GOVERNMENT NOTIFICATION.—No. 33.

The following Report of the Director of the Observatory for 1897 is published.

By Command,

J. H. STEWART LOCKHART,
Colonial Secretary.

Colonial Secretary's Office, Hongkong, 29th January, 1898.

HONGKONG OBSERVATORY,
15*th January*, 1898.

SIR,—I have the honour to submit my annual report for 1897 to His Excellency the Governor. My thirteenth volume of "Observations and Researches" was published at the end of last year. My fourteenth volume is now ready. It contains the third edition of "The Law of Storms in the Far East," which was finished in 1896. The typhoons about which little was known in 1883, when the Observatory was built, have since been so thoroughly investigated that they are now among the best understood atmospheric disturbances in the world, and it is almost certain that any amount of further investigation based on observations made here or on board vessels at sea would add nothing whatever to our knowledge. For further contributions to this branch of science we must now look to experiments made in physical laboratories in Europe and America and to analytical investigations based upon such experiments.

2. During my absence on leave during the summer and autumn Mr. F. G. FIGG acted for me, and I found everything in good order on my return. Mr. FIGG has investigated the typhoons of 1897, but has not met with any new facts. Although some of the typhoon-paths that occurred in 1897 are rare, they had occurred before. Early last year the Manager of the Eastern Extension, Australasia, and China Telegraph Company requested me to arrange a code for transmitting meteorological observations and information about typhoons. In submitting a code, as desired, I explained that the circumstances obtaining out here were such as to preclude any advantage being obtained from any code as far as the transmission of the observations was concerned. Later, during the autumn, the Manager adopted my views and arranged with Mr. FIGG's assistance a code for transmitting storm-warnings only. This code has been published by Mr. FIGG by order of the Government, and has been adopted by the Telegraph Company.

3. The comparison of the weather forecasts, issued daily about 11 a.m., with the weather subsequently experienced has been conducted on the same system as last year (Comp. Annual Report for 1896 § 5). We have:

Success 65 %, partial success 31 %, partial failure 3½ %, total failure ½ %.

Following the method used in meteorological offices and taking the sum of total and partial success as a measure of success, and the sum of total and partial failure as a measure of failure, we find finally that:—

96 % of the weather forecasts were successful.

4. At the beginning of February, 1897, the storm-signals, invented by Admiral FITZROY in 1861, were introduced in Hongkong, and the typhoon-gun was fired when the drum was hoisted.—On the 14th September at 9 p. the North Cone was hoisted. It was blowing N by E 5 at the time. The maximum wind force (11) was reported from Gap Rock on the 17th at 6 p. On the 18th at 5.30 a. the Cone was lowered.—On the 5th October at 11.15 a. the North Cone was hoisted. It was blowing NE 4 at the time. The maximum wind force (7) was reported from Gap Rock at 11 p. on the same day. On the 6th at 2.25 p. the Cone was lowered.—On the 17th November at 11 a. the North Cone was hoisted. It was blowing NNE 2 at the time. The maximum wind force (8) was reported from Gap Rock at 2 p. on the same day. On the 18th at 6 a. the Cone was lowered.—The Drum was added to the Cone and the gun fired on the 17th September at 2.30 p. At 5 p. on the same day the anemograph at the Observatory registered 56 miles.

5. In spite of the great advantages accruing from the adoption of the system of storm-signals in use in England and other countries, it has been decided to revert to the system in use here from 1884 to 1896 inclusive. This has been decided on the suggestion of the Committee of the Chamber of Commerce, who stated: "Those signals, having been in use for 13 years, were becoming gradually

more and more understood and rightly interpreted by the boat and seafaring people as the time went on, as is always the case, the Committee believe, when a system of signalling is introduced. They likewise convey to masters of ships intimations of the state of the weather at a distance on the voyages on which they are about to sail, information which the present storm-warnings do not supply."

6. The China Coast Meteorological Register was printed daily at the Observatory, and information regarding storms was telegraphed to and exhibited on notice-boards in Hongkong and other ports in China and neighbouring countries as often and as fully as such information could be justified by the weather telegrams received. This happened on 69 days in 1897.

7. Telegraphic connection with Victoria was interrupted on the 16th April, 1897, from 10 a. to noon; from the 8th May at 8.12 a. to 9th May at 8.12 a.; on the 18th May from 11.45 a. to 2.26 p., from the 21st at 5.50 p. to 23rd May at 6.48 a.; on the 23rd May from 10.15 a. to 1.34 p.; on the 24th May from 1.10 a. to 9.8 a.; on the 27th May from 4.13 p. to 5 p.; from the 30th May at 11.55 a. to 31st May at 1.34 a.; on the 5th from 4 p. to 6.45 p.; on the 17th June, from 1.10 a. to 6.20 a. and from 7.26 a. to 10.30 a.; on the 15th July from 2.58 p., to 7.54 p.; on the 28th August from 9.50 a. to 10.43 a.; on the 8th November from 11.25 a. to 0.20 p. Interruptions occurred therefore on 16 days, and, of course, during thunderstorms.—Telephone connection with the Peak was interrupted on the 15th January from 6 a. to 11 a.; from the 8th April at 8 a. to 10th April at 6 a.; from the 1st August at 11 a to 2nd August at 10 a.; from the 17th September at 5 p. to 18th September at 6 a.; from the 6th October at 6 a. to 20th October at 1 p.; from the 13th November at 6 p. to 15th November at 6 a., *i.e.*, on 26 days as well as during thunderstorms.

8. During 1897 in addition to meteorological registers kept at 40 stations on shore, 2,635 ship-logs have been copied on board or forwarded by the captains. The total number of vessels, whose log books have been made use of, was 283. The total number of days' observations (counting separately those made on board different ships on the same day) was 20,899.

9. The following is a list of ships from which logs have been obtained in 1897. The majority are steamships, and the others are distinguished as follows: bk., barque; sh., ship; bqt., barquentine:—*Activ, *Aden, *Agenor (sh.), *Aglaia, *Airlie, *Amara, *Ancona, *Antenor, *Argyll, *Ariake Maru, *Arratoon Apcar, *Ask, *Astral, *Atagosan Maru, *Australian, *Bayern, *Belgic, *Bellona *Benalder, *Benlarig, *Benledi, *Bisagno, *Bormida, *Borneo, *Braemar, *Brindisi, *Calédonien, *Canton, *Canton, (P. & O.), *Carmarthenshire, *Catherine Apcar, *Centurion (H.M.S.), *Ceres, *Ceylon, *Changsha, *Chelydra, *Chênnan (C. C. H.), *Chihli, *China, *Ching Ping, *Chingtu, *Ching Wo, *Chi Yuen, *Chowfa, *Chowtai, *Choysang, *Chun Sang, *Chunshan, *Chusan, *City of Rio de Janeiro, *Clara, *Congo, *Cosmopolit, *Daphne (H.M.S.), *Dardanus, *Decima, *Deike Rickmers, *Deucalion, *Deuteros, *Devawongse, *Diomed, *Donar, *Dordogne, *Doric, *Doyo Maru, *Ekaterinoslav (R.V.F.), *Else, *Empress of China, *Empress of India, *Empress of Japan, *Energia, *Ernest Simons, *Esmeralda, *Falkenburg, *Federation, *Formosa, *Formosa (P. & O.), *Framnes, *Frejr, *Frigga, *Fushun, *Gaelic, *Ganges, *Gerda, *Gisela, *Glenartney, *Glenavon, *Glenfalloch, *Glenturret, *Grafton (H.M.S.), *Guthrie, *Hailan, *Hailoong, *Haimun, *Haiphong, *Haitan, *Hangchow, *Hansa, *Hector, *Hertha, *Hikosan Maru, *Hinsang, *Hiogo Maru, Hiroshima Maru, Hohenzollern, *Hoihow, *Hongkong, *Hongleong, *Humber (H.M.S.), *Hupeh, *Hydaspes, *Idzumi Maru, *Independent, *Ingraban, *Irene, *Irene (H.G.M.S.), *Jacob Christensen, *Jacob Diederichsen, *Japan, *Java, *Kachidate Maru, *Kagoshima Maru, *Kaisar-I-Hind, *Kaiserinn Augusta (H.G.M.S)., *Kalgan, *Kamakura Maru, *Kanagawa Maru, *Kashing, *Keong Wai, *Kiangnan, *Kinai Maru, *Kintuck, *Kiushiu Maru, *Kongbeng, *Kostroma (R.V.F.), *Kriemhild, *Krim, *Kutsang, *Kwanglee, *Kyoto Maru, *Laurel Branch, *Letimbro, *Likin (I.M.C.C.), *Loongmoon, *Loosok, *Loyal, *L. Shepp (sh.), *Lyeemoon, *Macduff, *Machew, *Malacca, *Maria Valeria, Marquis Bacquehem, *Mathilde, *Mazagon, *Medusa, *Meefoo, *Melbourne, *Melpomene, *Memnon, *Menmuir, *Merionethshire, *Mirzapore, *Mogul, *Mongkut, *Monmouthshire, *Morven, *Mount Lebanon, *Moyune, *Myrmidon, *Namoa, *Namyong, *Nanchang, *Nanshan, *Nanyang, *Nestor, *Ningchow, *Niobe, *Oanfa, *Ocampo, *Océanien, *Olympia, *Omba, *Omi Maru, *Onsang, *Oolong, *Oopack, *Orestes, *Oscarshal, *Oslo, *Pakhoi, *Pakling, *Panther, (H.A.M.S.), *Pathan, *Patroclus, *Pectan, *Peiyang, *Peru, *Petrarch, *Phra Chom Klao, *Phra Chula Chom Klao, *Phra Nang, *Phœnix (H.M.S.), *Picciola, *Pingsuey, *Poating, *Pongola, *Port Adelaide, *Poseidon, *Preussen, *Priam, *Prinz Heinrich, *Progress, *Pronto, *Queen Elizabeth (sh.), *Rainbow (H.M.S), *Ravenna, *Rohilla, *Rosetta, *Sabine *Rickmers, *Sachsen, *Sakura Maru, *Salazie, *Sarpedon, *Sendai Maru,

*Senta, *Shanghai, *Shantung, *Sherard Osborne, *Siam, *Singan, *Sishan, *Smit. *Socotra, *Spinaway (bqt.), *Store Nordiske, *Strathallan, *Suising, *Sumatra (bk.), *Sunda,* Sungkiang, *Süllberg, *Sydney, *Szechuen, *Tacoma, *Taicheong, *Taichiow, *Tailee, *Taisang, *Taiwan, *Taiyick, *Taksang, *Tancarville, *Tantalus, *Terrier, *Tetartos, *Thales, *Thames, *Thekla, *Tientsin, *Tokio Maru, *Tordenskjold, *Toyo Maru, *Trieste, *Tritos, *Triumph, *Troas, *Tsinan, *Vega (bk.), *Verona, *Victoria, *Victoria (N.P.S.S.Co.), *Vindobona, *Wakasa Maru, *Woosung, *Wosang, *Wuotan, *Yamashiro Maru, *Yamaguchi Maru, *Yarra, *Yashima (H.J.M S.), *Yuensang, *Zafiro.

10. The entry of observations made at sea in degree squares for the area between 9° south and 45° north latitude, and between the longitude of Singapore and 180° East of Greenwich for the construction of trustworthy pilot charts has been continued, and 161,784 observations in all have now been entered.

Table I.

Meteorological Observations entered in 10° Squares in 1893, 1894, 1895, 1896 and 1897.

Square number.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	October.	Nov.	Dec.
19	1	0	0	0	0	0	5	1	0	0	0	0
20	28	11	7	25	23	10	6	8	7	24	23	22
21	22	22	26	32	41	1	10	2	7	25	19	36
22	8	3	12	28	34	25	29	10	0	11	0	1
23	205	252	62	48	14	1	104	78	34	42	67	172
24	295	239	297	284	201	215	415	325	268	308	392	295
25	133	86	92	85	97	96	125	112	109	184	199	146
26	1716	1636	2201	2133	2580	2738	3063	3221	2885	2645	1863	1895
27	0	0	0	0	1	1	0	2	3	1	0	0
55	20	29	26	16	18	24	16	13	16	1	12	12
56	19	51	30	12	24	19	18	37	12	22	19	10
57	29	57	37	40	42	12	17	18	12	29	22	26
58	41	43	71	39	71	32	24	24	19	17	46	40
59	118	123	87	26	66	63	87	31	15	68	120	84
60	183	213	184	144	113	170	284	184	110	79	123	150
61	1582	1629	2214	2072	2619	3043	3255	3230	3131	2655	2124	1804
62	1377	1528	1776	1673	1906	2051	1925	1940	1916	1792	1456	1459
63	7	10	9	9	12	14	9	6	12	8	1	3
91	9	44	23	37	11	16	2	17	24	21	37	54
92	10	41	32	34	12	13	7	11	25	6	33	58
93	7	30	30	22	0	11	1	18	18	19	10	49
94	25	34	6	29	1	12	4	8	23	15	22	19
95	61	100	53	63	57	59	21	21	47	76	46	93
96	1513	1325	1372	1379	1799	1776	1870	1739	1605	1635	1420	1408
97	649	594	742	689	817	870	814	834	835	785	771	729
98	191	126	131	168	227	340	322	321	352	270	227	228
127	99	35	66	47	29	39	54	29	30	59	82	43
128	89	46	77	61	32	57	60	34	26	76	101	63
129	99	50	95	101	52	95	62	63	38	94	137	98
130	211	167	256	195	289	326	382	337	261	270	271	278
131	314	263	305	290	375	478	445	526	399	354	326	264
132	818	659	915	1003	1427	1590	1951	1606	1497	1359	1289	845
133	0	0	60	57	78	95	113	55	55	70	47	13
163	80	55	74	103	119	174	189	199	136	121	72	70
164	108	98	114	158	158	248	259	251	223	184	116	105
165	128	115	108	132	210	234	294	252	246	166	142	113
166	36	43	44	42	78	64	106	47	97	69	58	45
167	6	0	0	3	16	41	74	98	71	44	28	0
168	0	0	0	0	0	0	0	1	2	2	5	0
199	30	28	22	44	22	28	36	23	58	28	34	31
200	11	5	2	4	0	3	5	0	19	5	13	1
202	0	0	0	0	0	1	2	1	5	1	0	0
203	0	0	0	0	0	0	2	1	2	0	0	0
318	0	0	0	1	0	0	0	0	0	0	0	0
319	11	8	16	19	1	0	0	0	1	13	7	13
320	4	0	25	16	13	35	9	2	0	3	0	0
321	0	1	0	1	4	11	0	2	0	0	0	0
322	11	20	15	24	49	17	24	22	21	8	18	3
323	282	178	196	159	137	108	165	120	129	104	160	240
324	203	140	106	59	81	63	103	97	121	157	182	155
325	177	192	189	277	278	280	378	379	340	193	186	187
	10966	10329	12205	11883	14234	15599	17146	16356	15262	14118	12326	11360

11. As stated in the "Instructions for making Meteorological Observations, etc.", meteorological instruments forwarded by observers who regularly send their registers to the Observatory are verified

here free of cost. During the past year 7 barometers, 5 anëroids and 10 thermometers were verified. In addition, several hundred barometers and anëroids on board ship were compared with our standard.

12. The following table shows the spectroscopic rainband as observed daily at about 10 a. The mean value for the year was 2.1.

Table II.

Rainband in 1897.

Date.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1,	1	2	2	3	1	2	2	5	2	2	2	1
2,	1	1	2	1	2	2	2	5	2	2	1	1
3,	2	2	2	1	2	3	2	3	2	2	1	2
4,	2	2	2	2	2	2	3	3	2	2	1	2
5,	2	2	1	3	3	2	3	3	2	3	1	2
6,	2	2	2	3	2	3	3	2	2	4	2	2
7,	2	4	2	1	2	3	2	2	2	3	2	2
8,	2	2	2	2	3	2	2	2	2	3	2	2
9,	2	2	2	2	3	2	3	3	2	3	2	1
10,	2	3	2	3	4	3	2	3	2	2	2	2
11,	2	0	3	3	2	2	2	4	3	2	2	1
12,	2	0	2	2	2	3	2	3	2	2	2	1
13,	3	1	2	2	2	2	2	3	2	2	2	2
14,	2	1	2	1	2	2	2	4	3	2	2	2
15,	2	2	2	2	2	2	2	4	2	3	2	1
16,	2	1	2	2	3	3	2	3	2	2	2	2
17,	3	2	2	3	3	3	2	3	2	2	3	2
18,	1	2	2	2	2	3	2	3	3	2	2	1
19,	2	2	2	1	3	3	2	2	3	2	2	2
20,	1	2	3	1	3	3	2	2	2	2	3	1
21,	1	3	2	1	5	4	2	2	2	2	2	1
22,	1	2	2	2	5	4	2	2	2	2	1	1
23,	1	2	2	2	4	4	2	2	2	2	1	1
24,	1	3	2	2	3	3	2	2	2	1	1	2
25,	1	2	2	2	3	4	3	2	2	2	0	1
26,	1	2	2	2	2	3	2	2	2	2	0	1
27,	1	2	2	1	2	3	2	2	2	2	1	0
28,	2	2	2	2	2	4	3	2	2	3	1	1
29,	2	...	2	1	2	3	3	2	2	2	0	2
30,	3	...	2	2	2	3	3	3	2	2	1	2
31,	2	...	3	...	2	...	3	2	...	2	...	3
Mean,	1.7	1.9	2.1	1.9	2.6	2.8	2.3	2.7	2.1	2.2	1.5	1.5

13. Mr. PLUMMER observed 402 transits for time determination in 1897, and the axis of the transit instrument was levelled 171 times, *i.e.*, upon each day when observations were made. The rates of the standard clocks are given in the accompanying tables (III and IV), and are compared with the rates given by the formulæ at the head of the tables. No alteration has been made to either clock during the year, and although it was found necessary to clean the contact springs of the sidereal standard clock on November 29th, this was effected without in any way interfering with the going of the clock.

The errors of the Time Ball are given in table V. The time ball has twice been under repair, namely, from March 5 to 10, when the base of the piston was found to have been shattered, and a new brass base was fixed to it by the Hongkong and Whampoa Dock Company in place of the original cast iron one; and again from July 13 to 19, when the zinc tube within the ball was found to be crumpled up and pressing against the mast. On July 7 the lock was under repair. There were five failures of the time ball in 1897, viz., on March 11 owing to an error of the workmen in centering the new brass base of the piston; on June 25, in consequence of the discharging spring being too weak; on July 6 because the tooth of the lock (being much worn) allowed the piston to jamb against the opposite side of the cylinder; on July 8, because the Assistant failed to raise the piston high enough to free the tooth of the lock; and on July 12, for the reason already given as rendering the repairs necessary on the days immediately following. The ball is not dropped on Government holidays and on one other occasion (Sunday, May 9) in consequence of the illness of two Assistants it was intermitted. It was successfully dropped 332 times in this year. The probable error was in January $\pm 0^s.33$, in February $\pm 0^s.19$, in March $\pm 0^s.16$, in April $\pm 0^s.12$, in May $\pm 0^s.16$, in June $\pm 0^s.13$, in July $\pm 0^s.09$, in August $\pm 0^s.13$, in September $\pm 0^s.10$, in October $\pm 0^s.14$, in November $\pm 0^s.16$, in December $\pm 0^s.12$.

Table III.

Rate of Dent Sidereal Standard Clock in 1897.

$r_c = +1^s.29 - 0^s.063 (\tau - 70°)$.

Period.			Observed rate. r_o	Temp. τ	Arc. a			Calculated rate. r_c	$r_o - r_c$.
			s.	°	°	′	″	s.	s.
December	30—January	9,	+1.59	66.9	2	57	30	+1.49	+0.10
January	9— "	19,	+1.26	65.5	2	54	42	+1.57	−0.31
"	19— "	29,	+1.63	62.9	2	59	33	+1.74	−0.11
"	29—February	8,	+1.52	65.2	3	0	13	+1.59	−0.07
February	8— "	18,	+2.08	58.7	3	1	26	+2.00	+0.08
"	18— "	28,	+1.94	60.5	3	1	30	+1.89	+0.05
"	28—March	10,	+1.70	63.2	3	1	19	+1.72	−0.02
March	10— "	20,	+1.56	64.4	3	0	49	+1.65	−0.09
"	20— "	30,	+1.33	66.2	3	0	24	+1.53	−0.20
"	30—April	9,	+1.41	68.5	3	1	3	+1.38	−0.03
April	9— "	19,	+1.46	68.6	3	1	22	+1.38	+0.08
"	19— "	29,	+1.30	71.6	3	2	33	+1.19	+0.11
"	29—May	9,	+0.95	76.0	3	2	37	+0.91	+0.04
May	9— "	19,	+0.63	80.8	3	2	20	+0.61	+0.02
"	19— "	29,	+0.61	80.6	3	2	30	+0.62	−0.01
"	29—June	8,	+0.49	84.3	3	3	10	+0.39	+0.10
June	8— "	18,	+0.50	84.4	3	2	43	+0.39	+0.11
"	18— "	28,	+0.40	83.1	3	2	51	+0.47	−0.07
"	28—July	8,	+0.63	79.0	3	3	15	+0.73	−0.10
July	8— "	18,	+0.52	83.0	3	2	37	+0.47	+0.05
"	18— "	28,	+0.45	84.7	3	3	41	+0.36	+0.09
"	28—August	7,	+0.42	84.0	3	3	12	+0.41	+0.01
August	7— "	17,	+0.33	83.5	3	2	40	+0.44	−0.11
"	17— "	27,	+0.46	82.4	3	2	20	+0.51	−0.05
"	27—September	6,	+0.43	83.7	3	2	49	+0.43	0.00
September	6— "	16,	+0.44	83.8	3	3	18	+0.42	+0.02
"	16— "	26,	+0.61	81.5	3	3	27	+0.56	+0.05
"	26—October	6,	+0.52	82.6	3	3	47	+0.50	+0.02
October	6— "	16,	+0.70	79.2	3	3	42	+0.71	−0.01
"	16— "	26,	+0.84	77.4	3	4	17	+0.82	+0.02
"	26—November	5,	+0.84	78.5	3	4	17	+0.76	+0.08
November	5— "	15,	+0.79	77.9	3	4	30	+0.79	0.00
"	15— "	25,	+1.16	70.7	3	4	30	+1.25	−0.09
"	25—December	5,	+1.77	62.4	3	3	26	+1.77	0·00
December	5— "	15,	+1.61	65.7	3	3	23	+1.56	+0.05
"	15— "	25,	+1.80	62.0	3	3	3	+1.79	+0.01
"	25—January	4,	+1.75	63.3	3	3	46	+1.71	+0.04

Table IV.

Rate of Brock Standard Mean Time Clock in 1897.

$r_c = +0^s.70 - 0^s.073\ (\tau - 75^\circ) - 0^s.0020\ (t^d. - \text{July } 1.)$

Period.	Observed rate. r_o	Temp. τ	Arc. α	Calculated rate. r_c	$r_o - r_c$
	s.	°	° ′ ″	s.	s.
December 30—January 9,............	+1.36	72.1	4 9 42	+1.27	+0.09
January 9— „ 19,............	+1.39	71.2	4 7 30	+1.34	+0.05
„ 19— „ 29,............	+1.52	68.1	4 6 18	+1.52	0.00
„ 29—February 8,............	+1.35	70.2	4 4 54	+1.25	+0.10
February 8— „ 18,............	+1.81	62.7	4 6 24	+1.88	−0.07
„ 18— „ 28,............	+1.70	63.2	4 3 48	+1.82	−0.12
„ 28—March 10,............	+1.58	67.4	4 0 0	+1.49	+0.09
March 10— „ 20,............	+1.49	68.9	4 1 18	+1.37	+0.12
„ 10— „ 30,............	+1.12	71.2	4 2 0	+1.18	−0.06
„ 30—April 9,............	+1.23	71.4	4 0 30	+1.14	+0.09
April 9— „ 19,............	+1.15	72.0	4 0 24	+1.08	+0.07
„ 19— „ 29,............	+0.90	74.5	4 1 18	+0.78	+0.12
„ 29—May 9,............	+0.56	78.5	4 1 30	+0.56	0.00
May 9— „ 19,............	+0.53	82.3	4 0 24	+0.27	+0.26
„ 19— „ 29,............	+0.51	82.1	4 1 12	+0.26	+0.25
„ 29—June 8,............	+0.22	85.7	4 1 18	−0.02	+0.24
June 8— „ 18,............	+0.17	84.2	4 1 18	+0.07	+0.10
„ 18— „ 28,............	+0.02	82.6	4 0 48	+0.17	−0.15
„ 28—July 8,............	+0.13	79.4	4 0 54	+0.38	−0.25
July 8— „ 18,............	−0.01	83.1	4 0 30	+0.09	−0.10
„ 18— „ 28,............	−0.06	84.5	4 0 36	−0.03	−0.03
„ 28—August 7,............	−0.02	83.6	4 0 24	+0.01	−0.03
August 7— „ 17,............	0.00	82.7	4 0 24	+0.06	−0.06
„ 17— „ 27,............	−0.03	81.7	4 0 6	+0.11	−0.14
„ 27—September 6,............	−0.10	83.1	3 59 36	−0.01	−0.09
September 6— „ 16,............	−0.09	82.7	4 0 24	0.00	−0.09
„ 16— „ 26,............	−0.03	82.1	4 1 0	+0.02	−0.05
„ 26—October 6,............	−0.06	81.8	4 0 24	+0.02	−0.08
October 6— „ 16,............	+0.10	79.4	4 1 42	+0.18	−0.08
„ 16— „ 26,............	+0.12	76.8	4 1 42	+0.35	−0.23
„ 26—November 5,............	−0.02	78.5	4 2 6	+0.20	−0.22
November 5— „ 15,............	+0.08	79.1	4 2 24	+0.14	−0.06
„ 15— „ 25,............	+0.48	71.9	4 4 48	+0.65	−0.17
„ 25—December 5,............	+1.11	67.5	4 4 36	+0.95	+0.16
December 5— „ 15,............	+0.76	71.2	4 3 54	+0.66	+0.10
„ 15— „ 25,............	+0.99	68.0	4 4 18	+0.87	+0.12
„ 25—January 4,............	+0.72	70.2	4 5 36	+0.69	+0.03

Table V.

Errors of Time-Ball in 1897.

− means too late. + means too early.

Date.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	...	−0.2	0.1	0.1	0.1	0.1	0.1	+0.2	0.1	0.1	0.1	0.1
2	...	...	0.1	0.1	0.1	0.1	0.1	...	0.1	0.1	0.1	0.1
3	0.1	−0.3	0.1	0.1	0.1	−0.2	0.1	+0.4	0.1	0.1	0.1	0.1
4	+0.2	−0.4	0.1	0.1	0.1	0.1	0.1	+0.5	0.1	+0.2	+0.2	0.1
5	0.1	−0.5	...	0.1	+0.3	0.1	0.1	+0.4	0.1	+0.3	+0.2	0.1
6	+0.3	−0.4	..	0.1	+0.3	0.1	...	0.1	0.1	+0.3	+0.2	0.1
7	+0.4	−0.3	...	0.1	+0.5	..	...	0.1	0.1	+0.3	+0.3	0.1
8	+0.4	−0.3	...	−0.2	+0.6	0.1	...	0.1	0.1	+0.3	+0.3	0.1
9	+0.6	−0.3	...	−0.3	...	0.1	0.1	0.1	0.1	+0.2	+0.4	0.1
10	+0.7	0.1	...	−0.4	+0.7	+0.2	0.1	0.1	0.1	0.1	0.1	0.1
11	+0.8	−0.2	...	−0.5	+0.3	0.1	−0.2	−0.2	0.1	0.1	0.1	0.1
12	+0.9	0.1	0.1	−0.2	0.1	0.1	...	0.1	0.1	0.1	−0.2	+0.3
13	+1.0	0.1	0.1	0.1	0.1	0.1	...	0.1	0.1	0.1	0.1	0.1
14	+1.1	+0.2	+0.2	0.1	0.1	0.1	...	0.1	0.1	0.1	0.1	0.1
15	0.1	0.1	+0.2	0.1	0.1	0.1	...	0.1	+0.2	0.1	0.1	+0.2
16	+0.4	0.1	0.1	...	0.1	+0.2	...	0.1	0.1	0.1	0.1	+0.3
17	+0.8	+0.2	0.1	0.1	−0.3	+0.3	...	+0.2	0.1	0.1	+0.2	+0.3
18	+0.8	+0.2	0.1	...	−0.2	+0.2	...	+0.3	−0.2	0.1	+0.3	0.1
19	−0.2	+0.2	+0.2	...	0.1	+0.2	...	0.1	−0.3	+0.2	+0.3	0.1
20	−0.2	+0.2	+0.3	0.1	0.1	+0.4	0.1	0.1	0.1	+0.2	+0.3	0.1
21	−0.2	+0.2	+0.4	0.1	0.1	+0.2	0.1	0.1	0.1	0.1	+0.3	0.1
22	−0.3	+0.2	+0.7	0.1	0.1	...	0.1	0.1	0.1	0.1	+0.2	−0.2
23	−0.3	+0.3	+0.4	0.1	0.1	...	0.1	0.1	0.1	0.1	+0.2	−0.2
24	−0.4	+0.3	+0.2	0.1	...	0.1	0.1	0.1	0.1	0.1	0.1	−0.4
25	−0.2	+0.2	+0.2	0.1	+0.2	...	0.1	0.1	0.1	−0.2	0.1	...
26	0.1	0.1	+0.2	0.1	0.1	0.1	0.1	0.1	0.1	−0.2	−0.3	+0.2
27	0.1	0.1	+0.2	0.1	0.1	0.1	0.1	0.1	0.1	−0.2	0.1	...
28	0.1	+0.2	0.1	0.1	0.1	−0.2	0.1	0.1	0.1	−0.3	0.1	0.1
29	0.1	...	0.1	0.1	0.1	−0.3	0.1	0.1	0.1	−0.2	−0.2	0.1
30	0.1	...	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	−0.2	0.1
31	0.1	...	0.1	...	0.1	...	0.1	0.1	...	0.1	...	0.1

14. Observations for latitude by Talcott's method have been continued throughout the year and 1359 observations of pairs of stars have been observed, distributed as follows:— In January 101 pairs, in February 61 pairs, in March 7 pairs, in April 51 pairs, in May 134 pairs, in June 26 pairs, in July 144 pairs, in August 152 pairs, in September 165 pairs, in October 147 pairs, in November 230 pairs, in December 141 pairs. The relative numbers give a clear indication of the way in which the atmospheric conditions interfere with astronomical observations in Hongkong. From the 1st June till the 31st December Mr. Plummer made all the observations.

15. The cisterns of the barograph and standard barometers are placed 109 feet above M.S.L. The bulbs of the thermometers are rotated 108 feet above M.S.L., and 4 feet above the grass. The solar radiation thermometer is placed at the same height. The rim of the rain-gauge is 105 feet above M.S.L., and 21 inches above the ground.

16. The monthly Weather Reports are arranged as follows:—

Table I. exhibits the hourly readings of the barometer reduced to freezing point of water, but not to sea level, as measured (at two minutes to the hour named) from the barograms.

Tables II. and III. exhibit the temperature of the air and of evaporation as determined by aid of rotating thermometers. Table II. exhibits also the extreme temperatures reduced to rotating thermometer. Table III. exhibits also the solar radiation (black bulb in vacuo) maximum temperatures reduced to Kew arbitrary standard.

Table IV. exhibits the mean relative humidity in percentage of saturation and mean tension of water vapour present in the air in inches of mercury, for every hour of the day and for every day of the month, calculated by aid of Blanford's tables from the data in Tables II. and III.

Table V. exhibits the duration of sunshine expressed in hours, from half an hour before to half an hour after the hour (true time) named.

Table VI. exhibits the amount of rain (or dew) in inches registered from half an hour before to half an hour after the hour named. It exhibits also the estimated duration of rain.

Table VII. exhibits the velocity of the wind in miles and its direction in points (1—32). The velocity is measured from half an hour before to half an hour after the hour named, but the direction is read off at the hour.

Table VIII. exhibits the amount (0—10), name (Howard's classification) and direction whence coming of the clouds. Where the names of upper and lower clouds are given, but only one direction this refers to the lower clouds. With regard to the names of clouds nimbus (nim) is only entered when the rain is seen to fall; when no rain is seen to fall cumulo-nimbus (cum-nim) is entered, and this name is also used to indicate clouds intermediate between cumulus and nimbus. Cumulo-stratus (cum-str) is the well known thunder cloud, and strato-cumulus (str-cum) signifies a cloud intermediate between stratus and cumulus.

Table IX. exhibits for every hour in the day the mean velocity of the wind reduced to 4 as well as 2 directions, according to strictly accurate formulæ, and also the mean direction of the wind.

Below this is printed a list of the phenomena observed.

17. The following annual Weather Report for 1897 is arranged as follows:—

Table VI. exhibits the mean values for the year (or hourly excess above this) obtained from the monthly reports. The total duration of rain was 1036 hours. There fell at least 0.01 inch of rain on 166 days.

Table VII. exhibits the number of hours during a portion of which at least 0.005 inch of rain (or dew) was registered.

Table VIII exhibits the number of days with wind from eight different points of the compass. The figures are obtained from the mean daily directions in Table VII. of the monthly reports. Days, with wind from a point equi-distant from two directions given, are counted half to one of these and half to the other, *e.g.*, half of the days when the wind was NNE are counted as N, and the other half as NE.

Table IX. exhibits the number of days on which certain meteorological phenomena were registered, and also the total number of thunderstorms noted in the neighbourhood during the past year.

Table X. shows the frequency of clouds of different classes.

Table XI. is arranged as last year.

Table XII. exhibits the monthly and annual extremes. The extremes of humidity and vapour tension are only approximate as the hourly values are not calculated.

Table XIII. contains five-day means.

Tables XIV., XV., XVI. contain magnetic observations.

18. Observations of magnetic declination and horizontal force were made with the unifilar magnetometer Elliott Brothers, No. 55, and the dips were observed with dip-circle, Dover No. 71.

The methods adopted in making the observations and in determining and applying the corrections are explained in *Appendix G. of Observations and Researches made in 1885:* "On the verification of the unifilar magnetometer Elliot Brothers No. 55." The value of log π^2 K was 3.44905 at 24°. The value of P was + 5.818. The mean value of the magnetic moment of the vibrating needle was 0.44872 in English units and 585.84 in C.G.S. units.

The times of vibration exhibited in the table are each derived from 12 observations of the time occupied by the magnet in making 100 vibrations, corrections having been applied for rate of chronometer and arc of vibration.

The observations of horizontal force are expressed in C.G.S. units (one centimeter, one gramme, one second), but the monthly synopsis exhibits X, the horizontal, as well as Y, the vertical, and total forces, which have been computed by aid of the observed dips, and their values are also given in English units (one foot, one grain, one second) and in Gauss's units (one millimeter, one milligram, one second).

I have the honour to be,

Sir,

Your most obedient Servant,

W. DOBERCK,
Director.

The Honourable
THE COLONIAL SECRETARY,
&c., &c., &c.

Table VI.

Mean Values and Hourly Excess above the Mean of Meteorological Elements in 1897.

	1 a.	2 a.	3 a.	4 a.	5 a.	6 a.	7 a.	8 a.	9 a.	10 a.	11 a.	Noon.	1 p.	2 p.	3 p.	4 p.	5 p.	6 p.	7 p.	8 p.	9 p.	10 p.	11 p.	Midt.	Mean or Total.
Pressure, ...	+.004	−.006	−.014	−.017	−.012	.000	+.017	+.032	+.043	+.044	+.034	+.016	−.008	−.027	−.040	−.045	−.040	−.031	−.016	.000	+.013	+.020	+.019	+.013	29.814
Temperature, ...	− 1.3	− 1.6	− 1.8	− 2.0	− 2.1	− 2.0	− 1.4	− 0.5	+ 0.5	+ 1.4	+ 2.0	+ 2.4	+ 2.6	+ 2.6	+ 2.3	+ 1.8	+ 1.0	+ 0.2	− 0.2	− 0.4	− 0.6	− 0.8	− 1.0	− 1.2	71.7
Diurnal Range, ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8.3
Humidity, ...	+ 5	+ 5	+ 5	+ 5	+ 5	+ 4	+ 3	0	− 2	− 5	− 6	− 7	− 7	− 8	− 6	− 5	− 3	− 1	0	+ 2	+ 3	+ 3	+ 5	+ 5	79
Vapour Tension, ...	+.011	+.006	+.004	+.001	−.003	−.004	−.005	−.005	−.007	−.009	−.008	−.007	−.007	−.007	−.004	−.004	−.007	−.003	+.002	+.006	+.010	+.011	+.014	+.013	0.654
Sunshine (Total), ...	...	...	...	...	...	6.6	84.6	137.5	160.6	176.3	185.9	182.7	188.7	180.7	174.6	155.0	96.5	16.1	...	...	...	...	...	...	1745.8
Rainfall, (Total), ...	3.705	5.025	6.260	8.640	6.185	7.450	7.890	6.895	5.825	2.485	1.995	2.710	2.305	3.899	3.075	2.285	3.020	3.580	3.280	1.625	2.415	1.900	2.650	4.940	100.030
Hours of Rain (Total), ...	41	43	53	53	52	47	51	46	47	38	23	33	32	34	33	32	28	27	32	30	37	36	38	45	931
Intensity of Rain, ...	0.090	0.117	0.118	0.163	0.119	0.159	0.155	0.150	0.124	0.065	0.087	0.082	0.072	0.114	0.093	0.071	0.108	0.133	0.102	0.054	0.065	0.053	0.070	0.110	0.107
Wind-Velocity, ...	− 0.6	− 0.7	− 1.0	− 0.7	− 1.0	− 1.1	− 1.3	− 0.6	+ 0.2	+ 0.8	+ 2.0	+ 1.7	+ 1.6	+ 1.4	+ 1.3	+ 1.1	+ 0.6	− 0.4	− 0.8	− 0.7	− 0.7	− 0.5	− 0.3	− 0.4	13.4
Wind-Direction, ...	− 2°	− 1°	− 2°	− 5°	− 7°	− 5°	− 9°	− 10°	− 7°	− 1°	+ 4°	+ 7°	+ 11°	+ 13°	+ 12°	+ 11°	+ 9°	+ 4°	− 2°	− 4°	− 7°	− 5°	− 4°	− 3°	E 2° S
Cloudiness, ...	+ 1	...	...	+ 4	...	...	+ 3	...	...	+ 1	...	...	− 3	...	...	− 1	...	...	− 2	...	...	− 3	...	...	71
Solar Radiation, ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	124.7
Excess of do. do., ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	18.4

Table VII.

Number of Hours during a portion of which it rained for each Month in the Year 1897.

Month.	1 a.	2 a.	3 a.	4 a.	5 a.	6 a.	7 a.	8 a.	9 a.	10 a.	11 a.	Noon.	1 p.	2 p.	3 p.	4 p.	5 p.	6 p.	7 p.	8 p.	9 p.	10 p.	11 p.	Midt.	Total.
January, ...	3	2	2	2	3	4	1	2	3	2	2	3	3	2	2	2	0	0	0	0	1	2	1	4	46
February, ...	1	2	4	5	3	6	7	8	3	2	1	0	1	1	2	3	4	2	2	2	4	3	4	1	71
March, ...	3	3	3	3	2	2	3	2	3	0	0	0	0	1	1	2	1	0	0	1	2	2	0	2	36
April, ...	4	3	4	4	3	4	3	2	1	1	1	1	2	1	1	1	1	1	1	1	3	3	3	4	53
May, ...	3	3	3	4	5	4	5	5	4	4	2	3	4	5	3	3	2	1	3	2	2	2	2	3	77
June, ...	5	10	13	12	10	7	9	7	7	7	8	8	9	5	4	5	4	5	6	5	3	3	6	7	165
July, ...	5	5	7	5	8	5	6	4	3	5	3	4	1	2	1	3	2	2	3	1	6	2	3	3	92
August, ...	6	5	7	8	6	5	6	8	11	8	6	9	6	8	9	4	6	5	6	3	3	5	4	6	150
September, ...	1	2	2	1	3	3	2	3	4	4	0	2	1	4	3	1	2	2	3	4	5	3	2	3	60
October, ...	6	5	4	6	4	2	1	1	3	2	0	2	2	3	5	4	3	5	4	3	3	3	6	5	82
November, ...	4	2	2	2	3	3	6	2	2	2	0	0	2	1	2	3	2	2	2	2	2	5	5	5	61
December, ...	0	1	2	1	2	2	2	2	3	1	0	1	1	1	0	1	1	2	2	3	3	3	2	2	38
Total, ...	41	43	53	53	52	47	51	46	47	38	23	33	32	34	33	32	28	27	32	30	37	36	38	45	931

Table VIII.

Number of Days with Wind from eight different points of the Compass during each Month of the Year 1897.

Month.	N.	NE.	E.	SE.	S.	SW.	W.	NW.
January,	2	4	20	2	1	...	1	1
February,	7	6	13	...	...	...	1	1
March,	...	1	28	2	...	...	...	...
April,	3	3	24	...	...	...	...	...
May,	...	1	15	2	4	7	2	...
June,	...	1	12	1	4	11	1	...
July,	...	2	6	6	5	11	1	...
August,	...	...	11	5	4	7	4	...
September,	2	4	11	...	2	5	5	1
October,	3	4	24	...	..	...	...	...
November,	8	9	12	...	...	...	1	...
December,	14	5	11	...	..	...	...	1
Sums,	39	40	187	18	20	41	16	4

Table IX.

Total Number of Days on which different Meteorological Phenomena were noted and Total Number of Thunderstorms during each Month of the Year 1897.

Month.	Fog.	Electric Phenomena.	Lightning.	Thunder.	Thunder-storms.	Unusual Visibility.	Dew.	Rainbows.	Lunar Halo.	Lunar Corona.	Solar Halo.	Solar Corona.
January,	5	...	...	...	...	...	6	...	...	...	...	...
February,	5	...	...	...	...	3	...	...	...	...	...	...
March,	14	2	2	1	...	1	...	...	1	1	...	...
April,	9	5	4	2	2	3	5	...	...	1	...	...
May,	4	15	15	8	2	6	8	3	...	1	...	...
June,	2	23	21	20	4	3	5	3	8	5	5	...
July,	4	17	16	7	2	4	9	9	8	2	6	1
August,	5	18	17	12	8	5	11	6	4	1	6	...
September,	4	20	19	7	2	7	16	...	9	5	3	...
October,	1	1	1	...	...	1	3	...	1	4	2	...
November,	2	1	1	1	1	3	4	1	4	2	2	1
December,	2	...	...	...	...	1	3	...	1	2	...	...
Sums,	57	102	96	58	21	37	70	22	36	24	24	2

Table X.

Total Number of Times that Clouds of different forms were observed in each Month of the Year 1897.

Month.	c.	c-str.	c-cum.	sm-cum.	cum.	cum-str.	str.	R-cum.	cum-nim.	nim.
January,	...	1	4	61	116	...	24	9	11	25
February,	...	1	...	22	69	...	61	4	22	37
March,	1	2	6	33	133	...	46	1	16	42
April,	...	6	11	46	106	...	43	1	17	25
May,	...	2	33	31	170	1	13	1	7	33
June,	...	12	68	42	160	1	19	...	12	50
July,	...	26	66	40	200	...	11	...	7	20
August,	...	11	60	30	144	2	21	1	18	46
September,	...	23	67	30	145	1	10	1	6	21
October,	1	9	29	56	127	...	16	9	13	29
November,	...	10	27	35	106	...	16	2	2	32
December,	...	3	12	54	68	...	37	2	3	21
Sums,	2	106	383	480	1544	5	317	31	134	384

Table XI.

MONTH. 1897.	Barometric Tide.	Mean Diurnal Variability of Temperature.	Weight of Water Vapour in Troy Grains in each cubic foot of Air.	RAINFALL.		Hourly Intensity of Rain.	MEAN DIRECTION OF CLOUDS WHENCE COMING.			NUMBER OF DAYS WITH CLOUDS BELOW	
				Mean.	1897.		Lower.	Upper.	Cirrus.	2000 ft.	1000 ft.
January, ...	0.103	2°.64	5.22	0.98	2.260	0.036	E 24° S	W 24° S	...	15	9
February, ...	0.106	2 .36	3.86	1.32	1.820	0.015	E 11° N	W 27° S	...	20	12
March, ...	0.107	2 .75	5.83	3.24	0.815	0.006	E 28° S	W 29° S	...	23	16
April, ...	0.098	2 .49	6.18	5.27	3.240	0.047	E 22° S	W 5° S	...	16	8
May, ...	0.095	2 .14	8.96	12.54	14.860	0.193	S 19° W	W 29° S	...	19	4
June, ...	0.067	1 .59	9.61	15.81	23.355	0.163	S 29° W	N 22° W	...	15	4
July, ...	0.061	0 .66	9.16	15.98	5.565	0.101	S 6° W	N 34° E	...	11	1
August,.........	0.068	1 .16	9.53	14.85	25.550	0.197	S 12° W	N 17° E	...	18	8
September, ...	0.089	1 .01	8.88	12.65	8.340	0.174	E 5° S	E 4° N	...	3	1
October, ...	0.087	1 .37	7.49	5.36	6.425	0.085	E 10° N	N 40° E	WSW	8	2
November, ...	0.098	1 .56	5.53	1.17	7.320	0.126	E 25° N	W 29° S	...	2	2
December,......	0.113	2 .39	4.00	1.00	0.480	0.008	E 12° N	W 49° S	...	7	2
Mean,......	0.091	1 .84	7.02	90.17	100.030	0.096	E 37° S	...	...	157	69

Table XII.

Monthly Extremes of the Principal Meteorological Elements registered during the year 1897.

MONTH.	BAROMETER.		TEMPERATURE.		HUMIDITY.	VAPOUR TENSION.		RAIN.		WIND VELOCITY.	RADIATION.
	Max.	Min.	Max.	Min.	Min.	Max.	Min.	Daily Max.	Hourly Max.	Max.	Sun Max.
January, ...	30.267	29.706	79.2	46.7	45	0.748	0.153	1.360	0.510	42	140.9
February, ...	.368	.775	76.7	41.0	23	0.727	0.076	0.540	0.425	43	132.9
March, ...	.110	.658	82.1	54.7	60	0.825	0.308	0.425	0.220	45	136.8
April, ...	.083	.651	83.2	57.5	32	0.808	0.222	1.795	0.440	44	139.3
May, ...	29.943	.447	90.0	67.6	60	1.001	0.514	5.225	1.765	36	147.8
June,............	.795	.363	89.8	72.0	58	1.045	0.597	6.030	2.550	40	152.6
July,............	.851	.447	90.3	74.6	54	0.983	0.548	1.755	0.615	34	150.1
August,.........	.850	.288	89.2	73.1	61	1.054	0.752	5.015	1.840	38	150.8
September, ...	.924	.577	91.8	72.3	41	0.954	0.485	4.005	1.720	56	153.5
October, ...	30.023	.687	86.8	66.3	39	0.920	0.374	2.500	0.510	40	144.6
November, ...	.247	.607	85.6	51.1	12	0.846	0.070	5.875	1.620	41	144.7
December,......	.312	.851	76.4	47.9	29	0.581	0.127	0.195	0.045	32	131.4
Year,......	30.368	29.288	91.8	41.0	12	1.054	0.070	6.030	2.550	56	153.5

Table XIII.

Five-Day Means of the Principal Meteorological Elements observed at Hongkong in 1897.

FIVE-DAY PERIODS.	Barometer.	Temperature.	Humidity.	Vapour Tension.	Wind Velocity.	Nebulosity.	Sunshine.	Rain.
January 1- 5	30.061	65.9	77	0.492	16.2	4.6	6.5	0 000
„ 6-10	29.945	66.4	86	0.555	13.2	7.1	3.2	0.010
„ 11-15	.834	63.5	86	0.511	16.9	9.1	0.5	0.402
„ 16-20	30.056	55.6	70	0.322	18.8	9.7	0.2	0.026
„ 21-25	.167	59.8	72	0.372	10.3	7.9	3.0	0.000
„ 26-30	29.863	66.5	86	0.568	14.9	7.5	4.2	0.011
„ 31- 4	.951	60.2	87	0.472	12.6	9.7	1.1	0.142
February 5- 9	30.053	53.3	87	0.355	13.9	10.0	0.0	0.127
„ 10-14	.205	50.4	55	0.211	19.4	4.3	7.0	0.003
„ 15-19	.055	54.7	79	0.347	11.0	8.7	1.4	0.006
„ 20-24	.019	53.0	83	0.336	10.8	10.0	0.1	0.076
„ 25- 1	29.887	57.5	94	0.444	21.8	9.6	1.5	0.015
March 2- 6	.973	59.1	85	0.426	20.5	8.9	1.6	0.028
„ 7-11	.888	64.4	92	0.561	15.3	8.6	3.1	0.002
„ 12-16	.983	59.5	87	0.441	19.3	9.6	2.4	0.012
„ 17-21	.909	61.9	88	0.493	19.7	9.8	0.5	0.110
„ 22-26	.941	64.0	92	0.554	20.6	10.0	0.9	0.008
„ 27-31	.809	71.3	94	0.723	14.4	8.6	4.8	0.001
April 1- 5	.890	64.8	72	0.448	18.4	8.8	3.1	0.188
„ 6-10	.818	66.6	84	0.550	22.1	9.7	1.5	0.036
„ 11-15	.885	69.5	90	0.653	17.9	8.2	4.2	0.015
„ 16-20	.929	65.0	76	0.472	15.8	8.0	3.6	0.397
„ 21-25	.829	73.1	81	0 665	11.5	4.8	8.9	0.000
„ 26-30	.914	71.2	82	0.626	18.1	8.2	3.3	0.012
May 1- 5	.740	74.9	82	0.710	10.4	5.5	6.1	0.000
„ 6-10	.664	77.0	91	0.840	18.3	9.7	1.9	1.934
„ 11-15	.809	80.3	85	0.871	6.5	3.8	10.3	0.000
„ 16-20	.703	82.8	82	0.918	10.8	6.2	8.9	0.104
„ 21-25	.753	78.2	88	0.851	13.7	8.8	2.1	0.912
„ 26-30	.767	80.4	82	0.849	10.9	4.2	8.0	0.010
„ 31- 4	.692	84.0	79	0.926	11.1	7.1	6.9	0.270
June 5- 9	.707	82.5	82	0.916	11.5	7.2	7.0	1.332
„ 10-14	.680	83.2	80	0.909	7.7	6.7	8.1	0.073
„ 15-19	.603	81.7	87	0.937	8.8	8.4	3.9	0.274
„ 20-24	.509	80.8	87	0.920	12.0	9.3	3.5	0.893
„ 25-29	.451	78.4	91	0.886	19.2	9.9	0.2	1.830
„ 30- 4	.542	78.1	74	0.717	14.7	9.2	1.9	0.025
July 5- 9	.688	80.4	87	0.903	10.2	8.2	3.9	0.551
„ 10-14	.783	82.3	80	0.878	11.0	6.1	8.7	0.134
„ 15-19	.720	83.0	76	0.860	9.6	4.0	10.6	0.121
„ 20-24	.722	83.4	76	0.871	7.7	4.3	10.5	0.054
„ 25-29	.601	83.5	79	0.908	10.5	6.3	6.3	0.075
„ 30- 3	.539	81.7	84	0.910	11.4	8.7	3.0	2.141
August 4- 8	.597	82.1	83	0.909	13.0	5.9	8.6	0.165
„ 9-13	.469	82.8	84	0.948	13.1	9.3	2.5	0.804
„ 14-18	.756	77.5	91	0.861	8.0	9.9	0.4	1.530
„ 19-23	.684	81.4	84	0.900	5.6	6.7	6.7	0.162
„ 24-28	.769	80.6	84	0.877	5.5	3.9	8.3	0.355
„ 29- 2	.779	81.3	83	0.887	5.8	4.1	7.7	0.122
September 3- 7	.700	83.2	78	0.885	6.1	4.8	10.1	0.000
„ 8-12	.761	81.4	84	0.894	8.4	6.5	7.0	0.124
„ 13-17	.708	78.1	73	0.703	18.5	8.8	2.6	0.693
„ 18-22	.839	80.2	85	0.872	17.3	4.4	7.4	0.801
„ 23-27	.809	81.9	78	0.846	9.1	3.1	9.6	0.035
„ 28- 2	.752	81.3	71	0.754	11.4	4.8	8.8	0.036
October............ 3- 7	.761	78.1	75	0.721	20.5	7.6	2.6	0.847
„ 8-12	.846	78.3	82	0.800	23.5	8.6	2.5	0.265
„ 13-17	.895	77.2	78	0.735	20.1	8.7	3.1	0.084
„ 18-22	.907	76.3	71	0.648	9.9	6.5	5.9	0.000
„ 23-27	.902	74.2	69	0.588	15.4	4.8	7.2	0.018
„ 28- 1	.884	75.9	80	0.711	10.1	5.1	6.7	0.045
November 2- 6	.853	78.2	78	0.752	7.8	2.7	9.3	0.000
„ 7-11	.885	75.0	72	0.623	17.8	9.5	1.2	0.011
„ 12-16	.875	76.0	76	0.686	19.8	7.6	5.5	0.157
„ 17-21	.917	65.0	80	0.493	11.7	9.6	0.7	1.236
„ 22-26	30.114	60.9	40	0.228	12.8	2.0	9.2	0.060
„ 27- 1	.055	61.0	37	0.204	10.8	1.2	9.7	0.000
December......... 2- 6	.106	62.8	63	0.360	9.9	8.5	1.9	0.002
„ 7-11	.014	64.4	70	0.430	10.0	5.2	7.3	0.000
„ 12-16	.037	59.1	81	0.408	9.2	9.1	0.9	0.041
„ 17-21	.113	57.7	65	0.310	8.6	5.0	7.3	0.000
„ 22-26	.205	59.0	61	0.305	12.1	5.0	6.1	0.000
„ 27-31	.031	60.4	72	0.386	12.7	6.3	3.9	0.053

Table XIV.

Observations and Magnetic Declination and Dip.

1897.	H.K.M.T.	Declination East.	Observer.	H.K.M.T.	Dip North.	Needle No.	Observer.
February, ...	15d. 4h. 30m. p.	0° 24′ 52″	J.I.P.	15d. 3h. 26m. p.	31° 38′.22	3	J.I.P.
	16 2 32 p.	25 30	"		38 .63	4	"
	18 2 33 p.	24 48	"	16 3 56 p.	37 .72	3	"
	19 2 33 p.	24 39	"		37 .54	4	"
April, ...	12 4 33 p.	23 47	"	12 3 27 p.	36 .63	3	"
	14 2 35 p.	22 59	"		37 .75	4	"
	15 2 51 p.	22 11	"	14 4 2 p.	38 .79	3	"
	16 2 31 p.	23 23	"		38 .82	4	"
June, ...	14 4 34 p.	21 51	"	14 3 26 p.	38 .25	3	"
	16 2 32 p.	22 4	"		36 .85	4	"
	17 2 46 p.	20 55	"	16 4 5 p.	35 .07	3	"
	18 3 01 p.	22 36	"		35 .75	4	"
August, ...	16 4 35 p.	23 13	"	16 3 36 p.	34 .60	3	"
	18 2 32 p.	22 16	"		36 .63	4	"
	19 2 46 p.	22 23	"	18 3 56 p.	37 .09	3	"
	20 2 44 p.	21 52	"		36 .16	4	"
October, ...	18 3 14 p.	23 53	"	19 3 36 p.	36 .06	3	"
	19 4 36 p.	24 0	"		36 .97	4	"
	21 2 41 p.	23 36	"	21 3 59 p.	35 .97	3	"
	22 2 53 p.	22 52	"		35 .29	4	"
December, ...	13 4 26 p.	23 56	"	13 3 26 p.	35 .07	3	"
	15 2 30 p.	24 59	"		36 .25	4	"
	16 2 41 p.	23 8	"	15 3 56 p.	37 .72	3	"
	17 2 34 p.	23 54	"		37 .85	4	"

Table XV.

Observations of Horizontal Magnetic Force.

Date.	H.K.M.T.	Time of one Vibration.	Temperature Cent.	Log m X.	Value of m.	H.K.M.T.	Distance in Centimetres.	Temperature Cent.	Deflection.	Log $\frac{m}{X}$	Observer.
1897.											
February, ...	17d. 3h. 19m. p.	3s. 6234	15° .4	2.33090	586.80	17d. 2h. 41m. p.	40	14° .8	2° 52′ 18″	3.20608	J.I.P.
							30		6 50 10		
						4 10 p.	40	14 .8	2 52 46		
							30		6 50 40		
April, ...	13 3 19 p.	3.6320	24 .5	2.33041	585.65	13 2 47 p.	40	24 .9	2 51 06	3.20488	"
							30		6 47 51		
						4 05 p.	40	24 .6	2 51 20		
							30		6 48 05		
June, ...	15 3 25 p.	3.6369	31 .6	2.33116	586.00	15 2 50 p.	40	31 .4	2 50 35	3.20464	"
							30		6 46 21		
						4 07 p.	40	31 .0	2 50 46		
							30		6 46 36		
August, ...	17 3 19 p.	3.6338	26 .4	2.33042	585.37	17 2 41 p.	40	26 .4	2 50 55	3.20444	"
							30		6 47 05		
						4 08 p.	40	26 .4	2 50 56		
							30		6 47 24		
October, ...	20 3 17 p.	3.6351	27 .6	3.33065	585.53	20 2 42 p.	40	27 .2	2 50 45	3.20446	"
							30		6 46 53		
						4 03 p.	40	26 .8	2 51 04		
							30		6 47 16		
December, ...	14 3 11 p.	3.6293	19 .4	3.33025	585.67	14 2 38 p.	40	19 .0	2 51 40	3.20506	"
							30		6 48 40		
						3 57 p.	40	19 .5	2 51 54		
							30		6 49 01		

Table XVI.

Results of Magnetic Observations in 1897.

Month.	Declination East.	Dip North.	MAGNETIC FORCE.								
			ENGLISH UNITS.			METRIC UNITS.			C. G. M. UNITS.		
			X.	Y.	Total.	X.	Y.	Total.	X.	Y.	Total.
February, ...	0° 24′ 57″	31° 38′ 02″	7.9183	4.8779	9.3002	3.6510	2.2491	4.2882	0.36510	0.22491	0.42882
April, ...	23 05	31 38 00	7.9249	4.8818	9.3079	3.6540	2.2509	4.2917	0.36540	0.22509	0.42917
June, ...	21 52	31 36 29	7.9338	4.8825	9.3158	3.6581	2.2512	4.2954	0.36581	0.22512	0.42954
August, ...	22 26	31 36 07	7.9288	4.8782	9.3094	3.6559	2.2493	4.2924	0.36559	0.22493	0.42924
October, ...	23 35	31 36 04	7.9309	4.8793	9.3117	3.6568	2.2498	4.2935	0.36568	0.22498	0.42935
December, ...	23 59	31 36 43	7.9217	4.8757	9.3021	3.6526	2.2481	4.2890	0.36526	0.22481	0.42890
Year, ...	0 23 19	31 36 54	7.9264	4.8792	9.3079	3.6547	2.2497	4.2917	0.36547	0.22497	0.42917

Appendix A.

THE LAW OF STORMS IN THE EASTERN SEAS.

INTRODUCTION.

The first chapter of the following paper treats of the law of storms and was first published in Hongkong in September, 1886. It was read before the British Mercantile Marine Officers' Association on the 17th May, 1893. It is now reprinted with later additions. The second chapter treats of the management of ships in typhoons, and was originally included in the pamphlet on the law of storms. It was read as a separate lecture before the Shipmasters' Society, London, on the 16th January, 1896, and is now reprinted with a few additions. The third chapter was printed in the *Government Gazette*. The fourth and fifth chapters, on different classes of typhoons and on winter-typhoons in the southern part of the China Sea, appeared in "Zeitschrift für Meteorologie" in 1897.

Plate I illustrates the different classes of typhoons enumerated in § 4. Figure 1 shows how the wind blows in a typhoon as determined by aid of observations made at the Hongkong Observatory during the years 1884-87 inclusive. Figure 2 shows a typhoon in the Formosa Channel on the 21st and 22nd August, 1884. The height of the barometer is noted near the isobars. The arrows fly with the wind, whose force is given in numbers. The large arrow shows the direction in which the whole disturbance was progressing. Figure 3 shows a typhoon that was lying a little N of Formosa on the 17th July, 1890. The number of feathers on the arrows indicates half the wind-force, *e.g.*, 5 feathers means force 10. Figure 4 shows a typhoon in the China Sea on the 15th November, 1891. Figure 5 one on the 20th November, 1891, that was moving towards SW. Figure 6 one on the 13th November, 1895.

§ I.—THE TYPHOONS IN THE EASTERN SEAS.

It appears that typhoons in the China Sea originate in elongated slight depressions, which sometimes lie across the Philippines as well as the China Sea, but usually exist only over the sea extending sometimes far into the Pacific. To the north of them it blows moderate NE breezes and south of them somewhat less strongly from the SW. The NE breezes reach generally only as far as northern Formosa in summer, but in autumn the NE (and farther north the NW) monsoon blows much farther north. Sometimes the SW breezes to the south of the axis of the depression are stronger than the NE breezes to the north of it, and extend apparently down to the equator and are probably a continuation of the SE trade. To the E of these depressions in the Philippines there are light S and SE breezes. In Annam it probably blows from the N. In summer these depressions begin with rising pressure in the interior of China or in Japan. In autumn it seems the pressure rises slightly near the equator and SW winds extend gradually northward over the China Sea. In January and February depressions do not occur. During the rest of the year they occur about once a month on an average. During the summer months and in autumn they frequently give rise to a typhoon or a small circular depression. The trough-like depression then ceases to exist. In spring they do not alter into typhoons but cease to exist owing to the NE monsoon filling them and spreading to the southward.

The depressions have their major axes lying E and W, or ENE and WSW. Their average latitude from June to September is 17° N, later more southerly, and in November perhaps 10° N. They do not appear to move at all, and they may be traced for 3 or 4 days. The barometer is read little more than a tenth of an inch lower in the axis than along the coasts all round them. Along these coasts light winds circulate against the hands of a watch. In such depressions the weather is squally and wet, and the wind variable,—frequently in heavy squalls with great downpour of rain, but thunder is seldom heard. It appears that in such squalls S wind happens to extend itself northwards and N wind southwards, and revolving storms are thereby generated. If this occurs in the middle of the China Sea, it is likely to give rise to a typhoon. Of course, it more often happens that a circular storm originates near the E and W end of the elongated depression as the winds there already revolve as in a rotary storm except to the W or E of the centre forming, so that the N or respectively S squalls need only gain ground on one side, but in such cases only minor circular depressions or very small typhoons are originated.

When the trough stretches from south of Hainan through the Bashee Channel right out into the Pacific to the south of Japan and the NE and SW winds on either side of it are fresh or strong, the conditions have often been mistaken for two typhoons, one in the China Sea and one to the south of Japan, before ever any typhoon was formed.

The heavy rain is, of course, not the cause of the phenomena, for the rain itself is caused by the air rising in the axis of these depressions, also the water-vapour condensing gives out heat and thus in the first instance makes the mercury rise in the barometer before a squall, but there cannot be any doubt that the quantity of water-vapour condensed to form perhaps 10 inches of rain per day, and whose pressure is thus abstracted from the barometric pressure of the air, causes the permanency of the depressions. It is different with the rainfall in the SW monsoon. That is spread over a large area and does not give rise to a low pressure in one spot surrounded by higher pressures.

It is rather difficult to say whether a depression in the China Sea, when its existence has been ascertained, is a typhoon or only a minor disturbance, but if the following signs are observed exactly as now to be explained, then it is certain to be a typhoon. A minor depression gives signs less well marked and more confused.

The earliest signs of a typhoon are clouds of the *cirrus* type—looking like fine hair, feathers or small pale white tufts of wool—travelling from the east or thereabout, their direction backing towards the north, a slight rise in the barometer, clear and dry but hot weather, calms or very light winds. If cirrus come from W, they prove that there is no typhoon. If they come from the S, then there may be a typhoon more than 600 miles to the southward. This fine weather lasts for days and the existence of a typhoon at a great distance is a cause of fine weather all round and contributes therefore to the safety of ships at sea,—a fact that is not sufficiently appreciated by mariners.

The cirrus clouds, which frequently assume fantastic shapes, make their appearance within 1,500 miles of the centre of a typhoon. They show that water-vapour has risen about 6 miles in the atmosphere through the air rising near the centre. The barometer is generally rising beyond 600 miles of the centre, and the mean of the twenty-four hours' temperature rises in Hongkong above 81 deg. Halos round the sun and the moon, phosphorescence of the water and also glorious sunsets with grand twilight rays, appear to be frequently noticed before typhoons.

Cirrus radiate from various directions but when there is a typhoon, and the radiation is very distinct, it is usually from the same direction as the bearing of the centre.

An increasing swell in the sea is noticed from 300 to 600 miles from the centre, or farther off, but this depends greatly upon the situation of the nearest land, and particularly upon whether land intervenes between the observer and the typhoon centre. The swell arises from the heavy seas that accompany a typhoon, and form the real danger to ships, which are usually well fit to stand the force of the wind without too serious damage. As the velocity of waves in the sea is much greater than the velocity of the centre, the swell is frequently of great help in forecasting a typhoon, but it appears that the bearing of the centre is not well determined from the swell; besides the swell would indicate where the typhoon was at a certain time previous when the waves that caused the swell were raised by the wind. For instance, N of Formosa, *i. e.*, between the E coast of China and SW Japan there is usually a heavy E to SE swell, when a typhoon centre is approaching from SE or E, and the sea there gets very high when the centre is yet at a great distance. A heavy cross swell is a certain indication of a typhoon, except near rocky land, where cross swell may be caused by reflection of the direct swell. The cross swell arises from the heavy confused cross seas raised by strong winds from different directions round the centre.

Within 600 miles of the centre the sky is often half overcast with cumulus, above which cirro-cumulus is seen, the sky being frequently paled by high and faint cirro-stratus. S and SW of and beyond 200 miles of the centre, thunderstorms and cumulo-stratus are seen. They may also occur to the W and E of and as close as 250 miles to the centre, but there they are rare, at least during the NE monsoon. In fact, the belief of the Chinese that where there is a thunderstorm there will be no typhoon appears to be well founded. If thunder and lightning should appear to the N of the centre, little or no rain falls at the time. The old accounts of typhoons are probably sometimes to be explained as mere thunderstorms, while on the other hand during a typhoon the noise of the wind and waves might easily be mistaken for thunder.

On approaching nearer than 500 miles to the centre, the cloudiness increases, and the mercury begins to fall slowly (seldom as much as a tenth of an inch in 24 hours) in the barometer. Then the air becomes oppressive, a slight haze is observed during the morning hours, and the sky presents a threatening and vaporous appearance. The weather is then most unhealthy and depressing. Many people find it impossible to get any sleep owing to the very high night temperature. All sorts of vermin, including snakes, spiders, beetles, and typhoon flies (dragon flies), are unusually active.

Within 300 miles (or in different typhoons between 200 and 400 miles) of the centre there is a heavy cross sea, which therefore gets up some time before, and lasts longer than the wind. Within 250 miles in front of the centre the sky becomes overcast, and the temperature falls in consequence.

Within 200 miles of the centre the temperature falls quickly, owing to the heavy roll-cumulus with which the sky is densely overcast. About this distance, just in front of the centre, the air becomes sometimes abnormally dry, and the sky at the same time presents a peculiar black and ominous appearance. And meantime the wind has risen and blows generally with the force of a strong breeze rising to a moderate gale in the squalls. But this depends also upon the bearing of the centre, the wind being usually strongest in the right-hand semi-circle. Within 200 miles of the centre there is usually a mountainous cross sea.

Within 200 miles to the N, and within 150 miles in front of and to the S of the centre, heavy rain begins to fall, and within 60 miles (or from 60 to 150 miles) it pours down in torrents. The temperature near the centre in Hongkong is often about 78° and over the China Sea 76°, but on board ship a temperature as high as 83° has been registered, but that is very unusual.

The dimensions of different typhoons vary much and near land the strong winds are often so irregularly distributed than in a place near the centre less wind may actually be experienced than at some distance farther away from it. The approach of the centre is judged by the fall of the mercury in the barometer and by the increase in the strength of the squalls.

No conclusions can be drawn with certainty from the reading of the barometer concerning the distance of the centre. The readings differ in different typhoons occurring during the same month and are also different in different months (owing to the annual variation in monthly mean pressure). Taking the mean of several typhoons I obtained at 40 miles 29.20, at 50 miles 29.30, at 100 miles 29.40, and at 200 miles 29.50.

The force of the wind is also different according to the dimension of the typhoon. On an average we have force 12 within 35 miles of the centre, force 11 at 50 miles, force 10 at 75 miles, force 9 at 110 miles, force 8 at 145 miles, force 7 at 180 miles, force 6 at 220 miles, and force 5 at 250 miles; but it often blows force 6 at 300 miles from the centre and then the area with strong wind is increased in proportion.

Within from 2 to 15 miles of the centre the wind calms down, or nearly so, and the sky usually clears overhead, more or less, at sea (or over an island), being now covered there by only very light clouds or haze, through which the sun or the brighter stars are visible. The sea is often seen to boil like a cauldron. Its surface has been whipped into foam, and a lot of air has been caught by the waves, which escapes under the low air-pressure in the bull's eye of a typhoon. The sea is as a rule mountainous and confused, but sometimes near land it calms down when the diameter of the calm area exceeds 20 miles. Quantities of sea-birds, and, closer to the shore, also land-birds, butterflies, and other insects cover a ship caught in the centre of a typhoon. The centre of the calm area, round which the wind circulates, does not always exactly coincide with the point where pressure is lowest, *i.e.*, the centre of the isobars. It has been found that the calm followed some 20 miles after the lowest barometer reading, but such is not always the case, and the reverse has been suspected on more than one occasion. Very deceitful lulls occur during the raging of a typhoon. They last sometimes long enough to be mistaken for the central calm, but when the wind rises again it comes from nearly the same direction. Thus in case of typhoons moving W or NW in the China Sea in summer there is sometimes an area, some 60 or 70 miles behind or to the S of the centre, where the wind falls to a fresh or strong breeze, which again increases rapidly and even a couple of hundred miles farther away it blows stronger than over that area. The diameter of the central calm in a low latitude in summer is about 4 miles, and the sea is mountainous from all directions, but farther north or late in the year the diameter reaches sometimes from 40 to 50 miles, and the sea then often goes down together with the wind, but the character of the bull's eye is then less well defined. The weather becomes dry, though in one or two cases torrential rain has been registered within the central calm. Inland in China the bull's eye has never been observed.

When the wind rises in a typhoon it blows in gusts and the mercury heaves in the barometer. When the wind has reached force 11 it blows in fierce squalls of sometimes about 10 minutes' duration, while the mercury heaves up and down as much as a tenth of an inch. The mercury often gives a jump upwards as the wind begins to veer in a squall. Then it drops down and gives another upward jump as the wind comes back to nearly its old direction. During these squalls an enormous quantity of rain falls in a few minutes. The temperature falls and rises a fraction of a degree or more. The wind does not return to quite the former direction, except just in front of the centre. At the time when the centre is nearest, a fierce squall is usually felt, and in that squall the direction of the wind changes considerably, and the barometer begins to rise. The squalls appear to be caused by an up-and-down movement of the air. As the air comes rushing down the rain drops evaporate in the hotter stratum near the earth's surface, and owing to the increased tension of water-vapour, the barometer (after a fall caused by the cold of evaporation) begins to rise. The wind veers towards the direction of the wind above, which latter is known from the motion of the clouds. Then the air starts to rise with a deluge of rain, caused by the condensation of vapour arriving at the cooler stratum above, while the barometer (after a rise caused by the heat of condensation) drops down, owing to the cessation of the pressure of water-vapour condensed into the rain fallen, and the wind resumes the direction determined by the central depression; for the latter is so great in a typhoon and gradients so steep near the centre that subsidiary depressions have never occurred in the China Sea.

It is a fact that more damage to vessels is caused by the fearful seas than by the wind. Fortunately masters of ships are now making use of oil to calm the waves, a remedy which has been used with good effect for the last three thousand years. Thick oil is best—mineral oil is of no use—and it should be allowed to ooze out of canvas bags half full of cotton waste and slung from the weather bow, or it may be left to ooze out of other openings, such as water-closets. It is still more effective when fired from the vessel towards approaching seas from mortars or rockets.

On shore perhaps as much damage is caused by rain as by wind; but, of course, the former adds impetus to the latter. The wind blowing from all sides into the centre raises the level of the sea there, and the sea-surface is also raised about a foot for every inch the barometer falls below its height outside of the typhoon. When this storm-wave approaches the shore near the time of high water, which somehow seems to happen rather often, it raises the sea, and is apt to cause extensive and disastrous inundations over low-lying shores, as the crests of the waves (which at sea may be 30 feet high or more) on entering shoal water may rise 60 feet or upwards above sea-level in a typhoon.

The incurvature of the wind in a typhoon depends upon the monsoon. In May, June, July, and August the angle between the wind (direction whence coming) and the bearing of the centre is 11 points in front of the centre, $10\frac{1}{2}$ points in the right-hand quadrant, 12 points behind the centre and $11\frac{1}{2}$ points in the left-hand quadrant. During September, October, and November it is 11 points in front, $11\frac{1}{2}$ to the right, 12 in rear, and 11 points to the left. This shows that the monsoon blows in towards the centre and combines with the cyclonic winds. It will be remarked that the wind blows across the path in front and helps a vessel to run across the path in front of the centre, keeping the wind on the starboard quarter 3 points from the stern. In rear the wind blows more straight in towards the centre, and it also blows stronger in rear than in front.

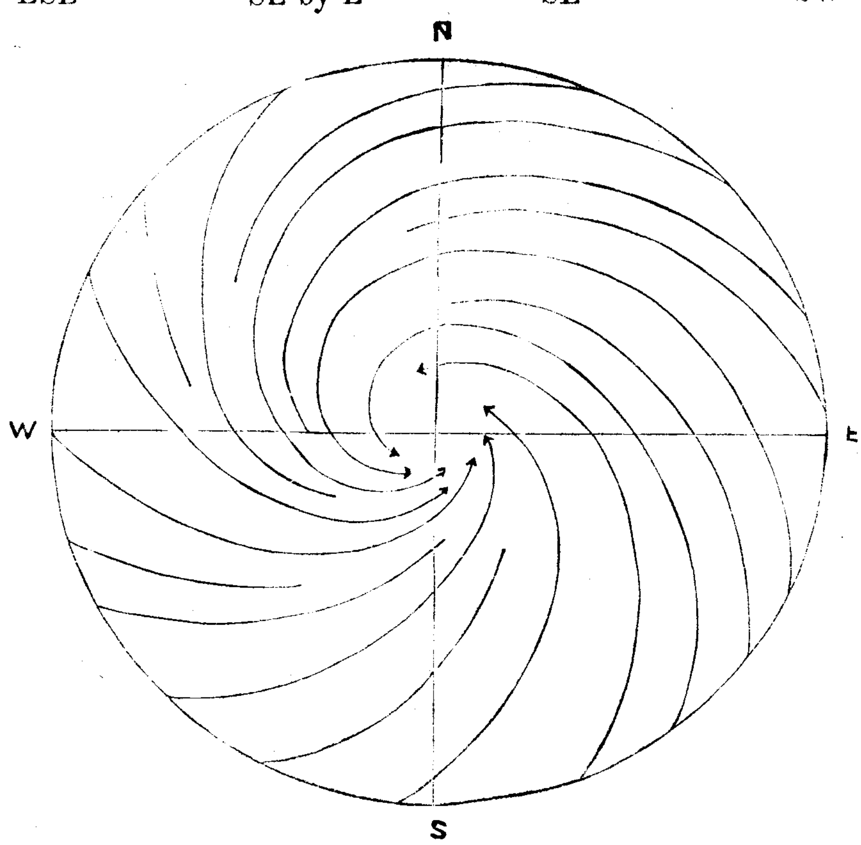
The angle depends also upon the distance from the centre. At 25 miles it is $10\frac{1}{2}$ points (very uncertain), at 75 miles it is 11 points, at 125 miles it is $11\frac{1}{2}$ points, at 150 miles it is $11\frac{3}{4}$ points, at 200 miles it is 12 points, at distances greater than 300 miles the centre bears perhaps about 15 points from the wind (very uncertain).

The angle depends also to some extent upon the latitude though south of Northern Formosa the connection cannot be traced. But in 30° N the average angle is about 10 points and beyond Japan 9 points might perhaps be allowed.

These rules fail, however, near some shores if the centre is not very close. Thus there often blows a steady E gale along the S coast of China when a typhoon is crossing the China Sea. The wind blows into the China Sea through the Balingtang Channel and blows along the S coast of China from E. If the centre is passing to the southward at a distance of several hundred miles, this reminds one of the NE monsoon, but now it blows harder the lower the pressure falls, while in the NE monsoon it blows harder the higher the pressure rises. About the N entrance to the Formosa Channel,—one of the windiest places in the world—the gale blows often steadily from NE while there is a typhoon to the S moving westward. Again near the coast of Annam, the wind is likely to hang long about N. This action of the coastline in certain localities favours sometimes the birth of a typhoon, thus when the NE monsoon has set in along the S coast of China, and blows from N along the coast of Annam, the SW monsoon (deflected towards the right) is hemmed in by the Island of Palawan and forced into a more southerly direction to the W of Mindoro, and it is found that typhoon centres are formed near that locality; and also SE of Hainan in an area one side of which is exposed to strong E wind coming through the Balingtang Channel, the other to SW winds when pressure is high near the equator.

As far as Hongkong is concerned, the following table, constructed by aid of observations made here during the years 1884–1887 inclusive, gives the details. The first column shows the direction of the wind at the Observatory, the second the direction of the wind at the Peak, the third the direction whence the clouds are coming, and the fourth the bearing of the centre. The results differ from the rules given above because the centre is inland whenever its latitude is greater than that of the Observatory, except far away to the NE, and as soon as the centre of a typhoon enters the mainland it begins immediately to fill, ceases to exist as a typhoon, and can be traced as only a slight depression:—

Wind at the Observatory.	Wind at the Peak.	Clouds.	Centre.
E by N	E	E	S
NNE	NE	NE	SE
NW by N	N	N	E
W by N	NW by W (?)	NW by W	NE
SW by W	W by S	WSW	N
S by W	SW by S	SW by S	NW
SE by S	S by E	S	W
ESE	SE by E	SE	SW



A Typhoon in Hong Kong.

Very low clouds in a typhoon move with the wind, but if the clouds are higher they move round the centre in front and to either side, but more in towards the centre in rear. A heavy nimbus cloud passing to leeward causes heavy squalls, veering or backing regularly; and to windward it has the opposite effect. The cause of this is obvious.

The wind blows from a region where the air pressure is higher towards one where it is lower. It is, however, deflected towards the right in the northern hemisphere. The force of the wind depends upon the difference of pressure between one place and another situated in the direction where the barometric slope or gradient is greatest. The gradient is measured in hundredths of an inch per 15 nautical miles. The force of the wind corresponding to a certain gradient is greater the hotter the air is, and is different in a typhoon from what it is in the trade, owing to the path of the air particles being curved. They are almost logarithmic spirals, but somewhat different from such curves. A gradient of 0.01 corresponds to force 4, 0.02 to 6, 0.03 to 7, 0.04 to 8, 0.05 to 9, 0.06 to 9½, 0.07 and 0.08 to 10, 0.09, 0.10 and 0.11 to 11, 0.12 and above this to 12. The steepest gradient usually met with is a third of an inch in 15 nautical miles. Gradients above this are rare, but sometimes they are much greater. The steepest gradient (1 inch in 15 miles) ever met with occurred in a low latitude in the Pacific. That corresponds to a wind velocity of perhaps about 160 miles per hour at sea level. Such velocities are not uncommon at an altitude of 2,000 feet in severe typhoons. Anything above 80 miles per hour is called a typhoon. It is seen that there is as great difference between the force of one typhoon and another as between a calm and a storm which nearly reaches typhoon force.

When a typhoon is blowing it is of great importance to have a house well shut-up. Windows and doors should be firmly locked, bolted and barred. Damage is frequently caused by shutters being out of repair. Once the wind enters a broken window, it begins to blow through and its force is then quickly felt. As long as all apertures are thoroughly shut on both sides a fearful howling and whistling is heard, the rain blows in through the smallest openings and the house may shake, but damage is seldom done. Should a fierce squall get the chance to blow into a house, the roof is often the first part to give way. It is believed that pressure falls so quickly outside that the air confined in the house bursts through the roof like an explosion, but there is no foundation for that belief; it is more likely that a fierce squall would break through the windows and doors and through the roof as well. But if any fear is entertained of the air being confined inside, it is merely necessary to leave the chimneys open so that pressure inside will be nearly the same as on the outside.

In many typhoons the barometer, reduced to the temperature of freezing water and to sea-level, does not fall below 28.80 inches. In others it falls as low as 28.50. Lower readings are rare, but sometimes it falls much lower.

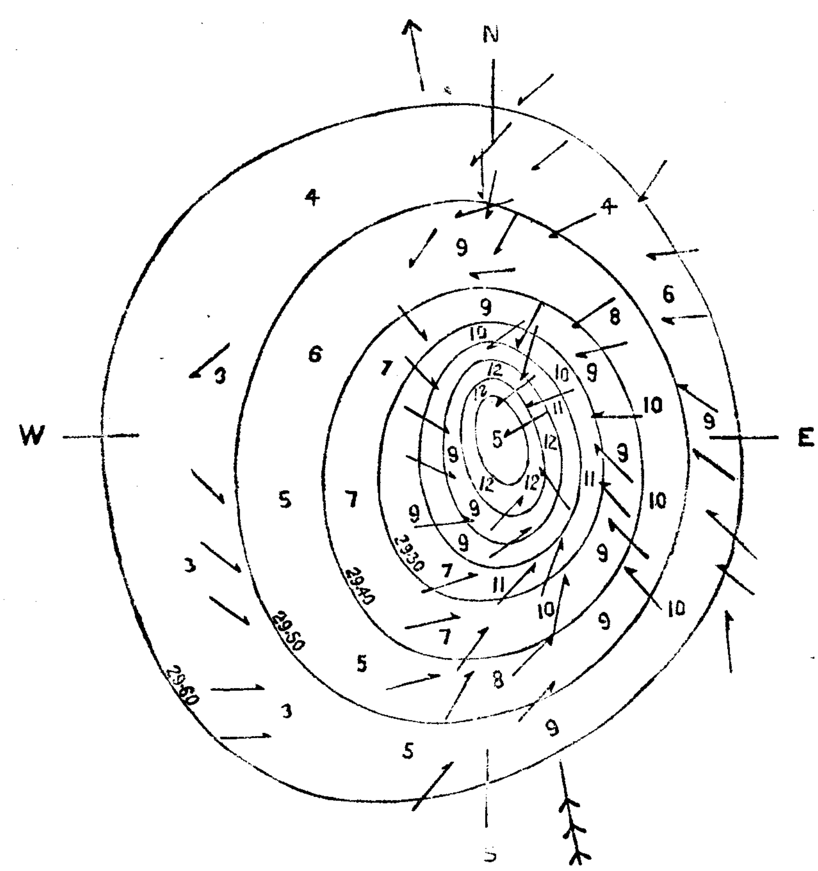
No typhoon ever stands still. As soon as it is formed, it is carried forward by the prevailing wind. That is why the isobars* are elongated, except near the centre where the force of the prevailing wind is of no account. The isobars could be circular only in a stationary typhoon. That is also why typhoons move so as to keep the areas of high barometer on their right, and so as to recede from areas where the barometer is high, and so as to approach low-pressure areas. Most of the typhoons that originate in the Pacific to the East of the Philippines or Formosa move Westward at first, then NW, then N., then they recurve to the NE, and beyond Japan they move Eastward. That is under the influence of the high-pressure area in the Northern Pacific, which they rotate around in the same direction as the hands of a watch. When there are two typhoons about at the same time, they rotate round each other in the opposite direction, that is, abstracting from the influence of the high-pressure areas, which may cause them to move somewhat differently from this simple rule. In the China Sea there is sometimes a low-pressure channel between high pressures in China and in the Southern part of the China Sea. A typhoon in the Pacific at such times is attracted towards the China Sea and passes along the low-pressure channel, because the winds blowing to either side of this channel agree with the winds round the centre of a typhoon, and they move according to the principle of least action. During the typhoon season typhoons follow each other quickly, and there are often several at one time raging in different parts of the Far East. Then they cease, and there are none maybe for several weeks; but during the height of the season in August and September that is most unusual.

As explained above, the paths of typhoons in the Pacific look often like parabolas, but those in the China Sea are quite different and the difference must be due to the distribution and land and sea. The latter do not as a rule recurve, *i.e.*, move North-eastward after having moved North-westward and Northward. Some of them, in fact, disappear in the China Sea after turning to the SW. Others recurve between 20 deg. N and 40 deg. N, and between 115 deg. E and 130 deg. E. The Middle Dog lighthouse at the Northern entrance to the Formosa Channel is the centre of the region of recur-

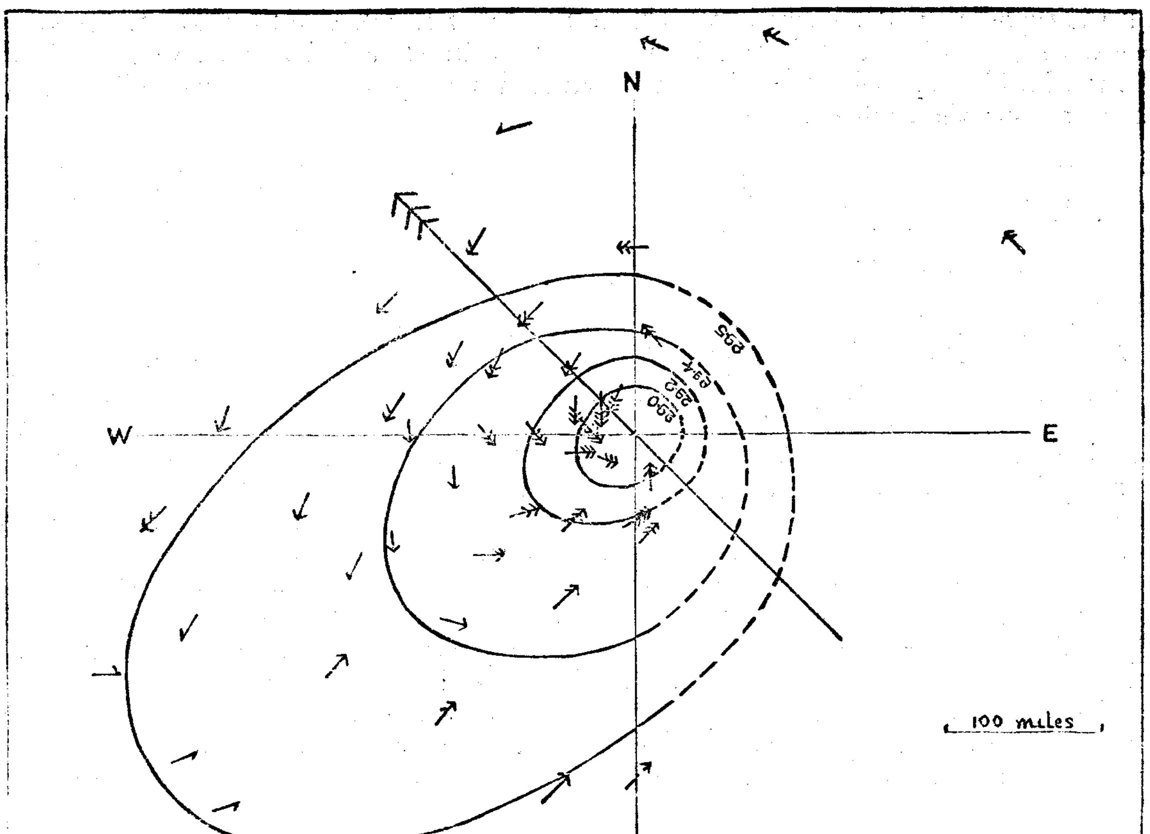
* Curved lines drawn on a map through places from which the same height (corrected and reduced) of the barometer is reported or between those that report a slightly higher and lower pressure are called isobars. The gradient lies at a right-angle to the isobar. These are the most important elements for forecasting the weather. The curvature of isobars indicates the existence of depressions beyond the area where the telegraphic reporting stations are situated, but it is of course impossible to lay down the centre accurately from such data, *e.g.*, while over the sea its position and motion can only be guessed at, not known with certainty.

vature, if the typhoons that recurve in the China Sea are not taken into account. A vessel having experienced a typhoon is not likely to fall in with it again after it has recurved, but it happens to vessels in the Pacific, especially to such as have suffered damage and been carried all round the centre when they first met the typhoon.

Typhoons cease to exist, except as minor depressions, as soon as the centre enters the mainland. The centres of different typhoons often enter the coast in the same place: where it is low, as for instance, the Lien-chau peninsula; near Huilingsan; the Canton river, etc. The typhoons originate during squalls in hot and damp places near sea-level and over the sea. Storms in N China originate higher up in the air on the mainland across which they move, and they do not appear to increase in strength so quickly as the typhoons, when the centre reaches the sea. Islands—even Formosa with its high mountains—do not affect a typhoon's path much though they tend to break the typhoon up, to some extent, as is particularly noticeable in case of typhoons remaining long over the southern Philippines or crossing Formosa moving from S towards N. On the contrary, open channels such as the Balingtang Channel, the Formosa and Korea Channels, have much greater effect on the path. It has already been remarked that the progression of a typhoon is the effect of the wind prevailing at the time at or near the earth's surface. Now, the wind rushes with such force through open channels, with more or less high mountains on both sides, as to deflect the typhoons and accelerate their speed. This is sometimes seen in the China Sea, when the centre of a typhoon is moving slowly northwards. As soon as the centre approaches the latitude of the Balingtang Channel, the centre bends its way suddenly to the Westward, and rushes towards Hainan perhaps thrice as quickly as it moved before. Typhoons entering the Formosa Channel and at times the Korea Channel are deflected to the Westward and have their speed accelerated by the strong NE winds in those Channels. As long as the SW monsoon is strong, the typhoons move in some Northerly direction. It is only late in the year when the NE monsoon happens to blow very fresh that typhoons move South-westward in the China Sea.



Typhoon in the Formosa Channel
1884 August 21-22.



Typhoon of July 17
1890

The average rate of progress of the centre of a typhoon in 11 deg. latitude is 5 miles an hour. In 13 deg. it is 6½. In 15 deg. it is 8. In 20 deg. it is 9. In 25 it is 11. In 30 deg. it is 14, and in 32½ it is 17 miles an hour. South of 13 deg. the speed does not vary perceptibly, so it is useful for mariners to know it, but it is more variable the farther north you go. In 32½ deg. N it ranges from 6 to 36 miles an hour, so that you cannot be sure that a typhoon encountered there will travel at anything like the average rate of speed. We have not traced the centre of a typhoon nearer to the Equator than about 9 deg. N. But a very slightly falling barometer, a squally SW wind, a lumpy sea, and some swell, may at times be traced nearly all the way down to the Equator.

The prevailing wind not only carries the centre along with it, but combines with the rotary storm, causing the wind in the right-hand (the dangerous) semi-circle to be stronger and to blow more nearly round the centre than in the left-hand (the manageable) semi-circle, where the wind is more moderate and blows with greater incurvature towards the centre. It also causes the wind to blow nearly straight in towards the centre behind the typhoon and to blow more across the path in front of the centre. It also makes the weather heavier after the centre is past than it was while the centre was approaching.

Less than half a mile up in the air the incurvature of the wind towards the centre disappears in the average of the different quadrants, but it still blows in towards the centre in the rear. It is really the wind at this altitude that carries the typhoon along, for late in autumn there are every year typhoons that move along against the NE monsoon, but we know that that monsoon is at times very shallow and there is SW wind above it. These typhoons disappear sometimes suddenly; evidently when the NE monsoon increases in depth and intensity.

At a still higher level the air, which has been carried in towards the centre and raised over the area where it is raining, blows away from the centre, and as the friction of air against air under low pressure is insignificant, it sometimes rushes away with such speed as to cause the upper air to be sucked down into the central calm. This is the reason why the sky clears over the bull's-eye.

Typhoons originating in the Pacific in a low latitude (say 13 deg. N) are very small and very fierce. The isobars are nearly circular, as the centre moves very slowly, and the incurvature is 45 deg. in all directions; but there is this important difference between a typhoon and a tornado—that the latter is taller than it is broad, whereas the former forms a flat disc. As typhoons reach a higher latitude their dimensions become greater, the violence of the wind near the centre abates, and then there is nothing to distinguish them from storms originating in northern latitudes. This makes it most unlikely that the latter originate from causes at all different from those which give rise to a typhoon.

§ 2.—HOW TO MANAGE YOUR SHIP IN A TYPHOON.

Long before the nature of hurricanes was understood it had been remarked by mariners that it was safer to heave to in a storm than to run, but the reason of that was not apparent. When the law of storms was first discovered it did not all at once mend matters, for, according to the old eight-point rule, all you had to do when a typhoon approached was to run with the wind on the star-board beam under as much canvas as your ship could carry, except when on the path right in front and the centre moved quicker than the vessel. That should have taken you out of the neighbourhood of bad weather, but it did not always do so, and since typhoons have been investigated, we know that the wind never blows round the centre in a circle, and that the eight-point rule, laid down by Redfield, Reid, Thom, and Piddington, is very far from the truth. It is just as much out as Espy's rule, according to which the wind blows always straight towards the centre. According to the twelve-point rule, which I have proved to obtain in typhoons (see "Observations and Researches made at the Hongkong Observatory in 1885") you must still run on the starboard tack, but you must keep the wind only four points from the stern. A steamer can do so easily enough, but it is not possible to keep a vessel going ahead under square sails nearer than about six points to the wind. She therefore cannot within two points run straight away from the centre and her risk is much greater than it would be if the old rule had proved true. The twelve-point rule may be stated as follows:—Stand with your back to the wind and you will have the centre on your left and about four-points in front of your left-hand. It appears that a ten-point rule obtains in about 30 degrees latitude and a sailing vessel can then just manage to steer, full and by, a course that will take her straight away from the centre; but in a tropical hurricane we see that the danger is much greater even if the force of the wind were not stronger.

The force of the wind and the appearance of the weather do not furnish a trustworthy guide to determine the distance of the centre of a typhoon. The dimensions are different in almost all typhoons, and near land the strong winds are often so irregularly distributed that in a place near the centre less wind may actually be experienced than at some distance farther away from it. In such cases the approach of the centre is judged of by the fall of the mercury in the barometer. But on the high sea the increase or decrease in the strength of the squalls, and the state of the weather and sea, enable the approach of the centre to be known, and this, together with its direction which is known from the direction of the wind and perhaps also from the clouds, enables the master of a vessel at sea to lay down the path of the typhoon, with reference to his vessel, with more or less accuracy. The great difficulty is, that the typhoon may be increasing or decreasing in violence and the barometric depression getting steeper or filling up. To the eastward of the Philippines and near their western shores the former is likely to take place, while the latter would probably happen near the western shores of the China Sea. In such cases it may become more or less impossible for a seaman to know how the centre moves, except in so far as he can judge by published paths of previous typhoons.

Once the bearing of the centre has been ascertained from the direction of the wind, you require to know in which semi-circle your vessel is situated: if in the right-hand semi-circle the wind will veer, *i.e.*, shift with the sun, and in the left-hand semi-circle it will back, *i.e.*, shift in the opposite direction. But this rule fails if your vessel is moving with the typhoon and quicker than the centre is moving. Then the rule may be reversed. Masters of vessels are therefore advised to heave to early and observe how the barometer behaves and how the wind changes; but it is so dangerous to lose any time in a storm that carries you into the centre, that this should not be done except when absolutely necessary. You may happen to be right in front of the centre and lose your chance of getting out of its track. Here it is that a knowledge of the paths of past typhoons such as have been annually published from this Observatory during the past fourteen years, becomes so useful. That may enable you to know at once in which semi-circle your vessel is situated, *e.g.*, with NE wind in the China Sea you are pretty certain to be in the right-hand semi-circle. The wind shifts faster the nearer the centre you are, but the direction of the sea does not change so fast as the wind. If the bull's eye of the typhoon overtakes your vessel, the wind bursts again from the opposite quarter, and with perhaps greater violence than before, that is, when the centre is past. Very deceitful lulls occur during the raging of a typhoon and last sometimes long enough to be mistaken for the central calm, but in such a case the wind bursts again from about the same direction as before.

The rate at which the barometer falls depends upon your approach to the centre, and in consequence upon the rate at which the latter is travelling. You cannot therefore safely draw conclusions concerning the amount of wind to be expected from the rate at which the barometer is falling, but to some extent that may be done. Remember that at sea when the barometer has fallen to the lowest point and is beginning to rise again, you may expect as much, if not more, bad weather than you have already gone through although it will be, on the whole, improving.

The right-hand semi-circle is called the dangerous semi-circle; there you are carried not only in towards the centre, but also towards the path in front of the centre; besides, the force of the wind is greatest in the right-hand semi-circle, but fortunately the wind usually veers in the squalls in the same direction as it veers with the progress of the typhoon. Here you must make up your mind at once which of the following courses open to you you will choose :—Either heave to on the starboard tack (if there is no chance of the centre approaching too near) which will allow your ship to come up to the wind and not be taken aback; or (if in the front quadrant of the dangerous semi-circle) run across the path in front of the centre into the left-hand semi-circle. The incurvature of the wind is less in front of the centre than behind (except in some exceptional case when a typhoon is moving against the monsoon). That helps you to cross the path, and you can run with the wind on the starboard quarter, three points from the stern. If you are within a point, or even two, of the path of the centre, it is generally quite impossible to know in which semi-circle you are, as the wind does not change much, and such change as there is takes place very often in a misleading way. In that case it is decidedly wrong to heave to. Run at once. It may, of course, also happen that you can run close-hauled on the starboard tack if that shortens your voyage and if you have reason to think that the centre will not come down on you.

The left-hand semi-circle is called the manageable or the navigable semi-circle. Here you are carried more straight into the centre, but at the same time the wind carries you towards the path behind the centre, where the danger is less, and moreover the force of the wind is not so great in the manageable as in the dangerous semi-circle. On the other hand, the wind does not always change in the same direction as the squalls. In this semi-circle you can run close-hauled with the wind on the starboard tack, but must heave to on the port tack, so as not to be taken aback when the wind backs. Therefore you cannot run so long in this as in the other semi-circle, or you may not be able to wear your ship, and when you heave to on the wrong tack, you run great risk of being dismasted or having your vessel thrown on her beam ends, when you may have to cut away the masts to right her, although they may not go clean overboard. They will not do so unless all the shrouds and ropes were cut before the mast went, and your vessel may have her bottom stove in when she clears them after they have gone overboard and she is drifting to leeward. A dismasted ship is carried round the typhoon and into the centre in a spiral course. Many a sailer has been lost through being on the wrong tack in a typhoon and, as explained above, you have not always the means of knowing with certainty which tack to choose.

All this is on the supposition that you have ample sea-room, so much the more as your dead reckoning may be very much out when navigating in a typhoon. Sometimes a master does not know where he is within a hundred miles. It is no unusual thing for a vessel caught in a typhoon in the China Sea, where dangerous shoals abound, to be carried sixty miles out of her course before it is possible to take sights. Lee-way, strong currents, and uncompensated heeling errors account for that. Heave the lead as often as possible.

When running to the southward across the path of a typhoon moving westward, you will most likely be to the eastward of your dead reckoning from the effect of uncompensated heeling error, but this is not always so. If the permanent magnetism of your ship has been properly corrected by permanent magnets, including a vertical magnet to correct the permanent vertical magnetism, and if the induced horizontal magnetism has been corrected by Airy's soft iron balls, and if the induced vertical magnetism has been corrected by a Flinders' bar, then the heeling error ought to be nearly insensible. But, on the other hand, if the semi-circular deviation arising from induced magnetism has been corrected by permanent magnets, then the heeling error may be considerable, say, one point, which may carry you as much as 40 miles out of your dead reckoning in a day. When on the magnetic equator, where there is no vertical force, you should always adjust your permanent magnets. It is better to remove Flinders' bar while that is being done, as it may chance to interfere somewhat by acting as a short horizontal soft iron bar.

When hove to on the proper tack you should, if you are on board a steamer, keep the engines going ahead dead slow and use oil to calm the sea and prevent it from breaking on board. A small steamer, with insufficient engine power, may resort to a home-made deep-sea anchor. A steamer sometimes rides most easily when stem straight on towards the sea, a position by all means to be avoided by a sailer, who must be kept four points from the wind. Some mariners are in the habit of heaving to stern to wind and sea, or even lashing the helm amidship and allowing the ship to select its own position: that will not do in a typhoon, where a vessel so handled would quickly be carried in towards the centre.

A great deal now depends upon how you are laden. Much has been said against overloading, but quite as many vessels have been lost for lack of ballast or from shifting ballast, as from overloading. A heavy roller might possibly even be safer than a vessel that keeps very steady from having its centre of gravity high up near the metacentre and consequently little stability. With regard to trim, a vessel behaves usually best on even keel. If she is down by the head she steers badly, and if she is down by the stern, the wind and sea may throw her head off to leeward. A vessel with a hurricane deck has a great advantage over those with solid bulwarks. If in soundings, and she will not come up otherwise, you must clubhaul her, in order to get her head to wind, but it should be sufficient to pay out a hundred fathoms of chain or upwards in order to prevent her from falling off into the trough of the sea. A sailing vessel may when drifting before the wind pay out a long hawser astern but it would be dangerous to try that on board most screw-propelled steamers, as the hawser might foul the screw, when the vessel is pitching in a high sea. When a typhoon is blowing you can not set the spanker to get her up, as the sails are usually blown clean out of the gaskets. Extra strong storm-staysails are carried till they blow away, in order to steady the ship. A sailer usually behaves better than a steamer, as even under bare poles she has enough tackle aloft to offer resistance to the wind and keep her bows out of the water. Should the masts go overboard, a sailer, in proper trim, has still a better chance than a steamer, when her deck is swept by the seas, as the hatches may be more easily kept battened down than on board a steamer with its engine-room skylights, etc., but the way of battening down hatches leaves much to be desired. In 1886 I suggested that they should be screwed down like the covers of the portholes, and you ought not to trust to wedges or even to chains. Lately this suggestion has been taken up, at the Shipmasters' Society, London. Any vessel labouring in a mountainous cross sea near the centre of a typhoon is, however, in a most helpless condition. By that time there is nothing further to be done. It must therefore be your aim to avoid that contingency.

The most dangerous typhoons have been encountered in the Pacific in a low latitude, say 12°, and 130° or 140° longitude. They are so small there and move so slowly that it ought to be easy to avoid them on board a steamer. They move WNW-ward, and you are safest to the SE-ward of them. You can see such a typhoon coming up in the shape of an arch at first perhaps whitish in appearance, but soon developing into a dark and threatening cloud. Its dark appearance and the extreme slowness of its motion,—in fact it does not appear to move at all,—distinguishes it from an arched squall, which is moreover often brighter in the centre. If the direction of the motion of the clouds in it is seen to be nearly perpendicular to the bearing of the top of the arch, then there is no doubt that it is a typhoon. Even in Hongkong I have seen a typhoon approach like that.

If after leaving Singapore bound for Hongkong in the SW, monsoon, you find that the barometer falls more than it ought to, the monsoon begins to freshen in squalls, and you notice a cross swell, a lumpy sea, and other signs of a typhoon, then you ought to shape your course to the south-eastward, so as to sail round the centre and benefit by the favourable SE wind behind the centre. But if the season is late in the year, you had better make sure that it is not travelling south-westward, in which case you may be overtaken by the cyclone. Such typhoons are often the cause of high seas in the Gulf of Siam, but as their progressive motion is usually slow, you can "heave to" in order to make observations without losing ground perceptibly. Up to within the last few years steamers often kept their course and travelled from the navigable into the dangerous semi-circle, where they suffered great damage and delay. But that happens seldom now.

If after leaving Hongkong bound for a northern port you fall in with a typhoon coming through the Bashee Channel, and moving NW-ward into the Formosa Channel, you ought to run to the southward, and if bound for Yokohama you may afterwards shape a northern course along the east coast of Formosa, where the Kuro Siwo current occasionally sets fast towards the NE. As the typhoons are nearly always moving northwards you are usually safest to the S or rather SE of the centre.

Ships between Foochow and Ningpo are liable to experience the NW gales that precede a typhoon travelling westward and about to strike the coast in that neighbourhood. If you do not like to expose your vessel to the high confused seas round northern Formosa, you should run into shelter early, and wait there till the barometer rises and the weather improves and the tide allows you to get out again.

Between Shanghai and Japan you are liable to fall in with a typhoon travelling in any direction between WNW, N and E. You are therefore safest to the S of the centre but that may be in the dangerous semi-circle and the wind is strongest there. North of this latitude you would prefer to be W of the centre. Near Japan most typhoons move NE-ward. They generally travel quickly and do not give so long warning as further south. In these typhoons you cannot know in which semi-circle you are till the wind shifts. They are as a rule not so violent as within the Tropics, though sometimes they are just as bad, but the incurvature is not so great.

You all know that though typhoons are dangerous on the open sea, they are still more to be feared in open anchorages and near lee shores, such as in Formosa, where you must be ready to run to sea at very short notice, as you could not lie there with any chance of riding out a typhoon, except in the inner harbour of Takow. When you then experience a N gale and a failing barometer, by far the surest signs of an approaching typhoon, and appearances quickly get worse, you must run to the SW with the N gale and bring your ship into a most dangerous position in front of the centre (unless there is time to cross the path) rather than remain at an unsafe anchorage. When at anchor up against a lee shore there is not only danger of being thrown on the shore, but also danger of going down at your moorings. The waves running into shoal water are at first very much increased in height, the slope along the wave-front gets steeper, and when in the hollow of a wave that may be forty feet below the crest, there is a chance of having the bottom knocked out of a vessel, except when the ground is soft mud. Waves on the open sea do not exceed thirty feet in height, measured from crest to hollow, but still it is not known how high they rise in a cross sea near the centre of a typhoon.

A knowledge of typhoons and their paths is often required when you have to decide whether to remain at your moorings or to slip your cable and run: for instance a vessel between Hongkong and Swatow in an anchorage sheltered against N and E winds will be safe while a typhoon is moving from E to W across the China Sea, but should the centre move northwards the vessel might be thrown on a lee shore when the wind backs through W to S.

A steamer at anchor, when a typhoon is approaching, should get up steam and a sailer should, if possible, take down the top masts as soon as it blows a fresh breeze in the squalls. With reference to a sailing vessel the time when to begin striking the top masts must, of course, depend upon the extent to which she is undermanned. Striking the masts increases the rolling. A sheltered anchorage must be selected, and when the centre passes very near, the berth may have to be changed to the other shore before the wind shifts to the opposite quarter, but along the China coast it does not blow so hard after the centre has entered the mainland as before. A vessel moored by single anchor will swing with the sun in the right-hand semi-circle, and against the sun in the left-hand semi-circle. If two anchors are dropped, the anchor on the advancing bow should be let go first. Therefore a vessel in the right-hand semi-circle should first drop her port, and afterwards her starboard anchor, so as to ride with open hawse, and a vessel in the left-hand semi-circle should first drop her starboard anchor. But now it is usual to ride to a single anchor with a scope as long as possible,—over a hundred fathoms should be paid out,—as the strain on two cables at a great angle is more or less increased, and very irregular owing to the labouring of the vessel in the high sea. A second anchor is paid out in line with the first to veer upon if the first should not hold, and a third anchor is kept ready. A vessel depending upon a single anchor, or upon two anchors dropped at an angle, may go ashore if a link should break. The engines can be kept going ahead dead slow unless the steamer is too light, so as to relieve the anchors, but as this increases the irregularity of the strain, you had better stand by, so as to start the engines whenever necessary. Shallow river boats pay out cables on either side so as to help the vessel to keep upright, but at the same time they must have a single anchor paid out ahead to ride to, for no cable at a great angle could stand the strain caused by a typhoon.

A vessel in ballast steaming ahead dead slow may at times entirely relieve the strain on the cables and then fall off into the trough of the sea. Should then a squall strike her broadside, she is pretty sure to drag her anchors or even break a link in her cable and go ashore. It is therefore of no use turning the propeller slowly if she is light, and especially not if she is down by the stern, as it only increases the yawing and dragging.

With reference to typhoon anchorages in China beginning with Hainan, we have Backli bay (19° 7′ N. 108° 39′ E.) with shelter against winds between NNE. and S. only. It is not a very good harbour, and the natives are not to be trusted. In southern Hainan we have Yulinkan bay 18° 12′, 109° 33′), an excellent typhoon harbour in case the centre is to the S. of Hainan, as often happens. Gaalong bay (18° 13′, 109° 34′) may also be used. Maniu harbour (19° 57′, 109° 52′) can be used when the centre is to the north of Hainan. Hunghom bay (20° 17′, 110° 23′) is shallow and is not often used except when no better place is within reach. Hui-ling-san (21° 34′, 111° 47′) and Namo harbour (21° 35′, 112° 34′,) are available between Hainan and Hongkong. Near Hongkong is the excellent harbour by Saint John's Island (21° 40′, 112° 42′,) which is commonly used. Vessels of great draught anchor to the S. of the position given. Tongku harbour (22° 35′, 113° 55′) is used in case of typhoons crossing the China Sea. It offers no shelter against W. winds. This is at the mouth of the Canton River. Higher up the river ships anchor under the Bogue forts although typhoon centres pass over that spot, but then it does not blow so hard as out at sea, when the centre is inland. Inside the Capsingmoon pass to the W. of Mahwan is shelter against typhoons, but Chingwan bay (22° 22′, 114° 6½′) is one of the best harbours in China. In consequence it is too crowded during a typhoon. To the NW. of Stonecutter's Island (22° 20′ 114° 8′) launches find shelter. Tytam bay to the S. of Hongkong is an excellent harbour. Deep bay (22° 17½′, 114° 16′) gives better shelter than Kowloon bay (22° 18½′, 114° 13′) but some vessels prefer the latter as the storm-signals can be seen from there. A position between Taipintong and the Channel Rocks makes the best anchorage. Mirs bay (22° 33½′, 114° 27′) under Pengchau offers shelter to vessels bound for Hongkong from a northern port. Between Mirs bay and Swatow there are no very good typhoon harbours, but shelter may be found against NE. winds. By Namoa Island (23° 28′, 116° 57′) is excellent anchorage. Tongsang harbour (23° 47′, 117° 35′) is much used, and also Amoy harbour. Makung harbour (23° 32′, 119° 33′) by the Pescadores is excellent. In Pihquan harbour (27° 10′, 120° 31′) there is good shelter against NE. winds to vessels under 15 feet draught. The Haitan Straits (25° 26′, 119° 44′) are very much used. There are several anchorages round Chusan. In Luzon there is an anchorage at the entrance to Manila bay, N. of Corregidor Island (14° 25′, 120° 33′). On the S. coast of Mindoro we have Garza bay (12° 13′, 121° 11′).

§ 3.—WEATHER-FORECASTS AND STORM-WARNINGS ISSUED FROM THE HONGKONG OBSERVATORY.

WEATHER-FORECASTS AND STORM-WARNINGS.

METEOROLOGICAL SIGNALS.

Meteorological Signals are hoisted on the Mast beside the Time-Ball at Kowloon Point for the information of Masters of Vessels leaving the Port. They do not imply that bad weather is expected here.

A DRUM ■ Indicates a Typhoon to the East of the Colony.

A BALL ● Indicates a Typhoon to the West of the Colony.

A CONE ▲ *Point Upwards* indicates a Typhoon to the North of the Colony.

A CONE ▼ *Point Downwards* indicates a Typhoon to the South of the Colony.

RED SIGNALS indicate that the Centre is believed to be more than 300 miles away from the Colony.

BLACK SIGNALS indicate that the Centre is believed to be less than 300 miles away from the Colony.

NIGHT SIGNALS.

TWO LANTERNS Hoisted Vertically indicate bad weather in the Colony and that the wind is expected to veer.

TWO LANTERNS Hoisted Horizontally indicate bad weather in the Colony and that the wind is expected to back.

The Signals are repeated on the Flagstaff of the Godown Company at Kowloon, and also, by day only, at the Harbour Office and on H. M.'s Receiving Ship.

LOCAL STORM-WARNINGS.

The Colony itself is warned of approaching Typhoons by means of the TYPHOON-GUN placed at the foot of the Mast, which is fired whenever a strong gale of wind is expected to blow here.

NOTICE BOARDS.

Observations made at 10 a.m. and 4 p.m. are exhibited shortly after 10 a.m. and 4 p.m. on Notice Boards placed at the Eastern Extension, Australasia and China Telegraph Company's Offices, at Peddar's Wharf, at the Harbour Office, and at the Office of the Kowloon Godown Company.

Weather-forecasts and Storm-warnings are exhibited daily about 11 a.m. and also at other hours, day and night, whenever necessary while Typhoons are raging in the Far East.

The China Coast Meteorological Register is exhibited about Noon (Sundays and Government Holidays excepted).

THE LAW OF STORMS.

Further information concerning the weather to be expected while signals are hoisted, and sailing directions, are given in "The Law of Storms in the Eastern Seas."

Shipmasters may obtain by telegraph the latest information as to weather at any station reporting to this Observatory by payment for a reply of at least ten words (*i.e.*, twelve words including the address). Application may also be made for similar information to be telegraphed on some future specified day.

When the red drum is hoisted the weather is generally fine in Hongkong, and settled fine if the centre moves northward, so that this signal does not by any means imply bad weather here. Steamers bound for northern, western or southern ports should then lose no time in starting, as they may expect more or less fine weather. Those bound for the Philippines should take precautions to avoid the cyclone as explained above. Sailing vessels bound for western or southern ports should lose no time in starting, but those that are bound for the north or east ought to remain in the harbour awaiting information, as they may expect to fall in with calms or contrary breezes after starting, even should the wind be westerly here at the time.

More or less persistent SW winds, at times accompanied by thunderstorms, may be expected when the red cone pointing upwards is hoisted, and ships leaving the port are not likely to run any risk from the typhoon. Sailing vessels bound for the north should start as soon as possible so as to benefit by the southerly breezes to run through the Formosa Channel, and avoid the way round Formosa. By following the latter route a sailer, moreover, runs the risk of falling in with the next typhoon east of Formosa, particularly during the months of August and September.

A cone pointing downwards usually implies fresh E veering to SE winds in Hongkong. As such a typhoon may travel N and NE, the master of a vessel desirous of avoiding bad weather should consult the latest weather-intelligence or remain in port till the barometer rises. Then the danger is past.

When a ball is hoisted ships starting for northern, eastern, or southern ports may expect breezes from E round to S and SW. Those starting for western ports run no risk as long as the glass continues to rise. Should it ever happen to fall: heave to and, if necessary, take refuge in a typhoon anchorage such as Saint John's harbour.

Mr. FIGG has analysed his weather-forecasts for 1896 with the following results:—

The results for wind direction, force, and weather are treated separately in the first instance. The forecast wind direction is considered successful if the wind at Gap Rock blows the greater part of the 24 hours from a direction that does not differ more than 45° from the forecast (93 % were successful). Forecast wind force: "light," is successful if the mean force registered at Gap Rock is a light breeze, or if the wind force does not reach the force of a moderate breeze; "moderate," if the mean is a moderate breeze, or if the wind force exceeds a light breeze and falls short of a strong breeze; "fresh," if the mean is a fresh breeze, or if the wind force exceeds a gentle breeze and falls short of a moderate gale; "strong," if the mean is a strong breeze, or if the wind force exceeds a moderate breeze and falls short of a fresh gale; "gale," if it blows more than 40 miles per hour at Gap Rock (93 % were successful).

The weather is successful when "fine" is forecast if the mean amount of clouds is below 7-tenths of the whole sky, if sunshine or starlight prevails, and when it does not rain more than one hour out of twenty-four; when "fair, cloudy," if the amount of clouds exceeds 3-tenths and it does not rain more than one hour; when "showery," if it rains at intervals and is fair at intervals; when "wet, rainy" if it rains more than 4 hours (77 % were successful). Counting days on which all three elements were correctly forecast as "success," those when two elements were justified and one failed as "partial success," those when one element was justified and two failed as "partial failure," and those when all elements failed as "total failure," we have:—

Success 67 %, partial success 30 %, partial failure 2 %, total failure 1 %.

Following the method used in meteorological offices and taking the sum of total and partial success as a measure of success, and the sum of total and partial failure as a measure of failure, we find finally that:—

97 % of the weather-forecasts were successful.

The amount of success attached to the firing of the typhoon gun to indicate local gales has been determined according to the method adopted at meteorological offices at home. According to this method of counting, the storm-signal is justified if followed by a gale of force 8 and upwards within 48 hours at a place near sea-level within 50 miles of the place where the signal is hoisted. It is a failure because "too late" if it blows a strong gale (force 9) before the signal is hoisted. According to this way of counting, a failure has to be recorded every time the gun is not fired during the winter for a "Norther," although we did not presume to forecast those.

The typhoon gun has been fired 27 times one round, since the Observatory was started on the 1st January, 1884, *i.e.*, during the past 13 years. During the same period it has 30 times blown a gale of force 8 and upwards: Once in February (norther), once in June (typhoon), 5 times in July (typhoons), 3 times in August (typhoons), 11 times in September (typhoons), 7 times in October (typhoons), and twice in December (northers).

There was 75% of success counting all the gales and all the times the gun was fired, or 83% of success if the "northers" be left out of account. This compares favourably with the percentage of success in the British Isles 58% only of which are justified by subsequent gales of force 8 and upwards (mean of the 10 years 1884-93 inclusive). This leaves out of account the fact that in those isolated instances, where the gun was not fired, warning was given by notices issued and of late years, by lanterns hoisted.—During the first eight years the gun was fired when the wind blew 37 miles per hour on an average, while during the past four years it was fired when the wind blew only 27 miles per hour on an average. This shows an improvement with the increase of staff in the Observatory that took place in the meantime, and with the increase in the number of telegraphic reporting stations. Detailed particulars concerning every typhoon that occurred during the past thirteen years and every warning issued have been published in the "Government Gazette" and in the "Observations and Researches" issued yearly from here.

Instructions for keeping the Meteorological Log.

Observations should be made every four hours, and the latitude and longitude of the vessel should be entered at each observation.

If convenient an observation should be made in or near Hongkong.

Observations are required between 10° South and 45° North latitude and between Singapore and 180° E of Greenwich.

When a mercurial barometer is read the thermometer attached to it is also entered.

When an anëroid is read no thermometer reading should be entered.

Force of wind is given from 0 to 12, and weather in Beaufort's initials.

For further particulars the "Instructions for making Meteorological Observations prepared for use in China" published in 1883 by the writer, may be consulted.

The forms are forwarded free through British Post Offices in China if addressed on service. They should be posted as soon as convenient after the vessel enters Hongkong harbour. Vessels bound for London from ports in the China Sea should post the forms in Singapore.

In 1896 the total number of days' observations made on board 325 ships and forwarded to this Observatory was 18,541 (counting separately those made on board different ships on the same day).

The surest of all warnings is furnished by the standard barometer on shore and the compensated anëroid on board ship; you are all right if you can put your vessel on the tack that will keep your barometer rising. But in order to understand the indications of the barometer you will have to keep a regular meteorological register. The master of a vessel who does not look at his anëroid till he is in a typhoon, does not derive half the benefits from his observations that he would have enjoyed had he watched it beforehand. He might perhaps have avoided the weather he is now experiencing, or even have benefited by the favourable winds and sailed round the typhoon. No doubt, the time is approaching when underwriters will stipulate that the indications of an anëroid or a marine barometer must be regularly registered on board a vessel insured by them.

On the other hand it would not be fair to ask the mariners to keep complete meteorological records, such as are kept in the lighthouses out here. Some seamen have a taste for this kind of work and make very useful and fairly accurate observations, but, for instance, the readings of dry and damp bulb thermometers taken on many vessels are of very little use.

The tube of the marine barometer has to be so much contracted to stand the incessant pumping and danger of breakage, that the instrument is sluggish and often reads half an inch or more too high near the centre of a typhoon. Some cheap wooden barometers cannot be registered below a certain height, the cistern being too small to hold the mercury that comes out of the tube and there is the great objection to wooden mercurial barometers that the readings cannot be accurately reduced to freezing point and the temperature correction is larger than in case of instruments made of brass. Of course, some cheap anëroids are no better, and even a first class compensated instrument requires to be thoroughly verified, as the scale is never quite correct and the readings depend somewhat upon the temperature and in a manner different for each single instrument, so that general tables for correcting to freezing point are not available, but they act more quickly than the marine barometer, and for use on board ship the instrument that is quickest in its indications must be preferred. The objection to the use of the anëroid is founded on the fact that its index-correction changes gradually; but then this can be determined and allowed for by reading it off as often as the vessel enters a port, such as Hongkong, where correct meteorological observations are constantly being made.

The best hours for making observations are 4 a.m., 8 a.m., etc., up to midnight inclusive.

From 4 a.m. to 10 a.m. the barometer is rising, falling from 10 a.m. to 4 p.m., rising from 4 p.m. to 10 p.m., and falling from 10 p.m. to 4 a.m. It reads highest at 10 a.m. and lowest at 4 p.m. The daily variation is twice as great in midwinter as it is in midsummer. During the approach of a typhoon this regular daily variation may be masked, but it goes on all the same and must be taken into account when the barometer begins to fall before a typhoon. Thus if it has fallen a certain amount between 10 a.m. and 4 p.m. you must subtract the normal descent between these hours in order to know how much of the fall is due to the approach of the typhoon, and if it were between 4 p.m. and 10 p.m. that it fell, you must add the normal rise for the same purpose.

§4.—ON THE DIFFERENT CLASSES OF TYPHOONS AND THE SEASONS OF THE YEAR IN WHICH THEY APPEAR.

In 1886 I expressed the hope that it might be possible to construct average paths of all the different varieties of typhoons, when a couple of hundred tracks were available. This has just been effected on the basis of 244 typhoons, registered during the past 13 years,—or on an average 19 typhoons per year. They are distributed among the different months of the year as follows: January 1, February 0, March 1, April 4 (2 per cent), May 10 (4 p.c.), June 24 (10 p.c.), July 45 (19 p.c.), August 43 (18 p.c.), September 57 (23 p.c.), October 31 (13 p.c.), November 22 (9 p.c.), December 6 (2 p.c.).

In 1884 I suggested the division of typhoons into four classes (Comp "Observations and Researches made at the Hongkong Observatory in 1884," app. M) but the final arrangement of sub-classes could not then be effected:

Ia α	originate in the China Sea (most frequently near 18° to 20° N and 113° to 116° E) north of 15° N and enter, or at least approach the mainland to the W of Hongkong. 10 p.c. of all the typhoons registered belong to this class. They prevail from the middle of June till the end of September.
Ia β	originate in the Pacific and enter the China Sea north of 15° N and enter, or at least approach the mainland to the W of Hongkong. 12 p.c. of the typhoons belong to this class. They prevail from the beginning of July till the middle of October.
Ib	originate in the Pacific and enter the China Sea north of 15° N, move SW and disappear at sea. Only one or two cases of this kind have ever been registered (late in the year).
Ic	originate in the China Sea and move N, but describle vastly different paths, moving in various directions between W, round by N, to ENE. Sometimes they recurve after entering the mainland They occur from June till the end of September, but they are most common at the beginning of the typhoon season (4 p.c.).
Id	originate in the China Sea, where they recurve, and sometimes move into the Pacific passing near South Formosa. They occur from May till September incl. (2 p.c.).

Typhoons of classes Ia and Ic (26 p.c. of all typhoons) are frequently felt in Hongkong.

CLASS II.

IIa	originate in the Pacific, enter the China Sea north of 15° N, and enter China to the E of Hongkong. There they pass (IIa_1) N, or (IIa_2) W. They occur in July, August, and September (2 p.c).
IIb	originate in the Pacific and move into the Formosa Channel. They occur from June to September incl., and are most common in August and September (7 p.c.).
IIc	originate in the Pacific, pass N of Formosa, and enter China. They occur from June till September, with a distinct maximum in July (3 p.c.).
IId	originate in a high latitude in July and August and move W-ward into China (4 p.c.).

With the exception of IIa_1 which sometimes cause fierce SW gales in Hongkong, typhoons of Class II are not dangerous to this Colony.

CLASS III.

These typhoons originate and rage mainly in the Pacific.

IIIa	enter the coast of Luzon but recurve (usually before the centre enters the China Sea). They prevail in October and November ($1\frac{1}{2}$ p.c.).
IIIb	enter the coast of Formosa but recurve, usually in October (1 p.c.).
IIIc	move N and enter Korea in July, August and September (4 p.c.).
IIId	recurve in the Pacific and enter Japan between June and October incl. They are most frequent in August and September (15 p.c).
IIIe	remain in the Pacific. They occur from May till December incl. Their average latitude decreases on the whole with the altitude of the midday-sun, 10 p.c. of all the typhoons registered belong to this class, but there must be many that are not met by ships and therefore not registered. Their prevalence may be estimated at $12\frac{1}{2}$ p.c.).

CLASS IV.

IVa α	originate in the China Sea south of 15° N and move towards Hainan and Annam. They occur from May till December incl., but are rarely encountered in August ($8\frac{1}{2}$ p.c.). In November they often originate in about 11° N and 116° E.
IVa β	originate in the Pacific and enter the China Sea south of 15° N. They are less common than those originating in the China Sea, as the long passage across the southern Philippines tends to break them up. They occur at the beginning and end of the typhoon season (3 p.c.).
IVb	enter the China Sea after crossing the Philippines in a low latitude, and then move SW and disappear at sea. They occur from the beginning of September till the beginning of December, but are most common in November ($4\frac{1}{2}$ p.c).
IVc	recurve in the China Sea and re-enter the Pacific. They occur at the beginning and end of the typhoon season but mostly in May (4 p.c.).
IVd	occur in the Gulf of Siam in April and December (1 p.c.).

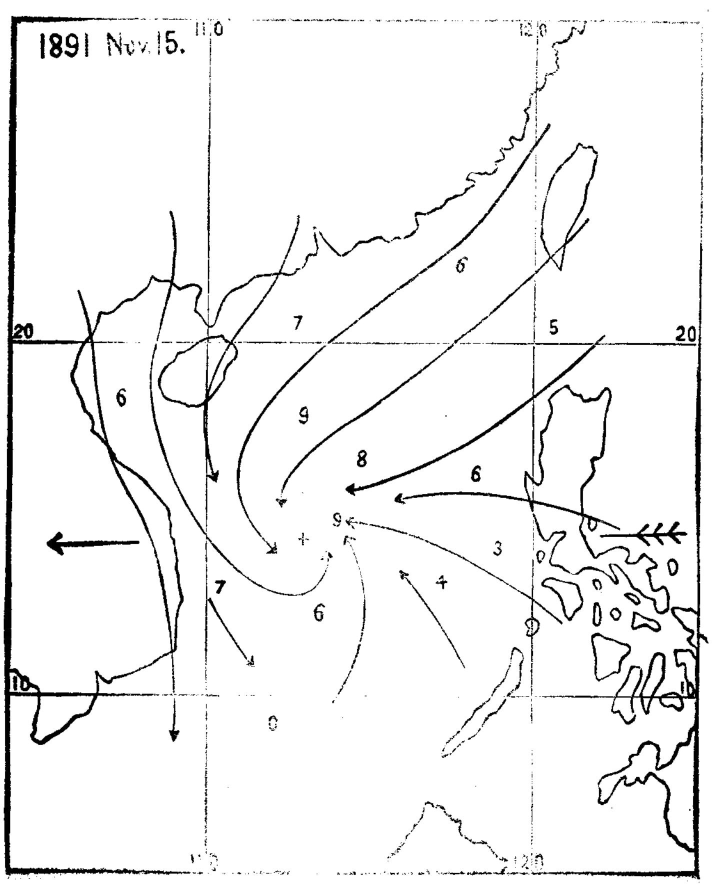
The accompanying plate illustrates the average paths of these different kinds of typhoons. The average rate of progress in 24 hours is also marked, but it must be remembered that individual typhoons move in very irregular orbits, whose vagaries have disappeared from the average paths. Also they travel at very different rates. It is presumably as useful to the travelling public, and the freight-carrying public to know where and when typhoons prevail, as to the weather-forecaster, who in default of precise observations reaching him by wire, must forecast according to such paths as these.

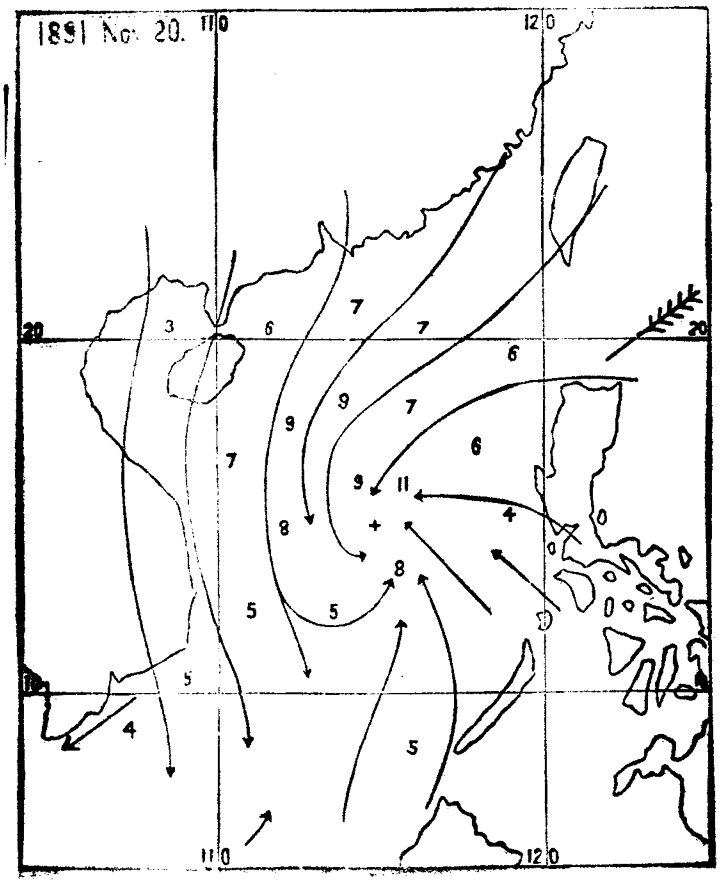
§ 5.—WINTER TYPHOONS IN THE SOUTHERN PART OF THE CHINA SEA.

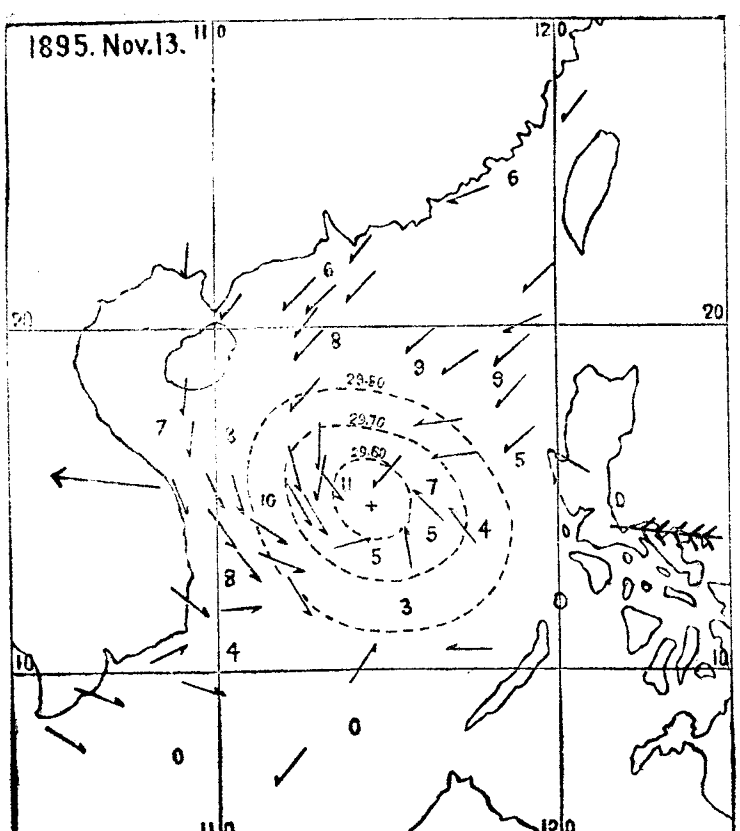
In the typhoons of the summer months,—the SW monsoon period,—which move towards WNW or NW in the N part of the China Sea and enter the coast in the neighbourhood of the Gulf of Tongking, the area over which the winds become strong with a decided fall in the barometer in front of the centre is generally small. This is accounted for by the low pressure prevailing over the Gulf of Tongking and the continent beyond it. For the same reason the winds in rear are not only stronger but also long continued, the more particularly as it seems that depressions on entering the coast frequently become diffused over a large area. In the autumn months (September and October)—the NE monsoon period,—these conditions are reversed and we find that in front pressure begins to give way and strong winds usually blow at great distances, while in rear the area over which winds are governed by the depression is comparatively small. Moreover, at this period the depression fills up rapidly on entering the mainland, which is then dry. In consequence a vessel in front of a typhoon, moving as stated, will usually get much shorter notice of the advance of a typhoon from the barometer in summer than in autumn, and while in summer the bad weather lasts a long time in rear, in autumn it improves rapidly when the centre is past and a strong NE monsoon sets in. For instance, N gales frequently blow late in the season off the Annam and Cochin China coasts with a typhoon centre a long distance off on the E side of the China Sea.

Typhoons of classes IV*a*, IV*b* or I*b* occur especially late in the year in an unusually low latitude over the China Sea, during the height of the NE monsoon which blows much stronger in these seas than the SW monsoon. Taking as an example of such, the typhoons of the 15th November, 1891, of the 20th November, 1891, and of the 13th November, 1895, it is seen that there is very little W, SW or S wind except within perhaps at most 50 miles of the centre. And to the S or SSW of the centre, where SW gales might be expected their place is taken by dead calms or light variable winds. No stronger argument could be adduced to show that the winds round a typhoon-centre are composed of the cyclonic winds on one hand and the prevailing wind on the other. In these cases where the cyclonic SW gales are combined with the NE monsoon gales, calms are the result. Unfortunately, I have not succeeded in drawing the isobars, as the anëroid observations on board ship are too rough to be of much assistance for this purpose, and the currents are strong, but the isobars might be inferred from the wind-directions laid down on the maps.

When all the wind forces round the centre of a typhoon are resolved into N and E components, positive or negative as the case may be, and the resultant direction and velocity are computed and compared with the direction of motion and velocity of the centre, it is found that the latter moves from a greater azimuth (counting from N) than the wind. This might be expected as it then agrees with the wind at a greater altitude. These November typhoons move from a direction from 2 to 7 points different from the resultant wind. As the NE monsoon is shallow, this probably agrees with the direction of the wind at an altitude of about half a mile, but the speed is only a fraction of the resultant wind velocity.




1891 Nov. 20.
110
120
20
110
120


1895. Nov.13.
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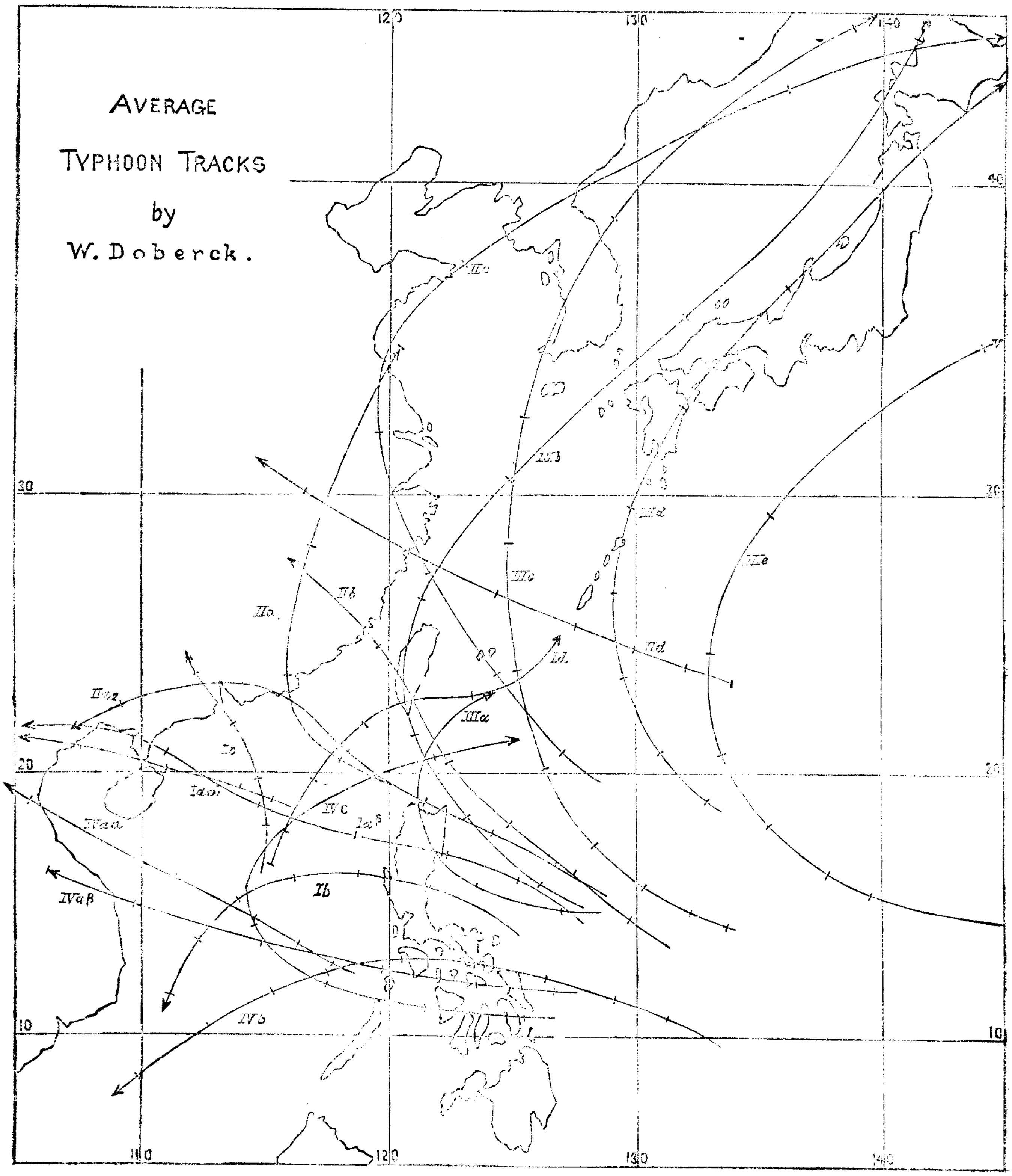
AVERAGE
TYPHOON TRACKS
by
W. Doberck.
120
130
140
40
30
20
10
110
IIb
IIa
Id
IIIa
Ic
Iaα
IVc
Iaβ
Ib
IVaα
IVaβ
IVb
IIe
IId
IIIc