WEATHER BUREAU
Western Region

Salt Lake City, Utah

October 1967

Verification of Operational Probability of Precipitation Forecasts, April 1966–March 1967

W. W. DICKEY

Technical Memorandum WBTM WR-25

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

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

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

Weather Bureau Technical Memorandum WR-25

VERIFICATION OF OPERATIONAL PROBABILITY OF PRECIPITATION FORECASTS, APRIL 1966 - MARCH 1967

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WESTERN REGION
TECHNICAL MEMORANDUM NO. 25

SALT LAKE CITY, UTAH
OCTOBER 1967

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VERIFICATION OF OPERATIONAL PROBABILITY OF PRECIPITATION FORECASTS, APRIL 1966 - MARCH 1967

I. INTRODUCTION

This memorandum summarizes the verification of a portion of the probability-of-precipitation forecasts issued to the public during the first full year, April 1966 - March 1967, of such forecasts in the Western Region. The forecasts verified are those issued in the early morning between about 1000Z and 1200Z for the periods "Today" (1200-0000Z); "Tonight" (0000Z-1200Z); and "Tomorrow" (1200-0000Z).

The scores presented in this report are for the entire 12 months of forecasts and for each station as a whole except as noted. These statistics, therefore, give an overall picture of how probability forecasting is going, but give no information on the variations of the scores with season nor on the performance of individual forecasters. The desirability of each forecaster accumulating his own forecasts, computing his own Brier score, and constructing his own reliability table or graph cannot be stressed too strongly. Following these suggested procedures will enable each forecaster to discover his own biases and limitations, improve his own forecasts, and thus raise the level of performance of the station and the Region.

II. DEFINITIONS OF SCORES

The scores and quantities presented in the tables and figures have the following definitions:

Observed Precipitation (%) - This is the percentage occurrence of precipitation for the entire 12 months, April 1966 - March 1967. (The number of precipitation periods divided by the total number of periods times 100.)

B_f - Abbreviated Brier Score [1] for the forecasts. Values of this score in Table 1 are the averages of the twleve monthly values. The term Abbreviated Brier Score is used since these scores are based only on the forecast probability of precipitation, and are therefore equal to only one-half of the full Brier Score (referred to as "P-Score" in monthly machine printouts).

B_c - Abbreviated Climatological Brier Score. Values of this score in Table 1 are the averages of the twleve monthly values. They are not computed from the yearly climatological and observed percentage values.

I (%) - Percent improvement of B_f over B_c, i.e.,

$$I\ (\%) = \frac{B_c - B_f}{B_c}\ (100)$$

Average Deviation - This is a simple measure of reliability of the forecasts. It is the average deviation of the forecast probabilities from the observed percent of precipitation occurrences in each of the probability categories. The deviation in each forecast category is weighted by the number of forecasts in each category and the sum divided by the total number of forecasts. The low values of deviations result from the larger number of cases in the 10% or less categories and therefore are not representative of deviations for the higher probability categories.

III. VERIFICATION RESULTS

In Table 1, in the order given above, are listed the above defined quantities for each station. The stations are listed by Forecast Center for greater ease of comparison with other stations in the same general area, and with stations which have received guidance from the same source. To further facilitate these comparisons and to make comparisons more meaningful, a number of graphs and charts have been prepared.

Brier Scores: Figure 1 shows the relationship between the observed frequency of occurrence of precipitation and the average climatological Brier Scores. The separate scores for each forecast period for each station have been plotted on this graph. The increase in B_c is almost entirely dependent upon the observed frequency. The deviations from a perfect quadradic relationship are accounted for by the deviation of the observed frequency of precipitation from the long-term climatic frequency, which normally is not large. The equation for B_c is:

$$B_c = (C-R)^2 + R\ (1-R)$$

where C is the long-term climatological frequency of precipitation and R is the observed ratio of precipitation occurrences to the total number of forecasts (the observed percent frequency). The dashed curve in Figure 1 was drawn "by eye"; and since the scatter is so small, it gives a reliable relationship between B_c and observed frequency of precipitation for the period April 1966 through March 1967.

Figure 2 shows the relationship between the observed frequency of precipitation and the Brier scores for the forecasts for the first period, "Today". While a definite relationship exists (the greater the frequency of occurrence, in general the larger the Brier score), there is considerable scatter reflecting the variation of skill among stations. The solid line has been drawn "by eye" to represent the average or expected Brier score for a given observed frequency of occurrence of precipitation. Station personnel can get at least a qualitative idea of their standing in relation to other stations in the Region by determining whether its B_f score falls above (worse than average) or below (better than average) the solid line. The dashed line is the climatological relationship taken from Figure 1, for comparison.

For example, if station indicated by A and B on Figure 2 are compared, they both have a B_f score of 0.11; but station A is well below average and station B is above the Regional forecast average. Table 1 can be used to locate specific stations on this and subsequent figures.

Similar relationships are shown in Figure 3 for the second period (Tonight); in Figure 4 for the third period (Tomorrow); and in Figure 5 for all three periods combined. Note that the relationship between B_f and the observed precipitation frequency approaches the climatological relationship as the forecast period is extended further into the future.

To further illustrate the relationships between the Brier score and the observed frequency of precipitation, the geographical distributions of the observed frequencies and the forecast Brier scores for all three periods combined are shown in Figures 6 and 7, respectively. The isolines on these charts have been smoothed to fit the plotted values with no attempt to take into account topographic features. The similarity between the patterns of the isolines is quite apparent.

This apparent dependence of the Brier score upon the observed frequency of precipitation is not inherent in the scoring system itself; skillful forecasts will result in a low Brier score regardless of the frequency of occurrence of precipitation. It results from the rather universal inability to adequately forecast precipitation. It suggests that in the range of climatic frequencies of precipitation observed in the United States (generally less than 50%), there is a mean expected probability forecast error associated with precipitation events which is considerably larger than the mean expected probability forecast error associated with no-precipitation events. Hence, the error accumulates with each precipitation event leading to an increased Brier score with increasing frequency of precipitation. This being the case, a much fairer and more meaningful comparison between stations is the deviation from some mean curve as those drawn on Figures 2 - 5, rather than a comparison of the raw Brier scores.

IV. IMPROVEMENT OVER CLIMATOLOGY

The I-Score, percent improvement over climatology, is also an attempt to "equalize" or "normalize" the Brier score so that scores from different climatic regimes can be compared with some meaning. This score has drawbacks which are discussed by Hughes in Weather Bureau Technical Note 20-CR-3. However, at least in the Western Region, this score does not appear to be dependent upon the observed frequency of occurrence and is the best score thus far devised for comparing forecasts from different climatic regimes. Figure 8 shows that the I-Scores for the 12 months summarized here have no significant relationship to the observed frequency of precipitation.

At the top of Figure 9 are shown the frequency distributions of the I-Scores for "Today", "Tonight", "Tomorrow" and all periods combined. Note the marked decrease in mean percent improvement from "Today" to "Tonight".

In the lower portion of Figure 9 is shown the Cumulative Percent Frequency distributions of the I-Scores. These curves are convenient for determining the decile or quartile into which a particular score falls. For example, in the lower right portion of Figure 9 are the ranges of the I-Scores for the quartiles. A station can determine its relative standing in the Region on this particular 12-month verification sample either from the curves or from the Table.

For example, San Francisco with I-Scores of 44%, 38% and 22% for the respective three forecast periods (obtained from Table I) is average for the first period with 50% of the 43 stations in the program better and the other 50% worse than San Francisco. For the second and third forecast periods only 8% of the stations (3) are better than San Francisco.

Other statistics of interest can be taken from the curves in Figure 9, such as:

Statistic	Today	Tonight	Tomorrow	All Periods Combined
Percent of Stations worse than climatology	0%	0%	10%	0%*
50% of stations showed improvement over climat equal to or greater than:	44%	18%	8%	15%
10% of stations showed improvement over climat equal to or greater than:	66%	36%	22%	40%

*All stations are better than climatology when the average I of the three periods is considered.

V. RELIABILITY SCORES

The weighted average deviation of the forecast probabilities from the observed percentage occurrence of precipitation in each forecast probability category is a simple and easily visualized measure of the reliability of the forecasts. Since the squares of these deviations form a part of the Abbreviated Brier Score, one would expect that the average deviation from perfect reliability is also related to the observed frequency of precipitation. That this is so can be seen in Figures 10, 11 and 12. Here again, as in Figures 2 - 5, lines of best fit have been drawn "by eye" to represent the average or expected average deviation as a function of the observed percentage. Since the simple difference between the forecast probability and the observed percent frequency of occurrence has been used here, rather than the square of the deviation which is involved in the computation of the Brier score, a linear relationship has been assumed on these graphs. Station personnel can determine, at least qualitatively, their relative standing among their peers by noting whether their average deviation is below (better than average) or above (worse than average) the line. A better and more detailed look at the reliability of the forecasts is obtained from a Reliability Graph in which the forecast probabilities are plotted versus the observed percentage of occurrence in each probability category, and it is recommended that each station staff construct such graphs from the tables at the bottom of the monthly computer printouts of the local verification program. Such reliability graphs for the Region as a whole based on these 12 months of verification data were presented in [2].

VI. CONCLUDING REMARKS

The scores and graphs presented in this report and in Technical Attachment No. 67-28 indicate that considerable success was achieved during the first 12 months of "public" probability forecasting in attaching meaningful probabilities to the precipitation forecasts. There is, of course, much room for improvement, especially in the second and third forecast periods. Improvement in the reliability of the forecast can be achieved through preparing and studying verification data for each forecaster's forecasts. Construction of reliability graphs to discover individual biases and limitations is recommended. Reliability, however, is only a small part of the Brier score. By far the greater portion of the Brier score results from lack of resolution in the forecasts (see [1]). Improvement in resolution (the ability to attach high probabilities to rain situations, and low probabilities to no-rain situations), unlike improvement in reliability, cannot be accomplished from study of verification results, no matter how long the record. Improved resolution in forecasts requires:

(1) more detailed and careful study of each forecast situation,

(2) better circulation progs, and

(3) more detailed knowledge of the relationships between the occurrence of precipitation in a local area and circulation patterns and parameters.

Only the field forecaster on the "firing line" can accomplish the first of these; NMC continuously strives to accomplish the second; and the Techniques Development Laboratory, Technical Procedures Branch, WRH Scientific Services Division and the field forecasters are attempting to contribute to the third.

VII. REFERENCES

[1] Western Region Technical Attachment No. 67-23, June 20, 1967.

[2] Western Region Technical Attachment No. 67-28, August 1, 1967.

* * * * * * *

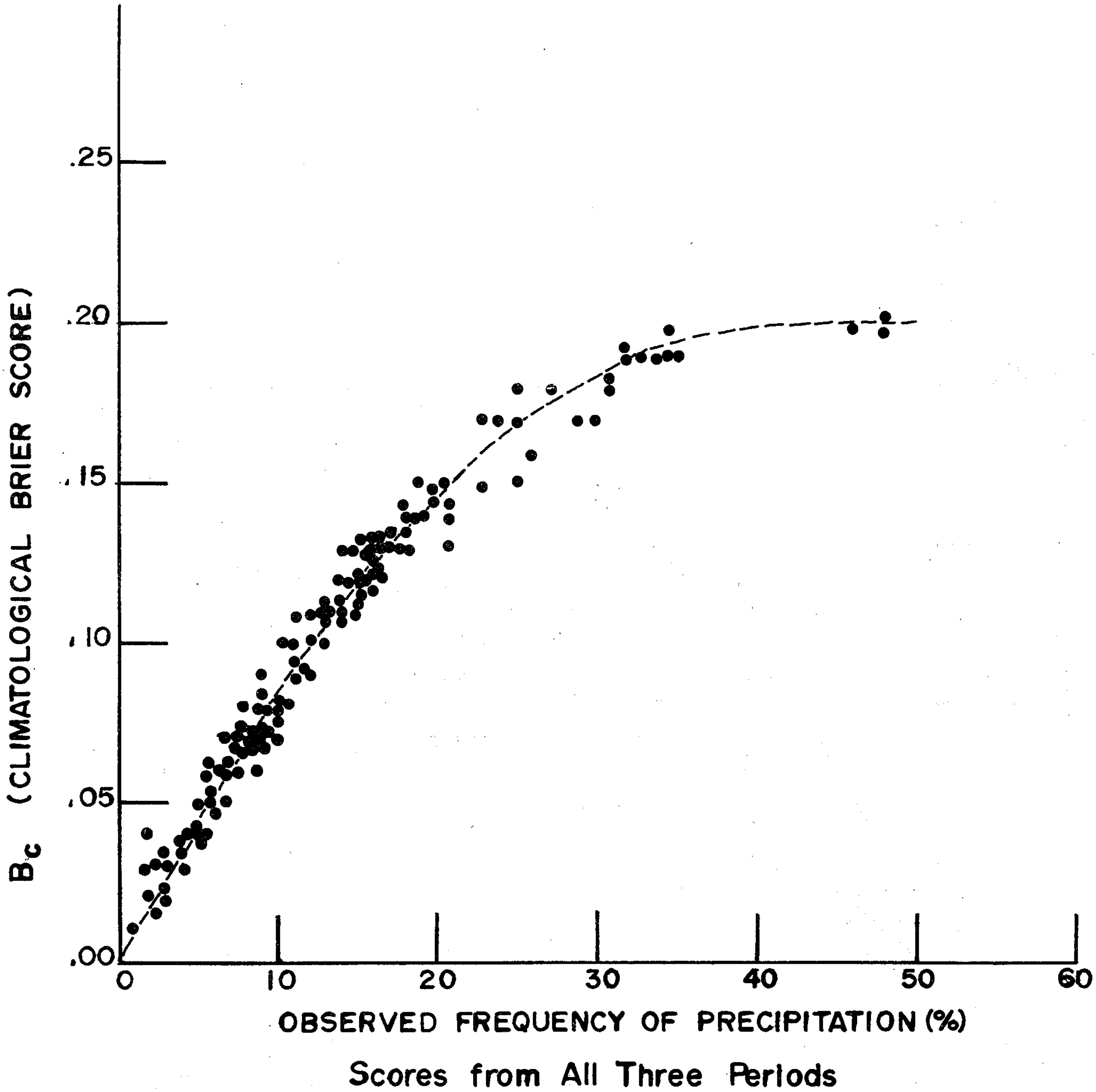


FIGURE 1 - Relationship between percent frequency of occurrence of precipitation and average climatological Brier scores, April 1966 - March 1967, for the three forecast periods "Today", "Tonight", and "Tomorrow". The dots represent values for 43 Western Region stations in the program. (3 dots for each station.)

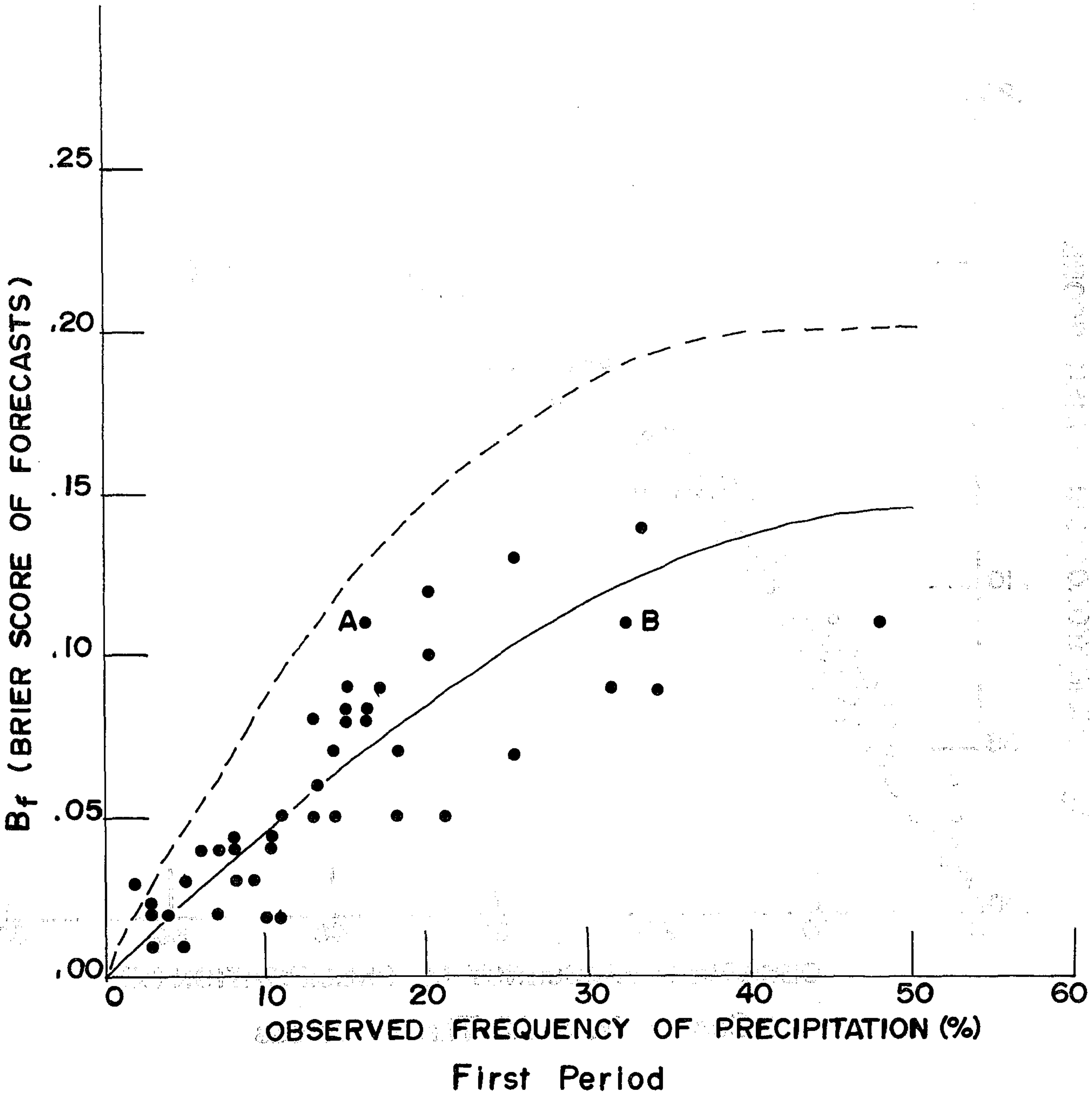


FIGURE 2 - Relationship between percent frequency of occurrence of precipitation and Average Abbreviated Brier score of the forecasts for the first period, "Today", April 1966 - March 1967. The solid curve was drawn "by eye" as an estimate of the "best fit" curve. The dashed line is the climatological curve taken from Figure 1. The average improvement over climatology is the vertical distance between the two curves. Dots "A" and "B" refer to examples discussed in Section III of text.

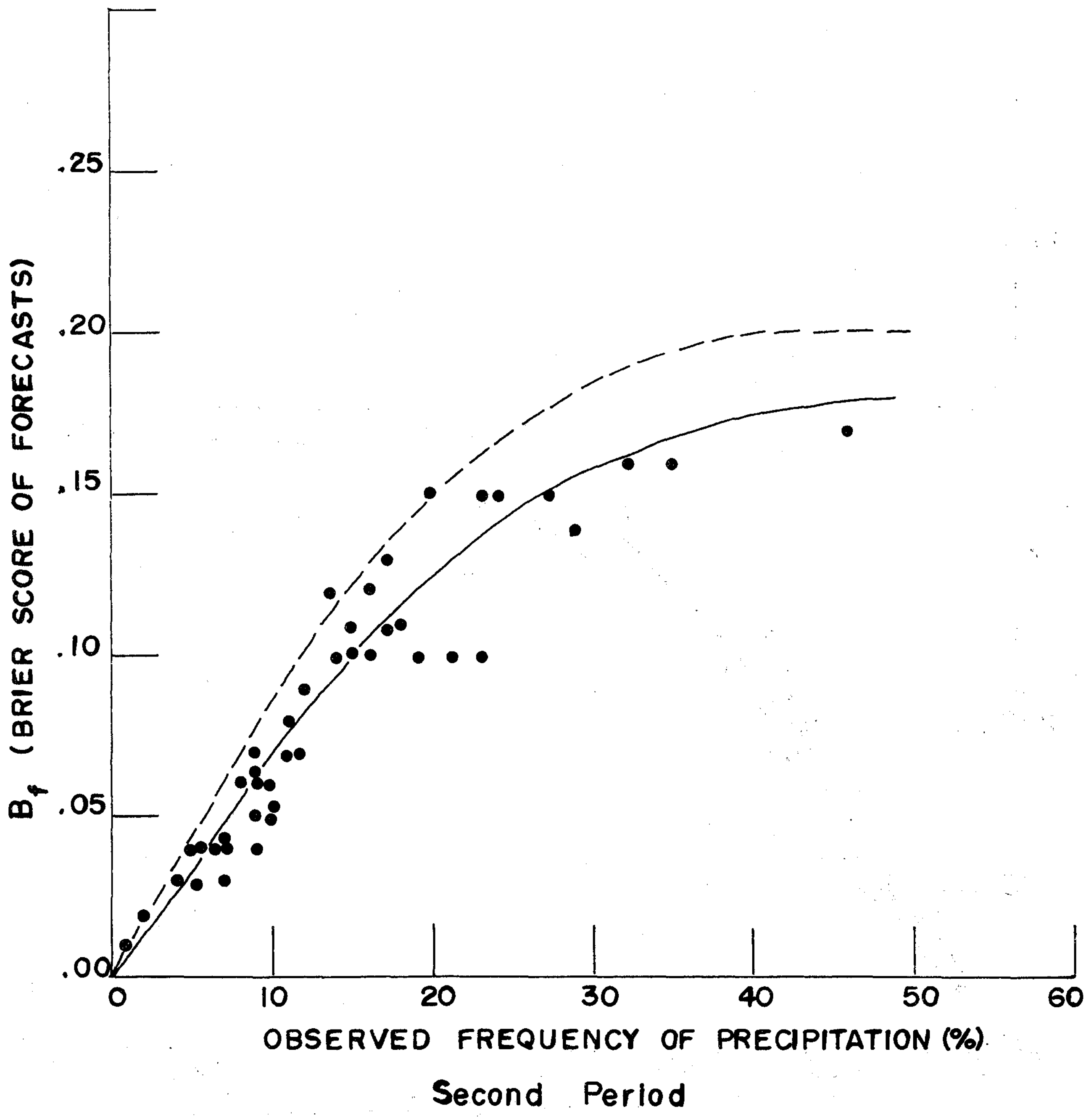


FIGURE 3 - Relationship between percent frequency of occurrence of precipitation and Average Abbreviated Brier score of the forecasts for the second period, "Tonight", April 1966 - March 1967. The solid curve was drawn "by eye" as an estimate of the "best fit" curve. The dashed line is the climatological curve taken from Figure 1. The average improvement over climatology is the vertical distance between the two curves.

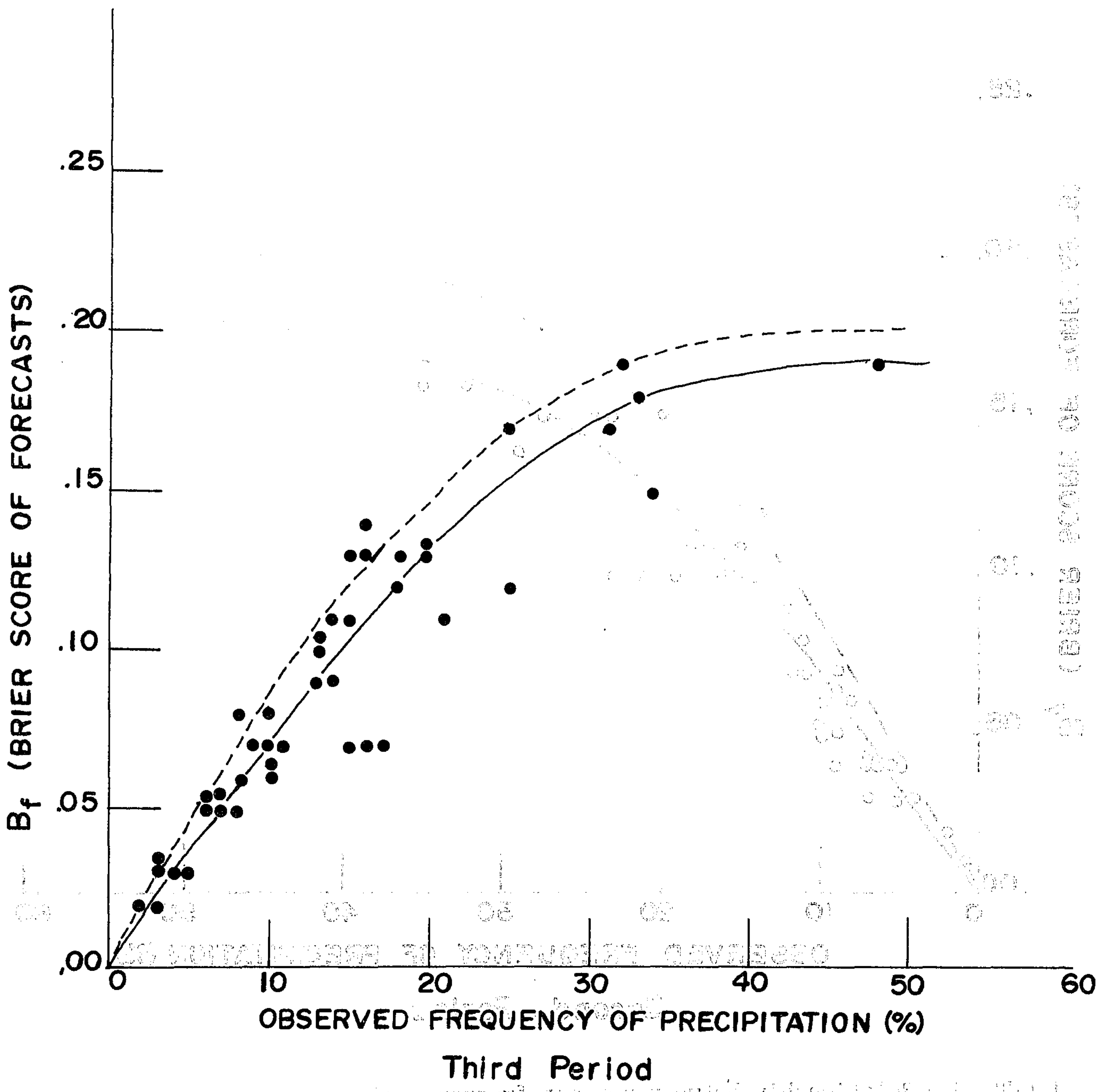


FIGURE 4 - Relationship between percent frequency of occurrence of precipitation and Average Abbreviated Brier score of the forecasts for the third period, "Tomorrow", April 1966 - March 1967. The solid curve was drawn "by eye" as an estimate of the "best fit" curve. The dashed line is the climatological curve taken from Figure 1. The average improvement over climatology is the vertical distance between the two curves.

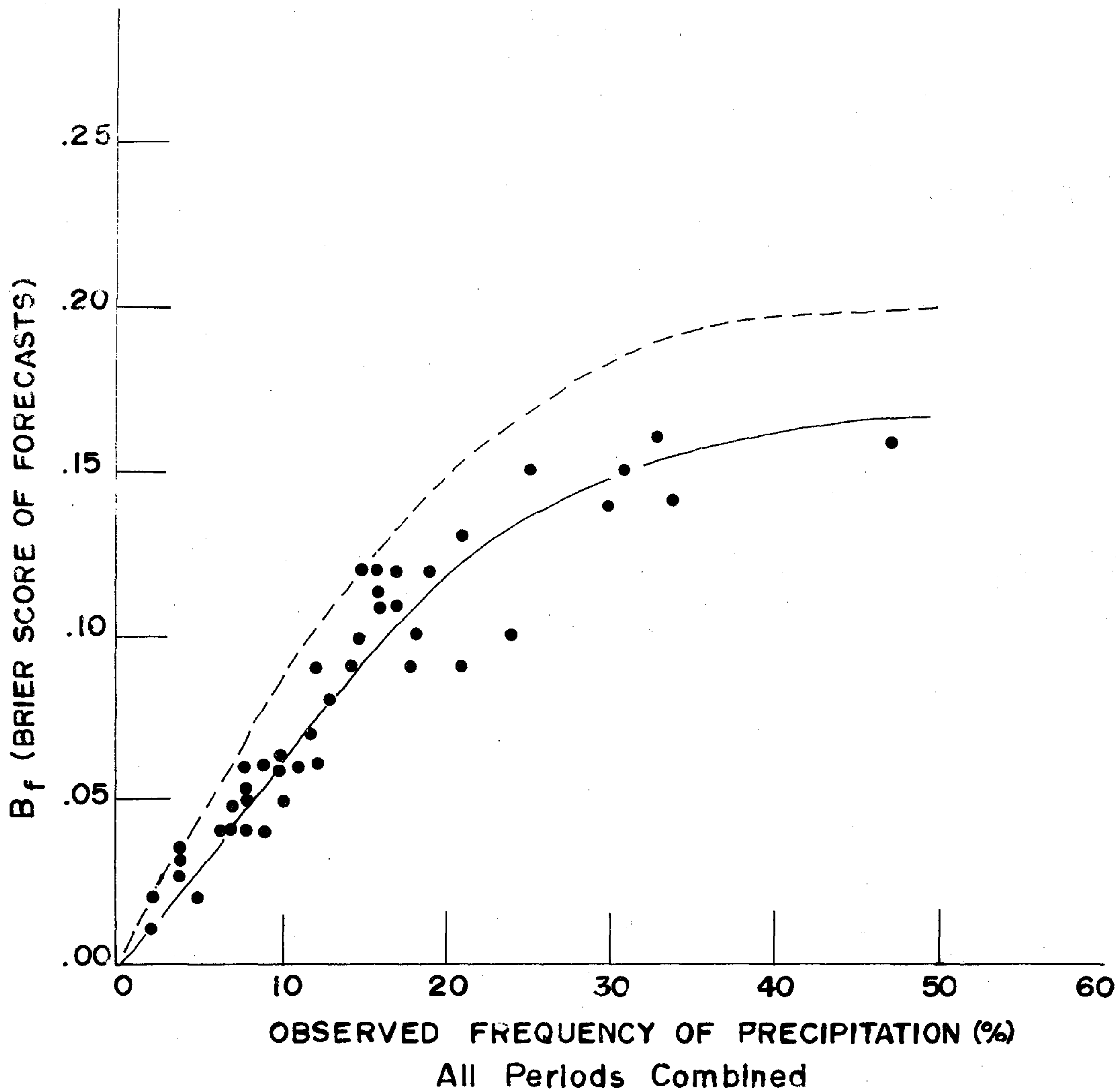


FIGURE 5 - Relationship between percent frequency of occurrence of precipitation and Average Abbreviated Brier score of the forecasts for all three periods combined, April 1966 - March 1967. The solid curve was drawn "by eye" as an estimate of the "best fit" curve. The dashed line is the climatological curve taken from Figure 1. The average improvement over climatology is the vertical distance between the two curves.

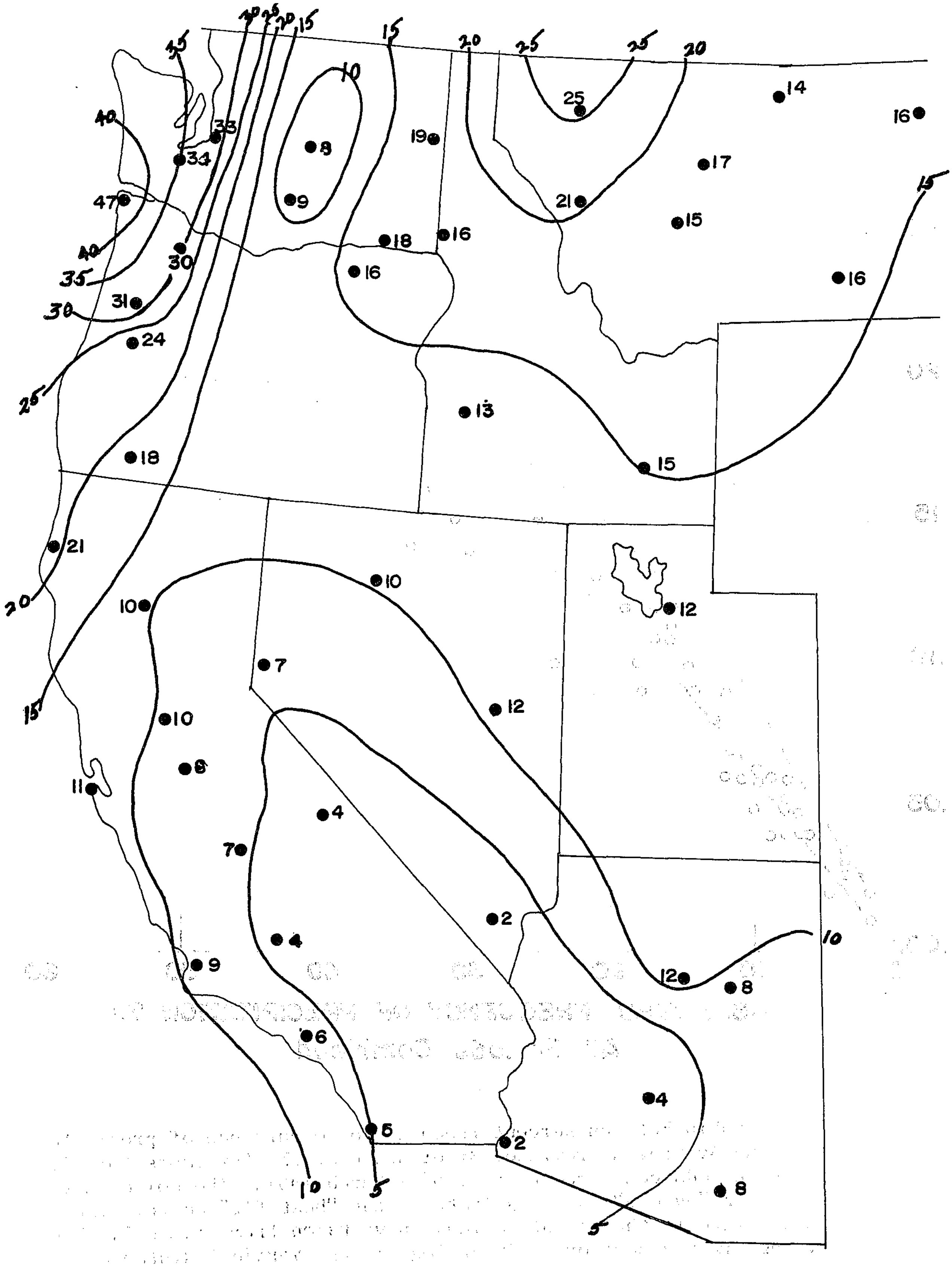


FIGURE 6 - Areal distribution of percent frequency of occurrence of precipitation, April 1966 - March 1967, for all three forecast periods combined. Isolines are smoothed to fit plotted values with no attempt to take topography into account.

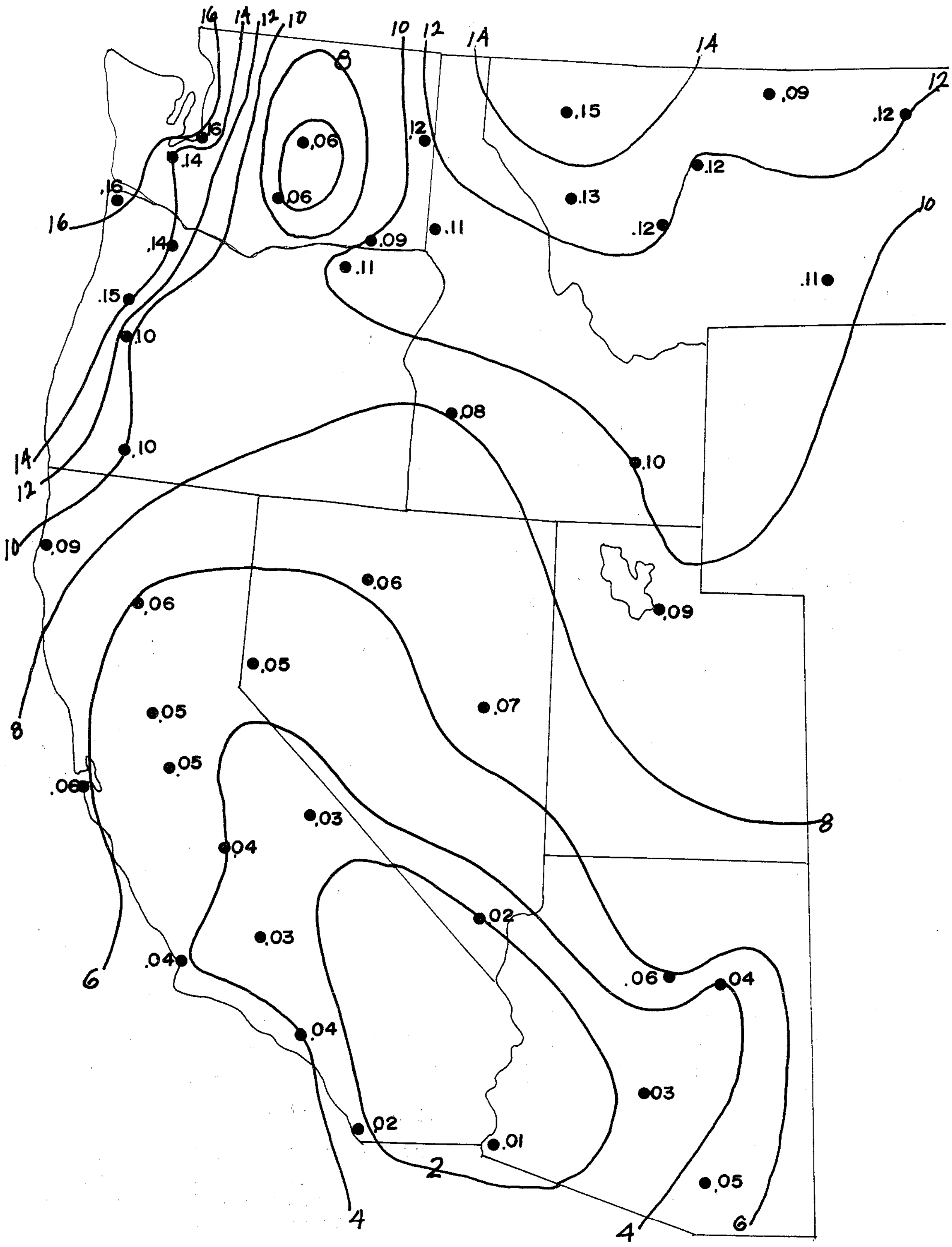


FIGURE 7 - Areal distribution of the Average Abbreviated Brier scores, April 1966 - March 1967, for all three forecast periods combined.

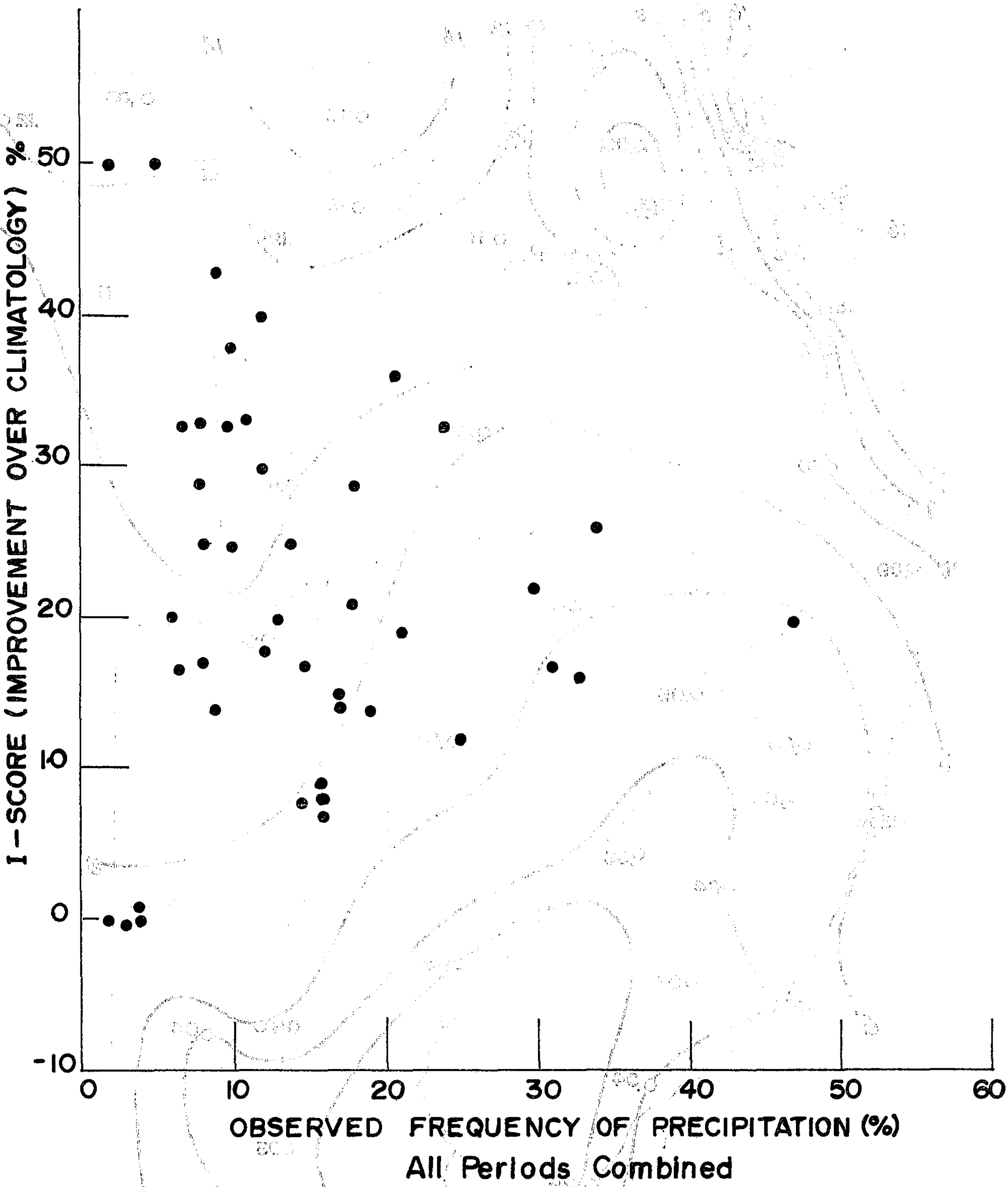
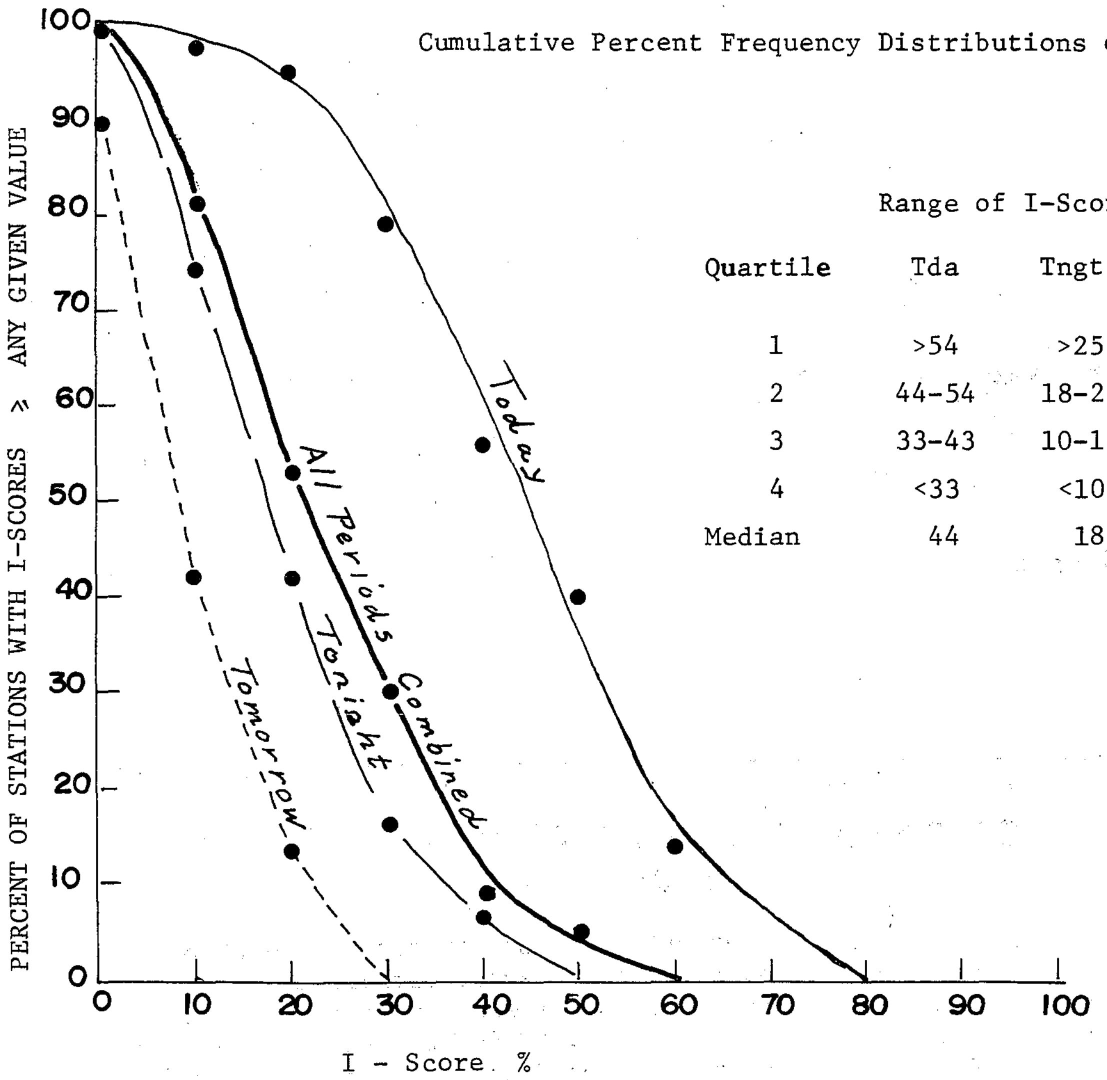


FIGURE 8 - The percent frequency of occurrence of precipitation versus the improvement over climatology for all three forecast periods combined. The extreme scatter of the plotted points indicates no significant relationship between these two quantities.

FREQUENCY DISTRIBUTIONS OF I-SCORES
(43 STATIONS)

I-Score(%)	Today	Tonight	Tomorrow	All Periods Combined
LD	0	0	4	0
0-9	1	11	21	8
10-19	1	14	12	12
20-29	7	11	6	10
30-39	10	4	0	9
40-49	7	3	0	2
50-59	11	0	0	2
60-69	3	0	0	0
70-79	3	0	0	0
Mean	42	18	8	22

Cumulative Percent Frequency Distributions of I-Scores



Range of I-Scores

Quartile	Tda	Tngt	Tmw	All Prds
1	>54	>25	>15	>32
2	44-54	18-25	8-15	22-32
3	33-43	10-17	3-7	13-21
4	<33	<10	<3	<13
Median	44	18	8	22

FIGURE 9 - Graph of Cumulative Percent Frequency Distribution of I-Scores, April 1966 - March 1967.

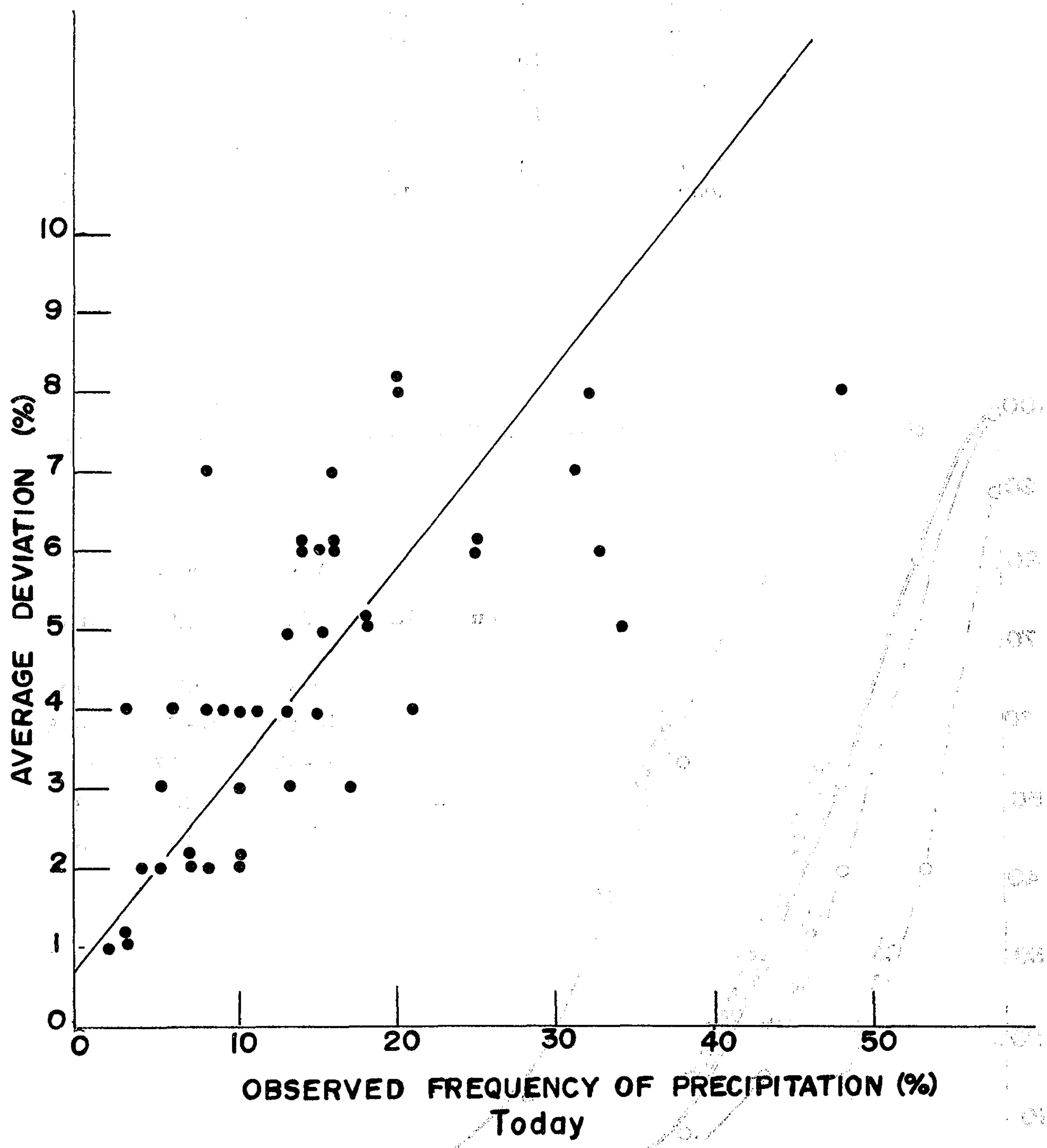


FIGURE 10 - Relationship between percent frequency of occurrence of precipitation and average deviation of forecast probabilities from observed percent frequency of occurrence in each forecast probability category for first period, "Today", April 1966 - March 1967. The solid line is a "by eye" estimate of the straight line of best fit to the plotted points.

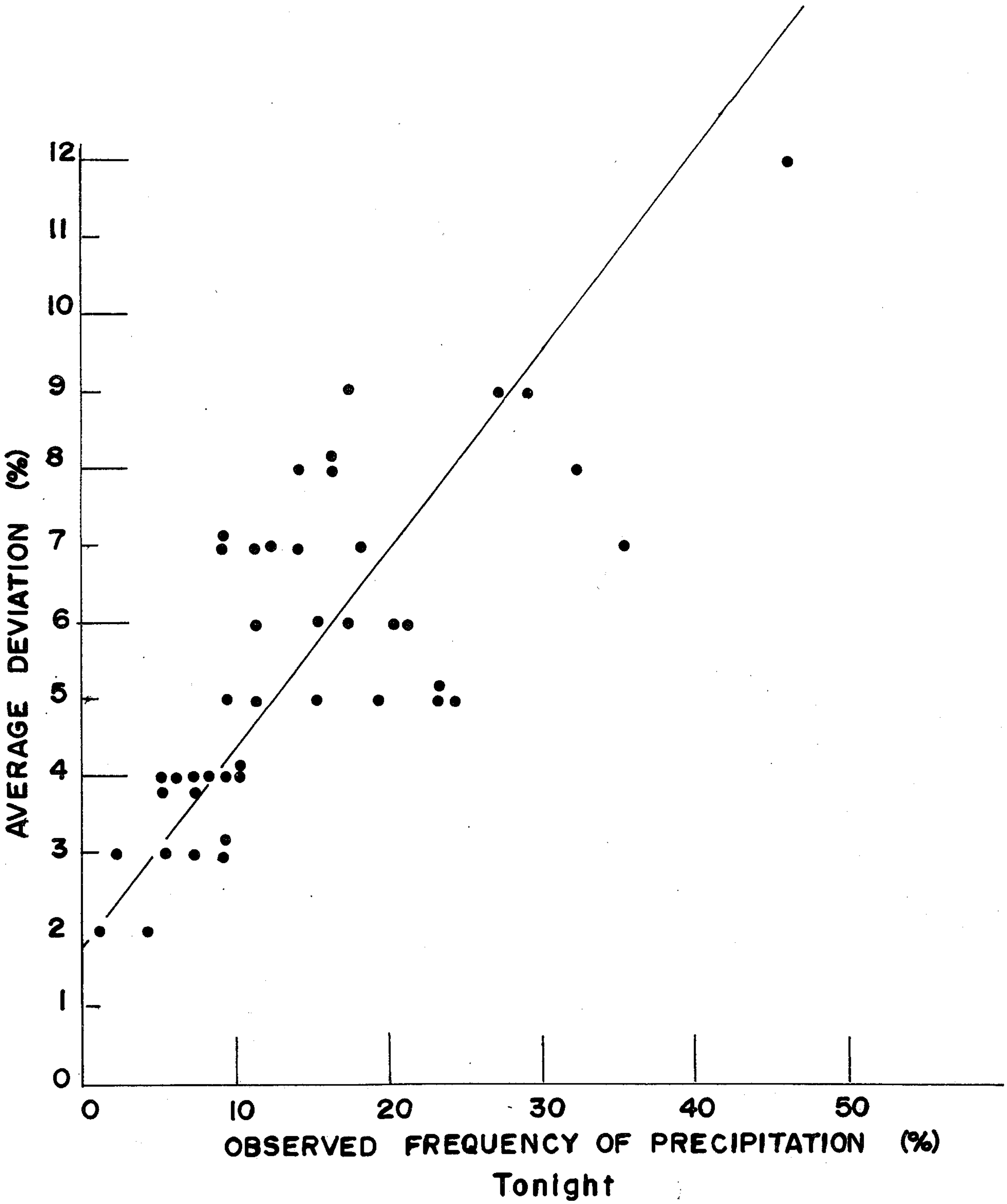


FIGURE 11 - Relationship between percent frequency of occurrence of precipitation and average deviation of forecast probabilities from observed percent frequency of occurrence in each forecast probability category for the second period, "Tonight", April 1966 - March 1967. The solid line is a "by eye" estimate of the straight line of best fit to the plotted points.

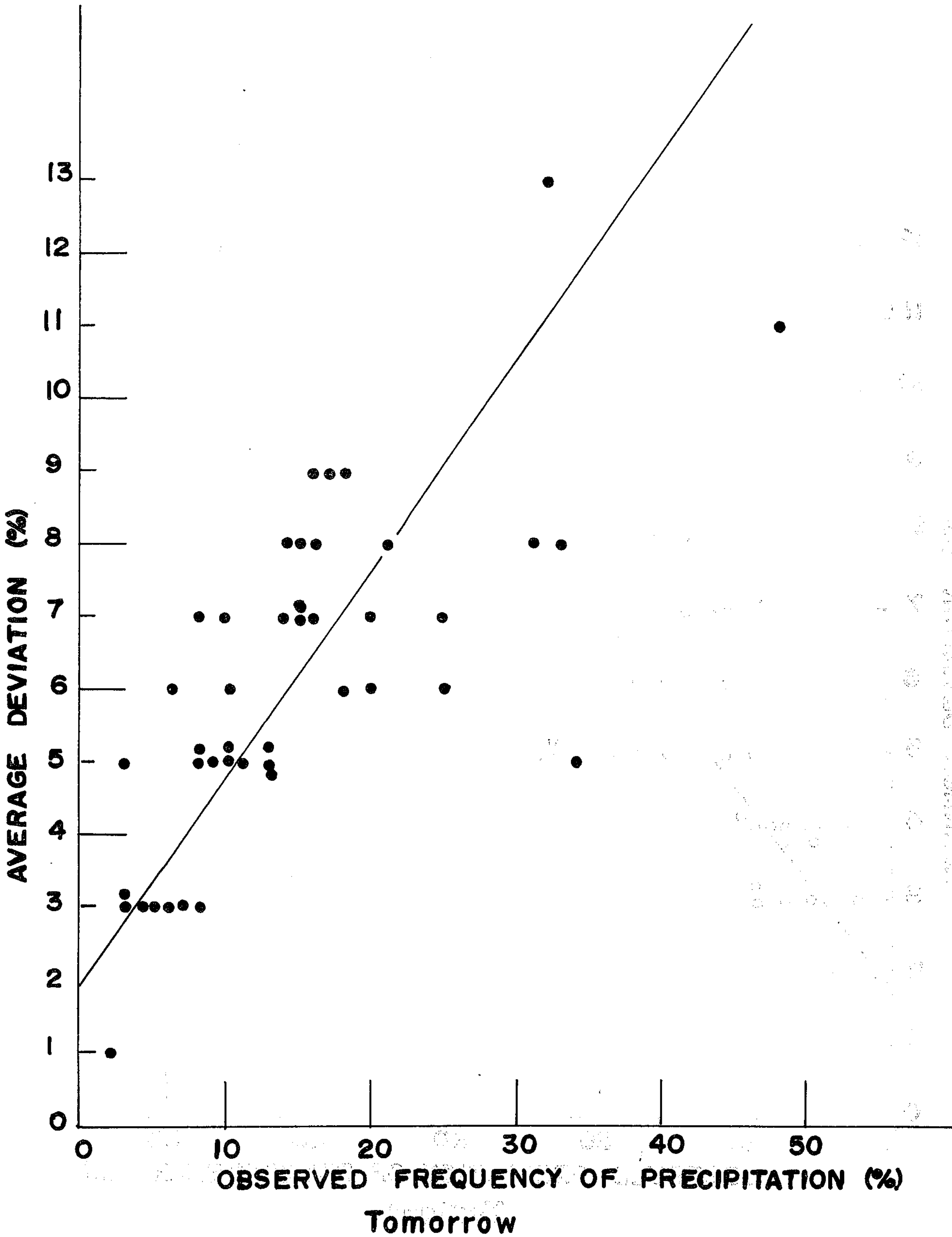


FIGURE 12 - Relationship between percent frequency of occurrence of precipitation and average deviation of forecast probabilities from observed percent frequency of occurrence in each forecast probability category for the third period, "Tomorrow", April 1966 - March 1967. The solid line is a "by eye" estimate of the straight line of best fit to the plotted points.

TABLE I

PROBABILITY OF PRECIPITATION VERIFICATION SCORES FOR INDIVIDUAL STATIONS FOR APRIL 1966 THROUGH MARCH 1967 (LISTED BY FORECAST CENTER)

Station	Today					Tonight					Tomorrow					All Periods Comb.			
	Obs. Pcpn %	Bf	Bc	I(%)	Avg Dev. %	Obs. Pcpn %	Bf	Bc	I(%)	Avg Dev. %	Obs. Pcpn %	Bf	Bc	I(%)	Avg Dev. %	Obs. Pcpn %	Bf	Bc	I(%)
Albuquerque																			
Flagstaff	14	.05	.11	55	6	9	.05	.07	29	5	14	.09	.11	18	8	12	.06	.10	40
Phoenix	3	.02	.03	33	4	5	.04	.04	0	4	3	.03	.03	0	5	4	.03	.03	0
Tucson	7	.04	.06	33	2	9	.06	.07	14	3	7	.05	.06	17	3	8	.05	.06	17
Winslow	8	.03	.07	57	4	7	.04	.05	20	4	8	.05	.07	29	3	8	.04	.06	33
Yuma*	3	.01	.02	50	1	1	.01	.01	0	2	3	.02	.02	9	3	2	.01	.02	50
Great Falls	15	.09	.12	25	6	20	.15	.16	6	6	15	.12	.13	8	7	17	.12	.14	14
Billings	17	.09	.13	31	3	16	.12	.13	8	8	17	.12	.13	8	9	17	.11	.13	15
Glasgow	16	.08	.13	38	6	17	.13	.13	0	9	16	.14	.13	-8	9	16	.12	.13	8
Havre**	14	.07	.11	36	6	15	.10	.13	23	6	14	.11	.11	0	7	14	.09	.12	25
Helena	16	.11	.13	15	7	14	.12	.13	8	8	16	.12	.12	0	7	15	.12	.13	8
Kalispell	25	.13	.18	28	6	24	.15	.17	12	5	25	.17	.17	0	7	25	.15	.17	12
Lewiston*	15	.08	.12	33	4	17	.11	.13	15	6	15	.13	.12	-8	7	16	.11	.12	8
Missoula	20	.10	.15	33	8	23	.15	.17	12	5	20	.13	.15	13	6	21	.13	.16	19
Los Angeles	5	.03	.05	40	3	7	.03	.05	40	3	6	.05	.05	0	3	6	.04	.05	20
Bakersfield	4	.02	.04	50	2	4	.03	.03	0	2	4	.03	.03	0	3	4	.03	.03	0
Bishop*	3	.02	.03	33	1	5	.04	.04	0	4	3	.03	.03	0	3	4	.03	.03	0
Las Vegas	2	.03	.03	0	1	2	.02	.02	0	3	2	.02	.02	0	1	2	.02	.02	0
San Diego	5	.01	.04	75	2	5	.03	.04	25	3	5	.03	.04	25	3	5	.02	.04	50
Salt Lake City	13	.08	.11	27	5	11	.08	.10	20	6	13	.10	.11	9	5	12	.09	.11	18
Ely	13	.05	.11	46	3	9	.06	.07	14	4	13	.09	.11	18	5	12	.07	.10	30
Boise	13	.06	.10	40	4	12	.09	.10	10	7	13	.10	.10	0	5	13	.08	.10	20
Pocatello	15	.08	.12	33	5	14	.10	.12	17	7	15	.11	.12	8	8	15	.10	.12	17

*Based on 10 months (April 1966 - January 1967 incl.)
**Based on 10 months (June 1966 - April 1967)

TABLE I (CONTINUED)

PROBABILITY OF PRECIPITATION VERIFICATION SCORES FOR INDIVIDUAL STATIONS FOR APRIL 1966 THROUGH MARCH 1967 (LISTED BY FORECAST CENTER)

Station	Today					Tonight					Tomorrow					All Periods Comb.			
	Obs. Pcpn %	Bf	Bc	I(%)	Avg Dev. %	Obs. Pcpn %	Bf	Bc	I(%)	Avg Dev. %	Obs. Pcpn %	Bf	Bc	I(%)	Avg Dev. %	Obs. Pcpn %	Bf	Bc	I(%)
San Francisco	11	.05	.09	44	4	10	.05	.08	38	4	11	.07	.09	22	5	11	.06	.09	33
Eureka	21	.05	.13	62	4	21	.10	.14	29	6	21	.11	.14	21	8	21	.09	.14	36
Fresno	7	.02	.06	67	2	6	.04	.06	33	4	7	.05	.06	17	5	7	.04	.06	33
Red Bluff	10	.02	.09	78	2	11	.07	.09	22	7	10	.08	.09	11	7	10	.06	.09	33
Reno	6	.04	.05	20	4	8	.06	.07	14	4	6	.05	.06	17	6	7	.05	.06	17
Sacramento	10	.04	.08	50	2	10	.05	.08	38	4	10	.06	.07	14	5	10	.05	.08	38
Santa Maria	10	.02	.07	71	3	7	.04	.07	43	4	10	.06	.07	14	6	9	.04	.07	43
Stockton	8	.04	.07	43	2	9	.04	.07	43	3	8	.06	.06	0	5	8	.05	.07	29
Winnemucca	10	.04	.08	50	4	11	.07	.09	22	5	10	.07	.08	13	5	10	.06	.08	25
Seattle	33	.14	.19	21	6	32	.16	.19	16	8	33	.18	.19	5	8	33	.16	.19	16
Astoria	48	.11	.20	55	8	46	.17	.20	15	12	48	.19	.20	5	11	47	.16	.20	20
Eugene	25	.07	.16	56	6	23	.10	.15	33	5	25	.12	.15	20	6	24	.10	.15	33
Medford	18	.07	.14	50	5	18	.11	.14	21	7	18	.13	.14	7	6	18	.10	.14	29
Olympia	34	.09	.19	53	5	35	.16	.19	16	7	34	.15	.20	25	5	34	.14	.19	26
Pendleton	16	.08	.13	39	6	15	.11	.12	8	5	16	.13	.12	-8	8	16	.11	.12	8
Portland	31	.09	.18	50	7	27	.15	.18	17	9	31	.17	.17	0	8	30	.14	.18	22
Salem	32	.11	.19	42	8	29	.14	.17	18	9	32	.19	.18	-6	13	31	.15	.18	17
Spokane	20	.12	.15	20	8	16	.10	.12	8	8	20	.13	.15	13	7	19	.12	.14	14
Walla Walla*	18	.05	.13	62	5	19	.10	.14	29	5	18	.12	.13	8	9	18	.09	.13	31
Wenatchee*	8	.04	.08	50	7	9	.06	.08	25	7	8	.08	.09	11	7	8	.06	.08	25
Yakima	9	.03	.07	57	4	9	.07	.08	13	7	9	.07	.07	0	5	9	.06	.07	14

*Based on 10 months (April 1966 - January 1967 incl.)

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