THE WIDESPREAD SMOKE LAYER FROM CANADIAN FOREST FIRES DURING LATE SEPTEMBER 1950

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INTRODUCTION

During the latter part of September 1950, an extensive layer of smoke originated from forest fires in the Canadian Provinces of British Columbia and Alberta. Subsequently it spread over large areas of Canada and the eastern United States. The resulting unusual appearance of the sky and sun and the diminution of normal daylight caused widespread interest among meteorologists and the public alike. This report describes some of the information about this phenomenon which has been collected and analyzed during the first three weeks in October.

THE SOURCE AND SPREAD OF THE SMOKE

The weather in British Columbia and Alberta was unseasonably warm and dry during the first half of September, contributing materially to the onset of extensive forest fires. According to conservative estimates furnished by the Canadian Embassy at Washington, D. C., approximately 60 fires burned in British Columbia, and 37 were counted by forestry officials in Alberta. The fires, beginning about mid-September, extended west from Grande Prairie, Alberta, through Fort St. John, British Columbia, to the foothills of the Rockies and north to Fort Nelson, British Columbia, with others raging near Wanham, Alberta, 340 miles northwest of Edmonton, Alberta, and Newbrook, Alberta, 70 miles north of Edmonton. The dashed hatching in figure 1 indicates the principal fire area. Undoubtedly other scattered forest or tundra fires in western Canada contributed smoke to the atmosphere since the fall season is usually fraught with such fires. During the last week of September, light snow and rain helped extinguish most of the fires.

The smoke from the fires spread eastward passing over central Canada, then southward over the Great Lakes region and the eastern United States as far south as Georgia and Tennessee. The denseness and unusual optical effects of the smoke first became very noticeable over the northeastern United States on September 24. The weather observer at Idlewild, N. Y., reported that the sun appeared pink; at Allentown, Pa., and Buffalo, N. Y., it looked purple; at Findlay, Ohio, and Parkersburg, W. Va., blue; and at Washington, D. C., lavender. The sky was usually described as yellowish or greyish-tan. Williamsport, Pa.; Dunkirk, N. Y.; Martinsburg, W. Va.; Sault Ste. Marie, Mich.; and Nakina, Ontario, were some of the stations reporting unusually dark conditions during the day with a few experiencing reduction of light to nighttime darkness. By noon September 26, the smoke had been carried across the Atlantic as indicated by the observation of a blue sun from the Isle of Man in the British Isles. Later other reports of unusual optical effects came from European stations.

The smoke aloft persisted over the northeastern United States at least until the afternoon of September 29 when generally cloudy conditions prevented further observations of it from the surface. It was certainly absent from the Washington area by 1630 EST September 30 when clear skies were again reported.

Such widespread smoke from forest fires has been observed in past years. In 1918 forest fires in Minnesota produced smoke which was observed as far away as Texas and South Carolina [1]. The record of dark days in the United States resulting from smoke pollution extends back to 1706 according to Plummer [2]. The effects of smoke pollution have also been observed for centuries as dry fogs and colored rains. Forest fires are the chief cause of widespread smoke aloft, but many notable ex-

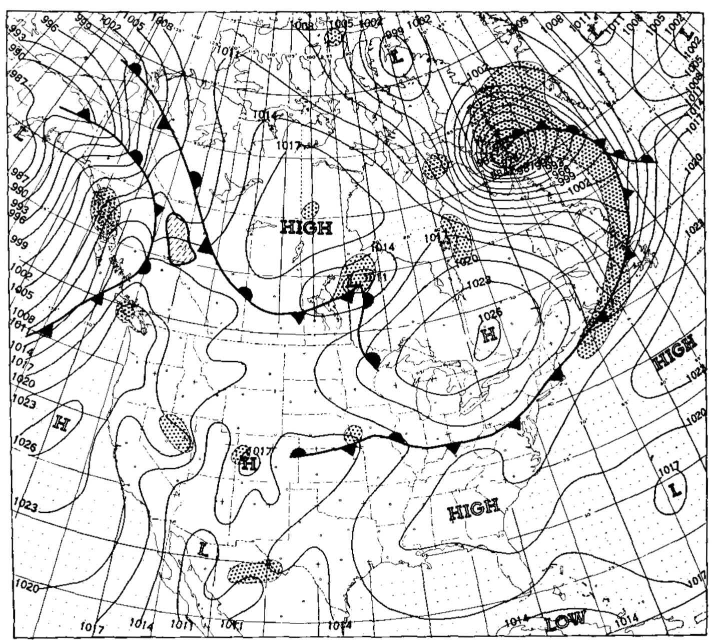

FIGURE 1.—Surface weather map for 0030 GMT, September 20, 1950. Shading indicates areas of active precipitation. Dashed hatching indicates principal area of forest fires.

amples of smoke and dust from volcanic eruptions are recorded as well [3]. The cruption of Krakatoa in 1883 is well known as the cause of very extensive smoke and dust aloft as well as of brilliant optical effects [4].

THE SYNOPTIC SITUATION IN THE FIRE AREA

During the period September 5 to 23, that part of British Columbia and Alberta shown in figure 1 as the fire area experienced a drought principally due to a ridge of high pressure at the surface and aloft which occupied the region most of that period. The ridge acted as an efficient blocking obstacle to the passage of the customary train of maritime fronts. The fronts that moved up to the ridge weakened markedly or frontolized; consequently almost no precipitation occurred in the region. Figure 1 illustrates one such weak maritime Pacific front that passed through the area. The region between the maritime occlusion and the stationary polar front experienced temperatures in the mid-seventies. Some rain fell west of the Rockies, but the east side remained dry due to the combined effect of topography and the semi-permanent ridge which weakened the front as it approached. These conditions are representative of the drought period preceding the forest fires.

As would be expected in a persistent ridge, the surface winds were generally light and variable. These factors contributed not only to the production of the forest fires, but also to the accumulation of a large amount of smoke in the fire area. An examination of the surface observations in the area for September 17–24 clearly shows the large, dense supply of smoke available for transport by the winds to other regions. The observations of September 22, 23, and 24, the period of maximum fire activity, contain evidence of the smoke in the form of reduced visibility (less than 1 mile at many stations), obscured skies, remarks of smoke aloft, or pilot reports of smoke and forest fires in the vicinity.

UPPER AIR CONDITIONS SEPTEMBER 22–27, 1950

Since the smoke produced at the surface in British Columbia and Alberta was observed several days later as a thick layer aloft far to the east it was obviously necessary to examine the upper air conditions to establish a sequence of events in the movement of the smoke. The 700-mb. charts of 0300 GMT September 22, 24, and 27 were selected to illustrate the upper air flow (figs. 2, 3, and 4). The pattern of flow at 500 mb. was similar to that at 700 mb.

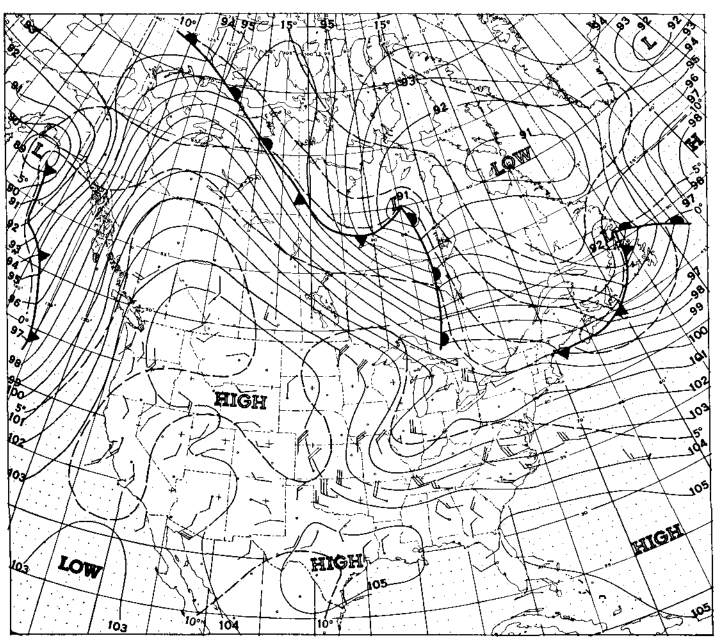

FIGURE 2.—700-mb. chart for 0300 GMT, September 22, 1950. Contours (solid lines) at 100-foot intervals are labeled in hundreds of feet. Isotherms (dashed lines) are in intervals of 5° C. Barbs on wind shafts are for wind speeds in knots; full barb = 10 knots, half barb = 5 knots, and pennant = 50 knots.

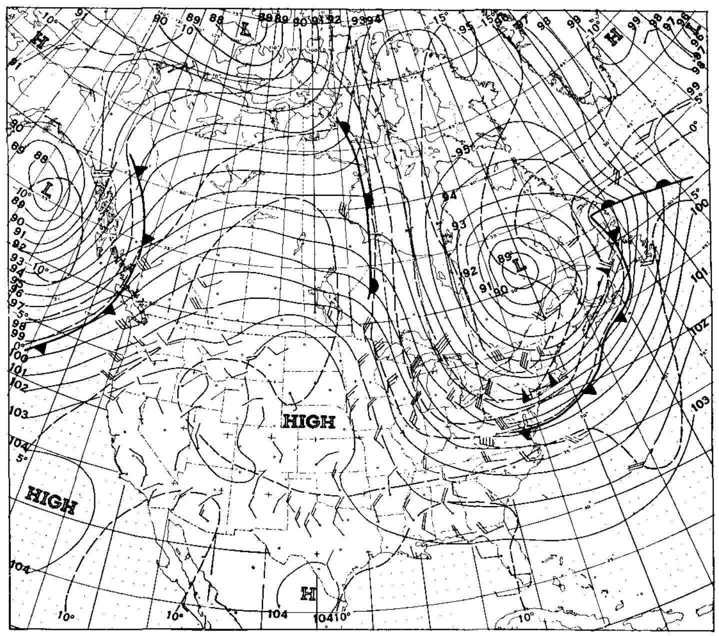

FIGURE 3.—700-mb. chart for 0300 GMT, September 24, 1950.

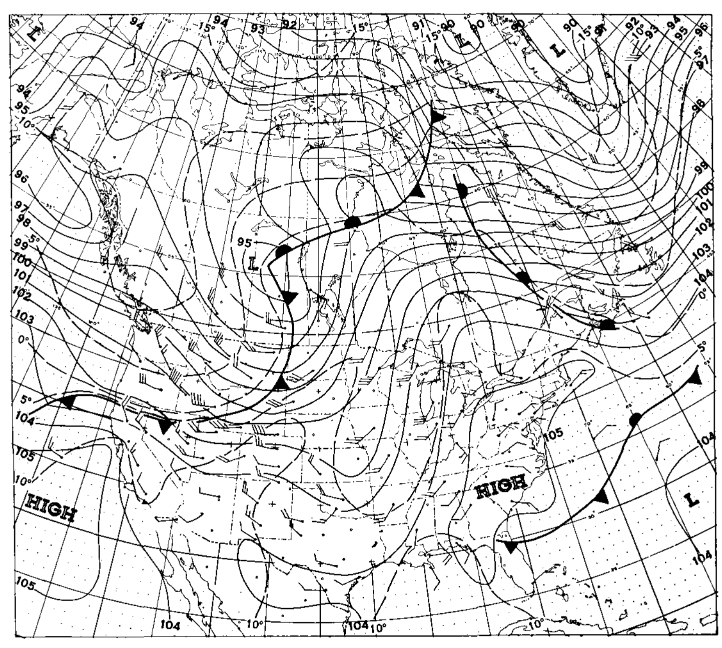

FIGURE 4.—700-mb. chart for 0300 GMT, September 27, 1950.

The period September 22 through 24 was characterized by a ridge over the western United States and Canada and a Low in eastern Canada with a well defined northwesterly or northerly current over central Canada and the eastern United States. Figures 2 and 3 are sufficient to give the general impression that smoke added to the atmosphere over the fire area was swept over central Canada and southward over eastern United States. An attempt was made to demonstrate this by calculating trajectories both up and down stream on the 700-mb. and 500-mb. surfaces. It was found that such trajectories did not correspond to the observed location of the smoke layer or to the proper time sequences. In order to track the smoke more precisely the following procedure was used.

All available reports of the height of the base and top of the smoke layer were studied. These consisted mainly of pilot reports over the eastern United States. It was found, as might be expected, that the smoke layer was not observed at the same height from place to place and time to time. Also multiple layers were reported by pilots. On September 24 the base was reported variously 12,000 to 14,000 feet over Pennsylvania, and a pilot reported that he was in dense smoke at 17,000 feet over Sault Ste. Marie. On September 25, the base was reported variously 11,000 to 14,000 feet and the top 14,500 feet to indefinitely higher. By September 26, the base was 9,000 to 11,000 feet and top around 14,500 feet. Then by September 27 and 28, the base was 6,000 to

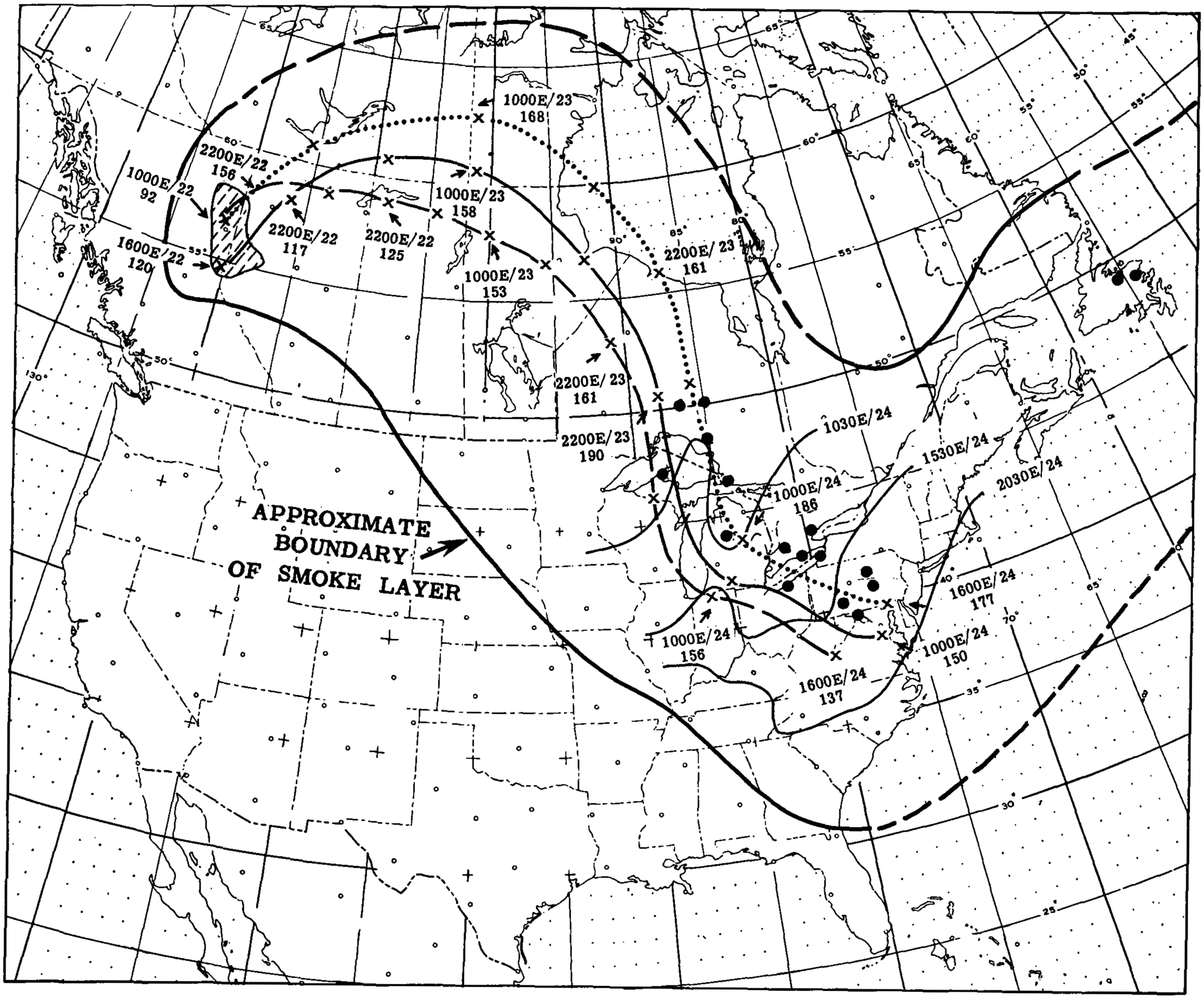

FIGURE 5.—Trajectories of air parcels calculated on isentropic charts of $\Theta=312°$ A. Dashed hatching indicates fire area. Three-digit numbers by trajectory points are heights in hundreds of feet. Large dots near Great Lakes mark stations reporting greatly diminished daylight on September 24. Large dots in Newfoundland mark the same condition on September 25. Dashed parts of smoke boundary are problematical. Thin solid lines across the Great Lakes and eastern United States are isochrones at 5-hour intervals on September 24 showing southeastward progress of the smoke layer.

9,000 feet and top 10,000 to 15,000 feet. The appropriate adiabatic diagrams were examined in order to coordinate the reported heights with significant lapse rate changes. It was found that the reported heights did not correspond to a constant pressure surface; however, the potential temperature of 312° A was common to a majority of the heights. This suggested that a series of isentropic charts of potential temperature 312° would be superior to constant pressure charts for reconstructing trajectories of air parcels from the fire area. A series of 7 such isentropic charts spaced at 12-hour intervals was prepared for the period 0300 GMT September 22 through 0300 GMT September 25 and trajectories were calculated in 6-hour steps using the isentropic stream functions and a set of geostrophic wind scales designed to give velocities in knots. Sample trajectories calculated on these charts are shown in figure 5.

The examination of the adiabatic charts revealed the atmosphere over western Canada to be conditionally unstable to 6,000 feet and at times as high as 18,000 feet. The convection caused by the heat from the fires carried the smoke several thousand feet aloft initially, and the instability of the air assisted farther rise to heights corresponding to those of the 312° potential temperature surface. In figure 5 the heights (accurate to ±300 feet) along the trajectory on the 312° surface are shown to vary between 9,200 and 15,600 feet in the fire area.

The trajectories beginning 1000 EST September 22 (dashed) and 2200 EST September 22 (dotted) in the fire area show the approximate path of the main stream of smoke. Note how the dotted trajectory runs through the middle of the group of marked stations near the Great Lakes. The marked stations are some that reported very dark sky conditions or reduction of light to nighttime conditions on September 24 indicating a thick, dense, smoke layer aloft. The marked stations in Newfoundland experienced the same condition on September 25.

Trajectories were also calculated upstream from points in the northeastern United States. One is shown in figure 5 (solid line). It also corresponds well with the main stream of smoke. In the calculations of trajectories it was found the resulting particle path is very sensitive to the choice of the starting place and time. By varying each initial condition it can be shown that air passing over the fire area moved over approximately the area designated in figure 5 as that covered by the smoke.

The three isochrones in figure 5 were drawn after summarizing the hourly surface reports. They agree reasonably well with the times on the trajectory points and illustrate the southward progress of the smoke.

While the smoke proceeded eastward, a polar outbreak developed in the Hudson Bay region as a cyclone on the polar front deepened over Hudson Bay. The low contour center aloft associated with the surface cyclone deepened rapidly forming a strong northerly current just west of Hudson Bay as illustrated by figures 2 and 3. The smoke layer was caught up by this rapid current above the cold dome and accelerated to speeds greater than 50 knots. If this development had not occurred it is improbable that the smoke layer would have covered such large areas of the United States.

The cold dome of continental polar air that moved southward over the northeastern United States on September 23 and 24 extended to approximately 14,000 feet. Comparing this height with the height of the smoke layer as reported by pilots it is established that the smoke layer was in the maritime Pacific air above the polar dome. The Pittsburgh sounding reproduced in figure 6 shows the top of the continental polar air near 600 mb. (approximately 14,000 feet) with a potential temperature of approximately 310° A. The Washington sounding of 3 days later, also illustrated in figure 6, shows the continental polar dome had subsided to 740 mb. (approximately 8,500 feet) with a potential temperature of approximately 308° A. This height corresponds well with the reported height of the smoke layer on September 27.

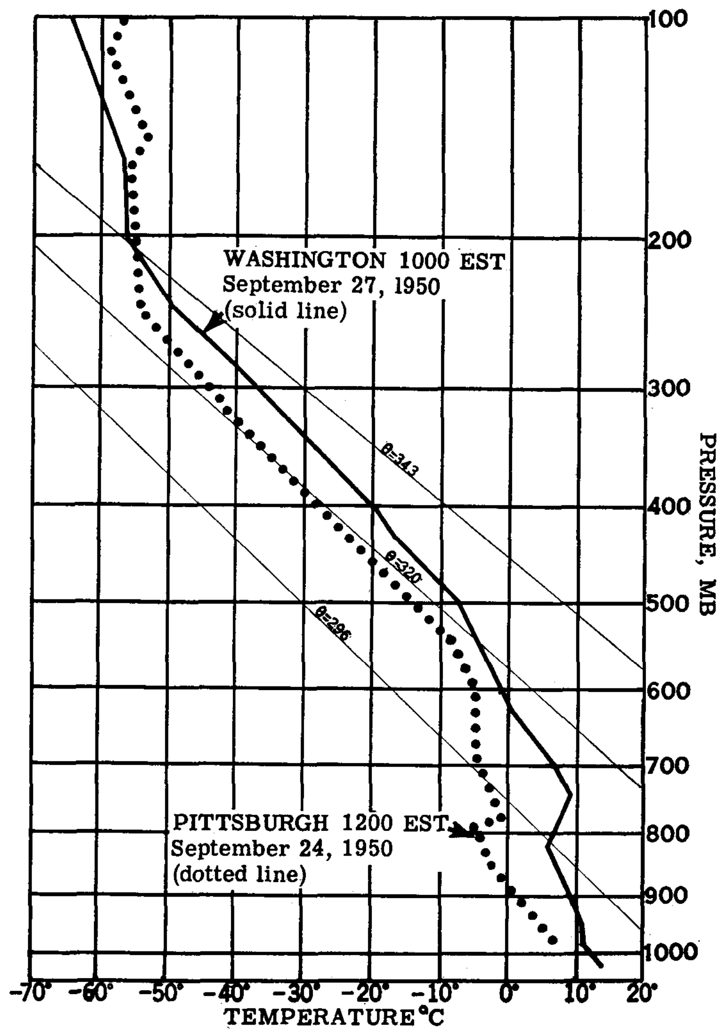

FIGURE 6.—Radiosonde observations plotted on a pseudo-adiabatic diagram: Pittsburgh, Pa., 1200 EST, September 24, 1950; Washington, D. C., 1000 EST, September 27, 1950.

One of the interesting aspects of the smoke layer was its persistence over the northeastern United States during most of the week beginning September 24. An examination of the upper air situation revealed one explanation for the persistance. On September 24 and 25, a ridge located to the west of this area contributed to the production of the northwesterly current over the area as shown in figures 2 and 3. This current provided a continuous supply of smoke on those days. By September 26, the ridge had moved over the area producing a large region of light, variable winds aloft. Figure 4 illustrates this condition. Apparently a large quantity of the smoke was cut off from the main stream of the westerlies and remained trapped over the northeastern United States.

EFFECTS OF THE SMOKE LAYER

The smoke layer reduced the amount of solar radiation received at the ground, and consequently the temperatures recorded by stations in the smoky area were affected. Mr. Sigmund Fritz of the U. S. Weather Bureau, investigating the effect on the temperature at Washington on September 26 and 27, has made preliminary estimates that the maximum temperature was lower than it otherwise would have been by about 10° F., and the minimum temperature higher by a smaller amount.

This paper has dealt with the synoptic aspects of the smoke layer. Additional information about the insolational and optical aspects can be found in a paper by Dr. H. Wexler published in *Weatherwise* [5].

ACKNOWLEDGMENTS

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