

# Variability of the Critical Frequency foF2 during Minimum and Maximum Phases of Solar Cycles 20 and 21: A Comparative Study between American and African Equatorial Regions

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**How to cite this paper:** M'Bi, K., Abidina, D. and Frédéric, O. (2022) Variability of the Critical Frequency foF2 during Minimum and Maximum Phases of Solar Cycles 20 and 21: A Comparative Study between American and African Equatorial Regions. *Atmospheric and Climate Sciences*, 12, 105-112.

<https://doi.org/10.4236/acs.2022.121008>

**Received:** November 10, 2021

**Accepted:** January 2, 2021

**Published:** January 5, 2021

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## Abstract

The present work is a comparative study between the foF2 variabilities for two equatorial regions (Ouagadougou: lat. 12°21'N; long. 1°30'E, dip. 1.43° in Africa and Huancayo: Lat. 12°S; Long. 75°12'W in America) during solar cycles 20 and 21 minima and maxima phases under geomagnetic extreme conditions (quiet and disturb). Profiles from these two stations are very similar for all the seasons over the solar cycles. However, measured data from Huancayo station are higher than those from Ouagadougou station during winter with a reverse phenomenon for summer. The investigations suggest that the gap between foF2 values and the reverse phenomenon observed for the two stations may be explained by their hemispheric location (Huancayo in south hemisphere and Ouagadougou in North one). Longitudinal irregularities in ionosphere may also contribute to that little difference observed during the time interval of our investigation.

## Keywords

foF2, Longitudinal Variation, Seasonal Variation

## 1. Introduction

The ionosphere is an ionized layer of Earth's atmosphere. It is one of the most important layers of Earth's atmosphere for its role in wave propagations (communication). Understanding the behavior of this region may be useful for inves-

tigations of solar disturbances and their terrestrial impacts. To better seize the level of the variations of this region in the equatorial region through its critical frequency foF2 profiles many authors have reviewed the seasonal variations of foF2 [1]-[14]. This ionospheric parameter through its in situ measurements allowed [6] to classify foF2 diurnal profiles as follow: 1) Morning peak profile characterized by a predominance morning peak; 2) Plateau profile; 3) Dome profile; 4) Reverse profile characterized by predominance afternoon peak; 5) noon bite out profile due to the presence of double peaks (morning and afternoon peaks) with trough around midday. All these previous investigations have provided useful suggestions for the prediction in the GNSS recordings.

The objectives of our present investigation are to better understand the dynamic of the ionosphere in two regions (Ouagadougou: lat. 12°21'N; long. 1°30'E, dip. 1.43° in Africa and Huancayo: Lat. 12°S; Long. 75°12'W in America).

In the current study, foF2 data from Ouagadougou and Huancayo ionosonde stations are used to illustrate the various characteristics of the F2 layer of the ionosphere through its critical frequency foF2 seasonal time variation during solar cycle minima and maxima for Ouagadougou and Huancayo.

## 2. Data and Methodology

### 2.1. Data

1) The ionospheric parameter studied is the critical frequency of the F2 layer (foF2) taken from [www.spidr.ngdc.noaa.gov](http://www.spidr.ngdc.noaa.gov). 2) The values of sunspots Rz are obtained from the SPIDR database (URL <http://sidc.oma.be/sunspot-data/>). 3) The geomagnetic index aa used to selected quiet days conditions are from [http://isgi.unistra.fr/data\\_download.php](http://isgi.unistra.fr/data_download.php). **Figure 1** is an example of pixel diagram displaying aa index as a table and allowing us to select geomagnetic conditions [15] [16].

### 2.2. Methodology

The Solar cycle phases are determined using sunspot number Rz [17] and criteria fully described in many works [18] [19]: 1) the minimum phase:  $Rz < 20$ ; 2) the ascending phase:  $20 \leq Rz \leq 100$  and Rz greater than the previous year’s value; 3) the maximum phase:  $Rz > 100$ ; 4) the decreasing phase:  $100 \geq Rz \geq 20$  and Rz less than the previous year values.



Figure 1. Diagram pixel of year 1979.

Local (north hemispheric) seasons are classified as followed: winter (December, January, and February); spring (March, April, May); summer (June, July, August) and autumn (September, October and November).

To perform our study, we proceed as follow:

- 1) At solar maximum and solar minimum: select days with the highest  $R_z$  and the lowest  $R_z$  respectively;
- 2) Choose five days the most disturbed (highest  $aa$  index) and five quietest ( $aa$  lowest index);
- 3) Monthly and seasonal average (hourly) of foF2 per cycle and solar activity.

### 3. Results and Discussion

In this section we present and analyze the results of our investigations in order to allow comparison between measurements from two equatorial regions: Africa and America.

Figures 2-5 present the diurnal variation of foF2 during geomagnetic quiet

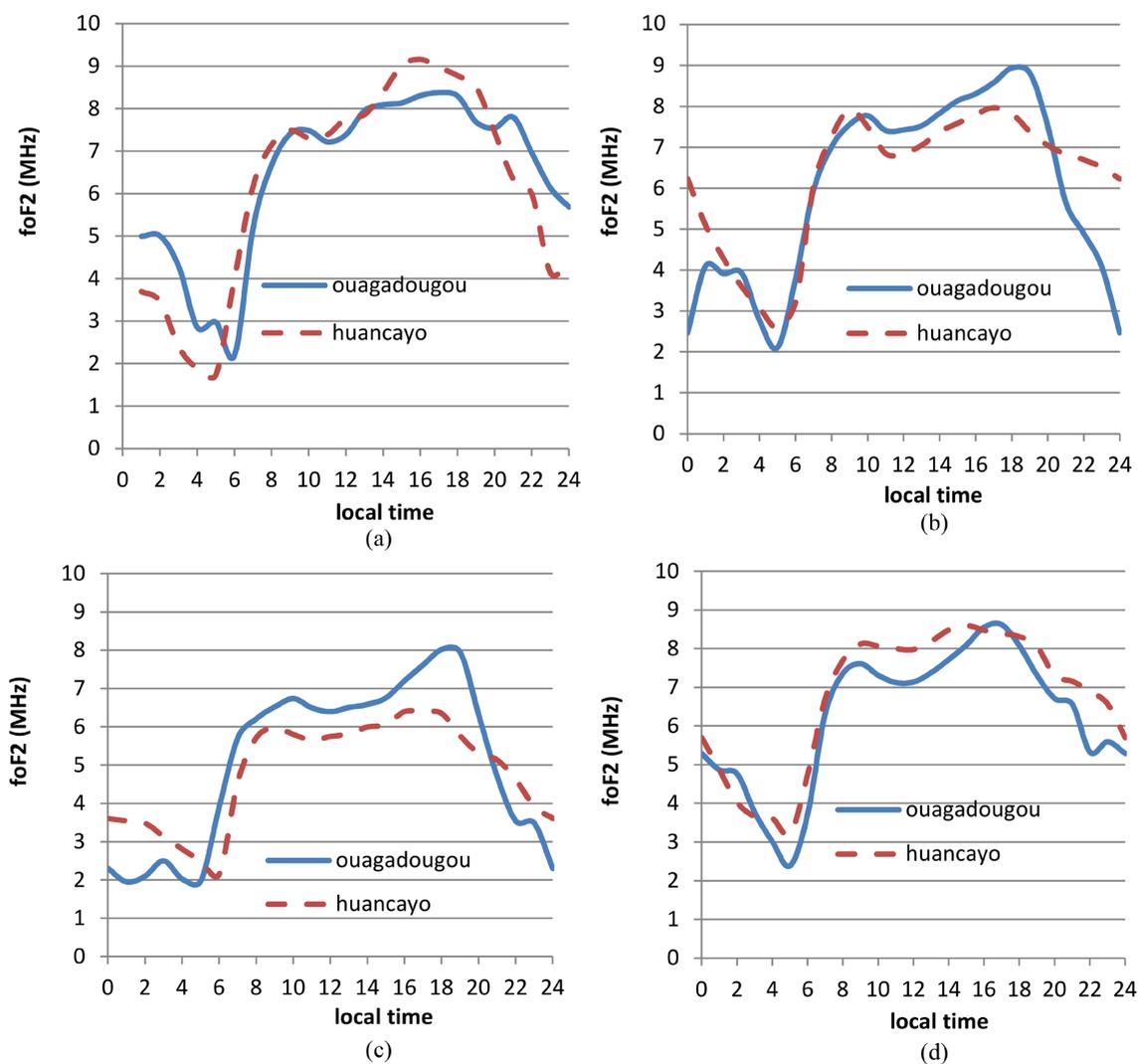


Figure 2. Diurnal and seasonal foF2 during solar minimum phase of the cycle solar 20.

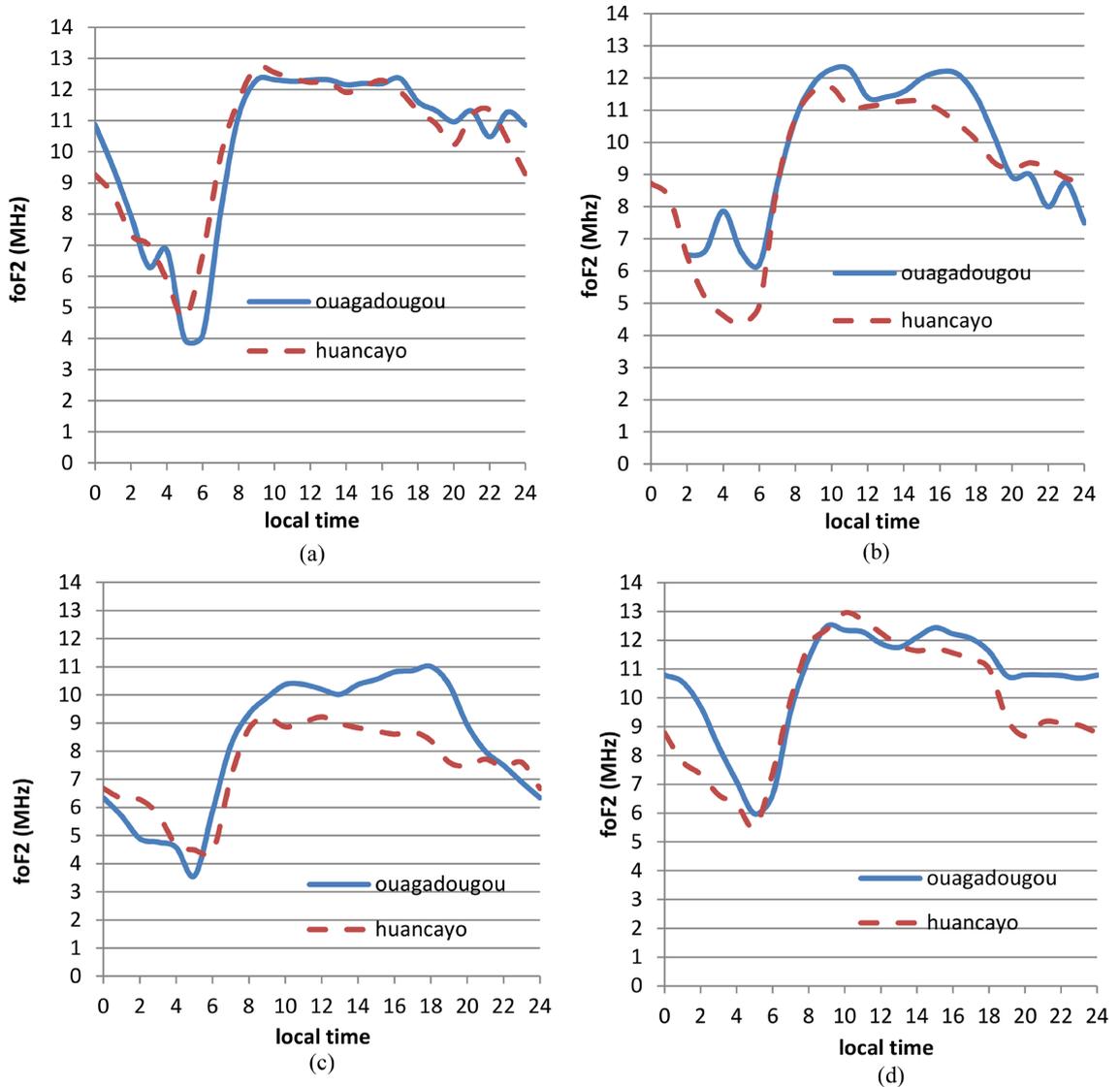
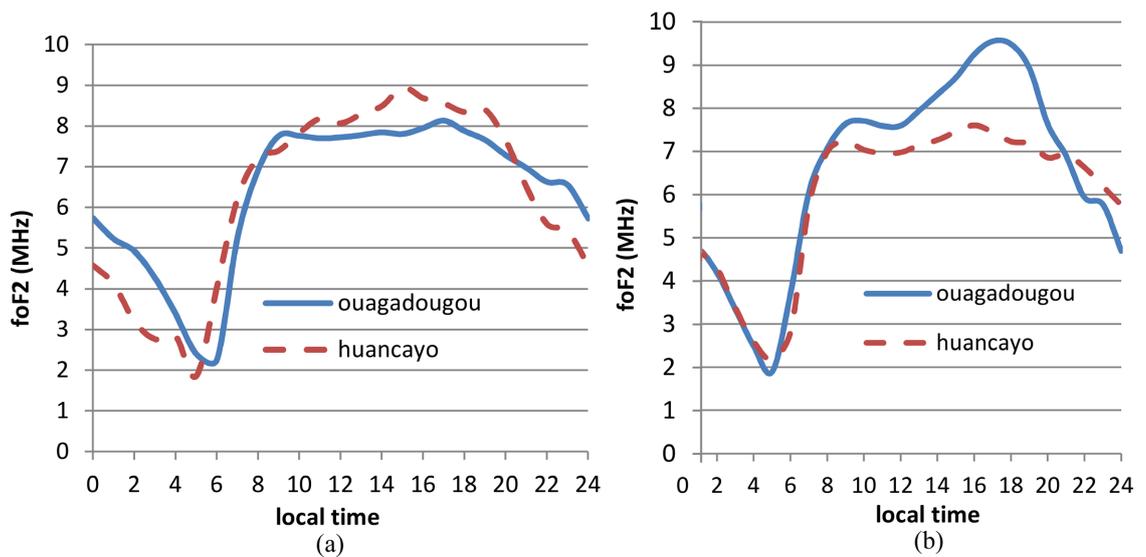


Figure 3. Diurnal and seasonal foF2 during solar maximum phase of the cycle solar 20.



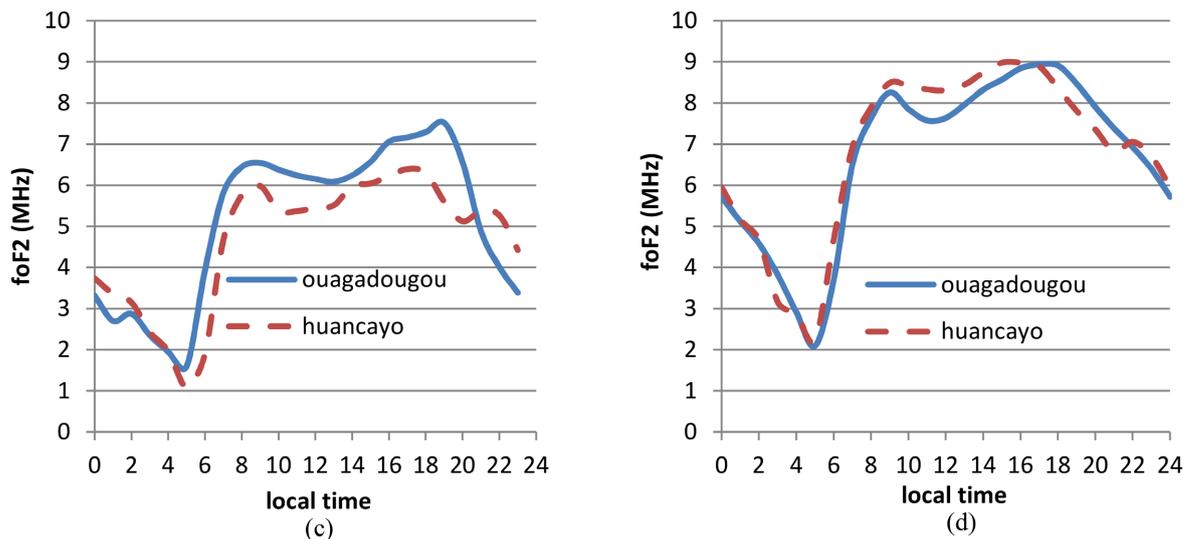


Figure 4. Diurnal and seasonal foF2 during solar minimum phase of the cycle solar 21.

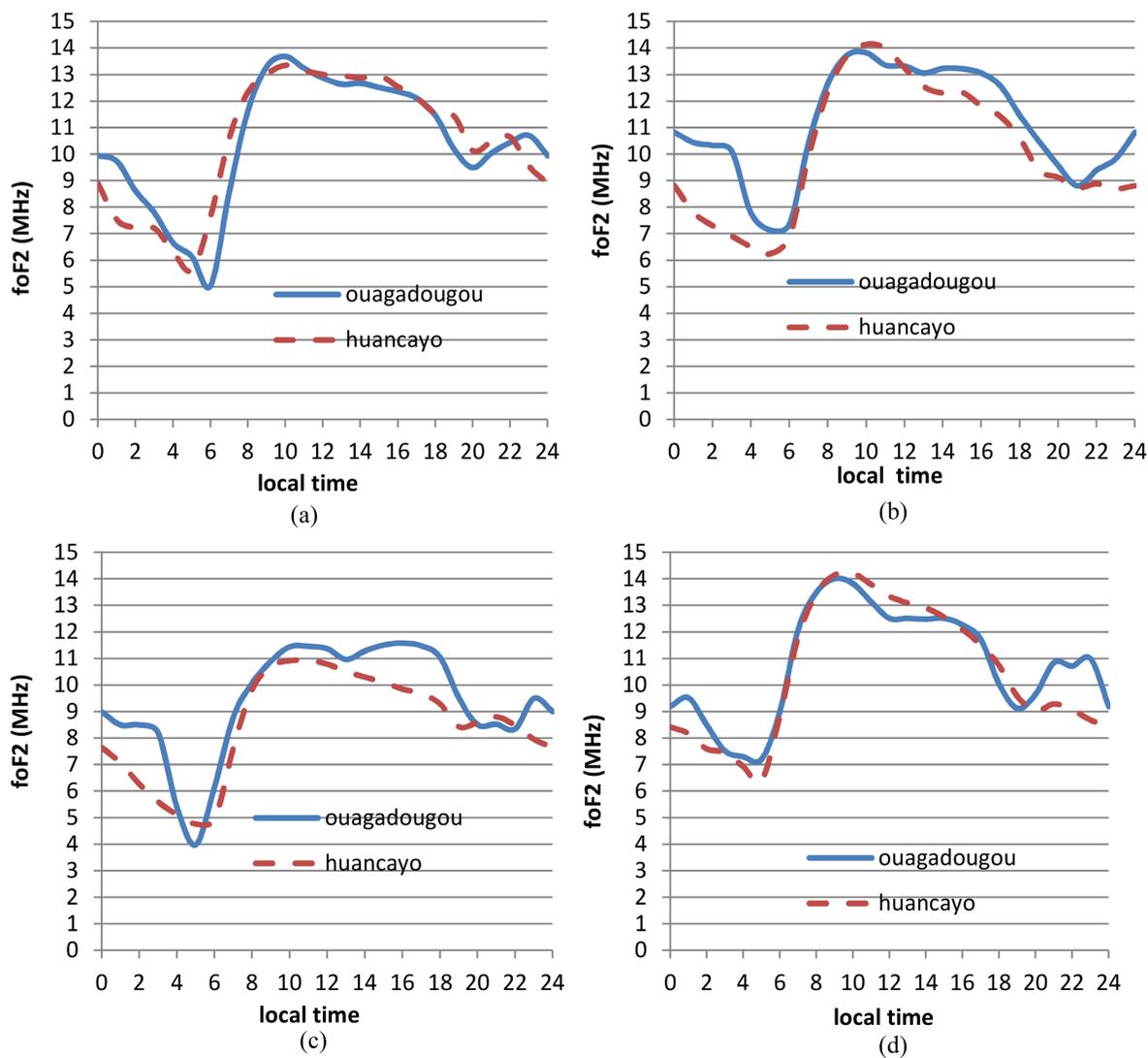


Figure 5. Diurnal and seasonal foF2 during solar maximum phase of the cycle solar 21.

activity for solar minima and disturbed geomagnetic activity for solar maxima at Ouagadougou and Huancayo stations over the solar cycle 20 (1965-1976) and the solar cycle 21 (1976-1986). Each figure shows the seasonal (a—Winter, b—Spring, c—Summer, d—Autumn) behavior of foF2 during our investigation period. It is easy to remark that all the profiles suggested by [12] for equatorial region in Africa are reproduced at Huancayo station. During the minimum phase of the solar cycle 21 foF2 presents “Dome” or “D” profile characterized by a double peak (morning and evening) in winter while “Noon bite out” or “B” profile characterized morning is recorded for the three other seasons (Figure 4). Regardless of the season, foF2 presents “Morning Peak” or “M” profile during the solar maximum phases for both solar cycles 20 and 21 (Figure 3 and Figure 5). During the minimum phase of solar cycle 20, foF2 presents “Noon bite out” or “B” profile for all the seasons except winter where foF2 is characterized by “Reversed” or “R” profile.

From these investigations it appears for both solar cycles 20 and 21, foF2 presents similar profiles for the two stations. The little difference in magnitude may be attributed to the longitudinal irregularities in the F2-layer [20]. Table 1 summarizes the most important seasonal values of foF2 during solar cycle and solar activity for Ouagadougou and Huancayo stations.

In general, the recorded values of foF2 at Huancayo station are higher than those from Ouagadougou station during winter. A reverse phenomenon is observed during summer. These observations for two equatorial regions may be due to the fact that they are not located in the same hemisphere (seasons are permitted).

#### 4. Conclusion

Seasonal and diurnal profiles of foF2 values measured at the stations of Huancayo and Ouagadougou present a similar morphology with little difference during winter and summer. The difference observed during these seasons can be

**Table 1.** Comparative value of most significant values of foF2 during season and solar cycle phases Ouagadougou and Huancayo stations.

Stations	Solar Cycle phases	Winter foF2 (Mhz)	Spring foF2 (Mhz)	Summer foF2 (Mhz)	Autunm foF2 (Mhz)
Ouagadougou	Minimum of Cycle 20	08.30	08.82	07.95	08.62
	Maximum of Cycle 20	12.36	12.27	11.01	12.49
	Minimum of Cycle 21	08.13	09.56	07.52	08.91
	Maximum of Cycle 21	13.68	13.73	11.60	14.21
Huancayo	Minimum of Cycle 20	09.02	07.56	06.35	08.60
	Maximum of Cycle 20	12.55	11.83	09.91	12.71
	Minimum of Cycle 21	08.94	07.61	06.39	08.98
	Maximum of Cycle 21	13.35	14.13	10.13	14.15

explained by the fact that the two stations are located in different hemispheres. The season may be reversed in the hemispheres strongly link to the ionization phenomenon. Solstice anomaly is observed only during the intense geomagnetic activity (solar maximum) as summarized in table for these two stations.

### Acknowledgements

The authors thank Brest Telecom for providing Ouagadougou ionosonde data and ISGI and SPIDR data center for providing the aa indices and foF2 respectively.

Many thanks are sent to ACS editors and anonymous reviewers of our paper.

### Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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