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On the Effect of Topography on the Precipitation in Japan.

(Contribution III. from the Geophysical Seminary in the Physical Institute, College of Science).

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1. As to the general distribution of precipitation in Japan, there is an early investigation of Prof. Kiyoo Nakamura[1] He pointed out a marked difference of the annual course of the precipitation on the Pacific and Japan Sea sides. According to his results, Japan Sea side has abundunt precipitation in autumn and winter compared with spring and summer; the maximum falls in December and the minimum in May; but the seasonal fluctuation is generally small on this side. On the contrary, the Pacific side is characterized by abundunt precipitation in summer and autumn and also by a large fluctuation. He divided the Pacific side into five districts and described the peculiarities of each district in some details. Besides, he alluded to the remarkable effect of topography in some examples.

Recently, a Decennial Report of Precipitation,[2] 1901–1910, was published by the Central Meteorological Observatory, in which monthly records of observations in 1570 stations are given. In a note appended to the Report, Prof. Fujiwhara gave a brief account of the general distribution of precipitation in entire Japan, and confirmed in the main the results obtained by Prof. Nakamura. He also discussed the dependency of precipitation on the latitude

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[1] K. Nakamura, Dai-Nippon Hûdohen 大日本風土編 (Climatology of Japan), 1897, Chapter VI.

[2] Uryô-Zyûnenhô 雨量十年報. 1914.

and pointed out a peculiar fact that the decrease with the latitude is comparatively small in Southern Japan, but remarkable in the Northern, the dependency being quite different from those obtained by Murray and Supan.[1] He compared the relation with that of the temperature and precipitation and suggested an intimate physical connection between the latter elements. Moreover, he gave brief but suggestive discussions on the influences of the shielding mountains, altitude of the station, the slope of land, the distance from the sea *etc.*

In a previous communication,[2] we have shown a remarkable influence of topographical condition on the distribution of rain accompanying cyclone. The present note which gives a resumé of some statistical investigations on the relation of the geographical distribution of the yearly and mean monthly amounts of precipitation with the prevailing barometric gradients, may be regarded as a supplement to the previous note.

It may be remarked that the subject in question is not without interests also from the seismological point of view, since as already shown by Prof. Omori,[3] there exists a correlation between the yearly seismic frequency of some localities and the annual amount of precipitation in some other districts. It seems, however, still an open question whether the precipitation is the direct agent acting as a secondary cause of earthquakes, or it is rather the barometric gradient which affects the seismic origin and the precipitation at the same time. We will add later a few remark on this latter point, though unfortunately we were not yet able to trace the relation in any conclusive manner, on account of the want of data.

2. The data used for the yearly mean barometric pressure and precipitation were taken from Kisyôyôran of the Central Meteorological Observatory, the epoch ranging from 1900 to 1917, while for the monthly means, the materials were taken from the

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[1] Hann. Lehrbuch, 2. Aufl. p. 295.

[2] Terada, Yokota and Otuki, Journ. Coll. Sci. 37, Art. 4, (1916).

[3] F. Omori, Bull. I.E.I.C. Vol. II. No. 2.

Climatological Table of Japan[1] recently issued by the Central Meteorological Observatory.

Since it was our main purpose to study the effect of the discontinuity of wind velocity on land and sea, only those stations were chosen which are situated not far from the open coast facing either to the Pacific or to Japan Sea. The stations of which the yearly courses of rainfall were to be studied were grouped into the following six regions:

I. Akita and Niigata, representing the Northern Japan Sea coast.

II. Miyako, Isinomaki and Tyôsi, the Northern Pacific coast.

III. Husiki, Kanazawa and Hukui, the central Japan Sea coast.

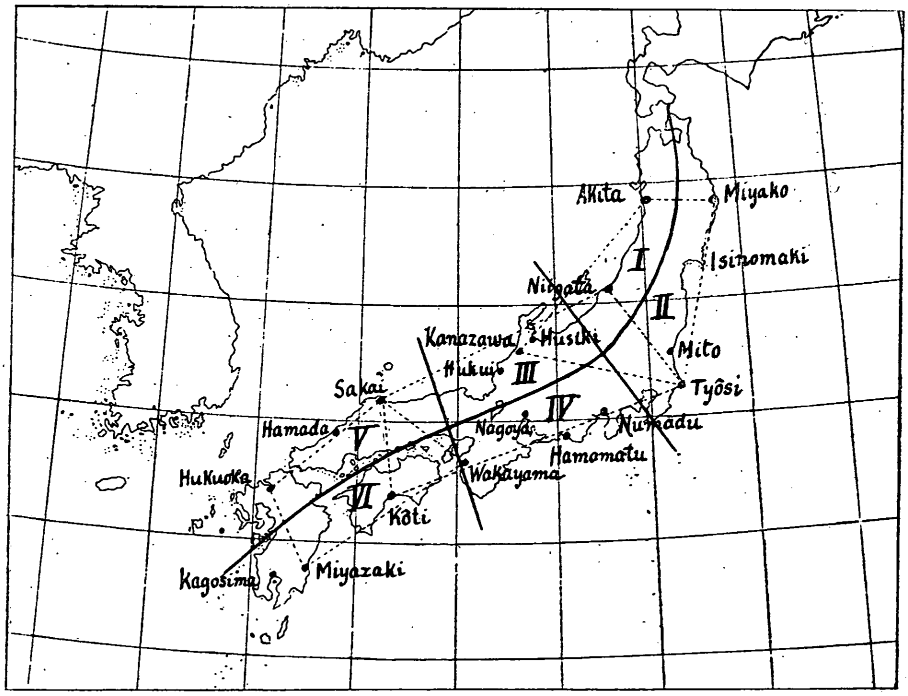

Fig. 1.

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[1] Kisyô-Zassan (氣象雜纂) Vol. I. No. 4, (1918).

IV. Numadu, Hamamatu and Nagoya, the central Pacific coast.

V. Sakai, Hamada and Hukuoka, the Southern Japan Sea coast.

VI. Kôti, Miyazaki and Kagosima, the Southern Pacific coast.

The distribution of the stations are shown in Fig. 1.

The choice of the stations may seem somewhat arbitrary, but we were led to it by different subsidiary considerations.

In some stations, the observations were interrupted once or twice during the interval of eighteen years taken. In order to fill up the gap, the following procedure was taken. When the amount of precipitation is wanting for a certain year at a given station, the ratio of the mean amount for the remaining seventeen years for the other stations in the same group to that of the station in question was taken and multiplied to the mean value of the year concerned of the other stations and the result was assumed as the reduced value to be replaced for the wanting data.

Though the annual amounts of precipitation recorded in Kisyô-yôran are given in mm. and its fractions so that the numbers are made up of five figures, it was considered convenient and rather reasonable for the present purpose to cut the figures to only three, stopping at the place of cm.

The data thus reduced are given in Table I.

TABLE I.*

Group	Year	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	Mean
I	Akita	186	165	185	214	196	196	154	155	154	148	184	220	175	178	198	177	167	234	183
	Niigata	195	186	169	188	(204)	213	171	174	161	169	204	223	181	189	191	172	192	232	190
	Mean	191	176	177	201	200	205	163	165	158	159	194	222	178	184	195	175	180	233	186
	%	103	95	95	108	108	110	88	89	85	86	104	119	96	99	105	94	97	125	**M.a.= 8.8**
	100 Anom./Mean Anom.	34	- 57	- 57	91	91	114	-136	-125	-170	-159	45	216	- 45	- 11	57	- 68	- 43	284	
II	Miyako	97	160	133	179	146	144	124	124	109	140	161	192	146	114	98	151	134	133	138
	Isinomaki	91	123	101	124	128	(118)	104	92	112	118	137	133	120	111	103	122	130	112	116
	Mito	130	124	162	163	128	151	120	153	142	154	174	168	170	166	146	163	773	133	151
	Mean	106	136	132	155	134	138	116	123	121	137	157	164	145	130	116	145	146	126	135
	%	79	101	98	115	99	102	83	91	90	102	116	121	107	96	86	107	108	93	**M.a.= 8.9**
	100 Anom./Mean Anom.	-236	11	- 22	169	- 11	22	-157	-101	-112	22	180	236	79	- 45	-157	79	90	- 79	
III	Husiki	218	211	201	256	222	267	218	(197)	200	241	252	(253)	210	215	237	182	235	301	229
	Kanazawa	254	256	253	299	268	287	263	223	254	274	258	294	242	268	252	212	272	348	269
	Hukui	230	221	239	245	265	230	226	218	250	250	269	271	238	237	203	222	264	339	245
	Mean	234	229	231	267	252	261	236	213	235	255	260	273	230	240	231	205	257	329	247
	%	95	93	94	108	102	106	96	86	95	103	105	111	93	97	94	83	104	133	**M.a.= 8.1**
	100 Anom./Mean Anom.	- 62	- 86	- 74	99	25	74	- 49	-173	- 62	37	62	136	- 86	- 37	- 74	-210	49	407	
IV	Numadu	177	168	215	279	176	235	192	233	222	203	306	250	185	157	200	331	219	188	213
	Hamamatu	193	203	201	250	176	210	174	248	212	213	264	259	169	141	189	194	214	207	207
	Nagoya	156	144	188	213	209	212	155	192	175	168	176	168	136	130	134	179	183	172	172
	Mean	175	172	201	247	187	219	174	224	203	195	249	226	163	143	174	201	205	189	197
	%	89	87	102	125	95	111	88	114	103	99	126	115	83	73	88	102	104	96	**M.a.=11.3**
	100 Anom./Mean Anom.	- 97	-115	18	221	- 44	97	-112	124	27	- 9	230	133	-150	-239	-106	18	35	- 35	
V	Sakai	172	175	209	193	215	223	192	197	178	183	198	209	187	178	190	203	226	191	196
	Hamada	144	147	157	159	155	178	174	149	137	164	165	182	155	131	161	153	198	178	160
	Hukuoka	180	171	174	146	152	220	161	150	172	180	172	(187)	159	126	182	190	168	168	170
	Mean	165	164	180	166	174	207	176	165	162	176	178	193	167	145	178	182	197	179	175
	%	94	94	103	95	99	118	101	94	93	101	102	110	95	83	102	104	113	102	**M.a.= 6.1**
	100 Anom./Mean Anom.	- 98	- 98	49	- 82	- 16	295	16	- 98	-115	16	33	164	- 82	-279	33	66	213	33	
VI	Kôti	300	260	335	313	180	324	243	252	284	241	230	323	250	234	263	281	338	220	271
	Miyazaki	261	261	276	261	150	345	270	(238)	252	274	201	254	266	206	271	265	266	262	254
	Kagosima	192	274	279	217	148	355	283	220	228	232	205	249	284	160	239	275	182	191	234
	Mean	251	265	297	264	159	341	265	237	255	249	212	275	267	200	258	274	262	224	253
	%	99	105	117	104	63	135	105	94	101	98	84	109	106	79	102	108	104	89	**M.a.=10.6**
	100 Anom./Mean Anom.	- 9	47	160	38	-349	330	47	- 57	9	- 19	-151	85	57	-198	19	75	38	-104	

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* For each station, the amount of precipitation is given in cm. The line % gives the amount in percentage of the mean value averaged over 18 years. The next line with the entry, 100 Anom./Mean Anom., is the deviation of the percentage value given in the preceding line from 100 expressed in percentage of the mean anomaly or deviation given in the last column. ( ) means the reduced value for the year **devoid of the datum.**

3. Referring to the above Table, it will be remarked that the mean annual precipitation is most abundunt in the region VI and least in II. In the middle Japan, the Japan Sea side III has decidedly larger precipitation than the Pacific side IV. On the contrary, in the SW Japan, the Pacific side VI has 1.44 times more precipitation than the Japan Sea side. In the NE part of Japan, it is again the Japan Sea side which has more precipitation, though the contrast is comparatively more pronounced than in the case of III and IV. The mean values of I-II, III-IV and V-VI are respectively 161, 222 and 214, while the difference, Japan Sea side minus Pacific side are respectively 51, 50 and –78.

According to our previous theory, this result might have been explained at least qualitatively, if we could assume an area of inland high pressure near the junction of the central and SW parts of Japan. That this is really the case may be seen from the annual isobar map. In the map, we see a general fall of pressure from the Asiatic continent toward the Pacific. The general slope is, however, disturbed by a remarkable tong or promontory protruding from Corea toward the central part of Japan along the axial line of the land. Such a distribution may conveniently be interpreted as due to the superposition of an elongated area of high pressure having its ridge near the western part of Honsiu, upon the nearly uniform slope from the continent to the ocean. Hence, according to our rule, the Japan Sea side has more and the Pacific less precipitation on the NE side of high area, compared with the ideal case where no such high existed. The reverse may be said with regard to the SW side of the high. The very marked contrast between III-IV and V-VI, shows that the above effect of the "tong" is rather prominent.

4. In discussing the matter more minutely, it is desirable to take the seasonal distribution of precipitation instead of the annual. In Table II. the mean monthly amounts of precipitation are given for the six regions concerned:

TABLE II.*

Group	Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	M=Mean S=sum
	Akita	122	99	106	111	113	146	198	187	191	162	184	171	S=1789
	Niigata	193	127	108	109	92	132	166	130	183	154	184	235	S=1813
	Mean	158	113	107	110	103	139	182	159	187	158	184	203	M=150
	%	105	75	71	73	69	93	121	106	125	105	123	135	M.a.=19.9
	100 Anom. / Mean Anom.	25	-126	-146	-136	-156	-35	106	30	126	25	116	176	
II	Miyako	71	66	88	99	124	135	143	179	206	161	69	63	S=1404
	Isinomaki	47	49	76	95	121	124	148	122	156	119	56	44	S=1157
	Mito	61	59	119	141	161	163	150	165	211	159	67	55	S=1509
	Mean	60	58	94	112	135	141	147	155	191	146	64	54	M=113
	%	53	51	83	99	119	125	130	137	169	129	57	48	M.a.=34.8
	100 Anom. / Mean Anom.	-135	-141	-49	- 3	55	72	86	106	198	83	-124	-149	
III	Husiki	239	164	137	134	114	151	193	160	204	151	200	323	S=2172
	Kanazawa	269	186	164	170	147	181	202	180	226	194	259	357	S=2534
	Hukui	249	218	163	159	151	192	190	168	188	166	213	335	S=2391
	Mean	252	189	155	154	137	175	195	169	206	170	224	338	M=197
	%	128	96	79	78	70	89	99	86	105	86	114	172	M.a.=19.7
	100 Anom. / Mean Anom.	142	-20	-107	-112	-152	-56	- 5	-71	25	-71	71	366	
IV	Numadu	83	77	150	200	187	220	234	229	280	172	104	75	S=2012
	Hamamatu	63	68	147	203	212	240	214	205	271	157	100	69	S=1949
	Nagoya	60	64	129	170	166	225	192	181	243	148	81	52	S=1712
	Mean	69	70	142	191	188	228	213	205	265	159	95	65	M=158
	%	44	44	90	121	119	144	135	130	168	101	60	41	M.a.=36.6
	100 Anom. / Mean Anom.	-153	-153	-27	57	52	120	96	82	186	3	-109	161	
V	Sakai	203	143	144	136	113	166	163	131	221	162	157	195	S=1931
	Hamada	115	98	112	138	123	193	164	128	177	121	100	114	S=1592
	Hukuoka	68	81	112	136	125	249	245	140	189	101	72	76	S=1583
	Mean	129	74	123	136	120	203	191	133	196	128	110	128	M=142
	%	91	52	87	96	85	143	135	93	138	90	77	90	M.a.=21.3
	100 Anom. / Mean Anom.	-42	-226	-61	-19	-70	202	164	-33	178	-47	-108	-47	
VI	Kôti	69	98	186	300	292	355	328	279	419	225	125	79	S=2754
	Miyazaki	81	101	187	245	271	383	270	255	349	226	125	74	S=2566
	Kagosima	92	92	158	232	229	415	291	175	240	139	91	84	2240
	Mean	81	97	177	259	264	384	296	236	336	197	114	79	M=210
	%	39	46	84	123	126	183	141	112	160	94	54	38	M.a.=40.8
	100 Anom. / Mean Anom.	-150	-132	-39	56	64	203	100	29	147	-15	-113	-152	

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* Precipitation is given in mm: The line % gives the monthly mean of different stations expressed in % of the mean for all month. The next line gives the deviation of the % values from 100, expressed in % of the mean value of diviation (m.a.)

TABLE III.

Mean & Diff.	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
$\frac{1}{2}$(I+II)	109	86	101	111	119	140	165	157	189	152	124	129
$\frac{1}{2}$(III+IV)	161	130	149	173	163	202	204	187	236	195	160	202
$\frac{1}{2}$(V+VI)	105	86	150	198	192	294	244	185	266	163	112	104
I—II	98	55	13	−2	−32	−2	35	4	−4	12	120	149
III—IV	183	119	13	−37	−51	−53	−18	−36	−59	11	129	273
V—VI	48	−23	−54	−123	−144	−181	−105	−103	−140	−69	−4	49

In Table III., we give the mean values and the difference of the Japan Sea and Pacific sides of the NE, Central and SW parts of Japan respectively. Referring to the latter, we may remark several interesting facts. Firstly, the mean values of the both sides, are greatest in the Middle part III-IV, during the colder months Oct.-Feb., while it is so in the SW part during the warmer months, Mar.-July and Sept. While during the colder months, the NE and SW regions have nearly same amounts of precipitation, contrasted with the large amount in the Middle Japan, the amount of precipitation during the warmer season continously falls off from the SW towards the NE districts. Secondly, the difference, Japan Sea side minus Pacific side show quite parallel course, but the mean value successively falls off from the Northern part to the Southern. Thirdly, among different possible combinations of cases,

I>II, III>IV, V>VI occurs in January and December,
I>II, III>IV, V<VI occurs in February, March, October and November,
I<II, III<IV, V<VI occurs in April, May, June, and September,
I>II, III<IV, V<VI occurs in July and August.

But the remaining two cases:

I<II, III<IV, V>VI, and I<II, III>IV, V>VI

do not occur actually.

A full discussion of these characteristic distributions will be given in the later part of this paper. Here, it may suffice to draw the attention of the readers to the remarkable mode of distribution in which the influence of topography plays an important rôle.

5. Turning our attention to the amount of the yearly fluctuation, the most prominent feature is the difference of the mean anomalies on the both sides of the land; the Japan Sea side showing generally less fluctuation than the Pacific. On the latter side the amount is least in II and greatest in VI, while on the Japan Sea side it is the least in V.

In Table I, we have given the yearly amount of precipitation also in percentages of the mean value and besides, the percentage fluctuation of the yearly percentage values are given in the next line. We reproduce here in Table IV. the mean anomalies of the percentage values for the six regions. On the Pacific side the anomaly is the least on the northern part of Japan whereas in the Japan Sea side it is least in the Southern. While the mean values of the anomalies of the both sides are not very different for the different parts, the contrast between the both sides is most prominent in the southern part.

TABLE IV.

	NE	Middle	SW	Mean
Japan Sea Side	I 8.8	III 8.1	V 6.1	7.7
Pacific Side	II 8.9	IV 11.3	VI 10.6	10.3
Mean	8.85	9.7	8.35	9.0
Difference	0.1	3.2	4.5	2.6

6. The mean of the amount of precipitation for the Japan Sea side I, III, V is 203 and for the Pacific side II, IV, VI 195. The difference is not remarkable. On the other hand, the mean anomaly for the Japan Sea side is 7.7 while is it 10.3 for the Pacific. Thus it appears that the Pacific side is generally more "sensitive" to the main causes of the fluctuation, among which

the barometric gradiet must be one of the most important. If such be the case, due consideration must be paid to this point, if we are to attempt to compare the amount of precipitation on both sides of the land and thereby deduce some topographical relation with respect to the barometric gradient. If this precaution is not made, the difference between the both sides will be largely determined by the side on which the amount is decidedly larger. Hence the deviation of the yearly percentage value from the mean, *i. e.* 100, was divided by the mean anomaly. These quotients (Table I.) were adopted for the final data to be used in the comparison with the barometric gradient.

7. The barometric gradients of the different parts of Japan, to be used for the comparison with the precipitation may be obtained in different ways. Referring to the mean annual isobar chart, the isobaric surface over the land is far from being nearly plane, chiefly due to the protruding area of high pressure lying along the axial line of the land. On account of the latter, the actual gradients on both sides in different parts of Japan may differ considerably from each other and may even have nearly opposite directions. In the present investigation, however, we will at first put the axial high out of consideration, which is in all probability very shallow phenomena, brought out by the reduction to sea level, and take the gradient obtained from the coastal stations. The general procedure taken is as follows. For the Northern Japan I II, for example, we choose four coastal stations, say Akita, Kanazawa on the Japan Sea side and Miyako, Tyôsi on the Pacific side, forming the angular points of a quadrilateral, as nearly rectangular as possible, including the region in question. The difference of the pressure on both sides divided by the mean distance may be taken as the measure of the gradient in the direction combining the centre of the opposite sides.[1] If the quadrilateral be nearly rectangular, we obtain thus the two rectangular components of the gradient. The stations chosen for the purpose are as follows (see Fig. 1) :

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[1] In the case when the isobaric surface is nearly plane, it will be plausible to take a triangle for the determination of gradient. But in such a case as is here concerned, the procedure mentioned above seems more advisable as giving a kind of mean gradient.

Akita, Kanazawa, Miyako and Tyôsi for Northern Japan I-II,

Niigata, Sakai, Tyôsi and Kôti for Middle Japan III-IV,

Sakai, Hukuoka, Wakayama and Miyazaki for Southern Japan V-VI.

The difference of the means, Japan Sea pair minus the Pacific, reduced to the gradient corresponding to 111 km. distance was taken as the x-component. For the y-component, the difference was taken between the mean value on the opposite sides of the rectangle running transverse to the axis of the land, the positive sign corresponding to the case when the SW side is higher than the NE side. The mean distance between the opposite side was roughly estimated on a map, scale 1:16,000,000.

Thus the component gradients x_1, y_1, x_2 y_2, x_3 y_3, for the three regions I-II, III-IV, V-VI, respectively were obtained according to the following schema:

$$x_1=\left(\frac{\text{Akita}+\text{Kanazawa}}{2}-\frac{\text{Miyako}+\text{Tyôsi}}{2}\right)\times 0.386$$

$$y_1=\left(\frac{\text{Kanazawa}+\text{Tyôsi}}{2}-\frac{\text{Akita}+\text{Miyako}}{2}\right)\times 0.248$$

$$x_2=\left(\frac{\text{Niigata}+\text{Sakai}}{2}-\frac{\text{Tyôsi}+\text{Kôti}}{2}\right)\times 0.435$$

$$y_2=\left(\frac{\text{Sakai}+\text{Kôti}}{2}-\frac{\text{Niigata}+\text{Tyôsi}}{2}\right)\times 0.165$$

$$x_3=\left(\frac{\text{Sakai}+\text{Hukuoka}}{2}-\frac{\text{Wakayama}+\text{Miyazaki}}{2}\right)\times 0.463$$

$$y_3=\left(\frac{\text{Hukuoka}+\text{Miyazaki}}{2}-\frac{\text{Sakai}+\text{Wakayama}}{2}\right)\times 0.267$$

It must be remarked that in the case of x_1 y_1, the two components are not even nearly rectangular, so that this point must be remembered when a quantitative relation is concerned. But for the most purpose in the present investigation, the general qualitative relations are not seriously modified by treating the components as rectangular. The values of the components thus obtained are contained in Table V.

TABLE V.

Region	Component \ Year	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	Mean
I, II.	x_1	.15	.15	.15	.31	.17	.10	.19	.12	.17	.15	.21	.29	.31	.29	.25	.14	.17	-.10	.18
	y_1	.10	.05	.05	.07	.06	.11	.10	.07	.06	.05	.01	.09	.07	.09	.11	.09	.01	-.09	.06
III, IV.	x_2	.00	.22	.17	.17	.07	.11	.22	.15	.17	.20	.28	.28	.33	.30	.15	.22	.22	.13	.19
	y_2	.10	.12	.08	.10	.07	.02	.10	.04	.10	.07	.11	.06	.12	.13	.12	.07	.07	.20	.11
V, VI.	x_3	.16	.19	.09	.12	.16	.09	.16	.19	.19	.14	.16	.14	.19	.23	.07	.14	.14	.09	.15
	y_3	-.01	.00	-.03	-.01	.04	-.05	-.01	.00	.03	.00	.04	.03	.05	.08	.04	0.3	.00	.16	.02

TABLE VI.

Diff. \ Year	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	Mean
I—II	270	-68	-35	-78	102	92	21	-24	-58	-181	-135	-20	-124	34	214	-147	-124	363	+5.4
III—IV	35	29	-92	-122	69	-23	63	-297	-89	46	-168	3	64	202	32	-228	14	442	-1.1
V—VI	-89	-145	111	-120	333	-35	-31	-41	-124	35	184	79	-139	-81	14	- 9	175	137	+1.8

8. In comparing the yearly barometric gradient with the difference of yearly precipitation on both sides of the land, several procedures were tried among which the following seems to be most convenient for demonstrating the topographical influence.

To take, for example, the case of the Northern Japan I-II, a vector diagram (Fig. 2) of the yearly barometric gradient was plotted on a sheet of coordinate paper, the end point of the vector for each year being marked and numbered according to the number of the year. On the other hand the *difference* of the values:

$$\frac{\text{Yearly anomaly of the percentage value of precipitation}}{\text{Mean anomaly ,, ,, ,, ,,}}$$

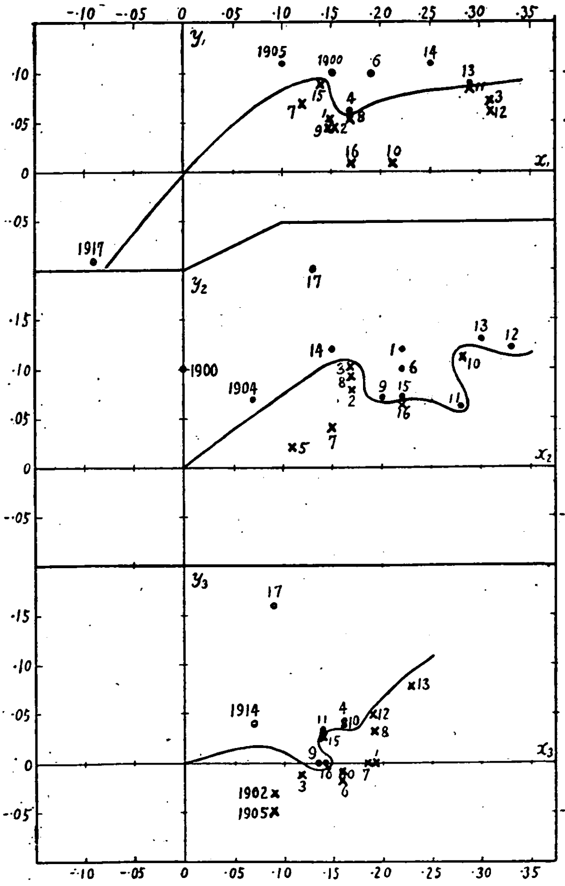

Fig. 2.

of the region I and II, was taken (Table VI) for successive years. Then the points on the vector diagram were classified according as the above difference of the both sides is positive or negative. Carrying out the procedure, it was found that the points belonging to the two classes may be separated by a boundary line dividing the area of the diagram into two halves. Though the line of demarcation is more or less sinuous, it may be compared for very rough approximation with a straight line making an angle of about 20° or 30° with the axis of x.

This latter result is exactly what may be expected from our previous elementary theory, except that the angle expected from the calculation was 13° instead of 20 or 30°. The fact that the actual angle is decidedly larger than the calculated, points to the conclusion that the difference of the angles between the wind and the barometric gradient on land and sea must be assumed much larger than in the previous paper. This discrepancy may probably be explained if we consider that the angle between the gradient and the wind increases generally with the height and also that in calculating the vertical displacement of air caused by the discontinuity of the horizontal flow on the boundary of land and sea, it is reasonable to take the data of calculation from a certain mean or "effective" height from the sea level. If the years of observation be multiplied several times, we may obtain sufficient number of points on the vector diagram for drawing a more definite line of demarcation and thence deduce something about the effective height above mentioned. Moreover, it seems quite possible that the sinuosity of the boundary curve may have a real significance, since the "effective height" may be a function of the velocity of wind as well as the direction of wind determined by the irregularity of topography. These latter points of interests must be postponed to a future when a sufficient materials would have accumulated.

9. In passing, it may be observed that vector diagram above described is very convenient for investigating the sensibility of different stations with respect to the barometric gradient, or in other worlds the mode and degree in which the topographic conditions affect the precipitation of the stations. Taking the

diagram for a given region, we classify different years according as the precipitation of a certain station situated in the said region, is above or below the normal value, and mark the corresponding points with proper signs. Then if the station is especially sensitive to the gradient, the points belonging to the two classes will be separated by a definite line of demarcation on the area of the diagram. Carrying out the procedure for the different stations chosen above, it was found that some Pacific stations such as Numadu, Hamamatu, Kôti *etc.* show striking dependency on the topographical rain, whereas most of the Japan Sea stations show rather irregular aspects. It was suspected that the latter fact could be explained by the influence of the high pressure zone along the axial line of the land. Choosing a number of stations near the axial lines, we have calculated the gradient between these axial stations and the coastal stations on both sides of the land respectively. It was found that the gradient between the axial part and the Pacific coast, say *s*, is generally parallel or at least have the same sign with the x-component above obtained, whereas the pressure difference between the axial and the Japan Sea regions, say *n*, has frequently different signs with x. On plotting n-y diagram instead of x-y diagram, however, the distribution of the years belonging to the above two classes for the case of the Japan Sea stations is still very irregular. We may therefore infer that on this side of Japan some other terms predominates over the effect above considered, as far as the annual amount of precipitation is concerned. We will resume the question in a later section in connection with the seasonal distribution.

10. A similar comparison can be made with respect to the

TABLE VII.

Region	Month / Compt.	I	II	III	IV	V	VI	VII	VIII	XI	X	XI	XII	Year
I, II.	x_1	.66	.66	.50	.17	.06	-.17	-.14	-.27	-.15	.17	.42	.61	.23
	y_1	.27	.27	.14	.06	.04	-.04	-.06	-.10	-.10	-.06	.14	.33	.07
III, IV.	x_2	.43	.54	.52	.20	.02	-.15	-.15	-.15	.11	.41	.39	.30	.17
	y_2	.36	.34	.15	-.02	-.01	-.06	-.04	-.11	-.11	.01	.18	.40	.10
V, VI.	x_3	.21	.32	.25	.09	.00	-.14	-.21	-.12	.19	.37	.23	.21	.09
	y_3	.20	.16	.01	-.03	-.03	-.03	-.04	-.09	-.13	-.05	.08	.31	.04

TABLE VIII.

Diff. \ Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
I—II	160	15	−97	−133	−211	−107	20	−76	−72	−58	240	325
III—IV	295	133	−80	−167	−204	−176	−101	−153	−161	−74	180	527
V—VI	108	−94	−22	−75	−134	− 1	64	−62	31	−32	5	105

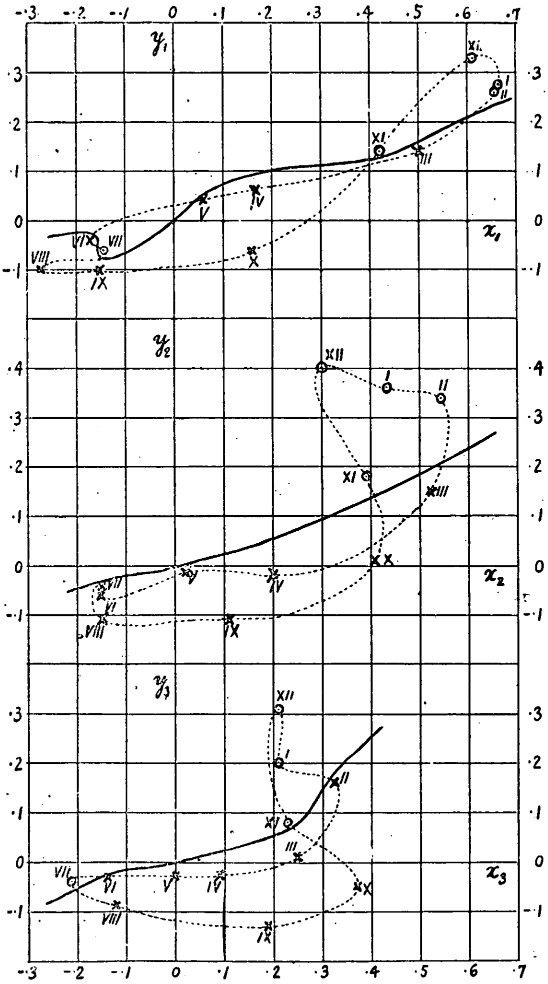

Fig. 3.

monthly value of precipitation and the barometric gradient. Table VII gives the mean monthly gradient to be compared with the precipitation given above in Table II. In Table VIII, the differences of the percentage anomaly, obtained in similar manner as in Table VI are given. The vector diagrams plotted in exactly same manner are given in Fig. 3. Here also the months with more than usual excess of precipitation on the Japan Sea side, are distributed on the one side of a line of demarcation, similar as in the case of the yearly amount.

From the results thus far obtained, it seems certainly worth while to apply the vector diagram method to the relation of the precipitation and barometric gradient of each month of each year, instead of taking the monthly or the yearly means, since as is well known the fluctuation of the monthly means of the both elements are considerable. At present, we must refrain from the task on account of the want of time, with a hope that in some days we will be able to resume the investigation.

11. In section 3, we have already alluded to the peculiar distribution of the precipitation of the different regions in different seasons. We will now make an attempt to interprete or analyse the actual distribution in terms of the elementary theory proposed.

Let us put at first for a trial:

$$\begin{aligned} r_1 &= R_1 + c_1, & r_2 &= R_1 - c_1'. \\ r_3 &= R_2 + c_2, & r_4 &= R_2 - c_2', \\ r_5 &= R_3 + c_3, & r_6 &= R_3 - c_3', \end{aligned} \qquad \text{(A)}$$

where c_1, c_2, c_3 *etc* represent the effects of the topography which will be considered as some functions of the barometric gradients, varying from month to month. R_1, R_2, R_3 represent the principal terms which will prevail in absence of the topographical influence. It seems plausible to assume that the c's are proportional to c''s, if not equal, so that we will put

$$c_1' = ac_1, \quad c_2' = ac_2, \quad c_3' = ac_3.$$

The factor a must vary with season, but it must be generally positive if our theory be valid. Further, on the basis of the approximate equality of the annual amounts of $r_3 + r_5$ and $r_4 + r_6$, we will assume provisionally that $R_2=R_3=R'$ Putting R for R_1, the above expressions (A) assume the following forms:

$$\begin{aligned} r_1&=R+c_1, & r_2&=R-ac_1, \\ r_3&=R'+c_2, & r_4&=R'-ac_2, \\ r_5&=R'+c_3, & r_6&=R'-ac_3, \end{aligned} \qquad \text{(B)}$$

from which we may determine the values of R, R', a, c_1, c_2 and c_3:

$$\begin{aligned} a &= \frac{r_3-r_5}{r_6-r_4}, & & \\ c_1 &= \frac{r_1-r_2}{1+a}, & R &= r_1-c_1, \\ c_2 &= \frac{r_3-r_4}{1+a}, & R' &= r_3-c_2. \\ c_3 &= \frac{r_5-r_6}{1+a} & & \end{aligned} \qquad \text{(C)}$$

The results of calculation are given in Table IX. and Fig. 4.

TABLE IX.

Month	a	c_1	c_2	c_3	R	R'
I	0.098	89.2	166.7	43.7	69	85
II	0.235	44.5	96.3	−18.6	68	93
III	1.094	6.2	6.2	−25.8	101	149
IV	3.780	−0.4	−7.7	−25.7	110	162
V	4.471	−6.0	−9.3	−26.3	109	146
VI	−5.570	0.4	11.6	39.6	139	163
VII	20.75	1.6	−0.8	−4.8	180	196
VIII	0.861	2.2	−19.3	−55.4	157	188
IX	7.100	−0.5	7.3	−17.3	188	213
X	0.905	6.3	5.8	−36.2	152	176
XI	0.167	102.8	110.5	−3.4	81	113
XII	0.067	139.6	255.9	45.9	63	82

It may be remarked that a comes out generally positive, except in June. It is generally less than unity in the colder season and greater than unity in warmer months. Each of c_1, c_2, c_3,

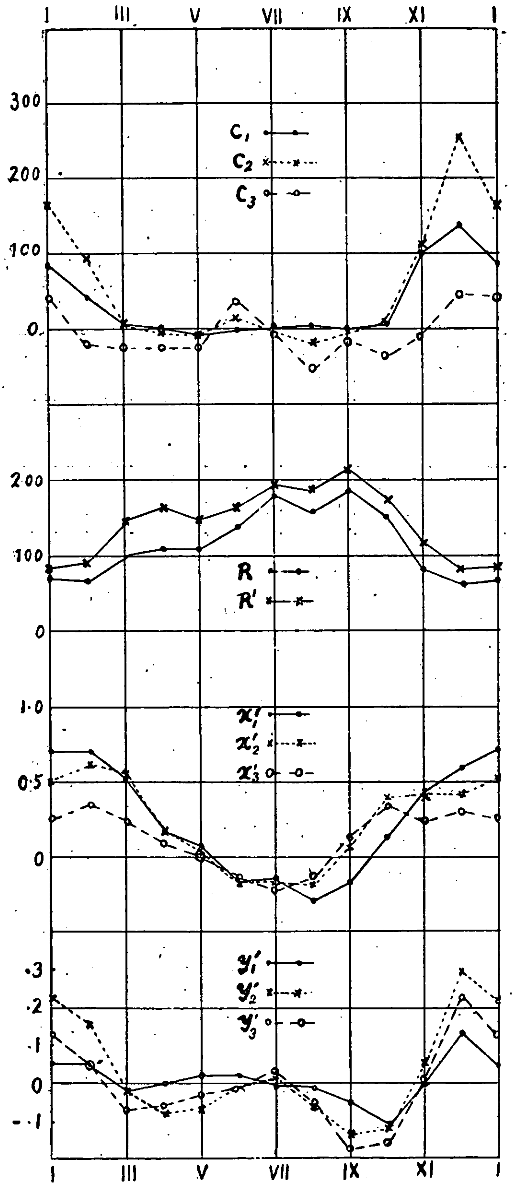

Fig. 4.

which run nearly parallel to each other, shows a maximum in winter and a secondary maximum in summer. We may also remark a parallelism of R and R'.

The fact that a for June becomes negative is no serious objection to our theory, but rather due to the inadequacy of the simple assumption (B). This might have been easily avoided if for an instance we distinguish R_2 and R_3 instead of putting them equal to each other. Assuming $a=12.6$ which is the mean values of a's for May and July, and putting

$$r_5=R'+R''+c_3,$$
$$r_6=R'+R''-ac_3$$

we obtain $R''=39$, $c_1=-.15$, $c_2=-3.90$ and $c_3=-13.30$. Thus the positive values of c's disappears. Substituting these values of c's, however, the general feature of the c-curves is not altered.

According to our previous theory, the values of c's must chiefly depend on the component of the barometric gradient parallel to the y'-axis making an angle of about 20° with the y-axis. Calculating the x'- and y'-components by

$$x' = x \cos 18^\circ + y \sin 18^\circ$$
$$y' = y \cos 18^\circ - x \sin 18^\circ$$

it was found that the general course of the y'-component (Table X and Fig. 4) is quite similar to that of c.

TABLE X.

Region	Month / Compt.	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
I, II.	x_1'	.71	.71	.52	.18	.07	-.17	-.15	-.29	-.17	.14	.44	.59	.24
	y_1'	.05	.05	-.02	.00	.02	.02	-.01	-.01	-.05	-.11	.00	.13	.01
III, IV.	x_2'	.52	.62	.54	.18	.02	-.16	-.16	-.18	.07	.39	.43	.41	.19
	y_2'	.22	.16	-.02	-.08	-.07	-.01	.01	-.06	-.14	-.12	.05	.29	.02
V, VI.	x_3'	.26	.35	.24	.08	-.01	-.14	-.22	-.14	.14	.34	.24	.30	.10
	y_3'	.13	.05	-.07	-.06	-.03	.01	.03	-.05	-.18	-.16	.01	.23	-.01
Mean	x'	.50	.56	.43	.15	.03	-.16	-.18	-.24	.01	.29	.37	.43	.18
	y'	.13	.09	-.04	-.05	-.03	.01	.01	-.04	-.12	-.13	.02	.22	.01

As to the terms R and R' which represent the parts of the precipitation independent of the local topography, we may remark that the general annual variation is such as to be easily explained by yearly course of temperature and humidity, though the high values in September and October may probably be due to the cyclones prevalent in this season.

From the above results, it may be seen that on the Pacific side, the seasonal fluctuations of the general term R and R' are generally enhanced by the topographical effect in warmer as well as in the colder seasons, whereas on the Japan Sea side the seasonal variation is partially compensated by the topographical influence. This is the formal explanation based on the present theory why the seasonal variation is small on the latter side.

In a previous paragraph we have mentioned that on the Japan Sea side, the yearly fluctuation of the precipitation shows no regular relation with the gradient components x and y, and inferred that on this side some other agents must prodominate over the above gradient. It is interesting to observe that here in the seasonal fluctuation, the effect of topography appears conspicuous, the effects of the other agents being apparently eliminated by taking average of different years.

The formula (B) fails in the case of the yearly variations, the values of c's obtained showing no regular relation with the components of the barometric gradient. Besides, their values are generally a small fractions of the general terms R and R'. The simple assumption is therefore inadequate in this case. One point of interest is that the values of a thus obtained are generally positive and their mean value is very nearly equal to unity, being, 1.002, which points to the inference that on an average $r_3-r_5 =r_6-r_4$. The latter fact could only be explained by the presence of the high pressure area on the axial line of the land, as already mentioned in § 3.

From the mere mathematical points of view, the above method of analysis is nothing more than the substitution of the six given amounts of precipitation by the new six quantities R, R', a and c's. Neither is the substitution the unique one possible. The chief physical interests, however, consist in the fact that the apparently irregular distributions of the precipitation may thus be explained at least in its main feature by the combination of the topographical effects on the basis of the simple elementary theory. These results may turn out useful for the practical purpose, as soon as the long period forcast of the barometric conditions becomes a matter of practice, the possibility of which is nowaday anything more than the dream of the modern meteorologists.

12. As already cited at the beginning of this note, Prof. Omori shew that there exists a remarkable parallelism between the yearly amount of precipitation at Niigata, a Japan Sea station, and that of the earthquake at Tôkyô. In the present invesigation, the earthquakes originating in the submarine zone extending from Kinkwazan to Idu were chosen from the Kisyô-yôran. The yearly number of occurrence is given in the first line of the Table XI and plotted in Fig. 5. Comparing the graph with that of precipitation in different stations or regions, it was found that the correlation is rather remarkable in the case of the mean fluctuation of precipita-

TABLE XI.

Year	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917
Earthquake No.	—	6	24	26	40	48	42	28	23	42	37	44	31	24	29	64	26	22
Bar. Diff.	-.20	-.53	-.50	-.43	-.20	-.38	-.23	-.28	-.40	-.43	-.18	-.25	-.18	-.35	-.53	-.33	-.23	-.38
Precip. (II+IV+VI)/3.	-1.14	-.19	.52	1.43	1.35	1.50	-.74	-.11	-.25	-.02	.86	1.51	-.05	-1.61	-.81	.57	.54	-.73

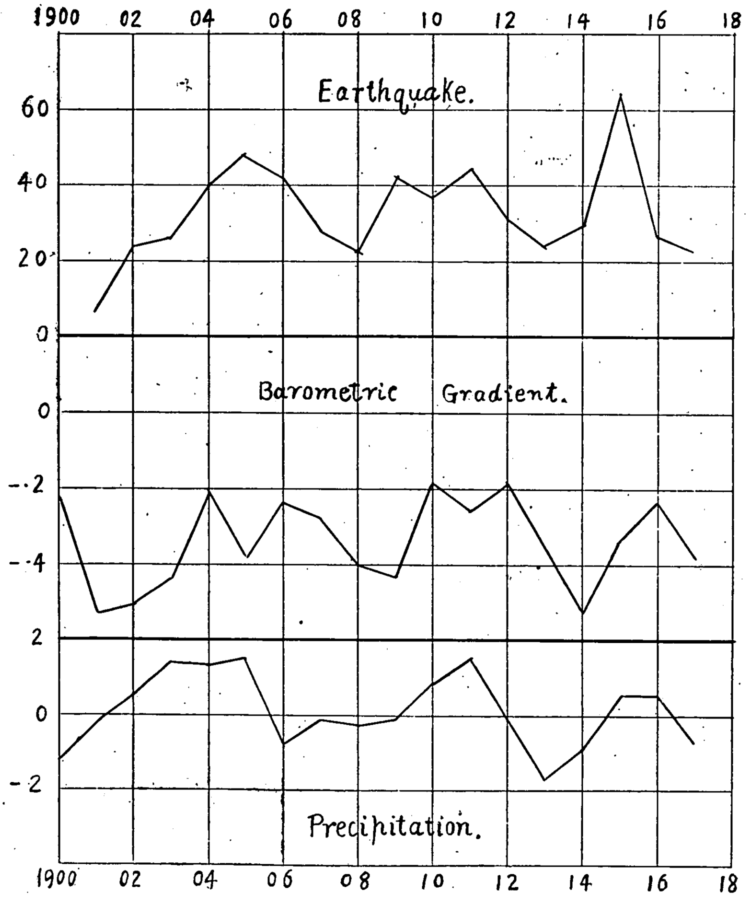

Fig. 5.

tion of the entire Pacific regions, *i.e.* (II+IV+VI)/3,[1] which is given in the third line of the Table. The Japan Sea side, (I+III+V)/3 shows nearly similar yearly variation as the Pacific, except in a few years.

Since the intimate relation of the earthquake frequency and the barometric gradient has been already fully established by the investigations[2] of one of the authors and also of K. Hasegawa and Saemontarô Nakamura, it was suspected that it may be also the barometric gradient that directly determines the rainfall on the one hand and the earthquake on the other hand. Hence the earthquake frequency was compared with the different components of the gradient prevailing in different parts of the land. After a series of trials, it was found that the difference of the barometric pressure, the Japan Sea stations minus the inland stations, shows a parallel course with the earthquake frequency. Taking for the inland stations Matumoto, Takayama, Hikone and Osaka, and for the Japan Sea coastal stations Niigata, and Sakai, the difference is given in the second line of the Table. XI.

Comparing this with the earthquake frequency (Fig. 5), it will be seen that the earthquake curve shifted about one year earlier, shows a rather remarkable parallelism with the gradient curve. Whether the very curious correlation is merly accidental or not, cannot be ascertained at present from such a scanty material. Though the apparent relation may appear rather absurd, the possibility of such a coincidence cannot be excluded by a superfical consideration, if we consider for an instance that the precipitation of the last year may affect the barometric pressure of the year concerned.

A further investigation in this line is now in progress and we hope will be able to clear up the apparent mystery in a near future.

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[1] Here the values of (anomaly)/(mean anomaly) was averaged for the three regions.

[2] T. Terada, Proc. Tôkyô Math.-Phys. Soc., vol. IV (1908) p. 454; K. Hasegawa, *ibid.* Vol. VII (1913), p. 181; S. Nakamura. *Ibid.* Vol. VIII (1915), p. 69.

Summary.

1. The remarkable influence of topography on the distribution of precipitation is demonstrated with respect to the yearly as well as the monthly amounts.

2. A vector diagram method of investigating the different relations of the precipitation with the barometric gradient is illustrated.

3. The neccesity of taking the percentage values of the precipitation is emphasized.

4. The rainfalls in different districts are analysed in terms of the topographical effects. It is shown that the effect is largely determined by the component of the barometric gradient taken in a direction a little inclined to the axial line of the land, as was expected from the elementary theory proposed.

5. A peculiar relation between the earthquake frequency and the barometric gradient is pointed out.

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