better understanding of the atmospheric layer by analysing variations in ionospheric parameters, in particular the electron density at Ouagadougou station at low latitude during the solar cycle 23.

This variation is the result of the disturbances that are regularly observed in the ionosphere, which is the upper part of the Earth's atmosphere ionised by solar radiation.To do this, we used the IRI (International Reference Ionosphere) in its 2016 version, which is an empirical model that was used to extract data for the days of the months characteristic of the minimum and maximum phase of the solar cycle

We found that the variability of the electron density of the F (NmF) layer and the variability of the electron density of the E (NmE) layer, follow the evolution of sunlight intensity due to the geographical situation close to the ionospheric equator of our study station. NmE and NmF present significant values ​​during the day, because the ionization produced by the sun's rays is important

At the limit of the E and F layers, the ionospheric day corresponds to the period where the NmE and NmF values ​​are important and conversely during the ionospheric night the values ​​of NmE and NmF are very insignificant.

**Key words**: Electron density, ionosphere, phase maximum, phase minimum,quiet days.

**INTRODUCTION**

Ultraviolet light from the sun is the main source of the ionised environment of atoms and molecules in the Earth's upper atmosphere. This ionization increases as the altitude increases, and we can distinguish three main layers of the ionosphere: layers D, E and F[6] [7].The electron density (Ne) varies not only with altitude but also with the solar cycle, season, day and time. In this article, it will be a question of devoting ourselves to study of the variation : of the electron densities NmF and NmE in the boundary region E and F of the ionosphere in low latitudes of the African sector. The study will be carried out at the Ouagadougou station located in West Africa, latitude 12.4°N and longitude 358.5°E [8] [9] [10]. The quiet periods of maximum and minimum phase of solar cycle 23 are considered. The International Radio Consultative Committee (CCIR) and International Radio-Scientific Union (URSI) of the 2016 version of the International Reference Ionosphere (IRI-2016) model are used [11] [12]. At the end of the stimulation study, it appeared that the variation in electron density is a function of solar irradiation, the season, the months of the season, the quiet days of the month, the hours of the day, at a given altitude at the boundary of layers E and F [13] [14] [15].

1. **MATERIALS AND DATA**

The study was carried out at Ouagadougou station, at the boundary of layers E and F as shown in Figure 1.



150

E and F layer boundary

Figure 1: The boundary zone of layers E and F.

For modeling we use the semi-empirical IRI model, to determine the electronic densities. IRI is available online at *www.irimodel.org* in the following conditions:

Firstly, solar cycle phases 23: the minimum and maximum phases of cycles. Solar cycle is characterized by the number of sunspots Rz, if Rz >100, the solar cycle corresponding is maximum phase, where magnetic activity is at its highest, and if magnetic activity is lowest, for Rz < 20 the solar cycle corresponding is minimum phase[16] [17] [18].

The average duration of a solar cycle is 11 years, so for solar cycle 23, 1996 is the year corresponding solar minimum phase and 2008 is the year corresponding of solar maximum phase.

Four months are used to characterize the seasons of 1996 and 2008, the four months are: March, June, September December. The characteristic months correspond to the four seasons of the year [19].

March describes spring, June describes summer, September describes autumn and December describes winter. five quiet days of the month Are also considered. these calm days are characterized by the Aa index <20 nT. The study take place at the Ouagadougou station.

We considered the geographic coordinates of the Ouagadougou station, the study station: the latitude and longitude of the site, and a height of 150 km. Profile time between [0h - 24h] with a difference of 1 hour. Local time in Ouagadougou station corresponds to Universal Time [20].

Once all these parameters have been taken into account and entered in IRI, we obtain the NmE and NmF data in matrix form the five calm days during the 24 hours of day of each month characteristic of the solar cycle. These output data will then be outputs will be processed on EXEL [21]. Global electron densities are determined by calculating the monthly hourly average of the NmE and NmF values. The critical frequency, also called plasma frequency and the electron density are related by equation (1):

fp= $\frac{1}{2π}$($\frac{n\_{e}. q\_{e}^{2}}{m\_{e }.\in \_{0}}$)1/2.  (1)

With:

qe: electron charge : 1.6022\*10-19 Coulombs.

me: electron masse : 9.1095\*10-31 kg.
ne : electron number by unit volume, électron/m3
εo :dielectric constant of free space : 8.8542\*10-12 farad-mètre -1

after simplification and calculation, we obtain:

f = 9.$\sqrt{n}$ (2)

f : Hz

ne : electron number by unit volume, électron/m3

In conclusion, fc=9.$\sqrt{Nm}$ ; (3)

fc: critical frequency, Nm: electron density.

Nm of the characteristic month, is the daily hourly average of the five quiet days.

Nm =$\frac{\sum\_{i=1}^{5}Nm^{i}}{5}$ (4)

 F layer, NmF =$\frac{\sum\_{i=1}^{5}NmF^{i}}{5}$ (5)

E layer, NmE =$\frac{\sum\_{i=1}^{5}NmE^{i}}{5}$ (6)

**ii. RESULTS**

after data processing, calculation of hourly averages of electron density for quiet days for E layer and F layer, we represent the values obtained on a graph for each month characteristic of each phase of solar cycle 23. Figure 2-5 represents the minimum phase of solar cycle and Figure 6-9 represent the maximum phase of solar cycle.

Figure 2: variability of NmE and NmF in Spring 96 Figure 3 : variability of NmE and NmF in summer 96

Figure 4: variability of NmE and NmF in autumn 96 Figure 5 : variability of NmE and NmF in winter 96

Figure 6: variability of NmE and NmF in Spring 08 Figure 7 : variability of NmE and NmF in summer 08

Figure 8 : variability of NmE and NmF in autumn 08 Figure 9 : variability of NmE and NmF in winter 08

**iii. DISCUSSION**

after analyzing different graphs, you can see that:

At the boundary of layers E and F, at altitude of 150 km, profiles of electrons densities for year 1996 depends on the season and the Local Time.

At the boundary of layers E and F, at altitude of 150 km, profiles of electrons densities for year 2008 depends on the season and the Local Time.

The values ​​of the electron densities are lower at solar minimum phase than at solar maximum phase of solar cycle 23. This is explained by the fact that solar activity during the minimum phase is low compared to the maximum phase [22].

During the maximum and minimum phases of the solar cycle 23 , NmE and NmF have lower values in winter than in summer.

Observation of the seasonal variation profiles NmF and NmE, function of time shows us three parts, a horizontal part, an increasing part and a decreasing part.

The seasonal variation profiles NmF and NmE have a parabolic shape. We can also see that the two profiles intersect at two points[23].

* For layer E;

From 0 LT to 6 LT and from 18 LT to 24 LT, the values ​​of NmE are almost zero, the profile of is horizontal, this period correspond to ionospheric night.

From 6 LT to 12 LT, the values ​​of NmE begin to increase, NmE profile is increasing.

At 12 LT, we reach the highest value of NmE.

From 12 LT to 18 LT, the values ​​of NmE begin to decrease, NmE profile is decreasing.

* For layer F;

From 0 LT to 8 LT and from 16 LT to 24 LT, the values ​​of NmF are almost zero, the profile of is horizontal, this period correspond to ionospheric night.

From 8 LT to 12 LT, the values ​​of NmF begin to increase, NmF profile is increasing.

At 12 LT, we reach the highest value of NmF.

From 12 LT to 16 LT, the values ​​of NmF begin to decrease, NmF profile is decreasing.

**CONCLUSION**

Analysis of the NmF and NmE seasonal variability of E and F layers of the ionosphere at the Ouagadougou station shows that electron density is a parameter which depends on the phase of the solar cycle, the season and the Local Time at altitude of 150km.

During ionospheric nights where solar irradiation is at its lowest, the NmF and NmE profiles are very weak (almost zero values) [24] [25].

During ionospheric days, solar irradiation begins to increase, we observe an increase in the values ​​of NmF and NmE [24] [25].

NmF and NmE respectively reach their maximum value at around 12 LT, time when the ionization of solar rays is at the highest level.

The electron density of the layers and the critical frequency being linked, this study allowed us to highlight the maximum frequency not to be exceeded by a radio wave at the risk of not being reflected by layers E and F at 150 km.

**References**

[1] Simon PA. et Legrand JP, Solar cycle and geomagnetic activity: A review for geophysicists. Part II. The solar sources of geomagnetic activity and their links with susnspot cycle activity.

[2] Annales geophysicae. 1989:7(6):579‐594 Van Allen JA, Ludwig GH, Ray EC CE. McIlwain, Observations of high intensity radiation by satellites 1958 Alpha and Gamma, Jet Propul. 1958;28:588– 592.

[3] Wolf Johann Rudolf, Sunspot Observations of Rudolf Wolf from 1849 – 1893 Solar Phys. 2016;291:2505–2517
DOI: 10.1007/s11207-016-0907-0

[4] NANEMA E. "Modeling of NmF2, foF2 and hmF2 at Ouagadougou station during solar cycle 22 by TIEGCM 1.94 and assessment of their predictions". disondaas 137geston %asivas Favaron esperes

[5] Ouattara F., Nanéma E., Quiet time foF2 variation at Ouagadougou station and comparison with TIEGCM and IRI-2012 prediction for 1985 and 1990” Physical Science International Journal. 2014;4(6):892-902

[6] Bauer, S. J., & Jackson, J. E. (1962). Rocket measurements of the electron density distribution in the topside ionosphere. Journal of Geophysical Research, 67, 1675-1677.

[7] Bauer, S. J., Blumble, L. J., Donley, J. L., Fitzenreiter, R. J., & Jackson, J. E. (1964). Simultaneous rocket and satellite measurements of the topside ionosphere. Journal of Geophysical Research, 69, 186-189.

[8] Richmond AD, Ridley EC, Roble RG.

[9] Russel CT, Elphic RC, ISEE observations of flux transfert events at the dayside magnetopause, Geophys. Res. Lett. 1979;6:33–36.

[10] Samuel Heinrich Schwabe Astronomische Nachrichten [Astronomical News] (in German).

[11] A Thermosphere/Ionosphere General Circulation Model with Coupled Electrodynamics. Geophysics Research Letters.1992;19:601-604. Available:https://doi.org/10.1029/92GL004 01

[12] Schunk RW. Handbook of Ionospheric Models, Chap. A Coupled Ther- mosphere-Ionosphere Model (CTIM). Utah

[13] State University, Logan, Utah. 1996;217- 238.

[14] Anderson DN, Mendillo M, Herniter B. A Semi-Empirical, Low- Latitude Ionospheric Model. Radio Science. 1987;22:292-306. Available:https://doi.org/10.1029/RS022i00 2p00292

[15] Richardson IG, Cliver EW, Cane HV, Sources of geomagnetic activity over the solar cycle: Relative importance of coronal mass ejections, high-speed streams, and slow solar wind. J. Geophys. Res. 2000;105(A8):18,200-18,213. Available:https://www.google.com/urlionos phere-couche-atmospherique-superieure- quoi-sagit-

[16] Richardson IG, Cane HV., Sources of geomagnetic activity during nearly three solar cycles (1972-2000) J. Geophys. Res. 2002;107:A8:1187.

[17] Rishbeth, H. and Muller-Wodarg, I.C.F. (2006) Why Is There More Ionosphere in January than in July? The Annual Asymmetry in the F2-Layer. Annales Geophysi- cae, 24, 3293-3311. https://doi.org/10.5194/angeo-24-3293-2006

[18] Nanéma, E., Konaté, M., Zoundi, C., Kotia, A.O., Zerbo, J.L. and Ouattara, F. (2021) Evaluating the Rate of Total Electron Content (TEC) Production in Ionosphere F2-Layer to Highlight Winter Anomaly by Running Thermosphere-Ionosphere- Electrodynamics General Circulation Model. African Journal of Environmental Science and Technology, 15, 379-383. https://doi.org/10.5897/AJEST2021.3051

[19] Nanéma, E., Konaté, M. and Ouattara, F. (2019) Peak of Electron Density in F2- Layer Parameters Variability at Quiet Days on Solar Minimum. Journal of Modern Physics, 10, 302-309. https://doi.org/10.4236/jmp.2019.103021

[20] Gnabahou, A. and Ouattara, F. (2012) Ionosphere Variability from 1957 to 1981 at Djibouti Station. European Journal of Scientific Research, 73, 382-390.

 [21] Ouattara, F., Zoundi, C. and Fleury, R. (2012) Comparison between CODG TEC and GPS Based TEC Observations at Koudougou Station in Burkina Faso. Indian Journal of Radio and Space Physics, 41, 617-623. https://hal.archives-ouvertes.fr/hal-00940398

[22] Nanéma, E., Gnabahou, D. A., Zoundi, C., & Ouattara, F. (2018). Modeling the Ionosphere during Quiet Time Variation at Ouagadougou in West Africa. International Journal of Astronomy and Astrophysics, 8, 163-170.

[23] Nanéma, E., Konaté, M., Gnabahou, A. D., & Ouattara, F. (2018). Effects of Height of F2-Layer on Critical Frequency by Use of Data at Ouagadougou Station. Applied Physics Research, 10(5), 57-60.

[24] Nanéma, E., Ouédraogo, I., Zoundi, C., & Ouattara, F. (2018). Electron bulk Surface Density Effect on Critical Frequency in the F2-Layer. International Journal of Geosciences, 9, 572-578.

[25] Zerbo, J.L., Ouattara, F., Zoundi, C. and Gyébré, A. (2011) Solar Cycle 23 and Geo- magnetic Activity since 1868. Revue CAMES Série A, 12, 255-262.