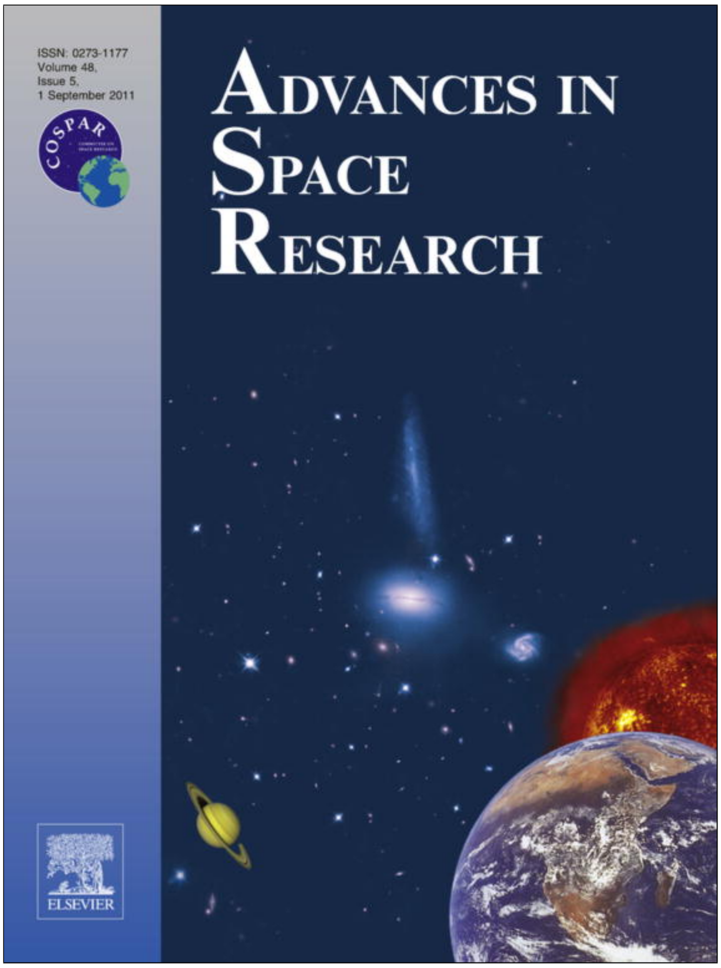
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Response of the lower atmosphere to intense geomagnetic storms

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Abstract

In this short paper we examine the possible connection between atmospheric parameters measured at low and middle altitudes and geomagnetic storms occurred in 2000 and 2003. For that, from a chain of stations located near the meridian 60°W we compare the storm time values of temperature and wind speed with their standard deviation 2σ obtained from quiet time values. We observed statistically significant variations at several altitudes during the storm recovery phase and after it, both in neutral wind speed and temperature. The results obtained suggest that atmospheric parameters could be affected by geomagnetic storms.

Keywords: Geomagnetic storm; Atmospheric temperature; Wind speed

1. Introduction

Perturbations of the ionosphere in association with geomagnetic storms have been an object of a close attention of the specialists on the ionosphere for several decades and therefore are relatively well known. Electric fields at equatorial latitudes, high latitude particle precipitation, thermospheric composition and circulation changes occur, which have been considered as physical mechanisms to explain the ionospheric reaction to geomagnetic storms observed in the ionosphere at different latitudes and different stages of the storms (see for example Fuller-Rowell et al., 1994; Prölss, 1995; Buonsanto, 1999; Danilov, 2001, and references therein).

The effects of geomagnetic storms at low altitudes have been little studied. Rocket measurements of temperature in the upper and middle stratosphere were summarized by Lastovicka (1988). The strongest influence on temperature was observed at high latitudes. Its "height profile" was: lower thermosphere and upper mesosphere: heating; middle mesosphere (~70 km): cooling; lower mesosphere (~60 km): moderate heating; and upper stratosphere: positive, but rather marginal, correlation. Lastovicka (1996) summarized some observational studies as a consequence of geomagnetic storms: a decrease of pressure after strong sporadic geomagnetic storms, particularly developed in the northern Atlantic-European and eastern Siberia-Aleutian sectors (Mustel et al., 1977); changes of the meridional profile of the zonal atmospheric pressure during geomagnetic storms (Pudovkin and Veretenko, 1992) and decreases of surface air pressure in the northern Atlantic, a deepening of the Icelandic low, and a considerable zonalization of the 500 hPa circulation over the northern Atlantic and Europe (Bucha, 1991).

Moreover, the physical mechanisms are still unknown and what exists is matter of controversy. In the troposphere, although there is some evidence of effects of geomagnetic storms, a mechanism able to explain the relations and correlations observed has not been established yet (Lastovicka, 1997).

The aim of this paper is to provide evidence of the potential connection between geomagnetic storms and atmo-

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Table 1
Stations used in this study.

	Geographic latitude	Geographic longitude
Grantley Adams	13.06°N	59.48°W
Manaus	3.15°S	59.98°W
Vilhena	12.70°S	60.10°W
Is. Malvinas	51.81°S	58.45°W

spheric parameter variations at low altitudes, i.e., between 5.5 km and 17 km. To do this, a latitudinal chain of four stations located near the meridian 60°W is considered. The atmospheric data were downloaded from the stratospheric processes and their role in climate (SPARC) website (www.atmosp.physics.utoronto.ca/SPARC/index.html).

2. Results

This study is based on the analysis of the data obtained from weather balloon flights carried out in the above mentioned region. The station names and their locations are listed in Table 1. The three considered geomagnetic storms occured on 06 April 2000 (peak Dst = −321 nT); 15 July 2000 (peak Dst = −300 nT) and 20 November 2003 (peak Dst = −422 nT). The data consist of values of the atmospheric temperature in Celsius degrees and velocity of the neutral wind in knot units (1 knot is equal to approximately 1.85 km/h) at heights from about 5500 m to 17000 m. The observations were made twice per day: 00 and 12 UT. The geomagnetic index Dst is used to represent the level of geomagnetic activity. The hourly values of Dst were obtained from the world Data Center at the University of Kyoto database (http://swdc.kugi.kyoto-u.ac.jp/dstdir).

By considering the index Dst we select the five quietest days of the month of the storm and calculate average values and standard deviation σ for the analyzed parameters separately for 00 and 12 UT because σ is different for different UT. In some stations (where the data are available) we calculated average values using observations for ten magnetically quiet days and no significant difference is

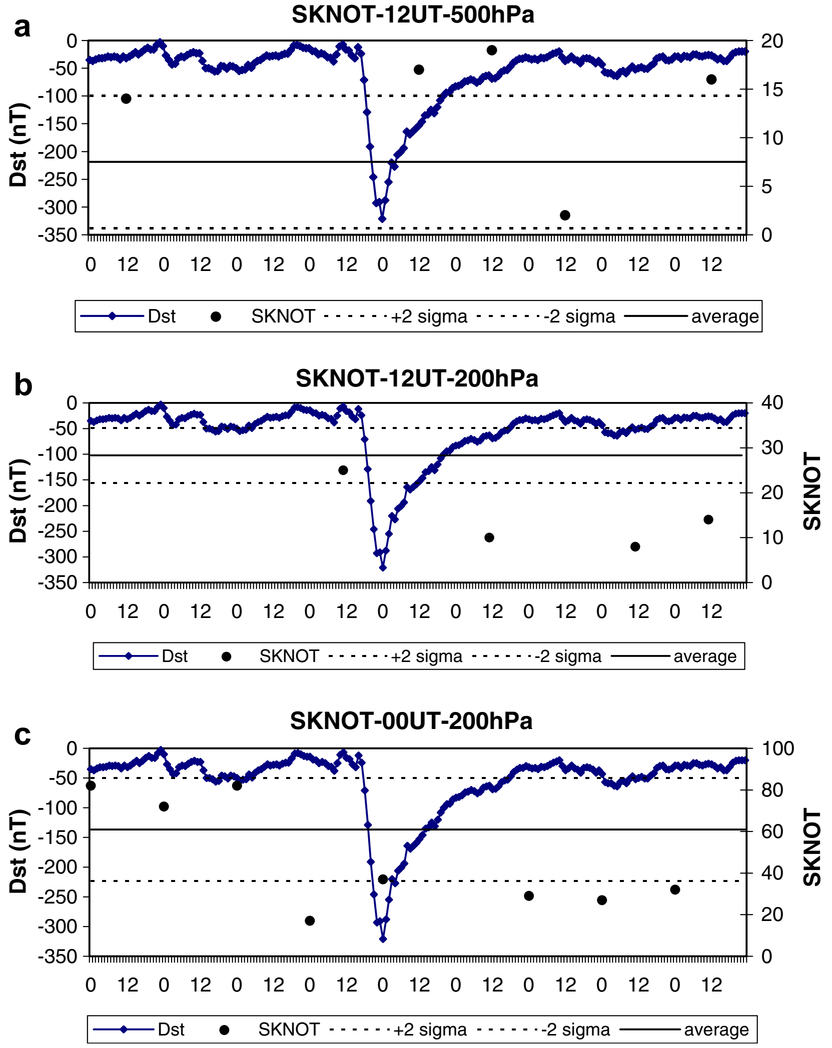

Fig. 1a–c. Variation of index Dst for the 3–11 April 2000 storm period together with data of neutral wind speed (dots) at Grandley Adams, Manaus and Is. Malvinas respectively at 00 and 12 UT. Full line: quiet time average; dashed lines show its 2σ uncertainty.

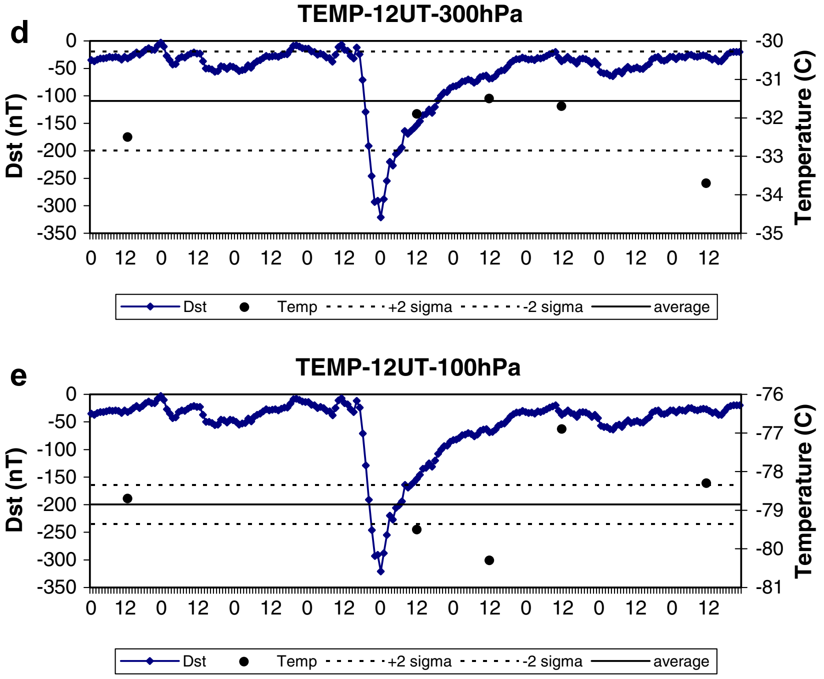

Fig. 1d and e. Variation of index Dst for the 3–11 April 2000 storm period together with data of temperature (dots) at Grantley Adams for two different isobaric surfaces: 300 and 100 hPa. Full line: quiet time average; dashed lines show its 2σ uncertainty.

observed with respect to the average value calculated using only five values. The storm effects in the atmospheric parameters may be considered as significant if the deviation exceeds 2σ. This is a usual criterion normally used to demonstrate the existence of an effect in variations of any geophysical parameter. For each geomagnetic storm and for each station, from the Northern to the Southern Hemisphere (if the data of wind velocity and temperature respectively were available) a picture was drawn. Only cases with most noticeable statistically significant deviations ($>2\sigma$) are shown in the paper.

Fig. 1a–c shows the evolution of geomagnetic index Dst for the 3–11 April 2000 storm period together with the neutral wind speed at Grandley Adams, Manaus and Is. Malvinas respectively, the average value (line) and $\pm 2\sigma$ (dashed lines). It is noticed that the most noticeable statistically significant values take place during the recovery phase of the storm and slightly later period both at 00 and 12 UT. No significant changes are observed at lower altitudes. Similar behavior is observed at Manaus at 00 UT (not shown here) with decreases of the wind velocity during the recovery phase of the storm and after it. Temperature presents in general an irregular behaviour during the storm period. Fig. 1d and e presents the temperature at Grandley Adams for two different isobaric surfaces: 300 and 100 hPa (~10 and 17 km). It can be noticed that the temperature behavior seems to depend on altitude: statistically significant increases or decreases can be noticed during the recovery phase depending on the height level. Is. Malvinas also presents values of temperature at 100 and 200 hPa outside the 2σ band a few after the recovery phase of the storm (not shown here).

Fig. 2a presents the variation of Dst index for the 11–19 July 2000 storm period together with the experimental val-

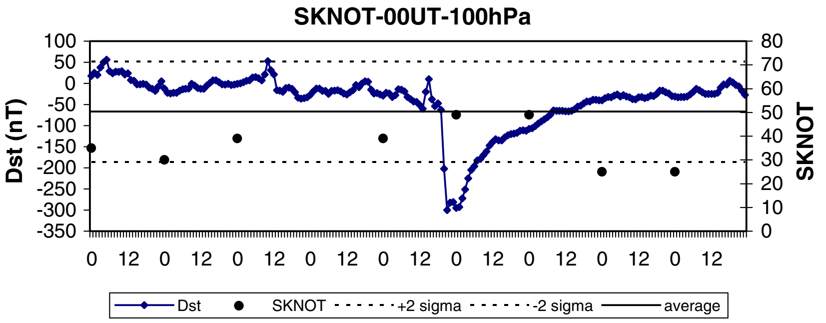

Fig. 2a. Variation of index Dst for the 11–19 July 2000 storm period together with data of neutral wind speed (dots) at Is. Malvinas for the 100 hPa level (00 UT). Full line: quiet time average; dashed lines show its 2σ uncertainty.

ues of neutral wind speed, average value and the relative deviation ±2σ at Is. Malvinas for the 100 hPa level (00 UT): as in previous storm, statistically significant depressed values are observed after the recovery phase. Unfortunately, wind data are not available at the remaining stations for the mentioned period, which prevents to determine if statistically significant effect related to the storm is also seen in other latitudes. With respect to the temperature, Fig. 2b and c (Is. Malvinas at 00 UT) shows the typical behavior observed at low levels of isobaric surfaces (300 and 500 hPa): values located outside the 2σ band during the main phase and end of the recovery phase. It is not possible to determine the behavior at higher altitudes because no data were available.

As examples of the third storm event, Fig. 3a and b shows the variation of index Dst during the 17–26 Novem-

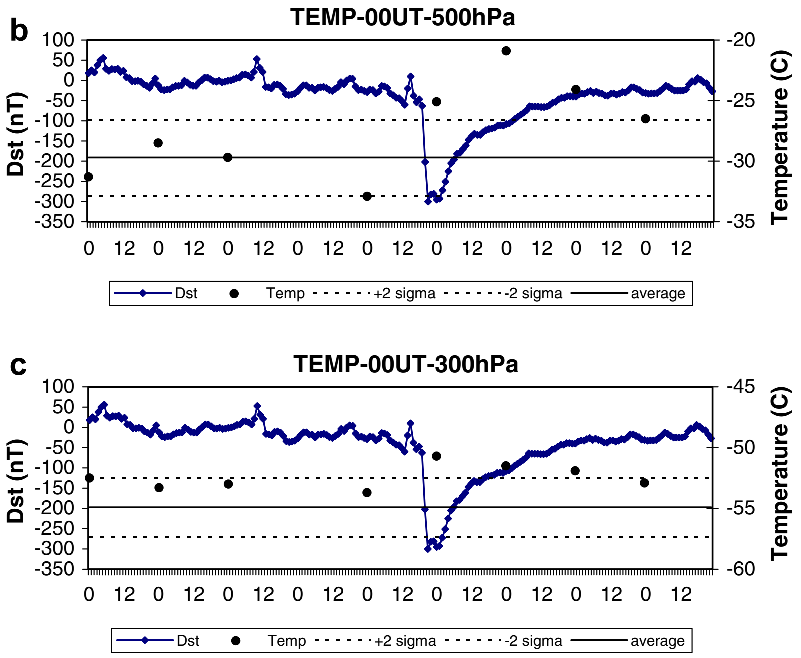

Fig. 2b and c. Variation of index Dst for the 11–19 July 2000 storm period together with data of temperature (dots) at Is. Malvinas for the 500 hPa level (00 and 12 UT). Full line: quiet time average; dashed lines show its 2σ uncertainty.

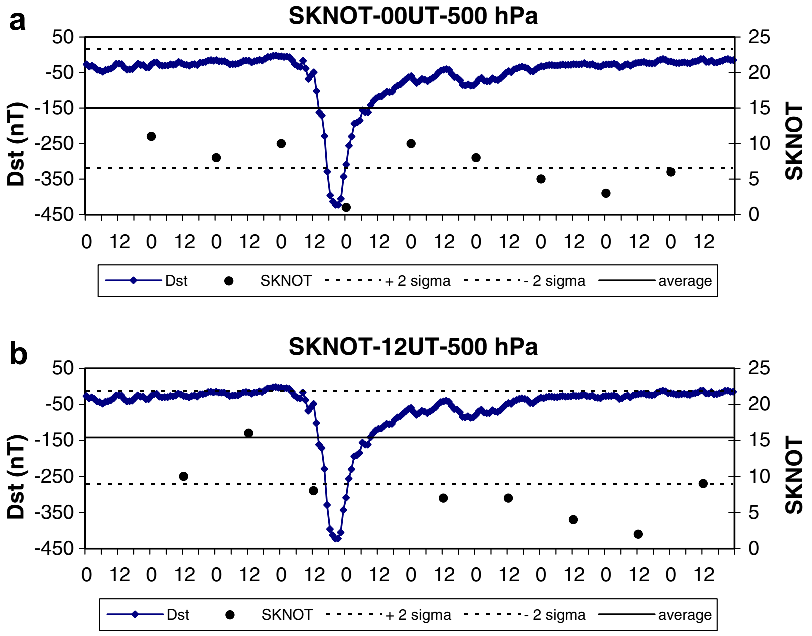

Fig. 3a and b. Variation of index Dst for the 17–26 November 2003 storm period together with data of neutral wind speed (dots) at Manaus for the isobaric surface 500 hPa (00 and 12 UT respectively). Full line: quiet time average; dashed lines show its 2σ uncertainty.

ber 2003 storm period together with the behavior at Manaus of the neutral wind speed, its 2σ uncertainty and the average value quiet days at 00 and 12 UT respectively on the isobaric surface corresponding to 500 hPa (~6 km). It is noticed that statistically significant decreases in wind velocity can be observed after the recovery phase of the storm during both daytime and nighttime hours. At Grandley Adams the neutral wind shows values slightly above $+2\sigma$ in the 100 hPa level and below -2σ in the 500 hPa level (not shown here). Vilhena and Is. Malvinas exhibit similar decreases (not showed here) which also take place after the recovery phase. Temperature presents statistically significant values below -2σ at Malvinas in the 500 hPa level after the last stage of the storm (not shown here). No significant effect related to the storm is observed in the rest of the stations during the considered storm period.

3. Conclusions

In this study, measurements of wind speed and temperature from four stations located near the meridian 60°W are used to study possible connection between geomagnetic disturbances and variations on these parameters. For this purpose, the storm time values of the wind velocity and temperatures are compared with their average values and the standard deviation 2σ separately for 00 and 12 UT. These average values were obtained by considering five magnetically quiet days outside the analyzed storm time period.

The results presented here may show evidence to support that atmospheric parameters at heights of the troposphere and lower stratosphere, at least over the sector analyzed, could be possibly related to geomagnetic storms. The atmospheric parameter disturbances observed at different latitudes and altitudes are seen during the recovery phase of the storm and slightly later period.

The experimental results may be summarized as follows:

- Following a strong geomagnetic storm, statistically significant values of the wind velocity outside the 2σ band are recorded at several altitudes during the last stage of the storm and after it at daytime and nighttime hours.
- Temperature also shows statistically significant effects during the storm recovery phase and after it, but the disturbances seem to be reduced.
- The statistically significant deviations appear only after the storm, which give to think that no meteorological factor is responsible for the reported effects.

Moreover, since the station network considered refers both to low and medium-high latitudes it can be seen that at the same altitude and time neutral wind data show an increase with latitude during the storm recovery phase. However, with the available data no clear latitudinal dependence of temperature can be found.

So, the data show a possible influence of the geomagnetic disturbances on the lower stratospheric and tropospheric circulation but in general the atmospheric parameter disturbances seem to be different at different altitudes.

Summarizing, the observation of statistically significant deviations from the mean values of the neutral wind velocity and temperature at different latitudes during the recovery phase and slightly later period suggests a potential connection between the atmospheric parameter variations and geomagnetic storms. Obviously, no definite conclusion can be established by considering only three cases. More events need to be studied before to obtain a pattern of behaviour of the variations of temperature and wind speed depend on geomagnetic storms. The detailed analysis of aforementioned effects will permit a better understanding of this relationship and the knowledge of physical mechanisms involved and/or the improvement of predictive models of the atmosphere which is far from being solved.

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