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THE WINTERTIME ARCTIC FRONT AND ITS EFFECTS ON FAIRBANKS

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ABSTRACT

Surface and upper-air data for a four month period during the winter of 1974-75 were examined. The purpose is to determine a method to locate and predict the movement of the wintertime arctic front over Alaska. Ten cases each of the front passing north and south over Fairbanks were studied. Frontal effects on Fairbanks were noted and methods to forecast the timing of the frontal passage at Fairbanks were determined. Movement of the arctic front over interior Alaska was found to be directly related to the location and movement of large low pressure systems in the Gulf of Alaska.

Only very light snowfall accompanied the front as it passed northward over Fairbanks. However, southward passage of the front accounted for 77% of the Fairbanks snowfall during the 4 month period of study. A marked temperature and moisture difference was evident between the two air masses separated by the arctic front. Periods of extreme cold with clear skies and ice fog were possible when the front remained south of Fairbanks for several days. Cloudy skies and mild temperatures predominated when the front was to the north. The 850 mb analysis using 2°C isotherm separation and 30 m height difference and the plotted Fairbanks radiosonde are suggested as tools for use in forecasting the movement of the arctic front across Fairbanks.

INTRODUCTION

The existence of the arctic front over Alaska during the winter months has been recognized by several authors. However, such articles have usually dealt with climatological positions or case studies. Investigations concerned with the structure and movement of the arctic front and associated weather over Alaska have been notably absent.

Billello (1974) described briefly the arctic front over Alaska and the synoptic situations which govern its movement. Williams (1958) described the passage of what he referred to as the secondary arctic front over interior Alaska as well as the associated synoptic situation. He stated this front, under particular conditions, is associated with significant winter weather patterns. Hare (1968) recognized the reality of an arctic front over Siberia and North America throughout the year, but found it is not simply related to surface controls. However, Reed (1960), using surface positions, found that a Siberian-Canadian arctic front through Alaska exists in summer only and has no winter counterpart. Barry (1967) identified the arctic front over Alaska based on 850 mb charts and located the front over interior Alaska at least 50% of the time in January. McIntyre and Lee (1954) and McIntyre (1958) briefly discussed the continental arctic front over interior Alaska and an associated continental arctic jet stream.

It is interesting to note that Reed (1960) failed to locate the surface arctic front over Alaska during winter, whereas Barry (1967), using 850 mb data, found the front was present a large percent of the time. Locating the arctic front during the winter months over interior Alaska from surface observations can be very difficult. Local variations in sky cover and wind can greatly affect surface temperatures. In some instances, surface temperatures south of the front have been found to be colder than those immediately north of the front.

The interaction between the surface based temperature inversion and the arctic front must also be considered. Benson (1970) found the inversions at Fairbanks to be among the steepest in the world and Wendler and Nicpon (1975) found that from November 1967 through February 1968 a surface inversion was observed 95% of the time. The presence of very cold surface air results in frontal systems frequently being forced aloft. Depending on the temperatures of the two air masses, even cold arctic fronts usually "float" on this cold pool of surface air. The existence of a surface arctic front over interior Alaska is subject to question. Although little published work has been done on the interaction between the surface inversion in Alaska and frontal systems, forecasters have observed the arctic front with its associated weather and have been plagued with the problem of trying to forecast the movement of the front from only sparse surface observations and 12 hour interval upper-air reports. Alaskan forecasters have realized the futility of locating the arctic front from surface observations and have relied on detailed 850 mb analyses for general placement of the frontal system. However, the exact position is seldom known and forecasting

future movement is extremely difficult. Because of the protective surface cold dome, hourly reports have only limited value and great emphasis must be placed on the 12 hour upper-air reports.

Although little work has been done on the arctic front over interior Alaska, several authors have indirectly mentioned the system. Benson (1970) and Bowling and others (1968) referred to the cooling aloft observed at the beginning of an ice fog period at Fairbanks. Bodurtha (1952) briefly mentioned the pre-existence of cold air in the low and middle troposphere over Alaska during anticyclogenesis and Robinson (1955) briefly mentioned significant cooling at 1500 m observed with unstable surface conditions at Eielson Air Force Base, near Fairbanks. In all the above, conditions were similar to those found in this study during the passage of the arctic front.

The Weather Service Forecast Office at Fairbanks was formed in April 1974. During the early winter of 1974, it became apparent that an investigation into the arctic front and associated weather could be beneficial to Fairbanks' forecasters. The purpose of this paper is to establish tools which can be used to forecast the movement of the arctic front over the immediate Fairbanks area and to construct a model for the passage of the front when moving from north to south and south to north. Such a model would be invaluable to the Alaskan forecaster. Because of the varied topography and paucity of data in Alaska, a model of the front would allow the forecaster to understand the physical processes which are occurring during the passage of the arctic front. Also a simple model would assist the forecaster by relating weather conditions to the synoptic situation. Such synoptic models, which have prevailed in the mid-latitudes for many years, are severely lacking over northern Alaska. The presence of numerous mountain ranges in Alaska which hinder the flow of moisture, and the presence of strong surface-based inversions, result in synoptic situations for which no mid-latitude models are applicable. Although computer prognostic charts are becoming very accurate over northern Alaska, the existence of a perfect prognostic package does not necessitate a perfect forecast. A model of the movement of the arctic front and associated weather over central and northern Alaska in general and over Fairbanks in particular is greatly needed.

DATA AND PROCEDURE

When the data was first compiled, the Weather Service Forecast Office (WSFO) in Fairbanks had been in operation for only one year, so only the data for winter (November-February) of 1974-1975 were available for this study. Surface and upper-air analyses prepared by the National Meteorological Center and the WSFO Anchorage were examined. Upper-air charts from the above offices consisted of 60 m height contours and 5°C isotherms. Also available were 850 mb analyses routinely prepared by the WSFO in Fairbanks that depict 30 m height contours and 2°C isotherms. Other data examined were hourly aviation weather observations for interior Alaskan stations, plotted pseudoadiabatic charts, and time cross sections for Fairbanks.

The 850 mb analysis prepared by the WSFO at Fairbanks was the basic tool used for locating the arctic front. Twelve-hour 850 mb temperature changes were examined to detect the movement of the front across Fairbanks and other upper-air observing stations. An 850 mb temperature change of at least 7°C in 12 hour or 10°C in 24 hour periods was arbitrarily set as the minimum temperature change necessary to qualify as a frontal passage at Fairbanks. Undoubtedly, weaker fronts passed over Fairbanks during the period of interest, but the above criteria were established to depict only the stronger fronts. It was felt that conditions which applied to strong frontal passages would also apply to weaker fronts, yet synoptic conditions with the stronger fronts would be more clearly delineated.

Based on the above frontal passage criteria, 10 cases each of the front moving north and south over Fairbanks were found during the four month study period. Two additional special cases were found to fit the frontal passage criteria, but represented special instances when the front moved from the southwest. It is recognized that 10 cases for each direction of frontal movement is a very small sample. However, our purpose is not to establish climatological means, but to identify parameters which could aid in accurately forecasting frontal movement and to construct a synoptic model of the front as it affects Fairbanks. Since certain conditions were found to exist during all the observed cases, it is quite probable that these same conditions apply to most frontal passages.

In each of the 20 frontal passage cases, 850 mb and 500 mb temperatures, height changes, and wind velocities were compared for all upper-air stations before and after frontal passages at Fairbanks to identify possible forecast parameters. Also examined were location, movement, and change of intensity of pressure systems both at the surface and aloft. Observed weather parameters at Fairbanks, such as sky cover, pressure, temperature, and the amount and duration of precipitation during each frontal passage were examined. In addition, Fairbanks pseudoadiabatic charts and vertical wind profiles were studied beginning 48 hours before frontal passage and continuing through 48 hours after the passage.

Following comparison of the parameters within each case, the cases of the front moving south and the cases of the front moving north over Fairbanks were compared for similarities. Favored positions and movements of surface and upper-air systems within 12 hours before frontal passage at Fairbanks were noted as well as changes in surface and upper-air meteorological variables that could indicate the approach of the front or the initial stage of the frontal passage.

TOPOGRAPHIC EFFECTS

The geographic location of Fairbanks relative to mountain ranges and moisture sources is extremely important in governing the amount of precipitation observed during movements of the arctic front across Fairbanks. Fairbanks

(FAI) lies near the center of interior Alaska in the Tanana River Valley (Fig. 1) and is generally isolated from the influx of moist maritime air. The Alaska Range effectively shields the area from low level moisture from the Gulf of Alaska to the south. To the east through north and west no significant moisture sources exist in winter.

On occasion, large amounts of moisture can be advected into the interior from the Bering Sea to the southwest. There are no significant mountain barriers in southwestern Alaska to inhibit the flow of moisture laden air northeastward into the Fairbanks area. Heavy snows in Fairbanks are usually the result of this type of flow. Low level moisture can also be advected into the area from the southeast. In these cases the moisture moves down the Tanana Valley from the western Yukon Territory. In general, it can be safely stated that the only directions from which abundant low-level moisture can reach Fairbanks during the winter are southwest and, to a lesser extent, southeast.

FRONTAL WEATHER

Although the purpose is not to present a detailed study of the precipitation distribution associated with the arctic front, a brief discussion is necessary to illustrate its importance. From November 1974 through February 1975, 77% of the snow which fell at Fairbanks was associated with the 22 passages of the arctic front as described above. If the snowfall, which occurred while the front was near Fairbanks but was not passing over the area, is considered, 94% of the snow which fell at Fairbanks during the winter can be attributed to the arctic front. Although such a percentage may not occur during other years, it can be readily seen that the location and movement of the arctic front over Alaska is of utmost importance to forecasters.

Of the 20 cases during which the front moved north or south over Fairbanks (10 cases each), nearly all of the significant snowfall occurred during the southward movement. Significant snowfall also occurred with two special cases of frontal movement from the southwest. However, the frontal movement in these cases did not fit the usual pattern and will be discussed only briefly.

Of the 142.5 cm of snow observed at Fairbanks during the winter, only 3.8 cm could be attributed to northward passages of the front. This is contrasted to 68.3 cm attributed to the southward passages of the arctic front. The two special situations when the front moved from the southwest accounted for 37.9 cm. Movement of the front from the southwest can be forecast by standard techniques. It is the movements of the front from the north and south which are more common, and which appear to be responsible for most of the winter precipitation in Fairbanks, that require special consideration.

NORTHWARD FRONTAL PASSAGE

During periods when the arctic front is located south of Fairbanks, average surface temperatures generally run from slightly above to well below normal. Likewise, when the arctic front is to the north of Fairbanks, average surface temperatures are well above normal. Barry (1967) found the January median position of the continental arctic front at 850 mb to be south of Fairbanks. When the arctic front is south of Fairbanks, 850 mb temperatures are normally colder than -15°C. During these periods surface temperatures range from -30°C to -40°C and continue to cool as a result of the negative radiation balance (Wexler, 1936, and Wendler and Jayaweera, 1972). If the cold air mass persists, surface temperatures may reach -50°C. It is during these cold periods that ice fog blankets the populated areas and poses a threat to safe operation of motor vehicles and aircraft.

During the winter months, cold arctic air is entrenched in interior Alaska. Because of the proximity of the Alaska Range, the cold air can be displaced from only two directions - southeast and southwest. For the arctic front to pass Fairbanks from the southwest, a strong surface low pressure center must be located near the Bering Strait with strong southwest to west flow at all levels over western Alaska. Experience has shown that such a track into the northern Bering Sea during the winter months is rather unusual. This is supported by the infrequency with which the front moved from the southwest to the northeast. A more common cyclone track would be from the north Pacific Ocean east-northeastward into the Gulf of Alaska as suggested by frequency charts of cyclone centers (Petterssen, 1956).

In order to identify the synoptic features associated with the 10 cases of the northward passage of the arctic front, surface, 850 mb, and 500 mb charts for the periods 12 and 24 hours before frontal passage at Fairbanks were examined. It was found that the location of the main synoptic features on these charts were similar for all cases. At 500 mb, the position of the main low center was displaced from its mean location in eastern Siberia to over western Alaska (Fig.2). The position of the low centers at the surface and at 850 mb were farther to the south. The low-level low centers were moving towards the east-northeast, from the north Pacific Ocean into the western Gulf of Alaska. South to southwest flow predominated over southern portions of the state above 800 mb.

In 9 of the 10 cases, a band of maximum winds at 500 mb could be found moving northward over southern Alaska during the period of frontal passage. The average wind speed in the band of maximum winds was about 25 mps from the south-southwest. The polar jet stream was displaced northward to near Fairbanks. The 850 mb chart showed south to southeast flow in all cases upwind from Fairbanks; however, 850 mb temperature changes at Anchorage (ANC) and Yakutat (YAK) seldom showed the marked change that was observed at Fairbanks during frontal passage, and could not be used as indicators of the front moving north toward Fairbanks.

The surface charts in all cases indicated a rather strong pressure gradient from east-northeast to west-southwest over the southeastern half of the state which created gusty east winds of 10 - 20 mps at Big Delta (BIG). Surface pressures at Fairbanks were falling in most cases, indicating movement of the warm air aloft northward over the station. Cloud cover averaged 10/10 with bases higher than 1500 m above ground level. The average temperature rise was about 15°C in 24 hours. Snowfall of .25 cm or more was observed in only 3 cases, with the total for the 10 cases being 3.8 cm.

Thus it would appear that movement of a surface and 850 mb low pressure center into the favored area depicted in Fig. 2 with a circulation extending to Fairbanks will create a related weather pattern at Fairbanks. With the low level center in the favored area, a strong south to southwest flow is observed over Fairbanks above 800 mb. The proximity of the Alaska Range to the south will result in cloud bases above 1500 m; however, in the lee of the range, the sky will be overcast as a result of the advection of mid and high-level moisture. Measurable snow (.25 cm or more) would be possible but generally accumulations should be less than this amount. Surface temperatures would rise significantly (as much as 15°C in 24 hours) due to increased cloud cover and warm air advection.

As the general circulation of a low pressure system located in the favored area moves over Fairbanks, two rather localized circulation regimes are established in the Tanana Valley; one in the layer below the top of the Alaska Range and one above this level. In the low levels, a strong pressure gradient develops down the Tanana River Valley from Northway (ORT) towards Fairbanks (Fig.3). In response to the pressure gradient, a band of strong east winds is created which extends from southeast of Big Delta (BIG) to just south of Fairbanks (FAI) and westward (Mitchell, 1956, and Marvill and Jayaweera, 1975).

Figure 3 shows the band of strong winds associated with a low-level pressure gradient down the valley as deduced from satellite imagery (Marvill and Jayaweera, 1975). As shown by Marvill and Jayaweera and as shown by Fig.3, the Fairbanks area below 600 m appears to be sheltered from the strong east winds by foothills of the White Mountains. Consequently, the cold surface air remains over Fairbanks whereas a few miles to the south, the inversion is partially or totally destroyed by the east winds.

Figures 4a through 4c show a typical sequence of soundings during northward passage of the arctic front. The topographic configuration and the orientation of the pressure gradient generally result in an easterly flow near the surface. Since warm air advection is occurring on the east side of the low pressure center, the wind veers with increasing altitude and becomes more parallel to the Tanana Valley (southeasterly) to at least 850 mb or about 1500 m. Gradient flow predominates in the higher layers above the effect of channelling by the Tanana Valley. The frontal passage at 850 mb took place just prior to the sounding taken at 1200 GMT 14 February.

Figures 4a through 4c also show the thermal advection pattern observed over Fairbanks. As the circulation of the low pressure system in the favored position in the western Gulf of Alaska advances over Fairbanks and the eastern Alaskan interior, two wind regimes are established above the surface as described above. At levels above the Alaska Range, warm air advection begins almost immediately and a pronounced bulge in the Fairbanks sounding is observed above 820 mb (Fig.4a). If strong warm air advection exists above the mountains, a very strong inversion may form as seen in Fig.4b.

Below about 820 mb, the rate of temperature change is a function of the wind velocity and the location of the arctic front. If the cold air is firmly entrenched in the Tanana Valley and the western Yukon Territory with the arctic front consequently south of the Alaska Range, significant warming in the low levels at Fairbanks will begin 12 hours to 36 hours after warming above the mountains. The delay in the low-level warming is undoubtedly due to the time required for the warm air to "sift" through the passes in the Alaska Range into the Tanana Valley. If the arctic front is between the Alaska Range and Fairbanks, warming below the ridge tops (to the surface) occurs nearly coincidental with the onset of the warming above the mountains, and the strong inversion at 830 mb observed in Fig. 4b may be considerably weakened. Figure 4a represents a sounding taken when the arctic front was south of the Alaska Range. Warm advection above 820 mb began prior to 0000 GMT 14 February 1975 (Fig.4a) and was quite strong by 1200 GMT the same date (Fig.4b). During the 12 hours ending at 1200 GMT 14 February, levels immediately above the mountains warmed between 8°C and 13°C, whereas in the low levels no significant warming had occurred. However, during the next 12 hour period, temperatures in the low levels increased 6°C to 8°C and those above the inversion only 1°C to 3°C (Fig.4c).

Since Big Delta experiences strong east winds with associated vertical mixing of the lower layers, the surface temperature at Big Delta can be related to the temperature advection in the lower layers down the Tanana Valley; thus, giving an indication of the advance of the warm air into the interior.

As the warmer air moves over Fairbanks, a mechanically mixed layer is sometimes formed with a characteristic near-adiabatic lapse rate in a shallow layer located somewhere between 950 mb and 850 mb (not shown). This layer, which is formed due to turbulent flow over the mountains to the south, extends upward to the inversion caused by warming above the mountains. The effect of the mechanically mixed layer is to strengthen the inversion near the mountain tops. On occasion, the mixed layer extends downward to the top of the surface based inversion, strengthening this inversion also. Surface based inversions strengthened in this manner are suspected to be related to periods of extremely high levels of carbon monoxide air pollution observed in downtown Fairbanks (Bigler et al., 1973).

Based on observations of various synoptic patterns prior to frontal passage at Fairbanks, the 850 mb chart appears to be the best tool to use in fore-

casting the frontal movement, although both the 500 mb and surface analyses may be used as supplemental charts. The pseudoadiabatic charts serve to illustrate the sequence of events which occur in the atmosphere over Fairbanks, but furnish little lead time to the forecaster. In using the 850 mb chart, the forecaster must watch for an 850 mb low center to move into the western Gulf of Alaska from the west-southwest toward the area of favored 850 mb low center positions. The low must be sufficiently large to cause a southerly flow of air throughout the northern Gulf of Alaska as it moves into position. Warming above about 820 mb begins almost immediately but the advent of low level warming will depend on the location of the arctic front. Increased cloud cover and moderating temperature with little, if any, snowfall occurs at Fairbanks.

SOUTHWARD FRONTAL PASSAGE

During periods when the arctic front is north of Fairbanks, 850 mb temperatures at Fairbanks generally range from -5°C to -15°C, which indicates the relative warmth of the air mass. Sky cover varies greatly depending on the amount of moisture advected by the prevailing southerlies aloft; however, cloud bases are generally higher than 1500 m. Surface temperatures vary greatly depending on cloud cover, wind, and temperatures at the top of the surface inversions (Wexler, 1936) yet, surface temperatures are generally above normal. When conditions become favorable, the cold air mass to the northwest begins to push southeastward. The arctic front, which constitutes the leading edge of this cold air mass, may then move southeastward across Fairbanks.

Significant snowfall occurred at Fairbanks during the southward passage of the 850 mb arctic front in 9 of the 10 cases. Snowfall durations were approximately 24 to 36 hours with 12 hour amounts usually from 1 - 4 cm. The maximum 12 hour amount was 8.6 cm. Therefore, although the southward moving front is responsible for a large percentage of the Fairbanks winter snowfall, amounts are seldom large enough to meet the National Weather Service heavy snow criteria of 10.2 cm. (4 in) in 12 hours, or 15.3 cm. (6 in) in 24 hours. The exact location of the moisture source for this snowfall was not determined. However, it is likely that sufficient moisture is brought northwestward up the Tanana Valley or northward through passes in the Alaska Range during the time the front is north of Fairbanks.

Surface, 850 mb, and 500 mb charts for the times before frontal passage at Fairbanks were examined in the same manner as with the northward movement of the front. The locations of the main synoptic systems at each level were similar in each of the southward moving cases. At 500 mb the preferred position of the main low center was just off the northwest coast of Alaska as shown in Fig. 5. In 7 of the 10 cases studied, it occupied this position. A trough was oriented north-south from the low with the low moving towards the east.

At 850 mb, the locus of the positions of the main low centers was well south of the 500 mb position as shown in Fig.5. An 850 mb trough extended northward from the low center into the western interior of Alaska. The 850 mb lows and troughs were moving toward the east and weakening in most cases. Although the Fairbanks 850 mb winds showed no correlation between cases before frontal passage, after frontal passage the winds were always from the west to northwest at 2 - 10 mps. The 850 mb thermal analyses indicated the front moved from northwest to southeast in all but one case. With the one exception movement was directly from the north to the south. The 850 mb analyses also indicated the front to be a continuation of the arctic front over northwest Canada as shown by Willis and Grice (1975). Heights were rising at 850 mb in all cases over western Alaska with the advance of the cold air.

The locus of the positions of the surface low pressure centers is shown in Fig.5. The lows were usually stationary, occasionally with an occluded frontal system extending from the low center eastward along the Gulf Coast. No fronts were present farther north on the surface analyses. The presence of the low center in the Gulf of Alaska was also noted by Billello (1974), who stated the southward movement of the cold front in interior Alaska is caused by an intense storm moving into the Gulf of Alaska.

In the cases studied, the pseudoadiabatic charts gave the first indication of the influx of cold air as the front pushed over Fairbanks. The amount of cooling first observed on the charts is a function of the strength of the rate of cold air advection and the elapsed time between the movement of the front over Fairbanks and the atmospheric sounding time. Cooling of 2-15°C in the lowest 100 mb from just above the surface based inversion began prior to the frontal passage at 850 mb. This was followed by another 8 - 16°C in the next 12 hours. The winds in the cold air were usually from the west to northwest.

The weather and cooling observed during the passage of the arctic front in all cases agree quite well with that observed by Bowling and others (1968) during the preliminary phase of a normal ice fog event. They found that the cooling in the lower troposphere over Fairbanks could be attributed to cold air advection.

Figures 6a through 6d show a typical sequence of soundings at Fairbanks during the southward passage of the arctic front. Figure 6a shows the temperature profile 12 - 24 hours before frontal passage at 850 mb. A very strong inversion (18°C) exists between the surface and 910 mb with 8 - 10 mps east winds prevailing from just above the surface (135m AGL) to 800 mb. Surface winds were calm. During the following 12 hours, cold arctic air moved over the station in the lower layers and eliminated the surface inversion. The most pronounced change occurred at 910 mb where 15°C cooling was observed in the 12 hour period (Fig.6b). The cooling at 950 mb was 9°C and the surface temperature rose 8°C. Although the surface warming might at first seem to be attributed to solar insolation, it is quite unlikely since the amount of

insolation received during February is quite small and on this particular day skies were cloudy. Undoubtedly, the surface warming can be attributed to radiation from the clouds which accompany the arctic front.

The rapid cooling through the surface inversion layer by the arctic front, and the warming of the surface by the associated clouds during the 12 hour period ending 0000 GMT 19 February, resulted in a superadiabatic lapse rate near the surface (Fig.6b). In all cases, the superadiabatic layer near the surface was observed, eliminating the possibility that the cooling just above the surface was due to radiation. Such unstable wintertime lapse rates near the surface have also been observed by Robinson (1955) at Eielson Air Force Base located 33 km southeast of Fairbanks.

The top of the cold air is depicted by the frontal inversion around 850 mb in Fig.6b. During the following 12 hours, the top of the arctic air rose to about 760 mb and remained near that level (Figs. 6c and 6d). Winds in the cold air advection layer were generally less than 5 mps and from the southwest through northwest. Surface winds remained variable at 5 mps or less.

Figure 7 is a time cross section for Fairbanks during the passage of a strong arctic front in late December 1974 and early January 1975. From Fig.7 it can be seen that the front is quite shallow, extending to only about 750 mb. Palmen and Newton (1969) refer to the existence of a low tropospheric arctic front, and in 8 of the 10 cases examined in this study, the arctic front failed to exceed 750 mb in height. The remaining two cases showed evidence of the front to 600 mb, but the discontinuity was very weak.

As indicated earlier, the only mechanism of sufficient strength to force the cold air to the north and northwest of Fairbanks was an intense low center in the western Gulf of Alaska. Following low-level warming over Fairbanks, an 850 mb trough becomes established over western Alaska with the arctic front oriented northeast-southwest to the west of this trough, thence eastward across northern Alaska. If the 850 mb center in the Gulf of Alaska continues eastward, the associated trough moves toward the east or southeast resulting in the passage of the arctic front southward over Fairbanks. However, if the low center remains over the western Gulf of Alaska and weakens, the arctic front may remain over western Alaska, continuing to move to the west-northwest or dissipate. The mechanism which will cause the front to intensify and move into Fairbanks again is a building or moving high pressure system from eastern Siberia or the Arctic Ocean. Frontogenesis occurs to the east of the high pressure center as the high moves towards Fairbanks.

A set sequence of events occurs as the arctic front moves southward across Fairbanks. The front moves along the top of the layer of cold surface air with the height of the lower boundary of the front determined by the density of the arctic air and the density of the cold surface air. As the front moves over the city, it is usually accompanied by clouds and snow (only one out of the ten cases was not accompanied by precipitation). Temperatures above the surface inversion cool rapidly due to cold air advection but sur-

face temperatures rise as a result of increased clouds. As the cold air becomes deeper, skies slowly clear and surface temperatures begin to drop due to radiational cooling. This sequence of events is illustrated in Fig. 7.

Since significant snowfall, followed eventually by a marked drop in surface temperature, is usually observed at Fairbanks with the southward passage of the arctic front, the ability of the forecaster to predict the timing of the frontal passage is very important. The 850 mb analysis again appears to be the best forecast tool. An 850 mb low center moving eastward into the preferred area as shown in Fig. 5 should indicate to the forecaster that the arctic front will begin to move southeast through interior Alaska. The sounding should then be analyzed for any trace of cooling in the lowest 100 mb. Snow should be forecast within 12 hours after the low becomes positioned in the favored area and cooling appears in the lower layers of the sounding. Clearing skies and rapidly falling surface temperatures should be forecast 24 to 48 hours following frontal passage. Significant surface wind seldom accompanies the front, although on one occasion (Willis and Grice, 1975), post frontal surface wind gusting to 16 mps was observed at Fairbanks.

EXAMPLES OF FRONTAL PASSAGE OVER FAIRBANKS

A nine day period near the end of December is an example of both southward and northward movement of the arctic front over Fairbanks. The front had moved north of Fairbanks between 0000-1200 GMT 22 December. The relatively warm moist airmass persisted until the front again moved south over Fairbanks on 26 December. During this period, between 22 - 26 December, skies were generally cloudy with surface temperatures ranging from -18°C to -26°C and periods of very light snow. Temperatures at 850 mb were from -7°C to -18°C. By 1200 GMT 26 December, the surface, 850 mb, and 500 mb low centers had moved into or through the favored position for southward movement of the front. The first indication of cooling aloft was evident on the sounding at 1200 GMT 26 December. Maximum cooling of 4°C took place at about 905 mb. Although very light snow had been observed, the intensity increased at about 1600 GMT 26 December. The soundings at 1200 GMT 26 December and 1200 GMT 27 December (Figs. 8a and 8b) give an indication of the amount of cooling during passage of the front. The 850 mb analyses at 1200 GMT 26 December (Fig.9) and 0000 GMT 27 December (Fig.10) show the typical orientation of the arctic front before and after southward frontal passage at Fairbanks. The 850 mb temperature dropped from -11°C at 0000 GMT 26 December to -29°C at 0000 GMT 28 December, showing the marked temperature difference between the two air masses. The snow continued until 2100 GMT 27 December with a total of 3.1 cm of new snow observed between 1800 GMT 26 December and 1800 GMT 27 December. Snowfall in this case was somewhat less than normal for southward passage of the front. The sky began to clear about 1800 GMT 27 December with the surface temperature dropping from -23°C at 1200 GMT 27 December to -38°C within 24 hours and to -44°C within 36 hours with ice fog prevalent throughout the latter half of the period. Surface temperatures remained below -40° C until 1200 GMT 30 December, by which time the arctic front was again

moving northward toward Fairbanks. High clouds began to push northward over the station at this time as warmer more moist air moved in. The 850 mb low in the western Gulf of Alaska had moved into the favored position for northward movement of the front, as had the surface and 500 mb lows. The surface temperature rose from -42°C at 1200 GMT 30 December to -31°C within 24 hours and to -25°C within 36 hours. The sounding for 1200 GMT 30 December just before frontal passage is shown in Fig.11a. Note the southeasterly flow in the layers just above the surface which is directed up the Tanana Valley and the mechanically mixed layer of air from 931 mb to 908 mb caused by southerly flow over the Alaska Range to the south. The sounding for 0000 GMT 31 December (Fig.11b) shows the temperature over Fairbanks after frontal passage and indicates the amount of warming that took place with passage of the front. The 850 mb analyses shown in Fig. 12 and 13 illustrate the movement of the front aloft as it passed northward over Fairbanks between 1200 GMT 30 December and 0000 GMT 31 December. This particular period of warming was of rather short duration. By 1200 GMT 31 December, the front once again began moving southward toward Fairbanks with low clouds and snow observed as the front moved over the station during the following 24 hours.

CONCLUDING REMARKS

The arctic front plays a major role in determining the type of weather experienced in Fairbanks and quite probably over most of interior Alaska. The unusual feature of the arctic front over interior Alaska during the winter is the interaction of the front with the cold surface air. It appears from this study that the arctic front "floats" on this cold pool of air. As a consequence, the exact location of the front cannot be determined from surface observations. It is also quite possible the surface inversion was the main reason Reed (1960) was not able to identify the wintertime surface front over interior Alaska but Barry (1967), using 850 mb data, found the arctic front to exist a large portion of the time.

The wintertime arctic front over interior Alaska can be identified using a detailed 850 mb thermal analysis (2°C) and height analysis (30m). This is done routinely at the WSFO at Fairbanks. However, lack of upper-air observing stations over interior Alaska poses a problem to the exact placement of the front. Also, due to lack of data, sequential positions of the moving front cannot be determined or used as a forecast tool. Therefore, general location of major weather systems at the surface and aloft just prior to frontal passage at Fairbanks were determined to be the best forecast tool.

The 850 mb chart is suggested as the most reliable tool since the surface charts do not give a good indication of the location of the front aloft, and the upper air analyses above 850 mb are above the height of the arctic front. When the 850 mb low moves into the favored area, frontal passage at Fairbanks should occur shortly thereafter. The Fairbanks sounding should be watched closely for signs of temperature change which would give the first indication of the movement of the front over the station.

Significant snowfall nearly always occurs with southward frontal passage. Snowfall amounts with a southward moving front are seldom more than 8 - 10 cm with the period of snowfall from 24 to 36 hours. Rapid surface cooling can be expected 24 to 48 hours following frontal passage. A drop in surface temperature of 10 to 15°C would not be uncommon and ice fog would be probable during the subsequent cold period.

When the front is expected to move northward over Fairbanks, generally cloudy weather with periods of very light snow and rising temperature should be expected. Extreme cold and prolonged periods of ice fog should not be anticipated.

It should be emphasized that since data from only one year were used, the relative frequency of frontal passages at Fairbanks may not be typical. However, since all the cases exhibited certain features, it is quite probable that the physical relationships cited in this paper hold true for most passages of the arctic front.

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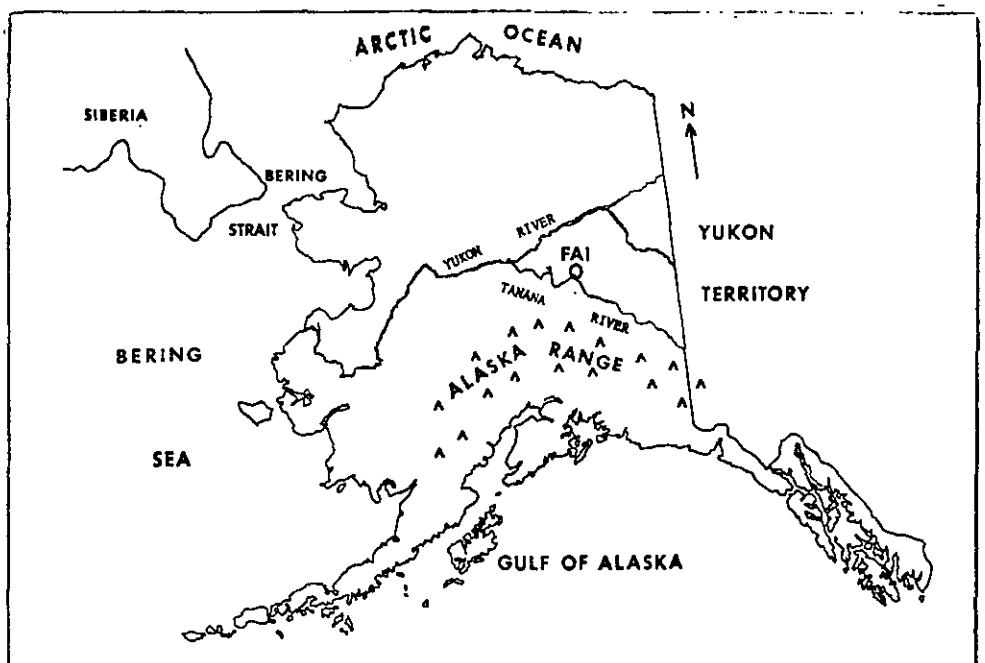


Fig. 1. Alaska and surrounding water and land areas.

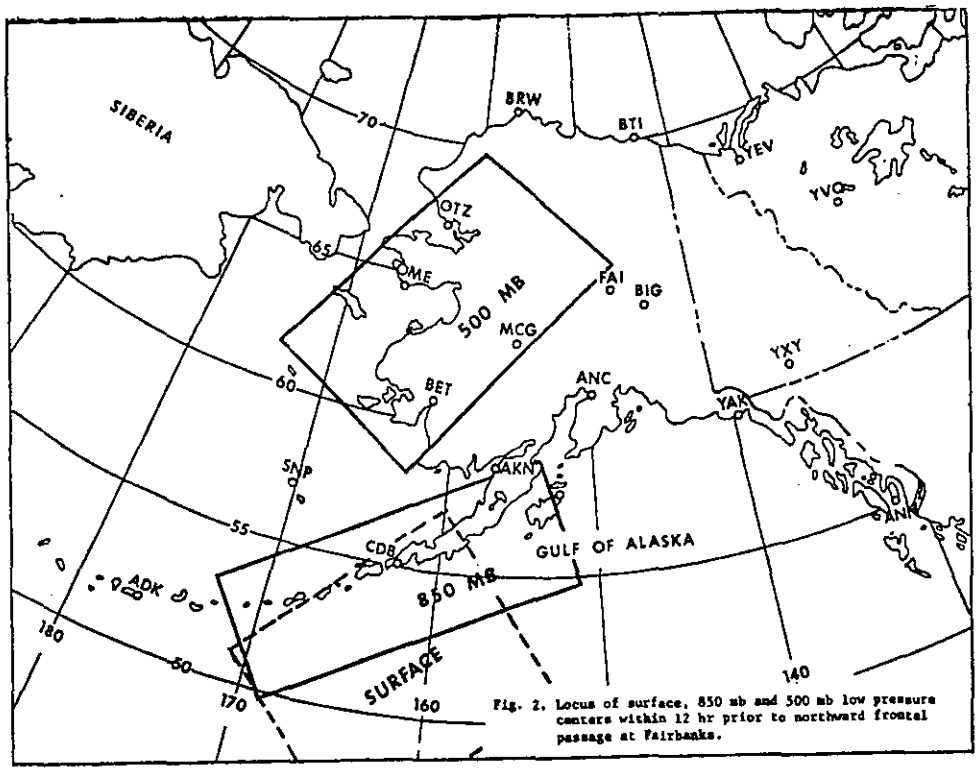


Fig. 2. Locus of surface, 850 mb and 500 mb low pressure centers within 12 hr prior to northward frontal passage at Fairbanks.

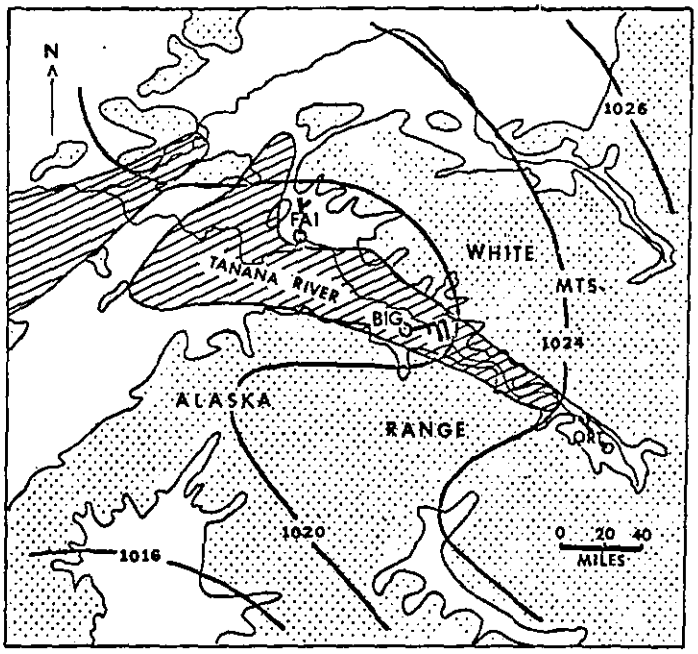
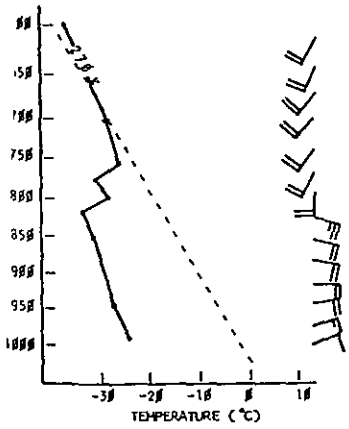


Fig. 3. East central Alaska showing areas with elevation above 600 m MSL (stippled). Hatched area indicates areas where strong east winds develop down the Tanana River Valley. Solid lines, sea level pressure in millibars. Whole wind barb, 5 mps.



0000 GMT 14 FEBRUARY 1975

Fig. 4a. Fairbanks sounding: solid line, temperature; whole wind barb, 5 mps.

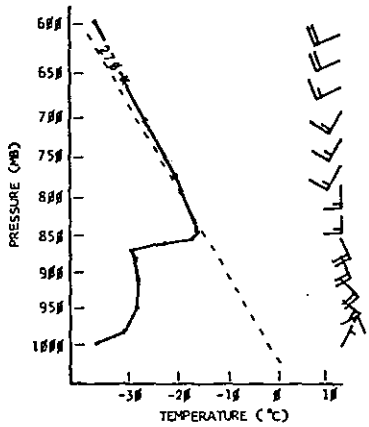


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Fig. 4b. Fairbanks sounding: solid line, temperature; whole wind barb, 5 mps.

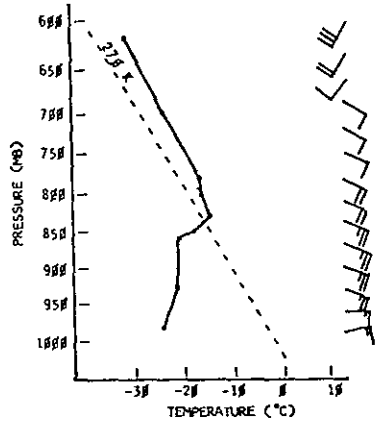

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Fig. 4c. Fairbanks sounding: solid line, temperature; whole wind barb, 5 mps.

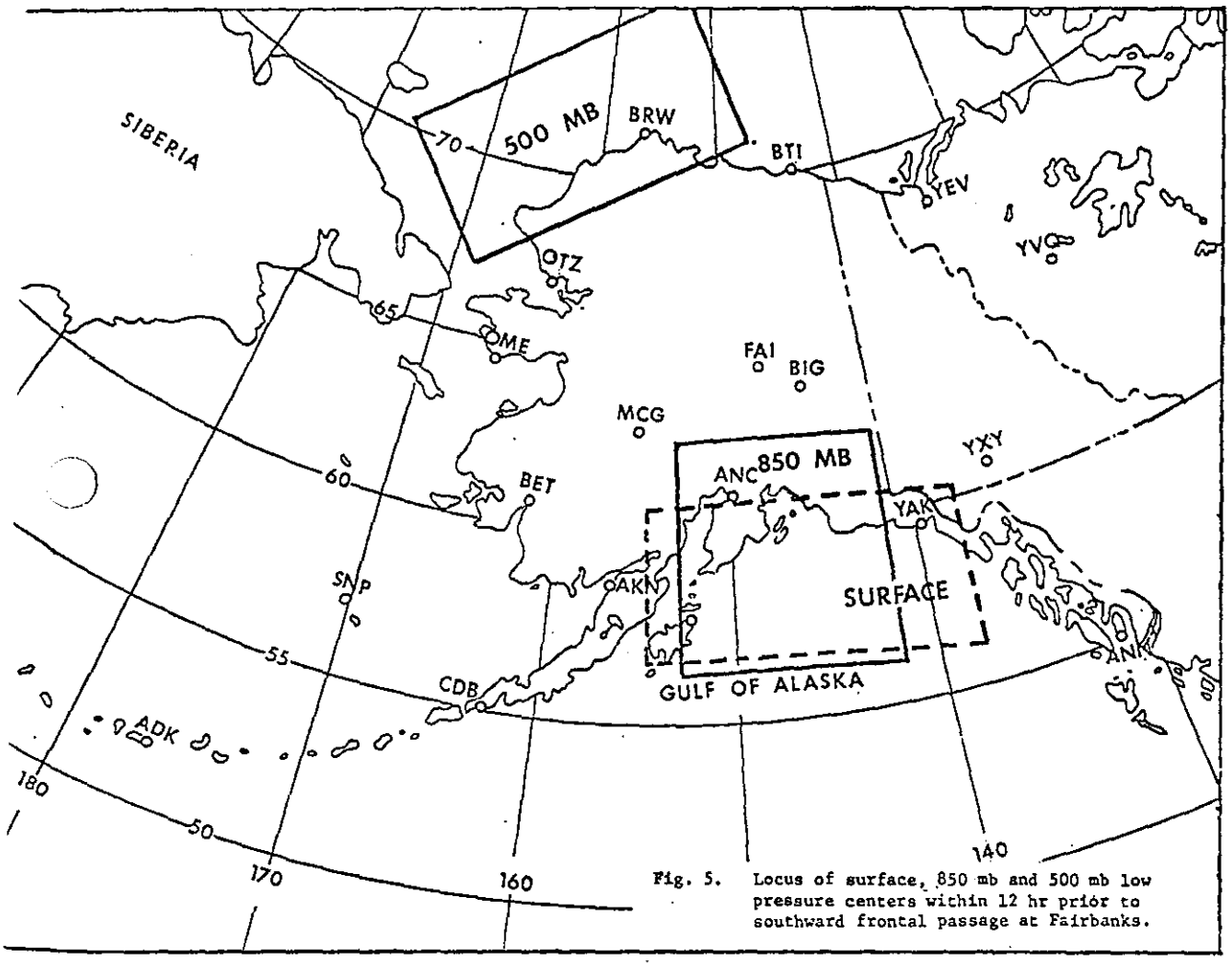

Fig. 5. Locus of surface, 850 mb and 500 mb low pressure centers within 12 hr prior to southward frontal passage at Fairbanks.

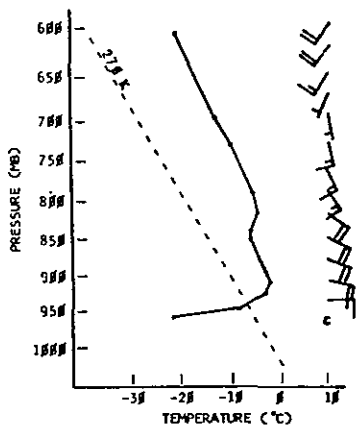

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Fig. 6a. Fairbanks sounding: solid line, temperature; whole wind barb, 5 mps.

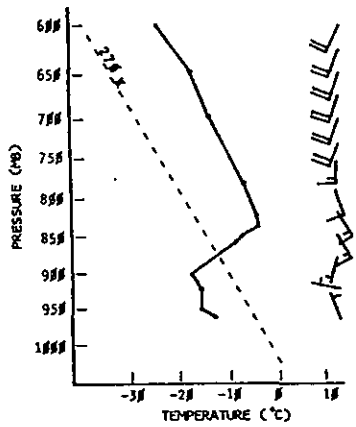

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Fig. 6b. Fairbanks sounding: solid line, temperature; whole wind barb, 5 mps.

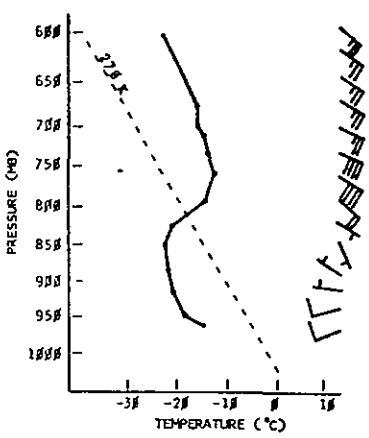

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Fig. 6c. Fairbanks sounding: solid line, temperature; whole wind barb, 5 mps.

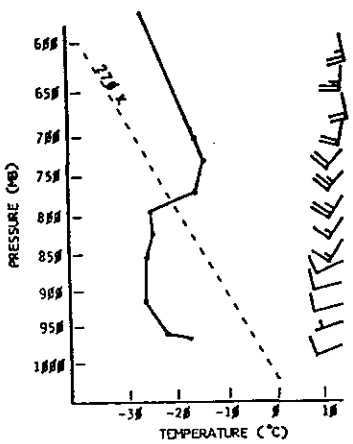

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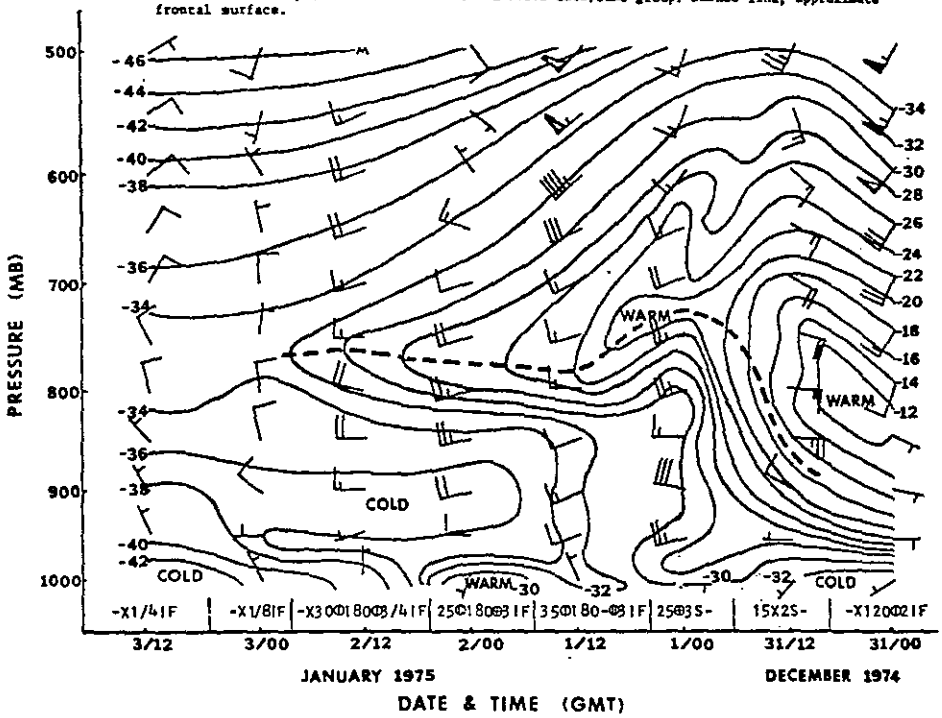
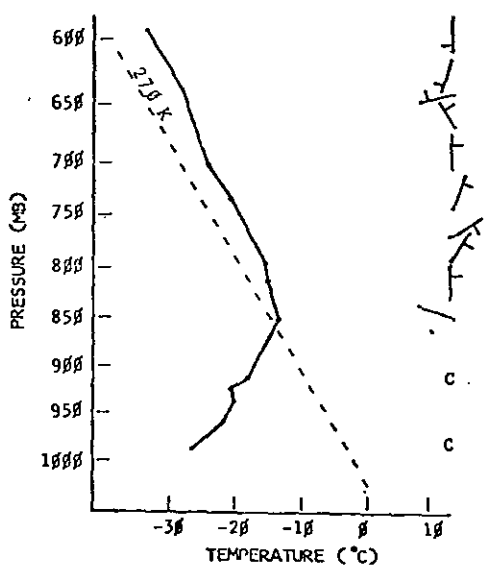
Fig. 6d. Fairbanks sounding: solid line, temperature; whole wind barb, 5 mps.

Fig. 7. Time cross section for Fairbanks: solid lines, isotherms degrees C; whole wind barb, 5 mps; shaded barb, 25 mps; observed weather shown above date/time group. Dashed line, approximate frontal surface.





1200 GMT 26 DECEMBER 1974

Fig. 8a. Fairbanks sounding: solid line, temperature; whole wind barb, 5 mps.

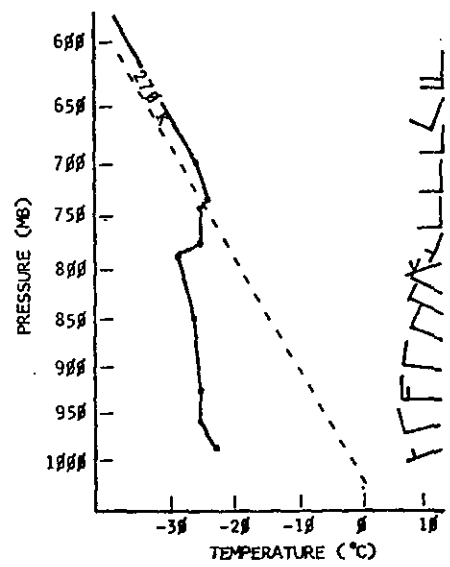


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Fig. 8b. Fairbanks sounding: solid line, temperature; whole wind barb, 5 mps.

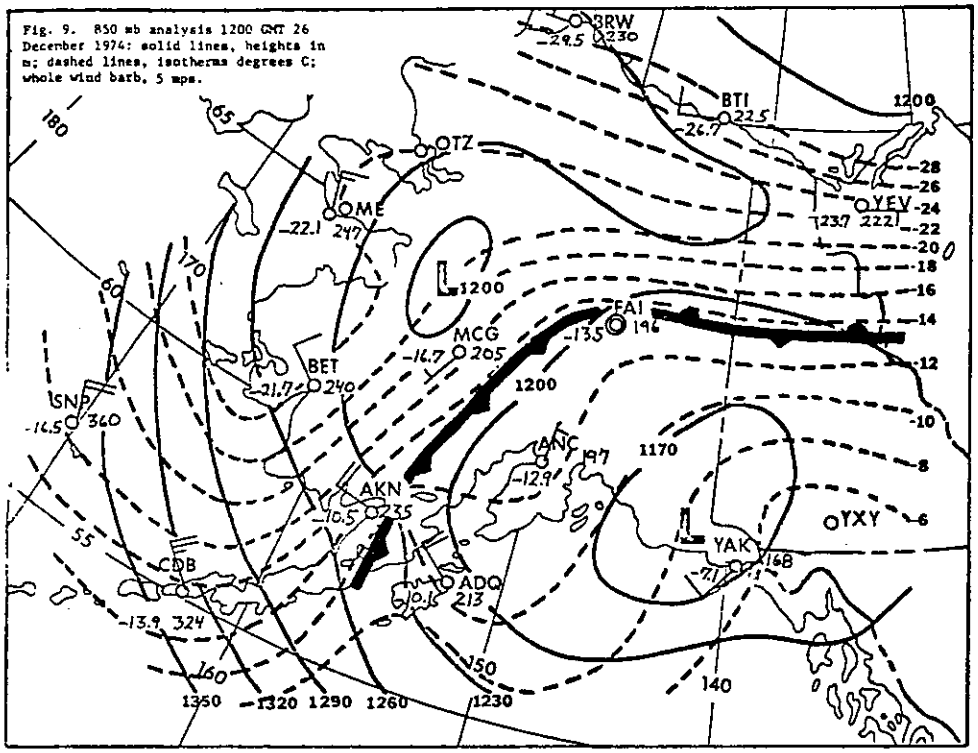


Fig. 9. 850 mb analysis 1200 GMT 26 December 1974: solid lines, heights in m; dashed lines, isotherms degrees C; whole wind barb, 5 mps.

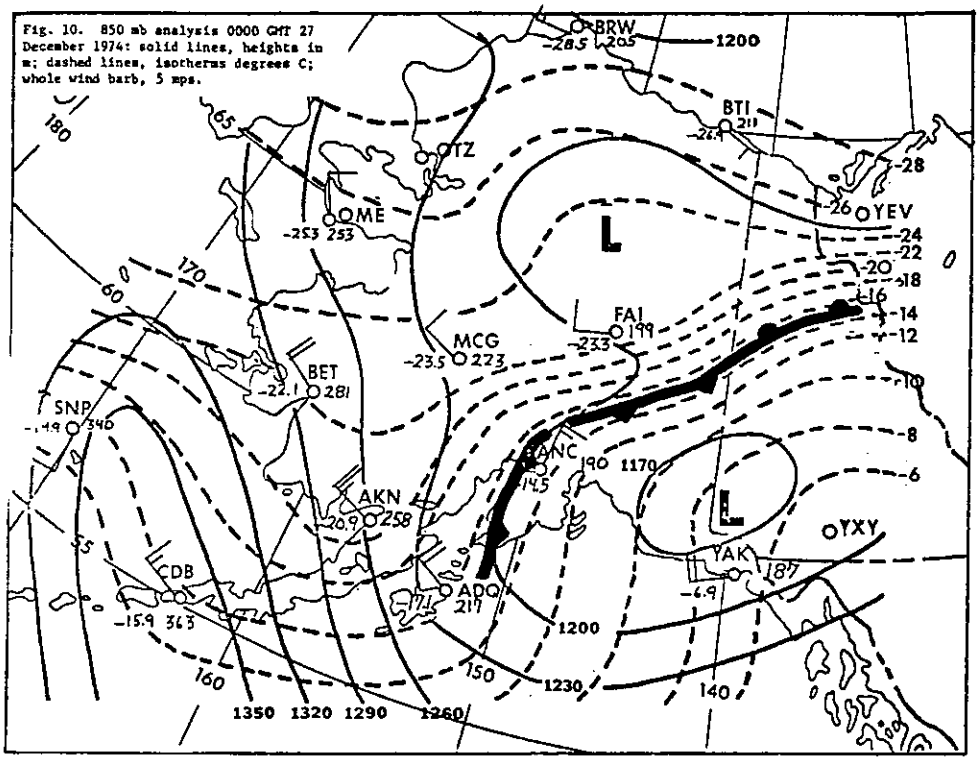
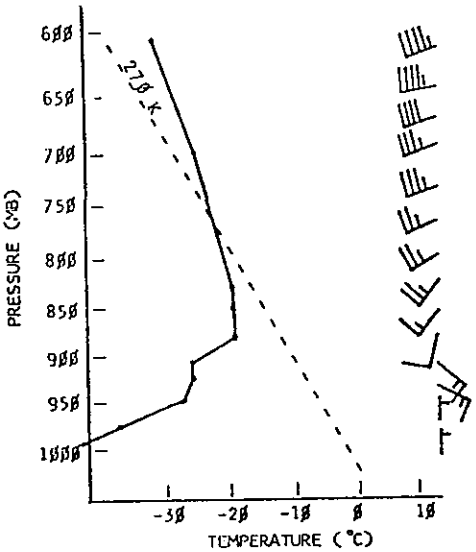


Fig. 10. 850 mb analysis 0000 GMT 27 December 1974: solid lines, heights in m; dashed lines, isotherms degrees C; whole wind barb, 5 mps.



1200 GMT 30 DECEMBER 1974

Fig. 11a. Fairbanks sounding: solid line, temperature; whole wind barb, 5 mps.

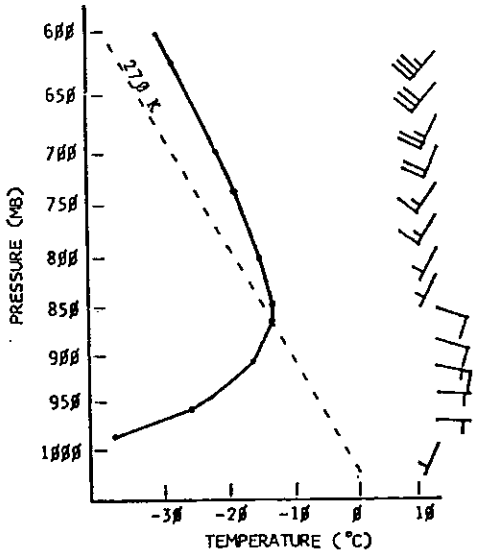


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Fig. 11b. Fairbanks sounding: solid line, temperature; whole wind barb, 5 mps.

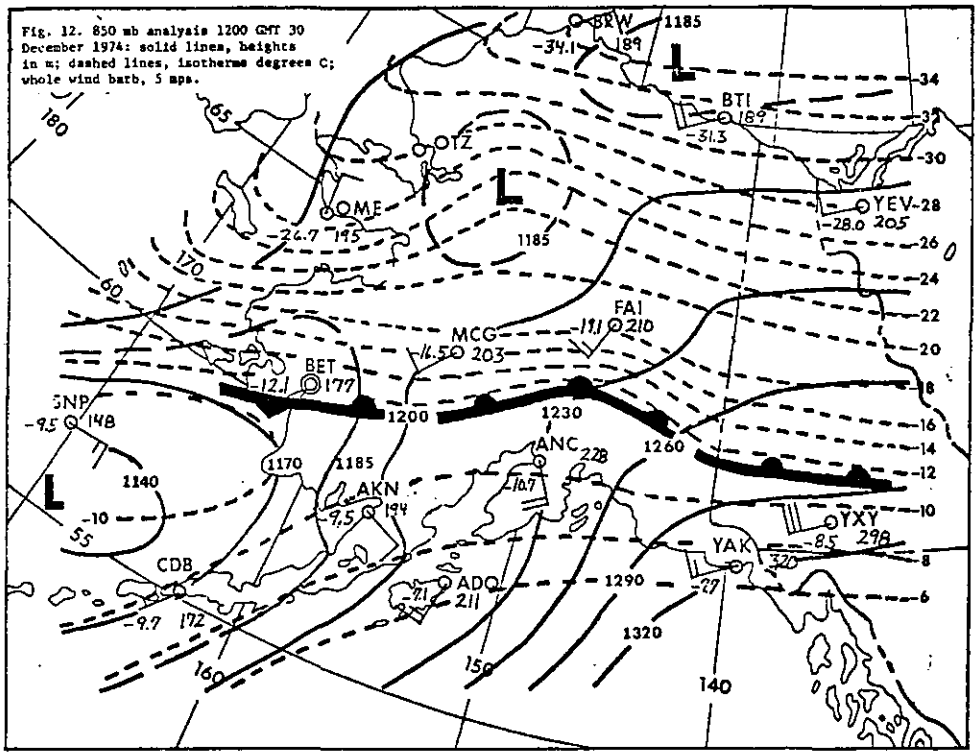

Fig. 12. 850 mb analysis 1200 GMT 30 December 1974: solid lines, heights in m; dashed lines, isotherms degrees C; whole wind barb, 5 mps.

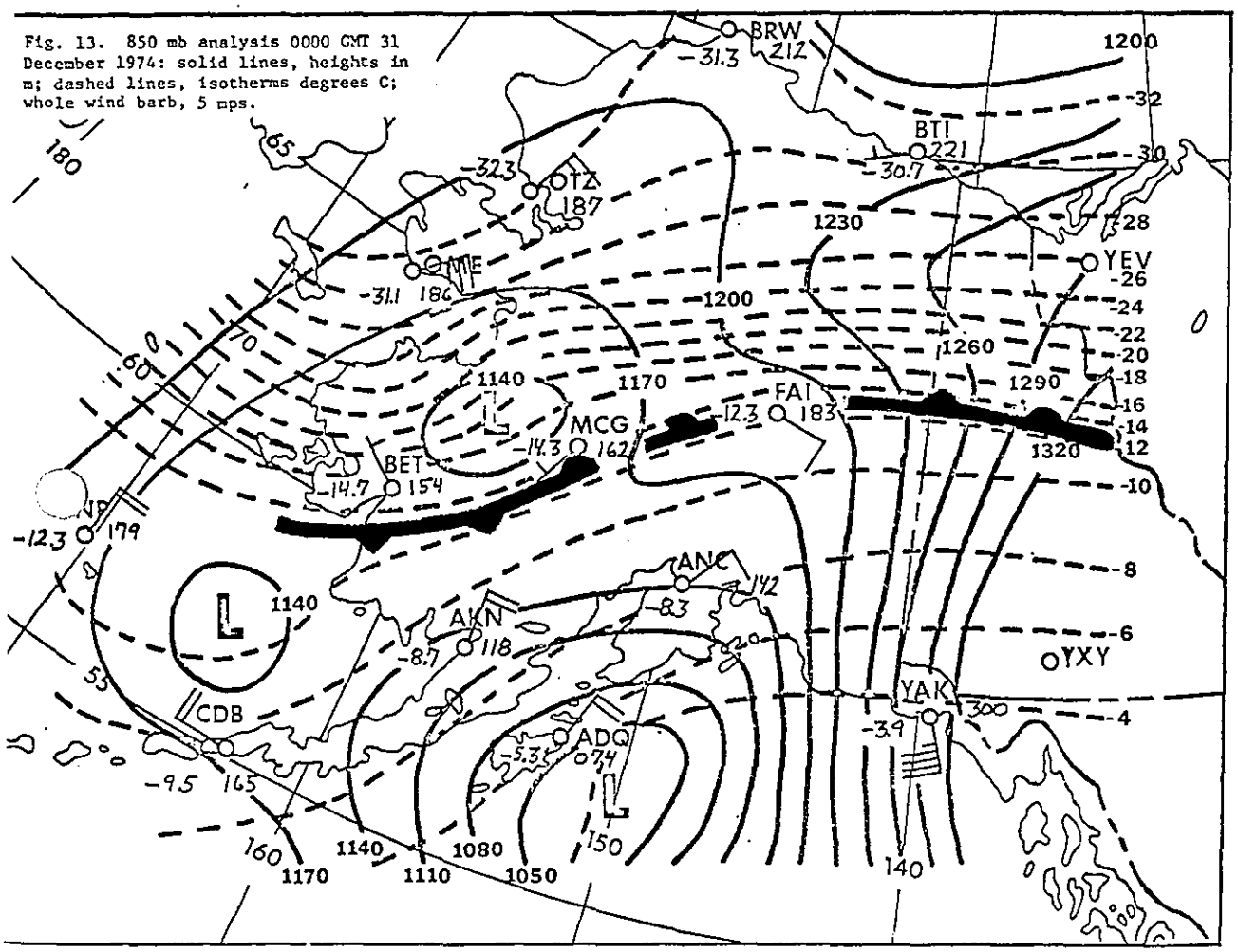

Fig. 13. 850 mb analysis 0000 GMT 31 December 1974: solid lines, heights in m; dashed lines, isotherms degrees C; whole wind barb, 5 mps.