AN UNUSUAL SURGE OF COLD AIR ACROSS THE NORTHWEST UNITED STATES ON AUGUST 22 AND 23, 1950

H. DEAN PARRY AND LEWIS C. NORTON

WBAN Analysis Center, U. S. Weather Bureau
Washington, D. C.

INTRODUCTION

One of the few marked weather changes which occurred in the United States during the relatively inactive month of August 1950 was the sharp drop in temperatures which took place in the northwestern States on August 22 and 23. For example, on August 22 the maximum temperature at Boise, Idaho was 101° F. while on August 23 the maximum at this station reached only 73° F. Figure 1 shows the sharp decreases in maxima which occurred throughout Washington and Oregon with the influx of cold air. Note that in the area just west of the Cascades 24-hour decreases of between 10 and 25 degrees occurred. Cooler weather for the area in which the most marked cooling took place was correctly predicted as early as the forecast made from the 0530 MST map of August 21. No cooling for the area east of the Cascades was forecast from the 0530 MST map of August 21, however.

Figure 2 shows the result of the continued eastward advection of the unusually cold air with cooler temperatures occurring throughout most of Washington and Oregon and eastward beyond the Continental Divide. Cooling which occurred east of the Divide was due, in a large measure at least, to a southward surge of Polar Continental air.

The continued advection of the cold air eastward across the Cascades was not anticipated. For example, no cooling was forecast for Idaho, eastern Washington, or western Montana from the 0530 MST map of August 22, and the 30-hour prognostic charts made from the 2330 MST map of August 21, and from the 1130 MST map of August 22 issued by the WBAN Analysis Center indicate no cold front moving in from the west. The fact that these latter changes were not anticipated by synoptic meteorologists and forecasters indicates that this synoptic situation and its antecedents were sufficiently unusual to justify a review.

SOURCE OF THE COLD AIR

In looking for the source of the cold air the twice-daily radiosonde observations from the stationary weather ship

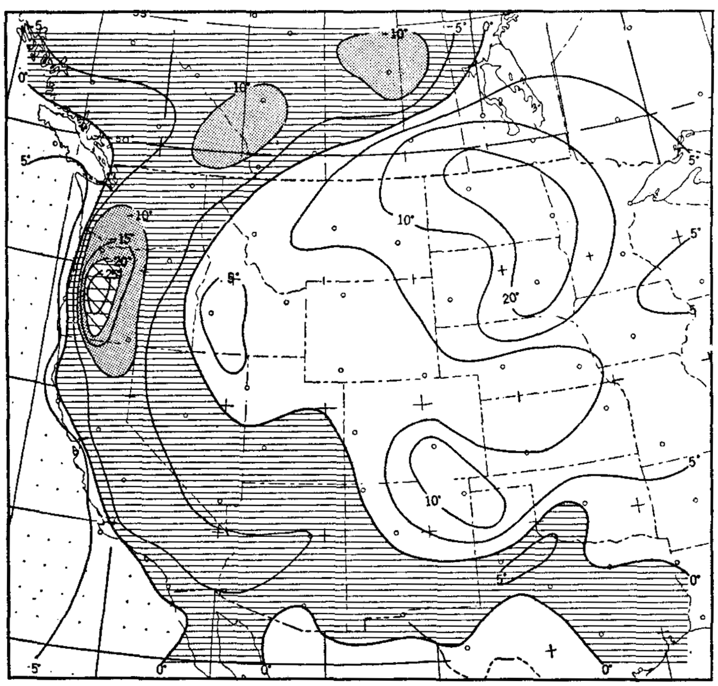

FIGURE 1.—Change of maximum temperature from August 21 to August 22, 1950.

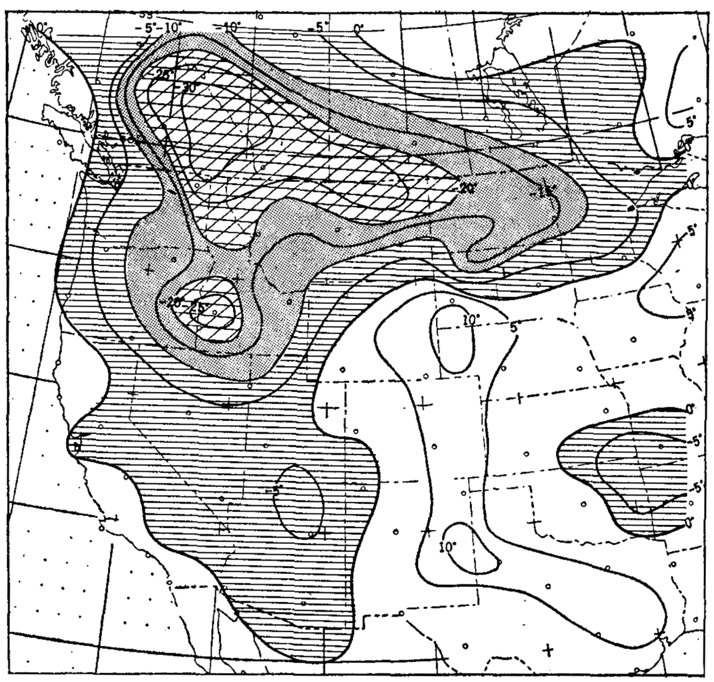

FIGURE 2.—Change of maximum temperature from August 22 to August 23, 1950.

at 50° N., 145° W. were first examined. No significant cooling is shown in these soundings until 2000 MST August 22 at which time the cold air in which we are interested had already moved inland. The cold air, therefore, did not follow a normal track from the west-northwest to the Pacific Coast.

Naturally, temperature changes aloft paralleled the changes in surface temperatures. During the 24-hour period, ending at 0800 MST August 23, cooling at 700 mb. of 9.0° C. was reported at Boise, Idaho, and 7.4° C. at Spokane, Wash. This suggested tracing the trajectory of the cold air at 700 mb. By tracing each 12-hour segment of the trajectory along the appropriate 700-mb. contour shown on the WBAN Analysis Center charts, it was possible to trace the cold air back to the cold core of a Low that had become stagnant over the Pacific at 46° N., 141° W. This Low had remained inactive and nearly stationary since its formation on August 8. Therefore, in the absence of a dense network of surface and upper air ship reporting stations off the west coast, satisfactory forecasting of the cold outbreak depended upon discovering the mechanism which changed the circulation pattern in such a way that the cold air was advected eastward.

TRAJECTORY OF THE COLD AIR

It was at first presumed that the change in the low level circulation pattern was due to some marked change in the upper air pattern which preceded the surface change or which, at least, could have been foreseen in time to forecast the cold outbreak. However, investigation of the charts drawn in the WBAN Analysis Center shows no marked changes in the circulation which could have been used for this purpose.

The possibility that a fresh surge of cold air from the west disturbed the stationary condition within the cold Low was next investigated. Charts for the week preceding August 20, the date on which the cold air south of the stationary Low began to move eastward, were reexamined. Special attention was given to conditions at 700 mb. At 2000 MST August 16, a reconnaissance plane at 700 mb. reported an abrupt rise in temperature of about 5° C. and an accompanying wind shift during flight from about 52° N., 165° E. to 45° N., 150° E. This suggests that the flight passed through a front. On the chart for the time of this flight, Attu, Alaska, reported a temperature of −6.5° C. at 700 mb. This was in contrast to the last previously reported value of −1.8° C. at 2000 MST August 14.

Upon this evidence a cold front was introduced on the chart for the 17th from a point just east of Attu, thence south-southwestward, then westward along the 48th parallel, and finally west-northwestward passing just south of Kamchatka (see fig. 3). After extrapolating this front westward at the speed of the appropriate geostrophic winds, it was found that it explained certain temperature changes which had been noted over Kamchatka during

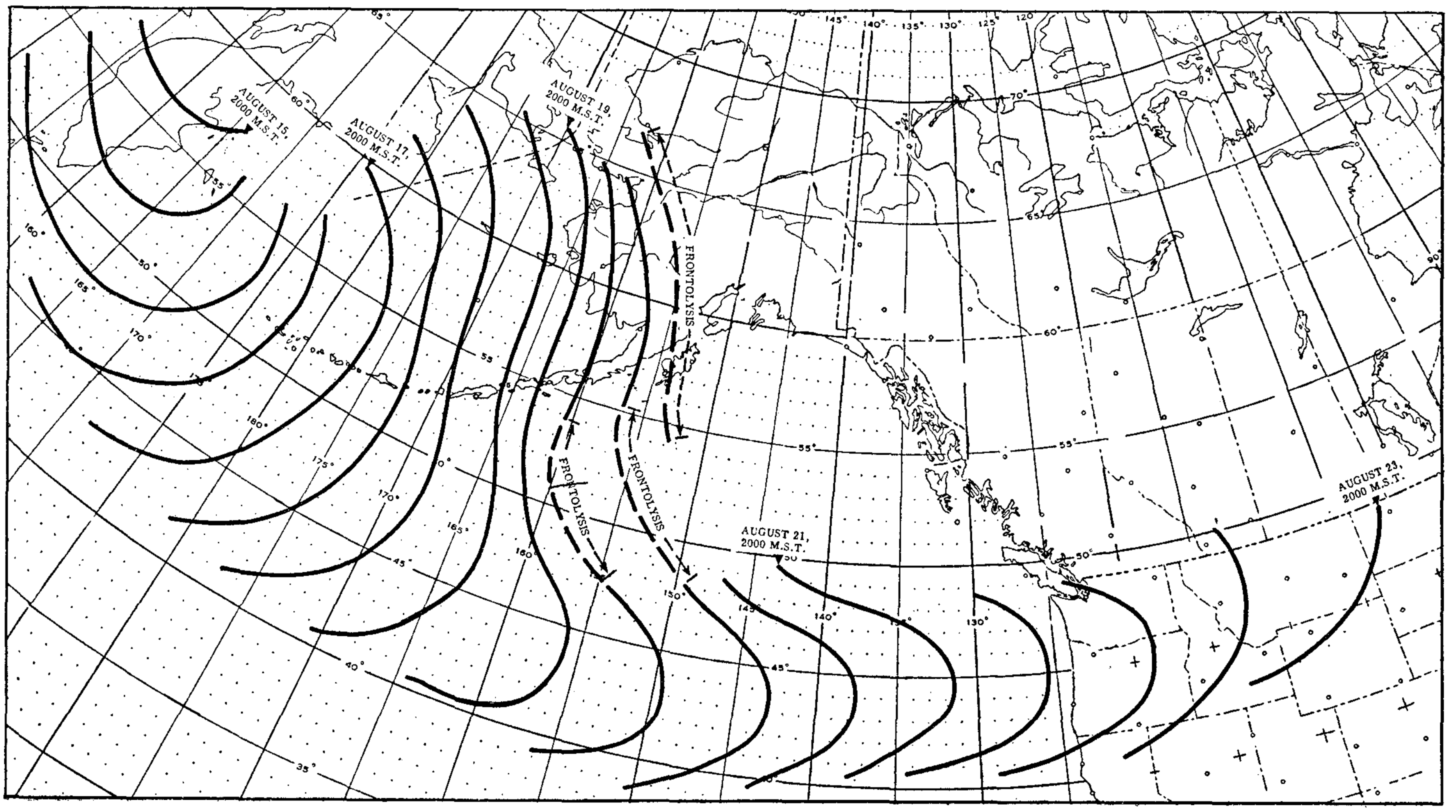

FIGURE 3.—Successive positions, at 12-hour intervals, of the cold front at the 700-mb. level.

the preceding 48 hours. Furthermore, when the cold front was moved eastward with the approximate speed of the geostrophic winds, its passage at Adak, Alaska, coincided very well with the drop of the 700-mb. temperature from +0.5° C. at 2000 MST August 17 to −5.5° C. at 0800 MST August 18. Similarly, the passage at St. Paul Island checked well with the change in temperature at the 700-mb. level from −1.2° C. at 0800 MST August 18 to −5.5° C. at 0800 MST August 19. This evidence establishes the existence of a cold outbreak which came originally from the north-northwest. Furthermore, extrapolating eastward with the instantaneous geostrophic flow in the cold air behind several segments of the front, one obtains a frontal position as shown in figure 3 for the time 2000 MST, August 18.

At this point it seems appropriate to investigate the constant vorticity trajectory of the air behind this cold air outbreak. Because very few reports were available in the area where the cold air first appeared, it is not possible to determine the exact speed and direction of movement of the cold air, and to fix exactly the inflection point used in computing the trajectory. However, based on data available, it appears that the cold air surge came from a north-northwesterly direction at approximately 30 k. and the center of the surge (and therefore the region of minimum shear) was about long. 160° E. The flow was further assumed to be straight at 52.5° N., 160° E. Using the initial conditions specified above, one obtains the constant vorticity trajectory shown in figure 4. (It should be noted that this trajectory does not apply to the flow pattern shown in figure 4 but is for an earlier time.)

If this trajectory were followed, the cold air outbreak would recurve to the north across Alaska, and enter the United States from east of the Continental Divide in Canada. The cold air actually reached the United States from the west. The explanation of this departure of actual trajectory from constant vorticity trajectory is found in the equation

$$div_2\, \boldsymbol{V} = -\frac{d\zeta}{dt}\frac{1}{f+\zeta}$$

where div_2 is the two dimensional (horizontal) divergence, $\boldsymbol{V}$ is the velocity, ζ is the two dimensional (horizontal) curl of the velocity, or vorticity, and f is the Coriolis parameter (cf. Petterssen [1]). Since it can be shown that $(f+\zeta)$ must always be positive, it follows, and is well known, that divergence produces more anticyclonic flow. In developing this relationship a term $\nabla\alpha\times-\nabla p$ was neglected, where α is specific volume and p is pressure. Immediately behind a cold front in a region of cold air advection this term would be larger than within a homogeneous air mass, but is still negligible except in the area in the frontal zone proper. The effect of the term, however small, in the region of cold air advection would work in opposition to the effect of divergence.

It should also be mentioned that the vorticity may be expressed as two components; viz., a term involving shear and a term involving instantaneous curvature of the flow. The discussion that follows applies to one or more streams of air, within which the velocity reaches a maximum near the center at which point the velocity gradient vanishes. Thus in dealing with the center of such streams only the curvature term of the vorticity is considered.

As was originally pointed out by Ryd [2, 3] and has more recently been emphasized by Scherhag [4] and Wobus [5] directional divergence in the isobaric (or contour) field produces divergence in the flow. Examination of figure 4 and of 700-mb. charts preceding this (not shown) shows marked divergence of the contours at this level within the cold air behind the cold front. A similar pattern existed in the surface analyses for the 18th

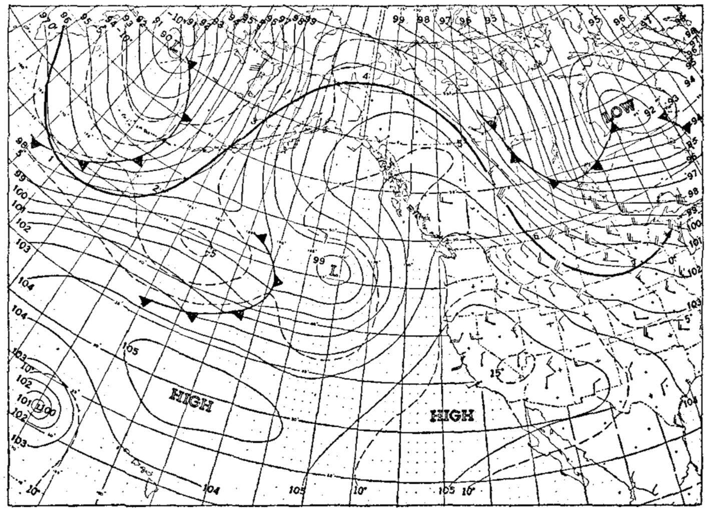

FIGURE 4.—700-mb. chart for 0800 MST, August 20, 1950. Contours (solid lines) are labeled in hundreds of geopotential feet. Isotherms (dashed lines) are drawn for intervals of 5° C. Barbs on wind shafts show wind speed in knots (full barb for every 10 knots, half barb for every 5 knots, and pennant for every 50 knots). Heavy black line shows constant vorticity trajectory of a 30-knot flow from the north-northwest at 52.5° N., 160° E.

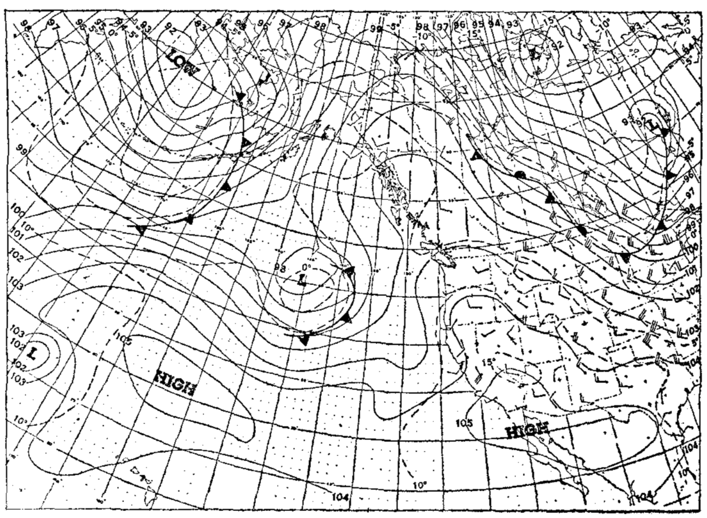

FIGURE 5.—700-mb. chart for 0800 MST, August 21, 1950.

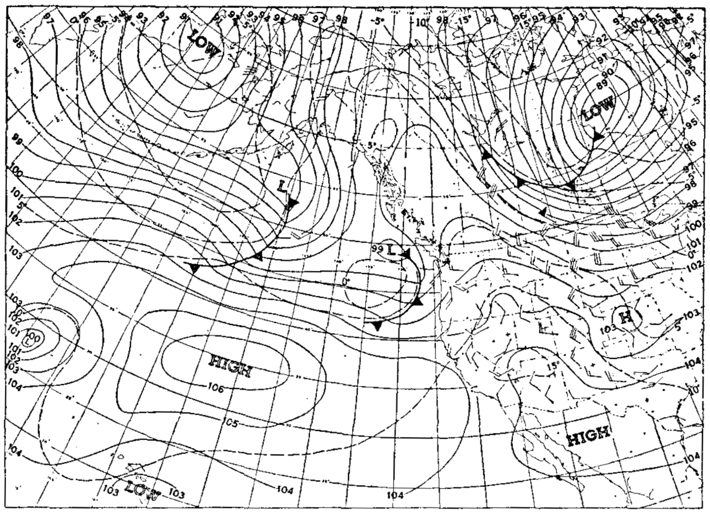

FIGURE 6.—700-mb. chart for 0800 MST, August 22, 1950.

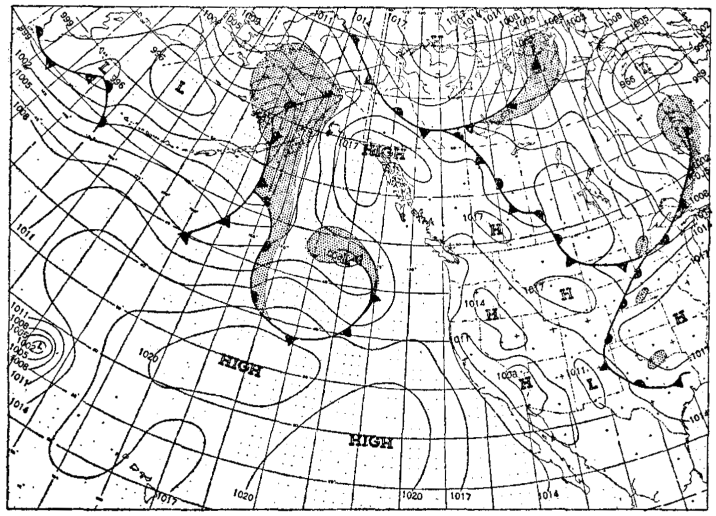

FIGURE 9.—Surface weather map for 0530 MST, August 21, 1950.

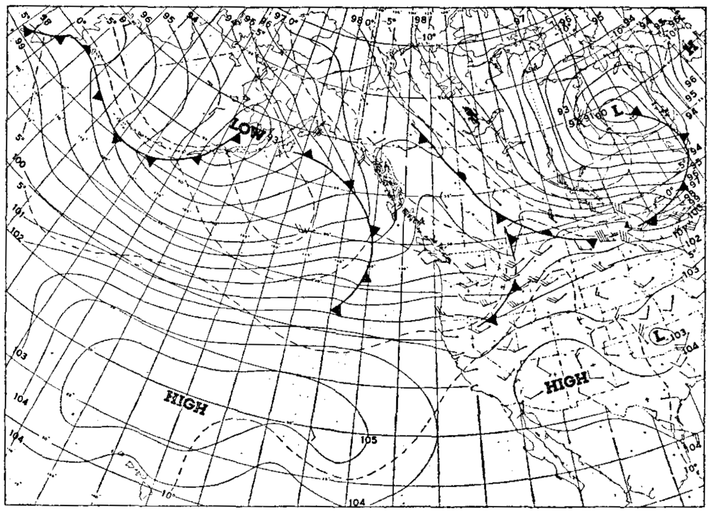

FIGURE 7.—700-mb. chart for 0800 MST, August 23, 1950.

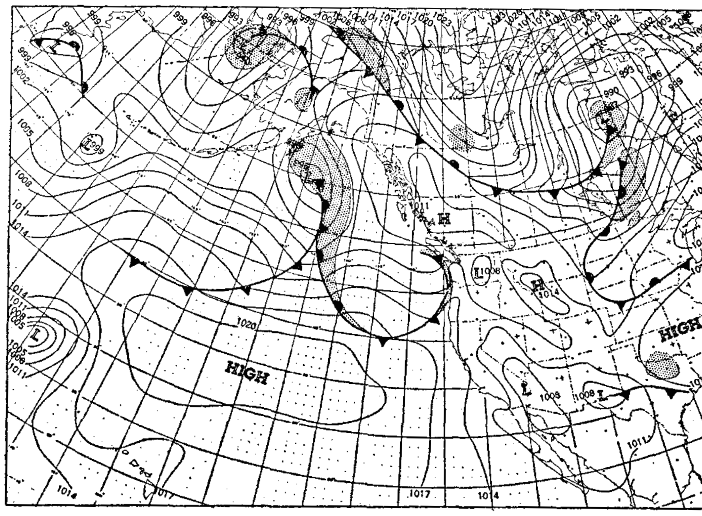

FIGURE 10.—Surface weather map for 0530 MST, August 22, 1950.

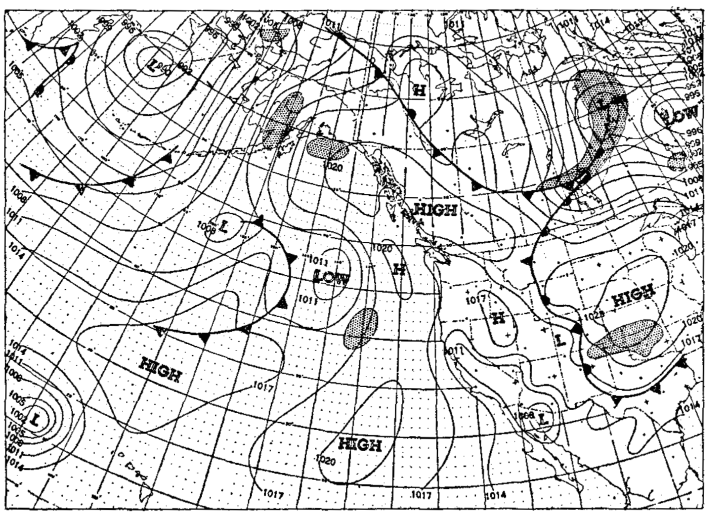

FIGURE 8.—Surface weather map for 0530 MST, August 20, 1950. Shading indicates areas of active precipitation.

and 19th of August. The charts of 2330 MST, August 18 and 0530 MST, August 19, which have several ship reports in the area in question, show marked divergence of the isobars within the cold air. Strong divergence (in the hydrodynamical sense) was therefore occurring throughout the layer between 700 mb. and the surface.

As was noted above, the effect of this divergence is to cause the actual trajectory to depart from the constant vorticity trajectory in such a way that the actual path becomes increasingly anticyclonic with time. Therefore, instead of recurving northward the more southerly branch of the cold air outbreak continued in such a manner that the direction of flow was from the west-northwest. Consequently, the original cold outbreak was broken into two branches, one of which recurved to the north and the second of which flowed east-southeastward across the Pacific, south of the stationary ship at 50° N., 145° W. and, because of horizontal divergence and

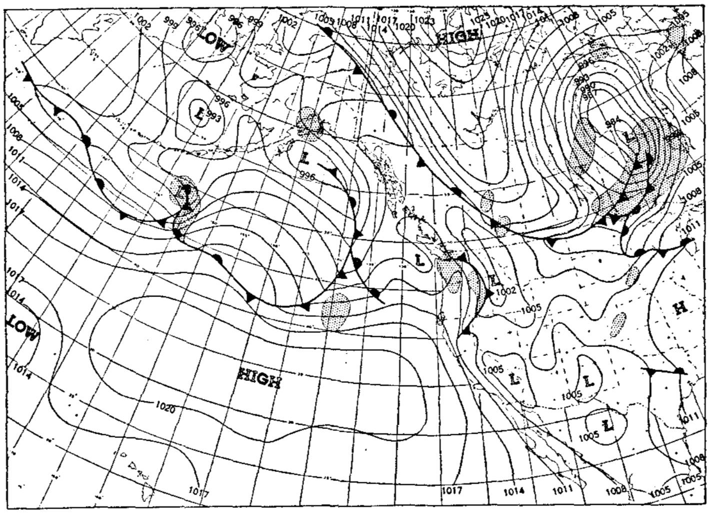

FIGURE 11.—Surface weather map for 1730 MST, August 22, 1950.

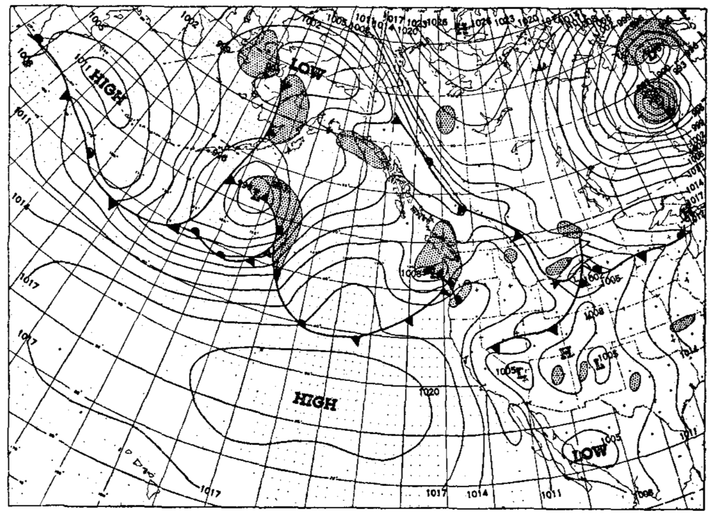

FIGURE 12.—Surface weather map for 1730 MST, August 23, 1950.

resultant subsidence, arrived just west of the cold Low with about the same temperature at the 700-mb. level as the air within the core. The affect of this cold influx was to break down the stationary Low and replace it with westerly flow which carried the cold air inland. Extrapolating the cold air eastward with the geostrophic flow, as obtained from the charts, gives successive frontal positions for 12-hour intervals as shown in figure 3. The successive positions of the cold front at 700 mb. for 24-hour intervals can also be seen on figures 4 through 7. Figures 8 through 10 show successive surface positions of the cold front for a period corresponding to the first three 700-mb. charts.

As the front passed inland across the coast line evidences for it on the surface map were rather poor and obscure, although considerable rain occurred along the coast during this time. By the time the cold air had advanced eastward as shown in figure 11, the front had become very marked and active accompanied by thunderstorms, sharp windshifts, marked pressure tendency differential, and sharp cooling. This was due largely to the great contrast which developed as the cool maritime air from the west came into contact with the very warm air east of the Cascades. In this connection it is well to point out that active surface fronts are not produced by this contrast in this area unless some outside influence changes the normal flow pattern and sets up active cold advection from the west.

Although thunderstorms accompanied the front as it moved eastward in the area east of the Cascades, amounts of precipitation produced by it were very light. This was to be expected since the cold air had lost a good deal of its moisture in passing over the Cascades and the warm air was of continental origin and therefore dry.

By 1730 MST of August 23 (see fig. 12) the cold air had covered the entire northern mountain area and the front had induced a wave in a polar continental front which had been moving slowly down from the north. The subsequent history of the Pacific front was short as it dissipated just east of the Continental Divide. Cold air advection continued, however, in the middle troposphere so that a squall line developed over western Kansas during the late evening of August 24 and the resultant shower activity continued in this area during most of the night. The mechanism of a squall line produced by the eastward advection of a relatively narrow tongue of cool air at intermediate heights is not self-perpetuating. This condition tends rather to destroy itself. The release of instability, which is a manifestation of the squall line, tends to destroy the cold tongue. The effect of the upward transport by convection of the heat realized by condensation tends likewise to destroy the tongue. In this manner the remnants of the cold surge were finally destroyed.

REFERENCES

1. Sverre Petterssen, *Weather Analysis and Forecasting,* McGraw-Hill Book Co., Inc., New York and London, 1940.
2. V. H. Ryd, "Meteorological Problems. I. Travelling Cyclones." *Meddelelser, Nr. 5,* det Danske Meteorologiske Institut, Kjøbenhavn, 1923.
3. V. H. Ryd, "Meteorological Problems. II. The Energy of the Winds." *Meddelelser, Nr. 7,* det Danske Meteorologiske Institut, Kjøbenhavn, 1927.
4. Richard Scherhag, *Neue Methoden der Wetteranalyse und Wetterprognose,* Springer-Verlag, Berlin, Göttingen, Heidelberg, 1948.
5. Hermann B. Wobus and Lewis C. Norton, "Some Synoptic Aspects of a Change in Weather Regime during February 1950," *Monthly Weather Review,* vol. 78, No. 2, February 1950, p. 31–40.

U. S. GOVERNMENT PRINTING OFFICE: 1950