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THE UNIVERSITY OF ALBERTA

MAP TYPES AND RELATED WEATHER OVER THE
MACKENZIE VALLEY

by



PETER ROSS SCHOLEFIELD

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

IN

METEOROLOGY

DEPARTMENT OF GEOGRAPHY

EDMONTON, ALBERTA

FALL, 1976

THE UNIVERSITY OF ALBERTA
FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and
recommended to the Faculty of Graduate Studies and Research,
for acceptance, a thesis entitled "Map Types and Related
Weather over the Mackenzie Valley", submitted by Peter Ross
Scholefield in partial fulfilment of the requirements for
the degree of Master of Science in Meteorology.

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Date

12 July 1976

DEDICATION

*This thesis is dedicated to
my loving wife, Heather
son, Scott
and
daughter, Melina*

ABSTRACT

Knowledge of the relationship between synoptic surface weather-map patterns and various weather parameters is fundamental to the production of an aviation forecast. A sound training in atmospheric dynamics, combined with actual forecast experience, enables a forecaster to obtain an understanding of this complex relationship. Statistical information, based on historical data, would be a useful aid to the aviation forecaster in that it would objectively expand his knowledge gained through experience. This thesis examines the relationships between objectively determined surface map types and associated weather. Percent probabilities of occurrence of aviation weather parameters associated with the map types are calculated, and those for ceiling and visibility categories are used as a simple conditional-probability forecast model. The map-type forecasts are tested against pure climatological forecasts using an independent data sample.

A catalogue of surface-map types occurring over the Mackenzie River Valley during the three coldest winter months is developed from 27 years (1946-1972) of MSL grid-point pressure data. The computerized correlation methods developed by the United States Air Force (USAF) at Colorado Springs were used to produce the catalogue. The catalogue comprises a summary of the occurrence and pressure characteristics of map types in addition to a chronological listing of the types assigned to each of the 3814 maps in the data

base. Interesting relationships between map types in the catalogue and climatic anomalies at Yellowstone are presented.

Recent years (1953-1972) of hourly weather data for Yellowstone are used to examine the relationships between map types and aviation weather parameters. Percent probabilities of occurrence of ceiling and visibility categories, precipitation, wind speed and wind direction, associated with map types, are calculated from the first 16 years of hourly data. The conditional probabilities of ceilings and visibilities are used to forecast these same parameter occurrences during the four years 1969-1972. Map-type forecasts were generally better than pure climatological forecasts over this period. Poor forecast reliability, caused by over-stratification of the data, emerged as a major problem when the map types were stratified by pressure gradient. Methods to improve reliability and some suggestions are presented.

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CHAPTER I

INTRODUCTION

1.1 Statistical Weather Prediction by Correlation Methods

With continued advances of computer technology into the field of meteorology there has been increasing interest in the development of statistical weather prediction techniques. Two of the more common approaches to the development of probabilistic forecast aids are through the development of regression equations and through the association of weather with map patterns. A desirable feature of the map pattern approach is that it conforms to the traditional forecasting practice of relating weather parameters to synoptic map patterns. Until recently this approach has been hampered by the subjectivity required in the identification of similar map patterns or types.

The objective correlation technique, developed by Lund (1963) and later modified by the USAF, has been used in several studies to classify and identify weather map types. It entails calculating the simple linear correlation coefficient between the values of a specific meteorological quantity on a weather map and those values at the same location on other weather maps. Maps that are highly correlated with each other are grouped into designated types. Those maps that

do not correlate highly with any of the maps are assigned to an uncorrelated group. This group may also contain some maps that correlate highly with only a few maps which, when taken as a group, are not numerous enough to constitute a type.

Once the maps have been grouped into types, climatic data from within the map-type region are used to study the relationships between weather phenomena and the map types. Most of these correlation studies have involved the relationship between precipitation and map types (Augulus, 1969 and 1970; Hartranft et al., 1970b; Paegle and Kierluf, 1974; Kociuba, 1974; Paegle and Wright, 1975).

1.2 USAF Applications of Map-Type Climatology to the Prediction of Visibilities and Ceilings

The incorporation of objective map-type classification and identification techniques into the statistical prediction of ceilings and visibilities was proposed in the United States Air Force (USAF) publication on map typing by Hartranft et al. (1970a) in Colorado Springs. They suggested the development of seasonal, surface map-type catalogues for six designated areas or "windows" across the continental United States (CONUS). It was believed that stratifying conditional climatology tables (CC) according to the catalogued map types would improve this type of objective forecast aid by incorporating the causative synoptic situation into these purely climatological tables.

CC tables give the climatological probabilities of the ceiling and visibility categories occurring at selected time

intervals after an initial time when the initial categories are given. The standard tables are usually stratified by season and time of day. Restivo (1966) elaborates on the development of these tables which are also referred to as persistence probability tables. CC tables were produced for several of the winter map types in the Great Lakes window using November hourly weather data from Duluth, Minnesota. Results based on the dependent data sample showed that map-type-stratified, conditional climatology (MTCC) tables offered a significant improvement over the standard CC tables.

After two years of continued research of map-typing concepts, refinement and documentation of development techniques at Colorado Springs (Sabin, 1972; Sabin and Nieman, 1972; Scholefield, 1972 and 1973a; Wold, 1973; Sabin, 1974) a map-type forecast system was officially proclaimed by the USAF Air Weather Service in June of 1972 (Scholefield, 1973b). A Map-Typing Project Office was established at Colorado Springs which produced map-type catalogues for fourteen CONUS windows, two in Europe and one for Japan. MTCC tables were produced from these catalogues for several USAF forecast offices. It had been planned to incorporate MTCC into the USAF Global Weather Center's automated terminal forecast model as a climatological check in the forecast procedure. CC tables stratified by wind direction (WSCC) were currently being used for this purpose.

1.3 Verification Results

In 1974, at Colorado Springs, a verification procedure was carried out using two years of independent data to compare the

performance of CC, MTCC and WSCC models in the forecasting of ceiling and visibility categories. Tables were developed from thirteen to sixteen years of dependent data. Contingency tables were constructed for the three forecast models and for a persistence model. Skill scores were calculated for each model against chance and persistence. The overall results showed little difference between the four models. The results of this verification have not yet been published, but they indicate that stratification of the standard CC tables by map types or wind direction do not significantly improve the forecasting ability of the standard tables. This conclusion is contrary to what had been previously indicated by tests involving only dependent data.

Air Weather Service is currently concentrating its statistical prediction efforts on the model output statistics (MOS) approach to the objective forecasting of ceilings and visibilities (Bocchiere et al., 1972 and 1974). Results of the rigorous verification of the MOS models for forecasting ceilings and visibilities have been encouraging. Forecasts from MOS models have been shown to be an improvement over climatology and persistence forecasts. They even verified better than official subjective forecasts beyond the short range period. There are some disadvantages to the MOS approach, including the short period of data available for model development and the fact that the models become obsolete with the introduction of new or improved numerical weather prediction models.

One advantage that the map-type approach has over regression models such as MOS is that the verification results can be stratified by the relevant synoptic weather situation. The map-type forecast can then be shown to give relatively better or worse results under

different synoptic situations. The Colorado Springs verification did not consider this aspect nor was there any attempt made to improve the verification results by further stratification of ceiling and visibility data. Further research and a more detailed verification is required to assess the usefulness of map-type climatology in the development of automated forecast aids.

The Map-Typing Project Office in Colorado Springs is currently in the process of dissolution because of the disappointing verification results and the current USAF involvement with MOS techniques. The possibility exists that the map-type catalogues will not be used for their intended purpose of providing a regional synoptic history of surface pressure patterns which, when related to aviation weather parameters, could be a useful aid to the aviation forecaster.

1.4 Purpose

It is the intent of this thesis to apply the basic map-type techniques developed in Colorado Springs to the development of a surface map-type catalogue for the Mackenzie River Valley for the three coldest winter months. Included in the catalogue are statistics on the frequency of occurrence of map types, sequences of types and a listing of the map types occurring on each day of the 27-year period.

Yellowknife hourly weather observations at map time and at three hours before and after map time are examined to show the relationship between significant weather parameters and the map types near the time of their occurrence. Percent probabilities of occurrence

of the parameters are determined for sixteen years of dependent data. These probabilities are used to predict the occurrence of ceiling and visibility categories and the results are verified using four years of independent data.

Hourly observations at three-hour intervals from six hours before a map-type occurrence to twenty-four hours after its occurrence are used in the verification procedure. In addition to comparing verification results at different hours, a comparison is made between verification results for 00Z, 12Z and combined 00Z and 12Z maps. The final step in the verification procedure is an analysis of the results of forecasts based on map types that have been stratified according to pressure gradients. The purpose of these comparisons is to determine the best way to proceed in the development of an automated objective forecast aid. The improvement of map-type forecasts over pure climatological forecasts is carefully documented in order to assess the usefulness of this objective forecast technique.

CHAPTER II

THE BASIC DATA

2.1 Geographical Area

The difficulty in accurately forecasting weather for aviation terminals in the Mackenzie River Valley was appreciated during a forecasting assignment at the Arctic Weather Centre (AWC) in the summer of 1974. The sparseness of observational data and the formidable mountain ranges west of the valley are factors which challenge a forecaster's ability. A well-tested and readily accessible meteorological synoptic forecast aid could be of considerable benefit to the forecasters at the AWC.

The window used in the map-typing procedure is shown on Figure 1, located in Appendix 1. The window includes the 20° latitude and longitude lines numbered in the figure. Its size conforms with the guidelines established by the Map-Typing Project Office to delineate the map area (Nichols and Sabin, 1972). It is large enough to encompass most synoptic systems but not so large that small synoptic features are ignored in the correlation of the overall pressure pattern. Figure 2 are the location

identifiers of those terminals for which 12-hour Terminal forecasts (FT's) are routinely prepared by the Atmospheric Environment Service (AES). Yellowknife (YZF) has the most extensive and complete set of hourly weather records in the Northwest Territories and for this reason was chosen as the principal site to be used in this study.

2.2 Surface Data

A 26-year data base (1946-1971) of mean sea level (MSL) pressures located at grid points on a standard 381 km grid was acquired from the Map-Typing Project Office in Colorado Springs. The data, arranged by month, are stored on two magnetic tapes. Pressures are available for 306 grid points on an 18 x 17 grid network which encompasses all of Canada including the Arctic Islands and the Beaufort Sea. December, January and February pressure values at the twenty Mackenzie-window grid points were extracted from the two master tapes and stored on one smaller tape. MSL 12Z pressures are available for every year and 00Z values are available for the years 1956-1960 and 1963-1971. There is an exception in the case of December which has 00Z pressure values for the years 1955-1959 and 1962-1971. Consideration was given to incorporating upper-level patterns into the scheme by developing a catalogue of 500-1000 mb thickness patterns. Unfortunately, a comparable set of 500 mb height data was not readily available.

Twenty years (1953-1972) of continuous hourly weather observations for Yellowknife were obtained from the AES. The data are chronologically ordered and stored on magnetic tape in the

standard AES card 1 type format. Data for November 30, all of December, January, February and March 1 were extracted from this tape and stored on a separate tape.

To maximize the use of the twenty years of observations, 1972 grid-point pressure values for the three coldest months were extracted by hand from 00Z and 12Z surface analyses stored at the AWC. These maps were also used to acquire pressure data for missing and incorrect data in the 26-year data base. A date check of the pressure data base had uncovered several errors and duplications which had to be corrected.

2.3 Aviation Weather Parameters

The selection of ceiling and visibility categories was based on a discussion with the Officer-in-Charge of the AWC, and on the classification that is used in hourly data summaries (Climatology Division, 1958). The categories are defined in Table 1.

Table 1

Significant categories of ceilings and visibilities

Category	Ceiling (feet)	Visibility (miles)
A	0 - 400	0 - 3/4
B	500 - 900	1 - 2 1/2
C	1000 - 4500	3 - 5
D	≥ 5000	≥ 6

Categories A and B are below, and C and D are above the standard Visual Flight Rules (VFR) limits of 1000-foot ceiling and three-mile visibility. The 2000-foot ceiling and six-mile visibility limits are used in the international TAFOR code to delineate conditions significant to aviation. The occurrence of any amount of precipitation in excess of a "trace" is considered significant. Ice crystals, blowing and drifting snow are not considered as precipitation in this context. Expected windspeeds less than or equal to 12 miles per hour need not be forecast on an FT, but winds greater than 12 miles per hour are considered significant.

Wind direction is not usually a critical aviation forecast parameter and is not as difficult to forecast as are the other parameters already mentioned. Wind direction is, however, very dependent on the pressure configuration. It was therefore decided to use five simple direction categories to verify the anticipated good relationship between wind direction and the map types. The categories are defined as follows:

N - north northwest to northeast

E - east northeast to southeast

S - south southeast to southwest

W - west southwest to northwest

0 - calm

It has been previously mentioned that the hourly data were stratified according to pressure gradient. Increased stratification is desirable in order to define more accurately the conditions associated with the significant weather parameters. Too much strat-

ification will reduce the number of cases available for calculating the probabilities of occurrence to such an extent that the resulting statistics would not be reliable. Having only four categories of ceiling and visibility, instead of five or six, will help alleviate this problem. The available data are further maximized by considering a three-month cold season instead of individual months.

2.4 The Cold Season

Winter is the longest season of the year in the Mackenzie Valley and the winter months have greater percentages of poor aviation weather than summer months. Ten years (1957-1966) of Yellowknife hourly data summaries (Climatology Division, 1968) of temperature, precipitation, visibility and ceiling categories were examined. It was determined that a relatively uniform cold season exists for the three months of December, January and February.

Figure 1 shows the monthly frequency of occurrence of weather below VFR ~~conditions~~. The predominance of "bad" weather during the winter is the principal reason why a three-month cold season is used in the study. The reduced number of bad-weather cases during the warmer months could create statistical reliability problems for highly stratified data.

The figure does show significant differences in the monthly frequencies of bad weather in the winter. The frequencies are greater than 20 percent in the earlier part of the winter and drop to less than six percent in late winter. Much of this bad weather in October and November is probably due to the influence of Great Slave Lake

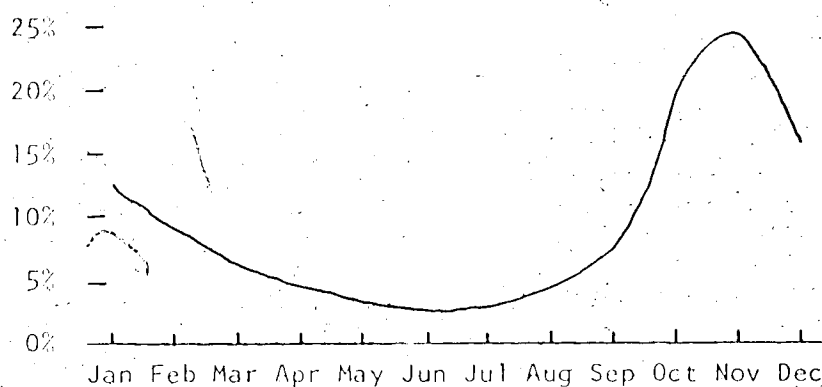


Figure 1. Average percent frequency of weather below VFR (ceiling 0-900 feet and/or visibility 0-2½ miles) based on ten years (1957-1966) of hourly observations at Yellowknife.

which does not freeze over until December (Allen and Cudbird, 1971).

The three coldest months are therefore desirable for this study because relationships between map types and bad weather during this cold period are not so likely to be complicated by lake effects.

CHAPTER III

THE SURFACE MAP TYPES

3.1 Developing the Basic Types

The surface map types for the Mackenzie window were developed using the techniques of the Map-Typing Project Office in Colorado Springs. In particular, the batch technique of Sabin and Nieman (1972) and the computer programs of Wold (1973) were used to derive the Mackenzie catalogue. These methods, used extensively in the generation of the CONUS and Alberta map-type catalogues, are described in detail by Kociuba (1974) in Chapter III of his M.Sc. thesis.

One month's surface pressure data for the twenty grid points in the Mackenzie window were used to correlate all 12Z maps from 1954-1971 with each other. The formula for the product-moment linear correlation coefficient (r) for n pairs of values is:

$$r_{xy} = \frac{\sum_{i=1}^n \{X_i - \bar{X}\} \{Y_i - \bar{Y}\}}{\left\{ \sum_{i=1}^n [X_i - \bar{X}]^2 \sum_{i=1}^n [Y_i - \bar{Y}]^2 \right\}^{\frac{1}{2}}} \quad (1)$$

The map that correlated with the largest number of maps in the 18-year sample at or above $r = 0.8$ was chosen as the key map for the first map type. That map and all others correlated with it were then removed from the sample. Of the remaining maps, the map which had the largest number of maps correlating with it became the key map for the second map type. This procedure of selection and removal was repeated until the number of maps assigned to a type became less than six. All the maps in the monthly sample were then reassigned to those particular types with which they correlated most highly at or above the threshold value of $r = 0.8$. Any map type having fewer than two percent of the total maps was eliminated as a map type. Those maps which did not correlate with any type at or above $r = 0.8$ were assigned to an uncorrelated group.

This process was repeated for each of the three coldest months. Table 2 shows the derived map types for each month, the number of maps assigned to each type initially, and the number after the reassignment procedure. The map types are listed in the order in which they were initially developed. This results in a decrease in the number of maps correlated with each type because maps correlated with a given type were eliminated from the sample as the procedure progressed.

Sabin (1974) justifies the use of the threshold value $r = 0.8$ by showing that it is a good compromise value. It results in a good overall description of pressure regimes, produces an acceptable number of uncorrelated maps, and gives an adequate description of the climatology within each type.

Table 2.

Key dates of monthly and seasonal¹ map types with the number of maps before/after reassignment in the development sample (122 maps, 1954-1971).

DECEMBER			JANUARY		FEBRUARY	
Number of Types	Map Type Date	Number in each Type	Map Type Date	Number in each Type	Map Type Date	Number in each Type
1	<u>621213</u>	62/38	<u>570122</u>	90/62	<u>650207</u>	57/44
2	<u>621227</u>	53/38	<u>690139</u>	50/34	<u>640217</u>	49/37
3	<u>591222</u>	46/35	<u>560101</u>	42/35	<u>550225</u>	41/35
4	<u>621216</u>	32/30	<u>570124</u>	38/30	<u>640222</u>	30/32
5	<u>561211</u>	31/17	<u>610108</u>	30/32	<u>600202</u>	25/31
6	<u>681221</u>	23/26	<u>550111</u>	28/26	<u>600223</u>	19/20
7	<u>681223</u>	18/20	<u>650126</u>	19/26	<u>540211</u>	17/17
8	<u>561219</u>	16/14	<u>590128</u>	15/26	<u>690207</u>	16/20
9	<u>601203</u>	13/17	<u>540101</u>	14/15	<u>590206</u>	12/13
10	<u>621224</u>	11/11	<u>590131</u>	11/21	<u>610217</u>	11/11
11	<u>571230</u>	11/23	<u>710108</u>	10/16	<u>600210</u>	10/11
12	<u>661205</u>	10/11	<u>680105</u>	10/11	<u>560210</u>	10/11
13	<u>551209</u>	10/14	<u>550115</u>	10/11	<u>650211</u>	9/10
14	<u>671204</u>	8/12	<u>540102</u>	9/11	<u>580213</u>	9/10
15	<u>631221</u>	8/20	<u>610131</u>	8/19	<u>680207</u>	8/9
16	<u>621222</u>	8/20	<u>640120</u>	7/10	<u>570210</u>	8/9
17	<u>611219</u>	8/11	<u>600103</u>	6/9	<u>680219</u>	6/6
18	<u>601219</u>	7/7	<u>560117</u>	6/7	<u>630216</u>	6/16
19	<u>701203</u>	6/7	<u>550124</u>	6/8	<u>600216</u>	6/7
20	<u>591227</u>	6/8	<u>550113</u>	6/6		
21	<u>551215</u>	6/13				
22	<u>541227</u>	6/7				
Uncorrelated		158			143	159
Total Maps		557			558	508

¹The final seasonal map types are underlined.

As would be expected, the reassignment procedure reduced the number of maps assigned to the more numerous types and increased the number assigned to most of the less numerous types. There was little change in the order of predominance of the more numerous types, but there were substantial changes in the order of those types which were initially not very frequent. For example, Map Type 18 in February became the ninth most frequent type after reassignment, and Types 15 and 16 in December moved up to seventh in the order of frequency.

To obtain the cold-season types, all 61 monthly map types were correlated with each other using the correlation coefficient threshold of $r = 0.8$. The correlation procedure was the same as that used previously, except that there was no reassignment step, and those maps not eliminated in the initial assignment were designated as final seasonal map types. This procedure resulted in 24 cold-season map types, and the respective key dates for these types are outlined in Table 2. The key date of each map type and the corresponding grid-point pressure values are listed in Appendix 1.

3.2 Assigning Maps to Map Types

After the surface pressure data had been corrected and the data base expanded to include 1972 data, each of the 3814 00Z and 12Z maps were correlated with the 24 map types. The maps were assigned to the map type with which they correlated most highly at or above $r = 0.8$. If the maximum correlation coefficient between a given map and all of the types was less than the threshold value, then the map was

assigned to a group of maps designated as uncorrelated Map Type U. The common feature of these maps is their non-conformity with any of the 24 map types. For this reason they are treated as a distinct group of their own so that Map Type U becomes the 25th "map type".

Of all the maps assigned, 34 percent had a maximum correlation coefficient less than $r = 0.8$. This is a relatively high proportion of Map Type U, compared to the 20-30 percent of uncorrelated maps in the catalogues developed by the Map-Typing Project Office in Colorado Springs. The proportion of uncorrelated maps can easily be reduced by lowering the threshold correlation coefficient used in the assignment procedure. The use of threshold values of $r = 0.75$ and $r = 0.70$ resulted in the reduction of uncorrelated maps to 21 and 13 percent, respectively.

Lowering the threshold value of r reduces the average correlation coefficient of all maps assigned to a particular type, thereby "diluting" the distinctiveness of each set of map types. This will only be a problem in this study if the distinctiveness of the weather associated with each set of map types is also blurred. Verification tests were performed on the probability forecast model to assess the effects of using map-type data assigned at the threshold levels of $r = 0.75$ and $r = 0.70$. The uncorrelated maps were included as predictors during these tests. The verification results of these ceiling and visibility forecasts will be examined in Chapter VI.

No attempt was made to test the model using map types assigned at thresholds higher than $r = 0.8$ because of the undesirability of increasing the proportion of uncorrelated maps. Any such

increase would be at the expense of the maps assigned to the 24 correlated types. This reduction in numbers would result in a decrease in the reliability of the probability statistics derived from the 24 map-type predictors.

Increasing the data base by combining monthly data into a relatively uniform season was the most obvious way to increase the reliability of the probability statistics. Another way to increase the number of hourly observations associated with a given map type was to consider an additional type when a map is correlated above $r = 0.80$ with two maps and the difference between the correlation coefficients is small. In such cases the hourly data are associated with both types. It was arbitrarily decided by the Map-Typing Project Office to follow this procedure when the second-highest correlation coefficient was within 0.05 of the highest correlation coefficient. This procedure was followed in this study. The effects of using map-type predictors based on this artificially expanded data base are assessed in Chapter VI.

The complete results of the map-type assignment procedure are listed in Appendix 2. The dates of each map are listed in chronological order, followed on the same line by the highest correlation coefficient and associated map type resulting from the correlation between the map and the 24 map types. An "S", "M" or "W" attached to the map type designator classifies the average pressure gradient of the map as being strong, medium or weak, respectively. Listed next, and on the same line, is the second-highest correlation coefficient. It is followed by the associated map type if $r \geq 0.8$. When the second map type is listed and the difference between the

highest and second highest correlation coefficient is less than or equal to 0.05, the second map type is marked with an asterisk (*).

If the map is of Type U, a group of asterisks takes the place of the second highest correlation coefficient, followed by the map type with which Type U correlates most highly. This pertinent feature regarding uncorrelated maps was unfortunately omitted from the map-type catalogues developed by the Map-Typing Project Office.

CHAPTER IV

MAP-TYPE CHARACTERISTICS

4.1 Map-Type Occurrence Statistics

The individual occurrence statistics for each map type, including the uncorrelated maps, are given in Appendix 3. At the top of each page is an actual, dated surface weather map showing the isobaric configuration of the key map. All of the maps in each type correlate most highly with the key map, and the correlation coefficient is greater than or equal to $r = 0.8$. Beneath the key map are the characteristics of the map type, stratified by season and by month. The seasonal statistics were derived from 3700 maps of synoptic patterns observed in 26 cold seasons, from the winter of 1946-47 to the winter of 1971-72. The monthly statistics for January and February 1946, and for December 1972 are not included in the seasonal characteristics, but are included in the monthly characteristics. The correlated map types in Appendix 3 are numbered and listed in the order of their frequency of occurrence during the cold season. The uncorrelated maps of Map-Type U have their characteristics listed on the last page of the appendix. The predominance of un-

correlated maps is consistent through each month of the cold season, with the highest percentage (36 percent) occurring during December. The frequencies of occurrence of the predominant correlated types will now be discussed.

Map Type 1 is the predominant type throughout the cold season, with a frequency maximum of 13 percent in January. This compares with seven percent in December and eight percent in February. Since January is the coldest winter month, it is not surprising that the most frequent map type is one which features a cold Arctic high-pressure ridge paralleling the Mackenzie River Valley from the Beaufort Sea into northeastern Alberta.

A low-pressure system located in the Gulf of Alaska is a very common synoptic situation during the winter months. When this low is well developed and located in the northeastern part of the Gulf, the Mackenzie Valley Arctic ridge is often forced eastward into the District of Keewatin. This synoptic development results in a southeasterly pressure gradient over the Mackenzie Valley, the Yukon and eastern Alaska. Map Type 2 has this isobaric configuration. It occurs consistently about seven percent of the time throughout the cold season. In December and February it slightly exceeds the frequency of Map Type 1.

Map Types 3 and 4 have nearly identical frequencies of occurrence throughout the cold season, and follow a monthly occurrence pattern similar to Map Type 1. They both have frequencies of five and three percent, respectively, in December and February, and maximum monthly occurrences of eight percent in January. Both map patterns are dominated by Arctic high-pressure centers, which may account for

their relatively high occurrence frequency in January. The high pressure area in Type 3 is centered just southwest of Norman Wells while Type 4 has a high centered over the Yukon, just north of Whitehorse.

Map Type 5 has a trough of low pressure extending along the Arctic coast from a low-pressure system over Alaska. This configuration produces a southwesterly flow over most of the window, with a resultant influx of mild air south of the trough. As would be expected, this type is predominant in December, the mildest of the three cold months.

The five most frequent types account for nearly one-third of all the occurrences in the 26 winters. Despite the fact that the three months are well within the winter season, there are changes in the map pattern occurrences that are climatically consistent with the advance of the season.

4.2 Annual Variability in Map-Type Occurrences

Map types show considerable variation in frequency of occurrence from year to year, as can be seen by examining Table 3, which shows the maximum annual anomalies of seasonal and monthly occurrences for all types. The absolute differences between the percent frequency for a given year, and the averages over all 27 years, were compared for each map type. Those types with the greatest absolute differences are listed in Table 3. This method of determining anomalies was chosen because it highlights the characteristics of the more frequently occurring types. Occasionally, though, a type

Table 3

Maximum annual anomalies of seasonal and monthly occurrences¹

Year	Season	December	January	February
1946			6-16.1 (3.7)	6-17.8 (5.8)
46-47	10- 6.6 (2.3)	1-16.1 (7.1)	16- 9.7 (2.0)	10-10.7 (3.1)
47-48	U-40.0 (34.1)	2-29.0 (7.3)	U-54.8 (31.8)	4-20.7 (2.9)
48-49	U-45.0 (34.1)	U-48.4 (35.6)	5-16.1 (4.2)	3-10.7 (3.2)
49-50	1-20.0 (9.3)	3-19.4 (4.7)	4-29.0 (7.5)	11-10.7 (1.9)
50-51	U-42.5 (34.1)	18- 9.7 (1.4)	6- 9.7 (3.7)	10.7 (3.2)
51-52	7-11.4 (1.2)	4-19.4 (5.2)	7-22.5 (4.3)	7 (5.8)
52-53	18-11.3 (1.4)	2-12.9 (7.3)	1-25.8 (12.8)	(1.8)
53-54	1-15.0 (9.3)	6-22.6 (5.2)	1-22.6 (12.8)	(7.7)
54-55	7-12.5 (4.2)	13-12.9 (1.6)	2-16.1 (5.5)	(1.6)
55-56	4-12.6 (5.1)	U-41.9 (35.6)	4-17.7 (7.5)	U- (1.8)
56-57	U-26.4 (34.1)	3-13.1 (4.7)	3-23.0 (7.8)	1-2 ()
57-58	2-13.3 (6.8)	6-19.4 (5.2)	2-17.7 (5.6)	7-16. ()
58-59	1-23.3 (9.3)	1-19.4 (7.1)	1-37.1 (12.8)	U-46.4 ()
59-60	1- 3.8 (9.3)	5-14.5 (6.3)	1- 6.5 (12.8)	6-15.5 (5.2)
60-61	8-10.0 (2.7)	20- 9.7 (0.8)	6-22.6 (3.7)	9-14.3 (3.2)
61-62	2-11.3 (6.8)	17- 9.7 (1.1)	7- 0.0 (4.3)	U-21.4 (34.8)
62-63	U-29.4 (34.1)	U-25.8 (35.6)	20- 7.9 (0.8)	10-12.5 (3.1)
63-64	U-40.7 (34.1)	8-16.1 (3.2)	U-41.9 (31.8)	7-13.8 (5.8)
64-65	3-12.7 (5.3)	U-48.4 (35.6)	U-22.6 (31.8)	3- 7.1 (3.2)
65-66	U-41.6 (34.1)	5-11.3 (6.3)	U-45.2 (31.8)	11- 7.1 (1.9)
66-67	1- 3.3 (9.3)	11-16.1 (3.2)	4-16.1 (7.5)	1- 1.8 (7.7)
67-68	U-41.2 (34.1)	15-11.3 (2.0)	U-55.8 (31.8)	7-10.3 (5.8)
68-69	5- 9.3 (5.1)	23- 8.1 (0.5)	3-16.1 (7.8)	2-21.4 (7.8)
69-70	2-11.1 (6.8)	8- 9.7 (3.2)	1-25.8 (12.8)	U-44.6 (34.8)
70-71	1-13.8 (9.3)	1- 1.6 (7.1)	1-27.4 (12.8)	6-14.3 (5.8)
71-72	4-13.2 (5.1)	2- 1.6 (7.3)	4-19.4 (7.5)	1-19.4 (7.5)
1972		4-19.4 (5.2)		

¹The format under each time period is as follows:

Map Type - Percent Frequency (Average Percent Frequency over all years).

Negative occurrence anomalies are underlined.

that has a low frequency will appear as the maximum anomaly. Map Type 18, for example, occurred with a frequency of 11.3 percent in the 1952-53 cold season, which is about eight times higher than its average frequency of 1.4 percent.

The two most frequent patterns, Type U and Type 1, are also the dominant anomalies: they both occurred 13 times as monthly anomalies. Moreover, on a seasonal basis, Type U appears as an anomaly eight times, and Type 1 six times. These two types predominate to an even greater extent those maximum anomalies that arise due to a frequency that is much lower than average. These negative-occurrence anomalies are underlined in Table 3.

The highest frequency anomaly appeared in January, 1968, when Type U occurred some 56 percent of the time. Of the correlated maps, Type 1 had the highest anomaly when it occurred with a frequency of some 37 percent in January, 1959. This was almost three times its average value of 13 percent and the difference from the average was the largest of any map type including Type U. Types 1 and U also had the highest seasonal anomalies for correlated and uncorrelated types; 23 percent in 1958-59 and 45 percent in 1948-49, respectively.

Map Type 23 had the maximum anomaly - the greatest increase relative to its average frequency - with an eight percent occurrence in December, 1968. This is 16 times higher than its monthly average of 0.5 percent. The most anomalous season was 1958-59 with summed absolute differences for the season and the individual months equalling 62.2 percent. In the least anomalous season, 1946-47, the sum of the differences equalled 28.6 percent.

The season with the greatest variety of map types was 1965-66, when all types except Type 24 occurred at least once. This season also had a very high frequency of uncorrelated maps (42 percent). This suggests that the 1965-66 season was characterized by frequent changes in the pressure patterns with a minimum of map-type persistence. Clearly the persistence of map types affects the variability of their occurrence frequencies; this relationship is examined in the next section.

4.3 Map-Type Persistence

The degree of persistence of individual map types can be determined by examining the *most frequent duration* characteristic, a quantity listed in Appendix 3. The term *persistence* is used to denote two or more consecutive occurrences of a map type which has been assigned at 12-hourly intervals, using a threshold correlation coefficient of $r = 0.8$. The persistence information is based only on 15 to 16 years of data when both 00Z and 12Z data were available. It should be noted that the frequency of consecutive occurrences is the percent frequency of groups (1, 2, 3 ... etc.) of occurrences, not the percentage of maps that fall within a group. This form conveniently gives the percent probability of consecutive occurrences after a given initial occurrence. This is useful prognostic information.

Over the entire season, Map Type 1 is the most persistent configuration, appearing as a group of two or more consecutive occurrences 53 percent of the time. Map Types 4, U, 2, 3, 5 and 6

are the next six most persistent types. It is no coincidence that these most persistent types are also among the most frequently occurring types. The good relationship between frequency and persistence is further substantiated by the fact that Map Types I and U share the longest run of 11 consecutive occurrences. However, this relationship is not exact and, in the case of less frequently occurring types, the correspondence is poor. Map Type 11, for example, is the 19th most persistent type, and Map Type 22 is the 15th most persistent type.

The persistence of all map types combined can best be examined by considering the percentage of maps that fall into a group of two or more consecutive occurrences. For those years when 00Z and 12Z data were available, some 65 percent of the maps appear in sequences of two or more consecutive map-type occurrences. The random probability of two consecutive occurrences is 14.6 percent compared with the actual frequency of 27.2 percent. Synoptic map patterns are, therefore, persistent features over the Mackenzie Valley during the coldest winter months.

Each of the seven most persistent types appears at least three times as a maximum anomaly, as shown in Table 3. Despite this good correspondence, not all occurrence anomalies are associated with a persistent map type. Thus, Type 18 is the least persistent, appearing as a single occurrence 90 percent of the time. In February, 1953, it occurred four times, all non-consecutively; this is the maximum anomaly for February. The non-persistency of Type 18, and its relationship to map-type sequences is discussed in the next section.

4.4 Sequences of Map Types

In Appendix 3, the types most frequently following each of a given map type are listed in order of their frequency of following occurrence. To glean information on a sequence of more than two 12-hourly occurrences, the following-type information on a particular, most frequently following type should be consulted.

Two features of the following-type data are prominent and generally consistent with previous remarks. Map Type U is the most frequently following type for 13 of the 25 seasonal map types. This appears reasonable in view of the very high frequency of occurrence of uncorrelated maps. Ten of the twelve remaining map types follow themselves most frequently. Included in these 10 types are the seven most persistent types mentioned in the previous section. This is entirely consistent with the conclusion that the surface map patterns are very persistent during the cold season.

A different explanation is required to account for the uncorrelated maps being relatively more predominant as a following type, than as an occurring type. In the light of the findings of the preceding paragraph, it can be concluded that only two map types evolve frequently into another correlated map type. Ninety-two percent of the types most frequently persist or are followed by an uncorrelated map. This general pattern of synoptic evolution is in agreement with Burns' (1970) climatic study of the Mackenzie Valley. He found that the cold dome of Arctic air that prevails over the valley during winter forms a block to the migrating frontal lows. This blocking action would seem to account for the high persistence of map types,

and the limited degree of map-type evolution.

The highest frequency of following occurrence is 60 percent when Type 0 follows Type 23. This map type follows itself 27 percent of the time and, therefore, only evolves into another correlated type 13 percent of the time. This behavior is not unexpected because the key map shows no closed pressure center, but only a broad trough extending north over Great Slave Lake, and northwest to the Mackenzie delta. This configuration also has one of the lowest average pressure gradients of all the correlated types.

The second-highest frequency of following occurrence (52 percent) is ascribed to Map Type 2, following Type 18. From the key map, this sequence shows a low-pressure center moving southeastward out of northeastern Alberta. A high-pressure center over Banks Island moves southward while an associated ridge builds in behind a migrating low. It is significant and appropriate that Type 18, the least persistent of all, also appears in the most frequent map-type sequence.

4.5 Mean Pressure Characteristics of Map Types

One of the most significant aspects of the correlation method of selecting map types is that the maps assigned to a type are only similar in respect to their isobaric configurations and direction of flow patterns. Scholefield (1973) showed that the correlation coefficient between two maps of identical configuration does not change when one of the maps is altered with respect to its pressure gradient or its overall pressure magnitude. This characteristic will

become evident during the analysis of gradients and mean pressures.

During the map-type assignment procedure, the average of the 101 pressure values at the 20 grid points was calculated for each map. After 115 maps were assigned, the mean values for each map within a type were averaged. These mean map-type pressures, minus 1000 mb, are listed with the map-type characteristics in Appendix 3.

Map Types 20, 23 and 24 have the highest mean pressure, all being very close to 1026 mb. A quick glance at the key maps shows Map Types 20 and 24 to be dominated by high-pressure centers and ridges. The reason for the high mean pressure is not obvious in the Type 23 key map, where a low pressure trough appears to be the major feature. Type 23 is a good example of how much the magnitude and gradient of isobars within the member of a type can vary. The key map has the lowest mean pressure (1010.4 mb) of all the maps of Type 23. Its pressure gradient of 3.06 mb/grid interval is also well below the type average of 4.04. These values are in sharp contrast to the monthly mean average pressure of 1032.8 mb and mean pressure gradient of 4.29 mb/grid interval of the six Type 23 maps of December. The key map does show a weak high-pressure ridge extending from the Yukon into the southern Mackenzie Valley. The intensity of this ridge must be very marked in the December maps.

Map Types 3, 1 and 4 have previously been mentioned as types that are dominated by Arctic high-pressure systems. These types along with Map Type 8 are in the next-highest group of mean pressures in the range 1024-1025 mb. They all have monthly maximum pressures in January, a consequence of the intensity of the Arctic high pressure

systems in this cold month. This expected relationship is not obvious in the group with the highest mean pressures, but their low frequencies of occurrence make the monthly statistics unreliable.

Map Type 12 has the lowest mean pressure of 1011.7 mb. The range in average pressures of maps of this type is greater than for Type 23. Thus the Type 12 map of January 22, 1960 has an average pressure of 1033 mb, while the map of January 1, 1948 has an average pressure of only 990.1 mb.

4.6 Pressure Gradients of Map Types

Over relatively uniform topography, the strength of the low-level winds is proportional to the surface pressure gradient. The gradient is also a good indicator of the intensity of nearby pressure systems. Both wind speed and pressure-system intensity are important weather elements, but the correlation procedure does not resolve such features. This is the principal weakness of this map-typing technique. To alleviate this problem it was decided to investigate the pressure gradient characteristics of map types subjectively by attempting to subdivide the maps assigned to each type according to their pressure gradients.

The absolute value of the pressure gradient can be easily calculated from grid-point pressure values using the following five-point grid formula:

$$\text{Gradient } (X_5) = 0.5 [(X_1 - X_3)^2 + (X_2 - X_4)^2]^{1/2} \text{ mb/gi}$$

where X_1, X_3 and X_2, X_4 refer to adjacent pairs of grid points

surrounding grid point X_{ij} .

The gradient about a grid point may vary considerably from point to point throughout the window. A specific gradient value was assigned to a map by averaging the absolute values of the gradients at all eight interior grid points. As part of the assignment process, the standard deviations of the grid-point pressures and the differences between maximum and minimum values were also calculated as indicators of gradient. The mean of the absolute gradient about the eight interior grid points was chosen to define map pressure-gradients because it was more comprehensive than the other indicators. The values are expressed in logical gradient units of mb/grid interval (gi) and the values may be evaluated at any one of the eight locations within the window.

It was arbitrarily decided to subdivide the map type into three classes based on the standard deviation (s.d.) of the mean gradients of all maps within a type. The mean gradients that are within one s.d. of the total map-type mean are classified as "medium". The gradients that are more than one standard deviation below the mean are classified as "weak" and those more than one s.d. above the mean "strong". The critical value of the standard deviation for each map type is listed in Appendix 1 along with the grid-point pressures for the key maps.

Appendix 3 contains the mean gradient characteristics of each type in units of mb/gi. The mean maximum and minimum gradients were calculated by taking the average of the highest and lowest values, respectively, that occurred at the eight central grid points on each map.

A singular feature of the mean gradient statistics is the generally weak gradients associated with uncorrelated maps. The mean pressure gradient of Type U maps is only 4.04 mb/gi which is the lowest. Map Type 23 also has a low value of 4.04 mb/gi, but this statistic is questionable because there were only 17 occurrences of this type. The mean minimum and maximum gradients of 1.57 and 7.03 mg/gi for Map Type U are also very low. The lowest mean gradient for any map is found on the 12Z uncorrelated map of January 17, 1961 with a value of only 0.65 mb/gi. The weak gradient characteristic of uncorrelated maps is a good reason for grouping them into a separate Map Type U.

The similarity in characteristics of Types 3 and 4 shows up also in their maximum mean gradients of 6.61 and 6.07 mb/gi, respectively. They also have the highest mean maximum gradients. The Type 4 map of 00Z, January 16, 1957 has the highest individual mean-map gradient of 15.03 mb/gi. The highest gradient present at one grid point was 22.64 mb/gi on the Type 1 map of January 15, 1957. Individual grid-point gradients of 0.0 mb/gi are also found on occasion.

The differences in gradients between map types are apparent, but they are small compared to some of the differences between the gradients within the same type. The difference between mean gradients of the relatively strong gradient Type 3 and weak gradient Type U is only 2.57 mb/gi. There are a couple of individual maps of Type 3 with gradients less than 3.0 mb/gi and several uncorrelated maps with mean gradients in excess of 10 mb/gi. These large in-type gradient differences illustrate the inability of the correlation technique to

discriminate between gradients. For this reason the map types will be stratified by gradients when testing a simple probability model relating ceilings and visibilities to map types.

CHAPTER V

RELATING YELLOWKNIFE WEATHER TO MAP TYPES

5.1 Climatic Averages and Anomalies

The characteristic climatic feature of the Yellowknife winter is the cold weather which, as noted in Chapter IV, is related to Arctic high-pressure systems. In the climatic data there is good evidence of a quantitative relationship between low temperature regimes and the occurrence of certain map types. In 1949-50, the coldest of the 26 seasons, the mean daily temperature was -23°F . As shown in Table 3, Type 1 has the maximum seasonal anomaly, while Types 3 and 4 have maximum monthly anomalies of occurrence during this coldest season. Types 1, 3 and 4 also appear as anomalies in the next four coldest seasons, in 1946-47, 1948-49, 1951-52 and 1955-56.

It is interesting that the five coldest winters occurred in the earlier part of the 26-year data period. The five-year moving averages, calculated for the entire period, show a pronounced warming trend through the 1950's. There was no obvious corresponding trend in map-type occurrences. However, the negative-occurrence anomaly of Type 1 in the 1959-60 season is significant, because it was the

warmest season, with a mean temperature of -0.9°F .

The moving averages showed no well-defined temperature trend through the 1960's, but a cooling trend developed during the last three winters of the decade. The winter of 1971-72 was one of the coldest since 1955-56, with the mean temperature dropping to -12.8°F . Associated with this cold season were maximum occurrence anomalies of Types 1 and 4.

The maximum precipitation recorded at Yellowknife during any season was 3.15 inches in 1960-61, with one-half falling in January, 1961. Referring again to Table 3, it is seen that Type 6 was the maximum occurrence anomaly during this snowy month, present some 23 percent of the time. The key map for Type 6 shows a low pressure system in northwestern Saskatchewan with an easterly circulation over Great Slave Lake, a favorable synoptic situation for precipitation.

Precipitation was recorded on 51 days of the 1957-58 season, the highest number of precipitation days in any of the seasons. A total of 2.82 inches of precipitation fell during this period, the second highest seasonal amount. Type 6 again appears in Table 3 as a maximum occurrence anomaly of 19 percent in December, when 1.27 inches of precipitation fell. Type 2 is the maximum anomaly for the month of January and the entire season. The key map for Type 2 shows the Arctic high east of Great Slave Lake, with a southeasterly flow over most of the window. A well-developed Gulf-of-Alaska low is the dominant feature outside the window. This synoptic situation favors the advection of moist, relatively mild Pacific air into the Mackenzie Valley, overrunning the dome of cold Arctic air and producing cloud

and precipitation.

Based on average conditions these pronounced anomalies indicate a fairly direct relationship between some of the map types and the weather at Yellowknife. To investigate this relationship in more depth, the hourly weather observations pertinent to each map type were examined in detail. The results of this study follow in the next section.

5.2 Relating Yellowknife Hourly Weather to Map Types

The Yellowknife hourly weather observations from January, 1953 to December, 1968 were analyzed as follows: the occurrences of weather parameters at three hours prior to map time, at map time and at three hours after map time were summed. This gives a six-hour associated weather period, centered around the time of a map-occurrence. There is also no overlap in the observations associated with types assigned at 12-hourly intervals. These 16 seasons of hourly data form the dependent data sample from which a conditional probability forecast model was developed. The three-hour interval between observations corresponds to that used in the forecast model.

The calculated statistics were based on the total number of weather-parameter occurrences associated with each type. Each category of ceiling, visibility and wind direction is treated as a separate parameter. For each type, the frequency of a weather parameter was calculated relative to the same parameter occurrence associated with other types. These relative frequencies are very strongly dependent on the number of type occurrences. The frequency of parameter occurrence relative to the map type occurrence gives a

much better indication of the association between weather and map types. This frequency was calculated by dividing the number of hourly observations of a parameter by the total number of hours associated with the corresponding map type. Such a frequency can be interpreted as the conditional probability of the parameter occurring, given a map-type occurrence.

Table 4 lists the four best associations for 11 weather parameters. In the center of the table are the parameter descriptions, including the total number of parameter occurrences and climatic frequency over the 16-year period. Listed to the right are the number of hourly parameter occurrences, the frequencies relative to the parameter and those relative to the associated map type. The statistics describing each associated map type are listed on the left side of the Table. The statistics on each parameter are listed in the order of the degree of association with the related type, as measured by the frequency relative to the type.

5.3 Ceilings, Visibilities and Precipitation

Ceilings and visibilities below VFR limits, and precipitation are the most significant aviation weather parameters; they are also most difficult to forecast. Frequently these three "poor-weather" elements occur simultaneously with certain synoptic situations. Map Type 6 provides a good example: it shows a relatively high degree of association with all three elements. Indications of this "poor-weather" association with Type 6 appeared previously in section 5.1 during the analysis of climatic anomalies.

Table 4

Significant weather parameter - map-type associations,
based on Yellowknife hourly weather observations at
all map times and at three hours before and after,
during 16 years, 1953-1968.

Map Type	Num	Freq ¹	Weather Parameter	Num	Wea. Freq ¹	Type Freq ¹
14	48	1.9	Low Ceilings	24	4.9	16.7
6	105	4.3	(<1000 ft)	45	9.2	14.3
11	51	2.1	Total Num = 488	17	3.5	11.1
5	130	5.3	Clim Freq = 6.6%	43	8.8	11.0
6	105	4.3	Low Visibilities	48	9.7	15.2
12	48	1.9	(<3 miles)	21	4.2	14.6
17	48	1.9	Total Num = 495	17	3.4	11.8
11	51	2.1	Clim Freq = 6.7%	17	3.4	11.1
19	33	1.3	Precipitation	65	2.4	65.7
6	105	4.3		193	7.2	61.3
15	46	1.9	Total Num = 2680	82	3.1	59.4
13	49	2.0	Clim Freq = 36.2%	84	3.1	57.1
24	8	0.3	High Ceilings	24	0.4	100.0
23	12	0.5	(≥ 5000 ft)	35	0.6	97.2
16	40	1.6	Total Num = 5570	113	2.0	94.2
10	54	2.2	Clim Freq = 75.3%	149	2.7	92.0
20	20	0.8	Good Visibilities	60	0.2	100.0
10	54	2.2	(≥ 6 mi)	160	2.5	98.8
24	8	0.3	Total Num = 6357	23	0.4	95.8
3	127	5.1	Clim Freq = 85.9%	251	5.5	92.1

continued ...

¹Frequencies are given as percentages

Table 4 continued:

Map Type	Num	Freq ¹	Weather Parameter	Num	Wea. Freq ¹	Type Freq ¹
1	209	8.5	Wind > 12 MPH	279	18.8	44.5
11	51	2.1		64	4.3	42.4
12	48	1.9	Total Num = 1487	56	3.8	38.9
3	127	5.1	Clim Freq = 20.1%	134	9.0	35.2
19	33	1.3	North Winds	77	3.8	77.7
23	12	0.5	(NNW-NE)	25	1.2	69.4
13	49	2.0	Total Num = 2024	92	4.5	62.6
7	107	4.3	Clim Freq = 27.3%	184	9.1	57.3
11	51	2.1	East Winds	141	5.4	92.2
12	48	1.9	(ENE-SE)	123	4.7	85.4
2	169	6.9	Total Num = 2600	430	16.5	84.8
15	46	1.9	Clim Freq = 35.1%	116	4.6	84.1
5	130	5.3	South Winds	120	21.0	30.1
17	48	1.9	(SSE-SW)	37	6.5	25.7
4	111	4.5	Total Num = 571	81	14.2	24.3
14	40	1.9	Clim Freq = 7.7%	23	0.0	16.0
3	127	5.1	West Winds	321	17.2	84.3
10	57	2.3	(WSW-NW)	113	6.1	69.8
1	209	8.5	Total Num = 1866	384	20.6	61.2
20	20	0.8	Clim Freq = 25.2%	37	2.0	61.2
17	48	1.9	Calm Winds	16	4.7	11.1
8	67	2.7			5.3	9.4
16	40	1.6	Total Num = 340	10	2.9	8.3
4	111	4.5	Clim Freq = 4.6%	24	7.1	7.2

Low visibilities and ceilings seem to be related in the synoptic situations of Type 11, because both elements occur together some 11 percent of the time with Type 11 regimes. The key map for Type 11 has a weak trough extending into the southern Mackenzie Valley from a low-pressure center just north of Banks Island. The resulting southeasterly flow over Yellowknife is conducive to the development of low ceilings and visibilities. The key map of Type 14 also shows a southeasterly flow over Yellowknife. In this case the trough runs along the 60th parallel from an Alaskan Gulf Low. Type 14 regimes produce low ceilings 16.7 percent of the time, which is the highest frequency of low ceilings associated with any type (see Table 4).

Despite the association between the "poor-weather" elements, the precipitation frequencies are much greater than the low-ceiling and visibility frequencies. This suggests that much of the precipitation falls from higher clouds or the intensity is low. This precipitation characteristic can be attributed to the predominance of the Arctic air which is usually very dry. Influxes of milder, moist air into the region are forced to rise over the cold Arctic dome, forming clouds above the Arctic inversion. Some of the precipitation that is released from these clouds may never reach the ground due to sublimation in the dry Arctic air.

Fresh southward surges of Arctic air through the Mackenzie Valley and into Alberta are often accompanied by extensive areas of cloud and light snow, especially north of the Arctic Front. The Type 19 key map is a good example of this synoptic situation. Some 66 percent of the observations associated with Type 19 reported

precipitation. Types 13 and 15 are two other precipitation types listed in Table 4. Their key maps show a similar easterly circulation pattern over Great Slave Lake. Air-mass convergence and over-running of moist air from low-pressure systems in northern Alberta account for the high association of precipitation with regimes of Types 13 and 15.

The predominance of "good weather" at Yellowknife during the cold season is clearly indicated by the high climatic frequencies of 75.3 and 85.9 percent, respectively, for high ceilings and good visibilities. Some of the map types whose key maps are dominated by high pressure systems have considerably higher frequencies of good weather associated with them. Table 4 shows that both Map Types 24 and 20 have 100 percent of their associated observations in the highest ceiling and visibility categories, respectively. The other types listed are associated with high-category observations in excess of 90 percent of time. Map types are, therefore, much better discriminators of "good weather" than "poor weather".

5.4 Winds

Strong winds are a significant aviation weather parameter. Table 4 shows that wind speeds greater than 12 miles per hour occur less frequently than precipitation, but more frequently than low ceilings and visibilities. As is the case for all parameters listed in the table, the frequency of the parameter associated with given map types is considerably greater than the climatic frequency. The most significant feature of this section of the table is the presence

of Types 1 and 3. The association with strong winds is undoubtedly related to their previously described strong pressure gradients. The converse relationship between weak gradient map types and calm winds is not pronounced.

All maps belonging to a given type have very similar flow patterns. This is clearly illustrated by the high degree of association between map type and wind direction. Table 4 shows that 92 percent of the observations grouped with Type 11 have easterly winds. The other wind directions also exhibit high degrees of association with specific map types, with the possible exception of south winds which have a low climatic frequency of only 7.7 percent.

The absence of Type U from Table 4 shows that there are no weather parameters that are highly associated with uncorrelated maps. Most of the associations in Table 4 show the parameter frequencies of occurrence with map types to be greater than twice the climatic frequencies of these parameters. This suggests close relationships between map types and synoptic weather. The next chapter will examine the possibilities of using these relationships to predict weather in an independent data sample.

CHAPTER VI

PREDICTING CEILINGS AND VISIBILITIES AT YELLOWKNIFE BASED ON MAP TYPES

6.1 Developing the Probability Forecast Model

The computer program that determined the association of weather parameters with map types also calculated and stored for future use the probabilities of occurrence of the associated parameters over the 16-year dependent data period. These conditional probabilities were determined for 11 separate times associated with each map-type occurrence. The times were at three-hourly intervals; from six hours prior to map time up to 24 hours after a map type occurrence. Separate calculations were made for those observations associated with 00Z maps, 12Z maps and combined 00Z and 12Z maps. Climatic probabilities were also calculated using the identical procedure. For all climatic calculations, the hourly data were stratified only according to the hour of the map occurrence and the associated times before and after map time.

The basic statistical characteristics of the dependent data base are depicted in Table 5. They pertain to the 2467 hourly observations made at map time. An identical number of observations

Table 5

Number of occurrences and climatic probabilities of ceiling and visibility categories at 00Z and 12Z for the months of January, February and December 1953-1968.

Category	00Z		12Z		00Z + 12Z	
	Num	Prob	Num	Prob	Num	Prob
Ceiling A	11	1.1	48	3.3	59	2.4
Ceiling B	41	4.0	55	3.8	96	3.9
Ceiling C	185	18.1	277	19.2	462	18.7
Ceiling D	<u>786</u>	<u>76.8</u>	<u>1064</u>	<u>73.7</u>	<u>1850</u>	<u>75.0</u>
Total	1023	100.0	1444	100.0	2467	100.0
Visibility A	17	1.7	29	2.0	46	1.9
Visibility B	56	5.5	62	4.3	118	4.8
Visibility C	70	6.8	123	8.5	193	7.8
Visibility D	<u>880</u>	<u>86.0</u>	<u>1230</u>	<u>85.2</u>	<u>2110</u>	<u>85.5</u>
Total	1023	100.0	1444	100.0	2467	100.0

are used to calculate probabilities at each of the other ten times associated with map types. The gaps in the 00Z map-type data result in there being fewer observations associated with 00Z.

Slight diurnal influences on the ceilings and visibilities can be detected by examining their probabilities of occurrence.

ions at 12Z have a greater percentage of the "poor" weather

y A than do the 00Z maps. Good weather in category D, on

is more frequently associated with 00Z maps.

The infrequent occurrences of category A are the principal reason why no additional ceiling or monthly stratification was introduced to the model. Because of the significance of this weather category to

aviation, it is desirable to have the related statistics as stable as possible.

6.2 Testing the Forecast Model

Once the probability statistics were calculated for all types, the results were used to forecast ceiling and visibilities according to the prevailing map type. Four years (1969-1972) of map-type data and Yellowknife hourly weather were used as the independent data sample to test the forecast model.

The main difficulty in verifying probability forecasts by using standard contingency methods is converting the probability forecasts to a categorical forecast. For example, it is difficult to determine which ceiling category will be forecast, given the probability forecasts for each of the four categories. One solution is to assign to each category a weight in proportion to the relative significance of accurately forecasting the category. Each categorical probability forecast is multiplied by its respective weight, and that category with the highest weighted probability becomes the categorical forecast.

One verification method that indirectly incorporates a weighting scheme is the Brier P-score, specifically developed to verify probability forecasts. The weighting is accomplished by raising the score of a group of categorical forecasts whose probabilities are not distributed ideally into one categorical forecast of 100 percent and the remainder into zero percent. If this measurement of the resolution of a forecast was the only criterion used in determin-

ing the score, then efforts to improve scores would likely lead to probability forecasts being either too high (overforecasting) or too low (underforecasting). To account for these possibilities, a further penalty is added when the probability of the forecast category does not correspond to the frequency of the category's occurrence. When there is little difference between the forecast probabilities and the frequency of category occurrences, the forecast is said to be reliable.

The resolution and reliability components of the P-Score are not at all obvious in the original formula developed by Brier (1950). The P-score formula is thoroughly analyzed in Appendix 4, where it is transformed into a formula which can be used to verify individual category forecasts, rather than a complete group of categorical forecasts. The transformed Brier Score formula for N forecasts of an event or category is¹

$$B = \frac{1}{N} \sum_{k=1}^n M_k [(f_k - \phi_k)^2 + \phi_k(1 - \phi_k)] , \quad (2)$$

where k refers to one of n probability classes and f_k is the probability that represents each class. In this study, 11 classes cover the full range of probabilities. Representing the lowest range of probabilities, from 0-4 percent, is $f_1 = 0.0$; the next highest class from 5-14 percent is represented by $f_2 = 0.10$... etc. and the highest range of probabilities, from 95-100 percent, is represented by $f_{11} = 1.00$.

The first term within the brackets of Equation (2) is the reliability term, while the second is the resolution term, and ϕ_k is

¹ See Appendix 4.

the frequency of the event relative to the number of event forecasts. The maximum score of zero occurs when the event probability and relative frequency are both equal to zero percent or 100 percent. The worst score possible is $B = 1$.

A root-mean-square error in reliability can be defined from the reliability term in Equation (2) as

$$RMSE = \frac{100}{N} \sum_k^n M_k (f_k - \phi_k)^2 . \quad (3)$$

The RMSE is used in this study to monitor the effect of reducing the number of event occurrences through increased stratification of the data. Good reliability results from having a suitably large number of events in a sample so that the probability statistics are stable.

Brier Score verification was also applied to the independent data forecasts that were made using the climatic probabilities. These climatology scores are compared with the scores calculated from the forecasts made using map-type-stratified conditional probabilities. If both scores were calculated on forecasts of the dependent data, then the map-type-stratified forecasts would always show an improvement over purely climatological forecasts. This will not necessarily be the case for map-type-stratified forecasts of independent data, for two reasons: first, there is no guarantee that the climatology of the independent data is going to be the same as the dependent data. Secondly, assuming that there is a relationship between map patterns and weather, certain map types will be better predictors than others, depending on the strength of the relationship. It is conceivable that a map type that is a relatively poor predictor will produce a

Brier Score that is worse than a climatology forecast score, when the forecasts are made on independent data.

It can be seen that the Brier Score is an ideal verification method for this study. It is specifically designed to verify probability forecasts, and gives a convenient measure of the forecast reliability as well as resolution. Moreover, the scores are calculated in such a manner that comparisons can readily be made with respect to different models, map types, weather elements and categories. One of the disadvantages of the method is that it gives no suitable measure of the effectiveness of a forecast that is to be used operationally. However, the concern of this thesis is to examine possible methods that could be used in the development of an operational model. When the model appears to be suitable for operational use, then some measure of its operational effectiveness should be determined.

6.3 The Verification Program

A computer program was developed for verifying four categorical forecasts at a time; using cold-season data for four years. The input data consisted of 660 maps at all 00Z and 12Z map times, 7986 hourly Yellowknife weather observations, climatic probabilities and conditional probabilities of the four category occurrences. The program progresses chronologically through the independent data, recording the number of times each category occurred and was forecast, the probability class in which the correct forecast was made, and for which of the 11 associated times the forecast was valid.

The results for each category were stored in a four-dimensional array, with each element of the array containing, in one computer word, the total number of forecasts and the number of correct forecasts. The four dimensions of the array correspond to the map time, the associated map-type time, the map type and the category. The Brier Scores were calculated from the storage arrays, and the results were listed in 11 tables. The tables are organized into three sets of 11 tables, for the 00Z, 12Z and combined map times, respectively. The tables in each set contain results for the 11 times associated with each map type.

Table 6 shows a typical verification table containing results for ceiling forecasts valid at map time for all 00Z and 12Z maps. The average results for each category were calculated by weighting each score according to the number of related map types. This is equivalent to weighting the scores according to number of forecasts in each probability class as indicated in Equation (2), because each map-type score is based on only one probability class. For the purpose of comparison, the scores for climatology forecasts are listed immediately below the average scores.

Some characteristics of the scores given in this table require explanation. It has been stated that lower P-Scores indicate better forecasts. It would appear from Table 6 that the relatively rare category-A events are forecast more accurately than the more frequent category-D events. This can be explained by recalling that the best scores are given to those accurate category forecasts close to the limiting values of zero or 100 percent. All category-A probability forecasts score very close to zero, and since this

Table 6

An example of the verification results for one of 11 times associated with all map types and a summary of the set of 11 verification tables.

P-SCORES AND RELIABILITIES BASED ON ALL MAPS FOR CEILING FORECASTS AT MAP TIME + (0) HOURS

TYPE	CIG-A		CIG-B		CIG-C		CIG-D		AVERAGE	
	P-SCORE	RLBY(%)	P-SCORE	RLBY(%)	P-SCORE	RLBY(%)	P-SCORE	RLBY(%)	P-SCORE	RLBY(%)
4	0.049	0.24	0.0	0.0	0.088	0.00	0.095	1.19	0.058	0.36
8	0.063	0.11	0.0	0.0	0.0	0.0	0.107	0.79	0.042	0.23
1	0.0	0.0	0.0	0.0	0.221	2.66	0.157	0.00	0.094	0.67
3	0.0	0.0	0.0	0.0	0.031	0.54	0.031	0.54	0.016	0.27
6	0.0	0.0	0.111	1.23	0.268	2.09	0.250	0.08	0.157	0.85
7	0.0	0.0	0.0	0.0	0.313	6.48	0.210	0.00	0.131	1.62
2	0.096	0.92	0.056	0.18	0.038	0.43	0.229	0.23	0.105	0.44
17	0.0	0.0	0.0	0.0	0.0	0.0	0.010	1.00	0.003	0.25
14	0.0	0.0	0.110	0.06	0.010	1.00	0.150	0.25	0.077	0.33
9	0.0	0.0	0.0	0.0	0.0	0.0	0.040	4.00	0.010	1.00
12	0.0	0.0	0.0	0.0	0.223	0.11	0.227	0.44	0.112	0.14
5	0.111	1.23	0.112	0.08	0.036	0.46	0.214	0.82	0.119	0.65
11	0.067	0.44	0.133	1.78	0.250	12.76	0.235	0.06	0.171	3.76
18	0.167	2.78	0.0	0.0	0.090	9.00	0.227	0.44	0.121	3.06
23	0.0	0.0	0.0	0.0	0.0	0.0	0.000	0.00	0.000	0.00
21	0.0	0.0	0.0	0.0	0.040	4.00	0.160	16.00	0.050	5.00
19	0.0	0.0	0.0	0.0	0.390	20.25	0.350	20.25	0.155	10.12
10	0.0	0.0	0.0	0.0	0.143	2.04	0.010	1.00	0.038	0.76
24	0.0	0.0	0.0	0.0	0.0	0.0	0.000	0.00	0.000	0.00
12	0.083	0.69	0.010	1.00	0.235	0.06	0.260	1.00	0.147	0.69
20	0.0	0.0	0.0	0.0	0.010	1.00	0.040	4.00	0.013	1.25
16	0.0	0.0	0.0	0.0	0.125	1.56	0.110	0.06	0.059	0.41
15	0.0	0.0	0.0	0.0	0.360	36.00	0.250	0.69	0.152	5.17
22	0.0	0.0	0.0	0.0	0.0	0.0	0.250	25.00	0.063	6.25
0	0.033	0.11	0.019	0.04	0.122	0.41	0.203	0.03	0.094	0.15
AVPG	0.0324	0.23	0.0266	0.16	0.1308	2.13	0.1726	0.71	0.0906	0.81
CLIM	0.0348	0.12	0.0303	0.09	0.1364	0.16	0.1530	0.18	0.0986	0.14

PERCENT IMPROVEMENT OF MAP TYPE P-SCORES OVER CLIMATOLOGY P-SCORES
AT DIFFERENT TIMES BEFORE AND AFTER THE OCCURRENCE OF ALL MAPS

TIME	CIG-A		CIG-B		CIG-C		CIG-D		AVERAGE	
	P-SCORE RLBY(%)		P-SCORE RLBY(%)		P-SCORE RLBY(%)		P-SCORE RLBY(%)		P-SCORE RLBY(%)	
	XDIFF	DIFF	XDIFF	DIFF	XDIFF	DIFF	XDIFF	DIFF	XDIFF	DIFF
-6	-20.54	-0.227	10.57	0.189	4.36	-1.200	2.57	-0.846	-0.76	-0.524
-3	-4.14	-0.161	10.08	-0.218	12.91	-0.490	4.22	-0.988	5.76	-0.464
0	6.98	-0.110	12.17	-0.065	4.07	-1.974	10.56	-0.521	8.45	-0.670
3	-12.96	-0.234	-11.15	-0.181	3.06	-1.745	9.42	-1.294	-2.91	-0.863
6	-20.80	-0.191	-45.56	-0.377	-2.78	-1.482	2.11	-0.943	-16.76	-0.748
9	9.91	-0.075	5.16	-0.444	10.26	-0.733	11.17	-1.363	9.12	-0.654
12	15.81	-0.054	-12.68	-0.257	9.19	-1.178	3.82	-0.687	5.03	-0.594
15	1.41	-0.091	3.24	-0.347	0.20	-1.777	15.44	-1.016	5.07	-0.808
18	3.40	-0.144	-13.21	-0.226	-3.19	-1.845	8.23	-1.017	-1.19	-0.808
21	12.00	-0.055	-0.21	-0.246	10.68	-0.306	5.66	-1.170	7.08	-0.444
24	7.76	-0.174	-16.12	-0.454	6.45	-1.291	6.45	-0.850	1.13	-0.692

FOR ALL MAPS, THE TOTAL AVERAGE MAP TYPE P-SCORE IS 0.0925 AND RELIABILITY IS 0.83 PERCENT
THE TOTAL AVERAGE CLIMATOLOGY P-SCORE IS 0.0974 AND RELIABILITY IS 0.17 PERCENT

category occurs very infrequently, it results in scores which are low.

When comparing scores between categories, it is more useful to consider the percent improvement of the map-type scores over the climatology scores as the measure of the forecast skill of the map-type forecast model. For example, the results in Table 6 show the map-type model as having greater skill in forecasting category D than category A, because the respective percent improvements over climatology are 10.6 and 7.0 percent.

It may also seem incongruous that category A, with the fewest occurrences, has a better reliability component than the most frequently occurring category D. Table 6 shows that the higher average reliabilities in the more frequently occurring categories are primarily due to a few very high-percent reliabilities present only with certain rather uncommon types - a factor which likely accounts for their poor reliability scores. For example, in the presence of Type 23, ceiling category C has a class frequency of 0.40, as determined from the dependent data. During the independent data period, Type 23 appeared 12 times, and each time the ceiling was in category C; this means its relative frequency in category C is 1.0. The square of the difference between the relative and forecast frequency results in a high reliability of 36 percent. The resolution component in this example is zero, so the P-Score is 0.36. The much lower number of category-A occurrences reduces the potential for high reliabilities, which explains why the average percent reliabilities are low.

Listed at the end of each set of tables is a summarization table giving the percent improvement over climatology of the category

forecasts of the 11 times associated with map types. An example of such a table is shown at the bottom of Table 6, a summary of the set from which the table above it was extracted. The bottom two lines give the overall scores and reliabilities for the set. The significance of these statistics is discussed in the next section.

6.4 Averaged Verification Results

Average verification scores were calculated over all four categories of ceilings and visibilities, and for all 11 times associated with all map types. The averages were calculated separately for forecasts based on 00Z, 12Z and combined 00Z and 12Z map times. These results, along with percent improvements over climatology, are listed in Table 7. In an attempt to improve the verification scores, the forecast model was modified in several ways. The averaged results of the modified versions of the basic model are also listed in Table 7.

The results for the basic model are listed first. The outstanding result is that map-type forecasts are a definite improvement over climatological forecasts of ceiling and visibility categories. There is, however, a significant difference in the forecast skills for ceiling and visibility forecasts. Based on all map times, the map-type ceiling forecasts are 5.03 percent better than climatology forecasts, whereas visibility forecasts are only 0.80 percent better. This discrepancy in forecast skill is understandable in view of the fact that the map-type patterns are synoptic features, and categories of cloud ceiling are more synoptic in nature than those of visibility. The best visibility forecasts are based on 00Z map times, which is

Table 7

Brier verification scores and reliabilities averaged over all weather categories, map types and 11 associated times (at three-hourly intervals) for map-type-stratified and climatology forecasts of independent data from 1969-1972.

Map Time	Weather Element	Map Type	Climat P-Score	Percent Better ^h	Reliability (%) ⁵	
					Map Type	Climat
00Z	ceilings	0.0953	0.0953	4.72	0.91	0.14
12Z	(r = 0.80)	0.0977	0.0977	3.38	0.88	0.18
ALL		0.0925	0.0974	5.03	0.83	0.17
00Z	Visibilities	0.0972	0.0982	1.02	1.55	0.43
12Z	(r = 0.80)	0.1009	0.1017	0.79	1.54	0.58
ALL		0.0996	0.1004	1.80	1.42	0.46
00Z	Ceilings	0.0899	0.0953	5.67	0.88	0.14
12Z	(r = 0.75)	0.0945	0.0977	3.28	1.03	0.18
ALL		0.0915	0.0974	6.06	0.80	0.17
00Z	Visibilities	0.0978	0.0982	0.41	1.66	0.43
12Z	(r = 0.75)	0.1004	0.1017	1.28	1.62	0.58
ALL		0.0988	0.1004	1.59	1.48	0.46
00Z	Ceilings	0.0901	0.0953	5.46	0.86	0.14
12Z	(r = 0.70)	0.0953	0.0977	2.46	1.05	0.18
ALL		0.0916	0.0974	5.95	0.81	0.17
00Z	Visibilities	0.0976	0.0982	0.61	1.61	0.43
12Z	(r = 0.70)	0.1006	0.1017	1.08	1.58	0.58
ALL		0.0994	0.1004	1.00	1.43	0.46

continued...

Table 7, continued:

Map Time	Weather Element	Map Type P-Score	Climat P-Score	Percent Better	Reliability (%)	
					Map Type	Climat
00Z	Ceilings	0.0907	0.0953	4.83	0.90	0.14
12Z	($r = 0.80$)	0.0944	0.0977	3.38	0.88	0.18
ALL	Expanded ²	0.0925	0.0974	5.03	0.78	0.17
00Z	Visibilities	0.0969	0.0982	1.32	1.53	0.43
12Z	($r = 0.80$)	0.1009	0.1017	0.79	1.54	0.58
ALL	Expanded	0.0985	0.1004	1.89	1.36	0.46
00Z	Ceilings	0.0967	0.0953	-1.47	2.21	0.14
12Z	($r = 0.80$)	0.0967	0.0977	1.02	2.	0.18
ALL	Gradient ³	0.0966	0.0974	0.82	2.06	0.17
00Z	Visibilities	0.1020	0.0982	-3.87	2.73	0.43
12Z	($r = 0.80$)	0.1043	0.1017	-2.56	2.96	0.58
ALL	Gradient	0.1017	0.1004	-1.29	2.49	0.49

¹ r - refers to the correlation coefficient used in the map type assignment procedure.

²Expanded - indicates that the dependent map type data base has been expanded to include maps that have their second highest correlation coefficient greater than or equal to $r = 0.8$, and within .05 of the highest r .

³Gradient - indicates that all 25 map types have been subdivided into three pressure gradient classes.

⁴Precipitation forecasts, based on surface map types over Alberta, were on an average 6.5 percent better than climatology for 23 stations (Kociuba, 1974).

⁵The average percent reliability for precipitation forecasts for 23 stations in the Alberta window was 1.08 percent (Kociuba, 1974).

indicative of a local diurnal factor rather than synoptic factor.

It was mentioned in Section 3.2 that when maps were assigned to types using a threshold correlation coefficient of $r = 0.75$ and $r = 0.70$, there was a successive reduction in the proportion of uncorrelated maps. These two additional map-type data sets were used in the forecast model in place of the basic set of map types which had been assigned at $r = 0.80$. The averaged verification results from this procedure are displayed in Table 7. Only in the case of visibility forecasts based on 00Z maps, and ceiling forecasts based on 12Z maps, are the results worse than those of the basic model. The forecasts based on all 00Z and 12Z map types of the $r = 0.75$ data have P-Scores better than the other models, for both visibilities and ceilings. For the latter, the improvement over climatology is 6.06 percent, or more than one percent greater than the basic model results, but only slightly better than the results of the model using maps assigned at $r = 0.7$.

The P-Score improvements were not so convincing as to warrant an immediate change in the correlation threshold used in assigning maps. There is enough evidence, however, to suggest further experimentation with other threshold levels using different years of independent hourly data at Yellowknife. To determine an optimum assignment threshold for the Mackenzie window, similar experiments to those just mentioned should be applied to other observing sites within the window.

The dependent hourly data associated with secondary map types were incorporated into the calculation of conditional probabilities. If a particular map was correlated with more than one map type

at or above $r = 0.80$, and the difference between the highest and second highest correlation coefficients was within 0.05, then that map was assigned to both types. In such a case the 11 associated hourly observations are used to represent the weather related to each type. The result of applying this process to the dependent data increased the total number of map-type cases from 2467 to 2792.

The probabilities determined from this "expanded" data base were used in the forecast model. The resulting verification scores for ceiling forecasts, shown on Table 7, are essentially unchanged from the scores of the basic model. The percent reliability for ceiling forecasts based on all map times, showed a slight drop from 0.83 to 0.78, but there was no change in the P-Score; this means that the resolution components of the forecasts are not as good as for the basic model. There is some improvement in the visibility forecasts based on all map times. The average reliability improved from 1.42 to 1.36 percent and the forecast skill increased from 0.80 to 1.89 percent, a significant improvement over climatology.

It was stated in Section 4.6 that all maps within the types were subdivided into three classes of strong, medium and weak gradients. The chronological listing of map types in Appendix 2 indicates the gradient class of each map. These gradient types were used in the forecast model. The verification results are the last two sets in Table 7. The P-Scores and reliabilities are clearly the worst in the Table, with reduced skill shown for ceiling forecasts, and negative skill for the visibility forecasts.

The probability statistics for the gradient types were based on the association of hourly weather with 75 types. Tripling the

number of types greatly reduces the number of observations associated with each type, resulting in a sharp increase in the percent reliabilities. For ceiling forecasts the reliabilities jumped above the two percent level, compared to less than one percent for the basic model.

The resolution components of the P-Scores were definitely lowered, but not enough to compensate for the poor reliabilities. Consider, for example, the ceiling forecasts based on all map times. Verification of the basic model forecasts produced an average P-Score of 0.0925, the sum of a reliability component of 0.0083, and a resolution component of 0.0842. For the type forecasts the resolution component was lowered to 0.024, but the reliability increased to 0.0204, yielding a worse P-Score of 0.0966.

The importance of reliable statistics in the development of a successful forecast model was aptly demonstrated when using pressure gradients for further stratification of the data. Two additional conclusions can be derived from the reliability statistics in Table 7. First, the percent reliabilities for visibility forecasts are consistently worse than those for ceiling forecasts. This indicates greater local variability in the occurrences of visibility related to map types. Secondly, the reliability of forecasts based on combined 00Z and 12Z map times is better than the reliability based on the individual times. This can be directly attributed to the increased number of maps in the combined map-times data sample. The improved reliabilities are one reason why the skill of ceiling forecasts based on all map times is greater than of forecasts based on the individual map times. From the Table 7 results

it may be generally stated that better reliabilities and improved P-Scores result from enlarging the stratified data bases.

6.5 Significant Results from the Detailed Verification

The verification program produced a total of six summary tables, identical in format to the one shown with Table 6: one table for each of the three groups of visibility and ceiling forecasts based on the 00Z, 12Z and combined 00Z and 12Z map times. An analysis of all these tables showed no apparent trend in the skill of the forecasts for the 11 times associated with the types. However, for the three summary tables of the basic model ceiling forecasts, the skill at map time was always greater than the skill 24 hours after map time. The relationship for visibility forecasts was not quite as good. Similar comparisons were made between the skill scores for forecast pairs at -3 and +21 hours and at -6 and +18 hours relative to map time. For 12 of the 18 pairs in all six tables, the forecast skill was greater at the hour nearest to map time. This indicates that forecasts near map time are more skillful than forecasts 24 hours later.

A result that stands out clearly on all summary tables of the basic model verification is the fact that map-type forecasts show less skill than climatology in forecasting weather in the two below-VFR categories. For example, the ceiling forecasts of the low categories based on all map times were, on the average, 2.5 percent worse than climatology forecasts, and the visibility forecasts were 4.1 percent worse. In contrast to these results, the map-type forecasts

of the two highest categories of ceilings and visibilities were 6.1 and 10.8 percent better than climatology.

The types that showed the best relationship between low ceiling and visibility categories in the dependent data set are given in Table 4. For each of these types, the frequency of the associated low category weather was significantly greater than the climatic frequency. If this had held true in the independent data sample, the P-Scores for these types would have been lower than the climatology P-Scores. As it turned out, the frequencies of the low categories for a majority of the associated times in the independent data were closer to the climatic frequency of the dependent data, resulting in the P-Scores for climatology forecasts being better for these types than the map-type forecasts. This agrees well with the results given in the previous paragraph.

Map Type 10 was a "good" weather type in the dependent data sample as shown in Table 4, with 92 percent of the associated ceilings and 99 percent of the visibilities in the highest weather category. This compares with 75.3 and 85.9 percent, respectively, for climatology. During the independent data period, type 10 occurred 15 times. The P-Score for category-0 ceiling forecasts related to this type is 0.0497, a score averaged over the 11 associated times, and based on forecasts at all map times. This is 73.3 percent better than the 0.1859 average P-Score for climatology forecasts. The comparable visibility forecasts have verification P-Scores of 0.0529 vs. 0.1918 or a 72.4 percent improvement over climatology forecasts.

The forecasts related to the other "good" weather types, with the notable exception of Type 24, also produce considerably better P-Scores than the climatological forecasts. Table 4 shows that during eight occurrences of Type 24 in the dependent data sample, 100 percent of the ceilings and 95.8 percent of the visibilities associated with the type are in category D. This type appeared only three times in the independent sample. During the same six-hour associated-weather period, all nine observations were in category D, which means that the P-Score for this period was a perfect zero. The forecasts at the remaining eight associated times were, however, far from perfect, giving an average verification score of only 0.2715. This was 47.6 percent worse than the average climatology P-Score for the same period. As might be expected, poor reliability was one reason for the high scores. The average reliability over the eight hours is 10.5 percent, compared with only 0.39 for climatology.

As an individual map type, the uncorrelated group of maps exhibits some interesting verification results. The averaged P-Scores for the basic model forecasts related to Type U are better than climatology for both low weather categories and the highest category. The largest improvements over climatology are for the low categories: visibility forecasts improved 6.3 percent, and ceiling forecasts 5.8 percent.

When the number of maps in Type U were lowered by assigning maps at $r = 0.70$, the skill with which Type U forecast category D was enhanced, the ability to forecast the two lowest categories was reduced, but still slightly better than climatology forecasts. More significantly, the P-Scores related to the four types best associated

with the low categories improved, and the scores related to the types best associated with highest weather category worsened. Since these results apply to both ceiling and visibilities, they are significant. This suggests that the maps removed from the uncorrelated group when the assignment threshold was lowered to $r = 0.70$ had appreciable amounts of below-VFR weather associated with them.

CHAPTER VII

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

7.1 The Surface Map-Type Catalogue

A catalogue of surface map-type patterns over the Mackenzie Valley has been developed using the computerized procedures of the USAF Map-Typing Project Office in Colorado Springs. The data consisted of 00Z and 12Z MSL pressures for December, January and February at 20 grid points in the Mackenzie window over a 27-year period from 1946-1972.

The correlation procedure produced 24 distinct map types. The first three appendices constitute the catalogue of types. The basic information used to assign maps to types is listed in Appendix 1. It includes, in Table 8, the MSL pressures at the 20 grid points for the key maps representing each type. Also listed in the table are the standard deviations of the mean pressure gradient used to assign a gradient class to each type. Appendix 2 contains a chronological listing of all maps and the assigned types. The gradient class of each map is appended to the type designator. The pressure pattern of the key map for each type is illustrated in Appendix 3. Statistical

information on the pressure and occurrence characteristics is listed beneath each key map.

The key map patterns and the mean pressure statistic clearly show the Mackenzie Valley to be dominated by high-pressure systems during the three coldest months. This was anticipated in a region with a highly continental climate. The information on occurrences indicates a high degree of map-type persistence which can be related to the predominance of the continental Arctic air mass.

Just over one-third of all maps did not correlate with any of the types during the map-type assignment procedure. This high percentage of uncorrelated maps reduced the number of maps assigned to the correlated types to such an extent that statistical reliability became a problem when relating hourly weather to individual types.

The wide range of mean pressure gradients between maps of the same type substantiates the conclusions of Scholefield (1973) who used simple hypothetical maps to show that the correlation method does not discriminate between pressure gradients. Classifying map types according to their pressure gradient produced "sub-types" with similar pressure gradients as well as isobaric configurations.

The monthly occurrence statistics in Appendix 3 indicate slight changes in map-type frequencies that can be related to the advance of the winter season. The changes do not appear large enough to prevent an expansion of the three-month cold season. Such an expansion is recommended as a means of combatting statistical reliability problems.

7.2 Yellowknife Weather Related to Map Types

A few good relationships were found between the annual occurrence anomalies of map types and the climatic anomalies of temperature and precipitation. There was no evidence of a trend in map-type occurrences associated with a pronounced cooling trend that began in the late 1940's and continued through the following decade.

The results of summarizing 16 years of hourly observations of aviation weather parameters, present near the time of map type occurrences, were encouraging. In all cases, the frequency of weather parameters relative to a given type were considerably greater than the corresponding climatic frequencies. The four map types that had the highest degree of association with a given parameter were noted. The best associations were found between map types and the highest categories of ceiling and visibility, and the wind direction. The association between types and precipitation was also fairly good. The worst associations were between map types and the lowest ceiling and visibility categories. Despite these poor associations, the best relative frequencies were still significantly larger than the climatic frequencies.

Map Type U was never one of the four best types associated with a given weather parameter. This suggests that types which were highly associated with parameters should be better than Type U as a predictor of that parameter. However, verification results of low category ceiling and visibility forecasts showed this not to be the case.

7.3 Predicting Ceiling and Visibility Categories

A simple conditional-probability forecast model was developed based on the frequencies of ceiling and visibility categories associated with map types during a 16-year dependent data sample. The model was tested by calculating P-Scores on probability forecasts over four years of independent data. The skill of these map-type forecasts was measured by comparing their P-Scores with those calculated from forecasts based on pure climatological frequencies.

The overall results showed map-type forecasts to be better than climatological forecasts. Ceilings, being more often of synoptic-scale extent than visibilities, were forecast with greater skill than visibilities. Ceiling forecasts based on the combined map times of 00Z and 12Z were slightly better than those based on individual 00Z or 12Z times only. This was largely due to improved forecast reliability. Verification results of the model based on gradient-stratified map types were the worst of any model, despite improvements in forecast resolution. Over-stratification of the data was entirely responsible for these poor results.

As this study progressed, it became evident that the statistical stability of the data was the most important factor affecting the verification results. P-Scores worsen in every case where the data are stratified too much. Conversely, those stratified weather parameters that occur frequently enough to be statistically stable, are forecast relatively better than overstratified parameters. This factor explains why the map-type-stratified model does not forecast the lowest categories as skillfully as climatology. It also explains

why the low category forecasts associated with the relatively frequent Map Type U are better than those low category forecasts associated with more highly associated, but less frequent types. The excellent verification results shown by map-type forecasts of the highest weather category can be related to the statistical stability of the category-D observations.

An attempt was made to increase the number of observations associated with each type by assigning more than one type to a map when the second highest correlation coefficient was close to the first. The number of correlation types was also increased by lowering the correlation coefficient threshold during the assignment procedure. In both cases there was some improvement in the reliability and P-Scores of the forecasts.

These verification results are promising, considering that no initial weather condition is incorporated, and the only atmospheric predictor is the synoptic weather pattern. There are enough positive results to warrant further study.

7.4 Recommendations for Further Study

To improve this map-type forecast model to the stage where it could be successfully used as an objective aid to aviation forecasting, the following recommendations are made:

- (i) The model should be applied to another location in the Mackenzie window and comparisons made with the Yellowknife

- (ii) There is no need to alter the correlation coefficient threshold ($r = 0.8$) used in developing the map types, but the assignment threshold should be lowered to reduce the number of uncorrelated maps and improve verification results.
- (iii) The data base should be expanded by increasing the length of the season, by considering maps at the intermediate hours of 06Z and 18Z, and by obtaining additional hourly data.
- (iv) Forecast reliability could be improved by combining the two lowest ceiling and visibility categories; also consideration should be given to other significant parameters, such as precipitation and strong winds which, essentially, have only two categories: occurrence and non-occurrence.
- (v) The data should be stratified according to an initial weather condition which introduces local effects and persistence. This should improve the forecast resolution more than the subsequent loss of reliability.
- (vi) In addition to the P-Score, the "Improved" model should be verified against persistence and official FT's, using contingency table methods. A utility score should be included to measure the operational effectiveness of the forecasts.
- (vii) Gradient stratification should be considered for

Select types that occur frequently enough to ensure statistical reliability.

- (viii) If the "improved" model should produce disappointing results, consideration should be given to redeveloping the map-type catalogue by incorporating derived atmospheric parameters such as vorticity and thickness.

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APPENDIX 1

SURFACE MAP-TYPE WINDOW, GRID-POINT PRESSURE VALUES AND STANDARD DEVIATIONS OF THE MEAN PRESSURE GRADIENT

The surface map type window (dashed lines) is illustrated in Figure 2 with the 20 grid points and the locations within the window for which terminal forecasts are regularly issued. The date and grid-point pressure values of the key map for each type are listed in Table 8. The standard deviations of the mean pressure, listed in the table, were calculated from all the maps assigned to each type. The units are in mb/grid interval (381 km).

TABLE 8 GRID POINT PRESSURE VALUES AND STANDARD
DEVIATIONS OF THE MEAN PRESSURE GRADIENT
(CONTINUED)

MAP TYPE	KEY	AP DATE	S.D. OF MEAN GRADIENT	GRID POINT PRESSURES ON KEY MAP (MSL PRESSURE - 1000 MB)
8	12Z	21 DEC 63	1.41	14 22 21 22 27 30 26 28 31 31 28 32 34 31 30 34 35 31 34 34
9	12Z	19 DEC 56	1.19	15 14 6 16 17 11 7 17 18 15 7 15 17 17 7 15 17 17 13 17
10	12Z	16 FEB 63	1.16	32 34 25 36 34 27 24 35 31 21 27 33 28 21 24 27 25 22 24 23
11	12Z	30 DEC 57	1.53	21 20 19 22 20 21 20 22 23 26 20 21 25 31 21 20 27 33 24 29
12	12Z	9 DEC 55	1.64	13 16 3 8 10 15 6 7 7 12 2 3 4 13 5 4 10 20 10 18
13	12Z	10 FEB 56	1.46	31 24 12 21 24 17 21 27 25 21 14 2 22 23 11 16 21 25 9 12
14	12Z	27 DEC 59	1.26	19 22 3 13 18 13 4 13 17 15 10 15 19 19 18 20 24 27 28 30
15	12Z	4 DEC 67	1.78	7 0 -5 4 3 9 3 4 5 14 -3 0 3 15 -6 -5 3 17 -6 3
16	12Z	5 DEC 66	1.32	20 11 28 23 13 1 23 24 14 5 14 20 15 11 7 13 16 16 2 12
17	12Z	19 DEC 61	1.41	28 21 28 28 19 15 27 29 22 15 27 32 28 22 26 33 34 30 34 37
18	12Z	7 FEB 68	1.17	17 26 14 21 31 41 20 26 35 39 25 28 30 33 26 25 23 24 23 19
19	12Z	16 FEB 60	0.97	31 32 31 33 36 30 31 34 37 41 29 30 31 31 25 24 24 21 20 23
20	12Z	19 DEC 60	1.32	38 43 35 45 49 41 39 48 49 38 41 47 44 32 40 45 40 28 41 37
21	12Z	10 FEB 57	1.07	16 10 8 15 10 8 1 14 11 11 -3 -5 7 14 -2 2 9 18 9 16
22	12Z	3 DEC 70	0.82	29 22 36 30 23 21 33 33 29 27 28 34 34 34 27 30 33 34 27 30
23	12Z	13 JAN 55	0.78	7 13 13 14 13 18 15 14 10 12 12 11 8 9 8 7 6 10 3 4
24	12Z	19 FEB 68	0.74	31 36 15 29 32 28 24 30 29 26 23 33 29 23 26 33 31 22 29 29
U			1.47	

APPENDIX 2

CHRONOLOGICAL LISTING OF THE MAP TYPES ASSIGNED TO EACH MAP

The map types that were assigned to each of the 3814 surface maps, using the correlation coefficient threshold of $r = 0.8$, are listed in chronological order. The first eight-digit number in a group contains the year, month, day, and hour (GMT) of the map. The second number is the highest correlation coefficient resulting from the correlation between the map and the 24 map types. This is followed by the designator of the corresponding type which has appended to it a pressure gradient classification, which is either strong (S), medium (M) or weak (W). The second highest correlation coefficient follows next, except for uncorrelated maps (Type U) where asterisks (*) replace the correlation coefficient. If the second highest correlation coefficient is greater than or equal to the threshold value, then the designator of the corresponding type is listed. If this secondary type is listed, and its corresponding correlation coefficient is within 0.05 of the highest correlation coefficient, the type is marked with an asterisk (*).

60011212	0.850	2M	0.761	60011300	0.726	2M	0.772	60011412	0.761	2M	0.761
60011412	0.854	12M	0.837	60011500	0.742	12M	0.802	60011512	0.837	12M	0.837
60011512	0.874	22M	0.598	60011600	0.716	22M	0.716	60011612	0.598	22M	0.598
60011612	0.928	5M	0.723	60011700	0.730	5M	0.730	60011712	0.723	5M	0.723
60011712	0.831	10M	0.771	60011800	0.744	10M	0.744	60011812	0.771	10M	0.771
60011812	0.844	12M	0.689	60011900	0.756	12M	0.756	60011912	0.689	12M	0.689
60011912	0.842	1M	0.784	60012000	0.771	1M	0.771	60012012	0.784	1M	0.784
60012012	0.890	1M	0.698	60012100	0.785	1M	0.785	60012112	0.698	1M	0.698
60012112	0.843	15M	0.752	60012200	0.792	15M	0.792	60012212	0.752	15M	0.752
60012212	0.819	24M	0.737	60012300	0.804	24M	0.804	60012312	0.737	24M	0.737
60012312	0.855	15M	0.801	60012400	0.816	15M	0.816	60012412	0.801	15M	0.801
60012412	0.855	15M	0.801	60012500	0.834	15M	0.834	60012512	0.801	15M	0.801
60012512	0.855	15M	0.801	60012600	0.846	15M	0.846	60012612	0.801	15M	0.801
60012612	0.855	15M	0.801	60012700	0.858	15M	0.858	60012712	0.801	15M	0.801
60012712	0.855	15M	0.801	60012800	0.870	15M	0.870	60012812	0.801	15M	0.801
60012812	0.855	15M	0.801	60012900	0.882	15M	0.882	60012912	0.801	15M	0.801
60012912	0.855	15M	0.801	60013000	0.894	15M	0.894	60013012	0.801	15M	0.801
60013012	0.855	15M	0.801	60013100	0.906	15M	0.906	60013112	0.801	15M	0.801
60013112	0.855	15M	0.801	60013200	0.918	15M	0.918	60013212	0.801	15M	0.801
60013212	0.855	15M	0.801	60013300	0.930	15M	0.930	60013312	0.801	15M	0.801
60013312	0.855	15M	0.801	60013400	0.942	15M	0.942	60013412	0.801	15M	0.801
60013412	0.855	15M	0.801	60013500	0.954	15M	0.954	60013512	0.801	15M	0.801
60013512	0.855	15M	0.801	60013600	0.966	15M	0.966	60013612	0.801	15M	0.801
60013612	0.855	15M	0.801	60013700	0.978	15M	0.978	60013712	0.801	15M	0.801
60013712	0.855	15M	0.801	60013800	0.990	15M	0.990	60013812	0.801	15M	0.801
60013812	0.855	15M	0.801	60013900	1.002	15M	1.002	60013912	0.801	15M	0.801
60013912	0.855	15M	0.801	60014000	1.014	15M	1.014	60014012	0.801	15M	0.801
60014012	0.855	15M	0.801	60014100	1.026	15M	1.026	60014112	0.801	15M	0.801
60014112	0.855	15M	0.801	60014200	1.038	15M	1.038	60014212	0.801	15M	0.801
60014212	0.855	15M	0.801	60014300	1.050	15M	1.050	60014312	0.801	15M	0.801
60014312	0.855	15M	0.801	60014400	1.062	15M	1.062	60014412	0.801	15M	0.801
60014412	0.855	15M	0.801	60014500	1.074	15M	1.074	60014512	0.801	15M	0.801
60014512	0.855	15M	0.801	60014600	1.086	15M	1.086	60014612	0.801	15M	0.801
60014612	0.855	15M	0.801	60014700	1.098	15M	1.098	60014712	0.801	15M	0.801
60014712	0.855	15M	0.801	60014800	1.110	15M	1.110	60014812	0.801	15M	0.801
60014812	0.855	15M	0.801	60014900	1.122	15M	1.122	60014912	0.801	15M	0.801
60014912	0.855	15M	0.801	60015000	1.134	15M	1.134	60015012	0.801	15M	0.801
60015012	0.855	15M	0.801	60015100	1.146	15M	1.146	60015112	0.801	15M	0.801
60015112	0.855	15M	0.801	60015200	1.158	15M	1.158	60015212	0.801	15M	0.801
60015212	0.855	15M	0.801	60015300	1.170	15M	1.170	60015312	0.801	15M	0.801
60015312	0.855	15M	0.801	60015400	1.182	15M	1.182	60015412	0.801	15M	0.801
60015412	0.855	15M	0.801	60015500	1.194	15M	1.194	60015512	0.801	15M	0.801
60015512	0.855	15M	0.801	60015600	1.206	15M	1.206	60015612	0.801	15M	0.801
60015612	0.855	15M	0.801	60015700	1.218	15M	1.218	60015712	0.801	15M	0.801
60015712	0.855	15M	0.801	60015800	1.230	15M	1.230	60015812	0.801	15M	0.801
60015812	0.855	15M	0.801	60015900	1.242	15M	1.242	60015912	0.801	15M	0.801
60015912	0.855	15M	0.801	60016000	1.254	15M	1.254	60016012	0.801	15M	0.801
60016012	0.855	15M	0.801	60016100	1.266	15M	1.266	60016112	0.801	15M	0.801
60016112	0.855	15M	0.801	60016200	1.278	15M	1.278	60016212	0.801	15M	0.801
60016212	0.855	15M	0.801	60016300	1.290	15M	1.290	60016312	0.801	15M	0.801
60016312	0.855	15M	0.801	60016400	1.302	15M	1.302	60016412	0.801	15M	0.801
60016412	0.855	15M	0.801	60016500	1.314	15M	1.314	60016512	0.801	15M	0.801
60016512	0.855	15M	0.801	60016600	1.326	15M	1.326	60016612	0.801	15M	0.801
60016612	0.855	15M	0.801	60016700	1.338	15M	1.338	60016712	0.801	15M	0.801
60016712	0.855	15M	0.801	60016800	1.350	15M	1.350	60016812	0.801	15M	0.801
60016812	0.855	15M	0.801	60016900	1.362	15M	1.362	60016912	0.801	15M	0.801
60016912	0.855	15M	0.801	60017000	1.374	15M	1.374	60017012	0.801	15M	0.801
60017012	0.855	15M	0.801	60017100	1.386	15M	1.386	60017112	0.801	15M	0.801
60017112	0.855	15M	0.801	60017200	1.398	15M	1.398	60017212	0.801	15M	0.801
60017212	0.855	15M	0.801	60017300	1.410	15M	1.410	60017312	0.801	15M	0.801
60017312	0.855	15M	0.801	60017400	1.422	15M	1.422	60017412	0.801	15M	0.801
60017412	0.855	15M	0.801	60017500	1.434	15M	1.434	60017512	0.801	15M	0.801
60017512	0.855	15M	0.801	60017600	1.446	15M	1.446	60017612	0.801	15M	0.801
60017612	0.855	15M	0.801	60017700	1.458	15M	1.458	60017712	0.801	15M	0.801
60017712	0.855	15M	0.801	60017800	1.470	15M	1.470	60017812	0.801	15M	0.801
60017812	0.855	15M	0.801	60017900	1.482	15M	1.482	60017912	0.801	15M	0.801
60017912	0.855	15M	0.801	60018000	1.494	15M	1.494	60018012	0.801	15M	0.801
60018012	0.855	15M	0.801	60018100	1.506	15M	1.506	60018112	0.801	15M	0.801
60018112	0.855	15M	0.801	60018200	1.518	15M	1.518	60018212	0.801	15M	0.801
60018212	0.855	15M	0.801	60018300	1.530	15M	1.530	60018312	0.801	15M	0.801
60018312	0.855	15M	0.801	60018400	1.542	15M	1.542	60018412	0.801	15M	0.801
60018412	0.855	15M	0.801	60018500	1.554	15M	1.554	60018512	0.801	15M	0.801
60018512	0.855	15M	0.801	60018600	1.566	15M	1.566	60018612	0.801	15M	0.801
60018612	0.855	15M	0.801	60018700	1.578	15M	1.578	60018712	0.801	15M	0.801
60018712	0.855	15M	0.801	60018800	1.590	15M	1.590	60018812	0.801	15M	0.801
60018812	0.855	15M	0.801	60018900	1.602	15M	1.602	60018912	0.801	15M	0.801
60018912	0.855	15M	0.801	60019000	1.614	15M	1.614	60019012	0.801	15M	0.801
60019012	0.855	15M	0.801	60019100	1.626	15M	1.626	60019112	0.801	15M	0.801
60019112	0.855	15M	0.801	60019200	1.638	15M	1.638	60019212	0.801	15M	0.801
60019212	0.855	15M	0.801	60019300	1.650	15M	1.650	60019312	0.801	15M	0.801
60019312	0.855	15M	0.801	60019400	1.662	15M	1.662	60019412	0.801	15M	0.801
60019412	0.855	15M	0.801	60019500	1.674	15M	1.674	60019512	0.801	15M	0.801
60019512	0.855	15M	0.801	60019600	1.686	15M	1.686	60019612	0.801	15M	0.801
60019612	0.855	15M	0.801	60019700	1.698	15M	1.698	60019712	0.801	15M	0.801
60019712	0.855	15M	0.801	60019800	1.710	15M	1.710	60019812	0.801	15M	0.801
60019812	0.855	15M	0.801	60019900	1.722	15M	1.722	60019912	0.801	15M	0.801
60019912	0.855	15M	0.801	60020000	1.734	15M	1.734	60020012	0.801	15M	0.801
60020012	0.855	15M	0.801	60020100	1.746	15M	1.746	60020112	0.801	15M	0.801
60020112	0.855	15M	0.801	60020200	1.758	15M	1.758	60020212	0.801	15M	0.801
60020212	0.855	15M	0.801	60020300	1.770	15M	1.770	60020312	0.801	15M	0.801
60020312	0.855	15M	0.801	60020400	1.782	15M	1.782	60020412	0.801	15M	0.801
60020412	0.855	15M	0.801	60020500	1.794	15M	1.794	60020512	0.801	15M	0.801
60020512	0.855	15M	0.801	60020600	1.806	15M	1.806	60020612	0.801	15M	0.801
60020612	0.855	15M	0.801	60020700	1.818	15M	1.818	60020712	0.801	15M	0.801
60020712	0.855	15M	0.801	60020800	1.830	15M	1.830	60020812	0.801	15M	0.801
60020812	0.855	15M	0.801	60020900	1.842	15M	1.842	60020912	0.801	15M	0.801
60020912	0.855	15M	0.801	6							

62012312	0.863	15	0.787	62012412	0.843	22*	0.676	62012512	0.837	165	0.816	11*
62012712	0.933	17*	0.523	62012812	0.781	7*	0.676	62012612	0.850	32	0.751	
62013112	0.958	2*	0.729	62020112	0.912	15*	0.611	62012812	0.719	9*	0.611	1
62020512	0.795	2*	0.795	62020512	0.589	10*	0.600	62020212	0.719	9*	0.719	6*
62020912	0.901	2*	0.765	62020912	0.832	21*	0.600	62020312	0.723	10*	0.723	5
62021212	0.879	18*	0.854	62021312	0.913	6*	0.600	62021412	0.659	15*	0.659	
62021512	0.812	15*	0.739	62021712	0.702	6*	0.600	62021512	0.659	15*	0.659	
62022012	0.951	9*	0.735	62022112	0.977	2*	0.758	62021712	0.659	15*	0.659	
62022412	0.866	1*	0.700	62022512	0.719	32*	0.600	62022012	0.659	15*	0.659	
62022812	0.812	18*	0.673	62120100	0.437	7*	0.747	62022312	0.659	15*	0.659	
62120512	0.805	9*	0.673	62120300	0.749	0*	0.666	62022312	0.659	15*	0.659	
62120912	0.833	5*	0.704	62120500	0.891	2*	0.666	62022312	0.659	15*	0.659	
62121212	0.778	0*	0.600	62120700	0.647	0*	0.600	62022312	0.659	15*	0.659	
62121512	0.802	1*	0.619	62120900	0.817	16*	0.600	62022312	0.659	15*	0.659	
62121812	0.892	85	0.892	62121100	0.907	55	0.653	62022312	0.659	15*	0.659	
62122112	0.869	19*	0.825	62121300	0.864	18*	0.613	62022312	0.659	15*	0.659	
62122412	0.819	185	0.756	62121500	0.813	6*	0.658	62022312	0.659	15*	0.659	
62122712	1.000	65	0.753	62121700	0.931	65	0.758	62022312	0.659	15*	0.659	
62123012	0.938	8*	0.824	62121900	0.931	5*	0.684	62022312	0.659	15*	0.659	
62123312	0.613	0*	0.600	62122100	0.312	1*	0.647	62022312	0.659	15*	0.659	
62123612	1.000	35	0.642	62122300	0.931	35	0.758	62022312	0.659	15*	0.659	
62123912	0.811	4*	0.504	62122500	0.931	35	0.758	62022312	0.659	15*	0.659	
62124212	0.905	4*	0.743	62122700	0.765	0*	0.600	62022312	0.659	15*	0.659	
62124512	0.887	3*	0.771	62122900	0.931	35	0.600	62022312	0.659	15*	0.659	
62124812	0.808	4*	0.813	62123100	0.710	4*	0.765	62022312	0.659	15*	0.659	
62125112	0.697	0*	0.600	62123300	0.419	0*	0.600	62022312	0.659	15*	0.659	
62125412	0.830	0*	0.600	62123500	0.728	0*	0.600	62022312	0.659	15*	0.659	
62125712	0.883	6*	0.777	62123700	0.922	0*	0.600	62022312	0.659	15*	0.659	
62126012	0.653	65	0.797	62123900	0.922	0*	0.600	62022312	0.659	15*	0.659	
62126312	0.878	15	0.815	62124100	0.752	0*	0.600	62022312	0.659	15*	0.659	
62126612	0.822	5*	0.600	62124300	0.915	0*	0.600	62022312	0.659	15*	0.659	
62126912	0.931	1*	0.849	62124500	0.925	105	0.765	62022312	0.659	15*	0.659	
62127212	0.353	1*	0.810	62124700	0.925	105	0.765	62022312	0.659	15*	0.659	
62127512	0.892	10*	0.873	62124900	0.912	205	0.772	62022312	0.659	15*	0.659	
62127812	0.820	19*	0.816	62125100	0.851	1*	0.600	62022312	0.659	15*	0.659	
62128112	0.944	75	0.818	62125300	0.895	1*	0.600	62022312	0.659	15*	0.659	
62128412	0.911	20*	0.514	62125500	0.713	05	0.600	62022312	0.659	15*	0.659	
62128712	0.701	05	0.600	62125700	0.947	0*	0.600	62022312	0.659	15*	0.659	
62129012	0.327	15	0.657	62125900	0.952	1*	0.600	62022312	0.659	15*	0.659	
62129312	0.342	4*	0.773	62126100	0.795	0*	0.600	62022312	0.659	15*	0.659	
62129612	0.931	7*	0.831	62126300	0.915	0*	0.600	62022312	0.659	15*	0.659	
62129912	0.868	10*	0.827	62126500	0.795	0*	0.600	62022312	0.659	15*	0.659	
62130212	0.939	0*	0.600	62126700	0.795	0*	0.600	62022312	0.659	15*	0.659	
62130512	0.933	2*	0.766	62126900	0.669	15*	0.600	62022312	0.659	15*	0.659	
62130812	0.975	14*	0.812	62127100	0.735	14*	0.600	62022312	0.659	15*	0.659	
62131112	0.434	0*	0.600	62127300	0.931	10*	0.600	62022312	0.659	15*	0.659	
62131412	0.863	5*	0.850	62127500	0.842	6*	0.600	62022312	0.659	15*	0.659	
62131712	0.708	0*	0.600	62127700	0.795	0*	0.600	62022312	0.659	15*	0.659	
62132012	1.000	10*	0.731	62127900	0.931	0*	0.600	62022312	0.659	15*	0.659	
62132312	0.572	0*	0.600	62128100	0.710	0*	0.600	62022312	0.659	15*	0.659	
62132612	0.956	8*	0.931	62128300	0.830	85	0.600	62022312	0.659	15*	0.659	
62132912	0.853	18*	0.743	62128500	0.833	8*	0.600	62022312	0.659	15*	0.659	
62133212	0.845	16*	0.658	62128700	0.916	0*	0.600	62022312	0.659	15*	0.659	
62133512	0.782	0*	0.600	62128900	0.496	2*	0.600	62022312	0.659	15*	0.659	
62133812	0.810	2*	0.727	62129100	0.534	0*	0.600	62022312	0.659	15*	0.659	
62134112	0.555	0*	0.600	62129300	0.513	0*	0.600	62022312	0.659	15*	0.659	
62134412	0.693	05	0.785	62129500	0.713	0*	0.600	62022312	0.659	15*	0.659	
62134712	0.845	14*	0.674	62129700	0.784	0*	0.600	62022312	0.659	15*	0.659	
62135012	0.830	0*	0.600	62129900	0.797	0*	0.600	62022312	0.659	15*	0.659	
62135312	0.838	5*	0.713	62130100	0.786	0*	0.600	62022312	0.659	15*	0.659	

[illegible]

69010912	0.827	3A	0.794	69011000	0.798	34	0.798	69011012	0.815	17M	0.761	69011100	0.804	22M	0.645
69011000	0.819	15M	0.691	69011100	0.836	6M	0.800	69011200	0.836	6M	0.800	69011300	0.810	19M	0.809
69011100	0.819	15M	0.715	69011200	0.836	6M	0.800	69011300	0.836	6M	0.800	69011400	0.810	19M	0.792
69011200	0.819	15M	0.715	69011300	0.836	6M	0.800	69011400	0.836	6M	0.800	69011500	0.810	19M	0.792
69011300	0.819	15M	0.715	69011400	0.836	6M	0.800	69011500	0.836	6M	0.800	69011600	0.810	19M	0.792
69011400	0.819	15M	0.715	69011500	0.836	6M	0.800	69011600	0.836	6M	0.800	69011700	0.810	19M	0.792
69011500	0.819	15M	0.715	69011600	0.836	6M	0.800	69011700	0.836	6M	0.800	69011800	0.810	19M	0.792
69011600	0.819	15M	0.715	69011700	0.836	6M	0.800	69011800	0.836	6M	0.800	69011900	0.810	19M	0.792
69011700	0.819	15M	0.715	69011800	0.836	6M	0.800	69011900	0.836	6M	0.800	69012000	0.810	19M	0.792
69011800	0.819	15M	0.715	69011900	0.836	6M	0.800	69012000	0.836	6M	0.800	69012100	0.810	19M	0.792
69011900	0.819	15M	0.715	69012000	0.836	6M	0.800	69012100	0.836	6M	0.800	69012200	0.810	19M	0.792
69012000	0.819	15M	0.715	69012100	0.836	6M	0.800	69012200	0.836	6M	0.800	69012300	0.810	19M	0.792
69012100	0.819	15M	0.715	69012200	0.836	6M	0.800	69012300	0.836	6M	0.800	69012400	0.810	19M	0.792
69012200	0.819	15M	0.715	69012300	0.836	6M	0.800	69012400	0.836	6M	0.800	69012500	0.810	19M	0.792
69012300	0.819	15M	0.715	69012400	0.836	6M	0.800	69012500	0.836	6M	0.800	69012600	0.810	19M	0.792
69012400	0.819	15M	0.715	69012500	0.836	6M	0.800	69012600	0.836	6M	0.800	69012700	0.810	19M	0.792
69012500	0.819	15M	0.715	69012600	0.836	6M	0.800	69012700	0.836	6M	0.800	69012800	0.810	19M	0.792
69012600	0.819	15M	0.715	69012700	0.836	6M	0.800	69012800	0.836	6M	0.800	69012900	0.810	19M	0.792
69012700	0.819	15M	0.715	69012800	0.836	6M	0.800	69012900	0.836	6M	0.800	69013000	0.810	19M	0.792
69012800	0.819	15M	0.715	69012900	0.836	6M	0.800	69013000	0.836	6M	0.800	69013100	0.810	19M	0.792
69012900	0.819	15M	0.715	69013000	0.836	6M	0.800	69013100	0.836	6M	0.800	69013200	0.810	19M	0.792
69013000	0.819	15M	0.715	69013100	0.836	6M	0.800	69013200	0.836	6M	0.800	69013300	0.810	19M	0.792
69013100	0.819	15M	0.715	69013200	0.836	6M	0.800	69013300	0.836	6M	0.800	69013400	0.810	19M	0.792
69013200	0.819	15M	0.715	69013300	0.836	6M	0.800	69013400	0.836	6M	0.800	69013500	0.810	19M	0.792
69013300	0.819	15M	0.715	69013400	0.836	6M	0.800	69013500	0.836	6M	0.800	69013600	0.810	19M	0.792
69013400	0.819	15M	0.715	69013500	0.836	6M	0.800	69013600	0.836	6M	0.800	69013700	0.810	19M	0.792
69013500	0.819	15M	0.715	69013600	0.836	6M	0.800	69013700	0.836	6M	0.800	69013800	0.810	19M	0.792
69013600	0.819	15M	0.715	69013700	0.836	6M	0.800	69013800	0.836	6M	0.800	69013900	0.810	19M	0.792
69013700	0.819	15M	0.715	69013800	0.836	6M	0.800	69013900	0.836	6M	0.800	69014000	0.810	19M	0.792
69013800	0.819	15M	0.715	69013900	0.836	6M	0.800	69014000	0.836	6M	0.800	69014100	0.810	19M	0.792
69013900	0.819	15M	0.715	69014000	0.836	6M	0.800	69014100	0.836	6M	0.800	69014200	0.810	19M	0.792
69014000	0.819	15M	0.715	69014100	0.836	6M	0.800	69014200	0.836	6M	0.800	69014300	0.810	19M	0.792
69014100	0.819	15M	0.715	69014200	0.836	6M	0.800	69014300	0.836	6M	0.800	69014400	0.810	19M	0.792
69014200	0.819	15M	0.715	69014300	0.836	6M	0.800	69014400	0.836	6M	0.800	69014500	0.810	19M	0.792
69014300	0.819	15M	0.715	69014400	0.836	6M	0.800	69014500	0.836	6M	0.800	69014600	0.810	19M	0.792
69014400	0.819	15M	0.715	69014500	0.836	6M	0.800	69014600	0.836	6M	0.800	69014700	0.810	19M	0.792
69014500	0.819	15M	0.715	69014600	0.836	6M	0.800	69014700	0.836	6M	0.800	69014800	0.810	19M	0.792
69014600	0.819	15M	0.715	69014700	0.836	6M	0.800	69014800	0.836	6M	0.800	69014900	0.810	19M	0.792
69014700	0.819	15M	0.715	69014800	0.836	6M	0.800	69014900	0.836	6M	0.800	69015000	0.810	19M	0.792
69014800	0.819	15M	0.715	69014900	0.836	6M	0.800	69015000	0.836	6M	0.800	69015100	0.810	19M	0.792
69014900	0.819	15M	0.715	69015000	0.836	6M	0.800	69015100	0.836	6M	0.800	69015200	0.810	19M	0.792
69015000	0.819	15M	0.715	69015100	0.836	6M	0.800	69015200	0.836	6M	0.800	69015300	0.810	19M	0.792
69015100	0.819	15M	0.715	69015200	0.836	6M	0.800	69015300	0.836	6M	0.800	69015400	0.810	19M	0.792
69015200	0.819	15M	0.715	69015300	0.836	6M	0.800	69015400	0.836	6M	0.800	69015500	0.810	19M	0.792
69015300	0.819	15M	0.715	69015400	0.836	6M	0.800	69015500	0.836	6M	0.800	69015600	0.810	19M	0.792
69015400	0.819	15M	0.715	69015500	0.836	6M	0.800	69015600	0.836	6M	0.800	69015700	0.810	19M	0.792
69015500	0.819	15M	0.715	69015600	0.836	6M	0.800	69015700	0.836	6M	0.800	69015800	0.810	19M	0.792
69015600	0.819	15M	0.715	69015700	0.836	6M	0.800	69015800	0.836	6M	0.800	69015900	0.810	19M	0.792
69015700	0.819	15M	0.715	69015800	0.836	6M	0.800	69015900	0.836	6M	0.800	69016000	0.810	19M	0.792
69015800	0.819	15M	0.715	69015900	0.836	6M	0.800	69016000	0.836	6M	0.800	69016100	0.810	19M	0.792
69015900	0.819	15M	0.715	69016000	0.836	6M	0.800	69016100	0.836	6M	0.800	69016200	0.810	19M	0.792
69016000	0.819	15M	0.715	69016100	0.836	6M	0.800	69016200	0.836	6M	0.800	69016300	0.810	19M	0.792
69016100	0.819	15M	0.715	69016200	0.836	6M	0.800	69016300	0.836	6M	0.800	69016400	0.810	19M	0.792
69016200	0.819	15M	0.715	69016300	0.836	6M	0.800	69016400	0.836	6M	0.800	69016500	0.810	19M	0.792
69016300	0.819	15M	0.715	69016400	0.836	6M	0.800	69016500	0.836	6M	0.800	69016600	0.810	19M	0.792
69016400	0.819	15M	0.715	69016500	0.836	6M	0.800	69016600	0.836	6M	0.800	69016700	0.810	19M	0.792
69016500	0.819	15M	0.715	69016600	0.836	6M	0.800	69016700	0.836	6M	0.800	69016800	0.810	19M	0.792
69016600	0.819	15M	0.715	69016700	0.836	6M	0.800	69016800	0.836	6M	0.800	69016900	0.810	19M	0.792
69016700	0.819	15M	0.715	69016800	0.836	6M	0.800	69016900	0.836	6M	0.800	69017000	0.810	19M	0.792
69016800	0.819	15M	0.715	69016900	0.836	6M	0.800	69017000	0.836	6M	0.800	69017100	0.810	19M	0.792
69016900	0.819	15M	0.715	69017000	0.836	6M	0.800	69017100	0.836	6M	0.800	69017200	0.810	19M	0.792
69017000	0.819	15M	0.715	69017100	0.836	6M	0.800	69017200	0.836	6M	0.800	69017300	0.810	19M	0.792
69017100	0.819	15M	0.715	69017200	0.836	6M	0.800	69017300	0.836	6M	0.800	69017400	0.810	19M	0.792
69017200	0.819	15M	0.715	69017300	0.836	6M	0.800	69017400	0.836	6M	0.800	69017500	0.810	19M	0.792
69017300	0.819	15M	0.715	69017400	0.836	6M	0.800	69017500	0.836	6M	0.800	69017600	0.810	19M	0.792
69017400	0.819	15M	0.715	69017500	0.836	6M	0.800	69017600	0.836	6M	0.800	69017700	0.810	19M	0.792
69017500	0.819	15M	0.715	69017600	0.836	6M	0.800	69017700	0.836	6M	0.800	69017800	0.810	19M	0.792
69017600	0.819	15M	0.715	69017700	0.836	6M	0.800	69017800	0.836	6M	0.800	69017900	0.810	19M	0.792
69017700	0.819	15M	0.715	69017800	0.836	6M	0.800	69017900	0.836	6M	0.800	69018000	0.810	19M	0.792
69017800	0.819	15M	0.715	69017900	0.836	6M	0.800	69018000	0.836	6M	0.800	69018100	0.810	19M	0.792
69017900	0.819	15M	0.715	69018000	0.836	6M	0.800	69018100	0.836	6M	0.800	69018200	0.810	19M	0.792
69018000	0.819	15M	0.715	69018100	0.836	6M	0.800	69018200	0.836	6M	0.800	69018300	0.810	19M	0.792
69018100	0.819	15M	0.715	69018200	0.836	6M	0.800	69018300	0.836	6M	0.800	69018400	0.810	19M	0.792
69018200	0.819	15M	0.715	69018300	0.836	6M	0.800	69018400	0.836	6M	0.800	69018500	0.810	19M	0.792
69018300	0.819	15M	0.715	69018400	0.836	6M	0.800	69018500							

70020812	0.749	7M	0.749	7	70020900	0.336	19M	0.714	6	70020912	0.891	19M	0.799	70021000	0.695	5M	0.779	11
70021012	0.845	7M	0.824	7	70021100	0.837	6M	0.724	6	70021112	0.738	6M	0.693	70021200	0.779	5M	0.779	11
70021212	0.858	2M	0.811	2	70021300	0.826	2M	0.754	19	70021312	0.817	6M	0.693	70021400	0.603	5M	0.754	11
70021412	0.810	24M	0.674	18	70021500	0.797	0M	0.754	19	70021512	0.826	9S	0.717	70021600	0.720	0S	0.754	5
70021612	0.750	0S	0.753	10	70021700	0.729	0M	0.753	10	70021712	0.678	0M	0.688	70021800	0.732	0M	0.753	19
70021812	0.811	20M	0.753	12	70021900	0.694	0M	0.753	20	70021912	0.695	0M	0.688	70022000	0.763	0M	0.753	2
70022012	0.752	0M	0.840	9	70022100	0.936	6M	0.702	13	70022112	0.943	1M	0.688	70022200	0.654	20M	0.753	2
70022212	0.892	2M	0.837	12	70022300	0.892	5M	0.620	13	70022312	0.943	1M	0.688	70022400	0.654	20M	0.753	2
70022412	0.931	8S	0.684	7	70022500	0.892	5M	0.620	13	70022512	0.943	1M	0.688	70022600	0.654	20M	0.753	2
70022612	0.828	1M	0.725	7	70022700	0.843	16M	0.647	19	70022712	0.943	1M	0.688	70022800	0.654	20M	0.753	2
70022812	0.945	16M	0.618	23	70022900	0.843	16M	0.647	19	70022912	0.943	1M	0.688	70023000	0.654	20M	0.753	2
70023012	0.913	16M	0.618	23	70023100	0.843	16M	0.647	19	70023112	0.943	1M	0.688	70023200	0.654	20M	0.753	2
70023212	0.865	6M	0.618	23	70023300	0.843	16M	0.647	19	70023312	0.943	1M	0.688	70023400	0.654	20M	0.753	2
70023412	0.865	6M	0.618	23	70023500	0.843	16M	0.647	19	70023512	0.943	1M	0.688	70023600	0.654	20M	0.753	2
70023612	0.865	6M	0.618	23	70023700	0.843	16M	0.647	19	70023712	0.943	1M	0.688	70023800	0.654	20M	0.753	2
70023812	0.865	6M	0.618	23	70023900	0.843	16M	0.647	19	70023912	0.943	1M	0.688	70024000	0.654	20M	0.753	2
70024012	0.865	6M	0.618	23	70024100	0.843	16M	0.647	19	70024112	0.943	1M	0.688	70024200	0.654	20M	0.753	2
70024212	0.865	6M	0.618	23	70024300	0.843	16M	0.647	19	70024312	0.943	1M	0.688	70024400	0.654	20M	0.753	2
70024412	0.865	6M	0.618	23	70024500	0.843	16M	0.647	19	70024512	0.943	1M	0.688	70024600	0.654	20M	0.753	2
70024612	0.865	6M	0.618	23	70024700	0.843	16M	0.647	19	70024712	0.943	1M	0.688	70024800	0.654	20M	0.753	2
70024812	0.865	6M	0.618	23	70024900	0.843	16M	0.647	19	70024912	0.943	1M	0.688	70025000	0.654	20M	0.753	2
70025012	0.865	6M	0.618	23	70025100	0.843	16M	0.647	19	70025112	0.943	1M	0.688	70025200	0.654	20M	0.753	2
70025212	0.865	6M	0.618	23	70025300	0.843	16M	0.647	19	70025312	0.943	1M	0.688	70025400	0.654	20M	0.753	2
70025412	0.865	6M	0.618	23	70025500	0.843	16M	0.647	19	70025512	0.943	1M	0.688	70025600	0.654	20M	0.753	2
70025612	0.865	6M	0.618	23	70025700	0.843	16M	0.647	19	70025712	0.943	1M	0.688	70025800	0.654	20M	0.753	2
70025812	0.865	6M	0.618	23	70025900	0.843	16M	0.647	19	70025912	0.943	1M	0.688	70026000	0.654	20M	0.753	2
70026012	0.865	6M	0.618	23	70026100	0.843	16M	0.647	19	70026112	0.943	1M	0.688	70026200	0.654	20M	0.753	2
70026212	0.865	6M	0.618	23	70026300	0.843	16M	0.647	19	70026312	0.943	1M	0.688	70026400	0.654	20M	0.753	2
70026412	0.865	6M	0.618	23	70026500	0.843	16M	0.647	19	70026512	0.943	1M	0.688	70026600	0.654	20M	0.753	2
70026612	0.865	6M	0.618	23	70026700	0.843	16M	0.647	19	70026712	0.943	1M	0.688	70026800	0.654	20M	0.753	2
70026812	0.865	6M	0.618	23	70026900	0.843	16M	0.647	19	70026912	0.943	1M	0.688	70027000	0.654	20M	0.753	2
70027012	0.865	6M	0.618	23	70027100	0.843	16M	0.647	19	70027112	0.943	1M	0.688	70027200	0.654	20M	0.753	2
70027212	0.865	6M	0.618	23	70027300	0.843	16M	0.647	19	70027312	0.943	1M	0.688	70027400	0.654	20M	0.753	2
70027412	0.865	6M	0.618	23	70027500	0.843	16M	0.647	19	70027512	0.943	1M	0.688	70027600	0.654	20M	0.753	2
70027612	0.865	6M	0.618	23	70027700	0.843	16M	0.647	19	70027712	0.943	1M	0.688	70027800	0.654	20M	0.753	2
70027812	0.865	6M	0.618	23	70027900	0.843	16M	0.647	19	70027912	0.943	1M	0.688	70028000	0.654	20M	0.753	2
70028012	0.865	6M	0.618	23	70028100	0.843	16M	0.647	19	70028112	0.943	1M	0.688	70028200	0.654	20M	0.753	2
70028212	0.865	6M	0.618	23	70028300	0.843	16M	0.647	19	70028312	0.943	1M	0.688	70028400	0.654	20M	0.753	2
70028412	0.865	6M	0.618	23	70028500	0.843	16M	0.647	19	70028512	0.943	1M	0.688	70028600	0.654	20M	0.753	2
70028612	0.865	6M	0.618	23	70028700	0.843	16M	0.647	19	70028712	0.943	1M	0.688	70028800	0.654	20M	0.753	2
70028812	0.865	6M	0.618	23	70028900	0.843	16M	0.647	19	70028912	0.943	1M	0.688	70029000	0.654	20M	0.753	2
70029012	0.865	6M	0.618	23	70029100	0.843	16M	0.647	19	70029112	0.943	1M	0.688	70029200	0.654	20M	0.753	2
70029212	0.865	6M	0.618	23	70029300	0.843	16M	0.647	19	70029312	0.943	1M	0.688	70029400	0.654	20M	0.753	2
70029412	0.865	6M	0.618	23	70029500	0.843	16M	0.647	19	70029512	0.943	1M	0.688	70029600	0.654	20M	0.753	2
70029612	0.865	6M	0.618	23	70029700	0.843	16M	0.647	19	70029712	0.943	1M	0.688	70029800	0.654	20M	0.753	2
70029812	0.865	6M	0.618	23	70029900	0.843	16M	0.647	19	70029912	0.943	1M	0.688	70030000	0.654	20M	0.753	2

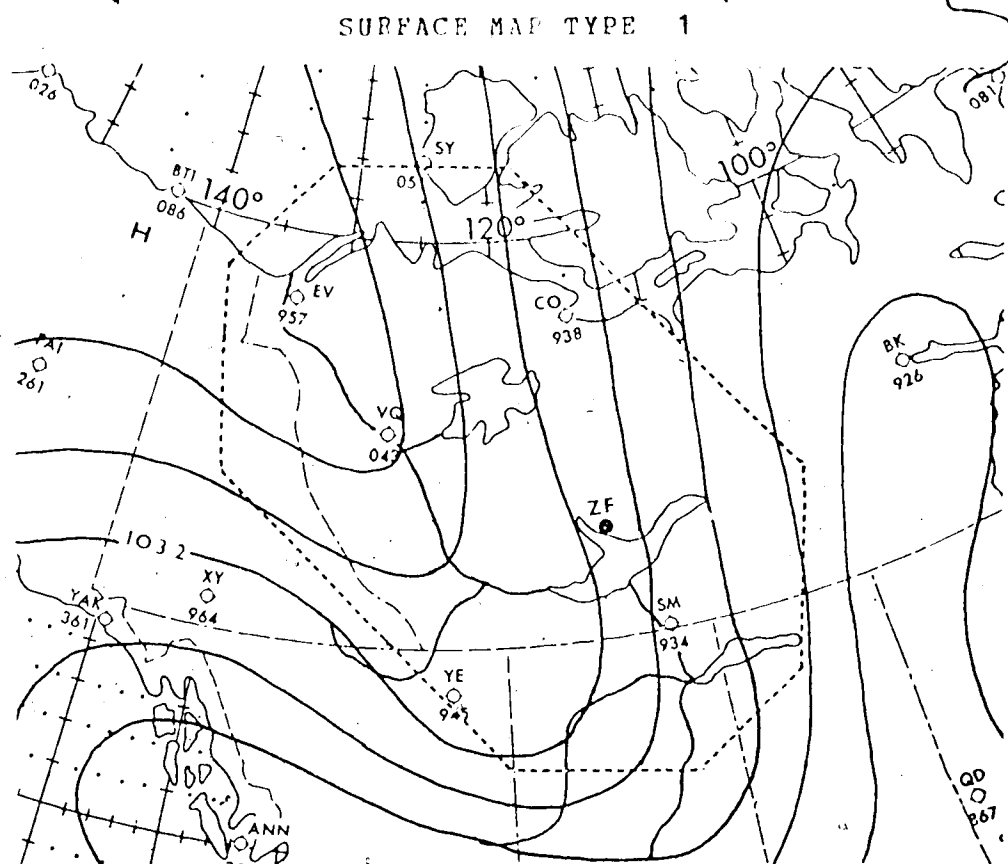
APPENDIX 3

SURFACE MAP TYPES AND CHARACTERISTICS

At the top of each page is an illustration of the isobaric configuration of the key map for a type. The dashed lines form the boundaries of the Mackenzie window. One isobar is labelled and the isobars are drawn at intervals of four millibars.

The characteristics of all maps within a type are summarized by season and month. The months of January and February in 1946, and December, 1972 were not used in the determination of seasonal characteristics. The number of times the map pattern occurred during each period over the 27 years (1946-1972) is listed along with the percentage frequency relative to each period. This is followed by the average of the correlation coefficients resulting from the correlation between the key map and all maps assigned to the type. The mean map pressures listed have been subtracted from 1000 mb. The pressure gradient values are given in units of mb/grid interval (381 km).

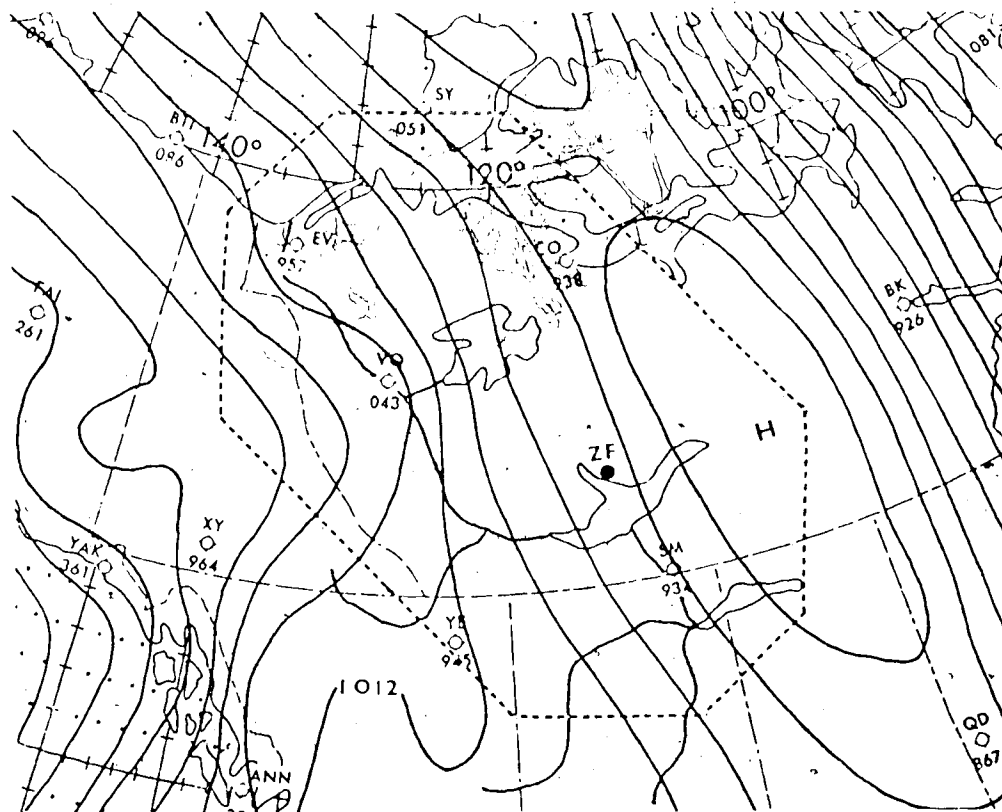
Following the gradient information is a list of the types which most frequently follow the given type and the corresponding percentage. Finally, the duration of the map type is indicated by the number of 12-hour periods that the type persisted, and the corresponding percentage.



KEY DATE - 12Z, 25 FEB 55

PERIOD	SEASON	DEC	JAN	FEB
OCCURRENCES/FREQUENCY	343/ 9	94/ 7	167/ 13	92/ 8
MEAN CORRELATION	0.881	0.879	0.881	0.883
MEAN PRESSURE (MSL)	24.42	24.95	25.01	22.83
MEAN PRESSURE GRADIENT	6.01	5.79	6.43	5.49
MEAN MAXIMUM GRADIENT	9.13	8.69	9.85	8.29
MEAN MINIMUM GRADIENT	2.78	2.73	3.00	2.42
MOST FREQUENTLY.	1/ 51	1/ 51	1/ 57	1/ 46
FOLLOWING MAP TYPE	U/ 21	U/ 21	U/ 17	U/ 30
(MAP TYPE/FREQUENCY)	3/ 14	3/ 15	3/ 16	3/ 10
	10/ 4	7/ 3	10/ 4	10/ 5
	4/ 2	23/ 3	20/ 3	4/ 3
MOST FREQUENT DURATION	1/ 47	2/ 40	1/ 48	1/ 65
(NUMBER OF 12-HOUR	2/ 29	1/ 34	2/ 27	2/ 16
PERIODS/FREQUENCY)	3/ 13	3/ 23	3/ 8	3/ 10
	4/ 6	8/ 3	4/ 6	4/ 6

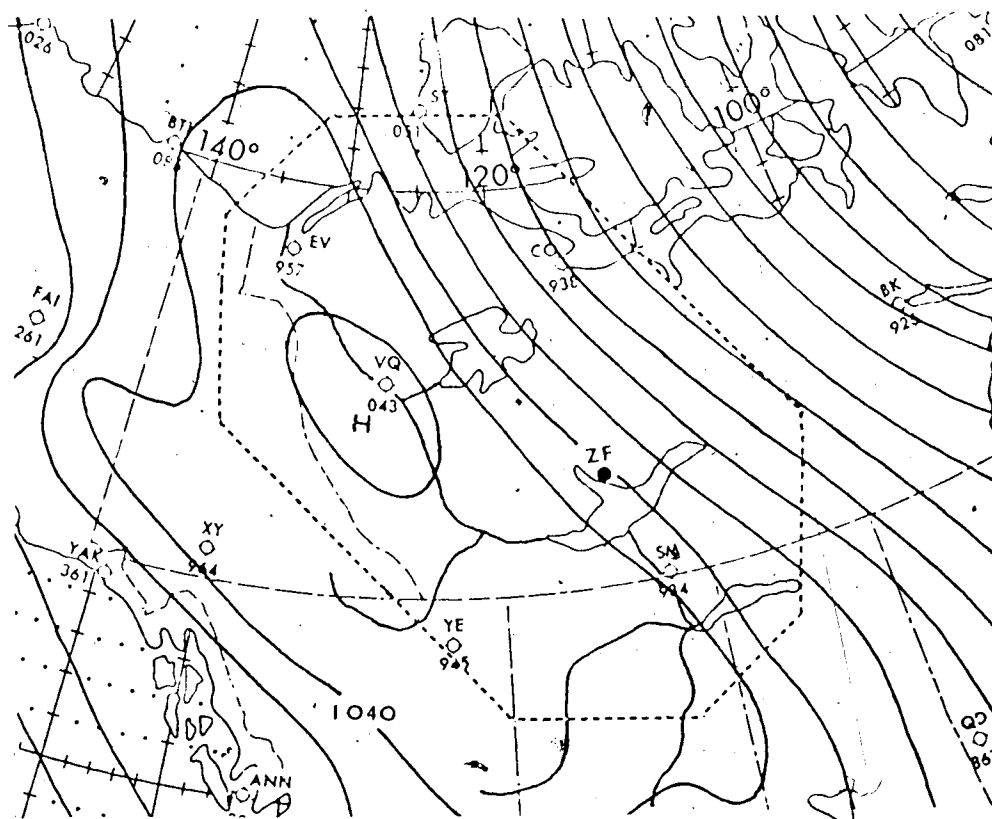
SURFACE MAP TYPE 2



KEY DATE - 12Z, 13 DEC 62

PERIOD	SEASON	DEC	JAN	FEB
OCCURRENCES/FREQUENCY	253/ 7	97/ 7	72/ 6	93/ 8
MEAN CORRELATION	0.891	0.889	0.897	0.887
MEAN PRESSURE (MSL)	18.30	14.90	19.82	20.68
MEAN PRESSURE GRADIENT	5.89	5.88	6.37	5.52
MEAN MAXIMUM GRADIENT	8.71	8.67	9.42	8.21
MEAN MINIMUM GRADIENT	3.18	3.18	3.42	3.00
MOST FREQUENTLY FOLLOWING MAP TYPE (MAP TYPE/FREQUENCY)	2/ 42 U/ 12 11/ 11 12/ 9 6/ 6	2/ 42 U/ 14 11/ 13 12/ 9 15/ 6	2/ 47 U/ 17 12/ 11 11/ 8 6/ 6	2/ 34 11/ 13 U/ 10 6/ 9 15/ 7
MOST FREQUENT DURATION (NUMBER OF 12-HOUR PERIODS/FREQUENCY)	1/ 54 2/ 30 3/ 9 4/ 5	1/ 54 2/ 35 4/ 5 3/ 3	1/ 42 2/ 27 3/ 23 4/ 8	1/ 64 2/ 26 3/ 7 4/ 2

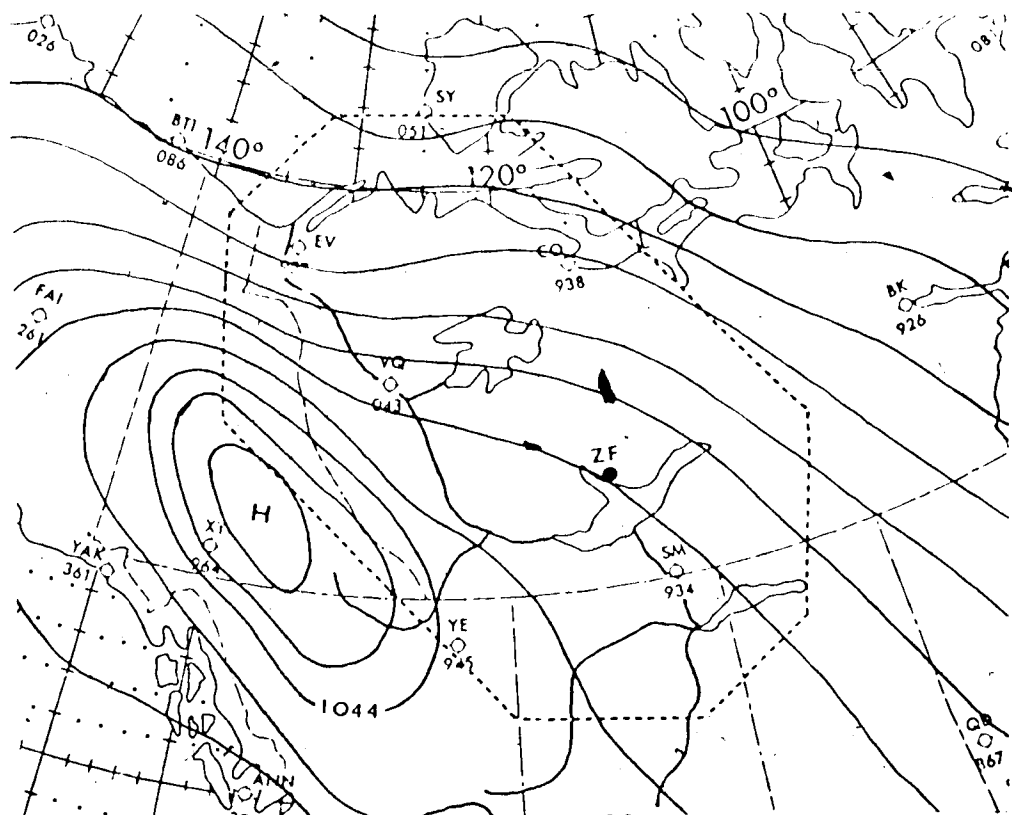
SURFACE MAP TYPE 3



KEY DATE - 12Z, 22 DEC 62

PERIOD	SEASON	DEC	JAN	FEB
OCCURRENCES/FREQUENCY	197/ 5	63/ 5	102/ 8	39/ 3
MEAN CORRELATION	0.873	0.861	0.876	0.886
MEAN PRESSURE (MSL)	25.28	25.71	25.80	23.26
MEAN PRESSURE GRADIENT	6.61	7.05	6.64	5.85
MEAN MAXIMUM GRADIENT	9.88	10.39	9.93	8.94
MEAN MINIMUM GRADIENT	3.22	3.26	3.31	2.95
MOST FREQUENTLY FOLLOWING MAP TYPE (MAP TYPE/FREQUENCY)	3/ 47 U/ 20 1/ 18 4/ 7 17/ 3	3/ 52 U/ 21 4/ 8 1/ 8 16/ 4	3/ 53 1/ 20 U/ 15 4/ 8 17/ 1	1/ 30 3/ 26 U/ 26 17/ 11 4/ 4
MOST FREQUENT DURATION (NUMBER OF 12-HOUR PERIODS/FREQUENCY)	1/ 56 2/ 18 3/ 12 4/ 9	1/ 50 3/ 23 4/ 14 2/ 9	1/ 49 2/ 20 3/ 11 4/ 11	1/ 70 2/ 25 3/ 5

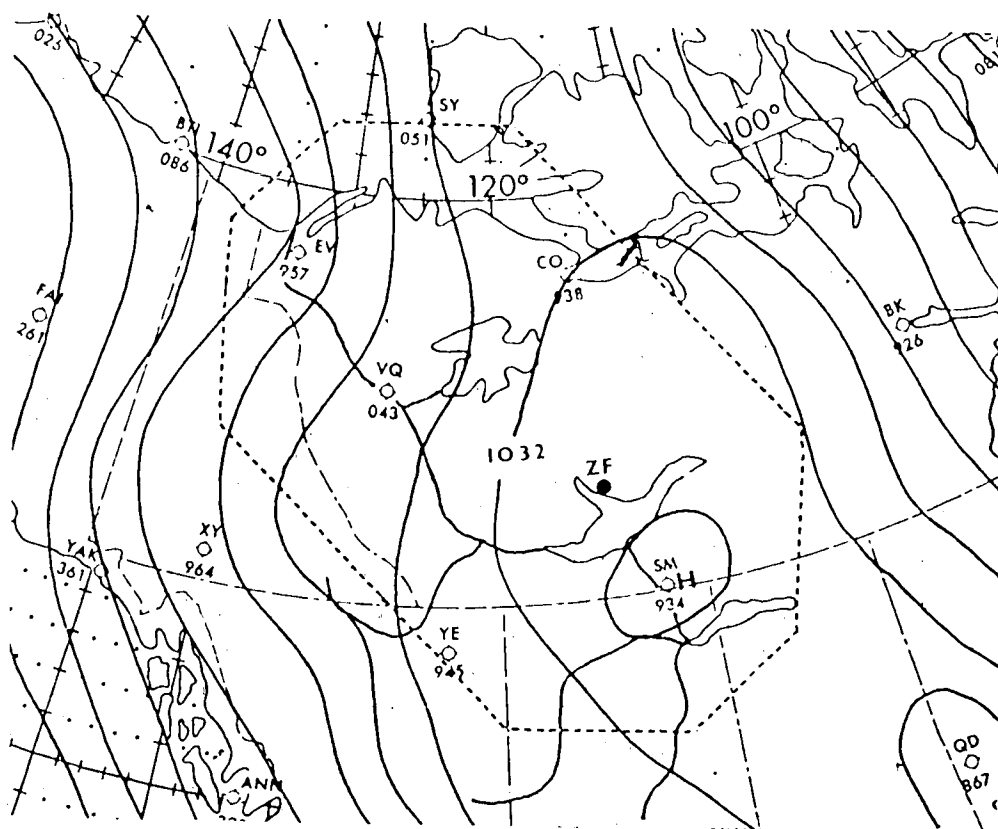
SURFACE MAP TYPE 4



KEY DATE - 12Z, 24 JAN 57

PERIOD	SEASON	DEC	JAN	FEB
OCCURRENCES/FREQUENCY	190/ 5	69/ 5	98/ 8	35/ 3
MEAN CORRELATION	0.874	0.878	0.871	0.876
MEAN PRESSURE (MSL)	24.63	23.89	25.81	22.78
MEAN PRESSURE GRADIENT	6.07	6.03	6.04	6.24
MEAN MAXIMUM GRADIENT	9.89	10.07	9.72	10.00
MEAN MINIMUM GRADIENT	2.72	2.64	2.76	2.77
MOST FREQUENTLY FOLLOWING MAP TYPE ^a (MAP TYPE/FREQUENCY)	4/ 49 U/ 29 3/ 9 17/ 6 5/ 6	4/ 44 U/ 32 5/ 9 3/ 5 17/ 4	4/ 54 U/ 29 3/ 7 17/ 6 5/ 3	4/ 45 U/ 25 3/ 20 17/ 5 5/ 5
MOST FREQUENT DURATION (NUMBER OF 12-HOUR PERIODS/FREQUENCY)	1/ 48 2/ 28 3/ 16 5/ 3	1/ 48 2/ 34 3/ 10 4/ 3	1/ 52 2/ 19 3/ 19 4/ 3	1/ 44 2/ 33 3/ 22 /

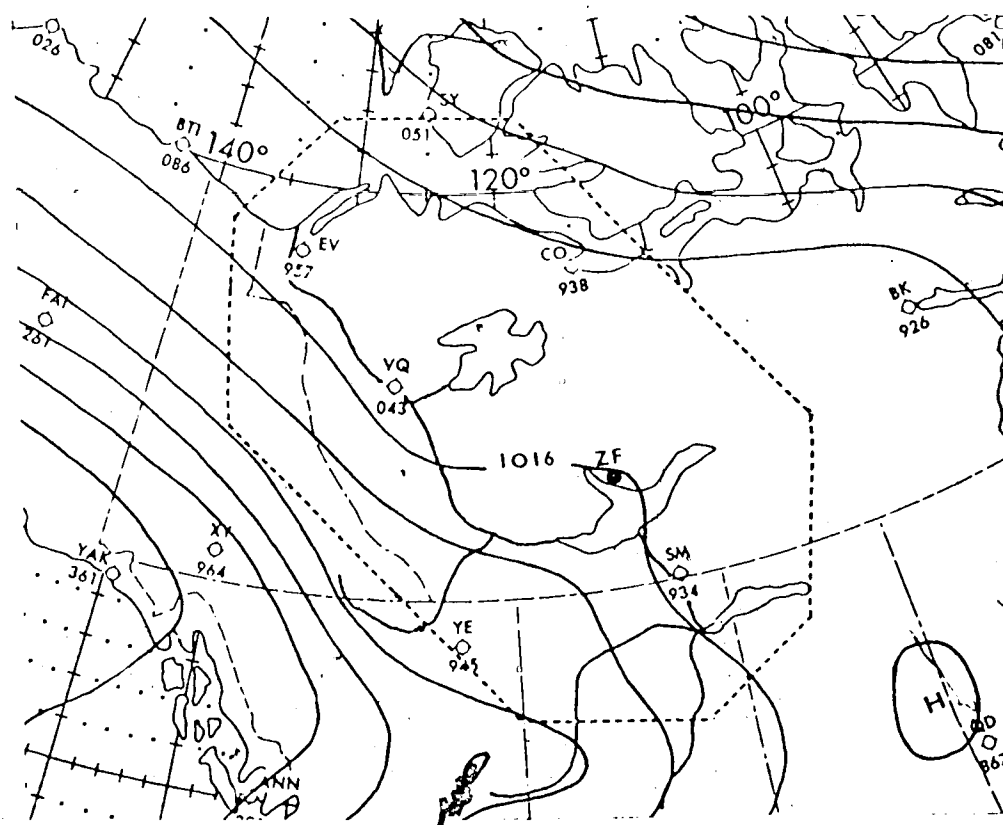
SURFACE MAP TYPE 8



KEY DATE - 12Z, 21 DEC 63

PERIOD	SEASON	DEC	JAN	FEB
OCCURRENCES/FREQUENCY	99/ 3	43/ 3	32/ 2	28/ 2
MEAN CORRELATION	0.883	0.899	0.881	0.859
MEAN PRESSURE (MSL)	24.05	22.05	25.69	25.23
MEAN PRESSURE GRADIENT	4.81	4.95	4.88	4.52
MEAN MAXIMUM GRADIENT	8.17	8.20	8.52	7.71
MEAN MINIMUM GRADIENT	1.71	1.75	1.80	1.55
MOST FREQUENTLY FOLLOWING MAP TYPE (MAP TYPE/FREQUENCY)	5/ 31 8/ 23 2/ 23 U/ 14 11/ 6	5/ 31 8/ 28 2/ 17 U/ 14 11/ 10	2/ 35 8/ 29 5/ 24 12/ 6 U/ 6	5/ 39 2/ 22 U/ 22 8/ 11 11/ 6
MOST FREQUENT DURATION (NUMBER OF 12-HOUR PERIODS/FREQUENCY)	1/ 80 2/ 14 3/ 4 5/ 2	1/ 81 2/ 10 3/ 5 5/ 5	1/ 67 2/ 25 3/ 8	1/ 88 2/ 13

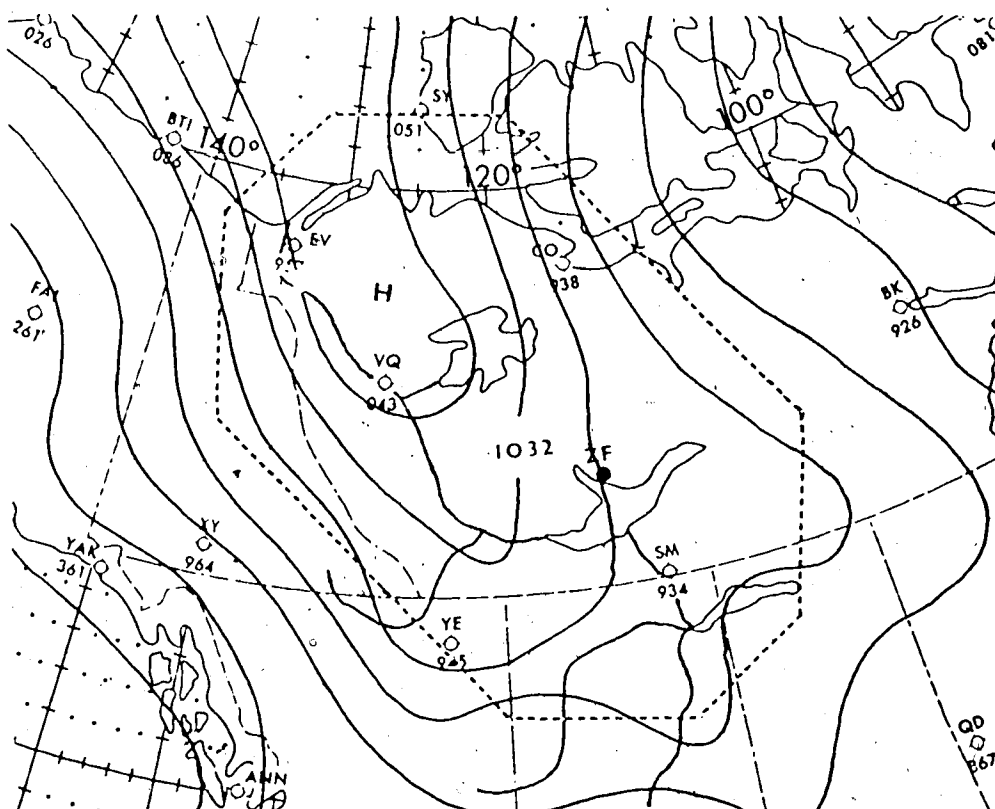
SURFACE MAP TYPE 9



KEY DATE - 12Z, 19 DEC 56

PERIOD	SEASON	DEC	JAN	FEB
OCCURRENCES/FREQUENCY	86/ 2	24/ 2	26/ 2	39/ 3
MEAN CORRELATION	0.859	0.853	0.857	0.864
MEAN PRESSURE (MSL)	19.28	18.22	17.98	20.78
MEAN PRESSURE GRADIENT	4.40	4.36	4.15	4.59
MEAN MAXIMUM GRADIENT	7.59	7.34	7.11	8.06
MEAN MINIMUM GRADIENT	1.24	1.27	1.21	1.24
MOST FREQUENTLY FOLLOWING MAP TYPE (MAP TYPE/FREQUENCY)	9/ 30 U/ 23 6/ 12 2/ 8 21/ 8	U/ 50 6/ 19 9/ 13 2/ 6 21/ 6	9/ 33 12/ 17 15/ 17 U/ 17 7/ 11	9/ 38 2/ 15 U/ 15 6/ 12 21/ 12
MOST FREQUENT DURATION (NUMBER OF 12-HOUR PERIODS/FREQUENCY)	1/ 74 2/ 14 3/ 7 4/ 5	1/ 86 2/ 14	1/ 70 2/ 10 3/ 10 4/ 10	1/ 60 2/ 20 3/ 13 4/ 7

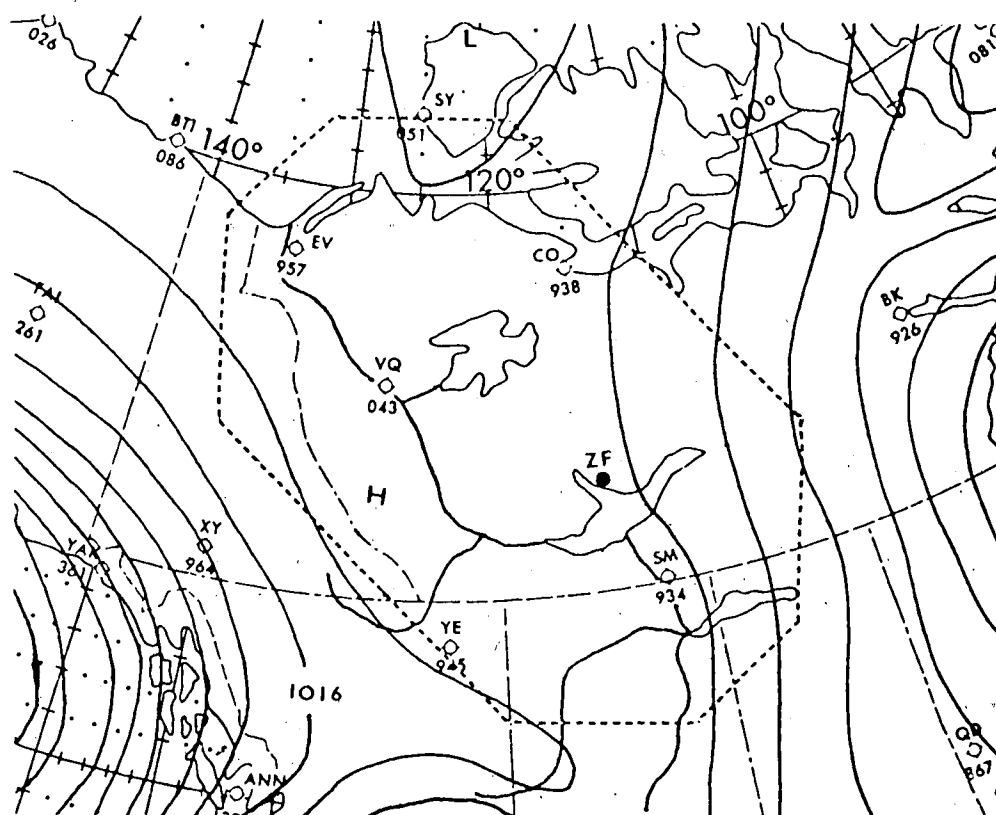
SURFACE MAP TYPE 10



KEY DATE - 12Z, 16 FEB 63

PERIOD	SEASON	DEC	JAN	FEB
OCCURRENCES/FREQUENCY	86/ 2	24/ 2	26/ 2	37/ 3
MEAN CORRELATION	0.869	0.863	0.869	0.874
MEAN PRESSURE (MSL)	21.47	22.24	18.00	23.41
MEAN PRESSURE GRADIENT	4.55	4.41	4.63	4.58
MEAN MAXIMUM GRADIENT	7.30	7.17	7.62	7.16
MEAN MINIMUM GRADIENT	2.06	2.09	2.14	1.99
MOST FREQUENTLY FOLLOWING MAP TYPE (MAP TYPE/FREQUENCY)	U/ 31 10/ 30 3/ 8 9/ 8 1/ 6	U/ 38 10/ 19 3/ 13 9/ 13 1/ 6	U/ 40 10/ 30 1/ 5 3/ 5 7/ 5	10/ 30 U/ 26 7/ 11 1/ 7 3/ 7
MOST FREQUENT DURATION (NUMBER OF 12-HOUR PERIODS/FREQUENCY)	1/ 64 2/ 31 3/ 2 4/ 2	1/ 77 2/ 23	1/ 54 2/ 46	1/ 67 2/ 28 3/ 6

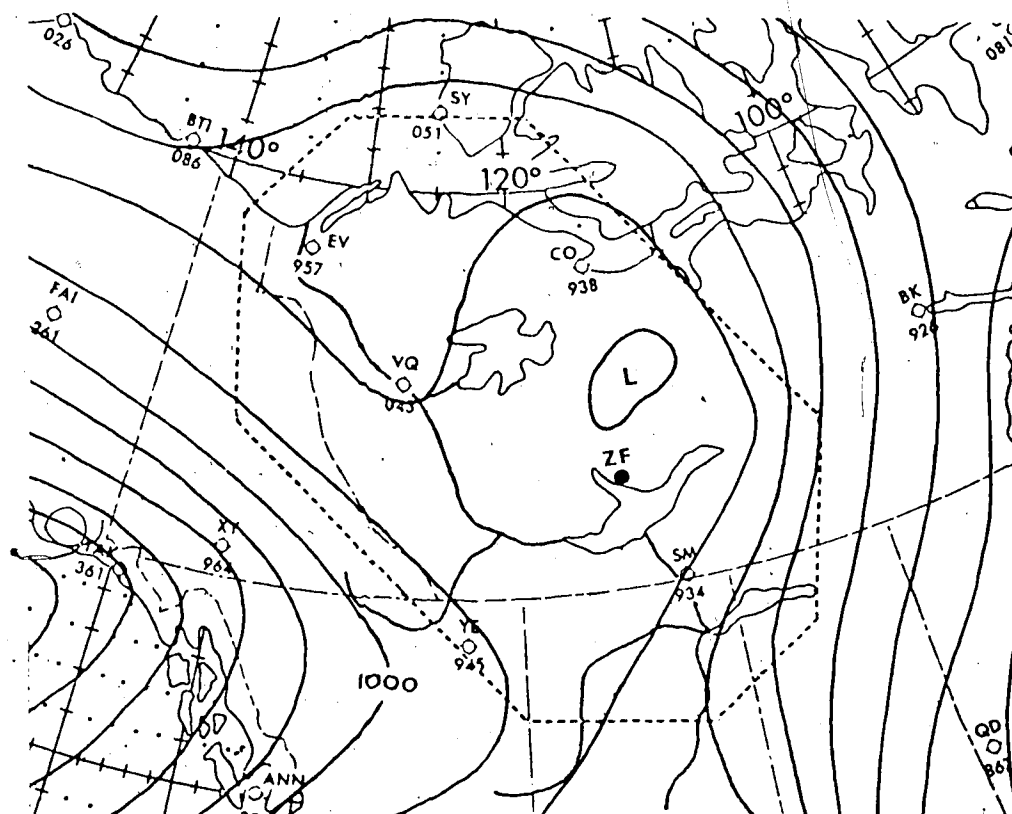
SURFACE MAP TYPE 11



KEY DATE - 12Z, 30 DEC 57

PERIOD	SEASON	DEC	JAN	FEB
OCCURRENCES/FREQUENCY	76/ 2	42/ 3	13/ 1	22/ 2
MEAN CORRELATION	0.874	0.870	0.883	0.875
MEAN PRESSURE (MSL)	14.16	12.90	16.70	15.07
MEAN PRESSURE GRADIENT	4.62	4.68	5.19	4.17
MEAN MAXIMUM GRADIENT	8.15	8.42	8.95	7.16
MEAN MINIMUM GRADIENT	1.78	1.85	1.76	1.66
MOST FREQUENTLY FOLLOWING MAP TYPE (MAP TYPE/FREQUENCY)	U/ 38 11/ 26 5/ 8 12/ 8 2/ 5	11/ 34 U/ 29 12/ 11 2/ 9 5/ 6	U/ 44 11/ 33 21/ 11 15/ 11	U/ 53 14/ 13 5/ 13 9/ 7 11/ 7
MOST FREQUENT DURATION (NUMBER OF 12-HOUR PERIODS/FREQUENCY)	1/ 80 2/ 11 3/ 4 4/ 2	1/ 78 2/ 9 3/ 4 4/ 4	1/ 67 2/ 17 3/ 17	1/ 93 2/ 7

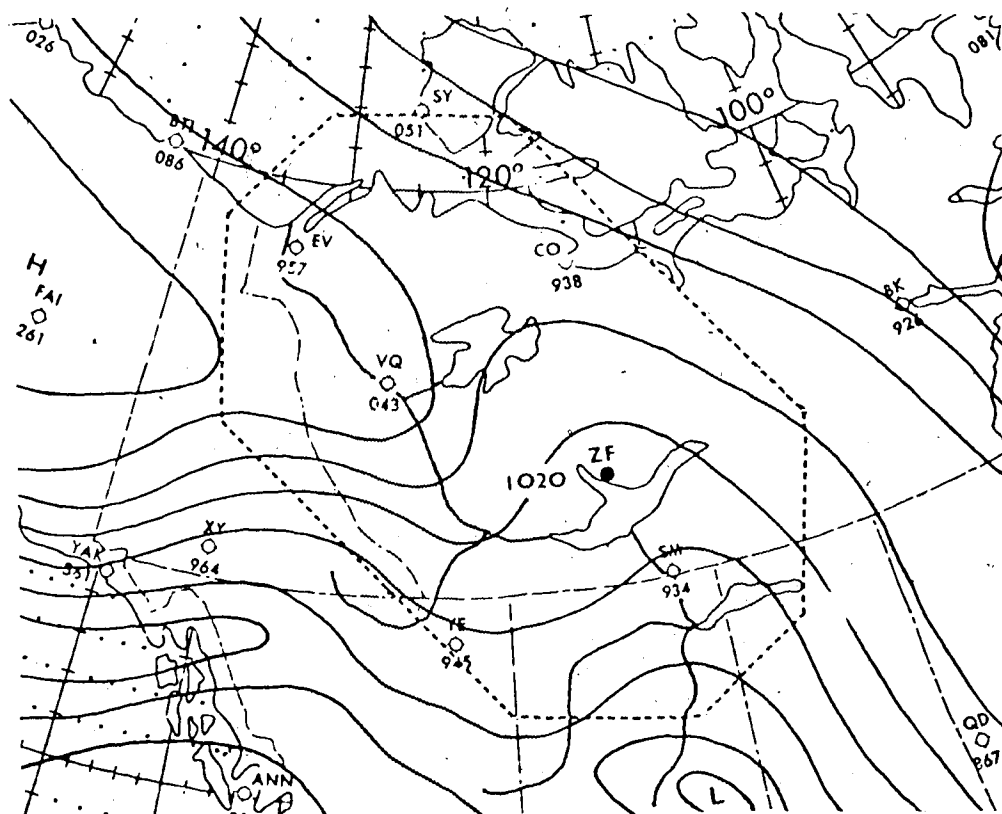
SURFACE MAP TYPE 12



KEY DATE - 12Z, 9 DEC 55

PERIOD	SEASON	DEC	JAN	FEB
OCCURRENCES/FREQUENCY	71/ 2	26/ 2	26/ 2	20/ 2
MEAN CORRELATION	0.866	0.883	0.859	0.854
MEAN PRESSURE (MSL)	11.71	8.92	12.27	14.62
MEAN PRESSURE GRADIENT	5.18	5.26	5.21	5.04
MEAN MAXIMUM GRADIENT	8.85	9.29	8.51	8.70
MEAN MINIMUM GRADIENT	2.41	2.26	2.50	2.48
MOST FREQUENTLY FOLLOWING MAP TYPE (MAP TYPE/FREQUENCY)	U/ 43 12/ 22 6/ 15 7/ 9 2/ 4	U/ 45 6/ 20 12/ 20 1/ 5 7/ 5	U/ 48 6/ 19 12/ 19 7/ 10 9/ 5	U/ 38 12/ 23 7/ 15 2/ 8 11/ 8
MOST FREQUENT DURATION (NUMBER OF 12-HOUR PERIODS/FREQUENCY)	1/ 76 2/ 19 3/ 5	1/ 77 2/ 15 3/ 8	1/ 81 2/ 13 3/ 6	1/ 70 2/ 30

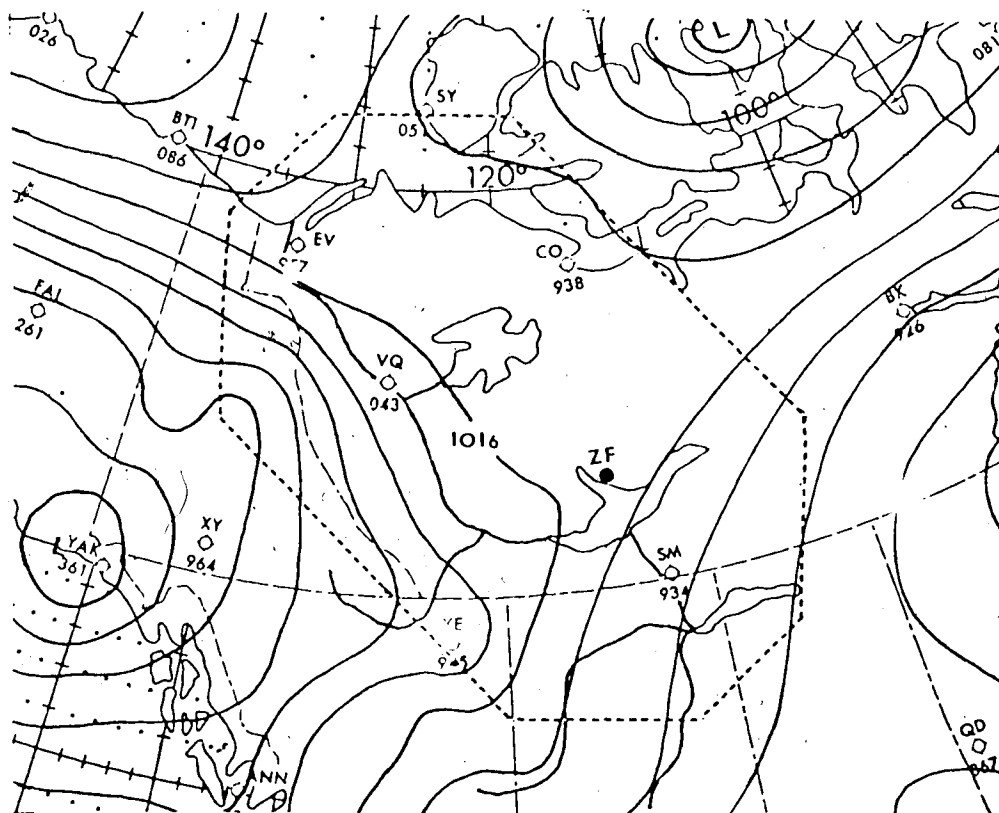
SURFACE MAP TYPE 13



KEY DATE - 12Z, 10 FEB 56

PERIOD	SEASON	DEC	JAN	FEB
OCCURRENCES/FREQUENCY	70/ 2	21/ 2	24/ 2	25/ 2
MEAN CORRELATION	0.862	0.877	0.856	0.854
MEAN PRESSURE (MSL)	21.09	21.91	20.62	20.84
MEAN PRESSURE GRADIENT	4.70	4.58	4.63	4.86
MEAN MAXIMUM GRADIENT	7.52	7.41	6.99	8.11
MEAN MINIMUM GRADIENT	2.06	1.99	2.17	2.01
MOST FREQUENTLY FOLLOWING MAP TYPE (MAP TYPE/FREQUENCY)	U/ 38 13/ 27 1/ 22 16/ 11 19/ 2	13/ 36 U/ 29 1/ 21 16/ 14	U/ 47 13/ 24 1/ 18 19/ 6 16/ 6	U/ 36 1/ 29 13/ 21 16/ 14
MOST FREQUENT DURATION (NUMBER OF 12-HOUR PERIODS/FREQUENCY)	1/ 70 2/ 24 3/ 6	1/ 67 3/ 22 2/ 11	1/ 67 2/ 33	1/ 73 2/ 27

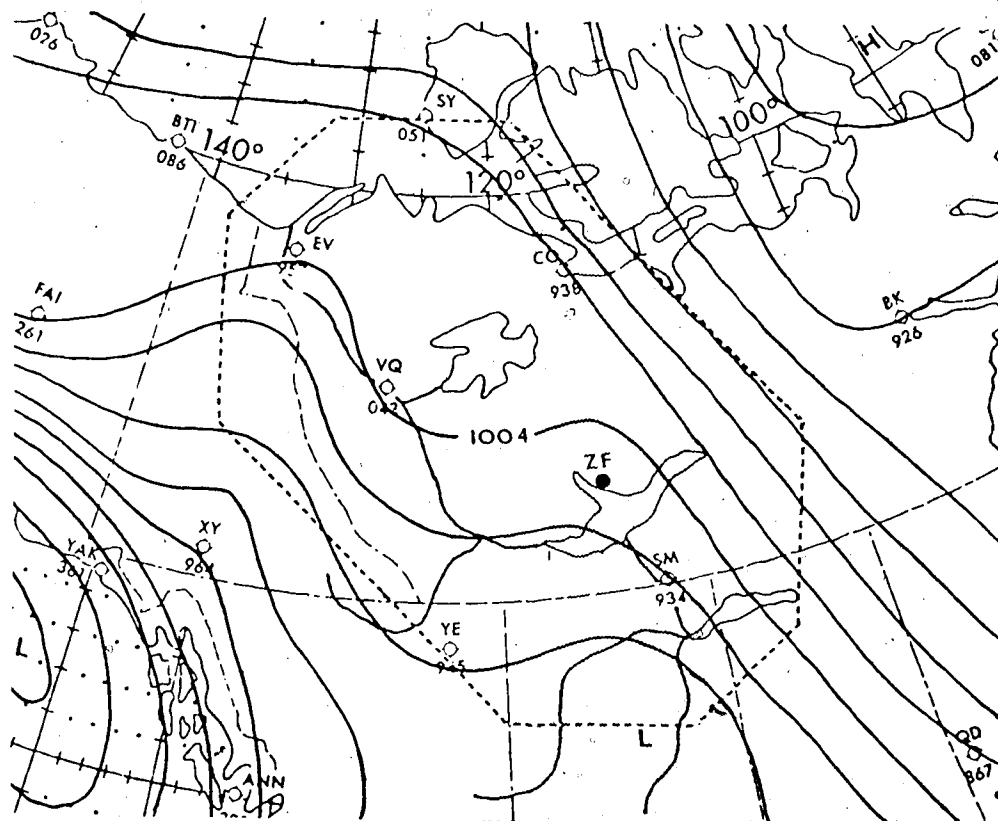
SURFACE MAP TYPE 14



KEY DATE - 12Z, 27 DEC 59

PERIOD	SEASON	DEC	JAN	FEB
OCCURRENCES/FREQUENCY	64/ 2	20/ 2	12/ 1	32/ 3
MEAN CORRELATION	0.867	0.860	0.870	0.870
MEAN PRESSURE (MSL)	14.43	12.58	16.38	14.85
MEAN PRESSURE GRADIENT	4.31	4.66	4.06	4.17
MEAN MAXIMUM GRADIENT	7.45	8.71	7.15	6.78
MEAN MINIMUM GRADIENT	1.54	1.67	1.05	1.65
MOST FREQUENTLY FOLLOWING MAP TYPE (MAP TYPE/FREQUENCY)	U/ 40 14/ 21 12/ 15 7/ 6 11/ 6	U/ 46 14/ 31 2/ 8 5/ 8 12/ 8	12/ 38 0/ 38 7/ 13 14/ 13	U/ 38 14/ 19 11/ 12 7/ 8 12/ 8
MOST FREQUENT DURATION (NUMBER OF 12-HOUR PERIODS/FREQUENCY)	1/ 79 2/ 18 3/ 3	1/ 56 2/ 44	1/ 86 2/ 14	1/ 85 2/ 10 3/ 5

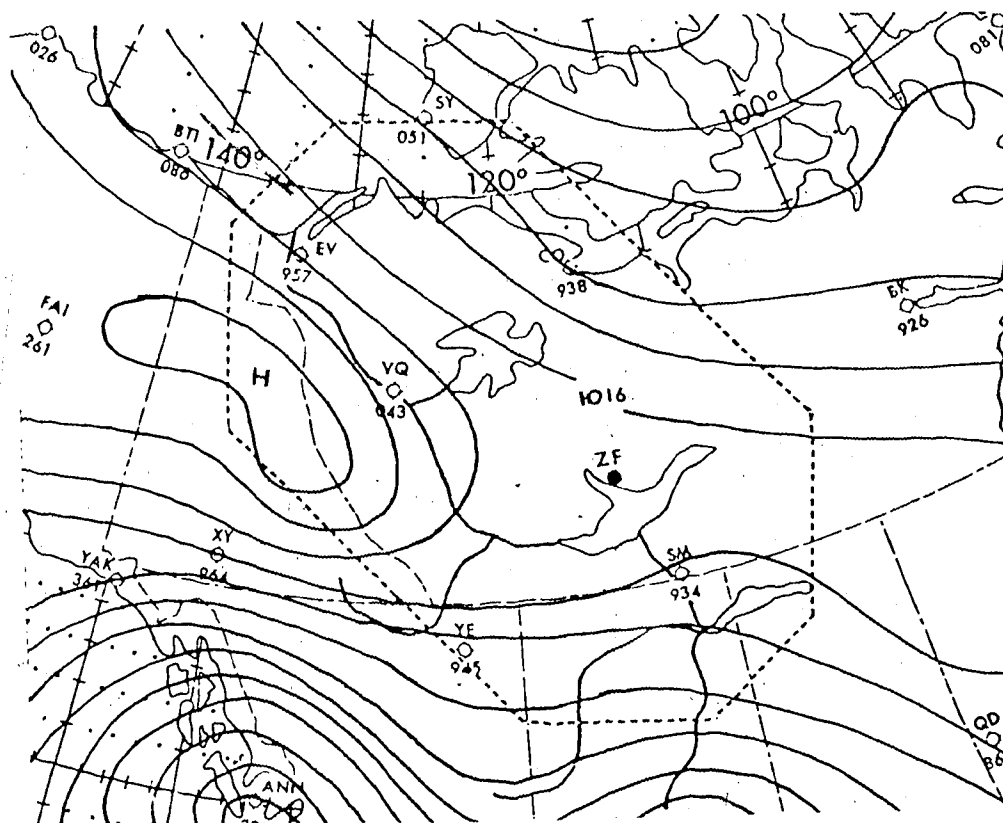
SURFACE MAP TYPE 15



KEY DATE - 12Z, 4 DEC 67

PERIOD	SEASON	DEC	JAN	FEB
OCCURRENCES/FREQUENCY	64/ 2	27/ 2	18/ 1	19/ 2
MEAN CORRELATION	0.857	0.865	0.847	0.855
MEAN PRESSURE (MSL)	15.81	12.13	20.03	17.06
MEAN PRESSURE GRADIENT	5.00	4.74	5.12	5.26
MEAN MAXIMUM GRADIENT	8.63	7.65	10.67	8.10
MEAN MINIMUM GRADIENT	2.29	2.27	2.19	2.42
MOST FREQUENTLY FOLLOWING MAP TYPE (MAP TYPE/FREQUENCY)	15/ 32 0/ 24 6/ 18 2/ 14 7/ 2	15/ 50 0/ 18 6/ 9 2/ 9 9/ 5	0/ 38 6/ 31 15/ 19 2/ 6 13/ 6	2/ 36 15/ 18 0/ 18 6/ 9 7/ 9
MOST FREQUENT DURATION (NUMBER OF 12-HOUR PERIODS/FREQUENCY)	1/ 68 2/ 26 3/ 3 6/ 3	1/ 40 2/ 40 3/ 10 6/ 10	1/ 75 2/ 25	1/ 78 2/ 22

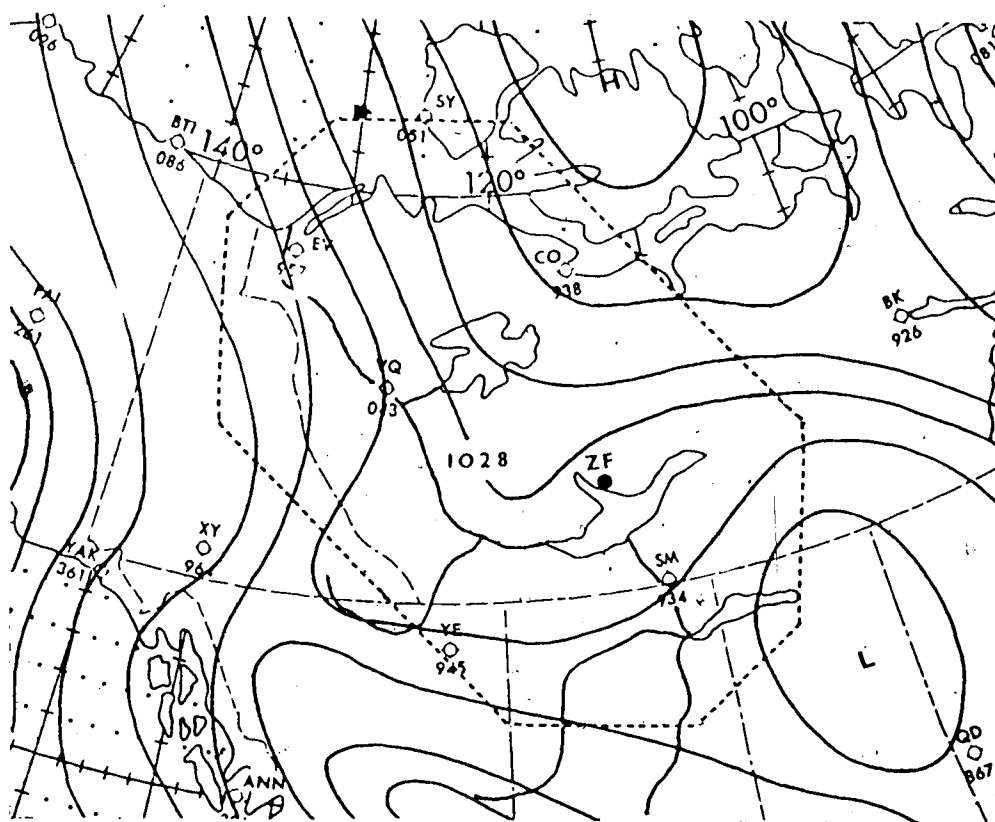
SURFACE MAP TYPE 16



KEY DATE - 12Z, 5 DEC 66

PERIOD	SEASON	DEC	JAN	FEB
OCCURRENCES/FREQUENCY	61/ 2	26/ 2	26/ 2	12/ 1
MEAN CORRELATION	0.864	0.870	0.860	0.860
MEAN PRESSURE (MSL)	21.72	21.02	22.76	20.97
MEAN PRESSURE GRADIENT	5.15	5.30	5.41	4.27
MEAN MAXIMUM GRADIENT	8.36	8.12	8.74	8.03
MEAN MINIMUM GRADIENT	2.01	2.32	2.13	1.06
MOST FREQUENTLY FOLLOWING MAP TYPE (MAP TYPE/FREQUENCY)	16/ 35 0/ 29 4/ 15 3/ 6 17/ 4	16/ 39 4/ 30 0/ 17 22/ 9 6/ 4	16/ 35 0/ 25 3/ 15 17/ 10 4/ 5	0/ 56 16/ 33 13/ 11
MOST FREQUENT DURATION (NUMBER OF 12-HOUR PERIODS/FREQUENCY)	1/ 67 2/ 23 3/ 7 4/ 3	1/ 67 2/ 17 3/ 17	1/ 50 2/ 42 3/ 8	1/ 83 4/ 17

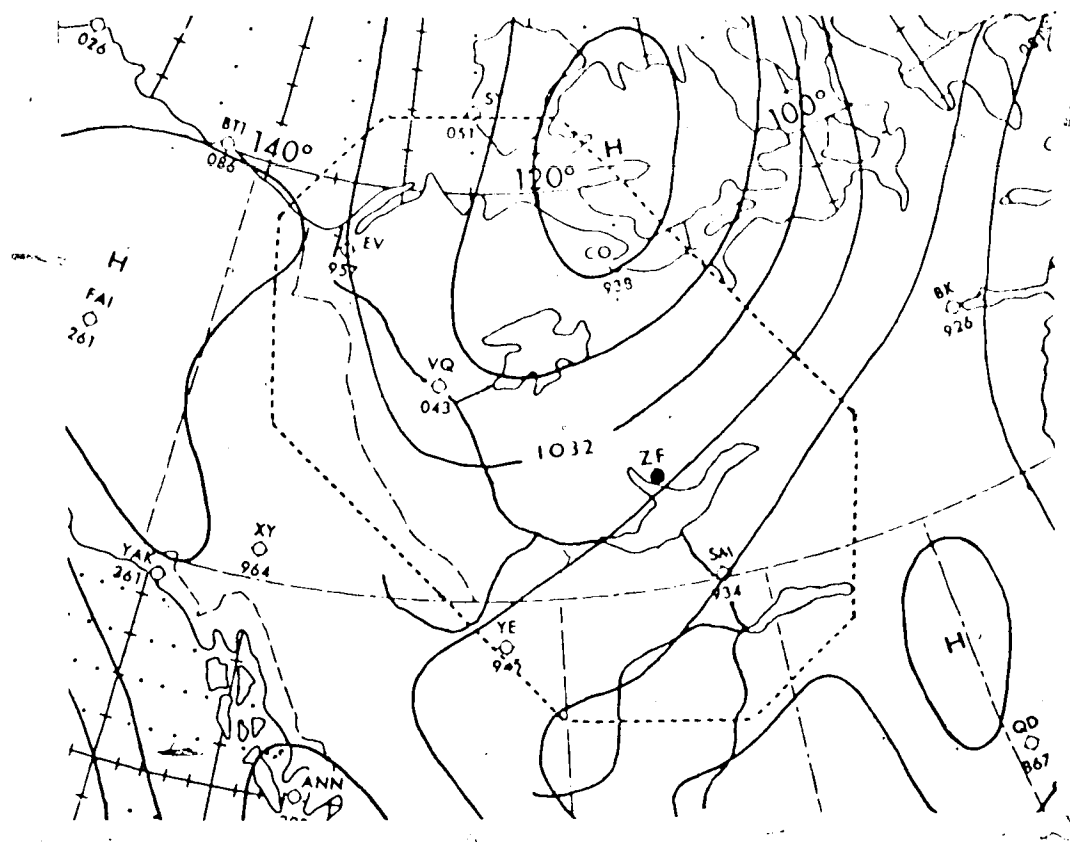
SURFACE MAP TYPE 18



KEY DATE - 12Z, 7 FEB 68

PERIOD	SEASON	DEC	JAN	FEB
OCCURRENCES/FREQUENCY	50/ 1	19/ 1	13/ 1	21/ 2
MEAN CORRELATION	0.853	0.848	0.862	0.851
MEAN PRESSURE (MSL)	16.54	12.08	18.50	19.36
MEAN PRESSURE GRADIENT	4.39	4.47	4.24	4.40
MEAN MAXIMUM GRADIENT	7.47	7.53	7.14	7.61
MEAN MINIMUM GRADIENT	1.93	1.94	1.82	2.00
MOST FREQUENTLY FOLLOWING MAP TYPE (MAP TYPE/FREQUENCY)	2/ 52 0/ 22 8/ 9 6/ 9 18/ 9	2/ 50 0/ 38 6/ 13	2/ 33 18/ 33 0/ 33	2/ 60 8/ 20 6/ 10 7/ 10
MOST FREQUENT DURATION (NUMBER OF 12-HOUR PERIODS/FREQUENCY)	1/ 90 2/ 10	1/100	1/ 50 2/ 50	1/100

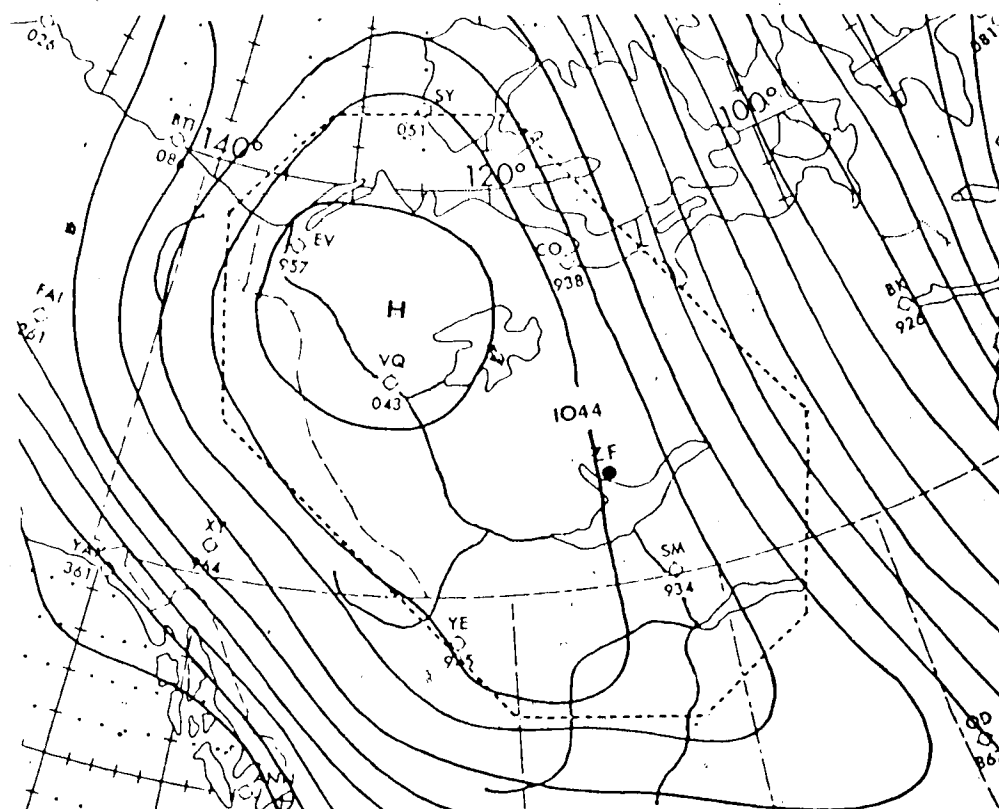
SURFACE MAP TYPE 19



KEY DATE - 12Z, 16 FEB 60

PERIOD	SEASON	DEC	JAN	FEB
OCCURRENCES/FREQUENCY	46/ 1	16/ 1	18/ 1	13/ 1
MEAN CORRELATION	0.851	0.857	0.839	0.861
MEAN PRESSURE (MSL)	19.71	12.12	22.82	24.74
MEAN PRESSURE GRADIENT	4.64	4.36	5.17	4.25
MEAN MAXIMUM GRADIENT	8.51	7.94	10.35	6.67
MEAN MINIMUM GRADIENT	1.96	2.23	1.80	1.85
MOST FREQUENTLY FOLLOWING MAP TYPE (MAP TYPE/FREQUENCY)	U/ 32 19/ 26 6/ 10 2/ 10 18/ 10	18/ 27 19/ 18 U/ 18 1/ 9 6/ 9	19/ 33 U/ 25 6/ 17 2/ 8 23/ 8	U/ 57 19/ 29 2/ 14 1
MOST FREQUENT DURATION (NUMBER OF 12-HOUR PERIODS/FREQUENCY)	1/ 70 2/ 26 3/ 4	1/ 78 2/ 22	1/ 63 2/ 25 3/ 13	1/ 60 2/ 40

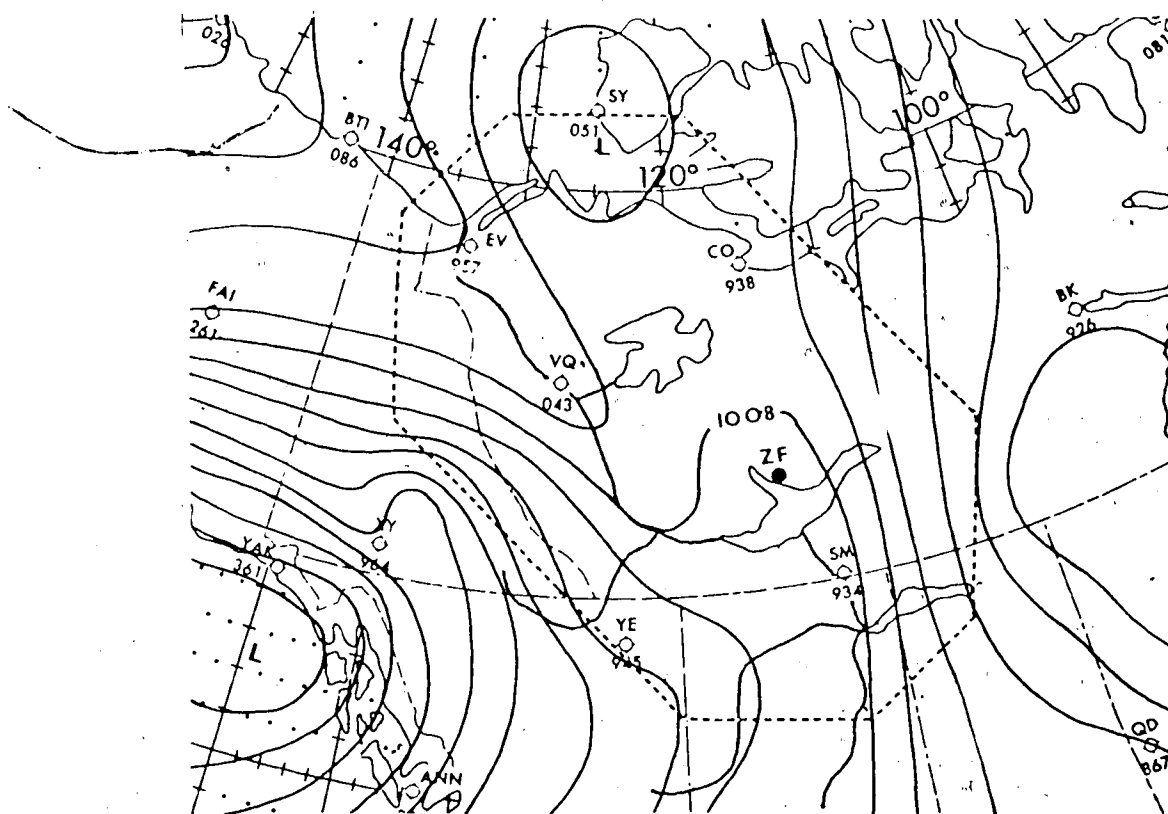
SURFACE MAP TYPE 20



KEY DATE - 12Z, 19 DEC 60

PERIOD	SEASON	DEC	JAN	FEB
OCCURRENCES/FREQUENCY	34/ 1	11/ 1	11/ 1	12/ 1
MEAN CORRELATION	0.859	0.865	0.851	0.862
MEAN PRESSURE (MSL)	26.57	22.34	28.48	28.70
MEAN PRESSURE GRADIENT	4.35	4.03	4.82	4.20
MEAN MAXIMUM GRADIENT	7.42	6.66	8.57	7.07
MEAN MINIMUM GRADIENT	1.60	1.63	1.58	1.59
MOST FREQUENTLY FOLLOWING MAP TYPE (MAP TYPE/FREQUENCY)	U/ 43 20/ 19 8/ 10 2/ 10 1/ 5	20/ 40 U/ 40 8/ 20	U/ 33 20/ 22 7/ 11 2/ 11 13/ 11	U/ 57 8/ 14 2/ 14 24/ 14
MOST FREQUENT DURATION (NUMBER OF 12-HOUR PERIODS/FREQUENCY)	1/ 82 2/ 12 3/ 6	2/ 67 1/ 33	1/ 83 3/ 17	1/100

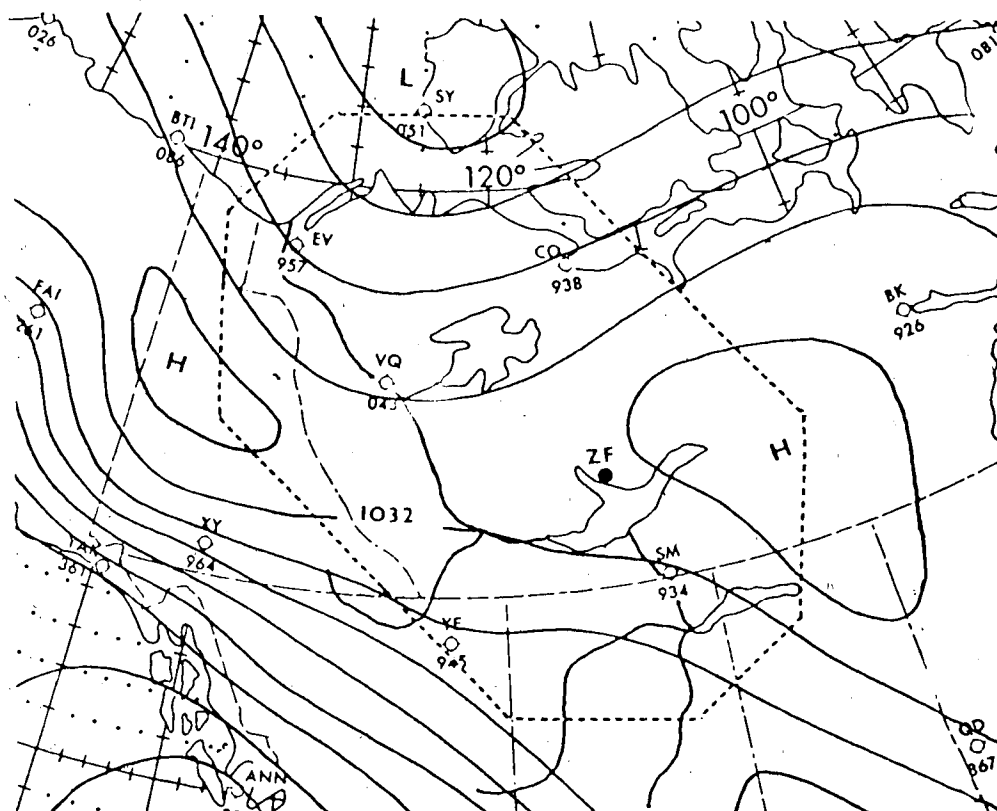
SURFACE MAP TYPE 21



KEY DATE - 12Z, 10 FEB 57

PERIOD	SEASON	DEC	JAN	FEB
OCCURRENCES/FREQUENCY	32/ 1	10/ 1	5/ 0	18/ 2
MEAN CORRELATION	0.861	0.8	0.857	0.864
MEAN PRESSURE (MSL)	14.57	11.84	18.37	15.02
MEAN PRESSURE GRADIENT	4.64	4.62	4.38	4.71
MEAN MAXIMUM GRADIENT	7.96	8.45	7.80	7.73
MEAN MINIMUM GRADIENT	1.62	1.25	1.71	1.79
MOST FREQUENTLY FOLLOWING MAP TYPE (MAP TYPE/FREQUENCY)	U/ 41 13/ 32 21/ 14 6/ 5 19/ 5	13/ 29 0/ 29 21/ 14 19/ 14 15/ 14	U/ 80 21/ 20	13/ 45 0/ 27 4/ 9 6/ 9 21/ 9
MOST FREQUENT DURATION (NUMBER OF 12-HOUR PERIODS/FREQUENCY)	1/ 84 2/ 16	1/ 83 2/ 17	1/ 67 2/ 33	1/ 89 2/ 11

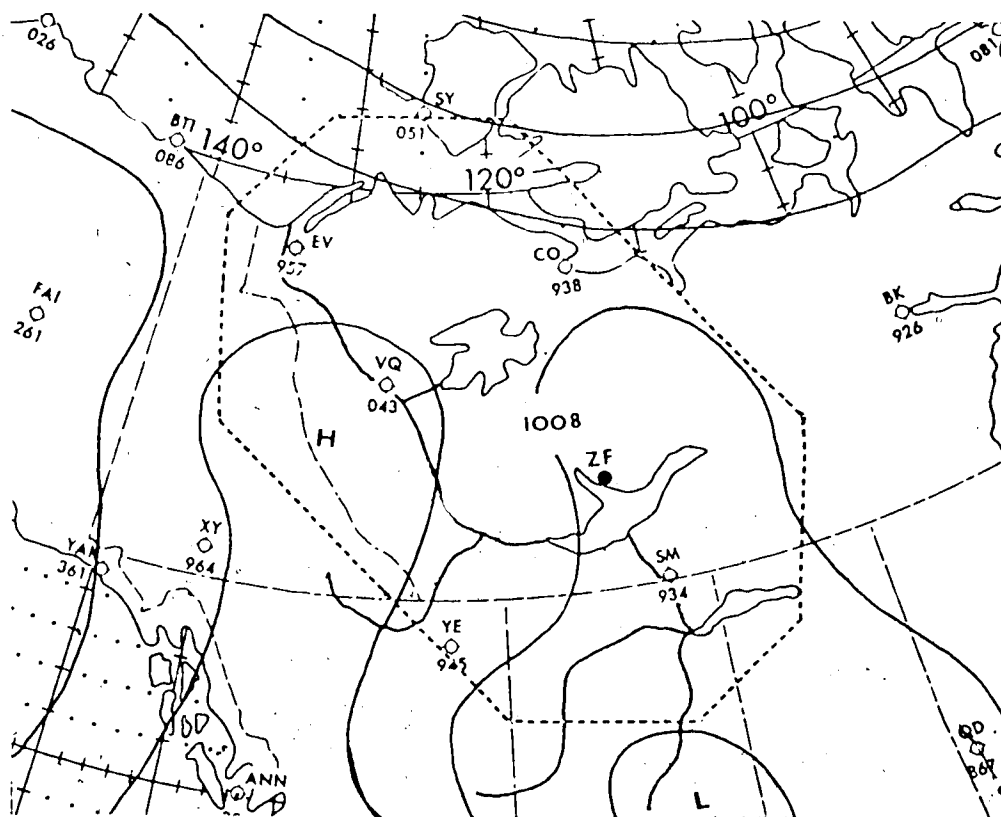
SURFACE MAP TYPE 22



KEY DATE - 12Z, 3 DEC 70

PERIOD	SEASON	DEC	JAN	FEB
OCCUPRENCES/FREQUENCY	21/ 1	13/ 1	6/ 0	3/ 0
MEAN CORRELATION	0.847	0.858	0.822	0.851
MEAN PRESSURE (MSL)	21.40	19.15	27.55	18.85
MEAN PRESSURE GRADIENT	4.40	4.82	3.87	3.68
MEAN MAXIMUM GRADIENT	8.23	9.16	7.34	6.59
MEAN MINIMUM GRADIENT	1.52	1.58	1.57	1.17
MOST FREQUENTLY FOLLOWING MAP TYPE (MAP TYPE/FREQUENCY)	0/ 40 4/ 27 22/ 20 13/ 13	0/ 33 22/ 25 4/ 17 13/ 17 16/ 8	0/100	4/100
MOST FREQUENT DURATION (NUMBER OF 12-HOUR PERIODS/FREQUENCY)	1/ 75 2/ 25	1/ 67 2/ 33	1/100	1/100

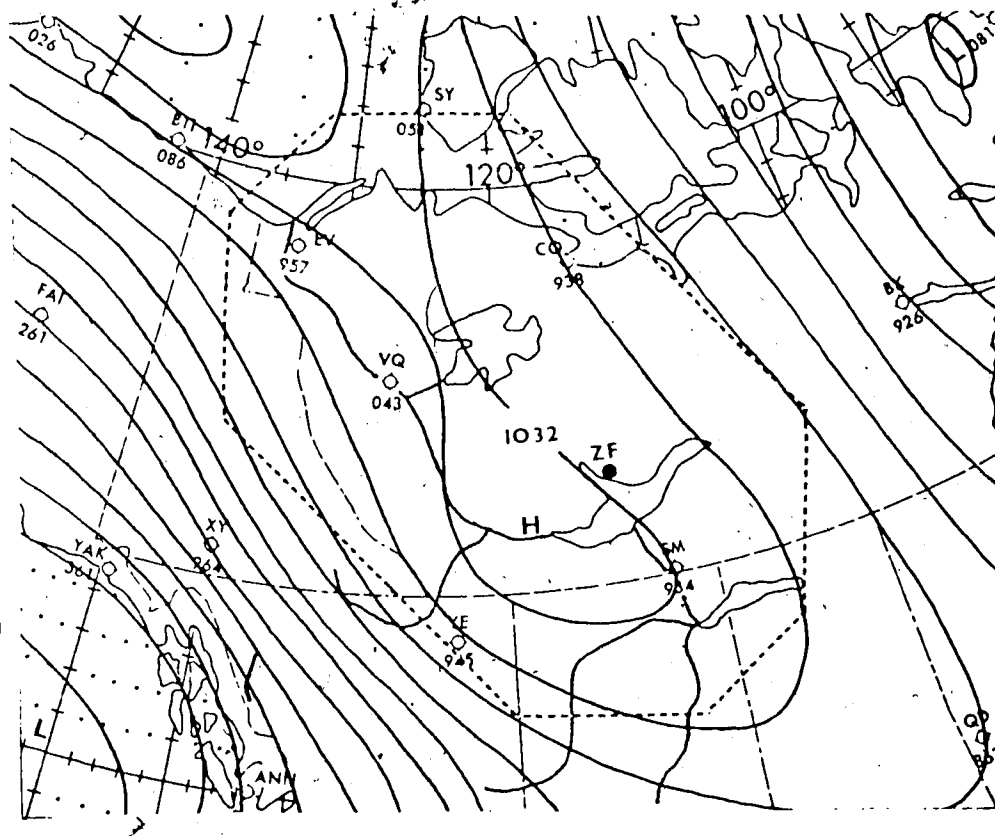
SURFACE MAP TYPE 23



KEY DATE - 12Z, 13 JAN 55

PERIOD	SEASON	DEC	JAN	FEB
OCCURRENCES/FREQUENCY	17/ 0	7/ 1	8/ 1	2/ 0
MEAN CORRELATION	0.862	0.870	0.861	0.839
MEAN PRESSURE (MSL)	28.40	32.79	27.36	17.20
MEAN PRESSURE GRADIENT	4.04	4.29	3.80	4.13
MEAN MAXIMUM GRADIENT	6.45	6.39	6.22	7.60
MEAN MINIMUM GRADIENT	1.21	1.45	1.11	0.75
MOST FREQUENTLY FOLLOWING MAP TYPE (MAP TYPE/FREQUENCY)	U/ 60 23/ 27 1/ 7 19/ 7	23/ 57 U/ 43	U/ 67 1/ 17 19/ 17	U/100
MOST FREQUENT DURATION (NUMBER OF 12-HOUR PERIODS/FREQUENCY)	1/ 82 2/ 9 4/ 9	1/ 33 2/ 33 4/ 33	1/100	1/100

SURFACE MAP TYPE 24



KEY DATE - 12Z, 19 FEB 68

PERIOD	SEASON	DEC	JAN	FEB
OCCURRENCES/FREQUENCY	11/ 0	2/ 0	1/ 0	8/ 1
MEAN CORRELATION	0.853	0.858	0.819	0.856
MEAN PRESSURE (MSL)	26.05	24.65	26.95	26.29
MEAN PRESSURE GRADIENT	4.30	3.55	3.88	4.54
MEAN MAXIMUM GRADIENT	8.38	7.10	6.02	8.99
MEAN MINIMUM GRADIENT	1.72	2.25	2.06	1.55
MOST FREQUENTLY FOLLOWING MAP TYPE (MAP TYPE/FREQUENCY)	U/ 45 7/ 18 2/ 18 9/ 9 24/ 9	7/ 50 2/ 50	9/100	U/ 63 7/ 13 2/ 13 24/ 13
MOST FREQUENT DURATION (NUMBER OF 12-HOUR PERIODS/FREQUENCY)	1/ 90 2/ 10	1/100	1/100	1/ 86 2/ 14

SURFACE MAP TYPE U

PERIOD	SEASON	DEC	JAN	FEB
OCCURRENCES/FREQUENCY	1263/ 34	471/ 36	415/ 32	414/ 35
MEAN CORRELATION	0.702	0.697	0.702	0.706
MEAN PRESSURE (MSL)	19.65	17.17	22.01	20.12
MEAN PRESSURE GRADIENT	4.04	4.14	4.10	3.88
MEAN MAXIMUM GRADIENT	7.03	7.25	7.07	6.74
MEAN MINIMUM GRADIENT	1.57	1.63	1.58	1.48
MOST FREQUENTLY FOLLOWING MAP TYPE (MAP TYPE/FREQUENCY)	0/ 52 1/ 6 4/ 4 8/ 4 7/ 4	0/ 54 1/ 7 4/ 6 8/ 4 5/ 4	0/ 50 4/ 7 1/ 7 2/ 5 8/ 4	0/ 51 2/ 6 1/ 5 7/ 5 14/ 5
MOST FREQUENT DURATION (NUMBER OF 12-HOUR PERIODS/FREQUENCY)	1/ 49 2/ 25 3/ 14 4/ 5	1/ 46 2/ 28 3/ 16 4/ 5	1/ 56 2/ 21 3/ 13 4/ 4	1/ 50 2/ 26 3/ 9 4/ 7

APPENDIX 4

THE BRIER P-SCORE

The simple forecast model used in this study is based on the conditional probabilities of ceiling and visibility categories. Root (1962) stresses the importance of resolution and reliability when evaluating weather forecasts that contain numerical probability statements. Forecasts with good resolution have forecast probabilities near zero percent or 100 percent. Those with poor resolution have probabilities near the climatological frequency. Forecasts with good reliability have event forecast probabilities which correspond closely with the relative frequency of the respective events.

In this study, weather events are related to synoptic situations. Hence, successive hourly forecasts for a given situation are not likely to be independent. Thus, where the number of forecasts in a given category is small, a single synoptic situation may account for a large percentage of the cases. This introduces a bias in the observed frequency of occurrence. A stable observed frequency of event occurrence is required to maintain good forecast reliability; this can best be accomplished by having a large number of occurrences. Reliability is important in this study because increased data stratification results in fewer cases available for calculating forecast conditional probabilities. Hopefully, any loss of reliability due to increased stratification can be more than compensated for by better

resolution.

A good verification score to use in this study is the Brier P-Score (Brier, 1950) because it measures both the resolution and reliability of probability forecasts. The score is calculated from the formula

$$P = \frac{1}{N} \sum_{j=1}^r \sum_{i=1}^N (f_{ij} - E_{ij})^2, \quad (A4-1)$$

where on each of N occasions an event can occur in one of r possible categories, and f_{ij} represents the probability that the forecast was for a category j occurrence. In this study the r categories for each forecast parameter are mutually exclusive and exhaustive, i.e.,

$$\sum f_{ij} = 1$$

E_{ij} takes the value of one or zero, depending on whether or not the event occurred, respectively, in category j . The best score for perfect forecasting is a value of zero and the worst value possible is two. This score represents essentially the mean of the squares of the difference between the forecast and observed probability distributions. It is desirable to have a minimum difference; therefore, a good score has a small value.

To isolate the reliability factor in the P-Score formula, it is best to consider each individual category forecast separately, rather than referring to a set of category forecasts. The Brier Score for N forecasts now reduces to

$$B = \frac{1}{N} \sum_{i=1}^N (f_i - E_i)^2, \quad (A4-2)$$

and the maximum possible value is one, rather than two.

The forecast reliability is determined by comparing the forecast probabilities against the observed percent occurrences of an event. To facilitate such a comparison, the forecast probabilities can be subdivided into intervals of 10 percent width, so that all probabilities f_i , are expressed in tenths. This results in 11 classes

$$f_i = 0.0, 0.1, 0.2, \dots, f_k, \dots$$

where f_1 contains probabilities from 0.0 to 0.04, f_2 from 0.05 to 0.14 ... etc.

Consider a class "k" which consists of M_k probability forecasts of a category, and a total of R_k event occurrences. The ratio of event occurrences to probability forecasts for the k^{th} class is

$$\phi_k = \frac{R_k}{M_k} \quad (\text{A4-3})$$

For example, if the ceiling category A occurred seven times, and was forecast at a probability of 80 percent to occur ten times, then

$$\phi_9 = \frac{7}{10} = 0.7.$$

From (A4-2), the contribution to the Brier Score for the event occurrences is $1/M_k (f_k - 1)^2 R_k$, and the contribution for non-occurrences is $1/M_k (f_k - 0)^2 (M_k - R_k)$. The Brier Score for the k^{th} class becomes

$$B_k = (f_k - 1)^2 \phi_k + f_k^2 (1 - \phi_k). \quad (\text{A4-4})$$

By adding and subtracting ϕ_k^2 and rearranging terms, (A4-4) can be

written as

$$B_k = (f_k - \phi_k)^2 + \phi_k (1 - \phi_k). \quad (A4-5)$$

The score for the whole set of N forecasts of a category is the weighted average of the scores obtained in the 11 classes

$$B = \frac{1}{N} \sum_{k=1}^{11} M_k B_k = \frac{1}{N} \sum_{k=1}^{11} M_k \{(f_k - \phi_k)^2 + \phi_k (1 - \phi_k)\}. \quad (A4-6)$$

In this form the Brier-score formula is separated into its reliability and resolution components.

The reliability term, $(f_k - \phi_k)^2$, measures the difference between the forecast probability f_k and the relative frequency of occurrence of the event, ϕ_k . A root-mean-square error (RMSE) in reliability can be defined from (A4-6) as

$$RMSE = \frac{100}{N} \sum_{k=1}^{11} M_k (f_k - \phi_k)^2, \quad (A4-7)$$

with the values expressed as percentages.

The second term in (A4-6) expresses the resolution of the forecasts and depends only on the value of ϕ_k . It has a minimum value when ϕ_k is either one or zero. This happens when the event always occurs when forecast at 100 percent probability, or when the event never occurs when forecast at zero percent. When $\phi_k = 0.5$, the resolution term has its maximum value of 0.25.

In this study Brier Scores are used to verify probability forecasts based on pure seasonal climatic frequencies, as well as those based on climatic frequencies that have been stratified by map type and pressure gradient. To compare results, a simple skill score

is used that gives the percentage improvement of stratified-climatology forecasts over pure climatology forecasts. It is calculated from the formula

$$S = 100 (1 - sB/cB),$$

where sB is the Brier Score for stratified forecasts and cB is the score for climatology forecasts.