FIELD-ALIGNED CURRENTS OBTAINED FROM THE INTERKOSMOS-BULGARIA-1300 SATELLITE DATA.

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Keywords: measurements of magnetic field, magnetospheric field-aligned currents

Abstract:*Single satellite observations allow the correct calculation of the value of field-aligned currents (FAC) only when the scale of field-aligned current band in the latitudinal direction is much smaller then such scale in the longitudinal direction. The analysis shows that the change of the measured on satellite tangential component of the magnetic field in the case of finite current sheet is less than such change when the sheet is infinite (with same current density). This effect leads to underestimation of the value of field-aligned currents. The appeared systematic error of the calculation of field-aligned currents is evaluated. The magnetic field measurements aboard satellite Intercosmos-Bulgaria-1300 in the period August - December 1981 are used. The statistical pictures of the distribution of density and scales of field-aligned current bands are obtained.*

Introduction

Field-aligned currents are the main agents of magnetosphere-ionosphere interactions; therefore correct determination of their properties is very important for the understanding of main magnetospheric processes. The statistical picture of large-scale field-aligned current distribution has been obtained by Iijima and Potemra [1976] and by many satellite observations including latest Iridium results (Waters et al. [2001]). At the same time it is well known that large-scale field aligned current sheets are frequently stratified on multiple sheets (see Kamide and Rostoker [1977]). Antonova et al. [1998] discussed the mechanisms of such stratification. Investigations of the stratifications of large-scale field-aligned current bands on multiple field-aligned current sheets were limited by the assumption of the existence of infinite homogeneous current sheets. However, this assumption works when the width of the current sheet in the longitudinal direction exceeds significantly its size along a meridian. This allowed reducing the three-dimensional problem to one-dimensional one. In this work we try to evaluate the corrections considering a finite size of the sheet in the longitudinal direction and showing the efficiency of this methodology using the Interkosmos-Bulgaria-1300 magnetic field measurements.

Model of a finite current sheet.

To understand possible errors introduced but finite size of the field-aligned current sheet in the longitudinal direction we model the disturbance of the magnetic field by current sheet infinite in Z direction and having finite scales in X,Y directions. For the first simplified estimations we suggest that current sheet in X,Y directions has a rectangular form and constant current density inside the rectangular: j=const if $a_1 \le x \le a_2$, $b_1 \le y \le b_2$ and j=0 outside this interval. The normal component of the magnetic field disturbance for such configuration is symmetric with respect to the tangential surface of symmetry and antysymmetric with respect to the normal one. The tangential component is antysymmetrical with respect to the tangential surface of symmetry and

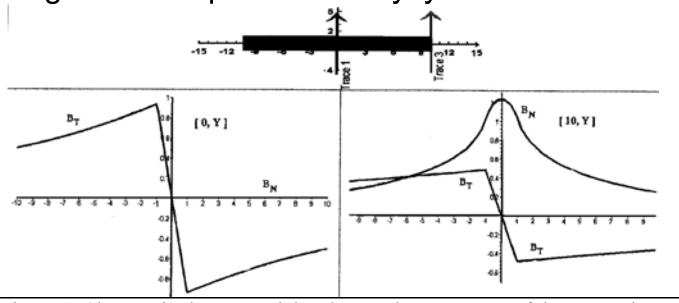

Figure 1. Changes in the tangential and normal components of the magnetic field corresponding to the field-aligned current sheet shown at the top, the satellite orbit is perpendicular to the sheet. One sheet, trajectories are normal to the sheet

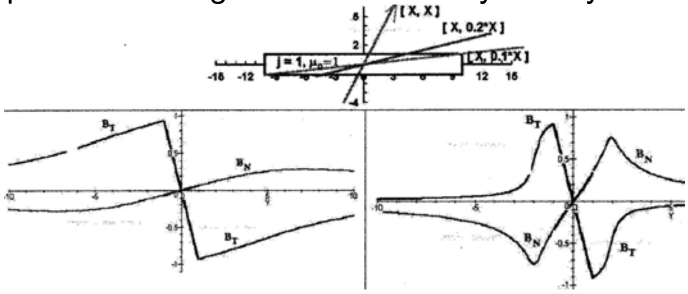

Figure 2. Changes in the tangential and normal MF components of the current sheet shown on the top for different angles between the sheet and the satellite orbit.

symmetrical with respect to the normal one. This property is very important for the analysis of the real data to obtain the thickness and the position of the current sheet. For infinite current sheet ($a_1=-\infty$ и $a_2=\infty$) the normal component of the disturbance of the magnetic field is zero and the tangential component is constant outside and alters linearly inside the sheet. Figures 1 and 2 illustrate such statements. Figure 1 show values of tangential to the sheet (B_T) and normal to the sheet (B_N). Variations of magnetic field changes in both components, measured on board a satellite for orbits being perpendicular to the sheet. Values of magnetic components are expressed in relative units and not in T (tesla) (we put the magnetic permeability of vacuum $\mu_0=1$ and current density inside the rectangular $j_0=1$). In the figures 1 and 2 scale of the current sheet in normal to the sheet direction is 20 times smaller then in tangential direction. The difference between normal components of magnetic field at both boundaries should be zero and the difference between tangential components should be 2 in the case of infinite current sheet. Figure 1 corresponds to traces 1 and 3 of satellite crossings perpendicular to current sheet. (Trace 1 is far from the edge of the sheet, controversy Trace 3 is at the edge) The situation becomes more complicated in the case of oblique crossings of current sheets (see Figure 2). It is possible to see analyzing the results of our simple modeling that the finite scale of current sheet in tangential direction leads to the underestimation of the value of field-aligned current density. One can see that significant change in tangential component of MF persist also in cases when the satellite don't cross the sheet. But in these cases the change in the normal component is bigger. This outcome could be used as a criterion for prevention of erroneous FAC measure.

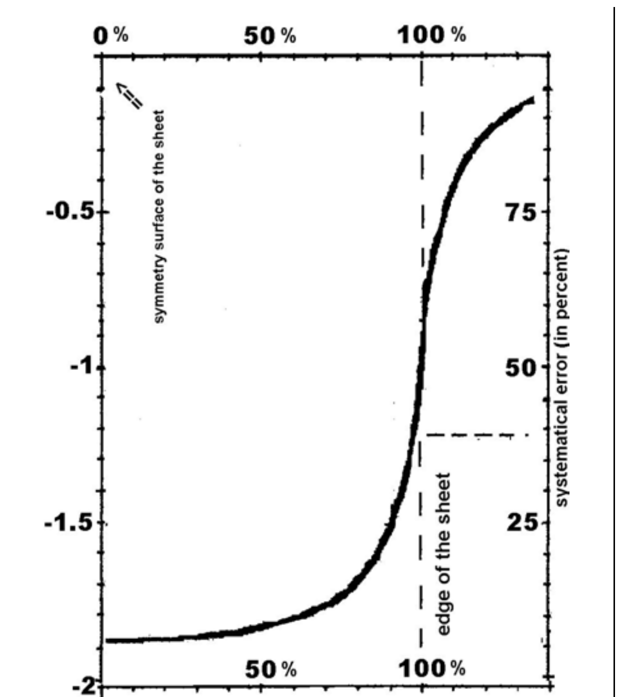

Figure 3. Difference between the tangential component of the magnetic field on both boundaries of the sheet **(must be 2 in case of infinite sheet)**, X-axis - the distance (in percents) from trajectory to symmetry surface (100%

The results of the modeling of finite current sheet and singe satellite trajectory are:

- The estimated current density is always less than the real one; in some cases *if the satellite crosses a sheet rather far from the edge* (variation of BN is small) dBT/dx estimation works well.
- There exists cases when the satellite don't crosses the sheet but the change in tangential component is significant and we have criteria to prevent from erroneous FAC estimation

◦ The properties of symmetry can help us to predict the position of the "middle" of the sheet (left or right to satellite trajectory)

Figure 3 summarize results of the modeling. Especially, at the right hand one can see the region of "false" currents (X > 100%).

3. Field-aligned currents obtained using the Interkosmos-Bulgaria-1300 magnetic field measurements

The main objective of this section is to illustrate the methodology developed above using the Inrecosmos-Bulgaria-1300 magnetic field measurements. The satellite had a circular, low-altitude polar orbit (perigee: 800 km, apogee: 900 km, inclination: 81º). A three-component fluxgate magnetometer with 2 nT sensitivity (Arshinkov et al., [1983]) provided a good alignment of magnetic and geometric axes, which allow an overall error in orthogonality between the three axes in the order of 10'. Combined with an accurate rigid 1.25m boom precisely aligned with the geometrical axes of the satellite and the satellite's relatively high stability-of the order of 30', the experiment provides fairly accurate measurements of the Earth's magnetic field vector and its three components.

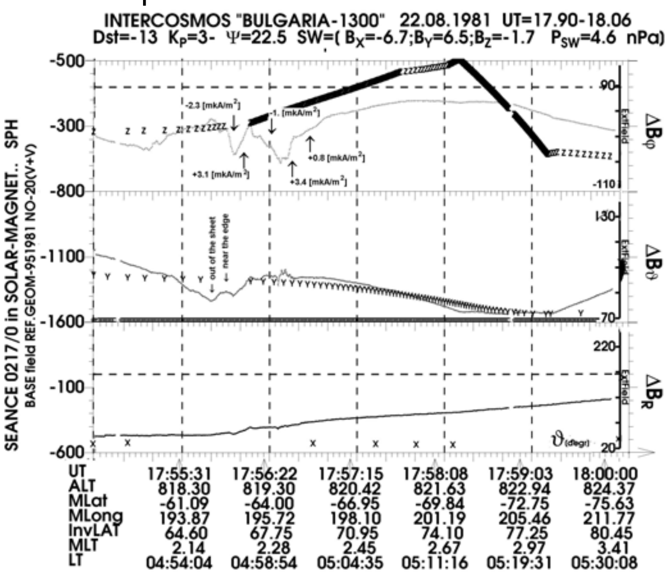

Figure 4-a. Examples of the magnetic field measurement by Interkosmos-Bulgaria-1300 satellite. Tsyganenko-2001 model field is plotted with symbols. Left axis corresponds to changes in measured MF. The right one corresponds to changes in model. The perturbation in measured field is more then 10 times greater. Five current sheets are observed over one in model.

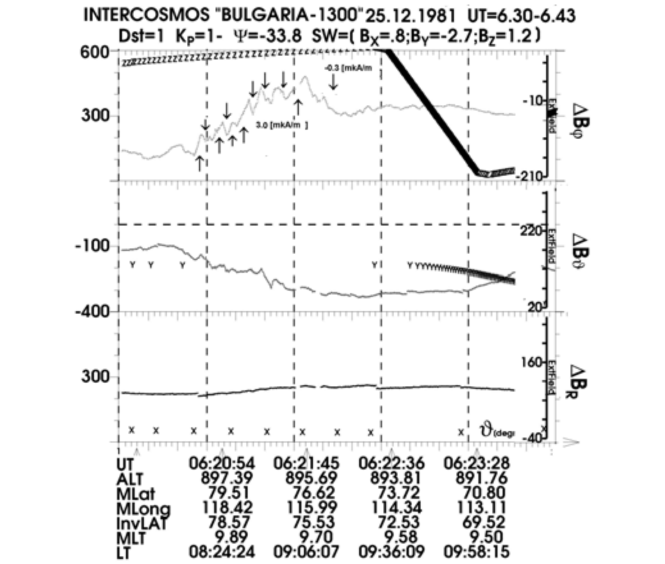

Figure 4-b. The same as in figure 4-a The perturbation in measured field is approximately10 times greater. Ten current sheets are observed over one in model. The average current density is 0.2 [mkA/m2].

Figure 4 shows some results of these measurements. To obtain the variation of magnetic field caused by field-aligned currents we subtracted the IGRF98 geomagnetic field model from the measured field. The components of the magnetic field are transformed to spherical one in the Solar Magnetic (SM) coordinate system (Z_{SM} axis coincides with the geomagnetic dipole axis; XZ_{SM} plane contains the Earth-Sun direction, Y_{SM} supplements the right three, toward to the dusk). The magnetic field R component is directed along the radius vector, Θ component is directed Southwards along the geomagnetic meridian, φ is directed Eastwards along the geomagnetic parallel. On the horizontal axis, the polar angle (in SM KS) is marked. This is dipole system what relation is with solar magnetic system?

We compare the results of satellite measurements with field-predicted in Tsyganenko-2001 model (see Tsyganenko [2002]). To obtain the input parameters for the model we interpolate the hours data values from OMNI-WEB. The results of such calculations are shown by special symbols on Figure 4 and 4a.

Figure 4a corresponds to near midnight crossing, Figure 4b to near cusp crossing. In spite of the comparatively good coincidence of field-aligned current positions, the real divergence is also possible to see. Such, for example, the magnetic disturbances on Figure 4a are more than 10 times greater than the predictions of the model. There are 11 small-scale FAC structures with different strong current densities associated with two large-scale sheets during the cusp crossing (Figure 4b).

4. Statistics of current sheets

Investigations of the variations of magnetic field on the satellite Intercosmos-Bulgaria-1300 and developed method of the evaluation of the thickness of field-aligned current sheets give the possibility to obtain the statistical pictures of current distributions. 107 current sheets are investigated.

It is possible to see that more than 60% of observed current sheets have thickness less than 1.5^0.

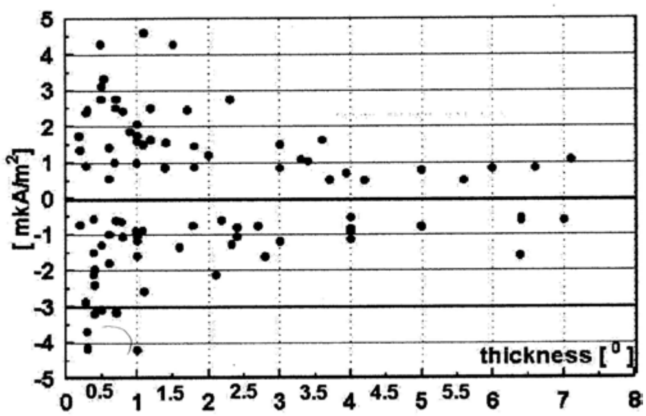

Figure 5. FAC density thickness distribution measured on the ICB-1300 satellite

Figure 5 shows the intensity distribution of field-aligned current in sheet on the thickness of current sheet. The most intensive field-aligned currents (FAC) have sheet thickness within 0.25^0-1.5^0 (inward FAC) and 0.25^0-2^0 (outward FAC).

Conclusions and discussion

The conducted analysis shows that both components (meridional and zonal) of the magnetic field must be taken into account when estimating the FAC density and position, to eliminate the false groups of sheets. Estimated in situ FAC density is always smaller than the real one, up to 25% at the end of the sheet. Ordinarily used calculations of FAC density as $\Delta BY/\Delta X$ can lead to the error till 100%. The FAC density is greater and thickness is smaller than usually accepted.

We compared the results of our analysis with Tsyganenko [2002] and Papitashvili et al. [2001] models and results of Lukianova et al. [2001]. It is possible to mention that Intercosmos-Bulgaria-1300 observations show that FAC density is greater and thickness is usually smaller, than in these works. Unfortunately we have no sufficient data to investigate the dependence of FAC's density or thickness on other parameters like Kp, Dst or Solar Wind parameters.

Acknowledgments

The research was supported by INTAS grant 03-51-3738, RFBR grants and the program Universities of Russia

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