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SURFACE PRESSURE-PATTERNS AND WEATHER AROUND THE YEAR IN HONG KONG

By

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Printed and Published by The Government Printer, Hong Kong.

1953

Price $5

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SUMMARY

The daily weather charts for a period of 20 years are classified into six types. Frequency curves of the occurrence of these characteristic types of surface pressure-pattern show well-marked seasonal variations, which are discussed in relation to the winter and summer monsoons and the transition periods between them. The persistence of each pressure-pattern is examined, together with the frequency of winter monsoon surges. A statistical analysis of the daily weather associated with each pressure-pattern leads to the conclusion that wind and temperature in Hong Kong are closely related to the pressure distribution prevailing at the surface; cloud and precipitation are less closely related, as they are governed to a greater extent by conditions aloft. The relationships of thunderstorms and fogs to the pressure-pattern are also examined. A calendar is given, summarizing the seasonal trends and singularities in the weather in Hong Kong.

1. INTRODUCTION.

Although Hong Kong lies just within the tropics, it enjoys a variety of weather unusual in tropical regions. Seasonal changes are well-marked and are due to Hong Kong's position on the south-eastern coast of the Asiatic continent; the cooling of the great land mass in winter, and its heating in summer, give rise to monsoon winds on a very large scale, which exert a profound influence on the climate of the regions over which they blow.

The diversity of the seasons in Hong Kong is illustrated by a comparison with Honolulu, situated on an oceanic island in approximately the same latitude. In Hong Kong the monthly mean temperature varies between 82.1°F in the hottest month (July) and 59.1°F in the coldest (February)—a range of 23.0°F. In Honolulu the corresponding figures are 78.2°F (August) and 72.0°F (February)—a range of only 6.2°F. The rainfall data for these two places show a similar contrast, Hong Kong having a pronounced wet season in summer and dry season in winter, while in Honolulu the rainfall is fairly evenly spread over the year.

Furthermore, the day-to-day weather at most times of the year in Hong Kong is remarkably changeable for a tropical station. These frequent variations are sometimes due to changes in the upper-air circulation which are not yet well understood; they are also due to the sharp contrasts in surface temperature between mainland and ocean which exist in this region during much of the year, with the result that a change in wind direction will often give rise to a marked alteration in the properties of the air reaching Hong Kong. Rapid and sometimes violent changes in weather are also brought about by the passage of tropical cyclones in summer and autumn.

The march of the seasons has doubtless been familiar to countrymen in South China since earliest times. Although the calendar in common use in China is a lunar one, and is consequently out of step with the sun, the traditional dates for farming operations were long ago fixed in relation to the solstices and equinoxes; as Ramage (1952) has pointed out, the times of planting out and harvesting the two rice crops of South China take full advantage of the normal variations in rainfall around the year.

Features such as the onset of the winter monsoon, the cloudy period in early spring, the beginning of the summer rains, and the occurrence of spells of the summer monsoon, are well known to meteorologists, who have a fairly accurate idea from their individual experience as to when the seasonal changes are likely to take place. The frequency of occurrence of tropical cyclones from month to month has been extensively studied, and the term "typhoon season" is in common usage. Since the introduction of synoptic charts, the surface pressure-patterns characteristic of the different seasons have also been recognized, and their relation to weather is a daily concern of forecasters.

The present paper is an attempt to codify our ideas on the subject by means of a statistical study of the complete cycle of changes in the pressure-patterns and weather around the year. The results of such an analysis, by indicating the probability of occurrence of a given type of weather on a given date, and the times at which seasonal changes may normally be expected, should be more reliable than the local weather-lore and should help to crystallize the experience which individual meteorologists have acquired in the course of their daily work in Hong Kong. Seasonal trends and spells of weather have been the subject of many studies in other countries since the time of Buchan; the methods of analysis used in the present paper follow to a large extent those of Lamb (1950) in his study of the types and spells of weather in the British Isles.

TABLE I—TYPES OF SURFACE PRESSURE PATTERNS.

Type	Surface Pressure-Distribution (Dominant feature affecting Hong Kong)	Surface Wind	Period of Occurrence	Period of Predominance
N. Northerly (Winter monsoon).	Anticyclone over China; pressure usually higher over Tonkin than at Hong Kong.	N'ly, from mainland of China. (Anticyclonic flow).	Oct.—mid-April.	Never predominates.
NE. North-easterly (Winter monsoon).	Anticyclone over China, often extending over the Eastern Sea and S. Japan.	NE'ly, from Eastern Sea and Formosa Strait. (Anticyclonic flow).	Mid-Sept.—May.	30th Sept.-12th Mar.
E. Easterly or South-easterly.	Anticyclone centred E of 130°E and N of 20°N, often with ridge extending to Formosa. Pressure usually lower over Tonkin than at Hong Kong.	E'ly or SE'ly, from Pacific. (Anticyclonic or straight flow).	Whole year.	17th Apr.-17th May.
T. Trough.	Low-pressure trough with axis extending approximately E-W over or to the south of Hong Kong.	E'ly or variable. (Cyclonic flow).	Mid-Apr.—early Oct.	27th May-8th June, 21st Aug-28th Sept.
S. Southerly or South-westerly (Summer monsoon).	Quasi-stationary low-pressure area over China.	S'ly or SW'ly, from China Sea. (Cyclonic flow).	Mid-Apr.—Sept.	9th June-3rd Aug.
C. Cyclonic	Hong Kong within circulation of travelling cyclone.	Any direction. (Cyclonic flow).	May—Nov.	Never predominates.

2. CLASSIFICATION OF SURFACE PRESSURE-PATTERNS.

Analysis of the Charts. The daily weather charts drawn at the Royal Observatory over a period of 20 years were classified; this involved the examination of nearly 20,000 charts. A continuous series of charts was not available, and the periods covered were July 1923 to June 1937, the year 1938, and the years 1946-1950 inclusive; charts were drawn twice a day before the Japanese war, and latterly four times a day. The choice of such a long period ruled out the possibility of including upper-air charts in the analysis, for these were not drawn as routine until 1946.

Types of Pressure-Pattern. It was found that the great majority of surface pressure-patterns over the region surrounding Hong Kong could be classified into six fairly well-defined types. These are listed in Table I, which also gives the criteria used in the classification. It was found that some 99% of the charts could, without unduly stretching the criteria, be regarded as falling under one or other of these six types, or were transitional from one type to another. Actual weather charts representing the different types are reproduced in Figs. 1—6.

Since Hong Kong is sufficiently far from the equator to allow the pressure-gradient to control the wind, it was possible to classify the airflow in the neighbourhood according to the prevailing pressure-pattern. The usual direction of the surface wind and the recent history of the air reaching Hong Kong are shown in Table I for each type. No attempt has been made to label the air masses, or to trace their tracks back to their sources, for this would have greatly complicated the classification.

Types N and NE represent the pressure-patterns associated with the winter monsoon. In type N the centre of the continental anticyclone is often over western China, and there is an outflow of cold dry northerly winds across the South China coast. Type NE is the more usual pattern of the winter monsoon; the anticyclone covers the mainland, and the winds follow the coastline of South China after blowing over the cool waters of the Eastern Sea and Formosa Strait.

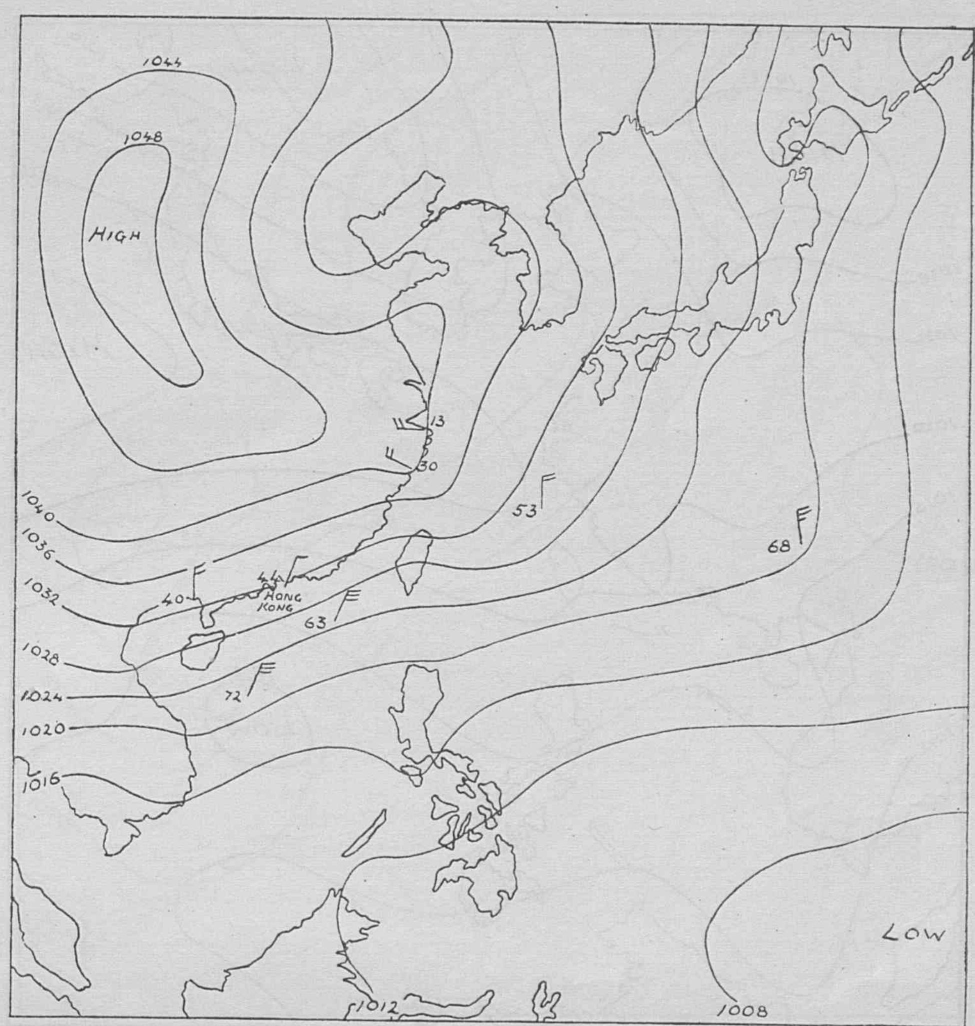

Fig. 1 — Northerly type (N). 00h. G.M.T., 20th December, 1947.

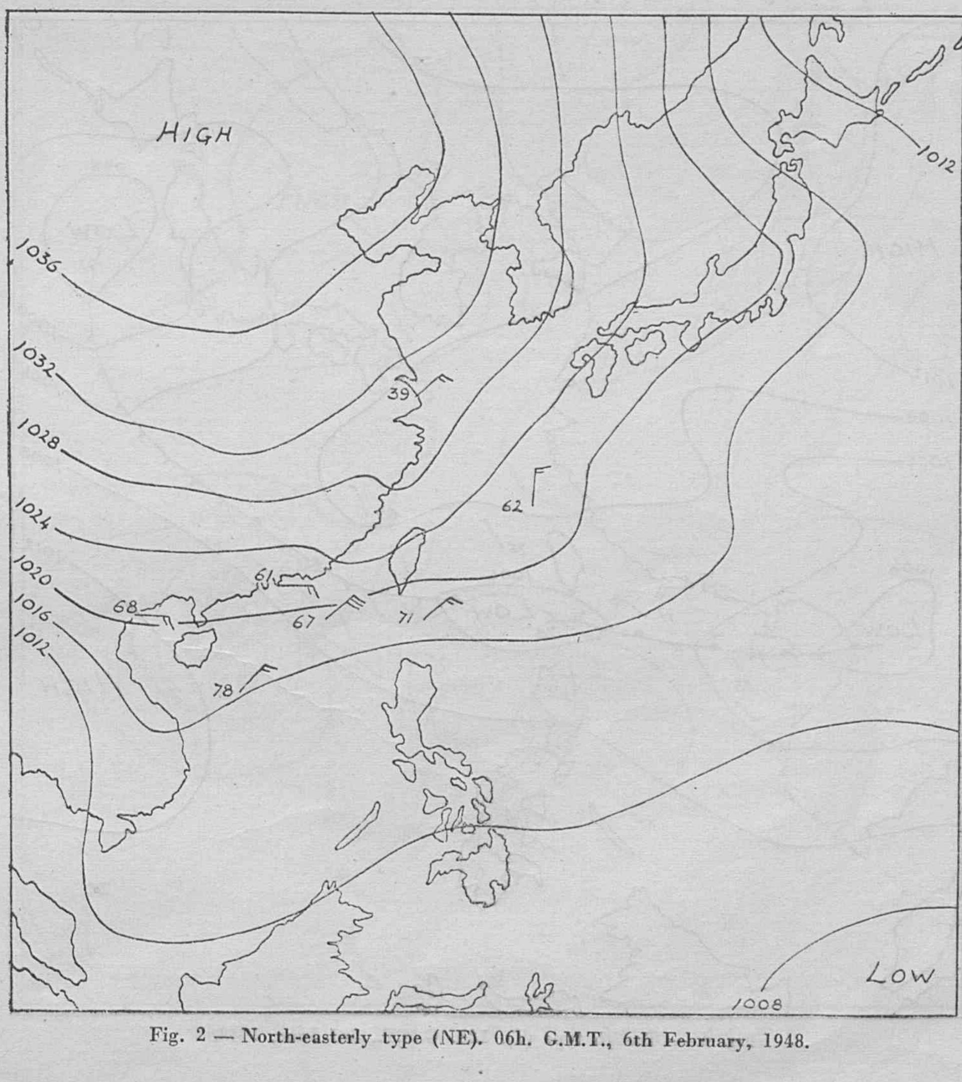

Fig. 2 — North-easterly type (NE). 06h. G.M.T., 6th February, 1948.

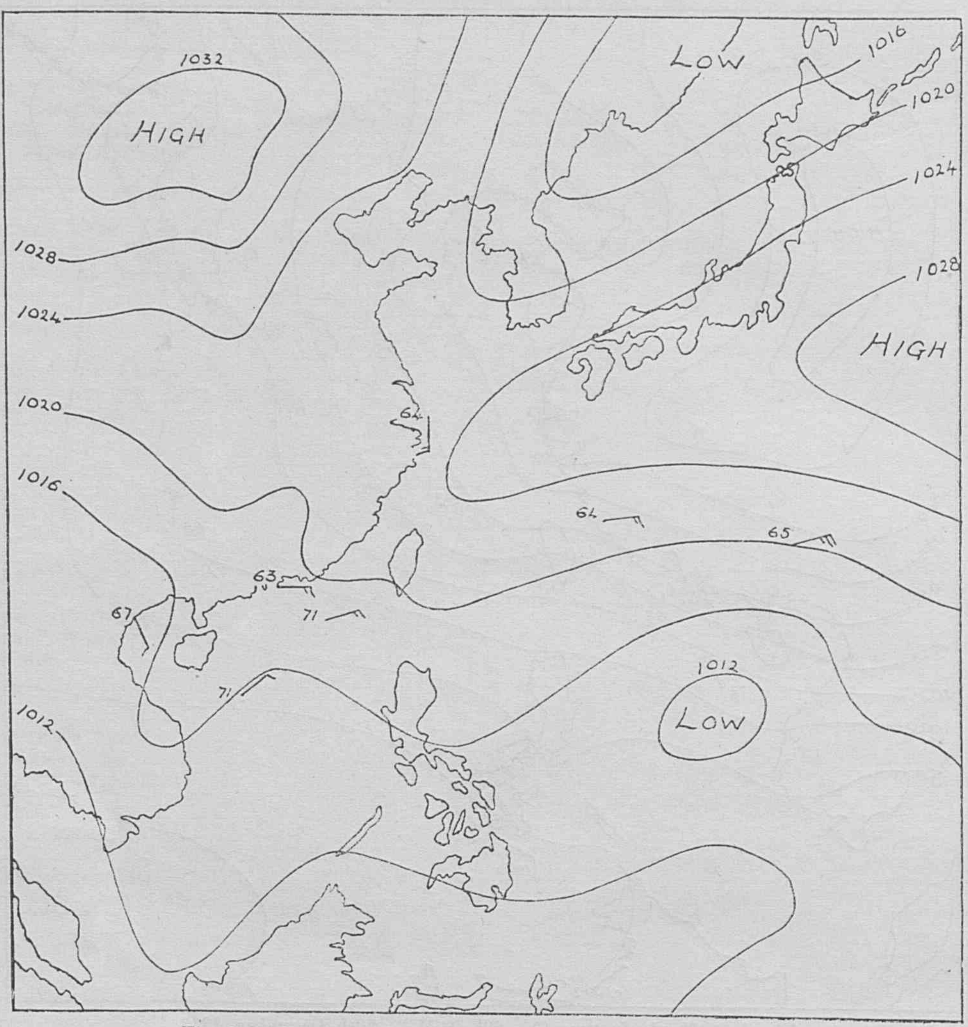

Fig. 3 — Easterly type (E). 12h. G.M.T., 20th January, 1948.

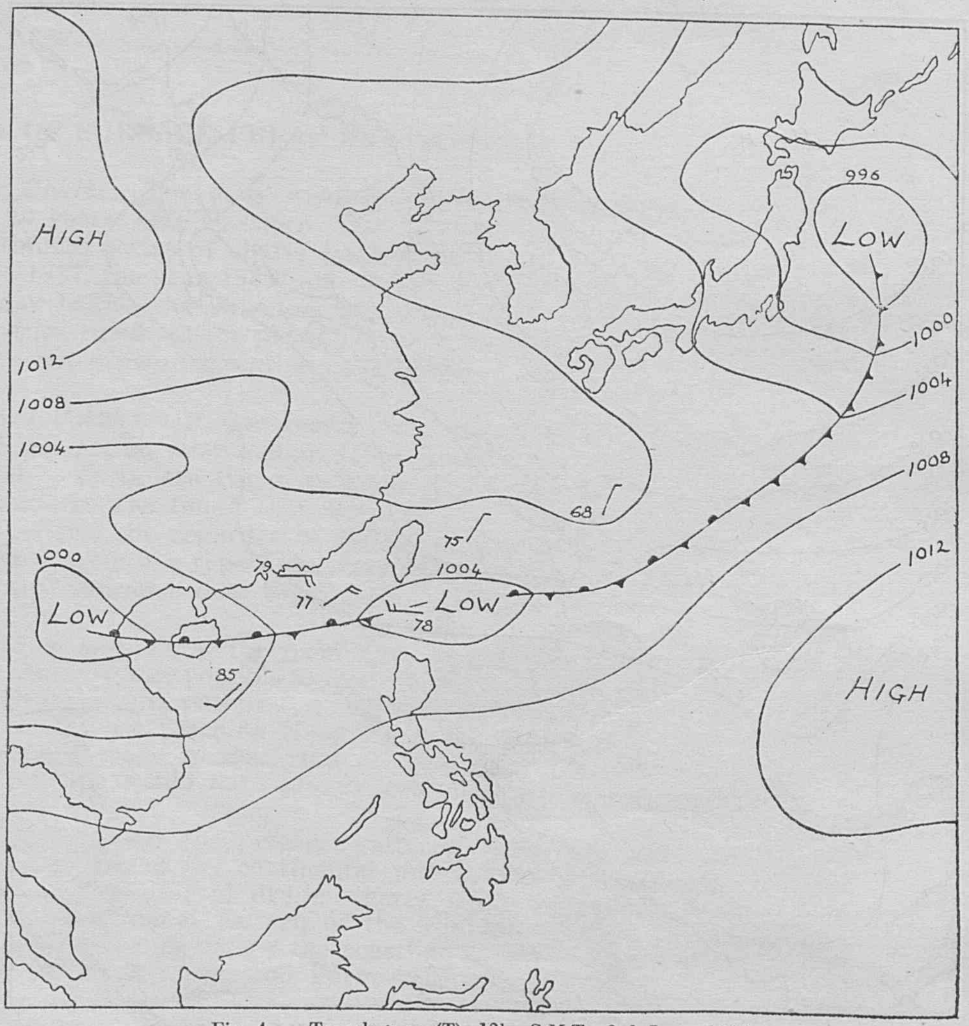

Fig. 4 — Trough type (T). 12h. G.M.T., 3rd June, 1948.

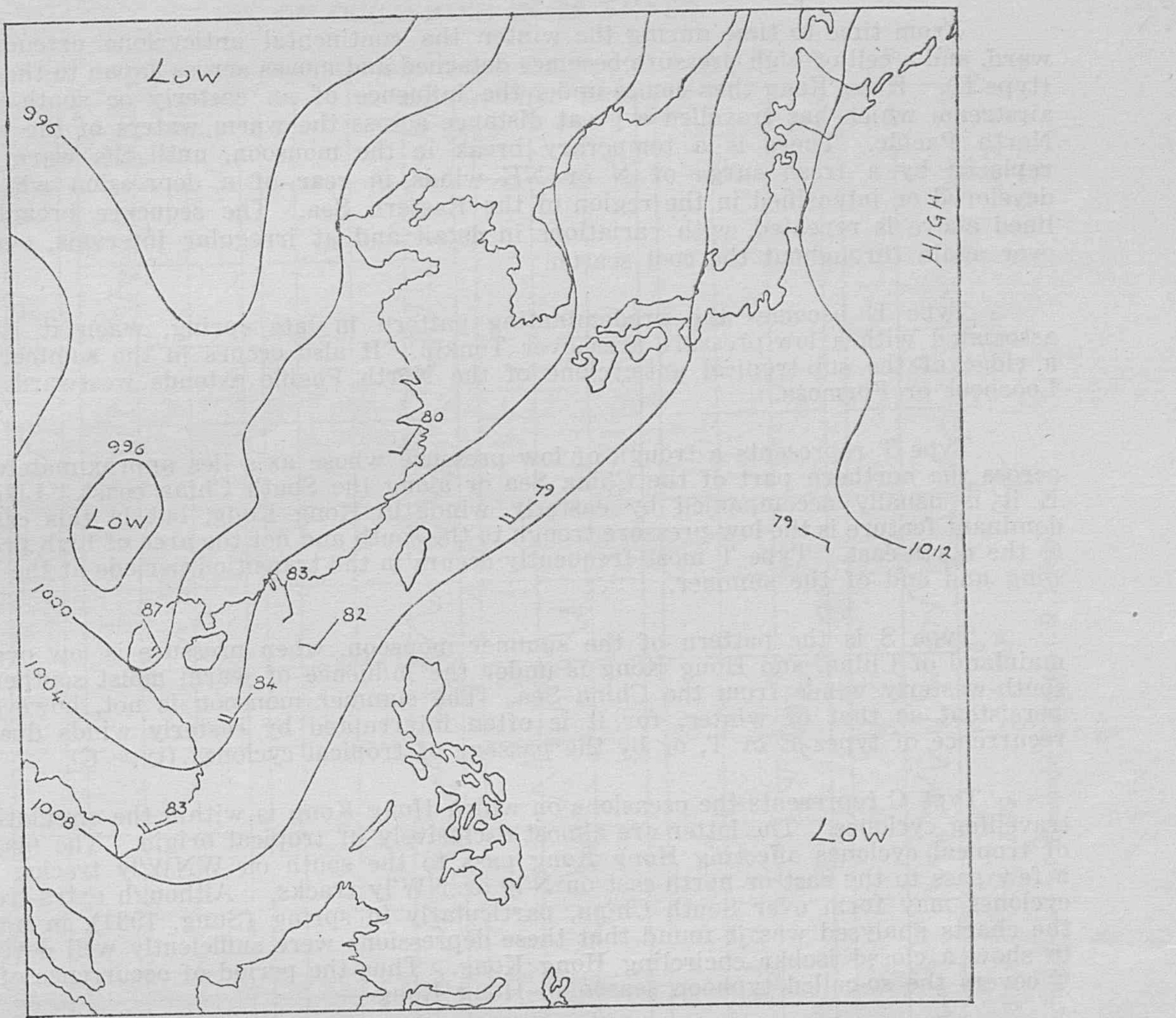

Fig. 5 — Southerly type (S). 12h. G.M.T., 27th June, 1948.

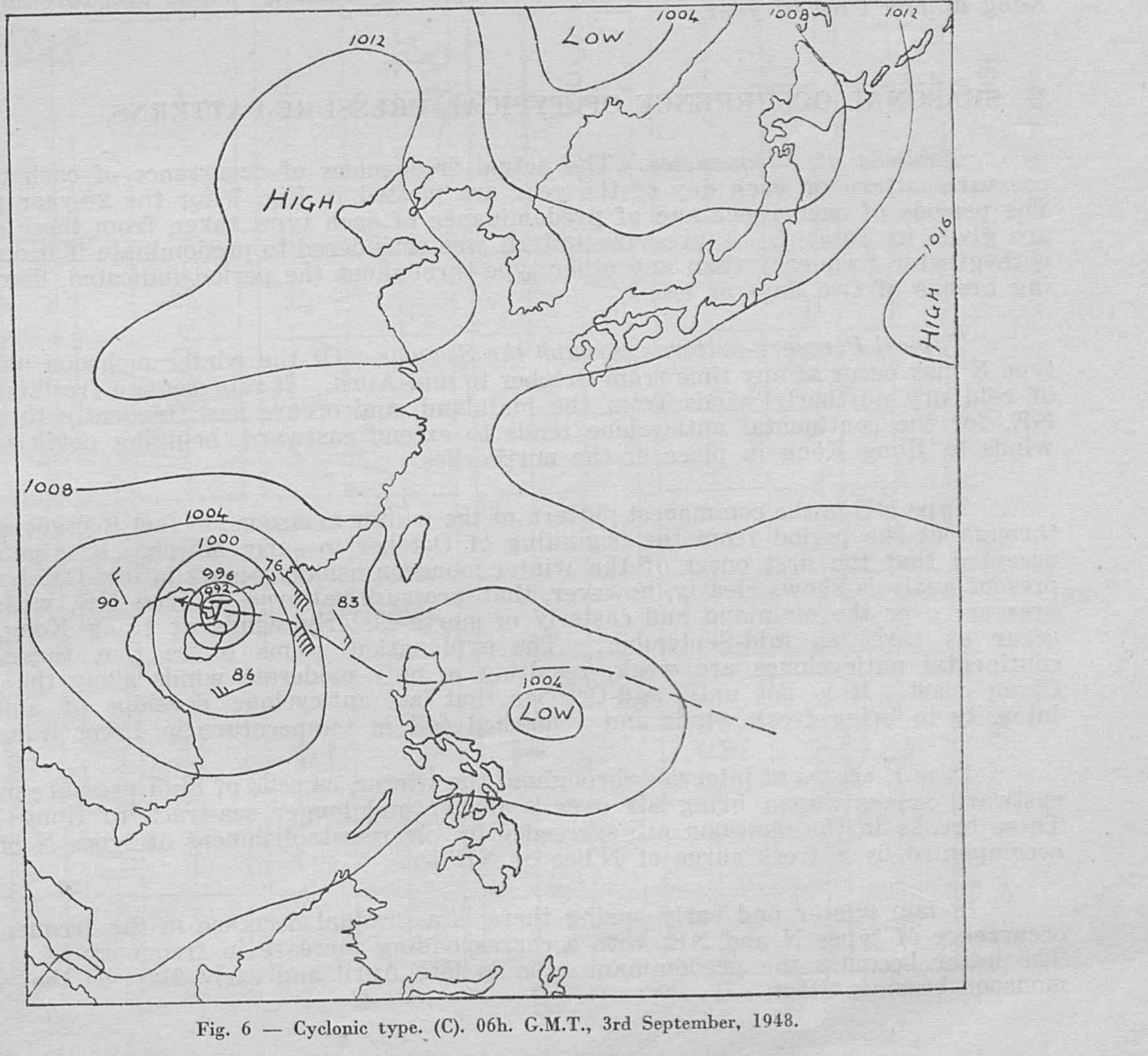

Fig. 6 — Cyclonic type. (C). 06h. G.M.T., 3rd September, 1948.

From time to time during the winter the continental anticyclone extends eastward, and a cell of high pressure becomes detached and moves across Japan to the Pacific (type E). Hong Kong then comes under the influence of an easterly or south-easterly airstream which has travelled a great distance across the warm waters of the western North Pacific. There is a temporary break in the monsoon, until the warm air is replaced by a fresh surge of N or NE winds in rear of a depression which has developed or intensified in the region of the Eastern Sea. The sequence broadly outlined above is repeated, with variations in detail and at irregular intervals, over and over again throughout the cool season.

Type E becomes the predominating pattern in late spring, when it is often associated with a low-pressure area over Tonkin. It also occurs in the summer when a ridge of the sub-tropical anticyclone of the North Pacific extends westward to the Loochoos or Formosa.

Type T represents a trough of low pressure whose axis lies approximately E-W across the northern part of the China Sea or along the South China coast. Like type E it is usually accompanied by easterly winds in Hong Kong, but in this case the dominant feature is the low-pressure trough to the south and not the area of high pressure to the north-east. Type T most frequently occurs in the transition periods at the beginning and end of the summer.

Type S is the pattern of the summer monsoon, when pressure is low over the mainland of China, and Hong Kong is under the influence of warm moist southerly or south-westerly winds from the China Sea. The summer monsoon is not, however, so persistent as that of winter, for it is often interrupted by easterly winds due to a recurrence of types E or T, or by the passage of tropical cyclones (type C).

Type C represents the occasions on which Hong Kong is within the circulation of travelling cyclones. The latter are almost exclusively of tropical origin. The majority of tropical cyclones affecting Hong Kong pass to the south on WNW'ly tracks, while a few pass to the east or north-east on N'ly or NW'ly tracks. Although extra-tropical cyclones may form over South China, particularly in spring (Sung, 1931), in none of the charts analysed was it found that these depressions were sufficiently well developed to show a closed isobar encircling Hong Kong. Thus the period of occurrence of type C covers the so-called typhoon season in Hong Kong.

It will be noted that there is no type W; westerly winds are rare in Hong Kong at any time of year.

3. SEASONAL OCCURRENCE OF TYPICAL PRESSURE-PATTERNS.

Analysis of Frequencies. The actual frequencies of occurrence of each type of pressure-pattern on each day of the year are plotted in Fig. 7 for the 20-year period. The periods of occurrence and of predominance of each type, taken from these curves, are given in Table I. A pressure-pattern was considered to predominate if it occurred with greater frequency than any other type throughout the period indicated, disregarding breaks of two days or less.

Typical Pressure-patterns through the Seasons. Of the winter monsoon patterns, type N may occur at any time from October to mid-April. It represents a fresh outburst of cold dry northerly winds from the mainland, and occurs less frequently than type NE, for the continental anticyclone tends to extend eastward, bringing north-easterly winds to Hong Kong in place of the northerlies.

Type NE is the commonest pattern of the winter monsoon; in fact it predominates throughout the period from the beginning of October to early March. It is generally accepted that the first onset of the winter monsoon usually occurs in mid-October; the present analysis shows clearly, however, that pressure-patterns of type NE, with high pressure over the mainland and easterly or north-easterly winds at Hong Kong, may occur as early as mid-September. The explanation seems to be that these early continental anticyclones are weak, resulting in only moderate winds along the South China coast. It is not until mid-October that an anticyclone develops of sufficient intensity to bring fresh winds and a marked fall in temperature in Hong Kong.

Type E occurs at intervals throughout the winter, as cells of high pressure moving eastward across Japan bring air over a longer and longer sea-track to Hong Kong. These breaks in the monsoon are succeeded by the re-establishment of types N or NE, accompanied by a fresh surge of N'lies or NE'lies.

In late winter and early spring there is a gradual decrease in the frequency of occurrence of types N and NE, with a corresponding increase in frequency of type E. The latter becomes the predominant type in late April and early May, as the winter monsoon becomes fitful.

NO. OF OCCASIONS IN 20 YEARS.

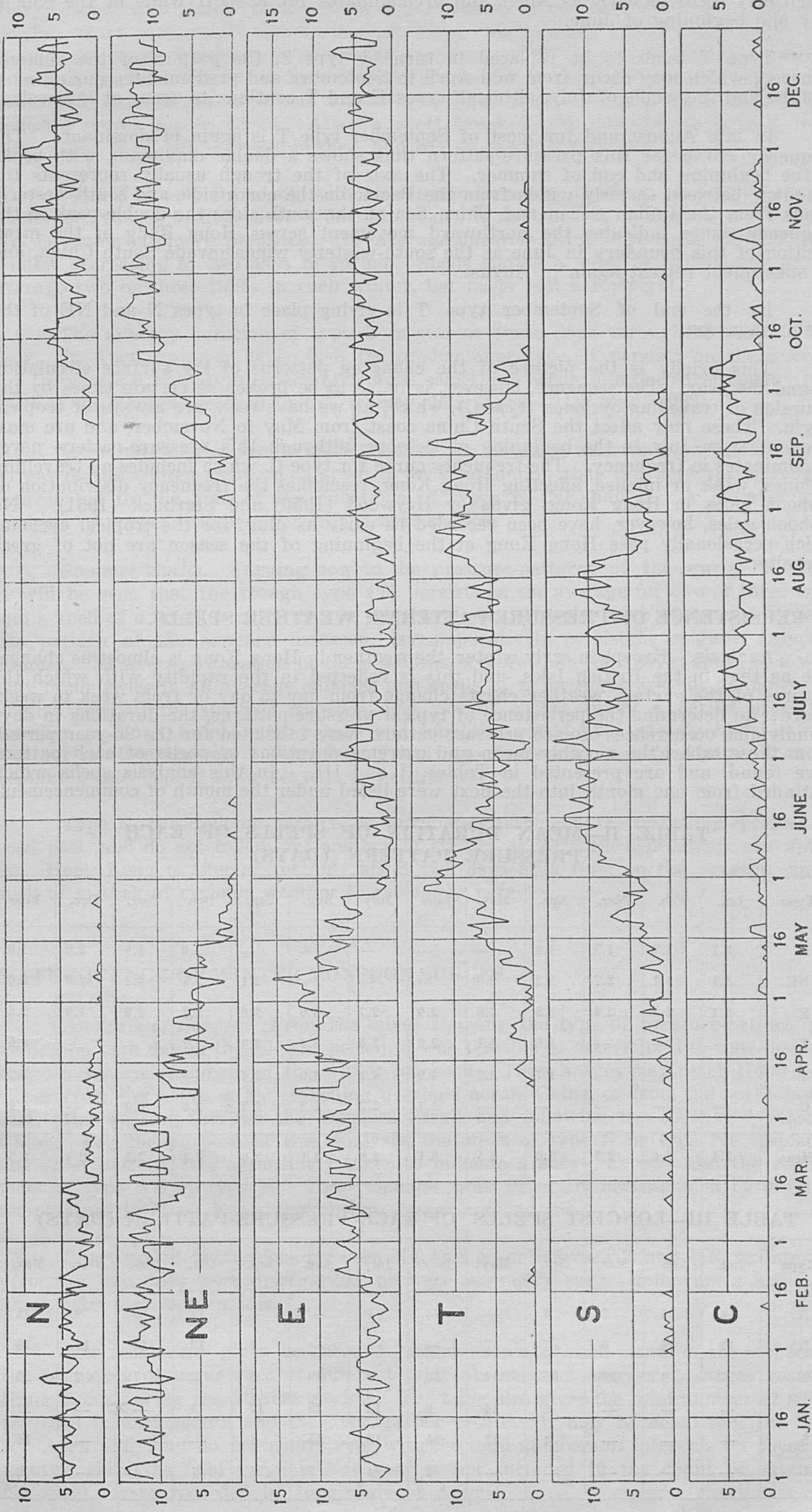

Fig. 7 — Frequency of Occurrence of Different Types of Pressure Pattern (20 Years).

As the spring advances, type E tends to be replaced by type T (the trough pattern), which may occur as early as April, and predominates for a short while at the end of May and beginning of June.

Type T tends to be replaced in turn by type S, the pattern of the summer monsoon, which may occur from mid-April to September and predominates during most of June and the whole of July, although types E and T continue to occur at intervals.

In late August and for most of September type T is again predominant. The frequency curve for this pressure-pattern thus shows a double maximum, with peaks at the beginning and end of summer. The axis of the trough usually represents the boundary between easterly winds from the Pacific on the north side, and south-westerly winds from the Indian Ocean and China Sea on the south side; the double peak in the frequency curve indicates the northward movement across Hong Kong of the mean position of this boundary in June as the south-westerly winds invade South China, and its subsequent retreat again in August.

By the end of September type T is giving place to types N and NE of the winter monsoon.

This briefly is the picture of the changing patterns of the surface circulation around the year. The sequence, however, is liable to be broken at certain times by the incursion of travelling cyclones (type C), which, as we have seen, are always of tropical origin. These may affect the South China coast from May to November, and are most frequent from July to the beginning of October, although this pressure-pattern never predominates in frequency. The frequency curve for type C, which includes all travelling cyclones, weak or intense, affecting Hong Kong, resembles the frequency distribution of typhoon gales in Hong Kong, given by Heywood (1950) and Starbuck (1951). No typhoon gales, however, have been recorded as early as May, for the tropical cyclones which occasionally pass Hong Kong at the beginning of the season are not of great intensity.

4. PERSISTENCE OF PRESSURE-PATTERNS; WEATHER SPELLS.

Analysis. Except in early winter, the weather in Hong Kong is almost as changeable as that in the British Isles, and this is reflected in the rapidity with which the features of the surface weather charts change from day to day or from week to week. In order to determine the persistence of typical pressure-patterns, the durations in days of individual occurrences of each pressure-pattern were tabulated for the 20-year period. From these tables the monthly mean and extreme durations of spells of each pattern were found, and are presented in Tables II and III. In this analysis spells which continued from one month into the next were listed under the month of commencement.

TABLE II—MEAN DURATION OF SPELLS OF EACH PRESSURE PATTERN (DAYS)

Type	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
N	2.1	1.7	1.5	1.1	—	—	—	—	—	2.0	1.9	2.0	1.8
NE	3.1	3.1	2.7	2.3	2.0	—	—	—	3.1	3.5	3.2	2.9	2.9
E	2.1	2.5	2.4	3.5	2.8	2.9	2.7	3.0	2.5	2.2	2.0	1.9	2.5
T	—	—	—	1.6	3.1	2.8	2.6	3.3	2.9	1.7	—	—	2.6
S	—	—	—	1.7	2.2	4.9	4.1	4.0	2.4	—	—	—	3.2
C	—	—	—	—	—	1.7	2.2	2.3	2.2	2.6	2.0	—	2.2
Mean	2.4	2.4	2.2	2.0	2.5	3.1	2.9	3.1	2.6	2.4	2.3	2.3	2.5

TABLE III—LONGEST SPELLS OF EACH PRESSURE-PATTERN (DAYS)

Type	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Max.
N	8	6	7	4	—	—	—	—	—	11	8	9	11
NE	**12**	**13**	9	7	7	—	—	—	8	**12**	**12**	**11**	13
E	7	9	**10**	**25**	**14**	10	9	10	5	8	7	7	25
T	—	—	—	6	**14**	9	12	**15**	**17**	3	—	—	17
S	—	—	—	4	13	**16**	**15**	**15**	8	—	—	—	16
C	—	—	—	—	—	2	4	7	4	7	4	—	7

Winter Spells. The early winter is normally a time of settled weather in Hong Kong; sunshine is abundant, the wind is persistently from between north and east, rainfall apart from slight drizzle is rare, and droughts occur almost every year. Yet the surface pressure-pattern is frequently varying during the winter monsoon period; a fresh surge from the north (type N) soon gives way to the north-easterly type as the anticyclone extends eastward, and this in turn gives way to type E as a cell of high pressure moves across Japan. After a short break in the monsoon there is a fresh surge; type N or NE is re-established, and the sequence is repeated.

Type N is only transient, with an average duration of about two days in early winter decreasing to little over a day in spring; a spell lasting a week is rare. Type NE is somewhat more persistent, the average duration being over three days in early winter, decreasing to two days in spring. Spells lasting a week or more occur on the average two or three times in each winter, but never last a fortnight.

The average duration of type E is two or three days throughout most of the year. In April, however, when E is the predominant type, it persists on the average for three and a half days; spells of a week sometimes occur, and one exceptionally long spell of 25 days commenced in this month (26th April—21st May, 1932).

It would appear from Table II that the average interval between successive surges of the winter monsoon is about a week, assuming that this interval is roughly represented by the sum of the durations of types N, NE and E. A more detailed analysis of surges will be given in the next section.

Summer Spells. Turning now to the pressure-patterns of the warm half-year, it will be seen that the trough type (T) persists on the average for two or three days, and a spell of a week or more may be expected once or twice each summer. Type S, the pattern of the summer monsoon, is comparatively persistent in June, July and August. Its average duration in these months is more than four days; spells of a week may occur twice in an average summer and spells of a fortnight are not unknown. A longish spell of the summer monsoon does not of course imply a period of settled weather in Hong Kong; temperature and humidity remain persistently high, but the weather is often showery. Both type T and type S are very transient patterns at the beginning and end of their seasons of occurrence.

Type C, the cyclonic pattern, is fortunately transient; the travelling cyclones are soon past, and do not follow one another in strings as Atlantic depressions are apt to do. Hong Kong is affected for only about two days at a time on the average, and a spell of a week of cyclonic weather is extremely rare.

5. FREQUENCY OF WINTER MONSOON SURGES.

Analysis of Surges. From the tables showing the type of pressure-pattern prevailing on each day of the 20-year period, it was possible to determine the time-intervals between successive surges of the winter monsoon. These surges may reach Hong Kong either from the north, after travelling overland across China, or from the north-east or east, after passing through the Formosa Strait and following the south-east coast of China. For the purpose of this analysis, the onset of type N or type NE, replacing any other pattern, was accordingly taken to indicate a surge, as was also the replacement of type NE by type N. These changes were generally accompanied by a fall in temperature in Hong Kong, though not always a sharp one.

Short-period fluctuations between NE and N, or between E and NE, at intervals of one or two days were disregarded, as were secondary surges following a main outbreak after two days or less.

The results are given in Table IV, which shows for each month of the cool season the frequency of occurrence of different intervals between successive surges reaching Hong Kong during the 20-year period. The table also gives the total number of surges recorded in each month and the average per month. It may be noted that the totals for April and May do not correspond with the total numbers of intervals for these two months, since the final surge in any year is not included in the count of intervals. No surges were recorded in June, July or August.

TABLE IV—FREQUENCY OF OCCURRENCE OF DIFFERENT INTERVALS BETWEEN SUCCESSIVE SURGES OF THE WINTER MONSOON
(Taken over a 20-year period)

Month	Interva in days													Total no. of surges (20 years)	Average no. of surges
	3	4	5	6	7	8	9	10	11	12	13	14	>14		
Sep. ...	—	—	—	2	2	2	1	—	4	2	—	—	**11**	24	1.2
Oct. ...	—	1	4	5	5	4	4	7	**15**	3	2	—	8	58	2.9
Nov. ...	2	4	**9**	**9**	8	4	2	7	4	2	4	4	8	67	3.3
Dec. ...	5	6	5	9	**10**	4	7	5	3	5	3	1	7	70	3.5
Jan. ...	3	4	7	4	**8**	4	**8**	7	6	6	3	3	5	68	3.4
Feb. ...	4	**13**	7	6	6	8	4	3	2	2	3	—	9	67	3.3
Mar. ...	1	3	**10**	5	3	8	4	2	4	6	6	7	6	65	3.3
Apr. ...	—	2	3	3	6	**7**	6	4	6	3	4	5	6	58	2.9
May ...	—	1	**5**	2	3	1	—	1	—	—	1	1	3	35	1.7
Total	15	34	50	45	51	42	36	36	44	29	26	21	63	512	25.6

NOTE:—Entries show the number of intervals *commencing* in each month.

Discussion. Surges follow one another at very irregular intervals, ranging from a few days to more than a fortnight throughout the cool season. On the whole, intervals of from 5 to 8 days are the most frequent, although in September surges are comparatively rare, and in October intervals of 11 days predominate; in February, on the other hand, the most frequent interval is only 4 days. The average number of surges per month rises from 1.2 in September to rather more than 3 throughout the months November to March, and falls again to 1.7 in May.

The briefness of many of the intervals between surges may seem surprising; it should be noted, however, that not all the surges included in the foregoing analysis were major outbreaks of Siberian air, accompanied by a marked freshening of the wind and fall in temperature in Hong Kong. Often the change to a north-easterly or northerly pattern is less extensive, the surge less vigorous, and the resulting change in conditions in Hong Kong less marked. The frequency of major surges is consequently somewhat less than is indicated in Table IV.

The average numbers of surges reaching Hong Kong in each month agree closely with the numbers passing Peking and Nanking, as given by Lu (1937). Even if we allow for some difference in the methods of analysis, this would indicate that the great majority of surges which sweep across Central China during the cool season penetrate at least as far as the south coast.

6. WEATHER ASSOCIATED WITH DIFFERENT PRESSURE-PATTERNS.

Analysis of Daily Weather. The surface winds and temperatures in the region of Hong Kong are governed to a great extent by the surface pressure-distribution, and reasonably reliable forecasts of these elements can therefore be made from a study of the surface charts, provided the latter contain an adequate coverage of synoptic reports. Other meteorological elements, particularly cloud and precipitation, are more dependant on conditions aloft, and cannot be forecast with sufficient accuracy from the surface charts alone.

In order to determine statistically to what extent these elements are related to the surface pressure-pattern, the weather recorded at the Royal Observatory on each day of the 20-year period was analysed and classified as follows:—

Fair, or variable sky—cloud amount<8/10 for at least 18 hours out of the 24. No precipitation.

Cloudy—cloud amount 8/10—10/10 for at least 18 hours out of the 24. No precipitation.

Light precipitation—highest hourly rainfall 0.10″

Moderate „ — „ „ „ 0.11-0.30″

Heavy „ — „ „ „ >0.30″

The day's weather was entered against the day's pressure-pattern, and the half-monthly frequency of occurrence of each type of weather with each pressure-pattern was determined over the 20-year period. Days of transition from one pressure-pattern to another were separately analysed (see below). Days on which the pressure-pattern was indeterminate were excluded.

The resulting percentage frequencies are given in Table V and plotted in Fig. 8. To simplify the presentation of the results, the half-monthly frequencies have been combined for periods within which they showed little variation.

The weather associated with certain transitions from one pressure-pattern to another was analysed in the same way, and the results are given in Table VI and Fig. 8. The transitions in pressure-pattern selected for analysis were as follows:—types NE to N, E to N, E to NE and T to NE (winter monsoon surges); T to S and S to T (advance and recession of summer monsoon). Each of these transitions involves a more or less clear-out change in the air-mass reaching Hong Kong, and may therefore be expected to be significant in regard to weather. Other transitions were not analysed, either because they occur too infrequently to allow of statistical treatment, or because they are normally gradual changes not involving a replacement of air-mass over Hong Kong. A transition from type NE to E, for instance, is a gradual one, for it represents the movement of a high-pressure centre eastward from China to the region of Japan, bringing air over a progressively longer sea-track to Hong Kong.

TABLE V—WEATHER ASSOCIATED WITH DIFFERENT PRESSURE-PATTERNS — PERCENTAGE FREQUENCIES.

Type	Period	Weather					Total no. of days.
		Fair	Cloudy	Light ppt.	Moderate ppt.	Heavy ppt.	
N	Oct. 1-Dec. 31	60%	14%	24%	1%	1%	308
	Jan. 1-Apr. 15	21	16	55	8	—	246
NE	Sep. 1-30	28	5	41	16	10	68
	Oct. 1-Dec. 31	60	6	31	2	1	822
	Jan. 1-May 31	28	12	51	6	3	1,042
E	Oct. 1-Dec. 15	61	5	31	2	1	200
	Dec. 16-May 15	37	11	46	3	3	731
	May 16-Sep. 30	30	1	41	16	12	351
T	Apr. 16-Oct. 15	22	1	42	15	20	917
S	Apr. 16-Sep. 15	19	3	47	16	15	836
C	June 1-Nov. 15	22	2	26	13	37	307

TABLE VI—WEATHER ASSOCIATED WITH CHANGES IN PRESSURE-PATTERNS — PERCENTAGE FREQUENCIES.

Transition	Period	Weather					Total no. of occasions
		Fair	Cloudy	Light ppt.	Moderate ppt.	Heavy ppt.	
NE—>N	Oct.-Dec.	49%	11%	37%	3%	—%	132
	Jan.-Apr.	23	7	56	12	2	136
E—>N	Oct.-Dec.	49	9	33	2	7	45
	Jan.-Apr.	11	4	63	13	9	46
E—>NE	Sep.-Dec.	40	5	48	3	4	93
	Jan.-May	25	5	55	6	9	198
T—>NE	Apr.-May, Sep.	26	3	41	12	18	34
T—>S	Apr.-Sep.	15	4	38	25	18	121
S—>T	Apr.-Sep.	13	—	31	20	36	166

Pressure-patterns and Weather. The results plotted in Fig. 8, although not without significance, indicate that it is possible for almost any kind of weather to occur with any given type of surface pressure-pattern. Moreover, the chances of occurrence of a certain kind of weather appear to depend more on the season than on the prevailing pressure-pattern. For example, the frequencies of occurrence of fair weather with types N, NE or E in early winter are about 60% in each case, while in summer fair weather only occurs on about 20% of the days with any of the types T, S or C.

These conclusions are not very encouraging to the forecaster, working as he is in a region where there is a great scarcity of information from all levels except the surface; they are, however, hardly unexpected, for it is now recognized that in tropical regions upper-air conditions rather than the surface pressure-distribution are the main factors controlling the weather. The surface chart, however inadequate, is still our primary forecasting tool and is likely to remain so for some time; it is therefore necessary to examine the statistics in an endeavour to find significant relationships between the surface pressure-patterns and the weather.

Weather in the Cool Season. Early occurrences of type NE in September are more likely than not to be accompanied by precipitation. In early winter (October to December) the chance of fair weather, as already mentioned, is about 60% with any of types N, NE or E, but there is slightly less chance of light precipitation with type N than with the other patterns. The likelihood of fair weather is less during onsets of monsoon in early winter (transitions NE to N, E to N, E to NE). This is particularly so with transitions E to NE, which are accompanied by precipitation on 55% of the occasions, though on only 7% is the precipitation moderate or heavy.

Cloud and precipitation become more frequent with types N, NE and E in late winter and early spring (January to April or May). The frequency of occurrence of fair weather with type N in this season is only 21%, while type E gives the best chance of fair weather (37%). There is again a greater chance of precipitation during onsets of the monsoon than at other times. Changes from E to N, for instance, are accompanied by precipitation of 85% of occasions in late winter, and there is an appreciable chance that the precipitation may be heavy.

There is thus a marked contrast between the settled fair weather of early winter and the cloudy skies with occasional fair breaks in late winter in Hong Kong; this cannot be explained by any general change in the surface pressure distribution around mid-winter, for, as we have seen, the same pressure-patterns repeat themselves at frequent but irregular intervals throughout the cool season. The reason is to be found in the

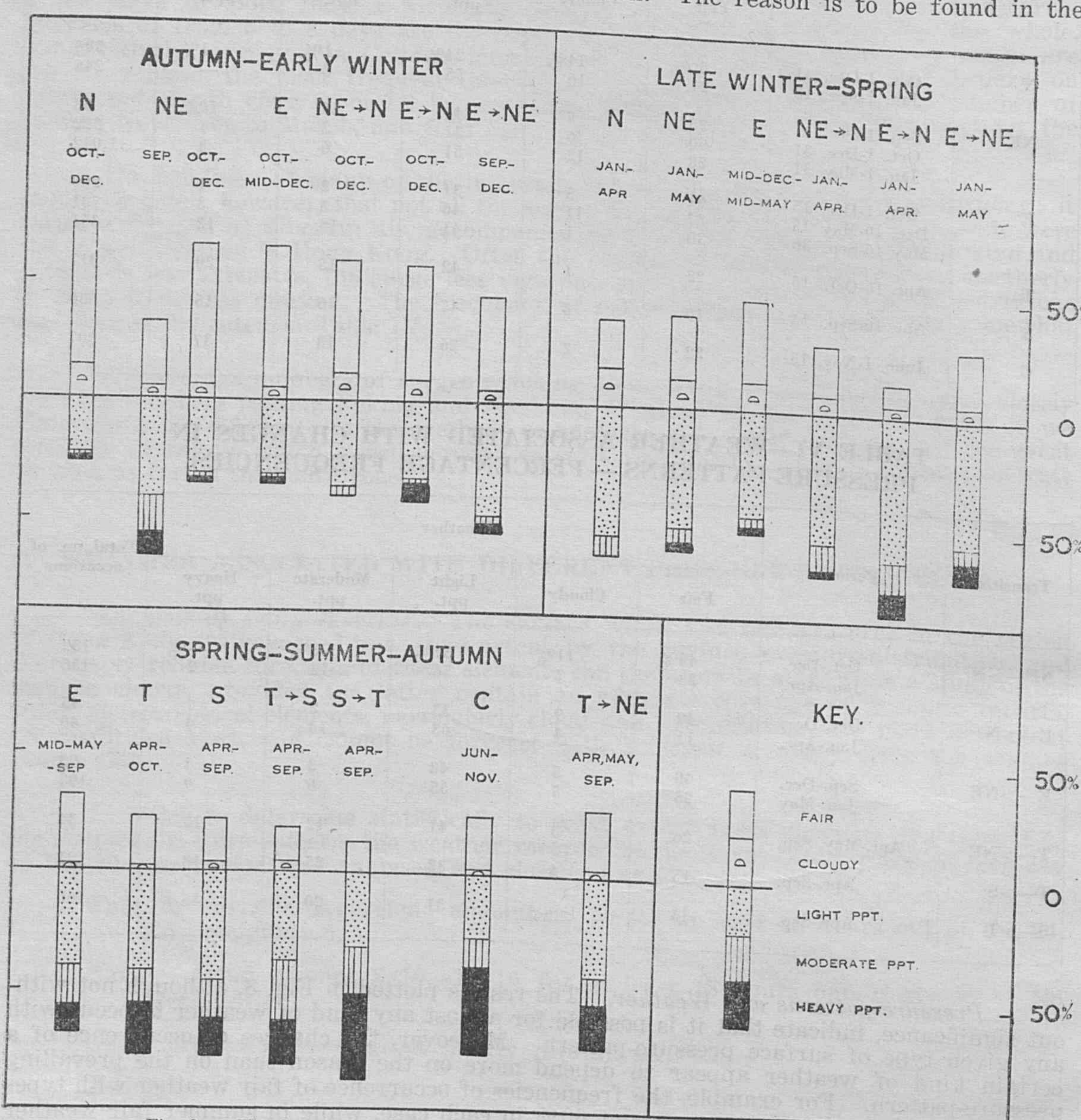

Fig. 8 — Weather Associated with Different Pressure-Patterns; Percentage Frequencies.

increasing frequency with which southerly componants appear in the upper winds at intermediate heights over Hong Kong as the winter progresses, but a discussion of the underlying cause of these southerly components would be outside the scope of this paper.

Weather in the Warm Season. In the warm half-year, precipitation is more likely than not to occur on any given day, whatever the pressure-pattern, and heavy rain is of more frequent occurrence than in the winter months. Type E, with 30% fair days and only 12% days with heavy rain, gives the best chance of fair weather in the warm half-year, for it is the only pressure-pattern which is not associated with cyclonically curved flow over Hong Kong in these months. Types T and S both give about 20% fair days and a large proportion of days with precipitation.

Changes in type from T to S and from S to T, representing the onset and retreat of the summer monsoon, are generally accompanied by very unsettled weather. The change from S to T in fact, with 36% days of heavy precipitation and only 13% fair days, is more likely to give rain than even the cyclonic type C.

Type C, although giving 37% days with heavy rain, also has 22% fair days. These are mostly accounted for by the well-known occurrence of a short spell of fine weather which is the first effect in Hong Kong of a tropical cyclone approaching from the southeast, and is due to divergence in the winds aloft (Thompson, 1951). Light precipitation is rarer with type C than with any other summer pressure-pattern.

Changes in type from T to NE in spring and autumn, representing very late or very early onsets of the winter monsoon, are less likely than the summer pressure-patterns to be accompanied by rain, but more likely than the early winter patterns.

Cloudy or overcast days without precipitation are noticeably absent in the warm half-year.

7. TEMPERATURE ASSOCIATED WITH DIFFERENT PRESSURE PATTERNS.

Analysis of Daily Temperatures. The mean temperature for each day during the 20-year period was compared with the normal for that day, and the deviations from normal were classified as follows:—

Very warm	—	5°F or more	above normal	(+ +)
Warm	—	2° - 4.9°F	„ „	(+)
Normal	—	Within 2°F	of „	
Cool	—	2° - 4.9°F	below „	(—)
Very cool	—	5° or more	„ „	(— —)

These terms, of course, are only relative; a "very warm" day in summer would be uncomfortably hot, while a "very cool" day in mid-winter would be decidedly cold for Hong Kong.

The temperature anomalies were then entered against the type of pressure-pattern for each day, and the frequencies analysed for different patterns in the same manner as the weather frequencies. The resulting percentage frequencies are given in Table VII and Fig. 9. The temperature anomalies on days when the pressure-pattern was changing from one type to another were not analysed.

TABLE VII—TEMPERATURE ASSOCIATED WITH DIFFERENT PRESSURE-PATTERNS—PERCENTAGE FREQUENCIES.

Type	Period	Temperature Deviation					Total no. of days.
		++	+	Normal	—	— —	
N	Oct.1—Dec.31	2%	8%	33%	30%	27%	309
	Jan.1—Apr.15	—	4	13	20	63	244
NE	Sep.1—Feb.28	4	24	52	16	4	1,431
	Mar.1—May31	1	7	41	33	18	505
E	Oct.1—Dec.31	28	44	28	—	—	242
	Jan.1—Mar.31	61	28	11	—	—	331
	Apr.1—Jun.15	13	35	41	10	1	449
	Jun.16—Sep.30	—	9	80	9	2	262
T	Apr.16—Sep.15	—	9	66	21	4	804
	Sep.16—Oct.15	1	23	70	6	—	123
S	Apr.16—Sep.15	7	39	49	5	—	840
C	Jun.1—Nov.15	5	25	49	17	4	308

Pressure-patterns and Temperatures. In winter the temperature in Hong Kong is closely associated with the surface pressure-pattern, which may therefore be used with some confidence for forecasting temperatures. Thus in early winter, type N, which is associated with winds off the mainland, generally gives cool weather; 57% of the days are "cool" or "very cool", and only 10% are "warm" or "very warm". With type NE, which is the common winter monsoon pattern, the temperatures are fairly evenly distributed about the normal, and rarely deviate from it by as much as 5°F. Type E, representing breaks in the monsoon when the air reaching Hong Kong has travelled over warm seas, gives mild weather; 72% of the days are "warm" or "very warm", and none at all are "cool" or "very cool".

In late winter the contrast between the temperatures experienced with type N and with type E is even greater; the chances are considerably in favour of temperature being 5°F or more below normal with type N, and 5°F or more above normal with type E. With type NE temperatures tend to be somewhat below normal, as the waters off the China coast over which the air has blown are at their coldest at this season.

During the winter months, when a continental anticyclone is extending eastward over Japan (transition from type NE to type E) a marked rise in temperature in Hong Kong does not take place until a day or two after the commencement of the eastward extension of the anticyclone. This is attributable to the fact that NE winds often continue to blow in the Formosa Strait and along the China coast while an anticyclonic cell is moving eastward in the region of Japan, and some time must elapse before these winds are replaced by warmer air from the Pacific.

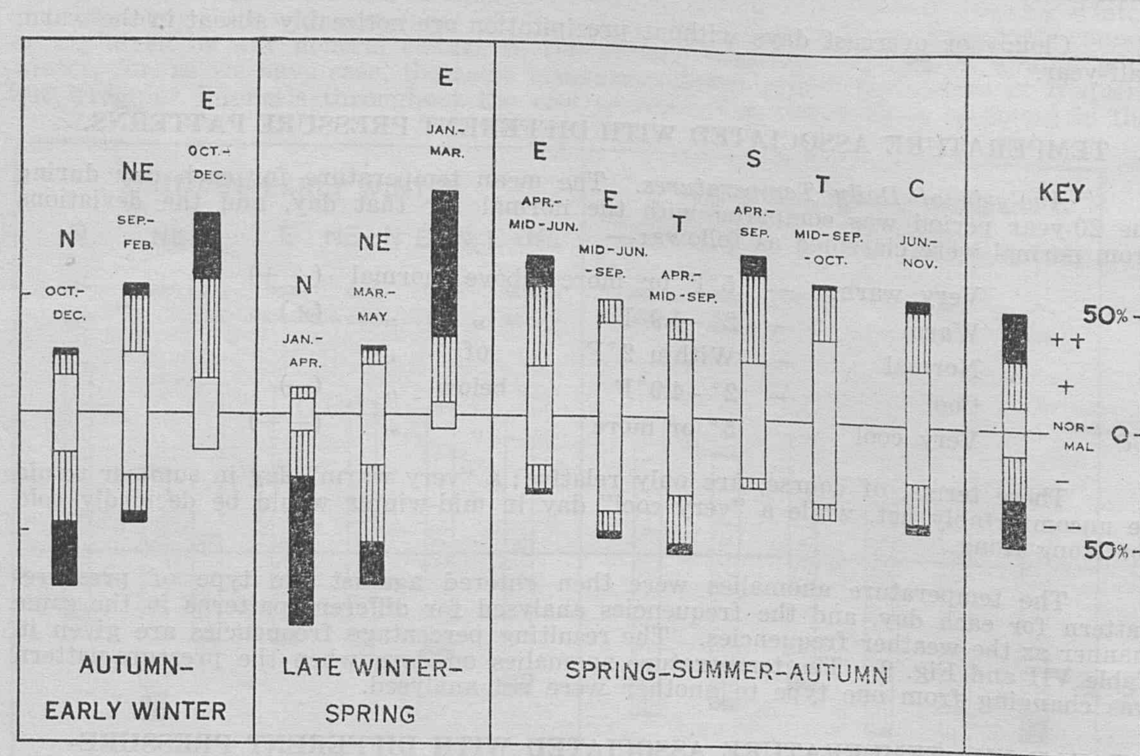

Fig. 9 — Temperature Associated with Different Pressure-Patterns; Percentage Frequencies.

In spring and early summer there is still a tendency for temperatures to be above normal with type E, while in late summer they are usually normal under these conditions.

With type S, the summer monsoon pattern, temperatures tend to be above normal, while with type T, the trough pattern, they tend to be below. This is consistent with the results of upper-air soundings in Hong Kong which show that a southerly airstream in summer is usually rather warmer and more humid than an easterly one. The hottest days in summer occur with the southerly monsoon.

In autumn type T may give temperatures above normal, as the easterlies of types E and T are then alternating with the first onsets of the cooler air of the winter monsoon.

With type C, the cyclonic pattern, there is a fairly wide range of temperatures above and below normal. The warm days are due to the short sunny spells experienced in advance of typhoons, while the cool days may be explained by the cooling of the air by rain in the central region of the storms.

8. THUNDERSTORMS.

The monthly percentage frequencies of occurrence of days with thunderstorms (thunder and lightning occurring together) relative to the total number of days, for each pressure-pattern and change in pressure-pattern, are given in Table VIII.

TABLE VIII—THUNDERSTORMS ASSOCIATED WITH DIFFERENT PRESSURE-PATTERNS—PERCENTAGE FREQUENCIES.

Type	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
N	0	0	7	0	—	—	—	—	—	1	0	0
NE	0	2	3	6	3	—	—	—	0	0	0	0
E	2	1	4	3	7	9	8	2	6	2	0	0
T	—	—	—	43	14	8	12	11	6	9	—	—
S	—	—	—	9	24	15	11	16	21	—	—	—
C	—	—	—	—	0	16	18	18	12	2	0	—
NE—>N	0	2	16	10	—	—	—	—	—	0	0	0
E—>N	0	0	0	0	—	—	—	—	—	0	0	0
E—>NE	0	7	5	11	6	—	—	—	17	4	0	0
T—>NE	—	—	—	0	18	—	—	—	8	—	—	—
T—>S	—	—	—	0	33	25	8	21	11	—	—	—
S—>T	—	—	—	57	45	39	24	19	39	—	—	—

Thunderstorms are rare in the cool season, October to March, whatever the pressure-pattern. The only situation giving a frequency of over 10% in these months is a change in type from NE to N in March, representing late surges of northerly winds from the continent. It is curious, however, that no thunderstorms have been recorded during changes in type from E to N in any month.

In the warm season, April to September, thunderstorms are still rare with type E, but occur with rather more frequency with types T and S. They are particularly likely to occur with type T in April (43%). Thunderstorms sometimes occur with type C (the cyclonic pressure-pattern) in the months June to September; these are partly attributable to the thundery outbreaks which occasionally take place over Hong Kong when northerly winds are first setting in on the edge of a typhoon approaching from the south-east.

The situation most likely to give rise to thunderstorms in the summer months is a transition from type S to type T, representing the replacement of southerly or south-westerly winds by easterlies along the axis of a low-pressure trough. In April this change is more likely than not to be accompanied by thunderstoms (frequency 57%).

The curve for the annual variation of frequency of days with thunderstorms shows two peaks, the first at the end of May and beginning of June corresponding to the period of predominance of type T, the second in early August when the summer monsoon is nearing its end and type S is beginning to be replaced by type T.

9. FOGS.

Table IX shows the monthly percentage frequencies of occurrence of days with fog for different pressure-patterns and changes in pressure-pattern. A day with fog was taken as one on which visibility at the Royal Observatory fell to less than one mile at any hour of the twenty-four.

TABLE IX—FOGS ASSOCIATED WITH DIFFERENT PRESSURE-PATTERNS—PERCENTAGE FREQUENCIES.

Type	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
N	0	0	0	0	—	—	—	—	—	0	0	0
NE	2	3	1	2	0	—	—	—	0	0	1	2
E	20	25	36	21	7	0	0	0	0	0	1	6
T	—	—	—	13	2	2	1	1	0	0	—	—
S	—	—	—	9	3	0	0	0	0	—	—	—
C	—	—	—	—	0	0	0	0	0	0	0	—
NE—>N	2	2	8	0	—	—	—	—	—	0	0	2
E—>N	8	45	24	17	—	—	—	—	—	8	0	13
E—>NE	18	37	33	23	11	—	—	—	0	0	0	8
T—>NE	—	—	—	27	0	—	—	—	0	—	—	—
T—>S	—	—	—	25	0	5	4	7	0	—	—	—
S—>T	—	—	—	29	3	0	0	3	0	—	—	—

It will be seen that fogs are most frequent in late winter and early spring, and are rare at other times of year. The highest percentage frequencies occur in February, March and April, and are usually associated with type E or with transitions from this type to a more northerly one (36% with type E in March, 45% during changes from E to N in February, and 37% during changes from E to NE in February). It should be noted that the *actual* number of days with fog in these months with type E considerably exceeds the number occurring with transitions from E to N or NE, as days of transition are infrequent compared with days of a given pressure-pattern.

It has long been recognized that the spring fogs of the South China coast occur during breaks in the monsoon when there is an inflow of warm moist air from east or southeast (Figg. 1906). At this season the surface temperature of the coastal waters is considerably lower than that of the Pacific to the eastward, and advection fog is liable to form when warm air from the latter reaches the colder water off the coast. This accounts for the frequency with which fogs are observed with type E in early spring. Those which occur on days of change from type E to types N or NE, representing renewed onsets of the winter monsoon, may be attributed either to advection fog present before the onset of the cooler air, or to mist and drizzle caused by turbulent mixing during the transition.

Changes in pressure-pattern from T to NE, T to S and S to T in April are also liable to be associated with fog, but as these transitions are uncommon in this month the fact is of little significance for forecasting purposes.

In all other situations fogs are rare. None have been recorded with type N, when the air reaching Hong Kong is of continental origin and dry. Nor have fogs been recorded with type C, which indicates that occasions when the visibility was reduced to less than a mile by heavy rain were not entered as fogs in the observation book.

A detailed analysis of the fogs occurring at Waglan Island to the southeast of Hong Kong, and in the harbour area, has recently been carried out by Hung (1951).

10. SEASONAL TRENDS AND SINGULARITIES.

The results given in the previous sections can now be summarized in the form of a weather calendar showing the seasonal trends in the surface pressure distribution and weather in Hong Kong. Curves showing the annual variation of the meteorological elements, based on 5-day means over a period of 60 years, will be found on pp. 38 and 39 of *Hong Kong Meteorological Records and Climatological Notes* (*1952*). It should again be mentioned that the weather is often changeable from day to day, particularly in spring and autumn, and the meteorological elements on any given day may therefore vary considerably from the normal values shown by these curves. The weather of the different seasons in Hong Kong has previously been described by Claxton (1916) on the basis of a 30-year series of observations, and more recently by Starbuck (1952).

Certain features in the annual curves, sufficiently well marked to be classed as singularities, are included in the calendar. They do no more than indicate that during the past 60 years the chance of a singularity in weather occurring at or near the given date has outweighed the chance of its non-occurrence, and it should not be inferred that a similar weather spell is bound to recur at or near the given date in future.

The seasonal trends and singularities in the meteorological elements are in most cases related to the frequency curves for the different types of pressure-pattern given in Fig. 7, and these relationships have been noted in the calendar. Sometimes, however, it is difficult to trace any connexion between the two sets of curves; for example, the very marked minimum of rainfall and maximum of sunshine, occurring around 12th July in the middle of the rainy season, does not synchronize with any obvious peculiarity in the surface pressure-distribution.

CALENDAR OF TRENDS AND SINGULARITIES AFFECTING HONG KONG.

(S) indicates a Singularity.

Early January—Early February. *Winter Monsoon. Increasingly cold and cloudy.*

The NE'ly type predominates. Onsets of cold N'ly air (type N) are fairly frequent, as are breaks in the monsoon (type E).

Atmospheric pressure reaches its maximum for the year in early January, and then begins to fall. Temperature and dew-point continue to fall slowly and irregularly, reaching their minima for the year in early February (58.0°F and 50°F respectively). Cloud amount increases rapidly, and fogs begin to occur, associated with type E. Rainfall scanty, usually in the form of drizzle; measurable falls are infrequent, and droughts occur in most years.

(S) 6-10 January. *Cold Spell.* Peak in pressure, secondary minima in temperature, dew-point and cloudiness, corresponding with slightly increased likelihood of N'lies as compared with NE'lies and E'lies.

(S) 11-15 January. *Mild Spell.* Secondary minimum in pressure, secondary peaks in temperature and dew-point, corresponding with increased likelihood of E'lies as compared with N'lies.

Mid February—Early April. *Winter Monsoon. Cloudy with occasional fog; increasingly warm.*

Type NE continues to predominate until 12 March, but breaks in the monsoon become increasingly common. N'ly outbreaks decrease in frequency and become rare by end of period.

Mean temperature and dew-point are rising, but temperature is very variable owing to repeated onsets and breaks in the monsoon. Cloudiness is at its maximum for the year (75-85%), and fogs reach their highest frequency in March, associated with type E. Rainfall continues slight until the end of March, when it tends to increase. Thunderstorms, extremely rare throughout the winter, are occasionally recorded in late March, and thereafter increase in frequency.

(S) 12-16 March. *Cold Spell.* Secondary peak in pressure and check in rise of temperature, corresponding with late peak in frequency of N'lies and temporary drop in frequency of NE'lies.

(S) 22-26 March. *Cloudy, windy spell.* Cloudiness and wind speed reach their maximum for the year, connected with the fact that the winter monsoon, still vigorous, now has an increasing E'ly component and so blows more freely through Hong Kong harbour; turbulence results in much low cloud.

Mid April—Early May. *Spring transition period. Changeable weather.*

The winter monsoon is becoming fitful. Type NE decreases in frequency, and N'ly outbreaks are almost unknown. Type E rises to its maximum frequency for the year, and predominates for most of the period. Earliest occurrences of type T and type S.

Mean temperature and dew-point continue to rise; actual temperature is still very variable. Cloudiness decreases slightly and sunshine increases, owing to fair days associated with westward extensions of the Pacific anticyclone (type E). At the same time rainfall increases, for moderate or heavy falls, sometimes thundery, may occur with late onsets of the winter monsoon or early onsets of the summer types T and S. Fogs decrease in frequency.

(S) 6-10 May. *Fair spell.* Secondary peak in sunshine and minimum in cloudiness, associated with the highest frequency of type E for the year occurring on 6 May.

Mid May—Early June. *Trough conditions preceding summer monsoon. Rainy season begins.*

Type T increases rapidly in frequency, becoming predominant for a short while, and replacing type E which becomes rare. The position of the trough is variable, and S'lies penetrate to the South China coast with increasing frequency. Tropical cyclones (type C) begin occasionally to affect Hong Kong, but are not yet intense. Onsets of NE'lies become very rare.

Mean temperature and dew-point are still rising, though less steeply. Cloudiness again increases slightly. Summer rains commence in early May, and the rapid increase in rainfall during this period corresponds with the increase in frequency of trough and summer monsoon conditions. Thunderstorms, often associated with type T, reach a maximum frequency in early June. Resultant wind direction veers from E to SE. Fogs become rare.

(S) 21-25 May. *Wet Spell.* Secondary peaks in rainfall and cloudiness, corresponding with early secondary peak in frequency of type S.

Mid June—Mid August. *Summer Monsoon. Hot and humid; often showery. Occasional tropical cyclones.*

Type S replaces type T as the dominant pressure-pattern. The summer monsoon, however, is not so persistent as the winter one, and there are fairly frequent reversions to the trough type, or sometimes to type E. Tropical cyclones affect Hong Kong with increasing frequency, reaching their first peak for the season in late July, then becoming less common in August as a greater proportion move NW towards the Eastern Sea.

Mean pressure reaches and passes its minimum for the year. Temperature and dew-point are consistently high (around 82° and 76° respectively), for the air reaching Hong Kong has almost invariably travelled over tropical or equatorial seas, and is hot and humid. Clouds are generally broken in the S'ly monsoon, and mean cloud amount consequently decreases. Mean rainfall and resultant wind direction are very variable (see below for singularities). Thunderstorms are fairly frequent, rising to a second maximum in early August, as trough conditions are again beginning to replace the summer monsoon. Fogs are very rare.

(S) 10-14 July. *Sunny spell.* Sunshine reaches its peak for the year (7.8 hours); secondary minimum in cloudiness, and very marked secondary minimum in rainfall; secondary peak in pressure. This outstanding singularity in the mean rainfall curve occurs at about the same time throughout South China, and is so well marked that it undoubtedly indicates a real tendency for a comparatively dry spell to recur at about this period. It takes place soon after the summer monsoon has reached its height, and seems to be connected with the fact that trough conditions have become fairly infrequent, while the increase in frequency of tropical cyclones which occurs in late July has not yet begun. Ramage (1952) explains this sunny spell by changes in the upper-air circulation, and points out that it coincides with the first rice harvest in South China.

(S) 15-19 July. *Wet spell.* Rainfall reaches its maximum for the year in a very marked peak (17.5 mm. per day), corresponding with a temporary increase in the frequencies of types T and C at the expense of type S. This singularity may therefore be considered as a break in the summer monsoon, and is related to a backing of the resultant wind direction from SSE to ESE, before veering to SSE again in early August.

Late August—Mid September. *Trough conditions following summer monsoon. Continuing warm and humid, often showery. Tropical cyclones more frequent.*

Type T reaches its second maximum, predominating throughout the period and replacing the S'lies, which decrease rapidly in frequency and become rare by mid-September. Tropical cyclones are on the increase. Weak onsets of the winter monsoon (type NE) are occasionally recorded as early as the second week in September.

Temperature and dew-point begin to fall. Cloudiness and rainfall decrease slightly; thunderstorms still fairly frequent, often associated with a trough near Hong Kong. Resultant wind direction backs to E/N. Fogs are very rare.

Late September.—Early October. *Autumn transition period. Changeable weather. Tropical cyclones pass their greatest frequency. End of summer rains.*

The trough type decreases rapidly in frequency, and becomes rare after the first week in October. It is replaced by NE'lies, which have become predominant by the end of September, when the earliest onset of N'lies may also occur. Tropical cyclones reach their greatest frequency for the year, then fall off rapidly.

Mean temperature and dew-point are falling. Rainfall decreases and becomes slight by the end of the period, but as yet there is no marked decrease in mean cloudiness. Thunderstorms become infrequent. Fogs are unknown.

(S) Second half of September. *Greatest risk of gales.* A marked secondary peak in mean wind speed corresponds with the period in which tropical storms or typhoons are most likely to cause gales in Hong Kong.

Mid October—Late December. *Winter monsoon. Fair and dry; increasingly cool.*

The NE'ly type predominates. Onsets of N'lies are also fairly frequent. Breaks in the monsoon (type E) are less frequent than in late winter. Tropical cyclones rarely affect Hong Kong in late October and November, and are almost unknown in December.

Though mean temperature and dew-point are decreasing steadily throughout the autumn, it is not until mid-October that onsets of N'lies and NE'lies are sufficiently strong to produce very noticeable falls in actual temperature and humidity. Minimum cloudiness for the year (44-59%). Sunshine abundant in late October; thereafter, owing to shortening of the days, sunshine durations decrease to less than those of late summer and autumn. Rainfall is scanty, usually in the form of drizzle; droughts occur almost every year. Thunderstoms almost unknown. Fogs, very rare at first, are occasionally recorded with type E in late December.

(S) 13-27 October. *Sunny spell.* Peak in sunshine curve almost equals that for 10-14 July; minimum cloudiness for year, corresponding with establishment of full winter monsoon conditions.

We see from this calendar that the seasonal trends are broadly symmetrical. A prolonged winter monsoon season is preceded and followed by short transition periods in which the monsoon is fitful or weak. A comparatively brief summer monsoon season is preceded and followed by short periods in which the trough type of pressure-distribution predominates, and the boundary between easterlies and southerlies is, on the average, first advancing northward and subsequently retreating southward over the South China coast.

Regarding these trends in a different way, the easterlies, which would prevail throughout the year in this latitude were it not for the effect of the land mass of Asia, are only prevalent in spring and autumn while types E or T predominate, and are interrupted by a winter monsoon lasting about 6 months and by a summer monsoon lasting about 2½ months.

The winter and summer monsoon seasons are centred some three weeks after the winter and summer solstices respectively, while the turning points in the normal annual temperature curve lag more than a month behind the sun.

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