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Precipitation Detection Probabilities by Salt Lake ARTC Radars

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*Out of Print
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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
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PRECIPITATION DETECTION PROBABILITIES BY SALT LAKE ARTC RADARS

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PRECIPITATION DETECTION PROBABILITIES BY SALT LAKE ARTC RADARS

I. INTRODUCTION

It is quite important for radar analysts and users of radar data to know the limitations of detection capability for each radar. The range to which a precipitation target can be detected is not only a function of the radar design characteristics, but is also dependent on siting, target reflective qualities, and radar-beam propagation. Figure 1 shows the location of the seven Salt Lake City ARTC radars in the Intermountain Region. All these radars are of similar design and have a maximum range of 200 nautical miles as indicated by the circles drawn. However, the range to which precipitation targets can be detected will vary considerably from one radar site to the next, due to reasons noted above.

The purposes of this study were:

1) to delineate the areas of "good" and "poor" detection capability of the Salt Lake City ARTCC radar, and

2) to assign values representing the degrees of confidence a user should place in the ability of these radar to detect precipitation areas.

II. RADARS

In June 1966, the Weather Bureau and the Federal Aviation Administration established a joint-use radar program, making available weather information from Air Route Traffic Control radars [1]. This radar weather information is collected, analyzed, and disseminated directly from the Salt Lake City ARTC Center by a staff of Weather Bureau radar observers.

The design parameters of the ARSR-1 type radar used by the ARTC are shown in Table I. These radars were designed, sited, and equipped with special circuitry to provide the best possible detection of aircraft targets. Unfortunately this design does not provide for optimum detection of precipitation. In fact, some of the special circuitry, e.g., moving target indicator (MTI) and circumpolarization (CP), is designed specifically to remove most weather target returns from the radarscope. In spite of these shortcomings, ARTC radars have still been found capable of providing much useful weather data [1].

III. DATA COLLECTION

The range detection variability of weather targets by any radar system is a function of:

1. Radar beam blocking by terrain.

2. Reflective qualities of target.

3. Radar beam propagation.

4. Height of target.

Since each listed factor can vary considerably, their combined effect is most complex. Fortunately, from the field forecasters' point of view, it is not necessary to isolate the contribution or effect of each variable, since we are only interested in the combined or integrated effect. This integrated effect was studied by comparing surface reports of precipitation with precipitation areas indicated by radar. A slight bias was allowed in this comparison in that an echo occurring within 10 miles of reported precipitation was considered positive verification. In Figure 1, small black dots represent precipitation network stations, and crosses show locations of radar sites.

Data for this study were collected over a period of 13 months beginning October 1, 1966. Only data collected when the radar systems were operating at peak performance were included in the tabulations. Tabulated data are shown in Table II.

IV. ANALYSIS OF DATA

Of several factors listed which can affect the range of detection of precipitation, reflective qualities of the target and target height are related to meteorological conditions. Further, the influence of these two factors can be determined rather easily. Radar beam blocking by terrain is essentially a nonvariant, since it is determined by radar siting. The problem of beam propagation is highly variable and almost impossible to determine under average field conditions, so we have assumed normal atmospheric refraction in this study.

The data were analyzed in three categories: (1) thunderstorms, (2) rain and rain showers, and (3) snow and snow showers. By using these three categories, we are essentially considering problems of target reflectivity and target height as well as beam blocking and radar capability. Only precipitation reported as light or greater was considered, i.e., very light intensities were excluded.

It was anticipated that verification of thunderstorms would yield the best results, since they normally reach to greater heights and associated precipitation is usually quite heavy and composed of large droplets and some hail.

Figure 2 shows results of the study of reported thunderstorms in the form of isolines of probability for the detection of thunderstorms by radar. At the 32 stations located within 100 nautical miles of radar sites, positive verification ranged from 50 to 100 percent, with the majority falling in the 80- to 100-percent bracket. A study of local terrain features contributed strongly to the opinion that lower verification values were due to beam blocking by terrain. Verification in the 100- to 200-nautical mile range varied from a low of 11 percent to a high of 83 percent, both at approximately the same range (140 nm). No thunderstorms were detected at four stations that reported them, but all four stations were at least 170 nautical miles from a radar.

Figure 3 shows contours of probability for the detection of rain or rain showers of at least light intensity. Rain at nine stations, all within 60 nautical miles of a radar, was verified by radar over 90 percent of the time. Within 100 nautical miles of a radar, the overall verification was near 70 percent. From 100 to 200 nautical miles verification ranged from a low of 1% to a high of 75%. Rain at seven stations, all at least 170 nautical miles from a radar, was not verified.

Despite similarities in the pattern of detection between Figures 2 and 3, a close look shows a much sharper drop in verification percentages with range when rain rather than thunderstorms are considered. This is believed to be due to the limited vertical extent of some rain showers resulting in overshooting of the radar beam when these showers occurred only a short distance from the radar. The blocking pattern becomes more pronounced with rain, also, again due to the lower tops.

Snow detection probabilities, shown in Figure 4, produced the poorest results. This is partially due to the lower altitudes at which snow occurs. Another factor influencing detection of snow is the temperature of the air mass in which it occurs. When the air mass is cold, i.e., surface temperatures are 25°F. or less, snow is usually dry and has low radar reflectivity. At higher temperatures snow is wetter and its reflectivity is higher.

The presence of wet and dry snow is suggested in Figure 4 by the overall latitudinal gradient of increasing probabilities with decreasing latitude. Over the surveillance areas of the Boise, Ashton, and Lovell radars, verification was rather poor even at close range. Snow occurrence in these areas is usually associated with cold polar or arctic air masses. Consequently, several inches of snow may fall in a very short period of time in such air masses and yet not be detected by radar due to effects of overshooting (low cloud-tops) and low reflectivity. The warmer air masses normally found in lower latitudes are associated with higher snow reflectivity, higher precipitating tops, and consequently better verification.

The contour lines drawn on Figures 2, 3, and 4 may be somewhat biased due to the sparse network of reporting points. The analyst tried to take into account the blocking effects of local terrain.

To sum, in general the detection pattern is about the same for showers and thunderstorms but the probabilities of detection of snow are much lower. Some effect from blocking may be noted southwest of Salt Lake City, near Hanksville, Utah, and north of Baker, Oregon. The overall pattern, however, shows the effect of overshooting more than any other factor.

V. REFERENCE

[1] "Evaluation of the Operational Feasibility of Utilizing ARTC Radar at Salt Lake City for Weather Surveillance", H. P. Benner, Weather Bureau Western Region Publication, December 1965.

TABLE I

ARSR-1 PERFORMANCE CHARACTERISTICS

Peak Transmitted Power	5 megawatts
PRF	360 PPS average, 3 periods staggered (stagger ratio 6:7:8)
Pulse Width	2 micro seconds
Frequency	1280-1350 megacycles
Antenna Gain	34 db
Beam Width	Horizontal 1.2 degrees Vertical 3.75 degrees specially shaped to 45 degrees
Antenna Rotation Speed	6 RPM
Reflector Size	46 feet by 23 feet
Antenna Feed	Horn feed; with choice of horizontally-linear or circular polarization remotely controlled
Types of Presentation	Normal Video Integrated Normal Video MTI Video Beacon or IFF Video Video Map Adjustable combinations of the above
Anticlutter Features	IAGC, STC, FTC, and Circular Polarization
System Noise Figure	3.5 db

TABLE II
SUMMARY OF RESULTS OF RADAR VERIFICATION PROJECT

STATION	TRW REPORTED (Surface)	TRW VERIFIED (Radar)	R-RW REPORTED (Surface)	R-RW VERIFIED (Radar)	S-SW REPORTED (Surface)	S-SW VERIFIED (Radar)	PCPN DETECTED NONE REPORTED	TOTAL CASES REPORTED
MXN	1	0	101	0	103	0	0	205
MSO	3	0	73	0	43	0	0	119
HLN	11	5	34	3	62	1	0	107
GTF	10	0	42	0	100	0	0	152
LWT	6	2	43	14	96	2	4	145
MLS	6	5	33	5	70	3	4	109
BTM	16	9	41	11	99	3	11	156
BZN	26	23	28	18	45	7	26	99
LVM	24	15	53	35	72	11	20	149
BIL	15	15	53	41	93	25	36	161
SHR	19	19	77	60	92	30	63	188
CPR	22	15	30	7	61	0	8	113
DLN	21	15	39	29	40	10	28	80
IDA	13	10	48	42	38	9	84	99
PIH	16	11	62	32	43	4	33	121
WRL	11	11	28	19	33	3	45	72
LND	29	24	40	24	40	3	37	109
BOI	7	7	82	52	28	5	76	117
GNG	0	0	15	5	10	0	9	25
BYI	6	3	24	9	17	0	8	47
MLD	18	16	35	26	32	12	32	85
SLC	37	33	199	105	46	32	131	202
OGD	18	17	83	72	58	40	122	159

TABLE II (Continued)

STATION	S-SW REPORTED (Surface)	S-SW VERIFIED (Radar)	S-SW REPORTED (Surface)	S-SW VERIFIED (Radar)	S-SW REPORTED (Surface)	S-SW VERIFIED (Radar)	PCPN DETECTED NONE REPORTED	TOTAL CASES REPORTED
LAR	38	18	29	2	47	0	7	114
CYS	25	5	26	1	39	0	0	90
LOL	5	5	41	36	19	10	23	65
WMC	5	4	47	33	33	19	23	85
BAM	6	5	27	25	27	19	59	60
EKO	7	6	54	53	35	17	82	96
ENV	8	5	21	8	20	3	14	49
LAS	7	5	18	10	0	0	3	25
ELY	29	17	43	14	61	2	17	133
DTA	15	11	27	18	28	6	22	70
MLF	21	16	25	24	26	12	63	72
CDC	41	37	56	54	24	14	96	121
HVE	19	11	14	5	5	0	8	38
BCE	73	63	60	59	56	40	76	189
GJT	9	1	16	2	8	0	2	33
RIL	3	2	9	1	4	0	2	16
EGE	10	2	10	1	14	0	1	34
EED	2	1	2	0	0	0	0	4
PRC	30	13	12	5	9	0	5	51
FLG	61	27	10	5	25	0	2	96
INW	12	5	14	3	7	0	1	33
FSR	0	0	10	0	13	0	3	23
GEG	1	0	83	0	24	0	0	108
LWS	2	1	91	2	16	0	0	109

TABLE II (Continued)

STATION	S-SW REPORTED (Surface)	S-SW VERIFIED (Radar)	S-SW REPORTED (Surface)	S-SW VERIFIED (Radar)	S-SW REPORTED (Surface)	S-SW VERIFIED (Radar)	PCPN DETECTED NONE REPORTED	TOTAL CASES REPORTED
MEH	2	1	58	9	96	2	2	156
BKE	13	13	42	34	27	7	21	82
RNO	9	7	22	2	21	1	3	52
TPH	14	5	8	6	16	0	6	38
MUO	8	5	33	15	22	0	14	63
DPG	13	10	39	25	32	5	19	84
NFL	15	1	13	4	5	3	3	33
EVW	10	10	94	89	84	61	127	188
RKS	21	19	49	46	33	23	73	103
RWL	18	14	51	49	42	11	54	111
ALW	2	1	86	0	12	0	0	100
PDT	0	0	87	1	10	0	0	97

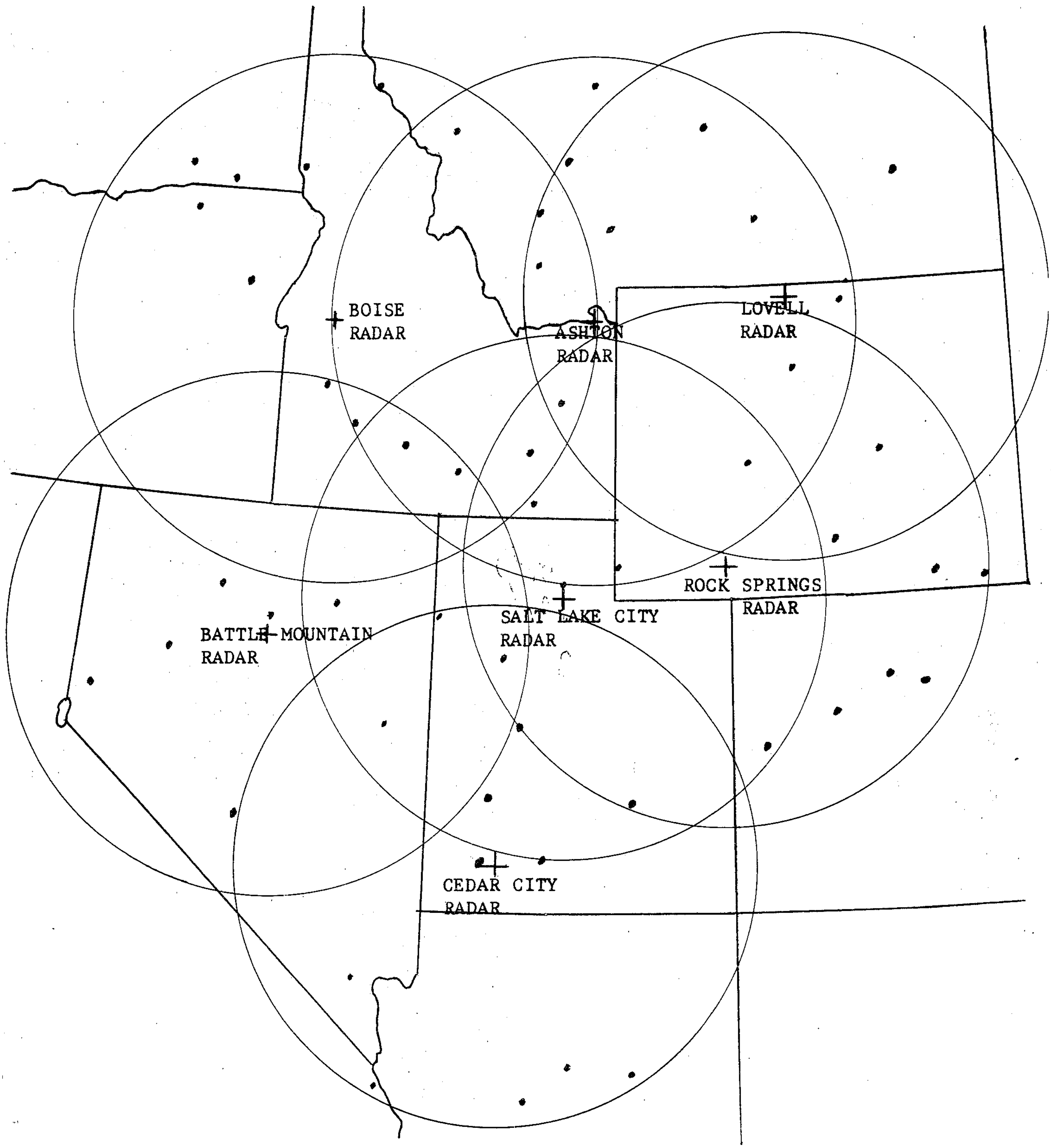

FIGURE 1
SURVEILLANCE AREA OF THE SALT LAKE
CITY ARTCC RADAR SYSTEM

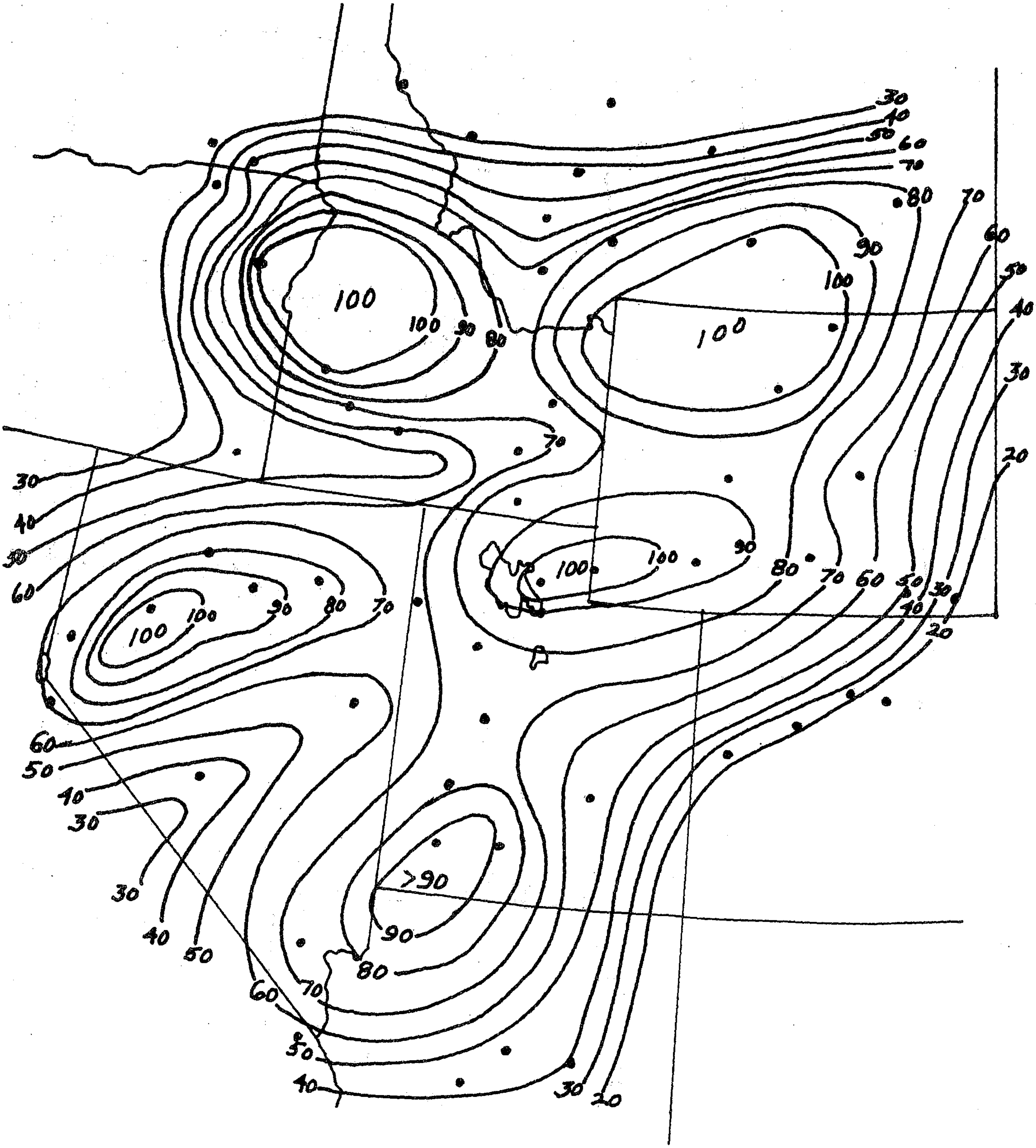

FIGURE 2
PROBABILITY OF DETECTION
OF THUNDERSTORMS

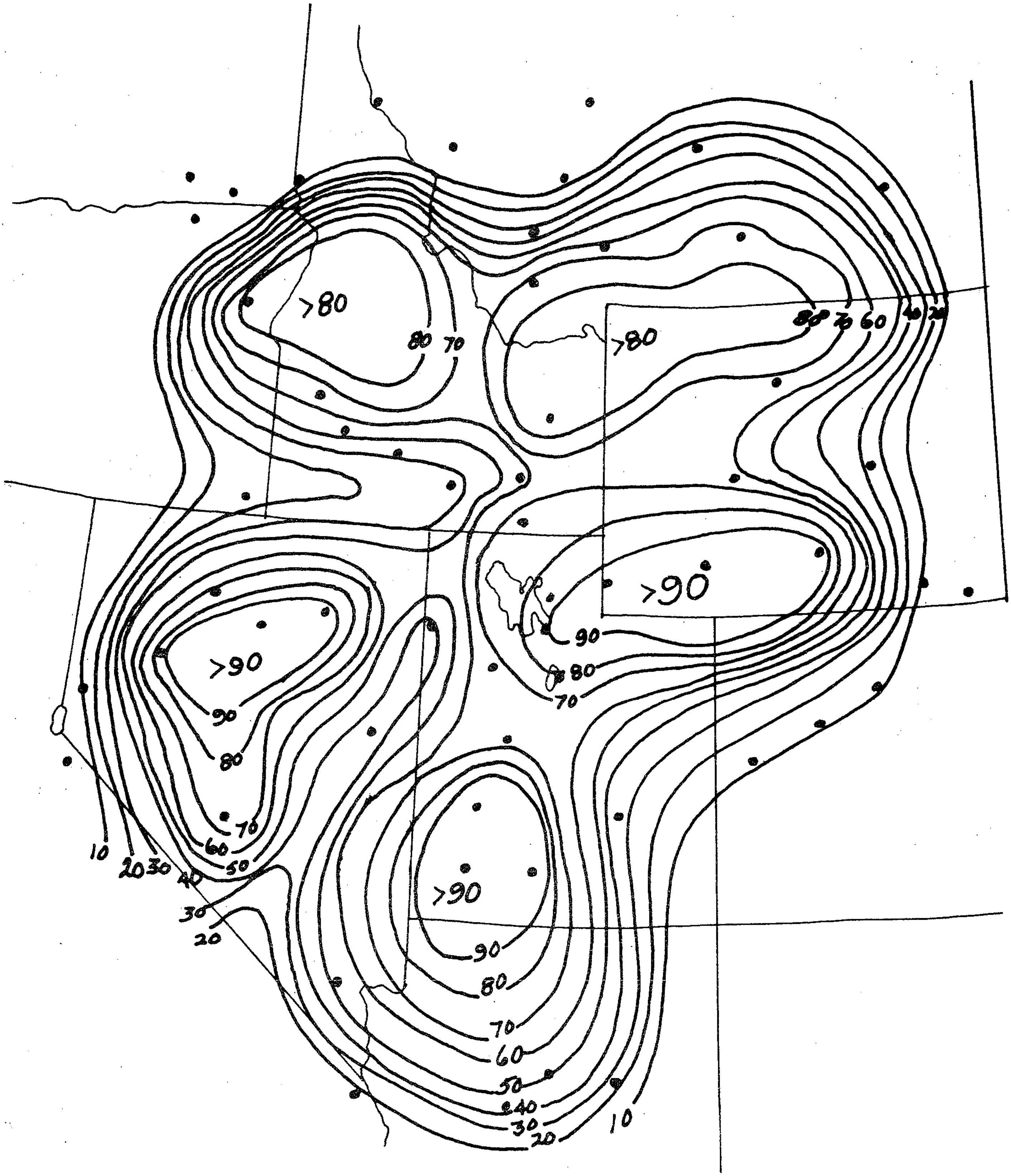

FIGURE 3

PROBABILITY OF DETECTION OF RAIN OR RAIN SHOWERS

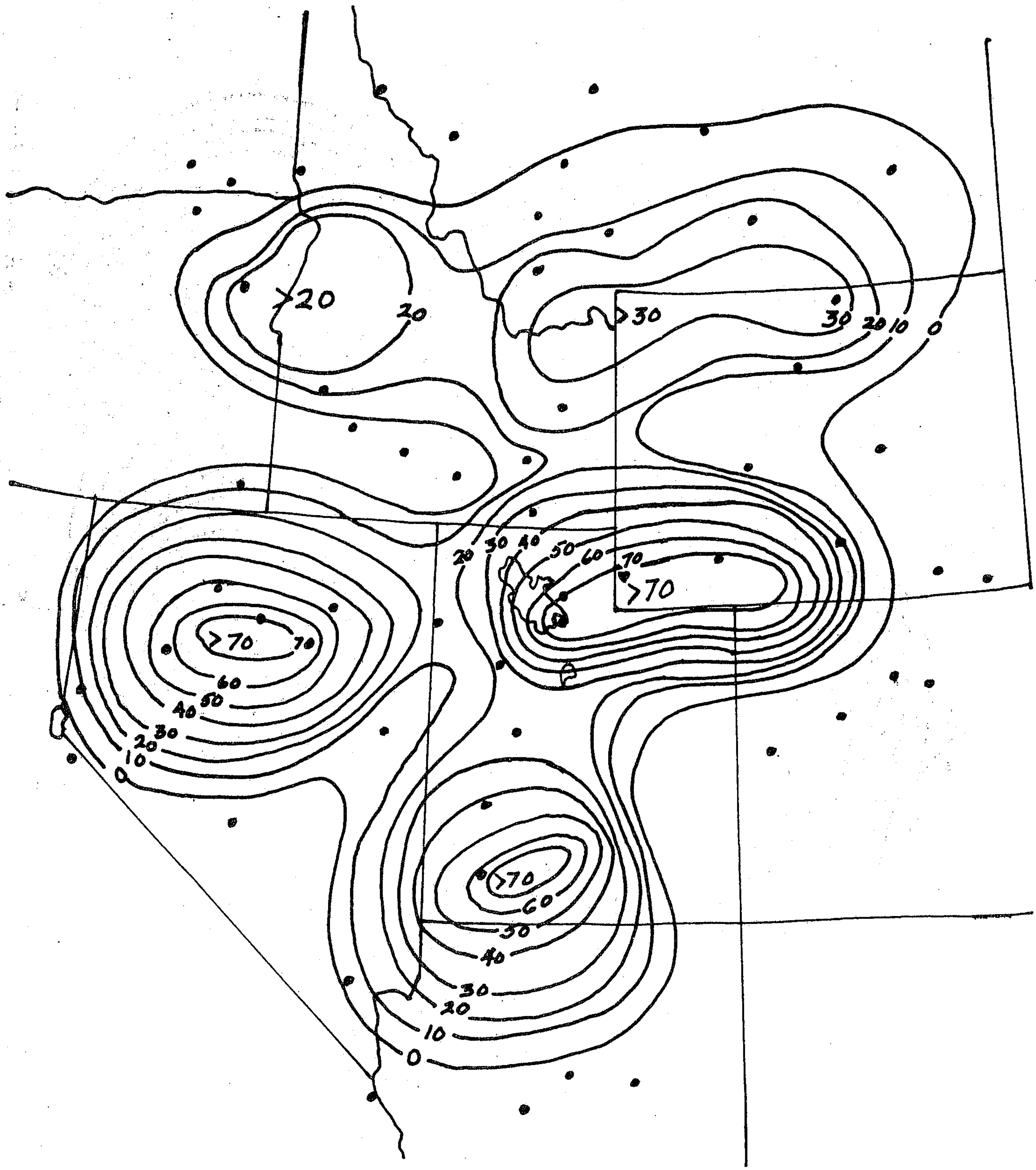

FIGURE 4

PROBABILITY OF DETECTION OF SNOW OR SNOW SHOWERS

Western Region Technical Memoranda (Continued):

No. 24 Historical and Climatological Study of Grinnell Glacier, Montana. Richard A. Dightman. July 1967.

No. 25 Verification of Operational Probability of Precipitation Forecasts, April 1966 - March 1967. W. W. Dickey. October 1967.

No. 26 A Study of Winds in the Lake Mead Recreation Area. R. P. Augulis. January 1968.

No. 27 Objective Minimum Temperature Forecasting for Helena, Montana. D. E. Olsen. February 1968.

No. 28** Weather Extremes. R. J. Schmidli. April 1968.

No. 29 Small-Scale Analysis and Prediction. Philip Williams, Jr. May 1968.

No. 30 Numerical Weather Prediction and Synoptic Meteorology. Capt. Thomas D. Murphy, USAF. May 1968.

**Revised.