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52. Elimination of Non-local Changes from Total Intensity Values of the Geomagnetic Field.

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Summary

Simultaneous measurements of the total geomagnetic field intensity at a few stations in Japan are compared. Non-local changes such as magnetic storm, S_q and the like cannot be removed by making simple differences between the values observed at two stations. After a number of trials, it is concluded that the best way of eliminating non-local changes is to make use of night-time data and to compute a weighted difference. The weight for a certain combination of stations is empirically determined. The smallest standard deviation of difference values thus estimated for stations in the central part of Japan amounts to 2.2 γ for an individual observation. The standard deviation could become smaller if we make use of averaged data during night-time only. Statistics separately made for disturbed and undisturbed days does not prove a marked contrast. The technique presented in this paper is going to be refined in the hope of detecting possible seismo-magnetic effect by proton precession magnetometer network covering Japan.

1. Introduction

A 5-year plan for earthquake prediction research in Japan[1] as proposed by the Sub-committee for Earthquake Prediction, National Committee for Geodesy and Geophysics, the Science Council of Japan has been under way since 1964. Among the various items of the plan, the writer has been specially involved in the planning of geomagnetic observation.

In order to bring out local anomalous changes in the earth's magnetic field that might be associated with seismic activity with a high accuracy, precise observation of secular variation is planned to be made by proton

1) T. RIKITAKE, *Journ. Tectonophys.*, 3 (1966), 1.

precession magnetometers at 21 magnetic observatories scattered all over Japan. In addition to this, a number of observatories will be equipped with differential proton precession magnetometers which can record difference in the total intensity of the geomagnetic field between two stations a few kilometers distant from one another. Details of the magnetometers will be reported elsewhere.

Since the magnetometers are free from drift, it is not difficult to observe the total intensity (F) of the geomagnetic field with an accuracy of $\pm 1\gamma$. It is required, however, to eliminate effects of non-local geomagnetic changes such as those due to daily variation, magnetic storm and so on from raw data. A customary way of eliminating such effects has been to refer to observation at a standard magnetic observatory. Supposing that a total intensity value F_A is observed at a station called A at a certain instant, we denote the total intensity value at the standard observatory by F_S at the same instant and so $F_A - F_S$ is simply regarded as the difference in the total intensity which is free from non-local field. If a time-sequence of $F_A - F_S$ is available, it is thought to indicate the local change at A relative to S. In recent years, however, it has become apparent that such a simple difference technique sometimes results in a serious error. Fujita[2] and Yukutake et al[3] reported, for instance, that differences in geomagnetic variations between two stations, 100 km apart say, may well exceed 10γ, their discussions being based on the work related to reduction of results of magnetic survey and a post-earthquake change observation of the geomagnetic field.

Fujita[2] argued that accuracy of eliminating non-local change would be less than $\pm 5\gamma$ for a first-order survey for which an average of observations during one day with an hour interval was used. In the case of a second-order survey for which only a few observations are available, the accuracy would be less than $\pm 10\gamma$.

It has been reported by Japanese geomagneticians, notably by Rikitake[4], that geomagnetic variations of short period are extremely anomalous over Japan Islands. In the central part of Japan, it is not uncommon that changes in the vertical component of the geomagnetic field range from zero to those equal to the horizontal component within a distance of 100–200 km at times of geomagnetic bays and similar changes. A distinct phase shift of the vertical component of daily variation (S_q) has also

2) N. FUJITA, *Journ. Geod. Soc. Japan*, **11** (1965), 8.
3) T. YUKUTAKE et al., *Spec. Bull. Earthq. Res. Inst.*, **8** (1964), 52.
4) T. RIKITAKE, *Geophys. Journn. Roy. Astr. Soc.*, **2** (1959), 276.

been found at Japanese observatories. Such anomalous behaviours of geomagnetic variations of various kinds have been supposed to be caused by electromagnetic induction in the earth's crust and mantle in which the distribution of the electrical conductivity is incredibly complicated. It cannot be helped, therefore, that instantaneous values of geomagnetic element widely vary from place to place even though the fields arising from outside the earth are distributed fairly regularly over Japan.

Whitham and Niblett[5] examined errors introduced into total intensity values observed in the course of aeromagnetic survey because of geomagnetic time variations. They made use of analogue data of proton magnetometers operated at stations around Meanook Magnetic Observatory in Canada. Although they found large local differences as great as a few scores of gammas for distances amounting to a few tens of kilometers, such a large gradient of geomagnetic variation field seems to be attributable to the fact that the experiment was made close to the auroral zone.

A similar experiment based on digital data of proton magnetometers was made by Stacey and Westcott[6] in England where no outstanding conductivity anomaly within the earth had been found. They made use of about 33,000 sets of synchronized measurements with a 36 sec. interval. They are specially interested in determining a limit of observability of possible seismo-magnetic effect arising from local irregularities of geomagnetic variation. The difference values between two stations, 25 km apart, were found to scatter around the mean values respectively with standard deviations 0.85γ and 0.21γ for the individual and 24-hour average values.

Although Stacey and Westcott concluded that a seismo-magnetic change of magnitude a few gammas, which lasts more than a few minutes, could be unambiguously observable under the conditions of their experiments, it is doubtful that a similar conclusion can be applied to observation in Japan where we have been observing an extremely intense geomagnetic variation anomaly. Since it is very important to know the limit of observability of seismo-magnetic effect before we establish a network of proton magnetometers covering Japan, it is the writer's intention in this paper to make a reconnaissance study of elimination technique of non-local changes from total intensity values of the geomagnetic field which could be applied to parts of Japan.

As data collection with punched paper-tape system has just been started

5) K. Whitham and E. R. Niblett, *Geophysics*, **26** (1961), 211.
6) F. D. Stacey and P. Westcott, *Nature*, **206** (1965), 1209.

on Oshima Island, about 100 km south of Tokyo, under the observation scheme of the five-year plan for earthquake prediction research, we have to rely at the moment on data so far obtained by means of proton magnetometers of manual operation, analogue recording and digital printing types. On the occasion of the Niigata Earthquake that occurred on June 16, 1964, a team[3] was sent to the earthquake area from the Earthquake Research Institute for observing changes in the geomagnetic field. Fairly large sets of total intensity data were then obtained at Awashima Island, off Niigata Prefecture, and Shioya. Both the stations are indicated on the map in Fig. 1. A more extensive observation[7, 8] covering a long period has been carried out at Matsushiro, Nagano Prefecture, in relation to the Matsushiro Earthquake Swarm that had been taking place since August, 1965. Meanwhile, analogue recording proton magnetometers have been at work at Kanozan Geodetic Observatory and Oshima Magnetic Observatory. The following statistics will be based on data from these observatories. In Fig. 1 are also shown the localities of Matsushiro, Kanozan and Oshima Island.

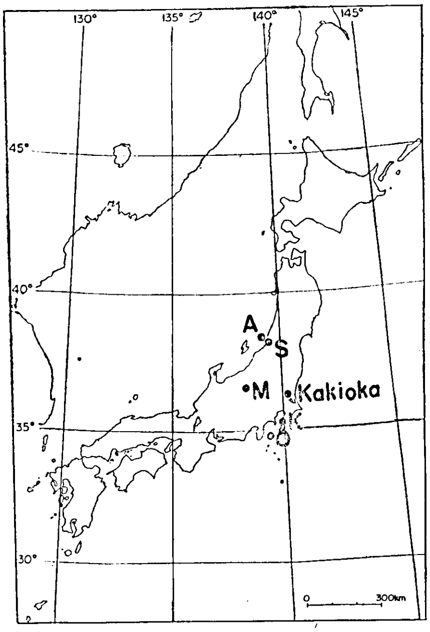

Fig. 1. Locations of stations. A: Awashima, S: Shioya, M: Matsushiro, K: Kanozan, O: Oshima.

2. Analysis of the data from Matsushiro, Kanozan and Oshima

2-1. Data

A proton magnetometer of manual operation type has been at work at a station approximately in the central area of the Matsushiro Earthquake Swarm since November, 1965. All the values of intensity observed there (F_M) up to the beginning of February, 1966 were reported by Riki-

7) T. RIKITAKE et al., *Bull. Earthq. Res. Inst.*, 44 (1966), 363.
8) T. RIKITAKE et al., *Bull. Earthq. Res. Inst.*, 44 (1966), 409.

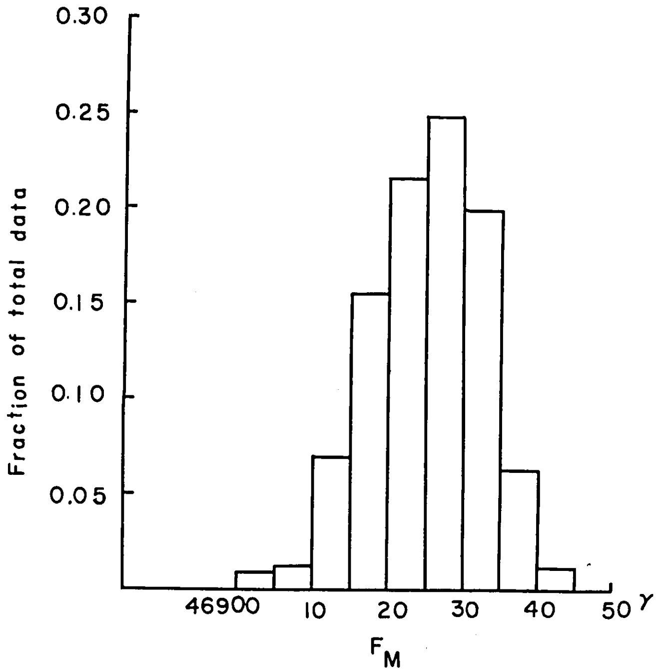

Fig. 2a. Histogram of individual values of the total geomagnetic field intensity at Matsushiro.

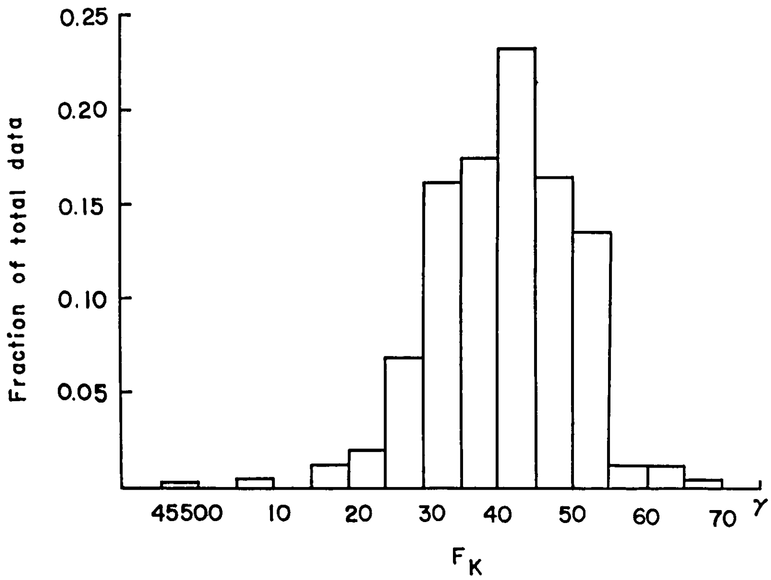

Fig. 2b. Histogram of individual values of the total geomagnetic field intensity at Kanozan.

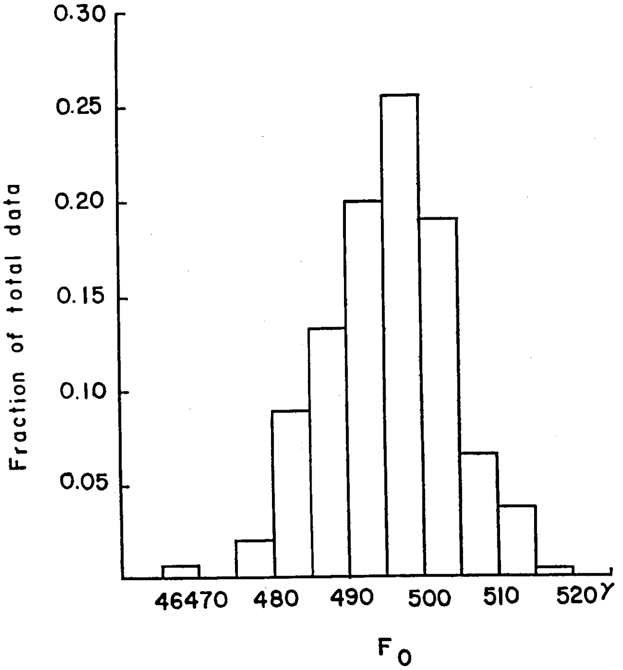

Fig. 2c. Histogram of individual values of the total geomagnetic field intensity at Oshima.

take et al[7), 8)], while those at Kanozan (F_K) and Oshima (F_0) at instants when measurements at Matsushiro were made were read off from the analogue records. Some additional data were also taken from the latter two observatories. Sets of total intensity data, 462 for F_M, 528 for F_K and 473 for F_0 in number are thus provided for analysis.

First of all, histograms of F_M, F_K and F_0 are made as shown in Figs. 2a, 2b and 2c. Although the geomagnetic field was generally calm during the period, individual values of F_M, F_K and F_0 are distributed in a wide range of a few scores of gammas. The mean values, are estimated as 46926.0, 45541.5 and 46496.2γ for F_M, F_K and F_0 with standard deviations 7.9, 8.8 and 8.1γ respectively.

Rikitake et al[7), 8)] also reported on averages of F_M observed on each day. Although observations are usually made several times a day and

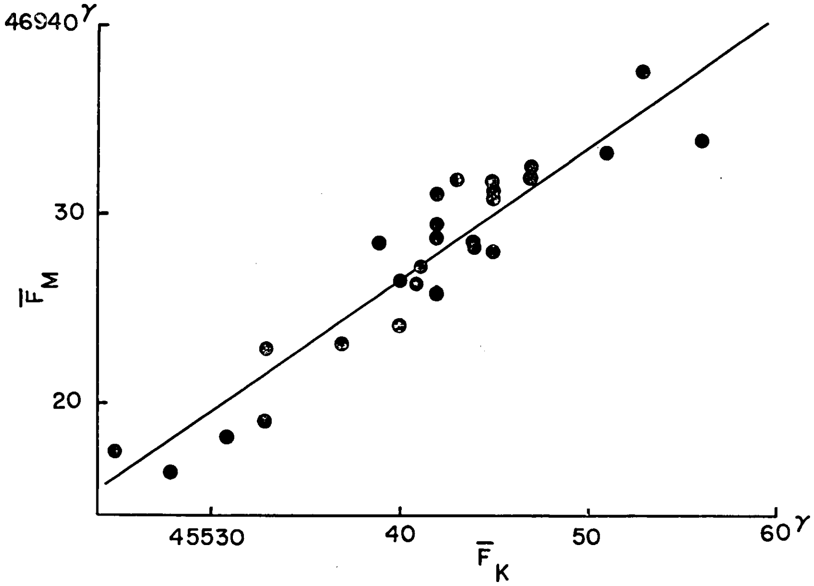

Fig. 3a. $\overline{F}_M$ versus $\overline{F}_K$ relation.

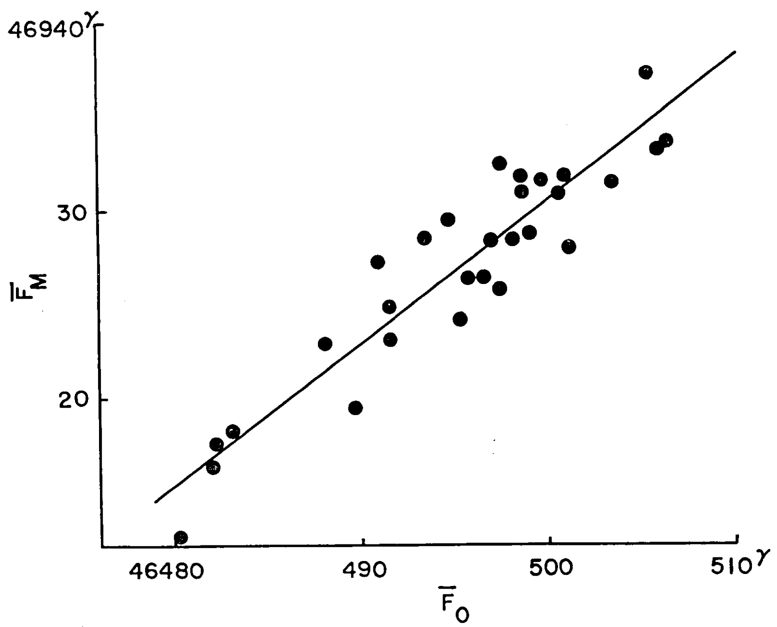

Fig. 3b. $\overline{F}_M$ versus $\overline{F}_O$ relation.

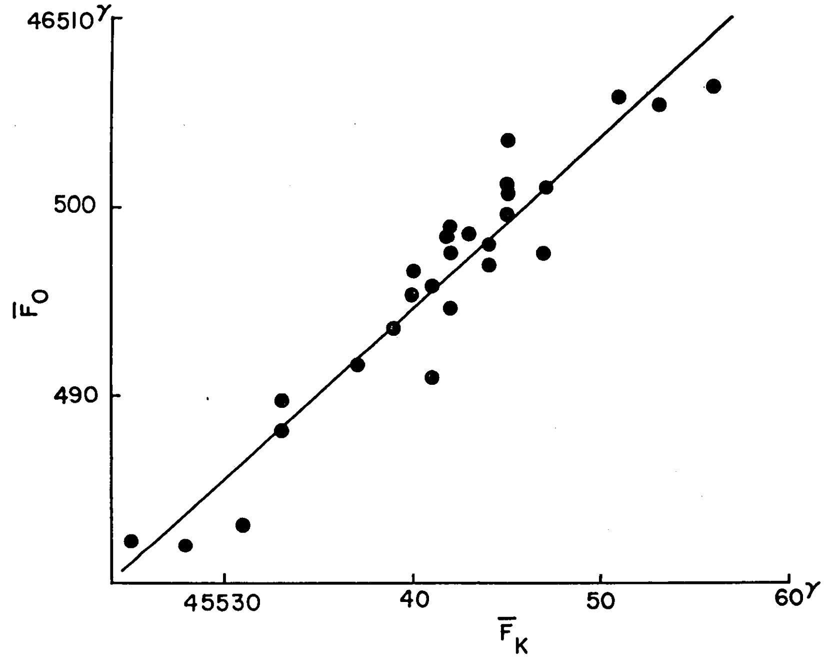

Fig. 3c. $\overline{F}_O$ versus $\overline{F}_K$ relation.

so the average is not based on a set of uniform data, we may call such an average the daily mean in this paper and denote by $\overline{F}_M$. Similar averages for F_K and F_0 at corresponding times are also denoted by $\overline{F}_K$ and $\overline{F}_0$.

2-2. Relations between $\overline{F}_M$, $\overline{F}_K$ and $\overline{F}_0$

Figs. 3a, 3b and 3c show respectively the $\overline{F}_M-\overline{F}_K$, $\overline{F}_M-\overline{F}_0$ and $\overline{F}_0-\overline{F}_K$ relations plotted from the data from Nov. 19 to Dec. 19, 1965. It may be said from these figures that changes in these three quantities ($\Delta\overline{F}_M$, $\Delta\overline{F}_K$ and $\Delta\overline{F}_0$) are approximately in linear relations. The proportional constants are calculated by means of the least squares technique as

$$\begin{aligned} \Delta\overline{F}_M/\Delta\overline{F}_K &: \ \alpha=0.702, \\ \Delta\overline{F}_M/\Delta\overline{F}_0 &: \ \beta=0.762, \\ \Delta_0\overline{F}/\Delta\overline{F}_K &: \ \gamma=0.912. \end{aligned} \qquad (1)$$

It is noticeable that the $\Delta\overline{F}_M$ is about 30 per cent smaller than $\Delta\overline{F}_K$ and $\Delta\overline{F}_0$. Such a tendency is well illustrated if we make a $\overline{F}_M-\overline{F}_K$ versus $\overline{F}_K$ relation as has already been shown in Fig. 9 of the previous

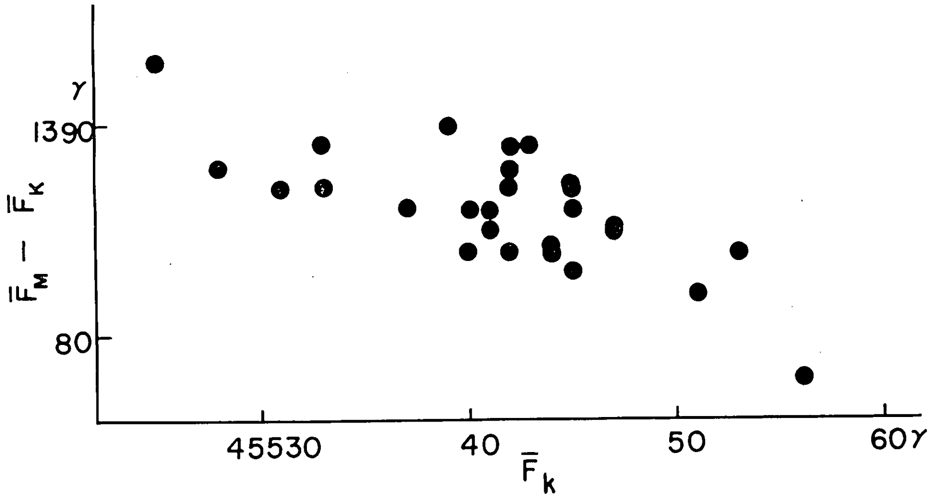

Fig. 4. $\bar{F}_M - \bar{F}_K$ versus $\bar{F}_K$ relation.

paper[7] and also reproduced in Fig. 4 here. It is clearly indicated in the figure that, when $\bar{F}_K$ takes on a large value, $\bar{F}_M - \bar{F}_K$ tends to take on a small value. Although such a fact seems likely to be caused by some difference in daily variation between the two observatories, it was brought to light only recently by the geomagnetic observation related to the Matsushiro Earthquake Swarm. The great difference in the total intensity value between the two stations, the distance between which amounts to

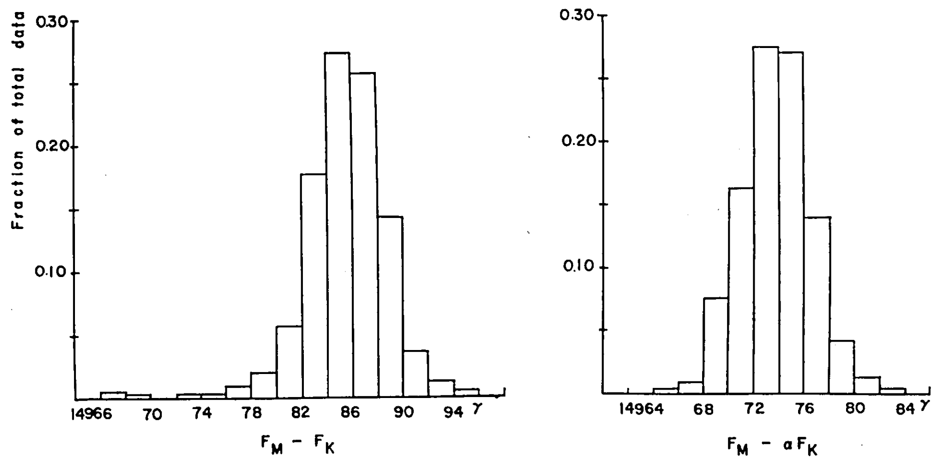

Fig. 5a. Histograms of simple $(F_M - F_K)$ and weighted $(F_M - \alpha F_K)$ differences for the whole data.

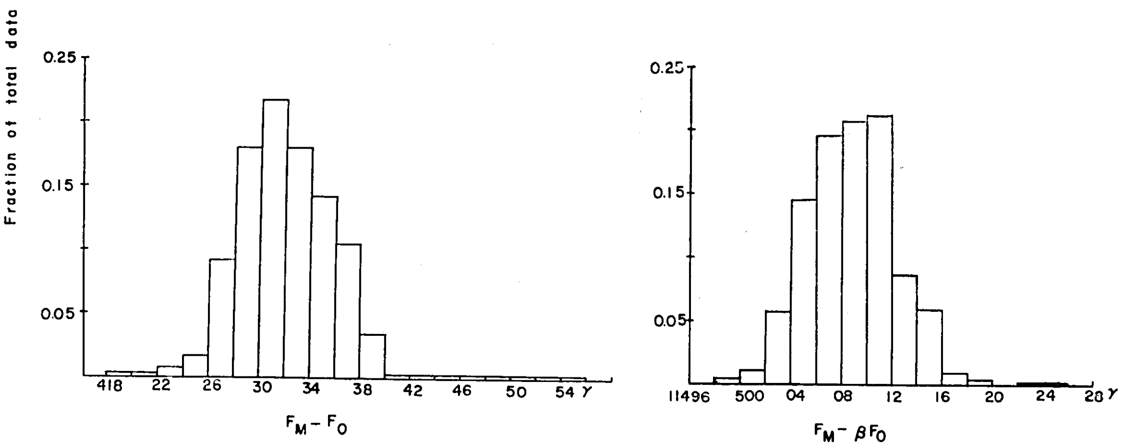

Fig. 5b. Histograms of simple (F_M-F_O) and weighted ($F_M-\beta F_O$) differences for the whole data.

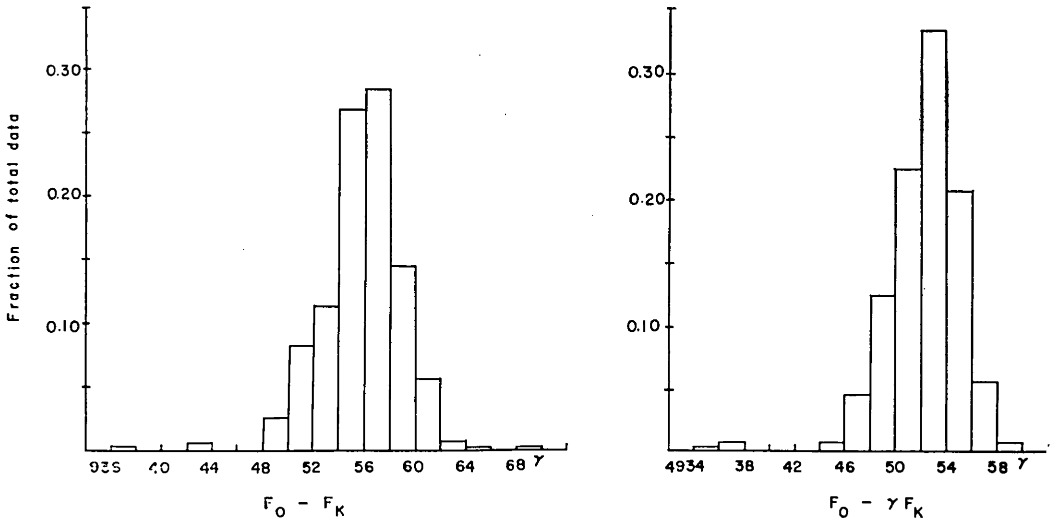

Fig. 5c. Histograms of simple (F_O-F_K) and weighted ($F_O-\gamma F_K$) differences for the whole data.

only 200 km or so, suggests that it would be no easy matter to get rid of non-local geomagnetic changes.

2–3. Simple and weighted differences for individual values

In order to see to what extent non-local changes can be eliminated by means of simple difference technique, F_M-F_K, F_M-F_0 and F_0-F_K are computed and so their histograms are shown on the left-hand sides of Figs. 5a, 5b and 5c. It is disappointing for elimination of non-local changes that the difference values are widely scattered around the mean values, the total ranges being 30–40γ. It is observed, however, that the distribution curve for F_0-F_K is the steepest probably because of the proximity of Kanozan and Oshima, the distance between them amounting to 80 km. The standard deviations and total ranges for the distributions are given in Table 1a.

Table 1a. Standard deviations and total ranges in γ for simple differences between all the individual values.

	F_M-F_K	F_M-F_0	F_0-F_K
Standard deviation	2.8	3.5	2.8
Total range	30	38	34

The tendency for the total intensity values of the present statistics are approximately in linear relations, as pointed out in the last subsection, may suggest that weighted differences such as $F_M-\alpha F_K$, $F_M-\beta F_0$ and $F_0-\gamma F_K$ would provide better eliminations of non-local change than the simple differences. Adopting α, β and γ as given in (1), histograms for the weighted differences are computed and illustrated on the right-hand sides of Fig. 5a, 5b and 5c.

It is observed that dispersion of the distribution becomes somewhat improved by the weighted difference technique especially for the differences between F_0 and F_K. For the other two cases, only slight improvement can be seen although extreme values which widely deviate from the mean disappear from the histograms. The standard deviations and total ranges for the distributions are given in Table 1b.

Table 1b. Standard deviations and total ranges in γ for weighted differences between all the individual values.

	$F_M-\alpha F_K$	$F_M-\beta F_0$	$F_0-\gamma F_K$
Standard deviation	2.8	3.5	2.6
Total range	20	28	26

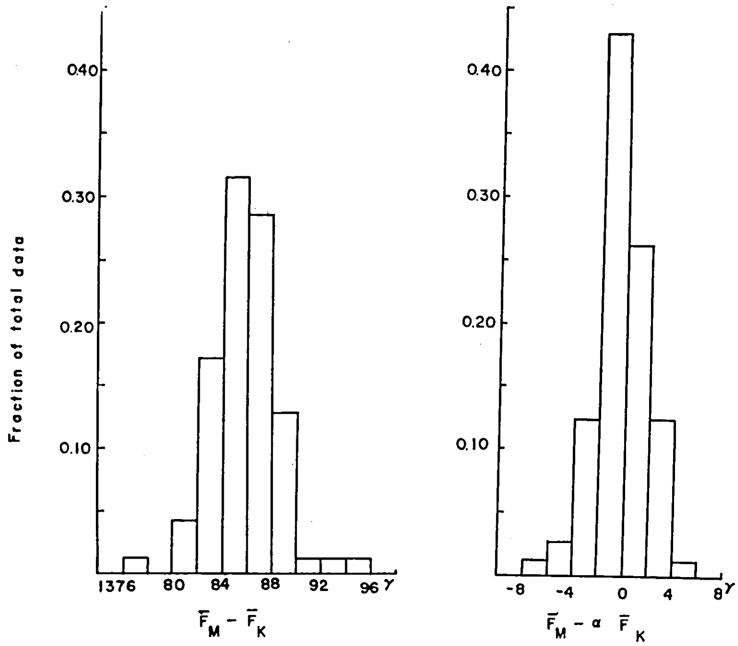

Fig. 6a. Histograms of simple $(\bar{F}_M - \bar{F}_K)$ and weighted $(\bar{F}_M - \alpha\bar{F}_K)$ differences of the daily means.

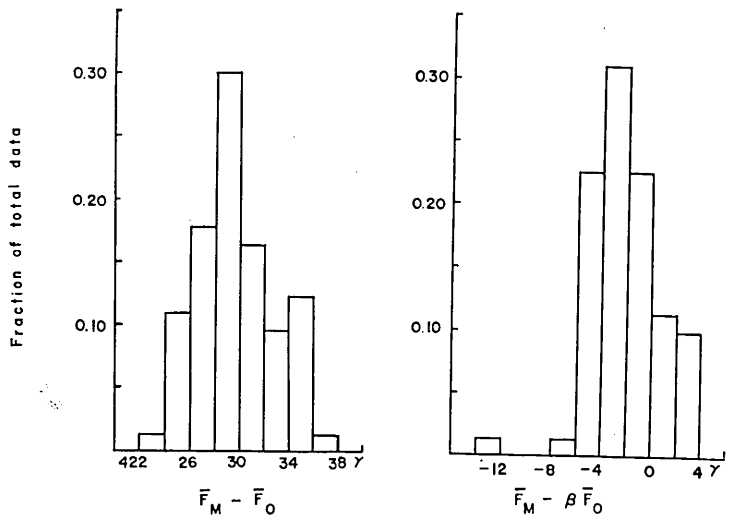

Fig. 6b. Histograms of simple $(\bar{F}_M - \bar{F}_O)$ and weighted $(\bar{F}_M - \beta\bar{F}_O)$ differences for the daily means.

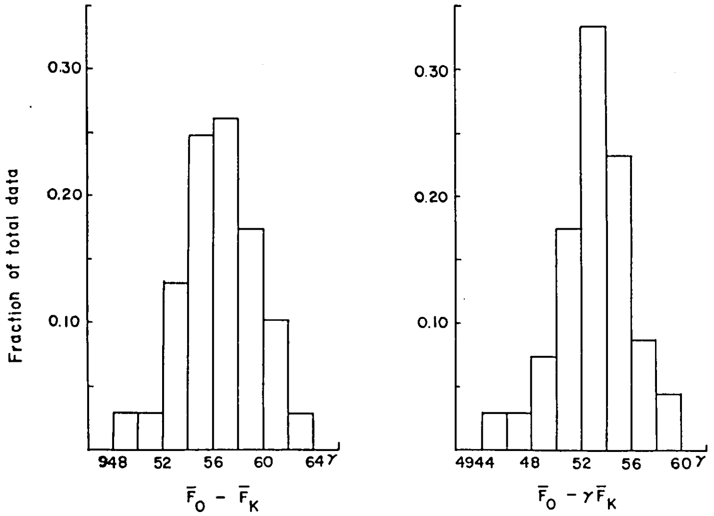

Fig. 6c. Histograms of simple ($\bar{F}_O - \bar{F}_K$) and weighted ($\bar{F}_O - r\bar{F}_K$) differences for the daily means.

2-4. Simple and weighted differences for daily means

The same procedures as that of the last subsection is also applied to the daily mean values, i.e. $\bar{F}_M$, $\bar{F}_K$ and $\bar{F}_0$. The total numbers used are 70, 72 and 69 for the combinations ($\bar{F}_M$, $\bar{F}_K$), ($\bar{F}_M$, $\bar{F}_0$) and ($\bar{F}_0$, $\bar{F}_K$) respectively. The smallness of the sets of data seems to give rise to some irregularities in the statistics. The histograms are shown in Figs. 6a, 6b and 6c and the standard deviations and total ranges are given in Tables 2a and 2b.

Table 2a. Standard diviations and total ranges in γ for simple differences between all the daily means.

	$\bar{F}_M - \bar{F}_K$	$\bar{F}_M - \bar{F}_0$	$\bar{F}_0 - \bar{F}_K$
Standard deviation	2.4	2.9	2.8
Total range	20	16	16

Table 2b. Standard deviations and total ranges in γ for weighted differences between all the daily means.

	$\overline{F}_M-\alpha\overline{F}_K$	$\overline{F}_M-\beta\overline{F}_0$	$\overline{F}_0-\gamma\overline{F}_K$
Standard deviation	2.0	2.6	2.8
Total range	16	18	16

It seems likely that steepness of histogram can be somewhat increased by making use of daily mean values. Since, however, the daily mean available here is an average of several measurements in a day, it is naturally expected that no dramatic improvement of dispersion is possible. Further investigation based on an average of a uniform set of data like hourly values should be made in order to have a better improvement. It

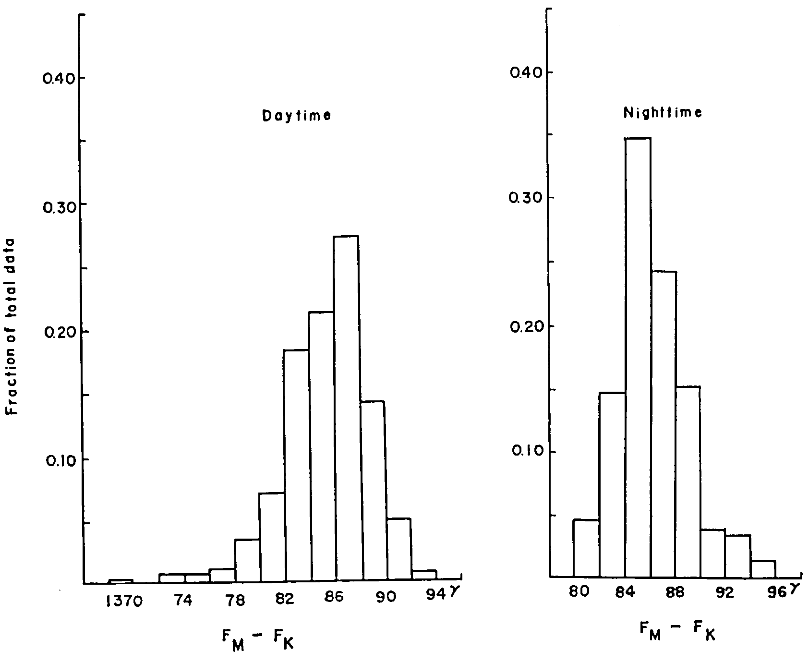

Fig. 7a. Day-time and night-time histograms of F_M—F_K.

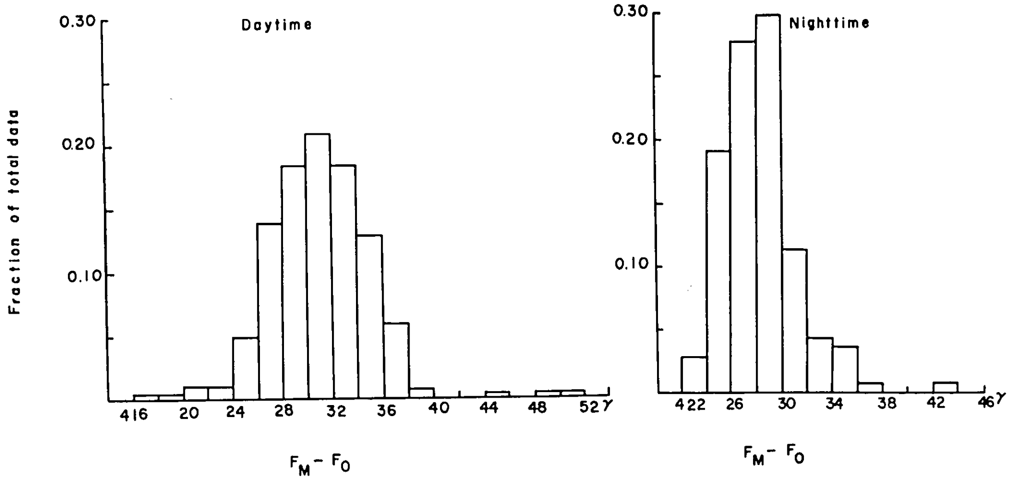

Fig. 7b. Day-time and night-time histograms of F_M—F_O.

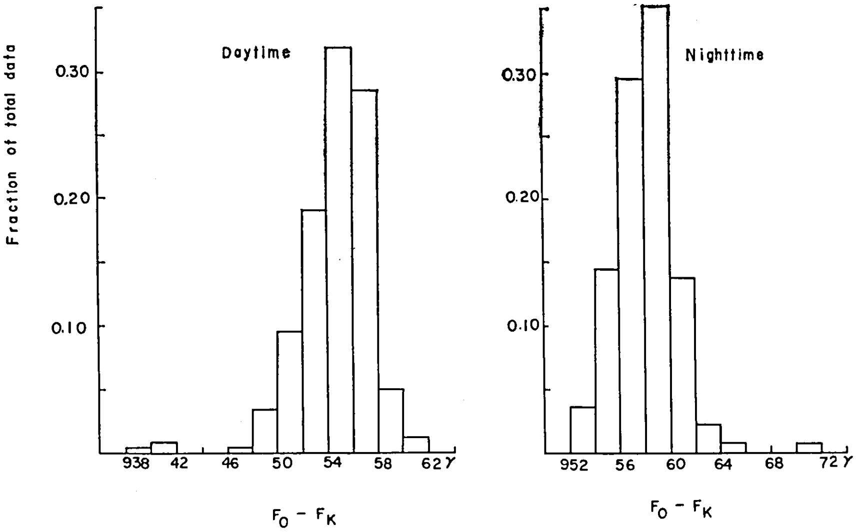

Fig. 7c. Day-time and night-time histograms of F_O—F_K.

is noticeable, however, that great deviation from the mean values can be avoided by the procedure as can be seen by comparing the histograms for daily means (Figs. 6a, 6b and 6c) to those for individual values (Figs. 5a, 5b and 5c). Such a tendency is also supported by the fact that the total ranges become drastically small.

2–5. Statistics separately made for day-time and night-time data

It has been known that inequalities of S_q sometimes affect seriously local values of geomagnetic elements as has been experienced in the case of reduction procedure for magnetic surveys. It is hence important to examine to what extent scattering of difference values in the total intensity will be lessened by using data observed only during night-time when the effect of S_q should be small. All the individual data are therefore divided into two classes, day-time and night-time say. The day-time is here defined as to cover a time-range from 6h 00m to 17h 59m in local time, while the remaining is defined as the night-time. The numbers of data for the present analysis are indicated in Table 3.

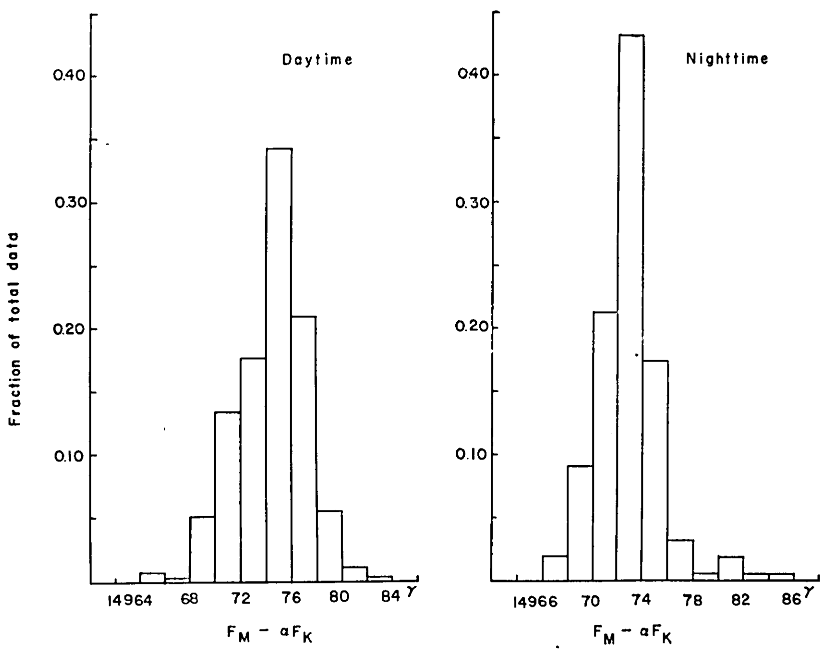

Fig. 8a. Day-time and night-time histograms of $F_M - \alpha F_K$.

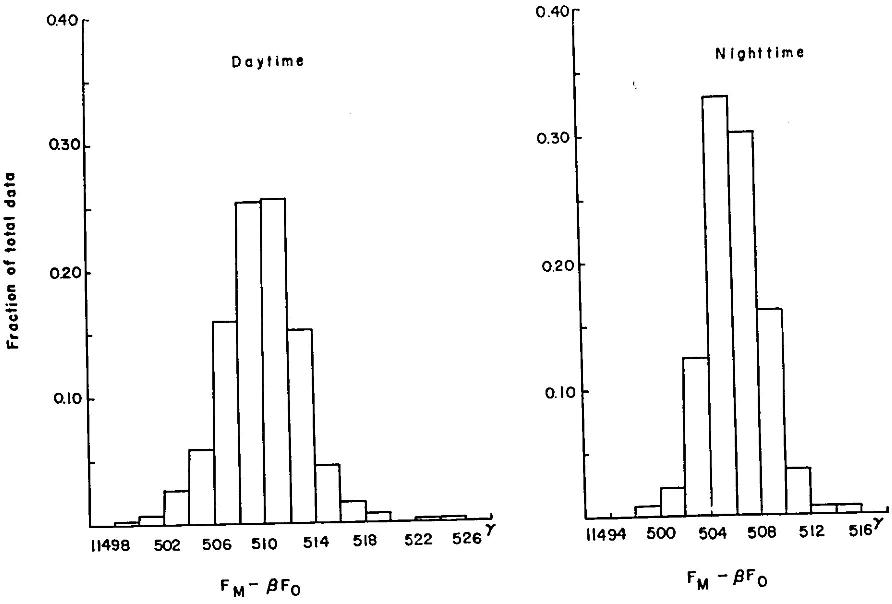

Fig. 8b. Day-time and night-time histograms of $F_M - F_O$.

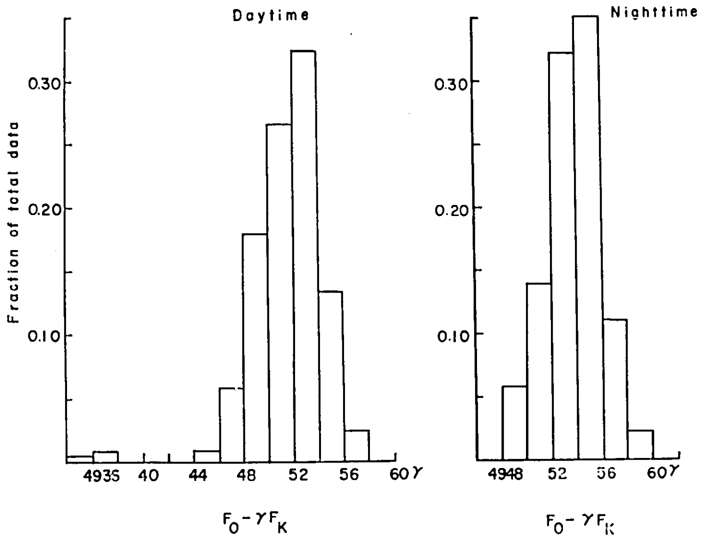

Fig. 8c. Day-time and night-time histograms of $F_O - \gamma F_K$.

Table 3. The numbers of data.

	$F_M—F_K$	$F_M—F_0$	$F_0—F_K$
Day-time	267	285	262
Night-time	157	143	142

Histograms for F_M-F_K, F_M-F_0, F_0-F_K, $F_M-\alpha F_K$, $F_M-\beta F_0$ and $F_0-\gamma F_K$ are computed and shown in Figs. 7a, 7b, 7c 8a, 8b and 8c. In these figures are drawn day-time histograms on the left and night-time ones on the right. The standard deviations and total ranges are given in Tables 4a and 4b.

Tabe 4a. Standard deviations and total ranges in γ for day-time data.

	$F_M—F_K$	$F_M—F_0$	$F_0—F_K$	$F_M—\alpha F_K$	$F_M—\beta F_0$	$F_0—\gamma F_K$
Standard deviation	2.9	3.7	2.7	2.8	2.9	2.5
Total range	26	36	24	22	28	24

Table 4b. Standard deviations and total ranges in γ for night-time data.

	$F_M—F_K$	$F_M—F_0$	$F_0—F_K$	$F_M—\alpha F_K$	$F_M—\beta F_0$	$F_0—\gamma F_K$
Standard deviation	2.6	2.6	2.3	2.2	2.3	2.2
Total range	16	22	20	20	18	12

The standard deviations and total ranges in the tables clearly indicate that they get smaller according to an order, i.e. day-time simple difference (DSD), day-time weighted difference (DWD), night-time simple difference (NSD) and night-time weighted difference (NWD). The tendency that the standard deviations and total ranges tend to be improved as we move on following the DSD-DWD-NSD-NWD order is schematically shown in Figs. 9a and 9b.

It is therefore disirable for elimination of non-local changes to make use of data during night-time and, wherever possible, application of a

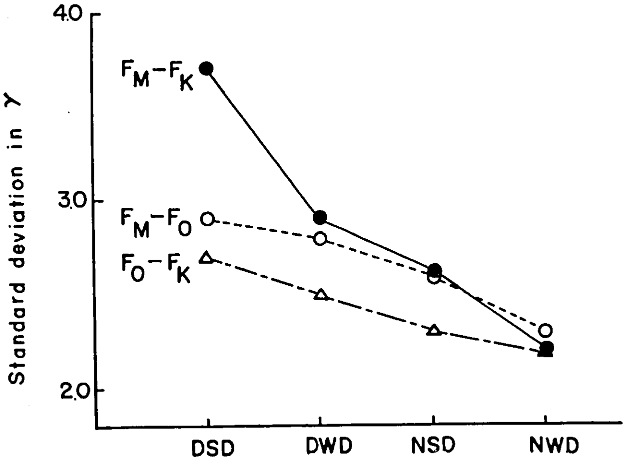

Fig. 9a. Schematic diagram showing how the standard deviations change as we move on according to an order, i.e. day-time simple difference (DSD), day-time weighted difference (DWD), night-time simple defference (NSD) and night-time weighted difference (NWD).

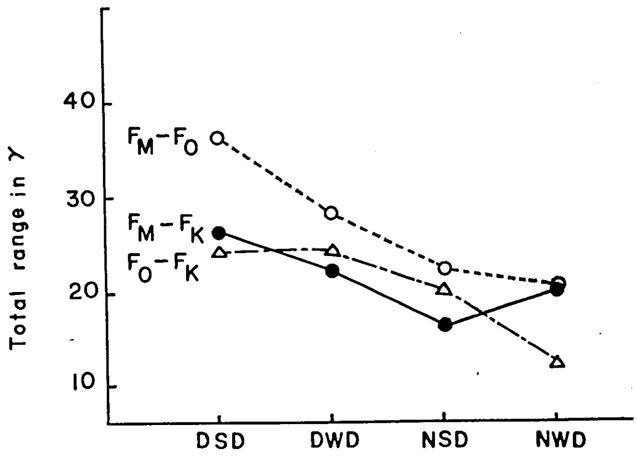

Fig. 9b. Schematic diagram showing how the total ranges change according to a DSD—DWD—NSD—NWD order.

weighted difference technique certainly leads to a better result. As far as the present data are concerned, the smallest standard deviation that can be attained is 2.2γ for individual data. It may be said, therefore, that 68 per cent of night-time weighted differences in the total intensity between stations, the distances between which amount to 100–200 km, in the Matsushiro-Kanozan-Oshima area fall in a range of $\pm 2.2\gamma$ around the mean values.

2-6. Statistics separately made for disturbed and undisturbed days

It is also interesting to examine how difference values in the total intensity fluctuate according to geomagnetic activity. Extremely large differences in the vertical component between stations in the central part of Japan have been found at times of geomagnetic bay and similar change. It is expected, therefore, that large deviations from the mean value should be experienced when difference data taken during magnetic storms are made use of.

The geomagnetic condition during the period under examination being generally calm, the maximum daily sum of K-index (ΣK) was only 28 and did not exceed 20 except on Jan. 22. All the days are classified into two classes, the days for which $\Sigma K > 10$ and $\Sigma K \leqq 10$. The numbers of days for respective classes are given in Table 5. K-indices are determined at the Kakioka Magnetic Observatory which is also shown in Fig. 1.

Table 5. Classification of days according to ΣK.

	$\Sigma K>10$	$\Sigma K\leqq 10$
Number of days	38	35

Histograms for F_M-F_K, F_M-F_0, F_0-F_K, $F_M-\alpha F_K$, $F_M-\beta F_0$ and $F_0-\gamma F_K$ are shown in Figs. 10a, 10b, 10c, 11a, 11b and 11c in which for $\Sigma K\leqq 10$ and $\Sigma K> 10$ are drawn respectively on the left and right. Looking at these histograms, no marked differences between those for $\Sigma K> 10$ and $\Sigma K\leqq 10$ are found. Tables 6a and 6b indicate the standard deviations and total ranges respectively for simple and weighted differences classified according to daily sum of K-index.

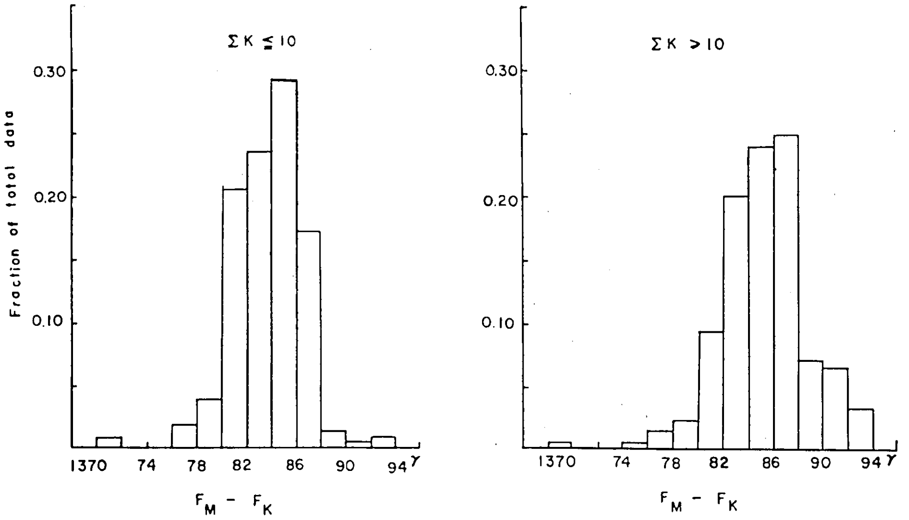

Fig. 10a. Histograms of $F_M - F_K$ on undisturbed and disturbed days.

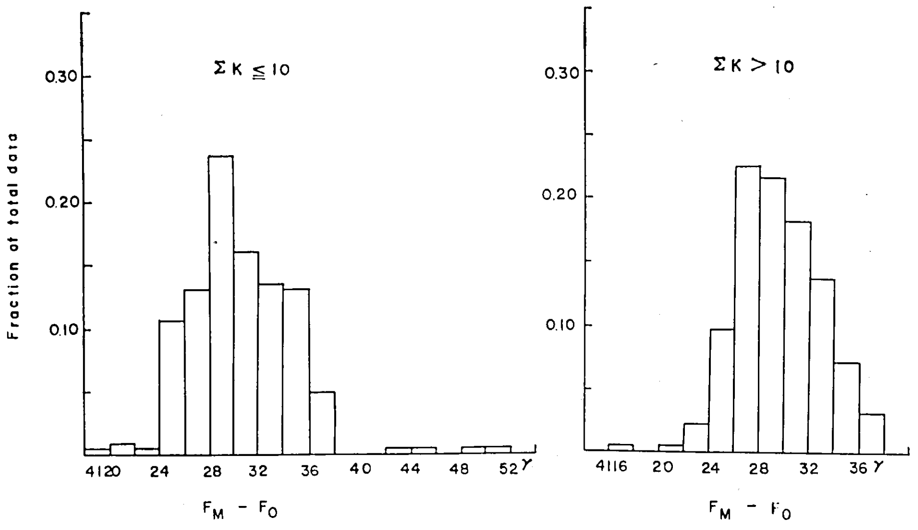

Fig. 10b. Histograms of $F_M - F_O$ on undisturbed and disturbed days.

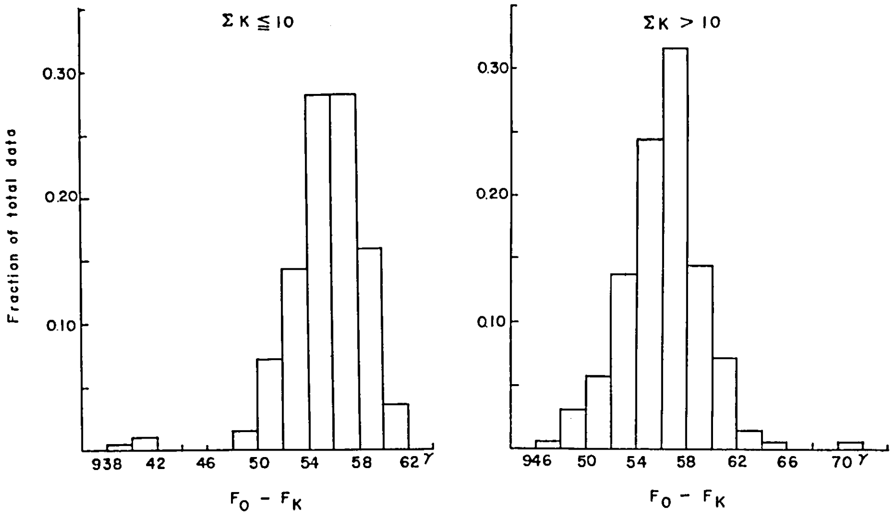

Fig. 10c. Histograms of F_O—F_K on undisturbed and disturbed days.

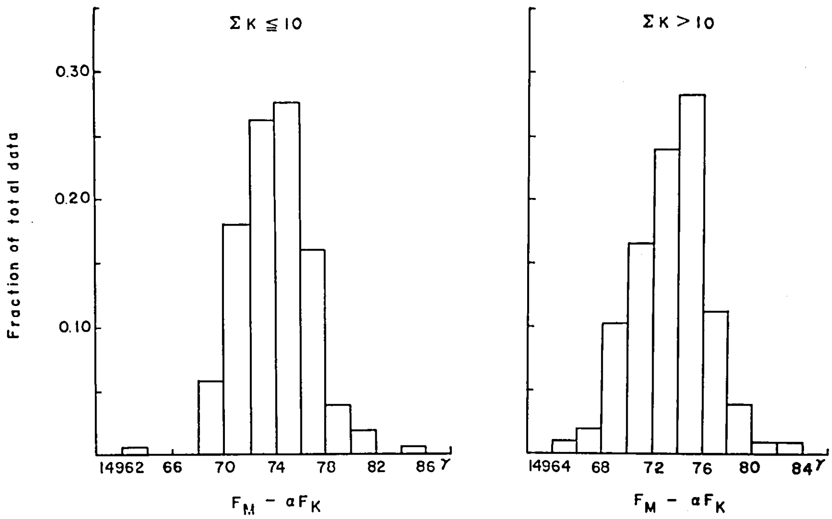

Fig. 11a. Histograms of F_M—αF_K on undisturbed and disturbed days.

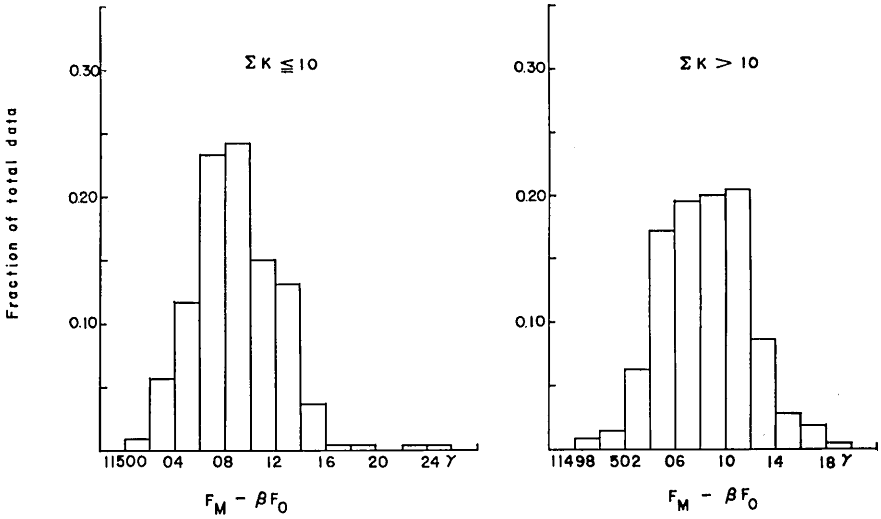

Fig. 11b. Histograms of $F_M - \beta F_O$ on undisturbed and disturbed days.

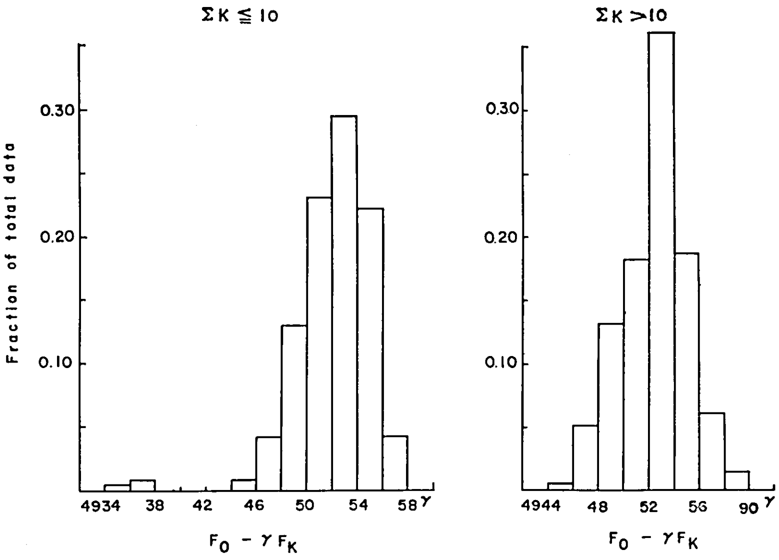

Fig. 11c. Histograms of $F_O - \gamma F_K$ on undisturbed and disturbed days.

Table 6a. Standard deviations and total ranges in γ for $\Sigma K \leqq 10$.

	$F_M - F_K$	$F_M - F_0$	$F_0 - F_K$	$F_M - \alpha F_K$	$F_M - \beta F_0$	$F_0 - \gamma F_K$
Standard deviation	2.7	3.9	2.7	2.7	3.3	2.9
Total range	24	34	24	24	26	24

Table 6b. Standard deviations and total ranges in γ for $\Sigma K > 10$.

	$F_M - F_K$	$F_M - F_0$	$F_0 - F_K$	$F_M - \alpha F_K$	$F_M - \beta F_0$	$F_0 - \gamma F_K$
Standard deviation	3.4	3.5	2.7	2.9	3.8	2.6
Total range	26	22	26	20	24	24

The results given in the figures and tables in this subsection emphasize that no great improvements of standard deviation and total range are possible even if we select data on geomagnetically undisturbed days. It seems likely, therefore, that difference values in the total intensity are more sensitive to day-to-day variation of S_q rather than to the degree of disturbance as expressed by the daily sum of K-index as far as data on moderately disturbed and quiet days are concerned.

2-7. Discussion and conclusions for the data from Matsushiro, Kanozan and Oshima

It has been estimated that the standard deviations of difference values in the total intensity of the geomagnetic field amount to about 3γ or more for individual data. Even if we make use of the weighted difference technique with proportional constants as determined in Subsection 2-2, no drastic improvements of standard deviation seem to be possible although total ranges can be made smaller to some extent by the procedure.

If we make statistics separately for day-time and night-time data, however, a marked improvement of standard deviation and total range resulted for night-time data. Applying furter the weighted difference technique to the night-time data, standard deviations and total ranges respectively as small as 2.2γ and 12γ were obtained for one of the combinations of the stations, i.e. Oshima and Kanozan.

The night-time weighted difference results for individual data are also a little better than the results for daily mean data, so that it would naturally be supposed that, if we make use of mean values of night-time data, we would have a very sharp distribution of difference values although no such statistics were possible in this paper because the sets of data were not sufficiently large.

No marked contrast was found between statistics made separately for disturbed and undisturbed days. This would partly be attributable to the fact that we had no violently disturbed days during the period concerned.

It seems likely that the total intensity values at each station may be subjected to some seasonal variation. The Matsushiro data may also reflect some seismo-magnetic effect[8]. These factors tend to increase dispersions of the histograms. If we make a study similar to the present one at stations free from such factors, a little better dispersion would be obtained. At any rate, it has been proved that a comparison between the total intensity at two stations widely separated in Central Japan can be made with an accuracy of a few gammas provided we take suitable care.

3. Analysis of the data from Awashima, Shioya and Kanozan

3–1. Data

A team for observing possible post-earthquake geomagnetic changes was sent by the Earthquake Research Institute to the earthquake area immediately after the Niigata Earthquake on June 16, 1964. A proton precession magnetometer of manual operation type was set on Awashima Island, a small island in the Japan Sea about 20 km distant from the nearest coast of the mainland, while another magnetometer of digital printing type which had been originally designed as a ship-borne one was set at Shioya in Niigata Prefecture. The distance between the two stations amounts to about 40 km. The observation period was from June 24 to July 7.

In a fashion similar to the last section, we denote individual total intensity values at Awashima, Shioya and Kanozan by F_A, F_S and F_K.

3–2. Statistics separately made for day-time and night-time data

According to the definition in Subsection 2–5, the numbers of the available difference values are given in Table 7.

Table 7. The numbers of data.

	F_A—F_S	F_A—F_K	F_S—F_K
Day-time	265	313	244
Night-time	74	136	85

Histograms for F_A-F_S, F_A-F_K and F_S-F_K are computed and shown in Figs. 12a, 12b and 12c. In these figures are drawn day-time histo-

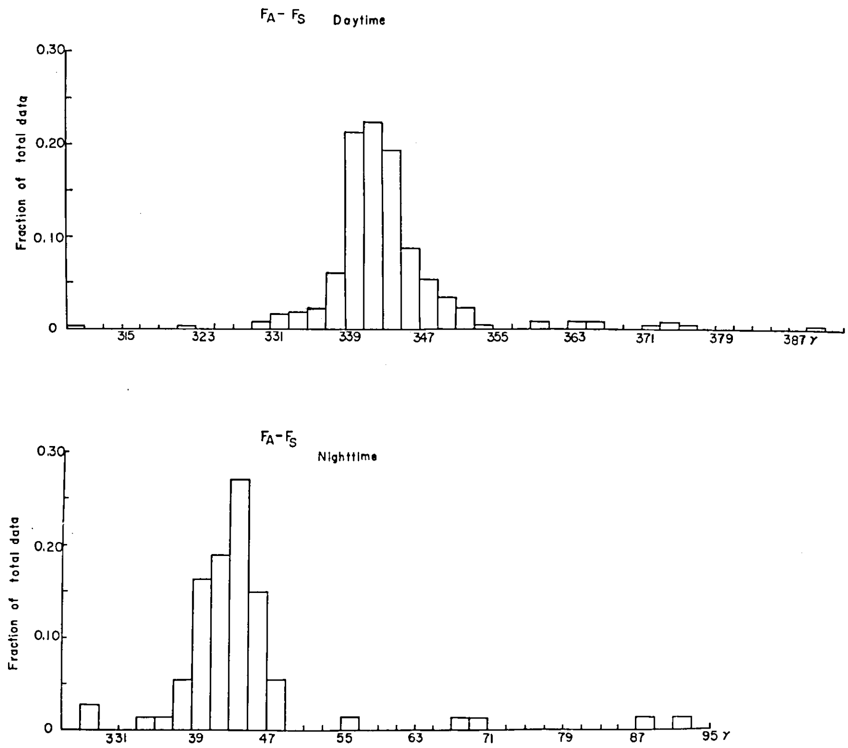

Fig. 12a. Day-time and night-time histograms of F_A—F_S.

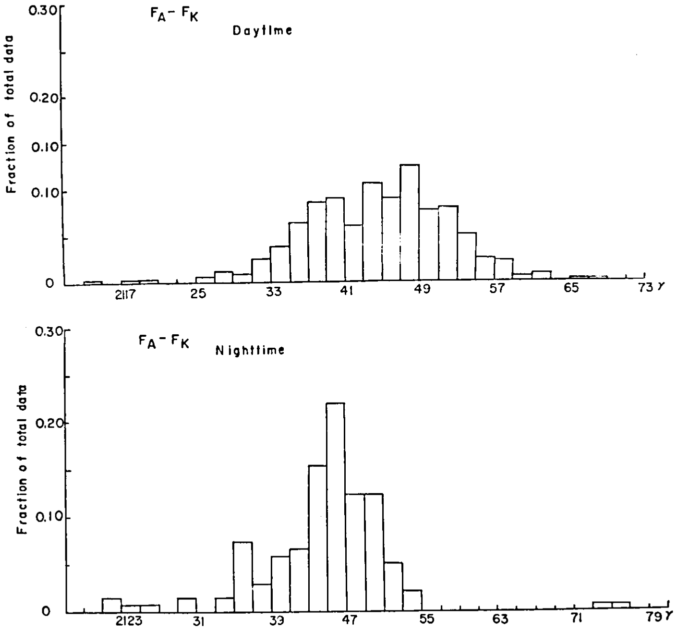

Fig. 12b. Day-time and night-time histograms of $F_A - F_K$.

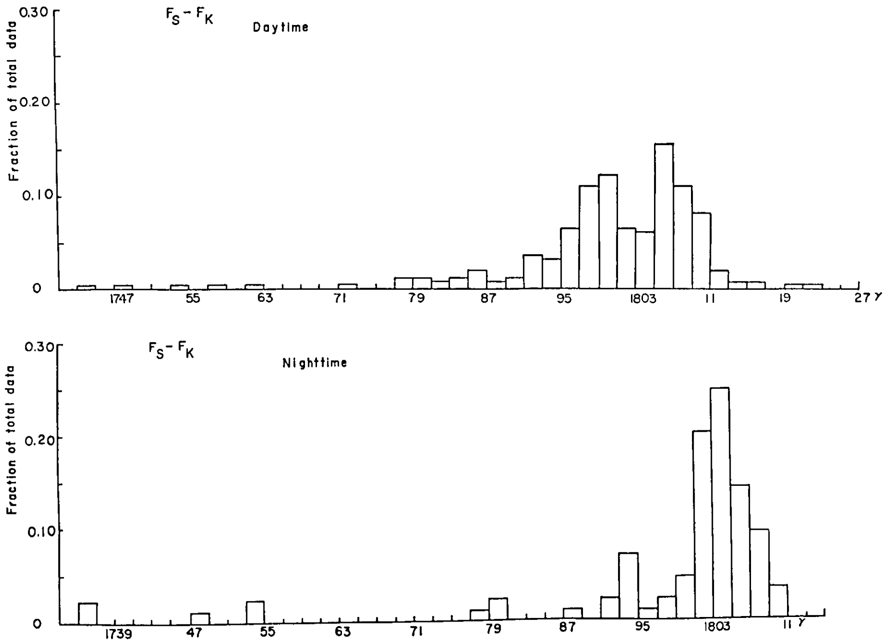

Fig. 12c. Day-time and night-time histograms of $F_S - F_K$.

grams on the top and night-time ones at the bottom. The standard deviations and total ranges are given in Tables 8a and 8b.

Table 8a. Standard deviations and total ranges in γ for day-time data.

	F_A—F_S	F_A—F_K	F_S—F_K
Standard deviation	3.8	7.6	7.2
Total range	80	56	80

Table 8b. Standard deviations and total ranges in γ for night-time data.

	F_A—F_S	F_A—F_K	F_S—F_K
Standard deviation	3.3	4.2	3.7
Total range	66	55	76

Looking at these histograms we see that the dispersions are surprisingly large in every case. Although some of the extreme values of F_A-F_S and F_S-F_K are likely to be caused by miscounts of the digital printing magnetometer at Shioya, the wide total ranges and the large standard deviations are very disappointing for eliminating non-local geomagnetic changes. Even so, it is noticeable that the dispersion of F_A-F_S is smaller than those of F_A-F_K and F_S-F_K probably because of the proximity of the two stations and that the night-time histograms are definitely sharper than the day-time ones.

It is not intended to conduct a detailed analysis of the Awashima-Shioya-Kanozan data because the observation period was very short.

3-3. Discussion for the data from Awashima, Shioya and Kanozan

Although no detailed analysis of the data from Awashima, Shioya and Kanozan was possible, the point that difference in the total geomagnetic intensity between two stations only 40 km distant with each other exhibits fairly large fluctuations, the standard deviation of individual observation amounting to 3.8 and 3.3γ respectively for day-time and night-time data, is important. Unlike the data in Section 2, the data in this section were taken during the summer, so that the S_q and its variability are large. As Awashima Island is a small island in Japan Sea and Shioya is very close to the coast-line, electric currents induced in the sea might seriously affect the geomagnetic elements at both the stations. Although nothing certain about the cause of the large dispersion of difference values is known at the moment, attention should be paid to the fact that a simple difference between individual values at two closely located stations may largely be contaminated by non-local changes.

4. Discussion and conclusion

It has been demonstrated in the above that a simple difference technique leads to a very poor result for eliminating non-local geomagnetic changes even for data from closely located stations in Japan. It is made clear that day-time data should not be used for comparing total intensity values at two stations between which the distance exceeds a few tens of kilometers. If we apply a weighted difference technique as described in Section 2 to night-time data, it turns out that non-local changes can best be eliminated. The standard deviation for an individual observation after applying the technique is estimated as about 2γ for combinations of stations in the central part of Japan. Although it seems hard to attain an accuracy of comparison higher than 2γ for an individual observation, the accuracy would certainly be improved by taking an average of a number of night-time measurements. It seems likely that we may be able to detect a local anomalous change, if any, having a duration of a few months say, with an accuracy of 1γ by making use of night-time data only. It is at the moment difficult to detect such a change of short duration, say a few minutes, with such a high accuracy.

In order to carry out a proton magnetometer network observation over Japan aiming at possible detection of seismo-magnetic effect, the writer is of the opinion that a better way of eliminating non-local changes should be established. In view of the intense underground conductivity anomaly in this country, the best proportional constant, as obtained in (1) for example, would be different from place to place. It is therfore required to conduct as many comparison measurements as possible at various parts of Japan on every available occasion.

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52. 非局地的磁場変化の除去に関する研究

地震研究所　力　武　常　次

地震予知研究計画にもとづいて，プロトン磁力計観測網が設定され，地磁気永年変化の精密観測および地震に伴なう地磁気変化の検出が企図されている．この時点で，磁気嵐や日変化などの非局地的磁場変化をどの程度除去できるかまたその方法としては何がよいかを検討してみた．

松代地震および新潟地震に関連して得られた資料によって解析を行なった．その結果，夜間の資料を用いて，特定の観測所の組合せについて固有の weight を用いる weighted difference をつくることが最良であることがわかった．この場合日本中央部の観測所については，個々の測定差については 2γ 程度の標準偏差となるが，さらに資料をふやして平均値をとればさらに精度をあげることもできよう．単純差にもとづく議論は，長期間にわたる変化は別として，非常に非局地的磁場変動に影響されているので注意を要する．