MAGNETIC FIELD OBSERVATIONS OF THE DAYSIDE POLAR CUSP

Dr. Donald H. Fairfield

Important information on the entry of particles into the magnetosphere was obtained by the IMP 5 spacecraft which made the first systematic measurements of the polar or dayside cusp. This region is illustrated in Figure 1, which is a view of the magnetosphere in the noon-meridian plane. The Sun is toward the left. Various boundaries and regions are labeled appropriately. The dashed lines represent magnetic dipole lines force and the solid lines represent more realistic distorted lines of force. The IMP 5 spacecraft makes passes through the region labeled "polar cusp," which separates the lines that close on the dayside of the Earth from those that go back over the polar cap.

The plasma instrument of Dr. Frank observes magnetosheath-like plasma in the polar cusp region down to altitudes of about 4 Earth radii. Low-altitude polar-orbiting spacecraft also detect magnetosheath-like plasma just above the ionosphere; apparently this magnetosheath-type plasma has access to the magnetosphere through the polar cusp region.

Today I would like to talk about the magnetic field measurements in this region. A very important subject that has been discussed for many years is the question of whether magnetosphere magnetic field lines become connected to the magnetosheath lines at a neutral point or is the magnetopause tangential discontinuity such that the field lines in the magnetosheath are completely isolated from the field lines of the magnetosphere. If any connection were found to occur it would provide an easy explanation for the entry of plasma to the cusp region and also provide insight into the question of how energy is put into the magnetosphere. IMP 5 passes through the polar cusp in just the region where we would hope to be able to answer this question.

Figure 2 represents 4 hr of magnetic field data beginning outside the bow shock at about 12 Earth radii and continuing to about 6 Earth radii where the instrument becomes saturated. The top trace indicates the magnitude of the field on a logarithmic scale. Below this is ΔB, which is defined as the measured magnetic field minus the value of an internal reference field extrapolated from surface measurements. The inclination I and declination D are defined in the conventional sense and they indicate the direction of the field. The bottom trace is a standard deviation δ, which is a measure of the higher frequency fluctuations that are occurring at this time.

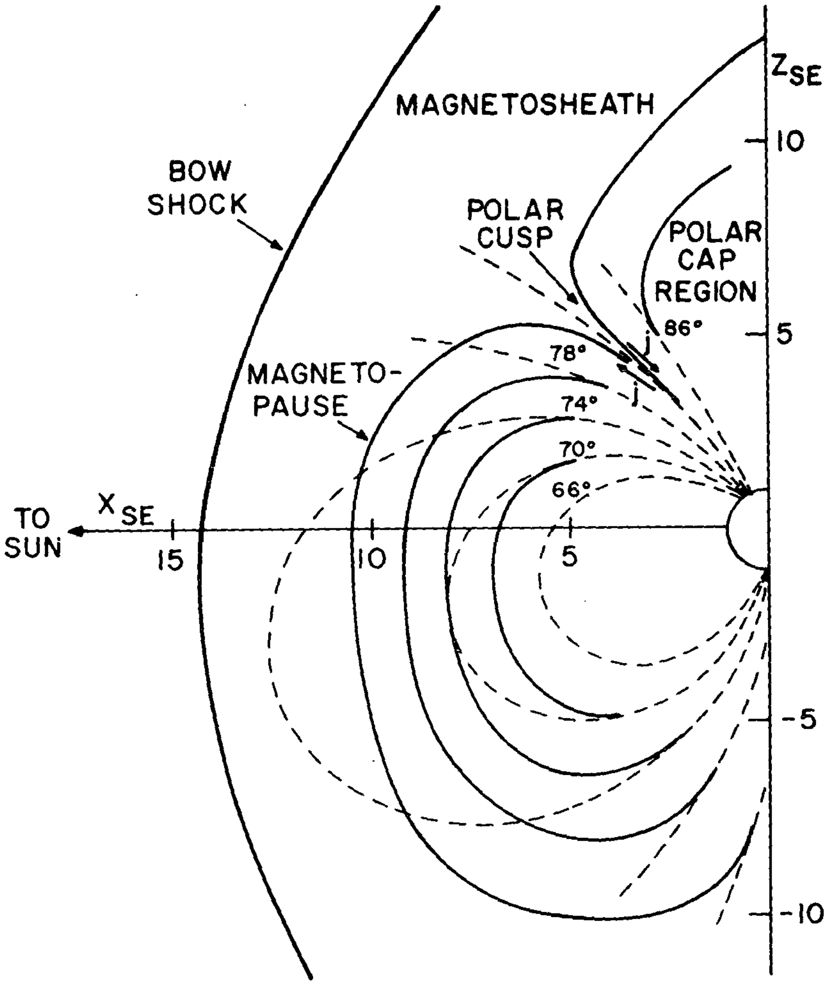

Figure 1–The magnetosphere in the noon-meridian plane.

The vertical dashed lines represent the boundaries of the polar cusp as defined by Dr. Frank's plasma experiment (Ref. 1). The primary characteristic of the magnetic field is the depressed nature of the field in this region. Field strengths are as much as 130 nT (130 γ) below the reference field in this region centered on the polar cusp. This means that field lines that certainly must connect to the Earth have field strengths that are only 30 to 40 percent of the dipole value.

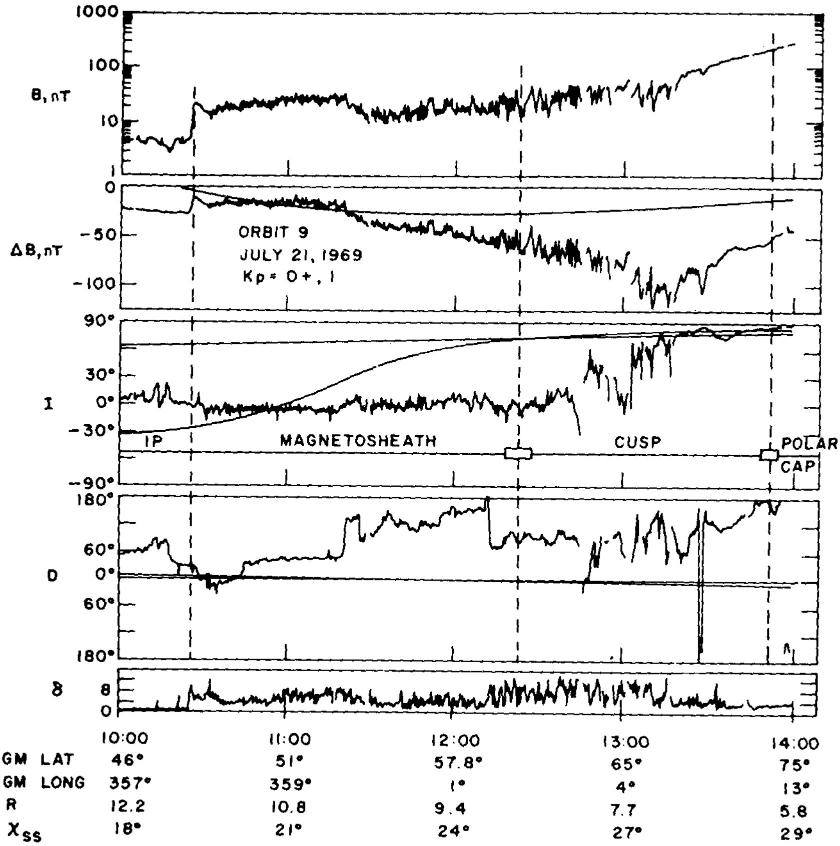

Figure 2–Magnetic field data obtained by IMP 5.

The second characteristic is the absence of a well-defined magnetopause on this pass. On the left portion of the magnetosheath, the field direction is determined by whatever the interplanetary field happens to be and on the right the direction is determined by the Earth's dipole. The transition between these two regions is gradual and many large fluctuations in direction are observed.

A third characteristic of the polar cusp is the presence of very large amplitude higher frequency fluctuations as are indicated by higher values of δ. Power spectra computed for this interval indicate more power than had been found on more than 70 similar intervals at lower latitudes in the magnetosheath.

The question of interconnection of field lines is usually approached by searching for a field component normal to a magnetopause boundary. Since a magnetopause boundary cannot even be found in this case, such an analysis obviously cannot be carried out. The question being asked is "what is the path of a field line in this region?" One must remember that a magnetometer makes a vector measurement at a given point in space. Therefore, only if the field retains this direction over a distance scale of many thousands of kilometers can anything be said about the path of the field line. In the case of the polar cusp the field is fluctuating rapidly with large amplitudes, so it is not easy to determine where the field line goes.

In summary, the magnetic field measurements in the polar cusp are characterized by unusually low magnitudes and large fluctuations. The low magnitudes can probably be explained by currents on the magnetopause and the diamagnetic effect of the plasma. The transition between the magnetosheath and the cusp portion of the magnetosphere is not characterized by a well-defined magnetopause as at low latitudes. The fact that there is no well-defined discontinuity is consistent with the interconnection of magnetosheath and magnetosphere magnetic fields, but there is no definitive proof that such reconnection does occur.

REFERENCE

1. Frank, L.: Plasma in the Earth's Polar Magnetosphere. J. Geophys. Res., Vol. 76, 1971, p. 5202.