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The study of foF2 on low latitude over Cocos Island during the inclining phase of 25 solar cycle

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ABSTRACT: Background: The ionospheric F2-layer critical frequency (foF2) is an important parameter for understanding ionospheric variability and radio wave propagation. Its behavior is strongly influenced by solar activity, seasonal effects, and local geophysical conditions, particularly at low-latitude stations.
Purpose: This study aims to examine the variability of foF2 during the year 2023 at Cocos Island (12°11′13″ S, 96°49′42″ E), a low-latitude station, during the rising phase of Solar Cycle 25.
Method: A statistical analysis was carried out using foF2 data collected at Cocos Island. The database consists of hourly measurements obtained across multiple seasons. The analysis focuses on the diurnal, monthly, and seasonal variations of foF2, based on hourly observations throughout the year.
Conclusion: The results indicate that foF2 gradually decreases from 15:00 LT to 23:00 LT and then increases from 06:00 LT to 15:00 LT. The peak values rise during daytime and decline during nighttime. Seasonal analysis shows that foF2 variations are greatest during the equinox and lowest during the summer season. Among the months studied, July exhibits the lowest variability in foF2, whereas October shows the highest variation.

Keywords: foF2, Ionosphere, low latitude, diurnal and seasonal variation, 25th solar cycle

1. Introduction

The critical frequency of the layer (foF2), or the highest radio frequency that the ionospheric F2 layer can reflect, is related to the ionospheric peak electron density in the layer. Accurate long-term foF2 variations are usually obtained from ionosonde observations. We need to use a range of parameter types to understand the latitudinal variance of the F2 layer. The critical frequency of the F2 layer is very important since it directly quantifies the number of electrons per square meter, which is an essential parameter in radio transmission. A prominent and persistent feature of the upper atmosphere, ionospheric variability is quantified as variation from the climatologically mean and occurs on an hourly, daily, monthly, and solar cycle timeframe. An excellent measure of solar activity is the solar radio flux at 10.7 cm (2800 MHz). [1] Diabaté et al. (2018) discuss the effects of varying activity on the F2 layer of the ionosphere through changes in its critical frequency. They examined yearly, diurnal, and seasonal variations of foF2 during solar cycles 21 and 22, phases covered by data from the Ouagadougou ionosonde station (Lat: 12.5 N; Long: 358.5 E) under variable wind conditions. [2] Khubchandani et al. (2017) examined the day-to-day variations of the F region of the ionosphere throughout the high, moderate, and low solar activity phases of the 23rd solar cycle at Australia's low-latitude station Darwin (120 S, 1310 E). The fluctuation of foF2 has been examined daily, seasonally, and annually. To analyse the variability, the hourly values' relative standard deviations for each month during the years of High (2000), Moderate (2003), and Low (2008) solar Activity periods are analysed. [3] Kouris et al. (1998) studied the relative deviations

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of the hourly daily values of the critical frequency foF2 from their corresponding monthly median. [4] (Rama Rao et al., 1997), the improvement of which depends on increasing knowledge of the ionosphere. The behaviour of the ionosphere. Since the ionosphere varies from place to place and from time to time, in other words, the ionosphere exhibits both temporal and spatial variation, I need to study in as many places as possible and for as long as possible.

In the present study, we studied the seasonal, monthly, and daily variations of the critical frequency (foF2) of the F2 layer at the low-latitude station during the inclining phase of solar cycle 25 in the year 2023. With the help of the hourly value of foF2, the seasonal, monthly, and diurnal characteristics of the critical frequency (foF2) for low latitudes are investigated.

2. Methods and Material

In this paper, we collected foF2 data GIRO (Global Ionospheric Radio Observatory) (uml.edu). The diurnal, monthly, and seasonal variations of foF2 with local time are examined using the data collected from the Cocos Island station during 2023. Many fluctuations are revealed by the data. Here, we observed trends in the hourly foF2 values throughout 2023 for both monthly and diurnal variations in foF2, as well as across the seasons (summer, equinox, and winter). The peak and dip values of foF2 have also been examined. The data was analyzed using statistical methods, such as computing the hourly, daily, and seasonal average values of foF2 for 2023.

3. Results and Discussion

Diurnal Variation of foF2: The term "diurnal variation" describes the variations that take place over 24 hours. We may observe how foF2 varies during the day from the graph shown in Fig. 1. Figure 1 displays the foF2 diurnal curve. The graph shows that the foF2 value peaks at 15:00 LT and dips at 05:00 LT. It seems that foF2 gradually decreases from 15:00 hours (LT) to approximately 23:00 hrs (LT), then increases from 06:00 hrs (LT) to 15:00 hrs (LT). The value of the height rises throughout the day and falls at night. This variation pattern is due to the diurnal variation of ionospheric conductivities.

Monthly Variations of foF2: The average foF2 for each month in 2023 is utilized. Figure 2 clearly shows that the variation of foF2 peaks in October and July exhibits the lowest value. The graph distinctly illustrates that the foF2 value increases from January to March, decreases from April to July, and rises again from August to October.

***Seasonal Variations*:** The graph below (3) is created for 2023 across three distinct seasons (summer, equinox, and winter). The foF2 values reach their peak at 16:00 Hours (LT) and their lowest at 5:00 Hours (LT) across all seasons as depicted below. The value of foF2 declines at night and increases during the day.

To comprehend the latitudinal differences of the F2 layer, we must utilize an array of parameters. The critical frequency of the F2 layer is an essential attribute as it offers a clear signal of the number of electrons per square meter that is vital for radio transmission. Low latitude possesses distinct temporal and geographical characteristics. It has also been observed that foF2 exhibits a linear correlation with sunspot numbers at mid-latitudes but an uneven relationship at low latitudes. [5] Agrawal et al. (2018) investigated the nighttime improvement in foF2 at Jicamarca (12° S, 76 90° W) during the 23rd and 24th high solar activity phases at low latitudes. They utilized ionosonde data for the critical frequency of the F2 layer to examine the nighttime enhancement of the ionosphere. The unusual nighttime F-region is analyzed using hourly data from the years 2002 (High solar activity period for the 23rd solar cycle) and 2014 (High solar activity period for the 24th solar cycle) of foF2. They discovered that pre-midnight hours exhibit more occurrences at low latitude stations than post-midnight hours in both years. The year 2002 had a higher frequency of occurrences compared to 2014 in terms of quantity. [6] Bi Cheng et al. (2022) introduced a hybrid neural network combined with a quantile mechanism to forecast variations in the ionospheric F2 layer critical frequency (foF2) parameters during low and high solar activity years (solar cycle-24) and space weather events. The proposed model was trained and evaluated using

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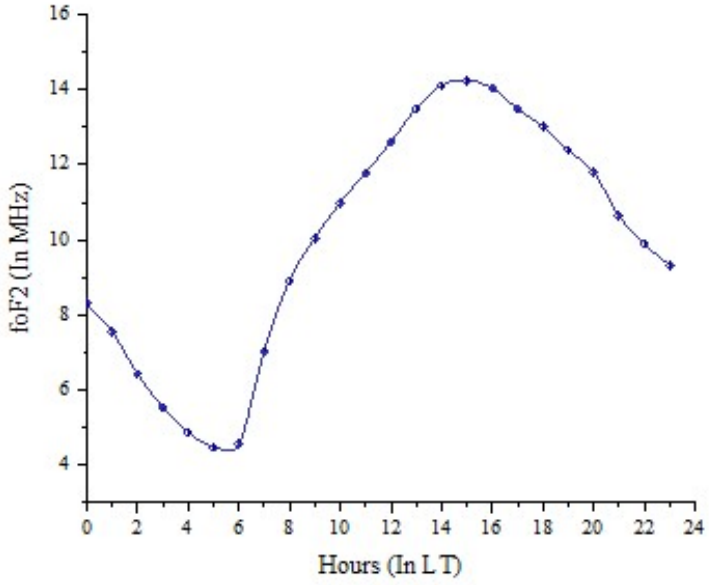


Figure 1: Figure1: shows the Diurnal Variation of foF2 at low latitude during 2023

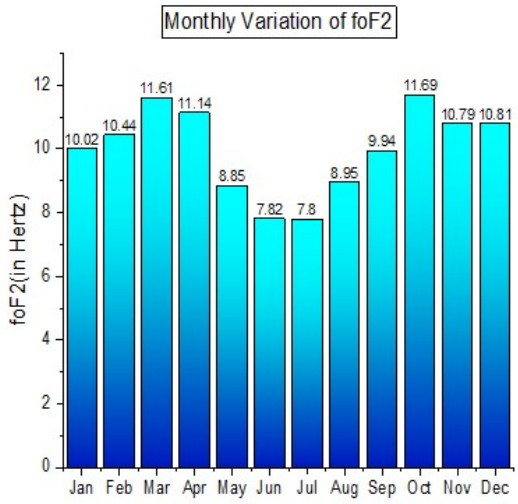


Figure 2: Shows the monthly variation of foF2 during 2023

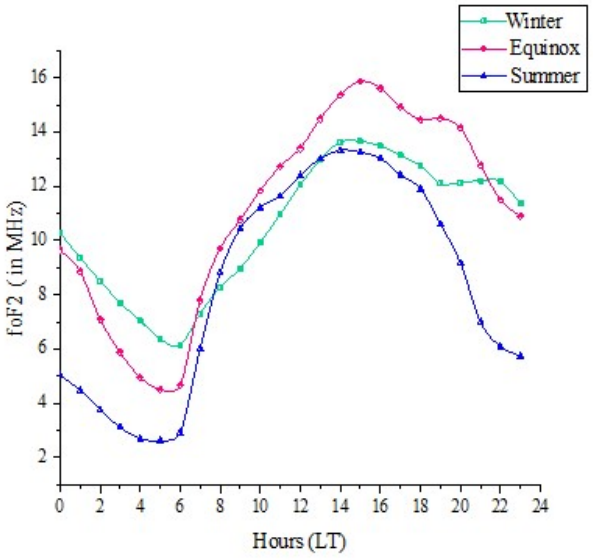


Figure 3: Shows Seasonal Variation of foF2 at low latitude during 2023

five years of ionospheric foF2 observation data from the Advanced Digital Ionosonde situated in Brisbane, Australia. Results indicated that the proposed model outperformed the International Reference Ionosphere 2016 (IRI-2016), long short-term memory (LSTM), and BiLSTM ionospheric forecasting models. Diabaté et al. (2018) address the influence of fluctuating activity on the F2 layer of the ionosphere through changes in its critical frequency. They investigated yearly, diurnal, and seasonal fluctuations of foF2 during solar cycles 21 and 22, phases represented by data from the Ouagadougou ionosonde station (Lat: 12 5 N; Long: 358 5 E) under varying wind conditions. This study illustrates that the annual variations of foF2 are synchronized with the solar cycle. Except during the solar maximum, when a morning peak is observed, indicating that the vertical drift E×B is disturbed, the diurnal variation typically features a “noon bite out” during that period. The seasonal alterations indicate that certain equatorial ionosphere characteristics, such as electrojet and vertical drift E×B, are not significantly impacted by varying activity. Nevertheless, one notable effect observed during changing activity is the increase of the electric field pre-reversal event in

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autumn. Across all latitudes, the diurnal and seasonal variations of ionospheric parameters linked to electron density features are believed to result from changes in the ion production rate governed by the zenith angle. In our current work, it is shown that the peak height value increases during the day and decreases at night. For monthly variation, the foF2 value peaks in October and reaches its lowest in July. The graph indicates that the foF2 value increases From January to March, decreases in April to July, and then increases again in August to October. For seasonal variation, during nighttime, the foF2 time value diminishes, and during daytime it increases.

4. Conclusion

In this research, we examined the diurnal, monthly, and seasonal fluctuations of foF2 data obtained from Cocos Island Station during the ascending phase of the 25th solar cycle in 2023 at low latitude.

1) For diurnal variation, foF2 steadily decreases from 15:00 hours (LT) to around 23:00 hours (LT), and then rises from 06:00 hours (LT) to 15:00 hours (LT). The peak height value increases throughout the day and decreases at night.

2) For monthly variation, the foF2 value is highest in October and lowest in July. The graph clearly shows that the foF2 value increases from January to March, decreases from April to July, and then increases again from August to October.

3) For seasonal variation, the foF2 values are highest at 16:00 hours (LT) and lowest at 05:00 hours (LT) across all seasons as illustrated below. During nighttime, the foF2 value drops, while it rises during daytime.

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Authorship contribution: Deepshikha kedare : Methodology, Writing - Original Draft; Kaisar Jan: Data Analysis; Madhuri Singh : Investigation, Data Collection; Kalpana Maski : Literature Review; S. K Vijay : Supervision.

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Declaration: It is an original data and has not been sent or published anywhere.

Similarity Index: The authors hereby confirm that there is no similarity index in abstract and conclusion while overall is less than 10% where individual source contribution is 2% or less than it.

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