

Comparative Study of High and Mid Latitude foF2 during Low Solar Activity

Ritesh Yadav¹, A. K. Gwal²Research Scholar, Department of Physics, Barkatullah University, Bhopal-462026, India¹Professor, Department of Physics, Barkatullah University, Bhopal-462026, India²

ABSTRACT: In the present investigation we have compared the climatology of mid and high latitude F-layer ionosphere. To accomplish this study we have taken a high and a mid latitude station, Soyawa (69.0°S, 39.6°E) and Bhopal (23.25°N, 77.40°E) respectively. The investigation is carried out during the extremely low solar activity period 2007, the deep minimum of cycle 24. To compare the variability of ionosphere at both the stations we have used the ionosonde measurements and considered the critical frequency of F2 layer (foF2). The foF2 is an important and most widely used parameter for studying the ionospheric variability. The variability of ionosphere through foF2 is studied diurnally, monthly and seasonally. To compare the variability of ionosphere at both stations we derived the ratio of foF2 two stations i.e. $foF2_{Soyawa}/foF2_{Bhopal}$ and investigated its variability monthly. We also derived the correlation between the changes in foF2 observed at two stations. The correlation coefficients calculated between the Bhopal foF2 and Soyawa foF2 are 0.48, 0.47 and 0.64 during equinox, winter and summer respectively.

KEYWORDS: foF2, Ionosphere, Solar activity.

I. INTRODUCTION

The ionosphere is not only controlled by the radiation of the Sun but also due to the coupling with the neutral atmosphere and other local phenomena. All these influences whether solar or local disturb the ionosphere and make it irregular. This results in the spatial and temporal variability of the ionosphere. It is now established that the state of ionosphere changes from hour to hour, day to day, season to season, year to year and even from place to place. A number of studies conducted in the past have revealed some important similarities and differences between the high, mid and low latitude ionosphere [1, 2, 3]. It is believed that the ionospheric variability at low, mid, and high-latitudes is caused by variations in the external forces that originate from the thermosphere, the magnetosphere, and the lower atmosphere [4].

The characteristic features of foF2 at the low latitude differ significantly from those of the mid-latitude [5]. It was observed that at mid latitudes, foF2 shows nearly a linear relationship with sunspot number, though this relation is nonlinear for low latitudes [6]. Therefore, attempts have been made to study the similarities and differences in the variation of foF2 at a low latitude station and the mid latitude station [7]. At middle latitudes, storm enhanced plasma densities (SEDs) are frequently observed during periods of enhanced geomagnetic activity. These bands of largely increased density structures, caused by storm-time electric fields which transport plasma from low to middle latitudes [8].

There are several mechanisms known to be responsible for causing high-latitude irregularities (soft electron precipitation, gradient drift instability and shears). In the polar cap region, ionospheric F layer polar cap irregularities which are believed to be produced by gradient drift instabilities are responsible for the production of ionospheric variability [9, 10].

In the light of previous, in the present study we have also studied the similarities and differences in the ionospheric variability at the mid and high latitudes.

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II. DATASETS AND METHODOLOGY

We have studied and compared the ionospheric variability at high and mid latitudes. To accomplish this study we have selected a high latitude station Soyawa (69.0S, 39.6E) and a mid latitude station Bhopal (23.25N, 77.40E). To study the ionospheric variability at both the station we have used the ground based ionosonde observation.

In our study we have used the foF2 to study and compare the ionospheric variability at the two stations. For Bhopal station the data was collected from the radio sounding observations carried out over Bhopal. A digital ionosonde is installed at Space Science Laboratory, Department of Physics, Barkatullah University, Bhopal and the regular observations are being conducted since 2003. The ionosonde gives 15 min values of foF2 as well as other parameters. Form the 15 minute values we have obtained the hourly value. We have also calculated the daily as well as monthly medians and averages.

The data of foF2 at Soyawa station were obtained from the database of National Institute of Information and Communication (NICT), Japan. NICT maintains a huge database of ionospheric data and can be downloaded from NICT website <http://wdc.nict.go.jp/IONO/HP2009/ISDJ/index/>. The NICT Ionosonde data contains 15 minute and hourly values both in manually scaled and automatic scaled modes and also their daily and monthly medians. For the present study we have used the manually scaled hourly values of foF2. From the hourly values we have calculated the daily medians as well as monthly medians. We have also constructed the daily and monthly averages of the fof2.

The study was conducted during the low solar activity period 2007. The solar activity was extremely low during the year 2007 where Sun went spotless for months together.

III. RESULTS AND DISCUSSION

We begin the presentation of our results as follows. First we show the hourly variability of foF2 at Bhopal station during all the 12 months of the year 2007. The hourly variability of foF2 at Bhopal station during all the months of the year 2007 is shown on figure 1. Here we have plotted the hourly values of the monthly median of each month instead of plotting the hourly values of all the days of the months. From the graph it is clear that foF2 follows a typical diurnal variability, starts increasing from the local morning and achieves a peak around the local afternoon and again decreases as the day progresses. The diurnal peak during all the months was observed during 12:00 to 16:00 Hrs LT with peak values ranging between 08MHz - 13 MHz. The lowest peak values of foF2 were observed during the month of February, June, July and November, while highest peak values were observed during the months of March, April, September and October.

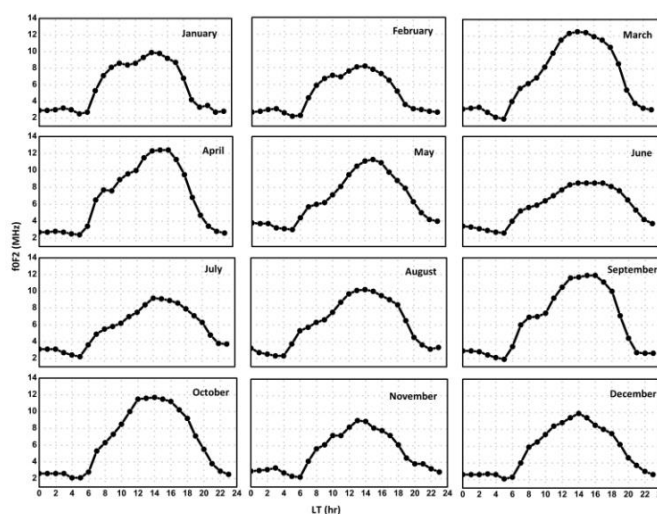


Fig. 1. Diurnal variability of foF2 at Bhopal during all the months of the year 2007.

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Similarly we plotted the hourly values of monthly median at Soyawa station during all the months of the year 2007 and is shown in figure 2. Here we do not notice a typical diurnal peak during all the months of the year. Although a diurnal peak is clearly noticeable during the months of January, February, March, April, October and November the same is absent during the months of May, June, July and August. The diurnal peak observed during the months of January, February, March, April, October and November also does not occur around the same time. The shifting of the diurnal peak can be clearly observed in figure 2. The peak values of foF2 were observed to be between 50 MHz and 60 MHz which are comparatively much higher than those observed at Bhopal. The highest peak values were observed to occur during the months of January, February, March and October. The lowest peak values were observed to occur during the months of May, August, September and November.

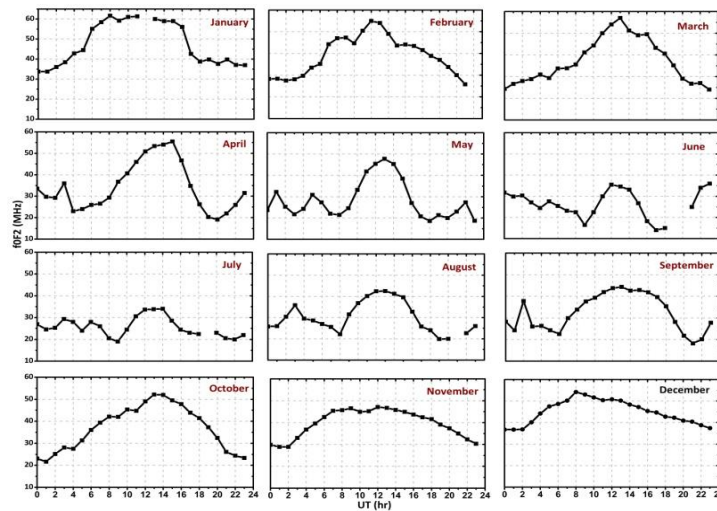


Fig. 2. Diurnal variability of foF2 at Soyawa during all the months of the year 2007.

Next we present the monthly variability of ionospheric foF2 at Bhopal and Soyawa stations. The monthly variability of foF2 is shown in figure 3. From the figure 3 we notice that the monthly variability of foF2 is almost opposite at two station. At Soyawa the value of foF2 starts decreasing from the month of January and reaches a minimum value in the month of July and then again starts increasing and achieves a maximum value in the month of December. However, at Bhopal foF2 starts increasing from the month of January and achieves a maximum value in the month of April and then starts decreasing and reaches the minimum in the month of July and then again starts increasing achieving a maximum in the month of October. On the other hand the monthly variability at both the stations follows a regular and well defined pattern.

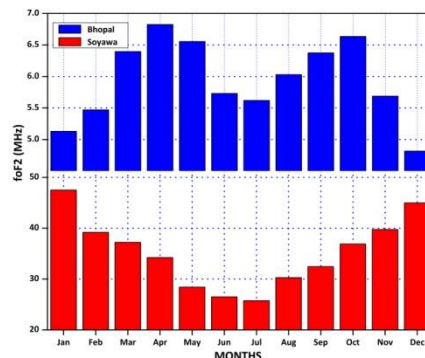


Fig. 3. Monthly variability of foF2 at Bhopal and Soyawa stations during the year 2007.

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We now examine and compare the seasonal variability of foF2 at Bhopal and Soyawa stations. The seasonal variability of foF2 at Bhopal and Soyawa stations is shown in figure 4. The value of foF2 is highest during the summer season at Soyawa and during equinox at Bhopal. However, the least values of foF2 are observed during the winter season at both the stations.

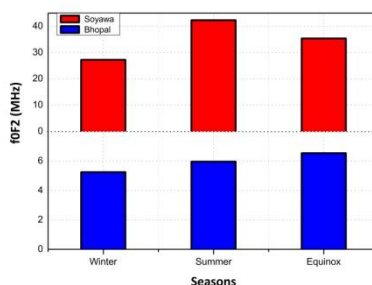


Fig. 4. Seasonal variability of foF2 at Bhopal and Soyawa during 2007.

In order to compare the variability of foF2 at high and mid latitude station i.e Soyawa and Bhopal we derived the ratio of high latitude foF2 to low latitude foF2 ($foF2_{Soyawa}/foF2_{Bhopal}$) and investigated the variability of this ratio. The monthly variability of this ratio is depicted in figure 5. From the figure we observe a very interesting and striking feature. The monthly variability of $foF2_{Soyawa}/foF2_{Bhopal}$ follows a typical second order polynomial relationship. There is very slight change in the ratio during the months of March to September while large changes are observed during the other months of the year 2007. Hence the deviations in the foF2 at two stations are very small during the months of March to September while the monthly changes in the foF2 are extremely different during the other months at two stations.

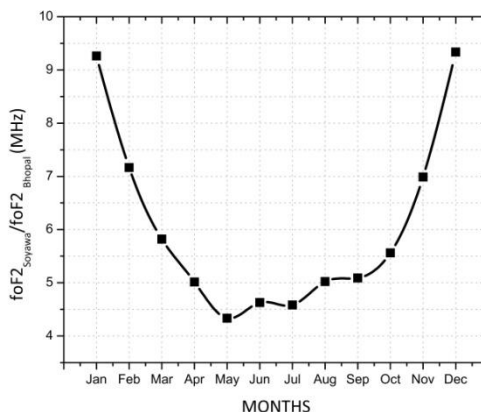


Fig. 5. Monthly variability of ratio of high to low latitude foF2 during 2007.

We then performed a correlation analysis to compare and quantify the variability of the foF2 at two stations. We constructed the scatter plots of foF2 at Bhopal and Soyawa and performed the single regression analysis. The correlation analysis between Bhopal foF2 and Soyawa foF2 during the three different seasons of the year is depicted in figure 7. From the figure we find that a good correlation exists between the Bhopal foF2 and Soyawa foF2 during all the season of the year. However, the magnitude of correlation is stronger during the summer season followed by equinox and the least during the winter season. The correlation coefficients between Bhopal foF2 and Soyawa foF2 during summer, equinox and winter were found to be 0.64, 0.48 and 0.47 respectively.

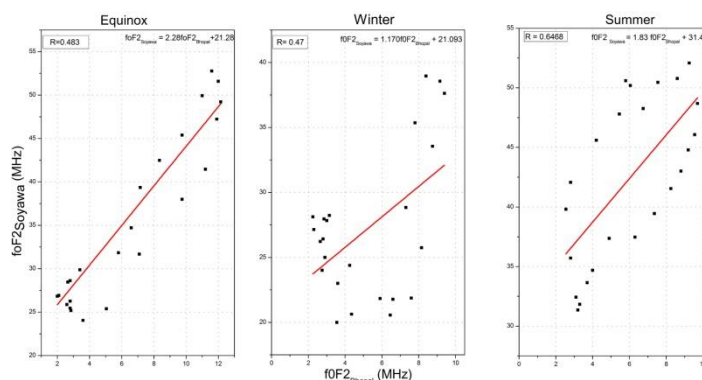


Fig. 6. Correlation between Bhopal and Soyawa foF2 during summer, winter and equinox seasons of 2007.

IV. CONCLUSIONS

1. On comparing the diurnal variability of the ionospheric foF2 at high and mid latitude stations, Soyawa and Bhopal, we found that a typical diurnal peak is observed at Bhopal during all the months of the year while at Soyawa the diurnal peak exists only during some months. Moreover at Bhopal the time of occurrence of diurnal peak is almost same while at Soyawa a time shift in the occurrence of the diurnal peaks is clearly noticeable. The peak values of foF2 are comparatively much higher at Soyawa than at Bhopal.
2. The monthly variability of foF2 at Bhopal and Soyawa are almost opposite but the variability at both the stations follows a regular and well defined pattern.
3. The seasonal variability almost follows a similar pattern at both the stations. The value of foF2 is lowest during winter season at both the stations while highest during equinox season at Bhopal and during summer season at Soyawa.
4. The monthly variability of foF2Soyawa/foF2Bhopal follows a typical second order polynomial relationship. The deviations in the foF2 at two stations are very small during the months of March to September while the monthly changes in the foF2 are extremely different during the other months at two stations.

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