SHORT PAPER

Rationale of the method for studying the nature of fluctuations of geophysical parameters

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To study the causes of fluctuations in a geophysical parameter, it is advantageous to know the nature of these fluctuations, e.g. whether these are increases above, decreases below or, just oscillations about a given level. The method usually employed to determine this is as follows.

Figure 1 shows sample plots illustrating (a) increases above a base level (b) oscillations about a mean level and (c) decreases below an initial level.

The periodicities of these fluctuations could be various, e.g. yearly, seasonal, 27 day, diurnal (24 hourly) etc. If the fluctuations are as obvious as shown in Fig. 1, even a visual examination is enough to judge the nature of the fluctuations. However, in practice, statistical as well as other fluctuations are superimposed and the problem is to minimize their effect. This is done by first estimating the Range for successive periods and then correlating the Range with parameters like the Mean for the period, or the Maximum value, or Minimum value. For example, let the plots of Fig. 1 refer to daily variation. Then the daily Range would be as shown by the arrow lengths. For every day, we can have four parameters viz. the daily Range, the daily Mean (i.e. average of 24 successive hourly values), the Maximum value and the Minimum value. Plots of the latter three versus the Range are shown in Fig. 2 where (a), (b), (c) refer to the same cases as in Fig. 1.

Thus, for the case (a) when the fluctuations are increases above a base level, the Maximum values increase linearly with the Range and Minimum values remain constant. The Mean values show an inbetween slope. For case (c) corresponding to decreases below an initial level, the Maximum values remain constant and the Minimum values show a linear decrease, the Mean values showing a slope in between. For case (b) corresponding to oscillations, the Maxima increase linearly, the Minima decrease linearly and the Mean remains constant. Thus, from the nature of the plots of Maxima, Minima and Means versus Ranges, one can guess the nature of the fluctuations.

The success of this method depends entirely upon how good the causal relationship between these parameters is and how well extraneous and/or statistical fluctuations are eliminated. If, for example, the daily mean intensity level is changing violently for reasons unconnected with the daily variation as happens so often during storms as illustrated in Fig. 3, the Mean intensity changes or changes in the values of Maxima or Minima may be wrongly attributed to different categories of the Range and hence lead to erroneous conclusions. The above method
Fig. 1. Sample plots of intensity fluctuations showing: (a) Increases above a base level; (b) Oscillations about a mean level; (c) Decreases below an initial level.

Fig. 2. Plots of range versus Maximum, Minimum and Mean values for the three cases (a), (b), (c) of Fig. 1.
Rationale of the method for studying the nature of fluctuations

was first adopted by Heerden and Thambyahpillai (1955) for finding out whether the 27-day fluctuations in cosmic ray intensity are increases or decreases. After omitting periods during which large Forbush decreases occurred, their analysis showed that 27 day fluctuations were essentially decreases. However, the negative correlation obtained by them between Range and the Mean is not at all high, which shows that storm-time effects have not been eliminated completely. The same idea was extended by several workers (Sarabhai and Bhavsar, 1958; Sarabhai and Satyaprapakh, 1960; Ahluwalia, 1960) to find the nature of the daily variation of cosmic ray intensity and it was claimed that large negative deviations at certain hours (LT) were associated with higher or lower values of daily mean intensity. However, as shown by Kane (1963), the daily variation ranges involved in these analyses were only of the order of a fraction of a percent while the fluctuations of daily mean intensity amounted to several per cent. Thus, a substantial pollution from Forbush decrease type effects was still involved and the averages had a large actual error due to a wide scatter of values in the same group. The conclusions drawn should, therefore, be considered unreliable.

Recently, the same method is applied by Sarabhai and Nair (1969) to study the nature of the daily variation of the horizontal component $H$ of geomagnetic field. The daily range $\Delta H$, defined as $H_{\max}$ minus $H_{\min}$, is plotted versus the Minimum value $H_{\min}$ and the negative correlation so obtained is interpreted as indicating that the daily variation of $H$ is caused by a nighttime depression rather than a daytime enhancement (at mid-latitude stations) as envisaged in the $Sq$ current system. This is an important, revolutionary conclusion. However, for this analysis, no precaution is taken to exclude days of geomagnetic storms during which geomagnetic field gets depressed, for reasons which may have nothing to do with diurnal variation. During storms when the level of $H$ is undergoing violent changes, even an estimate of the range $\Delta H$ becomes difficult. For example, in Fig. 3, the range $H_{\max}$ minus $H_{\min}$ will be very high if no allowance is made for the continuous decrease of $H$, yielding a fictitious relationship between Range $\Delta H$ and $H_{\min}$. A better estimate of the range would be obtained if $H_{\max}$ refers to average of some hours near noon and $H_{\min}$ to average of night hours on either side of the maximum (e.g. hr. 0, 1, 2 and 21, 22, 23 LT). Even this estimate will be erroneous during days on which $H$ values go through a point of inflection. Errors

Fig. 3. Sample plot of daily variation superimposed on violent, storm-type changes of mean intensity.
due to such slope and curvature effects are discussed in detail elsewhere (Kane, 1961, 1962). In general, rate of decrease of intensity is faster as compared to the rate of recovery during magnetic storms. Hence, even linear slope effects may not cancel out.

The exact characteristics of daily variation of \( H \) during quiet and disturbed periods are being presently examined. The purpose of the present note is to point out that the method described above is useful only in periods when the mean intensity is not suffering violent changes as during storms. This purpose could be achieved by confining the analysis to quiet days (low \( K \) or \( A \) values) only. When this was done (Kane, 1970) for \( H \) values, the \( \Delta H \) range was found to have a positive correlation with \( H_{\text{max}} \) and negligible correlation with \( H_{\text{min}} \), indicating that the quiet day variation of \( H \) was caused essentially by a daytime increase (at mid-latitude stations) rather than a nighttime decrease as concluded by Sarabhai and Nair (1969).

It seems, therefore, that an indiscriminate use of the above method will have to be guarded against, to avoid arriving at unreliable conclusions. In view of the way in which the method has been used so far, a word of caution seemed overdue. Hence this note.

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References


