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ASYMMETRY IN SUBSTORM DEVELOPMENT IN THE EARTH'S NORTHERN AND SOUTHERN HEMISPHERES

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Abstract

The asymmetry in the intensity of H-component bays at the auroral stations at the conjugate points of geomagnetic field in the northern and southern hemispheres caused by the IMF B_Y has been established. At $B_Y < 0$ and $|B_Z|/|B_Y| < 1$, the bay amplitude in the geomagnetic field H-component in the auroral zone of southern hemisphere is greater than in the northern one. In some events at $B_Y < 0$ the typical substorm in the southern hemisphere and geomagnetic disturbances in the northern hemisphere consisting of short-term variations of small amplitude are observed.

One of the possible mechanisms of the found asymmetry is the irregular redistribution in hemispheres of currents forking from the magnetotail equator into the ionosphere.

Introduction

The aim of this work is to show that in certain conditions the substorms in the northern and southern hemispheres develop asymmetrically: the ratio of substorm disturbance amplitudes in the northern and southern hemispheres $|\Delta H|_{max\,N} / |\Delta H|_{max\,S}$ depends on the sign of IMF B_Y.

The dependence of maximum variation of negative bays of geomagnetic field H-component at the magnetic conjugate stations on the IMF B_Y during substorms of small and middle intensities with $|\Delta H|_{max} < 750$ nT developed at $B_Z < 0$ and $|B_Z/B_Y| < 1$ has been investigated. By data of Kotzebue ($\Phi = 64{,}5^o$; $\Lambda = 249{,}7^o$) and Macquarie Isl. ($\Phi = -64{,}5^o$; $\Lambda = 247{,}8^o$) stations in the eastern hemisphere and Leirvogur ($\Phi = 65{,}3^o$; $\Lambda = 68{,}2^o$) and Syowa ($\Phi = -66{,}1^o$; $\Lambda = 71{,}0^o$) stations in the western hemisphere it was shown that at $B_Y < 0$ absolute magnitudes of negative bays $|\Delta H|_{max}$ are larger in the southern hemisphere, and at $B_Y > 0$ they are larger in the northern hemisphere. It is supposed that in substorm current wedge field lines between the northern and southern hemispheres the finite potential difference is set up and more intense field-aligned currents flow at $B_Y > 0$ from the northern to southern hemisphere, and at $B_Y < 0$ conversely, from the southern to northern hemisphere.

Results and Discussion

Experimental data are the magnetograms of two pairs of auroral zone stations in the northern and southern hemispheres for the 1993 to 1996 period. Each pair of stations is magnetic conjugate. The events are selected by the geomagnetic field H-component registered at the observatory located in the southern hemisphere when during the passage from magnetoquiet to disturbed conditions the isolate negative bays of moderate intensity are observed. For each disturbance the moment of bay onset identified as a substorm onset is determined. Based on IMP-8 and Wind satellite 1-min data the average values of the IMF B_Y and B_Z components, solar wind speed V_X and electric field component $Ez = -V_X \cdot B_Y$ 30 min before T_0 are calculated. The lists of events, amplitudes $|\Delta H|_{mN}$, $|\Delta H|_{mS}$ of magnetic bays, their ratio $A = |\Delta H|_{mN} / |\Delta H|_{mS}$, IMF B_Z, B_Y, $|E_Z|$ are presented in Tables 1 and 2. Events observed at the stations of western hemisphere are marked by an asterisk.

As an example, the Figure presents 4 events illustrating discovered regularities in the asymmetric distribution of substorm intensity in the geomagnetic field: for the western hemisphere on February 7, 1995 at $B_Y > 0$ and on February 4, 1995 at $B_Y < 0$; for the eastern hemisphere on June 10, 1994 at $B_Y > 0$ and on April 10, 1996 at $B_Y < 0$. It is seen from the Figure and Tables 1 and 2 that the IMF B_Y-component creates the regular asymmetry in substorm intensity in the northern and southern hemispheres. At $B_Y > 0$ the amplitude $|\Delta H|_m$ of geomagnetic field H-component variation is larger in the northern hemisphere, and at $B_Y < 0$ it is larger in the southern hemisphere. As this regularity is observed during all seasons, it cannot be explained by the seasonal variation of ionosphere conductivity only.

In the work by Velichko et al., 2001 the regular asymmetry of longitudinal distribution of field-aligned current amplitudes in the substorm current wedge is shown. In the northern hemisphere a band of flowing out field-aligned currents from the ionosphere is wider at $B_Y > 0$, and at $B_Y < 0$ it is wider for the flowing in currents. At $B_Y > 0$ ($B_Y < 0$) the substorm asymmetric current wedge can be represented as superposition of the symmetric Birkeland loop and a band of field-aligned currents flowing out (flowing in) from the ionosphere of northern hemisphere. Such a direction have field-aligned currents caused by the IMF B_Y flowing along open field lines of the magnetotail [Leontyev and Lyatsky, 1974].

Table1. List of events at $B_Y > 0$

№	Date	Time, UT	B_Z, nT	B_Y, nT	$\lvert B_Z/B_Y \rvert$	$\lvert \Delta H \rvert_{mN}$, nT	$\lvert \Delta H \rvert_{mS}$, nT	A	$\lvert E_Z \rvert$, mV/m
1.	27.03.94	1221	-1,3	2,9	0,4	250	160	1,5	1,1
2.	21.04.94	1116	-1,4	1,6	0,8	18	12	1,5	0,8
3.	22.04.94	1124	-2,5	3,2	0,8	130	90	1,4	1,5
4.	20.05.94	1329	-0,3	2,9	0,1	310	170	1,8	1,4
5.	10.06.94	0926	-2,8	4,3	0,6	730	270	2,7	1,8
6.	06.07.94	1109	-0,5	2,4	0,2	90	40	2,25	
7.	17.07.94	0927	-2	3,6	0,5	410	170	2,4	2,7
8.	21.07.94	1207	-4,5	5,2	0,7	210	30	7	2,4
9.	22.07.94	1320	-0,1	0,6	0,2	75	30	2,5	0,2
10.	15.08.94	1010	-2,1	3,6	0,6	520	170	3	1,9
11.	07.02.95*	0027	-2	7,3	0,2	435	300	1,4	2,9
12.	25.02.95	1207	-0,4	3,9	0,1	21	12	1,75	
13.	02.09.95	1243	-1,6	2,7	0,6	45	21	2,1	0,8
14.	12.09.95	1145	-1	2,4	0,4	170	30	5,7	1,1
15.	02.09.95	1243	-1,6	2,7	0,6	32	19	1,7	0,8
16.	22.11.95	1504	-2,2	3,6	0,6	180	130	1,4	1,2
17.	24.04.94	1002	-1,8	2,1	0,8	115	60	1,9	0,8
18.	19.07.94	0957	-1,4	2,1	0,6	270	140	1,9	1,1

Table 2. List of events at $B_Y < 0$

№	Date	Time, UT	B_Z, nT	B_Y, nT	$\lvert B_Z/B_Y \rvert$	$\lvert \Delta H \rvert_{mN}$, nT	$\lvert \Delta H \rvert_{mS}$, nT	A	$\lvert E_Z \rvert$, mV/m
1.	15.12.93	1228	-1,7	-11,6	0,14	440	480	0,91	
2.	16.12.93	0933	-3,96	-11,5	0,34	220	430	0,51	6,3
3.	22.12.93	1229	-1,6	-3,2	0,5	220	560	0,39	1,7
4.	15.01.94	1229	-1,2	-3,8	0,31	280	380	0,73	2,4
5.	16.01.94	1104	-1,2	-4,9	0,24	300	525	0,57	3,1
6.	18.02.94	0939	-1,2	-1,3	0,92	120	140	0,85	0,5
7.	20.02.94	1045	-1	-1,7	0,59	175	220	0,8	0,9
8.	20.03.94	1055	-0,17	-4,15	0,04	230	275	0,84	1,9
9.	08.01.95*	0107	-0,85	-2,26	0,38	148	192	0,77	1,4
10.	18.01.95*	2210	-0,14	-3,8	0,04	167	241	0,7	1,9
11.	04.02.95*	2131	-1,85	-4,26	0,43	65	271	0,24	2,4
12.	06.02.95*	0020	-0,81	-2,22	0,36	128	272	0,47	0,8
13.	16.03.95	1230	-1,1	-3,4	0,32	220	250	0,88	1,6
14.	30.09.95	1055	-1,7	-3	0,57	80	95	0,84	0,9
15.	22.11.95	1109	-0,7	-4,4	0,16	70	75	0,93	1,5
16.	05.03.96*	0148	-1,1	-3,2	0,34	25	250	0,1	1,4
17.	06.03.96	0954	-1,9	-3,5	0,54	120	195	0,62	1,4
18.	10.04.96	0837	-1,6	-2,3	0,7	30	60	0,5	1,1
19.	13.04.96	1313	-1	-2	0,5	125	75	1,67	0,8
20.	26.06.95*	0242	-1,9	-10,6	0,18	494	708	0,7	5,4
21.	27.07.95*	0130	-3,4	-4,6	0,74	370	450	0,82	1,7

Apparently, at the substorm expansion phase, when the longitudinal resistance in field tubes, passing through a current wedge, becomes finite, the finite potential difference is created between the auroral ionospheres of northern and southern hemispheres, and the field-aligned currents flow from the northern to southern hemisphere at $B_Y > 0$, and they flow in the opposite direction at $B_Y < 0$. The current flowing out from the ionosphere causes the additional precipitation of electrons, the increase of ionosphere conductivity and the rise of geomagnetic variation amplitude.

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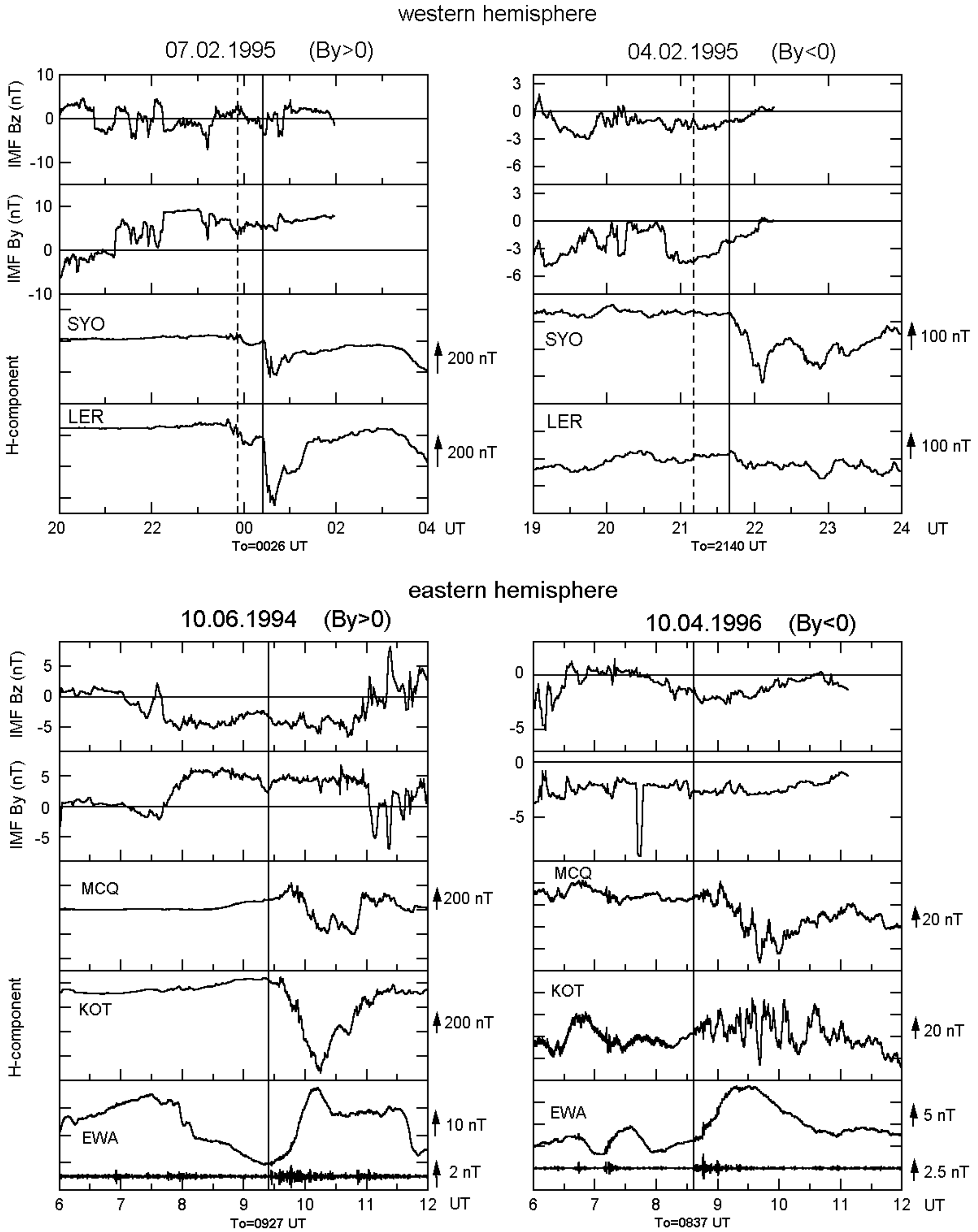

Fig.1. Variations of the IMF and magnetic field H-component parameters in magnetic conjugate points of the Earth The solid and dashed vertical lines are the substorm onset (T_0) and the growth phase onset, respectively. Stations and their geomagnetic coordinates are: Syowa (SYO, Φ = - 66,1^o; Λ = 71,0^o); Leirvogur (LER, Φ = 65,3^o; Λ = 68,2^o); Macquarie Isl. (MCQ, Φ = - 64,5^o; Λ = 247,8^o); Kotzebue (KOT, Φ = 64,5^o; Λ = 249,7^o); Ewa Beach (EWA, Φ = 21,6^o; Λ = 269,4^o).