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II-4-25. A New Study of the Cosmic Ray Diurnal Variation in Relation to Geomagnetic Activity

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A comparison is being made between three ways of grouping the days according to their K_p indices. The C.R. diurnal variation on the most disturbed days is seriously affected by U.T. variations, the latter sometimes obliterating the true diurnal variation. Major phase shifts, not correlated with geomagnetic activity, are also a disturbing factor, although of less importance. The phase of the diurnal variation decreases with increasing geomagnetic activity. This is in accordance with an explanation offered in previous papers.

In some previous papers, dealing with the diurnal variation during periods before 1951, it was shown that the time of maximum decreased with increasing geomagnetic activity[1),2)]. The amplitude displayed a tendency to increase with the latter. In this early study the days were divided inio five classes according to their maximum K_p index. Class I contained days with $[K_p]_{\max} \leqq 1^+$, Class II days characterized by $1^+ < [K_p]_{\max} \leqq 3^+$ and so on until Class V characterized by $7^+ < [K_p]_{\max} \leqq 9^\circ$. Some examples of this study are to be found in Fig. 1.

Similar studies have been carried out concerning the records from the Swedish C.R. stations during the IGY and afterwards[3)]. These studies have been published only in part. In general the phase shift has been found to display the same tendency towards early hours as was found in the first study[1)]. The amplitudes behave in a less consistent way. The phase shifts are apparently not independent of the direction of observation as it was found to be the case in the first study. It has been considered if the discrepancies could not be due to an inadequate way of distinguishing the days according to geomagnetic activity. $[K_p]_{\max}$ for a single day might refer to a disturbance of very short duration putting that day into a class where, rightly, it does not belong. Accordingly it would be more appropriate to divide the days into classes according to the ΣK_p of each day. It is possible, also, that the original classes cover too big intervals. Therefore the days have been grouped in

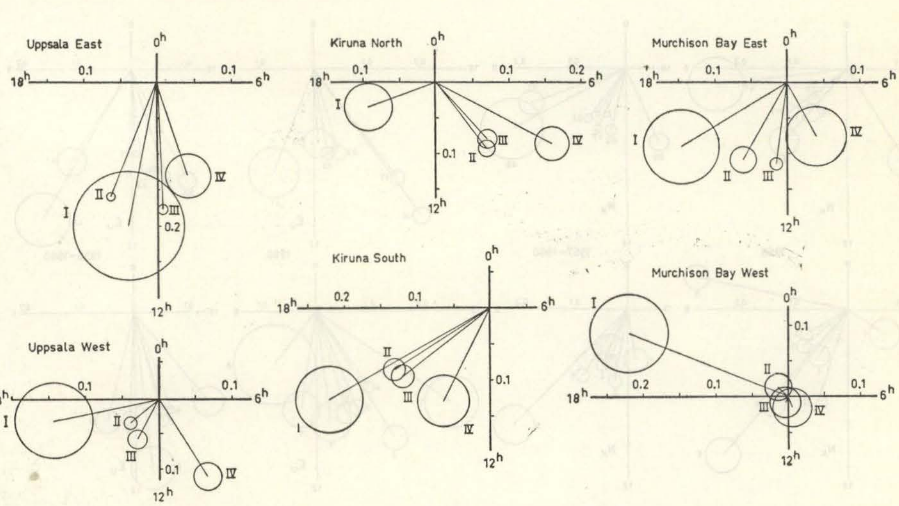

Fig. 1. Clock diagrams for 1958. Inclined meson telescopes. The original grouping of days according to $[K_p]_{\max}$. Compare text for explanation of notations.

the following two ways:

Class 1: $[K_p]_{\max} \leq 1^+$	Class 00: $\Sigma K_p \leq 8$
2: $1^+ < [K_p]_{\max} \leq 2^+$	09: $8 < \Sigma K_p \leq 16$
3: $2^+ < [K_p]_{\max} \leq 3^+$	17: $16 < \Sigma K_p \leq 24$
4: $3^+ < [K_p]_{\max} \leq 4^+$	25: $24 < \Sigma K_p \leq 32$
5: $4^+ < [K_p]_{\max} \leq 5^+$	33: $32 < \Sigma K_p \leq 40$
6: $5^+ < [K_p]_{\max} \leq 6^+$	41: $40 < \Sigma K_p \leq 48$
7: $6^+ < [K_p]_{\max} \leq 7^+$	49: $48 < \Sigma K_p \leq 72$
8: $7^+ < [K_p]_{\max} \leq 8^+$	

All days have been discarded which are known to contain a F.d. or part of one. This completely obliterates Classes 9 ($[K_p]_{\max} > 8^+$) and 57 ($\Sigma K_p > 56$).

At present the study has been confined to the directional telescopes. The meson telescopes at Kiruna pointing north (N_K) and south (S_K) with zenith angles of 32° furnish valuable informations. This is partly due to their differing considerably as to phase. The meson telescopes at Uppsala pointing east (E_U), also with a zenith angle of 32°, furnish records corresponding to a mean asymptotic direction making a small angle with the equatorial plane[4]. The amplitudes are big and the influence of the statistical fluctuations is not too disturbing even for a small number of days. The records from the west-pointing telescopes at Uppsala (W_U), as well as those at Murchison Bay pointing east (E_{MB}) and west (W_{MB}), all display small amplitudes. This is especially true concerning W_{MB}[4]. The records from Murchison Bay cover the period 1 September 1957–30 April 1958 only. N_K, S_K, and E_U were selected for comparing different ways of treating the data (Fig. 2).

To cut down the influence from statistical fluctuations it is tempting to study a period covering all available data. However, as there are phase shifts not correlated with geomagnetic activity, it is to be feared that averages over periods longer than one year will become misleading, especially as regards the amplitudes. For comparison two extended periods have been included in Fig. 2, one being 1 Sept. 1957–31 Dec. 1960 (N_K) and the other 1 Sept. 1956–31 Dec. 1960 (E_U).

From a comparison between the upper and lower rows of clock diagrams in Fig. 2 it appears as if the division of the days according to ΣK_p is slightly more adequate than a division according to $[K_p]_{\max}$. Both seem to reveal more details than the original division of days according to $[K_p]_{\max}$ (Fig. 1). It ought to be remembered that there are only a few days with very low and very high K_p values. As concerns the extreme classes of days the averages do not actually correspond to regular means for the periods in question. General phase changes taking place in between such widely separated days will affect the averages in a way for which it is very difficult to account. This might explain part of the erratic behaviour of the vectors representing these classes.

From Fig. 2 can be gathered that the correlation between phase and geomagnetic ac-

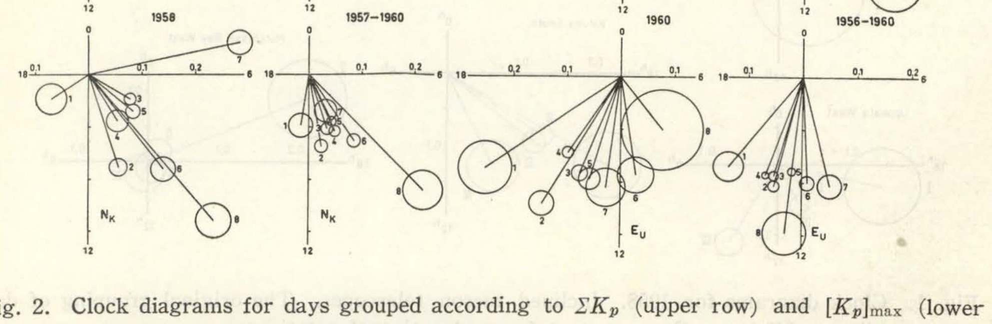

Fig. 2. Clock diagrams for days grouped according to ΣK_p (upper row) and $[K_p]_{\max}$ (lower row). Compare text for explanation of notations.

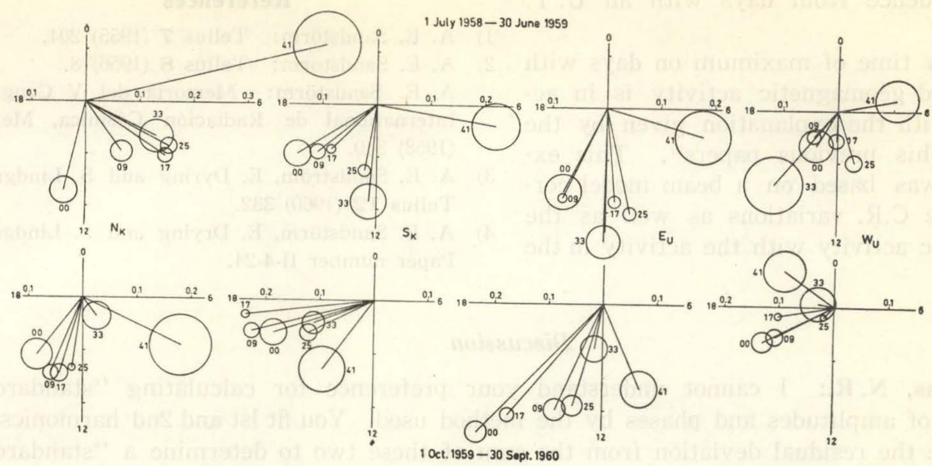

Fig. 3. Clock diagrams for the two 12-monthly periods before and after the big variations July-Sept. 1959. Compare text for explanation of notations.

tivity is of the same kind when the periods are extended over more than one year. However, as can be seen, especially concerning the clock diagram for N_K, the dispersion of the vectors appears to have become less pronounced.

It is known that very big phase shifts took place during Aug.-Sept. 1959[4]. To eliminate an eventual influence from these shifts, two 12 monthly periods have been studied, one before and one after the two critical months. The results are illustrated in Fig. 3.

Concerning both periods it is at once apparent that the correlation between phase and geomagnetic activity is more consistent as compared to the extended periods (Fig. 2). Only the clock diagrams relating to W_U are bewildering. Partly this is certainly due to the amplitude normally being rather small for this direction.

No days belonging to Class 49 are included in the study illustrated by Fig. 3. According to Fig. 2 they are characterized by very big amplitudes. Thus, it appears to be possible to make them the subject of a harmonic analysis of single days. Such an analysis was performed on all the records from the Swedish C. R. stations including those from the duplex cubical telescopes and the neutron monitors. It turned out that, within twice the standard errors, many days with extremely big amplitudes displayed the same phase irrespective of the direction of observation. This includes also the nucleon component. In these cases the true diurnal variation is evidently concealed under a very big U.T. variation. As concerns the remaining days it is obvious that the phase is very much affected by a U.T. variation. This rules out all days with $\Sigma K_p > 48$, unless means are found to separate the U.T. and diurnal variations.

It is possible that days with prominent U.T. variations are to be found also among the other classes of days, especially as concerns Classes 8 and 41. Accordingly the harmonic analysis of single days ought to be extended to include all available days. However, the influence from days with a U.T. variation will decrease with the number of days furnishing the average values. The amplitude will be more affected than the phase. Therefore the discussion will be postponed as far as the former are concerned.

As found from Fig. 2 analyses of the present kind ought to be performed on periods not covering major phase changes. It is evident, also, that harmonic analyses of single days have to be carried out for the purpose of excluding days with prominent U.T. variations.

All the three ways of characterizing the days geomagnetically have their advantages. Figs. 1 to 3 show that as far as the inclined directions are concerned, the time of maximum decreases with increasing geomagnetic activity. The discrepancies are probably due to the influence from days with an U. T. variation.

The early time of maximum on days with an increased geomagnetic activity is in accordance with the explanation given by the author in his previous papers[2]. This explanation was based on a beam model correlating the C.R. variations as well as the geomagnetic activity with the activity in the sun.

References

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2) A. E. Sandstörm: Tellus **8** (1956) 8.
A. E. Sandstörm: Memoria del V Congreso International de Radiación Cósmica, Mexico (1958) 340.
3) A. E. Sandström, E. Dyring and S. Lindgren: Tellus **12** (1960) 332.
4) A. E. Sandstörm, E. Drying and S. Lindgren: Paper number II-4-24.

Discussion

Parsons, N. R.: I cannot understand your preference for calculating "standard errors" of amplitudes and phases by the method used. You fit lst and 2nd harmonics, then use the residual deviation from the sum of these two to determine a "standard error" of the amplitude and phase of the first harmonics alone.

It seems to me that this tells us practically nothing about either a) the possible magnitude of purely statistical errors in recording or b) the "goodness of fit of the first harmonic alone.

What we are trying to do in experiments of the type discussed is to decide whether there are significant differences between amplitudes and phases of the variation observed by different instruments or under different circumstances. I feel that your method is not satisfactory for this purpose and feel also that standard errors based purely on the statistical accuracy of recording should be quoted, at least for comparison, in any such report.

Sandström, A. E.: When we try to calculate the standard errors of phase and amplitude we run into difficulties as our primary values constitute a time series. Moreover, a method of handling this problem was indicated already by Gauss. The standard errors calculated from the residuals include also what Dr. Kane has alluded to as distortion. As to the question of comparisons I can assure you that the differences between the standard errors calculated from the residuals and those calculated from the Poisson distribution would not have shown up in the slides presented here. As I have pointed out at a former discussion they usually are of the same order of magnitude.

Kane, R. P.: It is necessary to calculate the standard errors not from the usual Poisson considerations but from the actual scatter of a, and b, values constituting the mean amplitude r_1, in a given group. If this is not done, one would find that if the group is broken into two arbitrary parts, the mean values of r_1 for the two group will differ by more than times Poisson standard errrors which creates a ridiculous situation.