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Research Article

Comparative Study of F_2–Layer Critical Frequency: Solar Cycle 22

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Abstract: This study pertained to the relationship between critical frequency of F_2 layer (foF_2) and solar activity indices at three low latitude ionospheric stations during solar cycle 22 (1985-1996). The selected ionospheric stations lie in the latitudinal range of Pakistan: therefore, this investigation may also be useful to understand the impact of solar activity relevant to our region. The monthly median values of foF_2 for Okinawa, (26.3^{O}N, 127.8^O E), Guangzhou, (23.10^O N, 113.4^O E) and Chongqing (29.50^O N, 106.40^O E) have been plotted against sunspot number (SNN) and solar radio flux (F10.7cm). The main purpose of this analysis was to compare the foF_2 values at low latitude ionospheric stations. A comparison of different phases of solar activity with foF_2 at the subject stations revealed almost similar patterns. The correlation coefficients between SSN and critical frequency of F_2 layer (foF_2) on hourly basis for all months were compared. These trends helped in understanding foF_2 occupancy in the region of Pakistan during solar cycle 22. A strong dependence was observed between solar activity and foF_2 during this period. Ikubanni et al. [14] have already investigated the trends of F_2 layer critical frequency at a low latitude station, during solar cycle 22. This comparative study of foF_2 was regarding Chongqing, Okinawa, and Guangzhou that have not been explored as yet. These studies emphasized the behavior of foF_2 for all these stations and identified the latitude dependency of foF_2 on solar activity. A better agreement was observed during the year of moderate solar activity (MSA). An International Reference Ionosphere (IRI) model has been used to reveal foF_2 missing values.

Keywords: Critical frequency, F_2 layer, sunspot number (SSN), solar cycle-22, correlation coefficients, solar radio flux (F10.7)

1. INTRODUCTION

The Earth's ionosphere is formed mainly through the photo ionization by solar Extreme Ultra Violet (EUV) and X-rays. Some solar activity indices have served as a very good proxy. Examples of these indices are the sunspot number (SSN) and the solar radio flux at 10.7cm (F10.7) wavelength. Solar activity varies over different time scales and the 11-year solar cycle (SC) is its most prominent variation. SC variation of solar activity appears repeatedly, but varies from cycle to cycle [1-4]. Various researchers have observed the ionosphere to behave differently during different solar epochs have attributed the variation of the ionosphere in respect with the solar, geomagnetic, and meteorological influence [5-6]. Sunspot Numbers (SSN) are very low at solar minimum and highest at solar maximum. Significant variations of solar Extreme Ultra Violet (EUV) irradiance have been described using its long term continuous measurements. Different models have been developed from these measurements [7]. Most significantly, Bilitza [8] had advocated the continual measurement of the EUV for use in the International References Ionosphere (IRI) model. In most ionospheric models, such as solar activity indices, i.e. SSN and F10.7 were used rather than the EUV due to their long-term availability [8-9]. However, variations of these indices for different time and space have not been investigated in detail.

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In the present study, the variation of these indices and their relation to the critical frequency of the F_2 layer (foF_2) during seasons of the year as well as phases of the solar cycle have been investigated. The different phases are: high solar activity (HSA) phase, low solar activity phase (LSA), moderate solar activity (MSA) phase. This investigation presents the trends of foF_2 over all stations during solar cycle 22 and investigates the differences in diurnal, seasonal and yearly trends.

2. MATERIALS AND METHODS

The relationship between the critical frequency of the F_2 layer (foF_2) and some solar activity indices was studied over a span 11-year solar cycle (1985-1996) with maximum activity in the middle of the cycle. The solar activity indices include: monthly-hourly averages of the F_2 layer critical frequency (foF_2 in MHz) deduced from ionograms; and two solar activity proxies, F10.7 index and SSN, obtained from SPIDR (Space Physics Interactive Data Resource) a standard data source for solar-terrestrial physics, functioning within the framework of the ICSU World Data Centers. The ionograms were recorded by the Ionospheric Prediction Services (IPS) WGS-84 located in Japan, Okinawa (latitude 26.3° N, longitude 127.8° E), DPS-4 in China, Guangzhou (23.1° N, 113.4° E) and Chongqing (29.5° N, 106.4° E). The F10.7 index refers to the flux of radio emission from the Sun at a wavelength of 10.7 cm (2.8 GHz frequency). It trails the changing pattern of the solar UV radiation over the solar cycle (SC) and measured in solar flux unit (sfu) (1 sfu = 10-22Wm^{-2} Hz^{-1}). Using the data, the following behavior was investigated: (i) trend of foF_2 with F10.7 over a solar cycle 22. (ii) behavior of foF_2 in response to the solar activity indices during different solar epochs of all stations and then compared their behaviors with each other. Three typical years of different solar activity level were chosen for the study: (i) a year of high solar activity – 1989; (ii) a year of moderate solar activity – 1992; and (iii) a year of low solar activity – 1985. It must be noted that the year of moderate solar activity was in the decreasing phase of solar cycle 22.

3. RESULTS

3.1 Ionospheric Variations

3.1.1 Chongqing Station

The highest latitude station among all, observed that the March equinox and the December solstice, followed almost similar trends as SSN, i.e., increase and decrease with SSN during the same years, whereas in the September equinox, during 1989 to 1991, a perfect equilibrium was observed. The June solstice exhibited totally different behavior as compare to other season (as shown in Fig.1). In 1989, the March equinox exhibited the highest peak. In 1995, the June solstice showed the lowest peak. Two prominent peaks were observed at March equinox and the December solstice in the year 1989 and 1991 to 1992. It has been observed that foF_2 was relatively higher at the equinoxes than solstice from year 1988 to 1992. From year 1985 to year 1987 (years of low solar activity) foF_2 show zero variation (i.e., perfect equilibrium) in all seasons except in December, as it was following the same trend as SSN during the years of low solar activity i.e. from 1985 to 1987.

The sinusoidal trend in SSN was replicated in foF_2, i.e., minimum and maximum of foF_2 and SSN lie in the same year. In solar cycle 22, the highest value of the SSN was around 200 and then slightly change was observed in its value around 180 respectively in year 1989 and year 1991.While its minimum value is around 20 in year 1986 was noted. Observed foF_2 in year 1989 was 12.85 MHz in March, 11.3 MHz in September, 10.7 MHz in December and 9.6 MHz in June which were decreased to 5.1 MHz in March, 5.75 MHz in September, 3.1 MHz in December, and 5.55 MHz in June in the year 1996.

It was observed that for each year, the value of foF_2 for equinox months (March, April, September, October) was highest among summer (May, June, July, August) and winter (November, December, January, February) months.

Winter months have the highest value of foF_2 than summer around the solar maximum year and having the lowest values than summer around the

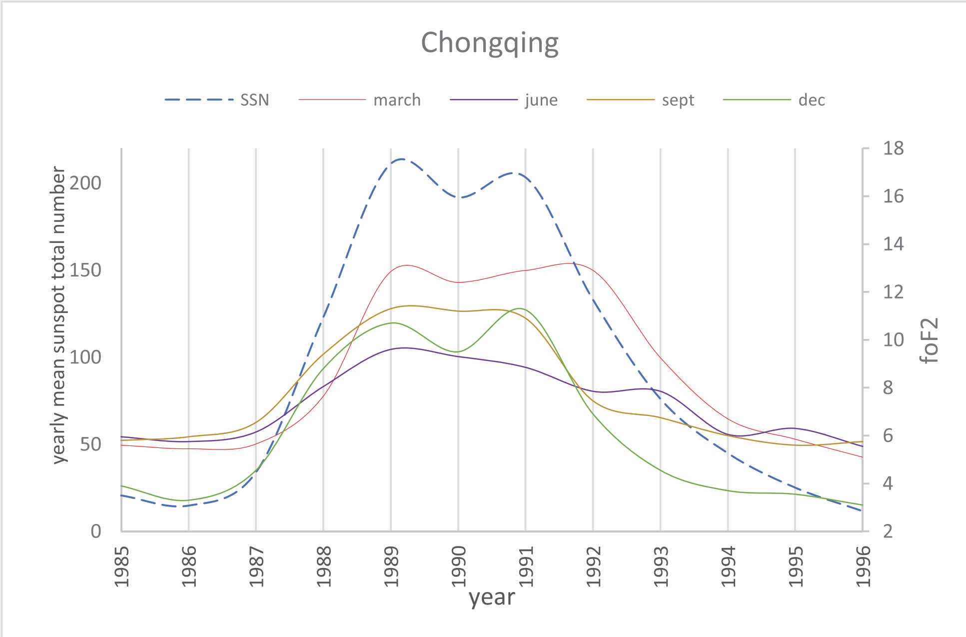

Fig. 1. Behavior of F_2 layer critical frequency and yearly mean sunspot number at equinox solstice of Chongqing station.

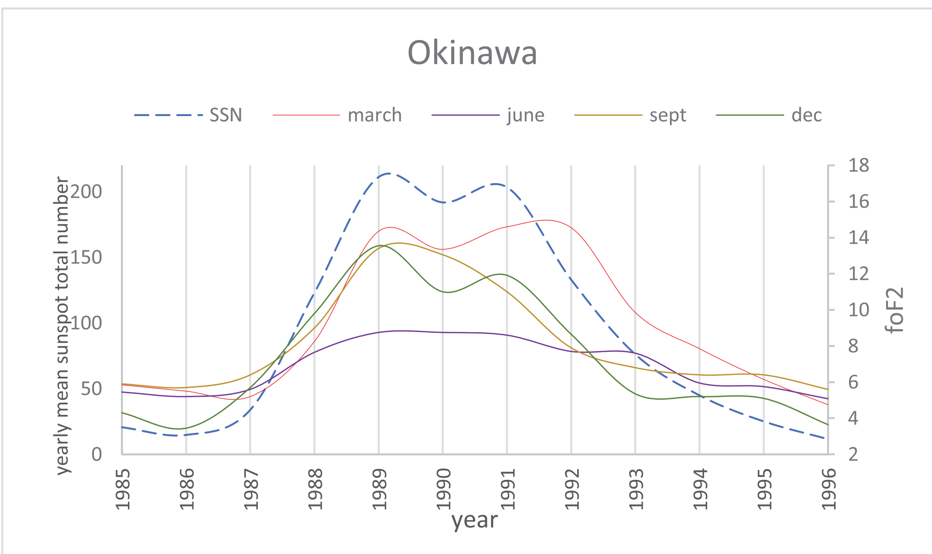

Fig. 2. Behavior of F2 layer critical frequency and yearly mean sunspot number at equinox solstice of Okinawa station.

solar minimum year. The overall mean value of foF_2 for summer was 7.27 MHz, which was greater than winter mean value 6.15 MHz. Equinox mean value was around 8.5 MHz for March and 7.7 MHz for September which were higher than both summer and winter months.

3.1.2 Okinawa Station

Seasonal trend of Okinawa is depicted in Fig. 2. It was observed that for each year, the value of foF_2 for equinox months (March, April, Sep, Oct) was highest among summer (May, June, July, Aug) and winter (Nov, Dec, Jan, Feb) months. Winter months have the highest value of foF_2 than summer around the solar maximum year and having the lowest values than summer around the solar minimum year. The overall mean value of foF_2 for summer was 6.84 MHz, which was smaller than the winter mean value 7.30 MHz. Equinox mean value was around 9.18 MHz for March and 8.12 MHz for September which were higher than both summer

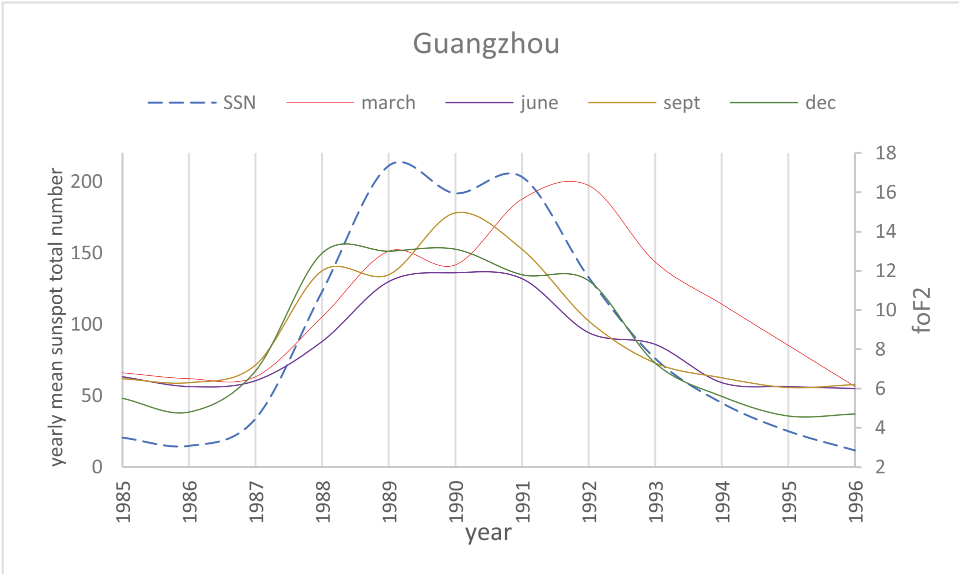

Fig. 3. Behavior of F2 layer critical frequency and yearly mean sunspot number at equinox solstice of Guangzhou station.

and winter months.

Observed foF_2 in year 1989 was 14.35 MHz in March, 13.4 MHz in September, 13.5 MHz in December and 8.75 MHz in June which were decreased to 4.75 MHz in March, 5.6 MHz in September, 3.65 MHz in December, and 5.08 MHz in June in the year 1996.

Observed foF_2 values following relatively same trends as yearly mean sunspot total number for March equinox and December solstice just like in Chongqing but with more variation, whereas, June solstice shows the minimum variation among all months. In September, slightly variation was observed, i.e. 7.9 MHz in the year 1992 which was decreased to 5.6 MHz in 1996. The two peaks were observed in March and December.

3.1.3 Guangzhou Station

Similarly seasonal trend of Guangzhou were noticed (as revealed in Fig. 3). It has the lowest latitude among all station under investigated. It was observed that for the each year, the value of foF_2 for equinox months (March, April, September, October) was highest among summer (May, June, July, August) and winter (November, December, January, February) months. Winter months have the highest value of foF_2 than summer around the solar maximum year and the lowest values than summer around the solar minimum year. The overall mean value of foF_2 for summer was 8.16 MHz, which was smaller than winter mean value 8.47 MHz. Equinox mean value was around 10.32 MHz for March and 8.95 MHz for September which were higher than both summer and winter months.

Observed foF_2 in year 1989 was 13 MHz in March, 11.8 MHz in September, 13 MHz in December and 11.45 MHz in June which were decreased to 6.1 MHz in March, 6.2 MHz in September, 4.7 MHz in December, and 6 MHz in June in the year 1996.

3.2 Comparison of Stations

There found a pronounced dependency on latitude as move from high latitude to low latitude station (i.e., Chongqing to Okinawa to Guangzhou). With reference from Fig. 1 to 3, it depicted that, maximum values of foF_2 increase as move from high latitude to low latitude as given, i.e., Chongqing (12.9 MHz), Okinawa (14.5 MHz) and Guangzhou (16 MHz). The difference in maximum value from high to low latitude was 81.6 MHz for Okinawa and 82.5 MHz for Guangzhou. Calculated foF_2 mean value also increases from high to low latitude (revealed in Table 1). It was depicted that, June solstice show different behavior as compared to other seasons, in

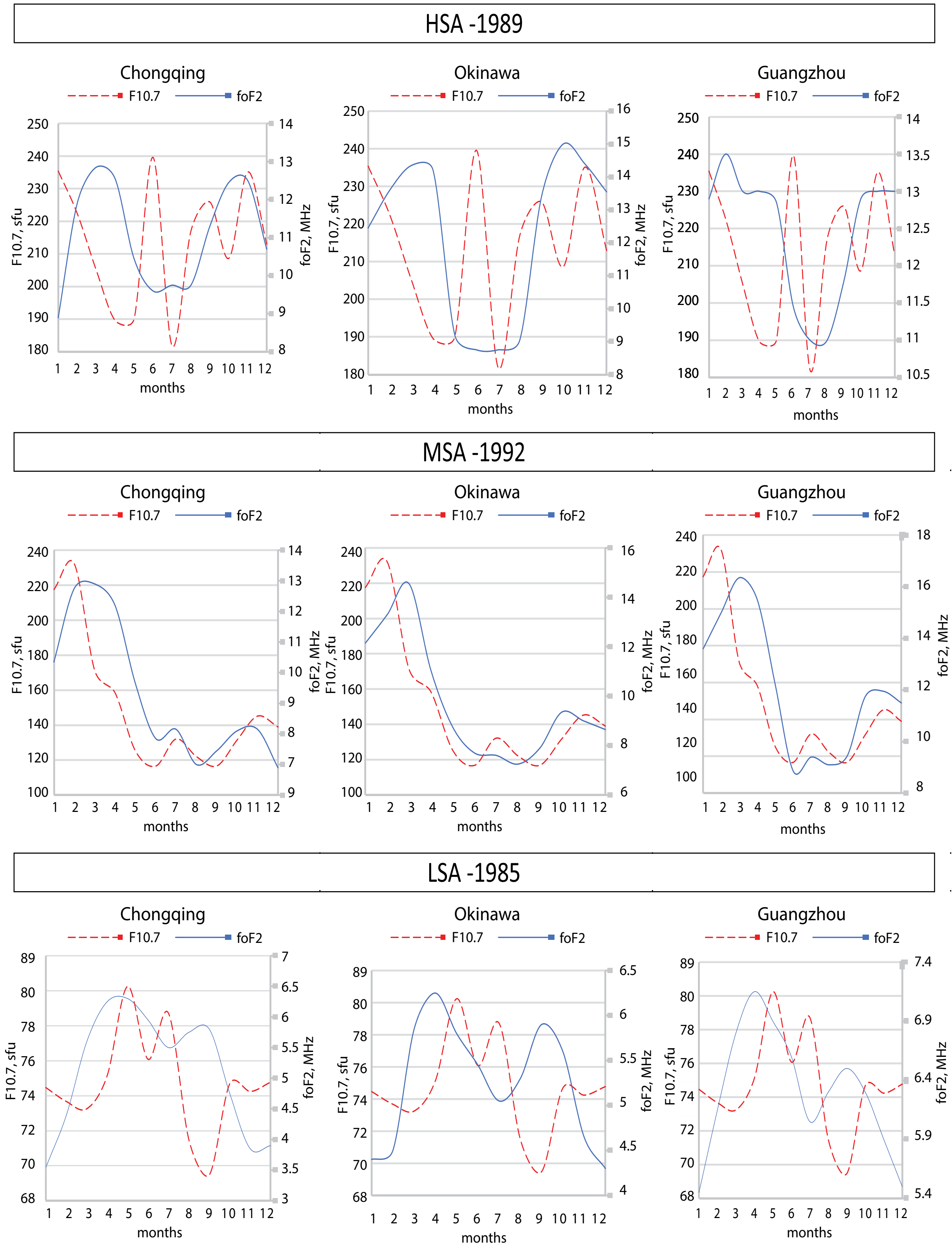

Fig. 4. Monthly variation of the F2 layer critical frequency (foF2) and solar radio flux F10.7, during different solar epochs.

Table 1. Mean value of foF_2 from high to low latitude.

Season	Seasons	Okinawa	Guangzhou
March equinox	8.52	9.18	8.16
June solstice	7.27	6.84	8.16
September equinox	7.72	8.12	8.9
December solstice	6.15	7.3	8.4

Chongqing (high latitude station) has high value 7.27 MHz then in Okinawa 6.84 MHz (low latitude station).

3.3 Monthly Variation of foF_2 During Different Solar Phases

3.3.1 High Solar Activity (HSA), Year 1989

For the year of HSA, both F10.7 and foF_2 followed the same trend (as reveled in Fig. 4). There was a distinct seasonal variation as shown in the 1st row. During the March equinox, F10.7 decrease rapidly while foF_2 increase but rather gradually. From the start of the June solstice, F10.7 increase rapidly to a peak around mid-season and then decrease rapidly to a minimum towards the end of the season while foF_2 decrease rapidly from the start of the season to a minimum, as the solar index, towards the end. In the September equinox, the solar activity index (F10.7) increase from the minimum in June solstice until mid-season; it then decrease towards the end of the season (say October). However, foF_2 increase from the same point as the solar activity until around October before decreasing through the December solstice. For F10.7, there was a crest around November. During the year, two crests and one trough of foF_2 values were observed. The first crest was formed towards the end of the March equinox and the second towards the end of the September equinox, while the trough was formed towards the end of the June solstice.

3.3.2 Moderate Solar Activity (MSA), Year 1992

The trend of the solar activity index and the foF_2 through the year was observed to be clearly different in the year of MSA 1992 [2nd row] from observations in the year of HSA 1989 [1st row] (as revealed in Fig. 4). During the March equinox, decrease in solar activity (F10.7) index was observed from around February to a minimum around mid-June solstice season. Solar activity (F10.7) index then increased slightly before decreasing to another minimum in the early part of the September equinox. From there, it increase slightly till the season end before decreasing through December solstice. There seems to be a better agreement between solar activity indices and foF_2 compared to what was observed in a year of HSA.

3.3.3 Low Solar Activity (LSA), Year 1985

Trend pattern of F10.7 was quite different from those observed in a year of HSA and MSA, especially towards the end of the March equinox through the next two seasons (June solstice and September equinox) (as revealed in Fig. 4). Solar activity was relatively stable from the first month until towards the end of March equinox and then increase into June solstice.

Two peaks were observed during the June solstice. The first peak was formed in the early season and the second, which was lower than the first, was formed towards the end of the season. After the second peak, there was a rapid decrease in solar activity level, which reached a minimum around mid-September equinox. It then increase again towards the end of the season and became relatively stable since then and through the December solstice.

As the solar activity continued, the indices F10.7 decrease during the September equinox to a minimum in mid-season and then increase towards the end of the season (say October). However, foF_2 increase from the end of the June solstice till around October before decreasing through the December solstice. It is worthwhile to note that

Table 2. The hourly correlation coefficient for twelve months of Chongqing station. (LT is the local time in hours).

LT(Hr)	J	F	M	A	M	J	J	A	S	O	N	D
0	0.97	0.97	0.88	0.88	0.93	0.87	0.93	0.94	0.99	0.93	0.97	0.90
1	0.97	0.97	0.90	0.88	0.83	0.75	0.93	0.96	0.98	0.97	0.95	0.89
2	0.98	0.98	0.89	0.86	0.80	0.78	0.94	0.98	0.99	0.98	0.93	0.89
3	0.99	0.97	0.95	0.90	0.89	0.82	0.95	0.95	0.98	0.97	0.91	0.88
4	0.96	0.98	0.98	0.97	0.94	0.89	0.93	0.96	0.98	0.96	0.88	0.93
5	0.97	0.99	0.98	0.99	0.87	0.93	0.94	0.98	0.97	0.95	0.90	0.81
6	0.95	0.96	0.96	0.98	0.96	0.93	0.95	0.99	0.88	0.97	0.92	0.84
7	0.95	0.97	0.97	0.92	0.98	0.87	0.96	0.97	0.85	0.99	0.97	0.90
8	0.98	0.95	0.98	0.98	0.96	0.84	0.96	0.99	0.97	0.98	0.92	0.96
9	0.99	0.99	0.97	0.97	0.97	0.90	0.95	0.99	0.95	0.98	0.98	0.98
10	0.99	0.99	0.96	0.97	0.94	0.93	0.94	0.99	0.96	0.98	0.98	0.98
11	0.99	0.98	0.97	0.97	0.95	0.94	0.96	0.97	0.96	0.98	0.96	0.97
12	0.97	0.97	0.95	0.94	0.92	0.91	0.96	0.98	0.97	0.97	0.93	0.98
13	0.98	0.95	0.91	0.91	0.91	0.90	0.96	0.97	0.96	0.95	0.92	0.98
14	0.98	0.93	0.90	0.93	0.87	0.88	0.97	0.96	0.95	0.90	0.88	0.96
15	0.98	0.91	0.92	0.92	0.87	0.86	0.97	0.96	0.92	0.89	0.85	0.95
16	0.98	0.94	0.93	0.93	0.88	0.86	0.97	0.96	0.91	0.91	0.90	0.96
17	0.98	0.95	0.95	0.94	0.87	0.85	0.95	0.96	0.93	0.91	0.93	0.98
18	0.98	0.97	0.97	0.91	0.87	0.88	0.96	0.96	0.95	0.97	0.95	0.99
19	0.99	0.98	0.98	0.93	0.85	0.88	0.95	0.95	0.98	0.98	0.96	0.96
20	0.98	0.98	0.98	0.97	0.87	0.72	0.93	0.96	0.96	0.98	0.97	0.96
21	0.96	0.96	0.98	0.97	0.93	0.91	0.93	0.97	0.97	0.97	0.95	0.92
22	0.97	0.95	0.88	0.84	0.93	0.86	0.84	0.96	0.95	0.95	0.98	0.98
23	0.98	0.92	0.87	0.88	0.92	0.71	0.84	0.98	0.96	0.93	0.99	0.99

Table 3. The hourly correlation coefficient for twelve months of Okinawa station. (LT is the local time in hours).

LT(Hr)	J	F	M	A	M	J	J	A	S	O	N	D
0	0.94	0.98	0.96	0.97	0.87	0.86	0.94	0.94	0.96	0.93	0.77	0.83
1	0.90	0.95	0.91	0.96	0.88	0.89	0.94	0.97	0.97	0.95	0.80	0.80
2	0.91	0.96	0.94	0.96	0.87	0.90	0.94	0.96	0.99	0.95	0.78	0.81
3	0.98	0.95	0.98	0.94	0.91	0.88	0.97	0.98	0.97	0.97	0.95	0.92
4	0.75	0.93	0.91	0.94	0.90	0.90	0.95	0.94	0.98	0.89	0.65	0.80
5	0.96	0.70	0.89	0.93	0.92	0.91	0.94	0.92	0.95	0.86	0.52	0.66
6	0.72	0.87	0.97	0.90	0.95	0.91	0.93	0.94	0.82	0.79	0.53	0.72
7	0.80	0.95	0.97	0.96	0.91	0.92	0.94	0.97	0.95	0.98	0.97	0.76
8	0.99	0.99	0.98	0.95	0.90	0.90	0.95	0.93	0.97	0.99	0.82	0.66
9	0.99	0.99	0.98	0.96	0.88	0.88	0.95	0.90	0.95	0.98	0.98	0.97
10	0.99	0.95	0.98	0.96	0.92	0.88	0.93	0.93	0.98	0.99	0.83	0.69
11	0.96	0.90	0.97	0.95	0.84	0.93	0.97	0.95	0.97	0.97	0.94	0.83
12	0.94	0.91	0.97	0.96	0.86	0.93	0.95	0.94	0.98	0.98	0.98	0.91
13	0.97	0.96	0.97	0.91	0.95	0.94	0.99	0.93	0.98	0.97	0.97	0.97
14	0.96	0.95	0.97	0.90	0.90	0.97	0.91	0.93	0.97	0.96	0.92	0.93
15	0.98	0.95	0.96	0.93	0.92	0.86	0.94	0.91	0.96	0.94	0.92	0.94
16	0.99	0.93	0.95	0.91	0.92	0.90	0.95	0.91	0.95	0.96	0.92	0.94
17	0.98	0.95	0.98	0.89	0.93	0.86	0.94	0.92	0.96	0.97	0.95	0.97
18	0.97	0.95	0.96	0.92	0.95	0.88	0.95	0.95	0.96	0.98	0.94	0.97
19	0.99	0.98	0.98	0.97	0.90	0.90	0.94	0.92	0.94	0.99	0.94	0.95
20	0.99	0.96	0.97	0.95	0.85	0.81	0.92	0.90	0.94	0.98	0.96	0.94
21	0.99	0.99	0.99	0.95	0.87	0.84	0.93	0.92	0.98	0.98	0.97	0.94
22	0.97	0.98	0.97	0.92	0.78	0.91	0.93	0.83	0.87	0.95	0.93	0.91
23	0.97	0.96	0.97	0.97	0.81	0.88	0.94	0.96	0.92	0.95	0.85	0.91

Table 4. The hourly correlation coefficient for twelve months of Guangzhoustation. (LT is the local time in hours).

LT(Hr)	J	F	M	A	M	J	J	A	S	O	N	D
0	0.99	0.98	0.94	0.90	0.96	0.89	0.97	0.98	0.95	0.97	0.99	0.92
1	0.98	0.97	0.95	0.92	0.92	0.87	0.97	0.97	0.94	0.96	0.99	0.93
2	0.94	0.97	0.96	0.92	0.97	0.87	0.96	0.97	0.94	0.97	0.99	0.93
3	0.95	0.94	0.93	0.96	0.91	0.85	0.94	0.96	0.94	0.94	0.98	0.95
4	0.97	0.96	0.95	0.99	0.93	0.82	0.91	0.97	0.94	0.94	0.96	0.86
5	0.98	0.90	0.98	0.98	0.93	0.87	0.93	0.97	0.97	0.96	0.97	0.91
6	0.97	0.94	0.98	0.99	0.97	0.91	0.96	0.99	0.98	0.96	0.95	0.95
7	0.99	0.95	0.88	0.98	0.95	0.87	0.92	0.98	0.95	0.90	0.97	0.96
8	0.99	0.96	0.94	0.98	0.92	0.92	0.94	0.89	0.97	0.98	0.99	0.96
9	0.98	0.98	0.94	0.97	0.93	0.87	0.90	0.94	0.97	0.99	0.96	0.98
10	0.98	0.98	0.90	0.92	0.94	0.87	0.92	0.97	0.93	0.97	0.93	0.97
11	0.97	0.98	0.88	0.89	0.94	0.90	0.93	0.97	0.91	0.90	0.89	0.95
12	0.93	0.93	0.74	0.75	0.81	0.91	0.93	0.93	0.87	0.86	0.87	0.91
13	0.91	0.91	0.64	0.48	0.81	0.89	0.92	0.87	0.78	0.63	0.77	0.87
14	0.84	0.83	0.59	0.30	0.75	0.85	0.89	0.79	0.72	0.63	0.76	0.85
15	0.86	0.84	0.56	0.28	0.67	0.76	0.88	0.77	0.64	0.56	0.61	0.76
16	0.86	0.88	0.57	0.34	0.77	0.80	0.83	0.70	0.68	0.64	0.66	0.84
17	0.91	0.89	0.66	0.36	0.76	0.82	0.84	0.67	0.60	0.78	0.74	0.88
18	0.91	0.90	0.75	0.47	0.78	0.78	0.86	0.68	0.75	0.88	0.80	0.92
19	0.95	0.91	0.82	0.69	0.86	0.81	0.93	0.73	0.84	0.89	0.87	0.95
20	0.97	0.95	0.84	0.86	0.92	0.88	0.96	0.87	0.88	0.92	0.90	0.96
21	0.97	0.97	0.88	0.87	0.95	0.90	0.98	0.91	0.91	0.95	0.89	0.96
22	0.98	0.98	0.90	0.90	0.95	0.93	0.98	0.92	0.91	0.96	0.95	0.97
23	0.99	0.98	0.91	0.91	0.96	0.91	0.97	0.97	0.93	0.97	0.97	0.94

during the year, two crests and one trough of foF_2 values were observed similar to observation during the year of HSA. However, unlike HSA, the first crest was formed at the start of the March equinox. Although it was generally observed that the foF_2 trend look similar in different solar epochs, the solar activity trend was not similar for different solar epochs.

3.3.4 Correlation Analysis

Chongqing station, the highest latitudinal station among all shows highest correlation during the whole year (as revealed in Fig. 5, with refrence of Table 2). The lowest correlation of about (r = 0.7) was observed in June around 0LT to 5LT. Magnetic dips were observed in May and June during sunrise and night time, whereas, in September and December sudden dips was found around 5LT to10LT, while in October and November dips were observed around 15LT to 20LT.

Okinawa station, have the lowest correlation observed in November around 5LT to 10LT (as revealed in Fig. 6, with refrence of Table 3). It shows more variation during sunrise local time, whereas, most of the month show high and relatively stable correlation during all hours.

Guangzhou station, the low latitude among all stations show more variation in correlation throughout the day, it was relatively high during sunrise and low during daytime (as revealed in Fig. 7, with refrence of Table 4). The lowest correlation was observed in April around 15LT to 20LT.

4. DISCUSSION

4.1 Seasonal Variations

Earth's axes are tilted at a degree of 23.45o; each hemisphere receives varying amounts of sunlight during the year, that's why we have different season and variation i.e. due to the different angles of the sun.

4.2 Monthly Variations

The relationship between solar activity index (F10.7) and the F_2 layer critical frequency have

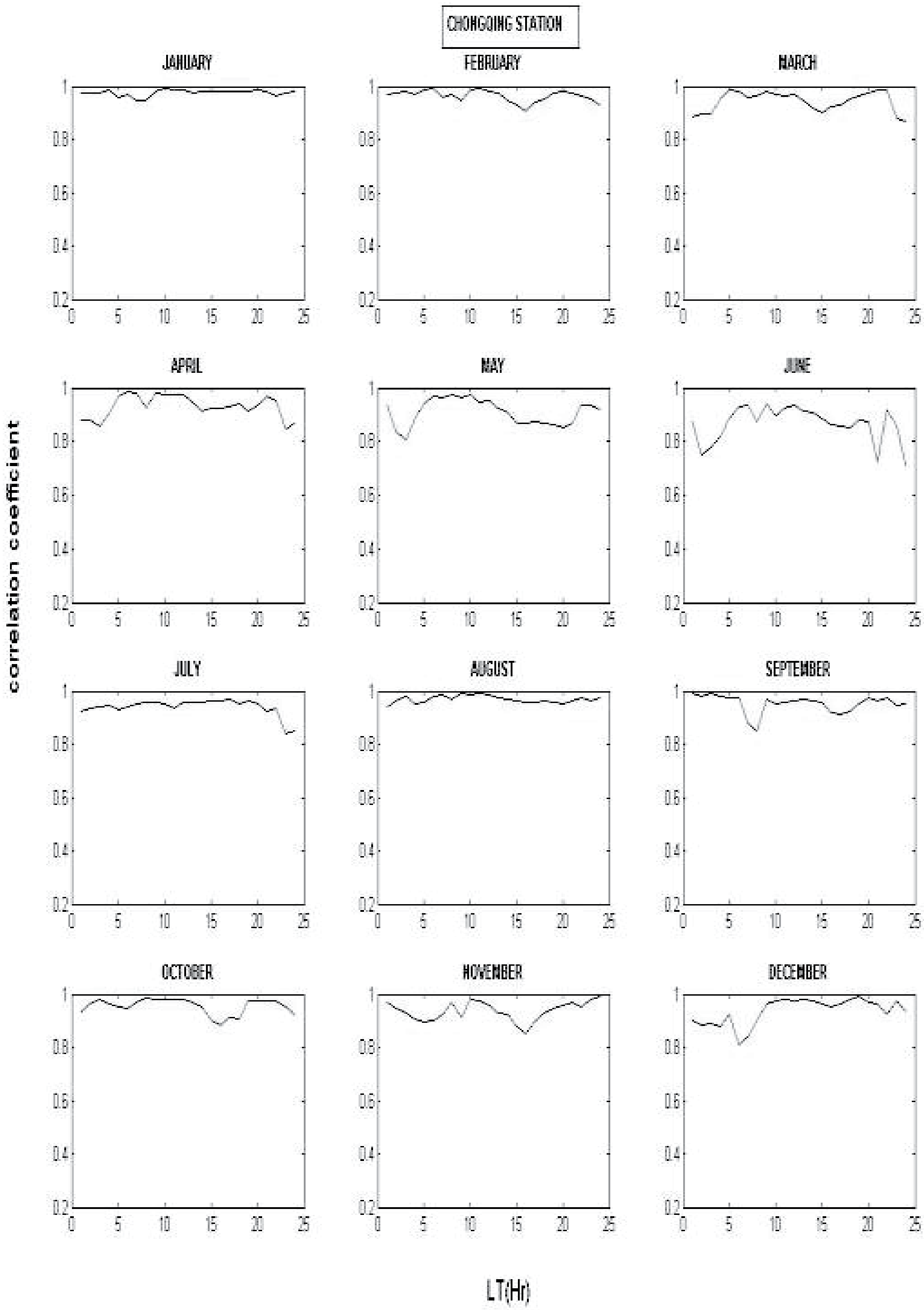

Fig. 5 Diurnal variation in the correlation of f_oF_2 with SSN for different months of Chongqing station.

been investigated during different solar epochs. The foF_2 saturates at high solar activity due to high electron density in the ionosphere. Significant variations with season and solar activity level were identified. This was similar to the observation of Brum et al [10] where foF_2 has a strong solar activity dependence, i.e. increase with increasing sunspot numbers, but varying with the seasons. These variations have been observed to be due to factors, such as thermospheric wind [11], neutral

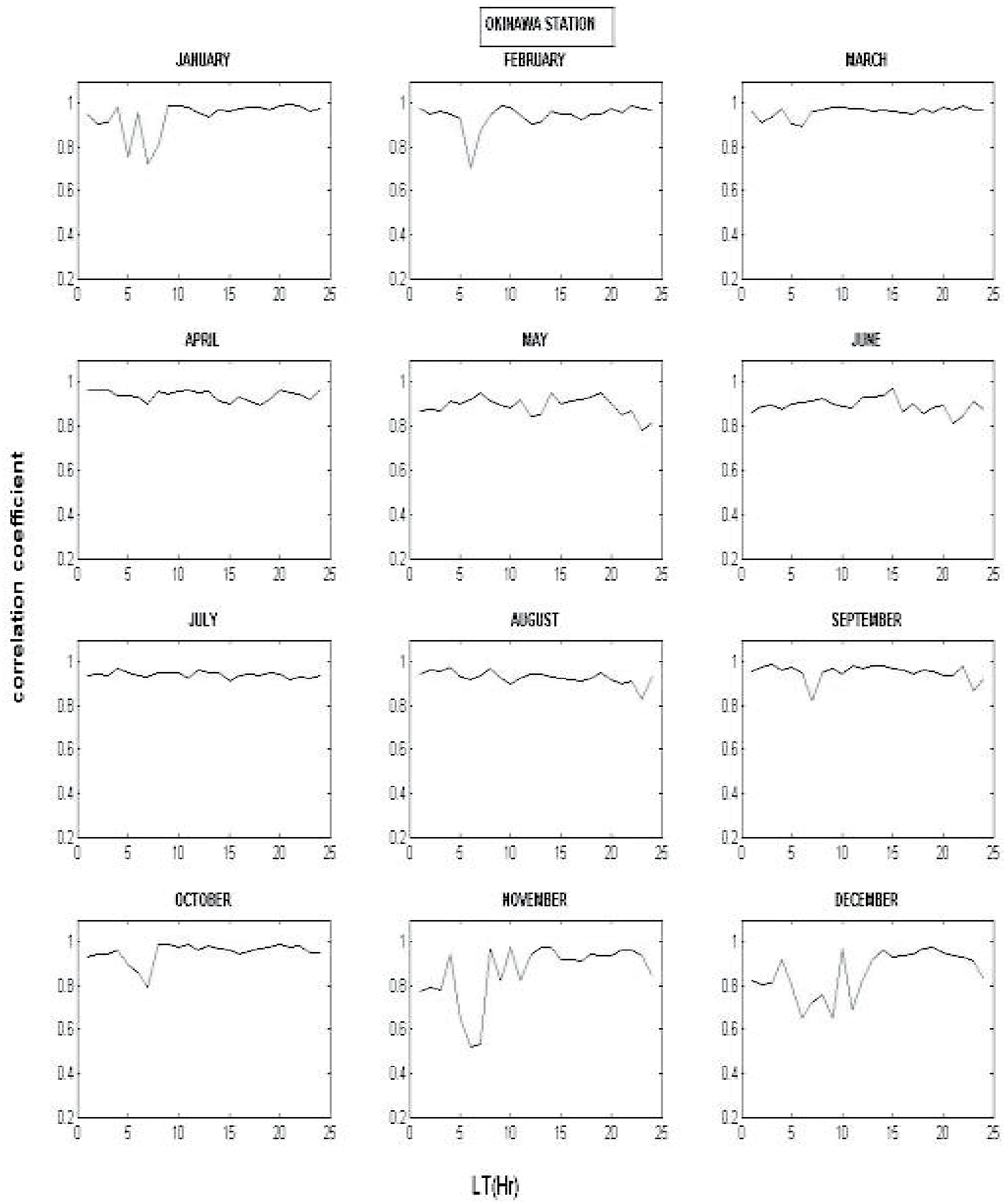

Fig. 6 Diurnal variation in the correlation of f_oF_2 with SSN for different months of Okinawa station.

winds, dynamo electric field [12], which varies seasonally, its combined effect and the varying Sun-Earth distance due to the Earth's elliptical orbit round the Sun [10-14]. Solar activity dependence of foF_2 was strongest in the year of MSA (which was the decreasing phase of the solar cycle) than in HSA and LSA (the LSA year was in the cycle 21/22 minimum).

Second, the relationship between F10.7 and foF_2 in the low Latitude region varies significantly with the season. The variation during HSA and LSA was significant in the first half of the year (from early March equinox to the end of June solstice). Moreover, seasonal variation of foF_2 may be due to the changes in neutral composition. Stubbe [15] had earlier stated that seasonal F-region variation is caused by changes in the composition of the neutral gas. In addition, the effect increases with rising solar activity. The poleward movement causes electron density enhancement in both equinoctial periods, but the September equinox experiences larger winds than the March equinox.

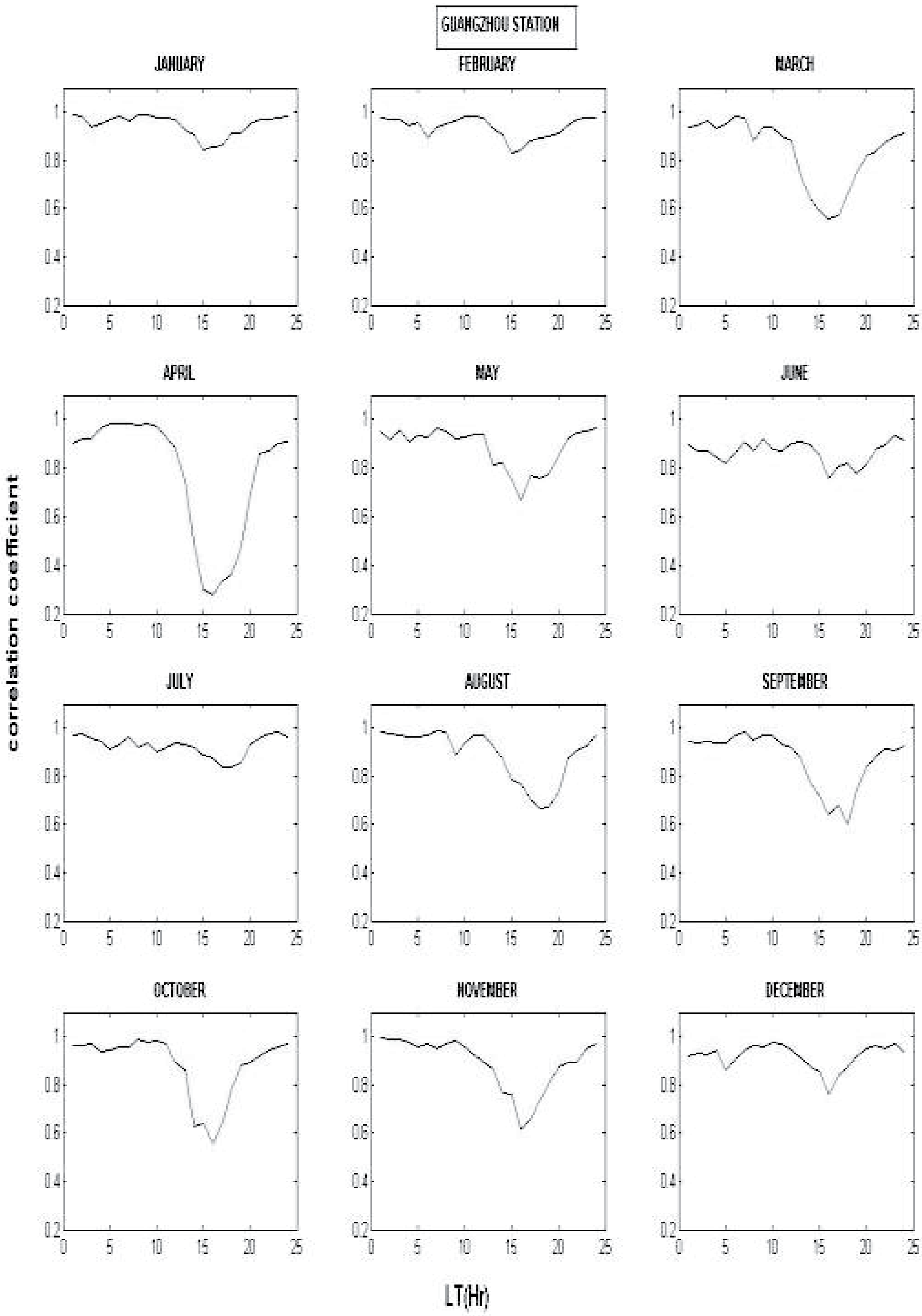

Fig. 7 Diurnal variation in the correlation of f_oF_2 with SSN for different months of Guangzhou station.

5. CONCLUSIONS

From this study it can be conclude that trend of solar activity, as represented by the indices, varies across each season in different solar epochs. There is a pronounced dependency on latitude as we move from high latitude to low latitude station (i.e., Chongqing to Okinawa to Guangzhou). Likewise, annual variation was distinct for three years of the study. There seems to be a better agreement between solar activity indices and foF_2 in year of MSA as compared to what was observed in the year of HSA and LSA.

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