Lunar Tidal Effect consideration on the Bottom Side of the Ionosphere through the Variation of Critical Frequencies and Height of the E-layer Plasma in Mid-Latitude

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Abstract: Ionosphere is a part of the atmosphere which is formed due to solar ultraviolet radiation on the atmosphere. It stretched from high altitudes heights above the earth surface to near the Earth's. It is divided into different layers such as D, E, and F and… due to the ionization rate and the density of electrons and ions and some other factors. Ionosphere is known as an environmental plasma medium. The lunar tide has always been regarded interesting as one of the notable phenomenon in the ionosphere, and significant due to fact that is indicates a close correlation between ionosphere and specifications of the layered shape of the plasma movements .In this study the lunar tide in the E layer of the ionosphere in the mid-latitude, has been determined by the analysis of the foE and hmE parameters in 2009 year, while the selected site is Boulder Colorado. When the moon is experiencing one of its four main phases, the tide goes to its maximum or minimum values. So we study correlation of the height (hmE) and critical frequency (foE) in these days. The investigations revealed that, the correlation coefficient between the hmE and foE varies with the variation of the moon phase, but these variations are the same for each of the moon main phases in different months.
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1- Introduction

Ionosphere is part of the earth atmosphere that is formed in heights more than 80 kilometers above the earth with a permanent ionization, which is called ionospheres plasma. The electrons and ions are produced by the emission of solar ultraviolet radiation to the earth ionosphere [1]. the amounts of these electric charges related to the energy levels of solar radiations and composition of ionosphere in different height where ionization is produced. Electron density in the earths ionosphere shows tree different layers which their distance together their existence change with day and night times and seasons of the year. In this study ionospheres plasma of E layer are taken under consideration. The E layer is the middle layer from 90 km to 120 km above the surface of the earth. Ionization is due to soft X-ray (1-10 nm) and ultraviolet (uv) solar radiation induced ionization of molecular Oxygen (O_2)in the medium. The vertical structure of the E layer primarily determined by the competing effects of ionization and recombination. At night the E layer rapidly disappears because the primary source of ionization is no longer present [2]. The gravitational force of the moon is well known to produce variations in ionospheric currents. periodic oscillations of the ionospheric height and density plotted in lunar time have been called the ionospheric lunar tide, which name has come from the analogous oscillations of the ocean and the surface atmosphere [3]. the lunar tide has attracted significant attention despite the fact that it has a considerably smaller amplitude compared to other mechanism which drive variations in the ionosphere, such as the solar tide and geomagnetic storms. The lunar tide is of considerable interest due to the fact that the forcing mechanism is known exactly, providing ideal conditions for comparison between numerical models and observations in both the neutral atmosphere and ionosphere [4]. The existence of a lunar tide in the E-layer of the ionosphere was first demonstrated by Appleton and Weekes [5]. Since then, many tidal investigations have been made by various workers for the other layers, but very little is still known about the E-layer tide [6]. Notable lunar variations in ionospheric layer heights and electron densities occur chiefly in the day time, when the E layer present [7]. Therefore, in this investigation, by using available data, we study the lunar tidal effects on the E-plasma occurrence in mid-latitude.

2- Lunar tides

Gravity is one of the major force that creates tides. In 1687, Sir Isaac Newton explained that ocean tides result from the gravitational attraction of the sun and moon on the oceans of the earth. The moon has a major influence on the Earth's tides, but the sun also generates considerable tidal forces. Solar tides are about half as large as that of the lunar tides and are expressed as a variation of lunar tidal patterns, not as a separate set of tides [8]. When the sun, moon, and Earth are in alignment (at the time of the new or full moon), the solar tide has an additive effect on the lunar tide creating extra-high tides, and very low tides-both commonly called spring tides. One week later when the sun and moon are at right angles to each other, the solar tide partially cancels out the lunar tide and produces moderate tides known as neap tides. During each lunar month, two sets of spring tides and two sets of neap tides occur [9].

3- Seasonal variation of lunar tide

The investigations showed that distribution of Lunar tides depend on seasons and Maximum domain occurs along winter and minimum domain occurs in summer times [10]. Thus in very investigations of Lunar tidal effects on the ionospheric layers, the followings are usual periods : months of winter solstice (January, February, November, December), equinoctial months (March, April, September and October), months of summer solstice (May, June, July, August) [11].

4- Data and Methods of Investigation

The data utilized in this paper are the hourly data of the height and critical frequency of the E-plasma layer at days of four main phase of the moon (new moon, first quarter, full moon, last quarter) in Boulder Colorado site located N40^0 E 255^0 observatory during the period of low solar activity. This investigation has performed for the year 2009. For statistical analysis of correlation between height and critical frequency of the E-plasma layer, the method of determination of correlation coefficient between two sets of data (obtained from Excel) is used. Correlation coefficient at the time of main phase of the moon for tree periods of winter solstice, equinox and summer solstice are calculated and results are compared. Figs. 1, 2, 3, 4 and 5 show variation between height and critical frequency and correlation coefficient (r) between these two parameters at days of main phase of moon.

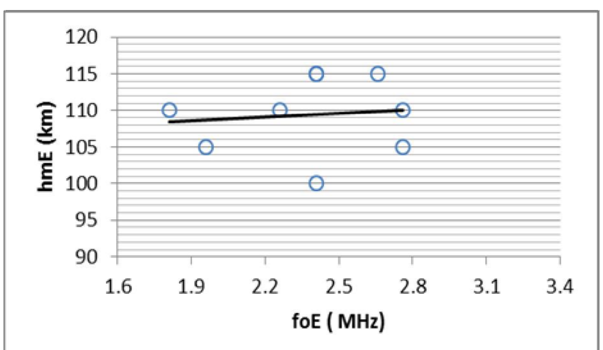

Fig-1. Variation of hmE vs. foE on December 2th, 2009 (full moon), r = 0.11

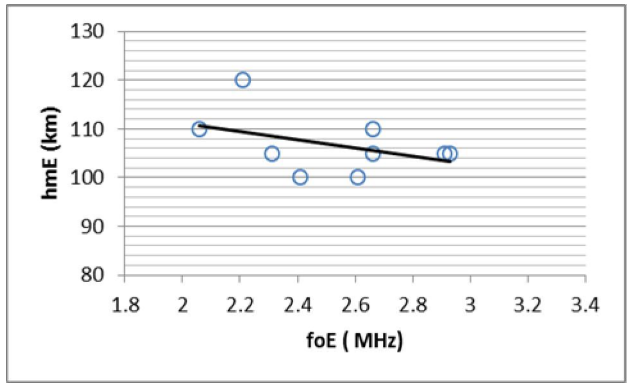

Fig- 2. Variation of hmE vs. foE on December 9th, 2009 (last quarter), r = - 0.42

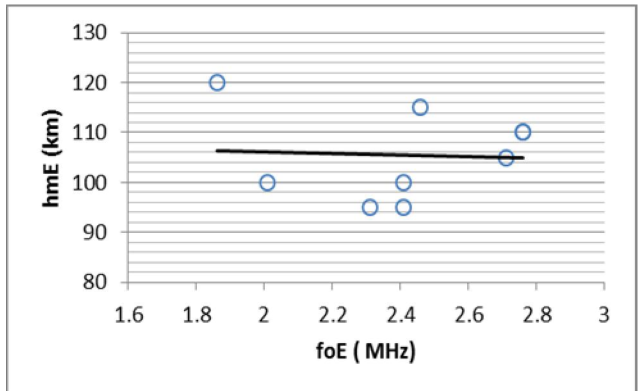

Fig- 3. Variation of hmE vs. foE on December 16th, 2009 (new moon), r = - 0.05

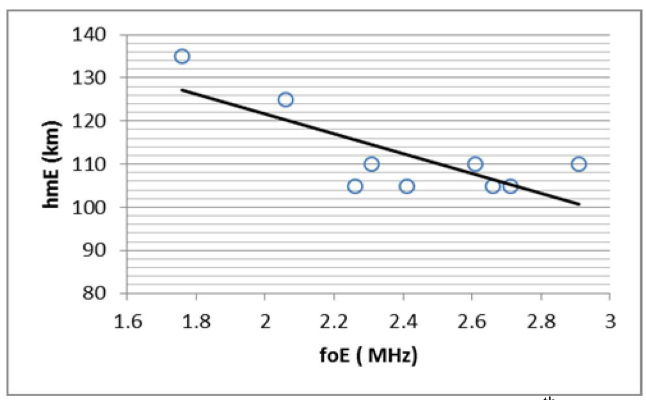

Fig.-4.Variation of hmE vs. foE on December 24th, 2009 (first quarter), r = -0.77

5- Results and Discussion

Correlation coefficients between height and critical frequency of E- Layer plasma in the year2009 in tree periods are categorized in tables below.

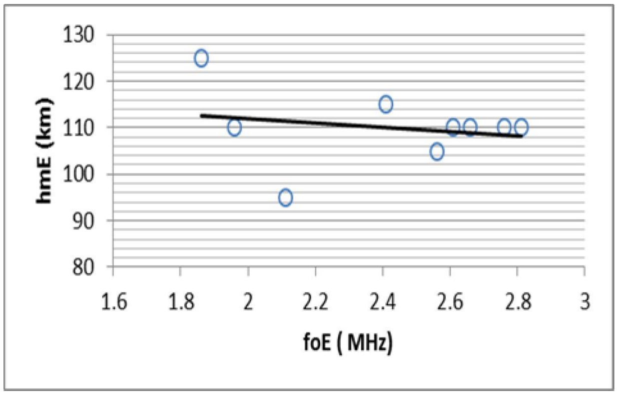

Fig- 5. Variation of hmE vs. foE on December 31th, 2009 (full moon), r = -0.2

Table- 1. Correlation coefficients, period winter solstice in 2009

Moon phases	New moon	First Quarter	Full moon	Last Quarter
November	-0.79	-0.57	0.11	-0.5
December	-0.05	-0.77	0.11, -0.2	-0.42
January	-0.23	-0.36	-0.65	-0.89
February	-0.13	-0.41	-0.22	-0.6

Table- 2. Correlation coefficients, period Equinox in 2009

Moon phases	New moon	First Quarter	Full moon	Last Quarter
March	-0.62	-0.54	-0.25	-0.6
April	-0.52	0.24	-0.41	-0.74
September	-0.89	-0.76	-0.41	-0.85
October	-0.36	-0.75	0	-0.7

Table - 3. Correlation coefficients, period summer solstice in 2009

Moon phases	New moon	First Quarter	Full moon	Last Quarter
May	-0.73	-0.32, -0.34	0.3	-0.5
June	-0.4	0.2	0.28	-0.47
July	-0.97	-0.61	0.05	-0.68
August	-0.21	-0.47	0.054	0.01

As noted from Tables 1, 2 and 3 it can be seen that:

5-1: In winter solstice period, when the moon is in quarter phase, correlation is negative and strong. And at time of full moon or new moon, correlation coefficients are negative and almost weak. Correlation coefficients of these periods are showed in Table -1.

5-2 : In equinox period, when the moon is first and last quarter, correlation is negative and strong. Correlation coefficients of these periods are showed in Table- 2.

5-3: In summer solstice period, correlation is almost weaker than that of the other periods, but in this period, correlation at the first quarter and also at the third quarter is negative and almost strong, similar to other periods. at the time of new moon, correlation is negative and strong while when the moon is full, negative and weak correlation is observed. Correlation coefficients of these periods are showed in Table- 3.

6- Conclusion Remarks

In this study by comparing tables and investigation of correlation coefficients, it can be concluded that correlation between height and critical frequency of E-layer plasma varies with changes in moon phases so these correlation coefficient in each phases of the moon in tree periods are almost the same. So when the moon is in the first and last quarter, correlations are almost stronger than when the moon is full or new. In this research correlation between height and critical frequency of E-layer plasma in mid-latitude was investigated.

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