ROYAL OBSERVATORY, HONG KONG.

TECHNICAL NOTE NO. 10

HONG KONG FORECASTERS' MANUAL

Edited by

C.S. Ramage

HONG KONG FORECASTERS' MANUAL

INTRODUCTION

This manual is not intended to be a detailed text-book on forecasting in the Far East. Rather its purpose is to remind experienced forecasters of ideas and techniques with which they are already familiar and to direct the attention of less experienced forecasters to potentially troublesome situations. Practical problems of day to day forecasting will be our chief concern. The items in the Royal Observatory bibliography provide detailed expositions of particular forecast problems. Each forecaster should have a set of these papers.

For general reference, only four publications are suggested:- x

1. Weather in the China Seas and in the western part of the north Pacific Ocean, Vols. I-III, M.O. 404 a - c.

2. Oceanographic and meteorological observations in the China Seas and the western part of the North Pacific Ocean; Dutch Met. Inst. publ. No.115.

3. Climatological Atlas of East Asia by E. Gherzi.

4. Tropical Meteorology by H. Riehl.

The first three together provide a detailed climaotological picture of the sea and land areas of the Far East, the fourth ably expounds the "modern" theory of tropical meteorology. Forecasters will find it useful in the summer season when our weather is generally tropical or equatorial maritime in origin. The sections on continental and monsoon meteorology are rather inadequate and the gap must be filled by reference to Royal Observatory papers. The first and fourth of the above publications contain exhaustive lists of references, almost all of which are available in the Observatory library.

The manual contains three main sections:

1. Analysis.
2. Forecasting (general)
3. Season distribution of synoptic situations and the particular forecasting problems involved.

Amendments and additions to the manual will be made from time to time.

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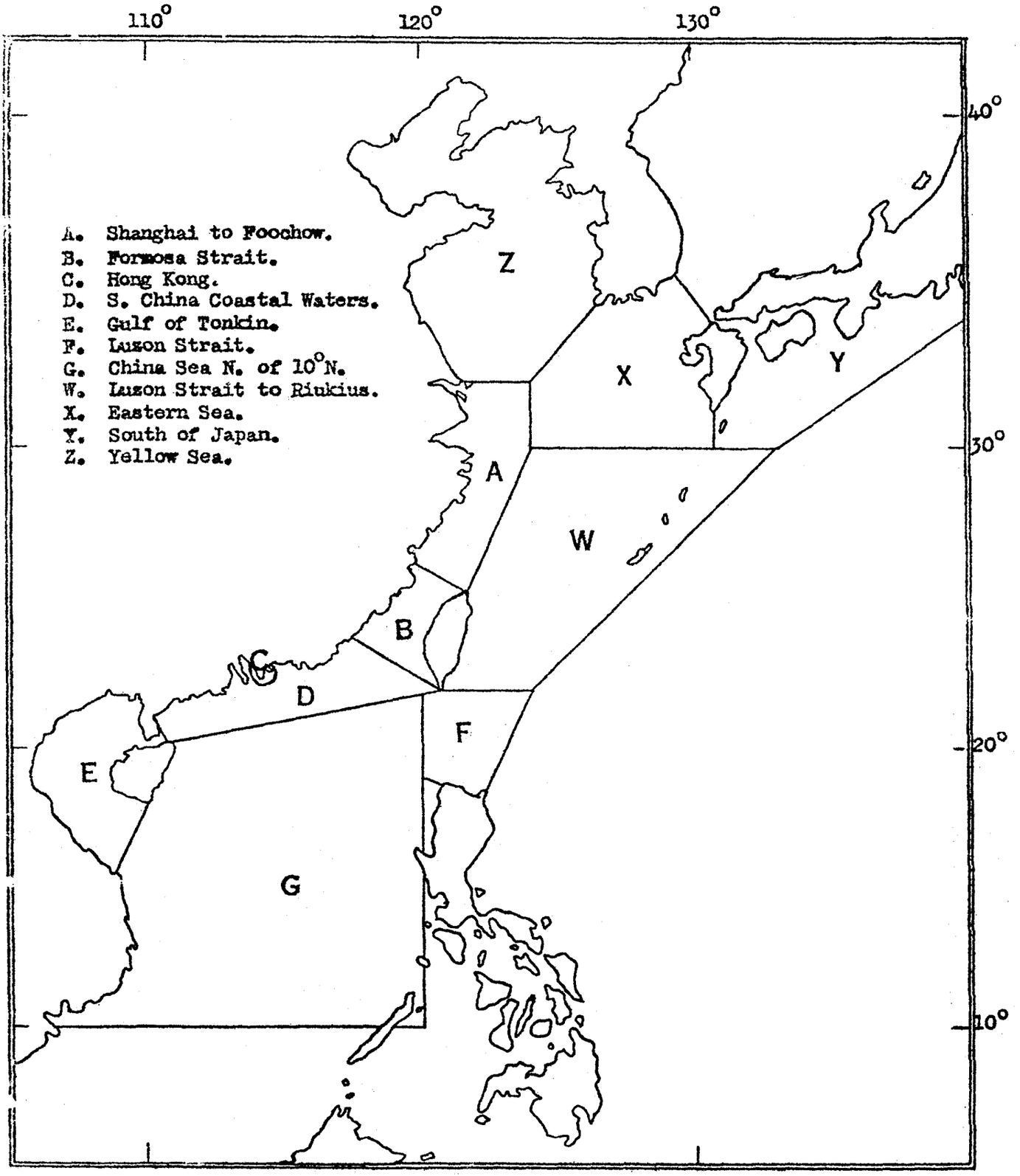
x

The most prolific pre-war writers on synoptic meteorology in the Far East were Depperman and Gherzi. Many of the ideas each propounded are sound but were often buried in a mass of theory which was anything but sound. Their writings reflect the struggle to apply the Norwegian frontal theory to the tropics and Depperman's papers in particular strike a meteorologist newly arrived in the tropics as sensible and understandable. For that reason the newcomer should not expose himself to their plausibilities. True fronts (density discontinuities) do not exist in the circulation of typhoons as anyone whom Depperman has converted eventually realises.

MARINE FORECAST AREAS



ANALYSIS.

Each analytical method used, surface, upper air, with space or time coordinates presents and emphasises a different aspect of the overall meteorological situation. No single method gives the whole picture. A successful forecast is more probable after carefully made analyses are reconciled with each other and then integrated harmoniously in the forecaster's mind.

(i) Sea-level isobaric analysis.

A recognised analyst, no matter how many years' experience he has, never lines in isobars directly. A poor and often inaccurate analysis results, for due note cannot be taken of doubtful or unrepresentative reports. orographic effects or small but significant distortions. It is perhaps significant that the "go it in one" analyst often omits to label his isobars; the analysis is usually so slapdash that true labelling is impossible. A useful technique is first to sketch in isobars at 4 mb intervals (2 mb in tropics) than after carefully drawing in the intermediate isobars finally rub out and draw in the original isobars. Smooth drawing and smoothly varying isobar spacing result.

Continuity is most important. Plotting the previous tracks of pressure centres on the current chart is good practise for extra-tropical as well as tropical circulations.

Cool season analysis. Frontal continuity is important. Everyone knows that a front can only exist in a region of cyclonic vorticity and great efforts are made to "kink" the isobars at the front. What is not so well realised is that a front cannot persist if the surface wind normal to it immediately in rear has a higher speed than the front. Forecasters tend to hold fronts back (possibly because they half expect a Norwegian model to appear). Winds in the frontal zone quickly show up the defects in many such forced analyses. Often in winter, a cold front moves eastward in the wake of depression over Manchuria or Korea. Surface high pressure remains unbroken to the south and the analyst manfully holds back the front in the region of Shanghai. Some hours later evidence shows the front extending from the southern Loochoos in a continuous sweep to the low now over Hokkaido. Hong Kong's dew point meanwhile has started gradually to fall. This is no impossibility for the front did not exist at the surface south of Shanghai until it reached the strongly frontogenetic region of the Loochoos. At Hong Kong it probably possessed the characteristics of a weak polar trough.

Cold fronts over Japan and the northern Loochoos often resemble the classical models. South of 25°N they almost never do. However they may still separate markedly differing air masses and as they pass a station, temperature, dew point and wind change sharply. However, a cold front which may have given considerable precipitation over the Loochoos, willusually (because of the persistent subsidence south of the jet stream) give little or no rain over south China (F., Fig. 3).

Easily identified fronts are confined to the cool season. This is the season of steep sea surafce temperature gradients and the forecaster must be continually aware of the rapid and massive modifications continental air masses undergo as soon as they move off the coast. As a general rule, as long as air flow in rear of a cold front has a component across the sea surface isotherms from low to high temperatures, the front will persist. As soon as the flow parallels the isotherms rapid frontolysis takes place although a shear line may persist for some time afterward.

When there is any difficulty in positioning a front which from continuity should still exist, carefully sketch the isobars first, determine the region of the trough and then place the front in this region, fitting it to the individual observations.

Cyclogenesis is more properly treated in later sections. However it is well to note that there are strongly preferred regions for extra tropical cyclogenesis (F, Fig 6). Quite often as P.C. Chin has pointed out surface cyclogenesis occurs in a region of no surface fronts and it is only after the circulation has intensified that frontogenesis occurs. During the cool season the first surface sign of cyclogenesis is often given by rain which may start when surface flow is just beginning to be less anticyclonic.

Warm season analysis. Generally speaking, air mass differences are so small that fronts can rarely be detected on the surface charts. Atmospheric processes are essentially dynamic and not advective. Because of intense heating, surface pressure distribution over land bears little relation to weather, while flabby gradients and light winds over the oceans do not seem to tie up with the distribution of showers. Even more so than in winter, precipitation (over the sea) provides the first indication of subsequent cyclogenesis. Organisation of showers into a more or less circular region of rain usually signifies that a disturbance has developed which can then be expected to move in the general flow, much as a tropical storm does. Thus in summer, careful delineation of rain on the surface chart helps analysis and prognosis considerably.

The surface isobaric chart only becomes the prime tool of the forecaster when a well developed tropical storm is in the area (see later sections).

(ii) Streamline analysis.

Aircraft observations continue to decrease and those that we still receive, instead of being clustered about the 10,000 ft. level now range from 8000ft. to 20000ft. Turbo-jet and jet aircraft will make the spread even greater. One can now seldom draw streamline charts detailed enough to use in prognosis. However, forecasters should become familiar with the simpler principles of streamline and isotach analysis. xx

Although upper wind observations have become more scattered, representative surface wind observations (from ships and coral islands) are becoming more and more numerous. Whenever the large scale observatory chart is used, surface streamlines, isotachs and hydrometers can be drawn on a transparent overlay. 2000ft. winds from land stations in low lying country help extend the analysis.

From accurate surface streamline/isotach analysis one can derive quantitative estimates of convergence, divergence and vorticity and through them a more fundamental understanding of weather processes and distribution. Using appropriate scales it is possible to evaluate both divergence and vorticity from a streamline/isotach chart.

Horizontal velocity divergence $= \frac{\partial V}{\partial S} + K_o V$ ———— I

Relative vorticity $= -\frac{\partial V}{\partial n} + KV$ ———— II

Where V = horizontal wind speed

K = curvature of streamline

K_o = curvature of streamline orthogonal.

∂S = element of arc on the streamline

∂n = element of arc on orthogonal

Since the streamlines are surface ones, (I) will indicate regions of rising and falling air which should correspond with areas of good and bad weather. Assume the theorem of the conservation of potential vorticity ($\frac{f + q}{\Delta p}$ = const.) is valid where

xx See "The Equatorial Front" by C.E. Palmer.

f = coriolis parameter
q = relative vorticity
} $f+q$ = absolute vorticity

Δp = pressure difference between top and bottom of a column of air.

Should successive streamline charts show that air is flowing in such a way as to come into a region of increasing absolute vorticity then there must be stretching of the column and weather deterioration. The converse of course would also apply.

Until we can devise speedy methods of graphical evaluation the technique of using divergence and vorticity charts will be confined to postmortems and research. However if the principles involved are clearly understood a forecaster can make useful qualitative assessments of vertical motion by carefully looking at an analysed surface streamline chart.

(iii) Contour analysis.

Occasionally one can make a passable contour analysis for the 500 mb surface over the oceanic and tropical areas of our region. Very rarely is it possible to do the same at 300 mb. Breaks in chart sequence prevent identification of long and short waves, jet stream positions or regions of energy dispersion. Except when the major long wave trough lies in the Japan-Loochoos region the charts have little prognostic value.

Careful analyses combining streamlines in the tropics with contours further north probably succeed in giving the best current picture of the wind field.

(iv) Time section analysis.

Although the number of reports at any one height or pressure level has decreased, the number of stations in the Far East making rawin and rawinsonde ascents has increased. Time-sections help utilise these data to the full.

A time-section should contain:-

(a) All available upper wind information, the code figure being entered as well as the arrows and feathers.

(b) Temperature, contour height and dew point at each standard pressure level.

(c) Heights of inversion bases and tops.

(d) 3 hourly surface observations.

(e) 24 hour changes in pressure heights and surface pressures entered at the mid point of the 24 hour interval.

(f) Depending on the season, space is available for plotting surface dewpoints, hourly or 3 hourly rainfall, maximum gust velocities, etc.

The time section is best analysed by drawing isolines of equal 24 hour pressure height changes, the zero lines being dashed and intersecting the ground surface at a point where the 24 hour surface pressure change is zero.

When pressure systems are progressing steadily from east or west one finds that the zero height change line usually coincides with a wind shift indicating passage of a trough or ridge at the station and that the slope of the zero line corresponds to the slope of the

trough or ridge. Should winds and zero line not coincide one concludes that steady motion or steady state is interrupted and, depending on the relative times of the wind shift and zero line that the systems have either accelerated, become stationary, retrograded, deepened or filled.

A single time section has limited value as a prognostic tool. a series of sections of different stations can be of considerable use. It can provide a three dimensional picture of moist and dry layers, and the slope, speed and intensity of fronts and troughs. Each section combines both surface and upper level information; onset and cessation of rain, often inexplicable in terms of a single level become understandable. Incorrect or impossible winds, temperatures or pressure-heights which are difficult to detect on contour charts show up on time-sections. Time sections aid in accurate placing of troughs and ridges on the contour charts.

(v) Tephigram analysis.

The first of many disappointments experienced by a forecaster newly arrived in Hong Kong concerns the tephigram. Despite what many text books say one cannot use the plot of the local ascent as a shower forecast tool. During summer, the period of minimum shower activity occurs around and after the surface temperature maximum and the period of maximum activity not long after dawn.

Although it does not help prognosis much, the tephigram in conjunction with rawin observations can sometimes give clues to physical processes which have been taking place. During the cool season for example, on a special slide rule (available) one can calculate the 24 hr. temperature change to be expected in a certain layer due to advection. The difference between the calculated and actual change can then be related to dynamical changes and to vertical motion.

At present in our region one tephigram or even a group of tephigrams seem to have less prognostic promise than other tools the forecaster uses.

In clear weather the tephigram may indicate the chances of turbulent cloud developing with an increase of wind. The probable base of that cloud is however better estimated from surface temperature and dew point.

The curves of temperature and dewpoint also help to explain adequately the local cloud distribution at the time of the ascent.

(vi) Thickness Pattern Analysis.

The purpose of this section is to outline the theory associated with thickness charts in order that they may be used intelligently as a forecast tool. The limitations upon their use imposed by the approximations made in the theory are discussed. A short bibliography is appended.

(a) Thickness Equation. Assuming there are only small vertical accelerations in the atmosphere, then we have the approximate relationship

$$\delta p = -g\rho\delta z$$

but $\quad p = \rho RT \quad$ where T is the adjusted virtual temperature

$$\therefore \int_{P_o}^{P} dp/p = -g/R \int_{z_o}^{z} dz/T$$

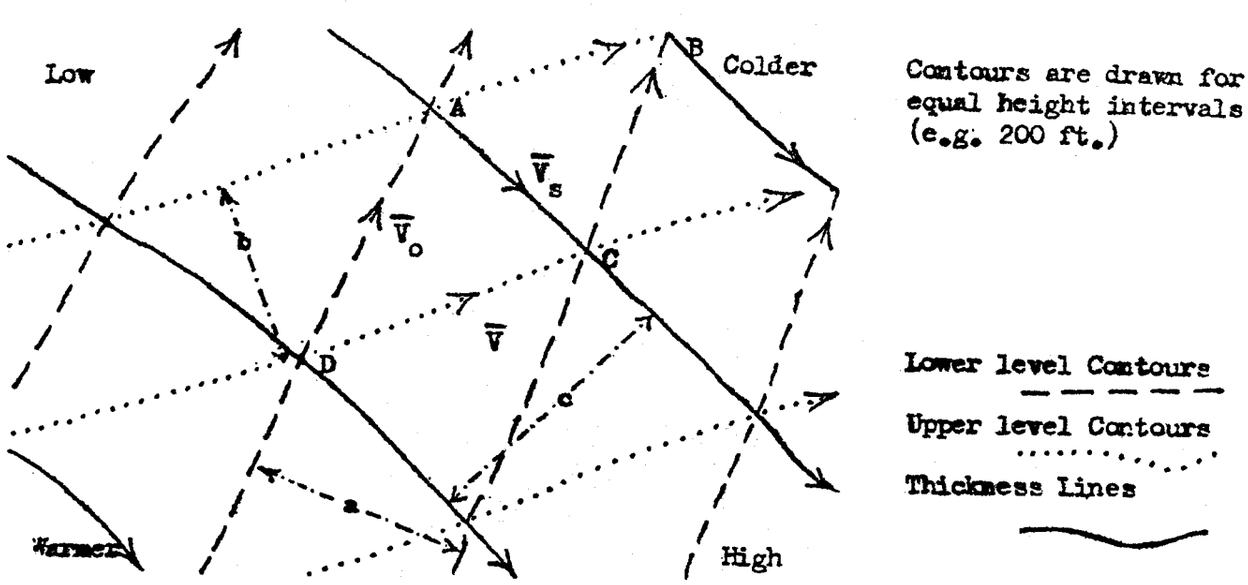
If we define the mean adjusted virtual temperature, Tm, for the column of air between z_o and z by

$$1/T_m \int_{z_o}^{z} dz = \int_{z_o}^{z} dz/T$$

then $\quad z - z_o = T_m R/g \ln(p_o/p) \quad$ the Thickness Equation

This indicates that $z - z_o$, the thickness of the layer of air between the two pressure levels p_o and p is proportional to T_m which may be regarded as the temperature of an equivalent isothermal layer of dry air.

(b) Thickness Charts and Thermal Winds



The diagram represents a portion of the combined contour and thickness chart. The thickness lines, which are isopleths of equal thickness for the air between the two pressure surfaces, may be obtained by "gridding" of the two contour patterns.

The geostrophic wind at the level p is given by

$$V = g/f \; (\partial z/\partial k)_p$$

where f is the Coriolis parameter, and k is measured at right angles to the contour lines

ABCD is approximately a parallelogram.

$$\therefore \text{ Area ABCD} = DA.a = DC.b$$

$$DA : DC = 1/a : 1/b \doteqdot (\partial z/\partial k)_{p_o} : (\partial z/\partial k)_p$$

$$= V_o : V$$

Thus, since the geostrophic winds flow along the contour lines and the lengths DA and DC are proportional to the magnitudes of the geostrophic winds, we see that $\overrightarrow{DA}$ and $\overrightarrow{DC}$ may be used to depict vectorially the geostrophic winds at the lower and upper levels.

If the flow is assumed to be geostropic then the vertical shear, or thermal wind, is by definition

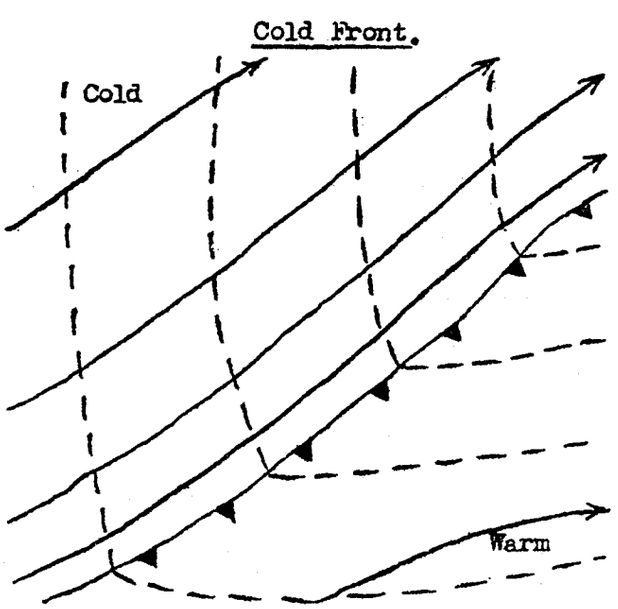
$$\vec{V}_s = \vec{V} - \vec{V}_o = \overrightarrow{DC} - \overrightarrow{DA} = \overrightarrow{AC}$$

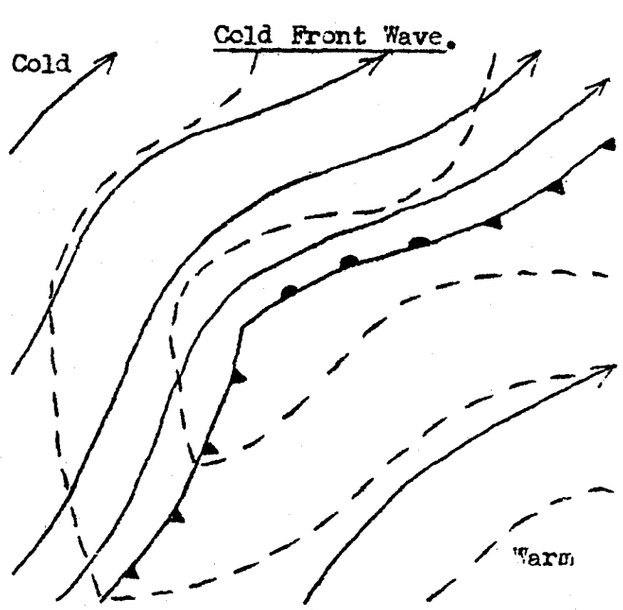
further $\quad$ Area ABCD $= DA.a = DC.b = AC.c$

$$\therefore V_o : V : V_s = 1/a : 1/b : 1/c$$

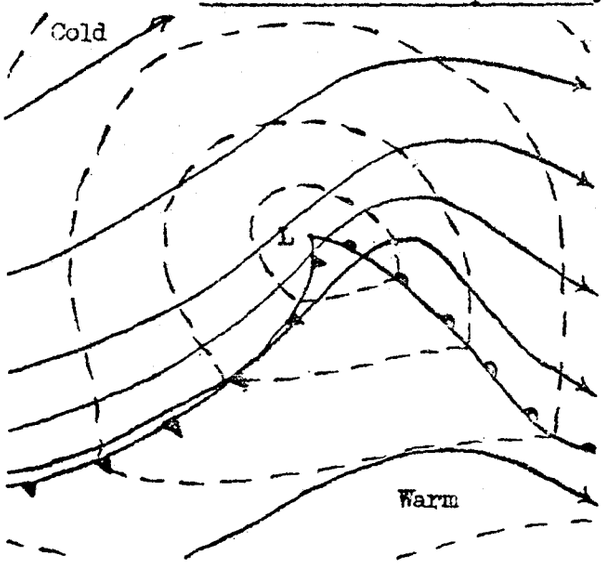
Thus the thermal wind may be represented by a vector tangential to the thickness lines, and of magnitude inversely proportional to their spacing. The sense of direction is with the colder air (i.e. smaller Tm) to the left (Northern hemisphere). It will be seen that the same geostrophic scale may be used to measure the lower, upper and thermal winds at a given latitude.

(c) <u>Surface pressure systems and their related thickness patterns</u>
When upper air data are lacking it is often possible to deduce tentatively the structure of the thickness pattern from the surface chart and a knowledge of the air mass history. The following examples indicate the ideas involved.

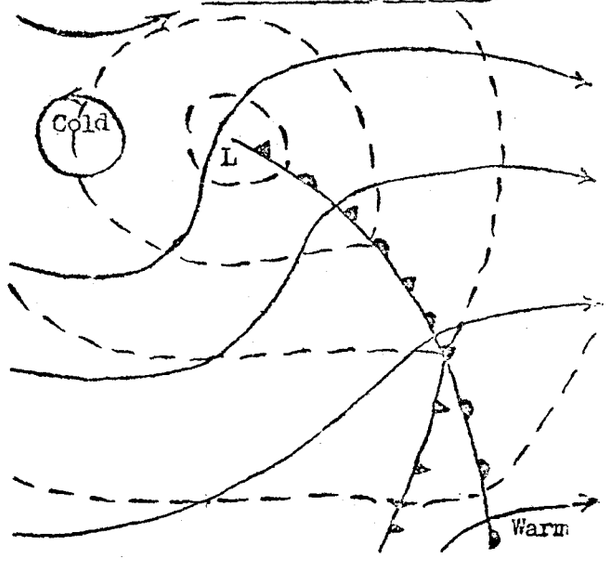




Matured Frontal Depression.

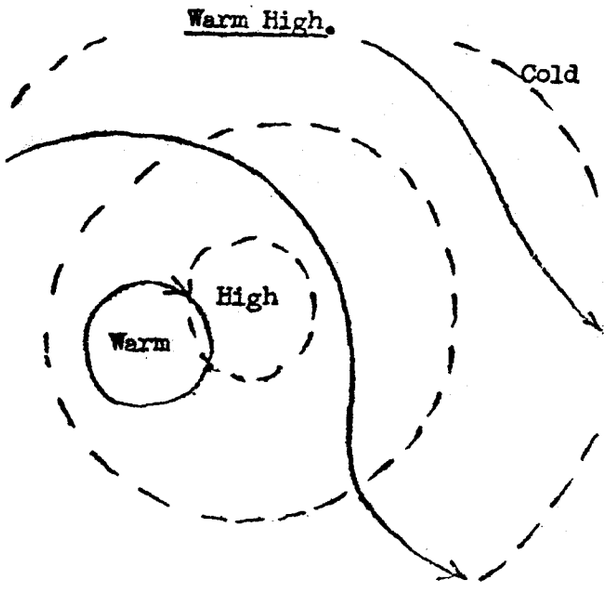


Occluded Depression.

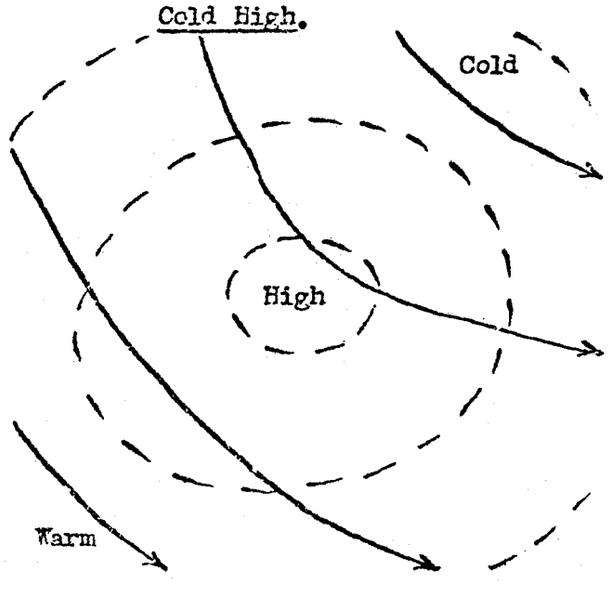


With the cold front, the temperature differences across the frontal surface, together with its slope, determine the spacing and value of the thickness lines. The closest spacing is in the cold (surface) air near the front. As a wave develops and warm air intrudes northward, the thermal pattern is modified as shown; the thickness lines tending to keep parallel to the front. If the depression is moving over an area where the surface temperature is uniform and no non-adiabatic changes are occurring, then the thickness line along the surface position of the front remains associated with the front. In practice this is often approximately true in temperate latitudes. The packing of thickness lines may increase with advection behind the front and is the most commonly noted feature on the thickness pattern of an intensifying front. Generally, due to the greater slope of the cold frontal surface, the thickness lines associated with it are more closely packed than those of the warm frontal surface. As the depression matures, and the cold front sweeps southwards, temperature gradients along the front steepen. This results in thickness lines crossing the fronts. As occluding proceeds, the modification of the thickness lines in the frontal region becomes less marked.

Warm High.

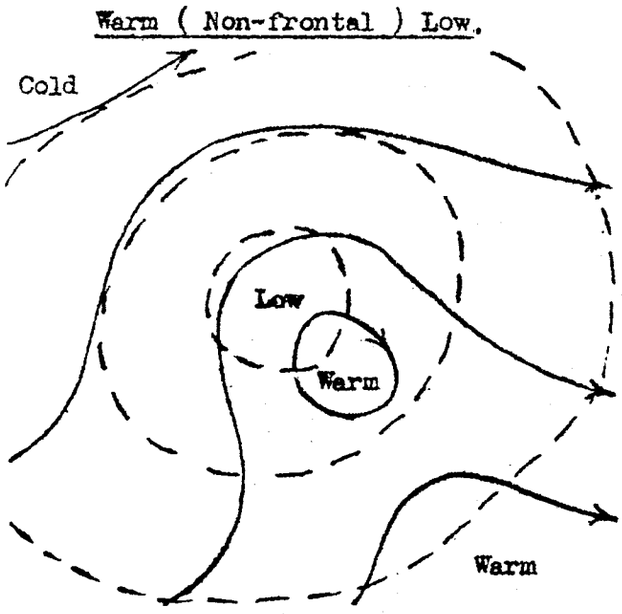


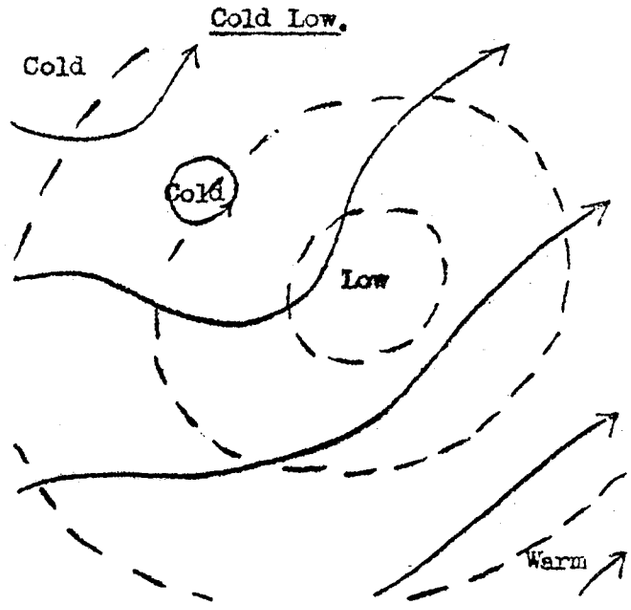
Cold High.



With deep stationary or slow moving anticyclonic systems the thickness lines show warm centres. In our area an example of this type is the Pacific anticyclone.

Due to their shallow depth cold anticyclones only slightly modify the thickness pattern. Thermal winds remain generally westerly. The Siberian high is of this type.





Examples:- The N. Indochina heat low and tropical cyclones.

Example:- The Aleutian low of winter.

(d) The Theory of Development. A significant feature of atmospheric dynamics is the relative constancy of surface pressure. It has been pointed out by various authors that the pressure tendency at the surface is only a small residue of large but opposing effects at different levels. In order to derive an expression for estimating these effects, the vertical integral of the horizontal divergence of a column of air from the top to the bottom of the atmosphere is assumed to be zero.

Now $\overline{V} = \overline{V}_o + \overline{V}_s$

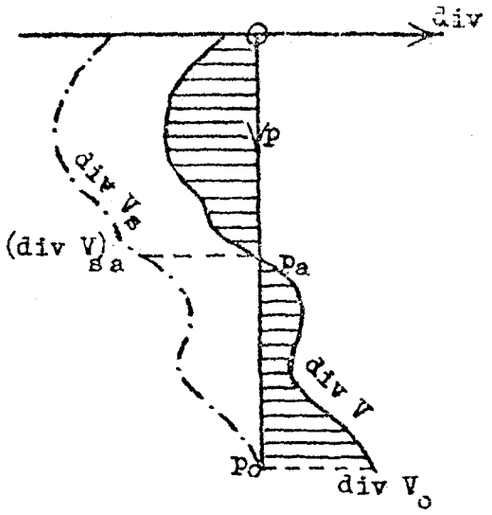
$$\therefore \quad \text{div } \overline{V} = \text{div } \overline{V}_o + \text{div } \overline{V}_s$$

where div refers to the horizontal divergence

Integrating, $$\int_o^{p_o} \text{div } \overline{V} \, dp = \int_o^{p_o} \text{div } \overline{V}_o \, dp + \int_o^{p_o} \text{div } \overline{V}_s \, dp \doteqdot 0$$

$$\therefore \quad \text{div } \overline{V}_o = -1/p_o \int_o^{p_o} \text{div } \overline{V}_s \, dp$$
$$= -(\text{div } \overline{V}_s)a$$

where the suffix 'a' indicates the pressure mean value



A distribution of div V and div V_s for low level convergence.

In other words, the development at low levels, which is one of the forecaster's major preoccupations, is approximately equal to but opposite in sign to the development of the thermal wind field at some intermediate level. The word 'development' is used here to describe convergence or divergence. From the above equation it may be seen that the horizontal divergence at the level 'a' is zero and this is usually referred to as the level of non-divergence. In practice the level of 500 mb is assumed to be non-divergent and the thermal wind field between 1000 and 500mb as shown by the thickness pattern is used to locate areas of development.

R.C. Sutcliffe has derived the following expression for development which enables an estimate of it to be made from surface and thickness charts:

$$\text{div } \overline{V}_s = -V_s/f \; \frac{\partial}{\partial s} \; (f + q_s + 2\, q_o)$$

where $\frac{\partial}{\partial s}$ denotes differentiation along the thickness line in the direction of the thermal wind
q_o and q_s are the relative vorticities of the lower and thermal wind field respectively.

This expression usefully indicates large scale synoptic developments but it suffers from the following defects:-

i Non-adiabatic effects are ignored e.g. radiation, earth-atmosphere heat transfer.

ii Thermal changes due to vertical motion are neglected e.g. subsidence warming.

iii There is assumed to be no variation in the direction of shear (thermal wind) with height between the lower and upper levels.

iv Atmospheric motions are taken to be approximately geostrophic.

v The expression cannot be applied satisfactorily to the immediate vicinity of frontal regions or to the centres of intense depressions where factors ignored in the derivation of the expression are not insignificant.

$$\text{div } \overline{V}_o = V_s/f \frac{\partial}{\partial s} (f + q_s + 2q_o)$$

For low level cyclonic development, div $\overline{V}_o < 0$

For low level anticylonic development, div $\overline{V}_o > 0$

(e) Application of Theory to determination of development areas. We will now discuss in more detail the terms contained in the development equation and show how they can be estimated from the low level contour and thickness charts.

V_s/f Since the magnitude of development, div $\overline{V}_o$, is proportional to the thermal wind V_s, areas of significant development are likely to be located near regions of strongest thermal winds. The effect on this term of the variation of f is negligible for the small latitude ranges normally considered.

$\frac{\partial f}{\partial s}$ Except in equatorial regions this term is generally small and may be neglected, as the thermal winds are normally westerly and therefore inclined at small angles to lines of latitude.

The development equation thus simplifies to

$$\text{div } \overline{V}_o = V_s/f \frac{\partial}{\partial s} (q_s + 2q_o)$$

$2\,\partial q_o/\partial s$ Physically, vorticity is a measure of circulation, thus q_o generally will be positive in regions of low level cyclonic systems, (large and positive near centres of deep depressions), and negative near anticyclonic ones. e.g. if the thermal wind associated with a surface low is westerly, then $\partial q_o/\partial s$ is negative ahead of the depression. This implies surface convergence ahead and divergence behind. In practice, it is only necessary to consider the vorticity due to the curvature of the low level contours since the shear vorticity is more difficult to evaluate. It should be noted that in order to evaluate this term, it is necessary to study the inter-relationship of the low level contour and thickness charts; an advantage of a "gridded" chart.

$\partial q_s/\partial s$ This term depends entirely on the geometry of the thicknes pattern, and is called the thermal development term.

Since $q = |\text{curl } \overline{V}| = \partial V/\partial n + KV$ = (Shear Vorticity) + (Curvature Vorticity)

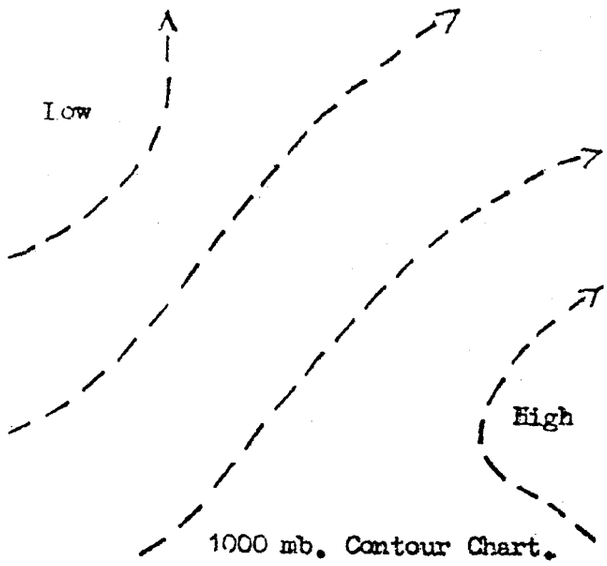
where K is the curvature of the streamline

$$\partial q_s/\partial s = \frac{\partial}{\partial s} (\partial V_s/\partial n + KV_s)$$

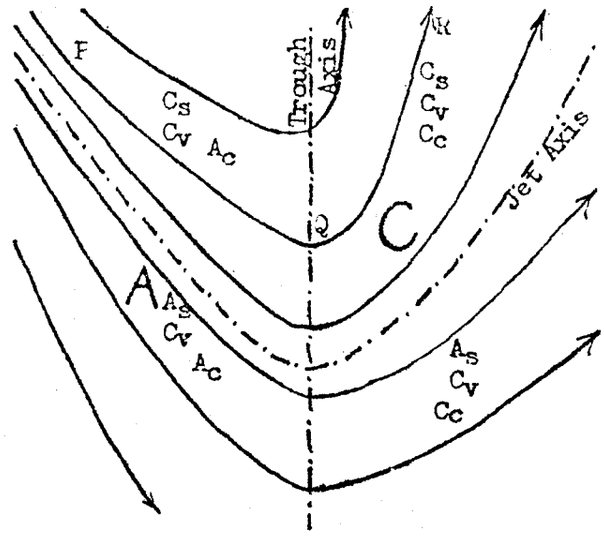
$$= \frac{\partial}{\partial s} (\partial V_s/\partial n) + K\, \partial V_s/\partial s + V_s\, \partial K/\partial s$$

It is seen from above tat thermal development will depend on the change along the thickness lines of (i) shear, of (ii) velocity and of (iii) curvature.

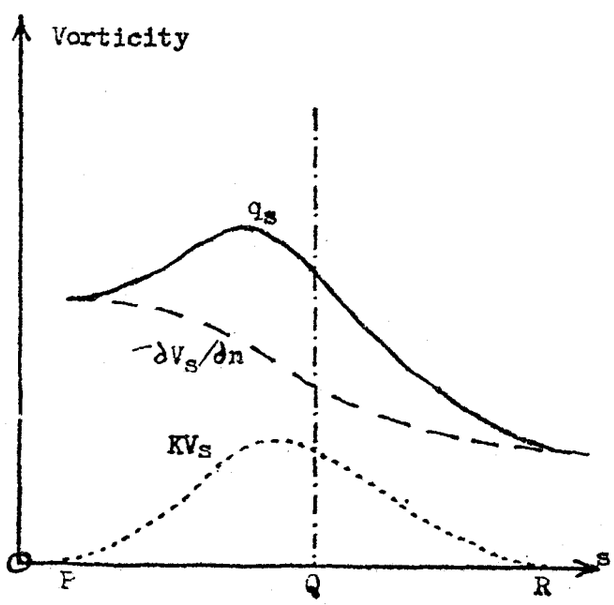
Example. Instead of attempting to lay down rules, the following is given to illustrate how the various factors above may be evaluated.



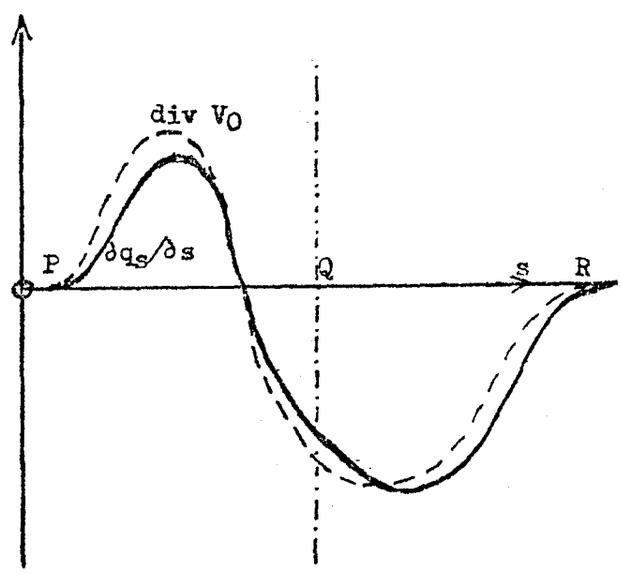
1000 mb. Contour Chart.



500-1000 mb. Thickness Chart.



Curvature, Shear and Total Thermal Vorticities along PQR.



$\partial q_s/\partial s$ and div V_0 along PQR.

The lower level contour chart has a slack gradient over the whole area. This indicates small q_0 and consequently the contribution due to $\partial q_0/\partial s$ is likely to be small and, if other terms are relatively large, it may be neglected in this case.

The thickness pattern is a difluent thermal trough. The jet axis is the region of strongest thermal wind. We will now consider the three factors in the thermal development term.

The shear vorticity $-\partial V_s/\partial n$ is positive above the jet axis and large to the left of the trough axis where the gradient is tight. It is negative below the jet. Thus $\partial/\partial s\,(\partial V_s/\partial n)$ is negative above the jet and positive below. The areas of low level cyclonic and anticyclonic development due to shear (thermal) are marked C_s and A_s respectively.

The factor $K\partial V_s/\partial s$ is negative over the entire pattern since the thermal wind decreases from left to right and K for cyclonic curvature is positive. If V_s decreases steadily along the thickness line ($\partial V_s/\partial s \doteq$ const.), then cyclonic development C_v will be most pronounced near the trough axis where K is greatest.

Since K is a maximum at the trough axis, $\partial K/\partial s$ is positive to the left and negative to the right. Taking into account the effect of V_s in the term $V_s \partial K/\partial s$, we see this results in relatively large anticyclonic development A_c to the left and small cyclonic development C_c to the right.

With experience, in simple cases, it is possible to make a combined estimate of the effect of $K \partial V_s/\partial s + V_s \partial K/\partial s$ $(= \partial KV_s/\partial s)$ the variation of curvature vorticity.

The resultant effect of all the above terms shows a most probable cyclonic development area (C) at the left hand side of the jet axis downstream from the trough, and anticyclonic development area (A) at the right hand side of the jet axis upstream. The influence of the thermal wind should not be forgotten when considering the magnitude of the terms.

Diagrams are given to show how the thermal vorticity and low level divergence vary along a selected thickness line PQR.

Standard patterns are given in various texts showing the most probable areas of development, but care must be exercised in applying the results to actual situations since an unusually large value of any one of the factors may significantly alter the positions of the cyclonic and anticyclonic development areas. A frequently occurring pattern in winter is the confluent trough lying over the Loo Choos (see F, Fig.6).

(f) Suggested technique of applying Sutcliffe's development theory to construct a Prebaratic Chart. (e.g. 0300z actual to 1500z prebaratic).

i Make sure the current thickness and surface charts are as mutually consistent as the observations allow. See Section(c).

ii Analyse the 0300z charts for anticyclonic and cyclonic areas as indicated in Section(e).

iii Make sure the current and previous charts are drawn so that the past changes in surface systems are as consistent with the actual and previous anticyclonic and cyclonic areas as observations allow.

iv Consider the past differences between geostrophic and actual displacement of the thickness lines. Attempt to relate these differences with specific dynamic and non-adiabatic processes, e.g. local heating, warming by subsidence, warming or cooling by vertical ascent depending upon the stability of the air, heating or cooling during advection etc.

v Sketch tentative 1000mb prontours for 1500z using normal synoptic procedure.

vi Use 0300z actual contour chart to advect thickness lines to 0900z and the 1500z prontour to advect from 0900z to 1500z. Make adjustments suggested by iv .

vii Check that the forecast thickness pattern agrees with the 1000mb prontour. Check that the 1000mb prontour agrees with the anticyclonic and cyclonic areas on both the 0300z current and the 1500z forecast thickness chart. Make any necessary adjustments.

APPENDIX I

Conversion of surface isobars into 1000 mb contours.

From the thickness equation

$$z - z_o = T_m R/g \ln (p_o/p)$$

we have

$$200 = 221.1\ T_m \log (p_o/1000)$$

where the 1000mb contour is 200ft above the surface.

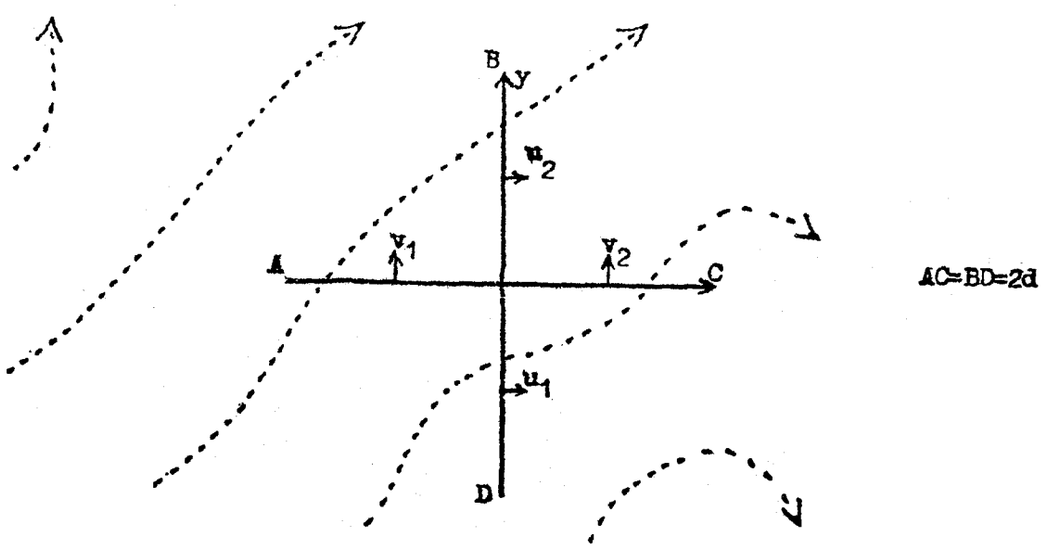
hence

$$p_o = 1008 \text{ mb for most normal temperatures}$$

∴ the 1008 mb isobar of the surface chart is approximately coincident with the 200ft contour of the 1000mb contour chart. Similarly the 992mb isobar corresponds to the -200ft contour etc. For hightemperatures, the pressure interval correponding to 200ft is less than 8 mb e.g. $T_m = 80^oF$ the interval is 7.3 mb.

APPENDIX II

Scale for measuring vorticity of contour and thickness patterns.



Vorticity $q = |\text{curl } \bar{V}| = \partial v/\partial x - \partial u/\partial y$ in Cartesian coordinates

Now $\partial v/\partial x = (v_2 - v_1)/d$

$$\propto \frac{(z_C - z_E) - (z_E - z_A)}{d}$$

$$\propto \frac{(z_C + z_A - 2z_E)}{d}$$

Similarly $\partial u/\partial y \propto \dfrac{(2z_E - z_B - z_D)}{d}$

$$\therefore \quad q \propto (z_A + z_B + z_C + z_D - 4z_E)$$

APPENDIX III

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FORECASTING (GENERAL)

(i) The Meteorological elements and their local peculiarities.

Our present methods of forecasting are a makeshift, and our standard can only be improved (a) if each individual forecaster watches the weather every day and makes the fullest possible use of his own experience, and (b) by a concerted effort to obtain adequate upper-air information, to present it in the most suitable form and to study the relationships between conditions aloft and subsequent weather in the light of recent work on the subject.

The surface chart is still one of our main forecasting tools in the cool season. Surface winds and temperatures are governed to a large extent by the surface pressure-distribution, and can usually be forecast fairly successfully from this chart. Cloud and precipitation are more dependent on conditions aloft, and cannot be forecast with sufficient accuracy from the surface chart alone.

An analysis of the weather associated with different pressure-patterns, and with transitions from one pressure-pattern to another, will be found in (6).

Persistence Forecasting. We often fall back on this when the situation appears to be unchanging, or when changes in it cannot be foreseen. Provided due attention is paid to diurnal variation, this can give a reasonable percentage of successes at certain times of year, e.g. in early winter, or during prolonged spells of the SW monsoon. But it is most unwise to use this method at times when rapid changes of weather are likely to take place for reasons not fully apparent on the surface chart.

There is a strong tendency to use the latest actual weather reports when forecasting for marine areas or aircraft routes - in other words to use the persistence method. Every effort should be made to anticipate changes in the situation.

(ii) Wind.

An analysis of ships' observations by G.S.P.H. (M.S. notes) indicates that, although the geostrophic relation does not hold accurately in our marine forecast areas A to G, the winds in the open sea are to a large extent governed by the pressure field in these latitudes. The average angle of inflow was found to be about 30°. The ratio observed/gradient wind speed varied from about 45% in lat. 25-30°N to 65% in lat. 10-15°N. The scatter about these mean values increased with decreasing latitude.

The surface pressure-pattern therefore gives an indication of the surface winds in the open sea as far south as 10°N.

Large-scale orographic effects. The funneling of winds through the Formosa Strait is well known. This effect is accentuated during the NE monsoon owing to the stability of the air and its inability to escape over the mountain ranges on either side.

Similar effects have been noted off C. Padaran in strong NE'lies, and in the Luzon St. and west of Luzon in strong E'lies.

Local effects. Kai Tak winds are very unrepresentative, and forecasts of wind for the general public should be mainly based on the anticipated Observatory winds; these are fairly representative of the town and harbour area where most of the population is concentrated.

Strong N'lies at Kai Tak - see Ch. 4.

At Kai Tak the gustiest winds are from NE although the strongest gusts at these times usually come from N. Winds off the harbour have comparatively little turbulence.

In the central part of the harbour SW winds may be gusty and squally.

Strong monsoon winds of 25 knots or more in the harbour may be forecast with considerable confidence within 12 hours or less when a combination of the following conditions occurs:-

(a) Anticyclone over China beginning to extend over Eastern or Yellow Seas.

(b) Isobars approximately E-W in immediate neighbourhood of Hong Kong.

(c) Pressure at Haiphong and Hanoi at least 1 mb below that at Hong Kong.

(d) Steep pressure-gradient (2 mb per 60 - 100 miles) in Formosa Strait and usually also in region of Hong Kong.

(e) 30 knot winds from NE or NNE in Formosa Strait.

(f) E'ly wind at Waglan increasing in speed.

Often only a few hours elapse between the development of these conditions and the occurrence of 22 knot winds in the harbour, though there is usually a further interval before sustained 25 knot winds set in. See also (I).

An analysis of the diurnal variation of vector resultant winds at the Observatory over 50 years (G.S.P.H. - M.S. diagrams) shows a veering during the day until about 15h and a backing during the night, in those months when E'lies prevail. The effect is most marked in October and November. In June, July and August the monthly mean diurnal variation is small and irregular.

No doubt this land and sea breeze effect is greater on sunny days than in cloudy weather. It appears to be more pronounced at Kai Tak than at the Observatory.

An incomplete analysis of P.B. observations indicates that at 5000' the upper parts of the sea and land breeze circulations dominate with a backing of prevailing E'lies during the day and a veering at night.

(iii) Low cloud.

Shallow gradients and light winds are often associated with fair weather in Hong Kong, while strong winds (except those off the mainland) are usually associated with turbulence cloud.

Thus in 1953, for example, fine days (mean daily cloud amount up to 20%) were never windy at the Observatory (mean wind vel. $<$10kt). Windy days ($\geq$20kt.) were always cloudy ($>$80%). On the other hand cloudy days occurred on a number of days with light or moderate winds for reasons other than low-level turbulence or orographic lifting.

(iv) Visibility.

Generally speaking the air is clearer in summer than in winter. In summer it is of maritime origin and any particles it contained may recently have been washed out of it by precipitation. In winter it is of continental origin and is almost always hazy to some extent.

Strong winds, however, tend to reduce the visibility in maritime air, owing to the presence of salt particles from breaking spray. An analysis of the noon observations at Waglan for the year 1953 showed that while visibility of 25 miles or more occurred on 62 days, on only 2 of these was the wind speed 20 kts. or more. On each of these occasions the wind was offshore.

Advection fogs. See (III)

Radiation mist and fog are not observed in the harbour area, and rarely occur at Sek Kong and other low-lying places in the New Territories.

(v) Diurnal variation of low cloud and visibility. (XI)

Throughout the year, combinations of low cloud and poor visibility unfavourable to flying most often occur just after dawn. In general the period from dawn to midday has the worst weather and the period from midday to midnight (except for a short spell around dusk) has the best.

(vi) Precipitation.

Light or moderate rain falls from "warm" clouds in this region. It is probable however, that heavy rain rarely occurs except when the clouds extend through the freezing level.

Local Effects. Rainfall distribution over the Colony is extremely uneven owing to the complicated topography. Orographic rainfall is of course heaviest over high ground. In the SW monsoon a succession of showers may drift to leeward off Victoria Peak and Lantau Peak leaving a lane of fair weather between.

Duration of rainfall. Except in typhoons, rainfall is unlikely to interrupt landings and take-offs for more than an hour at a time.(IV)

Rainfall intensity. See (VI) for maximum falls of rain in different time-intervals.

(vii) Temperature.

Reasonably accurate forecasts of temperature in Hong Kong can generally be made from the surface chart, taking into account the recent history of the air reaching the Colony. See (6) p.13.

(viii) The wording of forecasts.

The following notes are intended as suggestions rather than hard and fast rules; a certain amount of individuality in the wording of forecasts makes for variety. There are, however, some general rules which the forecaster should bear in mind:-

Avoid ambiguity; use specific statements even at some sacrifice of brevity.

On the other hand avoid unnecessary prolixity; every word has to be telegraphed in morse.

Forecasts should not contain information in greater detail than is justified by the observations. This applies particularly to distant areas where observations are scanty and our local knowledge is slight. (But we should strive to improve that knowledge).

If the forecaster feels unjustified in making any forecast, he may write "none issued owing to lack of information", or "no information".

Two degrees of probability are suggested:- (a) a plain unambiguous statement of expected conditions. (b) A statement qualified by "risk of" should only be used when the risk is of thunderstorms. Avoid "possible", "probable", "likely" or equivalent circumlocutions such as "may expect".

When writing the local forecast, bear in mind the diurnal variation of cloudiness and rainfall.

Winds. Approximate equivalents:-

Light ...	Beaufort Force 1-2	... ...	1-6 kts.
Moderate ...	3-4	... ...	7-16
Fresh ...	5	... ...	17-21
Strong ...	6-7	... ...	22-33
Gale ...	8-10	... ...	34-55

The words "gusting"and "squalling" should be avoided.

State of sky. The following definitions are to be used:-

Fine	Total cloud amount	0/8 - 2/8
Fair		3/8 - 5/8
Cloudy		6/8 - 8/8
Overcast		8/8 cloud in an impervious layer.

"Fair" may also be used to describe a sky more than 5/8 of which is covered with thin medium or high cloud which allows plenty of light to penetrate.

"Fair" conveys the impression that no precipitation is expected. If showers are anticipated with a mean cloud amount of 3/8 to 5/8, the forecast should be worded so as to imply an alternative between showers and fair weather; e.g. "Fair apart from isolated showers", "showers with fair intervals".

Never use "mainly" without qualifying it. A forecast of "mainly cloudy" is a meaningless hedge.

Precipitation. Definitions of "showers", "intermittent rain" and "continuous rain" as in Observer's Handbook.

The limits given in the Observer's Handbook for "light", "moderate" and "heavy" rain are somewhat low for a tropical station. I suggest that these should be re-defined for Hong Kong, with the lower limits for heavy rainfall at, say, 10mm/hr.

Temperature. Temperature should be mentioned in forecasts for the general public whenever there is reason to expect:-

(a) Mean daily temp. 5°F or more above or below the average for the time of year.

(b) A rise or fall of 5°F or more in the mean daily temperature.

Suggested terms:-

Winter - "colder", "cold", "milder", "mild", or "rather mild".

Summer - "hotter", "hot", "very warm", "cooler", "rather cool".

Visibility. Definitions of "fog", "mist" and "haze" as in Observer's Handbook.

SEASONAL DISTRIBUTION OF SYNOPTIC SITUATIONS AND THE PARTICULAR FORECASTING PROBLEMS INVOLVED.

Two methods of seasonal classification have been developed at the Observatory. One (6) describes the seasonal distribution of surface pressure patterns in relation to conditions in Hong Kong, finding a significant connection with winds and temperatures but none with weather. The other embodies three dimensional ideas and is designed chiefly to fit the weather regimes of our marine forecast areas.

Since the two classifications have quite different seasonal subdivisions (see diagram) they are presented separately.

THE SURFACE PRESSURE CLASSIFICATION (WIND AND TEMPERATURE).

(i) Winter Monsoon (Mid-October to late March).

Surges. The development of a depression in the region of the Eastern Sea is almost invariably followed sooner or later by a surge in Hong Kong. In autumn and early winter, depressions north of the Shantung Peninsula may trigger surges which eventually reach Hong Kong.

(a) The cold front in rear of the depression may not extend to the China Coast. In this case the intensification of the high over China merely results in a steepening of the gradient over the coast. The winds freshen in Hong Kong, but as there is no change in air mass there is no sudden fall in temperature. But the surge brings air from farther and farther north, so a gradual fall in temperature may be expected (see Chap. 2).

(b) A diffuse cold front extends into China from the depression. Although at its western end the front is more or less parallel with the isobars it continues to move south since the cold air behind it is usually blowing outward at a considerable angle to the isobars. As it passes Hong Kong there is a marked freshening of the wind followed by a gradual fall in temperature lasting a day or two.

(c) More rarely the front passing Hong Kong may be sharp and well-defined, accompanied by a sudden freshening of the wind and fall in temperature. (e.g. 30/4/49 - see autographic records).

Surges may reach Hong Kong either from N after travelling overland, or from ENE after travelling along the coast.

Northerly surges are at present unpredictable, though some indication of their approach may sometimes be obtained through the Communist press and possibly through anomalous propagation of radar signals beamed towards N and NW. During a surge strong N'lies may sweep through Shatin Pass, down the lee slopes below it and across the airport, rendering the runways unusable. The flow is enhanced by the katabatic effect and is usually most vigorous in early morning (C.S.R. - M.S. notes). By the time it reaches the Observatory 3 miles to leeward the flow has diverged, and strong N'lies are seldom recorded there in winter. The Helm Wind in Cumberland shows similar features.

Easterly Surges. Given a few observations along the coast between Hong Kong and Shanghai, the approach of a coastal surge can be followed and its arrival in Hong Kong timed with fair accuracy 12 hours or so ahead. Be bold, and forecast a freshening of the wind from ENE and a fall in temperature. Your successes will then outnumber your failures, though occasionally the N'lies may get here first, and occasionally the surge may slow down before reaching Hong Kong (e.g. when an approaching front was unaccountably held up from 17th to 26th December, 1948 between Canton and Hong Kong).

Strong winds associated with surges or following a surge see (I).

Dépressions crossing Manchuria on an E'ly track may not give rise to a surge in Hong Kong, particularly if pressure remains high over China and in a ridge extending eastward over the Loochoos.

Condition following a surge. Winds will veer to NE and E as the high over China begins to extend eastward, but it is difficult to forecast when this change will take place. Often the wind will veer temporarily to E in the afternoon with the sea breeze effect, backing to N again at night.

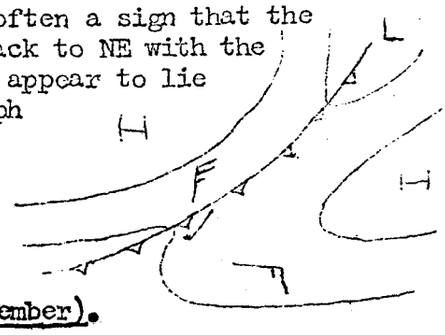
Breaks in the monsoon. These occur with increasing frequency as winter progresses. The usual sequence is for the high over China to extend eastward in a ridge over the Loochoos or Japan. The ridge sometimes but not always buds off as a separate anticyclonic cell.

While this is happening an orographic ridge of high pressure persists along the SE coast of China. Winds continue to blow along the coast, and do not moderate and veer to SE in Hong Kong (except perhaps temporarily in the afternoons) until the high cell is well over Japan or even further eastward.

Similarly it is not until the high has extended well out over Japan that there is a marked rise in temperature in Hong Kong, since it takes some time for air to reach here from the warm seas to the S. of Japan.

For these reasons the forecaster should not be in too much of a hurry to predict a break in the monsoon, with a veer of wind to SE and milder weather. ((6) p.14).

A marked lull in the winds in winter is often a sign that the next surge is imminent. E or SE winds cannot back to NE with the passage of a cold front; although the front may appear to lie more or less parallel with the isobars, anemograph records always show a veering of wind from E through S and west in the frontal zone with the westerly wind often very light and short lived. Hence the lull.



(ii) Early Winter (Mid-October-Late-December).

Weak onsets of the NE monsoon may occur as early as mid-September, but at first result in no very marked fall in temperature since the land and sea areas to N and NE of Hong Kong have not yet cooled down.

The first vigorous surge of relatively cool dry air generally arrives about mid-October. From then on surges recur at an average frequency of rather more than 3 per month, though the intervals between them are very irregular ((6) p.10). Complete breaks in the monsoon seem to be rarer in early winter than in late, as there is less tendency for high cells to migrate eastward across Japan.

N'ly surges are more frequent in early winter than in late, E'ly surges less frequent.

Surges are usually initiated by the development of a low in the region of the Eastern Sea (see above), but occasionally in October and November a N'ly surge may be initiated by a typhoon or tropical storm which has recurved and is moving N or NE in the region of the Loochoos.

(iii) Late Winter (Early January to Early April).

Strong E'lies, rare in the harbour area in early winter, reach their maximum frequency in March. (I).

In general, weather becomes more changeable as spring advances; avoid persistence forecasting - there are times when forecasting by opposites would give better results.

(iv) Spring (Mid-April early May).

Late surges of the winter monsoon may give fresh winds and rather cool temperatures in Hong Kong while a westward extension of the Pacific high can bring warm humid easterlies to Hong Kong.

(v) Summer Monsoon. (Mid-June - mid-August.

Some of us are reluctant to use the term "monsoon" for the SW'lies owing to the fact that the wind may temporarily revert to E with the recurrence of a trough situation at any time during this period. Yet spells of the SW'lies can be more persistent than those of the winter monsoon. ((6) p.9). Also the SW'lies of the China Sea are the same air mass as those of the Indian Ocean. So I prefer to retain the term "SW monsoon" or "Summer monsoon". This airstream brings the hottest stickiest weather to Hong Kong.

(vi) Trough conditions following summer monsoon. (Late August-mid-September.

Onsets of the SW monsoon as far as the S. China coast decrease rapidly in frequency, and the commonest situation is a trough lying E-W to the S of Hong Kong. Weather remains hot and sultry.

(vii) Autumn Transitions. (Late September - early October).

First weak onsets of winter monsoon may bring temperatures below 70°F.

THREE DIMENSIONAL AND PRECIPITATION CLASSIFICATION

Since the region has possessed adequate upper air data only since the war, suggestions in this section are necessarily more tentative than those in the preceding section. However, many of them are based on ideas which have already stood up to two or three years' testing.

(i) Eastward moving disturbances. (Mid-January to late June or early July.

This long period is one of steadily increasing rainfall in the subtropical parts of the marine forecast areas. Exceptions are the east coast areas of Annam and the northern Philippine Islands. There, orographic rain diminishes as the winter monsoon weakens.

Aloft, two important features, the polar westerlies and the subtropical ridge dominate the circulation. In January and February, both are well marked and persistant. The westerlies contain a sharply defined jet stream extending along the Yangtse valley and across south Japan while the nearly vertical axis of the subtropical ridge above 10,000ft. lies along 17-18°N. Surface cyclogenesis is usually confined to the region east of a major long wave trough in the westerlies lying along or to the east of 125°E. Except near the jet stream axis, in the cyclogenetic region and along the east coasts of Annam and the northern Philippines weather in the region is normally dry.

More and more often from February onward this well defined distribution breaks down and the divisions between dry and wet areas become increasingly blurred. The westerlies weaken and the subtropical ridge fluctuates considerably sometimes moving well south of 15°N sometimes jumping north of 25°N. Its axis often slopes equatorward with height. Although "normal" conditions occur on a high proportion of days in January and February, the norm in April, May and June is one of rapid weather changes.

All precipitation producing disturbances north of the subtropical ridge move eastward. Except in rare cases and in the south of Area G, rain moves in from west across the marine forecast region.

Surface "air mass" weather (see G). Before considering situations which are products of distortions extending through the troposphere we can consider those which belong to the lowest layers of the atmosphere (below 700 mb).

Chinese meteorologists long favoured air mass analysis. It was not as they hoped the answer to all their problems and has fallen into disrepute. However, analysis of air masses and of their modifications can play a useful although minor part in successful forecast practice.

In the first part of this period (mid January to end of April), surges of the NE monsoon alternate with lulls. There is a steady trend from northerly surges to easterly surges and from brief lulls to prolonged lulls as the season advances.

Northerly surges are usually dry and free from low cloud along the coast of China and inland but as the air moves out across the much warmer sea, heat and moisture are rapidly added and an almost continuous layer of convectional cloud, (a sort of "lumpy"stratocumulus) develops. With tops around 8000 to 10000 ft. the cloud is often deep enough to produce showers, especially over the warm Kuroshio Current.

At the other end of the surge spectrum are the easterly surges where air reaching the China coast has previously passed over warmer sea areas to the east. Distribution of cloud is now the direct reverse. Air over the sea, having for some time flowed nearly parallel with the surface isotherms is in a state of equilibrium; convection has subsided and clouds are scattered. However, once this air begins to move over the cold coastal waters it is cooled and should turbulence be sufficient, stratiform cloud which may give drizzle quickly forms above the lifting condensation level.

Most surges fall somewhere between these two extreme examples. A knowledge of trajectories and normal sea surface temperature distribution will help foretell cloud and weather distribution.

Lulls between surges occur when the continental anticyclone or a cell budded off from it moves eastward. Winds south of the high pressure centre veer, convection cloud over the warm seas decreases and cooling along the coast may produce turbulent cloud. Little change occurs in short lulls but when they are prolonged, high pressure over China may break down altogether and a wedge from the Pacific anticyclone extend across the area and on to the mainland. Then weather over the sea areas becomes almost cloudless but in the cold coastal water zone rapid cooling may result in low stratus cloud and drizzle or even sea fog (III), the crachin of south China.

The trend in surges and lulls mentioned above results in an increasing number of easterly surges, increasingly long lulls between surges and more persistent crachin, as the year advances. Thus from February onward the forecaster's chief day to day chore is trying forecast incidence of low cloud in coastal areas. Turbulence, topography, diurnal heating and dew point/sea temperature differences, all play important parts in determining when and where crachin will form and what form it will take. The interrelations of these factors along the coast may be extremely complex. Wind speed decreases 5 kt. as the temperature maximum approaches and an apparently permanent layer of thick stratus dissipates. A slight change in wind direction and a previously fog freebay is rapidly enveloped. A range of hills more than 1000ft. high can greatly modify stratus distribution while even lower lying land can hold up advancing sea fog. Each area has its local peculiarities. Since vigorous crachin usually occurs in the col or trough-region west of a surface high, it is associated with winds veering with height. Conversely it is unlikely when winds back with height. With no information from China, wind turning with height at Hong Kong first indicates whether the centre of the high cell to the north lies either west (backing) or east (veering) of the Colony.

Surges of the NE monsoon may be important crachin modifiers. However, from February onward even moderate surges may not dissipate crachin, for the air behind the front can still be undergoing surface cooling along the coast. A temporary lifting in cloud base but no break in cover is usual. Particularly in the Formosa Strait - south China area, crachin can be modified without any surge at all. With ENE

flow, air reaching the south China coast has usually passed down the Formosa channel over a heating surface; this may happen with easterly flow but then again if the air reaching south China has previously swung around S. Formosa it will have crossed a cooling surface. Thus, when general flow direction is critical, minute disturbances can switch the air from one track to another and coastal weather from partly cloudy to fog.

The longer a lull in the monsoon persists the warmer and moister the air reaching the coast becomes. Cloud base steadily lowers and eventually sea fog forms. At Hong Kong (and probably in the rest of the crachin zone) dew point rises steadily during a lull. If the air is moving around a high centred near Japan, the rise averages 3°F/24 hours; should it be moving around a wedge from the Pacific high, (more common in March and April) the rise averages 4°F/24 hours. Since sea temperature tends to remain steady over such intervals, one can often estimate the time dew point and sea temperature will coincide and sea fog form.

Sometimes in January and February general high pressure over China breaks down. Frontal systems extend from west to east across north China and south of the Yangtse and small high cells move eastward across south China. Apart from some Ac when troughs between the cells pass, coastal weather stays fine and westerlies occasionally reach the surface. Marked lowering of the base of the westerlies and general weakening of low level winds presage this development. Coastal areas south and southeast of a cell centre may have moderate or fresh SE winds but with the air having so recently passed over land, no significant dew point rises or low cloud occur.

Until late April, low cloud is almost always stratiform; from May onward, almost always cumoloform except in Area Z.

In the second part of the period (May to late June or early July), surface air mass discontinuities are rapidly ironed out. Diminishing temperature differences between coastal waters and the open sea spread steadily northwards. At the same time however, the winter monsoon has died out and tropical maritime air often reaches north China coastal waters. Crachin is almost unknown in areas C, D and E after early May but reaches a frequency maximum in area Z during the same month. However, in rear of a May tropical storm moving westward across the China Sea the strong southerly flow over relatively cold coastal waters can bring dense fog to areas C, D and E.

Except in northern coastal areas, air and sea are generally in temperature equilibrium with one another and scattered cumuloform cloud is the rule in undisturbed conditions.

In May, over coastal and inland areas of China, Korea and Japan, there first appears the peculiar early morning rainfall maximum typical of all the summer months (see D). Generally speaking the morning maximum occurs about dawn inland, but sometime later along the coast where it probably coincides with onshore movement of a sea breeze convergence zone. Inland, a second maximum which occurs in the afternoon and evening, reflects convection resulting from intense surface heating.

Tropical trough (see H and C). "Tropical trough" is a name given to a disturbance which may first appear around mid-January over India at and above 30,000ft. The trough, moving eastward sharply interrupts the prevailing southwesterlies of these layers. The lower tropopsphere is little affected until the trough reaches Port Blair but from then on it intensifies and colder air feeds in from north. From the view point of our present operations, Bangkok rawins provide the best warning. High level winds there turn westerly, veer and strengthen as the trough passes.

Rarely, the trough continues eastward at more than 20 knots, having little effect on surface weather until it reaches the strongly

frontogenetic region east of Formosa.

Normally, tropical troughs intensify and become stationary west of our marine forecast areas.

From mid-January to the end of April tropical troughs generally intensify, slow and stop over Siam - Indo China. When this happens, weather to the east deteriorates, usually along the line of a previously quiescent polar front marking the southern limit of the most recent NE monsoon surge. As long as the trough remains stationary, wave disturbances move along the polar front, producing highly variable and unsettled weather to the north. Eventually as the upper southwesterlies re-establish over India and the Bay of Bengal the tropical trough weakens. It may then move east of Hong Kong but usually dies in situ. India observations are essential for one to detect onset of this phase.

Hong Kong surface conditions, apart from rain remain about average during a tropical trough situation. Generally a moderate NE monsoon and slightly below normal temperatures during the active period, slackening winds and rising temperatures as the trough weakens.

Tropical troughs become more frequent as the year advances. Most of the rainfall of March and April, south and west of the Loochoos, can be attributed to them and their activity largely determines the precipitation pattern of these months. In April, and at times in March, the polar front usually lies over the northern part of the China Sea and through the southern Loochoos with true Tm instead of Pm air to the south. When the front is activated, thunderstorms are common.

From May to late June or early July, tropical troughs generally intensify and become stationary over the Bay of Bengal. Transition from Siam - Indo China to this region occurs either in the first or third weeks of May. Thus Burma, instead of always lying in a region of subsidence west of the intensified trough, is now to the east. The dry season abruptly finishes as the summer monsoon "bursts" over the country.

Surface weather further east develops as in the earlier months. As surface temperature gradients slacken a cold water remnant persists along the China coast which becomes a favourite place for the polar front to sit. Thus when the front is activated, soth China often experiences heavy rain. Development of rain and thick altostratus sheets over SW Burma and Siam indicates subsequent (not too long after) deterioration further east.

By June, surface frontal discontinuity along the polar front is hard to find but at higher levels temperature contrasts may still exist. Disturbances on the front can be more easily located at 5000 or 10000ft. than on the surface. Properties of the polar front at this time of year are not well understood.

Occasionally in May or June the polar front lies across south China. The coastal region then suffers from the hot humid but relatively rain-free "SW monsoon".

When tropical troughs are active the subtropical ridge aloft is displaced well south and east of its normal position over the China Sea. When this happens in May and June, true tropical storms neither form in nor move into the China Sea. With no tropical trough activity, the ridge moves west and north and tropical depressions have room to form in or to move into the China Sea. Often these disturbances have no surface closed isobar but one can sometimes trace a rain-area and a wind-shift line around the subtropical high cell and on to the China coast (see C). Tracking a rain area is not too hard for at this time of year weather over the China Sea is usually very fine and rain shows up well.

Major displacements of the subtropical ridge. Only one type of situation seems capable of giving prolonged clear weather over south China and the Loochoos in March or April. On an average, once every

2 or 3 years (in response probably to a sharp change in the hemispheric circulation), the Himalayan jet stream disappears and the subtropical ridge aloft shifts several degrees northward. The eastern part of a ridge cell overlies south China. NW winds at all heights bring in phenomenally dry air liberally laced with Tibetan dust and possibly Burma smoke. This situation may last a week with southward moving fronts rapidly dissipating over southern Japan. It breaks down gradually and without rain.

In June, the subtropical ridge aloft tends to move north. At times during the month the ridge axis may move north of 20°N. South China now lies in the western part of a ridge cell and experiences fine weather and light SE winds. However, such a temporary axis shift exposes the coast to westward moving storms. Statistics show that the risk is slight; only 2 June storms moving from east have given gales in Hong Kong in 70 years.

The West China trough (mid-January to end of April). In winter the major Far Eastern long wave westerly trough lies along about 125°E and surface cyclones usually develop east of this longitude. However, a few times every cool season (rarely more than four) the trough along 125°E dissipates or moves rapidly eastward. A warm wedge extends westward from the Pacific anticyclone bringing fine weather to the Loochoos and China and sea fog to the China coast. The Siberian anticyclone retreats northward and westward and over south China dew point and temperature rise and pressure falls. At this stage, a trough in the low latitude westerlies moving east from India will intensify over west China. This results in the region of surface cyclogenesis being displaced about 20 degrees westward. As long as the trough remains over west China, central China and areas A and B experience extremely unsettled weather.

When hemispheric flow returns to normal the west China trough moves eastward. The wedge from the Pacific anticyclone has earlier brought tropical maritime air far inland and warm front and cold front thunderstorms are common. West of the trough line there is vigorous subsidence, an intense anticyclone builds behind the surface cold front and normal conditions return. Just ahead of and at the trough the surface front and depression system may travel sufficiently far south to give rain to south China and northern Indochina although weather stays fair south of 20°N.

Since we plot no China observations at Hong Kong, formation of a west China trough must be deduced from indirect evidence.

Usually three to five days elapse from the time a west China trough develops to the time it reaches 125°E, the normal long wave trough longitude.

Occasionally a west China trough situation lasts from ten to twenty days. The trough and its associated depression may move eastward. However, there is no rapid anticyclogenesis west of the trough line. Instead, pressure falls again over China and upper winds back from NW to SW. The eastward moving trough weakens as a new deep cold trough intensifies over west China. While it remains stationary it is a source of shallow disturbances travelling ENE. South of the disturbance track, south China experiences persistent southerly winds and unseasonably warm and humid weather. When the trough finally moves eastward the continental anticyclone is restored to its usual position.

Towards the end of April, heating of the continent flattens temperature gradients and the west China trough ceases to be of significance.

Local forecasting in tropical or west China trough situations. When the position or intensity of the upper trough is in doubt, the saying "Red sky at night is a shepherd's delight" can usefully be applied. (During the period of westward moving disturbances the converse is more likely to be true).

Cold fronts moving across the Colony are rarely accompanied by thunderstorms except when an active trough lies to the west.

(ii) Hybrid storms of the China Sea (usually in June but occasionally in July, August or September).

By June the N-S temperature gradient has weakened sufficiently for easterlies to appear just below the tropopause south of 25°N (V). During this month tropical troughs often activate the polar front or its remnant shear line across the northern part of the China Sea. Rather meagre evidence suggests that at such times a westward moving disturbance in the high easterlies superimposing on the lower level disturbance may result in the slow development of a surface circulation. Strong winds are first confined to the eastern semicircle and then slowly extend around the centre. They seldom exceed 45 knots, possibly because of the considerable initial shearing between layers and proximity to the coast. During development the storm is stationary or moves slowly and erratically; when finally the circulation extends throughout the troposphere, the centre moves westward. On an average one hybrid storm develops every June.

A similar initial distribution of westerlies in the lower and middle troposphere and easterlies above is found over the China Sea when a typhoon is filling over south or southeast China. Thus hybrid storms may form (although rarely) in July, August or September.

(iii) Subtropical ridge (late June or early July to mid July).

Available evidence indicates that early in July in most years the northern hemisphere subtropical ridge aloft "jumps" northward. Over southeast Asia the shift occurs so regularly that it produces the most important weather singularity of the year.

In June, the ridge axis usually lies along 20°N. Thus apart from area G all our marine forecast areas lie in the region of the upper westerlies and are affected by eastward moving disturbances. By mid July, however, the ridge is usually found along 28°N and all the areas to the south are overlain by deep easterlies.

As the ridge moves north, weather over south China becomes fine and the land dries out as it passes. The season of westward moving disturbances begins and the region lies open to the great storms of the Carolines and the China Seas.

(iv) Westward moving disturbances (mid July to mid October, (see 3.4, C).

With all forecast areas south of 30°N covered by a deep easterly flow, the typhoon season proper begins. Storms forming anywhere east of the Philippines now move steadily WNW and eventually fetch up on the coasts of China or Indochina. Recurvature south of Hong Kong is almost unknown. Rain comes from typhoons, tropical storms and easterly waves.

Generally rainfall is more concentrated than in early summer although totals stay about the same. There are more rainless days for there is always a fine clear day or two in the divergent zone ahead of the right front quadrant of an advancing storm. For Hong Kong this has meant that valuable upper wind observations could be made and preliminary storm precautions carried out with minimum of inconvenience.

Typhoon forecasting as practised in Hong Kong is largely empirical and extrapolatory. Since 200 mb. charts are not drawn one cannot apply modern techniques and is compelled to rivet attention on the surface chart, supplemented by time sections.

During the typhoon season, surface winds are usually light and fitful. Over the sea, showers are scattered or sometimes in E-W lines. We cannot detect storms in their very early stages east of the Philippines but over the China Sea it is possible to anticipate birth.

Showers organising into an area of precipitation coupled with the lightest of cyclonic circulations should be acted on. Ask ships

in the area for 3-hourly reports and then as the circulation develops, extend the area of frequent reports and possibly ask for hourlies. In the early stages, climatology decides forecast movement and intensification; once the storm develops, extrapolation and whatever the upper air can tell. Remember that in a weak cyclonic circulation over the sea there is always a chance a small but vigorous storm has already developed.

Topography plays an important part. Well developed storms almost never fill over the Philippines although land station observations there may deceptively indicate that. (As a rule, where the full typhoon gale strikes, lines come down and reports are not made; the few sheltered spots reporting give a false picture). When a storm strikes the land it seems to slow down with the centre held against the mountains. Some hours later the centre suddenly appears well west of the land, having apparently leapt across. On most occasions, above the level of the mountain tops the centre progresses steadily while the surface centre holds up, dissipates and then suddenly reforms further on. Unless there is strong contrary evidence, extrapolate both speed and direction as a storm approaches the Philippines to cover the time it is moving over land. Similarly for Formosa although this island with its higher mountains is fairly often a typhoon graveyard. If a typhoon approaches the mainland at a small angle it will probably skirt the coast with the centre just offshore. This is a surface steering effect, the storm moving to retain its energy source. One should not report a storm moving inland after a small approach angle until positive information comes in. Storms may remain intense some time after moving inland over the flat country of south China or the Yangtse delta. These areas consisting of flooded paddy provide almost as frictionless a surface as the sea and are even better sources of heat and moisture.

Tropical storms drift in the general current and streamline charts (provided there is enough information) may usefully indicate the probable movement of small and medium sized vortices. Recurvature is really the one sided effect of a small mass (typhoon) revolving mutually with a large mass (anticyclone). Every year "super" typhoons develop with winds over 150 knots and with a huge area of strong winds. These storms have masses of the same order of magnitude as an anticyclone's and so the high's movement in the process of mutual revolution becomes apparent. It extends westward and the typhoon instead of recurving as a lesser storm would, tends to keep steadily on its way. Many great Loochoos and east China storms have thus had NW or NNW tracks to well north of 35°N.

The belt of maximum storm frequency which lies through areas C, D, E and F in July and early August shifts northward to areas A, B and W in late August and then, following the sun, southward again. The subtropical ridge axis behaves similarly. Thus on an average storms recurve furthest north in August.

Local typhoon forecasting in Hong Kong. The fine spell in advance of a typhoon or tropical storm lasts on the average until the centre is 300 miles away. With very small storms, the distance may be only 150 miles.

The first clouds to appear may be either Ci Cs or rather hard-edged bands of Ac.

Evening thunderstorms sometimes occur on the edge of the typhoon circulation particularly if the typhoon is moving northward in the Formosa area; possibly these are heat storms carried from inland as the N'ly winds set in.

When once Hong Kong is within the circulation a close watch should be kept on the upper winds by soundings and frequent nephoscope observations. These often give an early indication as to whether the centre will pass to N or S of the Colony.

A typhoon crossing the coast to the NE of Hong Kong on a W'ly or NW'ly track is likely to produce less wind than one passing

at a similar distance to the south. This is because a typhoon which has entered the coast is already beginning to fill up by the time the centre is nearest. But it is by no means unknown for a typhoon passing to N or NE to produce a gale, though the most destructive typhoons have been those which passed to the S.

In this connection, a W'ly gale causes much more trouble than an E'ly one in the harbour (cf. "Rita", September 1953).

The Kai Tak forecaster must keep in mind the probability of strong N'lies rendering the runways unusable some time before the wind reaches gale force.

After the passage of a centre to the S the wind seldom veers beyond SE, and tends to revert to E as it moderates since a trough is usually re-established in the wake of the storm. When a large storm moves inland over Tonkin fresh SE winds and squally showers may persist for several days.

(v) Eastward and westward moving disturbances (mid October to mid January) (see 3.4. H).

During October the subtropical ridge aloft, now moving southwards reaches the same average latitude it occupied in June. By January it has reached its normal winter latitude along about 17°N.

North of the ridge eastward moving disturbances or recurved tropical storms account for most of the precipitation, south of the ridge typhoons or easterly waves follow west or sometimes WSW tracks.

From this superficial description one would expect weather patterns of October and November to resemble those of May and June but this is not so. Whereas in early summer the west Pacific typhoons are few and ill developed, in autumn they are numerous and reach their greatest intensity. In addition, the tropical trough is unknown in autumn.

This period, in the marine areas south of 30°N is one of ebb and flow between the NE monsoon and typhoons; the latter dominate at first but by January only feeble storm remnants or weak easterly waves penetrate west of 125°E.

Monsoon bursts are generally from N or NE, giving fine weather along the coasts but considerable convection cloud and some showers offshore where heating and moisture addition reach their maxima for the year. Onset of the monsoon coincides with establishment of the normal winter flow pattern aloft. South of the jet stream subsidence flattens the cumoloform clouds of summer into the stratiform clouds of winter.

The China coast north of Amoy is typhoon-free during this period, but typhoons, especially in October, frequently pass across area G. They present a difficult forecast problem, especially for south China. If a storm heads across the northern part of the China Sea during a monsoon lull it may give the coast prolonged battering (the two longest typhoon gales at Hong Kong occurred in October) and may even recurve nearby. On the other hand, storms approaching the south China coast frequently lose intensity and occasionally completely fill. This occurs when comparatively cold dry air from China enters the storm, causing the air circulating around the centre to lose potential energy.

For a source of cold dry air to exist over China, the Siberian anticyclone must already have spread south into north China and become fairly well established. Thus one would expect an approaching storm to lose intensity if pressure over central China were above normal. This usually happens, but occasionally when central China pressure is well above normal, an approaching typhoon shows no sign of weakening. Surface pressure indications are therefore not always reliable.

Hong Kong surface wind direction and dew point are much more

reliable criteria. Using them, two specific cases have been studied, one of storm centred 300 miles east of Hong Kong, i.e. between 119 and 120°E, the other of a centre 150 miles east of Hong Kong, i.e. at about 117°E. When storms are centred at these positions, hoistings of the local preliminary and gale warning signals are being considered. The study provided two tentative empirical rules:

(a) If when an approaching storm is centred between 119° and 120°E, the Hong Kong surface wind has a component toward the storm centre and the Hong Kong dewpoint is more than 1°F below normal, the storm will usually fill before entering the coast.

(b) If when an approaching storm is centred near 117°E the Hong Kong surface wind has a component toward the centre and the Hong Kong dewpoint is more than 3°F below normal, the storm will usually fill before entering the coast.

In this period, low level flow across the China Sea has a dual character. In the north it forms part of the circulation around the continental anticyclone, in the south it is part of the deep easterly stream of tropical maritime air south of the subtropical ridge. Easterly waves, often the remnants of stormsmove in this stream. In the south, weather is typically fine ahead of a wave and unsettled to the rear; in the north, particularly if a disturbance in the polar westerlies is present, weather may become unsettled some distance ahead of the trough line and worsen somewhat after its passage. Many fully developed storms heading west to the south of the subtropical ridge aloft may influence weather north of the ridge in the manner of a vigorous easterly wave.

Over the China Sea after October the subtropical ridge aloft seldom possesses a marked cellular structure and storms moving westward on its southern side normally do not recurve. Should they do so, weakening is so rapid that there is little chance of their retaining destructive winds. Because of the generally steady movement of storms and waves, extrapolation based on previous tracks gives adequate results. However, storms in December or January may have their westward progress across the China Sea suddenly checked by a surge of the NE monsoon. Movement is then slow and erratic and filling often ensues.

A rather obscure type of situation may give torrential rain to south China in either November or December. A Bay of Bengal cyclone moves inland over Burma and dissipates in the lowest layers. Then, somehow maintaining its identity aloft it travels eastward across Siam, Indochina and south China, embedded in the westerlies. In these two months, keep tabs on Bay of Bengal storms and watch for bad weather over north Siam after a storm goes inland.

By mid-January (except rarely in southern area G) the winter monsoon is so dominant that westward moving tropical disturbances never affect the marine forecast areas. South of the jet stream the tropical trough and the west China trough begin to appear.

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