CONCLUSIONS

1. The method of forecasting described here is highly objective. It can reduce differences of opinion as to map types and reduce the number of differing forecasts. However, it should be used as an aid to rather than as a substitute for the usual forecasting precepts. Study of additional maps is necessary in order to either confirm the results in this paper or to develop more efficient parameters.

2. Although data are based on 1300 GMT maps experience has shown that satisfactory results can be obtained with maps for other times of the day.

3. In this method of determining map types by mathematical relationships between circulation indices, successive 6-hourly maps may fluctuate between two or even three types when one or both indices are small. The movement of a Low or a small High across one of the key coordinates will cause a fall and rise of several millibars within the course of a day. This results in a slight change in one of the indices, but often the change is sufficient to shift the maps from one type to another when maps are only six hours apart. In such cases it is advisable to assume the original type unless there is evidence that the change in type is permanent.

4. From forecasts made by this method from successive 6-hourly maps the time of beginning and ending of rain often can be anticipated within a few hours. This manner of timing can be useful when the location or speed of fronts cannot be determined, and useful also during periods of shower activity.

5. Whenever the objective forecast is strongly opposed to the forecast obtained in the usual manner it is advisable for the forecaster to examine the maps more carefully and review his reasoning. In day-to-day tests four instances of this kind are recalled. A reevaluation of the data on the maps revealed evidence of phenomena which would cause rain, and the original analyses were revised. Reports were scarce and the little data had to be weighed carefully, nevertheless these phenomena were borne out by subsequent charts.

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ADDITIONAL TESTS OF COUNTS' OBJECTIVE METHOD OF FORECASTING WINTER RAIN FOR PORTLAND, OREGON

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The Weather Bureau District Forecast Staff at Seattle, Washington, made practical use of Counts' objective method of forecasting precipitation for the second day in advance at Portland, Oregon, during the winter season of 1948–49. In the application of the method, the Seattle Staff rigidly followed the rules set forth by Counts, except that the forecast period was considered to be 24–48 hours after map time instead of 20–44 hours used by Counts; for the purpose of this test no attempt was made to improve the forecasting results by following suggestions contained in his article. A record of the M and Z values for the 0030 GMT and 1230 GMT maps was kept during the months of November, December, January, February and March. Each case was immediately classified and the forecast obtained from the scatter diagrams was recorded and also used by the staff forecaster as an aid in making the official forecast.

There were 302 maps used in the test and they were segregated as follows:

Class	Number of maps	Rain days	No-rain days
I	26	18	8
II	133	113	20
III	72	48	24
IV	61	27	34
V	10	2	8
Total	302	208	94

The ratio of "rain" days to "no-rain" days is very nearly the same as found in Counts' original investigation of 297 cases. The greater number of Class II cases and fewer Class IV cases in the present test compared to the original study is very noticeable.

VERIFICATION RESULTS FOR WINTER 1948–49

Verification of the objective forecasts for Portland for the 302 cases is given in Table 1:

TABLE 1.—*Verification of objective forecasts for Portland, winter 1948–49*

		FORECAST: Rain	No rain	Total	
CLASS I	Rain	15	3	18	
OBSERVED	No rain	3	5	8	Percent correct=77
	Total	18	8	26	Skill score=.50
CLASS II	Rain	113	0	113	
OBSERVED	No rain	20	0	20	Percent correct=85
	Total	133	0	133	Skill score=.66
CLASS III	Rain	40	8	48	
OBSERVED	No rain	8	16	24	Percent correct=78
	Total	48	24	72	Skill score=.53
CLASS IV	Rain	15	12	27	
OBSERVED	No rain	1	33	34	Percent correct=79
	Total	16	45	61	Skill score=.58
CLASS V [1]	Rain	0	2	2	
OBSERVED	No rain	0	8	8	Percent correct=80
	Total	0	10	10	Skill score=.67
ALL CLASSES	Rain	183	25	208	
OBSERVED	No rain	32	62	94	Percent correct=81
	Total	215	87	302	Skill score=.60

[1] Editor's note—Counts' data for Class V were too few to permit obtaining significant results and developing an objective procedure. Thus, this part of table 1 is not a verification of forecasts by Counts' method, but is a verification of forecasts made on the assumption that all class V cases give "no-rain."

Before commenting on the results of the 1948–49 test, it might be well to point out three factors which undoubtedly contributed to scores lower than those in Counts' paper. First, as already mentioned, this test verified forecasts 24–48 hours after map time, while Counts used the period 20–44 hours after map time. In other words, the method was tested for a forecast period four hours farther into the future than the period for which it was developed. Next, the winter season was extreme with respect to precipitation and temperature over the Pacific Northwest.[2] The weather of the test months may be described briefly as follows: November, moderately wet and cold; December, precipitation moderately above normal and exceptionally cold; January, extremely cold and extremely dry; February, very cold and wet; March, rather cool with less than normal precipitation. Finally, bias introduced by testing with extreme data was approximately doubled by verifying forecasts made on two maps daily instead of one as in the original paper. While Counts concluded that the objective method could be used with maps for times other than 1300 GMT, it was found in this study that the percentage of correct forecasts on 1230 GMT data was 82 and on 0030 GMT data was 80. Possibly this variation is not great enough to be significant, but had the 0030 GMT data been discarded for the past season it would have given a higher percentage of verification to the scheme.

DISCUSSION OF VERIFICATION RESULTS

CLASS I

Table 1 shows that the percentage of correct forecasts for Class I during the 1948–49 season was 77, a value 20 percent below that for Counts' original data and 8 percent below that in Counts' test for independent cases. The increase in errors was mostly in the "no-rain" forecasts—rain occurring when none was forecast. Figure 9 of Counts' article shows a curve clearly separating "rain" cases from "no-rain" cases. A similar scatter diagram prepared for the 1948–49 data did not disclose any grouping which would permit easy separation of cases. Counts states that his diagrams were prepared on relatively few cases and that the results should be used with caution. The test by the Seattle Staff suggests that additional study is necessary to select better parameters for stratifying the Class I cases which were plotted on Figure 9.

CLASS II

Class II cases produced the highest percentage of correct forecasts of all classes in the 1948–49 test. The percentage, 85, was slightly lower than the 91 percent for Counts' original data but was the same as for Counts' test data.

Noting that Counts' method calls for a forecast of "rain" for all Class II cases, the Seattle Staff found two factors which, if taken into account, might increase the accuracy of forecasts for this class by providing for a forecast of "no-rain" in certain situations. First, when the western half of the North American Continent is covered by cold air there is a tendency for Lows of the northwesterly type to move southeastward off the west coast of the United States far enough out to sea that the precipitation area of the storm does not extend to Portland. Second, for cases which result in "no-rain" and which have a large Z value, the error of the "rain" forecast is often an error in timing—the rain usually occurs prior to the verification period.

[2] See Klein, William H., "The Unusual Weather and Circulation of the 1948–1949 Winter," *Monthly Weather Review*, vol. 77, No. 4, April 1949, pp. 99–113.

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CLASS III

The percentage of correct forecasts for Class III cases was only 78 as compared with 91 percent for Counts' original data and 83 percent for Counts' test data.

Improvement in forecasting for this Class by favoring rain forecasts for large values of Z is suggested by the important role played by the westerlies and southwesterlies in producing rain over the Pacific Northwest. If a line having the equation $10Z+7.5M-75=0$ is drawn on Count's figure 2 it will be noted that there are fewer "no-rain" cases on the side having the greater Z values. Had the Class III cases for which the objective method forecast no rain at Portland and which fell to the right of the line been changed to call for rain, the verification of this Class in the test by the Seattle Staff would have been increased to 85 percent and the skill over Climatological forecast raised to .68.

CLASS IV

Seventy-nine percent of the objective forecasts for Class IV cases were correct during the 1948–49 season. The exceptions are baffling. A few days of rain when none was forecast could be attributed to precipitation occurring with wave development on the cold front of outbreaks of Polar Air west of the Continental Divide. Seven of the misses occurred in January, 2 in February and 3 in March. The fact that January was extremely cold over the Pacific Northwest undoubtedly lessens the value of data for this month as test data.

CLASS V

There were too few cases of this class in the original work and tests for Counts to draw conclusions. Data gathered during the past season indicate that Class V cases will verify high on "no-rain" forecasts (table 1).

APPLICATION OF METHOD TO OTHER STATIONS

In using the objective technique, the Seattle forecasters appreciated the simple set of coordinates which Counts selected and also the fact that the same set is used for all classes. Obviously, a method such as Counts' will work best for locations where precipitation is closely related to the flow pattern of the lower part of the atmosphere as reflected by surface isobars. Even though mountain barriers influence precipitation over all of the Seattle Forecast District and the circulation of the atmosphere at higher levels becomes more important than the surface flow in the production of precipitation, it was decided to apply the forecasts for Portland obtained by Counts' technique to the stations at Seattle, Medford, Spokane, and Boise. The results of the verification by months are tabulated in Table 2:

TABLE 2.—*Percentage of correct forecasts by Months and Seasons and Skill over Climatological Forecast for Season*

Station	*Nov.*	*Dec.*	*Jan.*	*Feb.*	*Mar.*	*Season*	*Skill Score*
Portland	92	77	68	88	77	81	0.60
Seattle	90	76	65	80	69	77	.53
Medford	77	68	79	80	76	75	.52
Spokane	75	74	66	70	64	70	.41
Boise	73	68	79	68	61	70	.43

The final results are much as expected and indicate that the objective forecasts for Portland might be applied with some reservations to Seattle and Medford and produce creditable results. For instance, it was noted that Class II frequently failed to give rain at Seattle because the city lies in the lee of the Olympic Mountains when the flow is from the northwest.

November and February proved to be the best verification months for all stations except Boise which had a high verification for January, and Medford with highs in January and February. In January there were a large number of "hits" credited for "no-rain" forecasts at Boise when a trace of rain occurred and also credited for "rain" forecasts when a trace of rain fell on the day before or following a day having a measurable amount, in accordance with verification procedure used by Counts. The fact that Medford verified so high in January may be attributed to the reason mentioned earlier that Class II was affected by the cold air over the continent: the storms forced south of Portland frequently gave rain to Medford.

Since the method did not give good results for Spokane and Boise, much time was spent trying to find coordinates and parameters which would work equally well for Boise as for Portland. Results were negative and it will probably be necessary to correlate upper air data in order to obtain satisfactory results.

CONCLUSIONS

This investigation revealed that the splendid and successful results obtained by Counts stemmed from long hours of research and a thorough knowledge of forecasting for the Pacific Northwest. It was found that his method does what he claims and is best considered as an aid to the forecaster and not a tool which will supplant reasoning in forecasting. The method does, however, suggest techniques for the use of high speed electronic computers which would be able to handle many more variables simultaneously.