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THE PLACE OF ORIGIN AND RECURVATURE OF TYPHOONS

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(NOTE.—This paper constitutes the concluding section of Dr. Coching Chu's paper "A new classification of the typhoons of the Far East," begun in the December, 1924, number of the MONTHLY WEATHER REVIEW.)

In order to ascertain the zones of formation of typhoons, it is necessary to have a network of meteorological stations in the region of the Caroline and Ladrone Islands. Such stations are not available to-day, nor are they likely to be in the near future. In the following discussions, therefore, the zone of formation of typhoons can only be approximately indicated. The Weather Bureau stations at Guam, in the Ladrone Islands, and at Yap, in the Carolines, were established in June, 1904,[1] the first year of the period with which this paper deals. The importance of these two stations can not be overemphasized. The observers there cable warnings to the Manila Observatory whenever the pressure indicates the exist ence of a typhoon, or the development of one. They serve as the advance guards to protect the eastern coast of Asia, Japan, and the Philippines from the sudden invasion of a destructive cyclone. These warnings were regularly transmitted to the Manila Observatory until lately, when owing to the war the reports have stopped.[2]

The Philippine Weather Bureau, having in its possession the reports from Guam and from Yap, can determine the latitude and longitude of origin of many storms with more or less accuracy. The Japanese weather service does not trace the typhoons to their origin, but plots only that portion of the tracks which is north of latitude 20° N. The place of origin is usually determined by the wind directions and pressure oscillations observed at Guam (lat. 13° 26′ N., long. 144° 40′ E.) and at Yap (lat. 9° 29′ N., long. 139′ E.).

The latitude and longitude of origin and recurvature of the typhoons of the period 1904–1915, taken mostly from the Manila *Monthly Bulletin*, have been computed, and three tables have been prepared. Table 6 shows the average location of the origin and of the recurvature of the typhoons of the different months. The data given by Father Algué have also been tabulated for the sake of comparison. Table 7 gives the number of typhoons and depressions of each month which originated in different latitudes. Table 8 gives the average location of the origin and of the recurvature for the different types of typhoons.

The latitude of origin moves northward from May, when it is 13° 20′ N., to August, when it is 16° 05′ N. It then decreases until December, when it is 8° 30′ N. The number of storms in the months of January to April, inclusive, is too small to obtain a good average, but the latitude of origin probably remains as low as that of December, if it is not still lower. The storms originate farther to the west as the season advances from January to June, when the zone of formation begins to shift eastward until the month of December. As a whole, the average longitude and latitude of origin for the different months as calculated from the 247 typhoons observed during the period 1904–1915 agrees very well with the limits set by Father Algué.

The vertex of the parabolic tracks of typhoons reaches the highest latitude in the month of July, and, like the origin, it goes farther toward the west in June than in any other month.

From Table 7 we see that 253 cases out of 303 cyclones and depressions originated between lats. 8° to 20° N. This is 85 per cent of the total. The lowest latitude in which a storm appeared during the period 1904–1915 is lat. 2° N. This happened in the storm of December 2–4, 1909.[3] The highest latitude in which a tropical storm originated during the same period is lat. 25° N. This typhoon occurred in August 3–8, 1909.[4] If it were not for the fact that the storm went westward, it might have been taken as an extratropical storm, for it traveled in a remarkably high latitude. Originating in lat. 25° N., long. 149° E., it traveled westward, crossing the Island of Kiusiu and entering China near latitude 35° N. The average latitude of origin of 303 typhoons and depressions which have been studied is 13° 40′ N.

Concerning the origin of typhoons, Father Chevalier said:[5]

> There are typhoons which originate in the China Sea, but there are very few, and they will be pointed out as exceptions to the trajectories regularly followed. Very commonly the typhoons originate east of the Philippines, in the square roughly included within the meridians 125° to 145° east of Greenwich and the parallels 10° and 25° north. Whether they originate further eastward is not sure, but it is rather probable. But if there are some, they do not come so far westward as to make their appearance either on the Chinese or the Japanese coast.

Father Algué, after quoting the same statement, added:[6]

> Generally speaking, there are many typhoons which form in a lower parallel than 10° N. and very few in a higher parallel than 20° N. somewhere to east-northeast of Luzon. With regard to the longitudinal limit of formation assigned by Father Chevalier, we judge it to be sufficiently approximate for those of which he speaks, as well as those which are experienced here in the Philippines and in Japan. This refers chiefly to the cyclones which are some way or another felt in the Philippines. If we take into consideration the cyclones which we classify in chapter 10 as cyclones of the Marianas and Magallanes, type 5a, we can extend the limits in longitude for the cyclones formed in the Pacific to meridian 125°–152° east of Greenwich.

From Table 7 we see that out of 303 storms only 1 originated at or above lat. 25° N., while 65, or 21 per cent of the total, originated below lat. 10° N. Therefore, as is pointed out by Father Algué, Father Chevalier's lower limit of the latitude of origin is too high. Father Chevalier was doubtful whether typhoons ever originated

[1] Monthly Bulletin of the Philippine Weather Bureau, September, 1905, p. 378.
[2] This paper was written before the ending of the European war.

[3] Monthly Bulletin of the Philippine Weather Bureau, December, 1909.
[4] *Loc. cit.*, August, 1909.
[5] S. Chevalier, *Loc. cit.*, p. 88.
[6] J. Algué, *loc. cit.* p. 23.

east of long. 145° E. The following table, computed from 247 typhoons observed during the years 1904 to 1915, throws some light on the subject.

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Number of typhoons observed during the period 1904–1915	3	1	6	4	11	13	39	51	46	36	22	15	247
Number of typhoons originating east of longitude 145° E			1	1		1	1	9	15	8	4	3	43
Percentages						8	3	18	33	22	18	20	17

In the average for the year about 17 per cent of the typhoons originate east of long. 145° E. During the month of September, the percentage is very high; almost one out of three starts from a region east of long. 145° E. There were two cases of storms which formed east of long. 160° E. The first occurred April 20–30, 1905. It originated in the neighborhood of lat. 7° N. and long. 163° E. The natives of the eastern Carolines pronounced it the worst typhoon they had seen, as cyclones generally originate between the east and the west Carolines. On the island of Ascension, 15 persons were killed, and out of 2,150 houses on the island only 1 remained standing after the storm.[7]

TABLE 6.—*Positions of origins and recurve of typhoons in different months*

[Calculated from the 247 typhoons of the period 1904–15]

	Origin				Recurve[1]			
	Latitude		Longitude		Latitude		Longitude	
	°	′	°	′	°	′	°	′
January	8	00	145	00				
February	7	00			12	00	136	00
March	6	30	141	30	15	30	134	00
April	8	50	136	10				
May	13	20	125	40	18	10	123	00
June	14	55	124	30	23	40	120	00
July	15	00	133	50	28	00	121	55
August	16	05	137	00	25	50	127	30
September	14	40	137	30	24	20	128	50
October	11	30	137	00	24	40	139	50
November	10	10	139	30	20	00	129	00
December	8	30	142	30	16	20	128	30

	Origin[2]		Recurve,[3] latitude
	Latitude	Longitude	
December, January, February, March	5°–12°	143°–145°	15°–19°
April, May, October, November	6°–17°	129°–142°	16°–21°
June, July, August, September	8°–20°	126°–139°	21°–25°

[1] Compare with results given in Louis Froc. *loc. cit.*, Table 3.
[2] Algué, *loc. cit.*, p. 23.
[3] *Loc. cit.*, p. 79.

TABLE 7.—*Latitude of origin of typhoons and depressions observed during the period 1904-1915*

Latitude	25°+	20–25	18–20	16–18	14–16	12–14	10–12	8–10	5–8	5–0	Total
Month											
January		1?	1?					1			3
February								1	1		2
March				1?				2	3		6
April							1	4	1		6
May			2	2	5	1	4	2	1		17
June		2		5	3	4	2	1			17
July		1	4	9	8	7	1	1			31
August	1	9	15	8	12	6	3	6	2		62
September		7	8	14	8	11	11	4	3		66
October				2	8	10	13	4	5		42
November		1	1	1		6	11	5	6		31
December			2		1	1	4	6	5	1	20
Total	1	21	33	42	45	46	50	37	27	1	303

[7] Monthly Bulletin of Philippine Weather Bureau, April, 1905.

TABLE 8.—*Mean positions of origin and recurve for different types of typhoons*

Type of typhoon	Origin					Recurve				
	Latitude N.		Longitude E.		Number of cases	Latitude N.		Longitude E.		Number of cases
	°	′	°	′		°	′	°	′	
1a	16	45	142	40	3	33	30	118	00	2
1b	15	45	137	50	27	27	30	116	00	5
1c	11	50	140	55	17	26	45	114	30	4
1d	18	20	116	50	7	22	00	114	00	1
2a	14	45	141	00	40	25	20	128	30	32
2b	13	30	145	30	1	19	00	122	00	1
2c	13	40	140	50	11	29	45	124	00	7
2d	19	45	118	15	4					
3a	12	45	140	30	5					
$3b_1$,[1] $3c_1$	12	30	133	00	12	22	30	106	00	1
$3b_2$,[2] $3c_2$	8	00	136	00	11					
3d	17	00	116	30	7					
4a	11	30	130	45	5					
4b	7	20	142	30	9					
4c	10	15	142	20	10	17	45	117	50	7
4d										
5a	13	30	144	20	40	21	20	134	30	34
5b	16	30	136	00	10	22	10	125	50	6
5c	9	50	142	00	7	16	55	125	20	6
5d	17	10	117	00	7	24	00	123	00	1

[1] $3b_1$, typhoons of Gulf of Tongking passing through Luzon.
[2] $3b_2$, typhoons of Gulf of Tongking passing through Visayas and Mindanao.

The second storm was also a notable one. It occurred on March 29–April 1, 1907, and was known as the Easter storm, as Easter of that year fell on March 31. It originated in the vicinity of lat. 5° N., long. 160° E. At 10 a. m. on March 29, the barometer on the Wlea Island, in the west Caroline group, stood at 691.89 mm., or 27.24″. The decrease of pressure in 24 hours from 10 a. m. of the 28th to 10 a. m. of the 29th was 62.5 mm.[8] The settlements on the island of Wlea were completely destroyed and 200 persons were killed.[9]

If the 43 typhoons that originated east of long. 145° E. are classified according to their type, we have the following result:

Type	1b	2a	5a	All others
Number of typhoons during years 1904 to 1915	28	45	42	132
Number of typhoons originating east of longitude 145° E	6	12	16	9
Per cent of the total	21	27	38	7

The above table shows that the percentage of storms of type 5a (which Father Algué calls the cyclones of Magallanes or Marianas) that originated east of long. 145° E. is very large, while the percentages of the typhoons of types 1b and 2a were also greater than the average, which is 17 per cent. It also proves that Father Chevalier's statement that storms which originate farther eastward than long. 145° E. do not come so far westward as to make their appearance either on the Chinese or Japanese coast is not well founded.

Turning to the typhoons that have their origin in the China Sea, the result obtained from the study of 247 typhoons which occurred during the years 1904 to 1915 agree with Father Chevalier's statements that these storms are very few in number as compared with those which originate in the Pacific. Only about 10 per cent of all these typhoons are formed in the China Sea, according to the data given in Table 8. Doberck seems to have given the typhoons that originated in the China Sea too large a percentage. Table 2 is a summary of the classification given by Doberck in "The Law of the Storms in the Eastern Seas."[10] Types 1a, 1c, 1d, and 4a of Do-

[8] J. Hann, *loc. cit.*, pp. 607–608.
[9] Monthly Bulletin of the Philippine Weather Bureau, March, 1907.
[10] Hongkong, 1898, pp. 33-35.

berck all originate in the China Sea, and make up altogether 24.5 per cent of the total, which is two and one-half times as many as the percentage computed from Table 8 of the present paper. This discrepancy is very likely due to the fact that Doberck often reckoned the typhoons that form in the Pacific and enter the China Sea by crossing Visayas and Mindanao as storms that originate in the China Sea. Father Algué states in "Cyclones of the Far East:"[11]

In the trajectories published by the Hongkong Observatory we frequently find typhoons which appear to be formed in the China Sea to the northwest or north of Prague, between the 10th and 14th parallels; but remembering the notices of typhoons given by our observatory, it will easily be seen that many of said baguios did not originate in the China Sea, but proceeded from the Pacific and crossed the archipelago by way of the Visaya Islands or of Mindanao, previous to following the trajectories traced by the director of the Hong Kong Observatory.

With regard to the probable limits of the zone of formation of typhoons originating in the China Sea, Father Algué says:[12]

The number of these baguios or cyclones is relatively insignificant when compared to the many which are formed in the Pacific, and therefore we will briefly say of them that the zone of their formation may be limited by the 5th and 20th parallels and the 112th and 120th meridians, east of Greenwich. It is to be noted, nevertheless, that those formed between the 5th and 14th parallels are few in number, and the great majority of them are formed between parallels 14 and 20 to the west or northwest of Luzon and almost always at a distance from Manila greater than 120 miles.

The average latitude of origin of 25 typhoons observed during the years 1904 to 1915 is 17° 45′ N. Only one storm was formed north of lat. 20° N. and one south of lat. 15° N., while none originated below lat. 14° N.

In Table 8 the average latitude and longitude have been computed for the different types of typhoons. It is interesting to note that the typhoons of north China (type 1a), Japan (2a), Korea (2b), the Philippines (types 4b and 4c), and the Pacific (5a), those formed in the China Sea being excepted, originate mostly east of lat. 140° E., while the typhoons of south China (1b), those of Indo-China which have crossed the Philippines (3b, 3c), those of the Philippines which recurve in the China Sea (4c), and those of the Loochoo group (5b), originate nearer the archipelago. The average latitude of origin of storms formed in the China Sea is 4° higher than the general average, while the storms that go to the Philippine Archipelago proceed from a latitude 3° lower than the general average.

Whenever the origin and the vertex of a typhoon are known, the direction of the first branch of its parabolic path can generally be determined by the laws of spherical trigonometry. The following scheme, which is used to determine the direction of typhoons of the different months before they recurve is mainly of theoretical interest, as storms do not always maintain the same direction when traveling from the origin to the vertex of the recurve. Supposing *a b c* (fig. 1) is the path of a typhoon, originating at *a* (lat. ϕ, long. λ), and recurving at *b* (lat. ϕ', long. λ'). The angle α between the parallel of latitude *ad* and the rhumb line *ab* on the globe will be defined as the bearing of the vertex *b* from the origin *a*. Now, on the Mercator projection, meridians and parallels of latitude as well as rhumb lines all become straight lines. Hence the triangle *abd* is a rectilinear right triangle on the plane of the chart. Moreover the angle which a straight line joining any two places on the chart makes with the meridians or the parallels is equal to that which the rhumb line joining the same two places on the globe makes with the meridians or the parallels.[13]

Angle α as computed from the chart is equal to the angle between the small circle *ad* and the rhumb line *ab* on the globe, or the bearing of the vertex *b* from the origin *a*.

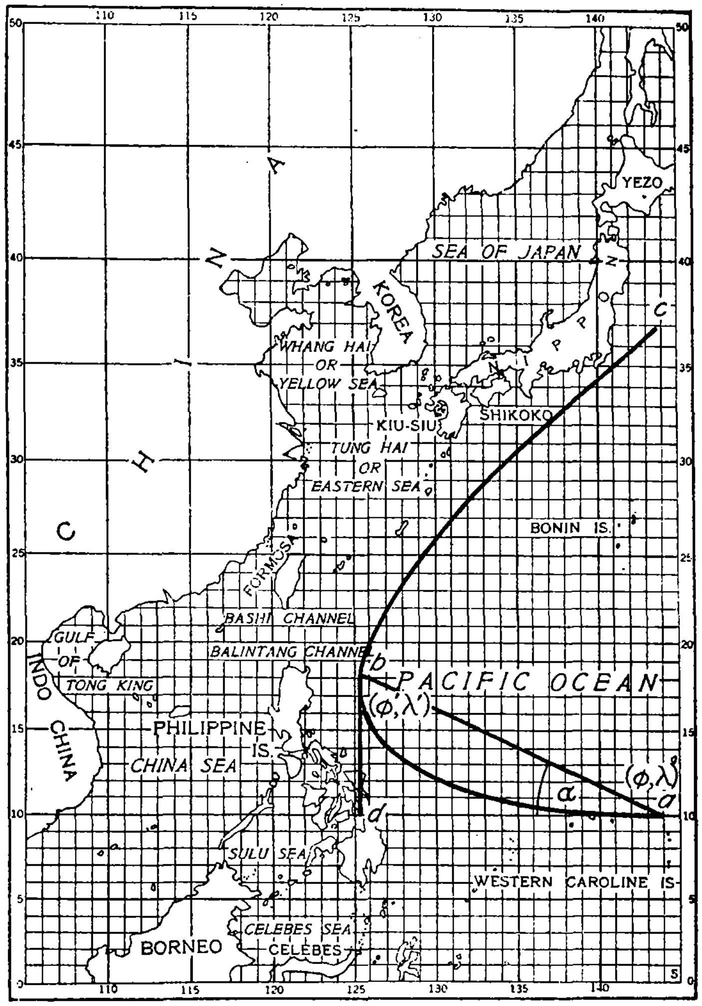

FIG. 1.—Example of the computed trajectory of a typhoon having a given point of origin

Thus[14] $\tan \alpha = \frac{A}{B}$

Where $A = \text{Log. } \tan\left(\frac{\phi'}{2}+\frac{\pi}{4}\right) - \text{log. } \tan\left(\frac{\phi}{2}+\frac{\pi}{4}\right)$

or if we take the length of 1 equatorial degree on Mercator chart as unity,

$$A = \frac{\text{Log. } \tan\left(\frac{\phi'}{2}+\frac{\pi}{4}\right) - \text{log. } \tan\left(\frac{\phi}{2}+\frac{\pi}{4}\right)}{\text{Log. } \tan\left(\tfrac{1}{2}+\frac{\pi}{4}\right)}$$

and $B = (\lambda' - \lambda)$ in the same unit.[15]

[Attention should be called to the fact that the Naperian logarithms are here used.—ED.]

[11] Algué, Cyclones of the Far East, p. 24, footnote 1. See also S. S. Visher, *loc. cit.*, p. 587.
[12] *Ibid.*

[13] John Riddle, "A Treatise on Navigation and Nautical Astronomy," 9th ed. London, 1871, p. 10.
[14] W. F. Osgood, "Differential and Integral Calculus." New York, 1917, p. 332. Also A. R. Hinks, "Map Projection." Cambridge, 1921, p. 104.
[15] Assuming the earth as a perfect sphere.

The following table is computed by this formula. The last column in the table indicates that the bearing of the vertex from the origin of a typhoon in the months of July, August, and September is northwest, while in the months of May, June, and October it inclines to a more northerly direction, and in the month of December it inclines to a more westerly direction.

TABLE 9.—*The direction of the vertex of the recurve from the origin of typhoons of different months*

	A	B	Tan a	a
				° ′
March	9.15	7.50	1.22	50 40
April	-----	-----	-----	-----
May	5.02	2.67	1.88	62 00
June	9.27	4.50	2.06	64 10
July	14.00	12.10	1.16	49 15
August	10.45	9.50	1.10	47 45
September	10.22	8.76	1.17	49 30
October	13.86	7.16	1.93	62 40
November	10.18	10.50	.97	44 10
December	8.00	14.00	.57	29 40

The velocity of translation of typhoons is not always given in the published reports. Moreover, the observatories of the Far East differ in their way of indicating the velocity of the typhoon's progress. Thus the Japanese reports give the velocity of progression of typhoons from day to day; the Zikawei reports give only the average velocity between the point of origin and the place where the typhoon disappears or is lost sight of; the reports of the Manila Observatory do not even always mention the rate of progression.

In view of this diversity of practice it was thought necessary to determine the velocity by measuring the tracks as plotted on maps of the Mercator projection. The result thus obtained can not, of course, be strictly exact, as the typhoons' tracks plotted on these maps are only approximately accurate. Since the typhoons are plotted from day to day on the maps, the velocities obtained are the daily means. The rate of progression at the point of recurvature, which is less than the average rate, can not be satisfactorily ascertained, because of the fact that the actual process of recurving may occupy only a few hours. In order to ascertain the velocities of progression in different latitudes, e. g., lats. 0° to 10°, 10° to 20°, etc., it is necessary to measure separately the different portions of the typhoon tracks.

The length of degrees of both latitudes and longitudes in maps on the Mercator projection is distorted, the distortion being greater the higher the latitude. A correction must therefore be applied to the distances as measured along the typhoon tracks.[16] The length of a longitudinal degree on a globe decreases as the cosine of the latitude, being greatest on the Equator and vanishing at the poles, while on a Mercator chart the length of a degree of longitude remains the same from the Equator to pole. On a globe the length of a latitude degree varies but little from latitude to latitude, but on a Mercator chart the distance of any parallel from the Equator is equal to $\left(\frac{d\phi}{\cos\phi} \text{ or } \log\tan\left(\frac{\phi}{2}+\frac{\pi}{4}\right)\right)$. As shown in Table 10 a degree of latitude calculated according to this formula increases very rapidly with latitude until at the pole it is infinity.

The amount of correction for distances measured along the typhoon tracks on a Mercator chart is calculated according to the data furnished by Table 10, following. It is found to be approximately 30 per cent for tracks that lie between latitudes 40° to 50°, 18 per cent for lats. 30° to 40°, and 9 per cent for lats. 20° to 30°. There is practically no correction for lats. 0° to 20°. The correction is negative, as the distortion is positive both longitudinally and latitudinally, and the amount of distortion in the two directions is the same.

The "average velocity" given at the bottom of the table is the mean velocity of the different months of the year, and not the mean velocity of all the typhoons which have been studied. The average thus obtained is higher than the arithmetical mean because it gives equal weight to the velocities of both winter and summer. It should be remembered that many more typhoons occur in summer than in winter and also that the velocity is higher in winter than in summer.

TABLE 10.—*Corrections to be applied to the velocity measured on Mercator's charts*

Latitude	Relative length of 10 degrees of latitude	Distance on the map divided by Calculated distance	Average correction
	Units		*Per cent*
0°–10°	175	1.0050	0.0
10°–20°	181	1.0368	3.6
20°–30°	193	1.1054	9.0
30°–40°	214	1.2239	18.4
40°–50°	248	1.4197	30.0
50°–60°	306	1.7550	43.0

TABLE 11.—*Velocity of progression of typhoons*

Latitude	5°–10°		10°–20°		20°–30°		30°–40°		40°–50°	
Month	Km. per hour	Nautical miles per hour	Km. per hour	Nautical miles per hour	Km. per hour	Nautical miles per hour	Km. per hour	Nautical miles per hour	Km. per hour	Nautical miles per hour
January	23	12	22	12	50	27	51	27	-----	-----
February	-----	-----	-----	-----	51	27	-----	-----	-----	-----
March	20	11	16	9	34	18	37	20	-----	-----
April	16	9	21	11	-----	-----	-----	-----	-----	-----
May	14	8	19	10	35	19	37	20	-----	-----
June	-----	-----	23	12	25	13	43	23	-----	-----
July	17	9	19	10	19	10	28	15	44	24
August	-----	-----	17	9	16	9	27	15	42	22
September	18	10	21	11	19	10	33	12	42	22
October	22	12	21	11	23	12	36	20	-----	-----
November	26	14	22	12	25	13	54	29	-----	-----
December	24	13	25	14	42	23	-----	-----	-----	-----
Mean	20	10.8	20.2	10.9	30.8	16.7	38.3	20.7	42	23.3

From Table 11 it is clear that the rate of progression of typhoons increases from low to high latitudes and from summer to winter. The variation in velocity with the season is particularly noticeable in that portion of the typhoon tracks which lies between lats. 20° to 30° for the reason that more typhoons recurve north of latitude 20° N. in the summer than in the winter months, and this helps to increase the difference in velocity between winter and summer. On the other hand, for that portion of the typhoon tracks that lies between lats. 10° to 20° the seasonal variation in velocity is small, owing to the fact that many typhoons recurve in these latitudes during the winter, and hence travel at a retarded velocity, while in summer they generally recurve in higher latitudes.

In connection with the velocity of progression of typhoons, Father Algué says:

> A typhoon is said to travel rapidly in the Philippines if its velocity exceeds 12 nautical miles an hour; it moves with a regular velocity when traveling from 6 to 12 miles an hour; its progress is slow if its onward movement amounts to less than this rate. Of typhoons which have been studied up to date, 180 have crossed the archipelago or the adjoining regions of the ocean with regular velocity, 40 with rapid, and 30 with small speed, while a few remained stationary for several days.[17]

[16] W. F. Osgood, "Differential and Integral Calculus." New York, 1917, p. 332. The distance can also be calculated from C. H. Deetz and O. S. Adams' "Elements of Map Projection." Washington, D. C., 1921, pp. 117-136, Mercator protection table.

[17] Algué; "Cyclones of the Far East," p. 92.

The Philippines and the adjoining regions of the ocean may be said to cover lats. 5° to 20°. The average hourly velocity for these latitudes according to Table 11 is approximately 11 nautical miles, which is well within the limit set by Father Algué.

Doberck gives the following average velocities of typhoons: [18]

Latitude	11°	13°	15°	20°	25°	30°	30.5°	Extremes
Velocity m. p. h	5	6.5	8	9	11	14	17	6-36
Kilometers	9	12	15	17	20	26	31.5	11-67

The velocities as given by Doberck are about 4 miles per hour lower than those given in Table 11 for the same latitudes. The Zikawei Observatory at Shanghai has recently issued a pamphelet entitled "Code de Signaux, 1918," in which there is a tabulation of the mean and extreme velocities of typhoons at different latitudes before and after recurvature. The following data are abstracted from that pamphlet.[19]

Average velocity of typhoons in nautical miles per hour

Latitudes	5-15	15-20	20-25	25-30	30-35	35-40	40-50
Before recurvature	9	10	11	11	-----	-----	-----
After recurvature	-----	10	17	18	20	21	21

For the sake of comparison, the results obtained in the present investigation are here again tabulated:

Latitudes	5-10	10-20	20-30	30-40	40-50
Mean velocity, m. p. h	10.8	10.9	16.7	20.7	23.3

The average velocities as given in the above two tables agree remarkably well. It appears therefore that the velocity of typhoons as given by Doberck is too low. Further, Doberck gave the velocity at lat. 30° N. as 14 miles an hour, and 30.5° N. as 17 miles an hour. It hardly seems as if a difference of half a degree of latitude could make as much difference as 3 nautical miles an hour in the average velocity.

[18] Doberck; "The Law of Storms in the Eastern Sea," 1898, p. 16; see also Hann, "Lehrbuch der Meteorologie," 1915, p. 607.

[19] "Code de Signaux, 1918." Extrait du Calendrier-annuaire pour, 1918. Zikawei, près de Changhai, 1917, p. 15-16. Compare also Louis Froc, "Atlas of the Tracks of 620 Typhoons, 1893-1918," Tables Nos. 1 and 2.

CONCLUSIONS

One of the most important problems connected with typhoons is the immediate cause of these remarkable phenomena. In order to solve this problem, it is necessary to have a network of weather stations in the regions of the west Caroline and the Ladrone Islands, to have complete and accurate observations of the surface pressure and wind conditions, and also to secure meteorological records from the upper air 5 or 10 kilometers above the surface. Without such data any theory that may be advanced in explanation of the origin of typhoons necessarily rests upon rather insecure foundations. What at present can be done is to organize the material which has already been obtained by the various meteorological observatories in the Far East, and thus to throw some light upon the question. A clear and well-defined classification of typhoons is a step in that direction, for the various types of typhoons not only come in different seasons and visit different regions, but also differ in their point of origin. Besides giving a new classification, the present discussion has brought out three points which need emphasis.

In the first place, the word "typhoon" has been given a definite meaning. While hitherto "typhoon" has been used to denote almost all the tropical storms which have been observed in the Far East, and in a few cases even to include extratropical cyclones, the term has been defined to mean a well-developed tropical storm in the Far East in which a wind velocity of Beaufort scale 6 or more has been observed. Standardization of the term is necessary in order to make the reports of different observatories on typhoons strictly comparable.

Secondly, in the past the storm tracks have been studied by plotting the mean tracks. These mean tracks are ususally too much generalized and give very little idea as to the limits of the area frequented by the storms and their relative frequency in the different regions. In the present paper the typhoon tracks are studied by means of charts of composite tracks of the different months. Thus the storm tracks of a certain month in a given period are presented graphically as a whole.

Certain new facts connected with the pressure, temperature, and wind conditions in the center of typhoons, reported during the 12 years from 1904 to 1915, have been collected and given by the writer in a condensed form [20] in a previous paper.

[20] Chu, Co-Ching, Some New Facts about the Centers of Typhoons. Mo. WEATHER REV., September 1918, 46: 417-419.

PRESSURE OVER THE NORTHEASTERN PACIFIC, AND WEATHER IN THE UNITED STATES, DECEMBER, 1924, AND JANUARY, 1925

By ALFRED J. HENRY

SYNOPSIS

This paper is an attempt to show the relation between the pressure distribution over the North Pacific Ocean, east of about the 180th meridian of west longitude, and the weather of the United States for corresponding periods.

The pressure charts used were those for the Northern Hemisphere prepared twice daily in the Forecast Division of the central office of the Weather Bureau.

It is fully realized that useful precepts for forecasting weather some days in advance, or other form of generalization can not safely be drawn from the record of a single month or so; nevertheless the most important tendencies may be pointed out. These are:

(1) A barometric minimum over the Gulf of Alaska or the Aleutians with fully developed cyclonic wind circulation does not readily pass inland as such, but rather oscillates back and forth with at times increasing and at times decreasing pressure at its center, until the conditions are favorable for (*a*) the passage of the cyclone in its entirety inland, evidently a very rare occurrence, or (*b*) the entrance of a mass of warm and moist air from it over the continent which later may or may not form a cyclone.

(2) The Aleutian or Northeast Pacific LOW must be considered as the origin of the great majority of low-pressure systems (cyclones) that pass from west to east across the Rocky Mountains. While at times it is difficult to trace the LOWS in a continuous path back to the Pacific, it seems reasonably certain that the original impulse that created them came from the Pacific.

(3) The most interesting and important place for study is the point of first contact of oceanic cyclones with the shore line of the continent where pronounced discontinuities in both temperature and moisture must be found.