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Final Report

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Correlative Studies of the Solar Wind, the Interplanetary Magnetic Field, and Their Effects on the Geomagnetic Cavity Using Explorer 33 and 35 Data

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INTRODUCTION

The Institute of Geophysics and Planetary Physics proposed to continue the use of data from Explorer 33 and 35 in conjunction with data from UCLA space flight experiments to extend present studies of the effects of the solar wind and interplanetary magnetic field on the bow shock and geomagnetic cavity. This renewal proposal was rejected due to lack of funds. We are now submitting this proposal as our final report. The work completed on this grant is covered in detail by this report, as well as work that was under way but not yet complete, and a discussion of what remains to be done in the proposed area of study.

I. WORK COMPLETED

1. Data Acquisition

Our correlative data from the Explorer 33 and 35 magnetometer consist of three types: microfilm plots, 1 hour averages, and 81.2 second averages. We have obtained the microfilm plots from the National Space Science Data Center for Explorer 33 from July 1966 to July 1969 and for Explorer 35 from July 1967 to July 1969. From the Ames Research Center we have obtained hourly averages for the years 1967 and 1968 and the 81.2 second averages. The 81.2 second averages are on magnetic tape and cover the period from March to November 1968. These data were originally on IBM 7094 7-track magnetic tapes and we have reformatted them into IBM 360 9-track tapes, thus providing data compatible with the computers of a larger segment of the scientific community.

We have also acquired orbit data for Explorer 33 for the period from January 14, 1968, to August 6, 1968, and November 11, 1968, to February 4, 1969, on microfilm (predicted world maps). Data for the intervening period have been acquired on magnetic tapes.

2. Computer Programs

We have written programs to read, print, and plot the high resolution Explorer 33 and 35 data for correlation studies with other satellite data. Further, we have written a specialized analysis program using the Explorer 33 or 35 field direction and the OGO 5 orbital data to give the angle between the interplanetary field and the shock normal and also to find the position of intersection on the bow shock of the field line through OGO 5.

3. Research

a. Polar Cusp. Explorer 33 data in IPM showed that repeated encounters of the polar cusp by OGO 5 on November 1, 1968 were due to the changing north-south component of interplanetary magnetic field.[1] Specifically, when the interplanetary field was southward the polar cusp moved equatorward. Further analysis of the Explorer 33 and OGO 5 data has revealed other and perhaps more important control of the polar cusp by the interplanetary magnetic field.[2] When the interplanetary field is northward, the electron temperature is a factor of 2 higher inthe polar cusp than when the interplanetary field is southward. Further, the currents in the polar cusp are stronger when the interplanetary field is southward than when it is northward.

b. Substorms. The Explorer 33 and 35 data have been used to study the effect of the interplanetary magnetic field on the growth phase of substorms. Specifically, it is found that the growth phase occurs when the interplanetary field turns southward[3] and that quiet geomagnetic periods occur during intervals of northward interplanetary field.[4]

c. Geomagnetic Activity. Our correlative work on the effect of the orientation of the north-south component of the interplanetary magnetic field on both the magnetopause and the polar cusp using the Explorer 33 and 35 data plus the experience gained in coordinate transformations required for these correlations led us to attempt to solve an age-old problem of geomagnetism: the semi-annual variation of geomagnetic activity.[5] Our explanation is simply that the changing orientation throughout the year of the solar magnetospheric coordinate system, in which the interaction at the magnetopause is controlled, relative to the solar equatorial coordinate system in which the interplanetary field is ordered, leads to a varying probability throughout the year that the interplanetary field will be southward. This southward field then causes substorms and hence increases geomagnetic activity. Although this project affected the amount of time we were able to spend on the detailed correlation analysis that we had expected to undertake, it represented a direct application of the knowledge we had been gathering during these analyses and hence we judged this project a valuable investment of our efforts.

d. North-South Component of the Interplanetary Magnetic Field. The dependence of the average north-south component (in solar equatorial coordinates) of the interplanetary field on the polarity of the field (towards or away from the sun) which was originally found with Mariner data, has been confirmed using Explorer 33 and 35 data in 1967 and 1968.[6] The relationship found is such that for an interplanetary field directed outward from the sun, the mean value of B_θ was negative above the equatorial plane and positive below it and vice versa for an inward field.

e. Publications

1. Russell, C.T., C.R. Chappell, M.D. Montgomery, M. Neugebauer, and F.L. Scarf, OGO-5 observations of the polar cusp on November 1, 1968, J. Geophys. Res., 76(28), 6743, 1971.

2. Russell, C.T., M. Neugebauer, M.G. Kivelson, and F.L. Scarf, The dependence of the polar cusp on the north-south component of the interplanetary magnetic field, to be submitted to J. Geophys. Res., 1972.

3. McPherron, R.L., C.T. Russell, G.K. Parks, D.S. Colburn, and M.D. Montgomery, Satellite studies of magnetospheric substorms on August 15, 1968, Note 2, Solar wind and inner magnetosphere, submitted to J. Geophys. Res., 1972.

4. Aubry, M.P., M.G. Kivelson, R.L. McPherron, and C.T. Russell, A study of the outer magnetosphere near midnight at quiet and disturbed times, submitted to J. Geophys. Res., 1972.

5. Russell, C.T. and R.L. McPherron, The semiannual variation of geomagnetic activity, submitted to J. Geophys. Res., 1972.

6. Rosenberg, R.L., P.J. Coleman, Jr., and D.S. Colburn, North-south component of the interplanetary magnetic field: Explorer 33 and 35 data, J. Geophys. Res., 76(28), 6661, 1971.

f. <u>Papers Presented at Meetings</u>

Aubry, M.P., R.L. McPherron, C.T. Russell, and D.S. Colburn, Changes in the cusp of the geomagnetic tail during magnetospheric substorms, presented at the National AGU Meeting, April, 1971 (abstract) EOS, Trans. Amer. Geophys. Union, 52(4), 324, 1971.

*McPherron, R.L., Magnetic signature of substorms in the near tail, presented at the National AGU meeting, April, 1971 (title only), EOS, Trans. Amer. Geophys. Union, 52(4), 328, 1971.

*Russell, C.T., OGO-5 observations of the polar cusp on November, 1968, presented at the National AGU meeting, April, 1971 (title only), EOS, Trans. Amer. Geophys. Union, 52(4), 319, 1971.

*Russell, C.T., The magnetotail and substorms, presented at the Fall AGU meeting, December, 1971 (title only), EOS, Trans. Amer. Geophys. Union, 52(11), 900, 1971.

Russell, C.T. and R.L. McPherron, The semiannual variation of geomagnetic activity, presented at the Fall AGU meeting, EOS, Trans. Amer. Geophys. Union, 52(11), 908, 1971.

*Invited review papers

II. WORK IN PROGRESS

1. Computer Programs

Work was underway to make daily plots of both the Explorer 33 and 35 data for the period of March 1 to November 1, 1968. These would serve the same purpose as ground based magnetograms and would have similar formats.

2. Research

a. Polar Cusp. The study of the polar cusp as revealed in the OGO 5 data and the influences of the interplanetary magnetic field was continuing. We were concentrating on the currents within the polar cusp.

b. Substorms. The study of individual substorms in the tail and the effects of changes in the interplanetary medium was continuing. We also were beginning to use new ground indices constructed from low latitude observatories and compare with the ATS 1 magnetometer data.

c. The Magnetopause. We had reinitiated our study of the magnetopause and had begun to analyze the energetic particle data, low energy particle data and the magnetic field as a function of the orientation of the interplanetary magnetic field.

d. The Magnetosphere. In the low latitude predawn region of the magnetosphere at about 8 R_e, many OGO 5 passes reveal an oscillation of the plasma sheet boundary with a period of 5-10 minutes. We have examined the interplanetary magnetic field for evidence of similar fluctuations in the interplanetary medium and have found none. However, in each of these instances examined to date, the interplanetary field was southward.

e. The Shock Front. The structure of the earth's bow shock is quite varied. Preliminary studies using the Explorer data to measure the orientation of the interplanetary field, have shown that some ordering of the shock structure is achieved by considering the angle between the interplanetary field and the local normal to the earth's bow shock. When this angle is large, the shock is a simple discontinuity. At progressively smaller angles precursor waves appear. At small angles, the shock front is turbulent and irregular in structure.

f. North-South Component of Interplanetary Magnetic Field. As the Explorer data for 1970 are analyzed we shall receive tapes of the 1 hour averages of the data of the interplanetary magnetic field. The north-south component and the polarity of the interplanetary magnetic field was then be analyzed. The year 1970 is of particular interest because it is at and right after solar maximum when the activity starts to decrease and the dipolar field at the sun's poles may change.

III. PROPOSED RESEARCH

The correlation study undertaken between the Explorer 33 and 35 data and the OGO 5 data has been very rewarding to date, and the role of the interplanetary field in controlling magnetospheric processes has been revealed to be even more universal than previously expected. Not only does the southward component control the growth phase of substorms, in which the flux of the dayside magnetosphere is eroded and transported to the tail, but it also controls the processes occurring in the polar cusp. Further evidence for this control is the success of our model of the semiannual variation of geomagnetic activity in which the interplanetary magnetic field is the primary agent. Further, we note that even the bow shock is affected by the orientation of the field.

Finally, we note that our studies have revealed a new ordering to the interplanetary field itself. The interplanetary field is skewed with respect to the simple Parker spiral.

Although this study has been quite successful, resulting in six publications, as we have shown in Section II, there are many unfinished projects. We would like to understand in detail what changes occur in the polar cusp, what is the change in the structure of the magnetopause, how do the oscillations of the plasma sheet arise, how can ground data be used to determine what is occurring in the tail and in interplanetary space, and what is the exact dependence of the bow shock structure on the interplanetary magnetic field. We note further that some groups still do not accept the control of the interplanetary magnetic field in producing the growth phase of substorms, and thus, we must yet analyze further substorms in detail. Finally, we note the importance of continuing the study of the properties of the interplanetary magnetic field as the solar magnetic field evolves during the present solar cycle. The 1970 data span is a critical period during which this phase of the variations of the interplanetary field should be carefully analyzed.

The method we have found that is most fruitful and most convincing in our correlation studies is the analysis in detail of several individual events. We feel that further analysis should be carried out in this way. For if one can explain the many details of a specific sequence of events, one demonstrates that he understands the controlling mechanisms. Thus, we would choose events in the OGO 5 data, such as a series of shock crossings, magnetopause encounters, or substorms and compare them in detail with the interplanetary field. Since the data files for Explorer and OGO 5 exist in readily accessible form we need not carry out any expensive data processing but rather could proceed with a low cost analysis program.