THE DEEPENING STORM OVER ILLINOIS ON APRIL 11-12, 1951

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INTRODUCTION

One of the weather forecaster's most difficult problems, of which the synoptic situation of April 11–12, 1951, provides an interesting example, is to anticipate deceleration, stagnation, and later acceleration of a low pressure center, together with accompanying changes in intensity. A newly formed wave, centered about 100 miles northeast of Fort Worth, Tex., at 0030 GMT, April 11, moved rapidly eastward then northward to near Peoria, Ill., deepening as it moved. It then performed a complete counterclockwise loop at greatly reduced speed, after which it moved eastward, accelerated, and began to fill. It is of interest to examine some of the associated phenomena and reasons for unusual behavior of this Low.

SYNOPTIC HISTORY

On April 9 a maritime polar air mass pushed southeastward across the Continental Divide into the western United States. On April 10, the mP front was reenforced by a flow of fresh continental polar air from Canada. The influx of colder air gradually changed the weak pressure field existing over the United States to a field marked by a strong pressure ridge centered over the Great Plains.

On April 10 at 0630 GMT, the push of the maritime polar air brought the front into southeastern Colorado where it was joined to an east-west front separating a modified stagnant mass of cold air on the north from an air mass to the south which was gradually assuming the properties of maritime tropical air.

The upper air picture preceding the storm development over Illinois is given by the 500-mb. chart for 1500 GMT, April 10 (fig. 1). The United States, except for the west coast, was dominated by one large cold trough. The cold Low over Detroit, Mich. was the result of an earlier cold outbreak, and the trough eastward into the Atlantic along the 45th parallel, of still earlier invasions of cold air.

A strong jet from the southwest over stationary ship "Peter" at 50° N., 145° W. turned anticyclonically and entered the continent in the vicinity of Juneau, Alaska. Over Canada, it turned southeastward approximately along the Continental Divide and continued into the United States. Over New Mexico, the jet swung east-southeastward to the northern Gulf Coast and then eastward into the Atlantic Ocean to the vicinity of Bermuda.

Associated with the jet at 500 mb. over the Continental

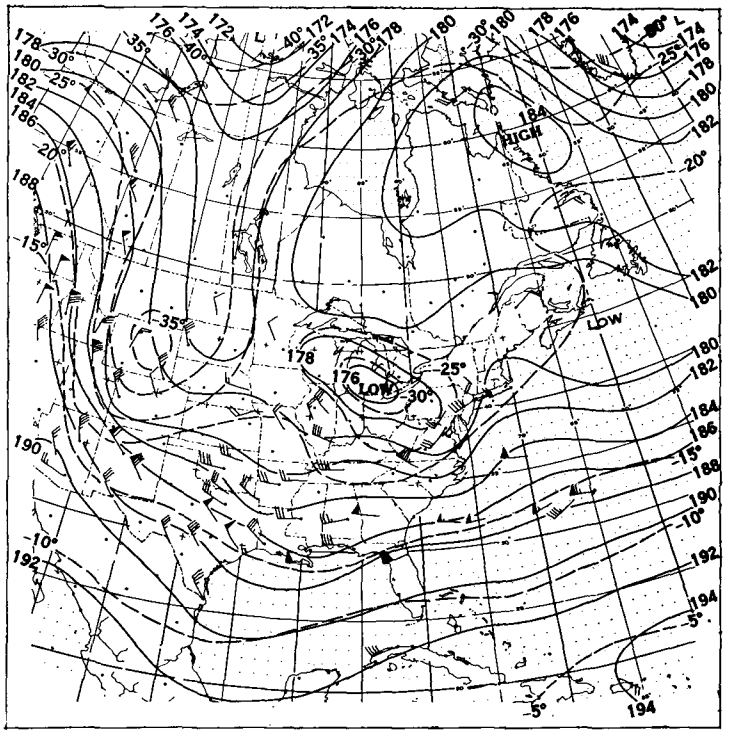

FIGURE 1.—500-mb. chart for 1500 GMT, April 10, 1951. Contours (solid lines) at 200-ft. intervals are labeled in hundreds of geopotential feet. Isotherms (dashed lines) are drawn for intervals of 5° C. Barbs on wind shafts are for wind speeds in knots, (pennant=50 knots, full barb=10 knots, and half barb=5 knots).

Divide was a definite packing of the isotherms in such a manner as to indicate strong cold advection into the southern Great Plains States. During the previous 12 hours considerable amounts of cold air had already been brought into the United States as shown by temperature changes at 500 mb. of −10.3° C. at Denver, Colo., −9.3° at Grand Junction, Colo. and −8.7° at Lander, Wyo. Lander recorded the lowest temperature, −34.5° C.

Just to the east of the cold air was a very weak ridge from Oklahoma City to Des Moines, Iowa, with slight warm advection indicated over the Mississippi Valley.

The surface picture leading up to the storm under discussion is given by the surface chart for 0030 GMT, April 11 (fig. 2). The most striking feature of this chart was the flat gradient over the eastern half of the United States with very poorly defined frontal systems, contrasted with the very strong north-south flow from the Dakotas to western Texas. The trough along the cold front in the southwest was elongated with a main center near Del Rio, Tex.

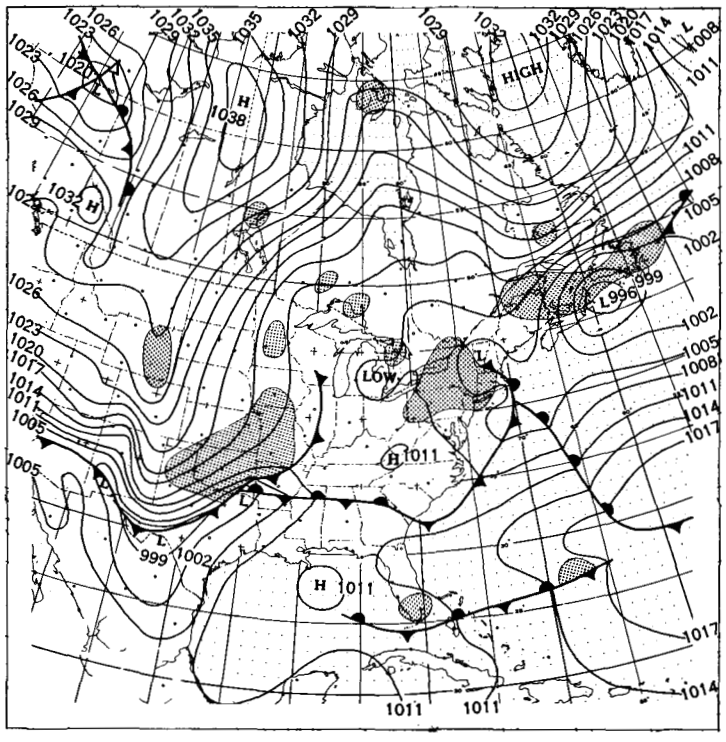

FIGURE 2.—Surface weather map for 0030 GMT, April 11, 1951. Shading indicates areas of active precipitation.

DEVELOPMENT

The 12-hour sea level pressure change chart for 0030 GMT, April 11 (fig. 3), showed a large rise area associated with the cold air over the Great Plains. Two centers of maximum rise were evident, one of 16 mb. near Amarillo, Tex., and one of 17 mb. near Grand Junction, Colo. There was also a general rise area extending from Fargo, N. Dak. southeast into Virginia, evidence of the filling of the cold Low that had existed over Detroit at upper levels (fig. 1), and its replacement by a ridge.

According to Scherhag [1], the rise centers evident over Colorado and Texas (fig. 3) should have moved in the direction of, and with 50–60 percent of the speed of the 500-mb. flow. From the 500-mb. chart for 0300 GMT, April 11 (not shown) an average wind of 60 knots was indicated by the gradient for the area concerned. By applying the above rule, the rise area would have been expected to appear 12 hours later at a point approximately 6 degrees of latitude south-southeast of its position at 0030 GMT, April 11. The centers of rise near Amarillo and Grand Junction (fig. 3) did move, as suggested by Scherhag's forecasting technique, to near Del Rio, Tex. and Alamogordo, N. Mex., respectively.

Evident on the pressure change chart (fig. 3) was a region of falls pushing southeastward on the east side of the Continental Divide into Montana. Here was an indication that the supply of cold air for this system was being cut off by warmer air from the Pacific.

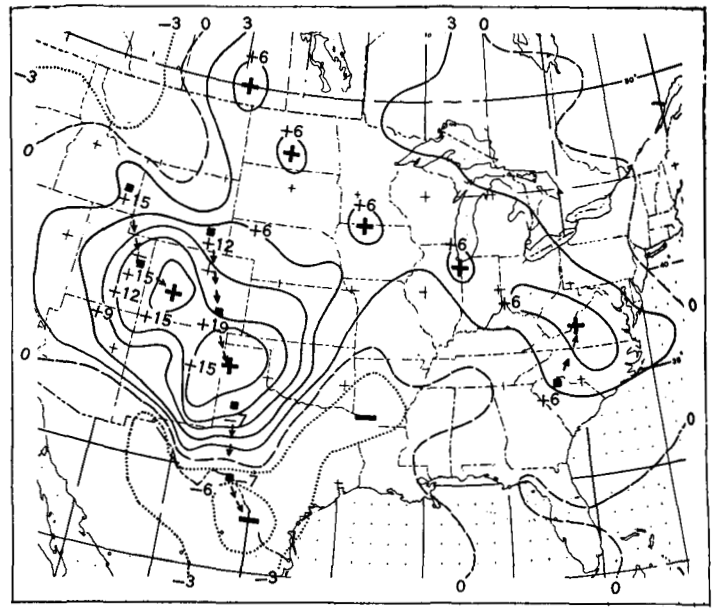

FIGURE 3.—12-hour sea level pressure change chart for 0030 GMT, April 11, 1951. Isolines are for 3-mb. intervals. Dashed lines indicate no change. Dotted lines denote regions of fall, solid lines regions of rise. Tracks indicate previous 6-hour positions. All values are corrected for diurnal variations.

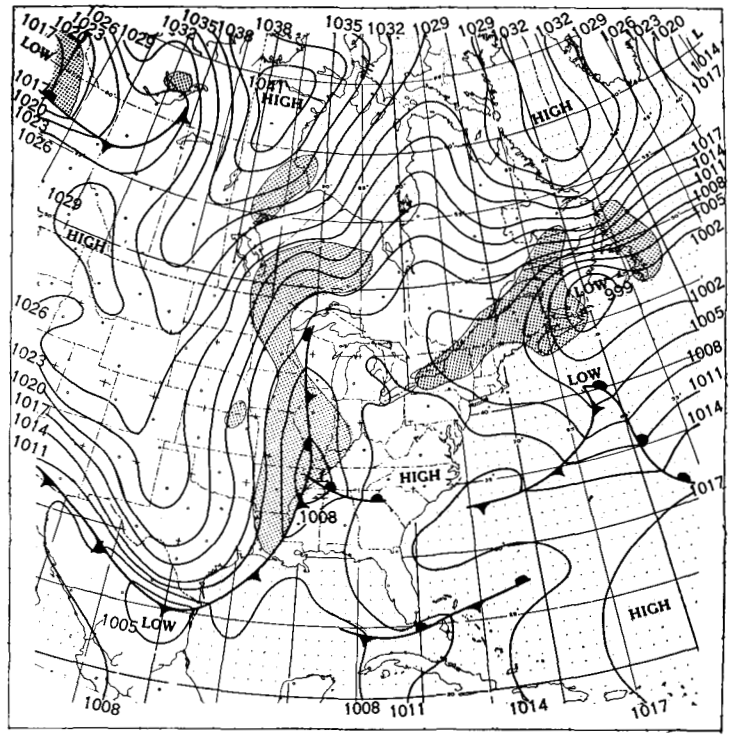

FIGURE 4.—Surface weather map for 1230 GMT, April 11, 1951.

The surface weather picture for 1230 GMT, April 11, 12 hours after figure 2, appears in figure 4. The flow of cold air across Wisconsin and Illinois had been halted, but the cold air continued to be carried deep into Texas and eastward across Arkansas and Louisiana.

The Low that had appeared in the southeastern corner of Oklahoma on the chart for 0030 GMT, April 11 (fig. 2),

as a weakness on an elongated trough, developed a stronger circulation with three closed isobars. A distinct southerly flow became established over Tennessee and Illinois in contrast to the light variable flow shown on the previous chart. The southerly winds east of the Low were intensified by the westward building of the Bermuda High. All of these factors added together brought an ever-increasing amount of warm air into the region just east of the low center.

Figure 5 shows the 12-hour pressure change chart for 1230 GMT April 11, 12 hours after the chart shown in figure 3. The 12-hour fall center of minus 9 mb. near Memphis, Tenn., was a strengthening of the weak center indicated over Arkansas in figure 3. The warm air moving northwestward aloft to the north of the Low joined the warm air from the Pacific over Montana. Thus the deep cold air from Canada was effectively cut off. The region of falls extended from Juneau, Alaska southeastward to Tampa, Fla.

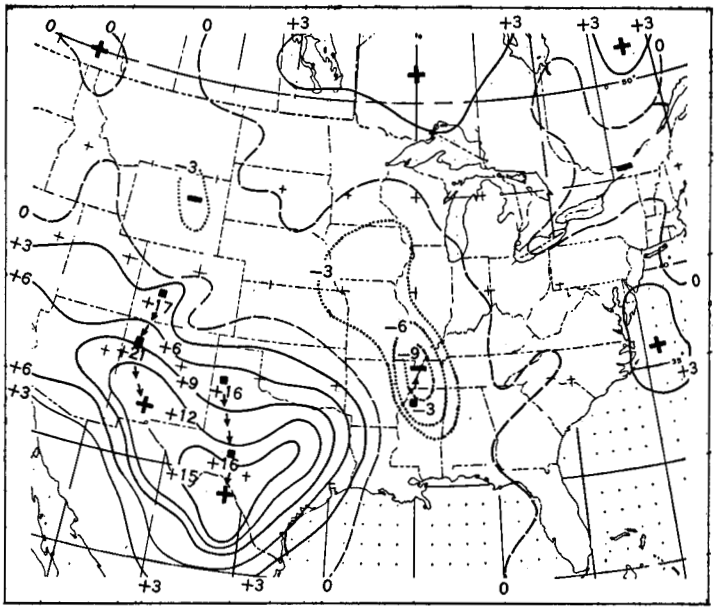

FIGURE 5.—12-hour sea level pressure change chart for 1230 GMT, April 11, 1951.

In support of the suggestion of northwestward flow of warm air, was the precipitation pattern over southern Ontario, Minnesota, and Iowa (fig. 4). Both the steady-type precipitation and the cloud types indicated stable air mass conditions.

The 500-mb. chart for 1500 GMT April 11 is given in figure 6. The trough over the Dakotas (fig. 1), had deepened sharply in the southern end to form closed circulation along the Nebraska-Kansas border. The tongue of cold air carried southward along the west side of the Low showed weakening.

The strong winds over Idaho and Utah in figure 1 spent some of their energy in deepening and accentuating the trough along the leading edge of the cold air (see fig. 6). This is in keeping with the ideas of Wobus and Norton "that a surge of more rapidly moving air parcels, on overtaking the trough line, contributes a portion of its kinetic energy toward sharpening the trough line" [2]. As the trough line sharpened, the winds from southern Texas to the Allegheny Mountains backed and increased in speed.

Associated with the sharpening trough line was the changing thermal structure at 500 mb. Isotherms along the west side of the upper trough became more nearly in phase with the contours while those in advance indicated stronger warming to the east. It should then be expected that the eastward motion of the trough would decelerate and might eventually retrograde [3]. A retrogression or stagnation of the upper trough often results in a similar condition at the surface.

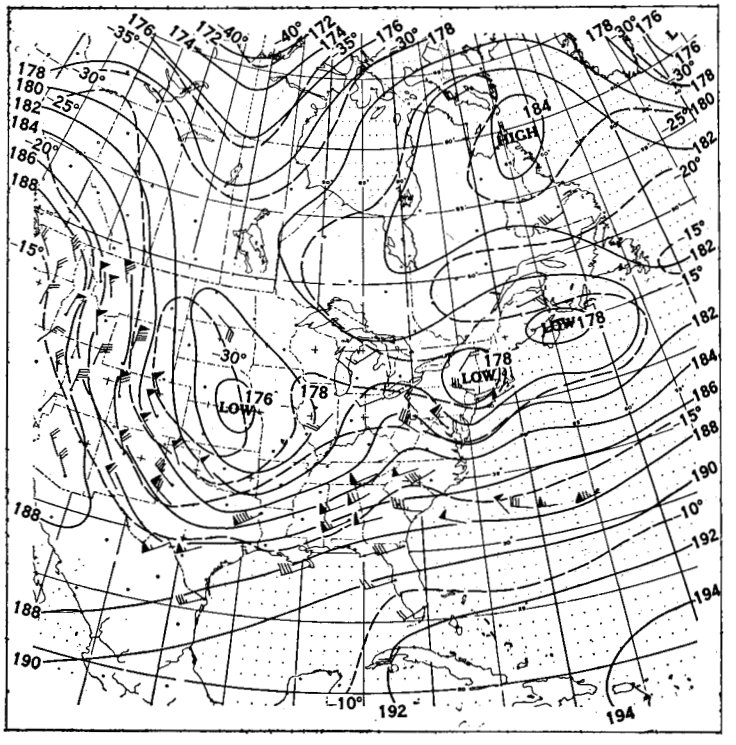

FIGURE 6.—500-mb. chart for 1500 GMT, April 11, 1951.

THE LOOP OVER ILLINOIS

During the 12-hour period from 1230 GMT April 11 (fig. 4) to 0030 GMT April 12 (fig. 7), the Low advanced

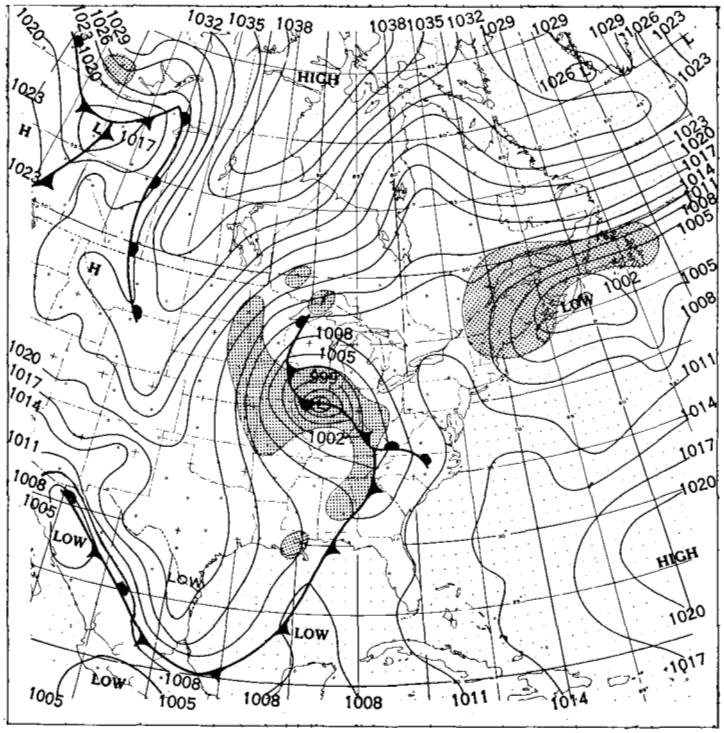

FIGURE 7.—Surface weather map for 0030 GMT, April 12, 1951.

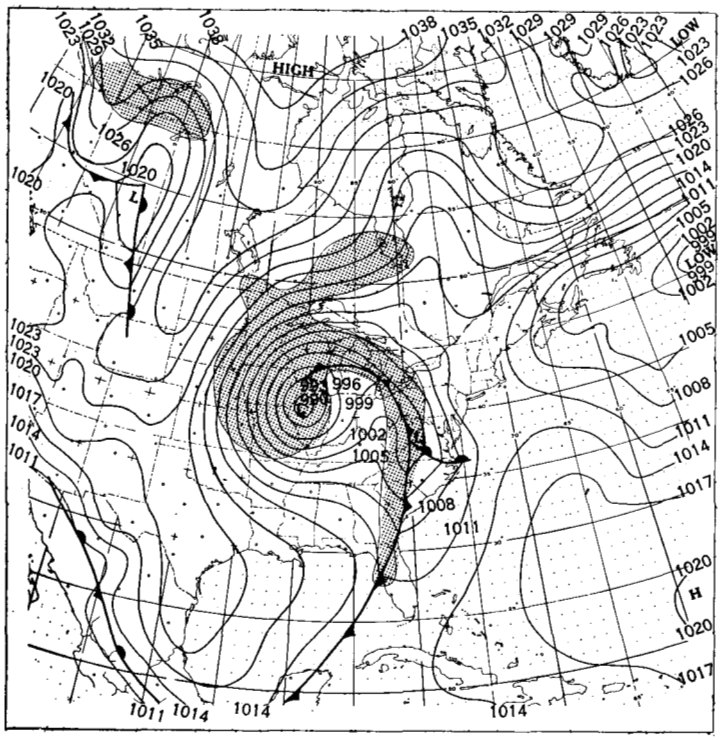

FIGURE 8.—Surface weather map for 1230 GMT, April 12, 1951.

rapidly north-northeastward and deepened 11 mb. From then on, however, there was a decided deceleration in the forward speed, and the surface Low (figs. 8 and 11) moved in a counterclockwise loop around a point about 20 miles northeast of Peoria, Ill. The radius of the loop was approximately 40 miles.

The exact physical processes that went on in the atmosphere to produce this phenomenon are not known. However, some interesting relationships between the surface and 500-mb. systems, bearing on the motion of the Low, will be discussed, and two raobs from Rantoul, Ill., will be examined for changes aloft associated with the surface pressure fall as the Low approached.

Figure 9 shows the track of the surface and 500-mb. centers. The positions for the surface Low at 3-hour intervals and the positions every 12 hours for the 500-mb. level plus the central pressure (mb.) or height (ft.) values in each case are shown. It will be noted that at 1500 GMT of the 11th, the horizontal distance between the surface Low and the 500-mb. Low was about 400 miles. However, at the same time that the surface system was moving northward, the 500-mb. center advanced eastward at 30 knots. At 0300 GMT of the 12th then, the two centers were only 90 miles apart with the axis tilted with increasing altitude toward the south.

By that time, there was a strong closely related cyclonic circulation from the surface to 500 mb. This action had the effect of rotating the tongues of warm and cold air around the almost vertical axis in a manner suggestive of a pinwheel. This is illustrated by the 500-mb. chart for 1500 GMT April 12 (fig. 10). Relative to the upper air center a surface center must move toward the warmer air. Usually the warm tongue assumes a northeast orientation ahead of the upper air trough. In this case, the strong cyclonic circulation carried the warm air to the northwest and finally to the southwest. The surface Low had to follow the movement of the warm tongue as long as the upper level cyclone maintained its intensity.

Finally the warm tongue lost its identity due to adiabatic cooling and mixing within the strong cyclonic circulation (fig. 12). When this happened the axis of the Low became vertical and the path of the surface center was dependent only upon the movement of the upper air cyclone. This phase of the loop is shown in figure 9 from 1500 GMT on the 12th to 0300 GMT on the 13th.

As long as the tilt of the axis of a thermally asymmetric Low has a flat slope with height the speed may be rapid. When the tilt of the axis becomes steep and a strong cyclonic circulation is developed at all levels the speed will decrease and the surface Low may perform a loop. This loop would be expected to be counterclockwise since the warm tongue must rotate cyclonically around the Low. When finally the system becomes a symmetrically

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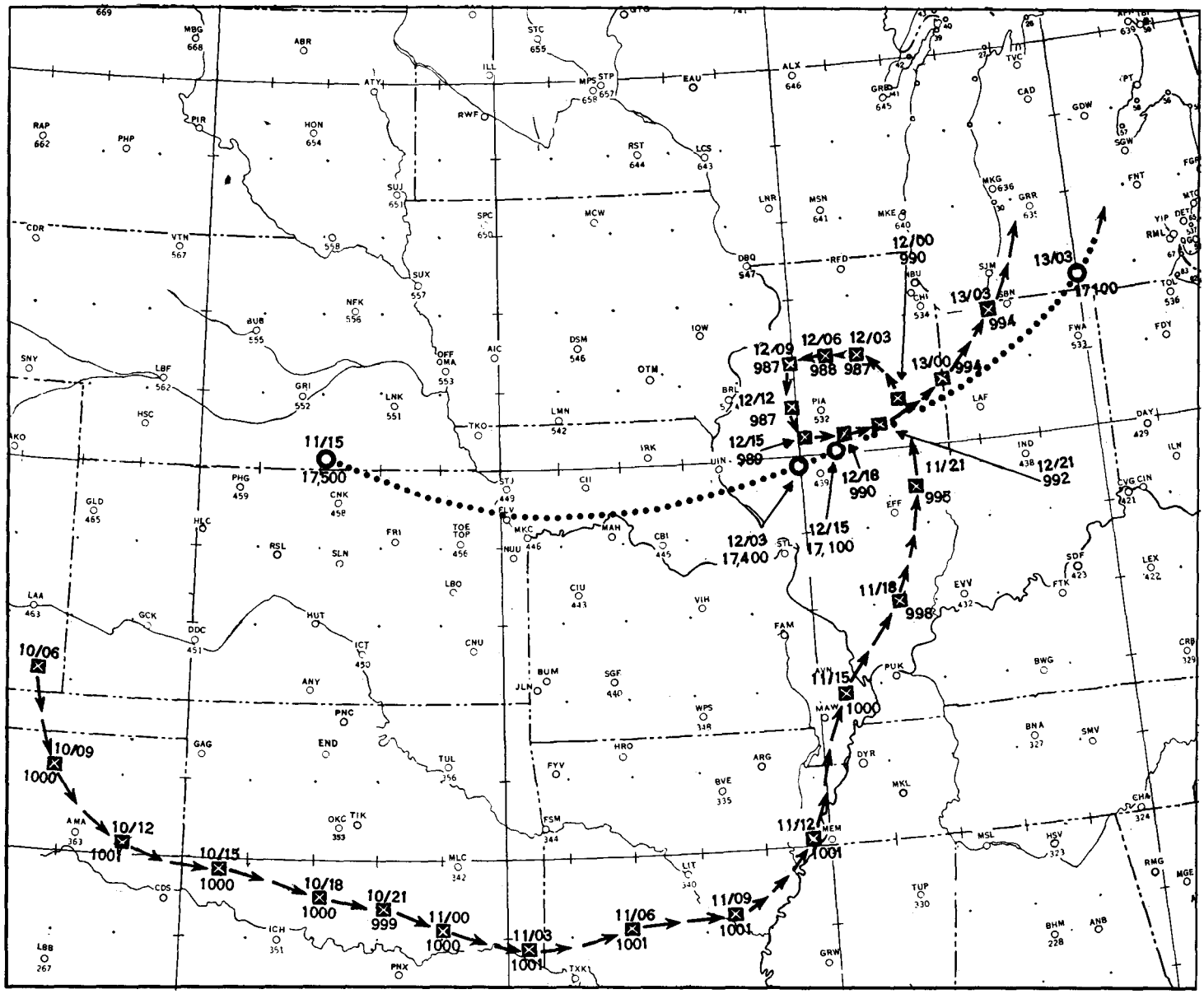

FIGURE 9.—Storm tracks. Small squares indicate 3-hour positions of the surface Low. Numbers above are date and time (GMT). Numbers below are central minimum pressure (mb.). Small circles are 12-hour positions of the 500-mb. Low. Numbers above are date and time (GMT). Numbers below are minimum heights (ft.) at center.

cold Low, the surface Low moves in the direction of the upper air system.

The raobs of 1500 GMT and 2100 GMT, on April 11 for Rantoul, Ill., are shown in figure 13. At 1500 GMT the sea level pressure was 1006.4 mb., with the storm about 230 miles south of the station. During the ensuing 6 hours, as the storm moved northward, the sea level pressure at Rantoul fell 10.8 mb. to 995.6 mb. At that time (2130 GMT April 11) the storm was approximately 60 miles south of the station.

Analysis of the two raobs indicated that there were several levels of slight warming and cooling up to 300 mb. Above 300 mb. the most marked warming was observed. The net warming in the layer from the surface to 500 mb., was counteracted by a cooling of equal magnitude of the layer from 500 mb. to 300 mb. There was enough warming between 300 mb. and 100 mb. to cause a stretching in that layer of 300 feet. The height of the 300-mb. surface fell 310 feet while that of the 100-mb. surface fell only 10 feet. This stretching corresponds to the fall of

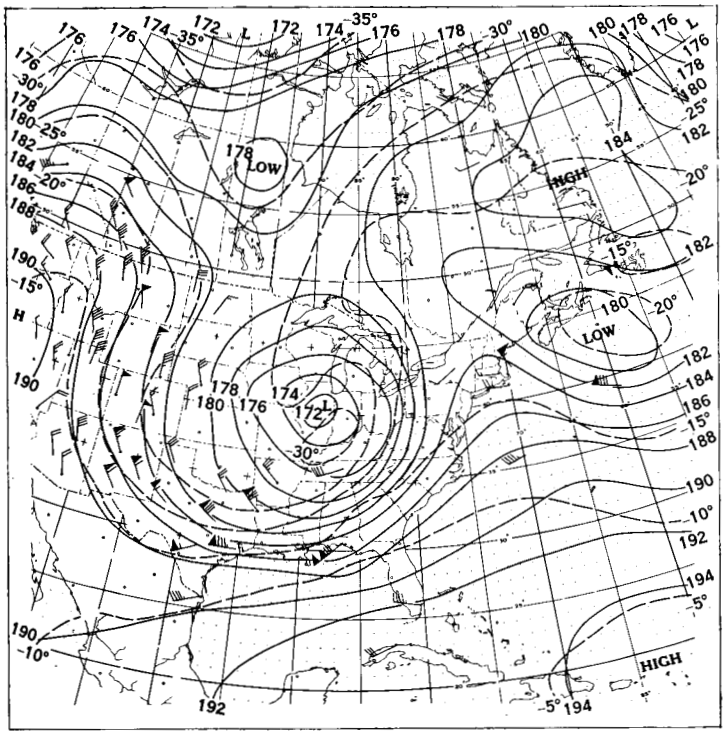

FIGURE 10.—500-mb. chart for 1500 GMT, April 12, 1951.

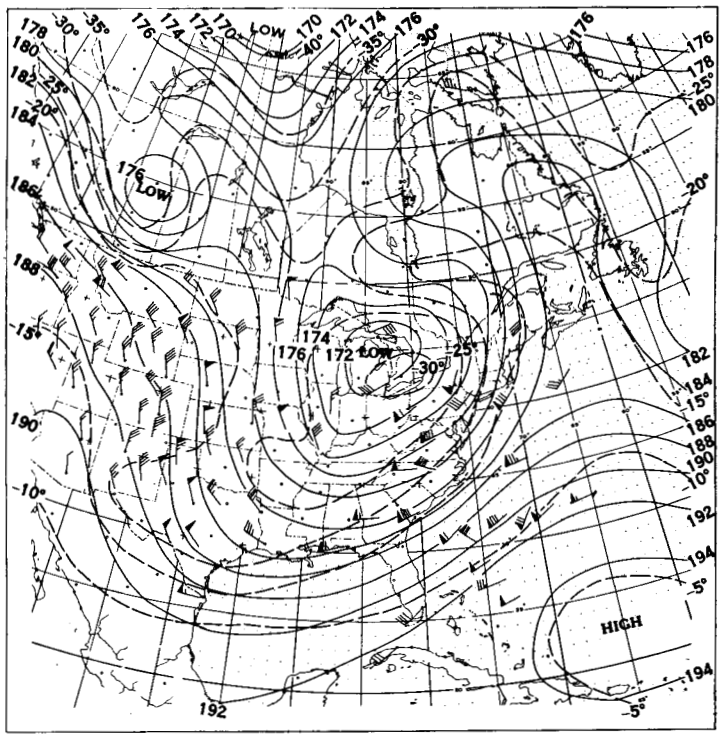

FIGURE 12.—500-mb. chart for 1500 GMT, April 13, 1951.

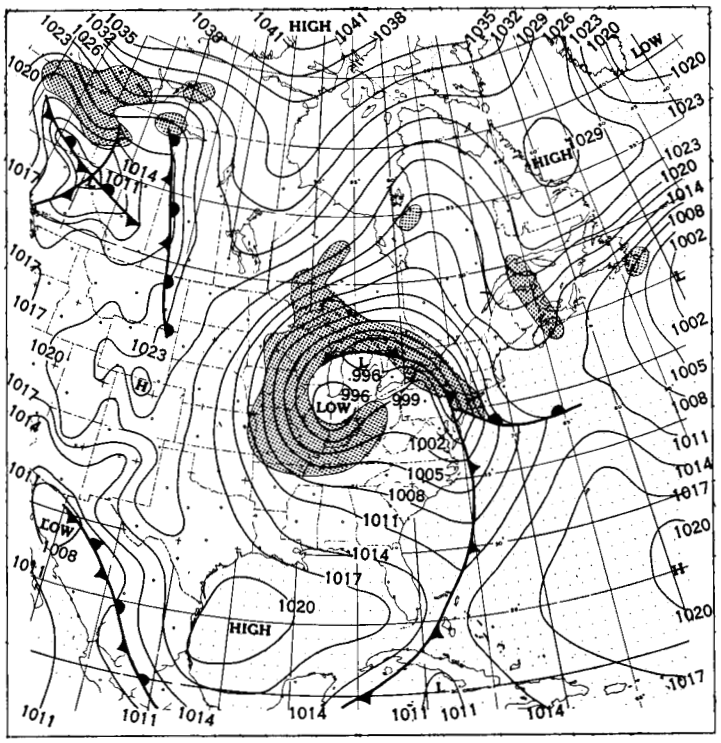

FIGURE 11.—Surface weather map for 0030 GMT, April 13, 1951.

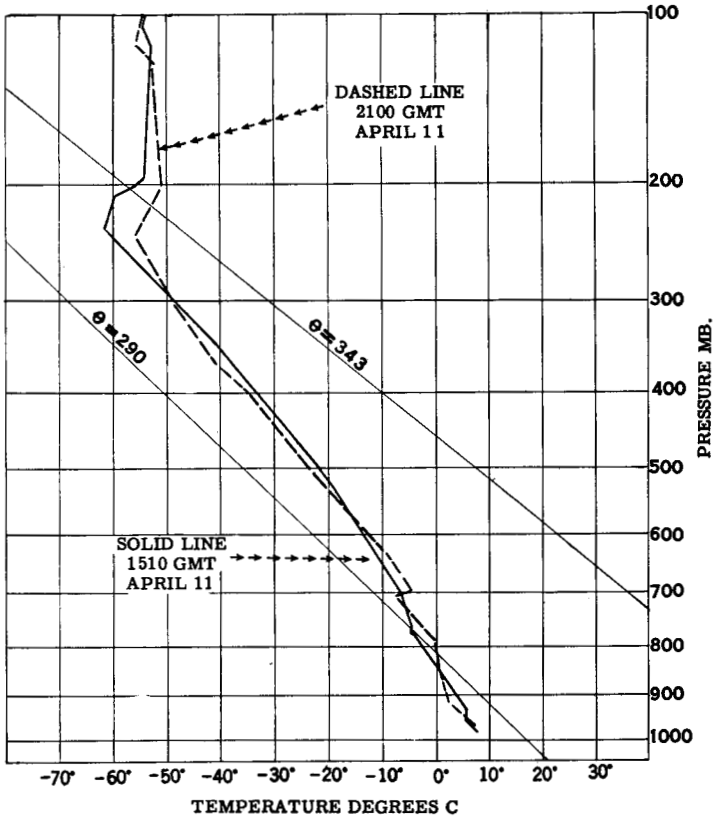

FIGURE 13.—Radiosonde observations of 1500 GMT and 2100 GMT, April 11, 1951, for Rantoul, Ill. plotted on a pseudoadiabatic diagram.

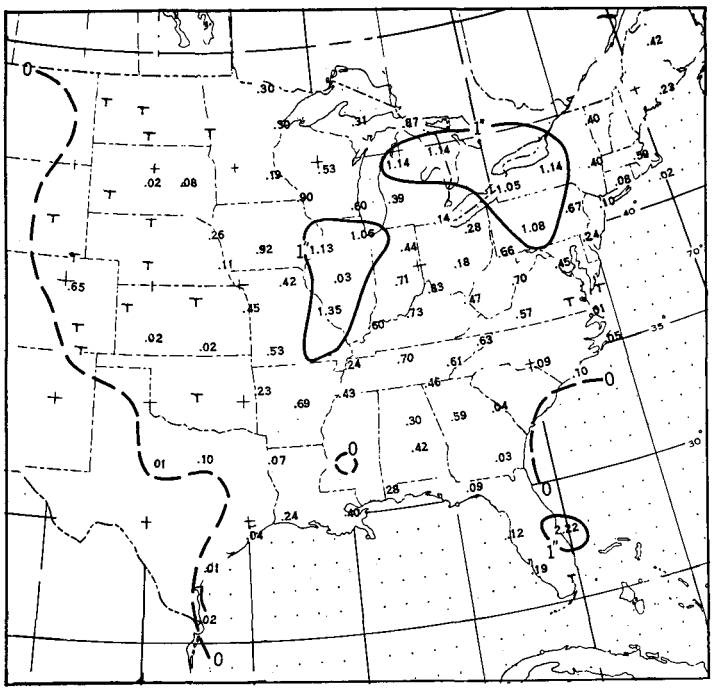

FIGURE 14.—Chart of precipitation amounts for the 48-hour period 0630 GMT, April 11 to 0630 GMT, April 13, 1951. Amounts are in inches.

310 feet of the 1000-mb. surface and a 10.8-mb. fall of the sea level pressure [4, 5].

PRECIPITATION

During the 2-day period 0630 GMT, April 11 to 0630 GMT, April 13, this deep Low produced an extensive area of precipitation (fig. 14). Nowhere was the precipitation very intense but almost all stations east of the Continental Divide recorded at least a trace of precipitation. A large area west of the storm received a late spring snowstorm with snow falling as far south as Springfield, Mo.

The area in excess of 1 inch for this period, covering nearly all of Illinois, was a result of the 24-hour stay of the storm over this area. The larger area over Pennsylvania, New York, and west into northern Michigan probably resulted from a fresh supply of moisture from the Atlantic and the newly developed storm.

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