12. *A Statistical Study of the Itô Earthquake Swarms.*

by Naomi MIYABE,

Earthquake Research Institute.

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1. In 1930, a number of earthquakes were felt in regions around the Sagami Bay, the epicentres of which were found to be in the neighbourhood of Itô. During the period between February 14 and April 10 the number of these earthquakes reached to about 3700. They are regarded as belonging to the earlier swarm. In May of the same year, another swarm broke out; their epicentres being in nearly the same region. The number of earthquakes felt then was about 500.

As to these earthquake swarms, Prof. Imamura and his collaborators, and Mr. K. Sagisaka of the Central Meteorological Observatory have already pointed out that, in the beginning of the period of the earlier swarm,[1] earthquakes frequently occur at ebb tide. A number of authors have also argued[2] that the tidal loads, tide generating forces, atmospheric pressure and its gradients are more or less correlated with earthquake frequency. These factors are of course important as secondary causes[3] of earthquakes.

The writer, in this paper, discusses the simple and multiple correlations between the fluctuations in daily frequencies of the Ito earthquake swarms and the tidal range, atmospheric pressure and their derivatives with regard to time and space.

2. In studying the correlations between fluctuations in the daily earthquake frequencies and secondary causes, it may be necessary to eliminate the effect of the primary cause. As this however is almost

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1) A. IMAMURA and others, *Disin*, 2 (1930), (in Japanese).
K. SAGISAKA, *Kensin-Zihô*, 5 (1930), 131~153, (in Japanese).

2) F. OMORI, *Rep. Imp. Earthq. Inv. Comm.*, No. 68A (1910), 21~29.
K. HONDA, *Proc. Phys.-Math. Soc. Tokyo*, [ii], 2 (1903~1906), 63~73.
T. TERADA, *Journ. Met. Soc.*, 28 (1909), 1, (in Japanese).
S. T. NAKAMURA, *Jap. Jaurn. Astr. Geophys.*, 3 (1925), 115; 4 (1926), 139.
S. YAMAGUTI, *Bull. Earthq. Res. Inst.*, 8 (1930), 393.
D.M.Y. SOMMERVILL, *M.N.R.A.S., Geophys. Suppl.*, 3 (1932), 1.

3) In our ignorance of the mechanism of earthquakes, it may be needless to speak of "secondary" and "primary" causes. I use the term "secondary cause," following general usage, meaning the external factors governing the occurrence of earthquakes.

impossible, since we have little knowledge of the primary cause, the fluctuations in the present investigation are calculated on simple assumptions, though it is impossible to know whether such assumptions are appropriate or not.

Firstly, the fluctuations in the daily earthquake frequencies are calculated as deviations in the daily frequencies from the mean values, that is,

$$N-\overline{N}.$$

This assumption indicates that the effect of the primary cause is constant throughout the active period of the earthquake swarms.

A glance at the distribution of the daily earthquake frequencies with respect to time shows the seismic activity to have gradually increased to a certain maximum after which it died out. This suggests that the distribution of frequencies may be expressed like a probability curve. Secondly, therefore, we calculate the fluctuations

$$N-N_c,$$

where N is the actual frequency of the earthquakes and N_c is given in the from

$$N_c=N_0e^{-h^2(x-x_m)^2},$$

where x is the number of days counted from February 14 for the earlier swarm and from May 1 for the later swarm.

Constants N_0, h^2, x_m in the above expression have been determined by the method of least squares to be

$$N_0=160,\ h^2=0{\cdot}0065,\ x_m=24$$

for the earlier swarm, and

$$N_0=70,\ h^2=0{\cdot}06,\ x_m=12$$

for the later swarm. Deviations in the actual daily earthquake frequencies from those calculated $N-N_c$ and are given in Table I.

Table Ia. N and $N-N_c$. for earlier swarm.

Date	N	$N-N_c$	Date	N	$N-N_c$
Feb. 14, 1930	8	3	Feb. 17, 1930	12	9
15	6	5	18	22	18
16	1	−1	19	6	1

(to be continued.)

Table Ia. (*continued.*)

Date	N	$N-N_c$	Date	N	$N-N_c$
Feb. 20, 1930	47	40	March 17, 1930	112	−31
21	77	67	18	67	−66
22	88	76	19	82	−37
23	40	24	20	46	−63
24	69	40	21	54	−44
25	21	− 5	22	109	22
26	12	−20	23	44	−31
27	4	−35	24	114	49
28	40	− 6	25	99	44
March 1	138	83	26	93	47
2	40	−25	27	9	−30
3	143	68	28	1	−31
4	100	13	29	133	107
5	74	−22	30	102	82
6	144	35	31	79	63
7	117	− 2	April 1	48	36
8	151	8	2	6	− 4
9	209	66	3	2	− 5
10	98	−53	4	72	67
11	162	4	5	3	− 1
12	147	−16	6	2	− 1
13	115	−52	7	62	60
14	112	−53	8	2	1
15	55	−103	9	23	23
16	51	−100	10	5	5

Table Ib. N and $N-N_c$ for later swarm.

Date	N	$N-N_c$	Date	N	$N-N_c$
May 1, 1930	1	1	9	101	59
2	2	2	10	43	−13
3	5	4	11	17	−49
4	4	2	12	17	−53
5	3	− 2	13	26	−40
6	6	− 3	14	51	− 5
7	4	−13	15	49	7
8	47	19	16	15	−13

(*to be continued.*)

Table Ib. (*continued.*)

Date	N	$N-N_c$	Date	N	$N-N_c$
May 17, 1930	44	27	May 25, 1930	3	3
18	46	37	26	8	8
19	9	4	27	1	1
20	1	−1	28	2	2
21	1	0	29	0	0
22	25	25	30	0	0
23	4	4	31	4	4
24	3	3			

Needless to say, several other assumptions may be possible besides those mentioned above for eliminating the fluctuations in seismic activity due to the primary cause during certain decades.

3. In the present study, the coefficients have been calculated of the correlations of the fluctuations in earthquake frequencies with the following elements:

(i) Tidal range. The amplitudes of daily variations in the sea level, that is, the tidal range, vary with a period of about 15 days. The data employed in the present study are not the actual tidal range, but those calculated on the assumption that the tidal range varies from spring to nip with a period of 15 days in such a manner as may be expressed by a sinusoidal function of time (number of days).

The values of the tidal ranges employed in the present study are referred to the data of spring and nip ranges at Misaki,[4] the fluctuations of which are shown in Table II together with those of the other elements.

The values of spring and nip ranges at Misaki are approximately equal to those at Itô, the region where the earthquake swarms under consideration occurred.

(ii) Rate of change in the tidal range. The rate of change in the tidal range, that is, the differences in tidal ranges on successive days may be correlated with the fluctuation in the daily earthquake frequencies.

(iii) It is to be regretted that there are no data covering atmospheric pressure at Itô. In the circumstance, the values of the atmospheric pressures, P, as observed at Numadu, at 6 a.m. every day, are used.[5] Numadu is the nearest station to the region of the earthquake swarms. As will be referred to later, earthquakes seem to be more strongly correlated with the pressure gradients than with mere pressure.

4) The data from *Bull. Hydr. Depart., Imp. Jap. Navy*, **7** (1399).

5) The data from *weather charts*.

There may however be no essential difference between pressure and pressure gradients, so long as they are taken as factors for correlation with fluctuations in the daily earthquake frequencies, as there may be some characteristic features in the mode of distribution of the atmospheric pressure.

(iv) Rate of change in atmospheric pressure, $\frac{\partial P}{\partial t}$. There may be several cases in which earthquake occurrence may be affected by certain dynamical properties of the atmospheric pressure. The writer therefore took as one of the elements the differences in atmospheric pressures on successive days.

(v) Atmospheric pressures gradients. As already discussed by Prof. Terada,[6] earthquake occurrence may be affected to some extent by the pressure gradients in the region where the earthquakes under consideration occurred. The writer therefore calculated the gradients of atmospheric pressure $\frac{\partial P}{\partial x}$ and $\frac{\partial P}{\partial y}$ by combining the data observed at Kôhu and Yokohama with those of Numadu. As the distance between Kôhu and Numadu and that between Yokohama and Numadu are approximately equal, and as moreover the lines connecting these two sets of stations are approximately perpendicular to each other (see Fig. 1),

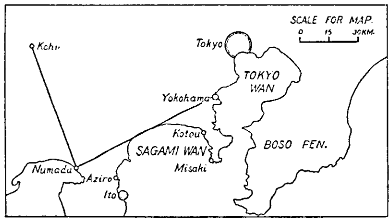

Fig. 1. Map showing the localities of stations.

(pressure at Yokohama)—(pressure at Numadu)

are regarded as $\frac{\partial P}{\partial x}$, and

(pressure at Kôhu)—(pressure at Numadu)

are regarded as $\frac{\partial P}{\partial y}$.

(vi) Rate of pressure gradients. As referred to in (iv) as for pressure, the variation in pressure gradients may sometimes be taken into consideration as one of the elements that are related in some way or other to the occurrence of earthquakes.

The numerical values of atmopheric pressures observed at Numadu, Yokohama and Kôhu are given in Table II.

The modes of variation of these elements are compared with those of the fluctuations in the daily earthquakes frequencies in Fig. 2.

6) T. TERADA, *loc. cit.*, 2).

Table IIa. Atmospheric pressures at Numadu, Yokohama and Kôhu during the period of former swarm.

Date	Numadu	Yokohama	Kôhu	Date	Numadu	Yokohama	Kôhu
Feb. 14, 1930	767·4mm	767·2mm	769·9mm	March 14	53·5mm	52·4mm	54·1mm
15	68·1	68·7	69·9	15	57·7	57·3	58·2
16	65·4	66·1	66·1	16	56·8	57·1	58·6
17	59·8	60·2	61·7	17	62·9	63·0	64·4
18	68·9	69·3	71·2	18	59·0	59·2	61·0
19	69·2	69·7	69·8	19	60·6	60·7	61·2
20	64·3	64·4	65·5	20	61·7	62·8	63·1
21	69·2	69·5	70·3	21	63·2	63·5	65·4
22	67·1	67·4	68·5	22	66·3	67·3	67·9
23	66·5	67·0	67·4	23	66·0	66·8	68·5
24	56·0	55·7	56·2	24	68·3	68·4	70·0
25	53·9	54·2	54·4	25	66·3	67·5	67·2
26	59·5	59·5	60·6	26	67·4	67·3	68·1
27	58·2	58·8	58·9	27	70·4	71·3	70·7
28	67·8	69·0	68·3	28	68·1	67·9	68·2
March 1	67·2	67·3	68·4	29	56·4	55·3	57·1
2	65·7	65·9	66·9	30	59·0	60·0	60·1
3	63·5	63·9	64·4	31	65·3	66·2	66·4
4	55·6	56·2	57·1	April 1	—	—	—
5	65·3	66·3	66·3	2	—	—	—
6	66·2	68·2	68·1	3	59·1	59·4	60·8
7	75·0	75·8	74·9	4	64·0	64·7	66·0
8	67·5	68·8	70·6	5	64·3	64·8	65·7
9	62·5	62·7	63·7	6	63·6	64·4	64·8
10	62·7	63·0	64·3	7	61·6	61·0	61·8
11	67·1	67·8	69·6	8	61·2	62·2	62·5
12	72·8	73·5	75·1	9	55·3	55·2	55·9
13	66·1	66·8	67·5	10	61·7	62·1	61·8

Table IIb. Atmospheric pressures at Numadu, Yokohama and Kôhu during the period of the later swarm.

Date	Numadu	Yokohama	Kôhu	Date	Numadu	Yokohama	Kôhu
May 1	766·2mm	767·0mm	766·6mm	May 4	65·7mm	66·0mm	67·5mm
2	65·5	66·5	66·9	5	63·5	63·4	63·6
3	60·0	60·1	61·0	6	54·6	55·6	54·1

(to be continued.)

Table IIb. (*continued.*)

Date	Numadu	Yokohama	Kôhu	Date	Numadu	Yokohama	Kôhu
May 7	57·7mm	57·6mm	58·9mm	May 20	50·2mm	48·9mm	51·9mm
8	65·4	65·0	66·6	21	56·2	57·0	56·5
9	62·2	61·3	63·7	22	56·5	55·7	56·9
10	50·5	50·0	51·2	23	54·3	53·8	55·4
11	57·5	58·1	58·2	24	62·3	62.8	62·8
12	59·9	60·9	60·8	25	61·9	62·2	62·7
13	59·9	61·0	60·2	26	64·9	65·0	66·0
14	64·8	65·7	65·5	27	64·8	65·4	65·7
15	68·2	67·7	68·7	28	57·3	58·3	59·6
16	65·6	65·5	66·5	29	57·3	57·8	58·3
17	59·5	59·9	61·0	30	58·9	58·5	59·4
18	64·6	65·5	65·5	31	59·7	59·4	61·8
19	66·2	66·1	67·3				

4. For each separate earthquake swarm, simple correlation coefficients are first calculated for both cases of fluctuations in earthquakes frequencies calculated on different assumptions.

The simple correlation coefficients thus calculated between each of the two cases of fluctuations, $N-N_c$ and $N-\overline{N}$, and each of the fluctuations of the elements, R, $\frac{\partial R}{\partial t}$, P, $\frac{\partial P}{\partial t}$, $\frac{\partial P}{\partial x}$, $\frac{\partial P}{\partial y}$, $\frac{\partial}{\partial t}\frac{\partial P}{\partial x}$, $\frac{\partial}{\partial t}\frac{\partial P}{\partial y}$ are given in Table III.

Table III. Simple correlation coefficients for former swarm.

	R	$\frac{\partial R}{\partial t}$	P	$\frac{\partial P}{\partial t}$	$\frac{\partial P}{\partial x}$	$\frac{\partial P}{\partial y}$	$\frac{\partial}{\partial t}\frac{\partial P}{\partial x}$	$\frac{\partial}{\partial t}\frac{\partial P}{\partial y}$
$N-N_c$	−0·27	0·04	0·15	0·10	−0·02	−0·03	0·17	−0·15
$N-\overline{N}$	−0·43	0·34	0·33	0·22	0·28	0·67	0·41	−0·05

Of the correlation coefficients given in the foregoing table, that between $N-N_c$ and $R-\overline{R}$ is the strongest in the case of fluctuations $N-N_c$. The other coefficients, except for those between $N-N_c$ and $(P-\overline{P})$, $\left(\frac{\partial}{\partial t}\frac{\partial P}{\partial x}-\overline{\frac{\partial}{\partial x}\frac{\partial P}{\partial x}}\right)$, $\left(\frac{\partial}{\partial t}\frac{\partial P}{\partial y}-\overline{\frac{\partial}{\partial t}\frac{\partial P}{\partial y}}\right)$, which are of the order of 0·15 or so, are very small compared with those just mentioned.

As to the correlation coefficients between $N-\overline{N}$ and the other elements, we notice that the numerical values of the coefficients are generally greater than those in the case of the correlation of $N-N_c$

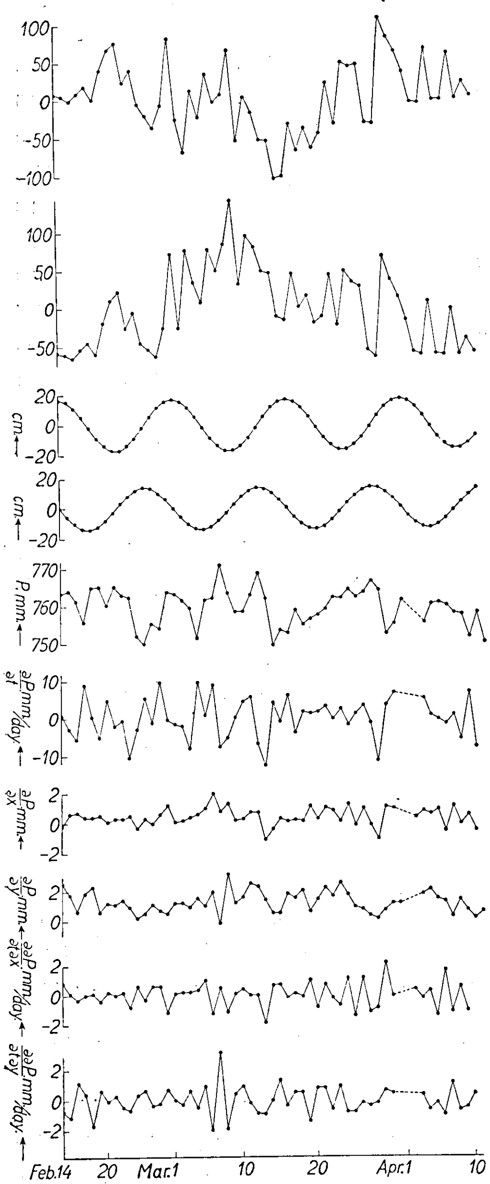

Fig. 2a. Variation in frequency of earthquakes and other elements, R, P, etc., during the period Feb. 14∼Apr. 10, 1930.

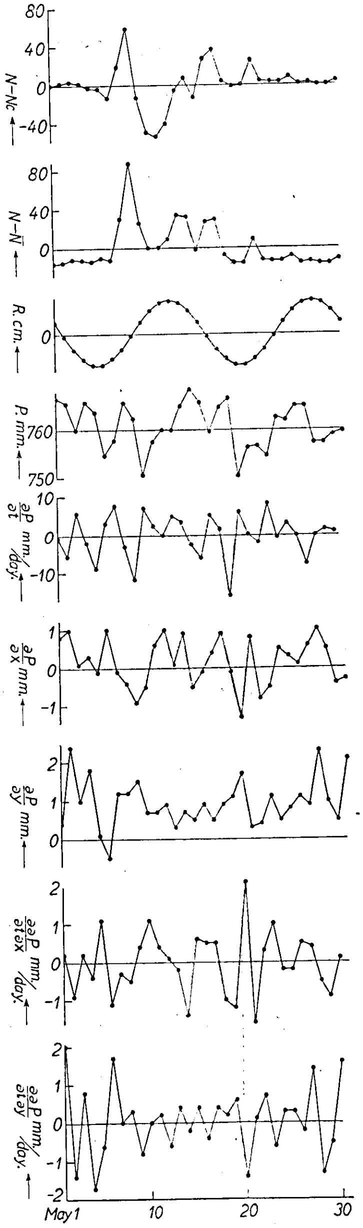

Fig. 2b. Variation in frequency of earthquakes and other elements, R, P, etc., during the period May 1∼May 30, 1930.

with the other elements. Although the correlation coefficient between $N-\overline{N}$ and $\left(\frac{\partial P}{\partial y}-\overline{\frac{\partial P}{\partial y}}\right)$ in particular is exceedingly large, the coefficients between $N-\overline{N}$ and $\left(\frac{\partial}{\partial t}\frac{\partial P}{\partial y}-\overline{\frac{\partial}{\partial t}\frac{\partial P}{\partial y}}\right)$ are very small.

In calculating the coefficients of multiple correlations between $N-N_c$ or $N-\overline{N}$ and a certain set of elements R, P, etc., elements having smaller correlation coefficients with $N-N_c$ or $N-\overline{N}$ are disregarded, that is in the case of $N-N_c$, the multiple correlation coefficients are calculated with regard to sets of elements; (i) R, P, $\frac{\partial}{\partial t}\frac{\partial P}{\partial t}$, $\frac{\partial}{\partial t}\frac{\partial P}{\partial y}$, (ii) R, P, $\frac{\partial}{\partial t}\frac{\partial P}{\partial x}$, and (iii) R, P, respectively, while in the case of $N-\overline{N}$, the multiple correlation coefficients are calculated with regard to sets of elements; (i) R, $\frac{\partial R}{\partial t}$, P, $\frac{\partial P}{\partial x}$, $\frac{\partial P}{\partial y}$, $\frac{\partial}{\partial t}\frac{\partial P}{\partial x}$, and (ii) R, $\frac{\partial P}{\partial y}$, $\frac{\partial}{\partial t}\frac{\partial P}{\partial x}$. The multiple correlation coefficients thus calculated are given in Table IV, from which it will be seen that the multiple correlation is stronger in the case of $N-\overline{N}$, to the set elements R, $\frac{\partial P}{\partial y}$, $\frac{\partial}{\partial t}\frac{\partial P}{\partial x}$, while, in the case of $N-N_c$, to the set of elements R, P.

Table IV. Multiple correlation coefficients for former swarm.

Case	Multiple correlation coefficient
I i) $N-N_c$: R, P, $\frac{\partial}{\partial t}\frac{\partial P}{\partial x}$, $\frac{\partial}{\partial t}\frac{\partial P}{\partial y}$	0·18
ii) 〃 : R, P,	0·26
iii) 〃 : R, P, $\frac{\partial}{\partial t}\frac{\partial P}{\partial x}$	0·06
II i) $N-\overline{N}$: R, $\frac{\partial P}{\partial y}$, $\frac{\partial}{\partial t}\frac{\partial R}{\partial x}$	0·66
ii) 〃 : R, $\frac{\partial R}{\partial t}$, P, $\frac{\partial P}{\partial x}$, $\frac{\partial P}{\partial y}$, $\frac{\partial}{\partial t}\frac{\partial P}{\partial x}$	0·07

As to the May swarm of earthquakes, the simple and multiple correlation coefficients are calculated quite similarly. In this case however the factor $\frac{\partial R}{\partial t}$ is disregarded. The numerical values of the coefficients of simple and multiple correlations are given in Tables V and VI respectively.

Table V. Simple correlation coefficients for later swarm.

	R	P	$\frac{\partial P}{\partial t}$	$\frac{\partial P}{\partial x}$	$\frac{\partial P}{\partial y}$	$\frac{\partial}{\partial t}\frac{\partial P}{\partial x}$	$\frac{\partial}{\partial t}\frac{\partial P}{\partial y}$
$N-N_c$	−0·37	0·07	−0·30	−0·30	0·13	−0·05	0·004
$N-N$	0·08	0·02	0·13	−0·28	0·02	0·04	−0·06

Table VI. Multiple correlation coefficients for later swarm.

Case	Multiple Correlation Coefficient
I i) $N-N_c$: $R, \frac{\partial P}{\partial t}, \frac{\partial P}{\partial x}, \frac{\partial P}{\partial y}$	0·32
ii) 〃 : $R, \frac{\partial P}{\partial t}, \frac{\partial P}{\partial x}$	0·30
II $N-\overline{N}$: $\frac{\partial P}{\partial t}, \frac{\partial P}{\partial x}$	0·31

In these cases, the multiple correlation coefficients are nearly the same in each case; having an approximate value of 0·3.

5. Since, as just stated, $N-N_c$ or $N-\overline{N}$ is correlated with the elements or sets of elements R, P and their derivatives, any value of $N-N_c$ or $N-\overline{N}$ may be expressed as a function of the corresponding values of the elements, that is, we can form an equation of a regression plane, expressed as

$$(N-N_c) \text{ or } (N-\overline{N})=b_{12}(R-\overline{R})+b_{13}\left(\frac{\partial R}{\partial t}-\overline{\frac{\partial R}{\partial t}}\right)$$

$$+b_{14}(P-\overline{P})+\ldots\ldots+b_{19}\left(\frac{\partial}{\partial t}\frac{\partial P}{\partial y}-\overline{\frac{\partial}{\partial t}\frac{\partial P}{\partial y}}\right).$$

The factors b_{12}, b_{13}, ...b_{19} in the above equation can be determined in terms of simple correlation coefficients r_{1p} by using the relation

$$b_{1p}=-\frac{\Delta_{1p}}{\Delta_{11}}\frac{\sigma_1}{\sigma_p}, \quad (p=2, 3\ldots.9)$$

where Δ_{11} and Δ_{1p} are minor determinants of Δ[7] and σ_1, σ_p are standard deviations. The suffixes 1, 2, ...9 of b, r, Δ, and σ designate $N-N_c$ or $N-\overline{N}$ and the elements $(R-\overline{R})$, $\left(\frac{\partial R}{\partial t}-\overline{\frac{\partial R}{\partial t}}\right)$, etc., respectively.

The equations of regression planes thus determined for the cases in which the multiple correlation coefficients are greater than 0·1 are

(A) Earlier Swarm (Feb. 14—Apr. 10, 1930)

I. i) $N-N_c$: $R, P, \frac{\partial}{\partial t}\frac{\partial P}{\partial x}, \frac{\partial}{\partial t}\frac{\partial P}{\partial y}$;

$$N-N_c=-1{\cdot}2(R-\overline{R})+0{\cdot}6(P-\overline{P})$$

7) The determinant Δ is given in the form

$$\Delta=\begin{vmatrix} r_{11} & r_{12} & \cdots & r_{19} \\ r_{21} & r_{22} & \cdots & r_{29} \\ \vdots & & & \\ r_{91} & \cdots & \cdots & r_{99} \end{vmatrix}, \quad \begin{array}{l} r_{12}=r_{21},\ r_{23}=r_{32},\ \ldots, \\ r_{11}=r_{22}=r_{33}=\ldots r_{99}=1. \end{array}$$

$$+4.7\left(\frac{\partial}{\partial t}\frac{\partial P}{\partial x}-\overline{\frac{\partial}{\partial t}\frac{\partial P}{\partial x}}\right)-6{\cdot}6\left(\frac{\partial}{\partial t}\frac{\partial P}{\partial y}-\overline{\frac{\partial}{\partial t}\frac{\partial P}{\partial y}}\right).$$

ii) $N-N_c$: $R,\ P$;

$$N-N_c=-1{\cdot}0(R-\overline{R})+2{\cdot}1(P-\overline{P}).$$

II. $N-\overline{N}$: $R,\ \frac{\partial P}{\partial y},\ \frac{\partial}{\partial t}\frac{\partial P}{\partial x}$;

$$N-\overline{N}=-0{\cdot}6(R-\overline{R})+16{\cdot}5\left(\frac{\partial P}{\partial y}-\overline{\frac{\partial P}{\partial y}}\right)+12{\cdot}3\left(\frac{\partial}{\partial t}\frac{\partial P}{\partial x}-\overline{\frac{\partial}{\partial t}\frac{\partial P}{\partial x}}\right)$$

(B) Later Swarm (May 1—May 31, 1930)

I. i) $N-N_c$: $R,\ \frac{\partial P}{\partial t},\ \frac{\partial P}{\partial x},\ \frac{\partial P}{\partial y}$;

$$N-N_c=-0{\cdot}5(R-\overline{R})-0{\cdot}1\left(\frac{\partial P}{\partial t}-\overline{\frac{\partial P}{\partial t}}\right)-1{\cdot}0\left(\frac{\partial P}{\partial t}-\overline{\frac{\partial P}{\partial x}}\right)+2{\cdot}8\left(\frac{\partial P}{\partial y}-\overline{\frac{\partial P}{\partial y}}\right).$$

ii) $N-N_c$: $R,\ \frac{\partial P}{\partial t},\ \frac{\partial P}{\partial x}$;

$$N-N_c=-0{\cdot}5(R-\overline{R})-1{\cdot}1\left(\frac{\partial P}{\partial t}-\overline{\frac{\partial P}{\partial t}}\right)-6{\cdot}4\left(\frac{\partial P}{\partial x}-\overline{\frac{\partial P}{\partial x}}\right).$$

II. $N-\overline{N}$: $\frac{\partial P}{\partial t},\ \frac{\partial P}{\partial x}$;

$$N-\overline{N}=-1{\cdot}1\left(\frac{\partial P}{\partial t}-\overline{\frac{\partial P}{\partial t}}\right)+4{\cdot}9\left(\frac{\partial P}{\partial x}-\overline{\frac{\partial P}{\partial x}}\right).$$

With these equations we can calculate the theoretical values of $N-N_c$ or $N-\overline{N}$ by substituting the given values of $(R-\overline{R})$, $\left(\frac{\partial R}{\partial t}-\overline{\frac{\partial R}{\partial t}}\right)$, $(P-\overline{P})$, $\left(\frac{\partial P}{\partial t}-\overline{\frac{\partial P}{\partial t}}\right)$, $\left(\frac{\partial P}{\partial x}-\overline{\frac{\partial P}{\partial x}}\right)$ etc.

The theoretical values of $N-N_c$ or $N-\overline{N}$, calculated by the equations of regression planes given above, and the deviations in the actual values of $N-N_c$ or $N-\overline{N}$ from those theoretically calculated are shown in Table VII.

Table VIIa. $(N-N_c)_{obs.}-(N-N_c)_{cal.}$ and $(N-\overline{N})_{obs.}-(N-\overline{N})_{cal.}$ for various cases of former swarm.

Case / Date	I, i)	I, ii)	II	Case / Date	I, i)	I, ii)	II
Feb. 14	19	19	−79	Feb. 16	22	9	−46
15	14	14	−62	17	16	25	−61

(*to be continued.*)

Table VIIa. (*continued.*)

Date \ Case	I, i)	I, ii)	II	Date \ Case	I, i)	I, ii)	II
Feb. 18	2	8	−64	March 16	−76	−66	−12
19	− 6	−17	−50	17	− 8	−11	49
20	23	28	−29	18	−45	−42	− 4
21	47	42	3	19	−41	−23	27
22	58	55	7	20	−53	−58	−14
23	7	7	−19	21	−51	−49	−42
24	35	50	− 2	22	2	6	31
25	6	17	−30	23	−41	−49	−44
26	−15	− 3	−56	24	−17	26	17
27	−21	−10	−54	25	−16	28	47
28	22	8	7	26	29	33	17
March 1	102	95	16	27	−32	−43	−27
2	− 9	−11	−19	28	−23	−32	−32
3	−50	−54	87	29	120	+136	56
4	20	38	28	30	108	110	58
5	−21	−25	23	31	—	—	—
6	17	24	78	Apr. 1	—	—	—
7	− 5	−37	59	2	—	—	—
8	−21	−13	58	3	5	13	−74
9	51	55	132	4	63	67	− 5
10	−63	−62	13	5	−14	6	−75
11	− 9	− 9	10	6	−13	−12	−55
12	−28	−34	62	7	43	51	−16
13	−43	−49	71	8	−15	− 7	−62
14	−36	−19	66	9	7	30	−47
15	−74	−73	2	10	4	3	−35

Table VIIb. $(N-N_c)_{obs.}-(N-N_c)_{cal.}$ and $(N-\overline{N})_{obs.}-(N-\overline{N})_{cal.}$ for various cases of later swarms

Date \ Case	I, i)	I, ii)	II	Date \ Case	I, i)	I, ii)	II
May 1	− 6	− 6	−12	May 6	−15	− 2	−11
2	− 2	0	− 5	7	−19	− 9	−23
3	1	− 6	−19	8	14	7	30
4	− 6	− 6	−10	9	56	39	95
5	− 8	−21	− 6	10	− 9	− 7	15

(*to be continued.*)

Table VIIb. (*continued.*)

Date \ Case	I, i)	I, ii)	II	Date \ Case	I, i)	I, ii)	II
May 11	−41	−38	− 1	May 21	− 3	− 2	−14
12	−43	−40	4	22	22	12	5
13	−28	−26	3	23	3	8	−25
14	5	12	33	24	8	8	−12
15	0	6	31	25	10	13	−17
16	−10	−18	3	26	16	16	−10
17	29	34	22	27	10	4	− 6
18	34	39	30	28	8	15	−11
19	− 4	−22	8	29	7	10	−18
20	−11	−12	30	30	4	0	−21

6. The deviations in actual values of $N-N_c$ or $N-\overline{N}$ from the calculated values given in Table VII are plotted in Fig. 3.

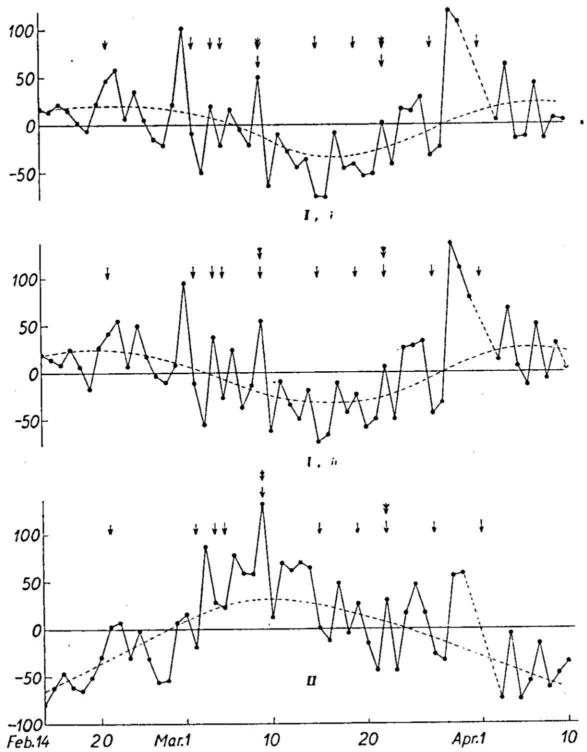

Fig. 3a. Differences between observed and calculated frequencies of earthquakes for different cases. (Feb. 14∼Apr. 10, 1930).

In the curves shown in Fig. 3, we notice general trends as denoted by the dotted lines, superposed by fluctuations having considerable amplitudes.

From the general trends of the curves in Fig. 3, it may be suggested that the assumption on which we have calculated the effects of the primary cause were not satisfactory, that is, $N_{cal.}$ does not fit in well with the general mode of the variation of actual N. To be more concise, N_c is over-estimated for the values of the middle epoch and under-estimated for the values of adjacent epochs during the period of activity of the earthquakes swarms, while $\bar{N}$ is under-estimated for the values of the middle epoch and over-estimated for the values of the initial and end epochs.

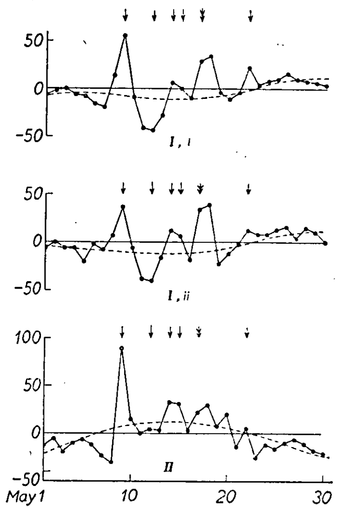

Fig. 3b. Differences between observed and calculated frequencies of earthquakes for different cases. (May 1 ~May 30, 1930).

It may therefore be necessary to calculate the simple and multiple correlation coefficients and regression planes for another series of N_c based on some other assumption that would harmonize better with the actual values of N, but as it was thought that recalculation would not give better or greater values for the correlation coefficients, it was not attempted.

As to the possible causes of the fluctuations superposing the deviations curves shown in Fig. 3, we have the following:

(i) The use of the daily earthquake frequencies and the fluctuations in the other quantities may be the source of the disparity.

(ii) There may be several other fluctuating quantities that correlate with that of earthquakes.

(iii) The internal seismic activity itself may fluctuate without being affected either by external disturbances or secondary causes.

Factor (i) is referred to in the next paragraph. Factor (ii) however does not admit of discussion.

Of factor (iii) we have some knowledge, that is, we know that there were fluctuations in the intensities of the earthquakes. The stronger earthquakes are marked by double and single arrows in Fig. 3. In several cases, these arrows are seen to coincide with the peaks of the curves, that is, much stronger earthquakes occurred when the actual earthquake frequencies were greater than those estimated from external or secondary causes. This fact does not contradict our experience that strong earthquakes are generally accompanied by a number of smaller shocks. There may besides be another cause for the fluctuation in seismic activity, such as that discussed by Prof. Terada[8] in connection with fluctuations in frequencies of the fall of camelia flowers (Camelia Japonica).

7. As a probable source of disparity between the calculated and the actual valus of $N-N_c$ or $N-\overline{N}$, as just pointed out, may be mentioned the improper selection of data of the factors that were regarded as correlated with the fluctuations in the daily earthquakes frequencies.

In the present study, for instance, the fluctuations in tidal range were used as data of the tidal forces that may be related to the fluctuations in earthquake frequency. This seems to be an example of improperly selected data, for earthquake frequency was proved to be more closely correlated with the heights of the sea level, that is to say, earthquakes occurred most frequently at the time of low water, they being hardly felt at the time of high water, as shown in Fig. 4. reproduced from Prof. Imamura's paper.[9]

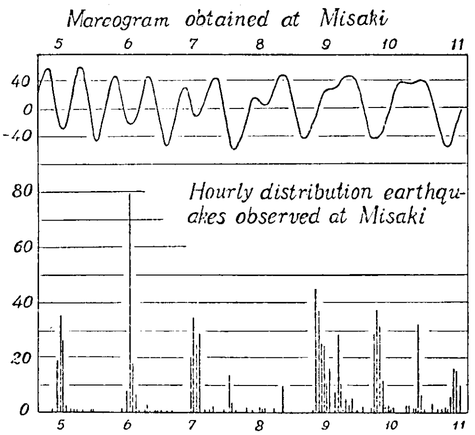

Fig. 4. Relation between frequency of earthquakes and tides. (Reproduced from *Disin*, 2 (1930).)

For investigating these points however more detailed data of atmospheric pressures are required, the very thing that is wanting at present. These points will be discussed in greater detail in a future paper.

In conclusion, the writer wishes to express his sincere thanks to Professor Torahiko Terada for his kind advices and suggestions. Cordial thanks are also due to Dr. C. Tsuboi for the many valuable hints received in the course of discussions with him.

8) T. TERADA, *Bull. Earthq. Res. Inst.*, 10 (1932), 29.

9) A. IMAMURA and others, *loc., cit.* 1).

12. 伊東地震群に關する統計

地震研究所 宮 部 直 巳

昭和 5 年に頻發した伊東附近の地震は，2 月 14 日乃至 4 月 10 日と 5 月 1 日乃至 5 月 31 日の 2 群に分けることが出來，その地震頻數が，潮汐と密接な關係のあることが，從來指摘されてゐる．又，別の地震群について，氣壓の頻度などと相關々係のあることが知られてゐる．

筆者は，潮汐や氣壓やそれ等の導來函數と伊東地震群の日々の頻數との間の單並びに重相關々係を調べ，地震の頻數が，それ等の要素を變數とする一次函數で表はされるとした場合の係數を統計的に定めた． この式から豫期される頻數と實際の頻數とを比較してみると，尙多少の剩餘がある．是等の剩餘は，data の取り方の不適當なことから生ずるものと，地震活動それ自身の消長に fluctuation のあることから生ずるものとが含まれてゐると考へられる．