Statistical Procedure to Test Significance in the Analysis of Cosmic Ray Data by Superposed Epoch Method–III: Comparison of Test Results from Two Techniques

Y. P. Singh and Badruddin
Department of Physics, Aligarh Muslim University, Aligarh-202 002, India

Abstract

In this paper we compare the test results by two statistical procedure, one based on $t-$test and another based on $F-$test. The effectiveness of shock transit velocity on transient modulation of cosmic rays is studied and tested by both techniques. It is found that both the techniques lead to similar conclusions. Both demonstrate that the effect of interplanetary shocks on transient modulation of cosmic ray intensity can be considered as statistically significant if shock transient velocity exceeds certain limits.

1. Introduction

Superposed epoch (Chree) analysis procedure is an important and widely used method for demonstrating periodicity and for evaluating the statistical relationship between events of two different types. In general, when dealing with the solar/ heliospheric/ magnetospheric/ cosmic ray data, there are other (superimposed) real effects (e.g. solar cycle variation effect), in addition to the one under study, which can cause the measured phenomenon to vary significantly due to the 'other real effects'. First application of the Chree analysis reported a 27−day recurrence tendency in geomagnetic data [4]. Forbush et al. [5] have emphasized the importance of statistical test before reaching at a conclusion and have given a method for statistical test evaluating quasi-persistency in the data. In addition to reveal certain periodicities in the activities on the sun surface (sunspot number), in the geomagnetosphere (geomagnetic data) and heliosphere (Cosmic ray data), this method has been used to demonstrate the effect of one parameter over the other. But rarely statistical tests have been performed to see the significance of the results.

2. Method

In this paper, we compare the assessment of the reality of an average variation, obtained from the superposed epoch analysis, by adopting the two procedures discussed in [1, 2]. Both the test procedures, one based on Student's

pp. 3647–3650

$t-$test and other on $F-$test, have been applied on the Chree analysis results of daily average cosmic ray intensity. Key days correspond to the shocks arrival time. For this purpose all the interplanetary shocks under consideration [3] were divided into three groups on the basis of their transit velocities (i) V_t <700 Km/sec, (ii) 700 Km/sec< V_t¡900 Km/sec, (iii) V_t >900 Km/sec. Before and after correcting the data for solar cycle effects, both the statistical procedures(discussed in paper I and II [1, 2]), are applied to three sets of data and their average variations.

3. Results

Fig. 1 shows the superposed epoch results of cosmic ray intensity for all the three groups considered. The decrease in cosmic ray intensity reaches minimum value ($\bar{I}_{min}$) on the second day after it reaches the earth. The 95% confidence interval for $\bar{I}_{min}$, calculated using the procedure described in paper I [1], are shown by solid vertical line. The mean intensity for all days ($\bar{I}$) is shown by horizontal line. The 95% confidence limits, calculated by the use of procedure given is paper I, are shown by two horizontal lines above and below the mean value. Values of F are also calculated using the method discussed in paper II [2]. The importance of correcting the data for solar cycle effect, before applying the test procedure, has been explained in paper I and II. Thus both the tests for determination of confidence level have bben applied after correction. The results are shown in Fig. 1 and Table-1.

Table 1. Comparision of results obtained for two tests.

Group	Data	F	F-test results	t-test results
I (V_t <700 Km/sec)	Uncorrected	0.055	Insignificant	Insignificant
	Corrected	0.357	Insignificant	Insignificant
II (700 Km/sec< V_t < 900 Km/sec)	Uncorrected	0.871	Insignificant	Insignificant
	Corrected	7.710	Significant	Significant
III (V_t >900 Km/sec)	Uncorrected	2.152	Significant	Significant
	Corrected	12.860	Significant	Significant

The 95% confidence interval of $\bar{I}_{min}$ for V_t <700 Km/sec in to the area bounded by two horizontal lines, the observed decrease is statistically signifi-cant. On the other hand, the vertical bar in case of 700 Km/sec< V_t < 900 Km/sec and V_t >900 Km/sec is statistically significant. The F values tabulated in Table-1 are consistent with these conclusions based on statistical analysis using Student's $t-$ test.

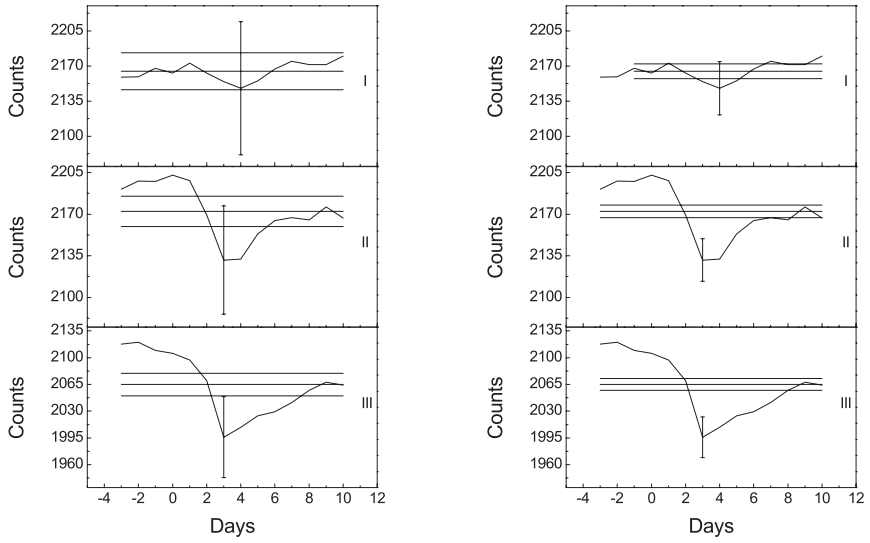

Fig. 1. Chree analysis results of cosmic ray neutron monitor counts alongwith the t-test results (95% confidence interval) for minimum intensity (vertical bar) and mean intensity (upper and lower horizontal bars) alongwith the mean intensity (middle horizontal bar) before (left) and after (right) the correction for solar cycle effect. Zero day corresponds to the arrival of three groups of shocks with different transit velocities; I(V_t < 700 Km/sec), II(700 Km/sec < V_t <900 Km/sec) and III(V_t >900 KM/sec).

4. Discussion

The effects of solar flares, high speed solar wind streams, interplanetary shocks, CMEs and/or magnetic clouds on solar wind parameters in the heliosphere (proton temperature, density, total presume etc.), geomagnetic parameter (Ap, Kp, Dst etc.), charge particle flux (cosmic ray counts) and on ionospheric behavior (total electron content) have been studied by using Chree analysis. Influence of sudden changes in cosmic ray intensity (Forbush decreases) or tropospheric conductivity, cloud cover, atmospheric circulation, ionospheric absorption, rainfall, sunshine data, pressure level heights, temperature profile, wind characteristics, vorticity area index, solar radiation input in the lower atmosphere, and air earth current density and total ozone content etc. have been studied by using Chree analysis. But a proper test of significance is not done in most of these (and

other) studies before arriving at a definite conclusion.

5. Conclusion

Two statistical procedures developed to test the significance of the results obtained by Chree analysis have been applied and effectiveness of the shocks, with different transit velocities, on cosmic ray intensity is tested. Both the techniques lead to similar conclusions. Both tests demonstrate that effect observed in cosmic ray variation, due to shocks with V_t <500 Km/sec, is not significant. Similarly both tests lead to conclusion that the decrease in intensity due to group of shocks with 700 Km/sec< V_t < 900 Km/sec and V_t >900 Km/sec is significant and not due to random fluctuations of sampling. It is suggested that before reaching at the conclusion about periodicity in a parameter or the effect of one phenomenon over the other, based on Chree analysis, the significance of the observed variations should better be tested even if the standard errors of the mean bars on each epoch day have been plotted.

6. References

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