Variability of f_oF_2 at Karachi & Islamabad during Solar Maximum (1999–2000) & Solar Minimum (2006–07) and its Comparison with IRI

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Abstract

The variability of f_oF_2 is examined with the help of digisonde DGS-256 data of two Pakistani stations; Karachi (24.95^0N, 67.14^0E) and Islamabad (33.75^0N, 72.87^0E) during 1999–2000 (solar maximum) and 2006–07 (solar minimum). The %variability is 3% greater during solar maximum for both stations with higher values at nighttime. The comparison of f_oF_2 values with IRI-2001 shows the same seasonal trend with overestimation. Generally, CCIR model values are closer during solar maximum with less %deviation for Islamabad. For Karachi both URSI & CCIR show high relative deviation module mean and %deviation values during both solar periods.

1. Introduction

The behavior of F-region is fairly irregular and is usually classified into a number of anomalies such as equatorial anomaly, seasonal anomaly, evening anomaly, etc. *[1-3]*. During the period of maximum solar activity i.e. in 1999–2000 the Smoothed Sunspots Number (SSN) was 120.1 whereas during the period of minimum solar activity i.e. in 2006–07 it was 9.5. The objective of the present paper is to compare the f_oF_2 variability at Karachi and Islamabad and evaluate the IRI values. Many research papers have been produced on the comparisons between observed ionospheric data and the International Reference Ionosphere (IRI) model predictions [4-9]. IRI is an empirical ionospheric model based on experimental observations of the ionospheric plasma. Its main purpose is to provide monthly averages of the electron density, ion composition and ion & electron temperatures [10, 11]. It uses two different computer programs as subroutines: one being the CCIR model and other the URSI model [12-14]. During the study the nomenclature CCIR and URSI have been taken into account.

2. Data Analysis Technique

The ionospheric data of Karachi (URSI ID KA225) and Islamabad (URSI ID IS233) employed in the present study have been acquired by means of Digisonde DGS-256 being operated at the stations (the URSI station IDs will be used in the paper hereafter). The critical frequency of F_2 layer, f_oF_2, is aquired at hourly intervals from the ionograms and monthly hourly medians of f_oF_2 are determined both for KA225 and IS233 stations. The monthly hourly medians of f_oF_2 both at KA225 and IS233 for 1999–2000 and 2006–07 have been plotted for comparison. The seasons have been classified as D, E & J-months i. e, for winter, equinoxes and summer months respectively. The annual cycle has been chosen from Nov to Oct. In order to quantify the variability and deviation with respect to IRI, the monthly median, upper and lower quartiles of f_oF_2 have been taken. We define percentage variability as

$$\%V = \frac{UQ - LQ}{M} \times 100 \qquad (1)$$

where %V is the percentage variability, UQ and LQ represent upper and lower quartiles respectively and M is the monthly median of f_oF_2.

$$rdmm = \sum \frac{1}{N}\left[\frac{OV - MV}{MV} \times 100\right] \qquad (2)$$

$$\%D = \frac{OV - MV}{OV} \times 100 \quad (3)$$

where rdmm is root mean module mean, N is total number of values, %D is the percentage deviation, OV and MV represent observed and model values respectively.

3. Results and Discussions

It has been observed that on average the %V is higher during nighttime for both stations and solar activity periods. At KA225 in D & J-months of solar minimum and J-months of solar maximum, the %V is high during daytime while for IS233 nighttime %V remains high for all seasons of both solar activity periods. At low latitude station (KA225), minimum %V observed during nighttime is 4.88% in D-months of solar minimum and 4.78% during daytime in E-months of solar maximum on the other hand highest values of %V is 21.13% during nighttime observed in E-months and 11.65% during daytime in D-months of solar maximum. At mid latitude station (IS233), lowest value of 5.32% has been observed in J-months while highest value of 30.02% observed in E-months during nighttime in solar maximum while daytime lowest value is 4.50% again observed in J-months and highest value of 13.05% is observed in D-months of solar maximum. The highest difference of %V between day and nighttime is observed in E-months of solar maximum for both stations i.e. 16.35% for KA225 and 19.08% for IS233 while the lowest difference of %V of -1.75% is observed in J-months of solar minimum at KA225 station and 0.82% observed in J-months of solar maximum at IS233 station.

The seasonal variations in the ionosphere of earth may occur due to electron density variation which might arise from the changes of the temperature, composition or both. It has been observed that %V during solar maximum for both the stations during D & E-months is greater than the corresponding solar minimum values, whereas J-months values of %V exhibit negative trend. The highest %V on average is observed in E-months at both stations. The difference of %V of D-months of both solar activity periods for both stations is approximately same i.e. 7.27% for KA225 and 7.11% for IS233 while the difference in %V of solar maximum and solar minimum for E- months is very large at IS233 as compare to KA225 station i.e. 8.97% for IS233 and 3.81% for KA225. We have found that %V is high during nighttime in E-months while for D-months %V is high during post sunset and remains low in J-months for the whole 24 hours during solar maximum period for IS233. The similar situation has been observed for KA225 with a peak of %V observed at noon in D-months during solar maximum. At IS233, in solar minimum, %V is high during nighttime for J-months whereas for E-months its peak appears at 0700LT (LT = UT + 0500) with an increasing trend from 1400LT to 2300LT. In D-months %V is slightly high just near the pre & post sunrise periods while it remains low for the remaining hours. At KA225 during solar minimum a prominent peak of %V is observed at 2100 LT in E-months while slightly high values are observed during post sunrise period in E and D-months. In J-months the maximum %V appears just after sunrise another considerable maxima exists at 1500LT.

At low latitude (KA225), %V during solar maximum is 12% while during solar minimum is 9%. At mid latitude (IS233) %V during solar maximum is 13.35% while during solar minimum it is 10.3% thus during solar maximum. The difference of %V shows the same trend for both the stations. On average %V in ionosphere at IS233 is 1.38% higher than KA225 during both the solar activity periods. The model values on average overestimates f_oF_2 values for all seasons at both stations and solar activity periods. In order to observe the harmony between observed and model values of f_oF2, we used relative deviation module mean (rdmm), *Bertoni, 2004 & 2006*. It is found that the model values show reasonable to poor agreement (<0.06 according to Bertoni, 2004 & 2006) during solar maximum but very poor agreement (≥0.06 according to Bertoni, 2004 & 2006) during solar minimum for KA225 (for both URSI & CCIR) whereas for IS233 CCIR shows good agreement and URSI exhibits reasonable to poor agreement during both the solar activity periods. Only D-months of solar minimum have values of rdmm lower than the D-months of solar maximum at both stations. The lowest value of rdmm of 0.009 (CCIR) & 0.315 (URSI) observed in E-months of solar maximum and the highest value of 0.36 (CCIR) & 0.356 (URSI) observed also in E-months of solar minimum at KA225 whereas at IS233, URSI shows poor agreement (0.23) in E-months of solar minimum while CCIR shows the good agreement (0.01) in the same period, the same trend has been observed in J-months of solar minimum (0.22 URSI & 0.01 CCIR).

At KA225 the daytime %D is high as compare to the nighttime in all seasons during both periods except E-months of solar maximum with the least %D during E-months of solar maximum. In case of IS233 the daytime %D is less than nighttime during solar maximum while during solar minimum no particular trend has been observed. At KA225 observed values have been underestimated by CCIR between 0000 – 0600LT and by URSI between 0300 to 0600LT while overestimated for almost the whole 24 hours in D-months of 2007 while in D-months of solar maximum CCIR underestimated observed values between 0300 – 0500LT and URSI overestimated the values for

whole 24 hours. During E-months of solar minimum model values overestimated the observe values for whole 24 hours while at 0400LT URSI shows the value very close to observed ones. During solar maximum model values have underestimated the observed values from 0300 – 0600LT, 0700 – 0800LT and 1500 – 1900LT whereas overestimation has been observed for the remaining hours. During J-months of solar minimum CCIR has overestimated the observed values for the whole 24 hours while URSI has underestimated from 2000LT – 2100LT while in solar maximum the model has underestimated the observed values from 0300 – 0500LT and overestimated the for the remaining hours. At IS233 during D-months of solar minimum, CCIR has overestimated the observed values for the whole 24 hours while URSI has underestimated the values at 0000LT, from 0300 – 0500LT and 2000 – 2300LT. During D-months of solar maximum the model has underestimated the observed values only at 0400LT while overestimated for the whole 24 hours. During E-months of solar minimum URSI has overestimated the observed values for the whole 24 hours whereas CCIR has underestimated from 0000 – 0400LT and 1100 – 1700LT. During E-months of solar maximum the model has underestimated the observed values from 18000 – 1900LT. In J-months of solar minimum URSI has overestimated the observe values for the whole 24 hours whereas CCIR underestimated from 0000 – 0200LT and 1500 – 2000LT whereas in case of J-months of solar maximum the model has underestimated the observed values at 1800LT. Generally, IRI-2001 underestimates the values of f_oF_2 as compared to the measurements around pre-sunrise and sunrise period.

The CCIR and URSI model curves exhibit a reasonable agreement between them except for the solar minimum at IS233 it means that the %D of CCIR is less than the %D of URSI for IS233 during solar minimum as compared to KA225. The f_oF_2 values are higher for KA225 (near the crest of equatorial anomaly region) than for IS233 (near the mid latitude region) for all seasons of both the solar activity periods. The CCIR and URSI both predict this behavior except during solar minimum where CCIR predict that the values of f_oF_2 during D-months are higher than E-months while generally higher values are observed in E-months at both stations during both solar activity periods. The IRI-2001 on the whole has overestimated the values of f_oF_2 for both stations.

4. Conclusion

- At KA225, the %V is higher in D and E-months during solar maximum but in J-months it is higher during solar minimum whereas similar trends appear at IS233 with a greater diversity during J-months.
- At KA225 the daytime %V is lower except in D & J-months of solar minimum, whereas the same trends has been observed at IS233 for all the seasons of both solar activity periods.
- The lowest and highest %D (as well as of rdmm) values at KA225 have been observed during E-months, whereas at IS233 these extremities exist during D-months of both solar activity periods. In general no regular trend in rdmm values has been observed at both stations during both solar activity periods.
- In general CCIR shows good to reasonable agreement with f_oF_2 whereas URSI shows reasonable to poor agreement except in D-months of solar minimum for both stations. It is seen that CCIR and URSI curves are close to each other with a prominent diversity during solar minimum at IS233.
- The model has overestimated the observed values in general while underestimation has been observed at pre sunrise (showing the sunrise anomaly) and/or sunset.

5. References

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Table 1: Annual and Seasonal %V of Karachi and Islamabad stations

Seasons	KA225		IS233		(1999-2000) – (2006-07)	
	2006-07	1999-2000	2006-07	1999-2000	KA225	IS233
D Months	7.61%	14.88%	7.54%	14.65%	7.27%	7.11%
E Months	9.15%	12.96%	11.51%	20.48%	3.81%	8.97%
J Months	10.14%	8.01%	11.94%	4.91%	-2.13%	-7.03%
Mean	**8.97%**	**11.95%**	**10.33%**	**13.35%**	**2.98%**	**3.02%**

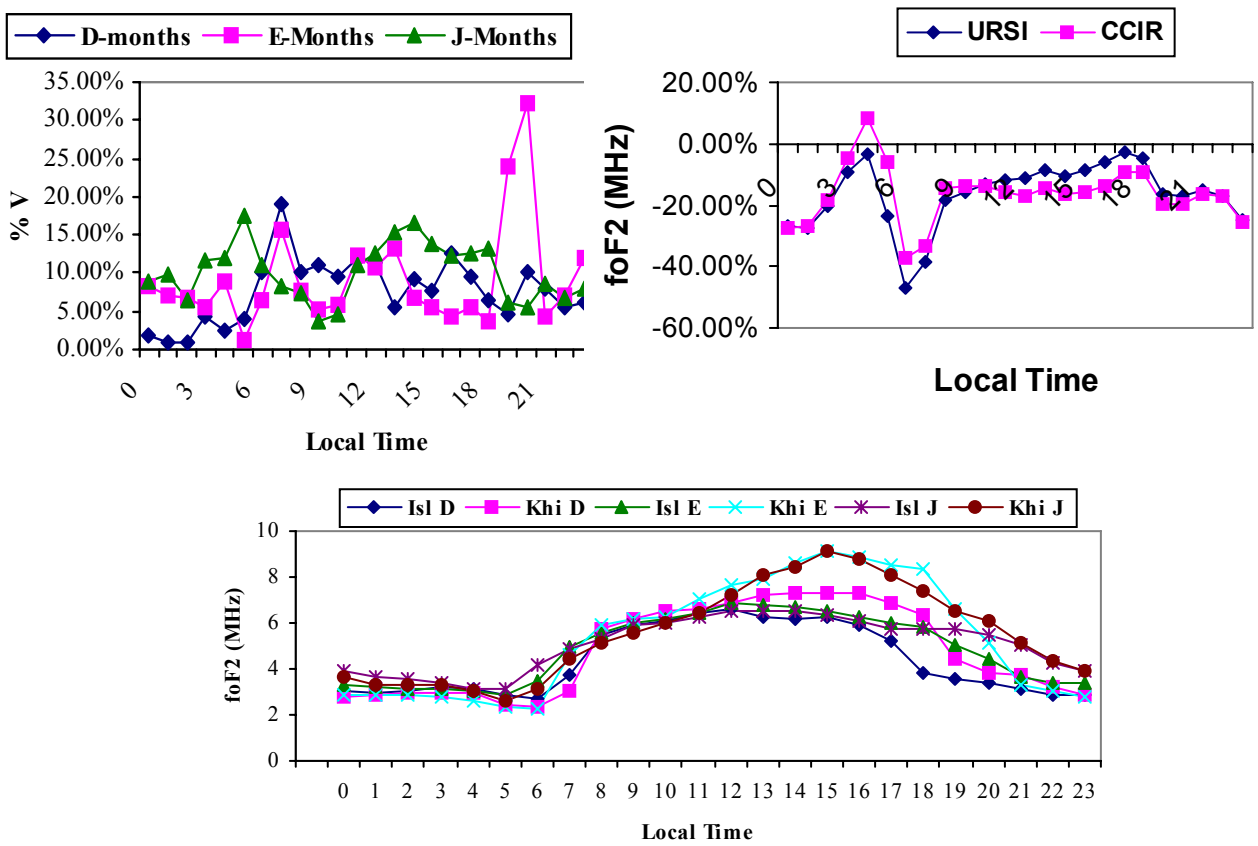

Figure 1:
Left top: %V of foF2 at Karachi (2006-07)
Right top: %D in foF2 at Islamabad (1999-2000)
Left bottom: Observed foF2 at both stations (2006-07)