Geofísica Internacional (2004), Vol. 43, Num. 1, pp. 113-117

Comparison between indices during geomagnetic disturbances

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Received: March 31, 2002; accepted: August 26, 2002

RESUMEN

En este trabajo se comparan los índices aurorales AE, AU, AL y el índice PC de Troshichev, medido en Thule, durante perturbaciones geomagnéticas de distintas intensidades. Para la identificación de las mismas se han usado los índices Dst y AE. Se han analizado catorce tormentas, con valores mínimos de Dst entre –50 nT y –600 nT (86% de las cuales eran tormentas fuertes). El coeficiente de correlación lineal, r, entre AE y PC, es mayor de 0.65 para todas las tormentas analizadas; para el índice AL los valores de correlación son similares a los de AE; para AU los valores de r no son tan buenos. Durante las tormentas analizadas se identificaron treinta y cinco subtormentas, con valores de AE máximo entre 271 nT y 2218 nT. El 81% de las mismas tienen un coeficiente de correlación entre AE y PC mayor o igual a 0.6 y el 47% supera 0.8. Los valores obtenidos son independientes de la intensidad de la perturbación. Los resultados indicarían que el índice PC puede ser usado como un indicador preliminar de la actividad magnética global en el óvalo auroral aun durante grandes perturbaciones.

PALABRAS CLAVE: Tormentas magnéticas, subtormentas, índices geomagnéticos, índice del casquete polar.

ABSTRACT

Auroral indices AE, AU, AL, and Troshichev index from Thule, PC (Polar Cap) are compared for geomagnetic disturbances of different intensities. To identify perturbations, the indices Dst and AE have been used. Fourteen storms have been analyzed, with Dst index minimum value between –50 nT and –600 nT (86% of them are great storms). The correlation coefficient, r, between AE and PC is above 0.65 for all storms analyzed. For AL index the correlation values are close to those of AE; but r is low for AU index. Thirty-five substorms were identified, with AE maximum values between 271 nT and 2218 nT. Eighty-one percent of them have a correlation coefficient between AE and PC above 0.6 and 47% above 0.8. The values obtained do not depend on disturbance intensity. The results suggest that PC index can be used as a fast indicator of global magnetic activity in the auroral oval even during great disturbances.

KEY WORDS: Geomagnetic storms, geomagnetic substorms, geomagnetic indices, polar cap index.

INTRODUCTION

A geomagnetic storm is an interval of time when a sufficiently intense and long-lasting interplanetary convection electric field leads, through a substantial energization in the magnetosphere-ionosphere system, to an intensified ring current enough to exceed some key threshold of the quantifying storm time Dst index (Gonzalez *et al*., 1994). Dst index was introduced by Sugiura (1964) to provide a measure of the strength of the symmetric ring current. Storms are typically divided into three phases according to the signatures in Dst: Initial Phase (Dst increases to positive values up to tens of nT); Main Phase (Dst can reach negative values of hundreds of nT) and Recovery Phase (Dst gradually returns to the normal level). Following the terminology of Sugiura and Chapman (1960), storms can be classified: great or intense, those with a peak in Dst of -100 nT or less; moderate, with a peak in Dst between –50 nT and –100 nT; and weak, those with a peak in Dst between –30 nT and –50 nT. A storm has a lifetime from the order of hours to several days.

A magnetospheric substorm is an episode of energy transport and dissipation in the Earth's ionosphere and magnetosphere, which takes place in response to a time limited increase in energy input from the solar wind to the magnetosphere (Rostoker *et al*., 1999). Each substorm has a lifetime from the order of 10 minutes to 3 hours, very shorter than the one of a magnetic storm.

The auroral indices AE, AL and AU were introduced by Davis and Sugiura (1966) and were officially adopted by the International Association of Geomagnetism and Aeronomy (IAGA) in 1969. They have widely and frequently been used for the analysis of individual substorms and like a measure of auroral oval magnetic activity. AL measures the intensity of the westward electrojet, whereas AU measures the intensity of the eastward electrojet. However, these indices also contain contributions from other zonal currents in the ionosphere and magnetosphere, mainly the ring current, thus AE is defined as AU – AL so as to remove any symmetric zonal contribution.

The PC index, based on an idea by Troshichev *et al.* (1979) and Troshichev *et al.* (1988), is derived from the horizontal magnetic perturbation, measured at a single station being located very near to the pole. Both the stations, Thule in the northern hemisphere (85.4° corrected geomagnetic latitude) and Vostok in the southern hemisphere (-83.4° corrected geomagnetic latitude) have been used for PC index derivation. PC index is aimed to monitor the polar cap magnetic activity generated by solar wind parameters like the southward component of the Interplanetary Magnetic Field (IMF), the azimuthal component of the IMF (Friis-Christensen *et al.*, 1972) and the solar wind velocity. This index is a signature of the magnetic activity named DP 2 activity (Troshichev *et al.*, 1988), associated with polar cap two-cell equivalent current pattern. It was officially adopted by IAGA in 1999. The magnetic perturbation sources in near pole region are: (1) ionospheric Hall currents in the polar cap and (2) distant field-aligned currents at the poleward rim of the auroral electrojets.

During sunlit conditions the dominant source is ionospheric Hall currents, while the distant field-aligned currents are dominant in darkness. This was to be expected since the ionospheric conductivity in the polar cap is created mainly by solar UV radiation (Vennerstrøm *et al.*, 1991).

The aim of this work is to analyze the relation between PC and the auroral indices AE, AL and AU during giving disturbances of different intensities.

DATA ANALYSIS AND RESULTS

The geomagnetic perturbations analyzed in this paper are listed in Table 1. The data of auroral indices, with one-minute time resolution, were provided by the World Data Center C2 of Kyoto and the PC data, with fifteen-minutes time resolution, by the National Geophysical Data Center of the NOAA. Only data from Thule has been used. To obtain the same temporal resolution for the later statistical analysis, the auroral indices data were averaged to 15-minutes using mean value.

First, we consider fourteen storms with Dst minimum values between -50 nT and -600 nT (Table 1). The 86% of them are great storms (Dst minimum value ≤ -100 nT), distributed along the different seasons of the year.

The linear correlation coefficient, r, between auroral indices and PC index as a function of Dst minimum values, for the storms analyzed, are shown in Figure 1a-c for AE, AL and AU, respectively. From Figure 1a, r is over than 0.65 for all the storms analyzed. In the case of AL index (Figure 1b) the correlation values are near to those of AE; but r is not good for AU index (Figure 1c). The correlation coefficients have been tested with t-student test. For all the storms analyzed, r between AE, AL and PC are significant at level greater than 99%, meanwhile r between AU and PC are significant at level greater than 95% for Dst > -200 nT.

During storms analyzed, thirty five substorms have been identified with AE maximum values between 271 nT and 2218 nT (Table 1). These disturbances have different onset times of substorm expansive phase along the day.

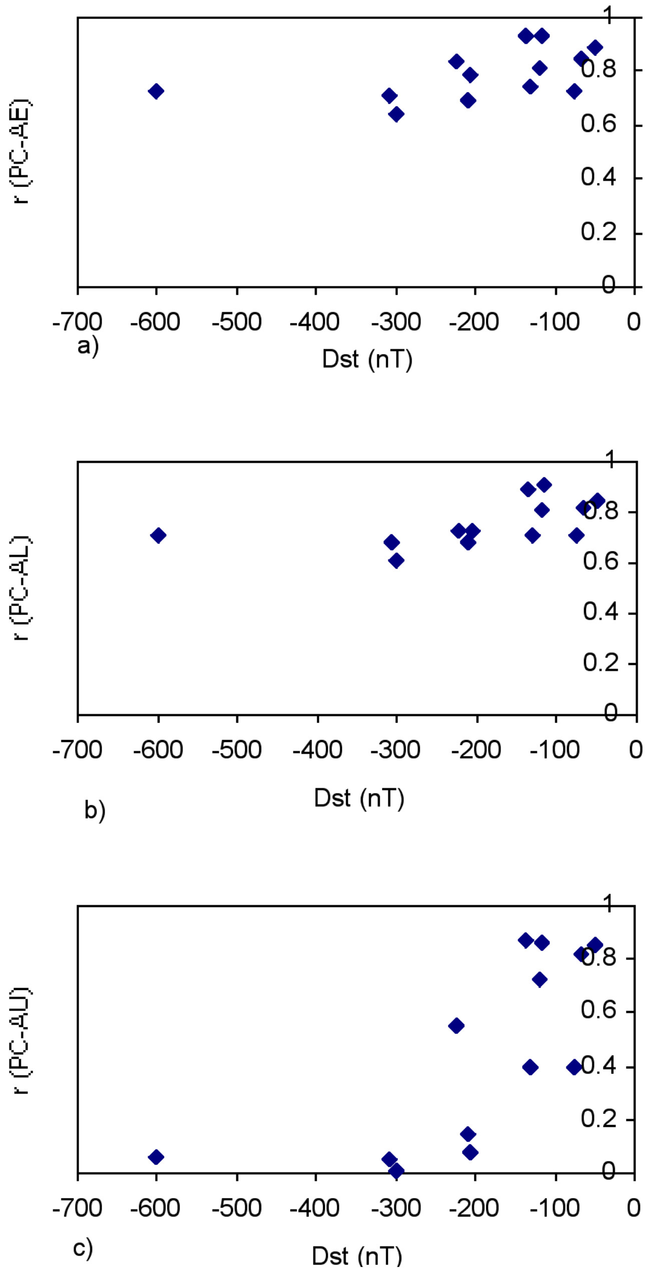

Fig. 1a-c. The linear correlation coefficient, r, between AE, AL and AU indices and PC index versus Dst minimum values, respectively, for the storms listed in Table 1.

Table 1

Geomagnetic perturbations analyzed in this paper. It also included the number of points of each substorm.

Date	Minimum Dst (nT)	Substorm AE Max (nT)	Substorm number of points	Date	Minimum Dst (nT)	Substorm AE Max (nT)	Substorm number of points
Nov.26-28,	-50	1035	29	Sep. 21-22,	-210	2218	17
1995		409	42	1982		2133	12
Jul. 2-3,	-67					1831	22
1993						1699	18
Sep. 23,	-75	2014	37			1622	7
1984		1436	42			1304	17
		1408	18			1071	20
						981	15
Feb. 17,	-117	1303	66	Jun. 5-6,	-223	2086	27
1993		834	42	1991		1515	70
						1426	30
						1148	25
Jul. 26-27,	-120	985	47	May. 9-11,	-300	1597	22
1979				1992		1352	43
						1243	42
Sep. 9-10,	-130	1567	40	Sep. 8-9,	-307	408	32
1992		1286	13	1986		281	15
		935	13			225	16
Aug. 27,	-137	1770	78	Mar. 13-14,	-600		
1993		1130	30	1989			
Feb. 21,	-144	358	17				
1994		170	18				
May. 3-5,	-205	1714	27				
1998		986	62				

The linear correlation coefficient, r, between auroral indices and PC index as a function of AE maximum values are shown in Figure 2a-c for AE, AL and AU, respectively. From Figure 2a, the 81% of the substorms have the correlation coefficient between AE and PC greater or equal than 0.6 and 47% greater or equal than 0.8. These percentages decrease to 70% and 42%, respectively, for AL index (Figure 2b). The correlation values are rather poor for AU index (Figure 2c). The correlation coefficients have been tested with t-student test too. For all the substorms analyzed, r between AE and PC are significant at level greater than 99%, meanwhile r between AL and PC are significant at level greater than 95% and r between AU and PC are not significant.

CONCLUSIONS

During geomagnetic disturbances the auroral indices, AE, AU, AL and PC index, derived from Thule, have been compared.

The conclusions are summarized as follows:

- The correlation is much better with AE and AL than with AU in all cases analyzed.

- Vennerstrom *et al*. (1991), considering AE maximum values lower than 600 nT, concluded that the correlation between AE and PC gradually decreases with increasing level of activity. We do not confirm their results because the 81% of the substorms analyzed (in 85% of them, AE maximum values are greater than 600 nT) have r greater or equal than 0.6, no depending on the disturbance intensity.

- The obtained results agree with the electrojet currency (eastward or westward) in the auroral oval according the time that the substorm breakups.

- The seasonal effects over r between AU and PC found by Vennerstrom *et al*. (1991) for quiet periods, should be cov-

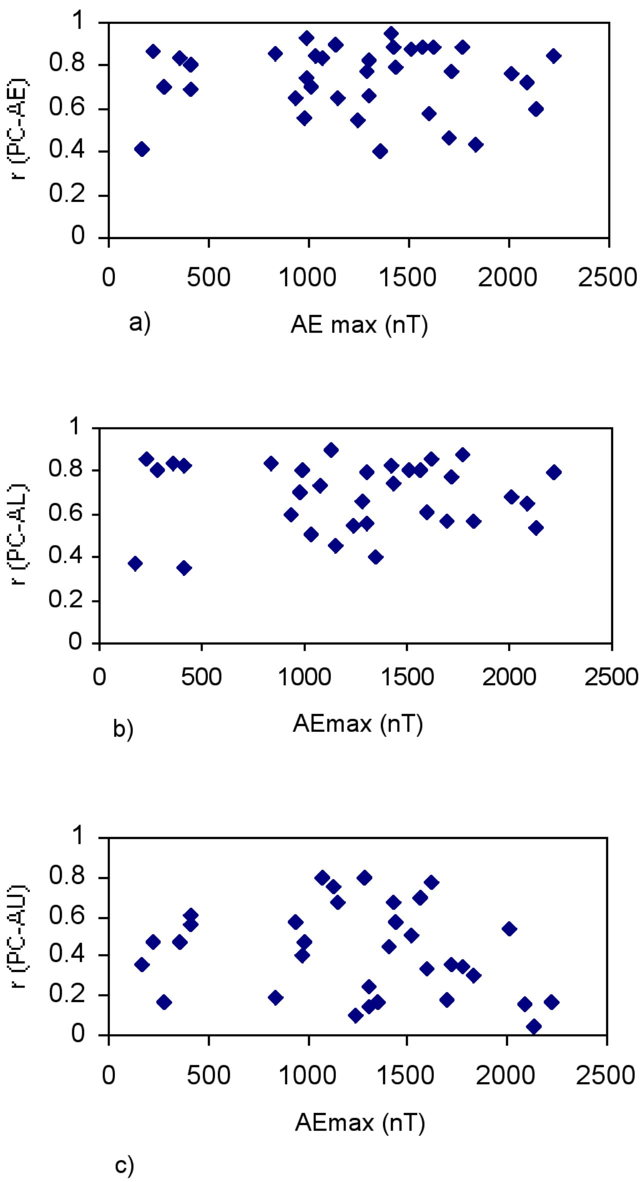

Fig. 2a-c. The linear correlation coefficient, r, between AE, AL and AU indices and PC index versus AE maximum values, respectively, for the substorms listed in Table 1.

ered up by the disturbance sources (i.e., field aligned currents, ionospheric currents, ring current, and wedge current) in the cases studied.

- The r value between the auroral indices and polar cap index for a storm shows significant differences from those obtained for the substorms occurred in the same period. This result would support the idea that the geomagnetic storms and substorms are independent processes; that is, the ring current development is not the result of the frequent occurrence of substorms, but that of enhanced convection caused by the large southward IMF (Iyemori and Rao, 1996)

- The low correlation between AU y PC would be due the magnetic local time of maximum effect at the polar cap is different from the local time sector where eastward electrojet is stronger. That is the case of the substorms occurred during September, 21-22, 1982 and February 21, 1994.

The analysis of IMF and solar wind parameters involved with the generation of the geomagnetic perturbations, would drive us to find physical mechanisms that justify obtained results. For that, it would be necessary to increase the statistics with periods where we count on the needed information. The PC index and the AE and AL indices have a high correlation for the disturb periods analyzed in this paper. These fact would indicate that the PC index may be used as a prompt indicator of the global magnetic activity in the auroral oval even during great disturbances.

BIBLIOGRAPHY

DAVIS, T. N. and M. SUGIURA, 1966. Auroral electrojet activity index AE and its universal time variations. *J. Geophys. Res., 71,* 785-801.

FRIIS-CHRISTENSEN, E., K. LASSEN, J. WILHJELM, J. M. WILCOX, W. GONZALEZ and D. S. COLBURN, 1972. Critical component of the interplanetary magnetic field responsible for large geomagnetic effects in the polar cap. *J. Geophys. Res., 77,* 3371-3376.

GONZALEZ, W. D., J. A. JOSELYN, Y. KAMIDE, H. W. KROEHL, G. ROSTOKER, B. T. TSURUTANI and V. M. VASYLIUNAS, 1994. What is a geomagnetic storm? *J. Geophys. Res., 99,* 5771- 5792.

IYEMORI, T. and D.R.K. RAO, 1996. Decay of the Dst field of geomagnetic disturbance after substorm onset and its implication to storm-substorm relation. *Annales Geophysicae, 14,* 608-618.

ROSTOKER, G., 1999. The evolving concept of a magnetospheric substorm. *J. Atmosph. Sol. Terr. Phys., 61,* 85-100.

SUGIURA, M., 1964. Hourly values of equatorial Dst for the IGY. Annual International Geophysical Year, 35, 9, Pergamon, N.Y.

SUGIURA, M. and CHAPMAN, 1960. The average morphology of geomagnetic storms with sudden commencements, Abh. Akad. Wiss., Göttingen, Sonderheft 4.

TROSHICHEV, O. A., N. P. DMITRIEVA and B. M. KUZNETSOV, 1979. Polar cap magnetic activity as a signature of substorm development. *Planet. Space. Sci., 27*, 217-221.

TROSHICHEV, O. A., V. G. ANDREZEN and S. VENNERSTROM, 1988. Magnetic activity in the polar cap- A new index. *Planet. Space. Sci., 36,* 1095-1102.

VENNERSTRØM, S., E. FRIIS-CHRISTENSEN, O. A TROSHICHEV and V. G. ANDRESEN, 1991. Comparison between the Polar Cap Index, PC, and Auroral Electrojet Indices AE, AL and AU. *J. Geophys. Res., 96,* 101-113.

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