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October 1968

The WSR-57 Radar Program at Missoula, Montana

R. GRANGER

Technical Memorandum WBTM WR-34

U.S. DEPARTMENT OF COMMERCE / ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION

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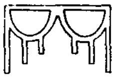

A western Indian symbol for rain. It also symbolizes man's dependence on weather and environment in the West.

U. S. DEPARTMENT OF COMMERCE
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
WEATHER BUREAU

Weather Bureau Technical Memorandum WR-34

THE WSR-57 RADAR PROGRAM AT MISSOULA, MONTANA

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WESTERN REGION
TECHNICAL MEMORANDUM NO. 34

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THE WSR-57 RADAR PROGRAM AT MISSOULA, MONTANA

I. INTRODUCTION

This report on the Missoula, Montana radar program, and summary of radar studies, is intended to show the development of a year-round operational program adapted to the needs of local and regional users. This support includes: routine observation for aviation year round and special observations for River Forecast Centers and fire-weather interests. The radar data gathered by time-lapse film and radar overlays are catalogued systematically and available for weather investigations. This report includes samples of various overlays used at Missoula.

II. DESCRIPTION

The Missoula, Montana WSR-57 radar started daily operation on November 1, 1961. The antenna and receiver are located on Point Six Mountain, 8.7 miles north of the airport at an altitude of 7972 feet, mean sea level (msl). The radar console, containing the controls and radarscopes for the radar system, is located at the airport office of the Missoula Weather Bureau. The radar is remote controlled through a Motorola MR-20 microwave system. This was the first remotely operated mountaintop Weather Bureau radar in the nation. The cost of installation, including roadways, was approximately $750,000. The Forest Service and Corps of Engineers contributed funds to the installation.

The mountaintop facilities are not manned; however, maintenance trips are accomplished on the average of once a week, over a distance of 19 miles by road. In winter, travel is made by snow vehicle. For the first two winters, such travel was extremely arduous and sometimes impossible. When steep, snowy slopes were too risky for snow vehicles, it was necessary to walk long distances on snowshoes. On these occasions the trip one way took over eight hours and involved overnight stays at the radar site living quarters. Over the past several summers trees have been cleared, roads improved, and guard rails installed. These improvements have made winter trips safer and shorter. Also, the development of a nearby ski resort has aided in providing shortcuts to Point Six. The mountaintop can now be reached in approximately two hours most winter days. During breakdowns of the snow vehicles or when portions of the road are closed by large drifts, emergency maintenance trips are made by helicopter.

III. WEATHER DETECTION CAPABILITY

Ground Clutter: As shown in Figure 1, Missoula radar has an extensive ground clutter pattern. However, after a period of training, this pattern becomes firmly implanted in the mind of the radar observer, and precipitation echoes can be located among the ground clutter. By using the iso-echo capability of the radar [1], it is possible to depress ground clutter thus making precipitation echoes stand out (Figure 2). Areas of side-lobe return from valleys north and south of the radar remain brilliant on the PPI scope when the iso-echo circuit is used because this return is weak compared to the main-lobe mountain return. At times this side-lobe effect can interfere with the detection of precipitation in these particular areas.

Ground clutter is especially bothersome within 40 nautical miles (nm); however, nearly all precipitation areas can be detected within this range by use of sensitivity time control (STC), and by elevating the antenna from 1/2 to 2 degrees.

Beam Blocking: There is partial blocking of the radar beam by surrounding mountains even though the antenna is located at approximately 8,000 feet msl. The beam blocking pattern is given in Figure 3. This diagram takes the earth's curvature into account. The isopleths indicate the height above sea-level that precipitation must extend vertically to be detected by the Missoula radar beam under normal propagation conditions [2].

Detection of Precipitation: Precipitation type and vertical extent determine the detectability of precipitation by radar. Snow, of course, is more difficult to detect than rain. Under certain conditions, snow has been detected at ranges up to 120 nm, but at other times it is very difficult to detect at a range of 70 nm. Results of a local snow-detection study [3] conducted during the winters of 1961-62 and 1962-63, show that in Arctic air masses, very light snow (S- -) is detected only about 50% of the time at 40 nm and only 17% at 80 miles. Light snow (S-) is detected 73% of the time at 40 nm, and 37% of the time at 80 miles. In Pacific air masses, S- - is seen 65% of the time at 40 nm, and 37% of the time at 80 miles. S- is seen 90% of the time at 40 nm, and 73% of the time at 80 miles. Only slight improvement in detection was noted for moderate or heavy snow. The reason for limited detectability is that air cannot hold much moisture at extremely cold Arctic air temperatures. Since radar reflectivity increases with the "wetness" of the snow, reflectivity from the very cold, dry snowflakes is low.

Another factor is the lower vertical extent of most wintertime precipitation. Precipitation tops are often 11,000 feet msl or lower. Pacific air masses are much warmer than Arctic air, and therefore can hold more moisture. This results in the water content of precipitating snow being greater, the tops of the precipitation higher, and therefore, the reflectivity better than in Arctic air masses.

Most significant liquid precipitation within a radar range of 150 to 200 miles of Missoula is detected except for general precipitation that accompanies widespread upslope conditions east of the Continental Divide in Montana. In a weather pattern such as this, precipitation tops are generally below 15,000 feet msl. On those occasions when precipitation is detected in this area, the areal extent is indicated rather well but intensity estimates are frequently poor. In contrast, similar upslope conditions along the west slopes of the Bitterroot Mountains of Idaho are more frequently detected and estimates of precipitation amounts here are quite accurate.

In general, precipitation intensities can be accurately measured using radar echo intensities if the precipitation has a vertical extent of 15,000 feet or greater. Figure 4 gives derived precipitation amounts observed by radar during the storm of 6/6/67 when the Musselshell River reached record flood conditions. The vertical extent of observed echoes in this storm is in excess of 30,000 feet msl. During this period, rainfall reports indicated small areas of 5 or more inches of rain. Radar measurements did not approach these figures, but they did locate the areas of heavy precipitation very clearly.

Frequency of Echoes: Weather related echoes have been observed on the Missoula radar on 52% of all observations. An operations summary is given in Table 1. The hours of weather detection per month range from 612 in January 1964 to 139 in October 1965. Downtime due to outage or routine maintenance averages 4.5% or about 33 hours per month.

IV. RADAR PROGRAMS

Hydrology:

One of the primary missions of the Missoula radar is to provide the River Forecast Centers at Portland, Oregon, and Kansas City, Missouri with quantitative and areal estimates of precipitation falling within radar range. It is well known that precipitation rates vary considerably in level terrain, and are *extremely* variable in mountainous areas. During the period December 1961 to January 1964, a study was conducted in an effort to arrive at reasonable precipitation estimates based on radar data [4]. After considerable trial and error, the final study produced favorable results [5]. A brief description of the operational hydrologic program utilizing the results and techniques developed in this study follows.

The radar hydrology program begins in October and extends through June. Each hour precipitation echo areas larger than 10 nm square are outlined on the main PPI scope and coded to eight categories of intensity. These categories range from 1.2 mm^6/m^3 (-109 dbm) to 1.3 x $10^3 nm^6/m^3$ (24 db). The outlined areas are copied onto a

100 nm overlay (Figure 5) that is divided into 10 nm grid squares. The precipitation rate for each square is determined according to range, height, and intensity. Precipitation estimates for each square are totaled for six hourly periods corresponding to synoptic observation times. The six-hour grid amounts are then summarized to the nearest tenth of an inch for teletype transmission (Figure 6). This special message (RAPCPN) is filed on Service A for the Portland River Forecast Center; and on RAWARC for the Kansas City River Forecast Center. Figure 7 shows the RAPCPN data as replotted by the user station. The hourly "hydrology" overlay data are also entered on punch cards for use later in preparing summaries and studies in cooperation with the Corps of Engineers and Portland River Forecast Center. The entire radar hydrology program requires an average of 20 minutes each hour during periods of precipitation.

Fire Weather:

Primary mission of the radar unit, during summer months, is to provide thunderstorm location, intensity, and movement to fire-weather forecasters and the U. S. Forest Service. A local study of convective cell movement [6] within 150 nm of the radar, showed that the 14,000 feet msl wind was the best indicator of convective cell motion. Further, echo movement was found to be within 10° of the 14,000 feet wind directions 73% of the time, and within 10 knots of the 14,000 feet wind speed 90% of the time. The study also showed that 500-mb wind data correlated better with echo movement than the 700-mb wind. At 500 mb, 76% of the winds were within 10 knots of the echo speed, while at 700 mb this percentage dropped to 64%.

Another study [7] considered possible applications of radar to fire-weather problems. This study investigated the use of eight-hour Polaroid composite photographs of radar echoes for the purpose of locating areas where thunderstorms may have occurred. An association of radar echoes to locations of lightning-caused fires was established. The use of automatic digitized radar processors for collection of precipitation data was discussed. Application of these data to a Fire Danger Rating System was described.

A 1963 study of convective radar echoes [8] was instrumental in establishing a routine observational program to locate, identify, and track thunderstorms quickly for fire-weather purposes. Echoes were copied on paper overlays (Figure 8) at very weak, weak, moderate, strong, or very strong levels of reflectivity as defined by the WSR-57 Radar Manual. When these data were compared with surface weather data, the following conclusions were made:

1. Convective echoes beyond 40 nm can be considered thunderstorms if they have a reflectivity of moderate or greater.

2. Weak convective echoes beyond 100 nm will be thunderstorms 66% of the time; however, due to range attenuation and

overshooting, only 50% will be thunderstorms in the 100 - 150 nm range, 18% in the 150 - 200 nm range, and 6% in the 200 - 250 nm range.

3. Very weak convective echoes in the 100 - 150 nm range will be thunderstorms 63% of the time, and 80% of the thunderstorms will be detected. Beyond 150 nm 77 - 80% of the echoes will be thunderstorms. 41% of the thunderstorms will be detected in the 150 - 200 nm range; 8% will be seen in the 200- 250 nm range.

4. A convective echo should be considered a thunderstorm if it is detected beyond 175 nm.

5. An echo within 100 nm should be considered a thunderstorm if the top exceeds 30,000 feet msl.

A technique for detecting echoes at elevation angles of 1° to 3° was developed during the study, in order to detect precipitation forming or moving through the ground pattern within 50 nm.

Radar support to the fire-weather mission consists of preparing hourly paper overlays outlining the convective echoes at the very weak, weak, moderate, strong, or very strong levels of intensity. A special overlay showing forest boundaries, with a 10-minute latitude and 15-minute longitude grid background is used; see Figure 8. The small grids are enclosed in larger 1° x 1° grids. This provides a small grid size of about 10 nm square. This type grid was chosen because it can be constructed on any map for any area by drawing latitude and longitude lines. The large grids (1° x 1°) are given letter-number designation. Twenty four smaller grids (10 minutes by 10 minutes) make up each larger grid and are numbered, left to right, 1 through 24. By using large and small grid numbers, it is possible to locate convective echoes. These grid locations are summarized hourly into a teletype message and transmitted over a Forest Service-Weather Bureau teletype network [9].

The data are used by various forest dispatchers in keeping abreast of weather conditions over the forests. Shown along the top of Figure 8 is a short verbal summary indicating weather type and movement, which is also given to the user. From 5 p.m. to 5 a.m., a number of Forest Service ranger stations are not manned; so, the radar unit prepares a 12-hour composite map (9A) of convective activity for this period. A 12-hour summary, Figure 9B, is coded and transmitted on the teletype network each morning. The 12-hour composite data are used as an aid in planning fire patrol flights.

The entire radar fire-weather program, which consists of preparing overlays and summarizing and transmitting the data on teletype, occupies approximately 30 minutes each hour.

When mobile fire-weather units are in the field, radar echo data are transmitted to them either by radio facsimile or voice radio. Various research units of the North Forest Fire Laboratory also make use of the convective echo overlays.

Aviation:

The Missoula radar also supports the aviation program in western Montana. Except for the period from July - September when forest boundary overlays are being used, the paper overlay prepared hourly from the radar scopes is designed for aviation use. Airways are entered on base maps (Figure 10). Echoes are outlined by intensity categories of: very weak, weak, moderate, strong, and very strong. These are then color coded for convenience. A verbal summary of radar weather, along with a plastic overlay showing the location of radar echoes, is provided to the local Flight Service Station (FSS) for display and broadcast. The verbal radar weather summary is placed on a continuous weather broadcast and is also broadcast by FSS in their weather summary at 45 minutes past the hour.

The paper overlay prepared for aviation is displayed in the Weather Bureau office, along with other weather charts, to keep forecasters up to date on radar weather. Cloud cover and weather from stations within radar range are entered hourly on the paper overlays. This makes it possible to determine if precipitation extends beyond radar detection.

If radar indicates significant weather which has not been forecast, the radar observer will alert the Great Falls Forecast Center to these indications. Pilots are briefed from the radar overlays and furnished overlay copies of the echo pattern along their route. The aviation program of the radar unit involves about 25 minutes each hour.

Applied Research Study:

The first radar studies conducted at Missoula were aimed at relating observed weather at the ground to radar observations. An earlier study using radar time-lapse film for the summer of 1962 was used [10]. This study concluded that, within 20 nm of the observing station:

1. Moderate or strong echoes comprised 12% of the total (196) echoes studied, and were associated with thunderstorms 70% of the time.

2. Weak to moderate echoes comprised 40% of the total echoes studied. Thunderstorms were associated with these echoes approximately 25%, rain 25%, and cumulonimbus or virga 30% of the time. During the remaining 20% of the time, only nonprecipitating clouds were reported.

3. Weak echoes comprised 41% of the echoes studied. Thunderstorms were associated with them 25% of the time, rainshowers 25%, cumulonimbus or virga 25%, and clouds with no visible precipitation 25%.

4. Very weak echoes comprised 7% of the total echoes studied. Clouds with no visible precipitation were associated with these echoes approximately 60% of the time. Rainshowers or virga were reported 40% of the time.

This study also made note of the fact that severe lightning storms (10 or more cloud-to-ground lightning strikes within a 15-minute period) were associated with moderate or strong echoes 75% of the time and with weak or very weak echoes 25% of the time. There were echoes associated with all reported thunderstorms within a range of 150 nm. Many light rainshowers or cumulonimbus were not detected between 100 - 150 nm range.

The Missoula radar unit has cooperated with the University of Montana in supplying data and ideas for several masters' theses One of these dealt with the association of radar echoes and lightning discharges [11]. This study showed a definite relationship between intensity of a radar echo and number of observed cloud-to-ground lightning discharges. The greater the echo intensity, the greater number of lightning strikes (Figures 11a and 11b).

Another thesis established the relationship between radar echoes and lightning fires [12]. The study concluded that within the forests studied:

1. Most lightning fires can be correlated with radar echoes.

2. Most lightning-caused forest fires occur within areas covered by weak intensity radar echoes. Areas covered by more intense echoes showed little lightning fire activity. The precipitation associated with moderate and strong intensity echoes must be sufficient to override the dryness of fuels previous to the storm.

Quantitative estimates of precipitation for a 7 square mile watershed located 30 nm east-southeast of the radar from May through December 1967 were made recently [13]. It was found that radar data underestimated the precipitation most of the time with a tendency for the greatest underestimation during periods of heavy precipitation.

Missoula Radar was one of ten stations whose data were included in a report of thunderstorm penetration of the tropopause [14]. Penetration of the tropopause by more than 5000 feet occurred 12 times in 1962, 39 times in 1963 and 11 times in 1964 for a three-year total of 58. For comparison Sacramento had a total of 21 such penetrations and Kansas City 620.

Figure 12 is a graph showing the diurnal distribution of tropopause penetrations at Missoula, 1962-1964.

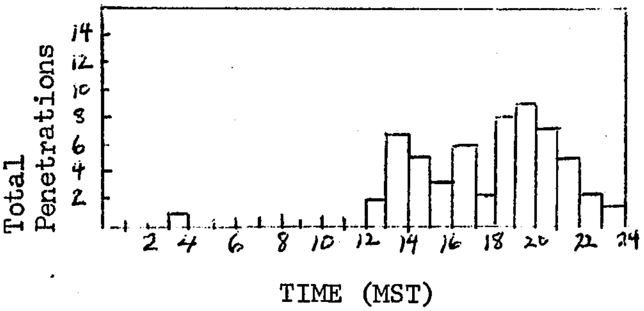


Figure 12

Missoula radar data have been included in a WSR-57 radar station climatological report of radar echoes [15]. The publication is a collection of tables showing frequencies of echoes, and tops for various azimuth angles, maps of probability of precipitation with convective echoes, and thunderstorm probabilities.

V. REFERENCES

1. R. Granger, "Use of Iso-echo in Determining Precipitation Areas in Mountainous Terrain", Progress Report No. 12 on the WSR-57 Radar Program, March 1963.

2. R. G. Pappas, "Derivations of Radar Horizons in Mountainous Terrain", Western Region Technical Memorandum No. 22, Page 6, April 1967.

3. R. Granger, R. A. Honkala, R. L. Murray, J. P. Osborne, M. L. Vick, "Snow Detection in the Northern Rockies", Progress Report No. 12 on the WSR-57 Radar Program, March 1963.

4. R. Granger, "A Preliminary Analysis of a Grid Method of Determining Precipitation Amounts by Radar Over the Upper Portions of the Columbia Basin", Proceedings of the Tenth Weather Radar Conference, April 1963.

5. R. Granger, "A Grid Method for Estimating Precipitation Amounts by Using the WSR-57 Radar", Western Region Technical Memorandum No. 19, December 1966.

6. J. P. Osborne, R. L. Murray, M. L. Vick, "Convective Echo Movement Over the Northern Rockies as Determined by Radar", Progress Report No. 13 on the WSR-57 Radar Program, November 1963.

7. R. R. Peterson, "Radar Observations and Fire Weather", Unpublished paper presented at the Western Fire Weather Meteorologist Conference, March 1964.

8. R. Granger, W. H. Henning, R. L. Murray, J. P. Osborne, M. L. Vick, "Radar - A Fire Weather Tool (A Convective Analysis by Radar", Unpublished paper distributed at the Western Fire Weather Meteorologists Conference, March 1964.

9. R. R. Peterson, "Transmitting Radar Echo Locations to Local Fire Control Agencies for Lightning Fire Detection", Western Region Technical Memorandum No. 20, March 1967.

10. R. R. Peterson, "The Significance of WSR-57 Radar Data in Fire Weather Forecasting", Unpublished paper presented at the Western Fire Weather Meteorologists Conference, March 1963.

11. R. A. Honkala, "Radar Echoes and Cloud to Ground Lightning Discharges", Master of Arts in Geography Thesis, University of Montana, 1966.

12. R. D. Wahlfeld, "Radar Echoes and Their Relationship to Lightning Fires in the Northern Rockies", Master of Science in Forestry Thesis, University of Montana, 1967.

13. W. H. Poliquin, "A Hydrologic Study of the North Fork Experimental Watershed", Master of Science in Forestry Thesis, University of Montana, 1967.

14. M. J. Long, "A Preliminary Climatology of Thunderstorm Penetrations of the Tropopause in the United States", Journal of Applied Meteorology, August 1966.

15. D. D. Grantham, A. J. Kantor, "Distributions of Radar Echoes Over the United States", Air Force Cambridge Research Laboratories, April 1967.

TABLE 1

OPERATIONS SUMMARY

Total hours of radar weather each month. Parentheses indicate total hours in month.

	Jan (744)	Feb (672) (696)	Mar (744)	Apr (720)	May (744)	Jun (720)	Jul (744)	Aug (744)	Sep (720)	Oct (744)	Nov (720)	Dec (744)
1961											273	508
1962	338	422	348	315	311	470	497	424	248	296	372	410
1963	388	285	334	372	486	603	433	462	375	310	314	313
1964	612	366	424	432	399	516	376	394	268	259	387	528
1965	428	407	245	468	458	373	420	447	354	139	407	357
1966	448	379	304	260	282	439	338	315	412	268	255	396
1967	434	341	412	390	329	455	452	282	277	377	358	419
Avg.	441	367	345	373	378	476	419	387	322	275	338	419

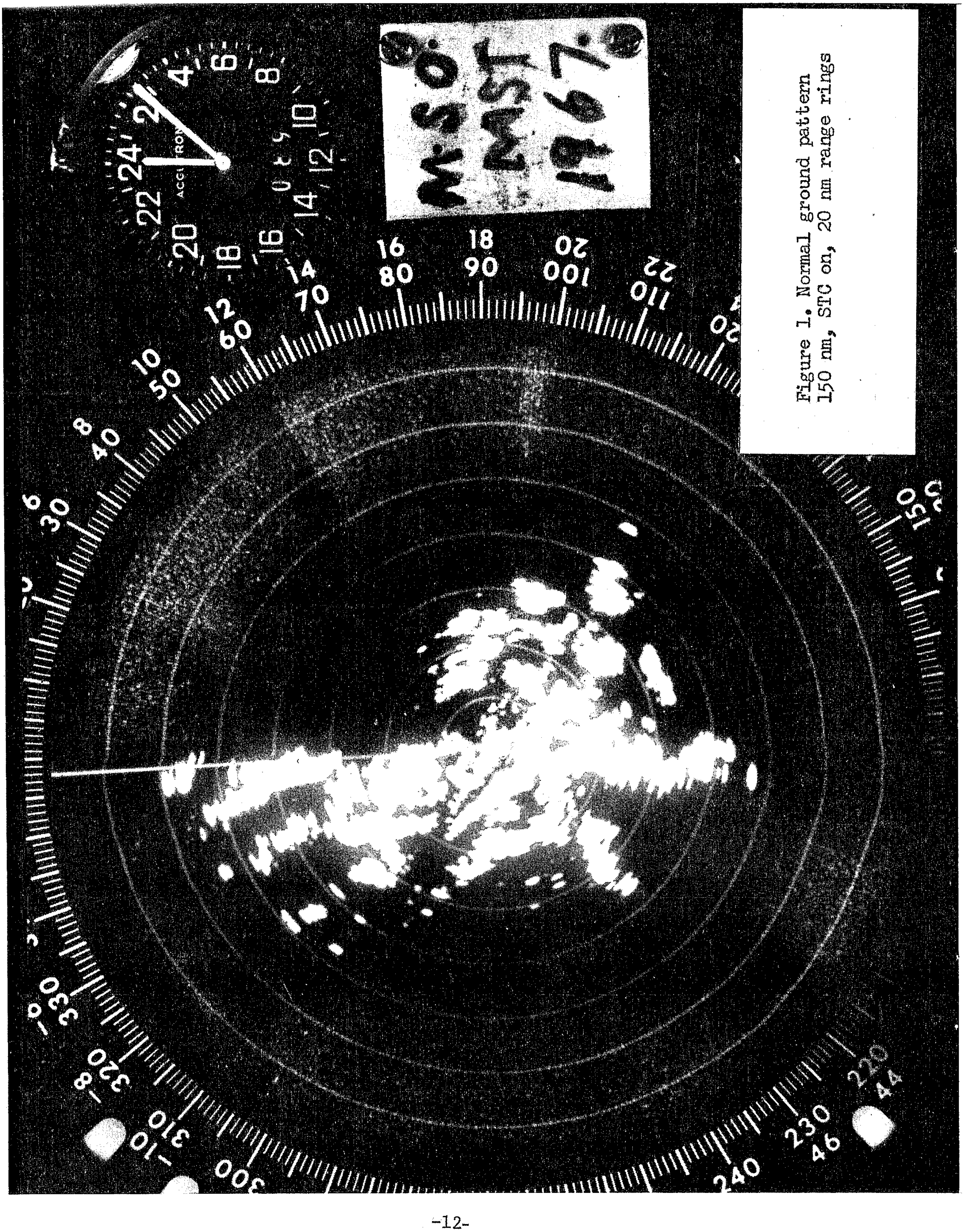
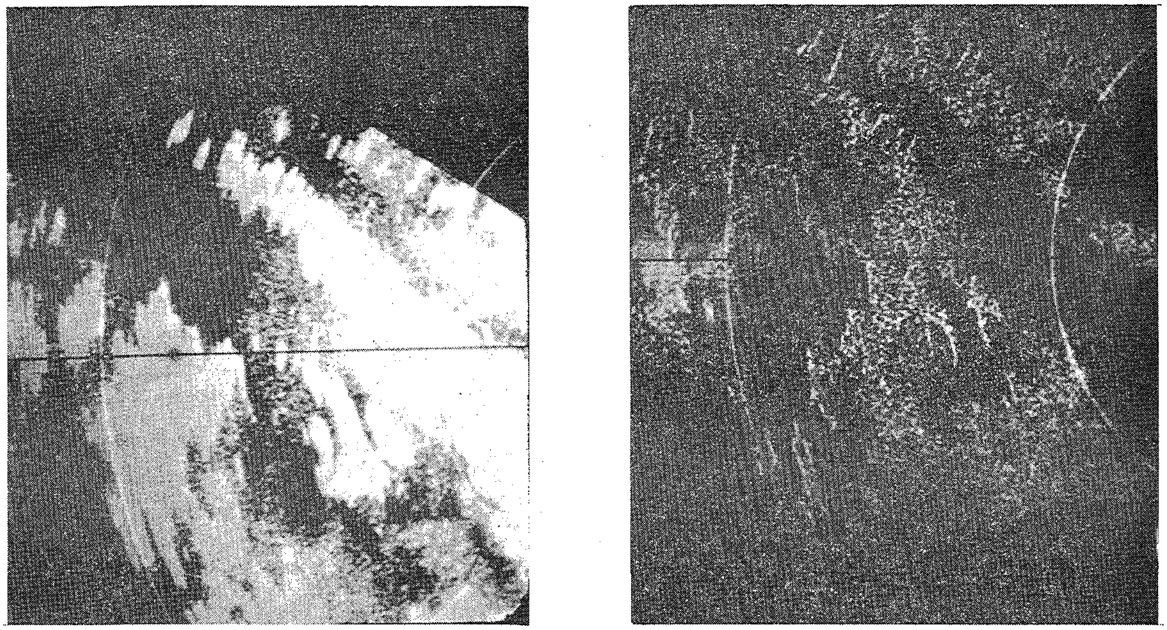
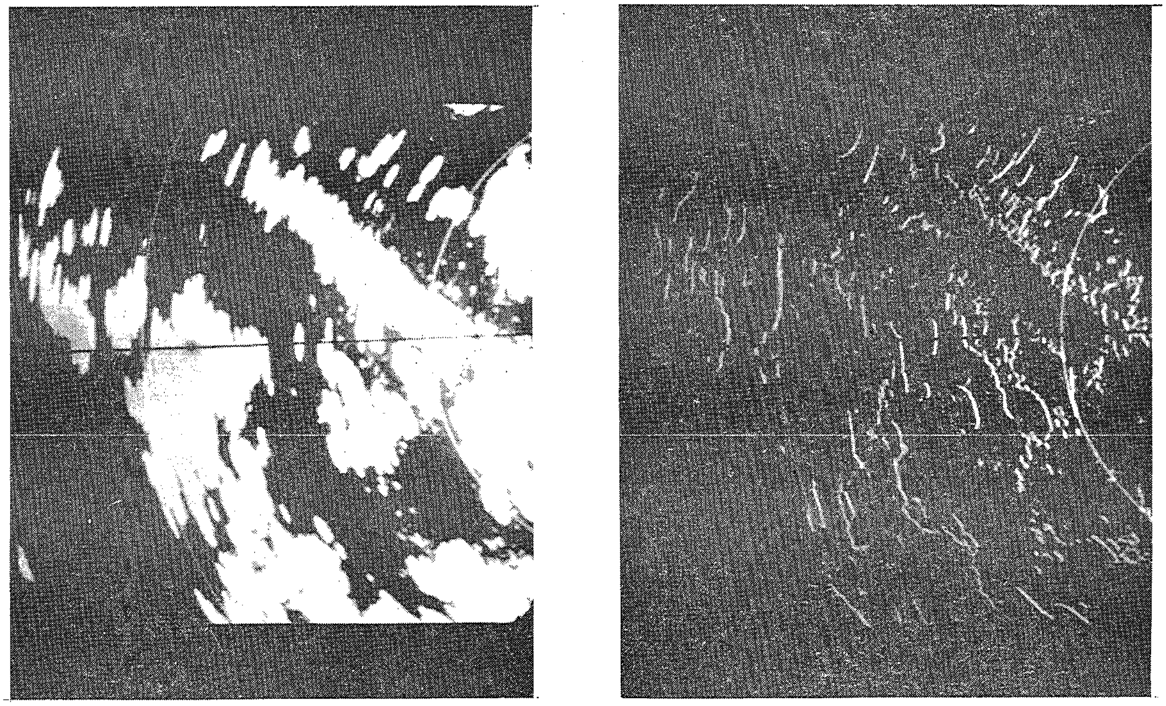


Figure 1. Normal ground pattern
150 nm, STC on, 20 nm range rings



Weak stratiform area. Azimuth 270° 6 db, 0 elevation. 20 and 40 mile range markers.

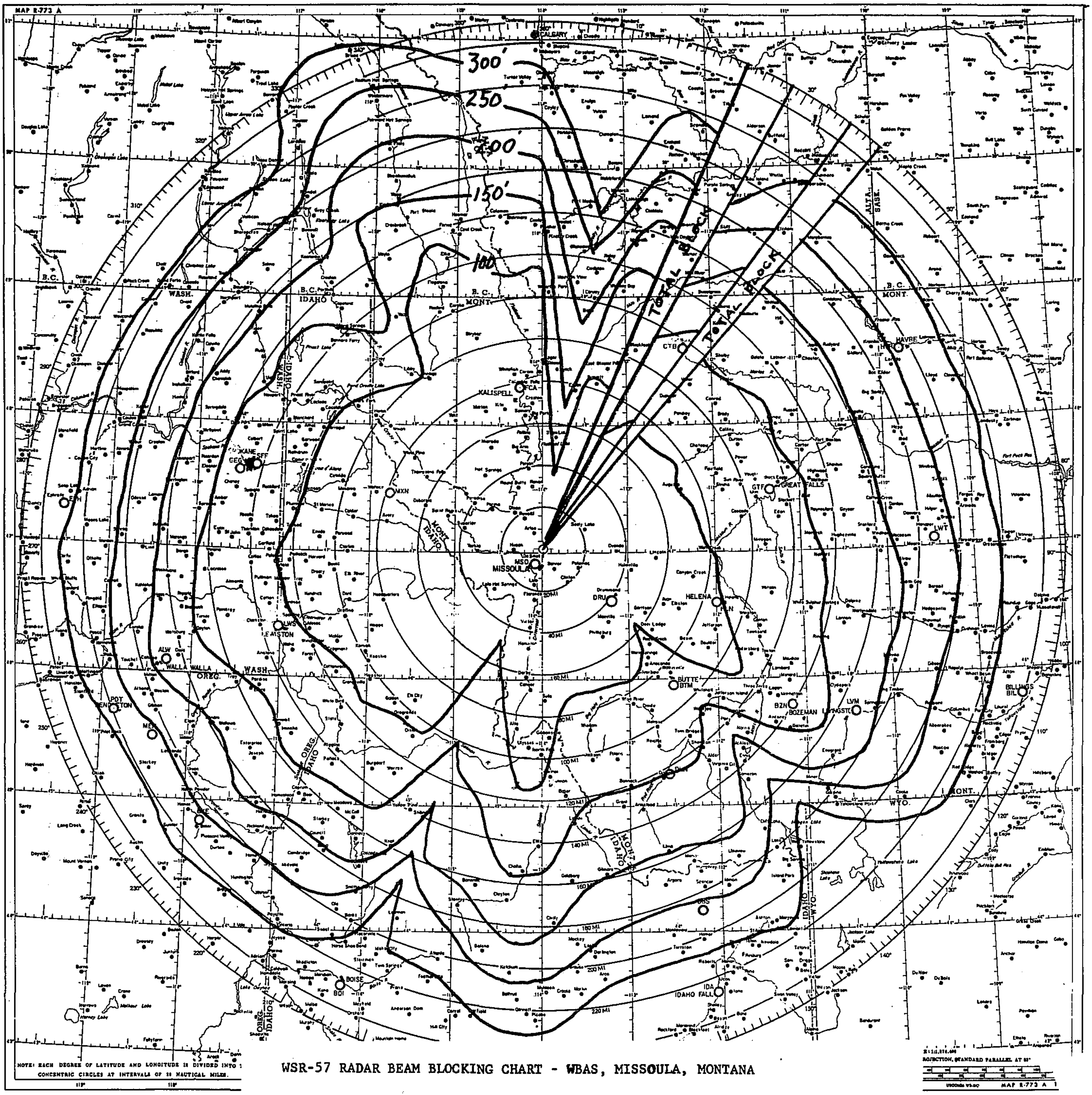
Same area with iso-echo to eliminate main portion of mountain return.



Same area without weather. 6 db, 0 elevation.

Same area without weather. Iso-echo to eliminate mountain return.

FIGURE 2



WSR-57 RADAR BEAM BLOCKING CHART - WBAS, MISSOULA, MONTANA

FIGURE 3

On 6/6/67 massive areas of rain and thunderstorms occurred along and east of the Continental Divide in Montana. At this time rivers were high from snow melt run-off. The storm period was from 0000M to 1700M. An attempt to show areas of heavy precipitation was made in a post analysis using precipitation rates assigned within 100 nm. Musselshell basin is indicated by stippling. Areas of heavy rain accumulations as indicated by radar are outlined. Numbers are hundreths of inches.

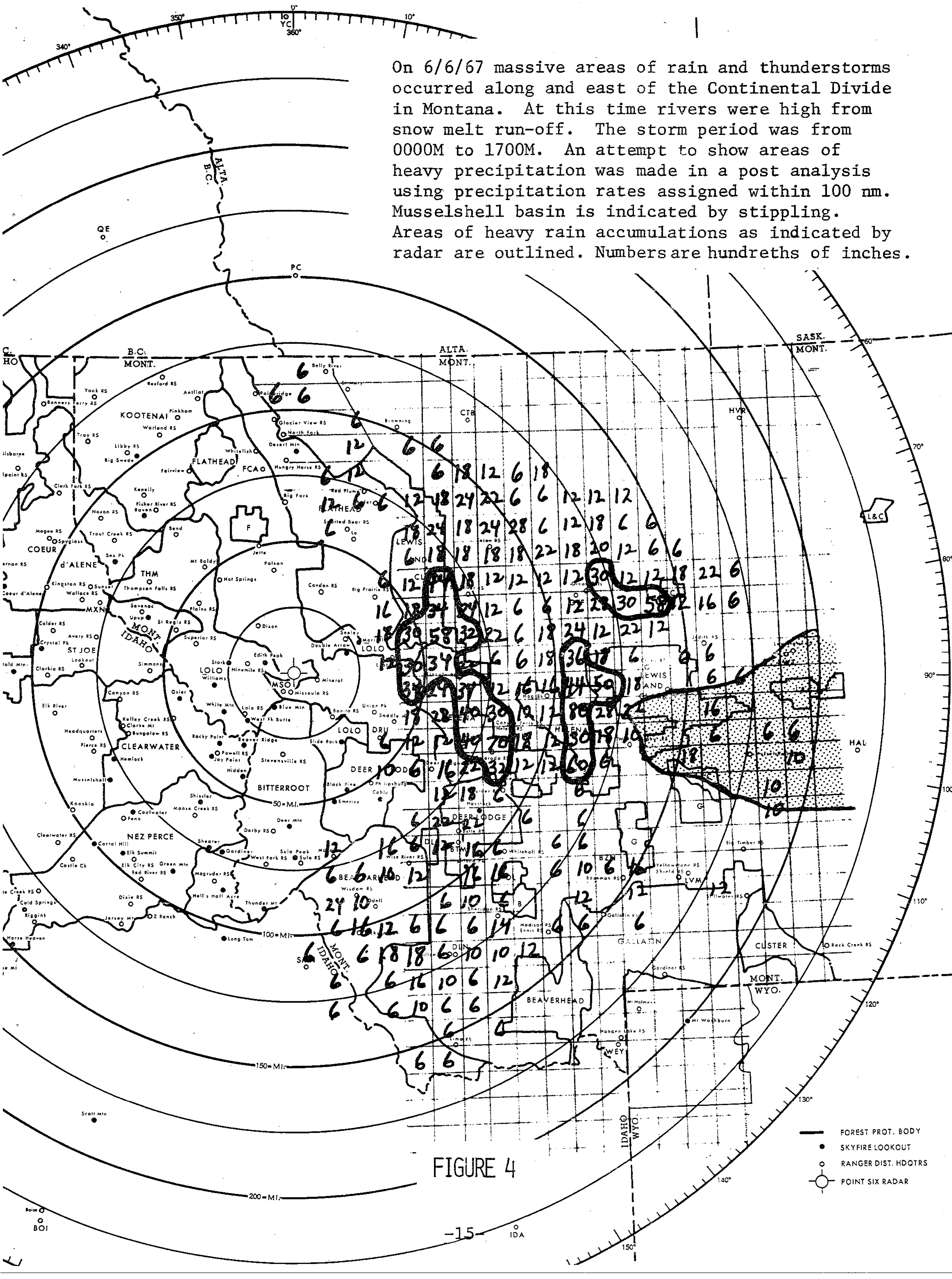


FIGURE 4

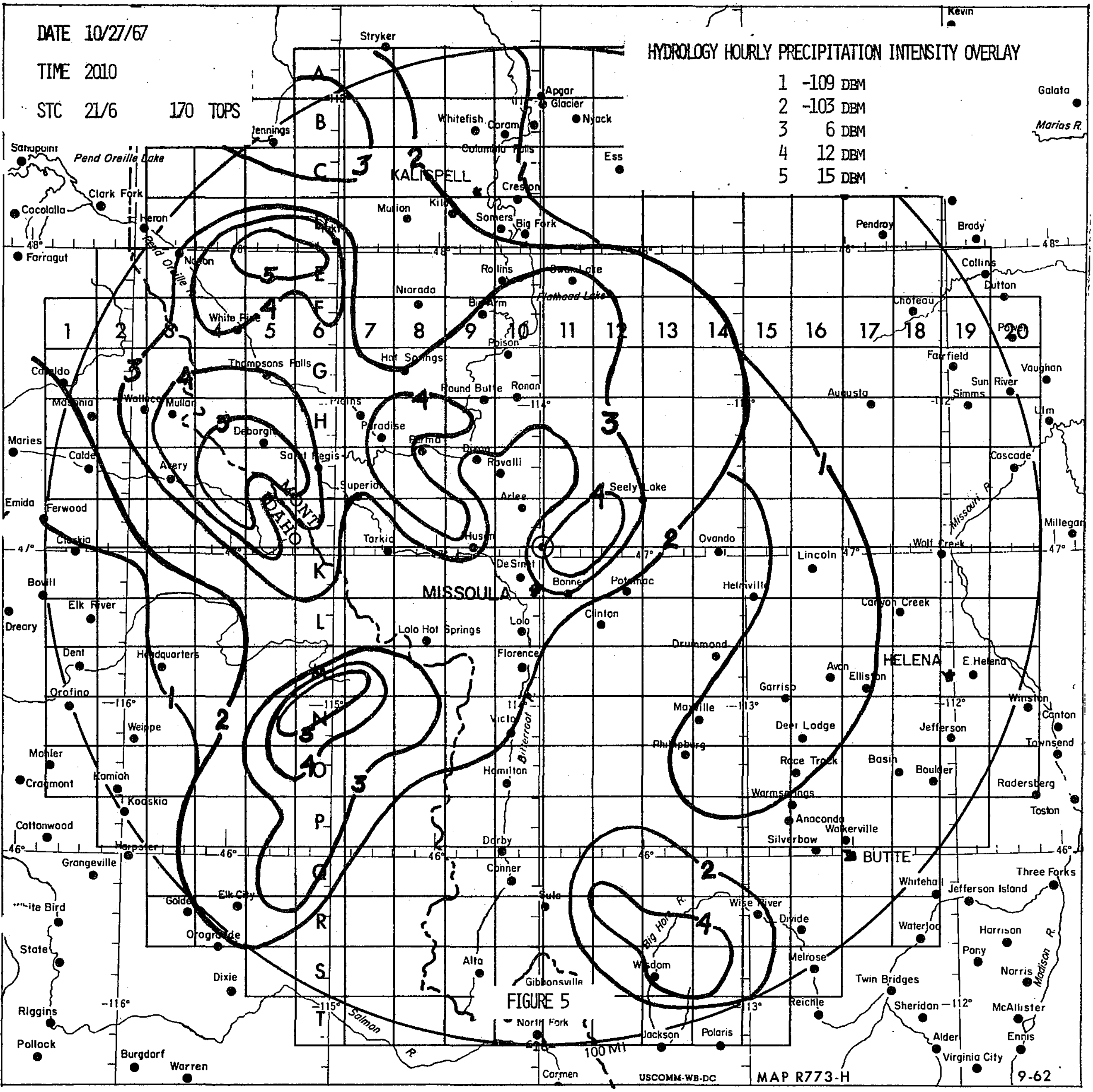

DATE 10/27/67
TIME 2010
STC 21/6 170 TOPS
HYDROLOGY HOURLY PRECIPITATION INTENSITY OVERLAY
1 -109 DBM
2 -103 DBM
3 6 DBM
4 12 DBM
5 15 DBM
KALISPELL
MISSOULA
HELENA
BUTTE
MONT
IDAHO
Flathead Lake
Pend Oreille Lake
Bitterroot R.
Big Hole R.
Salmon R.
Missouri R.
Madison R.
Marias R.
100 MI
USCOMM-WB-DC
MAP R773-H
9-62

FIGURE 5

SIX HOURLY SUMMARY CODED PRECIPITATION AMOUNTS FOR TELETYPE TRANSMISSION

```
MSO  SD  0600Z
06Z 6 HR RAPCPN 0.1 A 8-10  B  9-12  C  7-10 12 13  D 8-10
E 7-10 14  F 7-10  G 8-11  15  H 9-11 15  I 7 8 11-16  J 1
7-10 12 13 16  K 1 7-10 12 13 16  L 1 2 10-12 17  M 1 2 10 17
N 1 2 9 10  P 2 3 11 12 14  Q 3 8 11 14  R 4-8 11 15  S 9-12
14 15  T 10-12
0.2  A 7  B 7 8  C 11  D 6 7 13  E 6 13  F 11 13 14  G 6 7
13 14  H 6-8 12 14  I 6  J 2 6 11 12  K 2 3  L 3 7-9  M 3 9
O 2 8  Q 6 7 13  R 12 14  S 13
0.3  B 5 6  C 4-6  D 3 11 12  E 2 11 12  F 2 5 6 12  G 4 5 12
H 1 4 5 13  I 1 2  J 3-5  K 4-6 11  L 6  M 8  N 3 8  O 3  P 7
Q 4 5 12  R 13
0.4  D 4 5  E 3-5  F 3  G 1-3  H 2 3  I 3-5  L 4  M 4 6 7
N 7  P 4 6
0.5  L 5  M 5  N 4  O 4 6 7  P 5
0.6  F 4  N 5 6  O 5  AVG TOPS 170
```

FIGURE 6

DATE 10/17/67
TIME 1700M - 2300M

STC 21/6 170 TOPS

RAPCPN MESSAGE AS PLOTTED BY USER
PRECIPITATION (TENTHS OF AN INCH)

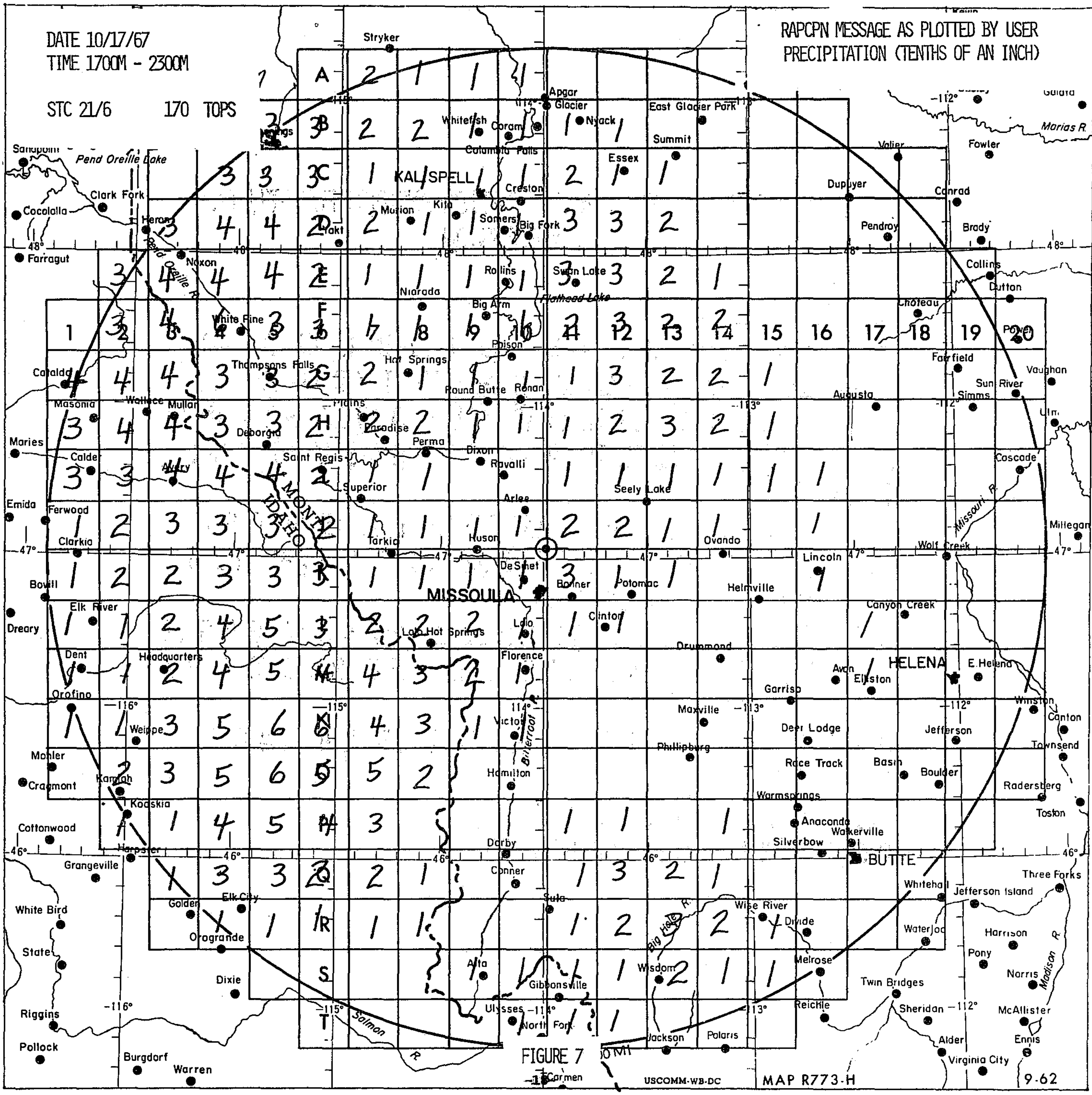
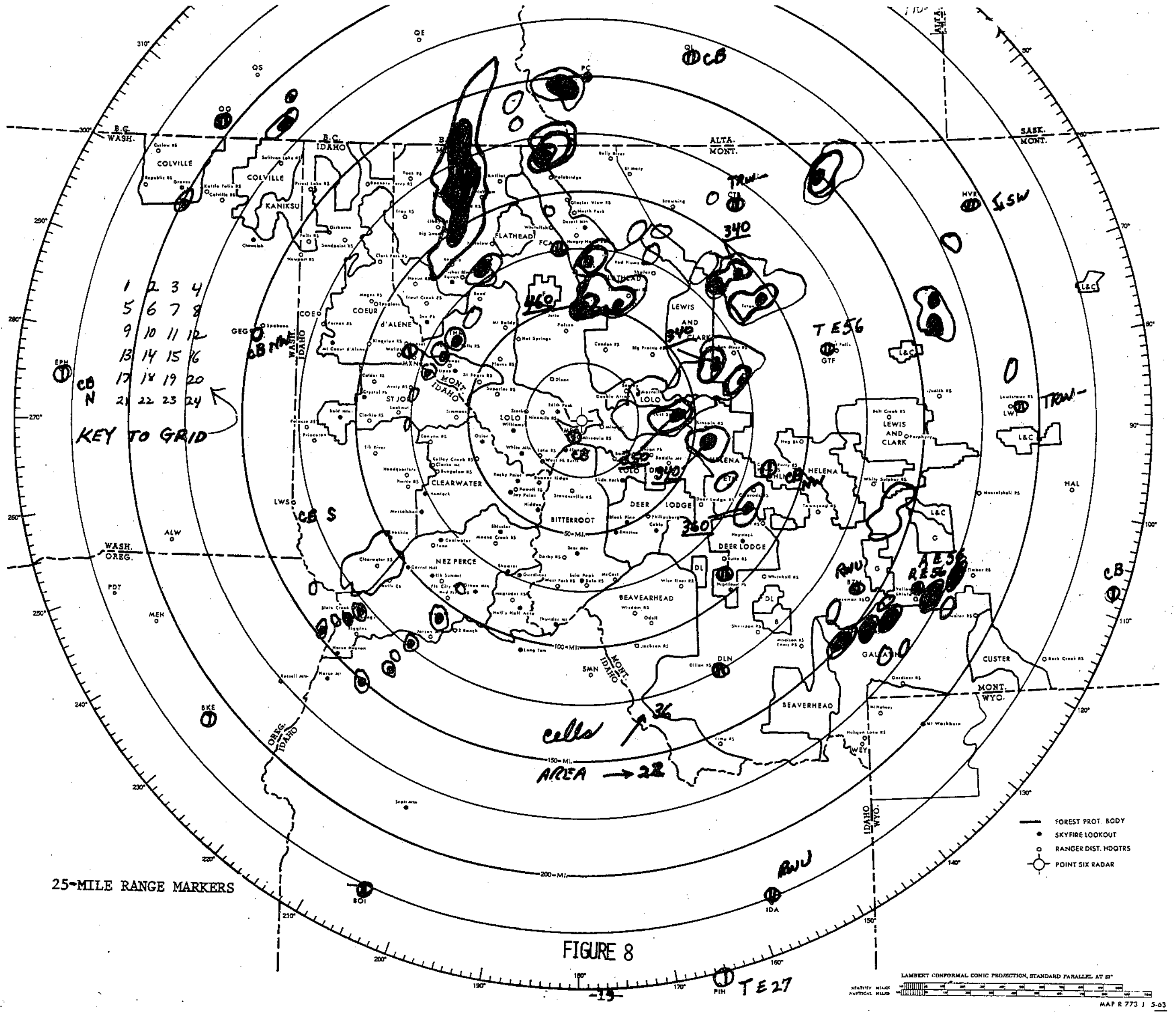


FIGURE 7

HOURLY FIRE-WEATHER OVERLAY

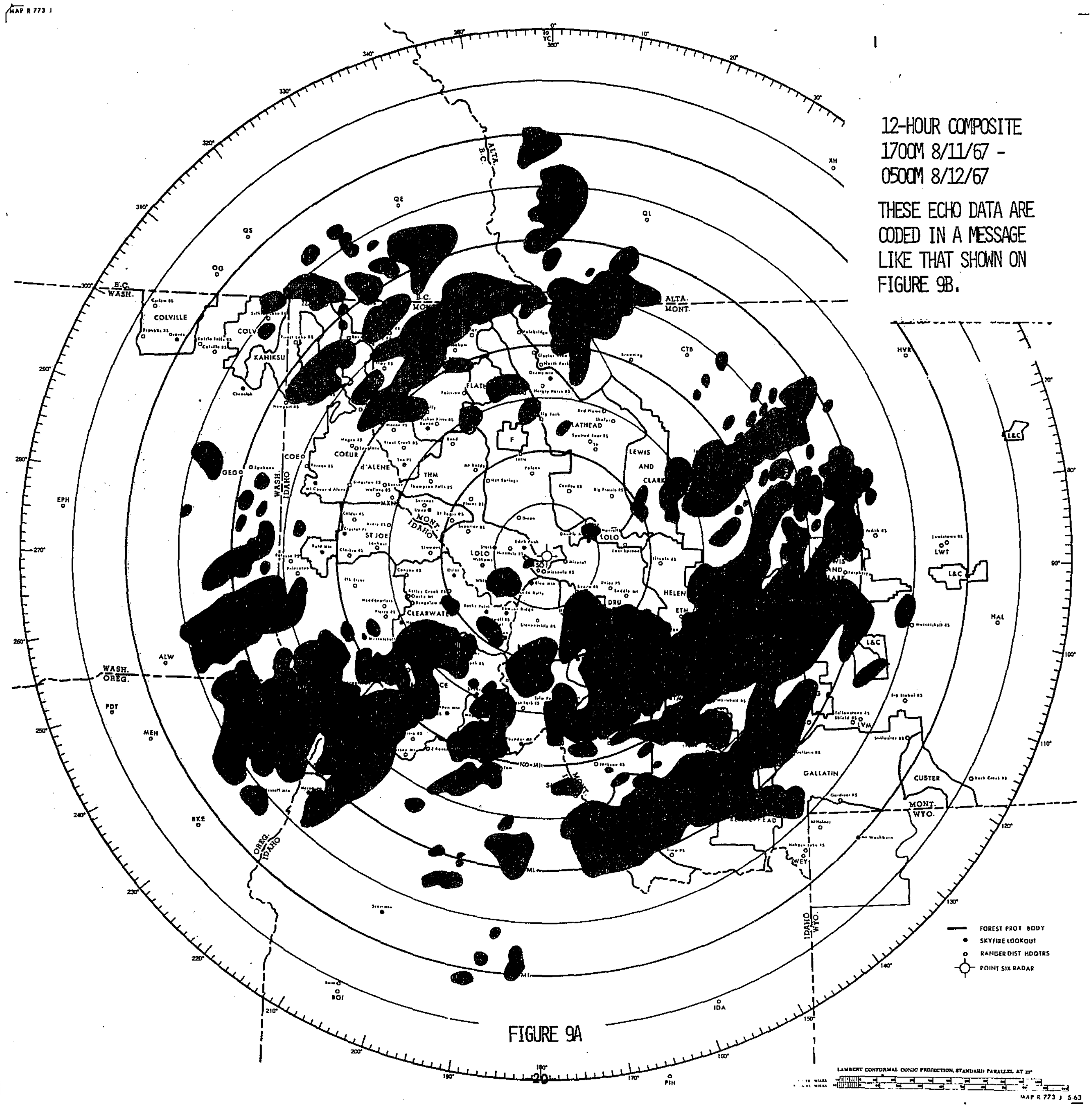
8/6/67 MSO SD 1840M

AREA SCTD TRW/NC BNDD 100 NNW FCA 45 NW HVR 20 N LWT 50 SE BZN 35 E BKE. MOVMT 2622. CELLS 2336. TOPS 360. INCLS TRW+/NC AVG DIAM 15 CNTRD 40 N FCA AND 30 SSE FCA. TOP 460. PSBL HAIL.



25-MILE RANGE MARKERS

FIGURE 8



12-HOUR COMPOSITE
1700M 8/11/67 -
0500M 8/12/67

THESE ECHO DATA ARE CODED IN A MESSAGE LIKE THAT SHOWN ON FIGURE 9B.

FIGURE 9A

EXAMPLE OF CONVECTIVE ECHOES CODED FOR TRANSMISSION ON FOREST SERVICE-WEATHER BUREAU TELETYPE CIRCUIT

SIGNIFICANT RADAR ECHOES AT 1840 MST 8/6/67

Z2	20 23 24
Z4	16 19 20 23 24
Z5	14-17 21-24
A1	11 15
A4	2-4 6-8 10-12 15 16 18 19 22 24
A5	2 3 11 17 21 24
A6	15-24
A7	10 18-24
B4	8 10 11 14 17
B5	4 8
B6	1-3 19 20 22-24
B7	2-4 7 8 10-19 21 22
B8	1 2
B9	3 4 7 8 11 12
C3	20 23 24
C6	2-4
C7	1 2 10-12 15 16 19
C9	13 14 17 18 21
D3	3 4 7 8 10 11 14 20 23
D4	7 10 11 13 17
D8	11 12 15 16 19
D9	4 7-12 17 18

PREDOMINATELY THUNDERSTORMS SOUTHEAST-EAST-NORTH OF MSO. CELL MOVEMENT FROM SOUTHWEST AT 40 MPH.

FIGURE 9B

HOURLY AVIATION OVERLAY

1/21/68 MSO SD 1940M

0940M

AREA BRKN R-S NO CHANGE, BNDD 20 SE FCA 30 ENE BZN 40 NE BKE. MOVMT 2725. MAX TOPS 170.

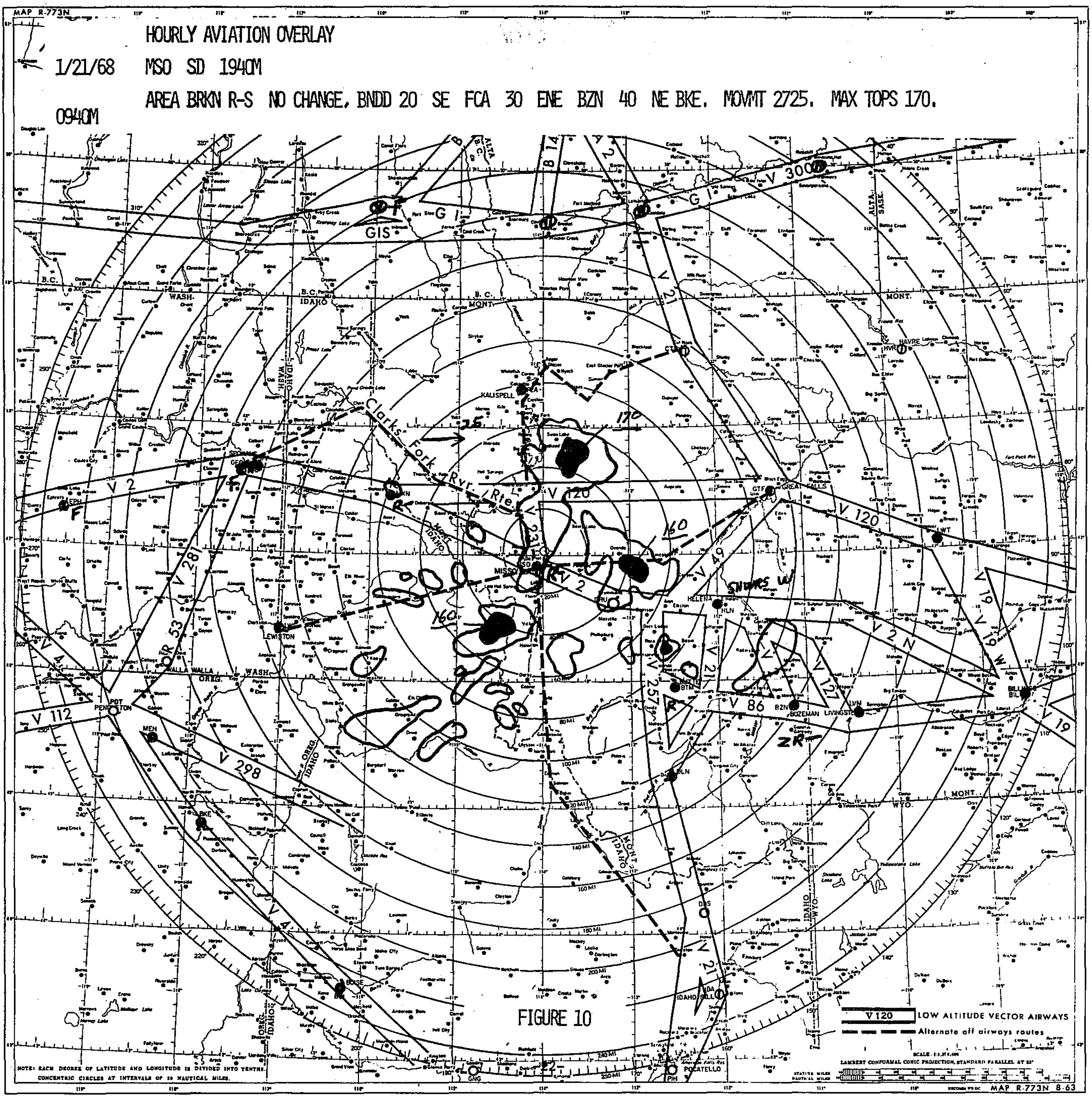
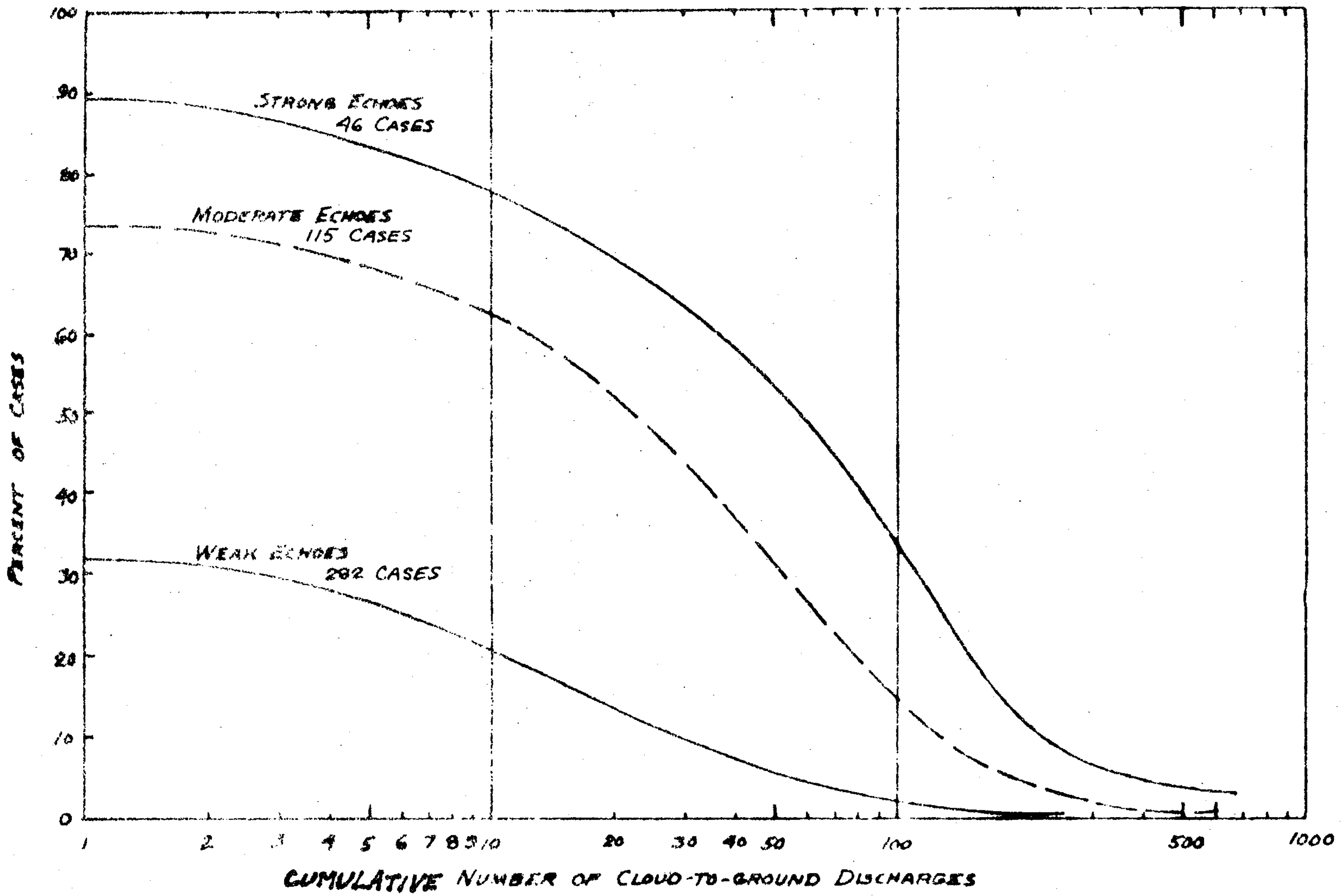


FIGURE 10



75-125 MILES FROM POINT SIX RADAR
443 CASES

FIGURE 11B

25-75 MILES FROM POINT SIX RADAR
313 CASES

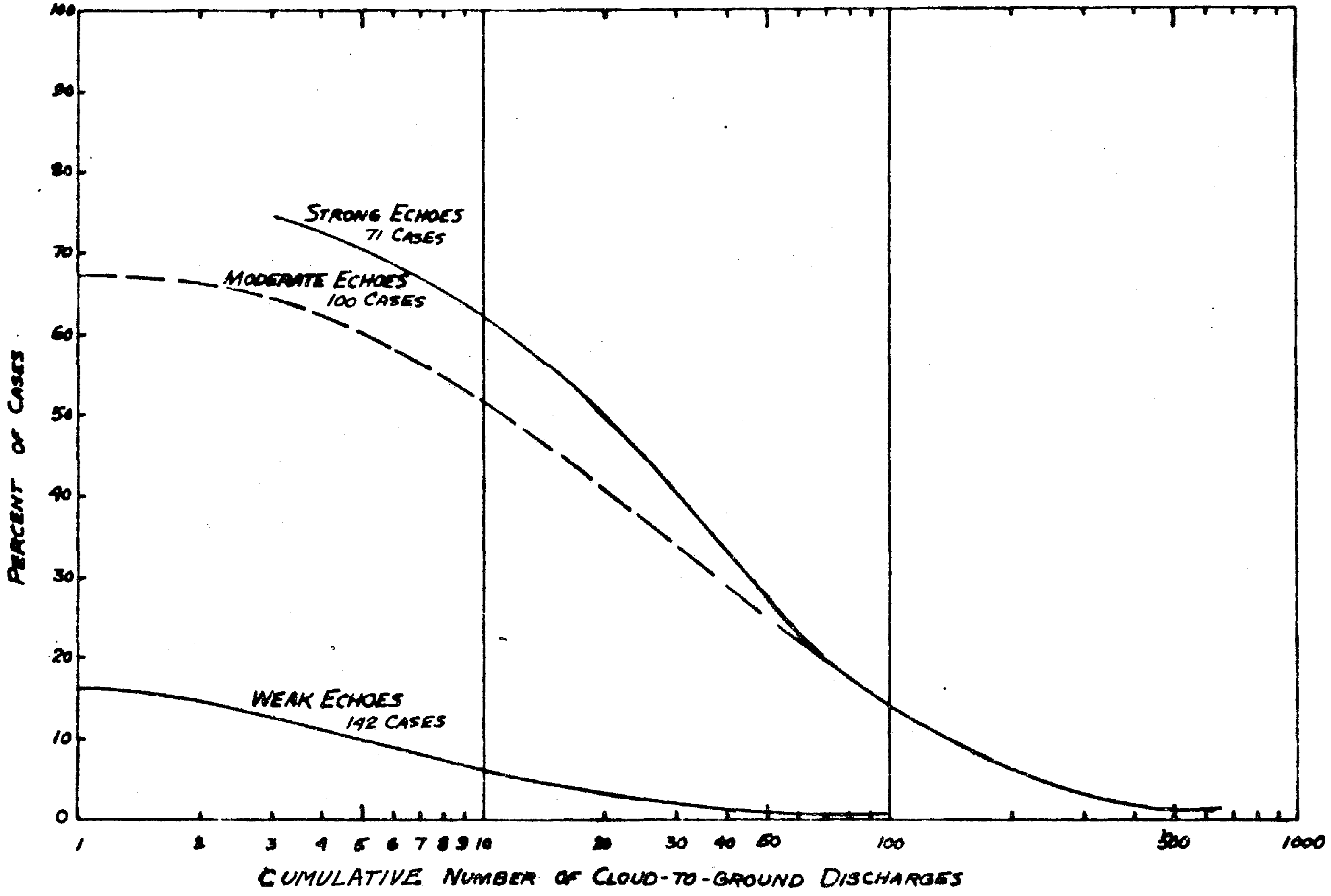


FIGURE 11A