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Evolution of total electron content and slab thickness at Tucumán, Argentina during some geomagnetic storms

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Resumen

En este trabajo se estudia la evolución que presentan el contenido electrónico total y el espesor de capa equivalente en Tucumán, Argentina, durante las tormentas geomagnéticas del 12 de junio de 1982, 16 de julio de 1982, 6 de agosto de 1982, 10 de diciembre de 1982 y 4 de febrero de 1983. Se encuentra que los efectos observados presentan un buen acuerdo con los llamados comportamientos "regulares". Se discuten además el papel que desempeñan los campos eléctricos y los vientos termosféricos meridionales.

PALABRAS CLAVE: Tormenta geomagnética, contenido electrónico total, espesor de capa, campo eléctrico, vientos meridionales.

Abstract

The evolution of total electron content and slab thickness at Tucumán, Argentina, during the geomagnetic storms of 12 June 1982, 16 July 1982, 6 August 1982, 10 December 1982 and 4 February 1983 is studied. It is found that the storm effects present a good agreement with so-called "regular" storms. The role of electric fields and thermospheric winds is discussed.

KEY WORDS: Geomagnetic storm, total electron content, slab thickness, electric field, meridional winds.

Introduction

Total electron content and slab thickness show irregular effects during geomagnetic storms. Studies performed principally with stations located in the northern hemisphere for storms with sudden commencement during daytime show enhanced total electron content values (positive phase) in the afternoon or evening of the same day, followed by depressed values (negative phase). These storms may be termed "regular". If a storm suddenly begins after sundown, either only a negative phase is seen or the positive phase is delayed until next afternoon ("delayed" positive storms). As to slab thickness, if sudden commencement occurs during daytime, a positive phase is seen throughout the rest of the day but on the following days a negative phase arises in the winter hemisphere while in the summer hemisphere, slab thickness shows a positive phase during the entire storm period (Titheridge and Andrews, 1967; Jones, 1971; Mendillo, 1973).

In order to check the above mentioned average patterns at South American latitudes, the total electron content (TEC) and slab thickness at Tucumán (26.9 S; 64.5 W) during a few storms from June, 1982 to February, 1983 are studied. We are mainly interested in the positive effects. The total electron content was found from the VHF signals transmitted from the geostationary satellite ATS-3. The slab thickness was calculated using the relation

$$\tau = Tec/NmF2 \quad (1)$$

with the peak electron density given by

$$NmF2 = 1.24\ 10^{-2}\ (foF2)^{2}\ . \quad (2)$$

The ionosonde data were taken from a station located at Tucumán.

The storms onsets ocurred on June 12, 1982 (1043 LT, peak Dst=-69 nT); July 16, 1982 (1118 LT, peak Dst=-106 nT); August 6, 1982 (1236 LT, peak Dst=-173 nT); December 10, 1982 (0322 LT, peak Dst=-80 nT) and February 4, 1983 (1215 LT, Dst=-169 nT). The storm in July 1982 occurred three days after the eighth largest storm within the Dst tape interval from 1957 to 1986. Simultaneous measurements of TEC and foF2 during the period of observation of ATS-3 satellite were obtained for only five storms.

Observations

We describe the disturbances on the storm day and the two following days. In all figures the continuous curve represents either the total electron content or equivalent slab thickness; the dashed curve represents their monthly median and the arrow indicates the storm sudden commencement (ssc).

The results for the June 12, 1982 storm are shown in Figure 1. Observe the enhanced values of TEC from around 20 LT on the day of the storm until around midnight of the following day of ssc. Slab thickness shows a pronounced positive phase from 16 LT on the storm day to 03 LT the next day. The positive correlation between both parameters after sunset indicates a strong lifting mechanism of plasma through the F2-layer into regions of decreased loss. The τ values remain close to the mean until around 20 LT on

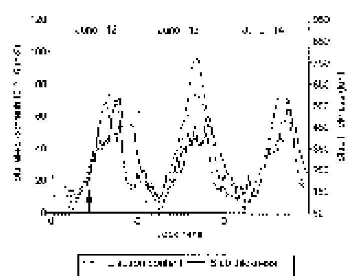

Fig. 1. Variations in the ionospheric total electron content and slab thickness during the magnetic storm of June 12, 1982. The dashed lines give the monthly mean.

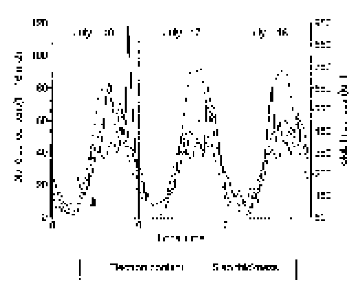

Fig. 2. As in Figure 1, for the magnetic storm of July 16, 1982.

June 13 after which they increase until 02 LT on the second day. On this day there is another increase between 15 LT and past midnight.

Data for the magnetic storm of July 16, 1982 at Tucumán are shown in Figure 2. TEC values are consistently above median values from local noon until near dusk

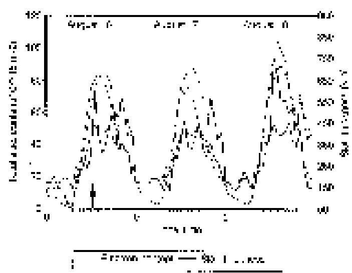

Fig. 3. As in Figure 1, for the magnetic storm of August 6, 1982.

of the day of the storm. The same is true for the two following days after ssc. Slab thickness peaks on the storm day, also from noon until dusk.

The results for the magnetic storm of August 6, 1982 are shown in Figure 3. TEC values are lower than average from near past noon until midnight on the day of the storm, and during the following day of ssc. In the early hours of August 8 the TEC values are very close to the mean but they show a positive effect during a few hours, from around 11 LT to 17 LT. At dusk they are below the mean again. The behavior of τ shows fluctuations but the tendency is a negative phase from dusk until midnight on the storm day and throughout the following day. On the second day after ssc a positive effect from 09 LT to 19 LT is observed.

Figure 4 presents the changes in TEC and τ for the geomagnetic storm of December 10, 1982. The TEC values are very close to average from the sudden commencement until near 10 LT on the storm day, when a short positive effect (two to three hours) followed by a negative phase from 13 LT to 19 LT, is observed. Undisturbed values prevail until around 23 LT on the following day when TEC values are again below normal during seven hours. Slab thickness is enhanced from ssc until around noon on the storm day, after which it drops below the mean until near dusk on December 11 when it recovers mean values.

Figure 5 shows the behavior in TEC and τ for the storm of February 14, 1983. TEC values are enhanced from ssc until around dusk on storm day. The rest of that day, throughout the following day and until dawn on February 6, they are below mean values. The analysis of τ is incomplete because foF2 data from ssc until afternoon of the following day are unavailable, but a negative effect is seen from around 17 LT on February 5 until midnight. Later there are enhanced values until 10 LT with subsequent depressed values.

Discussion

A few deviations from the average pattern are observed. For a starting storm time as in June, July, August (winter storms) and February (summer storm) one might expect a positive phase on the storm day (in the afternoon or evening) and a negative phase afterwards. The storm in August does not show this behavior in TEC on storm day. The rest of the storms show marked agreement with the expected behavior. The storms of June and July show positive effects throughout the day following ssc while the storm on February shows an important negative effect after a brief positive. The storm on December 10, 1982 shows a negative phase in TEC past noon up to 19 LT on storm day, matching average behavior; the negative effects appear also during nighttime.

The slab thickness values are higher than the mean from around local noon until near midnight on the storm day in two winter storms (June and July) and they are very close to their mean values the day after ssc. The observed response in τ during these storms coincides with the expected behavior. In December storm, the slab thickness shows a behavior as expected. Moreover, in two of the

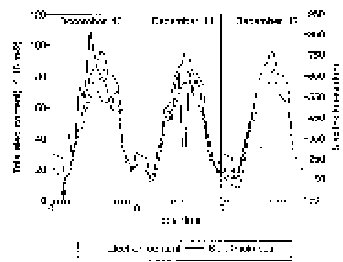

Fig. 4. As in Figure 1, for the magnetic storm of December 10, 1982.

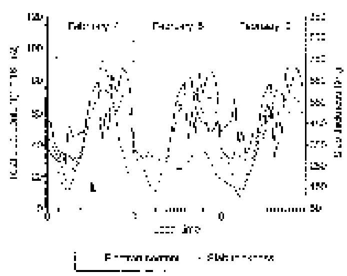

Fig. 5. As in Figure 1, for the magnetic storm of February 4, 1983.

winter storms considered here (June and July) the major increase of the total electron content occurs during the afternoon of the day following the ssc, but in summer storms it presents a negative phase on the following day of the ssc. In all storms the observed values of TEC reach a minimum during sunrise of the second day after ssc.

The positive phase may be explained by electric fields

(Martyn, 1951; Tanaka and Hirao, 1973; Mendillo *et al.*, 1987; Jakowski *et al.*, 1992) or by southernly winds carried equatorward by traveling atmospheric-ionospheric disturbances (TAIDs) (Jones and Rishbeth, 1971; Prölss and Jung, 1978; Prölss *et al.*, 1991).

The conspicuous positive effects on July 16, 1982 and on February 4, 1983 storms are nearly simultaneous with the sudden commencement. If several hours are required for the storm winds to propagate from auroral to mid-latitudes, the enhancements observed in the first stage of the storm may be due to a fairly rapid mechanism, such as an intensified magnetospheric electric field which lifts the plasma up to regions where the losses by recombination are lower. The "all day" enhancements on some storms may be an effect of equatorward winds produced by Joule heating at auroral latitudes during storm periods, which promote or substitute for the initial effect of the electric field. It is unlikely that the magnetosphere could maintain a large-scale electric field for many hours (Hagan, 1979; Volland, 1979; Forbes, 1989).

No important storm effects are seen during the night. Presumably, the plasma is pushed to higher altitudes by an electric field (geomagnetic storm of December 10, 1982) or by southerly winds. As the nighttime electronic density is lower than during the day and the layer is initially at higher altitudes, a lower rate of recombination would produce only a small effect (Fuller-Rowell *et al*., 1994).

The negative phases after the positive effects, or during most of the storm period, are also caused by these southerlies which transport nitrogen-rich air from auroral to high-latitude and middle-latitude regions. The composition disturbances produced by geomagnetic storms affect the ionization of the upper atmosphere; a close correlation between magnetic storms increases of N_2/O density ratio and depletions of the ionospheric plasma density has been found (Prölss, 1980).

Long-lasting positive storm effects may also be produced by changes in the neutral gas composition, since a moderate decrease of the N_2/O density ratio is often observed (Prölss, 1987). The resulting reduction in the ionospheric loss rate will contribute to any increase of the electron density. However, this mechanism remains to be established for large positive effects.

Thus, thermospheric winds play a crucial role in the maintenance of the positive phases (uplifting the plasma) and for the negative phases (transport of molecular constituents).

In conclusion, the study of a few storms suggests a good agreement with the "average" patterns. However, some contradictions are found. This is not surprising, since the F region plasma is controlled by a number of competitive mechanisms. More simultaneous measurements of total electron content and critical frequency of F2-layer are required at South American latitudes, in order to obtain a better insight on disturbed periods and a more precise average patterns.

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