Investigating the Influence of the Solar activity on the Electron Density of Mars's Ionospheric Layer

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Abstract
The study of Mars's ionosphere was made by investigating the measurements of the electron density (N_e) depending of the variation of the solar activities through different local time, different seasons, and different altitudes. The datasets has been taken from MARSIS on board the Mars Express spacecraft, the investigation for the solar indices and the electron density (N_e) have been made for two period of time depending on the strength of the geomagnetic storms, the first one was taken when the geomagnetic storms was low as in years (1998 & 2005), the data was chosen for three seasons of these years, Winter (December), Summer (June) and Spring (April). The second period was taken for the years (2001 & 2002) when the geomagnetic storms was high and the data also was chosen for three seasons as well except for Spring (March). The result of the analytical study that have been made for the electron density profile shows fluctuations that are inversely proportional with the solar flux and the sunspot number .This is attributed to the lack of the magnetic field that existed on Planet Mars.

Keywords: Mars, Ionosphere, Solar indices, Electron Density

التحقيق في تأثير النشاط الشمسي على الكثافة الالكترونية لطبقه الايونوسفير للمريخ

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الخلاصة:
أن دراسة أيونوسفير المريخ وأستجابته للنشاط الشمسي يتطلب التحقيق في حساب الكثافة الالكترونية خلال اوقات، فصول، وارتفاعات مختلفة. تم اخذ البيانات من القمر الصناعي MARSIS والموضوع على المركبة الفضائية Mars Express ، اختيرت مدتين من الزمن للتحقيق في النشاط الشمسي والكثافه الالكترونية اعتمادا على قوة العواصف الكهرومغناطيسية، المدة الاول تتضمن السنوات 1998 و 2005 والتي تكون فيها العواصف الكهرومغناطيسية واطئة، اختيرت لثلاث فصول المتمثلة بالشتاء (كانون الاول)، الصيف (حزيران)، والربيع (نيسان). المدة الثاني أختير للسنين 2001 و 2002 عندما تكون العواصف الكهرومغناطيسية عالية واختيرت لنفس الفصول السابقة ماعدا الربيع كان للشهر (أذار). عند اجراء تحليل النتائج لمنحني الكثافه الالكترونية ، تبين وجود تغييرات كانت تتناسب عكسيا مع الفيض الشمسي والبقع الشمسية . السبب لهذا يعزى الى ضعف المجال المغناطيسي لكوكب المريخ.

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Introduction:

In 1973 the Electron densities on the dayside ionosphere of Mars were measured by the radio occultation measurements of a series of Mariner and Mars missions, and the Viking 1 and 2 orbiters. Pre-MGS studies on the electron density profiles by Kliore, et.al [1]. In 1983 R. N. Singh and R. Prasad found that the electron density obtained due to impact ionization is significant above approximately 180 km. This is the height at which the measured electron density begins to oscillate. Thus it appears that the variable super thermal charged particles of solar wind origin and the orientation of interplanetary magnetic field play a significant role in the upper ionosphere of Mars [2]. According to the radio occultation data, the dayside peak electron densities of Mars exhibit ideal Chapman layer-like behavior. The altitude of the ionospheric peak increases while the density decreases with the solar zenith angle (SZA), which is defined as the angle between the local zenith of the satellite and the line of sight to the sun [3]. C. Martinis, J. Wilson and M. Mendillo in 2003 investigated the changes in calculated electron density profiles, under the assumption that the only variable parameter is the solar irradiance [4]. The next year in 2004 J.-S.Wang and E.Nielsen showed that the altitude of the main electron density peak in the Martian ionosphere is closely related to the height of Mars' surface at the occultation point. This is direct evidence for topographic effects on the Martian ionosphere [5].

Violence and variable phenomena in the Sun's atmosphere are collectively referred to as the solar activities which are tied to the complex magnetic field of the Sun [6]. Any fluctuations of these activities Such as solar wind, sunspot number and solar flux will initiate huge variations in the neutral winds, electric fields as well as the density and temperature of the ions, neutrals and electrons in the ionosphere of Mars [7]. Incident solar wind at Mars encounters an extended hot exosphere, a conductive ionosphere, and strong localized crustal magnetic fields [8]. The deflection of the solar wind around Mars, downstream of the bow shock (BS) which formed when the solar wind flows around Mars results from its interaction with the top atmosphere and the conducting dayside ionosphere [9]. The solar activity dependence of the ionosphere is a key and fundamental issue in ionospheric physics, providing information essential to understanding the variations in the ionosphere and its processes. So in this study we will investigate the ionosphere of Mars through the great effects of Sun solar activates in terms of (solar wind speed, sunspot number and the solar flux) on the ionosphere parameter N_e of Mars.

Data selection:

In this research the data was chosen to reveal the effect of the solar indices (solar wind speed, sunspot number and solar flux) on the ionospheric electron density of Mars according to the availability of the data which have been taken from Mars Advanced Radar for Subsurface and Ionospheric Sounder (MARSIS) on board Mars Express. To investigate the behavior of the ionosphere of Mars through the profile of the electron density (N_e) the daily average has been taken. The selected data for the solar indices and (N_e) was divided into two periods of time depending on the strength of the solar activity, the first one was taken when the solar activity was low as in years (2002 and 2005), and data was chosen for three seasons of the years; winter (December), summer (June) and spring (April). The second period was taken for the years (1998 and 2001) at high solar activity and the data also was chosen for the same seasons except for spring (March).

To explain the relation between N_e and the solar indices figure-1 to figure-6 which represent the daily average had been plotted for N_e as a function of the solar indices; solar wind speed (SW), sunspot number (SSN) and solar flux (F), which was arranged in ascending order according to the selected years, in these figures the green curve is for solar flux, the red curve is for sunspot number (SSN), the black curve is for solar wind speed (SW) and the blue curve is for electron density (N_e).

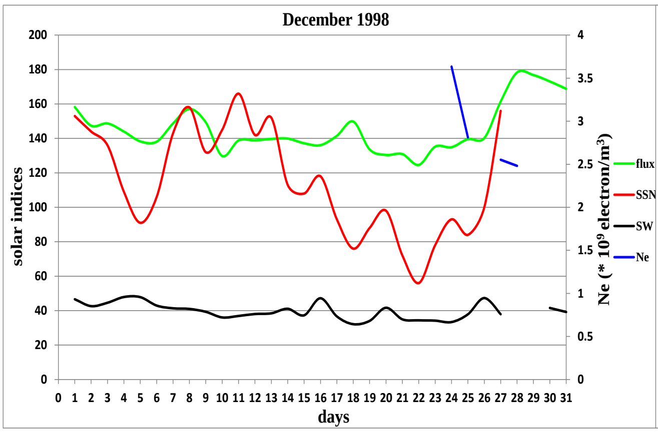


Figure 1-The daily average N_e with the solar indices [Solar flux, SSN, SW] for December 1998

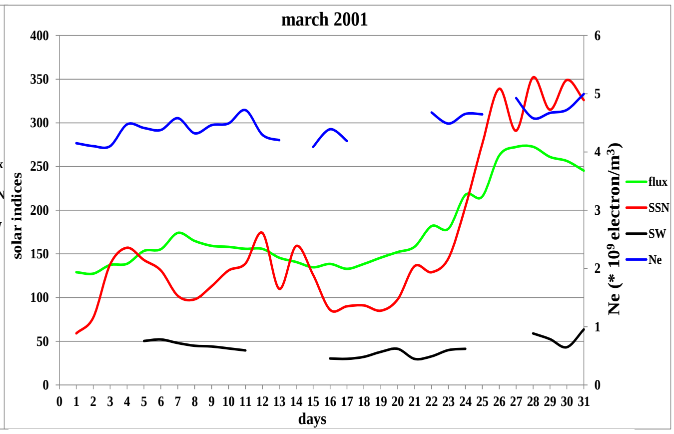


Figure 2-The daily average N_e with the solar indices [Solar flux, SSN, SW] for March 2001

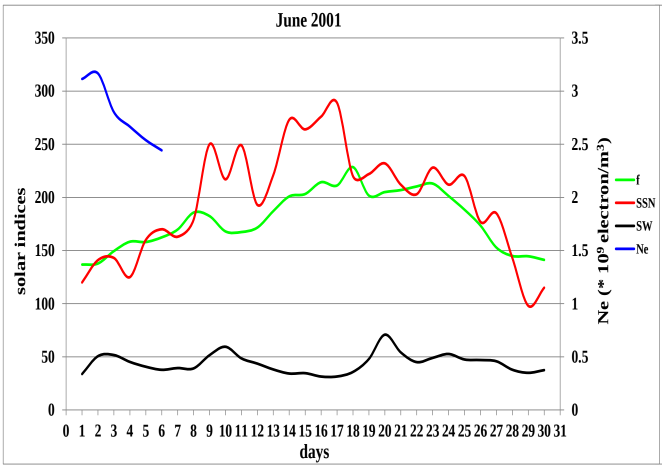


Figure 3-The daily average N_e with the solar indices [Solar flux, SSN, SW] for June 2001

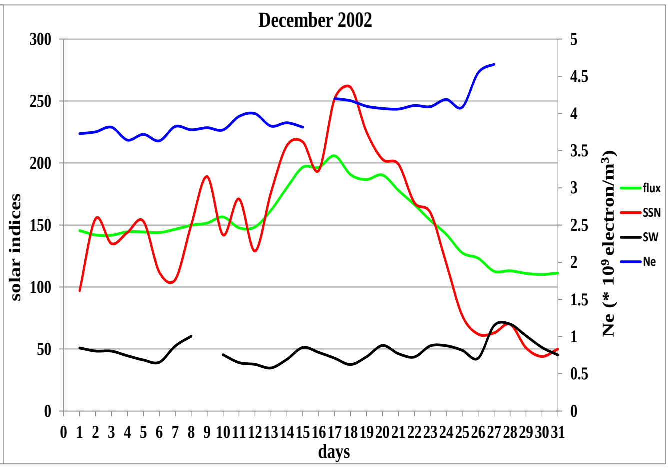


Figure 4-The daily average N_e with the solar indices [Solar flux, SSN, SW] for December 2002

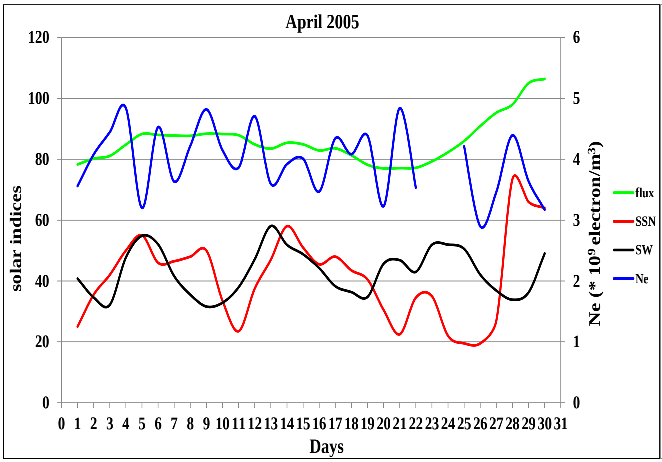


Figure 5-The daily average N_e with the solar indices [Solar flux, SSN, SW] for April 2005

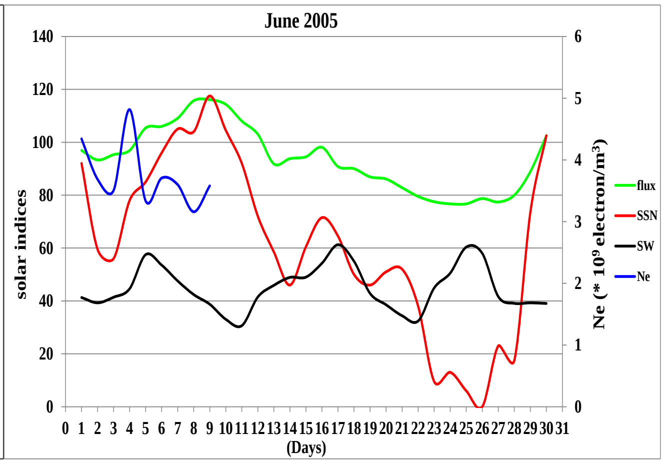


Figure 6-The daily average N_e with the solar indices [Solar flux, SSN, SW] for June 2005

Discussion

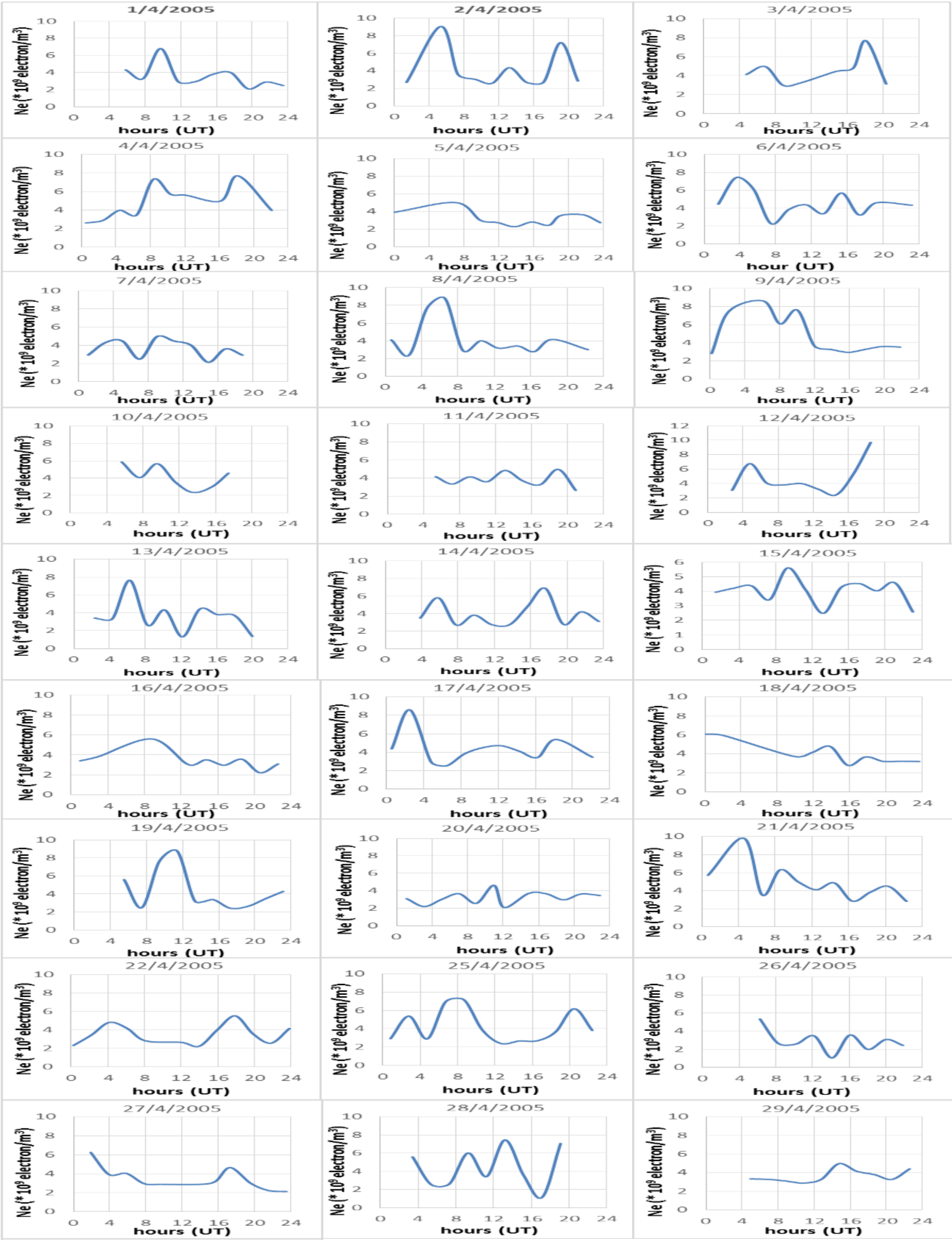
In this work the influence of the solar activity on the N_e of the ionosphere of Mars have been investigated as follows; in figure-1 (the winter time of December 1998) the solar flux shows a slight fluctuation with small humps but that fluctuation increased rapidly during the last three days of the month to reach about 180 ($W.m^{-2}.Hz^{-1}$) while the (SSN) shows a great variation with the peak at the second trimester of the month reaching about 170 and then decreased to about 50 at the last trimester. The (N_e) was only visible at the last trimester of the month because of the strong geomagnetic storms (Minimum Disturbance storm time Dst below -100 nT) which lead to a miss in the data, moreover we can see that the (SW) has approximately the same behavior as the profile of the electron density.

Figure-2 March 2001, reveals a miss in the data of Ne due to the strong geomagnetic storm of the Sun. The biggest evidence of the effect of the solar geomagnetic storms on the electron density of the ionosphere of Mars was at June 2001, see figure-3, where the N_e curve was visible only for the first seven days and then disappeared because the geomagnetic storm became strong at the end of the solar cycle 23 (1996-2008). In figure-4, there is a smooth fluctuation in the electron density curve that nearly corresponds with the solar wind fluctuation, which gives an indication that the solar wind has more effect on N_e than the other indices. In figure-5, the curve of the electron density fluctuates very strongly with the solar wind, while in figure-6 the fluctuation is not clear because the electron density data was not available for all the days.

By comparing the two curves in figure-2 and figure-5, which representing the spring time of the two years (March 2001 and April 2005) respectively, it reveals that when the solar geomagnetic storms decreases the solar flux decreases too because the density of the solar radiation will decrease due to the recombination of electrons and ions. In general when the solar activity was high the electron density was also high reaching values to about (4.08-4.99) electrons/m^3*10 due to the ionization process.

To illustrate the day to day variation of the electron density April 2005 has been chosen because of the great fluctuations in the electron density at this month, in figure-7 it's clearly noticeable that in days (4, 5 and 6) a great decrease in the electron density occurs, at the same days there is an obvious increase in the sunspot (see figure-5), we notice that the decrement happened at mid-day this decrement is clear at the days 4 and 6 in spite of the fluctuations of solar indices during these two days.

By comparing N_e of the days 11 and 14 it's noticeable that the decrease in the electron density is very clear in day 11 where it's values is between (3 - 5 electron/m^3 * 10) while at day 14 increased to reach values between (3 - 7 electron/m^3 *10). For more clarification, comparison between days 26 and 28 revealed clearly the decrement in the electron density, in day 26 its value was very low (1 - 5 electron/m^3 * 10) with the minimum peak at (1 electron/m^3 * 10) and the maximum peak at (5 electron/m^3 * 10) while in day 28 the electron density increased to reach (7 electron/m^3 * 10) but decreased to reach (1 electron/m^3 *10) as in day 26. By taking a second look on figure-5 we will also notice that at the same days the solar wind was decrease and increase respectively.



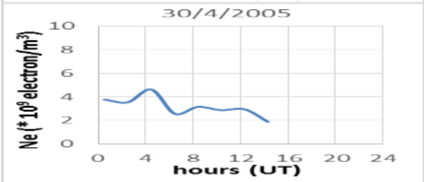


Figure 7-The hourly average of the electron density for April 2005 with an altitude range of about 90-200 km.

Conclusion:

From the obtained results, it has been found that there is a strong relation between the solar activities (solar wind speed, sunspot number and solar flux) and the electron density N_e therefore we can conclude that the electron density profile is fluctuating with the solar wind but it is inversely proportional with the solar flux and the sunspot number which means that the solar wind has greater effect on the N_e than the other indices. In general because Mars lack the presence of a magnetic field the solar activities will directly influence the ionospheric parameter (N_e) hence there will be great effects on the ionosphere of Mars.

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