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Historical Evidence Of A Link Between Asymmetry In Solar Activity And A Displacement Of The Neutral Sheet

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ABSTRACT

Data from four solar activity cycles (two solar magnetic cycles) from 1930 to 1967 are presented to support the hypothesis that when there is excess activity on one hemisphere of the sun, the heliospheric neutral sheet is displaced (on average) away from that more active hemisphere.

1. INTRODUCTION

In a previous paper, which will be referred to as SHSS, Swinson, Humble, Shea and Smart (1991), looked at measures of activity on the sun's northern and southern hemisphere from 1965 through 1983 in order to find a connection between asymmetry in activity on the sun and a possible displacement of the long-term average position of the neutral sheet relative to the solar equatorial plane. During this period the IMF was directed toward the sun above the neutral sheet (the negative configuration) from 1965 to 1968 and in 1982 and 1983; the IMF was directed away from the sun above the neutral sheet (the positive configuration) from 1972 to 1978. During these periods there were four distinct epochs; in 1965-1968 and in 1975-1978 there was greater activity on the sun's northern hemisphere, while in 1972-1974 and 1982-1983 there was greater activity on the sun's southern hemisphere.

In SHSS the activity on the sun's two hemispheres was determined using a continuous set of observations by Koyama (1985) which spanned the period of the study. Koyama's data included sunspot number (total, northern hemisphere and southern hemisphere) for as many days as possible through this period. The IMF polarity in the vicinity of the earth for a given day was determined using data from a number of sources. For the majority of days its direction was obtained from direct measurements from various spacecraft (Couzens and King, 1986). These direct measurements were supplemented with IMF polarity data inferred from polar magnetograms (Svalgaard, 1976), checked by separate estimation from the Stanford Mean Solar Magnetic Field (Solar-Geophysical Data Prompt Reports) moved forward in time by five days. Using these various IMF data sources, measurements or estimates of the IMF direction at the earth were available for most days between 1965 and 1983.

SHSS showed that for each of the four epochs in that study the observed results indicated a situation in which excess activity on one hemisphere of the sun coincided with an excess of days whose IMF polarity (toward or away from the sun) were consistent with the neutral sheet being displaced (on average) away from the hemisphere with excess activity.

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In the present study the years from 1930 to 1967 are examined in an attempt to test the same hypothesis (that excess activity on one solar hemisphere and a displacement of the neutral sheet are correlated with each other) over a longer period of time. For most of this period there were no spacecraft (except for planet earth) from which to make direct measurements of the IMF in the vicinity of the earth. Nevertheless, Svalgaard (1972, 1976), has been able to infer the polarity of the IMF in the vicinity of the earth from the influence of the IMF on the geomagnetic field at high latitudes. In the earlier publication (Svalgaard, 1972) all days are assigned a polarity (either toward or away) for each year from 1926 to 1971. In the second publication (Svalgaard, 1976), in addition to noting days which are toward or away, days for which the polarity is mixed are also identified.

The data used here for north-south asymmetry in solar activity are from White and Trotter (1977), who have published plots of the distribution of sunspot areas between the north and south solar hemispheres from 1874 to 1971.

2. ANALYSIS

The four periods used in the present study are 1930-1936, 1939-1946, 1949-1956 and 1959-1967. They each represent the period between successive solar maximums. The year of solar maximum and the adjacent years have not been included in this study (as was also the case in SHSS) since these years are the period when the heliospheric magnetic field reverses, and the magnetic configuration of the heliosphere is very irregular and not well-behaved. For each year of each period the total number of toward days and away days have been determined from Svalgaard (1972) in the case of the periods 1930-1936 and 1939-1946, and from Svalgaard (1976) in the case of the periods 1949-1956 and 1959-1967. For each year the data are expressed in terms of a fraction of the total days (toward plus away) for which the IMF polarity was away from the sun. From the White and Trotter (1977) data the asymmetry in solar activity for each year is expressed in terms of the ratio $A_n/(A_n + A_s)$ where A_n represents the area of activity on the sun's northern hemisphere and A_s represents the area of activity on the sun's southern hemisphere.

If the above hypothesis is correct, and the magnetic state of the heliosphere is positive (IMF away from the sun above the neutral sheet), then increased northern hemisphere activity should result in the neutral sheet spending more time below the earth than above it, with a resultant increase in the annual fraction of away days. Conversely, when the magnetic state of the heliosphere is negative (IMF toward the sun above the neutral sheet), increased northern hemisphere activity should still result in the neutral sheet spending more time below the earth than above it, but the result in that case would be an increase in the annual fraction of toward days and therefore a decrease in the fraction of away days.

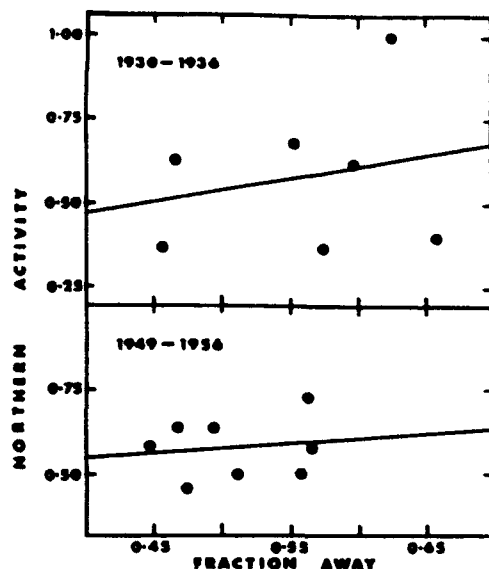


FIGURE 1

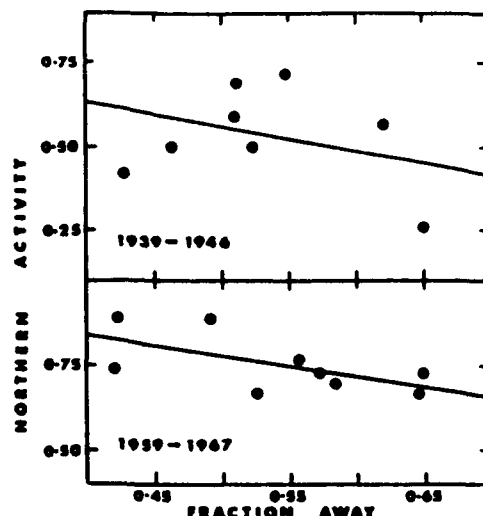


FIGURE 2

Figures 1 and 2. Plots of yearly northern hemisphere solar activity asymmetry in the form $A_n/(A_n + A_s)$ from White and Trotter (1977) versus fraction of days per year of IMF directed away from the sun (Svalgaard, 1972, 1976). The line in each graph is the best-fit straight line from linear regression analysis applied to the data. In Figure 1 the top graph is for period I (1930-1936) and the bottom graph is for period III (1949-1956). During both periods the heliospheric magnetic configuration is positive. In Figure 2 the top graph is for period II (1939-1946) and the bottom graph is for period IV (1959-1967). During both periods the heliospheric magnetic configuration is negative.

In Figures 1 and 2 we plot northern hemisphere activity (expressed as a fraction of total activity) against the fraction of days in each year when the IMF polarity was away from the sun. We also show the best-fit straight line to each data set using a linear regression analysis. From visual inspection of the data points in Figures 1 and 2 it is clear that the choice of a linear relation between the two variables is not a compelling conclusion. Nevertheless, the statistical conclusion is that for each of the four time periods the slope of the best-fit straight line obtained from the linear regression analysis is of the correct sign predicted by the hypothesis that excess solar activity on one solar hemisphere results in a displacement of the neutral sheet away from the solar hemisphere with the excess activity. It should not be unexpected that on occasion the linear regression analysis between these two variables will not always lead to a strong linear relation, because the asymmetry in solar activity varies considerably from year to year and even from cycle to cycle (Swinson, Koyama and Saito, 1986). It is probably worth noting that the highest correlation coefficient, r , occurs during the last of the four periods, which was

the period during the last one hundred years when the asymmetry was most pronounced (Swinson, Koyama and Saito, 1986). Conversely, one would not expect a high correlation coefficient in a period when there is little or no variation in solar activity asymmetry between the two solar hemispheres.

3. CONCLUSION

The results presented here, taken together with the results in SHSS, cover a time period from 1930 to 1983 and constitute six solar activity cycles or three solar magnetic cycles. Combining the results from each paper there are eight multi-year epochs which represent almost the entire time span, excluding periods of heliospheric magnetic field reversal. In each of these eight multi-year periods the results of the analysis are consistent with the hypothesis that the neutral sheet is displaced (on average) away from the solar hemisphere with the excess solar activity, resulting in an excess of either toward or away IMF days near the earth, the nature of the excess depending on the direction of the solar activity asymmetry and the prevailing magnetic configuration of the heliosphere.

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