NOAA Technical Memorandum NWS ER-59

DIGITAL RADAR DATA AND ITS APPLICATION IN FLASH FLOOD FORECASTING

David D. Sisk
WSFO Pittsburgh, Pa.

Scientific Services Division
Eastern Region Headquarters
March 1975

noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION / National Weather Service

NOAA TECHNICAL MEMORANDA
National Weather Service, Eastern Region Subseries

The National Weather Service Eastern Region (ER) Subseries provides an informal medium for the documentation and quick dissemination of results not appropriate, or not yet ready for formal publications. The series is used to report on work in progress, to describe technical procedures and practices, or to relate progress to a limited audience. These Technical Memoranda will report on investigations devoted primarily to regional and local problems of interest mainly to ER personnel, and hence will not be widely distributed.

Papers 1 to 22 are in the former series, ESSA Technical Memoranda, Eastern Region Technical Memoranda (ERTM); papers 23 to 37 are in the former series, ESSA Technical Memoranda, Weather Bureau Technical Memoranda (WBTM). Beginning with 38, the papers are now part of the series, NOAA Technical Memoranda NWS.

Papers 1 to 22 are available from the National Weather Service Eastern Region, Scientific Services Division, 585 Stewart Avenue, Garden City, N.Y. 11530. Beginning with 23, the papers are available from the National Technical Information Service, U.S. Department of Commerce, Sills Bldg., 5285 Port Royal Road, Springfield, Va. 22151. Prices vary for paper copy; $2.25 microfiche. Order by accession number shown in parentheses at end of each entry.

ESSA Technical Memoranda

ERTM 1 Local Uses of Vorticity Prognoses in Weather Prediction. Carlos R. Dunn April 1965
ERTM 2 Application of the Barotropic Vorticity Prognostic Field to the Surface Forecast Problem. Silvio G. Simplicio. July 1965
ERTM 3 A Technique for Deriving an Objective Precipitation Forecast Scheme for Columbus, Ohio. Robert Kuessner. September 1965
ERTM 4 Stepwise Procedures for Developing Objective Aids for Forecasting the Probability of Precipitation. Carlos R. Dunn. November 1965
ERTM 5 A Comparative Verification of 300 mb. Winds and Temperatures Based on NMC Computer Products Before and After Manual Processing. Silvio G. Simplicio. March 1966
ERTM 6 Evaluation of OFDEV Technical Note No. 17. Richard M. DeAngelis. March 1966
ERTM 7 Verification of Probability of Forecasts at Hartford, Connecticut, for the Period 1963-1965. Robert B. Wassall. March 1966
ERTM 8 Forest-Fire Pollution Episode in West Virginia November 8-12, 1964. Robert O. Weedfall. April 1966
ERTM 9 The Utilization of Radar in Meso-Scale Synoptic Analysis and Forecasting. Jerry D. Hill. March 1966
ERTM 10 Preliminary Evaluation of Probability of Precipitation Experiment. Carlos R. Dunn. May 1966
ERTM 11 Final Report. A Comparative Verification of 300 mb. Winds and Temperatures Based on NMC Computer Products Before and After Manual Processing. Silvio G. Simplicio. May 1966
ERTM 12 Summary of Scientific Services Division Development Work in Sub-Synoptic Scale Analysis and Prediction - Fiscal Year 1966. Fred L. Zuckerberg.
ERTM 13 A Survey of the Role of Non-Adiabatic Heating and Cooling in Relation of the Development of Mid-Latitude Synoptic Systems. Constantine Zois. July 1966
ERTM 14 The Forecasting of Extratropical Onshore Gales at the Virginia Capes. Glen V. Sachse. August 1966
ERTM 15 Solar Radiation and Clover Temperatures. Alex J. Kish. September 1966
ERTM 16 The Effects of Dams, Reservoirs and Levees on River Forecasting. Richard M. Greening. September 1966
ERTM 17 Use of Reflectivity Measurements and Reflectivity Profiles for Determining Severe Storms. Robert E. Hamilton. October 1966
ERTM 18 Procedure for Developing a Nomograph for Use in Forecasting Phenological Events from Growing Degree Days. John C. Purvis and Milton Brown. December 1966
ERTM 19 Snowfall Statistics for Williamsport, Pa. Jack Hummel. January 1967
ERTM 20 Forecasting Maturity Date of Snap Beans in South Carolina. Alex J. Kish. March 1967
ERTM 21 New England Coastal Fog. Richard Fay. April 1967
ERTM 22 Rainfall Probability at Five Stations Near Pickens, South Carolina, 1957-1963. John C. Purvis. April 1967
WBTM ER 23 A Study of the Effect of Sea Surface Temperature on the Areal Distribution of Radar Detected Precipitation Over the South Carolina Coastal Waters. Edward Paquet. June 1967 (PB-180-612)
WBTM ER 24 An Example of Radar as a Tool in Forecasting Tidal Flooding. Edward P. Johnson. August 1967 (PB-180-613)
WBTM ER 25 Average Mixing Depths and Transport Wind Speeds over Eastern United States in 1965. Marvin E. Miller. August 1967 (PB-180-614)
WBTM ER 26 The Sleet Bright Band. Donald Marier. October 1967 (PB-180-615)
WBTM ER 27 A Study of Areas of Maximum Echo Tops in the Washington, D.C. Area During the Spring and Fall Months. Marie D. Fellechner. April 1968 (PB-179-339)
WBTM ER 28 Washington Metropolitan Area Precipitation and Temperature Patterns. C.A. Woollum and N.L. Canfield. June 1968 (PB-179-340)
WBTM ER 29 Climatological Regime of Rainfall Associated with Hurricanes after Landfall. Robert W. Schoner. June 1968 (PB-179-341)
WBTM ER 30 Monthly Precipitation - Amount Probabilities for Selected Stations in Virginia. M.H. Bailey. June 1968 (PB-179-342)
WBTM ER 31 A Study of the Areal Distribution of Radar Detected Precipitation at Charleston, S.C. S.K. Parrish and M.A. Lopez. October 1968 (PB-180-480)
WBTM ER 32 The Meteorological and Hydrological Aspects of the May 1968 New Jersey Floods. Albert S. Kachic and William Long. February 1969 (Revised July 1970) (PB-194-222)
WBTM ER 33 A Climatology of Weather that Affects Prescribed Burning Operations at Columbia, South Carolina. S.E. Wasserman and J.D. Kanupp. December 1968 (COM-71-00194)
WBTM ER 34 A Review of Use of Radar in Detection of Tornadoes and Hail. R.E. Hamilton. December 1969 (PB-188-315)
WBTM ER 35 Objective Forecasts of Precipitation Using PE Model Output. Stanley E. Wasserman. July 1970 (PB-193-378)
WBTM ER 36 Summary of Radar Echoes in 1967 Near Buffalo, N.Y. Richard K. Sheffield. September 1970 (COM-71-00310)
WBTM ER 37 Objective Mesoscale Temperature Forecasts. Joseph P. Sobel. September 1970 (COM-71-0074)

NOAA Technical Memoranda NWS

NWS ER 38 Use of Primitive Equation Model Output to Forecast Winter Precipitation in the Northeast Coastal Sections of the United States. Stanley E. Wasserman and Harvey Rosenblum. December 1970 (COM-71-00138)
NWS ER 39 A Preliminary Climatology of Air Quality in Ohio. Marvin E. Miller. January 1971 (COM-71-00204)
NWS ER 40 Use of Detailed Radar Intensity Data in Mesoscale Surface Analysis. Robert E. Hamilton. March 1971 (COM-71-00573)
NWS ER 41 A Relationship Between Snow Accumulation and Snow Intensity as Determined from Visibility. Stanley E. Wasserman and Daniel J. Monte May 1971 (COM-71-00763)
NWS ER 42 A Case Study of Radar Determined Rainfall as Compared to Rain Gage Measurements. Martin Ross. July 1971 (COM-71-00897)
NWS ER 43 Snow Squalls in the Lee of Lake Erie and Lake Ontario. Jerry D. Hill. August 1971 (COM-72-00959)
NWS ER 44 Forecasting Precipitation Type at Greer, South Carolina. John C. Purvis. December 1971 (COM-72-10332)
NWS ER 45 Forecasting Type of Precipitation. Stanley E. Wasserman. January 1972 (COM-72-10316)
NWS ER 46 An Objective Method of Forecasting Summertime Thunderstorms. John F. Townsend and Russell J. Younkin. May 1972 (COM-72-10765)
NWS ER 47 An Objective Method of Preparing Cloud Cover Forecasts. James R. Sims. August 1972 (COM-72-11382)
NWS ER 48 Accuracy of Automated Temperature Forecasts for Philadelphia as Related to Sky Condition and Wind Direction. Robert B. Wassall. September 1972 (COM-72-11473)
NWS ER 49 A Procedure for Improving National Meteorologiacal Center Objective Precipitation Forecasts. Joseph A. Ronco, Jr. November 1972 (COM-73-10132)
NWS ER 50 PEATMOS Probability of Precipitation Forecasts as an Aid in Predicting Precipitation Amounts. Stanley E. Wasserman. December 1972 (COM-73-10243)
NWS ER 51 Frequency and Intensity of Freezing Rain/Drizzle in Ohio. Marvin E. Miller. February 1973 (COM-73-10570)
NWS ER 52 Forecast and Warning Utilization of Radar Remote Facsimile Data. Robert E. Hamilton. July 1973 (COM-73-11275)
NWS ER 53 Summary of 1969 and 1970 Public Severe Thunderstorm and Tornado Watches Within the National Weather Service, Eastern Region. Marvin E. Miller and Lewis H. Ramey. October 1973 (COM-74-10160)
NWS ER 54 A Procedure for Improving National Meteorological Center Objective Precipitation Forecasts - Winter Season. Joseph A. Ronco, Jr. November 1973 (COM-74-10200)
NWS ER 55 Cause and Prediction of Beach Erosion. Stanley E. Wasserman and David B. Gilhousen. December 1973 (COM-74-10036)
NWS ER 56 Biometeorological Factors Affecting the Development and Spread of Plant Diseases. V. J. Valli. July 1974 (COM-74-11625/AS)
NWS ER 57 Heavy Fall and Winter Rain In The Carolina Mountains. David B. Gilhousen. October 1974 (COM-74-11761/AS)
NWS ER 58 An Analysis of Forecasters' Propensities In Maximum/Minimum Temperature Forecasts. I. Randy Racer. November 1974 (COM-75-10063/AS)

(Continued On Inside Rear Cover)

NOAA Technical Memorandum NWS ER-59

DIGITAL RADAR DATA AND ITS APPLICATION IN FLASH FLOOD FORECASTING

David D. Sisk
WSFO Pittsburgh, Pa.

Scientific Services Division
Eastern Region Headquarters
March 1975

UNITED STATES
DEPARTMENT OF COMMERCE
Frederick B. Dent, Secretary

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION
Robert M. White, Administrator

National Weather
Service
George P. Cressman, Director

INTRODUCTION

This paper describes Digitized Radar Experiments (D/RADEX) now being conducted at the Weather Service Meteorological Observatory in Pittsburgh (WSMO PIT). In these experiments, development, testing and evaluation of techniques are in progress for automatic processing and presentation of weather radar data in real-time for operational applications. Basically, a minicomputer and its related processing and interface equipment are used to take over control of the radar for approximately twenty seconds to collect radar video returns for archiving and printout displays. D/RADEX is a project of the Systems Development Office, National Weather Service.

WORKING CONCEPT OF D/RADEX

A WSR-57 PPI (Plan Position Indicator) scope is scanned automatically every twelve minutes, at H+00, H+12...H+48, by the minicomputer. The information can also be collected every six minutes if needed. The radar video returns are collected as observed for each 2° of azimuth and for each one nautical mile (n.m.) (1.852 Km.) of range from 11 to 125 n.m. (20-232 Km.), at an antenna elevation of 1/2°. The data are stored in the computer's memory, and then archived on magnetic tape for future use. Since the radar operator at all times can have complete manual control of the radar and thus can prevent a scheduled D/RADEX observation, D/RADEX has been designed to "retry" automatically, within a five-minute wait period, to perform its twenty-second scan function.

After each observation various printout digital displays can be routinely requested and obtained at WSMO PIT. Among these are:

1. A standard digital IJ MATRIX printout of the radar video returns as observed from the WSR-57 PPI console, with circular 25 n.m. (46 Km.) range marks indicated out to a 100 n.m. (185 Km.) radius (Figure 1). This display became effective March 1975. The WSMO site is located at grid point 0,0 with grid point interval increments of 5 n.m. (9.3 Km.) north to south and 3 n.m. (5.6 Km.) east to west. Each digit represents the maximum Video Integration and Processor (VIP) level (1-6) occurring within each square of size 3 x 5 n.m. (15 sq. n.m.). The first 10 n.m. (18.5 Km.) radius is blanked out. Ground clutter, which cannot be distinguished from precipitation in the program, appears within approximately the first 25 n.m. (46 Km.). Echo returns of the mountain ridges also appear 45 - 55 n.m. (82 - 101 Km.) to the southeast. Figure 2 displays radar video returns (VIP levels) to the north and east of Pittsburgh. The blackened areas represent ground clutter and mountain ridge echo returns. Under certain atmospheric conditions anomalous propagation (AP) echoes appear and cannot be distinguished as such.

2. Tops Map Grid, consisting of a 25 row x 25 column Matrix with each grid point representing a square of size 10 x 10 n.m. (18.5 x 18.5 Km.). The highest echo top reported in each grid square is printed to the nearest 1,000 feet (305 meters). The azimuth and range for the five highest tops are also displayed thus assisting the radar operator in his RHI (range-height indicator) scan.

3. A hydrological printout for a 120 n.m. (222 Km.) range, consisting of a 25 row x 25 column Matrix, each square representing an area 10 x 10 n.m. (18.5 x 18.5 Km.). A printed coded value represents the average accumulated rainfall over a three-hour period, as estimated by radar, for each grid square. This information is automatically transmitted at three-hourly intervals to RFC CIN via high speed dial-up teletype.

Further development of the DVIP (Digital Video Integrator and Processor) and its incorporation into the WSR-57 radar is underway at WSMO PIT. The DVIP will allow a choice of range increments from 1/4, 1/2, 1 or 2 miles, and choice of beam width increments from 1/2°, 1°, 2° or 4°. Thus the IJ Matrix printout will allow presentation of maximum intensity levels occurring within varying grid square size (i.e., 1 x 1, 2 x 2 n.m. etc.). Further details on operation of DVIP are described by Shreeve (1974).

CASE STUDY

A case study illustrates how D/RADEX can assist in determining areas of potential flash flooding. The D/RADEX hydrological printout is used and illustrated (Figure 3).

In this hydrological printout a 30 n.m. (55 Km.) radius area from the radar site is blanked out and echo returns of the mountains to the southeast are blacked out. The code values used, 1-4, reflect the three-hour accumulated rainfall estimated by radar within each 10 x 10 n.m. grid square . Table 1 presents the range of average rainfall amounts in inches and millimeters (mm) represented by each code value. The estimated rainfall rate was obtained by increasing the Marshall and Palmer (1948) equation by a factor of 2, based on results from past D/RADEX experience. The equation thus becomes $Z=66R^{1.6}$ (Greene, 1975) where Z is the reflectivity measured and R is the rainfall rate. This Z-R relation will continue to be adjusted as further research and experimentation is conducted. Echo intensity is normalized for range before solving the equation.

Table 1.

D/RADEX HYDROLOGICAL CODE

Code Value	Rainfall Amount
1	trace (T) - 0.49" (T - 12 mm)
2	0.50 - 0.99" (13 - 25 mm)
3	1.00 - 1.49" (25 - 38 mm)
4	1.50 - 1.99" (38 - 50 mm)

This case deals with echoes over Southeastern Ohio having two characteristics of a flash flood producing storm; echoes of moderate to very strong intensity (VIP levels 2-4) and slow movement. Precipitation that resulted from this storm is described in the following message which was transmitted by Grant Vaughan (Hydrologist, WSO Akron):

> SEVERE THUNDERSTORMS OCCURRED OVER MUSKINGUM GUERNSEY AND MORGAN COUNTIES IN OHIO THE NIGHT OF JUNE 20 21 1974. MAXIMUM RAINFALL 5.03 INCHES FELL AT NORWICH WHICH IS 12 MI EAST OF ZANESVILLE. 3.22 FELL AT CAMBRIDGE AND 3.3 AT MCCONNELSVILLE AND 3.52 AT RINGOLD WHICH IS 10 SW OF MCCONNELSVILLE. THE TWO INCH ISOHYET COVERS MOST OF THE THREE COUNTIES. NUMEROUS ROADS WERE FLOODED AND WASHED OUT. THE LOCAL RESIDENTS CALL THE STORM... THE SEVEREST EVER.

Very heavy rainfall that produced flash flooding occurred between 0500Z and 0800Z, and within two of the present 40 x 40 n.m. (74 x 74 Km) grid square boxes used in the manually digitized radar (MDR) system of the National Weather Service (Moore, Cummings and Smith, 1974). In particular the southern half of the MDR grid square box that includes Zanesville (ZZV) and northern half of the adjacent grid box to the south of ZZV. The MDR values, presented in Table 2, were in this case an excellent indicator of heavy rain producing echoes, although lacking the resolution of D/RADEX data.

Table 2.

MDR VALUES AND OBSERVED PRECIPITATION AMOUNTS - JUNE 21, 1974

MDR Grid Box That Includes ZZV Reported Precipitation 00Z to 12Z		MDR Grid Box South of ZZV Reported Precipitation 00Z to 12Z	
ZZV	2.90" (73.7 mm)	McConnelsville	3.30" (83.8 mm)
Norwich	5.03" (127.8 mm)	Ringold	3.52" (89.4 mm)
Cambridge	3.22" (81.8 mm)	Tom Jenkins Lake	2.77" (70.4 mm)

MDR Values (ZZV box)	Time	MDR Values (box south of ZZV)
2	0335Z	4
4	0435Z	4
6	0535Z	6
6	0635Z	6
6	0735Z	6
2	0835Z	2

ZZV box: 22 (4 hour sum) for 0435Z–0735Z; 20 for 0535Z–0835Z.
Box south of ZZV: 20 for 0335Z–0635Z; 22 (4 hour sum) for 0435Z–0735Z; 20 for 0535Z–0835Z.

The three-hourly D/RADEX hydrological code values for 0601Z to 0901Z are presented in Figure 3.

The grid location on Figure 3 of the six precipitation observing sites listed in Table 2 are presented in Table 3 below. Also presented in Table 3 is the sum of the average precipitation totals estimated by D/RADEX for four consecutive 3-hourly periods, from 00Z to 12Z, for each 10 x 10 n.m. (18.5 x 18.5 Km.) square grid that includes the precipitation observing station. The upper limit of the range represented by each code number (Table 1) was used to arrive at this D/RADEX estimated precipitation.

The three three-hour D/RADEX hydrological printouts for 00-03Z, 03-06Z and 09-12Z, 21 June (not illustrated here) each showed a code value of 1 (T-0.49"), for the grid square areas of concern in southeastern Ohio:

Table 3.

D/RADEX ESTIMATED PRECIPITATION VERSUS OBSERVED PRECIPITATION

	D/RADEX Printout Location		Average Precipitation Estimated by D/RADEX	Precipitation Observed
	Row	Column	21/00Z-12Z	21/00Z-12Z
Zanesville	16	5-6	2.5 - 3.0"	2.90"
Norwich	16	6	3.0"	5.03"
Cambridge	16	7	3.0"	3.22"
McConnelsville	18	6	3.0"	3.30"
Ringold	19	5-6	2.5 - 3.0"	3.52"
Tom Jenkins Lake	19	5	2.5"	2.77"

The manually prepared radar overlays and MDR indicated the heaviest rains occurred after 0435Z and prior to 0835Z. Although the heavy rain that fell approximately 60-90 n.m. (111 - 167 Km.) west southwest of WSMO PIT was depicted accurately in time and location by D/RADEX, the three-hour D/RADEX hydrological information arrived too late to use operationally in issuing flash flood warnings before the flooding occurred. It is now possible, however, to acquire this output for shorter periods (0-1 hour, 0 - 1 1/2 hours, 0-2 hours) essential in identifying potential flash flood areas quickly. Also, the hydrological grid will soon be changed from the present 25 x 25 Matrix to a 51 x 51 Matrix, and made available to forecasters at the Weather Service Forecast Office in Pittsburgh. Each square in the new Matrix will represent a 5 x 5 n.m. (9.3 x 9.3 Km.) area, thus increasing the area resolution of the present system by a factor of four.

Research and evaluation of real-time situations will provide a better correlation between hydrological code values and observed rainfall. Limited telemetered and DARDC (Device for Automatic Remote Data Collection) rain gage data in the future will be fed into the D/RADEX system. Analysis of the combined data can be performed, in real time, to provide operational people with best estimates of the area and time distribution of rainfall amounts. This information, when compared to the predetermined amounts of precipitation required for flash flooding, will improve our warning services. Under the National Weather Services future concept for the Automation of Field Operations and Services (AFOS), D/RADEX data along with telemetered and DARDC data will be merged.

REFERENCES

Greene, Douglas R., 1975: "Hydrological Application of Digital Radar Data." Sixteenth Radar Meteorology Conference Report, pp. 353-360, Houston, Texas, April 22-24, 1975.

Marshall, J. S. and W. M. Palmer, 1948: "The Distribution of Raindrops With Size." Journal of Meteorology, Vol. 5, pp. 165-166.

Moore, P. L., A. D. Cummings and D. L. Smith, 1974: "The National Weather Service Manually Digitized Radar Program and Some Applications." NOAA Technical Memorandum NWS-SR-75.

Shreeve, K. S., 1974: "Design and Operation of a Digital Video Integrator Processor (DVIP)." NOAA Technical Memorandum NWS EDL 13.

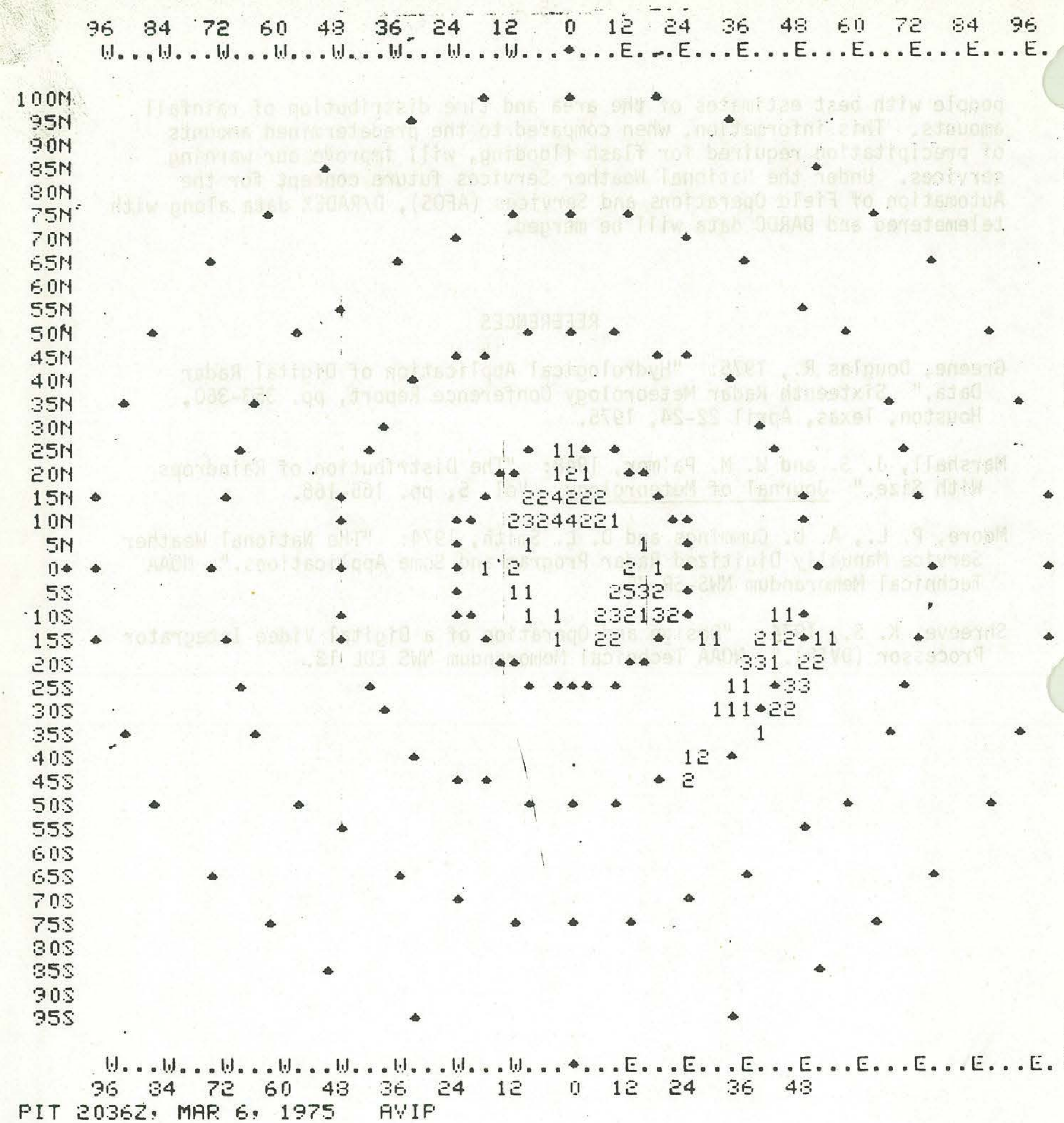

Figure 1

D/RADEX printout of 25 n.m. range markers and video returns due to ground clutter and mountain ridges as observed by the WSR-57 Radar at WSMO PIT. No precipitation was occurring at the time of this observation.

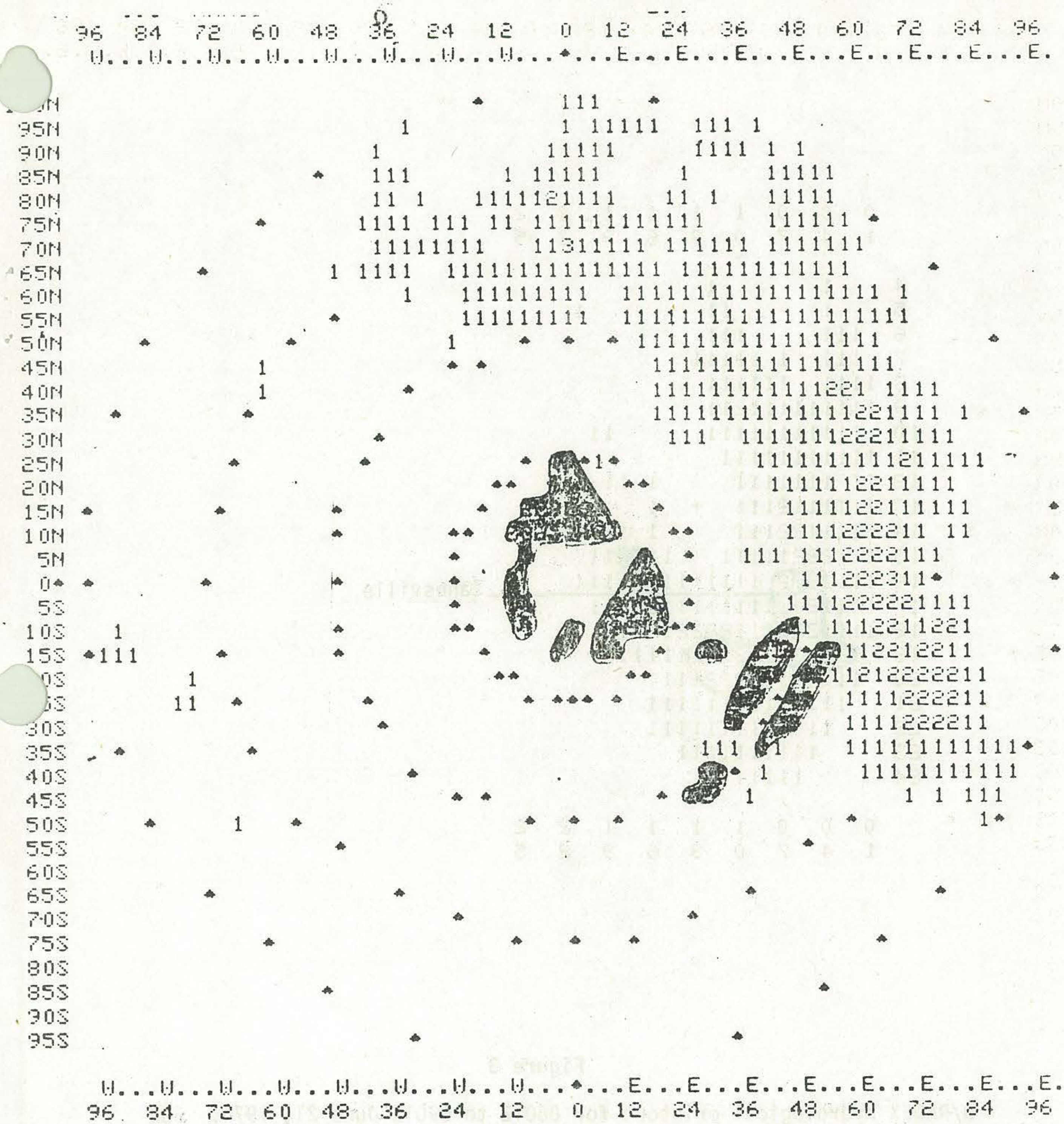

Figure 2

D/RADEX printout of precipitation echo intensities observed at WSMO PIT. The first 10 n.m. radius is blanked out. Shaded areas represent ground clutter and mountain ridge echo returns. 25 n.m. range markers are indicated by asterisks except where echoes are being reported.

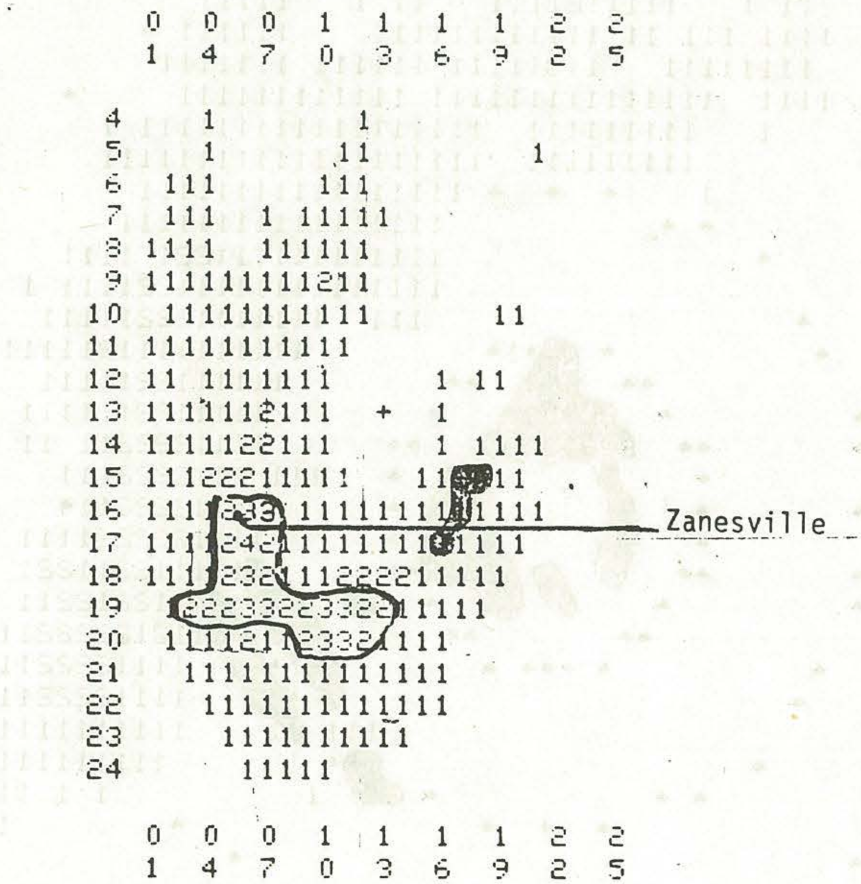

Figure 3

D/RADEX hydrological printout for 0601Z to 0901Z June 21, 1974. See text for explanation of printout. Outlined area includes Southeastern Ohio, where heavy rain occurred.