NOAA Technical Memorandum NWS WR-171

VERIFICATION OF 72-HOUR 500-MB MAP-TYPE PREDICTIONS

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96 Map Type Precipitation Probabilities for the Western Region. Glenn E. Rasch and Alexander E. MacDonald, February 1975. (COM-75-10428/AS)
97 Eastern Pacific Cut-Off Low of April 21-28, 1974. William J. Alder and George R. Miller, January 1976. (PB-250-711/AS)
98 Study on a Significant Precipitation Episode in Western United States. Ira S. Brenner, April 1976. (COM-75-10719/AS)
99 A Study of Flash Flood Susceptibility--A Basin in Southern Arizona. Gerald Williams, August 1975. (COM-75-11360/AS)
102 A Set of Rules for Forecasting Temperatures in Napa and Sonoma Counties. Wesley L. Tuft, October 1975. (PB-246-902/AS)
103 Application of the National Weather Service Flash-Flood Program in the Western Region. Gerald Williams, January 1976. (PB-253-053/AS)
104 Objective Aids for Forecasting Minimum Temperatures at Reno, Nevada, During the Summer Months. Christopher D. Hill, January 1976. (PB-252-866/AS)
105 Forecasting the Mono Wind. Charles P. Ruscha, Jr., February 1976. (PB-254-650)
106 Use of MOS Forecast Parameters in Temperature Forecasting. John C. Plankinton, Jr., March 1976. (PB-254-649)
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117 The Relative Frequency of Cumulonimbus Clouds at the Nevada Test Site as a Function of K-Value. R. F. Quiring, April 1977. (PB-272-831)
118 Moisture Distribution Modification by Upward Vertical Motion. Ira S. Brenner, April 1977. (PB-268-740)
119 Relative Frequency of Occurrence of Warm Season Echo Activity as a Function of Stability Indices Computed from the Yucca Flat, Nevada, Rawinsonde. Darryl Randerson, June 1977. (PB-271-290/AS)

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UNITED STATES
DEPARTMENT OF COMMERCE
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National Oceanic and
Atmospheric Administration
John V. Byrne, Administrator

National Weather
Service
Richard E. Hallgren, Director

I consider this a useful study to assist Western Region forecasters in the use of the map type correlation bulletins issued twice daily by NMC (AFOS call sign: 5TCNMC). My subjective opinion is that since NMC replaced the 7-layer PE model with the spectral model in August 1980 the quality of 72-hour 500-mb prognoses have improved. Thus, we can expect even better verification of the types than indicated here.

This Technical Memorandum has been reviewed and is approved for publication by Scientific Services Division, Western Region.

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FIGURES AND TABLES

VERIFICATION OF 72-HOUR 500-MB MAP-TYPE PREDICTIONS

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I. INTRODUCTION

The 500-mb map types presented by Rasch and MacDonald (1975) provide the basis for twice daily bulletins of correlation coefficients for the initial map and PE prognostic maps out to 72 hours. The bulletin contains the map type and correlation coefficient for the three map types that correlate best with the initial map and the forecast maps at intervals of 12-, 24-, 36-, and 72-hours. The method of typing assures that no map type will be highly correlated with any of the other types and, according to the authors, it is responsive to large-scale map features but does not handle small-scale systems well.

The 500-mb map types have been used successfully to stratify a variety of weather parameters. Included in such endeavors is an elaborate conditional climatology for the Yucca Weather Station, produced by John Cornett during his tenure at WSNSO (Cornett, 1978). Paegle and Kierulff (1974) used the map typing procedure with a large grid area to stratify 500-mb winter flow patterns. The effects of this stratification were described in terms of related fields which included precipitation frequency at stations in the Western Region of the National Weather Service. Lund (1972) applied the technique with a small grid area to predict the probability of precipitation at a single point in California. The results of these endeavors leave little doubt that the correlation technique stratifies airflow into distinctive patterns which are useful in forecasting, and produce a respectable improvement over unconditional climatology.

The 72-hour 500-mb PE prognostications are generally believed to be fairly good with the long waves (large-scale features). In consideration of the success in developing climatologies and prediction schemes conditioned on the map types it seems appropriate to have a verification of the map types. This verification should serve as an objective verification of 72-hour forecasts since the long waves are handled best by both the map types and the 72-hour forecasts, and the map types minimize the short waves which are a weakness in the 72-hour forecasts.

II. THE DATA BASE

The data base consists of 552 00Z and 633 12Z 72-hour forecasts, out of 2109 possible forecasts, from 25 January 1976 through 19 January 1979. The large number of missing forecasts is attributed primarily to failure of the map-type bulletin to meet the Service C teletype schedule and lack of attentiveness in clearing the teletype (the bulletin was hard to spot). The forecasts are fairly uniformly distributed by initial hour and season and there seems to be no reason to suspect that the sample is biased. The frequency of occurrence of each map type and the expected frequency are given in Table 1 by season, initial time, and initial times combined. The expected frequency is based on the distribution of map types in the sample used to develop the types. The maps were not segregated by initial time in the developmental set.

The map-type bulletins were rearranged in rows consisting of the initial map and the 12-, 24-, 36-, 48-, and 72-hour forecasts verifying on that map. The rearranged bulletins were punched on cards in preparation for computer processing. The verification presented in this report is based on a hand tabulation from a listing of the punched data. There were some counting errors but these are very likely few enough in number to be insignificant.

III. VERIFICATION

The verification tabulation was keyed to the threshold correlation coefficient of 800 (decimal omitted for convenience) used in developing the map types and was designed to reveal the quality of the verification and differences in verification for the initial times of 00Z and 12Z. The levels for categorizing quality in terms of verifying correlation coefficient were arbitrarily set at 860 and 920. Selected statistics from this tabulation are presented in Table 2. Table entries are cumulative from the left and give the proportion of the forecasts that verified at, or better than, the indicated correlation coefficient and position in the bulletin. Forty-three forecasts (3.6 percent of the forecasts) for which the best correlation with a map type was less than 800, are included in the tabulation. In the developmental sample only 0.7 percent of the maps did not correlate at 800 or better with one of the map types. Perusal of Table 2 reveals that (1) there is very little difference between the verification of forecasts made from the initial hour 00Z and those made from the initial hour 12Z, (2) the map type that appears in the first position of the bulletin (i.e., correlated best with the forecast map) verifies best, (3) verification of the spring forecasts is substantially poorer than for the other season, (4) on an annual basis 85.5 percent of the forecasts in the first position of the map-type bulletin verified at, or above, the threshold correlation value of 800, (5) a substantial proportion of the forecasts in the second (58.9 percent) and third (39.5 percent) positions of the map-type bulletin verified at, or above, the threshold correlation value of 800 on an annual basis, and (6) there is a substantial amount of shifting of positions between forecast and verification; i.e., a map type may verify in a higher or lower position in the bulletin and/or at a higher or lower level of correlation than forecast.

Variations in the verification correlation with respect to forecast correlation were examined for the winter season as a function of map type. All map types without regard to position in the 72-hour portion of the bulletin were included in this tabulation. The results are presented in Table 3 as joint distributions of forecast and verification correlation coefficients for each map type and all types combined. The diagonal representing common class intervals for forecast and verification is identified by underlining the entry. There were an appreciable number of tabulation errors but these are believed to be few enough in number so that the general conclusions which can be drawn from Table 3 are very likely valid.

The proportion of the 72-hour forecasts that verify at, or above, the threshold correlation of 800 can be found in the cumulative row for each map type in Table 3. Verification is best for type 1 which verifies on 81.5 percent of the occasions when it appears in the bulletin. Verification is poorest for type 5 at 12.5 percent. For all map types combined the verification is 65.0 percent. There is an indication that the quality of the verification varies directly with the frequency with which the map type occurs. This is shown in Figure 1 in which the logarithmic curve provides a realistic fit to the data and clearly shows that the greater the frequency of occurrence of a map type the better the verification. Type 1 is the most common type and represents a very simple flow pattern. The less common types, like 5, represent very complex flow patterns. Furthermore, the representative map for each type contains all of the minor perturbations associated with the small-scale features present on a specified date. The suggestion is that the correlation coefficient is sensitive to the position and intensity of the short wave features moving within the long wave patterns. The more complex the flow pattern the more precisely the short wave features have to be positioned to correlate well with the map type.

It is also apparent in Table 3 that there is a substantial over-forecasting bias in the 72-hour map-type forecasts. This can be seen for each map type by comparing the proportion of the forecasts in the cumulative column which correlate above a given threshold value with the proportion of the verifications in the cumulative row which correlate above the same threshold value. All map types show a tendency toward over-forecasting with type 1 having the least bias. For all types combined the bias is on the order of 22 percent (.793 ÷ .650 = 1.22). One should note, however, that in a fairly substantial proportion of the verifications (14.1 percent for all types) the forecast type does not qualify as one of the best three when the 3rd best correlation is 800 or better. The bias would almost certainly be reduced if these correlations were known because some of these forecasts could be expected to verify above the threshold value.

The proportion of the forecast map types in each correlation class interval which verify above the threshold correlation value of 800 during the winter season for all map types combined is shown in Table 4. The verifying proportions are very likely low since on some occasions the verification correlation is not known because the map type does not verify as one of the three best when the correlation for the third best is 800 or greater. While it is quite clear that the proportion of the forecasts which verify decreases as the correlation decreases, the forecast also verifies above the threshold correlation on a rather substantial proportion of the occasions when the forecast correlation is less than 800.

Verification of 72-hour map-type forecasts is compared with shorter period forecasts in Table 5 for the winter season 1976/77. This table gives the proportion of the map-type forecasts verifying above the threshold correlation of 800 with respect to the forecast and verifying positions in the bulletin. The cumulative proportions from left to right are given in parenthesis. The tabulation for this single winter shows that (1) the quality of the forecasts deteriorates as the length of the forecast interval increases, (2) the forecast map type verifies most often in the same position of the bulletin as it was forecast, and (3) the lower the position of the forecast map type in the bulletin the poorer the verification.

IV. DISCUSSION

At first glance it appears that the 72-hour 500-mb map-type forecasts verify very well. The map type that appears in the first position of the bulletin verifies above the threshold correlation on 85.5 percent of the occasions on an annual basis. There are, however, rather frequent occasions when the forecaster has to exercise judgment in interpreting the bulletin because the forecast map correlates almost equally well with two (or even three) map types; or, there are critical differences in a specific area of concern between the forecast map and the representative map for the map type. The forecaster may well be justified, on occasion, in choosing a map type other than the one in the first position of the bulletin as a basis for his forecast. There is a degree of risk with such choices, however, because of the deterioration in the quality of the verification for map types in the second and third positions of the bulletin. There is also the possibility that the forecaster will be rewarded for his decision when a map type in the second or third position of the bulletin subsequently verifies better than the map type in the first position. It is therefore desirable to gain some insight into what is achieved by the map typing technique and the relevance of the correlation coefficient.

It is enlightening to look at a few examples of map typing on different scales based on the method proposed by Lund (1963) and employed by Rasch and MacDonald (1975) to produce the operational 500-mb map types. In all of these the choice of a threshold correlation coefficient has been subjective with a major consideration being to minimize the number of maps not qualifying as one of the types. Lund (1972) applied the technique with a 13-point grid to stratify 1000-mb flow as an aid in forecasting precipitation at Travis AFB, CA. The maps representing eight basic flow patterns in winter are shown in Figure 2. He experimented with smoothing flow patterns by averaging without any improvement in the probability of precipitation forecasts. His smoothed maps are almost identical to the representative maps and are not reproduced here. It is clear from Figure 2 that it is the direction in which the pressure surface slopes that is the key factor in stratifying the 1000-mb maps by type. The slope orientations represent directions of flow that approximate the 8-point compass with some apparent distinctions between cyclonic and anticyclonic curvature in the flow. It is important to note that the gradient of the slope has no effect on the correlation coefficient for parallel flows; i.e., a steep and a gently sloping surface having the same orientation will have a correlation coefficient of 1. The technique assures that the map types are not well correlated with each other so that on this small scale the flow patterns are relatively simple and averaging of maps within a type can be expected to have little affect on the orientation of the contours.

Paegle and Kierulff (1974) used the map correlation technique to stratify 500-mb maps in winter relative to the NWS Western Region. They used the 52 points shown as grid 1 in Figure 3 to produce the map types presented in Figure 4. The flow patterns are shown by contours of the departure of the average height at grid points from 5572 meters. The large area covered by the grid brings the trough/ridge configuration into play to a much greater extent than the small grid area used by Lund (1972) for Travis AFB. The smoothed flow patterns present rather straightforward variations on westerly flow which are fairly easy to interpret with respect to differences in precipitation frequency as seen in Figure 5. The standard deviation of height included in Figure 4 identifies the position of the grid in which the map type experiences the greatest variability. The contour pattern of type 1 is practically identical to that of the non-stratified maps but there is a significant difference between the two; i.e., there has been approximately a 60 percent reduction in the variance of the height of the 500-mb surface in the Eastern Gulf of Alaska. This does not have an appreciable affect on the precipitation frequencies since apparently equal numbers of precipitation and non-precipitation cases are removed from the sample by the other types. It is the simplicity of the smoothed flow patterns and the resultant ease with which differences contained in a subsequent forecast map can be interpreted that is so appealing.

Rasch and MacDonald (1975) used the 182 points shown as grid 2 in Figure 3 to produce the map types used to generate the operational map-type bulletin. This grid introduces large areas in Central Canada and east of the Rockies and, according to the authors, does a better job of typing the large-scale features of this 500-mb flow than the 52-point grid (grid 1) but may not do well on small-scale features. The winter map types and associated precipitation frequencies are presented in Figure 6 for comparison with the Paegle and Kierulff (1974) map types. An analysis of the non-stratified set of Paegle and Kierulff has been added to facilitate the comparison. The 7 years of data used in the Paegle and Kierulff study are common to the 8 years used by Rasch and MacDonald so that variations in precipitation frequency due to sample differences should be minor. The obvious difference between the two sets of map types is the complexity of the flow patterns of Rasch and MacDonald. The main reason for this is that the flow patterns of Paegle and Kierulff have been averaged and the Rasch and MacDonald map types are represented by individual patterns in which the intensity of a short wave is often the dominant feature.

A feel for the diversity of the two sets of map types is given in Table 6 where the representative maps of the Paegle and Kierulff map types are identified with the Rasch and MacDonald map type with which they are included. Paegle and Kierulff map-types 6 and 7 distinguish between flow patterns in which short waves dig southeastward onshore (type 6) and off the coast (type 7). This is evident in the patterns of both standard deviation and precipitation frequency. Type 6 shows an elongated axis of maximum standard deviations on short with increased precipitation frequency in the eastern half of the region. Type 7 shows the axis of maximum standard deviations off the coast with an area of greatly enhanced precipitation frequency oriented northeastward through central California. The representative maps for both of these types are included with Rasch and MacDonald map-type 4 for which the pattern of precipitation is a reasonable fit to Paegle and Kierulff type 6. The area of increased precipitation frequency northeastward from central California characteristic of type 7 appears to be associated with Rasch and MacDonald type 7. Paegle and Kierulff map-types 1 and 2 make a significant distinction in precipitation frequency in the Pacific Northwest yet the representative maps for both of these types are included in Rasch and MacDonald type 1. Paegle and Kierulff type 4 is dry over the entire Western Region; i.e., well below average precipitation frequency at all stations. The representative map for this type is included with Rasch and MacDonald type 6 which is also dry over most of the Western Region except Montana and, in this respect, is very similar to type 9. The implication of these examples is that expanding the grid area does not really improve on the stratification of 500-mb flow patterns with respect to precipitation frequency; and, there is a fine line between which of two map types, with distinctly different precipitation patterns, a given map will be included.

It is clear from the preceding map typing projects on three substantially different scales that the complexity of the flow patterns increases as the size of the grid increases. The small area covered by the grid of Lund (1972) produces flow patterns approximating the 8-point compass. The larger area covered by the Paegle and Kierulff (1974) grid results in fairly straightforward variations on westerly flow after the heights are averaged. The expanded grid used by Rasch and MacDonald (1975) introduces extensive areas in Central Canada and east of the Rockies and produces representative maps with complex flow patterns which often appear to be dominated by short wave features. Comparison of representative maps and precipitation frequency in relation to map types for the latter two studies indicates that (1) the typing procedure is rather crude, (2) the larger grid area does not appear to handle the long waves any better, (3) the averaging process smoothes out the short waves so that the resulting flow patterns can be more easily interpreted with respect to the long waves, and (4) useful information about the short waves relative to the long waves is contained in the standard deviations which are a convenient by-product of the averaging process.

V. CONCLUSIONS

The operational 500-mb map types do provide a degree of synoptic scale stratification of 500-mb maps. This is evident in the variations in precipitation frequencies over the Western Region which are presented as part of the map types, Rasch and MacDonald (1975). It is also evident in the Cornett (1978) Yucca Weather Station climatology conditioned on the map types that stratification is achieved for a point within the Western Region. The work of Lund (1972) suggests that in order to fine-tune the map typing technique to a single point it is desirable to reduce the grid area in order to better define the slope of the pressure surface relative to the point of interest. His winter map types pretty well stratify flow patterns representing the 8-point compass as one would sort of expect and hope for when dealing with a small area relative to a single point. The operational map types are rather crude in this respect because of the large grid area. Except for broad bands of westerly flow with low amplitude wave structure, the Western Region is just too large to have really meaningful flow patterns common to the entire region. The complexities introduced by split flows and high amplitude wave structures make it rather difficult to recognize the long wave structure relative to the region.

It appears to be desirable to smooth the flow patterns by averaging rather than using a single map to represent the type. This eliminates the distortion in the flow pattern due to small-scale features contained in the representative map and allows for greater ease in interpreting a given synoptic pattern relative to the flow for the map type. An analysis of the variance of heights at grid points can be produced as a by-product during the averaging process and this enhances the understanding of variations in flow patterns identified with a map type.

This is the suggestion of the presence of the long waves in the map types and in this respect they provide a meaningful and objective approach to grading the quality of 72-hour 500-mb forecast maps. The goodness of the map-type forecasts does not necessarily carry over to a given weather element for a specific point within the Western Region even though the implication is that for a set of forecasts of a given map type that verify above the threshold value that weather element will occur with the relative frequency specified by a climatology conditioned on the map types. In other words, point forecasts should tend to be reliable over an extended period of time if the map types verify well.

The map type that appears in the first position of the bulletin (i.e., correlates highest with the forecast map) verifies above the threshold value on 85.5 percent of the occasions annually, 88.8 percent in winter, 75.3 percent in spring, 90.0 percent in summer and 88.5 percent in fall. The map types that appear in the second and third positions of the bulletin may also verify above the threshold value, but less frequently than the map type in the first position. They occasionally verify better than the map type in the first position.

Verification of winter map types only indicates that (1) the higher the correlation between the forecast map and the map type the higher the verification correlation, (2) there are appreciable differences in verification between map types with the types that occur most frequently verifying better than the less frequently occurring types, and (3) there is a substantial overforecasting bias; i.e., the map type correlates with the forecast map above the threshold value more often than it verifies above the threshold value.

Verification for the winter of 1976/77 indicates that the verification deteriorates as the length of the forecast interval increases.

VI. REFERENCES

[1] Cornett, J.S. The Yucca Flat Weather Associated with 500-mb Map Types, WSNSO 351-67, 7pp. Weather Service Nuclear Support Office, Las Vegas, Nevada, 1978.

[2] Lund, Iver A. Map-Pattern Classification by Statistical Methods. J. Appl. Meteor., 2, pp 56-65, 1963.

[3] Climatology as a Function of Map Type, Environmental Research Paper No. 391, AFCRL-72-0173, 15 pp., 1972.

[4] Paegla, Julia N. and Lawrence P. Kierulff. Synoptic Climatology of 500-mb Winter Flow Types, J. Appl. Meteor., 13, pp. 205-212, 1974.

[5] Rasch, Glenn E. and Alexander E. MacDonald. Map Type Precipitation Probabilities for the Western Region, NOAA Technical Memorandum NWS WR-96, 138 pp, 1975.

VII. ADDENDUM

Example of map-type bulletin as currently transmitted over AFOS.

```
NMC5TCNMC
FXUS3 KWBC  291200
500MB MAP TYPE CORRELATIONS OCT 29
INITL 12 HR 24 HR 36 HR 48 HR 72 HR
02898 02859 02817 02810 02813 05920
01777 04775 04755 01753 01796 02839
08745 01761 01750 05656 05778 01832
```

First two numbers of each 5-digit set represent the map type published in [5].

The last three numbers give the correlation of the current chart to the map type.

Example: The 24-hour 500-mb spectral prognosis valid 1200Z on October 30th correlates at 0.817 with map type two; 0.755 with map type four; and, 0.750 with map type one. The initial data time on which this bulletin was based is 1200Z October 29, 1981.

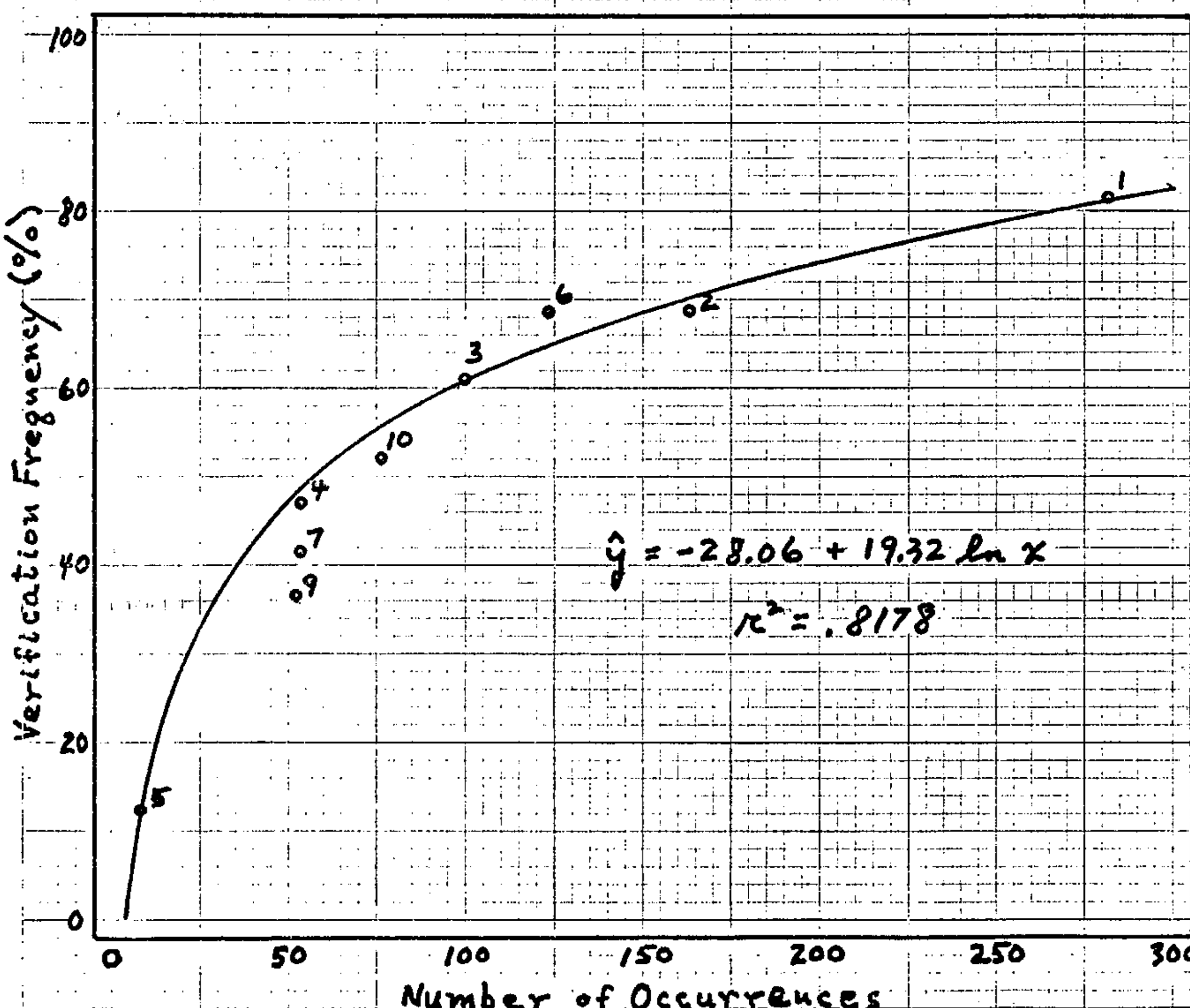

Figure 1. Verification frequency as a function of the frequency with which a map type occurs. Numbers with plotted points are winter map type.

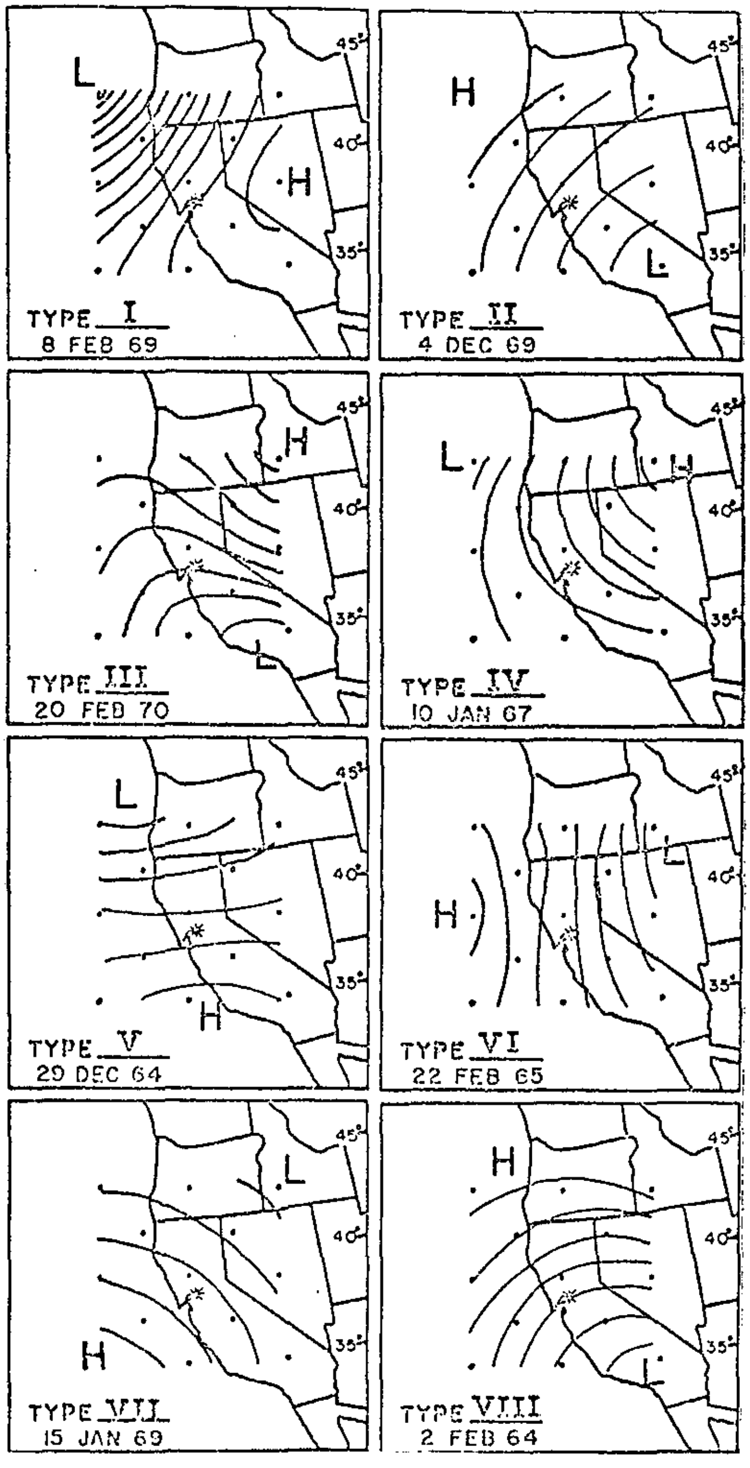

Figure 2. 1000mb winter map types for Travis AFB, CA. (From Lund, 1972)

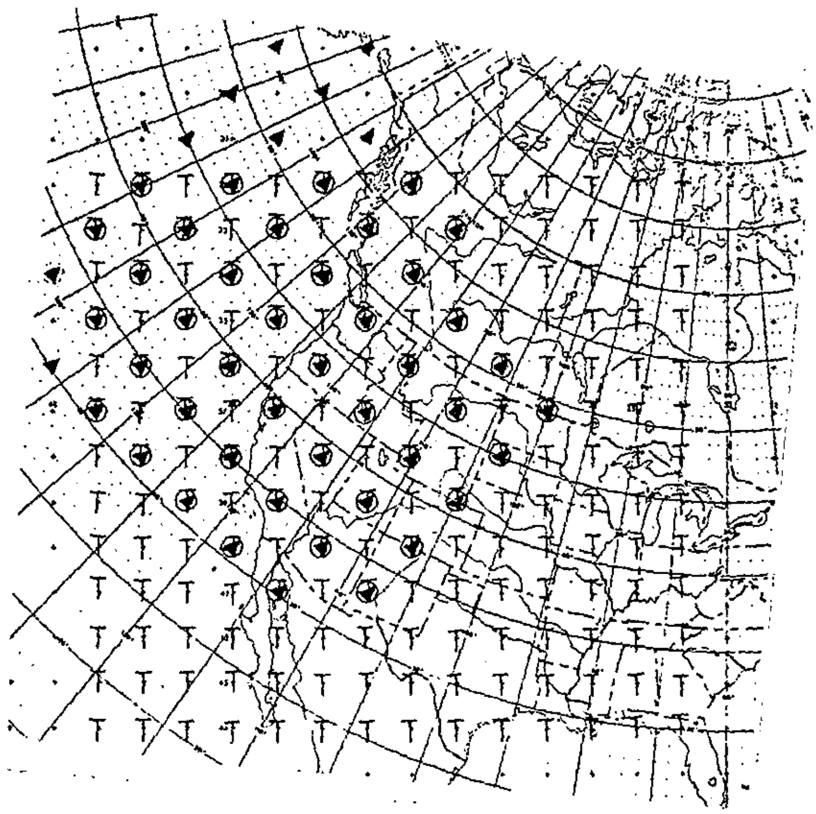

Figure 3. Grids 1 (▲), 2 (T) and 3 (O). (From Paegle and Kierulff, 1974)

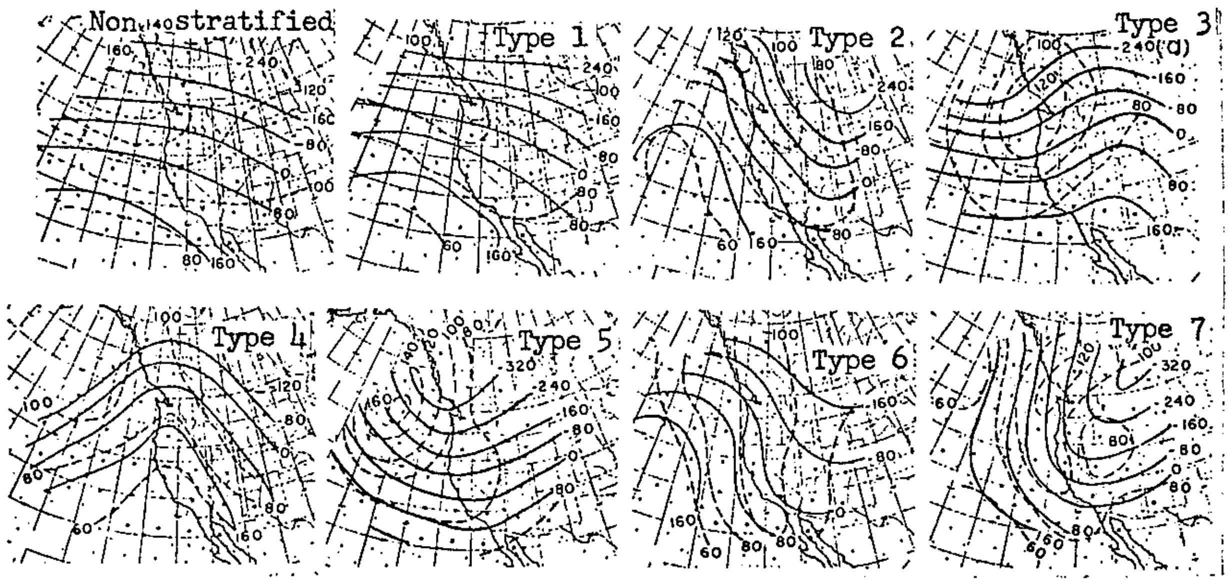

Figure 4. Paegle and Kierulff winter map types. Solid lines are departure from 5572 meters; dashed lines are standard deviation of 500mb heights. (From Paegle and Kierulff, 1974)

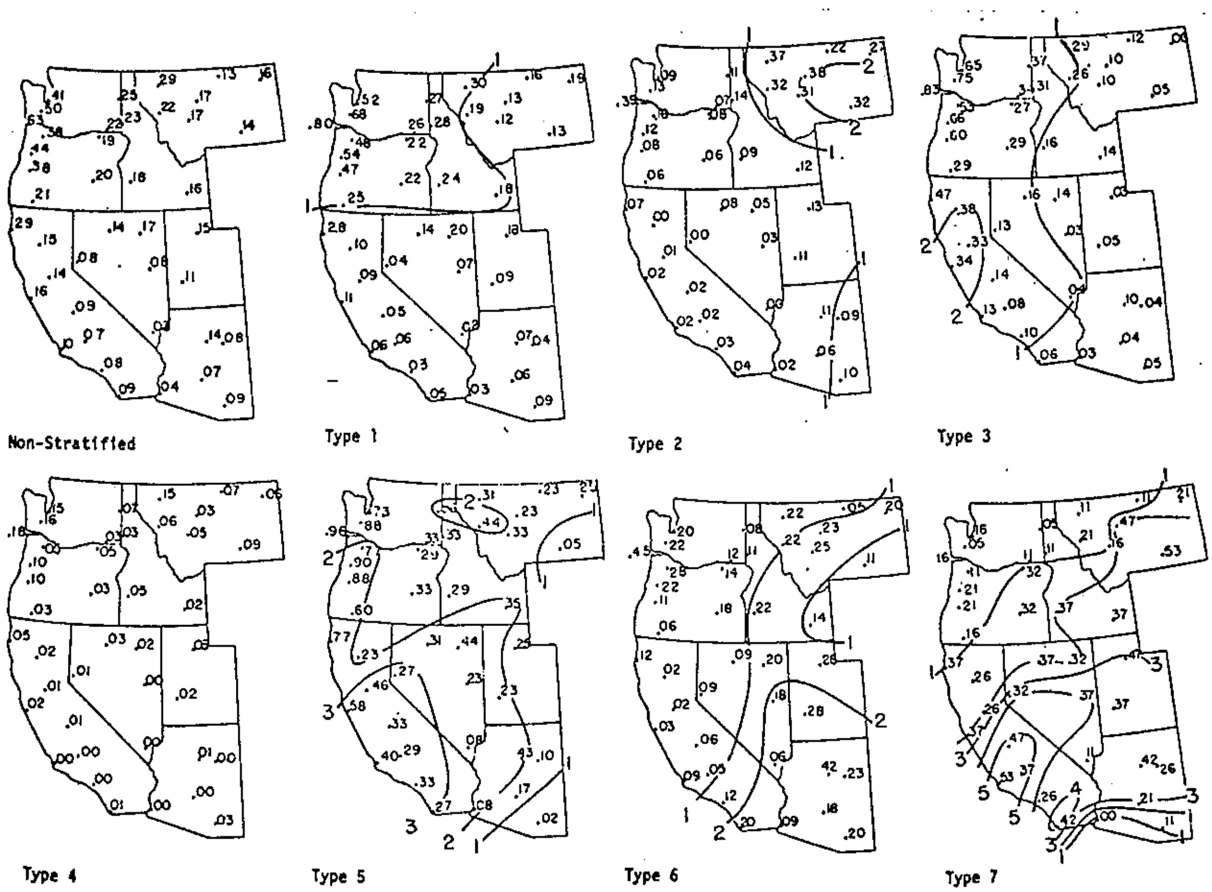

Figure 5. Precipitation frequency for Paegle and Kierulff winter map types. Solid lines are ratio of map-type precipitation frequency to non-stratified precipitation frequency. (From Paegle and Kierulff, 1974)

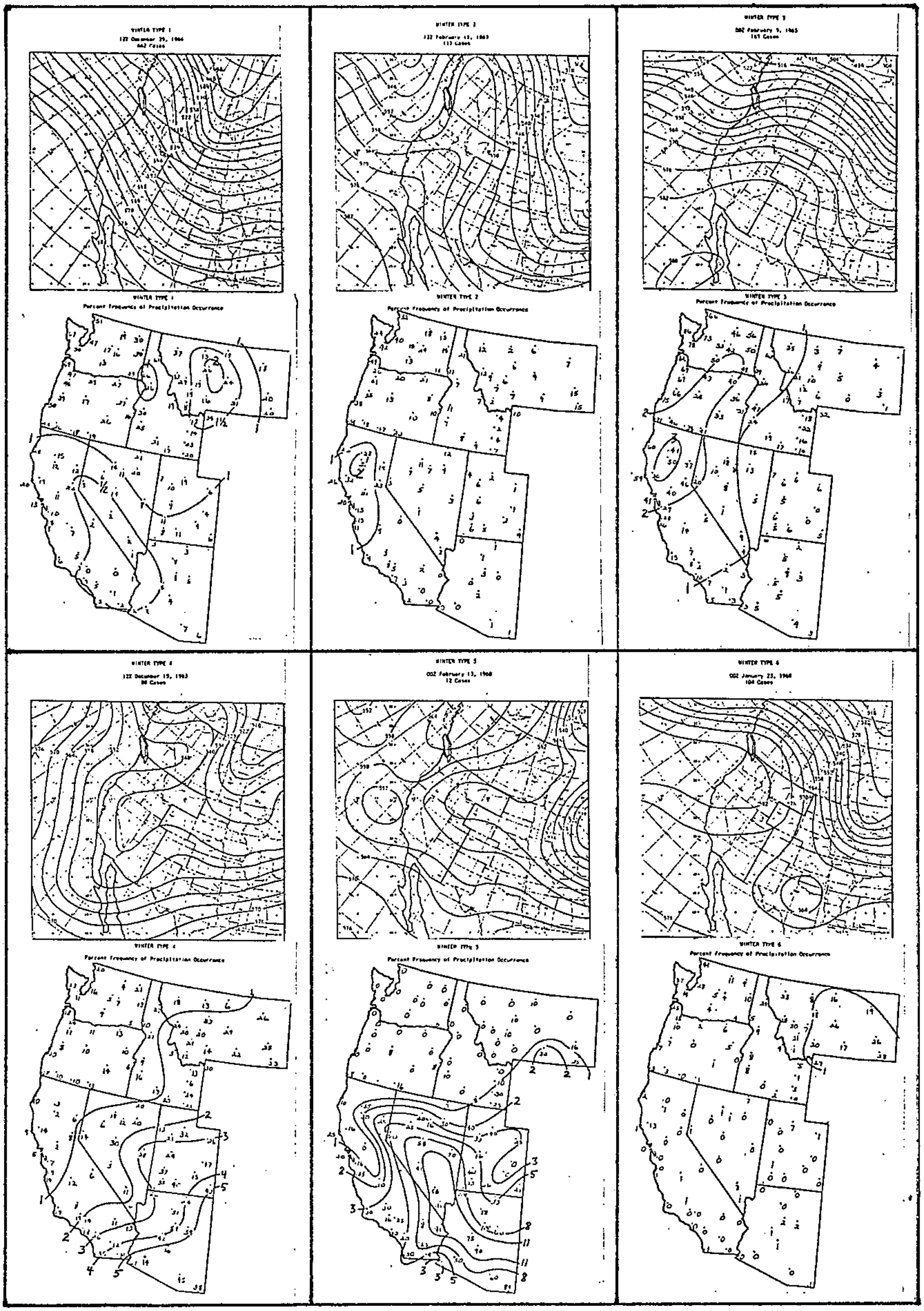

Figure 6. Rasch and McDonald (1975) winter map types. Solid lines on precipitation frequency charts are ratio of type frequency to non-stratified frequency.
(Figure Continued Next Page)

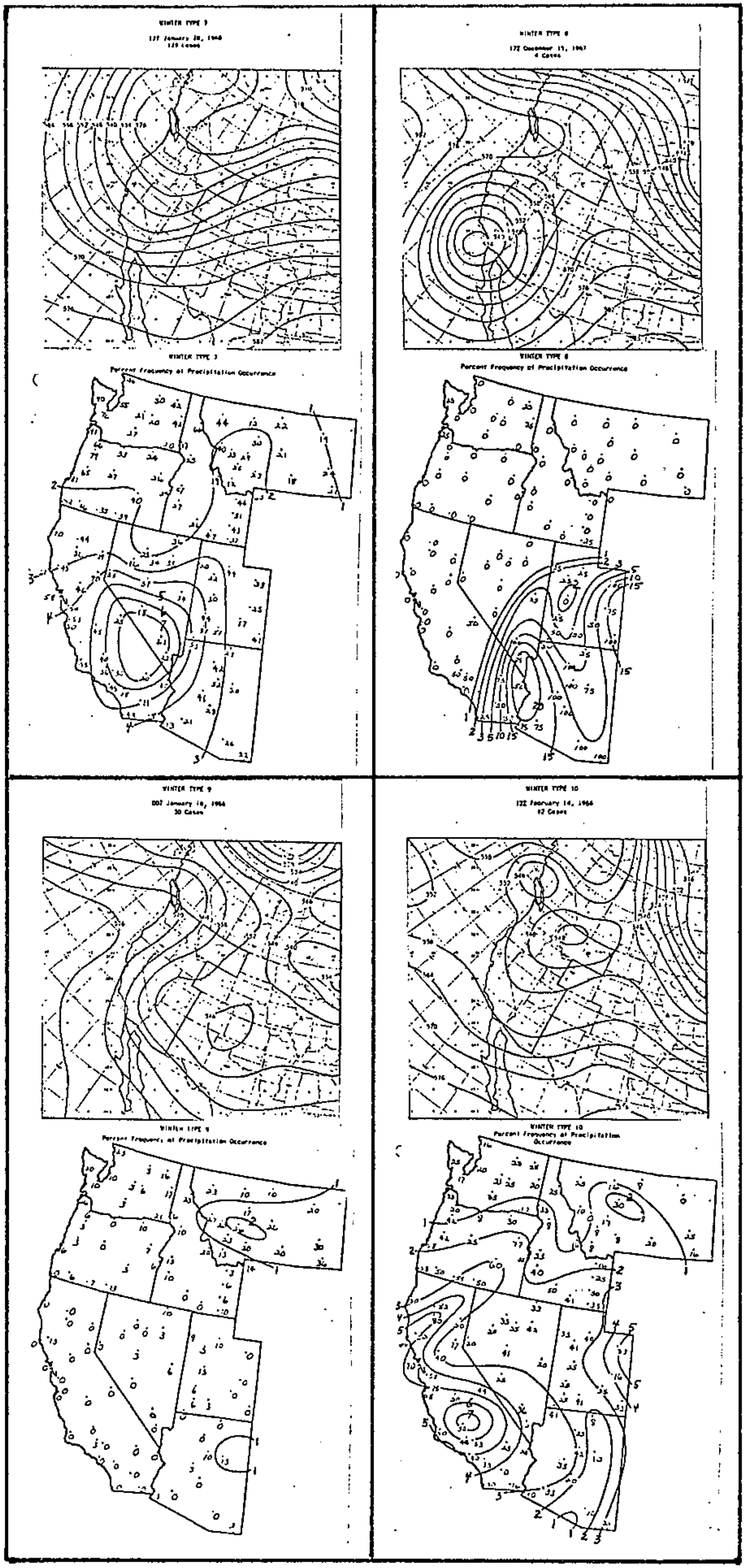

Figure 6. Continued.

Table 1. Frequency with which each map type appeared in the first position of the bulletin and the expected frequency based on the relative frequency in the sample used to develop the map types.

Type	Winter						Spring						Summer						Fall						Winter	
	00Z		12Z		00Z/12Z		00Z		12Z		00Z/12Z		00Z		12Z		00Z/12Z		00Z		12Z		00Z/12Z		1976/77	
	Obs	Exp	Obs	Exp	Obs	Exp	Obs	Exp	Obs	Exp	Obs	Exp	Obs	Exp	Obs	Exp	Obs	Exp	Obs	Exp	Obs	Exp	Obs	Exp	Obs	Exp
1	66	68	81	86	147	154	69	74	75	87	144	161	89	71	95	78	184	149	90	91	93	92	183	183	53	63
2	33	11	39	15	72	26	20	15	16	18	36	33	4	9	6	9	10	18	20	23	20	23	40	46	43	11
3	15	17	20	21	35	38	7	21	15	24	22	45	16	15	10	15	26	30	22	14	14	14	36	28	10	16
4	2	9	4	12	6	21	16	10	18	12	34	22	9	9	12	10	21	19	5	3	6	3	11	5	2	8
5	0	1	2	2	2	3	12	12	17	14	29	26	0	4	0	5	0	9	4	8	6	8	10	16	2	1
6	6	10	9	14	15	24	10	4	14	4	24	8	1	6	2	7	3	13	2	6	6	7	8	13	12	10
7	5	13	9	17	14	30	2	3	3	3	5	6	1	6	2	6	3	12	2	*	3	*	5	1	0	12
8	0	*	0	1	0	1	4	1	6	2	10	3	10	8	14	9	24	17	3	3	2	3	5	6	0	*
9	1	3	2	4	3	7	0	1	0	1	0	2	0	1	0	1	0	2							0	3
10	5	1	8	2	13	3	1	*	2	1	3	1	0	1	0	1	0	2							3	1
N	133		174		307		141		166		307		130		141		271		148		150		298		125	

* Indicates less than 0.5 occurrences expected.

Table 2. Proportion of the 72-hour 500mb map types which verified at, or better than, the specified levels. Verification values are cumulative from left to right.

Season	Forecast Position	Forecast Initial Hour	Forecast No. of Fcsts	≥920 1st	≥920 2nd	≥920 3rd	≥860 1st	≥860 2nd	≥860 3rd	≥800 1st	≥800 2nd	≥800 3rd	<800 1st	<800 2nd	<800 3rd	Not in 1st 3 ≥800	Not in 1st 3 <800
Wi	1st	00Z	133	.278	.278	.278	.556	.691	.699	.767	.805	.880	.903	.941	.957	.972	1.003
		12Z	174	.287	.293	.293	.552	.650	.690	.759	.851	.897	.932	.944	.961	.967	1.001
		All	307	.283	.286	.286	.553	.667	.693	.761	.829	.888	.917	.940	.956	.966	.999
	2nd	00Z	133	.045	.045	.045	.188	.316	.361	.377	.513	.611	.634	.687	.718	.854	1.004
		12Z	174	.034	.034	.034	.149	.310	.333	.368	.494	.603	.620	.683	.723	.895	.998
		All	307	.039	.039	.039	.166	.313	.346	.372	.502	.606	.626	.685	.721	.877	1.001
	3rd	00Z	133	0	0	0	.068	.136	.174	.174	.279	.460	.475	.513	.611	.851	1.002
		12Z	174	.011	.011	.011	.045	.131	.165	.188	.286	.453	.464	.487	.573	.848	.997
		All	307	.007	.007	.007	.056	.134	.170	.183	.284	.457	.470	.499	.590	.851	1.001
Sp	1st	00Z	141	.135	.135	.135	.404	.475	.475	.595	.701	.751	.786	.871	.928	.949	.999
		12Z	167	.102	.102	.102	.431	.461	.467	.605	.719	.755	.815	.881	.923	.941	1.001
		All	308	.117	.117	.117	.419	.468	.471	.601	.711	.753	.802	.877	.926	.945	1.000
	2nd	00Z	141	.021	.021	.021	.162	.204	.211	.274	.444	.536	.557	.678	.764	.807	.998
		12Z	167	.018	.018	.018	.096	.168	.180	.216	.414	.486	.516	.600	.744	.804	1.002
		All	308	.019	.019	.019	.126	.184	.194	.243	.428	.509	.535	.636	.753	.805	1.000
	3rd	00Z	141	0	0	0	.042	.077	.084	.133	.261	.339	.346	.396	.630	.723	1.000
		12Z	167	0	0	0	.054	.108	.114	.162	.222	.294	.318	.438	.576	.642	1.001
		All	308	0	0	0	.049	.094	.100	.149	.240	.315	.331	.419	.601	.679	1.000
Su	1st	00Z	130	.277	.277	.277	.585	.677	.685	.747	.847	.909	.909	.932	.932	.994	1.002
		12Z	142	.254	.254	.254	.536	.621	.628	.698	.825	.895	.902	.909	.944	.979	1.000
		All	272	.265	.265	.265	.559	.647	.654	.720	.834	.900	.904	.919	.937	.985	1.000
	2nd	00Z	130	.031	.031	.031	.184	.292	.307	.369	.561	.623	.623	.699	.799	.914	.999
		12Z	142	.077	.077	.077	.190	.303	.310	.359	.507	.577	.577	.661	.731	.886	.999
		All	272	.055	.055	.055	.187	.297	.308	.363	.532	.598	.598	.679	.764	.900	.999
	3rd	00Z	130	.015	.015	.015	.061	.122	.145	.153	.214	.298	.306	.329	.560	.753	.999
		12Z	142	.007	.007	.007	.063	.119	.140	.147	.245	.393	.393	.435	.640	.802	1.000
		All	272	.011	.011	.011	.062	.121	.143	.150	.231	.349	.353	.386	.603	.779	1.000
Fa	1st	00Z	148	.297	.297	.297	.628	.689	.689	.736	.817	.878	.878	.905	.939	.959	1.000
		12Z	150	.314	.314	.314	.614	.727	.747	.800	.867	.894	.901	.935	.968	.988	1.001
		All	298	.305	.305	.305	.620	.707	.717	.767	.841	.885	.888	.918	.952	.972	.999
	2nd	00Z	148	.047	.047	.047	.182	.425	.432	.466	.628	.702	.716	.770	.830	.905	1.000
		12Z	150	.020	.020	.020	.154	.274	.281	.314	.514	.587	.607	.667	.774	.907	1.000
		All	298	.034	.034	.034	.168	.349	.356	.390	.571	.645	.662	.719	.803	.907	1.001
	3rd	00Z	148	.013	.013	.013	.040	.107	.141	.148	.229	.452	.452	.493	.655	.797	.999
		12Z	150	.027	.027	.027	.074	.147	.167	.174	.254	.468	.475	.521	.675	.795	1.002
		All	298	.020	.020	.020	.057	.127	.154	.161	.242	.460	.463	.507	.665	.796	1.001
Ann	1st	00Z	552	.246	.246	.246	.543	.632	.636	.710	.792	.854	.868	.911	.938	.967	1.005
		12Z	633	.237	.239	.239	.531	.612	.631	.715	.815	.859	.888	.918	.950	.969	1.001
		All	1185	.241	.242	.242	.537	.621	.633	.712	.803	.855	.877	.913	.943	.969	1.000
	2nd	00Z	552	.036	.036	.036	.179	.312	.330	.373	.538	.620	.634	.710	.780	.870	1.000
		12Z	633	.036	.036	.036	.145	.262	.275	.313	.481	.563	.580	.653	.743	.872	1.000
		All	1185	.036	.036	.036	.161	.285	.300	.341	.507	.589	.605	.679	.759	.870	.999
	3rd	00Z	552	.007	.007	.007	.053	.111	.137	.154	.248	.391	.398	.436	.617	.782	1.001
		12Z	633	.011	.011	.011	.058	.125	.146	.168	.252	.400	.411	.470	.612	.770	.999
		All	1185	.009	.009	.009	.055	.118	.141	.160	.249	.395	.404	.453	.613	.774	.998

Table 3. Joint distribution of forecast and verification map-type correlations tabulated as the proportion of the times the map type appeared in the bulletin during the winter season. The number of times the map type appeared in any one of the three positions in the bulletin is given in the lower right-hand corner of the tabulation for each map type. The entry in the diagonal representing common class intervals for forecast and verification is underlined.

	Forecast Correlation	Verification Correlation ≥950	900-949	850-899	800-849	750-799	<750	Not One of Three, 3rd is ≥800	Not One of Three, 3rd is <800	Sum	Cumulative	Bias
Type 1	≥950	.060	.064	.011						.135	.135	1.47
	900-949	.021	.174	.092	.032		.004	.004		.327	.462	1.09
	850-899	.011	.067	.099	.046	.007	.007	.025	.004	.266	.728	1.08
	800-849		.028	.035	.039	.011		.021	.011	.145	.873	1.07
	750-799			.011	.018	.077	.014		.011	.061	.934	
	<750				.007	.014	.046			.067	1.001	
	Sum	.092	.333	.248	.142	.039	.071	.050	.026			
	Cumulative	.092	.425	.673	.815	.854	.935	.975	1.001			282
Type 2	≥950	.000								.000	.000	--
	900-949		.074	.086	.025			.006	.006	.197	.197	1.46
	850-899		.055	.178	.086	.018		.080		.417	.614	1.18
	800-849		.006	.104	.037	.006	.006	.067	.018	.244	.858	1.25
	750-799			.018	.018	.000	.006	.025	.025	.092	.950	
	<750					.012	.037			.049	.999	
	Sum	.000	.135	.386	.166	.036	.049	.178	.049			
	Cumulative	.000	.135	.521	.687	.723	.772	.950	.999			163
Type 3	≥950	.010	.010	.010						.030	.030	1.50
	900-949	.010	.102	.020	.010	.020		.010		.172	.202	1.05
	850-899		.051	.133	.051		.010	.051	.010	.306	.508	1.11
	800-849		.010	.092	.061	.020	.020	.020	.051	.274	.782	1.30
	750-799			.010	.020	.020		.010	.031	.092	.874	
	<750					.010	.102	.010		.122	.996	
	Sum	.020	.173	.265	.142	,070	.132	.101	.092			
	Cumulative	.020	.193	.458	.600	.670	.802	.903	.996			98
Type 4	≥950	.000								.000	.000	--
	900-949		.000	.020					.020	.040	.040	2.00
	850-899			.111	.130	.020		.037		.298	.338	1.63
	800-849		.020	.056	.020	.037		.148	.020	.301	.639	1.36
	750-799				.093	.020		.074	.056	.243	.882	
	<750				.020		.074	.020	.020	.134	1.016	
	Sum	.000	.020	.187	.263	.077	.074	.279	.116			
	Cumulative	.000	.020	.207	.470	.547	.621	.900	1.016			54
Type 5	≥950	.000								.000	.000	--
	900-949		.000							.000	.000	--
	850-899			.000						.000	.000	--
	800-849				.000	.125				.125	.125	1.00
	750-799					.250	.125			.375	.500	
	<750				.125		.250	.125		.500	1.000	
	Sum	.000	.000	.000	.125	.375	.375	.125	.000			
	Cumulative	.000	.000	.000	.125	.500	.875	1.00	1.000			8

(Table Continued Next Page)

Table 3. Continued.

	Forecast Correlation	Verification Correlation								Sum	Cumulative	Bias
		≥950	900-949	850-899	800-849	750-799	<750	Not One of Three, 3rd is ≥800	Not One of Three, 3rd is <800			
Type 6	≥950	.000								.000	.000	--
	900-949		.016	.081	.024					.121	.121	3.03
	850-899		.024	.185	.105	.008	.008	.073	.008	.411	.532	1.37
	800-849			.081	.145	.024		.129	.024	.403	.935	1.36
	750-799				.024	.008		.008	.016	.056	.991	
	<750						.008			.008	.999	
	Sum	.000	.040	.347	.298	.040	.016	.210	.048			
	Cumulative	.000	.040	.387	.685	.725	.741	.951	.999			124
Type 7	≥950	.000	.037							.037	.037	--
	900-949		.000	.037						.037	.074	0.96
	850-899		.020	.074	.037		.020	.037	.037	.225	.299	0.99
	800-849		.020	.056	.056	.020		.056	.037	.245	.544	1.31
	750-799			.020	.020	.037	.020	.020	.111	.228	.772	
	<750			.037		.020	.167		.020	.244	1.016	
	Sum	.000	.077	.224	.113	.077	.207	.113	.205			
	Cumulative	.000	.077	.301	.414	.491	.698	.811	1.016			54
Type 8 did not occur.												
Type 9	≥950	.000								.000	.000	--
	900-949		.000		.038					.038	.038	--
	850-899			.077	.077			.058		.212	.250	1.62
	800-849			.077	.058	.038	.038	.077	.(77	.365	.615	1.68
	750-799				.038	.038	.038	.077	.173	.364	.979	
	<750					.019	.000			.019	.998	
	Sum	.000	.000	.154	.211	.095	.076	.212	.250			
	Cumulative	.000	.000	.154	.365	.460	.540	.748	.998			52
Type 10	≥950	.000								.000	.000	--
	900-949		.013							.013	.013	0.14
	850-899		.052	.130	.078			.026	.013	.299	.312	1.26
	800-849		.026	.026	.117	.013	.013	.117		.312	.624	1.20
	750-799				.078	.013	.026	.065	.052	.234	.858	
	<750						.104	.013	.026	.143	1.001	
	Sum	.000	.091	.156	.273	.026	.143	.221	.091			
	Cumulative	.000	.091	.247	.520	.546	/689	.910	1.001			77
All Types	≥950	.020	.023	.004						.047	.047	1.52
	900-949	.008	.081	.060	.021	.002	.001	.003	.002	.178	.225	1.15
	850-899	.003	.045	.128	.070	.008	.005	.047	.007	.313	.538	1.16
	800-849		.015	.064	.063	.018	.007	.065	.023	.255	.793	1.22
	750-799			.009	.030	.014	.012	.023	.037	.125	.918	
	<750			.002	.004	.010	.058	.003	.004	.081	.999	
	Sum	.031	.164	.267	.188	.052	.083	.141	.073			
	Cumulative	.031	.195	.462	.650	.702	.785	.926	.999			912

Table 4. Proportion of the forecast map types which verify above the threshold value of 800 in relation to the forecast correlation.

Correlation	No. of Forecasts	No. Verifying ≥800	Proportion Verifying
≥950	43	43	1.000
900-949	163	155	.951
850-899	286	225	.787
800-849	231	129	.558
750-799	114	35	.307
<750	75	6	.080
All	912	593	.650

Table 5. Map-type verification for the winter season 1976/77 given as the proportion of the forecasts which verified above the threshold correlation value. Values in parenthesis are cumulative from the left.

Forecast Position	Forecast Interval	Verification Position				No. of Forecasts
		1st	2nd	3rd	Not Among 1st 3 or <800	
1st	12	.856	.120(.976)	.016(.992)	.008	125
	24	.783	.186(.969)	.023(.992)	.008	129
	36	.710	.218(.928)	.040(.968)	.032	124
	48	.683	.206(.889)	.063(.952)	.048	126
	72	.608	.232(.840)	.112(.952)	.048	125
2nd	12	.120	.648(.768)	.152(.920)	.080	125
	24	.186	.550(.736)	.124(.860)	.140	129
	36	.210	.484(.694)	.153(.847)	.153	124
	48	.230	.397(.627)	.167(.794)	.206	126
	72	.216	.272(.488)	.184(.672)	.328	125
3rd	12	.016	.144(.160)	.488(.648)	.352	125
	24	.031	.178(.209)	.434(.643)	.357	129
	36	.056	.161(.217)	.411(.628)	.371	124
	48	.048	.190(.238)	.310(.548)	.452	126
	72	.088	.192(.280)	.232(.512)	.488	125

Table 6. Representative map of the Paegle and Kierulff (1974) map types and the corresponding Rasch and McDonald (1975) map type with which the map is included.

Paegle & Kierulff		Rasch & McDonald
Map Type	Map Date, Time	Map Type
1	1/12/67,1200	1
2	2/13/66,0000	1
3	1/28/67,1200	3
4	12/31/61,1200	6
5	12/30/64,1200	7
6	12/16/65,1200	4
7	2/26/62,0000	4
8	1/31/63,0000	3