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Signatures of Geomagnetic Storms and Coronal Mass Ejections on Electron and Ion Temperatures At Low Latitude Upper Ionosphere

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Abstract

Geomagnetic storms affect the whole Earth's ionosphere. In the present analysis, the electron and ion temperature variation during the big magnetic storms are analyzed to investigate the thermal energy income and the thermal energy transfer to the ionosphere. From the events presented in this study it is seen that the electron and ion temperature in the low latitude upper ionosphere is disturbed during the storm. It is observed that the plasma temperature increases during CME observed days. These observations suggest an ionospheric heating just after the ejection of CME and reduced ionospheric temperature during recovery phase. The high temperatures were the result of energetic neutral particle precipitation at low latitudes from the ring current or from energy carried to equatorial ring current or from energy carried equatorial regions from high latitudes.

Introduction

The ionosphere undergoes significant changes associated with solar disturbances. The geomagnetic storm is the most important phenomenon in the complex chain of solar terrestrial relations and space weather. The geomagnetic storm is initiated by the solar wind energetic particles captured by the magnetosphere which are dissipated in the high-latitude ionosphere and atmosphere (Prolss, 1995; Lastovicka, 1996). It is now well established that major geomagnetic storms are the consequence of a sequence of events that originate in the Sun and result in a geo effective solar wind flow near Earth (Brueckner et al., 1998; Gopalswamy et al., 2005; Rodriguez et al., 2009; Szajko et al.,2012). During solar maximum period, solar activity is dominated by flares, erupting filaments and coronal mass ejections. Usually geomagnetic storms are identified using a few selected indices of geomagnetic activity like Kp, Ap or Dst. Coronal mass ejections (CMEs) has been observed to be the primary cause of geomagnetic storms and are more frequent around solar maximum. The long duration of southward interplanetary magnetic field (IMF) Bz, causes inter-connections with the Earth's magnetic field and allow for solar wind energy transport into the earth's magnetosphere (Joshua et al 2014). When CMEs hits the earth's magnetosphere, the magnetic field is disturbed and oscillates. This generates electric current in the Earth's ionosphere which in turn generates additional magnetic field variation leading to the occurrence of a geomagnetic storm.

Observations and Data Analysis

The ionosphere undergoes significant changes associated with solar disturbances. The studies conducted using Retarding Potential Analyzer payload onboard SROSS-C2 satellite data of electron and ion temperature is used to study the signatures of CME on electron and ion temperatures at low latitude upper ionosphere. SROSS-C2 satellite provides an excellent opportunity to study the features of electron and ion temperatures associated with magnetic storms during the rising face of solar activity. Characteristics of two large magnetic storms followed by a CME, during the period1998 and 1999 are studied. The details of the characteristics of CME and flare events were selected from SOHO space craft observations. The geomagnetic activity index Ap, solar wind velocity Vsw, F10.7 solar flux, solar flare index were used to investigate the solar and interplanetary influence on electron and ion temperatures. Flare index data used for this study were calculated by T. Atac and A. Ozguc of Boguzici University, Kandilli observatory, Istanbul, Turkey. Digital version of this data is available at **www.ngdc.noaa.gov/stp** in the solar and upper atmosphere online database.

Evolution of Te and Ti Associated with CME

The dates of the onset of CME and the occurrence of storm events are listed in table

Table 1: CME Associated Magnetic Storms

Sl. No	CME date	Geomagnetic storm date
1	2-5-1998	4-5-1998
2	18-10-1999	21-10-1999

From the Table 1 it is found that CME arrived at the Earth a few days after its ejection from the solar surface. While the electromagnetic disturbances from the Sun travel to 1 AU in minutes, the solar wind disturbances take a few days after originating at the Sun (Brueckner et al., 1998). The daytime and nighttime Te and Ti increases after the CME ejection and during the onset of associated storm days. The occurrence of the CME associated storm can be identified from the profiles of Ap and solar wind velocity. These profiles exhibit marked enhancement during storm days. Figures 1- 2 depicts the electron and ion temperatures, solar and magnetic activities during CME associated storm events.

Figure 1 depicts the variations in Te and Ti values during day and night, Ap index and associated changes in solar flare index, F10.7 and solar wind velocity. It is noticed that associated with the CME on 2nd May the geomagnetic storm occur on 4th May 1998. The solar wind velocity and associated Ap index show sharp enhancement around the CME-geomagnetic storm period. The solar radio flux also has larger value during this period. The electron and ion temperatures exhibit sharp enhancements during both day and night times. The flare index did not show any enhancement around this period.

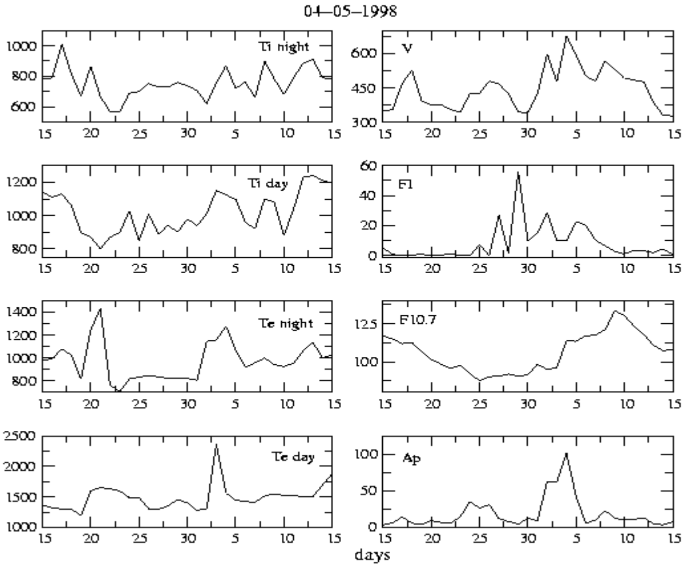

Figure 1: Geomagnetic storm time variations in Te, Ti, flare index, F10.7 index and geomagnetic activity index Ap associated with CME on 2-05-1998

Figure 2 depicts the variation in electron and ion temperatures and associated variations in solar wind and solar activity indices F10.7 and flare index. Associated with the CME on 18th October 1999geomagnetic storm started on 2oth October. Associated with the enhancements in solar wind velocity and solar activity, electron and ion temperatures also exhibit enhancements.

Discussions

It has been difficult or impossible to develop any unique theory that can explain the ionospheric responses at all latitudes for storms in general. Electrodynamic drifts, meridional winds, rapid changes in atmospheric heating and thermal expansion etc., have been invoked (Fejer et al., 1990; Oyama et al., 2005), with different degrees of success to suit particular events.

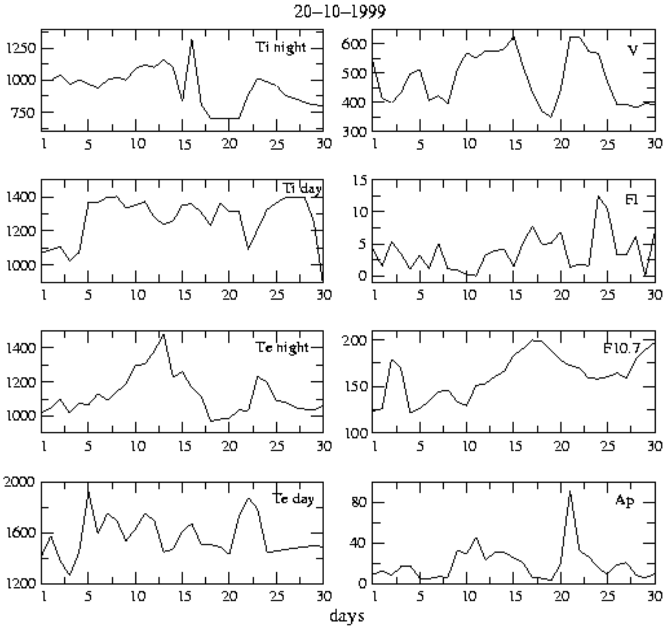

Figure 2: Geomagnetic storm time variation in Te, Ti, flare index, F10.7 index and geomagnetic activity index Ap associated with the CME on 20-10-1999

In the present analysis, the electron and ion temperature variation during the big magnetic storms are analyzed to investigate the thermal energy income and the thermal energy transfer to the ionosphere. This paper discussed the impact of CME on geomagnetic storms on low latitude upper ionospheric electron and ion temperatures. CMES are so energetic and eruptive by nature that they have very strong control on the geo-space environment. Solar output in terms of solar plasma and magnetic field ejected out in to interplanetary medium create the perturbation in the geomagnetic field. The forecasting of the storm is possible by observing the generation of solar coronal mass ejection events and predicting their subsequent path through the solar system. The result of this study show that the electron and ion temperatures increase during daytime and nighttime associated storm events. This suggests a significant heat input to low latitude ionosphere during storms (Lakshmi et al., 2000). It is established that a strong plasma temperature gradient exists in the topside ionosphere from equator to mid latitudes. The energetic neutrals produced through charge exchange with the ring current protons can precipitate in to low and mid latitude regions and the energy dissipation could be significant (Lekshmi et al., 2000). During geomagnetic storms the magnetospheric convection pattern expands equatorward and the flow is associated with a large-scale circulation system being driven from high to low latitudes during geomagnetic storm. Short lived electric fields produce significant effects on electron density and the ion temperature (Schunk et al., 1978) and these changes are the reason for the electron temperature disturbances. Ring-current protons precipitating in the equatorial F region, meridional winds and Joule heating is possible heat source for heating at low latitudes (Lakshmi et al., 2000).

Conclusion

In the present analysis, the electron and ion temperature variation during two big magnetic storms are analyzed to investigate the thermal energy income and the thermal energy transfer to the ionosphere. From the events presented in this study it is seen that the electron and ion temperature in the low latitude upper ionosphere is disturbed during the storm. It is observed that the plasma temperature increases during CME observed days. This analysis shows a relatively low temperature during the recovery phase of storms. These observations suggest an ionospheric heating just after the ejection of CME and reduced ionospheric temperature during recovery phase. The high temperatures were the result of energetic neutral particle precipitation at low latitudes from the ring current or from energy carried to equatorial ring current or from energy carried equatorial regions from high latitudes. The observations show that the ionospheric heating occur just after the ejection of CME and a reduction in temperature occur during the recovery phase of the following magnetic storm. These characteristic variations in electron and ion temperature show a strong dependence on solar transient event and the related magnetic storm characteristics.

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