REPORT OF INVESTIGATION No. 27 1955

STATE OF ILLINOIS
William G. Stratton, Governor

Department of Registration and Education
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THE OCTOBER 1954 STORM IN NORTHERN ILLINOIS

by

F. A. Huff, H. W. Hiser and G. E. Stout

State Water Survey Division
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Urbana, Illinois

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SUMMARY

In a three-day period, October 9-11,1954, an unusually heavy rainstorm produced a flood of record proportions over northern Illinois and northern Indiana. Most of the northern Illinois rain occurred on October 9 and 10, when rainfall in excess of one inch occurred over an area of 22,000 square miles. The average rainfall for this area for these two days was 3.95 inches, while amounts at the core of the storm exceeded 12 inches.

The greatest amount of rainfall occurred in the warm air in advance of a slow-moving cold front which became quasi-stationary north of the heavy storm area. Surface and upper air flow combined to produce moisture and stability conditions favorable for heavy thunderstorm precipitation in the warm air south of the front.

During a major portion of the storm period, radar observations of the storm were made from Champaign, Illinois, 100-150 miles south of the heavy rainfall area, with a high-powered 3-cra set (CPS-9). The radar-indicated storm pattern was compared with that obtained from recording raingage records in the storm area. Comparisons indicated that the CPS-9 is satisfactory for portraying the areal extent of light rainfall, where precipitation attenuation effects are small. In moderate to heavy rain, the set apparently does an excellent job of delineating the forward edge and the horizontal extent of an approaching storm in the absence of intervening precipitation. However, neither the depth nor the intensity of a storm is accurately portrayed by 3-cm radar.

ACKNOWLEDGMENTS

The radar data used in this report were collected in conjunction with a research project,entitled, "Research Study on Intensity of Surface Precipitation Using Radar Instrumentation," sponsored by the U. S. Army Signal Corps Engineering Laboratories under Contract DA-36-039 SO-42446.

The writers wish to acknowledge the assistance of M. Spock, Jr., who aided in the field survey following the storm. Douglas Jones, Eugene Mueller and Gerald Farnsworth, Survey staff members, were responsible for radar operations during the storm period.

INTRODUCTION

On October 9-11, 1954, an unusually heavy rainstorm occurred over northern Illinois and northern Indiana, resulting in a flood of record proportions. Although the storm was concentrated over the northern sections of Illinois and Indiana, heavy rains also fell over the southern sections of Michigan and Wisconsin, northwestern Ohio, eastern Iowa, and northeastern Missouri. This storm resulted in what was probably Chicago's most extensive flood on record. Total damage from the flood has been estimated to be approximately ten million dollars in Chicago and fifteen million dollars in suburban areas.[1]

This report is confined mainly to an analysis of conditions on October 9-10, since most of the rain occurred on these two days. Of the area subjected to heavy rains on the 9th and 10th, only the Chicago area and parts of northern Indiana received additional rain on the 11th. On the 9th and 10th, rainfall amounts in excess of one inch occurred over an area of 22,000 square miles in northern Illinois. The average rainfall for this area for the 2-day period was 3.95 inches, while amounts at the core of the storm exceeded 12 inches.

During a major portion of the October 9-10 storm period, observations of the storm were made by the State Water Survey's CPS-9 radar at Champaign, Illinois. On October 11-13, an extensive field survey of the flooded areas in northern Illinois west of Cook County was made by Water Survey personnel. The primary purpose of this report is to present a detailed analysis of the rainfall and radar data for northern Illinois, resulting from this storm. Supplementary discussions are presenting describing: 1) the synoptic weather conditions associated with the storm, and 2) wind storms on October 10.

SYNOPTIC WEATHER

Surface Weather Conditions

A detailed study of the synoptic weather conditions associated with the October 9-11 storm has been made by the U.S. Weather Bureau.[1] A brief summary of the Weather Bureau analysis follows. Reproductions of several of their maps are included.

A 1001 -mb low appeared in Alberta, Canada on the 1830 CST surface chart for October 7. This low moved eastward with a speed of 30 knots. At 2130 CST on October 9 (Figure 1), it was centered over northern Labrador and had deepened to 987 mb. From this cyclonic circulation, a cold front extended southwestward to just south of Chicago,* then westward to southern Nevada. The dashed lines in Figure 1 are thickness lines between 1000 and 700 mb. Since thickness lines are isotherms of mean virtual temperature, the thermal intensity of the front is clearly shown. Three hours later, the front had moved north of Chicago as a warm front, and throughout the remainder of the precipitation period on October 10, northern Illinois remained in the warm air.

From the same cyclonic circulation in Labrador, a second cold front extended through southern Canada, about 200 miles north of the front through the United States (Figure 1). By 0930 CST of the 10th, the eastern portion of this front had replaced the front over the United States, and the western portion had frontolized. This new cold front became quasi-stationary to the west of the belt of heaviest precipitation, where it remained until another cold front from the northwest reinforced it on the morning of October 13.

South of the front, the western nose of the Atlantic high pressure cell dominated the circulation over the Eastern States. A great quantity of warm air was brought northward by the southerly flow on the western periphery of this high.

A weak low pressure center which first appeared over central South Dakota late on October 8 drifted slowly southward, and at 2130 CST on the 9th, it was analyzed as a 1005-mb low center over western Kansas. This weak low moved northeastward, and at 2130 CST on the 10th (Figure 2), was centered about 170 miles northwest of Chicago and had deepened to 1001 mb. At this time, the surface chart showed a well-defined squall line from central lower Michigan to southeastern Kansas and a cold front in central Iowa. The low pressure center northwest of Chicago proceeded rapidly east-northeastward along the front and was centered near Caribou, Maine at 2130 CST on the 11th.

* "Due to the influence of precipitation and thunderstorms on the parameters used to locate fronts, the exact position of the segment of the front through northern Illinois at this time is difficult to determine."

Upper Air Conditions

"The 500-mb flow over North America during the period of heavy rains was predominantly zonal. The strong westerlies were responsible for the rapid movement of the surface low which originated over Alberta, Canada on October 7. At 2100 CST on October 9, a 500-mb high was centered over Alabama with a weak ridge extending north-northwestward to just east of International Falls, Minnesota (Figure 3). Farther west, this chart showed an area of weak cold advection eastward from a north-south trough extending from western Montana to southwestern Utah. This advection resulted in 300 to 500 ft of deepening in the next 24 hours as the ridge migrated eastward. At this time, the trough was well defined from southwestern Manitoba, Canada to southeastern Utah."[1] Twenty-four hours later, this trough had moved eastward into Minnesota, central Iowa, and northwestern Missouri.

Computations of precipitable water from the surface to the 400-mb level were made from the 2100 CST soundings for the period October 7-10, using Showalter's[2] method. Also, Showalter's stability indices[3] were computed for each of the soundings used in obtaining precipitable water. Figure 4 shows the isolines of precipitable water and stability indices at 2100 CST on October 9. Any positive value of +3° or less is considered likely to be associated with showers or thundershowers; thunderstorms have increasing probability as the index falls from +3 to -2°, and -3° or less may be indicative of severe thunderstorms. Note that the area in northern Illinois, northwestern Indiana, and southeastern Iowa is favored for heavy thunderstorm precipitation by the presence of a negative stability index and 1.75 inches of precipitable water. This favorable pattern moved east-northeastward and was centered over southern lower Michigan by 2100 CST on the 10th.

Further details on the October 9-11 synoptic weather conditions, including analysis of the low and high level jet streams, advection rates, and vorticity effects, may be obtained from the October 1954 issue of the Monthly Weather Review.[1]

RAINFALL ANALYSIS

Data for an analysis of the rainfall distribution on October 9-10 were collected from as many sources as could be found. In addition to data obtained from numerous Weather Bureau stations, about 100 measurements were obtained by Water Survey staff members in interviews with residents of the area, who owned raingages or made measurements by some other means. Figure 6 shows the distribution of rainfall measurements obtained for the October 9-10 period.

The rainfall analysis in this report has been restricted to the 36-hour period from 1200 CST, October 9 to 2400

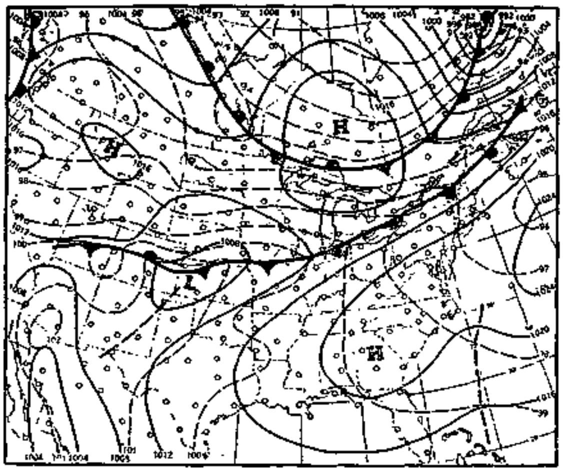

FIG. 1 - SURFACE CHART AT 2130 CST ON OCTOBER 9, 1954 AND 1000 MB. TO 700 MB. THICKNESS CONTOURS IN HUNDREDS OF FEET (DASHED) AT 2130 CST ON OCTOBER 9, 1954. SHADING SHOWS AREAS OF ACTIVE PRECIPITATION.

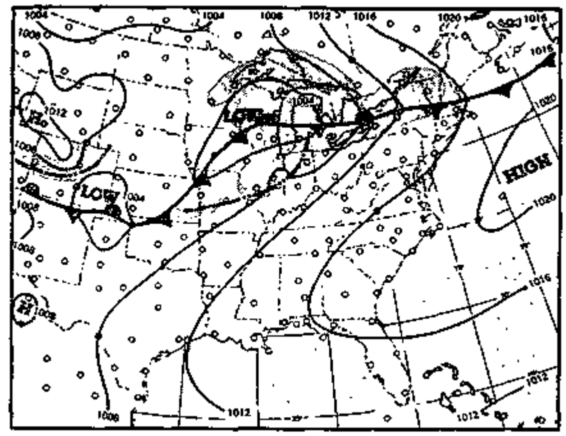

FIG. 2 - SURFACE CHART AT 2130 CST ON OCTOBER 10, 1954. NOTE THE SQUALL LINE EXTENDING FROM MICHIGAN THROUGH SOUTHERN ILLINOIS TO EASTERN KANSAS.

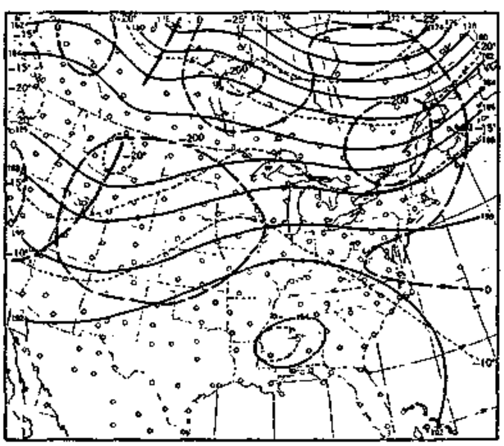

FIG. 3 - 500 MB. CHART AT 2100 CST ON OCTOBER 9, 1954. SOLID LINES ARE CONTOURS IN HUNDREDS OF GEOPOTENTIAL FEET. SHORT DASHED LINES ARE ISOTHERMS LABELED IN DEGREES CELSIUS. LONGER DASHED LINES DENOTE HEIGHT CHANGES IN FEET DURING THE PRECEDING 24 HOURS. THE TROUGH IS INDICATED BY THE BROAD DASHED LINE.

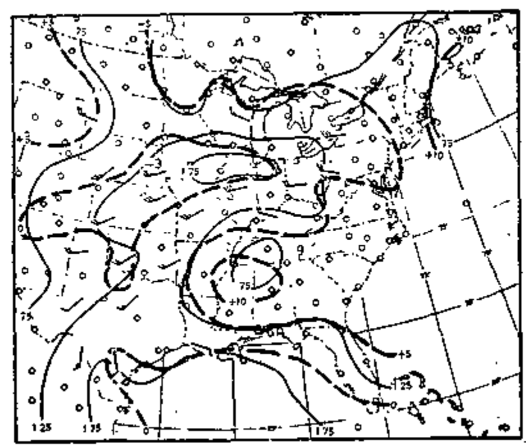

FIG. 4 – PRECIPITABLE WATER CHART AT 2100 CST ON OCTOBER 9 1954. PRECIPITABLE WATER IN THE CHICAGO AREA HAS INCREASED MARKEDLY AND SHOWALTER STABILITY INDICES ARE LOW. OMAHA HAS AN INDEX OF –3°C

CST, October 10. Except for the northeastern portion of the State, no appreciable rainfall occurred in Illinois on October 11. Additional precipitation, which occurred in northeastern Illinois on the 11th, is included on an isohyetal map for the October 9-11 period, covering Cook County and vicinity, which has been published by the Weather Bureau.[4]

Isohyetal Pattern

Figure 5 is an isohyetal map for northern Illinois for the October 9-10 period. The majority of the precipitation occurring in the 36-hour period covered by this isohyetal map took place from 1500 CST on the 9th to 1100 CST on the 10th,. and from 1400 CST to 2100 CST on the 10th.

Reference to Figure 5 shows that the storm axis or core was oriented approximately WNW-ESE across northern Illinois. The maximum amount recorded for the two-day period was 12.13 inches at Waterman in DeKalb County. Within the secondary storm core in northwestern Illinois, a maximum of 11.40 inches was recorded at Sterling in Whiteside County.

Storm Intensity

Figure 7 is a copy of a recording raingage trace at Aurora, about 35 miles west of Chicago in Kane County, where the rainfall total was 10.56 inches. The break shown on the trace between 0500 CST and 0900 CST on the 10th resulted from the pen arm running off the scale of the original raingage chart. The other break shown between 2000 CST, 10th and 1300 CST, 11th was made as a matter of convenience in reproducing the chart, since the trace was of little interest during this period due to the very light rainfall. Aurora is located to the southeast of the 12-inch core indicated on the isohyetal map in Figure 6. On the raingage trace, note that the storm was most intense between 2100 CST and 2200 CST on the 9th, and between 1500 CST and 1600 CST on the 10th. In general, these were the two periods in which the storm was most intense over northern Illinois.

While rainfall intensities observed in the October 9-10 storm were heavy, they were not unusual for thunderstorm situations. Heavier rates than those observed in this storm are frequently recorded in summer thunderstorms in Illinois. The outstanding characteristic of this particular storm, which resulted in the unusually heavy storm totals, was the long duration of the storm in which moderate to heavy thunderstorm rates prevailed.

Area-Depth Analysis

Figure 8 is an area-depth curve for the area enclosed by the 1-inch isohyetin Figure 5. For this area of 22,000 square miles, the average rainfall was 3.95 inches for the October 9-10 period. Within this overall area, the curve shows an average of 6-20 inches for 10,000 square miles, 7.80 inches for 5,000 square miles, 9.90 inchesfor 1,000 square miles and 11.80 inches for 100 square miles.

Comparative Magnitude of Storm

The magnitude of the storm is indicated by relating it to Weather Bureau records at Chicago, located to the east of the storm core (Figure 5). An official 5.63 inches of rain in 24 hours on October 9-10 was surpassed only by 6.19 inches on August 2-3, 1885, and greatly exceeded the next highest 24-hour amount on record, 4.34 inches, on August 11-12, 1908. The 6.72 inches in 48 hours on October 9-11 set a new record for a 48-hour period.[4] A 36-hour amount of 12.13 inches was measured 50 to 60 miles west of Chicago at Waterman (Figure 5), which is not an official Weather Bureau station. Several observations exceeding 11 inches were obtained in the storm.

Further evidence of the severity of this storm may be found by reference to the maximum 24 -hour precipitation records compiled by the U. S. Weather Bureau.[5] Their compilation for Illinois is based upon 145 stations having 10 or more years of record. This compilation shows that the three heaviest 24-hour amounts officially recorded in Illinois are 10.25 inches at LaHarpe in Hancock County on June 10, 1905, 9.15 inches at Galva in Henry County on August 20, 1924, and 9.08 inches at Marengo in McHenry County on September 7, 1894. Referring again to the Aurora raingage trace in Figure 7, it is seen that the total for the first 24 hours of this storm was 9.75 inches, which is exceeded only by the 10.25 inches at LaHarpe. A 3-inch non-recording gage located at the DeKalb Hybrid Com Company in Waterman, Illinois showed 11.45 inches in 24 hours, exceeding the Weather Bureau's published record for Illinois by 1.20 inches.

Table 1 shows comparative area-depth data for the October 9-10 storm and three previous record storms in Illinois. These include two recent storms investigated by the Water Survey: the July 8,1951 storm in North Central Illinois,[6] and the July 18-19,1952 storm in Rockford and vicinity.[7] The third storm occurred on June 10,1905 over western Illinois and southeastern Iowa and has been analyzed by the Corps of Engineers.[8]

TABLE I

COMPARATIVE AREA-DEPTH DATA

Area (Sq. Mi.)	June 1905	July 1951	July 1952	Oct. 1954
10	12.0	12.4	10.7	----
100	11.5	10.0	8.0	11.8
1000	10.0	6.7		9.9
2000	9.1	5.3		9.1
5000	7.3			7.8
10,000	5.6			6.2
20,000	3.9			4.3

Magnitude of Flood

A detailed report on stream flow and flood conditions in the October 9-11 storm has been prepared by the U.S. Geological Survey.[9] Their report contains a general de-

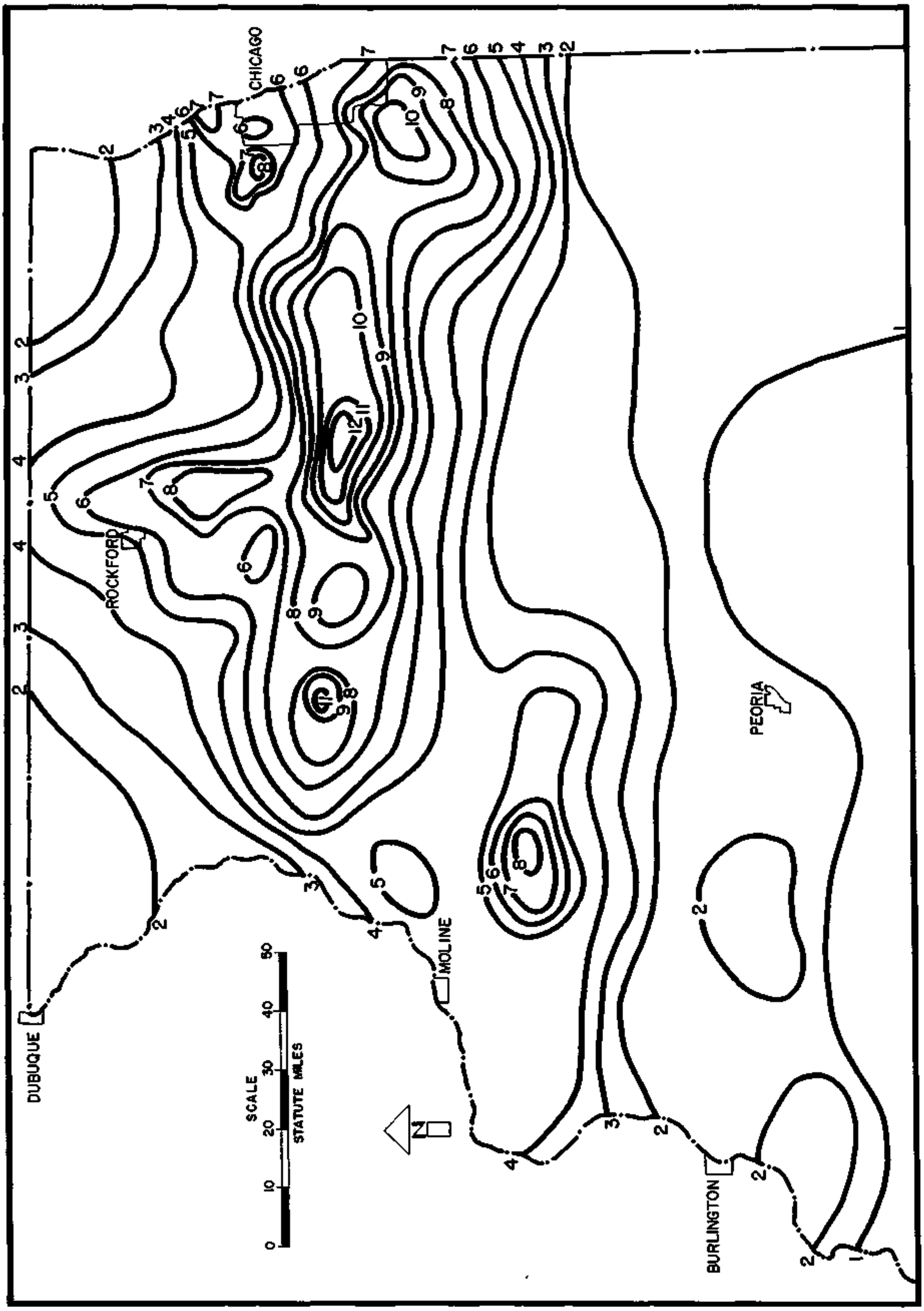

FIG. 5 - TOTAL STORM RAINFALL 9-10 OCTOBER 1954.

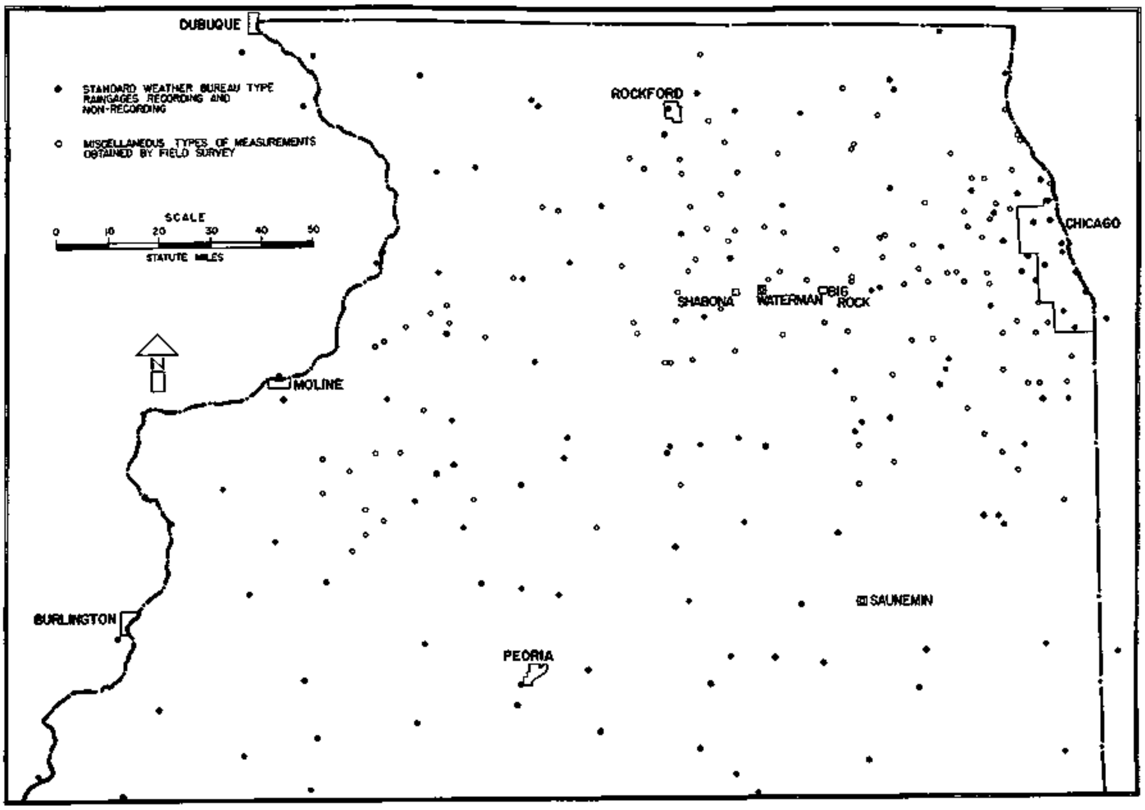

FIG. 6 - DISTRIBUTION OF RAINFALL MEASUREMENTS OCTOBER 9-10, 1954.

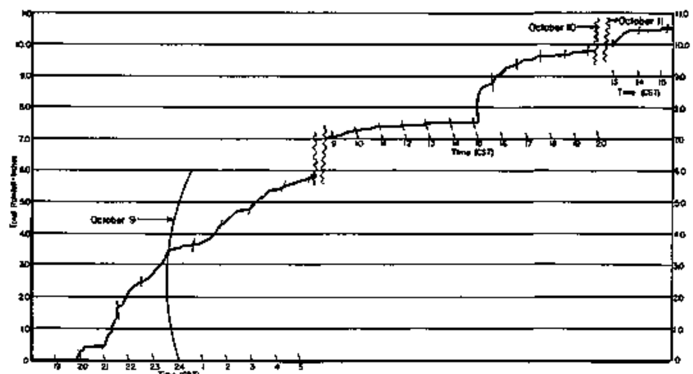

FIG. 7 - COPY OF RAINGAGE TRACE AT AURORA, ILLINOIS, 9-11 OCTOBER 1954.
(COURTESY OF W. PFEIFER OF THE SEWAGE TREATMENT PLANT)

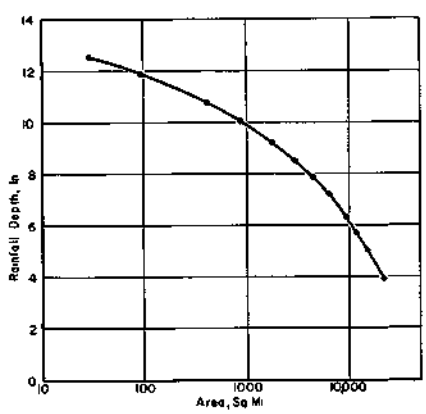

FIG. 8 - AREA-DEPTH CURVE FOR NORTHERN ILLINOIS.

scription of the flood; a summary of flood damage; stages and discharges at stream gaging stations in the area; and a discussion of flood frequency in the storm area, in which the October storm is compared with past storms.

Stream flow records are presented for 36 stations in Illinois and 14 stations in Indiana. For 24 gaging stations in northeastern Illinois, the crest discharge exceeded previous record maxima. The reader is referred to the above report for further information on the magnitude of the flood.

Figure 9 illustrates flood conditions at two towns near the center of the town. The upper photograph is an aerial view of Millington, about 50 miles WSW of Chicago and a few miles southeast of the 12-inch core shown on the isohyetal map in Figure 5. The lower photograph was taken at Lockport, about 20 miles southwest of Chicago, where over eight inches of rain was recorded.

RADAR PRESENTATION OF STORM

Radar observations of the storm were made with a CPS-9 radar, a high-powered 3-cm set, specifically designed for the detection, tracking and general meteorological analysis of storms. The Water Survey's set is equipped with an automatic gain reduction device which reduces the receiver gain with each antenna sweep, in order to delineate rainfall intensities within a storm. As the receiver sensitivity is reduced, heavier rainfall rates are required to produce a detectable signal, which is presented on the plan position indicator (PPI) as a white irregular area, known as the radar echo. Photographs of the PPI are made with a 35-mm camera for each antenna revolution.

Receiver gain reductions in this report are referred to as steps. Step 1 is full gain or maximum sensitivity and shows all portions of the storm from which a signal is received. Successive steps represent increasing gain reductions (decreasing sensitivity) and, therefore, heavier rainfall intensity. The amount of these reductions is usually expressed in decibels. For the October 9-10 storm, steps 3 and 5 represent gain reductions of 16 decibels and 26 decibels, respectively. A decibel is a unit of power level difference, measured by 10 log W_2/W_1, where W_2 is a power controlled by W_1. The gain step values may be expressed in terms of rainfall intensity by use of the general equation:

$$\log \frac{P_r R^2}{P_t} = a \log I - K \qquad (1)$$

where P_r and P_t are power received and power transmitted, R is range to the target, I is rainfall intensity, and K and a are constants depending on several radar parameters and on the relation between rainfall rate and radar reflectivity. Wexler[10] has derived the following relation between radar reflectivity (Z) and rainfall intensity (I) for 3-cm radar:

$$Z = 323\ I^{1.53} \qquad (2)$$

Austin and Williams[11] have found that the radar received power (P_r) from rainfall averages about 7 decibels lower than predicted by theory. Incorporating the Wexler Z-I relation, the Austin and Williams "theory" error, and the CPS-9 parameters into equation 1 gives:

$$\log \frac{P_r R^2}{P_t} = 1.53 \log I - 9.95 \qquad (3)$$

Radar-indicated values of rainfall rates for various gain steps at several ranges are shown in Table 2. During the major portion of the October 9-10 period, the storm core was 125 to 135 nautical miles from the radar station.

TABLE 2

RADAR-INDICATED RAINFALL RATES

Gain Step	Rainfall Rate (in/hr) at Given Range (Naut. Miles) 50	100	150	200
1	.003	.009	.015	.021
3	.06	.14	.22	.34
5	.20	.50	.84	1.25
7	.59	1.45	2.45	3.50
9	1.50	3.60	5.90	8.70

At wavelengths less than about seven centimeters, absorption and scattering cause rain to become an attenuating medium, resulting in a loss in the power reflected back to the radar from a storm (P_r in equation 1). From equation 1, it is evident that this will result in underestimates of rainfall intensity by short wavelength radars, such as the CPS-9. The loss in radar received power is proportional to the depth of the storm and the rainfall intensity within the storm. In the following pages, frequent reference will be made to precipitation attenuation effects during the October 9-10 storm.

Development of Echoes

The Water Survey's CPS-9 radar first detected echoes shortly before 1230 CST on October 9. These echoes were weak, being distinguishable only on full gain (Step 1). They were located in northeastern Illinois and northwestern Indiana, 25 to 70 nautical miles northeast of the radar station. By 1430 CST (Figure 10), a tracing of the radar scope photographs shows that there were weak echoes extending from north central Illinois to northwestern Indiana. The CPS-9 radar is located at CMI in Figure 10. Again, these echoes were very light and probably represented very light rain or possibly clouds approaching the precipitation stage.

By 1530 CST (Figure 10), the CPS-9 was showing a scattered line of echoes extending WNW to ESE across northern Illinois and northern Indiana. At this time, there were indications that the storm was intensifying, as shown by the presence of small areas of gain step 5 in

MILLINGTON

LOCKPORT

FIG. 9 - FLOOD CONDITIONS AT MILLINGTON, LOCKPORT

northeastern Illinois and northern Indiana. At 1630 CST, the echoes had increased appreciably in extent and intensity, the heaviest intensities being indicated over northeastern Illinois. The line of echoes was in approximately the same position as at 1530 CST.

By 1730 CST (Figure 11), the initial echo line had moved northeastward, extending southeastward from northwestern Illinois through Chicago into east central Indiana. An area of scattered echoes, some of which were distinguishable on step 5, had developed over northern Illinois to the west-southwest of Chicago. No radical changes had taken place in the pattern at 1830 CST (Figure 11) step 5 echoes still showing in the Chicago area and northeastern Illinois.

At 1830 CST, a cold front extended west southwest from central lower Michigan through northern Illinois just south of Chicago into southern Iowa. Most of the echo activity observed by the CPS-9 apparently occurred along, and to the south of, this cold front. However, very light rain showers were reported at 1830 CST in the cold air to the north of the front in southern Wisconsin, at Madison and Lone Rock. This precipitation was not detected by the CPS-9 at Champaign, apparently due to range and precipitation attenuation. The CPS-9 radar was turned off shortly after 1830 CST at the close of the work day, and turned on again at 2020 CST to check on the approach of rainfall toward the Water Survey's special research raingage networks in central Illinois.

At 2030 CST (Figure 11), a long line of echoes was extending from western Ohio through northern Indiana to Chicago and then westward to east central Iowa. The most extensive areas on steps 3 and 5 were located over northern Indiana.

Peak Intensity of Storm on October 9

The storm of October 9 reached a peak intensity around 2100 CST, according to raingage records and to interviews with area residents during the field survey. The radar echo plot for this time is shown in Figure 12. Total echo extent was about the same as at 2030 CST; however, there was a noticeable increase in intensity over northern Illinois as shown by the increase in area on steps 3 and 5. Similarly at 2130 CST there was little change in the overall extent and general pattern of the echoes, but there were indications of an appreciable increase in intensity in northern Indiana and northwest Illinois, as indicated by the growth in the step 5 echoes. By 2220 CST (Figure 12), the line of echoes across northern Indiana and northern Illinois showed a decided decrease in intensity, although the total echo coverage (Step 1) was still extensive. The CPS-9 radarwas turned off for the night at 2230 CST.

Development of Intense Storm on October 10

The first illustration in Figure 13 shows the radar presentation of the storm at 0837 CST on the 10th. The most intense portions of the storm appeared to be confined to north central and northeastern Illinois. The orientation had changed slightly from the previous evening, when it had a WNW to ESE orientation. Illustration 2 in Figure 13 shows the echo pattern as portrayed by the CPS-9 at 1430 CST on the 10th. The orientation and lateral extent of the storm was similar to that at 0837 CST (6 hours previous), but the depth of storm was much less. Since 3-cm wavelength radars are subject to precipitation attenuation, it is difficult to determine from the CPS-9 presentation whether this decrease in depth was real or due to masking out of the rear part of the storm by increasing intensities on the forward side of the storm.

The two-day storm reached a second peak in intensity at about 1500 CST on the 10th. At this time, the echo line had a wavy character as shown in Figure 13, with the most intense echo activity appearing over northern Illinois. By 1530 CST (Figure 14), the overall storm extent had changed very little, but there appeared to be a decrease in intensity, as shown by the decreased area of detectability on step 5.

At 1600 CST (Figure 14), the echo line still showed a wavy pattern. Intensification of the storm over northern Illinois was indicated by the appreciable increase in the areal extent of step 5 between 1530 and 1600. The radar echo pattern indicated that the storm was more intense at 1600 CST than at 1500 CST. However, results of the field survey and analysis of all available raingage records indicate that the storm reached its peak of intensity about 1500 CST. The discrepancy shown by the radar is again apparently due to precipitation attenuation effects, which present a serious problem in evaluating radar-indicated rainfall intensities at 3-cm wavelength.

At 1600 CST, a number of scattered echoes were developing in advance of the echo line, some as close as 50 miles to the CPS-9 radar station. By 1630 CST (Figure 14), the original echo line again showed indications of decreasing intensity and was moving slowly southeastward. Again increased precipitation attenuation from development of the intervening echoes undoubtedly contributed to the apparent decreasing intensity of the echo line.

Figure 15 indicates that the echo line had moved southeastward out of the area of the original heavy deluge of precipitation by 1730 CST. There was also evidence of a second line of scattered echoes forming 20 to 30 miles in advance of the major line. By 1830 CST (Figure 15), the advanced line had developed considerably and combined with the southwestern half of the major line. The apparent increase in rainfall intensity, as indicated by the increased areal extent of step 5 echoes, was partially due to decreasing range between the radar station and the echo line. The radar was piercing the echo line at this time and showing some weak echoes in western Illinois near the Mississippi River and in northeastern Missouri. These echoes were probably much more intense than indicated by the radar because of the attenuation produced by the intervening echoes. The Burlington Weather Bureau Station in southeastern Iowa reported a moderate thundershower at this time.

At 1830 CST, the surface weather chart indicated a low center in west central Wisconsin, with a cold front extending southwest from the low through central Iowa. Consequently, all echoes at 1830 CST in Figure 15 were in the warm air mass.

By 1930 CST on the 10th, the forward edge of the echo line was beginning to enter the ground pattern of the radar. At this time, the line was extending from north central Indiana, southwestward into eastern Missouri. From 1930 CST to 2130 CST, the CPS-9 was inoperative due to maintenance difficulties. When put into operation again at 2130 CST, there was moderate to heavy rain at the station, resulting in relatively severe attenuation. However, the radar was able to penetrate beyond 100 miles to the northwest, in the direction in which the rain was lightest, to detect echoes in western and central Illinois. The radar continued in operation throughout the night and echo activity continued within 100-120 miles of the radar station. By this time, little activity remained in the region of heavy flooding in northern Illinois.

COMPARISON OF RADAR STORM PATTERN WITH RAINFALL RECORDS

Figures 10-15 inclusive present radar echo plots and hourly rainfall amounts for comparison purposes for the two-day period. The radar plots shown represent the echo pattern at a particular time during the hour rather than a composite of the entire hour. However, the storm period for the most part was not characterized by rapid changes in echo pattern. The most significant change took place during the afternoon of the 10th, and plots at one-half hour intervals are presented in Figures 14 and 15 for this period in order to show these changes better.

The hourly rainfall amounts in Figures 10-15 have been plotted in conjunction with the radar echoes that existed on the half hour, that is at the midpoint of the period represented by the hourly rainfall total. During most of the storm, the radar plots on the half hour approximated the mean condition for the entire hour, since the storm was not changing in characteristic rapidly or moving as rapidly as squall lines usually do.

Except for one station in northern Indiana, none of the available recording raingage stations indicated rainfall up to 1600 CST, as shown in Figure 10. The echoes shown at 1430 CST in Figure 10 occurred between stations; thus, it is not possible to say whether they were associated with light rain at the surface, light rain evaporating before reaching the surface, or heavy cloud decks. By 1530 CST, however, several of the recording stations were beneath the radar echoes but recorded no rain, indicating that the lighter portions of the echoes, at least, were associated with evaporating light rain or heavy cloud decks. At 1700 CST, recording raingages were showing moderate rainfall amounts in the Chicago area. As shown in Figure 10, one of the two heaviest recorded rainfall amounts was to the rear of the echo line and the other barely within the rear edge of the echo line, demonstrating precipitation attenuation effects quite well. Note that the most intense echoes were between the radar station and the heaviest hourly totals in the Chicago region.

In Figure 11, the total rainfall amounts measured by recording raingages for the hour ending at 1800 CST correspond well with the radar echo pattern, the heaviest hourly amounts being recorded near the radar-indicated core of the storm in the Chicago area. There was little intervening echo between the radar station and the Chicago area at this time; consequently, relatively light precipitation attenuation would be expected. Figure 11 shows that the total extent of rainfall from 1800 CST to 1900 CST was measured adequately by the total extent of radar echoes as shown by step 1. However, note that the two heaviest amounts in the Chicago area, while within the overall echo area, were not located within the core of the storm as indicated by step 5.

As mentioned previously, the peak rainfall intensity in northern Illinois on October 9 occurred about 2100 CST. Referring to the radar echo plot at 2030 CST in Figure 11, it is seen that the overall extent of rainfall was well portrayed by the radar except in extreme northern Illinois, where precipitation attenuation was again taking its toll. Note that the heaviest rainfall amounts for the period 2000-2100 CST were again within the overall echo pattern but were not shown on steps 3 and 5, due to precipitation attenuation by intervening echoes. Progressing to Figure 12, it is seen that an increasing area of rainfall to the rear of the storm was not being detected by the CPS-9 radar due to attenuation. Note in the radar echo plot for 2220 CST that the heavy hourly rainfall of one inch in eastern Iowa produced no greater return than the 0.01 inch on the Mississippi River in extreme eastern Iowa.

Attenuation effects are further illustrated in Figures 13-15 for October 10. The peak rainfall intensity on the 10th occurred at approximately 1500 CST. Note on the radar echo and rainfall plots for the period 1400 CST to 1600 CST that moderate to heavy amounts in northern Illinois were not being detected. However, except to the northeast, the radar was portraying the forward edge and lateral extent of the rainstorm reasonably well, as would be expected when attenuation effects are insignificant. Figure 15 shows that light to moderate rainfall continued in northern Illinois as the storm moved southeastward. This rain was not detected by the radar due to attenuation from the intervening storm.

RADAR ECHOES ASSOCIATED WITH WIND STORMS AND TORNADOES ON OCTOBER 10

West of Chicago in an area encompassing the towns of Big Rock, Shabbona, and Waterman, considerable damage from strong winds occurred during the afternoon of October 10. At Saunemin, about 55 miles north of the

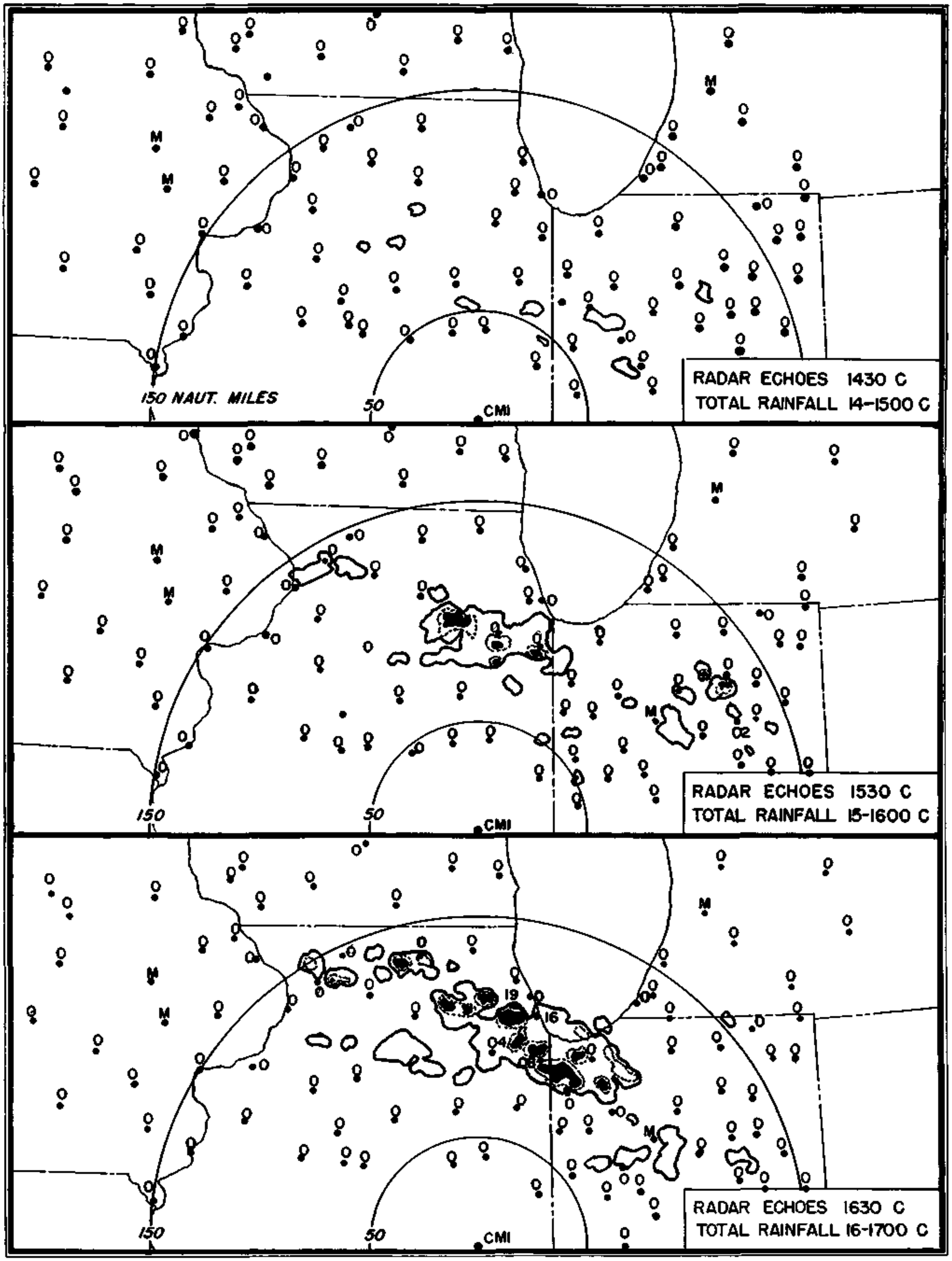

FIG. 10 - RADAR ECHOES AND HOURLY RAINFALL AMOUNTS, 9 OCTOBER 1954. SOLID LINES, FULL GAIN; DASHED LINES, 16-DB REDUCTION, SOLID AREAS, 26-DB REDUCTION.

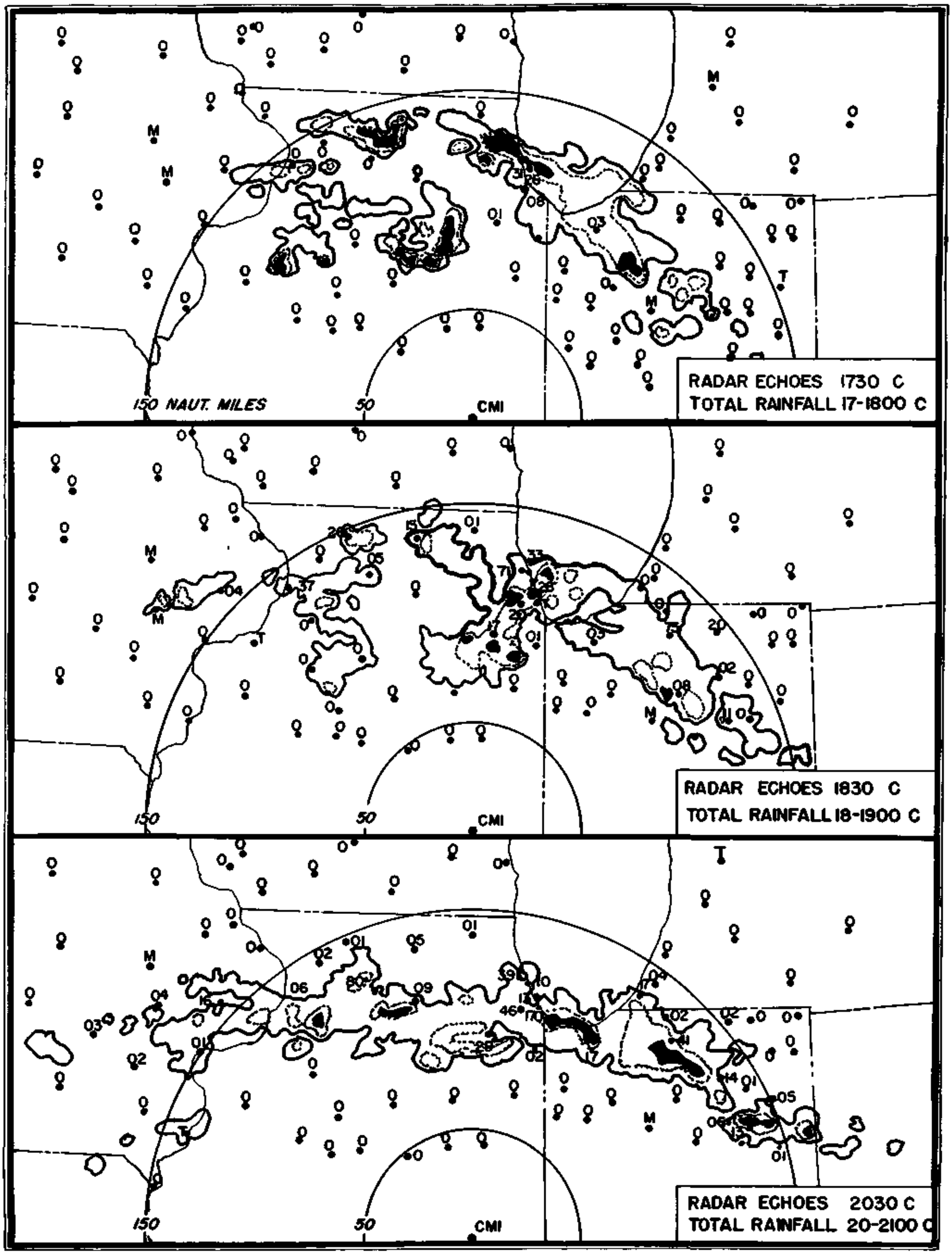

FIG. 11 – RADAR ECHOES AND HOURLY RAINFALL AMOUNTS, 9 OCTOBER 1954. SOLID LINES, FULL GAIN; DASHED LINES, 16-DB REDUCTION; SOLID AREAS, 26-DB REDUCTION.

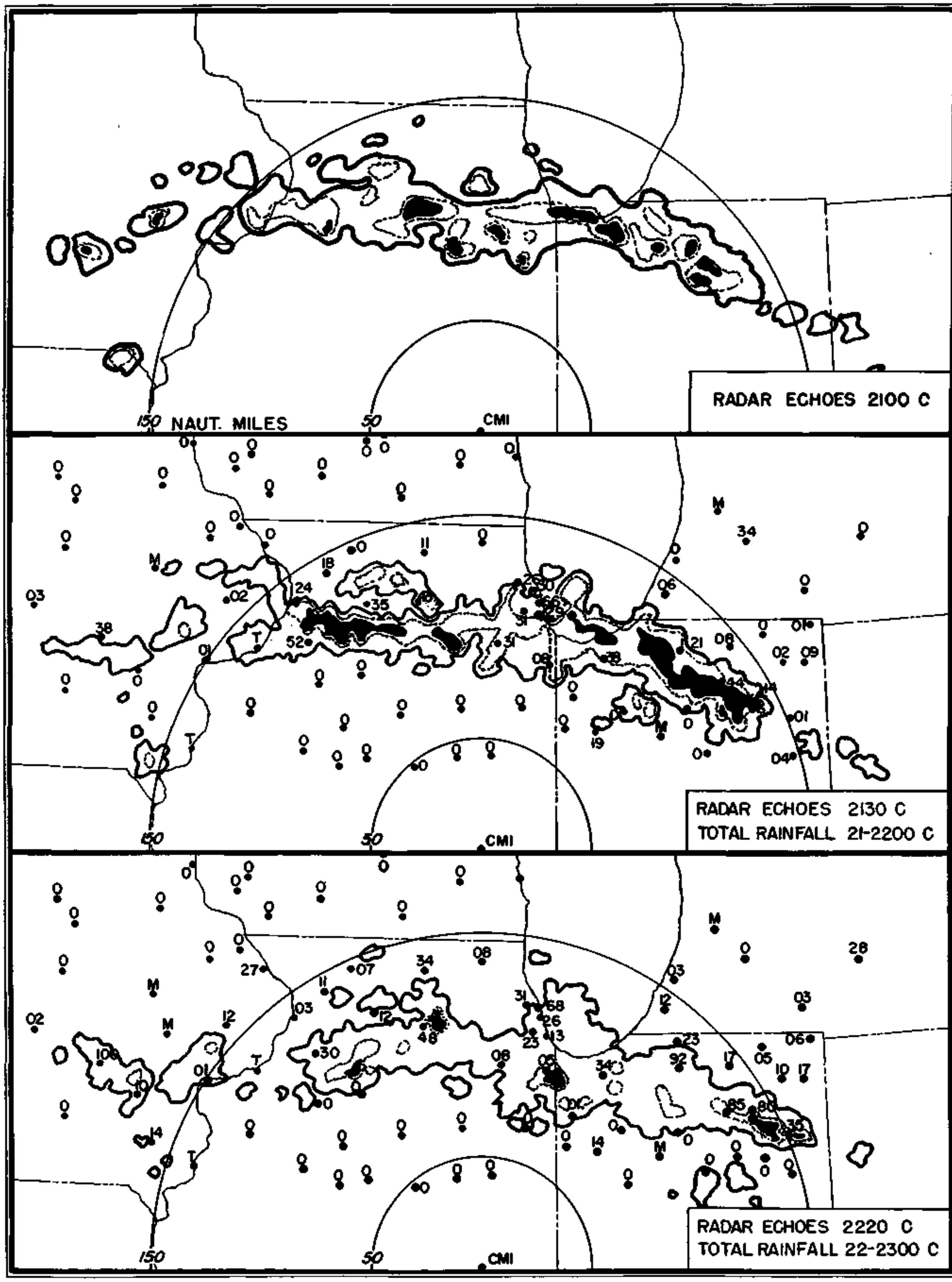

FIG. 12 - RADAR ECHOES AND HOURLY RAINFALL AMOUNTS, 9 OCTOBER 1954. SOLID LINES FULL GAIN; DASHED LINES, 16-DB REDUCTION; SOLE) AREAS, 26-DB REDUCTION.

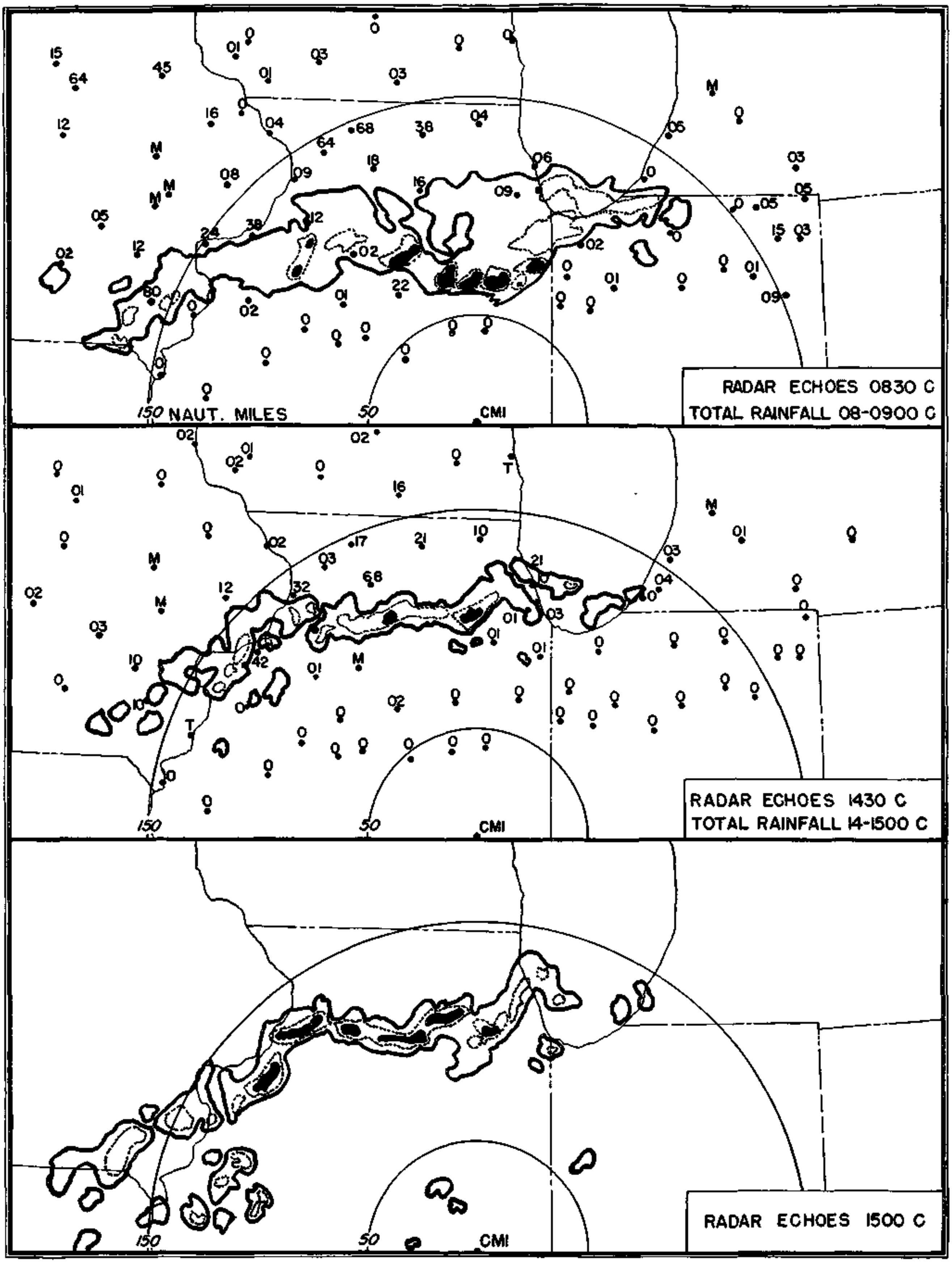

FIG. 13 - RADAR ECHOES AND HOURLY RAINFALL AMOUNTS, 10 OCTOBER 1954. SOLID LINES FULL GAIN; DASHED LINES, 16-DB REDUCTION; SOLID AREAS, 26-DB REDUCTION.

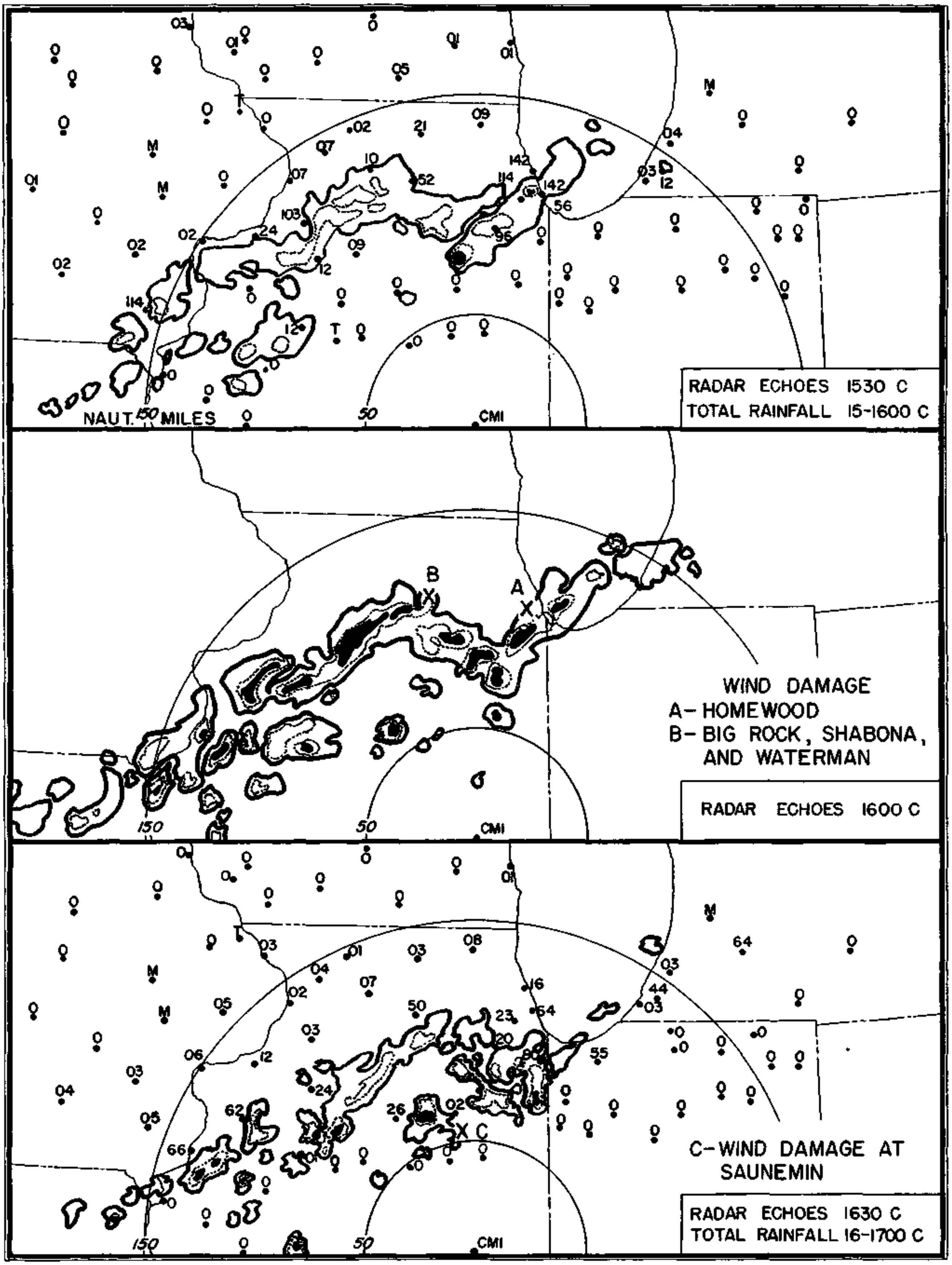

FIG. 14 - RADAR ECHOES AND HOURLY RAINFALL AMOUNTS, 10 OCTOBER 1954. SOLID LINES FULL GAIN; DASHED LINES, 16-DB REDUCTION; SOLID AREAS 26-DB REDUCTION.

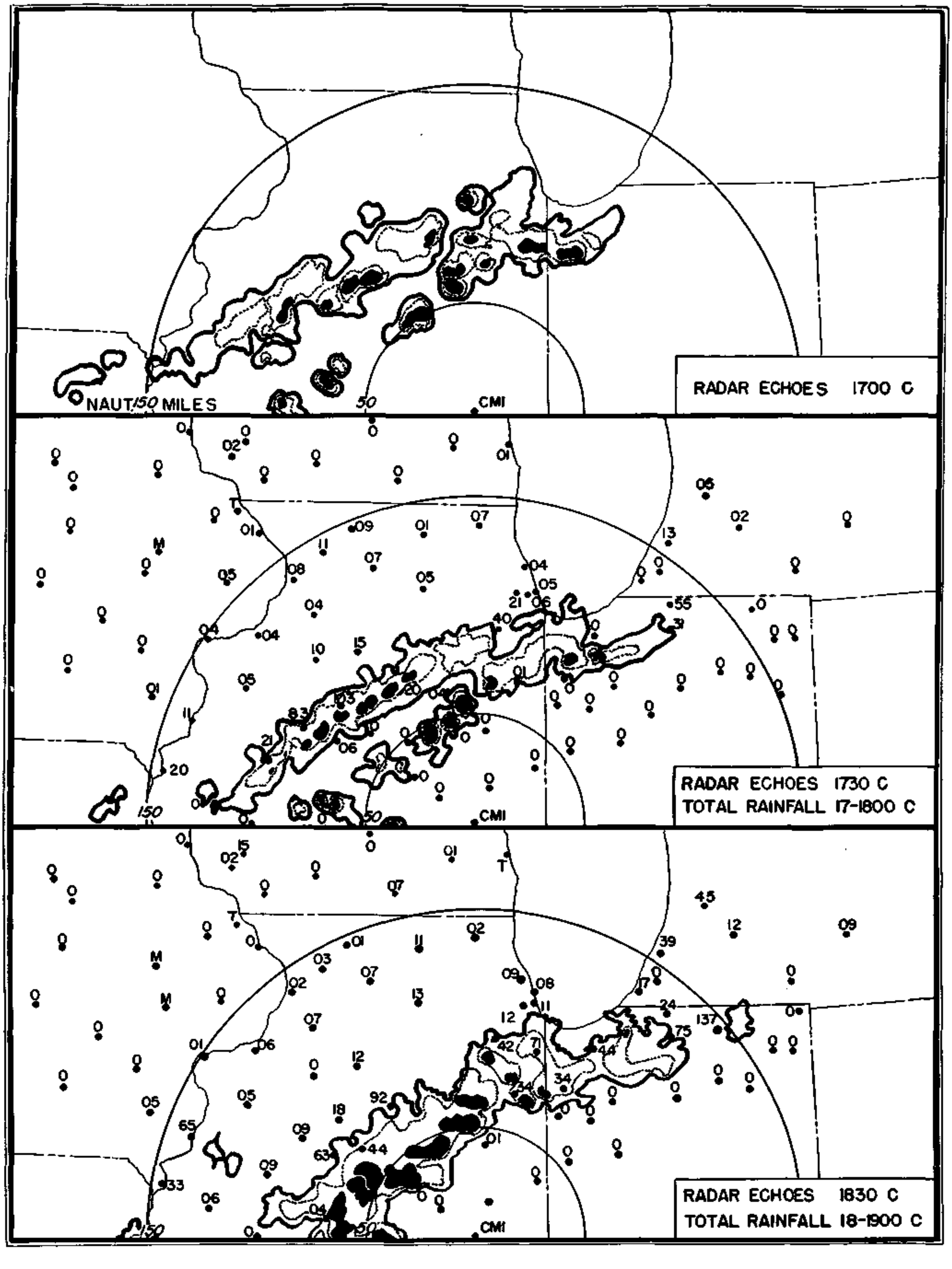

FIG. 15 - RADAR ECHOES AND HOURLY RAINFALL AMOUNTS, 10 OCTOBER 1954 SOLID LINES FULL GAIN; DASHED LINES, 16-DB REDUCTION; SOLID AREAS, 26-DB REDUCTION.

radar station, a small twister was reported to have occurred in the late afternoon to the west of town. At Homewood near Chicago, a small tornado occurred about 1530 CST. Numerous other small windstorms were reported but not confirmed. Approximate locations of the verified storms are shown in conjunction with the radar plots at A, B, and C in Figure 14. Exact locations are shown on the raingage map in Figure 6.

The CPS-9 radar film showed that the squall zone formed a wavy pattern during the afternoon. In previous studies, this pattern has been found to be associated with wind storms. These waves in the echo pattern occurred between 1430 CST and 1630 CST, being most pronounced during the period 1500 CST to 1600 CST. Figure 16 shows a sequence of radar scope photographs taken between 1500 CST and 1600 CST. For each time, there is one photograph on full gain and another with the gain reduced 16 decibels.

Examination of the radar film showed indication of several waves or vortices in the echo line shortly before the wind storms occurred in the Waterman area around 1500 CST to 1600 CST. There was strong evidence of cyclonic motion about some of these vortices, while in other cases the pattern became confused because of the close spacing between the waves or vortices. One of these confused areas of rapid changing echoes existed in the Waterman vicinity.

The small tornado at Homewood was apparently associated with heavy thunderstorms in the short line segment oriented NE to SW, approximately north of the radar station in the sequence of photographs in Figure 16. This line segment remained intense and moved eastward about 38 miles per hour through the Homewood area between 1500 CST and 1600 CST. There were no significant small scale features noted on this line segment to indicate the presence of a small tornado. At 1630 CST (Figure 15), a small appendage was present on the echo near Saunemin, where a small tornado was reported.

This case study of severe weather echoes verifies previous findings that an intense squall line with waves or vortices on it is associated with severe wind storms. However, present knowledge does not permit accurate delineation of the areas of wind damage along such lines.

In cases of waves on squall lines observed by this Survey in the past, it was found that the waves usually persisted for less than an hour. The October 10 wave pattern had an unusually long lifespan, lasting for about two hours.

CONCLUSIONS

Analysis of the October 9-10 storm indicates that the CPS-9 is satisfactory for portraying the areal extent of light rainfall, since attenuation effects are limited in light rain. In moderate to heavy rainstorms, this set apparently does an excellent job of delineating the forward edge and the horizontal extent of an approaching storm in the absence of intervening echoes. However, neither the depth nor the intensity of a storm is accurately portrayed. Consequently, objective methods of obtaining accurate quantitative radar-rainfall estimates do not appear feasible. However, an experienced radar meteorologist, using synoptic weather information and climatological relationships, along with knowledge of the fallacies of 3-cm wavelength radars, should be able to make better estimates of the rainfall in an area than can be obtained from analysis of the usual synoptic weather maps.

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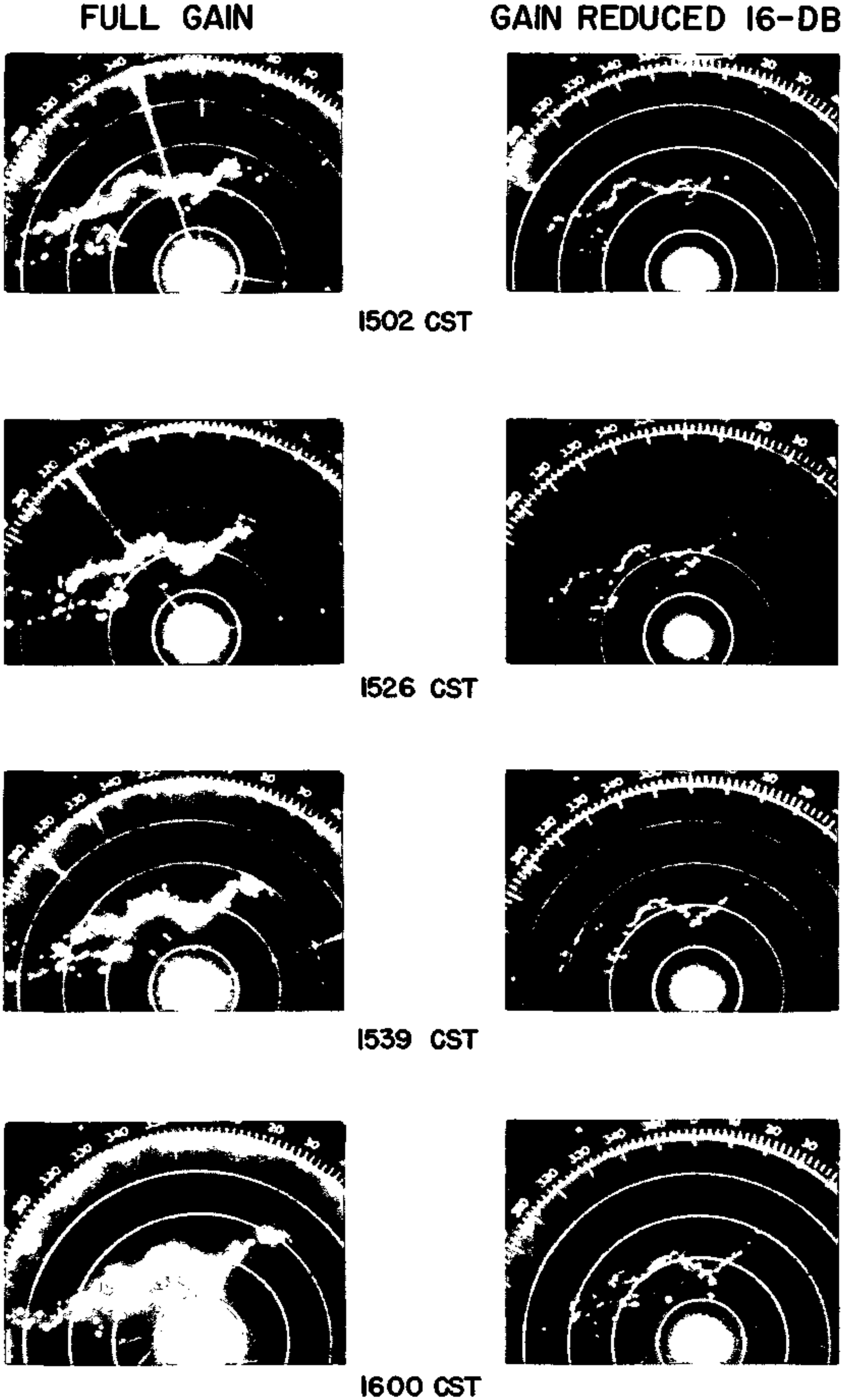

FIG. 16 - ECHOES DURING WINDSTORMS AND SMALL TORNADO.

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