"Physics of Auroral Phenomena", Proc. XXIV Annual Seminar, Apatity, pp. 37-40, 2001

Polar Geophysical Institute

AZIMUTH ASYMMETRY OF REGIONS OF FIELD-ALIGNED CURRENTS IN FLOWING AND OUT FLOWING FORM THE IONOSPHERE IN THE SUBSTORM CURRENT WEDGE

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Introduction

It is know [1-3], that the orientation of the IMF B_Y -component causes an asymmetry in the evening and morning vortices of the convection. At the IMF B_Y -component directed from morning to evening, the expansion of the convection evening vortex and the decrease of drift velocity of ionospheric plasma in the afternoon and evening hours are observed in the northern hemisphere [4]. In this case, the morning vortex is constricted but the convection electric field intensity in it increases. At $B_Y < 0$ the reverse picture is observed: the morning vortex is extended and the convection velocity increases in the afternoon and evening hours [4]. The influence of the IMF B_Y sign on the picture of convection in the southern hemisphere is opposite: at $B_Y>0$ the morning vortex and at $B_Y<0$ the evening vortex are extended [5]. It is shown [6-8], that the IMF B_Y -component defines the longitudinal location of substorm centers at the ionosphere level [6] and at the equator of magnetosphere [7] and also the localization of the Harang discontinuity [7,8]: with rise of the IMF B_Y from the negative to positive values the substorm centers and the Harang discontinuity in the northern hemisphere are shifted from evening to morning hours. In [9-11] it is marked, that the B_Y sign also defines the longitudinal ditribution of the large-scale systems of the field-aligned currents of 1 and 2 zone both at the ionosphere level [9,10] and at great heights [11]. The influence of the azimuth component on the longitudinal distribution of the in flowing currents and out flowin currents in the substorm current wedge (SCW) has not been considered earlier. The goal of the present work is to investigate the dependence of the longitudinal distribution of the inflowing and outflowing currents in the substorm current wedge on the orientation of the IMF B_Y and the relationship of the longitudinal extent of the SCW to the location and intensity of the largescale convection vortices.

Methods of Experimental Data Selection and Analysis

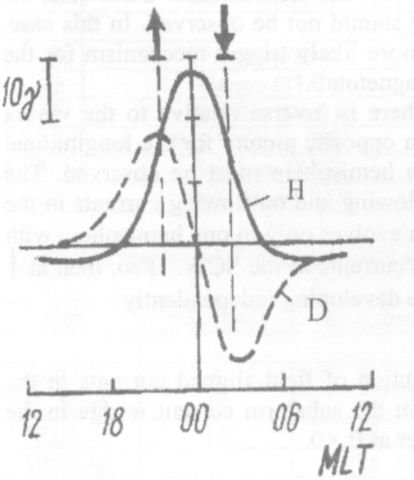

Fig.1.

During the substorm expansion phase in the night sector at middle latitudes the characteristic variations (bays) in the magnetic field D-component often occurred [12]. The sign of bay can be both positive and negative depending on the local time when this bay is fixed.

As shown in [13-14], a source of bay-shaped disturbances at the expansion phase is the Birkeland type field-aligned currents. At the substorm expansion phase at middle latitudes the disturbances in the D-component generated by ionospheric auroral zone currents are not as significant as the field-aligned effect. During substorms the observed distributions of disturbance vectors at middle latitudes are presented in Fig.1.

To analyse the data, we have selected the events when the substorm disturbances developed 1-1.5 hours after the magnetoquiet period at the IMF southern orientation ($B_Z<0$) and under the condition $|B_Z / B_Y|<1$[5,12]. The longitude of the substorm center localization was determined by the inverse of the D-component sign in the longitudinal distributions of geomagnetic variations ΔD. The onset of the substorm expansion phase was determined by the momemt of the sharp increase in the negative bays of the H-component near the longitude of the substorm center at auroral zone magnetovariation stations. The longitudinal distribution of the regions of the in flowing and out flowing field-aligned currents was constructed as the distribution of disturbances ΔD of the D-component by the magnetovariation stations. The value ΔD was calculated for every station from the averaged value 1,5 hours before the magnetoquiet level for the moments $t_1=T_0+5$ min, $t_2=T_0+10$ min, $t_3=T_0+15$ min, where T_0 is the time of the substorm expansion phase onset.

The longitude Λ_w of the eastern edge of the outflowing current region was determined as a middle of the interval between longitudes of the nearest stations which had registered $\Delta D \leq 0$ and $\Delta D>0$. The azimuth extent $\Delta\Lambda_w$ of the outflowing field-aligned current region was determined as the difference $\Delta\Lambda_w=\Lambda_w-\Lambda_c$ where Λ_c is the longitude of boundary between inflowing and outflowing currents regions. By analogy, we found the azimuth extent of $\Delta\Lambda_E$ of the inflowing field-aligned current band in SCW $\Delta\Lambda_E=\Lambda_E-\Lambda_c$, where Λ_E is the longitude of the western boundary of the inflowing current band. In those cases when the eastern boundary of the inflowing current regions in the morning sector was beyond the longitudinal chain of the stations, the size $\Delta\Lambda_E$ was estimated by the following way: the longitudinal distance from the centre of the current loop Λ_c to the station with the maximum negative value ΔD was taken as (1/2) $\Delta\Lambda_E$. The asymmetry δ in the longitudinal distribution of the inflowing and outflowing currents was determined as $\delta=\Delta\Lambda_w-\Delta\Lambda_E$. The error was supposed to be $\sigma_\delta=(2)^{1/2}\sigma$, where $\sigma=(\Delta\Lambda_{E+}\Delta\Lambda_w)/2n$, n is the number of longitudinal chain stations used to construct the longitudinal distribution of ΔD in the interval from Λ_W to $\Delta\Lambda_E$. In other words, σ is equal to the half-width of the mean interval between longitudinal chain stations. The multiplier $(2)^{1/2}$ in the expression for σ_δ takes into account that σ_δ is an error of difference. To estimate the reliability of difference in the azimuth extent of the inflowing and outflowing. This ratio is assumed to be the distribution close to the normal one. Then, t=1,7 corresponds to the fiducial probability P≈0,9.

Results and Discussion

We selected six events satisfying the above criteria: three of them are observed at B_Y >o and the other three at B_Y <0. The longitudinal distribution of ΔD (Figures 2-4) are constructed by the data of the world magnetovariational station net using longitudinal station chain located on the north-American continent. The list and coordinates of stations are given in Table 1. Table 2 presents the azimuth sizes of inflowing and outflowing field-aligned current regions, the difference δ, errors σ_δ and parameter t for times $t_1=T_0+$ 5 min, $t_2=T_0+$ 10 min, $t_3=T_0+$ 15 min. From figures 2-4 and Table 2 it is seen that in all events during all expansion phase of a substorm, the regular difference in the longitudinal distribution of inflowing and outflowing field-aligned currents in the SCW is observed: at B_Y >0 a band of in flowing currents in the northern hemisphere is broader than for the outflowing currents, and at B_Y <0 it is narrower. In the course of development of the substorm expansion phase this regularity is kept. The extension of currents during the substorm expansion phase is certainly marked only in the 16.02.96 event on the whole, on account of the increase of $\Delta\Lambda_w$. Thus, the results obtained show that the IMF azimuth component causes the asymmtry in the longitudinal disribution of the field-aligned currents of the substorm current wedge.

According to [4], at B_Y >0 the evening vortex of large-scale ionospheric convection in the northern hemisphere convection is broader but it is less intense than the morning vortex. The relation between the field-aligned currents in the substorm current wedge and the sizes of large-scale convection vortices in the northern hemisphere show that the formation of SCW is associated with the spatial distribution of magnetospheric convection and it reflects global processes in magnetosphere taking place at the substorm growth phase. From this it follows that the longitudinal location of the SCW center is not random and is defined by the convection vortex configuration. Therefore, it is unlikely that a mechanism for the SCW formation is related with a discontinuity of the current across the magnetotail on account of the anomalous resistance, where it is the most intense. Otherwise, the asymmetry in the distribution of field-aligned currents depending on IMF By should not be observed. In this case, the SCW must be developed in the region of the most intense vortex. The more likely trigger mechanism for the substorm expansion phase appears to be reconnection in the near part of the magnetotail.

In [5] it is show that the convection picture in the southern hemisphere is inverse relative to the vortex configuration in the northern hemisphere. Then in the southern hemisphere an opposite picture for the longitudinal distribution of the field-aligned current in the SCW relative to the northern hemisphere must be observed. The development of a substorm in both hemisphere with different asymetry of inflowing and outflowing currents in the SCW is umlikely. The more likely situation is that when $|B_z/B_y|<1$ substorm evolves only in one hemisphere with the appropriate asymmetry in the longitudinal distribution of the field-aligned currents in the SCW. If so, then at $|B_z/B_y|<1$ the substorms in the upper and top parts of the magnetotail should be developing independently.

Summary

It is show that $|B_z/B_y|<1$ the asymmetry in the longitudinal distribution of field-aligned currents in the substorm current wedge is observed. At $B_y>0$ a band of inflowing currents in the substorm current wedge in the northern hemisphere is broader than for the outflowing currents, and is narrower at $B_y<0$.

Acknowledgment. The authors thank the group of NSSDC Goddard Space Flight Center, headed by Dr.J.King, for Catalogue of Interplanetary medium data on CD-ROM, R.R.Lepping for data interplanetary space and magnetic field by measurement on IMF-8, International Geophysical Center of Data (SPIDR) for data magnetic field at auroral and mid-latitude stations.

The work has been carried out with inancial support by RFFI on grants on Arctic № 01-05-96222, № 01-05-96225.

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Table 1. List of stations

№	Station	Geom. longitude	Geom. latitude
	Middle	Latitudes	
1.	Anchorage (AMU)	263,8^0	61^0
2.	Sitka (SIT)	279,4^0	60^0
3.	Victoria (VIC)	295,5^0	54^0
4.	Newport (NEW)	302,7^0	55^0
5.	Boulder (BOU)	319,1^0	49,2^0
6.	Glenlea (GLN)	328,4^0	60,4^0
7.	Fredricksburg (FRD)	357,6^0	50^0
8.	Ottawa (OTT)	0,6^0	56,7^0
	Low	Latitudes	
9.	Fresno (FRN)	303,2^0	43,1^0
10.	Tucson (TUC)	314^0	40^0
11.	Del Rio (DLR)	326^0	39^0
12.	Bay St.Louis (BSL)	340^0	41,5^0
13.	San Juan (SJG)	9,77^0	30^0
14.	Saint Johns (STJ)	54,6^0	31,2^0

Table 2. Longitudinal extension and asymmetry of the inflowing and outflowing current regions in the SCW.

Data	t-T$_0$ (min)	$\Delta\Lambda_W$, deg	$\Delta\Lambda_E$, deg	$\delta=\Delta\Lambda_W-\Delta\Lambda_E$, deg	σ_δ, deg	$x=\delta/\sigma_\delta$
			B_Y<0			
19.02.91	5	44	69	-25	9	2.8
19.02.91	10	34	68	-34	8	4.3
19.02.91	15	43	68	-25	9	2.8
10.03.96	5	28	37	-9	6	1.5
10.03.96	10	17	56	-39	7	5.6
10.03.96	15	23	55	-32	10	3.2
15.05.96	5	46	64	-18	10	1.8
15.05.96	10	48	66	-18	10	1.8
15.05.96	15	48	66	-18	10	1.8
			B_Y>0			
31.03.87	5	55	29	26	7	3.7
31.03.87	10	54	25	29	7.3	3.9
31.03.87	15	63	22	41	7,3	5.8
20.01.96	5	60	45	15	8	1.9
20.01.96	10	60	45	15	8	1.9
20.01.96	15	63	45	18	8	2.3
16.02.96	5	68	43	25	4.6	3.8
16.02.96	10	86	70	16	9	1.8
16.02.96	15	102	50	52	9	5.8

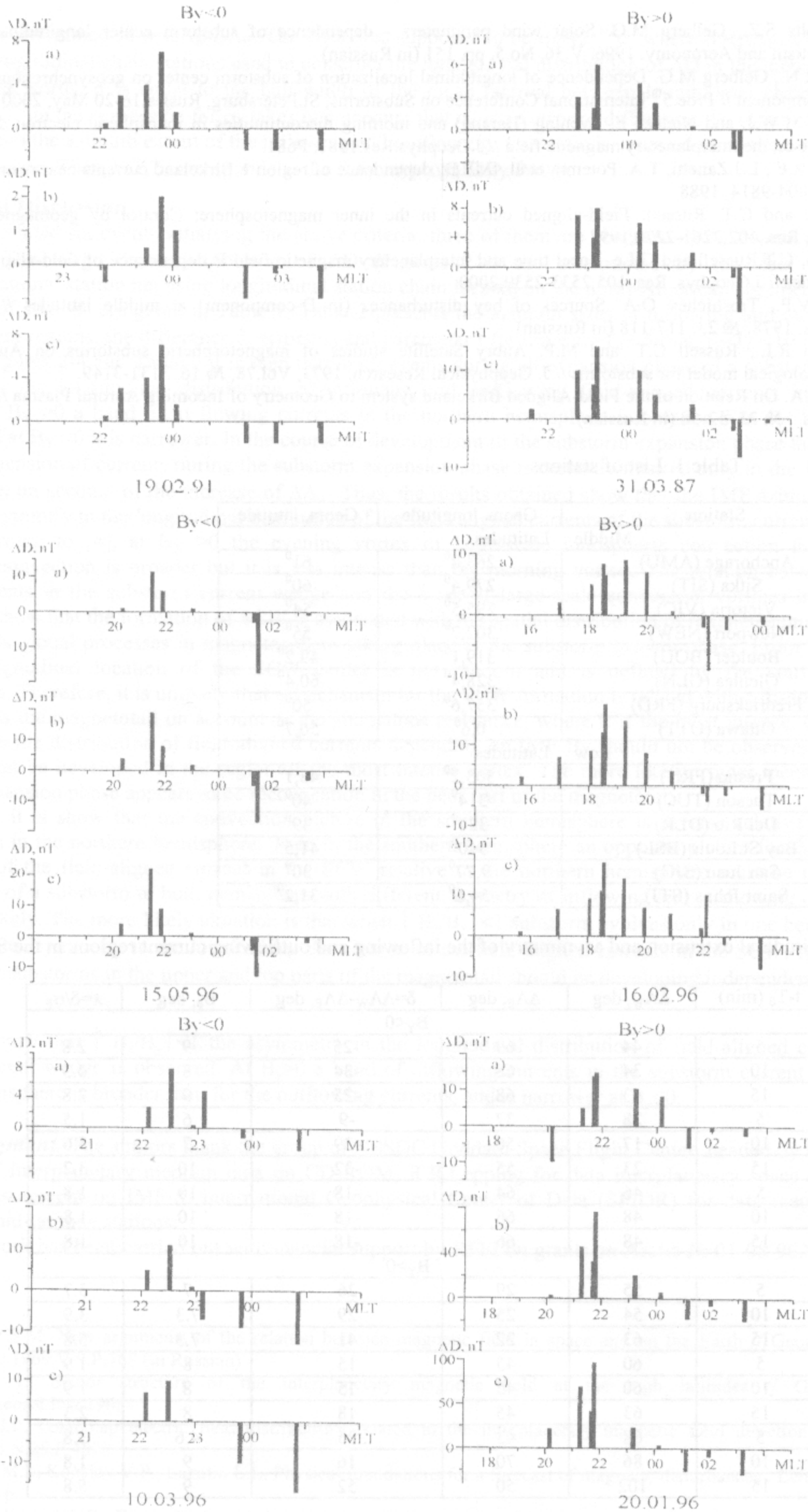
By<0
By>0
ΔD, nT
a)
b)
c)
MLT
19.02.91
31.03.87
15.05.96
16.02.96
10.03.96
20.01.96

Fig. 2