# ON THE RECENT SEA-LEVEL VARIATION AT THE DIFFERENT JAPANESE MAREOGRAPH STATIONS.

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With Plates XIV–XXII.

**1. *Introduction.*** In connection with the investigation of the cause of the Messina-Reggio earthquake of Dec. 28th, 1908, I made an examination of the recent variation in height of the mean sea-level at the different Italian and Austrian mareograph stations, and came to the conclusion that the great seismic disaster occurred in the year (1908), when the height of the sea-level was a minimum, or when the apparent elevation of the Tyrrhenean, the Ligurian, and the Adriatic coasts was at a maximum.* As the change in the water pressure at a sea bottom area must form one of the secondary causes of earthquakes, it is also seismologically important to examine the sea-level change along the coasts of Japan, which is so often convulsed by tremendous telluric disturbances. In the present paper I give, besides notes respecting Osaka and Yokohama, a discussion of the variation in height of the mean yearly sea-level, for the interval

* See the next Article.

of 1894 to 1910, at the following ten mareograph stations, belonging to the Military Survey Department :—

( 1 ) Misaki (Aburatsubo), near the city of Yokosuka, in Miura County, Province of Sagami.

( 2 ) Ayukawa, near the town of Ishinomaki, Province of Rikuzen.

( 3 ) Hanasaki, near the city of Nemuro, at the NE. extremity of Hokkaido.

( 4 ) Iwasaki, on the western coast of the province of Mutsu.

( 5 ) Wajima, on the NW. coast of the province of Noto.

( 6 ) Hamada (Tono-ura), Province of Iwami.

( 7 ) Fukabori, near the city of Nagasaki, Province of Hizen.

( 8 ) Hososhima, in the province of Hyuga.

( 9 ) Kushimoto, at the southern extremity of the Kii peninsula.

(10) Keelung, (Sharyo Isle), Formosa.

Of these ten stations, Keelung is in Formosa, Hanasaki in Hokkaido, and Fukabori and Hososhima are in Kyushu, while the remaining six are in the Main Island. Again, of the nine stations in Japan proper, Iwasaki, Wajima, and Hamada are situated on the Japan Sea coast, while all the others are on the Pacific coasts. (See Fig. 1.) The geographical positions of the different mareograph stations, (1) to (10), and the corresponding nearest sea-coast meteorological observatories, numbered (1′) to (10′), are as follows :—

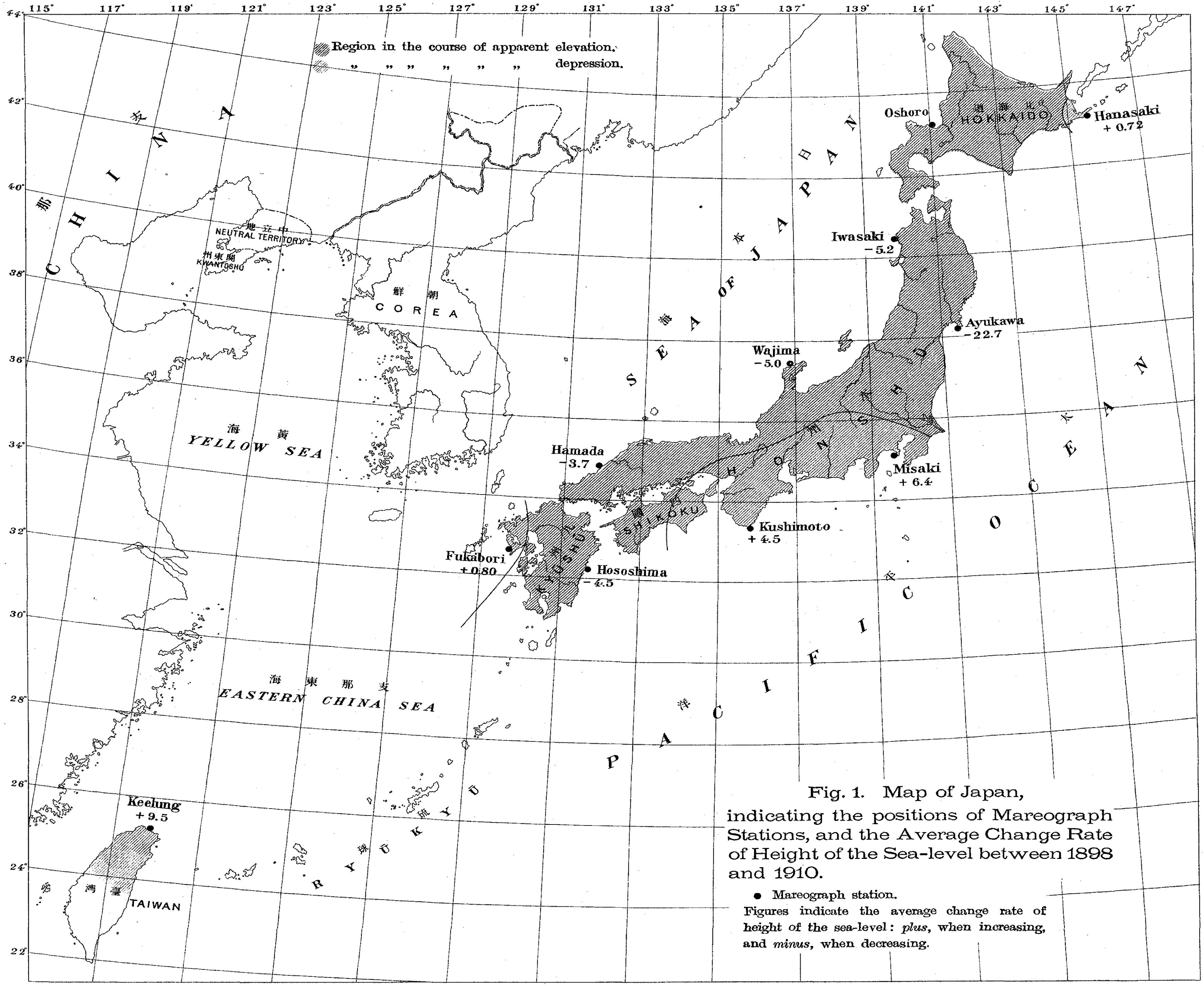



Fig. 1. Map of Japan, indicating the positions of Mareograph Stations, and the Average Change Rate of Height of the Sea-level between 1898 and 1910.

● Mareograph station.

Figures indicate the average change rate of height of the sea-level: *plus*, when increasing, and *minus*, when decreasing.

TABLE I. LIST OF THE MAREOGRAPH STATIONS AND THE METEOROLOGICAL OBSERVATORIES.

| Mareograph Station. | Latitude. (N) | Longitude. (E) | Meteorological Observatory. | Latitude. (N) | Longitude. (E) | Height above mean sea-level. |
|---|---|---|---|---|---|---|
| | | | | | | m |
| (1) Misaki | 35°10′ | 139°37′ | (1′) Yokosuka | 35°17′ | 139°40′ | 44.1 |
| (2) Ayukawa | 38 18 | 141 31 | (2′) Ishinomaki | 38 26 | 141 19 | 44.8 |
| (3) Hanasaki | 43 17 | 145 35 | (3′) Nemuro | 43 20 | 145 35 | 26.7 |
| (4) Iwasaki | 40 35 | 139 54 | (4′) Aomori | 40 51 | 140 45 | 4.3 |
| (5) Wajima | 37 24 | 136 54 | (5′) Fushiki | 36 47 | 137 03 | 4.0 |
| (6) Hamada | 34 55 | 132 04 | (6′) Hamada | 34 53 | 132 05 | 19.7 |
| (7) Fukabori | 32 41 | 129 49 | (7′) Nagasaki | 32 44 | 129 52 | 133.0 |
| (8) Hososhima | 32 25 | 131 40 | (8′) Miyazaki | 31 56 | 131 26 | 8.0 |
| (9) Kushimoto | 33 28 | 135 46 | (9′) Wakayama | 34 14 | 135 09 | 14.6 |
| (10) Keelung | 25 09 | 121 45 | (10′) Keelung | 25 09 | 121 45 | 3.4 |

The yearly mean values of the barometric pressure and of the air temperature at the different mareograph stations are, in the following pages, assumed to be identical with those of the corresponding meteorological observatories.

At each of the above mentioned tidal stations, which is furnished with an improved Thomson (Lord Kelvin) self-registering mareograph, the height of sea-surface is measured with reference to a point fixed in the observatory room, such that the higher levels correspond to the smaller figures and the lower to the greater. The height of the fixed point itself, determined at the outset with reference to an external bench mark, seems to have suffered slight alterations in the course of time. Thus, for instance, in the cases of Misaki and Hamada, the re-examination in July 1911 indicated the relative depressions of the fixed points respectively of 0.9 and 1.2 mm. I must here state my obligations to Mr. M. Sugiyama, of the Military Survey Department, who kindly furnished me with the yearly heights of the mean sea-level at the different stations from 1897 or 1898 to 1910. For the sea-level height between 1894 and 1896 at Misaki, Ayukawa, and Hamada, and for those in 1897 at Hanasaki and Kushimoto, I have consulted Prof. S. Hirayama's work, "Results of the harmonic analysis of tidal observations made at various ports of Japan," published in Vol. XXVIII of the Jour. Coll. Sc., Imp. Tokyo University. The mean sea-level height is always to be understood as being the arithmetical mean deduced from the marigrams, which was obtained, in the cases of the Military Survey Department Stations, by estimating with a planimeter the area enclosed between the tidal curve and the abscissa axis.

**2. *Mean yearly height of sea-level at Misaki, Ayukawa, Hanasaki, Iwasaki, Wajima, Hamada, Fukabori, Hososhima, and Kushimoto.*** Table II gives, for the time interval of 12 to 17 years between 1894 and 1910, the actual height of the mean yearly sea-level at the nine mareograph stations in Japan proper, namely, Misaki, Ayukawa, Hanasaki, Iwasaki, Wajima, Hamada, Fukabori, Hososhima, and Kushimoto. In Table III, deduced from Table II, the lowest position of the mean yearly sea-level at each station is taken as the datum. As will be seen from the graphical illustrations in Figs. 6, 7, and 8, (Pls. XVI, XVII, and XVIII), the mean yearly height in question indicates certain time variations with more or less definite points of similarity among the different stations.

### TABLE II. MEAN YEARLY HEIGHT OF SEA-LEVEL AT THE MAREOGRAPH STATIONS OF MISAKI, AYUKAWA, HANASAKI, IWASAKI, WAJIMA, HAMADA, FUKABORI, HOSOSHIMA, AND KUSHIMOTO.*

### 1894-1910.

| Year. | Misaki. | Ayukawa. | Hanasaki. | Iwasaki. | Wajima. | Hamada. | Fukabori. | Hososhima. | Kushimoto. |
|---|---|---|---|---|---|---|---|---|---|
| | (−) m | (−) m | (−) m | (−) m | (−) m | (−) m | (−) m | (−) m | (−) m |
| 1894 | — | 2.088 | — | — | — | — | — | — | — |
| 1895 | 2.146 | 2.085 | — | — | — | 2.135 | — | — | — |
| 1896 | 2.157 | — | — | — | — | 2.156 | — | — | — |
| 1897 | 2.180 | — | 2.439 | — | — | 2.270 | — | — | 2.284 |
| 1898 | 2.064 | 1.856 | 2.416 | 3.622 | 1.885 | 2.088 | 2.558 | 2.554 | 2.301 |
| 1899 | 2.056 | 1.843 | 2.417 | 3.576 | 1.856 | 2.098 | 2.579 | 2.538 | 2.278 |
| 1900 | 2.089 | 1.874 | 2.403 | 3.615 | 1.914 | 2.116 | 2.559 | 2.556 | 2.286 |
| 1901 | 2.063 | — | 2.420 | 3.633 | 1.942 | 2.133 | 2.556 | 2.564 | 2.307 |
| 1902 | 2.053 | 1.954 | 2.428 | 3.646 | 1.959 | 2.174 | 2.572 | 2.575 | 2.317 |
| 1903 | 2.061 | 1.925 | 2.463 | 3.622 | 1.949 | 2.168 | 2.556 | 2.555 | 2.298 |
| 1904 | 2.031 | 1.951 | 2.429 | 3.617 | 1.930 | 2.136 | 2.563 | 2.576 | 2.276 |
| 1905 | 2.033 | — | 2.396 | 3.621 | 1.924 | 2.126 | 2.537 | 2.554 | 2.275 |
| 1906 | 2.011 | 1.937 | 2.395 | 3.626 | 1.927 | 2.138 | 2.542 | 2.574 | 2.281 |
| 1907 | 2.015 | 1.989 | 2.384 | 3.660 | 1.961 | 2.166 | 2.569 | 2.598 | 2.301 |
| 1908 | 2.013 | 2.112 | 2.424 | 3.646 | 1.942 | 2.147 | 2.596 | 2.587 | 2.292 |
| 1909 | 2.003 | 2.128 | 2.443 | 3.686 | 1.951 | 2.165 | 2.554 | 2.603 | 2.251 |
| 1910 | 2.022 | 2.109 | 2.428 | 3.696 | 1.972 | 2.144 | 2.553 | 2.626 | 2.219 |
| Mean | 2.062 | 1.989 | 2.420 | 3.636 | 1.932 | 2.148 | 2.561 | 2.674 | 2.268 |

* The height of sea surface at each of the different stations is measured (as indicated by the minus sign) downwards from a point fixed in the mareograph room, so that the highest level corresponds to the smallest figure and the lowest level to the greatest figure.

**TABLE III. YEARLY HEIGHT OF THE SEA SURFACE AT THE DIFFERENT MAREOGRAPH STATIONS REFERRED TO THE LOWEST MEAN LEVEL. 1894-1910.**

| Year. | Misaki. | Ayukawa. | Hanasaki. | Iwasaki. | Wajima. | Hamada. | Fukabori. | Hososhima. | Kushimoto. | Average. |
|---|---|---|---|---|---|---|---|---|---|---|
| | (+) mm | (+) mm | (+) mm | (+) mm | (+) mm | (+) mm | (+) mm | (+) mm | (+) mm | (+) mm |
| 1894 | — | 40 | — | — | — | — | — | — | — | — |
| 1895 | 34 | 43 | — | — | — | 135 | — | — | — | 71 |
| 1896 | 23 | — | — | — | — | 114 | — | — | — | 69 |
| 1897 | 0 | — | 24 | — | — | 0 | — | — | 33 | 14 |
| 1898 | 116 | 272 | 47 | 74 | 87 | 182 | 38 | 72 | 16 | 100 |
| 1899 | 124 | 285 | 46 | 120 | 116 | 172 | 17 | 88 | 39 | 112 |
| 1900 | 91 | 254 | 60 | 81 | 58 | 154 | 37 | 70 | 31 | 93 |
| 1901 | 117 | — | 43 | 63 | 30 | 137 | 40 | 62 | 10 | 80 |
| 1902 | 127 | 174 | 35 | 50 | 13 | 96 | 24 | 51 | 0 | 63 |
| 1903 | 119 | 203 | 0 | 74 | 23 | 102 | 40 | 71 | 19 | 72 |
| 1904 | 149 | 177 | 34 | 79 | 42 | 134 | 33 | 50 | 41 | 82 |
| 1905 | 147 | — | 67 | 75 | 48 | 144 | 59 | 72 | 42 | 93 |
| 1906 | 169 | 191 | 68 | 70 | 45 | 132 | 54 | 52 | 36 | 91 |
| 1907 | 165 | 139 | 79 | 36 | 11 | 104 | 27 | 28 | 16 | 67 |
| 1908 | 167 | 16 | 39 | 50 | 30 | 123 | 0 | 39 | 25 | 54 |
| 1909 | 177 | 0 | 20 | 10 | 21 | 105 | 42 | 23 | 66 | 52 |
| 1910 | 158 | 19 | 35 | 0 | 0 | 126 | 43 | 0 | 98 | 53 |

The position of the mareograph at Ayukawa was changed in 1901 about 5 metres southwards, while the observation room was throughly repaired in 1905. Consequently the mean heights of the sea-level in these two years at Ayukawa are not given in the above table. Besides the nine stations contained in the latter, a mareograph station was established in 1906 at Oshoro, near Otaru, on the Japan Sea side of Hokkaido, the mean heights of the sea-level at this place during the five years 1906, 1907, 1908, 1909, and 1910, being respectively $-1.^{m}606$; $-1.^{m}628$; $-1.^{m}621$; $-1.^{m}628$; and $-1.^{m}618$.

According to Tables II and III, the highest and lowest sea-levels at the different stations were as follows :—

TABLE IV. HIGHEST AND LOWEST MEAN SEA-LEVELS AT THE DIFFERENT STATIONS.*

| Station. | Highest Sea-level. | Lowest Sea-level. | Difference between Highest and Lowest Sea-levels. |
|---|---|---|---|
| | (−) | (−) | |
| Misaki | $\overset{m}{2.003}$ (1909) | $\overset{m}{2.180}$ (1897) | $+\overset{m}{0.177}$ (12 yrs) |
| Ayukawa | 1.843 (1899) | 2.128 (1909) | −0.285 (10 „ ) |
| Hanasaki | 2.384 (1907) | 2.463 (1903) | +0.079 ( 4 „ ) |
| Iwasaki | 3.576 (1899) | 3.696 (1910) | −0.120 (11 „ ) |
| Wajima | 1.856 (1899) | 1.972 (1910) | −0.116 (11 „ ) |
| Hamada | 2.088 (1898) | 2.270 (1897) | +0.182 ( 1 „ ) |
| Fukabori | 2.537 (1905) | 2.596 (1908) | −0.059 ( 3 „ ) |
| Hososhima | 2.538 (1899) | 2.626 (1910) | −0.088 (11 „ ) |
| Kushimoto | 2.219 (1910) | 2.317 (1902) | +0.098 ( 8 „ ) |

Thus it will be seen that at Misaki the sea-level rose 177 mm in the course of the 12 years between 1897 and 1909, with the yearly mean of 14.8 mm. On the other hand, at Ayukawa the sea-level was lowered by an extraordinarily large amount of 285 mm in the course of the 10 years between 1899 and 1909, with

* In the 2nd and 3rd columns, the figure enclosed within brackets indicates the year in which the sea-level was highest or lowest, while in the 4th column it denotes the number of years between the occurrences of the highest and lowest sea-levels. Again, in the 4th column, the positive sign (+) means that the highest sea-level occurred subsequently to the lowest sea-level, while the negative sign (−) means that the reverse order was the case.

the yearly mean of 28.5 mm, which is equal, in the opposite sense, to twice the rate of change at Misaki. During the same time interval the sea-level was also lowered at Iwasaki, Wajima, and Hososhima, respectively by the amounts of 110 mm, 105 mm, and 65 mm, with the corresponding yearly means of 11 mm, 13.1 mm, and 6.5 mm. The level change at Hamada was very remarkable and indicated a rise of 182 mm in the course of the single year from 1897 to 1898. At the remaining three stations of Hanasaki, Fukabori, and Kushimoto, the extreme amount of the level fluctuation was from 59 to 79 mm.

**3. *Effect of barometric pressure.*** The height of sea-level at a given place must naturally be affected by the variations in the atmospheric pressure more or less according to either of the

Fig. 2.

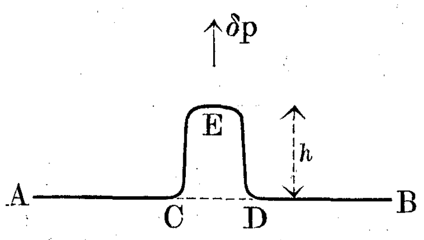
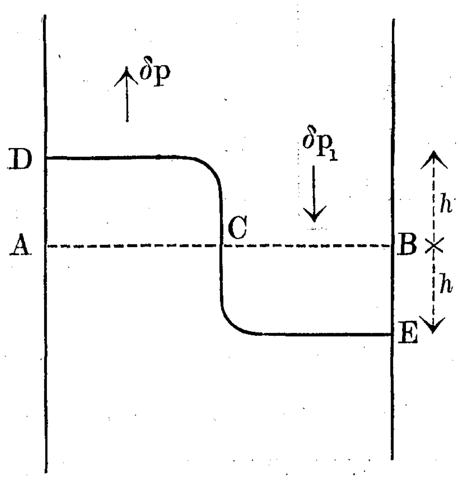



Fig. 3.




following two ways. (i) Let (Fig. 2) the barometric pressure be diminished (or increased) by $\delta p$ over a small area CD amid a wide expanse of the ocean surface AB. Then the water at CD would, to adjust itself to equilibrium, be elevated (or depressed) to E,

such that the height $h$ is equivalent to the pressure change multiplied by the density of sea water, namely: $h=13.3\times\delta p$.
(ii) Let (Fig. 3) the barometric pressure be diminished by $\delta p$ over one-half, AC, and increased by $\delta p_1$ over the rest, CB, of a limited portion, AB, of ocean or sea surface. Then, for adjusting to equilibrium, AB would be thrown, in consequence of the pressure changes into the surface DCE, such that the resultant elevation (AD) or depression (BE) is equivalent to $h$, as follows: $h=\frac{1}{2}\times 13.3(\delta p+\delta p_1)$. In other words, the total level difference is $2h=13.3(\delta p+\delta p_1)$. Let now the pressure distributions over the two portions AC and CB be reversed, then the total amount of the level fluctuation at A would be $2h$. In the case $\delta p$ is equal in magnitude to $\delta p_1$, we obtain: $2h=13.3\times 2\delta p$. If $\delta p$ denotes the amplitude, or semi-range, of the annual barometric variation, the corresponding level change is, according to the above relation, equivalent to the double amplitude of the latter multiplied by the coefficient 13.3, as in the case of (i).

(i) approximately represents the case of a cyclone or tornado passing over the sea surface, while (ii) may roughly be applied to explain the annual variation in height of sea-level consequent to the changes in the barometric pressure over the Northern Pacific and the neighbourhood of Japan. Thus, for instance, let AC (Fig. 3) denote the seas surrounding the Japanese islands, and CB the Northern Pacific. Then, during the summer months AC is under the influence of the low barometric area existing over the Eastern Siberia, while CB forms a high pressure region; the reverse being the case during the winter months.

In my previous notes, I have shown that the annual variation in the height of the sea surface is for several Japanese mareograph stations more or less symmetrical to the course of the barometric pressure;* the same characteristic being also shown in the sea-level and barometric changes at Pola. (See the next article.) To these examples may be added the case of Osaka, Table V giving for that place the mean relative monthly values of the height of the sea-level and of the barometric pressure, averaged from the observations during the three years 1909 to 1911. (See also Table XX.)

TABLE V. ANNUAL VARIATION IN HEIGHT OF SEA-LEVEL AND OF BAROMETRIC PRESSURE.** OSAKA, 1909—1911.

| Month. | Height of Sea-level. $951^{mm}+$ | Barometric Pressure. $756.4^{mm}+$ | Month. | Height of Sea-level. $951^{mm}+$ | Barometric Pressure. $756.4^{mm}+$ |
|---|---|---|---|---|---|
| I | 56 mm | 8.5 mm | VII | 249 mm | 1.5 mm |
| II | 0 | 8.6 | VIII | 325 | 0.0 |
| III | 124 | 7.7 | IX | 339 | 3.6 |
| IV | 159 | 5.4 | X | 270 | 6.5 |
| V | 131 | 4.0 | XI | 142 | 8.6 |
| VI | 181 | 0.3 | XII | 19 | 9.9 |

The annual variation in height of the sea-level is on the whole opposite to that of the atmospheric pressure. It will be noted, however, that the amount of change in height of the sea

* F. Omori: "Note on the annual variation of the height of sea-level at Ayukawa and Misaki," the *Publications*, No. 18; "On the annual variation of the height of sea-level along Japanese coasts," the *Bulletin*, Vol. II, No. 1.

** Reduction to standard gravity = −0.7 mm; Reduction to mean sea-level = +0.5 mm.

surface was, in the case of Osaka as well as in those of the other places before considered, much greater than could be counterbalanced by the barometric fluctuation alone. Thus, comparing the annual amplitudes of variation in height of the sea-level and of the barometric pressure, we have :—

**TABLE VI. ANNUAL AMOUNT OF VARIATION IN HEIGHT OF THE SEA-LEVEL COMPARED TO THAT OF THE BAROMETRIC PRESSURE.**

| Mareograph Station. | Year. | Difference between max. and min. monthly mean heights of Sea-level =W. | Atmospheric Pressure. | | Ratio: W/P. |
|---|---|---|---|---|---|
| | | | Difference between max. and min. monthly means. | Equivalent Water-column =P. | |
| Osaka . . . . . . . . . . . . . | 1909-11 | 339 mm | 9.9 mm | 131 mm | 2.58 |
| Misaki and Ayukawa* | 1902 | 248 | 9.3 | 124 | 2.01 |
| Do. * | 1903 | 214 | 8.1 | 108 | 2.00 |
| Otaru, Iwasaki, Wajima, Hamada. * | 1902 | 312 | 8.9 | 120 | 2.61 |
| Choshi . . . . . . . . . . . * | 1904 | 236 | 6.3 | 84 | 2.82 |
| Mean | — | 270 | 8.5 | 113 | **2.40** |

Thus the amount (W) of change in height of the sea-level at the different Japanese mareograph stations in question is on the average 2.4 times greater than that of the simple barometric compensation (P).

Let us now return to the cases of the different mareo-

* See the *Publications*, No. 18, and the *Bulletin*, Vol. II, No. 1.

graph stations (except Keelung) considered in § 2; Table XXI giving the mean yearly values of the barometric pressure between 1894 and 1910 at the meteorological observatories of Yokosuka, Ishinomaki, Nemuro, Aomori, Fushiki, Hamada, Nagasaki, Miyazaki, and Wakayama. The difference between the maximum and minimum values of the mean yearly barometric pressure at the different places varied, within the time interval under consideration, only from 0.9 to 1.5 mm, as follows :—

| | | | |
|---|---|---|---|
| Misaki (Yokosuka) | 1.1 mm | Hamada | 0.9 mm |
| Ayukawa (Ishinomaki) | 1.1 ,, | Fukabori (Nagasaki) | 1.1 ,, |
| Hanasaki (Nemuro) | 1.1 ,, | Hososhima (Miyazaki) | 1.1 ,, |
| Iwasaki (Aomori) | 0.9 ,, | Kushimoto (Wakayama) | 1.5 ,, |
| Wajima (Fushiki) | 1.0 ,, | | |

The course of variation from year to year of the barometric pressure was on the whole similar for the different stations; at most of the latter the maximum occurred in 1897, 1900, and 1903 (or 1905), and the minimum in 1898, 1901, and 1906. Assuming the barometric fluctuation to produce the change in the height of the sea surface simply equal to its own amount multiplied by the factor 13.3, I have calculated the correction necessary for reducing the mean yearly sea-level to the case of the 760 mm atmospheric pressure. (See Table VIII.) The difference between the maximum and minimum values of this correction for the different stations varied between 10 and 15 mm, with the exception of Kushimoto, for which it was 20 mm. The following table gives a comparison of the amount of the barometric correction to that of the fluctuation in the height of the sea-level, irrespective of the time relation.

TABLE VII. COMPARISON OF THE BAROMETRIC EFFECT AND THE AMOUNT OF FLUCTUATION IN THE YEARLY MEAN HEIGHT OF THE SEA-LEVEL.

| Mareograph Station. | (I). Difference between Max. and Min. Yearly Amount of Correction due to the Barometric Pressure. | (II). Difference between Highest and Lowest Positions of the Yearly Mean Sea-Level. | Ratio: $\frac{II}{I}$. |
|---|---|---|---|
| Misaki | −14 mm* | +177 mm** | 12.6 |
| Ayukawa | +15 | −285 | 19.0 |
| Hanasaki | −14 | + 79 | 5.6 |
| Iwasaki | −12 | −120 | 10.0 |
| Wajima | −13 | −116 | 8.9 |
| Hamada | −12 | +182 | 15.2 |
| Fukabori | ±12 | − 59 | 4.9 |
| Hososhima | −10 | − 88 | 8.8 |
| Kushimoto | −20 | + 98 | 4.9 |

Thus it will be seen that for Misaki, Ayukawa, Iwasaki, Wajima, and Hamada, the variation in height of the sea-level was considerable and amounted from 8.9 to 19 times the effect due to the fluctuation in the mean yearly barometric pressure, which in consequence, must be regarded as of a comparatively small magnitude. For the remaining four stations of Hanasaki, Fukabori, Hososhima, and Kushimoto, where the sea-level change was much smaller, the ratio in question was 4.9 to 8.8. In short, the variation in height of the mean yearly sea-level will be seen not to be

* Plus (+) when the maximum yearly barometric mean occurred before, and minus (−) when it occurred after, the minimum.

** Plus (+) when the level was increasing, and minus (−) when decreasing.

materially altered by the reduction to the case of the 760 mm atmospheric pressure, as considered above; the effect of the introduction of the barometric correction being equivalent to a general upward displacement by the average amount of 5 to 10 mm for all the stations, except Hanasaki, and a general downward displacement by 7 mm for the latter. It may here be added that for Misaki (Fig. 6) the variation of the barometric pressure was on the whole symmetrically opposite to the small fluctuations in that of the height of the sea-level. In the cases of all the remaining stations, however, no such relation was markedly indicated. It seems likely that the effect of the barometric pressure may cause the secondary changes in, but does not govern the general course of, the variation in height of the sea-level.

### TABLE VIII. LIST OF THE BAROMETRIC AND TEMPERATURE CORRECTIONS TO BE APPLIED TO THE YEARLY HEIGHT OF THE MEAN SEA-LEVEL AT THE NINE DIFFERENT MAREOGRAPH STATIONS IN JAPAN.

Barometric correction $= p$,........For the reduction to 760 mm.
Temperature „ $= t$,........ „ „ „ „ the mean temperature in 1902.

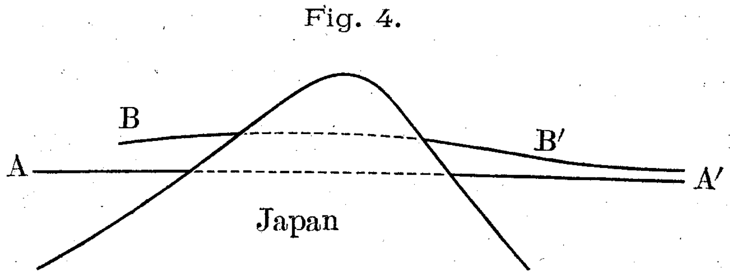
| Year. | Misaki. | | Ayu-kawa. | | Hana-saki. | | Iwasaki. | | Wajima. | | Hama-da. | | Fuka-bori. | | Hoso-shima. | | Kushi-moto. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $p$ | $t$ | $p$ | $t$ | $p$ | $t$ | $p$ | $t$ | $p$ | $t$ | $p$ | $t$ | $p$ | $t$ | $p$ | $t$ | $p$ | $t$ |
| | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm |
| 1894 | — | — | + 9 | −25 | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 1895 | + 8 | 0 | + 7 | − 7 | — | — | — | — | — | — | +16 | + 2 | — | — | — | — | — | — |
| 1896 | +15 | − 2 | +12 | −10 | — | — | — | — | — | — | +20 | + 5 | — | — | — | — | — | — |
| 1897 | +17 | + 8 | +17 | +13 | 0 | + 5 | — | — | — | — | +27 | + 5 | — | — | — | — | +28 | + 2 |
| 1898 | +12 | − 2 | +11 | 0 | −11 | + 7 | + 5 | − 3 | +16 | −12 | +15 | − 8 | +16 | −17 | +15 | − 8 | +17 | − 7 |
| 1899 | + 9 | 0 | +12 | − 5 | −12 | −13 | + 4 | −12 | +19 | − 8 | +19 | − 3 | +23 | + 2 | +17 | + 5 | + 8 | 0 |
| 1900 | +13 | + 3 | +15 | + 5 | − 8 | − 3 | + 9 | 0 | +24 | − 3 | +24 | + 3 | +24 | + 5 | +21 | + 5 | +24 | + 3 |
| 1901 | + 4 | − 2 | + 5 | − 7 | − 9 | −13 | + 3 | − 7 | +15 | − 3 | +17 | + 8 | +15 | +10 | +15 | +12 | +16 | + 3 |
| 1902 | + 8 | 0 | +11 | 0 | − 7 | 0 | + 4 | 0 | +17 | 0 | +19 | 0 | +19 | 0 | +15 | 0 | +17 | 0 |
| 1903 | +15 | 0 | +15 | − 7 | + 1 | −18 | + 9 | −12 | +23 | − 5 | +25 | 0 | +27 | + 2 | +21 | + 3 | +23 | − 2 |

| Year. | Misaki. | | Ayu-kawa. | | Hana-saki. | | Iwasaki. | | Wajima. | | Hama-da. | | Fuka-bori. | | Hoso-shima. | | Kushi-moto. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *p* | *t* | *p* | *t* | *p* | *t* | *p* | *t* | *p* | *t* | *p* | *t* | *p* | *t* | *p* | *t* | *p* | *t* |
| | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm |
| 1904 | +12 | 0 | +13 | 0 | − 7 | −25 | + 7 | − 7 | +19 | − 2 | +24 | + 2 | +27 | + 2 | +20 | + 5 | +20 | 0 |
| 1905 | +16 | + 7 | +20 | + 5 | + 1 | − 2 | +12 | 0 | +21 | − 2 | +20 | 0 | +20 | − 2 | +17 | − 3 | +21 | − 3 |
| 1906 | + 3 | +10 | + 7 | +12 | −13 | + 3 | + 0 | + 8 | +11 | + 5 | +15 | + 8 | +15 | + 5 | +12 | + 5 | +12 | + 7 |
| 1907 | +11 | + 3 | +13 | + 3 | − 5 | − 5 | + 7 | 0 | +12 | − 2 | +15 | + 5 | +16 | + 5 | +11 | +13 | +13 | + 7 |
| 1908 | +13 | + 7 | +15 | +12 | − 4 | +13 | + 8 | +10 | +17 | + 2 | +21 | + 2 | +23 | + 2 | +19 | +12 | +19 | + 3 |
| 1909 | +12 | + 2 | +13 | + 3 | − 3 | 0 | + 8 | + 3 | +20 | + 5 | +19 | + 2 | +20 | + 2 | +16 | +12 | +19 | + 5 |
| 1910 | + 4 | + 5 | + 5 | 0 | − 7 | − 7 | + 4 | + 3 | +13 | + 8 | +16 | + 8 | +17 | + 7 | +13 | +15 | +12 | + 5 |

**4. *Effect of temperature.*** The accurate determination of the temperature effect on the height of sea-level is a difficult problem, requiring a complete knowledge of the temperature distribution in the sea-water mass. In a note published in the Proceedings of the Tokyo Mathematico-Physical Society, 2nd Series, Vol. IV, (1908), Prof. H. Nagaoka made an attempt for estimating the temperature effect for the annual variation in height of the sea-level at Choshi. The procedure in this §, which is so to speak empirical, is a gross approximation and is to be regarded only as provisionary.

Let us again consider the annual variation in height of the sea-level. The temperature of the surface sea water is in the Northern Pacific about 10° C higher in the summer (August)than in the winter (February), while, along the coasts of Japan, the difference between its maximum and minimum monthly values amounts from 12° to 18° C, (Table XXII),

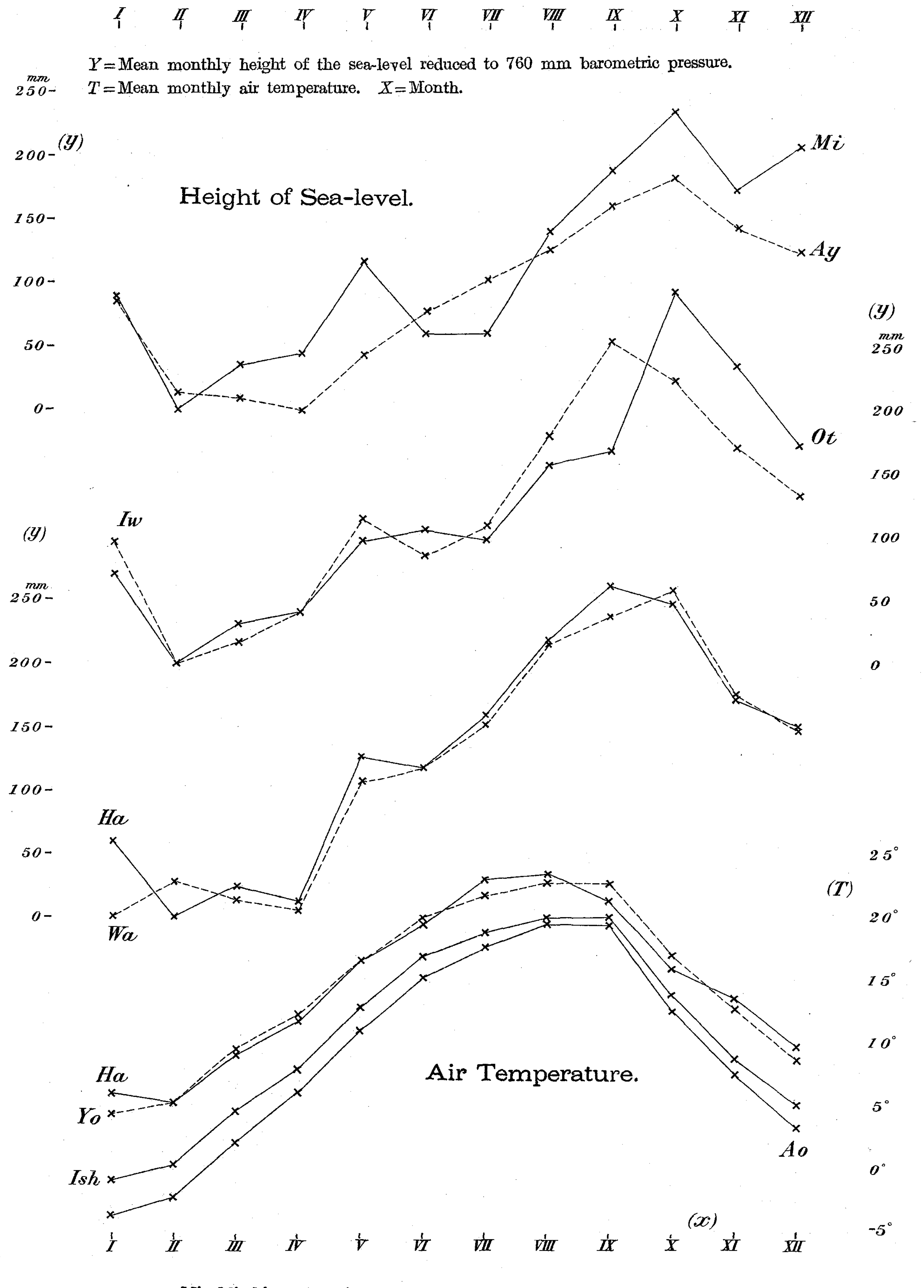
Fig. 4.



giving the average range of 15°.6 C. Thus, the sea-level about Japan in the winter, represented by AA′ in Fig. 4, would in the summer be elevated to some surface BB′ in consequence of the temperature increase, apart from the effect of the change in the distribution of the barometric pressure. In Table XXII, I give the mean monthly temperatures of the surface sea-water for the neighbourhood of the five mareograph stations of Misaki, Ayukawa, Hanasaki, Hamada, and Fukabori, deduced from the observations during the 20 years 1882 to 1901,* and the mean monthly air temperatures at the corresponding nearest meteorological observatories deduced from the observations during the 5 to 25 years ending with 1905. The maximum water temperature is, for the different stations, practically identical with the maximum air temperature, both occurring always in August. As is to be expected, however, the minimum water temperature was always a few degrees higher than the minimum air temperature, both occurring in January or February. In no case was the water temperature less than 4° C, except at Hanasaki. The amplitude of the yearly variation of the temperature of the air, which must be related to that of the water, may be assumed as being proportional to the temperature correction to be applied to the height of the mean sea-level, in absence of the accurate knowledge of the actual temperature distribution on the surface and in the mass of the sea water. Assume further the annual variation in height of the sea-level, reduced to the 760 mm barometric pressure, to depend entirely on that of the air temperature. As illustrative examples, let us consider the height of the sea-level in 1902 at

* Taken from Prof. Y. Wada's paper: Température Moyenne Annuelle de la Surface de la mer dans l'Ocean Pacifique occidental. *Bulletin of the Central Meteorological Observatory*, Tokyo, No. 1, 1904.

Fig. 5. Annual Variation in Height of the Sea-level compared with that of the Air Temperature. Misaki, Ayukawa, Otaru, Iwasaki, Hamada, and Wajima, 1902.




Mi = Misaki. Ay = Ayukawa. Ot = Otaru. Iw = Iwasaki. Ha = Hamada.
Wa = Wajima. Yo = Yokosuka. Ish = Ishinomaki. Ao = Aomori.

the 6 mareograph stations of Misaki, Ayukawa, Otaru,* Iwasaki, Wajima, and Hamada.** In Table XXIV are given, for each month of the year 1902, the mean relative heights of the sea-level at these places, as well as the mean barometric pressure and air temperature, and the resultant wind direction, at the meteorological observatories of Yokosuka (Misaki), Ishinomaki (Ayukawa), Sapporo (Otaru), Aomori (Iwasaki), Wajima, and Hamada. From Fig. 5 it will be seen that, for the different stations, the course of the annual variation of the height of the sea-level, corrected for the barometric pressure, is in a measure similar to that of the air temperature, rendering the above assumption respecting the influence of the latter not altogether improbable. According to § 3 and my two previous notes on the annual variation of the sea-level height,** I obtain the following results for Misaki and Ayukawa (1902 and 1903), Wajima and Hamada (1903), and Osaka (1909-1911) :—

**TABLE IX. COMPARISON OF THE ANNUAL AMOUNT OF FLUCTUATION IN HEIGHT OF THE MEAN SEA-LEVEL WITH THAT OF THE AIR TEMPERATURE.**

| Mareograph Station. | Year. | Difference between Maximum and Minimum Monthly Means. | |
|---|---|---|---|
| | | Height of Sea-level. (with barometric correction) | Air Temperature. |
| Misaki | 1902 | 361 mm | 18°.5 C. |
| ,, | 1903 | 291 | 20.0 |

* This was one of the two permanent mareograph stations in Hokkaido, its site being near the harbour pier of Otaru, at $\varphi=43°13'N$, $\lambda=141°01'E$. In 1905, the tide observatory was transferred to Oshoro, at $\varphi=43°13'N$, $\lambda=140°51'E$.

** See the *Publications*, No. 18, and the *Bulletin*, Vol. II.

| Mareograph Station. | Year. | Difference between Maximum and Minimum Monthly Means. | |
|---|---|---|---|
| | | Height of Sea-level. (with barometric correction) | Air Temperature. |
| Ayukawa | 1902 | 304 mm | 21°.0 C |
| „ | 1903 | 348 | 21.2 |
| Wajima | „ | 450 | 20.3 |
| Hamada | „ | 529 | 20.6 |
| Osaka | 1909 | 279 | 24.1 |
| „ | 1910 | 327 | 23.1 |
| „ | 1911 | 305 | 22.4 |
| Mean | .... | 355 | 21°.2 C |

Thus the average difference between the highest and lowest positions of the mean monthly sea-level was 355 mm, while the corresponding average amount of variation of the mean air temperature was 21°.2 C. This gives a change of 16.8 mm in height of the sea-level for 1° difference of the air temperature, namely: Level Change = Temperature Change × 16.8 mm. This relation very likely gives an unduly great importance to the temperature effect on the height of the sea-level. Let us now turn our attention to the evaluation of the temperature correction to be applied to the mean yearly height of the sea-level at the different mareograph stations. The mean yearly air temperature from 1894 to 1910 at the nine meteorological observatories of Yokosuka, Ishinomaki, Nemuro, Aomori, Fushiki, Hamada, Nagasaki, Miyazaki, and Wakayama, are given in Table XXIII. According to the latter the variation of the mean yearly air temperature at the different places was from 0°.7 to 1°.6 C in the respective time intervals, except Ishinomaki (Ayukawa) and Nemuro (Hanasaki), for each of which latter it was 2°.3 C, as follows :—

| | | | |
|---|---|---|---|
| Yokosuka (Misaki) | 0°.7 C. | Hamada | 1°.0 C. |
| Ishinomaki (Ayukawa) | 2.3 | Nagasaki (Fukabori) | 1.6 |
| Nemuro (Hanasaki) | 2.3 | Miyazaki (Hososhima) | 1.4 |
| Aomori (Iwasaki) | 1.3 | Wakayama (Kushimoto) | 0.8 |
| Fushiki (Wajima) | 1.0 | | |

It will be observed that the variation of the air temperature within the time interval under consideration was of the following two types : (i), in the western and central parts of Japan, including Miyazaki, Nagasaki, Wakayama, Hamada, Yokosuka, and Fushiki, the first maximum occurred in 1898 and a second mostly in 1905 ; (ii), in the northern part of the Main Island and in Hokkaido, including Ishinomaki, Aomori, and Nemuro, there was no maximum in 1898 and 1905. For most of the stations of both types, the temperature was minimum in 1897 and 1906. The temperature effect on the height of the sea-level is, however, neither uniform nor evident. Thus, comparing together the graphical representations for the different places of the variation in height of the mean sea-level (Figs. 6, 7, and 8), we see that the latter attained the well defined absolute maximum at Hamada in 1898, and at Ayukawa, Wajima, Iwasaki, and Hososhima, in 1899. The mean yearly air temperature, which was indeed highest in 1898 at Hamada, was in 1899 neither maximum nor minimum at Fushiki and Miyazaki, while it reached in that year an insignificant maximum at Ishinomaki and Aomori. Again, at all the mareograph stations, except Misaki and Hanasaki, the sea surface reached a conspicuous low level in 1902, in which year the variation of the mean temperature indicated a slight maximum at Miyazaki, Nagasaki, and Hamada, and a slight minimum at Fushiki, Ishinomaki, and Aomori.

Taking for reference the year 1902, in which the sea-level attained a distinct minimum height at the majority of the stations, the temperature correction has been calculated by means of the equation above obtained, on the assumption that the relation between the air temperature and the sea-level height in annual variation is also applicable to the case of the variation from year to year. As indicated in Table VIII, the difference between the maximum and minimum amounts of this correction was from 12 mm for Misaki to 39 mm for Ayukawa and Hanasaki, being for most of the stations much smaller than the difference between the highest and lowest sea-levels.

With respect to the possible effect of winds on the height of the sea-level, we note that the variation of the latter in 1902, with the barometric correction, was almost perfectly identical month by month for Hamada and Wajima (Fig. 5), except January and February; the resultant wind direction was nearly similar in these two latter months, but generally much different during the rest of the year, at the two stations. It may be remarked that both Hamada and Wajima are situated on the coasts, whose general direction is NE-SW, having sea on the NW side. Again, at Misaki and Ayukawa the sea-level was highest in October, when the resultant wind direction was at each place practically due N, while the southerly wind would have been most favourable to an accumulation of water in their neighbourhood. The effect of the wind on the height of the sea-level seems, in these particular examples, to have been, if any, not well marked, and for the present will be entirely neglected.

**5. *Mean yearly height of sea-level with barometric and temperature corrections.*** Table X gives the mean yearly height of the sea-level at Misaki and the other eight mareograph stations, reduced, according to the methods described in the two preceding §§, to the case of the atmospheric pressure of 760 mm and of the respective mean temperature in the year 1902. The introduction of the barometric and the temperature corrections causes modifications in detail in, but does not alter the general character of, the course of variation of the sea-level. In Table XI, deduced from Table X, the lowest position of the mean yearly sea-level at each station is taken as the datum.

TABLE X. YEARLY HEIGHT OF THE MEAN SEA-LEVEL AT MISAKI, AYUKAWA, HANASAKI, IWASAKI, WAJIMA, HAMADA, FUKABORI, HOSOSHIMA, AND KUSHIMOTO, REDUCED TO THE CASE OF THE ATMOSPHERIC PRESSURE OF 760 MM AND OF THE RESPECTIVE MEAN TEMPERATURE IN THE YEAR 1902.*
1894-1910.

| Year. | Misaki. | Ayu-kawa. | Hana-saki. | Iwasaki. | Waji-ma. | Hama-da. | Fuka-bori. | Hoso-shima. | Kushi-moto. |
|---|---|---|---|---|---|---|---|---|---|
| | (−) m | (−) m | (−) m | (−) m | (−) m | (−) m | (−) m | (−) m | (−) m |
| 1894 | — | 2.104 | — | — | — | — | — | — | — |
| 1895 | 2.138 | 2.085 | — | — | — | 2.117 | — | — | — |
| 1896 | 2.144 | — | — | — | — | 2.131 | — | — | — |
| 1897 | **2.155** | — | 2.434 | — | — | **2.238** | — | — | 2.254 |
| 1898 | 2.054 | 1.845 | 2.420 | 3.620 | 1.881 | 2.081 | 2.559 | 2.547 | 2.291 |
| 1899 | 2.047 | 1.836 | 2.442 | 3.584 | 1.845 | 2.082 | 2.554 | 2.516 | 2.270 |
| 1900 | 2.073 | 1.854 | 2.414 | 3.606 | 1.893 | 2.089 | 2.530 | 2.530 | 2.259 |
| 1901 | 2.061 | — | 2.442 | 3.637 | 1.930 | 2.108 | 2.531 | 2.537 | 2.288 |
| 1902 | 2.045 | 1.943 | 2.435 | 3.642 | 1.942 | 2.155 | 2.553 | 2.560 | **2.300** |
| 1903 | 2.046 | 1.917 | **2.480** | 3.625 | 1.931 | 2.143 | 2.527 | 2.531 | 2.277 |

* The lowest level at each station is indicated by thick numerals.

| Year. | Misaki. | Ayu-kawa. | Hana-saki. | Iwasaki. | Waji-ma. | Hama-da. | Fuka-bori. | Hoso-shima. | Kushi-moto. |
|---|---|---|---|---|---|---|---|---|---|
| | (−) m | (−) m | (−) m | (−) m | (−) m | (−) m | (−) m | (—) m | (−) m |
| 1904 | 2.019 | 1.938 | 2.461 | 3.617 | 1.913 | 2.110 | 2.534 | 2.551 | 2.256 |
| 1905 | 2.010 | — | 2.397 | 3.609 | 1.905 | 2.106 | 2.519 | 2.540 | 2.257 |
| 1906 | 1.998 | 1.918 | 2.405 | 3.618 | 1.911 | 2.115 | 2.522 | 2.557 | 2.262 |
| 1907 | 2.001 | 1.973 | 2.394 | 3.653 | **1.951** | 2.146 | 2.548 | 2.574 | 2.281 |
| 1908 | 1.993 | 2.085 | 2.415 | 3.628 | 1.923 | 2.124 | **2.571** | 2.556 | 2.270 |
| 1909 | 1.989 | **2.112** | 2.446 | 3.675 | 1.926 | 2.144 | 2.532 | 2.575 | 2.227 |
| 1910 | 2.013 | 2 104 | 2.442 | **3.689** | **1.951** | 2.120 | 2.529 | **2.598** | 2.202 |
| Mean. | 2.049 | 1.978 | 2.431 | 3.631 | 1.916 | 2.126 | 2.539 | 2.552 | 2.264 |

**TABLE XI. RELATIVE YEARLY HEIGHT OF THE MEAN SEA-LEVEL AT MISAKI, AYUKAWA, HANASAKI, IWASAKI, WAJIMA, HAMADA, FUKABORI, HOSOSHIMA, AND KUSHIMOTO. 1894-1910.** (With the barometric and temperature corrections).

| Year. | Mi-saki. | Ayu-kawa. | Hana-saki. | Iwa-saki. | Waji-ma. | Hama-da. | Fuka-bori. | Hoso-shima. | Kushi-moto. | Mean. |
|---|---|---|---|---|---|---|---|---|---|---|
| | (+) mm | (+) mm | (+) mm | (+) mm | (+) mm | (+) mm | (+) mm | (+) mm | (+) mm | (+) mm |
| 1894 | — | 8 | — | — | — | — | — | — | — | — |
| 1895 | 17 | 27 | — | — | — | 121 | — | — | — | 55 |
| 1896 | 11 | — | — | — | — | 107 | — | — | — | 59 |
| 1897 | 0 | — | 46 | — | — | 0 | — | — | 46 | 23 |
| 1898 | 101 | 267 | 60 | 69 | 70 | 157 | 12 | 51 | 9 | 84 |
| 1899 | 108 | 276 | 38 | 105 | 106 | 156 | 17 | 82 | 30 | 98 |
| 1900 | 82 | 258 | 66 | 83 | 58 | 149 | 14 | 68 | 41 | 90 |
| 1901 | 94 | — | 38 | 52 | 21 | 130 | 40 | 61 | 12 | 69 |
| 1902 | 110 | 169 | 45 | 47 | 9 | 83 | 18 | 38 | 0 | 54 |
| 1903 | 109 | 195 | 0 | 64 | 20 | 95 | 44 | 67 | 23 | 64 |
| 1904 | 136 | 174 | 19 | 72 | 38 | 128 | 37 | 47 | 44 | 73 |
| 1905 | 145 | — | 83 | 80 | 46 | 132 | 52 | 58 | 43 | 87 |

| Year. | Mi-saki. | Ayu-kawa. | Hana-saki. | Iwa-saki. | Waji-ma. | Hama-da. | Fuka-bori. | Hoso-shima. | Kushi-moto. | Mean. |
|---|---|---|---|---|---|---|---|---|---|---|
| | (+) mm | (+) mm | (+) mm | (+) mm | (+) mm | (+) mm | (+) mm | (+) mm | (+) mm | (+) mm |
| 1906 | 157 | 194 | 75 | 71 | 40 | 123 | 49 | 41 | 38 | 84 |
| 1907 | 154 | 139 | 86 | 36 | 0 | 92 | 23 | 24 | 19 | 60 |
| 1908 | 162 | 27 | 65 | 61 | 28 | 114 | 0 | 42 | 30 | 55 |
| 1909 | 166 | 0 | 34 | 14 | 25 | 94 | 39 | 23 | 73 | 48 |
| 1910 | 142 | 8 | 38 | 0 | 0 | 118 | 42 | 0 | 98 | 50 |
| Mean. | 106 | 134 | 50 | 58 | 35 | 112 | 32 | 46 | 36 | — |

(+).... The positive sign indicates that the height is here measured *above* the lowest yearly sea-level.

***6. Variation in height of mean sea-level at Misaki, 1895 to 1910.*** The variation in height of the mean yearly sea-level at Misaki which is situated at the southern extremity of the Miura peninsula, of tertiary formation, separating the Tokyo Bay from the Sagami Nada (Pacific) is highly interesting and indicates, as illustrated in Fig. 6, a general progressive upheaval from the commencement in 1895 of the mareograph observation down to the present time (1910). During this time interval the difference between the maximum and minimum values of the yearly mean was only 1.1 mm for the barometric pressure, and 0°.7 C for the air temperature; there being nothing special in the course of the variation of either which may lead to the steady increase or decrease of the sea-level. It seems probable that the fluctuations in the air pressure and temperature caused the secondary changes in, but were not responsible for the production of, the general level elevation. The actual mean sea-level, which had the lowest height of 2.180 m in 1897, was raised to 2.003 m in 1909, the difference amounting to 177 mm, with the average of 14.8 mm per year. If we take the sea-level variation corrected for the barometric pressure and the temperature, then the total amount of the elevation in question becomes 166 mm between the same two time limits, with the yearly amount of 14.0 mm. This latter is to be taken as the rate with which the coast at Misaki was *sinking* within the last 12 years or so. Should the land continue to be depressed uniformly with this speed, then its level would be lowered by 1.4 metres in the course of one century.

If the sea-level elevation be assumed to be the effect of the coast depression, then the relative height (denoted by y) in the different years (denoted by x) of the datum plane referred to the mean sea-level in 1909 is as given in the 3rd column of Table XII, being highest, 149 to 166 mm, in 1895-7.

TABLE XII. LAND ELEVATION AT MISAKI.

| Year. | x. | y=Relative Height of a fixed land point supposed to be in course of elevation. | Average Height (Actual). | Average Height calculated by Eq. (1). |
|---|---|---|---|---|
| 1895 | 0 | 149 mm | | |
| 1896 | 1 | 155 | 157 | 168 |
| 1897 | 2 | 166 | | |
| 1898 | 3 | 65 | | |
| 1899 | 4 | 58 | 69 | 77 |
| 1900 | 5 | 84 | | |
| 1901 | 6 | 72 | | |
| 1902 | 7 | 56 | 62 | 43 |
| 1903 | 8 | 57 | | |
| 1904 | 9 | 30 | | |
| 1905 | 10 | 21 | 20 | 25 |
| 1906 | 11 | 9 | | |
| 1907 | 12 | 12 | | |
| 1908 | 13 | 4 | 10 | 12 |
| 1909 | 14 | 0 | | |
| 1910 | 15 | 24 | | |

The general, or mean, variation in height of the datum plane between 1895 and 1910 may roughly be represented by the following relation:—

$$32.7x+2.6y+xy-637.2=0 \ldots\ldots (1)$$

in which $y$ is the relative height of the datum plane in the year $x$, whose 0 corresponds to 1895. The actual and calculated 3-yearly means given in the 4th and 5th columns of the preceding table agree more or less with each other. As may be judged from Fig. 9, the rate of the land sinking, or sea-level elevation, indicates a tendency to become asymptotic hereafter. Or, it may be that the land is approaching a limit of the depression, after which it would begin to be elevated. This latter view seems to be the more likely supposition.

The depression of the land seems not to be confined only to the immediate vicinity of Misaki, but is probably taking place in the whole of the Miura Peninsula and possibly also at some portion of the Kazusa-Awa Peninsula, whose geological formation is nearly similar to that of the latter. For the sake of comparison I give in Table XIII the mean yearly values during the 6 years, 1900 to 1905, of the height of the sea-level, the barometric pressure, and the air temperature, for Yokohama, which is situated about 35 km to the north of Misaki, on the Tokyo Bay. As illustrated in Fig. 6, the actual mean sea-level at Yokohama also indicates a rise of 67 mm within the time interval in question. The amount of the elevation, corrected for the barometric pressure and the temperature, was 64 mm, with the yearly average of 12.8 mm,

TABLE XIII. YEARLY HEIGHT OF THE MEAN SEA-LEVEL AT YOKOHAMA, 1900-1905.

$p$ = Reduction to the barometric pressure of 760 mm.
$t$ = " " " mean temperature of 1902.

| Year. | Height of Sea-level. | Barometric Pressure. | Air Temperature. | Correction. | | Corrected Height of Sea-level. |
|---|---|---|---|---|---|---|
| | | | | $p$ | $t$ | |
| | (+) m | mm | ° | mm | mm | (+) m |
| 1900 | 1.306 | 761.2 | 14.3 C | +16 | 0 | 1.322 |
| 1901 | 1.363 | 760.5 | 14.5 | + 7 | −3 | 1.367 |
| 1902 | 1.347 | 760.8 | 14.3 | +11 | 0 | 1.358 |
| 1903 | 1.362 | 761.3 | 14.4 | +17 | −2 | 1.377 |
| 1904 | 1.373 | 761.0 | 14.4 | +13 | −2 | 1.384 |
| 1905 | 1.367 | 761.3 | 14.2 | +17 | +2 | 1.386 |

The phenomenon of the apparent land elevation considered in this § relates of course to what is actually going on, and not to what took place several centuries or several decades ago, or in the past geological ages. As already hinted, the change in the sea-level height during the recent years forms probably a step or epoch in the variation of a much longer period.

**7. *Variation in height of mean sea-level at Ayukawa.*** The variation in height of the mean sea-level at Ayukawa, which reached the uppermost position in 1899, is remarkable for the great amount of the fluctuations, far surpassing those at the other stations. (See Fig. 7.) The actual mean sea-level rose 245 mm in the course of the 5 years from 1894 to 1899, while it is decreasing in height since the latter year, the total relative depression of 285 mm being reached in 1909. The corresponding

Fig. 6.

Variation in Height of the Mean Sea-level: Misaki, 1895-1910; Yokohama, 1900-1905.
Barometric Pressure and Air Temperature at Yokosuka, 1895-1910.

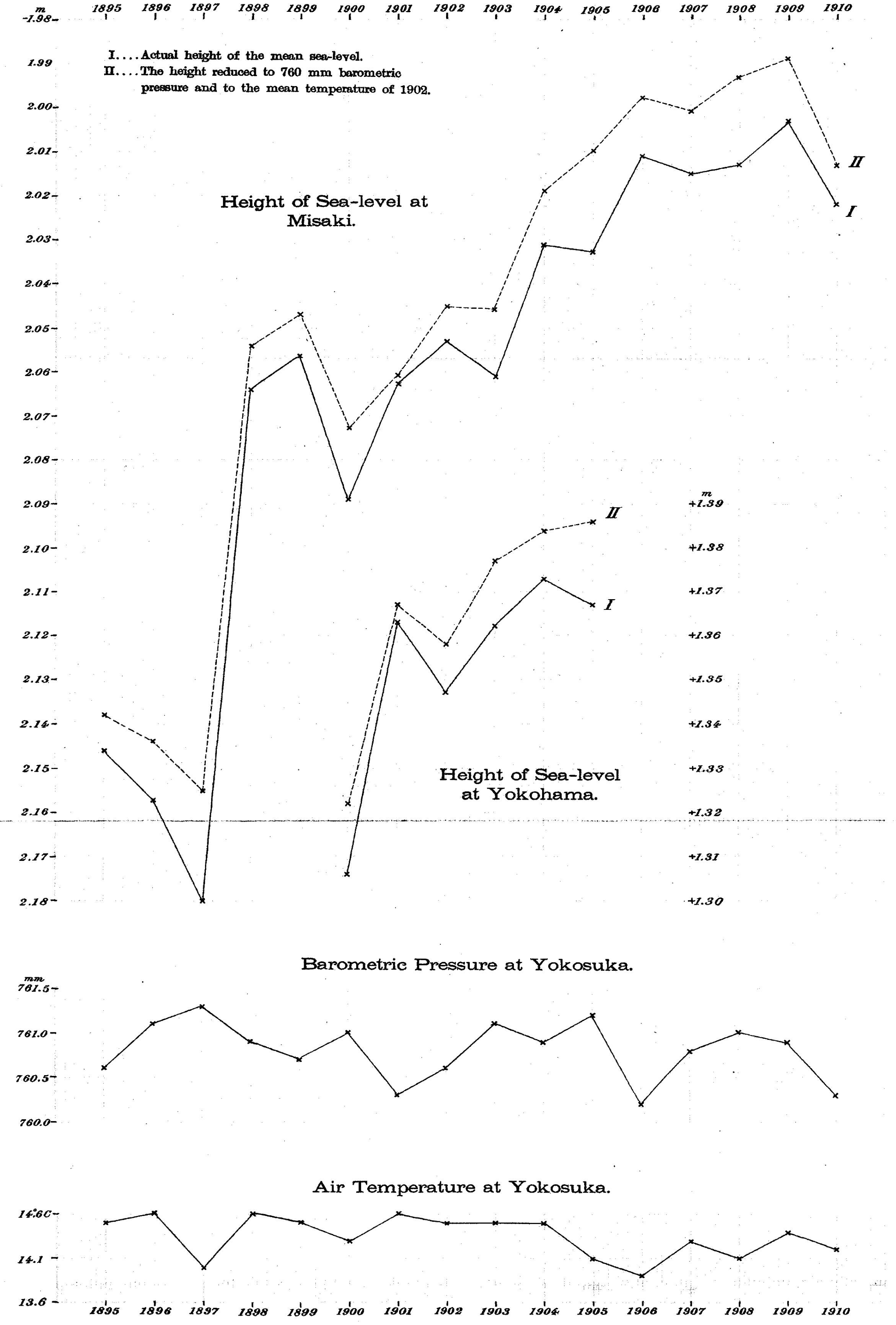


Fig. 7. Variation in Height of the Mean Sea-level: Ayukawa, 1894-1910; Wajima, Iwasaki, and Hososhima, 1898-1910.

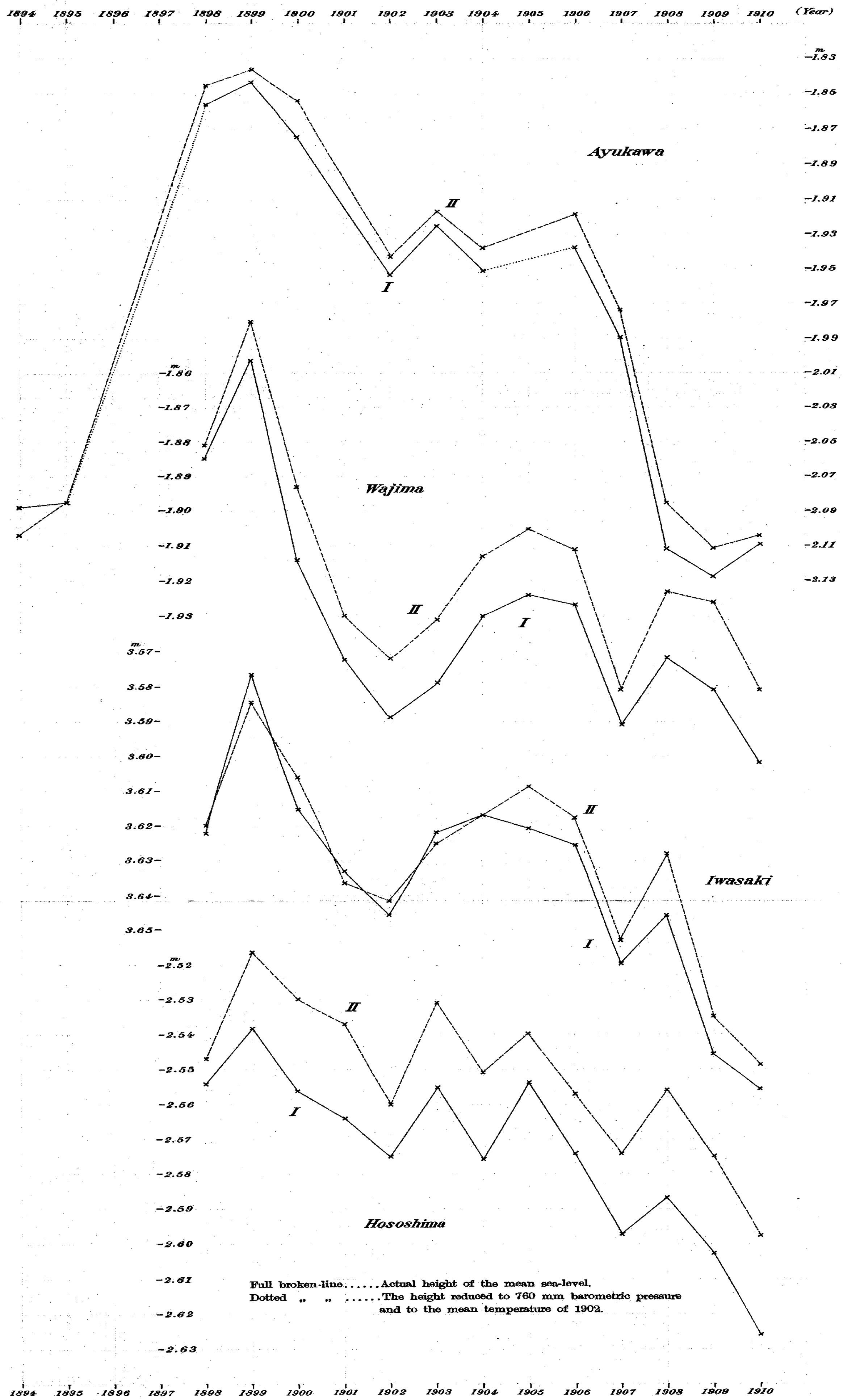


Fig. 8. Variation in Height of the Mean Sea-level: Hamada, 1895-1910; Fukabori, 1898-1910; and Kushimoto and Hanasaki, 1897-1910. Pl. XVIII.

Full broken-line...... Actual height of the mean sea-level.
Dotted „ „ ...... Height of the sea-level reduced to 760 mm barometric pressure, and the mean temperature of 1902.

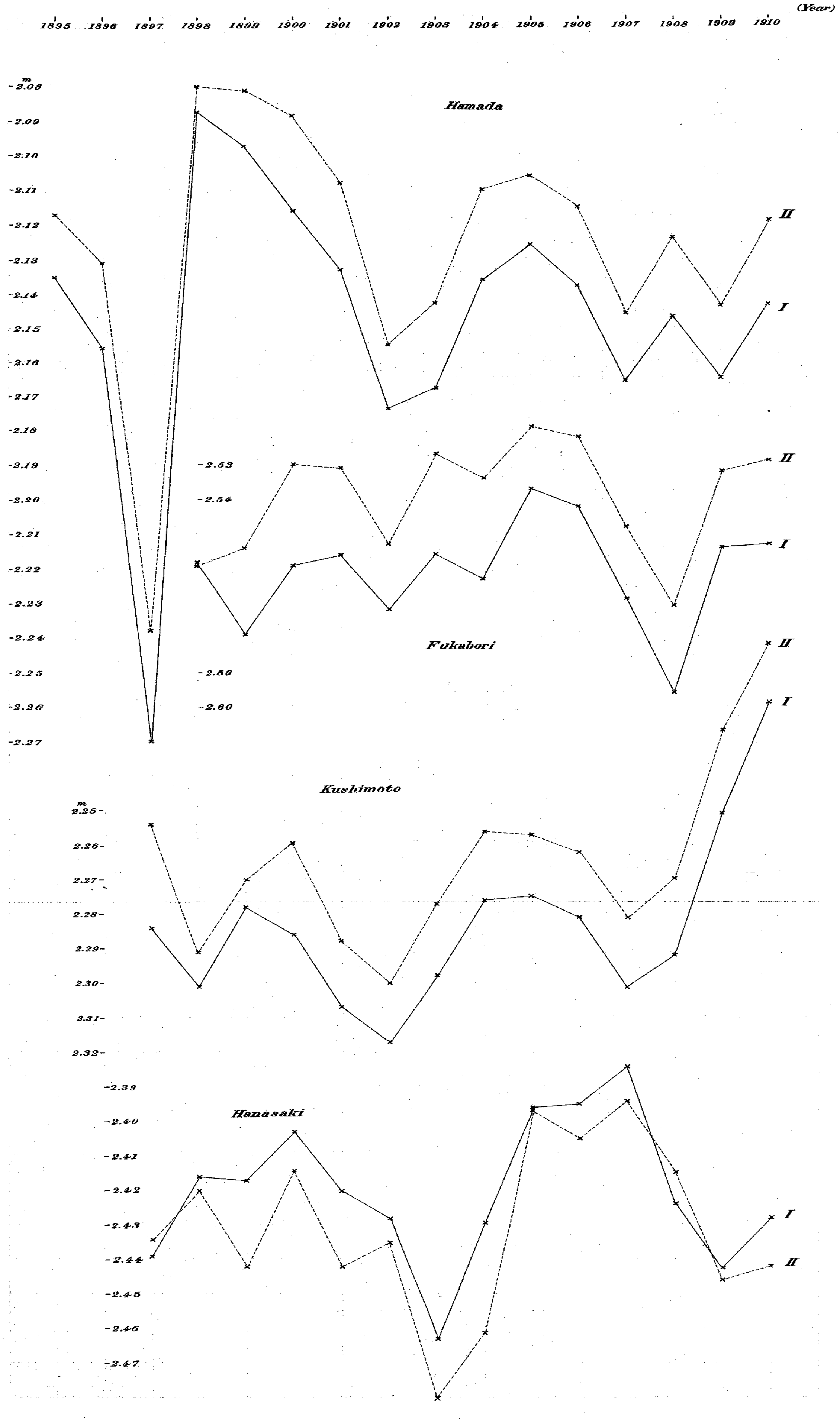


Fig. 9. Variation in Height of the Datum Level at Misaki, 1895-1910.

$y$ = Height of the datum referred to the mean sea-level in 1910.

$x$ = Time: (0)..........1895; (1)..........1896; ..................; (15)..........1910.

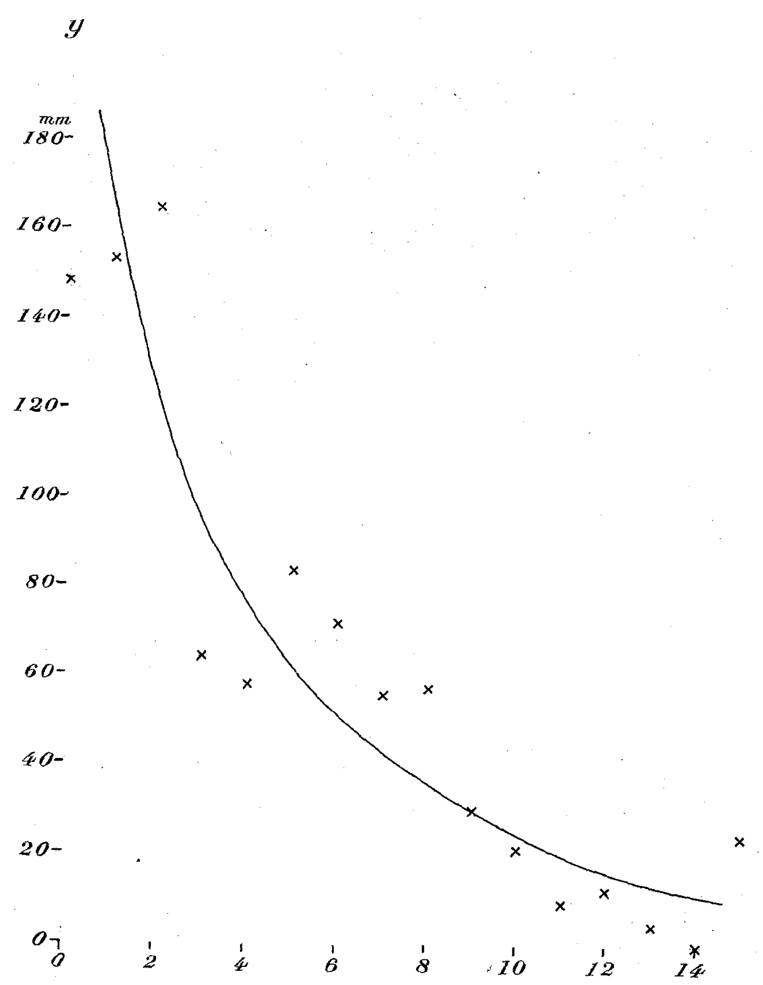
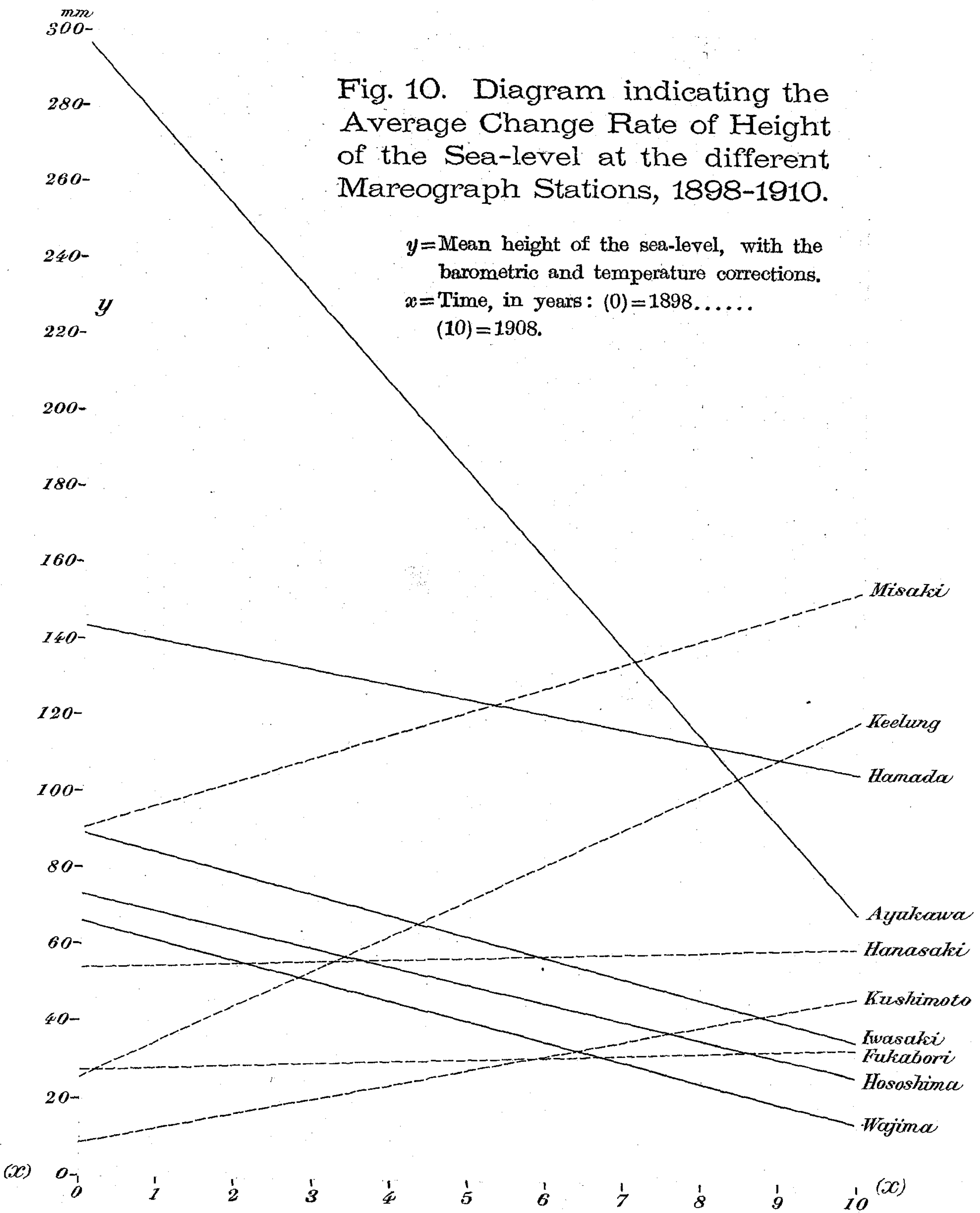



Fig. 10. Diagram indicating the Average Change Rate of Height of the Sea-level at the different Mareograph Stations, 1898-1910.

$y$ = Mean height of the sea-level, with the barometric and temperature corrections.

$x$ = Time, in years: (0) = 1898...... (10) = 1908.



amounts of the increase and the decrease in height of the mean sea-level, corrected for the atmospheric pressure and the temperature, were respectively 268 and 276 mm, giving the yearly average of 53.6 mm for the apparent depression, and 27.6 mm for the apparent elevation, of the land. It may be noted that, since 1899 the course of variation in height of the mean sea-level at Ayukawa was opposite in sense to, and double in amount of, that at Misaki.

**8. *Variation in height of mean sea-level at Hamada.*** The variation in height of the mean sea-level at Hamada indicates a series of fluctuations, the lowest and the highest positions being reached respectively in 1897 and 1898, with the difference (increase) of 182 mm in the course of a single year. With the barometric and temperature corrections this difference reduces to 157 mm, denoting the apparent depression of the coast.

**9. *Remarks on sea-level variation at different stations.*** Comparing together Figs. 6, 7, and 8, we see that the variation in height of the mean sea-level at all the stations, with the exception of Misaki, indicates more or less definite fluctuations. In particular, the course of variation was markedly similar for Ayukawa, Wajima, Iwasaki, Hososhima, and Hamada, notwithstanding the great mutual distances. Thus, at each of these different places, of which three are on the Japan Sea coast and the remaining two on the Pacific coasts, the mean sea-level was highest in 1899 (at Hamada, in 1898), and continued on the whole to fall since the latter year, indicating a well defined minimum height in 1902. At the three stations of Fukabori, Kushimoto, and Hanasaki, the height of the mean sea-level reached a minimum in 1902 or 1903, thence increasing to the maximum in 1905 or 1907, so that the average course of the variation shows a slight elevation. To obtain some rough idea respecting the general tendency of the variation in height of the sea-level at the different places, let us assume, for the interval of the 13 years between 1898 and 1910, the linear relation: $ax+y+c=0$, in which $x$ denotes the time, in years, counted from 1898, and $y$ the height of the corresponding mean sea-level, $a$ and $c$ being constants. Calculating the values of these latter by means of the data given in Table XI, we get the following results:—

**Group (i): Ayukawa, Iwasaki, Wajima, Hamada, and Hososhima, 1898-1910.**

Ayukawa, ..................$y=296.0-22.7x$
Iwasaki, ....................$y=89.0-5.2x$
Wajima, ....................$y=65.7-5.0x$
Hamada, ....................$y=143.3-3.7x$
Hososhima, ..................$y=73.3-4.5x$

**Group (ii): Misaki, Fukabori, Kushimoto, Hanasaki, and Keelung, (1898-1910).**

Misaki, ......................$y=89.7+6.40x$
Fukabori, ..................$y=27.1+0.80x$
Kushimoto, .................$y=8.3+4.52x$
Hanasaki, ..................$y=54.1+0.72x$
Keelung,* ..................$y=25.2+9.46x$

Thus the mean sea-level tended, since 1898, to decrease at the group (i) stations, and to increase at the group (ii) stations (Fig. 10), the average rate of the variation being as follows:—

* See § 10.

| Group (I): Decrease in height of Sea-level per Year. | | Group II: Increase in height of Sea-level per Year. | |
|---|---|---|---|
| Ayukawa | −22.7 mm | Misaki | +6.4 mm |
| Iwasaki | − 5.2 | Kushimoto | +4.5 |
| Wajima | − 5.0 | Hanasaki | +0.72 |
| Hamada | − 3.7 | Fukabori | +0.80 |
| Hososhima | − 4.5 | Keelung | +9.46 |

From the above it will be seen that, since 1898, the decrease rate of the sea-level was nearly alike, namely, 3.7 to 5.2 mm per year, at Iwasaki, Wajima, Hamada, and Hososhima, while it was abnormally high, 22.7 mm per year, at Ayukawa. The increase rate at the remaining five stations was greatest, 9.46 mm per year, at Keelung, and reached the amounts of 6.4 and 4.5 mm per year respectively at Misaki and Kushimoto, being only 0.72 to 0.80 mm at Hanasaki and Fukabori. Assuming the rise and fall of the mean sea-level to be due respectively to the depression and elevation affecting equally the coast and the adjacent land area, the above results may graphically be shown as in Fig. 1, from which it will be seen that the south-eastern part of the Main Island, the north-eastern corner of Hokkaido, and the vicinities of Nagasaki and Keelung are undergoing a depression, while the rest of Japan is being elevated, with the greatest rate at the neighbourhood of Ayukawa; the boundary lines between these two different groups of regions having been drawn by interpolating the variation rates for Misaki, Kushimoto, Hanasaki, Fukabori, and Keelung, with those for Ayukawa, Iwasaki, Wajima, Hamada, and Hososhima. Although these considerations are merely speculative, still it is worthy of note that the Group (i) region, along which the sea-level is rising at present, as well as the locality about Ayukawa, characterized by its enormous fall, are all on the Pacific side of the Japan Arc, off which tremendous earthquakes so often take place.

**10. *Variation in height of sea-level at Keelung, Formosa.*** The recent variation in height of the sea-level at Keelung ($\varphi=25°9'N$, $\lambda=121°45'E$) situated near the northern extremity of Formosa, presents many points of interest, enabling us to see amongst others the exact extent of the barometric and temperature influences on the height of the water. Table XIV, which has kindly been furnished me by Dr. K. Kawakami, Engineer in charge of the harbour works, gives the yearly and monthly height, expressed in *shaku* (1 *shaku*=303 mm), of the mean sea-level at the Sharyo Isle Mareograph Station, Keelung, during the 13 years between 1899 and 1911.* In Table XXV are indicated the mean yearly and monthly values of the barometric pressure and the air temperature at the meteorological observatory of Keelung during the same time interval.

TABLE XIV. YEARLY AND MONTHLY HEIGHT OF THE MEAN SEA-LEVEL. 1899-1911. KEELUNG, (FORMOSA). **

| Month. / Year. | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII | Mean. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1899 | 3.2 | 3.5 | 3.6 | 3.6 | 3.9 | 4.1 | 4.8 | 4.6 | 4.5 | 3.8 | 3.6 | 3.7 | 3.9 |
| 1900 | 3.8 | 3.6 | 3.6 | 4.1 | 4.1 | 4.4 | 4.4 | 4.7 | 4.3 | 3.8 | 3.7 | 3.4 | 4.0 |
| 1901 | 3.4 | 3.4 | 3.2 | 3.8 | 4.0 | 4.1 | 4.3 | 4.7 | 3.5 | 3.1 | 3.2 | 3.3 | 3.7 |
| 1902 | 3.2 | 2.8 | 3.3 | 3.4 | 3.8 | 4.1 | 3.9 | 4.1 | 4.0 | 3.5 | 3.3 | 3.3 | 3.6 |
| 1903 | 3.1 | 3.0 | 3.4 | 3.4 | 3.5 | 4.0 | 4.2 | 4.2 | 4.2 | 4.0 | 3.6 | 3.2 | 3.6 |
| 1904 | 3.3 | 3.3 | 3.5 | 3.5 | 3.7 | 4.1 | 4.4 | 4.6 | 4.4 | 4.1 | 3.6 | 3.3 | 3.8 |
| 1905 | 3.6 | 3.5 | 3.6 | 3.6 | 3.7 | 4.0 | 4.0 | 4.2 | 3.9 | 3.6 | 3.8 | 3.6 | 3.8 |

* The mareograph observatory of the Sharyo Isle was established in January 1899 by the Keelung Harbour Works Department. It was transferred in 1904 to the Military Survey Department.

** The height is expressed in *shaku* (1 *shaku*=303 mm). Greater numbers correspond to the higher levels, and smaller ones to the lower levels.

| Month. / Year. | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII | Mean. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1906 | 3.3 | 3.7 | 3.6 | 3.8 | 4.1 | 4.3 | 4.5 | 4.3 | 4.2 | 4.0 | 4.0 | 3.3 | 3.9 |
| 1907 | 3.4 | 3.6 | 3.6 | 3.7 | 3.9 | 4.2 | 4.3 | 4.4 | 4.4 | 4.2 | 4.0 | 3.4 | 3.9 |
| 1908 | 3.6 | 3.7 | 3.7 | 3.6 | 3.8 | 4.1 | 4.5 | 4.6 | 4.4 | 4.1 | 3.8 | 3.7 | 4.0 |
| 1909 | 3.9 | 3.8 | 3.9 | 4.2 | 4.4 | 4.5 | 4.7 | 4.9 | 5.0 | 4.5 | 4.0 | 3.6 | 4.3 |
| 1910 | 3.7 | 3.5 | 3.7 | 3.8 | 4.1 | 4.2 | 4.5 | 5.0 | 4.5 | 4.3 | 3.8 | 3.5 | 4.1 |
| 1911 | 3.4 | 3.5 | 3.8 | 3.9 | 4.0 | 4.4 | 4.5 | 4.7 | 4.6 | 4.2 | 3.8 | 3.6 | 4.0 |
| Mean. | **3.5** | **3.5** | **3.6** | **3.7** | **3.9** | **4.2** | **4.4** | **4.5** | **4.3** | **3.9** | **3.7** | **3.5** | **3.9** |

*Annual variation.* I give below the monthly averages of the height, expressed in mm, of the mean sea-level, and of the mean barometric pressure and the air temperature. As will be seen from the graphical illustrations in Fig. 11, the annual variation in height of the mean sea-level is simple and regular, and is almost symmetrically opposite to the course of the barometric pressure, and at the same time nearly parallel to that of the air temperature; its relation with the former being apparently even closer than with the latter. Thus the mean sea-level was highest in August and lowest in December to February, while the barometric pressure was lowest and highest respectively in these two epochs of the year; the air temperature being maximum in July and August, and minimum in February. The yearly range, or amount of fluctuation of the height of the mean sea-level, and of the mean barometric pressure, and the air temperature, were respectively 303 mm, 11.6 mm, and 13°.2 C.

TABLE XV. ANNUAL VARIATION IN HEIGHT OF THE MEAN SEA-LEVEL AT KEELUNG, (FORMOSA). 1899-1911.

| Month. | Mean Height of Sea-Level. | | | Mean Barometric Height.* | | Mean Air Temperature. | |
|---|---|---|---|---|---|---|---|
| | Actual. | Relative. | Calculated according to Equation (2). | Actual. | Relative. | Actual. | Relative. |
| | m 1+ | m 1.0606+ | | 700mm+ | 766.7mm− | C° | 14°.5 C+ |
| I | mm 60.6 | mm 0 | mm 15.2 | mm 66.4 | mm 0.3 | ° 15.9 | ° 1.4 |
| II | 60.6 | 0 | 4.1 | 66.4 | 0.3 | 14.5 | 0 |
| III | 90.9 | 30.3 | 46.5 | 64.5 | 2.2 | 16.6 | 2.1 |
| IV | 121.2 | 60.6 | 119.2 | 61.6 | 5.1 | 20.1 | 5.6 |
| V | 181.8 | 121.2 | 172.2 | 59.1 | 7.6 | 23.2 | 8.7 |
| VI | 272.7 | 212.1 | 230.3 | 56.5 | 10.2 | 26.2 | 11.7 |
| VII | 333.3 | 272.7 | 260.8 | 55.2 | 11.5 | 27.7 | 13.2 |
| VIII | 363.6 | 303.0 | 261.4 | 55.1 | 11.6 | 27.6 | 13.1 |
| IX | 303.0 | 242.4 | 207.6 | 58.3 | 8.4 | 26.3 | 11.8 |
| X | 181.8 | 121.2 | 126.1 | 62.5 | 4.2 | 23.2 | 8.7 |
| XI | 121.2 | 60.6 | 59.2 | 65.5 | 1.2 | 19.9 | 5.4 |
| XII | 60.6 | 0 | 21.5 | 66.7 | 0 | 17.2 | 2.7 |
| Mean. | **181.8** | **118.7** | **127.0** | **61.5** | — | **21.5** | — |

From the remarkable regularity and the mutual correspondence noted above, the annual variation in height of the mean sea-level at Keelung may be supposed to be due entirely to the fluctua-

*Reduction to stand gravity = −1.3 ; Reduction to mean sea-level = +0.3.

tions in the barometric pressure and the temperature. Thus let us assume the equation

$$(y-y_0)=b(p_1-p)+c(t-t_0), \quad \ldots\ldots\ldots\ldots (2')$$

in which the different notations have the following significations;—

$y$=Mean monthly height of the sea-level; minimum $y=y_0$.

$p$= ,, ,, barometric pressure; max. $p=p_1$.

$t$= ,, ,, air temperature; min. $t=t_0$.

$b$=Barometric coefficient.

$c$=Temperature coefficient.

Calculating the values of the constants $b$ and $c$ from the relative monthly height of the mean sea-level and the corresponding means of the barometric pressure and the air temperature given in the 3rd, 6th, and 8th columns of Table XV, we obtain:—

Barometric coefficient ...... $b$=13.56 mm

Temperature ,, ...... $c$= 7.94 ,,

Consequently Equation (2′) becomes

$$y=\overset{\text{mm}}{13.56}(p_1-p)+\overset{\text{mm}}{7.94}\,(t-t_0) \qquad (2)$$

The barometric coefficient, $b$, which denotes the amount of the rise or fall of the mean sea-level due to 1 mm decrease or increase in the mean atmospheric pressure, is thus found to be 13.56 mm, which is very nearly equal to the density of mercury. The temperature coefficient, $c$=7.94 mm, is the amount of the change in height of the sea-level caused by 1° C difference in the air temperature. As will be seen from the figures in the 4th column of Table XV and from Fig. 11, the height of the mean sea-level corresponding to the given values of the barometric pressure and the air temperature calculated by Equation (2) is not materially different from the true values. It may be added that the highest and lowest monthly sea-levels, corrected for the barometric effect according to the method of § 3 become respectively 148.7 mm (August) and −7.2 mm (April), with the extreme difference of 155.9 mm. If we suppose this amount of the fluctuation in height of the sea-level to be wholly due to that in the monthly temperature, namely, 13°.2C, then we get the following result:—1° air temperature difference corresponds to 11.8 mm change in sea-level, or about 4 mm larger than the value found above by the more rigorous process, These considerations seem to indicate that the barometric coefficient of 13.3 (§ 3) adopted for the different Japanese mareograph stations may be nearly correct, while the temperature coefficient of 16.8 mm was probably a few mm too large than was actually the case. As, however, the variation in the mean yearly temperature was very small, such an inaccuracy would not greatly modify the main features of the course of the variation in height of the sea-level.

For Keelung, the mean temperature of the sea water is very nearly equal to that of the air. Thus, according to the measurements made, between 1901 and 1911, each day at 10 o'clock in the morning at the coast of the observatory ground facing the harbour entrance, (Table XXV), the average monthly temperature of the sea water was as follows:—

| | | | |
|---|---|---|---|
| January ...... | 17°.0 C | July ........ | 28°.0 C |
| February ...... | 15.9 | August ........ | 27.8 |
| March ........ | 17.5 | September .... | 26.5 |
| April .......... | 20.8 | October ........ | 23.4 |
| May .......... | 23.7 | November ...... | 20.4 |
| June .......... | 26.4 | December ...... | 18.0 |

By comparing the above with the figures in the last column of Table XV, it will be seen that the temperature of air was, for the different months, only 0°.2 to 1°.4 C higher than that of the sea

Fig. 11. Annual Variation in Height of the Sea-level compared with those of the Barometric Pressure and of the Air Temperature. Keelung, (Formosa), 1899-1911.

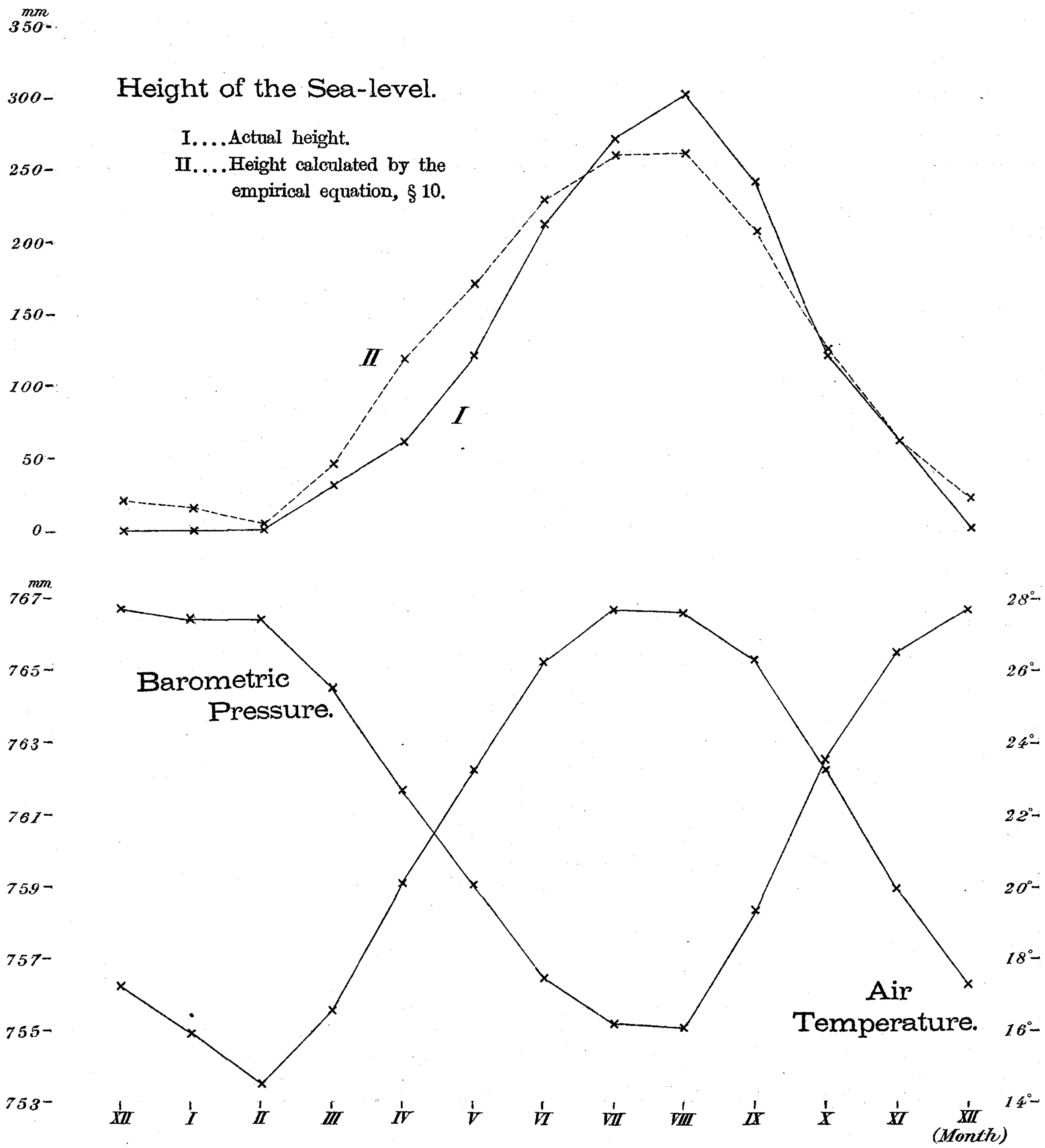
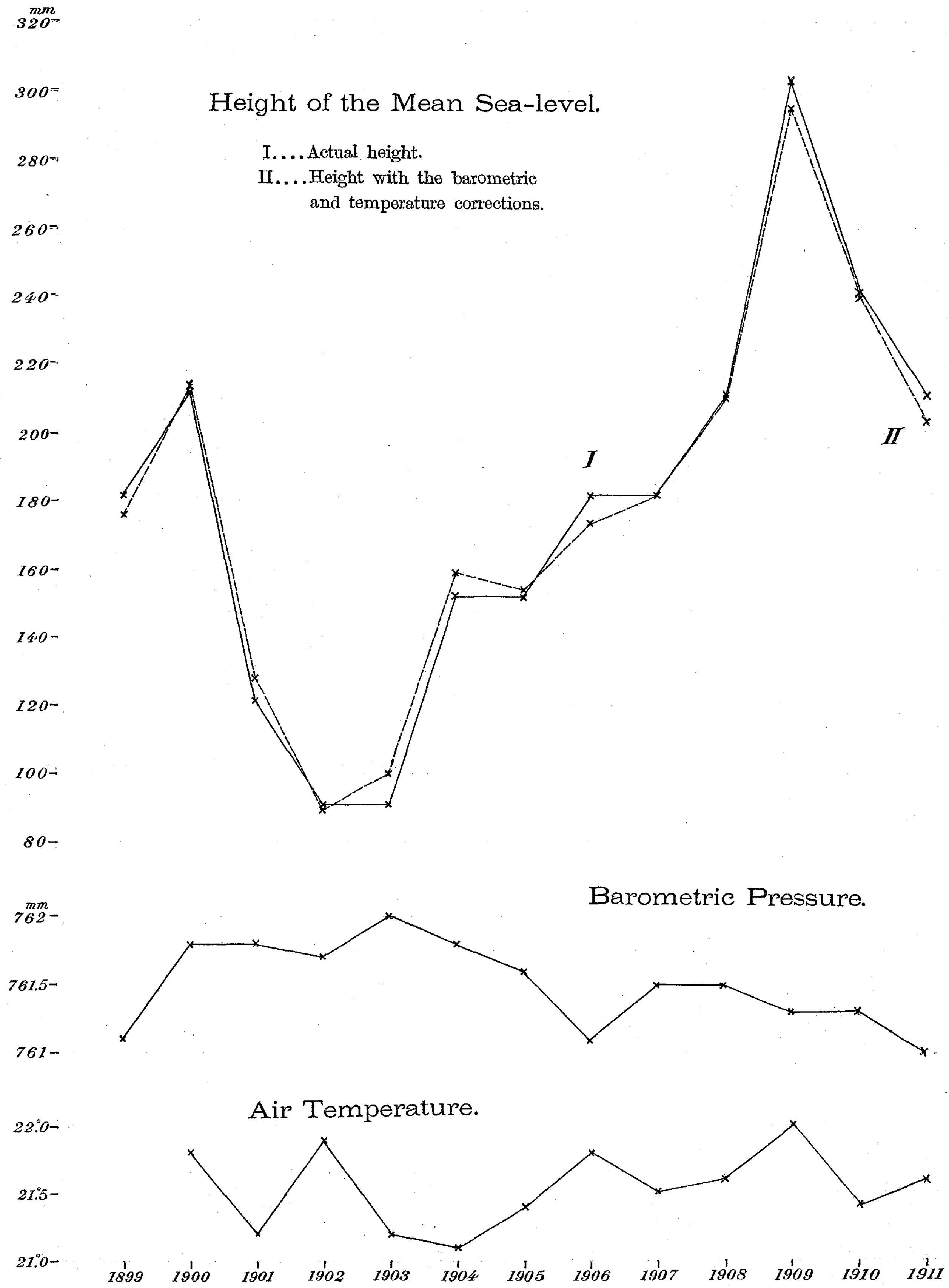


Fig. 12. Variation of the Sea-level Height, Barometric Pressure, and Air Temperature. Keelung (Formosa), 1899-1911.



water, the annual variation being practically identical in the two cases.

*Mean yearly height of sea-level.* In Table XVI are given the yearly values of the height of the sea-level, and of the barometric pressure and the air temperature for the interval of 1899 to 1911. (See Fig. 12.)

**TABLE XVI. MEAN YEARLY HEIGHT* OF THE SEA-LEVEL AND THE MEAN YEARLY BAROMETRIC PRESSURE AND AIR TEMPERATURE. KEELUNG, (FORMOSA). 1899-1911.**

| Year. | Height of Sea-level. | | | Barometric Pressure. | | Air Temperature. | | Correction to Height of Sea-level. | |
|---|---|---|---|---|---|---|---|---|---|
| | Actual. | With the Barometric Correction. | With the Barometric and Temperature Corrections. | Actual. | Relative. | Actual. | Relative. | Reduction to 761.5 mm Pressure. | Reduced to 21°.5 C Air Temperature. |
| | m 1+ | m 1+ | m 1+ | mm 700+ | mm 761.5+ | C° | 21°.5C+ | | |
| | mm | mm | mm | mm | mm | | | mm | mm |
| 1899 | 181.8 | 176.4 | 176.4 | 61.1 | −0.4 | — | — | —5.4 | — |
| 1900 | 212.1 | 216.2 | 213.8 | 61.8 | +0.3 | 21°.8 | +0°.3 | +4.1 | −2.4 |
| 1901 | 121.2 | 125.3 | 127.7 | 61.8 | +0.3 | 21.2 | −0.3 | +4.1 | +2.4 |
| 1902 | 90.9 | 93.6 | 90.4 | 61.7 | +0.2 | 21.9 | +0.4 | +2.7 | −3.2 |
| 1903 | 90.9 | 97.7 | 100.1 | 62.0 | +0.5 | 21.2 | −0.3 | +6.8 | +2.4 |
| 1904 | 151.5 | 155.6 | 158.8 | 61.8 | +0.3 | 21.1 | −0.4 | +4.1 | +3.2 |
| 1905 | 151.5 | 152.9 | 153.7 | 61.6 | +0.1 | 21.4 | −0.1 | +1.4 | +0.8 |
| 1906 | 181.8 | 176.4 | 174.0 | 61.1 | −0.4 | 21.8 | +0.3 | −5.4 | −2.4 |
| 1907 | 181.8 | 181.8 | 181.8 | 61.5 | 0 | 21.5 | 0 | 0 | 0 |
| 1908 | 212.1 | 212.1 | 211.3 | 61.5 | 0 | 21.6 | +0.1 | 0 | −0.8 |
| 1909 | 303.0 | 300.3 | 296.3 | 61.3 | −0.2 | 22.0 | +0.5 | −2.7 | −4.0 |
| 1910 | 242.4 | 239.7 | 240.5 | 61.3 | −0.2 | 21.4 | −0.1 | −2.7 | +0.8 |
| 1911 | 212.1 | 205.3 | 204.5 | 61.0 | −0.5 | 21.6 | +0.1 | −6.8 | −0.8 |
| Mean. | **181.8** | | | **61.5** | | **21.5** | | | |

* Greater numbers correspond to the higher, and the smaller ones to the lower, levels.

In the interval of 1899 to 1911, the difference between the maximum and the minimum yearly means was 1.0 mm for the barometric pressure and 0°.9 C for the air temperature, these corresponding, in virtue of the barometric and the temperature coefficients, $b$ and $c$, already obtained, respectively to 13.6 and 7.1 mm changes in height of the mean sea-level. In reality, however, the latter varied from the minimum of 90.9 mm in 1902 and 1903 to the maximum of 303 mm in 1909, through the range of 212.1 mm, which is far greater than the above mentioned amount of the level change due to the barometric and the temperature fluctuations. The average rate of the level increase between 1902 and 1909 was 30.3 mm per year. As may be seen from Table XVI and Fig. 12, the maximum amounts of the corrections for reducing the sea-level height in the different years to the case of the average barometric pressure of 761.5 mm and to the average air temperature of 21°.5 C, are respectively +6.8 and −4.0 mm, so that the sea-level height $y$ was practically unaffected by the introduction of these corrections. The mean course of variation in height of the yearly sea-level between 1899 to 1910 is expressed by the equation

$$y = \overset{\text{mm}}{25.2} + \overset{\text{mm}}{9.46}(x - 1899),$$

in which $x$ denotes the year. Thus in the time interval under consideration the mean yearly increase rate in height of the level was about 9.5 mm, which is greater than that for Misaki and Kushimoto (§ 9).

**11.** ***Average variation in height of the mean sea-level compared with the latitude variation at Mizusawa.*** What I discuss in the present § is simply meant as a hint on the connection, which may exist between the height of sea-level and the latitude variation, a subject already taken up by Professor H. G. van de

Sande Bakhuyzen and other eminent authorities. My method of procedure consists in merely comparing together the variation in height of the mean yearly sea-level with that of the latitude at Mizusawa. To eliminate the local peculiarity in a measure, and to find for the whole of Japan the general course of the variation of the sea-level, I have given in the last column of each of Tables III and XI the result obtained by averaging for the different years the mean heights at all the stations. The relative average height of the mean sea-level is as follows.

**TABLE XVII. AVERAGE HEIGHT OF THE SEA-LEVEL FOR WHOLE JAPAN.***

| Year. | Height of Sea-level. | | Year. | Height of Sea-level. | |
|---|---|---|---|---|---|
| | Actual. | With the Barometric and Temperature corrections. | | Actual. | With the Barometric and Temperature corrections. |
| 1895 | 57 mm | 32 mm | 1903 | 58 mm | 41 mm |
| 1896 | 55 | 36 | 1904 | 68 | 50 |
| 1897 | 0 | 0 | 1905 | 79 | 64 |
| 1898 | 86 | 61 | 1906 | 77 | 61 |
| 1899 | 98 | 75 | 1907 | 53 | 37 |
| 1900 | 79 | 67 | 1908 | 40 | 32 |
| 1901 | 66 | 46 | 1909 | 38 | 25 |
| 1902 | 49 | 31 | 1910 | 39 | 27 |

Thus, on the average, the sea-level was highest in 1899 and 1905–06, and lowest in 1897 and 1902, it being on the decrease since 1906. Confining our attention to the height corrected for the barometic pressure and the temperature, we see that the absolutely greatest level fluctuation was the rise of 75 mm, from

* For the 2 years 1895 and 1896, the means were obtained only from 3 and 2 stations respectively.

1897 to 1899, and the next greatest the fall of 44 mm, from 1899 to 1902.

In Table XVIII, I give the mean yearly value of the latitude of the International Latitude Observatory of Mizusawa, between 1900 and 1909,* and also, for the supplementary purpose, that of the Tokyo Astronomical Observatory between 1896 and 1901. For the data respecting the latter place I have to thank Dr. K. Hirayama, of the Tokyo Astronomical Observatory, while those respecting the former have been taken from Vols. III and IV of the Report on the International Latitude Observation published by the Central Bureau of the International Geodetic Association.

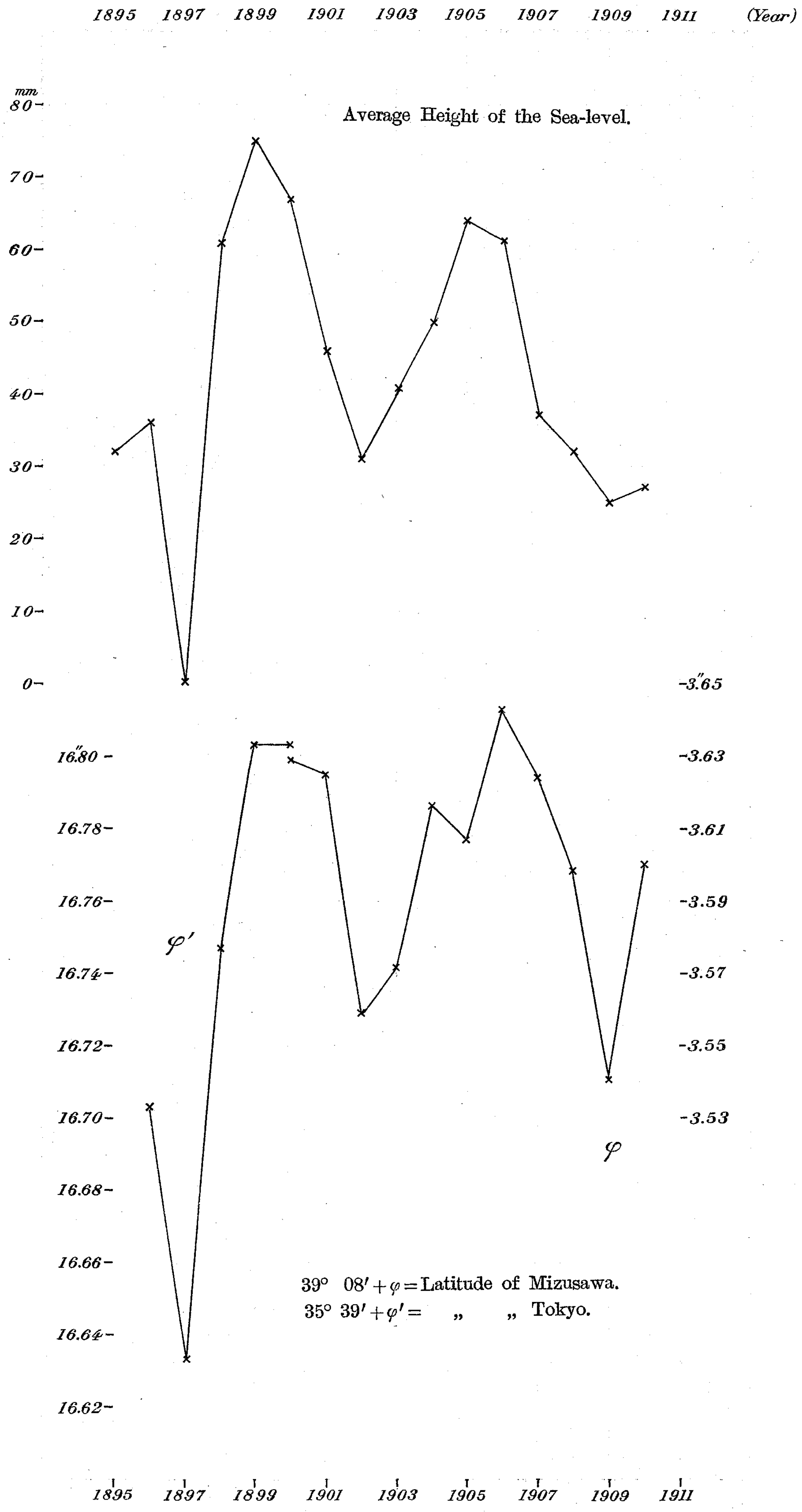
**TABLE XVIII. MEAN YEARLY VALUE OF THE LATITUDE AT MIZUSAWA, 1900—1909, AND AT TOKYO, 1896—1901.**

| Mizusawa. | | Tokyo. | |
|---|---|---|---|
| Year. | Latitude (*N*). | Year. | Latitude (*N*). |
| 1900 | 39° 8′ 3″.629 | 1896 | 35° 39′ 16″.703 |
| 1901 | 3.625 | 1897 | 16.633 |
| 1902 | 3.559 | 1898 | 16.747 |
| 1903 | 3.571 | 1899 | 16.803 |
| 1904 | 3.616 | 1900 | 16.803 |
| 1905 | 3.607 | 1901 | 16.804 |
| 1906 | 3.643 | | |
| 1907 | 3.624 | | |
| 1908 | 3.598 | | |
| 1909 | 3.54 | | |

From the graphical illustrations in Fig. 13, it will be seen that between 1896 and 1909, the variation in the average height (with the barometric and temperature corrections) of the mean

* The observation was started in 1899.

Fig. 13. Average Variation in Height of the Sea-level along the Japanese Coasts compared with the Latitude Variation at Mizusawa (and Tokyo). 1895-1910.



sea-level for Japan was on the whole similar to that of the Mizusawa (and Tokyo) latitude; the latter also indicating minimum in 1897 and 1902, and maximum at about 1890–1900 and in 1906. The approximate correspondence between the variations in height of the sea-level and of the latitude is as follows:—

**TABLE XIX. CORRESPONDENCE BETWEEN THE SEA-LEVEL AND THE LATITUDE VARIATIONS.**

| Epoch. | Latitude Variation. | Variation in Height of Sea-level (with barometric and temperature corrections). | Amount of change in height of Sea-level corresponding to 0″.1 of Latitude Variation. |
|---|---|---|---|
| 1897—1899 | ″ 0.170 increase. | 61 mm increase. | 36 mm |
| 1900—1902 | 0.070 decrease. | 36 ,, decrease. | 51 |
| 1902—1906 | 0.084 increase. | 33 ,, increase. | 39 |
| 1906—1909 | 0.103 decrease. | 36 ,, decrease. | 35 |
| Mean. | ...... | ...... | **40** |

Thus the average height of the sea-level in Japan increased and decreased in the time interval under consideration, *with* the latitude at Mizusawa (and Tokyo), the mean amount of the variation in the height of the former being 40 mm for 0″.1 of the latter. This relation, which is not materially altered by taking the actual height of the mean sea-level, is probably the consequence of the marked general elevation and depression of the Japanese Islands, completely masking or even apparently reversing the effect due to the latitude variation.

**12.** ***Concluding remarks.*** Japan proper, composed of the Main Island, Hokkaido, Shikoku, and Kyushu, forms an arc, whose convex side borders the Pacific and whose concave side the Japan Sea, the water being very deep in the former, but shallow in the latter. These marked geographical features are probably the result of a horizontal pressure applied from the inner side against the Japan arc, which is thus still in the process of change or growth, the consequence being the frequent production of seismic disturbances of gigantic magnitude. (See the *Bulletin*, Vol. I.) Under these circumstances it is natural that the land of Japan should present phenomena of the land elevation and depression. It seems probable that much light may be thrown on the instability of our earthquake country by a careful investigation of the variation in height of the sea-level. For this, however, the number of mareograph stations must be increased; it being also very desirable to repeat at certain time intervalsthe exact levelling across the more shaky regions.

## APPENDIX. METEOROLOGICAL TABLES.

**TABLE XX. ANNUAL VARIATION OF THE HEIGHT OF SEA-LEVEL,* BAROMETRIC PRESSURE, AND AIR TEMPERATURE. OSAKA, 1909-1911.**

| Month. | Height of Sea-level. | | | | Barometric Pressure.** | | | | Air Temperature. C. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1909 | 1910 | 1911 | Mean. | 1909 | 1910 | 1911 | Mean. | 1909 | 1910 | 1911 | Mean. |
| | cm | cm | cm | cm | mm | mm | mm | mm | ° | ° | ° | ° |
| I | 95.1 | 99.1 | 107.9 | **100.7** | 765.4 | 763.5 | 765.8 | **764.9** | 4.0 | 5.7 | 4.2 | **4.6** |
| II | 99.5 | 93.4 | 92.4 | **95.1** | 763.8 | 763.2 | 768.0 | **765.0** | 3.4 | 3.2 | 5.2 | **3.9** |
| III | 104.0 | 104.1 | 114.3 | **107.5** | 765.0 | 763.3 | 763.9 | **764.1** | 6.6 | 6.0 | 8.5 | **7.0** |
| IV | 113.3 | 101.8 | 117.9 | **111.0** | 761.2 | 762.8 | 761.5 | **761.8** | 13.7 | 12.3 | 12.8 | **12.9** |
| V | 108.7 | 112.7 | 103.3 | **108.2** | 759.7 | 759.8 | 761.8 | **760.4** | 17.5 | 18.0 | 16.9 | **17.4** |
| VI | 109.8 | 115.5 | 114.2 | **113.2** | 756.5 | 756.4 | 757.2 | **756.7** | 21.4 | 22.1 | 21.5 | **21.7** |
| VII | 113.1 | 122.7 | 124.3 | **120.0** | 759.7 | 756.1 | 758.0 | **757.9** | 26.1 | 26.3 | 25.7 | **26.0** |

* Greatest figure corresponds to the highest level, and the smallest figure to the lowest level.
** Reduction to Standard gravity = −0.7 mm; Reduction to mean sea-level = +0.5 mm.

| Month. | Height of Sea-Level. | | | | Barometric Pressure. | | | | Air Temperature. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1909 | 1910 | 1911 | Mean. | 1909 | 1910 | 1911 | Mean. | 1909 | 1910 | 1911 | Mean. |
| | cm | cm | cm | | mm | mm | mm | | ° | ° | ° | ° |
| VIII | 125.2 | 136.4 | 121.2 | **127.6** | 756.0 | 755.5 | 757.7 | **756.4** | 27.5 | 26.1 | 26.6 | **26.7** |
| IX | 130.1 | 124.9 | 131.9 | **129.0** | 759.1 | 759.7 | 761.2 | **760.0** | 23.8 | 22.4 | 24.5 | **23.6** |
| X | 120.4 | 122.9 | 122.9 | **122.1** | 763.4 | 763.3 | 762.1 | **762.9** | 15.6 | 16.8 | 16.7 | **16.4** |
| XI | 106.9 | 112.0 | 109.0 | **109.3** | 764.6 | 764.7 | 765.6 | **765.0** | 10.9 | 11.5 | 12.9 | **11.8** |
| XII | 92.8 | 96.4 | 101.8 | **97.0** | 766.2 | 765.6 | 797.1 | **766.3** | 5.5 | 5.9 | 6.6 | **6.0** |
| Mean. | 109.9 | 111.8 | 113.4 | — | 761.7 | 761.1 | 762.5 | — | 14.7 | 14.7 | 15.2 | — |

**TABLE XXI. MEAN YEARLY BAROMETRIC PRESSURE* AT THE DIFFERENT METEOROLOGICAL OBSERVATORIES, 1894-1910.**

| Year. | Yoko-suka. | Ishino-maki. | Ne-muro. | Ao-mori. | Fushi-ki. | Hama-da. | Naga-saki. | Miya-zaki. | Waka-yama. | Mean. |
|---|---|---|---|---|---|---|---|---|---|---|
| | mm 760+ | mm 760+ | mm 750+ | mm 760+ | mm 760+ | mm 760+ | mm 760+ | mm 760+ | mm 760+ | mm 760+ |
| 1894 | — | 0.7 | — | — | — | — | — | — | — | — |
| 1895 | 0.6 | 0.5 | 8.5 | 0.1 | 1.0 | 1.2 | 1.6 | 1.1 | 1.3 | 0.7 |
| 1896 | 1.1 | 0.9 | 9.4 | 0.2 | 1.4 | 1.5 | 2.2 | 1.6 | 2.2 | 1.2 |
| 1897 | 1.3 | 1.3 | 10.0 | 0.9 | 1.8 | 2.0 | 2.1 | 1.9 | 2.1 | 1.5 |
| 1898 | 0.9 | 0.8 | 9.2 | 0.4 | 1.2 | 1.1 | 1.2 | 1.1 | 1.3 | 0.8 |
| 1899 | 0.7 | — | 9.1 | 0.3 | 1.4 | 1.4 | 1.7 | 1.3 | 0.6 | 0.8 |
| 1900 | 1.0 | 1.1 | 9.4 | 0.7 | 1.8 | 1.8 | 1.8 | 1.6 | 1.8 | 1.2 |
| 1901 | 0.3 | 0.4 | 9.3 | 0.2 | 1.1 | 1.3 | 1.1 | 1.1 | 1.2 | 0.7 |
| 1902 | 0.6 | 0.8 | 9.5 | 0.3 | 1.3 | 1.4 | 1.4 | 1.1 | 1.3 | 0.9 |
| 1903 | 1.1 | 1.1 | 10.1 | 0.7 | 1.7 | 1.9 | 2.0 | 1.6 | 1.7 | 1.3 |
| 1904 | 0.9 | 1.0 | 9.5 | 0.5 | 1.4 | 1.8 | 2.0 | 1.5 | 1.5 | 1.1 |
| 1905 | 1.2 | 1.5 | 10.1 | 0.9 | 1.6 | 1.5 | 1.5 | 1.3 | 1.6 | 1.2 |
| 1906 | 0.2 | 0.5 | 9.0 | 0.0 | 0.8 | 1.1 | 1.1 | 0.9 | 0.9 | 0.5 |
| 1907 | 0.8 | 1.0 | 9.6 | 0.5 | 0.9 | 1.1 | 1.2 | 0.8 | 1.0 | 0.8 |
| 1908 | 1.0 | 1.1 | 9.7 | 0.6 | 1.3 | 1.6 | 1.7 | 1.4 | 1.4 | 1.1 |
| 1909 | 0.9 | 1.0 | 9.8 | 0.6 | 1.5 | 1.4 | 1.5 | 1.2 | 1.4 | 1.0 |
| 1910 | 0.3 | 0.4 | 9.5 | 0.3 | 1.0 | 1.2 | 1.3 | 1.0 | 0.9 | 0.7 |

* With the freezing point, sea-level, and gravity corrections.

## TABLE XXII. ANNUAL VARIATION OF THE SEA-WATER AND AIR TEMPERATURES AT MISAKI, AYUKAWA, HANASAKI, HAMADA, AND FUKABORI.

T′ = Mean monthly sea-water temperature, 1882-1901, (C).

T = „ „ air temperature at neighbouring meteorological station, (C).

| Month. | Misaki. | | Ayukawa. | | Hanasaki. | | Hamada. | | Fukabori. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | T′ | T (Yokosuka, 1901-1905). | T′ | T (Ishinomaki, 1895-1905). | T′ | T (Nemuro, 1896-1905). | T′ | T (Hamada, 1896-1905). | T′ | T (Nagasaki, 1881-1905). |
| January | 13° | 5.°2 | 9° | 0.°3 | 2° | −4.°6 | 10° | 5.°8 | 13° | 5.°8 |
| February | 13 | 5.1 | 7 | 0.5 | −1 | −5.7 | 12 | 4.9 | 12 | 5.8 |
| March | 14 | 7.9 | 8 | 2.9 | 0 | −3.0 | 12 | 7.6 | 12 | 9.3 |
| April | 16 | 12.8 | 10 | 8.6 | — | 2.7 | 14 | 12.2 | 16 | 14.4 |
| May | 17 | 16.4 | 12 | 13.3 | 5 | 6.7 | 16 | 16.4 | 18 | 18.0 |
| June | 20 | 20.6 | 17 | 17.1 | 9 | 9.6 | 21 | 20.4 | 22 | 21.7 |
| July | 23 | 23.0 | 20 | 20.3 | 13 | 13.9 | 24 | 24.0 | 24 | 25.7 |
| August | 25 | 24.1 | 23 | 22.4 | 17 | 16.6 | 27 | 25.5 | 27 | 26.8 |
| September | 24 | 22.2 | 22 | 19.5 | 16 | 14.8 | 25 | 21.5 | 25 | 23.6 |
| October | 21 | 16.9 | 18 | 13.7 | 13 | 10.4 | 22 | 16.2 | 23 | 18.1 |
| November | 16 | 11.7 | 16 | 7.8 | 8 | 4.4 | 18 | 12.0 | 20 | 12.7 |
| December | 15 | 7.5 | 12 | 2.6 | 3 | −1.4 | 17 | 7.8 | 16 | 7.8 |

**TABLE XXIII. MEAN YEARLY AIR-TEMPERATURE AT THE DIFFERENT METEOROLOGICAL OBSERVATORIES, 1894-1910.**

| Year. | Yokosuka (Misaki.) | Ishinomaki (Ayukawa). | Nemuro (Hanasaki). | Aomori (Iwasaki). | Fushiki (Wajima). | Hamada. | Nagasaki (Fukabori). | Miyazaki (Hososhima). | Wakayama (Kushimoto). | Mean. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1894 | — °C | 12.2 °C | 6.2 °C | 10.1 °C | 14.1 °C | 15.3 °C | 16.9 °C | 17.3 °C | 15.9 °C | — °C |
| 1895 | 14.5 °C | 11.1 | 5.4 | 9.1 | 13.2 | 14.5 | 16.0 | 16.6 | 15.3 | 12.9 |
| 1896 | 14.6 | 11.3 | 5.7 | 9.2 | 13.0 | 14.3 | 15.8 | 16.8 | 15.1 | 12.9 |
| 1897 | 14.0 | 9.9 | 4.6 | 8.4 | 12.7 | 14.3 | 15.8 | 16.8 | 15.2 | 12.4 |
| 1898 | 14.6 | 10.7 | 4.5 | 9.2 | 13.7 | 15.1 | 16.5 | 17.4 | 15.7 | 13.0 |
| 1899 | 14.5 | 11.0 | 5.7 | 9.7 | 13.5 | 14.8 | 15.4 | 16.6 | 15.3 | 12.9 |
| 1900 | 14.3 | 10.4 | 5.1 | 9.0 | 13.2 | 14.4 | 15.2 | 16.6 | 15.1 | 12.6 |
| 1901 | 14.6 | 11.1 | 5.7 | 9.4 | 13.2 | 14.1 | 14.9 | 16.2 | 15.1 | 12.7 |
| 1902 | 14.5 | 10.7 | 4.9 | 9.0 | 13.0 | 14.6 | 15.5 | 16.9 | 15.3 | 12.7 |
| 1903 | 14.5 | 11.1 | 6.0 | 9.7 | 13.3 | 14.6 | 15.4 | 16.7 | 15.4 | 13.0 |
| 1904 | 14.5 | 10.7 | 6.4 | 9.4 | 13.1 | 14.5 | 15.4 | 16.6 | 15.3 | 12.9 |
| 1905 | 14.1 | 10.4 | 5.0 | 9.0 | 13.1 | 14.6 | 15.6 | 17.1 | 15.5 | 12.7 |
| 1906 | 13.9 | 10.0 | 4.7 | 8.5 | 12.7 | 14.1 | 15.2 | 16.6 | 14.9 | 12.3 |
| 1907 | 14.3 | 10.5 | 5.2 | 9.0 | 13.1 | 14.3 | 15.2 | 16.1 | 14.9 | 12.5 |
| 1908 | 14.1 | 10.0 | 4.1 | 8.4 | 12.9 | 14.5 | 15.4 | 16.2 | 15.1 | 12.3 |
| 1909 | 14.4 | 10.5 | 4.9 | 8.8 | 12.7 | 14.5 | 15.4 | 16.2 | 15.0 | 12.5 |
| 1910 | 14.2 | 10.7 | 5.3 | 8.8 | 12.5 | 14.1 | 15.1 | 16.0 | 15.0 | 12.4 |

**TABLE XXIV. MONTHLY VALUE OF THE MEAN HEIGHT OF THE SEA-LEVEL AT MISAKI, AYUKAWA, OTARU, IWASAKI, WAJIMA, AND HAMADA; AND OF THE BAROMETRIC PRESSURE, AIR TEMPERATURE, AND THE RESULTANT WIND DIRECTION, AT THE RESPECTIVE NEIGHBOURING METEOROLOGICAL OBSERVATORIES.* 1902.**

| Month. | (1) Misaki. | (2) Ayukawa. | (3) Otaru. | (4) Iwasaki. | (5) Wajima. | (6) Hamada. |
|---|---|---|---|---|---|---|
| | Actual Mean Height of Sea-Level. | | | | | |
| I | 129mm | 121mm | 119mm | 137mm | 4mm | 89mm |
| II | 0 | 0 | 0 | 0 | 0 | 0 |
| III | 69 | 23 | 53 | 40 | 25 | 77 |
| IV | 103 | 45 | 116 | 106 | 41 | 91 |
| V | 188 | 96 | 159 | 182 | 176 | 247 |
| VI | 171 | 171 | 185 | 181 | 221 | 279 |
| VII | 175 | 197 | 175 | 205 | 261 | 313 |
| VIII | 226 | 184 | 199 | 238 | 305 | 362 |
| IX | 276 | 219 | 208 | 317 | 330 | 396 |
| X | 248 | 172 | 278 | 210 | 257 | 284 |
| XI | 164 | 117 | 212 | 147 | 150 | 190 |
| XII | 257 | 157 | 189 | 162 | 172 | 204 |
| | Mean Height of Sea-Level, with Barometric Correction. | | | | | |
| I | 91 | 88 | 70 | 97 | 0 | 61 |
| II | 0 | 14 | 0 | 0 | 29 | 0 |
| III | 36 | 9 | 32 | 17 | 14 | 24 |
| IV | 47 | 0 | 40 | 41 | 5 | 13 |
| V | 118 | 44 | 98 | 115 | 107 | 128 |
| VI | 61 | 79 | 105 | 85 | 117 | 119 |
| VII | 61 | 103 | 98 | 108 | 152 | 161 |
| VIII | 142 | 128 | 158 | 181 | 218 | 220 |
| IX | 191 | 162 | 168 | 256 | 239 | 263 |
| X | 238 | 184 | 295 | 223 | 260 | 249 |
| XI | 175 | 145 | 237 | 171 | 174 | 172 |
| XII | 208 | 125 | 173 | 133 | 149 | 151 |

| Month. | (1) Yoko-suka. | (2) Ishino-maki. | (3) Sapporo. | (4) Aomori. | (5) Wajima. | (6) Hamada. | (4') Akita.** |
|---|---|---|---|---|---|---|---|
| | Mean Barometric Pressure (reduced to 0°C). $760^{mm}+$ | | | | | | |
| I | 1.7 | 0.9 | −2.8 | 0.3 | 3.6 | 4.4 | |
| II | 4.6 | 4.4 | 0.9 | 3.3 | 6.1 | 6.5 | |
| III | 2.1 | 2.3 | −0.7 | 1.6 | 3.1 | 2.5 | |
| IV | 0.4 | 0.0 | −4.8 | −1.6 | 1.2 | 0.6 | |
| V | −0.7 | −0.5 | −3.7 | −1.7 | −1.3 | −2.5 | |
| VI | −3.7 | −3.5 | −5.1 | −3.9 | −3.9 | −5.6 | |
| VII | −4.0 | −3.7 | −4.9 | −4.0 | −4.3 | −5.0 | |
| VIII | −1.7 | −0.8 | −2.2 | −1.0 | −2.6 | −4.2 | |
| IX | −1.8 | −0.9 | −2.1 | −1.3 | −2.9 | −3.5 | |
| X | 3.8 | 4.3 | 2.2 | 4.3 | 4.1 | 3.8 | |
| XI | 5.4 | 5.5 | 2.8 | 5.1 | 5.7 | 5.1 | |
| XII | 0.9 | 1.0 | −0.3 | 1.1 | 2.2 | 2.5 | |
| | Mean Air Temperature. (C°.) | | | | | | |
| I | 4°3 | −0°9 | −7°5 | −3°7 | 2°1 | 5°9 | |
| II | 5.3 | 0.3 | −6.4 | −2.3 | 2.2 | 5.2 | |
| III | 9.5 | 4.5 | −0.6 | 2.1 | 7.0 | 9.1 | |
| IV | 12.3 | 7.8 | 4.3 | 6.0 | 9.5 | 11.7 | |
| V | 16.5 | 12.7 | 9.2 | 10.9 | 14.8 | 16.5 | |
| VI | 19.9 | 16.8 | 13.0 | 15.1 | 18.4 | 19.5 | |
| VII | 21.8 | 18.9 | 16.4 | 17.6 | 20.8 | 23.0 | |
| VIII | 22.8 | 20.0 | 17.9 | 19.6 | 22.7 | 23.5 | |
| IX | 22.7 | 20.1 | 17.3 | 19.3 | 21.2 | 21.2 | |
| X | 17.0 | 13.9 | 10.1 | 12.5 | 14.8 | 15.9 | |
| XI | 12.7 | 8.9 | 3.9 | 7.6 | 11.3 | 13.5 | |
| XII | 8.7 | 5.1 | −0.3 | 3.2 | 7.1 | 9.7 | |

* The meteorological stations (1), (2),....(6) are respectively the nearest to the mareograph stations (1), (2),....(6).

** Given for the sake of reference, as Akita is the sea-coast meteorological station nearest to Iwasaki.

| Month. | (1) Yoko-suka. | (2) Ishino-maki. | (3) Sapporo. | (4) Aomori. | (5) Wajima. | (6) Hamada. | (4') Akita.** |
|---|---|---|---|---|---|---|---|
| | | | Resultant Wind Direction. | | | | |
| I | N11°W | N57°W | N79°W | S 71°W | S 68°W | S 88°W | N64°W |
| II | N 4°W | N65°W | S 13° E | S 62°W | S 64°W | S 64°W | N66°W |
| III | N25°W | N26°W | S 89° E | S 56°W | S 52°W | N14° E | S 35°W |
| IV | N65°W | N45°W | S 38°W | S 89°W | S 51°W | S 78°W | S 60°W |
| V | S73° E | S 58° E | S 29° E | N63°W | S 21°W | N59° E | S 21°W |
| VI | S 6°W | S 88° E | N72° E | N16°W | N59° E | N28° E | S 5°W |
| VII | S 18°W | N76° E | S 69° E | N19° E | S 78°W | N27° E | S 30° E |
| VIII | N | N71° E | S 52° E | N49° E | N70° E | N52° E | S 40° E |
| IX | N50° E | N62° E | S 48° E | N67° E | S 14°W | N62° E | S 40° E |
| X | N 3° E | N 5°W | S 55° E | S 48°W | S 54°W | N49° E | S 71° E |
| XI | N 3° E | N 9°W | S 26°W | S 65°W | S 34°W | N53° E | S 68° E |
| XII | N12°W | N20°W | N36° E | S 74°W | N55°W | N23° E | N 9°W |

**TABLE XXV. MEAN YEARLY AND MONTHLY BAROMETRIC PRESSURE*, AND AIR AND SEA-WATER TEMPERATURES. 1899-1911. KEELUNG, (FORMOSA).**

| Month. | I. | II. | III. | IV. | V. | VI. | VII. | VIII. | IX. | X. | XI. | XII. | Mean. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Barometric Pressure. 700mm+ | | | | | | | | |
| | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm |
| 1899 | 66.6 | 64.6 | 64.6 | 61.2 | 58.3 | 57.0 | 51.9 | 55.5 | 59.0 | 64.1 | 65.5 | 65.0 | **61.1** |
| 1900 | 66.8 | 66.9 | 64.8 | 61.6 | 59.0 | 57.0 | 57.0 | 55.1 | 58.0 | 63.4 | 64.6 | 67.2 | **61.8** |
| 1901 | 66.1 | 69.2 | 66.4 | 60.8 | 59.3 | 56.2 | 56.6 | 54.6 | 58.6 | 61.2 | 66.1 | 66.8 | **61.8** |
| 1902 | 66.3 | 70.3 | 63.6 | 62.4 | 58.1 | 55.1 | 56.2 | 54.7 | 58.7 | 64.5 | 65.3 | 65.3 | **61.7** |
| 1903 | 67.7 | 69.6 | 63.0 | 61.9 | 60.2 | 56.7 | 55.6 | 55.8 | 59.7 | 61.0 | 65.2 | 67.2 | **62.0** |
| 1904 | 68.1 | 65.8 | 63.2 | 61.8 | 59.7 | 56.5 | 53.4 | 55.5 | 59.5 | 63.1 | 66.7 | 68.4 | **61.8** |
| 1905 | 63.8 | 66.6 | 64.7 | 62.2 | 60.2 | 55.6 | 55.5 | 56.3 | 59.2 | 62.4 | 66.8 | 65.7 | **61.6** |
| 1906 | 67.2 | 63.4 | 65.8 | 61.1 | 58.0 | 56.5 | 53.7 | 56.0 | 57.8 | 61.9 | 65.5 | 66.6 | **61.1** |

* Reduction to standard gravity $=-1.3$; Reduction to mean sea-level $=+0.3$.

| Month. | I. | II. | III. | IV. | V. | VI. | VII. | VIII. | IX. | X. | XI. | XII. | Mean. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm |
| 1907 | 66.6 | 66.7 | 64.8 | 61.9 | 59.1 | 56.0 | 55.5 | 55.2 | 57.7 | 61.8 | 64.9 | 67.5 | **61.5** |
| 1908 | 67.7 | 66.0 | 64.9 | 61.7 | 59.1 | 57.3 | 55.3 | 54.6 | 58.7 | 61.3 | 65.2 | 66.0 | **61.5** |
| 1909 | 65.1 | 65.7 | 64.8 | 61.2 | 60.0 | 56.8 | 57.2 | 55.5 | 56.5 | 61.0 | 64.7 | 67.3 | **61.3** |
| 1910 | 66.1 | 65.4 | 63.8 | 61.8 | 58.7 | 57.6 | 55.2 | 55.0 | 57.1 | 62.9 | 64.6 | 67.3 | **61.3** |
| 1911 | 65.3 | 62.6 | 63.5 | 61.4 | 58.9 | 56.4 | 54.8 | 52.9 | 56.8 | 63.6 | 65.8 | 66.7 | **61.0** |
| Mean. | **66.4** | **66.4** | **64.5** | **61.6** | **59.1** | **56.5** | **55.2** | **55.1** | **58.3** | **62.5** | **65.5** | **66.7** | **61.5** |
| | | | | | Air Temperature. C°. | | | | | | | | |
| 1899 | — | — | — | — | — | — | — | — | — | 21°.6 | 18°.9 | 18°.6 | — |
| 1900 | 15°.0 | 14°.7 | 15°.9 | 21°.3 | 24°.0 | 25°.6 | 27°.8 | 28°.2 | 26°.1 | 23.5 | 20.0 | 17.9 | 21°.8 |
| 1901 | 17.2 | 11.3 | 16.8 | 21.8 | 23.5 | 25.5 | 27.7 | 27.2 | 25.0 | 23.0 | 19.3 | 16.3 | 21.2 |
| 1902 | 16.7 | 14.5 | 18.5 | 21.2 | 24.4 | 25.8 | 27.5 | 27.6 | 24.7 | 22.6 | 21.4 | 17.7 | 21.9 |
| 1903 | 14.8 | 14.1 | 17.6 | 20.6 | 22.7 | 25.4 | 27.2 | 26.9 | 26.2 | 23.3 | 19.0 | 16.4 | 21.2 |
| 1904 | 15.4 | 16.2 | 16.3 | 20.6 | 22.4 | 25.4 | 26.3 | 26.4 | 25.9 | 23.7 | 19.1 | 15.7 | 21.1 |
| 1905 | 17.2 | 13.2 | 15.6 | 18.3 | 23.7 | 26.2 | 27.7 | 28.0 | 26.5 | 22.8 | 19.9 | 18.2 | 21.4 |
| 1906 | 15.1 | 14.6 | 16.0 | 20.9 | 24.2 | 27.6 | 27.9 | 28.2 | 27.7 | 22.8 | 19.5 | 17.3 | 21.8 |
| 1907 | 16.1 | 14.2 | 16.3 | 19.5 | 23.0 | 25.3 | 26.7 | 27.7 | 26.2 | 24.7 | 91.2 | 16.7 | 21.5 |
| 1908 | 16.3 | 15.1 | 16.1 | 18.5 | 22.4 | 25.6 | 28.1 | 27.2 | 26.6 | 24.4 | 20.0 | 18.3 | 21.6 |
| 1909 | 16.3 | 15.3 | 16.5 | 20.2 | 22.2 | 27.2 | 28.5 | 28.5 | 27.3 | 24.5 | 20.5 | 17.0 | 22.0 |
| 1910 | 15.2 | 14.9 | 16.5 | 19.1 | 23.0 | 27.3 | 28.5 | 27.8 | 26.3 | 22.6 | 19.8 | 16.1 | 21.4 |
| 1911 | 15.2 | 16.1 | 16.7 | 19.5 | 22.6 | 27.8 | 28.0 | 27.2 | 26.5 | 22.3 | 19.5 | 17.8 | 21.6 |
| Mean. | **15.9** | **14.5** | **16.6** | **20.1** | **23.2** | **26.2** | **27.7** | **27.6** | **26.3** | **23.2** | **19.9** | **17.2** | **21.5** |
| | | | | | Sea Water Temperature.* C°. | | | | | | | | |
| 1901 | 18°.2 | 14°.2 | 16°.9 | 21°.6 | 24°.2 | 25°.7 | 28°.6 | 27°.7 | 26°.2 | 23°.1 | 19°.4 | 17°.3 | 21°.9 |
| 1902 | 17.1 | 16.0 | 19.5 | 22.3 | 25.2 | 25.9 | 28.1 | 28.1 | 25.3 | 22.9 | 21.5 | 19.4 | 22.6 |
| 1903 | 16.7 | 15.8 | 17.7 | 21.5 | 23.6 | 26.3 | 27.7 | 27.0 | 26.8 | 23.4 | 19.5 | 17.1 | 21.9 |
| 1904 | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 1905 | — | — | — | — | — | — | — | — | — | 23.4 | 20.1 | 19.1 | — |

* Measured every morning at 10 o'clock at the coast of Sharyo Isle facing the harbour entrance.

| Month. | I. | II. | III. | IV. | V. | VI. | VII. | VIII. | IX. | X. | XI. | XII. | Mean. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1906 | 16°.5 | 16°.0 | 17°.1 | 21°.5 | 24°.9 | 27°.8 | 28°.5 | 28°.9 | 27°.0 | 22°.5 | 20°.2 | 18°.2 | 22°.4 |
| 1907 | 16.9 | 16.2 | 17.5 | 20.6 | 23.3 | 25.2 | 26.8 | 27.7 | 26.5 | 25.1 | 22.3 | 17.7 | 22.1 |
| 1908 | 16.7 | 16.4 | 16.9 | 17.8 | 22.0 | 25.1 | 28.4 | 27.6 | 26.9 | 24.3 | 20.9 | 18.2 | 21.8 |
| 1909 | 17.5 | 15.8 | 17.8 | 20.8 | 23.1 | 27.1 | 28.1 | 27.9 | 27.7 | 24.7 | 21.1 | 18.0 | 22.5 |
| 1910 | 17.0 | 16.7 | 17.1 | 20.1 | 23.9 | 27.0 | 28.4 | 27.6 | 25.6 | 21.8 | 19.2 | 16.2 | 21.7 |
| 1911 | 16.5 | 15.7 | 17.1 | 20.7 | 23.4 | 27.6 | 27.7 | 27.5 | 26.3 | 22.6 | 19.9 | 18.4 | 21.9 |
| Mean. | **17.0** | **15.9** | **17.5** | **20.8** | **23.7** | **26.4** | **28.0** | **27.8** | **26.5** | **23.4** | **20.4** | **18.0** | **22.1** |