FIELD ALIGNED CURRENT OBSERVED BY CLUSTER

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ABSTRACT

In this study, features of the Field Aligned Currents (FACs) distribution in the plasma sheet boundary layer are investigated. The current is calculated with the 4-point measurement of FluxGate Magnetometer (FGM) on board the Cluster in the period of July to October 2001. There are 172 FAC cases/events chosen for statistics. The results show that spatial distribution of the FAC has asymmetry in several aspects. The FACs occurrence is mainly Earthward in dawn side and is mainly tailward in dusk side. The FACs occurrence also has south-north hemisphere asymmetry.

1. INTRODUCTION

Field Aligned Current (FAC) is important for the Magnetosphere and Ionosphere dynamics. It exists in many goe-space regions, such as the polar ionosphere, Plasma Sheet Boundary Layer (PSBL), and so on.

Iijima and Potemra [1] researched the statistical characteristics of large-scale FACs above the ionosphere using magnetic field data by the TRIAD satellite at ~800 km in altitude. They investigated the region 1 and region 2 current in the polar region. Ohtani et al. Elphic et al. [2] analysed 189 plasma sheet boundary layer crossings also using ISEE 1 and 2 magnetometer data and concerned themselves only with the outermost FACs in the PSBL, they researched the tailward FAC and the earthward FAC. [3] found the polarity of the region 1 current system was consistent with the FAC in the PSBL in the magnetotail using ISEE 1 and 2 magnetometer data. The Hall current system was recently observationally identified in the magnetotail [4,5]. Fujimoto et al. [6,7] reported Geotail observations of the Hall-FACs flowing downward at location far from the reconnection site. Genta Ueno et. al. [8] statistically studied the outermost FACs observed by the Geotail spacecraft crossing the plasma sheet boundary layer inside X_{GSM} = -40 R_E.

All the research work mentioned above was using the magnetic field date obtained by single satellite. So the current could not be calculated accurately because time variation and spatial variation could not be distinguished by the measurement with single satellite. Thus only the estimated currents have been given. The Cluster satellite with a 4-point measurement provides us a very good opportunity to calculate the current with the so-called curlometer technique exactly [9,10]. In this study, we use the Cluster FGM 4-point data measured in the PSBL in the magnetotail with X_{GSM} about -19 R_E in 2001 to study the feature of the FAC statistically and the main results show the FAC spatial distribution has asymmetry in several aspects, especially the south-north hemisphere asymmetry. The paper is organized as follows. The criteria and method of the FAC case/event selections are first descrbied. This will be followed by the statistical results and summary.

2. CASES/EVENTS SELECTION

The data used for this study are the PP data of the instrument FGM on board the Cluster 4 satellites in 2001. We only choice the Cluster obits whose have plasma sheet across with Y_{GSM} from –15 R_E to 15 R_E to avoid the low latitude boundary region. As mentioned above, the FAC cases for us to study were in two PSBLs. One PSBL is in north hemisphere and the other PSBL is in south hemisphere. Fig.1 shows the two boundary layers (the black thick lines) in the magnetotail. To select the FAC case/event, the following conditions must be met (1) $\sqrt{B_X^2 + B_Y^2}$ >15 nT to exclude the cross-tail current region. It is known that the plasma sheet is always swaying in the Z direction and it is difficulty to decide PSBL using the fixed coordinate system. Ideally, one shall use ß to define the PSBL region. However, since in this study we limited our data to FGM data only, we apply $\sqrt{B_X^2 + B_Y^2}$ >15 nT condition as a proxmity; (2) Density of the FAC shall reach 3 pT / km (in this study, the curl B unit is given as pT/km which is a convenient equivalent of the current density unit of nA/m^2, note that 1 pT/km = 1.28 nA/m^2) To do so is for keeping from the current noise in background and the errors resulting from the current calculation using the tetrahedron approximation; (3)The separation between two cases is more than 10 minutes.

Fig.1 shows a sketch for the plasma sheet boundary layers in north hemisphere and south hemisphere or north PSBL and south PSBL.

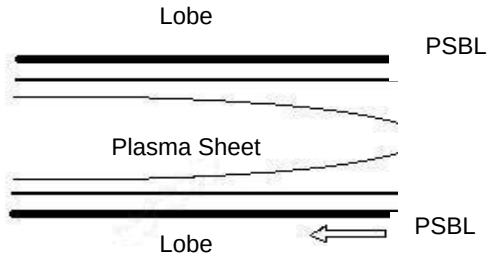

Fig.1 A sketch for the plasma sheet boundary layers

As we know, the current density and the magnetic vector are related through Ampere's law

$$\mu_0 \int_A \vec{J} \cdot ds = \oint_C \vec{B} \cdot dl \tag{1}$$

Here $\vec{J}$ is the current, $\vec{B}$ is the magnetic field, μ_0 is the magnetic constant. We calculate the current using the curlometer technique that is based on the Ampere's law but the integrals are numerically. Consider separation of each two Cluster satellites is about 2000 km in the 2001 and the configuration of the magnetic field is in the PSBL in the magnetotail, there is no problem to use the curlometer technique [9,10] in our study. With the calculated current, the FAC can be got with the form

$$J_{\parallel} = (\vec{J} \cdot \vec{B}) / \left| \vec{B} \right| \tag{2}$$

To ensure the data quality, we choice the data that obey the form

$$\left| \nabla \cdot \vec{B} \right| / \left| \nabla \times \vec{B} \right| << 1 \tag{3}$$

In the calculation, we took the ratio < 0.3.

3. STATISTICS RESULT

According to the description in the section II, there were 172 cases chosen to statistically study properties of the FACs .The Fig.2 shows all the chosen cases on the *Bx-By* plane. From the Fig. 2, we can see that all the cases distribute in the region of the $\sqrt{B_X^2 + B_Y^2}$ >15 nT. It means all the FAC cases chosen should took place in the PSBLs.

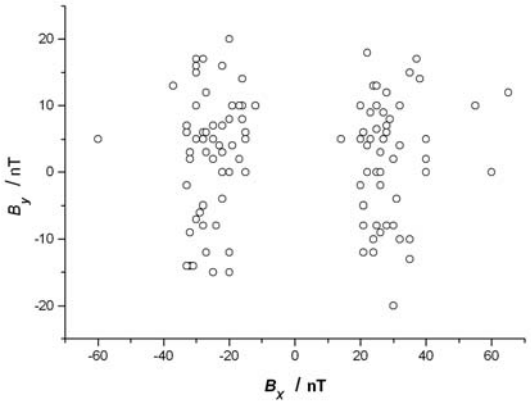

Fig. 2 The cases distribution on the *Bx – By* plane. It shows that the FACs cases were selected only in the plasmasheet boundary layer

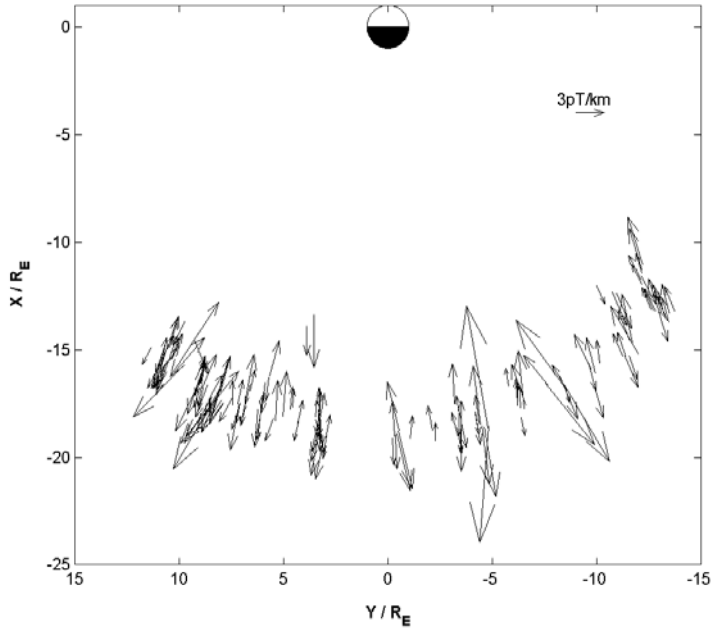

Fig. 3 FAC cases on the X-Y plane in the GSM system, it shows FACs's dawn-dusk asymmetry and Earthward –tailward asymmetry

Fig. 3 shows all of the cases on the X-Y plane in the GSM coordinate system. In the Fig.3, each arrow present a FAC case, the start point of the arrow is the location of the case taking place, the length of the arrow presents the density of the FAC in the unit of pT/km and the arrow direction presents the FAC direction. From Fig.3, we can see that some FACs took place in the dusk side and some took place in the dawn side, some FACs are earthward and some are tailward. The cases distribution in the dawn side is not same as that in the dusk side.

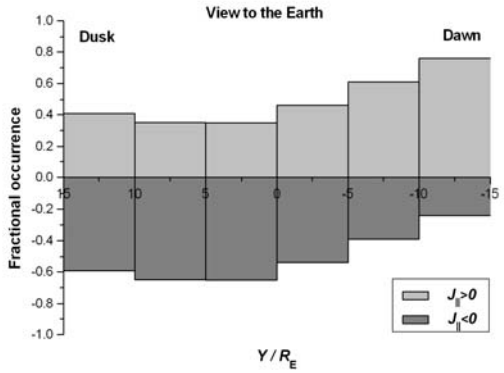

Fig. 4 Fractional occurrence of the FACs versus Y_{GSM}

Fig. 4 shows fractional occurrence of the FACs versus Y_{GSM}. In Fig.4, gray color presents the earthward FAC and the black color presents the tailward FAC. In each block, the height (from bottom of the black to top of the grey) is unit 1.The gray part of the block presents the earthward FAC's fractional occurrence and the black part of the block presents the tailward's. For example, in the block of Y_{GSM} from 10 R_E to 15 R_E, the height of the gray part is 0.42 and the height of the black part is 0.58, it means that fractional occurrence of the earthward FAC is 0.42 and of the tailward's is 0.58. From Fig.4 we can see more clearly that the earthward FAC in dawn side has a big occurrence than that in the dusk side and the tailward FAC in dusk side has a big occurrence than that in the dawn side. In the dusk side, the occurrence of the tailward FAC is higher than that of the earthward FAC. In the dawn side, in the region of Y_{GSM} =0 to -5 R_E, the occurrence of the tailward FAC is a little higher than that of the earthward but in the region of the Y_{GSM} = -5R_E to -15 R_E, the occurrence of the tailward FAC is lower than that of the earthward.

In this study, we found that the FAC has north-south hemisphere asymmetry. Fig. 5 illustrates the FAC (a) in the north hemisphere or north PSBL and (b) in south hemisphere or south PSBL. The arrow in the Fig. 5 is the same meaning as that in the Fig. 3.

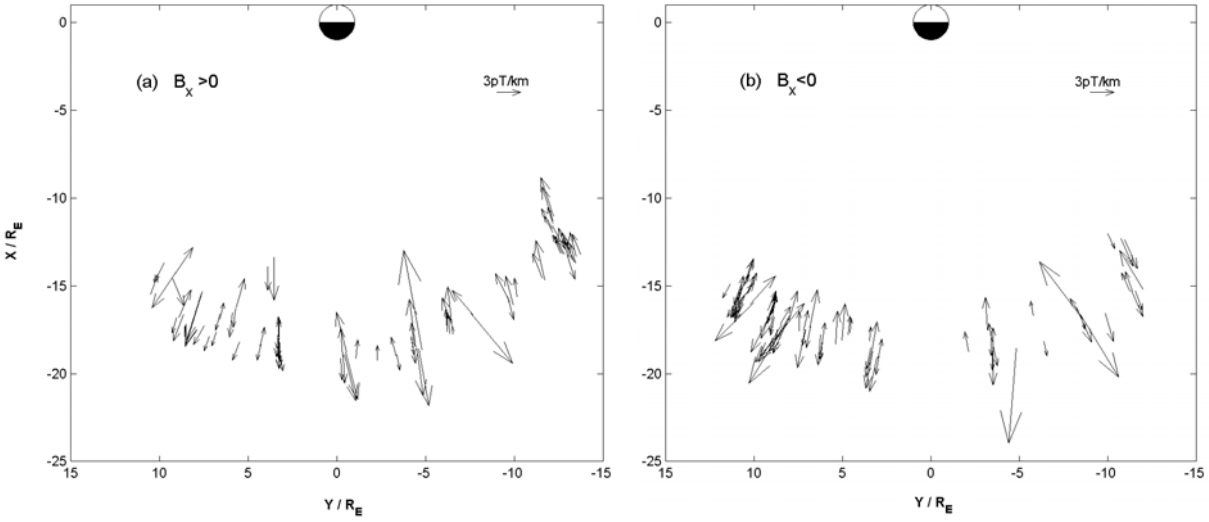

Fig. 5 The FAC cases on the X-Y plane in the GSM system in (a) north PSBL and (b) south PSBL

Table 1 FAC cases in north and south PSBL

	Dawn side		Dusk side	
	Earthward	Tailward	Earthward	Tailward
North	35	13	8	25
South	10	15	28	38

From Fig.5, we can see that the FAC distribution in the north hemisphere is not the same as that in the south hemisphere.

Table 1 shows the occurrence of FAC cases in different hemisphere or different PSBL. In the table 1, the numbers are the FAC occurrence numbers in difference sector, different direction and different PSBLs. From

the table1 1, we can see that in different side the FAC occurrence is different, in different direction the FAC occurrence is different, and in different PSBL the occurrence is different, too.

4. SUMMARY

We used the PP data of the Fluxgate Magnetometer on board the Cluster in the period of July to October 2001 and studied the features of the Field Aligned Current distribution in the plasma sheet boundary layer in the magnetotail. There are 172 FACs cases/events chosen for statistics. The current is calculated with the curlometer technique with the 4-point measurement. The main results show that occurrence of the FACs has asymmetry in several aspects: the dawn-dusk asymmetry, the earthward-tailward asymmetry and the south-north PSBL asymmetry.

The FACs density and the relationship between the FACs and the A_E are also researched in our study. We will show it in other papers.

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