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Penetration electric fields and inner magnetosphere dynamics - A model and data comparison

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First Annual Progress Report 3
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Summary: The initial substorm interval to be studied has been selected to be the magnetic storm of June 4, 1991, and following. The CRRES electric and magnetic field data has been processed. We have added DMSP ion drift and energetic particle data and further refined the CRRES data for intercomparison. The DMSP data increase the frequency of monitoring of the temporal response of the penetration electric fields to every 100 min. Energy is seen to flow between the ionosphere and magnetosphere at low L values during the main phase of the magnetic storm in the form of field-aligned Poynting flux. This indicates electrodynamic coupling of the regions with Alfvén waves. The first comparisons of the data with outputs of the Rice Magnetospheric Specification Model (MSM) were made. Both positive and negative correlation were seen as might be expected. Differences were especially evident in the time constants of the processes. Comparisons with the more physically self-consistent Rice Convection Model (RCM) with both electric fields and particle data are in progress to suggest physical constraints for our understanding of the phenomena.

Factual data and current analysis

The initial tasks were to select the first magnetic storm interval to study and to organize and process the data sets. We have selected the period from 2 June through 6 June, 1991, as the first interval to study. The combined DMSP and CRRES data bases provide a comprehensive description of the electric fields in the plasmasphere and inner plasmasheet during the June 4-6, 1991, magnetic storm. The CRRES data provide accurate electric field specification into L of 2 (45 degrees invariant latitude). By considering each orbit, the DMSP data extend the time resolution to every 100 minutes in each hemisphere. The evolution of the electric field structure during the storm can be followed.

The first step was to prepare the data base. Electric and magnetic field data from CRRES have been processed and displayed in MGSE and VDH coordinates for this period. MGSE is a spacecraft defined system similar to GSE coordinates. The Z axis is vertical and the Y axis is toward dusk in the equatorial plane. Both are constrained to the satellite spin plane. The X axis is along the satellite spin axis and roughly points toward the Sun. The two components of electric field are measured in the spin plane. The third component along the spin axis is extrapolated from the other two, using the $\mathbf{E} \bullet \mathbf{B} = 0$ assumption. We have selected intervals where the angle of the magnetic field to the spin plane is greater than 20° to minimize any increased errors caused by the extrapolation. This preserves reasonable accuracy for the vector electric field determination.

Electric and magnetic field data from CRRES during the early June, 1991, magnetic storm have been converted into VDH where V is the radially outward component, D is in the azimuthal direction and H is parallel to the Earth's magnetic dipole. The three VDH components were then rotated into magnetic field aligned coordinates to easily display the azimuthal and radial components of the perpendicular electric field. By reducing the information to two dimensions, the values are easily adaptable to projection along equipotential magnetic field lines for comparison with DMSP data and with results of the Magnetospheric Specification and Forecast Model (MSFM). We have also calculated the Poynting flux along the magnetic field using the procedure outlines in Maynard et al. [1996]. This provides a measure of magnetosphere-ionosphere coupling. For most of the data, values are small to non-existent as expected. However, during the main phase of the storm, we observe significant changes in the field-aligned component of the Poynting flux. This is indicates that Alfvén waves are probably present. We will investigate these results further. Using the energetic particle and plasma wave data we are able to locate the plasmapause and inner edge of the plasmasheet relative to the activity.

We have processed the ion drift data and energetic particle data from DMSP F8 during the interval from June 2 to June 6. Data from the faster temporal repetition of the DMSP orbit provides the context around the events in the more infrequent CRRES passes. DMSP F9 data was also checked; however, at first glance it is at the wrong local time to be of immediate use. DMSP F8 provides a measure of the cross-polar-cap potential as well as the structure of the ion drift at auroral and subauroral latitudes. Variable offsets typically restrict the interpretation of subauroral ion drift and electric field data. However, the CRRES data can be used to set the offset for close conjunctions. Similar behavior is seen in the CRRES and DMSP data sets and we will use CRRES data to refine the DMSP data so that we can follow changes the penetration electric field on a 100 min time scale (every orbit).

On 4 June the magnetospheric convection electric field of over 1 mV/m penetrated well inside the plasmasphere to an L value of 2.4 at 1500 MLT. One orbit later there was signs of overshielding in the inner plasmasphere, and the dawn to dusk electric field was confined to L values of greater than 4.0. Figure 1 shows and example of a quiet plasmaspheric electric fields from 3 June compared with the electric field observed on 4 June. Figure 2 shows stack plots versus magnetic latitude of the ion drift data for June 4 and 5. The horizontal drift component is equivalent to a radial electric field. The inward movement of the activity after the onset of the storm in the later part of June 4 is obvious. Note the variability of the inner boundary.

Of primary importance in improving our understanding of the physics of penetration electric fields are comparisons with models which best express our current knowledge. We have begun this process by comparing the model outputs from the Magnetospheric Specification Model (MSM) for the June storm with the CRRES and DMSP data sets assembled over the previous months. The MSM is in some respects a truncated version of the Rice Convection Model (RCM) built for operational use. The streamlining that was done in the physics of the RCM to produce the operationally oriented MSM removes the feedback and self consistency. The MSM does however provide a continuously updated magnetic field model based on conditions. Thus, both models have advantages and disadvantages. Several features were evident.

1. The agreement of MSM with CRRES E-field data was fairly good overall. Penetration was seen when predicted and MSM predicted that CRRES would be in the main flow region when it was.
2. MSM E-fields appeared to be a factor of 2 lower in magnitude. This may be deceptive because of the wave activity in the CRRES data that is not present in the MSM run.
3. The higher temporal resolution DMSP data also showed penetration where MSM showed penetration; however, the times do not line up well.
4. DMSP continues penetration much later than MSM. Time constants for establishing shielding in MSM do not agree with the data. Overshielding observed by DMSP was weak compared to the model.

While the model and the data are both showing penetrating electric fields and some consistency, the degree of penetration and the time constants for the process including the time constant to establish shielding and even overshielding do not match. It is obvious from the initial comparison that we will have to also compare the data to the RCM. It will be necessary to compare with both models in order to evaluate what the data are telling us about the models and our understanding of the physics. Adding particle comparisons between data and models will also help to resolve causes of differences.

We are in the process of running the RCM for this storm (to be completed by 1 March). A meeting has been set up at Rice on March 13 and 14 between Drs. Maynard and Wolf to compare and contrast the MSM and RCM runs with the experimental data. At that point we will be ready to proceed with the draft of a paper for this event.

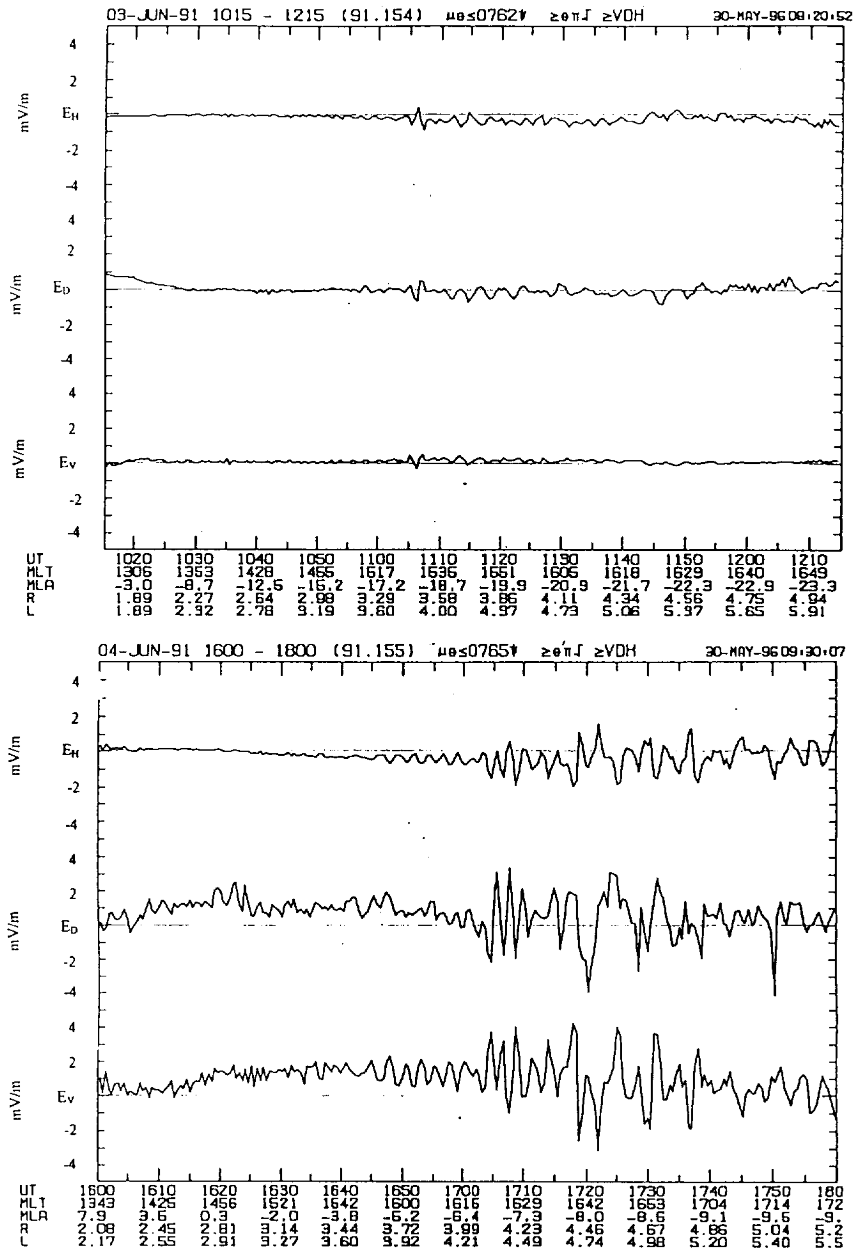

Figure 1: CRRES electric field data in VDH coordinates showing a quiet plasmasphere of 3 June in the top three panels and the dawn-dusk penetration electric field in the disturbed condition of 4 June.

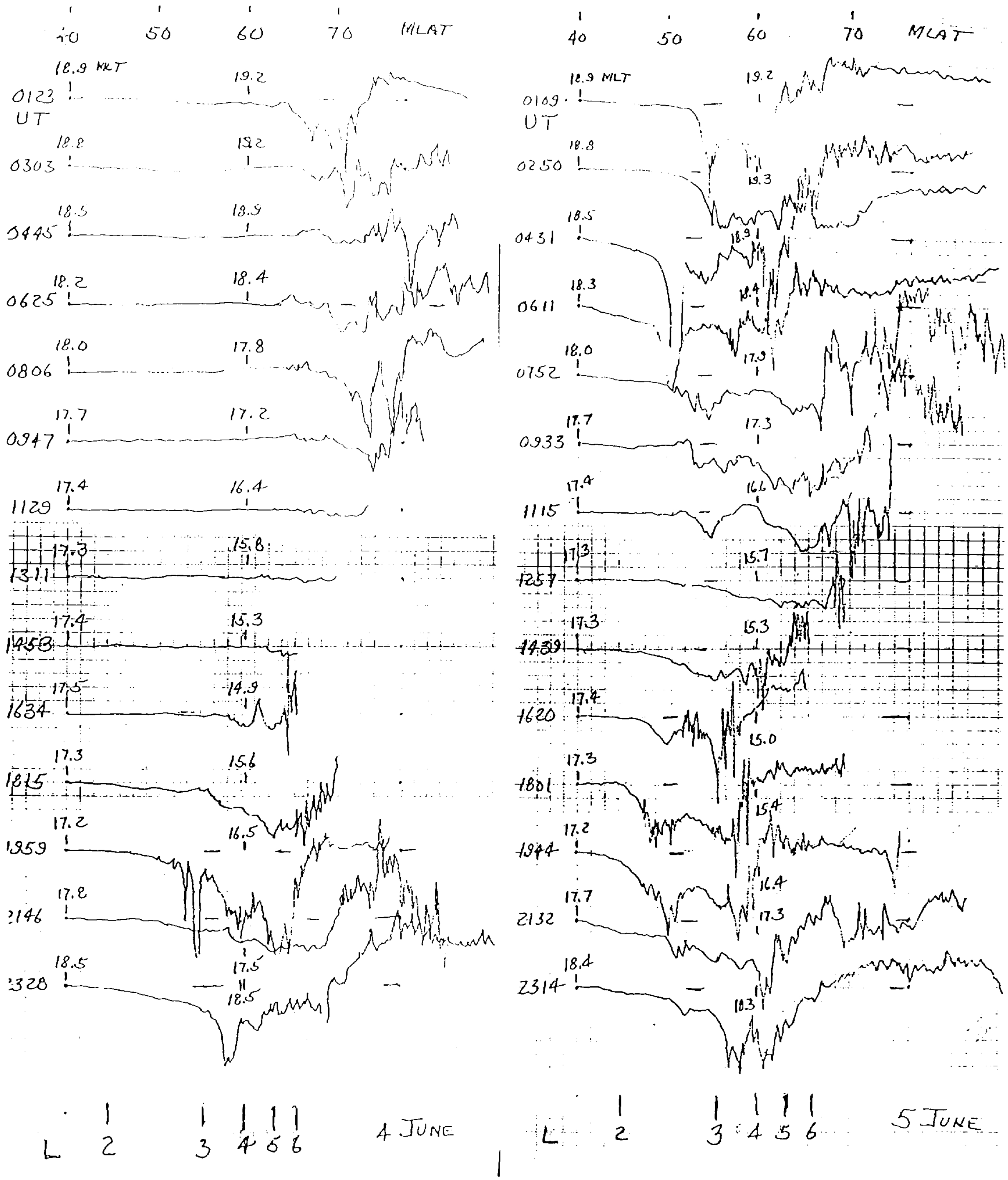

Figure 2 DMSP F8 ion drift data plotted against magnetic latitude for June 4 and 5, 1991. The UT of each pass is given at the left and the MLT of the 40 and 60 degree crossings is given over each curve. Negative cross track ion drift values are equivalent to poleward electric fields in these southern hemnisphere passes and would project to a radially outward perpendicular component at CRRES.