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Auroral Equatorward Shifts Observed at Belgrano Station

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RESUMEN

Se estudiaron los avances bruscos hacia el Ecuador, de las observaciones aurorales rayadas detectadas desde la Estación Belgrano (78.°S; 38.8° W) ocurridas durante los meses de invierno de 1981.

Se superpusieron las evoluciones temporales detectadas durante cuatro horas (alrededor del instante de comienzo del corrimiento del despliegue) de los índices de actividad geomagnética del casquete polar (PC) y del electrochorro auroral (AL y AU) y parámetros relevantes del viento solar y del campo magnético interplanetario (IMF), para 18 subtormentas.

El presente trabajo confirma la vinculación existente entre la componente sur del IMF (Bz) con la ocurrencia de subtormentas y con la intensidad del electrochorro auroral hacia el oeste.

ABSTRACT

Auroral observations of equatorward extent of the rayed auroral displays are researched. Ground-based observations at Belgrano Station (78.0° S; 38.8° W) during the southern winter months of 1981 are considered.

Four hourly sequences of geomagnetic indices AE, AL, AU and PC, the interplanetary magnetic field (IMF) and relevant solar wind parameters are superposed for 18 substorms.

The present work confirms (during the 240 minute intervals centered at the sudden equatorward shift event) the relationships existing between the southward interplanetary magnetic field component (Bz), and the auroral occurrence of substorms and the westward auroral electrojet intensity.

1. Introduction

The aurora is the visual manifestation of the interaction between the solar wind and the magnetosphere. In the auroral phenomena, a change in the auroral image on the polar upper atmospheric provides valuable information about changes in the electric and magnetic fields in the space around the Earth.

The intensification and expansion of the aurora reflect the temporal and spatial evolution of the disturbed region in the magnetosphere (Nakamura *et al.*, 1993). The solar wind energy couples into the magnetosphere with an effectiveness which depends notably on the orientation of the interplanetary magnetic field (IMF) relative to the geomagnetic field (Bargatze *et al.*, 1987). Prior papers (Fairfield and Cahill, 1966; Rostoker and Fälthammar, 1967) suggested the importance of the southward component of the IMF in producing geomagnetic disturbances.

Rostoker *et al.*, 1988, saw that the response of the current systems to a southward turning of the IMF depends on the level of magnetospheric activity prior to that southward turning. Troshichev, 1990; studied the global dynamics of the magnetosphere for northward IMF conditions, and verified that electric fields, field aligned currents, aurora and particle precipitation are different when the IMF is southward. These statistical studies also pointed out an association between interplanetary magnetic field and geomagnetic activity (Rangaranjan, 1991 and Murayama *et al.*, 1980).

Murayama *et al.* (1980), shown that AL/V^2 increases linearly with the southward interplanetary magnetic field component (when it is negative). Several examples of substorms have been described during which the morphological features of the solar wind plasma parameters did not show appreciable variations (Aubry and McPherron, 1971).

Foster *et al.* (1971), studied 86 isolated substorms, for the period from June to December 1967 by considering the AE index as a measurement of substorm activity to evaluate the relationship between the solar-wind proton, and the IMF magnitude and equatorial-plane components.

King (1986), researched fluxes of solar wind protons, momentum and energy for the years 1976 and 1979 to reconsider the distributions of relevant solar wind parameters and to reexamine the availability of near-Earth solar wind data.

The present work can be seen as a review and extension of prior studies that used Southern Hemisphere data (Silbergleit, 1994 and Silbergleit, 1995). We examine the temporal evolution of magnetic field parameters, plasma parameters, and magnetospheric substorms on a time scale of some 7.5 minutes during events of sudden equatorward shifts (SESs). In addition we study the possibility of using the auroral zone geomagnetic activity for estimating the solar wind velocity during the 240-minute intervals centered at the detected event.

2. Event Selection

To detect the auroral displays, all-sky camera recordings were used at 1 minute intervals, backed up by 15 minute visual observations collected at Belgrano Station (placed on the Antarctic continent at 78.0° S; 38.8° W).

Some 40 appearances of rayed aurorae, each consisting of AL index values smaller than 300 nT were selected for the period from May to August 1981, equatorward shifts of rayed auroral displays were considered, and the number of substorms was reduced to 18. Table 1 shows the date of these auroral substorms.

Table 1. Date of the auroral substorm considered in the present study.

Number of Substorm	Date	Time (UT)
1	April 23	3h. 42.5min.
2	May 6	3h. 35min.
3	May 7	1h. 51min.
4	May 10	23h. 50min.
5	May 23	0h. 45min.
6	June 1	8h. 40min.
7	June 2	3h. 22.5min.
8	June 25	21h.35min.
9	June 26	22h.12.5min.
10	June 27	10h. 17.5min.
11	June 29	3h. 57.5min.
12	June 30	20h. 57.5min.
13	July 1	3h. 22.5min.
14	July 2	2h. 05min.
15	July 3	5h. 55min.
16	July 28	3h. 20min.
17	August 12	5h. 20min.
18	August 13	5h. 50min.

Figure 1 shows an example of poleward and equatorward extent of a rayed aurora during the course of an auroral expansion. All-sky camera pictures show bright regions which indicate the equatorward expanding zone. The pictures were obtained on June 25, at 21h 35min and 21h 36min, respectively, the top is to the west and right is to the south.

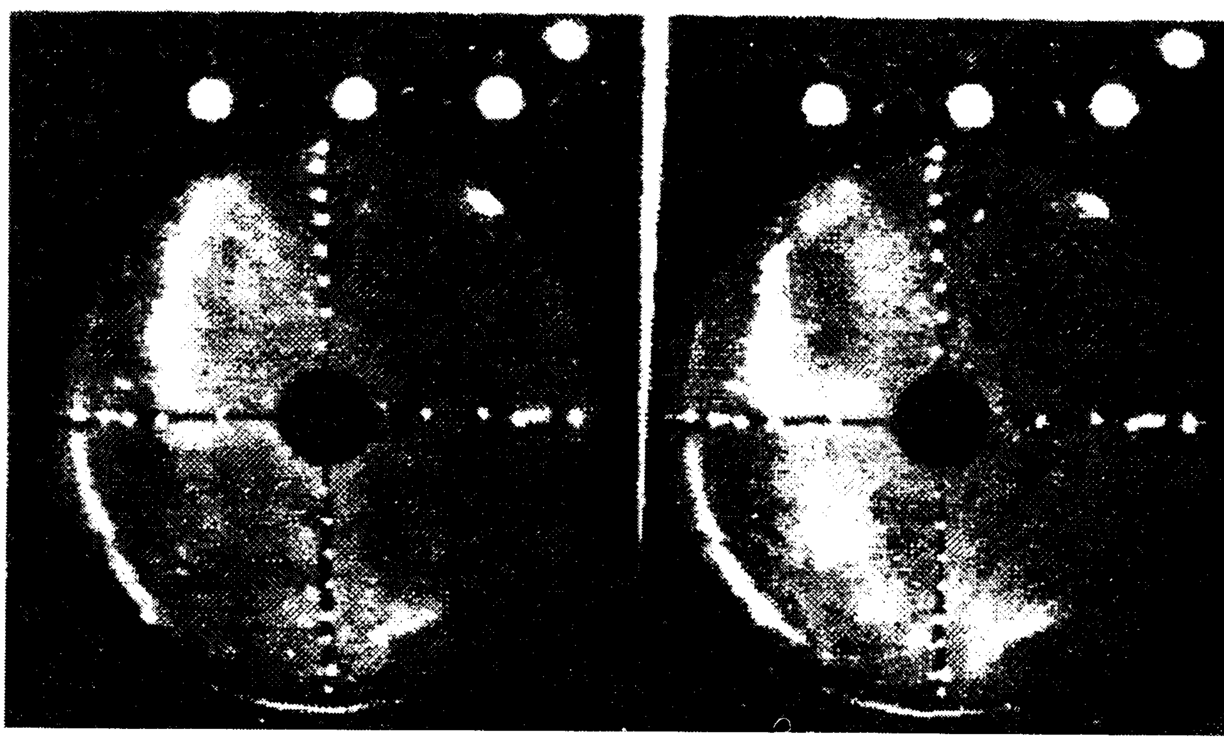
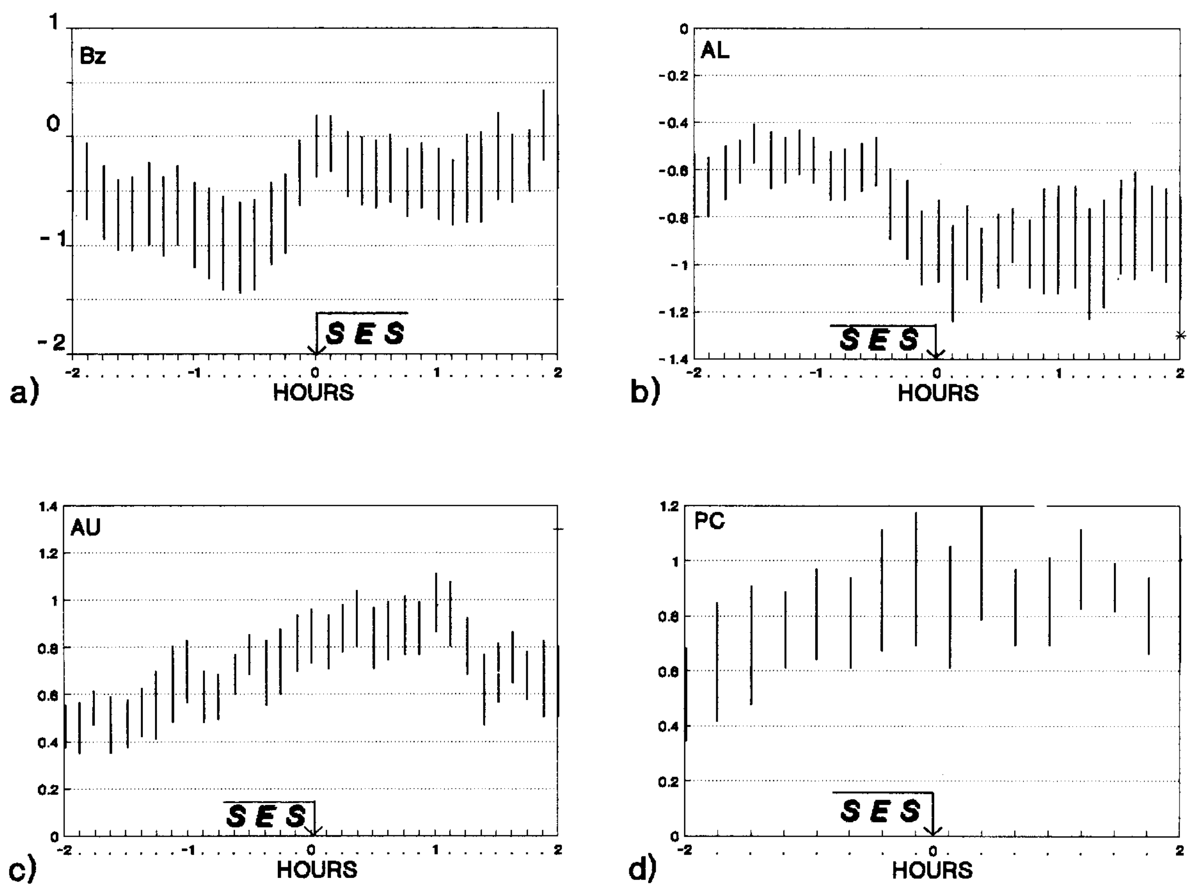


Fig. 1. Rayed auroral expansion as obtained by one-minute all-sky-camara records placed at Belgrano Station during the auroral substorm on June 25 at 21h.35min and 21h. 36min, respectively. Top is to the west and right is to the south.

The solar wind and interplanetary field parameters data existed continuously for the 4 hours studied for each isolated substorm. Solar wind and interplanetary field parameters were measured aboard IMP-8 spacecraft. Four hours of data were considered for each substorm, beginning 2 hours prior to SESs. We used the interplanetary parameters, the geomagnetic indices AU and AL and the polar cap index recordings at 7.5, 2.5 and 15 minute intervals respectively. The rectangular components of IMF were expressed in geocentric solar magnetospheric coordinates (GSM).

3. Results

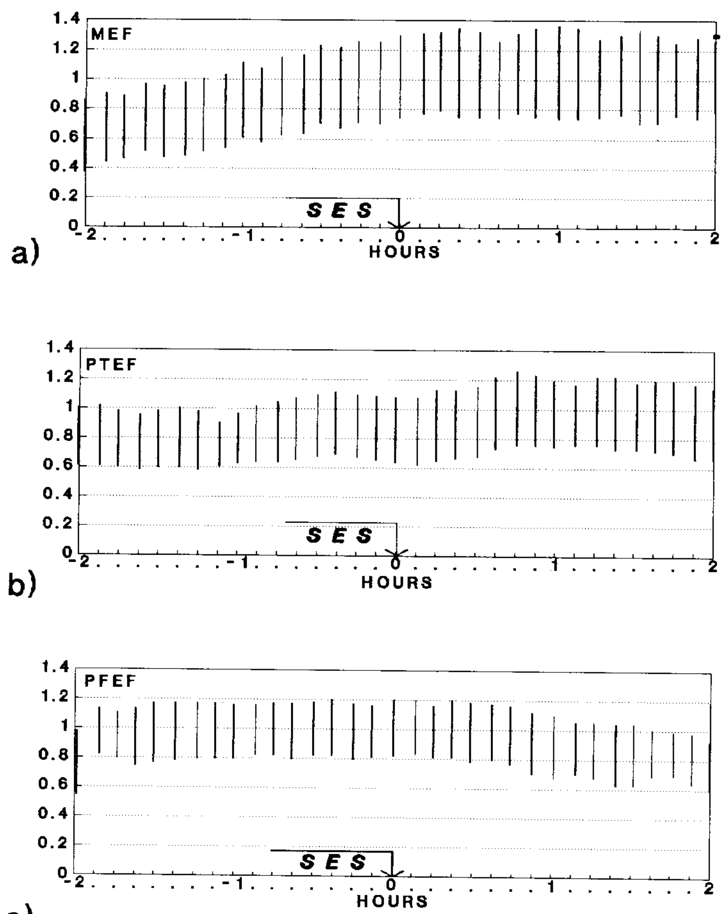
The 4-hour average values of the plasma parameters and the geomagnetic indices varied greatly from one substorm to another. A superposed epoch analysis technique was used to know the characteristics of the data, that were common to the majority of the isolated substorms considered (Bargatze *et al.*, 1993 and Foster *et al.*, 1971). It should be noted that the average values of substorms in general depends on the selection criteria used to identify isolated substorms as studied by Gonzalez *et al.* (1994). The ensembles average for the 18 events of geomagnetic indices, plasma parameters and fluxes of solar wind protons, momentum and energy were normalized to the value peak of the mean substorm. The vertical bars plotted in Figures 2 and 3 represent the magnitude of the standard-deviation and they reflect the wide range of values seen in the different isolated substorms.



Figs. 2a, b, c and d. Average development of the Bz component and the indices AL, AU and PC, respectively, for the group of 18 events selected. Figure 2a shows that Bz component of IMF is negative during the 4 hours considered and it shows a small peak around 30 minutes before the SES time.

Figure 2a represents the average development of Bz component of IMF. It is negative during the 240 minutes and it shows a small peak around 30 minutes before the SES event. The auroral electrojet activity index AL decreases greatly from -40 minutes to culminating soon after SES (as it is shown in Figure 2b). There is a delay of some 40 minutes between Bz and AL minimun values. The average AL index responses to the interplanetary parameters found here, confirms that it is closely related to the average Bz component. Figure 2c shows the temporal evolution of AU index, we can see that it increases around the SES (from -45 min. to 60 minutes). Figure 2d shows the superposed analysis of the polar cap index (PC). We can observe a gradual increase during the 240 minutes around the appearance of the SES.

Smoothed behaviour are obtained for the average magnitudes of: proton density (N), solar wind bulk speed (V), magnitude of the IMF (B), proton momentum flux (PMF = NmV^2) and proton number flux (PNF = NV) (not represented here).



Figs. 3a, b and c. Evolution of the magnetic energy flux (MEF), proton thermal energy flux (PTEF) and proton flow energy flux (PFEF) respectively, throughout the 240 min-interval. Figure 3a shows a gradual increase of the MEF during some 150 minutes without a special signature at SES, followed by a slight decline the scatter, compared with the general trends is great, and increases systematically. Figure 3b indicates that the PTEF is a roughly constant level from -120 min. till -75 min., followed by a slight minimum near than -70 minutes. After wards the general trend is upward, especially distinct after the SES till a peak at 45 minutes, possibly significant in spite of the slightly scatter. Figure 3c shows the smooth perfomance of PFEF during the 240 minutes with a constant level from -110 min. to about 30 minutes.

Proton flow energy flux (PFEF = $0.5NmV^3$, where m is the protonic mass), magnetic energy flux (MEF = $VB^2/8\pi$) and proton thermal energy flux (PTEF = 1.5NkTV, where k is the Boltzmann's constant) during the 4 hours studied are shown in Figures 3a, 3b and 3c. Moreover, the average proton temperature (T) and MEF show a gradual increase during the 240 minutes around the SES and PTEF, show an insinuating smooth mount around 22 minutes before SES.

Figure 4 shows the linear relationship between AL index and Bz component. The central solid line shows the best adjustment achieved from the fit, it agrees with: a) the prediction of Murayama *et al.* (1980) and b) the results published by Rangaranjan (1991). The dashed area points out the uncertainties obtained with the addition (upper line) or subtraction (lower line) of two-standard-deviations. The V values are taken in units of the most probable solar wind speed (400 km/s). The correlation coefficient obtained is r = 0.67.

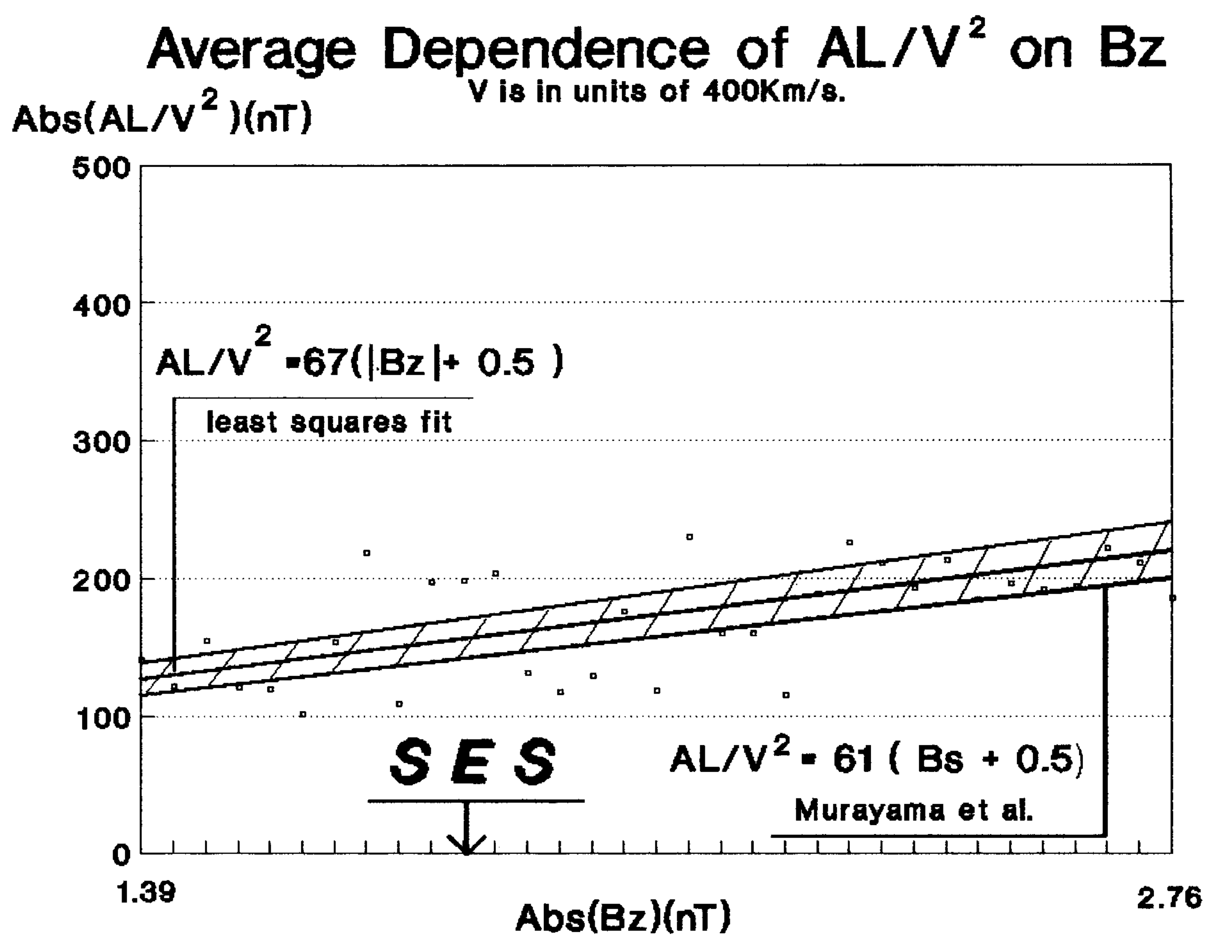


Fig. 4. Linear relation between the AL index and Bz component. This index only shows a significant relationship with the IMF when it is directed southward. In the present study the least squares fit predicts:

$AL/V^2 = 67[Abs(Bz)+0.5]$ with $Bz < 0$

The central solid line shows the best adjustment achieved from the fit. The lower solid line coincides with the results of Rangaranjan (1991).

Table 2 summarizes the average values of the interplanetary parameters and the fluxes of solar wind protons, momentum and energy obtained in the present study and published in prior papers.

Table 2. Mean values of IMF, solar wind parameters and the fluxes of solar wind protons, momentum and energy.

Magnitude	Prior authors			Present work
	1976(1)	1979(1)	1967(2)	
B(nT)			7.17	5.7+/-0.5
T (°K)x10^3			140	226+/-10
V (Km/s)	445+/-101	419+/-82	446	533+/-50
N (cm^{-3})	10.0+/-6.4	8.2+/-6.4	4.53	5.6+/-1.3
PNF (cm^{-2} s^{-1})	(4.1+/- 2.4)10^8	(3.3+/-2.4)10^8		(2.9+/-0.9)10^8
PMF (g/cm-s^{-2})	(3.0+/- 1.8)10^{-8}	(2.3+/-1.8)10^{-8}		(2.7+/-1.2)10^{-8}
PFEF (erg/s-cm^2)	0.68+/-0.54	0.49+/- 0.48		0.71+/-0.36
PTEF (erg/s-cm^2)	(6.8+/-7.6)10^{-3}	(4.6+/- 8.4)10^{-3}		(13.9+/-5.1)10^{-3}
MEF (erg/s-cm^2)	(6.0+/- 6.2)10^{-3}	(11.9+/-21.3)10^{-3}		(5.5+/-1.5)10^{-3}

(1) Taken from King, 1986.

(2) Taken from Foster et al., 1971.

4. Conclusions

This study presents the average development of 18 isolated substorms. We analyzed the time-evolution of the particle and field information during 4-hourly intervals centered at the instant of the SES observed at Belgrano Station.

The data examined verify the good correlation existing between the southward interplanetary magnetic field component and the occurrence of substorms.

The solar wind proton data and the interplanetary magnetic field magnitude exibit morphological features which can be related to the geomagnetic substorm development with only a modest degree of significance.

The ratio AL/V^2 increases linearly with Bz component, therefore it is indicative of a rectifier-like character of the AL index to Bz.

The magnetic field intensity B, is greater at solar active time, on the other hand, N, V, PNF, PMF, PFEF, PTEF and MEF values show a significant overlap in the range of parameters values for different solar active periods.

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