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Precipitation Probabilities in the Western Region Associated With Winter 500-mb. Map Types

Richard P. Augulis

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

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Weather Bureau Technical Memorandum WR-45/1

PRECIPITATION PROBABILITIES IN THE WESTERN REGION ASSOCIATED WITH WINTER 500-MB MAP TYPES

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WESTERN REGION
TECHNICAL MEMORANDUM NO. 45/1

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PRECIPITATION PROBABILITIES IN THE WESTERN REGION ASSOCIATED WITH WINTER 500-MB MAP TYPES

I. INTRODUCTION

The concept of typing weather charts and relating given pressure or wind patterns to meteorological phenomena is not new. Bowie and Weightman (1) stratified storms by their movement over geographical regions. Average tracks, expected direction of movement based on the storm's initial position, and average speeds were computed. California Institute of Technology in the early 1940s developed 6-day weather types using surface pressure patterns (2). The types were related to expected departures from normal of temperature and pressure. Elliott later associated the CIT surface types to mid-tropospheric flow patterns (3). In recent years Klein and others have done work on relationships of certain upper-air patterns to expected precipitation and temperature distributions (4). Synoptic climatology studies of this nature have proven very beneficial by associating weather phenomena quantitatively to pressure and wind patterns.

A meteorologist preparing a forecast associates certain pressure and flow patterns with expected weather. This mental process is subjective and quite dependent on a forecaster's experience, training, motivation, etc. There are well-known advantages to making this relationship objective. The recent introduction of more sophisticated Numerical Weather Prediction (NWP) models has significantly increased the accuracy of 500-mb prognoses to periods of 48 hours or longer. Objective applications of synoptic climatological information to NWP prognoses should lead to improved meteorological guidance and weather forecasts.

The general relationships of precipitation occurrence to 500-mb flow patterns are known. Certain patterns are more likely to cause precipitation over a geographical area than others, but there is need for more detailed knowledge of the probability of precipitation occurrence at various locations with different patterns. Synoptic climatology studies by Korte, Jorgensen and Klein (5) have related precipitation occurrence to closed upper-level lows, but again because of large variations in topography over the West, application of single station results to surrounding areas is questionable. Over much of the central and eastern sections of the U.S. this is not necessarily true. Thus it becomes necessary that more detailed synoptic climatology studies be prepared over western United States.

The Western Region Conditional Climatology Program was developed to add the required detail and also develop techniques for objective guidance. The following is a brief synopsis of the program. Typing of the basic upper-level flow (500mb) pattern employing a technique discussed by Lund (6) has been completed. An explanation of this technique and utilization of its results form the basis of this Technical Memorandum. The future part of the program will enlist the support of Techniques Development Laboratory, Weather Bureau Headquarters. Parameters such as initial 500-mb height and departure from normal, initial vorticity, vorticity advection, and moisture will be added to obtain the detail of a type's flow. These parameters within similar flow patterns or types will be mathematically screened through regression methods to find the best precipitation indicators. Use of the developed equations and Numerical Weather Prediction (NWP) products in the "perfect prog" approach will result in an objective probability forecast for the occurrence of measurable precipitation. This probability would then be "massaged" to a final man-machine-mix forecast. The ultimate goal is for computerization of all steps except the latter.

Twelve-hour precipitation climatologies as specified by 500-mb flow patterns were generated as the first step of this program. This Technical Memorandum is the first of four parts which will cover a precipitation climatology over the Western Region for four seasons. Discussion on development of types, proper usage, limitations, and other general information is presented in this first portion. Winter types along with their climatologies and a listing of type dates are also included. In the near future the other three parts of this Technical Memorandum covering the spring, summer, and fall seasons will be published. These will include only the type maps and respective climatologies along with a listing of type dates. All discussion pertinent to the winter types in this Part I will be applicable to the other seasons.

II. METHOD OF DEVELOPMENT

Data used to generate types were obtained from historical files of Techniques Development Laboratory. Upper-level height data located at points on the NMC grid (Figure 1) had previously been placed on magnetic tape for computer use. The period of data record ran from November 1961 through October 1968. All data were used in this work except the period June through August 1962 and March through May 1968. (These were not employed because of limited computer capacity and unavailability of data on magnetic tape.) An area covering western North America and the eastern Pacific was selected for typing. Areal boundaries were approximately 100° - 150°W. longitude and 30° - 60°N. latitude (see Figure 2). Fifty-two grid points as shown in Figure 2 were selected within this area and 500-mb heights for these points were extracted from the tapes. The data were divided into seasons of winter: December-February; spring: March-May; summer: June-August; and fall: September-November. Three-month seasonal divisions were chosen to minimize the workload and be comparable to seasonal divisions of Techniques Development Laboratory's synoptic climatology studies.

The winter season consisted of 1195 maps for 0000 and 1200GMT December 1961-67, January 1962-68, and February 1962-68. The fifty-two grid point 500-mb height values for each of the 1195 maps were read into a Univac 1108 computer. Each set of fifty-two heights was correlated with every other set. The final product was an 1195 x 1195 correlation coefficient matrix. A count was made of the number of correlations ≥.80 associated with each map, i.e., number of times each map was correlated with all other sample maps at .80 or higher. In the winter sample the map of 1200Z December 19, 1961 was correlated with 690 maps at ≥.80. This map was called type map 1 (see Figure 3a). Type map 1 and all maps correlated with it at ≥.80 were removed from the sample. From the remaining maps, the map that had the largest number of correlations ≥.80 was determined and designated type map 2 (see Figure 3b). Again type map 2 and all maps correlated with it at ≥.80 were removed from the correlation matrix. The same process continued through type map 3, type map 4, etc., until all maps were eliminated or until only 10 or less maps were correlated at ≥.80 to a sample map. Some maps could not be typed because of infrequent occurrence during this 7-year sample.

Twenty-five type maps were generated from the winter data. If all sample maps that correlated with a type map at ≥.80 were considered to be maps of that type, then a given map could be in more than one type. For example the map for 1200Z December 5, 1961 correlated with type map 1 at .900, type map 3 at .923, type map 6 at .804, and type map 10 at .868. However, to eliminate this redundancy, each map was placed in the type with which it correlated highest. The map of 1200Z December 5, 1961 was placed in type 3 since it correlated the highest (.923) with type map 3. In this manner each map was put into only one type called a pure type.

Figure 4 lists for the winter season a breakdown by type of the number of maps correlated ≥.80 with each type map, and the number of maps which were correlated highest with each type map. Column 1 indicates type number, column 2 the number of maps correlating with the type map at ≥.80, and column 3 the number of maps correlating the highest with a type map. For example, type map 1 had 690 maps correlated ≥.80, but of these 690 maps only 356 correlated the highest with it. The remaining 334 correlated higher with other types. Note that many of the type maps have a large number of correlations ≥.80; but when the number of highest correlations was counted, this number was reduced drastically, as in the case of type 7.

After each map had been placed into one type, a composite or pure mean type map was made. Although not used in this study, another composite mean called a "mixed" type was made from all maps within a type. Figure 5a-c and 6a-c show examples of a type map, its mixed mean, and its pure mean.

III. VARIABILITY WITHIN TYPES

A measure of the variability of maps within a type can be shown in a frequency distribution of correlation coefficients. Figure 7 is such a diagram. Of 146 type 2 maps, 80 percent were correlated $\geq .90$ with the type map, and more than 55 percent were above the .92 level. Similar percentages apply to other types.

It might be expected that a map correlating at $\geq .90$ with a pure map would exhibit a strong similarity in flow pattern. Generally this is true when dealing with the large broadscale flow over the grid area. Variations due to small disturbances over portions of the grid produce significant differences among maps of the same type. An example of variability within a type is shown in Figures 8a-f. All maps shown in these figures are classified as type 1. The type 1 pure mean for winter is shown in Figure 8a. The correlation of this map with each of the other type 1 maps (Figures 8b-f) is given in the lower left-hand corner of the respective type 1 map. Important features of the mean map (Figure 8a) are a broad flow of westerlies over the grid area with a trough extending southward from the Gulf of Alaska and flat ridge near 120°W. Flow features nearly identical to Figure 8a are exhibited by the sample map as shown in Figure 8b. This is also reflected in the .981 correlation coefficient. Similarity between Figures 8a and 8c is less because of ridging near 140°W. and northwesterly flow between 120 - 130°W. as shown in Figure 8c. However, large-scale features are quite comparable. This relationship again shows in the .961 correlation between the two. Figure 8d shows the same similarity in large-scale flow except that the southern portion of the western North America ridge is some 10° farther west than the ridge in the pure mean map. Again, the sample map shown in Figure 8e exhibits the same large-scale zonal flow of the type 1 mean map, but the very short-wave disturbances are almost 180 degrees out of phase. Figure 8f has a more significant dissimilarity in the cutoff low over southern California. This feature might lead to a conclusion that the map should not be a type 1. There might be some validity for this over the southwestern United States, but the flow over the remainder of the grid is similar to the pure mean map (correlation .951). Weather over southern California and Arizona with this pattern would be considerably different than that expected with the map of Figure 8a.

It can readily be seen by inspection of all 6 maps that the major features of broad fairly zonal westerlies between 40 - 50°N., low heights in the Gulf of Alaska, and above normal heights near or off the west coast of North America are common to all.

Another example of map variability is shown in Figures 9a-d. Figure 9a is the fall type map 1, Figure 9b is its pure mean type, and Figures 9c-d are type 1 maps. Of significance is the difference in flow pattern between figures 9c and 9d over western North America. The map in Figure 9c is quite similar to the one in Figure 9a with a trough in the eastern Pacific, southwest flow over the coast states, and northeast-southwest oriented ridging over the Western Region. In comparison the map in Figure 9d has substantial troughing over the western states. Correlation between Figures 9c and 9d is only .881. However both maps have been placed in fall type I because they correlated highest with type map I (.944 and .888 respectively). Figures 10a-e show the map of 1200Z December 5, 1961 (Figure 10a) as compared to winter type maps 1, 3, 6, and 10 (Figures 10b-e). Correlation of this specific map to each type map is given in the lower left-hand corner of the respective type map. Note how the basic similarity in flow is related to the correlation between two maps. The total pattern over the grid must be considered when subjectively typing a map. Minor differences should be ignored. Some maps may not be placed in any type. This usually applies to complicated split flows and blocking patterns. During transitional months, a given map may have more resemblance to a type of another season than to any of the season in which it occurs.

Objective typing by computer is a future goal. This approach would eliminate bias which occurs with subjective typing. Computation of correlation coefficients and determination of a map's type could be done at a central location like the National Meteorological Center (NMC). However at present the only approach is a subjective typing of maps at local station level.

IV. DEVELOPMENT OF TYPE PRECIPITATION CLIMATOLOGIES

A network of surface stations representing gross climatological areas and population centers of the Western Region was chosen (Figure 11). It consisted of Weather Bureau, FAA, second-order, and hourly precipitation substations. After all maps of a season were typed, a listing of dates of occurrence of each type was made. This listing is given in Appendix B. From station precipitation records the occurrence or nonoccurrence of measurable precipitation for the 12-hour period subsequent to maptime was tabulated and a summary of percent occurrence or climatological probability for each type was made. For instance Salt Lake City had 20 measurable precipitation occurrences in 80 winter type 8 cases giving a 12-hour precipitation probability of 25 percent. Similar calculations were done for all types, seasons, and stations. These were then summarized on geographical maps as shown in Figure 12.

Maps of winter type climatologies along with the associated type and pure mean maps are given in Appendix A. A transparent topographic overlay of the same scale as the climatology maps is also included. The placing of this overlay on the probability charts will aid in depicting possible orographic influences and causes of the observed precipitation frequency distribution.

It must be emphasized that the climatology for types that do not contain a sufficient number of maps should be used with caution. Types that contain less than 20 maps are likely to be unstable and more maps are necessary to obtain a representative numerical value for precipitation occurrence. For these types emphasis should be placed on the areal distribution of probabilities, i.e., areas of maximum and minimum precipitation occurrence.

Examination of the probability distribution within types indicates some interesting differences over relatively short distances. Examples of this are the low Portland probability compared to Astoria and Salem, Oregon for winter type 14 and the high Great Falls probability compared to Cutbank and Havre, Montana for winter types 11 and 12. See Appendix A. All data for these examples have been checked. Explanations for the observed climatology are not apparent, although some orographic effect and small sample might be possible answers. In the case of Portland, 3 traces were observed in the 13 cases. If these were measurable amounts, the climatology would be more comparable to surrounding stations.

V. LOCAL STUDIES EMPLOYING TYPING

The generation of type precipitation climatologies is one of many possibilities. The listing of dates under each type makes it possible to apply this technique to other weather phenomena. This might include winds, thunderstorms, clouds, precipitation amounts, visibility, surface dewpoints, mean relative humidity from surface to 500 mb, and others. Other meteorological variables might be included within types to further separate precipitation occurrence or nonoccurrence. A preliminary on-station study employing 500-mb height departure from normal (DN) within a type can be such a possibility. Application of FOUS 1-2 data within types might give useful results. Other suggestions are welcomed from the field.

VI. CONCLUSION

Although this Technical Memorandum is only part of the total Western Region Conditional Climatology Program, these first results can now be put to use by field personnel. Knowledge of type maps and their associated precipitation climatologies can be usable guidance to forecasters. Topographic influences on precipitation distribution over the Western Region are clearly shown. Knowledge of the dates of maps within a given type can be useful in studying local station forecasting problems.

VII. ACKNOWLEDGMENTS

Appreciation is expressed to Techniques Development Laboratory for use of their computer tapes of height data, Mr. Marvin Magnuson, Regional Climatologist, and the National Weather Records Center for obtaining the necessary climatological information and to Mrs. Lucianne Miller, Miss Vicky Owens, and Miss Leona Yee for their work in summarizing and computing precipitation climatologies. Helpful ideas and comments by the Western Region Scientific Services Division staff during preparation of this memorandum were also very much appreciated.

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6. Lund, I. A., "Map-Pattern Classification by Statistical Methods", Journal of Applied Meteorology, Vol. 2, No. 1, February 1963.

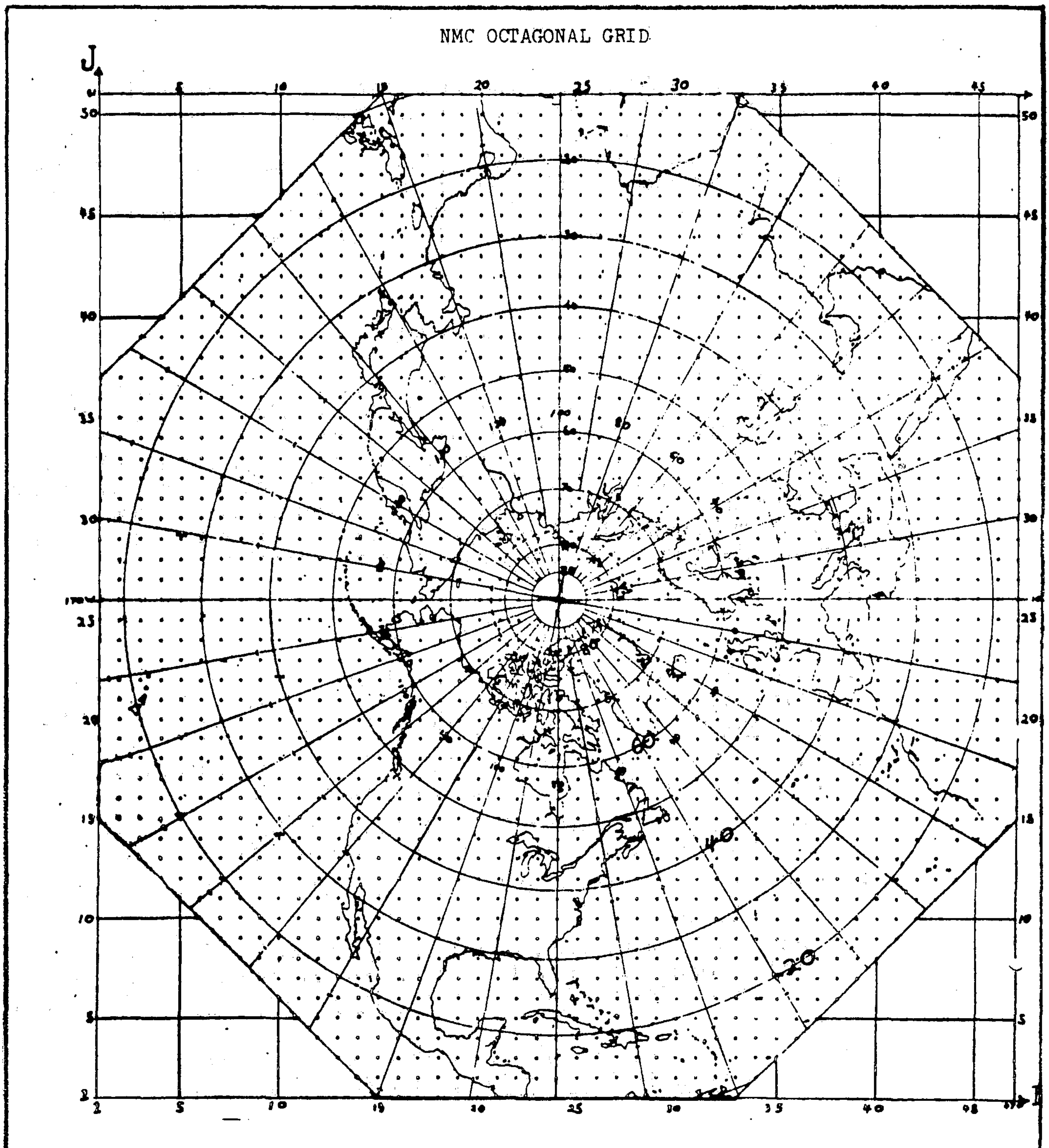


FIGURE 1: NMC 47x51 grid.
There are 1977 data points in the octagon.
The pole point is I,J = 24, 26.

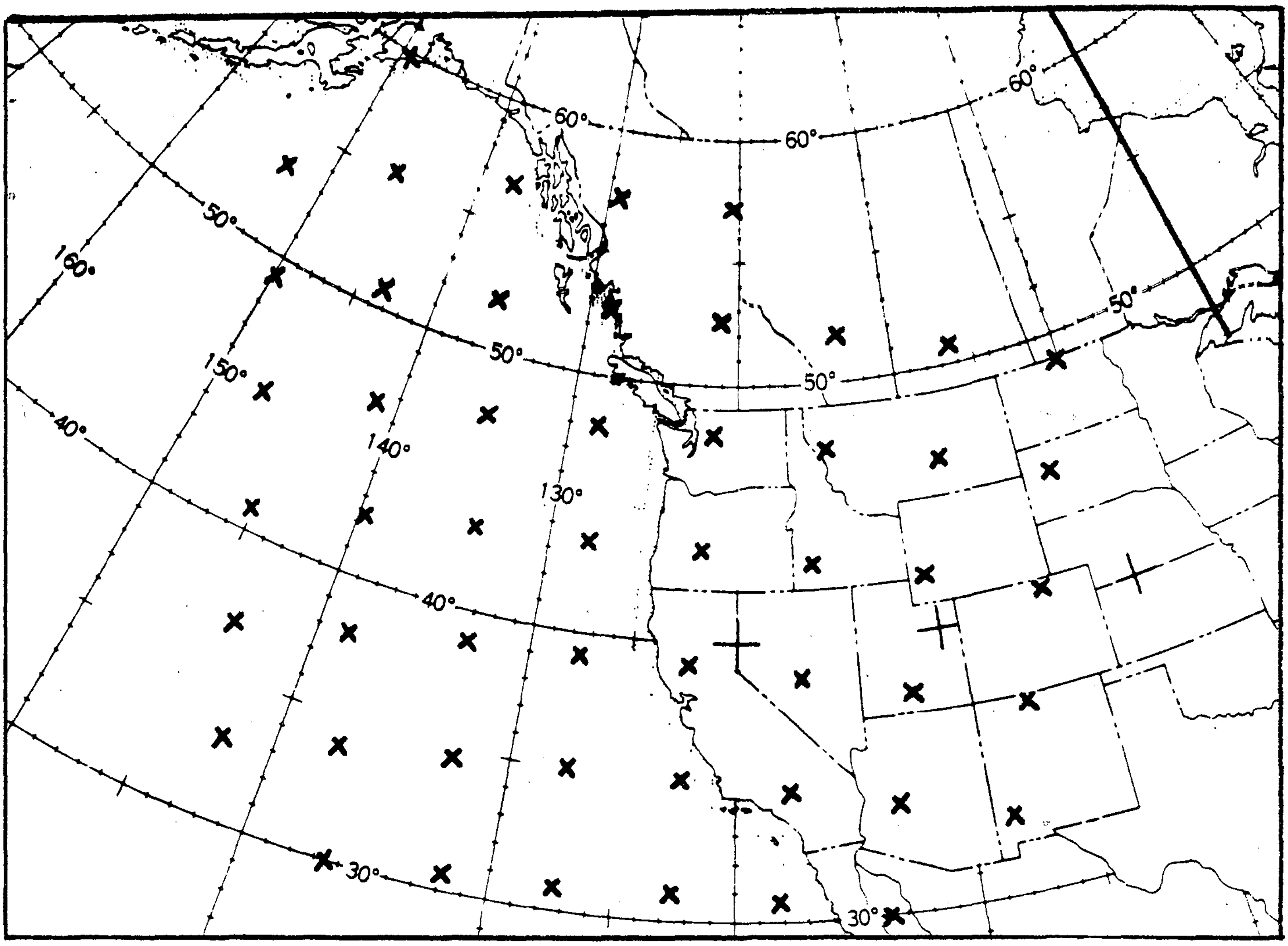


FIGURE 2 Distribution of 52 Grid Points over Typing Area

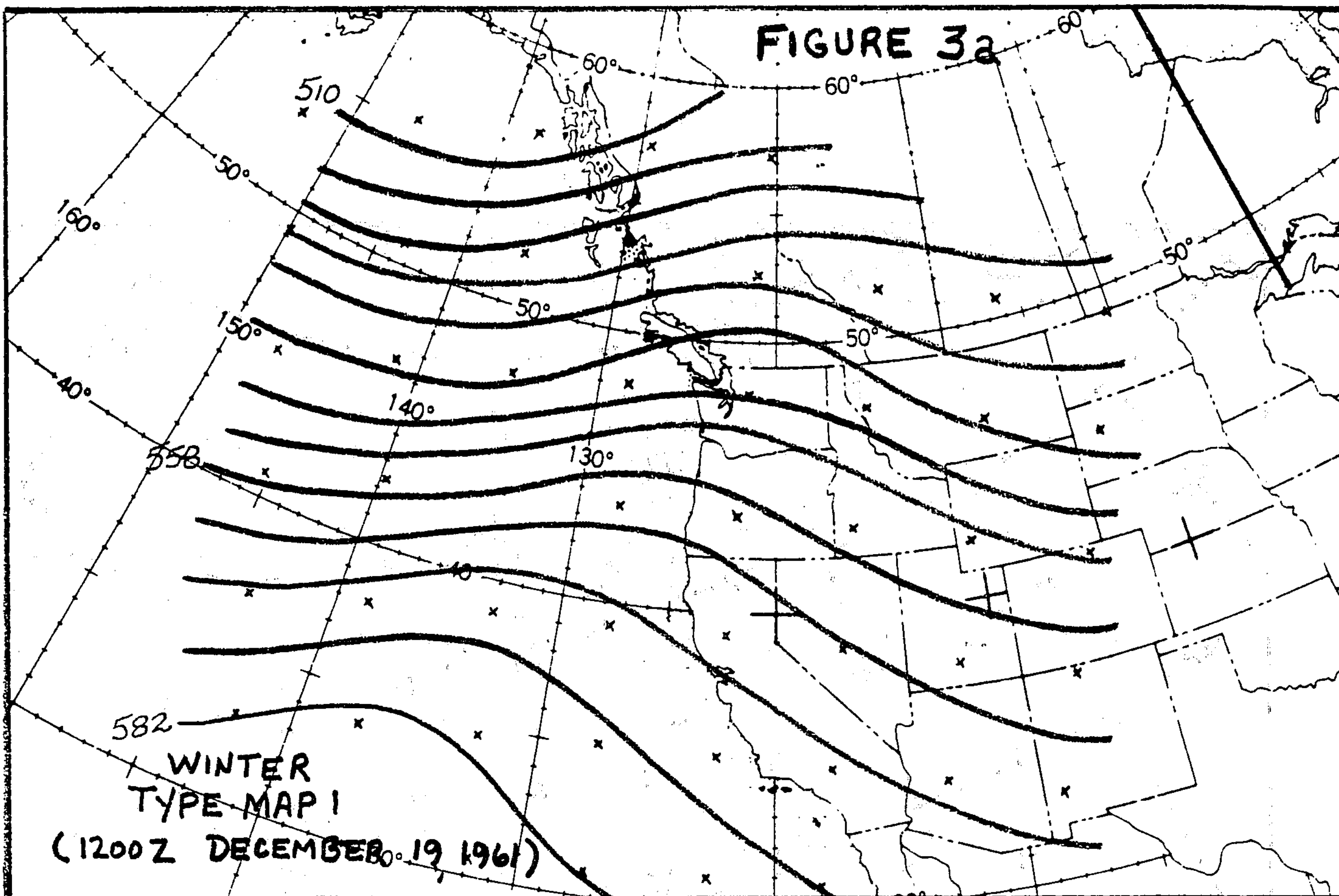


FIGURE 3a
510
558
582
60°
50°
40
160°
150°
140°
130°
40°
WINTER
TYPE MAP 1
(1200Z DECEMBER 19 1961)

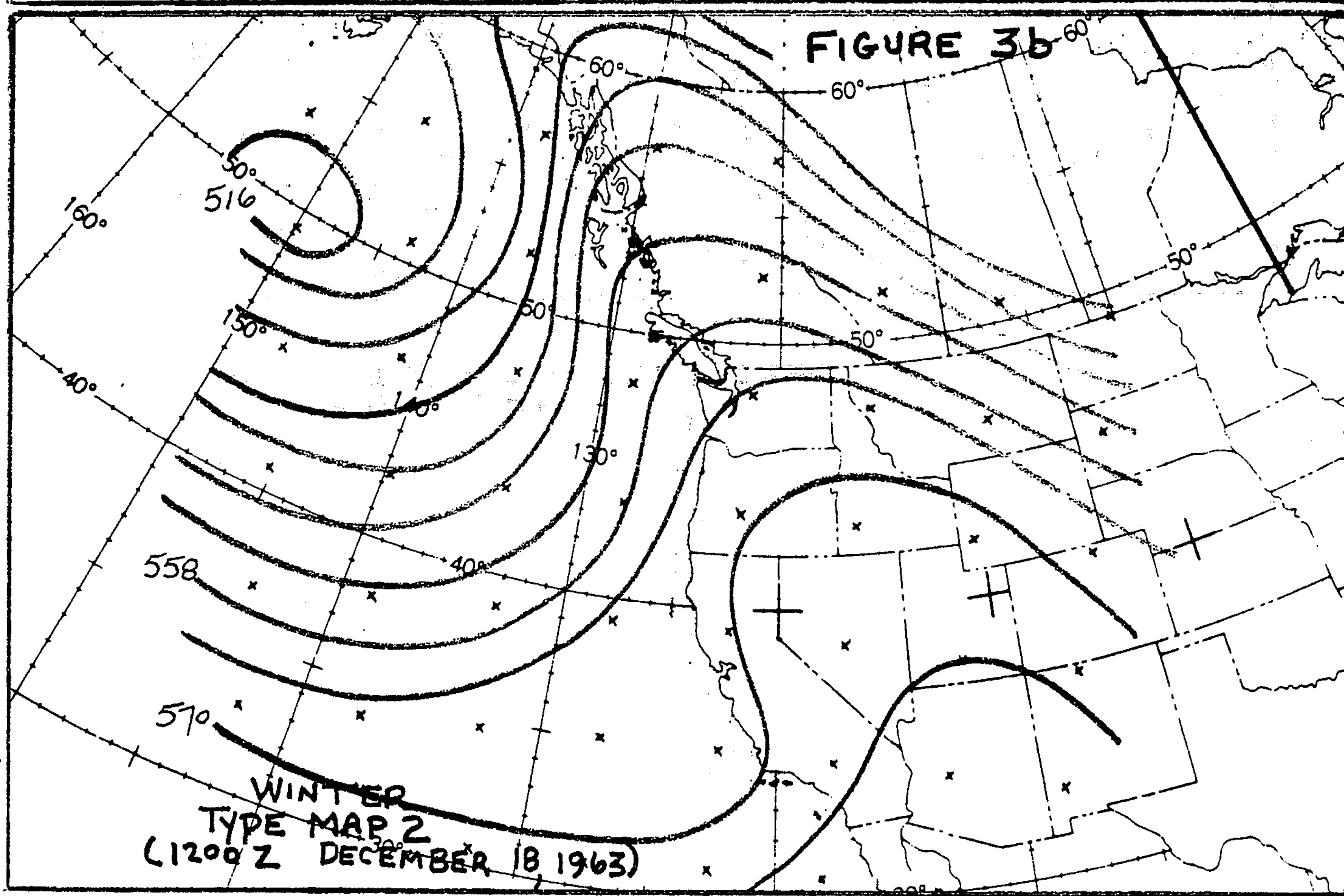


FIGURE 3b
516
558
570
60°
50°
40°
160°
150°
140°
130°
WINTER
TYPE MAP 2
(1200Z DECEMBER 18 1963)

FIGURE 4

Winter Season Map Type Information

TYPE	NO. MIXED MAPS	NO. PURE MAPS
1	690	356
2	388	146
3	388	145
4	300	98
5	223	52
6	219	64
7	202	16
8	143	80
9	140	26
10	123	10
11	98	13
12	96	26
13	89	14
14	86	13
15	81	25
16	58	12
17	55	20
18	54	11
19	53	10
20	43	6
21	42	5
22	19	7
23	17	5
24	12	3
25	10	6

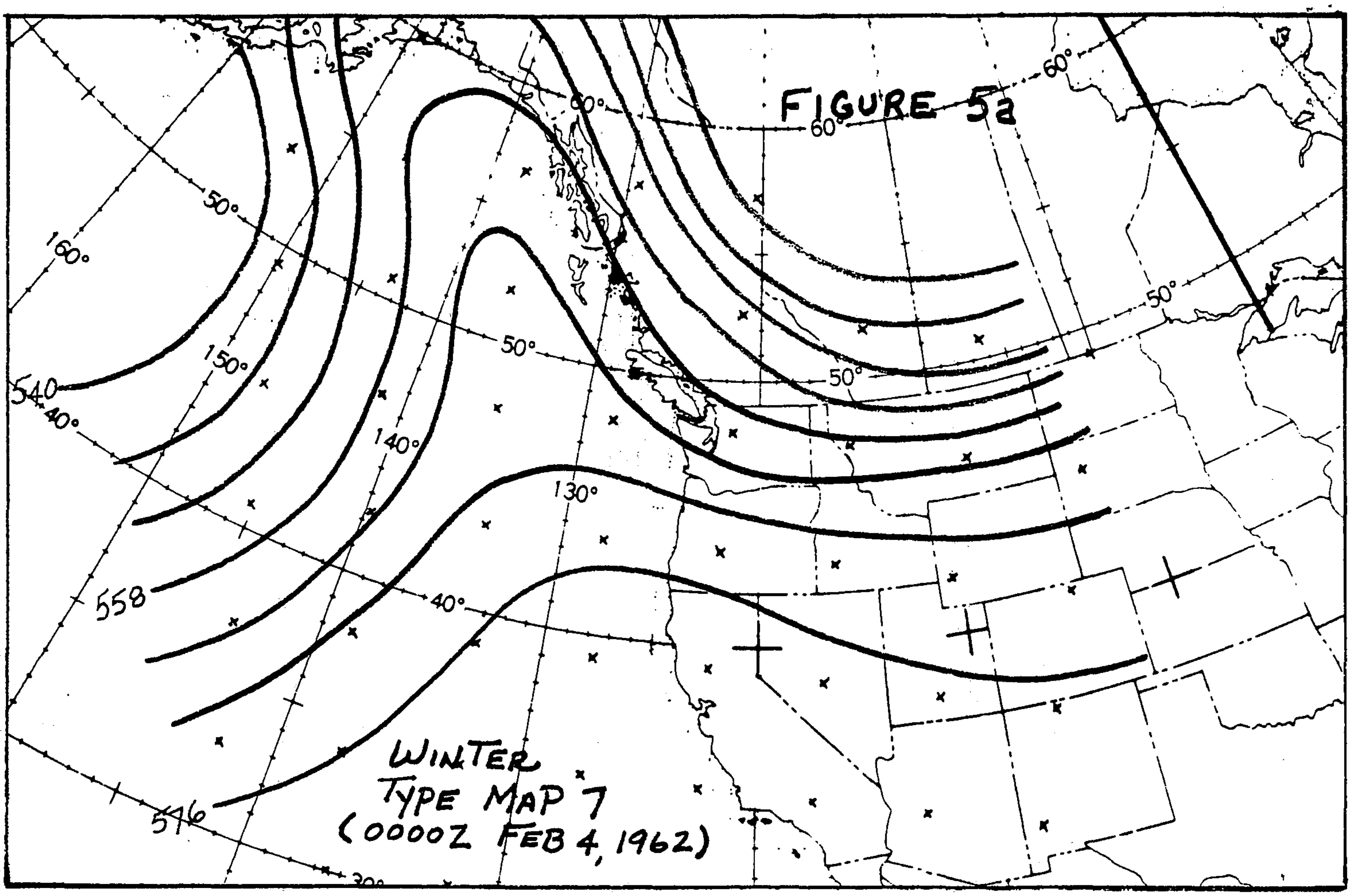


FIGURE 5a
WINTER
TYPE MAP 7
(0000Z FEB 4, 1962)
540
558
576
60°
50°
40°
160°
150°
140°
130°

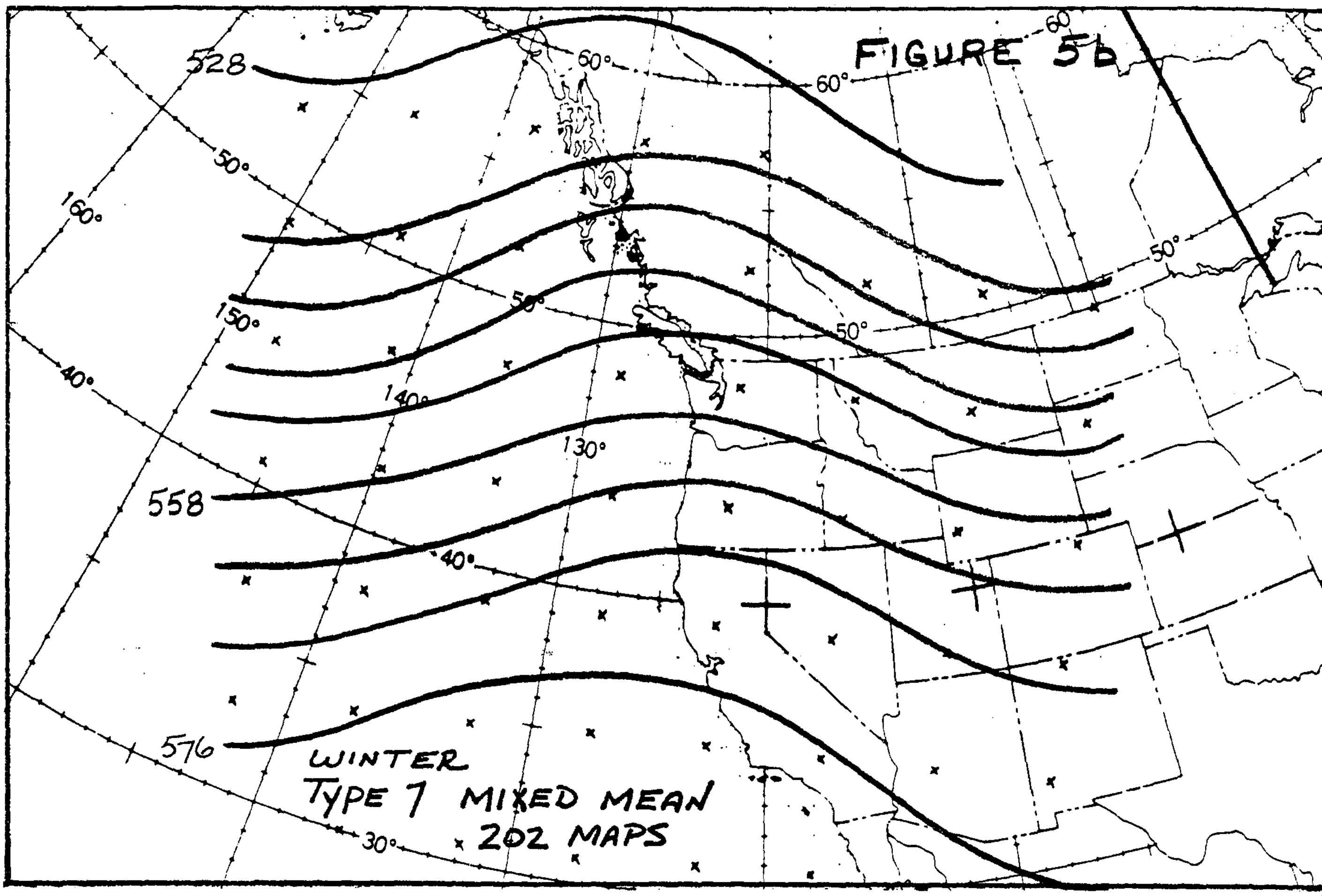


FIGURE 5b
528
558
576
60°
50°
40°
30°
160°
150°
140°
130°
WINTER
TYPE 7 MIXED MEAN
202 MAPS

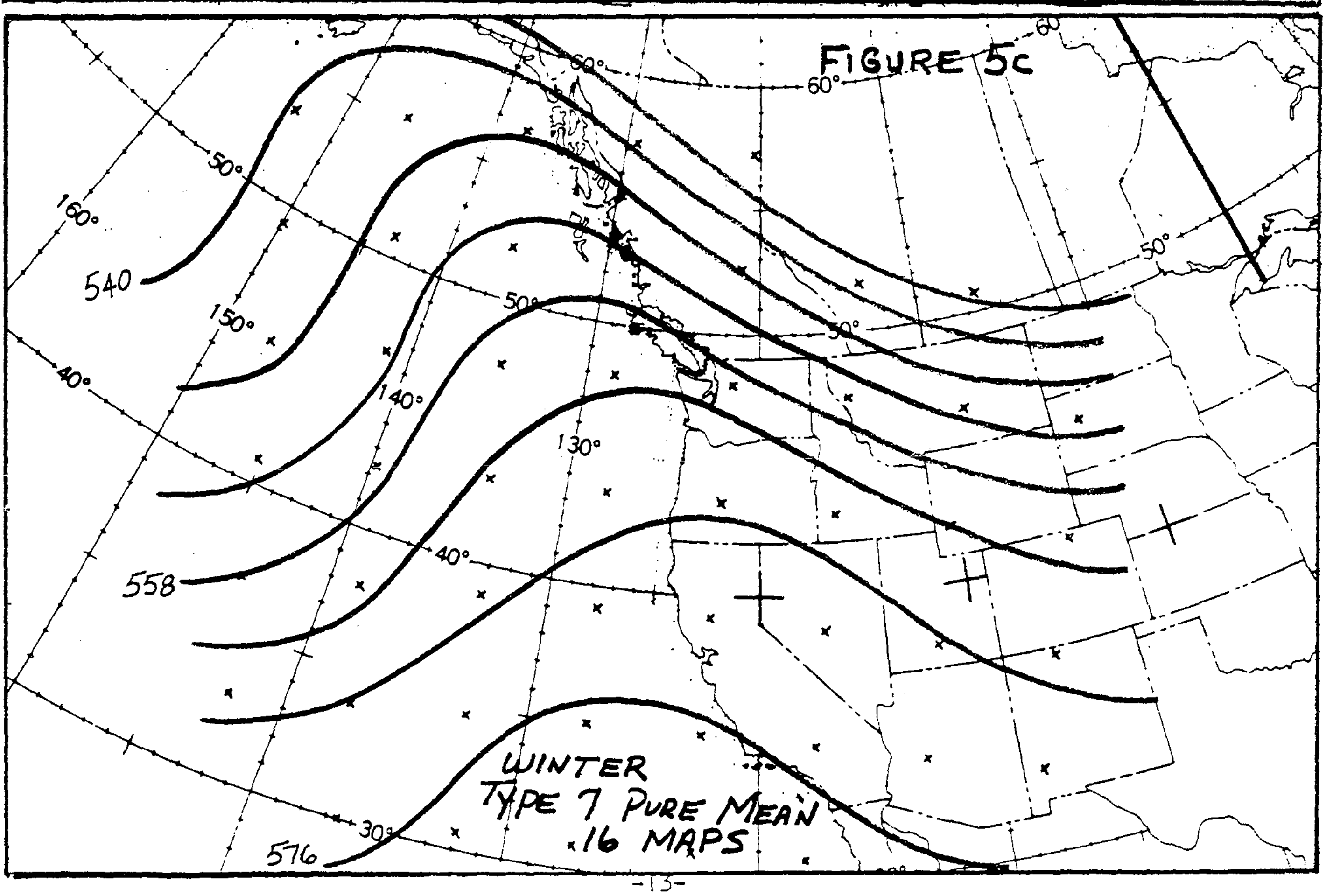


FIGURE 5c
540
558
576
60°
50°
40°
30°
160°
150°
140°
130°
WINTER
TYPE 7 PURE MEAN
16 MAPS

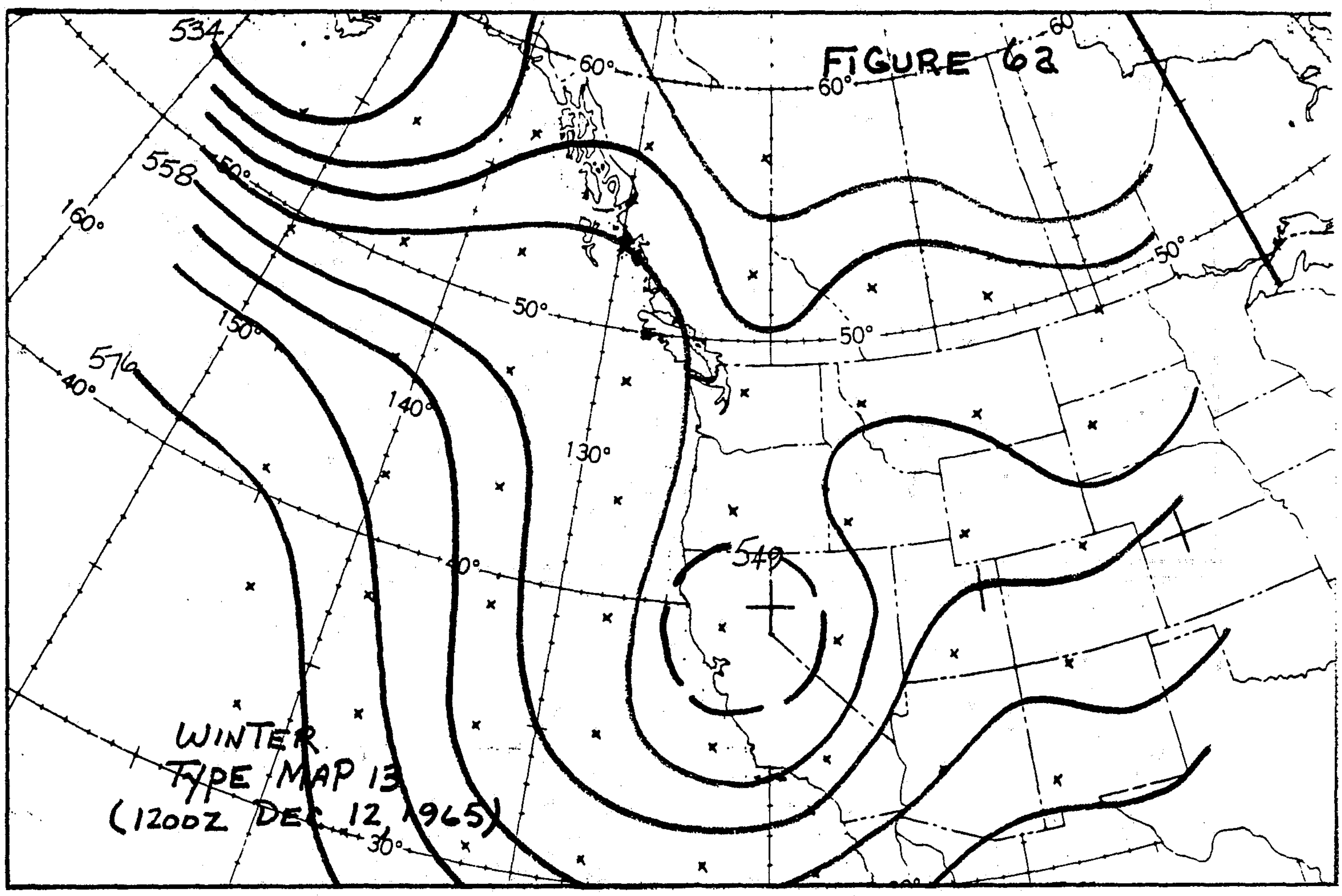


FIGURE 62
534
558
576
540
60°
50°
40°
30°
160°
150°
140°
130°
WINTER
TYPE MAP 13
(1200Z DEC 12, 1965)

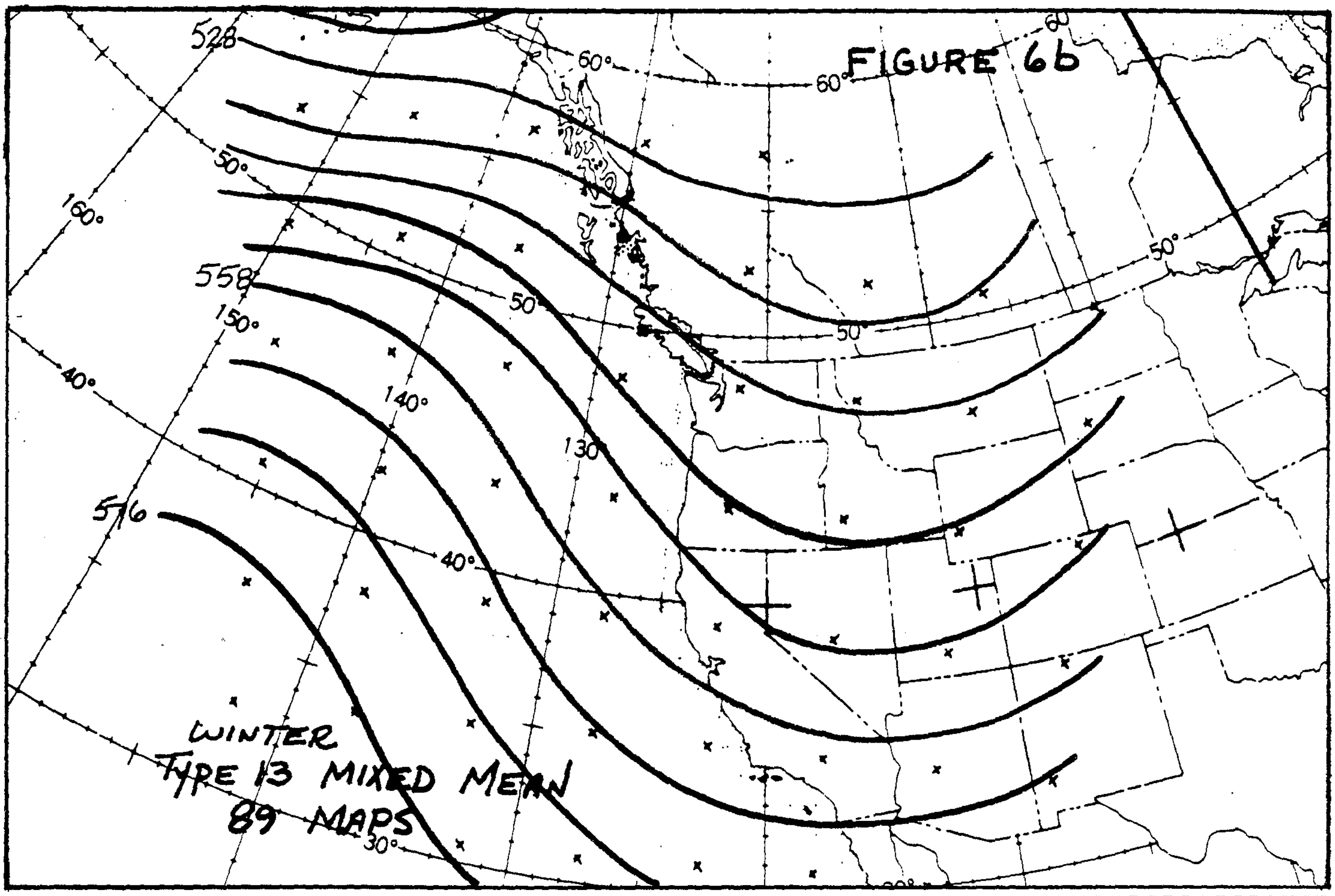


FIGURE 6b
528
558
576
60°
50°
40°
30°
160°
150°
140°
130°
WINTER
TYPE 13 MIXED MEAN
89 MAPS

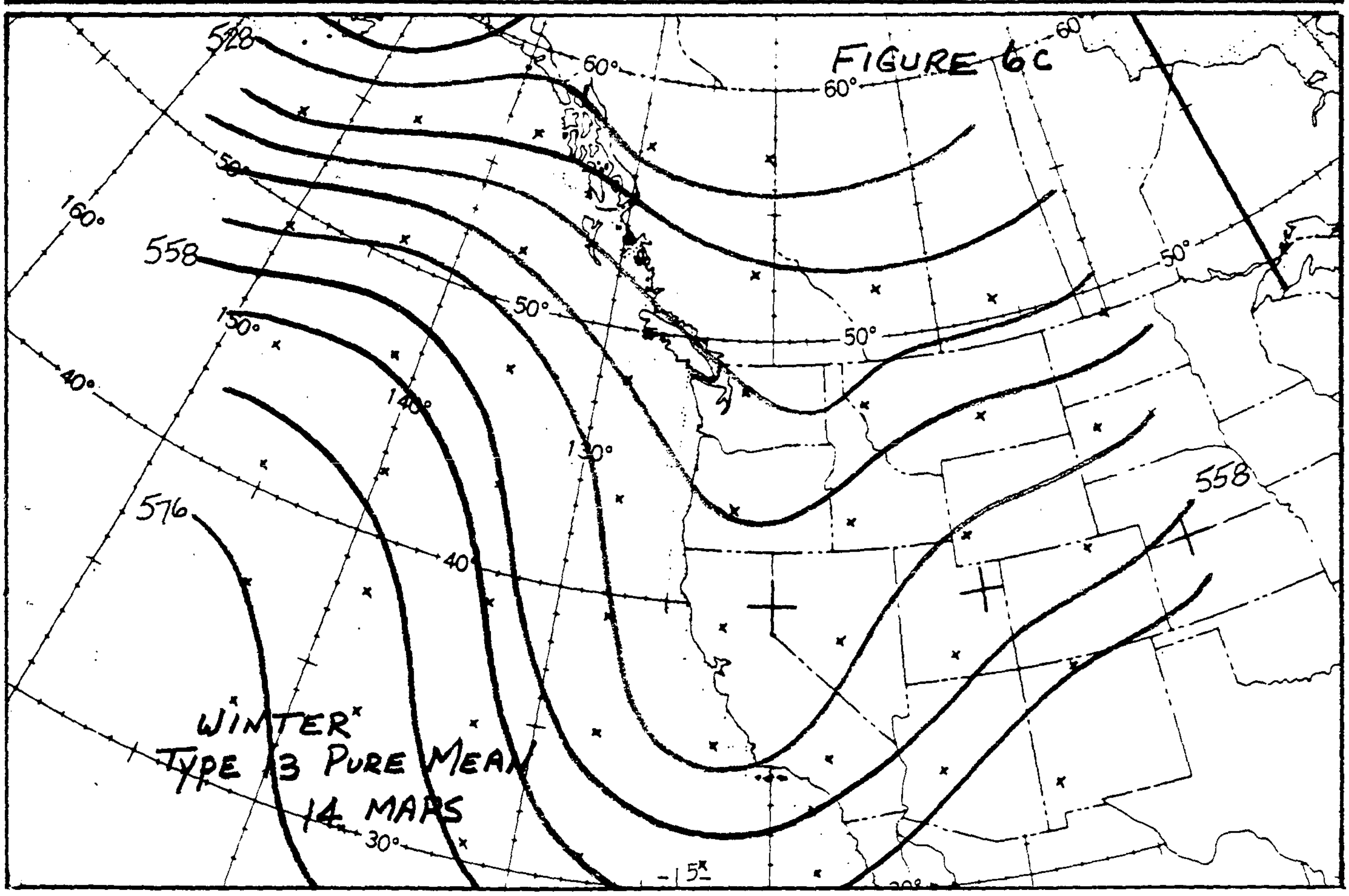
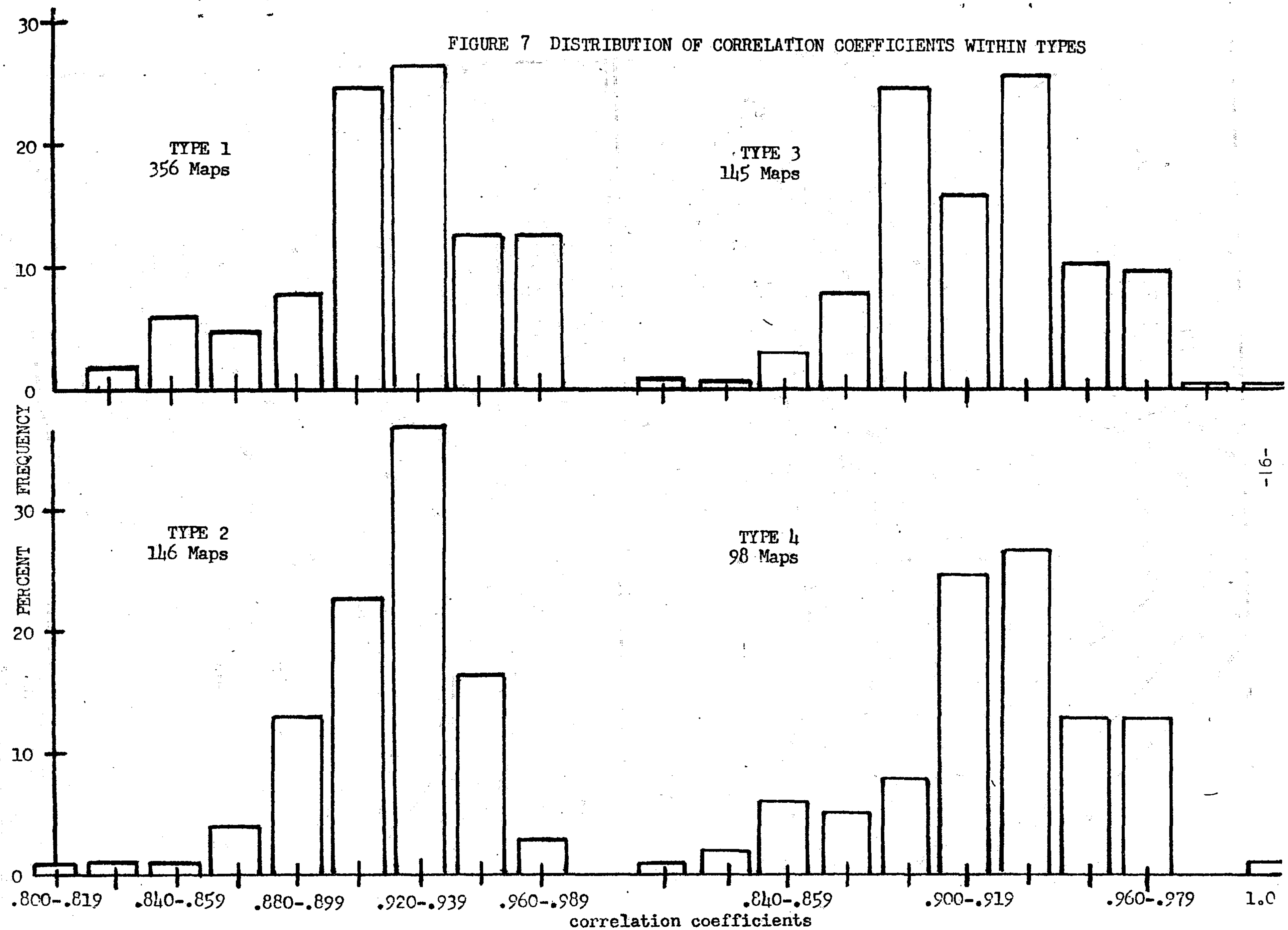
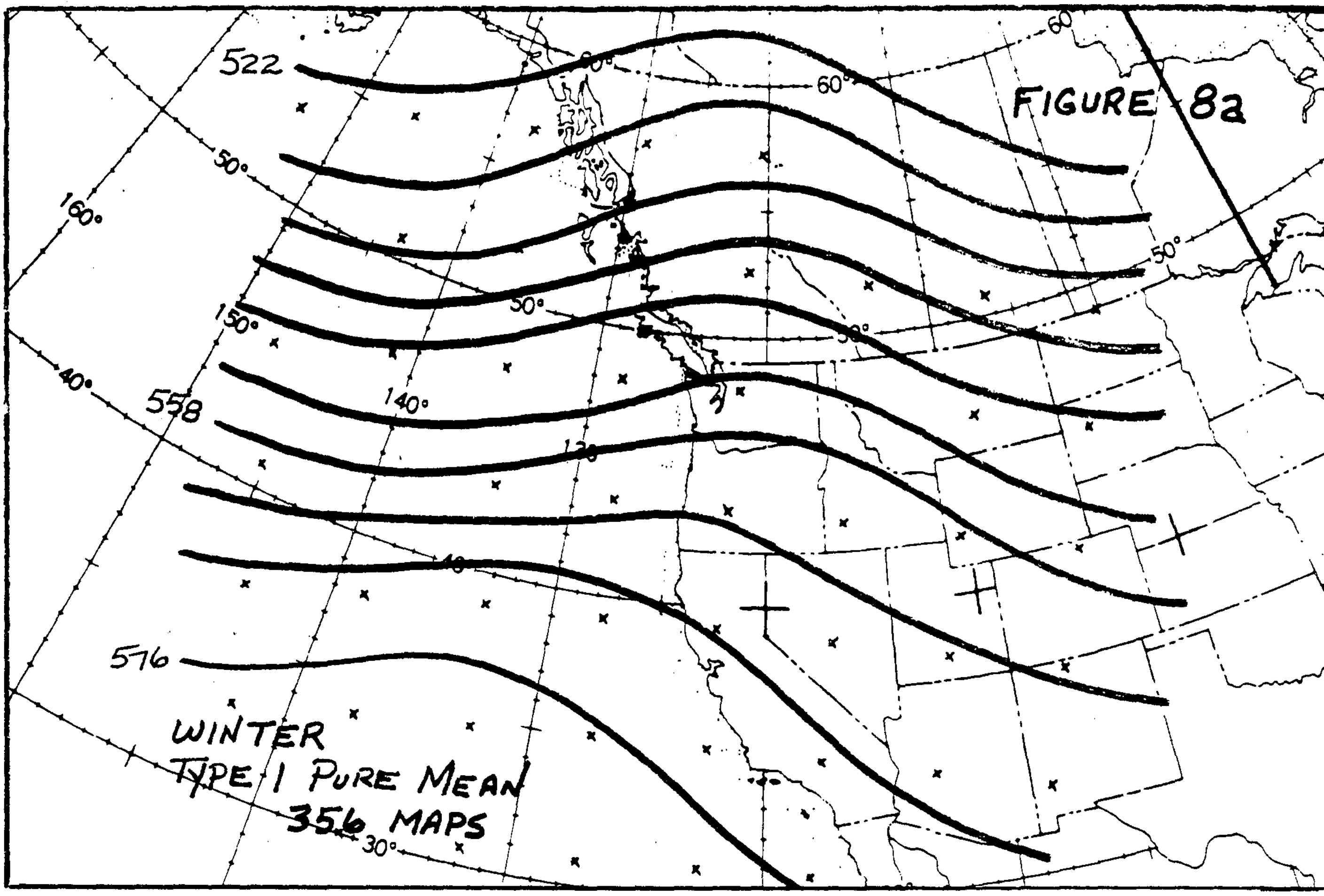
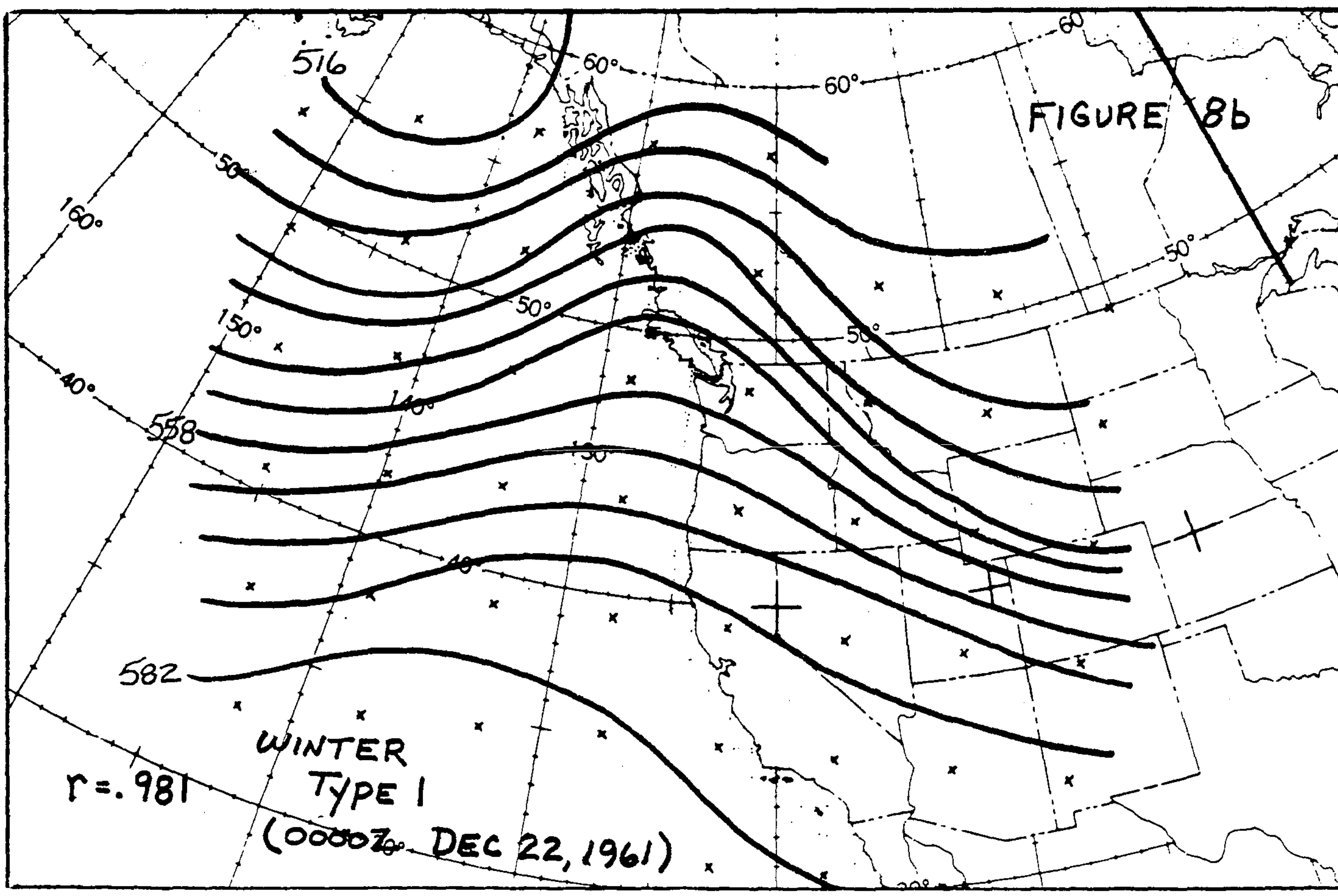


FIGURE 6c
528
558
576
558
60°
50°
40°
30°
160°
150°
140°
130°
WINTER
TYPE 13 PURE MEAN
14 MAPS

FIGURE 7 DISTRIBUTION OF CORRELATION COEFFICIENTS WITHIN TYPES




522
558
576
50°
60°
160°
150°
140°
130°
40°
30°
FIGURE 8a
WINTER
TYPE I PURE MEAN
356 MAPS


516
558
582
50°
60°
160°
150°
140°
130°
40°
FIGURE 8b
WINTER
TYPE I
(0000Z DEC 22, 1961)
r=.981

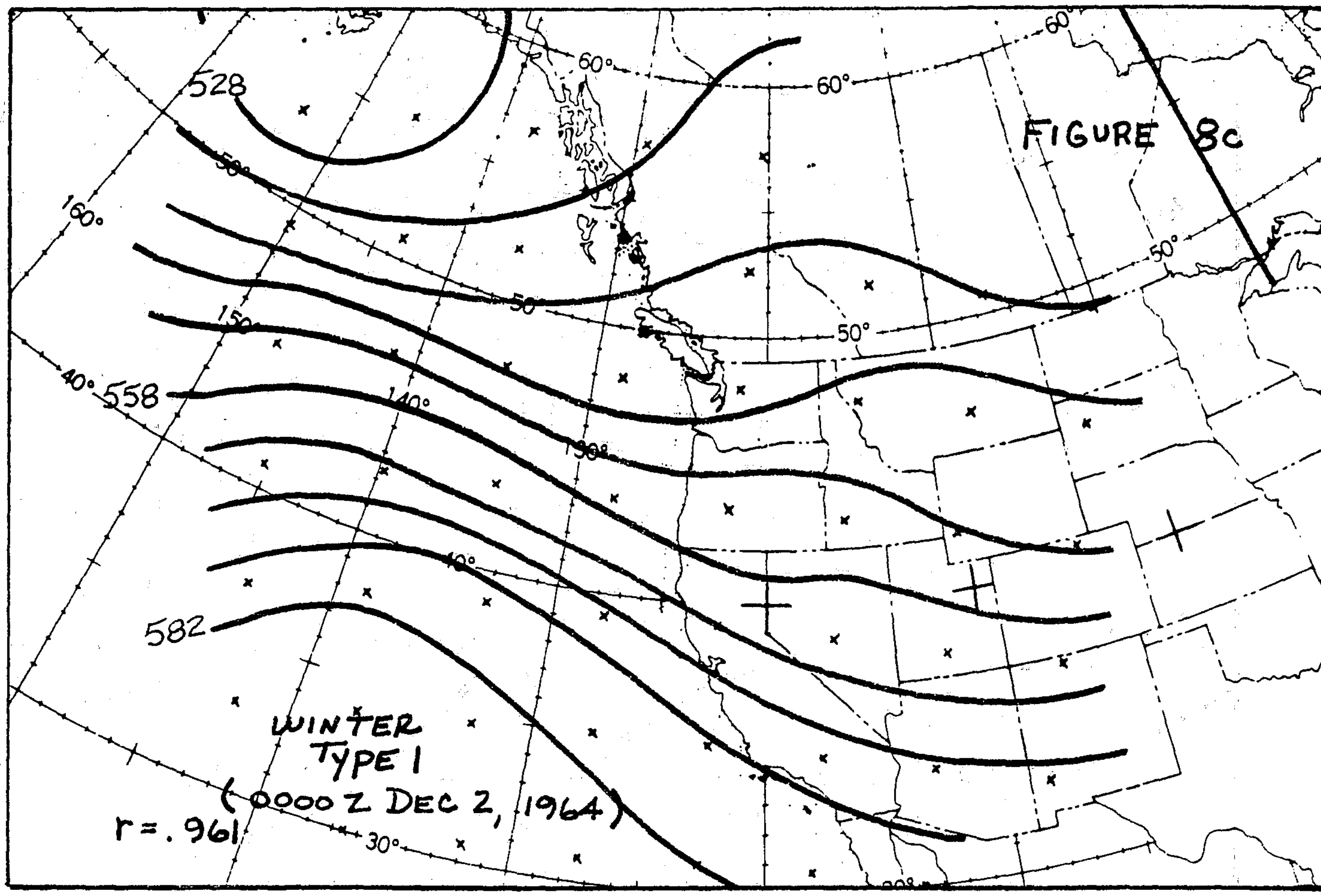


FIGURE 8c
528
558
582
WINTER
TYPE I
(0000 Z DEC 2, 1964)
r = .961

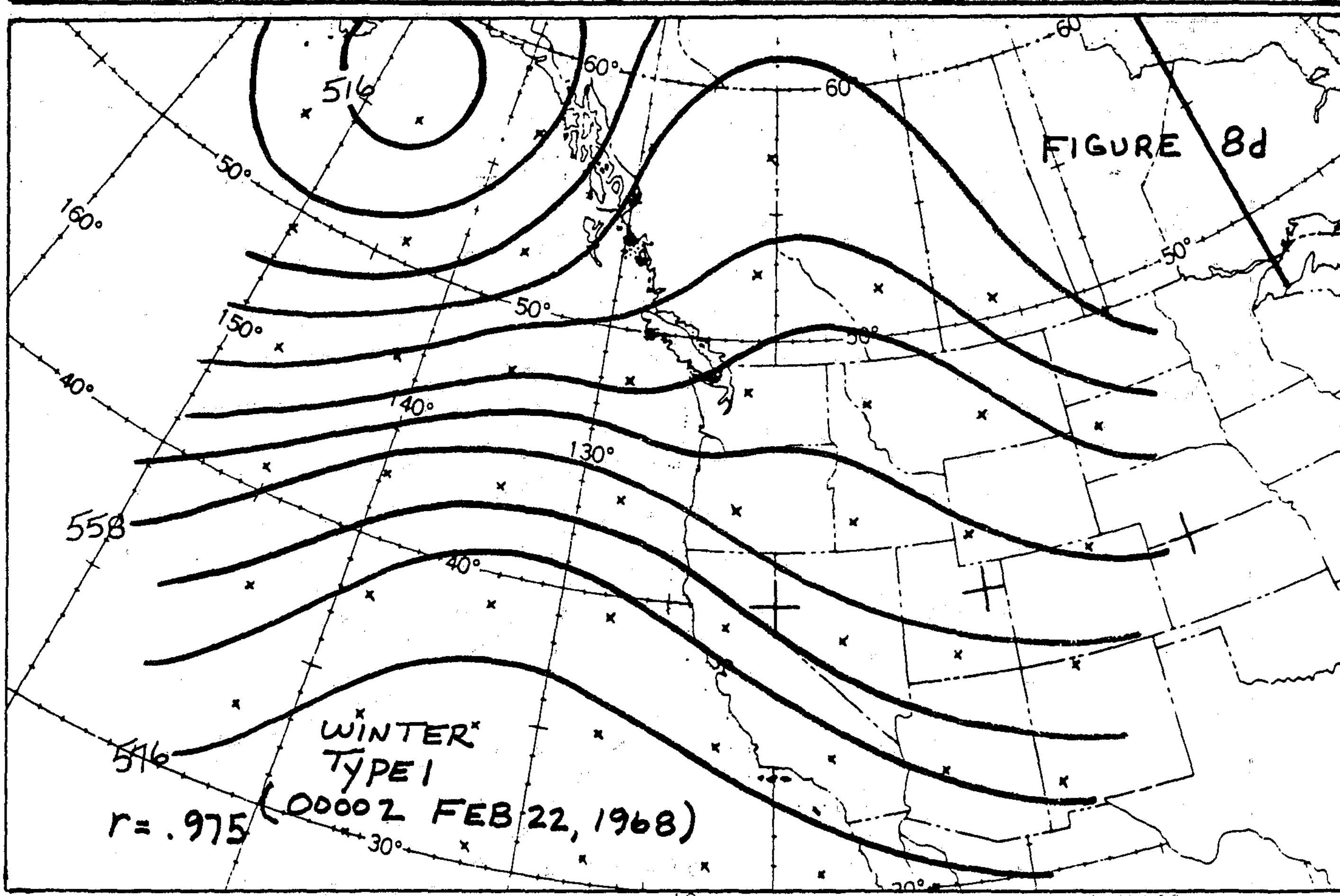


FIGURE 8d
516
558
516
WINTER
TYPE I
(0000 Z FEB 22, 1968)
r = .975

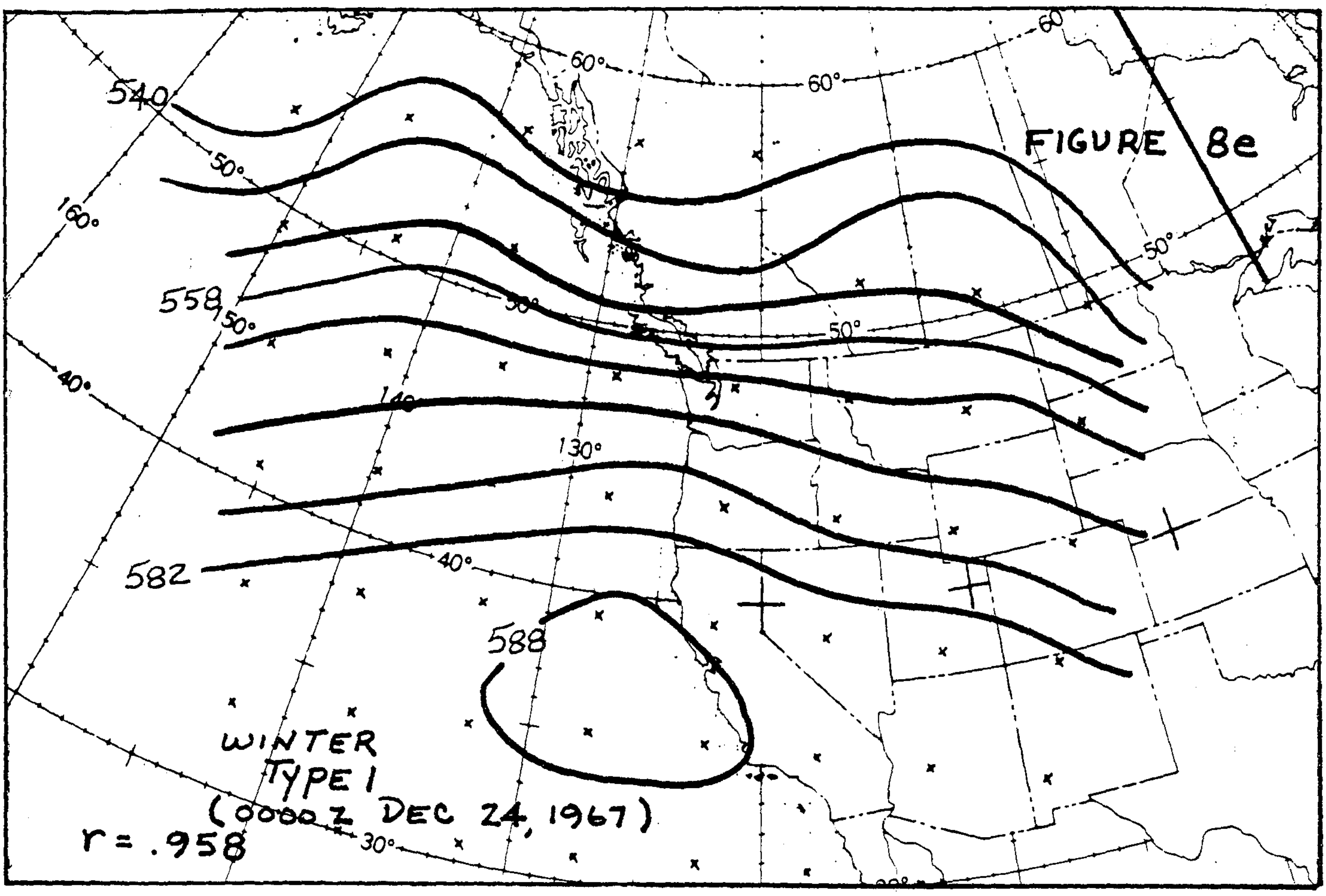


FIGURE 8e
540
558
582
588
WINTER
TYPE I
(0000 Z DEC 24, 1967)
r = .958

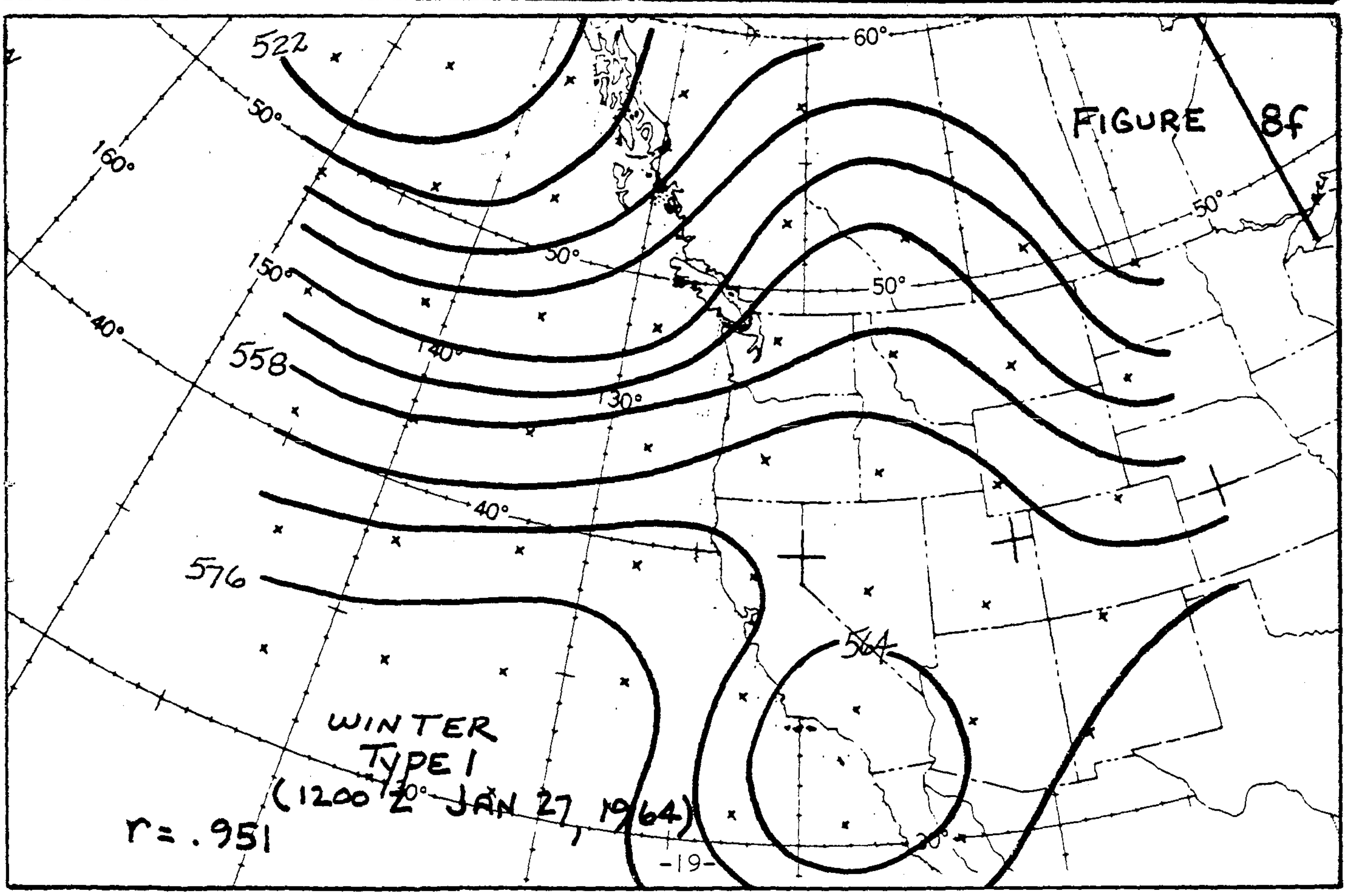


FIGURE 8f
522
558
576
564
WINTER
TYPE I
(1200 Z JAN 27, 1964)
r = .951

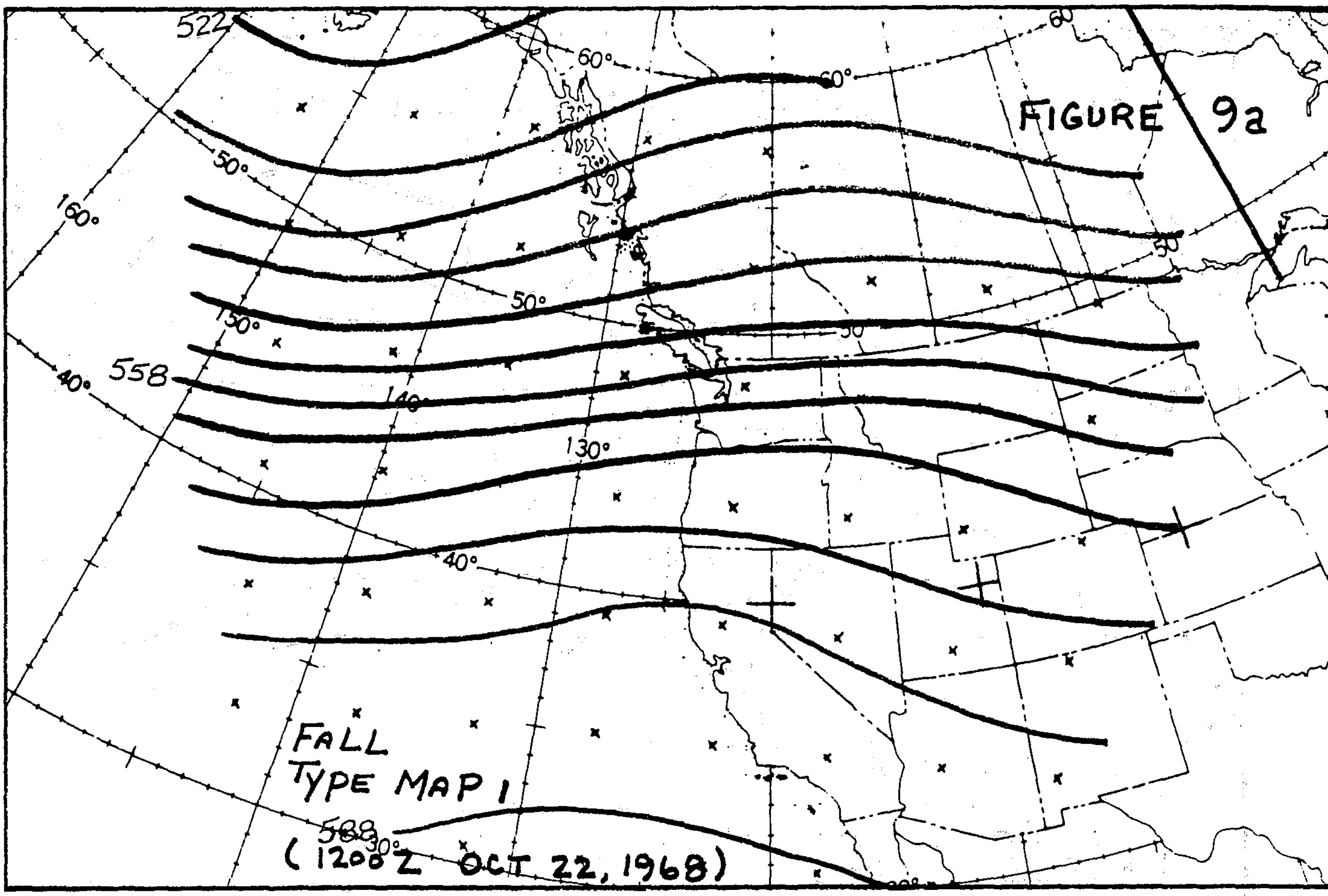


FIGURE 9a
522
558
588
60°
50°
40°
30°
160°
150°
140
130°
FALL
TYPE MAP 1
(1200Z OCT 22, 1968)

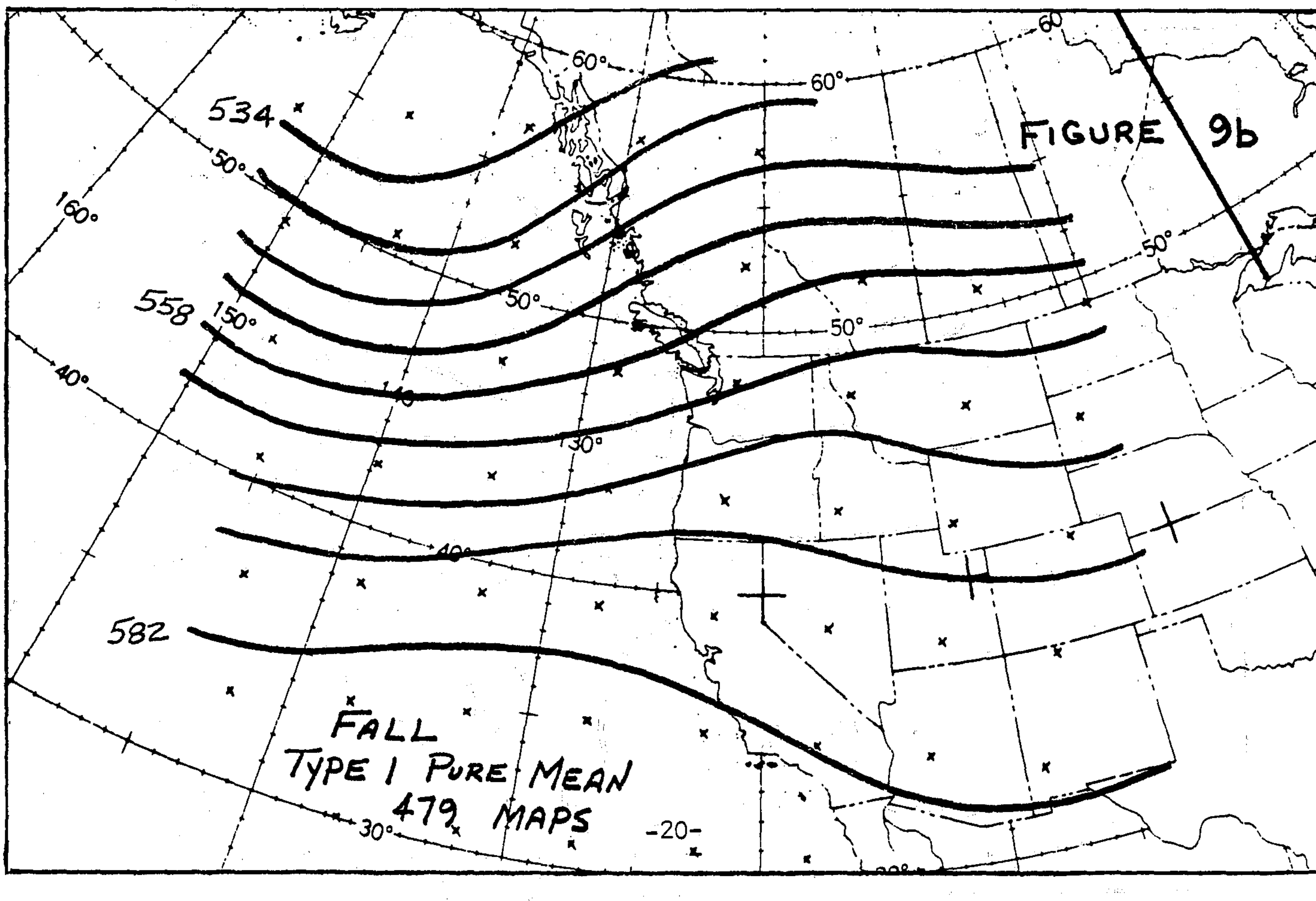


FIGURE 9b
534
558
582
60°
50°
40°
30°
160°
150°
140
130°
FALL
TYPE 1 PURE MEAN
479 MAPS

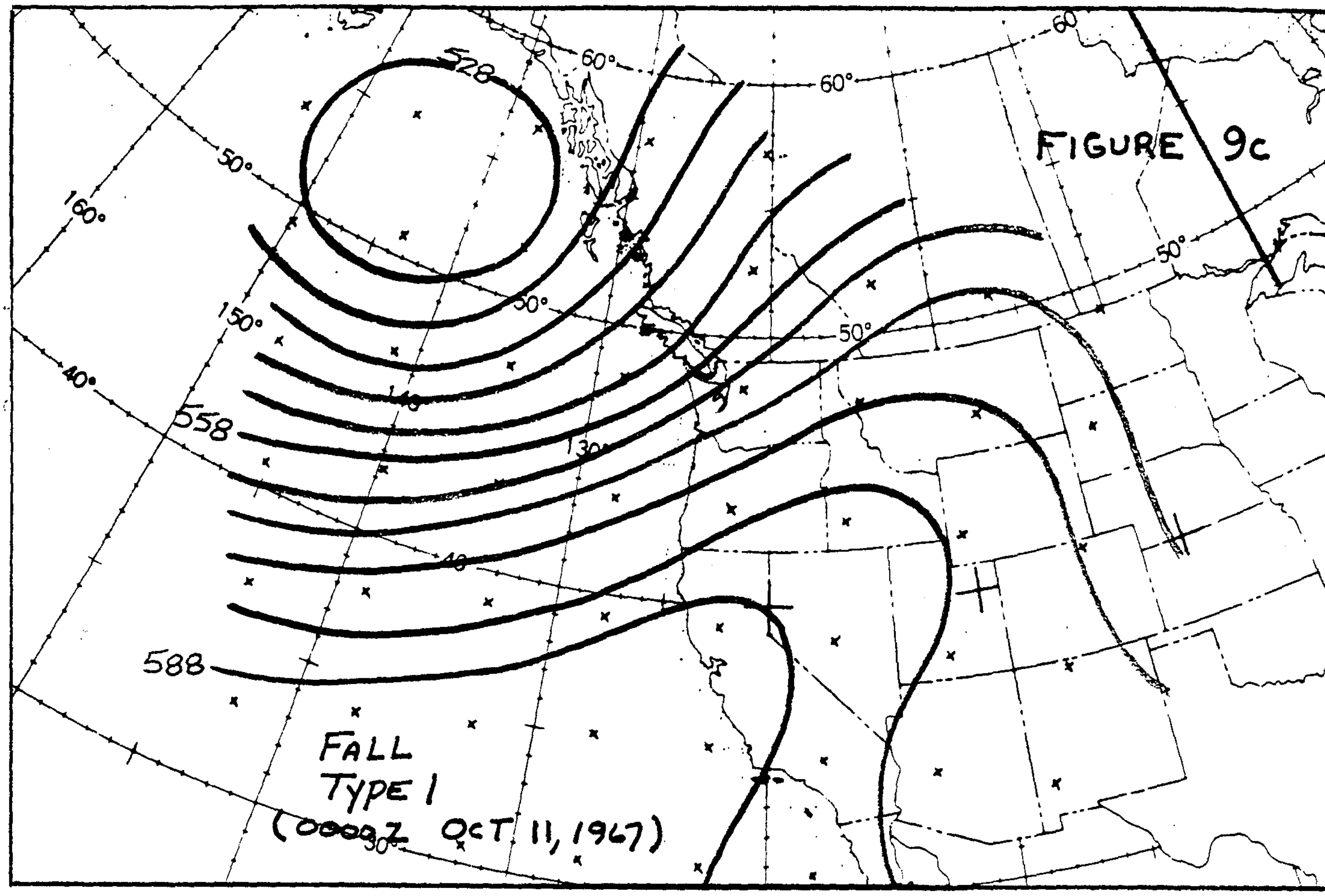


FIGURE 9c
FALL
Type I
(0000Z OCT 11, 1967)
528
558
588
60°
50°
40°
30°
160°
150°
140
130°

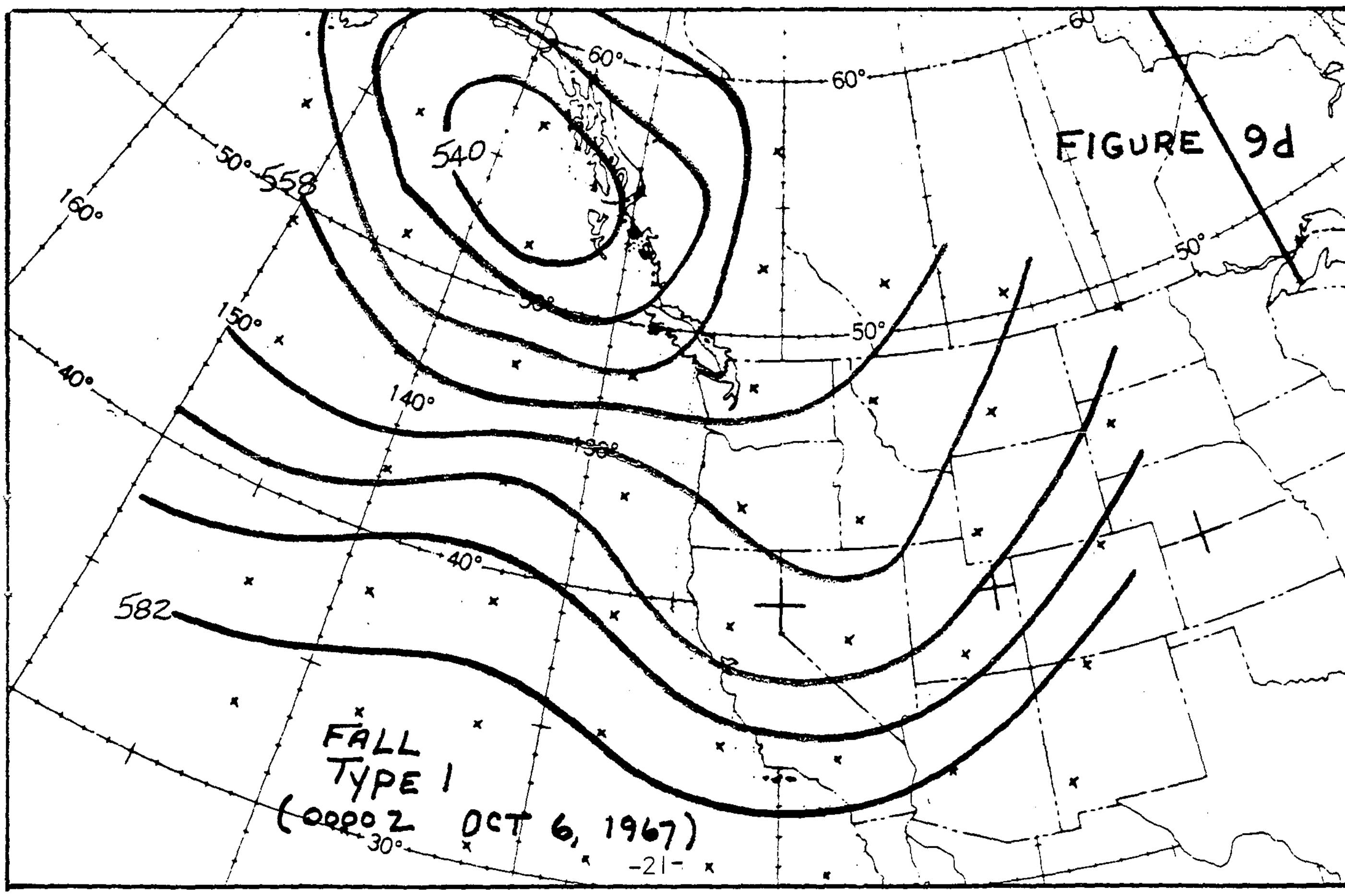


FIGURE 9d
FALL
Type I
(0000Z OCT 6, 1967)
540
558
582
60°
50°
40°
30°
160°
150°
140°

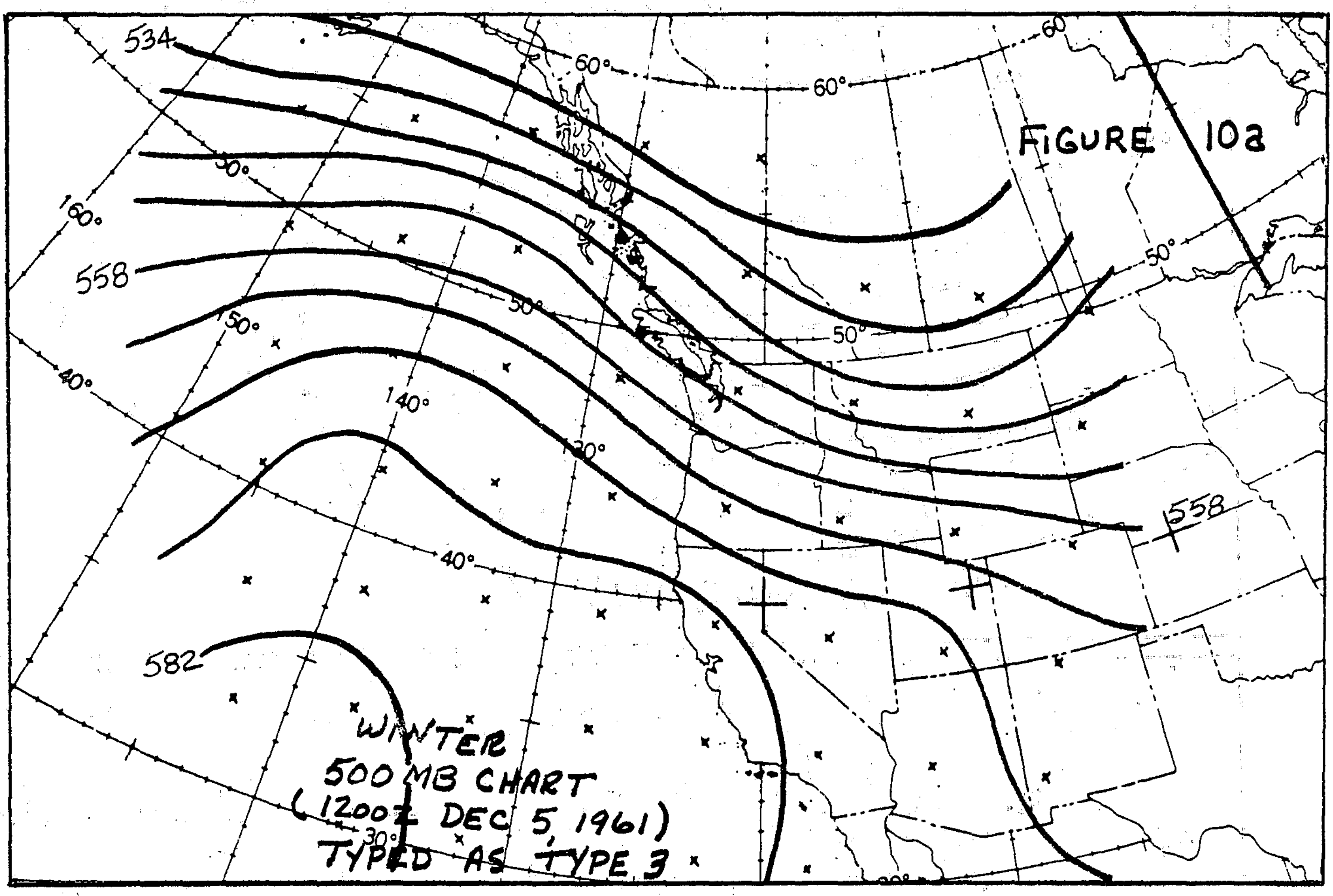


FIGURE 10a
534
558
558
582
60°
50°
40°
30°
160°
150°
140°
WINTER
500 MB CHART
(1200Z DEC 5, 1961)
TYPED AS TYPE 3

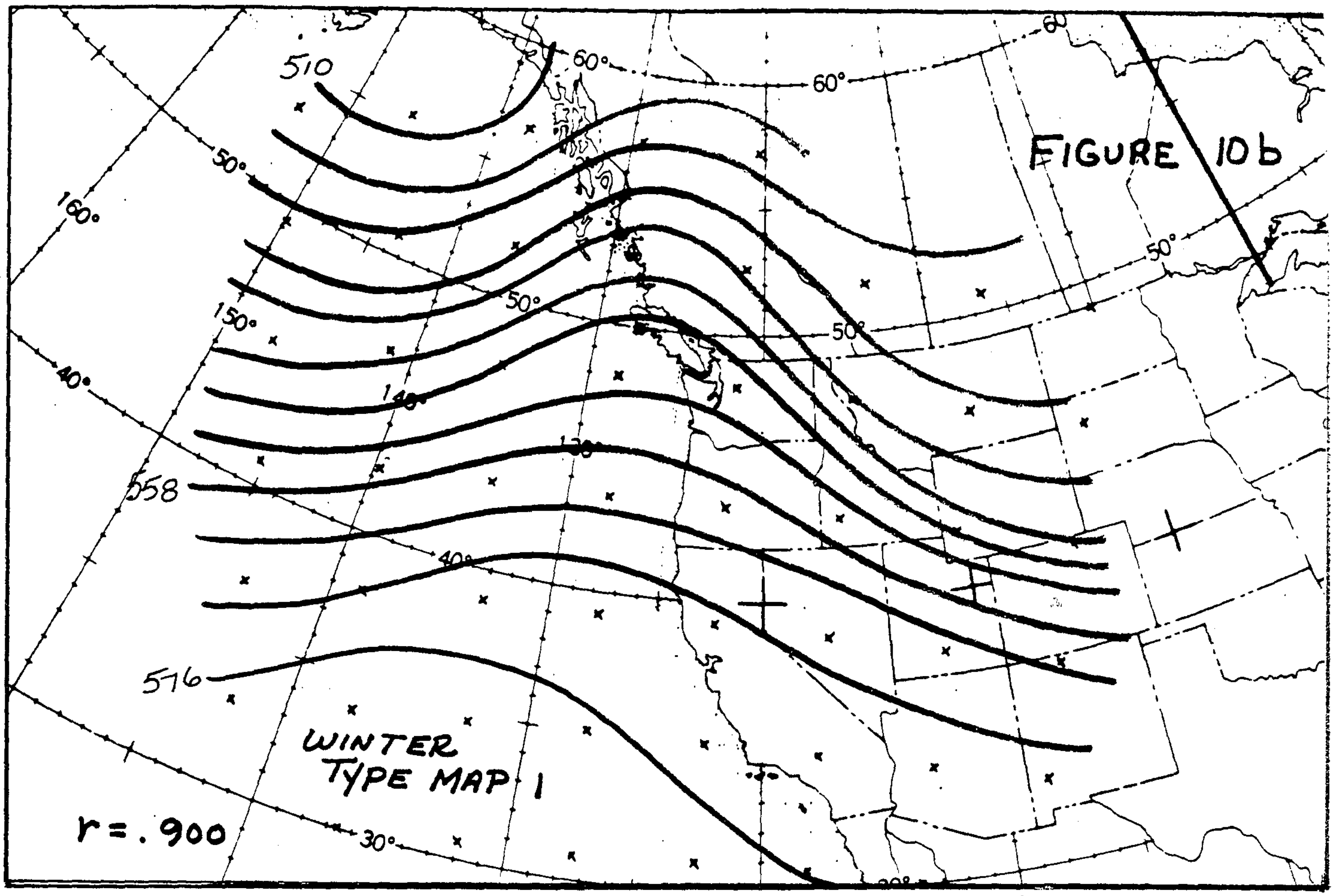


FIGURE 10b
510
516
558
60°
50°
40°
30°
160°
150°
140°
130°
WINTER
TYPE MAP 1
r = .900

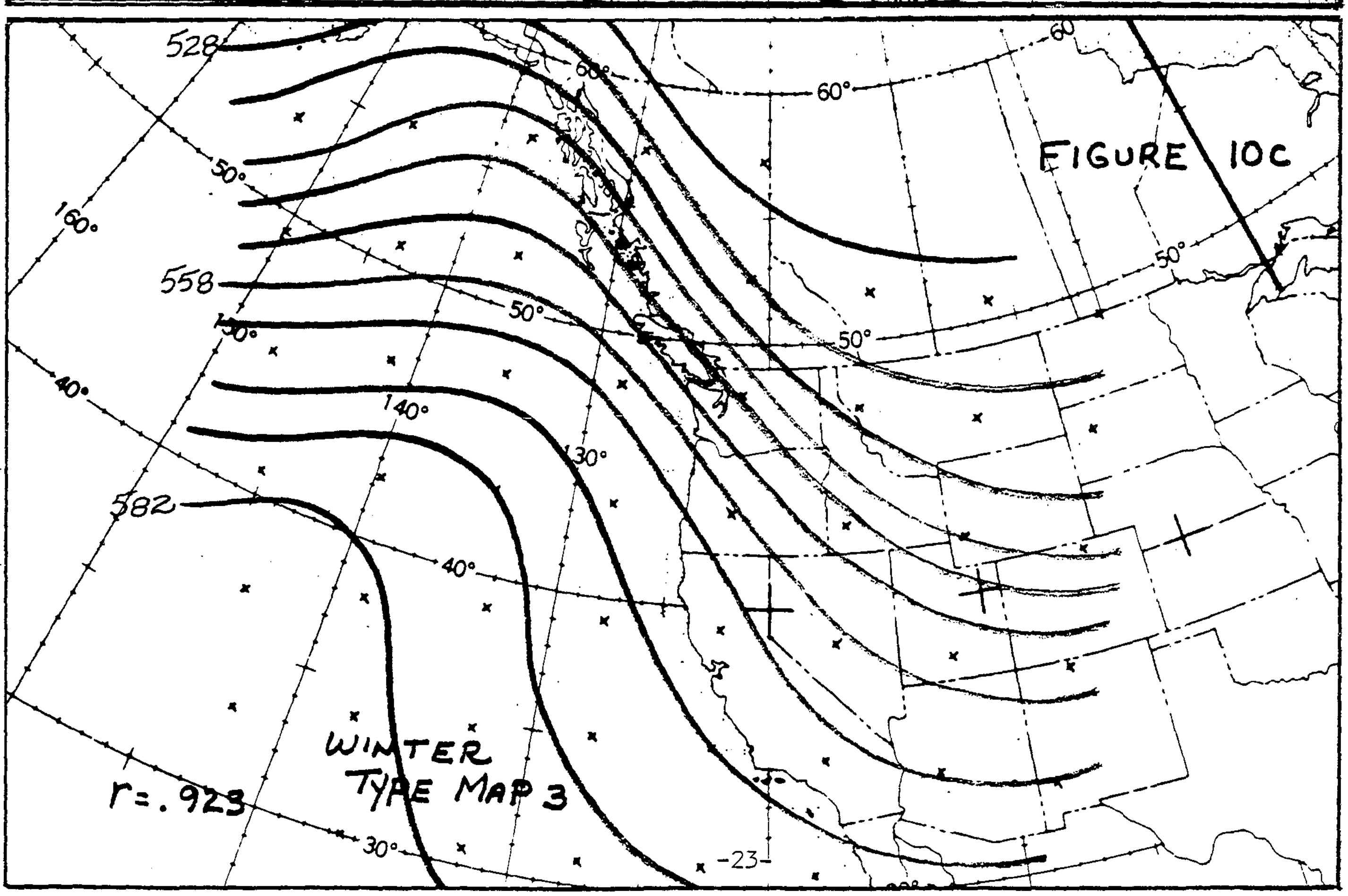


FIGURE 10c
528
558
582
60°
50°
40°
30°
160°
150°
140°
130°
-23-
WINTER
TYPE MAP 3
r = .923

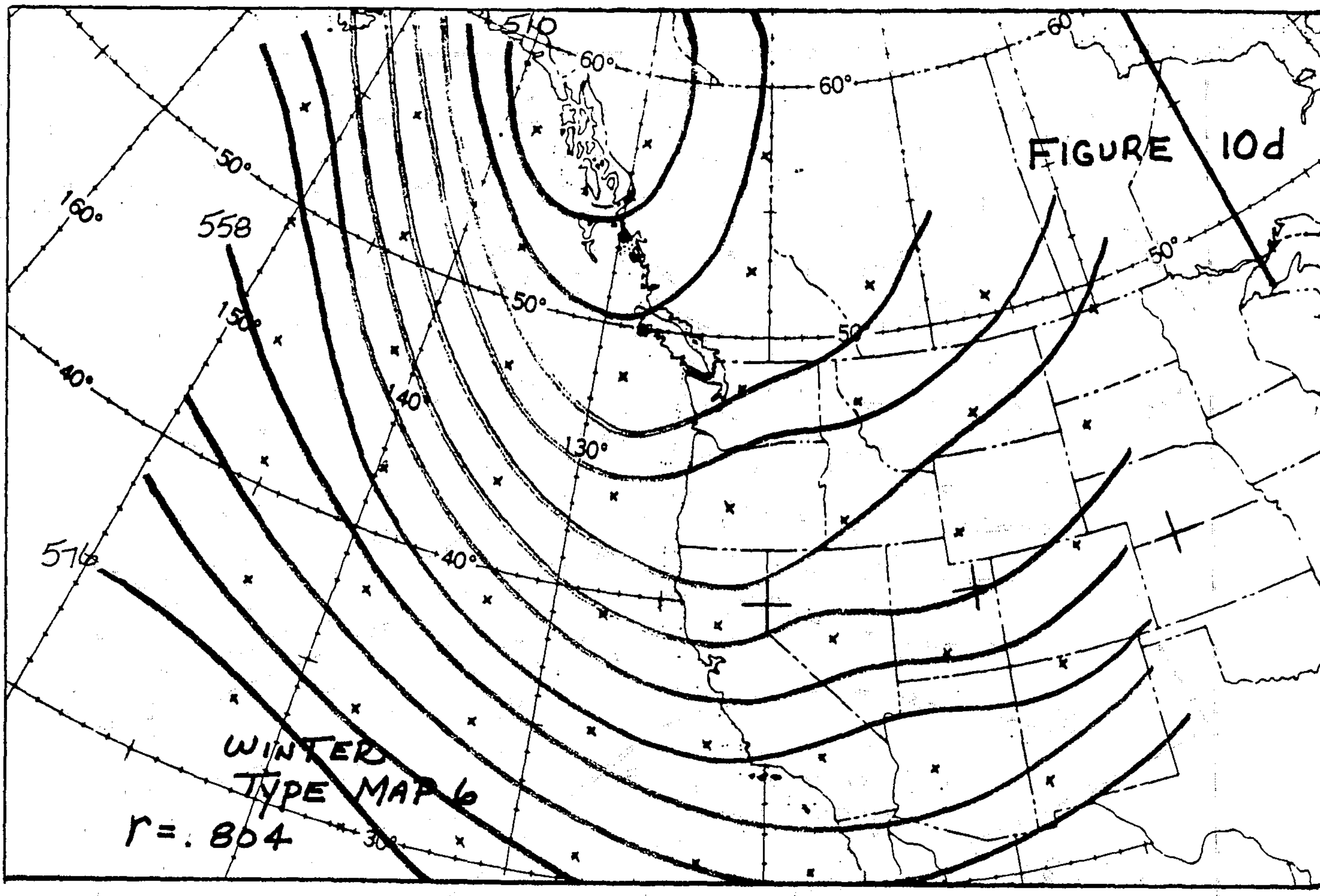


FIGURE 10d
510
558
576
WINTER
TYPE MAP 6
r=.804

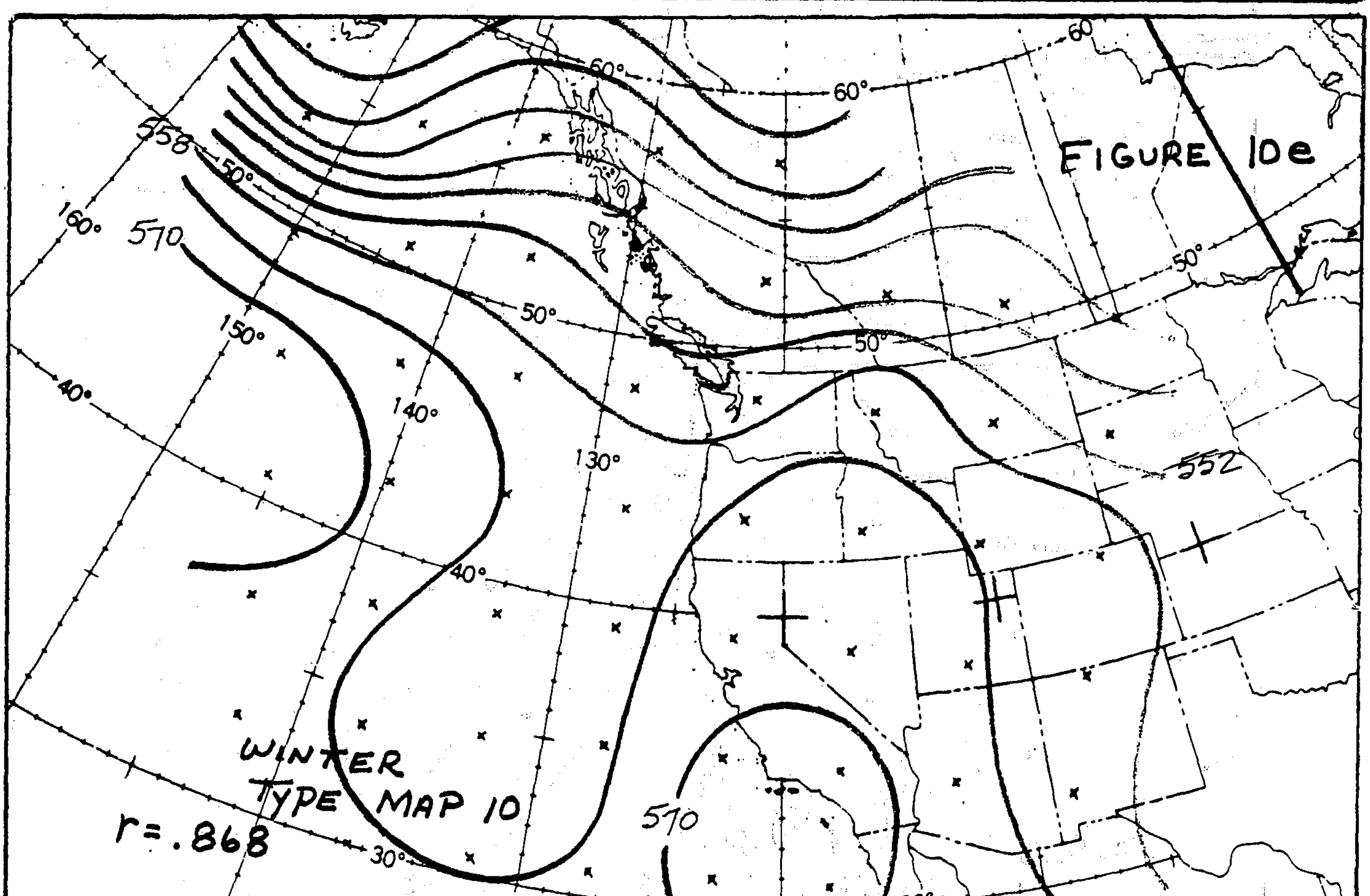


FIGURE 10e
558
570
552
510
WINTER
TYPE MAP 10
r=.868

FIGURE 11

DISTRIBUTION OF CLIMATOLOGICAL STATIONS

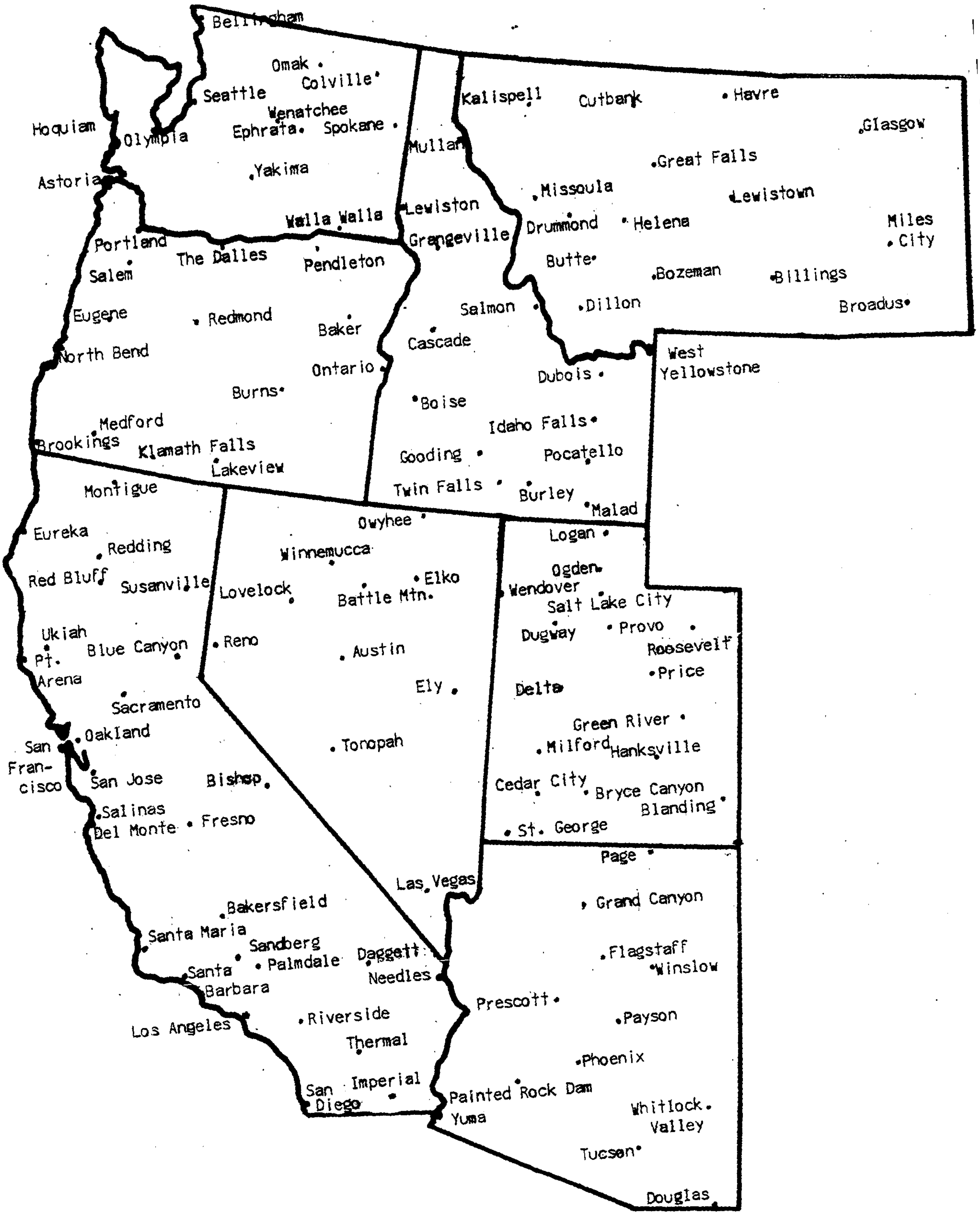
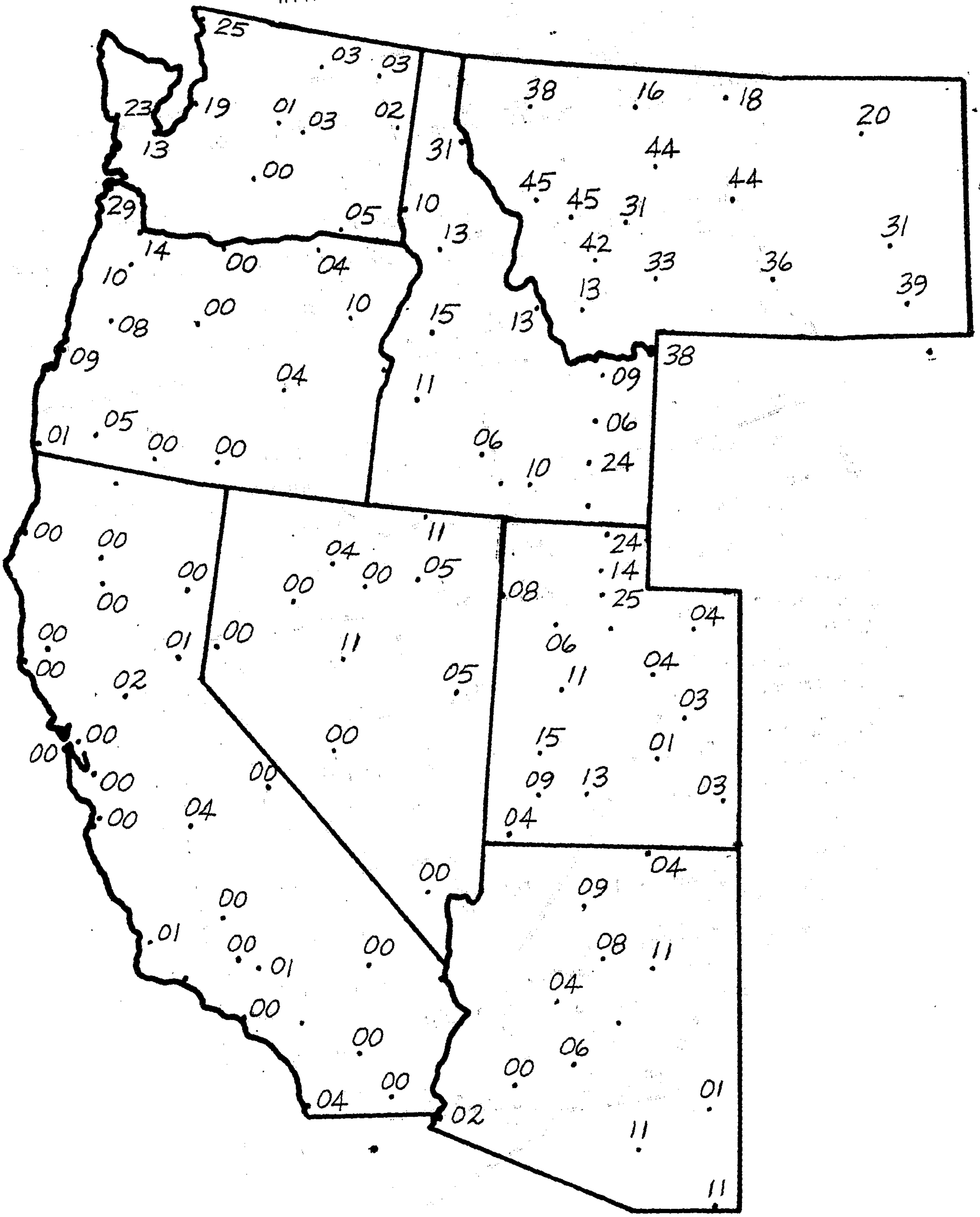


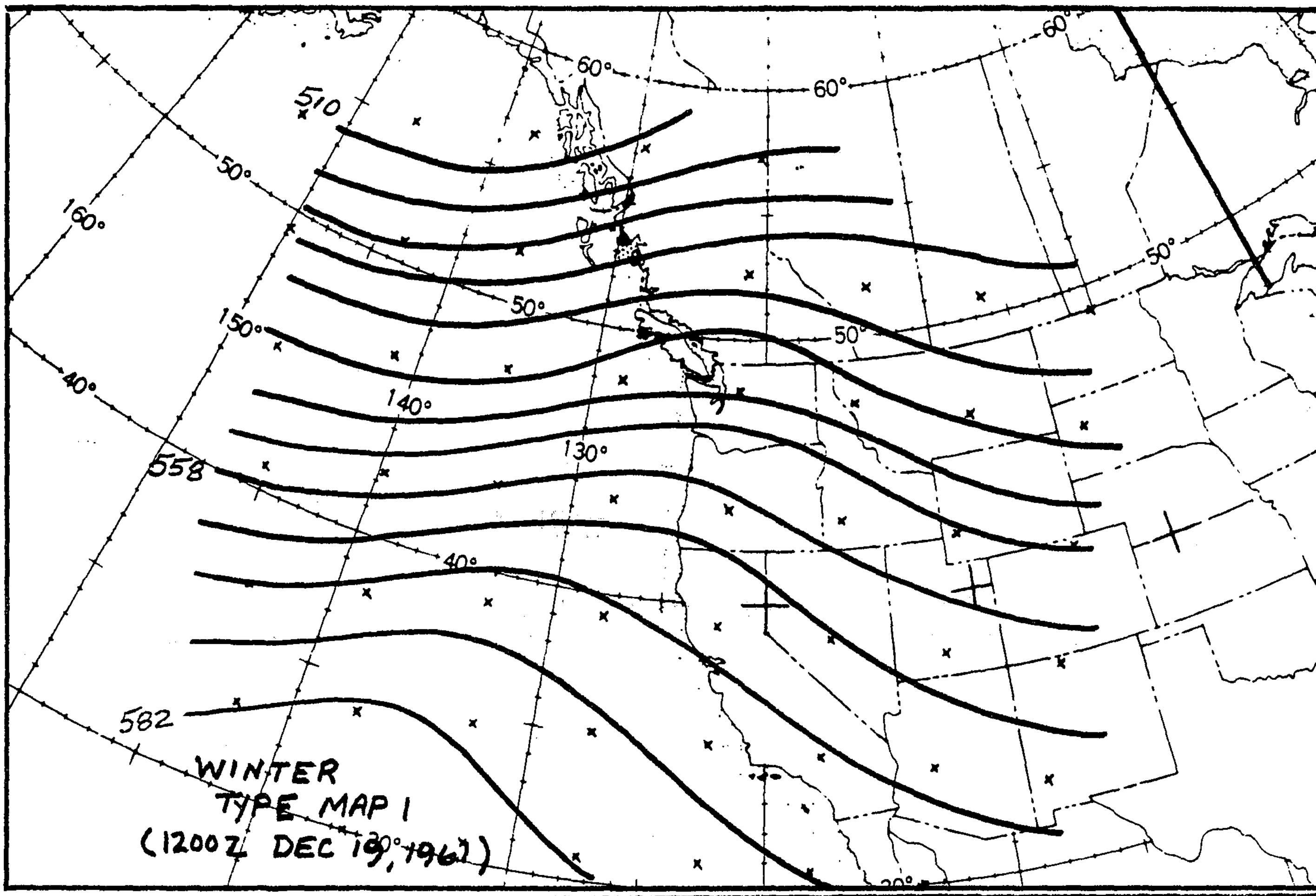
FIGURE 12

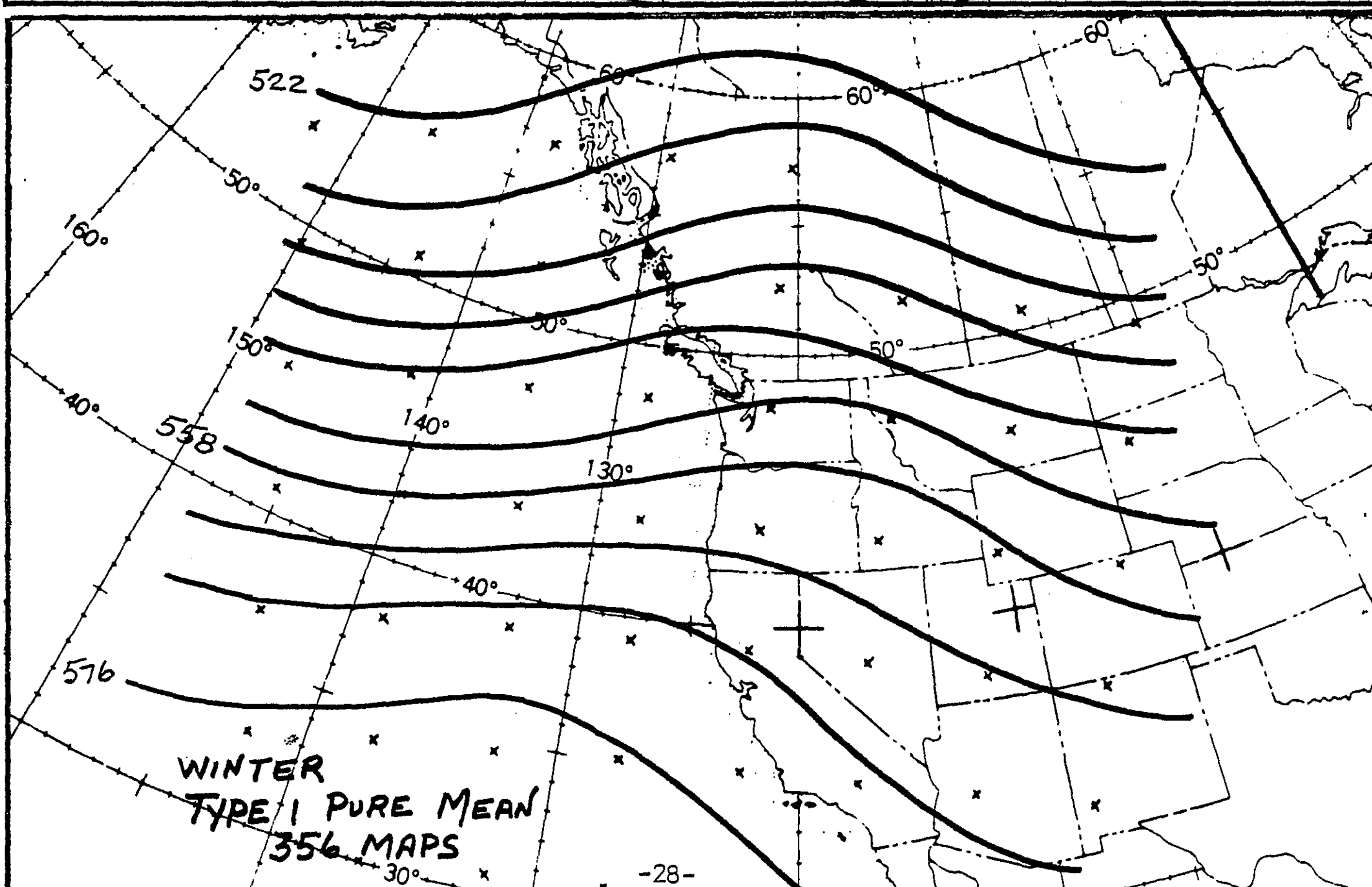
PERCENT FREQUENCY OF PRECIPITATION OCCURRENCE
WITH 500-MB WINTER TYPE 8



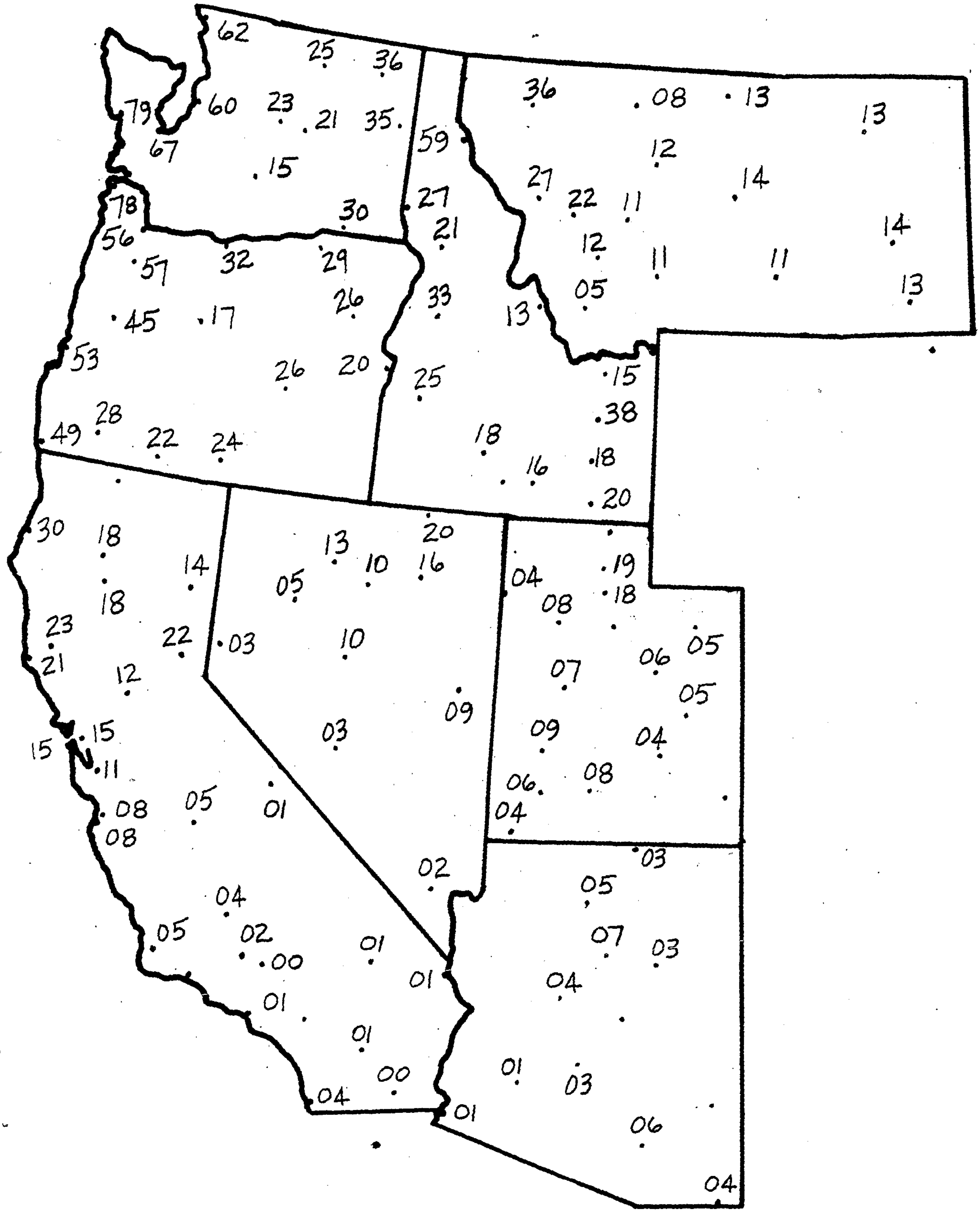
APPENDIX A

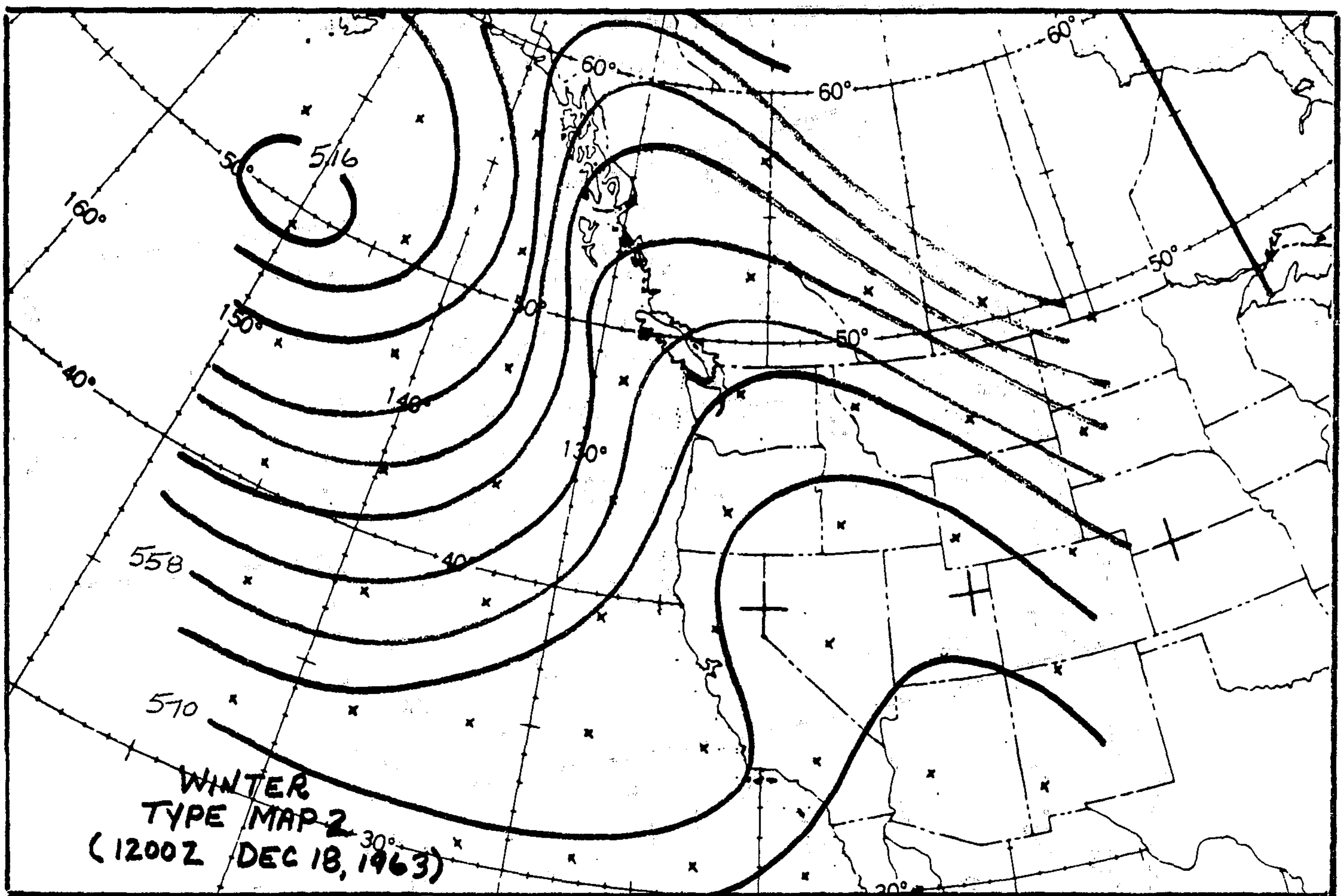
Winter Types and Associated Precipitation Climatologies

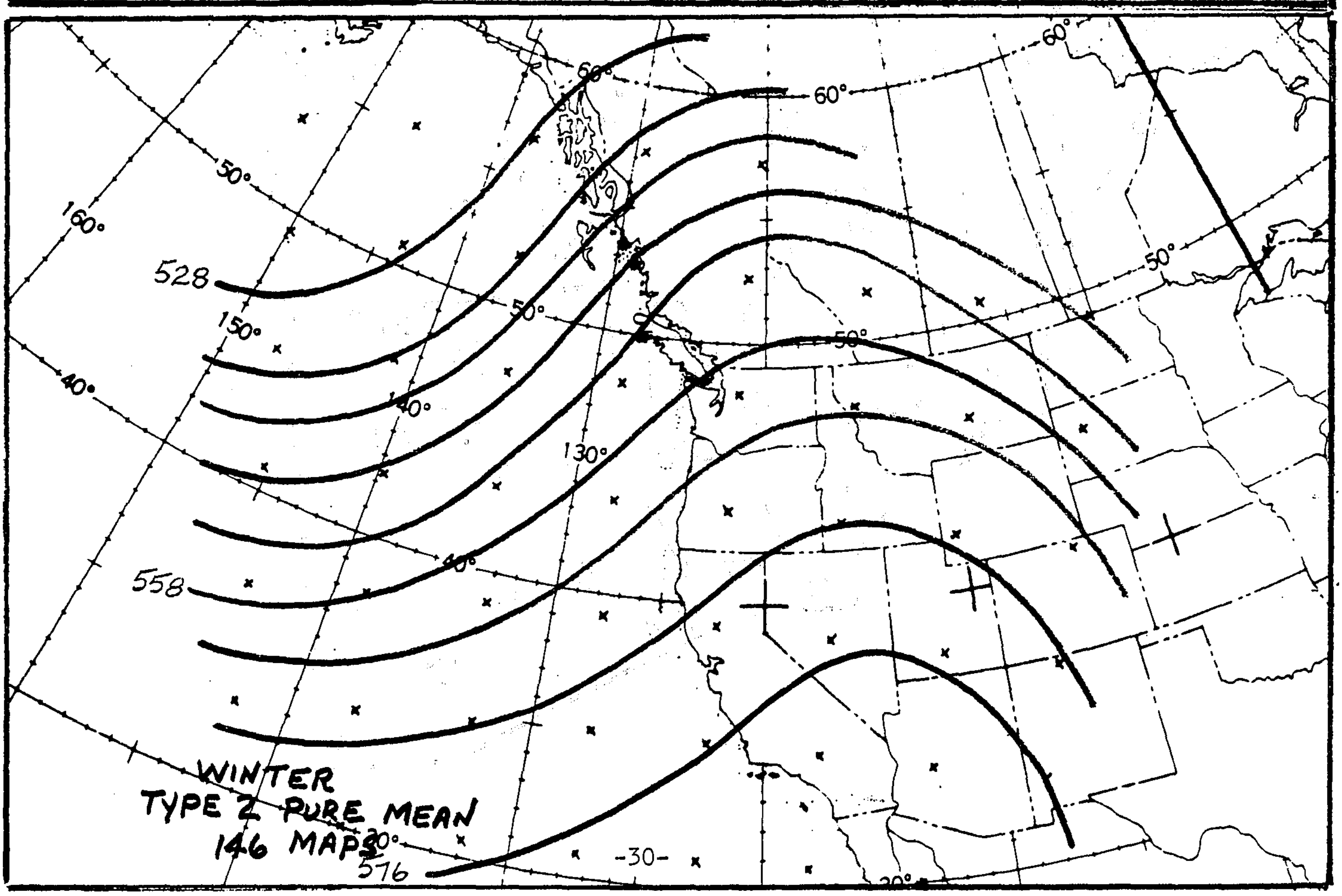

510
558
582
60°
50°
40°
160°
150°
140°
130°
WINTER
TYPE MAP I
(1200Z DEC 19, 1967)


522
558
576
60°
50°
40°
30°
160°
150°
140°
130°
WINTER
TYPE I PURE MEAN
356 MAPS

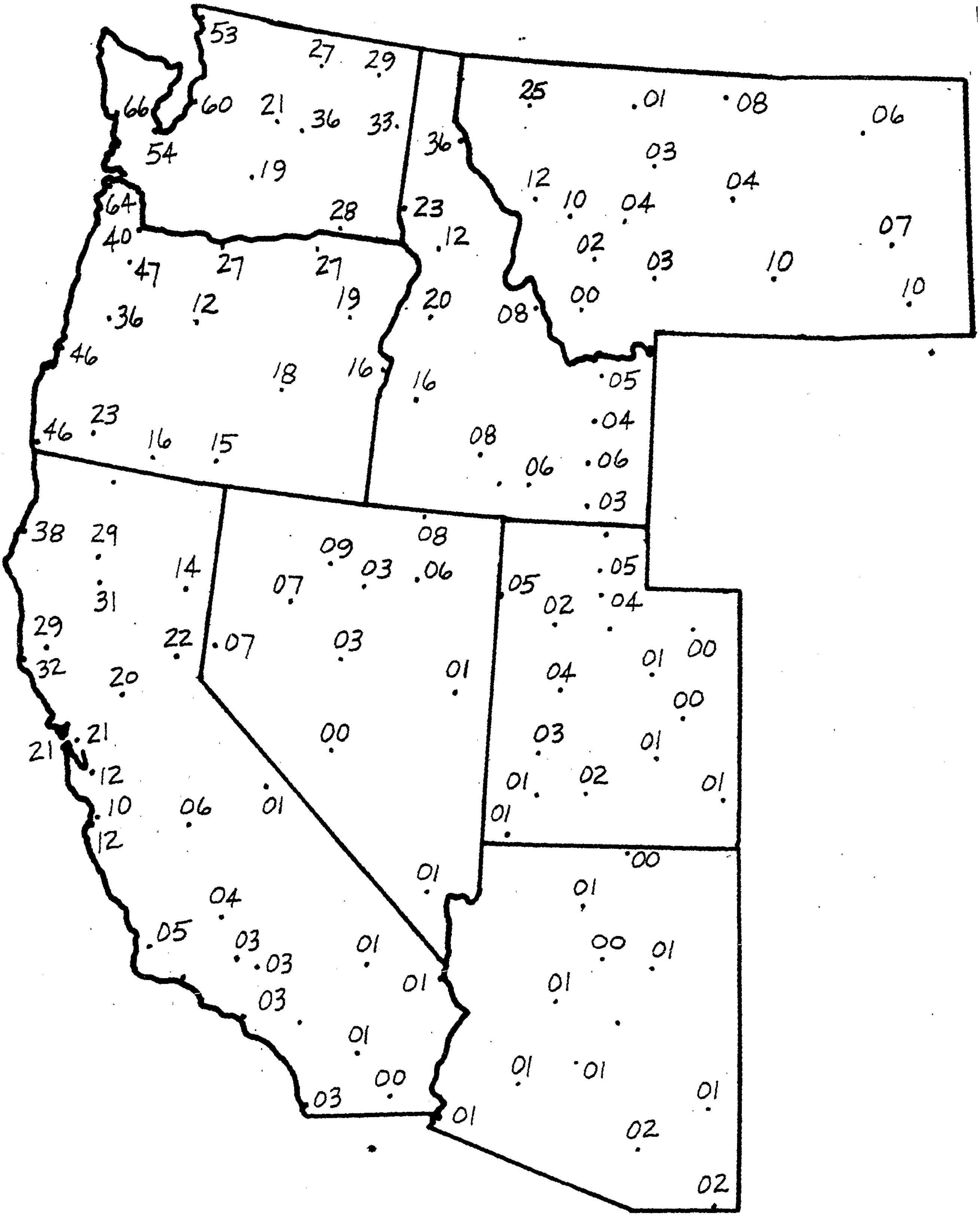
PERCENT FREQUENCY OF PRECIPITATION OCCURRENCE WITH 500-MB WINTER TYPE 1

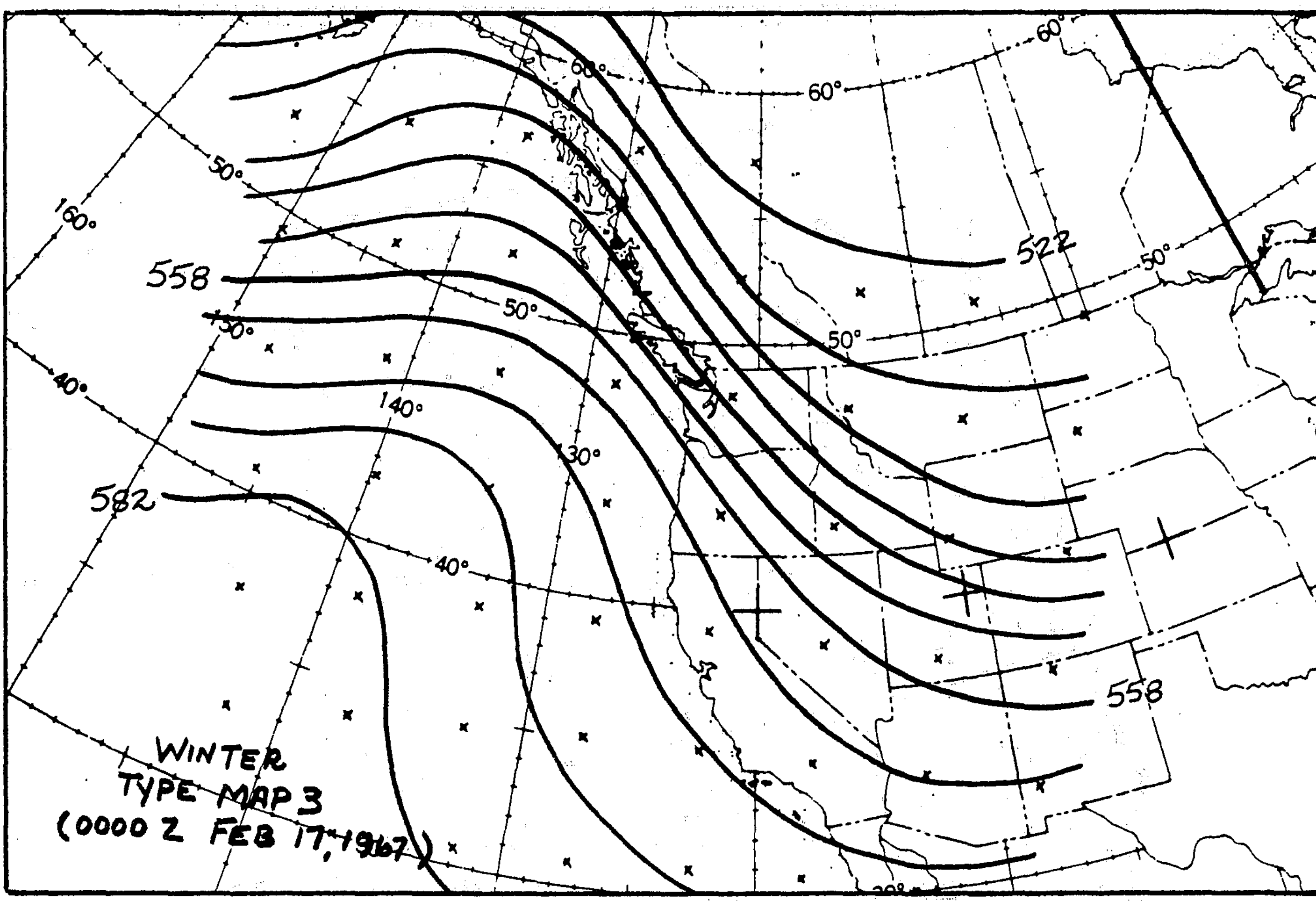


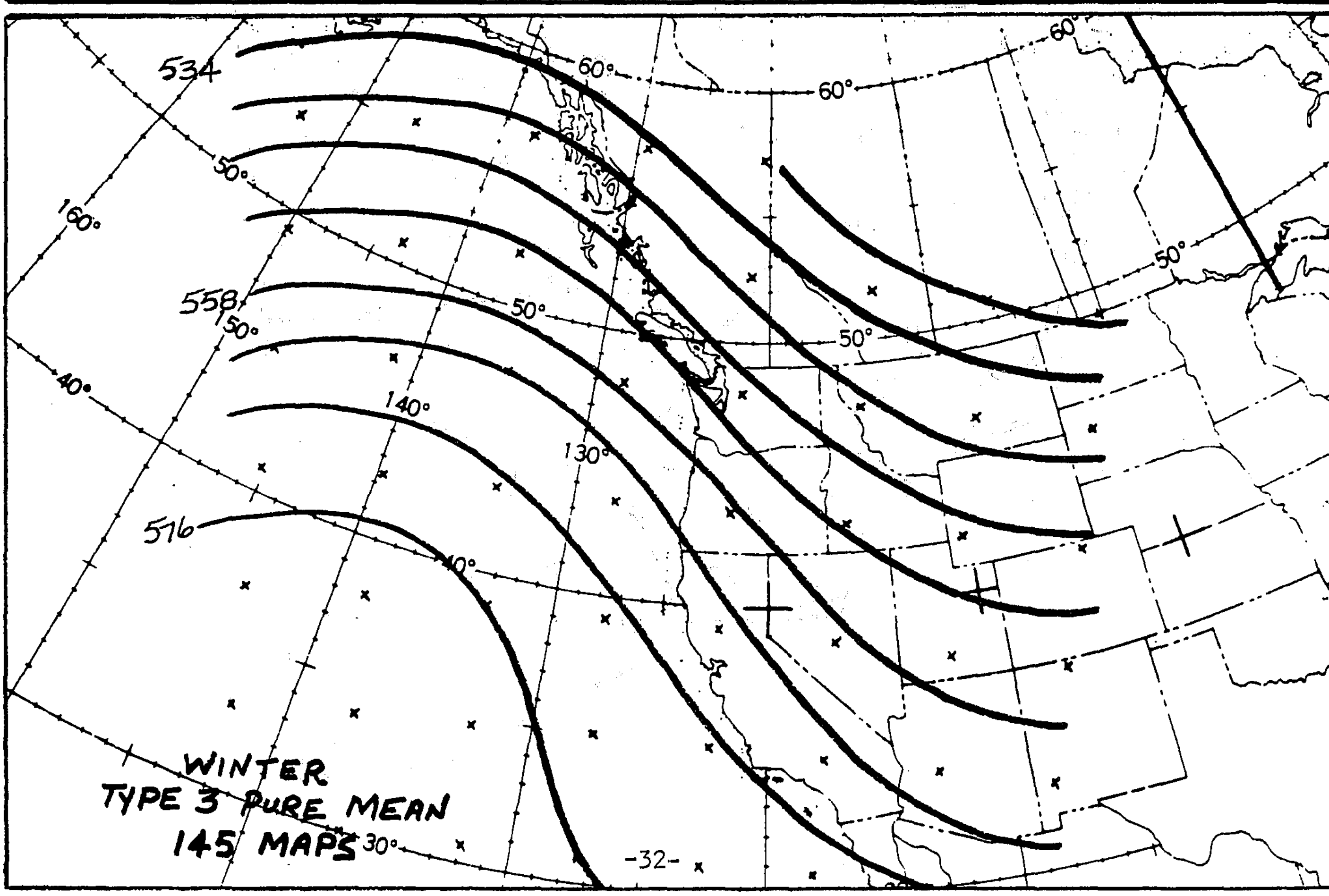

516
558
570
60°
50°
40°
30°
160°
150°
140°
130°
WINTER
TYPE MAP 2
(1200Z DEC 18, 1963)


528
558
576
-30-
60°
50°
40°
30°
160°
150°
140°
130°
WINTER
TYPE 2 PURE MEAN
146 MAPS

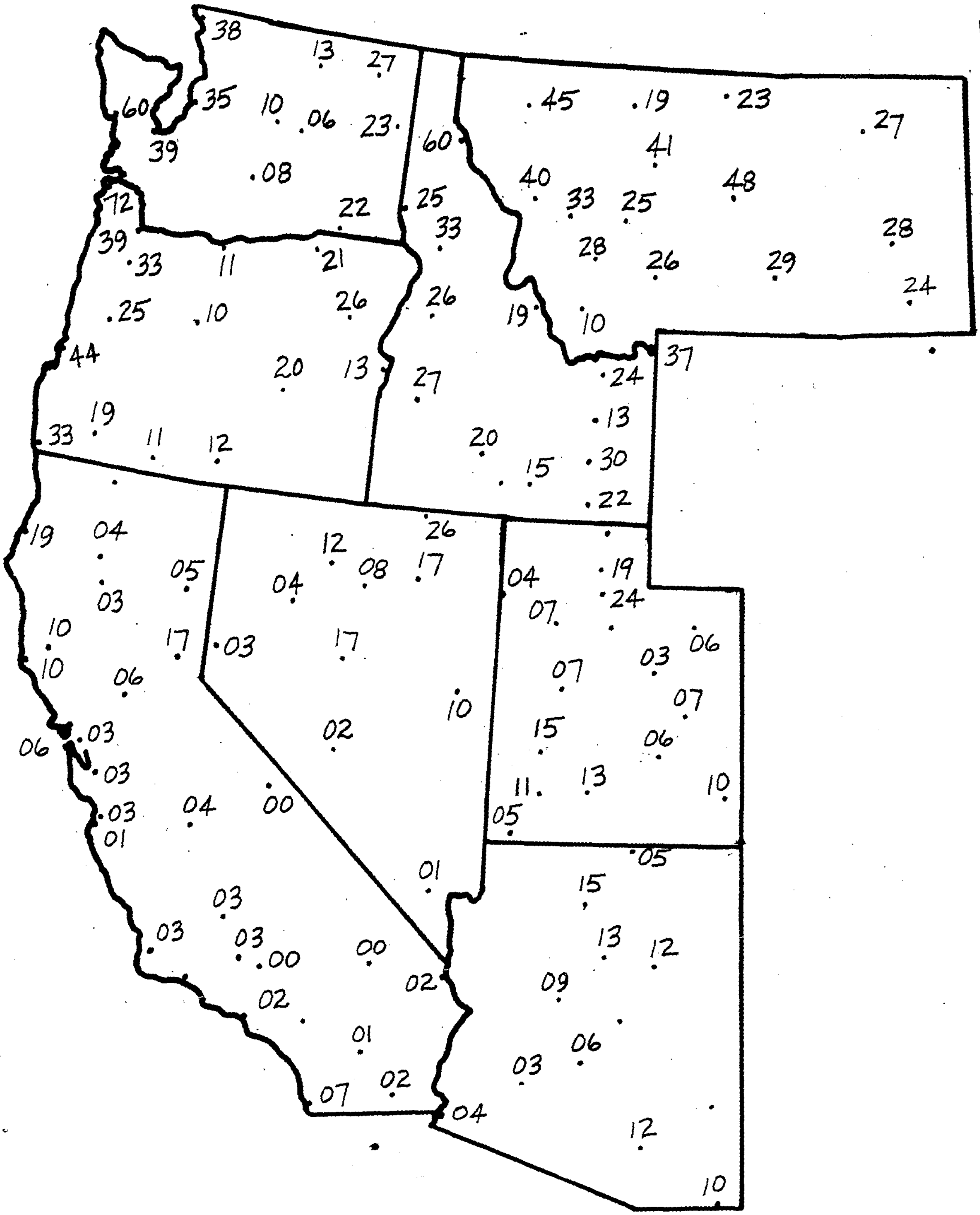
PERCENT FREQUENCY OF PRECIPITATION OCCURRENCE WITH
500-MB WINTER TYPE 2

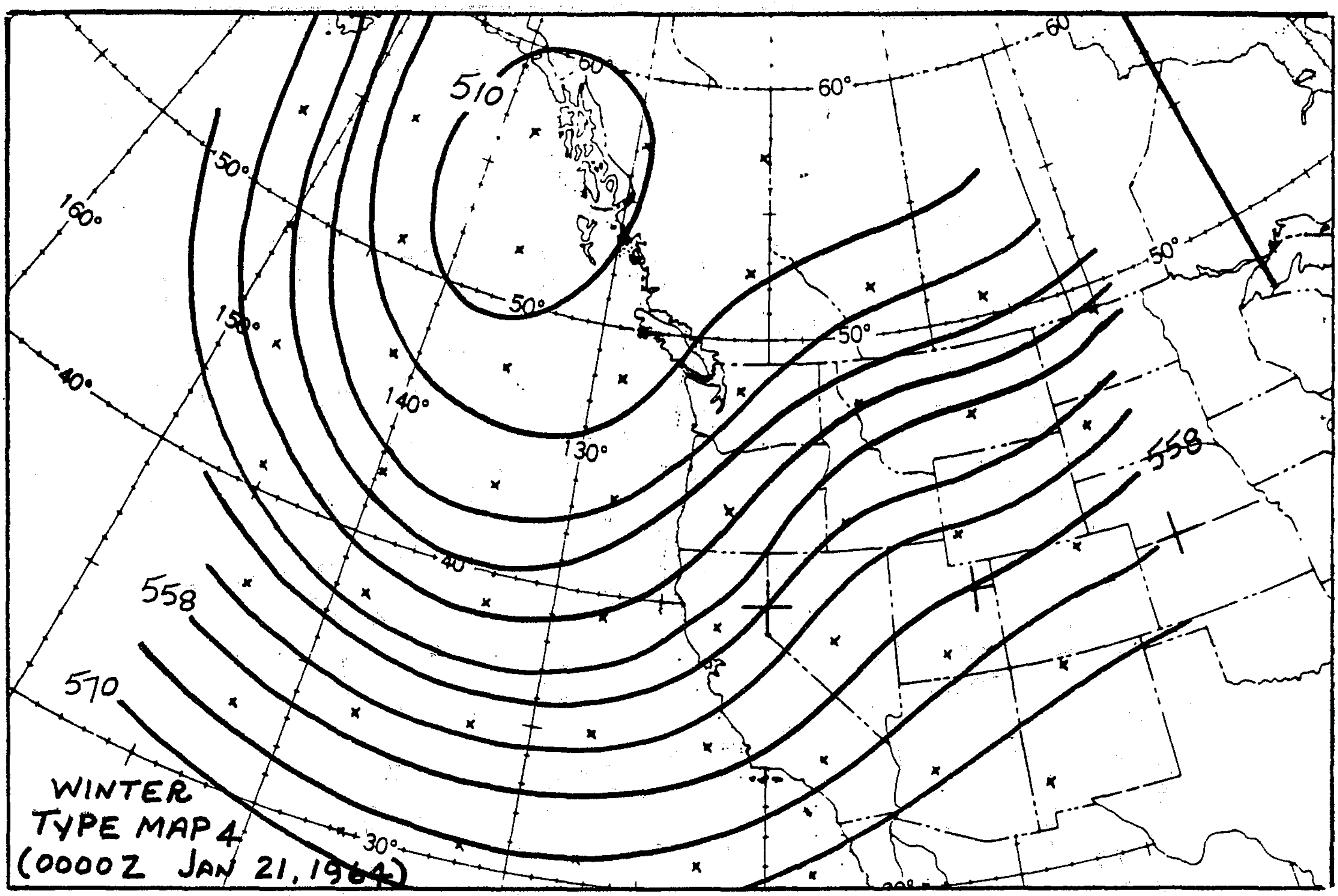


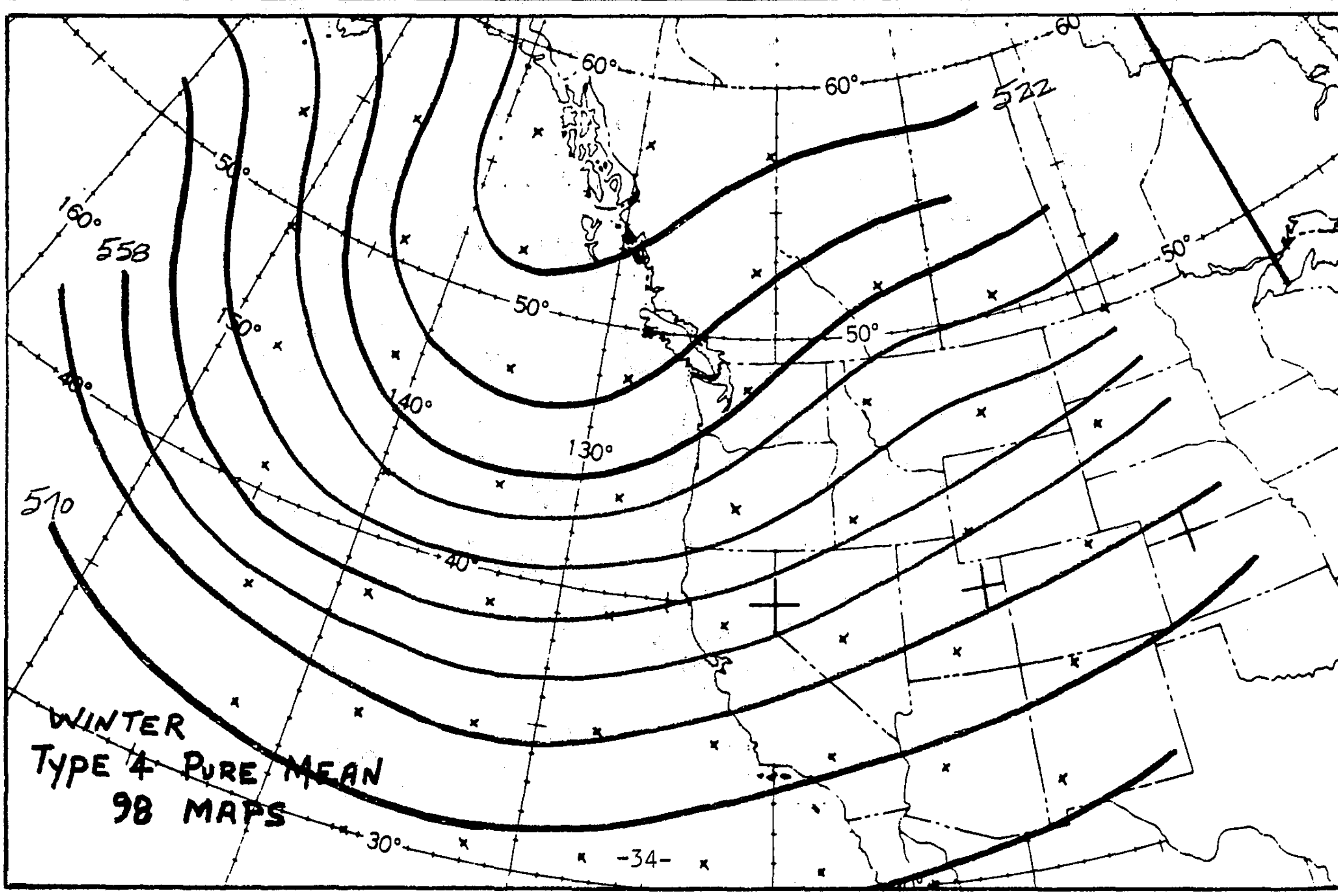

522
558
558
582
60°
60°
60°
50°
50°
50°
50°
40°
40°
160°
150°
140°
130°
WINTER
TYPE MAP 3
(0000 Z FEB 17, 1967)


534
558
516
60°
60°
60°
50°
50°
50°
50°
40°
40°
30°
160°
150°
140°
130°
WINTER
TYPE 3 PURE MEAN
145 MAPS

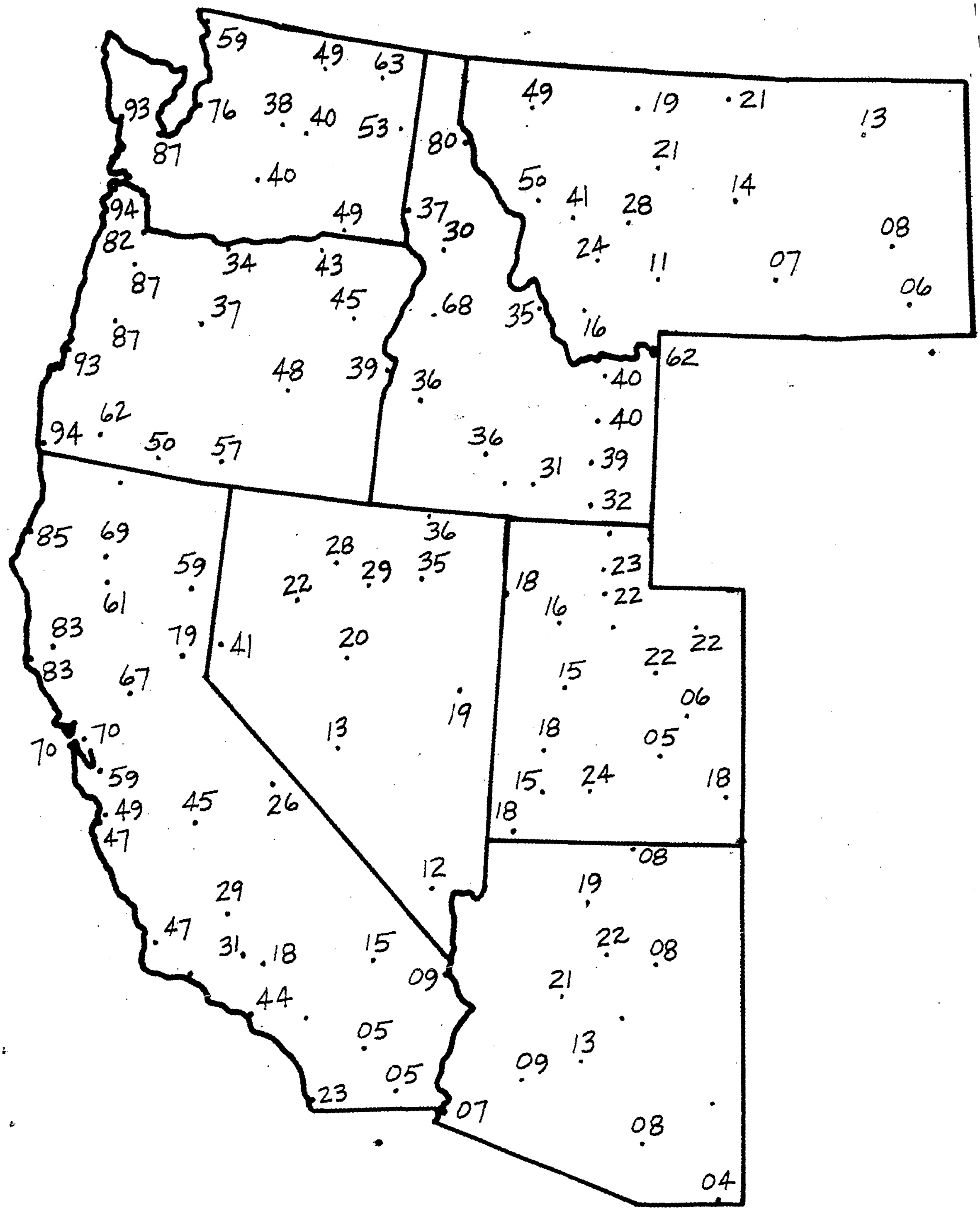
PERCENT FREQUENCY OF PRECIPITATION OCCURRENCE WITH
500-MB WINTER TYPE 3

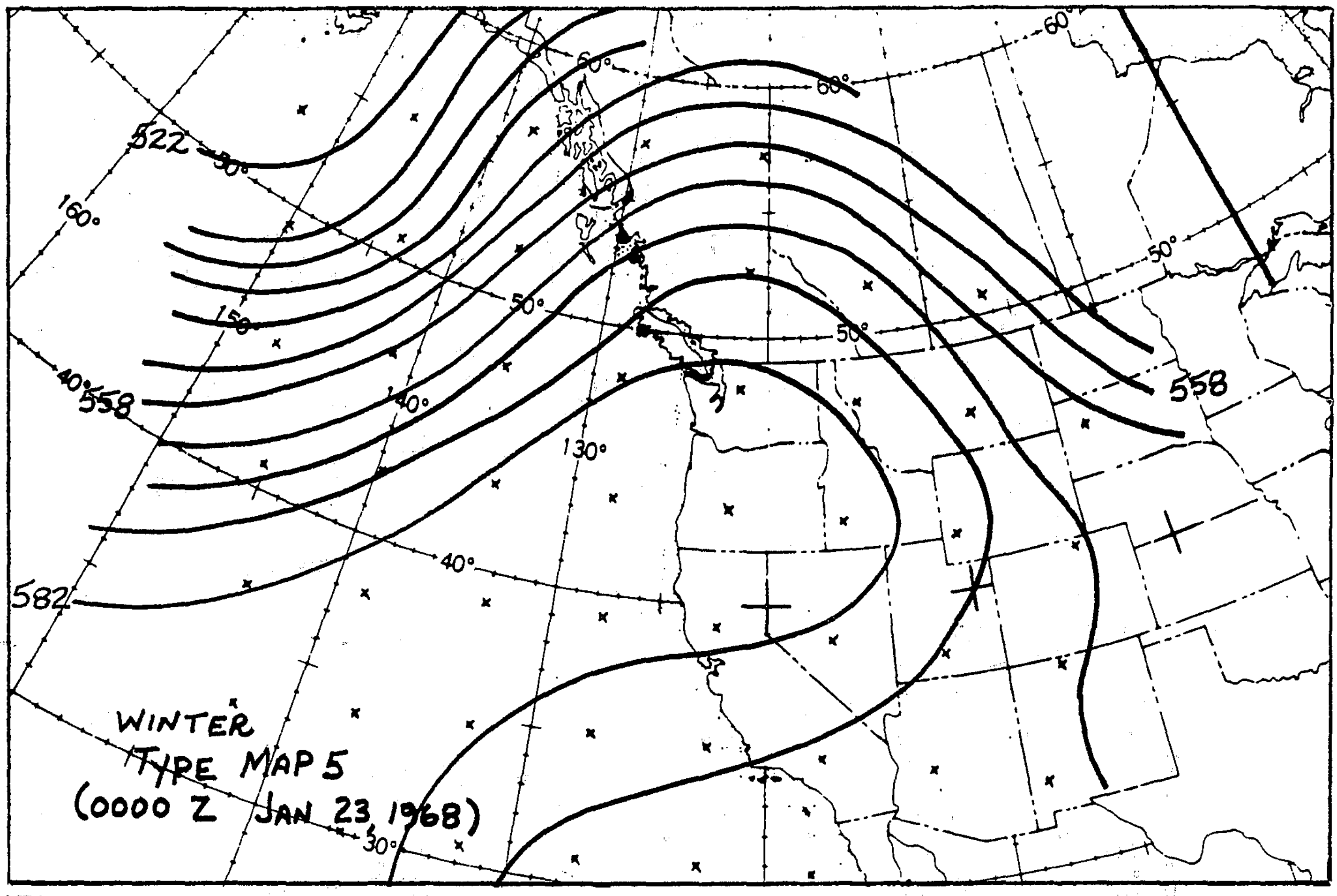


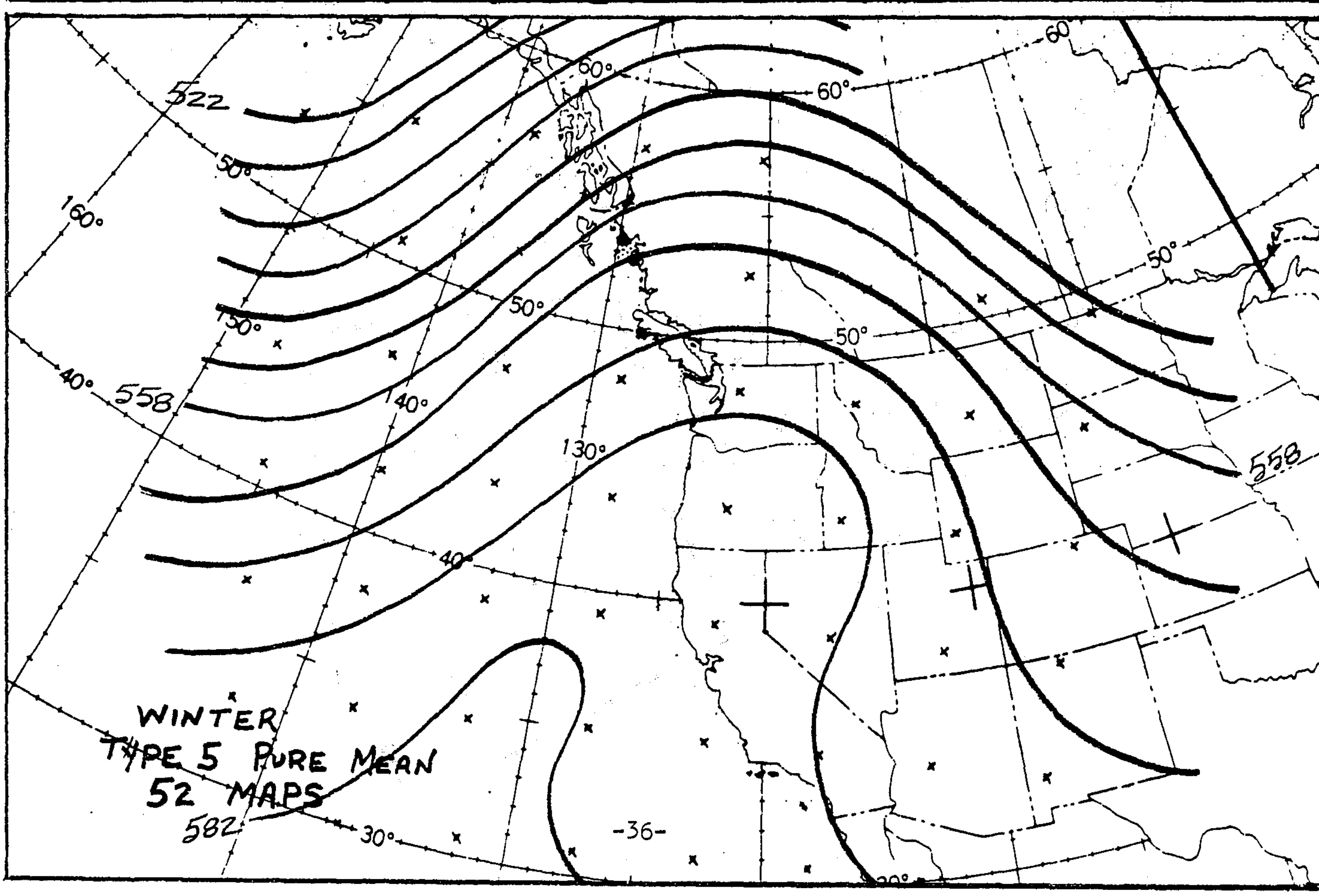

510
558
570
60°
50°
40°
30°
160°
150°
140°
130°
WINTER
TYPE MAP 4
(0000Z JAN 21, 1964)


522
558
510
60°
50°
40
30°
160°
150°
140°
130°
WINTER
TYPE 4 PURE MEAN
98 MAPS

PERCENT FREQUENCY OF PRECIPITATION OCCURRENCE WITH
500-MB WINTER TYPE 4

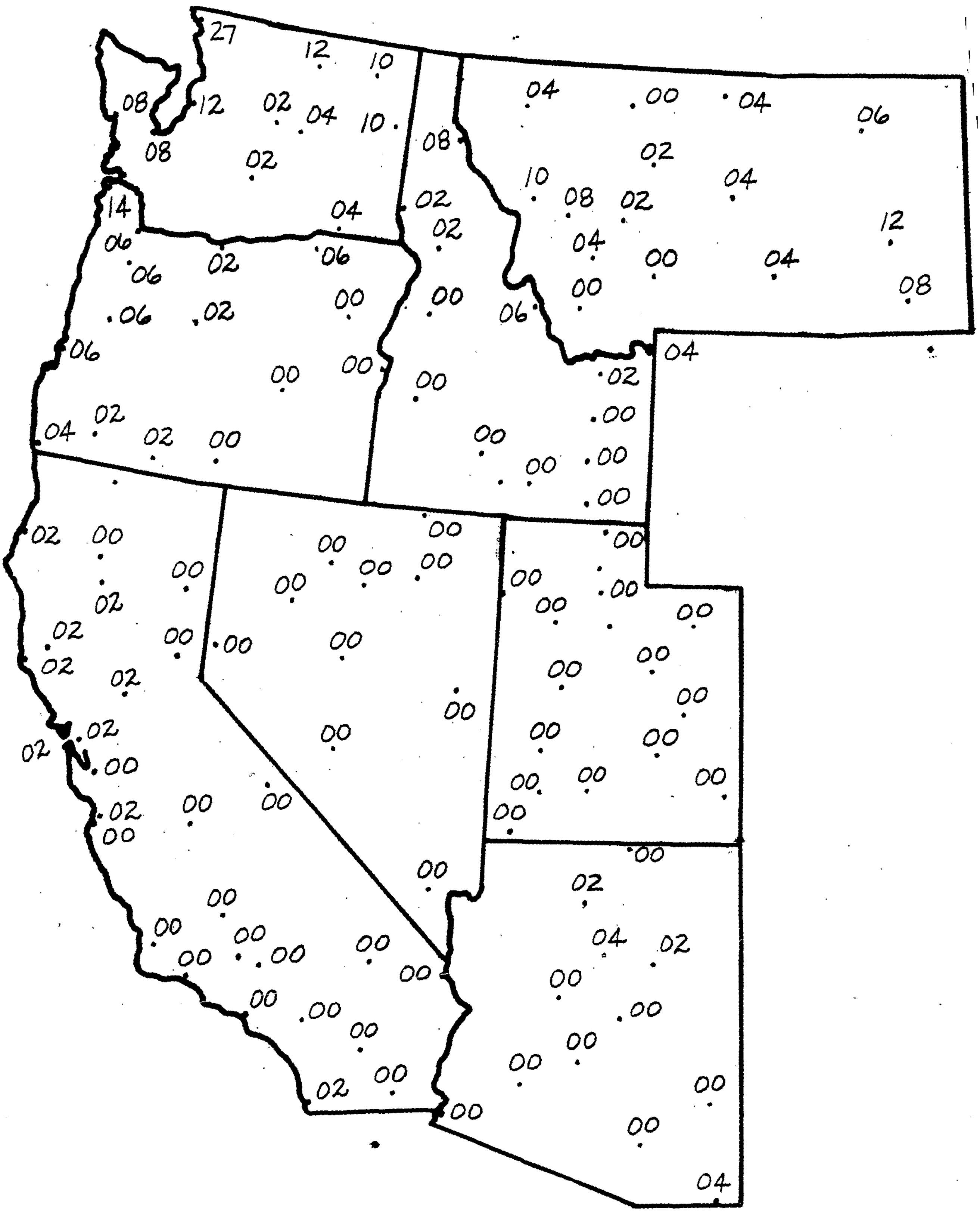


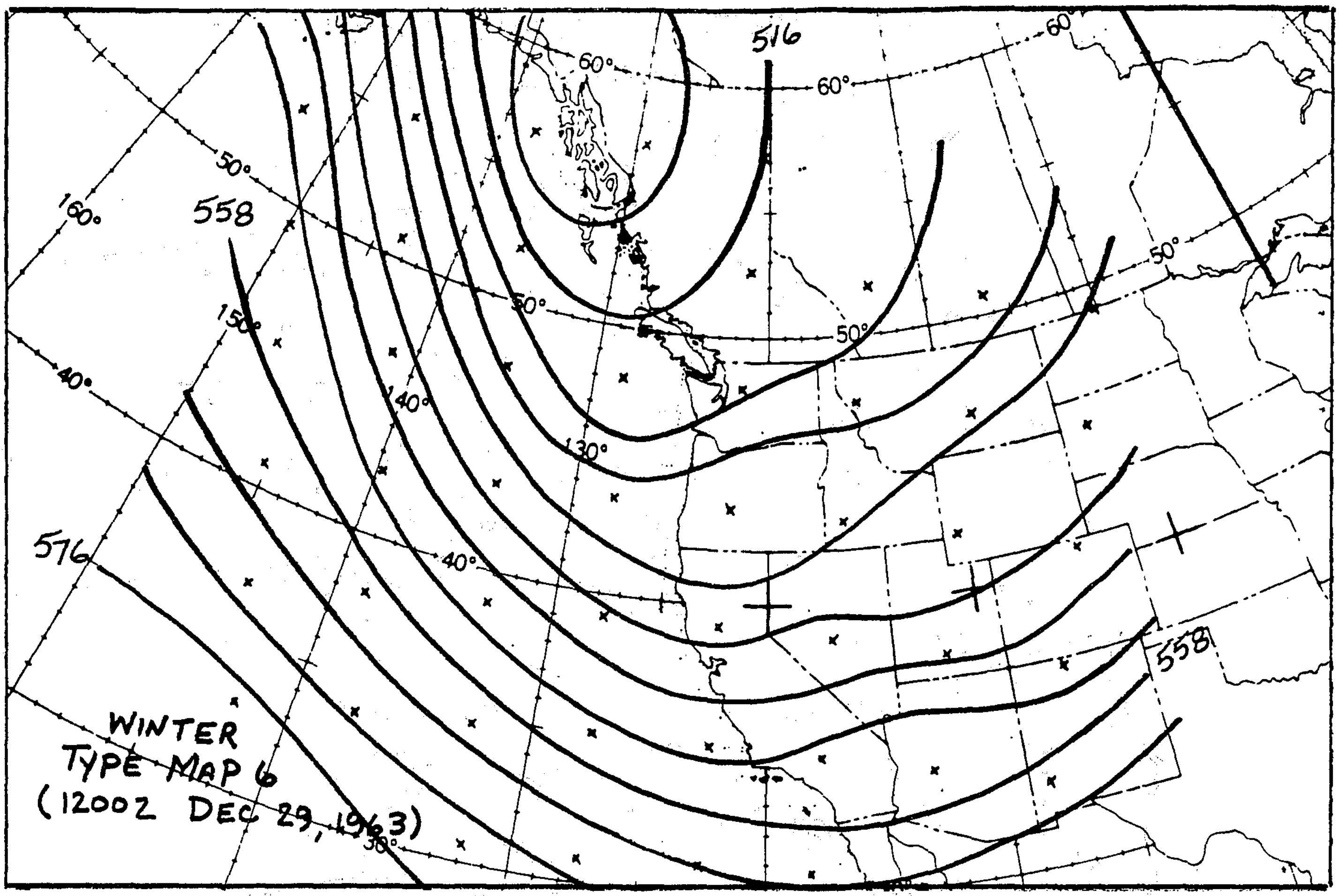

60°
60°
60°
522
50°
160°
150°
50°
50°
40°
558
140°
558
130°
40°
582
WINTER
TYPE MAP 5
(0000 Z JAN 23 1968)
30°

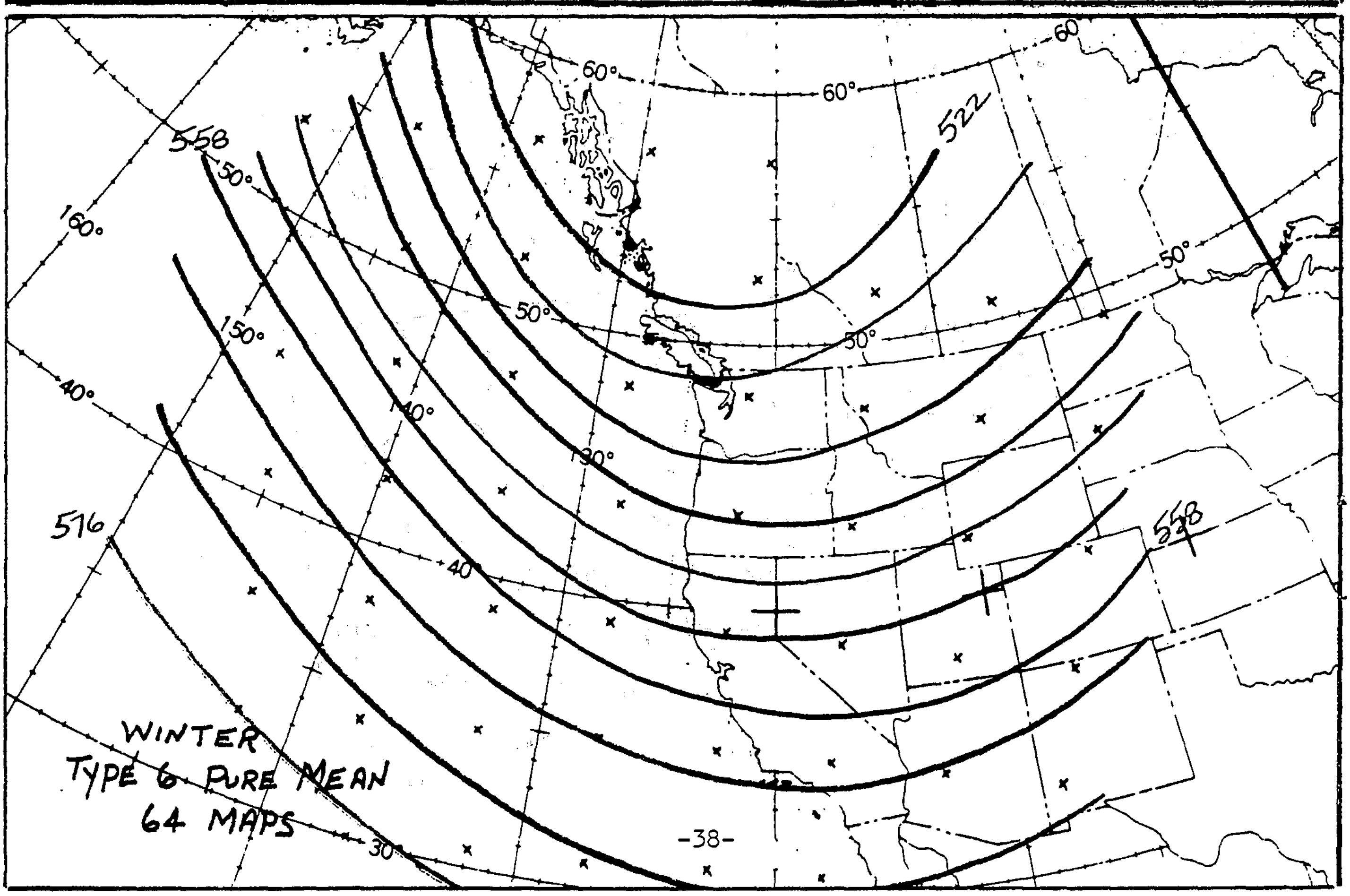

60°
60°
60°
522
50°
160°
150°
50°
50°
40°
558
140°
130°
558
40°
WINTER
TYPE 5 PURE MEAN
52 MAPS
582
30°

PERCENT FREQUENCY OF PRECIPITATION OCCURRENCE WITH

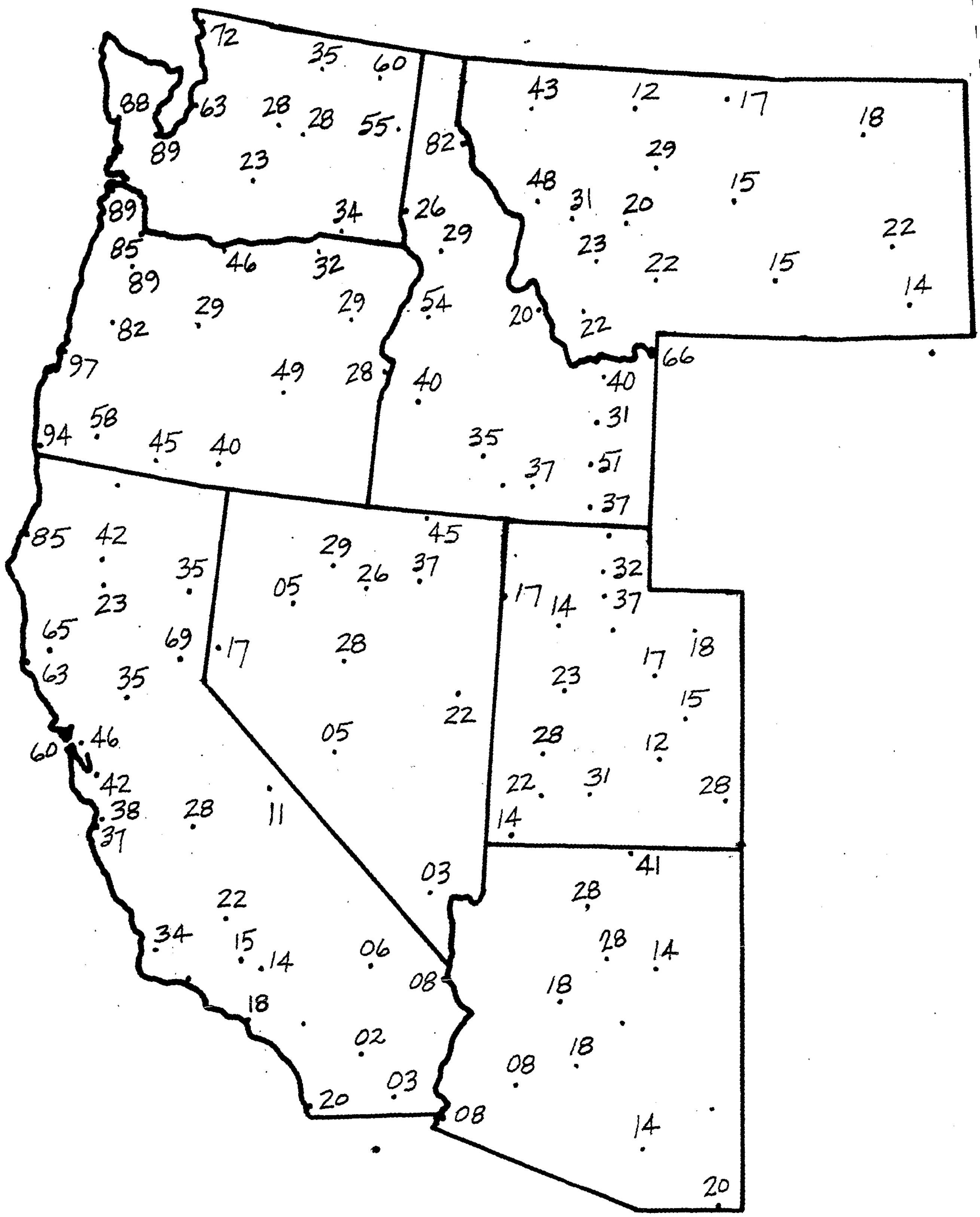
500-MB WINTER TYPE 5

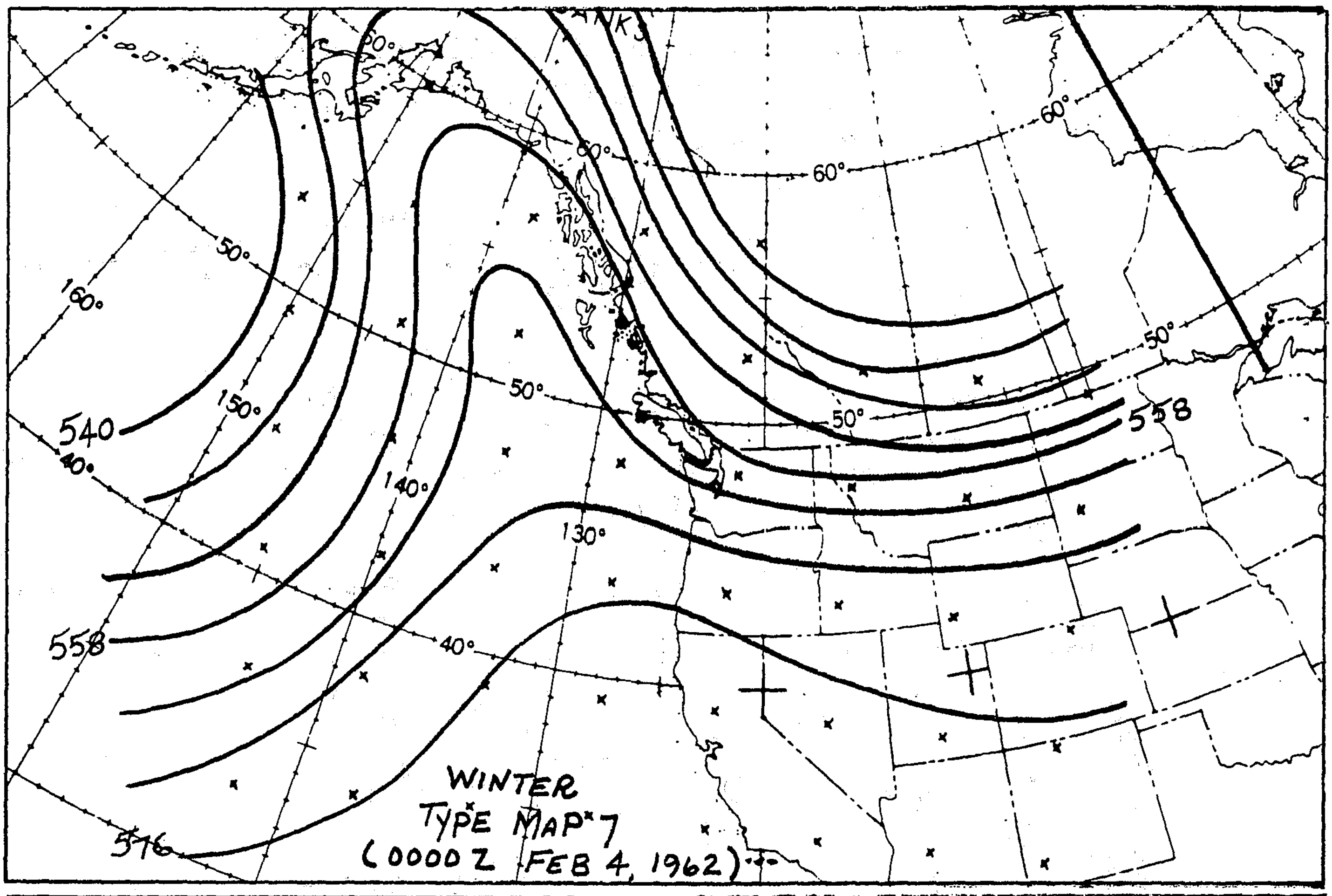


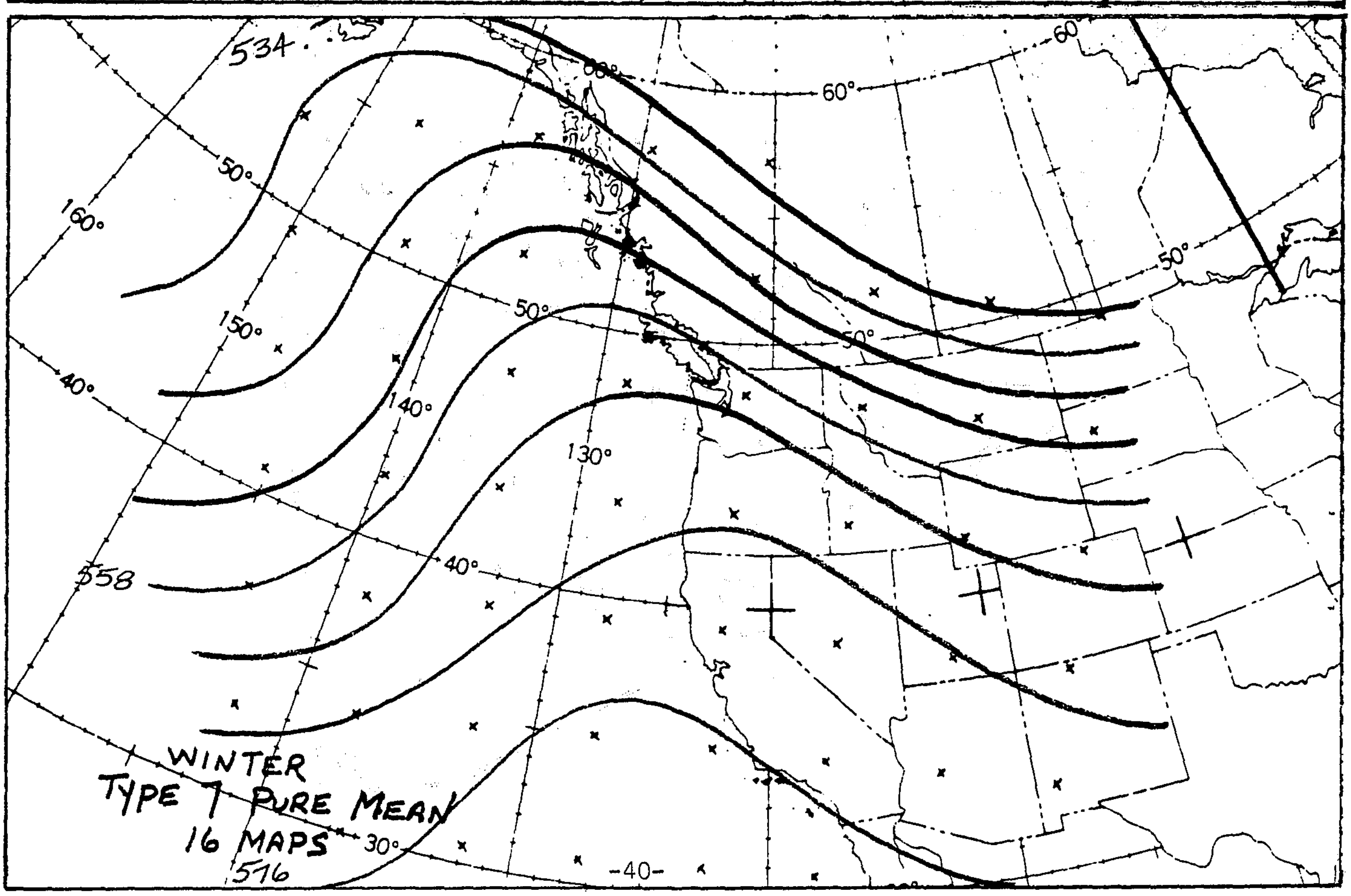

516
60°
60°
60°
50°
160°
558
150°
40°
140°
130°
50°
50°
50°
516
40°
558
WINTER
TYPE MAP 6
(1200Z DEC 29, 1963)
30°


60°
60°
60°
522
558
50°
160°
150°
40°
140°
30°
50°
50°
50°
516
40
528
WINTER
TYPE 6 PURE MEAN
64 MAPS
30°

PERCENT FREQUENCY OF PRECIPITATION OCCURRENCE WITH
500-MB WINTER TYPE 6

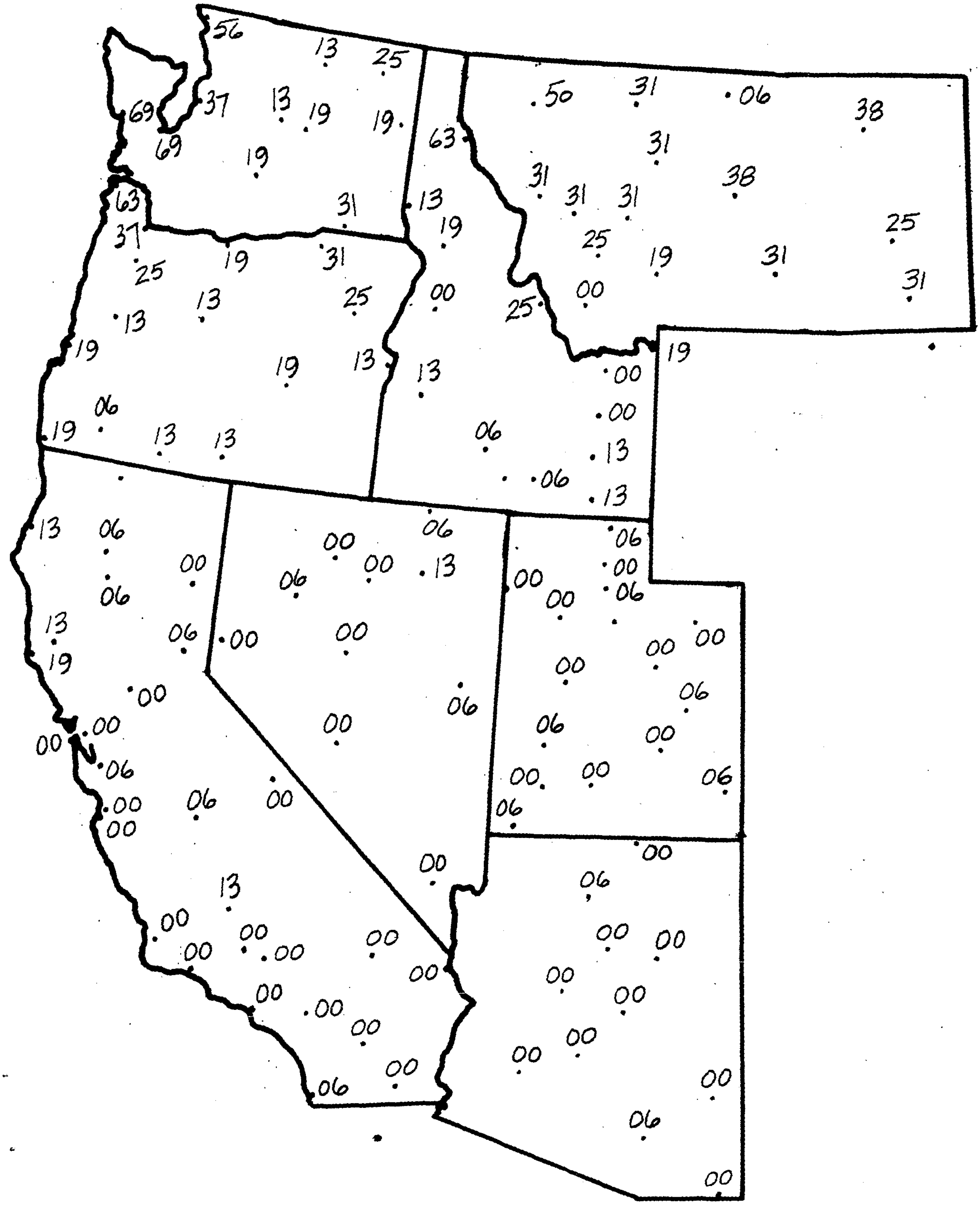


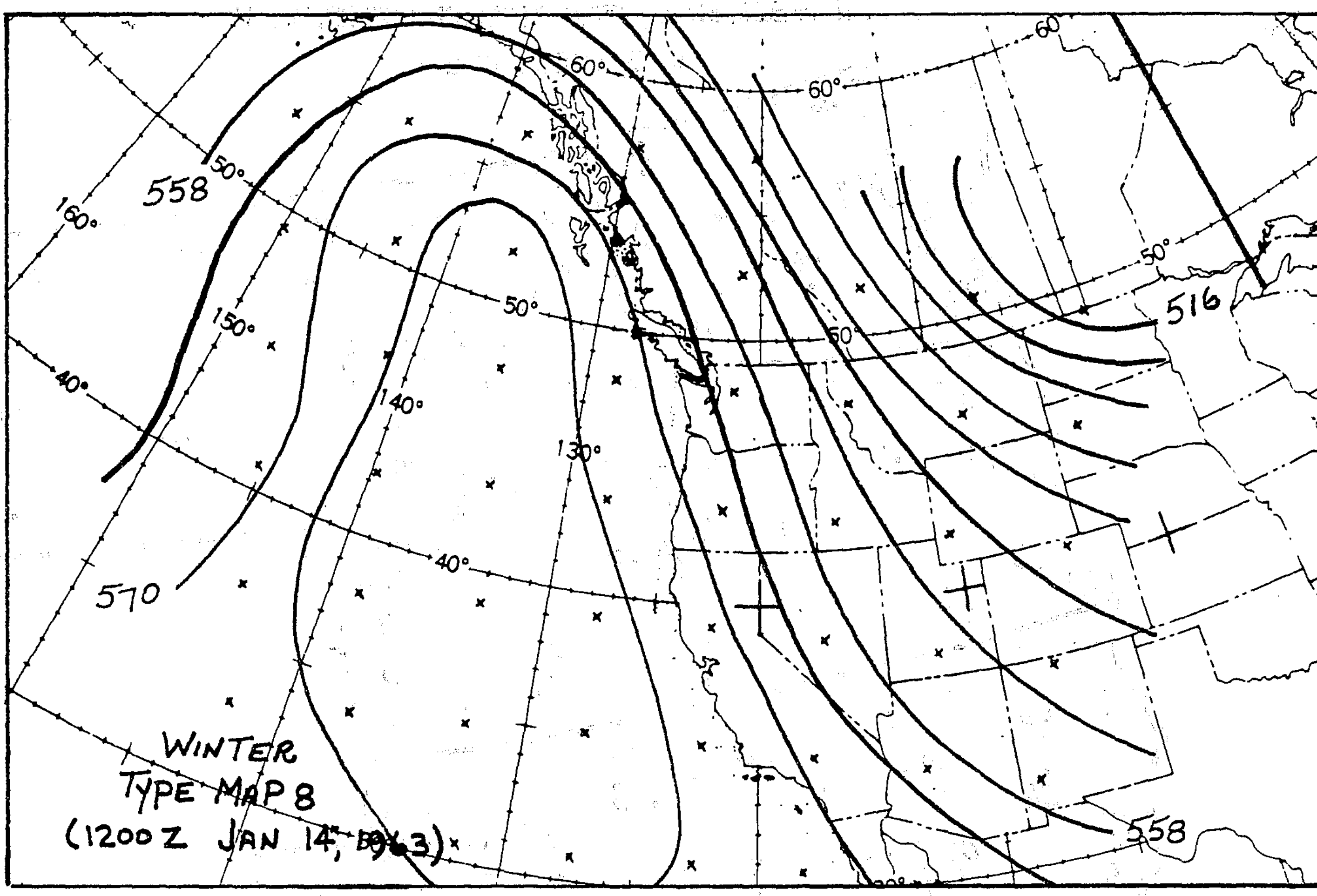

540
558
516
558
60°
50°
40°
160°
150°
140°
130°
WINTER
TYPE MAP 7
(0000Z FEB 4, 1962)

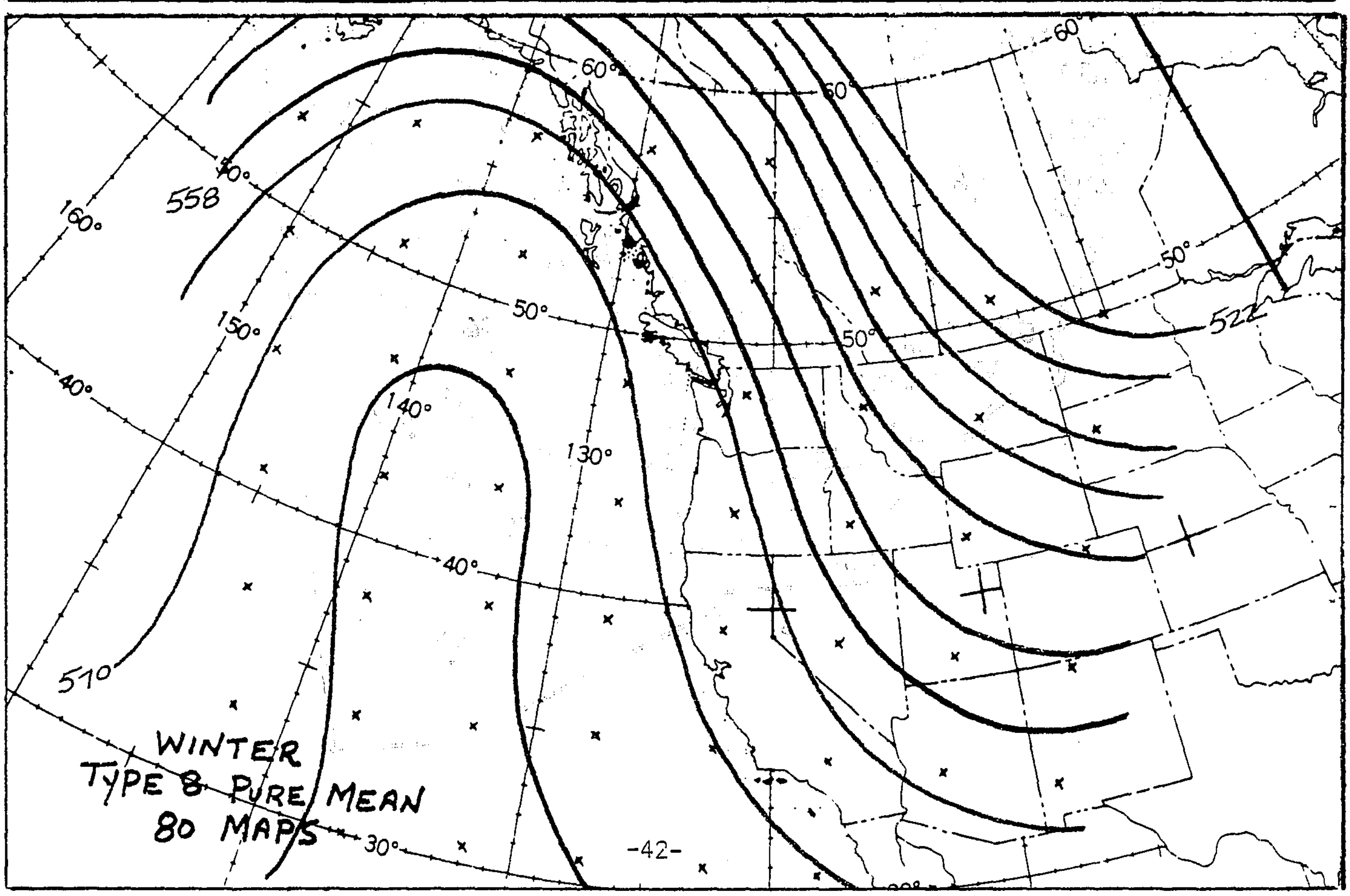

534
558
516
60°
50°
40°
30°
160°
150°
140°
130°
WINTER
TYPE 7 PURE MEAN
16 MAPS

PERCENT FREQUENCY OF PRECIPITATION OCCURRENCE WITH

500-MB WINTER TYPE 7

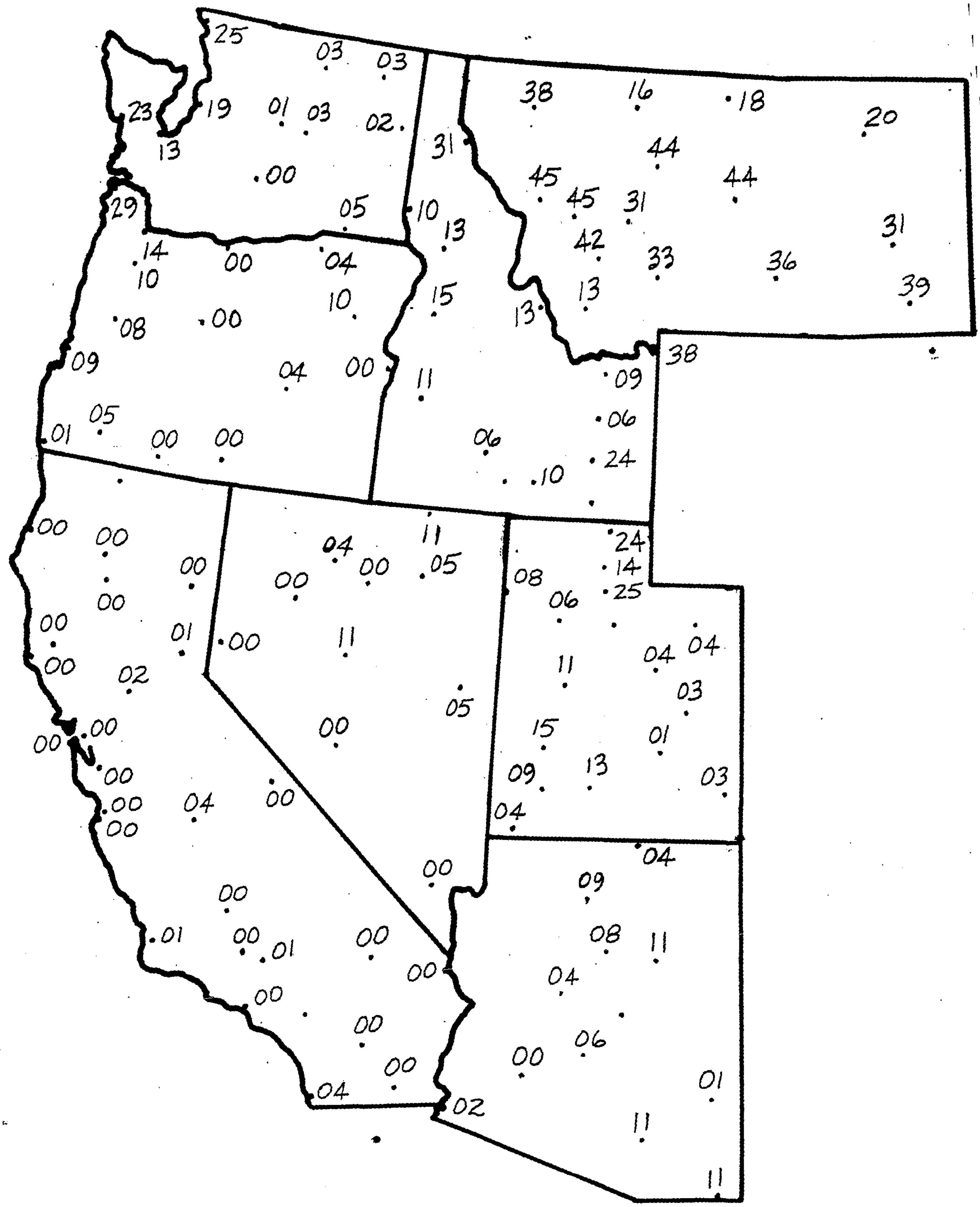


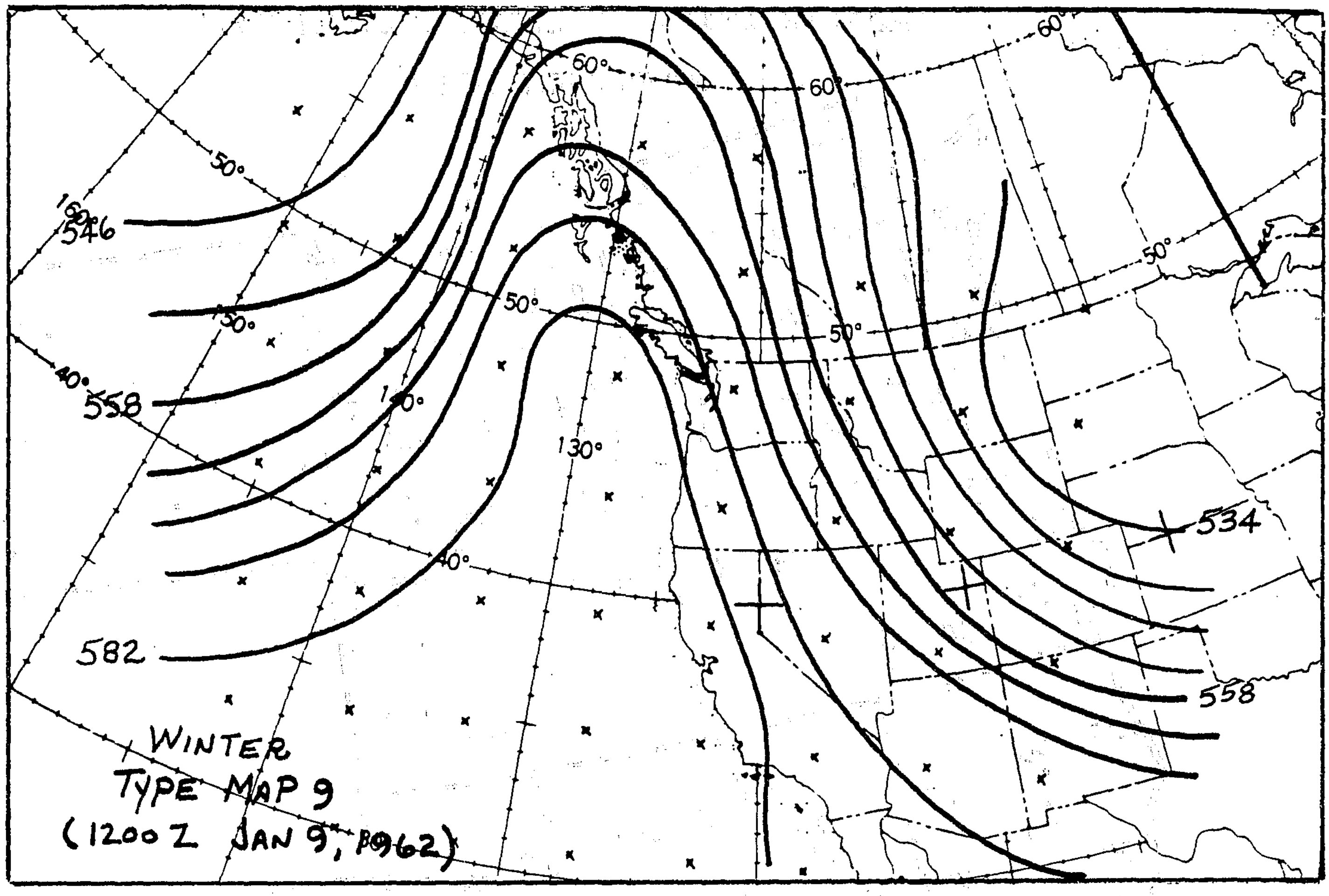

558
570
516
558
WINTER
TYPE MAP 8
(1200Z JAN 14, 1963)

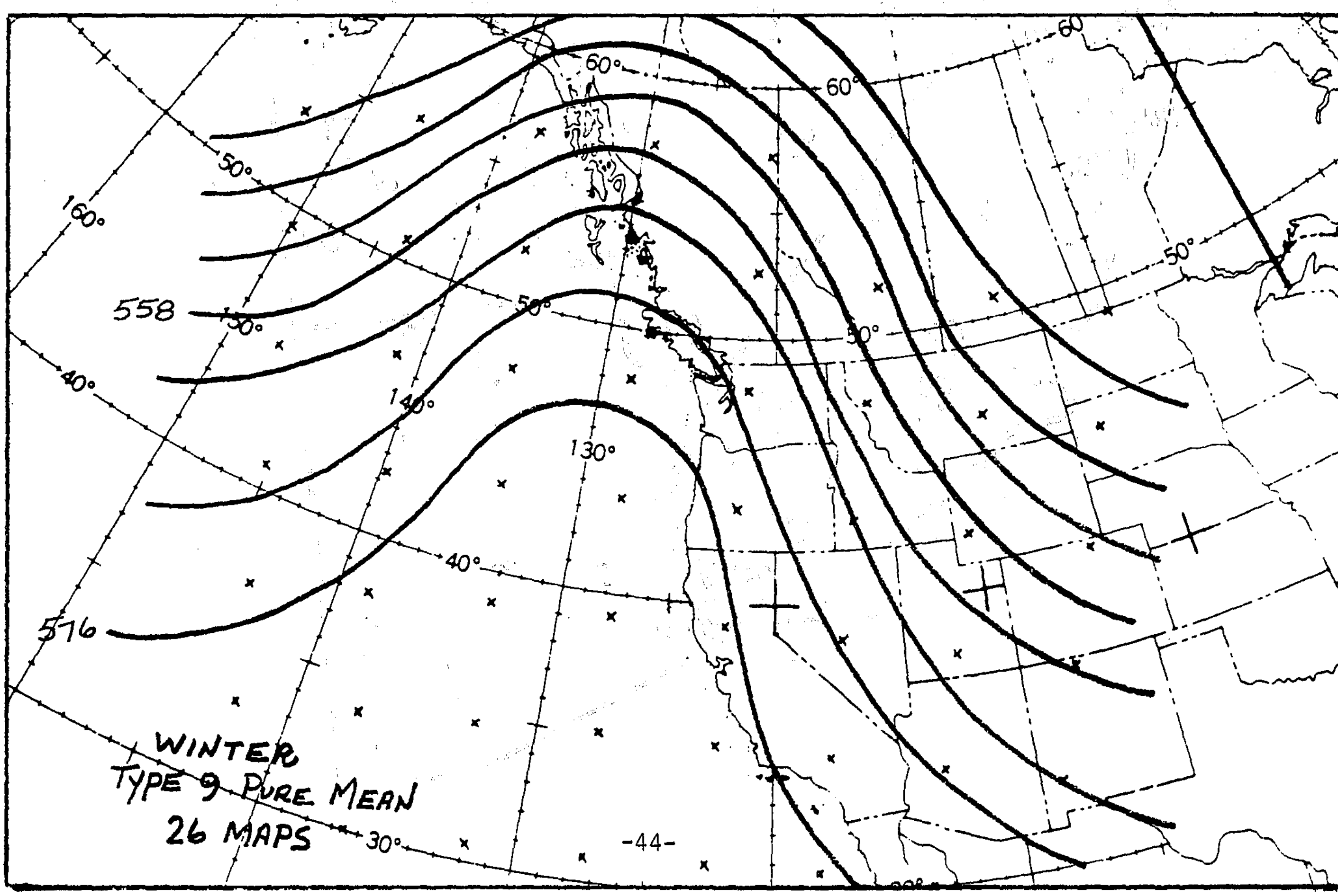

558
510
522
WINTER
TYPE 8 PURE MEAN
80 MAPS

PERCENT FREQUENCY OF PRECIPITATION OCCURRENCE WITH

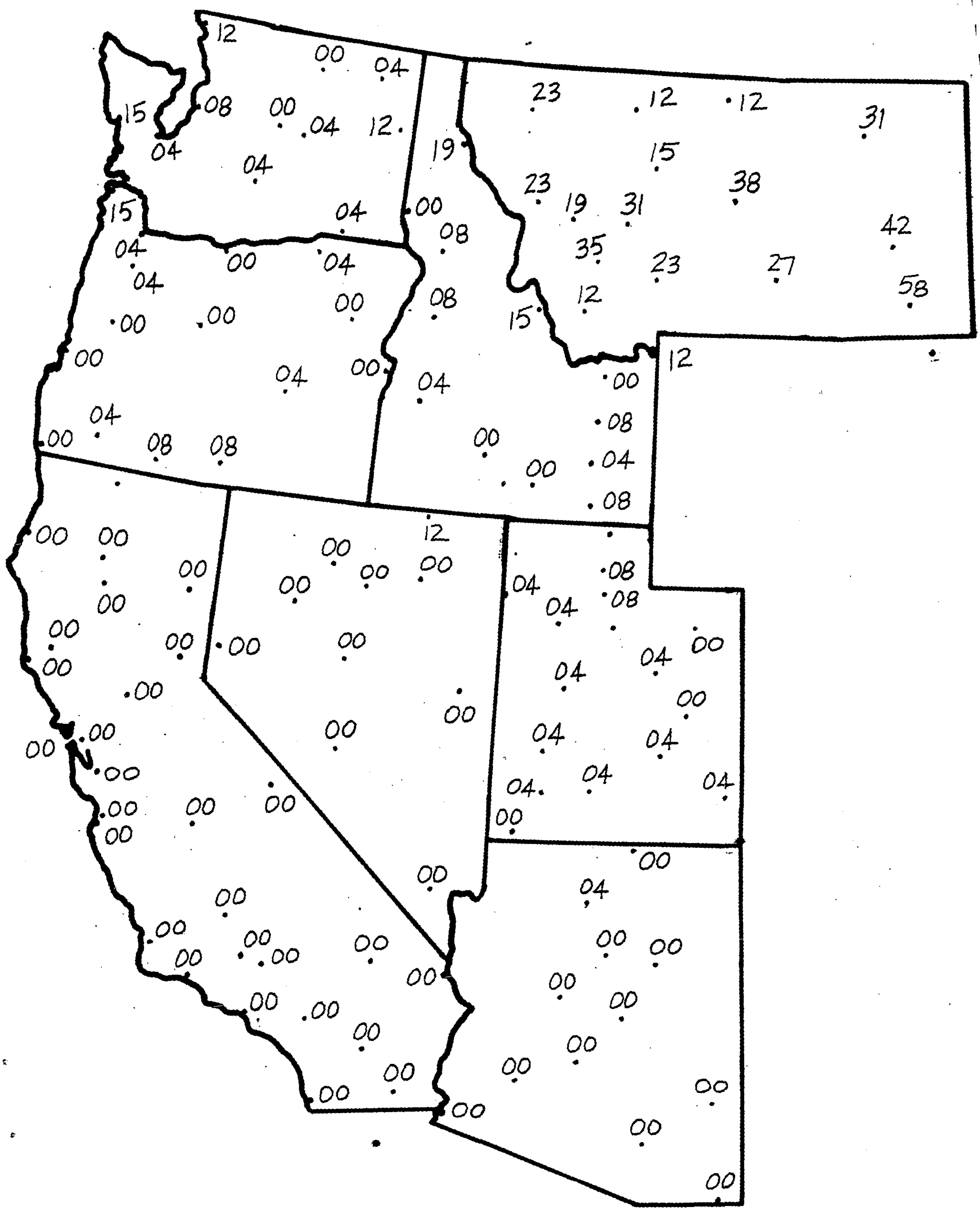
500-MB WINTER TYPE 8

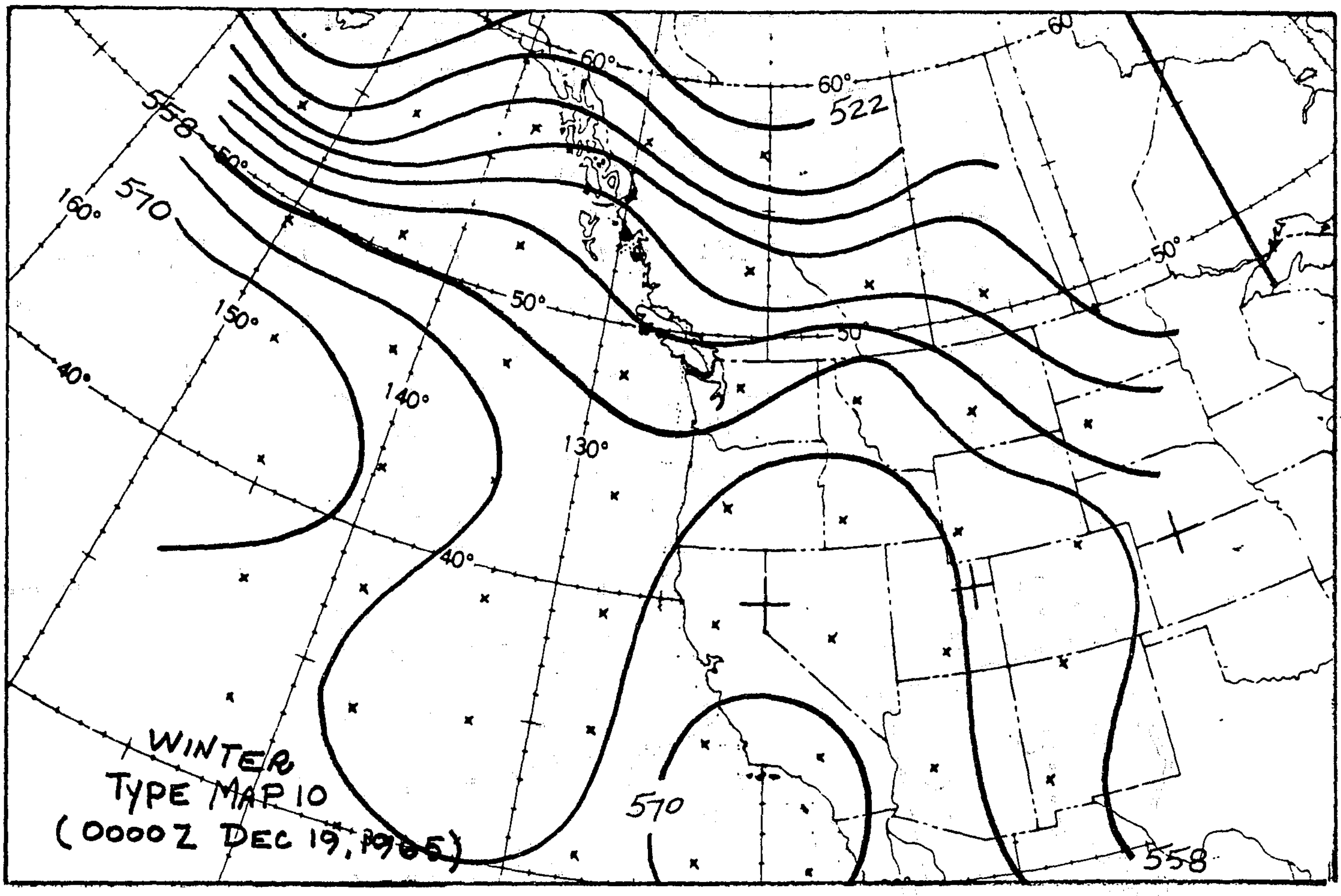


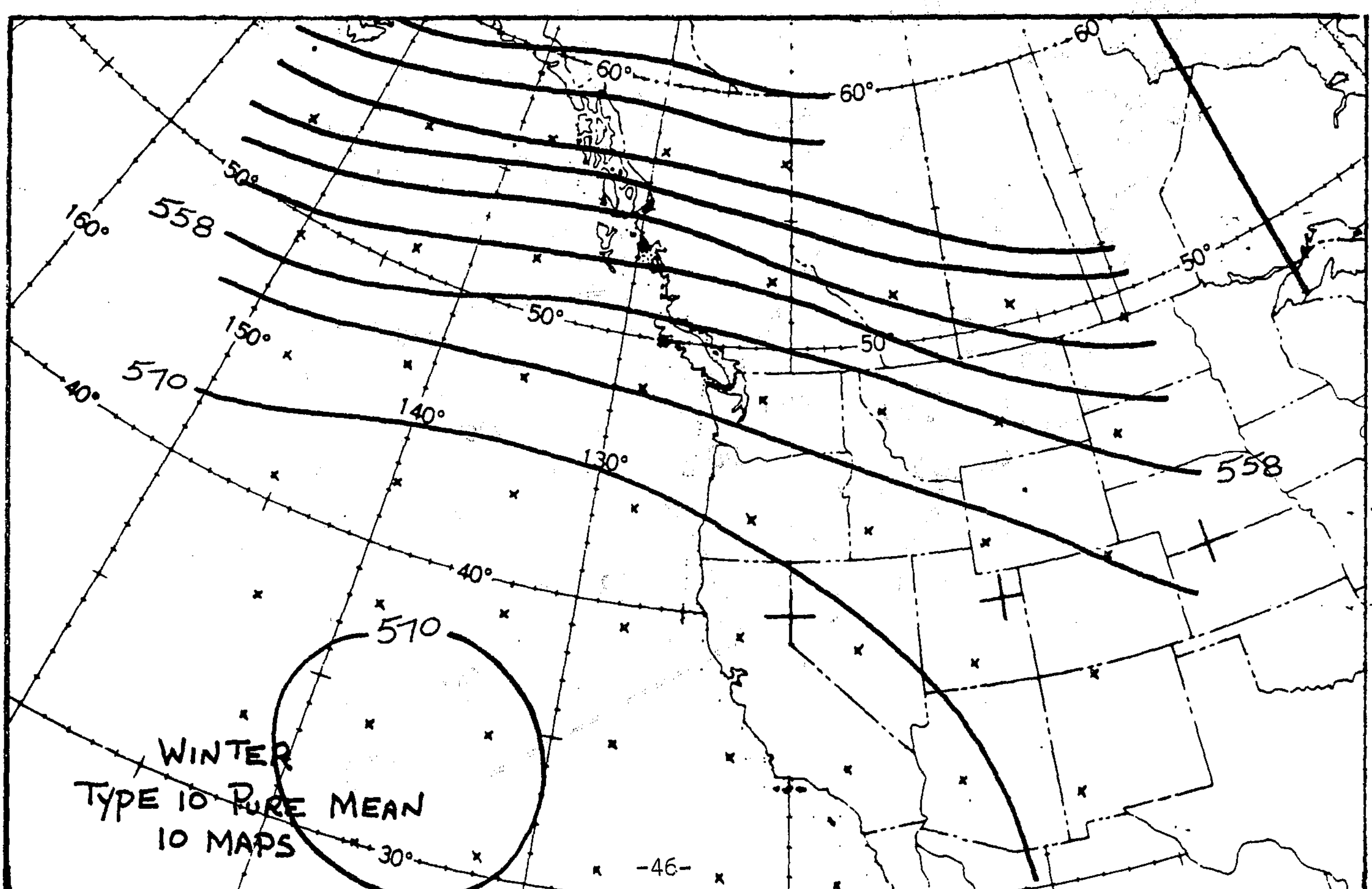

546
558
582
534
558
60°
60°
60°
50°
50°
50°
50°
40°
40°
160°
140°
130°
WINTER
TYPE MAP 9
(1200 Z JAN 9, 1962)


558
576
60°
60°
60
50°
50°
50°
50°
40°
40°
30°
160°
140°
130°
WINTER
TYPE 9 PURE MEAN
26 MAPS

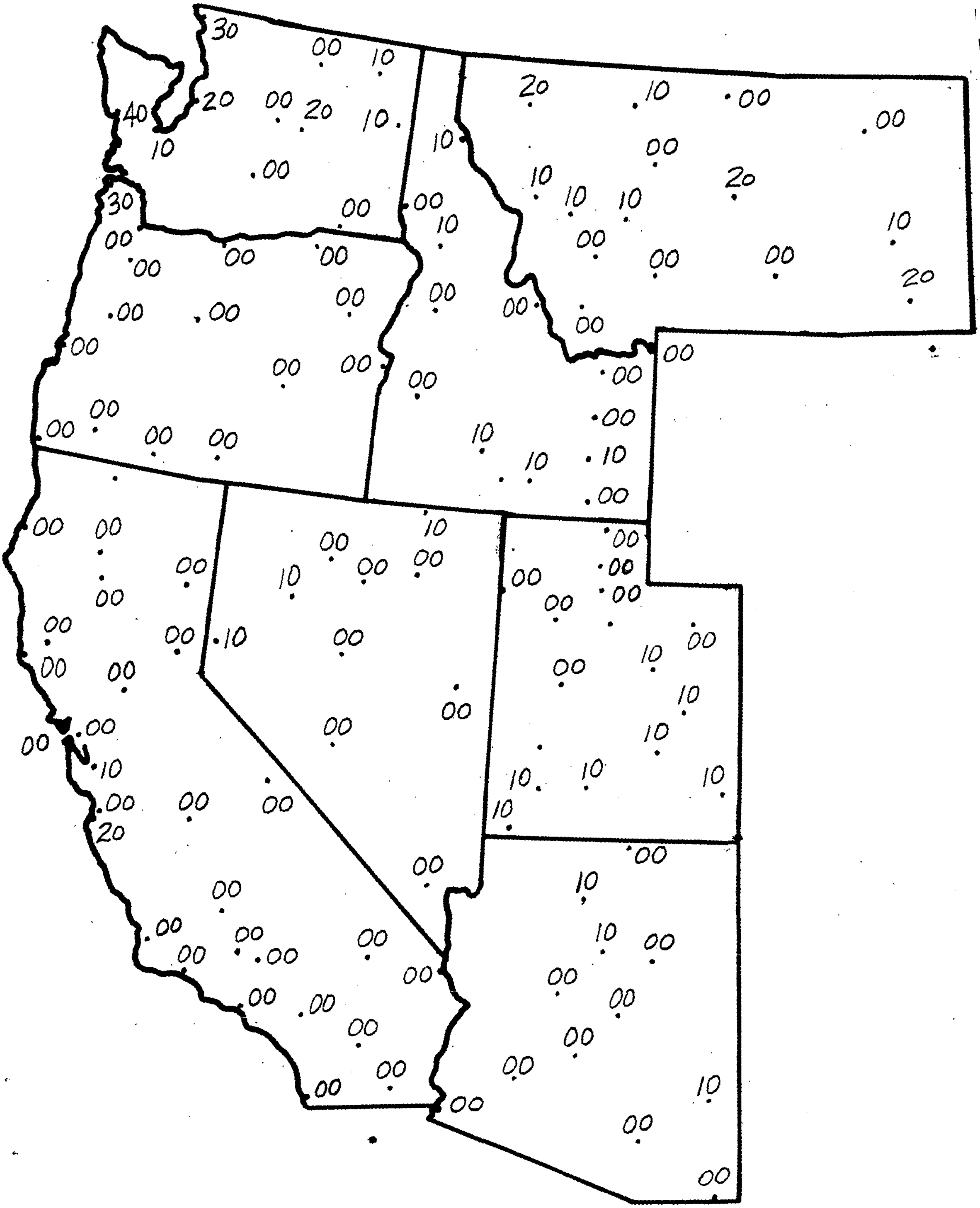
PERCENT FREQUENCY OF PRECIPITATION OCCURRENCE WITH
500-MB WINTER TYPE 9

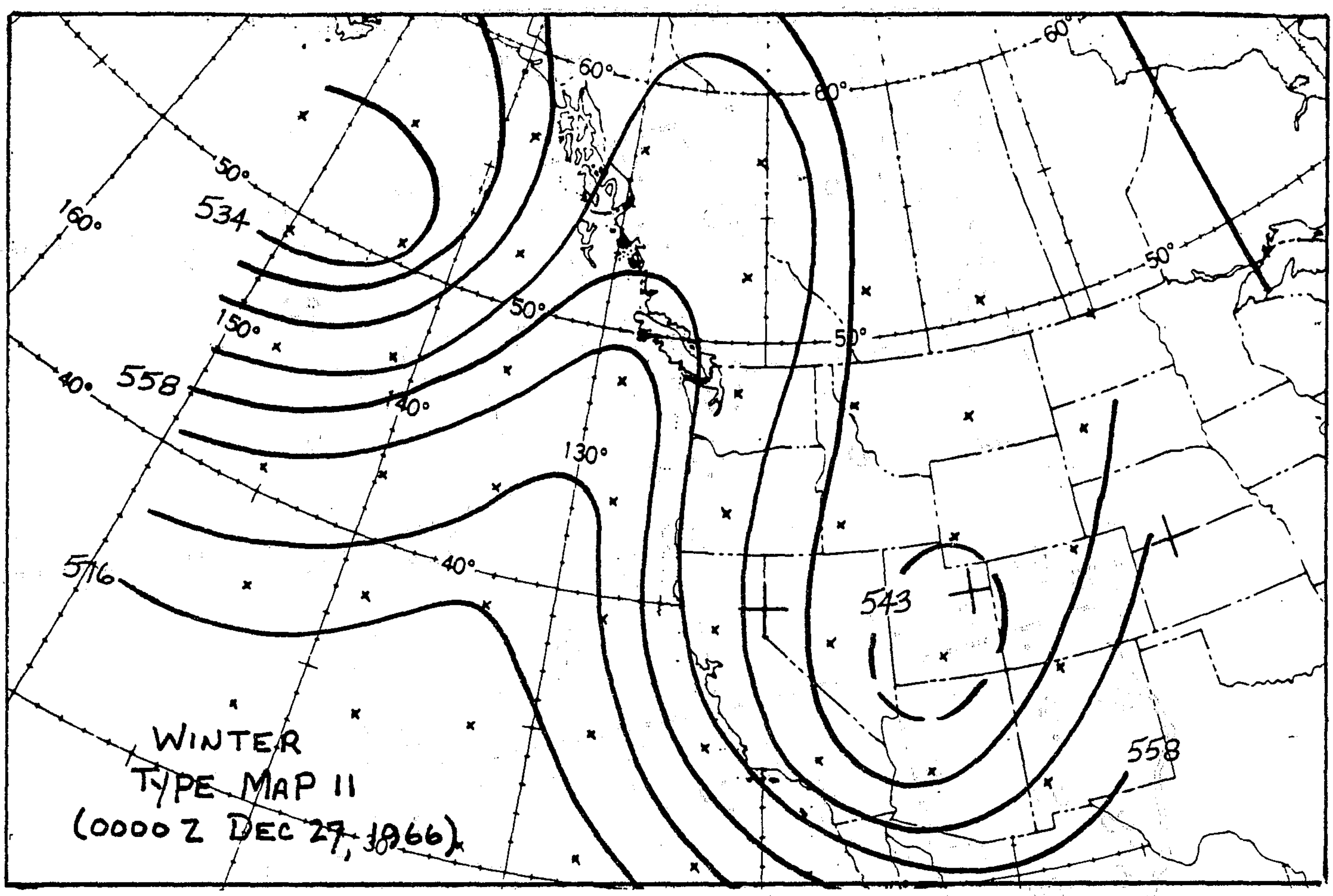


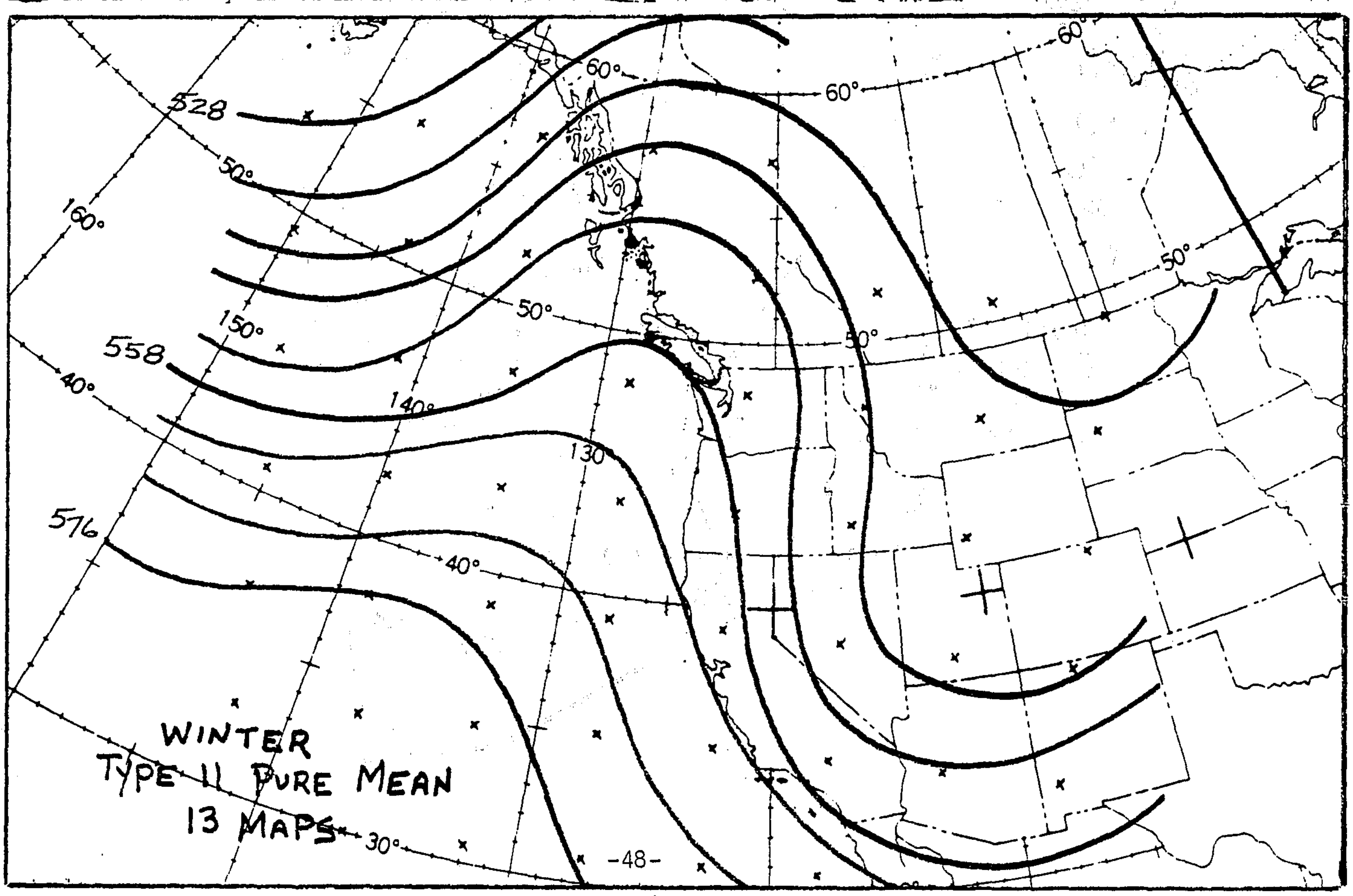

WINTER
TYPE MAP 10
(0000Z DEC 19, 1965)
522
558
570
510
558


WINTER
TYPE 10 PURE MEAN
10 MAPS
558
570
510
558

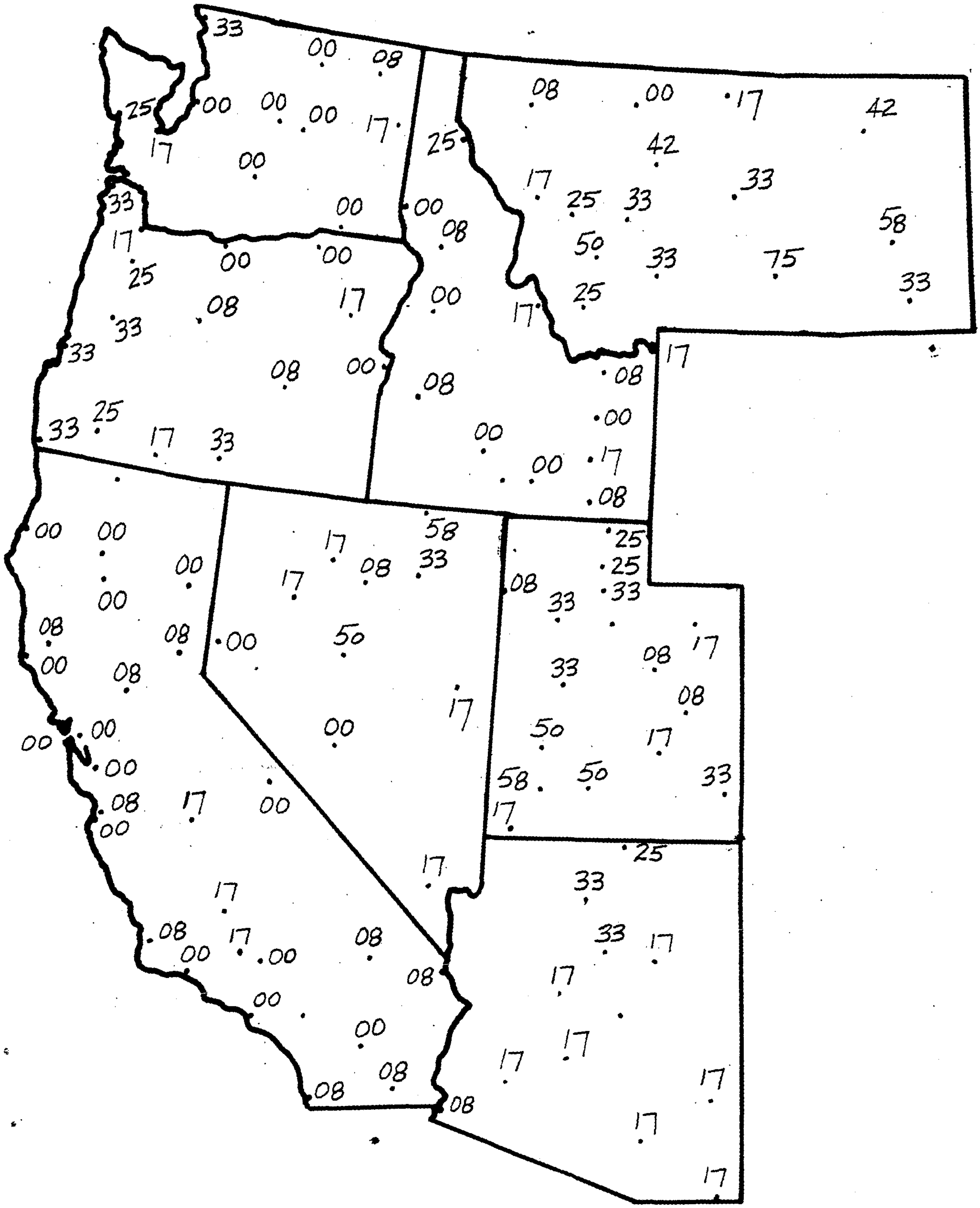
PERCENT FREQUENCY OF PRECIPITATION OCCURRENCE WITH
500-MB WINTER TYPE 10

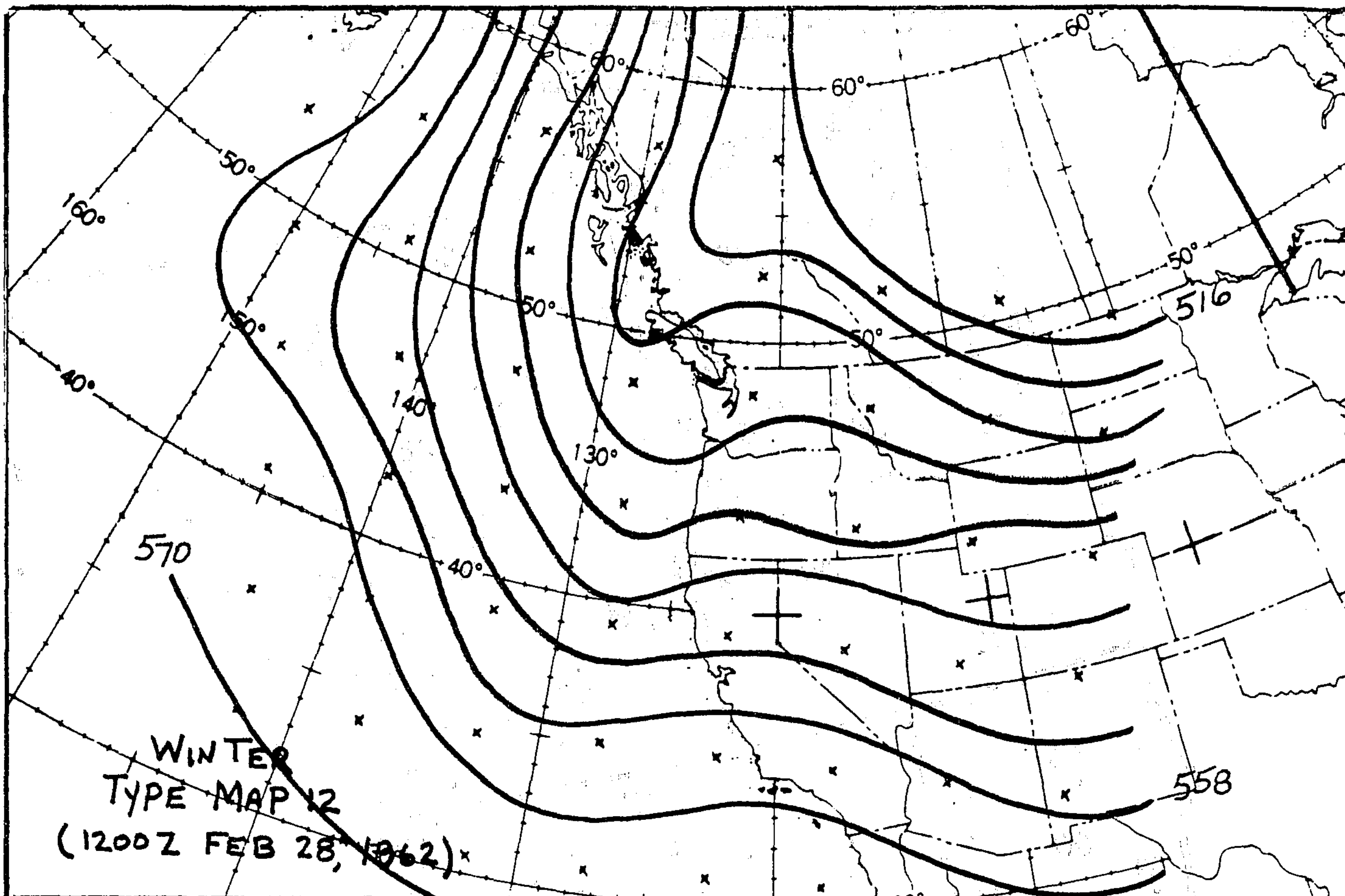


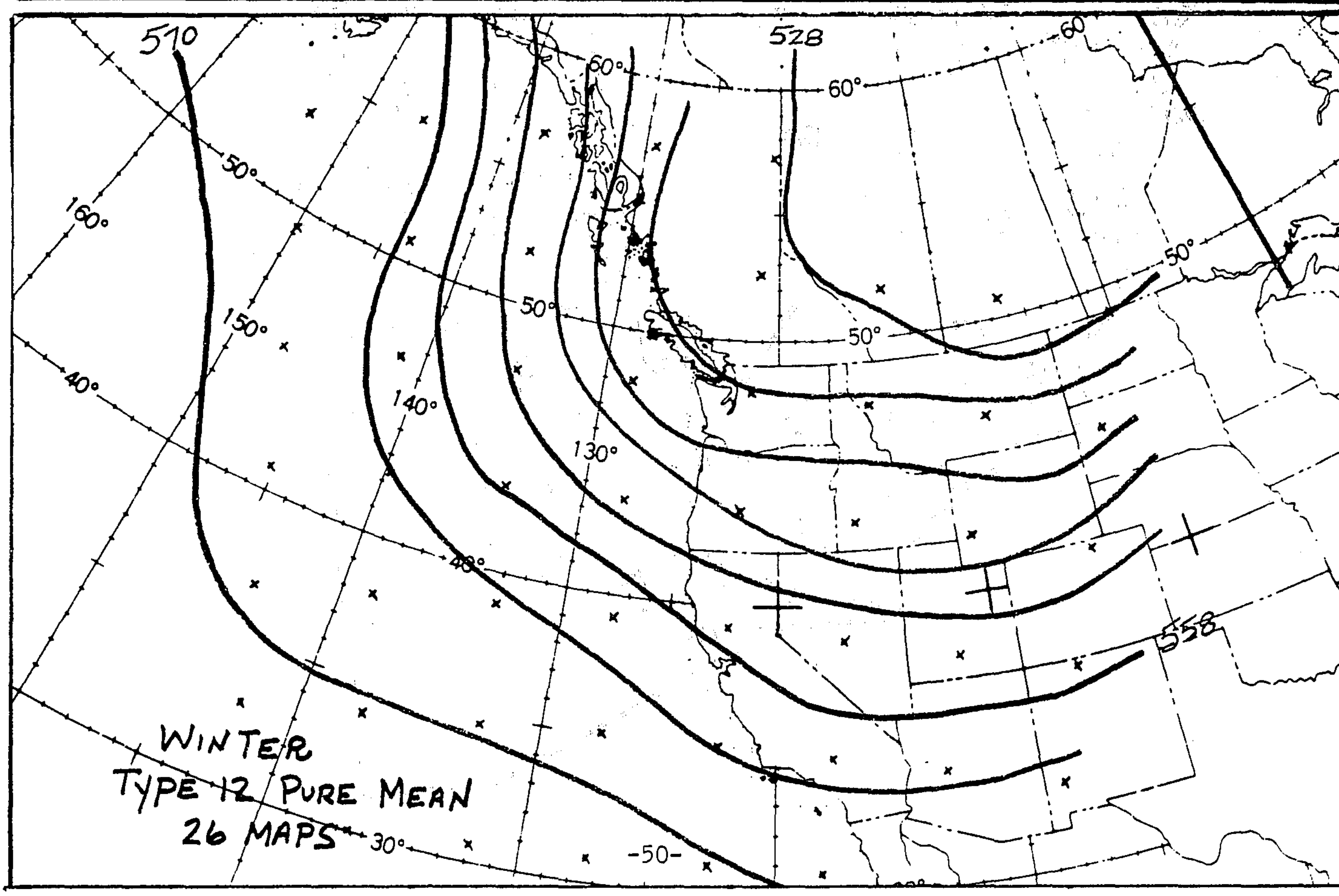

WINTER
TYPE MAP 11
(0000 Z DEC 27, 1966)
534
558
576
543
558
60°
50°
40°
30°
160°
150°
140°
130°


WINTER
TYPE 11 PURE MEAN
13 MAPS
528
558
576
60°
50°
40°
30°
160°
150°
140°
130°

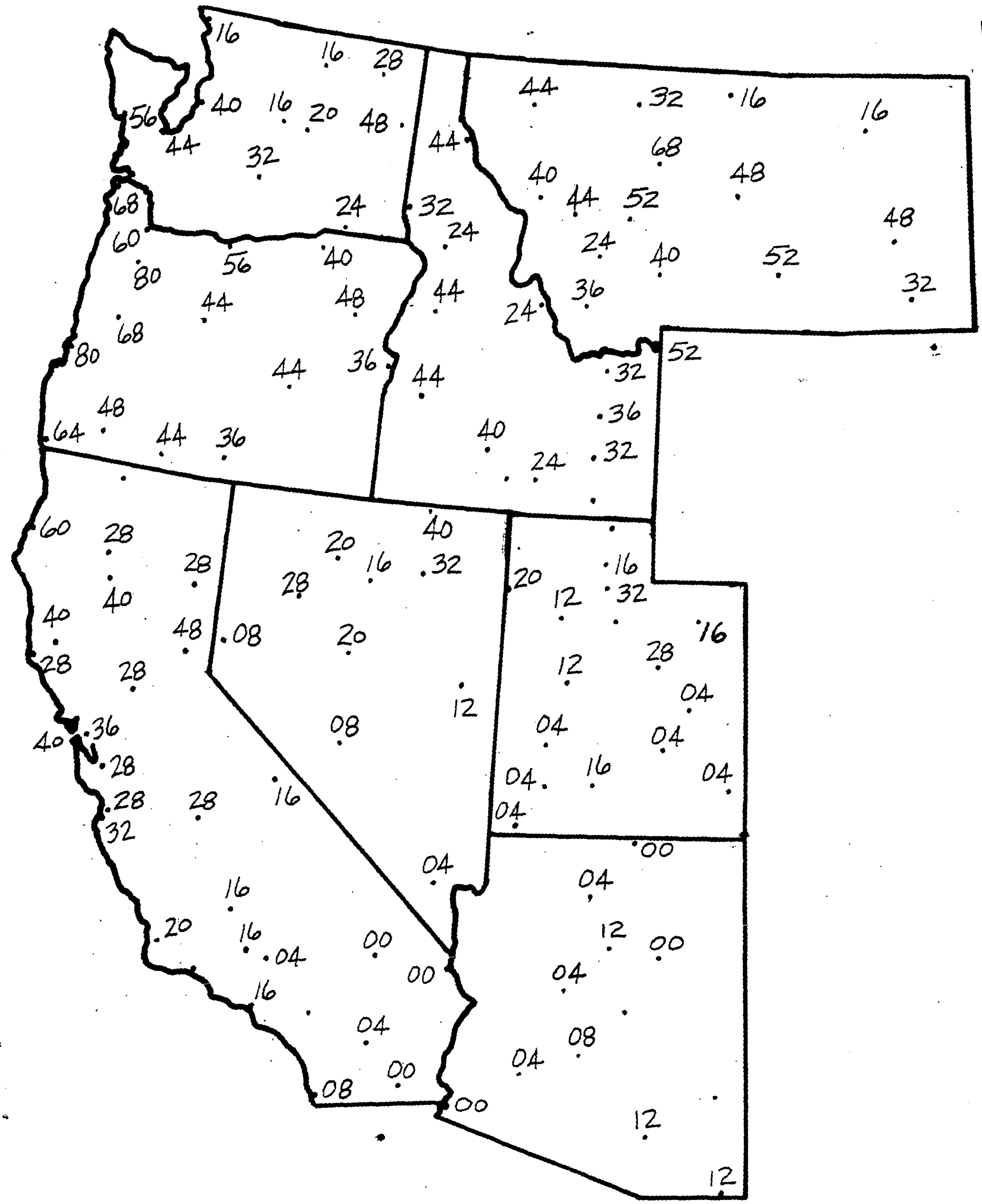
PERCENT FREQUENCY OF PRECIPITATION OCCURRENCE WITH
500-MB WINTER TYPE 11

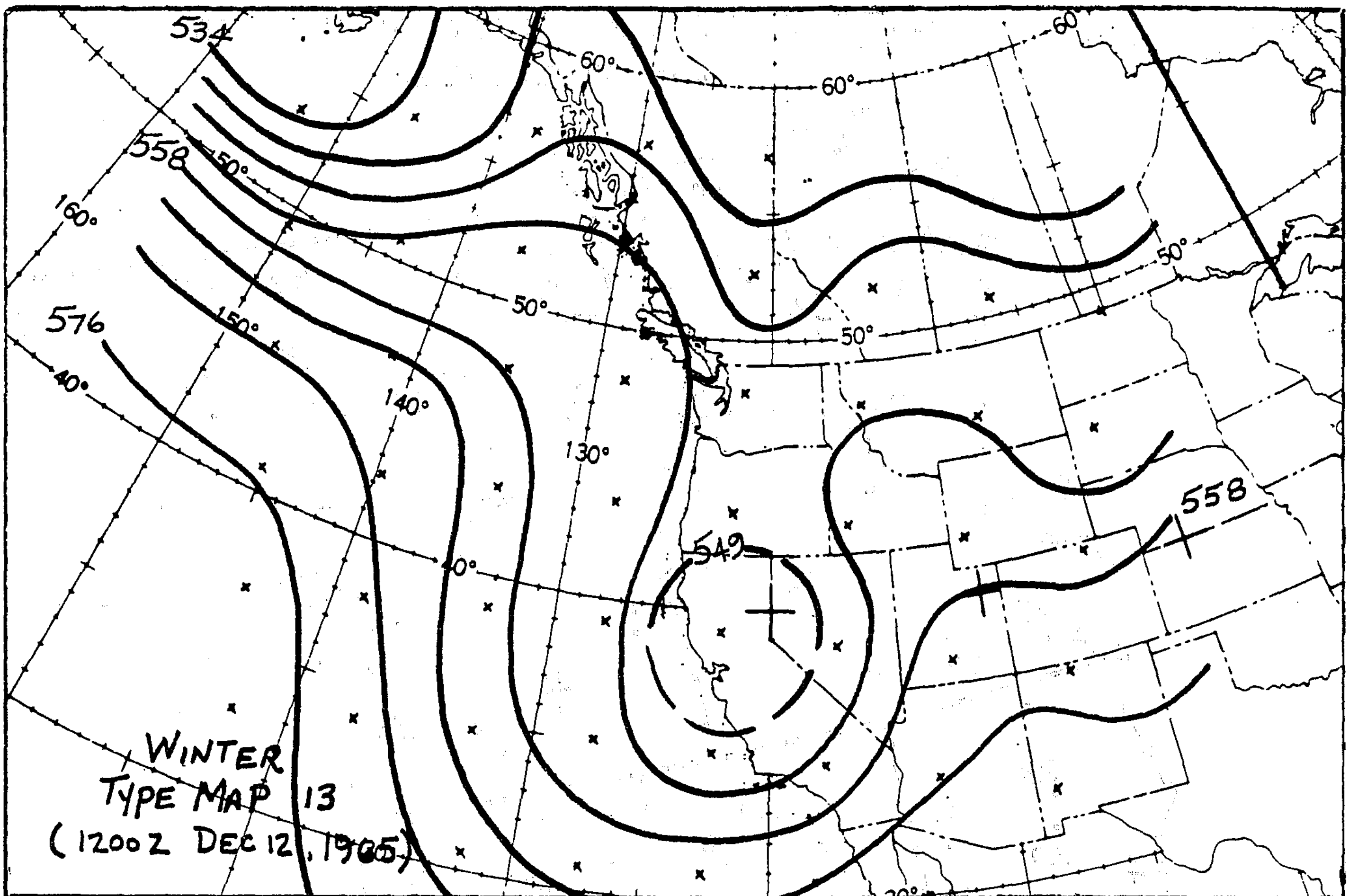


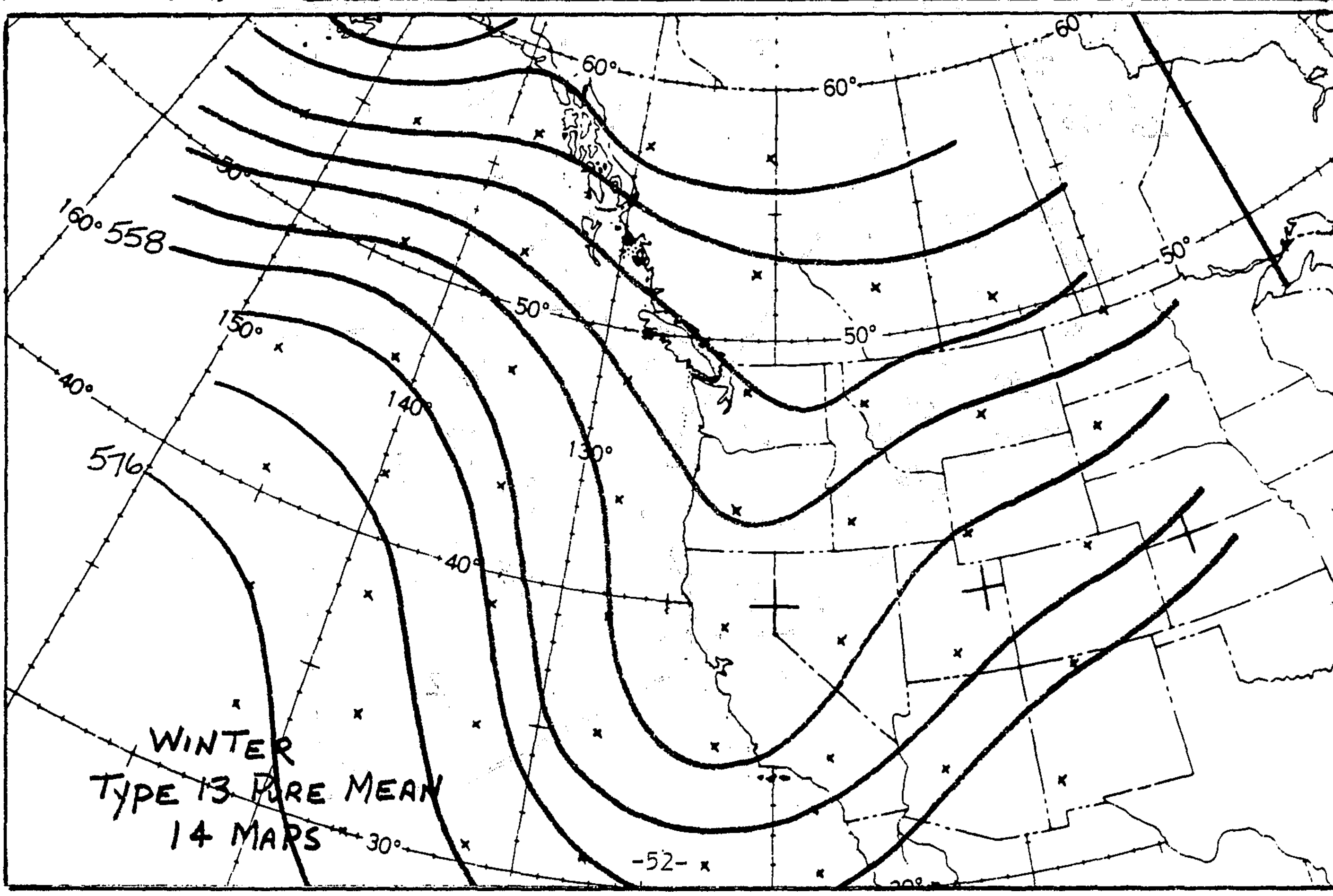

60°
50°
160°
150°
40°
140°
130°
516
570
558
WINTER
TYPE MAP 12
(1200Z FEB 28, 1962)


510
528
60°
50°
160°
150°
40°
140°
130°
558
WINTER
TYPE 12 PURE MEAN
26 MAPS
30°
-50-

PERCENT FREQUENCY OF PRECIPITATION OCCURRENCE WITH
500-MB WINTER TYPE 12

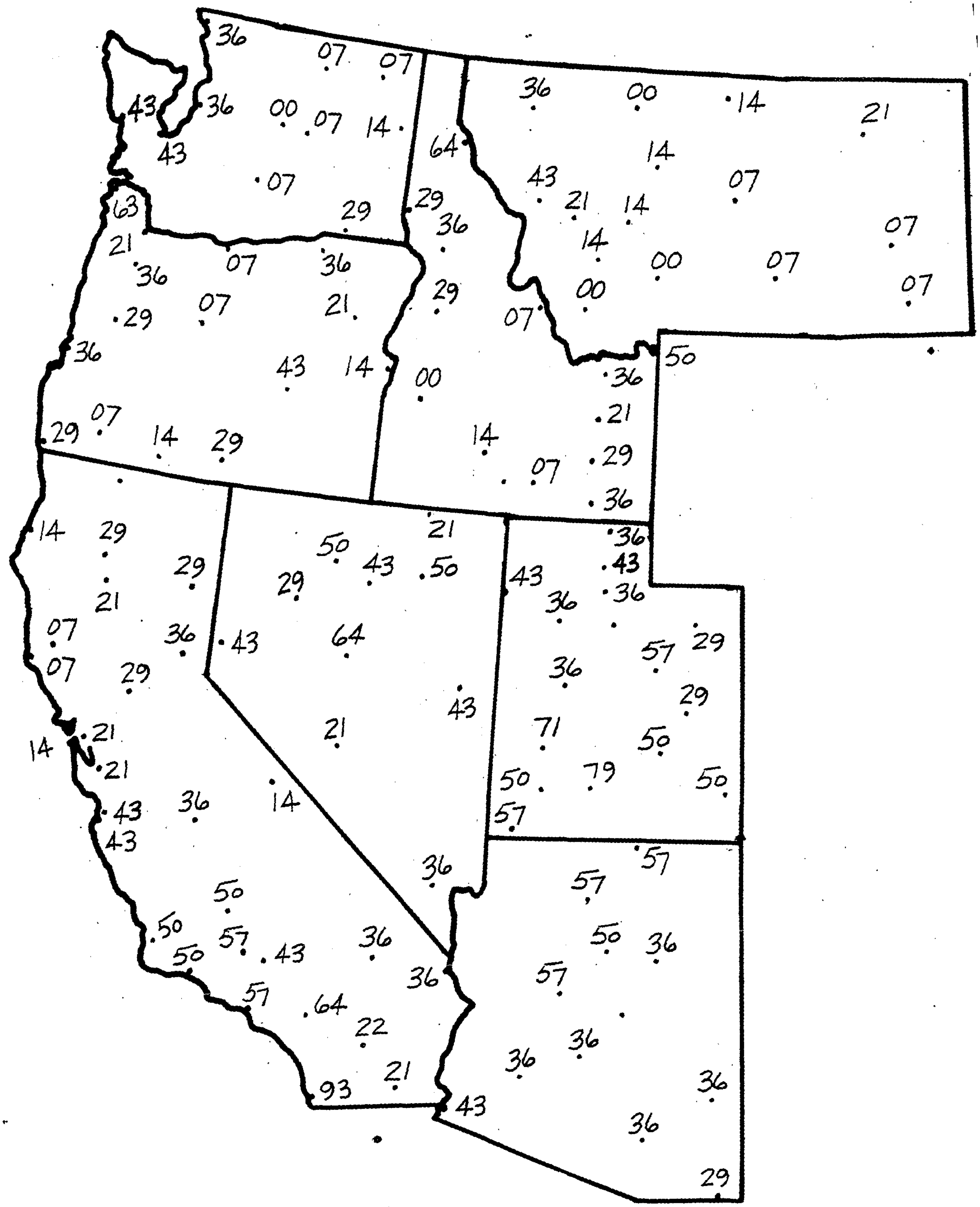


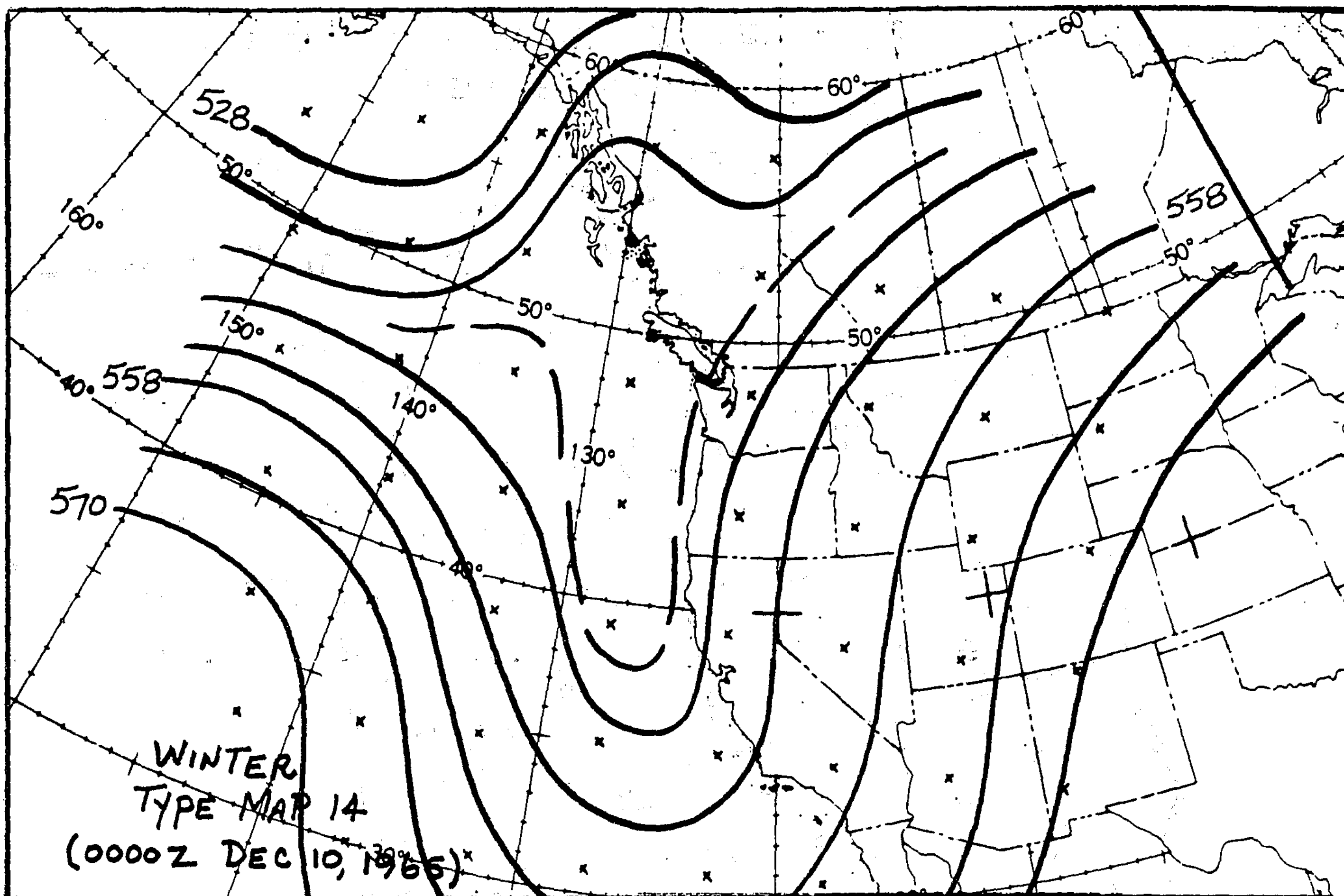

534
558
576
549
558
60°
50°
40°
160°
150°
140°
130°
WINTER
TYPE MAP 13
(1200Z DEC 12, 1965)

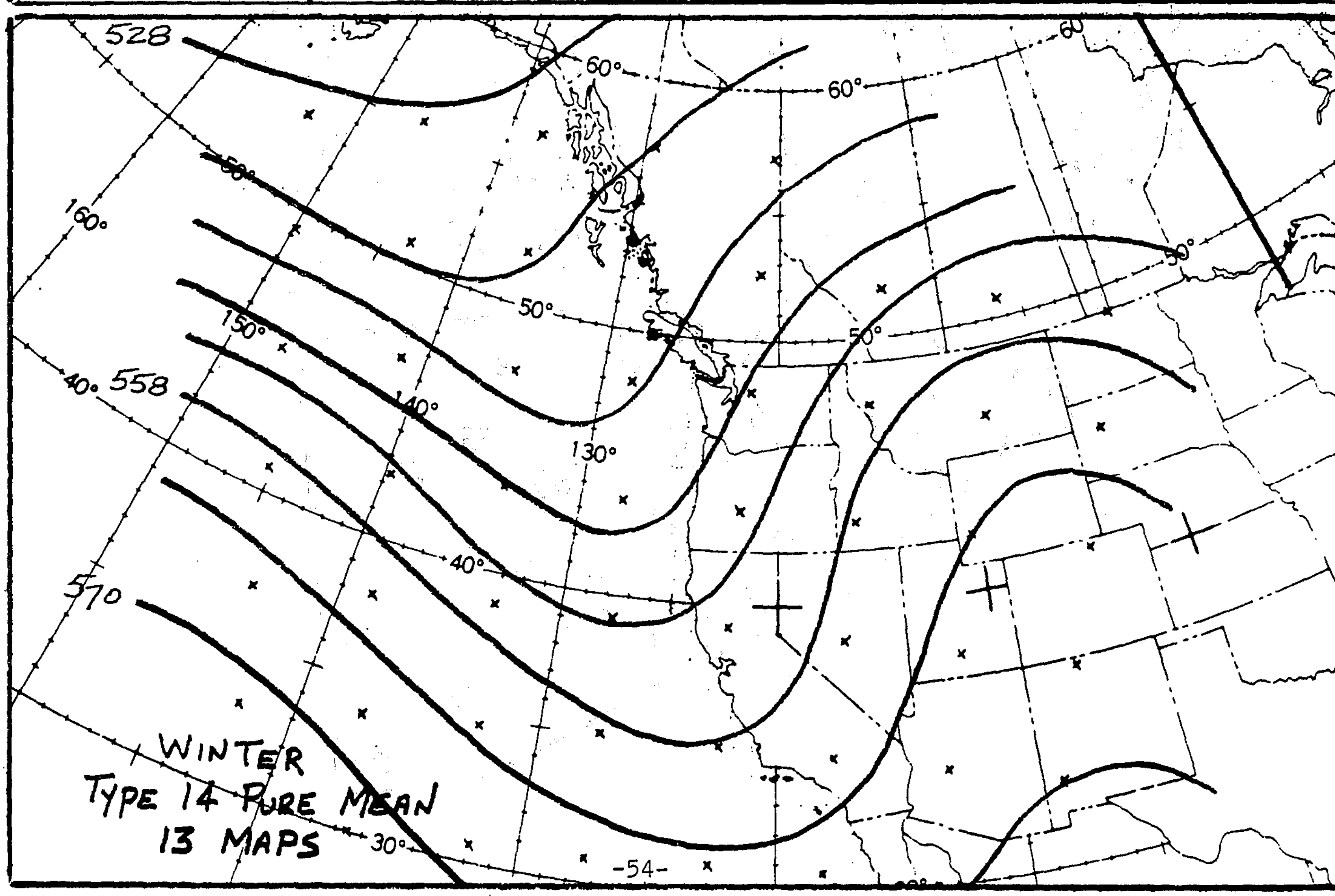

558
576
60°
50°
40°
30°
160°
150°
140°
130°
-52-
WINTER
TYPE 13 PURE MEAN
14 MAPS

PERCENT FREQUENCY OF PRECIPITATION OCCURRENCE WITH

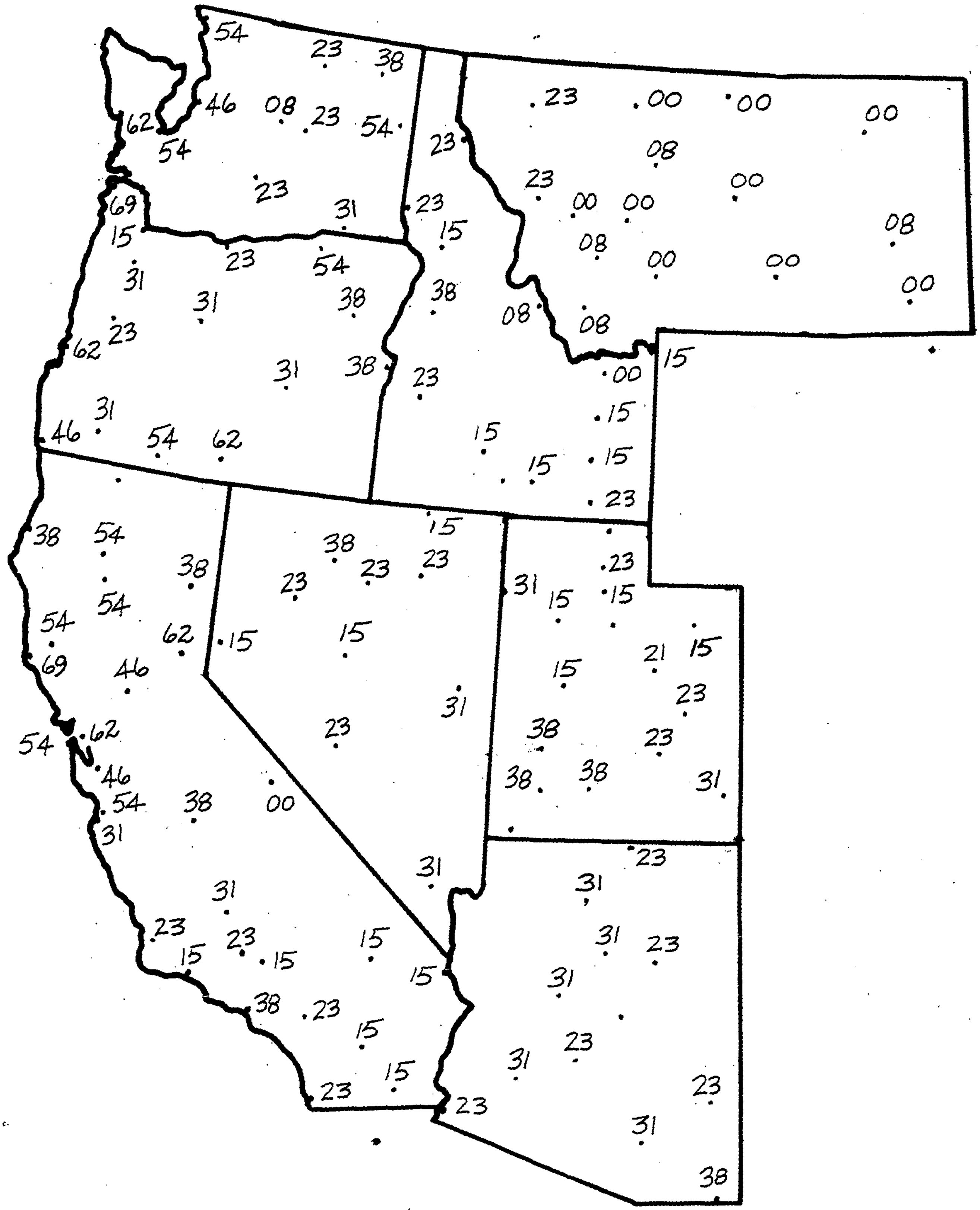
500-MB WINTER TYPE 13

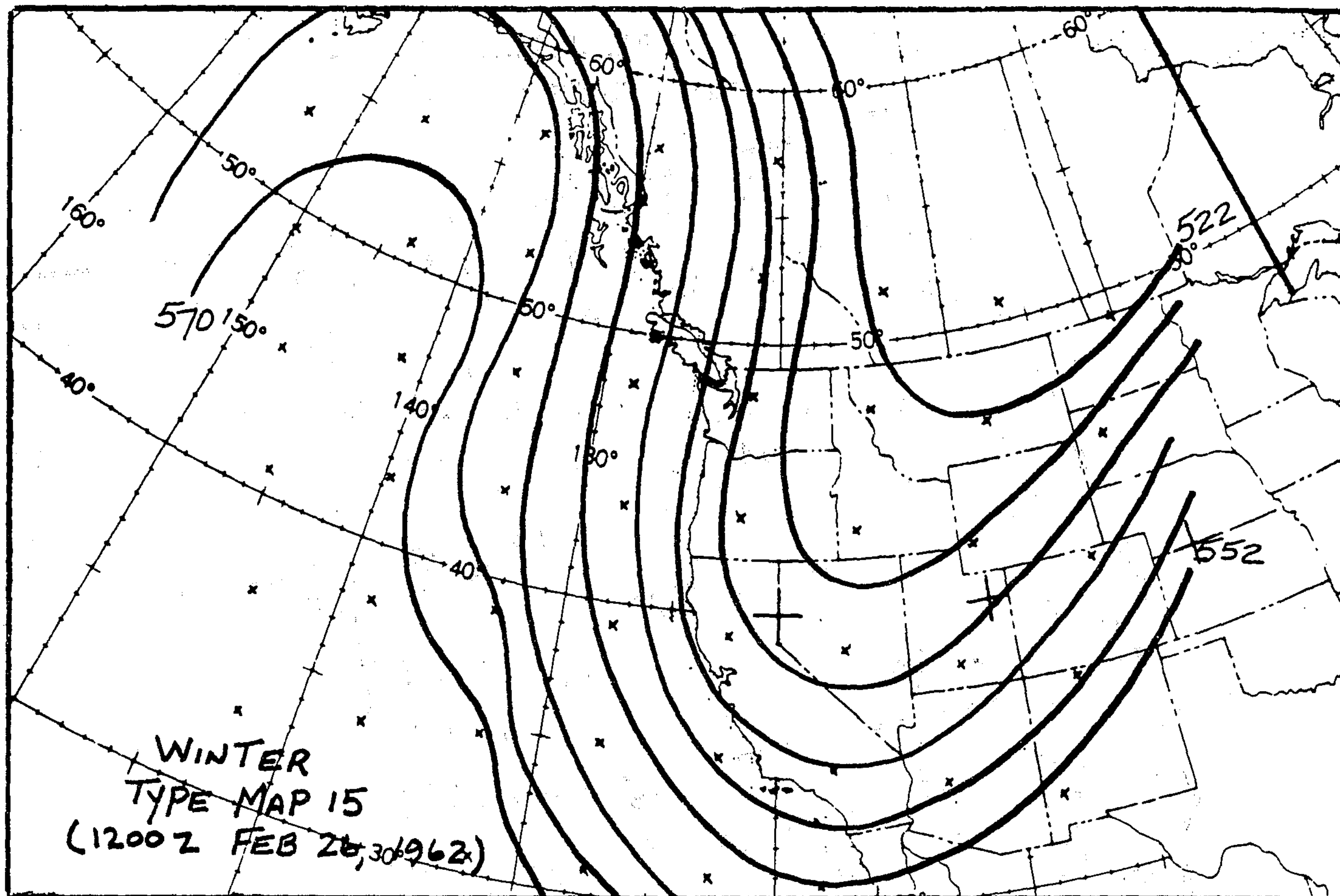


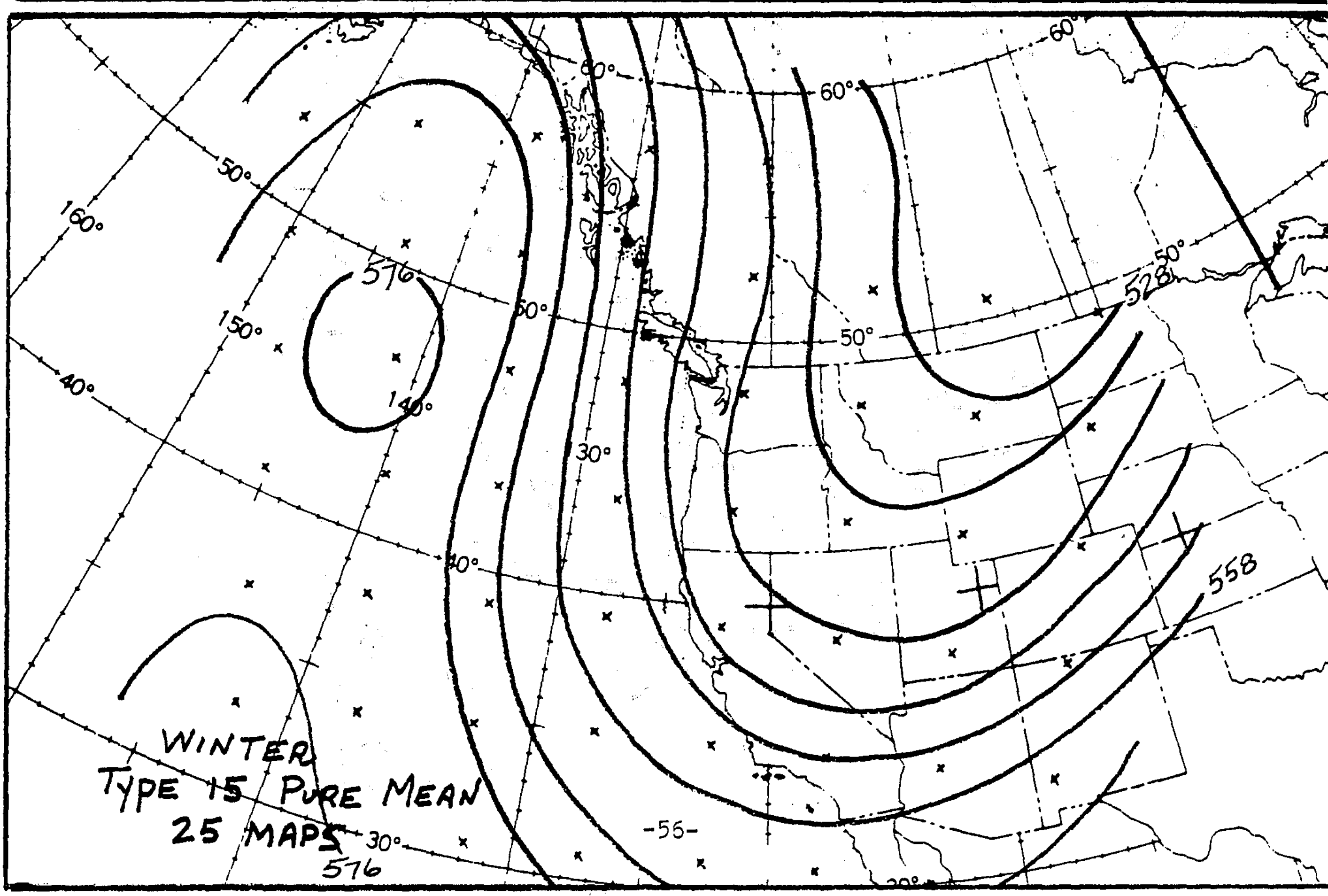

528
558
570
60°
50°
40°
30°
160°
150°
140°
130°
WINTER
TYPE MAP 14
(0000Z DEC 10, 1965)


528
558
570
60°
50°
40°
30°
160°
150°
140°
130°
WINTER
TYPE 14 PURE MEAN
13 MAPS

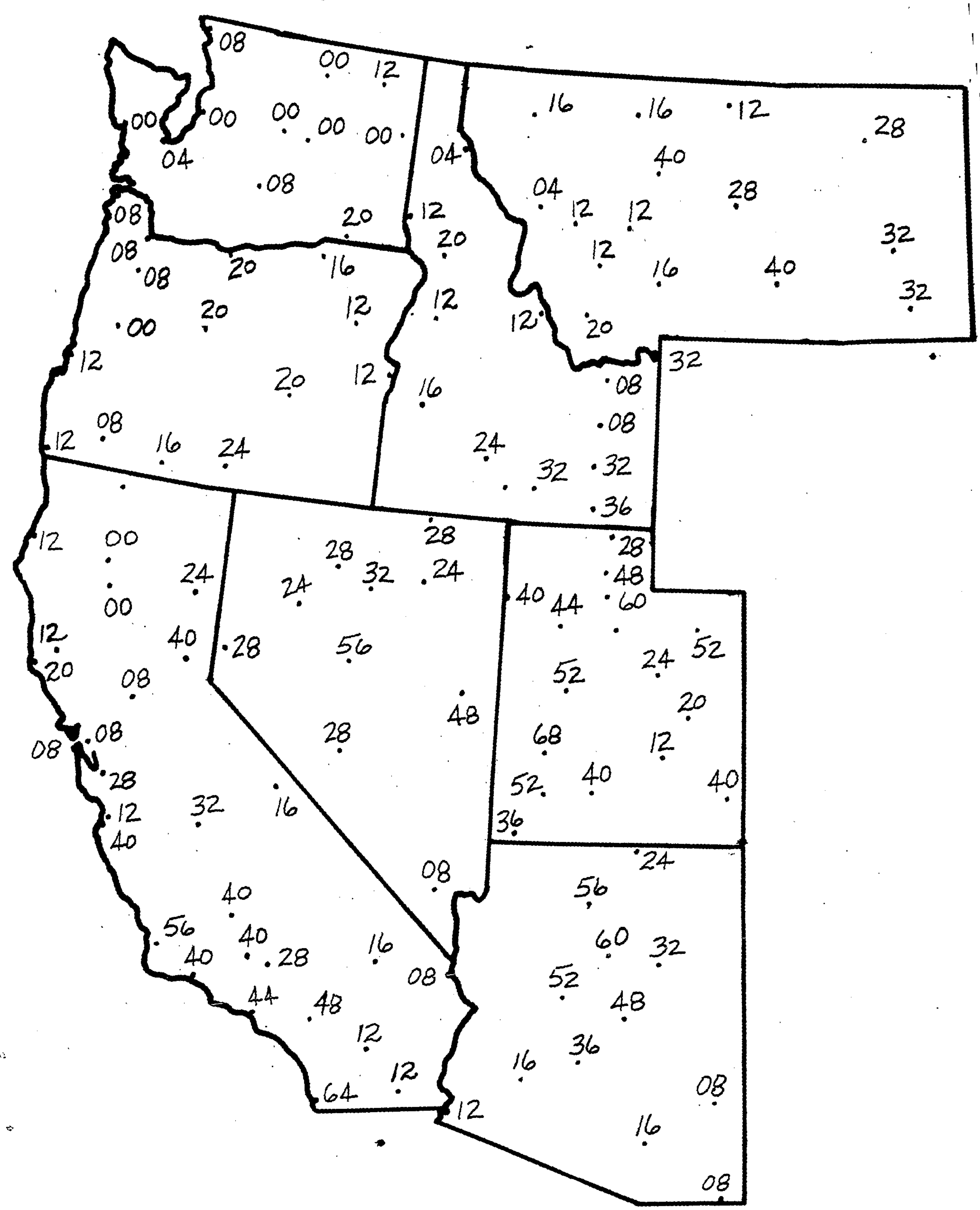
PERCENT FREQUENCY OF PRECIPITATION OCCURRENCE WITH
500-MB WINTER TYPE 14

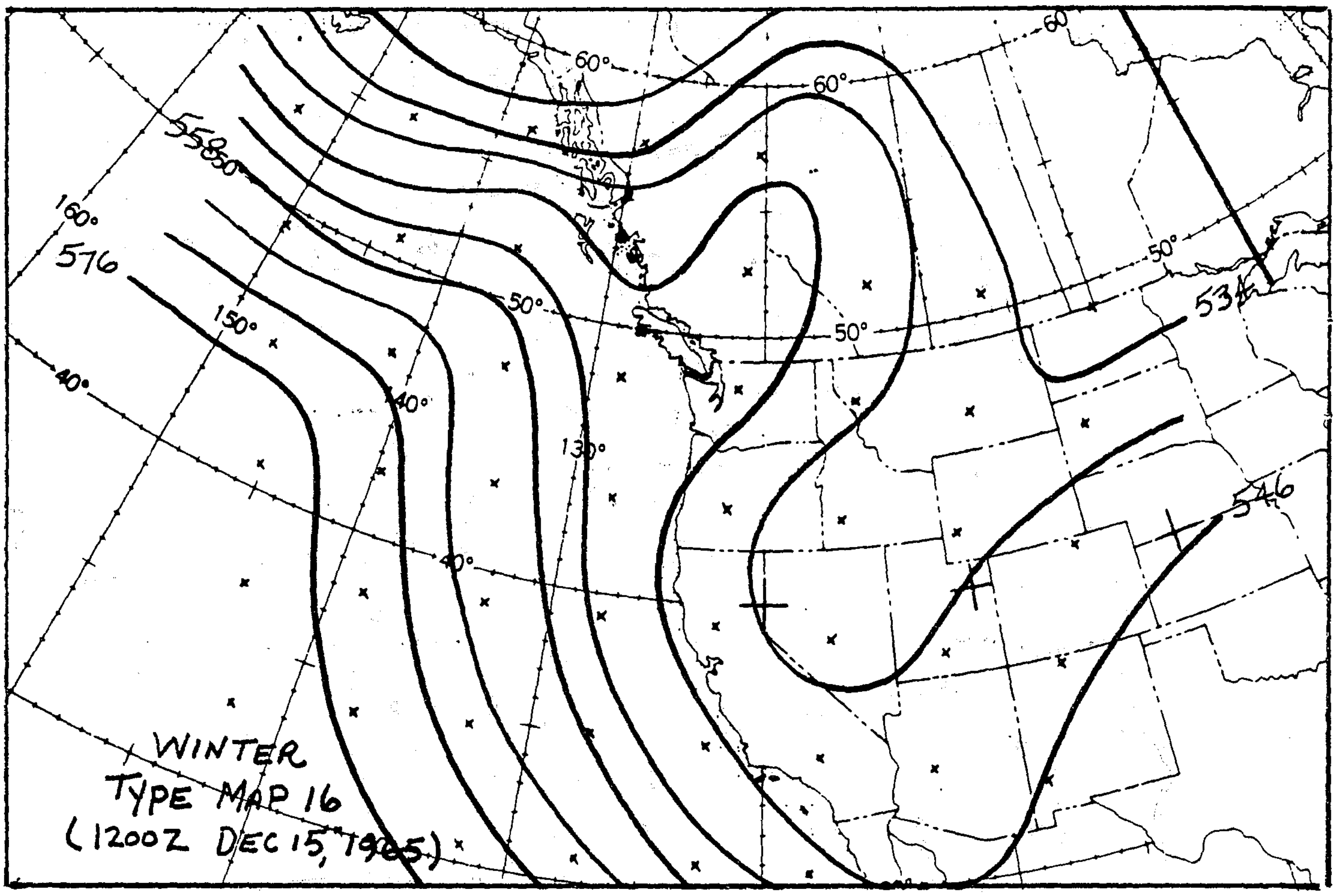


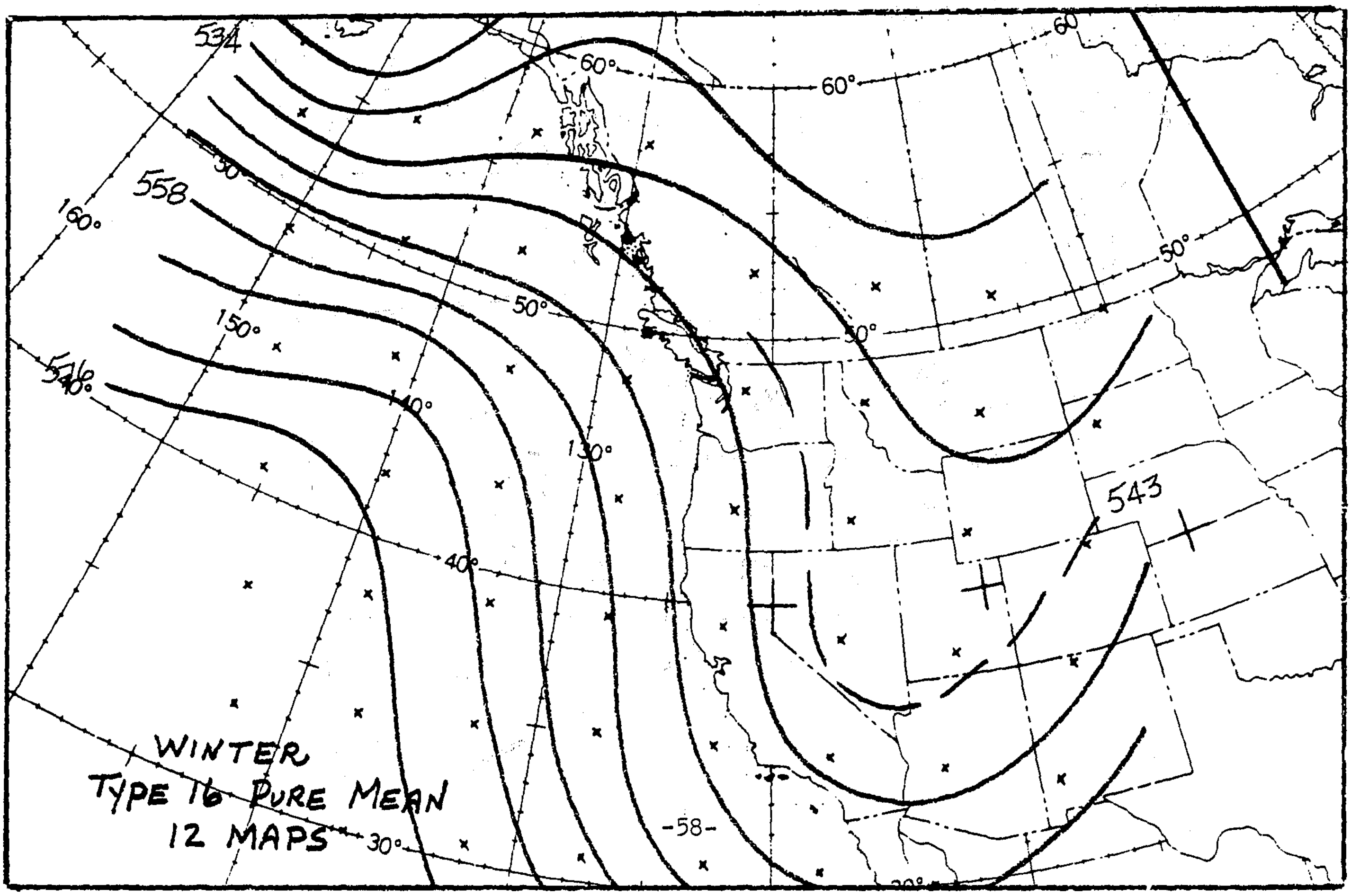

WINTER
TYPE MAP 15
(1200Z FEB 26, 1962)
570
522
552
60°
50°
40°
30°
160°
150°
140°
130°


WINTER
TYPE 15 PURE MEAN
25 MAPS
576
528
558
-56-
60°
50°
40°
30°
160°
150°
140°

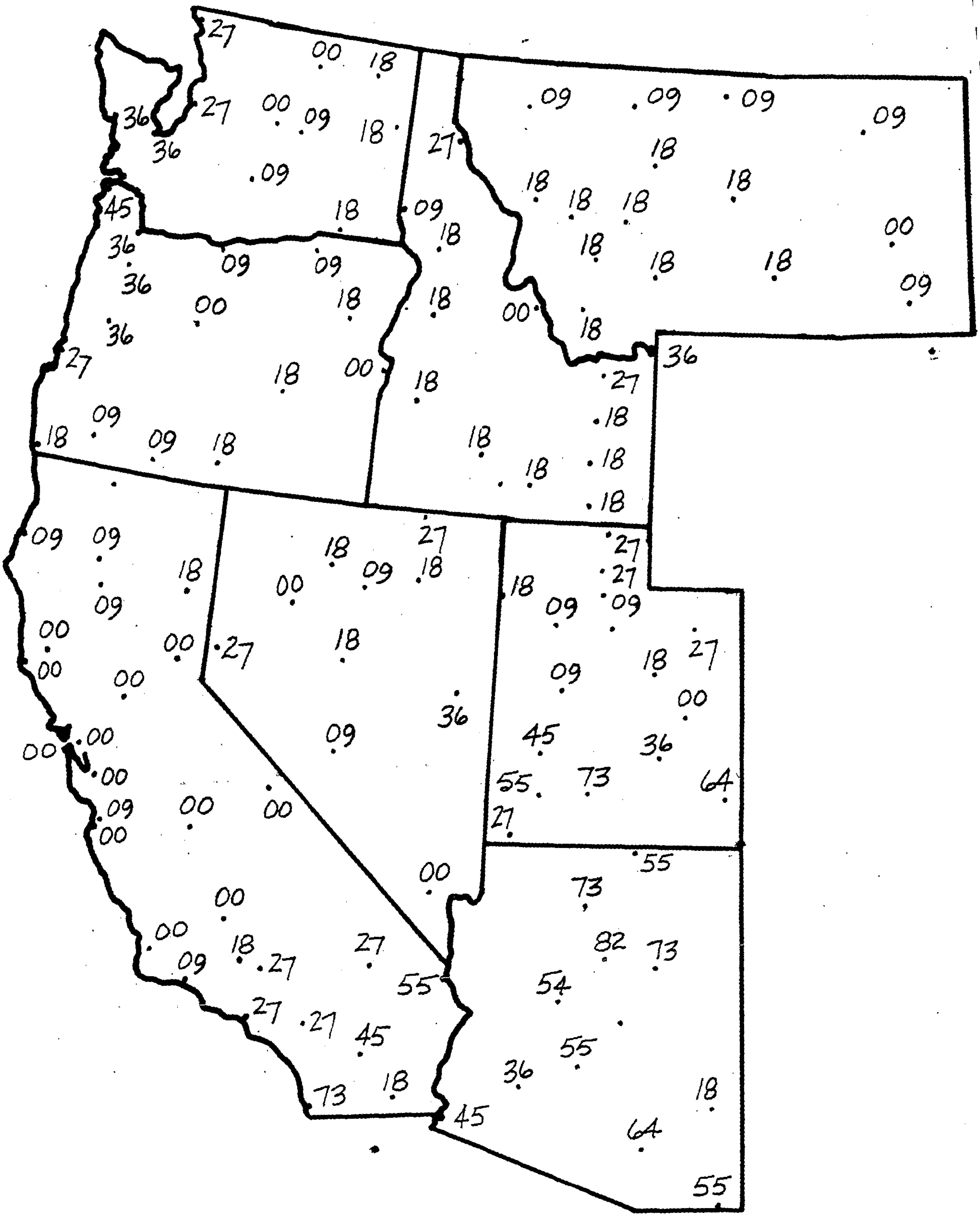
PERCENT FREQUENCY OF PRECIPITATION OCCURRENCE WITH
500-MB WINTER TYPE 15

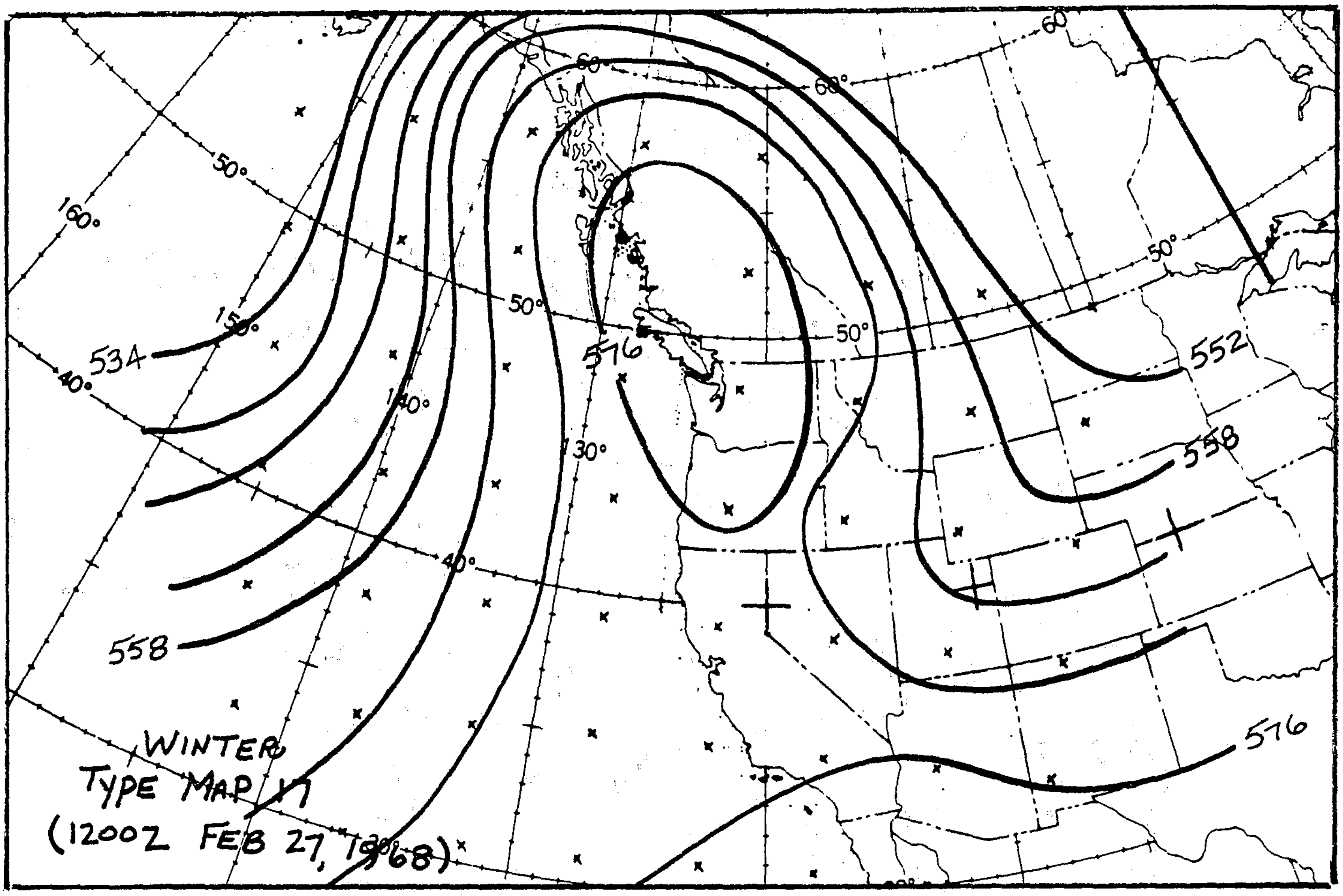



WINTER
TYPE MAP 16
(1200Z DEC 15, 1965)
576
558
534
546

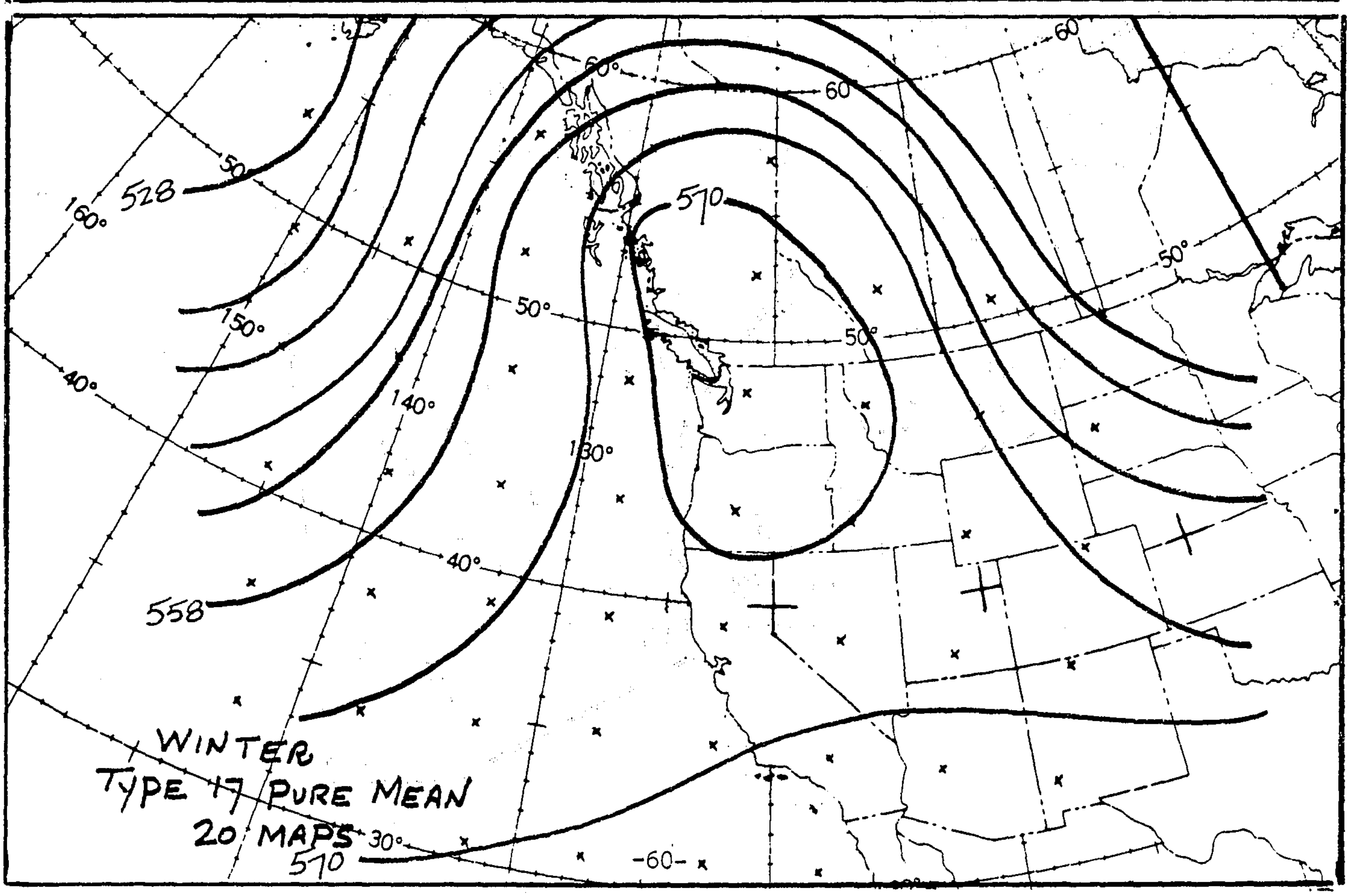

WINTER
TYPE 16 PURE MEAN
12 MAPS
534
558
546
543

PERCENT FREQUENCY OF PRECIPITATION OCCURRENCE WITH
500-MB WINTER TYPE 16



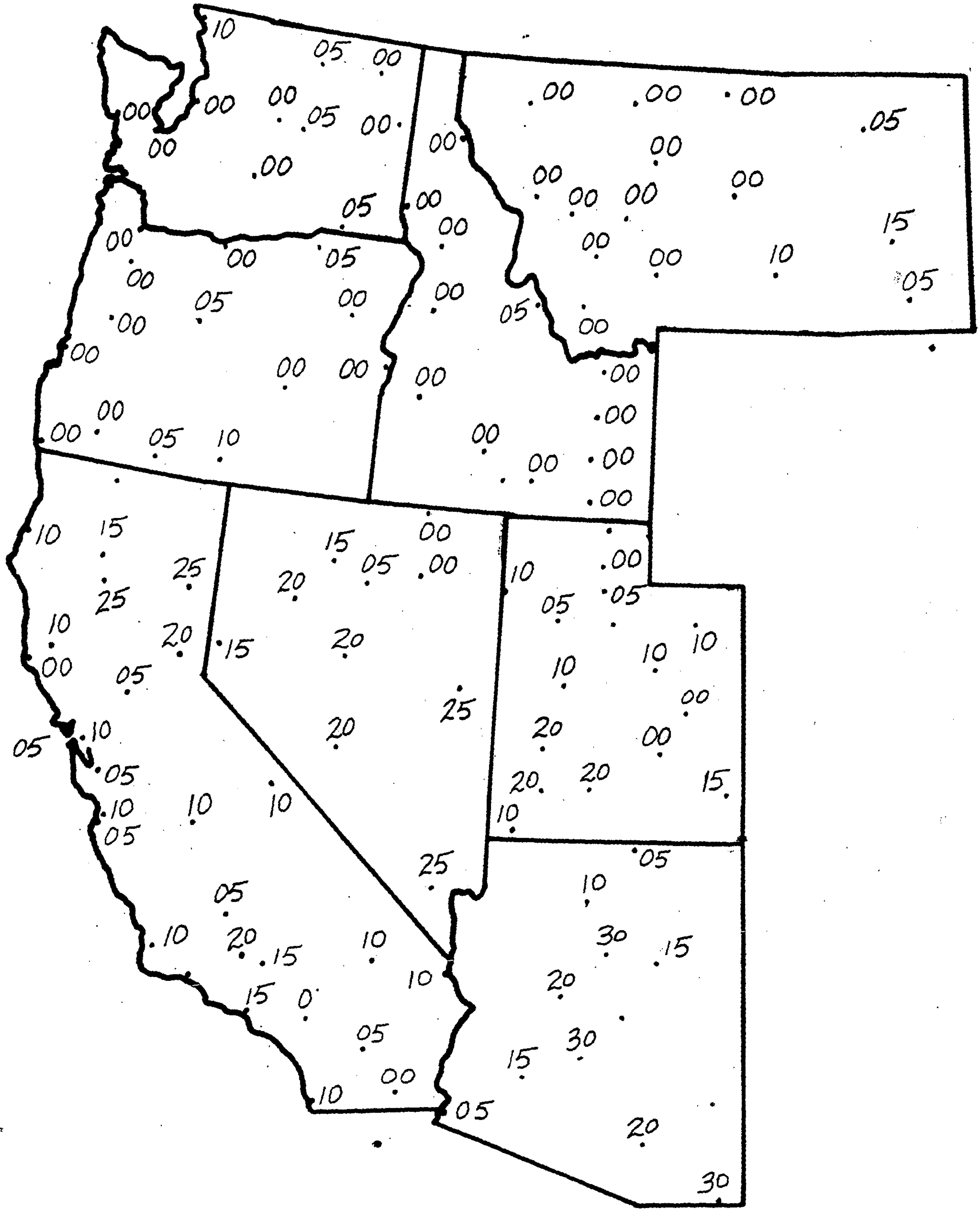


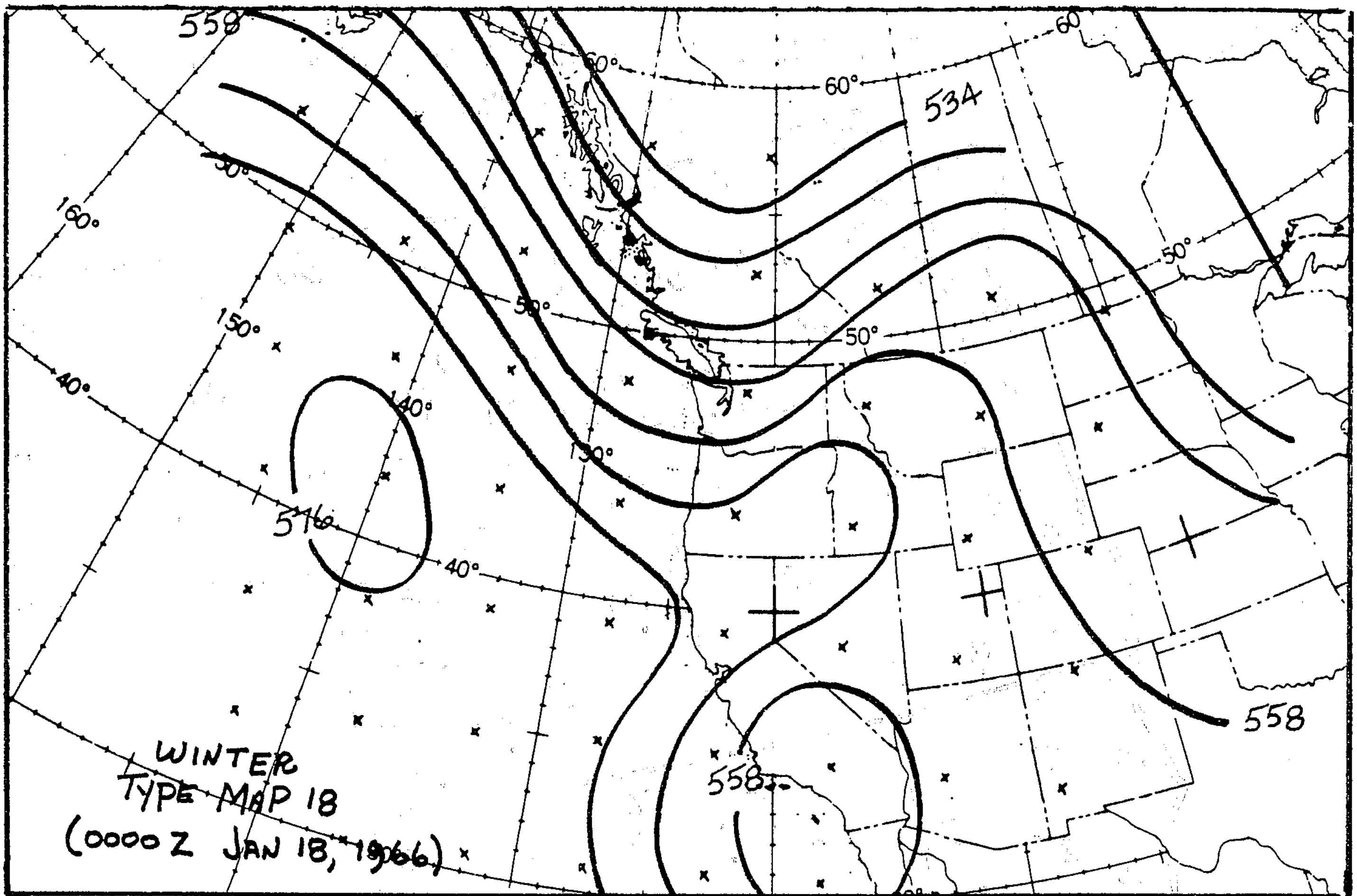
534
552
558
576
576
558
50°
60°
160°
150°
140°
130°
40°
WINTER
TYPE MAP 17
(1200Z FEB 27, 1968)

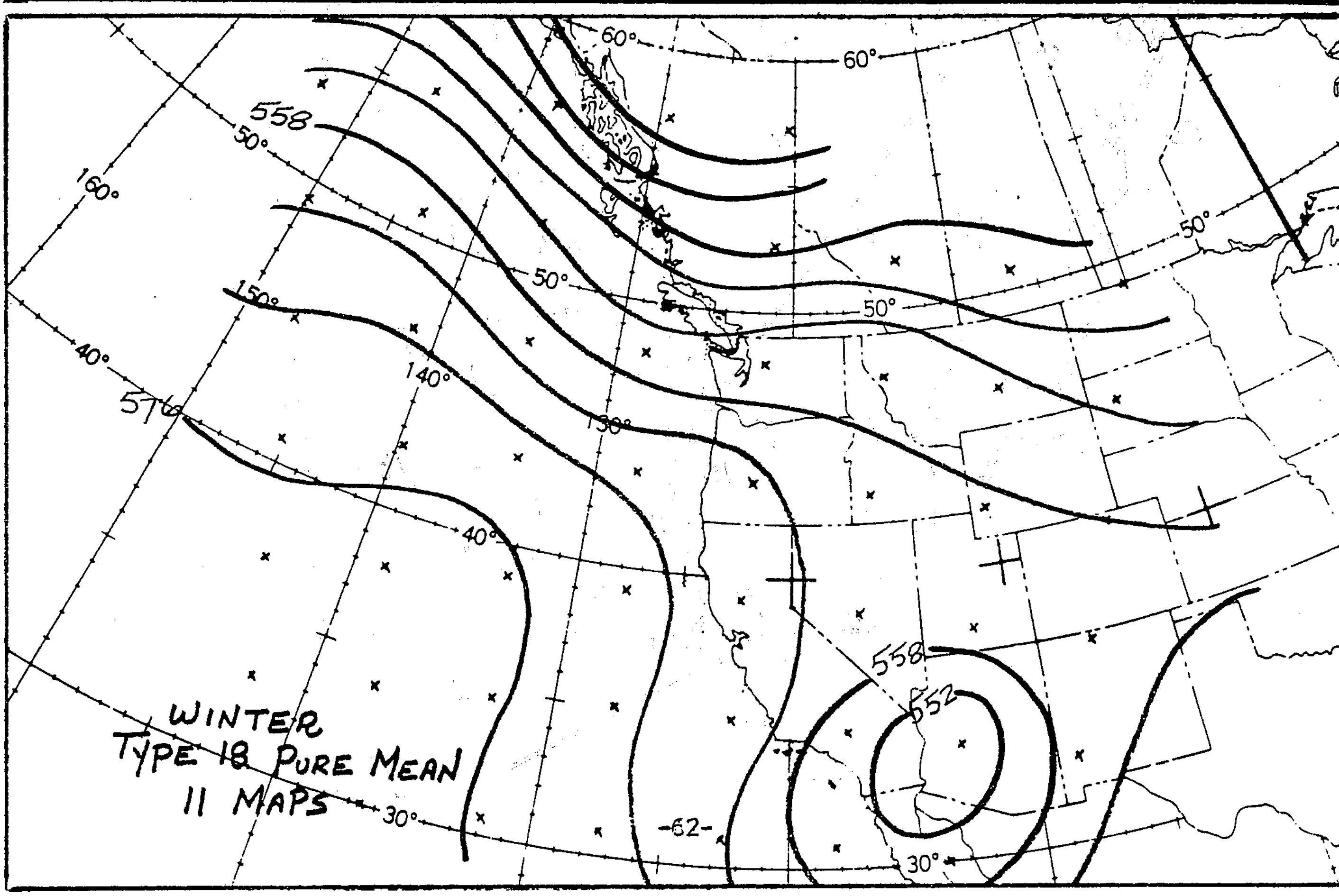


528
570
558
570
50°
60°
160°
150°
140°
130°
40°
30°
-60-
WINTER
TYPE 17 PURE MEAN
20 MAPS

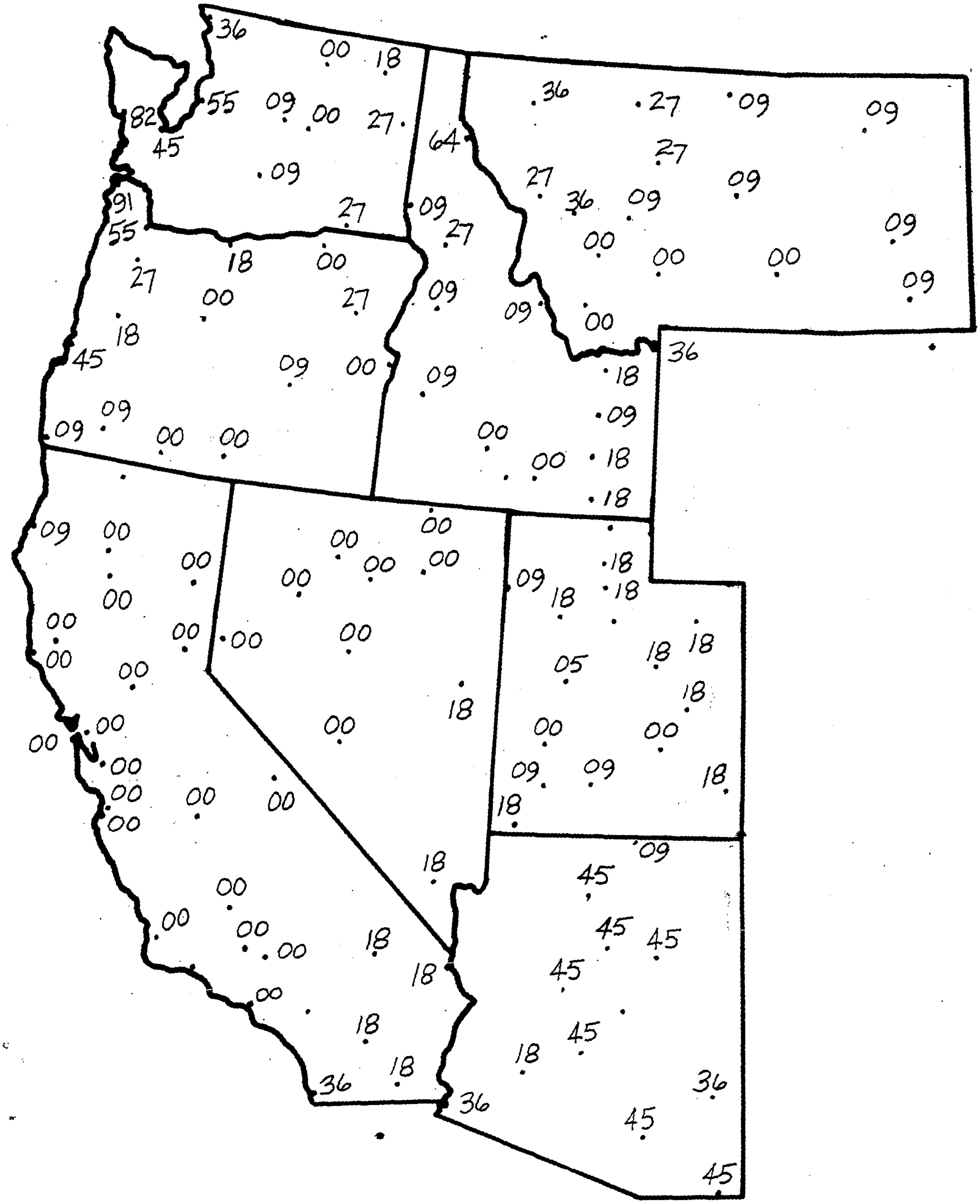
PERCENT FREQUENCY OF PRECIPITATION OCCURRENCE WITH
500-MB WINTER TYPE 17

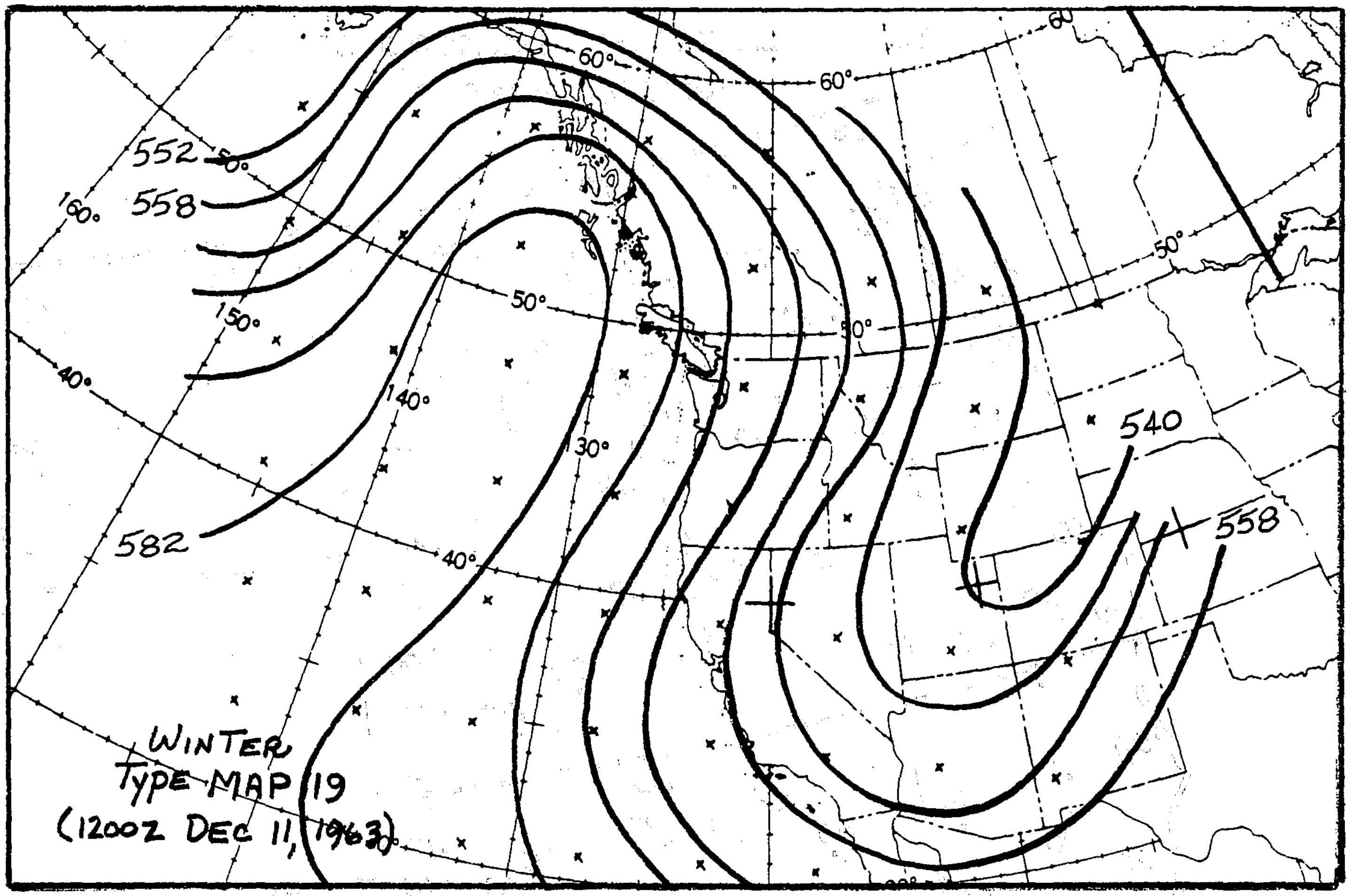



558
534
60°
50°
40°
160°
150°
140°
130°
546
558
558
WINTER
TYPE MAP 18
(0000 Z JAN 18, 1966)

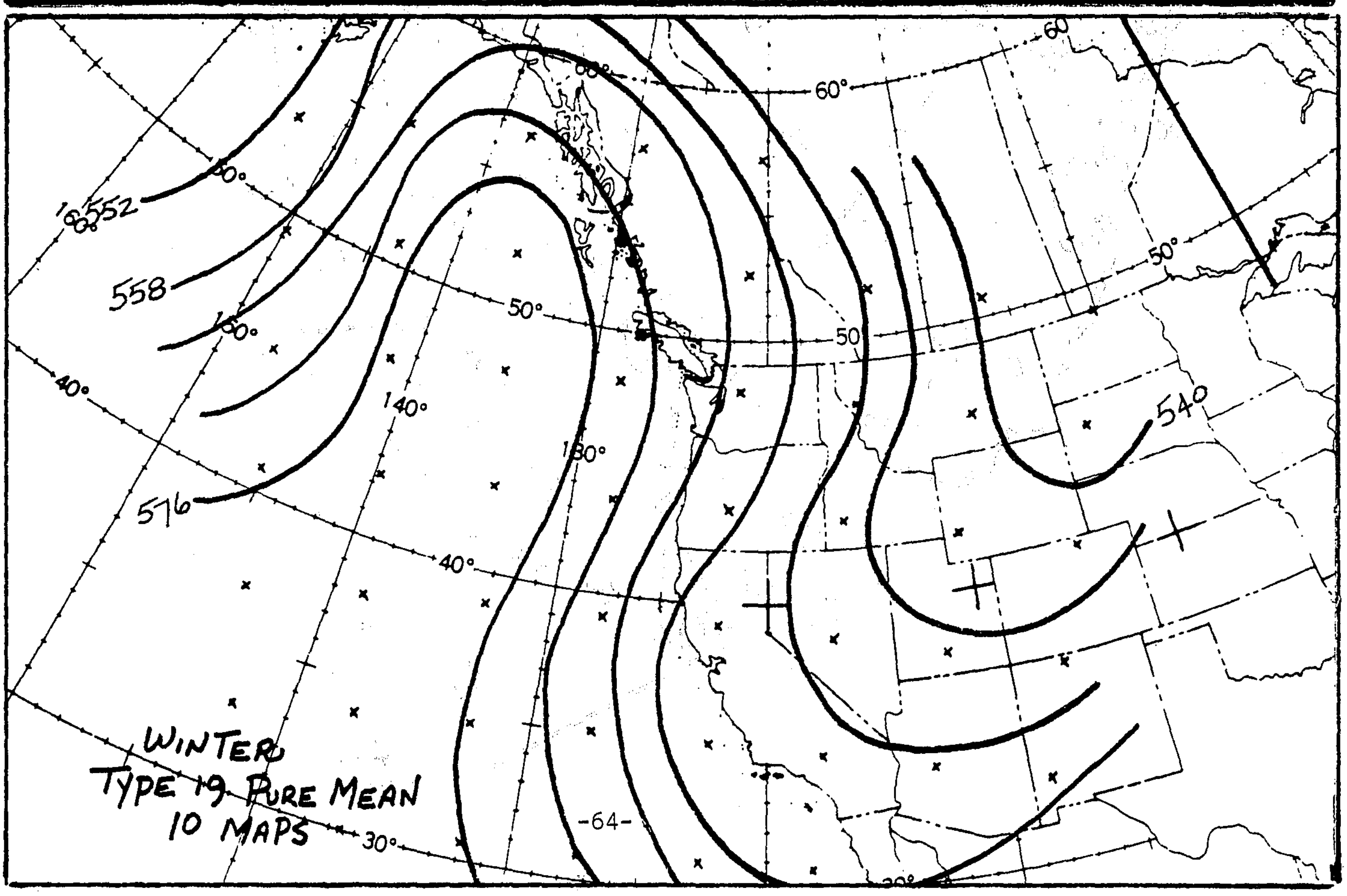

558
60°
50°
40°
30°
160°
150°
140°
130°
576
558
552
-62-
WINTER
TYPE 18 PURE MEAN
11 MAPS

PERCENT FREQUENCY OF PRECIPITATION OCCURRENCE WITH
500-MB WINTER TYPE 18





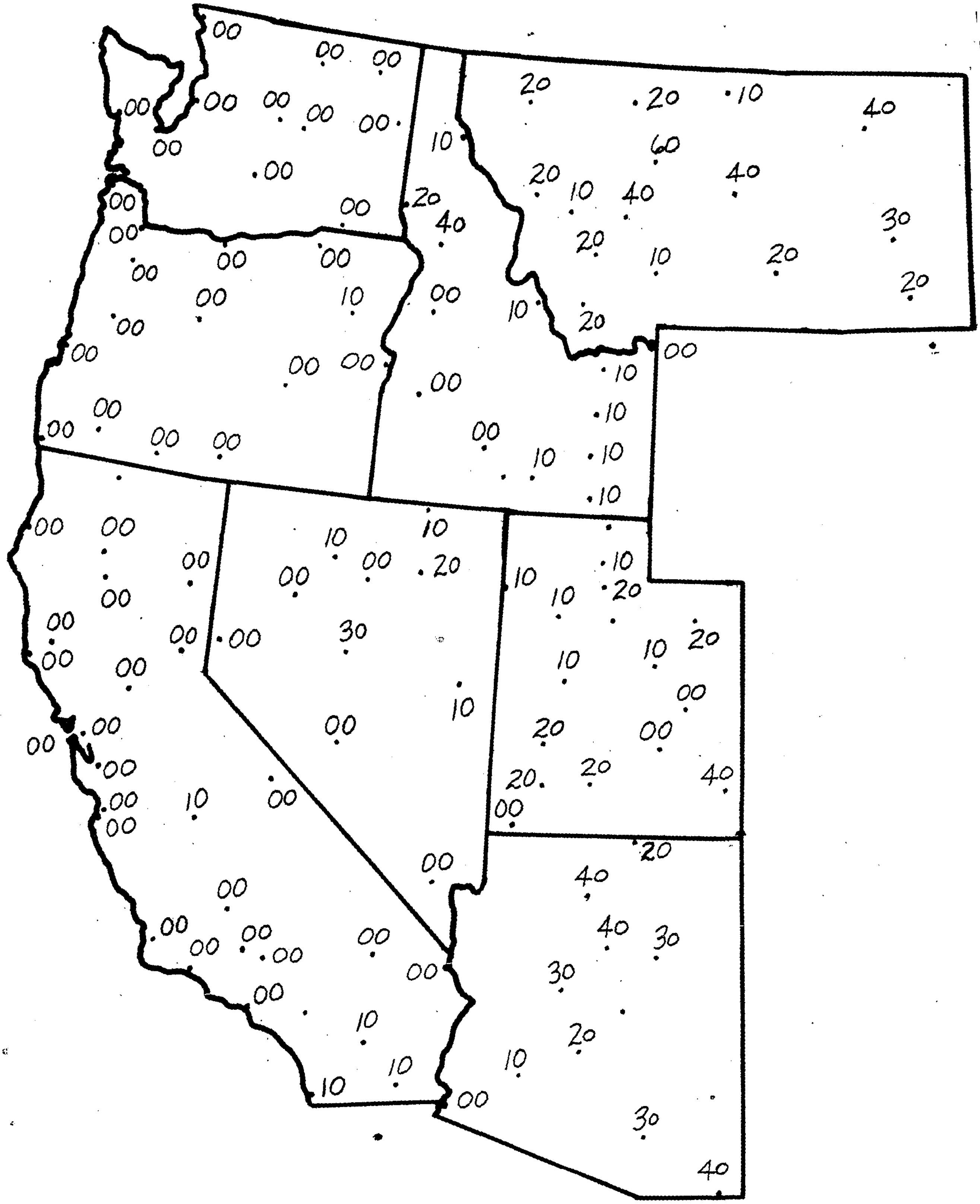
WINTER
TYPE MAP 19
(1200Z DEC 11, 1963)

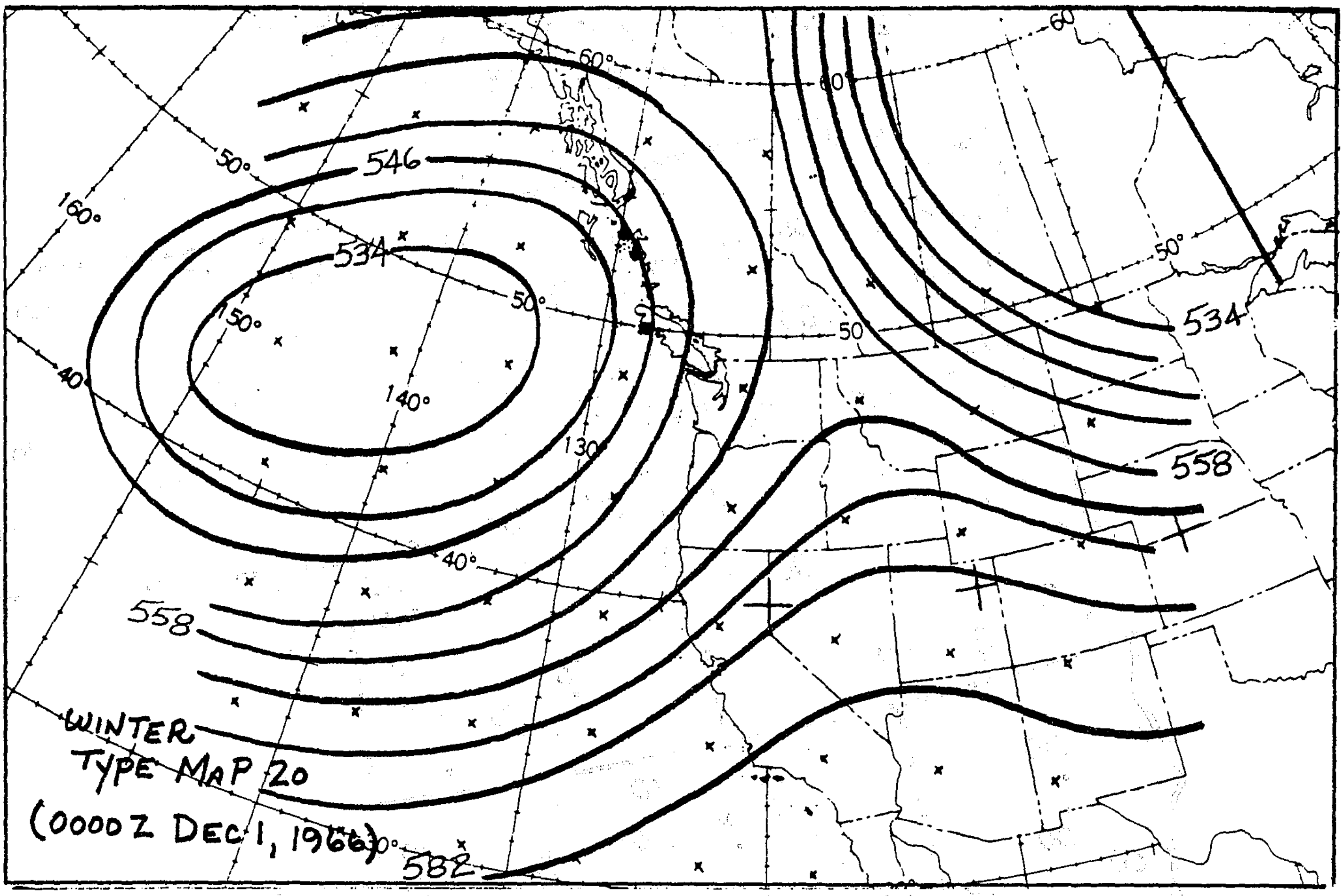


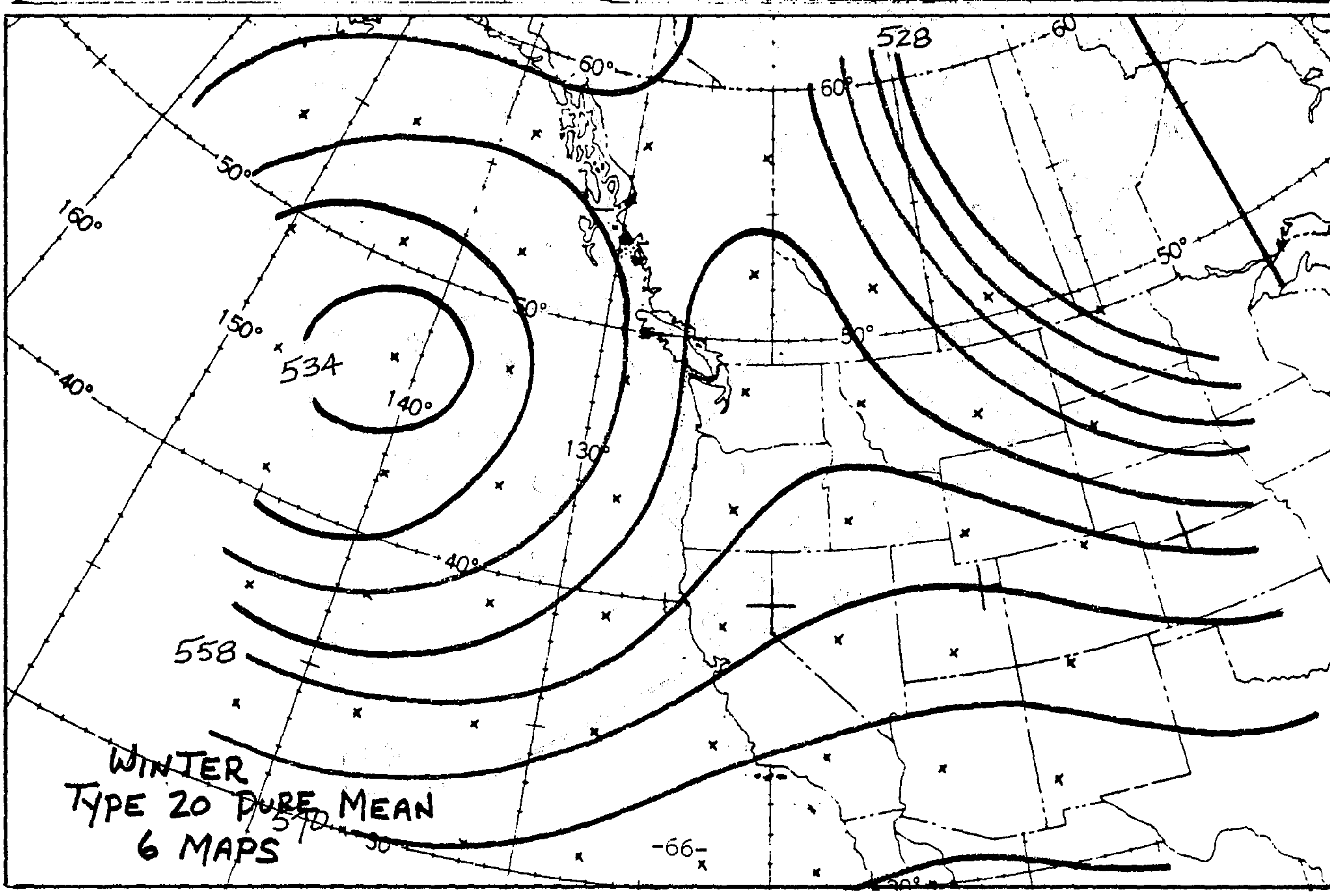
WINTER
TYPE 19 PURE MEAN
10 MAPS

PERCENT FREQUENCY OF PRECIPITATION OCCURRENCE WITH

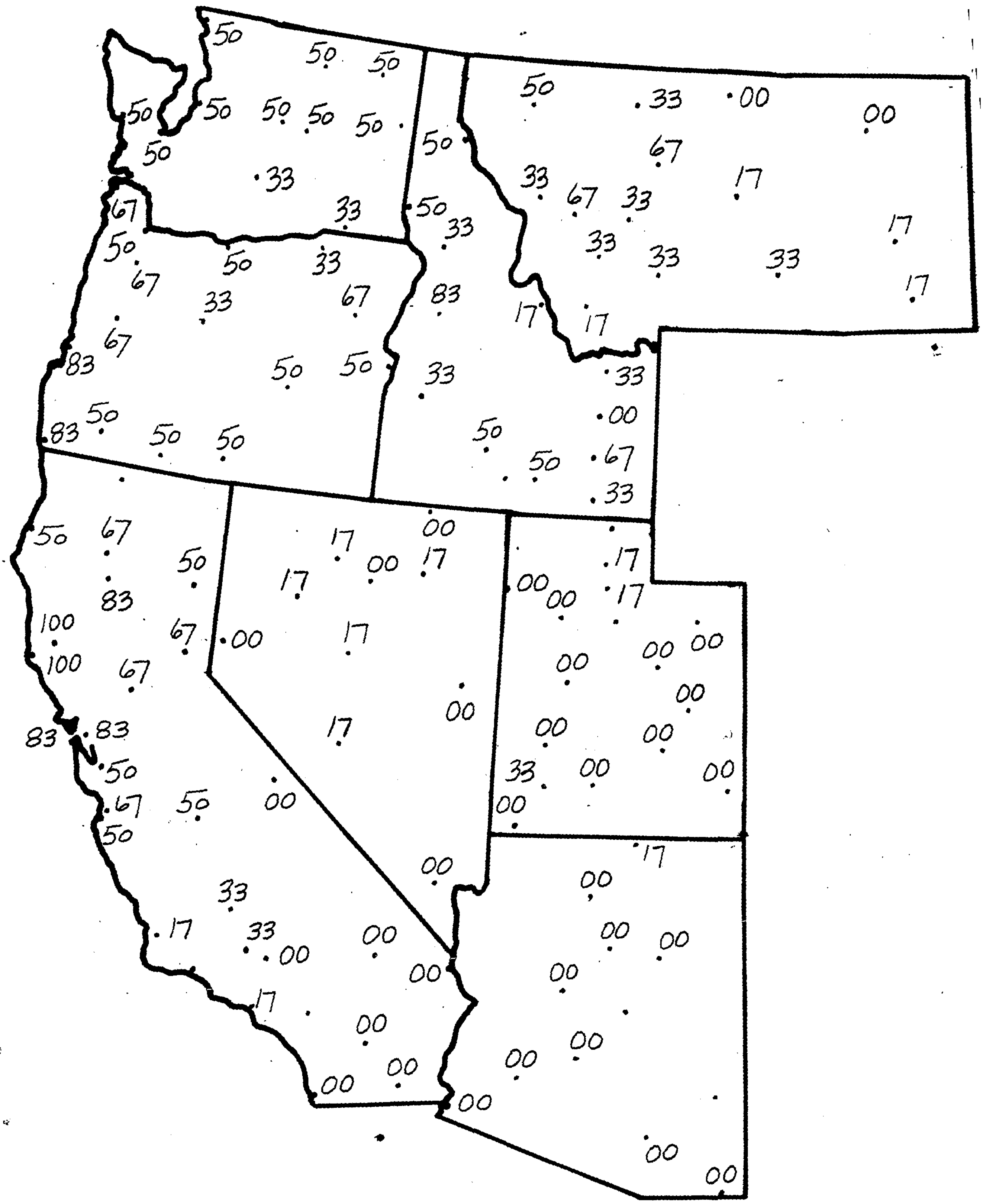
500-MB WINTER TYPE 19

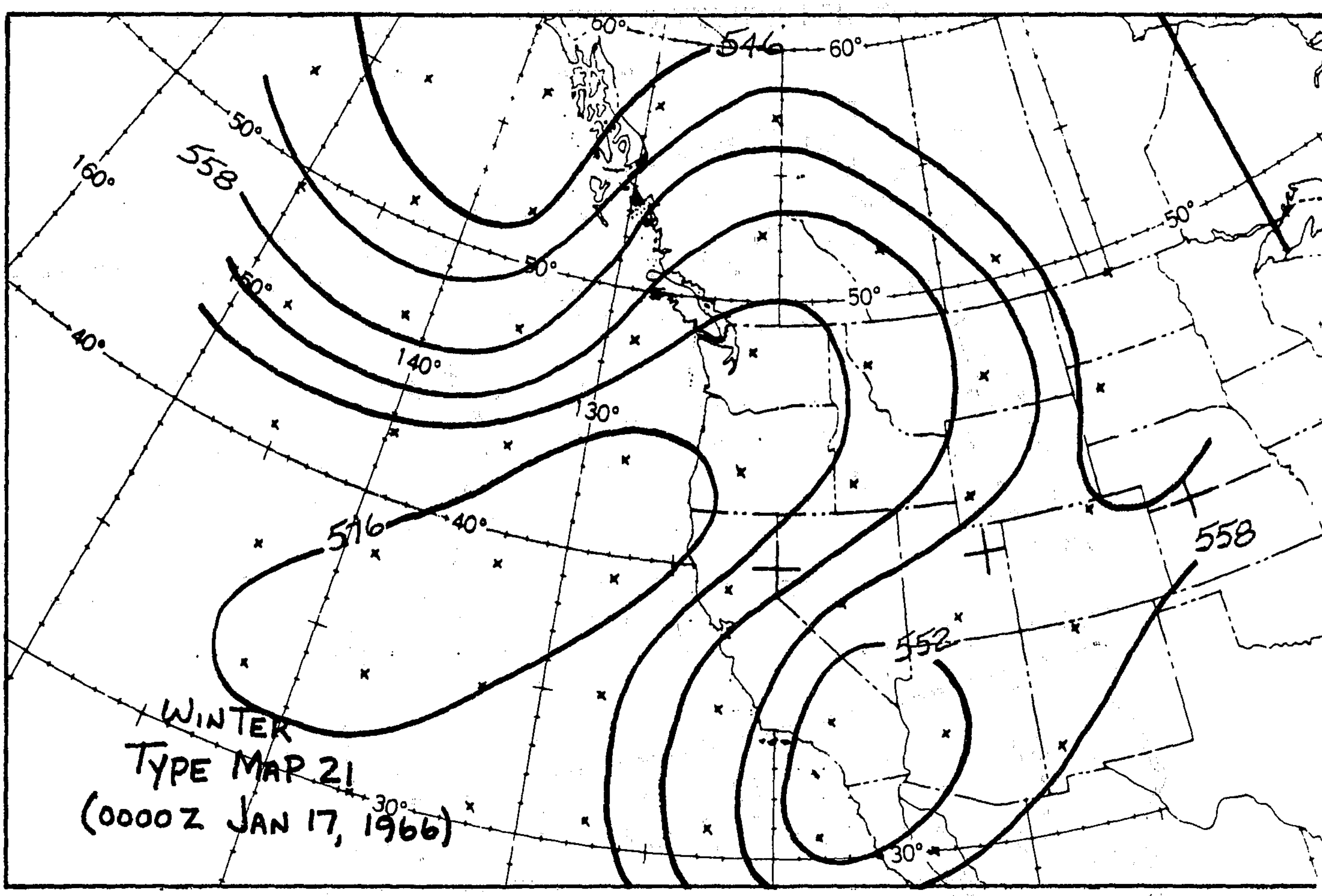


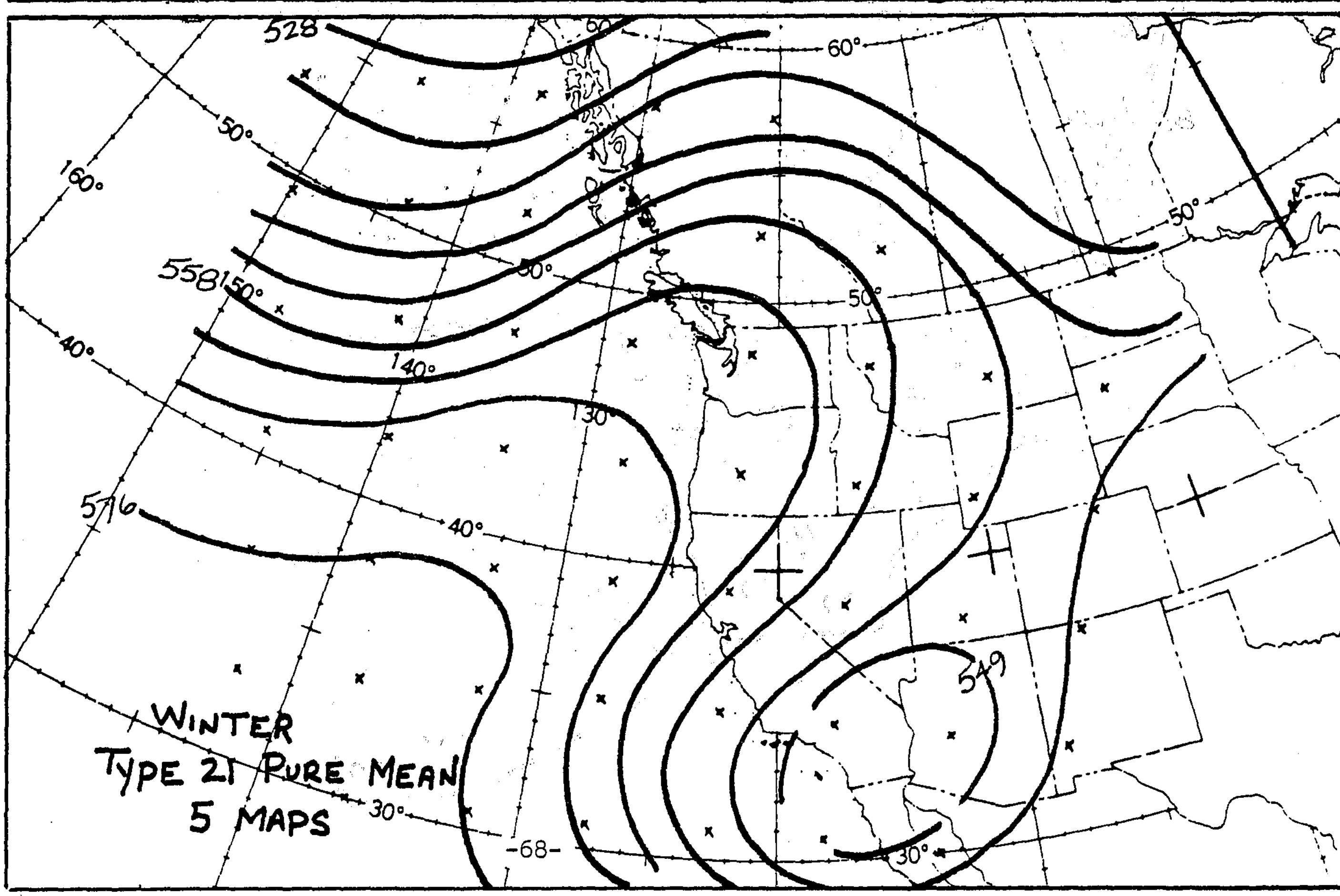

546
534
558
534
558
582
WINTER
TYPE MAP 20
(0000 Z DEC 1, 1966)


528
534
558
WINTER
TYPE 20 PURE MEAN
6 MAPS

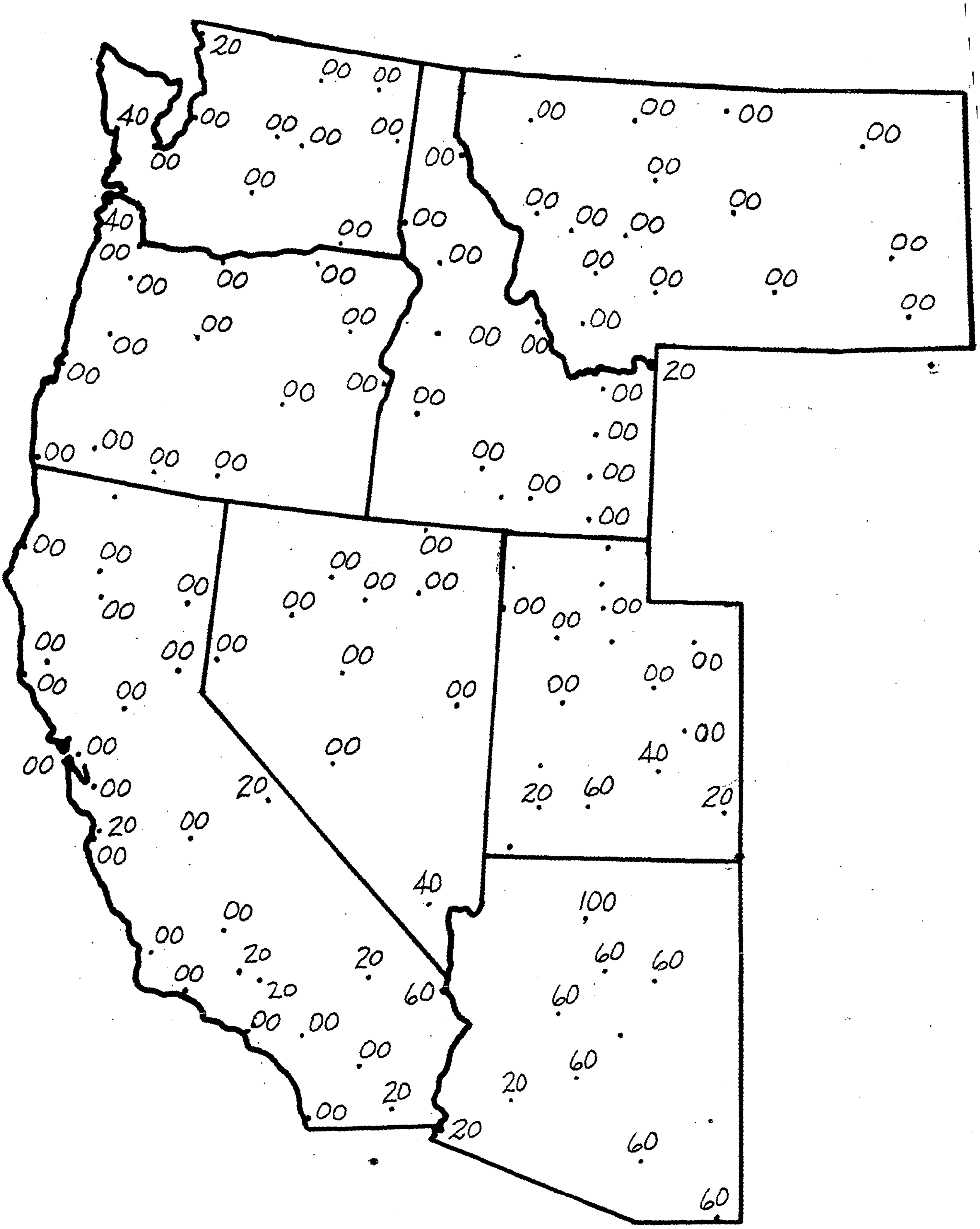
PERCENT FREQUENCY OF PRECIPITATION OCCURRENCE WITH
500-MB WINTER TYPE 20

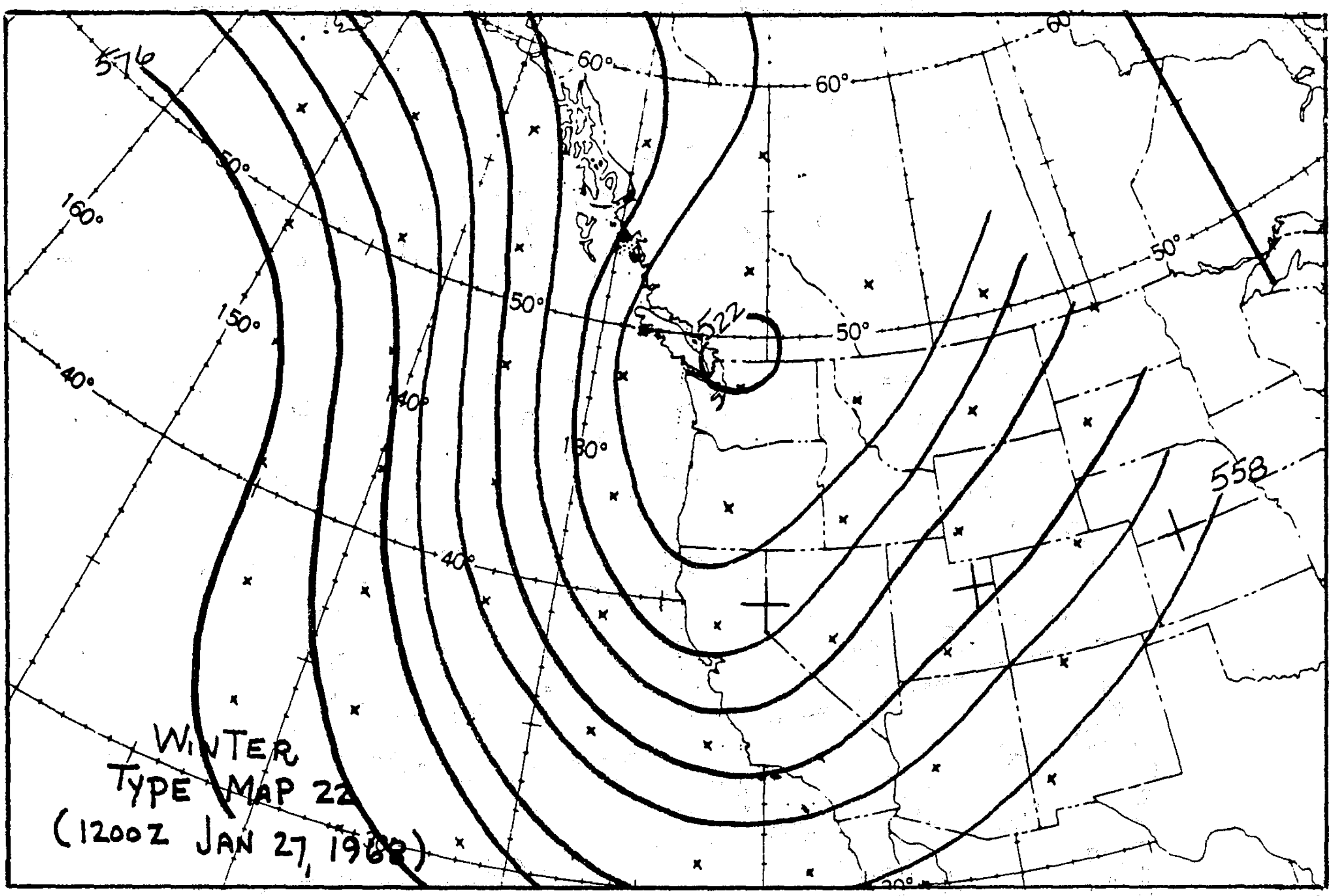


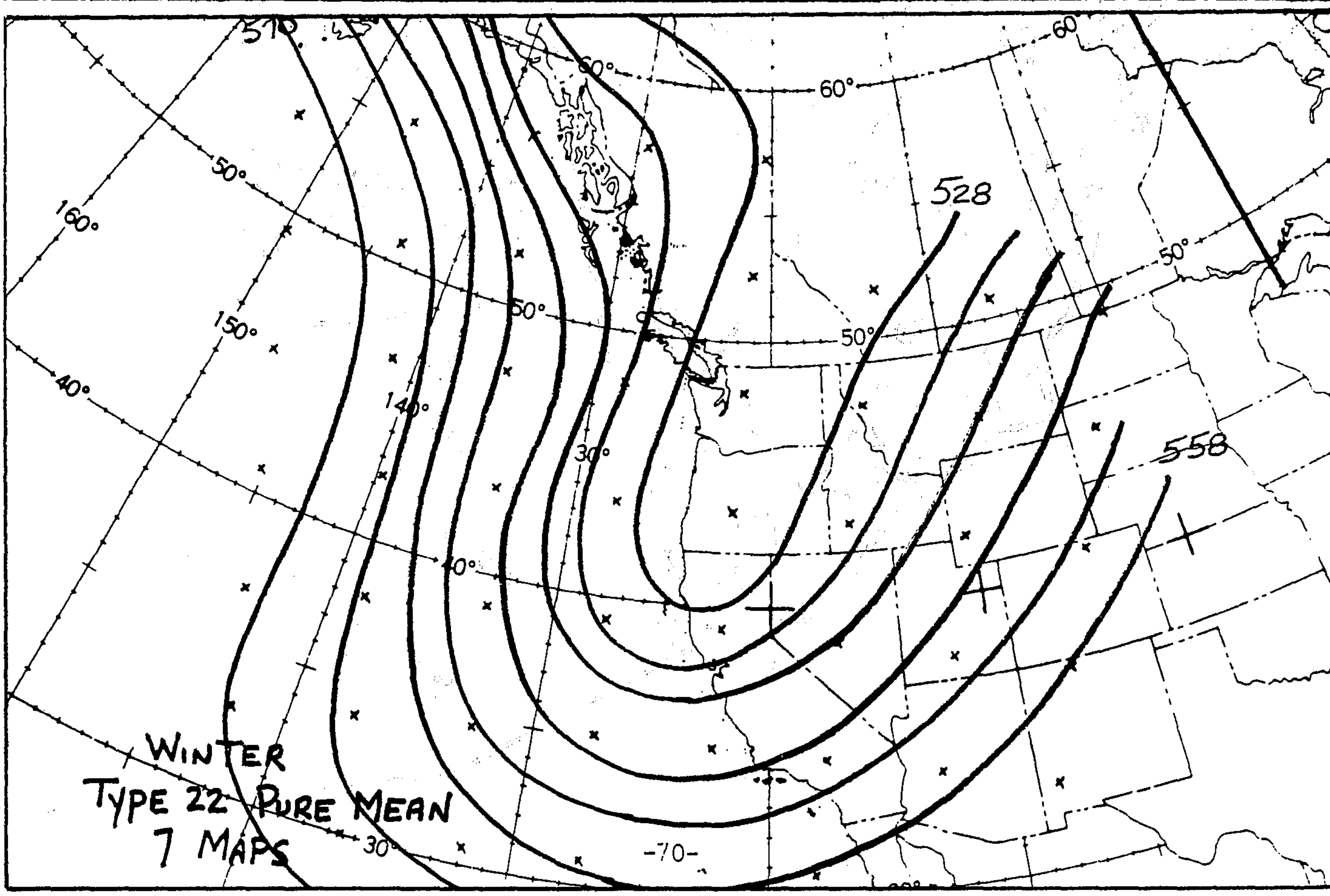

546
60°
50°
558
160°
50°
150°
40°
140°
50°
130°
516
40°
558
552
30°
30°
WINTER
TYPE MAP 21
(0000Z JAN 17, 1966)


528
60°
50°
160°
50°
558
150°
50°
40°
140°
130°
516
40°
549
30°
-68-
30°
WINTER
TYPE 21 PURE MEAN
5 MAPS

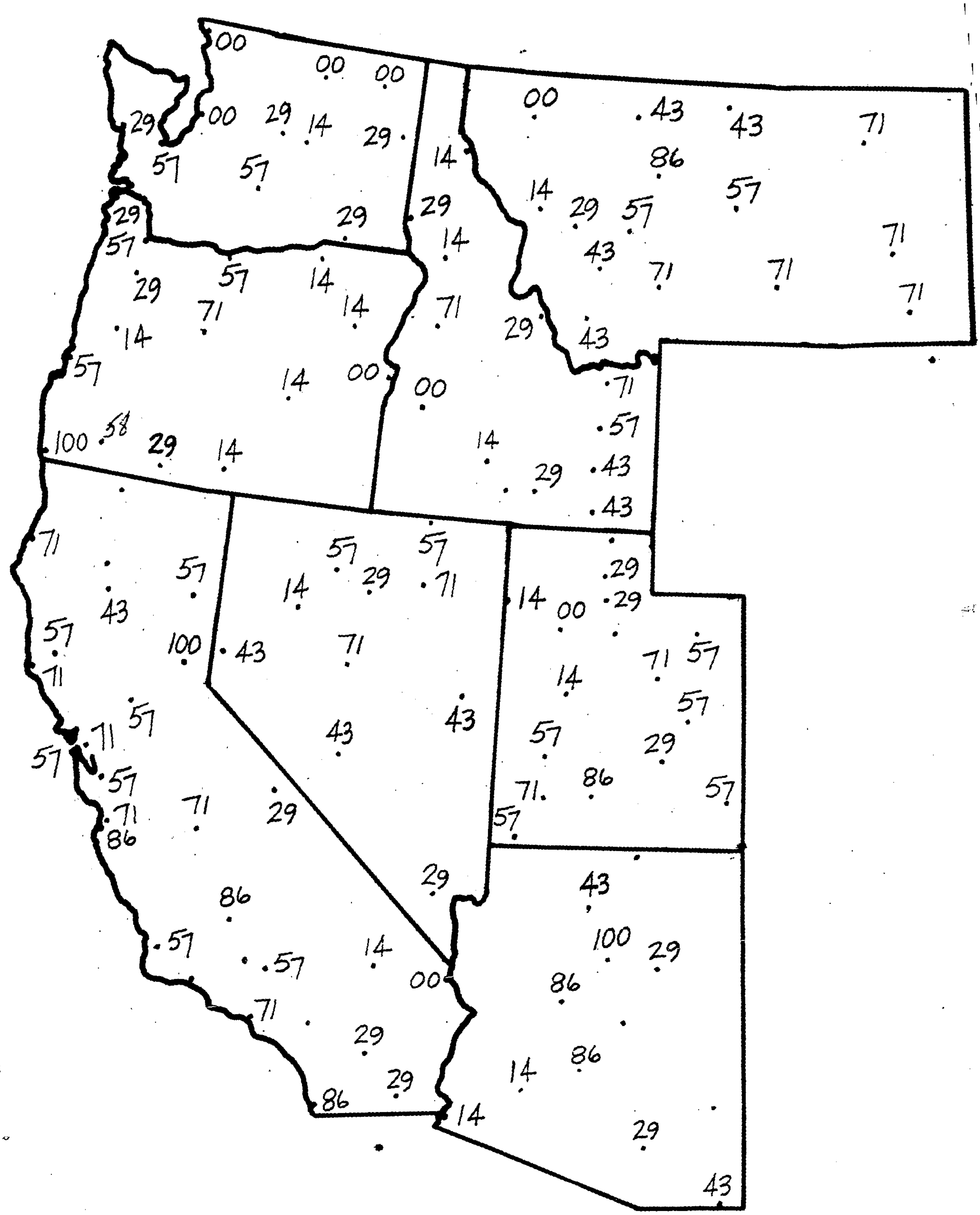
PERCENT FREQUENCY OF PRECIPITATION OCCURRENCE WITH 500-MB WINTER TYPE 21

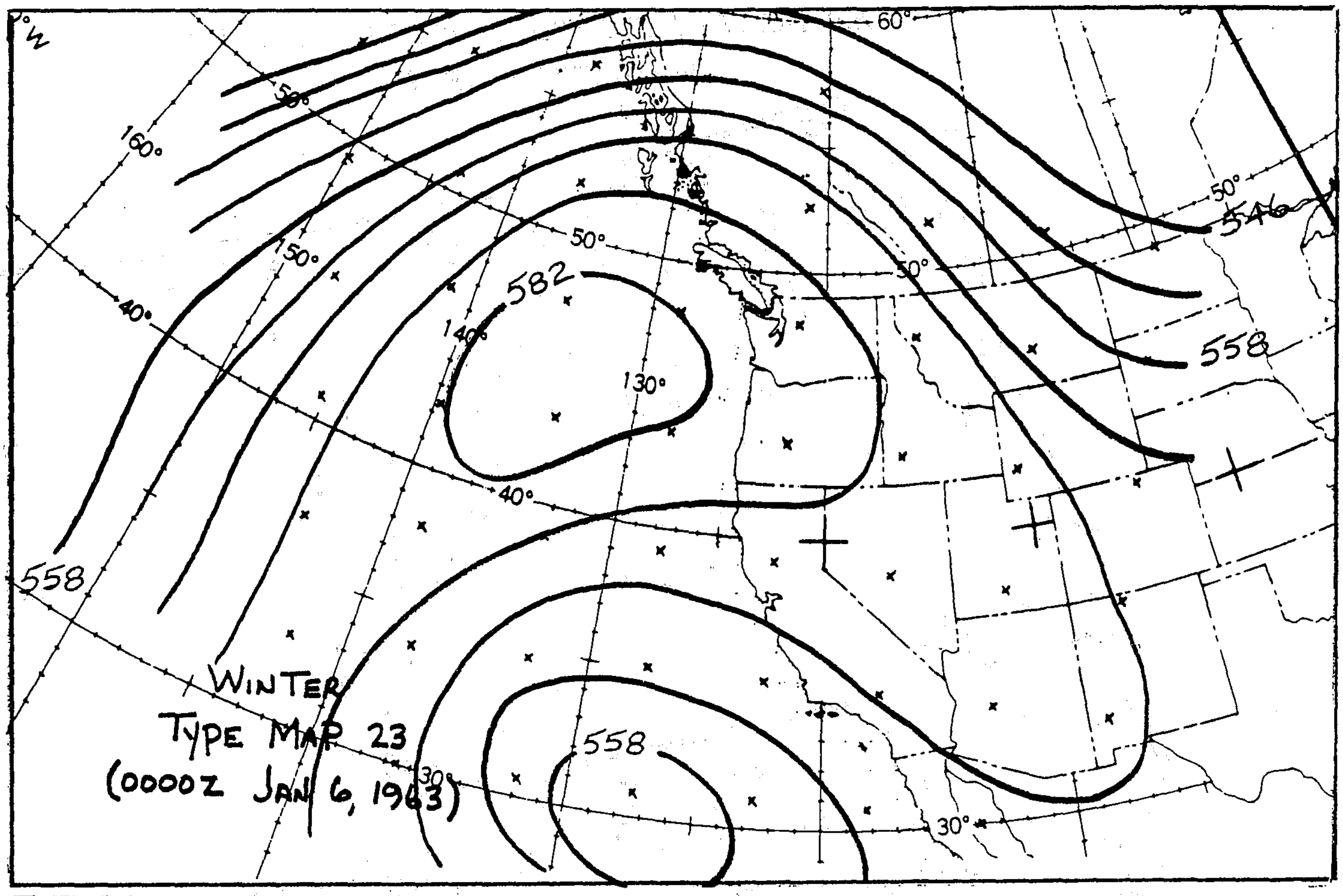



576
60°
60°
60
50°
160°
150°
40°
50°
522
50°
140°
130°
558
40°
30°
WINTER
TYPE MAP 22
(1200Z JAN 27, 1968)

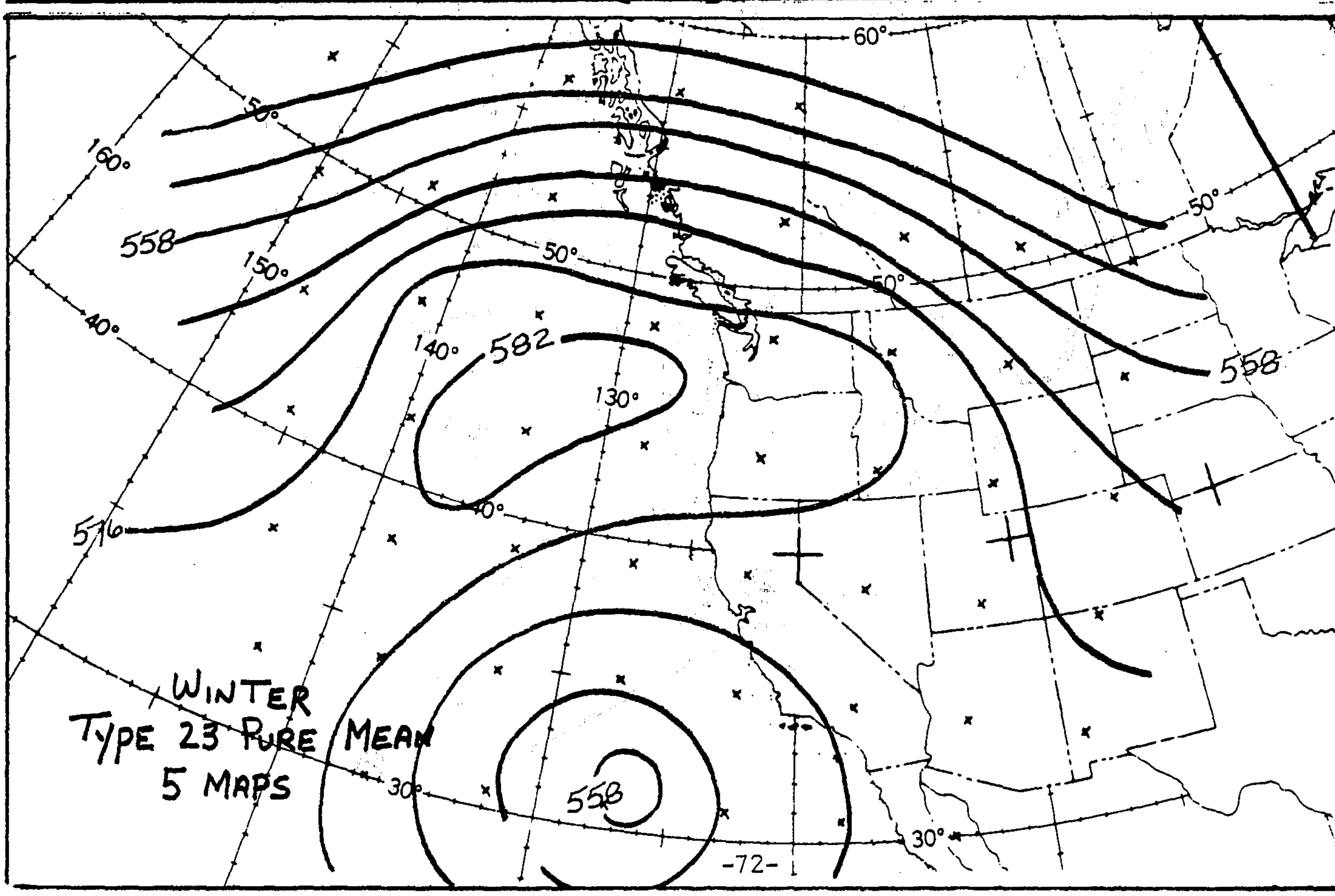

576
60°
60°
60
50°
160°
528
150°
50°
50°
40°
140°
130°
558
40°
WINTER
TYPE 22 PURE MEAN
7 MAPS
30°
-70-

PERCENT FREQUENCY OF PRECIPITATION OCCURRENCE WITH
500-MB WINTER TYPE 22



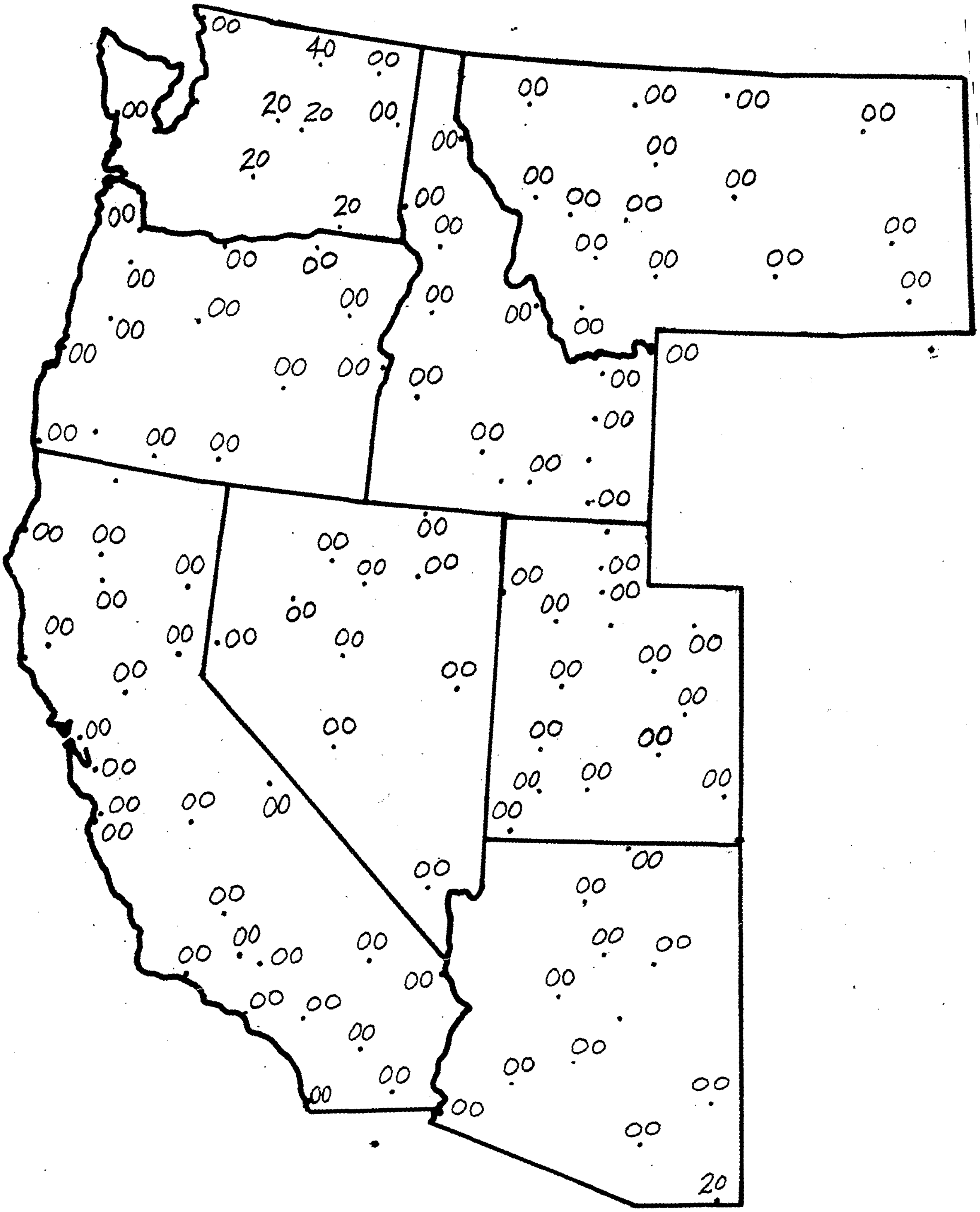


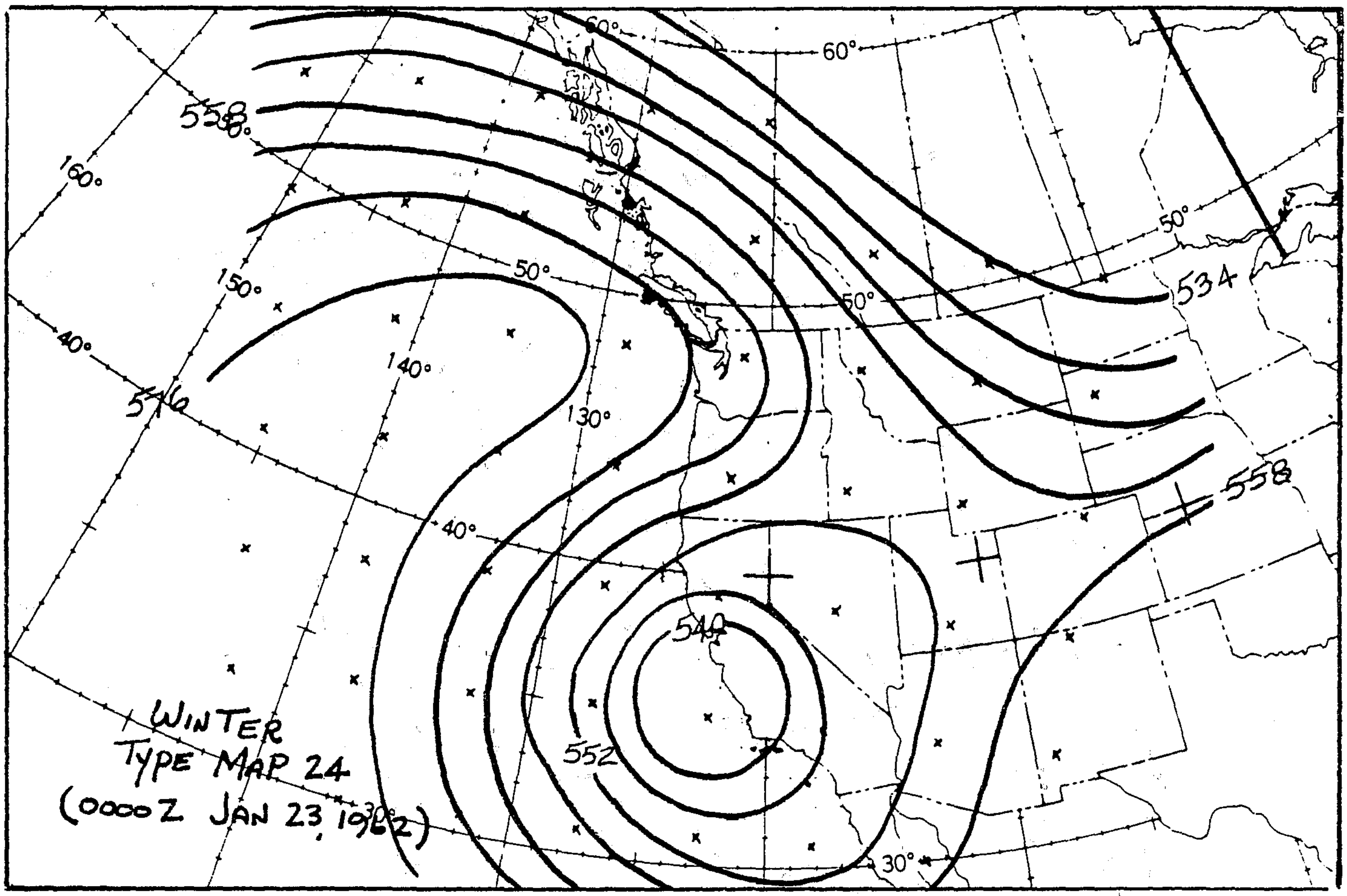
60°
50°
160°
150°
40°
50°
582
140°
130°
40°
546
50°
50°
558
558
558
WINTER
TYPE MAP 23
(0000Z JAN 6, 1963)
30°
30°

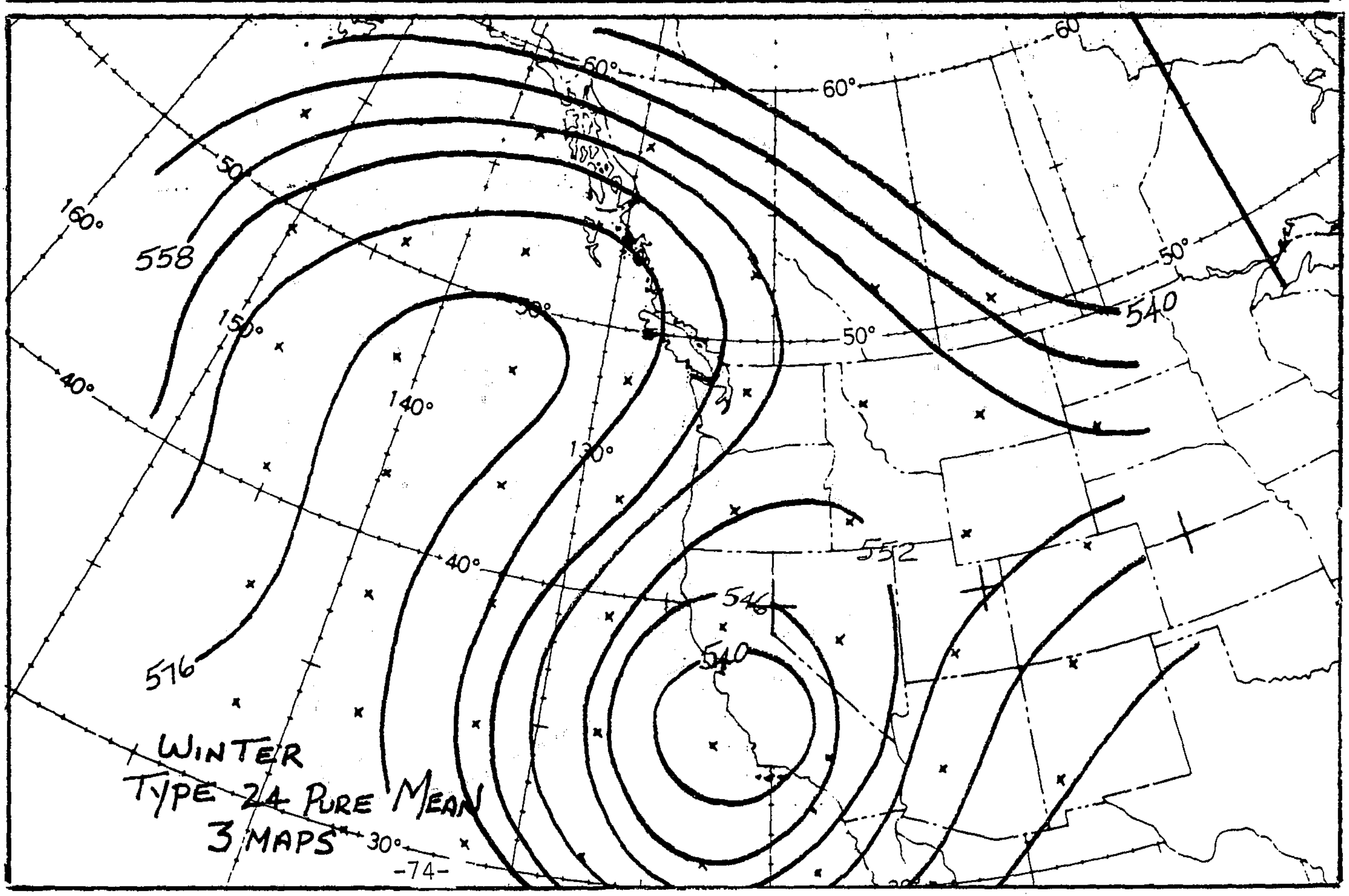


60°
50°
160°
558
150°
40°
50°
140°
582
130°
50°
50°
558
576
40°
WINTER
TYPE 23 PURE MEAN
5 MAPS
30°
558
30°

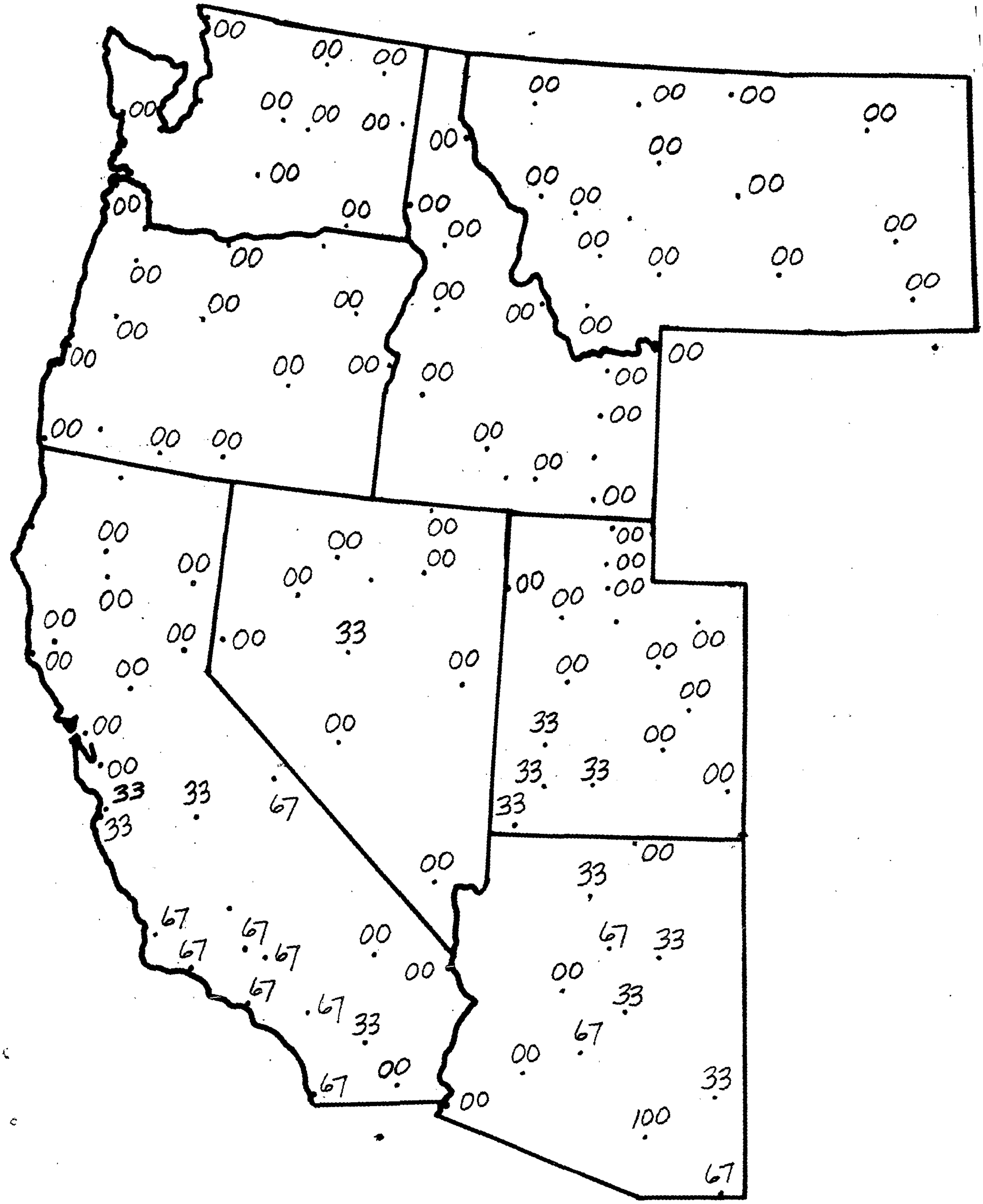
PERCENT FREQUENCY OF PRECIPITATION OCCURRENCE WITH
500-MB WINTER TYPE 23

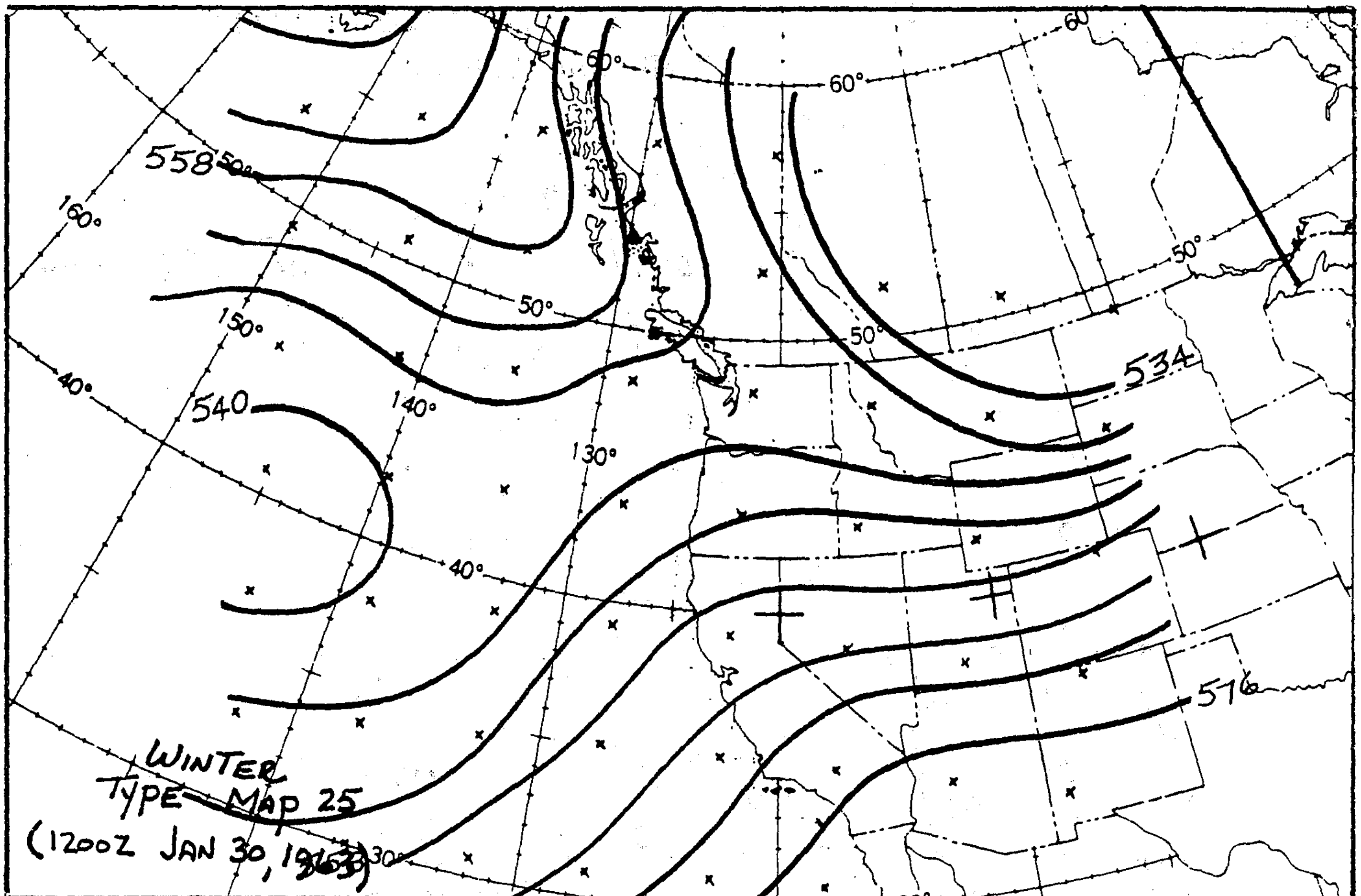


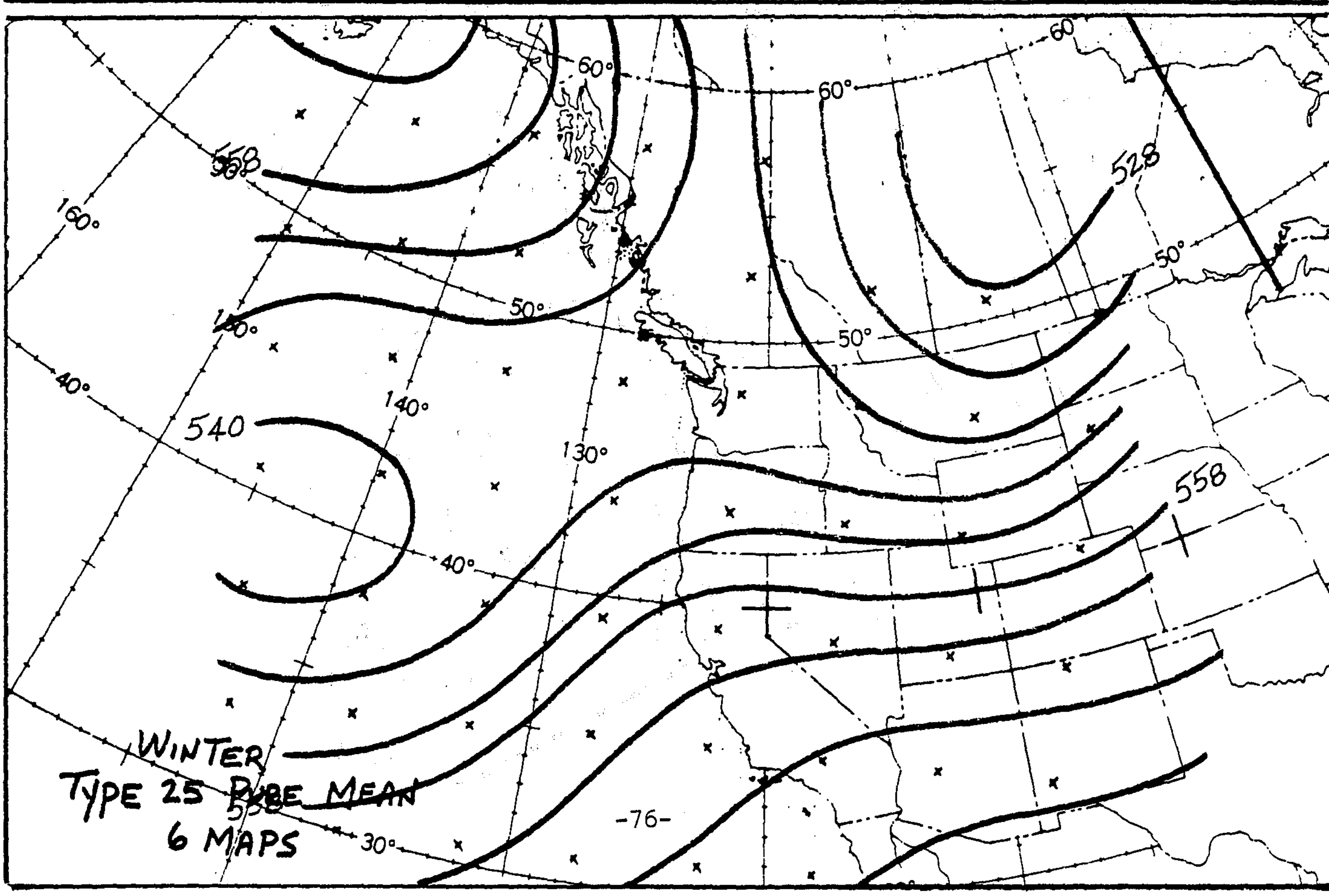

WINTER
TYPE MAP 24
(0000Z JAN 23, 1962)
558
534
558
540
552
516
60°
50°
40°
30°
160°
150°
140°
130°


WINTER
TYPE 24 PURE MEAN
3 MAPS
558
540
552
546
540
576
60°
50°
40°
30°
160°
150°
140°
130°

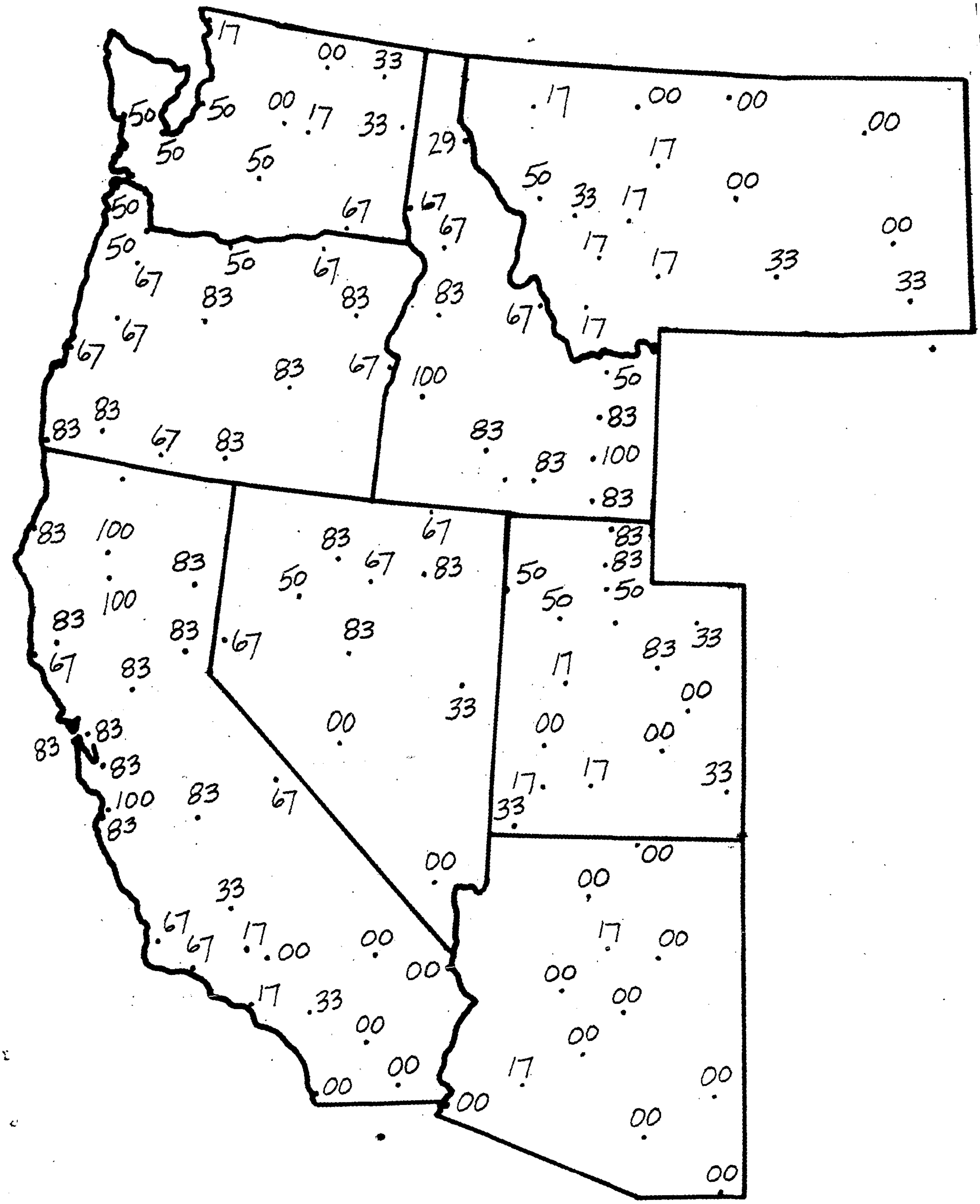
PERCENT FREQUENCY OF PRECIPITATION OCCURRENCE WITH
500-MB WINTER TYPE 24




558
534
540
576
WINTER
TYPE MAP 25
(1200Z JAN 30, 1963)


558
528
540
558
WINTER
TYPE 25 ~~PUBE~~ MEAN
6 MAPS

PERCENT FREQUENCY OF PRECIPITATION OCCURRENCE WITH
500-MB WINTER TYPE 25



APPENDIX B

Listing of Maps Within Each Type

TYPE I

Dec. 1961	Dec. 1962	Dec. 1963	Dec. 1964	Dec. 1965	Dec. 1966	Dec. 1967
4-00	1-00	5-00	1-00	1-00	9-00	1-00
4-12	1-12	5-12	1-12	1-12	9-12	1-12
5-00	2-00	6-00	2-00	2-00	10-00	2-00
10-12	2-12	6-12	4-12	2-12	12-12	6-00
17-00	3-00	7-00	5-00	11-00	14-00	7-00
18-00	3-12	7-12	8-00	11-12	14-12	7-12
18-12	4-00	8-00	8-12	17-12	15-00	8-00
19-00	4-12	15-00	9-12	18-00	16-00	8-12
19-12	5-00	15-12	10-00	20-00	17-12	9-00
20-00	5-12	16-00	10-12	20-12	20-12	9-12
20-12	6-00	20-12	13-12	21-00	21-00	10-00
22-00	6-12	21-12	14-00	23-00	24-12	10-12
22-12	7-00	22-00	23-12	23-12		11-00
23-00	7-12	22-12	24-00	24-00		22-00
23-12	20-00		24-12			23-12
24-00	20-12		25-00			24-00
24-12	21-00		25-12			24-12
25-00	31-12		26-00			
25-12			26-12			
26-00						
26-12						
27-00						
27-12						
28-00						
28-12						
29-00						
29-12						
30-00						
30-12						

Type I (Continued)

Jan. 1962	Jan. 1963	Jan. 1964	Jan. 1965	Jan. 1966	Jan. 1967	Jan. 1968
2-12	1-00	1-00	2-00	5-00	2-12	7-12
5-12	1-12	1-12	8-12	5-12	3-00	11-12
6-00	2-00	2-00	9-00	6-00	3-12	12-00
6-12	2-12	2-12	10-00	6-12	4-00	12-12
11-00	3-00	3-00	10-12	7-00	4-12	17-00
11-12	3-12	3-12	20-00	9-00	7-12	17-12
26-00		4-00	20-12	9-12	8-00	18-00
26-12		4-12	21-00	10-00	8-12	18-12
27-00		5-00	21-12	10-12	11-12	19-12
27-12		5-12	22-00	11-12	12-00	20-00
		6-00	22-12	12-00	12-12	21-12
		6-12	23-00	12-12	13-00	24-12
		8-12	23-12	13-00	15-00	
		9-12	26-12	13-12	15-12	
		12-00	27-00	14-00	19-00	
		12-12	27-12	14-12	19-12	
		13-00	28-00	15-00	20-00	
		13-12	28-12	25-00	26-00	
		14-00	29-12	25-12	30-12	
		14-12	30-00	27-12	31-00	
		15-00	30-12	28-00	31-12	
		15-12	31-00	31-00		
		16-00		31-12		
		17-00				
		17-12				
		19-00				
		19-12				
		20-00				
		24-00				
		24-12				
		25-00				
		25-12				
		26-00				
		26-12				
		27-00				
		27-12				
		28-00				
		29-12				
		30-00				
		30-12				
		31-12				

Type I (Continued)

Feb. 1962	Feb. 1963	Feb. 1964	Feb. 1965	Feb. 1966	Feb. 1967	Feb. 1968
2-00	15-00	1-00	2-12	1-00	1-00	1-00
2-12	15-12	1-12	3-00	1-12	1-12	1-12
17-00	16-00	2-00	8-00	2-00	2-00	2-00
17-12	16-12	4-12	13-00	2-12	2-12	2-12
	17-00	9-00	13-12	26-00	3-00	3-00
	17-12	9-12	16-00	26-12	3-12	3-12
	18-00	10-00	16-12	27-00	4-00	4-00
	18-12	10-12	17-00	27-12	4-12	4-12
	21-12	11-00	19-12	28-00	8-12	5-00
	22-00	15-00	21-00	28-12	9-00	5-12
	27-00	18-00	21-12		9-12	18-00
	27-12	18-12	22-00		11-12	20-12
	28-00	27-12	24-00		12-00	21-00
	28-12	28-00	24-12		12-12	21-12
		29-12	25-00		13-00	22-00
			25-12		13-12	22-12
					22-12	23-00
					23-00	23-12
					23-12	
					24-00	
					26-00	

TYPE 2

Dec. 1962	Dec. 1963	Dec. 1965	Dec. 1966	Dec. 1967
10-00	3-12	3-00	11-00	22-12
10-12	4-00	4-00	11-12	23-00
12-00	4-12	4-12	12-00	
12-12	17-12	5-00	12-12	
13-00	18-00	5-12	13-00	
13-12	18-12	6-00	13-12	
14-00	19-00	6-12	15-12	
14-12	19-12	7-00	16-12	
15-00	20-00	7-12	17-00	
18-00	23-00		18-00	
19-00	23-12		18-12	
29-12	24-00		19-00	
30-00	24-12		19-12	
30-12			20-00	
			21-12	
			22-00	
			22-12	
			23-00	
			23-12	

Jan. 1964	Jan. 1965	Jan. 1966	Jan. 1967	Jan. 1968
28-12	17-00	7-12	9-12	13-00
29-00	17-12	26-00	10-00	13-12
31-00	18-00	26-12	10-12	14-00
	18-12	27-00	11-00	14-12
	19-00	28-12	27-12	15-00
		29-00	28-00	15-12
			28-12	19-00
			29-00	

Type 2 (Continued)

Feb. 1962	Feb. 1963	Feb. 1965	Feb. 1966	Feb. 1967	Feb. 1968
3-00	3-00	3-12	3-00	24-12	17-12
5-12	3-12	4-00	3-12	26-12	18-12
6-00	4-00	4-12	4-00	27-00	19-00
6-12	4-12	19-00	19-00	27-12	19-12
7-12	5-00	26-00	20-12	28-00	20-00
	5-12		21-00		24-00
	6-00		21-12		24-12
	6-12		22-00		25-00
	7-00		22-12		25-12
	7-12		23-00		26-00
	8-00				29-12
	8-12				
	9-00				
	9-12				
	13-00				
	13-12				
	14-00				
	19-12				
	20-00				
	20-12				
	21-00				
	24-12				
	25-12				
	26-00				

TYPE 3

Dec. 1961	Dec. 1962	Dec. 1963	Dec. 1964	Dec. 1966	Dec. 1967
5-12	27-00	9-00	13-00	25-12	12-12
6-00	27-12	14-00	15-12	26-00	12-00
6-12		14-12	16-00	28-00	17-12
7-00			16-12	28-12	21-00
7-12			17-00	29-00	21-12
11-12			17-12	29-12	25-00
12-12				30-00	25-12
13-00				31-00	26-00
13-12					
14-00					
16-12					

Jan. 1962	Jan. 1963	Jan. 1964	Jan. 1965	Jan. 1966	Jan. 1967	Jan. 1968
7-00	9-00	7-00	11-12	19-00	1-00	1-00
12-00	24-12	7-12	12-00	19-12	1-12	4-12
13-12		8-00	12-12	20-00	2-00	5-00
14-00		10-12	25-00	20-12	6-00	5-12
14-12		11-00	25-12	21-00	6-12	6-00
15-00		23-12	29-00	21-12	7-00	6-12
15-12			31-12	22-00	13-12	7-00
24-00				22-12	14-00	
24-12				23-00	14-12	
				23-12	16-00	
				24-00	16-12	
					17-00	
					17-12	
					18-00	
					18-12	

Feb. 1964	Feb. 1965	Feb. 1966	Feb. 1967
5-12	1-00	9-12	5-00
8-00	1-12	10-00	6-12
8-12	2-00	12-12	10-00
11-12	7-00	17-12	10-12
13-00	9-00	18-00	11-00
13-12	9-12		15-12
16-00	10-00		16-00
16-12	10-12		16-12
17-00	11-00		17-00
17-12	14-00		17-12
19-00	14-12		18-00
26-12	15-00		18-12
	15-12		19-12
	22-12		20-12
	23-00		21-00
	23-12		
	28-12		

TYPE 4

Dec. 1961	Dec. 1962	Dec. 1964	Dec. 1965	Dec. 1966	Dec. 1967
1-00	31-00	19-00	8-00	2-00	2-12
1-12		19-12	8-12	2-12	5-00
21-00		20-00	9-00	3-00	5-12
		20-12	24-12	3-12	
		21-00	26-12	4-00	
		21-12	27-00	4-12	
		22-00	27-12	5-00	
		22-12	28-00	5-12	
		23-00	28-12	6-00	
		27-00	29-00	6-12	
		27-12	29-12		
		28-00	30-00		
			30-12		

Jan. 1964	Jan. 1965	Jan. 1966	Jan. 1967	Jan. 1968
20-12	2-12	4-12	20-12	9-12
21-00	3-00	8-00	21-00	10-00
21-12	3-12	8-12	21-12	10-12
	5-00	11-00	22-00	16-00
	5-12	29-12	22-12	16-12
	6-00	30-00	23-00	30-00
	6-12	30-12	23-12	
	7-00		24-00	
	24-00		24-12	
			25-00	
			26-12	
			27-00	
			29-12	
			30-00	

Feb. 1962	Feb. 1963	Feb. 1965	Feb. 1966	Feb. 1967
8-00	1-00	5-00	4-12	28-12
8-12	1-12	5-12	5-00	
		26-12	5-12	
		27-00	6-00	
			6-12	
			19-12	
			20-00	
			23-12	

TYPE 5

Dec. 1961	Dec. 1963	Dec. 1964
31-00	1-00	6-12
31-12	2-00	7-00
	2-12	7-12
	3-00	

Jan. 1962	Jan. 1963	Jan. 1965	Jan. 1968
4-12	4-12	13-00	20-12
5-00	5-00	13-12	21-00
28-00		14-00	22-00
28-12		14-12	22-12
29-00		15-00	23-00
29-12		15-12	23-12
30-00		16-00	24-00
30-12		16-12	
31-00			
31-12			

Feb. 1962	Feb. 1963	Feb. 1964	Feb. 1965	Feb. 1967	Feb. 1968
1-00	23-00	2-12	17-12	8-00	6-12
1-12		3-00	18-00		7-00
		3-12	18-12		7-12
		4-00			8-00
					8-12

TYPE 6

Dec. 1961	Dec. 1964	Dec. 1965	Dec. 1966	Dec. 1967
15-12	14-12	25-00	7-00	20-12
16-00	15-00	25-12	7-12	
17-12	18-00	26-00	8-00	
	18-12	31-00	25-00	
	29-12	31-12		
	30-00			
	30-12			
	31-00			
	31-12			

Jan. 1964	Jan. 1965	Jan. 1966	Jan. 1967	Jan. 1968
10-00	1-00	1-00	5-00	8-00
18-00	1-12	1-12	5-12	8-12
18-12	4-00	2-00	25-12	9-00
22-0	4-12	2-12		11-00
22-12	7-12	3-00		28-12
23-00	8-00	3-12		30-12
	23-12	4-00		31-00
				31-12

Feb. 1962	Feb. 1964	Feb. 1965	Feb. 1966	Feb. 1967
18-00	15-12	6-00	7-00	14-00
18-12	28-12	27-12		14-12
		28-00		15-00

TYPE 7

Dec. 1962	Dec. 1963	Jan. 1967
8-00	17-00	9-00
21-12		
22-00		
28-00		
28-12		
29-00		

Feb. 1962	Feb. 1963	Feb. 1966
3-12	2-00	18-12
4-00	2-12	
4-12	19-00	
5-00		

TYPE 8

Dec. 1961	Dec. 1962	Dec. 1963	Dec. 1967
8-00	22-12	12-12	12-12
12-00	23-00	13-00	26-12
	23-12	13-12	27-00
	24-00		27-12
	24-12		28-00
	25-00		28-12
	26-00		29-00
	26-12		29-12
			30-00
			30-12
			31-00
			31-12

Jan. 1963	Jan. 1968	Feb. 1962	Feb. 1964	Feb. 1966
10-12	3-00	22-00	21-12	13-00
11-00	3-12	22-12	22-00	13-12
11-12	4-00		22-12	14-00
12-00			23-00	15-00
13-12			23-12	15-12
14-00			24-00	16-00
14-12			24-12	16-12
15-00			25-00	17-00
15-12			25-12	
16-00			26-00	
16-12				
17-00				
17-12				
18-00				
18-12				
19-00				
19-12				
20-00				
20-12				
21-00				
21-12				
22-00				
22-12				
23-00				
23-12				
24-00				
25-00				
25-12				
26-00				
26-12				
27-00				
27-12				

TYPE 9

Jan. 1962	Jan. 1964
7-12	11-12
8-00	
8-12	
9-00	
9-12	
10-00	

Feb. 1963	Feb. 1964	Feb. 1965	Feb. 1967
23-12	6-00	12-12	5-12
24-00	6-12		6-00
	7-00		7-00
	7-12		7-12
	19-12		20-00
	20-00		21-12
	20-12		22-00
	21-00		
	27-00		

TYPE 10

Dec. 1965	Jan. 1963	Feb. 1964
18-12	4-00	5-00
19-00	8-00	6-00
19-12	8-12	20-00
		20-12

TYPE 11

Dec. 1964	Dec. 1965	Dec. 1966
3-00	14-12	26-12
3-12		27-00
		27-12

Jan. 1962	Jan. 1966
10-12	15-12
	16-00
	24-12

Feb. 1964	Feb. 1966
14-00	10-12
14-12	

TYPE 12

Dec. 1967	Jan. 1962	Jan. 1963	Jan. 1968	Feb. 1962	Feb. 1966
18-00	12-12	10-00	1-12	19-00	12-00
18-12	13-00	28-00	25-12	23-00	
	16-12	28-12	26-00	23-12	
	17-00		29-00	28-00	
	17-12		29-12	28-12	
	18-00				
	19-00				
	19-12				
	20-00				

TYPE 13

Dec. 1961	Dec. 1965	Feb. 1964	Feb. 1965	Feb. 1966
2-00	12-00	29-00	6-12	7-12
2-12	12-12			8-00
3-00	13-00			
3-12	22-00			
15-00	22-12			

TYPE 14

Dec. 1962	Dec. 1965	Dec. 1966	Feb. 1966	Feb. 1967
16-12	9-12	24-00	24-00	25-00
17-00	10-00		24-12	25-12
17-12	10-12		25-00	
			25-12	

TYPE 15

Dec. 1961	Dec. 1963	Jan. 1962	Jan. 1968	Feb. 1962
8-12	9-12	20-12	2-00	19-12
9-00	10-00	21-00	2-12	20-00
9-12		21-12		20-12
11-00		22-00		21-00
				21-12
				24-00
				24-12
				25-00
				25-12
				26-00
				26-12
				27-00
				27-12

TYPE 16

Dec. 1961	Dec. 1965	Dec. 1966	Feb. 1966
14-12	13-12	30-12	8-12
	14-00		9-00
	15-00		
	15-12		
	16-00		
	16-12		
	17-00		

TYPE 17

Dec. 1962	Dec. 1963	Feb. 1963	Feb. 1968
8-12	1-12	10-00	9-00
9-00		12-00	9-12
9-12			10-00
11-00			10-12
11-12			11-00
			11-12
			26-12
			27-00
			27-12
			28-00
			28-12
			29-00

TYPE 18

Dec. 1967	Jan. 1962	Jan. 1963	Jan. 1966	Jan. 1968
16-00	25-00	9-00	17-12	25-00
16-12	25-12		18-00	
			18-12	

Feb. 1965	Feb. 1966
8-12	11-12

TYPE 19

Dec. 1962	Dec. 1963	Dec. 1967	Jan. 1963
25-12	10-12	13-00	12-12
	11-00	13-12	13-00
	11-12	14-00	
	12-00		

TYPE 20

Dec. 1966	Feb. 1962	Feb. 1968
1-00	7-00	16-00
1-12		16-12
		17-00

TYPE 21

Dec. 1967	Jan. 1966	Feb. 1965	Feb. 1966
15-12	16-12	7-12	11-00
	17-00		

TYPE 22

Dec. 1967	Jan. 1968
19-00	26-12
19-12	27-00
20-00	27-12
	28-00

TYPE 23

Jan. 1963
5-12
6-00
6-12
7-00
7-12

TYPE 24

Jan. 1962
22-12
23-00
23-12

TYPE 25

Jan. 1963	Feb. 1968
29-12	15-12
30-00	
30-12	
31-00	
31-12	