Imperial Marine Observatory,[4] which has just reached the Weather Bureau library, Doctor Okada has presented some very interesting conclusions.

Two distinct ocean currents bathe the eastern shores of Japan—the northern, or cold, current, "Oyashiwo," and the warm, southern current called "Kuroshiwo," or Japan Current. From observational and other data available it now appears that the summer temperature in northern Japan depends largely on the temperature of the former, "Oyashiwo," flowing southwestward from the Bering Sea and neighboring waters. It was but natural to assume that with abundant ice in the northern waters, which feed this current, it would be cooler in the summer season than when scanty ice prevailed there. But this assumption was difficult to verify because of the lack of ice data from the north. In this emergency, Doctor Okada took the winter temperature at Nemuro in northern Japan as an index of the winter temperatures farther north and correlated these with the yield of rice in northern Japan for the 28-year period from 1892–1919. He found a parallellism represented by the correlation coefficient $+0.55 \pm 0.09$. In view of the length of the period covered and the admitted inadequacy of the temperature data utilized, this shows a remarkably close relation.

Next, the cause of the occurrence of severe and mild winters in the Bering Sea was investigated. He states on this subject:

[4] Vol. 1, No. 1.

As is well known, the winter temperature of the northern waters is chiefly controlled by the inflow of cold air from eastern Siberia, which is a member of the system of cyclonic circulations around the semi-permanent "low" over the Aleutian Islands. It may be supposed that in the year in which the activity of the Aleutian "low" is increased the inflow of cold air toward the Bering Sea and its neighborhoods becomes vigorous and, therefore, there the winter temperature becomes abnormally low. Again, we may suppose that in the year in which the activity of the Aleutian "low" is decreased, the winter of the northern waters is rather mild.

In the absence of observational data as to variations in the intensity of the Aleutian LOW from year to year, Dr. Okada again resorted to the best substitute available. The activity of the LOW is increased when the water is warmer, or the land is colder, than usual, and consequently he took the air temperature records at Dutch Harbor, Aleutian Islands, as an indication of pressure intensity and corresponding temperature conditions over the more northern waters. As Dutch Harbor is located on the warm side of the Aleutian LOW, it is readily conceivable that its pronounced activity would tend to comparatively high temperature there, with abnormally low temperature over the more northern waters in the cold quadrant of the depression. He correlated the Dutch Harbor temperature with the yield of the rice crop in Hokkaido in northern Japan for the 28-year period mentioned. This gave the significant coefficient of -0.63 ± 0.08. Thus we see that Dr. Okada's investigations point very strongly to an affirmative answer to the question at the head of this review.

NOTES ON TYPHOONS, WITH CHARTS OF NORMAL AND ABERRANT TRACKS.

By STEPHEN S. VISHER.

[Indiana University, Bloomington, Ind., Oct. 5, 1922.]

INTRODUCTION.

The writer is making a study of the tropical cyclones of the Pacific.[1] Data as to the occurrence of storms in the western portion of the South Pacific and in the southeastern portion of the North Pacific have already been presented in this journal.[2]

In respect to the tropical cyclones in the Far East, there called typhoons, much has been published by others. It was the writer's good fortune to have conferences about typhoons with Director J. Algué, of the Philippine Weather Bureau, with Director T. F. Claxton, of the Royal Observatory at Hongkong, with Director L. Froc, of the Zikawei Observatory, Shanghai, and with Director T. Okada, of the Imperial Marine Observatory, Kobe, Japan. From each of these special students of typhoons copies of publications and maps were obtained, as well as opinions in regard to numerous problems. Although each has studied typhoons for many years, most of their work consists of the plotting of pressure data and the frequent determination of the movement and the changes in the cyclones, with forecasts of future changes, together with the almost hourly issuance of warnings in case a typhoon is threatening. Indeed, each declared that he has almost no time and energy for a quiet study of these complex phenomena and endeavored to encourage the present writer to study typhoons as well as the tropical cyclones of other parts of the Pacific. These kindnesses and encouragements have induced the writer to call attention to the several publications concerning typhoons which have been prepared, often under great difficulties, within the Far East, to make more available some of the data they present and to attempt to contribute a little toward solving some of the problems presented by typhoons.

Annual frequency.—As to the annual frequency of typhoons there is considerable difference of opinion, for a storm which one person considers a true typhoon another may consider not severe enough to be so classed. Then, too, although each observatory attempts to cover the entire region, there is, in fact, a certain amount of specialization. This is frankly recognized by Coronas, who in his Climate and Weather of the Philippines, 1903–1918,[3] attempts to list only the typhoons which noticeably affected the weather of the Philippines. However, several lists of typhoons purport to be complete for the entire Far East. The variation in the annual number of typhoons reported by different authorities for certain years is shown in Table 1.

[1] The field investigations were financed by Yale and Indiana Universities and by the Bishop Museum of Honolulu.

[2] Tropical Cyclones in Australia and the South Pacific and Indian Oceans, Mo. WEATHER REV., 1922, 50: 288–295; and Tropical Cyclones in the Northeast Pacific between Hawaii and Mexico, ibid, 295–297, 1922.

[3] Government printer, Manila, 1920.

TABLE 1.—*Illustrating a lack of agreement as to number of typhoons.*

Year	Algué.	Froc.	Hongkong Observatory.	D. S. H.[1]
1884	21	....	19	19
1885	11	....	10	10
1886	16	....	14	12
1887	28	....	26	24
1888	16	....	14	6
1889	14	....	12	7
1890	27	....	16	4
1891	28	....	16	6
1892	24	....	19	....
1893	24	11	16	....
1894	34	31	16	....
1895	24	19	12	....
1896	20	13	20	....
1897	20	14	11	....
1898	25	22	21	....
1899	21	22	19	....
1900	23	23	13	....
1901	27	21	9	....

[1] J. Algué, Cyclones of the Far East, p. 86, Manila, 1904; L. Froc, L, Atmosphere en Extreme Orient, pp. 202–239, Paris, 1920; Kongkong Observatory, A list supplied by Director Claxton of the Royal Observatory; D. S. H., Deutsche Seewarte, Segel-Handbuch für den Stillen Ozean, p. 256, Hamburg, 1897.

In recent years, in spite of the wireless, differences of opinion as to whether or not a storm should be classed as a typhoon have not ceased to exist. For example, in 1918, while Claxton reported 18 typhoons, Froc reported 16 and Okada (then at the Central Meteorological Observatory, Tokio) reported 14 severe typhoons and 9 other tropical cyclones. Table 1 reveals the fact that some supposedly complete lists contain only a third, or occasionally a fourth, as many storms for some years as some other authoritative list. Hence any list may be criticized as either being incomplete or as including storms which should not be called typhoons. However, the desirability of having as complete a list as possible, particularly for the study of climatic cycles, is sufficiently great to justify Table 2. This is made up from three sources. For the years 1893 to 1918, inclusive, the list has been compiled from Froc's itemized list of 617 typhoons.[4] These are the storms which are charted in Froc's Atlas of the tracks of 620 typhoons, 1893–1918.[5] Froc's is the longest full list available compiled by a single observer. For the years 1880–1892, Algué's list is reprinted.[6] Although Father Algué is still director of the Philippine Weather Bureau, he informed me that no comprehensive list has been compiled there since 1904. For the years 1919 and 1920 the list supplied me by Director Claxton of the Royal Observatory, Hongkong, was used, as Father Froc has not yet compiled his lists for those years. A very incomplete list for the century before 1880 is given in the Segelhandbuch. However, because of the incompleteness of the list, no very safe deductions as to cycles in their occurrence can be based on these records.

From the foregoing list it appears that, on the average, about 23 severe tropical cyclones occur annually in the Far East. Froc's list for 1893–1918 averages 26 a year. The annual variation is great however—from 11 to 38 according to these data. In a smaller region it is still greater, of course. For example, in the Phillipines the number of especially severe ("remarkable") typhoons varied in the years 1903–1818 from one in 1916 to seven in 1911. Of the two dozen or so typhoons occurring in the Far East in an average year, perhaps half have winds of hurricane force over a wide and long belt. The others possesses winds of hurricane force in only a small area, or perhaps only gales.

Seasonal occurrence.—The months of occurrence of these 917 typhoons are indicated in Table 2. At the bottom of that table is a summary giving the number each month and the per cent of the total. The monthly distribution is shown graphically in Figure 1.

TABLE 2.—*Typhoons of the Far East, by years and months.*

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1880	0	0	0	0	0	0	2	4	2	2	1	0	11
1881	0	0	0	0	2	1	3	4	4	3	3	1	21
1882	0	0	0	1	0	0	3	.....	2	2	1	2	11
1883	0	0	1	1	3	1	3	4	4	4	1	0	22
1884	1	0	0	0	2	1	4	5	4	.....	2	2	21
1885	0	0	0	1	0	2	2	2	1	1	1	1	11
1886	0	0	0	1	1	2	.....	3	4	3	1	1	16
1887	0	0	1	3	3	1	5	2	7	3	3	0	28
1888	0	0	0	1	0	2	4	3	3	1	1	1	16
1889	0	0	0	0	0	0	2	3	2	4	1	2	14
1890	1	0	0	0	1	5	4	2	7	6	1	0	27
1891	0	0	0	1	2	2	7	5	6	0	4	1	28
1892	1	0	0	0	0	3	4	4	5	2	3	2	24
1893	0	0	0	0	1	0	3	2	2	3	0	0	11
1894	0	0	0	1	4	3	7	2	4	4	4	2	31
1895	0	0	0	0	1	4	4	3	4	3	0	0	19
1896	0	0	0	0	1	2	4	2	1	3	0	0	13
1897	0	0	1	0	0	0	4	1	3	4	1	0	14
1898	0	0	1	1	0	0	3	4	4	4	4	1	22
1899	1	2	0	0	2	1	2	4	4	3	3	0	22
1900	2	0	1	0	0	1	1	4	4	4	4	2	23
1901	2	1	0	1	2	2	1	3	2	5	1	1	21
1902	1	0	0	0	3	3	4	2	5	3	1	2	24
1903	3	1	1	1	1	1	3	4	6	6	2	2	31
1904	0	0	2	1	0	2	5	4	3	2	1	3	23
1905	1	0	2	1	1	2	3	4	3	4	1	2	24
1906	1	4	1	0	3	0	2	1	8	3	1	0	24
1907	3	3	1	1	1	2	3	6	4	4	4	0	32
1908	1	1	2	2	3	1	3	4	4	4	3	3	31
1909	5	0	1	1	2	1	4	3	6	6	2	4	35
1910	2	1	2	1	4	2	3	5	10	2	3	3	38
1911	1	2	0	1	1	2	7	6	3	4	2	1	30
1912	4	1	0	0	0	0	3	5	4	4	4	2	27
1913	1	0	0	0	1	0	5	4	5	5	1	1	23
1914	*0	0	1	0	1	3	4	6	4	2	2	2	25
1915	0	0	1	0	0	0	3	3	3	7	4	2	23
1916	3	1	0	1	1	1	2	3	6	1	3	1	23
1917	0	0	1	0	0	0	3	5	4	2	1	0	16
1918	0	0	0	1	0	1	4	4	3	3	0	0	16
1919	2	0	1	0	0	1	5	6	4	4	2	1	26
1920	1	0	0	1	0	1	3	6	4	2	2	0	20
Total	37	17	21	24	47	56	141	147	168	132	79	48	917
Per cent in each month	4.0	1.9	2.3	2.6	5.1	6.1	15.4	16.0	18.3	14.4	8.6	5.2	99.9

From Table 2 and Figure 1 it is seen that, although occurring in considerable numbers in every month of the year, tropical cyclones are most frequent in this area

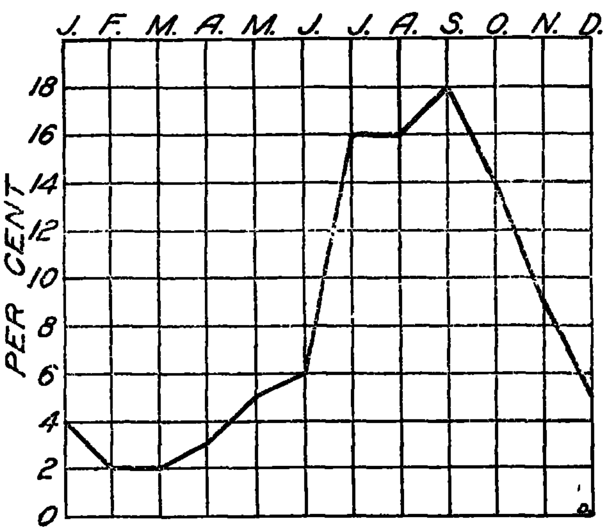


FIG. 1.—Monthly distribution of 917 typhoons in the Far East, 1880–1920.

in the four months July to October. The frequency of storms in July and August has usually been explained by the statement that in those months the doldrums

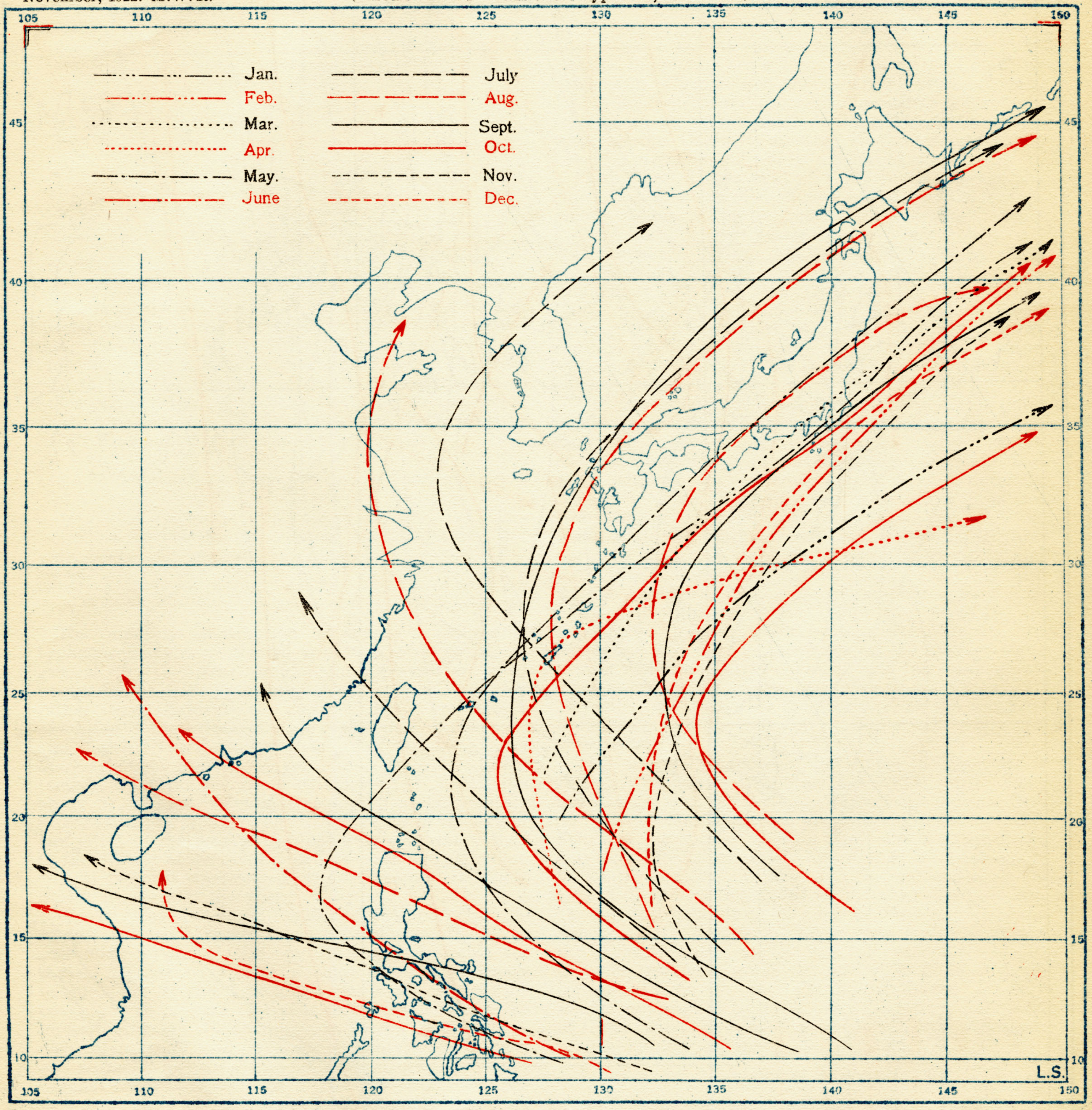
[4] L. Froc: "L'Atmosphere en Extreme-Orient," Deuxiune ed., pp. 202–239, Imprimerie Nationale, Paris, 1920.

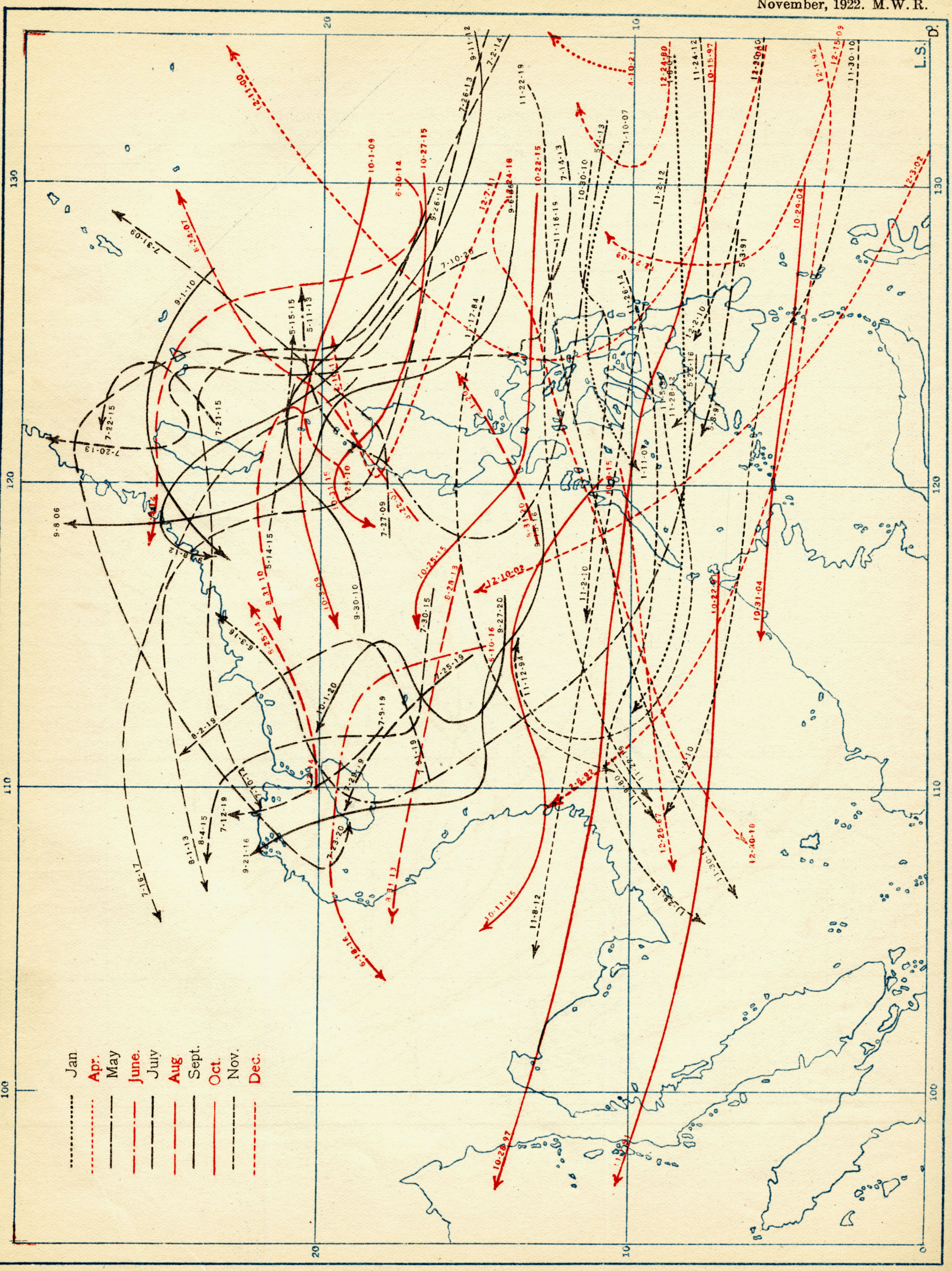
[5] Published in English, by the Zikawei Observatory, Shanghai, 1920. The 21 annotated charts were reprinted in the MO. WEATHER REV., August, 1920, to June, 1921 (vol. 48, Charts 128, 129, 143, 144, 174, 175; vol. 49, Charts, 14–16, 34–36, 50–52, 66–68, 81–83, 95).

[6] J. Algué: "The Cyclones of the Far East," 2d revised edition, p. 86, Manila, 1904.

S. S. V. **Chart I. Typhoons of an average year, month by month.**

(Based on Froc's "Atlas of 620 Typhoons, 1893-1918".)





S. S. V. Chart II. Typhoons which followed abnormal courses.

are farthest from the Equator. However, this explanation is inadequate, for by October, or at least by November, the doldrums are far south of their June position, a month of relatively few typhoons. Furthermore, typhoons are rarest in February and March, not in January, the coolest month.

The monthly distribution of cyclones in the Philippines is given in Table 3.[7]

TABLE 3.—*Average monthly distribution of tropical cyclones in the Philippines, 1903–1918.*

[Per cent.]

	January.	February.	March.	April.	May.	June.	July.	August	September.	October.	November.	December.	Storms per year.
Remarkable typhoons	1.7	0	0	1.7	5.0	6.7	10.0	15.0	21.7	21.7	10.0	6.7	4
Ordinary typhoons	4.9	0	4.9	4.9	9.8	3.3	9.8	3.3	13.1	13.1	24.6	8.2	5
Average	3.3	0	2.4	3.3	7.4	5.0	9.9	9.2	17.4	17.4	17.4	8.0	....

The monthly distribution of the storms of yet another special portion of the Far East merits particular attention. In a later table (7) 70 typhoons occurring in latitudes 3°–8° are listed. Tropical cyclones are relatively rare so near the Equator. Hence it is worth while to call especial attention to their frequency in the region under consideration. Table 4, based on Table 7, gives the number and the per cent in each month.

TABLE 4.—*The monthly distribution of 70 typhoons occurring in latitudes 3°–8°.*

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Number	4	2	4	1	6	6	5	4	4	9	9	16
Per cent	5.7	2.9	5.7	1.4	8.6	8.6	7.1	5.7	5.7	12.9	12.9	22.8

The monthly distribution of these subequatorial typhoons may be contrasted with that of typhoons in general (fig. 1). Near the Equator typhoons are most frequent later in the year than farther north, in December rather than September. Likewise they are rarest, according to these data, in April rather than in February and March. On the other hand, May and June have more typhoons near the Equator than August and September, while the reverse is strikingly true in latitudes above 8°. These latitudinal contrasts in the monthly distribution are probably due to variations in the extent and effect of the Asiatic high-pressure area rather than to the shifting of the doldrums, the common explanation. Indeed the heat equator is in the Southern Hemisphere during nearly half the year.[8]

Tracks followed.—Froc's "Atlas of the tracks of 620 typhoons" has already been mentioned. It is an extremely valuable atlas, but it seems desirable for several reasons to present a chart of average tracks based on the 21 charts he gives. So many charts, each covered with a maze of tracks, are bewildering, as he himself remarks. Furthermore, in textbooks in meteorology, geography, and physiography only a single chart can normally be used. The chief reason why Doberck's original chart is reproduced in recently published textbooks, in spite of its having been based on the very inadequate data available 40 years ago, appears to be the lack of a more satisfactory single chart. Chart I was obtained by drawing one average track for each 25 tracks given by Froc, this being done month by month. The 26 tracks thus obtained represent the average number of typhoons occurring annually in the years 1893–1918, according to Froc. The monthly distribution of the 26 typhoons occurring in an average year is indicated by the different symbols used for the storms of each month. This Chart I is both simple and fairly accurate. The greatest inaccuracy arises from the necessity of omitting the storms which follow very aberrant courses. Such storms are too few and too individualistic to be properly represented on such a chart of the tracks for a normal year. Hence Chart II, showing aberrant tracks alone, has been prepared and will be considered later.

From Chart I it is evident that on the average the storms are first recorded somewhere east of the Philippines. About a third cross the Philippines, while another third rather promptly move northward and northeastward, passing not far east of Japan. The remaining third move westward to the north of the Philippines and then turn northward across the east China Sea and Sea of Japan or across Japan itself. Among the storms which cross the Philippines many continue west-nortwestward onto the Asiatic coast, while a few recurve in the south China Sea and move north-northeast toward Japan.

The courses followed on the average by storms differ notably, however, with the seasons, as may be seen from Chart I. From January to April the storms usually move northward east of the Philippines, Formosa, and Japan, although the easternmost tip of Japan is normally crossed by a March storm. During May and June two storms cross the Philippines, one continuing to South China while the other recurves and crosses Japan from south to north. A third storm recurves promptly and strikes only the eastern tip of Japan. In July and August one storm crosses Luzon, another crosses Formosa, two others reach the Yellow Sea, while the remaining two pass along the western side of Japan. In September and October there are on the average eight storms, following diverse tracks and penetrating all large parts of the region except northern China. In November and December two storms cross the southern Philippines and two move off northeast well to the east of Japan.

This seasonal change in the course of typhoons is strikingly illustrated in another way by 12 small "Summary maps" in Froc's Atlas. These maps indicate that no typhoons normally reach the Asiatic coast in January, February, or March, while in April and December the only part crossed or closely approached by typhoons is far south, in Siam. In May and November the coastal area of danger has expanded northward to latitude 20°. On the other hand, from July 1 to October no part of the Asiatic coast is free from danger from typhoons except the extreme south. In October the coast north of 30° is again free from grave danger, while Siam is again threatened. As to the Philippines: Luzon is very seldom approached by typhoons in January, February, or March, while the danger is considerable in the southern islands during every month except August.

ABNORMAL TRACKS.

While most typhoons are fairly normal, there are on the average two or three a year which follow aberrant tracks along part of their tropical courses. Hence it is quite essential for navigators to understand that wide

[7] J. Coronas: The Climate and Weather of the Philippines, 1903–1918, pp. 181, 185, 1920.
[8] Griffith, Taylor: Australian meteorology, London, 1920.

departures from the normal should be expected. In order that the character of the departures may be readily apparent, Chart II has been compiled from many sources.[9]

The monthly distribution of the 57 aberrant storms plotted on Chart II is shown in Table 5.

TABLE 5.—*Monthly distribution of 57 typhoons which followed unusual paths along part of their tropical course.*

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Monthly number	2	0	0	1	4	1	11	6	5	7	11	8
Per cent (approximate.)	4	0	0	2	7	2	20	11	9	12	20	14

When this distribution is compared with that of typhoons in general, Table 2 and fig. 1, it becomes evident that abnormal typhoons have a less symmetrical monthly distribution than normal typhoons and that, although they are rare or lacking in February, March, and April when normal typhoons are rarest, they are not most abundant when typhoons are most frequent. Only 20 per cent of the abnormal storms occurred in August and September in contrast to 34 per cent of the normal storms. On the other hand, while only 14 per cent of all typhoons occur in November and December, 34 per cent of the aberrant storms occur in those two months. Many of the aberrant storms of November and December, however, are remarkable rather for the low latitude of their occurrence than for their abnormal direction of progression. It will be recalled that nearly 36 per cent of the typhoons occurring within 8° of the Equator develop in November and December. (See Table 4.) Additional facts concerning these aberrant storms are presented in Table 6.

TABLE 6.—*Abnormal movements of aberrant typhoons classified by months, etc.*

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Typhoons which moved easterly below lat. 20° (some without first recurving)	0	0	0	1	1	0	2	2	1	0	1	3	11
Typhoons which moved south of due east in latitudes below 15°	1	0	0	0	0	0	0	0	0	1	5	2	9
Typhoons which moved south of due east in latitudes north of latitude 15°	0	0	0	0	0	1	2	2	3	2	0	0	10
Typhoon tracks forming south curves or loops in low latitudes	0	0	0	0	0	0	5	2	4	3	2	0	16

From Table 6 it appears that there is slight likelihood that a typhoon occurring in February to May will move in a southerly direction. Indeed, south of latitude 15°, the chance of this particular abnormality remains almost negligible until October, but is considerable in November. The likelihood of a typhoon moving in an easterly direction in latitudes below 20° rather than in a westerly or northerly one appears to be greatest in December, July and August. The prospect of a sinuous course, perhaps with a loop, seems appreciable only in July to November, but in those months so many typhoons depart from a straight course or a simple parabolic curve that the possibilities of abnormal change of direction are considerable north of latitude 15°.

The abnormal typhoons dealt with in Chart II are of great scientific interest, too, for in respect to many natural phenomena, as well as in psychology and medicine, the abnormal may reveal more than do the normal in regard to fundamental causes and relations. The irregular movements of these typhoons emphasize the importance of irregular changes in atmospheric pressure. The importance of such changes have been recognized by a few meteorologists, but most students of storm movements have relied on the influence of regular rather than irregular forces to explain their movements. For example, relief features, the prevailing wind directions, and Ferrel's law of deflection to the right in the Northern Hemisphere have been called upon to explain the recurve of tropical cyclones. All three of these forces combined appear totally inadequate to explain many of the curves seen on Chart II. Many storm tracks fail to show any response to Ferrel's Law, while many appear to ignore the prevailing winds. Comparison of the winds in January and February and July and August, as shown by Köppen,[10] with the tracks of typhoons, reveals the fact that many typhoons advance toward the prevailing wind. Likewise, topographic features can not explain most of the curves, since a large majority of them take place far from land. The location of the recurve has been casually related by some authorities to the position of the permanent oceanic high-pressure area.[11] Nevertheless it is obvious from Chart II that, however much the average position of the recurve may be affected, many exceptions occur.

The irregularities in pressure conditions, believed responsible for the irregular course of many typhoons, are often difficult to explain, but that does not make them the less potent.

Typhoons within 8° of the Equator.—It has usually been considered that the small deflective effect of the earth's rotation near the Equator will prevent the development of cyclonic storms there. Instead of circling round and round, the air tends to flow directly in toward a depression and fill it up. This is so plausible that the occasional typhoon near the Equator has often been ignored. Indeed some writers on tropical cyclones state or imply that hurricanes can not occur within 8° of the Equator.[12] Hence it appears worth while to print Table 7. It will be noted that during the five years 1908–1912, 32 typhoons are recorded as having their center in or below latitude 8°. The annual range in those years was from four in 1908 to nine in 1910. Published information for the years of the World War is less complete than for the years 1908–1912, but I was informed by Director Okada, of the Japanese Imperial Marine Observatory, that the meteorological conditions at Jaluit in the Marshall Islands, where a reporting station was established as soon as the islands were captured by the Japanese, frequently indicate typhoons west and southwest of Jaluit (latitude 6° 8′, longitude 170° E.)

[9] Algue, loc. cit., Director Claxton and Doberck (before 1902) Maps of typhoons year by year in annual reports of Royal Obs., Hongkong; Froc, L. Atmosphere en Extreme-Orient, Carte 16–36, 1920; Coronas, Climate, and Weather of the Philippines, loc. cit.; T. Okada, Weekly Weather Report (daily weather maps and a summary of storm movement), Imperial Marine Obs., Kobe, Japan, 1920, 1921; H. Kondo, The Climate, Typhoons, and Earthquakes of Formosa, Meteorol. Obs. Taihoku, 1914; Deutsche Seewarte, Segelhandbuch fur den Stillen Ozean, 1897; W. E. Hurd: Cyclonic Storms and Typhoons of the North Pacific, article on the reverse of Meteorological Charts of the North Pacific, U. S. Weather Bureau, January, March, and April, 1913; and Monthly Pilot Charts of the North Pacific, U. S. Hydrographic Office, 1921.

[10] Reprinted in W. J. Humphreys's Physics of the Air, 1920, in Willis L. Moore's Descriptive meteorology, 1910, and in many other places.

[11] Vines, quoted by O. L. Fassig, Hurricanes of the West Indies, Bull. X, U. S. Weather Bureau, 1913.

[12] W. I. Milham; Meteorology, p. 274, 1912.

TABLE 7.—*Typhoons whose centers were from 3°–8° from the Equator, by months.*[1]

	Lat.	Long.		Lat.	Long.
	°	°		°	°
Jan. 8, 1907	8	136	Oct. 2, 1880	5	122
1, 1916	7	150	22, 1891[2]	7	118
13, 1916	8	128	13, 1897	7	140
22, 1916	7	128	16, 1897[3]	7	140
Feb. 13, 1911	8	136	29, 1904	5	130
25, 1911	6	142	26, 1909	8	138
Mar. 6, 1898	8	130	26, 1910	8	142
18, 1909	8	138	10, 1911	7	142
13, 1910	8	138	25, 1915	7	150
Apr. 8, 1918	6	143	Nov. 8, 1892	6	125
May 3, 1891	5	132	9, 1897	8	145
6, 1896	7	135	12, 1909	8	138
23, 1908	8	127	6, 1910	8	138
1, 1910	7	139	3, 1912	7	140
3, 1910	8	137	18, 1912	7	143
26, 1916	7	124	22, 1912	7	143
June 11, 1894	6	132	26, 1912	7	140
4, 1895	7	137	1, 1920	7	141
2, 1896	7	137	Dec. 1, 1892	5	125
30, 1905	6	169	12, 1900	4	139
10, 1914	8	133	18, 1905	7	150
24, 1914	8	140	2, 1908	7	143
23, 1918	8	144	3, 1908	7	134
July 5, 1881	8	124	3, 1909	7	134
12, 1895	7	145	15, 1909	5	143
22, 1895	7	138	15, 1909	3	146
30, 1896	8	136	1, 1910	4	140
12, 1913	8	133	1, 1910	7	137
Aug. 12, 1880	7	120	19, 1910	8	138
19, 1892	5	133	2, 1911	8	145
19, 1909	8	143	3, 1911	6	143
19, 1913	8	145	1, 1912	7	141
Sept. 24, 1897	8	133	2, 1912	8	145
10, 1901	8	133	20, 1918	6	146
19, 1908	7	137	30, 1918[4]	7	105
6, 1910	8	116			

[1] From charts or lists by Algué, Coronas, Froc, Claxton, U. S. Hydrographic Office and D. Segelhandbuch, all cited in full in previous foot notes.
[2] To Calcutta, crossed latitude 10° in longitude 97° E.
[3] To Bay of Bengal, crossed latitude 10° in longitude 122° E.
[4] End of previous storm.

Relative to the severity of some subequatorial typhoons the following quotations from Hurd are pertinent.[13] "It sometimes happens that typhoon-like storms lasting for three or four days break upon the Gilbert Islands, near the Equator (lat. 4° N. to 3° S.) and 174° E. The strong shifting winds, though of rare occurrence, inspire the natives with such fear that they prop their huts with stakes and tie them down to prevent them from blowing away. A brief account comes to us of a typhoon which visited Strong Island in latitude 5° 12′ N., longitude 163° E., during the early part of the nineteenth century and inflicted such destruction upon the breadfruit trees, the chief source of sustenance to the islanders, that a famine ensued which carried off nearly all the inhabitants. The island of Ponape, about 300 miles to the northwestward, in the Carolines, was at the same time similarly visited."

A hurricane did great damage in the southern Marshall Islands (latitude 6) on June 30, 1905. The barometer at Jaluit fell to 936 mb. (27.6 inches), while the tidal wave rose to a height of 46 feet at Mille.[14]

Concerning a typhoon which crossed northern Borneo (latitude 6°) on October 31, 1904, Algué reports as follows:[15] "This was a very destructive typhoon * * * very well developed and of great intensity * * * we think the minimum must have been below 742 mm. * * * The waves dislodged great rocks, some of them more than 3 cubic meters in size. * * * The storm destroyed a great part of the fruit trees and * * * wrought havoc among trees of every kind. * * * Numerous buildings were laid in ruins." The track of this storm is shown on Chart II. A typhoon which crossed the southern large island of the Philippines on November 28, 1912, is described by Algué and others as having been of terrible intensity and destructiveness, as well as being remarkable in having progressed due west at the rate of 21 miles an hour from south of Yap (longitude 138°) to longitude 127°, where it struck Mindanao in latitude 7°.[16]

Destructive tropical cyclones within 7° of the Equator are not limited to the Far East. For example, Ellice Island (latitude 5½° S., longitude 176° E.) experienced what the Admiralty Sailing Directions (British) characterized as "a very severe hurricane" on February, 1891. The American Pacific Island Pilot states that this hurricane almost devastated the islands. This storm later caused great destruction in Tonga, and was traced for over 1,500 miles. Five hurricanes have been recorded within 6° or 7° from the Equator near Timor, (longitude 125° E.).[17]

Longitude of origin.—Doberck, 30 years ago, thought that many typhoons originated in the China Sea. However, soon after the Philippine Meteorological Service was organized it was discovered that nearly all China Sea typhoons actually originated to the east of the Philippines. Algué pointed this out in 1904. With the establishment of reporting stations at Guam and Yap, the place of origin of many storms was found to lie much farther east than had been suspected, being to the east of these islands. To-day, although it is established that most typhoons first attain destructive violence west of longitude 150°, the recently established Japanese Meteorological Observatory on Jaluit, longitude 170°, latitude 6°, frequently reports to Doctor Okada that cyclonic disturbances pass on their way westward. Such observations make more plausible the suggestion of Kimball that some of the tropical cyclones which develop off the west coast of Mexico and Central America may cross the Pacific.[18] (It will be recalled that two hurricanes have been traced westward most of the distance across the Atlantic, from off the west coast of Africa to the West Indies.)

When questioned as to how far east typhoons sometimes originate, Algué, Froc, and Okada all expressed the belief that occasionally one develops far out in the Pacific.

Of the storms which originate fairly near reporting stations, there is considerable seasonal variation in latitude and longitude of place of origin. The latitudinal changes have been touched on already. In brief, the winter storms originate either farther south or farther north than the storms of the main typhoon season. On the other hand, in respect to longitude, Chart 1 and other data suggest that the winter and spring storms normally originate somewhat west of the average longitude of summer and autumn storms. However, Froc believes that the longitude of origin is progressively farther eastward month by month from October to January.[19]

Distances typhoons travel.—Although a good many typhoons "fill up" and disappear before having been traced more than a thousand miles, many more continue as lesser disturbances for much longer distances—several thousand miles. Some have been known to retain much of their original strength over a course of many thousands of miles, from east of the Philippines, north past Japan, and eastward across most of the North Pacific to off the British Columbia coast. A great many more weaken after having been typhoons for two or three thousand miles, become converted into extratropical cyclones, and proceed long distances, perhaps across North America and the Atlantic Ocean. In the other direction, two typhoons have been traced

[13] Willis E. Hurd: Cyclonic storms and typhoons of the North Pacific, loc. cit., on reverse of meteorological chart of the North Pacific, U. S. Weather Bureau, March, 1913.
[14] Pacific Islands Pilot, second edition, U. S. Hydrographic Office, vol. 1, p. 541, 1920.
[15] J. Algué Monthly Bulletin of the Philippine Weather Bureau, Nov., 1904, quoted by Coronas, loc. cit., p. 169.
[16] J. Algué: Bulletin for November, 1912, Weather Bureau, Manila, pp. 402–405, 1913.
[17] See appendix on hurricanes of Timor in S. S. Visher, Tropical cyclones of Australia, Commonwealth Bureau of Meteorology, Melbourne, Australia, 1922.
[18] J. H. Kimball, MO. WEATHER REV., 1915, 43; 486.
[19] Froc, Atlas, loc. cit., Chart 21, etc.

from east of the Philippines to the head of the Bay of Bengal, a distance of 4,500 miles in the case of one of the storms.[20]

The tendency for cyclonic storms to weaken markedly in areas of high pressure often causes them to be lost sight of before they have really disappeared. Both Froc and Okada told me of having traced typhoons far into Asia, and, after all ordinary signs of them had vanished except a slightly lower pressure, had seen them greatly intensify upon reaching the sea again. Both these authorities expressed the opinion that when sufficient pressure data are available a close study will prove that most typhoons give rise to what are generally known as extratropical cyclones.

Size of typhoons.—Although on the average a belt 300 or 400 miles wide experiences gales when a typhoon passes, sometimes the area is much smaller or vastly larger. Froc mentions two extreme cases. One destructive typhoon had no obvious influence on wind or pressure at a meteorological observatory only 75 miles from the center of its track, while another typhoon produced gales throughout a belt 1,800 miles across. Normally the size of the area affected increases as the typhoon progresses, especially where it reaches middle latitudes. The region of especial destructiveness is the strip usually from 10 to 30 miles wide over which the eye of the storm passes. Indeed it often happens that only in this narrow belt is much damage done by winds or waves, although torrential rains may cause a wider damage.

Rate of progression of typhoons.—Typhoons vary greatly in respect to speed of travel. Some remain almost stationary for a day or two, while others have been known to travel at the rate of 50 miles per hour, or 1,200 miles per day, past Southern Japan. The mean speed also varies in respect to the season, and especially with the particular portion of the course. In general it is greatest during the main typhoon season, and much faster when the storm is going northeastward, after recurring, than in lower latitudes. It will be noted, however, that the lowest mean speed for the storms of any month is 6 miles per hour, or 150 miles per day, while the fastest mean speed is 25 miles an hour, or 600 miles per day. Table 8 is from Tables 1 and 2 of Froc's Atlas.

TABLE 8.—*Mean and extreme speed of typhoons along their tracks in miles per hour, by months and regions.*[1]

[From Froc.]

Month.		China Sea north to latitude 18°.		North China Sea, latitude 18°-23°.		Formosa to latitude 30°.		Yellow Sea.		Near Japan.		Open Pacific.	
		NW.	NE.	NW.	NE.	NW.	NE.	NW.	NE.	NW.	NE.	NW.	NE.
Jan.	Mean	11.0	...	...	...	...	...	...	...	...	23.4	...	18.8
	Extreme	14	...	...	...	...	...	...	...	...	30	...	31
Feb.	Mean	9.0	...	...	...	...	...	...	...	13.3	16.0	...	21.6
	Extreme	9	...	...	...	...	...	...	...	18	18	...	40
Mar.	Mean	6.0	...	...	...	...	...	...	...	10.0	21.5	11.0	21.6
	Extreme	6	...	...	...	...	...	...	...	...	30	11	30
Apr.	Mean	9.7	...	...	...	...	...	...	...	7.5	20.7	13.7	26.0
	Extreme	12	...	...	...	...	...	...	...	8	28	10	43
May.	Mean	11.3	...	10.0	...	...	...	...	...	9.7	19.2	8.9	16.9
	Extreme	16	...	10	...	...	...	...	...	13	25	16	28
June.	Mean	10.1	...	10.0	...	11.5	18.7	...	...	...	14.0	9.0	17.1
	Extreme	15	...	12	...	16	23	...	...	...	14	10	32
July.	Mean	10.8	...	8.7	25.0	10.3	19.8	11.4	18.6	11.9	18.9	11.3	18.5
	Extreme	14	...	13	...	12	23	15	26	16	25	15	28
Aug.	Mean	10.7	...	10.2	12.0	11.1	20.2	12.9	18.7	11.1	18.9	13.2	18.0
	Extreme	14	...	16	12	22	26	20	27	21	40	17	25
Sept.	Mean	11.0	...	10.8	[40.0]	12.1	22.4	10.6	21.4	11.9	22.8	10.0	18.2
	Extreme	17	...	18	...	17	34	16	25	20	52	15	38
Oct.	Mean	10.6	...	9.9	10.0	13.5	...	...	21.0	11.9	21.5	12.5	17.0
	Extreme	16	...	12	10	15	...	...	21	20	39	20	25
Nov.	Mean	10.1	...	8.0	8.0	...	...	...	...	16.3	22.6	8.2	16.8
	Extreme	16	...	8	8	...	...	...	...	15	40	11	25
Dec.	Mean	11.8	...	12.0	...	...	...	...	...	11.0	25.0	12.0	19.7
	Extreme	16	...	12	...	...	...	...	...	12	38	12	28
	Mean	10.2	...	10.1	19.0	11.7	20.3	11.6	19.9	11.5	20.4	11.0	19.2

[1] NW.=typhoons moving northwest.
NE.=typhoons moving northeast.
Leader (...)=no storms of this type normally occur in this month.

[20] J. Algué: Cyclones of the Far East, loc. cit., pp. 219-229.

Destructiveness of typhoons.—While most typhoons cause little or no loss of human life, occasionally the losses are appalling. The Swatow typhoon of August 3–4, 1922, caused the death of over 50,000 persons.[21] The typhoon which struck Haifong, China, on October 8, 1881, was said to have caused the death of 300,000 persons. The two almost simultaneous typhoons of August 26–31, 1911, destroyed 44,000 houses in the southern part of Formosa, although only about 800 persons were killed or missing.[22] The destruction due to typhoons is of four chief kinds: (1) The wind itself demolishes houses, breaks off trees, and sometimes blows boats upon the rocks. (2) Waves produced by the wind often engulf boats or break them or drive them upon the shore. Such waves also occasionally do great damages upon low lying coasts. (3) The rise in sea level due to the piling up of the water in the center of the storm by the inblowing winds often is very destructive. Indeed the sea level itself is sometimes raised more than 10 feet by this means, and the great waves sometimes reach heights of 30 feet above normal sea level.[23] (4) The torrential rains commonly associated with typhoons frequently cause disastrous floods. Rainfall in excess of 30 inches in three days is not rare in connection with typhoons and occasionally that much falls in 24 hours.[24]

Anomalies in typhoons.—Father Algué presents a chapter on anomalies in cyclones which merits brief comment.[25] He remarks on (1) stationary cyclones, (2) cyclones without rain, (3) notable fall in barometer without corresponding wind, (4) strong wind with a slight fall in barometer, (5) cyclones which deviate much from mean normal trajectory (he also discusses some notable peculiarities, which he calls apparent anomalies), (6) bifurcation of cyclones, and (7) secondary cyclones. His remarks may with profit be briefly summarized with some additional comments. He considers that so-called stationary cyclones may have only a slow movement. Since 1904 additional data gathered in many parts of the world suggest that well-developed tropical cyclones do not actually stand still, although they often progress so slowly that they appear to be stationary. As a special cause of slow progression along the normal trajectory may be mentioned the loops which sometimes occur. In such a case from a moderate distance it might appear that the storm was stationary.

As to typhoons without rain, Algué thinks that such do not exist, although it often happens that at any given point only a little rain may fall when a typhoon passes near by. However, it certainly is true that there is a wide difference in the amount of precipitation occurring in storms of equal intensity. This is often illustrated in Australia.[26]

A notable fall in the barometer without corresponding wind Algué explains as probably due to the rise from off the ground of a part of the typhoon. Because tornadoes often rise off the ground, Algué thinks that typhoons may occasionally do so.

Strong wind with only a slight fall in the barometer occurs fairly frequently. Algué ascribes it to the existence of a secondary cyclonic nucleus, or by rapid condensation giving rise to rain squalls.

[21] Cf. MO. WEATHER REV., August, 1922, pp. 433–437.

[22] H. Kondo: The Climate, Typhoons, and Earthquakes of Formosa (Taiwan), p. 65, 1914.

[23] Waves reached 46 feet above sea level at the typhoon at Mille, latitude 6°, in the Marshall Islands, June 30, 1905, according to The Pacific Island Pilot, 2d ed., vol. 1, p. 541, 1920.

[24] S. S. Visher, Variability vs. Uniformity in the Tropics, Scientific Monthly, Vol. 15, p. 31, 1922.

[25] J. Algué: Cyclones of the Far East, pp. 230–236, 1904.

[26] E. T. Quayle: Tropical control of Australian Rainfall, Bull. 15, Commonwealth Bur. of Meteorol., 1920.

Deviation from the normal course Algué explains as usually due to the presence not far away of another typhoon. However, there is record of a hurricane in Fiji which recurved so sharply on its course that its center passed twice over the city of Levuka, and yet no other disturbance was known to be anywhere near. Furthermore, this hurricane traveled northwest from Levuka after its first passage over that city, the opposite direction from that which tropical cyclones normally take in that latitude in the southern hemisphere.[27]

Bifurcation of cyclones.—Sometimes it happens that a well-developed cyclone apparently divides into two independent, comparable storms, each of which henceforth follows an independent course. Algué suggests that topographic barriers may be the cause, but the cases he considers do not make this explanation altogether satisfactory.

Secondary whirls sometimes develop within a cyclone, producing destructive winds far from the center of the main cyclone. Algué has repeatedly observed such secondary centers in the Philippines. Doctor Okada reports that two or three secondary centers sometimes occur within a typhoon.

Typhoons and mountains.—It is stated in some standard meteorologies that tropical cyclones can not cross a mountain range 3,000 feet high. This is often disproven in the Far East, for typhoons sometimes cross mountains of greater height than this in Taiwan (Formosa), in the Philippines, in Japan, and elsewhere. Mountainous Formosa often appears to deflect typhoons which approach it at a small angle, and sometimes cuts the typhoon in two, according to Froc, but, on the other hand, other storms clearly cross it with no apparent regard for its mountains, the highest of which reach over 13,000 feet. Doctor Okada reports that studies made on lofty Fuji, near Yokohama, and on the higher mountains of Formosa indicate the depth of most typhoons to be approximately 5 or 6 kilometers (16,000 to 20,000 feet).

Although it is commonly stated that typhoons weaken decidedly as soon as they come upon the land, both Froc and Okada have observed many cases where this was not true in southeast China, the typhoons maintaining most of their force until encountering lofty mountains.

THE CHANGING ARCTIC.

By GEORGE NICOLAS IFFT.

[Under date of October 10, 1922, the American consul at Bergen, Norway, submitted the following report to the State Department, Washington, D. C.]

The Arctic seems to be warming up. Reports from fishermen, seal hunters, and explorers who sail the seas about Spitzbergen and the eastern Arctic, all point to a radical change in climatic conditions, and hitherto unheard-of high temperatures in that part of the earth's surface.

In August, 1922, the Norwegian Department of Commerce sent an expedition to Spitzbergen and Bear Island under the leadership of Dr. Adolf Hoel, lecturer on geology at the University of Christiania. Its purpose was to survey and chart the lands adjacent to the Norwegian mines on those islands, take soundings of the adjacent waters, and make other oceanographic investigations.

Dr. Hoel, who has just returned, reports the location of hitherto unknown coal deposits on the eastern shores of Advent Bay—deposits of vast extent and superior quality. This is regarded as of first importance, as so far most of the coal mined by the Norwegian companies on those islands has not been of the best quality.

The oceanographic observations have, however, been even more interesting. Ice conditions were exceptional. In fact, so little ice has never before been noted. The expedition all but established a record, sailing as far north as 81° 29′ in ice-free water. This is the farthest north ever reached with modern oceanographic apparatus.

The character of the waters of the great polar basin has heretofore been practically unknown. Dr. Hoel reports that he made a section of the Gulf Stream at 81° north latitude and took soundings to a depth of 3,100 meters. These show the Gulf Stream very warm, and it could be traced as a surface current till beyond the 81st parallel. The warmth of the waters makes it probable that the favorable ice conditions will continue for some time.

Later a section was taken of the Gulf Stream off Bear Island and off the Isfjord, as well as a section of the cold current that comes down along the west coast of Spitzbergen off the south cape.

In connection with Dr. Hoel's report, it is of interest to note the unusually warm summer in Arctic Norway and the observations of Capt. Martin Ingebrigtsen, who has sailed the eastern Arctic for 54 years past. He says that he first noted warmer conditions in 1918, that since that time it has steadily gotten warmer, and that to-day the Arctic of that region is not recognizable as the same region of 1868 to 1917.

Many old landmarks are so changed as to be unrecognizable. Where formerly great masses of ice were found, there are now often moraines, accumulations of earth and stones. At many points where glaciers formerly extended far into the sea they have entirely disappeared.

The change in temperature, says Captain Ingebrigtsen, has also brought about great change in the flora and fauna of the Arctic. This summer he sought for white fish in Spitzbergen waters. Formerly great shoals of them were found there. This year he saw none, although he visited all the old fishing grounds.

There were few seal in Spitzbergen waters this year, the catch being far under the average. This, however, did not surprise the captain. He pointed out that formerly the waters about Spitzbergen held an even summer temperature of about 3° Celsius; this year recorded temperatures up to 15°, and last winter the ocean did not freeze over even on the north coast of Spitzbergen.

With the disappearance of white fish and seal has come other life in these waters. This year herring in great shoals were found along the west coast of Spitzbergen, all the way from the fry to the veritable great herring. Shoals of smelt were also met with.

BIRDS STORM-SWEPT OVER THE NORTH ATLANTIC OCEAN.

By WILLIS E. HURD.

[Weather Bureau, Washington, D. C., Dec. 10, 1922.]

An interesting memorandum was recently received by the Weather Bureau in connection with a marine weather report from Mr. W. Scott, fifth officer of the American S. S. *Manchuria*. It deals with the appearance of several varieties of small land birds a considerable distance at sea on the 27th to 29th of October, 1922, during a voyage from New York to Hamburg, and is presented here, with an inclusion of the list of observed bird varieties, for the scientific interest involved.

S. S. *Manchuria*,
Voyage 50—N. Y.-HAMBURG,
October 28, 1922.

It may be of some interest to the Department of Plants and Animals or to the Smithsonian Institution to note that on October 27, latitude 40° 36′, longitude 66°, to noon 28th, latitude 41° 45′, longitude 59° 27′,

[27] R. L. Holmes: Quart. Journ, Royal Meteorol. Soc., January, 1905.