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On Some Remarkable Relations between the Yearly Variations of Terrestrial Phenomena and Solar Activities.

By

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With 17 text figures.

I. Frequency of Earthquakes.

In a previous communication[1] it was shown that the distribution of the barometric pressure in our region is apparently influenced, not only by the total area of faculæ passing the central meridian of the sun's disc, but also by the difference of the areas of those situated on the northern and southern solar hemispheres respectively. On the other hand, the present author has been long since engaged with the investigation of the barometric gradient as one of the important secondary causes determining the seismic frequency and already published some results obtained[2]. If the solar activities affect the barometric condition to a sensible degree, we will not be surprised, if they also would show some correlations with the frequency of occurrence of earthquakes. As a first step for testing this idea, the yearly frequency of earthquakes observed in different Japanese stations, were compared with the areas of sunspots and faculæ for an interval of thirty years, 1886–1916.

1) Japanese Journal of Astronomy and Geophysics, **1** (1922), No. 2; also in Papers dedicated to Prof. H. Nagaoka to commemorate the twenty-fifth anniversary of his professorship.

2) Proc. Tôkyô Phys.-Math. Soc., [1] **5**, p. 454. See also H. Nagaoka, *ibid.* **6**, p. 208; K. Hasegawa, *ibid.* **7**, p. 181; Saem. Nakamura, *ibid.* **8**, p. 69; T. Terada and S. Masuzawa, *ibid.* [2] **1**, p. 343.

The latter data were taken from Maunder's paper in the Monthly Notices of the Royal Astronomical Society, Vol. 80, 1920, in which the areas for the both hemispheres are separately tabulated. The seismological data were kindly placed at my disposal by Prof. Okada and Prof. Saem. Nakamura of the Central Meteorological Observatory, for which my best thanks are due. The materials consist of the records of the number of earthquakes observed in the chief meteorological observatories of Japan[1]. The shocks are generally classified into two kinds, i. e. those 'felt' and instrumentally recorded. The 'total' number, therefore, shows often a sudden increase after the introduction of the seismograph. Beside this apparent circumstance, it must be assumed that the said number is affected by many uncontrollable causes apart from the actual variation of the seismic activity. Hence, it was considered most plausible to take the following procedure for studying the actual influences of the secondary cause upon earthquakes.

The successive yearly numbers were plotted as the ordinates on a diagram with the years as abscissæ and the successive points were connected into a broken line or curve. Among the other irregularities presented by the diagram, one may worth special mention, i.e. when a destructive earthquake occurs in a district, the aftershocks are felt often during several years after it. In such case, the small variation of frequency due to the secondary cause may be entirely overlooked, if we pay our attention only to the absolute magnitude of the number. Hence, for the present purpose, the maxima and minima of the curve were determined by comparing each year only with the few neighbouring years. Any year at the top of a convex part, or at the bottom of a concave part of the graph was respectively called a 'maximum' or a 'minimum'. On the slope of frequency curve following a destructive earthquake, it may therefore happen that a 'minimum' is followed by a 'maximum' which is decidedly less in actual magnitude than the former. In short, the maxima and minima were judged by the *second difference* of the frequencies.

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1) Number of the years available varies from 18 to 30 for different stations. For sixteen stations, the observations of thirty years are at hand.

In the following, the 'total' number of the shocks was generally taken, except for a few stations for which the 'felt' ones were only available. In the former case, the number shows discontinuous increase at the introduction of the instrument as already mentioned. This will, however, scarcely affect the general results here concerned, even if we count a false minimum on this account.

After determining the years of maxima and minima for each station, the next procedure was to see if these years were associated with some peculiarities in the distribution of the solar activities upon the two hemispheres. For this purpose, it was considered most suitable to construct a diagram in which the abscissæ x and the ordinates y gave the areas of spot on the northern and the southern hemispheres respectively, N_s and S_s say. Each year is then represented by a point on the diagram with the coordinates $x=N_s$, $y=S_s$. Call this, for simplicity's sake, the *spots-diagram* to distinguish it from a similar one in which the area of faculæ on the two hemispheres, N_f and S_f say, stand for x and y respectively, i.e. the *faculæ-diagram*. Taking a given station, the points for the years corresponding to the maxima and the minima of the seismic frequency are marked with suitable signs, say ○ and × respectively. If there exists any systematic relation between the distribution of the solar activities and the earthquake, we may expect that the points with the same mark would be arranged in a definite portion or portions of the area of this diagram. On carrying out the plotting, it was found that such is actually the case. For a great number of stations the years with minimum frequencies are crowded in a narrow zone lying along the both sides of the straight line $x=y$, bisecting the angle between the axes of coordinates, while the years of maxima are arranged on both sides of the zone. For some other stations, the contrary was the case, the years of maxima being distributed near the line $x=y$.

Since the number of years taken was not great, the points of maxima and minima on the diagram were often too sparsely distributed to enable us to draw the line of demarcation separating the areas of maxima and minima. Hence, it was considered convenient to superpose the spot-diagram upon the faculæ-diagram;

by choosing suitable scales of the coordinates such that the ranges of variation on the diagrams were nearly equal for the two diagrams. This was approximately effected by taking the areas of faculæ as equivalent to twice the areas of the spots. On the *spots-faculæ-diagram* thus obtained, the lines of demarcation were drawn separating the areas with o and × respectively. Though the results are not quite simple, we may classify the different stations into the following three classes, according to the distribution of the years of maxima and minima, or the situation of the lines of demarcation upon the diagram:

Class I. Frequency is minimum when $|N_s - S_s|$ or $|N_f - S_f|$, or briefly $|N - S|$ is small. The stations belonging to this class are Tainan*[1], Taityû*, Naha, Kagosima, Nagasaki, Kumamoto, Hukuoka, Matuyama, Kôti, Tadotu, Tokusima, Wakayama, Hirosima, Hamada, Okayama, Hikone, Nagoya, Hukui, Kanazawa, Yagi*, Matumoto, Nagano, Kôhu, Utunomiya, Maebasi, Kumagae, Tyôsi, Mito, Mera*, Hukusima, Kanayama, Miyako, Yamagata, Aomori, Hakodate and Nemuro*.

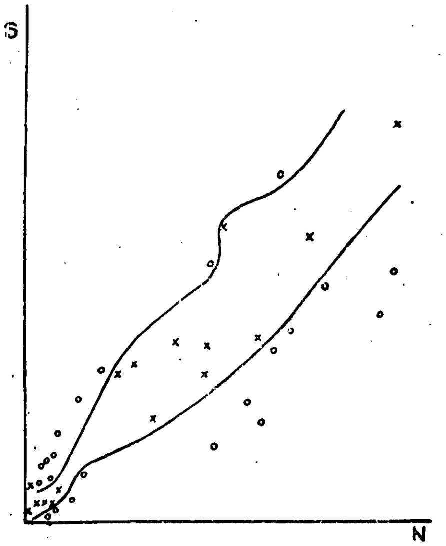

Fig. 1. Hirosima.

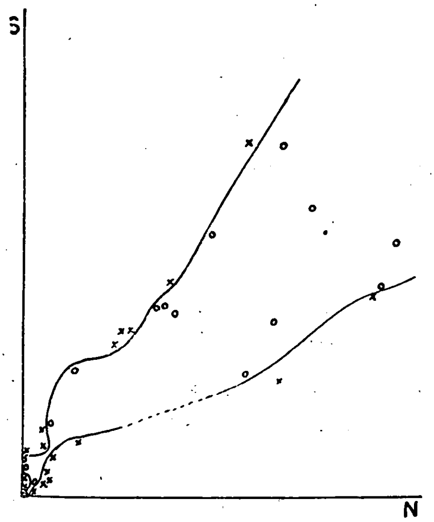

Fig. 2. Simonoseki.

1) The stations marked with * are those for which the 'felt' earthquakes only were taken.

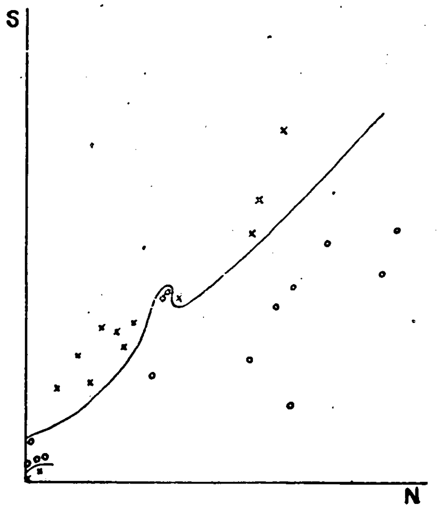

Fig. 3. Kyôto.

Class II. Frequency is maximum when $|N-S|$ is small and minimum when it is large. The stations of this class are Nase, Simonoseki, Ôsaka, Sakai, Niigata, Akita, Sapporo and Kusiro.

Class II′. For not very small value of N and S, the frequency of earthquakes is maximum when $N>S$ and minimum when $N<S$. For small values of $N+S$, the contrary is often the case, or the relation is similar to Class I. The stations of this type are Miyazaki, Ooita, Saga, Kôbe, Kyôto, Tu, Gihu, Husiki*, Hamamatu and Tôkyô.

The most typical examples of these classes are illustrated in figs. 1, 2 and 3.

Taking together all stations belonging to the same class, the number of stations with maximum or minimum of frequency in

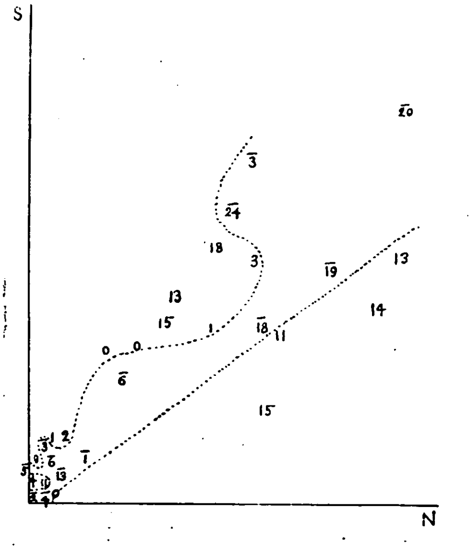

Fig. 4. Class I.

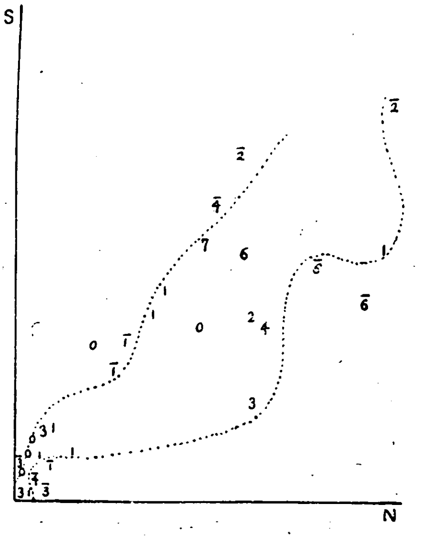

Fig. 5. Class II.

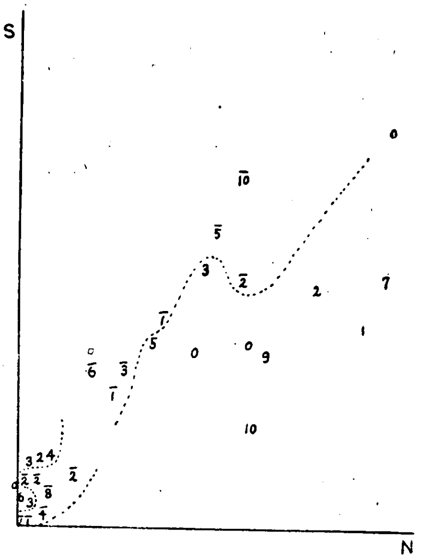

Fig. 6. Class II′.

each year was counted. The difference of the number of the maxima minus that of the minimum was then plotted on figs. 4, 5, 6 which refer to faculae. Similar diagrams referred to spots show quite similar aspects. It was seen that the Class II′ is similar to Class I for the small value of $N+S$ and rather resembles Class II for the large value of it, suggesting that Class II′ is a mixed type of I and II.

On the other hand, the yearly deviations from the mean of the number of stations of each class showing maximum or minimum were treated similarly. For Class I and II, the results are such as could be expected from the above. For Class

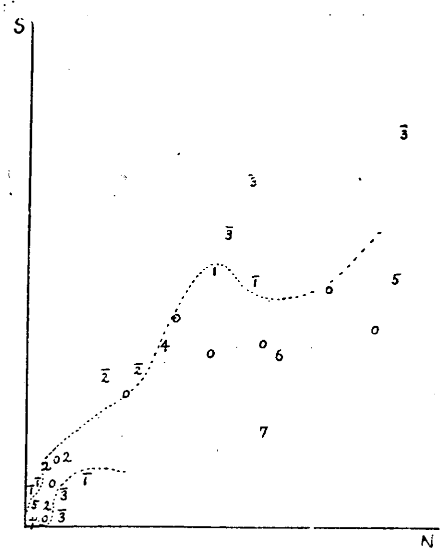

Fig. 7. Number of stations with maximum frequency.

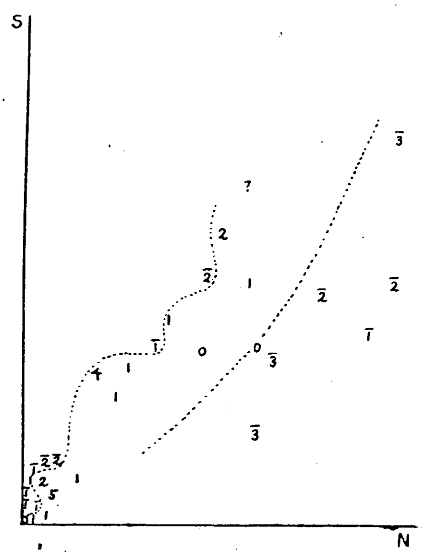

Fig. 8. Number of stations with minimum frequency.

II′, however, it may be remarked (figs. 7 and 8) that the number of minimum is of the type similar to Class I, while the number of maximum shows a distribution proper to Class II, especially for not very large value of $N+S$.

It must be remarked in passing that some stations show anomalous behaviour in changing the class to which they belong, by the choice whether the felt shocks only or the total numbers are taken. For example, Tôkyô belongs to Class II′ for the total frequency, but if the 'felt' only is taken, it belongs to I. Again, Maebasi and Aomori which belong to Class I for the total frequency, are transferred into Class II when the felt earthquakes are taken. It will be seen later that these stations are near the boundary of the areas separating the different classes.

Plotting the stations of different types on a suitable map of Japan (Fig. 9), we see that Class I and II shows a distinct geographical distribution, the latter class decidedly predominating on the Japan Sea coast. The region belonging to Class II′ appears

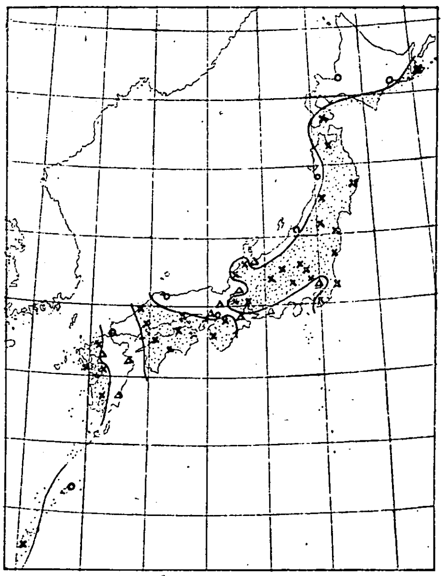

Fig. 9. × : Class I. ○: Class II.
△ : Class II .

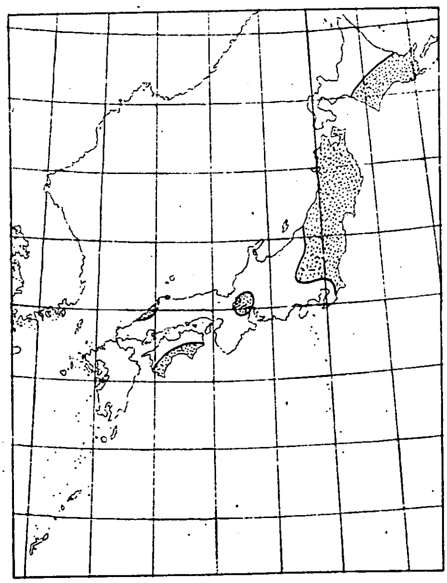

Fig. 10. Area dotted over shows maximum frequency in summer, while the remaining land area shows maxima in winter. (Corea and Manchuria are excluded).

intruding between the areas of Class I, as if it were the branches of the area for II. It may be noticed that the latter branched areas coincide nearly with the tectonic depression of Bungo Channel and a chain of depression formed by the Bay of Ise, Lake Biwa and the Bay of Wakasa.

Prof. Omori[1] has investigated, early in 1902, the seasonal variation of seismic frequency in different stations of Japan and distinguished two groups of districts according to the season in which the frequency is maximum. Those districts in which it is maximum in winter or in summer were called respectively Group A and B. Comparing his map reproduced in fig. 8, with fig. 7, a certain similarity of the distribution may easily be discerned. If in fig. 7, the areas for Class II and II′ be allowed to encroach upon that for Class I in the western and central part of Japan, while it be made to shrink back in northern Japan, the result may become quite similar to fig. 8. If this comparison is legitimate, the conclusions follow: The districts for which the seismic frequency is greater in summer correspond to those for which it is maximum when the 'hemispherical difference' of the solar activity $|N-S|$ is large, while those with the greater frequency in winter are those for which it is maximum when $|N-S|$ is small. If the yearly seismic frequency be chiefly influenced by the distribution of barometric pressure as it seems probable, we may therefore be justified to conjecture that the years with small hemispherical difference would probably correspond to those in which the continental pressure is relatively high and the oceanic one is relatively low, while the years with large difference would be characterized by relatively higher oceanic and lower continental pressure.

Referring to Table IV, B of the previous paper, it may be observed that the small $|n'-s'|$ is generally associated with the gradients with the western side higher. This may be regarded as a partial verification of the above conjecture.

Next, the yearly mean values of barometric pressure for different oriental stations were taken from Walker's memoir[2] and

1) F. Omori, Publications of the Earthq. Inv. Comm. in Foreign Language, No. 8.

2) G. T. Walker: "Sunspots and Pressure," Memoirs of the Indian Met. Dep., **21**, Part 12.

the years of maxima and minima of pressure were plotted on the spots-faculæ diagrams in exactly same manner as described above for the case of the seismic frequency. The result showed a remarkable fact that all stations may be divided into two distinct classes according as the maxima or minima of the pressure are associated with the small hemispherical difference $|N-S|$[1]. Among the stations investigated, Jakutsk, Irkutsk, Nicolaevsk, Ley, Zikawei etc. show maxima, while Tôkyô, Hongkong, Manila, Langoon and all Indian stations show minima of pressure for small $|N-S|$. This remarkable fact harmonizes well with the above conjecture that the small hemispherical difference is associated with the higher continental and lower oceanic pressure.

The above results confirm the undeniable influences of the difference of activities on the two hemispheres of the sun upon the terrestrial weather and at the same time emphasize the importance of the barometric distribution as the actual cause of earthquakes.

On the other hand, the number of earthquakes in Jamaica was taken from Maxwell Hall's paper[2] and plotted on a similar diagram. It was found that this district belongs to Class I, i. e. the maximum frequency is met with in the years with small hemispherical difference of the solar activities. According to Hall, the seasonal distribution of frequency shows a maximum in winter. Hence it may be supposed that the small $|N-S|$ tends to give winterly character to the barometric distribution. According to Berghaus's Meteorological Atlas, the winter gradient in this district is generally greater than the summer one. The yearly pressure at Florida, Texas and Mexico was found to show maxima in the years with small $|N-S|$, while Newcastle in Jamaica shows minima for the same. This relation therefore corroborates the above results for the Japanese earthquakes.

Next, yearly numbers of the earthquakes in different parts of the world which were reported in the 'London Times' and quoted by R. W. Sayles in his note on 'Earthquake and Rainfall,[3] were

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1) The results of these investigations will be given in the next chapter.

2) Maxwell Hall: Earthquakes in Jamaica, from 1688 to 1919.

3) R. W. Saylès, Bull. Seism. Soc. America, **3** (1913).

treated in a similar manner. The diagram obtained seems to belong to Class I. This shows probably that the Class I predominates in the entire seismic zones of the world. This point deserves a more detailed study with respect to sufficient materials.

II. Pressure and Temperature.

In the preceding chapter, I have shown that the yearly frequencies of earthquakes in Japan and Jamaica are closely associated with the absolute value of the difference of the spots or faculae area on the northern and southern solar hemispheres in the corresponding year, which we may call the 'hemispherical difference' and denote by $|N-S|$, or more properly with the quantity $|N-S|/(N+S)$ which we may denote by δ and call the 'specific hemispherical difference'. For the discussion of the results, it became necessary to investigate the similar relation with respect to the yearly mean pressure and temperature in different parts of the world. For this purpose, the most convenient materials near at hand was afforded by Walker's fifth and sixth memoirs on the 'Correlation in Seasonal Variations of Weather', frequently cited in my previous papers. The data given there were adopted without any reduction. Since the solar data available[1] were limited to the epoch 1886–1916, the terrestrial data before 1886 could not be utilized. Besides, the weather data do not extend beyond 1913 so that the epoch here treated refers at most to 1886–1912.[2] For a number of stations the data are missing still further. Notwithstanding the want of homogeneity, the whole data were subjected to the similar treatment, as it seemed most practical for the present preliminary investigation. Besides, the pressure and temperature data of Apia, Samoa, recently published by Angenheister[3] were untilized, since they are valuable in filling up the want of stations in the Pacific region.

1) E. W. Maunder: Note on the Distribution of Solar Faculae, Monthly Notices of the Royal Astronomical Society, **80** (1920), p. 728.

2) For Nagasaki and Tôkyô, the pressure and temperature data were available up to 1916.

3) From the abstract given in Meteor. ZS., 1922.

The method of investigation is quite similar to the previous one with regard to the frequency of earthquakes. The years of maximum and mininum pressure or temperature were distinguished according as the year is situated at the top of a convex part or at the bottom of a concave part of the pressure-or temperature-time curve. Next, a diagram was constructed for each station in which the abscissae and the ordinates represent the area of faculae or twice the area of spots upon the northern and southern solar hemisphere respectively. Each point on the diagram representing a year was marked with ○ or × according as the year corresponded to a maximum or minimum of the meteorological element. After superposing the faculae and spots diagrams thus obtained, the lines of demarcation were drawn such that they divide the area of the diagram into definite parts in which the marks ○ or × are grouped.

The results of the above investigations may be summarized as follows:

1) *Pressure.*

In the case of the mean pressure, the results were quite similar as in the case of the earthquake frequency. The different stations could be classified into two distinct classes or types:

Type I. in which the years of maximum pressure marked with ○ are crowded in a narrow strip of area along the line $x=y$ or $N=S$, bisecting the angle between the axes of coordinates. A pair of the lines of demarcation could be drawn which may more or less approximately be represented by two straight lines passing the origin and making certain angles with the bisector, or in other words by two line $x=(1+\varepsilon_1)y$ and $x=(1-\varepsilon_2)y$. Beyond these lines of demarcation, years with the mark × are scattered.

Type II. which is complementary to Type I, the years with minimum pressure, i. e. the points marked with × being distributed between the similar lines of demarcation.

Of course, the above classification refers to the most general features of the diagrams, disregarding many irregularities in detail. The lines of demarcation are indeed generally not straight, but

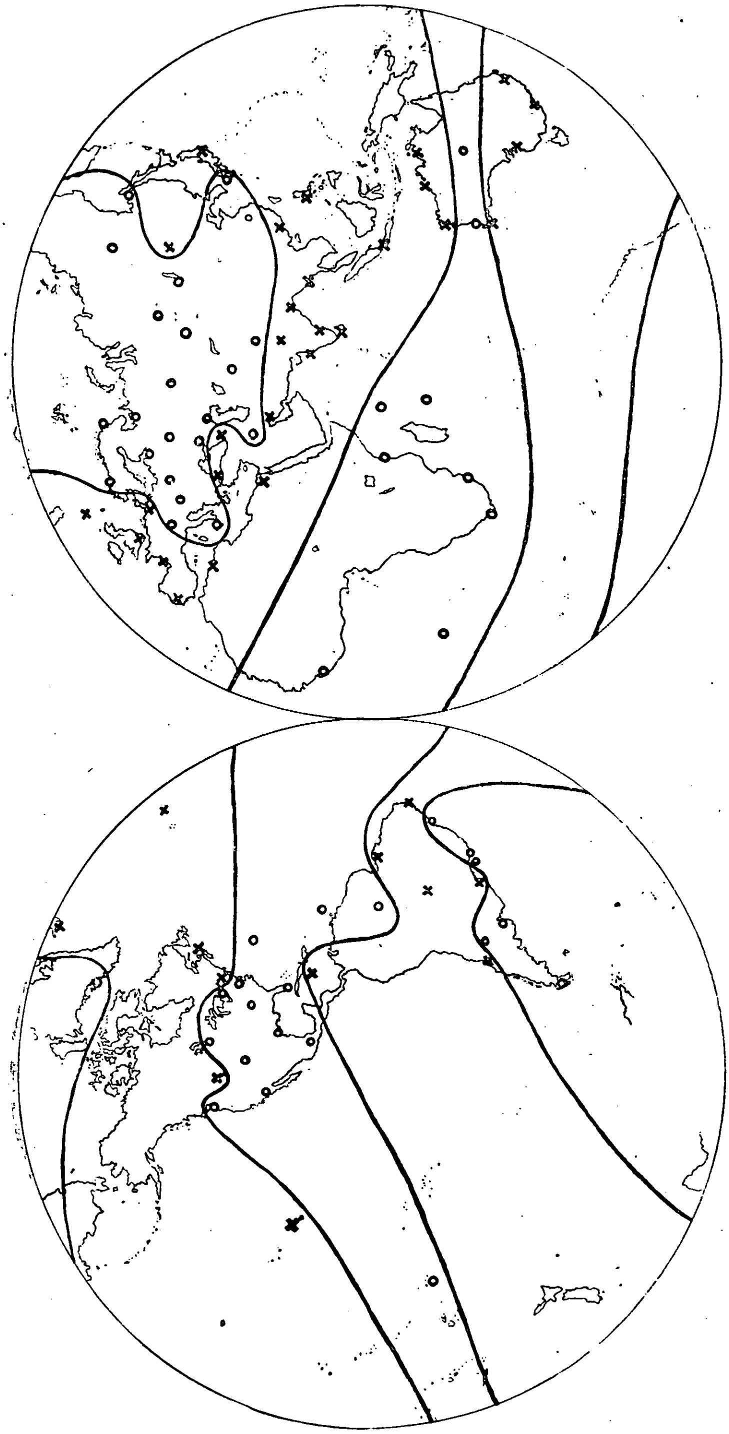

Fig. 11.

show often marked sinuousity. Still, it is possible in most cases to divide the area of the diagram into three sectors of which the middle one extending along the line $x=y$ is crowded with either ○ or ×.

The distribution of the stations belonging to each class on the earth's surface is shown in Fig. 11. Stations of Types I and II are distinguished by the marks ○ and × respectively. Though the density of the station is small, especially in the southern hemisphere, I have tried to draw a series of lines dividing the entire earth's surface into a number of hypothetical zones alternately belonging to Types I and II. The boundary lines of the zones thus assumed are shown in Fig. 11 with thick lines. It will be noticed that one of the poles of the zones falls somewhere near the northern part of Siberia. It is interesting to observe on the other hand that, if we suppose the distributions of land and water on the earth's surface were to be roughly represented by means of the zonal harmonics of the fourth order, the most suitable solution seems to conform roughly with the division above obtained. This suggests that the relation of the means annual pressure with the solar activity has something to do with the distribution of land and water and arouses the suspicion that the relation may be brought about by the fluctuation of the *heat* radiation of the sun. In order to advance the investigation in this line, it is necessary to consult the following results with respect to the temperature.

2) *Temperature.*

In the case of temperature, the results were generally similar as in the previous cases, but somewhat more complicated such that it was found in some cases difficult to divide the area of the diagram into three sectors by two lines of demarcations with no considerable sinuousity. It seemed more suitable to distinguish four types, instead of two, in the case of temperature:

Type I. in which the years of maximum temperature correspond to the small values of the specific hemispherical difference, $\delta=|N-S|/(N+S)$, in analogy with Type I in the case of pressure.

Type II. in which the years of minimum temperature are

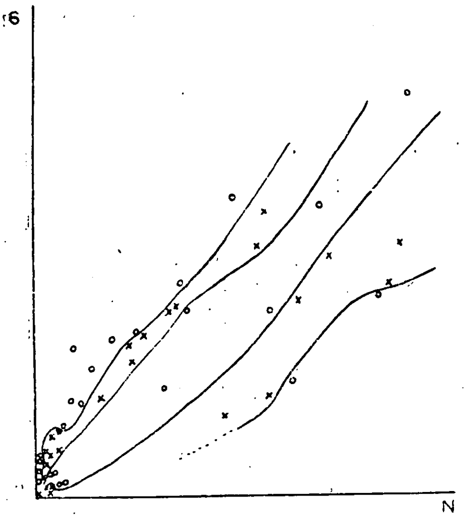

Fig. 12. Leh.

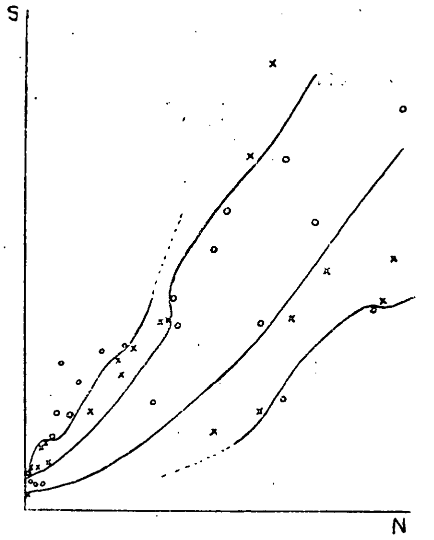

Fig. 13. 25 continental stations.

associated with the small values of δ, in analogy with Type II in the case of pressure.

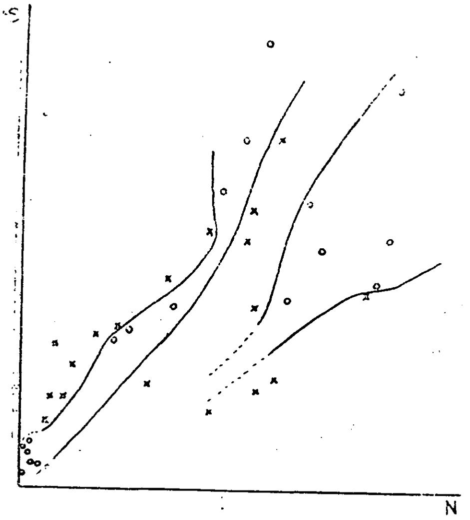

Fig. 14. Jacobshavn.

Type III. in which the area of the diagram may conveniently be divided into five sectors of which the middle and the outermost sectors contain the years with maximum temperature, or in other words, the maximum of temperature occurs in the years with small or large values of δ and the minimum occurs in those with the intermediate values of this solar quantity.[1] An example of this type is shown in Fig. 12.

Type IV. which is comple-

1) The yearly fluctuations of mean temperature for 17 American, 7 European and 1 Indian stations, given in p. 593 of Humphrey's "Physics of the Air", treated in the similar manner, show a very typical diagram of this Type III (Fig. 13). Since these stations are all continental, it may be said that this type is that characteristic for the land area.

mentary to Type III, the middle and the external sectors being occupied with the years of minimum temperature. An example is given in Fig. 14.

These results led me to revise the pressure diagrams and to examine if a similar quadruple classification is not possible also in that case. It was found that the marked sinuousity of the lines of demarcation could be avoided in some cases if we allow the existence of the four analogous types. On carrying out the revision, it was found however that the new classification affects the zonal distribution of the Map of Fig. 1 in no considerable way, if we take Types III and IV as the general cases of Types I and II respectively, as is quite natural, and denote them by the same mark ○ and × respectively.

3) *Relation between Pressure and Temperature.*

The relation between the pressure types and the temperature types is of the paramount importance for the investigation of the cause of the fact disclosed above. It is especially interesting to see whether high pressures correspond to high or low temperatures. For this purpose, the correspondence of pressure and temperature types was examined for all stations for which the determination of the type was possible for the both elements. Among the eighty seven stations available, fourteen were put aside, as the classification was more or less ambiguous. In forty six[1] among the remaining seventy three stations, I or II pressure type is associated with II or I temperature type respectively, while in twenty seven stations[2] the contrary relation is found. It may be observed that of the latter twenty seven stations, eighteen are those belonging

1) These are: Algier, Alice Spring, Apia, Archangelsk, Astrachan, Bagdad, Bahia, Barbados, Barnaul, Basel, Bermuda, Blumenau, Bombay, Bordeaux, Brisbane, Bushire, Calcutta, Carnarvon, Colombo, Cordoba, Cristiansund, Eniseisk, Helena (Montana), Hongkong, Honolulu, Irkutsk, Jacobshavn, Jakutsk, Lisbon, Lugansk, Madras, Mexico, Moscou, Nikolaevsk, Pelotas, Petrograd, Port Louis, Rio de Janeiro, San Diego, Scutari, Seychelles, Tokyô, Vardö, Victoria B.C., Winnipeg, Zikawei.

2) These are: Adelaide, Aden, Agra, Albany N. Y., Buenos Aires,* Derby, Ekaterinburg*, Galveston*, Greenwich, Hamburg, Keywest*, Ley*, Nagasaki, Ponta Delgada, Punta Arenas*, Rangoon, Recife, Santiago, Stykkisholm, Sydney (Austr.), Sydney N.S., Tashkent*, Tiflis, Valencia, Vienna*, Washington, Zanzibar*.

to the pressure type II and IV, i.e. to the 'water zone', while of the remaining nine stations[1], eight are situated near the boundary of O or the 'land zone'.

The above relation suggests that the zonal distribution of the yearly pressure is chiefly determined by the zonal distribution of the atmospheric temperature caused by some unknown mechanism of the solar influence. It is no wonder that the temperature distribution is not so simple as the pressure distribution, since the temperature observed at the surface of the earth are considerably affected by the local factors such as cloudiness, precipitations, the directions of wind etc. which are governed in their turn by the pressure distribution. The fact that the fluctuation of the pressure shows nevertheless a regular distribution seems therefore to indicate that the temperature of the air is affected up to the higher layer by the influence of the sun, in such a manner as to produce the above zonal distribution.

The above way of regarding the relation between the temperature and pressure is interesting inasmuch as it promises to explain in some measure the peculiar correlation often found between the pressure of a certain station with the temperature of another station situated in quite remote part of the earth[2]. If the yearly variations of pressure and temperature are related to the variation of solar activity as considered above, it is quite natural that these elements in different parts of the earth show positive or negative correlation as the case may be. The fact that the actual correlations are by no means so universal and also that remarkable relations are often found between one element in a certain month of a certain station and another element in another month of a distant station, is not surprising, if we consider that numerous local influences are always present tending to drown the general effect of the solar activity. Farther discussions on these lines will

1) Those marked with * in foot note (2) of the previous page.

2) For example, April and August pressure of Toronto is closely associated with the August temperature at Erimo, Hokkaidô (See T. Okada, Journ. Met. Soc. Jap., **36**, No. 6.) It may be remarked that yearly pressure of Toronto and yearly temperature of Tôkyô belongs to Type III.

however be better postponed till the similar investigations have been made with respect to the *monthly* variations of pressure and temperature.

From the results of the present investigation, we may suggest the followings at least as a kind of working hypothesis:

1) The yearly mean temperature of atmosphere, averaged throughout the entire air column above the surface, represented as a function of the geographical position and of the solar activity, contains a leading term of the form $F(\varphi)D(\delta)$, where F is a periodic function of the angular distance φ from a pole situated somewhere in the northern part of Siberia, and D is also a periodic function of the specific hemispherical difference of solar activity, denoted here by $\delta=|N-S|/(N+S)$. F expanded in terms of zonal harmonics will contain a term of the fourth order as a conspicuous member. D seems to be an even function of δ.

2) The pressure is chiefly determined by the temperature of the entire air column.

3) If $F(\varphi)$ is sheerly determined by the distribution of land and water on the earth's surface, we may regard D as an expression of the solar radiation as a function of δ. This idea harmonizes with the fact that most of those stations in which low pressure corresponds to the low temperature lie in the 'water-zone' while the contrary is the case in the 'land-zone'. It seems that the radiation is minimum for $\delta=0$, increases at first with δ and attains a maximum for a moderate value of that quantity, beyond which it again decreases.

These ideas which seem to be so far plausible for explaining the facts found, may be useful for planning a farther researches. If the above conjecture be confirmed by future studies, the physical interpretation of the function $D(\delta)$ will not fail to form a problem of some significance in the domain of the solar physics in general.

III. Other Meteorological Elements.

After the remarkable relations between the atmospheric pressure and temperature and the solar activity has been disclosed, we will not be surprised if similar relations were found with

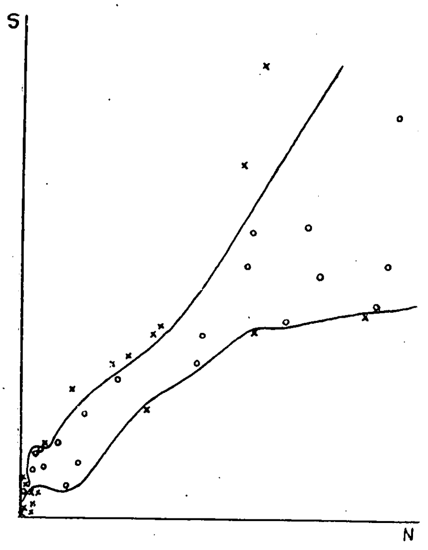

Fig. 15.

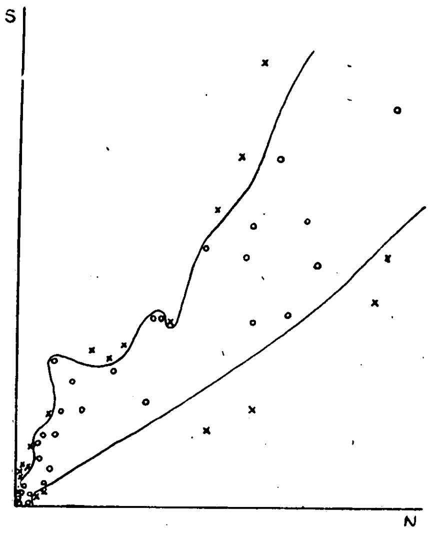

Fig. 16.

respect to widely varying classes of meteorological phenomena. For instances, we may cite the following fragmentary results:

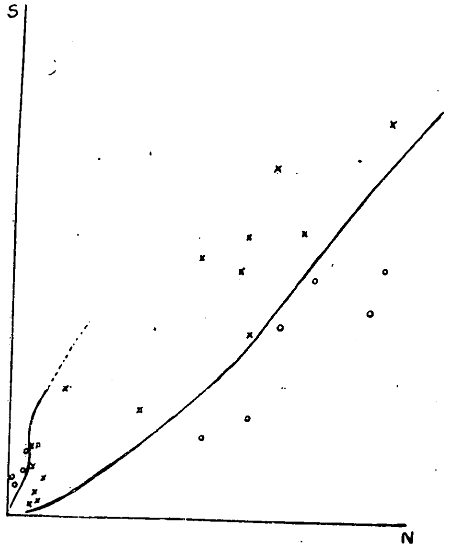

Fig. 17.

Number of typhoons. The number of conspicuous typhoons recorded in the Central Meteorological Observatory of Tôkyô[1] during 1887–1916 was treated similarly. A very conspicuous result was obtained that the maxima of the number occurs when δ is small, except for the years with very small solar activity, $N+S$, in which case the minima seem to prevail (Fig. 15).

Ice in Greenland Sea.

1) The data were kindly placed at my disposal by Mr. K. Saki of the Central Met. Obs., to whom my best thanks are due.

The ice-covered area in the Greenland Sea[1] shows a relation just contrary or complementary to the case of Japanese typhoon.

Rice crops in NE. Japan and Hokkaidô. With these crops[2] the relation is quite similar to the case of the typhoon The dependence upon δ is very simple and conspicuous (Fig. 16).

Wheat crop in Ohio, U. S. A. This crop[3] shows generally minima in the years with small δ, contrary to the case of Japanese rice.

Monsoon rain in India and Nile flood.[4] These shows a similar relation to each other and the division of the area of the spots-faculae diagrams belongs to Type III.

Number of fires due to lightenings, in Prussia. This number[5] is minimum for the years with small δ (Fig. 17).

Frequency of trade wind in Apia, Samoa.[6] This also shows minima for small δ.

The examples may be added still further. It seems probable that most of the periodicities of weather elements with the periods of 3–5 years, hitherto investigated by many meteorologists, are related to the rather irregular fluctuation of the solar quantity δ here called the specific hemispherical difference of activities.

In conclusion, it must be remembered with an emphasis that the years referred to in this paper as corresponding to the maxima or minima of the meteorological element in question were determined sheerly with regard to the convexity or concavity of the small portion of the time curve in the neighbourhood of the very year, so that it may occurs ometimes that the absolute value of a minimum is greater than that of a maximum in other parts of the curve. The irregular fluctuations treated in the present investigation which show so remarkable dependence on the quantity δ are

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1) Met. Zs., 1917, p. 320.

2) The data were taken from Prof. Okada's paper 'On the the possibility of forecasting the approximate yield of rice-crop for northern Japan, Journ. Met. Soc., **36**, No. 11. The epoch here utilized is 1886–1913.

3) From T. A. Blair's paper in Monthly Weather Review, **47** (1919), No. 12.

4) From the abstract given in Met. ZS., 1911.

5) *Ibid.*

6) Angenheister. *loc. cit.*

therefore those short period fluctuations which appear superposed on those variations with 11 years or still longer periods. What seems most remarkable to me is the fact that the correspondence of this short period waves with the variations of δ is so conspicuous that it seems to remove at least a greater part of the difficulties hitherto felt in correlating many terrestrial phenomena with the simple solar cycle of 11 years.

The results of further investigations now in progress will follow in due time.

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