A HIGH RESOLUTION SPECTRAL ANALYSIS OF
DAILY RELATIVE SUNSPOT NUMBER AND
10.7 CM. SOLAR FLUX

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ABSTRACT

Auto and cross-spectra of relative sunspot number and slowly varying component of solar radiation at 10.7 cm. have been computed for a 52-month period beginning September 1, 1958. Significant features of the spectra are relatively high variance at periods corresponding to one, three and four solar rotations. Statistically significant spectral peaks have been observed at three other frequencies and are ascribed to amplitude modulation of the 27-day component. The cross-spectral analysis indicates that during the period under investigation the solar 10.7 cm. flux leads the sunspot number for periods in excess of about 27.7 days; for shorter periods the flux lags behind the sunspot number. The coherence between the two time series, after an initial decrease from unity at zero frequency, assumes a maximum value of 0.985 at 27.7 days. The phase and coherence indicate that long-lived radio emission regions and spots appeared to co-rotate during 1958–62 with a period of 27.7 days.

1. INTRODUCTION

The frequency-domain analysis of time series is a relatively new technique in the study of periodicities. The methods for carrying out these analyses have been outlined by Blackman and Tukey1 and have been applied in the past several years to a variety of astrophysical time series. The spectra of the indices of solar activity, computed by Ward and Shapiro,2 show a large variance near zero frequency and pronounced peaks at frequencies of 1/27 cycles/day and at its harmonics.

The spectra of the indices of solar activity, however, differ from one solar cycle to another. They also vary during different periods of the same solar cycle. In the present communication auto and cross-spectra of relative sunspot number and 10.7 cm. flux, two of the most valuable primary indices
of activity, have been computed from daily values of these indices for a 52-month period beginning with September 1, 1958. It is well known that these two indices are well correlated when smoothed values, such as monthly means, are used to compute the correlation coefficients. However, the correlation is found to vary between wide ranges when the coefficients are computed for each month from daily values. The period of 52 months considered here was marked by a high degree of day-to-day similarity of the two indices, the correlation coefficients for 48 of the 52 months being 0.70 or higher. This period, a part of the declining phase of solar cycle 19 was, therefore, considered very suitable for an investigation of periodicities in the time series of daily values of the two indices. The phase and coherence have also been obtained by cross-spectral analysis to examine these near a frequency of 1/27 cycles-day, corresponding to period of one solar rotation.

II. ANALYTICAL PROCEDURE

The computations follow the method of Tukey as outlined by Munk et al. The time series $X_i$ and $Y_i$ composed of 1583 consecutive daily values of relative sunspot number and flux respectively were centralised about the means of the respective series. Auto- and cross-correlations were computed according to

$$A(k) = \frac{1}{N-k} \sum_{i=k+1}^{N} X_{i-k} X_i - \frac{1}{(N-k)^2} \sum_{i=k+1}^{N} X_{i-k} \sum_{i=k+1}^{N} X_i$$

$$B(k) = \frac{1}{N-k} \sum_{i=k+1}^{N} Y_{i-k} Y_i - \frac{1}{(N-k)^2} \sum_{i=k+1}^{N} Y_{i-k} \sum_{i=k+1}^{N} Y_i$$

$$C(k) = \frac{1}{N-k} \sum_{i=k+1}^{N} X_{i-k} Y_i - \frac{1}{(N-k)^2} \sum_{i=k+1}^{N} X_{i-k} \sum_{i=k+1}^{N} Y_i$$

$$D(k) = \frac{1}{N-k} \sum_{i=k+1}^{N} Y_{i-k} X_i - \frac{1}{(N-k)^2} \sum_{i=k+1}^{N} Y_{i-k} \sum_{i=k+1}^{N} X_i$$

where $A(k)$ and $B(k)$ are auto-correlations of $X_i$ and $Y_i$ respectively and $C(k)$ and $D(k)$ are the cross-correlations, $k$ is the lag and successively assumes values of 0, 1, 2, $\ldots$, $m$ with a maximum lag $m = 300$. $N$ represents the number of data points in the series and is 1583.