Austral electrojet indices derived for the great storm of March 1989

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Abstract
Available magnetic records from eight stations in the Antarctica, for the March 1989 geomagnetic storm, are used to construct the southern hemisphere auroral indices, analogous to the boreal ones. The results show a diurnal variation depending on the distribution of the stations. An acceptable correlation between the northern and southern hemisphere indices are found except for the index indicating the presence of the eastward auroral electrojet. However, differences in the amplitudes of both auroral electrojet indices were observed.

Key words *geomagnetic storms – auroral electrojet indices – southern hemisphere observations*

1. Introduction

Davis and Sugiura (1966) deduced the auroral electrojet indices which give information on the level of geomagnetic activity. The AE indices, adopted during the IAGA meeting in 1969, are calculated by the World Data Center C2 for Geomagnetism at Kyoto University (Japan), considering only northern hemisphere magnetic records. Austral electrojet indices are not available, because the distribution of geomagnetic observatories around the austral auroral oval is unsatisfactory.

Troshichev *et al.* (1988) devised the polar cap index (called *PC*) using data from a nearly south pole station (Vostok). This index could be considered a sign of the magnetic activity impeled by the south component of the interplanetary magnetic field. Maclennan *et al.* (1991) deduced austral auroral electrojet indices for perturbed periods in June 1982. This paper shows a reasonable agreement for the north and south *AE*, taking into account the non-ideal locations of the observatories in the two hemispheres.

Saroso *et al.* (1992) derived the southern cap *AE* indices for the years 1966 (near minimum solar activity) and 1980 (near maximum solar activity) using magnetic records of Scott Base, Dumont d'Urville, Vostok and Mirny.

This paper discusses the analogies and differences between the indices for both hemispheres from March 13 to 16, 1989.

2. The March 1989 great magnetic storm

The March 1989 large storm (Allen *et al.*, 1989) started with an SSC at 0128 UT on March 13, and a second SSC around 0747 UT. Large negative *H* bays were recorded at middle latitude southern hemisphere observatories as Eyrewell (−47.67°, 253.52°E geomag. coord.) and another two, in which the excursion of

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the magnetometer trace went out of scale; Gnangara (−43.02°, 187.40°E, geomag. coord.) from March 13 at 9 p.m. UT until March 14 at 6 a.m. UT and Hermanus (−33.59°, 81.99°E geomag. coord.) around 11.00 a.m., 12.00 a.m. and 06.30 p.m. UT, respectively.

Changes in ionosphere and thermosphere which occurred as a response to the variations in auroral precipitation and magnetospheric convection, are statistically related to the *Kp* indices. The *Kp* index and the local *K* indices calculated for Las Acacias (23°42′S; 10°7′W, geomag. coord.) and Trelew (31°47′S; 3°6′W, geomag. coord.) varied rapidly up to 9^- and 8 respectively during the first few hours of March 13.

For the studied interval the equatorial *Dst* index decreased to −600 nT at the beginning of March 14 (fig. 1).

During the night of March 13-14, auroras were observed in Argentina, at 25°S geomagnetic latitude (Schneider, 1989); farther north than usual. Meanwhile, in the northern hemisphere these events were observed northward of 41°N geomagnetic latitude (Allen *et al.*, 1989).

Satellite data indicate that throughout the period of this superstorm the low latitude boundary of the auroral zones was well equatorward of the pre and poststorm locations. According to King (1994), no interplanetary magnetic field and solar wind data were available between March 9 (from 05.00 a.m. UT) and 15 (till 11.00 p.m. UT).

3. Data analysis and results

The method of derivation of the austral auroral electrojet indices (called *AAE*, *AAL* and *AAU*) was similar to that proposed by Davis and Sugiura (1966).

To derive these indices the ideal situation should be to use as many observatories as possible with a uniform distribution in longitude, but unfortunately only a limited number of austral observatories are placed in the region in which auroral currents are expected (from 60°S to 70°S geomagnetic latitude). Magnetic recordings (*H* component) of eight auroral and

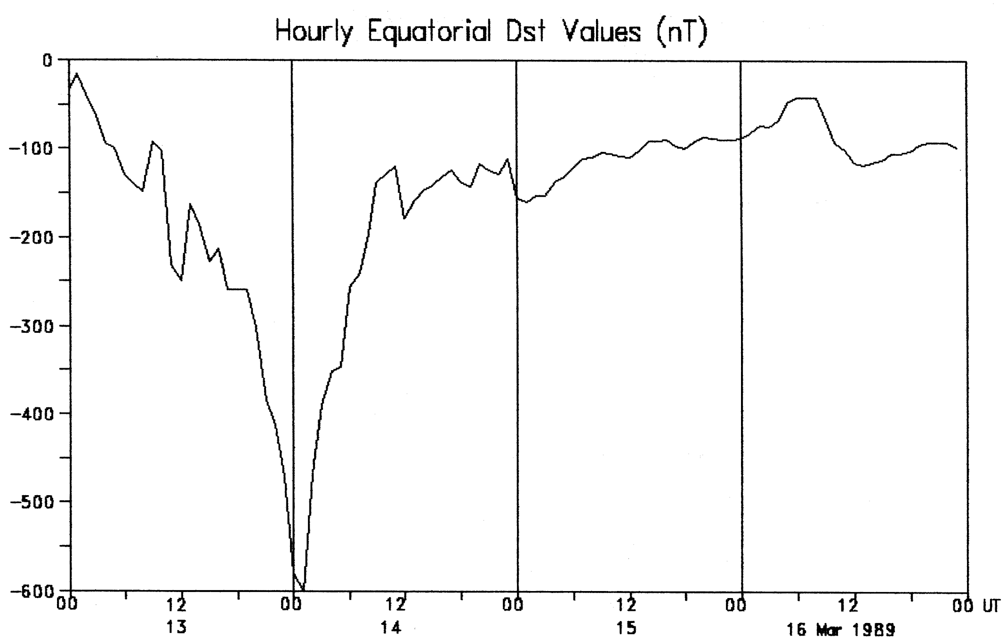


Fig. 1. Hourly *Dst* index values from 13th to 16th March 1989.

Table I. Location of the Antarctic station used in this work.

Station name	Geographic coordinates		Geomagnetic coordinates	
	Lat.	Long.	Lat.	Long.
Belgrano II	77°52′S	34°37′W	67°18′S	15°48′E
Dumont D'Urville	66°40′S	140°01′E	75°36′S	231°30′E
Halley Bay	75°36′S	26°46′W	65°48′S	24°18′E
Mirny	66°33′S	93°01′E	77°00′S	137°51′E
Molodezhnaya	67°40′S	45°51′E	70°06′S	84°36′E
Sanae	70°18′S	02°25′W	63°42′S	44°30′E
Syowa Base	69°00′S	39°35′E	69°42′S	78°06′E
Vostok	78°28′S	106°49′E	89°18′S	94°18′E

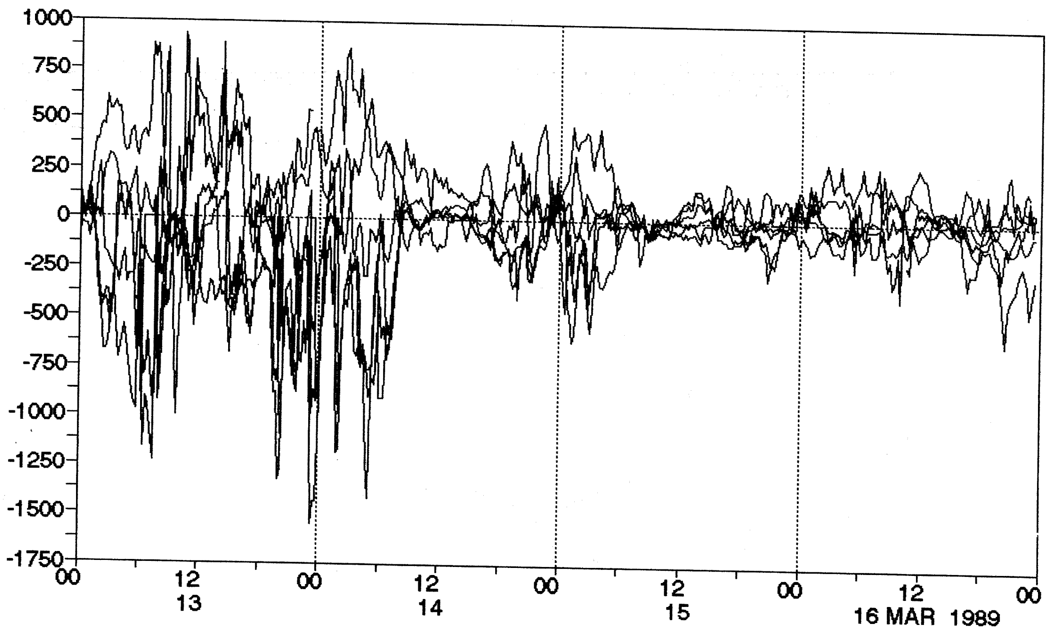
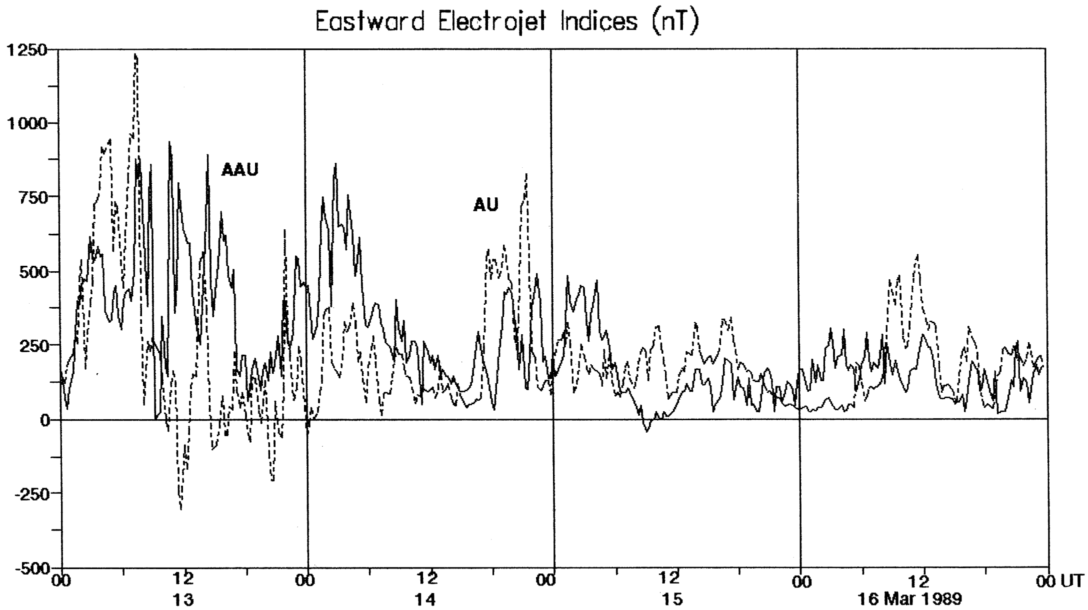


Fig. 2. Horizontal geomagnetic component, *H*, recorded in the stations used to calculate the south electrojet indices.

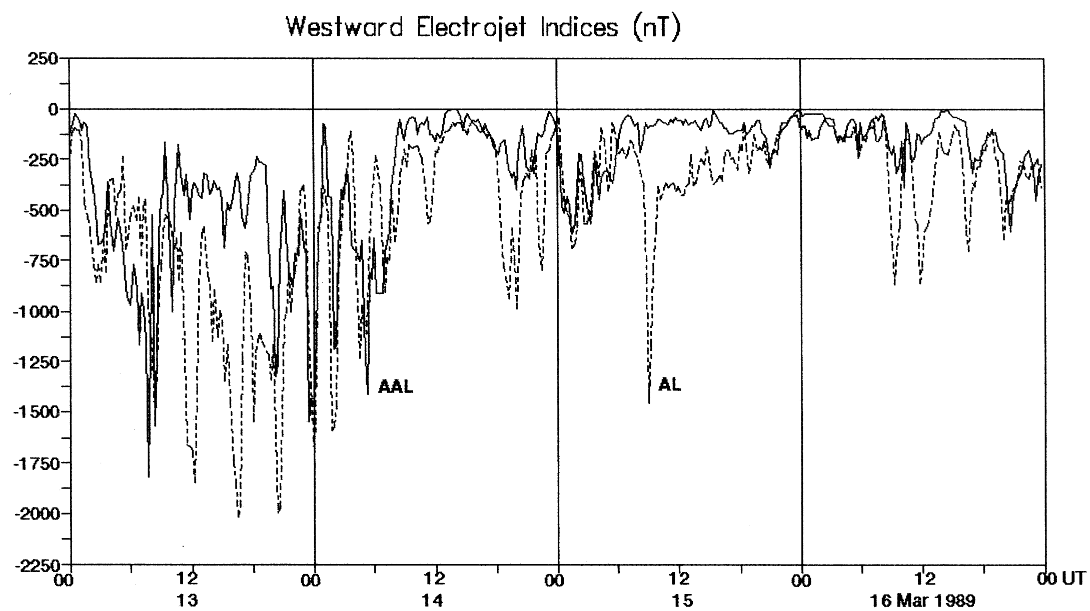
polar stations were used. Because the southern auroral zone is mostly occupied by the Antarctic Ocean, it was important to find a practical compromise for selecting the stations (table I).

Fifteen minute intervals (Mirny, Molodezhnaya, Syowa Base and Vostok) or one minute averaged (Belgrano II, Dumont D'Urville, Halley Bay and Sanae) digital data were used. Quiet time data (*Hr*) were considered a reference, to compare with instantaneous magnetic records at each station.

H-traces of magnetograms for the different stations, used to estimate the south electrojet indices are shown in fig. 2.


Eastward Electrojet Indices (nT)
1250
1000
750
500
250
0
-250
-500
AAU
AU
00
12
13
00
12
14
00
12
15
00
12
16 Mar 1989
00 UT

a


Westward Electrojet Indices (nT)
250
0
-250
-500
-750
-1000
-1250
-1500
-1750
-2000
-2250
AAL
AL
00
12
13
00
12
14
00
12
15
00
12
16 Mar 1989
00 UT

b

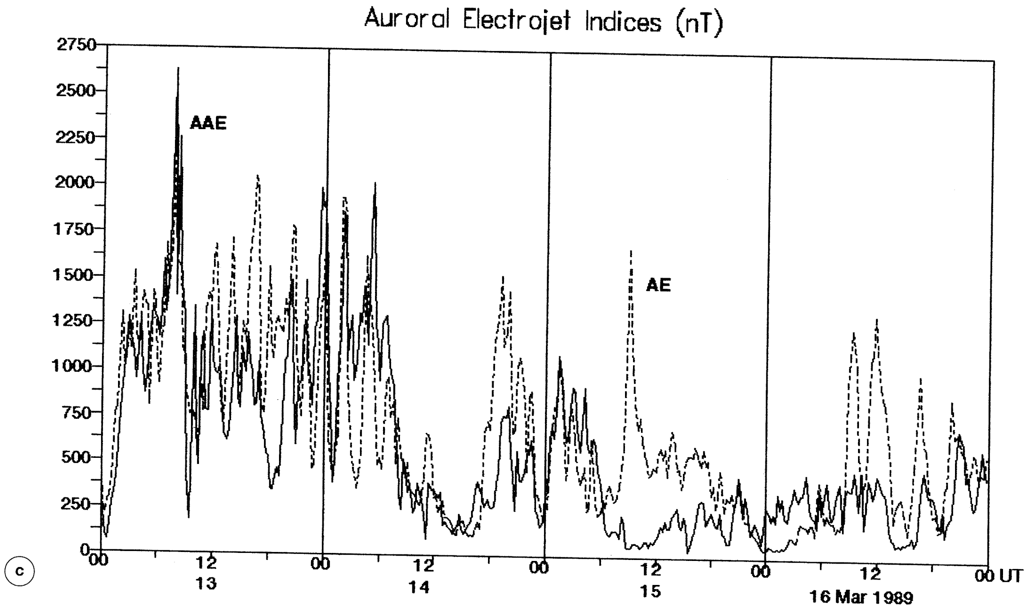


Fig. 3a-c. Indices for the northern (*AU, AL, AE* filled line) and southern (*AAU, AAL, AAE* dashed line) hemispheres from 13th to 16th March 1989, respectively. The indices were determined by averaging the values every 15 min.

The differences between *H* component and the reference levels are directly related to the magnitude of either the eastward or the westward electrojets according to the sign of the differences, $H\text{-}Hr > 0$ or $H\text{-}Hr < 0$ respectively. A similar criterion to calculate *AU, AL* and *AE* was used to determine *AAU, AAL* and *AAE*.

The 15-min time resolution indices were compared with the ones corresponding to northern hemisphere records.

Figures 3a-c show the northern and southern hemispheres indices during the studied disturbed period. Figures show similarities as well as differences in the temporal evolution of these indices.

AAL values lower than *AL* in the morning hours (*UT*) on 13th of March, with a similar behaviour for *AAE* with respect to *AE*, can be seen in these figures. This behaviour indicates a stronger southern than northern westward auroral electrojet. The behaviour reverses during the afternoon and dusk hours, this being coherent with what can be seen in the graph of the indices *AAU* and *AU*, meaning a stronger northern than southern eastward auroral electrojet.

During the *UT* morning hours (00 to 12-13 h), there are southern hemisphere (*SH*) auroral stations located at the nocturnal zone (Belgrano, Halley Bay, Molodezhnaya, Sanae, Syowa), which explains the more intense perturbation recorded at this interval of time. As can be seen, some intervals show values of *AAE* greater than *AE*, a fact which indicates a greater deposition of energy at the *SH*. On the other hand, during the *UT* afternoon hours, Mirny and Dumont D'Urville, located in the polar cap, cross the nocturnal zone, which is why significant effects on the *SH* auroral zone cannot be appreciated.

Figure 4 shows the time evolution of the difference *AAE-AE*, again indicating more intense effects on the southern auroral ring than

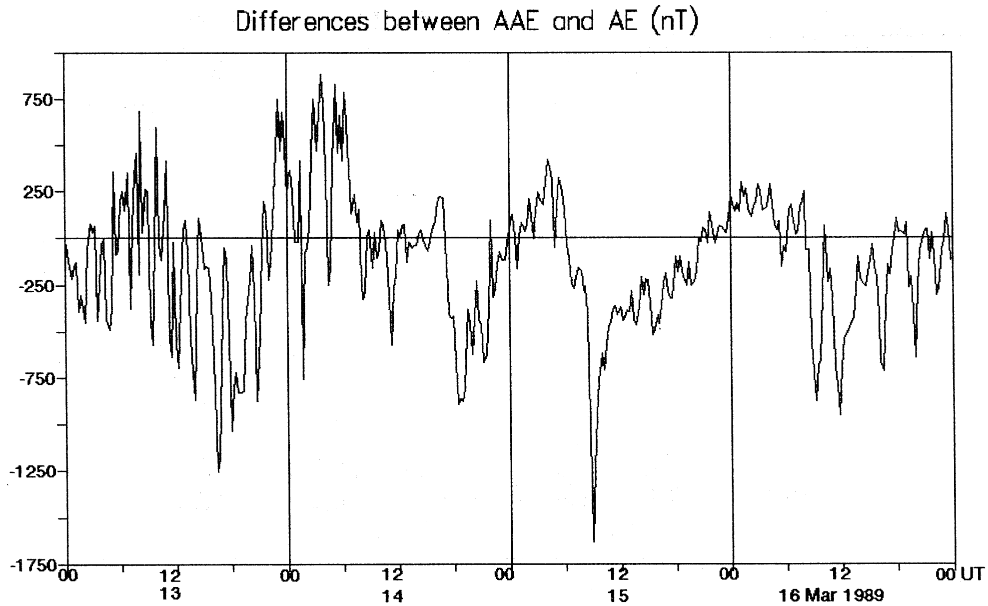


Fig. 4. Differences (*AAE-AE*) from 13th to 16th March 1989.

Table II. Correlation coefficients obtained by statistical analysis between auroral and polar cap indices.

Indices	Correlation coefficient (r)
AE and *AAE*	0.68
AL and *AAL*	0.58
AU and *AAU*	0.21
PC and *AAE*	0.50

on the northern one, during the morning hours for both 13th and 14th of March, the beginning of the main phase and of the recovery phase of the storm, respectively. This effect is in contradiction with what has generally been observed (Maclennan *et al.*, 1991).

Statistical analysis between southern and northern auroral indices was made. The corresponding correlation coefficients are shown in table II which also includes the correlation between *PC* and *AAE* indices. The values obtained agree with the expected result for a great level of activity. Figure 5 shows the temporal evolution of *PC* index from 13th to 16th of March.

4. Conclusions

Davis and Sugiura (1966) state that the derivation of the auroral electrojet indices should be made using geomagnetic data from a set of stations distributed uniformly along the auroral zone with a spacing of some 30° longitude. The distribution of the eight stations used here is far from this ideal because the austral auroral zone is mostly occupied by the Antarctic Ocean.

It must also be considered that the present index values are a lower limit as the auroral currents were well equatorward of the normal auroral zone stations.

The following conclusions were obtained:

– the big storm effects were important in both auroral network;

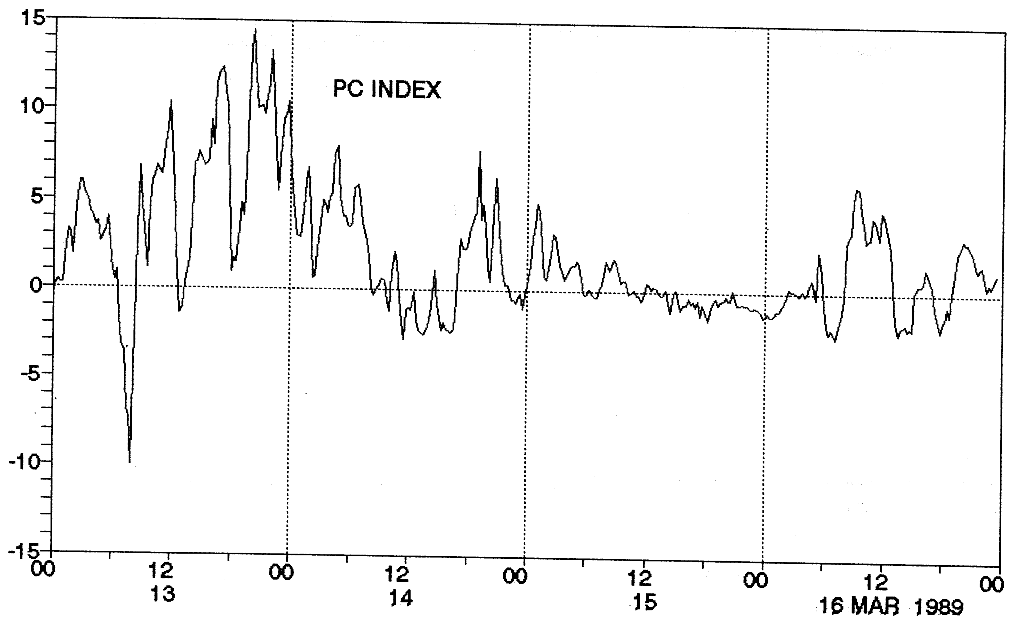


Fig. 5. Temporal evolution of *PC* index from 13th to 16th of March 1989.

– the statistical analysis (considering a time resolution of 15 min), shows that the correlation between *AAE* and *AE* indices is better than with *PC*. The correlation between *AAL* and *AL* is better than the *AAU* and *AU* one;

– differences between Artic and Antarctic auroral electrojets index amplitudes were observed with, in general, *AE*, *AL* and *AU* values greater than *AAE*, *AAL* and *AAU*. These differences might be related to hemispheric or seasonal asymmetries in ionospheric conductivities.

On the other hand, Sato *et al.* (1996) suggest that the asymmetry in the processes observed at both auroral regions are due to the fact that the triggering source of auroral breakup is not located near the equatorial plane of the magnetosphere, but it exists in the localized region between the magnetosphere and ionosphere in one hemisphere, in the present case the northern hemisphere. As a consequence, this circumstance could cause a major energy deposition in the northern auroral zone.

A direct way to check this assertion is to have access to data provided by satellite measurements at different places in the geomagnetic tail. An indirect way, besides that worked here using simultaneous measurements at both auroral regions, has yet to be devised.

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