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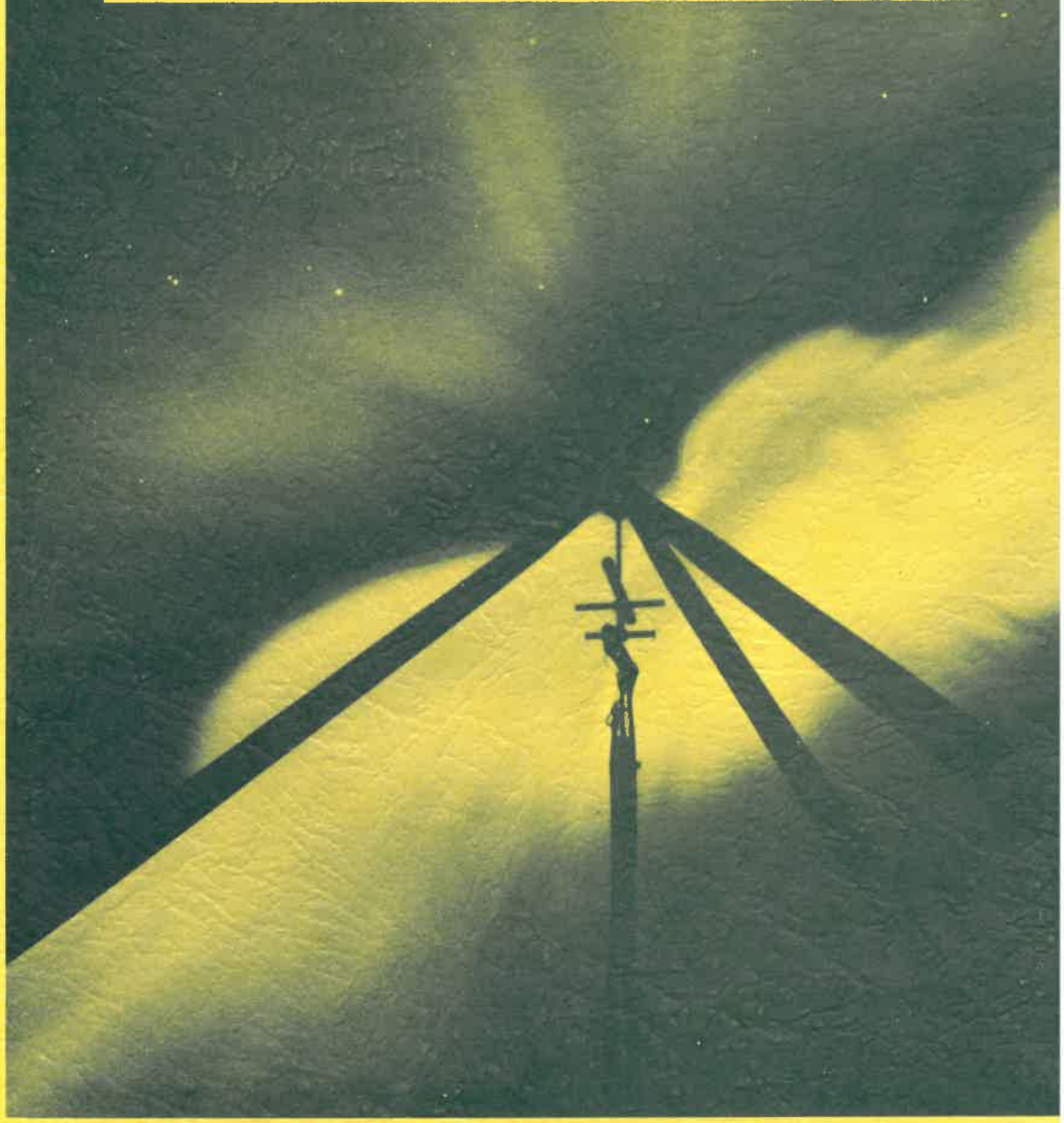

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A NOTE ON THE DS VARIATION OF GEOMAGNETIC STORMS:
A CRITICAL EXAMINATION OF METHOD OF ANALYSIS

by

Masahisa Sugiura

Scientific Report No. 4
Contract No. AF 19(604)-2163
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Geophysics Research Directorate
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Bedford, Massachusetts

Report approved by:

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ABSTRACT

The determination of DS variation of magnetic storms as a function of storm time is critically examined. The regular changes in the phase angles of harmonics for DS, found by Yokouchi (1958), are attributed to irregular features that are not adequately averaged out. This apparently paradoxical circumstance is explained with an illustrative example.

1. Introduction

Yokouchi of the Kakioka Magnetic Observatory wrote in 1958 an interesting paper, in which he showed some features of DS that must be considered as one of the most important properties of magnetic storms, if the features he found were real.

He derived DS (which is called SD in his paper*) for two groups of storms: (1) typical SC storms with clearly detectable initial and main phases; and (2) storms with sudden commencement followed by irregular variations of fairly long period. He selected 123 storms of the first kind, and 143 of the second, in the years 1924 to 1951. Judging from the Dst curves for these two groups of storms, which he presented in his previous paper (1957), the difference between these two groups appears to be only in their intensity and not in any fundamental characteristics, the first group being more intense than the second.

Yokouchi determined DS, for the two groups of storms, for each storm hour separately, using Kakioka records alone. For given storm time T, DS is a function of longitude λ relative to the sun. As such DS can be analyzed into harmonic components. He found that in both groups the second harmonic was of comparable magnitude as the first, and that the phase of the

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*Dst is defined as the average of the storm variation over all longitudes, and DS as the deviation of the storm variation from Dst. Hence DS is a function of storm time and longitude. When DS is averaged over one day, it is called SD. For detail, see Chapman, 1952, Sugiura and Chapman, 1960.

second harmonic changes with storm time with remarkable regularity. This is a very surprising result that will have important consequences in the interpretation of magnetic storms. Because of the difference in the method of analysis and presentation of the results these features were not revealed in the analysis made by Sugiura and Chapman (1956, 1957, 1958, 1960).

In this paper the method of analysis used by Yokouchi is critically examined.

2. Harmonic Dials for DS for Kakioka, San Juan, and Tucson

In order to confirm Yokouchi's results with independent data, the DS variation in the horizontal force, H, was determined for individual storm hours for our moderate storms (see Sugiura and Chapman, 1960) and its first four harmonic coefficients were computed. This analysis was made for Kakioka, San Juan, and Tucson. The number of storms used for each of these stations was 105, 126 and 103, respectively.

The results are shown in Figs. 1, 2 and 3. The scale is uniform in all the diagrams. The numbers 0 to 23 refer to storm hours. The origin of the dials refers to the level at storm hour -1.

Figure 1 shows the dialgrams for Kakioka. The first harmonic is not regular, but the second harmonic begins to show a regular change of phase; there appear to be two rotations in 24 hours. The third harmonic shows some irregularities, but it indicates a tendency to rotate three times. The fourth harmonic is of considerable magnitude, and is astonishingly regular. It clearly demonstrates four rotations.

Figure 2 gives the dialgrams for San Juan. The first harmonic is rather irregular as in Kakioka, but the second, third and fourth components are remarkably regular, and show rotations about the origin twice, three times, and four times, respectively.

The dialgrams for Tucson are shown in Fig. 3. Though the features demonstrated in Figs. 1,2 are less distinct for Tucson, a similar tendency is evident.

One may be tempted to interpret Yokouchi's results and those given above to imply that the phase of DS is varying with the same rate as that of the rotation of the earth, as if the disturbance field were frozen into the earth's atmosphere. If all the observatories in different longitudes, but in a same latitude, are all equivalent, the phases of the harmonics must be the same for all the observatories. But they are not necessarily equal with the three observatories considered here. This disagreement of the phase is found to be considerable for the third and fourth components.

3. Critical Examination of the Method of Analysis

When DS is determined as a function of storm time using data for many storms from one observatory, a few exceptional storms, whose variations differ considerably from the average

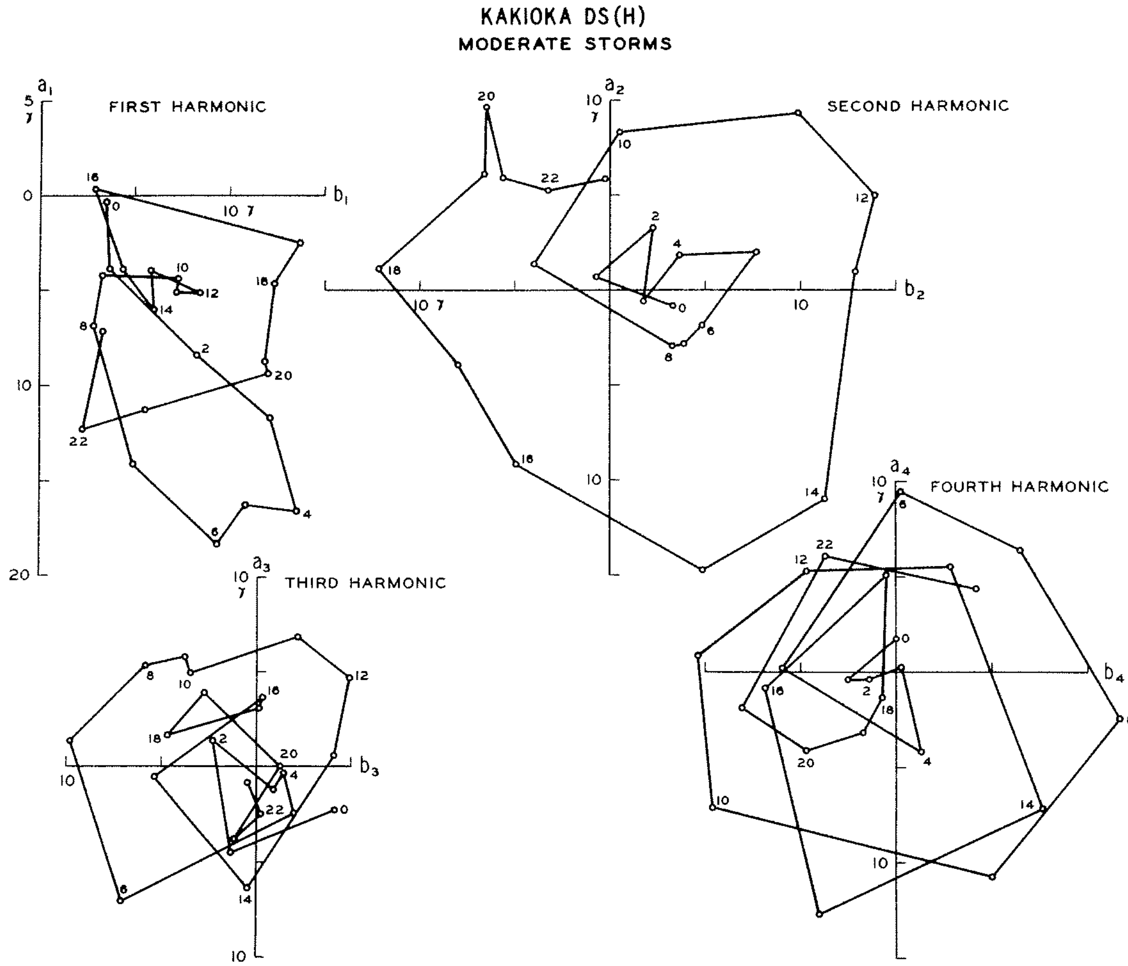

Fig. 1. Harmonic dials for DS(H) for Kakioka for the first to the fourth harmonic components. The numbers 0 to 23 refer to storm hours.

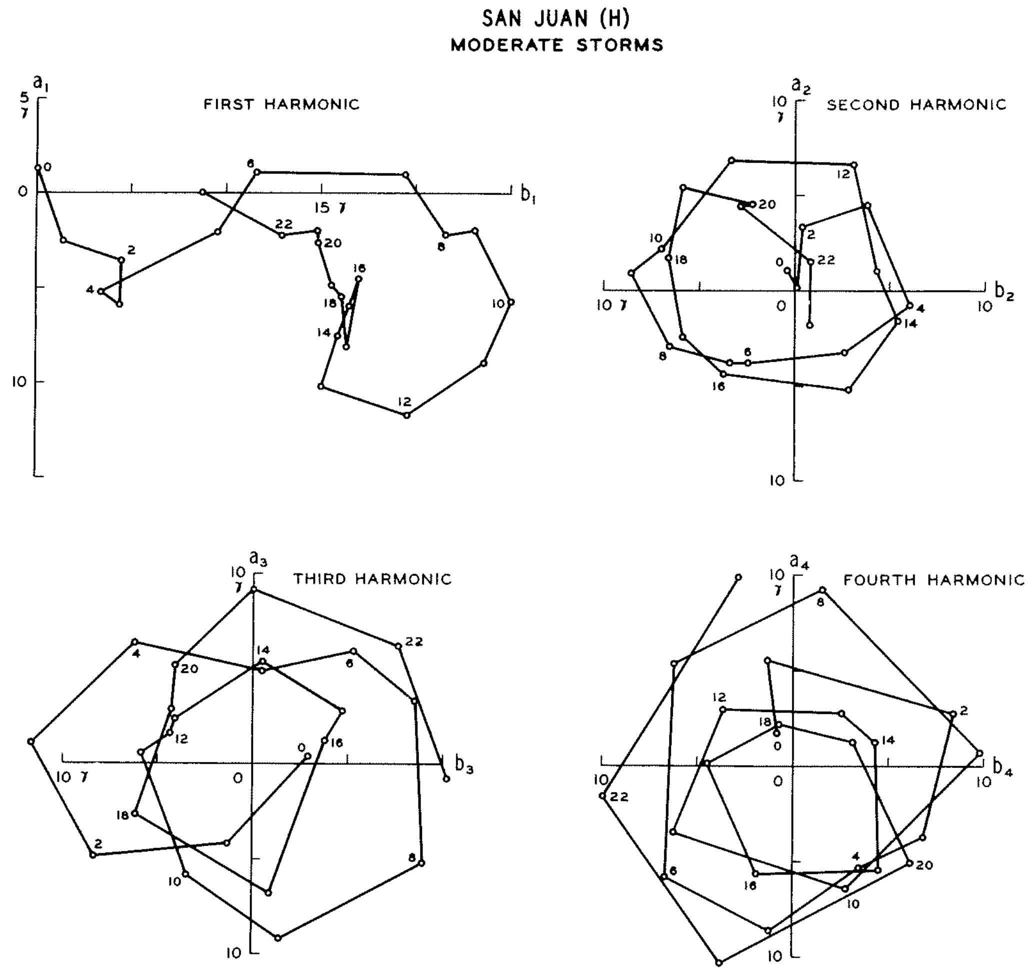

Fig. 2. Harmonic dials for DS(H) for San Juan for the first to the fourth harmonic components. The numbers 0 to 23 refer to storm hours.

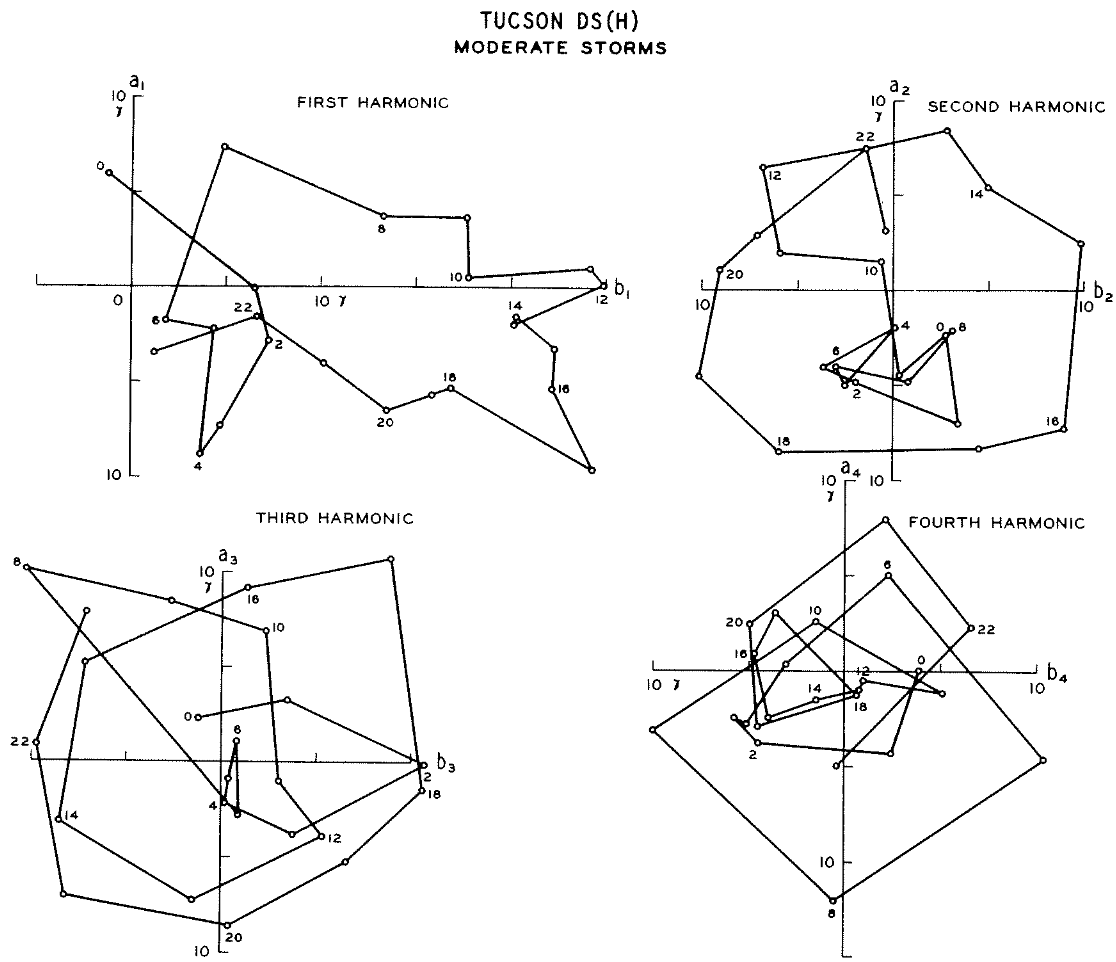

Fig. 3. Harmonic dials for DS(H) for Tucson for the first to the fourth harmonic components. The numbers 0 to 23 refer to storm hours.

of the other storms, could produce a feature that is quite similar to the one encountered in the previous section. That is, a few irregular storms can produce an apparently regular variation in DS. This paradoxical circumstance is explained below with an illustrative example.

Let us suppose that we have data for four storms from station P. We number these four storms as Nos. 1, 2, 3 and 4. We suppose that storm No. 1 commenced at local time 0 hour at P, No. 2 at 6 hours, No. 3 at 12 hours, and No. 4 at 18 hours. We denote the variation for storm i by $f_i(T)$, where T is storm time.

For the sake of simplicity, let us suppose that storms Nos. 1, 3 and 4 had exactly the same variation, namely $f_i(T<0) = 0$, $f_i(T\geq 0) = -3$ in arbitrary units, for i = 1, 3 and 4. We further suppose that storm No. 2 was drastically different from Nos. 1, 3 and 4 and that for No. 2, $f_2(T<0) = 0$, $f_2(T\geq 0) = 1$. These assumptions are illustrated in the two curves on the top of Fig. 4.

The Dst variation is then constant, and its constant value is $(-3 \times 3 + 1)/4 = -2$. The Dst curve is shown in the third graph in Fig. 4.

DS at storm time T is defined as the deviation of f from Dst(T). The four graphs in the bottom of Fig. 4 show DS for storm times T = 0, 6, 12 and 18 hours, respectively. In these graphs the local times (of P) at the respective storm hour for the four storms are indicated.

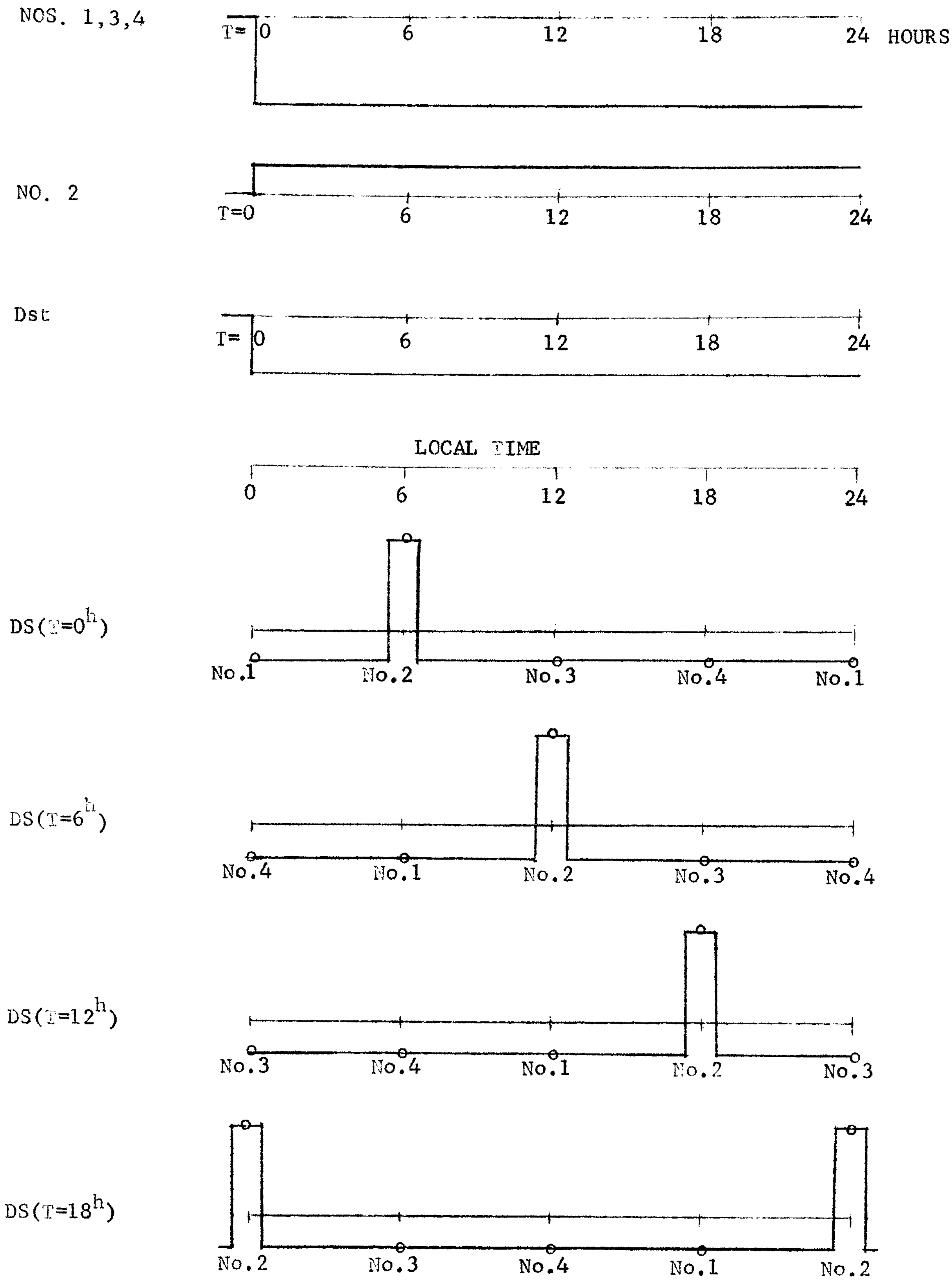

Fig.4. An illustrative example of Dst and DS. Storm variation f_i for storm i is $f_i(T\geq 0) = -3$, for i=1,3,4, and $f_2(T\geq 0) = 1$ for No.2, where T is storm time. $Dst(T)=\sum_{i=1}^{4} f_i(T)/4$, and $DS(T,\lambda_i)= f_{\lambda_i}(T) - Dst(T)$, where λ_i is the local time of the station at storm time T for storm i, and $f_{\lambda_i}(T)\equiv f_i(T)$.

DS is -1 at all local hours corresponding to storms Nos. 1, 3 and 4, and is +1 - (-2) = +3 at the local hour corresponding to storm No. 2. As storm time elapses, the local time of P for each storm increases; thus the point referring to each storm moves to the right in the sequence of DS diagrams.

If DS is then harmonically analyzed for individual storm hour, the phase angles of the harmonic components will change systematically with storm time.

4. Conclusions

In section 3 it was shown with an illustrative example that if DS is determined from one station alone, a few irregular storms may influence the phase angles of harmonics of DS appreciably. The narrower the width of the irregular variation the higher the harmonics that will show the systematic phase change.

Therefore, when DS is determined as a function of storm time, care must be taken so that all the irregular features are eliminated by averaging. This remark also applies to the interpretation of diagrams in which contours are drawn for DS with storm time and local time as the orthogonal axes. Such diagrams have been shown by Nagata and Ōno (1952) and Yokouchi (1958).

In the analysis made by Sugiura and Chapman, irregular features of storm variations were averaged out by combining results for several stations in different longitudes.

Acknowledgements

I would like to thank Professor S. Chapman for calling my attention to Yokouchi's papers, and Dr. S.-I. Akasofu for discussions.

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