# AN UPDATE ON THE CORRELATION BETWEEN THE COSMIC RADIATION INTENSITY AND THE GEOMAGNETIC AA INDEX

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ABSTRACT

A statistical study between the cosmic ray intensity, as observed by a neutron monitor, and of the geomagnetic aa index, as representative of perturbations in the plasma and interplanetary magnetic field in the heliosphere, has been updated to specifically exclude time periods around the reversal of the solar magnetic field. The results of this study show a strong negative correlation for the period 1960 through 1968 with a correlation coefficient of approximately -0.86. However, there is essentially no correlation between the cosmic ray intensity and the aa index for the period 1972-1979 (i.e. correlation coefficient less than 0.16). These results would appear to support the theory of preferential particle propagation into the heliosphere via the ecliptic during the period 1960-1968 and via the solar polar regions during 1972-1979.

1. Introduction. The work of Jokipii et al. (1977) and subsequent publications has created considerable interest and discussion with their suggestion that the modulation of the galactic cosmic ray intensity should have a component controlled by the state of the interplanetary magnetic field as transported out from the sun, and hence there should be a solar cycle effect on the drift of cosmic rays in the heliosphere. In this paper we report the results of a study correlating the cosmic ray intensity at the earth with a solar and a geomagnetic parameter for periods between successive solar maxima.

2. Data Utilized. For this study the following data were utilized:

Neutron monitor data. The monthly averages of the cosmic ray intensity as measured by the Mt. Washington neutron monitor were selected primarily because of the long data base (June 1954 to the present time), the stability of the station over this long time period, and the fact that this station, located at a geomagnetic cutoff of ~ 1.3 GV, monitors the full galactic cosmic ray intensity. In addition the monthly averages of the cosmic ray intensity as measured by the Chicago neutron monitor were also utilized for the period January 1953 until the monitor closed in December 1971. These data were used primarily to allow inclusion of data as far back as 1953. The correlations reported herein were repeated using both the Mt. Washington data and the Chicago data for periods of time where the data were both available; the results were essentially the same for those time periods.

Geomagnetic data. The monthly averages of the geomagnetic aa index were selected as the parameter describing the status of the geomagnetic field and hence is a measure of turbulent plasma in the ecliptic plane. This index is computed from the K index of two antipodal observatories (invariant magnetic latitude 50°) providing a quantative characterization of the magnetic activity which is homogenous throughout the long data base (1868 to the present). A full description of this index is given by Mayaud (1973). We have utilized the aa index as being representative of the geomagnetic activity at the earth; we consider this activity to be the product of the interaction between the earth's magnetic field and the interplanetary magnetic field carried past the earth by the solar wind. Cosmic ray transport in the heliosphere would be affected by turbulence in the plasma and the interplanetary magnetic field. In contrast to the sunspot number, which may have some relationship to the three dimensional structure of the heliosphere, the geomagnetic aa index should represent disturbances only in the ecliptic plane at the position of the earth.

Solar data. The monthly averages of the Zurich relative sunspot number, Rz, were selected as a solar parameter. Although the Zurich relative sunspot number does not directly control the galactic cosmic ray intensity observed at the earth, it is an indicator of activity on the sun and is inversely correlated with the cosmic ray intensity throughout a solar cycle. This is probably because the sunspot number reflects activity over a range of heliocentric latitudes from about 45°N to about 45°S, and hence has some relationship to the three dimensional structure of the heliosphere.

3. Method. Using the method of least squares, linear correlations between the monthly averages of the cosmic ray intensity and the (a) sunspot number and (b) aa index were calculated for selected time intervals. In contrast to an earlier study (Shea and Smart, 1981), the results reported here are restricted to the following intervals:

January 1953 (Chicago data) through August 1956 (44 months);
June 1959 through December 1968 (115 months);
March 1972 through December 1979 (94 months).

The polarity at the north and south solar pole does not change at the same time. For example, the south pole changed polarity in July-August 1969; the north pole in August 1971. Since we wanted to restrict this analysis to periods when the solar polar magnetic fields were well defined, we excluded the months from September 1956 through May 1959 and January 1969 through February 1972 from this analysis.

Galactic cosmic ray particles observed at the earth have propagated through the heliosphere and are affected by the magnetic inhomogeneities encountered on their transit. Since recent results indicate that the heliosphere extends well beyond 30 AU and this distance corresponds to a solar wind transit time of four months, correlations were made between the monthly average cosmic ray intensity and averages of the aa index and the sunspot number for successively longer time periods preceding the monthly cosmic ray intensity. For each specific interval being studied the monthly average cosmic ray intensity (as recorded by neutron monitors) for month N, was first correlated against the Zurich relative sunspot number (or the aa index) for the same month. Next the same monthly average cosmic ray intensity for month N, was correlated against the two-month average sunspot number (or the aa index) for months N and N-1 and similarly for the three-month average sunspot number (or the aa index) for months N, N-1, and N-2, etc., to a maximum of 30 months.

Variations of the cosmic ray intensity, the sunspot number and the aa index for the period 1954-1979 are illustrated in Figure 1. For simplicity 3-month averages are plotted in this figure although monthly averages were utilized in this analysis.

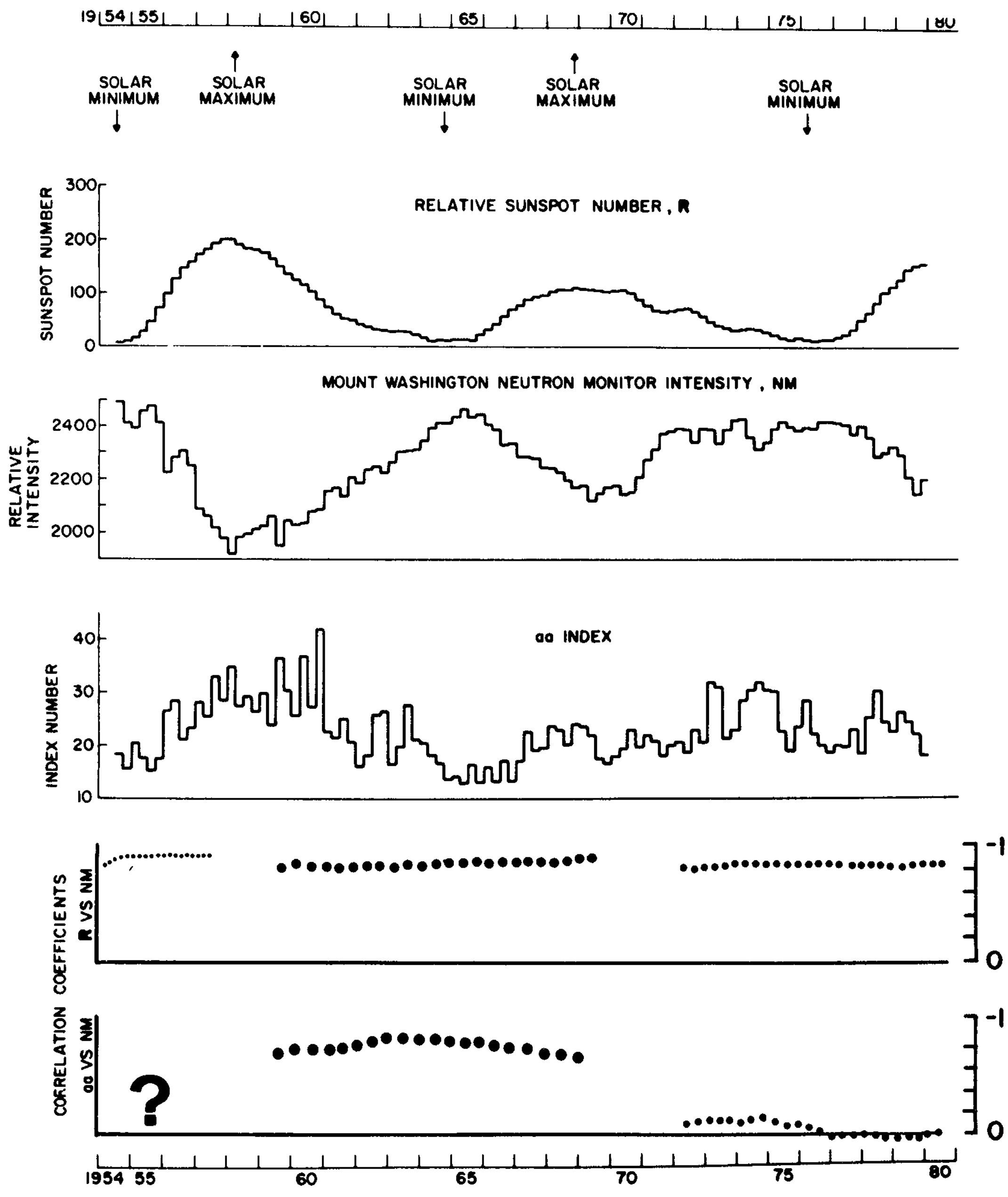


Fig. 1. The Zurich relative sunspot number, the cosmic ray intensity as measured by the Mt. Washington neutron monitor, and the aa index from 1954 through 1979. Solar minima and solar maxima are indicated at the top of the figure. The correlation coefficients are illustrated at the bottom of the figure where the individual dots represent the correlation coefficient for successively longer time lags. The question mark in the lower left indicates that it was not possible to reach any conclusion for the time period January 1953 to December 1957 because of the small time period. See text for additional description.

4. Results and Discussion. The values of the correlation coefficients for the various data sets studied are shown in the bottom section of Figure 1 where the individual dots represent the correlation coefficient for successively longer time lags. The relative position of each dot represents the time lag used for each correlation for the time period shown. For example, the first dot in each sequence represents the correlation coefficient when correlating the cosmic ray intensity for month N with the sunspot number (or aa index) for month N; the second dot represents the correlation of the cosmic ray intensity for month N with the sunspot number (or aa index) for months N and N-1 (i.e. 1-month lag), the third dot represents the correlation of the cosmic ray intensity for month N with the sunspot number (or aa index) for months N, N-1, and N-2 (i.e., two-month lag), etc. These results show that the cosmic ray intensity is inversely correlated with both the sunspot number and the geomagnetic aa index for the time interval essentially centered around the solar minimum between the 19th and 20th solar cycles. For the time period centered around the solar minimum between the 20th and 21st solar cycles, the correlation between the cosmic ray intensity and the sunspot number is approximately the same as for the earlier period; however, the value of the correlation coefficient between the cosmic ray intensity and the geomagnetic aa index reduces considerably to essentially zero.

These results are consistent with the suggestion that the sense of the drift of cosmic rays in the heliosphere is a component of the cosmic ray propagation as hypothesized by Jokipii et al. (1977), Jokipii and Kopriva (1979), and Jokipii (1981). Briefly they suggest that the drift component of cosmic rays (i.e., positively charged atomic nuclei) may have preferential entry into the heliosphere via the helio equatorial plane if the northern solar polar magnetic field is negative (i.e., direction of the field into the northern solar pole as was the case from 1959 to 1968) and that this drift component may have preferential entry into the heliosphere via the solar poles if the northern solar polar magnetic field is positive (i.e., directed out of the northern solar pole as was the case from 1972 to 1980). Thus if the cosmic ray flux has a significant drift component via the helio-equatorial plane an inverse correlation with the aa index would be expected, and if the cosmic rays have preferential entry via the solar poles, this correlation should be considerably smaller. This would be consistent with our correlation coefficients between the cosmic ray intensity and the aa index of -0.86 for June 1959-December 1968 and essentially 0 for March 1972-December 1979.

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