WEATHER BUREAU
Systems Development Office
Techniques Development Laboratory
Silver Spring, Md.

October 1967

Charts Giving Station Precipitation in the Plateau States from 700-Mb. Lows During Winter

Technical Memorandum WBTM TDL-12

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

ESSA TECHNICAL MEMORANDUM

WEATHER BUREAU

TECHNIQUES DEVELOPMENT LABORATORY

The primary purpose of the Techniques Development Laboratory of the Systems Development Office is to translate increases in basic knowledge in meteorology and allied disciplines into improved operating techniques and procedures. To achieve this goal, TDL conducts and sponsors applied research and development aimed at the improvement of diagnostic and prognostic methods for producing weather information. The lab carries out studies both for the general improvement of prediction methodology used in the National Meteorological Service System and for more effective utilization of weather forecasts by the ultimate user.

Material for this ESSA Technical Memorandum subseries is obtained from various sources. It is reproduced in this subseries to facilitate the rapid distribution of material which may be preliminary in nature. Papers appearing in this subseries may be published formally elsewhere at a later date.

The papers in the TDL subseries of ESSA Technical Memoranda are a continuation of the Weather Bureau Technical Notes-TDL. Papers listed below are available through the Clearinghouse for Federal Scientific and Technical Information, U.S. Department of Commerce, Sills Building, Port Royal Road, Springfield, Va. 22151. Price $3.00.

No. 1 Objective Prediction of Daily Surface Temperature. William H. Klein, Curtis W. Crockett and Carlos R. Dunn. October 1965.

No. 2 Hurricane Cindy Galveston Bay Tides. N. A. Pore, A. T. Angelo and J. G. Taylor. September 1965.

No. 3 Atmospheric Effects on Re-Entry Vehicle Dispersions. Karl R. Johannessen. December 1965.

No. 4 A Synoptic Climatology of Winter Precipitation from 700-mb. Lows for the Intermountain Areas of the West. D. L. Jorgensen, W. H. Klein and A. F. Korte. May 1966.

No. 5 Hemispheric Specification of Sea Level Pressure from Numerical 700-mb. Height Forecasts. William H. Klein and Billy M. Lewis. June 1966.

No. 6 A Fortran Program for the Calculation of Hourly Values of Astronomical Tide and Time and Height of High and Low Water. N. A. Pore and R. A. Cummings. January 1967.

No. 7 Numerical Experiments Leading to the Design of Optimum Global Meteorological Networks. M. A. Alaka and F. Lewis. February 1967.

No. 8 An Experiment in the Use of the Balance Equation in the Tropics. M. A. Alaka, D. T. Rubsam, and G. E. Fisher. March 1967.

No. 9 A Survey of Studies of Aerological Network Requirements. M. A. Alaka. May 1967.

(Continued on inside back cover)

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

Weather Bureau Technical Memorandum TDL-12

CHARTS GIVING STATION PRECIPITATION IN THE PLATEAU STATES FROM 700-MB. LOWS DURING WINTER

Donald L. Jorgensen
August F. Korte
James A. Bunce, Jr.

SYSTEMS DEVELOPMENT OFFICE
TECHNIQUES DEVELOPMENT LABORATORY

SILVER SPRING, MARYLAND
October 1967

CONTENTS

CHARTS GIVING STATION PRECIPITATION IN THE PLATEAU STATES FROM 700-MB. LOWS DURING WINTER*

by

Donald L. Jorgensen, August F. Korte and James A. Bunce, Jr.
Techniques Development Laboratory
Weather Bureau, ESSA
Silver Spring, Md. 20910

ABSTRACT

Precipitation resulting from 700-mb. low systems during the winter months has been examined for individual stations in the Plateau region. Marked differences are noted in the frequency with which precipitation occurs, depending upon the storm intensity and the relative positions of the upper low systems. Locations of the cyclonic centers with the heaviest amounts of precipitation and the highest frequencies of occurrence vary from positions directly over the observing station to positions several hundred miles to the east, north, and west. Lowest frequencies of occurrence and lightest amounts are generally observed when the center passes well to the south of the station. These differences between stations are explained in terms of geographic location and the local and broadscale surrounding topography. Use of the derived results as a forecast aid is illustrated.

---

* A condensation of this paper was presented at the annual joint meeting of the American Meteorological Society and the American Geophysical Union, Washington, D. C., April 17-20, 1967.

1. INTRODUCTION

Previous studies have shown that in the western intermountain region of the United States storm systems characterized by cyclonic circulation aloft are one of the most important causes of precipitation. The precipitation from these systems results from a combination of dynamic and orographic factors. The dynamic component from these systems has been investigated in an earlier study described by Klein et al. [3]. The results of the earlier study are presented in the form of a "synoptic climatology" of the precipitation from upper air centers at four different levels. The study was carried out through the use of a moving grid system with the low centered at the origin of the grid and with the associated precipitation in the grid area summarized by computer. Since the grid moved with the system, the precipitation recorded by the observing network gave an averaged precipitation pattern from which the orographic effect was essentially eliminated, leaving only the dynamic component.

For those stations for which a strong orographic component in precipitation is suspected (which includes nearly all stations in the area under investigation) and for which a satisfactory precipitation record is available, it is desirable to retain both the dynamic and orographic components. The two components can be retained in combination by holding the grid stationary relative to the underlying topography. This has been accomplished by reversing the computer program used in the earlier study. With this reversal, the station now becomes centered at the origin, and the upper low centers with the associated station precipitation are spotted in the surrounding grid area. Analyses for a selected number of stations for which satisfactory precipitation records are available can be obtained in this manner. Analyses have been prepared for 34 stations in the intermountain region. A number of the charts for individual stations will be presented in the following sections for illustrative purposes, with attention focused on the general topographic effects.

2. DATA AND PROCEDURES

The period investigated was the winter months of December, January, and February for the years 1951 through 1964. Figure 1 gives the area of study located in the Plateau region of the United States between the Continental Divide to the east and the Cascade-Sierra Nevada chain of mountains to the west. Also shown is the area over which upper lows were tabulated. Only 700-mb. cyclonic systems are used in this investigation. Hourly precipitation amounts were the same as those used in previous studies [1, 2, 3] and were obtained from the National Weather Records Center in Asheville, N. C., for the network of 280 observing stations located by the black dots. Twelve-hourly amounts centered at upper-air observation times (0000 or 0300 GMT and 1200 or 1500 GMT) were used to indicate occurrence and intensity of precipitation.

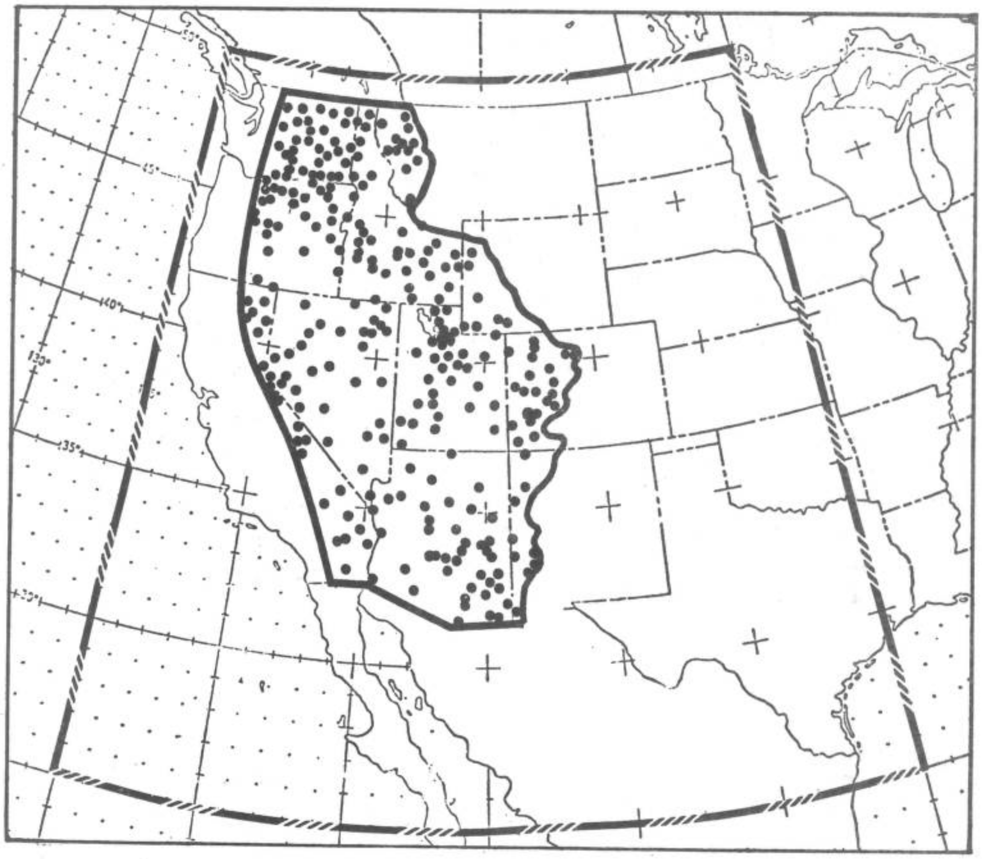


Figure 1. - Chart showing observational area (enclosed by heavy lines) from which upper low data were obtained and precipitation station network (black dots).

For the 13 years considered, the number of upper lows identified in the recovery area was 872. In order to take into account the intensities of the lows, they were classified into three classes of nearly equal ranges as was done in the earlier studies, depending upon the departure from local normal of the central height. (See Appendix A, extracted from a previous study [1], for classification procedures.) The 12-hour station precipitation occurrences and their amounts were related to the position of the associated 700-mb. low center for each intensity category by computer. The grid used is shown in Figure 2 and is made up of 324 cells one degree of latitude square. The origin is shown by the star which is the position of the observing station. The precipitation reported by the station is allocated to that cell in which the center of the associated 700-mb. low falls. If more than one low occurs within a given cell, an average of the precipitation amounts is taken. Only those lows are considered which fall within the grid area. If two or more concurrent lows occur within the grid area, the major low is generally chosen as indicated earlier [1]. Using data from the computer printout, charts are analysed showing the frequency with which measurable precipitation occurred at the station for lows located in the grid area. Average precipitation amounts for lows falling within the various frequency ranges have been obtained.

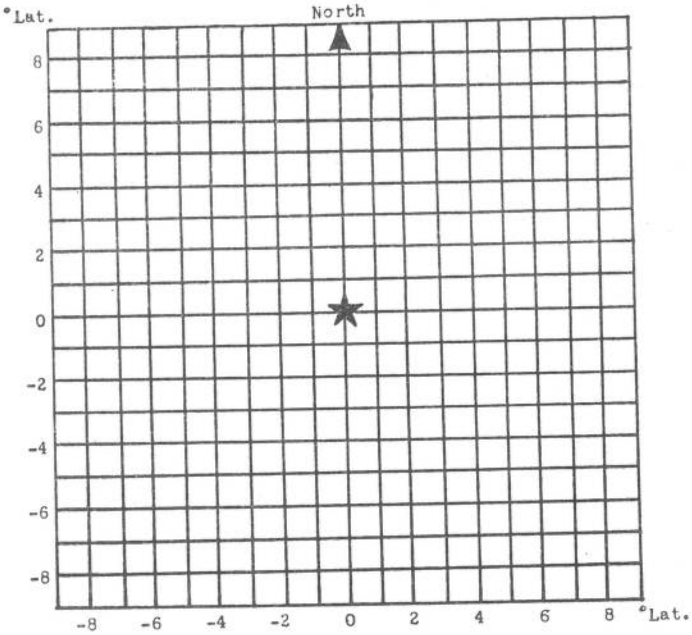


Figure 2. - Grid representation on plane surface. Grid system consists of great circles on the spherical earth with dimensional units equivalent to latitude degrees along the two axes.

3. RESULTS OF INVESTIGATION

The plotted data and analyses for the three intensity classes will be presented for Flagstaff, Arizona, and Salt Lake City, Utah, for illustrative purposes. In addition, special attention will be called to Ouray and Durango, Colorado, to illustrate the differing orographic effects occurring over short distances in mountainous areas. Charts designed for operational use are presented for the 34 selected stations in Appendix B. Analyses only are shown on these charts.

The analysis for Flagstaff for the least intense class of lows is given in Figure 3. In this chart, and the charts which follow, the relative frequency of precipitation cases compared to all cases has been examined for all sections of the chart to give percentage of precipitation occurrence. Only a few scattered precipitation occurrences are noted as indicated by the black dots, with non-precipitating lows indicated by open circles. Isopleths have been drawn approximately through centers of areas having equal frequency values for each 20 percent interval with the 10 percent interval added as a dashed line. An area with frequencies above 20 percent is analysed over and to the northeast of the station. Average precipitation amounts are indicated in the upper right-hand corner of the figure for the three frequency intervals, with the average based on all cases falling within the class interval. Amounts for this intensity class are light, averaging .02 inch or less.

Figure 4 shows a similar analysis for the Class II, or intermediate intensity, situations. We see that the 20 percent area has increased considerably, and a substantial area with frequencies greater than 60 percent is centered to the northwest of the station. Average precipitation amounts range upward to .12 for frequencies greater than 60 percent.

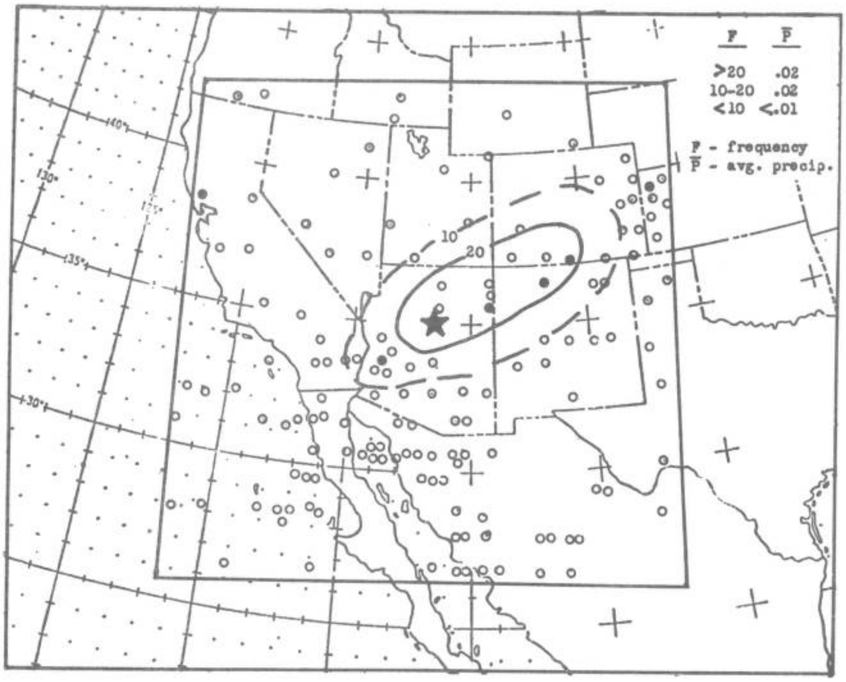


Figure 3. - Plotted positions of Class I lows for thirteen winter seasons. Whether or not measurable precipitation occurred at Flagstaff is indicated at the position of the low, with a dot representing precipitation and a circle the absence of precipitation. Average amounts for the frequency intervals are given in the upper right corner.

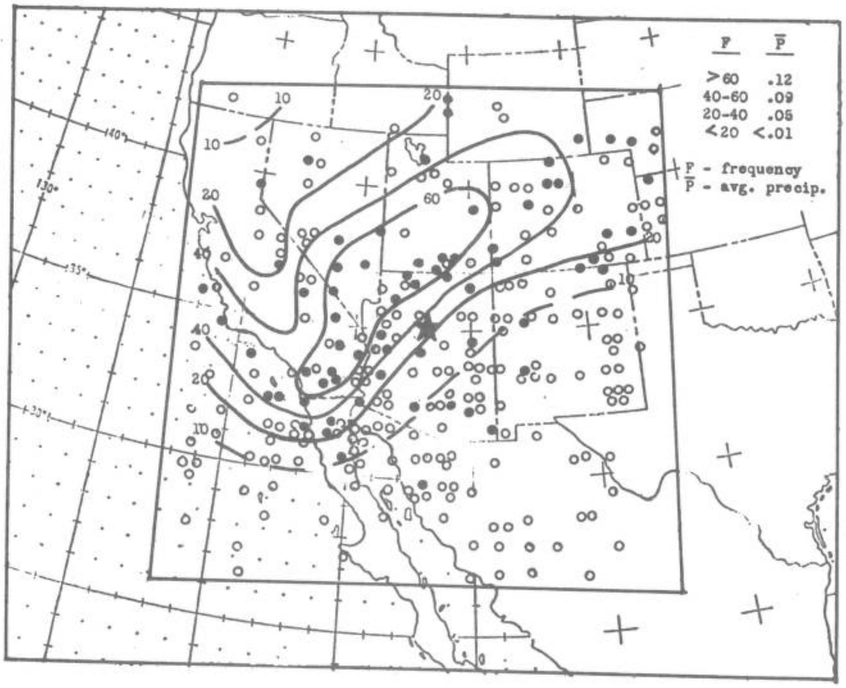


Figure 4. - Similar to preceding figure except for Class II situations.

The analysis for the most intense, Class III, situations is given in Figure 5. In this class, there are two areas where the frequency rises above 80 percent. The 80 percent area off the coast is of special interest in that a higher frequency of precipitation in this area was not indicated by the charts for the less intense classes. The second area centered to the north northwest of the station appears to be in an optimum position for a maximum orographic effect at Flagstaff. A low center to the northwest and north would cause southerly or southwesterly flow in the vicinity of Flagstaff which would be generally upslope. Precipitation amounts range upwards to .19 for the higher frequencies.

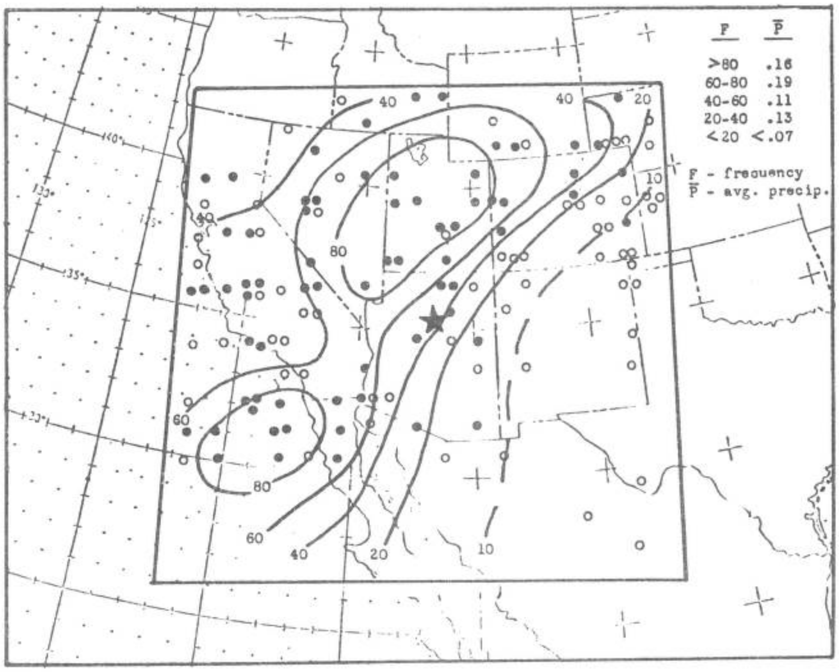


Figure 5. - Similar to preceding figure except for Class III situations.

It is of interest to compare the precipitation pattern given in Figure 5 with that which might be expected for a normal pattern from which the orographic effects have been averaged out. In Figure 6 is such a pattern obtained from the earlier four-level study [3]. Taking the graphical difference between this pattern and that shown in the previous figure gives the frequency pattern shown in Figure 7. This pattern can be interpreted as giving the orographic component of the precipitation frequency. A 60 percent area appears in the southwest corner of the grid, an area already mentioned and apparently associated with upper lows which cause an influx of moisture into the Flagstaff area. The positive area of above 30 percent located to the north of the station is in a position where the lows might be expected to have their greatest orographic effect.

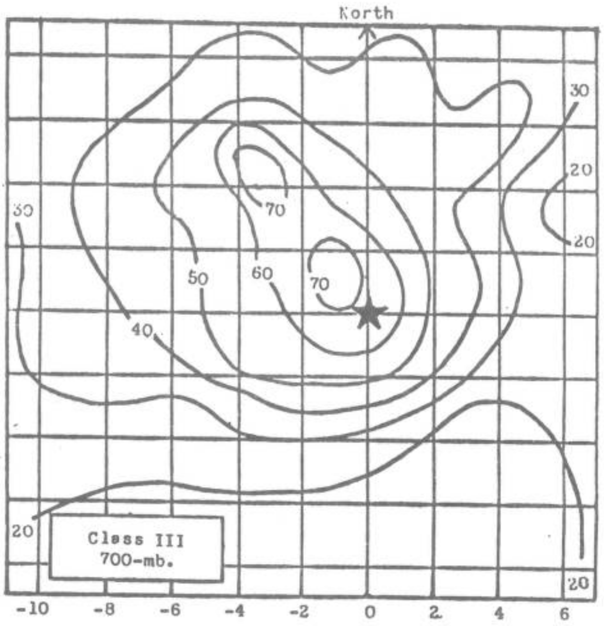


Figure 6. - Pattern giving frequency of occurrence of precipitation at a station located at the origin for Class III situations. Analysis is derived from generalized approach and gives frequency of precipitation at station when associated low is located in any portion of the grid.

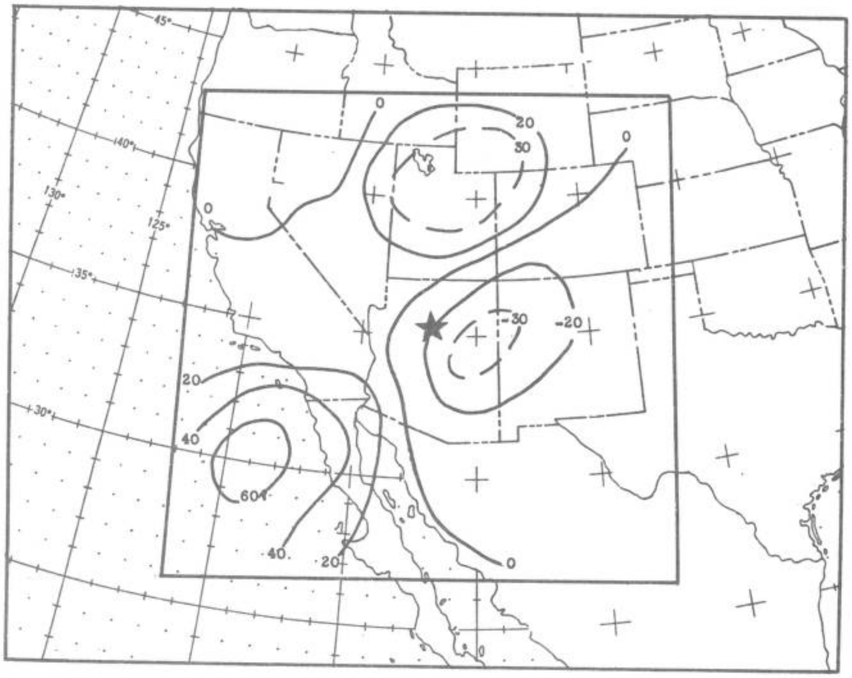


Figure 7. - Difference between frequency of occurrence patterns for Class III situations at 700-mb. for Flagstaff for stationary and moving grids (stationary minus moving grid patterns).

Charts for Salt Lake City similar to those shown above for Flagstaff are given in Figures 8 through 11. Figure 8 shows only a few scattered occurrences for Class I situations with all areas having less than 10 percent frequency of occurrence and with average amounts less than .01 inch. Class II situations are shown in Figure 9. Except in the southeast portion of the grid area, the frequency has increased substantially, and a rather broad area of greater than 60 percent is located to the north and northeast of the station. Here, again, the maximum area can be interpreted as being in response to the northwesterly flow needed to produce the maximum upslope air motion against the surrounding mountains. The average precipitation ranges upward to .18 inch. Figure 10 presents a similar pattern for the Class III situations but with the 60 percent area expanding in size, especially toward the west and southwest. An area of 80 percent frequency essentially replaces the 60 percent area observed for the intermediate intensity class. Precipitation amounts appear to be similar to those for the Class II situations.

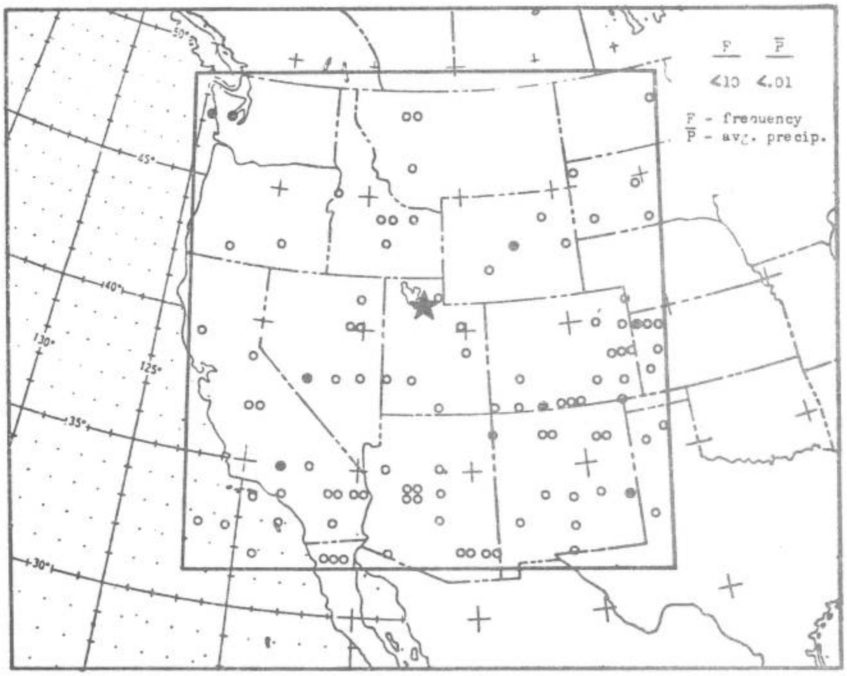


Figure 8. - Plotted positions of Class I lows for thirteen winter seasons. Whether or not precipitation occurred at Salt Lake City is indicated by dots and circles as in the preceding figures.

As done for Flagstaff, a comparison can be made between the non-orographic and the orographic patterns by taking the difference between the normal pattern given in Figure 6 and the pattern given in Figure 10 for the most intense lows. This difference is given in Figure 11 and shows a maximum of over 40 percent greater frequency of occurrence than normal for lows occurring over the Montana-Wyoming border, again indicating the area of greatest orographic effect for the lows.

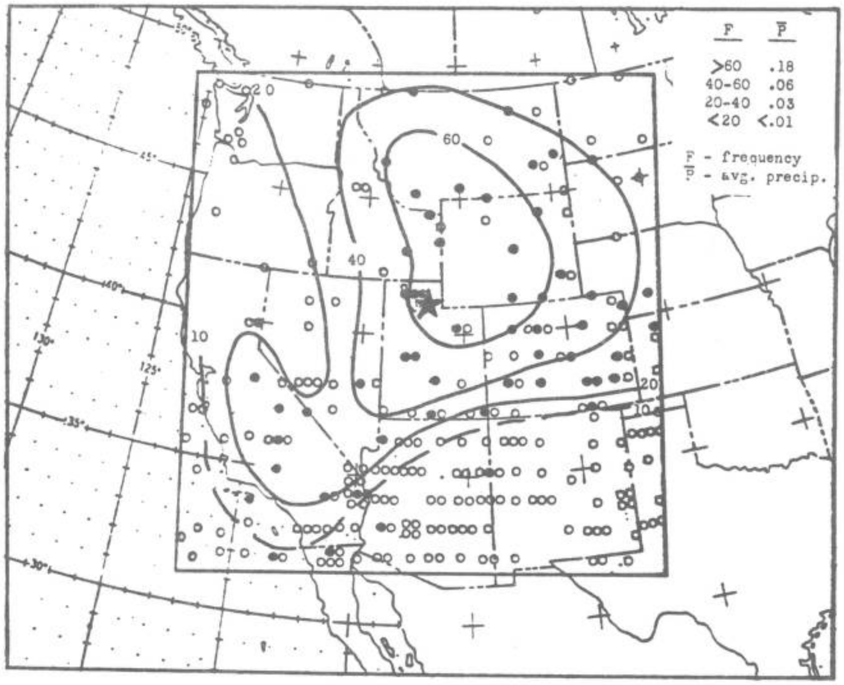


Figure 9. - Similar to the preceding figure except for Class II lows.

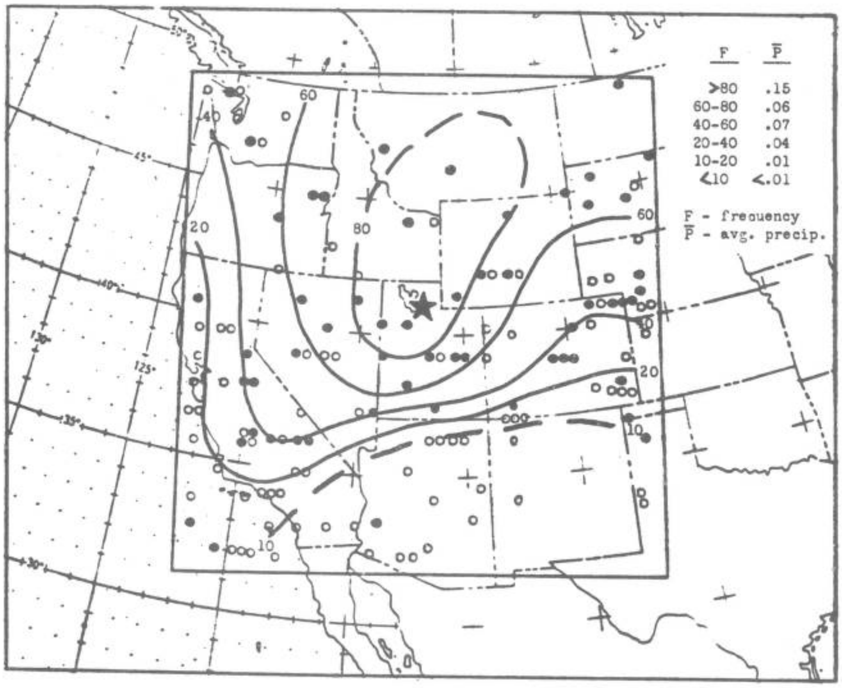


Figure 10. - Similar to the preceding figure except for Class III lows.

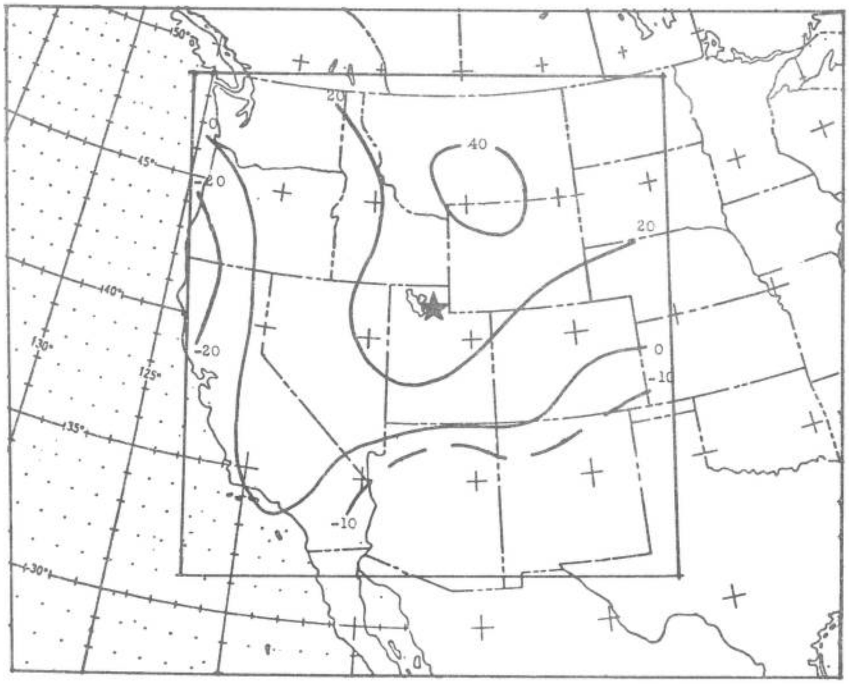


Figure 11. - Difference between frequency of occurrence patterns for Class III situations at 700-mb. for Salt Lake City for stationary and moving grids (stationary minus moving grid patterns).

A comparison of two mountain stations with differing orographic effects will shed additional light on the relationship between precipitation occurrence and topographic influences. In Figure 12 is shown the frequency pattern for Ouray, Colorado, for the most intense lows. This station is located on the north slopes of the San Juan Mountains at an elevation of almost 8000 feet. An area of over 90 percent covers most of Colorado with a maximum center to the east of the station. This is the position for which a low might be expected to give generally upslope winds in the vicinity of Ouray. Figure 13 shows a comparable analysis for Durango, Colorado. Durango is located about 60 miles south of Ouray but on the other side of the mountains and at a lower elevation. Upslope motion at this station requires a southerly flow. As seen in the figure, an area of 90 percent frequency is located to the northwest of the station, a position of the lows which could be expected to produce upslope movement over the Durango area. Taking the graphic difference, which is shown in Figure 14, a comparison is made between the frequency patterns at the two stations. A positive area of 70 percent over central Kansas indicates that with the low in this position, there is a 70 percent greater chance of precipitation at Ouray than at Durango. Conversely, when the low is in the northwest portion of the grid area, there is a 30 percent greater chance of precipitation at Durango than at Ouray. The distance between the two centers is 900 miles, representing a rather broadscale feature of the circulation.

The charts are, of necessity, based on relatively few cases, and as additional cases become available, there is no doubt that the patterns will change somewhat. However, the patterns appear sufficiently strong and consistent to indicate the main features.

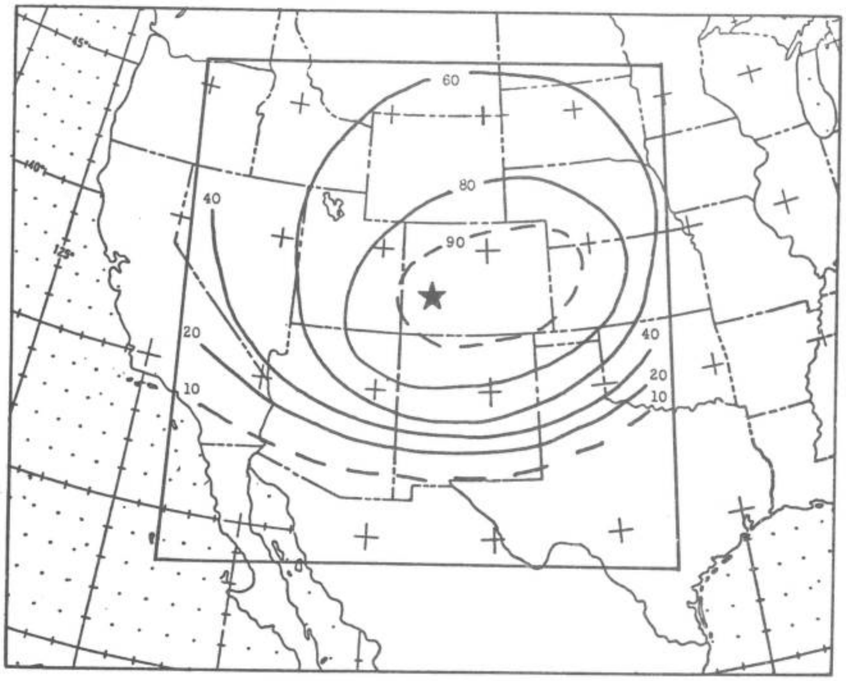


Figure 12. - Analysis for Ouray, Colorado, for Class III situations (data not plotted). Pattern gives frequency of occurrence of precipitation at Ouray for associated lows within the grid area.

4. OPERATIONAL EXAMPLE

An illustrative example is given to show how synoptic climatological charts of the nature of those shown here can be used by local forecast offices or for evaluating weather modification situations. Charts for Flagstaff and Salt Lake City have been applied to a storm which occurred over the southwest in January 1966. This storm occurred in a period not covered by the original data. A closed low at 700-mb. developed over Arizona and southern California during the morning of January 16, first making its appearance at position 1 in Figure 15. This low then retrograded slowly for 6 hours before recurving and moving eastward. The 6-hour positions of the low are shown by the solid squares, with position number 3 corresponding with the time of the chart. The derived charts for Flagstaff and Salt Lake City were then applied to this storm assuming the availability of "perfect progs."

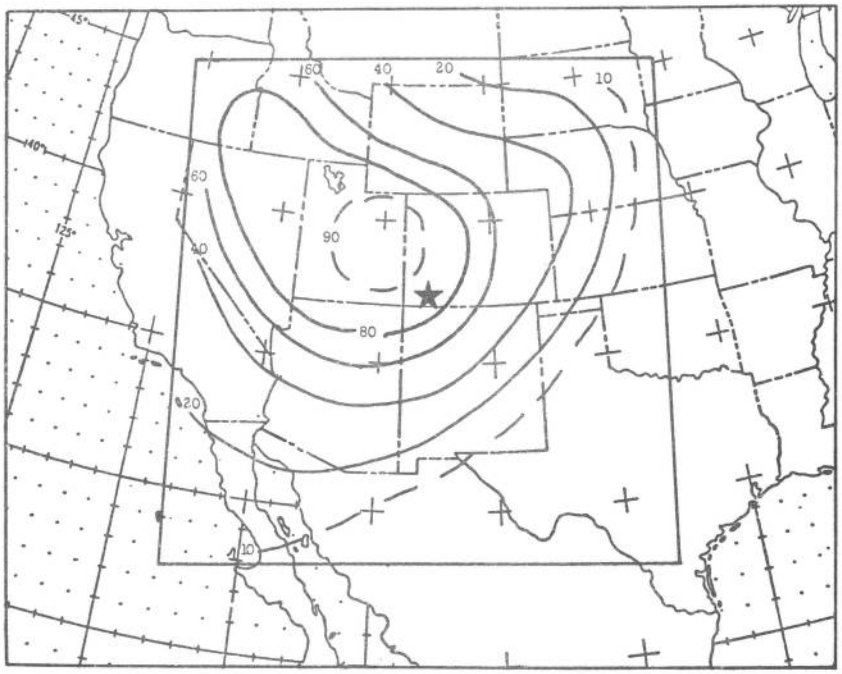


Figure 13. - Similar to preceding figure except for Durango, Colo.

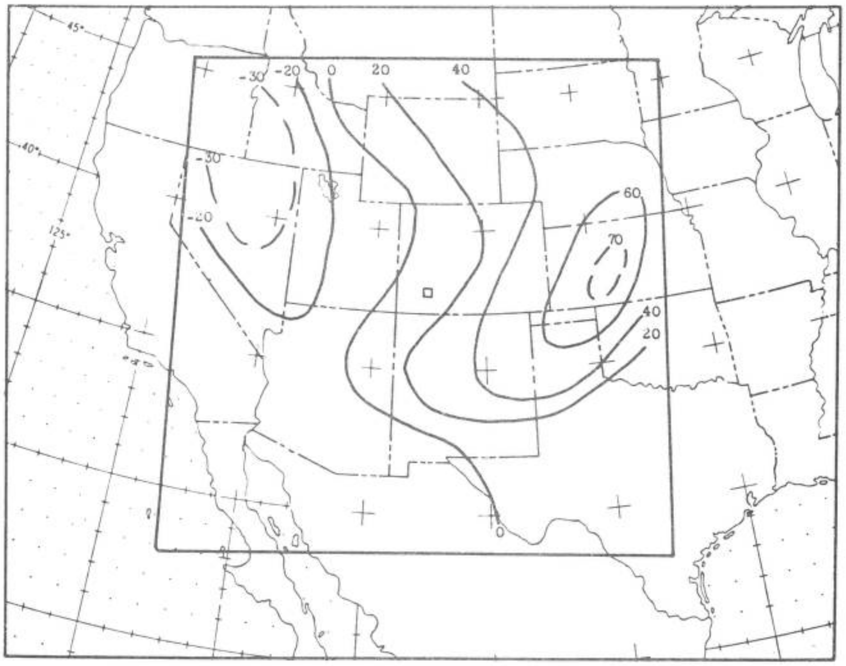
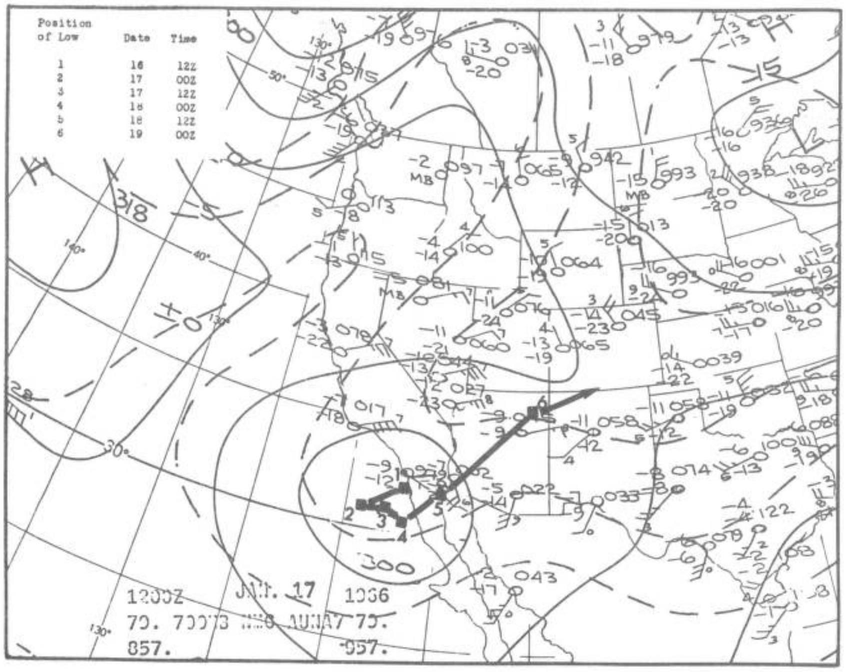


Figure 14. - Graphical difference between two preceding figures.



Position of Low	Date	Time
1	16	12Z
2	17	00Z
3	17	12Z
4	18	00Z
5	18	12Z
6	19	00Z

Figure 15. - Synoptic situation used as an illustrative example.

In the upper portion of Table 1, data are given describing the positions of the low, the central heights, the local normal height for the given positions and the resulting class of the low for the six positions. The low started out with Class II intensity, then increased to Class III for the following two positions, and then weakened to Class II for the last three positions after which it ceased to exist as an identifiable low.

In the lower portion of the table, the probabilities of occurrence of precipitation, the expected amounts, and that actually observed are given for a series of assumed forecasts for the two stations. For Flagstaff, probabilities of occurrence ranged from 15 to 82 percent with expected amounts for various probabilities given in the third column. Observed amounts in the next column show good agreement with the predicted amounts. For Salt Lake City, probabilities ranged from 5 to 12 percent with expected amounts less than .01 inch. No precipitation was recorded at Salt Lake City during the course of the storm.

In use, either in planning weather modification efforts or as local forecasting aids, charts of this nature can serve to give a first estimate of the probability of occurrence and the amount of precipitation expected once an upper low is established over the area or is predicted to move into the area of influence.

Table 1. - Data derived for illustrative example.

Illustrative Example Using Perfect Prognostic Charts. January 16-19, 1966

Low Position	Date	Time	Lat.	Long.	Central Height	Normal Height	Difference	Class
1	16	12Z	32°	117°	2970	3094	-124	II
2	17	00Z	31°	119°	2960	3100	-140	III
3	17	12Z	31°	118°	2970	3100	-130	III
4	18	00Z	30.5°	117°	2980	3102	-122	II
5	18	12Z	32.5°	115°	2970	3094	-124	II
6	19	00Z	35°	110°	2970	3069	-99	II

	Flagstaff Forecast			Salt Lake City Forecast		
Low Position	Probability(%)	Amount	Obs.	Probability(%)	Amount	Obs.
1	39	.05	T	12	<.01	0
2	83	.16	.19	8	<.01	0
3	82	.16	.13	8	<.01	0
4	75	.08	.04	5	<.01	0
5	30	.05	.11	9	<.01	0
6	15	<.01	.03	9	<.01	0

5. ACKNOWLEDGMENTS

This investigation was accomplished through the financial support of the Bureau of Reclamation, Department of the Interior. It was carried out under the direction of Dr. William H. Klein, Director, Techniques Development Laboratory, whose assistance in carrying out the project is gratefully acknowledged.

REFERENCES

1. Donald L. Jorgensen, William H. Klein and August F. Korte, 1966: "A Synoptic Climatology of Winter Precipitation from 700-mb. Lows for Intermountain Areas of the West." Washington, D. C., U. S. Department of Commerce, ESSA, Weather Bureau, Technical Note 45-TDL-4, 25 pp. (Available from Clearinghouse for Federal Scientific and Technical Information, U. S. Department of Commerce, Springfield, Va. 22151 as Stock No. PB 170635.)

2. Donald L. Jorgensen, William H. Klein and August F. Korte, 1967: "A Synoptic Climatology of Winter Precipitation from 700-mb. Lows for Intermountain Areas of the West." Journal of Applied Meteorology, American Meteorological Society, Boston, Massachusetts. (To be published in October 1967.)

3. William H. Klein, Donald L. Jorgensen and August F. Korte, 1967: "An Empirical Study of the Relation between Upper Air Lows and Winter Precipitation in the Western Plateau States." Monthly Weather Review, U. S. Department of Commerce, ESSA, Weather Bureau, Washington, D. C. (To be published.)

4. Billy M. Lewis, 1964: "Normal 700-mb. Height and Sea-Level Pressure Obtained by Harmonic Smoothing of Observed Data." Washington, D. C., U. S. Weather Bureau. (Unpublished manuscript.)

APPENDIX A

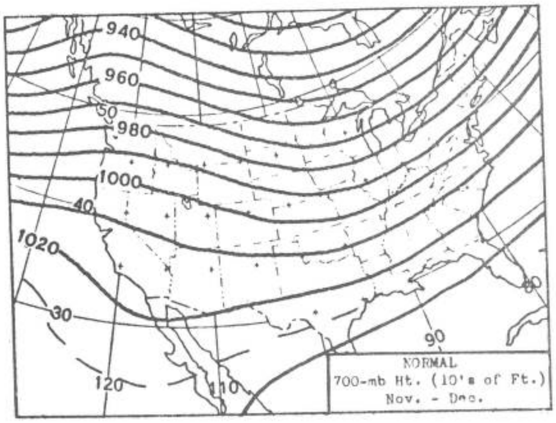
PROCEDURE FOR DETERMINING DEPARTURE FROM NORMAL CLASSIFICATION OF UPPER LOWS*

The 700-mb. Lows used in this investigation have been classified according to the departure from normal of the central height. Normal charts used for this purpose were supplied by the Extended Forecast Division of the U. S. Weather Bureau and are given in figure 16. These charts comprise normals for whole months and mid-month to mid-month periods based on 16 years of data. Dates applied to the individual charts are as follows:

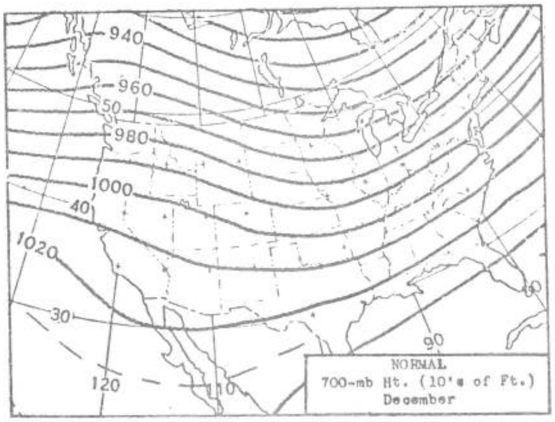
Inclusive Dates	Chart	Period
Nov. 23 - Dec. 7	(a)	Nov. - Dec.
Dec. 8 - Dec. 22	(b)	Dec.
Dec. 23 - Jan. 7	(c)	Dec. - Jan.
Jan. 8 - Jan. 22	(d)	Jan.
Jan. 23 - Feb. 7	(e)	Jan. - Feb.
Feb. 8 - Feb. 22	(f)	Feb.
Feb. 23 - Mar. 7	(g)	Feb. - Mar.

From this table, the position of the 700-mb. Low is located on the appropriate normal chart for the given date, and the normal height at this point is read off in 10's of feet. Since operational charts are analysed in meters (geopotential), the normal height read in feet must be converted to meters. A nomogram is given in figure 17 to aid in this step. The difference in the observed and normal heights (observed minus normal) in meters gives the departure from normal (DN) values which are then used to classify the individual situations according to the following class intervals:

Class I	$DN \geqslant -30.$ (meters)	(DN equal to or more positive than -30 m.)
Class II	$-30 > DN > -125$	(DN between -30 and -125 m.)
Class III	$DN \leqslant -125$	(DN equal to or more negative than -125 m.)



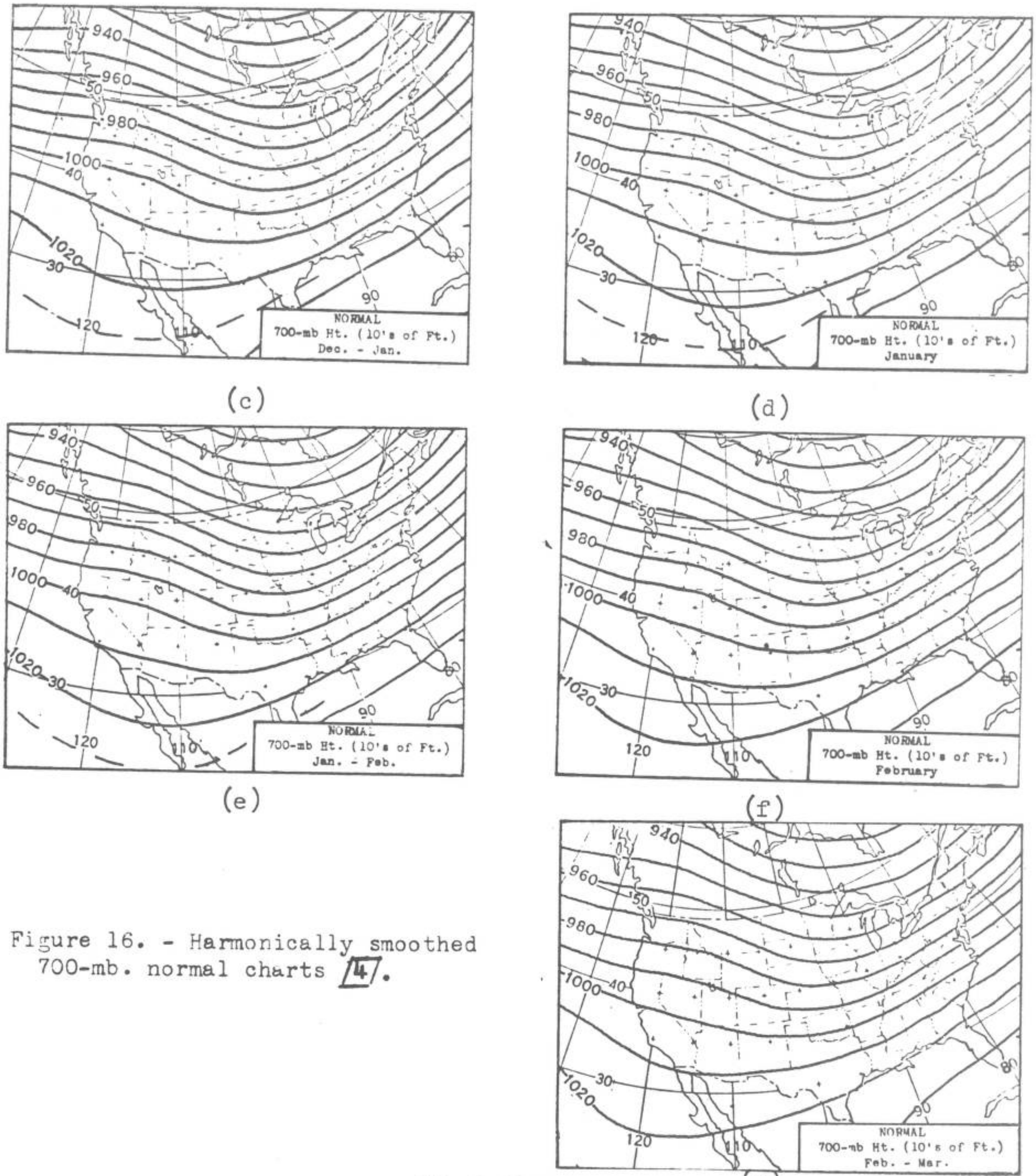
(a)



(b)

---

* Extracted from a previous report /1/



(c) (d)

(e) (f)

(g)

Figure 16. - Harmonically smoothed 700-mb. normal charts [4].

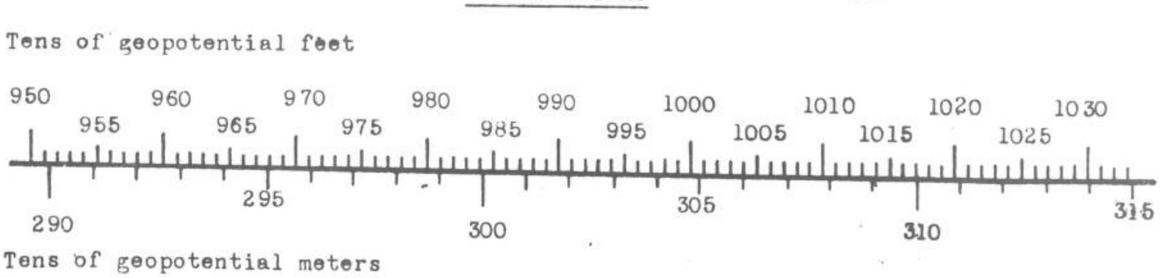


Figure 17. - Nomogram for converting 700-mb. heights read from normal charts into meters for comparison with values read from operational charts.

APPENDIX B

OPERATIONAL CHARTS

In the intermountain region with its varied and rugged terrain, each individual station will exhibit a unique topographic effect. As has been shown in the body of this report, the patterns giving the frequency of occurrence of precipitation for such stations as Flagstaff and Salt Lake City, and Ouray and Durango, show significant individual station characteristics. In order to illustrate further these characteristics and to make station charts available for operational use, charts have been prepared for a selection of 34 stations out of the 280 for which data are available. These stations have been chosen on the completeness of their precipitation records and to give a sampling of the various sections of the observing station network area.

Charts for each of the three intensity classes, Class I, II, and III, are given for each station. The stations for which charts have been prepared are given in the following list:

1. Antimony, Utah
2. Boise, Idaho
3. Bryce Canyon, Utah
4. Cedar City, Utah
5. Craig, Colorado
6. Crownpoint, New Mexico
7. Durango, Colorado
8. Eagle, Colorado
9. El Centro, California
10. Elko, Nevada
11. Ely, Nevada
12. Farmington, New Mexico
13. Flagstaff, Arizona
14. Grand Junction, Colorado
15. Greenriver, Utah
16. Iron Mountain, California
17. Jackson, Wyoming
18. Las Vegas, Nevada
19. Mogollon, New Mexico
20. Ogden, Utah
21. Ouray, Colorado
22. Parker Reservoir, California
23. Pocatello, Idaho
24. Prescott, Arizona
25. Price, Utah
26. Reno, Nevada
27. Rifle, Colorado
28. Rock Springs, Wyoming
29. Salt Lake City, Utah
30. Silver Lake Brighton, Utah
31. Tonopah, Nevada
32. Tucson, Arizona
33. Winslow, Arizona
34. Yuma, Arizona

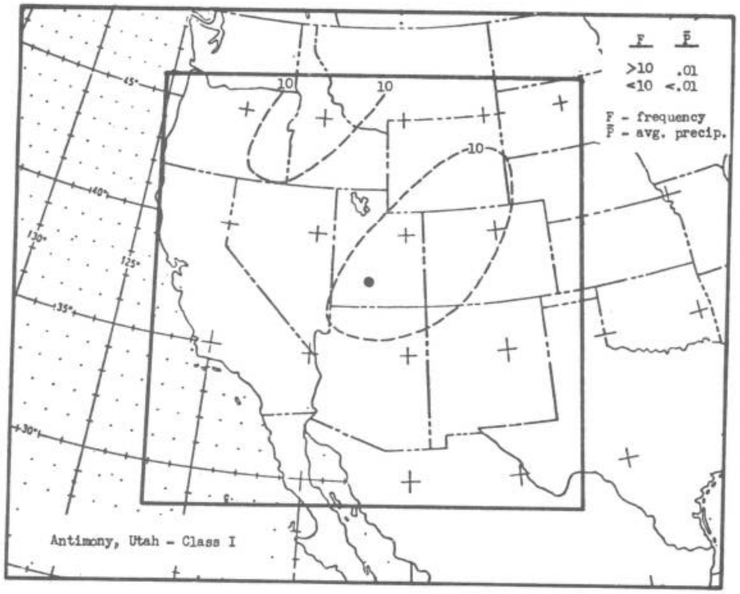


Chart 1 - I

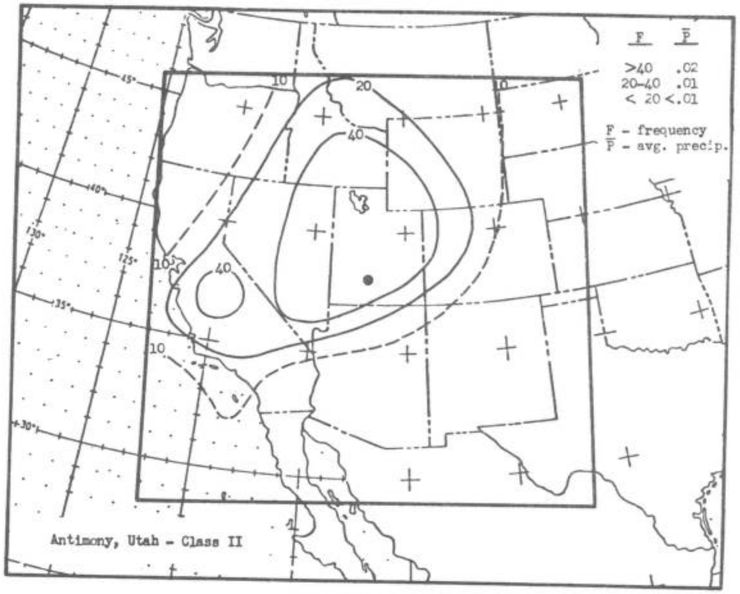


Chart 1 - II

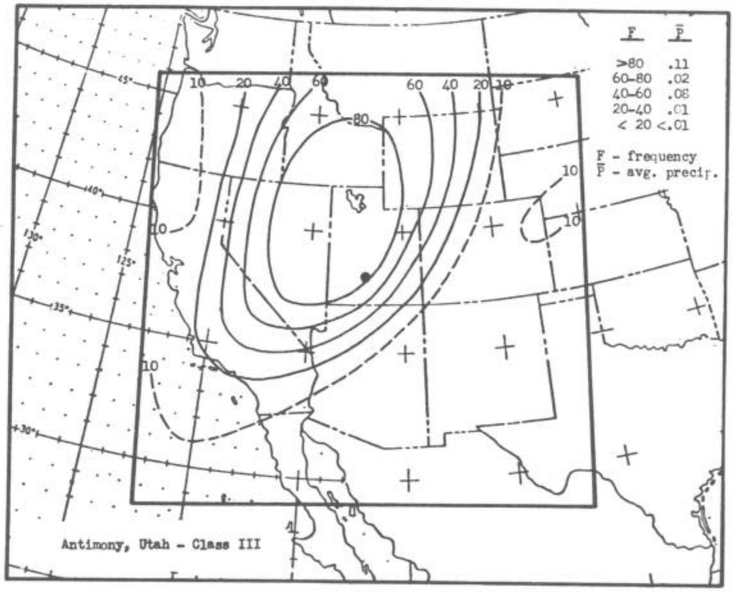


Chart 1 - III

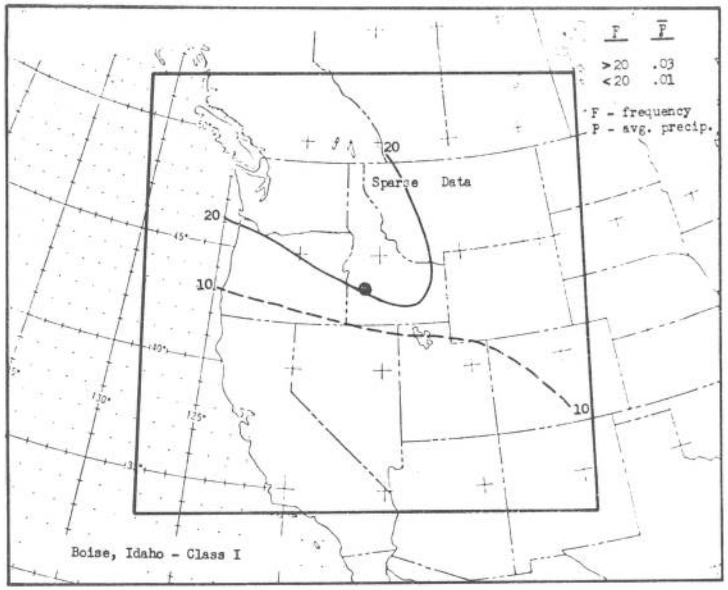


Chart 2 - I

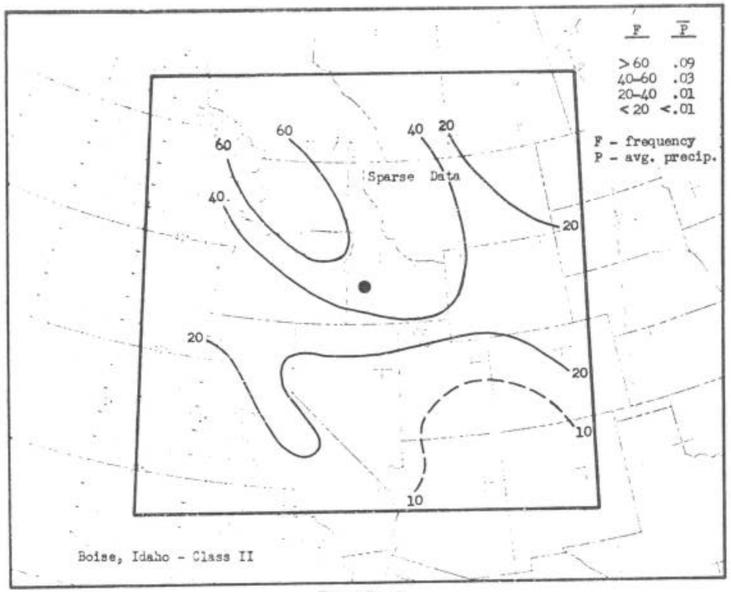


Chart 2 - II

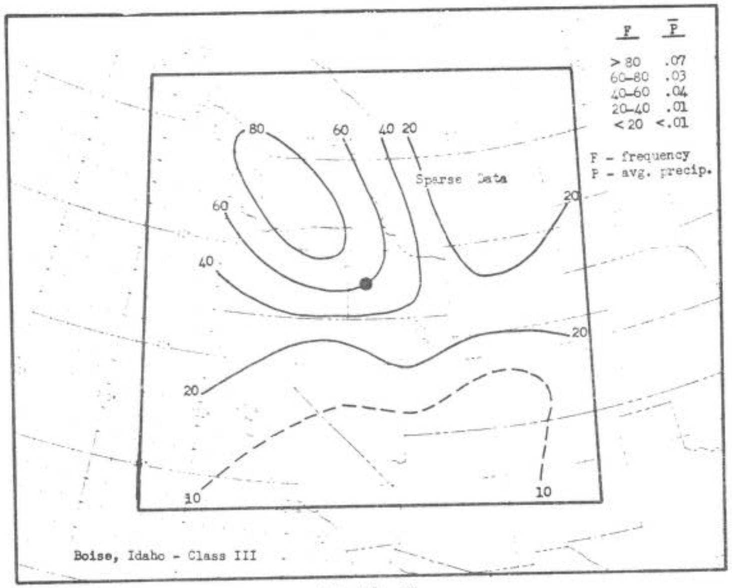


Chart 2 - III

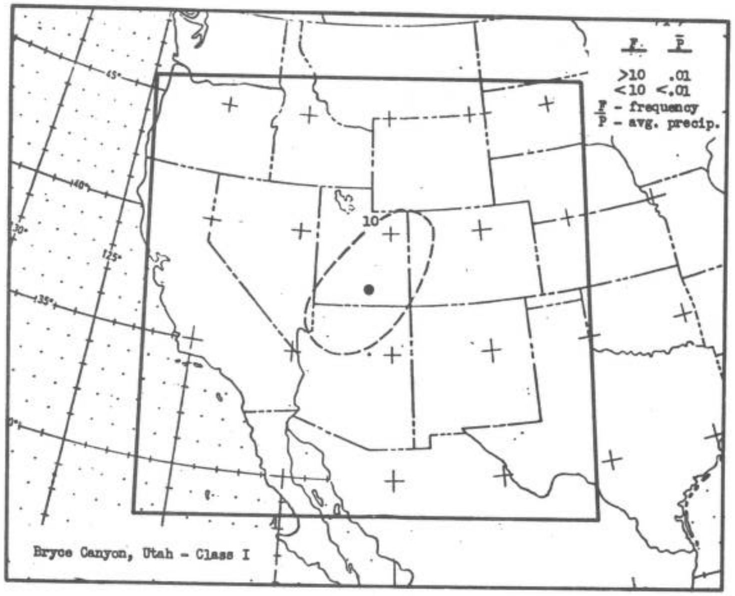


Chart 3 - I

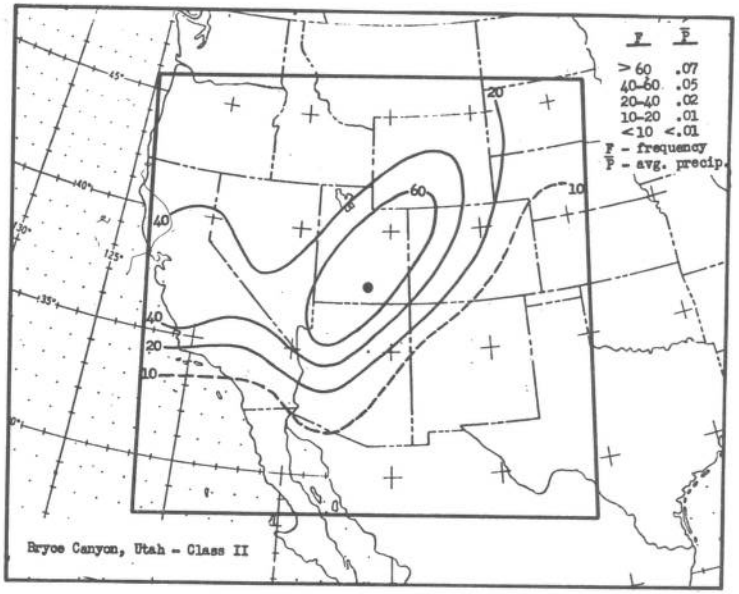


Chart 3 - II

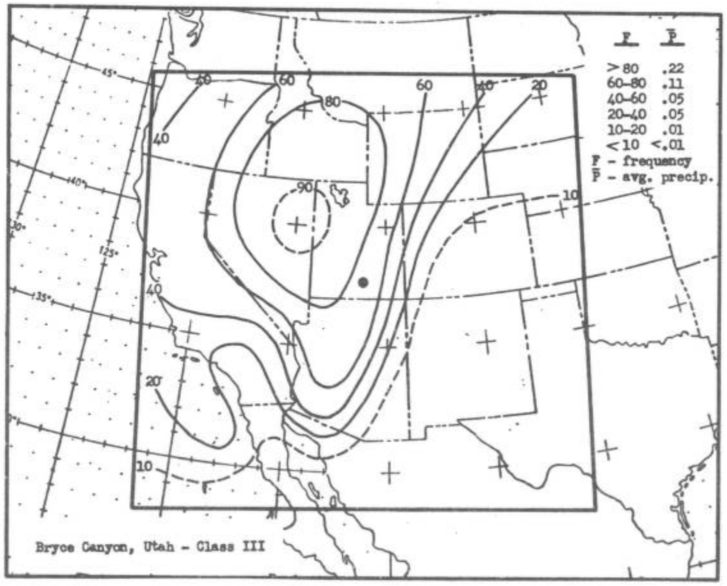


Chart 3 - III

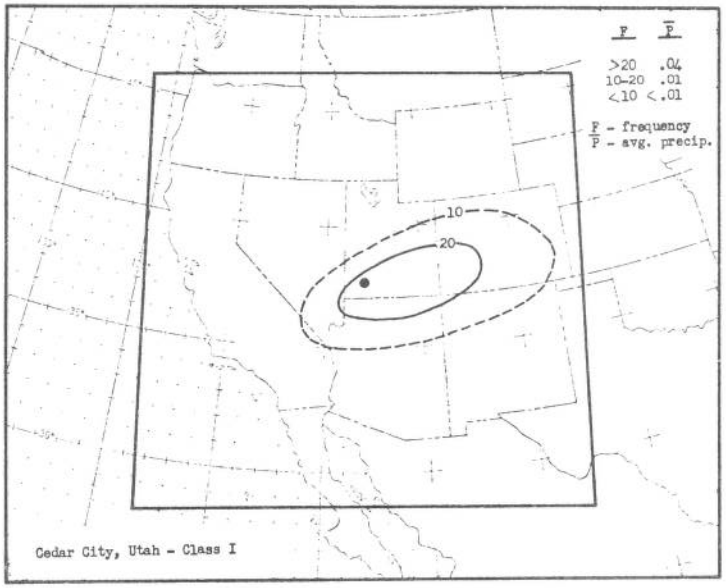

Cedar City, Utah - Class I

Chart 4 - I

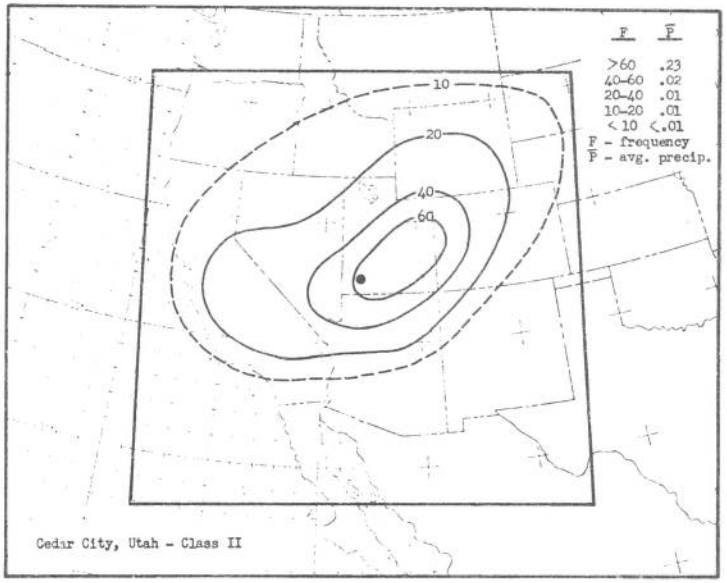

Cedar City, Utah - Class II

Chart 4 - II

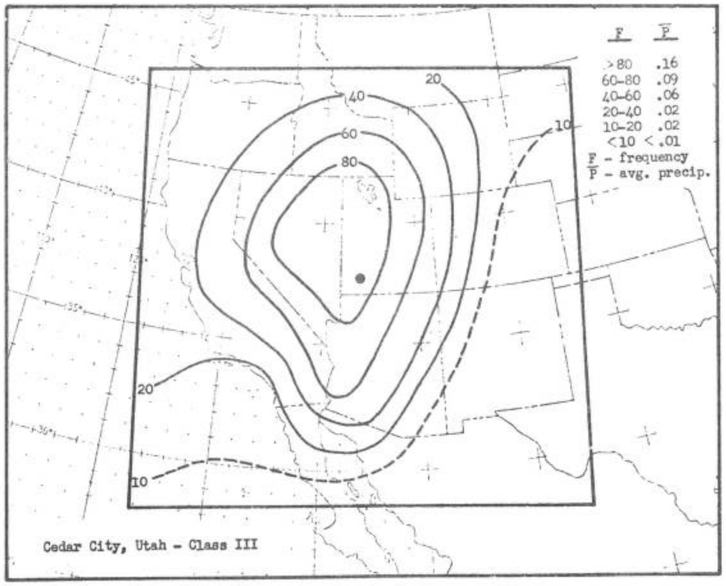

Cedar City, Utah - Class III

Chart 4 - III

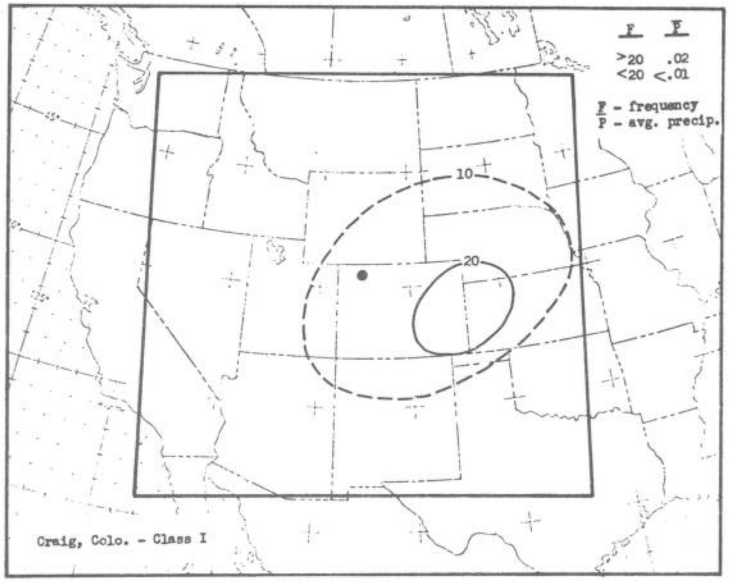


Chart 5 - I

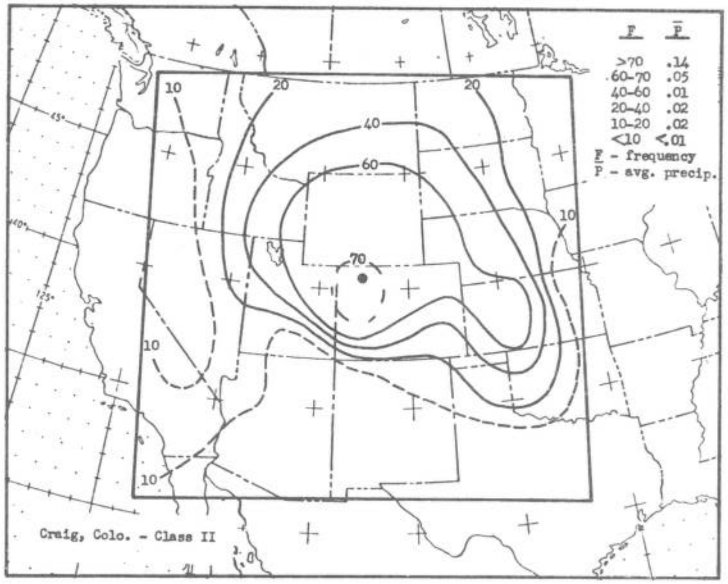


Chart 5 - II

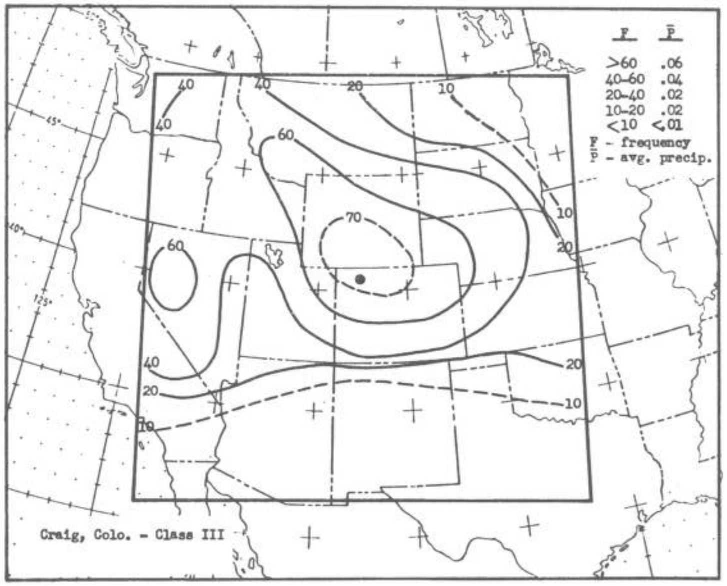


Chart 5 - III

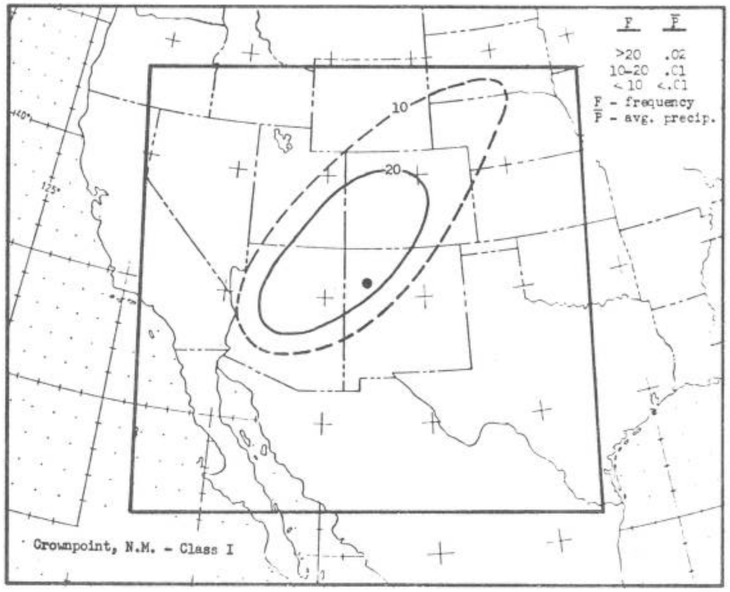


Chart 6 - I

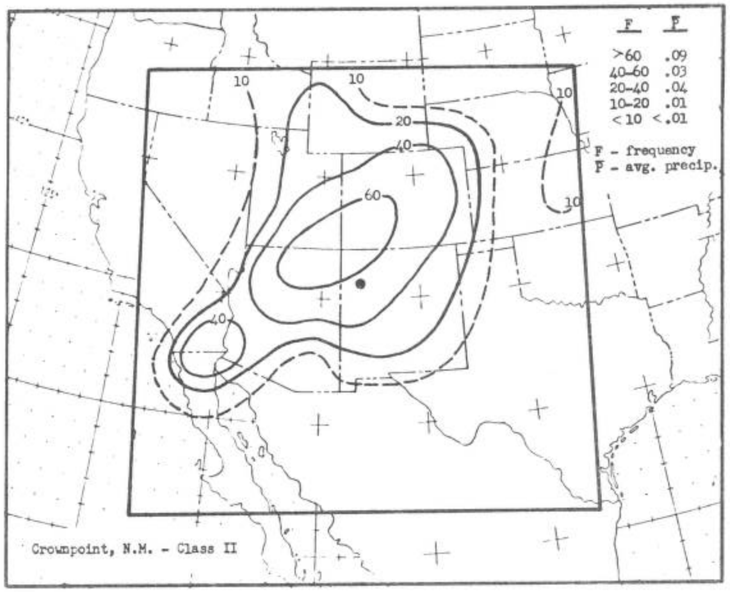


Chart 6 - II

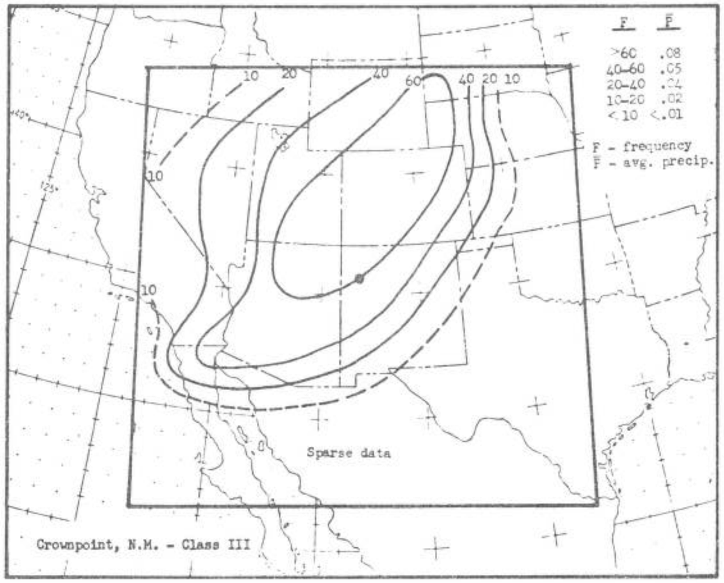


Chart 6 - III

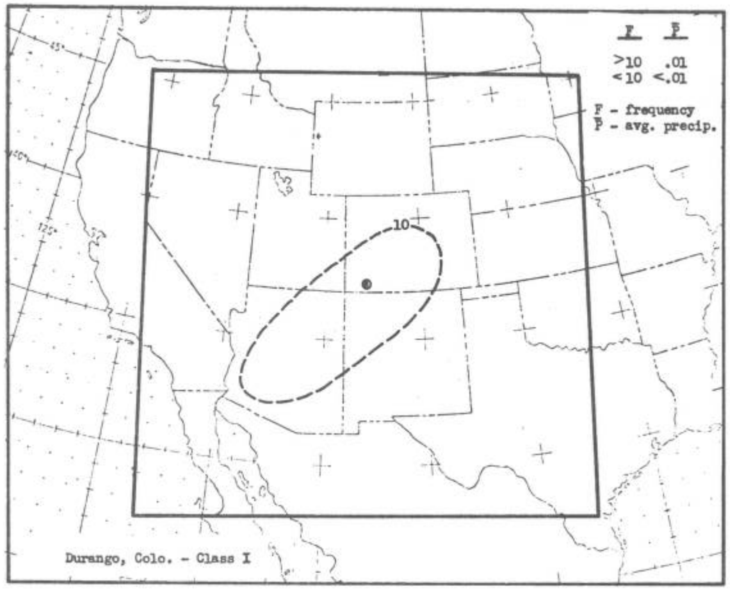


Chart 7 - I

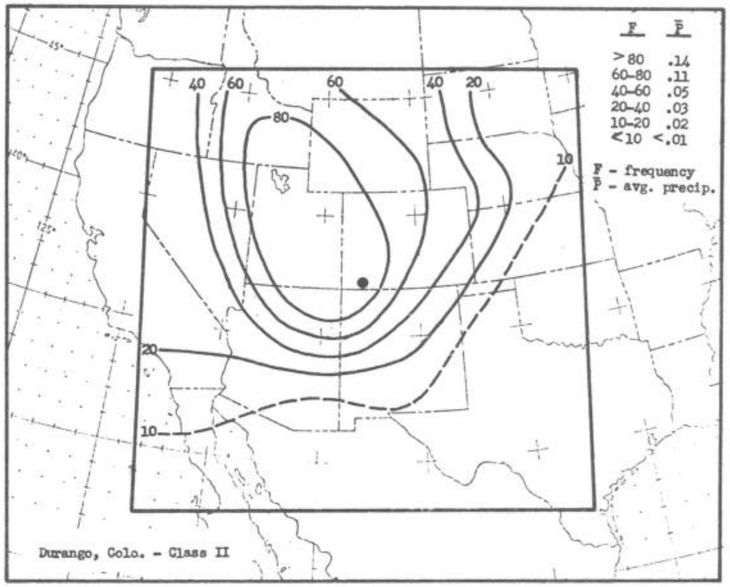


Chart 7 - II

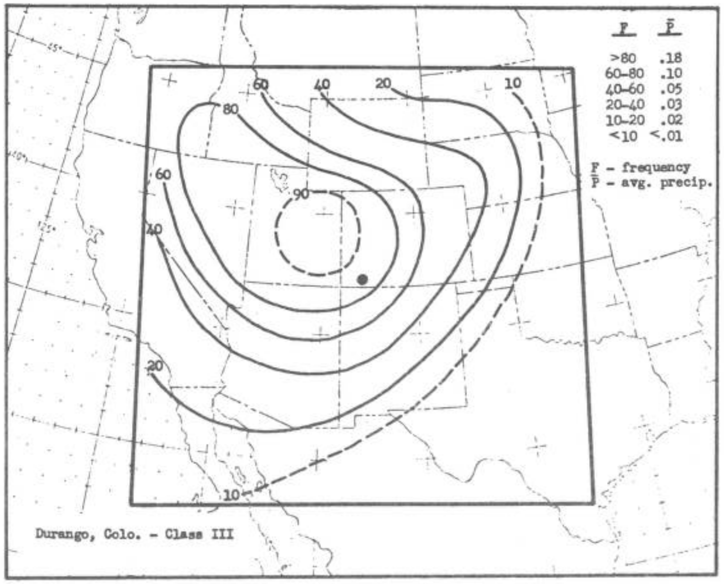


Chart 7 - III

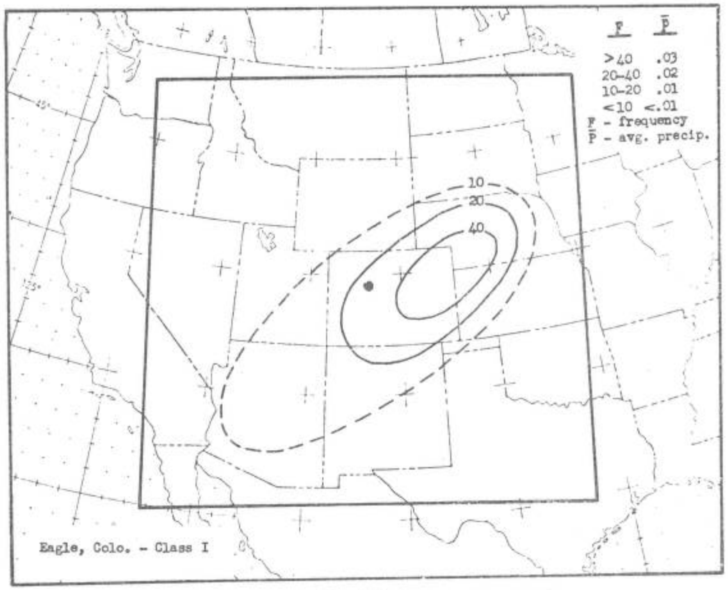


Chart 8 - I

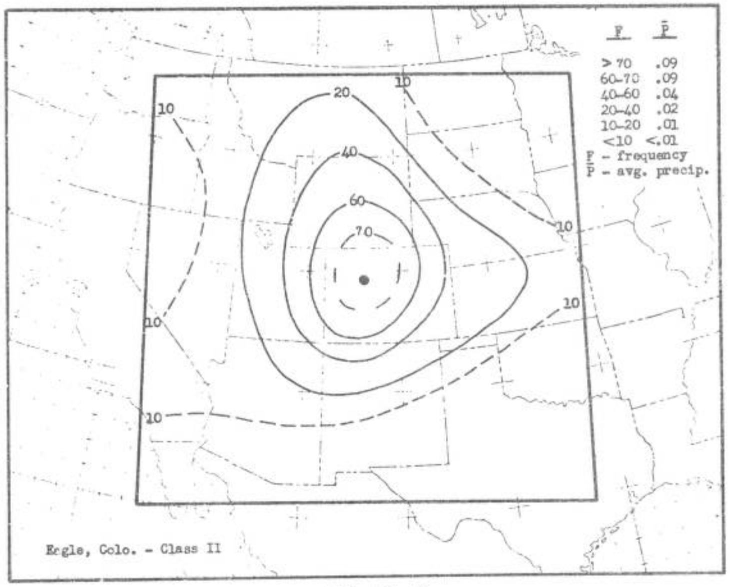


Chart 8 - II

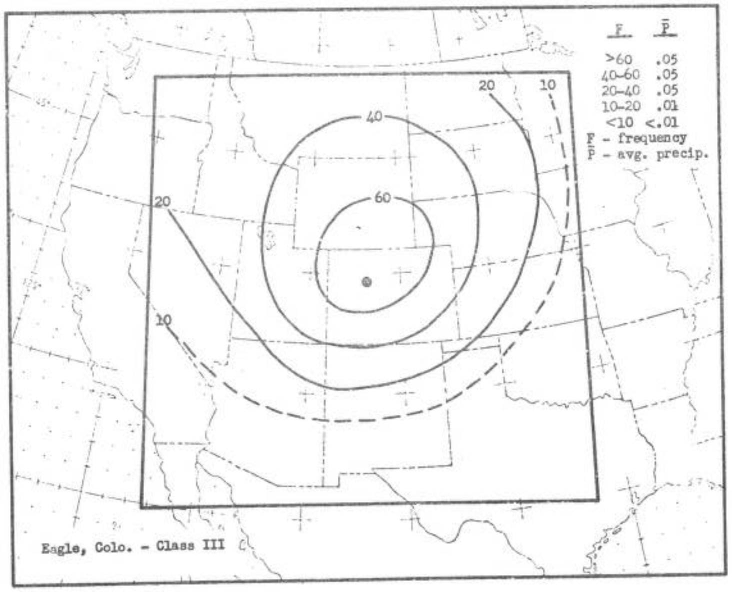


Chart 8 - III

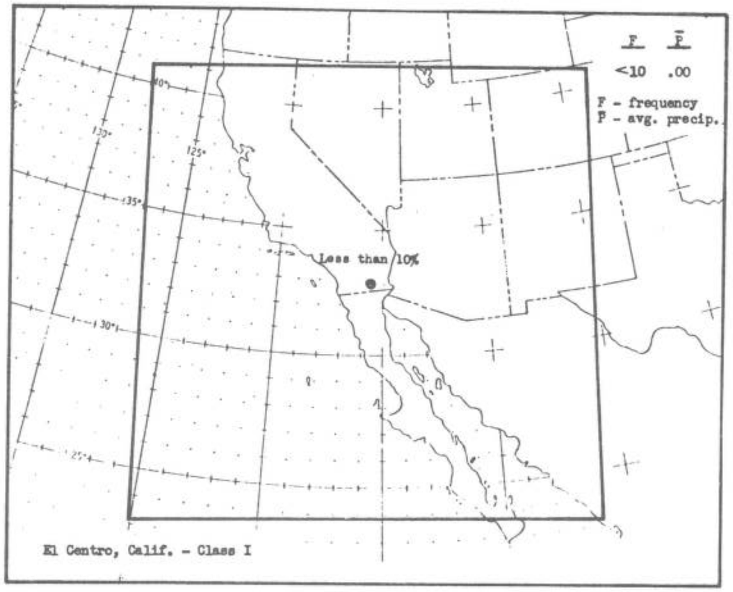


Chart 9 - I

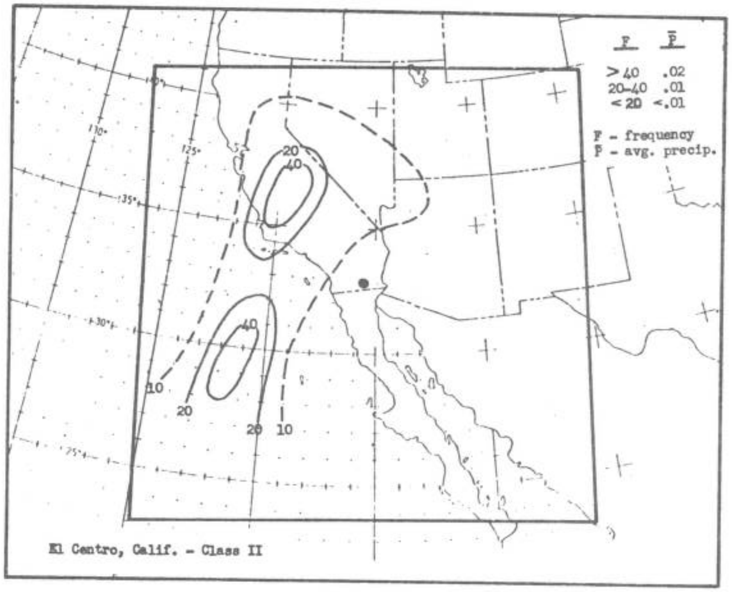


Chart 9 - II

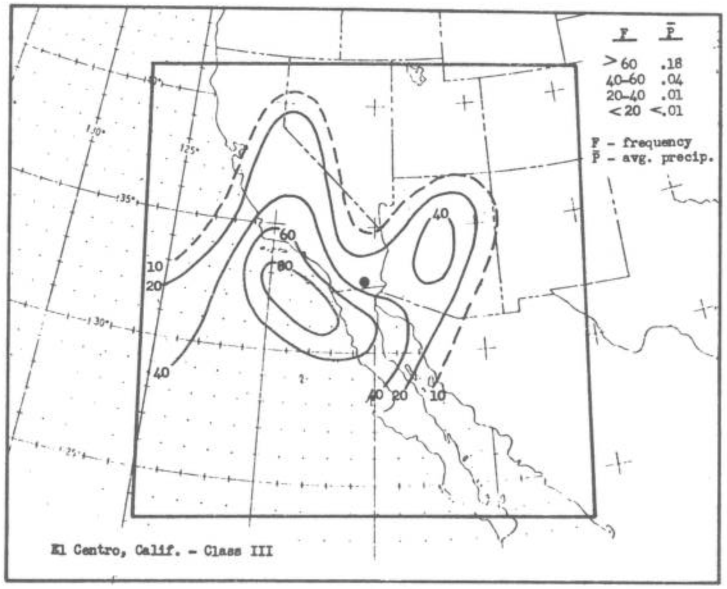


Chart 9 - III

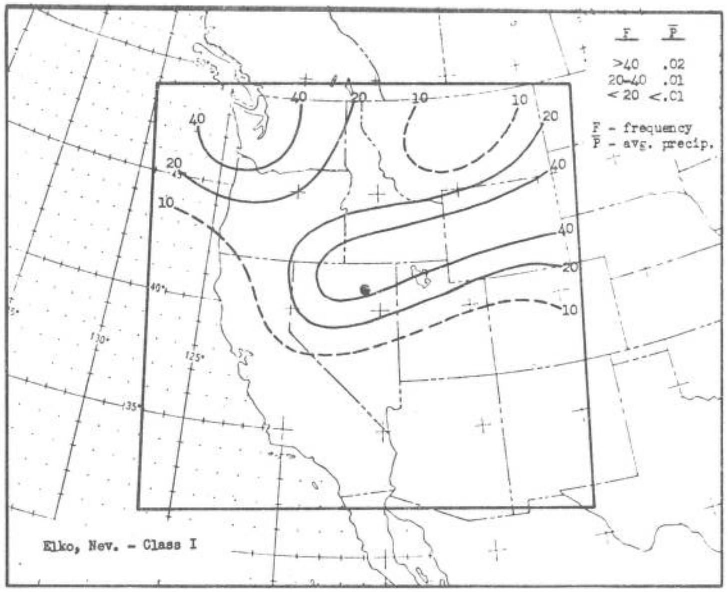


Chart 10 - I

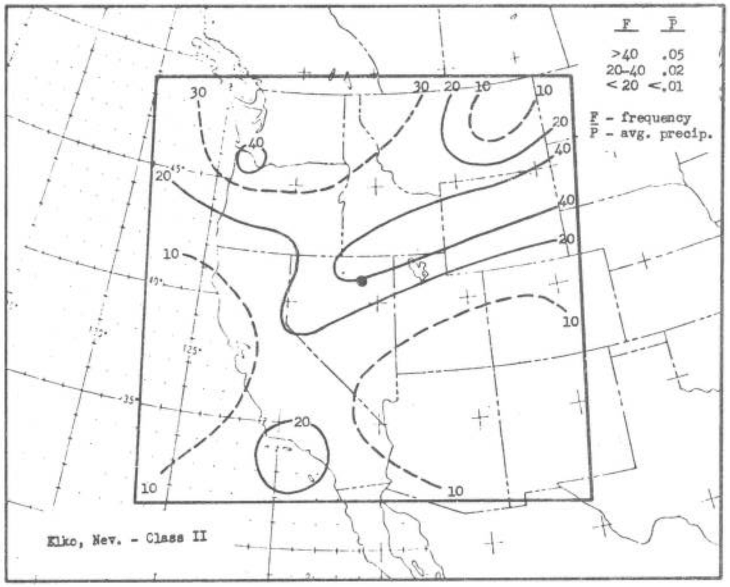


Chart 10 - II

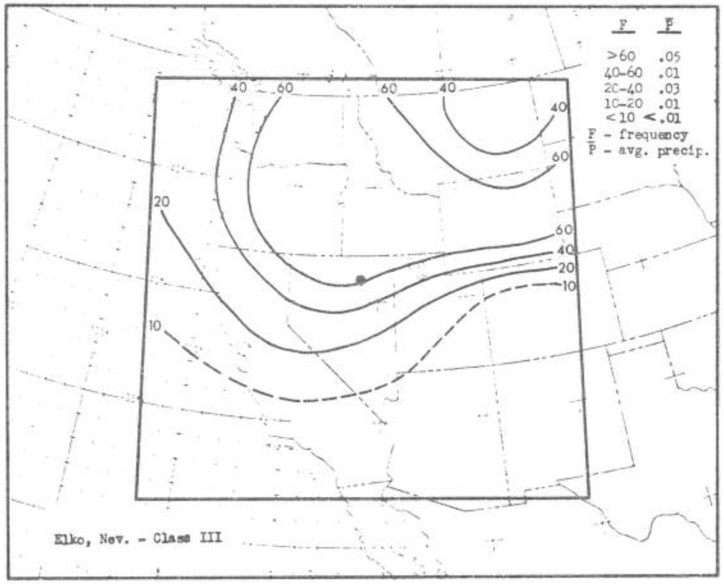


Chart 10 - III

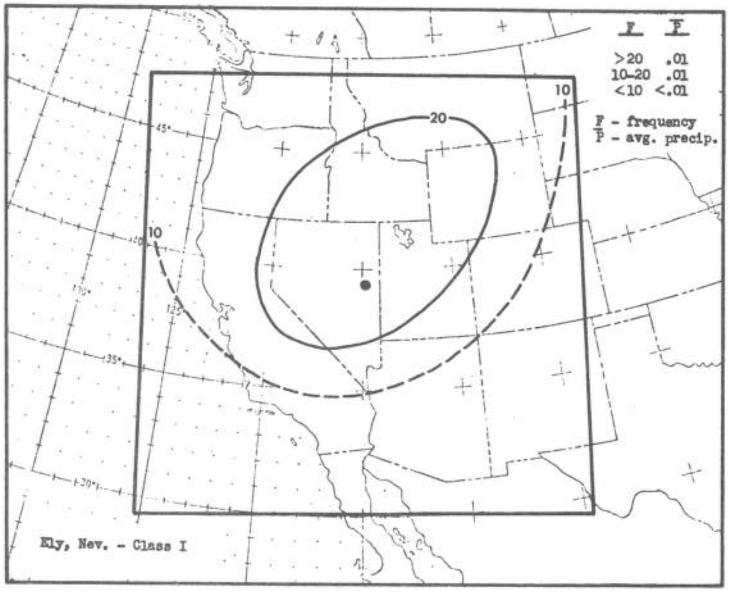


Chart 11 - I

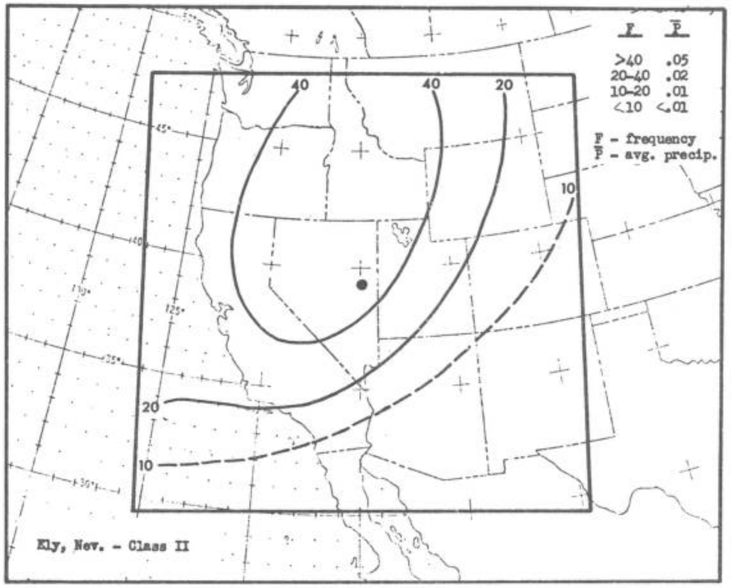


Chart 11 - II

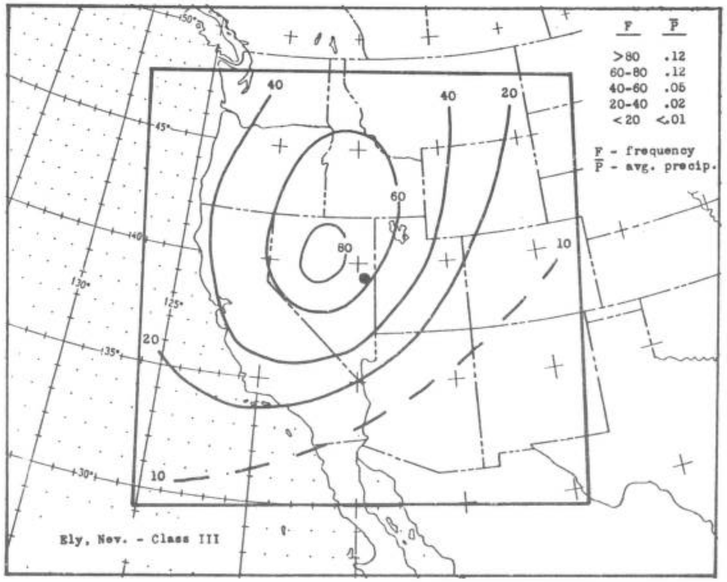


Chart 11 - III

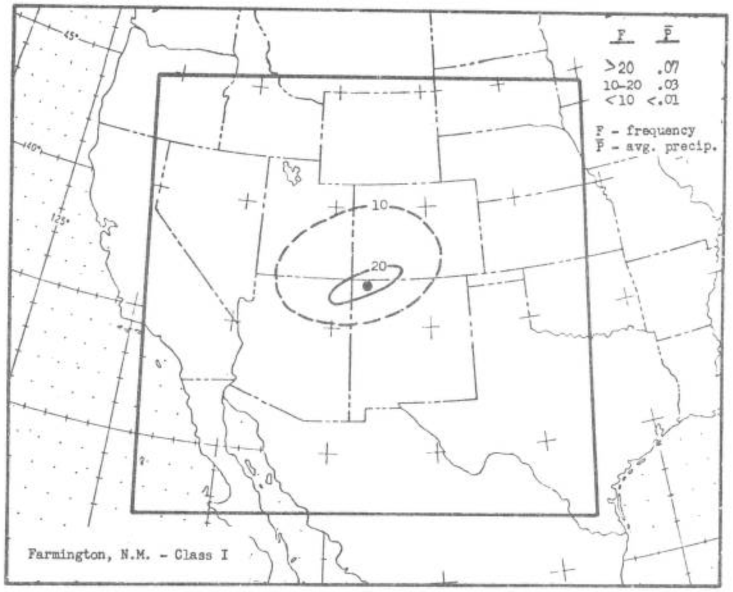


Chart 12 - I

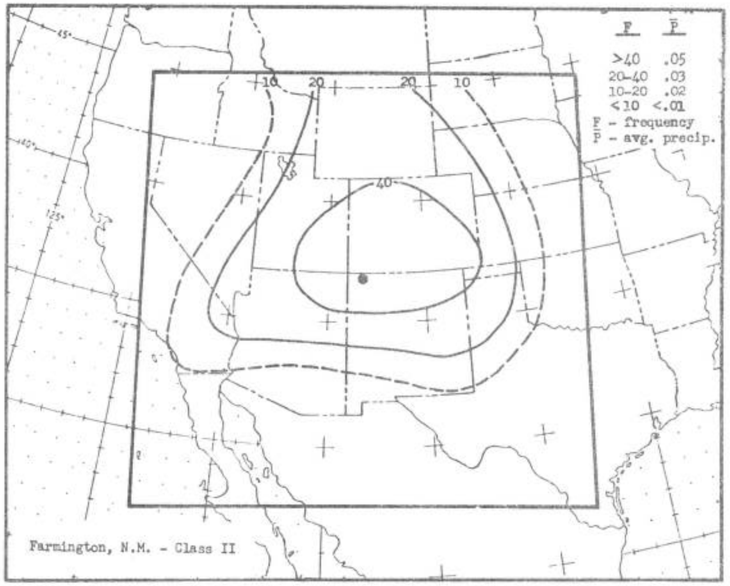


Chart 12 - II

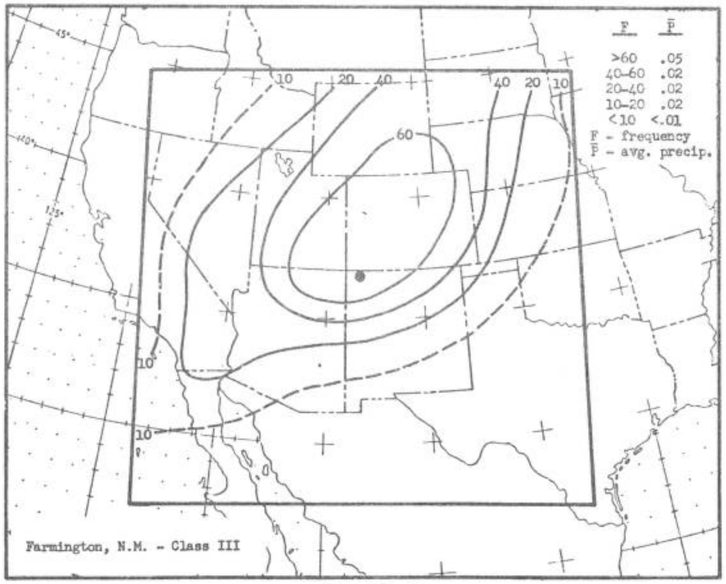


Chart 12 - III

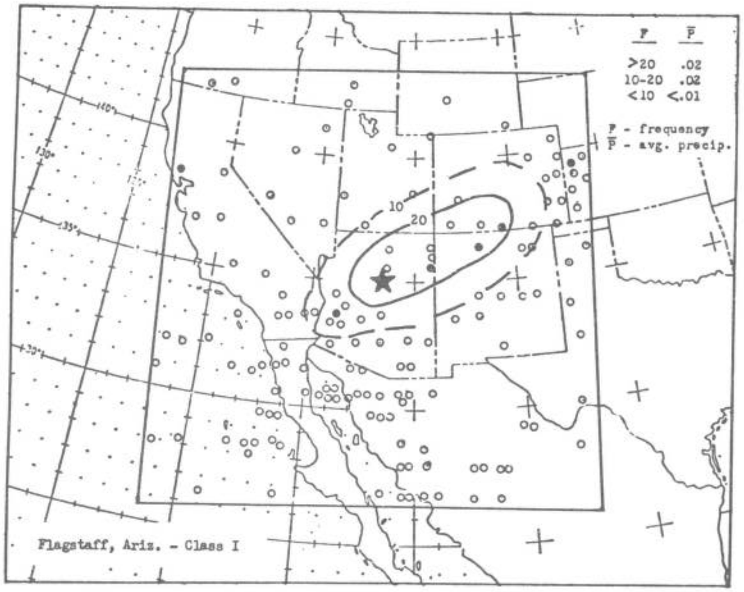


Chart 13 - I

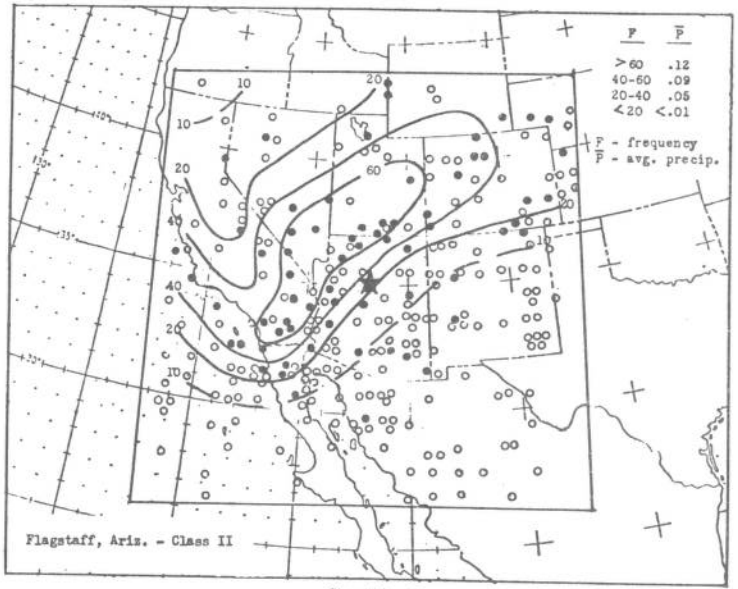


Chart 13 - II

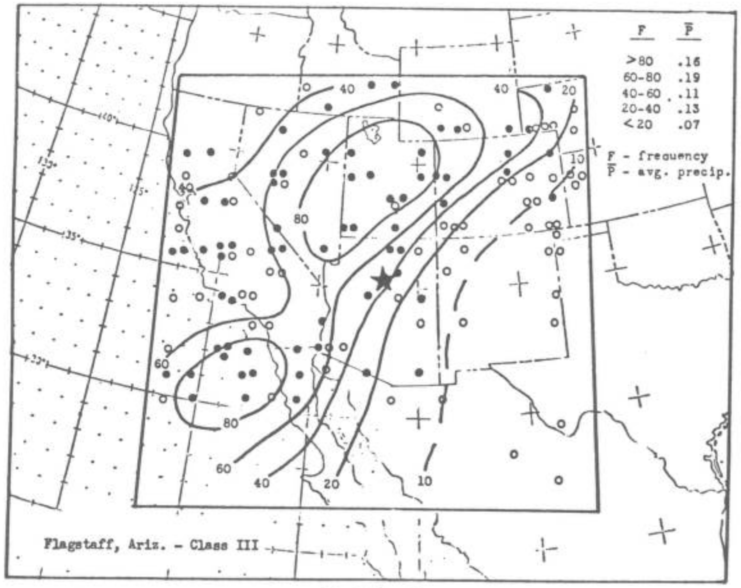


Chart 13 - III

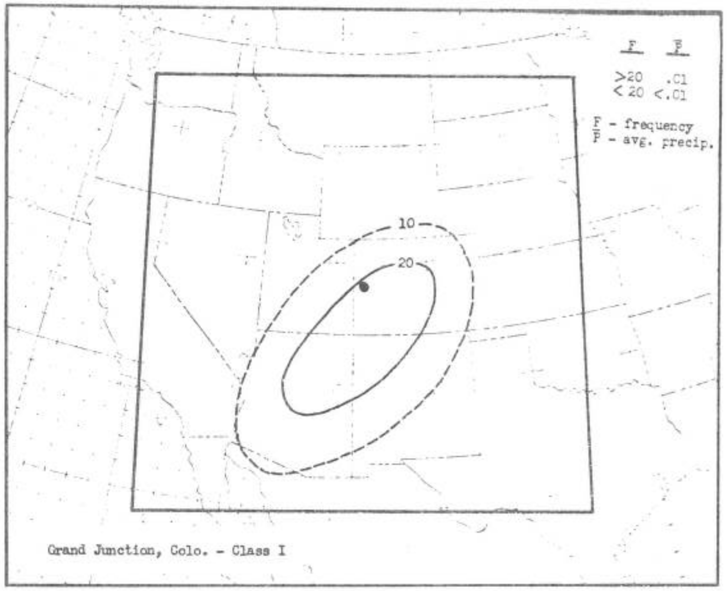


Chart 14 - I

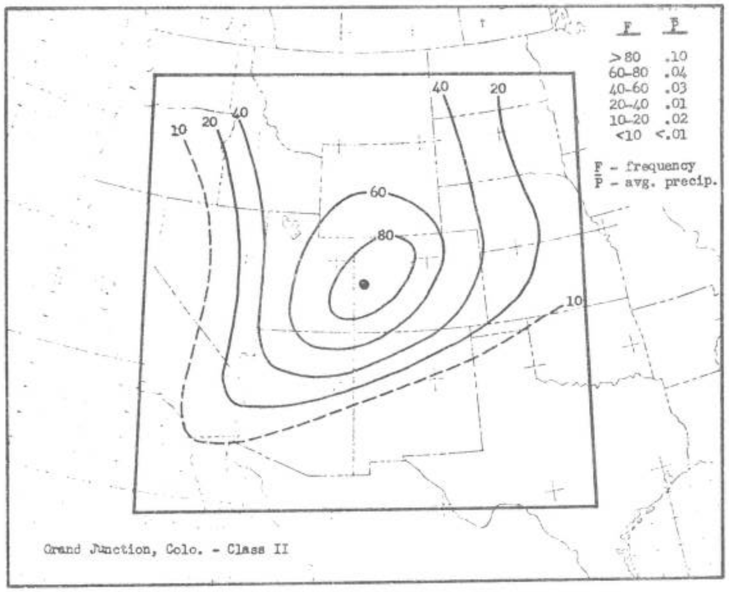


Chart 14 - II

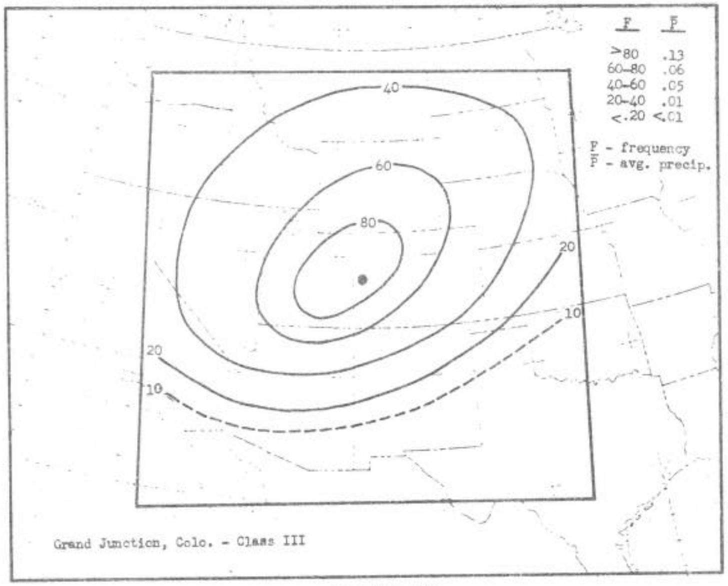


Chart 14 - III

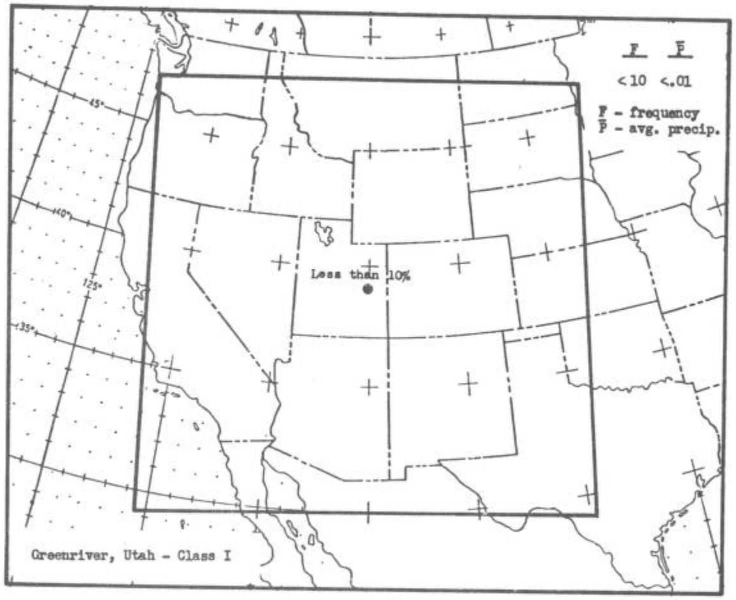


Chart 15 - I

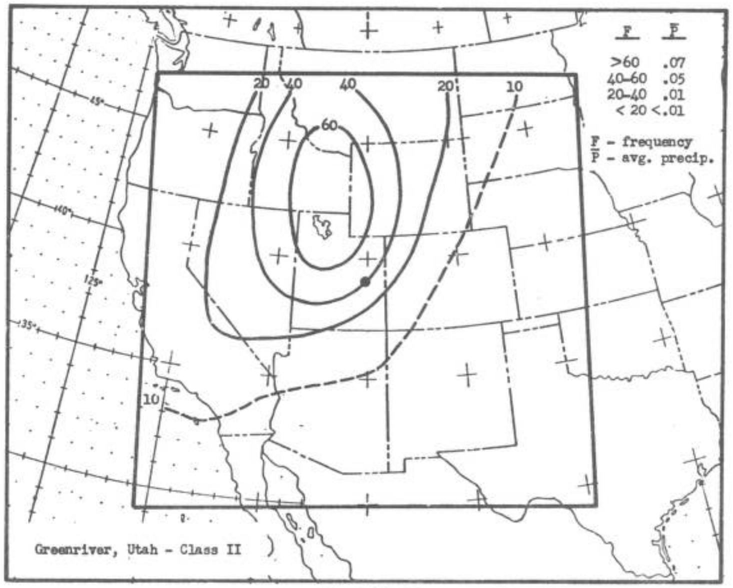


Chart 15 - II

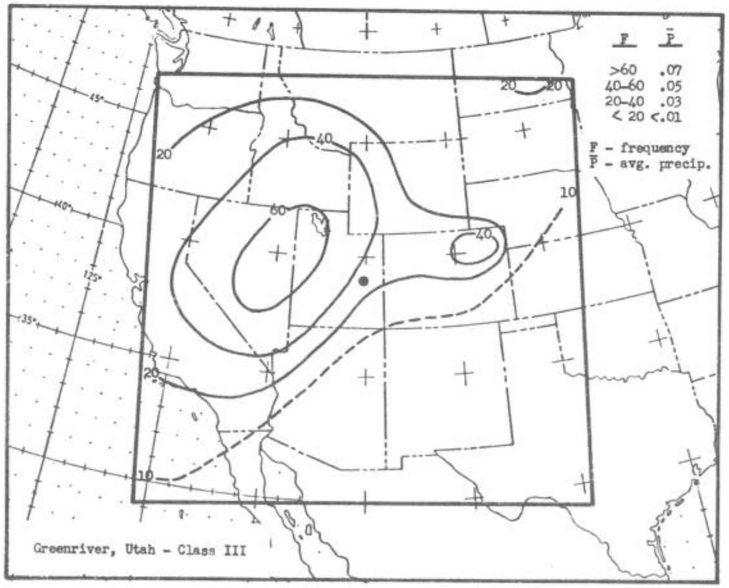


Chart 15 - III

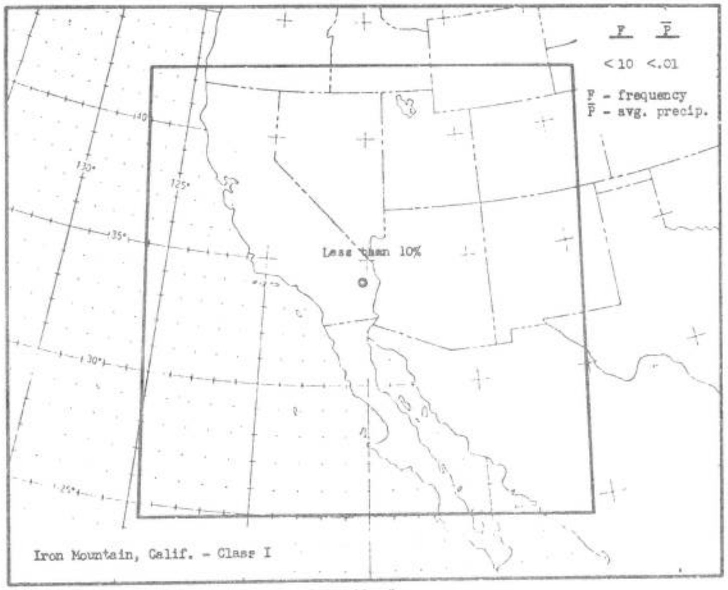


Chart 16 - I

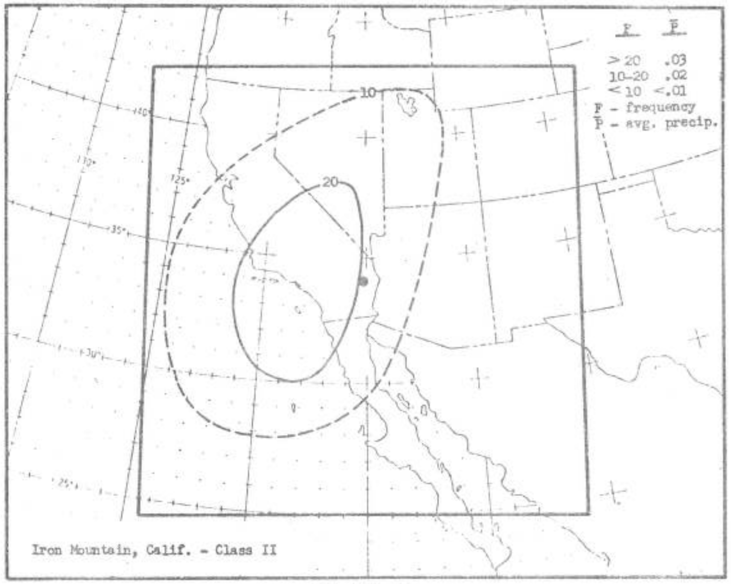


Chart 16 - II

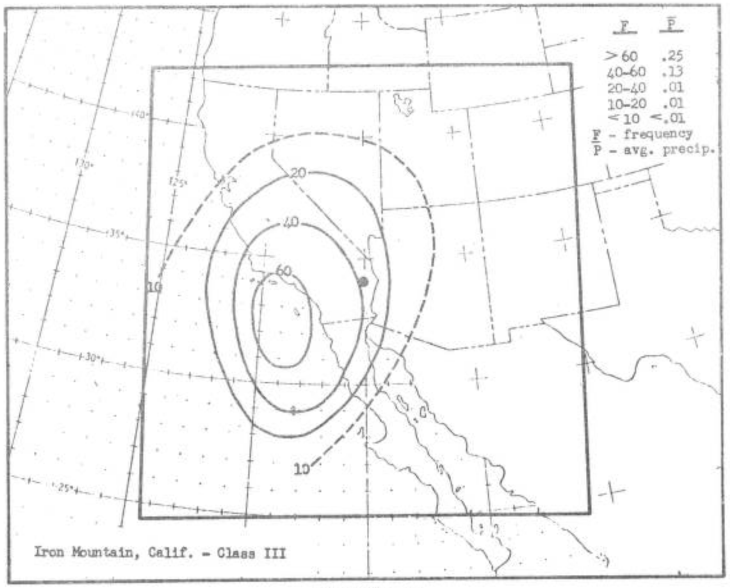


Chart 16 - III

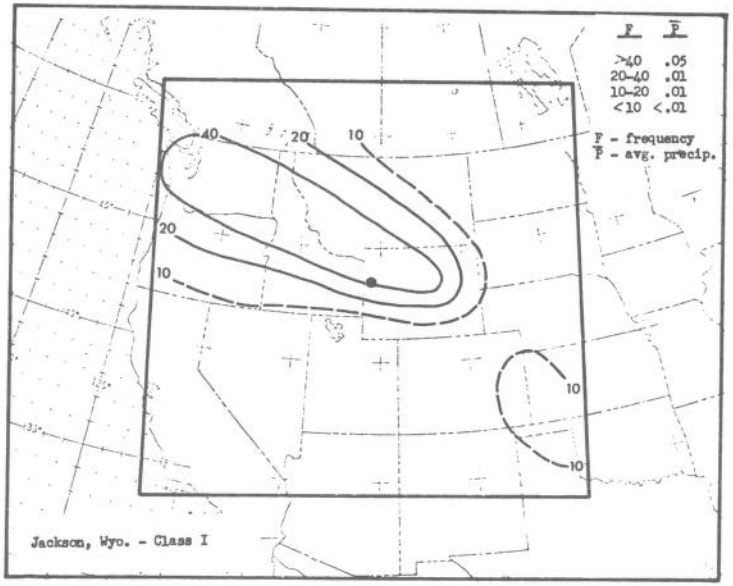


Chart 17 - I

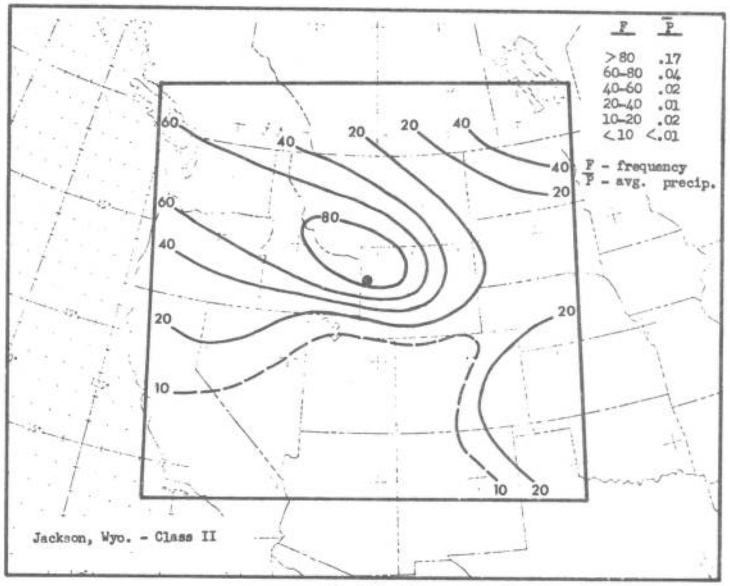


Chart 17 - II

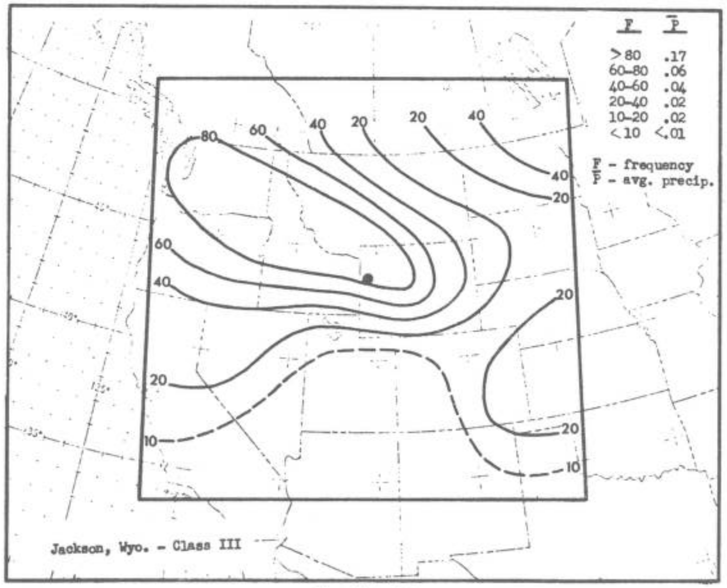


Chart 17 - III

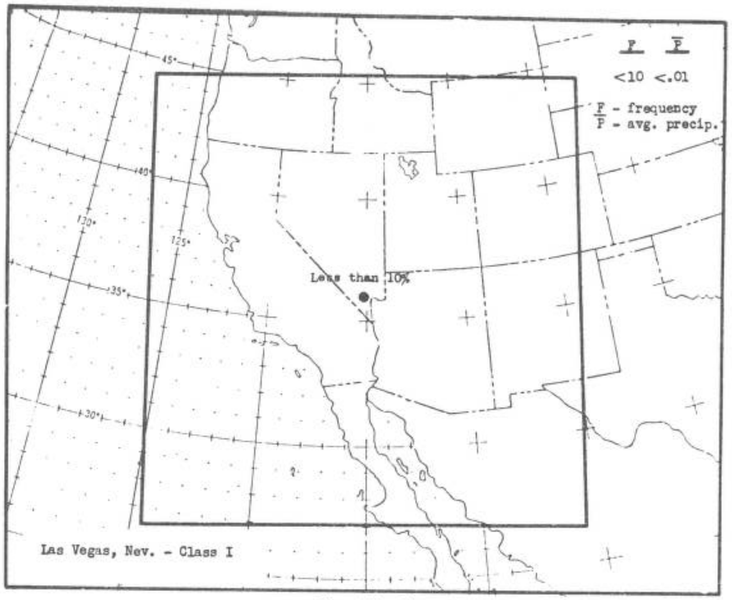


Chart 18 - I

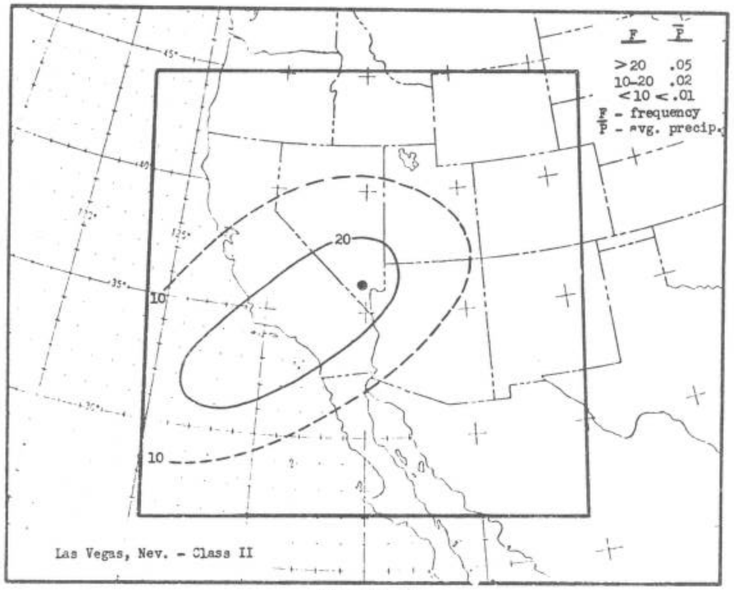


Chart 18 - II

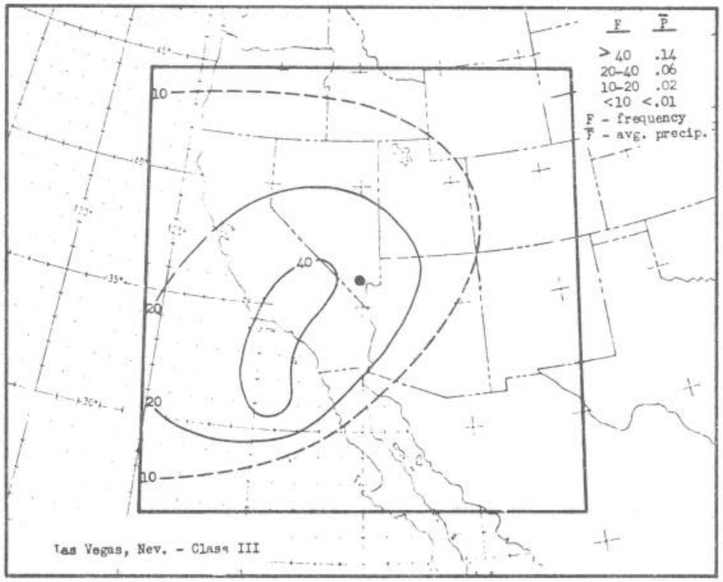


Chart 18 - III

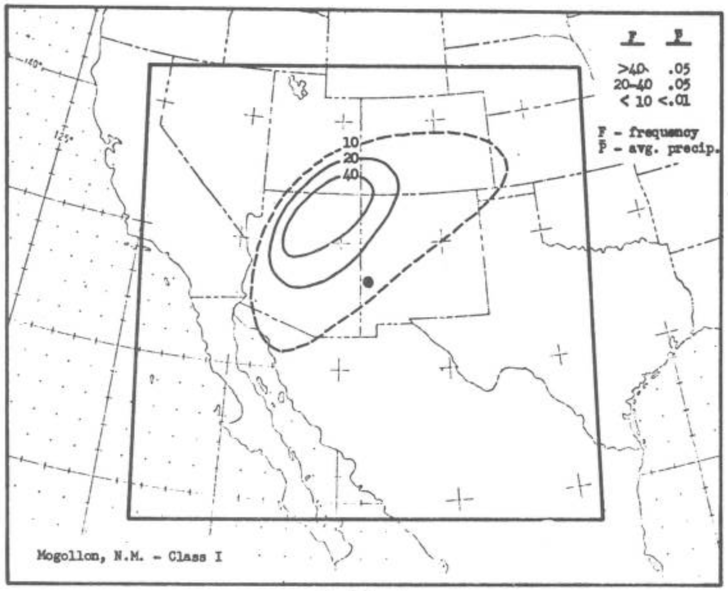


Chart 19 - I

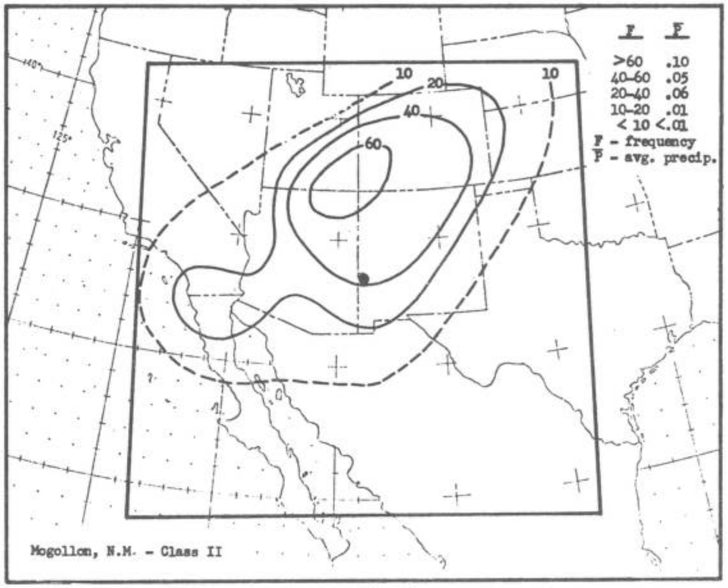


Chart 19 - II

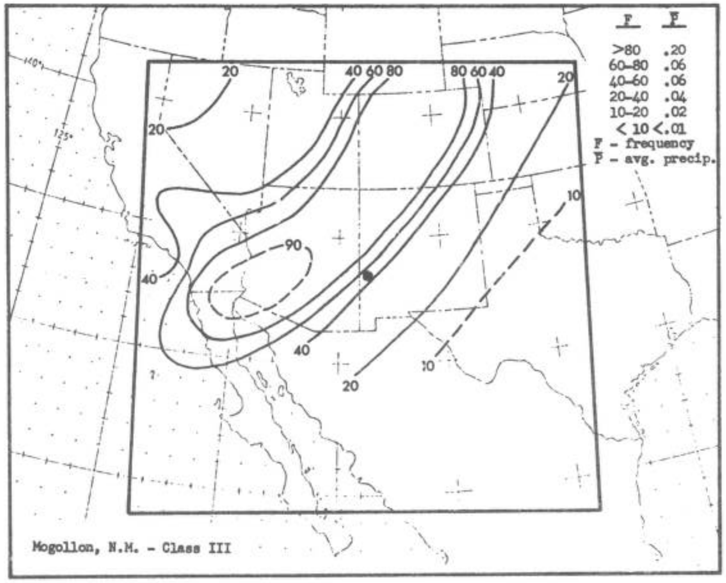


Chart 19 - III

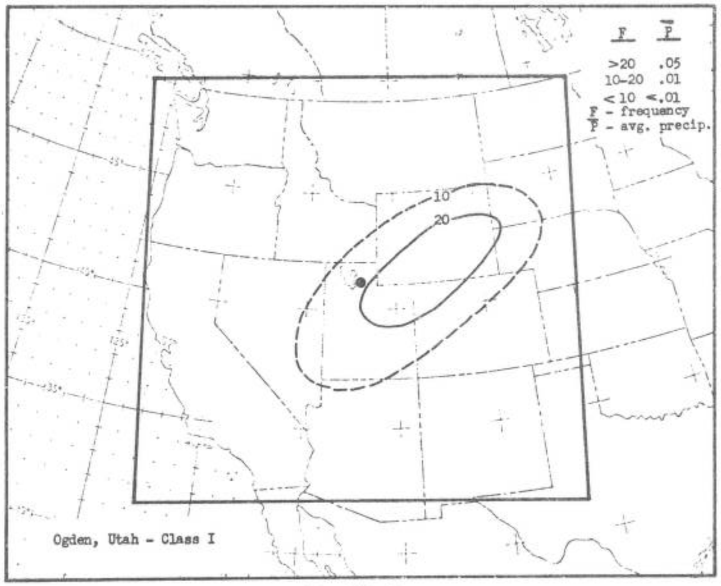


Chart 20 - I

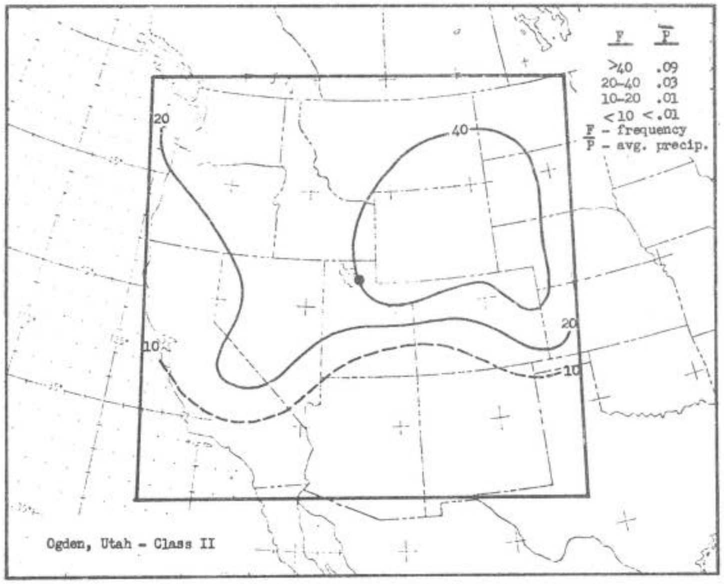


Chart 20 - II

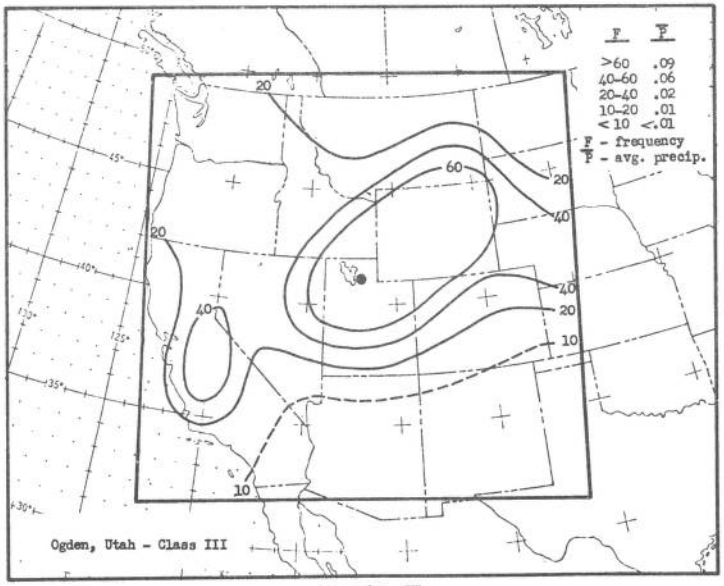


Chart 20 - III

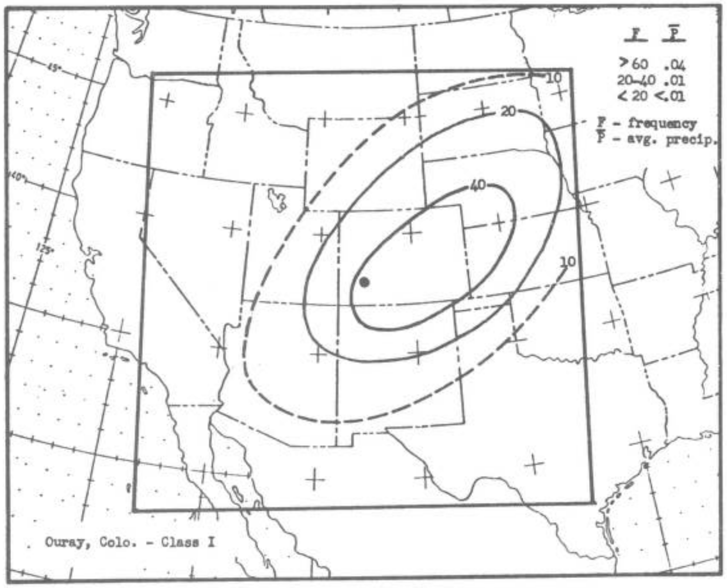


Chart 21 - I

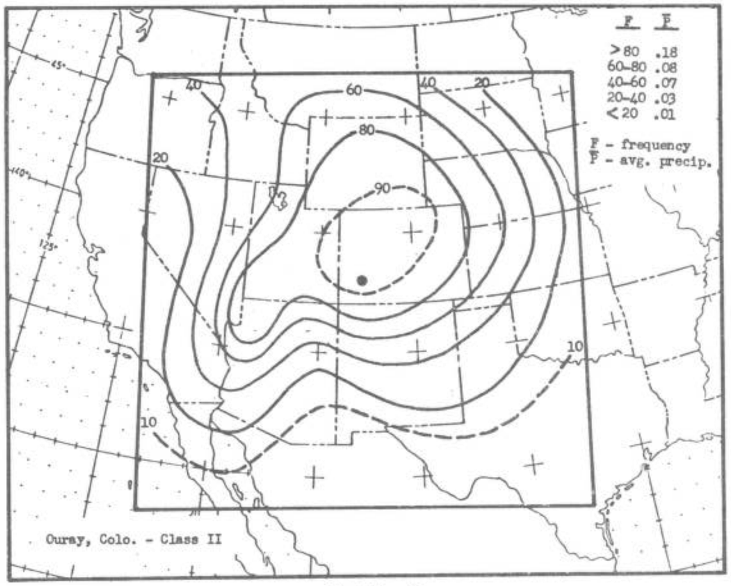


Chart 21 - II

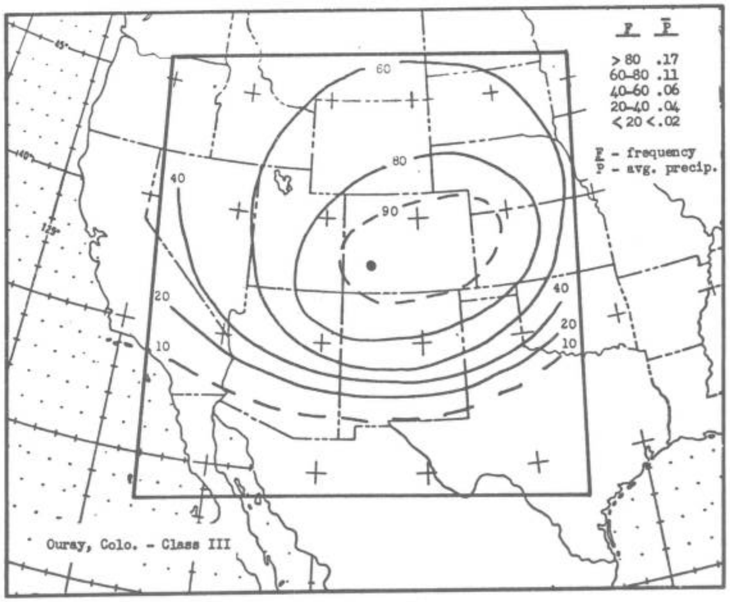


Chart 21 - III

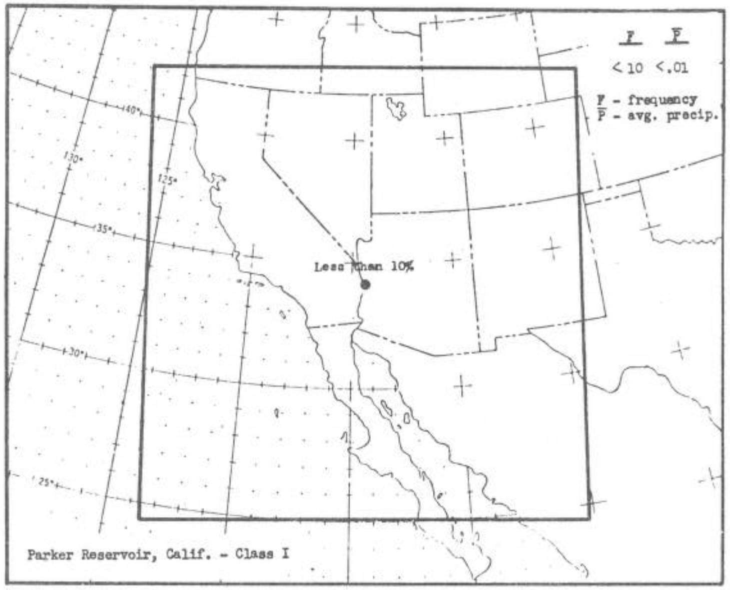


Chart 22 - I

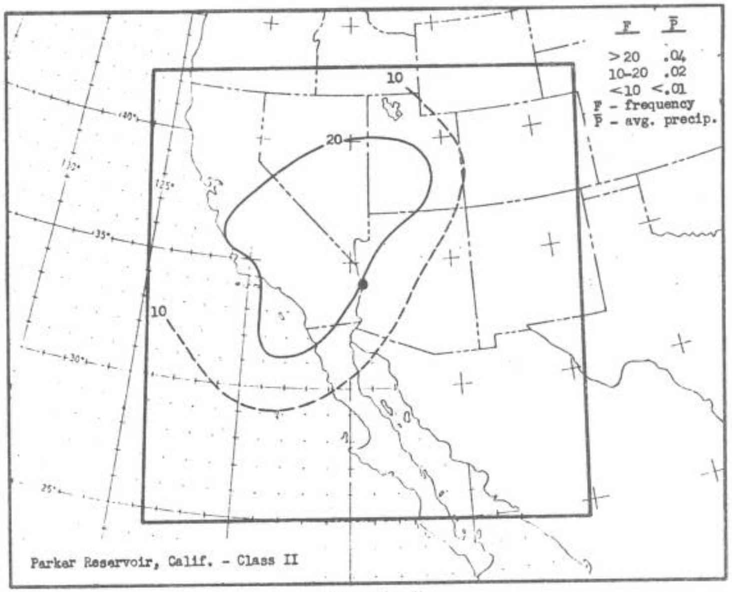


Chart 22 - II

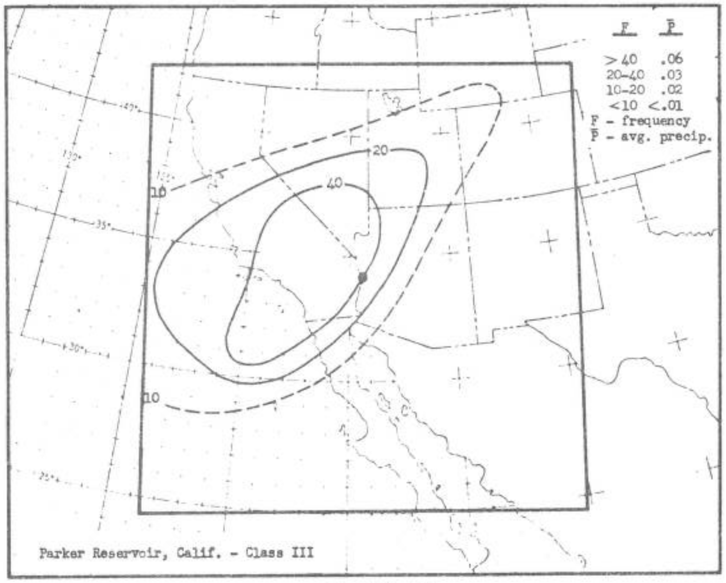


Chart 22 - III

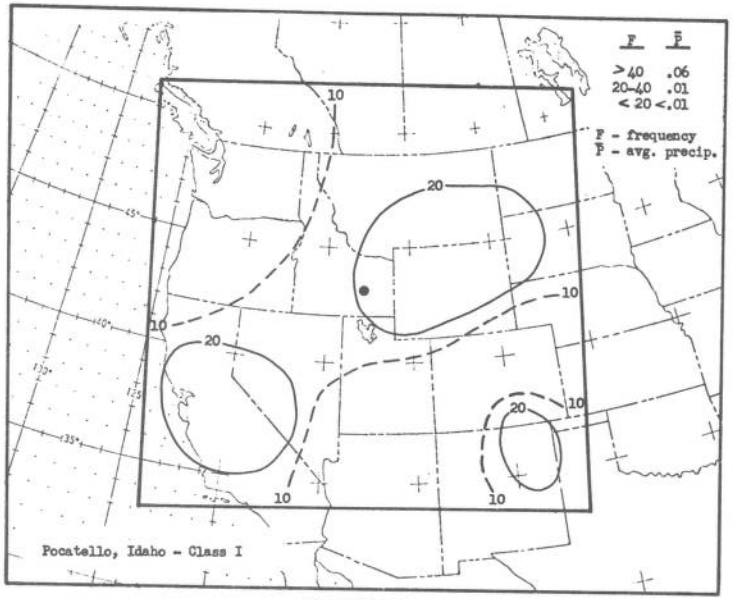


Chart 23 - I

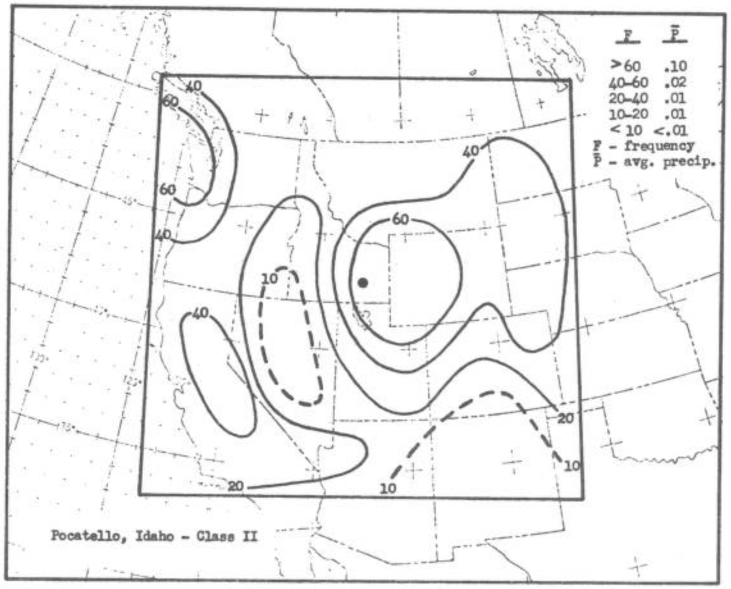


Chart 23 - II

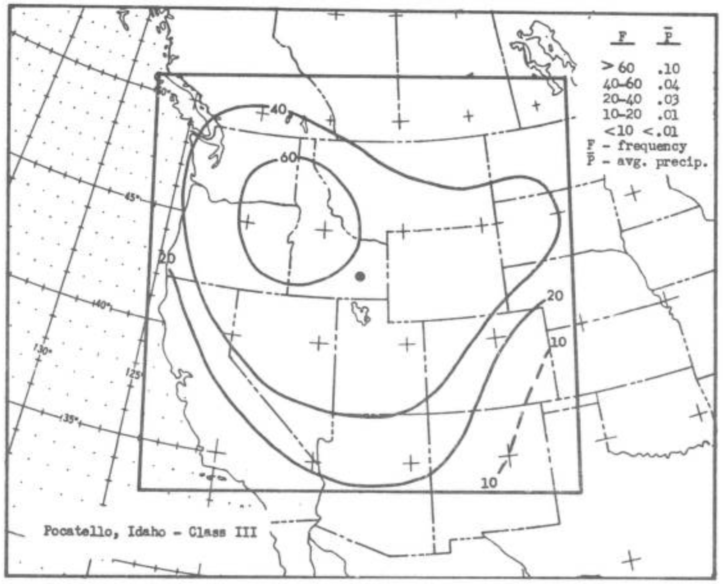


Chart 23 - III

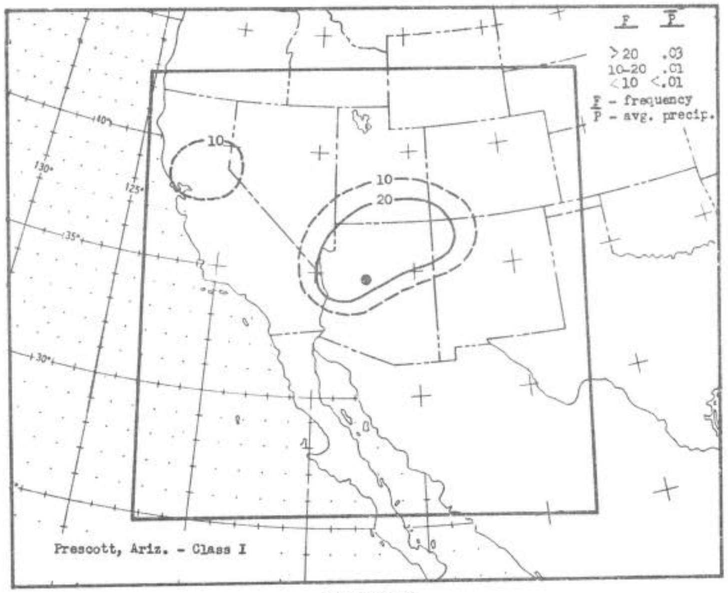


Chart 24 - I

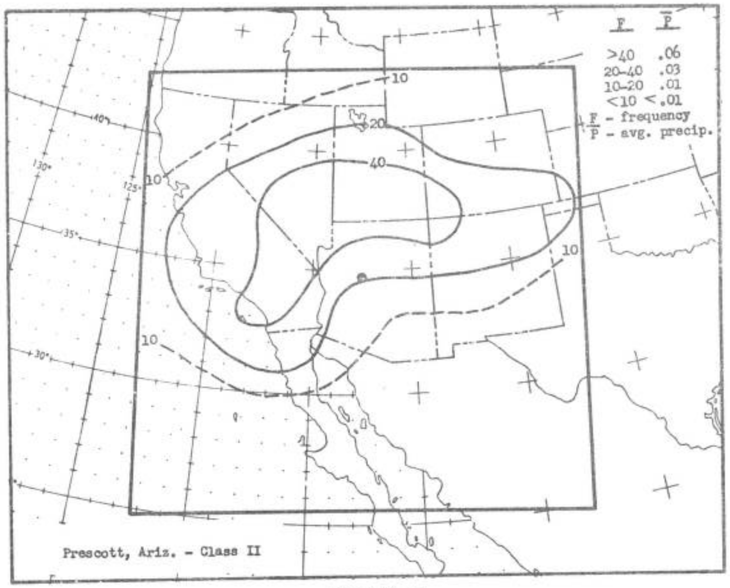


Chart 24 - II

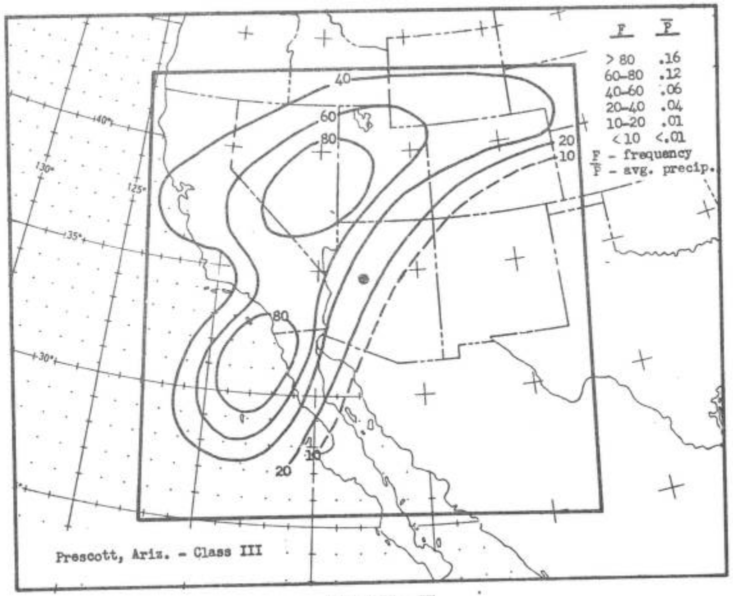


Chart 24 - III

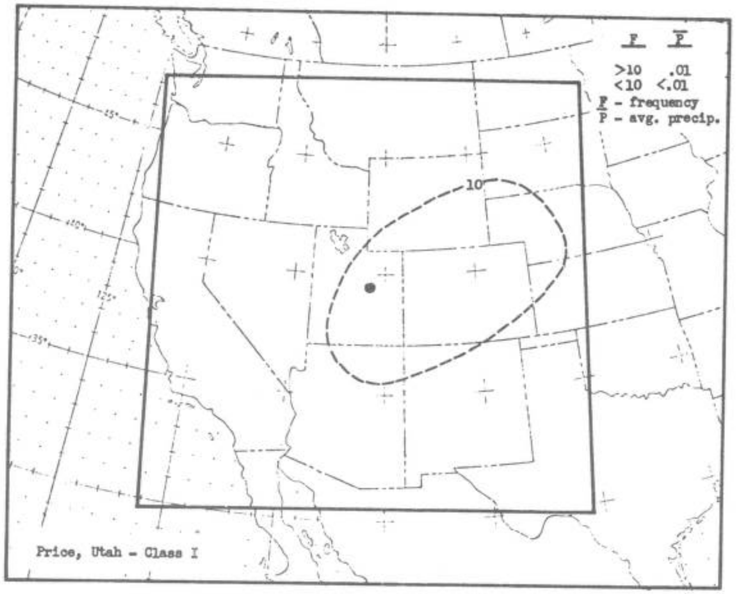


Chart 25 - I

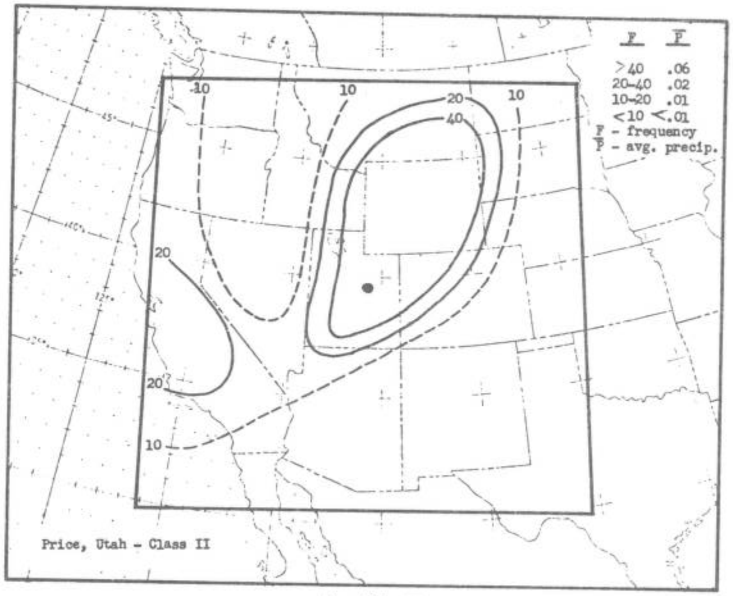


Chart 25 - II

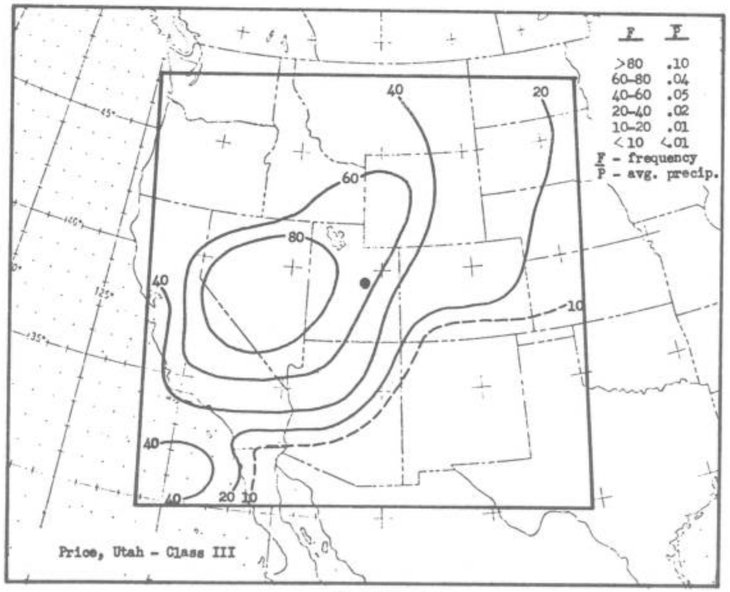


Chart 25 - III

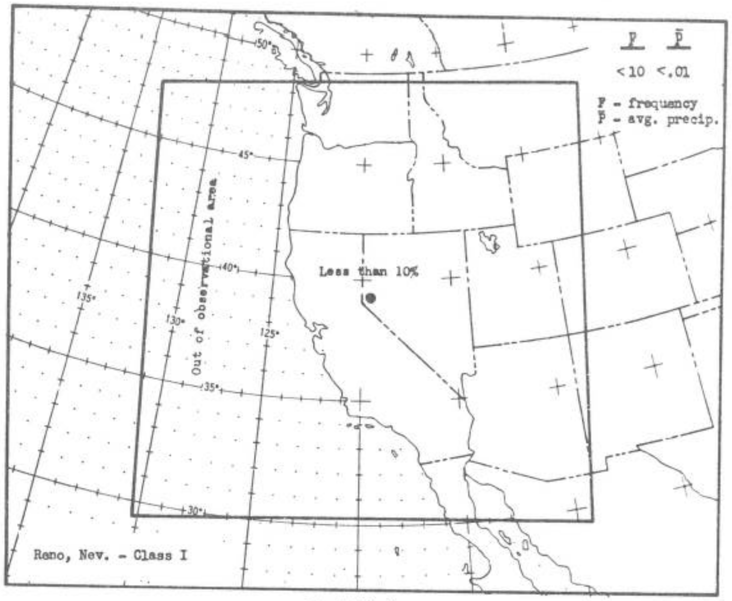


Chart 26 - I

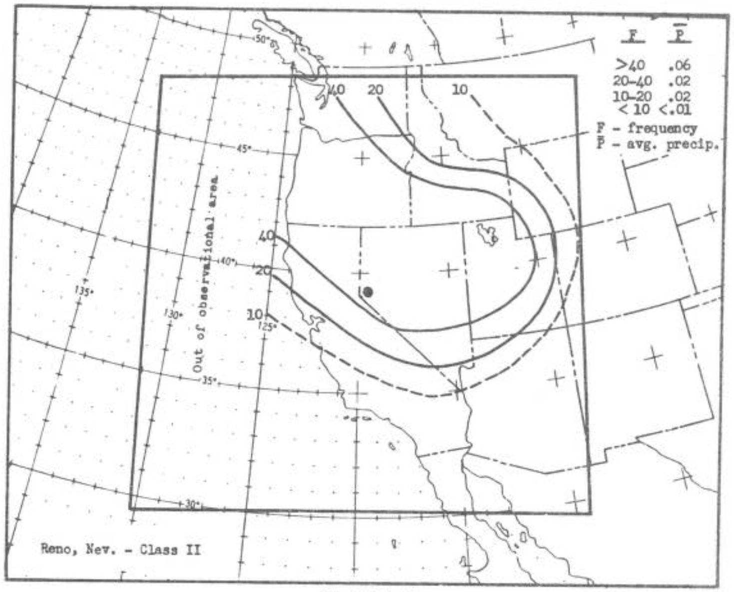


Chart 26 - II

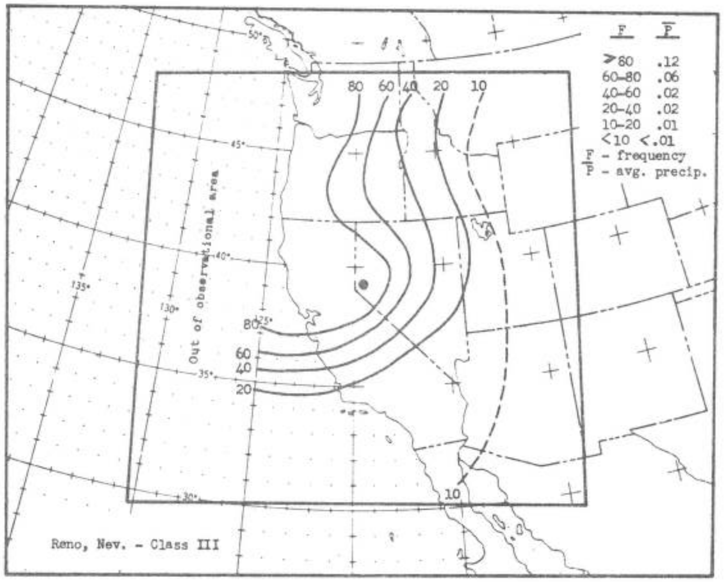


Chart 26 - III

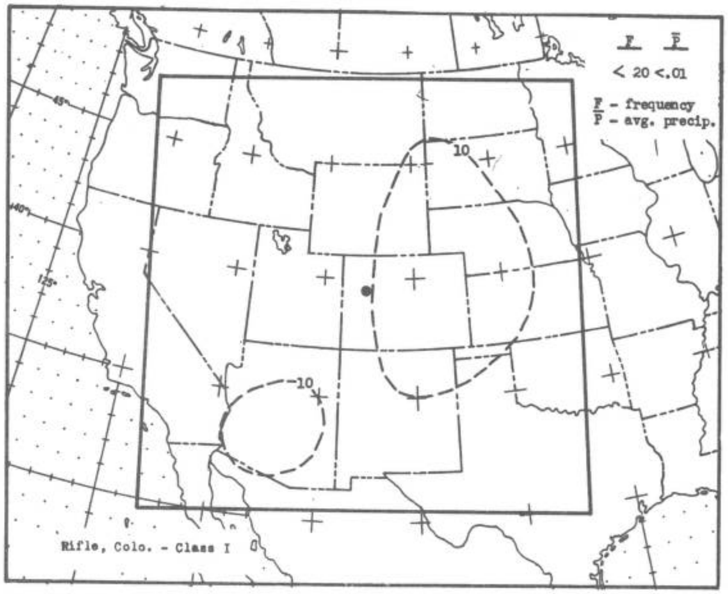


Chart 27 - I

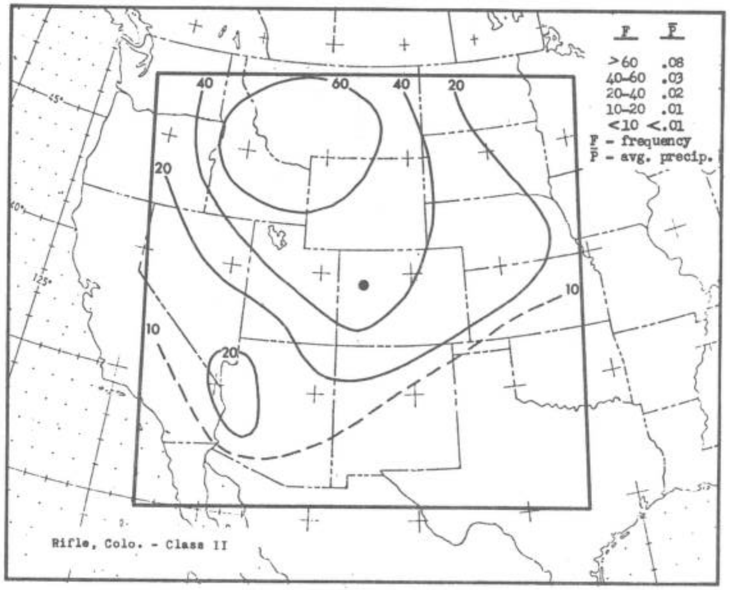


Chart 27 - II

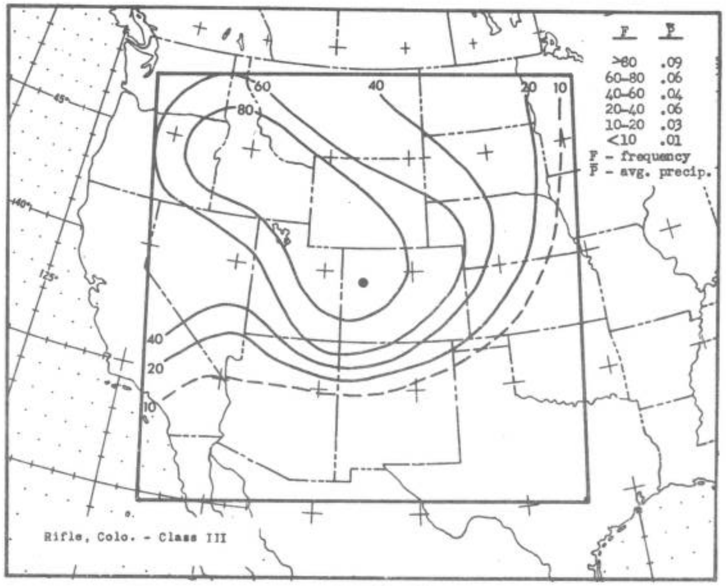


Chart 27 - III

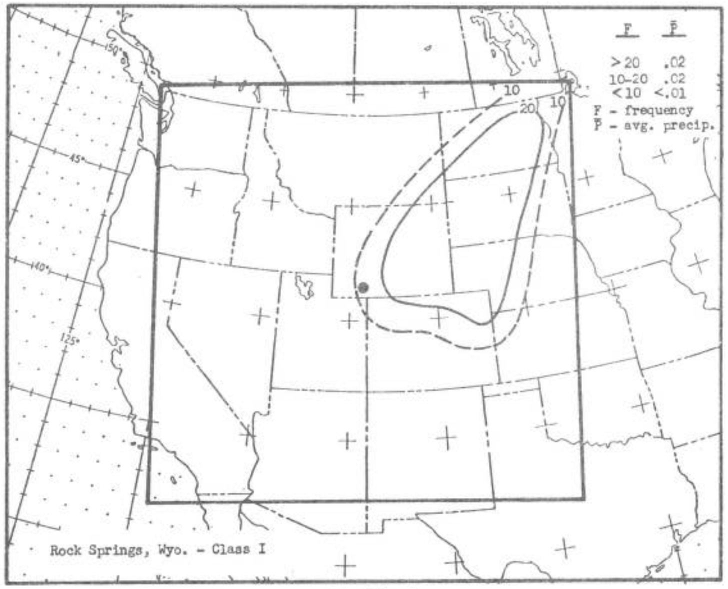

Rock Springs, Wyo. - Class I

Chart 28 - I

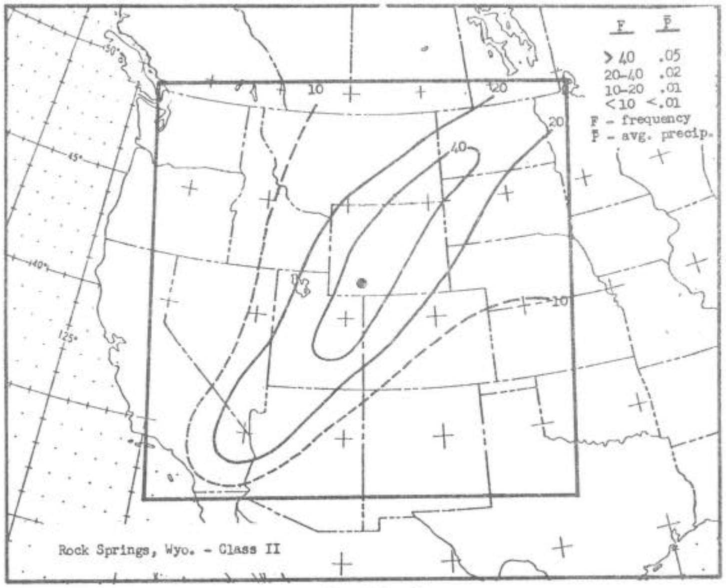

Rock Springs, Wyo. - Class II

Chart 28 - II

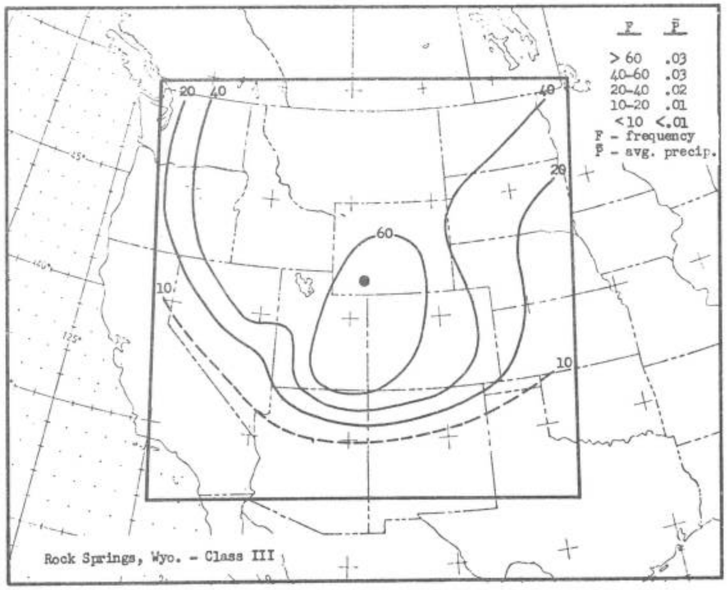

Rock Springs, Wyo. - Class III

Chart 28 - III

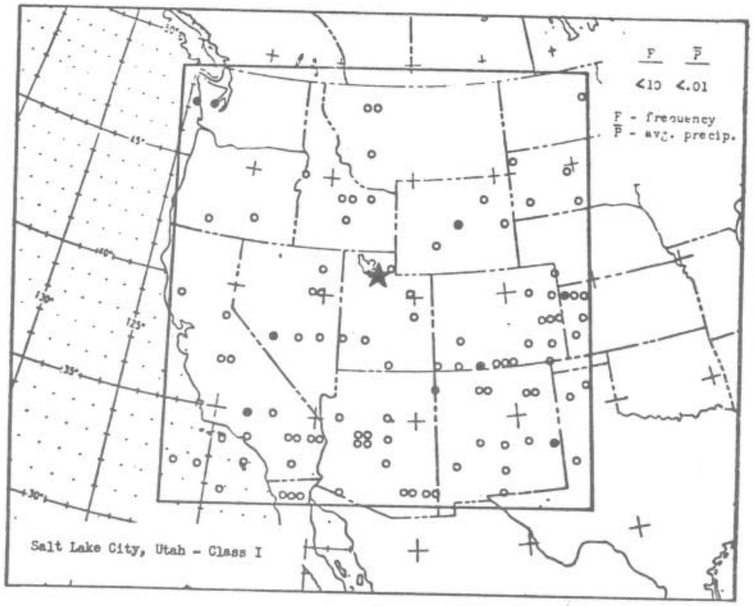


Chart 29 - I

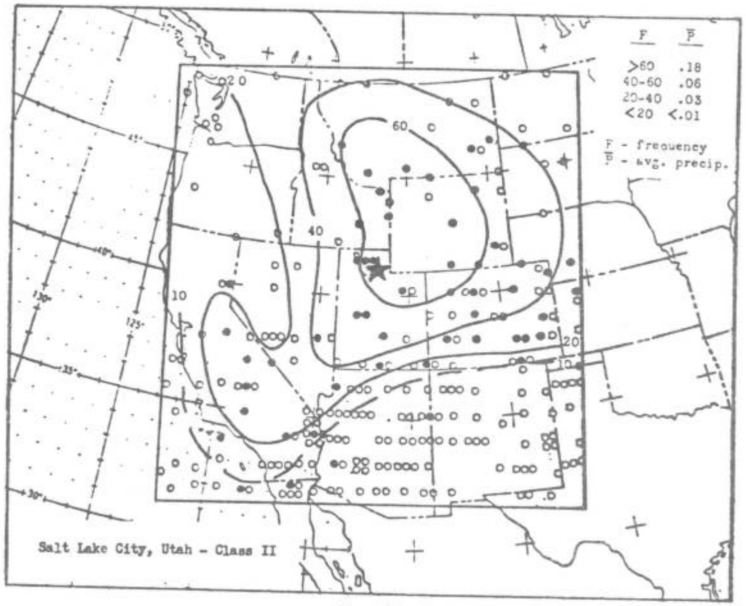


Chart 29 - II

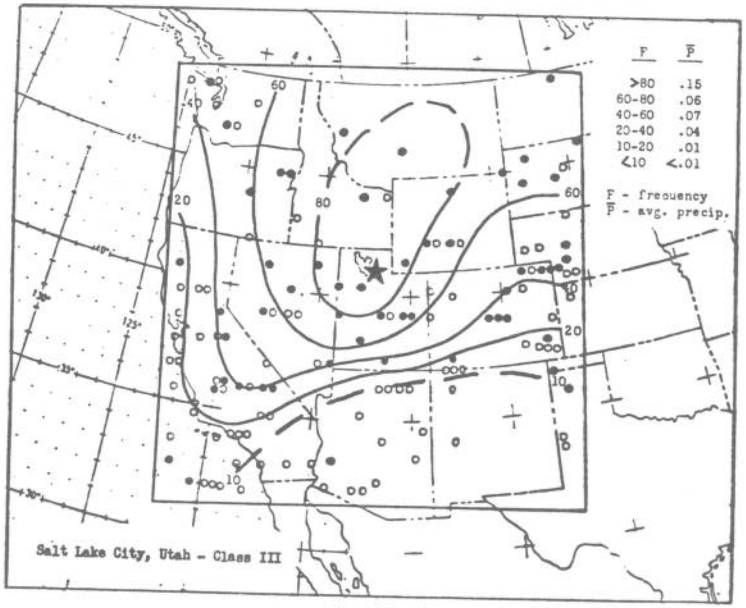


Chart 29 - III

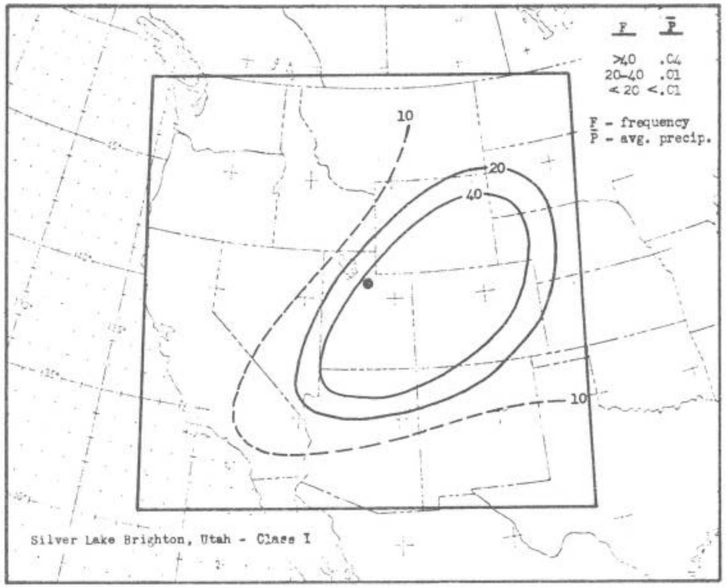


Chart 30 - 1

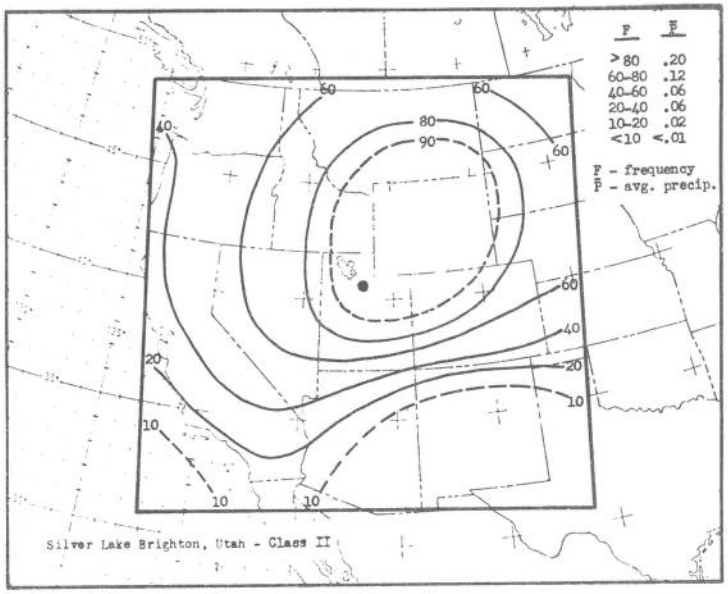


Chart 30 - II

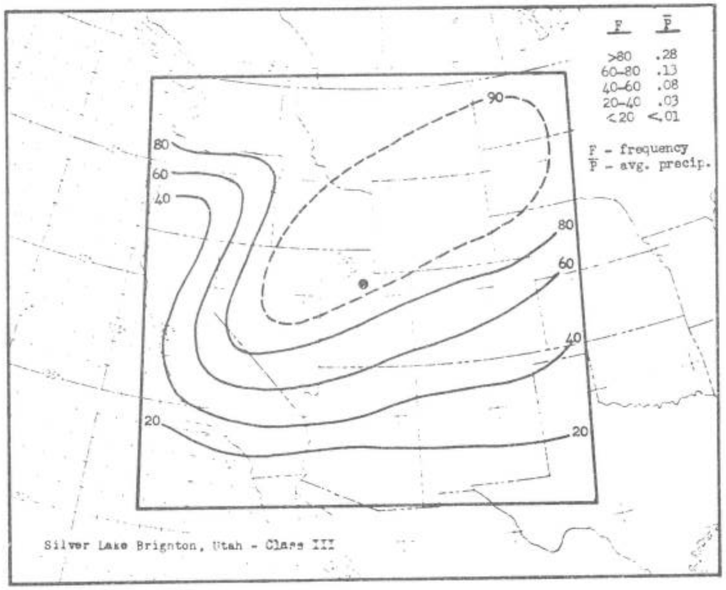


Chart 30 - III

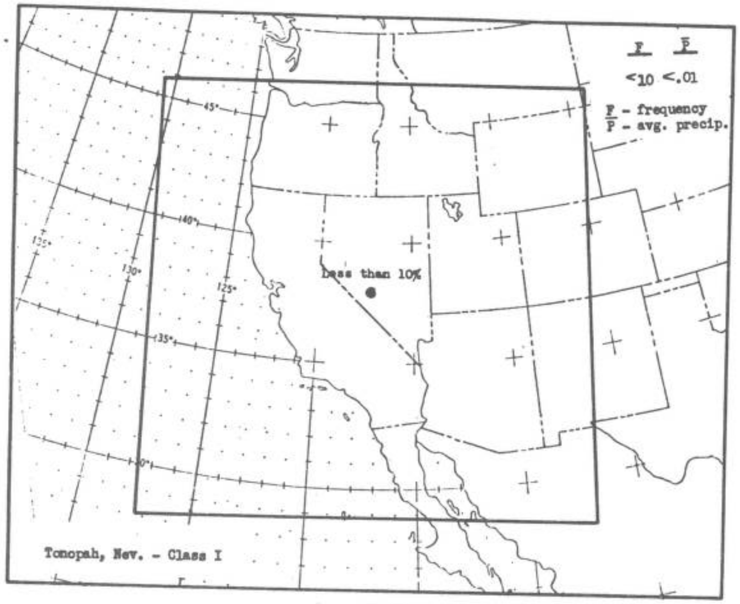


Chart 31 - I

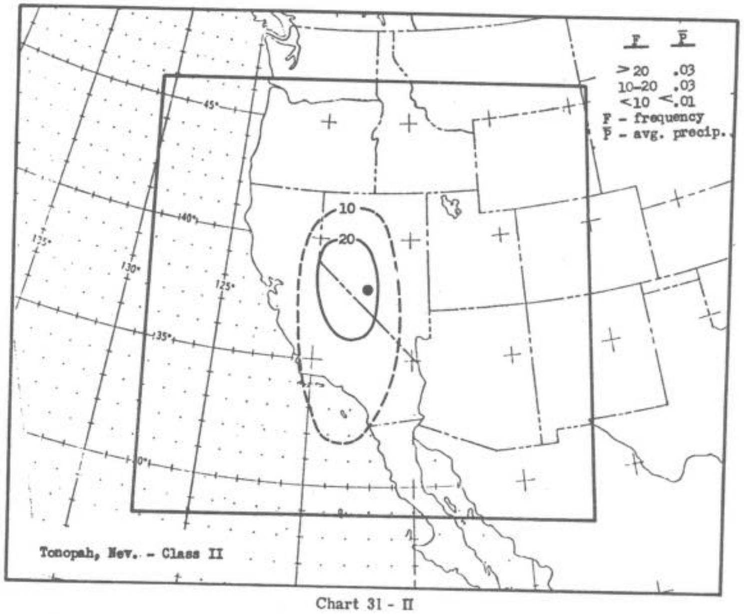


Chart 31 - II

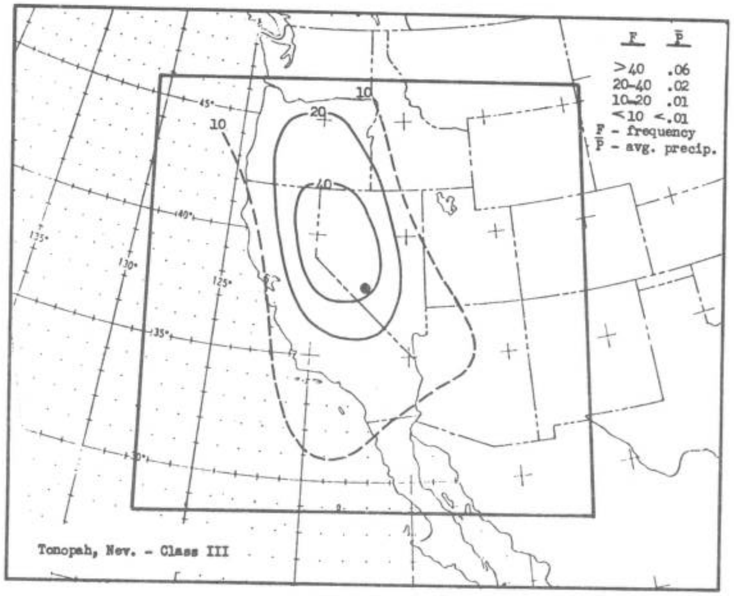


Chart 31 - III

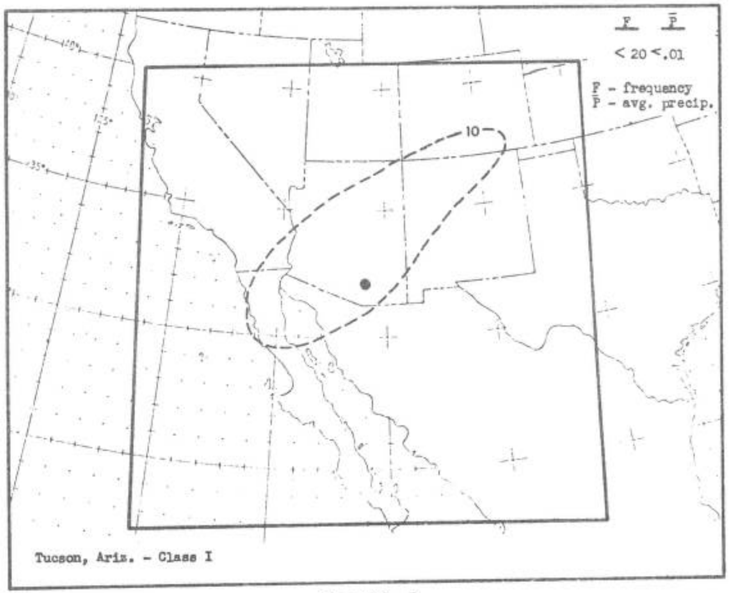

Tucson, Ariz. - Class I

Chart 32 - I

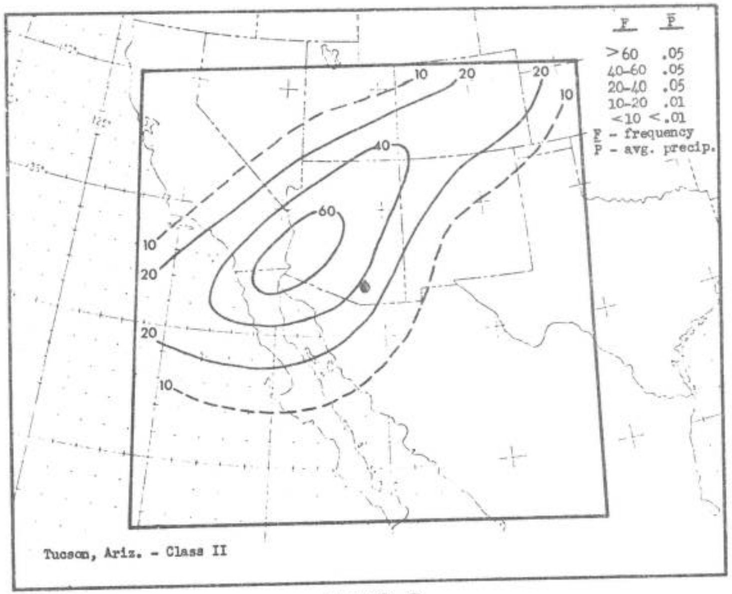

Tucson, Ariz. - Class II

Chart 32 - II

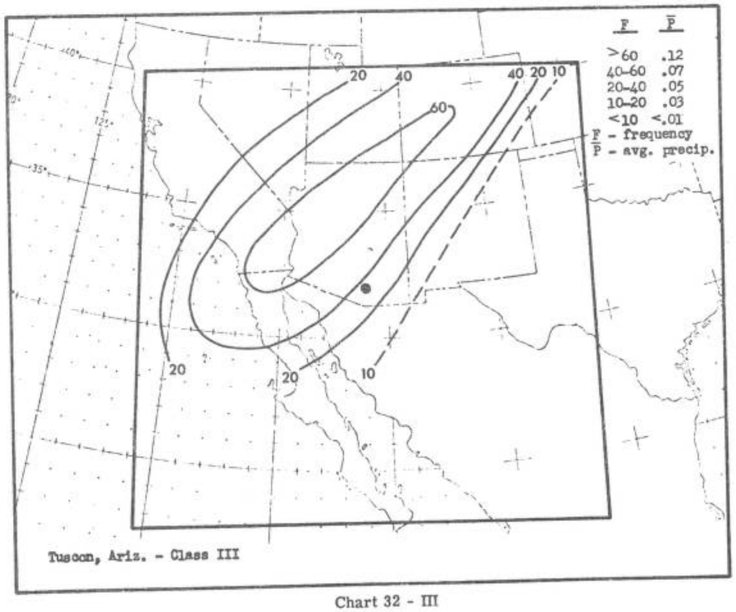

Tuscon, Ariz. - Class III

Chart 32 - III

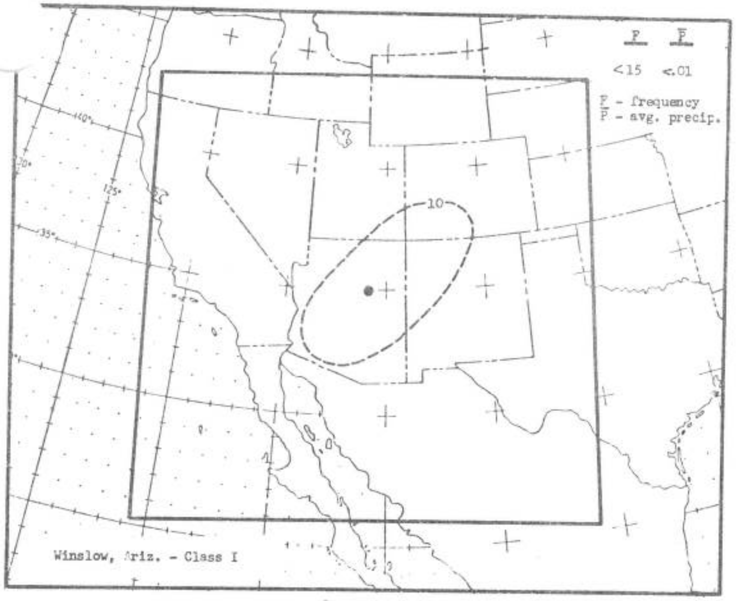


Chart 33 - I

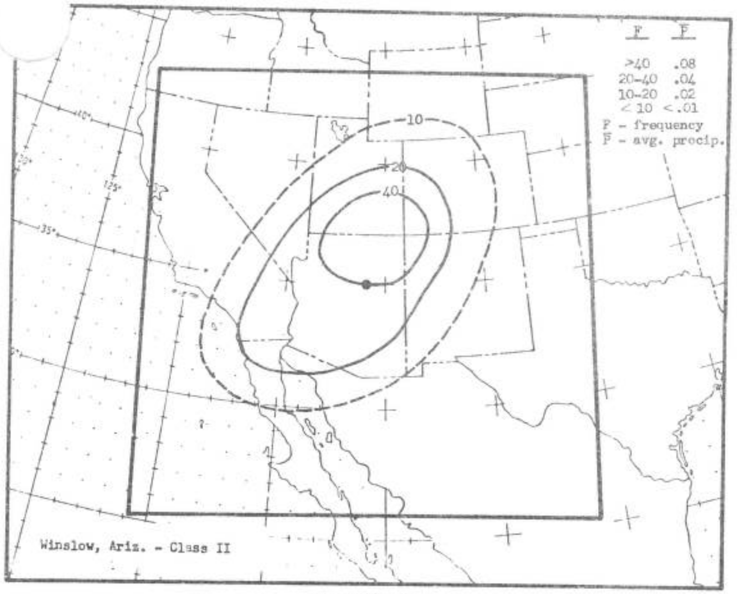


Chart 33 - II

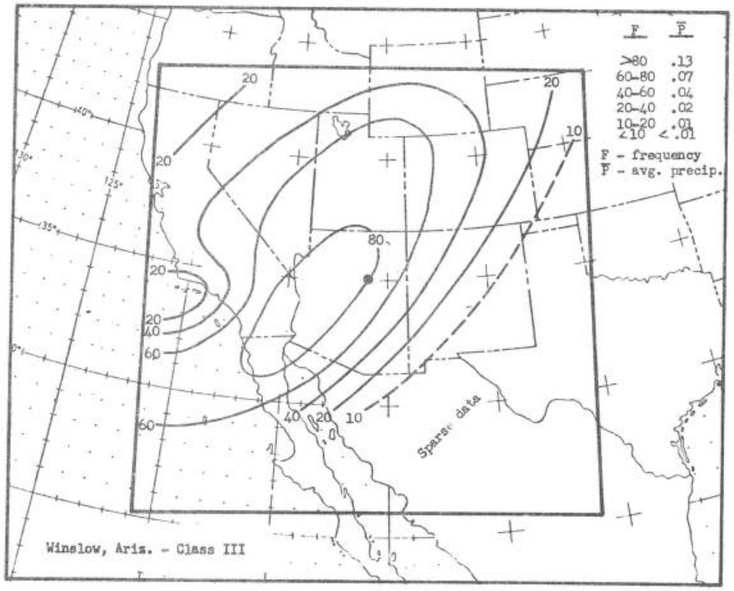


Chart 33 - III

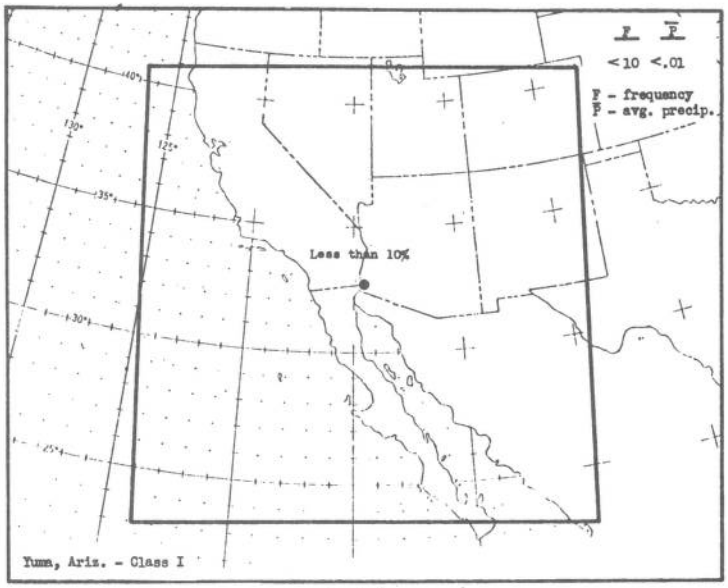


Chart 34 - I

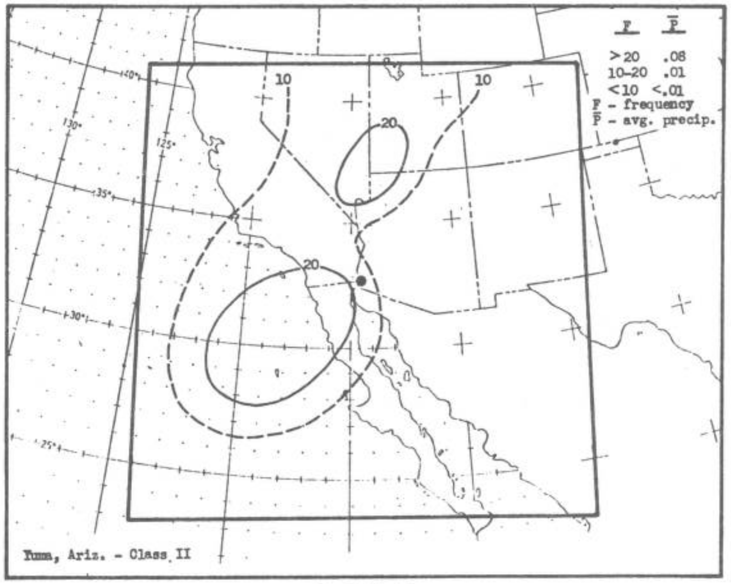


Chart 34 - II

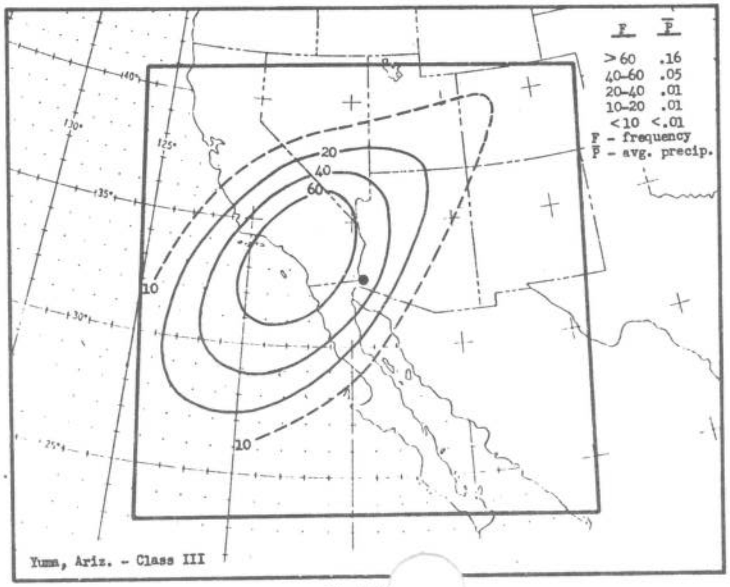


Chart 34

(Continued from inside front cover)

No. 10 Objective Determination of Sea Level Pressure from Upper Level Heights. W. H. Klein, F. Lewis, and J. D. Stackpole. May 1967.

No. 11 Short Range Subsynoptic Surface Weather Prediction. H. R. Glahn and D. A. Lowry. July 1967.