THE ZONAL WIND FIELD ALONG 80° W. FOR THE IGY PERIOD AND NORTHERN HEMISPHERE ANOMALIES OF WIND AND TEMPERATURE

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ABSTRACT

A descriptive rather than conclusive discussion of the zonal wind field along the 80° W. meridian for the International Geophysical Year period is presented. Anomaly charts of mid-seasonal months for the Northern Hemisphere and their relationship to general weather features during the IGY are discussed.

1. INTRODUCTION

The expansion of the upper air network in North America throughout the 1940's afforded opportunity for the publication of many significant studies of the vertical aspects of the atmosphere through cross-sectional analyses. Because of the proximity of a large number of stations to the 80° W. longtitude (fig. 1) this meridian became a natural favorite for detailed studies of the westerly current in the Northern Hemisphere. In one of the early studies, Hess [10] utilizing four years of data (1942–1945), included a wider range of latitude (2° S. to 73° N.) and used data more closely arrayed to 80° W. (6° range in longitude) than that of previous works [24]. Although investigations toward specific goals continued [8, 17], Kochanski [13] contributed directly to the 80° W. seasonal mean information by using winds scaled from mean maps [1] and extending the analysis to 30 km. [2]. More recently Landsberg and Ratner [14] have compiled January and July means of zonal wind and temperature along 80° W. using nearly 10 years of data, and Crutcher [4], using six years of data (1948–1953), has completed an extensive statistical study of the wind field with cross-sections for many longitudes and parameters including 80° W. and the zonal component. These last two references were used in preparing the anomaly charts presented here.

Limitations of data have necessarily restricted atmospheric investigations on a cross-sectional basis in the Southern Hemisphere. While some individual cases have been studied [12, 15] and means established for other meridians [7, 21, 23], no "mean" values as such have been established for a longitude near enough to 80° W. to permit construction of anomaly charts for a specific period of record.

Through the impetus of the International Geophysical Year (IGY) the addition of several cooperative stations in South America completed the observational chain between Panama and the Antarctic (fig. 1). Using this network, the U.S. Weather Bureau has prepared daily aerological cross-sections for the IGY period [25], along 80° W. in the Northern Hemisphere and within about 10° longitude of 70° W. in the Southern Hemisphere. As a natural by-product of these analyses on a daily basis, monthly mean cross-sections have also been prepared for the 18 months of the IGY [16] and these form the basis for this presentation.

2. HEIGHT-LATITUDE VARIATION OF MAXIMUM ZONAL WIND

Figure 2 shows the mean monthly positions of the maximum westerly wind component plotted against latitude and height for both hemispheres for the 18 months, July 1957 through December 1958. The cross-hatched areas show the range of the variation with height and latitude. The asterisks in the Northern Hemisphere portion indicate the mean mid-season positions according to Crutcher [4].

The heavy dashed line in the Southern Hemisphere traces the position of a secondary maximum of the zonal wind when this could be positively identified from the data available. As can be seen this secondary maximum was at a much higher latitude, but a lower height, and, for the five months it was in evidence, nearly paralleled the position of the primary maximum of the west wind component.

The graphic determination of the center of the rectangular cross-hatched areas immediately yields the mean of the 18 individual monthly positions of this west wind core at this longitude: 38° N. and 220 mb. (11.5 km.) in the Northern Hemisphere and 31° S. and 195 mb. (12 km.) in the Southern Hemisphere. It was necessary to identify these maximum westerly wind components as "near the tropopause" since there is conclusive evidence on the mean monthly cross-sections [16] that much stronger maxima existed at higher altitudes and latitudes during the winter months. This increase of zonal wind with height between 50° and 70 ° S. is well recognized and has

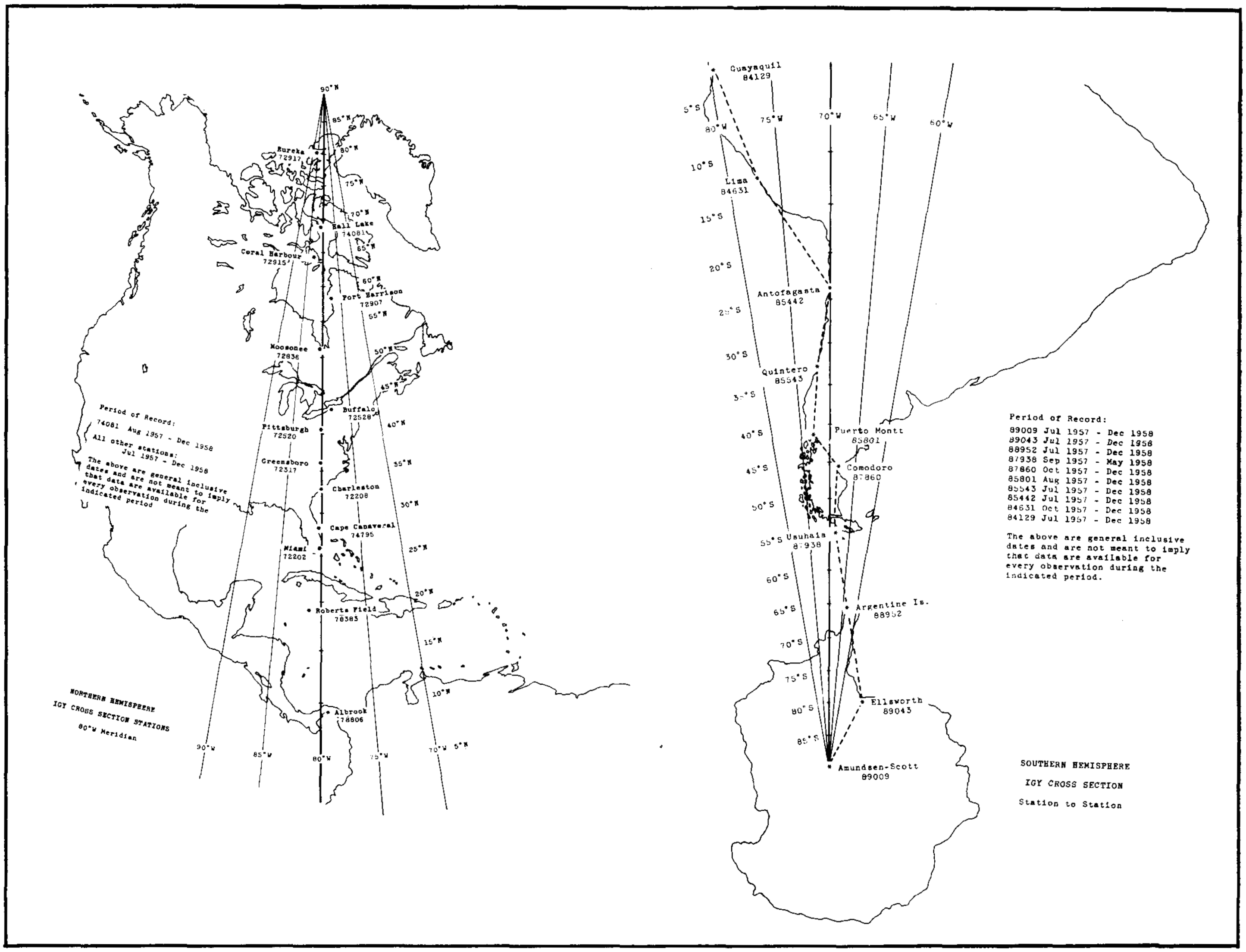

FIGURE 1.—Upper air station distribution along 80°/70° W. While the Northern Hemisphere network has been in existence for some time, the IGY promoted most of the Southern Hemisphere cooperatives which completed the pole-to-pole chain. Asterisks indicate actual locations of stations. Station numbers are according to WMO Block and Index designations.

been discussed by Taylor [21], van Loon [23], and Hofmeyr [11].

Of interest is the rather abrupt and definite equatorward shift of the zonal maxima in the Northern Hemisphere in fall and winter and the poleward march in spring and summer, as compared with similar but less well defined shifts in the Southern Hemisphere. Comparisons of speeds and latitude fluctuations between the zonal maxima of the two hemispheres can also be made readily from figure 2.

A comparison of the positions of the mean summer and winter jet streams along longitudes 130° E. and 150° E. [7] with the Southern Hemisphere zonal wind maxima in figure 2 is interesting, but far from conclusive. While the July 1957 maximum is similar in height, strength, and latitude (200 mb., 50 m./sec. and 27° S.) to the winter maximum along 130° E., a predominantly continental longitude, the 1958 winter with double maxima of less strength is more analogous to the winter mean along 150° E., a predominantly oceanic longitude. In comparing summer values, the January 1958 zonal maximum is not quite as strong but in the same position as the summer mean for 130° E. longitude. No summer double maxima occurred during the IGY to compare with those shown on the mean chart for 150° E. longitude by Gibbs [7], or along the 170° E. longitude as shown by Hutchings [12]. On the other hand, van Loon [23] found no double maxima in summer or winter on cross-sections for a Southern Hemisphere oceanic region. While it appears these differences are attributable in part to a continental influence, it is beyond the scope of this presentation to establish to what degree these referenced cross-sections are representative of the mean zonal wind over the Southern Hemisphere.

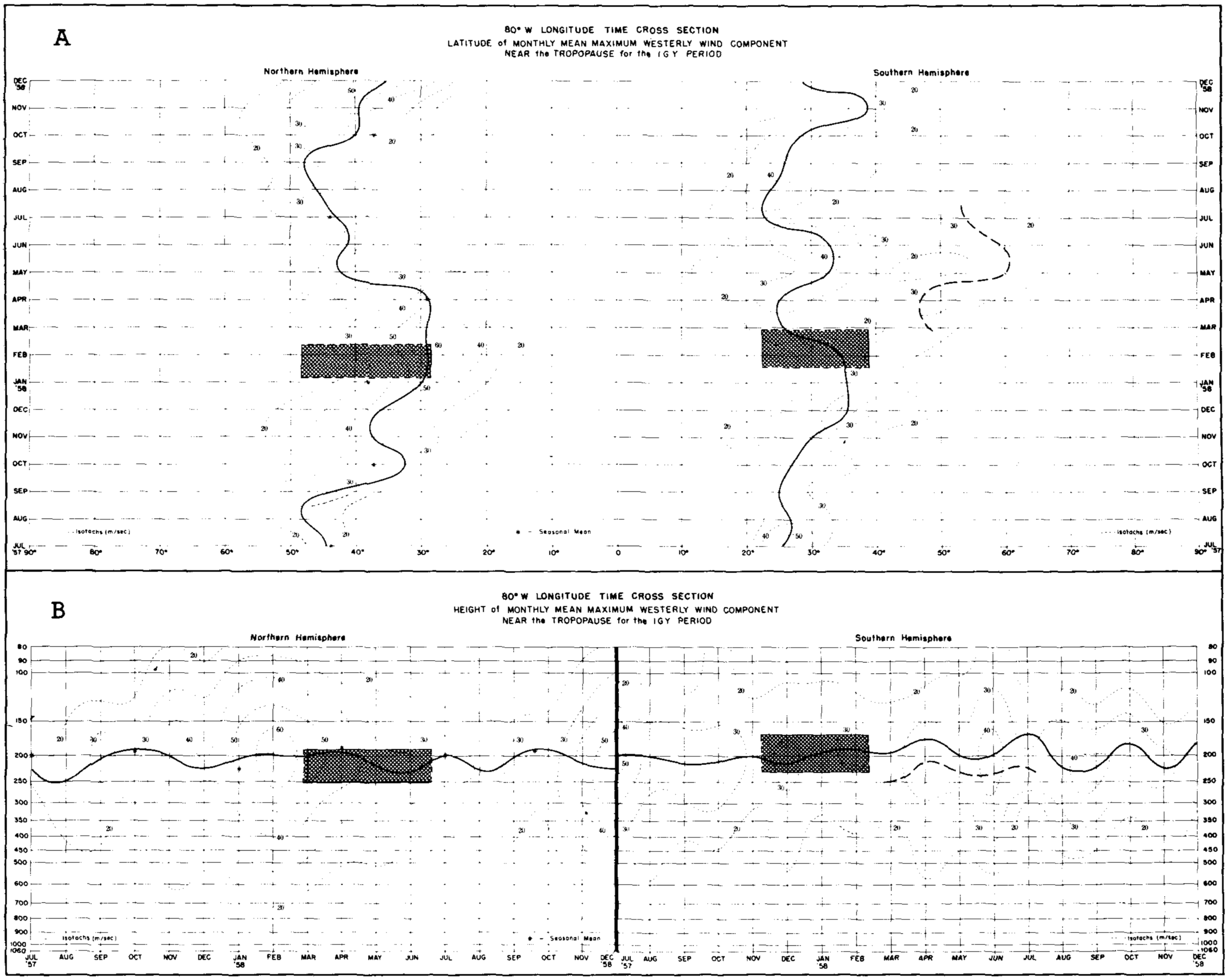

Figure 2.—Time cross sections by (A) latitude and (B) height of monthly mean westerly wind component near tropopause. Positions of the monthly mean west wind maxima are connected by the heavy solid line; isotachs in m./sec. are shown as dashed lines; range of latitudinal and height variation of west wind maxima for 18-month IGY period is cross-hatched. Seasonal mean positions (*) of west wind maxima are taken from [4].

3. NORTHERN HEMISPHERE ANOMALY CHARTS

Two sets of mean charts were used to subtract from the mean monthly charts in order to arrive at the anomaly charts presented. In addition to the interesting comparisons resulting from two independently produced sets of means, Crutcher [4] presented four seasonal charts to which the mid-season months of July, October, January, and April were compared, and Landsberg and Ratner [14], although preparing charts for only July and January, included temperatures and zonal winds to higher altitudes.

JULY 1957

The extremely flat gradients of west wind and temperature differences shown in figure 3 are significant in illustrating how nearly "normal" this month was in these parameters [9]. A trough off the east coast was effective in producing only slightly above normal west wind components and slightly cooler than normal temperatures (fig. 3B) in low and middle latitudes. The normality of the month is further evidenced by the proximity of the position of the seasonal to that of the actual mean west wind maximum as shown in figure 2. Of interest also is the coincident positioning at 55° N. of the 5 m./sec. deficiency of west wind component during the month, although these anomalies were computed independently from the two source means [4, 14]. It should also be noted that the greatest differences in the two anomaly charts for this month are in low latitudes.

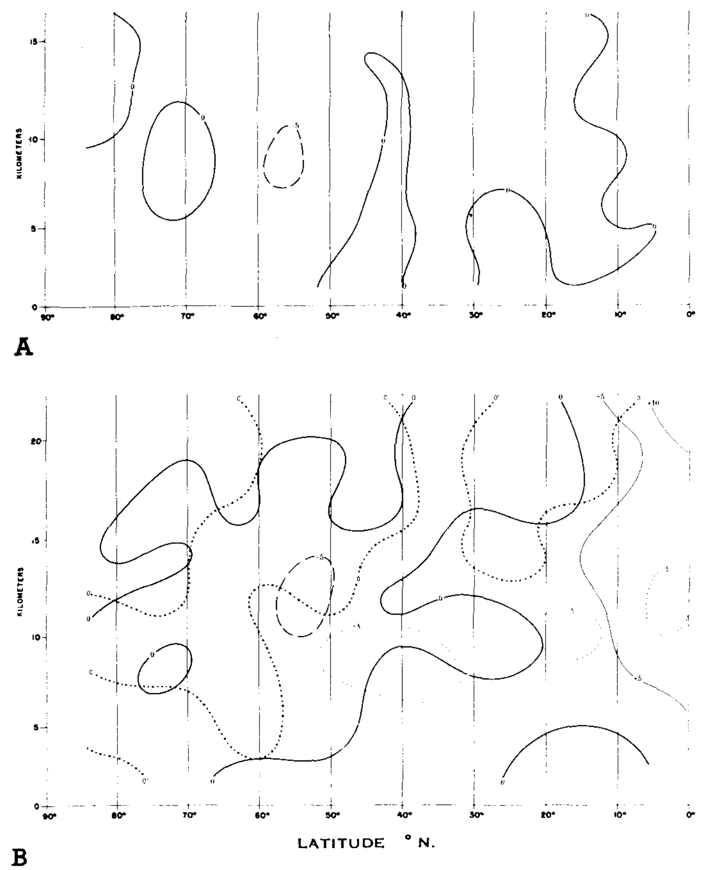

FIGURE 3.—July 1957: (A) west wind anomaly using means by Crutcher [4], and (B) west wind anomaly and temperature anomaly derived by subtracting west wind and temperature means by Landsberg and Ratner [14] from the July 1957 mean. Winds are heavy lines in intervals of 5 m./sec.; temperatures are broken or light-dashed lines in intervals of 5° C.

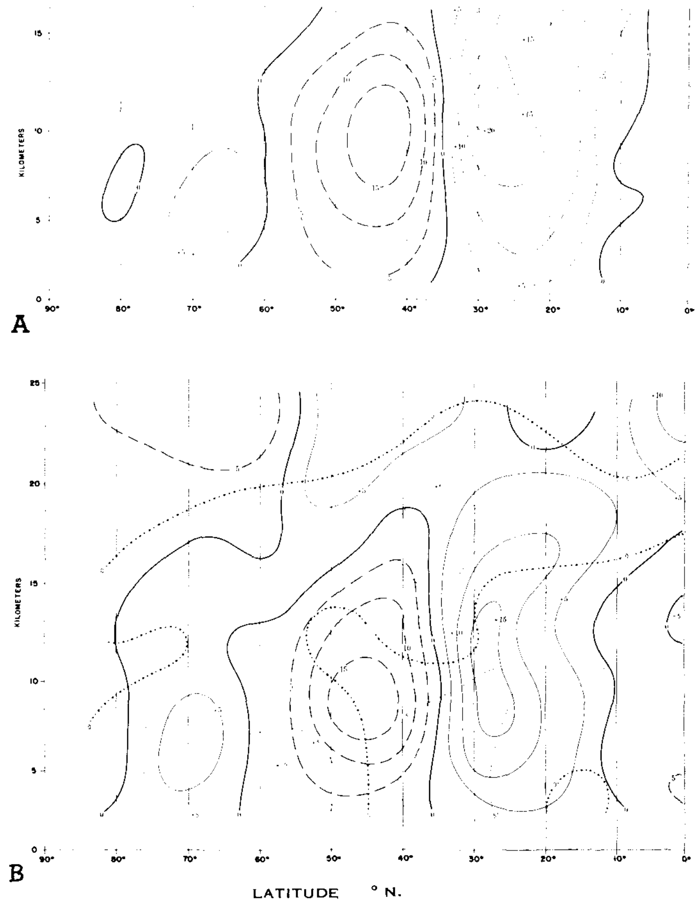

FIGURE 5.—January 1958: (A) west wind anomaly, and (B) west wind and temperature anomalies. Sources of means and contour intervals as explained for figure 3. Large anomalies result as mid-winter jet is displaced southward.

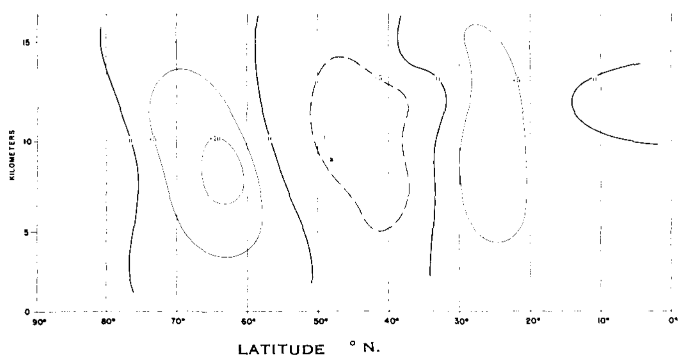

FIGURE 4.—October 1957 west wind anomaly. Excesses of west wind component over fall season mean [4] in higher and lower latitudes caused by a split in the main stream westerlies (see text).

OCTOBER 1957

As described more extensively in [6] the circulation for this month was characterized by a split in the westerlies resulting in two west wind maxima, one at 30° N. and another between 60° and 70° N. This feature was also reflected in the analysis of the mean monthly cross-sections, but since this double maximum feature existed only for one month it was not made a part of figure 2. This split is graphically presented in figure 4 as producing anomalies showing an excess of west wind component over the normal in the lower latitudes and even greater excesses about 65° N. As a natural result of this split in the main westerly stream away from its normal position at about 40° N., an extensive deficiency of west wind component appears near this latitude. More obviously evident here than in figure 3, but a feature on most of the anomaly charts presented, is the balancing in both extent and intensity of the areas of excesses and deficiencies of west wind components. This evidence of the conservation of the total momentum of the westerlies is a well known phenomenon and has been investigated in detail by Namias [18] and others.

JANUARY 1958

With the migration southward of the upper-level westerlies into the subtropics (see fig. 2), followed by the formation of an abnormally large blocking anticyclone in the Davis Strait [19], January turned out to be the most anomalous month of the series. These features are well reflected in figure 5 with excesses of west wind component from 10° N. to 35° N. and up to the 40-mb. level (22 km.)

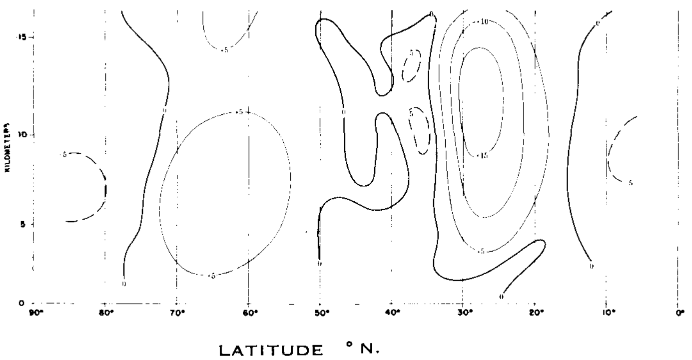

FIGURE 6.—April 1958 west wind anomaly. Large excesses of west wind component caused by circulation strength rather than by displacement from normal position. Notice the resulting excess of positive values over negative (deficiency of west wind from normal) values—a feature not evident in other months.

compensated for by similarly intense deficiencies of west wind from normal in temperate latitudes. The accompanying import of colder than normal temperatures in lower latitudes and up to the 10-km. (260-mb.) level is also evident. The striking similarity of west wind anomalies computed from the two different means is worthy of special note.

Near mid-month an almost record-breaking blocking anticyclone in the Davis Strait west of Greenland caused sustained advection of maritime air from the Atlantic to reach even farther inland than the 80° W. longitude [22]. The much above normal temperatures which resulted appear as +5° to +10° C. anomalies between 50° N. and 70° N. in figure 5B.

APRIL 1958

A fine illustration of the fact that *both* position *and* speed of the west wind maxima are important in reflecting excesses and deficiencies in the anomalies can be seen in figure 6. While the position of the mean maximum west wind for the month was coincident with the seasonal mean position (fig. 2), the excesses shown in figure 6 are of the same magnitude as those shown in figure 5 when the axis of the west wind component was displaced some 8° of latitude from the normal position. The excesses then, in figure 6, are the result of much stronger than normal west wind components during this particular month than would be expected in the mean.

April circulation through 80° W. longitude was also influenced by blocking in mid-latitudes resulting in a split of the jet stream at all levels up to 15 km. [20] and the corresponding west wind excesses between 60° N. and 70° N. as well as between 20° N. and 35° N. An incidental maximum is also evident in figure 6 at about 40° N.

As an exception to a statement made previously, the excesses far outweigh the deficiencies of west wind component for this month as shown in figure 6—at least through the lower 15 km.

JULY 1958

The main features of the circulation for this month,

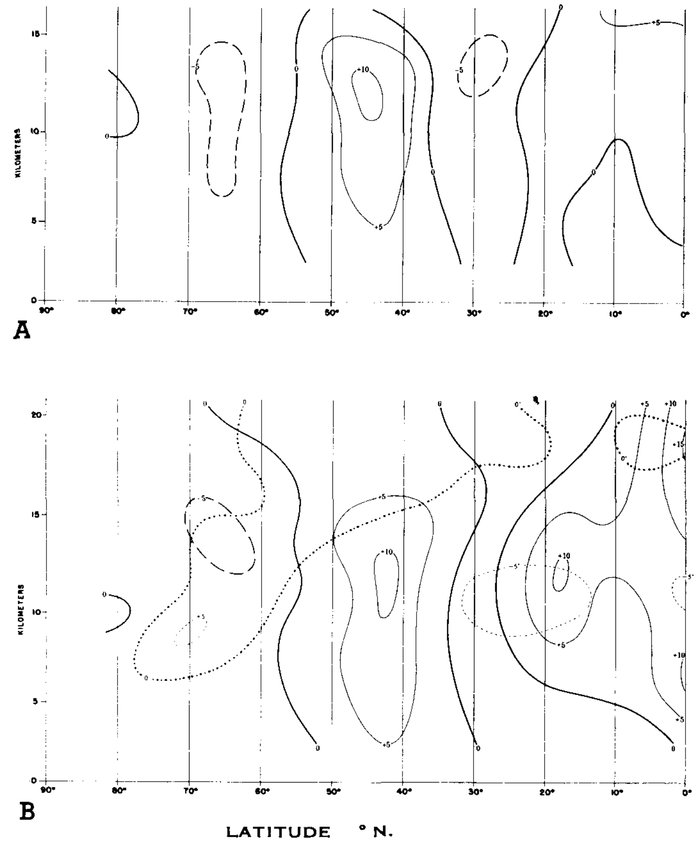

FIGURE 7.—July 1958: (A) west wind anomaly and (B) west wind and temperature anomalies (see legend to figure 3). Another example of reinforcement of west wind component in normal position. 10 m./sec. excess in mid-latitude as compared with July 1957 in figure 3 is also evident from isotachs in figure 2.

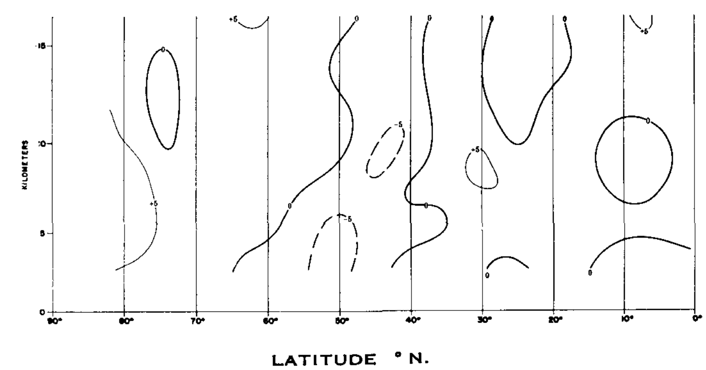

FIGURE 8.—October 1958 west wind anomaly. Although a large-amplitude cyclic variation of the zonal index was evident in the daily values (see text) the monthly mean west wind anomaly is relatively flat. The results of some splitting of the main westerly flow are also evident.

i.e., blocking in the North Atlantic and a stronger than normal Bermuda High [5], rather than shifting the position of the west wind jet, reinforced the jet in its normal position. That this strengthening amounted to about 10 m./sec. in the mean can be seen by comparing figure 7 with figure 3 and the relative positions and intensities of the west wind max'ma in figure 2 for July 1957 and July 1958.

As mentioned previously, the two sources of mean data show greatest differences for this month and in lower latitudes at about 12 km. (195 mb.).

OCTOBER 1958

One of the weaknesses of "mean" presentations of specific parameters is reflected in the rather flat west wind component anomaly pattern in figure 8. As pointed out in [3] the month did gain its character from a pronounced index cycle—high during the first half of the month and low during the latter half—but due to the averaging process the monthly mean value of the 700-mb. zonal index showed as small an anomaly as any month since August 1957!

A comparison of figures 4 and 8 reveals the marked similarities of the 1957 and 1958 circulation through 80° W. during this month of climatic transition. Both years were influenced by a blocking in central Canada which caused a split in the main core of westerlies. This division of the main stream of westerlies away from its usual location near 40° N. resulted in generally similar patterns of excesses and deficiencies of west wind components for both Octobers, i.e., positive areas in low and high latitudes toward which the split jets were shunted, and negative areas in mid-latitudes which usually experience the full force of the primary mean westerly flow.

As has been noted in other cases, figure 8 shows a rather striking balance between positive and negative areas.

4. SUMMARY

Time cross-sections of the monthly mean maximum westerly wind components for the IGY period show a range in position of approximately 20° of latitude and 1.5 km. of altitude in the Northern Hemisphere, and 17° of latitude and 1.7 km. of altitude in the Southern Hemisphere. Height of the mean position oscillated about the 220-mb. (11.5-km.) level in the Northern and near the 200-mb. (12-km.) level in the Southern Hemisphere.

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