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14. Abstract/Notes

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EFFICIENCY OF ELECTRIC FIELD TRANSFER AT EARTH'S MAGNETOPAUSE AND FLOW AMPLITUDES RELATED TO RECONNECTION

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ABSTRACT

Average of the "in situ" - large scale - electric and magnetic field measurements performed by the ISEE-1 satellite during eleven consecutive crossings of the magnetosheath - magnetopause - magnetosphere interface from 01:00 to 01:44 hours UT of day 324, 1977, are used to obtain estimates on the efficiency of transmission of the magnetosheath - electric field to the magnetopause and on some ExB flow amplitudes due to reconnection. Then, these results are compared to their equivalent magnitudes expected from large scale reconnection theories.

Keywords: Magnetopause reconnection, Magnetospheric electric fields.

1. INTRODUCTION

The electric field measurements carried out at the magnetosheath, magnetopause and magnetosphere by the ISEE-1 satellite, reported in Refs. 1-2, were consistent with the electric signature of the large scale-magnetopause-reconnection process. These measurements were obtained during eleven consecutive magnetopause crossings of the satellite and for a time interval when the B_z and B_y components (in solar ecliptic coordinates) of the magnetosheath field were southward and negative, respectively.

In the present work, averages of these measurements are used to obtain estimates on the efficiency of transmission of the Magnetosheath electric field to the magnetopause and on the magnitude of some ExB flows, under the assumption that the measurements are related to the reconnection process. Then, these results are compared to their equivalent magnitudes expected from large scale reconnection theories.

2. THE ISEE-1 MEASUREMENTS

The electric and magnetic field detectors on the ISEE-1 satellite were described in Refs. 3-4. The data, obtained in solar ecliptic coordinates, and their transformation to a local magnetopause coordinate system have been described in Refs. 1-2. These measurements were obtained during eleven consecutive crossings that occurred back and forth in the time interval (01:10 - 01:44) UT, centered at approximately 10:30 LT of day 324, 1977, during an inbound crossing of the magnetopause by the ISEE-1 satellite, and at an ecliptic latitude of about 23°. From these crossings, only ten were considered in the averages discussed below due to an abnormal magnetopause behaviour during one of the crossings, probaly caused by the occurrence of a magnetopause irregularity (Ref. 1). The magnetopause was at an average distance from the Earth of about 11.5 earth radii during these crossings.

Table 1 shows the mean values for the components of the quasi-static electric and magnetic fields in the solar wind (s), the magnetosheath (M), the magnetopause (m) and the magnetosphere (G), computed from the data collected by ISEE-1 before and during the magnetospause crossings (Refs. 1-2 and Mozer, private communication). These components are in solar ecliptic coordinates and the subscript "t" refers to the component of a vector on a plane transverse to the X-axis. The mean values in the solar wind refer to measurements obtained during approximately 30 minutes before the bow shock crossing, which occurred about two hours prior to the magnetopause crossings. The mean values in the magnetosheath and in the magnetosphere represent local behaviours of these fields near the magnetopause. Some of these averages differ slightly from the equivalent ones published in Ref. 1 due to our independent analysis of the raw data and to the inclusion of some updated corrections to the data (Mozer, private communication).

The most important feature on Table 1 is the indication of the existence of a positive E_y field at the magnetopause, with an amplitude of about 1 mV/m, during the magnetopause crossings. This essentially constant dawn-to-dusk electric field, together with the non zero B_x^m fields measured during all the crossings, constitute strong experimental evidence in support of a large scale reconnection process that seems to have been operating at the magnetopause during the time interval of these crossings (Ref. 2). The non zero B_x^m fields had negative amplitudes at the location of the satellite (see Figure 1), as expected from the topological features of the large scale reconnection process for this case (Refs. 5-6).

Table 1. Average values of the electric (mV/m) and magnetic (gammas) field components for the ISEE-1 magnetopause and bow shock crossings.

MAGNETOSHEATH	MAGNETOPAUSE	MAGNETOSPHERE
$<B_x^M> = 0$	$<B_x^m> = -7.5 \pm 2.3$	$<B_z^G> = 46.5 \pm 5.3$
$<B_y^M> = -17.36 \pm 5.21$	$<B_t^m> \sim 0$	$<E_y^G> = 1.20 \pm 0.45$
$<B_z^M> = -20.09 \pm 6.34$	$<E_x^m> \sim 0$	SOLAR WIND
$<\|B_t^M\|> = 28.30 \pm 4.52$	$<E_y^m> = 0.85 \pm 0.23$	$B_x^S \sim 0,\ B_y^S < 0,\ B_z^S < 0$
$<E_x^M> = -0.95 \pm 0.28$	$<E_z^m> = -0.41 \pm 0.16$	$<\|B_t^S\|> = 8 \pm 1$
$<E_y^M> = 1.12 \pm 0.34$	$<\|E_t^m\|> = 0.94 \pm 0.28$	$E_x^S \sim 0,\ E_y^S > 0,\ E_z^S > 0$
$<E_z^M> = -0.75 \pm 0.25$		$<\|E_t^S\|> = 2.40 \pm 0.62$
$<\|E_t^M\|> = 1.34 \pm 0.31$		

Actually, the reconnection electric field tangential to the magnetopause is a more general vector, namely $\underline{E}_t = \underline{E}_y + \underline{E}_z$ (Ref. 5). For large scale

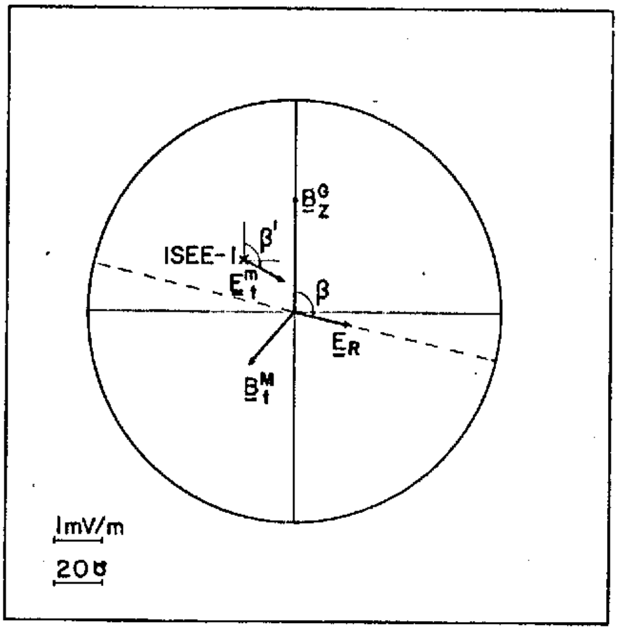

Fig. 1 A view from the sun of the average $\underline{B}^G$ and $\underline{B}_t^M$-fields measured by the ISEE-1 satellite, whose position during the magnetopause crossings is indicated by the x-mark. The dashed line is the computed reconnection line. See text about the angles β and β' and about the fields $\underline{E}_t^m$ and $\underline{E}_R$.

reconnection, this $\underline{E}_t$ field is usually assumed to be defined along the reconnection line (e.g. Refs. 5-6). Thus, since the ISEE-1 measurements occurred relatively close to the reconnection line, as illustrated in Figure 1, one can try to compare the measured $\underline{E}_t$ field with that expected from reconnection. This $\underline{E}_t$ field was measured, in average, with a direction and magnitude close to that suggested by the reconnection model of Gonzalez and Mozer (Ref. 5), as discussed below and also illustrated in Figure 1. The assumption that the ISEE-1 measurements were performed relatively close to the reconnection line is further substantiated by the fact that $<B_x^M> \sim 0$. This is a basic feature expected at the reconnection line (e.g. Ref. 6).

3. EFFICIENCY OF ELECTRIC FIELD TRANSMISSION

For the transmission of E_t^M to the magnetopause, resulting in the magnetopause-electric field E_t^m, we define the efficiency factor $F' \equiv E_t^m/E_t^M$. An efficiency factor equivalent to F', and defined in the reconnection model of Gonzalez and Mozer (Ref. 5), is a projection factor of E_t^M along the reconnection line given by

$$F = F(S,\theta) = (1-S\cos\theta)/(1-S^2-2S\cos\theta)^{1/2}, \quad (1)$$

with $S \equiv B^G/B_t^M$ and θ the angle between $\underline{B}^G$ and $\underline{B}_t^M$ (Ref. 7). Thus, the reconnection electric field, $E_R \equiv (F)\ E_t^M$, can be compared to $E_t^m = (F')\ E_t^M$ in order to have an idea on how well the projection factor F describes the transmission efficiency factor F'. Note that the scalar nature of the efficiency ratio F' follows from its assumed association to the scalar projection factor F.

From the average values for the electric fields shown in Table 1, we obtain the following average estimates for the efficiency factors mentioned above: $<F'> = 0.70$ and $<F> = 0.78$.

These averages estimates suggest, within their relative error of the order of 20%, that the efficiency of transmission of E_t^M to the magnetopause may be considered as mainly related to the projection of E_t^M along the reconnection line, as described by the Gonzalez and Mozer model (Ref. 5). In fact, in this model, the angle β between the Z-axis and the reconnection line is given by $F = \sin(\theta-\beta)$, which, from the ISEE-1 average measurements of Table 1, has an average value of $<\beta> \sim 102^o$. Whereas, from the directly measured averages $<E_y^m>$ and $<E_z^m>$, we get an average angle

$$<\beta'> \equiv 90^o + |\tan^{-1}[<E_z^m>/<E_y^m>]|, \quad (2)$$

between the Z-axis and the average $\underline{E}_t^m$ vector, of approximately 116°. Thus, the average magnitude and direction of $\underline{E}_t^m$ measured by ISEE-1 during the reported crossings, namely $<E_t^m> = 0.94$ and $<\beta'> = 116^o$, seem to be consistent with the equivalent estimates, $<E_R> \sim 1.15$ and $<\beta> \sim 102^o$, obtained from the reconnection model of Gonzalez and Mozer (Ref. 5). The angles $<\beta>$ and $<\beta'>$, the average fields $\underline{E}_t^m$ and $\underline{E}_R$ and the reconnection line are shown in Figure 1. This Figure also shows the average $\underline{B}^G$ and $\underline{B}_t^M$ measured fields, transposed to the nose, where the average direction of the reconnection line (given by $<\beta>$) was computed.

4. RECONNECTION FLOWS

Using the ISEE-1 average measurements of Table 1, we can also try to estimate some of the critical plasma flows at the reconnection region. For this purpose we use an Alfvén speed based on the average magnetosheath field (~28 gammas) and on the average proton density of 22 cm^{-3}, also measured by ISEE-1 during these crossings (Mozer, private communication). This Alfvén speed is

Start text $\langle V_A \rangle \approx 1.33 \times 10^7$ cm/sec. For our present case, with $\langle B_t^m \rangle \sim 0$ (Table 1), this average Alfvén speed is the same as that based on the difference of $\langle B_t^M \rangle$ and $\langle B_t^m \rangle$ (Ref. 8).

Following Petschek (Ref. 9), the average reconnection and post-reconnection flow rates are defined as $R \equiv \langle V_x^M \rangle / \langle V_A \rangle$ and $P \equiv \langle V_t^m \rangle / \langle V_A \rangle$, respectively. Using the Alfvén speed given above and values for $\langle V_x^M \rangle$ and $\langle V_t^m \rangle$, obtained from $c\, E_t^M / B_t^M$ and $c\, E_t^m / B_x^m$, respectively, with the corresponding averages of Table 1, we get R = 0.36 and P = 0.95. Although the value obtained for P is very close to that predicted by Petschek (P = 1), the reconnection rate R is somewhat bigger. However this value for R lies well within the range $\leq (1 + \sqrt{2})$, suggested by Sonnerup (Ref. 10).

Among other informations that one could try to obtain from the averages of Table 1, with respect to magnetopause features related to reconnection, the average value for the ratio $S \equiv B^G / B_t^M$, mentioned above, is about 1.6. This value could be used in studies of pressure balance at the magnetopause during the time interval of the magnetopause crossings studied in this report.

5. CONCLUSIONS

From the ISEE-1 magnetopause crossings discussed above, the similar values obtained for the average E_t^m and E_R fields suggest that the transmission efficiency of the magnetosheath E_t^M field to the magnetopause during reconnection may be considered as mainly due to the projection of E_t^M along the reconnection line, as prescribed by the reconnection model of Gonzalez and Mozer (Ref. 5).

From Table 1, $\langle E_x^M \rangle \neq 0$. The magnitude and direction of this component of the magnetosheath electric field at the magnetopause, combined with those of $\langle B_t^M \rangle$, suggest the presence of a finite magnetosheath flow tangential to the magnetopause and in a direction close to that expected from an aerodynamic flow (Ref. 11) at the position of the satellite. Thus, from this argument and from the value obtained for the reconnection rate (R = 0.36), one could suggest that the efficiency of the reconnection process during the ISEE-1 crossings studied in this report was < 1.

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