NOAA TECHNICAL MEMORANDUM NWS AR-16

FORECASTING AVALANCHES IN JUNEAU ALASKA

Richard Hutcheon and Leif Lie
National Weather Service Forecast Office
Juneau, Alaska

National Weather Service, Regional Headquarters
Anchorage, Alaska
January 1977

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Forecasting Avalanches in Juneau Alaska

Richard Hutcheon and Leif Lie
National Weather Service Forecast Office
Juneau, Alaska

ABSTRACT. *Weather is the critical factor in determining when an avalanche will occur once an adequate snowpack has been established on a slope. The most important step in predicting avalanche occurrence is to be able to forecast the weather in the slide area for 12 to 36 hours. Both wet avalanches and dry avalanches occur in the Juneau area. The synoptic weather pattern associated with each type of avalanche has been identified. Wet avalanches require an elongated low pressure area in the Gulf of Alaska with a southerly flow and warm air advection. Dry avalanches occur after a prolonged period of cold weather and gusty northeasterly winds. The synoptic pattern which produces this type of weather has a strong high pressure area over the Yukon Territory and northwestern British Columbia, and low pressure in the Gulf of Alaska. The Weather Service personnel at Juneau make avalanche forecasts based upon the prediction of these types of weather patterns.*

This paper was originally prepared for presentation at the Avalanche Workshop, Banff, Alberta, Canada, November 2, 1976.

1. Introduction

A. Background

Juneau lies in the rugged mountainous regions of Southeast Alaska. This region, with its many islands and deep fjords, is within the maritime influences of the Northeastern Pacific. The climate of this area is characterized by little sunshine, moderate temperatures, and abundant precipitation (Dept. of Commerce 1976). At times, however, the climate of Northern Southeast Alaska reverts to continental conditions. In winter this is characterized by temperatures below minus 18 degrees C (zero degrees F) and gusty northeasterly winds.

Annual temperatures throughout Southeast Alaska average between 5 degrees C (40°F) and 10 degrees C (50°F), but in the winter months temperatures may range from minus 29 degrees C (20°F below zero) to 16 degrees C (60°F) (Searby 1971).

Precipitation also varies greatly, with Little Port Walter 192 kilometers (120 Miles) south of Juneau averaging 478 centimeters (188 in.) annually and Skagway to the north averaging 66 centimeters (26 in.) annually. Comparing downtown Juneau's average annual precipitation, 234 centimeters (92 in.) with that of Juneau's Airport 14 kilometers (9 mi.) away, 140 centimeters (55 in.), demonstrates the wide variation within relatively short distances (Dept. of Commerce 1973).

The steep, rugged terrain combined with abundant precipitation and widely varying temperatures during the winter months, result in a high threat of avalanche activity throughout Southeast Alaska.

In the Juneau area, avalanche hazard zones exist along the Thane Road, which extends between the community of Thane and the city of Juneau, the residential Behrends Avenue area, east of Juneau along the south slopes of Mt. Juneau and recreational back country areas.

Avalanches occur annually along Thane Road, closing the road temporarily at least once each winter. In the Behrends Avenue area there is a record of slides in 1890, 1917, 1926, 1929, 1935, 1946, and 1962 (Hart 1967). Each winter avalanches occur in the back country areas, with increasing hazard as these areas become more and more utilized for recreation.

B. Purpose

This paper describes the avalanche forecasting techniques utilized at the Weather Service Forecast Office in Juneau. It presents

a general description of the physics of snow and the avalanche phenomena. It describes the types of avalanches that are of most concern to the forecasters in Juneau and the procedures used to forecast them, with particular emphasis on the synoptic weather patterns that trigger avalanches. In addition, a case study will be presented of one of the major avalanche episodes that occurred in the Juneau area during 1976.

On September 23, 1975, Dr. George P. Cressman, Director of the National Weather Service assigned the responsibility of routine avalanche forecasting to the Weather Service Forecast Office at Juneau. Juneau is the first National Weather Service Office to have avalanche forecasting responsibility, and it is our hope that the experiences of the forecasters at Juneau and the techniques used will be of some value to others engaged in avalanche forecasting.

2. Avalanches

A. The Snowpack

When a snowflake falls onto an existing snow surface, it connects itself and becomes part of the interconnected skeleton called the snowpack (Dept. of Agriculture 1975). A snowpack consists of a number of separate layers of different thicknesses. The particular properties of each layer are determined by meteorological conditions at the time of deposition and metamorphism after deposition. Metamorphism refers to changes in the snow characteristics caused by pressure and temperature conditions. The temperature of a layer determines the relative rate and stage of metamorphism.

Newly fallen snow is one of the most unstable substances found on the surface of the earth (Dept. of Agriculture 1975). The instability results in metamorphism of the snow crystal beginning immediately after it is deposited. Two types of metamorphism occurs in a dry, seasonal snowpack.

TG-metamorphism occurs in response to a strong temperature gradient within the ice skeleton. This results in the growth of individual ice crystals within the snow layer, while the connecting "necks" between the crystals remain constant (Dept. of Agriculture 1975).

ET-metamorphism involves the tendency of snow to simplify its form when not under the influence of a strong temperature gradient. The simplifying process results in a general rounding of the grains and a strengthening of the ice skeleton due to the formation and enlargement of necks between the grains (Dept. of Agriculture 1975).

Snow layers have the unusual ability to sustain large density changes. Layers are compressed to a higher density by the weight of the overlying snowpack. However, as the density of the layer increases, so does its resistance to further densification.

Densification results in the settlement of the snow surface on the order of one centimeter (0.4 in.) per day with greater settlement occurring after heavy snowfalls.

The flexibility of the ice skeleton accounts for the high compressibility of snow. The "necks" and other thin areas of the ice skeleton distort easily when pressure is applied allowing snow grains to move to new locations. The necks then reform, resulting in an irreversible deformation.

Free water is the amount of liquid water in a snowpack. The sources of free water are rainfall and melting of the snow. Free water flows down into the pack until it either freezes on contact with a cold layer, or until it is blocked by a hard layer.

"Lubrication" is an important cause of avalanches. Lubrication occurs when free water flows down onto a hard surface, such as the ground or an ice surface. If the water cannot penetrate the surface, it will spread out and dissolve the bond between the surface and the snow above.

B. The Avalanche

There are generally two types of avalanches: point avalanches (sometimes called loose snow avalanches) and slab avalanches.

Perla (1975) describes point avalanches as follows:

1) The snow layer is disturbed by more added weight or the warming of the layer to a state where cohesion is lost.

2) A small amount of the layer slips out.

3) The disturbed snow will either come to rest or will disturb and force out snow in its track causing an avalanche.

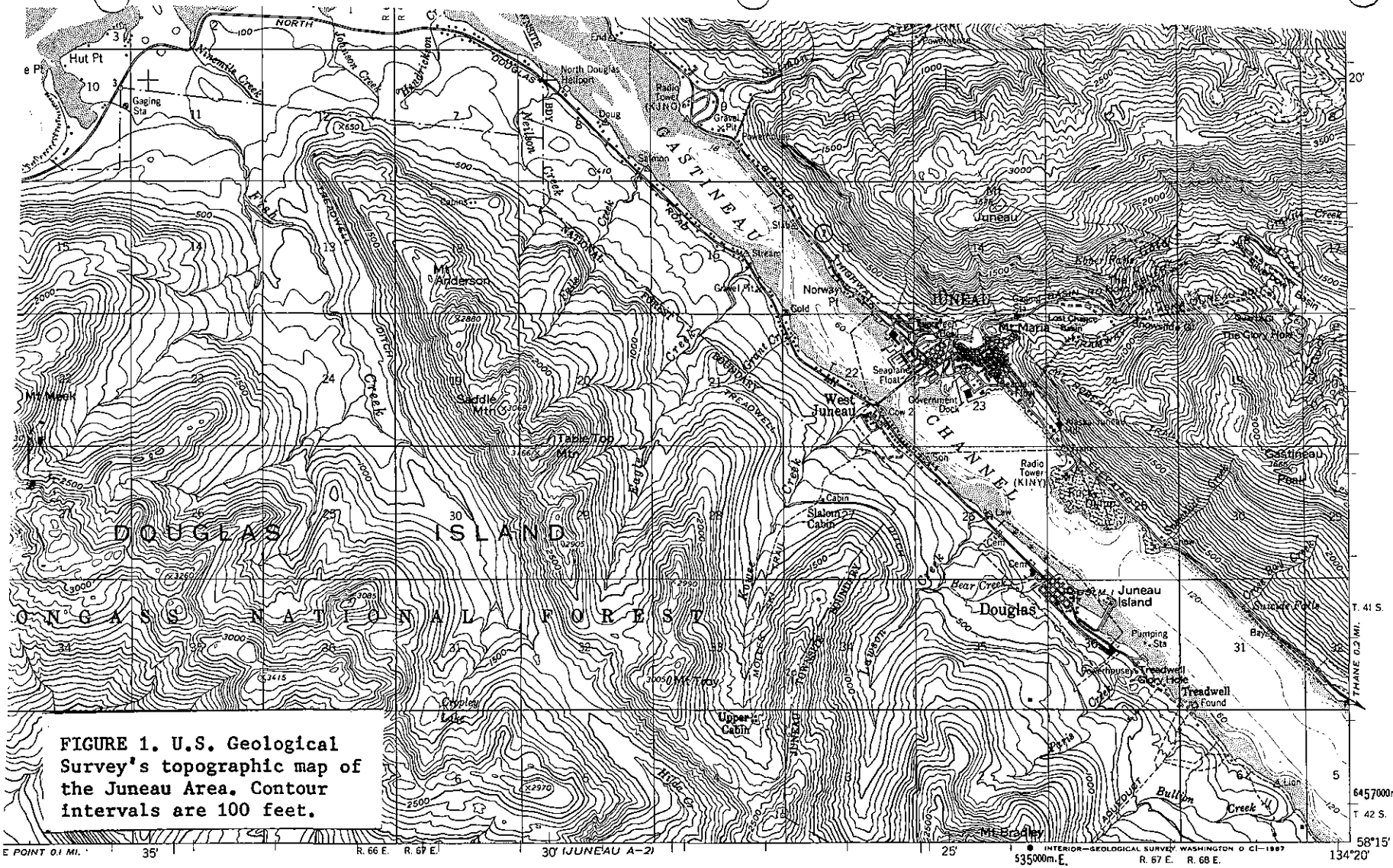
Slab avalanches occur when a fracture occurs around a layer or layers of snow on a slope. The fracture occurs rapidly and usually follows a unique path. Slab avalanches may contain large masses of snow, and when the slab breaks loose, it can bring down 10 to 100 times the initial amount of snow (Perla 1975).

Slab instability is greatest during and immediately after a storm because of the load and stress applied by the additional snow to the existing snow layer. With time, stability usually increases as settling and metamorphism occurs.

Slab instability is also caused by above freezing temperatures. The resulting thawing produces a large amount of free water in the snow pack, with the possibility of the free water dissolving the bonds between layers.

An especially hazardous situation exists during wintertime storms which begin with a heavy snowfall, then warm above freezing producing rain. This combined with gusty winds results in low stability and high avalanche potential.

The only constant factor in avalanche formation is the mountain slope (State of Alaska 1963). Avalanches can occur on a slope as slight as 15 degrees, and snow has been observed clinging to slopes as great as 60 degrees (Perla 1975). Avalanches are most likely to occur on slopes of 30 degrees to 45 degrees (Dept. of Agriculture 1974).


DOUGLAS ISLAND
TONGASS NATIONAL FOREST
GASTINEAU CHANNEL
JUNEAU
West Juneau
Douglas
Juneau Island
Treadwell
Mt Juneau
Mt Maria
Mt Anderson
Mt Meek
Mt Bradley
Saddle Mtn
Table Top Mtn
Hut Pt
Gaging Sta
North Douglas Heliport
Radio Tower (KINY)
Radio Tower (KINO)
Norway Pt
Seaplane Float
Government Dock
Slalom Cabin
Upper Cabin
Pumping Sta
Powerhouse
Gastineau Peak
Bear Creek
Sheep Creek
Cowee Creek
Hilda Cr
Bullion Creek
Cropley Lake
Eagle Creek
Fish Creek
Gold Creek
Taku Inlet
Taku Glacier
Lemon Creek
Johnson Creek
Nugget Creek
Sheep Creek
Slide Cr
Lost Chance Basin
Thousand Cr
The Glory Hole
Sunshine Falls
Bayard Cr
Sherman Cr
Dorothy Cr
Cropley Cr
Aqueduct
Perna
Lion
Found
Cow 2
Cabin
Gent
Low
Son
Stream
Gravel Pit
Powerhouse
Salmon
Doug
Mendenhall Bay
Mendenhall Creek
Lemon Creek
Johnson Creek
Nugget Creek
Hawkins Creek
Nugget Creek
Sheep Creek
Slide Cr
Dorothy Cr
Cropley Cr
Aqueduct
Perna
Bullion Creek
Sherman Cr
Bayard Cr
Sunshine Falls
Gastineau Peak
Taku Inlet
Taku Glacier
Lemon Creek
Johnson

3. Forecasting Methods

A. Terrain

The terrain in the Juneau area is ideal for avalanche activity (Figure 1). Three major avalanche paths exist along the Thane Road south of Juneau. The first of these, Snowslide Creek, is located three miles south of Juneau (Figures 2 and 3). This area has an average slope of 33 degrees, but it is steeper at the top than in the middle and lower sections. The second path is located directly below Gastineau Peak and has an average slope of about 30 degrees. Cross Bay Creek is the third major avalanche path (Figure 4). It has an average slope of slightly less than 30 degrees but it is considerably steeper at the top than in the middle sections.

The gullies associated with the creeks and the large unbroken slopes above timberline favor avalanche formation. Vegetation is sparse along the creek beds and in the area below Gastineau Peak

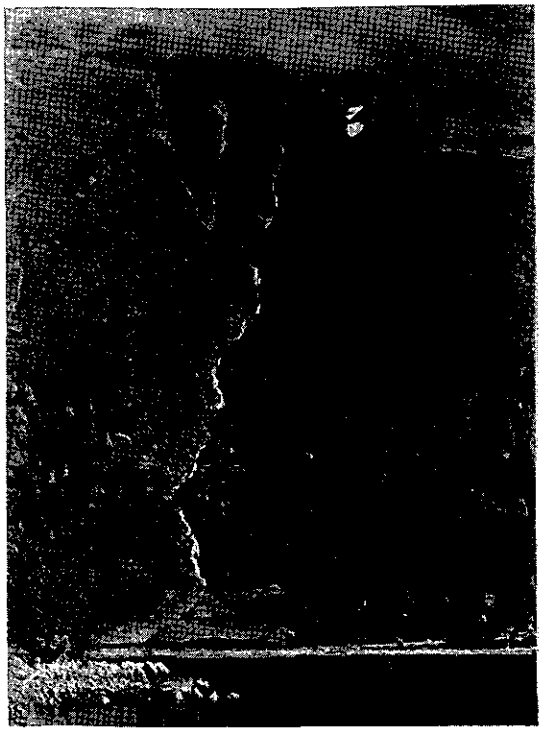


Figure 2. Snowslide Creek avalanche area pictured during the late summer. Thane Road can be seen near the shoreline.

Figure 3. Thane Road, near Snowslide Creek, shortly after one of the avalanches of 1976.

Figure 4. Dick Hamilton, maintenance engineer with the Alaska Department of Highways, surveys the snow removal effort 24 hours after an avalanche at Cross Bay Creek. Thane Road can be seen in the upper right.

Another area in which avalanches have occurred is the Behrends Avenue area on Mt. Juneau (Figures 5 and 6). This area has an average slope of 45 degrees with a steeper slope in the upper sections. Vegetation is sparse above the 150 meter (500 foot) level. Gullies in the slope favor avalanche formation.

B. Prelude to Avalanche Activity

The forecasting program at WSFO Juneau begins with the first snowfall in the Autumn. The first snow usually occurs in the latter part of October. Normally there is little accumulation in the lower elevations until the last of November. However, the higher elevations are usually covered by early October.

Beginning with the first snowfall, precipitation amounts and snow depths are measured daily as near as possible to the avalanche paths. In addition a record is made of wind and temperature in the avalanche area. The observation site is located near sea level within 1.6 kilometers (1 mile) of the major avalanche paths (Figure 7).

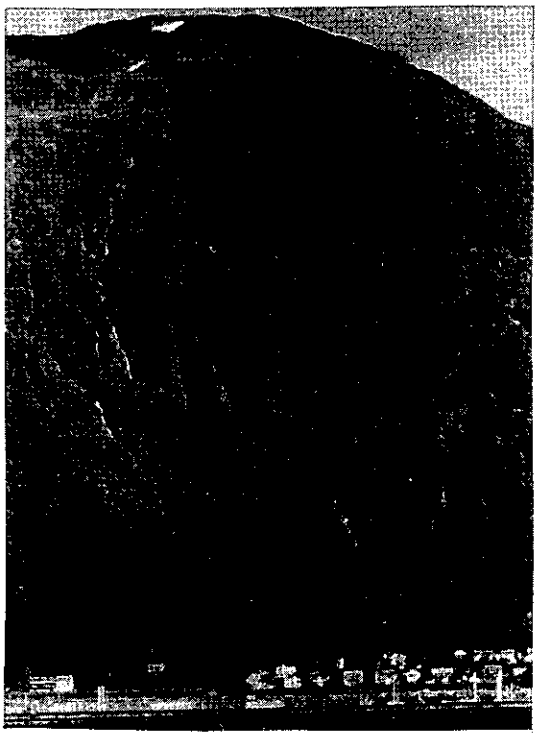
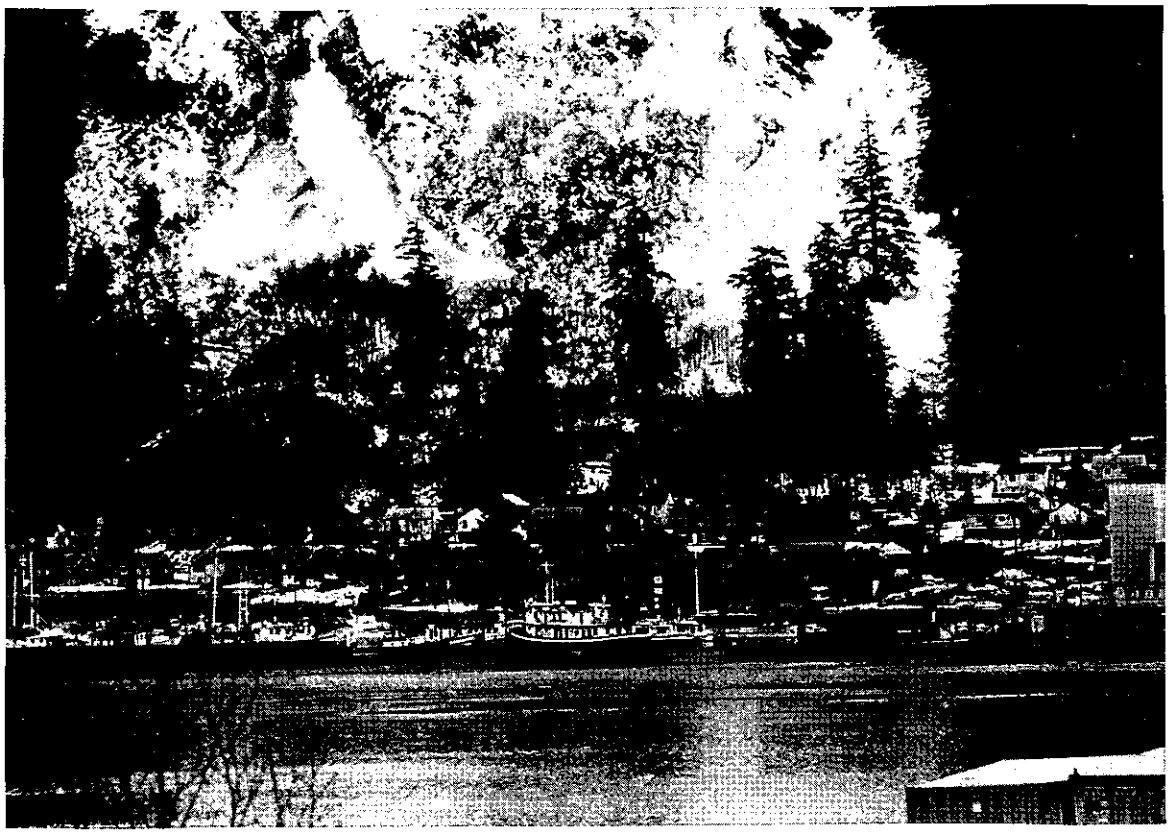


Figure 5. Behrends Avenue slide area on Mt. Juneau pictured in late summer.

Figure 6. Behrends Avenue slide area during the winter of 1976. Avalanches came within 60 meters (200 feet) of residences.



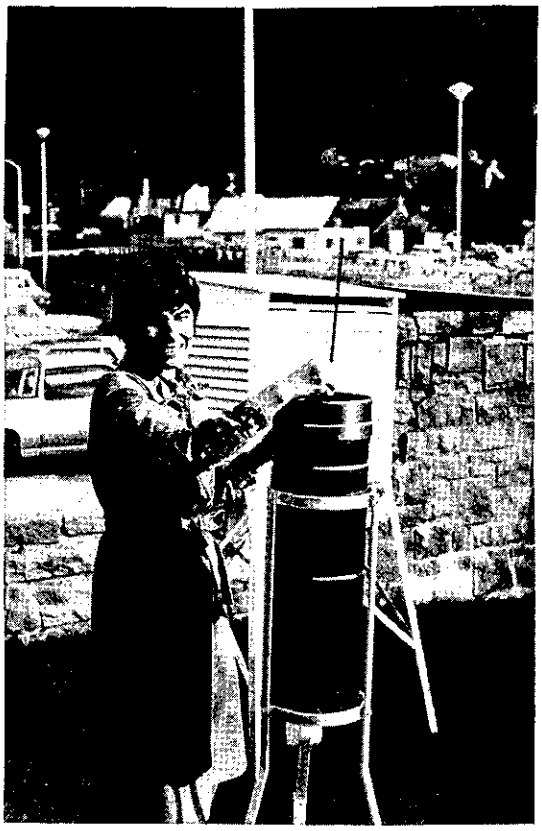


Figure 7. Elizabeth Mooney measures precipitation at the observational site located in downtown Juneau. Avalanche path can be seen in the upper right.

This along with visual observations of the avalanche paths, allows the forecaster to determine when enough snow has accumulated to provide a good sliding surface. This method also allows him to keep general track of the different snow layers.

Once enough snow is on the slope to cover the undergrowth, the forecasters watch for conditions that will provide a load on the slope. Records of snow depth, freezing level and the water equivalent of snow are examined daily along with visual observations of the slope.

When it is determined that sufficient snow is on the slope to allow an avalanche, the forecaster watches for conditions that will result in instability of the snowpack. Surface layers that have developed during the early winter are also considered. An estimate of the snow layers is made by examining the past record of snowfall amounts, temperatures, and wind in the avalanche areas.

Changes in the weather cause changes in the stability of the snowpack. The weather influences the extent, the occurrence, the type and the magnitude of avalanches for given terrain features. (Frutiger 1972). Once enough snow to allow an avalanche is on the slopes, the forecaster looks for changes in the weather that will cause the snowpack to become unstable.

Both wet avalanches and dry avalanches occur in the Juneau area. The key to forecasting both of these types of avalanches, once the slope has sufficient snow to avalanche, is the change in the weather.

The avalanche forecasters at WSFO Juneau examine, on a continuous basis, the synoptic weather patterns. They look for the formation of weather patterns that will result in the type of weather that causes instability in the snowpack. The synoptic pattern that produces dry avalanches is much different than the pattern that produces wet avalanches.

C. Wet Avalanches

Wet avalanches are the most frequent kind to occur in the Juneau area. These are also the easiest to forecast. The synoptic pattern associated with wet slab avalanches begins to take shape 24 to 36 hours before the avalanche occurs. A typical pattern at the 500mb level has a ridge of high pressure extending along the west coast of British Columbia and over Southeast Alaska. A deep low pressure area exists south of the Alaska Peninsula (Figure 8). The isotherm pattern shows warm air advection into the Gulf of Alaska. The surface analysis (Figure 9) associated with this upper air pattern shows a deep low south of the Alaska Peninsula with a front in the central Gulf of Alaska. Snow begins shortly after this map time in Northern Southeast Alaska as the upper level ridge moves eastward. As the front moves over Southeast Alaska, about 12 hours later, snow changes to rain as temperatures rise above freezing. As rain and warm air advection continues, the snowpack becomes more unstable. Wet slab avalanches will occur if rain continues 12 to 24 hours with an accumulation of 1.9 centimeters (0.75 in.) or more.

The freezing level should rise at least to 760 meters (2,500 ft.). In order for this to occur, the synoptic pattern at the surface must result in a persistent southerly flow, extending southward from northern British Columbia to south of 50 degrees north. The flow aloft should be from the south or southwest.

A higher threat of avalanches will exist if this situation is preceded by a period of cold weather and gusty northeasterly winds and blowing snow. This will add additional snow to the slopes and the cold weather will keep the layer from stabilizing.

D. Dry Snow Avalanches

The second type of avalanche that occurs in Juneau is the dry snow avalanche. This type of avalanche occurs less frequently than the wet avalanche and is more difficult to forecast.

Dry point avalanches require a sufficient amount of snow on the slope to provide a good sliding surface plus an adequate snowpack

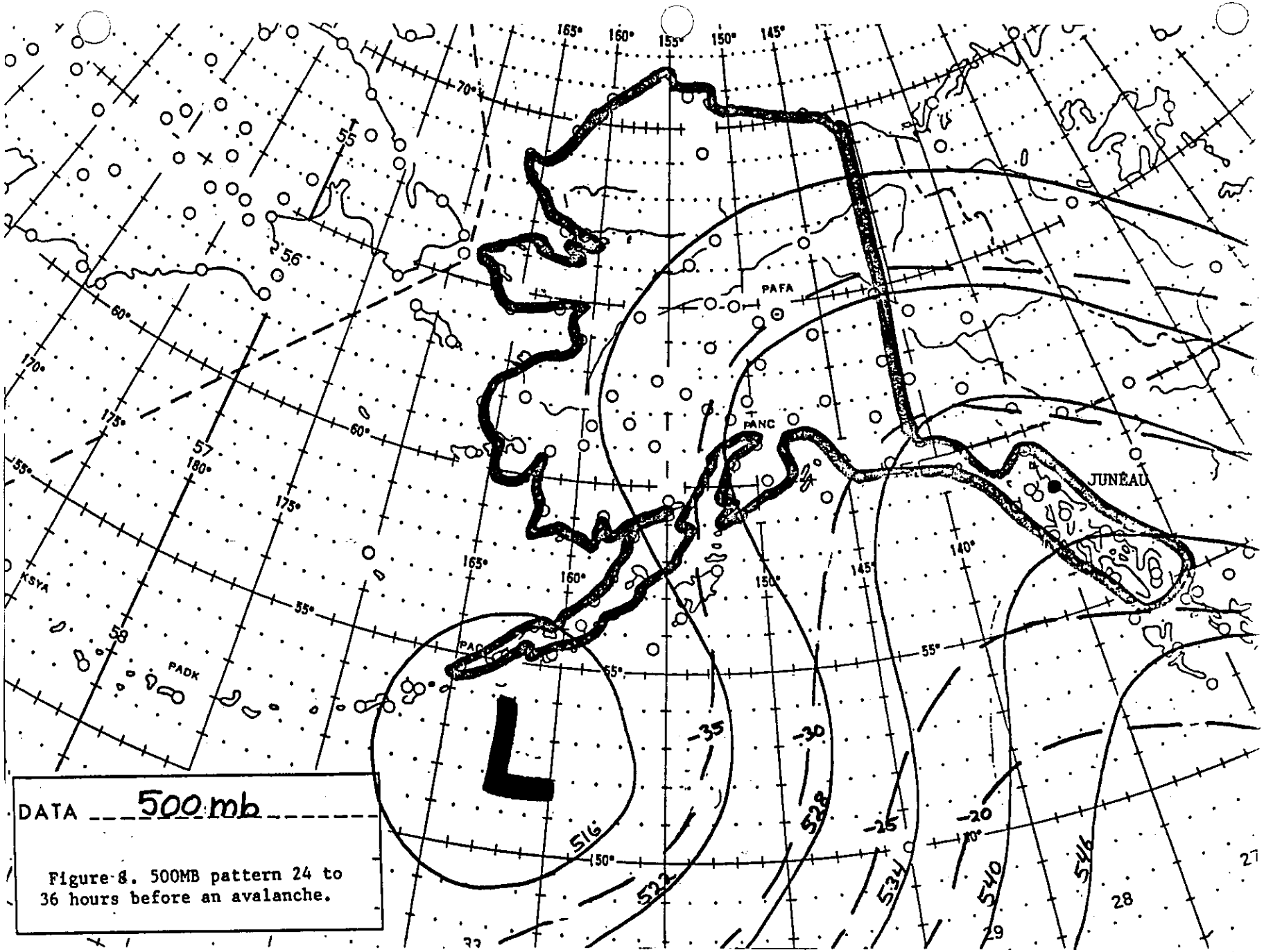
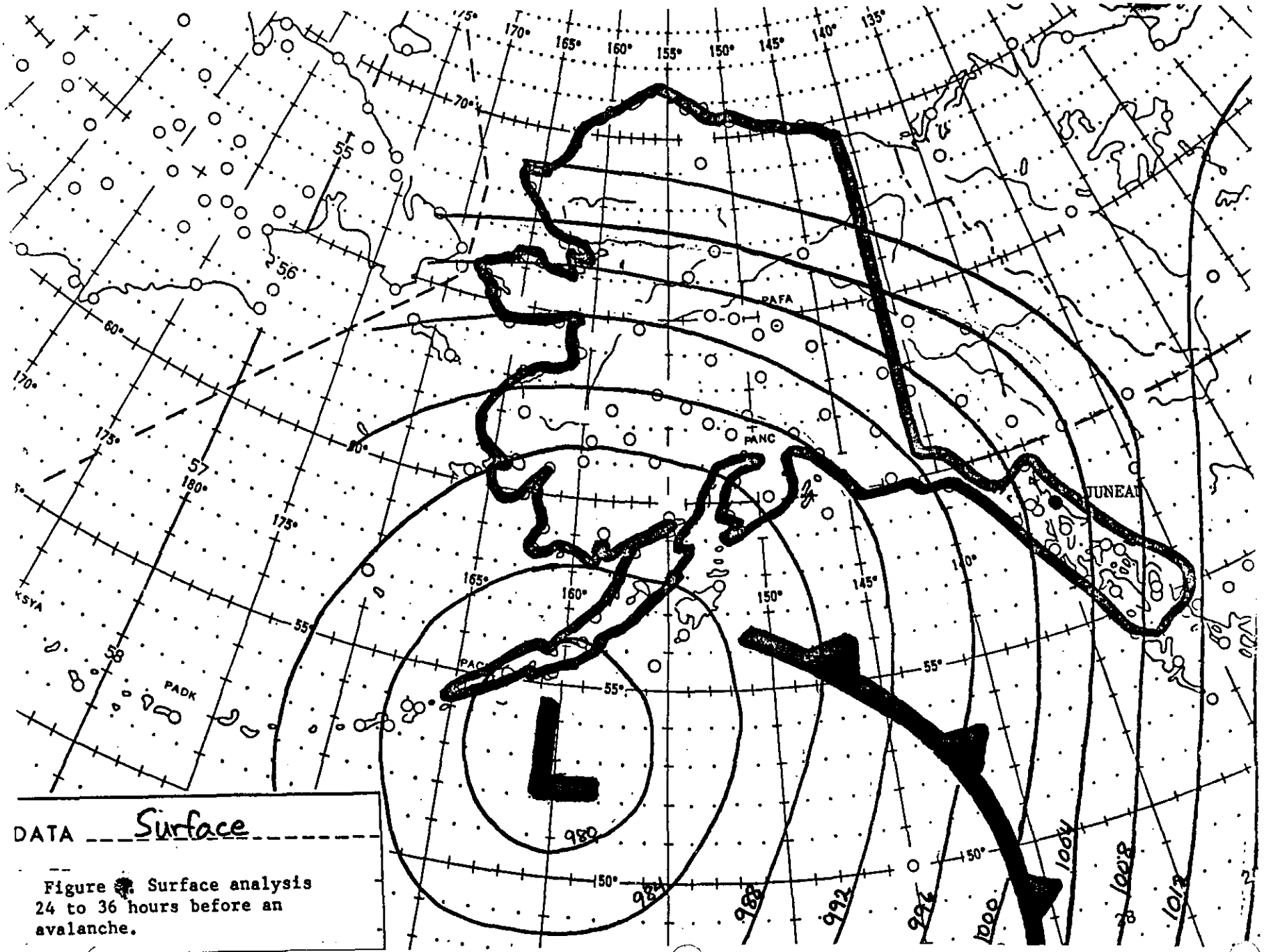


Figure 8. 500MB pattern 24 to 36 hours before an avalanche.



DATA Surface

Figure 8. Surface analysis 24 to 36 hours before an avalanche.

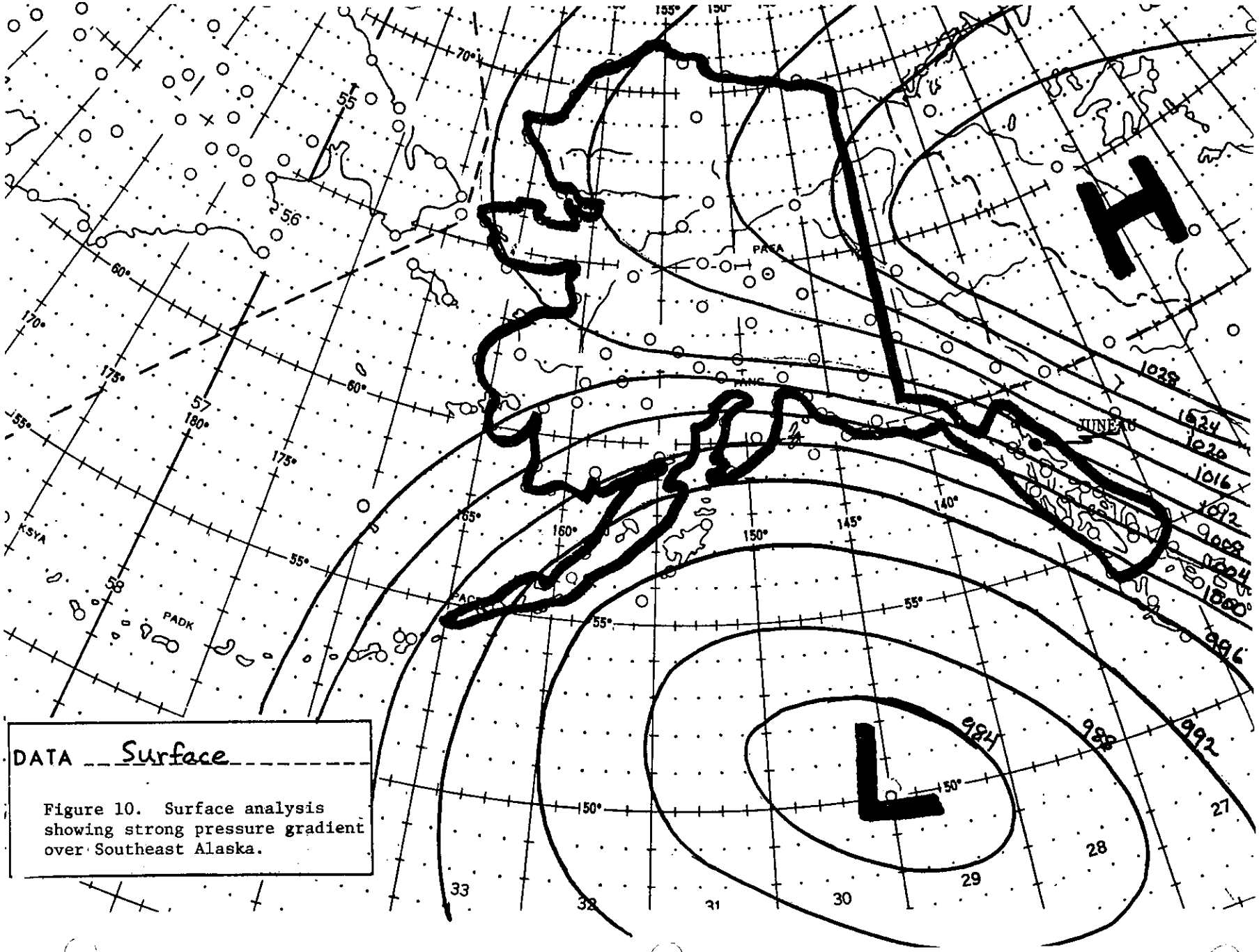
to avalanche. The triggering factor for the dry point avalanche is sufficient loading of the snowpack to cause instability. In the Juneau area this results from strong northeast winds transporting snow onto the slope.

Dry slab avalanches may occur when large snow slabs break off the upper shoulders of Mt. Juneau and sweep away additional unstable snow as they descend across the lower and steeper slopes. Such conditions occur during prolonged periods of low temperature, deep snowfall at all elevations, and strong northeast winds causing drifting snow at the top of the avalanche path (LaChapelle 1968).

Thirty centimeters (1 ft.) or more of new snow followed by a period of 3 or 4 days with winds transporting snow onto the slope is required to cause sufficient instability for avalanches to occur. In addition, temperatures must average 8 to 17 degrees C (15 to 30 degrees F) below normal so that metamorphosis will not occur to the newly deposited snow.

The synoptic pattern that produces sufficient winds to transport snow onto the slope is shown in Figure 10. This pattern has a very strong persistent high pressure area over northwestern Canada with low pressure in the Gulf of Alaska. A very tight pressure gradient exists over northern Southeast Alaska.

Variables such as wind speed and amount of snow transported make it difficult to determine when the loading on the slope has reached the critical level. However, after the proper conditions have been met, the forecaster will issue a statement that hazardous conditions exist and that the threat of avalanches will continue to increase as long as snow transport continues onto the slope. These conditions may last for several days.



DATA Surface

Figure 10. Surface analysis showing strong pressure gradient over Southeast Alaska.

4. Summary

In summary, the procedures used by the avalanche forecasters at Juneau are:

1) Determine, in the fall, when enough snow is on the slope to cover rocks and the smaller vegetation, and provide a good sliding surface. This is done by recording daily snow depth, temperature, and winds, and by visual examinations where observations are not practical.

2) Make daily measurements of snow depth and visual observations of stability near the avalanche slope to determine when the snowpack presents an avalanche threat.

3) Maintain a continuous watch of synoptic weather patterns to determine when weather conditions will occur which will cause the snowpack to become unstable, and add additional snow on the slopes.

4) For wet avalanches, issue an avalanche warning when gusty winds and rain are expected to continue for 12 to 24 hours. An accumulation in excess of 1.9 centimeters (0.75 in.) should occur with the freezing level rising to 762 meters (2,500 ft.).

5) For dry snow avalanches, issue an avalanche warning when an accumulation of 30 centimeters (1 ft.) or more of new snow is followed by 3 or 4 days with strong winds, transporting snow onto the avalanche slopes. Temperatures should be 8 to 17 degrees C (15 to 30 degrees F) below normal. Mean temperature for December is minus 3 degrees C (27 degrees F); for January, minus 4 degrees C (24 degrees F); for February, minus 2 degrees C (28 degrees F).

6) Discontinue avalanche warnings as soon as the stability in the snowpack increases.

5. Case Study

A major avalanche event occurred in the Juneau area on March 16, 1976. This late in the winter, sufficient snow was available to provide a good sliding surface on the mountains around Juneau. Several periods of snow occurred during the first half of the month, both of which were followed by cold temperatures and gusty northeast winds. By March 12, adequate snow for an avalanche was available on the slopes. The cold temperatures in between snowfalls had kept the snowpack from completely stabilizing.

A triggering mechanism was all that was needed to start an avalanche. The triggering mechanism began to develop on March 13, with the movement of a low pressure area into the northern Gulf of Alaska and the eastward movement of another low south of the Aleutians (Figure 11).

By the evening of the 13th, snow had spread over northern Southeast Alaska as the low in the northern Gulf moved northeastward. Warm advection aloft had begun by the morning of the 14th (Figure 12).

Snow continued in the Juneau area throughout the day of the 14th with an accumulation at the Juneau Airport of 10 centimeters (4 in.).

By the morning of the 15th, the low in the northern Gulf had moved into the southern Yukon territory and weakened (Figure 13). The low south of the Aleutians had moved into the central Gulf and split into two separate centers. A southerly flow of 28 to 37 kilometers per hour (15 to 20 knots) at low levels had developed over Southeast Alaska and had moved the Arctic Front north of Juneau by 12Z. This caused a rise in the surface temperatures and the snow changed to mixed rain and snow. The 500mb flow at this time (Figure 14) showed 65 to 74 kilometers per hour (35 to 40 knots) southwesterlies over Southeast Alaska. The 700mb chart (Figure 15) showed continued warm advection over Southeast Alaska.

By the morning of the 16th (Figure 16), the first low pressure area had moved into the northern Gulf of Alaska and the second low had continued eastward into the southern Gulf. A southerly low level flow of 37 to 46 kilometers per hour (20 to 25 knots) continued over Southeast Alaska.

In the Juneau area, the mixed rain and snow changed completely to rain in the lower elevations as surface temperatures during the morning climbed into the upper 30's. Low level winds in the area were southeasterly 37 to 56 kilometers per hour (20 to 30 knots). As the low and front in the southern Gulf moved northward during the day (Figure 17), moderate rain spread over Southeast Alaska. Rainfall for the 16th totalled 2.54 centimeters (1 in.) in downtown Juneau. By late afternoon (00Z) on the 16th, the freezing level over the Panhandle had risen to the 850mb level, nearly 1,500 meters (5,000 ft.) (Figure 18).

Major avalanche activity occurred in the Juneau area during the afternoon of the 16th. The Thane Road south of Juneau was closed in two places, with numerous other avalanches occurring in the mountains around Juneau.

After the frontal passage on the 17th (Figure 19). precipitation became showery over the northern sections of Southeast Alaska, reducing the amount of free water available in the snowpack. This combined with the stabilizing of the slopes that had already avalanched, resulted in a diminished threat of avalanches by the evening of the 17th.

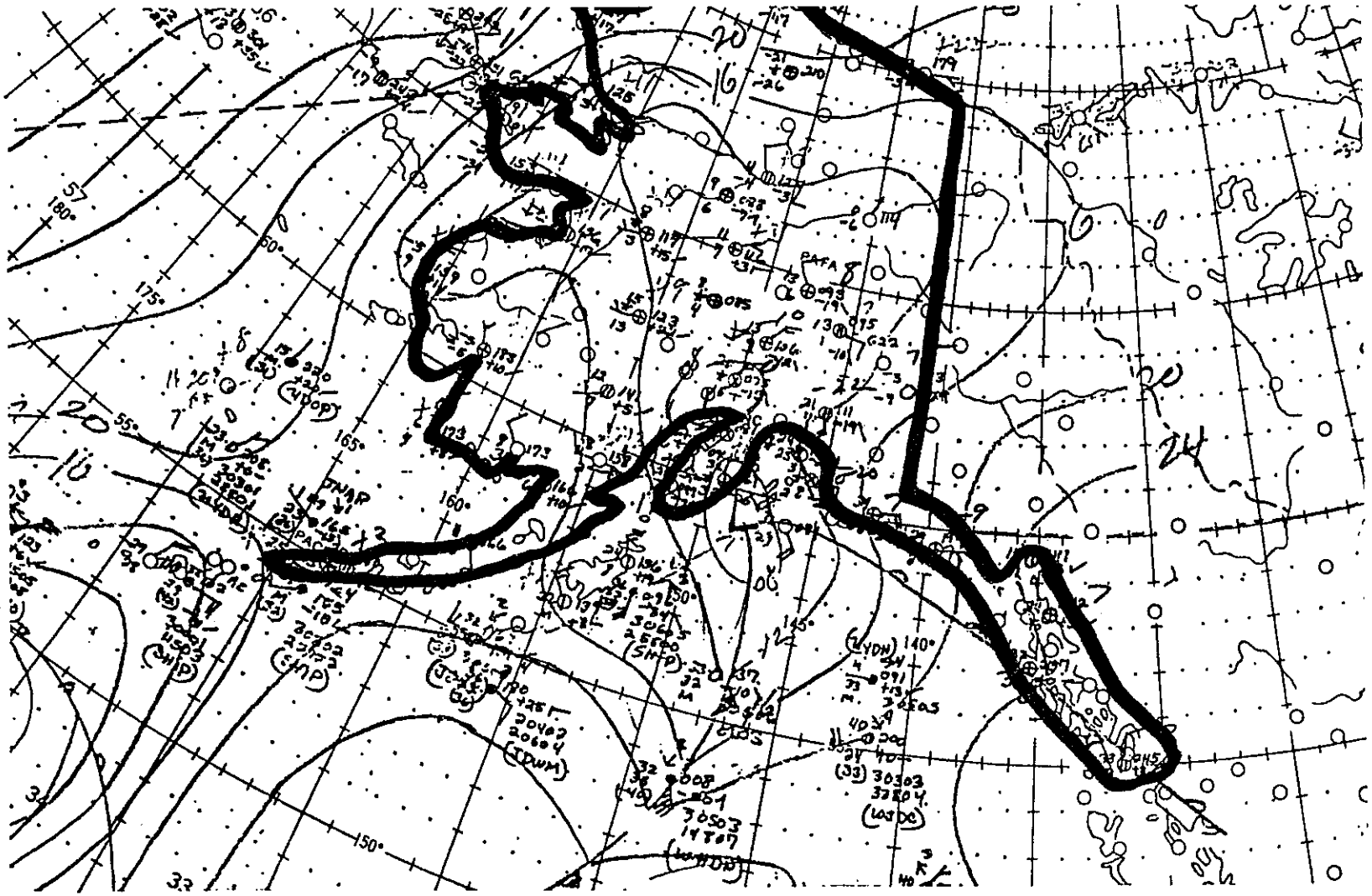


Figure 11
Surface Analysis for
18Z
March 13, 1976

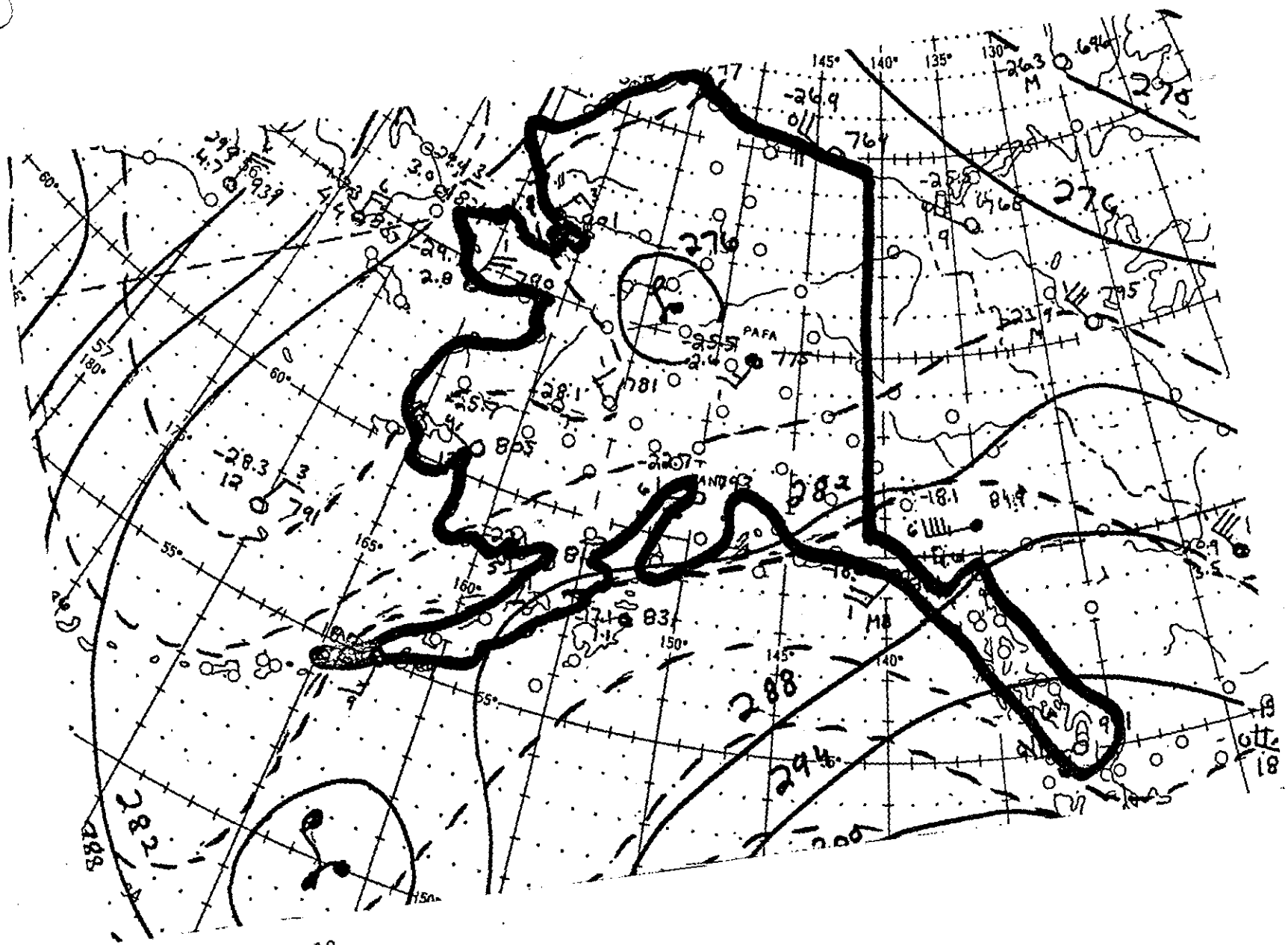


Figure 12
700mb Analysis for
12Z
March 13, 1976

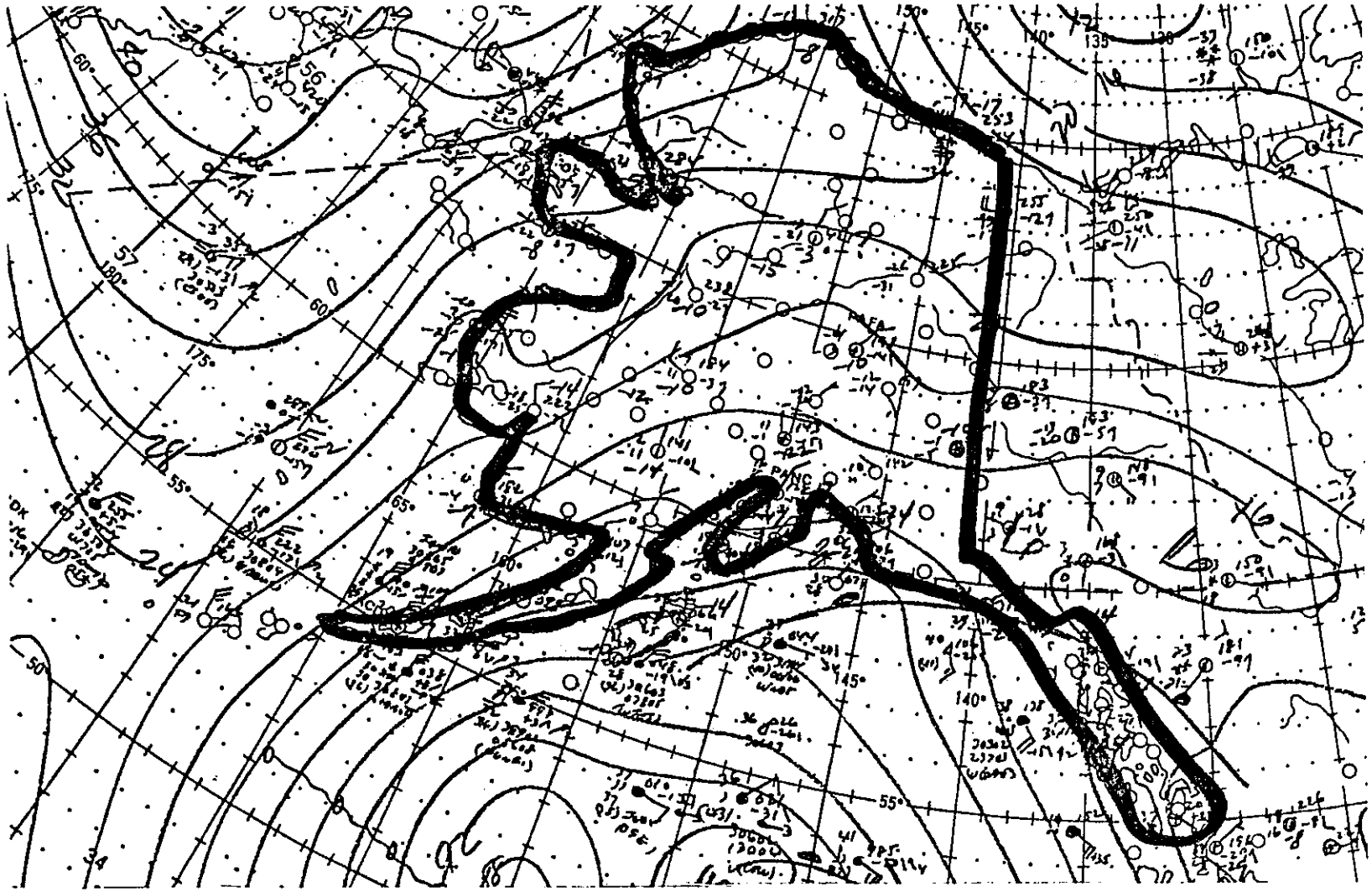


Figure 13
Surface Analysis for
12Z
March 15, 1976

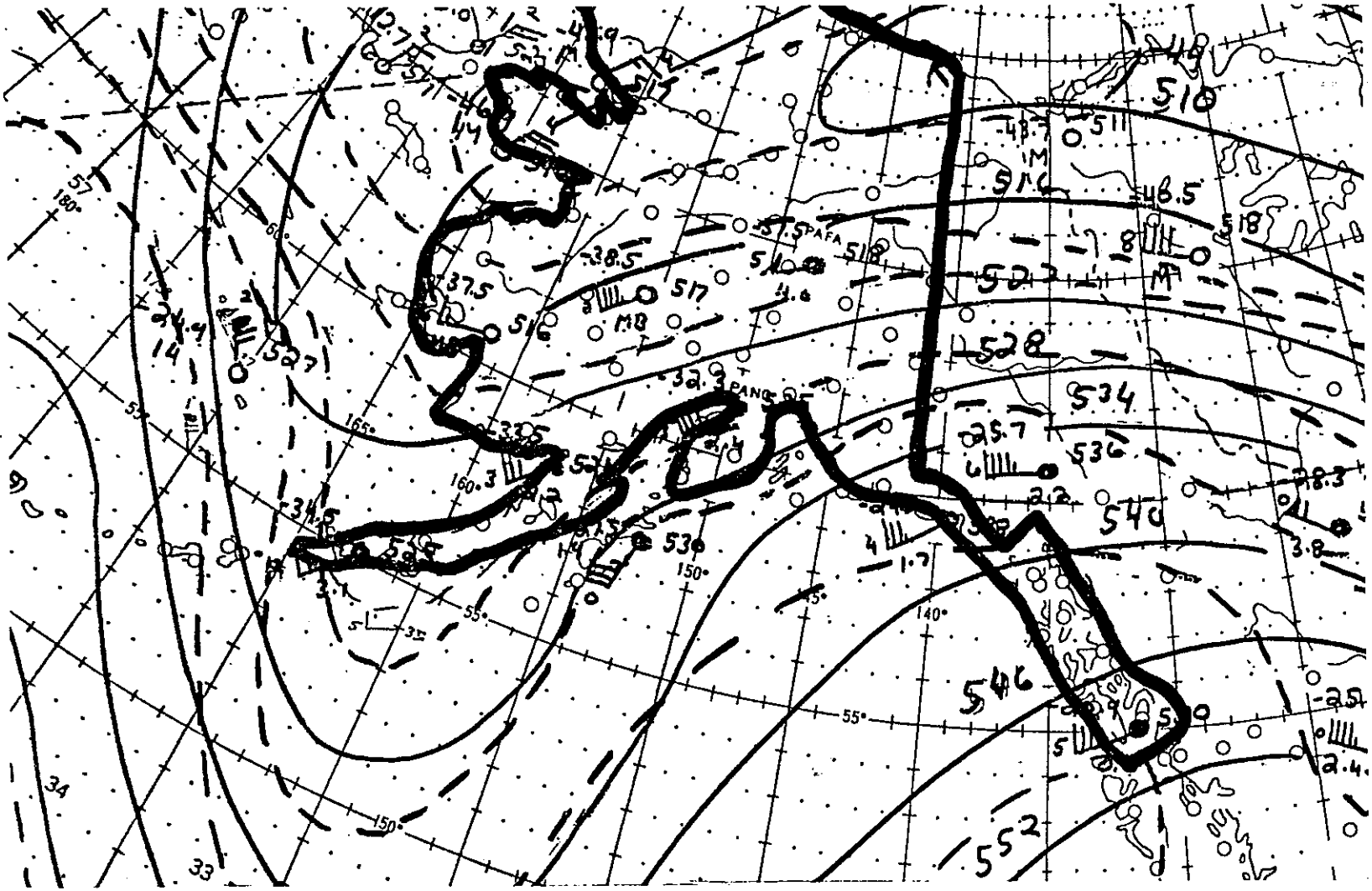


Figure 14
500mb Analysis for
12Z
March 15, 1976

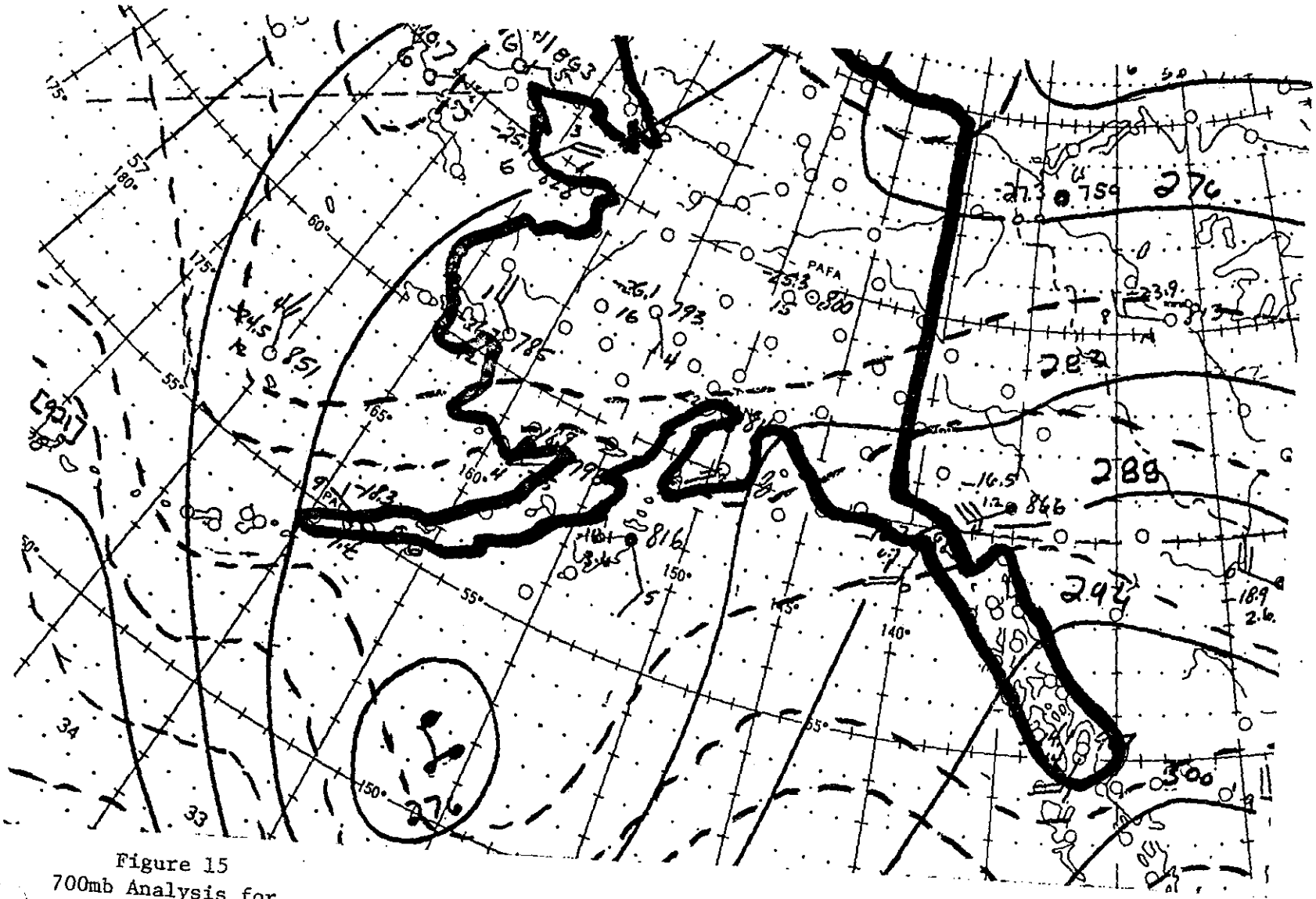


Figure 15
700mb Analysis for
12Z
March 15, 1976

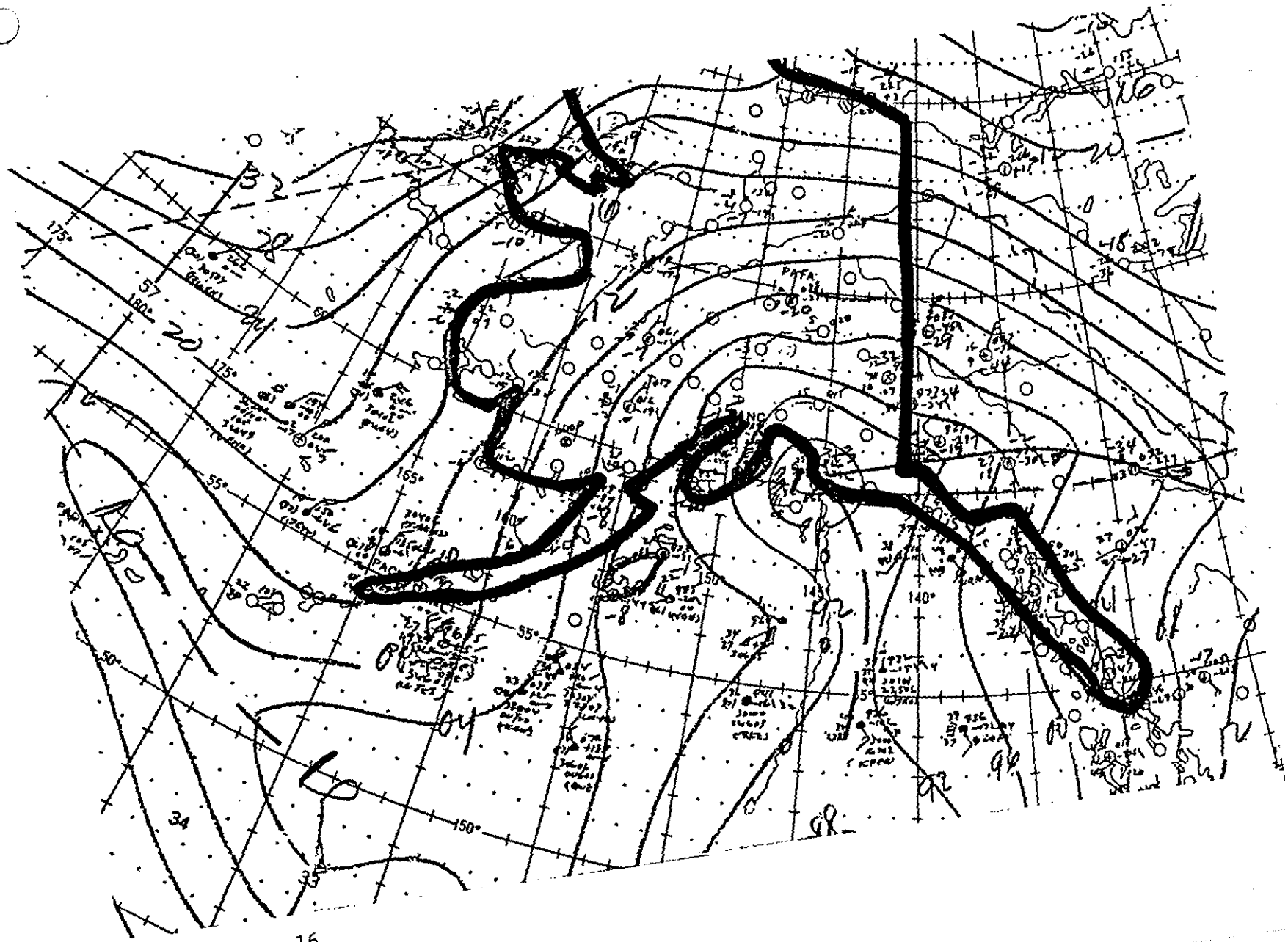


Figure 16
Surface Analysis
12Z
March 16, 1976

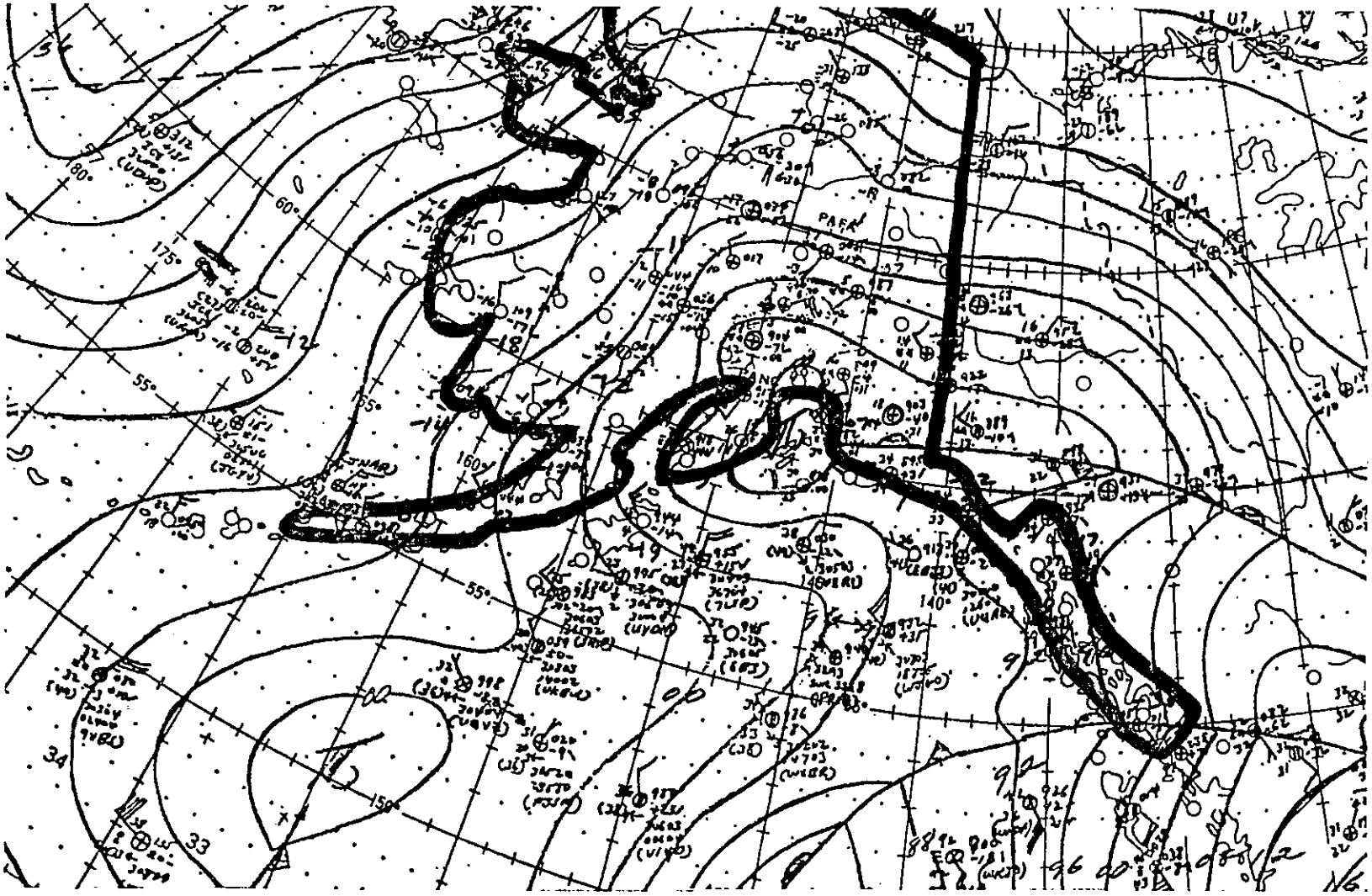


Figure 17
Surface Analysis for
18Z
March 16, 1976

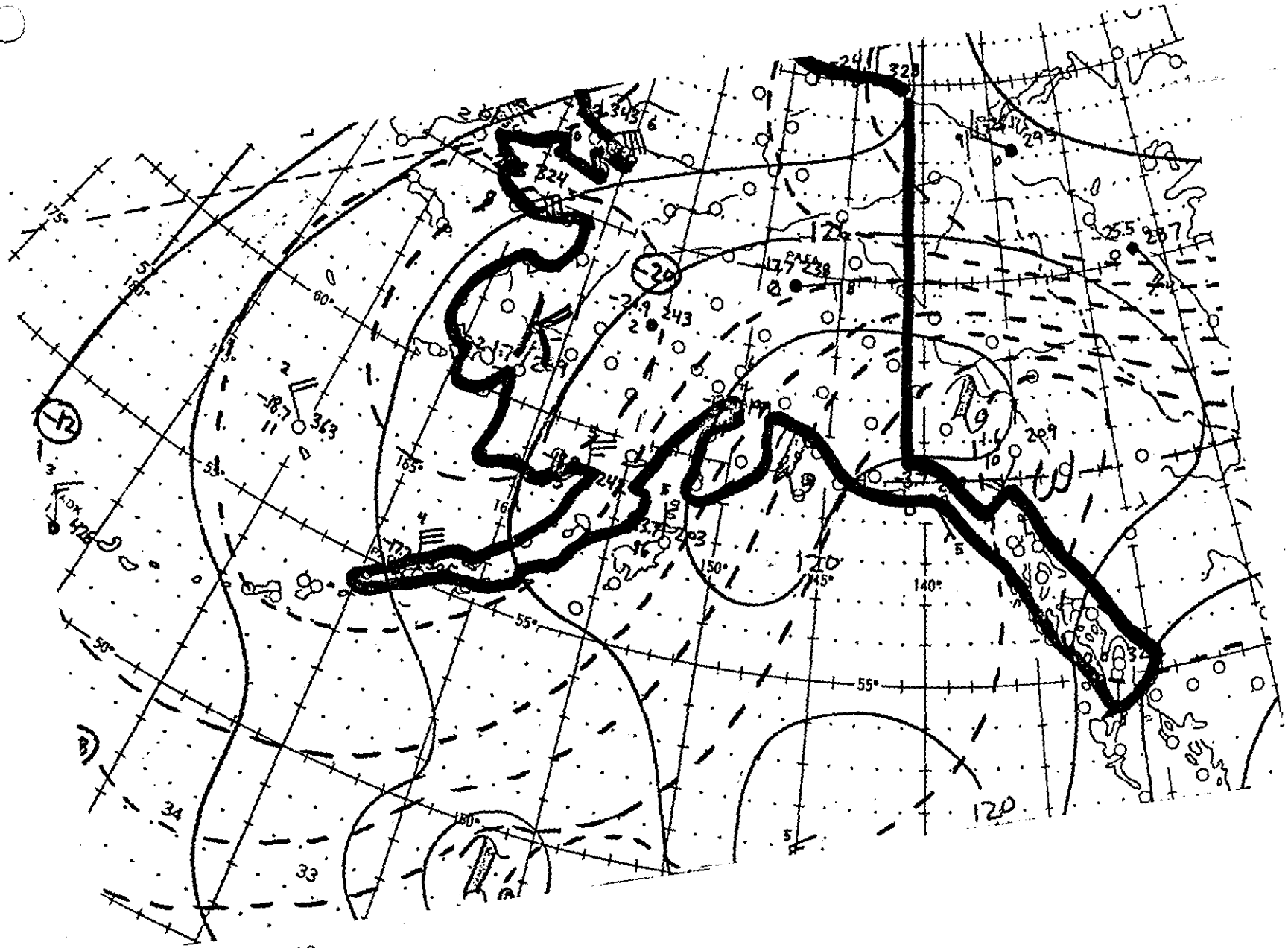


Figure 18
850mb Analysis for
00Z
March 17, 1976

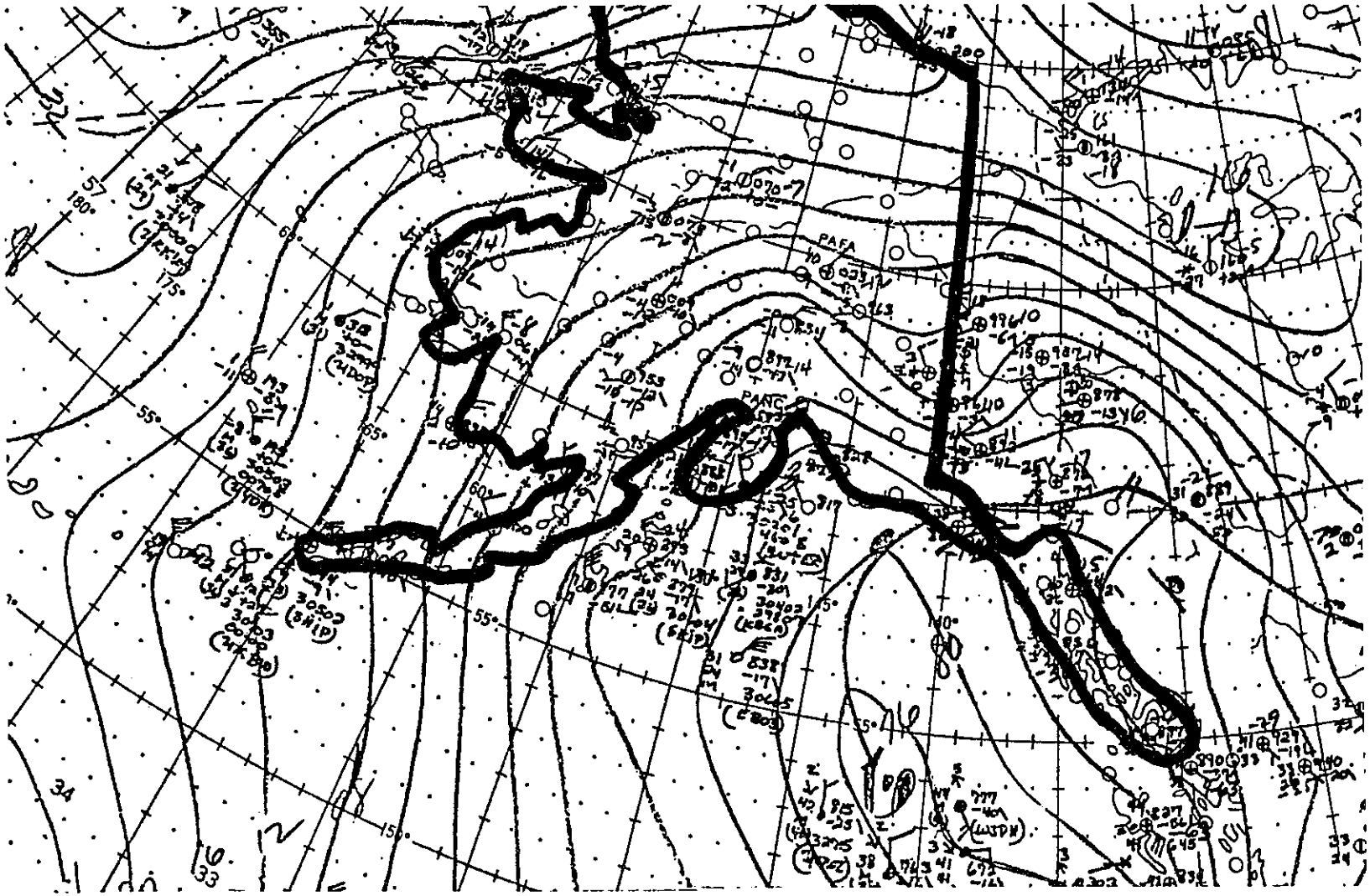


Figure 19
Surface Analysis for
12Z
March 17, 1976

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