Dai 3 Gô.

(Nukigaki)

Nippon no Kaigan no zyûnino Basyo ni okeru Kaze no nitinitino no Henkwa.

Syoin Rigakuhakusi TERADA-T.,
Syoin Rigakusi KOBAYASI-T.

Taiwan kara Hokkaido made irete, tugo 14-kasyo no Itto-sokkozyo no Maizi-kwansoku no 8-nen no aida no Zairy ni yotte, 4-, 8- oyobi 12-gwatu ni okeru, 2-zikan gotono, iroirono Muki no Kaze no Kwaisû wo sirabe, sore no *Resultant* no itinitidyûno Henkwa wo sirabeta.

Konoyô ni site eta Kwaisû no *Resultant* to, sokudo no *Resultant* to no Kwanken wo ronzi, hutatuno mono ga daitaini hireisuru koto wo simesita.

Tôkeitekino Sirabe no Kekkwa wo Du ni arawasite, iroirono Basyo no Tokutyô wo age, sore wo Toti no Eikyô nado de setumeisiyô to kokoromita. Tatoeba, Setonaikai-tihô no 'Yûnagi' no Setumei wo ataeta.

Ueno Kekkwa wo Tyôwabunseki ni kakete, sono Keisû ga Basyo narabini Kisetu ni yotte kawaru Moyô wo sirabeta. Kisetu-no-Kaze to itiniti- oyobi hanniti-syûkino Kaze to wo betubetuni sirabeta. Daen-undô no Katati ya Ookisa no tôkeitekino Kwankei, sore to Kisetu-kaze to no Kwankei nado wo ronzita. Mata, Umi ga Basyo no Kitagawa ni aru no to Minamigawa ni aru no to de itizirusii Tigai no aru koto nado wo setumeisita.

Saigoni, nitinitino Henkwa wo hutatu ni wakete, Kairikuhû no yôni semai Kuiki no Toti no Eikyo ni yoru Bubun to, sore yorimo zutto hiroi Rikuti zentai to Umi to no Kubarikata ni yoru Bubun to wo betubetuni sirabeyô to kokoromita. Sono Kekkwa tosite sirareta Koto wa, sukunakumo Wagakuni dewa, Tikyû-zentai no Kûki no Sindô ni yoru Kaze no Nitiniti-henkwa ni kurabete tihôtekino Eikyô ni yoru Henkwa no hô ga itizirusiku ôkina koto de aru.

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On the Diurnal Variation of Winds in Different Coastal Stations of Japan.

By

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1. Introduction.

The diurnal variations of wind velocity and direction have already been investigated by many meteorologists[1] for different localities and the main features of the remarkably regular variation of this meteorological element, intimately associated with the periodic change of solar radiation, are long since widely known. Nor are the theoretical explanations wanting as far as the most fundamental physical factors determining the phenomena are concerned. Still, it must be remembered that there remains a number of interesting problems awaiting elucidation when the inquiry is pushed a little further into the actual details of the matter. Moreover, the remarkable influence of local conditions on the allied phenomena makes it highly desirable that data from as different localities as possible should be accumulated and discussed, in order to get a clear insight of the mechanism of the phenomena in question. With these points in view, it will not be considered quite superfluous to describe here in some detail the results of our investigations of the diurnal change of the frequency of winds for a number of stations widely distributed along the entire coast of our country, especially because in these localities the effects of the geographical conditions

(1) In this country, Dr. Tsuiji's work on the wind of Nagasaki may be mentioned. Bulletin of the Central Meteorogical Observatory, No 4.

are very conspicuous, as will be seen later on. On the other hand, the present results may serve, we hope, as a provisional guide in this line for the airmen of this country.

As a matter of fact, the present investigations were taken up several years ago when one of the authors (T. K.), then a student of the College of Science, began a study of the remarkable occurrence of '*Yûnagi*' (evening calm), especially notorious in the Setonaikai districts, as a course of exercise in the Geophysical Seminary, in conjunction with Mr. Kizô Kabayama. The preliminary study soon made it clear that for the through investigation of this special phenomenon, it was desirable to extend the study to the entire coast of our land. After his appointment as a member of the Aeronautical Research Institute, he resumed the work and carried out the most laborious parts of the numerical calculations.

It is partly on account of the above circumstances that the present investigation refers entitely to the variation of the *frequency* of winds in different directions, leaving out of consideration the magnitude of the velocity. This point must be remembered from the outset in order to avoid any misunderstanding, though in the following paragraph we will attempt to show that there exists a rather intimate relation between the variation of the frequency here considered and that of the velocity.

2. Relation between the Resultant of the Frequencies of Wind and the Mean Velocity.

Fixing our attention on a certain hour of day in a given season or month, for a given station, we gather up the results of observations extending over a sufficient number of years. The results are then classified according to each of the sixteen directions.

The number of occurrence of a given direction of wind, divided by the number of days taken, gives the probability of that wind at the given hour of the given season or month for the station in question. Assigning this value to each corresponding direction, we obtain sixteen vectors, the resultant of which gives us a measure of the prevalent wind for the hour in question. It is this resultant with which we are here chiefly concerned and we call it the *frequency* for simplicity's sake. This quantity is of course essentially different from the usual *resultant* or *mean* wind corresponding to the same hour, in which the velocity is taken into account and the vector sum or mean of different winds is implied.

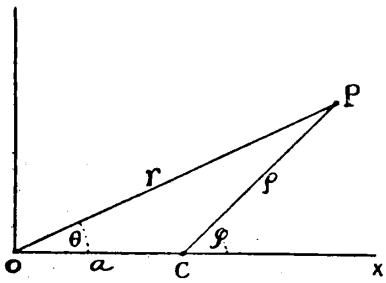
If we denote the probability of the wind falling in the direction interval θ to $\theta+d\theta$ by $f(\theta)$, and the mean velocity corresponding to that direction by $v(\theta)$, the components of the mean velocity are given by :

$$\begin{aligned} \text{East component} &= V_e = \int_0^{2\pi} f.v.\cos\theta\, d\theta \Big/ \int_0^{2\pi} f.d\theta, \\ \text{North component} &= V_n = \int_0^{2\pi} f.v.\sin\theta\, d\theta \Big/ \int_0^{2\pi} f.d\theta, \end{aligned} \qquad (1)$$

if θ is measured from E towards N. The special quantity with which we are here concerned is given by assuming $v=1$ in the avove. The latter assumption seems utterly inadequate even for a very rough approximation. It will however be interesting to consider the matter from another side and see if there does not exist a condition under which the two kinds of resultant become closely related to each other.

If we take a large number of observations of wind at the given hour and plot them as vectors on a suitable diagram, the end points of the vectors will be scattered over the diagram with more or less systematic distribution of density, according to the hour, the season and locality. If we consider that there exists a certain normal value of the wind velocity characteristic to the hour in question, upon which are superposed numberless accidental influences causing the departure of the actual winds from this normal value, it may be expected that the distribution will be in some measure similar to the usual one as given by the Gaussian formulæ. In actual cases, the disturbing influences are not perfectly accidental, since the effect of topography or that of the gustiness of winds, introduces a systematic deviation from the simple rule. Still, taken at large, the actual distribution may always be compared with the normal one, though with widely varying degree of approximation according to the circumstances.

Fig. 1.



Let r be the velocity of wind, θ the angle of direction as above defined and W the probability of wind corresponding to the intervals $r-r+dr$ and $\theta-\theta+d\theta$. Assuming the normal distribution, we have

$$W=\frac{h^2}{\pi}e^{-h^2(a^2+r^2-2ar\cos\theta)^2}r\,dr\,d\theta, \qquad (2)$$

a being the magnitude of the normal or mean wind in the direction of $\theta=0$. Strictly speaking, the elementary area $r\,dr\,d\theta$ must be replaced by $\rho d\rho d\varphi$, where ρ and φ are the polar coordinates referred to the mean wind as the origine, but in the cases actually met with, the errors due to the substitution may generally be neglected. For the probability of wind falling in the interval $\theta-\theta+d\theta$, we have

$$\frac{h^2}{\pi}e^{-h^2a^2\sin^2\theta}d\theta\int_{-\alpha}^{\alpha}e^{-h^2(r-a\cos\theta)^2}r\,dr=\frac{ha}{\sqrt{\pi}}e^{-h^2a^2\cos^2\theta}d\theta.$$

The resultant of probabilities for all directions falls of course in the direction of the resultant wind $\theta=0$, while its magnitude is given by

$$f=\frac{2ha}{\sqrt{\pi}}\int_0^{\frac{\pi}{2}}e^{-h^2a^2\sin^2\theta}\cos^2\theta\,d\theta. \qquad (3)$$

On evaluting the above integral as a function of ha, by an approximate graphical method, it is found that the above resultant of probability is nearly proportional to ha, provided that ha is not very large, or in other words, that deviations of the actual winds from the normal are not too small. In all practical cases, the latter condition is sufficiently fulfilled. Hence as far as the actual distribution is approximately normal and the value of h does not vary widely for different hours of the day, f varies approximately as a, and the diurnal variation of wind may approximately be copied by that of the resultant frequency here concerned.

In order to see to what extent the above simple theoretical consideration applies to actual problems, it is necessary to investigate the actual distribution of winds for different hours of different seasons as well as for different localities widely varying in meteorological conditions. For the present, however, we have been obliged to be content with studying the relation for a few number of hours for Tôkyô and Kôbe. The results of the preliminary investigation which will be shortly published in another place[1], showed that the above theory may be taken at least as a kind of first approximation, in so far as the general features of the diurnal variation of wind may also be represented by the method here adopted.

3. Materials and Methods of Investigation.

The data used in the following investigations were exclusively taken from the Monthly Reports of the Central Meteorological Observatory. The observations of winds for eight years, 1899–1906, in the following fourteen stations were taken:

Taihoku, Kumamoto, Nagasaki, Hukuoka,
Hirosima, Matuyama, Tadotu, Kôbe, Ôsaka,
Nagoya, Tôkyô, Hakodate, Sapporo, Nemuro.

The months chosen were April, August and December. Instead of the twenty four hours of the day, the twelve even hours were taken, in order to save time and labour, without missing the general features of the diurnal variation.

In the Reports mentioned, the monthly number of occurrences of wind in each of the sixteen directions for each hour are tubulated.

(1) Proc. of Phys. Math. Soc. Japan, [3] **4** (1922), p. 125.

The numbers for a given hour summed up for the eight years were assigned to each corresponding direction and the sixteen vectors thus obtained were taken as a measure of the frequency for that hour in the respective directions. By multiplying these values with sines and cosines of the direction-angles respectively, the north and east components of the resultant frequency for the given hour were obtained. The values of these components are given in Table I. If we divide these values by 8, values corresponding to the mean monthly frequencies are obtained. Again, dividing by 30, 31 *etc.*, we may obtain daily values of probability. The results are also plotted on the diagrams given at the end of the paper (Figs. 4-45), which we hope will be useful for various practical purposes. The hours refer of course to standard time, not local.

In passing, it may be remarked that the well known involuntary tendency of observers, to prefer the eight principal directions to the intermediate ones, actually met with also in the materials here utilized, does not affect the resultant values here concerned in any serious manner.

Table I. A. April.

Station. \ Hour.		0	2	4	6	8	10	12	14	16	18	20	22
Taihoku	N	31	9	0	−7	−5	34	88	92	84	76	69	48
	E	124	121	107	108	107	77	51	42	61	84	110	125
Kumamoto	N	35	64	95	100	89	13	−31	−36	−21	−1	27	39
	E	−16	−23	−18	−6	3	−4	−63	−82	−94	−78	−37	−13
Nagasaki	N	36	47	61	58	61	39	12	8	4	21	49	52
	E	19	36	41	57	61	31	−15	−69	−79	−61	−25	−5
Hukuoka	N	−55	−64	−48	−47	−52	24	94	120	122	94	17	−46
	E	61	63	64	77	62	−10	−39	−46	−50	−48	0	50
Hirosima	N	156	171	165	173	156	2	−68	−82	−61	−27	58	124
	E	66	67	75	75	67	−30	−90	−98	−111	−113	−13	49
Matuyama	N	0	0	0	−3	−7	23	16	−6	−52	−29	26	7
	E	38	47	38	36	−27	−135	−152	−143	−124	−104	40	37
Tadotu	N	−40	−76	−86	−91	−14	104	104	67	59	41	1	−3
	E	10	6	2	11	−3	−37	−72	−90	−85	−74	−50	−6

Station. \ Hour.		0	2	4	6	8	10	12	14	16	18	20	22
Kôbe	N	193	124	127	119	29	—23	—44	—55	—32	36	97	111
	E	—21	8	16	2	56	72	41	—13	—47	—57	—37	—29
Osaka	N	90	101	112	115	117	94	71	36	17	28	61	83
	E	82	83	95	101	93	39	—37	—77	—82	—58	9	56
Nagoya	N	39	57	81	111	119	91	14	—36	—38	—31	—10	11
	E	—54	—62	—64	—50	—64	—90	—96	—96	—92	—75	—53	—56
Tôkyô	N	27	80	110	121	128	116	24	—44	—55	—56	—36	—14
	E	20	— 6	—39	—43	—36	15	39	81	71	62	50	40
Hakodate	N	50	42	50	56	3	—63	—74	—69	—53	—31	9	32
	E	—42	—42	—48	—49	—57	—39	—24	—41	—50	—44	—48	—46
Sapporo	N	—75	—69	—52	—71	—41	— 3	33	30	47	32	—36	—74
	E	39	42	51	54	63	23	1	—22	—27	—23	— 3	25
Nemuro	N	—47	—44	—52	—50	—36	—18	—26	—39	—52	—59	—57	—60
	E	—29	—44	—44	—36	—54	—26	—17	— 3	3	5	1	—21

Table I. B. August.

Station. \ Hour.		0	2	4	6	8	10	12	14	16	18	20	22
Taihoku	N	—53	—78	—93	—98	—75	3	63	89	37	12	— 3	—27
	E	89	88	81	84	85	49	13	21	52	85	98	95
Kumamoto	N	— 3	10	13	40	22	—41	—82	— 90	—66	—55	—44	—15
	E	— 1	—16	— 4	— 1	— 4	— 6	—56	—100	—92	—69	—17	— 6
Nagasaki	N	—51	—48	—40	—44	—49	—62	—93	— 85	— 87	— 66	—62	—51
	E	6	16	34	59	68	17	—45	—106	—131	—112	—60	—19
Hukuoka	N	—83	—84	—95	—91	—100	—47	35	69	67	55	— 1	—68
	E	71	73	80	87	97	25	—13	—43	—24	—14	40	41
Hirosima	E	103	117	133	136	121	—82	—137	—136	—128	— 90	— 9	52
	E	44	62	61	64	41	—57	—106	—138	—136	—115	—47	24
Matuyama	N	— 4	— 4	—16	—32	— 38	28	34	— 5	— 24	—21	14	— 4
	E	78	86	64	17	—128	—144	—140	—135	—109	7	64	78
Tadotu	N	—94	—97	—121	—135	—24	116	130	112	62	8	—43	—83
	E	38	31	29	43	35	—34	— 53	—63	—63	—59	—21	13
Kôbe	N	97	92	94	97	—31	—90	—109	—115	—85	1	82	106
	E	—40	—23	—11	12	75	72	15	— 37	—74	—113	—80	—51
Ôsaka	N	65	79	91	102	99	56	24	— 2	— 23	— 7	9	51
	E	3	48	82	95	80	— 6	—57	—109	—118	—109	—53	—21
Nagoya	N	—59	—42	—38	— 7	19	14	—48	—104	—129	—135	—110	—84
	E	24	34	17	21	16	—50	—89	— 87	— 84	— 55	— 9	13

Station. \ Hour.		0	2	4	6	8	10	12	14	16	18	20	22
Tôkyô	N	—62	—38	—13	6	23	7	—48	—97	—100	—113	—100	—83
	E	42	6	— 8	—15	19	32	67	81	94	73	62	48
Hakodate	N	33	52	56	49	—21	—127	—138	—125	—110	—74	— 5	26
	E	39	26	27	29	38	45	44	38	45	51	59	41
Sapporo	N	—98	—96	—96	—90	—78	—32	—13	— 5	12	32	—33	—98
	E	95	98	91	85	115	102	89	51	18	24	45	68
Nemuro	N	—83	—73	—60	—51	—38	—39	—51	—72	—73	—74	—80	—83
	E	56	49	36	36	39	47	65	79	73	70	65	63

Table I. C. December.

Station. \ Hour.		0	2	4	6	8	10	12	14	16	18	20	22
Taihoku	N	19	23	18	10	0	22	54	67	68	56	42	24
	E	174	170	161	161	160	161	160	149	153	166	177	177
Kumamoto	N	108	126	120	140	135	103	64	18	25	73	83	81
	E	—42	—29	—45	—23	—14	—12	—27	—74	—104	—88	—59	—37
Nagasaki	N	137	128	122	117	114	96	108	108	125	139	146	139
	E	29	32	37	41	52	38	— 5	—42	—33	6	19	23
Hukuoka	N	—77	—78	—66	—57	—62	—68	12	72	77	— 6	—50	—45
	E	37	43	27	34	20	13	—55	—89	—86	—47	1	— 2
Hirosima	N	181	188	186	183	193	160	26	—1	44	112	170	174
	E	46	40	54	52	53	44	—30	—73	—73	—16	39	47
Matuyama	N	3	— 8	—14	—10	—22	—29	16	45	45	75	20	— 9
	E	23	39	17	21	38	—37	—115	—140	—125	7	14	20
Tadotu	N	—63	—85	—79	—89	—88	—21	64	66	37	0	—25	—37
	E	—51	—54	—50	—40	—38	—70	—126	—131	—120	—79	—53	—49
Kôbe	N	144	155	145	150	122	24	—11	6	37	126	141	138
	E	—96	—82	—77	—76	—74	—46	—55	—79	—103	—92	—83	—86
Osaka	N	84	91	99	96	99	77	26	7	29	42	63	77
	E	—14	8	4	19	29	— 8	—84	—114	—112	—84	—41	—35
Nagoya	N	140	140	151	152	147	148	156	141	132	127	137	142
	E	—105	—114	—107	—96	—94	—105	—119	—138	—144	—141	—126	—105
Tôkyô	N	154	160	163	170	167	160	152	117	76	81	100	130
	E	—119	—125	—118	—121	—119	—93	—51	— 5	10	— 3	—48	—98
Hakodate	N	112	105	102	118	117	97	82	71	85	99	107	110
	E	—98	—106	—111	—96	—105	—128	—129	—135	—130	—121	—108	—125
Sapporo	N	—48	—36	—30	—42	—40	—11	27	44	18	—17	—36	—37
	E	— 7	—19	—18	— 6	— 3	5	— 7	—10	—40	—43	—15	38
Nemuro	N	1	— 3	9	9	8	28	27	32	17	16	5	2
	E	—107	—113	—109	—107	—107	—112	—119	—99	—87	90	—93	—104

4. Explanation of the Statistical Results.

Passing under review the diagrams[1] given in Figs. 4–45, several interesting facts may be remarked. Firstly, the shape of the figures may conveniently be classified under the following types :

a) ElliPtical curves :

April :	Kôbe, Ôsaka, Nagoya, Tôkyô.
August :	Nagasaki, Tadotu, Kôbe, Nagoya, Tôkyô, Nemuro.
December :	Kôbe, Ôsaka, Tôkyô.

b) Curves remarkably elongated in particular direction :

April :	Hukuoka, Hirosima, Hakodate.
August :	Hukuoka, Hirosima, Ôsaka, Hakodate.
December :	Hukuoka, Tadotu, Ôsaka.

c) Curves resembling lemniscates or open "V" s.

April :	Kumamoto, Matuyama, Tadotu, Hakodate.
August :	Kumamoto, Hirosima, Matuyama.
December :	None.

d) ∞ shaped curves :

April :	Hukuoka, Tadotu.
August :	Ôsaka, Hakodate.
December :	Tadotu.

Among these different types, (a) shows that in the cases belonging to this type, diurnal variation of the simple harmonic type is predominant ; (b) suggests the prevailing influence of topography in causing preference of direction peculier to the locality ; again, (c) implies the existence of a conspicuous semi-diurnal componont in a direction perpendicular to the diurnal one. As for the type (d), it may apparently be attributed to a component with a period of eight hours, but it is

(1) The explanations of the diagram are given at the end of the paper, p. 71.

doubtul whether it involves any physical significance, especially as it is mostly of a very much elongated from with small transverse dimension. Type (d) may more probably be regarded as a modifications of type (c).

It will be remarked that the simple type (a) prevails in the region extending from Kôbe to Tôkyô, while the type (c) occurs in a region including some parts of Kyûshû and the Seto-naikai districts. The lemniscate shape is especially conspicuous in Matuyama and Hirosima. The occurrence of this semidiurnal component is of some interest so that we will recur to it later in § 9.

Next, turning our attention to the size of the diagrams, we may also remark different points worth notice. For a provisional measure of the dimensions of the curves, we take the "length" and the "breadth," the former being measured along the line connecting the farthest extremities of the figure, while the latter is taken as the maximum breadth measured crosswise to the length. From the results of measurements applied to the diagrams, the products of the length and breadth are obtained and tabulated as follows.

Table II. Products of Length and Breadth.
(*In arbitrary units.*)

Station.	April	August.	December.
Taihoku	56	83	12
Kumamoto	52	49	70
Nagasaki	58	67	41
Hukuoka	20	73	18
Hirosima	139	135	101
Matuyama	150	139	215
Tadotu	138	197	25
Kôbe	216	357	91
Ôsaka	62	40	29
Nagoya	68	187	9
Tôkyô	85	67	69
Hakodate	12	45	11
Sapporo	74	77	44
Nemuro	19	14	9

It will be remarked that the values become the exact measures of the areas when the curves are all of similar kind.

Referring to the table, it will be seeu that tha values are generally large for the station along the Seto-naikai coasts. Again, they are small in Hakodate as well as in Nemuro, both stations being in Hokkaidô. As to the seasonal variation, there are, on the one hand, such stations as Hirosima and Tôkyô with small variations, while on the other hand, Tadotu, Kôbe and Nagoya which show remarkable differences in different months. Generally speaking, however, a tendency may be noticed that the values are less in winter than in summer. We will resums these matters later with respect to a more suitable measure of the magnitude of the variation.

If we take the "centre of gravity" of the twelve points on the diagram representing the ends of the vectors corresponding to two-hourly resultant frequencies, the vector through the point thus obtained will represent the daily mean of the vectors in question and may be regarded as corresponding to the general wind peculiar to the season. A passing glance at the diagrams will reveal that this "seasonal part" is generally conspicous in December in comparison with April or August, as might well be expected from the prevalence of the monsoon. Again, the seasonal part for the stations in the Seto-naikai region is generally very small in August, and as will be seen later, even its direction shows a peculiar anomaly. Thie latter fact may probably be attributed to the influence of the characteristic situation of this region which is screened, as it were, by the mountainous land of Sikoku and Tyûgoku on the southern and northern side respectively.

The remarkable phenomenon of "*Yûnagi*" (evening calm) in the Seto-naikai region finds its natural explanation by reference to the wind dirgrams of these districts. The weakness of the seasonal wind gives rise to an undistrbed development of the land and sea breezes, so that the morning and evening hours are marked with perfect calm. This fact is confirmed also by examining the hourly strength of wind in these districts. The notoriety of the evening compared with the morning calm may be easily accounted for by the psychological effect of the associated high temperature. Again, it is interesting to compare these districts with such a locality as Tôkyô. In the latter station, the shape and size of the wind diagram, do not differ much for summer and winter, but the seasonal component is here well developed, so that the wind relation widely differs for morning and evening. The superposition of the seasonal part, together with the retardation of the phase of durnal variation here as compared with Seto-naikai, results in the prevalence of southern winds during the evening hours, rendering the end of the summer day quite tolerable. These relations, though introducing no essential novelty, may be most clearly explained in the above way, with reference to the diagrams here given.

5. Harmonic Analysis of the Statistic Results.

In connection with the above discussion, it was considered desirable to subject the statistical results to harmonic analysis in order to study the seasonal, diurnal and semidiurnal parts separately. The method of the analysis adopted was that given in Watson's "Text-book of Practical Physis," § 11. Each of the north- and east-components was represented by

$$\begin{aligned} F = A_0 + A_1 \sin kt + A_2 \sin 2kt + \cdots + A_6 \sin 6kt \\ + B_1 \cos kt + B_2 \cos 2kt + \cdots + B_6 \sin 6kt \end{aligned} \quad (4)$$

and by applying the twelve values given in Table I, together with the corresponding time-angles, the values of the coefficients, $A_0\, A_1\, A_2 \cdots\cdots A_6$, $B_1\ B_2 \cdots\cdots B_6$ could be determined. For the present, however, the terms of the orders higher than the third were not considered necessary, nor is the real physical significance of these terms clear, in view of the scantiness of materials involved. Hence, the analysis was carried out only so far as to determine the five coefficients A_0, A_1, A_2, B_1 and B_2. The results of the harmonic analysis are given in Table III.

Table III. Harmonic Coefficients.

Station.		April. A_0	April. A_1	April. A_2	April. B_1	April. B_2	August. A_0	August. A_1	August. A_2	August. B_1	August. B_2	December. A_0	December. A_1	December. A_2	December. B_1	December. B_2
Taihoku	N	44	−29	−7	−40	12	−9	−25	−19	−75	20	34	−15	5	−23	12
	E	39	−6	−3	36	−13	70	−13	8	30	−19	164	−6	−5	8	−4
Kumamoto	N	31	25	17	54	−21	−26	21	11	50	−15	90	26	0	42	−19
	E	−4	21	−14	33	−19	31	15	−14	40	−22	−46	27	−21	14	−10
Nagasaki	N	37	8	1	22	−14	−64	4	3	22	−8	126	−17	3	9	−4
	E	2	44	−10	42	−14	−23	61	−16	62	−23	16	16	−5	29	−20
Hukuoka	N	13	24	15	−59	23	−29	−42	14	−80	21	−29	−17	18	−61	28
	E	15	21	−3	65	−10	35	23	1	56	−20	−9	19	−9	57	−17
Hirosima	N	64	28	5	134	−28	1	37	17	145	−26	135	11	−3	81	−46
	E	−5	32	−10	99	−18	−25	33	−5	105	−16	15	16	−13	55	−32
Matuyama	N	−2	6	−19	7	−7	−6	−2	−21	−8	4	9	−26	17	25	8
	E	−37	18	8	108	−21	−12	−1	5	131	6	−20	10	4	76	−43
Tadotu	N	6	6	−35	−86	−1	−14	15	−37	−122	20	−23	−20	−11	−69	21
	E	−32	16	−6	50	−8	−9	17	−2	55	−9	−72	5	1	39	−25
Kôbe	N	49	−18	15	92	−17	11	−35	16	114	−22	98	−20	24	74	−27
	E	−1	49	−22	0	−4	−21	62	−26	4	−12	−79	15	−9	−5	−3
Ôsaka	N	77	30	−10	34	−9	45	38	−5	27	−9	58	15	0	37	−7
	E	25	39	−12	84	−23	−14	66	5	80	−19	−28	35	−3	54	−24
Nagoya	N	34	61	−5	42	−22	−60	63	−19	24	−14	143	9	−4	2	0
	E	−71	−4	2	21	−10	−21	5	0	63	−15	−116	14	−8	15	−8
Tôkyô	N	33	85	−5	49	−14	−51	59	−5	23	−13	136	35	−15	25	2
	E	23	−39	−12	−43	13	42	−29	−7	37	6	−74	−33	19	−59	9
Hakodate	N	−4	−4	11	66	−8	−32	−7	18	101	−11	101	2	0	15	−12
	E	−44	1	−6	−4	5	40	−7	−3	−8	−6	−116	3	3	15	−5
Sapporo	N	−23	−5	11	−61	12	−49	−18	14	58	1	−17	2	−0	−35	20
	E	19	25	−5	36	−8	73	31	−20	20	−1	−17	15	−9	1	−1
Nemuro	N	−45	13	−9	−7	3	−65	21	−1	−5	−6	13	5	−1	−14	3
	E	−22	−19	3	−18	0	57	−14	−2	−13	5	−104	−9	−7	−5	−3

In Figs. 46–84, the vector representing the seasonal parts and the twe ellipses represnting the variation of the diurnal and the semi-diurnal components are shown.

6. Seasonal Components.

From the values of A_0 for north- and east-components, the magnitudes and directions of the resultants were determined. These resultants which correspond to the seasonal wind are given in Table IV.

Table IV. Seasonal Winds.

Station.	April.		August.		December.	
Taihoku	103	ENE	71	E	163	ENE
Kumamoto	31	N	40	SW	101	NNW
Nagasaki	37	N	68	SSW	127	N
Hukuoka	20	NE	45	SE	30	SSW
Hirosima	64	N	25	W	136	N
Matnyama	37	W	13	WSW	22	WNW
Tadotu	33	W	16	SSW	76	WSW
Kôbe	49	N	24	WNW	126	NW
Ôsaka	81	NNE	47	NNW	64	NNW
Nagoya	79	WNW	64	SSW	184	NW
Tôkyô	40	NE	66	SE	155	NNW
Hakodate	44	W	51	SE	153	NW
Sapporo	30	SE	88	ESE	24	SW
Nemuro	50	SSW	86	SE	105	W

On examining the Table, the following points may be remarked, firstly with respect to the direction :

a) Taihoku is distinguished from the other stations by the fact that the direction of the seasonal wind is almost invariable for the three different seasons. This implies the prevalence of the influence of the trade wind. All the other stations show more or less influence of monsoon.

b) In August, the four northern stations including Tôkyô show south-eastern direction as might have been expected. However, most stations included in a wide region extending from Kyûsyû to the central part of Honsyû show more or less western components, and moreover the two stations Kôbe and Ôsaka even reveal norlhern components.

An examination of the isobaric chart of this month gives no apparent hint as to the explanation of these anomalies. It must be remarked that in most of these stations the magnitudes of the vectors are small compared with the northern stations. It is probable that the western components are due to the effect of the main part of Honsyû acting as an elongated ridge of low pressure, disturbing the general course of the monsoon. This idea is supported by ths fact that the track of cyclones in this season has a tendency to be attracted toward the central axis of the land.

c) In December, norther and western directions prevail as may be expected. As exceptions, however, Hukuoka, Tadotu and Sapporo show some southern components. This is evidently connected with the fact that these stations are situated on the northern side of land.

d) In April, northern and western components predominate, suggesting the remnants of the winter monsoon.

Secondly, with respect to the magnitude of the seasonal vector we may remark the followings:

e) In Taihoku, the values are invariably large for all seasons examined.

f) In August, the stations in the Seto-naikai region shows generally small values. This confirms the explanation of "*Yûnagi*" given above.

g) In December, the magnitudes are generally large, as is to be expected. However, the values for Hukuoka, Matuyama, Tadotu, Ôsaka and Sapporo are worth notice. Not only they are less than those of the other stations for the same season, but are also less in some cases than the corresponding values for the other seasons. Most of these stations have more or less extended land surfaces on their southen sides ; even Ôsaka has a considerable land area on its south-eastern side. The anomaly of these districts may therefore be explained by the effect of the land on the southern side causing a miniature monsoon of local nature which acts in opposite direction to the influence of the general monsoon. As already mentioned in (c), the local influence apparently predominates in Hukuoka, Tadotu and Sapporo and gives rise to the southern components, while in Matuyama and Ôsaka the northern components are merely weakened to some extents. It follows that in stations situated on the southern coast of land, the winter monsoon must be reinforced by the local effect. It seems therefore possible to analyse the general and local parts separately, provided we are furnished with the necessary data of two stations suitably situated on opposite sides of land. Unfortunately the stations here taken do not allow the choice of a suitable pair.

7. Shape of the Ellipses.

The lengths of the major and minor axes of the diurnal as well as the semidiurnal ellipses were approximately measured from the diagrams given in Figs. 46–87. The ratios of the minor to the major axes were calculated and are tabulated as follows :

Table V. Ratio of Axes. (*The unit*=0.01)

Station	Diurnal.			Semidiurnal.		
	Apr.	Aug.	Dec.	Apr.	Aug.	Dec.
Taihoku	40	25	32	33	15	17
Kumamoto	6	3	24	77	58	64
Nagasaki	14	13	61	36	23	15
Hukuoka	3	4	3	10	30	4
Hirosima	5	3	7	34	35	15
Matuyama	5	2	34	91	26	50
Tadotu	22	16	7	23	20	21

Station.	Diurnal.			Semidiurnal.		
	Apr.	Aug.	Dec.	Apr.	Aug.	Dec.
Kôbe	50	49	17	58	75	26
Osaka	11	9	9	11	31	6
Nagoya	26	63	23	16	41	24
Tôkyô	14	26	20	56	50	17
Hakodate	0	7	5	3	31	24
Sapporo	25	31	43	8	0	46
Nemuro	50	51	71	14	29	40
Sum	271	302	356	470	464	367

Examining the statistical distribution of the ratios given above, a characteristic difference between the diurnal and the semidiurnal components is revealed. Classifying the values according to the magnitudes, we have:

	Ratio.	Number.	Ratio.	Number.
Diurnal	0—10	16	41—50	4
	11—20	7	51—60	1
	21—30	7	61—70	2
	31—40	4	71<	1
Semidiurnal	0—10	6	51—60	3
	11—20	9	61—70	1
	21—30	9	71—80	2
	31—40	7	81—90	0
	41—50	4	91—100	1

In the case of the diurnal components, the number of occurrences is greatest for the least value of the ratio, while in the case of the semidiurnal component, it shows a maximum near the value 0.20. Again, referring to the sum of the ratios for all stations, as given at the bottom of the above table, it will be seen that the ratio is generally less, *i.e.* the ellipse is more elongatod in the case of the diurnal components than in the semidiural.

The above fact may be explained in some measure by the following consideration. According to the usual theory of the daily variation of the barometric pressure, there is a corresponding variation of wind with the diurnal and the semidiurnal periods, the hourly vectors of both components describing respective ellipses, of which the ratios of the axes are given as some function of latitude, if we neglect the effect of the distribution of land and water. Hence, if we take a limited area on the earth surface, we may expect that the ratios of axes for different stations situated within this area will show some statistical distribution about the normal value corresponding to the mean latitude, the deviations being caused by numerous local or accidental disturbances. it is well known that such disturbances are very remarkable in the diurnal component of the variation of barometric pressure in comparison with the semidiurnal. The similar characteristics of the diurnal component are also here revealed with respect to the variation of wind. Especially for the stations here concerned, it may be assumed that the 'planetary' part of the diurnal variation depending on the latitude is overpowered by the local effect of the land and sea breeze for which the variation is nearly rectilinear, and the said ratio of axes approaches zero.

This explains the characteristic predominance of the least values of the ratio in the case of the diurnal components. On the other hand, the existence of a maximum of frequency for a certain finite value of the ratio in the case of the semidiurnal component seems to imply the relative importance of the planetary part for this component. A systematic dependence of the ratio on latitude, however, cannot be traced. The local influences are in any case still very conspicuous.

As to the seasonal variation of the said ratio, no general tendency can be inferred. For example, in the case of the diurnal component the mean value of all stations is less for summer than for winter, while for the six stations from Tadotu to Hakodate the contrary is the case. These relations want a farther study with more abundant materials.

8. Size of Elipses. Relation to the Seasonal Wind.

In order to get a general idea of the daily extent of the variation of wind, the length of the major axes of the ellipses and also the products of the two axes are tabulated in Table VI and VII. The latter quantity which is proportional to the area of the ellipse may in some sense be taken as a measure of the diurnal variability of wind.

Table VI. Length of Major Axis.

Stations.	Diurnal Component.			Semidiurnal Component.		
	April.	August.	December.	April.	August.	December.
Taihoku	11.6	16.4	5.6	3.9	7.1	2.9
Kumamoto	14.1	14.0	11.1	5.7	5.5	5.0
Nagasaki	13.2	17.6	6.6	4.2	6.1	4.1
Hukuoka	18.9	21.8	17.4	6.0	6.4	8.2
Hirosima	34.7	37.0	20.3	6.5	6.8	11.3
Matuyama	21.8	26.2	16.0	4.4	5.0	8.8
Tadotu	19.9	26.9	16.5	7.0	8.3	7.2
Kôbe	18.9	24.0	15.8	5.3	6.3	7.3
Osaka	20.5	22,7	15.0	6.2	4.2	5.0
Nagoya	14.9	15.5	4.4	4.9	5.6	2.3
Tôkyô	22.6	15.3	15.7	4.1	3.0	7.5
Hakodate	13.2	20.6	4.3	3.2	4.2	2.4
Sapporo	14.7	13.7	7.0	3.8	4.7	3.9
Nemuro	5.2	5.1	2.8	2.2	1.7	1.5
Mean	17.4	19.8	11.3	4.8	5.4	5.5

Table VII. Product of Axes.

Stations.	Diurnal Component.			Semidiurnal Component.		
	April.	August.	December.	April.	August.	December.
Taihoku	52.2	67.2	10.1	5.1	7.8	1.5
Kumamoto	12.7	5.6	30.0	25.1	17.6	16.0
Nagasaki	25.1	40.5	26.4	6.3	8.5	2.5
Hukuoka	11.3	19.6	8.7	3.6	12.2	2.5
Hirosima	62.5	40.7	28.4	14.3	16.3	19.2
Matuyama	21.8	10.5	88.0	17.6	6.5	38.7
Tadotu	85.5	116.	18.1	11.2	14.1	10.8
Kôbe	180.	283.	42.7	16.4	29.6	13.9
Ôsaka	47.2	47.7	21.0	4.3	5.5	1.5
Nagoya	58.1	150.	4.4	3.9	12.9	1.2
Tôkyô	70.0	61.2	48.6	9.4	4.5	9.8
Hakodate	0.0	30.9	0.9	0.3	5.5	1.7
Sapporo	52.9	57.5	21.0	1.1	0.0	7.0
Nemuro	13.9	13.5	5.6	0.7	8.5	0.9
Mean	49.5	67.4	25.3	8.5	10.7	9.1

Examining firstly Table VI, it will be found that the major axis for the diurnal part is generally greater in August than in April, whereas for the semidiurnal part the difference is not so conspicuous. Though the regional distribution of the values is not systematic, it may be noticed that they are generally large in the Seto-naikai districts. The same may be said with regard to the values in the Table VII.

Classifying the values of Table VI according to the magnitude, we have

	Interval.	Number.	Interval.	Number.
Diurnal	0— 4.9	3	20.0—24.9	8
	5.0— 9.9	5	25.0—29.9	2
	10.0—14.9	9	30.0—34.9	1
	15.0—19.9	13	35.0—39.9	1

The values are thus systematically distributed about the most frequent value lying in the interval between 15 and 20.

	Interval.	Number.	Interval.	Number.
Semidiurnal	0 - 0.9	0	5.0—5.9	7
	1.0—1.9	2	6.9—6.9	7
	2.0 2.9	4	7.0—7.9	5
	3.0—3.9	5	8.0—8.9	3
	4.0—4.9	8	9.0<	1

The relation is quite similar to the above, showing the existence of a normal value.

On carrying out a similar classification with respect to the product of axes given in Table VII, a decidedly different feature is revealed :

Diurnal.	Number.	Semidiurnal.	Number.
0.0— 9.9	6	0.0— 1.9	9
10.0—19.9	8	2.0— 3.9	4
20.0—29.9	6	4.0— 5.9	5
30.0—39.9	2	6.0— 7.9	4
40.0—49.9	6	8.0— 9.9	4
50.0—59.9	4	10.0—11.9	2
60.0—69.9	3	12.0—13.9	3
70.0—79.9	1	14.0—15.9	2
80.0—89.9	2	16.0—17.9	5
90.0—99.9	0	18.0—19.9	1
100.0<	4	20.0<	3

Though the distribution is irregular, a general tendency may be observed that the frequency is greater for the smaller values of the product. It is evident that such a relation is partly determined by the distribution of the minor axis. It might well have been expected from the result mentioned in § 7, that at least the semidiurnal part might show a maximum value. The fact that this is not actually the case, implies that the dependence of the variation of the minor axis on that of the major axis is not a very simple one.

As will be seen from the above tables as well as from Table II. Tadotu, Kôbe and Nagaya show remarkable seasonal variation. Comparing these values with those of the seasonal parts given in Table IV, § 6, it is found that those stations with conspicuous seasonal parts are generally characterized by small values of the major axis or the area of the ellipse. Fig. 2 was plotted to illustrate this relation; for the abscissæ, the seasonal part given in Tablle IV is taken, while the ordinates represent the products axes for the diurnal part given in Table VII. Different seasons are distinguished by suitable marks and the points for the same station are connected by straight lines. Similar diagrams were platted, taking the values of Table II or those of Table VI for the ordinates, and found to be quite similar to Fig. 2 in general features.

Referring to the figure, it will be seen that the relation between August and December is generally similar to the case of the three stations above cited, *i.e.* the former season is characterized by less value of abscissæ and greater value of ordinates than the latter. The pasition of the points for April however shows no regularity. Taking the results as a whole we may notice the following:

a) When the area of the ellipse is remarkably large, the seasonal part is not conspicuous.

b) When the seasonal wind is well developed, the area is generally small.

c) The converse of (a) or (b) does not always hold.

The same may be said with respect to the major axis.

As to the explanation of the above, two things must be taken into cosideration. Firstly, a well developed seasonal wind may render a conspicuous local inequality of temperature infrequent and tend to suppress the occurrence of the local convection winds. Secondly, the above relation may be apparent, brought about by some systematic deviation from the proportionality of the "frequency resultant" here considered to the "true resultant" of wind. This latter point deserves careful examination.

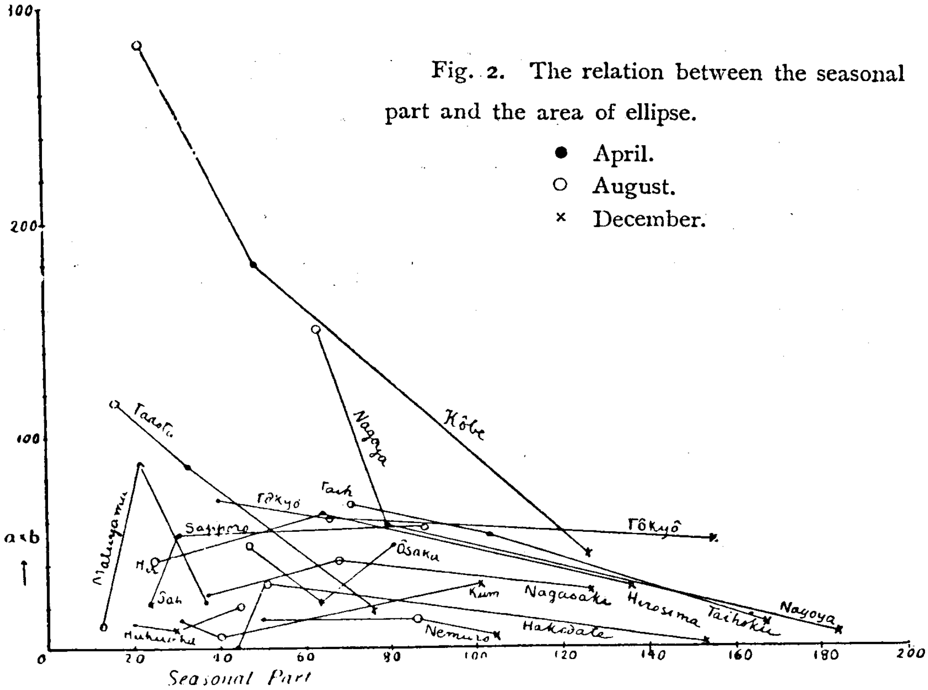


Fig. 2. The relation between the seasonal part and the area of ellipse.

● April.
○ August.
× December.

As explained in § 1, the quantity here concerned is proportional to *ha*, provided the statistical distribution is nearly normal. Hence if *h* vary widely for different seasons, our diagrams will show different linear proportions for different seasons with respect to the true *a*-diagram. This will, however, not affect the ratio of the axis of ellipse to the seasonal part as is actually the case as far as the hourly variation of *h* is not sensible, though the ratio of the *area* to the seasonal part may vary with *h*. On the other hand, the actual seasonal variation of *h* was investigated with respect to Tôkyô and Kôbe. Even in the case of Kôbe which shows the most remarkable seasonal difference in Fig. 2, no conspicuous difference, either seasonal or hourly in the value of *h* may be traced. Hence we may assume that (a), (b) and (c) apply in many cases also to the real velocity resultants.

In the four stations Kumamoto, Hukuoka, Matuyama and Sapporo, the relation between summer and winter is entirely different from the other cases. These stations have land areas extending tawards S or SE sides. This fact may probably account for the said anomaly.

9. Analysis of the Local Effects.

On arranging the diurnal ellipses of Figs. 46–87 on a suitable map of Japan, a remarkable fact is noticed. The major axes of ellipses are always situated in a direction nearly prependicular to the general course of the coast line near the respective stations or slightly inclined to that direction. This evidently implies the conspicuous rôle played by the local land- and sea-breezes. The end of the axis directed toward the sea always corresponds to an hour near noon. On the other hand, there may exist also an influence of a more wide region not confined to the immediate vicinity of the station, as is suggested by the abnormal behaviour of such stations as Matuyama, Tadotu, *etc.* Therefore, it seems of some interest to separate, if possible, this latter regional influence common to a number of stations, from the exclusively local effects peculiar to each station. For a trial, let the N-component of the diurnal variation for a given station be represented by

$$A_1 \sin kt + B_1 \cos kt = a_1 \sin (kt + \xi_1) + l_1 \cos \theta \sin (kt + \eta_1), \qquad (5)$$

where A_1 and B_1 are the harmonic coefficients as given in Table III. The first term of the righthand member denotes the regional part while the second represents the local part. The local part is considered to be a rectilinear periodic motion between land and sea of which the N-component is obtained by multiplying by the cosine of the angle θ, made by the line of motion toward the land with the north direction. By the assumption, a_1 and ξ_1 are constant for different stations in the region in question, while l_1 and η_1 may differ for different stations, being determined by the daily range of temperature, the distance from the coast *etc.* The angle θ is chiefly determined by the direction of the coast line, though of course also influenced by other features of topography. Hence, if we can estimate the values of l_1, η_1 and θ_1 in any way, the values of a_1, ξ_1 may at once be determined by (5). For the present, we assume that l_1 and η_1 are constant throughout the region and also that the angle θ is directly given by the direction of the major axis of the ellipse. The values of a_1, ξ_1 as well as l_1, η_1 are then determined in the following way.

From (5), $A_1 = a_1 \cos \xi_1 + l_1 \cos\theta \cos \eta_1$, $B_1 = a_1 \sin \xi_1 + l_1 \cos\theta \sin \eta_1$. (6)

There are as many sets of similar equations as there are stations in the region. Instead of applying the laborious method of least squares, we resorted to a convenient graphical method. in order to see to what extent the above assumption may be justified.

Putting $x_1 = a_1 \cos \xi_1$ and $y_1 = l_1 \cos \eta_1$, (7)

we have $A_1 = x_1 + \cos\theta\, y_1$ or $\dfrac{x_1}{A_1} + \dfrac{\cos\theta}{A_1} y_1 = 1$. (8)

If we refer to x_1 and y_1 as the rectangular coordinates, the above equation represents a straight line, with the intercept A_1 and $A_1/\cos\theta$ on the respective axes. The number of such lines is of course equal to that of the stations in the said region. If the above assumption be true, all lines must be concurrent and the common point of intersection will give x_1 and y_1 as defined by (7).

Similarly, putting $x_1' = a_1 \sin \xi_1$, $y_1' = l_1 \sin \eta_1$, (7')

and $B_1 = x_1' + \cos\theta\, y_1'$ or $\dfrac{x_1'}{B_1} + \dfrac{\cos\theta}{B_1} y_1' = 1$, (8')

we may determine x_1', y_1'. Combining these values of x_1, y_1, x_1', y_1', we may find the values of a_1, ξ_1, l_1, η_1.

Next for the E-component, we may put

$$A_1' \sin kt + B_1' \cos kt = b_1 \cos(kt + \xi_1') + l_1 \sin\theta \sin(kt + \eta_1) \quad (5')$$

$$
\begin{aligned}
A_1' &= -b_1 \sin \xi_1' + l_1 \sin \theta \cos \eta_1 = x_1 + \sin \theta\, y_1, \\
B_1' &= \quad b_1 \cos \xi_1' + l_1 \sin \theta \sin \eta_1 = x_1' + \sin \theta\, y_1',
\end{aligned} \tag{6'}
$$

whence we may obtain b_1, ξ_1', l_1, η_1. Thus we obtain two sets of values of l_1, η_1 from N- and E-components respectively. If the above assumptions are legitimate, the two sets will agree with each other to a more or less narrow extent.

In actual cases, the assumption cannot be realized except to a rather rough degree of approximation, so that the different straight lines intersect at sets of points scattered over a limited area. So far as the scattering of these points is not extremely wide, it will be plausible to take the centre of gravity of the points instead of the concurrent point in the ideal case for determining x_1, y_1, x_1', y_1' and thence a_1 b_1 *etc.* The comparison of the two sets of l_1, η obtained from the two components will then serve as a kind of control with regard to the legitimacy of the assumption for the case being.

In order to see to what extent the method will apply to the present examples, the stations were grouped into the following seven regions, each comprising three stations :

1. Kumamoto, Nagasaki, Hukuoka.
2. Hirosima, Matuyama, Tadotu.
3. Tadotu, Kôbe, Ôsaka,
4. Kôbe, Ôsaka, Nagoya.
5. Ôsaka, Nagoya, Tôkyô.
6. Nagoya, Tôkyô, Sapporo.
7. Hakodate, Sapporo, Nemuro.

In any case where a pair of the straight lines makes too small an angle with each other, the point of intersection will become uncertain, considering the uncertainty of the positions of the lines themselves. In the above groups, such pairs were avoided. It was found that the three points of intersection form in most cases a triangle of moderate size though the scattering was by no means always negligible in comparison with the magnitudes of the values to be determined.

In taking the centre of gravity of the triangle the following weights were allotted to the points of intersection according to the angle of intersection φ :

Angle of intersection. φ	Weight.
0°—10°	0
10°—20°	1/4
20°—40°	1/2
40°—90°	1

A more suitable weight is of course possible, for example that varying as cosec φ cot φ. For the present purpose, however, the above were considered most practical.

As for the angle θ, it seems possible to deduce its value from theoretical considerations, if we had the necessary knowledge about the so called "friction" provided also that the general trend of the coast line could be determind with no ambiguity. In actual cases, however, this seems gennrally hopeless because the latter condition is rarely fulfilled, the direction of the coast line varying widely according to the extent of the region considered. Hence we were obliged to assume the value of θ as directly given by the direction of the major semi-axis of the ellipse. This amounts to saying that the predominant part of the variation is the local convection. This will be justified in some measure by the results of rhe analysis given later, in which the value of l appears mostly prominent in comparison with that of a or b.

As already stated, the actual direction of the major axis is mostly perpendicular to the coast line, and even in cases in which the axis is sensibly inclined, the magnitude and often the sense of the inclination is not such as could be expected from the usual considerations. Since the land and sea breeses are limited to a shallow layer near the ground, the 'friction' will be considerable and will tend to eclipse the effect of the rotation of the earth. The effect of mountains *etc.* will complicate the matter to a farther extent. It is desirable to see if the relation is quite similar with respect to the true resultant of wind.

The angles determined in the above manner are different for different months. This may be partly due to the seasonal difference of the regional part, but it is no wonder if the actual direction of the local part is also subjected to a seasonal change, according to the variation of the effective arrangements of barometric pressure causing the local convection. Hence, the value of θ has been determined separately for different months. The results are shown in the following Table.

Table VIII. The Direction Angle of the Semi-major Axis of the Diurnal Ellipse, directed toward the Land, measured Clockwise from North, in Degrees.

Station.	Apr.	Aug.	Dec.	Station.	Apr.	Aug.	Dec.
Kumamoto	33°	38°	30°	Ôsaka	65	67	60
Nagasaki	70	77	92	Nagoya	8	50	68
Hukuoka	133	146	136	Tôkyô	—30	—36	—58
Hirosima	37	36	35	Hakodate	—3	—4	45
Matuyama	86	93	108	Sapporo	125	153	178
Tadotu	149	156	151	Nemuro	—74	—34	—170
Kôbe	—9	—9	—7				

The seasonal difference is conslicuous in the northern stations from Nagoya to Hokkaidô ; the angle for December especially deviates from those of other two seasons. It must be remarked that the ellipse for the winter is small for these stations, except for Tôkyô, corresponding to the weakness of the local part.

On carrying out the above analysis, the two sets of $l_1 \cos \eta_1$ and $l_1 \sin \eta_1$ obtained fram the N- and E-components respectively showed for some cases a fair agreement while for some cases they differed considerably. Notwithstanding this discrepancy, the mean values were taken, and the six quantities in question were calculated. The results are given in Table IY as follows :

Table IX. Amplitudes and Phase Angles of the Regional and Local Parts.

Diurnal Component.

APRIL.

Region.	a_1	ξ_1	b_1	ξ_1'	l_1	η_1
1. Kumamoto, Nagasaki, Hukuoka.	5	233°	38	23°	73	60°
2. Hirosima, Matuyama, Tadotu.	13	39	51	—43	122	86
3. Tadotu, Kôbe, Ôsaka.	21	—17	41	—73	90	98
4. Kôbe, Ôsaka, Nagoya.	35	13	28	—67	74	100
5. Ôsaka, Nagoya, Tôkyô.	24	99	13	63	94	49
6. Nagoya, Tôkyô, Sapporo.	31	—40	13	90	83	65
7. Hakodate, Sapporo, Nemuro.	5	—37	4	—56	54	74

AUGUST.

Region.	a_1	ξ_1	b_1	ξ_1'	l_1	η_1
1. Kumamoto, Nagasaki, Hukuoka.	17	205°	52	220°	58	67°
2. Hirosima, Matuyama, Tadotu.	11	41	30	—82	156	87
3. Tadotu, Kôbe, Ôsaka.	31	—32	45	—63	102	97
4 Kôbe, Ôsaka, Nagoya.	60	—10	40	—69	83	105
5. Ôsaka, Nagoya, Tôkyô.	33	65	19	55	86	45
6. Nagoya, Tôkyô, Sapporo.	27	—33	4	56	73	52
7. Hakodate, Sapporo, Nemuro.	8	230	12	265	64	58

DECEMBER.

Region.	a_1	ξ_1	b_1	ξ_1'	l_1	η_1
1. Kumamoto, Nagasaki, Hukuoka.	10	90°	54	68°	96	56
2. Hirosima, Matuyama, Tadotu.	17	166	44	—76	83	90
3. Tadotu, Kôbe, Ôsaka.	4	214	11	—53	70	82
4. Kôbe, Ôsaka, Nagoya.	62	—26	17	246	72	96
5. Ôsaka, Nagoya, Tôkyô.	66	—50	15	157	80	66
6. Tôkyô, Nagoya, Sapporo.	14	—8	8	220	52	65
7. Hakodate, Sapporo, Nemuro.	10	0	3	270	24	68

As already stated, the values of l_1, generally exceed those of a_1 and b_1, though in some cases, such as the winter in the region 4 and 5, the difference is not very remarkable.

The mean values for all regions are: April 84, August 89 and December 68. The ratio August to December is as 5 to 4. Calculating the ratio of the energy of solar radiation received by a horizontal surface at 35° of latitude in the middle of August to that in December, we obtain 1.77. On the other hand, if we assume l_1 to be proportional to the velocity of wind, the square of the ratio of l_1 will give the ratio of the energy of wind, for which we obtain 1.71. The agreement may be accidental, but still is worth notice.

Next, it will be noticed that the value of η_1 doss not show any conspicuous seasonal variation. The mean values for all stations are: April 76°, August 73°, December 75°. The fact that these values are nearly constant for different seasons, seems to justify in some measure the assumption of the local term as given in the equation (5). $\eta_1=75°$ implies that the maximum of the land breeze takes place at 3^h a.m.

With regard to the values of a_1, b_1 corresponding to the regional part, we will give the explanation a little later.

A similar analysis may be applied to the semidiurnal components, It suffices to replace kt by $2kt$ and the suffix 1 by 2. The value of θ was assumed the same as in the case of the diurnal component. The results of the analysis are given in Table X below:

Table X. Amplitudes and Phase Angles of the Regional and the Local Parts.

Semidiurnal Component.

APRIL.

Region.	a_2	ξ_2	b_2	ξ'_2	l_2	η_2
1. Kumamoto, Nagasaki, Hukuoka.	4	40°	28	146°	20	−63°
2. Hirosima, Matuyama, Tadatu.	29	−155	13	106	28	−38

Region.	a_2	ξ_2	b_2	ξ_2'	l_2	η_2
3. Tadotu, Kobe, Osaka.	18	—162	16	102	23	—31
4. Kôbe, Osaka, Nagoya.	20	—174	13	124	25	—47
5. Osaka, Nagoya, Tôkyô.	13	—173	6	121	24	—83
6. Nagoya, Tôkyô, Sapporo.	5	6	4	104	18	—99
7. Hakodate, Sapporo, Nemuro.	6	90	5	72	9	—117

AUGUST.

Region.	a_2	ξ_2	b_2	ξ_2'	l_2	η_2
1. Kumamoto, Nagasaki, Hukuoka.	6	0°	22	—121°	7	—118°
2. Hirosima, Matuyama, Tadotu.	16	176	17	148	33	—39
3. Tadotu, Kôbe, Osaka.	14	180	22	118	32	—26
4. Kôbe, Osaka, Nagoya.	4	—153	25	120	22	—20
5. Osaka, Nagoya, Tôkyô.	5	—56	5	143	15	—90
6. Nagoya, Tôkyô, Sapporo.	2	—90	9	100	16	—128
7. Hakodate, Sapporo, Nemuro.	11	10	9	111	13	—138

DECEMBER.

Region.	a_2	ξ_2	b_2	ξ_2'	l_2	η_2
1. Kumamoto, Nagasaki, Hukuoka.	6	—10°	35	90°	30	—94
2. Hirosima, Matuyama, Tadotu.	14	—28	21	117	40	—69
3. Tadotu, Kôbe, Osaka.	3	121	11	126	27	—62
4. Kôbe, Osaka, Nagoya.	26	140	10	119	26	—54
5. Osaka, Nagoya, Tôkyô.	9*	69*	7	—74	24	—125
6. Nagoya, Tôkyô, Sapporo.	10	133	4	106	15	—138
7. Hakodate, Sapporo, Nemuro.	0	—	7	102	11	—61

Also in this case, l_2 is generally greater than a_2 and b_2. The mean values of l_2 for all stations are: April 21, August 20, December 25. Thus the value is greatest for winter, contrary to the case of the diurnal

The values marked with * have small weight.

parts. The values of η_2 show more irregular variations than for the case of the diurnal parts. Taking neverthless the means of all stations we have: April $-68°$, August $-90°$, December $-86°$, and the mean of the three seasons $-81°$. The average hour of the maximum of this part of the wind falls therefore near 6^h morning and evening, the actual maxima being scattered within a range of about two hours before and after the said hour.

As for the geographical distribution of l_2, we may remark that the values are greatest in the Seto-naikai districts and decrease sensibly towards the north. The values of $-\eta_2$ are generally small in the regions extending from Seto-naikai to the middle part of Honsyû and show a tendency to increase farther north.

Next, taking the ratio of l_2 to l_1, we have;

Table XI. $l_2/l_1 \times 100$.

Region.	April.	August.	December.
1. Kumamoto, Nagasaki, Hukuoka.	27	12	31
2. Hirosima, Matuyama, Tadotu.	23	21	48
3. Tadotu, Kôbe, Ôsaka.	26	31	39
4. Kôbe, Ôsaka, Nagoya.	34	28	36
5. Osaka, Nagoya, Tôkyô.	26	17	30
6. Nagoya, Tôkyô, Sapporo.	22	22	29
7. Hakodate, Sapporo, Nemuro.	17	20	41
Mean	25	22	36

For each season the ratio varies in a rather limited range. Thus it will be seen that the most prominent factor giving rise to the variation of the character of the local part, taken as a whole, is the conspicuous difference of the phase angles for different stations. To illustrate this fact, we assumep $l_1=1.00$, $l_2=0.30$ and $\eta_1=+75°$, and plotted the values of

$$l_1 \sin(kt+\eta_1)+l_2 \sin(2kt+\eta_2)$$

for different values of η_2 varying from $-30°$ to $-150°$. From these diagrams the following may be remarked: For small values of $-\eta_2$, the maximum of the sea wind occurs early, being gradually retarded as $-\eta_2$ increases; besides, for small values of $-\eta_2$ the slope of the curve is less in the interval from minimum to maximum than in the interval from maximum to minimum, prolonging thus the duration of the weak indeterminate wind after the minimum. The latter fact may be cited in connection with "Yûnagi" in the Seto-naikai districts, for which $-\eta_2$ is generally small.

As the chief factors determining the value of $-\eta_2$, we may cite the distance of the station from the coast as well as the extent of the area effective in the production of the convection current and also the range and distribution of the temperature variation in different parts of the region concerned. A farther explanation with regard to the phase angle is not easy for the present.

Next, we will turn our attention to the regional parts represented by the amplitudes a_1, b_1, a_2, b_2. The elliptical motions as given by the values of a, b, ξ, ξ' were plotted in diagrams. Instead of reproducing these figures, we will give in the following Table, the lengths of the semi-axes, the direction angle of the major axis and the hour corresponding to the extremity of the major semi-axis. The unit of the length is the same as for a and b. The direction angle is here taken zero for E and counted toward N; that side of the semi-major axis which makes acute angle with the direction of the curved axial line of our land running in north-eastern direction, was taken for reference for the direction angle as well as the hour of maximum. The reason for the latter choice will be seen presently. It will be remembered that for the semidiurnal component, the maxima occur twice at the hour mentioned, a.m. and p.m.

Table XII. Elements of Regional Parts.

Region.	Station.	April.				August.				December.			
		Major axis.	Minor axis.	Direction of max.	Hour of max.	Major axis.	Minor axis.	Direction of max.	Hour of max.	Major axis.	Minor axis.	Direction of max.	Hour of max.
DIURNAL PART.													
1	Kumamoto, Nagasaki, Hukuoka.	75	13	—3°	22h	103	31	—6°	9h	118	18	5°	20h
2	Hirosima, Matuyama, Tadotu.	114	4	15	3	63	12	18	5	93	15	—20	6
3	Tadotu, Kôbe, Osaka.	89	23	25	6	98	70	27	7	24	1	—20	4
4	Kôbe, Osaka, Nagoya.	89	8	52	5	140	35	58	6	127	1	75	8
5	Osaka, Nagoya, Tôkyô.	51	20	69	23	68	38	79	1	133	27	84	10
6	Nagoya, Tôkyô, Sapporo.	66	16	110	8	54	0	98	20	31	10	64	7
7	Hakodate, Sapporo, Nemuro.	12	5	125	10	26	12	127	17	21	0	73	6
SEMIDIURNAL PART.													
1	Kumamoto, Nagasaki, Hukuoka.	58	2	—8°	1h	45	6	14°	4h	71	3	—9°	9h
2	Hirosima, Matuyama, Tadotu.	49	4	55	8	40	24	—42	2	46	21	—27	9
3	Tadotu, Kôbe, Osaka.	48	2	48	9	50	11	31	8	22	7	—5	8
4	Kôbe, Ôsaka, Nagoya.	47	11	57	8	61	0	9	8	52	18	80	10
5	Ôsaka, Nagoya, Tô y .	28	4	65	9	11	8	48	6	21	10	56	1
6	Nagoya, Tôkyô, Sapporo.	13	2	127	3	18		2	3	20	7	77	10
7	Hakodate, Sapporo, Nemuro.	12	9	46	11	28	3	126	3	14	0	0	6

The remarkable variation of the regional part revealed in the above Table seems to show how small is the part played by the plauetary component compared with that due to the geographical influences.

The relation of the quantities given in the above with each other is by no means simple. As for the length of the ellipse, there is a general tendency to decrease towards the north, though the transition is not regular. The most remarkable and interesting fact is, however, the geographical distribution of the direction of major axis for the diurnal part. The direction angles for April and August show a gradual increase toward north-east. Drawing on a map (Fig. 3) the

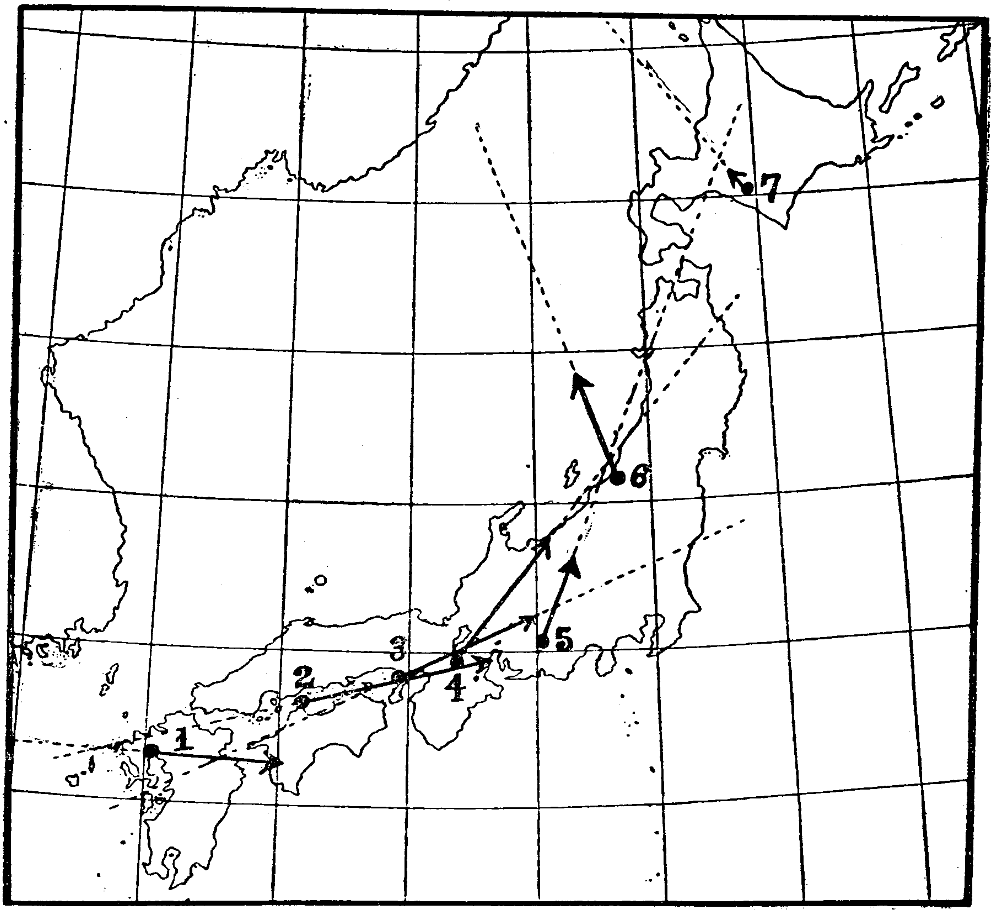


Fig. 3. Direction of major axes in April. The dots ● show the centers of regions The arrows give the axes in directions and magnitudes.

lines in the directions determined by the above angles from the centre of the triangles representing different regions, it will be seen that these lines show a tendency to form an envelope which coincides roughly with the axial line of the principal islands of Japan. In December, the relation is otherwise, the regions 2, 3 and 4, 5, 6, 7 forming apparently two separate groups.

Though the hour of maximum shows also a very irregular variation, a preponderance of morning hours may still be noticed for the diurnal part. This latter fact seems to show that the part here called "regional" is also a kind of local convection current similar to the land and sea breezes, only differing from the latter by the extent of the area concerned. From the peculiar distribution of the direction angle above cited, it may be suggested that the daily heating and cooling of the elongated strip of our land takeu as a whole, in contrast to the surrounding sea, constitutes an important part of the cause of the regional component. From this point of view, the anomalous behaviour of the regions 2, 3, 6, 7 in December will be understood as the disturbance due to the station situated on the norther side of the land.

The fact that the major axes of the regional part make acute angles with the axial line of the land iustead of being perpendicular to it, seems to show that this part of the convection current affects a comparatively higher atmospheric layer than that corresponding to the land and sea breeze in the proper sense.

The above attempt to analyse the local effects must be considered to have been a failure rather than a success. Still, it may be interesting as showing how remarkable is the influence of the part played by the convection between rather narrow extent of the land and sea.

It seems that if we could choose a suitable region with a sufficient number of stations within its boundary, we should be able to carry out a farther study with respect to the "*residuals*" of l and a, b in connection with the local distribution of the other meteorological elements. Such a study would not fail to bring out some results of practical importance, especially because for many practical problems, it is the local influences that decide the matter in question.

Fig. 4–87: The direction is N upward and E to the right as usual. The point MN denotes midnight and N noon. The other points correspond to 2^h, $4^h \cdots 22^h$, the arrow showing the direction in which the hours proceed.

Fig. 46–87: The seasonal part is shown by the straight line ending at a dot. The ellipse in full line corresponds to the diurnal component and that in dotted line to the semidiurnal. The point marked by **O** corresponds to 0^h.

Taihoku **Kumamoto**

April

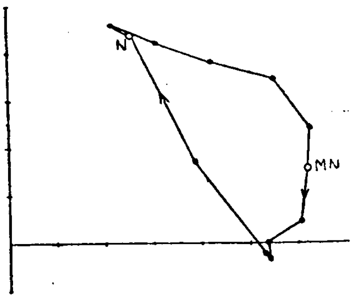


Fig. 4

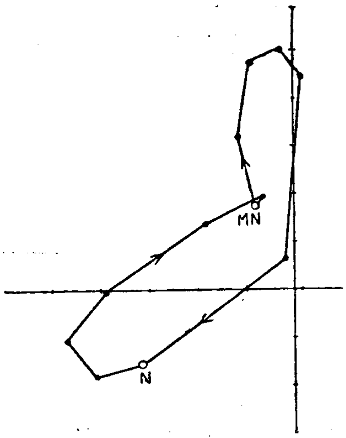


Fig. 7

August

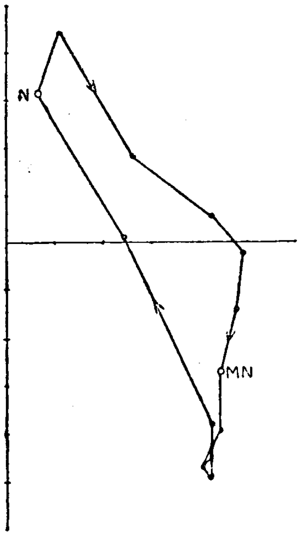


Fig. 5.

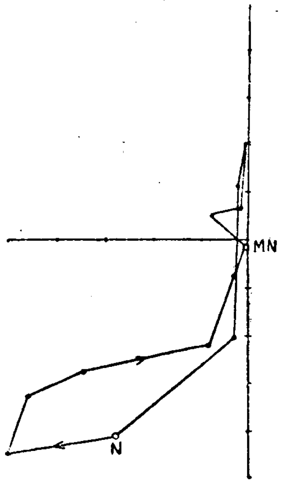


Fig. 8.

December

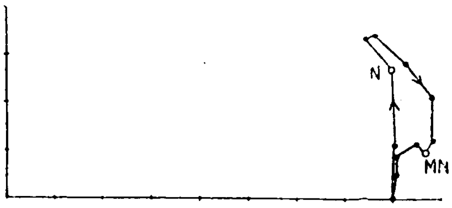


Fig. 6.

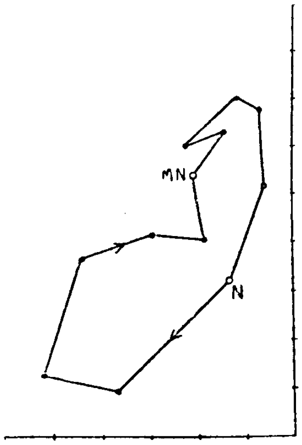


Fig. 9

Nagasaki **Hukuoka**

April

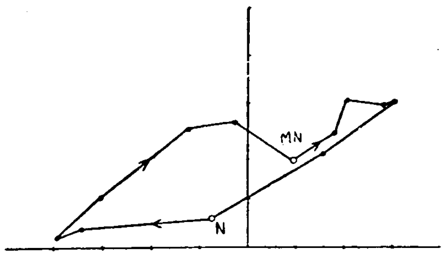


Fig 10

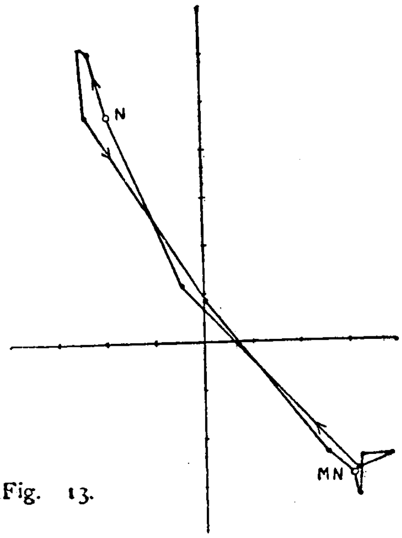


Fig. 13.

August

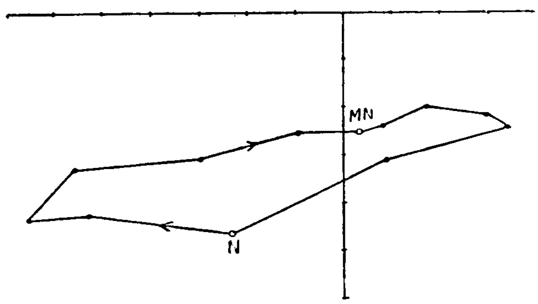


Fig. 11.

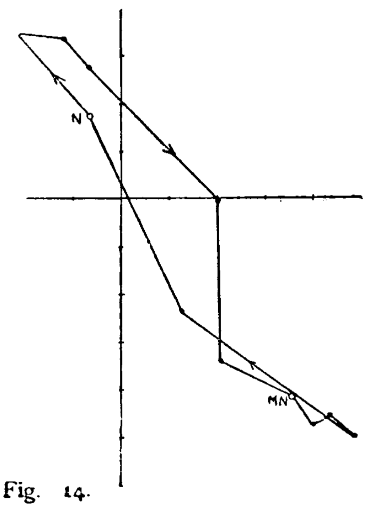


Fig. 14.

December

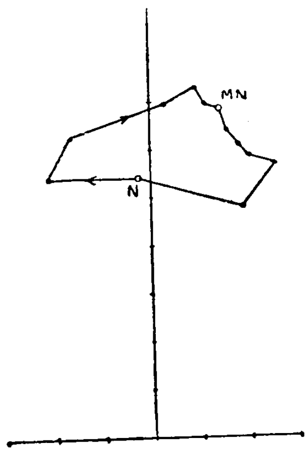


Fig. 12.

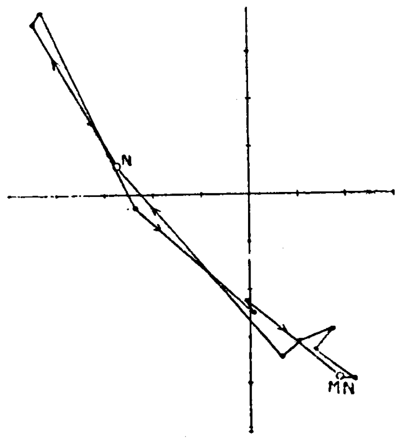


Fig. 15.

Hirosima

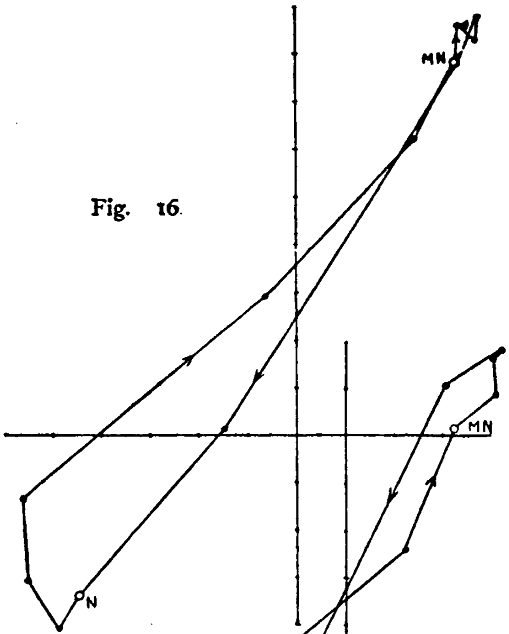


Fig. 16.

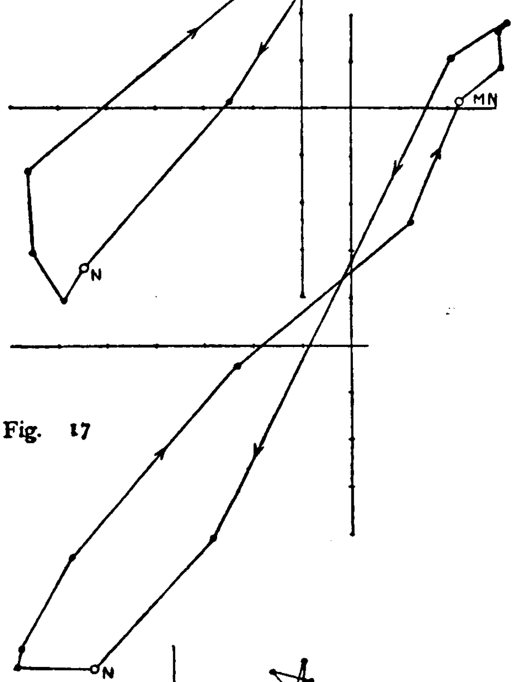


Fig. 17

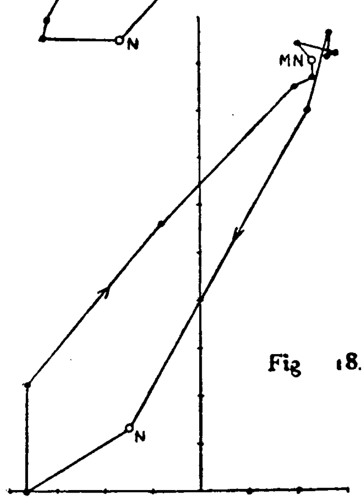


Fig 18.

Matuyama

April

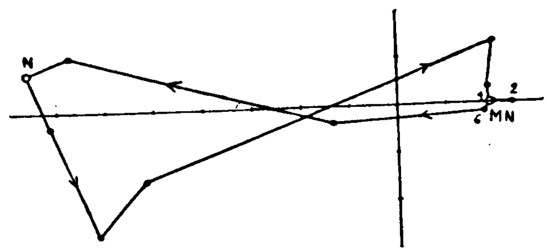


Fig. 19

August

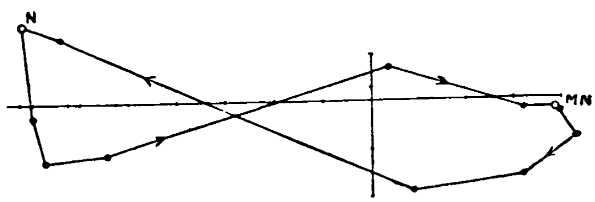


Fig 20.

December

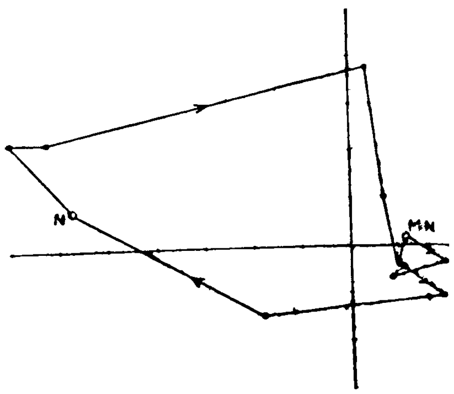


Fig. 21.

Tadotu **Kôbe**

April

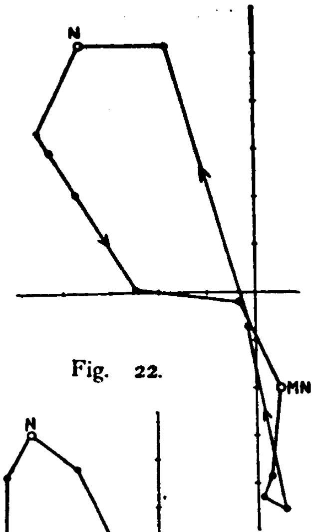


Fig. 22.

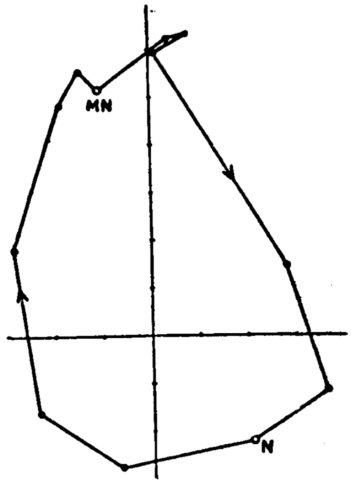


Fig. 25.

August

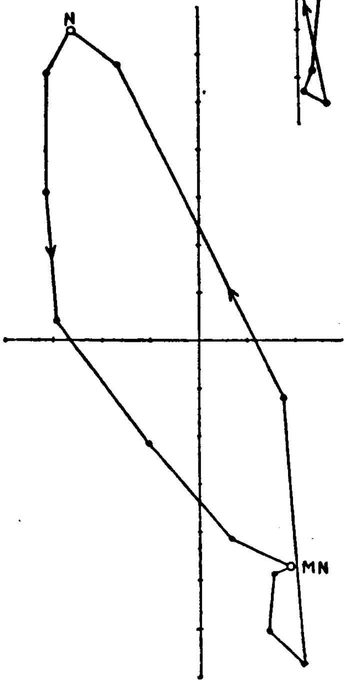


Fig. 23.

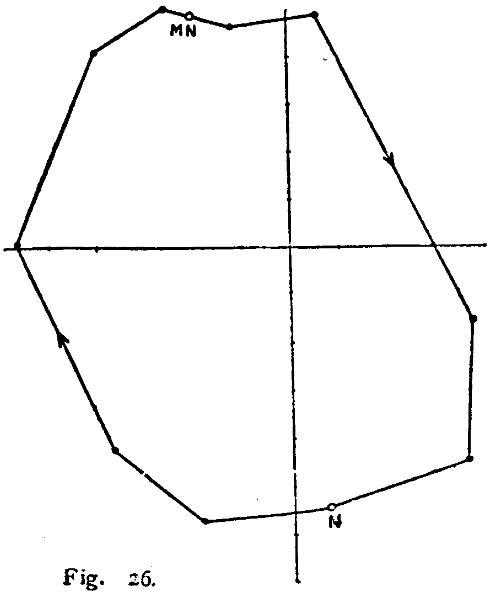


Fig. 26.

December

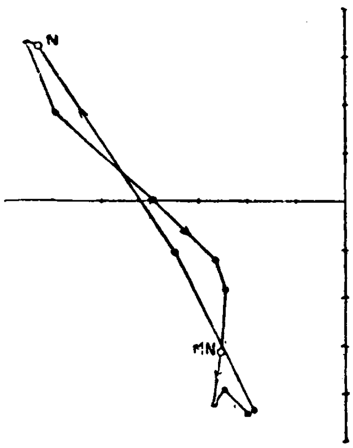


Fig. 24.

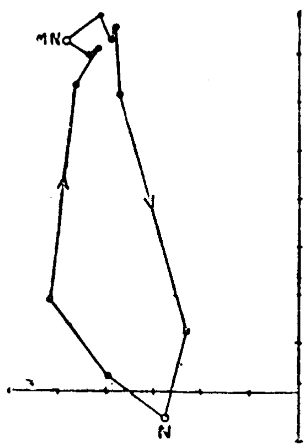


Fig. 27.

Ôsaka **Nagoya**

April

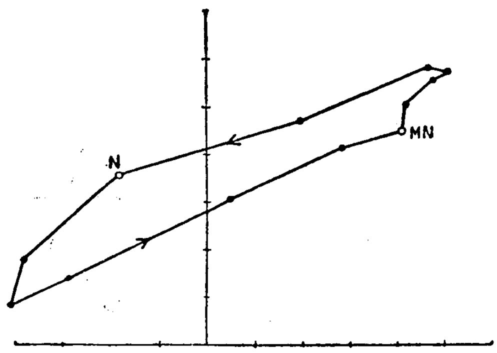


Fig. 28.

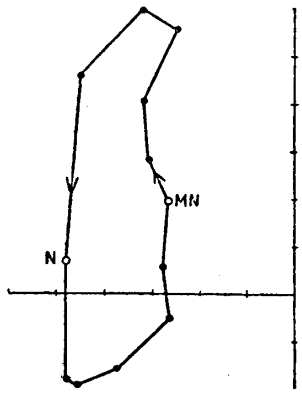
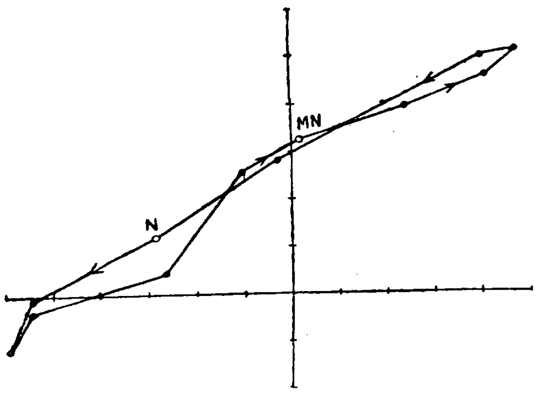


Fig. 31.

August



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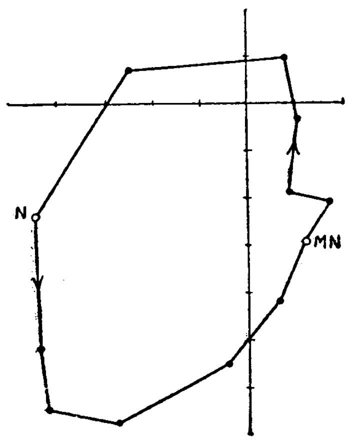
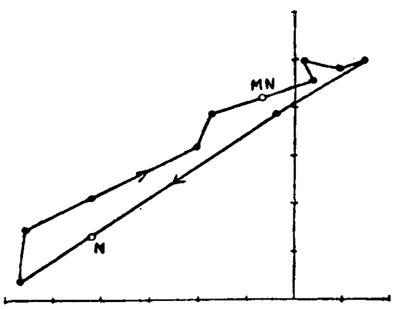


Fig. 32.

December



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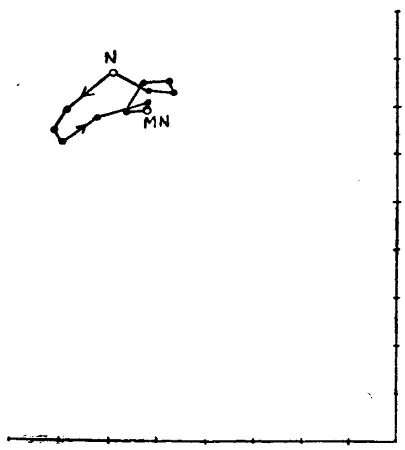
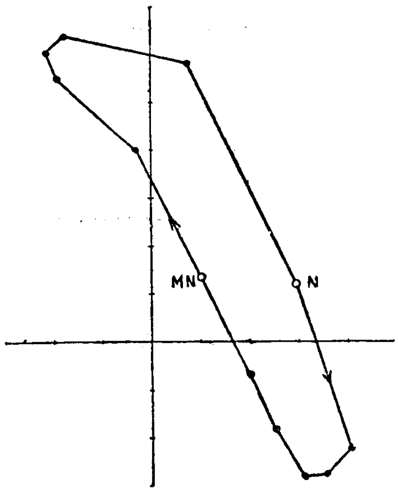


Fig. 33.

Tkôyô **Hakodate**

April



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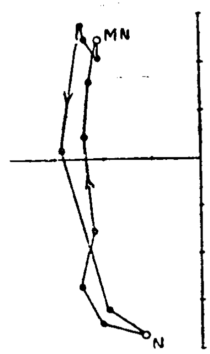
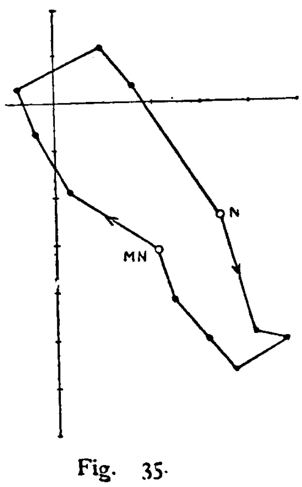


Fig. 37

August



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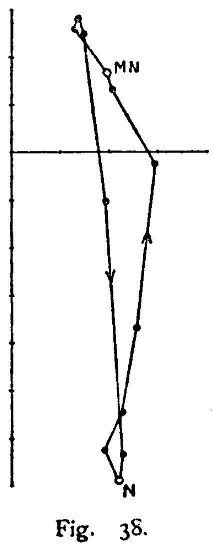


Fig. 38.

December

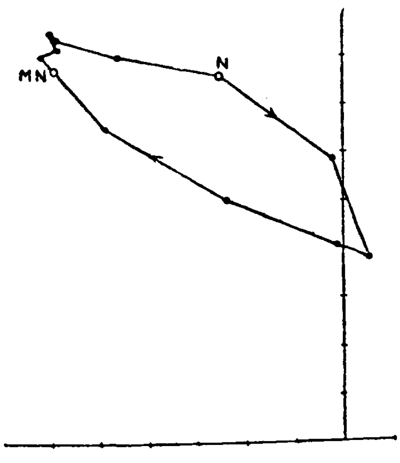


Fig. 36.

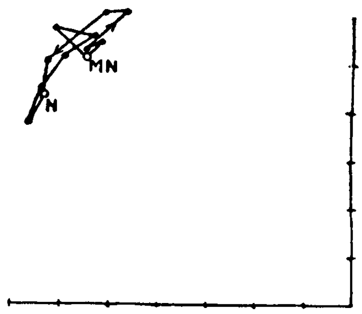


Fig. 39.

Sapporo **Nemuro**

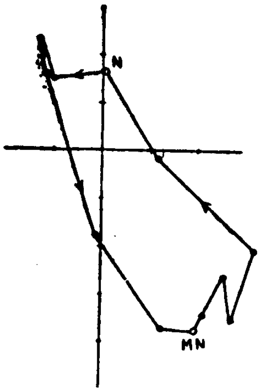


Fig 40

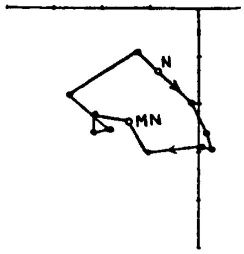
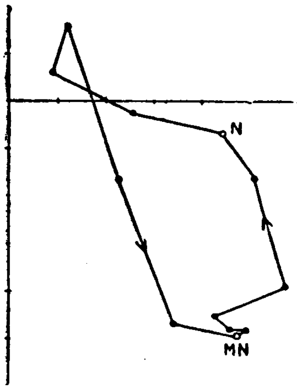


Fig. 43.

August



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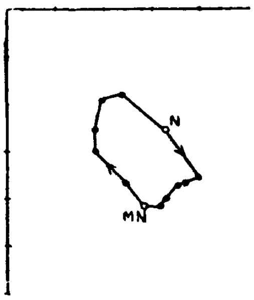


Fig. 44.

December

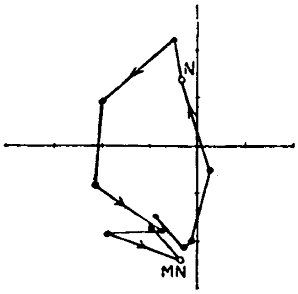


Fig. 42.

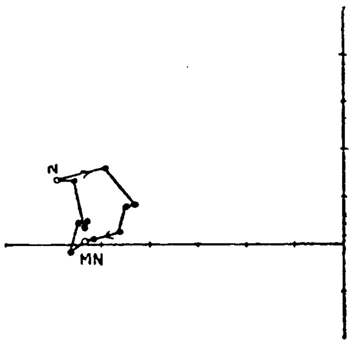


Fig. 45.

Taihoku | **Kumamoto**

April

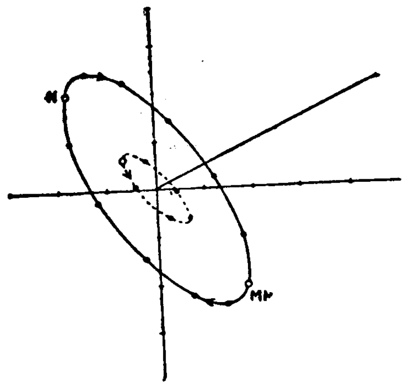


Fig. 46

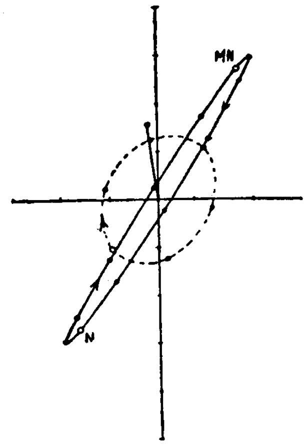


Fig. 49.

August

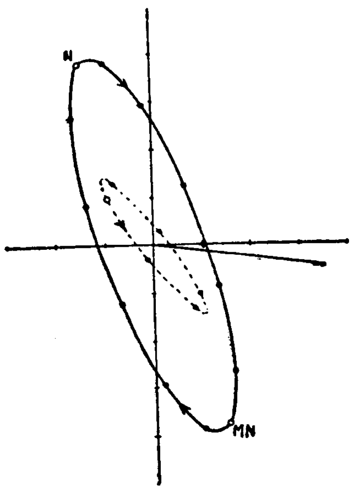


Fig. 47.

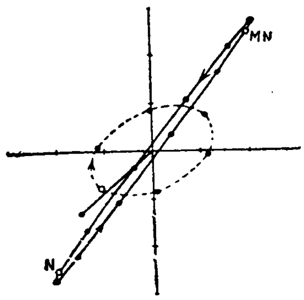


Fig. 50.

December

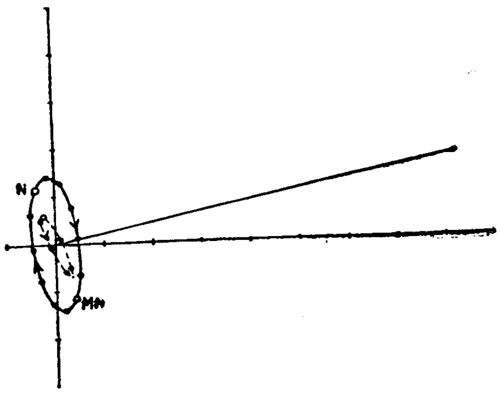


Fig. 48.

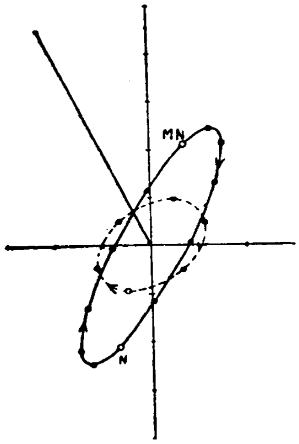
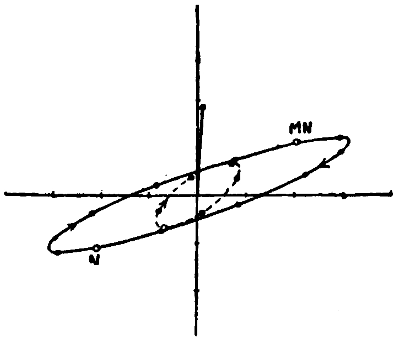


Fig. 51.

Nagasaki **Hukuoka**

April



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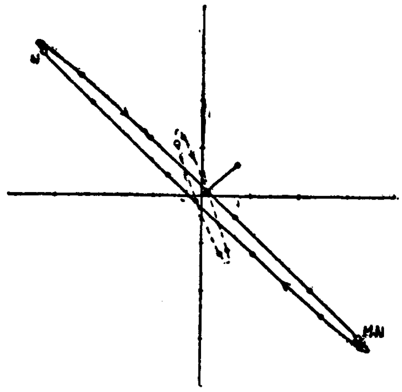


Fig. 55.

August

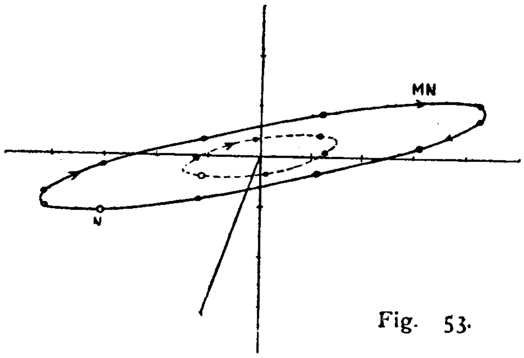


Fig. 53.

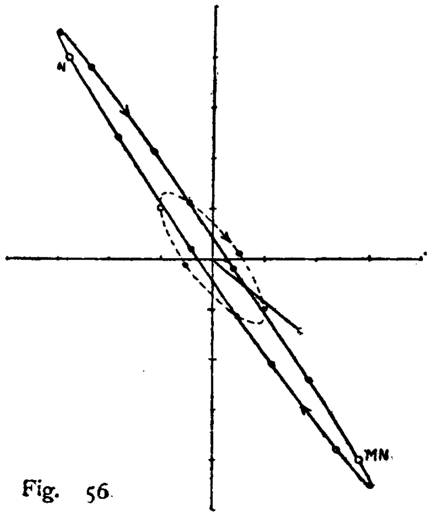


Fig. 56.

December

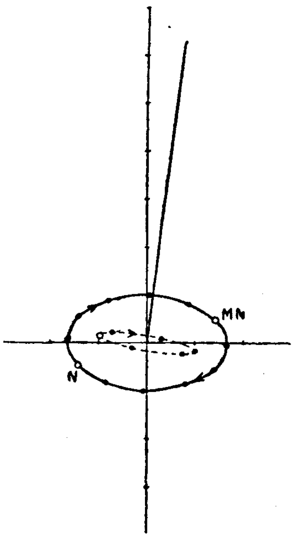


Fig. 54.

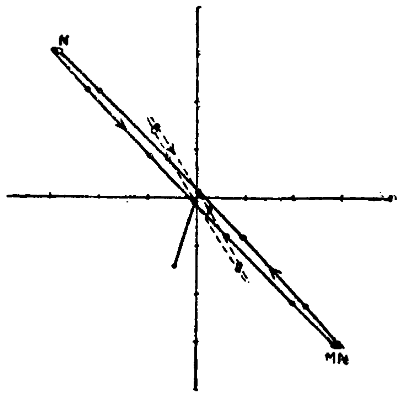
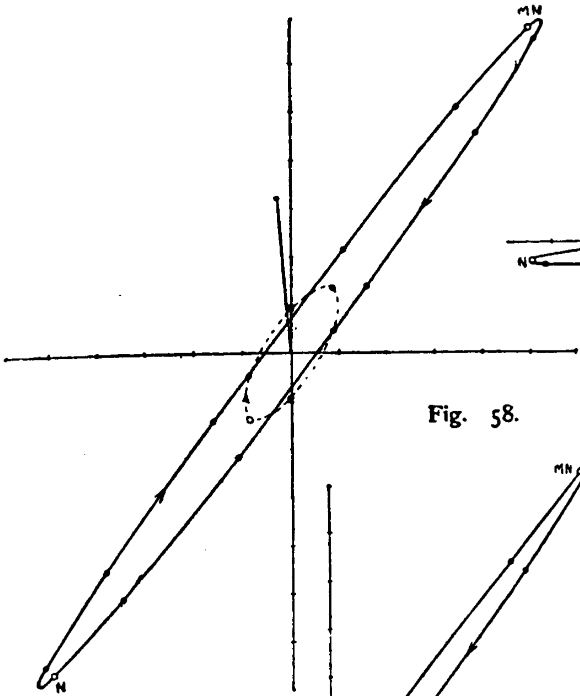


Fig. 57.

Hirosima



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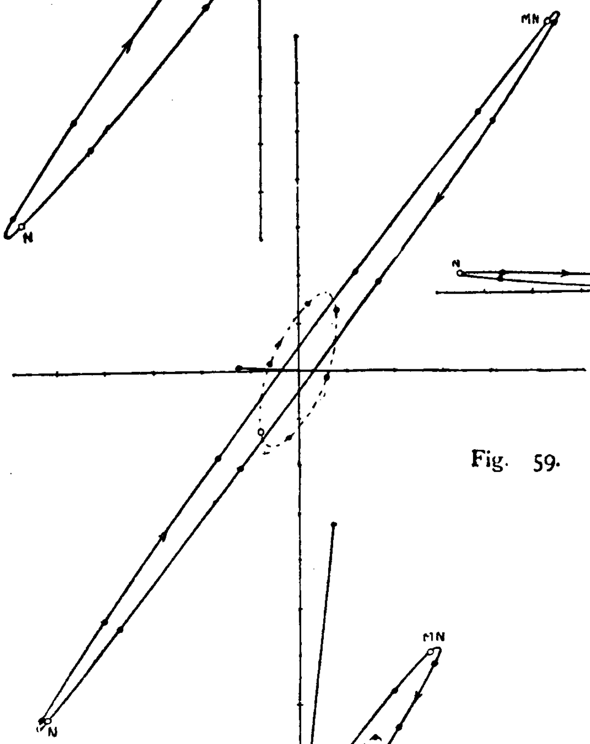


Fig. 59.

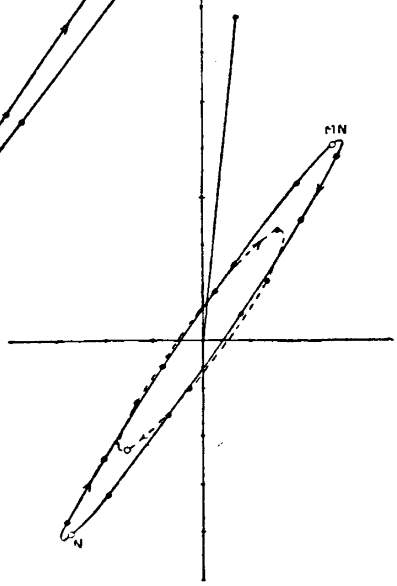


Fig. 60.

Matuyama

April

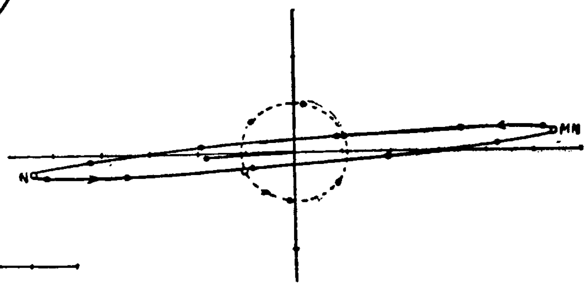


Fig. 61.

August

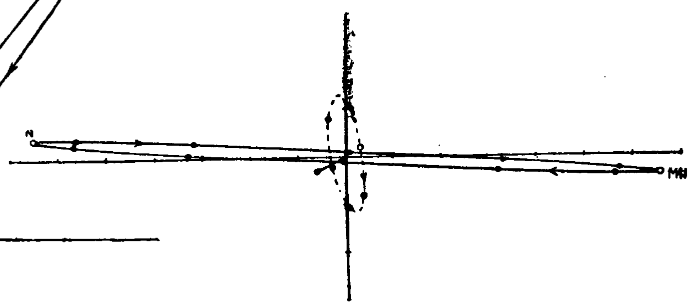


Fig 62.

December

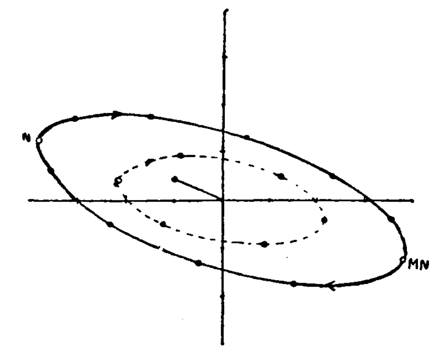


Fig 63.

Tadotu **Kobe**

April

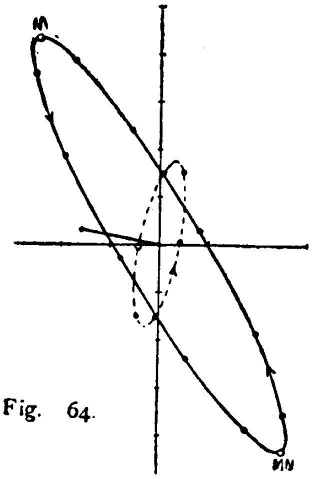
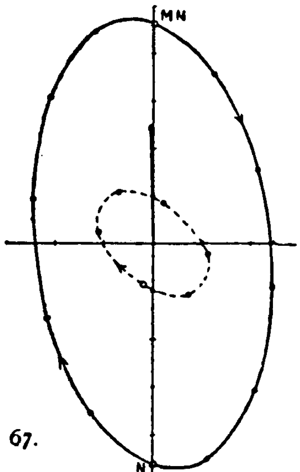


Fig. 64.



Fg. 67.

August

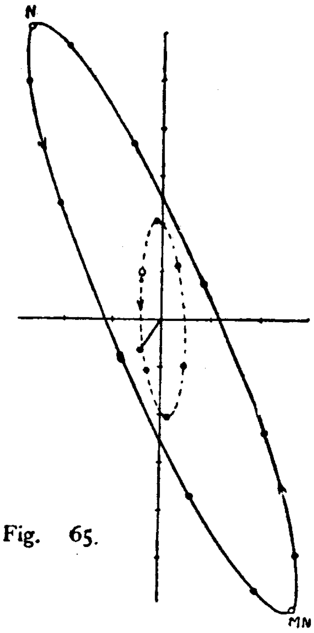


Fig. 65.

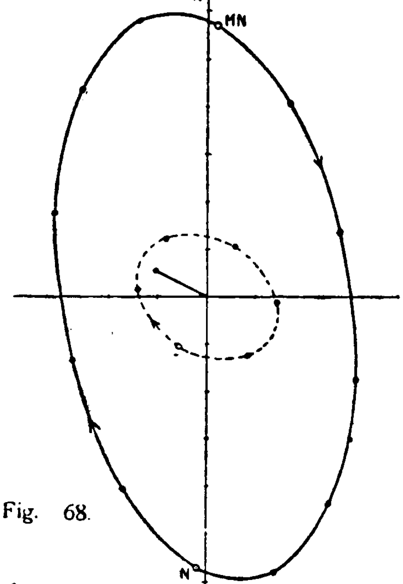


Fig. 68.

December

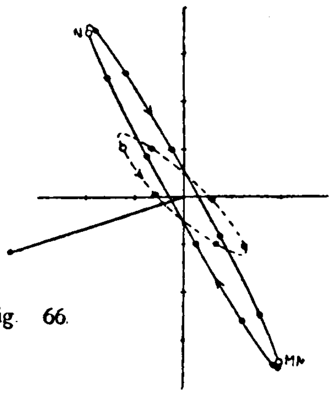


Fig. 66.

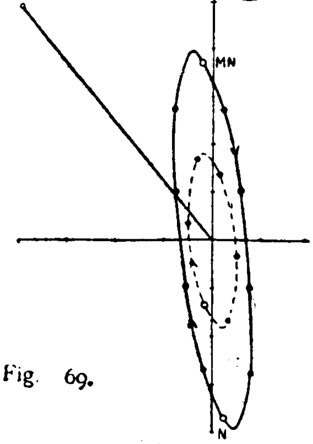


Fig. 69.

Ôsaka **Nagoya**

April

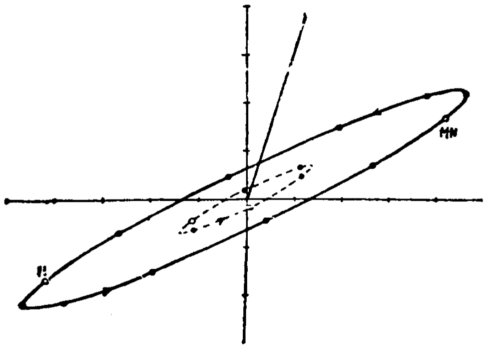


Fig. 70.

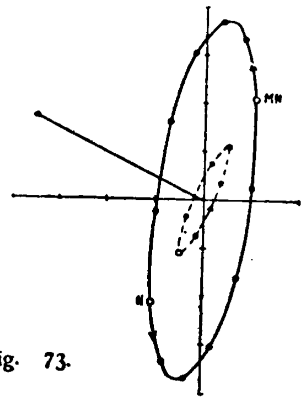


Fig. 73.

August

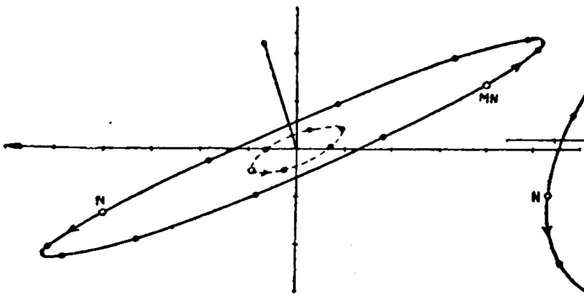


Fig. 71

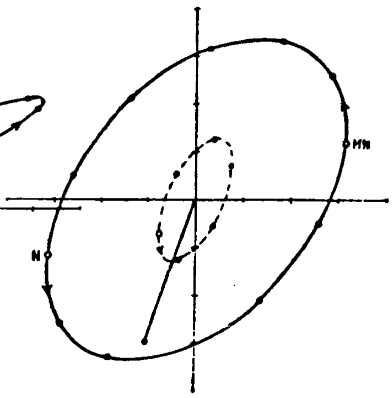


Fig. 74.

December

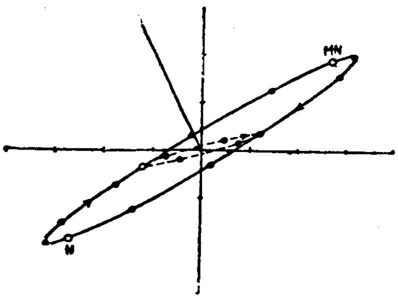


Fig. 72.

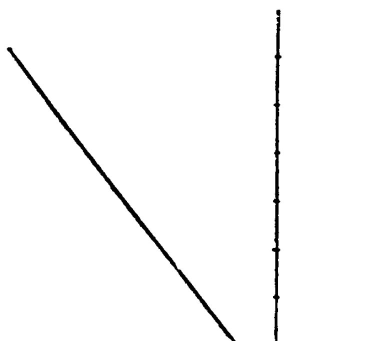


Fig 75.

Tôkyô **Hakodate**

April

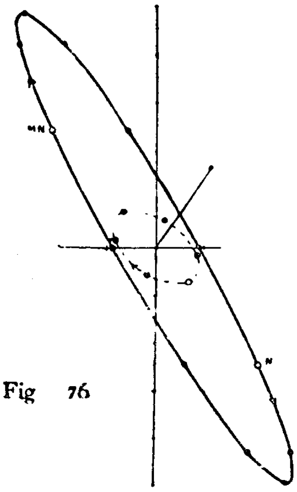


Fig 76

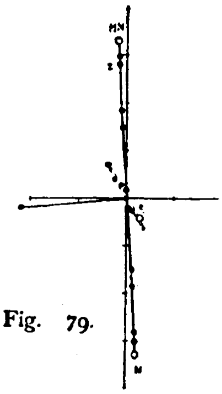


Fig. 79.

August

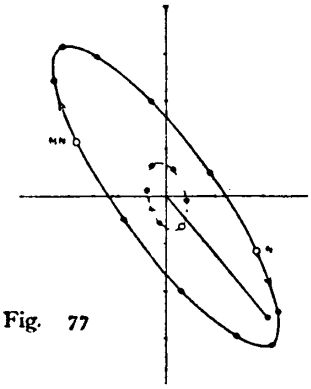


Fig. 77

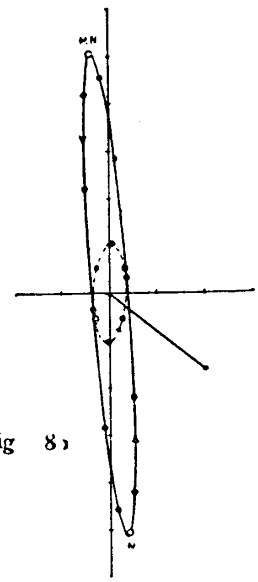


Fig 80

December

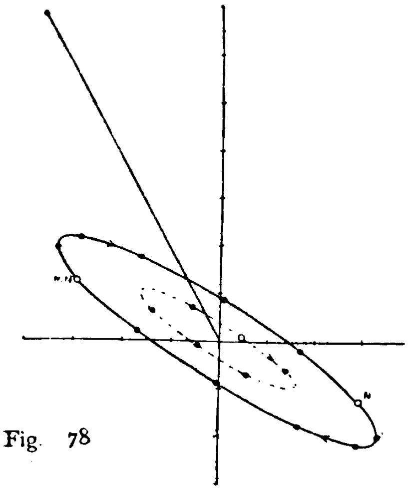


Fig. 78

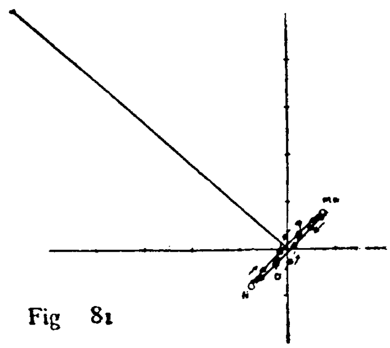


Fig 81

Sapporo **Nemuro**

April

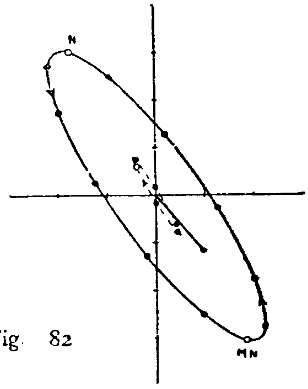


Fig. 82

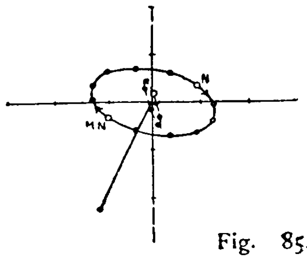


Fig. 85.

August

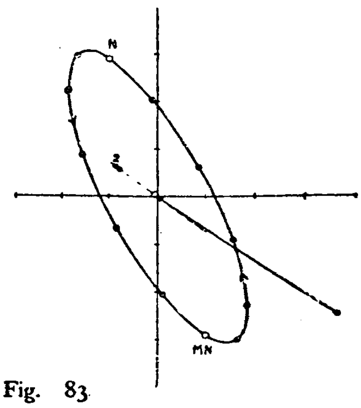


Fig. 83.

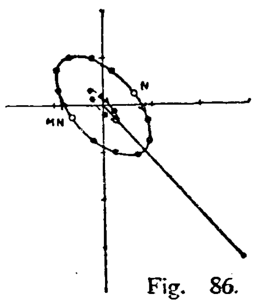
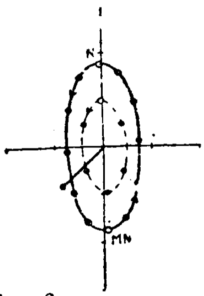


Fig. 86.

December



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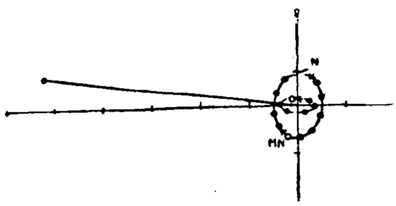

Fig. 87.