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Verification of the B.C. Fire Weather Precipitation Probability Forecasts for 1982

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Introduction

Fire Weather Precipitation Probability Forecasts for British Columbia have been issued since 1958 by the Pacific Weather Centre (PWC).

As the probability forecasts are essential in Forest Management and for the past thirteen years no attempt has been made to review the general accuracy (the most recent review was by Nikleva, 1971), it seems appropriate at this time to take another look at the forecasts. The well known verification scheme devised by Brier (1950) for probability forecasts was used.

Data

The PWC issues two Fire Weather Forecasts daily during the fire weather season (May-September). The early morning forecast (1345 GMT) is issued every day. The "noon" forecast (2030 GMT) is prepared only five days a week, but upon request may be issued over the weekend. Each forecast gives point probability values for the occurrence of rain for the locations shown on Fig. 1. The predicted probabilities are commonly expressed in 5% intervals (0,5,10,...,95,100%), and are valid for 24 hrs beginning at 1 PM each day.

For each station, six hourly precipitation amounts were available. Due to the recording times the 24 hr verification period had to be taken from 10 AM to 10 AM, instead of 1 PM to 1 PM.

For the study all probability forecasts for seven selected locations (Fig. 1) were then tabulated for 1982, May 1 to September 30 inclusive. In addition, for each forecast the corresponding precipitation record was examined. If a measurable amount of precipitation (0.2 mm or more) was recorded over 24 hrs (10 AM to 10 AM), a rain event was deemed to have occurred.

The long-term climatological relative frequency of the number of days with measurable rain (C) was derived from the Canadian Climate Normals (1951-80). The values of C are listed below Fig. 1. For example, the climatological probability of rain at Comox on any given day from May to September is only 29%. This value may then be compared with the actual forecast ones.

How Verified

The Brier score (B) may be expressed by (Sanders, 1963):

$$B = \frac{1}{N}\sum_{K=1}^{T} M_K (F_K - \bar{\phi}_K)^2 + \frac{1}{N}\sum_{K=1}^{T} M_K \bar{\phi}_K (1 - \bar{\phi}_K) \qquad (1)$$

where, $\phi_k = \frac{1}{M_K}\sum_{j=1}^{M_K} \phi_{Kj}$ and $N = \sum_{K=1}^{T} M_K$

N = total number of probability forecasts
T = total number of forecast probability categories or classes
F_k = forecast probability value of the k th forecast category
M_k = total number of forecasts belonging to the k th forecast category
ϕ_{kj} = the j th observation (0 = no rain, and 1 = rain event) corresponding to the j th forecast belonging to the k th forecast category
$\bar{\phi}_k$ = relative frequency of observed rain events for the k th forecast class.

Due to the limited sample size only T = 11 forecast classes were selected (F(1) = 0, F(2) = 0.1, ..., F(11) = 1.). Thus all forecast probabilities from 0 to 4% and 5 to 14% were assigned to classes F(1) and F(2) respectively, and so forth. Also considered was the effect of arbitrarily reducing the allowed number of categories to 5. Here the forecast probabilities 0-12%, 13-37, 38-62, 63-87 and 88-100% were assigned to categories F(1) = 0, F(2) = 0.25, F(3) = 0.5, F(4) = 0.75 and F(5) = 1 respectively.

Reliability - The first term on the right hand side of equation (1) is called the forecast "reliability" or "validity". It is a measure of the overall mean square error of the difference between the forecast probability and the observed relative frequency. A zero reliability term would mean zero error, all forecasts perfectly reliable. A value of unity (1) could only be obtained if forecasts fell into a category equal to 0 or 1 and were all incorrect.

Resolution - The "resolution" or "sharpness" is defined by the second term on the R.H.S. of equation (1). For a large number of forecasts, it is a good measure of the forecasters' ability to correctly identify nearly certain events (of rain/no rain) as often as possible. Perfect resolution, zero, would be attained if the observed frequency was zero or one for each forecast class. Alternatively, the term reaches its maximum value of 0.25 (worst case) if the observed frequency equals 50%.

The Brier score (B) is the sum of the above two terms. Thus ideally a perfect forecast set would score zero (B = 0) and a completely unskillful set would score unity (B = 1).

Skill Score - To relate the Brier score (B) to a non-skill forecast, a skill score (S) was employed (see Sanders, 1963):

$$S = 100\ (Bc - B)\ /Bc \qquad (2)$$

Here Bc is the climatological Brier score which is the Brier score with all the forecast probabilities replaced by the climatological frequency C instead. The optimum Skill, S = 100%, is reached with a zero Brier score. A negative or zero Skill score implies that the forecasts performed worse or no better than climatology.

Results and Conclusions

Table I summarizes the scores. All skill scores were positive (forecasts better than climatology). Along the west coast the skill scores ranged from 17 to 45% and 30 to 49% for the noon and morning forecasts respectively. For the interior the ranges were 5 to 22% and 22 to 34% for the noon and morning forecasts respectively. The greater skill shown on the coast is a reflection of the fact that coastal "rain" events tend to be associated with organized weather disturbances (more predictable), and those for the interior with rather unorganized unstable airmass conditions (less predictable). Furthermore, the morning forecast skill scores are significantly better than the ones for the noon forecasts. Also the reliability of the morning forecasts show a marked improvement (except Comox?). The resolution of the morning forecasts is only marginally better (lower value) in most cases than the noon resolution. A greater improvement was anticipated due to the shorter lead time for the morning forecast. These results suggest that the development of improved precipitation forecast techniques (summer season) for the interior should be supported. In addition, improved forecast techniques would likely assist the forecasters to recognize definite rain/no rain situations more often.

From a user's perspective, the forecast reliability is quite important. An user would appreciate that if a 40% probability was given, it means exactly that and not some value ranging between say 20 to 60% over the season. The reliability is graphically portrayed for each location in Figs. 1(a) to 7(b). A forecast set is perfectly reliable if all points lie on the diagonal line (line of perfect reliability). Notice that the forecasters do well in recognizing no rain situations as for probabilities of 20% or less all points are on or near the diagonal. At higher probabilities significant variation can be seen. The variation in resolution is illustrated in Fig. 8 for the lowest and highest values encountered.

As stated one other objective was to investigate if the reliability could be improved (for users) by using only 5 forecast categories (0%; 25%; 50%; 75%; 100%). Figures 9(a) and 9(b) give a comparison between the forecast and observed frequencies for the 5 and 11 forecast classes respectively. For all stations there is a marked reduction of the variability about the line of perfect reliability. However the Brier scores increased slightly, but this would not be of direct concern to an user. Users may well accept a reduced number of forecast probabilities which are fairly reliable as opposed to a wide variety of values with a greater degree of uncertainty.

Last, all results presented should be considered tentative, due to the limited number of forecasts used.

References

Brier, G.W., 1950: Verification of forecasts expressed in terms of probability. Mon. Wea. Rev., 78, 1-3.

Nikleva, S., 1971: Verification of Probability of Precipitation Occurrence Forecasts, Environment Canada, Technical Memorandum, TEC 749, 19 pp.

Sanders, F., 1963: On subjective Probability Forecasting, J. Appl. Meteor., 2, 191-201.

TABLE I

Summary of the 1982, May to September, Fire Weather Forecast verification scores of the point probabilities of rain for seven B.C. locations. Scores were computed for the "morning" and "noon" Fire Weather Forecasts, both valid over the same time period.

SCORE	S T A T I O N S						
	Comox	Cranbrook	Kelowna	Prince Rupert	Revelstoke	Terrace	Williams Lake
Skill (%)							
Noon	17	11	5	26	11	45	22
Morning	30	22	23	43	34	49	32
Brier							
Noon	0.16	0.22	0.20	0.19	0.22	0.13	0.20
Morning	0.14	0.18	0.17	0.15	0.17	0.12	0.17
Reliability							
Noon	0.010	0.035	0.052	0.022	0.025	0.015	0.030
Morning	0.013	0.015	0.015	0.016	0.013	0.006	0.009
Resolution							
Noon	0.15	0.18	0.15	0.17	0.19	0.11	0.17
Morning	0.12	0.17	0.16	0.13	0.16	0.11	0.16
# Forecasts							
Noon	107	106	106	108	106	108	108
Morning	153	153	151	153	153	153	152
# Rain Events							
Noon	29	38	32	47	41	33	45
Morning	40	53	49	71	63	46	65

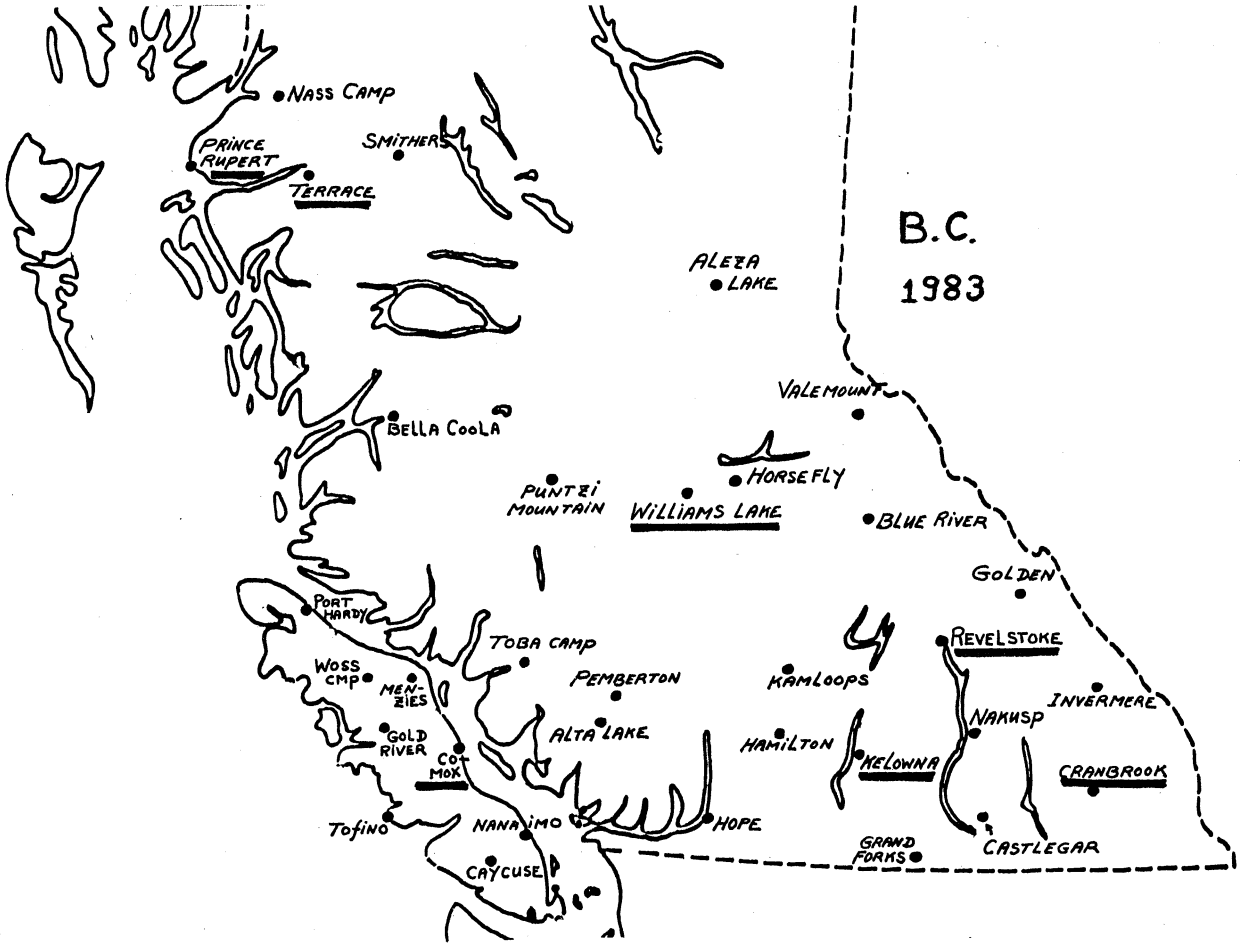


Fig. 1. A sketch of B.C. indicating the locations for which point forecast probabilities of the occurrence of rain are given in the Fire Weather Forecasts (Pacific Weather Centre). The underlined stations are the ones which have been examined in this study.

The long-term climatological frequencies of the number of days with a measurable amount of rain (0.2 mm or more) for the period May - September, for the seven locations studied, are:

Station	Frequency (%)
Comox	29
Cranbrook	25
Kelowna	27
Prince Rupert	56
Revelstoke	31
Terrace	43
Williams Lake	33

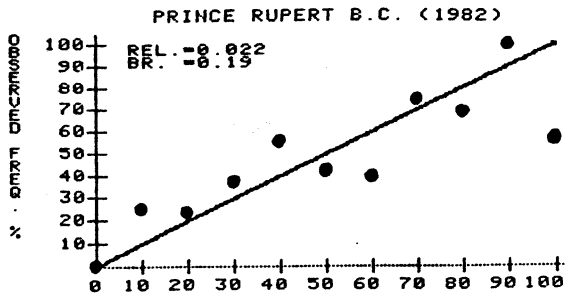


FIG. 1A

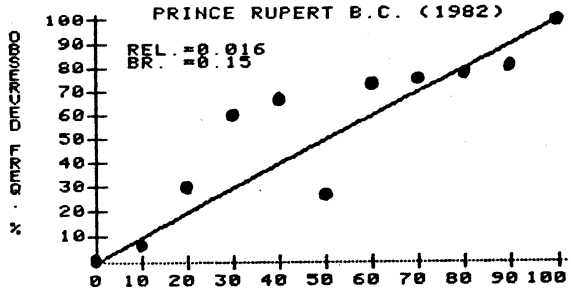


FIG. 1B

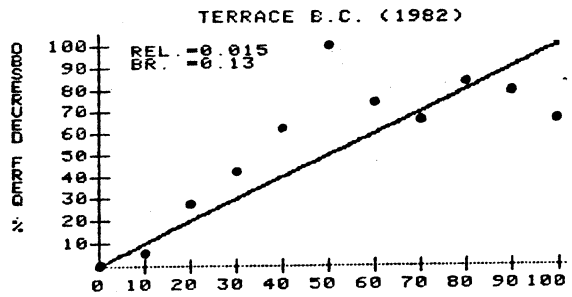


FIG. 2A

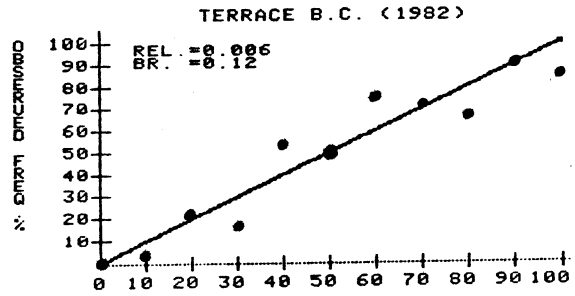


FIG. 2B

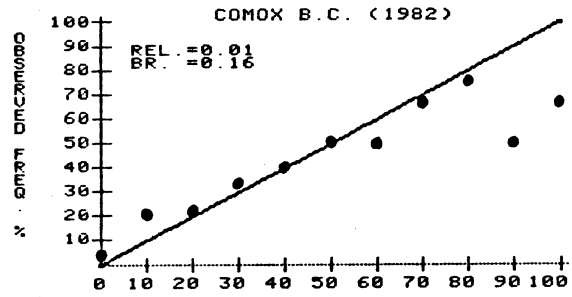


FIG. 3A

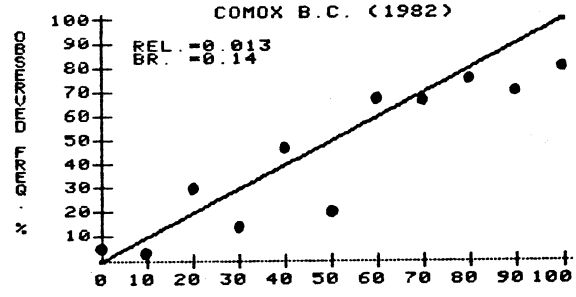


FIG. 3B

Figs. 1(a) - 3(b). The forecast probability versus the observed relative frequency of rain occurrence, for each forecast category (0, 10, 20,...100%). The Brier Score (BR.) and the forecast reliability (REL.) is given below each location name. For each location two graphs are presented, the L.H.S. one is for the "noon" issue of the Fire Weather Forecasts and R.H.S. for the early "morning" issue.

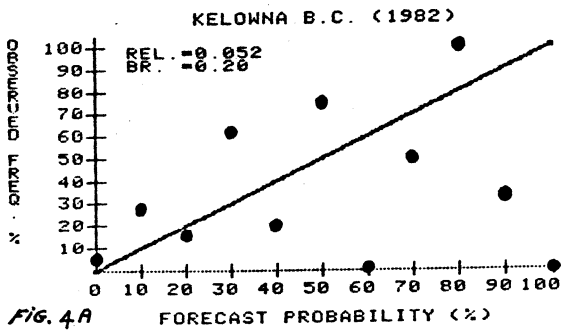


FIG. 4A

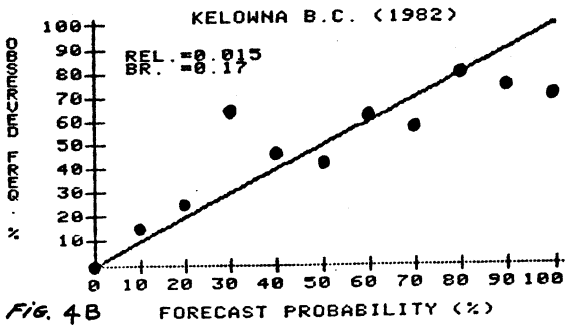


FIG. 4B

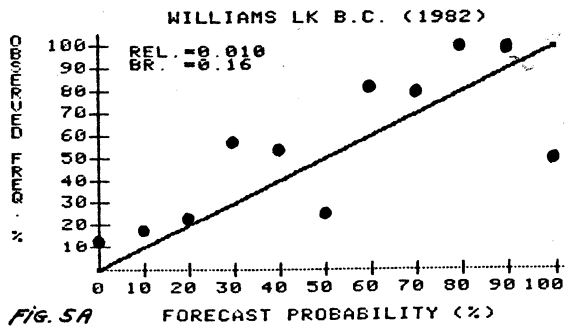


FIG. 5A

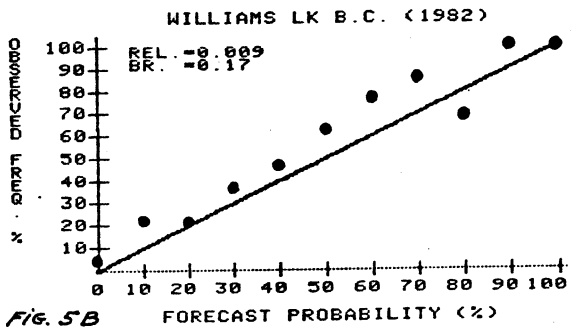


FIG. 5B

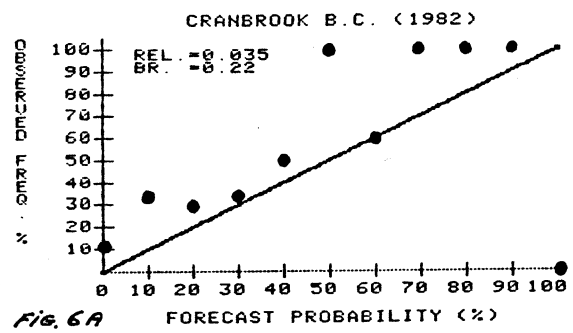


FIG. 6A

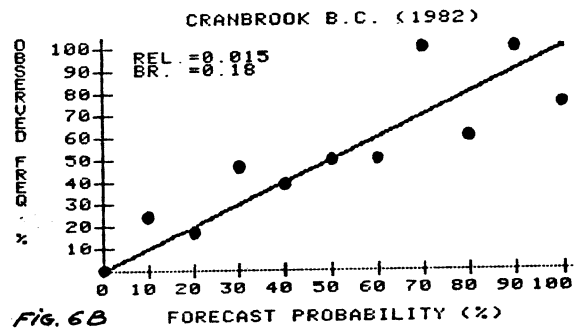


FIG. 6B

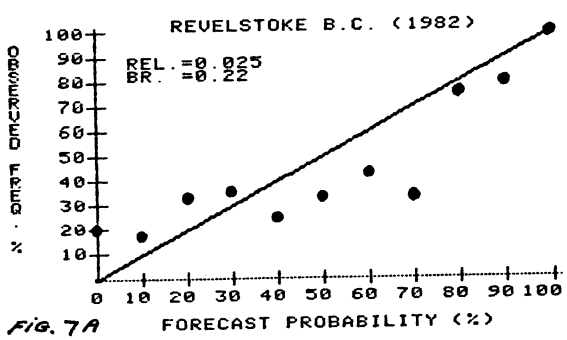


FIG. 7A

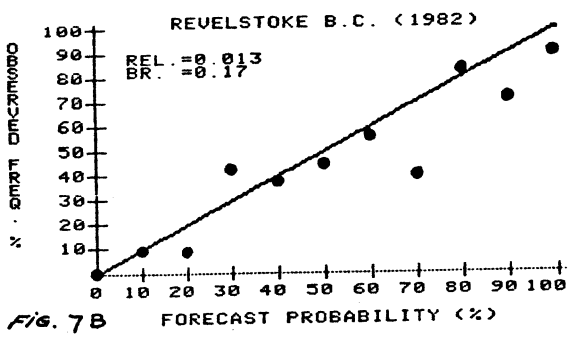


FIG. 7B

Figs. 4-7. The forecast probability versus the observed relative frequency of rain occurrence, for each forecast category (0, 10, 20,...100%). The Brier Score (BR.) and the forecast reliability (REL.) is shown below each location name. For each location two graphs are presented, the L.H.S. one is for the "noon" issue of the Fire Weather Forecasts and R.H.S. for the early "morning" issue.

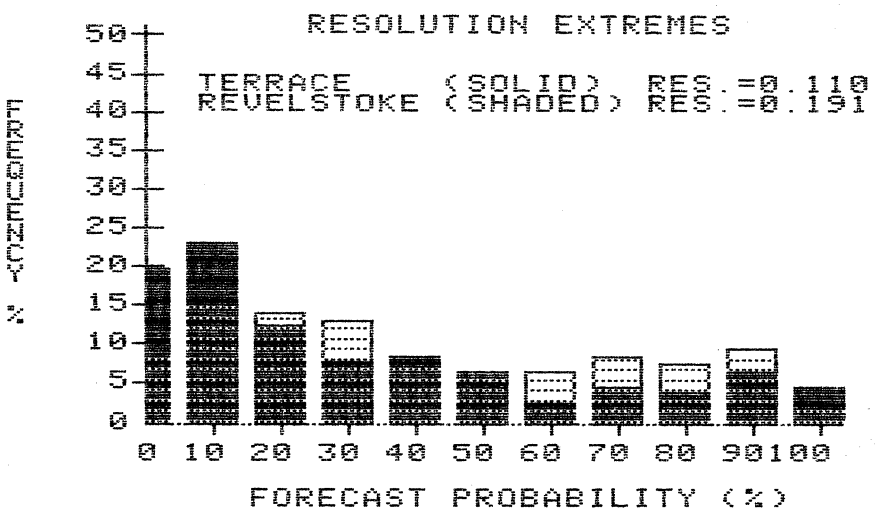
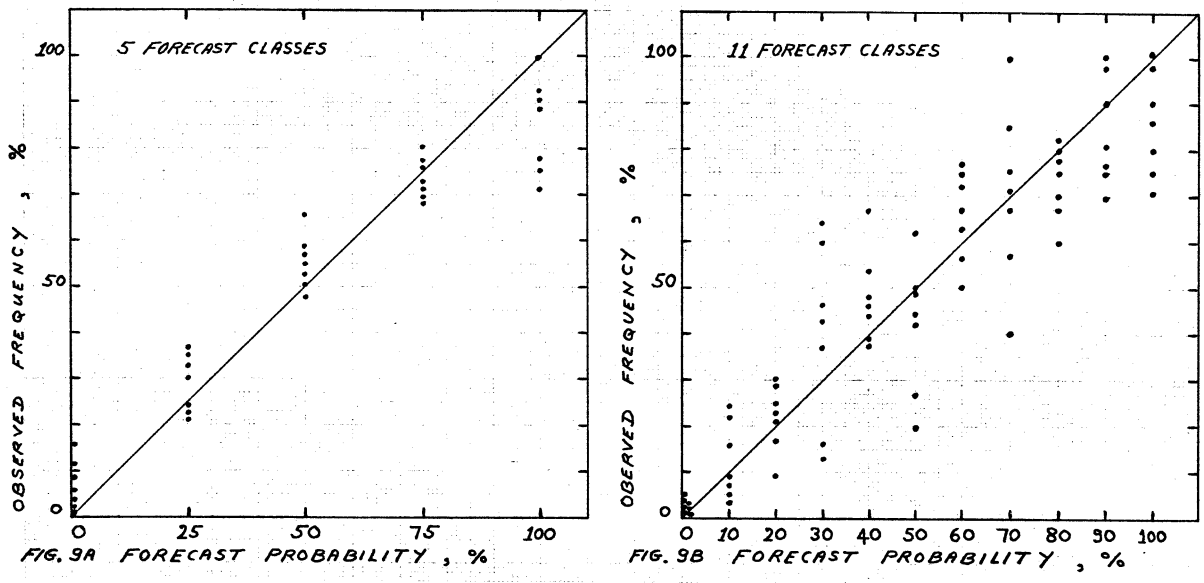


Fig. 8. Frequency distributions for the forecast point rain probabilities for Terrace and Revelstoke. The two distributions illustrate the variation in the resolution (RES.) encountered in the Fire Weather Forecasts issued near noon. Note that the forecast resolution improves (decreases in value) as the distribution becomes more bimodel.



The morning Fire Weather Forecast's probability of rain versus the observed frequency of occurrence. The distributions are illustrated for 5 and 11 forecast classes, figures 9A and 9B respectively. Summarized are the frequencies for all seven stations, each dot represents the forecast and oserved frequency for one station. The Brier score and the reliability are presented below for the two forecast categories:

Station	Brier Score (%)		Reliability (%)	
	Class (5)	(11)	Class (5)	(11)
Comox	13.6	13.7	0.6	1.3
Cranbrook	19.4	18.2	1.3	1.5
Kelowna	18.1	17.2	1.4	1.5
Prince Rupert	14.7	14.6	0.6	1.6
Revelstoke	17.9	16.8	1.0	1.3
Terrace	11.2	11.6	0.2	0.6
Williams Lake	18.1	17.2	1.0	0.9