SOME NOTES ON THE RECORD OF MULTIPLE STROKES OBTAINED WITH THE ATMOSPHERICS DIRECTION FINDER

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I. Introduction

On the phenomena of multiple strokes in the atmosphere, many works have been done in Europe, America and Japan with the Boys camera optically and by the wave form of atmospherics electrically.

Obtaining the figures of multiple strokes in the records of cathode ray direction finder, we studied statistically their frequency distribution, the discharge interval, the duration and etc. These results showed the same tendency as those of earlier workers (*viz.* Schonland in England, McEachron in U.S.A., S. Hoh in Japan, etc.).

We found that the C.R.D.F. is the one of useful apparata to observe these phenomena. For, by means of this records, many samples can be obtained easily and at the same time the exact position of occurence detectable. And also, it is convenient to consider the correlation of the meteorological phenomena.

In autumn 1952, we obtained the simultaneous records of the wave form of atmospherics and make sure of the facts that the records obtained by C.R.D.F. is certainly to indicate the multiple strokes.

We assumed further that the figures to be admitted for the multiple strokes are those groups in which indications of azimuth run quite parallel to each other and the time intervals have less than 0.5 sec. It may be also noted that, by the limits of the circuits and the film speed used, they were recognized only to have the discharge interval more than 0.01 sec.

II. Observation

Observation were made in summer 1950 for the purpose of the localization of origins of atmospherics at two stations simultaneously.—The one is in Toyokawa City and the other in Nagoya City. The measuring apparata used are the instantaneous type cathode ray direction finder with photographic recording instruments.

Recording instruments were used 16 mm movie camera and the film speed was 10 mm/sec. continuously. Time marks on both sides of the film were adopted the standard signal waves from JJY station.

The photograph in Fig. 1 (*a*) (see page 97) shows an example of the multiple strokes records obtained and in Fig. 1 (*b*) (see page 97) explanatory sketch of Fig. 1 (*a*). Six groups of multiple strokes can be identified. Symbol "M" in Fig. 1 (*b*) indicate the multiplicity.

III. Analysis of the Records Obtained

III-1. Class frequeucy and multiplicity of multiple strokes

On the records obtained during August and September 1950, the classification

TABLE 1

Number of stroke	Multiplicity	Number of record	Frequency (%)
1	0	681	79.7
2	1	97	11.3
3	2	40	4.6
4	3	18	2.1
5	4	9	1.05
6	5	4	0.45
7	6	2	0.2
8	7	1	0.1
9	8	〃	〃
10	9	〃	〃
11	10	〃	〃
12	11		
Sum		855	100

(Aug. 1950, Nagoya)

Number of stroke	Multiplicity	Number of record	Frequency (%)
1	0	1,186	70
2	1	221	14.75
3	2	41	2.74
4	3	26	1.78
5	4	16	1.07
6	5	6	0.40
7	6	2	0.13
8	7	〃	〃
9	8		
10	9		
11	10		
12	11		
Sum		1,500	100

(Sept. 1950, Nagoya)

of multiple strokes and its class frequency were showed in Table. 1. They shows that the number of single stroke is about 80% and the multiple one about 20% in the total recorded atmospherics. On the records obtained by S. Hoh using the low-speed Boys camera, the percentage of the former is 60% and the latter 40%. This difference of the frequency were caused by the difference of the resolvability of the time interval for the records. Namely, this difference of the frequency were caused by the fact that as our resolvability of the time interval was 0.01 sec. against 0.001 sec. by S. Hoh, the multiple strokes to have the time interval less than 0.01 sec. were recorded as a single stroke. The maximum number of stroke observed was 11 strokes by us, 11 strokes by S. Hoh, 29 strokes by Schonland and 40 strokes by Larsen.

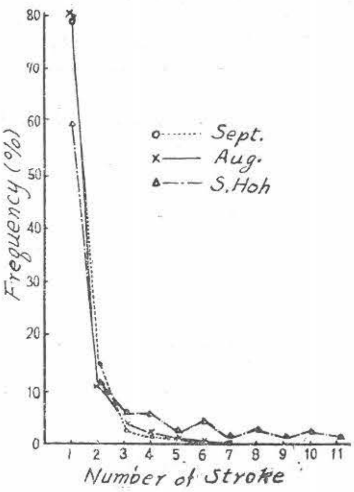


FIG. 2. Frequency distribution graph of multiple strokes, which is observed at Nagoya.

Fig. 2 shows the frequency distribution graphs for various multiplicity indicated on Table 1. As this graphs are comparatively systematic, then the *distribution function* for the multiplicity was assumed statistically.

Putting the single stroke in the group of the stroke multiplicity 0, then the frequency distribution of the multiplicity x makes Table 2 for August's records.

TABLE 2

x	0	1	2	3	4	5	6	7	8	9	10	Sum
$f(x)$	681	97	40	18	9	4	2	1	1	1	1	855

Calculating the mean ($\bar{x}$) and the variance (s^2) from Table 2:

$$\bar{x} = 0.389, \quad s^2 = 1.051\,.$$

Calculating $A = \frac{f(x+1)}{f(x)}(x+1)$, and $$B=\frac{s^2-\bar{x}}{s^2}x+\frac{\bar{x}^2}{s^2},$$

for $x=0, 1, 2, \ldots, 10$, then Table 3 is given.

TABLE 3

x	0	1	2	3	4	5	6	7	8	9
A	0.142	0.824	1.350	2.000	2.220	3.000	3.500	8.000	9.000	10.000
B	0.144	0.774	1.404	2.034	2.674	3.294	3.924	4.554	5.184	5.814

If the last three terms are omitted, A and B is approximately the same value. Then, as the *distribution function*, the Pólya-Eggenberger's distribution is assumed.

$$p(x)=\frac{h(h+d)\ldots(h+\overline{x-1}\,d)}{x!}(1+d)^{-\frac{h}{d}-x} \tag{1}$$

Where, $d=\text{const.}>-\frac{1}{2}$

$$p(0)=(1+d)^{-\frac{h}{d}},\quad h=\bar{x},\quad d=\frac{s^2}{\bar{x}}-1.$$

Calculating from Equation (1), theoretical class frequency shown on Table 4 is given.

TABLE 4

Multi-plicity	Stroke	1	2	3	4	5	6	7	8	9	10	11	Sum
	x	0	1	2	3	4	5	6	7	8	9	10	
Number	Observed number	681	97	40	18	9	4	2	1	1	1	1	855
	Calculated number	680.94	98.03	37.96	17.76	9.02	4.80	2.64	1.48	0.84	0.49	0.28	854.24

Using the test of χ^2 for the purpose of the test of goodness of fit, whether this assumption is fitted or not was exmined.

Where, $$\chi_0^2=\sum\frac{(\text{Observed number}-\text{Calculated number})^2}{\text{Calculated number}}=0.139\,.$$

According to the statistical table,

$$p\{x^2>0.139\}>0.98\,.$$

As the goodness of fit is agreeable, the distribution of the stroke multiplicity may be expected by Pólya-Eggenberger's Law. Those results obtained are shown in Fig. 3.

III-2. Discharge interval of multipule strokes

The frequency distribution of discharge interval of multipule strokes are shown in Fig. 4. At the same time, the records obtained by Schonland and S. Hoh are shown in Fig. 4 for comparison.

As the most frequent discharge interval, Schonland observed the time of 0.03-

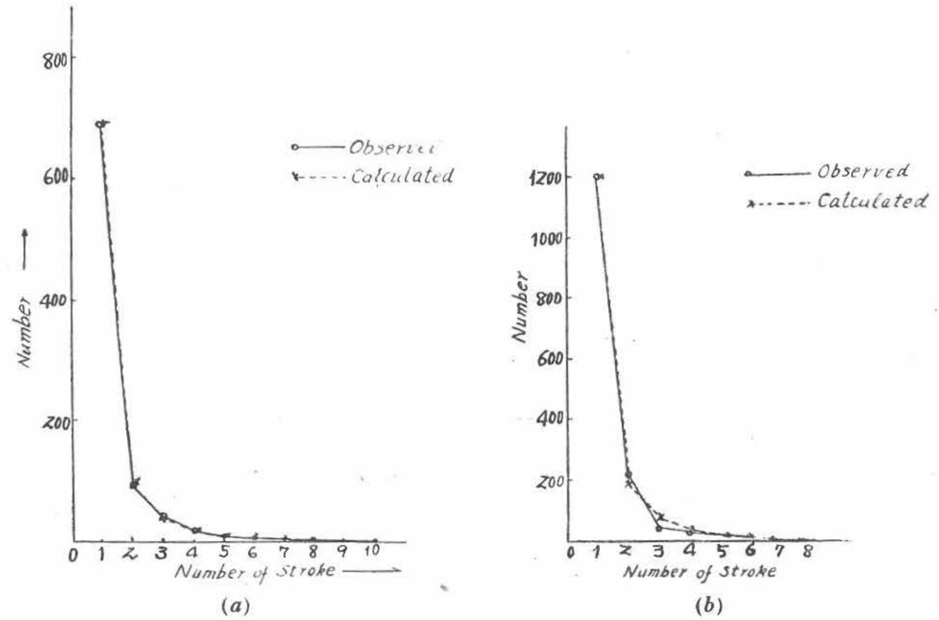


FIG. 3. (*a*) Frequency distribution of multiple strokes (August). (*b*) Frequency distribution of multiple strokes (September)

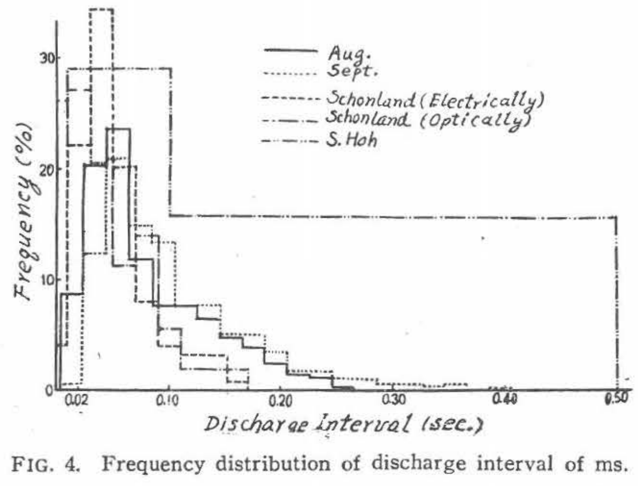


FIG. 4. Frequency distribution of discharge interval of ms.

0.04 sec., S. Hoh reported 0.01–0.1 sec. and we obtained 0.03–0.06 sec.

So as to find the ***distribution function*** of them statistically, the mean ($\bar{x}$) and the variance (s^2) are calculated from the table of frequency distribution shown in Table 5.

TABLE 5

x	0	1	2	3	4	5	6	7	8	9	10	11
Time interval (sec.)	0.035	0.055	0.075	0.095	0.115	0.135	0.155	0.175	0.195	0.215	0.235	0.255
$f(x)$	68	78	39	25	25	20	16	13	8	5	4	1

Then, $\bar{x} = 2.576$, $s^2 = 6.642$.

Calculatnig $$A = \frac{f(x+1)}{f(x)}(x+1),$$

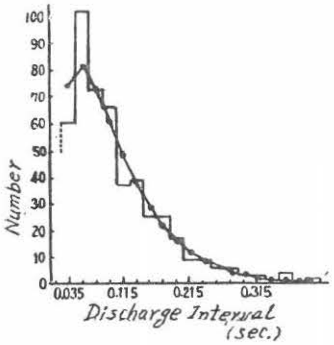
and $$B = \frac{s^2 - \bar{x}}{s^2}x + \frac{\bar{x}^2}{s^2},$$

for $x = 0, 1, \ldots, 11$, then Table 6 is given.

TABLE 6

x	0	1	2	3	4	5	6	7	8	9	10	11
A	1.147	1.000	1.93	4.000	4.000	4.800	5.691	4.920	5.625	8.000	2.750	
B	0.999	1.611	2.224	2.835	3.447	4.059	4.671	5.283	5.895	6.500	7.110	

Compared with the value of A and B in Table 6, these value were not considered equal, but considerably different. Then, the distribution of discharge intervals was assumed to follow Pólya-Eggenberger's Law. The frequency distribution calculated from this Law are shown in Fig. 5 (a), (b) and Table 7. Considering, from the distribution diagram shown in Fig. 6, that these phenomena are the spontaneous one and our records is restricted within some limits, this distribution function may be considered to have good fitness.



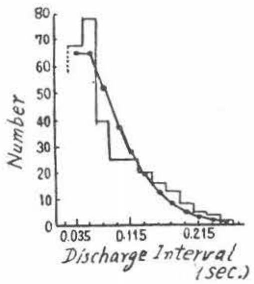


FIG. 5. Distribution of discharge interval.
(a)—*left*. August.
(b)—*right*. September.

TABLE 7

Discharge interval (sec.)	x	Frequency Observed	Frequency Calculated
0.035	0	68	65.00
0.055	1	78	64.95
0.075	2	39	52.33
0.095	3	25	38.78
0.115	4	〃	27.49
0.135	5	20	18.96
0.155	6	16	12.83
0.175	7	13	8.56
0.195	8	8	5.65
0.215	9	5	3.70
0.235	10	4	2.41
0.255	11	1	1.56
Sum		302	302.22

III-3. Duration of multiple strokes

A duration means the whole time from the first stroke to the last stroke. The obtained frequency diagram which is contained the record by S. Hoh for comparison is shown in Fig. 6.

As the most frequent du-

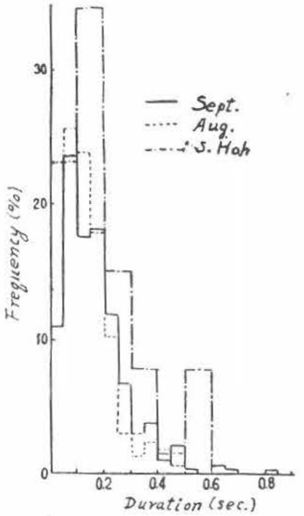
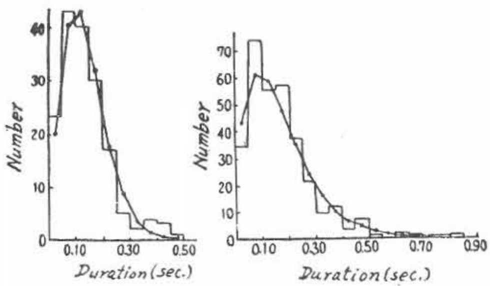


FIG. 6. Frequency distribution of duration.



(*a*) August (*b*) September

FIG. 7. Duration of multiple strokes.

ration, we obtained 60-150 ms and S. Hoh obtained 100-150 ms.

As we have concluded that Pólya-Eggenberger's Law is fitted for this distribution, we calculated the expected frequency from Equation (1) and indicated in Fig. 7 (*a*) and (*b*). Judgeing from the results, it was recognized that this Law also fitted to indicate this distribution.

III-4. Recorded type of multipule strokes

As the length of the indicated figure of the recorded multipule strokes is almost proportional to the discharge intensity, the type which is followed to the permutation ($_nP_s$), when one consisted of the arbitral number n takes any length of, s may be considered. The classification table of the recorded type shows in Table 8. (Here we indicated only for the type to have the multiplicity 1, 2 and 3.) On the intensity of multiple discharge, Schonland's results indicate that in the majority cases the crest magnitude of the first strok is the greatest, but this is

TABLE 8 (1). The Recorded Type of Multiplicity 1

Type \ Month	Aug.	Sept.
	58	105
	31	68
		4
Sum	89	177

TABLE 8 (2). The Recorded Type of Multiplicity 2

Type \ Month	Aug.	Sept.
	10	20
	8	8
	2	4
	3	4
	7	
	3	7
Sum	33	43

TABLE 8 (3). The Recorded Type of Multiplicity 3

Type \ Month	Aug.	Sept.
	3	4
		2
		1
	2	
	1	3
		1
	1	4
	1	
		2
	1	
		1
	1	1
	1	
		1
	1	
	2	
		1
Sum	14	21

not always the case, as for our observation the second or subsequent strokes are frequently the greatest. Probably because the charge center which attract the discharge first is not always considered to store the maximum charge in the clouds. This is suggested in Table 8. Obtaining the simultaneous records of the wave form of atmospherics, we make sure of the facts that the records by C.R.D.F. is certainly indicated the type of discharge. An example of the simultaneous records shows in Fig. 8 and 9.

III-5. Correlation of multipule strokes with weather phenomena

When the localized atmospherics origins classified the single and the multiple strokes, it may be interested that the multiple strokes are massed at the same region. As such region are examined meteorologically, we shall find that the atmospherics origin on the discontinuous plane of atmosphere have such tendency. For an example, we take the frontal type of the atmospherics origin accompanyed by Typhoon Kezia which attacked in Sept. 1950 and classify them as indicated in Table 9. The mean percentage of multiple strokes in this region is more than 30%. This is comparatively greater than the percentage for the non-frontal type one. (In generally, the ratio of the multiple strokes to the single one is less than 1 : 4.) Then we are assumed that the multiple strokes have the tendency occuring in the frontal type origins. Schonland also reported that multipule strokes are observed more in the frontal type lightning than in the thermal one.

TABLE 9

Date	13th Sept.		14th Sept.		
Time	17 h	23 h	8 h	18 h	19 h
Single stroke	20	27	37	18	16
Multiple strokes	8	9	13	14	14

IV. Conclusions

The purpose of this report has been to point out the *distribution function* for the multiple strokes and to recognize the merits for using C.R.D.F. to observe these phenomena and to find out the correlation with weather phenomena. The principal conclusions are as follows:

(i) From statistical point of view, the observation method of the multiple strokes by C.R.D.F. are useful one, as may samples can be obtained easily.

(ii) A majority of the recorded multiple strokes had multiplicity ranging from 1 to 3 (number of strokes from 2 to 4).

(iii) The most frequent stroke intervals were in the range from 0.03 sec. to 0.06 sec. and the most frequent stroke duration were in the range from 0.06 sec. to 0.15 sec.

(iv) A tendency was recognized that multiple stroke lightnings occured most frequent in the frontal type lightnings.

V. Acknowledgments

This work was done as a part of the studies of the nature of atmospherics at the Research Institute of Atmospherics, Nagoya University. I wish to thank Prof. A. Kimpara for much advise and also thanks the member of the Institute for assistance during the observation.

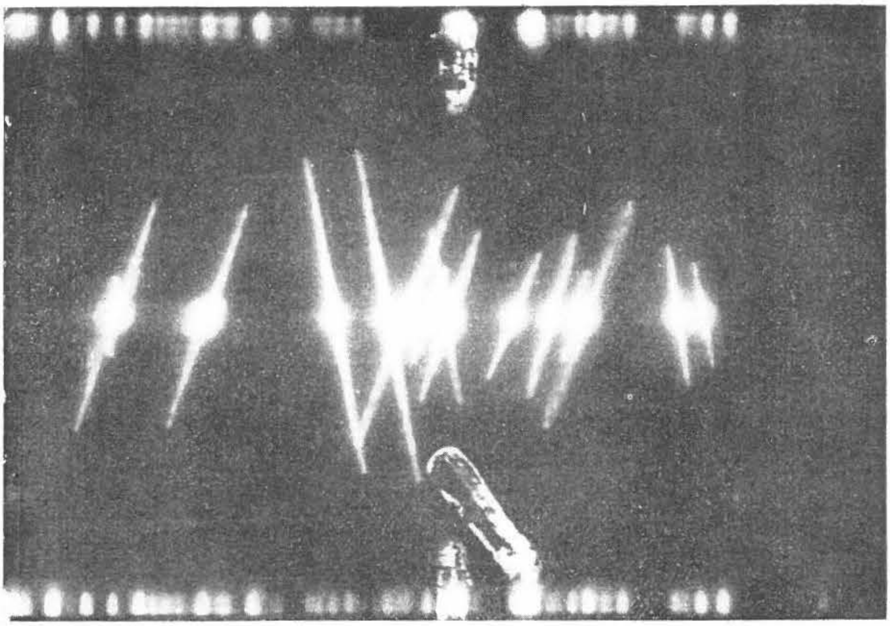


FIG. 1 (*a*)

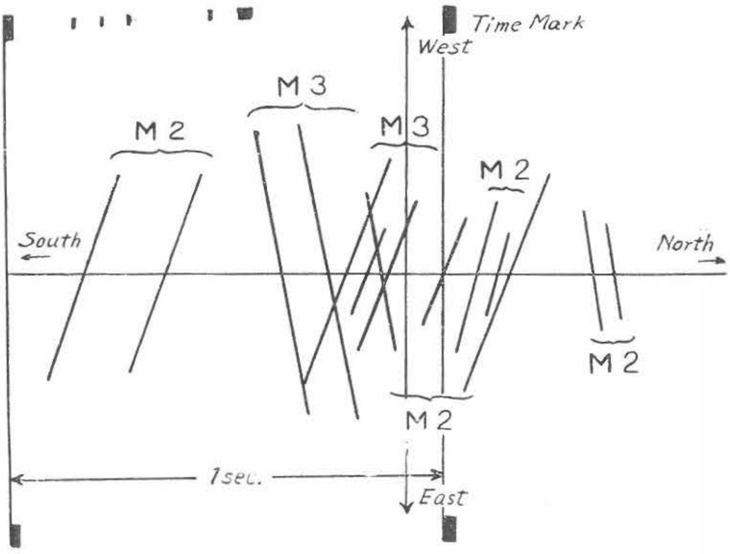


FIG. 1 (*b*)
Explanatory sketch of Fig. 1 (*a*).

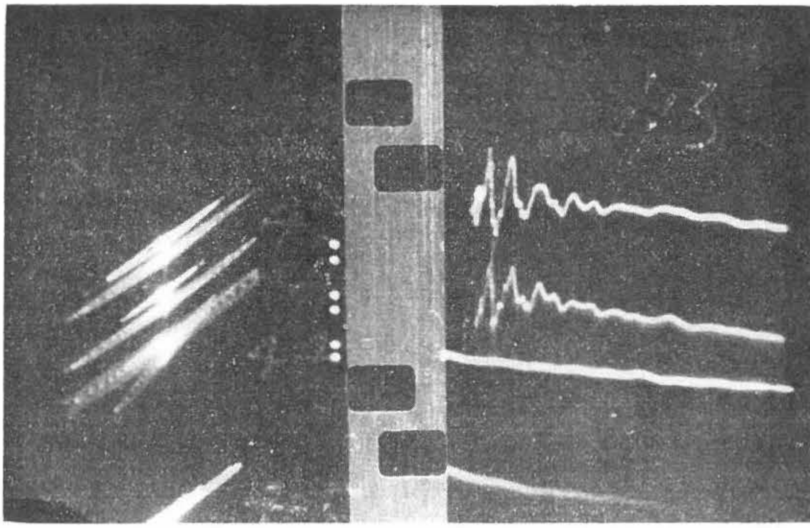


FIG. 8. Simultaneous record of direction finder and wave form of atmospherics.

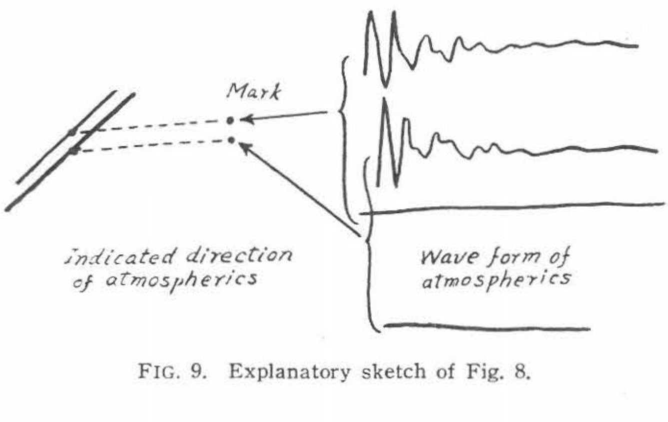


FIG. 9. Explanatory sketch of Fig. 8.

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