

IS THERE A RELATIONSHIP BETWEEN SUNSPOT NUMBERS AND PSYCHIATRIC ADMISSIONS?

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ABSTRACT: We examined the correlation between solar activity (sunspot numbers) and 96050 psychiatric admissions between July 1984 and December 1993, in Victoria, Australia. Calculation of the Pearson correlation coefficient gave a value of 0.399 (*P* value; 0.0001). This value however, may be an artefact of autocorrelations *within* the two series rather than a relationship *between* them as the Pearson correlation does not account for the serial nature of the data. To overcome this problem we calculated the prewhitened cross-correlation between the series and tested whether they were uncorrelated. The test was significant (*P* value; 0.006), which gives strong evidence for a relationship between sunspot number and psychiatric admissions.

1. INTRODUCTION

During periods of high solar activity there are greater X-ray, ultraviolet and radio emissions from the sun. In addition, solar flares are more frequent producing disturbances in the earth's magnetic field, disruptions to communications and power outages in high latitudes [1]. As well as producing disturbances to electronic communications there have been suggestions that high solar activity may also coincide with disturbances in biological systems.

As early as 1935 studies have reported correlations between various measures of solar and/or geomagnetic activity and psychiatric admissions. In 1935 Dull and Dull [2] examined 40,000 cases over a period of 60 months and described what appeared to be a relationship between magnetic storms and the incidence of nervous and mental diseases and suicides. This study however did not use any statistical analysis. In 1963 Freidman et al. [3] looked at 28642 admissions over 52 months, more recently Raps *et al* [4] and Kay [5] performed similar studies.

While these studies ([3], [4] and [5]) have reported a correlation between psychiatric admissions and solar activity, they have used only simple statistics such as the Pearson correlation coefficient to report their findings. Few of these studies have explicitly modelled the ordered nature of the data (e.g. monthly bivariate time series of solar activity and hospital admissions).

Failure to take the serial nature of the data into account is not only an inefficient use of data but may lead to mistaken inferences. Specifically, large correlations

between series (cross-correlations) may be spurious if there are large correlations (autocorrelations) within each series [6]. Autocorrelations are commonly encountered in serial ordered data such as time series data. Consequently we have undertaken the following study to look at the relationship between solar activity and psychiatric admissions using appropriate time series methods.

2. DATA

Data on all admissions into psychiatric hospitals in Victoria from 1 July 1984 to 31 December 1993 covering a period of 3471 days (114 months) were included. This data was obtained from the Psychiatric Records Information Systems Manager (PRISM) database maintained by the Department of Health and Community Services in Victoria. This database includes all formal psychiatric admissions into the Victorian public hospital system (43 hospitals) which covers a catchment area of approximately 4 million people. During the time period examined, there were 96050 admissions.

This is the first time a study has included such a large number of admissions over an extended period. It is also the first time such admissions represented the total admissions from a population rather than admissions gathered from selected psychiatric institutions. Therefore, the results presented here are less subject to selection biases.

Daily sunspot numbers were obtained from the National Oceanographic and Atmospheric Administration (NOAA), which provide a weighted average of measurements made from a network of cooperative observatories around the world.

Sunspots numbers act as indicators for solar activity and fluctuate in a cycle of approximately 11.1 years. The most recent maximum being in 1989 when some of the greatest sunspots on record were recorded.

3. METHOD

In this study the time series technique of *prewhitening* was used to examine the correlation between sunspot numbers between 1984–94 and 96050 psychiatric admissions in Victoria, Australia over the same period. In this context, prewhitening involves [7] 4 stages; 1) modelling the sunspot series as an autoregressive integrated moving average (ARIMA) process with a

white noise residual, 2) filtering the sunspot series with this model to get a white noise series, 3) filtering the admissions series with the sunspot model, 4) forming the cross-correlation of the filtered series of stage 3 with the white noise series of stage 2. For instance, a peak in the estimated cross-correlation function for the monthly series at lag d may indicate that number of admissions is related to the sunspot number after an interval of d months [8]. The estimated cross-correlation can be tested for the hypothesis that none of the correlations up to a given lag are significantly different from zero.

The motivation for the prewhitening approach comes from the area of time series forecasting and the notion of a transfer function (TF). If a time series (Y_t , i.e. admissions) is thought to be influenced by another (input) time series (X_t , i.e. sunspots) then a TF is hypothesised to exist that transforms X_t into Y_t . If the TF can be estimated then it is possible to forecast Y_t from X_t .

In this study our aim was not to predict psychiatric admissions from sunspot numbers but use the TF approach to test for a relationship between the two. If a TF exists then a white noise input should be altered so that cross-correlation of the noise input and resultant TF output is *not* that of two white noise series. As we do not know the form of the TF we infer its existence by reducing (filtering) the input series to a white noise series and applying this filter to the output. If the cross-correlation function of the filtered series is that of two noise series (null hypothesis) then no TF exists between them. If, however, the null hypothesis is rejected then a TF (relationship) does exist between the series.

4. RESULTS

The Pearson correlation coefficient between sunspot numbers and psychiatric admissions was 0.399 with a P-value (i.e. null hypothesis of no correlation) of 0.0001. This value is also the value of the zeroth order cross-correlation when neither series has been prewhitened. However, the calculation of the Pearson correlation assumes that the data are independent, that is, the order in which the data is presented is irrelevant. This is not the case with times series data. Both the sunspot number and psychiatric admission series show serial structure. The sunspot series exhibit a maximum between August 1988 and August 1991, while there is a less well defined increase in psychiatric admissions after August 1987.

A more appropriate method of examining the correlation between these series is to use the time series transfer function model (as discussed above). The ARIMA model of the sunspot series was found to be a first order moving average of the first differences (standard error of moving average coefficient is given in brackets) :

$$\text{Sunspot}_t - \text{Sunspot}_{t-1} = \text{error}_t - 0.4983(\pm 0.0823) * \text{error}_{t-1}$$

The resulting cross-correlation was significantly different (up to lag 11, P-value = 0.006) from that of two white noise series implying some relationship between the two. This is despite the significant autocorrelation exhibited by

both series. Note, that the zeroth correlation (equal to the Pearson correlation coefficient) of the prewhitened cross-correlation is 0.041. This is much smaller (and not significant) than the Pearson correlation coefficient of 0.399 calculated before prewhitening. Thus although the TF model suggests a relationship between sunspot numbers and psychiatric admissions such a relationship would be quite complex.

5. CONCLUSIONS

We conclude that there is strong statistical evidence for a correlation *between* solar activity as measured by sunspot numbers and psychiatric admissions. This evidence is strong for two reasons. First, we have been able to use psychiatric admission data (96050 admissions) from almost an entire population of 4 million (Victoria, Australia) so that our results are not an artefact of small or biased sampling. Second, we have used the time series method of prewhitening that explicitly models the serial structure within and between series. So our results are not an artefact of spurious correlations caused by the intrinsic autocorrelation within series.

It would be interesting to apply this method to admission data for other conditions such as cardiac events or epilepsy. However, more importantly these results should stimulate discussion as to their cause. If the methodology we employed is inadequate, how can it be improved? However, if the methodology is appropriate, then what is the mechanism of a relationship between sunspot numbers and psychiatric admissions?

6. REFERENCES

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