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*Radan Scape Interpretation of  
Wind, Hail and Heavy Rain Storms  
Between May 27 and June 8, 1954*

*by*  
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*Issued by*  
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## Radar Scope Interpretations of Wind, Hail, and Heavy Rain Storms Between May 27 and June 8, 1954 \*

G. E. STOUT AND H. W. HISER \*\*

### ABSTRACT

Detailed field data and radar observations were studied for a period in which five out of eight storms produced considerable damage. It appears that in many cases the radar offers additional information so that it might be useful in short range forecasting. Certain limitations are noted. Additional data and research are needed before the complete utilization of radar in the detection of severe storms can be established.

### INTRODUCTION

CONSIDERABLE interest has developed recently in the potential use of radar in severe weather studies. The Navy, [1, 2] University of Florida [3] and others have recorded the precipitation pattern associated with hurricanes, and have shown the value of radar in providing data to improve and expedite storm warnings for the protection of property and human lives. Numerous other investigators and projects such as the Thunderstorm Project [4], American Airlines [5], and Dow Chemical Company [6] have pointed out the utility of radar in detecting severe weather conditions. In 1952, this Survey under contract with the Navy [7] presented some rules for making short range forecasts from radar echoes, and showed examples of types of echo patterns associated with severe squally winds in the Midwest.

During the period of May 27 to June 8, 1954, eight storms were recorded by the Survey's APS-15 radar at Champaign, Illinois. Five of these storms produced widespread damage. Three heavy rains, two severe hailstorms, and a small tornado occurred within a rather small area in northern Illinois.

Some of the interesting features of these five storms as observed by radar are presented, along with photos of hailstones, upper air charts, and isohyetal maps for the heaviest rainstorms. Field surveys were made to collect detailed data on the time of occurrence and the extent of rainfall, hailstorms, and tornadoes.

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### HEAVY RAINSTORM OF MAY 27

The first of the five storms was a warm air mass squall line that occurred during the evening of May 27. An intense squall line moved southeastward across northern Illinois and then became nearly stationary in an E-W position about 40 miles north of the radar station. This stationary squall line produced up to five inches of rain in less than two hours. Maximum rainfall rates of 5.6 inches per hour were reported by residents of the area.

At 1700 CST the squall line was oriented NE-SW, in northwestern Illinois. It slowly moved southeastward and rotated about its western end so as to assume the nearly E-W position shown on the 850-mb chart for 2100 CST (FIGURE 1). From 1900 to 2300 CST, the squall line was oriented nearly parallel to the winds above 10,000 feet and nearly perpendicular to the southerly winds which prevailed from the surface to 5000 feet. During this period the line remained almost stationary. The individual echoes in the line

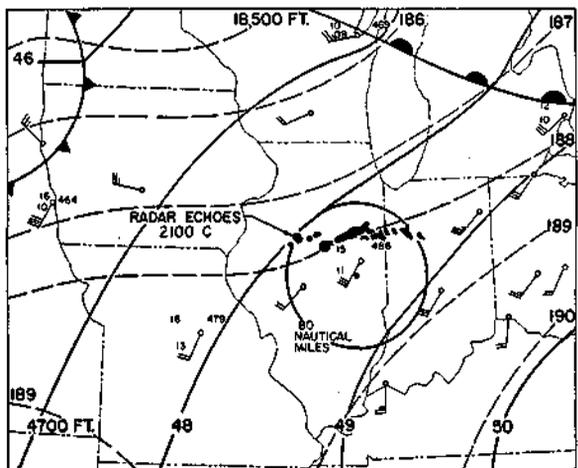


FIG. 1. 850-mb chart, 2100 CST, 27 May, 1954, Dashed lines indicate 500-mb contours.

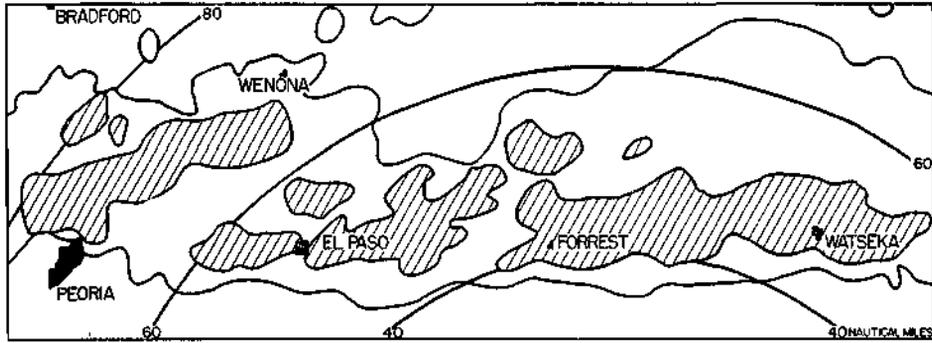


FIG. 2. Composite of echoes on full gain with heavier cores of 12 decibels reduced gain shown by hatched area 1900-2300 CST, 27 May, 1954.

moved from the west at about 30 miles per hour, indicating steering by the winds above 10,000 feet. The echoes continued forming at the western end of the line and dissipating as they moved to the east, thereby maintaining the line structure. By 2300 CST the entire line showed signs of dissipating and broke up rapidly.

The composite map (FIGURE 2) was constructed by superimposing the radar scope photos at 10-minute intervals onto a base map. The solid line represents the total extent of the echo pattern on maximum sensitivity (encompassing all rainfall) during the interval 1900-2300 CST. The hatched areas indicate the extent of the radar echo pattern on 12-decibels reduced sensitivity. These hatched areas represent the extent of the heavier rainfall during the period. Arcs of the 40-, 60-, and 80-mile range from the radar are included and indicate the scale of the map.

FIGURE 3 shows the isohyetal pattern for the 6-hour duration of the rainfall. The 4-hour period from 1900 to 2300 CST was selected for radar analysis because both the radar and reports of local residents in the affected area indicated that the amounts of rain which fell before and after the period 1900-2300 CST were insignificant.

Note the marked similarity between the radar and isohyetal patterns, FIGURES 2 AND 3.

Comparisons were made between the radar-indicated rainfall and the rainfall amounts obtained by the field survey. The radar-rainfall equation used was that of Wexler [8], corrected for 3-cm wavelength. Seven decibels were added to this equation by some investigators [9] to account for a discrepancy between measured and computed values upon which the radar-rainfall equation is based. The modified radar-rainfall equation indicated a maximum total of 1.2 inches of rain for the heaviest precipitation areas located 40-45 miles north and northeast of the radar station, and a maximum of 1.5 inches, 65-70 miles northwest of the radar station. These values fall somewhat short of the measured amounts of rainfall shown on the isohyetal map in FIGURE 3. Also, the rear of the storm was not completely shown by the radar. Both the low indicated rainfall and the lack of signal from the rear of the storm may have been the result of attenuation of the radar beam by heavy rainfall in the forward portions of the storm. However, knowledge of the synoptic situation, and experience with similar heavy lines of echoes that remained nearly stationary indicate

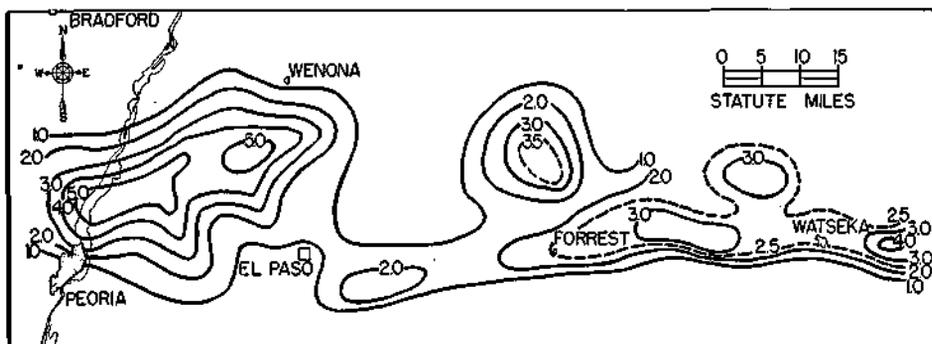


FIG. 3. Total precipitation for 1900-2300 CST storm 27 May, 1954.

that the rainfall would be much greater than that given by the modified radar-rainfall equation.

A small hailstorm was reported near the Illinois-Indiana line, but a careful search of the radar film failed to reveal any significant echo features. Lack of evidence may be due to the range from the radar, weakness of the hailstorm, or attenuation due to the hailstorm's position toward the rear of the echo, as seen from the radar station.

SQUALL LINE OF MAY 28

During the early afternoon of May 28, a NNE-SSW squall line moved eastward through the Peoria-Bloomington area in northern Illinois and dissipated about 45 miles north of the radar station. It reached a peak development about 1230 CST and had a total length of 80 miles. Nothing unusual was observed for this squall line; however, it added 1/2 to 1 1/2 inches of precipitation to the areas already inundated by the storm of the previous night.

HAIL, TORNADO, AND HEAVY RAIN OF MAY 28

A second squall line on May 28 produced extensive property damage and was the most severe one of the 11-day period. It was first detected in western Illinois during the late afternoon, after the earlier squall line had dissipated. It produced a severe hailstorm, a small tornado, and up to four inches of rain before it reached its maximum size at 1740 CST. The tornado developed as two echoes merged subsequent to the occurrence of the hailstorm.

This squall line was associated with the passage of a cold front which extended south-southwest from Chicago to Rantoul and then to the east of St. Louis at 1830 CST. The 1830 CST Weather

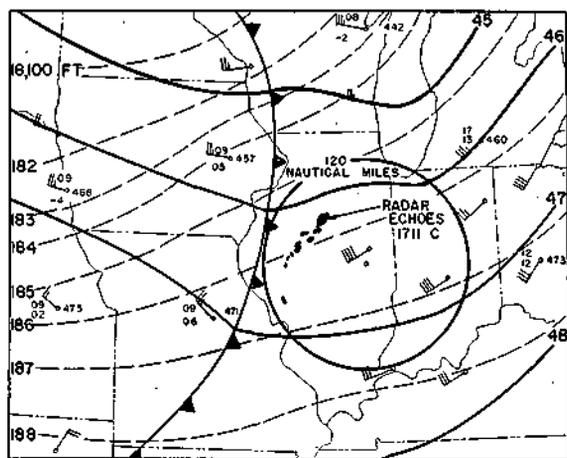


FIG. 4. 850-mb chart, 2100 CST, 28 May, 1954. Dashed lines are 500mb contours.

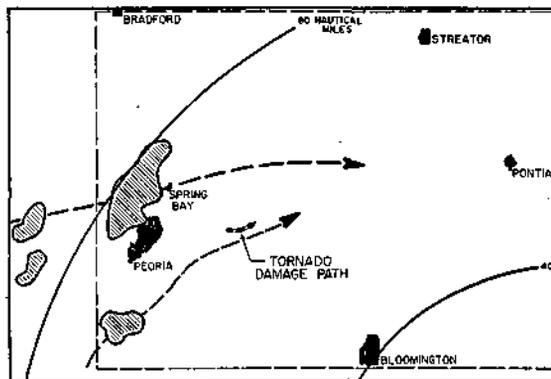


FIG. 5. Echoes at 1649 CST 28 May, 1954 and paths of centers of converging echoes. Dashed rectangle corresponds to precipitation map.

Bureau surface chart showed thunderstorms along the cold front from Wisconsin southwestward to Missouri. The line of radar echoes appears to have been nearly parallel to and advancing with the surface cold front. The jet stream at 30,000 feet was over southeastern Iowa and southern Wisconsin at 1500 CST. The 2100 CST, 850-mb chart (FIGURE 4) shows the position of the squall line at 1711 CST when the tornado developed. The flow pattern at higher levels was from the west-southwest up to at least 30,000 feet. The 500-mb contours (the dashed lines in FIGURE 4) are representative of the high level flow.

FIGURE 5 is a sectional plot of the echoes at 1649 CST. The paths of the centers of the two echoes which converged are shown by the dashed lines, and the tornado damage path is shown by the short heavy arrow. Each of the converging echoes had a speed of about 35 miles per hour. The arrow on the radar photograph at 1711 CST (FIGURE 6) shows a hook or V-shaped echo formed by the merger of the two echoes (FIGURE 5). An experienced radar operator on duty at the time, perceiving that a tornado might be present, notified other members of the staff. The tornado formed at about the time and place the edges of the echoes first touched. When the film was viewed in motion, a vortex motion was observable on the squall line where the tornado formed, both before and after the echoes merged. E. M. Brooks [10] has suggested that a micro cyclonic circulation is present during tornadoes.

The isohyetal pattern (FIGURE 7) shows that the greatest amount of rainfall, about four inches, occurred near Spring Bay, Ill., located northwest of the point where the tornado originated. Most of this rain fell within a 20-minute period beginning about 1700 CST. The severe hailstorm at Spring

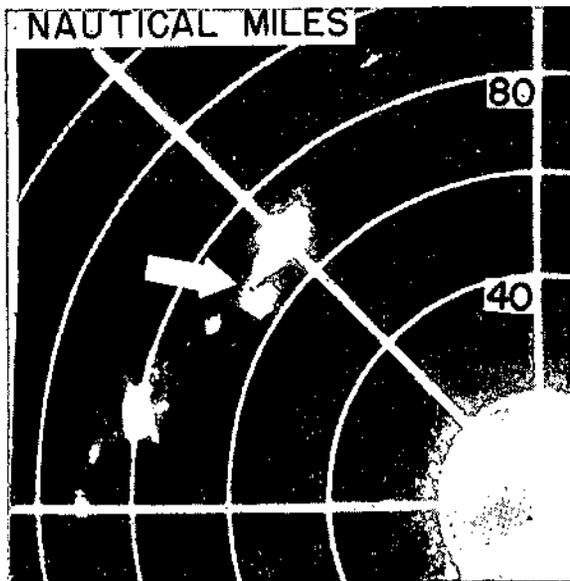


FIG. 6. PPI Photograph showing merging echoes 1711 CST, 28 May, 1954.

Bay accompanied the heavy burst of rain; FIGURE 8 shows some of the hailstones which were preserved in a deep freeze on a farm, located 1½ miles east of Spring Bay. These stones were picked up several minutes after they fell. At the time they were photographed (with a cigarette lighter for comparison) the major axes of the stones were about two inches in diameter. Reports by residents and observed property damage indicated that some hailstones nearly as large as baseballs fell in and around Spring Bay.

The hailstorm, produced by the larger of the two merging echoes (FIGURE 5) shortly before the time of the merger, occurred near the center

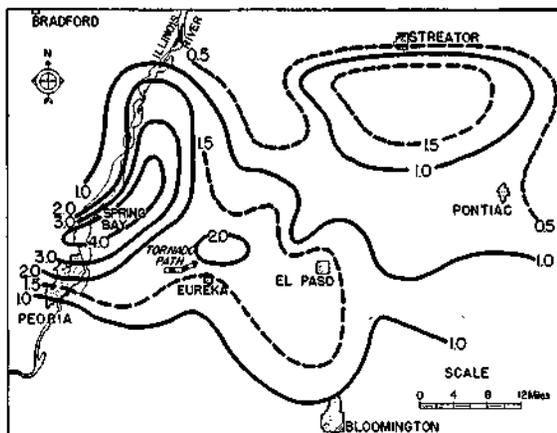


FIG. 7. Total precipitation for 1700-1900 CST storm, 28 May, 1954.

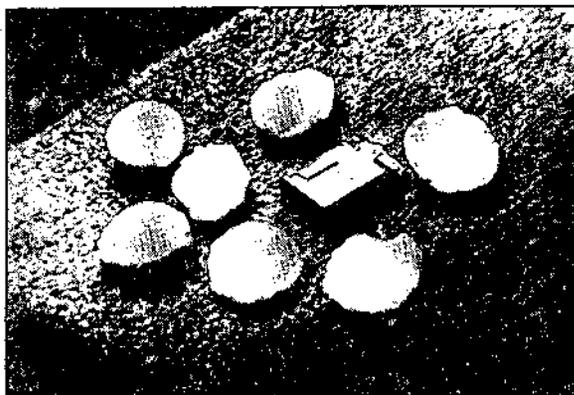


FIG. 8. Hailstones which fell 1½ miles east of Spring Bay about 1700 CST, 28 May, 1954.

of the larger echo and about 10 miles northwest of the point where the tornado first touched the ground. The intensity of the echo increased by 4 decibels during the time of the hailstorm; however, the precipitation was also heaviest at this time. The tornado developed to the southeast of the core of heavy rain during the latter part of the 20-minute period of intense precipitation.

Quantitative comparisons were made between the intensity of the echoes (FIGURE 5) and the rainfall amounts (FIGURE 7), using the Wexler radar equation [8] corrected for 3-cm wavelength plus 7 decibels [9]. The radar indicated that about 0.25 inch was the maximum total rainfall in the Spring Bay area. This is one-sixteenth of the measured maximum. The maximum rate of rainfall indicated was 0.75 inch per hour, which is about one-eighth of the observed rate at some points in the storm. Attenuation by the forward portion of the storm may have been sufficient to cause the low radar estimates. According to Langleben and Gunn [11], the attenuation at 3-cm wavelength by a water coated ice sphere is twice that for a water sphere of equal mass. The heavy hailstorm associated with this precipitation echo also may have been responsible for severe attenuation and the resulting poor rainfall estimate by the radar.

#### WINDSTORMS OF MAY 31

During the afternoon and evening of May 31 numerous tornado funnels were reported in northern and central Illinois. Apparently most of these did not reach the ground because tornado damage was not reported. However, some damaging hailstorms occurred. The heaviest damage reported seems to have been due to severe windstorms rather than tornadoes. Most of the wind damage

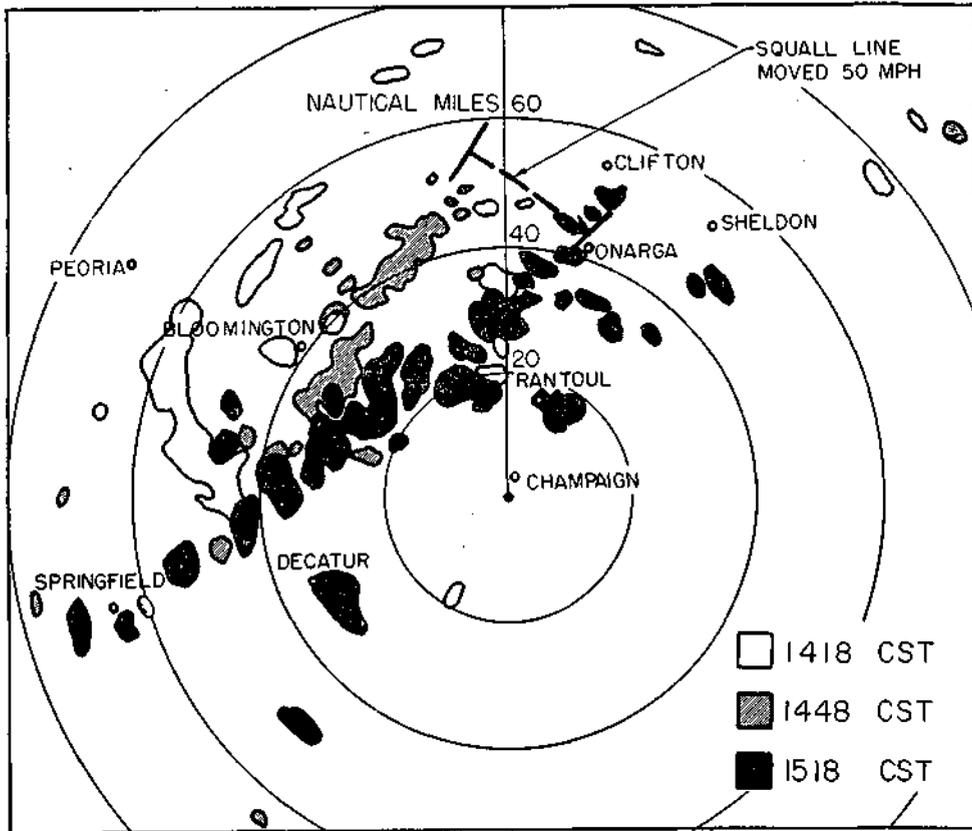


FIG. 9. Three PPI plots with gain slightly reduced (2 db), 31 May, 1954. Wind damage in the Clifton-Onarga-Sheldon area.

was associated with two squall lines, one during the afternoon and the other near midnight.

There appears to be nothing unusual about the shape of the echoes in either the afternoon or evening squall lines. However, in both cases the squall lines were intense and moved rapidly, especially at the northern ends where most of the wind damage occurred. This fast forward motion of the northern portions of the squall lines, combined with the speed of the peak gusts from the thunderstorms, could account for the destructive winds [4]. The northern portion of the afternoon squall line moved at about 50 miles per hour through the Clifton-Onarga-Sheldon area between 1445 and 1515 CST and produced considerable wind damage to trees and buildings, while the southern end of the line remained almost stationary (FIGURE 9). The radar echoes in the Clifton-Sheldon area were attenuated by intervening echoes south of Onarga and near Rantoul. At Clifton, 0.8 inch of rain fell in about five minutes. The heaviest wind damage oc-

curred around Clifton, while lighter damage occurred to the east around Sheldon.

FIGURE 10 shows the radar echoes existing at 2100 CST superimposed on the 2100 CST, 850-mb

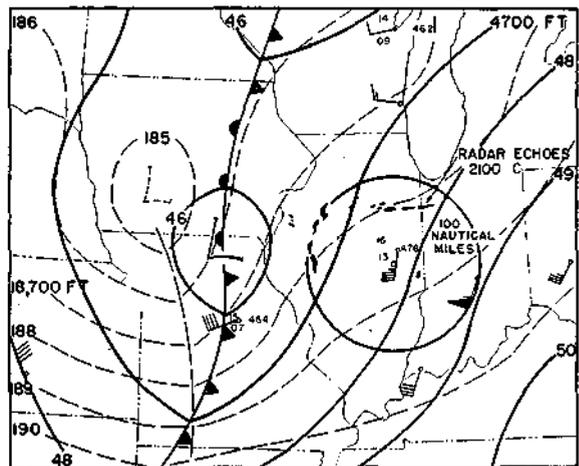


FIG. 10. 850-mb chart, 2100 CST, 31 May, 1954. Dashed lines are 500-mb contours.

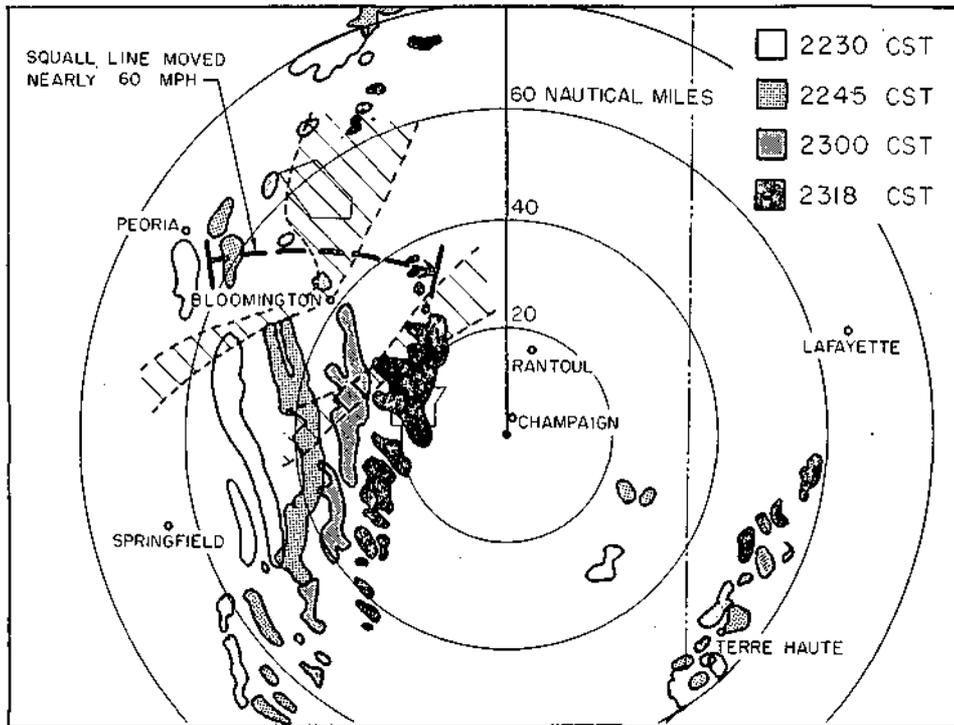


FIG. 11. Four PPI plots with gain slightly reduced (2 db), 31 May, 1954. Heaviest wind damage in hatched belts.

chart. The east-west line of echoes moved from the south, while the north-south line moved from the west. The individual echoes in the east-west line moved from the south at about 20 miles per hour, indicating steering by low level winds, while those in the north-south line moved from the southwest at about 30 miles per hour, indicating steering by winds above 10,000 ft. The echoes in the east-west line appeared to dissipate as they moved north. New echoes formed at the south end of the north-south line while the echoes at the north end dissipated. Several echoes located to the southeast of the radar are the remains of the afternoon squall line. By 2230 CST, the east-west line became almost extinct, while the north-south line remained well developed.

The radar plot for the period 2230 to 2318 CST, FIGURE 11, shows the squall line which uprooted trees, blew down power lines, unroofed buildings, and broke plate glass windows in Bloomington. The two lightly hatched belts on the radar plot indicate heavy power line damage, as reported by the Rural Electrification Association of Bloomington. Note that the general orientation of these wind damage belts corresponds to the direction of movement of the individual thunderstorms in the line, which is approximately the mean wind

direction for the layer from the surface to 20,000 feet (FIGURES 10 and 11).

After 2230 CST, the northern end of the north-south line began to move eastward at about 60 miles per hour, as shown on the radar echo plot between 2230 and 2318 CST (FIGURE 11), while the southern end moved at less than half that speed. As in the afternoon squall line, this rapid movement of the north end of the line, plus gusts from the thunderstorms, probably accounted for the destructive winds [4]. Gusts of 75-80 miles per hour were reported in Bloomington around 2300 CST.\*

#### HEAVY RAIN AND HAILSTORM OF JUNE 7-8

On June 7-8, three rainstorms and a hailstorm occurred in the Champaign area in a 24-hour period. These storms produced up to seven inches of precipitation as well as some severe hail damage. The first storm occurred shortly after 1500 CST on the 7th; the second, which was by far the most severe storm, occurred between 2000 and 2200 CST on the 7th and was accompanied by

\* This type of situation was observed again on August 18, 1954. The State Police radio tower at Springfield, Illinois was blown over by high winds which were associated with a pivoting squall line.

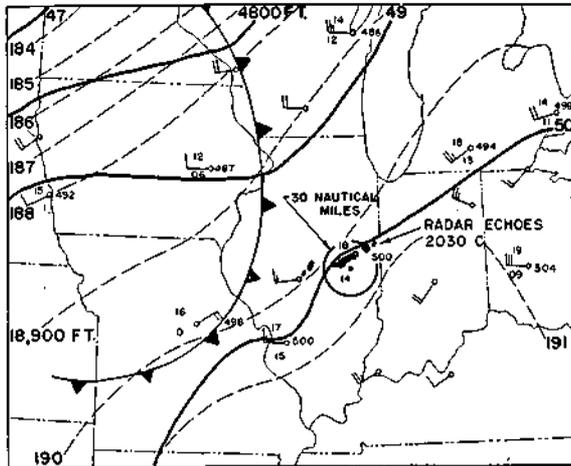


FIG. 12. 850-mb chart, 2100 CST, 7 June, 1954. Dashed lines are 500mb contours.

hail; while the third storm occurred between 1000 and 1100 CST on the 8th.

FIGURE 12 is a 2100 CST, 850-mb chart with the radar echoes as they appeared at 2030 CST plotted on it. The squall line was oriented approximately parallel to the flow from 5000 feet to 30,000 feet, and it slowly drifted southeastward at right angles to the flow. The individual echoes moved from the southwest with the upper flow at about 30 miles per hour. The southeastward drift of the squall line at about 15 miles per hour approximately equalled the speed of movement of the minor trough aloft which was associated with the cold front.

FIGURE 13 is a plot of the echoes at 2010 CST and at 2050 CST. The heaviest cores of precipitation on the plot at 2010 CST are indicated by the solid black areas which are receiver gain Step 5 (22 decibels below full gain). At 2050 CST, the echo is portrayed on reduced sensitivity in

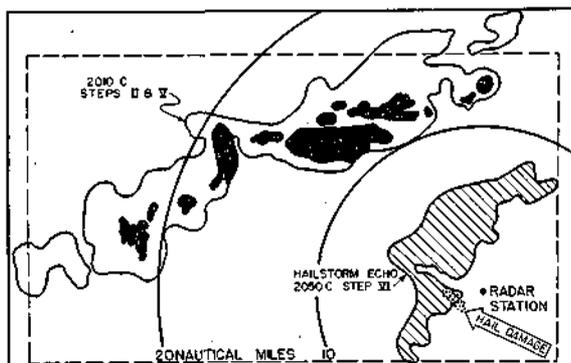


FIG. 13. PPI echoes on reduced gain, 7 June 1954. Dashed rectangle corresponds to precipitation map.

order to show the deep notch occurring in the echo at the time the storm was producing hail (Step 6 is a 34-decibel reduction in gain). The arrow in the radar scope photograph at 2024 CST (FIGURE 14) indicates a hook or wave starting to form in the squall line. A vortex motion is visible on the squall line at this point when the radar film is viewed in motion. This vortex motion becomes obliterated as the echo moves near the station. However, the portion of the squall line containing the vortex passed over the area where the hailstorm occurred, and may have played a role in the development of the hailstorm. Four other cases of such cyclonic vortices or waves on squall lines have been noted. All have been associated with some type of severe storm which usually produced destructive winds and hail.

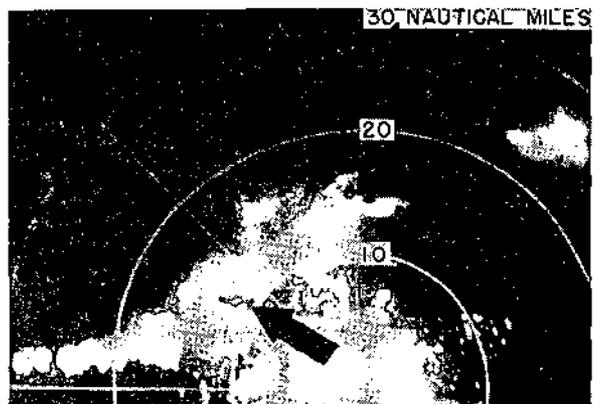


FIG. 14. PPI echo prior to hailstorm 2024 CST, 7 June, 1954. Arrow shows hook starting to form.

Probably the most interesting feature of the echoes on June 7 and 8 was the deep notch appearing in the echo on reduced gain from 2048 to 2053 CST on the 7th. This notch, as shown in the radar plot (FIGURE 13), was associated with the heavy hailstorm which moved south-southeast, just west of the radar station. The notch was probably associated with the hook or wave shown in FIGURE 14, which was observed on the line of echoes before it entered the radar ground pattern. The heaviest crop damage occurred near the position of the notch as shown at 2050 CST. Since the notch is open toward the radar station, it cannot be due to attenuation. Similar V-shaped notches or holes have been noted in other echoes associated with hail. Such were reported by United Airlines in their recent test of airborne radar [12]. Uncertainty as to the time the hail occurred made it impossible to say for certain whether the V-shaped notch occurred when the

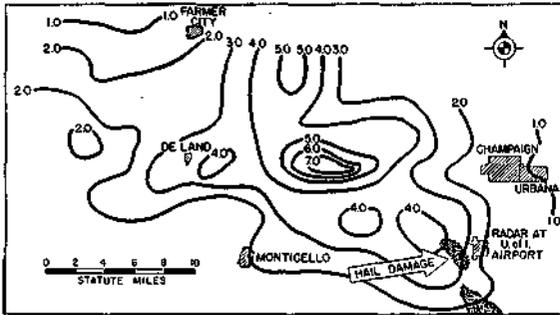


FIG. 15. Total precipitation for three storms of 7-8 June, 1954. Most precipitation occurred 1930-2100 CST, June 7.

hailstorm was in progress, or in association with the cloud area from which the hail had just fallen. If the hail had fallen by 2048 CST, then the notch might be the result of dissipation of a portion of the cloud accompanying the release of the hail.

FIGURE 15 is the isohyetal map showing total precipitation for the three storms, the greater portion of which occurred on the night of the 7th. The dashed rectangle in FIGURE 13 corresponds to the area of the isohyetal map in FIGURE 15. The areas of maximum hail damage are also shown on the isohyetal map (FIGURE 15).

The maximum intensity of the radar echo in this squall line, as it passed over the Goose Creek Raingage Network during the night of the 7th, was Step 5 (22 decibels below full gain). The raingage network encompasses most of the northwest quarter of the area shown on the isohyetal map (FIGURE 15). The radar indicated an average of 0.11 inch of rainfall for the 100 square mile raingage network, while the average as determined from 48 recording raingages was 1.55 inches. The presence of hail [11] in the cloud, plus high rainfall rates, may have been responsible for severe attenuation resulting in the poor rainfall estimate.

#### CONCLUSIONS

The five storms illustrate the importance of radar in detecting the precipitation patterns associated with severe storms. Significant echo features or patterns of motion were noted with every situation.

The presence of small scale vortex motion along a line of echoes seems to be particularly significant. It may be indicated by converging echoes, as on May 28; by the curling motion of

an appendage from a large echo; or, by a rotating motion about some point in the line, as in the June 7 case. In the case of the converging echoes, a cyclonic rotation was noted as the two echoes merged. Severe winds and/or hail have been associated with all cases of vortex motion observed to date. The vortex motion of the echoes cannot be easily detected on the PPI while the data are being collected, but is readily observed when scope photographs are later viewed in motion.

Pivoting squall lines appear to produce destructive winds, when the end opposite to the pivot point moves rapidly and has well-developed thunderstorms.

The presence of gaps or deep notches in heavy echoes associated with hailstorms appears to be significant, but no explanation of this feature can be given at present.

The least accurate rainfall estimates by the radar were associated with hailstorms. High attenuation values by wet ice spheres may have been a factor in these cases.

#### ACKNOWLEDGMENT

The authors wish to recognize the assistance of various staff members who collected field data or operated and calibrated the radar equipment.

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