Note on the Long-period Variations of the Atmospheric Pressure.

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With Pls. XLIV—XLVIII.

1. ***Introduction.*** From the discussion of the after-shocks of the Mino-Owari and other recent destructive earthquakes in Japan,* the seismic frequency has been found to have, besides the diurnal and annual variations, the periodicities approximately of the lengths of $4\frac{1}{2}$ days, 9 days, 12 days, 33 days, and 3 months; amongst others, the period of $4\frac{1}{2}$ days occurring very often. The present note, which is to be regarded as a supplement to my paper on the secondary causes of earthquakes (the *Bulletin*, Vol. II, No. 2), gives some account of the longer periods of variation of the barometric pressure, the object being the comparison of the seismic and atmospheric periodicities.

2. ***1st method of finding out the periodicity of barometric pressure.*** The daily or other mean barometric pressure at a given place of observation is plotted on a section paper, and the length of a period is obtained by taking the average

* F. Omori: "On the after-shocks of earthquakes," Jour. Sc. Coll., Tokyo Imp. Univ., Vol. VII, (1894). Also F. Omori: "On the Earthquakes in Formosa," Reports (Japanese) of the Imp. Earthquake Inv. Comm., No. 54 (1905).

from the mean curve drawn by free hand extended over several consecutive months. (See Figs. 1, 2, and 3.) I give next some examples relating to Tokyo, Gifu, and Mt. Tsukuba.

3. ***Barometric pressure at Tokyo, Gifu, and Mt. Tsukuba.*** As examples, I have taken the data relating to Tokyo, Gifu (province of Mino), and Mt. Tsukuba, and the average length of the different periods have been deduced from the curves, in which the ordinate is the mean barometric height corresponding to the time expressed in 1, 2, 5, or 10 days intervals. As may easily be imagined, the variation of the barometric pressure is generally very complex. In some cases, however, there is certain regularity, when the barometric variation indicates the periodicity of one kind or other. Thus, Fig. 1, which illustrates the variation of the daily mean pressure at Gifu between May 1 and Aug. 9, 1892, indicates a period of about $4\frac{1}{2}$ days. Again, in Fig. 2, which represents the same variation in 1903 at the top observatory of Mt. Tsukuba, a period of 8 or 9 days is shown between Jan. 10 and Feb. 4, and in three other epochs, while a period of about $4\frac{1}{2}$ days is shown during the rest of the year. Fig. 3 illustrates the 10-daily variation of the barometric pressure in Tokyo during the three years, 1887–1889, indicates more or less clearly a period of 3 months. The results obtained are summarized in the following table.

Time Interval.	The mean barometric pressure from whose variation the period has been deduced.	Average Length of Period.
	TOKYO.	
Oct. 1–Dec. 31, 1888.	Daily mean pressure.	4.7 days.
During the year 1888.	2-daily ,,	8.7 ,,
Jan. 1–Aug. 30, 1889.	2-daily ,,	32.0 ,,
During the 3 years, 1887–1889.	10-daily ,,	3 months.
	GIFU.	
Jan. 1–Sept. 9, 1892.	Daily mean pressure.	9.2 days ; 4.6 days.
Jan. 1–Aug. 31, 1893.	,, ,,	4.6 ,,
Sept. 1, 1891–March 31, 1892.	2-daily ,,	8.6 ,,
May 1–Dec. 31, 1892.	2-daily ,,	9.3 ,,
During the year 1893.	2-daily ,,	9.0 ,,
Do.	5-daily ,,	35.0 ,,
Do.	10-daily ,,	34.0 ,,
Sept. 1, 1891–Dec. 31, 1892.	10-daily ,,	3 months.
	MT. TSUKUBA.	
Nov. 18–Dec. 31, 1902.	Daily mean pressure.	8.6 days.
Jan. 10–Feb. 4, 1903.	,, ,,	8.3 ,,
Feb. 4–March 16, 1903.	,, ,,	4.4 ,,
March 19–April 13, 1903.	,, ,,	8.3 ,,
April 17–May 5, 1903.	,, ,,	4.5 ,,
May 5–May 31, 1903.	,, ,,	8.7 ,,
Oct. 17–Nov. 5, 1903.	,, ,,	5.0 ,,
Nov. 6–Dec. 23, 1903.	,, ,,	7.8 ,,

The different periods contained in the above table may be divided into 4 groups, i, ii, iii, and iv, as follows :—

i	ii	iii	iv
days	days	days	months.
4.7	8.7	32	3
4.6	9.2	35	
4.6	8.6		
4.4	9.3		
4.5	9.0		
5.0	8.6		
	8.3		
	8.3		
	8.7		
	7.8		
Mean..**4.6** days. ..	.....**8.7** days	.....33 days	.....3 months.

The mean values of the 4 different periods are **4.6** days, **8.7** days, 33 days, and 3 months, the first two occurring most frequently.

4. ***2nd method of finding out the periodicity of barometric pressure.*** Instead of considering the variation of atmospheric pressure at a given place as explained in the preceding §, let us find out the time interval between the successive epochs, when the whole of Japan is covered by high barometric pressure. Thus, Figs. 4 and 5 represent two consecutive cases separated by about 4 days, when the high pressure area extended over the principal Japanese islands. The mean values of the different periods in the pressure variation obtained by this method from an examination of the weather maps of Japan during the 4 years, 1900 to 1903, are given in the following table.

Time Interval.		Number of times when high pressure area extended over Japan.	Average interval between the successive high pressure epochs.	
			day	hour
Jan. 3 ; 6 am.—May. 14 ; 10 pm.	1900.	29	5	2
Sept. 29 ; 10 pm.—Dec. 28 ; 10 pm.	„	21	4	12
Jan. 2 ;2 pm.— Feb. 9 ; 2 pm.	1901.	9	4	19
Feb. 18 ; 6 am.—March 21 ; 2 pm.	„	8	4	10
March 26 ; 10 pm.—June 1 ; 10 pm.	„	14	5	4
Sept. 29 ; 10 pm.—Dec. 27 ; 10 pm.	„	24	3	21
Dec. 31 ; 10 pm. 1901—April 6 ; 10 pm.	1902.	24	4	4
April 18 ; 6 am.—May 15 ; 2 pm.	„	8	3	22
May 25 ; 6 am.—July 1 ; 10 pm.	„	5	9	10
July 17 ; 6 am.—Aug. 27 ; 10 pm.	„	5	10	10
Oct. 5 ; 10 pm. 1902—Jan. 1 ; 2 pm.	1903.	23	4	0
Jan. 5 ; 2 pm.—Jan. 24 ; 6 am.	„	5	4	16
„ 28 ; 10 pm.—May 4 ; 6 am.	„	22	4	3
May 9 ; 10 pm.—June 21 ; 10 pm.	„	8	6	6

Taking the means from the above table, we obtain the following two periods :—

	d	h	days	
(i)	4	14	=4.6	(averaged from 12 cases)
(ii)	9	22	=9.9	(„ „ 2 „)

5. Combining the results obtained in §§ 3 and 4, the mean values of the first two periods are found to be :—

1st period ..... 4.6 days.

2nd „ ..... 9.3 „

Thus, the length of the 2nd period is double that of the 1st period, the latter being probably the fundamental period in the

variation of the atmospheric pressure from day to day. It is quite possible that there exist, besides the period of 9.3 days and one of about 33 days, many others of longer or shorter durations, which are probably the multiples of the 1st period. The period of the length of 3 months may be of a different origin, being one of the harmonics of the annual period.

All the four periods in the variation of the barometric pressure as above obtained are evidently similar to, and likely to be the causes of, the corresponding periods in the variation of the earthquake frequency (§ 1).

I give next a short notice respecting the after-shocks of the Taito (Formosa) earthquake of 1903, whose frequency shows fluctuations parallel to those of the barometric pressure.

6. ***After-shocks of the Taito earthquake of Sept. 7, 1903.*** The following table gives the daily mean barometric pressure at Taito (Formosa) and the daily number of the after-shocks of the strong earthquake of Sept. 7, 1903, recorded at the same place by means of an Omori horizontal pendulum of 6 times magnification.

DAILY MEAN BAROMETRIC PRESSURE AND DAILY NUMBER OF EARTHQUAKES AT TAITO (FORMOSA). SEPT.—OCT., 1903.

Atmospheric Pressure.*			Daily Number of Earthquakes.		
Day \ Month	September	October	Day \ Month	September.	October.
	mm	mm			
1	760.0	754.6	1	———	0
2	58.8	56.5	2	———	0
3	58.6	57.8	3	———	0
4	59.2	53.6	4	———	0
5	59.6	53.2	5	———	0

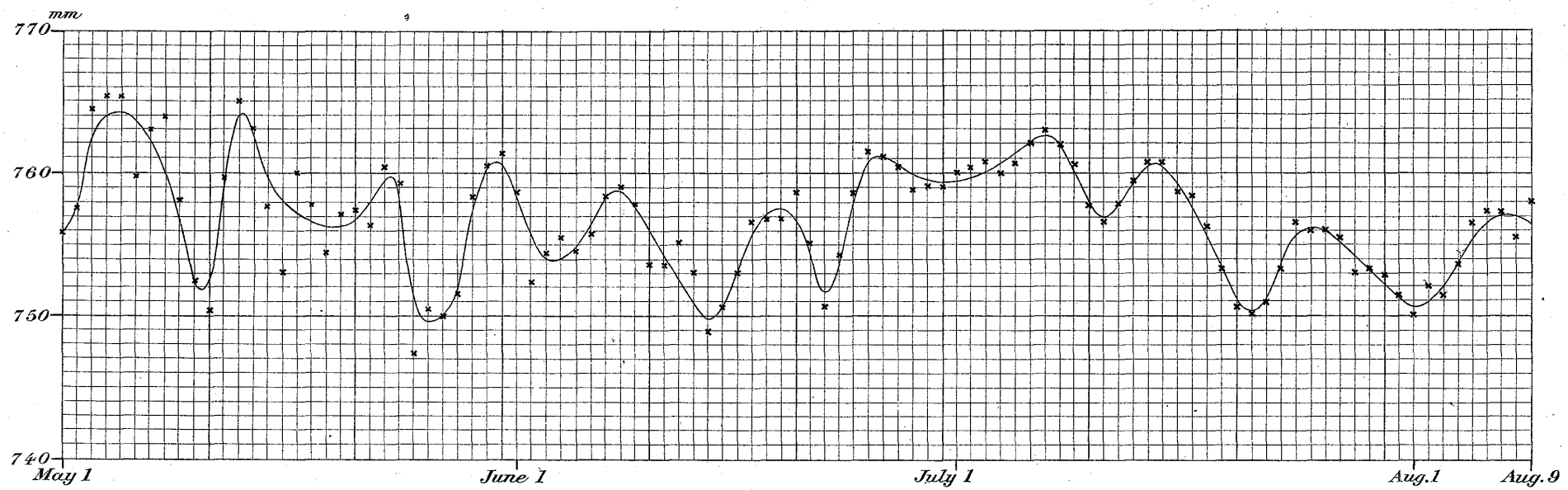
* With freezing point correction. Reduction to standard gravity = 1.4mm; that to mean ea level = 0.9 mm.

Atmospheric Pressure.*			Daily Number of Earthquakes.		
Day \ Month	September.	October.	Day \ Month	September.	October.
	mm	mm			
6	58.8	58.4	6	———	0
7	57.8	58.2	7	26*	8
8	57.5	57.7	8	6	0
9	58.3	58.9	9	5	0
10	58.1	59.5	10	9	0
11	57.8	59.9	11	2	0
12	59.5	60.3	12	2	0
13	60.0	62.1	13	5	0
14	60.0	62.6	14	4	0
15	59.8	61.5	15	0	0
16	58.7	59.8	16	2	0
17	59.2	58.3	17	1	
18	60.4	57.7	18	5	
19	60.1	57.8	19	0	
20	59.0	57.9	20	0	
21	58.4	56.7	21	0	
22	58.9	55.6	22	0	
23	59.2	57.7	23	10	
24	60.4	59.6	24	4	
25	61.0	59.2	25	2	
26	59.0	58.3	26	2	
27	58.4	59.6	27	0	
28	58.2	62.6	28	1	
29	58.4	64.9	29	0	
30	56.8	64.1	30	0	
31	———	65.0	31	———	

* The 1st shock took place at $2^{h}\ 59^{m}$ pm., on the 7th.

As will be seen from the graphical representations in Fig. 6, the variation of the barometric pressure between Sept. 8th and Oct. 8th (1903) indicates a period of the mean length of about 4.4 days, its maxima and minima corresponding, on the whole, respectively to the maxima and minima of the after-shock frequency.

Fig. 1. Variation of Daily Mean Barometric Pressure at Gifu.
May 1 to Aug. 9, 1892.



(1892)

Fig. 2. Variation of Daily Mean Barometric Pressure on Mt. Tsukuba.

Between Jan. 1 and May 31, and between Oct. 16 and Dec. 31, 1903.

{ Full line indicates short period Variation.
{ Dotted ,, ,, slow ,, ,,

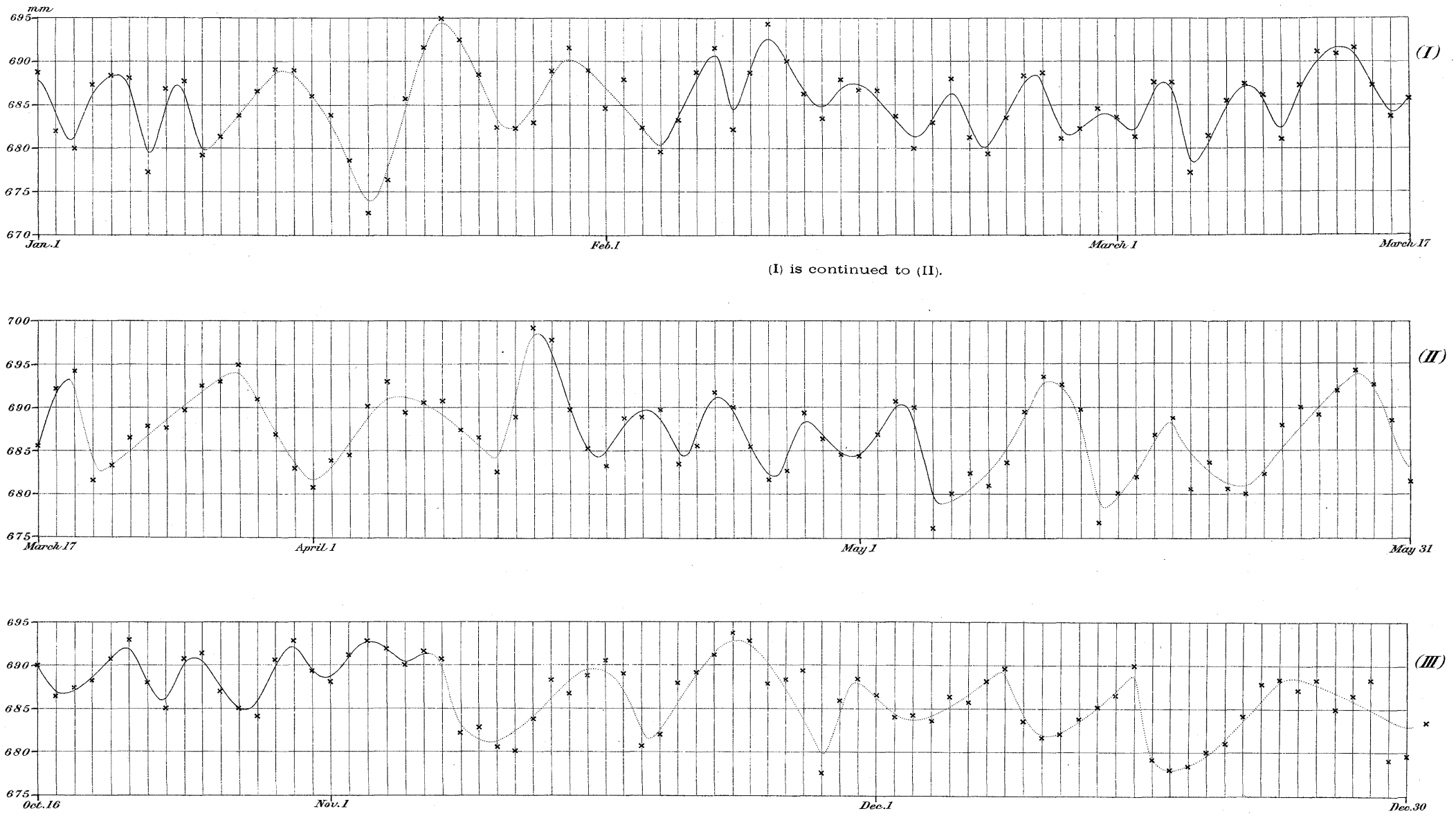
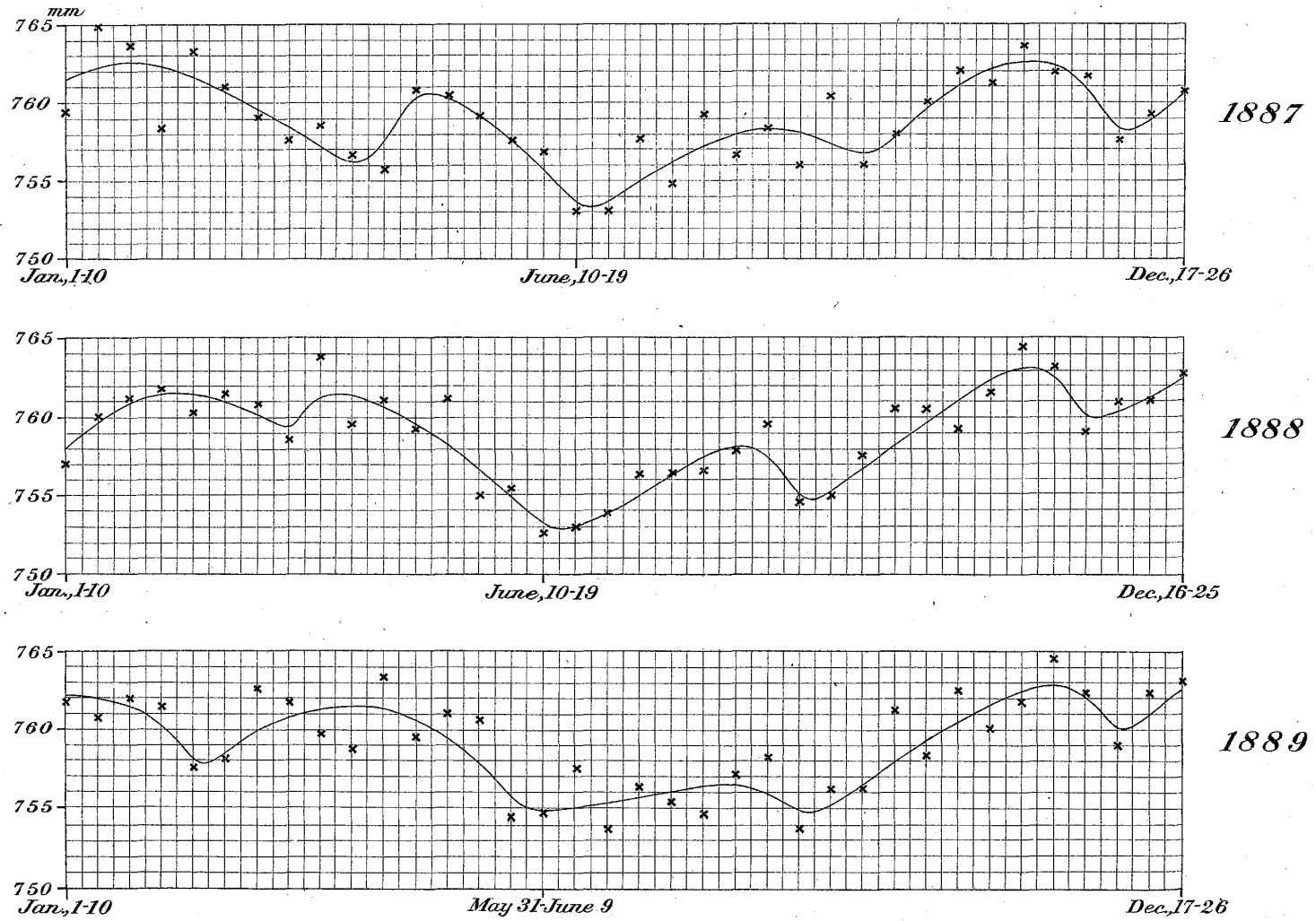


Fig. 3. Variation of 10-daily Mean Barometric Pressure in Tokyo.
1887, 1888, and 1889.



Maps showing the distribution of the Barometric Pressure over Japan.

Fig. 4. March 16, 1900; at 10 pm.

Fig. 5. March 20, 1900; at 10 pm.

Fig. 4.

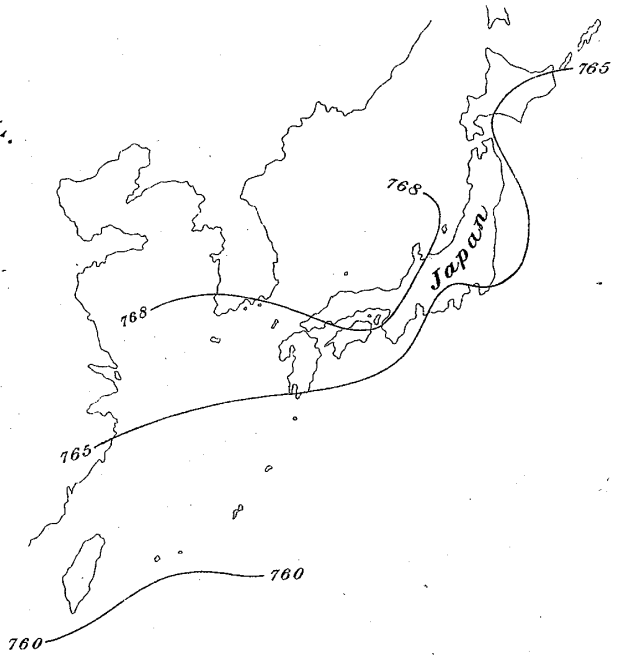
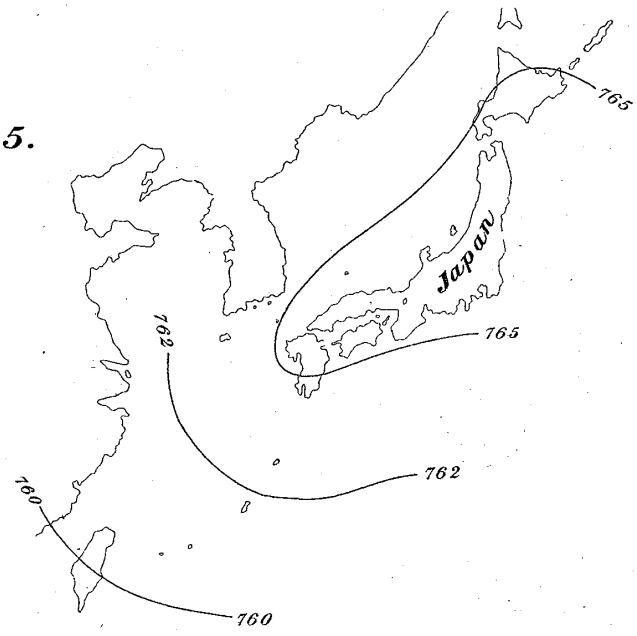


Fig. 5.



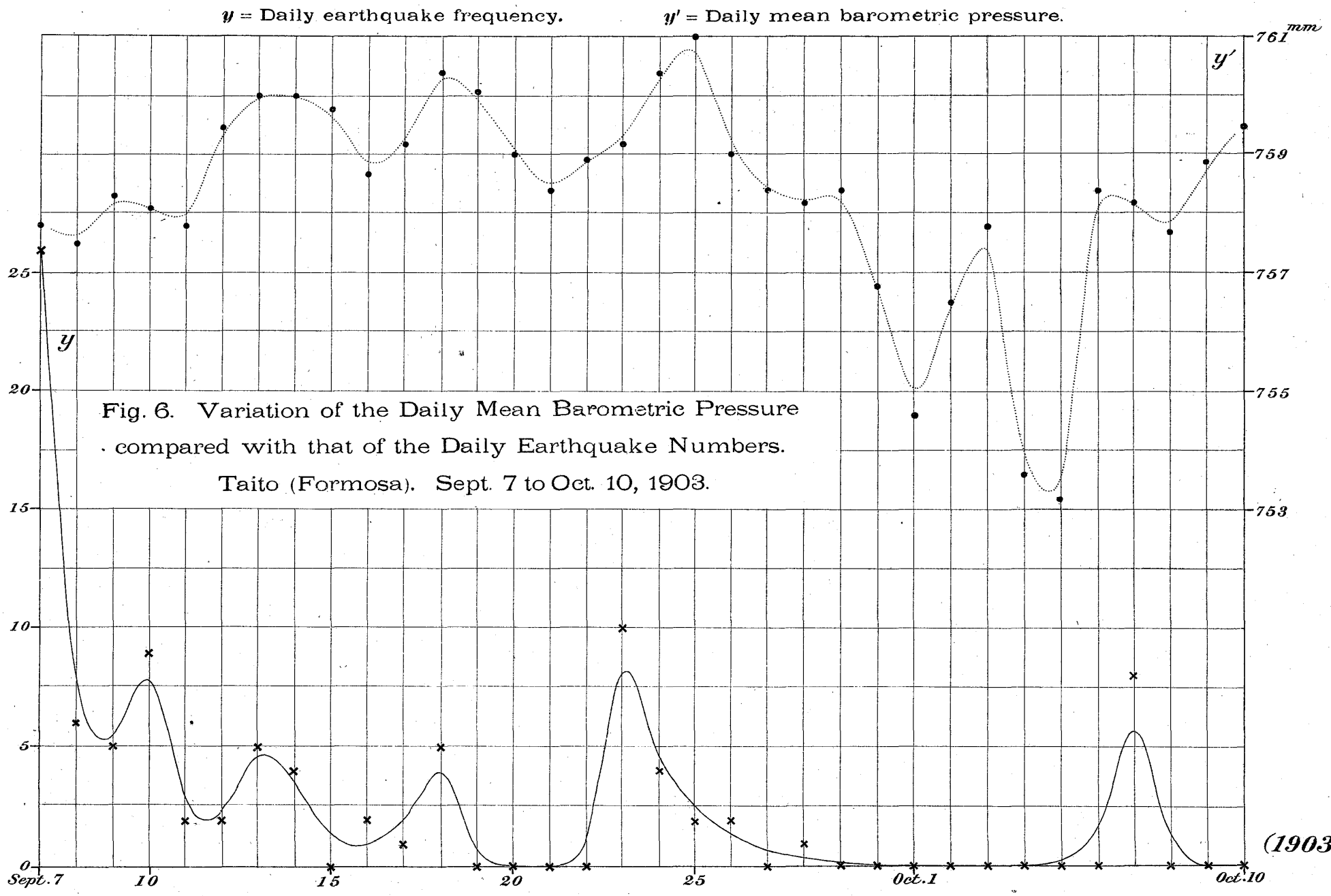


Fig. 6. Variation of the Daily Mean Barometric Pressure compared with that of the Daily Earthquake Numbers.

Taito (Formosa). Sept. 7 to Oct. 10, 1903.