44. *Relations between Earthquakes and Precipitation, Barometric Pressure, and Temperature.*

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Introduction.

In a previous papers[1], some possible effects of thunderstorm and also of cyclone upon the occurrence of earthquakes were studied. In connection with these problems, the relations between earthquakes and precipitations as well as barometric pressure and temperature, are investigated statistically in the present paper.

This problem was already investigated by Prof. F. Ômori[2], with the result that rather intimate correlation could be found between the earthquakes *observed* at Tôkyô and the precipitations at Niigata and Akita.

More reliable data in these days than in the time of Prof. Ômori for the earthquakes, as well as for the meteorological elements, could be taken from the Abridged Monthly Report of the Central Meteorological Observatory in Japan during the period of just ten years, from June, 1924 to May, 1934.

Method of Investigation.

As for the "felt" earthquakes which occurred in Kwantô District, they were classified into 5 groups according to the locality; these are, Iwaki Oki and Kasima Nada; Tyôsi Oki and Sagami Nada; Kinugawa, Tonegawa and Kasumigaura; Tôkyô and Bôsô Hantô; Sagami (land) and Idu Hantô. They were compared firstly, with the precipitations, the barometric pressure and the temperature on the Japan Sea side, and secondly with those on the Pacific side, and lastly with the differences of the two sides.

The meteorological elements in the Japan Sea side were taken from the data at three stations, Kanazawa, Takata and Niigata, for each

1) S. YAMAGUTI, *Bull. Earthq. Res. Inst.*, **12** (1934), 214 and 742.
2) F. ÔMORI, *Rep. Imp. Earthq. Inv. Comm.*, **68-1** (1910), 21.

season, namely, Spring (March～May), Summer (June～Aug.), Autumn (Sept.～Nov.), Winter (Dec.～Feb.), and denoted by Q_J, B_J, and T_J for the precipitations, the barometric pressure and the temperature, respectively. Those for the Pacific side were taken from the data at three stations, Tôkyô, Mito and Onahama, and denoted by Q_P, B_P, and T_P, respectively.

We have calculated the correlation coefficients, of the "felt" earthquakes in respective region above cited in each season, with respect to the corresponding values of Q's, B's and T's, applying the ordinary formula, $r=\frac{\sum \Delta x \Delta y}{\sqrt{\sum(\Delta x)^2 \sum(\Delta y)^2}}$.

Next, as for the "conspicuous and rather conspicuous" earthquakes, which occurred in Kwantô District, they were classified into two groups, according to their occurrences in land or in marine area, and the correlation coefficients of them with respect to the same meteorological elements as above taken, were calculated similarly as before.

The results are shown in Table I, II and III.

Table I. Correlation Coefficient between the Precipitations, Q (in 100 mm), and the Earthquakes in Kwantô Districts.

Season	Earthquake regions	"Felt" earthquakes					"Conspicuous and rather conspicuous"	
		Iwaki Oki Kasima Nada	Tyôsi Oki Sagami Nada	Kinugawa, Tonegawa Kasumigaura	Tôkyô Bôsô Hantô	Sagami (land) Idu Hantô	Land	Marine
Spring	J	0·16	−0·39	−0·24	0·22	−0·32	−0·25	−0·39
	P	−0·23	**0·43**	0·15	−0·25	−0·33	**−0·54**	0·16
	J−P	0·26	**−0·52**	−0·23	0·30	0·17	0·39	−0·27
Summer	J	0·14	**0·63**	**0·52**	−0·23	−0·06	−0·10	−0·20
	P	**−0·50**	−0·24	0·06	−0·01	0·24	−0·24	−0·04
	J−P	**0·41**	**0·49**	0·17	−0·22	−0·15	0·11	−0·08
Autumn	J	−0·06	−0·03	**0·62**	0·17	**0·78**	0·35	0·30
	P	−0·25	−0·32	0·23	0·21	0·20	0·03	−0·39
	J−P	0·19	0·26	0·07	−0·11	0·10	0·13	**0·47**
Winter	J	−0·07	**−0·57**	−0·06	**−0·73**	−0·36	0·21	**0·61**
	P	−0·38	0·09	0·09	**0·47**	−0·12	−0·16	−0·38
	J−P	0·05	**−0·52**	−0·08	**−0·77**	−0·28	0·23	**0·63**

Table II. Correlation Coefficient between the Barometric pressure, B (in mm. Hg), and the Earthquakes in Kwantô Districts.

Season	Earthquake regions	"Felt" earthquakes					"Conspicuous and rather conspicuous"	
		Iwaik Oki Kasima Nada	Tyôsi Oki Sagami Nada	Kinugawa Tonegawa Kasumigaura	Tôkyô Bôsô Hantô	Sagami (land) Idu Hantô	Land	Marine
Spring	J	0·29	**0·53**	0·01	0·01	−0·07	−0·14	**0·54**
	P	**0·49**	**0·45**	0·01	0·05	−0·05	−0·13	**0·57**
	J−P	**−0·73**	0·13	−0·03	−0·16	−0·05	0·02	−0·20
Summer	J	0·20	0·01	0·05	**0·47**	0·06	**0·42**	0·38
	P	−0·05	−0·11	−0·23	**0·52**	0·16	0·27	0·28
	J−P	0·34	0·16	0·37	−0·01	−0·12	0·18	0·09
Autumn	J	0·21	**0·42**	**−0·40**	0·09	0·13	−0·17	−0·10
	P	0·16	0·36	−0·36	0·20	0·10	−0·12	−0·08
	J−P	0·04	−0·02	0·12	**−0·44**	0·01	−0·09	0·01
Winter	J	0·08	**0·44**	0·05	**0·63**	0·34	−0·25	**−0·51**
	P	−0·02	0·35	0·01	**0·68**	0·32	−0·27	**−0·54**
	J−P	**0·47**	0·23	0·22	**−0·62**	−0·08	−0·13	**0·47**

Table III. Correlation Coefficient between the Temperature (in °C), and the Earthquakes in Kwantô Districts.

Season	Earthquake regions	"Felt" earthquakes					"Conspicuous and rather conspicuous"	
		Iwaki Oki Kasima Nada	Tyôsi Oki Sagami Nada	Kinugawa Tonegawa Kasumigaura	Tôkyô Bôsô Hantô	Sagami (land) Idu Hantô	Land	Marine
Spring	J	0·38	**0·74**	0·07	−0·01	−0·07	**−0·40**	**0·54**
	P	**0·59**	**0·46**	**0·44**	0·09	0·13	0·10	0·34
	P−J	−0·14	0·12	−0·18	0·16	0·01	−0·25	0·18
Summer	J	0·23	**0·47**	0·13	−0·21	**−0·47**	−0·25	0·05
	P	0·21	0·31	0·09	−0·06	**−0·49**	−0·10	0·23
	P−J	0·11	**0·41**	0·09	−0·31	−0·11	−0·31	−0·28
Autumn	J	0·08	**0·46**	**−0·60**	−0·02	**−0·50**	**−0·45**	−0·24
	P	0·15	0·26	**−0·51**	−0·08	**−0·49**	**−0·43**	−0·29
	P−J	−0·31	**0·46**	0·15	0·25	0·28	0·22	0·34
Winter	J	0·11	0·23	0·02	**0·59**	−0·22	−0·35	**−0·73**
	P	0·22	0·34	0·18	**0·50**	−0·38	−0·27	**−0·69**
	P−J	0·34	**0·52**	**0·71**	−0·21	**−0·76**	0·23	0·04

Results and Discussions.

As the period of investigation is only ten years, we can say nothing definite, but we may be able to suggest the following tendency:—

I. For the "felt" earthquakes.

1. The earthquakes in Iwaki Oki and Kasima Nada are liable to occur,
   (*a*) when the precipitation is abundant on the Japan Sea side, and scanty on the Pacific side in summer;
   (*b*) when the barometric pressure and also the temperature are high on the Pacific side, and low on the Japan Sea side in spring. This barometric condition is usually produced when the "high pressure" is prevailing on the Pacific Ocean.
2. The earthquakes in Tyôsi Oki and Sagami Nada are liable to occur,
   (*a*) when the precipitation on the Japan Sea side is comparatively little in winter and in spring; but it is contrary in summer;
   (*b*) when the barometric pressure and the temperature are high on the Japan Sea side in spring. This result is contrary to the case of Iwaki Oki and Kasima Nada.
3. The earthquakes in Kinugawa, Tonegawa and Kasumigaura, are liable to occur,
   (*a*) when the precipitation is abundant on the Japan Sea side in summer and in autumn; this result is similar to the case of Iwaki Oki and Kasima Nada, both regions being situated in the north side of Tonegawa;
   (*b*) when the temperature difference, $(T_P - T_J)$, is great in winter, and also when low temperature prevails on both the sides in autumn.
4. The earthquakes in Tôkyô and Bôsô Hantô are liable to occur,
   (*a*) when the precipitation is comparatively large on the Pacific side, and little in the Japan Sea side in winter; it is similar to the case of Tyôsi Oki and Sagami Nada, both regions being situated on the south side of Tonegawa; the result is contrary to that of Prof. F. Ômori;
   (*b*) when the barometric pressure and also the temperature are high on both sides in winter as well as in summer.
5. The earthquakes in Sagami (land) and Idu Hantô are liable to

occur,

(*a*) when the precipitation on the Japan Sea side is abundant in autumn;

(*b*) when the temperature on the Pacific side is higher than that of the Japan Sea side in winter, and also when the temperature is low on both sides in summer and in autumn.

II. For the "conspicuous and rather conspicuous" earthquakes.

6. The earthquakes in land are liable to occur,

(*a*) when the precipitation on the Pacific side is little in spring;

(*b*) when the barometric pressure is high on the Japan Sea side in summer;

(c) when the temperature is low on both sides in autumn.

7. The earthquakes in marine area are liable to occur,

(*a*) when the precipitation is abundant on the Japan Sea side, and little on the Pacific side, and also the differential precipitation, $(Q_J - Q_P)$, is great in winter; it is similar in autumn; this result corresponds to that of Prof. F. Ômori;

(*b*) when the barometric pressure is low on the Japan Sea side as well as on the Pacific side, and also the barometric pressure difference, $(B_J - B_P)$, is great in winter; this barometric distribution may be produced by a cyclone, frequenting the Pacific Ocean, of which the effect upon the occurrence of earthquakes is already investigated and reported in a previous paper[3]; and when, the barometric pressure is high on both sides in spring;

(c) when the temperature is low on both sides in winter, and it is high on the Japan Sea side in spring. The latter case is similar to the case of the "felt" earthquakes in Tyôsi Oki and Sagami Nada.

8. In general, the "felt" as well as the "conspicuous and rather conspicuous" earthquakes are liable to occur, when the meteo rological conditions are abnormal.

9. Large correlation coefficients are generally obtained in winter than in any other seasons, probably due to the fact that the monsoon is most markedly established in winter.

10. The winter precipitations on the Japan Sea side gives the positive correlation coefficient with respect to the "conspicuous and rather conspicuous" earthquakes in Kwantô District, but

3) S. YAMAGUTI, *loc. cit.*, 1).

it gives negative coefficient with respect to the "felt" earthquakes.

11. The effect of the precipitations on the Japan Sea side upon the occurrence of the earthquakes in Kwantô District is in opposite sense compared with the effect of the precipitation on the Pacific side, and the former is more effective than the latter.
12. To compare the result of the present investigation directly to that of Prof. Ômori, the yearly number, N, of the "conspicuous and rather conspicuous" earthquakes and also the corresponding precipitation, $Q_{J'}$, at Niigata, Yamagata and Akita, were taken, and the correlation coefficients between N and the precipitations at various stations, were calculated similarly as before as shown in Table IV.

Table IV. Correlation Coefficients.

Earthquake regions	Precipitations at various stations.				
	Kanazawa Takata Niigata	Niigata Yamagata Akita	Tôkyô Mito Onahama		
	Q_J	$Q_{J'}$	Q_P	Q_{J-P}	$Q_{J'-P}$
Land	0·06	0·32	−0·15	0·11	0·25
Marine	−0·02	0·21	−0·25	0·20	0·28

The result is not quite conclusive, and only coincides with that of Prof. F. Ômori as regards the sign of correlation. This is due to the fact, that the values of the coefficients vary considerably with the seasons.

Neither the data are sufficient for ensuring the result, so that a definite conclusion regarding the matter must be reserved for a future.

In conclusion, I wish to express my best thanks to Prof. Torahiko Terada under whose supervision the entire work has been carried out and who has given me many useful suggestions throughout the course of my investigation.

44. 地震と雨雪量，氣壓，及氣溫との關係

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前論文に於て地震に及ぼす雷雨並に低氣壓の影響の可能性に就いて既に研究された．之等の問題と關聯して今回は，地震と雨雪量並びに氣壓及氣溫との關係を統計的に調査して見た．

此問題は以前に大森博士が研究して東京で觀測された地震と新潟及秋田に於ける雨雪量との間には稍々密接な關係あることが報告されて居る．

今日の地震並びに氣象要素に關する材料は，大森博士の時代よりもつと信賴さるべきものと考へられるが故に，大正 13 年 6 月より昭和 9 年 5 月迄滿 10 個年の材料を中央氣象臺發行の氣象要覽より採つて，研究を試みた．

關東地方に起つた「有感覺地震」と，「顯著及稍顯著地震」とを別々に分類して，夫々日本海岸並びに太平洋岸の雨雪量其他の氣象要素との關係を調査して見た．

研究期間が僅かに 10 個年に過ぎないから確かな事は云はれないが，次の傾向あることを暗示することが出來るかと思ふ．

（1） 氣壓並びに氣溫が春太平洋岸に高く，日本海岸に低い時には，磐城沖及び鹿島灘の有感覺地震が起り易い．

（2） 春季日本海岸の氣壓並びに氣溫が高い時には，銚子沖及び相模灘の「有感覺地震」が起り易い．

此の結果は利根川を境として，北方にある磐城沖及び鹿島灘の場合と反對である．

（3） 冬季太平洋岸の溫度が日本海岸の溫度より高くして其差が大なる時に，鬼怒川・利根川霞ケ浦沿岸に「有感覺地震」が起り易い．

（4） 冬季雨雪量が太平洋岸に多くして，日本海岸に少ない時，東京及び房總半島の「有感覺地震」が起り易い．之は大森博士の結果と反對である．

（5） 秋に日本海岸の降雨量が大なる時，相模及び伊豆半島の「有感覺地震」が起り易い．

（6） 冬季及び秋季雨雪量が，日本海岸に多くして太平洋岸に少なく其差が大なる程關東地方の海底に「顯著及び稍顯著地震」が起り易い．之は大森博士の結果と同樣である．

冬季日本海岸並びに太平洋岸共，氣壓が低く然も氣壓差（$B_J - B_P$）が大なる時にも海底の顯著及び稍顯著地震が起り易い．此の氣壓配置は低氣壓が太平洋上に現はれた時に相當する．

（7） 一般に地震は氣象狀態が變調なる時に起り易い．

（8） 冬季は他の季節より一般に大なる相關係數を與へる．之は恐らく季節風が冬季には最も著しく固定する爲であらう．

（9） 日本海方面に於ける冬季の雨雪量は關東地方の「顯著並びに稍々顯著地震」とは，正の相關係數を與へるが，之に反して「有感覺地震」に對しては負の相關係數を與へて居る．

（10） 關東地方の地震に對する日本海方面の雨雪量の影響は，太平洋岸の雨雪量の影響と反對の結果を與へて居る．而して前者は後者よりも一層影響が大きい．