INTERNATIONAL JOURNAL OF SCIENCE AND NATURE

www.scienceandnature.org

STUDYING THE VARIATION OF IONOSPHEIC PARAMETERS WITH EARTH GEOGRAPHIC LATITUDES AND SUNSPOT NUMBER

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ABSTRACT
The monthly median critical frequency for ionospheric layers (f_oF2, f_oF1, and f_oE) variations were studied for different latitudes for (12) months from years (2003-2010) started from moderate to low sunspot number (SSN). The data selected from four ground ionosonde stations in Japan. From data analysis it reveal that all layers suffer great daily and seasonally changes due to variation of (SSN) and geographic latitude. From results, it is seen that in the years of moderate (SSN) the value of (f_oF2) increases with decreasing latitude and the (f_oF2) peak shifted as latitude decreases. In the years of low (SSN), it is the same as in the years of moderate (SSN) but with one difference that the value of (f_oF2) is less for all months. About $f_oF1$and f_oE it reveals that as we reach equator the values of critical frequencies increases and decreases with increasing latitude this appears in winter and less in summer solstice and equinox. The maximum value for f_oF1 broaden from eight mornings till three afternoons, but f_oE reach approximately maximum in noon time for all months and years chosen.

KEYWORDS: Ionosphere, Sunspot number, Critical frequency.

INTRODUCTION

The ionosphere is an ionized part of the Earth's atmosphere which is composed of electrons, ions and neutral particles that depends on the solar radiation[1], especially ultraviolet violet radiation (UV) and X-ray, which in turn works on the propagation of high frequency radio waves (HF, 3-30 MHz) and prevents them from going into outer space[2, 3]. The refraction of the radio waves depends on the electron density N_e (which increases by increasing the height of the Earth's surface), and the angle of the incident of radio waves on the ionosphere [4, 5]. All the ionospheric layers (F2, F1 and E) suffer from large and continuous changes from day to day, as well as seasonal changes influenced by changes in the number of sunspots[6], geographical coordinate's latitudes and longitude also the geomagnetic storms[7, 8]. The greatest frequency of radio waves is reflected by the ionosphere called the critical frequency (f_o). Each layer in the ionosphere has a certain frequency (f_oF2, f_oF1 and f_oE) which is affected by solar activity and geographic latitude. The critical frequencies (f_o) are directly related to the maximum electron density of the ionospheric layers (N_{max}), this can be indicated by the following relationship [9]:

$$f_o = 9\sqrt{N_{max}}$$

Several studies point to changes in critical frequencies with latitudes [10, 11]. In this study, the mid-latitude regions, particularly Japan, were used. The number of sunspots (R) is the most important factor in tracking the level of solar activity[12, 13]. Sunspots are mysterious phenomena that appear on the surface of the Sun with seasons and periods in average of eleven years (Figure 1) illustrates this [14].

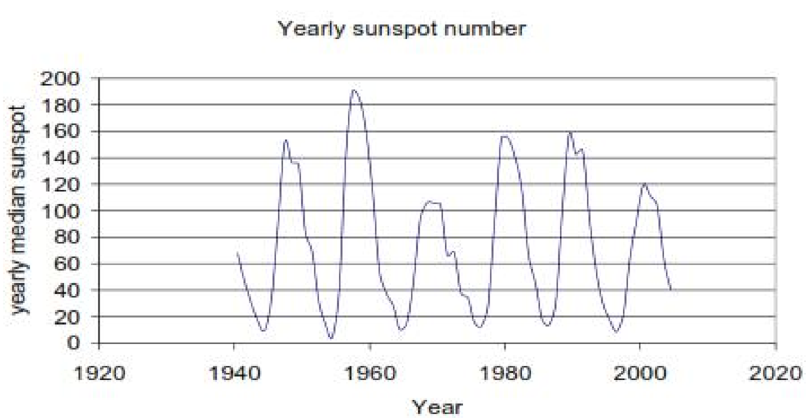


FIGURE 1. Sunspot number (R_{12}) and solar cycle

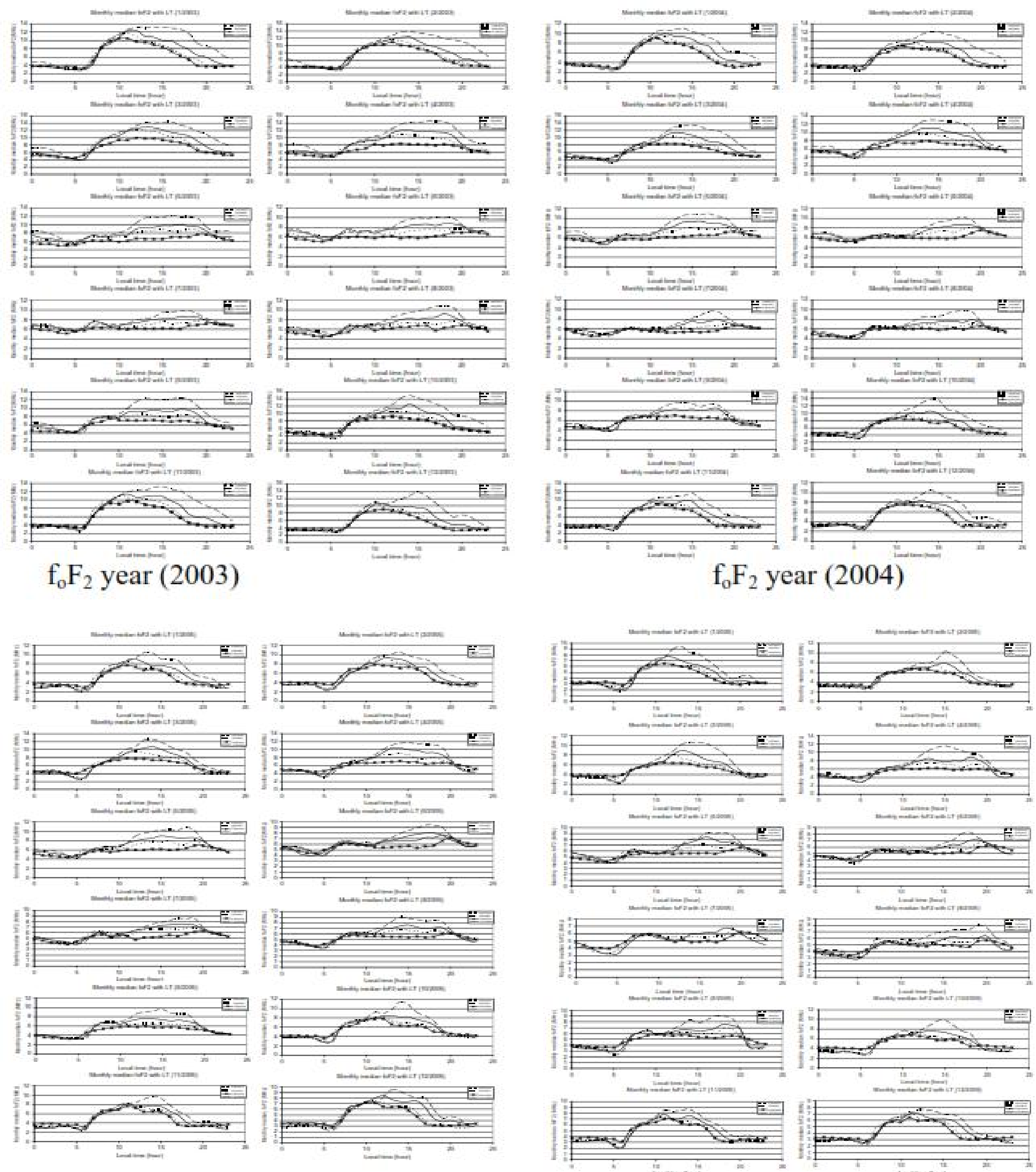
The daily anomaly of the ionosphere refers to the fact that the highest electron density of the layer usually appears at times other than those in the noon of the local time (between hours 13:00 and 15:00)[15]. The seasonally anomalies are represented by the fact that the electron density of the noon and in winter is higher than that in the summer [16, 17].

2. Data Selection

The data in this research work related to the critical frequencies of all ionospheric layers (f_oF2, f_oF1 and f_oE) were obtained from four stations in Japan located in the Northern Hemisphere and Table (1) showing the stations and their location (latitude and longitude). The years were selected from (2003-2010) and these years have different solar activity Table 2 shows the yearly average of sunspot number (R_{12}). The monthly average for 24 hours is taken from the site (http://wdc.kugi.kyoto-u.ac.jp/wdc). Data on the annual rate of sunspots and the same years were obtained from the site of Sunspot Index Data Center (http://sidc.oma.be/products/bul/) [14].

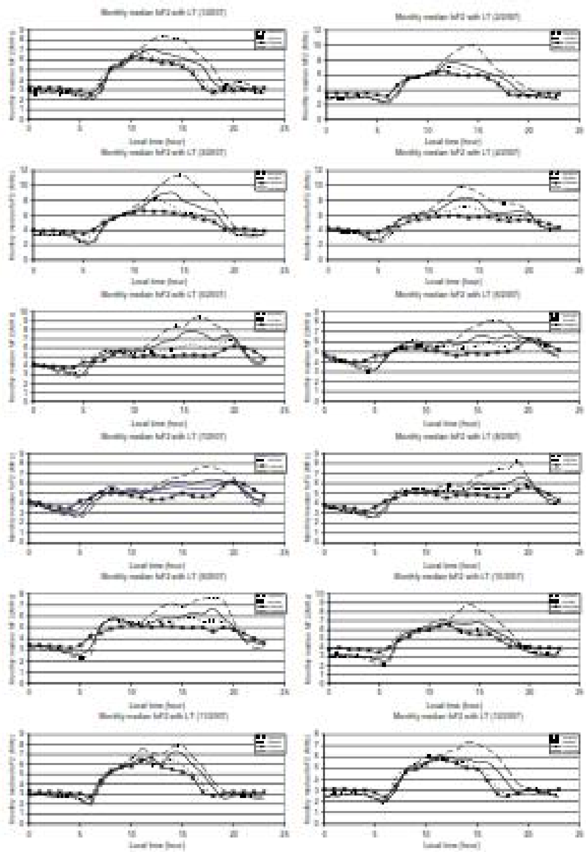
3. Data Analysis and Results

Figures (2-4) represent the monthly average for (24 hours) of the critical frequencies in MHz (f_oF2, f_oF1 and f_oE) and for the years 2003 to 2010 respectively, we can deduce from these that:

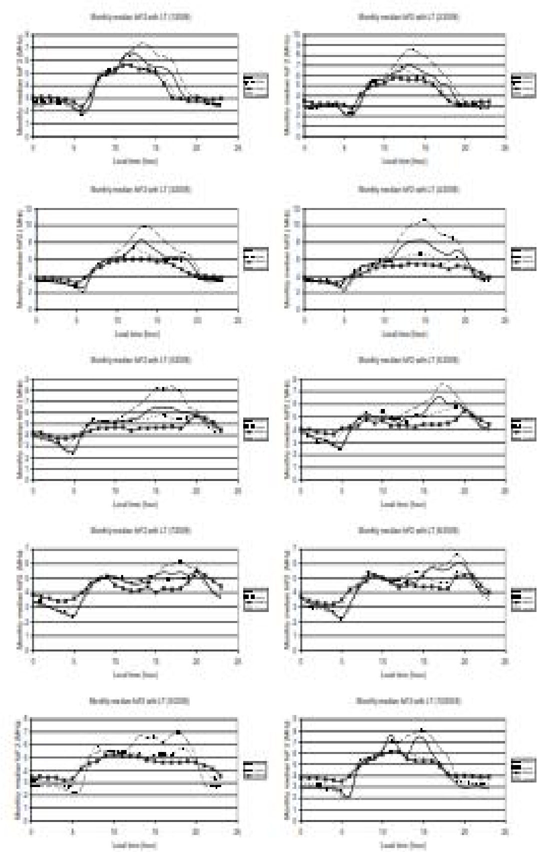


f_oF_2 year (2006) f_oF_2 year (2005)

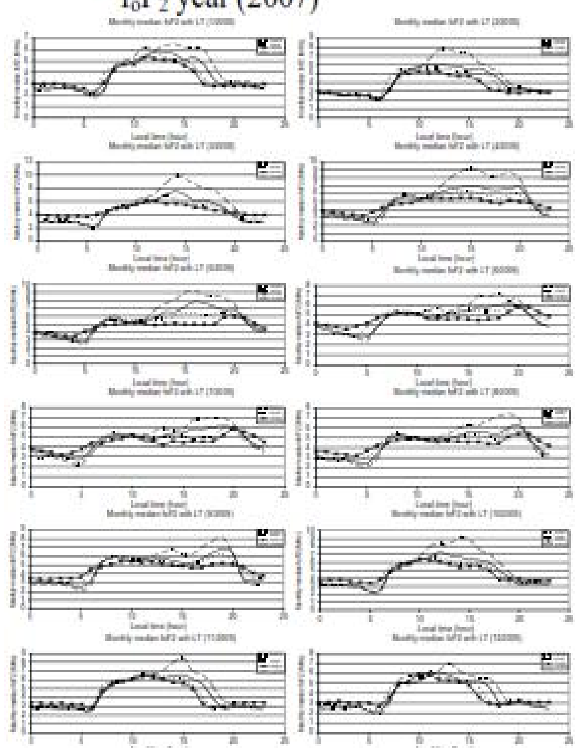
FIGURE 2. The daily average of f_oF_2 for years (2003-2010)



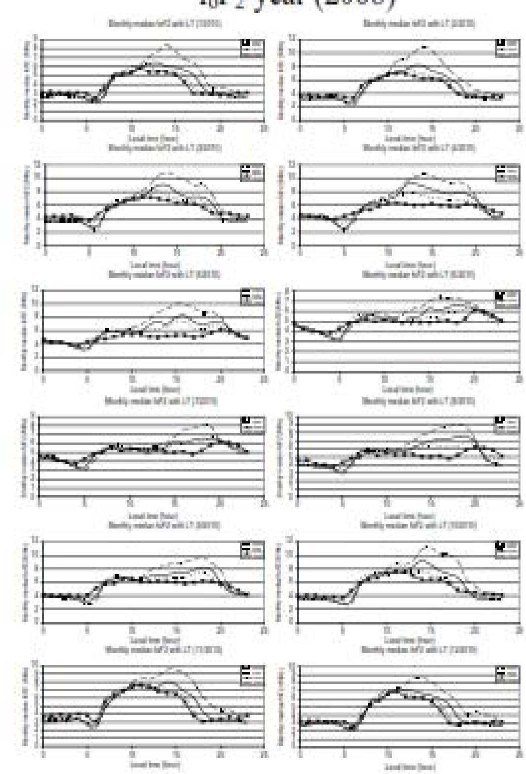
f_oF_2 year (2007)



f_oF_2 year (2008)



f_oF_2 year (2009)



f_oF_2 year (2010)

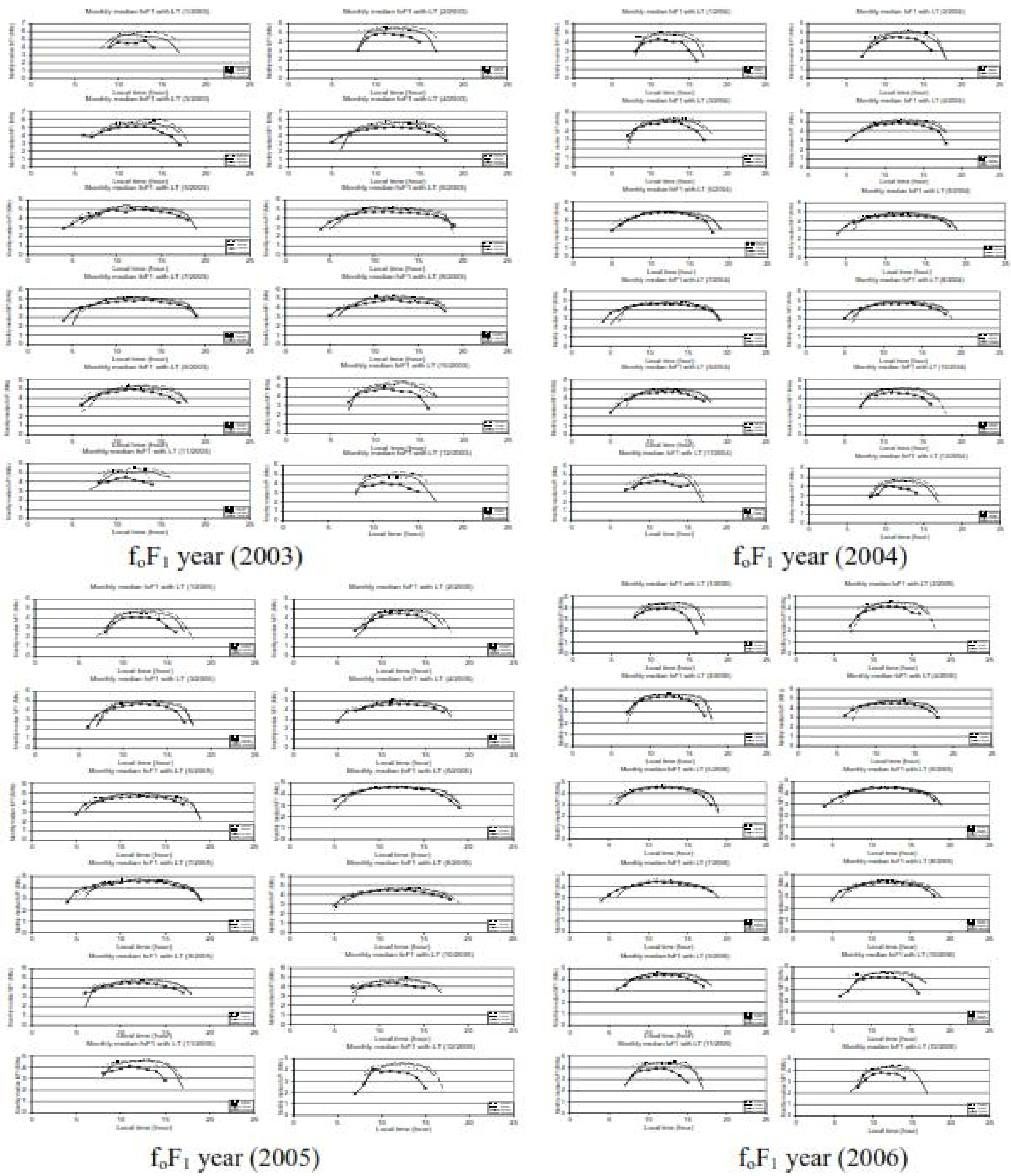


FIGURE 3. The daily average of f_oF_1 for years (2003-2010)

A/ The changes in critical frequencies of the F_2 layer

i. As shown in Figure (2), in the years in which the number of sunspots is moderate and for all months, the value of f_oF2 increases with decreasing geographic latitudes starting from local time 6:00 am or from sunrise till midnight.

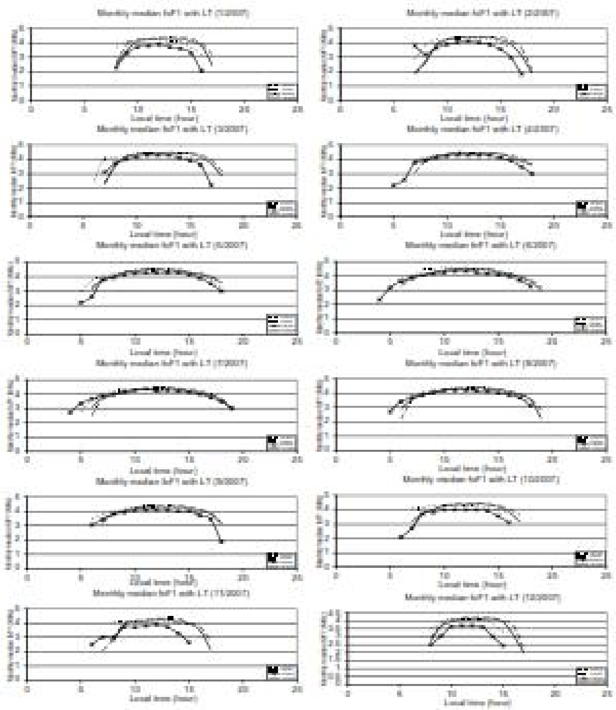
ii. There is a deviation or shift in the maximum value of the critical frequency towards the longer hours as the latitude decreases, it mean that there is an inversely relation in both cases with the appearing of two peaks in the summer.

iii. For the years in which the solar activity is low, the change is similar to what we observed in the years in which the solar activity are moderate with one difference that the value of the critical frequencies is lower and for all months.

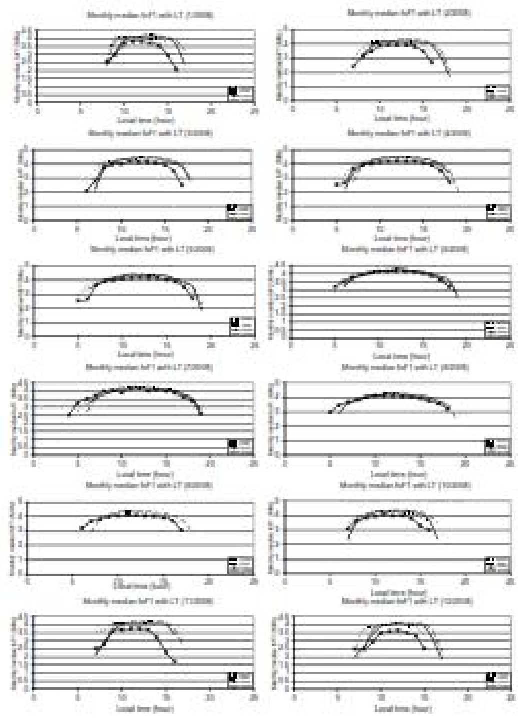
B/ Changes in critical frequencies of the F_1 layer

i. With respect to the critical frequencies of the F1 layer, there is an increase in the value of the critical frequencies f_oF1 as we approach the equator, this difference is clear in the winter and the difference is less in the equinoxes and the summer.

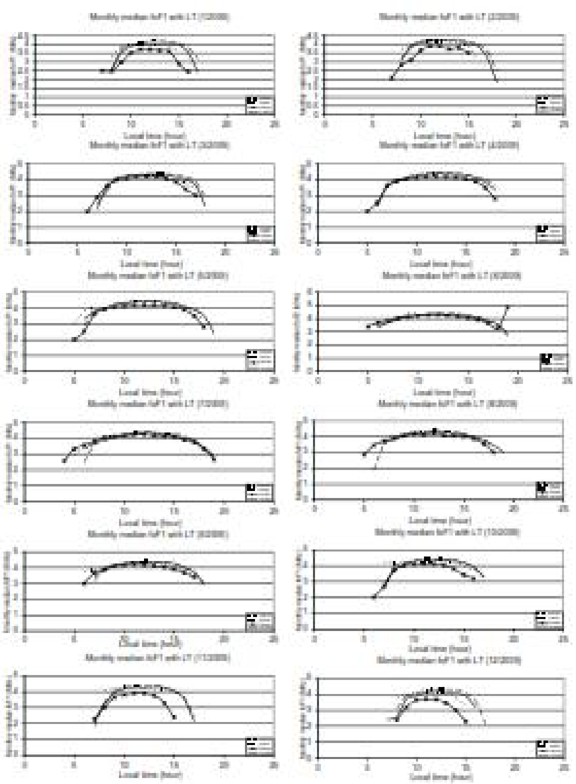
ii. From Figure (3), it reveals that the maximum value of critical frequencies will continue from hour 8:00 am during the day until about 3:00 pm for all months from the years chosen in this research and for all latitudes.



f_oF_1 year (2007)



f_oF_1 year (2008)



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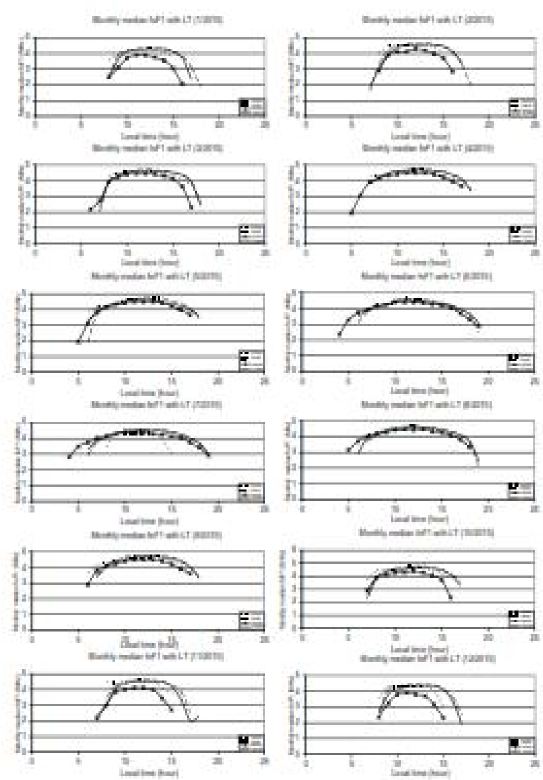
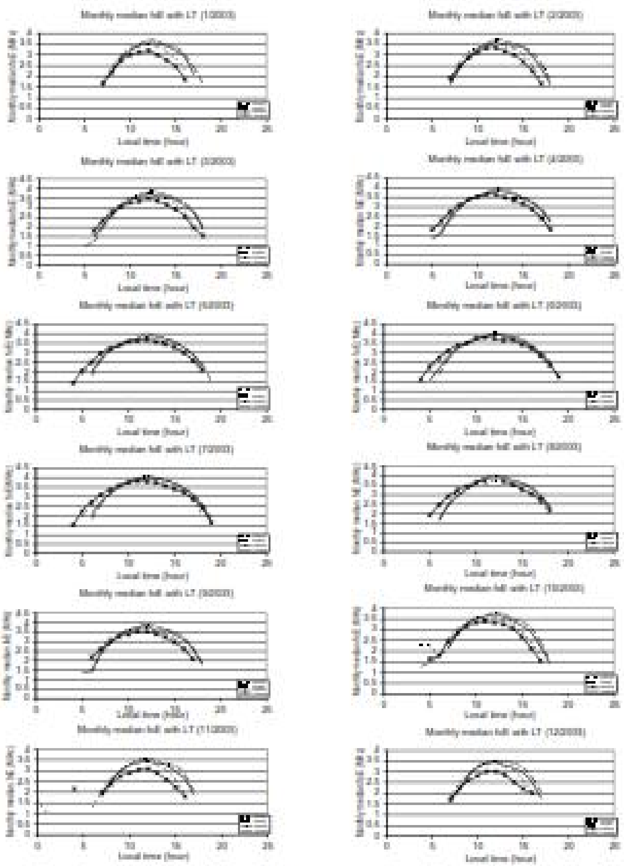
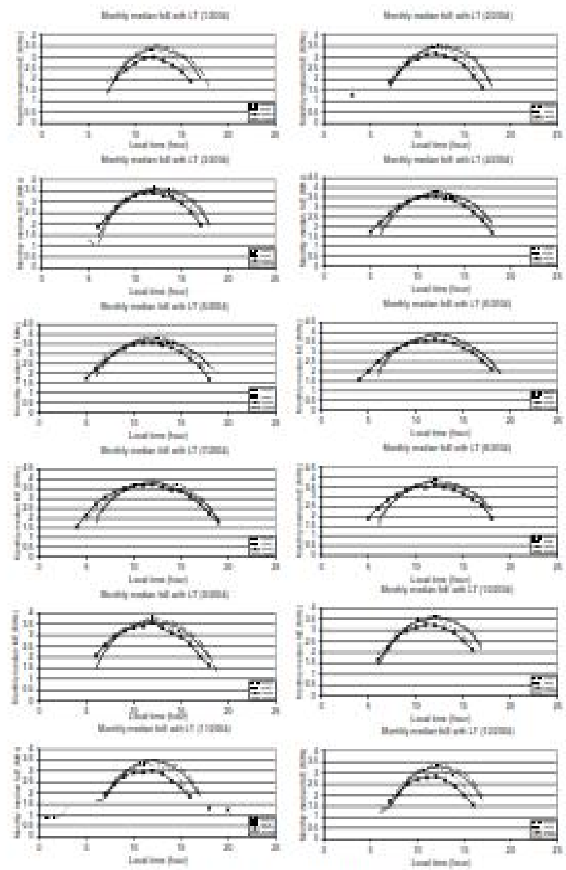


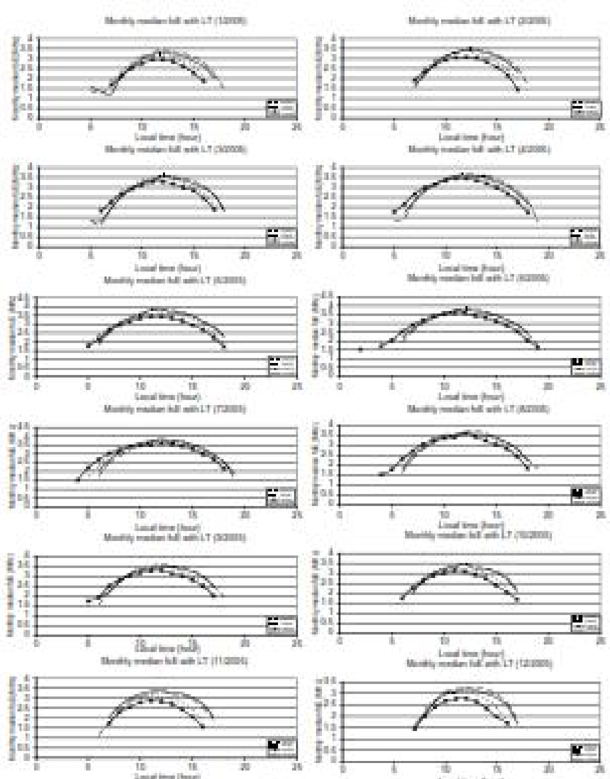
f_oF_1 year (2010)



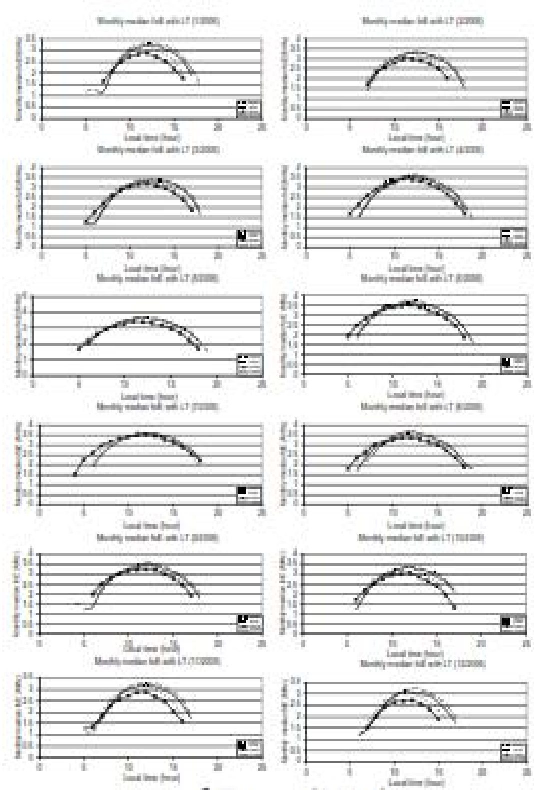
f_oE year (2003)



f_oE year (2004)



f_oE year (2005)



f_oE year (2006)

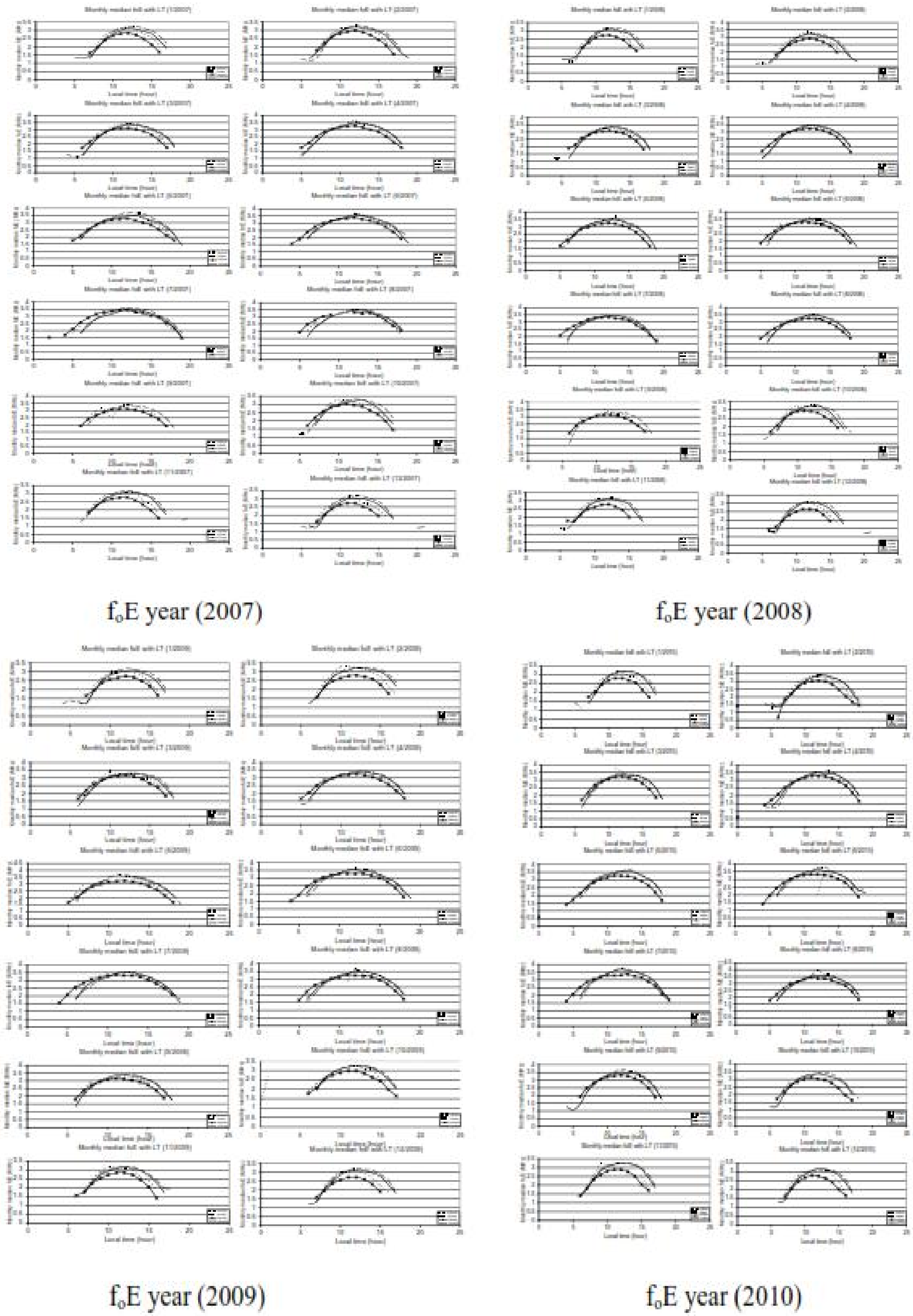


FIGURE 4. The daily average of f$_o$E for years (2003-2010)

C/ Changes in the critical frequencies of layer E

i. From Figure (4), it shows that there is an inverse correlation between the value of the f_oE and the latitude, where the values increased as the latitudes decreases. This difference is clear in the winter and less in the equinox seasons and summer and for all selected years.

ii. The maximum value of critical frequencies shall be at midday and for all selected seasons and years.

TABLE 1. The Coordinate of stations

Station	Latitude (degree)	Longitude (degree)
Okinawa	26^o 40.5$'$ N	128^o 9.2$'$ E
Yamagawa	31^o 12.1$'$ N	130^o 37.1$'$ E
Kokubunji	35^o 42.4$'$ N	139^o 29.3$'$ E
Wakkanai	45^o 23.5$'$ N	141^o 41.2$'$ E

TABLE 2. The yearly average of sunspot numbers (R_{12})

Year	R_{12}
2003	63.7
2004	40.4
2005	29.8
2006	15.2
2007	7.5
2008	2.9
2009	3.1
2010	16.5

ACKNOWLEDGEMENTS

This work relates to Baghdad University/ College of Science/ Department of Astronomy and Space. The data are provided from WDC for Ionosphere, Tokyo, National Institute of Information and Communications Technology, WDC Kyoto Japan and geophysics data from UK wdc, for whom I would like to introduce my utmost appreciation and thanks.

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