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EVALUATION OF A REMOTE WEATHER RADAR DISPLAY

Vol. I - Development and Field Tests

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Final Report

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16. Abstract

A two-month test of a weather radar data link between the National Severe Storms Laboratory (NSSL) and the Federal Aviation Administration Flight Service Station (FSS) at Oklahoma City has demonstrated usefulness of contoured displays for pilot briefing. The weather equipment is described and examples of the displays are discussed, with comments of NSSL meteorologists and FSS pilot briefers.

This research is divided in two parts. Volume I describes the installation of equipment, training of FSS briefers in operation and interpretation, and documentation of data transmitted during the tests. Volume II summarizes research efforts at NSSL to computerize further processing of the displayed data for rapid isolation and tracking of selected storms.

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METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

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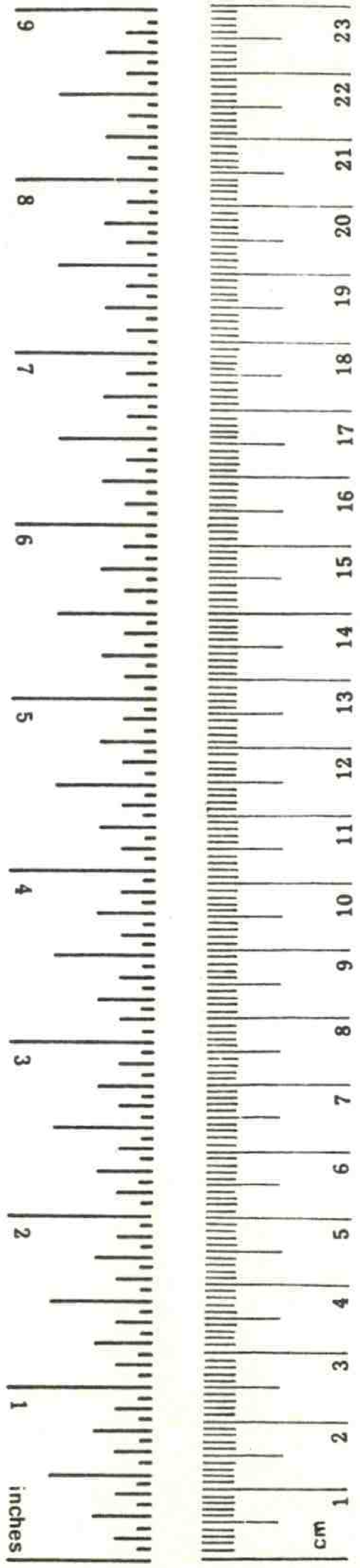
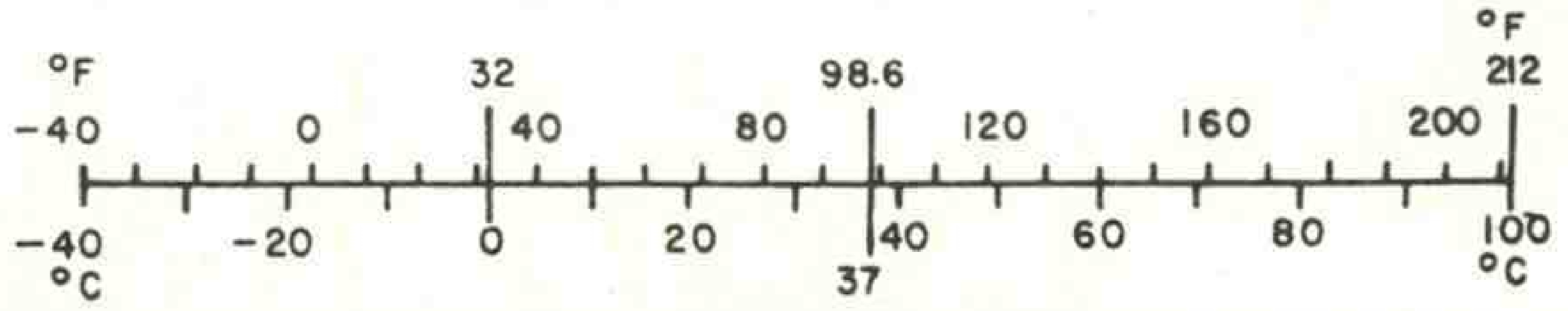
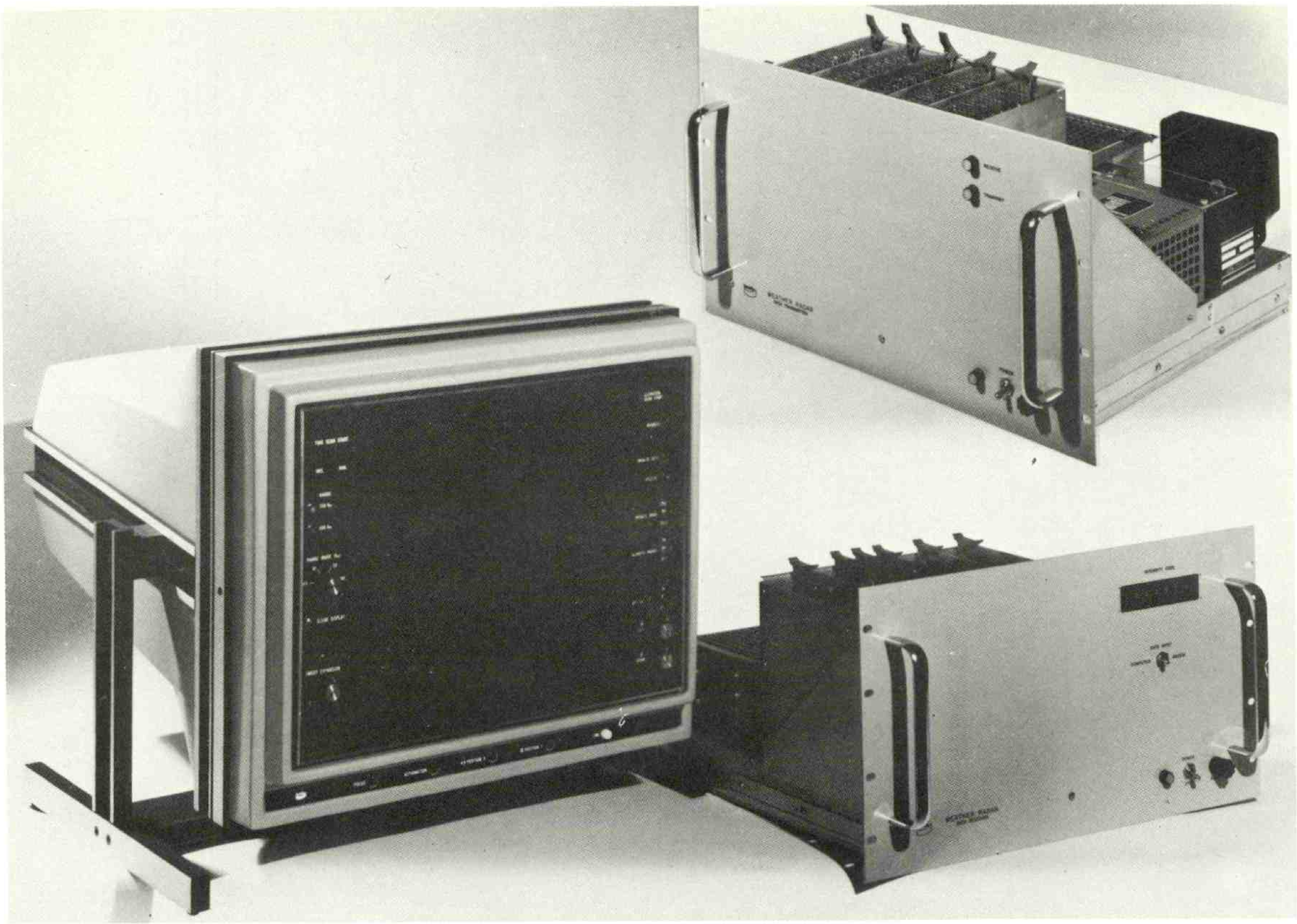
*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



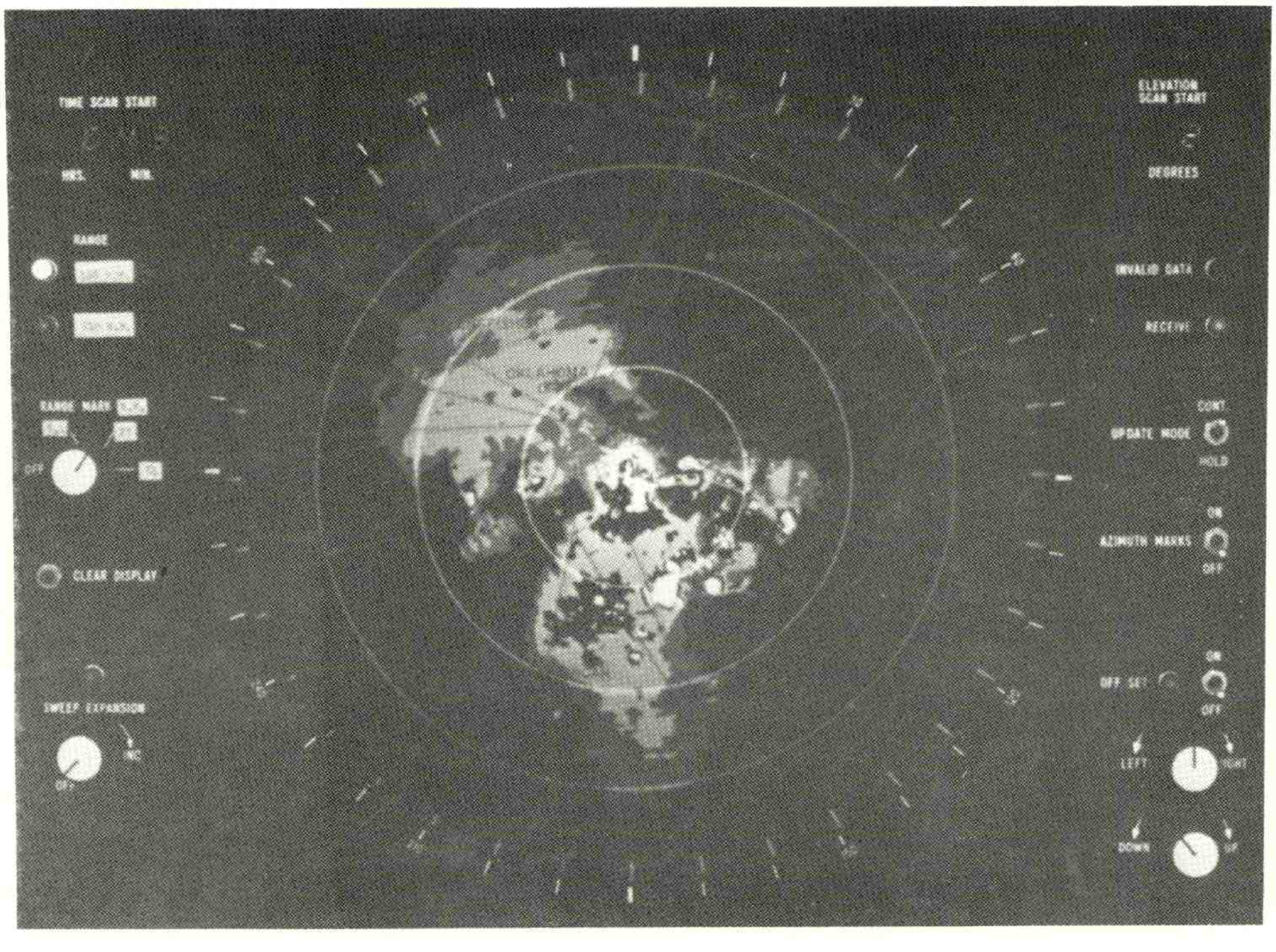
Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F





RADAR REMOTING SYSTEM



REMOTE DISPLAY OF WSR-57 RADAR

TABLE OF CONTENTS

FOREWORD

The Federal Aviation Administration and the National Severe Storms Laboratory are cooperating in search of improved methods for severe storm prediction and warning for aviation. Here NSSL Operations staff reports on tests involving transmission of contour-mapped WSR-57 weather radar from NSSL headquarters to a display unit at the Oklahoma City Flight Service Station.

Our study follows other investigations of the comparative value of various radar systems for severe storm surveillance. Improved signal processing and communication techniques and equipment now permit rapid dissemination of information concerning storm location, intensity, and movement and offer a new dimension in weather display for general aviation.

EVALUATION OF A REMOTE WEATHER RADAR DISPLAY FOR FLIGHT SERVICE STATIONS

VOLUME I

ABSTRACT

Evaluation of operational tests of weather data links between WSR-57 and Air Route Traffic Control Radar (ARSR1-D) radars and Federal Aviation Administration (FAA) Flight Service Stations (FSS) has determined the effectiveness of contoured displays for pilot briefing. The experimental remoting and display equipment is described and examples of the data displayed during the tests are discussed. Comments of National Severe Storms Laboratory (NSSL) meteorologists and FSS pilot briefers concerning the interpretations and usefulness of the data are included.

In Volume II, applications of computer technology to isolate and track the most severe storms are discussed, using some of the test data to illustrate the analysis procedures.

1. INTRODUCTION

This report describes tests of a Remote Radar Display conducted initially at the FSS at Wiley Post Airport in northwest Oklahoma City, Oklahoma, during September and October 1974. Similar tests were conducted a year later at Midland, Texas and Atlanta, Georgia. At Wiley Post, the digital intensity data were received, via voice grade telephone line, from the NSSL WSR-57 weather radar. At Midland, Texas, data were transmitted from the ARSR1-D located near Andrews, Texas. At Atlanta, Georgia, data were obtained from the National Weather Service (NWS) WSR-57 radar at Athens, Georgia.

The radar remoting equipment at all three test sites, consisting of a signal processor, transmitter, receiver, and display, provided high resolution quantitative weather radar information via telephone line, with the received video contour mapped on a bright display terminal in PPI format. The test operations were used specifically to evaluate the effectiveness of the display for pilot briefing and examine its potential as an aid for short range aviation forecasting. Generally, this research sought methods to improve the timeliness, quality and quantity of weather radar information at locations remote from the radar site. Much of this report deals with results of the initial tests at Wiley Post FSS, where NSSL staff were able to work closely with FAA personnel to document activities on a daily basis. Brief visits to Midland, Texas and Atlanta, Georgia, provided additional insight important to the evaluation. Results of a survey and other comments of FSS staff at each location are included. Observations and conclusions made jointly with FSS staff are identified in the text by script type.

The research is divided in two parts. Volume I describes the installation of equipment, training of FSS briefers in operation and interpretation, and documentation of data transmitted during the tests. Volume II summarizes research efforts at NSSL to computerize further processing of the displayed data for rapid isolation and tracking of selected storms.

2. BACKGROUND

Currently, the NWS provides weather radar information to most FSS's at one hour intervals in the form of a manually coded message (RAREP). Complete communication of the observation via the teletype circuit usually requires about thirty minutes. At the FSS, the message is decoded and plotted on a large base map visible to pilot briefers. Some of the information contained in the hourly summary is consistent with the hourly reporting scheme--some is not. Total echo coverage and motion are characteristics which generally change slowly; however, other characteristics such as individual echo tops and locations of high reflectivity cores, usually change frequently and are not consistently tracked by hourly observations.

Over the past two decades there have been numerous studies made in search of improved methods for classifying, encoding, and transmitting weather radar data. Changes in the reporting system have been small, probably because of lack of understanding by users of the nature of the radar signal. Only within the last decade (Lhermitte and Kessler, 1966; Sirmans and Doviak, 1973) have NWS forecasters, pilot briefers, and hydrologists seen contour-mapped displays of weather signals which allow rapid identification of storm location and intensity. With digitized replicas of the PPI's, researchers have attempted to apply computer processing and pattern recognition techniques to summarize important features shown on the PPI display (Blackmer et al., 1972; Östlund, 1974; Schaffner, 1974). To a great extent, important questions remain unanswered; what information should be extracted from radar? How often? How much of it should be remoted for evaluation by users? What predictive information is contained in the data? With what accuracy can storm locations and intensities be extrapolated for warning purposes?

Operational experience and severe storm research have provided a substanital base for building an improved system (Kessler and Wilson, 1971). Storm intensities in excess of 50 dBZ are indicative of hail (Ward et al., 1965); hook echoes are indicative of organized circulations within storms capable of producing tornadoes (Brown et al., 1974), regions within and near the 40 dBZ contour are known to contain severe turbulence (Lee, 1965); and convective showers with intensities stronger than 30 dBZ are likely to have frequent cloud-to-ground lightning (Kinzer, 1972). If these particular contours of intensity can be displayed at the FSS in quasi-real-time, do they provide useful information for pilot briefers to incorporate into briefing presentations? This is essentially the question which this project sought to answer.

3. RELATIONSHIPS BETWEEN STORM INTENSITIES MEASURED WITH WSR-57 RADAR AND SEVERE WEATHER EVENTS

The relationship between displayed contours of intensity and severe weather events have been defined from studies at NSSL and elsewhere, with most of the results expressed in statistical probabilities. Similar criteria are used currently by the NWS in severe storm diagnosis and issuance of warnings. Training of the FSS briefers for these tests emphasized the need for coordination with the NWS offices to assure consistency in the interpretation of the weather radar display.

The operational use of WSR-57 intensity data requires sufficient signal processing to measure the true average return power (Sirmans and Doviak, 1973). Contours of mean power can be presented as levels of brightness, as described in Appendix A. The relationship between these specific received power levels and severe weather events is summarized in the following paragraphs.

Figure 1 shows the distribution of Oklahoma hail occurrences, as reported by volunteer observers, in relation to maximum intensities of associated thunderstorms as observed with NSSL radar (Ward et al., 1965). Note that about 85 percent of the hail producing storms are identified by intensities greater than 50 dBZ. In a small fraction of cases with intensities less than 50 dBZ, 73 percent of hail diameters were 1/4 inch or less. With intensities less than 40 dBZ, hail is rare and small. At this time, we are not able to say with certainty what percentage of echoes of a specified intensity contains hail; only that when hail is reported, peak storm reflectivities are usually greater than 50 dBZ. Of course, tropical storms produce rainfall rates with comparable reflectivities, without hail, and radar measurements in coastal states may require other meteorological information for proper interpretation.

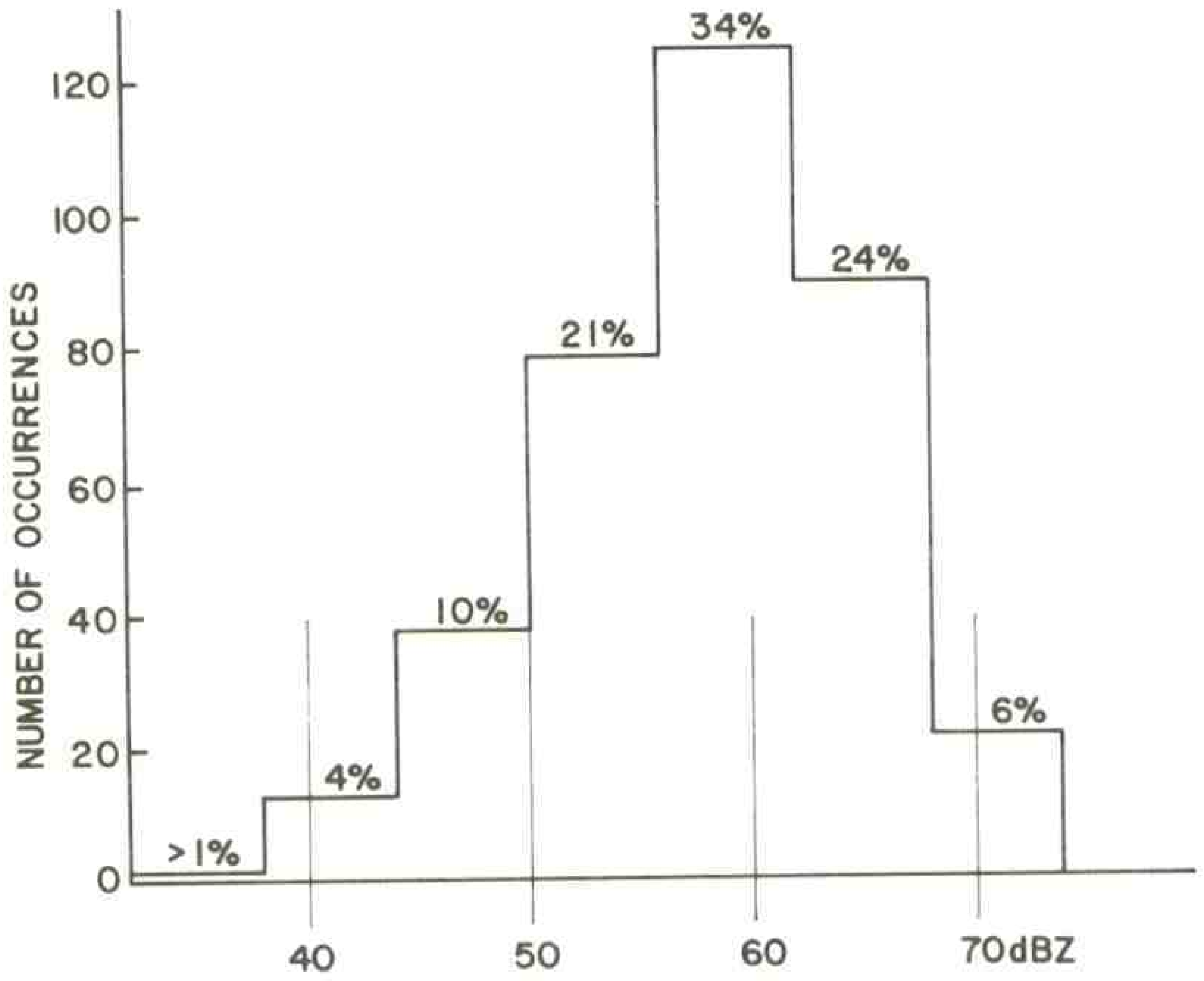
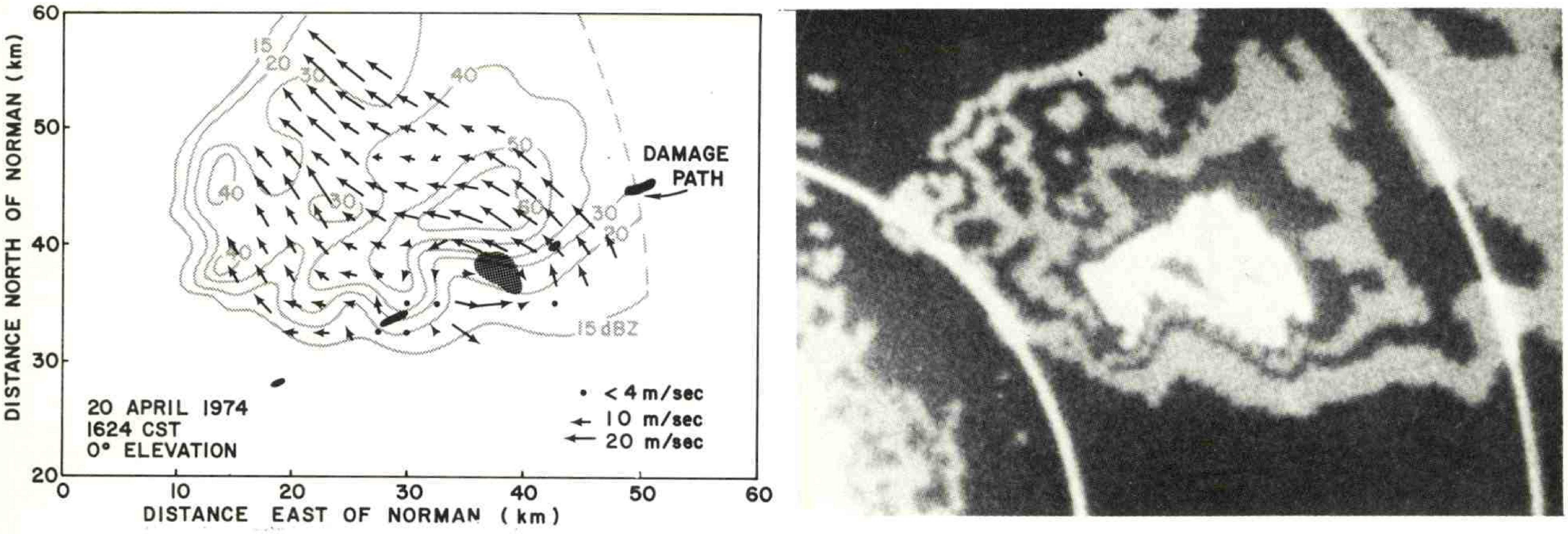


Figure 1. Distribution of Oklahoma hail occurrences in relation to the maximum radar reflectivity of storm cores. (From Ward et al., 1965.)

Freund (1966) related thirteen tornadic storms that occurred in 1964, between 20 and 100 n. miles of NSSL, to their radar echo signatures. Apparent hook echoes were observed in six cases, and in all but one case echoes were at least as reflective as thunderstorms producing small hail. However, no singular feature appears on the WSR-57 radar to distinguish clearly the echoes from other cellular rainstorms producing small hail.

An example of dual-Doppler wind fields and the simultaneous contouring of reflectivity pattern by the WSR-57 is shown in figure 2. Figure 2a represents two single-Doppler velocity fields that have been combined into relative horizontal wind vectors at grid points spaced 2.5 km apart (Brown et al., 1974). These vector are superimposed on a radar reflectivity field derived from measurements at the two Doppler radars. Figure 2b shows the WSR-57 contoured display for the same time. There is general southeasterly flow through the storm at this low altitude with a noteworthy region of non-uniform cyclonic circulation bounded on the west by a curved reflectivity pattern. This is the first dual-Doppler radar confirmation that cyclonic curvature suggested by the "hook echo" reflectivity pattern (fig. 2b) is a manifestation of mesoscale cyclonic circulation. Intermittent surface tornado damage caused by the storm is indicated by broad line segments. The darker stippled region at 38 km east,



(a) (b)

Figure 2. NSSL dual-Doppler wind fields and WSR-57 display: (a) Horizontal wind field (relative to the storm) at a height of 0.2 km deduced from the NSSL dual-Doppler system, (b) the WSR-57 contoured display for the same time. (From Brown et al., 1974.)

8 km north indicates an area where both radars measured Doppler spectrum variances so large that reliable mean velocity values could not be determined. These large variances signify strong velocity gradients within the radar beam width.

Figure 3 depicts a relationship between maximum storm intensity and categories of turbulence (Burnham and Lee, 1969). This relationship was established by comparing turbulence parameters recorded by the aircraft with concurrent intensity data from the WSR-57 radar. Lee (1965) concluded that the maximum reflectivity of the storm is presently the most reliable indicator of turbulence in thunderstorms and that severe turbulence is almost wholly confined to target storms in which the maximum radar reflectivity, Z_e, is $10^4 mm^6 m^{-3}$ or higher.

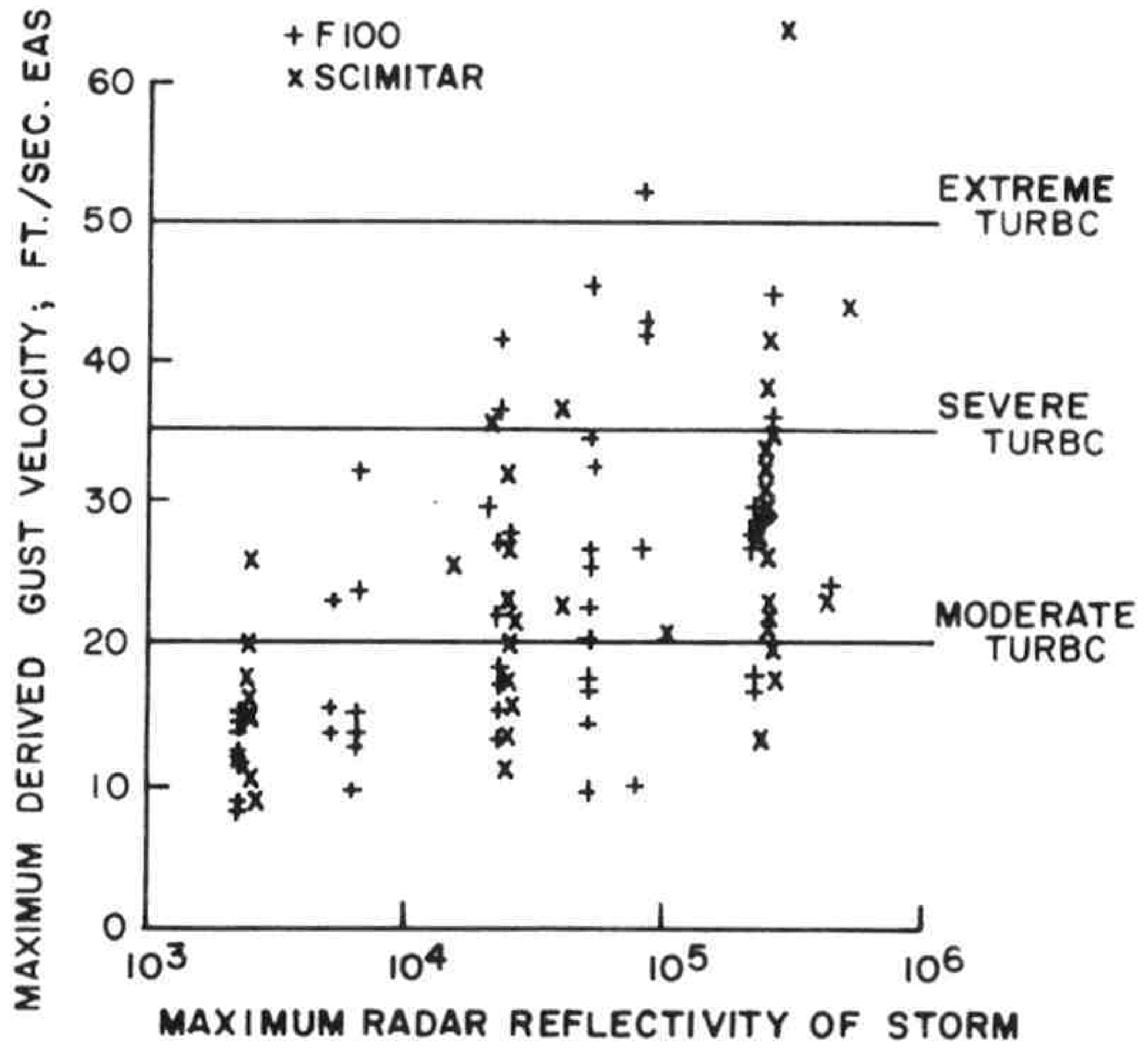


Figure 3. Maximum storm intensity and maximum derived gust velocities and categories of turbulence (Burnham and Lee, 1969).

The results of a study by Kinzer (1972), established a relationship between storm intensity and the occurrence of cloud-to-ground lightning flashes (fig. 4). The data suggest that areas of stronger reflectivity are likely to be areas of higher rates of cloud-to-ground lightning flashes. With adequate signal processing these storm centers are clearly labeled.

An example of an organized squall line with several intense centers of convection is shown in figure 5 (Barclay and Wilk, 1970). As the WSR-57 antenna is tilted (fig. 5c) the tall turrets are easily discerned. The juxtaposition of the low level storm centers with the tops when the antenna

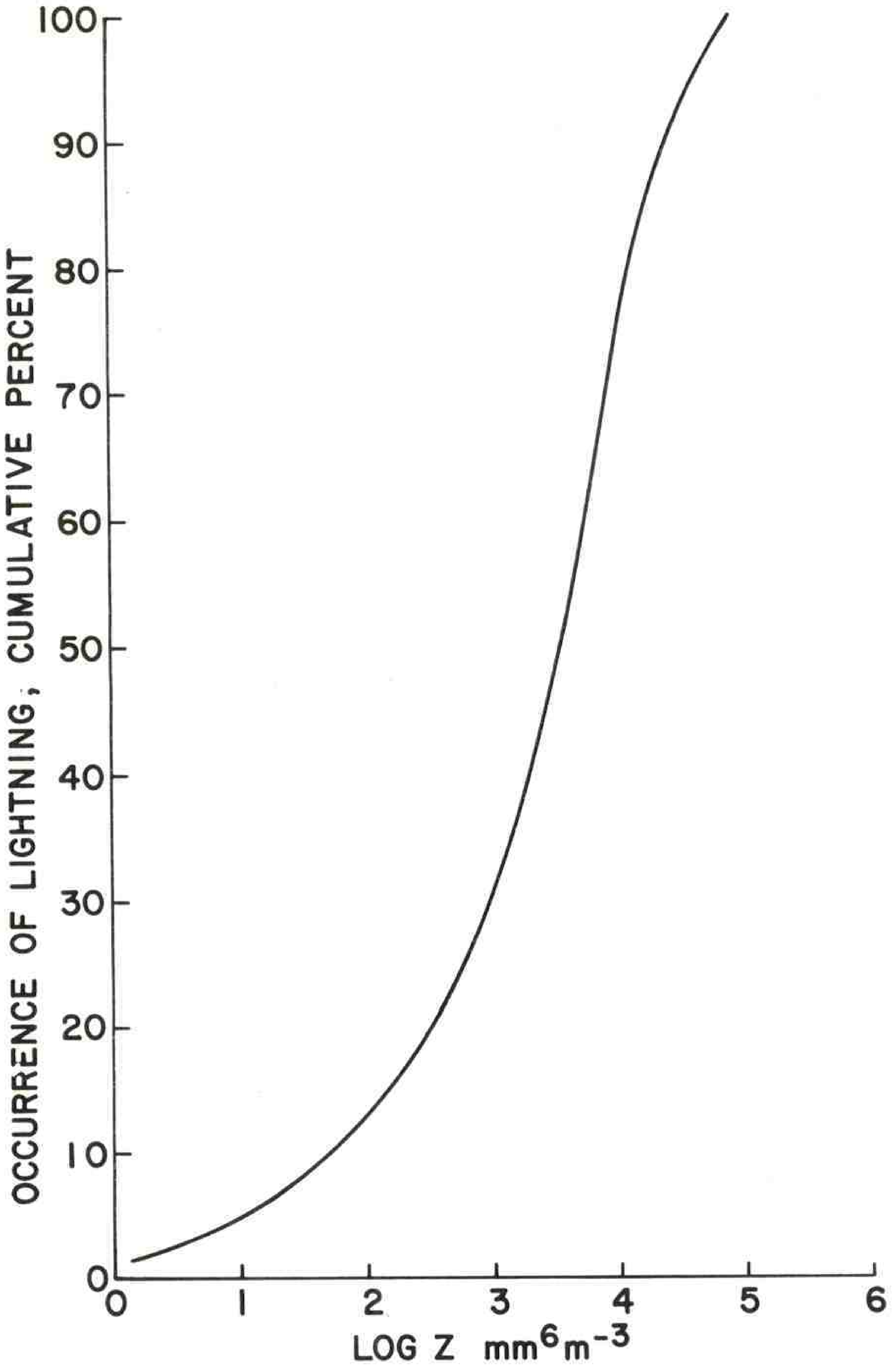


Figure 4. Storm intensity and the occurrence of cloud-to-ground lightning (Kinzer, 1972).

is tilted, illustrate the close relationship between the magnitude of the storm intensity at low levels and the congruent storm height as measured by radar. Figure 6 is a summary of 7000 measurements of low level (0.5° tilt) individual thunderstorm intensities and their associated tops. These data were obtained with 29 of the NWS's WSR-57 radars and represent all types of convective activity (e.g., air mass, frontal, squall lines, etc.) extending from southern Florida to Canada. Since the observations were made with a linear response receiver and an A-scope display, the estimated intensity values are about 6 dB higher than the true averaged power. With this offset corrected, the expected radar echo heights for storms with maximum reflectivities of 30, 40, 50, and 60 dBZ are about 25, 35, 42, and 47 thousand feet, respectively. The first standard deviation of the mean height is 5400 feet. Since the vertical growth period of individual echoes is generally about 20 to 30 minutes (Battan, 1953), and the average cell lifetime is about 40 minutes (Blackmer, 1955), it is probable that most hourly reports of echo tops are uncorrelated. Also, the error inherent in the extrapolation of these reports is probably as great as the error in estimating the echo top from the low level reflectivity. Of course, cell 'conglomerates', generally referred to as thunderstorm complexes, have lifetimes of several hours, and their average cell tops may be maintained at great heights for long periods (Browning and Ludlam, 1962). In such cases both vertical extent and high reflectivity are 'steady state', and commensurate with much longer reporting intervals.

A summary of the information contained in figures 1 through 6 is shown in Table 1 along with the current NWS radar reporting code, and the NSSL operational research code. Table 1 was provided to the FSS as guidance for selection and objective interpretation of remote display levels. For instance, when turning on the display for the first time, the briefer should start at Code I and proceed to Code II if a cancellation is present; then Code III when cancellation appeared in Code II, etc.

The arrows in Table 1 indicate the phenomena may be experienced anywhere within the listed contours. For example, when the maximum intensity (60 dBZ) is reached, severe turbulence will be encountered in the area covered by all other intensities including level one.

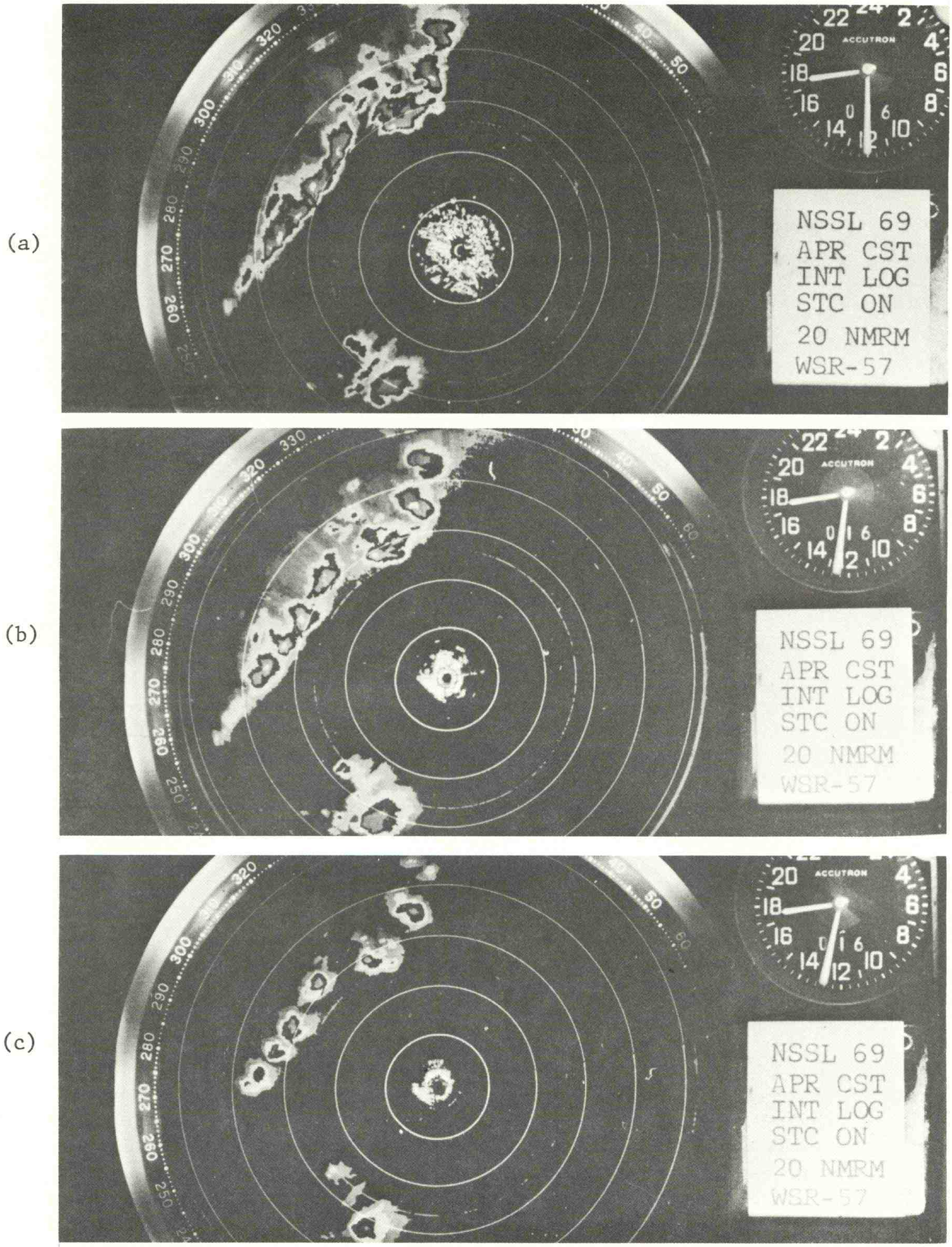


Figure 5. WSR-57 radar contoured 100 n mi display for April 16, 1969. The first intensity level, $Z = 10\ mm^6m^{-3}$; bright cores, $Z = 10^5 mm^6m^{-3}$. (a) antenna tilt is zero degrees (mean beam altitude of 2400 ft at 60 n mi), (b) antenna tilt is one degree (beam altitude of 8700 ft at 60 n mi), (c) antenna tilt is two degrees (mean beam altitude of 15,200 ft at 60 n mi).

Table 1.

Criteria for the selection and objective interpretation of the remote display levels along with the current NWS radar reporting code, and the NSSL operational research code.

WEATHER TYPE	CODE	DIGITAL LEVEL					
		1	2	3	4	5	6
STRATIFIED RAIN	1 123000	VERY LIGHT RAIN	MODERATE RAIN	HEAVY RAIN REDUCED VISIBILITY	GO TO CODE 11.		
STRATIFIED RAIN WITH EMBEDDED THUNDERSTORMS	II 120300	VERY LIGHT RAIN	MODERATE RAIN MODERATE TURBULENCE	SEVERE TURBULENCE LIGHTNING	THUNDERSTORM SEVERE TURBULENCE	GO TO CODE III	
SHOWERS AND THUNDERSTORMS	III 112030	MODERATE – SEVERE TURBULENCE		SEVERE TURBULENCE → LIGHTNING →		→ SEVERE THUNDERSTORM → HAIL ORGANIZED WIND GUSTS	GO TO CODE IV
SEVERE THUNDERSTORMS	IV 112203	SEVERE TURBULENCE →		LIGHTNING →			→ VERY SEVERE THUNDERSTORMS → LARGE HAIL, PSBL TORNADO, EXTENSIVE WIND GUST AND TURBULENCE
NATIONAL WEATHER SERVICE CODE	V 130130	MDS: NO RANGE NORMALIZATION RAREP CODE: WEAK	DBZ = 29.5 MODERATE	DBZ = 40.7 STRONG	DBZ = 45.5 VERY STRONG	DBZ = 50.3 INTENSE	DBZ = 56.1 EXTREME
NSSL CODE	VI 120130	DBZ = 10 MDS: RANGE NORMALIZED TO 200 KM	DBZ = 20 MIN. SIGNIFICANT RAINFALL RATE <2 C-G LIGHTNING FLASHES PER 5 MINUTES	DBZ = 30 THUNDERSTORM LEVEL FOR CENTROID TRACKING >2 C-G LIGHTNING FLASHES PER 5 MINUTES	DBZ = 40 LIMIT FOR SAFE PENETRATION BY PROJECT AIRCRAFT	DBZ = 50 SEVERE THUNDERSTORM: HAIL	DBZ = 60 VERY SEVERE THUNDERSTORMS LARGE HAIL

At the start of the program, it was recognized that strict application of these criteria without additional training and education would be premature. The FSS staff was instructed to treat this primarily as guidance information and to continue to check their consistency with the NWS hourly radar reports.

4. THE REMOTE WEATHER RADAR DISPLAY--GENERAL DESCRIPTION

Sirmans (1974) and Shear (1974) have prepared comprehensive descriptions of the components of the remote weather display shown on the first page of this report. Generally, they describe the system as follows: referring to figure 7, the radar information is extracted in real-time from the WSR-57 in polar coordinates on a 360° x 200 km grid at a spacing of 1° x 1 km. The radar information is converted from the 64 level (6 bit) intensity word to the prescribed 8 level (3 bit) dBZ categories, range normalized, and corrected for atmospheric attenuation. The radar site transmitter storage unit accepts the radar data and formats the data field. The unit can be visualized as an input multiplexer which, with the 2 bit timing word occurring at the beginning of each frame, the 360 x 200 x 3 data field and the 12 bit azimuth information for each radial into the parallel-serial 73,472 x 3 bit acquisition memory. Another multiplexer at the output of the memory performs a parallel to serial conversion of the three bit parallel output for serial input to the transmitter modem. The transmitter and receiver modems are Bell System 201C's modified for a continuous clock and fast recover. The data are transmitted at a rate of 2400 bits/sec; in about 92 seconds the entire PPI data field is transferred.

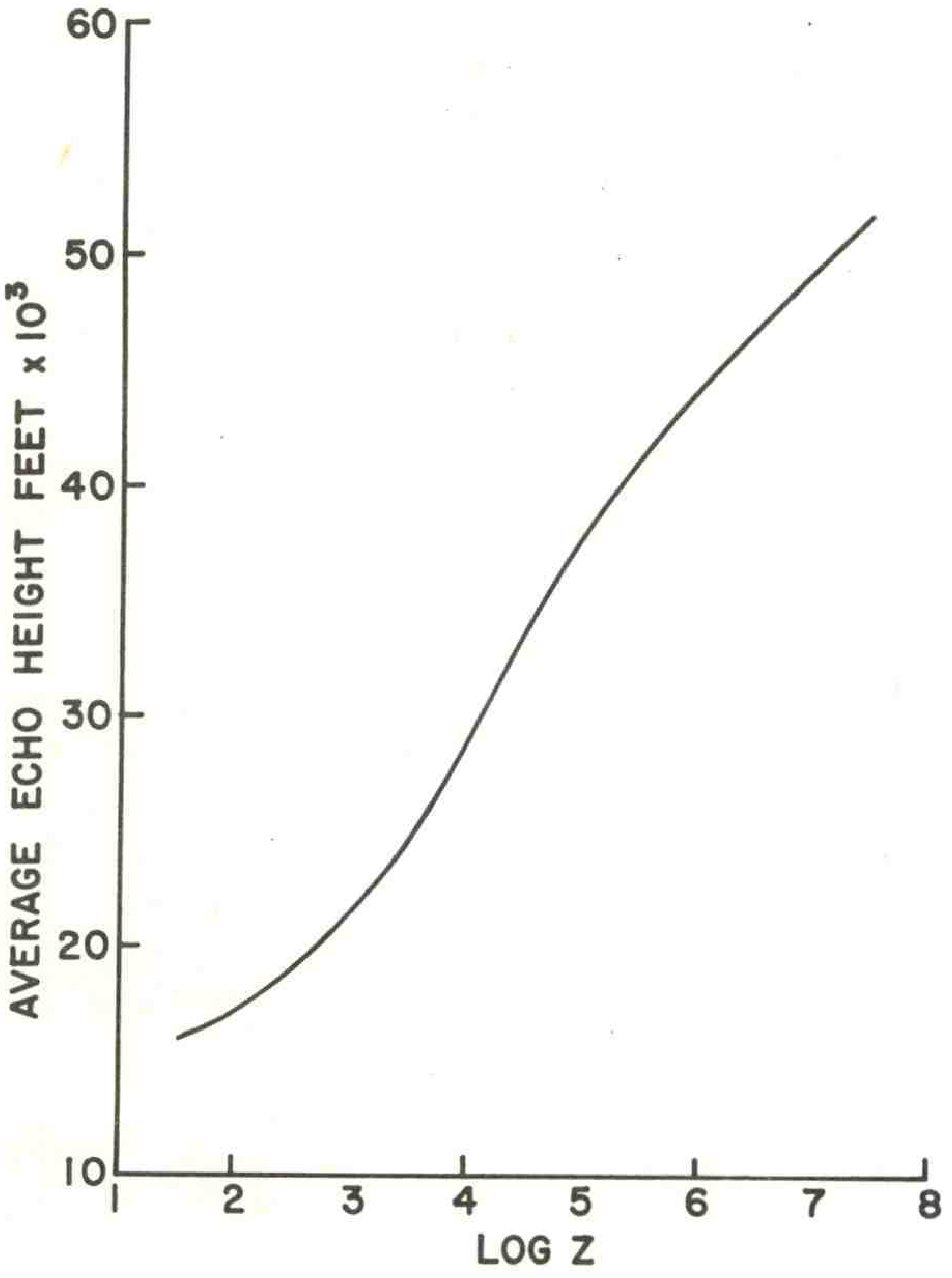


Figure 6. A summary of 7000 measurements of low level (0.5° tilt) individual thunderstorm intensities and their associated tops.

At the remote terminal, the display receiver accepts the serial output from the receiver modem and conditions it for PPI display. The receiver unit consists of an input multiplexer which performs a serial to parallel-serial conversion, a brightness code converter which translates the seven 10 $\log_{10}Z$ categories to three shades of brightness for display, a 72K x 2 bit refresh memory, and a timing and control generator. The 72K x 2 bit refresh memory serves as both the refresh and field storage memory. At operator option, data from the radar site is buffered by the display receiver and accepted into the display memory by radial, or frozen indefinitely with no new data accepted.

The display receiver also contains a computer input-output interface. This interface buffers the data from the receiver modem and supplies it to a computer in serial format. It can also accept data in serial format from a computer for display on the CRT.

The PPI display is a computer peripheral CRT (P-31 phosphur) deflected in polar coordinates. It is a 12-inch bright display, refreshed about 50 Hz. It contains the usual controls avialable on radar PPI scopes, including off-centering, range marks, and variable expansion. The selection of contour levels and their relative brightness is made by setting rotary switches on the adjacent receiver panel.

5. OPERATIONAL TEST AND EVALUATION

Prior to installation of the display at the FSS on August 16, 1974, several training sessions were held with pilot briefers and representatives of the NWS Office at Oklahoma City. In addition to material discussed previously, slides and 16 mm movies of contoured weather displays were used to familiarize the briefers with a great variety of scope patterns, and to show them rates of change of cell structure and intensity. Although these discussions seemed adequate, a more formal 40-hour training program spread over a five-week period is probably needed to ensure that all personnel are sufficiently trained for proper scope interpretation. In the present test, it was expected that daily (or hourly) telephone conversations with the Weather Service radar operator would assist in training. However, this was precluded by the operational workload on NWS staff. In fact, during the first few days of

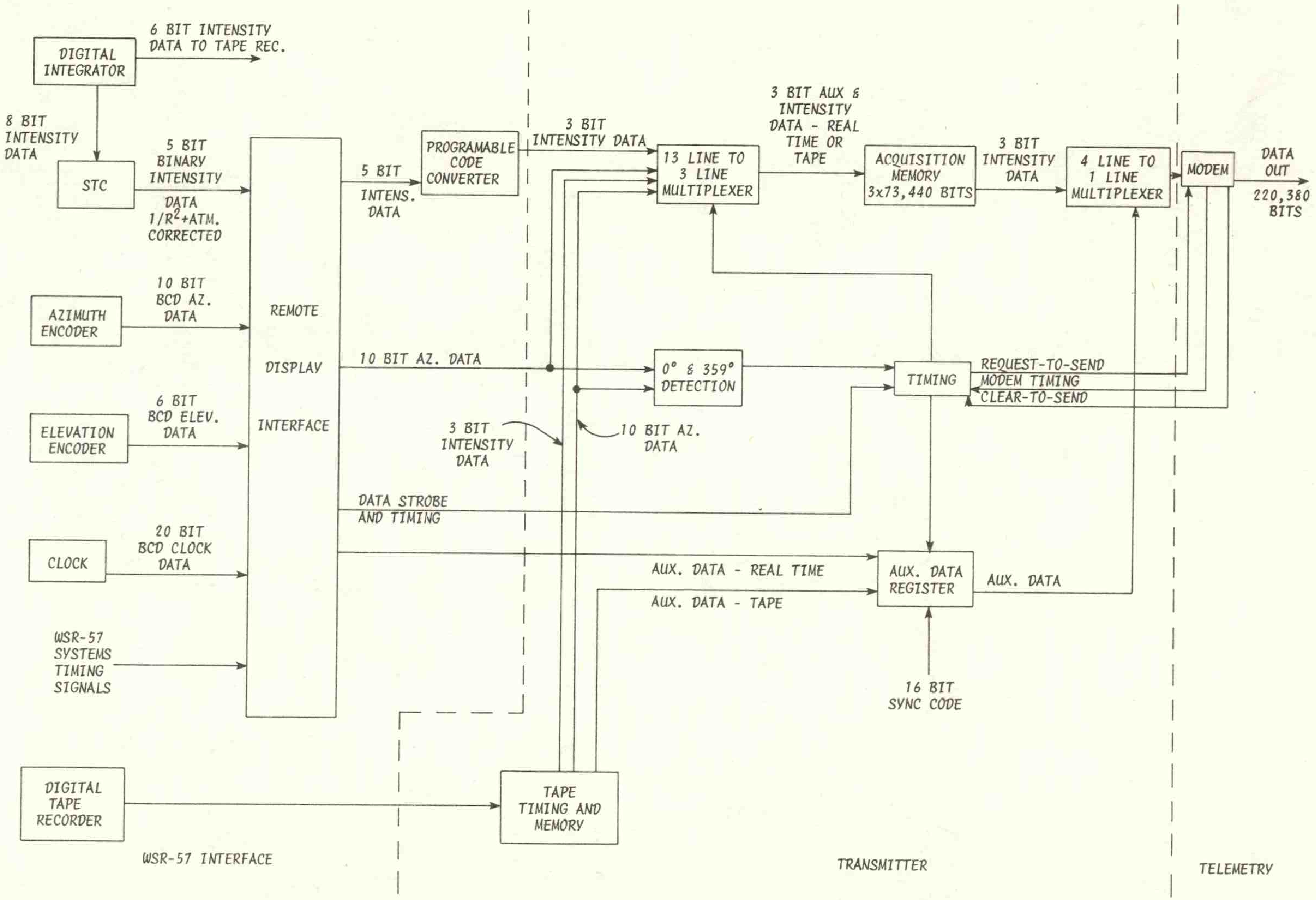


Figure 7. Flow diagram for acquisition of data for transmission to the remote display.

operations we found that such conversations led to overemphasis of fine scale details in echo patterns, which change quickly and are poorly correlated between hourly rareps and sometimes even between the OKC and NSSL radar displays. With encouragement of the NWS radar staff at OKC, we did align the NSSL contours to represent the same intensity levels specified by NWS (Table 1). However, differences in the displays were noted on several occasions; probably because of radar perspective and slight (1-3 dB) drift in calibrations.

For first evaluation of the effectiveness of the real time radar display at Wiley Post, we submitted an evaluation form to each FSS Specialist which asked eleven specific questions and sought general comments. Their responses are summarized in Appendix C.

Their overall reaction to this technique of displaying radar data was very favorable, since their previous data arrived by teletype. Most of the weather during the test period was low intensity (stratified rain), and there were few experiments with different contour codings. Severe weather occurred for brief periods on two days, and we urged that level settings be left in one mode to avoid any confusion regarding interpretation. When moderate to strong activity occurred, the FSS staff were extremely busy, and not in a position to manipulate the display auxiliary controls. After 0300Z, when traffic diminished, we had several lengthy telephone conferences in which the levels displayed at the FSS and NSSL were changed and compared and the cell locations and intensities discussed.

On a few occasions the display range (either 200 km or 400 km) was selected by the briefer. However, a fixed airways map overlay scribed on the face of the display CRT influenced the range used, and restricted use of the off-center and range expansion capabilities. *If an airways map is to be part of a future display, the briefers suggest that it be mixed with the weather video.*

One problem that surfaced rather quickly was the difficulty of associating quasi-real-time radar data available on the display with the NWS RAREP which was usually 30 minutes old at the time of receipt. *In order to report all echoes and keep observations a reasonable length, the NWS RAREP more nearly represents the synoptic scale, whereas FSS Specialists are interested in mesoscale features of the echo patterns.* This difference is portrayed graphically in the illustrations in Appendix D.

Radar data were transmitted to the FSS on 27 days during the test period, with a total of 276 hours of data being archived at NSSL. A summary of computer logic used for calibration of the radar display and archiving the data set is included in Appendix D. The weather patterns covered most of the precipitation spectrum, from severe thunderstorms to snow.

After final discussions with FSS staff, we concluded that pilot briefers equipped with remote radar displays should seek interpretational advice from the NWS forecasters instead of the radar operators, *since the information most important to the briefer after seeing the remote display is the expected location, intensity, and coverage of the precipitation in the future 20 to 120 minutes.* It is obvious that, even with the real time contoured display at the FSS, briefer's capabilities will continue to be limited to simple extrapolation of past storm positions, until more predictive information is made available by NWS.

Such advances may soon be possible with improvements in communications inherent in the AFOS (Weigel, 1973) and EFOS (Bromley, 1975) systems being implemented by NWS and FAA, respectively. However, the present state-of-the-art in severe storm forecasting does not offer precise predictions of the locations of new storms. Instead, the forecaster will be able to provide more timely observations of cloud development as viewed from satellites, and can provide a more comprehensive description of the weather patterns. Remoting of the weather patterns is a strong first step in improving this service to aviation.

6. ENGINEERING EVALUATION

The equipment functioned essentially as designed. Technicians were called on three occasions to trouble-shoot or align the system, but only one lengthy outage occurred. Considerable engineering time was spent on the tape playback interface. However, this hampered only long line transmission tests via tapes and did not affect the real time FSS experiment.

Both the Southwestern Bell Telephone Company's (SWB) 201 C and the International Communications Corporation's data phones were used successfully, transmitting at 2400 bits per sec. The SWB system was used exclusively for the FSS tests. Line noise on three occasions caused losses as great as ten scope presentations per hour (30%). These disruptions were usually intermittent, and there were sufficient complete presentations available to meet briefing requirements. At this time, we feel most transmission outages were related to sporadic line noise and would not be alleviated by slower data rates. The most common effect the noise had on the display was to shift the echo pattern in azimuth. This lag is progressive with each loss of azimuth data, and the displayed intensity data are rotated an amount corresponding to this accumulated loss of radials. Loss of the azimuth information is indicated on the display by the invalid data light. However, if the errors are in the echo free areas, the display appears normal, and the azimuthal shift may go unnoticed.

Minor problems in system alignment continued throughout the tests. A 60 cycle A.C. ripple appeared periodically as a background 'windmill' pattern on the display. This occurred after long periods of operation and is believed to be leakage on the D.C. power supply, possibly due to overheating.

There was slow drift in centering and azimuthal alignment. When this reached two degrees (over a period of about two weeks) we would correct it by the internal x-y adjustments. The focus and external centering adjustment were 'fine tuned' about every seven days. The display was generally stable and most of the alignments could be considered routine maintenance.

It was not necessary to adjust contour level brightness during the entire test program. Window and artificial light level in the OKC FSS briefing area is exceptionally well controlled and the display was easily visible. The environment light level must be controlled, however, or glare and reflections will negate briefing from remote locations. Further tests should be made under a variety of viewing conditions to determine the general adequacy of the size and brightness of the display at some locations. It may be preferable to use several smaller displays arranged for individual use. Other component failures occurred on the equipment installed at Midland, Texas and Atlanta, Georgia. These were of the type expected with prototype devices and will be solved in production equipment generally by adherence to usual FAA specifications. None of the three tests showed engineering weaknesses other than those listed above.

7. CONCLUSIONS

Specific conclusions reached as a result of these tests are summarized according to our ranking of their relative importance of the OKC FSS. Care should be taken in extrapolating these findings to other locations and FAA staff.

1. Weather radar information made available to the briefer by this display system is vastly superior to that currently provided via teletype (RAREP). Over-the-counter briefings are significantly improved by the visual aid of the display; and the real time display of specific geographical locations of individual precipitation areas provides new high level of pertinence and credibility for radio and telephone briefings.

2. Educational background, experience, and general meteorological aptitude of the pilot briefers at the OKC FSS provided easy transition to real time weather radar display. We had no difficulty training any of FSS staff in equipment operation or in mechanics of scope interpretation. There was insufficient time to review various severe weather patterns and reveal their association with subsynoptic and mesoscale phenomena. We repeatedly stressed the limitation of radar displays when used alone and discouraged briefers from predicting or extrapolating storm locations and intensities. However, it is obvious that routine predictions are not presently detailed in NWS advisories, except in the case of severe thunderstorms.

3. Seven intensity levels available on the display are excessive for daily operation. They are useful for seasonal adjustment from rain to snow, and for intense convective systems requiring a wide dynamic range of display as the storms develop. The most applicable code for use during convective precipitation in Oklahoma was Code III in Table 1, which codes meteorolgoical power levels as threshold to 30 dBZ, light grey; 30-40 dBZ, the next brightness level; 40-46 dBZ, cancellation; 50-57 dBZ as the third brightness level; above 57 dBZ, cancellation.

4. The 12-inch (30 cm) diameter display is usually sufficient for the OKC-FSS operation. During periods of heavy workload, individual displays would significantly improve briefing efficiency. Also, a centrally located, large display will require special attention to room lighting. Reflections from windows and bright lights may cause serious viewing problems.

5. Contrast in brightness between the three intensity levels is marginal. No attempt should be made to increase the number of levels (shades of grey) unless a color display is used. We recommend that the brightest level be reserved for delineation of the highest intensity level and that it be separated from the next lowest intensity by a cancellation. Otherwise, there is not sufficient contrast in brightness to distinguish levels easily.

6. Spatial resolution of two degrees and 1 km is adequate for display. Two degrees and 2 km (1 n. mile) resolution is not adequate because of a blocky character of echo elements, especially when expanded range is used. The 50 Hz refresh rate shows no flicker. Range compensation for brightness is marginal and should be carefully controlled, since brightness resolution between intensity levels, which is already marginal, is easily degraded.

7. Use of the scribed overlay for geographical reference is inadequate, and an electronic video mask should be generated locally. The 45 degree angle marks are not needed and range marks should be limited to 10, 50, and 100 n. miles.

8. Intensity codes should be preset and 'gang' switched by a single control on the display. A light near the clock should indicate the code in use. The 'hold' function on the display should include a choice of clock-timed update to provide choices among continuous (100 sec at 2400 BPS transmission), 5 minute, or ten minute update. The longer intervals are better used to estimate past storm motion and growth.

9. Physically, the display unit should keep the horizontal and vertical swivel mount. However, cabling should be rerouted through the mount rather than allowed to swing free from the back of the display. The display front and top covers are not adequately secured. The top cover should be hinged, or secured with clasps.

10. Data phones should remain as a lease item with Bell telephone. Maintenance checks on line quality and data phone performance are then the responsibility of a single contractor. Circuit logic in the receiver is well documented and routine maintenance can be performed by technicians. A system block diagram of data flow and the timing diagram are shown in Section 5.

All data collected during the test period have been processed for playback on the remote display. These data, combined with that collected during the 1973 and 1974 spring storm seasons, will serve as the data base for Phase II of this contract.

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APPENDIX A

The National Severe Storms Laboratory's Weather Radar System

The NSSL's WSR-57 radar is basically the same weather radar system currently used by NWS. Designed specifically for weather detection, its primary advantages are a conical beam, a receiver with sufficient dynamic range to span widely varying rainfall intensities, and a transmitter operating at a frequency of 2800 mHz--radiation that is essentially unattenuated by precipitation. Although the basic radar is not solid state, several modifications to the receiver and power supplies have stabilized system performance. In addition, equipment for real-time processing of the received signal was designed to provide calibrated contours of storm intensity. The first phase of this work was completed at NSSL in 1967. Since then, further refinements have been made to provide not only contours on the PPI, but also to write the equivalent digital replica on magnetic tape for rapid processing by computer, or for transmission to other locations.

On the other hand, the FAA ARSR1-D radar is designed and operated to direct air traffic. Since weather signals can obliterate primary return from aircraft, the FAA uses circular polarization (CP) and moving target indicator (MTI) techniques to suppress them. However, the sensitivity of the radar is high and the beam widths are sufficiently narrow to provide a relatively good estimate of precipitation intensity at ranges less than 200 km. Although too crude for use in hydrology, the data from these FAA route radars are sufficiently accurate for board classification of weak, moderate, intense, and very intense storms (Wilk et al., 1965). Also, contour mapping has been tested successfully in the Western United States where WSR-57 radars were not installed. Engineering changes required to make the radar signal output compatible with the remote display are minor, involving the use of a logarithmic response IF amplifier, an adjustable range normalization circuit, and 3-wire antenna position information.

The effectiveness of any radar system in providing useful information about storm intensity is determined by the resolving power of the beam and pulse length, system stability, and the accuracy with which the received signal can be processed, displayed, and recorded.

The intensity, I, of any storm or precipitation pattern is directly related through Probert-Jones equation (1962), to the radar received signal power, $\overline{P_r}$:

$$I = \frac{(1024 \ln 2)\, \lambda^2 r^2 P_r C}{\pi^3 P_t \theta \phi h G^2\, |K|^2} \quad . \tag{A1}$$

In logarithmic form, where the meteorological power, dBZ is defined as the power in decibels above a threshold value of I equal to unity (see, for example, Smith, 1970), we have

$$dBZ = P_{r_{dBm}} - 10[\log C' + K_a + K_p + 2 \log r] . \qquad (A2)$$

The terms K_a and K_p are corrections for the two-way attenuation by atmospehric gases and precipitation (Blake, 1970; Burrows and Attwood, 1949). These are defined in decibels per km by

$$K_a = 3.85 - 3.85\, e^{-5.5(10^{-3})r} \qquad (A3)$$

and

$$K_p = \int_{r_i}^{r_n} 6.86 \times 10^{-4}\, R\, dr \qquad (A4)$$

where r is range in km and R is rainfall rate in mm hr^{-1}. Correction for attenuation by atmospheric gases is a 'one-time' calculation based on the standard profile, and is incorporated with the r^{-2} range normalization in the radar signal processor. However, the correction for precipitation attenuation is step-wise and presently is not made in real time, but during archiving procedures with the NSSL central computer. An additional correction of about 3 dB for receiver bias is contained in C'.

In Oklahoma, $\overline{P_r}$ measurements range from about 10 dBZ for very light rain to 60 dBZ for high concentrations of rain and large hail. The radar receiver response over this range of returned power is checked at NSSL daily by inserting a test signal of known amplitude and measuring the receiver output voltage. An electronic circuit compensates for the range effect (removing r and K_a from equation [A2] and adjusting the constant).

As long as the storms are within the 'normalization' range, established for this program as 108 n mi. (200 km), the electronic range compensation adjusts the signal levels so that a contour has the same value, I, regardless of range. Beyond 108 n mi. the intensity represented by the contours changes with range and cannot be readily interpreted.

APPENDIX B

Summary of Computer Logic Used for Calibration of the Radar Display and Archiving the Data Set

As indicated in the text, the primary objective of the Remote Radar Display was to provide quasi-real-time transmission and display of quantitative weather radar information to the Flight Service Station. Contours of storm intensity selected for display to FSS pilot briefers are those indicative of hail, severe turbulence, and convective showers with high probability of cloud-to-ground lightning. As radar "signatures" of organized circulation are also important characteristics of patterns required at the FSS, the first level was set as close as possible to the minimum detectable signal of the radar.

Seven class intervals of intensity were transmitted using a 3 bit binary code. Simultaneous with this 3 bit data transmission, a 6 bit binary coded record of 64 (0-63) class intervals of intensity were recorded in the standard operational mode (Sirmans and Doviak, 1973) of NSSL on 7 track magnetic tape at the radar site. The 64 level record provides approximately 1 dB class intervals. Differences in the real time and recorded data formats are shown in Table B1.

Table B1.

Remote Radar Display and Recorded Radar Data Formats

	Remote Radar Display	Recorded Radar Record
Transmission code	3 bit	6 bit
Class intervals (intensity)	7	64
STC hardware status	On	Off
Radial collection	1°	2°
PPI coverage	Full 360°	Sector select
Collection start	0° required	Any odd-numbered radial

Computer programs were written to convert the operationally recorded data to computer tapes compatible with 3 bit line transmission for after-the-fact display. The processing program provides quality control checks on the data set, and prepares time and record indices required for continued processing (Program 73-23). The program used to generate the display tape is designated 74-115 and accomplishes the following:

1. Accepts calculated digital levels (on a scale of 0-63) which correspond to the seven class intervals transmitted to the remote display. These levels have been previously determined to correspond with different levels of intensity within the storm and are calculated using program number 74-41.

2. Range normalizes intensities to 200 kilometers (corresponding to the STC [Sensitivity Timing Circuit] hardware correction used in the transmitted data set). Options include corrections for attenuation due to atmospheric absorbtion, rainfall, and gradient bias.

3. Computes class intervals of intensity to the 7 level, 3 bit code.

4. Calculates intensity data for each 1° radial from the 2° data set.

5. Produces display tape containing "trigger" codes (to control display), housekeeping information, plus radials for the PPI from 000° through 359°. Areas void of reflectivity returns are entered as blanks (all bits off). A 2400 foot magnetic tape will store a maximum of 60 PPI display sectors.

Table B2 describes the display tape format. Table B3 is a listing of program 74-115. Information concerning programs 73-23 and 74-41 is available from NSSL. Tables B4-B6 list the radar characteristics, the correction for range and atmospheric attenuation values, and final calibration values used to select the power levels for remote display.

Table B2.

Remote Radar Display System Digital Magnetic Tape Format

The format of each radial is:

Col	1-3	Azimuth
	4-5	Elevation Angle
	6	Zero
	7-9	Julian Day
	10-15	Time (HHMMSS)
	16-19	Zero's
	20-219	Data Getes 1-200*

Each PPI sector consists of 360 such records and must begin with azimuth 000 and end with 359. Tapes are 7 track, 556 BPI, odd parity, binary.

*Only the 3 high-order bits are used for data entries.

Table B3.

A Listing of the Program Used to Generate the Display Tape

```
C
C     PGM NUMBER 74-115    MLW FOR KEN WILK         SEL 8600
C
C     PROGRAM TO PRODUCE RANGE NORMALIZED BENDIX FORMAT RADAR TAPES
C      FROM RAW WSR-57 RADAR TAPES
C
C     CARD INPUT
C
C          FIRST CARD -
C          ITH       CC1-10     F10.0      FIRST CALIB LEVEL (IN DB) ABOVE NOISE
C
C          SECOND CARD -
C          D(1-3)    CC1-30     3F10.3     DELAY (KM) CORRESPONDING TO GATE
C                                          LENGTH CODES 0,1,2
C          G(1-3)    CC31-60    3F10.3     GATE LENGTH (KM) CORRESPONDING TO
C                                          GATE LENGTH CODES 0,1,2
C
C          THIRD CARD -
C          BCALB(1-7) CC1-70 7F10.0        BENDIX CALIBRATION LEVELS - DIGITAL
C                                          LEVELS WHICH CORRESPOND TO LEVELS
C                                          1-7 ON BENDIX DISPLAY SCREEN
C
C          CARDS 4-11 -
C          CALB(1-64) CC1-80 8F10.0        64 LEVEL WSR-57 CALIBRATION
C
C          CARDS 12-N -
C          STANDARD INDEX CARDS FROM SUMMARY PROGRAM.  ONE SECTOR IS PROCESSED
C          FOR EACH INDEX CARD ENCOUNTERED
C
C     NOTE - OUTPUT TAPE RECORDS ARE 220 CHARACTERS LONG - MUST BE COPIED
C     ON 1401 USING PGM NO 74-68 TO 219 CHAR RECORDS
C
      COMMON CALB(64),RNG(200),BC(60),RFRT(64),DLY,GL,IAZ,BCALB(7),TH
      CHAR BUFF(220),ID(360,200),IHK(360,19),ITLT(2),IDTTM(9)
      CHAR IDUM(438)
      DIMENSION D(3),G(3)
      EQUIVALENCE (BUFF(1),IFULL)
      LOGICAL*1 COLL(360)
      BUFF(220) =0
C      SKIP FIRST RECORD OF EVERY TAPE
      CALL RRADAR(IDUM,LENGTH,$12345,$12345)
12345 CONTINUE
      READ(5,6)TH
      READ(5,6)D,G
    6 FORMAT(8F10.0)
      READ(5,6)BCALB
      READ(5,6)CALB
      C200=ALOG10(200.)
      A=23.02585
      DO 50 I=1,60
      DPR=.1*FLOAT(I)
   50 BC(I)=10.*(1.-.5*DPR+ALOG10((10.**DPR-1.)/(A*DPR)))
      DO 51 I=1,64
      IF(CALB(I).GT.0.)CALB(I)=-CALB(I)
      ALGZ=.1*CALB(I)+11.9716
      RFRT(I)=(10.**((ALGZ-C200)*.625))*.0394
      IF(CALB(I).EQ.0.)RFRT(I)=0.
   51 CONTINUE
1     DO 4  I=1,360
```

```
4     COLL(I)=.FALSE.
      READ(5,100,END=999) IDTTM,ITLT,IBA,IEA,IG
100   FORMAT(8X,3I1,2X,6I1,2X,2I1,12X,I3,I5,22X,I1)
      IF(IBA.EQ.999)GO TO 99
      WRITE(6,100)IDTTM,ITLT,IBA,IEA
      IF(IG.GT.2)STOP ERRG
      DLY=D(IG+1)
      GL=G(IG+1)
      R=DLY
      DO 10 I=1,200
      RNG(I)=R
   10 R=R+GL
5     CALL GTRAD(BUFF,$99)
      DO 2  I=1,9
      IF(BUFF(I+206).NE.IDTTM(I))GO TO 5
2     CONTINUE
      DO 3  I=1,2
      IF(BUFF(I+203).NE.ITLT(I))GO TO 5
3     CONTINUE
      IF((BUFF(201)*10+BUFF(202))*10+BUFF(203).NE.IBA)GO TO 5
      GO TO 8
7     CALL GTRAD(BUFF,$99)
8     DO 9  I=201,219
      IF(BUFF(I).GT.9)GO TO 98
9     CONTINUE
      IAZ=(BUFF(201)*10+BUFF(202))*10+BUFF(203)
      IF(IAZ.GT.359)GO TO 98
      COLL(IAZ+1)=.TRUE.
      IGOOD=IAZ+1
      IF(BUFF(206).EQ.1)GO TO 12
      CALL RANORM(BUFF)
   12 DO 11  I=1,19
11    IHK(IAZ+1,I)=BUFF(200+I)
      DO 13  I=1,200
13    ID(IAZ+1,I)=BUFF(I)
      IF(IAZ.NE.IEA)GO TO 7
      DO 20  I=1,360
      IF(.NOT.COLL(I))GO TO 25
      DO 21  J=1,19
21    BUFF(J)=IHK(I,J)
      DO 22  J=1,200
22    BUFF(J+19)=ID(I,J)
      IGOOD=I
      GO TO 24
25    K=I-1
      I1=K/100
      I2=(K-100*I1)/10
      I3=K-100*I1-I2*10
      BUFF(1)=I1
      BUFF(2)=I2
      BUFF(3)=I3
      DO 30  J=4,19
30    BUFF(J)=IHK(IGOOD,J)
      DO 31  J=20,219
      BUFF(J)=0
      K1=I-1
      K2=I+1
      IF(I.EQ.1)K1=360
      IF(I.EQ.360)K2=1
```

```
31      IF(COLL(K1).AND.COLL(K2))BUFF(J)=(ID(K1,J-19)+ID(K2,J-19))*.5+.5
24      CALL TPWRIT(8,BUFF,220,$888,$97)
20      CONTINUE
        GO TO 1
97      STOP WRERR
98      CALL BADRAD
        GO TO 7
888     ENDFILE 8
        REWIND 8
        PAUSE NEXTO/P
        GO TO 20
99      CALL GTREW
        PAUSE NEXT I/P
        CALL RRADAR(IDUM,LENGTH,$1,$1)
        GO TO 1
999     ENDFILE 8
        REWIND 8
        CALL GTREW
        STOP
        END


        SUBROUTINE GTRAD(BUFF,*)
C
C......READS RAW WSR-57 RADAR TAPE AND SEPARATES RADIALS
        CHAR BUFF(219),INT(438)
        EQUIVALENCE(IFULL,INT(1))
        DATA IOFF/0/,KOUNT/0/,IHAF/0/
        IF(IOFF.EQ.219)GO TO 1
98      CALL TRADAR(INT,LEN,$97,$99)
        IF(LEN.NE.438)GO TO 97
        IOFF=0
1         DO 2  J=1,219
2         BUFF(J)=INT(J+IOFF)
        IOFF=219-IOFF
        RETURN
97      KOUNT=KOUNT+1
        GO TO 98
C......END OF FILE RETURN
99      RETURN 1
C
C......REWIND INPUT TAPE
        ENTRY GTREW
        CALL RDRREW
        KOUNT=KOUNT+IHAF
        IF(KOUNT.EQ.0)RETURN
        WRITE(6,10) KOUNT
10      FORMAT(5X,I6,' RECORDS SKIPPED DUE TO READ ERRORS OR GARBAGED',
       1  ' HOUSEKEEPING.')
        RETURN
C
C......COUNT REJECTED RADIALS
        ENTRY BADRAD
        KOUNT=KOUNT+IHAF
        IHAF=1-IHAF
        RETURN
        END
```

```
      SUBROUTINE RANORM(BUFF)
C
      COMMON CALB(64),RNG(200),BC(60),RFRT(64),DLY,GL,IAZ,BCALB(7),TH
      CHAR BUFF(200)
      RN=200.
      RNS=RN*RN
      AKA=0.
      TDBL=0.
      DO 1 I=1,200
      DPR=0.
      R=RNG(I)
      IF(R.GT.200.)GO TO 11
C     RANGE CORRECTION
      K=BUFF(I)
      IF(K.EQ.0)GO TO 9
      PDBM=CALB(K)
      PW=10.**(.1*PDBM-3.)
      PN=PW*(R*R/RNS)
      PDBMN=10.*ALOG10(PN*1000.)
      IF(R.GT.40.)GO TO 6
      PTN=PDBMN
      GO TO 7
C       RAINFALL ABSORPTION CORRECTION
    6 IF(RFRT(K).EQ.0)GO TO 3
      TDBL=TDBL+(10.**(-1.80334+.96809*ALOG10(RFRT(K))))*GL
C     ATMOSPHERIC ATTENUATION CORRECTION
    3 AKA=3.85-3.85*EXP(-R*.0055)
C       GRADIENT BIAS CORRECTION
      IF(I.EQ.1)GO TO 4
      ID=IABS(K-IBB)
      IF(ID.EQ.0)GO TO 4
      DPR=BC(ID)
    4 PTN=PDBMN+TDBL+AKA+DPR
    7 IF(PTN.GE.TH)GO TO 14
      BUFF(I)=0
      GO TO9
   14 DO 2 J=1,64
      IF(PTN.GT.CALB(J))GO TO 2
      BUFF(I)=J-2
      IF(BUFF(I).LT.0)BUFF(I)=0
      GO TO 9
    2 CONTINUE
    9 IBB=K
   11 M=BUFF(I)
      DO 15 J=1,7
      IF(M.GE.BCALB(J))GO TO 15
      BUFF(I)=(J-1)*8
      GO TO 13
   15 CONTINUE
   13 CONTINUE
C     WRITE(6,10)IAZ,I,K,R,PDBM,PW,PN,PDBMN,TDBL,AKA,DPR,PTN,
C    1     M,J,BCALB(J),BUFF(I)
   10 FORMAT(3I5,2F8.1,2E12.4,5F10.2,2I5,F5.0,I5)
    1 CONTINUE
      RETURN
      END
```

Table B4.

WSR-57 Parameters

Wavelength	10 cm
Peak power	450 kW
Pulse length	4 sec
Pulse repetition frequency	164 sec^{-1}
Minimum detectable signal	-110 dBm*
Beam Width	2°
Antenna Gain	38.5 dB
Azimuthal scan rate	3 rpm for PPI displays and for magnetic tape recording

* The receiver can display a signal intensity of -110 dBm; however, the threshold signal chosen for display is -104 dBm, corresponding to $Z = 10\ mm^6m^{-3}$ at 100 n. miles.

Table B5.

Correction for Range and Atmospheric Attenuation

R_n (km)	α (dB)	$\alpha_{REF}-\alpha$ (dB)	$1/R^2$ (dB)	$1/R^2 + \alpha$* (dB)
200	2.57	0	0	0
180	2.42	.15	.92	1.07
160	2.25	.32	1.94	2.26
140	2.07	.50	3.10	3.60
120	1.86	.71	4.44	5.15
100	1.63	.94	6.02	6.96
80	1.37	1.20	7.96	9.16
60	1.08	1.49	10.46	11.95
40	.76	1.81	14.00	15.81
20	.41	2.16	20.00	22.16

R = range in km

α = two-way loss of zero degree ray in standard atmosphere

$1/R^2$ = intensity correction in dB assuming $1/R^2$

* = the composite correction is generated by adjusting the return power by adjusting the return power by 2.57 dB, the atmospheric attenuation at the reference range (200 km) and applying a correction which is equal to the difference between the true attenuation at a given range and this adjustment value.

Table B6.

Comparator Calibration

dBZ	$P_{r_{dBm}}$ + Atmospheric Corr. (2.57 dB at 200 km)	Digital Output (5/22/74 Calib.)	Encoded Values for FSS display (dBz)
10	-104.5	-	1(14)
15	-99.5	5	
20	-94.5	8	
25	-89.5	11	
30	-84.5	15	2(30)
35	-79.5	20	
40	-74.5	24	3(41)
45	-69.5	28	4(46)
50	-64.5	33	5(50)
55	-59.5	37	6(57)
60	-54.5	41	

The comparator is programmed with the correction values obtained from the receiver calibration. The 3 bit intensity-coded signal from the comparator is then fed to a level detector circuit in the data transmitter. A detector circuit was added to provide a quality control check of the comparator programming by providing a lamp indication for each of the 7 possible levels. Each of the levels are checked by slowly increasing the input power from a signal generator and then noting the setting where each lamp is lit.

APPENDIX C

FSS Staff Survey - A Summary

During periods when weather echoes were present did you incorporate the radar display in your briefings?

Occasionally (25% of the time) ______
Frequently (50% of the time) 1
Most of the time (90%-100%) 11

Range most frequently used: (Short (6) Long (0) Both (4)

Did the map overlay influence the range selected? Yes 8 No 3

What type of radar information proved to be the most useful in briefing? (Select order of priority)

Storm coverage 2
Storm location 1
Storm development 4
Storm intensity 3
Storm motion 5

} *Average priority*

Did you ever combine the information from the current National Weather Service RAREP with the radar display for briefing pilots?

Yes 12 Frequently 8
No ______ Seldom 3

Did you take advantage of the option to switch the intensity code?

Yes 10 No 2

Which coding was most used? 1230000 - *Influenced by type of weather*

What is your opinion as to the value of having this type of radar display for pilot briefing?

No value ______
Low ______
Moderate ______
High 12

What is your overall reaction to this technique of displaying radar data?

Favorable 12 Unfavorable ______

In your opinion:

Was the training provided adequate?

Yes 11 No 1

Is a formal course needed to provide adequate training?

Yes 7 No 5

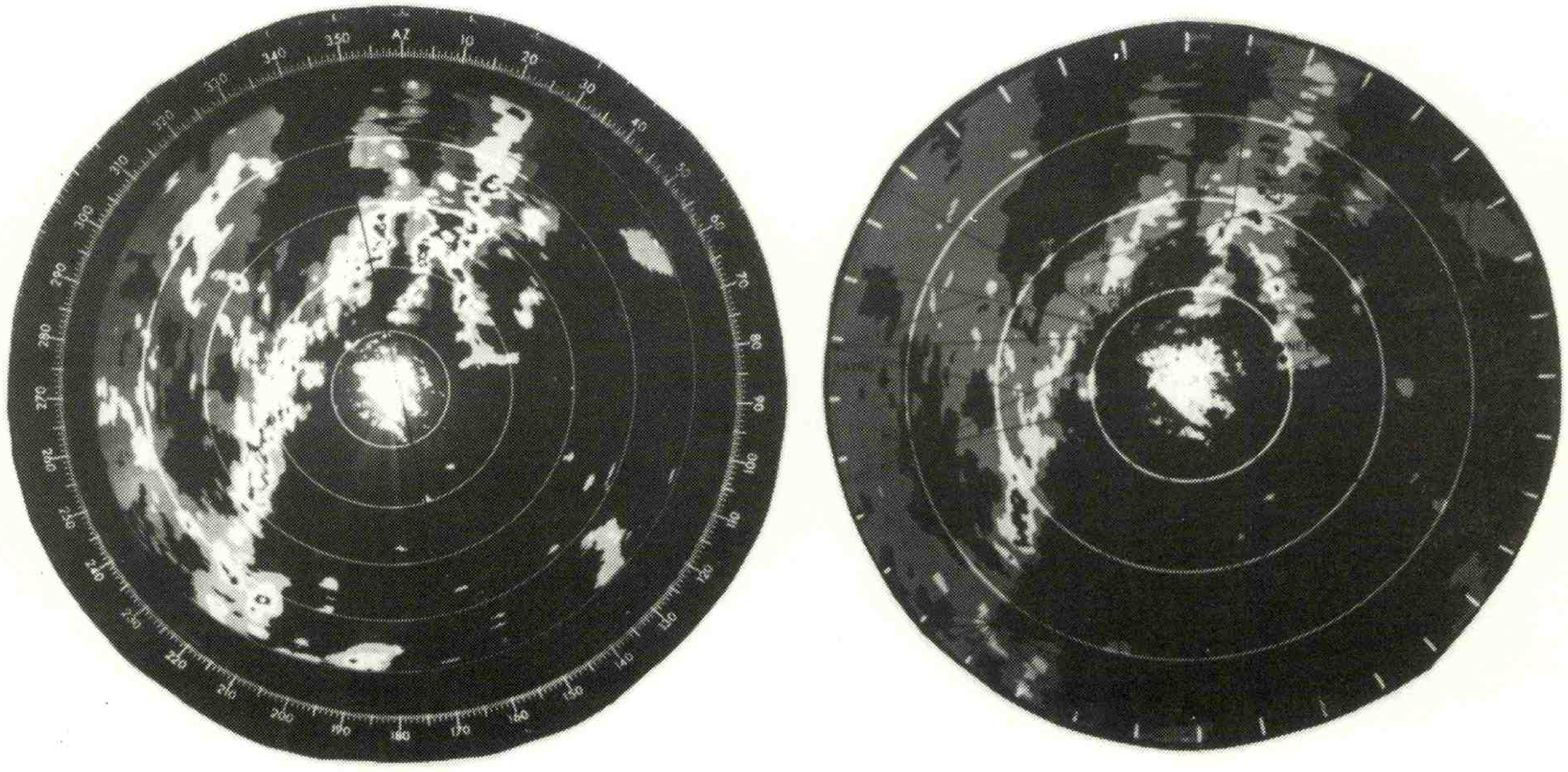
Other comments:

APPENDIX D

Summary of the Archived Data Set

The following pages contain PPI photographs which represent a cross-section of the type of weather patterns that occurred during the test period. Radar reports encoded by the National Weather Service at Oklahoma City are included for comparison. The range of the radar display and the RAREP are the same (200 km) with the exception of the PPI photographs for November 2, 1974, which are slightly off-center and expanded. The RAREP's have not been corrected so that the azimuth and range match the NSSL radar display. The date and time are shown with each set of photographs.

After the photographs, Tables D1-D3 represent a list of the number of digital PPI's recorded and transmitted to the FSS each hour during the operational test period.

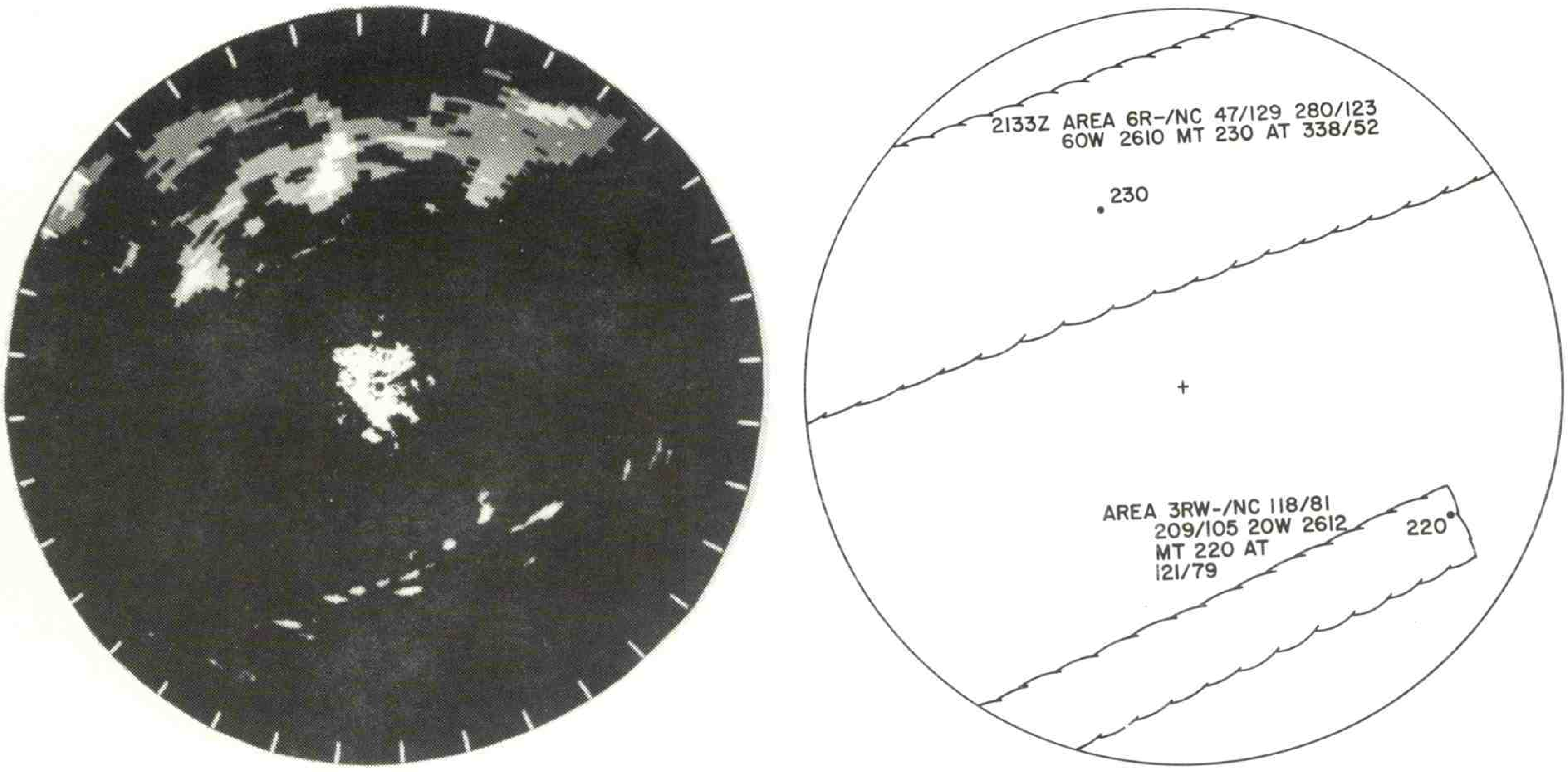


(a) 2023Z (b) 2018Z

Code III Showers and Thunderstorms

Figure D1. NSSL WSR-57 radar displays, (a) main console PPI scope, NSSL radar room, and (b) as received and displayed at the OKC FSS. The contour brightness coding at NSSL and the FSS were the same (dim, medium, cancel and bright), however, the corresponding power levels (dBZ) were encoded differently. Appropriate values at NSSL (FSS) were 10 (10), 20 (30), 30 (45), 40 (50).

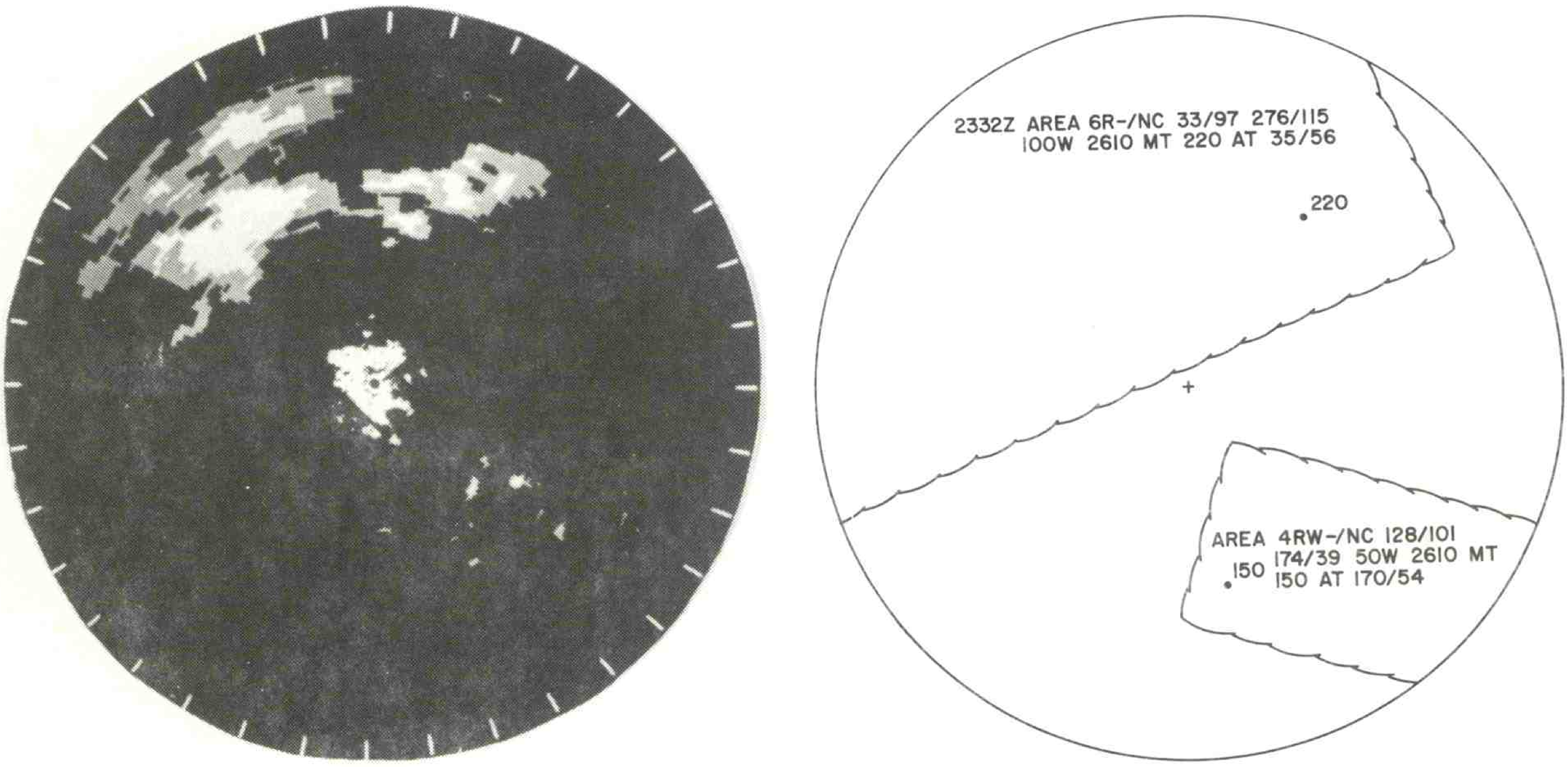
October 6, 1974



2046Z 2115Z

Code I Stratified Rain
and Scattered Showers

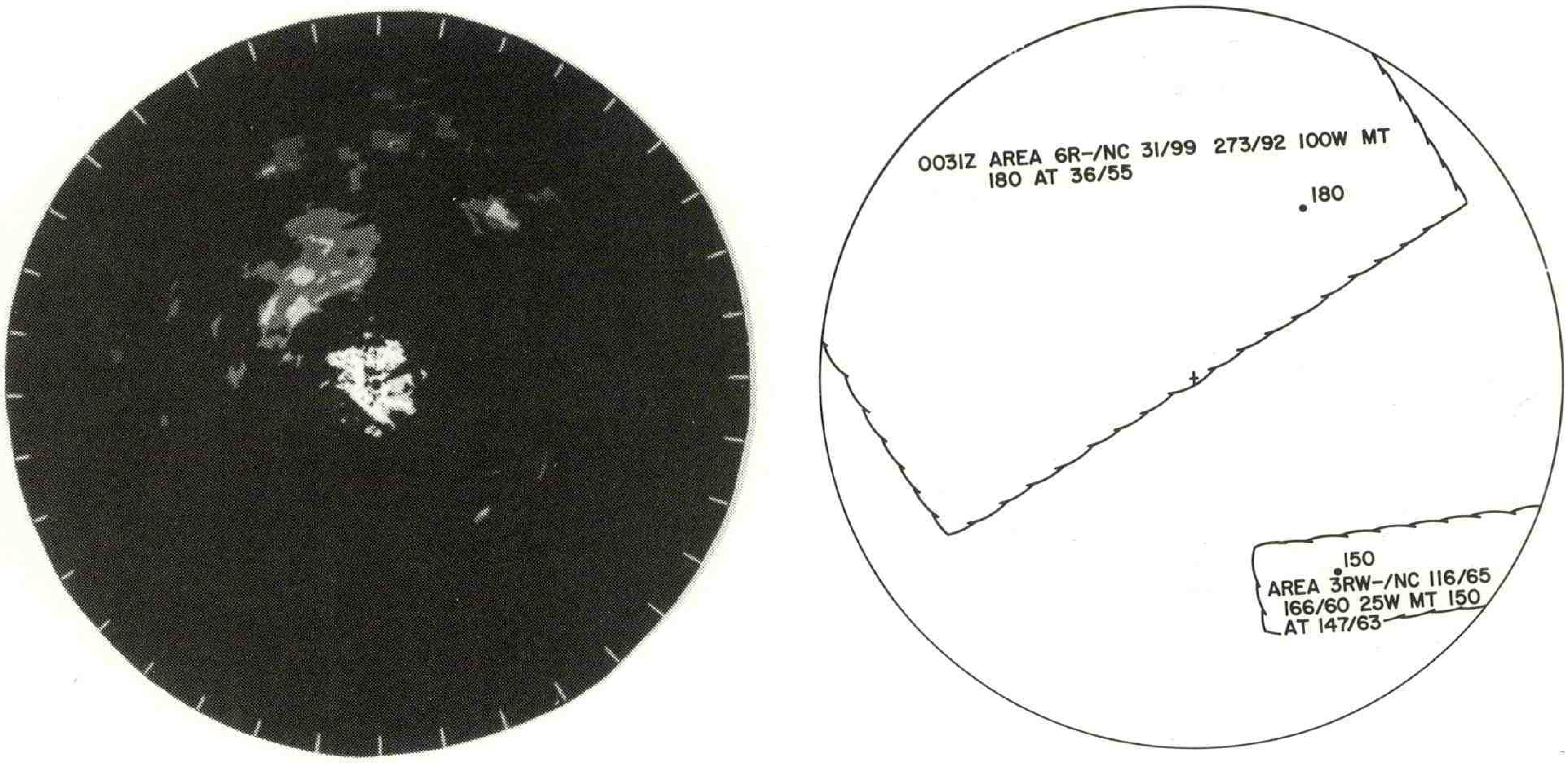
October 6, 1974



2330Z 2331Z

Code I Stratified Rain

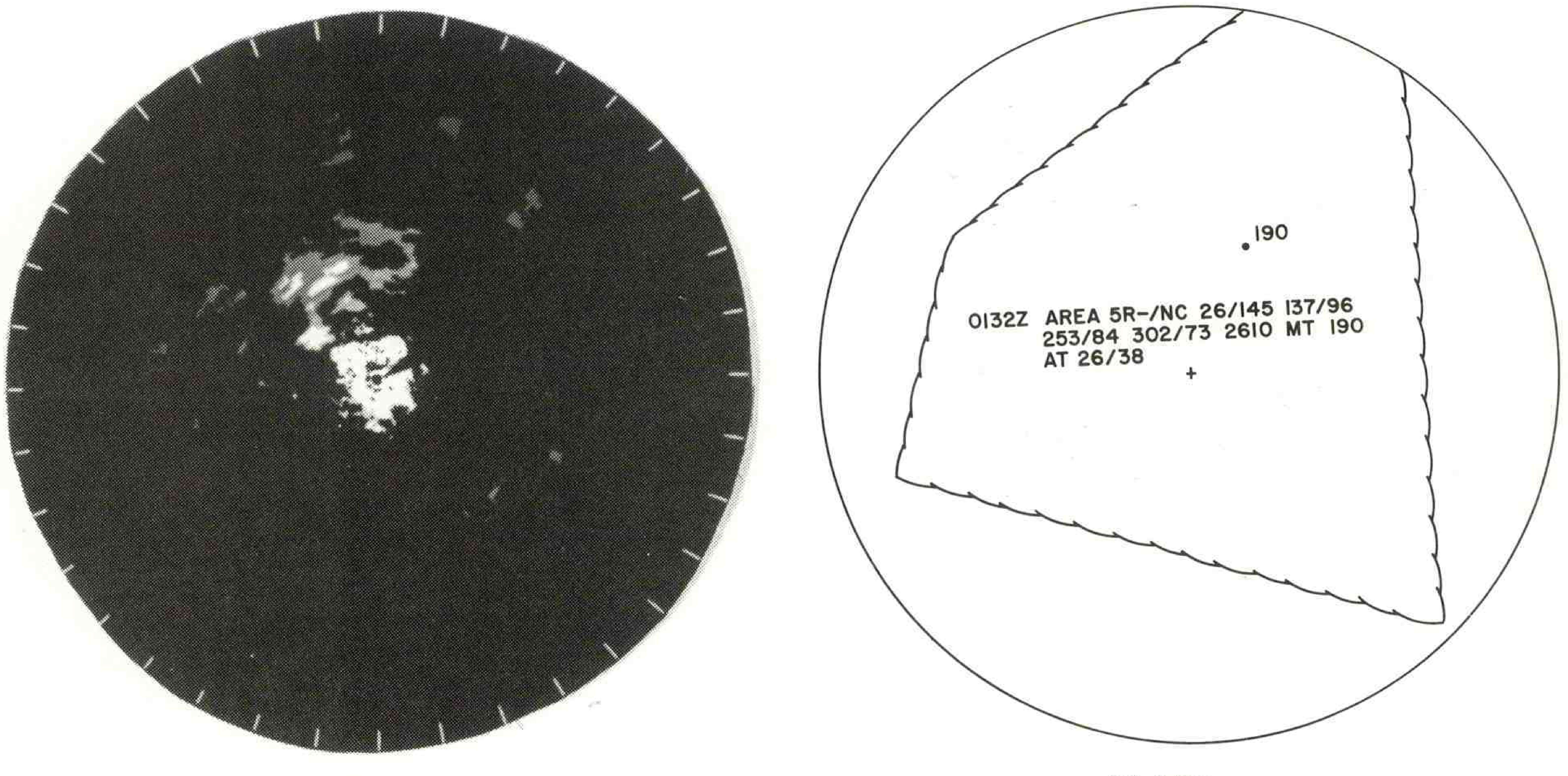
October 7, 1974



0045Z 0045Z

Code I Stratified Rain

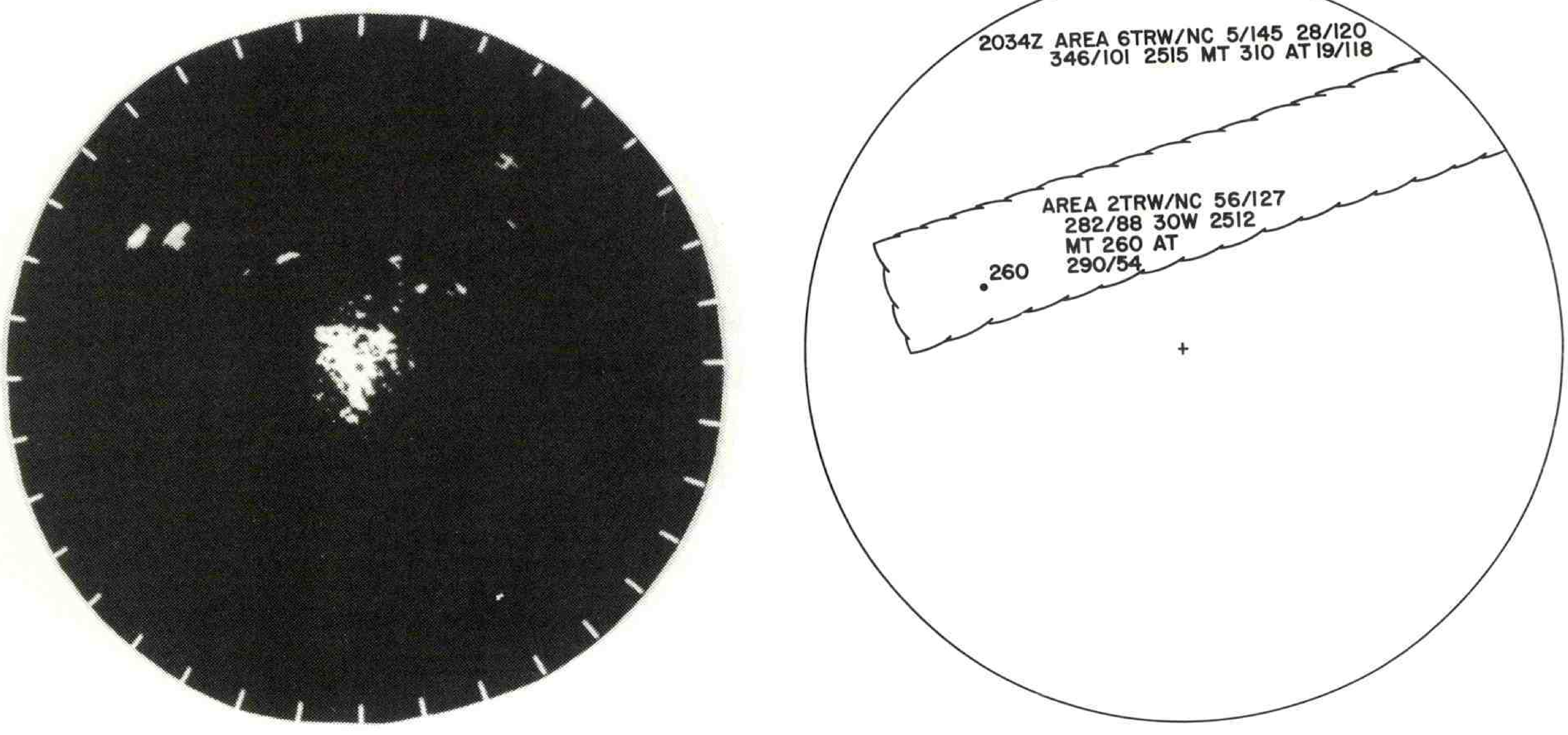
October 7, 1974



0116Z 0145Z

Code I Stratified Rain

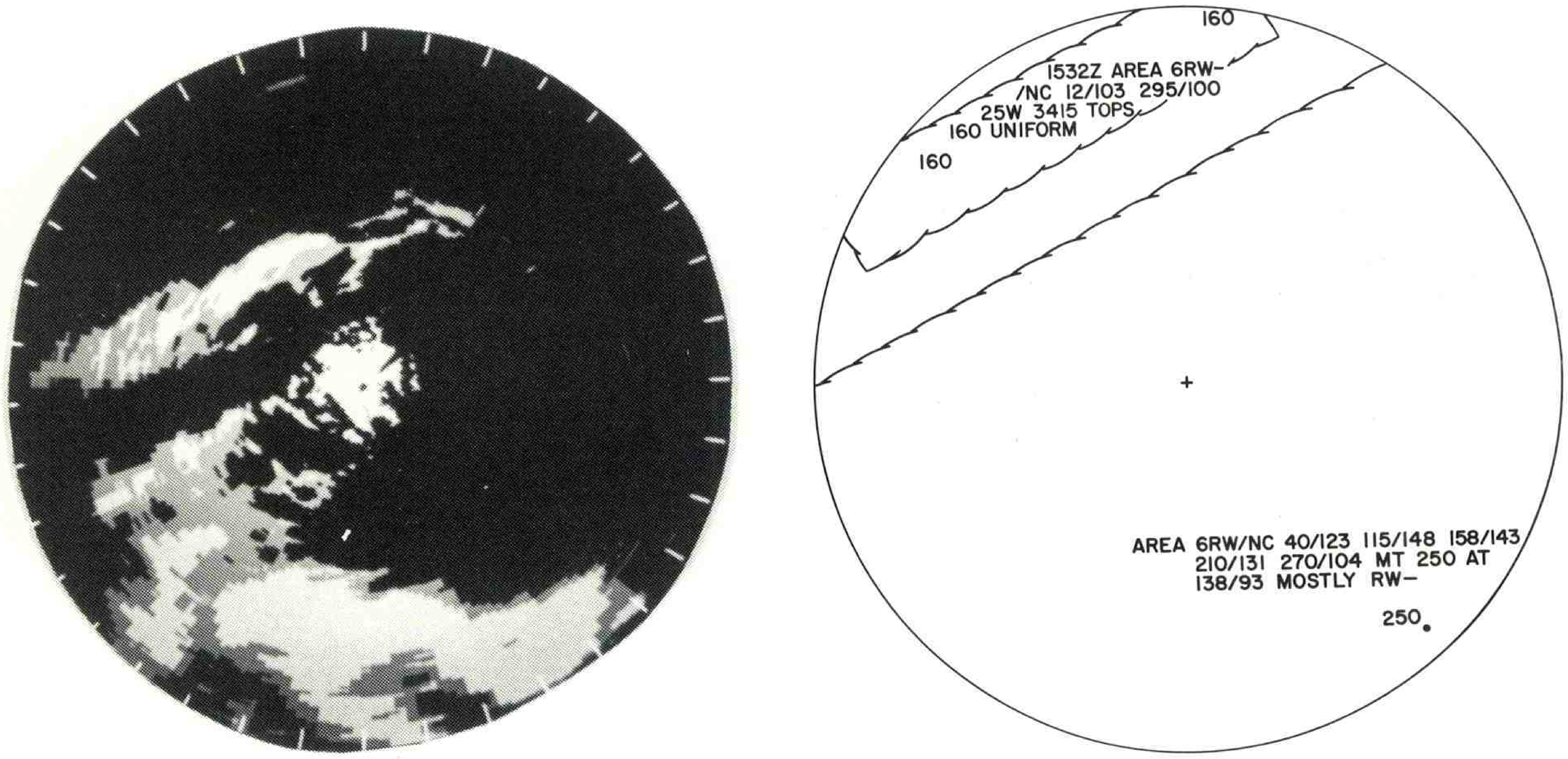
October 12, 1974



2046Z 2046Z

Code I Scattered Showers

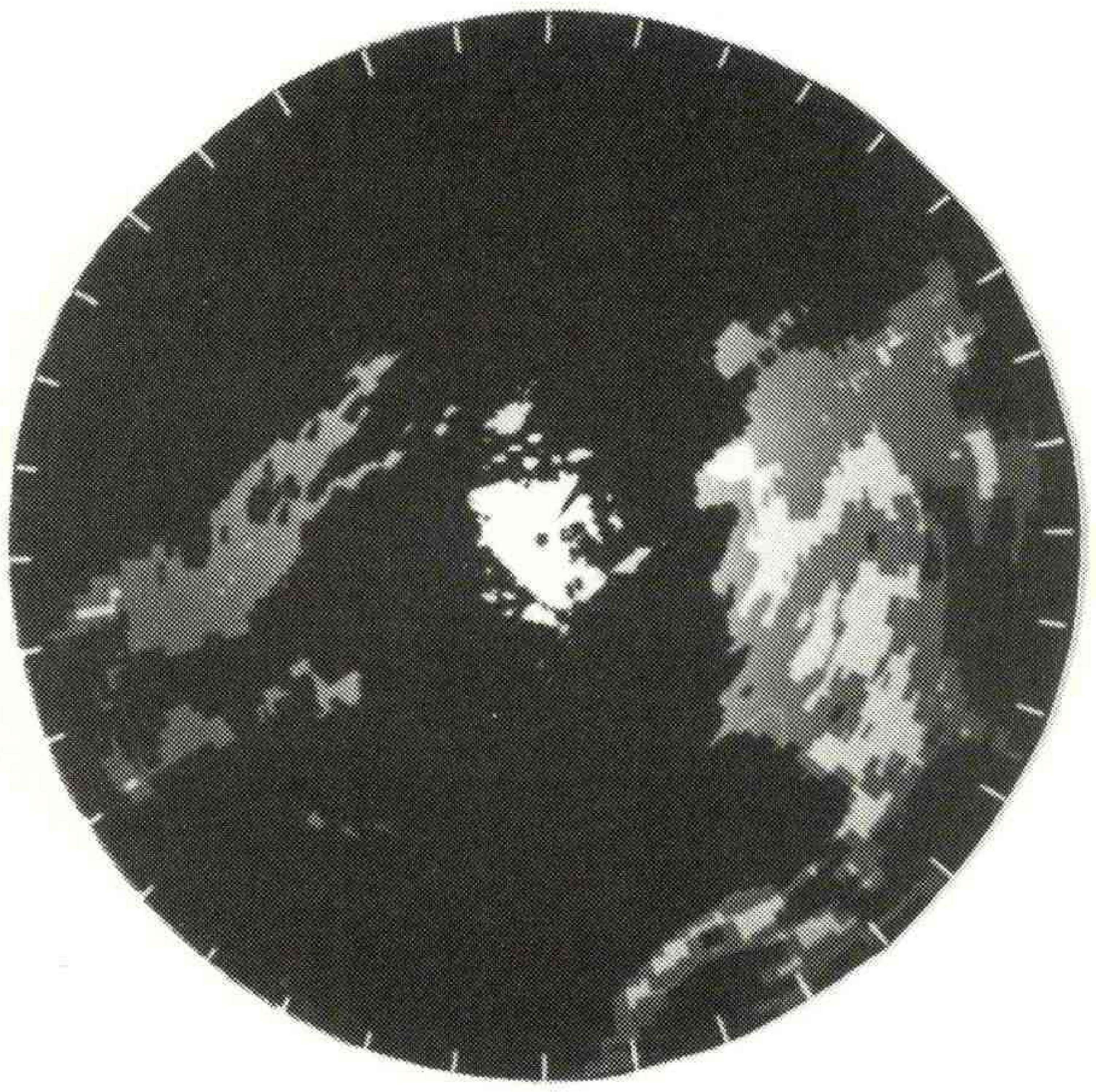
October 14, 1974



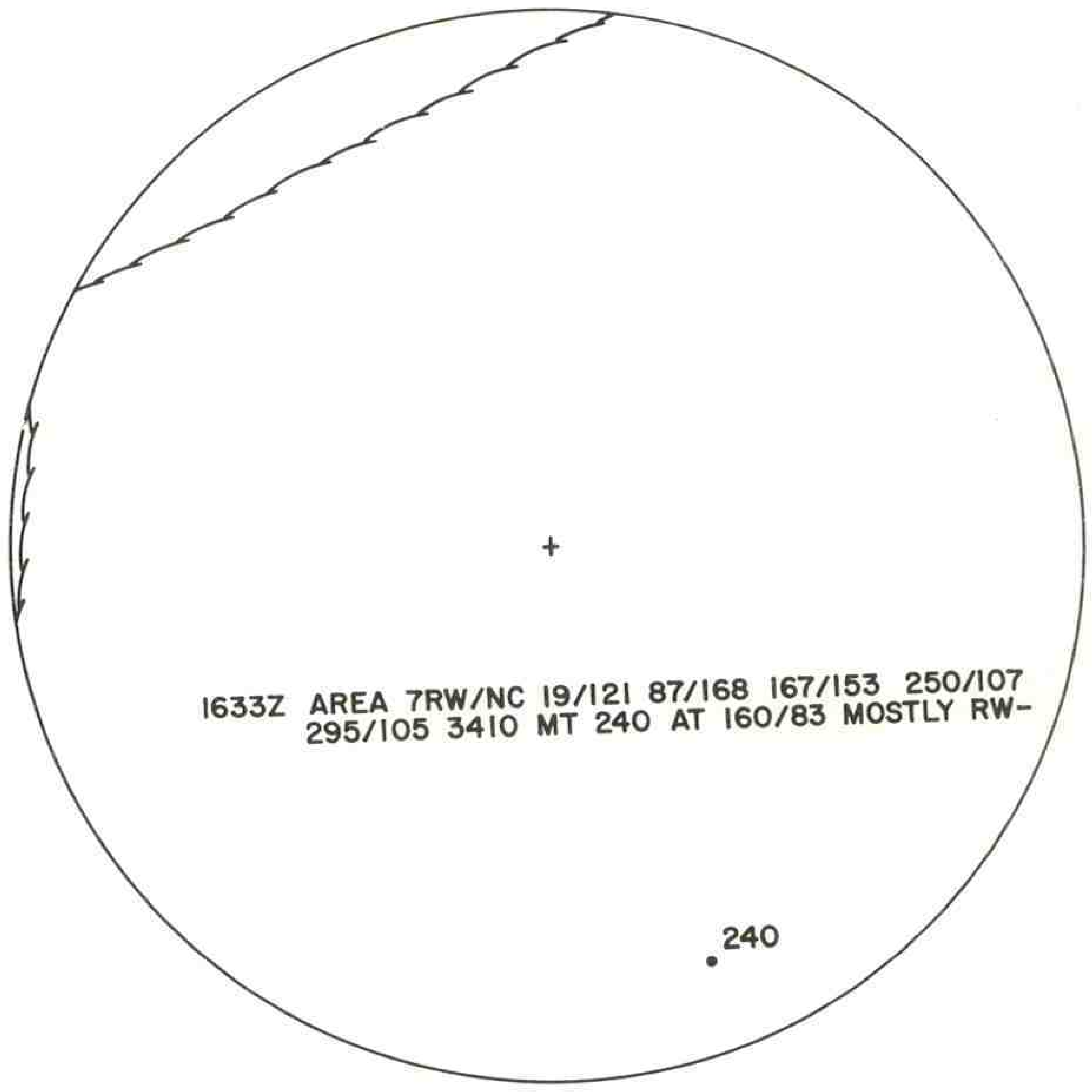
1541Z 1541Z

Code I Stratified Rain

October 14, 1974



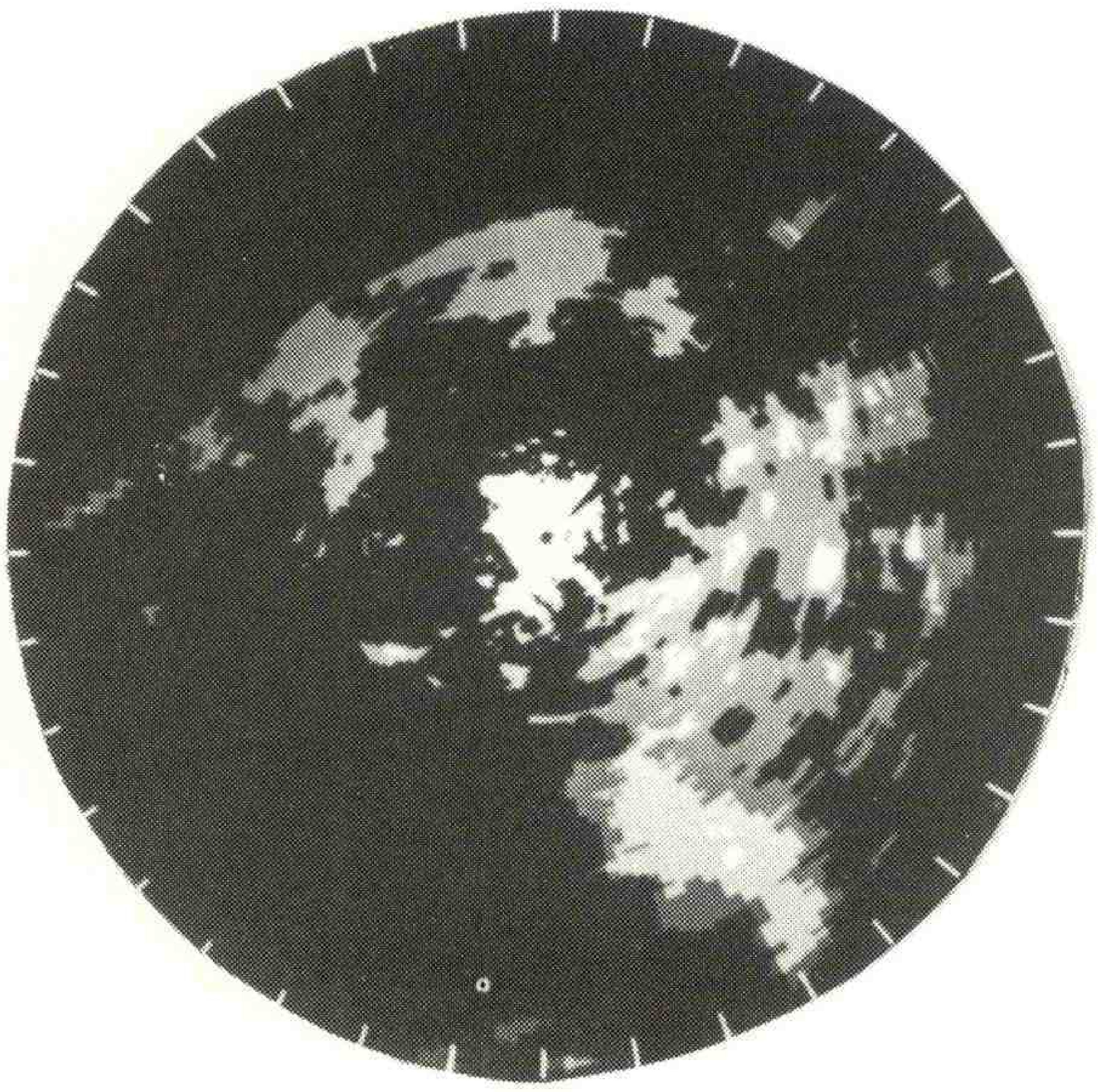
1641Z



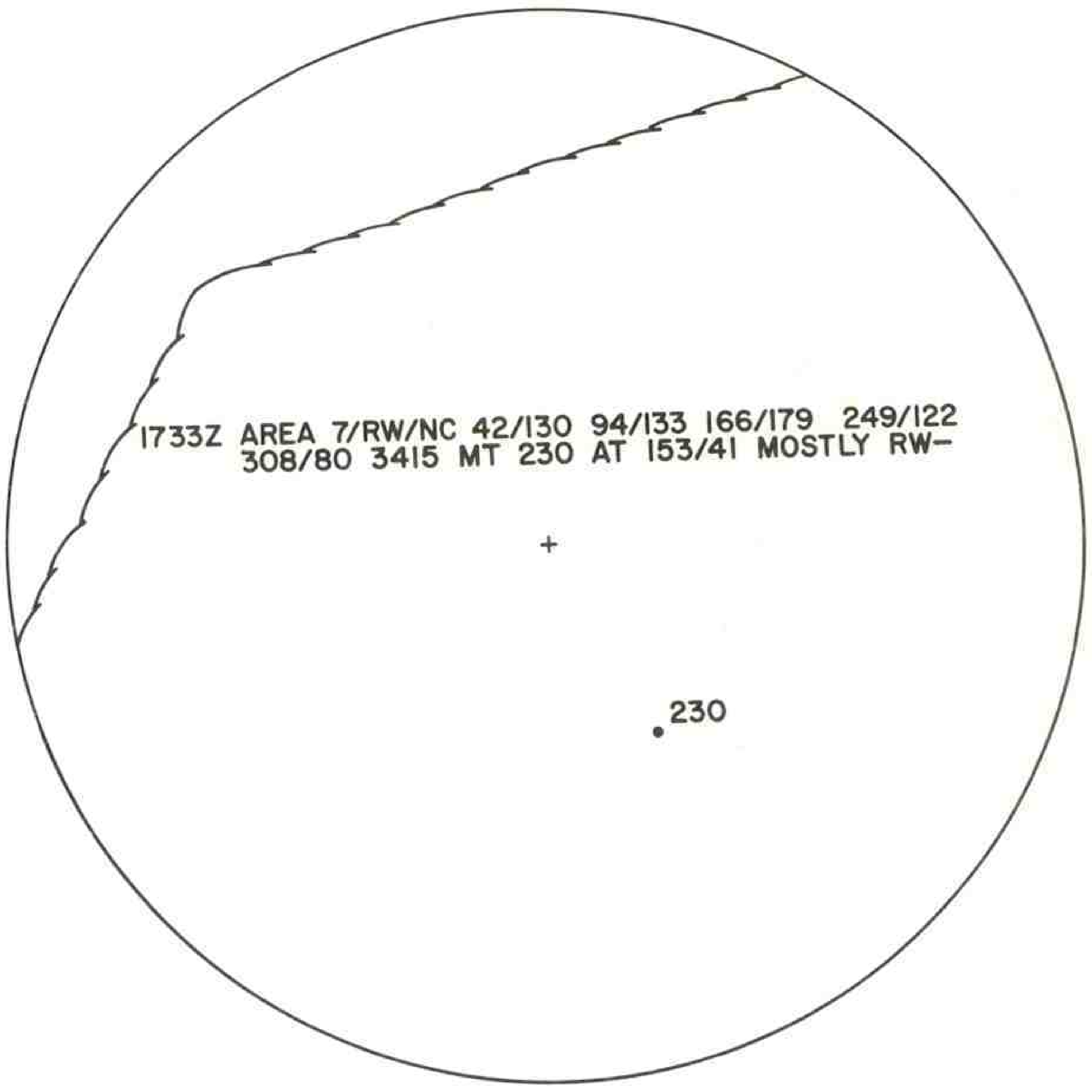
1641Z

Code I Stratified Rain

October 14, 1974



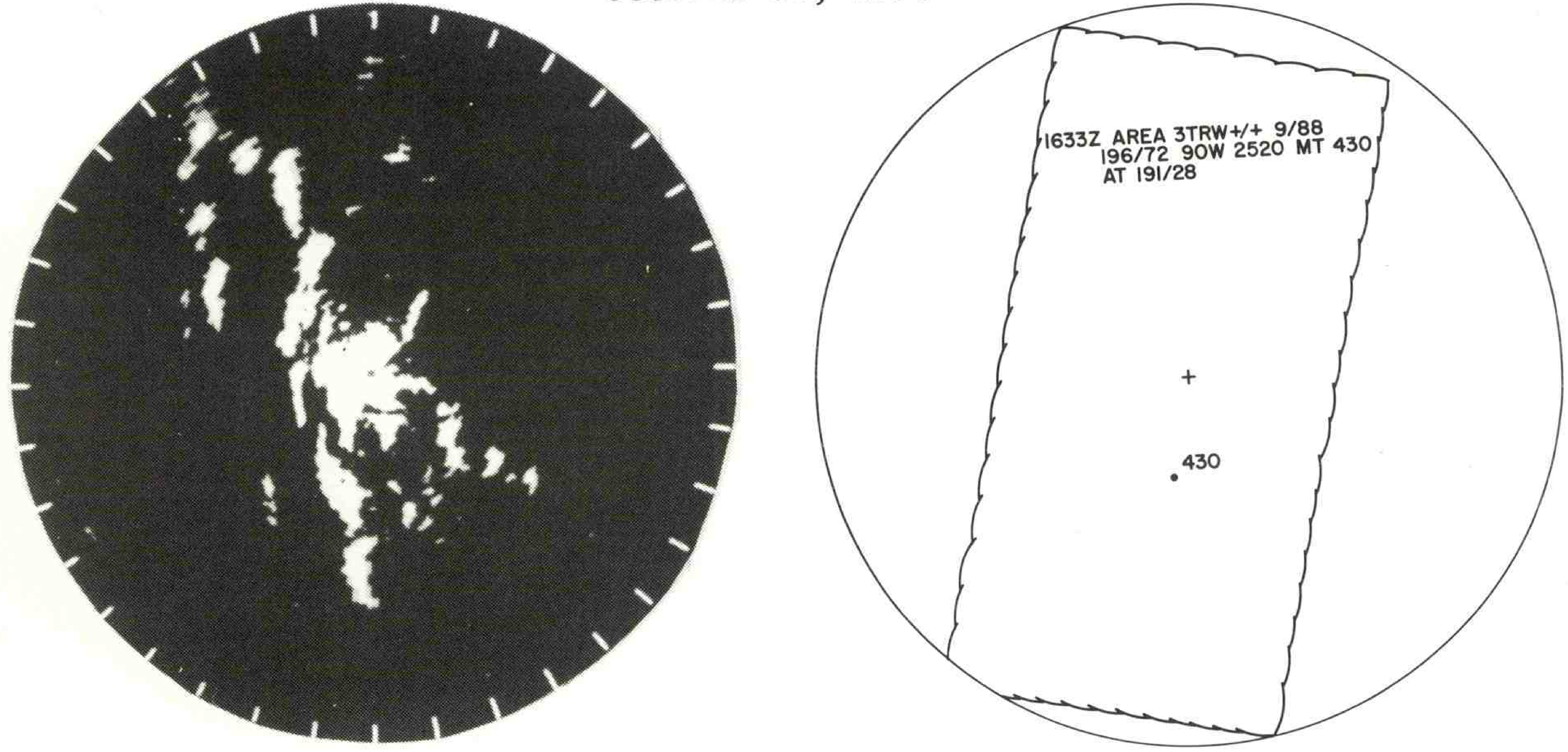
1741Z



1741Z

Code I Stratified Rain

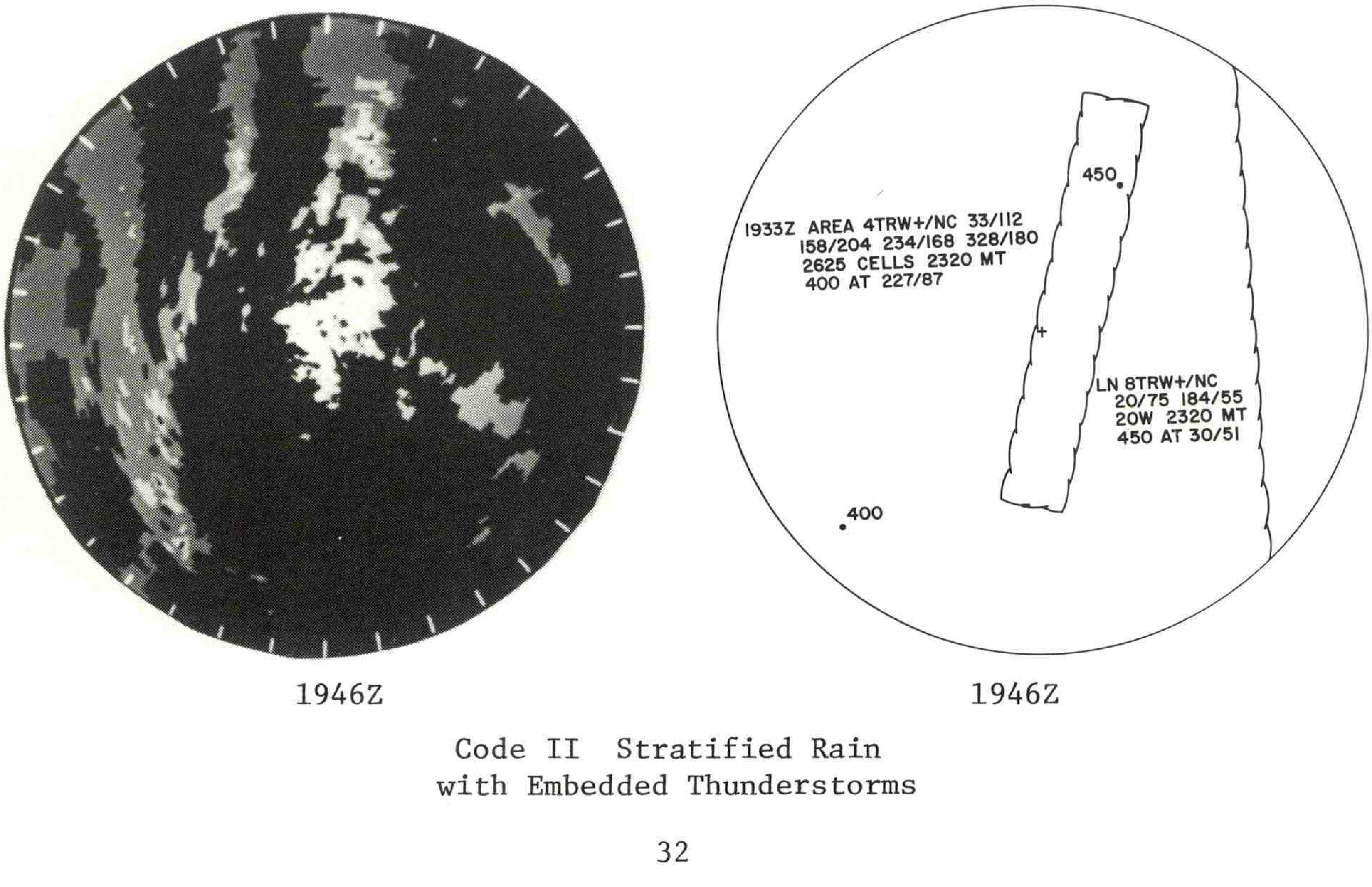
October 30, 1974



1646Z 1646Z

Code II Stratified Rain
with Embedded Thunderstorms

October 30, 1974



1946Z 1946Z

Code II Stratified Rain
with Embedded Thunderstorms

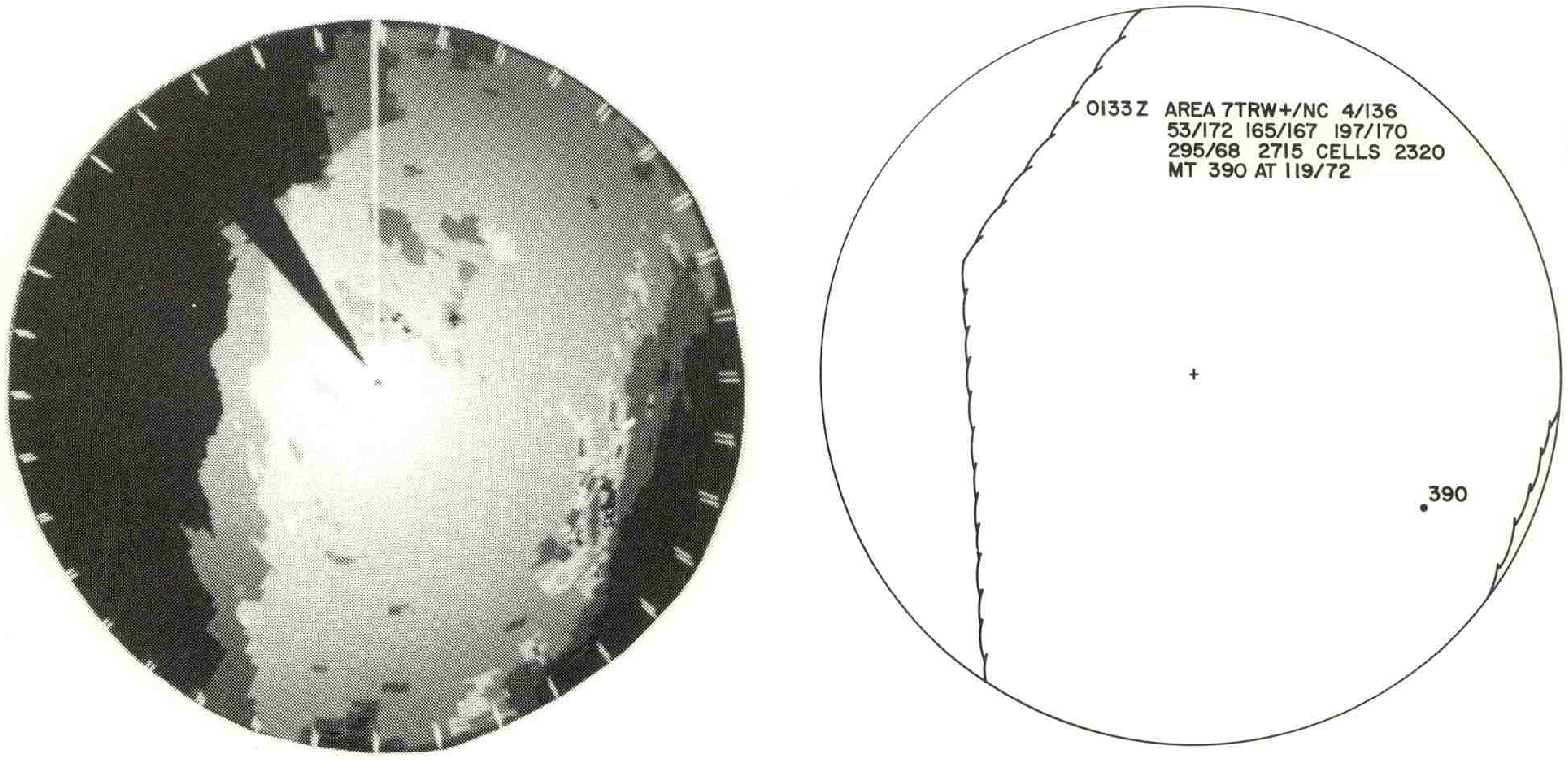
October 30, 1974

2045Z

2045Z

Code III Shower and Thunderstorms

October 31, 1974

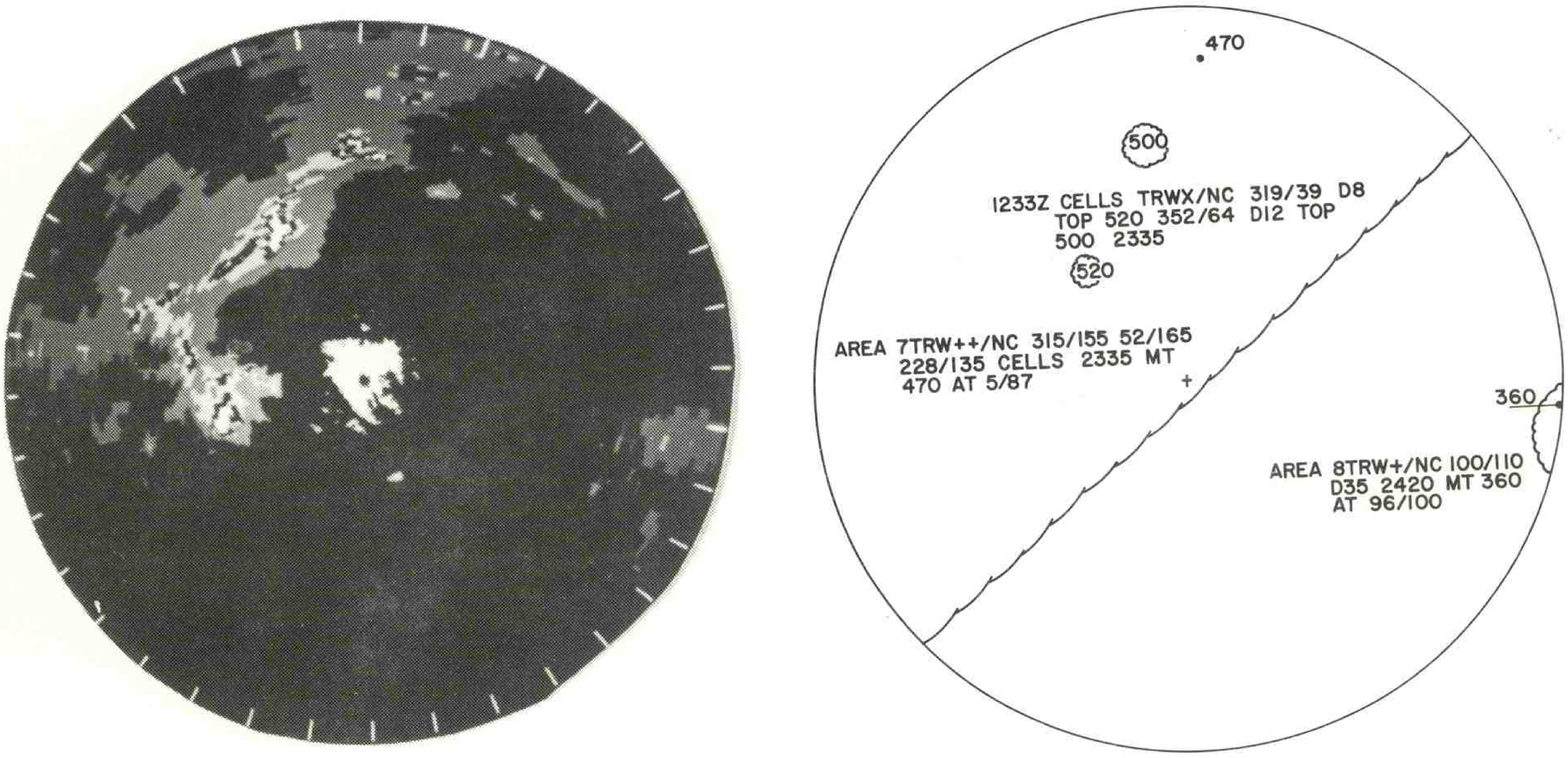


0240Z

0240Z

Code II Stratified Rain
with Embedded Thunderstorms

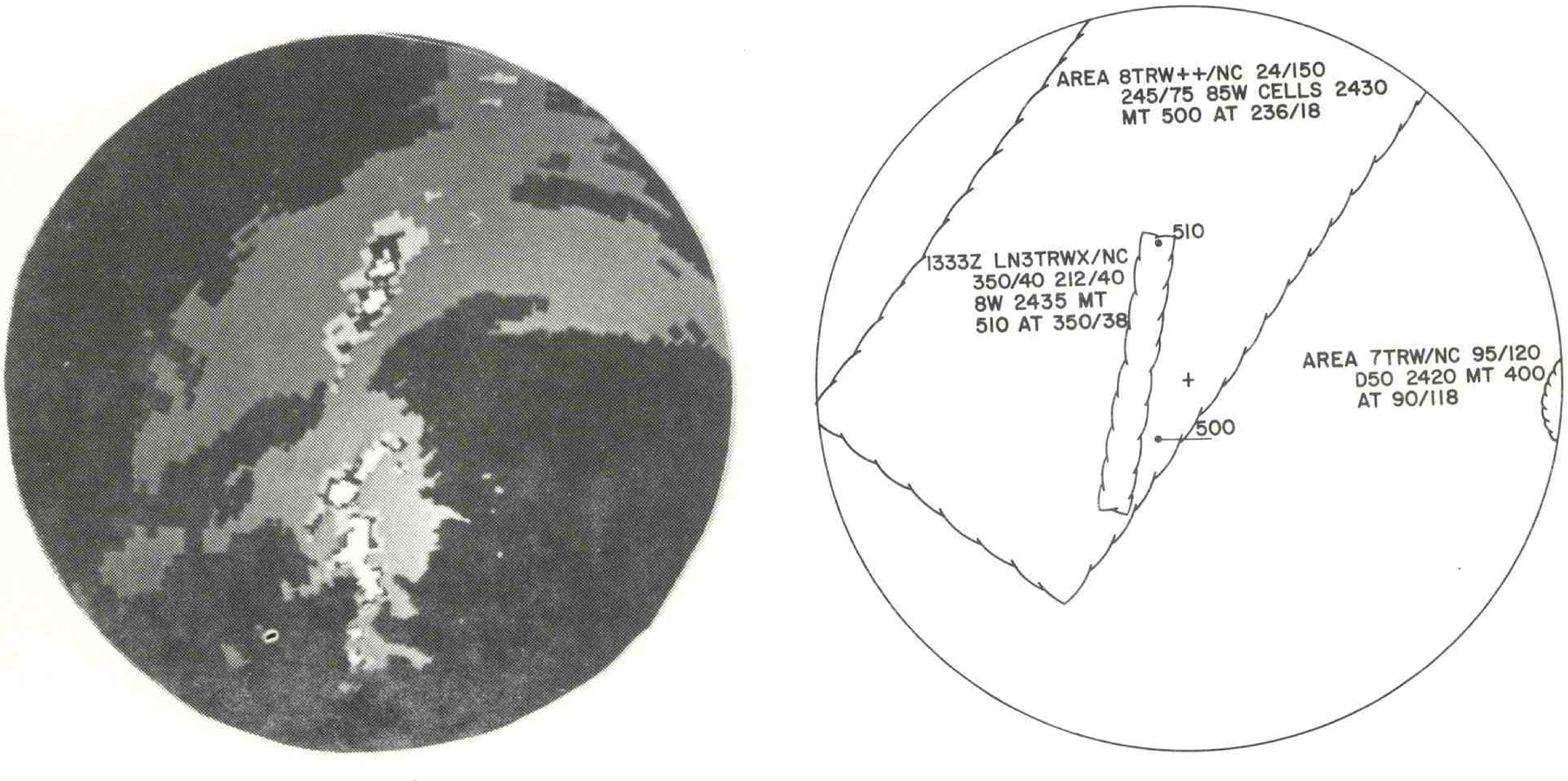
November 2, 1974



1230Z 1230Z

Code IV Severe Thunderstorms

November 2, 1974



1316Z 1331Z

Code IV Severe Thunderstorms

TABLE D1.

SEPTEMBER 1974 ARCHIVED RADAR

NUMBER OF ZERO DEGREE TILT SECTORS COLLECTED

DATE	HOUR GMT 00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1																								
2																								
3																								
4																								
5																								
6																								
7																								
8																								
9																								
10																								
11																								
12																								
13																								
14																								
15																			2	12	12	12	12	12
16	12	12	7												7	12	12	5 /	12	12	10/	9		
17																								
18																	3	12	12	11	12	12	12	12
19	12	12										7	12	33	12	12	12	12	4	12	12	12	12	12
20	12	12	1									14	12	12	12	12	12	12	12	12	12	12	12	12
21	12	11																						
22												11	12	12/										12
23	12	12	1									7	12	12	12	12	12	12	12	12	12	12	12	12
24	12	12	1									9	12	33	12	12	12	12	12	12	9	12	6	6
25	6	6	1									11	12	11										
26																								
27																						1	6	6
28	8	12	12	9								12	12	12	12	12	12							
29																								
30																								

/ -TILT DATA COLLECTED

TABLE D2.

OCTOBER 1974 ARCHIVED RADAR

NUMBER OF ZERO DEGREE TILT SECTORS COLLECTED

	HOUR GMT																							
DATE	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1														2	17/									
2																								
3																								
4																	4	12	12	12	12	7		
5													2	12	4								6	6
6	6	6	1									8	12	12	12	12	12	12	12	12	12	12	12	12
7	12	12	1									10	12	12	12	11	12	12						
8																								
9																								
10																								
11																								
12												9	12	12	12	3		9	12	12	12	12	12	12
13	12	10										10	12	12	12	12	10/	12	12	13	12	12	12	12
14	9 /	12									2	12	12	12	7	6	6	6	6	6	6	6	6	6
15	6	6	1																					
16																								
17																39/								
18																								
19																								
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22																								
23																								
24																								
25																					4	12	12	12
26	12	12	9																					
27																								
28																								
29																								
30															6	12	12	12	12	22	48	35/	13	7
31	6	6	6	6	3										5	6	6	6	6					

/ -TILT DATA COLLECTED

TABLE D3.

NOVEMBER1974 ARCHIVED RADAR

NUMBER OF ZERO DEGREE TILT SECTORS COLLECTED

HOUR GMT

DATE	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1																								
2													17	21/	0 /	0 /	0 /	0 /	1 /	3 /	1 /	12	12	32
3	13	12	12	12	12	12	1						2	12	11	12	12	12	12	12	12	12	12	12
4	12	12	12	12	1																			
5																								
6																								
7															6	12	12	12	12	11	11	12	7	
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28																								
29																	7	12	12	12	12			
30																								

/ -TILT DATA COLLECTED

GPO 911-847