—研究論文—
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Initial Results from Soviet Unmanned Magnetometer Network in Antarctica

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南極におけるソ連新無人磁力計網により得られた初期結果

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要旨: この 10 年間に，磁気経度 110° 線に沿って南極の polar cap 領域を通る無人観測網の観測が成功した．1978–1979 年の南極夏季に収録された地磁気変化に関する初期解析結果が得られた．その結果，南半球 polar cap 内の電離層など価電流系と惑星間空間磁場との関係は北半球の polar cap 内の電流系と類似している．しかし，この磁力計網観測は，南半球 polar cap 内の電流系と惑星間空間磁場 B_z, B_y 成分との関係に関して新しい事実を与えた．この新しい事実を解釈するために，新しく沿磁力線電流モデルの導入を思索した．

Abstract: During the last decade the unmanned magnetometer network across the southern polar cap along geomagnetic meridian 110° between corrected geomagnetic latitudes −75 and −89° has been successfully operated. Initial results of the analysis of geomagnetic variations for the austral summer of 1978–1979 have been obtained. The global features of the southern polar cap equivalent ionospheric current systems related to the interplanetary magnetic field (IMF) are similar to the northern polar cap patterns. Scanning by the meridian magnetometer chain of the southern polar cap revealed a new peculiarities in the current systems related to the B_z and B_y components of the IMF. For the explanation of these peculiarities a new model of the field-aligned currents was speculated.

1. Introduction

In recent decade, the analysis of the geomagnetic variations in polar caps connected with the interplanetary magnetic field (IMF) was successufully conducted using regressional technique (MAEZAWA, 1976; LEVITIN *et al.*, 1982; TROSHICHEV, 1982). This way the geomagnetic variations determined by the southward ($B_z<0$), northward ($B_z>0$) and azimuthal (B_y) components of the IMF were distinguished. All these results were obtained from the geomagnetic data for the northern hemisphere. Only a few works (SUMARUK and VORFOLOMEEVA, 1980; MANSUROV *et al.*, 1981; PAPITASHVILI *et al.*, 1983) were made to apply the regressional analysis to the geomagnetic data from the southern hemishphere. It was noted that there was a good agreement between southern and northern polar cap equivalent ionospheric current patterns according to SUMARUK and VORFOLOMEEVA (1980), but other authors (MANSUROV *et al.*, 1981; PAPITASHVILI *et al.*, 1983) found such agreement for variations connected with the

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B_z and $B_y>0$ components of the IMF only. The variations related to the $B_y<0$ component are identified as a separate equivalent current system; its main feature is the shift of the cusp currents to lower latitudes as compared to $B_y>0$ current system. It is necessary to note that in all works referred to here, the geomagnetic data were selected from observatories located in the different local time meridians. Condensed data of the regressional analysis, in the form of vectors, were then plotted in the polar coordinates, which are corrected geomagnetic latitude (Φ') and magnetic local time (MLT). This method of the data processing leads to the smoothening of the local peculiarities in the current patterns, but still demonstrates fairly well the regular global scale features of current systems.

The unmanned magnetometer stations (UMS) have been operating in the southern polar cap since 1975 (MANSUROV *et al.*, 1981), see Fig. 1. In this paper the initial results from unmanned magnetometer network are presented. Before coming to the

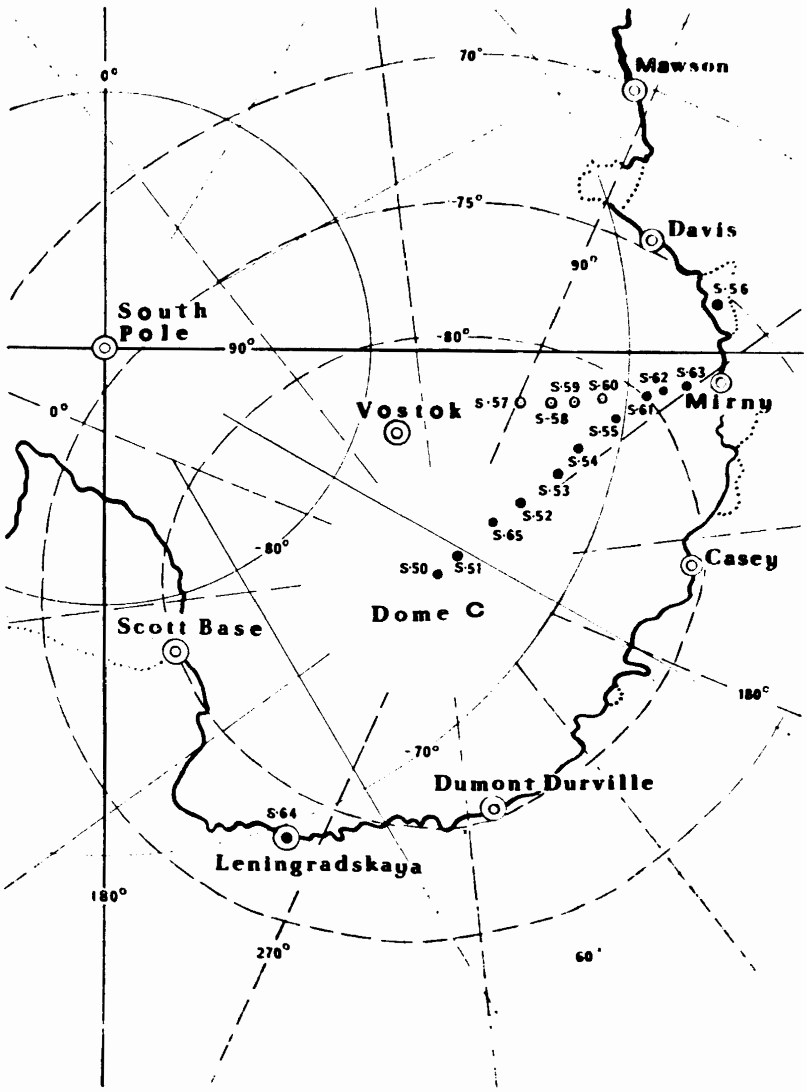

Fig. 1. The map of the Soviet Unmanned Magnetometer Network in Antarctica. Unmanned magnetometer stations (UMS) signed by S–NN.

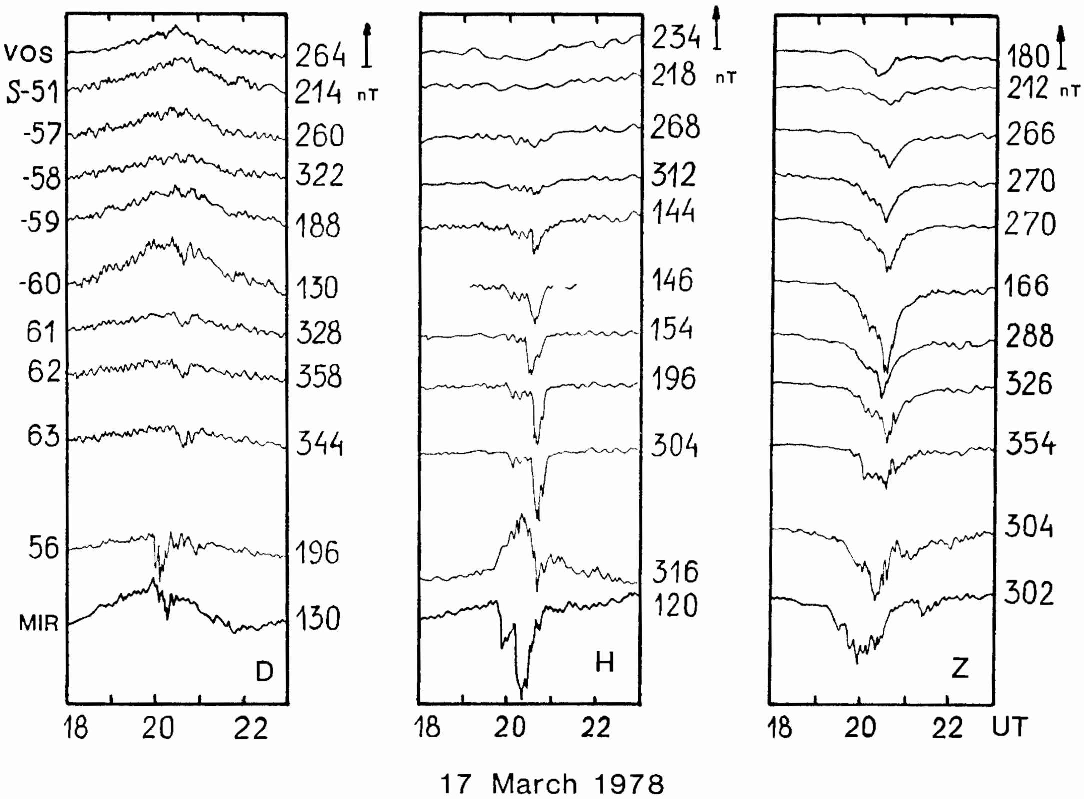

Fig. 2. Stacked magnetograms of the D, H and Z components of the geomagnetic field for the period 18:00–23:00 UT of March 17, 1978 from the UMS, Mirny and Vostok. Arrows indicate the scale factor for each station in nanoteslas.

results of the regressional analysis, we would like to show the samples of the data from the network. In Fig. 2 stacked magnetograms from unmanned magnetometer stations and Mirny and Vostok observatories are presented. These magnetograms show us the development of isolated substorms at 18:00–23:00 UT of March 17, 1978. Local midnight on this network occurred around 21:00–23:00 UT, so this substorm happened in the premidnight hours. The negative bay in H and Z components demonstrates that westward electrojet is located northward (equatorward) of the chain of stations. The influence of the electrojet is visible until latitude $-82°$ (S-57 station). On the other hand the stations, such as S-51, near the pole did not show a strong influence of currents from those electrojets. The sign change bay in the H component at S-56 station implies that an eastward electrojet existed in the evening hours. This stacked plot of magnetograms demonstrates the good quality of UMS data for the analysis of separate events. After the handling and processing of UMS data in a computer format, they become very suitable for use in statistical studies. A list of magnetometer stations in Antarctica, including the UMS, is presented in Table 1 (the coordinates in accordance with ALLEN *et al.* (1982)).

We use the regressional technique to search for a connection between the hourly mean values of B_x, B_y and B_z components of the IMF and horizontal (X' and Y') components of geomagnetic field variations from UMS (directed to the corrected geomagnetic pole and along geomagnetic latitude respectively) for the austral summer

Table 1. The list of magnetometer stations in Antarctica.

Station	Code	Geographic		Corrected geomagnetic		Local magnetic midnight (at a moment in UT)
		Latitude	Longitude	Latitude	Longitude	
Casey	CAS	66.3°S	110.5°E	80.9°S	154.9°E	18–20
Davis	DAS	68.6	78.5	74.5	99.0	22–10
Dumont Durville	DRV	66.7	140.0	80.6	235.3	12–55
Argentine Island	AIA	65.2	295.7	49.2	9.0	04–15
Halley Bay	HBA	75.5	333.3	60.8	28.2	03–15
Leningradskaya	LEN	69.5	159.4	78.4	277.0	09–55
Mawson	MAW	67.6	62.9	70.2	89.3	22–50
Mirny	MIR	66.6	93.0	77.2	121.6	20–35
Molodezhnaya	MOL	67.7	45.8	66.5	77.2	23–30
Novolazarevskaya	NVL	70.8	11.8	62.4	51.5	01–20
Russkaya	RUS	74.8	223.1	66.9	337.1	05–55
Sanae	SNA	70.3	357.5	59.9	43.4	02–20
Scott Base	SBA	77.8	166.8	79.9	327.0	06–35
South Pole	SPA	90.0	346.7	73.8	18.1	03–50
Syowa	SYO	69.0	39.6	66.1	70.8	00–20
Vostok	VOS	78.4	106.9	83.3	53.6	01–35
UMS	S-50	74.7	124.4	89.1	55.4	01–30
〃	S-51	74.5	121.0	88.4	85.5	23–05
〃	S-52	73.2	110.5	85.4	106.5	21–35
〃	S-53	72.2	105.4	83.7	110.7	21–20
〃	S-54	71.6	101.8	82.5	110.4	21–20
〃	S-55	70.5	97.8	80.8	112.5	21–10
〃	S-56	66.8	86.2	75.6	112.5	21–10
〃	S-57	74.1	97.5	82.0	89.6	22–50
〃	S-58	73.0	97.0	81.6	96.6	22–20
〃	S-59	72.2	96.6	81.3	101.6	21–55
〃	S-60	71.1	96.1	80.7	107.0	21–30
〃	S-61	69.5	95.3	79.6	113.8	21–00
〃	S-62	68.8	94.5	79.0	115.9	20–55
〃	S-63	67.9	93.8	78.2	118.3	20–50
〃	S-65	73.9	115.1	86.8	101.3	21–55

(November, December, January and February) of 1978–1979. The details of the analysis method we used are described in Troshichev (1982). The IMF data were obtained from ISEE-3 measurements in the solar-eclipitic coordinates and with a shift one hour back. In analysis we used eight unmanned stations (S-51, -53, -57, -58, -59, -61, -62, -56) and the Mirny observatory, which are located in the same LT sector. The data of the S-51 station were used with a shift two hours forward because of the difference in MLT between this station and other chain stations.

The results of the analysis are presented in Fig. 3 in the form of space-time distributions of equivalent current vectors which correspond to the change of IMF in one nanotesla. We will cover each type of variation separately.

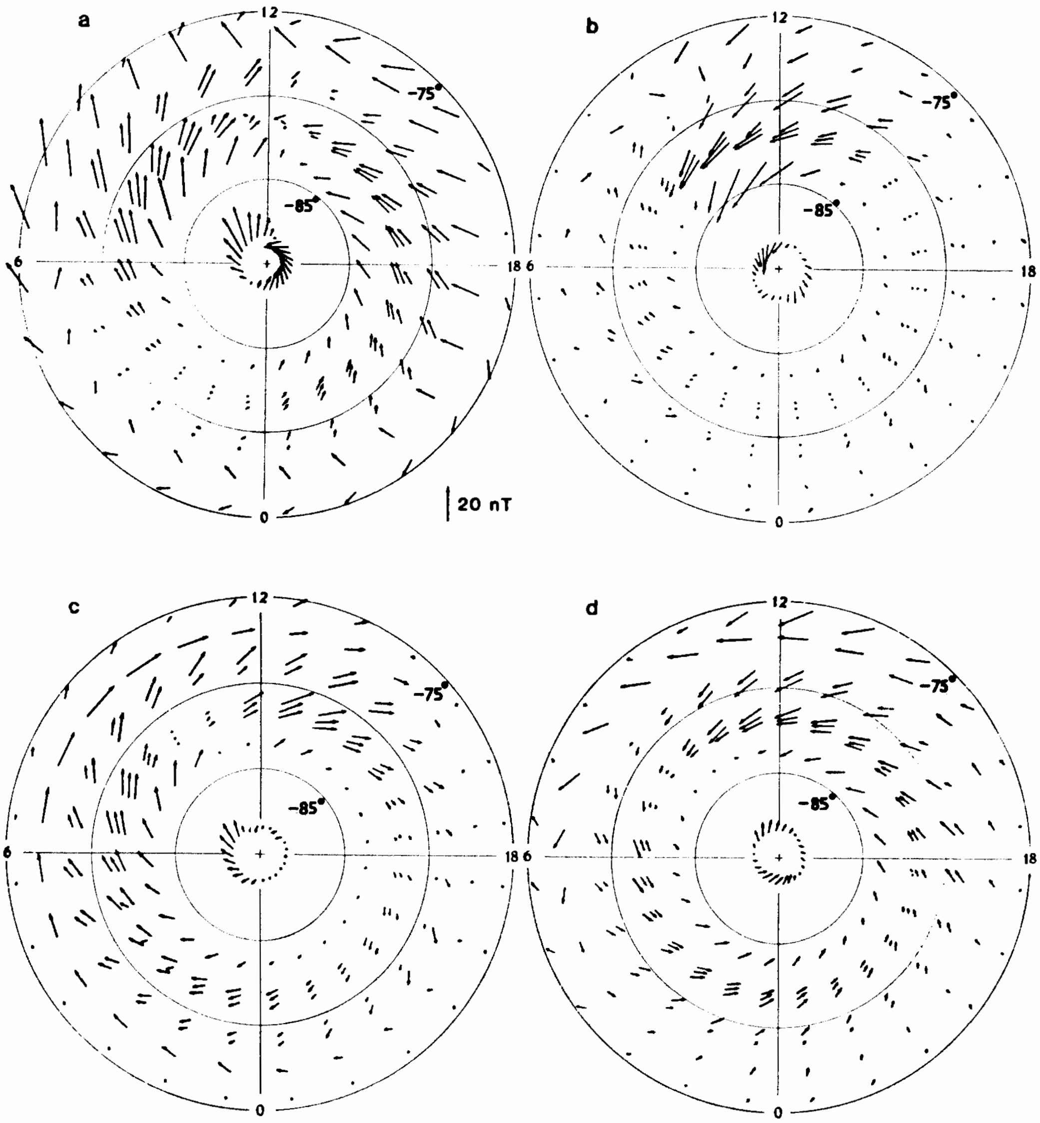

Fig. 3. The equivalent current vector distributions over the southern polar cap related to the IMF: a) $B_z<0$; b) $B_z>0$; c) $B_y<0$; d) $B_y>0$. Arrows indicate the scale factor 20 nT. Corrected geomagnetic latitude (Φ') —magnetic local time (MLT).

2. The Variation Controlled by the $B_z<0$ Component of the IMF

The equivalent current vectors for $B_z<0$ in the southern polar cap (Fig. 3a) confirm the existence of a transpolar current which flows from nightside to dayside. This current seems to be a part of the two-cell current system for high latitudes, and contains sharp bend in the afternoon hours. This change of direction in the current flow is interpreted by MAEZAWA (1976) as the influence of equivalent currents in a close loop of the three-dimensional current system related to the auroral westward electrojet. With the approach to low latitudes of the polar cap (S-56 station), the current vectors in the nightside rotate to the northeast again due to currents in the aforementioned close loop. It is necessary to note the increasing of current vectors in amplitude at all latitudes in the 17:00–19:00 MLT sector, which coincides with LT-noon hours. This effect was found earlier by LANGEL and SVALGAARD (1974). In the afternoon (11:00–14:00 MLT) and night sectors (23:00–04:00 MLT) on the $\Phi' \approx -77°$ the decreasing of vectors is often observed. In early works (MAEZAWA, 1976; LEVITIN *et al.*, 1982; TROSHICHEV, 1982) on the northern hemisphere data, this effect was not observed. But when the regressional analysis was used on the Greenland magnetometer chain data (FRIIS-CHRISTENSEN, 1979), the variations dependent of $B_z<0$ in the dayside sector decreased too (see Fig. 1 in referred work), although this point was not noted by the author himself.

As expected the current vector distribution for $B_z<0$ during the summer in the southern hemisphere lies in good agreement in global scale with such pattern for northern hemisphere, but has its own peculiarities such as the decreased vectors in tiny regions at the day and night sectors of MLT.

3. The Variation Controlled by the $B_z>0$ Component of the IMF

The equivalent current vectors for $B_z>0$ are presented in Fig. 3b. In the near pole region the vectors are pointed out in the opposite direction to the $B_z<0$ pattern. The focus of the morning cell located at $\Phi' \approx -79°$ is the 10:00 MLT meridian. For the evening cell the focus is situated not so clearly around the 17:00–18:00 MLT meridians. Some uncertainties as to the position of current cells and strong zonal current flow in the afternoon sector are the main peculiarities in the $B_z>0$ equivalent current vectors pattern for the summer in the southern hemisphere.

4. The Variation Controlled by the B_y Component of the IMF

The equivalent current vectors for B_y are presented in Figs. 3c and 3d. They appear as a single-cell pattern in which the current flow is controlled by the IMF, *i.e.*, when $B_y>0$ the current vectors are directed anticlockwise, and when $B_y<0$ the current vectors are directed clockwise. The current flow direction is opposite to those in the northern hemisphere (Svalgaard-Mansurov effect). The concentration of current vectors is observed at $\Phi' \approx -77° + -82°$ in the dayside. An increase in the amplitude of vectors also is observed in the nightside which was not observed in the northern hemisphere. In the prenoon (09:00–11:00 MLT) hours for $B_y<0$ a sharp decrease in the intensity of variations is noted at $\Phi' \approx -82°$. A small decrease is observed at 08:00–10:00 MLT at the same latitudes for $B_y>0$ too. Therefore, the presented patterns for the B_y component of the IMF clearly show its strong control of variations in the polar cap. Certain peculiarities in current vector distribution are still to be studied in detail.

5. The Variations Independent of the IMF

The residual equivalent current vectors which are independent of the IMF are presented in Fig. 4. The method of calculations for the residual part of the variations is described by (LEVITIN *et al.*, 1982). As a reference level for the variations we use the daily mean values of the free term of the multiregressional equation. The general view of the pattern is very similar to the $B_z<0$ pattern and the same patterns of the northern hemisphere. It is interesting to note that the intensity of the residual equivalent current vectors is five times more than any vectors under the IMF control. It seems very likely that this residual part is controlled by the density and the speed of the solar wind.

From Figs. 3 and 4 we may conclude that "scanning" of the southern polar cap by the meridian chain of magnetometers led us to new results: we found little distinctive decrease in the size of current vectors in limited space and time regions. Such regions coincide approximately with the projection of the cusp position in the ionosphere. Thus, we may explain that the observable peculiarities are due to the existence of field-aligned currents which flow downward on the dayside and upward on the nightside. The "curtains" of such currents may follow along the day and night meridians across the polar cap. The region of generation for such currents is evidently connected with field lines merged into the solar wind and the far part of the outer magnetosphere tail. If we follow this assumption we will find that the intensity of these field-aligned currents will depend on the moduli $|B_z|$ and $|B_y|$ components of the IMF. These assumed field-aligned currents coincide with the "curtain" of Region III according to IIJIMA and POTEMRA (1976). For the control of this assumption about the shape of the additional field-aligned currents we calculate them on the base of Fig. 3. The calculations were made on the method described elsewhere (see LEVITIN *et al.*, 1982) with the use of the homogeneous conductivity model in the polar cap iono-

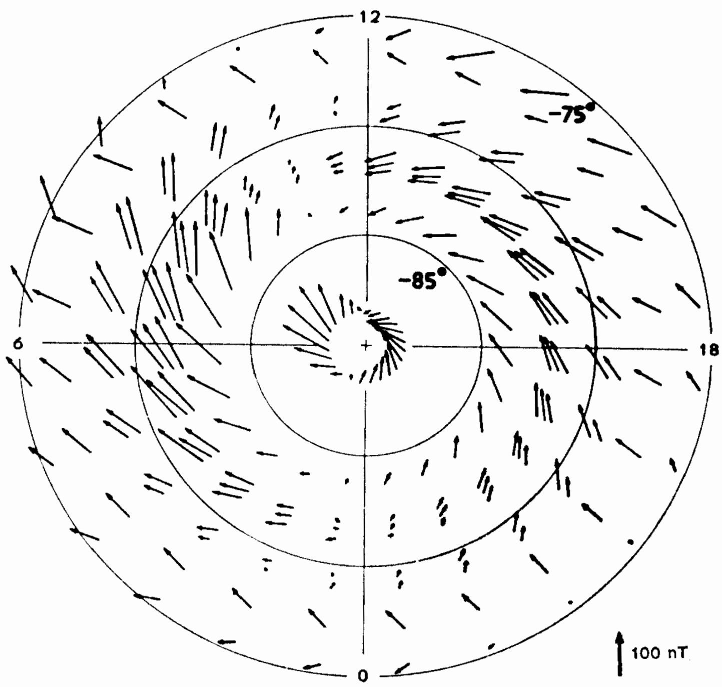

Fig. 4. The equivalent current vector distribution over the southern polar cap for the free term of the multiregressional equation. Scale factor is 100 nT.

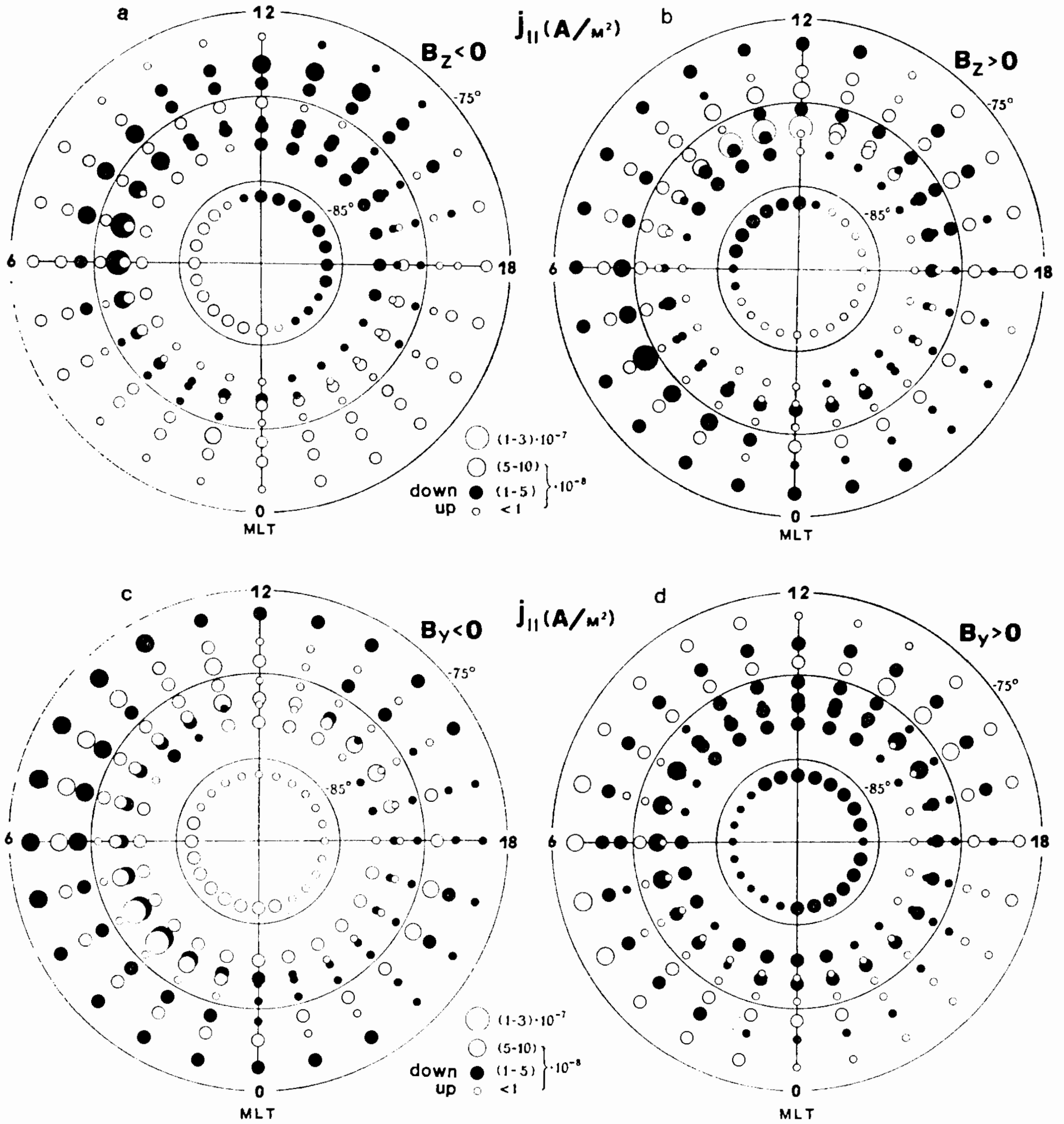

Fig. 5. Field-aligned current distributions over the southern polar cap related to the IMF: a) $B_z<0$; b) $B_z>0$; c) $B_y<0$; d) $B_y>0$. Black circles—downward currents, open circles—upward currents. Scale factors (from large to small circles) are $(1\text{–}3)\cdot 10^{-7}$, $(5\text{–}10)\cdot 10^{-8}$, $(1\text{–}5)\cdot 10^{-8}$ and less than $1\cdot 10^{-8}$ A/m^2 respectively.

sphere. In Fig. 5 we present our results of calculations in the form of space-time polar diagrames. The notation in the figures is generally accepted. In Fig. 5 for $B_z<0$ we have a strong field-aligned current strip flowing downward the morning hours. This strip extends Region I of global field-aligned current system poleward and decreases the variations (*i.e.* regressional coefficients) related to $B_z<0$. In the case of $B_z>0$ (see Fig. 5b), we have field-aligned currents in the cusp region flowing downward in the afternoon hours and upward in the morning hours. For such a loop we have an increase in field-aligned currents at the $\Phi'\approx-81°$. As a matter of fact, we have local downward currents in the morning hours near the pole. This spot of currents appears very well as a decrease of vectors (*i.e.* regressional coefficients) in the pattern in Fig. 3b. For the B_y vector distribution in Figs. 5c and 5d we observe well-known effects. For $B_y<0$ the field-aligned currents flow upward in high latitudes near the pole and downward on the border of the polar cap. For $B_y>0$ the direction of the field-aligned current pattern is the opposite. In this case we also have a few spots of opposite fieldaligned currents which coincide with the distribution of the depressional equivalent current vector for the B_y component patterns. Besides a very simple model of the ionosphere which was included in these calculations, we obtained a very good agreement between the current vector pattern and corresponding field-aligned currents and the IMF components.

6. Some Remarks and Acknowledgments

These intial results of analysis from the unmanned magnetometer network in Antarctica demonstrate a very good perspective for scientific studies. Besides some statistical studies which are now in progress, the UMS data base is suitable for use in studies of separate events and intervals, especially if we take into account the whole set of data from satellites which were in operation during the IMS period and whose data are becoming available now.

Our UMS project in Antarctica was formed by Dr. S. M. MANSUROV and memories of him were encouraging to everybody who participated in this project.

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