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Comparison of Day to Day Variability of foF2 at Low, Mid and High Latitude during 24 Solar Cycle

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Abstract: This paper present the analysis of the F region variability of the ionosphere during the Low solar activity period year 2009 for three stations of low, mid and high latitude Chongqing (29.43°N,106.92°E), Beijing (39.91°N,116.41°E) and Sodankyla (67.40°N,26.59°E) respectively. In the study we discussed the diurnal, seasonal, and monthly variability of foF2 at all the above mentioned stations. We observed that the peak values of foF2 are comparatively much higher at high latitude (25%) than at mid latitude (7%) and low latitude (9%). It is also observed that during the month of November, high and mid latitude shows the maximum variation of foF2 while low latitude location Chongqing shows it maximum in the month of March. Which clearly indicates that the presence of winter anomaly at high and mid latitude whereas low latitude maximum in summer month .
***Keywords**: Ionosphere, F- region, foF2 (Critical frequency of F2 layer), Day to day variability, Seasonal variation.*

I. INTRODUCTION

The F2 layer is the upper part of the ionospheric F region. It is ~250 km above sea level and plays a vital role in shortwave communications because it has a higher electron density in the ionosphere. The variations in the critical frequency (foF2) of the F2 layer imply the events occurring there. The critical frequency foF2 is another very important parameter because it measures the number of electron density, which grandly important in radio wave communication [1].

This parameter is continuously measured from several locations spread over the globe and global ionosphere maps of foF2 are made available for application in the ground-based radio wave communication [2]-[3]. This parameter also varies spatially and temporally characteristic features of foF2 of the low latitude differ prominent from those of the mid-latitude [2]. It was observed that at mid-latitudes, foF2 shows nearly a linear relationship with sunspot number, though this relation is nonlinear for low latitudes [4].

The day-to-day variability in F-region parameters which is slightly unrelated to any particular magnetic or solar event is perhaps the biggest challenge for ionospheric forecasters and this problem is particularly severe in tropical latitudes.T. Atac [5] have investigated the dependence of the foF2 variability on solar activity over different latitudes, different local times, and different seasons to improve the model. Al-Ubaidi [6] studied the diurnal variation of the F2-layer critical frequency (foF2) with daily sunspot number (R) during low and high solar activity periods for the mid-latitude station. Prasad [7] analyzed the simultaneous Ionosonde data (the virtual height of the F-layer (h'f) and the critical frequency of the F2-layer (foF2) over the low and mid-latitude stations.

The physics of the mid-latitude F2 layer has been studied rather extremely. This made it possible to develop ionospheric models, in the scope of which analytical dependences of the F2 layer parameters on the aeronomy parameters were obtained, which are applicable in a wide range of helio-geophysical conditions [8] –[10]. R.W. Schunk [3] has concluded that the ionospheric variability at low, mid, and high-latitudes is caused by variations in the external forces that arise from the lower atmosphere, the thermosphere, and the magnetosphere. Zhang [11] observed that the ionospheric variability is practical interest since the variation of the ionosphere has a vital impact on the trans- ionospheric radio communication. A quantitative study on ionospheric variability is important for developing any suitable modal for ionospheric incidence.

In this present work, we comparatively studied the diurnal, monthly, and seasonal variation of critical frequency (foF2) for the year 2009 for low solar activity period. The diurnal, monthly, and seasonal characteristics of critical frequency (foF2) for three stations for low, mid, and high latitudes are studied with the help standard deviation method.

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II. DATA AND METHOD OF ANALYSIS

The analysis is based on hourly values foF2 Chongqing (29.43°N,106.92°E), Beijing(39.91°N,116.41°E) and Sodankyla (67.40°N, 26.59°E). Hourly value of foF2 data obtained through the UK Solar System Data Centre (UKKSD) website (https://www.ukssdc) for the year 2009. The average hourly foF2 values are determined to represent the day to day variability. Day to day variability is calculated separately for each day, month and seasons of the year. To represent variability the standard deviation σ of hourly foF2 values from the monthly median value (X) is determined from which the ratio of (σ/X) in percentage is derived for each hour of each month of observation. The variability parameter (σ/ X) is calculated for three stations separately for each month and each season of the year. To understand the seasonal variation of foF2, it is divided into three seasons: winter (January, February, November, December), equinox (March, April, September, October) and summer (May, June, July, August).

III.RESULTS

A. Diurnal Variation of fOF2 at Low, Mid and High Latitude During 2009:

Figure- 1 represents the diurnal variation of foF2 for three stations low mid and high latitude Chongqing (29.43°N, 106.92°E), Beijing (39.91°N, 116.41°E) and Sodankyla (67.40°N, 26.59°E) respectively for the year 2009. It has been observed that variation of foF2 at Chongquing the low latitude station is a maximum of about 20% during night-time at 2100hrs LT, 17% during day time at around 0200hrs-0400hrs and it has decreased during noontime at around 1300hrs LT.

For Beijing the mid-latitude station it has been observed that the variability of foF2 increases 12-14% during the day time at around 1000hrs-1200hrs LT and that decreases 7-10% evening to night time at around 1500hrs - 2300hrs LT.

For Sodankyla the high latitude station it has been observed that the variation of foF2 25% maximum at around 0300hrs -0400hrs and it has 7% minimum at around 1200hrs -1800hrs LT.

We also observed that at 1200hrs LT the Chongqing and Beijing increase 14% whereas Sodankyla decrease 7%. We found that the peak values of foF2 are comparatively much higher at high latitude (25%) than at mid-latitude (7%) and low latitude (9%).

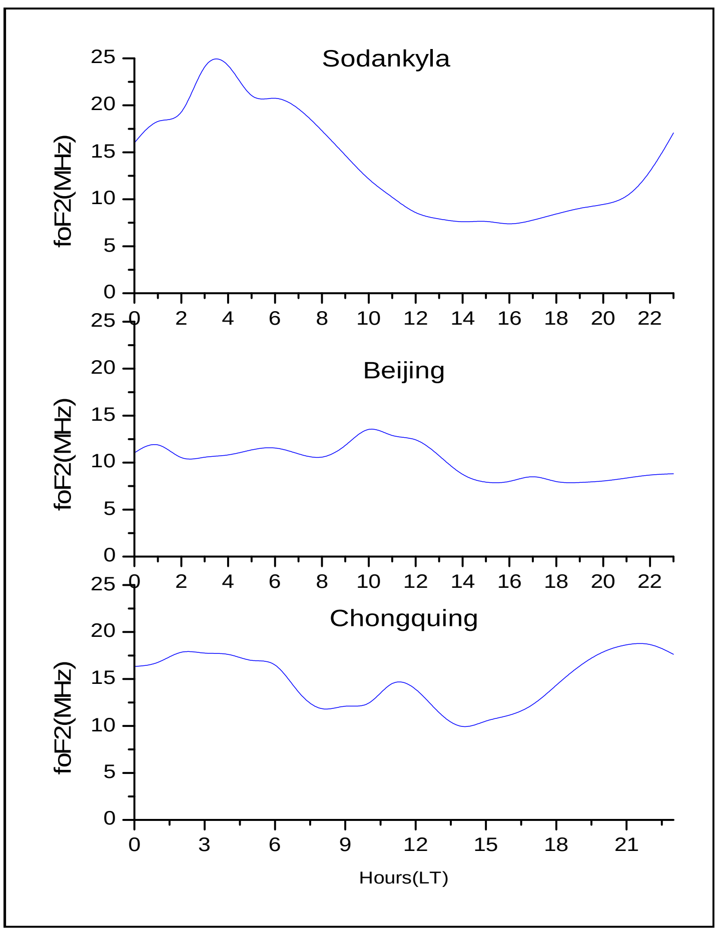


Figure-1 Diurnal Variation of foF2 hour (LT)

B. Monthly Variation of foF2 at Low, Mid and High Latitude During 2009:

Figure-2 represents the monthly variation of foF2 for low solar activity in the year 2009. It is observed that at low latitude location the variation of foF2 is a maximum of about 41% during March and it has been of about 14% decrease in the month of July. For the mid-latitude location, Beijing shows the maximum 28-31% variability of foF2 during the month of November and October and it has about 13% minimum in June month.

For high latitude location Sodankyla shows maximum 40% variability in foF2 during the November month and it has been 8% minimum in the month of June.

It has been seen that clearly in the winter month the variation of foF2 is maximum at high latitude location sodankyla mid-latitude location Beijing and at low latitude location Chongquing, the variation of foF2 is maximum during the summer month. High and mid-latitude location shows similar behaviour and the variation of foF2 at low, mid and high latitude decrease in June to July month.

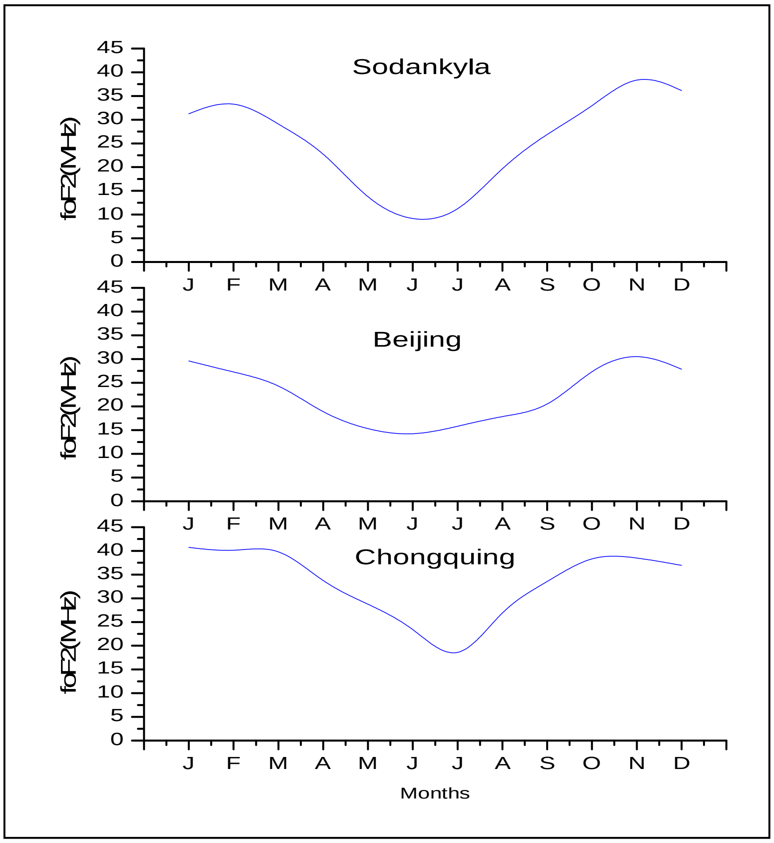


Figure-2 Monthly variation of foF2 hours (LT)

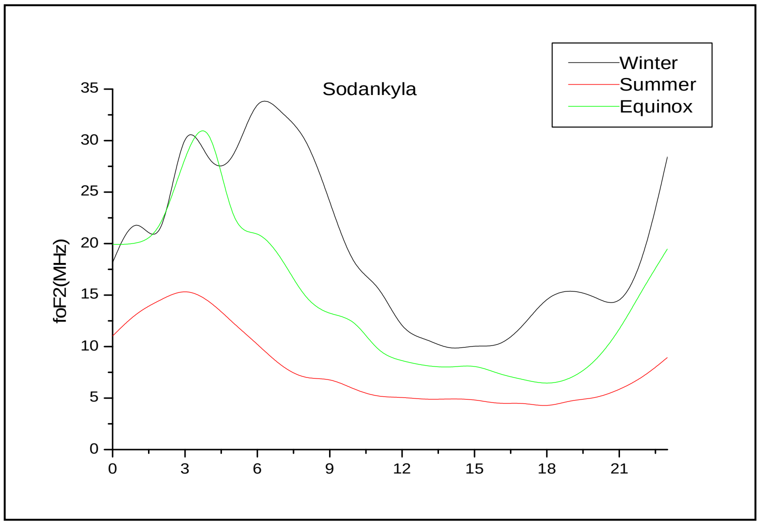
C. Seasonal Variation of fOF2 At Low, Mid and High Latitude During 2009:

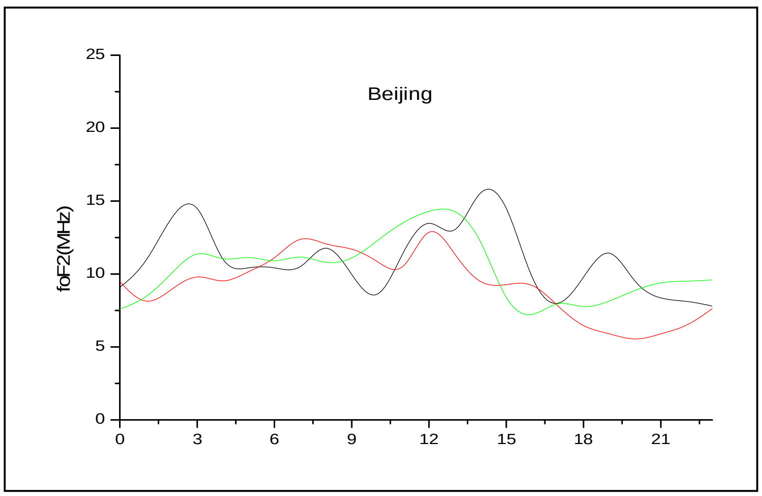
Figure- 3 shows the seasonal variation of foF2. It observed that the variation of foF2 at the low latitude location Chongqing shows 22% highest variability in the month of summer during the day time at 700hrs LT While lower for winter months. From the figure, it is clear that peaks of variability in foF2 are observed about 22% maximum in the month of winter during the night time at around 2100 hrs LT.

Over the mid-latitude location Beijing the variation of foF2 is maximum (15-17%) during the month of equinox and winter month during the day time at around while lower for summer months.

For the high latitude location sodankyla, it has been observed that the variation of foF2 is a maximum of about 32% in the winter month and about 30% maximum in equinox month while lower for the summer month. It has been clear that it decreases 4-10% at 1200 hrs LT during all seasons.

In the month of the equinox, all station shows the higher variability during the day time at 300hrs -1200hrs LT. From the figure, it is clear that a sharp decrease in foF2 is observed in pre-sunrise hours in all season at low, mid and high location station whereas variability is higher for winter month and equinox month .





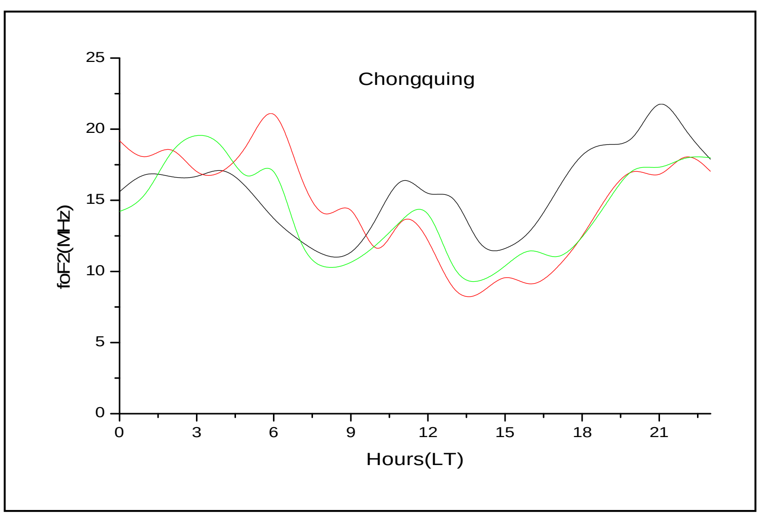


Figure-3 Seasonal variation of foF2 hours(LT)

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IV. DISCUSSION

The seasonal anomaly variation of the thermospheric neutral composition has been suggested to be the major source of the winter anomaly [12]- [21]. In our study, the seasonal variation at high and mid-latitude shows the winter anomaly whereas low latitude maximum in the summer month. Torr and Torr [22] concluded that the strong F2 layer winter anomaly exits at high northern mid-latitudes, primarily in the European /Northern American region between 45 N and 60 N geographic latitudes, and winter anomaly falls off in area and amplitude with decreasing solar activity. Akala [23] Using the foF2 data an equatorial and low latitude station for high, low and moderate solar activity have found that higher variability during the march equinox and concluded that the variability of foF2 increase with decreasing solar activity and it is higher during the night-time than day time.

Thomas [24]; Strobel and McElroy [25]; Torr [26]; Pavlov and Pavlova [27] have suggested that the Upwelling of the atmosphere in summer, dowelling in winter and summer to winter wind circulation induce different thermosphere neutral compositions between summer and winter. In summer increase in molecular gas in the F region, owing to upwelling, enhances the reaction of O+ with molecular gases, resulting in a plasma density decrease. The opposite process occurs in winter, resulting in a plasma density increase. The seasonal variation in the number density of the vibrationally excited molecular gases (N2 and O2) and electronically excited O+ also contributes to the generation of the winter anomaly.

Araujo-Pradere[28]; Risbeth and Mendillo [29] investigated the local time and seasonal variation in the ionospheric F layer variability are statically obtained by analyzing global ionosonde and they suggested that the grater variability at night, especially in winter, is partially due to the lower electron density, in a certain case due to the lack of the strong photochemical control that exists in the day time F2 – layer, but eventuate largely because the auroral sources of magnetic activity take place stronger and move to lower altitudes at night this effect is improved in the winter when nights are long.Apostolov [30] found the planetary wave-type oscillation contribution to be highest near the summer solstice and lowest near the winter solstice. Rishbeth and Mendillo [29] also found differences between the solstices: in general, variability at night is greater in winter than in summer, but by day the variability is greater in December than in June.

From the diurnal, it is observed that the value of foF2 is maximum at high latitude location Sodankyla compare to low latitude location Chongquing and mid-latitude location Beijing. Ritesh [31] have studied 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 the diurnal peak is almost the same while at Soyawa a time shift in the occurrence of the diurnal peaks is noticeable. The peak values of foF2 are comparatively much higher at Soyawa than at Bhopal.

R.S.Dabas [32] have suggested that for equatorial and low latitude location electrojet strength is a useful parameter for the prediction of day-to-day changes in the ionosphere as well as the latitudinal distribution of plasma. The predicted electron density for a particular day, few hours advanced, can be further used for various applications of radio communication. Chandra [33] have studied that the day-to-day variability in the critical frequency of F-layer (foF2) over Ahmadabad. They showed that the daytime deviations are of the same orders during different seasons the night-time, the deviation is slightest during equinoxes. The day time values of foF2 are mainly controlled by the equatorial electrodynamics and the following expansion of equatorial ionization anomaly the higher values during night-time has seen to be due to the variability in the thermospheric neutral temperature and winds.

V. CONCLUSION

The present study on the diurnal, monthly, seasonal and latitudinal variations of foF2 over three different locations Chongqing(29.43^{o}N, 106.92^{o}E), Beijing(39.91^{o}N, 116.41^{o}E) and Sodankyla (67.40^{o}N, 26.59^{o}E) during low solar activity indicates a significant latitudinal variation higher daytime values over all the latitudes. The outcome in the present study gives a complete picture of day to day variability of foF2 which is an important parameter of the F2 layer of the ionosphere. The main results are: The variation of foF2 is maximum in November at the high and mid-latitude and low latitude its maximum in the month of March. The variation of foF2 at mid and high latitude shows maximum during winter month, but at low latitude foF2 shows maximum variation during summer.

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