

North-South Asymmetry of the Diurnal Variation of the Geomagnetic Disturbance and the Polarity of the Interplanetary Magnetic Field

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The relationship between the polarity of the interplanetary magnetic field and the asymmetry of the diurnal variation of K indices between the northern and southern auroral zone is studied. It is found that the effect of the IMF polarity on the geomagnetic disturbance is stronger on the morning side in the northern hemisphere and on the evening side in the southern hemisphere when the IMF is directed away from the sun, and that the signature is reversed when the IMF is directed toward the sun. A possible interpretation of this effect is discussed in terms of the dawn-dusk asymmetry of the polar cap electric field as found by Heppner from the direct spacecraft measurements.

1. Introduction

In recent years, it has been established that the southward component (B_s) of the interplanetary magnetic field (IMF) plays an important part in the development of geomagnetic substorms (e.g. Russell and McPherron,¹⁾ Burch²⁾). Svalgaard³⁾ and Mansurov⁴⁾ have shown that the z -component of the geomagnetic field in the polar cap is strongly affected by the IMF polarity. Friis-Christensen et al.⁵⁾ have pointed out that this geomagnetic variation depends on the east-west component (B_y) of the IMF. Murayama and Hakamada⁶⁾ have shown that the auroral electrojet (AE) is affected not only by B_s but also by B_y in the northern hemisphere. Siebert⁷⁾ has found that the magnetic activity difference between two conjugate regions of the northern and the southern hemisphere obviously follows the rhythm of the IMF sector structure in a remarkable degree. Wilcox⁸⁾ has also shown the geomagnetic asymmetrical response to the IMF polarity. This IMF polarity dependence of the north-south asymmetry of the geomagnetic disturbance has been confirmed by Berthelier and Guerin⁹⁾ using a large amount of data covering about 70 solar rotations.

Heppner¹⁰⁾ has discovered a clear dawn-dusk asymmetry in the high-latitude electric field observed by spacecrafts related to the IMF polarity. From ionospheric electric field measurements, Mozer et al.¹¹⁾ and Mozer and Lucht¹²⁾ have also shown that, when B_y is positive (negative), two-cell convection pattern in the polar cap shifts toward dawn (dusk) in the northern hemisphere.

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If the dawn-dusk asymmetry of the high-latitude electric field as found by Heppner¹⁰⁾ is created by the B_y component of the IMF (Stern¹⁸⁾), and if this electric field affects the geomagnetic activity in the auroral zone, it should be observed that there is a visible difference between the geomagnetic daily variation of toward days; when the IMF is directed toward the sun, and that of away days; when the IMF is away from the sun, at the geomagnetic north-south conjugate pair stations. In this paper, we will study the relation between the inferred IMF polarity (Svalgaard¹⁴⁾) and the north-south asymmetry of the daily variation of K indices of toward days and of away days.

2. Procedure of Analysis

In this paper, we use K index of Cape Wellen (WE, 61.96° geomag. lat. 237.79° geomag. long.) in the northern hemisphere and that of Macquarie Island (MI, -60.92° geomag. lat. 243.86° geomag. long.) in the southern hemisphere as the measure of the geomagnetic disturbance during the period 1967 through 1969. The relation between these K indices and the inferred IMF polarity (Svalgaard¹⁴⁾) of the same period will be studied. The subtraction of K index of MI from that of WE is denoted as afo , that is, $afo = K_{WE} - K_{MI}$. The value of afo is obtained in each three-hourly interval.

K index contains a seasonal variation with its maximum in local summer. This also gives a seasonal variation in afo , that should be removed before the examination of the north-south asymmetry related to the IMF polarity. The deviation of afo from the smoothed curve calculated by 27-day (27×8 points) running mean method is denoted as afo and is hereafter used as the asymmetry factor.

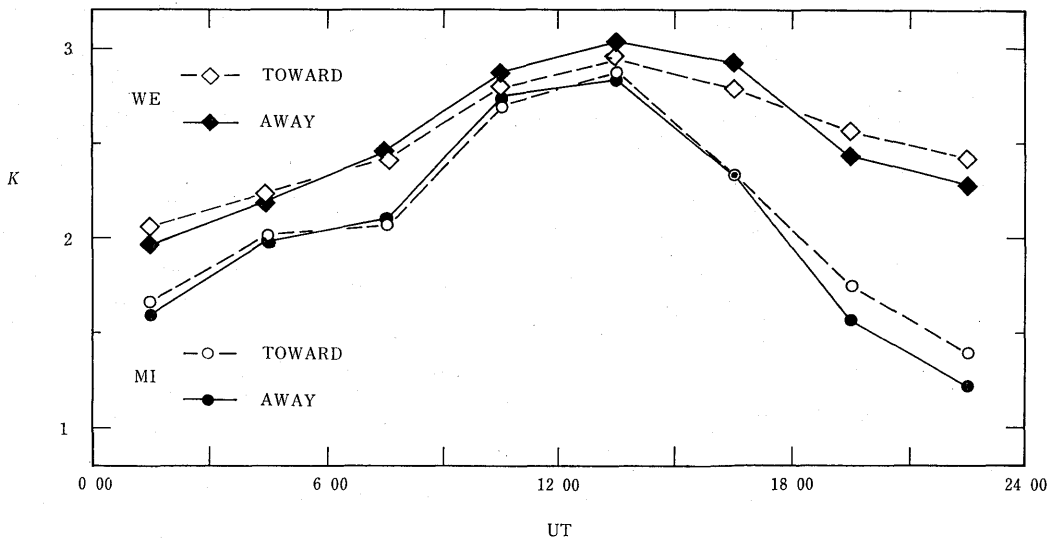


Fig. 1 Diurnal variation of K indices of WE and of MI.

Squares represent K indices of WE and circles represent those of MI. Black and white symbols are for away days and for toward days, respectively.

3. Results

(1) Diurnal variation of K indices of WE and of MI

Three-hourly K indices of both the stations are divided into two groups, away days and toward days, according to the inferred IMF polarity. The result is shown in Fig. 1. Squares represent K indices of Cape Wellen and circles represent those of Macquarie Island. Black and white symbols are for away days and for toward days, respectively. K indices of WE always exceed those of MI. The difference between them is minimum at about 1200 UT and is maximum at about 2400 UT.

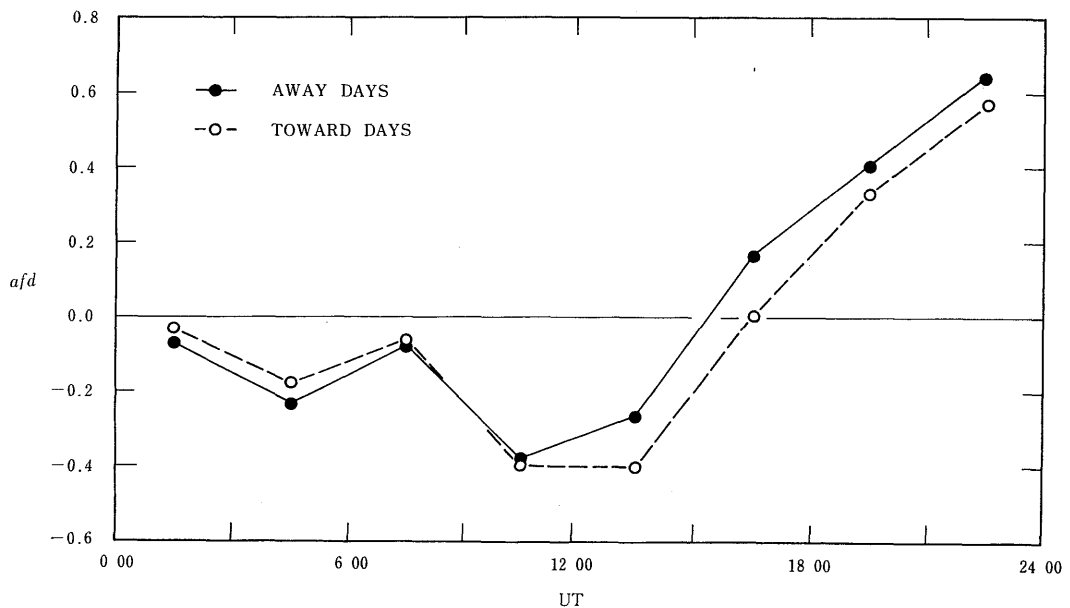


Fig. 2 Diurnal variation of afd .

Filled circles and open circles are three-hourly afd of away days and of toward days, respectively.

(2) Diurnal variation of afd and of af

Fig. 2 shows the diurnal variation of afd with its minimum at about 1200 UT and its maximum at about 2400 UT. The effect of the IMF polarity to the north-south asymmetry of the geomagnetic disturbance should be revealed in the difference between afd of toward days and afd of away days. This difference is denoted as af ($af = afd_{\text{tow.}} - afd_{\text{away}}$) and is shown in Fig. 3 with the best-fit sinusoidal curve. The chain line shows the average value of af .

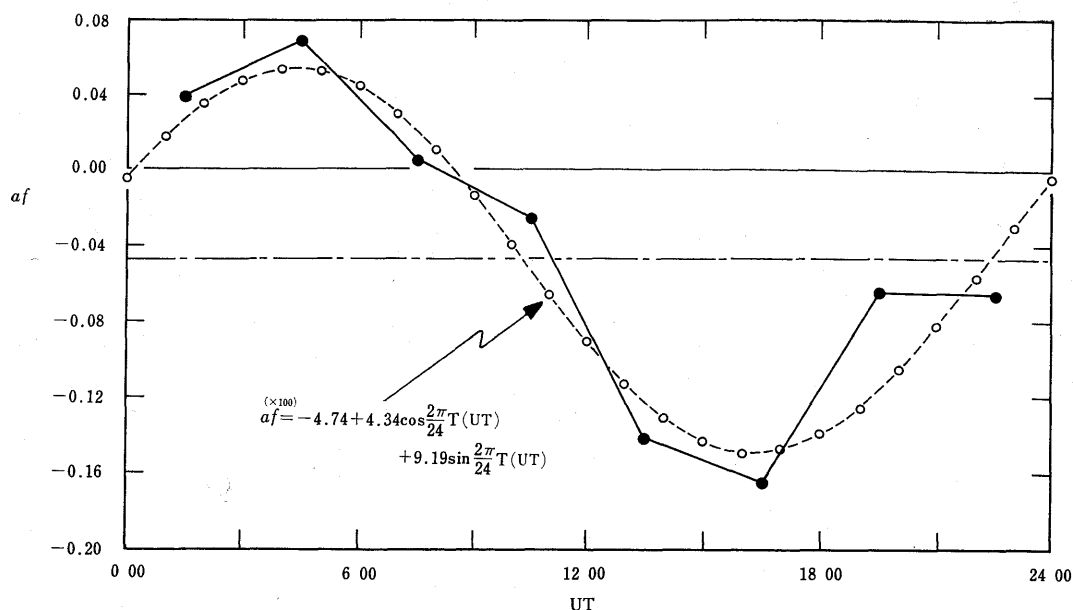


Fig. 3 Diurnal variation of af .

The dashed line is the best-fit sine curve for the broken line which reveals the diurnal variation of af . The chain line represents the mean value of af .

4. Discussion and Conclusion

Curves of the average daily variation of the K indices for the two stations have a similar sinuous form with each other. However, the absolute value of K indices of WE is different from that of MI. On an average, K indices of WE exceed those of MI at each three-hourly interval. The difference between them is greatest at local noon and is smallest at local midnight. Sagalyn et al.¹⁵⁾ found that the equatorial boundary of thermal ion density irregularities is consistently closer to the magnetic pole in the southern hemisphere than in the northern hemisphere. Therefore, the difference of K indices between WE and MI is possibly due to the latitudinal difference of the location where the ionospheric current flows.

Heppner¹⁰⁾ has discovered a rather clear dawn-dusk asymmetry in the high-latitude electric field observed by spacecrafts related to the polarity of the IMF. When the earth is immersed in an IMF away-sectors, the horizontal component of the polar electric field is maximum on the morning side at the northern high latitudes and on evening side at the southern high latitudes. When the earth is within an IMF toward-sectors the signature is reversed. From ionospheric electric field measurements, Mozer et al.¹¹⁾ and Mozer and Lucht¹²⁾ have also shown the same phenomena. The characters of the polar electric field are shown schematically in Fig. 4. There is about 180° phase lag between the difference of the northern and southern polar electric fields of

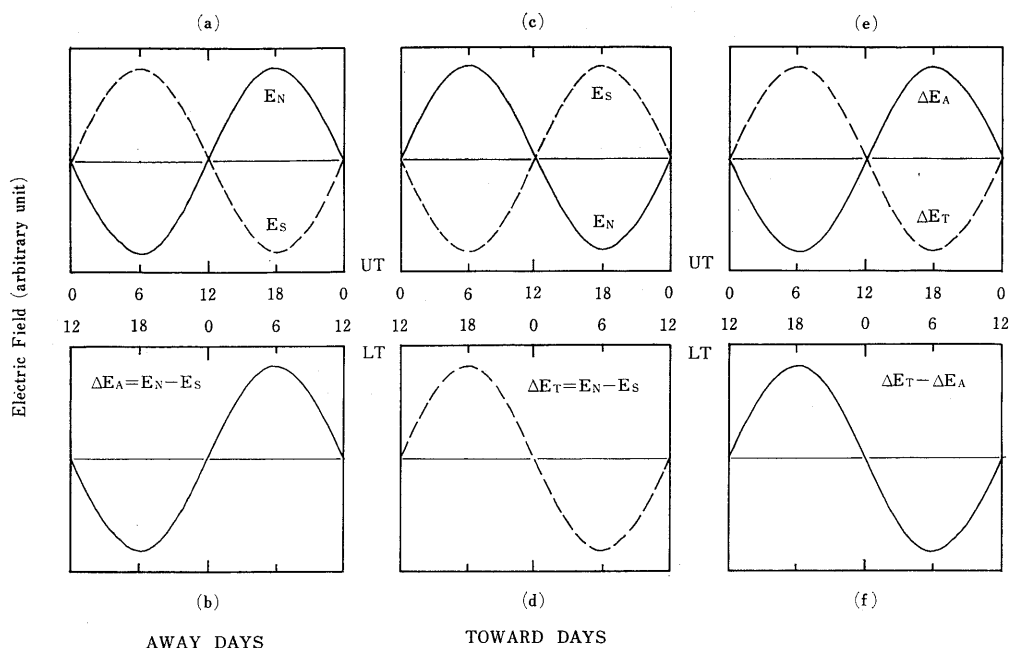


Fig. 4 (a) The solid line and the dashed line are the schematic daily variation of the polar electric field of away days at WE and at MI, respectively.

(b) The difference between the northern and the southern polar electric fields on away days.

(c) The solid line and the dashed line are the schematic daily variation of the polar electric field of toward days at WE and at MI, respectively.

(d) The difference between the northern and the southern polar electric fields on toward days.

(e) The solid line reveals ΔE_A and the dashed line reveals ΔE_T .

(f) The difference between ΔE_T and ΔE_A . This curve resembles the diurnal variation of af closely.

away days (ΔE_A) and that of toward days (ΔE_T). If the north-south and the dawn-dusk asymmetry of this polar electric field affects the development of the auroral electrojet, its effect on K indices at WE and at MI should have the same form as the electric field of Fig. 4 (b) and Fig. 4 (d). Thus, the result shown in Fig. 3 qualitatively corresponds to the curve in Fig. 4(f) which is obtained by taking the difference between the curves in Fig. 4(b) and Fig. 4(d).

Acknowledgements

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