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Report N.:



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METEOROLOGICAL BRANCH - DEPARTMENT OF TRANSPORT - CANADA

An Empirical Method for the Prediction
of Breaks in Hot Spells at Vancouver

by

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and
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This study was undertaken during the summer of 1962, while the authors, both undergraduate students at the University of British Columbia, were employed at the Vancouver Forecast Office.

UDC: 551.509.323.

CIR-3748
TEC-430
1 Nov. 62.

ABSTRACT

Detailed examination of synoptic charts during warm spells at Vancouver Airport showed that the behaviour of some features was sufficiently consistent to permit formulation of rules for forecasting the duration and the ending of these hot spells.

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METEOROLOGICAL BRANCH - DEPARTMENT OF TRANSPORT - CANADAAn Empirical Method for the Prediction
of Breaks in Hot Spells at Vancouver

by

A. A. Harms and D. C. Healey.1. INTRODUCTION

1.1. When the daily maximum temperature reaches 76°F at Vancouver Airport, the day can be described as warm. On such occasions, temperatures in urban areas will generally be two to four degrees higher and such temperatures are certainly characteristic of warm weather as far as this area is concerned.

1.2. Economically these hot spells are important, since humidity in the forests usually drops to very low levels if they are prolonged. If forestry work is suspended, logging operators must decide whether to underwrite the expense of keeping the crews in camp or of dispersing them and facing the task of reassembly later.

1.3. The tourist industry is also a major factor in the provincial economy. The great numbers of natives and visitors that spend their annual vacation in B.C. are vitally interested in these spells of warm weather, particularly when they last long enough to restrict public access to the forests.

1.4. And of course sales of certain merchandise increase very markedly during hot weather: Since much of it is perishable it is important to avoid overproduction toward the end of a prolonged hot spell.

1.5. Study of the records for the period 1952-1961 disclosed that the intervals when the maximum temperature equalled or exceeded 76°F at Vancouver Airport occurred only in the months May-September. Detailed examination of surface and 500 mb charts was made during such periods and showed that certain features recurred frequently and also underwent a cycle of changes that was related to the duration and ending of the hot spell. It was therefore considered worthwhile to study these both on the average and in particular cases in the hope that some rules could be devised for forecasting the duration and ending of these spells.

2. DEFINITIONS

2.1. A hot spell was defined to be any day or period of days with daily maximum temperatures at Vancouver International Airport equal to or greater than 76°F. A break in a hot spell was defined to be a maximum-temperature decrease of at least 5°F to less than 76°F (in 24 hours) or a

maximum-temperature decrease of at least 3°F to less than 76°F (in 24 hours) and a further drop of at least 3°F in the following 24 hours.

3. OBJECTIVE

3.1. The primary objective was to forecast, from surface and upper air charts up to and including 1200Z "this morning", whether or not a break will occur tomorrow. The secondary objective was to find parameters which would give, early in the hot spell, some indication of its duration. Both these objectives presuppose a correct forecast for maximum-temperature to be equal to or greater than 76°F for "today".

4. DATA

4.1. Weather charts for the ten year period 1952-1961 were available for this study. It was found that hot spells as defined above occurred only in the months May-September.

5. SYNOPTIC CHARACTERISTICS OF A HOT SPELL

5.1. Extremely warm weather along the southern coast of British Columbia appears to be associated most often with a ridge of high pressure both at the surface and at the 500 mb level. To obtain some idea of the general characteristics of this ridge, charts for the ten hot spells that occurred during the period 1960-61 were averaged. In the averaging process, the day of the break in the hot spell (D=0) was chosen as the reference day and mean daily charts for 1200Z (ie: 4 a.m. PST) were prepared for all days during the period extending from three days prior to the break until the day following. Since the data included hot spells of varying length, the earliest mean charts in the series (those for three and two days ahead of the break) actually include some individual charts representative of conditions before the onset of the hot spell. Consequently the development of significant features is somewhat clouded but nevertheless a characteristic pattern was apparent.

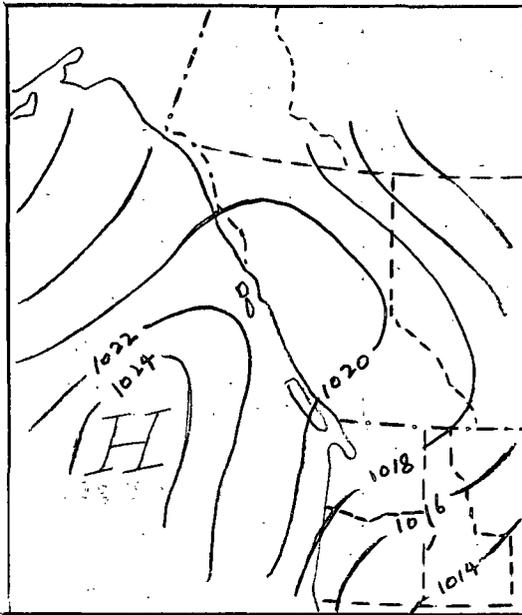
5.2. The mean charts obtained from this preliminary analysis are shown in figures 1 to 10. Three days before the break, there is at the surface level a pronounced ridge of high pressure extending from the southwest across the coast of British Columbia. The centre of the cell lies about 600 nautical miles off the coast with the axis oriented toward the northeast and crossing the coast in the vicinity of the Queen Charlotte Islands (fig 1). Characteristically, there is an area of low pressure in the northern Gulf of Alaska and another area of lower pressure over the intermountain region of the United States. The mean 500 mb chart for the same time shows a cyclonic circulation in the Gulf of Alaska with a nearly zonal flow across British Columbia. Mean 500 mb heights are about 19100 feet in the vicinity of Vancouver.

5.3. Two days before the break (fig 3 and 4), the axis of the ridge lies approximately in the same position but some eastward extension of the cell is apparent. In the area extending southeastward from the Queen Charlottes to the northwestern states, the surface pressures have begun to fall. This marks

the beginning of the development of the "thermal trough", a feature that will be discussed in more detail later. At the same time, the previously zonal flow at 500 mbs begins to distort with an upper ridge developing over British Columbia, a weak trough forming offshore and a slight filling of the cyclone in the northern Gulf of Alaska.

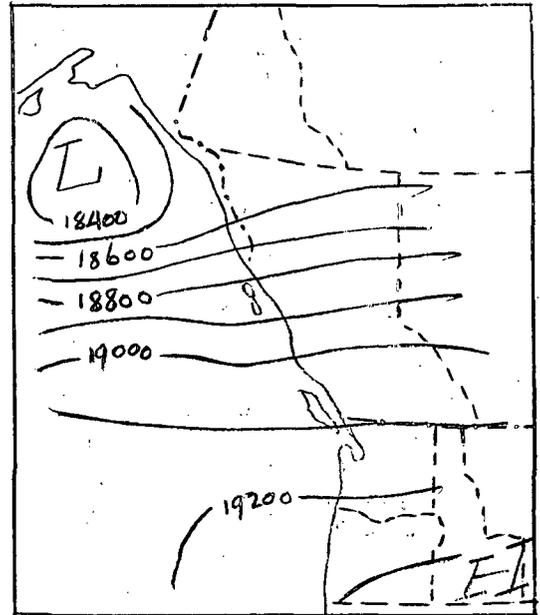
Three Days before the "Break"

fig 1



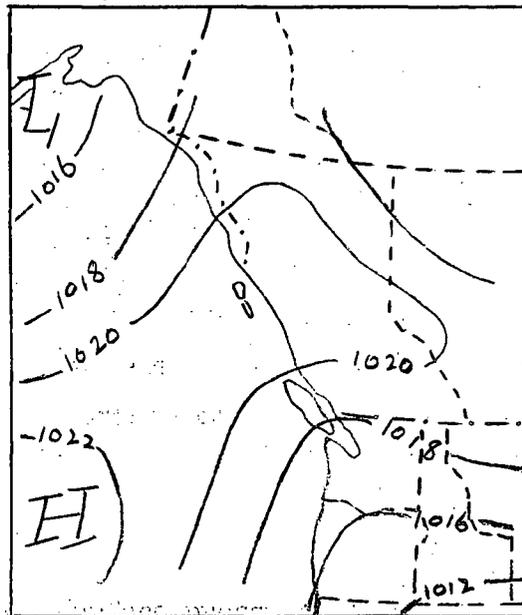
Surface pressure, 1200Z

fig 2



500 mb height, 1200Z

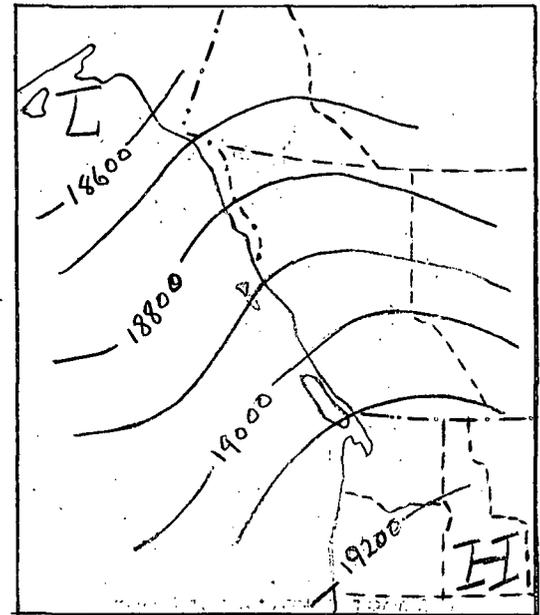
fig 3



Surface pressure, 1200Z

Two Days before the "Break"

fig 4

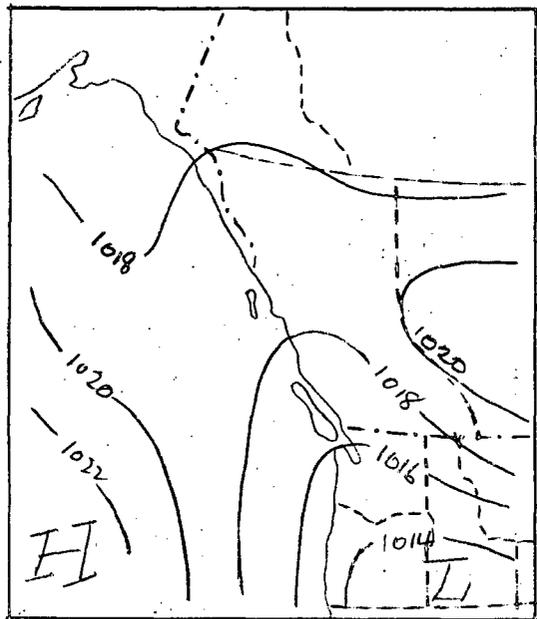


500 mb height, 1200Z

5.4. The charts for the day before the break show that these trends have continued. The thermal trough with its attendant offshore gradient flow now extends northward to the Queen Charlotte Islands and almost bisects the original surface cell of high pressure (fig 5). Intensification of the upper ridge has continued with the axis moving a few degrees toward the east. This movement is more noticeable in northern sectors but is significant in southern areas as well (fig 6).

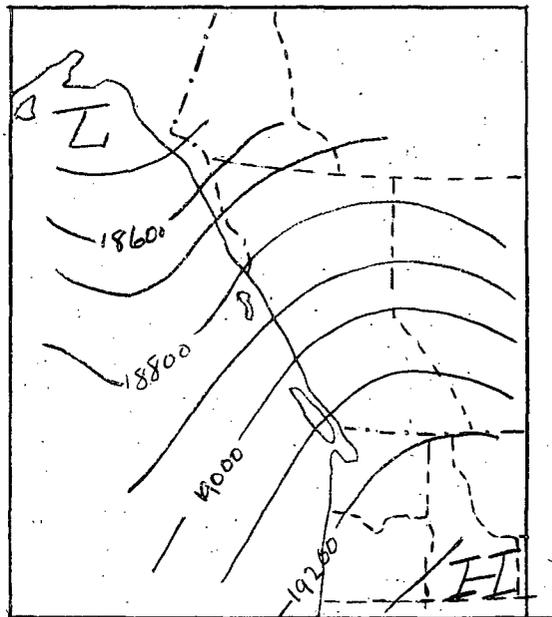
One Day before the "Break"

fig 5



Surface pressure, 1200Z

fig 6



500 mb height, 1200Z

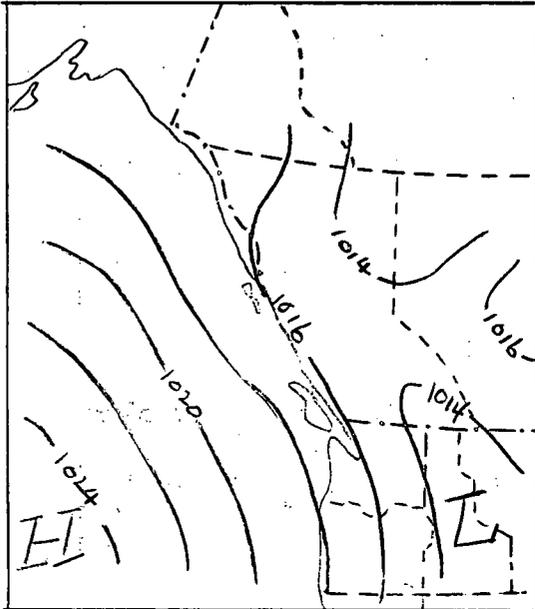
5.5. At this time it should be mentioned that data were extracted from basic charts using a grid of points approximately 250 miles apart. This rather coarse network may have obscured some details of the configuration of the thermal trough. At times, for example, this feature appears to exhibit a double structure, one axis extending from a southern low into the central interior of British Columbia with a second axis along the coast. However this pattern cannot be considered too definite since it may be produced in part by sea level corrections involving high mean temperature at high level inland stations. The synoptic network is almost too coarse to be sure of this pattern even on individual charts, although the noticeable sharpening of the interior trough at the end of a hot spell is some evidence of the consolidation of two axes.

5.6. On the day of the break, it is apparent that two major changes have taken place. Firstly the thermal trough has weakened and made a decisive eastward movement (on the average 250 miles). Although pressures along the immediate coast have not risen noticeably, the offshore surface pressure gradient has increased with the development of a high pressure cell several hundred miles to the southwest.

Secondly, the 500 mb ridge has moved eastward into Alberta while a mean trough has approached to within 300 miles of the coast (fig 7 and 8). During the preceding 24 hours, 500 mb heights at Vancouver have fallen about 150 feet on the average.

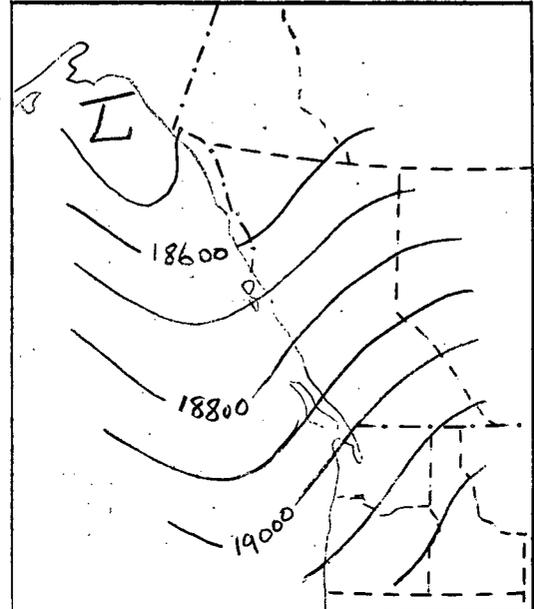
Day of the "Break"

fig 7



Surface pressure 1200Z

fig 8

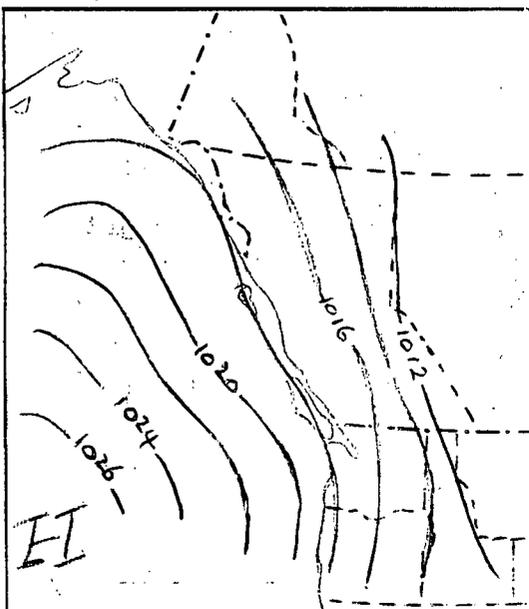


500 mb height 1200Z

5.7. At 1200Z on the day after the break, there is no evidence of the surface thermal trough anywhere in British Columbia while the upper flow at 500 mbs has become noticeably more zonal.

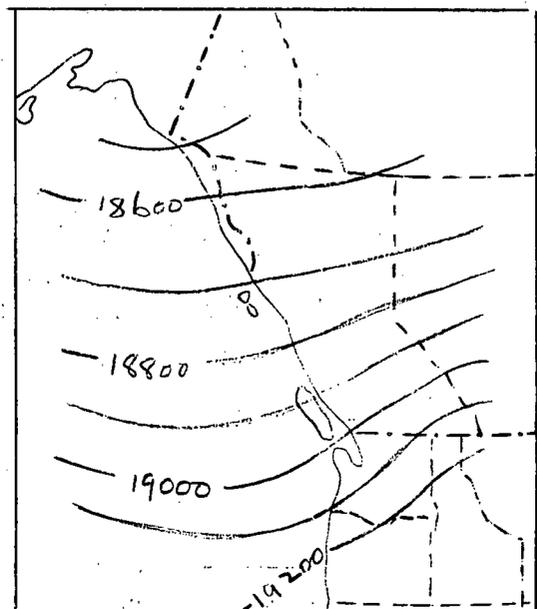
Day after the "Break"

fig 9



Surface pressure, 0000Z

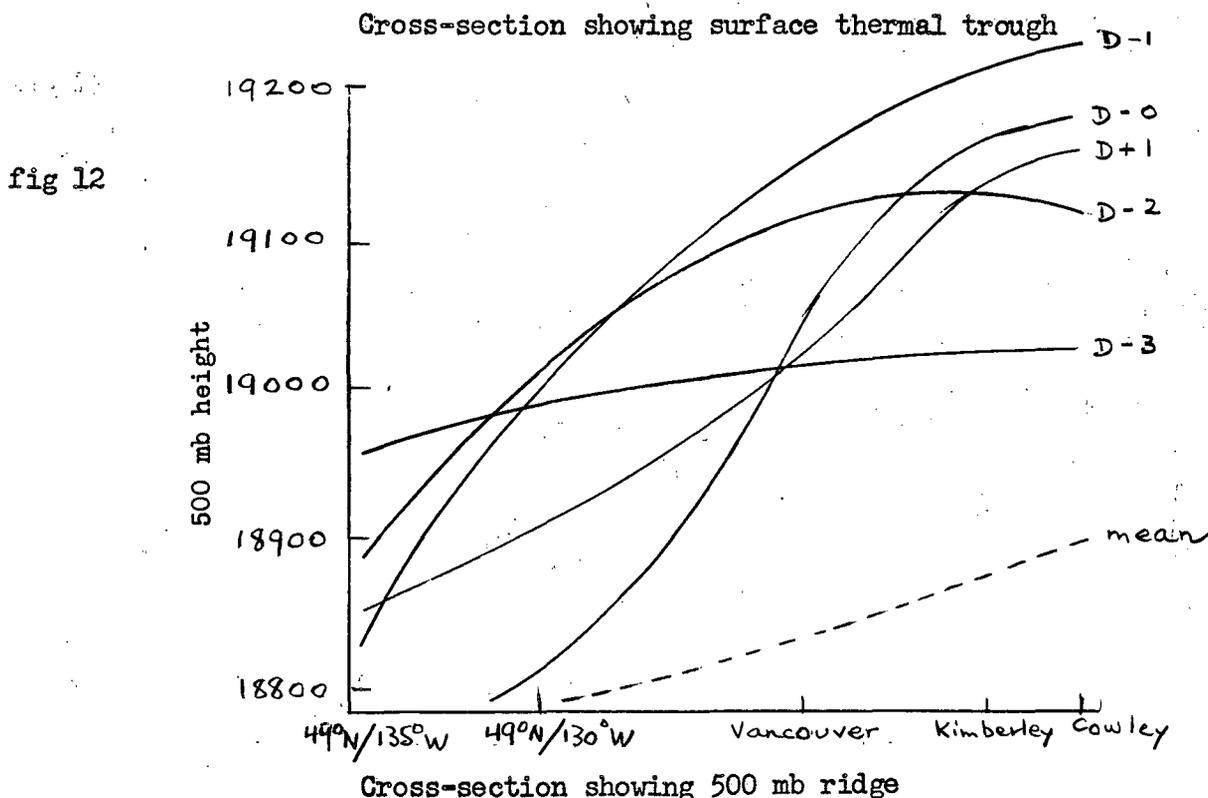
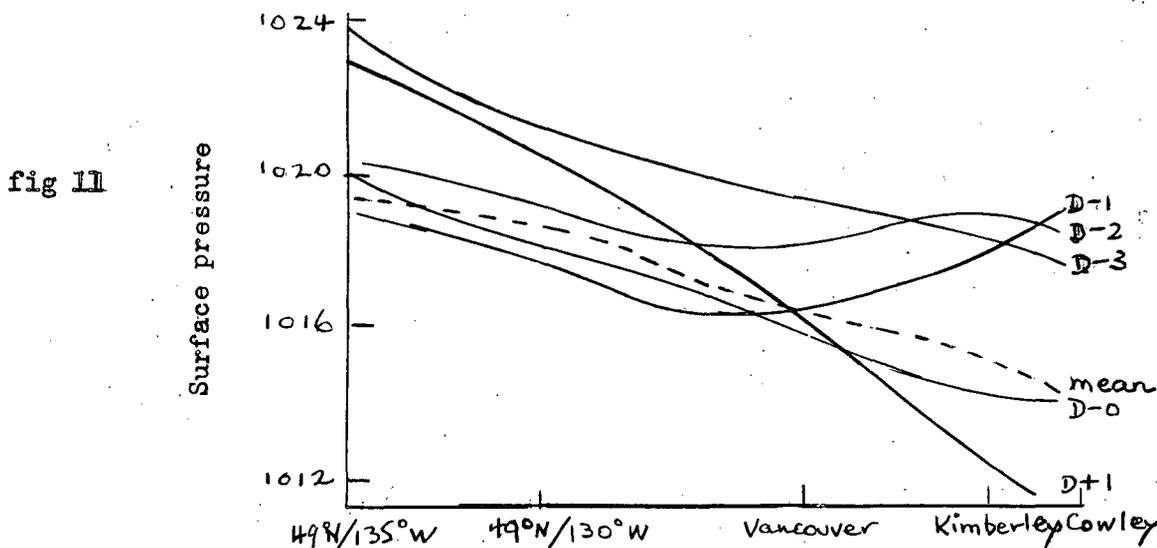
fig 10



500 mb height, 0000Z

5.8. The movement of the thermal trough eastward from the coastal region is followed by an influx of air from the ocean which is relatively cool at this time of year. The arrival of this marine stratum ends the hot spell. The pronounced change at low levels is shown in figure 13. It represents a series of temperature ascent curves for Sandpoint during one hot spell. The break in this particular spell occurred on August 16, 1961.

5.9. To confirm that the thermal trough and the upper ridge represent true departures from mean conditions, mean sea level pressures and 500 mb heights for a few points in southwestern B.C. were computed for the period June-August and compared with those found on the mean charts that typified hot spells during the same period. The results are shown on the following graphs:



5.10. These graphs portray cross-sections of the surface pressure and 500 mb height across the thermal trough and the upper air ridge.

5.11. The first graph shows that during hot spells (D-3 and D-2), the surface pressure is greater than average. The initial development of the thermal trough is seen on D-2, and it deepens considerably over Tofino and Vancouver by D-1. On the day of the break (D-0), the trough has moved eastward and this motion is continued on the day after the break (D+1).

5.12. The second graph shows that preceding and during the break in the hot spell, the 500 mb height is considerably above the mean summer height. Also the building of the ridge (D-3 and D-2) and its eastward motion (D-2, D-1, D-0 and D+1) as well as the approach of the trough (D-0, D+1) can be followed.

6. TYPICAL UPPER AIR FEATURES ACCOMPANYING A BREAK

6.1. As mentioned previously, the break in a hot spell is caused primarily by the influx of a cool marine stratum from the adjacent ocean. To illustrate the changes in air mass structure that accompany this influx, some temperature ascent curves are portrayed in figure 13.

6.2. The ascents are the standard radiosondes taken at Seattle twice daily at 4 a.m. and 4 p.m. local standard time. These cover the period from 4 p.m. August 13 to 4 a.m. August 16, 1961.

6.3. It is obvious that a great change in maximum temperature took place between 4 p.m. of the fourteenth and 4 p.m. of the fifteenth. The cooling is most pronounced and most regular near the surface. At higher levels, cooling is still evident although it is neither as pronounced nor as regular as that near the surface.

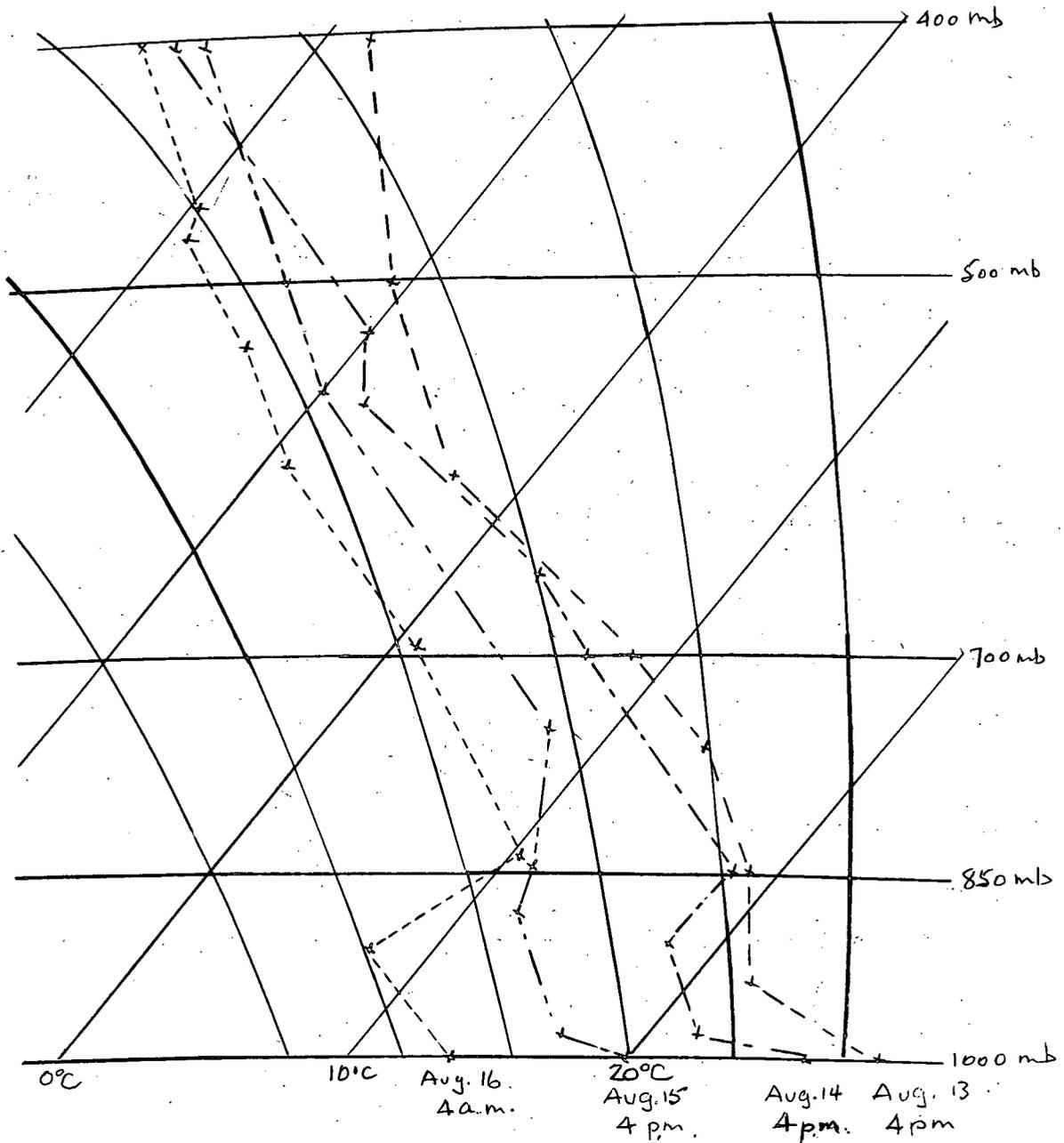
6.4. The full extent of surface cooling is shown in the 4 a.m. ascent for August sixteenth. The marine stratum, topped by a strong inversion at about the 900 mb level, is very evident in this ascent.

6.5. The upper cooling is indicative of the arrival of an upper trough or at least the recession of an upper ridge.

6.6. In this particular case, high level instability produced some rainfall, but on many occasions this does not happen.

6.7. It is of interest to note that by August 18, the maximum temperature had climbed again to levels approximating those of the fourteenth.

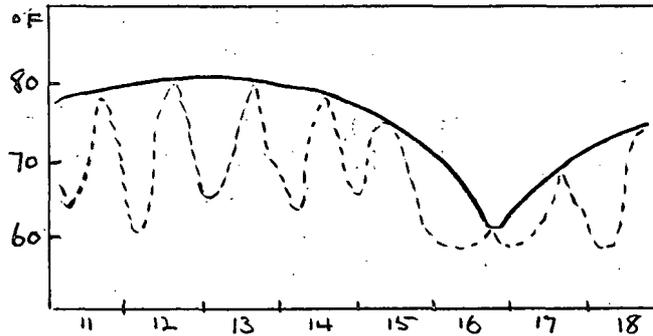
fig 13



Tephigram showing upper air features accompanying a break in a hot spell of August 1961. (Ascent at Seattle, 100 miles south of Vancouver, B.C.)

6.8. The following graph shows that the break occurred at Vancouver at a bout 0000LST on the sixteenth, or at least eight hours later than the Seattle cooling. This time delay is apparently caused by the 100 mile distance between Vancouver and Seattle.

fig 14



Daily temperature changes accompanying a break in the hot spell at Vancouver, B.C.

7.

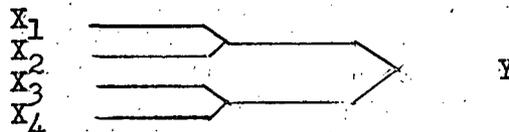
PRELIMINARY INVESTIGATION OF HOT SPELLS

7.1. Initially, graphs of the daily maximum temperatures at Vancouver Airport versus time were drawn to select the hot spells and the time of ending. Similar graphs were also drawn for Abbotsford and Nanaimo. Comparison with the Vancouver graph showed that the hot spells extended uniformly throughout the Lower Fraser Valley and Georgia Strait region and affected an area at least 80 miles in breadth.

8.

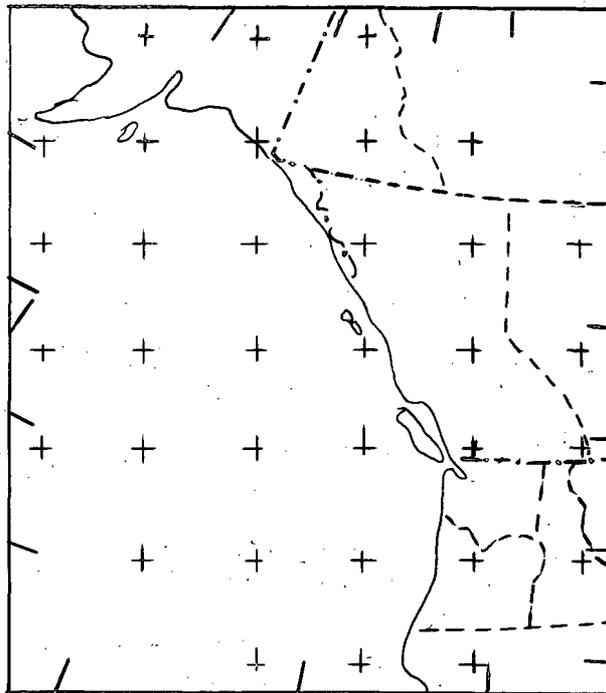
METHOD OF APPROACH

8.1. The general method adopted was to find significant parameters X_1 , X_2 , X_3 and X_4 which, when combined in the manner shown, would yield the predicant Y .



8.2. These parameters X_i were obtained from mean surface and upper air charts drawn for the periods of interest. The following grid was employed in drawing these charts:

fig 15



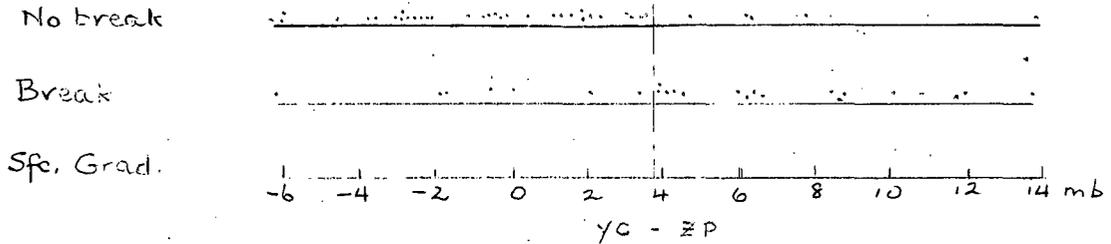
8.3. The grid was square, superimposed on a Lambert Conformal Conic Base chart. Grid distance was approximately 250 nautical miles.

8.4. The resulting mean charts were then differenced graphically to show the areas of most pronounced daily change both at the surface and upper air levels. The location and intensity of the difference patterns aided in the selection of parameters related to the ending of the hot spell or others that, during the first hot day, gave some indication of the probable length of the spell. Ideally, if each hot spell was the product of a definite synoptic pattern, charts for corresponding days in each spell would be almost identical. The derived mean charts would also be the same. Selection of parameters would then become relatively simple and would involve only the choosing of patterns that showed definite change from day to day and were not characteristic of charts for periods when no hot spell existed.

8.5. Forecast rules formulated under these conditions would be highly successful. However, in practice, each mean chart is the result of averaging charts that are not identical but only similar. This "scatter", in a sense, limits the efficiency of a chosen predictor and results in rules that are less than 100 percent effective.

8.6. Consequently, each predictor chosen from the mean charts was tested for significance using the chi square method (see appendix). This eliminated about 36 parameters out of 48 that appeared suitable during first inspection of the charts.

8.7. The following is an example of how the chi square test was applied to test the significance of a single parameter. In this case, the parameter is the surface pressure difference between Calgary and Sandspit. For each hot day, this difference was calculated from the 1200Z chart. Then, as is shown, this value was plotted along one of two straight lines, according to whether the occasion was a "break" or a "no-break" day.



8.8. When this had been done for all the hot days available, the value of the surface pressure difference which best separated the "breaks" from the "no-breaks" (in this case, 3.8 mb) was chosen and a vertical line drawn through it. Those days whose parametric value fell below 3.8 mb were forecast as "no-break" days and those days with a value above 3.8 mb as "break" days. From these data, the following contingency table was formed:

forecast

	break	no break	
break	17	7	24
no break	5	32	37
	22	39	61

8.9. Then the chi square value for this parameter was calculated in the manner described in the appendix. In this case, the value is 20.5 and as shown in the table contained in the appendix, the parameter is quite significant. If the chi square value had been less than 6.3, the parameter would have been rejected.

9. FIRST APPROACH

9.1. Using the ten last hot spells (those in the period 1960-61), mean charts (surface pressure and 500 mb height) were drawn for the three days preceding the break and the day following it. These charts were then differenced graphically to obtain 24 hour changes in an attempt to find parameters which would indicate a break in a hot spell the day before it was to occur.

Several parameters suggested themselves but when tested against all available data, they proved to be inconclusive.

10. SECOND APPROACH

10.1. It was felt that the grouping of hot spells of varying duration was possibly confusing the issue. The hot spells were therefore grouped according to length. Categories were chosen as follows:

- Group A ... one-day hot spells
- Group B ... two-day hot spells
- Group C ... three-day-plus hot spells

10.2. Another reason for this approach was that the one-day hot spells appeared to be essentially different from the longer hot spells. For the most part they appeared to be associated with features that moved or changed fairly quickly whereas the longer ones were associated with features that moved more slowly.

11. ONE-DAY HOT SPELLS

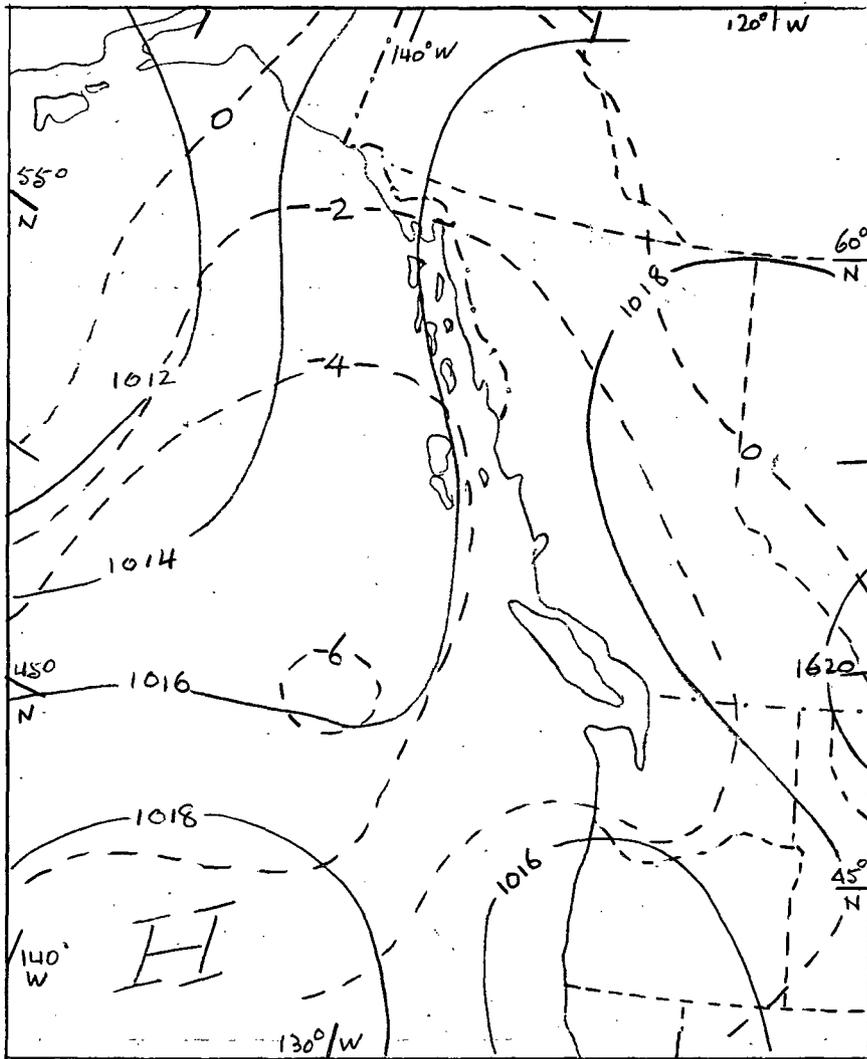
11.1. The one-day hot spells were arranged chronologically and every second one was chosen to form a subgroup. Using data from this subgroup, mean charts were drawn for the surface, 700 mb and 500 mb levels for 1200Z of the day before the hot spell and the first day of the hot spell (ie: the two days preceding the break). These charts were differenced graphically to locate parameters indicative of the impending break (see charts on page 15). These parameters were then tested by the chi square test.

11.2. In order to utilize the limited data to best advantage and to reduce any possible spurious effects which may have weighted our mean charts, the following data selecting scheme was adopted. Data for all parameters which were indicative of a break were drawn from the first day of all one-day hot spells used in drawing the mean charts plus one half of the remaining one-day hot spells not used in drawing the mean charts. Data for all parameters which were indicative of a no-break were drawn from the first day of all two-day and three-day-plus hot spells. One quarter of this data was left to be used as a test.

11.3. Of all the parameters found in this manner and tested by the chi square test, only four were found to be of sufficient significance to warrant further work. These were:

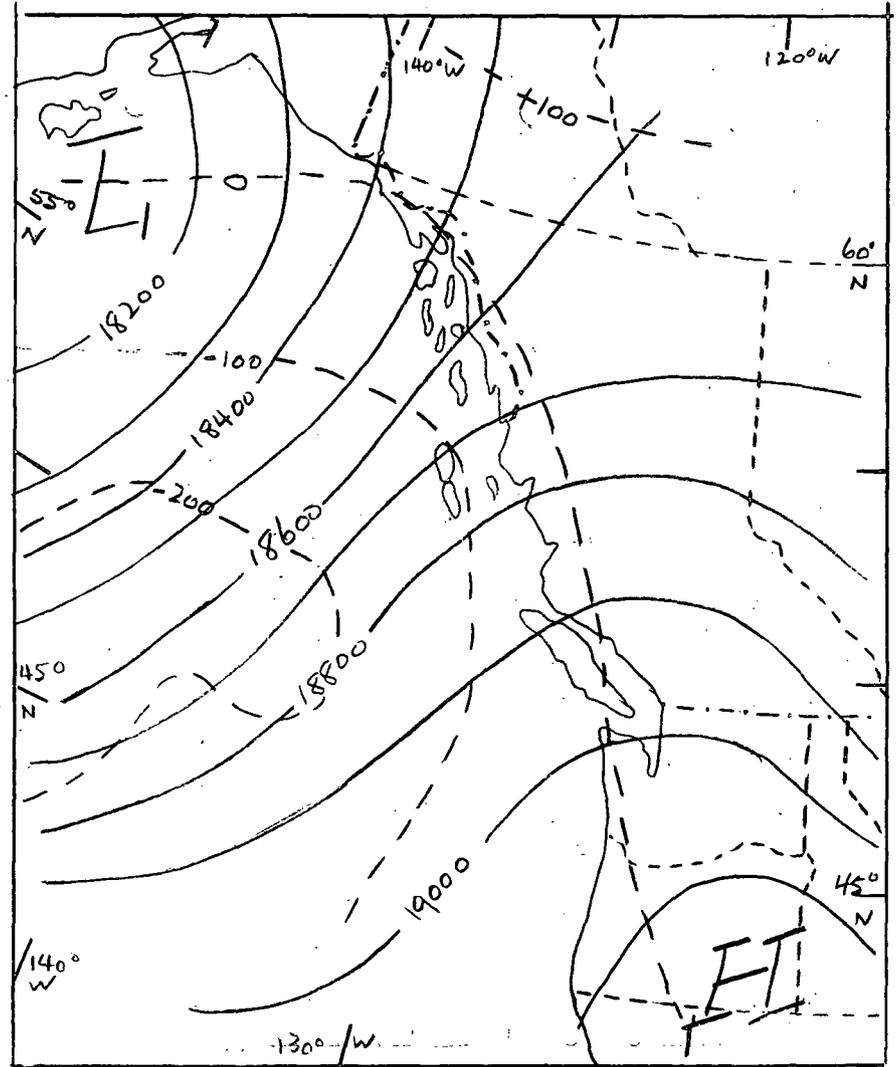
- X₁) 24 hour 500 mb height change at 45°N/146°W X² = 11.5
P = 9/10,000
- X₂) 500 mb height at Jasper X² = 7.0
P = 9/1000

fig 16



Surface pressure and 24 hour change (today minus yesterday)

fig 17



500 mb height and 24 hour change

Last Day of One-Day Hot Spell
(mean of 13 charts, 1200Z)

X_3) 24 hour surface pressure change at 47°N/135°W

$X^2 = 7.0$
 $P = 9/1000$

X_4) 700 mb height at 45°N/138°W

$X^2 = 8.9$
 $P = 5/1000$

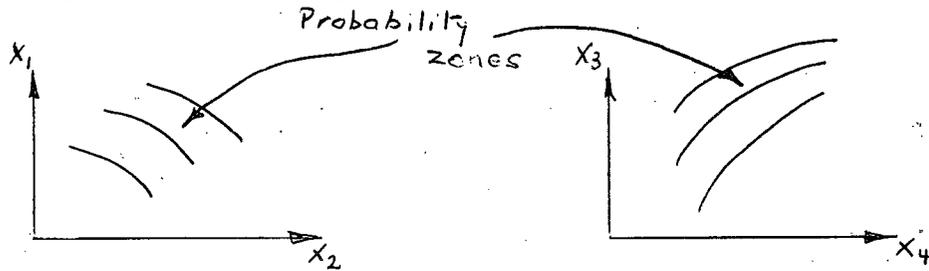
11.4. The symbols used are:

X_i = number associated with the parameter

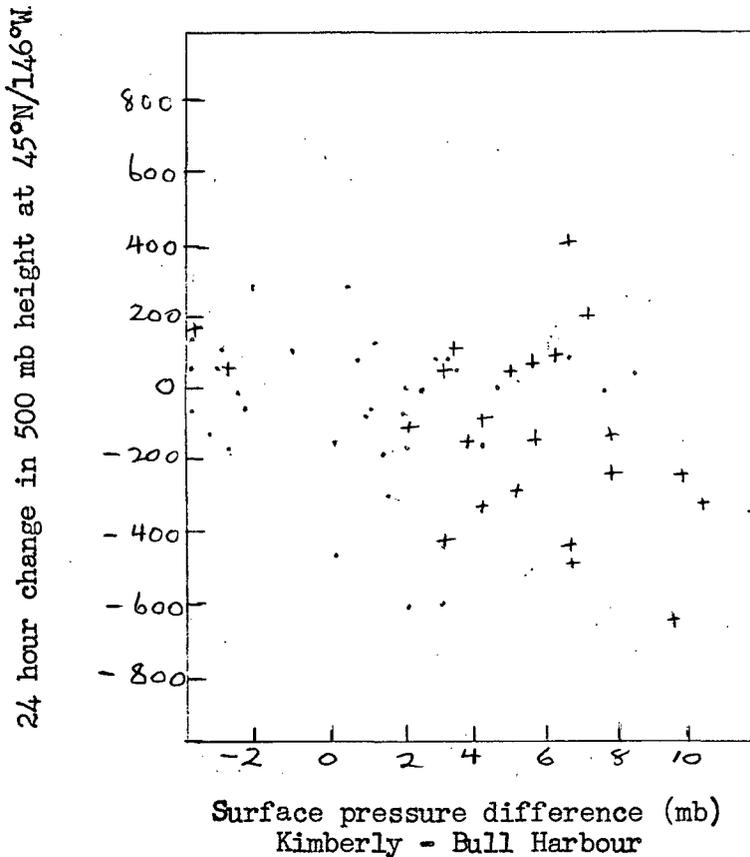
X^2 = chi square value (ie: a measure of the significance of the parameter)

P = probability that the parameter is caused by climatological chance.

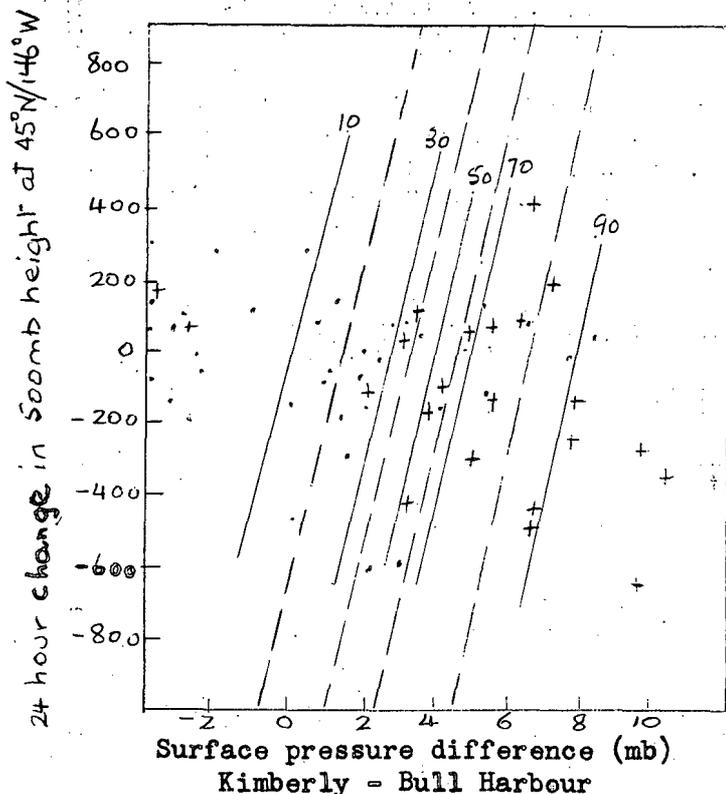
11.5. The relationship between the parameters X_i and predicant Y was brought out by plotting two scatter diagrams as shown:



11.6. As an example showing how the lines separating the probability zones were drawn, this process will be described for the graph numbered A-1 of figure 21. Without any lines on it, this graph looked as follows:

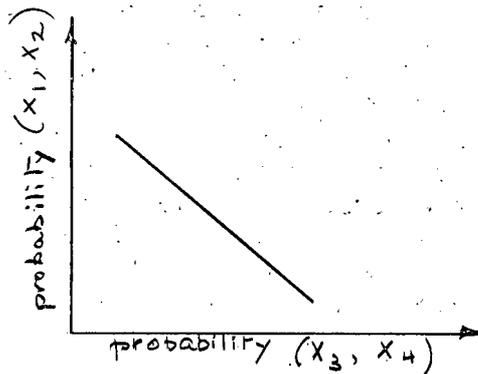


Light parallel lines were drawn to separate the distribution of dots and crosses into a number of approximately equally populated regions in such a way that, on moving from the concentration of dots to the concentration of crosses, the percentage of crosses in the regions rose steadily to nearly 100 percent. This percentage, calculated to the nearest ten percent, was interpreted as the probability that an event following into the region would be a "break". The percentages shown on this example may differ slightly from those used on the original graph A-1 because in the example both test and developmental data were plotted whereas only developmental data were used on the original.



Through the centre of each region, a heavy line was drawn. Each line was labeled with the probability value of its particular region. Where necessary, further lines were added by interpolation between existing lines until the graph was divided into probability zones by lines spaced about every twenty percent. Thus the two scatter diagrams pictured above were completed.

11.7. Each day which required a "break" or "no-break" decision was associated with four parameters. By using the two scatter diagrams, it was possible to associate two probabilities (of a "break") with each date. These two probabilities were then plotted on the third scatter diagram shown below.



11.8. A single straight line was drawn to separate the "breaks" from the "no breaks". In this connection there is no good reason why the final curve should be a straight line. However, if this method is to be effective, the curve should be simple. It is realized that the number of hot spells concerned was not very large. It is hoped that addition of future cases may result in some refinement of the curves.

11.9. The data which as yet had not been used at all (one quarter of the original data) was used as a test. The following results, using the before mentioned parameters, were found:

Developmental data
forecast

		break	no break	
observed	break	13	7	20
	no break	8	19	27
		21	26	47

Percent correct ... 68%

Skill score 0.38

Test data
forecast

		break	no break	
observed	break	2	3	5
	no break	2	6	8
		4	9	13

Percent correct ... 62%

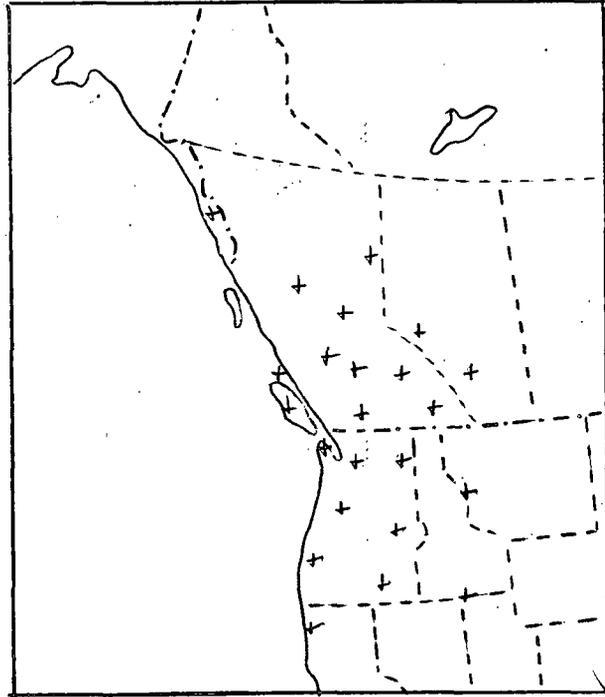
Skill score 0.17

11.10. The skill score is a measure of the skill involved in forecasting. It is unity when all forecasts are correct and zero when the forecasts are equal to those obtained by pure chance. It is further discussed in the appendix.

11.11. Since the results obtained for the prediction of break in a one-day hot spell did not seem too significant, it was decided to refine the grid to ensure that the finer details of the mean surface pattern were brought out. Hence, a revised and more detailed surface mean chart was drawn using sea level

pressures from actual stations in the Pacific North-West. The grid points used are shown on figure 18.

fig 18



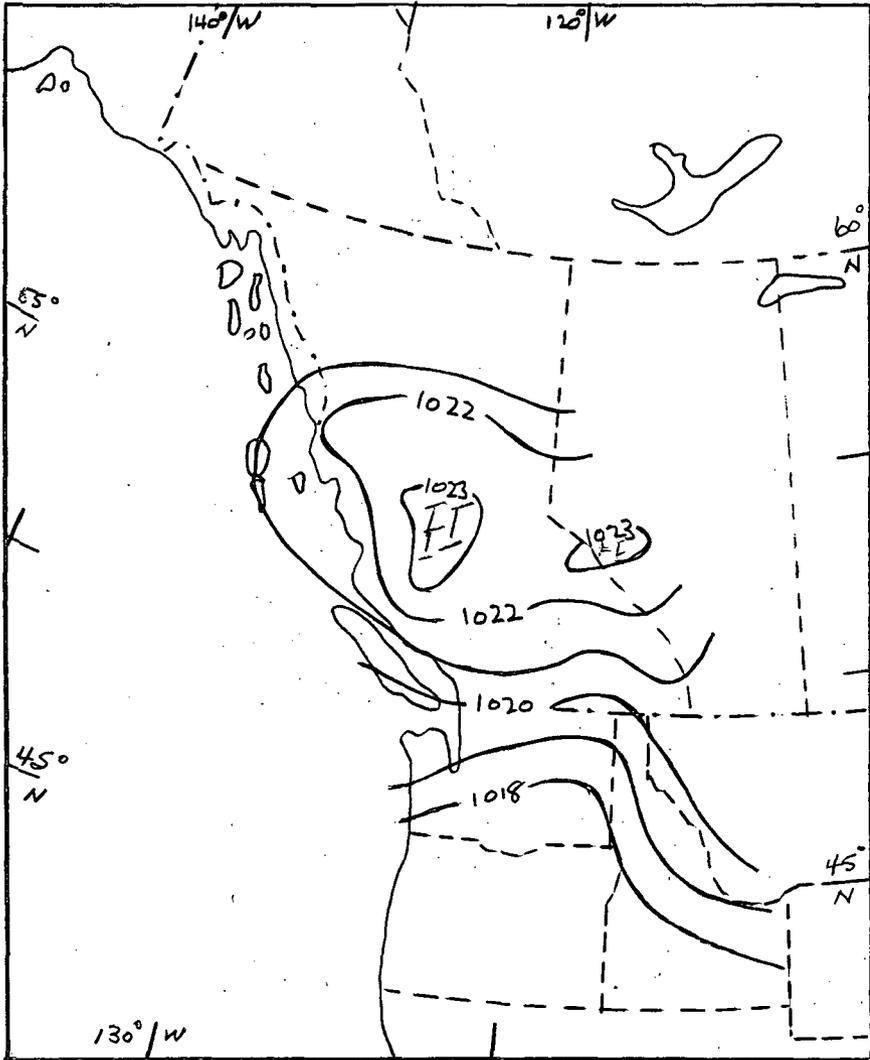
11.12. The mean surface charts thus obtained (shown on page 19) were treated in the same manner as the ones just discussed. The significant parameters found were:

- 1) surface pressure difference. Calgary minus Sandspit $X^2 = 19.0$
 $P = 1/100,000$
- 2) 24 hour change in pressure at Sandspit $X^2 = 11.7$
 $P = 8/10,000$
- 3) surface pressure difference, Kimberly
minus Bull Harbour $X^2 = 14.5$
 $P = 3/10,000$

To these three parameters was added the first parameter listed previously. The three graphs A-1, A-2 and A-3 were drawn in the manner previously described and are shown on page 21.

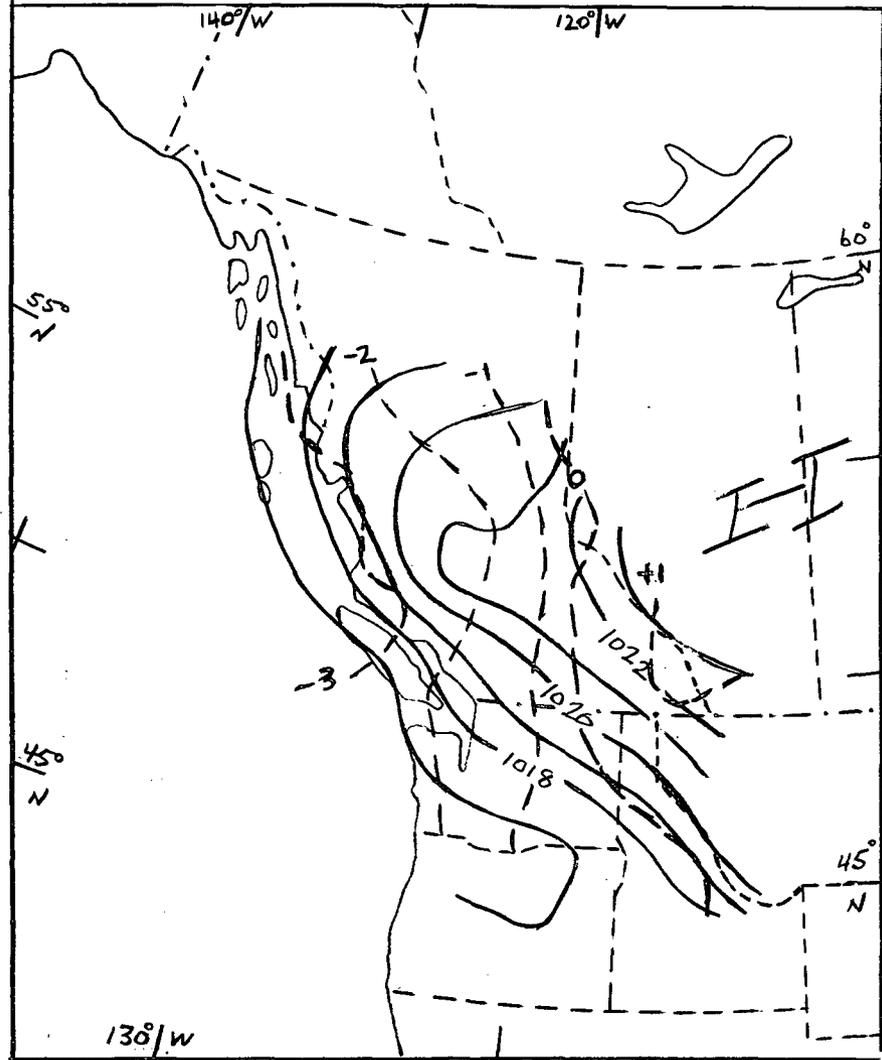
11.13. Inspection of the graphs A-1, A-2 and A-3 brings up some interesting points. Firstly, the slopes of the probability lines is an indication of the significance of the parameter being used. Thus, the parameters on the ordinates of A-1 and A-2 are not quite as significant at the corresponding parameters along the abscissae. This is well borne out by their chi square

Fig 19



Day before hot spell

Fig 20



Day of hot spell

Regional Surface Pressure Charts and 24 Hour Changes for One-Day Hot Spells
(mean of 14 charts, 1500Z)

values. Secondly, the separation of the "break" from the "no break" cases on A-1 and A-2 is not too evident. However, on A-3, it is quite clear. Thirdly, the position of the exceptions on A-3 is quite conspicuous; they are definitely not borderline cases. It is rather mystifying why these errors should be so drastic.

11.14. The following results were obtained:

Developmental data forecast				Test data forecast					
		break	no break			break	no break		
observed	break	16	3	19	observed	break	4	2	6
	no break	3	21	24		no break	4	9	13
		19	24	43			8	11	19

Percent correct ... 86% Percent correct ... 68%

Skill score 0.72 Skill score 0.33

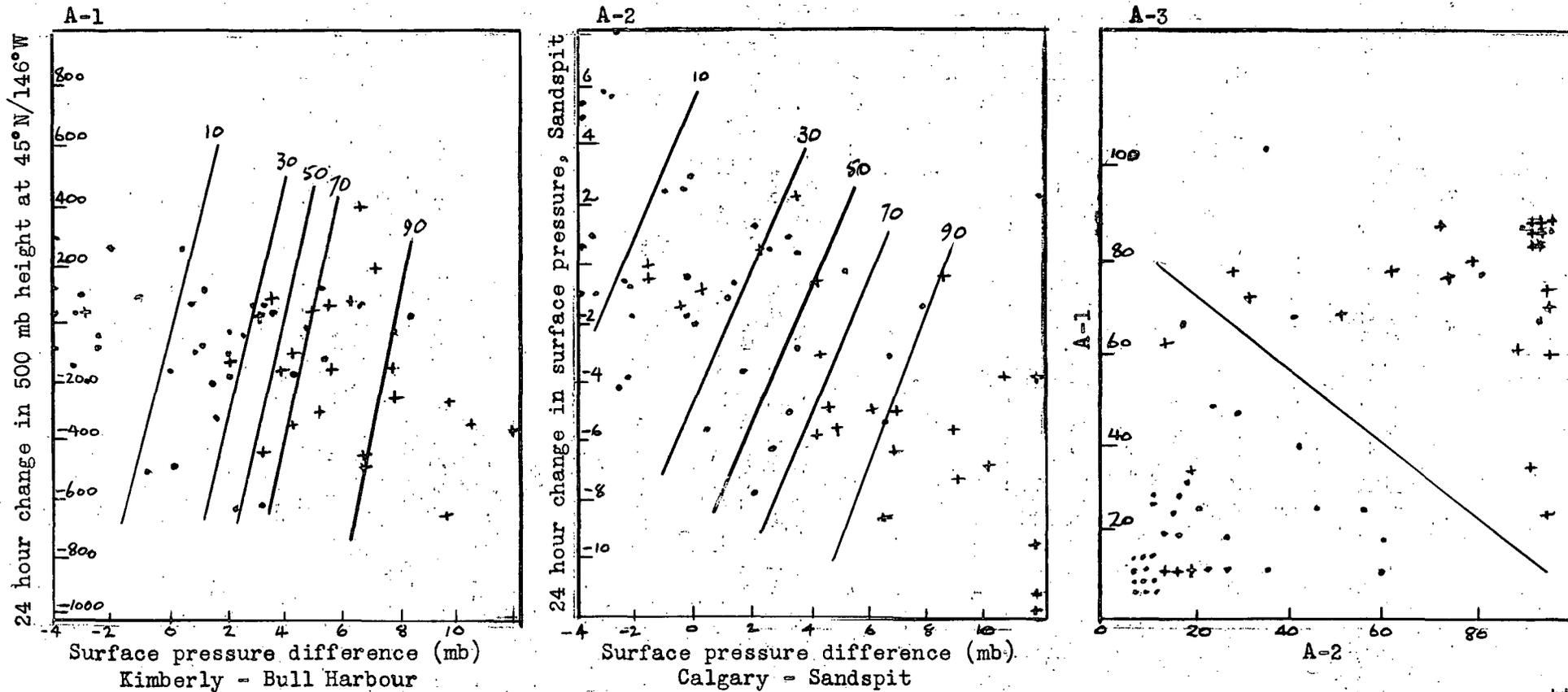
11.15. It is interesting to note that this particular test involving four parameters can be reduced to one involving one single parameter, the surface gradient between Calgary and Sandspit. Prediction of "break" if the pressure difference exceeds 3.8 mb and "no break" if it is less than 3.8 mb yields the following results:

	Developmental data	Test data
Percent correct	84%	74%
Skill score	0.66	0.42

12. TWO-DAY HOT SPELLS

12.1. The hot spells were arranged chronologically and data from about one half of them were used to draw mean charts of the surface pressure, 700 mb height and 500 mb height for 1200Z of the two days preceding the break. These charts, shown on page 22, were then graphically differenced to obtain parameters in the manner mentioned previously. Parameters obtained were again tested with the chi square test using about three quarters of the data. The four most significant parameters were:

One-Day Hot Spell



Graphs Showing the Separation of the "Breaks" (+) from "No Breaks" (°) on the First Day of the Hot Spell

Fig 21.

- 1) 24 hour 500 mb height change at 52°N/135°W $\chi^2 = 6.7$
P = 1/100
- 2) 500 mb height difference, Spokane minus Annette $\chi^2 = 8.8$
P = 5/1000
- 3) 700 mb height difference, Spokane minus Annette $\chi^2 = 11.0$
P = 1/1000
- 4) 500 mb height at 52°N/135°W $\chi^2 = 6.7$
P = 1/100

The corresponding set of three graphs is shown on page 24. The "no break" data were obtained from the second day of the three-day-plus hot spells. The following results were obtained:

Developmental data
forecast

	break	no break	
observed	break	9	3
	no break	2	13
		11	16
			27

Percent Correct ... 82%

Skill score 0.62

Test data
forecast

	break	no break	
observed	break	2	2
	no break	0	5
		2	7
			9

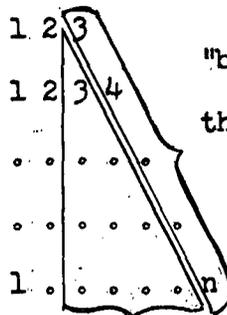
Percent Correct ... 78%

Skill score 0.52

13. THREE-DAY-PLUS HOT SPELL

13.1. These hot spells were treated in a manner similar to the two-day hot spells. The only difference was in the manner of selecting data. The "break" and "no break" data are best shown graphically as follows:

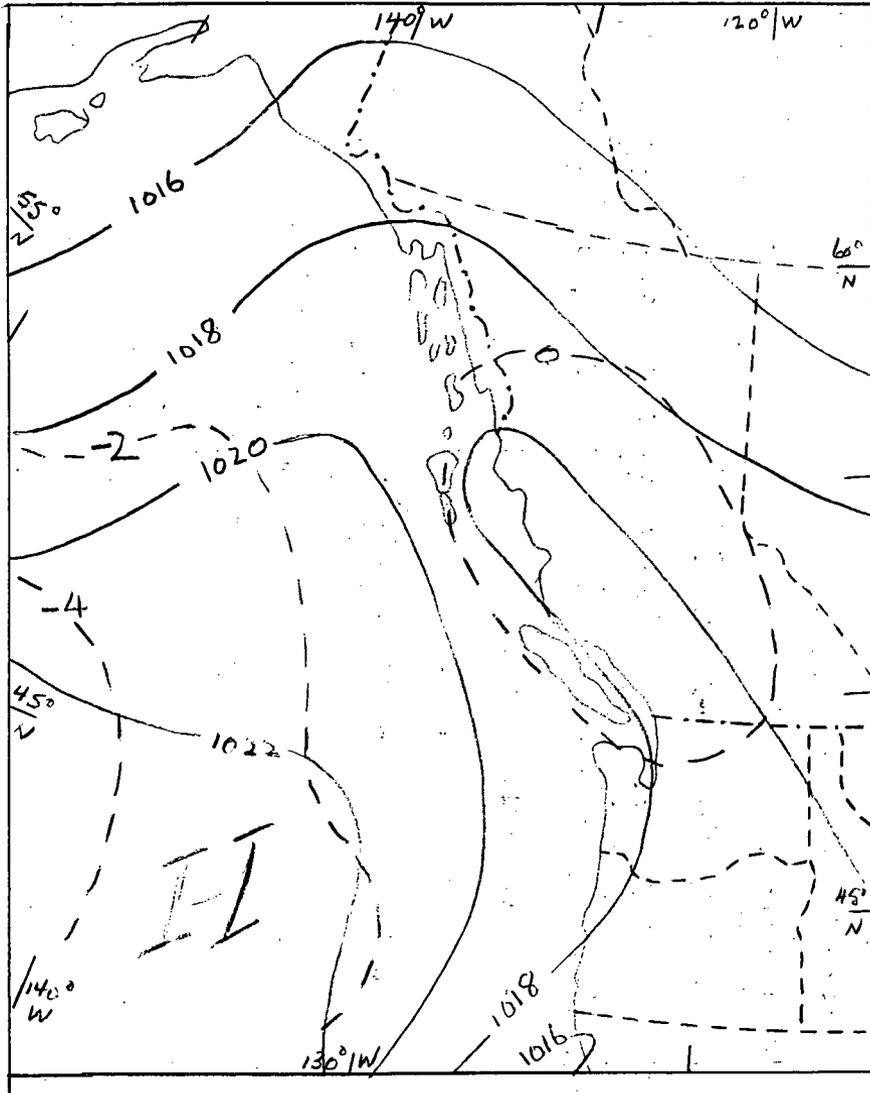
- One-day hot spell 1
- Two-day hot spell 1 2
- Three-day-plus hot spell ... 1 2 3



"break" data was drawn from these days

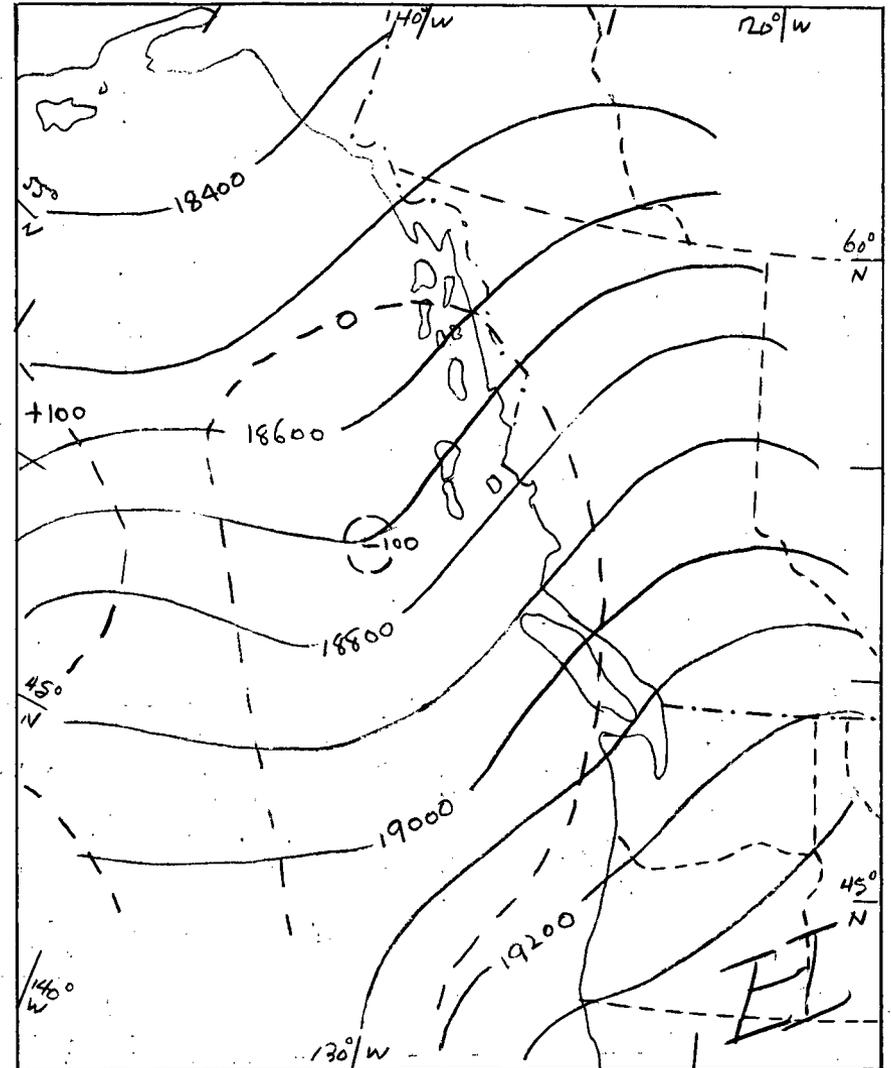
"no break" data was drawn from these days

fig 22



Surface pressure and 24 hour change

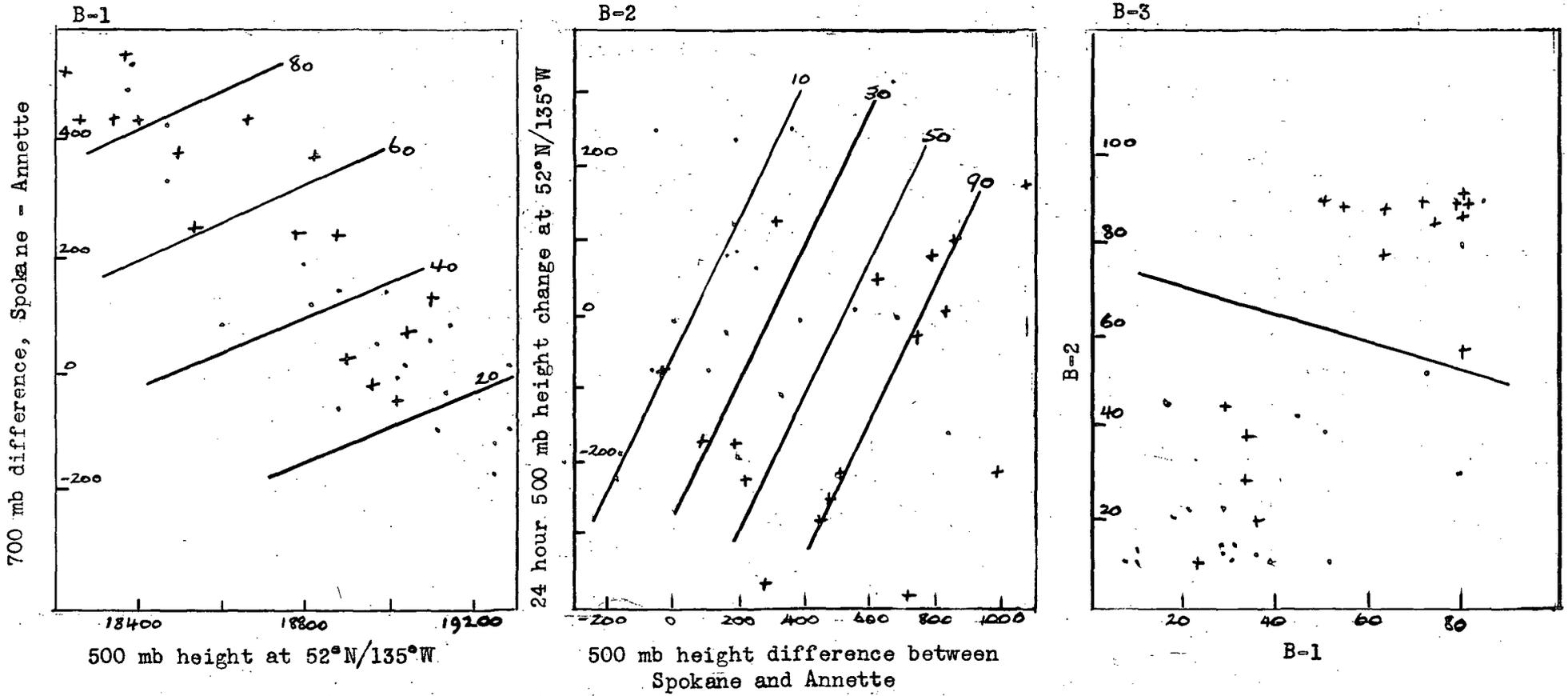
fig 23



500 mb height and 24 hour change

Last Day of Two-Day Hot Spell
(mean of 9 charts, 1200Z)

Two-Day Hot Spell



Graphs Showing the Separation of the "Breaks" (+) from the "No Breaks" on the Second Day of the Hot Spell

Fig. 24.

13.2. The resultant mean charts are shown on page 26. The significant parameters obtained were:

- | | |
|---|---------------------------------|
| 1) 24 hour 500 mb height change at Yakutat | $\chi^2 = 8.2$
P = 7/1000 |
| 2) 24 hour 500 mb height change at 57°N/143°W | $\chi^2 = 14.7$
P = 2/10,000 |
| 3) 500 mb height at 57°N/143°W | $\chi^2 = 12.2$
P = 1/100 |
| 4) 24 hour 700 mb height change at Yakutat | $\chi^2 = 6.8$
P = 1/100 |

13.3. The graphs shown on page 28 yield the following results:

		Developmental data forecast		
		break	no break	
observed	break	12	3	15
	no break	4	26	30
		16	29	45
Percent correct ...		85%		
Skill score		0.66		

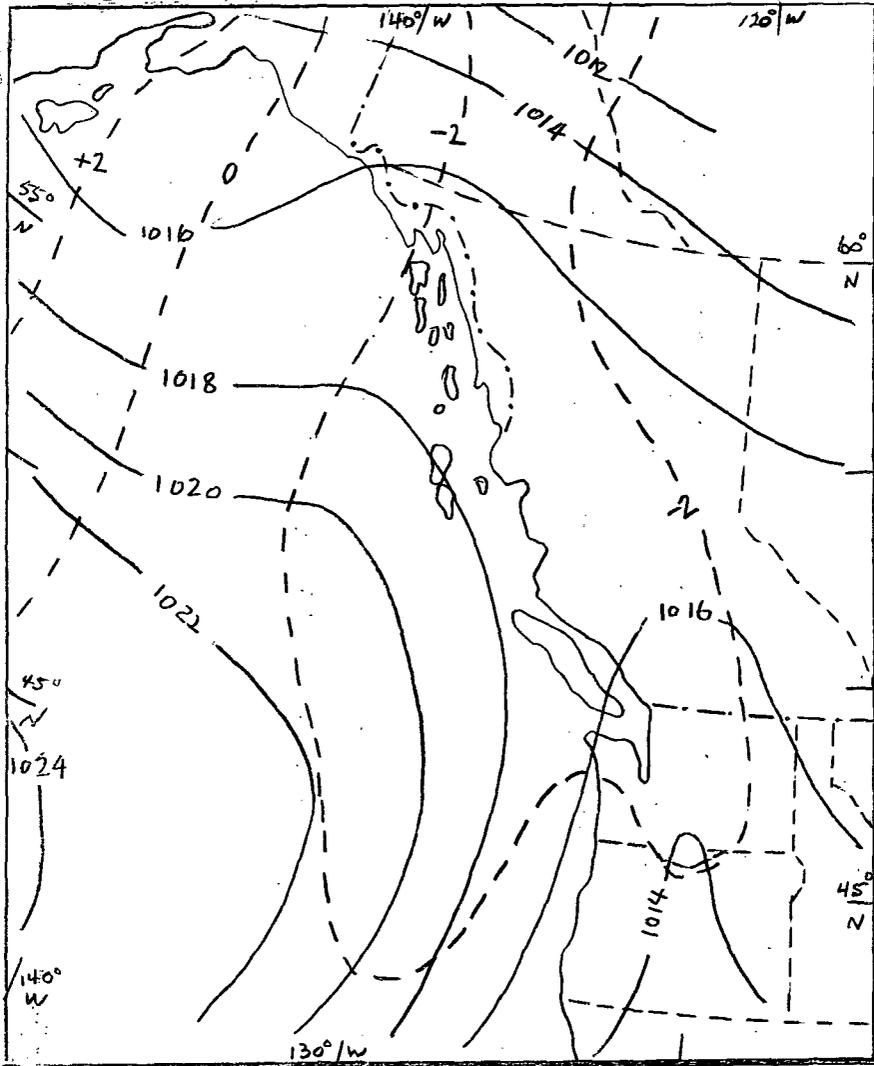
		Test data forecast		
		break	no break	
observed	break	3	1	4
	no break	2	6	8
		5	7	12
Percent correct ...		75%		
Skill score		0.47		

13.4. The pattern of probability lines on C-1 is sufficiently unusual to warrant some comment. The reason for the V-shaped pattern was to place the "no break" occurrences at the bottom of the graph in a lower probability zone and hence to cause their removal from the "break" region of C-3.

13.5. More information will be needed before it can be decided whether this pattern is caused by a chance distribution or is consistent. If the second of these alternatives is true, then a physical explanation will have to be found.

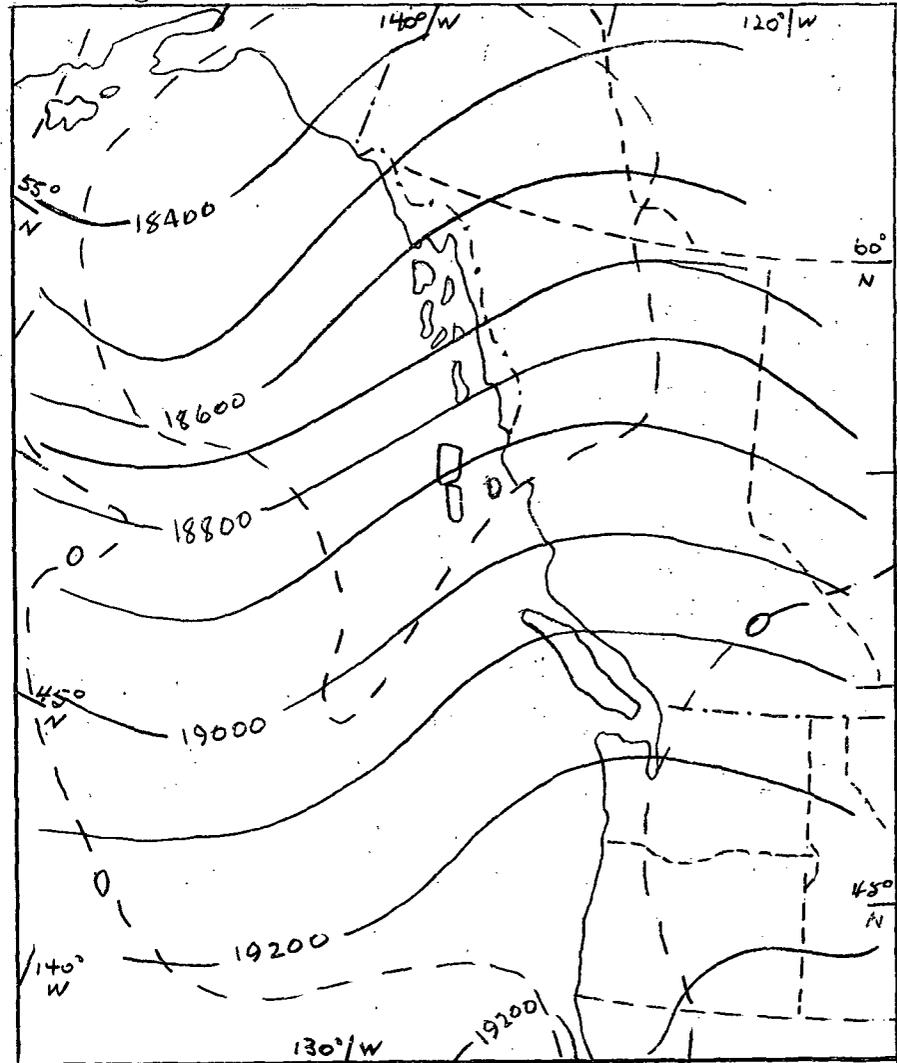
13.6. The parameter in question is the 500 mb height at 57°N/143°W, about 750 nautical miles north-west of Vancouver. A parametric value of about 18300 feet gives a strong indication of a "break" whereas values higher or lower than this tend to indicate a "no-break".

Fig. 25.



Surface pressure and 24 hour change

Fig. 26.



500 mb height and 24 hour change

Last Day of Three-Day-Plus Hot Spell
(mean of 10 charts, 1200Z)

13.7. In effect, the shape of the curves of figure 27, C-1 indicate that the 24 hour height change of the 700 mb level over Yakutat is a significant parameter only if the 500 mb height at 57°N/143°W is greater than 18,200 feet. Contour heights of less than this value would most of the time indicate the presence of a cold low in the vicinity. If a cold low does exist in the Gulf of Alaska, it is unlikely that a change occurring some hundreds of miles to the north of it could have any immediate influence on the weather in southern B.C.

14. LENGTH OF HOT SPELL

14.1. During the above investigation into the ending of hot spells of varying length, it was noted that certain parameters obtained on the first day of the hot spell tended to separate the three-day-plus hot spells from the two-day and one-day hot spells. The four most significant of these parameters were:

- | | |
|---|------------------------------|
| 1) 24 hour surface pressure change at 47°N/137°W | $X^2 = 7.4$
P = 8/1000 |
| 2) surface pressure at 43°N/138°W | $X^2 = 12.3$
P = 7/10,000 |
| 3) surface pressure at Sandspit | $X^2 = 11.8$
P = 8/10,000 |
| 4) 24 hour change in surface pressure at Sandspit | $X^2 = 9.9$
P = 3/1000 |

14.2. Using these parameters, the three graphs R-1, R-2 and R-3 on page 30 were drawn. The results were:

		Developmental data forecast		
		C	A,B	
observed	C	9	4	13
	A,B	3	27	30
		12	31	43

Percent correct ... 84%

Skill score 0.61

		Test data forecast		
		C	A,B	
observed	C	5	2	7
	A,B	2	10	12
		7	12	19

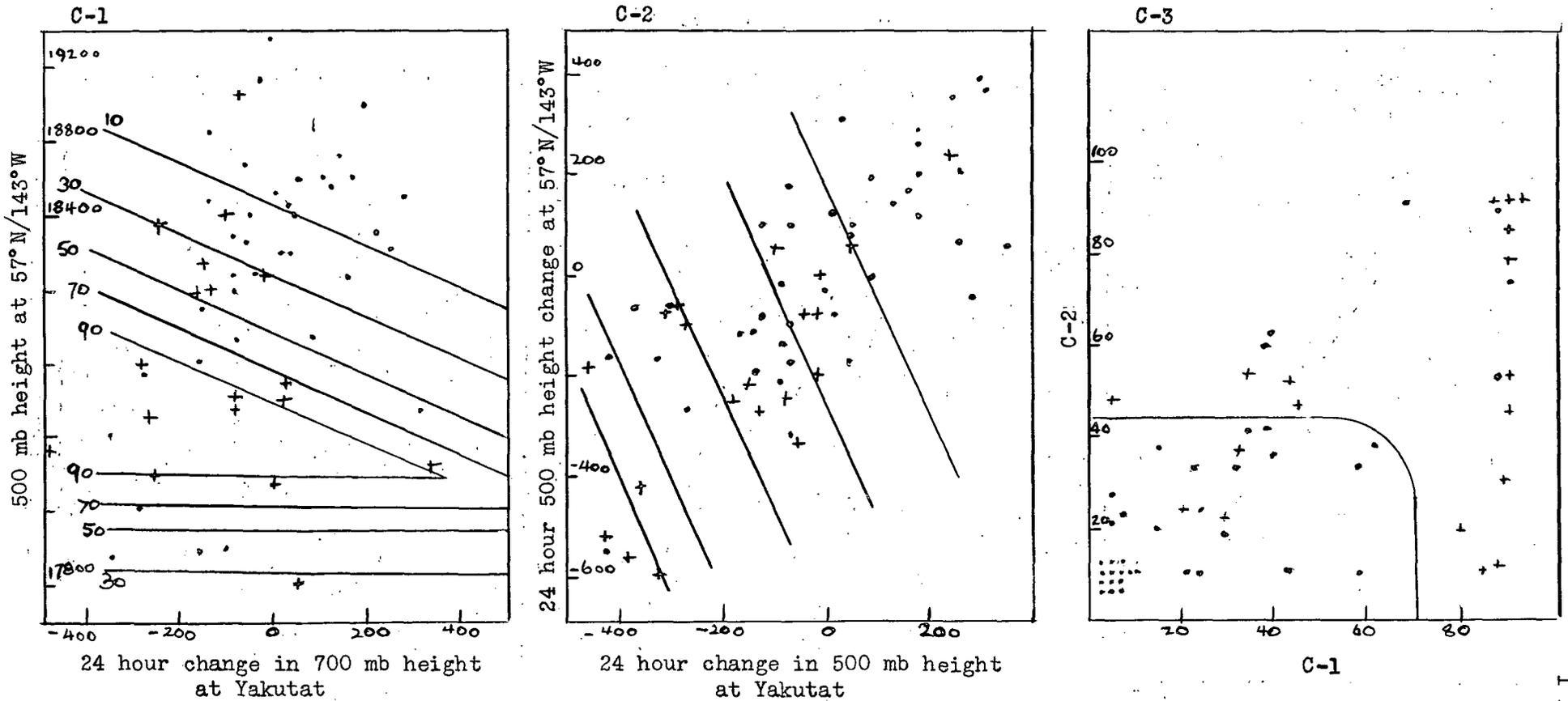
Percent correct ... 79%

Skill score 0.55

Symbols used: A,B ... one-day and two-day hot spells

C three-day-plus hot spells

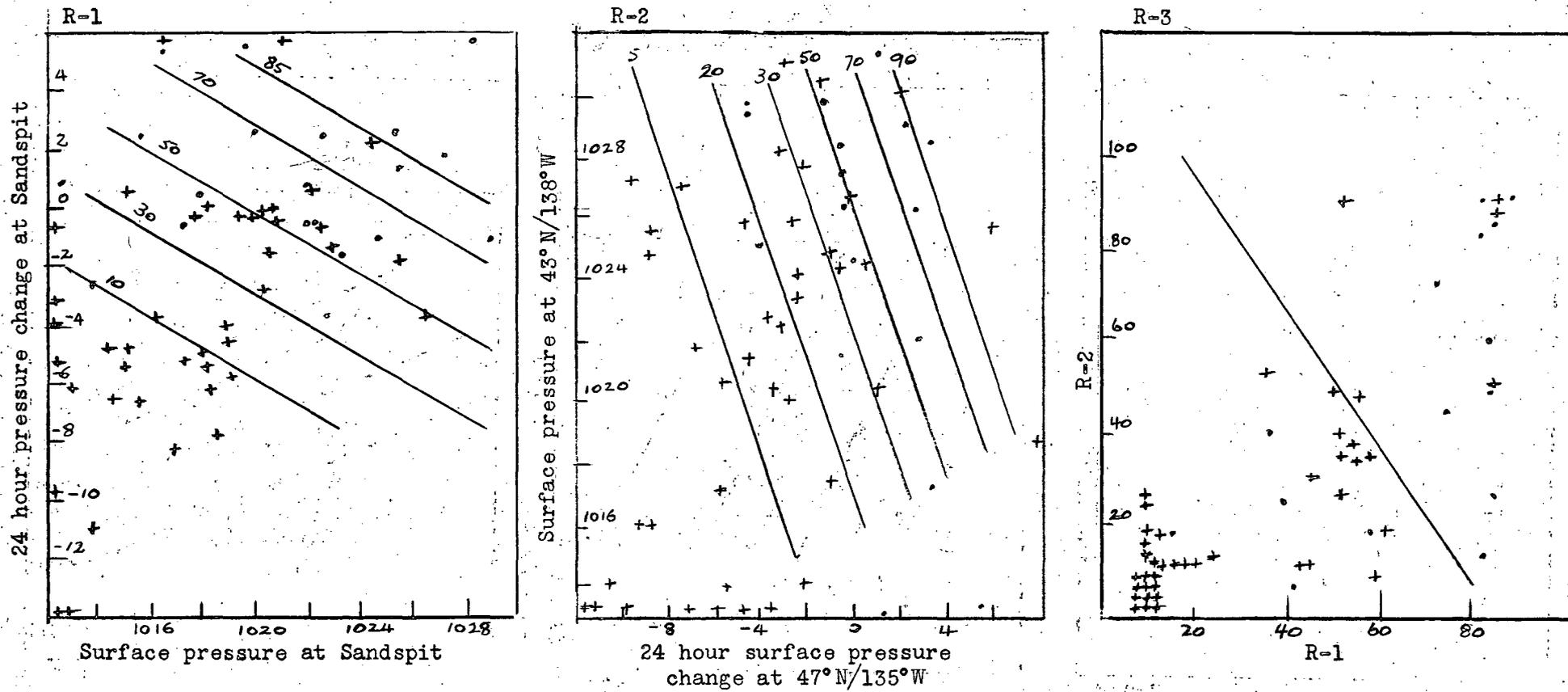
Three-Day-Plus Hot Spell



Graphs Showing the Separation of the "Breaks" (+) from the "No Breaks" (•) on the Third Day of the Hot Spell and Subsequent Hot Days

Fig. 27

Long Hot Spells.



Graphs Showing the Separation of Three-Day-Plus Hot Spells(°) from One-Day and Two-Day Hot Spells(+) on the First Day of the Hot Spell

Fig. 28.

15.

COMPARISON OF RESULTS

	Developmental data		Test data	
	Percent correct	Skill score	Percent correct	Skill score
Prediction of break in one-day hot spell (using 4 parameters)	86%	0.72	68%	0.33
Prediction of break in one-day hot spell (using 1 parameter)	84%	0.66	74%	0.42
Prediction of break in two-day hot spell (using 4 parameters)	82%	0.62	78%	0.52
Prediction of break in three-day-plus hot spell (using 4 parameters)	85%	0.66	75%	0.47
Prediction of three-day-plus hot spell (using 4 parameters)	84%	0.61	79%	0.55
Average	84%	0.65	75%	0.46

15.1. Predictions listed in the first four rows of the above table constitute forecasts, made early one morning, predicting an end to the hot spell on the succeeding day. Predictions in the last row are forecasts made early one morning forecasting that the hot spell beginning that day will continue for at least three days.

16.

DISCUSSION OF RESULTS

16.1. An analysis of this type produces a series of graphs. Each graph achieves some separation between cases of "break" and "no break". Ideally the final graph should have produced complete separation. In practice, since the parameters have an "efficiency" of less than 100 percent, separation is incomplete in the final chart; the "no break area will be slightly contaminated by occasions of "break" and vice-versa. As a rule, these situations should occur near the border between the groups. In this investigation some drastic exceptions occurred, an occasional event being found associated with values of parameters that were so extreme that its opposite was clearly indicated. Further analysis of these cases elicited the following possibilities:

- 1) It is possible that some breaks actually occurred on the day before the maximum temperature dropped, but after reaching a daily maximum which still satisfied the "no break" criterion.

- 2) A westerly sea breeze may have shortened a hot spell at the Vancouver Airport independently of any other parametric features.

16.2. A further limitation of this project was the lack of sufficient data. For the ten year period of investigation (1952-1961), the following number of hot spells was found:

- 25 one-day hot spells
- 17 two-day hot spells
- 6 three-day hot spells
- 3 four-day hot spells
- 3 five-day hot spells
- 3 six-day hot spells
- 3 seven-day hot spells
- 2 eight-day hot spells

To test the results, only a small number of cases could be used. Thus, with the test data, a single exception could weight the results considerably. However, this project is considered to be only an initial analysis of the problem. The methods outlined will be followed at the Vancouver Meteorological Office during the next few years. By then, it is hoped that data will be sufficient to effect further refinements in some areas of the charts and raise the efficiency of the method to a maximum.

16.3. A striking feature of this study is the relatively close agreement among the results for the various hot spells (refer to table, page 29). A further study of the exceptions might reveal subgroups which could be dealt with separately. The dates of all exceptions have been recorded to facilitate such a study.

16.4. The fourteen cases of prediction of "no break" when "break" actually occurred were checked in more detail. It was found that on only one of these occurrences did rain accompany the break. This is to be compared to the overall ratio of 24 "rain-breaks" and 38 "no-rain-breaks". That is, two out of every five breaks were accompanied by rain. Since 23 out of the 24 "rain-breaks" were correctly predicted, it would seem that the parameters used are particularly well attuned to rain. This is further emphasized by the fact that although 96% of the "rain-breaks" were correctly predicted, only 24 out of 38 (ie: 63%) of the "no-rain-breaks" were correctly forecast.

16.5. The official temperature forecasts made during the same hot spells were studied in order to obtain a measure of the usefulness of the forecasts which could be obtained based on the before mentioned tests.

16.6. A brief inspection of maximum-temperature predictions during hot spells showed that 75°F is far more frequently forecast than either 74°F or 76°F. Since an error of one degree in maximum-temperature forecasts is of little concern, it was decided to use 75°F as the critical maximum-temperature for the comparison instead of 76°F as had been stated in the definition. No inconsistency is brought about since the definition is concerned with actual temperatures only. Thus, for this comparison, a forecast maximum-temperature of greater than or equal to 75°F is labeled a hot spell and a maximum-temperature decrease to less than 75°F is labeled a break.

16.7. The results are best shown in tabular form. (Note: Forecasting "break tomorrow" is done only after a correct forecast of "hot spell today" has been made.)

	Forecast made this morning	Correct forecasts
One-day hot spell	hot spell today	9/25 = 36%
	break tomorrow	6/9 = 67%
Two-day hot spell	hot spell today	25/34 = 74%
	break tomorrow	3/5 = 60%
	no-break tomorrow	7/20 = 35%
Three-day-plus hot spell	hot spell today	94/100 = 94%
	break tomorrow	5/11 = 45%
	no-break tomorrow	69/83 = 83%

Contingency tables:

Two-day hot spells forecast

		break	no break	
observed	break	3	13	16
	no break	2	7	9
		5	20	25

Percent correct ... 40%

Skill score -0.03

Three-day-plus hot spells forecast

		break	no break	
observed	break	5	14	19
	no break	6	69	75
		11	83	94

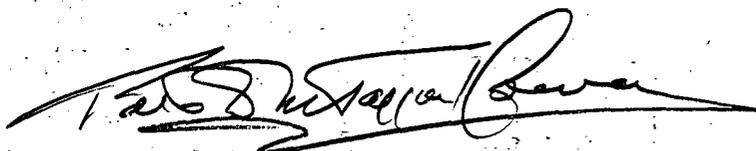
Percent correct ... 79%

Skill score 0.33

17. CONCLUSION

17.1 It was found possible to develop an objective method for predicting breaks in hot spells at Vancouver International Airport. The parameters needed are all obtainable from weather charts up to and including 1200Z "this morning"; this facilitates forecasting "break" or "no break" tomorrow. It was also found possible to predict the relative length of a hot spell on its first day. The present study of necessity was based on a limited amount of data. The method lends itself to further refinement as more information becomes available. This refinement will be a continuing project at the Vancouver Meteorological Office in succeeding summers.

APPROVED,



P. D. McTaggart-Cowan,
Director.

18. ACKNOWLEDGEMENTS

18.1. This paper was written while the authors were employed as Student Assistants in Meteorology at the Vancouver Meteorological Office during the summer of 1962. The authors gratefully acknowledge the advice and suggestions of Mr. D. Strachan, Chief Forecaster, and Mr. J. Mathieson, Project Meteorologist.

19. APPENDIX

19.1. Skill score

19.1.1. The skill score is a mathematical tool used to give a measure of skill in forecasting. It is equal to unity when all forecasts are correct, and it is zero when the number of correct forecasts equals the number that can be expected by climatological chance.

19.1.1.1. Consider the following contingency table:

		forecast		
		occurrence	nonoccurrence	
observed	occurrence	x_1	x_3	R_1
	nonoccurrence	x_2	x_4	R_2
		C_1	C_2	T

where x_i = number of events in that group

$$x_1 = x_1 + x_3$$

$$R_2 = x_2 + x_4$$

$$C_1 = x_1 + x_2$$

$$C_2 = x_3 + x_4$$

$$T = R_1 + R_2 = C_1 + C_2 \text{ total number of forecasts}$$

Let $F = x_1 + x_4$ = number of correct forecasts

The skill score (S) is defined by:

$$S = \frac{F - D}{T - D}$$

$$\text{where } D = \frac{C_1 R_1 + C_2 R_2}{T} = \frac{\sum_i^n C_i R_i}{T}$$

Chi square (X^2) test is a useful test for determining the significance of meteorological data.

It is defined by

$$X^2 = \sum \left[\frac{(f_o - E)^2}{E} \right]$$

$$= \frac{d^2}{E}$$

where f_o = observed frequency

$$d = x_i - \frac{(R_i C_i)}{T} \quad (\text{using the above mentioned contingency table})$$

E = expected frequency determined by chance

$$= T \left[\frac{1}{R_1 C_1} + \frac{1}{R_1 C_2} + \frac{1}{R_2 C_1} + \frac{1}{R_2 C_2} \right]$$

The probability of a parameter being caused by chance (P) is a single valued function of X^2 and is given by the following table:

P	.99	.98	.95	.90	.50	.10	.05	.02	.01	.001
X^2	(.00	.001	.004	.02	.46	2.7)	3.8	5.4	6.3)	10.8
	Parameter is insignificant....						inconclusive....		significant		

20.

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DEFINITIONS: Hot Spell: $\max T \geq 75^\circ\text{F}$

Break: $\Delta \max T \leq -5^\circ\text{F}$ to less than 75°F .

ONE-DAY HOT SPELLS

Object

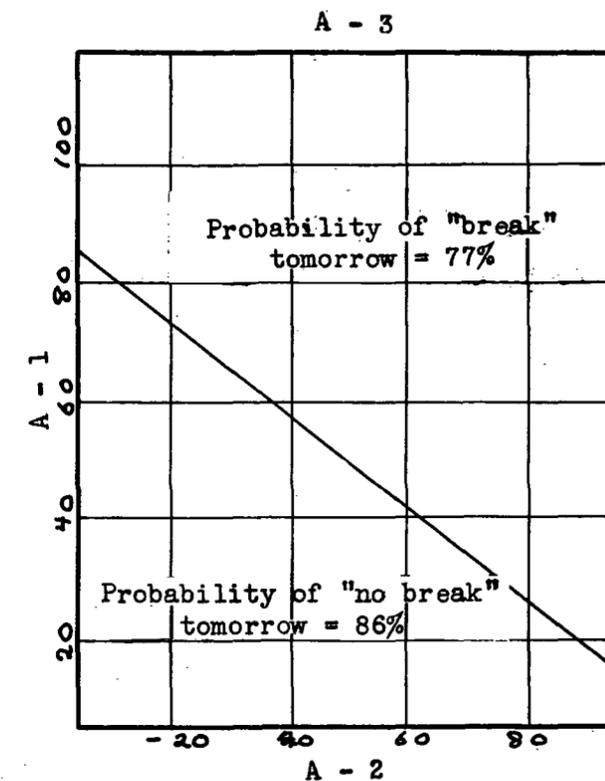
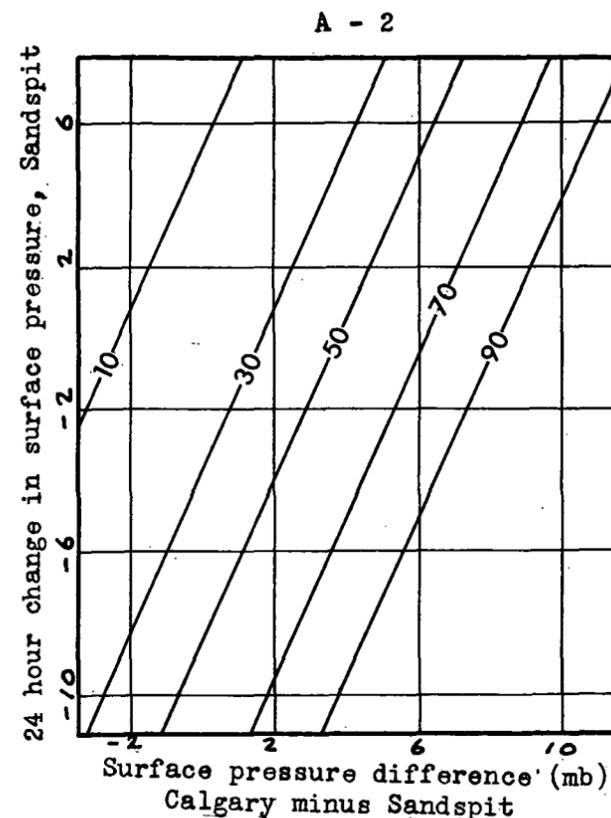
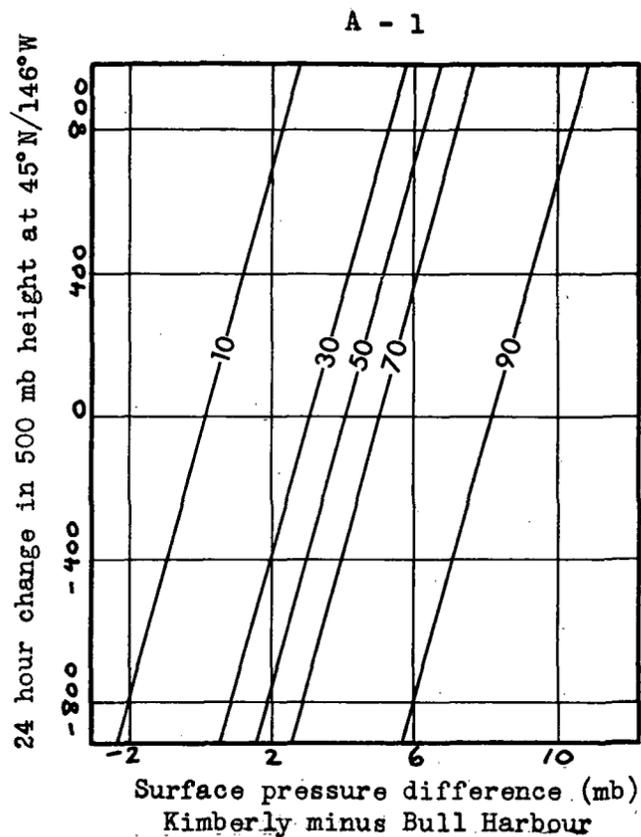
To forecast: "break" or "no break" for tomorrow

Prerequisites:

- a) $\max T$ yesterday $< 75^\circ\text{F}$
- b) $\max T$ forecast for today $\geq 75^\circ\text{F}$

Procedure:

1. Obtain and record parametric values for graphs A-1 and A-2 from 1200Z charts for this morning (and yesterday morning where necessary).
2. Obtain corresponding probabilities from A-1 and A-2.
3. Record both on A-3.
4. Resultant probability for "break" or "no break" is stated on graph A-3.



LONG HOT SPELLS

Object

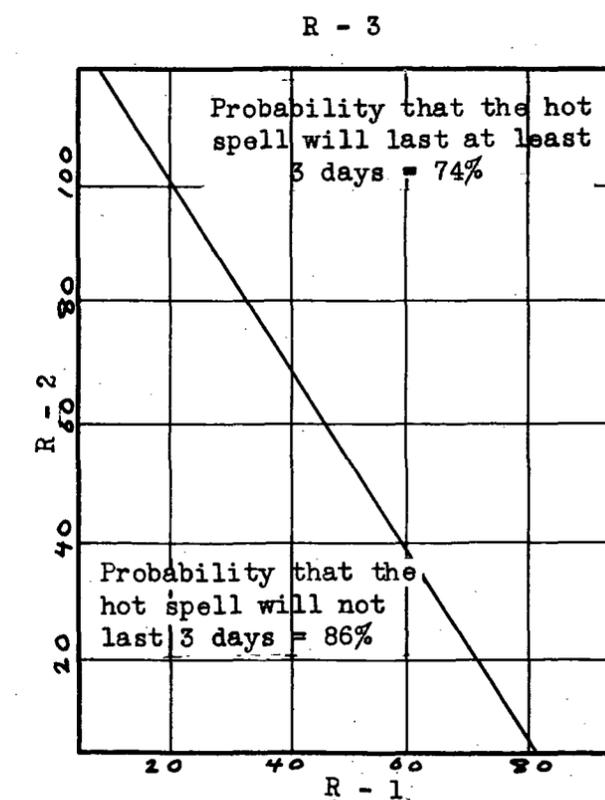
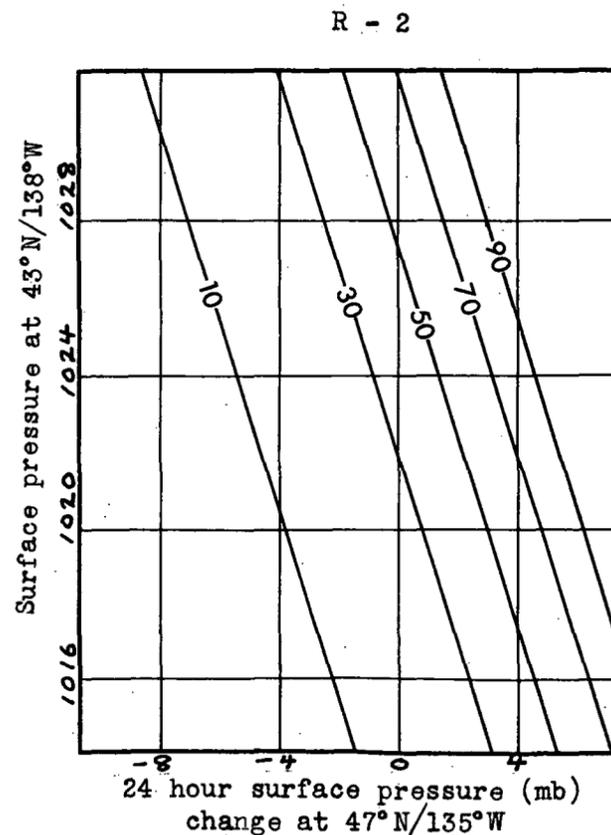
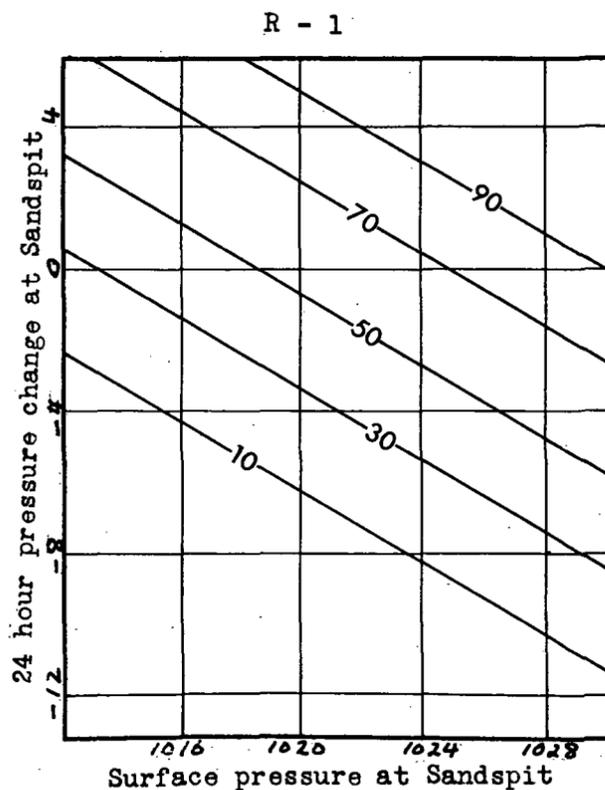
To forecast: hot spell will last at least three days or not.

Prerequisites:

- a) $\max T$ yesterday $< 75^\circ\text{F}$
- b) $\max T$ forecast for today $\geq 75^\circ\text{F}$

Procedure:

1. Obtain and record parametric values for graphs R-1 and R-2 from 1200Z charts this morning (and yesterday morning where necessary)
2. Obtain corresponding probabilities from R-1 and R-2.
3. Record both on graph R-3.
4. Resultant probability for length of hot spell is stated on graph R-3.



TWO-DAY HOT SPELLS

Object

To forecast "break" or "no break" for tomorrow

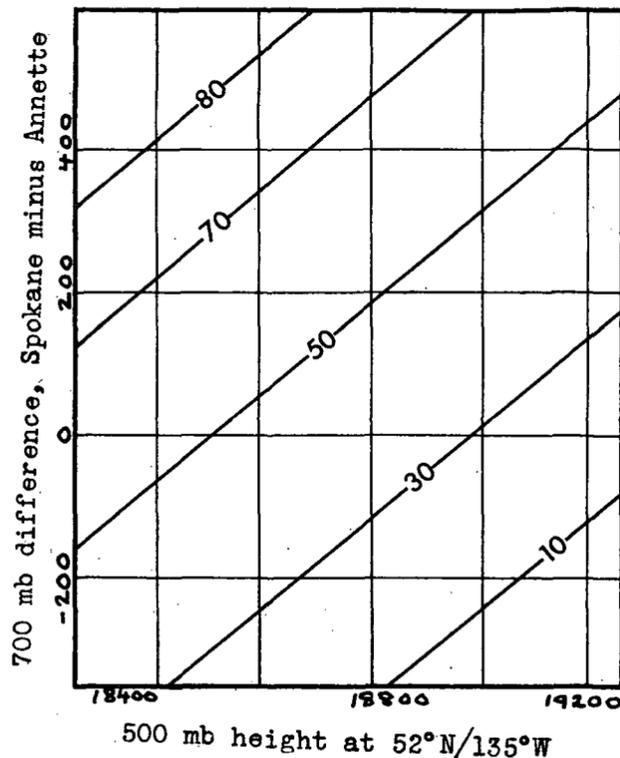
Prerequisites:

- a) max T 2 days ago < 75°F
- b) max T yesterday > 75°F
- c) max T forecast for today 75°F

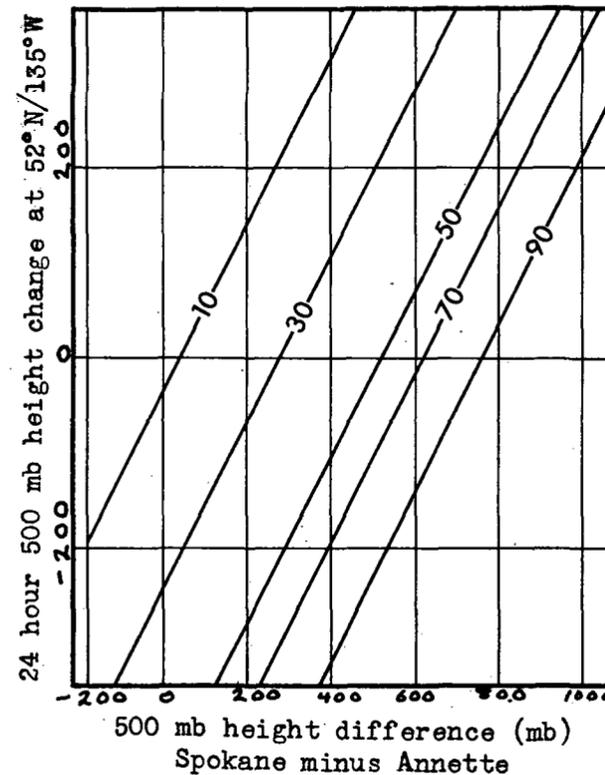
Procedure:

1. Obtain and record parametric values for graphs B-1 and B-2 from 1200Z charts this morning (and yesterday morning where necessary).
2. Obtain corresponding probabilities from B-1 and B-2.
3. Record both on B-3.
4. Resultant probability for "break" or "no break" is stated on graph B-3.

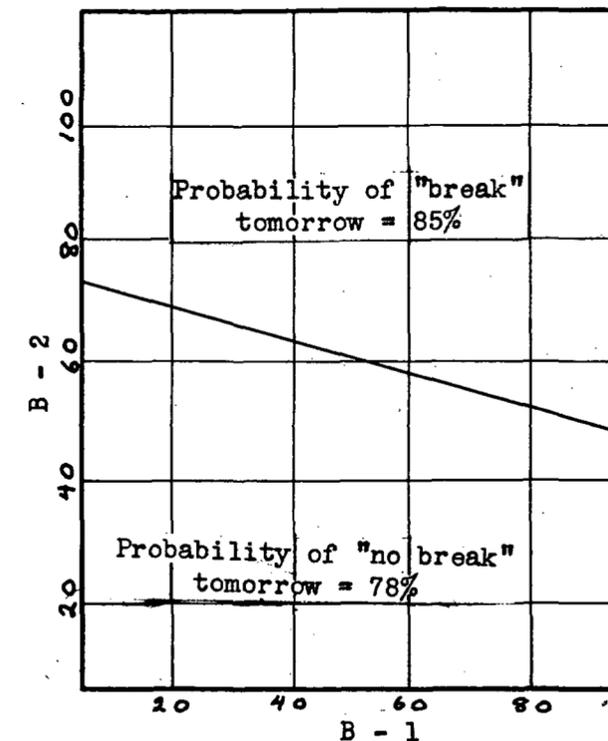
B - 1



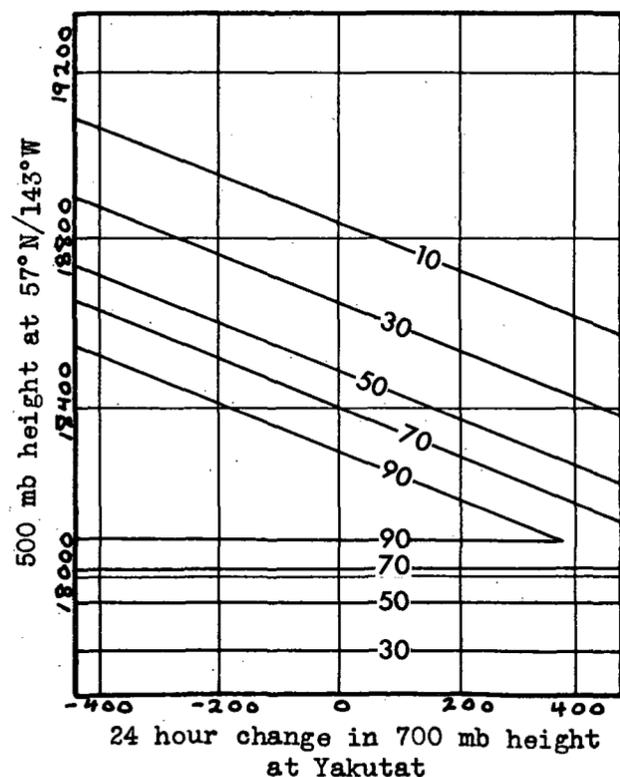
B - 2



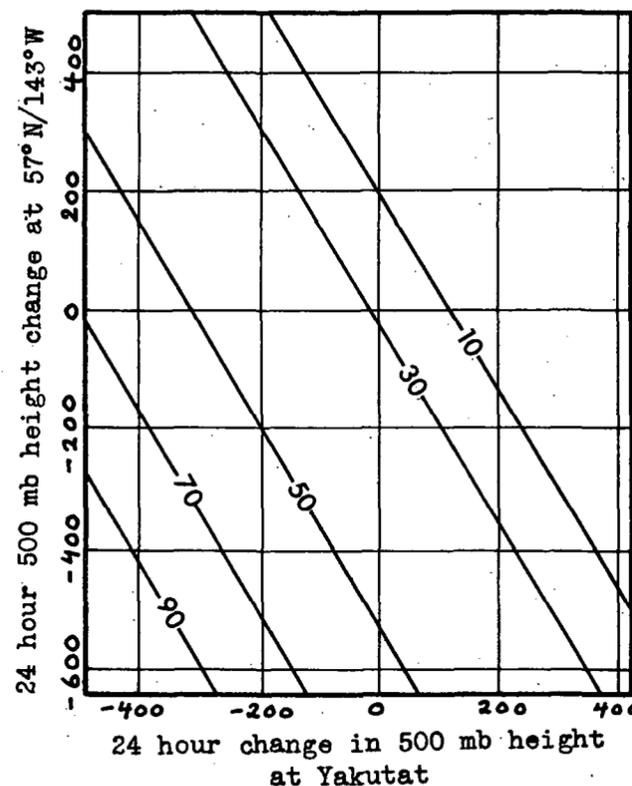
B - 3



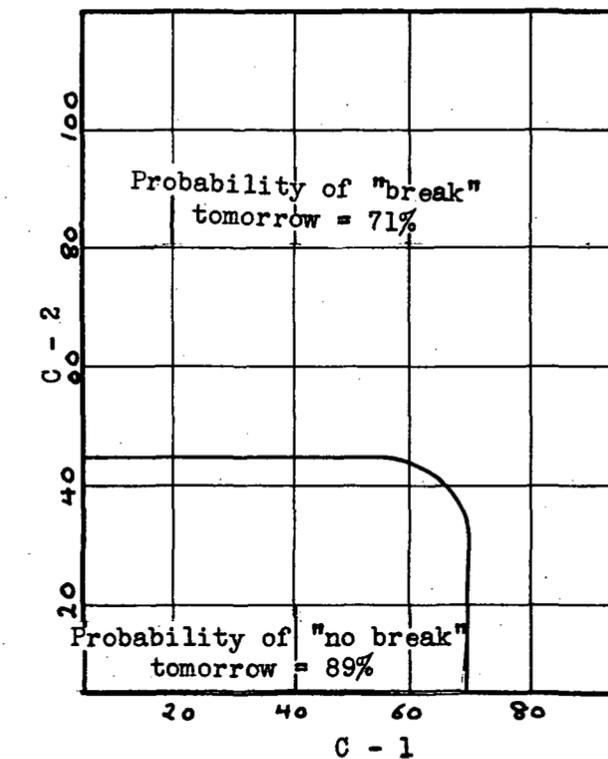
C - 1



C - 2



C - 3



THREE-DAY-PLUS HOT SPELLS

Object

To forecast: "break" or "no break" tomorrow

Prerequisites:

- a) max T for at least the past 2 days > 75°F
- b) max T forecast for today > 75°F

Procedure:

1. Obtain and record parametric values for graphs C-1 and C-2 from 1200Z chart this morning (and yesterday morning where necessary).
2. Obtain corresponding probabilities from C-1 and C-2.
3. Record both on graph C-3.
4. Resultant probability for "break" or "no break" is stated on graph C-3.