

Prediction of the Disturbance of a Radio Wave during certain periods in the D-region of the Ionosphere During quiet Geomagnetic Activity in the Solar Cycle 22

Nakolemda Roger¹, Abdoulaye Ali Ibrahima³, Drabo Nonlo Kadidia², Sawadogo Gédéon¹, and Nanéma Emmanuel²

¹Université Norbert ZONGO, Laboratoire de Recherche en énergétique et Météorologie de l'Espace (LAREME), BP 376 Koudougou, Burkina Faso.

²Centre National de la Recherche Scientifique et Technologie, Institut de Recherche en Sciences Appliquées et Technologies, 03 BP 7047 Ouagadougou 03, Burkina Faso.

³Université André Salifou de Zinder, Ecologie Santé et Environnement, PB 656 Zinder

*Corresponding author; Email: rogernakolemda.sea@gmail.com.

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ABSTRACT

The low electron density of the ionosphere characterises the D region. It is an electrically neutral plasma that is unstable with the seasons, formed by the photodissociation of neutral components by solar radiation. This region has an effect on the signal of an electric radio wave, which varies with the seasons during certain periods. The objective undertaken in this work is to predict certain disturbances in region D during the seasons when a radio signal is transmitted and defines the periods at which the signals are weakened. To achieve our objective, we used data from the IRI model in its 2016 version provided by the VITMO site of the National Aeronautics and Space Administration (NASA) in the city of Ouagadougou in Burkina Faso in West Africa. It appears from this work that the radio signal varies not only with the seasons but also with the critical frequency of region D..

I. Introduction

The D region of the ionosphere, located at altitudes of between 50 and 90 km, is influenced by solar radiation, mainly X-rays and extreme ultraviolet (EUV). The critical frequency of this region determines the ability of radio waves to penetrate or be reflected by the ionosphere. The D region varies as a function of solar radiation, causing a disturbance in the radio wave signal. The signal received then depends on the critical frequency. It is therefore important to monitor and model ionospheric activity and its effects on technological systems based on the transmission and/or reception of radio waves. The signal received depends on the critical frequency. It is therefore important to monitor and model ionospheric activity as well as its effects on technological systems based on the emission and/or reception of radio waves. Many models have been developed to study the ionospheric region [1]-[12]. The objective of each model is to obtain the best approach to the ionosphere and to achieve the different parameters. In this study, we use the International Reference Ionosphere (IRI) model to obtain the critical frequency of region D (foD) in the city of Ouagadougou, characterized by 12.4°N and 358.5°E. IRI is an empirical model of the ionosphere. The 2016 version is used in this work to obtain the foD parameters. This study only takes into account calm weather conditions [13]. The five calmest days of the minimum of solar cycle 22 are considered to characterize the monthly behavior of the parameters. The foD profile is obtained in different seasons, using the given values of the parameters by running the IRI model.

II. Research Method

In this present work, the minimum of solar cycle 22 is taken into account for the study of the critical frequency of region D. The International Reference Ionosphere (IRI) is the model used to determine the ionospheric parameter foD. IRI is a semi-empirical model, developed and updated every four years by a team of researchers. Modeling the ionosphere using IRI is based on the following three fundamental principles [14-17]: (i) The characteristic months of spring, summer, autumn and winter are respectively March, June, September and December; (ii) The five calmest days of each characteristic month ($Aa \leq 20$ nT) are considered; (iii) The solar minimum is characterized by the number of sunspots R_z and 1985 corresponds to the minimum of solar cycle 22. The following input parameters are used to run the IRI model during solar minimum: Year = 1985, Longitude = 358.5°E, Latitude = 12.5°N, Height = 75, Step size = 1. With the input parameters above, the critical frequency values are obtained on "List Model data". These values are exported to an Excel file for plotting. The Table below highlights the five quietest days selected in each season.

Table n°1: Selection of the calmest days

Solar phase	cycle minimum	Season	Winter	Spring	Summer	Autumn
		Month	December	March	June	September
22		Quiet days	8, 9, 21, 23, 29	9, 13, 21, 22, 25	3, 14, 16, 18, 19	2, 3, 4, 5, 29

The methodology for determining the critical frequency is based on the calculation of the monthly hourly average of the foD parameter in the five calmest days of each characteristic month. Thus, equation (1) defines the critical frequency as follows:

$$foD_h = \frac{\sum_{j=1}^5 foD_{h,j}}{5} \quad (1)$$

In relation (1), foD_h designates the critical frequency of layer D at time h for the characteristic month considered, $foD_{h,j}$, j is the value of the critical frequency at time h for day j. Thus, $h \in [0.24]$, and $j \in [1.5]$.

III. Results and discussion

The figures below represent the seasonal variation of the critical frequency of the D region of the ionosphere during the phase minimum of solar cycle 22 at the Ouagadougou station. The vertical axis represents the critical frequency and the horizontal axis defines the local time. The observation of these figures shows similar variations. During this phase of solar activity, the critical frequency profile shows:

- A decreasing part from 12.00 TL to 17.00 TL, increases during the day from 08.00 TL to 12.00 TL and peaks at 12.00 TL (0.236MHz) in spring;
- In summer, foD increases from 07.00 TL to 12.00 TL, peaks at 12.00 TL (0.235MHz) and decreases from 12.00 TL to 17.00TL;
- In autumn, foD increases from 08.00 TL to 12.00 TL, peaks at 12.00 TL (0.234MHz) and decreases from 12.00 TL to 17.00 TL;
- In winter, foD increases from 08.00 TL to 12.00 TL, peaks at 12.00 TL (0.223MHz) and drops from 12.00 TL to 16.00 TL.

It should be noted that this appearance of frequency is due to the ionisation of particles in the atmosphere by solar radiation. The critical frequency depends on the electron density in this region, which in turn depends on solar irradiance. During this phase, ionisation is significant and continues for a few periods after the maximum position (12.00TL) until it disappears.

The study shows an absence of foD during the following periods:

- TL $\in [00.00, 08.00] \cup [17.00, 24.00]$ for spring;
- TL $\in [00.00, 07.00] \cup [17.00, 24.00]$ for summer;
- TL $\in [00.00, 08.00] \cup [17.00, 24.00]$ for autumn
- TL $\in [00.00, 08.00] \cup [16.00, 24.00]$ for winter.

During these periods the ionisation of the D region due to solar radiation is not significant. Recombination is very rapid, so this frequency does not remain at these times when photoionisation has stopped. The seasonal variation in foD therefore depends on the weather, the season and the zenith angle.

The various figures obtained show a maximum critical frequency of less than 1 MHz. One reason why this layer does not appear on the ionograms (traces of the layers obtained by sounding) is because of its low critical frequency (the highest frequency likely to return to the ground after vertical incidence), which is lower than the classic limit frequency of 1 MHz for ion probes (sounding apparatus). The collision frequencies (ν_{en}) electron-neutral and (ν_{in}) ion-neutral are very high, resulting in strong absorption of HF radio waves and attenuation of waves at frequencies below 1 MHz. In the absence of the D region, a high wave signal can be obtained.

The intensity of the signal also varies from one night to the next due to the instability of the electron density in the D region. Before the D region appears, the signal will be very strong. During the appearance of this region and during propagation, the wave loses energy. In this case, the signal weakens and stabilises at a relatively constant level. This pattern reflects the constant bombardment of the ionosphere by solar radiation during this phase. Wave propagation is strongly affected by the characteristics of the ionosphere, which is subject to numerous variations. Calibration is therefore required for good communication across the D region.

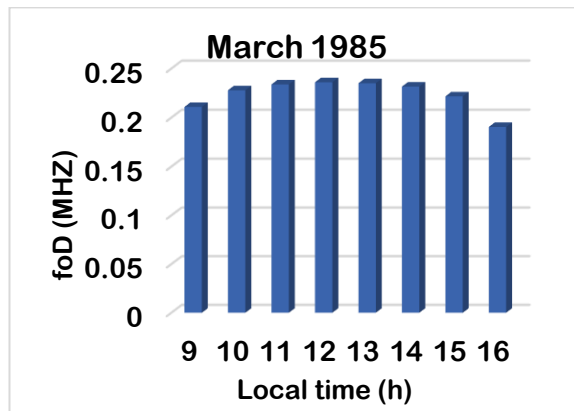


Fig. 1: Temporal variation of foD in spring

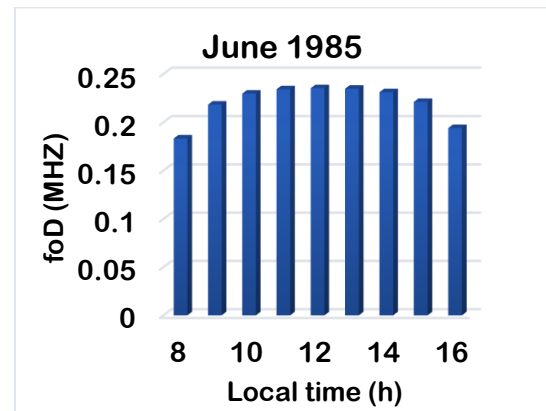


Fig. 2: Temporal variation of foD in Summer

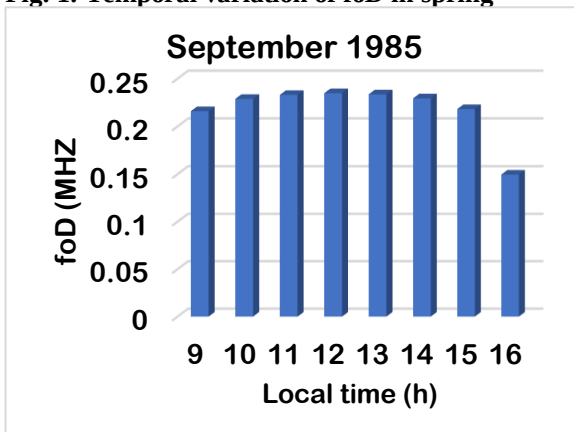


Fig. 3: Temporal variation of foD in Autumn

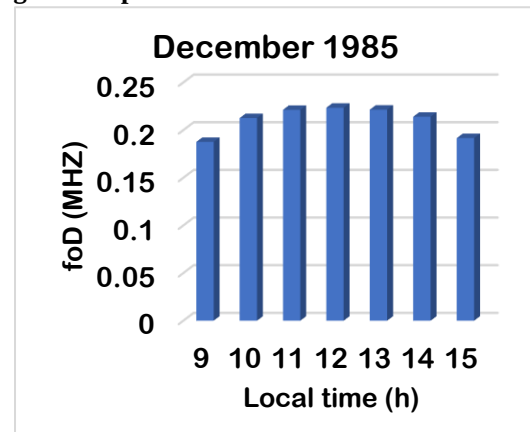


Fig. 4: Temporal variation of foD in Winter

IV. Conclusion

During the phase minimum of solar cycle 22, solar activity is reduced, leading to a decrease in ionisation in the D region of the ionosphere. This lowers the critical frequency, which is the maximum frequency at which radio waves can be reflected by this region. Radio waves with frequencies lower than the critical frequency undergo greater absorption, reducing their range and the quality of radio communications.

The instability of the electron density in the region has a considerable effect on the signal of a wave due to the collision frequency, which most affects wave whose energy is not too great for the effect to be noticeable. Consequently, the results found in this work can be used to predict certain disturbances in the D region when transmitting a radio signal.

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