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# Fast and Delayed Penetration of the Interplanetary Electric Field to the Earth's Magnetosphere

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Measured ionospheric electric fields at auroral latitudes through 18 balloon flights, and computed electric fields from an open magnetospheric model, show that the interplanetary electric field penetrates to the magnetosphere via a fast and a delayed mode. These modes are interpreted as' rarefaction and convection waves, respectively. Some implications of these results about the understanding of convection in the magnetosphere are presented for magnetically disturbed and not disturbed periods.

Campos elétricos medidos na ionosfera de latitudes aurorais a bordo de 18 balões, e campos elétricos computados de um modelo aberto da magnetosfera, mostram que o campo elétrico interplanetário penetra na magnetosfera por um modo rápido ou por um modo lento. Esses modos são interpretados como ondas de rarefação e convecção, respectivamente. São também apresentadas algumas das implicações dos resultados para o entendimento de convecção na magnetosfera para períodos magneticamente perturbados e não perturbados.

The purpose of this work is to show some results obtained on the local character of the interplanetary electric field penetration to auroral latitudes for an open magnetospheric model.

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More than 300 hours of electric field data collected with balloon flights between $L = 5.4$ and $L = 8.2$ (Mozer and Serlin, 1969; Mozer and Manka, 1971) has been used to obtain hourly values of the ionospheric electric field for each local time of the auroral region. The open magnetospheric model prepared by Gonzelez and Mozer (1974) has been used to compute hourly values of the interplanetary electric field at the magnetopause for the periods of balloon observation. Figure 1 shows the geometry of the interplanetary electric field at the magnetopause due to merging between the interplanetary and terrestrial magnetic fields. Figure 2 shows the potential drop computed by the model for measured values of the interplanetary magnetic field. For the present work, we have used measured values of the interplanetary magnetic field during the periods of balloon observations (Fairfield, private communication).

Therefore, for each local time, we had a collection of hourly values for the measured and computed electric fields with which we could do a TIME LAG analysis to find out properties of the interplanetary electric field penetration into the auroral region.

From the balloon flights, we selected those (18 flights) which did not have discontinuous data and for which we had interplanetary magnetic field data to compute the model electric field. From these flights, 10 belong to magnetically disturbed periods and 8 to not disturbed periods, according to average $K_P$ - indices computed for the periods of flight.

Most of the flights started at 22 hours local time and 'lasted for approximately 12 hours. For the time lag analysis, we selected a local time range between 02 and 09 hours local time, since for this range of hours the analysis showed good statistics, namely that at least 15, 8 and 6 flights were involved in the analysis of all, disturbed not disturbed cases, respectively.

The time lag analysis has been carried out both at the auroral ionosphere and at the equatorial plane in a non-rotatíng frame of reference

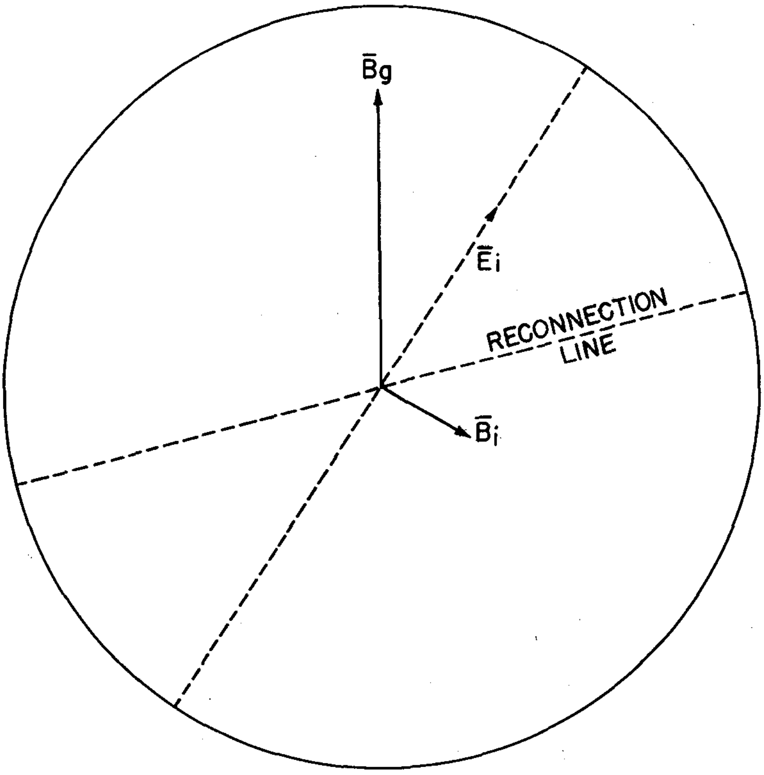

*Fig.1* – Interplanetary electric field and magnetic merging geometry at the magnetopause.

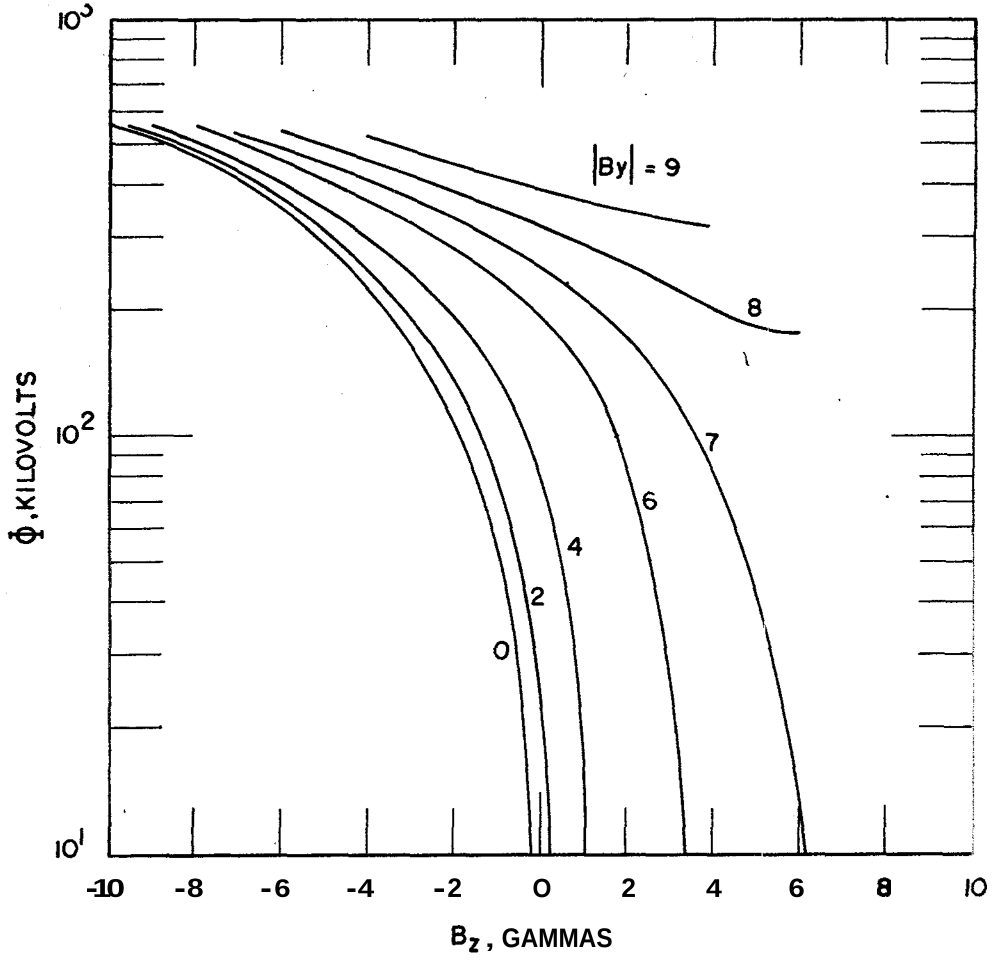

*Fig. 2* - Potential drop model at the magnetopause due to magnetic merging as a function of the interplanetary magnetic field.

between the computed electric field and the measured electric field (ionosphere) or mapped electric field (equatorial plane). The mapping procedure used for this analysis was described by Mozer (1970). For the ionospheric electric field, we choose the southward component ($E_S$) and for the equatorial field the dawn to dusk component ($E_{DD}$). The other components, ionospheric westward and equatorial tail to sun, showed poor correlations in the analysis and therefore were neglected.

Since the results obtained in the analysis of the equatorial plane are very similar to those of the ionosphere, we shall discuss ontly the ionospheric case and similar conclusions can be extended to the equatorial plane. Figure 3 shows the results of the analysis for each local time as a correlation coefficient against time lag and for all the selected flights. Since for each local time there are peaks of best time lag (with higher correlation coefficients), one for short delay times and the other for longer delay times, we shall consider them as due to two different processes which are goíng to be discussed later. In Figure 3, these two peaks are joined by dotted tines. From Figure 3, we selected the best time lags (BTL), defined as the hours of time lag with best correlation coefficients, and their associated values of correlation coefficient (CCBTL). Therefore, we had two groups of BTL and associated CCBTL as mentioned above. These values are plotted in Figure 4 against local time. The error bars are proportional to the uncertainty in obtaining the BTL values from Figure 3. The lines are best fits to those values, and are labeled CW and RW for reasons explained later. The best fit to the short delay-group of points is a line with approximately zero slope and with a uniform delay time of approximately one hour for all local times. The other group of points with a longer time delay has a best fit line with positive slope, intercepting midnight at approximately 6 hours of time delay, and shows further a time delay increase from midnight towards noon. Figures 5 and 6 are similar plots for the magnetically disturbed and not disturbed cases, respectively, and obtained from graphs similar to Figure 3.

Thus, the main result of this analysis seems to be that the interplanetary electric field penetrates to the auroral region via two equally

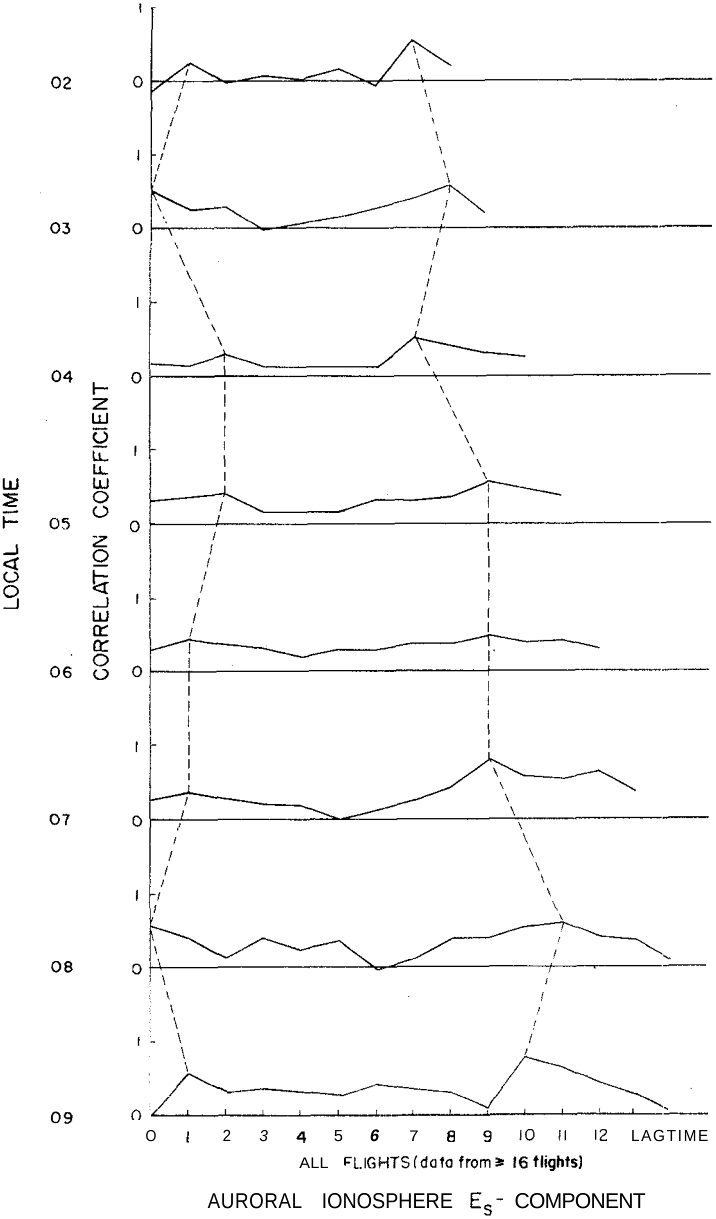

*Fig.3* - Correlation coefficient versus time lag for each local time involved in the analysis.

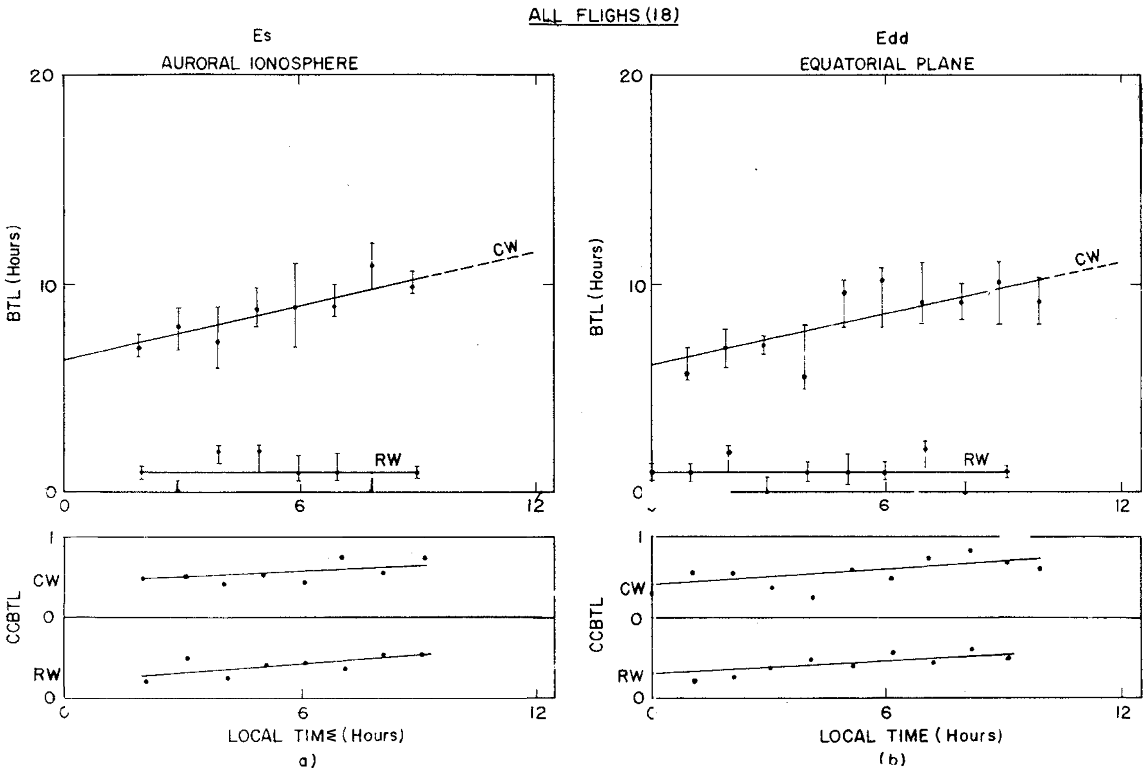

*Fig.4* - Best Time Lag (BTL) and associated correlation coefficients (CCBTL) versus local time for all the flights.

important ways. One is a short time penetration with 1 hour average time delay which may be the rarefaction wave (RW) described by Coroniti and Kénner (1973). This wave probably penetrates from the dayside magnetopause (merging region) directly towards midnight traveling inside the closed magnetosphere and around the plasmapause, sucking plasma and magnetic field lines and trying to get a steady states for the merging process. The l-hour of average time delay of this wave isprobably consistent with several Alfvén travel times between the clused magnetosphere and the ionosphere. The other way of penetration has a longer time delay, arrives to midnight after approximately 6 hours and then propagates toward noon with an average extra delay time of approximately 5 hours. This second way of penetration may be a convection wave (CW). The 5 hours of average extra delay from midnight to noon is consistent with the propagation time of a convecting flow around the plasmapause computed with the $\vec{E} \times \vec{B}$ velocity associated to the measured electric field and to a magnetic field model (Fairfield, 1968) averaged at the corresponding L-values of the convection region.

From Figures 4, 5 and 6, one can also make the following comments:

The average convection times between midnight and noon are approximately 5, 4 and 6.5 hours for all, disturbed and not disturbed cases, respectively. These numbers were obtained with the help of the dotted extrapolations of the best fit lines. This suggests that during disturbed periods either the travel path for the convecting flow is shorter or that the convection speed increases or both.

The convection wave takes approximately 6 hours to arrive at midnight, under both quiet and di'sturbed conditions. This conclusion may imply that the magnetospheric tail has similar convection properties both for disturbed and not disturbed periods.

The correlation coefficient increases from midnight toward noon which is probably consistent with the existence of higher parallel potential drops on field lines around midnight.

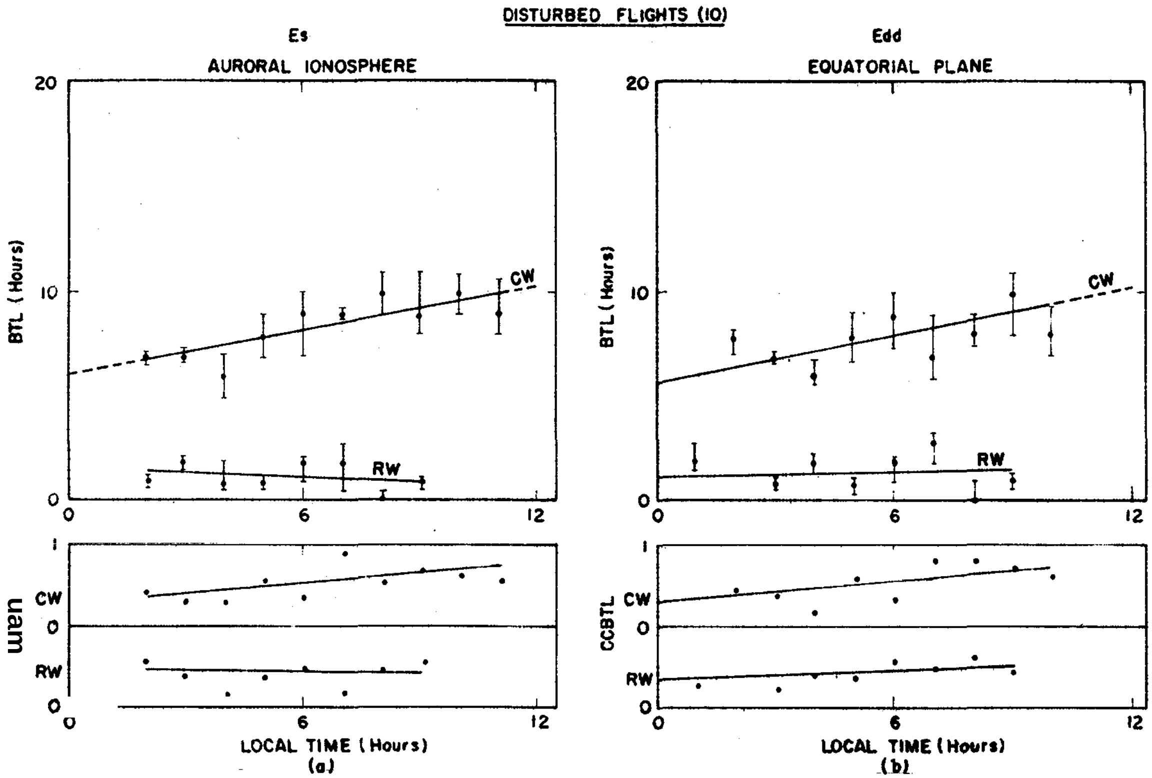

*Fig.5* - Best Time Lag (BTL) and associated correlation coefficients (CCBTL) versus local time for the disturbed cases.

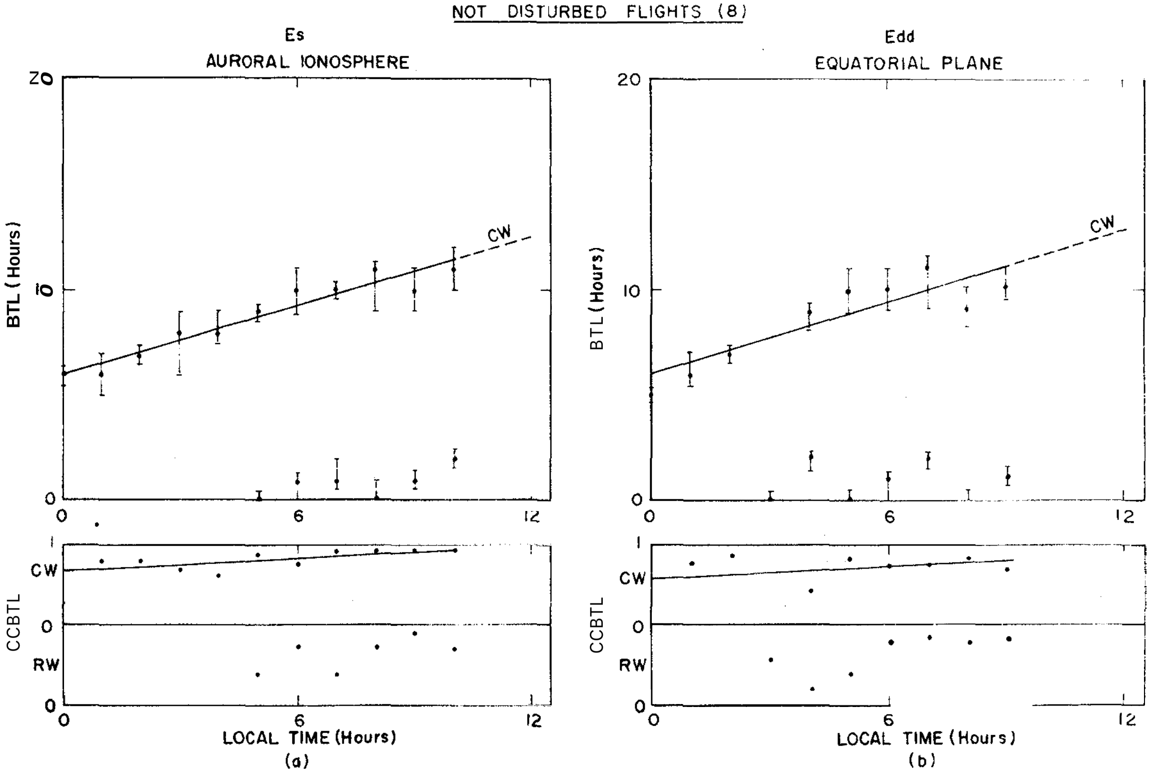

*Fig.6* – Best Time Lag (BTL) and associated correlation coefficients (CCBTL) versus local time for the not disturbed cases.

From Figure 6, it appears that the rarefaction wave is lost on its way toward midnight when the period is not disturbed.

We may conclude by saying that previous correlations concerning magnetospheric substorms have been probably dealing only with the rarefaction wave with an average delay time of 1-hour between the "southward shift" of the interplanetary magnetic field and the onset of a substorm. However, from this analysis one might as well suggest that equally important correlations may be found for longer time delays.

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