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# The Solar Wind Effect on Cosmic Rays and the Solar Activity

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ABSTRACT

The relation of cosmic ray intensity to solar wind velocity is investigated, using neutron monitor data from Kiel and Deep River. The analysis shows that the regression coefficient of the average intensity for a time interval to the corresponding average velocity is negative and that the absolute effect increases monotonously with the interval of averaging, $\tau$, that is, from -0.5% per 100km $s^{-1}$ for $\tau$=1 day to $\sim$-1.1% per 100km $s^{-1}$ for $\tau$=27 days. For $\tau$>27 days the coefficient becomes almost constant independently of the value of $\tau$. The analysis also shows that this $\tau$-dependence of the regression coefficient is varying with the solar activity.

## 1. Introduction

The relation of cosmic ray intensity to solar wind velocity has been studied by several authors. Duggal et al. (1977) pointed out the effect of high speed wind upon cosmic ray intensity, using neutron monitor data. Iucci et al. (1979) showed the coefficient to be -0.5% per 100km $s^{-1}$, applying Chree epoch method to neutron monitor data for the period from 1964 to 1974. Munakata et al. (1979) showed that there is a significant correlation between cosmic ray intensity and solar wind velocity. Fujimoto et al. (1983) pointed out that the solar wind effect depends on the solar activity ; its regression coefficient is about -0.8% per 100 km $s^{-1}$ in the maximum activity and -0.2% per 100km $s^{-1}$ in the minimum and the average value over a solar cycle is the same as the coefficient obtained by Iucci et al. (1979).

In the above-mentioned analysis, they used daily mean values for cosmic ray intensity and solar wind velocity. In the present paper, we tried to confirm whether the regression coefficient is determined irrespectively of the time interval of averaging, $\tau$, or not. Cosmic ray intensity is varying sometimes in relation with the solar rotation, while the dominant periodicity in solar wind velocity is of 13.5 days. Then, the regression coefficient was examined for the averaging time interval from $\tau$=1 day to 91 days, covering the wide range around 27 or 13.5 days.

## 2. Analysis and Result

Data used for the present analysis are daily mean values of neutron intensity at Kiel (1965-78) and Deep River (1965-76). These values (I's) are measured from their one-year running average level to eliminate the long term variation, they are divided by a time interval $\tau$, and a time series of $\tau$-day averages $\langle I \rangle_{\tau,i}$ (i=1,2,....n) are arranged. Then, the correlations between cosmic ray intensity $\langle I \rangle_{\tau,i}$ and the corresponding averages $\langle V \rangle_{\tau,i}$ of solar wind velocity are caluculated for various values of $\tau$. Fig. 1 shows the $\tau$-dependence of the regression coefficient ($\beta_\tau$) of $\langle I \rangle_{\tau,i}$ to $\langle V \rangle_{\tau,i}$. It is clearly seen in the figure that the absolute value of $\beta_\tau$ increases monotonously with $\tau$ and becomes almost constant for $\tau$>27 days. The numerical values of $\beta_\tau$ and of the correlation coefficient $r_\tau$ are listed in Table 1, in which the error for $\beta_\tau$ is of significance level of 67 %.

Next, data at Kiel are divided into two groups corresponding to the solar activity, that is, a group for the period of the solar maximum (1966-72) and another for the period of the minimum (1973-77). For both the groups the $\tau$-dependence of $\beta_\tau$ are analyzed. Fig. 2 shows the result and one can see that the critical time interval $\tau_c$ beyond which $\beta_\tau$ becomes constant is different from each other between both the periods of the solar maximum and the minimum.

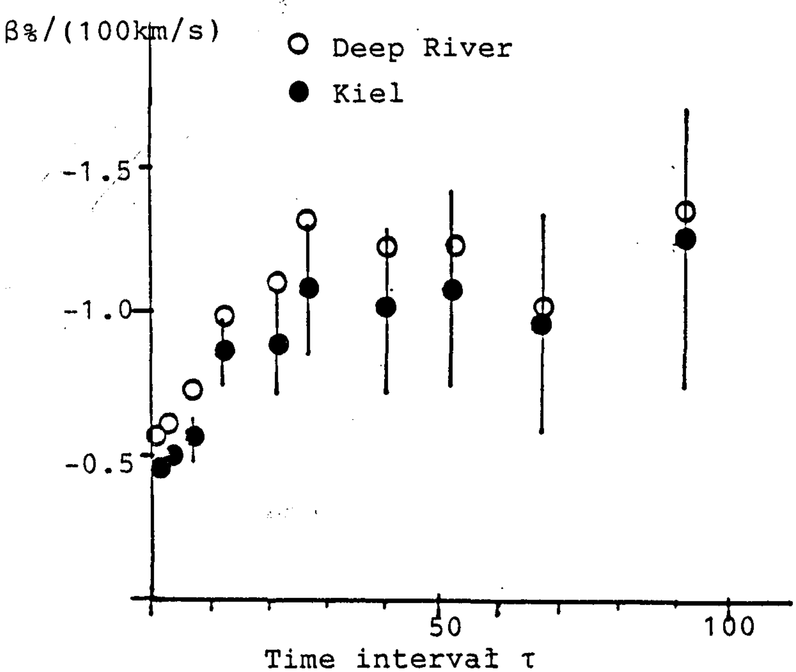


Fig. 1
The regression coefficients as a function of the time interval $\tau$

Table 1 τ-dependence of the regression coefficient (β%/(100km/s)) and of the correlation coefficient (r) of neutron intensity to solar wind velocity, for Kiel (1966-1977) and Deep River (1966-June 1976). n expresses the number of independent data.

| | KIEL | | | DEEP RIVER | | |
|---|---|---|---|---|---|---|
| τ (days) | n | $\beta_\tau$ | $r_\tau$ | n | $\beta_\tau$ | $r_\tau$ |
| 1 | 3585 | -0.45±0.024 | -0.29 | 2687 | -0.57±0.031 | -0.33 |
| 3 | 1226 | -0.49±0.044 | -0.30 | 925 | -0.61±0.056 | -0.33 |
| 7 | 545 | -0.56±0.081 | -0.28 | 406 | -0.72±0.10 | -0.32 |
| 13 | 301 | -0.86±0.13 | -0.35 | 223 | -0.98±0.17 | -0.35 |
| 21 | 184 | -0.88±0.20 | -0.31 | 136 | -1.10±0.27 | -0.33 |
| 27 | 145 | -1.07±0.25 | -0.33 | 107 | -1.30±0.34 | -0.34 |
| 41 | 97 | -1.00±0.31 | -0.31 | 73 | -1.20±0.45 | -0.30 |
| 51 | 78 | -1.07±0.38 | -0.30 | 59 | -1.21±0.53 | -0.29 |
| 67 | 60 | -0.95±0.41 | -0.29 | 45 | -0.98±0.56 | -0.26 |
| 91 | 45 | -1.22±0.49 | -0.35 | 34 | -1.33±0.68 | -0.32 |

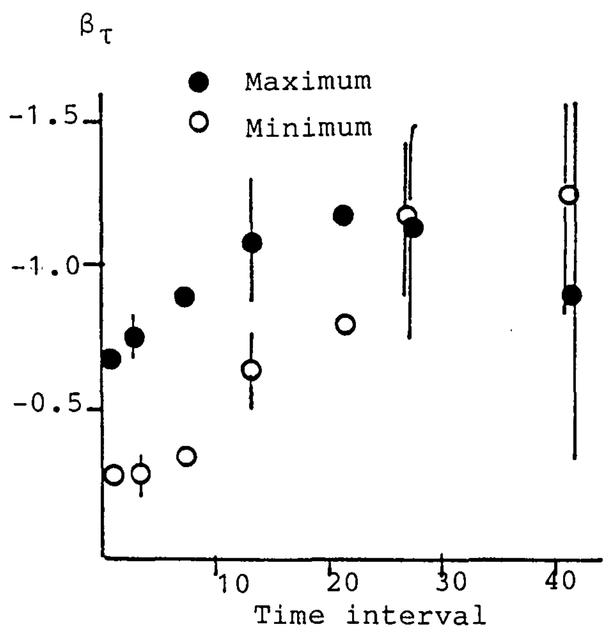


Fig. 2
The regression coefficient ($\beta_\tau$) as a function of the time interval τ. Solid circle is $\beta_\tau$ in the maximum period (1966-72) and open circle is $\beta_\tau$ in in the minimum (1973-77).

## 3. Discussion and Conclusion

As can be seen in Fig. 1, the absolute value of the regression coefficient of neutron intensity to solar wind velocity increases with $\tau$ and becomes almost constant for $\tau$>27 days. As the conclusion, at first, we like to emphasize that the regression coefficient has the $\tau$-dependence; the coefficient $\beta_{27}$ is twice as large as $\beta_1$ in magnitude.

The $\tau$-dependence of the correlation can be interpreted when we suppose that the variation of cosmic ray intensity at the earth is reflecting the integrated effect of electromagnetic condition over the interplanetary space within a distance $r_c$ ($=V\cdot\tau_c$) from the earth. The variations of cosmic ray intensity with periods shorter than $T_c$ ($=k\cdot\tau_c$) give little contribution to the variation of $\langle I\rangle_\tau$, while the variations with periods longer than $T_c$ contribute to the intensity variation, where k is a constant close to unity. Therefore the effect $\beta$ is expected to increase with $\tau$ up to $\tau_c$, and the effect does not vary so much with $\tau$ beyond $\tau_c$.

Second, as seen in Fig. 2, the $\tau$-dependence of the correlation varies with the solar activity. The critical time interval $\tau_c$ is shorter than 27 days in the solar maximum and is fairly shorter than the critical interval in the solar minimum.

Why the regression coefficient depends so much upon the solar activity has been left as a question which we shall solve, since we pointed out that dependence in Bangalore Conference. In the previous paper we showed that the coefficient varies over a wide range from -0.2 % per 100km $s^{-1}$ at the solar minimum to -0.8 % per 100km $s^{-1}$ at the solar maximum. Fig. 2 also shows the same dependence. If such a wide variation of the coefficient could be explained by particle diffusion coefficient varied with the solar activity, it would be necessary to consider the diffusion coefficient varying by a factor 2 between the solar minimum and maximum. Such a big change of the diffusion coefficient, however, can not be accepted in the comprehension of the eleven-year cosmic ray intensity variation. Therefore, it will be necessary to connect the solar wind effect $\beta$ with the abovementioned change of $\tau_c$ through the solar cycle.

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