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THE SUBTROPICAL JET STREAM OF THE EASTERN NORTH PACIFIC OCEAN IN JANUARY AND APRIL 1952

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THE SUBTROPICAL JET STREAM OF THE EASTERN NORTH PACIFIC OCEAN IN JANUARY AND APRIL 1952

By H. D. HOYLE, B.Sc.

Summary.—Daily maps of the main jet-stream cores in the eastern North Pacific Ocean in January and April 1952 are shown. The days are grouped into four types and average vertical cross-sections for each type are given. Two separate jet-stream cores are frequently present, one associated with the polar front and one, at a higher level, often 1,000 miles or more farther south.

Variation from day to day in the strength of the more southerly of the streams is discussed in relation to the upper air temperature field and the major surface synoptic features. The thermal-wind relation appears to hold reasonably well at these rather low latitudes and geostrophic advection of the temperature field seems to make an important contribution to these day-to-day variations in the intensity of the jet stream.

When there is only one jet-stream core, the upper air temperature field and the surface synoptic charts show interesting changes. This leads to a suggestion that the ageostrophic meridional circulation accompanying the subtropical high-pressure cell is important in establishing the upper air temperature field.

Introduction.—It has been demonstrated by several writers, among them Gilchrist[1]*, Bannon[2] and Cressman[3], that the belt of strong westerly winds in the upper troposphere, known as the subtropical jet stream, sometimes displays a two-core structure. Bannon[2] shows that the eastern North Pacific Ocean in January and April is an area especially notable for this. One core is clearly associated with the polar front, but the other, nearer the equator and at a higher level, is not so clearly associated with features of the surface synoptic weather map. Owing largely to the distribution of upper air reporting stations, most areas in which the high-level winds of the subtropics have been investigated are ones in which, in winter, the land–sea distribution gives rise to semi-

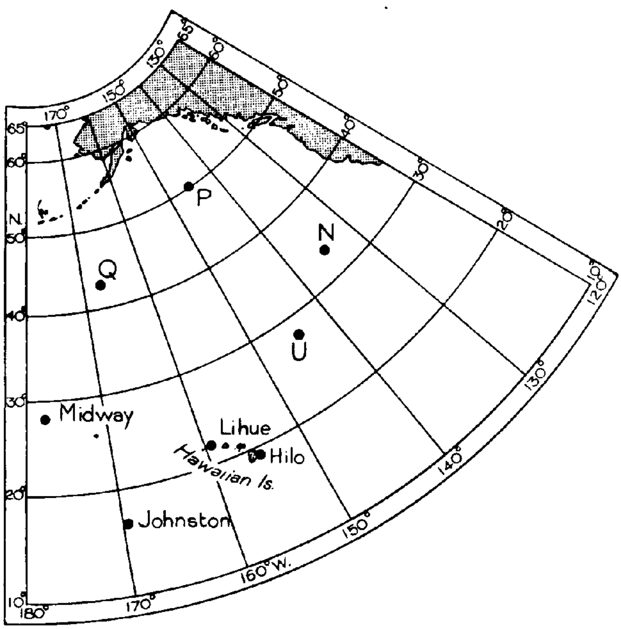


FIG. 1—REPORTING STATIONS
N, P, Q and U denote ocean weather ships

* The index numbers refer to the bibliography on p. 19.

permanent troughs and considerable equatorward penetrations of polar air, making distinction between the two streams more difficult than in the area studied in this note.

The area considered and the observing stations used are shown in Fig. 1. During April 1952 an almost complete set of observations was available from all the stations shown. In January 1952 observations were less complete and there were none from ocean weather station Q. Consequently, the analysis of the upper-level charts is less trustworthy in January than in April, particularly in the north-west portion of the area. To help in the construction of the mean and anomaly charts for January, values of contour height and temperature at a few latitude and longitude " grid " points were interpolated from the isopleths on the daily charts and their means calculated. April is therefore treated in rather greater detail in this note, January being used largely as confirmation.

As Fig. 1 shows, the network of observations is very open. Fine methods of analysis are thus inappropriate and this study is therefore restricted to the major features.

Classification into types.—Daily maps for 0300 G.M.T. were drawn of the contours at 500, 300, 200 and 150 mb. In addition, cross-sections were drawn, one or more a day. The plane of the cross-sections was not meridional but chosen to cut across the main flow, reported speeds being used and not components in any one direction. From these charts and cross-sections it was possible to find with reasonable accuracy the position of jet-stream cores on each day. The simplest method of distinction between the polar-front jet stream and the subtropical jet stream was the pressure at the core. This was about 200 mb. for the subtropical jet stream and 350–300 mb. or even 400 mb. for the polar jet stream.

Figs. 2 and 3 show the daily positions of both cores for April and January 1952 respectively. Positions of the polar front are also shown, these positions being taken directly from the analyses given in the published charts of the *Daily series synoptic weather maps*[4].

April 1952.—Study of Fig. 2 suggests classification of the April charts into three types as follows :—

Type 1. A strong jet stream roughly west–east near Hawaii and a separate polar-front jet stream clearly present to the north (3rd–5th, 11th–15th, 20th–23rd and 26th–30th).

Type 2. A subtropical jet stream, usually weaker than in Type 1, with a northerly wind component near Hawaii (1st, 2nd, 6th, 7th, 16th, 24th and 25th).

Type 3. A subtropical jet stream well north of its usual position (8th–10th and 17th–19th).

The classification is to some extent subjective and dependent on day-to-day continuity, but the main features of Types 1 and 3 are, on the whole, readily recognizable ; days not falling naturally into either of these types showed features in keeping with the definition of Type 2. The 6 days of Type 3 occurred in two spells of 3 days each and the 17 days of Type 1 were in four spells of 3–5 days each. The types occurred in some suggestion of a sequence, in that Type 2 followed Type 1 and preceded Type 3 on both occasions of a change from Type 1 to Type 3.

In order to represent diagrammatically the conditions prevalent in the three types mean cross-sections were drawn for each. The usual practice of plotting zonal wind components at appropriate latitudes on a meridional cross-section

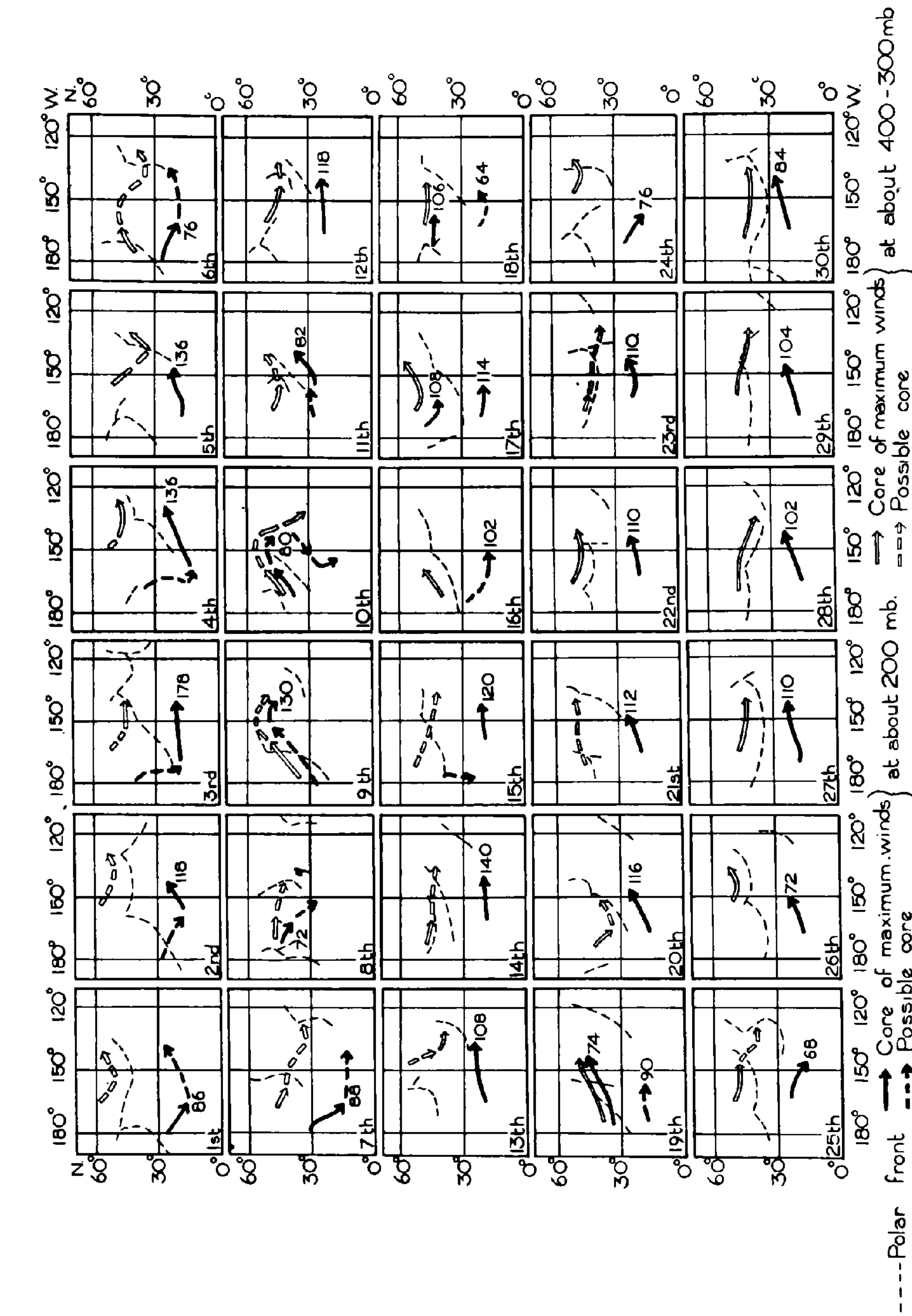


FIG. 2—DAILY SCHEMATIC CHARTS FOR 0300 G.M.T. APRIL 1952
The figure shown against a core represents the maximum reported wind speed in knots

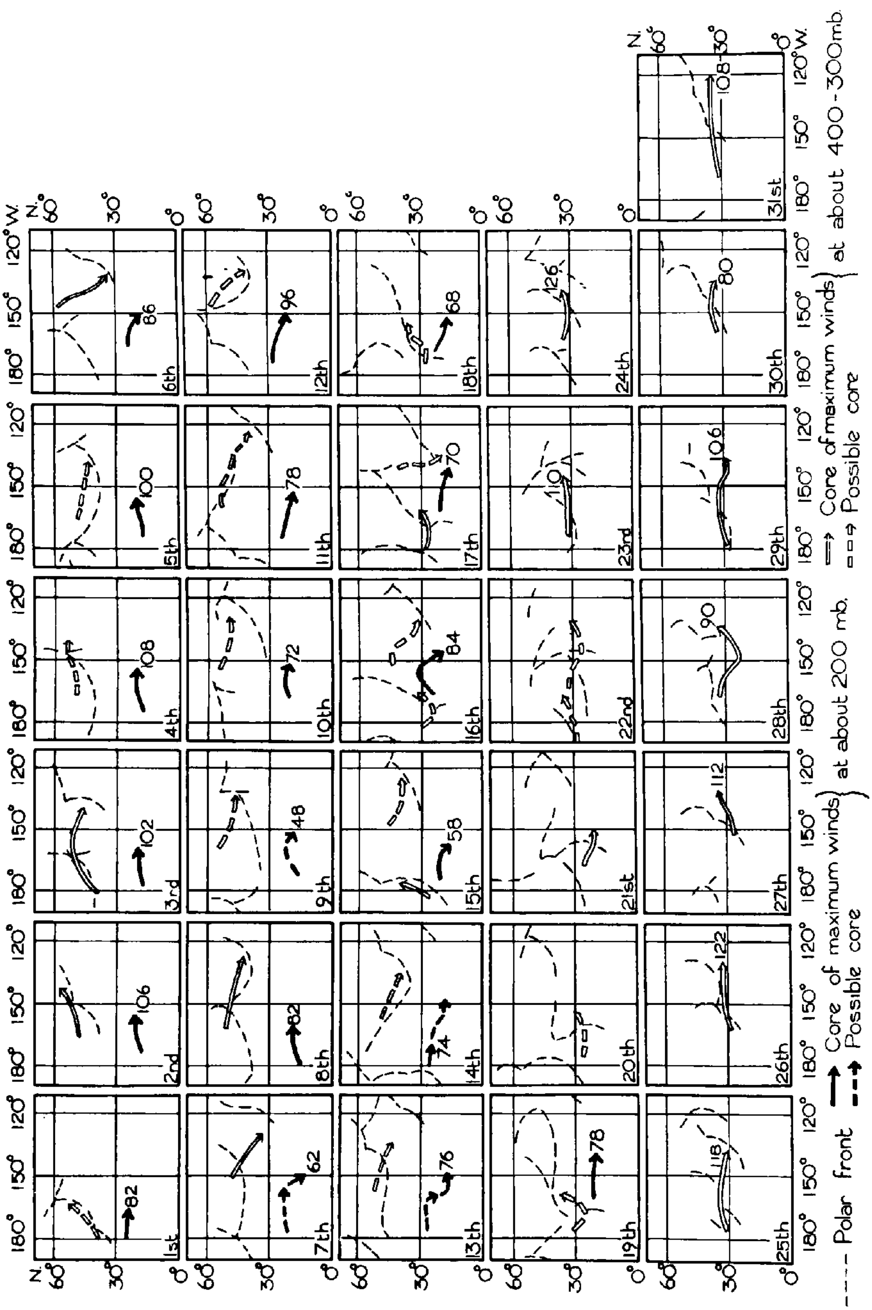


FIG. 3—DAILY SCHEMATIC CHARTS FOR 0300 G.M.T. JANUARY 1952
The figure shown against a core represents the maximum reported wind speed in knots

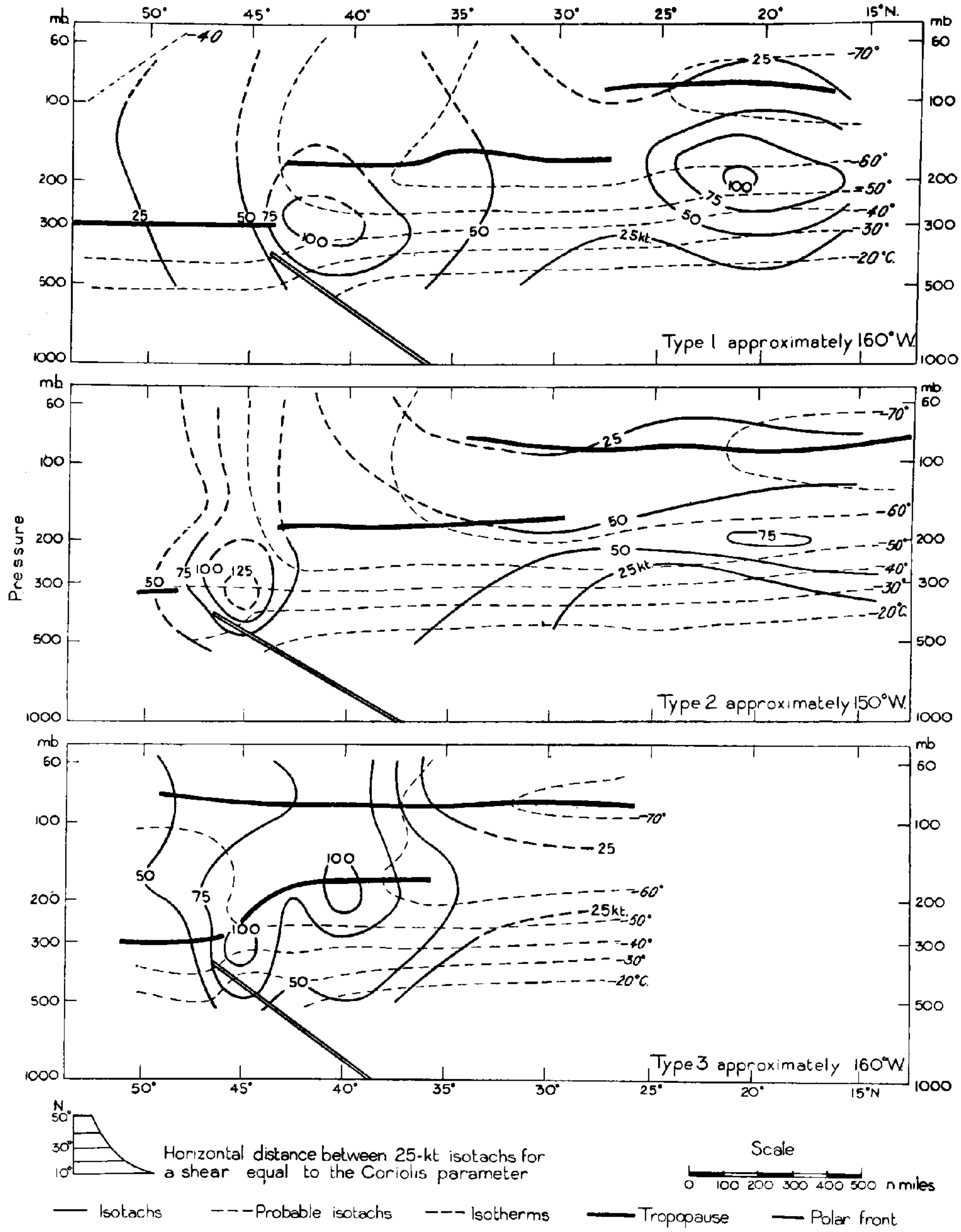


FIG. 4—VERTICAL CROSS-SECTIONS FOR APRIL 1952

was thought to give an unsatisfactory representation of the conditions, especially since, as noted previously by Bannon[5], strong northerly winds often exist near the Hawaiian Islands. Consequently, the mean cross-sections for each type were taken perpendicular to the axis of the jet stream, the observations being grouped according to perpendicular distance from the jet-stream core. Reported wind speed was thus used directly. Where a second, polar-front, jet stream was also present, a separate mean cross-section for the type was drawn in a similar manner relative to this core. The two were then combined into one diagram for each type by using the mean latitude of the surface position of the polar front as a basis of reference and placing the jets at their mean distances from this position.

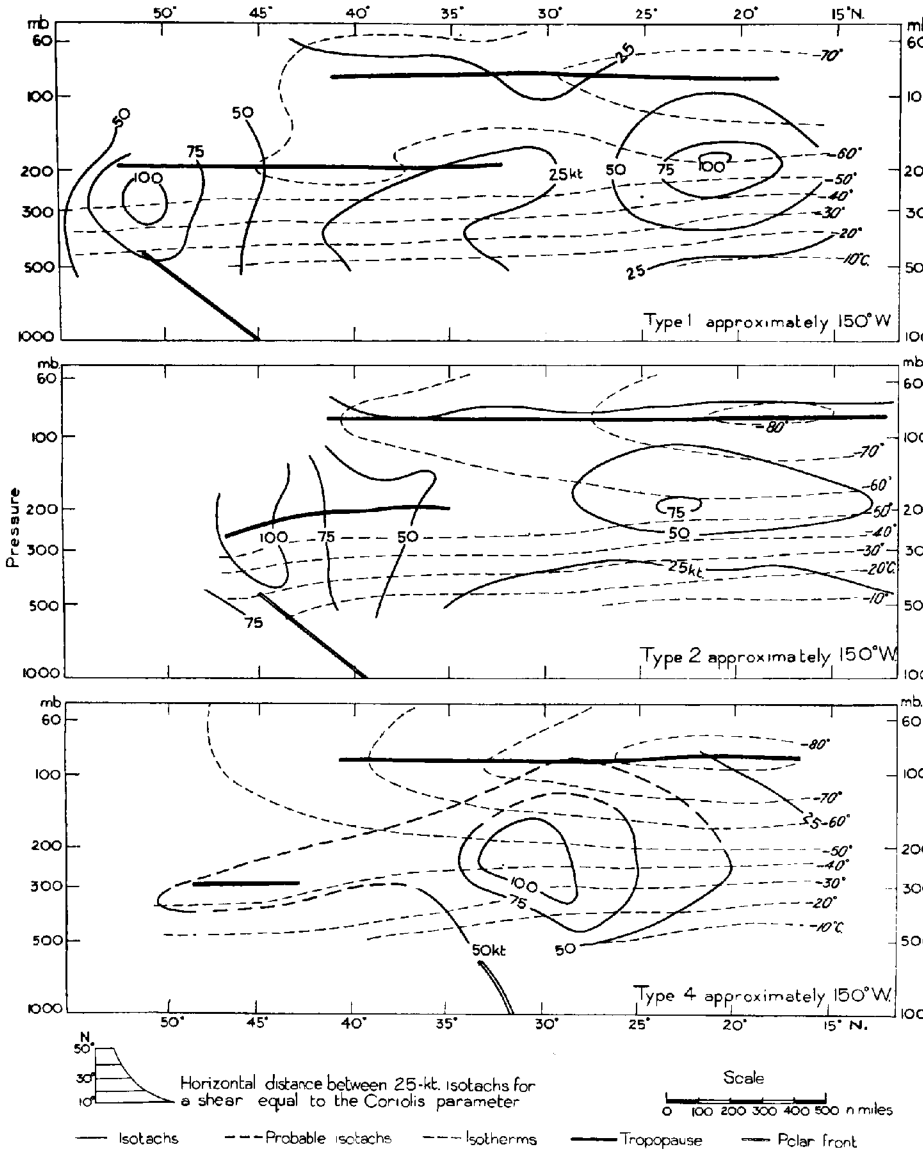
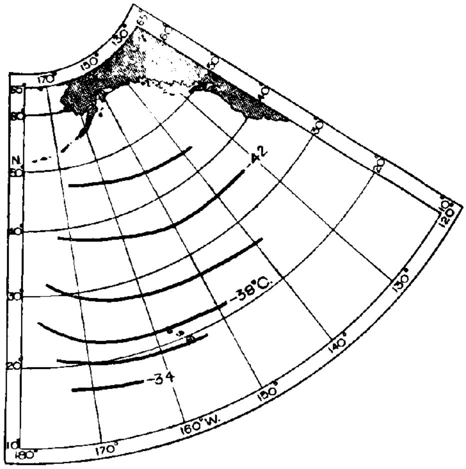


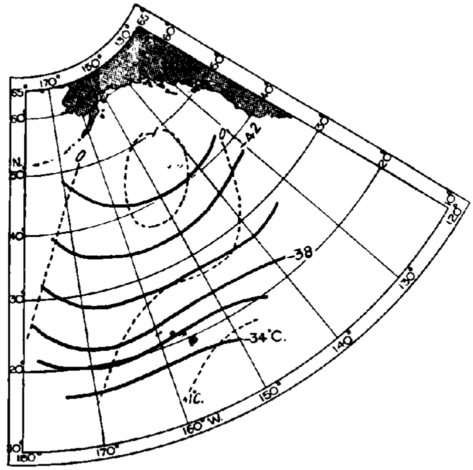
FIG. 5—VERTICAL CROSS-SECTIONS FOR JANUARY 1952

The resulting cross-sections are shown in Fig. 4. It is clear from the method of construction that although the scale of distance is quite precise the latitudes are only approximate, since the cross-sections are not strictly meridional. This does not interfere, however, with the assessment of wind shear.

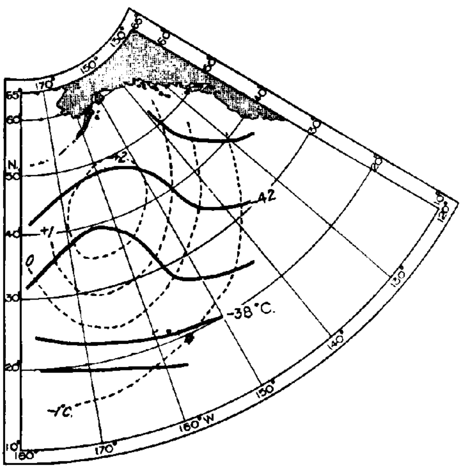
January 1952.—The January charts (Fig. 3) are more complex. There is little doubt that two separate jet streams existed on the first 15 days. During these days there is no certain evidence of the conditions classified as Type 3, but the days January 2–5 show reported winds of 100 kt. or more and clearly can be classified as Type 1. The remainder of the 15 days can be classified as Type 2. Mean cross-sections (Fig. 5), prepared as before, are very similar to those of equivalent type in April.



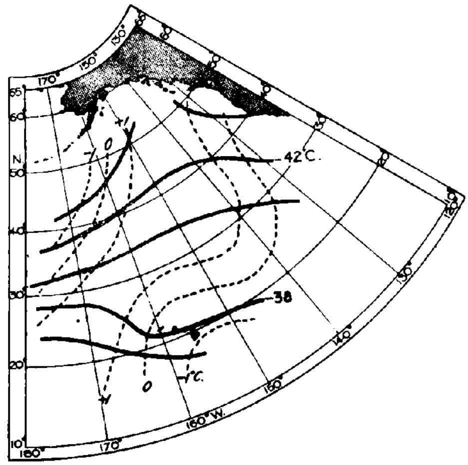
(*a*) Mean for the month



(*b*) Mean for Type 1



(*c*) Mean for Type 2



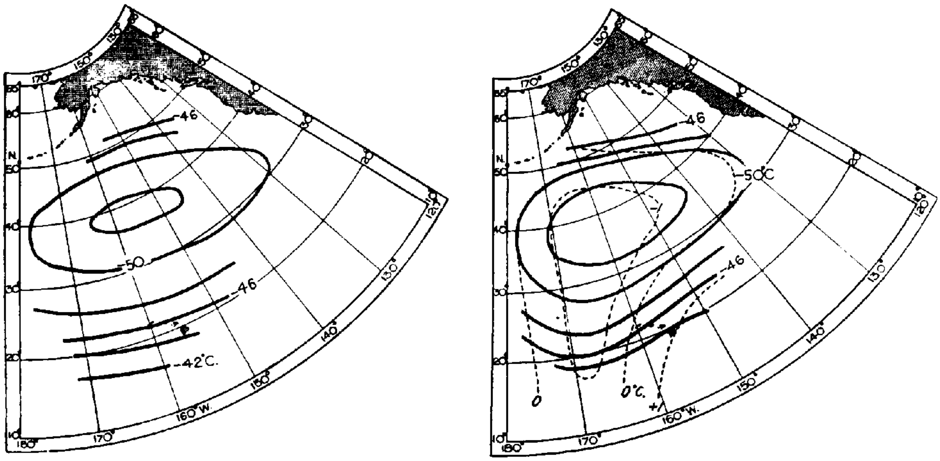
(*d*) Mean for Type 3

FIG. 6—300-MB. ISOTHERMS FOR APRIL 1952

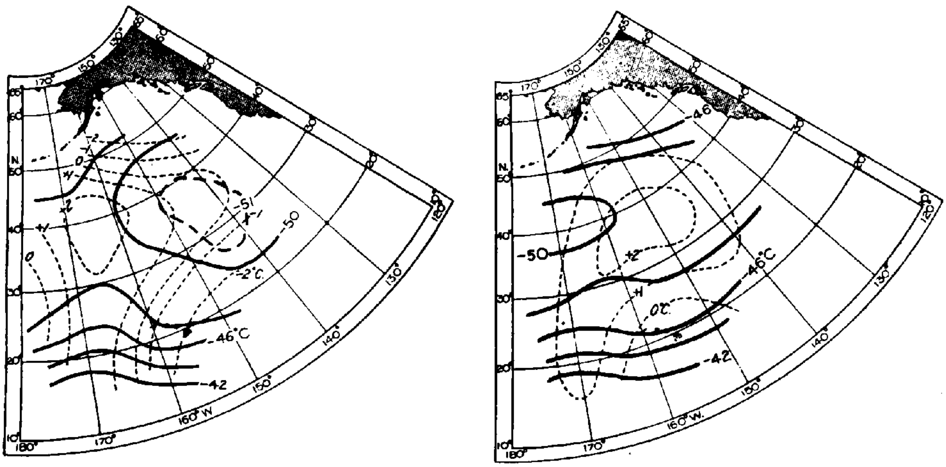
The dotted isopleths show the anomaly from the mean for the month

From January 16–22, 1952 the synoptic situation was disturbed in the Hawaii area by the formation of a depression of the " kona " storm type (see Palmer[6]). As this is a somewhat special situation these days are not analysed in detail. From January 23–31, 1952 the daily maps show only one jet-stream core, the type of flow pattern common in other longitudes. On none of these days was there any evidence of a second core distinguished by more than a 5–10-kt. variation of wind speed from level to level on the ascents, and even such variations were isolated reports with no day-to-day continuity, and thus very probably of no significance. A distinctive feature of these days was the position of the 300-mb. core, some 15°–20° latitude farther south than on other days. This has been called Type 4 and the appropriate mean cross-section for this type is shown in Fig. 5.

Discussion of the cross-sections.—In the types which show two clearly separate jet-stream cores (Types 1 and 2) the following major points are apparent, from Fig. 4 (April) :—



(*a*) Mean for the month (*b*) Mean for Type 1



(*c*) Mean for Type 2 (*d*) Mean for Type 3

FIG. 7—250-MB. ISOTHERMS FOR APRIL 1952

The dotted isopleths show the anomaly from the mean for the month

(i) There seem to be three tropopause levels defined by the temperature field ; a tropical tropopause at about 90 mb., a polar tropopause (poleward of the polar front) at about 300 mb. and an intermediate or subtropical tropopause at about 200 mb.

(ii) Just as the polar-front jet stream has its core at about the same level as the tropopause poleward of the polar front, so the subtropical jet stream has its core at about the same level as the subtropical tropopause on its poleward side.

The following features suggested by the mean cross-sections were more apparent on the cross-sections for individual days :—

(i) The subtropical jet stream is associated with a baroclinic zone. Unlike the baroclinic zone associated with the polar front this subtropical baroclinic zone is most marked between 400 and 200 mb. with virtually barotropic conditions at lower levels.

(ii) It appears that this subtropical baroclinic zone is connected with the temperature minimum associated with the subtropical tropopause. As pointed out by the writers of " The jet stream "[7] the fact that at 200 mb.

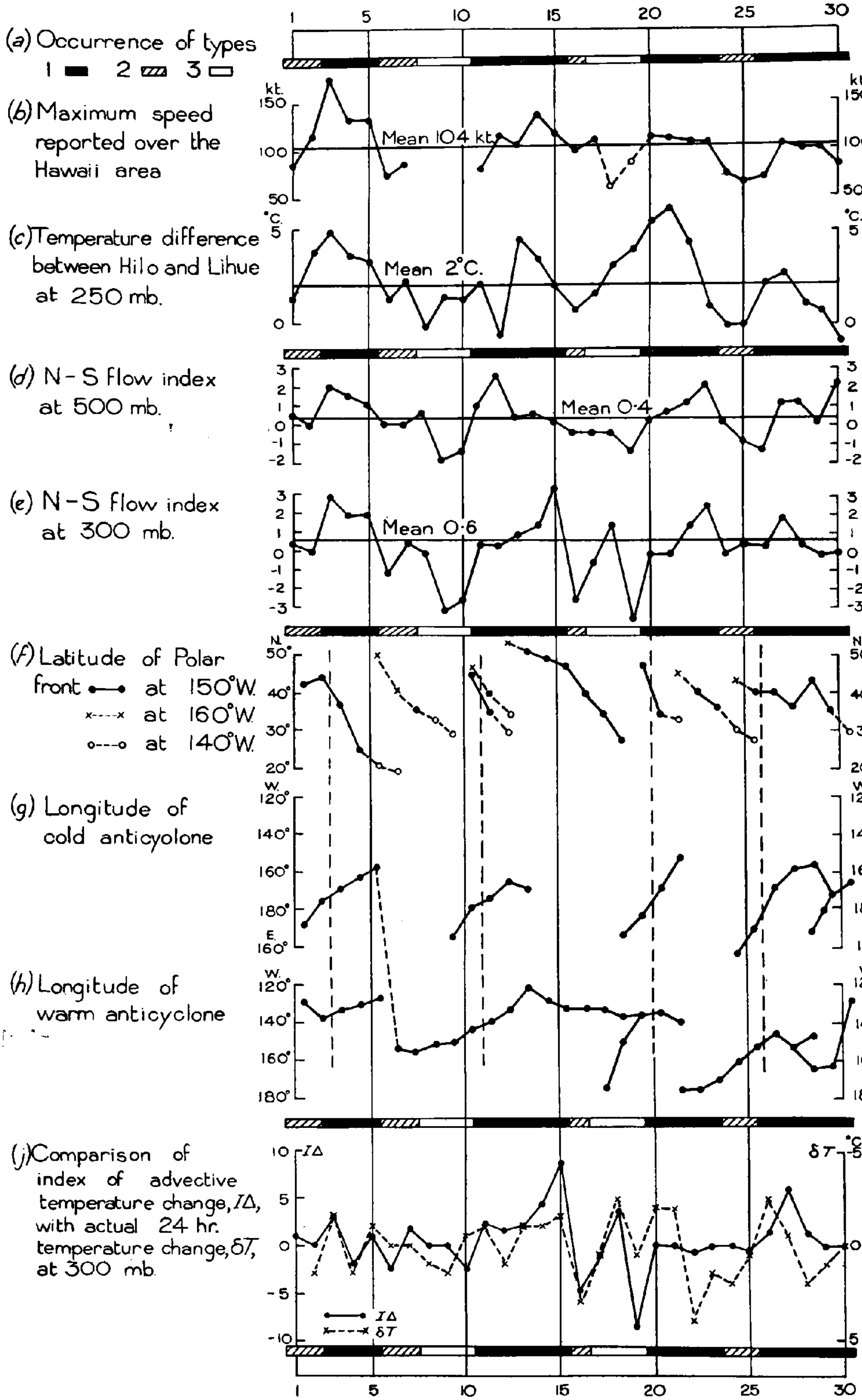


FIG. 8—DAILY VALUES OF VARIOUS PARAMETERS

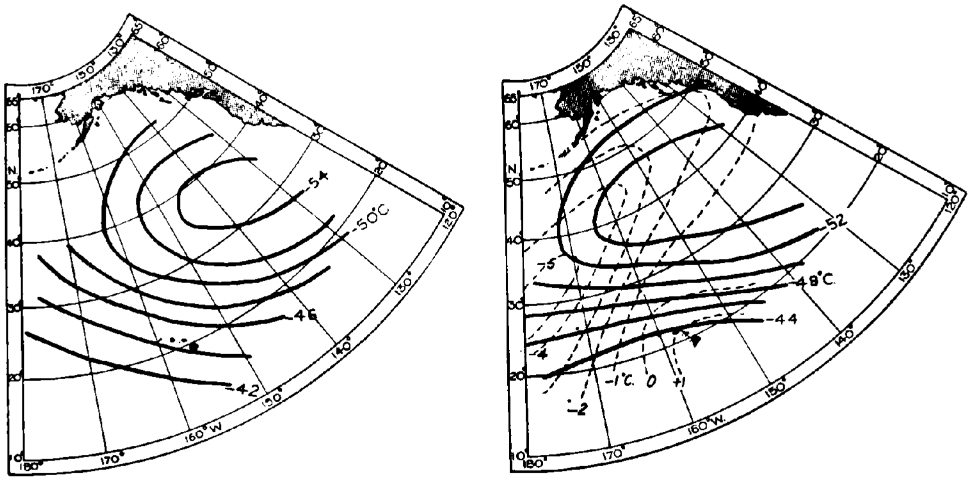
the temperature is lower at about 30°–40° N. than at any other latitude is a feature which calls for some explanation, and cannot be dismissed purely in terms of advection from other latitudes. The cross-sections suggest that this temperature minimum may be more clearly defined when the subtropical jet stream is strong (Type 1). When there is only one jet stream (Type 4) the intermediate subtropical tropopause is absent, and there is no sign of any temperature minimum at or near the 200-mb. level (see Fig. 5). It seems, therefore, that the existence of this temperature minimum at 200 mb. (and the associated three-tropopause scheme) may be an essential requirement for a subtropical jet stream separate from the polar-front jet stream.

Horizontal temperature distribution.—It is evident from the foregoing discussion that strong winds are associated with baroclinic zones, and this suggests that the geostrophic approximation through the thermal-wind relation may be roughly valid, even at latitudes as low as 20° N. There is thus some prospect that the variations in position and intensity of the subtropical jet stream may be understood if the variations in horizontal temperature gradient can be demonstrated and explained. The cross-sections show that the 400–200-mb. layer is the significant one as regards the thermal-wind contribution. Consequently, attention is directed to the 300-mb. and 250-mb. temperatures. Fig. 6 shows the 300-mb. temperature distribution for April 1952 and Fig. 7 similar charts for the 250-mb. level.

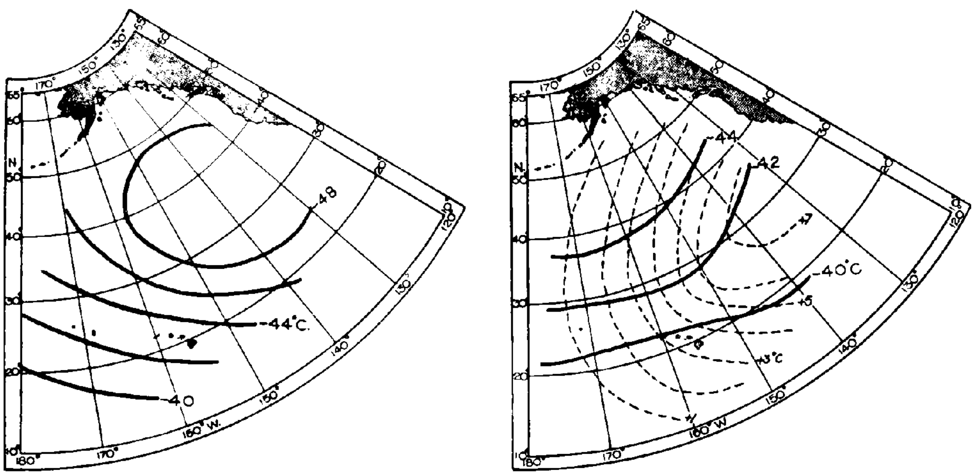
It is at once apparent that the mean for April displays a fairly steady north–south temperature gradient at 300 mb., but that the temperature minimum associated with the subtropical tropopause is apparent at 250 mb. The sequence of types (1–2–3–1 etc.) is noticeable, particularly at 250 mb., by the manner in which the coldest air is displaced eastwards (i.e. down stream) from Type 3 to Type 1 to Type 2. Fig. 6 shows at 250 mb. the steep temperature gradient near Hawaii for Type 1, the northerly component characteristic of Type 2 and the belt of thermal contrast at about 40° N. for Type 3. The mean for Type 3 at 300 mb. also gives a strong thermal gradient near Hawaii where, as inspection of Fig. 2 for the 17th, 18th and 19th shows, a residual subtropical jet stream can still exist, despite the re-creation of the main subtropical jet stream farther north. The cross-section of Type 3 for April does not extend south of about 30° N. as the method of construction of the cross-section is unsatisfactory at large distances from the main core when the flow is as distorted as that on April 9 and 10.

That the thermal wind relation holds approximately, down to 20° N., is borne out by the daily values in Fig. 8 which shows, amongst other things, the maximum reported wind speed in the subtropical jet stream near Hawaii and the reported temperature difference between Hilo and Lihue. Now a temperature difference of 2·5° C. between these stations at all levels from 500–200 mb. would be equivalent to a geostrophic thermal W. wind of about 100 kt. through this layer. There is clearly a rough similarity between the two curves (correlation coefficient 0·49) and the mean values of temperature difference and wind speed are approximately equal to those which the geostrophic relation requires.

The temperature anomalies (Figs. 6 and 7) show that, in the central portion of the area considered, temperatures are below normal during Type 1 and above normal during Type 3. The broad features of the observed temperature distribution and anomalies would be obtained if a portion of the monthly mean charts were displaced southward in Type 1 and northward in Type 3. Type 2 could be an intermediate stage in which the southward displacement is in the east of the area and the northward displacement in the west of the area. This suggests that advection may be an important factor in the type transitions.



(*a*) Mean. January 1st–15th (*b*) Type 1. Mean and anomaly from Fig. 9 (*a*)



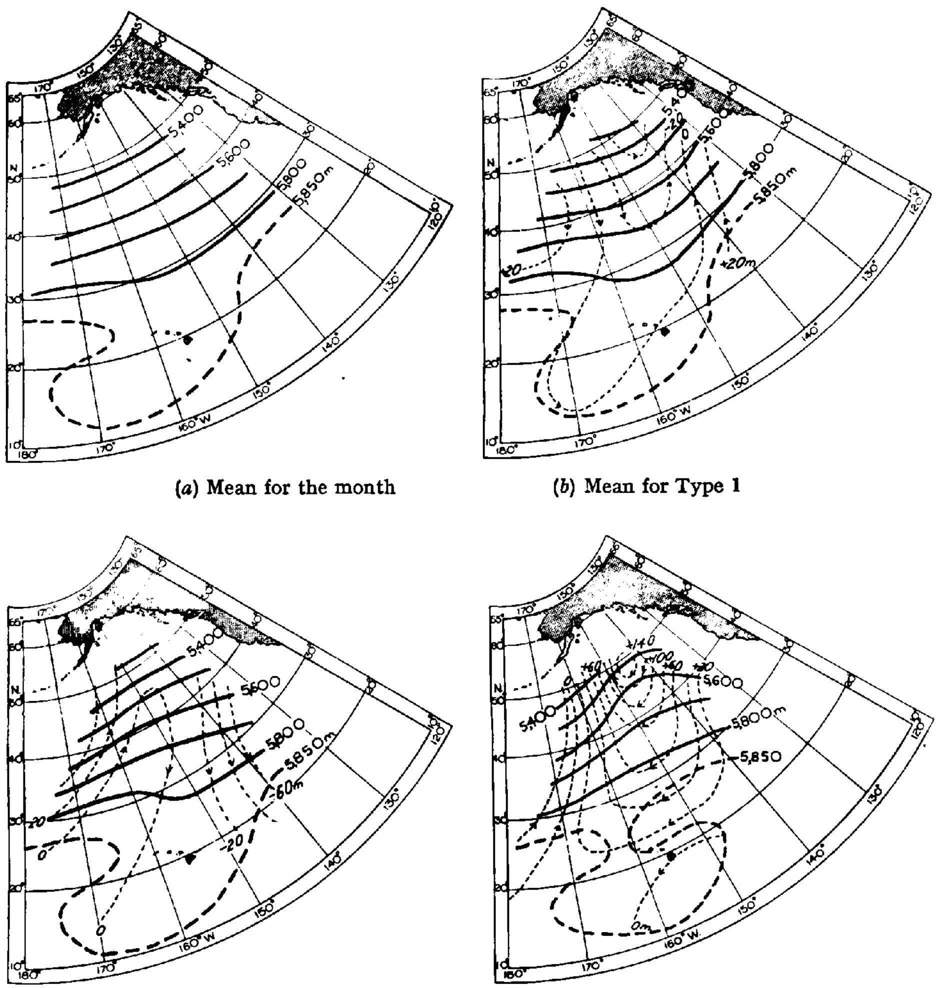
(*c*) 24-day mean (" kona " storm days omitted) (*d*) Type 4. Mean and anomaly from Fig. 9 (*c*)

FIG. 9—250-MB. ISOTHERMS FOR JANUARY 1952

Fig. 9 shows isotherms for January 1952 at 250 mb. Fig. 9 (*a*) shows the mean isotherms for the first 15 days. This is the mean for the days on which there were two separate jet streams and is thus comparable with the mean for April 1952. Fig. 9 (*b*) shows the mean for Type 1 during January 1952, the dotted isopleths being the anomaly from the 15-day mean. Although based on only four days, features similar to all those pointed out for Type 1 during April are readily apparent. As the mean chart for the 1st to 15th is almost entirely Type 2 no separate diagram for Type 2 is given.

It is interesting to note the different temperature field shown in Fig. 9 (*d*) for the period January 23–31, which was characterized by a single jet stream (Type 4). The absence of the area of minimum temperature shown on all other 250 mb. temperature charts is very striking and agrees with the deduction from the cross-section Fig. 5 (*c*). The dotted isopleths in Fig. 9 (*d*) are the anomaly from the 24-day mean of Fig. 9 (*c*), the latter being the mean for the month of January excluding the days affected by the " kona " storm.

Geostrophic advection.—Mean contour maps for April are shown for the 500-mb. level at Fig. 10 and for the 200-mb. level at Fig. 11. In view of the



(*a*) Mean for the month (*b*) Mean for Type 1

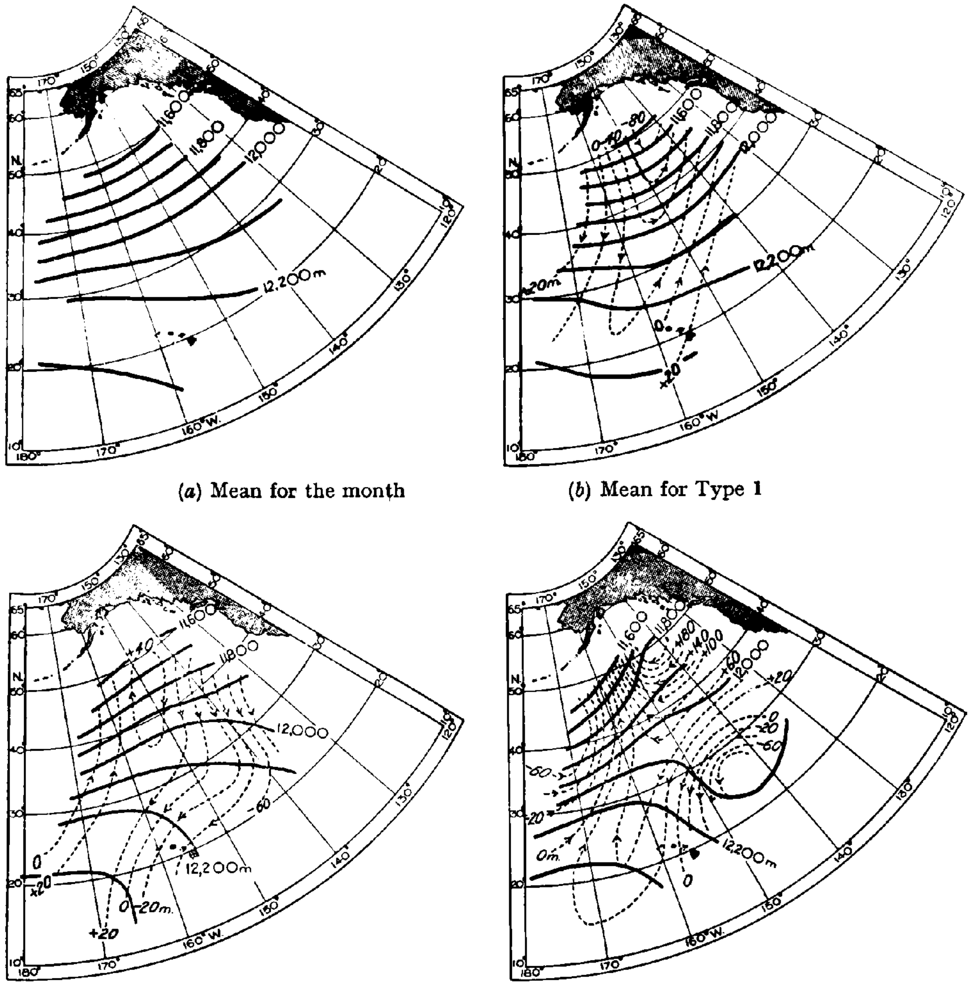
(*c*) Mean for Type 2 (*d*) Mean for Type 3

FIG. 10—500-MB. CONTOURS FOR APRIL 1952

The dotted isopleths show the anomaly from the mean for the month

strong zonal component over most of the area the essential features of meridional geostrophic advection show more clearly in the anomaly patterns. It is clear that in the region of 40° N. 160° W. Type 1 is characterized by a north–south-flow component and Type 3 by a south–north-flow component at the levels which contain the subtropical baroclinic zone. These appear not only in the mean charts but also in the daily charts.

A simple index of the north–south geostrophic flow in this area is given by the contour height difference between 40° N. 150° W. and 40° N. 170° W. The daily values of this flow index (positive for flow from north to south) are shown at Fig. 8 for the 500-mb. and 300-mb. levels. This index was measured in hundreds of metres per 20 degrees of longitude (at 40° N.) so that an index value of 1 corresponds to a mean geostrophic flow of about 13 kt. Comparison with Figs. 8 (*a*) and 8 (*b*) confirms the suggested association between the north–south-flow component and the type. It is further suggested that a strong north–south-flow component is associated with a strong jet stream, and in this connexion it may be noted that the correlation coefficient between the north–



(*a*) Mean for the month (*b*) Mean for Type 1

(*c*) Mean for Type 2 (*d*) Mean for Type 3

FIG. 11—200-MB. CONTOURS FOR APRIL 1952

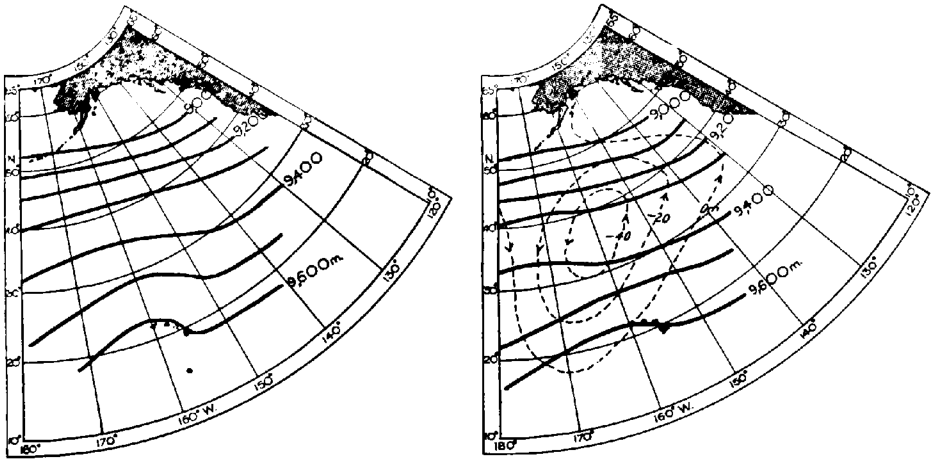
The dotted isopleths show anomaly from the mean for the month

south-flow index at 500 mb. and maximum reported speed in the jet-stream near Hawaii was 0·52. No lag relation was found, perhaps because the 24-hr. interval between observations was too long.

Following the discussion in the previous section and comparing Figs. 7 and 11, the geostrophic advection anomalies for the three types are such as to deform the mean temperature field in roughly the manner which is, in fact, observed.

An attempt was made to assess the advective temperature change directly using a geostrophic scale on the 300-mb. height and temperature isopleths. The process was found to be inaccurate and too easily affected by the subjective judgement of the analyst, and was therefore abandoned. As the usual method of assessing vertical motion is dependent upon an estimate of the temperature change due to advection no reliable analysis of the vertical motion was possible from the available data.

A more crude, but considerably more objective, method of estimating the advective temperature change at 300 mb. was then tried. If I is the north–south index of flow at 300 mb. and Δ is the north–south temperature gradient



(*a*) Mean for January 1st–15th (*b*) Mean for Type 1 and anomaly from Fig. 12 (*a*)

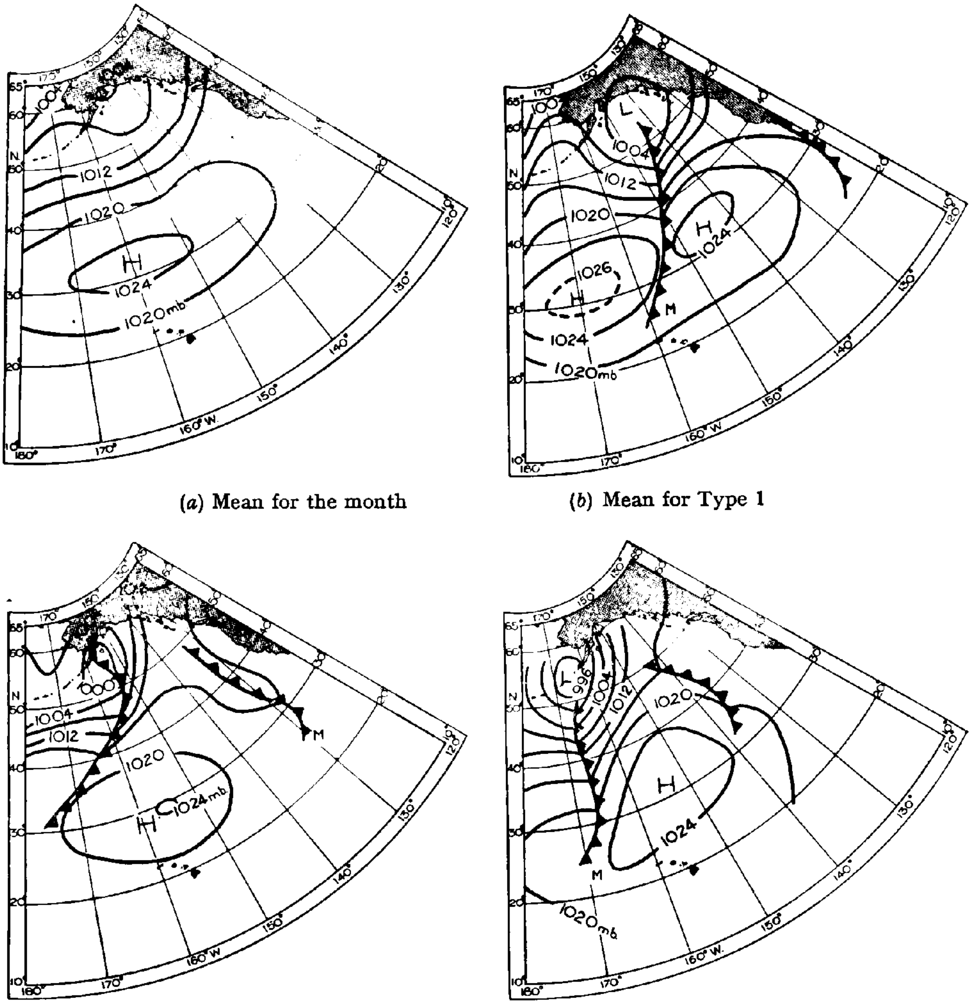
FIG. 12—300-MB. CONTOURS FOR APRIL 1952

in this area read from the daily charts for the 300-mb. level, then $-I\Delta$ is of the nature of an advective change of temperature. With I measured as indicated earlier and Δ measured in degrees Celsius per ten degrees of latitude, $-\frac{1}{2}I\Delta$ gives this rate almost exactly in degrees Celsius per 24 hours. Daily values of $I\Delta$ are shown in Fig. 8 (*j*). The dotted curve in Fig. 8 (*j*) shows the actual 24-hr. temperature change (since 0300 G.M.T. on the previous day) at 300 mb. These values are also for 40° N. 160° W. They were read from the isotherms and may well have an error of 1° C. or so owing to the open network of observations. It will be noted that in Fig. 8 (*j*) the scale for the actual temperature change is on the right and is twice as large as the scale for $I\Delta$. Close agreement between the two curves cannot be expected since the method ignores temperature changes due to west–east advection. Nevertheless the curves of Fig. 8 (*j*) show fair agreement in regard to both the occurrence and the magnitude of points of maximum and minimum.

The data for January show the same broad features of the contour patterns as those observed in April. Fig. 12 (*a*) shows the mean contours for the first 15 days of January 1952, whilst Fig. 12 (*b*) shows the mean for Type 1 and its anomaly from the 15-day mean. The stronger-jet-stream days are again associated with a marked north–south advection anomaly reasonably near to 40° N. 160° W., the slightly different position and orientation of this anomaly being in keeping with the slightly different position of the negative temperature anomaly in Fig. 9 (*b*) compared with that of Fig. 7 (*b*).

Although the effects of vertical motion may not be negligible there is thus considerable evidence suggesting that during the existence of two separate jet-stream cores the variations in position and intensity of the subtropical jet stream are largely controlled on a day-to-day basis by geostrophic advection of the temperature field.

Related features of the surface synoptic chart.—Daily values from the surface synoptic charts during April 1952 are included in Fig. 8. These values were taken directly from the published maps in the *Daily series synoptic weather maps*[4] which are for 1230 G.M.T. They are accordingly plotted on the time scale midway between the 0300 G.M.T. values for the other graphs. Fig. 8 (*f*) shows the latitude of the polar front at or near 150° W. As the polar front marking successive outbreaks of cold air (compare Palmén[8]) usually advances roughly



(*a*) Mean for the month (*b*) Mean for Type 1

(*c*) Mean for Type 2 (*d*) Mean for Type 3

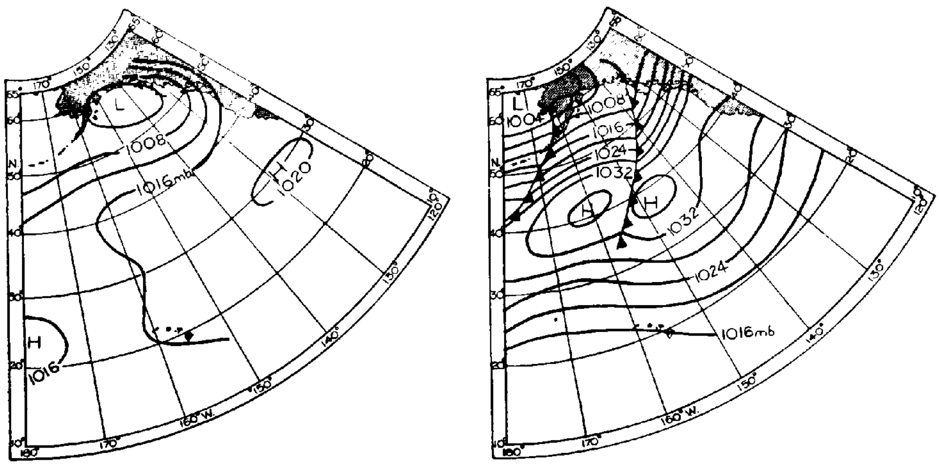
FIG. 13—MEAN SURFACE ISOBARS FOR APRIL 1952

M denotes the major cold front

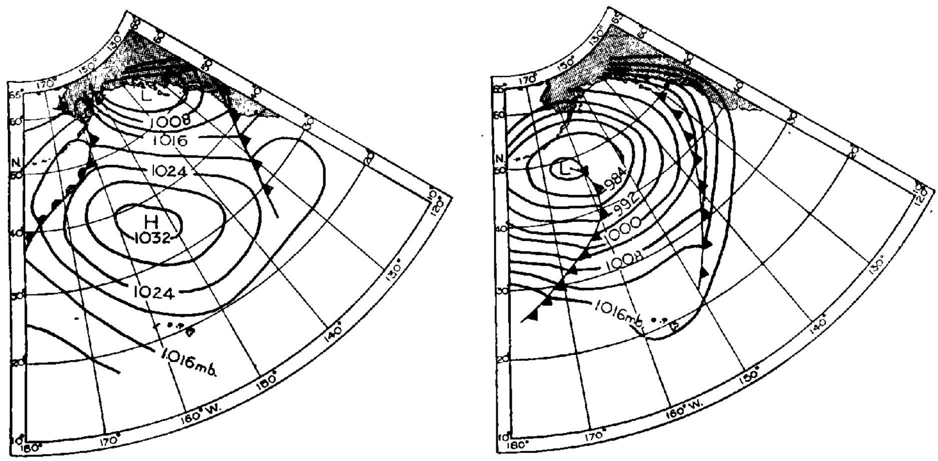
from north-west to south-east latitudes of the polar fronts were sometimes measured at 160° W. early in a polar outbreak and at 140° W. in the later stages of such an outbreak. Measurements at different longitudes are distinctively marked. It is noticeable that at the beginning of each period of Type 1 there is a cold front in about latitude 40° N. The converse is not however true, i.e. each cold front crossing 40° N. does not coincide with the beginning of a Type 1 period.

Figs. 8 (*g*) and 8 (*h*) show the longitudes of cold and warm anticyclones (situated respectively to north and south of the polar front). These show a remarkable correspondence between cold anticyclones reaching longitude 175° W. and the beginning of Type 1. Serebreny[9] pointed out the importance of an anticyclone in such longitudes to the accurate forecasting of the polar-front jet stream. It would seem to play an equally important role in the formation of a strong subtropical jet stream.

Fig. 13 shows mean surface charts (including mean frontal positions) for the month of April 1952 and for the three types during that month. Mean surface-pressure values were computed at 10° latitude and 10° longitude grid points



(*a*) 24-day mean (" kona " storm days omitted) (*b*) Mean for Type 1



(*c*) Mean for Type 2 (*d*) Mean for Type 4

FIG. 14—MEAN SURFACE ISOBARS FOR JANUARY 1952

from the surface maps published in the *Daily series synoptic weather maps*[4]. Mean frontal positions were obtained by averaging the longitudes at which the front intersected specified lines of latitude, separate means being taken to accommodate occasions with two fronts. There is some subjectivity involved in deciding which front to include in which mean, but the very good fit with the independent pressure values seems sufficient justification. It will be seen that the features of polar-front and anticyclone positions mentioned in the two previous paragraphs as associated with the onset of Type 1 conditions are clearly shown in Fig. 13 (*b*). It is noticeable too that the north–south advection component near 40° N. 160° W. characteristic of the upper-level flow during Type 1 is also evident at the surface, and similarly for the south–north advection during Type 3.

A further point of interest is observed if the mean frontal positions for Types 1, 2 and 3 are compared with the horizontal temperature distribution shown in Figs. 6 and 7. The major cold front on each chart of Fig. 13 has been denoted by the letter M showing east–west progression in the previously noted sequence of Types 3–1–2 etc. It will be seen that the major frontal region coincides with

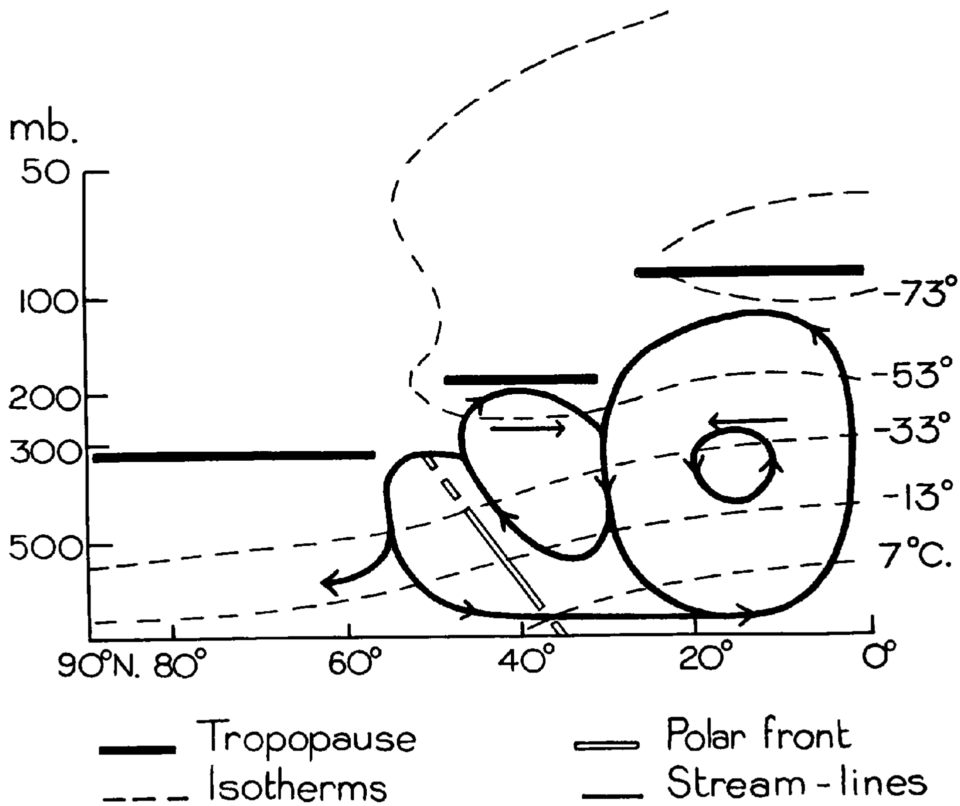


FIG. 15—GENERAL MERIDIONAL CIRCULATION PROPOSED BY PALMÉN

the lowest temperatures at 300 and 250 mb., the trough in the isotherms being over the frontal zone rather than behind it over the low-level cold air mass. This was quite noticeable on the daily charts.

Surface charts for January 1952 are shown at Fig. 14. Fig. 14 (*a*) shows the 24-day mean (i.e. mean for the month excluding only the " kona " storm days), whilst Figs. 14 (*b*), (*c*) and (*d*) show the mean charts for Types 1, 2 and 4 respectively. The positions of the polar-front and anticyclone cell for Types 1 and 2 are similar to those for April. The most striking feature of Fig. 14, however, is that for Type 4 (the single jet-stream type) there is no subtropical high-pressure cell. It is also noticeable that polar air has penetrated well south.

Relation to the general (meridional) circulation.—Fig. 15 shows the model of the general meridional circulation proposed by Palmén[8]; this is considered as a mean for all longitudes. Such mean meridional flow is therefore essentially ageostrophic, as opposed to the local day-to-day geostrophic meridional motion considered on p. 13. Fig. 15 also includes a sketch of the mean temperature distribution for all longitudes. It is apparent that the regions of low temperature associated with the tropical and subtropical tropopauses are situated above the regions of tropical and frontal ascent respectively. Whether or not these regions of cold air are the result of adiabatic cooling on ascent is a matter for conjecture. The vertical motion associated with the polar front is in the mean largely a result of the dynamically driven ascent in frontal depressions, and adiabatic cooling shown by the mean isotherms thus seems a likely result in this region.

The local existence of cold air in the upper troposphere above the polar front has already been pointed out, and thus the association of the two can be accepted, even if the causal relation is in doubt.

It will also be seen that the meridional circulation is such as to give confluence, and hence a steepening of the horizontal temperature gradient at just the levels and latitudes at which the subtropical baroclinic zone exists on occasions of the two-jet structure. It also gives diffluence, and hence a slackening of the horizontal temperature gradient in the lower levels of this region where observations suggest that conditions are largely barotropic. It would seem, therefore, that the meridional circulation involved in the usual concept of a subtropical high-pressure belt to the south of the polar-front region may be important in producing the type of temperature distribution associated with a subtropical jet stream separate from the polar-front jet stream. This is borne out by Fig. 14 (*d*) which shows a complete break-down of the usual polar front–subtropical anticyclone relation during the period in which there is only one jet stream in this region.

Conclusions.—The area of the Pacific Ocean considered frequently shows in January and April two separate jet streams ; one associated in conventional manner with the polar front having a core at about 300 mb., the other, often a thousand miles or more to the south of the polar front, with a core at about 200 mb.

Both jet streams show speeds in excess of 100 kt. on some days with pronounced shear in both the horizontal and vertical. The more southerly of the two streams weakens considerably at times and becomes a very broad stream with speeds of the order of 50–75 kt. and with little shear in the horizontal.

The two-jet type of flow is associated with a characteristic temperature distribution with three distinct tropopause levels—a tropical tropopause at about 90 mb., a subtropical tropopause at about 200 mb. and a polar tropopause at about 300 mb.

Day-to-day variations in the speed of the more southerly of the two jet streams seem to be dependent, through the geostrophic relation, upon day-to-day changes in the temperature field, largely brought about by geostrophic meridional advection.

The temperature distribution characteristic of the two-jet type of flow may well be a result of the ageostrophic meridional circulation accompanying the maintenance of a subtropical high-pressure belt to the south of the general polar front and frontal-depression region.

From the very limited number of occasions studied the occurrence in this region of a single-jet type of flow appears to accompany a break-down in the subtropical high-pressure belt with extensive equatorward penetration of polar air. The three-tropopause temperature structure also breaks down under these circumstances by the disappearance of the subtropical tropopause.

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