Local-time distribution of net field-aligned currents derived from high-altitude satellite data

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Abstract

The dawn-dusk asymmetry of the north-south geomagnetic disturbances at low and mid latitudes has been indicated by many studies. Some researchers have attributed such asymmetrical geomagnetic disturbances to net field-aligned currents, flowing into the ionosphere on the dayside and flowing out of the ionosphere on the nightside. However, those net field-aligned currents have not been established by low-altitude spacecraft observations yet. We statistically investigated the global structure of the geomagnetic disturbances generated by the field-aligned currents in the inner magnetosphere by using the magnetic field data obtained by the DE-1 satellite. On the basis of the results, local-time dependence of the net field-aligned currents was estimated. As a result, net downward currents are found in the pre-noon sector and net upward currents are found in the pre-midnight sector. In the post-noon and the post-midnight sector, there exist only small amounts of the net field-aligned currents. Considering that Region 2 currents are at lower latitudes than Region 1 currents, the result of this study can explain the features of geomagnetic disturbances at low and mid latitudes.

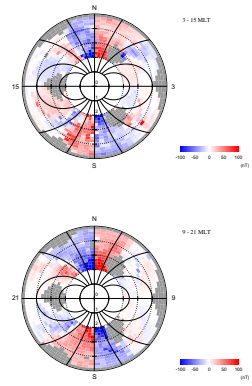

Fig. 1: Meridional distribution of azimuthal magnetic disturbances, $\Delta \boldsymbol{B}_\phi$ on the meridional planes of 3-15 MLT (top panel) and 9-21 MLT (bottom panel), under the condition of $AE > 300$. Eastward disturbances are represented by red and westward disturbances are represented by blue. (*Nakabe et al.* 1997)

Method

In order to treat data at different altitudes equally, it is assumed that magnetic disturbances parallel to the terrestrial field line is negligible. Then when we define a parameter A by

$$A = \frac{r}{R_E}\cos\lambda \Delta B_\phi,$$

r : radial distance from the center of the earth
λ : dipole latitude

A is approximately constant along a terrestrial field line. For the data in the southern hemisphere, the sign is inverted. The data in low latitudes ($|\lambda| < 20^\circ$) are not used in this analysis.

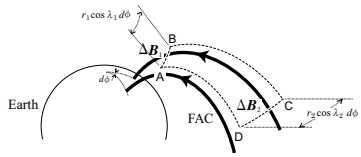

Fig. 2: Considering the Ampére integral of magnetic field of the closed path **ABCD**, the azimuthal magnetic field proves to be approximately inversely proportional to distance from the dipole axis of the earth ($r\cos\lambda$) along a terrestrial field line.

Azimuthal magnetic disturbances in the inner magnetosphere

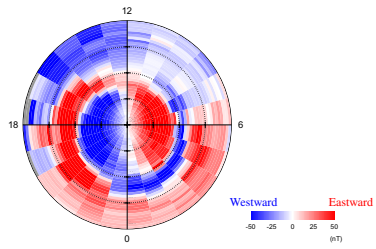

Fig. 3: The latitudinal and local-time distribution of A under the condition of $AE > 300$. Positive A represented by red denotes eastward disturbances and negative A represented by blue denotes westward disturbances in the northern hemisphere. At low latitudes, eastward disturbances are predominant on the nightside, and westward disturbances are predominant on the dayside especially in the afternoon sector.

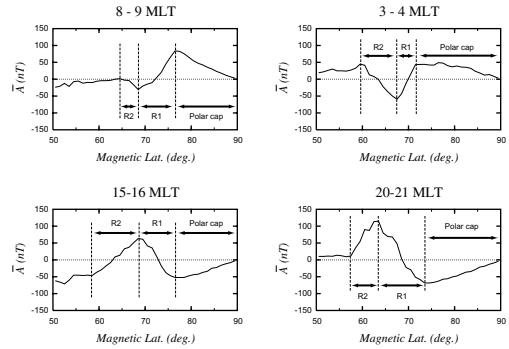

Fig. 4: The latitudinal profile of the averages of A under the disturbed condition at the meridian of 3-4 MLT (upper right), 8-9 MLT (upper left), 15-16 MLT (lower left), and 20-21 MLT.

Local-time distribution of net field-aligned currents

Suppose that the field-aligned currents are in sheet-like structures aligned at L-shells and the disturbance fields in other components than the azimuthal component are negligible, we can derive net field-aligned current density per longitude J at a meridian as:

$$J\,[\mathrm{A/deg}] \simeq \frac{\pi}{180}\frac{r\cos\lambda_1 \Delta B_\phi(\lambda_1) - r\cos\lambda_2 \Delta B_\phi(\lambda_2)}{\mu_0}$$
$$= \frac{\pi R_E}{180}\frac{\bar{A}(\tilde{\lambda}_1) - \bar{A}(\tilde{\lambda}_2)}{\mu_0}$$

where $\tilde{\lambda}_1$ and $\tilde{\lambda}_2$ are the latitudes of the footprints. Fig. 5 shows the local-time distribution of net field-aligned currents derived from latitudinal profiles of A as shown in Fig. 4.

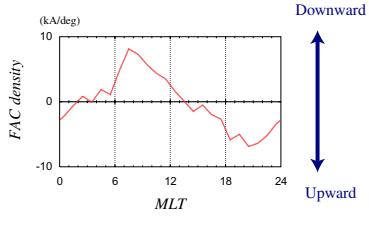

Fig. 5: The local-time profile of the net field-aligned currents.

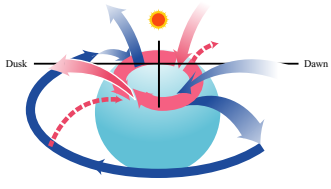

Fig. 6: A possible current system which explain our results.

Results

Structure of azimuthal magnetic disturbances

- At low latitudes, eastward disturbances are predominant on the nightside, and westward disturbances are predominant on the dayside.
- In the polar cap, uniform sunward disturbances are observed.

Local-time distribution of net field-aligned currents

- Net downward currents are mainly seen in the pre-noon sector, and net upward currents are mainly seen in the pre-midnight sector on the average.
- In the post-noon and the post-midnight, net field-aligned currents are relatively small, which means that Region 1 currents are almost balanced with Region 2 currents.

Effect on geomagnetic disturbances at mid-latitudes

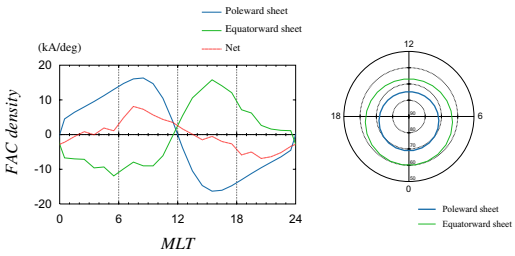

Fig. 7: Model field-aligned current distribution for the model calculation. The top panel indicates the local-time dependence of the field-aligned current density per longitude for each of double sheet currents in this model. The bottom panel indicates the spatial distribution of the field-aligned currents.

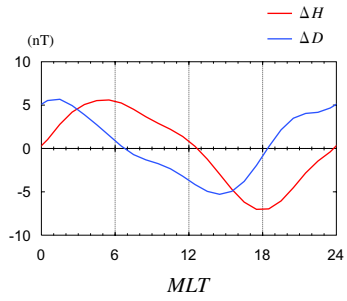

Fig. 8: Local-time dependences of the magnetic effects of the field-aligned currents on geomagnetic disturbances at 30° in dipole latitude derived from the model calculation.

Summary

- There are net downward currents in the pre-noon sector and net upward currents in the pre-midnight sector.
- In the post-noon and the post-midnight sector, there exist only small amounts of the net field-aligned currents.
- Considering that Region 2 currents are at lower latitudes than Region 1 currents, the result of this study can explain the features of geomagnetic disturbances at low and mid latitudes.