NOAA TECHNICAL MEMORANDUM NWS AR-25

SNOWFALL AT ANCHORAGE, ALASKA ASSOCIATED WITH COLD ADVECTION

Donald L. Finch and Jeffery P. Walker
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ABSTRACT. A relationship between significant snowfall at Anchorage, Alaska and cold advection at the 850mb level into southwest Alaska combined with strong positive vorticity advection at the 500mb level into Cook Inlet is examined. It appears this leads to cyclogenesis in Cook Inlet which results in snowfall. A forecast scheme using 850mb and 500mb level composite charts based on data from 10 cold advection cases has been developed. The limitations of numerical modeling associated with this type of snow event are also examined.

INTRODUCTION

The purpose of this paper is an attempt to isolate and identify a weather pattern which relates to significant snow in the Anchorage, Alaska area. The objective of this work, and any of our future work, is to improve the forecasts associated with particular weather events. Our ultimate goal is to develop a series of map "types" using 850mb and 500mb patterns associated with all significant weather events in the Anchorage area. We believe improved forecasts will result from additional insight into the physics and dynamics of these events along with an appreciation of the limits of numerical guidance. Although our method primarily employs imagery and analogy, it can lead to a quantitative approach.

In March and April of 1979, three significant precipitation events occurred in the Anchorage area, none of which were adequately forecast by the numerical guidance. Two features were common to all three events: (1) the southeastward movement of a 500mb trough out of northwest Alaska and (2) the development of a strong 850mb thermal gradient between McGrath and Anchorage, Alaska. Experience has shown that not only is it difficult to forecast the onset of snow associated with these features but, once the snow begins, it seems to be almost as difficult to determine the intensity and duration of the snowfall.

THE PHYSICAL SETTING

Anchorage is located near sea level at the eastern midpoint of a large basin having a north-south axis of nearly 480 km (300 mi). Its proximity to the Alaska Range to the north and west, and the Chugach and Kenai mountains to the east and south, can be seen from the topographic map of south-central Alaska shown in figure 1. Some 120 km (75 mi) southeast of Anchorage is the western edge of Prince William Sound, opening southward to the Gulf of Alaska; the Chugach Range is an effective barrier of about 1400 m (4500 ft) in that direction. The northern waters of the Gulf of Alaska are about 160 km (100 mi) to the south with the Kenai mountains being an effective barrier of about 1500 m (5000 ft) to the low-level moisture from that direction. Under the proper conditions, however, these waters provide an excellent moisture source for precipitation in the Anchorage bowl.

The Cook Inlet-Susitna Valley basin is separated from interior Alaska by the Alaska Range. During the Alaska winter months (October through early April), not only is interior Alaska itself

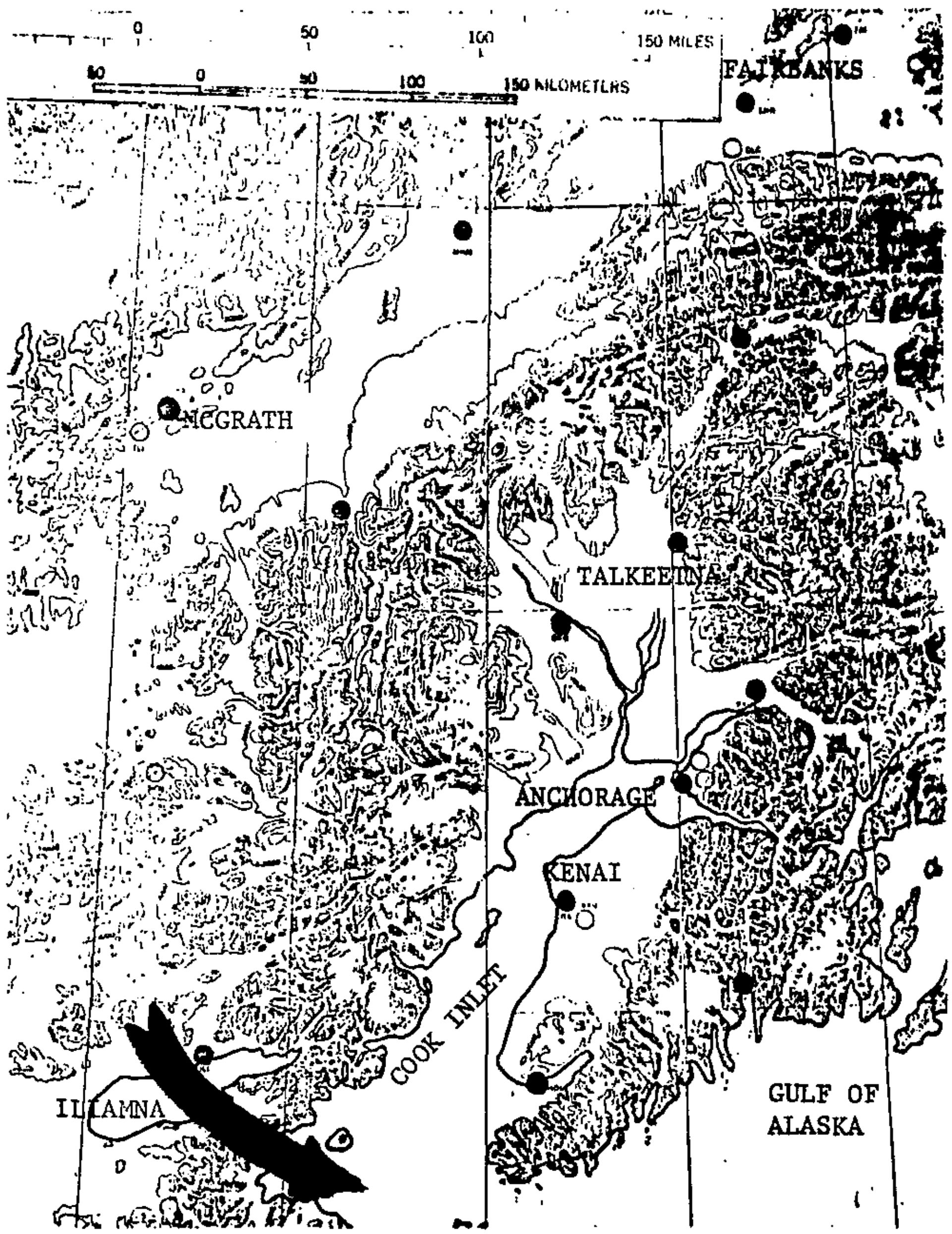


Figure 1. Topographic map of south-central Alaska. Contour intervals are 1,000 ft. The arrow in the bottom left corner depicts a "break" in the Alaska-Aleutian Range from Lake Iliamna southeastward into Kamishak Bay in lower Cook Inlet.

a source of arctic air but it is also open to intrusions of arctic air from the northwest through the northeast. During much of the winter, the Alaska Range provides an effective barrier to the arctic air of at least 1500-2000 m (5000-6000 ft).

THE APPROACH

We suspected that snowfall accumulations associated with the strong 850mb thermal gradient between McGrath and Anchorage would be in the range of 4-8 in and occur in a relatively short time. Since some upper air charts dating back to January 1973 were available at the Anchorage Weather Service Forecast Office, we investigated all snow cases in the neighborhood of 4-8 in which occurred in Anchorage since January 1973. After examining the records, we decided to concentrate our investigation on snow events of greater than 3 in.

The first step in the study was to isolate five snow events of greater than 3 in accumulation in less than 48 hours from the past two winters of 1977-78 and 1978-79 which had the two common features of a 500mb trough over western Alaska and a strong thermal gradient between McGrath and Anchorage at the 850mb level. From these five cases we developed composite maps of the 850mb and 500mb levels for the time nearest to the maximum intensity of the snowfall. If there were two or more peak periods, then the one occurring closest to the beginning of the snowfall was chosen.

We next examined all snow events of greater than 3 in from January 1973 through April 1977. We found another five cases[1] which we believed fit the type of pattern under investigation; from these we developed a second composite for the 850mb level. The similarity of the two 850mb level composites suggested we had a useful model.

We then developed a final composite for the 850mb and 500mb levels using all the cases. The next step was to build composites for these levels for the time 12 hr prior to the beginning of the snowfall and for 12 hr after the time of maximum intensity; surface charts of up to 24 hr prior to and through each event were also examined. After examining the surface charts, we felt that the major synoptic features were adequately described by the 850mb contours and isotherms. In fact, the features dealt with in these cases are easier to recognize at the 850mb level than at the surface due to topography and physical characteristics of the air mass.

[1]We later included the March 18-19, 1979 storm to give a total of 11 cases.

From the final composites we developed a set of antecedent conditions, not only to forecast the onset of snow but to give target amounts in the neighborhood of 4-8 in. The most obvious feature, common to all cases, was the strong thermal gradient between McGrath and Anchorage, with McGrath colder than Anchorage by at least 7 deg C (see figure 2). We then searched the 850mb charts for the past six winters looking for cases in which the gradient existed but Anchorage received little or no snow. We found four such cases and, in each of them, one or more of the antecedent conditions were absent or violated.

Our investigation showed that of 32 snow events which have occurred since January 1973, with accumulations greater than 3 in, 11 cases showed the development of a strong 850mb thermal gradient between McGrath and Anchorage. There were three snow events during the winters of 1973 and 1974 with accumulations greater than 3 in for which the upper air charts were missing. Consequently, we were not able to determine if these three cases had the same 850mb thermal pattern. It can be inferred, however, that this type of event occurs, on the average, about twice a year and accounts for about one third of all significant snow events. The average snowfall associated with these 11 cases was 6.8 in with an average duration of 23 hr.

A plot of accumulation against time (figure 2) shows that a high percentage of the snow occurs in a relatively short time, and in most cases shortly after the beginning of the snow. A graph similar to figure 2 was plotted for each of the 11 snow cases. These plots showed that during the initial phase of the snowfall the Anchorage 850mb temperature remained constant or warmed slightly. The McGrath 850mb temperature, however, showed significant cooling beginning 6 to 12 hr prior to the onset of snow at Anchorage. Because of this cooling at the McGrath 850mb level we decided to classify this type of snow event as a "cold advection" case.

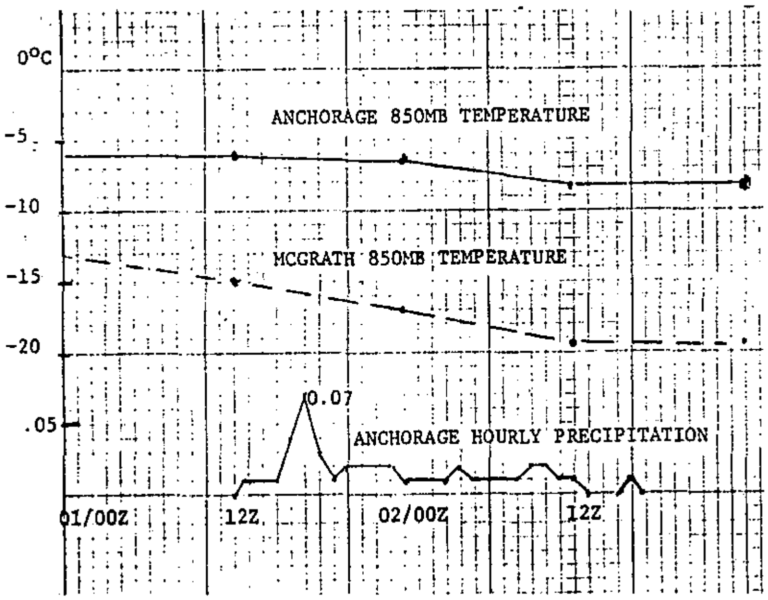


Figure 2. Anchorage hourly precipitation (0.01 in water equivalent) with the Anchorage and McGrath 850mb temperature profiles for the Dec. 1 and 2, 1974 snow case (10.3 in snow, 0.61 water equivalent).

COLD ADVECTION-TYPE SNOW EVENT

We define a cold advection-type pattern as one which exhibits the following characteristics (see figure 3):

At 850mb:

1. Cold thermal trough over western Alaska with strong packing of the isotherms from Cook Inlet into southwest Alaska, resulting in McGrath being at least 7 deg C colder than Anchorage.

2. A trough over southern Alaska and the northern Gulf of Alaska.

3. A ridge to the north and northwest of Alaska.

At 500mb:

1. Low over western interior of Alaska with a weak trough into the northwest Gulf of Alaska.

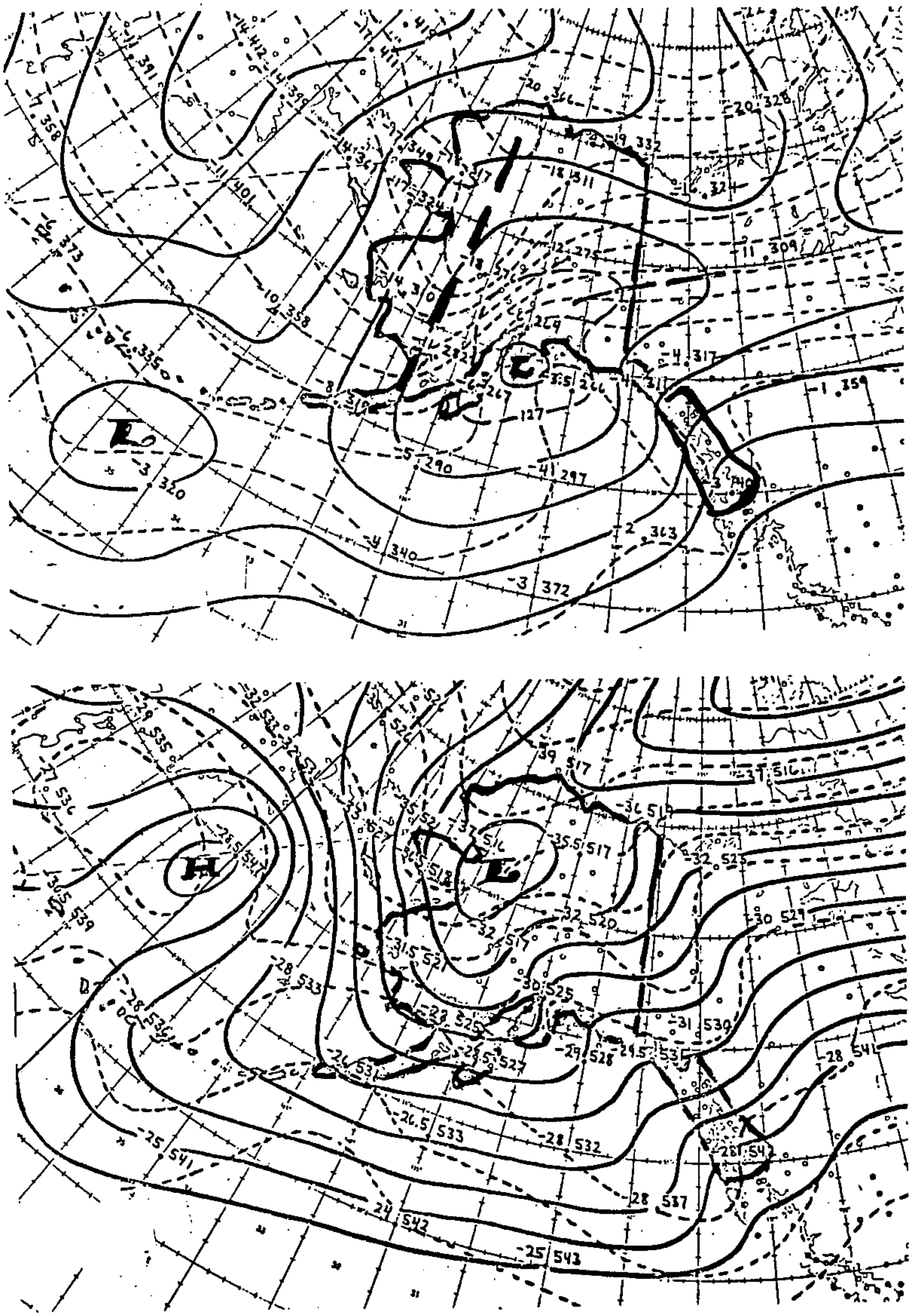


Figure 3. Cold advection-type patterns for 850mb composite (top) and 500mb composite (bottom). Contours are at 30 m intervals and isotherms are at intervals of 2 deg C. Composites are for time of maximum snowfall. Heavy dashed line on 850mb composite is position of thermal trough.

2. Northerly jet across the isotherms from the Chukchi Sea to the southwest coast of Alaska.

3. Ridge from the north-central Bering Sea to Siberia.

4. Closed low over the Canadian Arctic north of 75° N lat.

The sequence of events outlined in the following discussion was developed from our composite charts. We believe this sequence of events leads to cyclogenesis in Cook Inlet with the resultant significant snowfall at Anchorage:

A cold advection snow case occurs when arctic or polar air enters lower Cook Inlet with maritime air already present or being advected into the area. Some of this cold air obviously works eastward through the mountain passes and it is conceivable that, given cold air of sufficient depth, it could literally "spill over" into the Cook Inlet basin. However, the topographic map in figure 1 shows a break in the Alaska-Aleutian Range opening into the extreme southwest portion of Cook Inlet; this break is depicted by an arrow. It is suspected that this cold or arctic air flowing through the break results in frontogenesis in lower Cook Inlet which is an important ingredient in the process of cyclogenesis. This process and the events leading to it will be discussed in greater detail through the following discussion.

One of the fundamental characteristics of the cold advection-type development is the movement of the 850mb thermal trough (heavy dashed lines in figures 4, 5 and 6), between time t-12 (12 hours prior to the <u>beginning</u> of snowfall, figure 4) and time t (time of <u>peak</u> snowfall, figure 5), into western Alaska with the "pooling" of cold air over the Kuskokwim Valley due to the blocking effect of the Alaska Range. This pooling of cold air in the southwest interior of Alaska results in a strong baroclinic zone over western Alaska with an effective "granite" or mountain frontal boundary between the southwest interior and Cook Inlet. The actual surface frontal boundary, which is implied in the surface cyclogenesis, develops when the arctic air moves through the break in the Alaska-Aleutian Range and comes in contact with the maritime air in lower Cook Inlet.

At time t-12 the cold advection in southwest Alaska must be southward toward the trough of low pressure in the northwest Gulf of Alaska. As cyclogenesis continues in Cook Inlet through time 5, the low-level cold air is prevented from continuing southward by the developing circulation in the inlet. The low in the northern gulf then weakens as the Cook Inlet low intensifies.

Once cyclogenesis has taken place, the newly-developed low (time t+12, figure 6) can either remain stationary and weaken, or move north to northeast along the thermal jet (Sutcliffe and Forsdyke, 1950) according to the movement of the upper trough. If the 850mb low moves north or northeast, as is usually the case, the precipitation area moves into the Susitna and/or Matanuska Valley. Cold air then follows the low into the Anchorage area from the south. As this cold air moves into the Anchorage area, the snow either ends or diminishes to flurries, with the McGrath-Anchorage 850mb thermal gradient decreasing.

The second fundamental condition to the cold advection-type development is a 500mb trough over western Alaska with strong positive vorticity advection at that level into Cook Inlet. Petterssen and others have shown that "the overtaking by an upper trough (with positive vorticity advection in advance of it) of a frontal system in the lower troposphere is one of the most reliable indications of cyclone development at sea level" (Petterssen, 1940). An analysis of our composite cases suggests that not only do we have the overtaking of a front (the front here will be defined as the southeastern boundary of the baroclinic zone formed by the pooling of arctic air in the southwest interior) by an upper trough, but that there is a significant increase of positive vorticity advection into Cook Inlet when this happens.

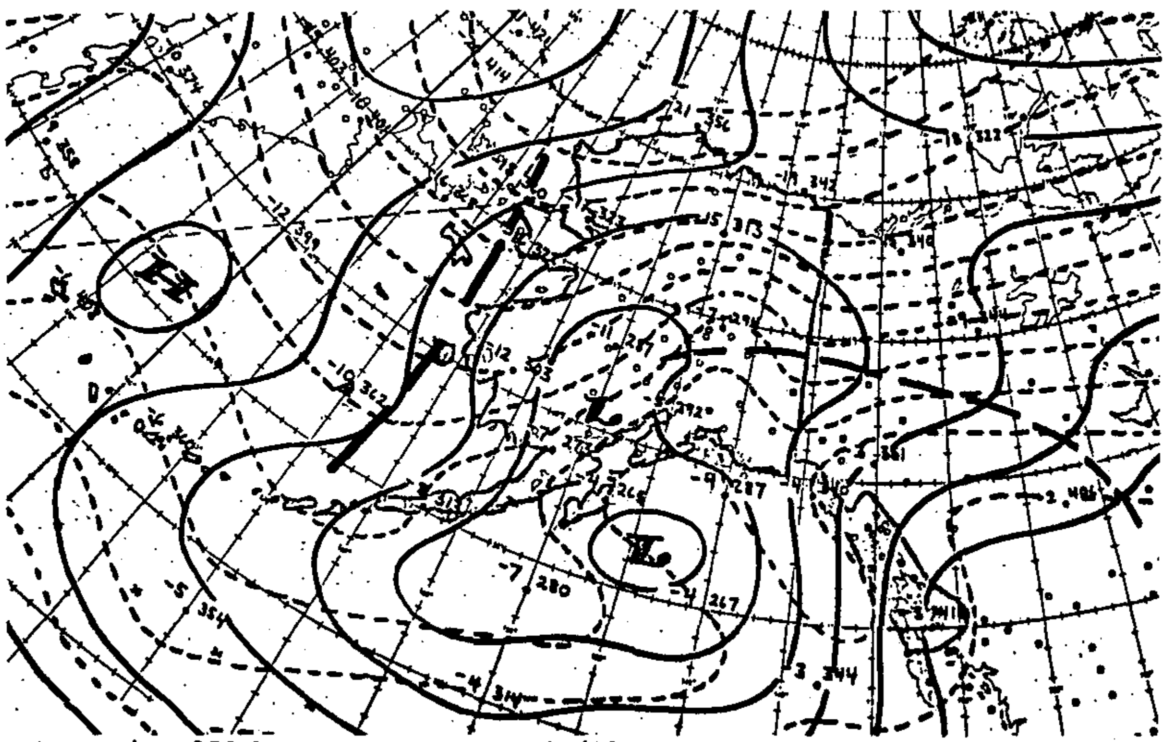


Figure 4. 850mb composite at t-12 (12 hr prior to the beginning of snowfall at Anchorage. Contours are at 30m intervals and isotherms are at intervals of 2 deg C.

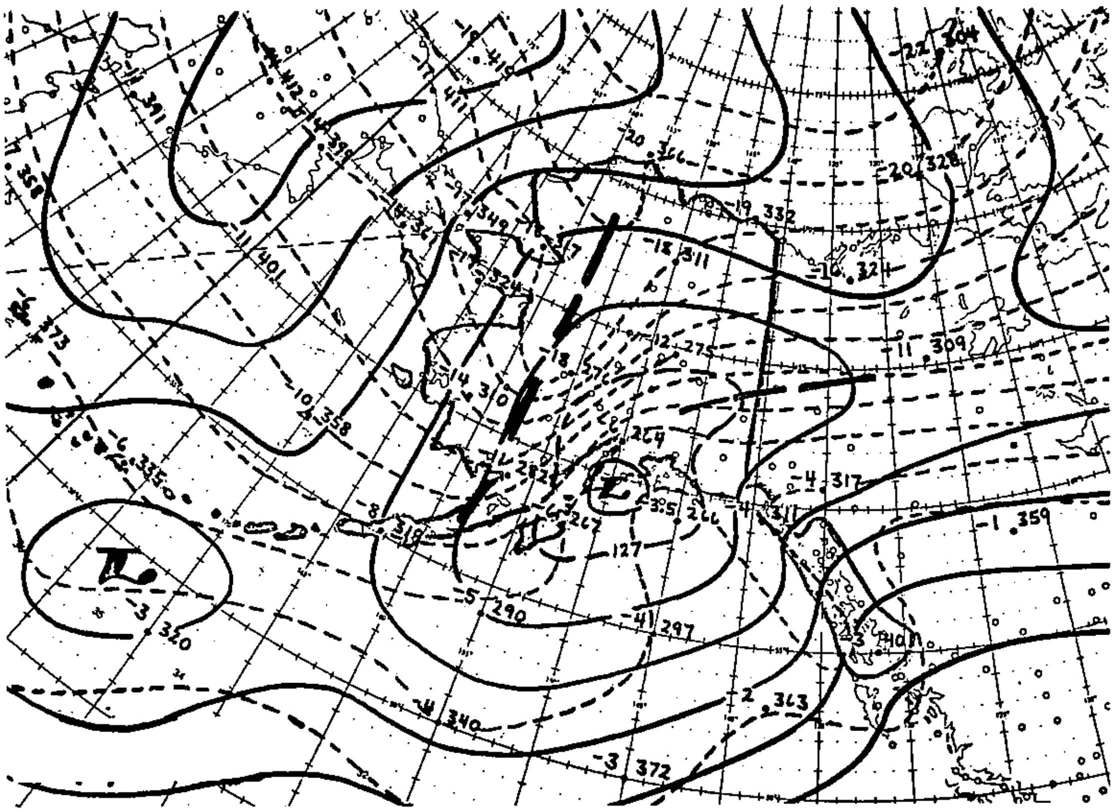


Figure 5. 850mb composite at time t (time of peak snowfall).

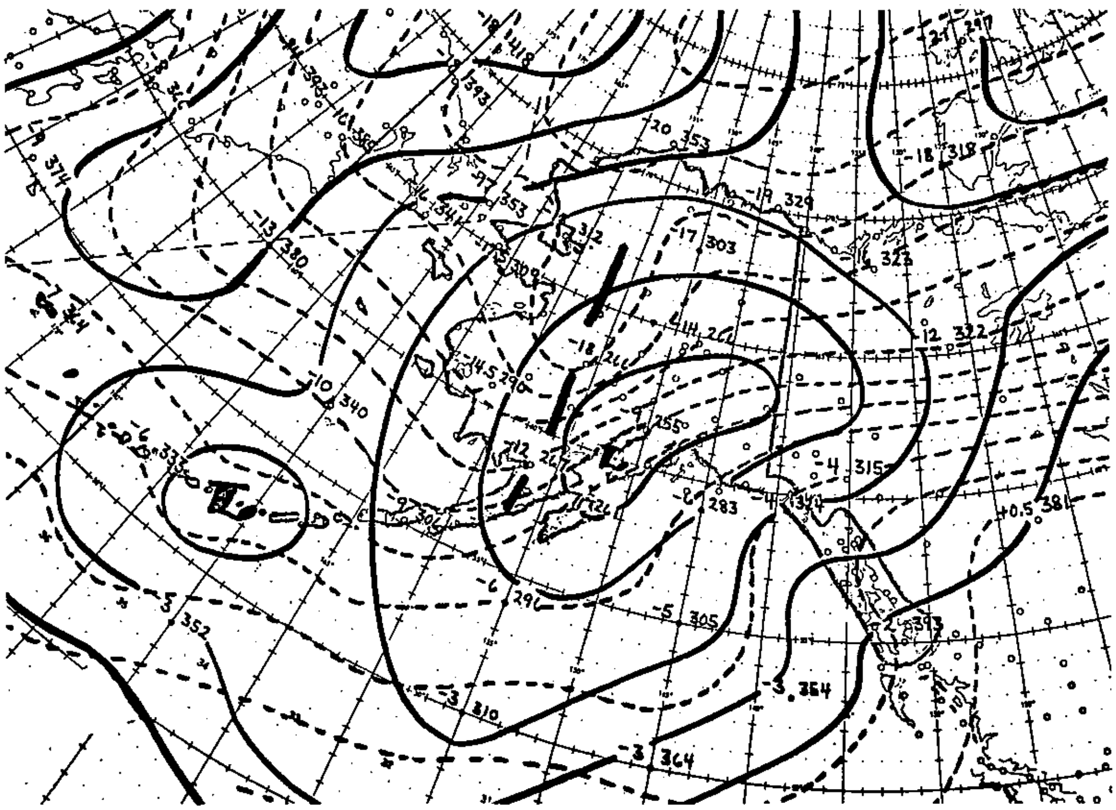


Figure 6. 850mb composite at time t+12 (12 hr after peak snowfall).

Note that the low center shown on these two composites over southern Alaska is a reflection of the filling low in the northwest Gulf and the developing low over Cook Inlet.

At time t-12 (figure 7), the 500mb trough is well established over western Alaska with a slight "negative tilt" to the southern portion of the trough across Kodiak Island to the weakness in the circulation over the northwest Gulf of Alaska. Because of the conservation of absolute vorticity, a parcel of air moving southward along the west coast of Alaska would have an increase of relative vorticity (assuming no horizontal divergence) (Byers, 1950). Between the time t-12 and time t (figures 7 and 8) the contours have tightened over southwest Alaska, increasing the shear term in the relative vorticity equation. The net effect is strong positive vorticity advection into the base of the trough with intensification of the trough (Petterssen, 1940).

By time t, the upper trough has moved over Cook Inlet. It is just prior to this time that perhaps the most significant event in the process of cyclogenesis occurs. The absolute vorticity is related to the pressure-depth of an air column

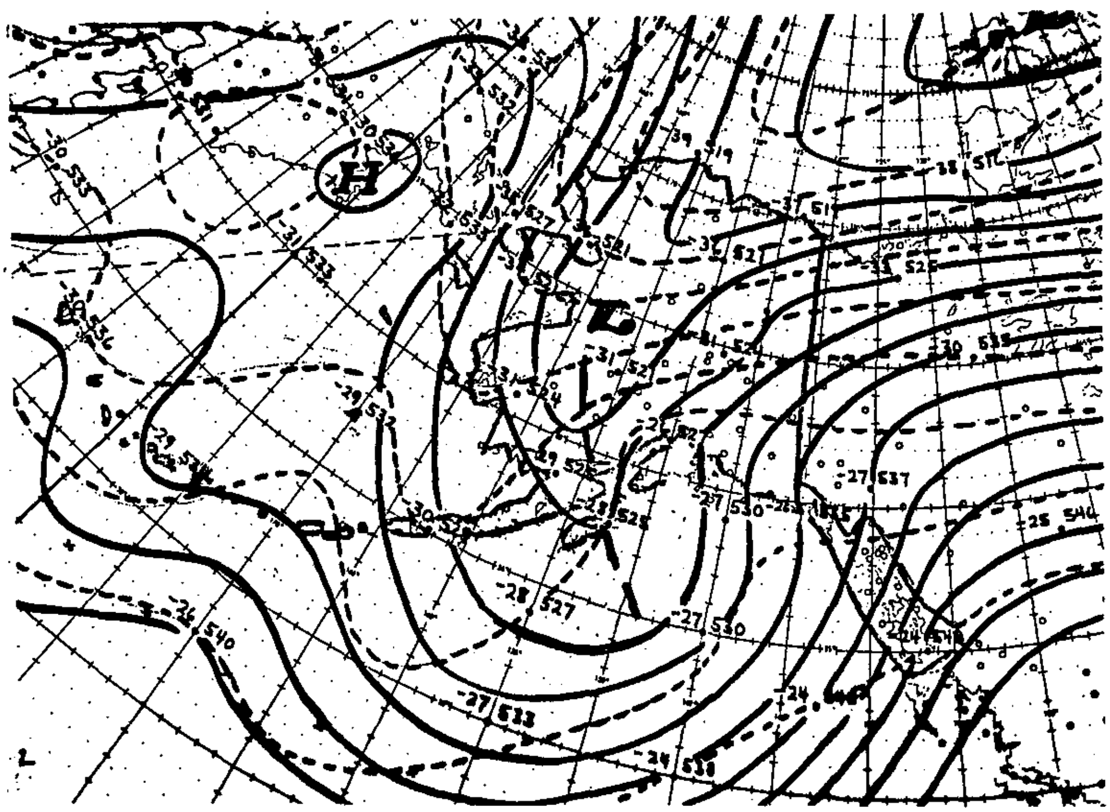


Figure 7. 500mb composite at time t-12 (12 hr prior to the beginning of snowfall at Anchorage). Contours are at 30 m intervals and isotherms are at intervals of 2 deg C.

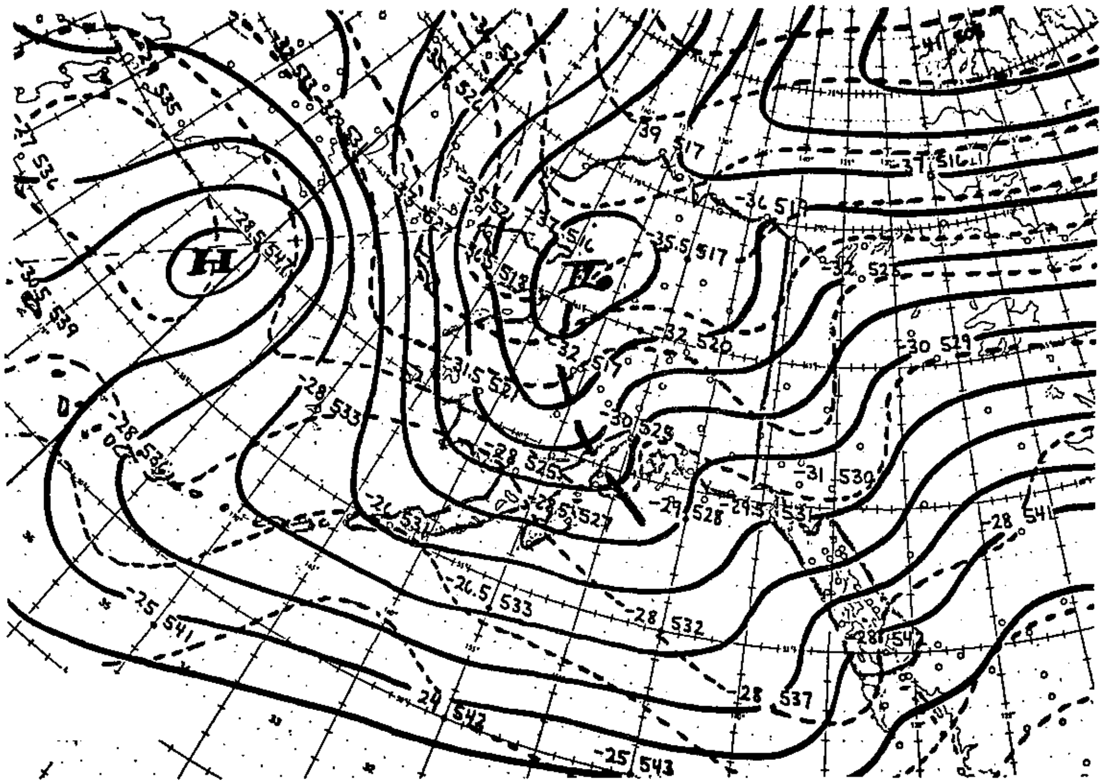


Figure 8. 500mb composite at time t (time of peak snowfall).

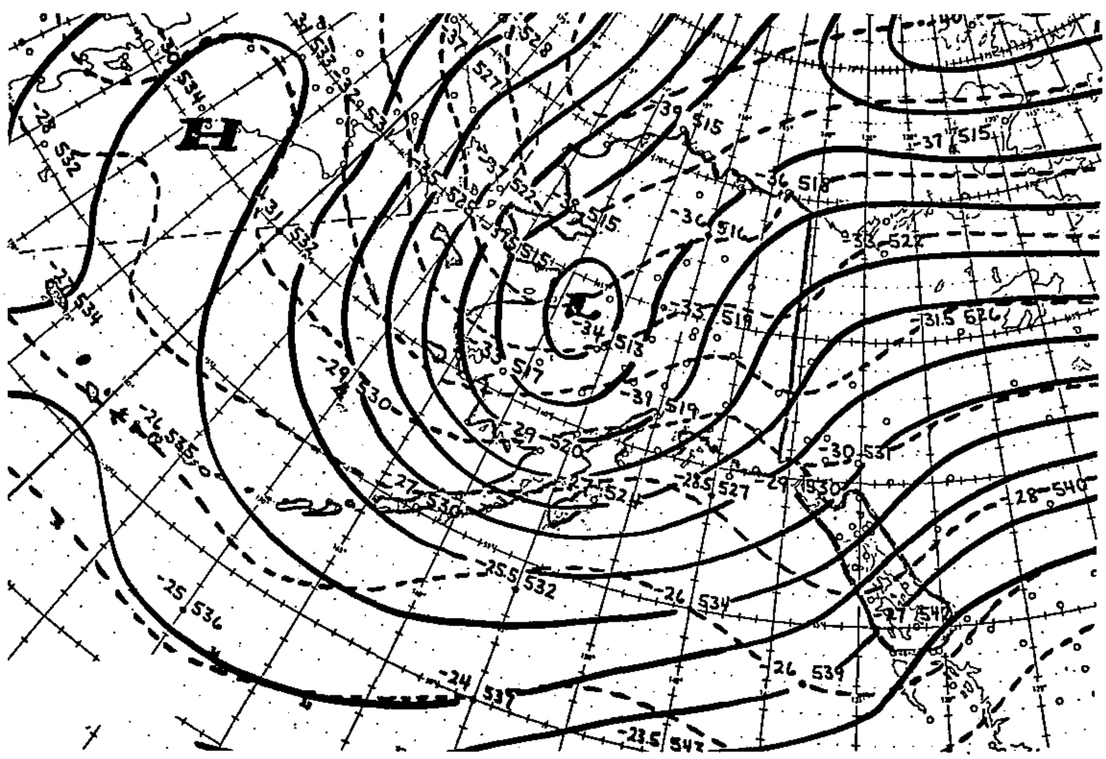


Figure 9. 500mb composite at time t+12 (12 hr after peak snowfall).

by the equation $(F+Q)/D$ = constant. As the trough rotates east, the planetary vorticity, or coriolis parameter, F, is constant; therefore any change in the air column D must result in a corresponding change in the relative vorticity Q (Byers, 1959). As the column of air moves against and over the Alaska Range there is shrinking of the column with horizontal divergence and a decrease in relative vorticity. But as the column passes east of the range into the inlet there is vertical stretching, resulting in horizontal convergence and an increase in the relative vorticity. Saucier (1965) has shown that if a vertical air column stretches to twice its vertical depth, the relative vorticity increases by 5×10^{-5} sec^{-1}.

The above discussion is based on idealized conditions which assumes symmetry of terrain, uniform flow, and that the upper and lower boundaries of the air column are isentropic surfaces of which the upper is far enough above the terrain that its elevation relative to sea level is constant. An examination of figure 1 shows that not only is the portion of the Alaska Range separating Cook Inlet from the interior far from symmetrical, but the eastern slopes are much steeper than those to the west. This asymmetry is further enhanced by the cold low level air. Panofsky (1956) suggests that a cold dome of air will have the same orographic effect on the vorticity field as a mountain barrier (see figure 10). Therefore, the combination of terrain and cold air to the west of the range results in a "plateau" effect such that the vertical stretching to the lee of the range is greater than the shrinking on the windward side. If this assumption is correct, there would be a net increase in relative vorticity as the air parcel moved into Cook Inlet.

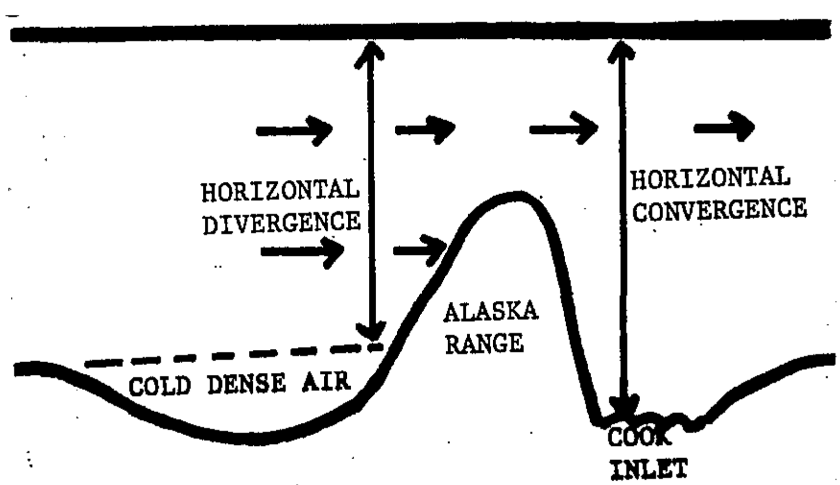


Figure 10. The "plateau" effect on an eastward-moving column of air.

It is the combination of this vorticity advection into Cook Inlet with the movement of low-level cold air into the southern inlet that leads to cyclogenesis and results in a "cold advection" snow event at Anchorage. The basic ingredients are: (1) the pooling of cold air in the lower layers over the southwest interior of Alaska, with some of this air moving southward into lower Cook Inlet, and (2) a 500mb trough over western Alaska with strong positive vorticity advection into Cook Inlet.

We did not extend our composites beyond 12 hr after the peak snowfall. In several cases, the snow associated with the cold advection-type pattern continued for several days at varying rates of intensity. However, the snow accumulation was not significant once the 850mb temperature gradient between McGrath and Anchorage had decreased. The exception to this was when the cold advection-type pattern gave way to an overrunning event (i.e. when warmer moist air from the Gulf of Alaska moves over the residual cold low-level air in the inlet).

The apparent key to ending the snow, or to any future development, is the structure of the upper trough. As long as the strong baroclinic zone persists over western Alaska there is potential for further cyclonic development in the inlet. If the trough to the west persists after the vorticity associated with the initial cyclogenesis has moved northeast -- leaving a diffluent area to the east of the trough at the 500mb level with a northerly jet max to the west of the trough -- reintensification can be expected. The cold advection-type event will end when the upper trough moves eastward as warm air at the 500mb level moves into southwestern Alaska.

TERRAIN MODELING IN NUMERICAL MODELS

A comparison of the actual Alaskan terrain (figure 11) with the terrain as modeled for numerical guidance (figures 12 and 13) points out an obvious forecast problem: the models do not recognize the Cook Inlet-Susitna Valley basin. It is therefore possible for the model to correctly forecast the movement of the upper trough, with its associated vorticity advection, and the thickness field, and still miss the snowfall at Anchorage. The forecaster must be aware of the differences between the actual terrain and the model terrain.

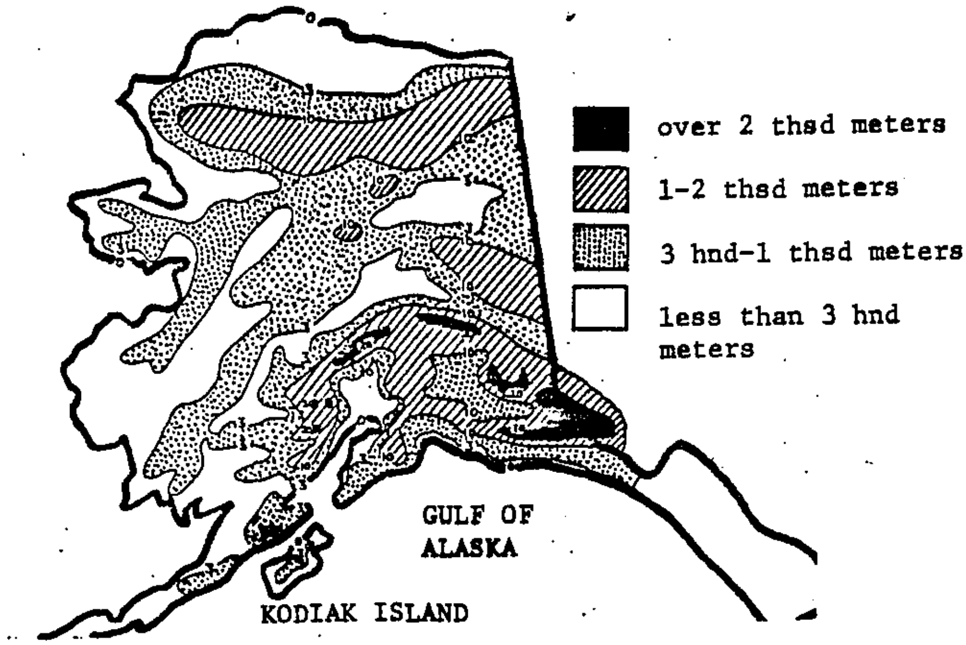


Figure 11. Topographic map of Alaska (in hundreds of meters).

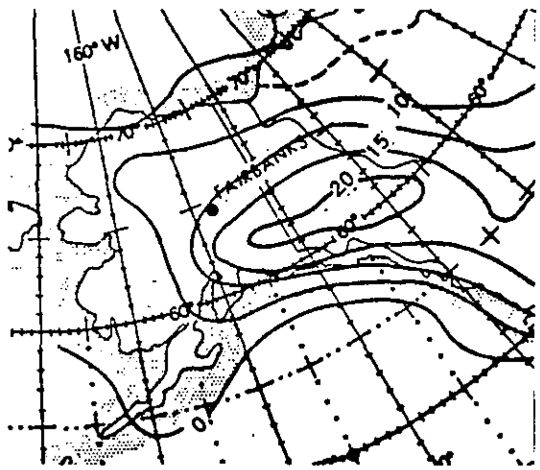


Figure 12. The 7-level PE model terrain (in hundreds of meters).

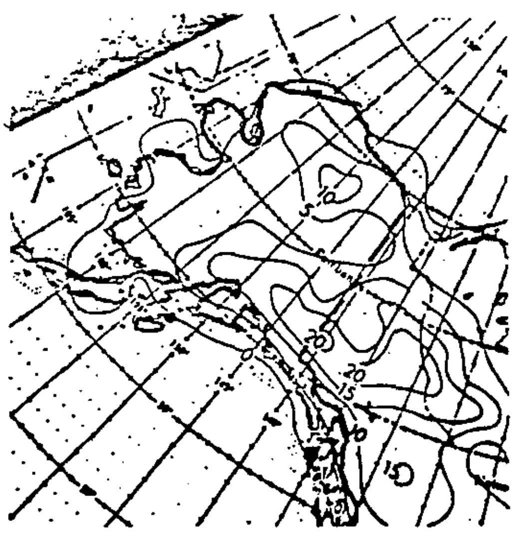


Figure 13. The LFM-11 model terrain (in hundreds of meters).

THE MARCH 1979 SNOW EVENT - A CASE STUDY

During the period March 15 through 20, 1979, 26.9 in of snow fell at Anchorage International Airport. This event can be divided into three separate cases: two that were the result of cyclogenesis associated with cold advection into southwest Alaska and one associated with overrunning.

The graph (figure 14) on page 19 is a plot of six-hourly precipitation at Anchorage (0.01 in water equivalent) compared to the Anchorage and McGrath 850mb temperature profiles for the period. The charts on pages 20 through 29 (figures 15 through 24) are, from top to bottom: 500mb, 850mb and surface. All references to snow in the following discussion are for Anchorage International Airport.

The main 500mb features 12 hr prior to the beginning of snow (figure 15) were a trough from south of Barter Island, Alaska to eastern Norton Sound, and a strong ridge over the eastern Bering Sea. At 500mb a north to northwest circulation of about 40 kt extended from the Bering Strait to Kodiak Island almost normal to the 850mb isotherms. The leading edge of the 850mb thermal packing was from just west of King Salmon, Alaska through McGrath to north of Fairbanks, Alaska; the 850mb thermal trough extended from northwest Alaska through eastern Norton Sound to just north of Bethel, Alaska. Moisture was already present at Anchorage at the 850mb level, due to the passage of an occlusion which had moved northward from the Gulf of Alaska during the previous 12 hours. At the surface, a strong high pressure area was centered northwest of Barrow, Alaska while a deep storm south of the Central Aleutians "pumped" warm air northward, building the upper ridge over the eastern Bering Sea. A weakening low was nearly stationary in the northern Gulf of Alaska.

By 00Z on the 16th (figure 16), just prior to the beginning of snow, the 850mb thermal trough had moved into southwest Alaska with McGrath cooling 6 deg C during the preceding 12 hr; the McGrath-Anchorage temperature gradient had increased from 2.2 deg to 7 deg C at the 850mb level. The 500mb trough had moved southeast and closed off near McGrath. The maximum vorticity value at the 500mb level would have to be to the south of the 500mb center, in the direction of strongest horizontal shear and curvature. Snow began about 03Z; by 10Z on the 16th, 5.2 in had fallen.

The snow had almost ended by 12Z on the 16th (figure 17). The 500mb trough was right over Anchorage. The 850mb McGrath-Anchorage temperature difference had decreased to 3 deg C (figure 14) as warm air moved into the southwest section of the state in advance of a Bering Sea occlusion; the 850mb thermal gradient was roughly north to south over the state. Cold advection was still evident into northwest Alaska where the 500mb flow formed a significant angle with the 850mb isotherms. 12 hr later (figure 18) a 500mb trough was evident from northeast of Barter Island to just south of Nome. The old Aleutian surface low was drifting east and filling near Cold Bay, Alaska as a new storm deepened in the western Pacific south of Attu, Alaska.

The 500mb trough had intensified over western Alaska by 12Z on the 17th (figure 19) and cold air was again moving south over the Kuskokwim Valley at the 850mb level. A 850mb low was developing just west of Anchorage and the McGrath-Anchorage temperature gradient had increased from 2.6 deg C to 7.4 deg C in 12 hr. Snow began falling shortly after 12Z on the 17th.

The western portion of the 500mb trough (figure 20) had closed off near McGrath by 00Z on the 18th. The winds at this level to the west and south of the center over southwest Alaska were in excess of 50 kt, indicating high values of relative vorticity due to horizontal shear and curvature. The 850mb isotherms were oriented roughly north to south from western Cook Inlet into the Kuskokwim Valley and eastern Bristol Bay; the McGrath-Anchorage temperature difference had increased to 9.8 deg C. The strong upper winds normal to this thermal packing at the 850mb level indicated strong baroclinicity. A closed 850mb low was centered just west of Anchorage. A comparison of the surface maps with the 850mb charts during this period (12Z on the 17th through 12Z on the 18th) shows that although a surface trough is evident in Cook Inlet it is the 850mb level which shows the closed circulation. The surface pressure curve for Anchorage (figure 14) for this period shows little significant change other than a rising trend toward the end of the storm (after 12Z on the 18th).

The rate of snowfall increased (see figure 14) through 12Z on the 18th as the 500mb trough moved into Cook Inlet (figure 21). The 850mb low and surface low began moving eastward with the upper trough and snow diminished after 12Z and ended by 00Z on the 19th. During the period from 12Z on the 17th through 00Z on the 19th, 12.9 in of snow fell, most of which fell during a 24 hr period from 18Z on the 18th through 18Z on the 19th (see figure 14).

Looking at the surface analysis for 12Z on the 18th (figure 21), you can see a frontal wave had developed south of Cold Bay, Alaska. As this wave moved north, warm air moved into Bristol Bay and southwest Alaska, weakening and accelerating the 500mb trough eastward. The 850mb temperature difference between McGrath and Anchorage decreased from 7.6 deg C at 12Z on the 18th to 4.2 deg C by 00Z on the 19th. Strong surface pressure rises were observed at Anchorage as warm air aloft moved over the station (figure 14).

As mentioned, snow ended at Anchorage just prior to 00Z on the 19th (figure 22) as the 500mb ridge moved over southwest Alaska. However, snow had begun again by 12Z on the 19th as warm air from the northwest Gulf of Alaska moved over the cold residual air in the northern Cook Inlet and the Susitna Valley. Note the orientation of the 850mb isotherms in relation to the 500mb winds over southern Alaska and the northwest Gulf of Alaska in figure 23. This pattern is typical of overrunning snow at Anchorage. An additional 6.2 in of snow fell in less than 18 hours before changing to rain at 00Z on the 20th (figure 24).

It is interesting that the 850mb temperature profile for Anchorage (figure 14) remained nearly constant through all three events while McGrath reached its lowest 850mb temperature just before or near the time of the maximum rate of snowfall at Anchorage. This phenomenon was typical of all the cold advection precipitation cases which we examined. Between 00Z and 12Z on the 19th, the McGrath temperature curve approached the Anchorage curve but by this time an overrunning situation had developed in the Anchorage area. The Anchorage upper air soundings for this last event are not available but the depth of the cold air at this time was probably not more than 2,000 ft in the Anchorage area and was decreasing as the snow changed to rain.

The local forecasts during the event did reflect the numerical guidance available. Therefore, some comment should be made on that guidance. In brief, an inspection of figure 14 shows that the Model Output Statistics (MOS) forecasts were poor for the two cold advection cases but improved considerably for the overrunning case at the end of the period. In the first snow case, the Limited-area Fine Mesh (LFM) model forecast for the period 00Z through 12Z on the 16th, issued 12 hr prior to the event, showed a weak area of positive vorticity moving southward over Anchorage, with Anchorage on the western edge of a small precipitation area of maximum water equivalent of only 0.06 in. The LFM model forecasts for the second cold advection event, based on data available 12 hr prior to the beginning of snow at Anchorage (figure 25), did an excellent job of handling the vorticity advection into south central Alaska but still had Anchorage on the western fringe of the precipitation area.

In view of the model's topographic limitation, it is not surprising that the precipitation was forecast to be east of Anchorage. From the model's point of view, Anchorage is on top of 1000 m of rock and Cook Inlet does not exist. So the "logical" position for a vorticity maximum moving southeastward out of the western interior to develop a surface low is in the northern Gulf of Alaska with the precipitation area to the north and east of this development.

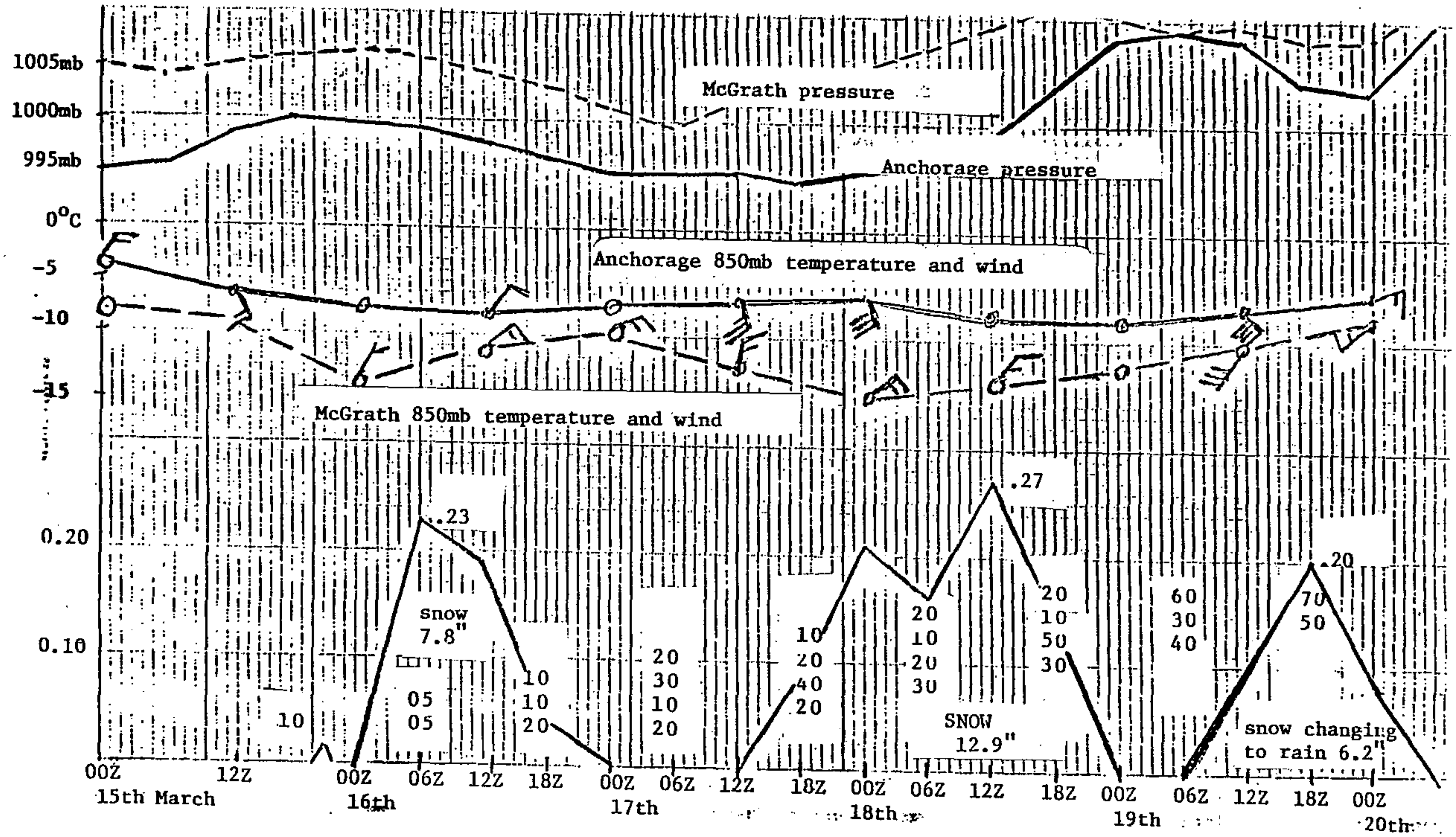
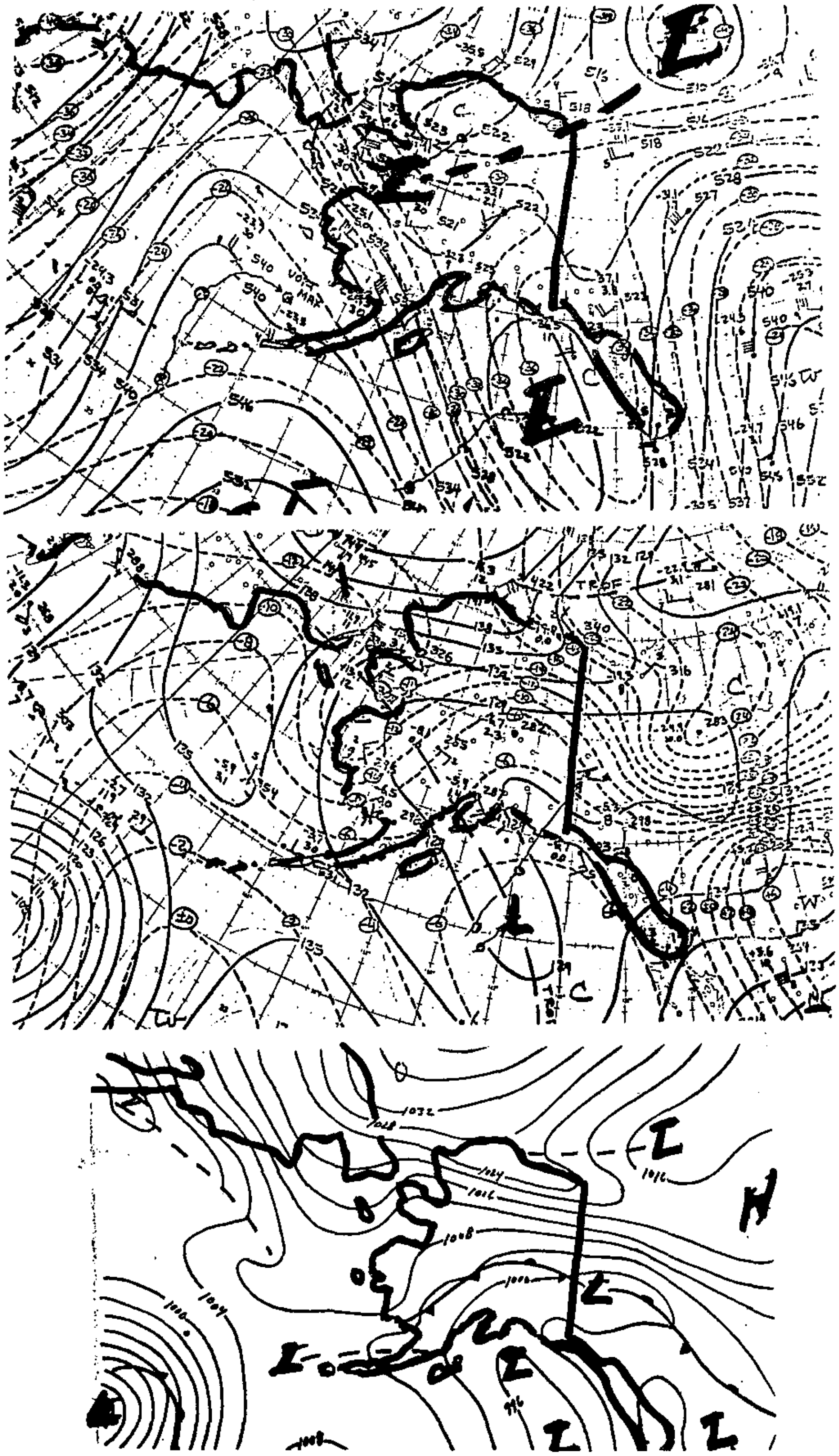


Figure 14. The snow storm of March 15-20, 1979. Anchorage 6 hr precipitation (0.01 in water equivalent) with the Anchorage and McGrath 850mb temperature profiles at 12 hr intervals. The lines at the top of the graph are the surface pressure curves for the event. The columns of numbers at 12 hr intervals are MOS POP forcasts for Anchorage for the four 12 hr periods beginning with output based on 00Z data of the 15th. The numbers are listed at the mid-point of the forecast period. For example the 20 at the top of the column for 06Z on the 17th is 20 percent probability for precipitation to occur during the period 00Z-12Z on the 17th based on data available at 12Z on the 16th. The forecast for the next two periods is also 20 percent and 30 percent for the fourth period.

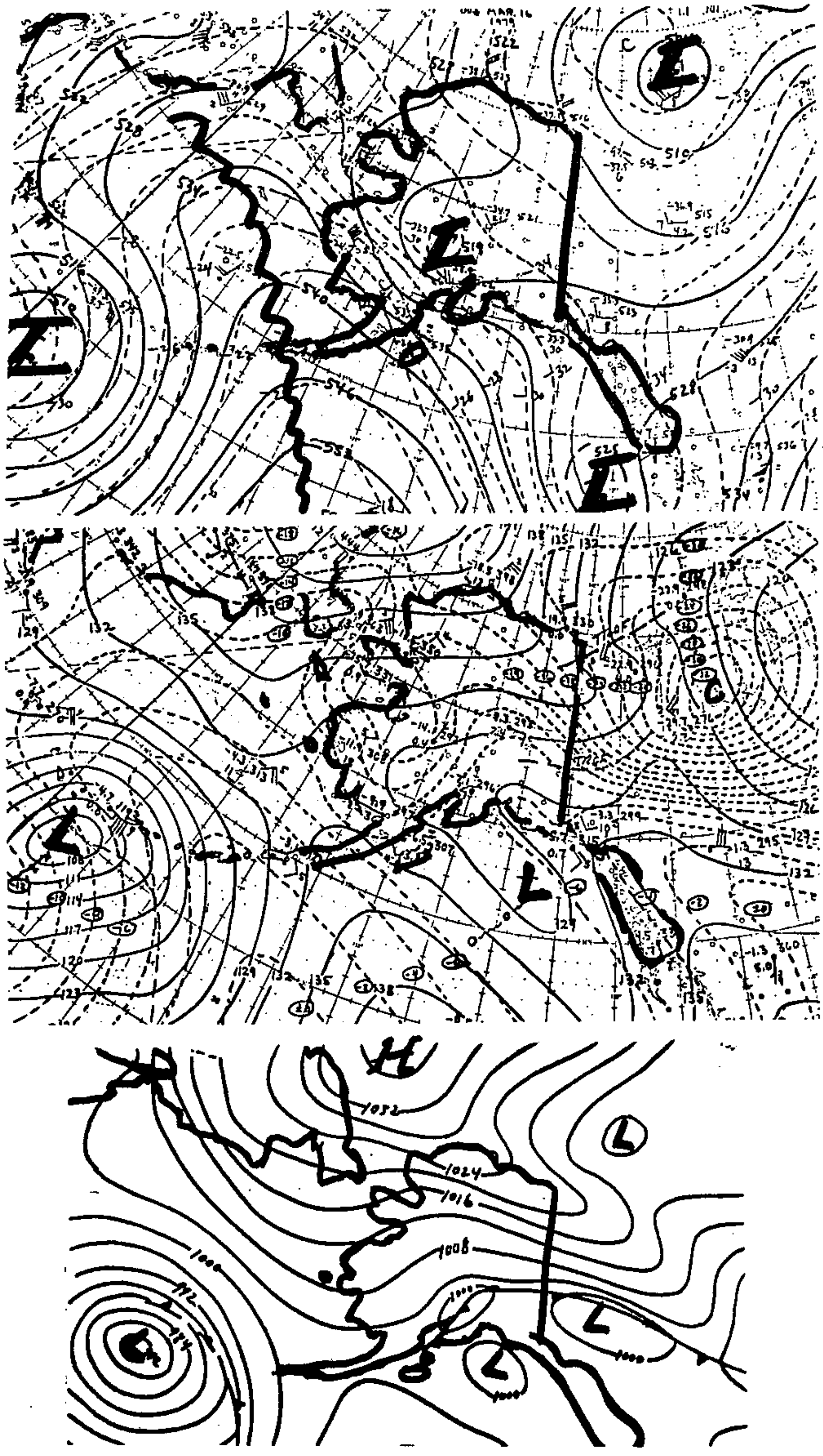


500mb

850mb

Surface

Figure 15. Conditions of 12Z March 15, 12 hr prior to the beginning of snow at Anchorage. A 500mb trough is to the northwest of McGrath while cold air begins pooling over southwest Alaska at the 850mb level.

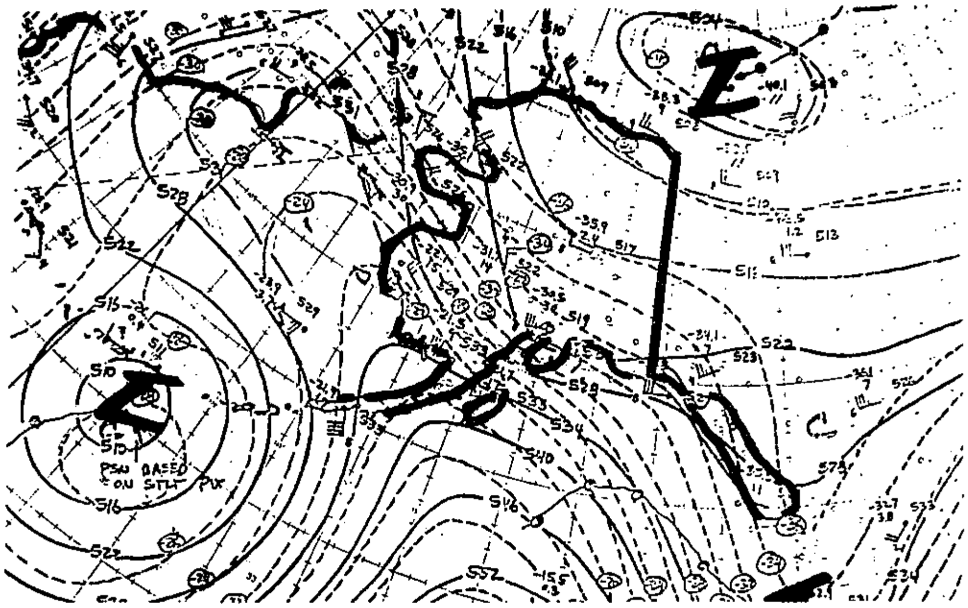


500mb

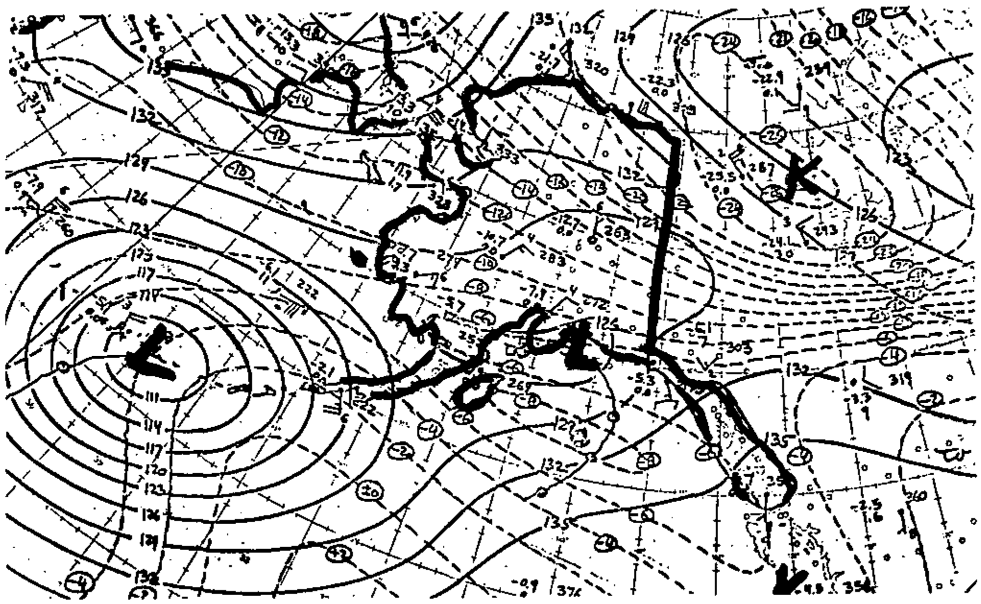
850mb

Surface

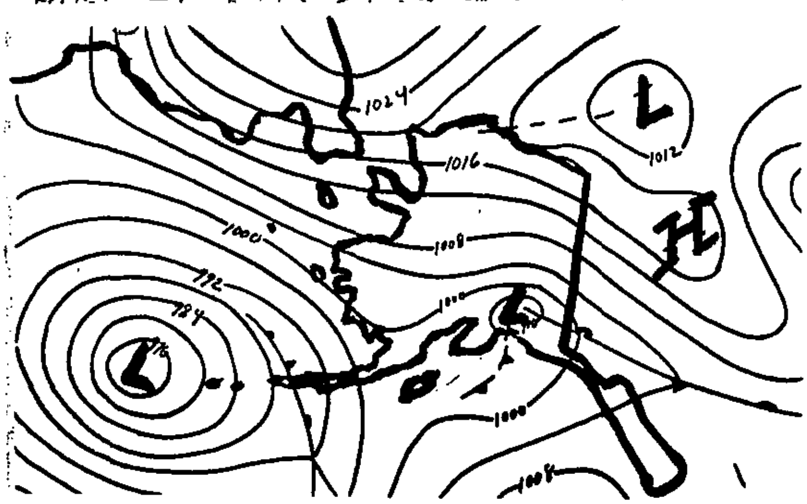
Figure 16. Snow begins at Anchorage, 00Z March 16. The 500mb low has closed off near McGrath. The McGrath-Anchorage 850mb temperature gradient is 7 deg C.



500mb

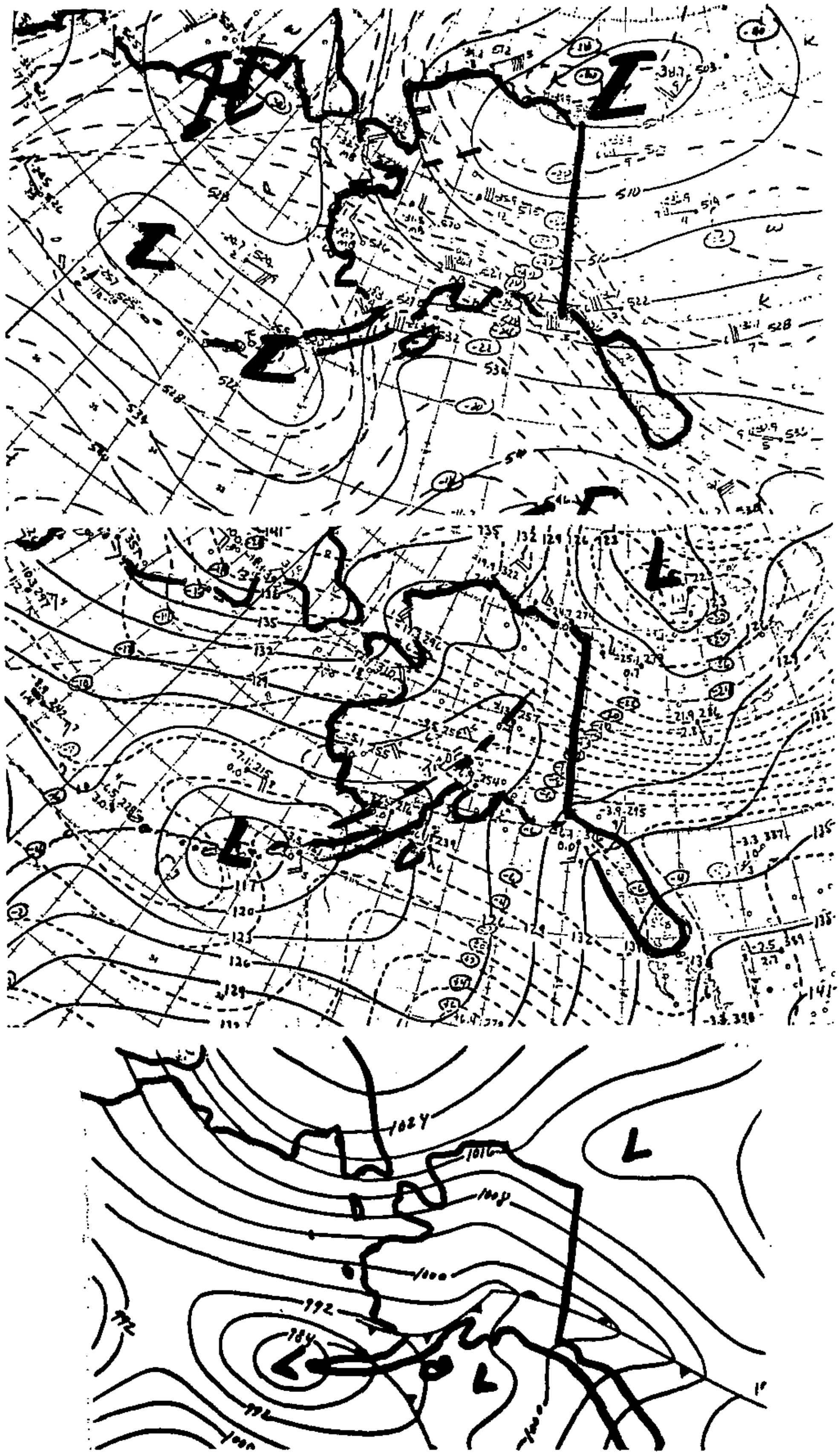


850mb



Surface

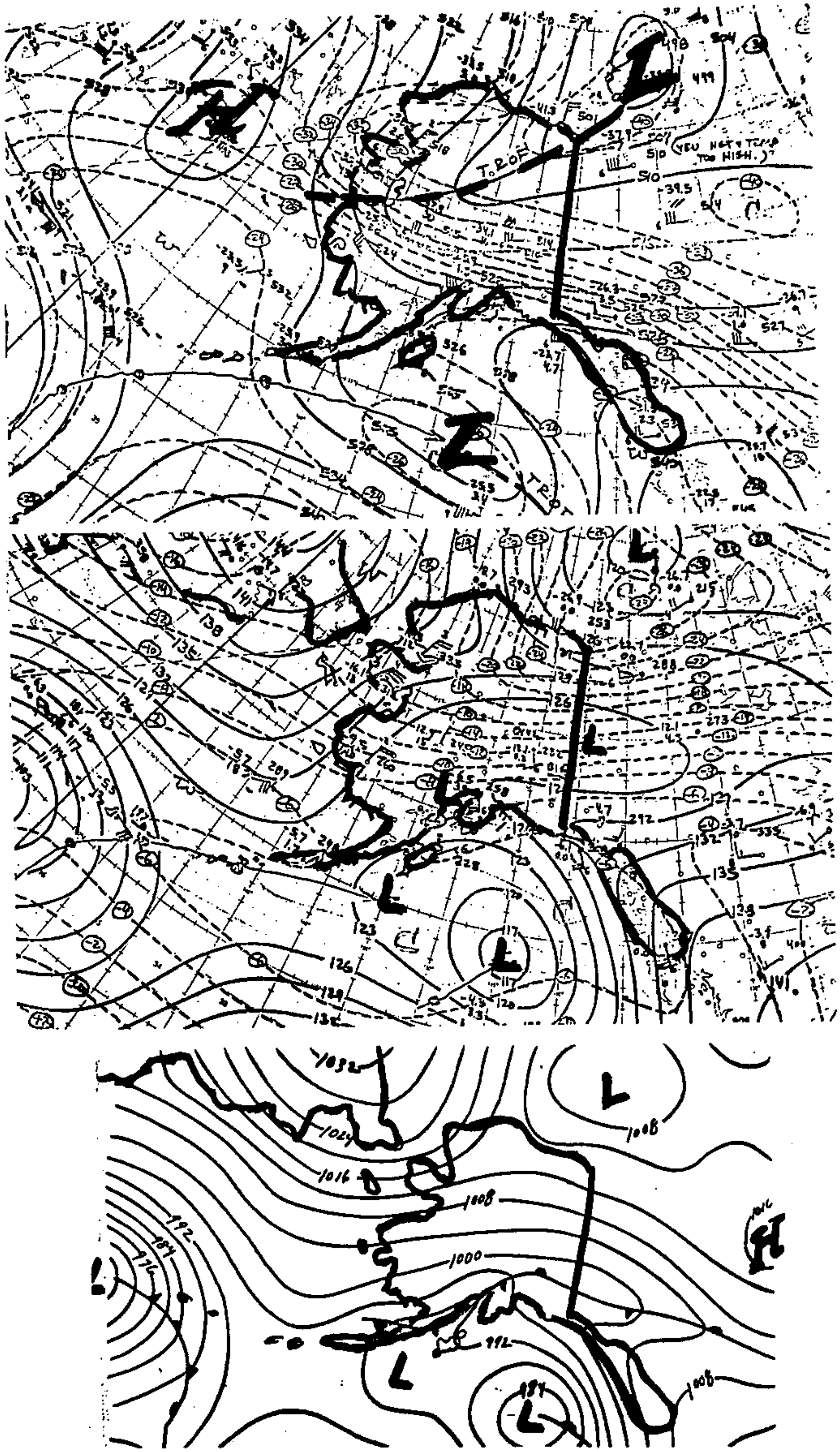
Figure 17. Snow diminishes at Anchorage, 12Z March 16. The McGrath-Anchorage 850mb temperature gradient has decreased to less than 3 deg C.


500mb

850mb

Surface

Figure 18. 00Z March 17. Snow has ended at Anchorage but a 500mb short wave trough has entered northwest Alaska.



500mb

850mb

Surface

Figure 19. 12Z March 17. A 500mb trough has moved southward while cyclogenesis is already evident at the surface and 850mb level.

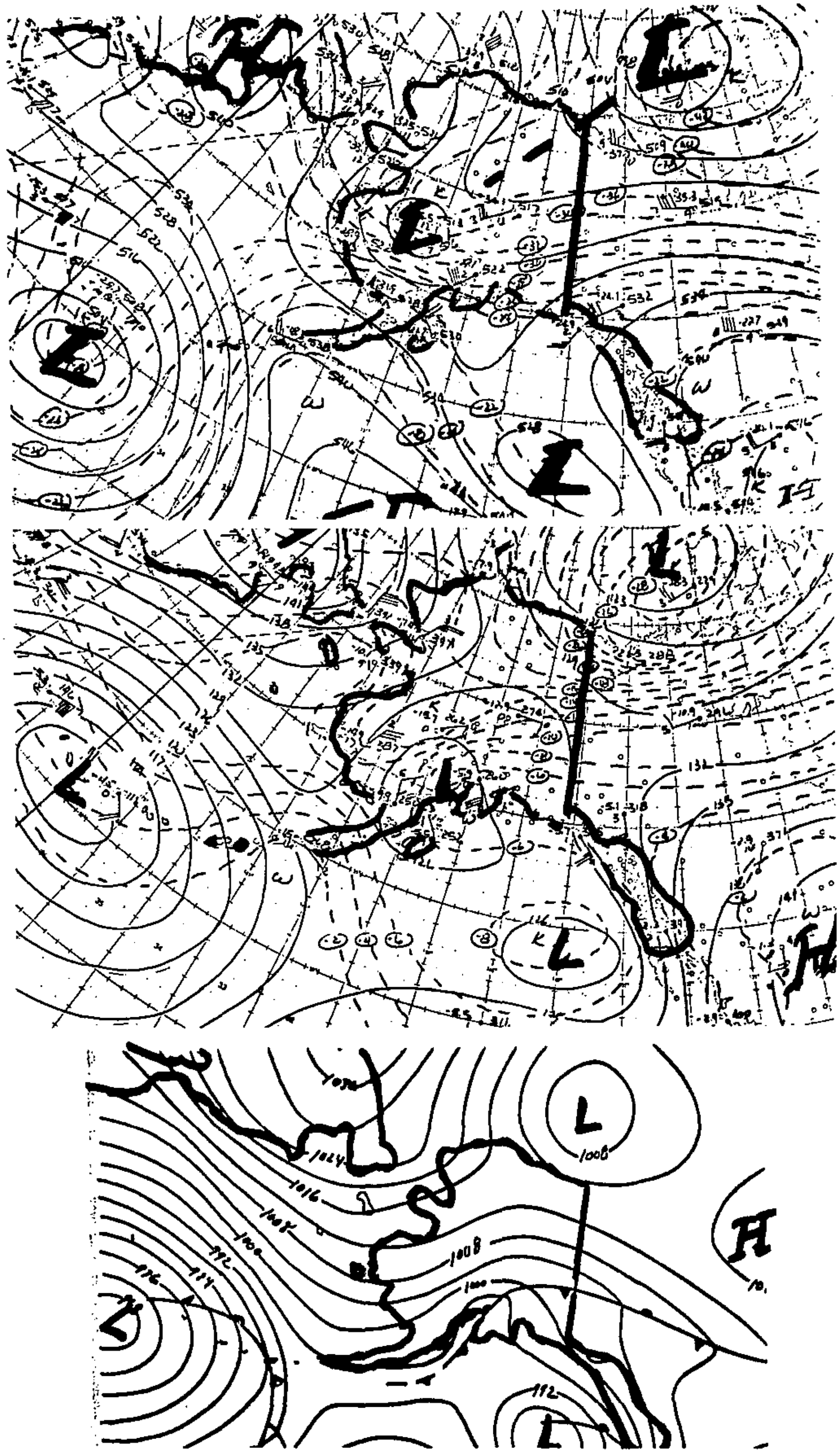
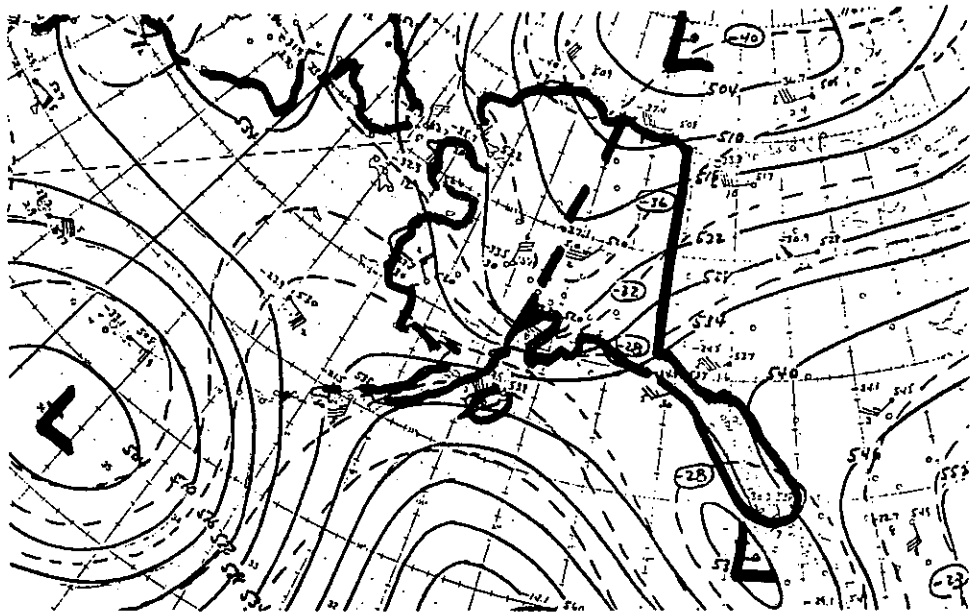
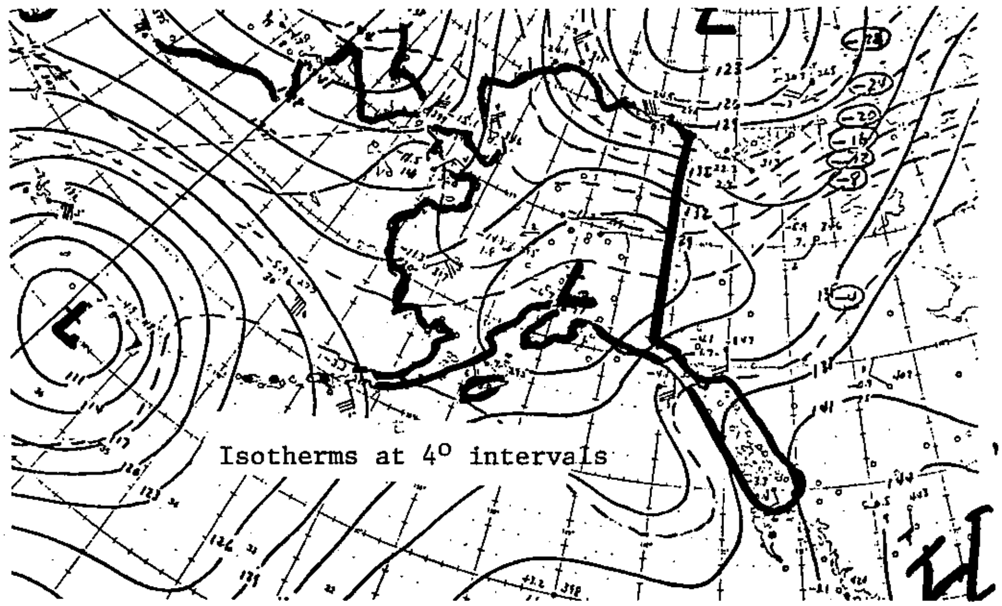


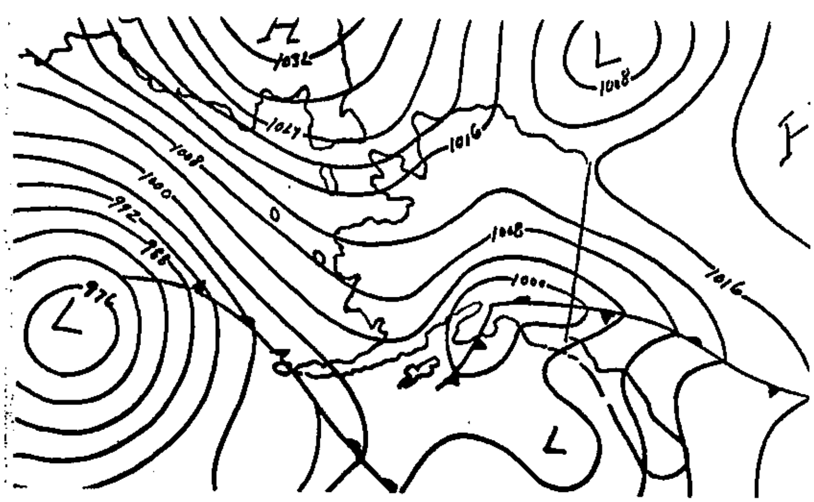
Figure 20. Snow begins again at Anchorage, 00Z March 18. A 500mb low has closed off near McGrath; a 850mb low is centered west of Anchorage.



500mb

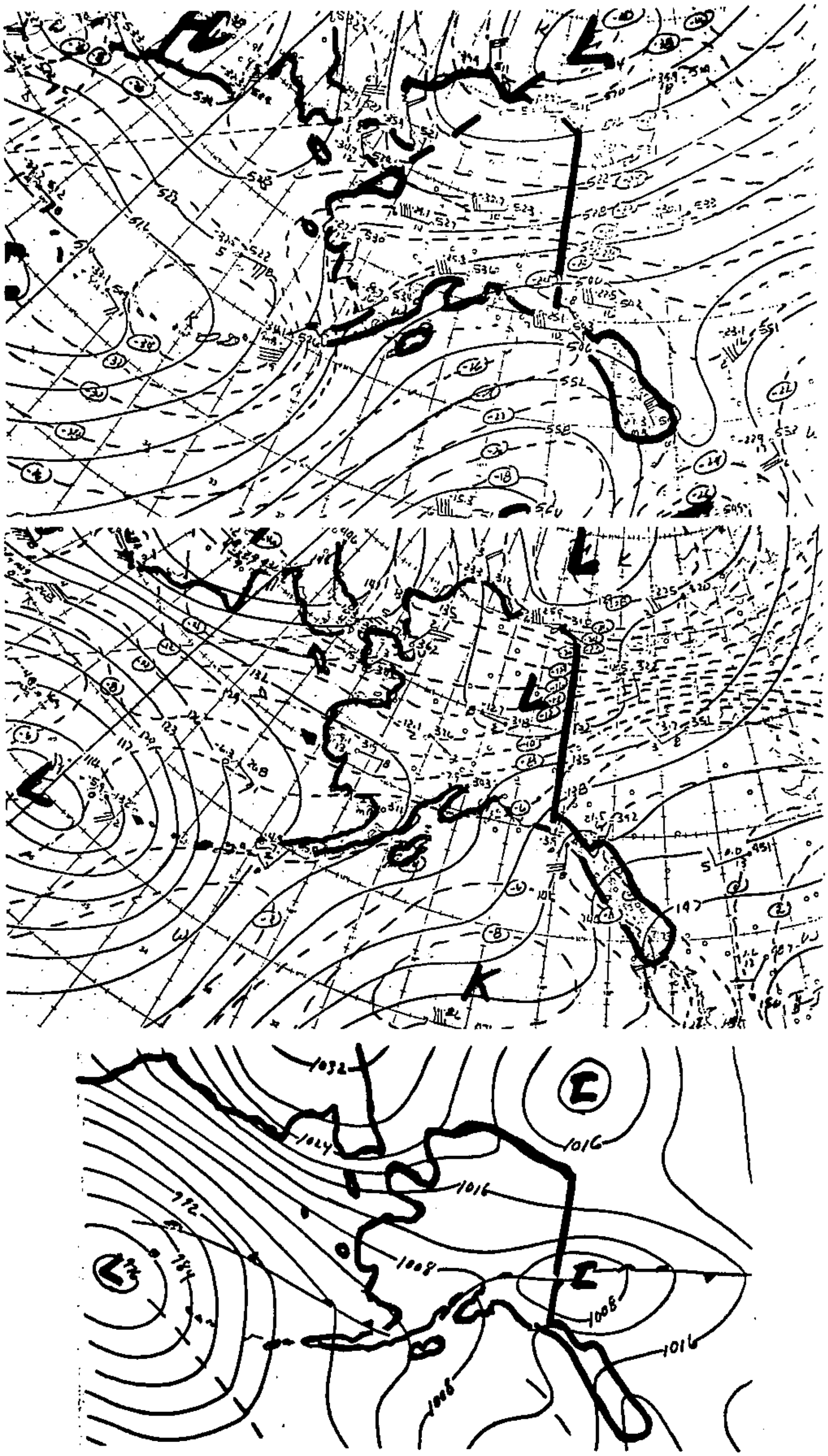


850mb



Surface

Figure 21. 12Z March 18. The rate of snowfall increases at Anchorage as the 500mb trough moves into Cook Inlet.



500mb

850mb

Surface

Figure 22. Snow has ended at Anchorage, 00Z March 19. The McGrath-Anchorage 850mb temperature gradient has decreased to 4.2 deg C.

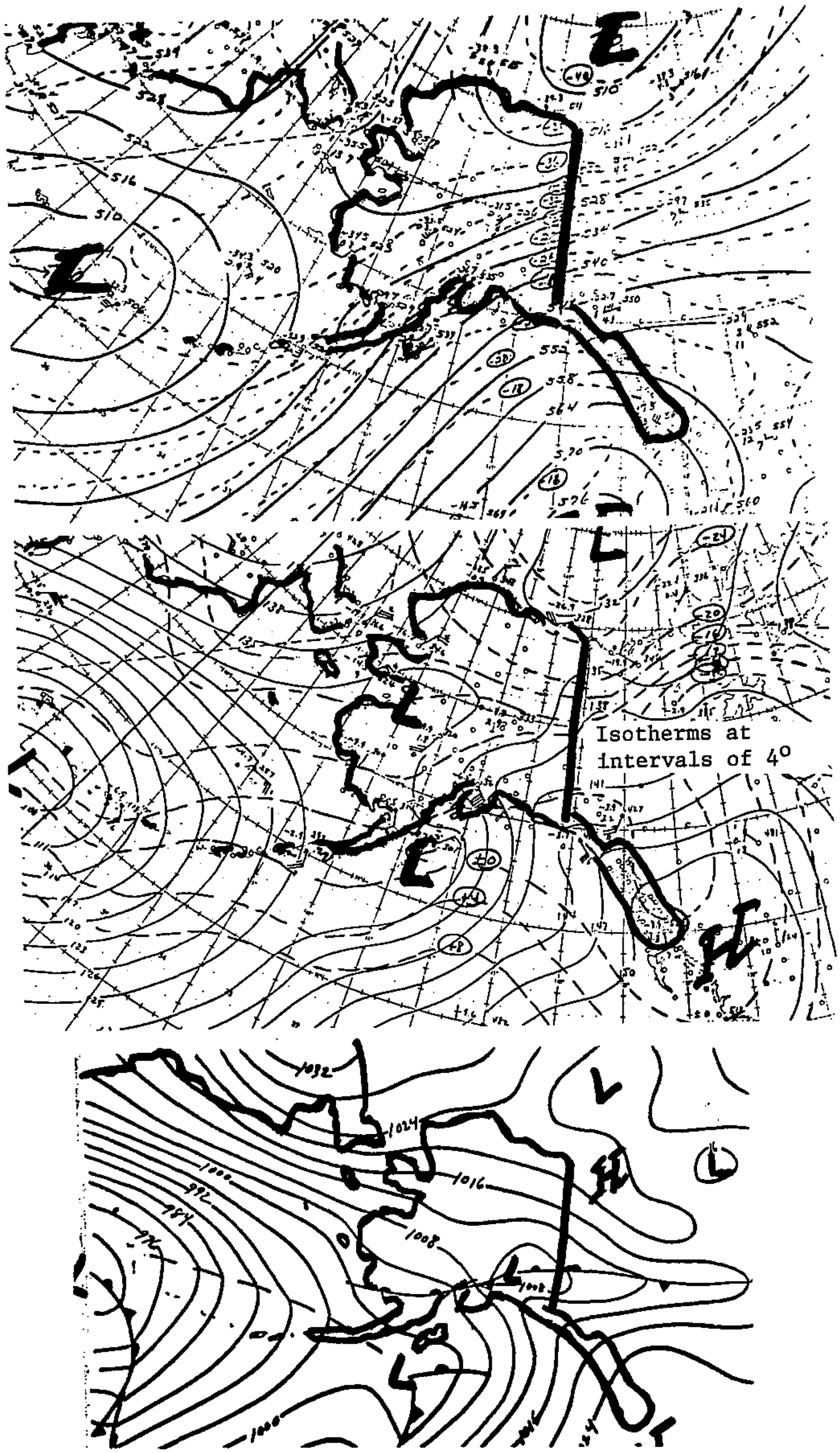
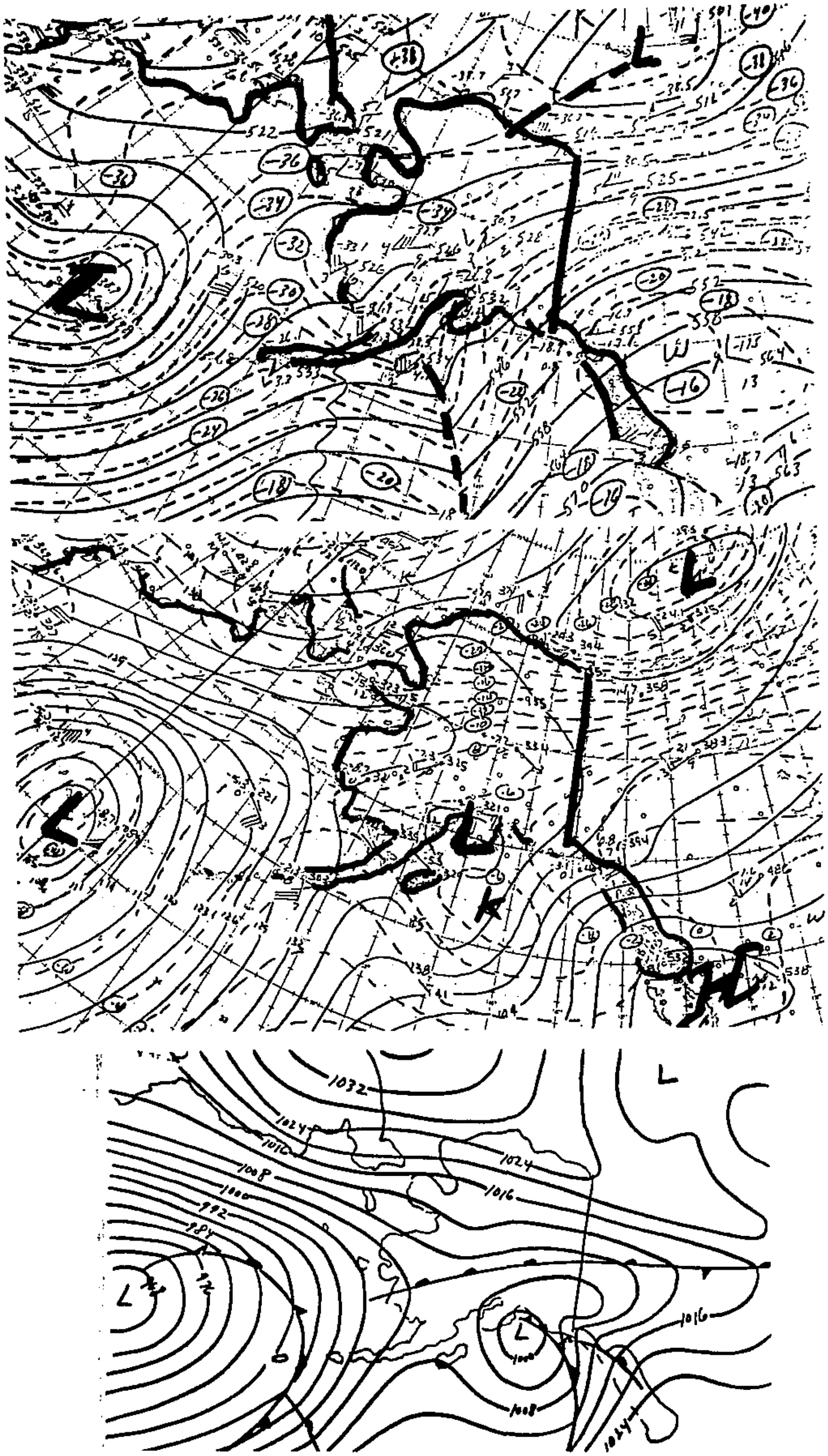


Figure 23. Snow, due to overrunning, begins again at Anchorage, 12Z March 19.

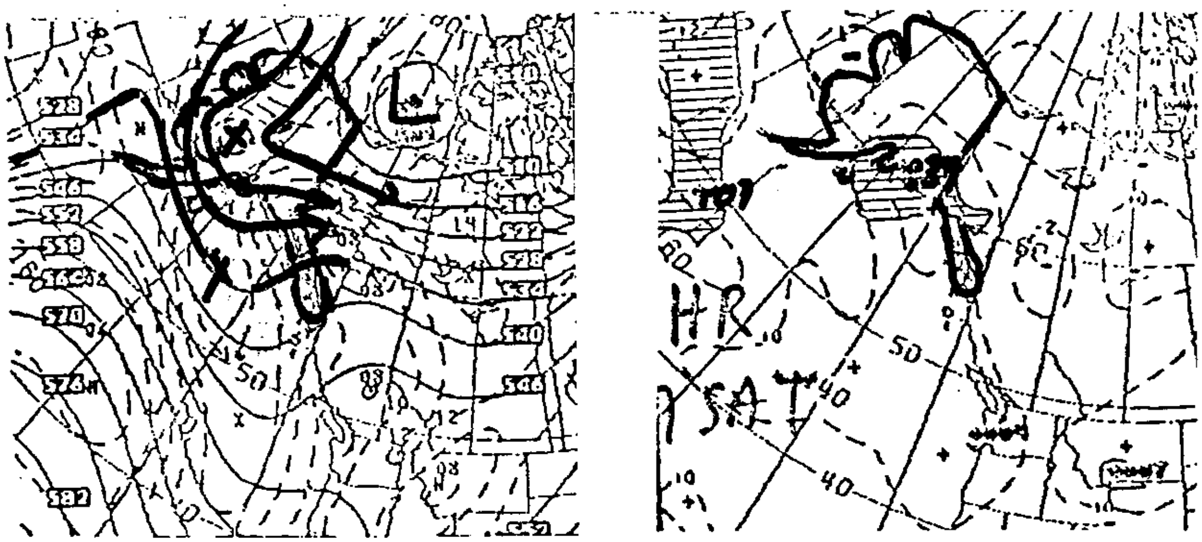


500mb

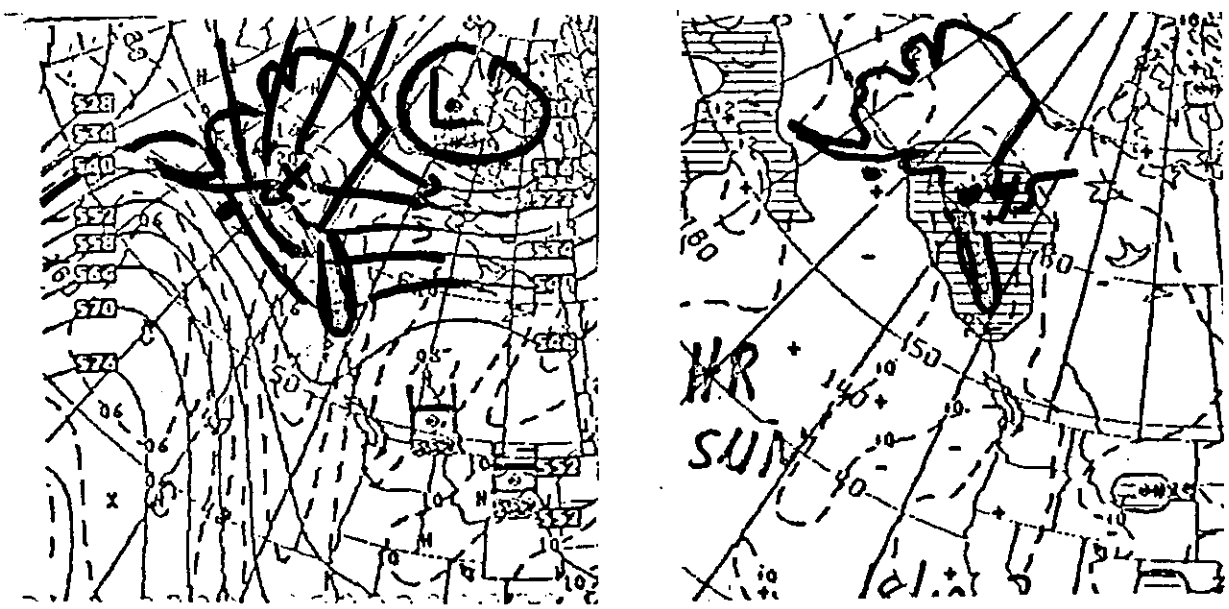
850mb

Surface

Figure 24. Snow changes to rain at Anchorage, 00Z March 20.



12 hour forecast, verifying at 00Z 18 March



24 hour forecast, verifying at 12Z 18 March

Figure 25. LFM-II forecasts based on data available at 12Z March 17. Charts on the left are forecasts of 500mb contours (solid lines) and vorticity isopleths (dashed lines). Hatched areas of charts on the right are 12 hr forecasts of precipitation (water equivalent).

CONCLUSIONS

The central points of this study are:

(1) the Alaska Range has a blocking effect on southward-moving low-level cold air which can result in a baroclinic zone developing over southwest Alaska

(2) when a 500mb trough or low moves southeastward over this baroclinic zone cyclogenesis is possible in Cook Inlet

(3) it is likely that the numerical models will accurately forecast the positive vorticity advection associated with a 500mb trough or low but will develop a surface low in the northern Gulf of Alaska rather than in Cook Inlet.

An analysis of the cases involved in the composite charts and the March 1979 case study focuses on an obvious but often overlooked point: the forecaster must understand not only the basic meteorological principles but also how the topography of the forecast area compares with the topographic modeling. Since changes in the numerical modeling on a scale of use to the Anchorage forecaster in these cold advection-type events are unlikely, it is up to the forecaster to understand the model's limitations.

We undertook this study in order to understand and solve a recurrent forecast problem. The preceding discussion and the material contained in the appendix are, we feel, a step in this direction. What we have done is to propose a general thesis which can be validated only with more experience.

There are still several open questions. For example, what effect, if any, does the degree of Cook Inlet ice coverage have on cyclogenesis? The area coverage of the snow is another unknown. We hope this paper will generate further investigation into these and other questions.

ACKNOWLEDGEMENTS

We wish to thank Mr. Richard L. Crisci, Mr. Albert L. Comiskey, Dr. Edward D. Diemer, and Mr. Wally Younker for their critique of this paper and helpful editorial comments. A very special thanks is due Mr. Ted Fathauer not only for his critique but also for his physical assistance. We also wish to thank Doris Brown who typed the drafts and final copies.

REFERENCES

(1) Byers, H. Robert, General Meteorology, 1959: McGraw-Hill Book Co., Inc., pp. 234 and 257.

(2) Panofsky, Hans, Introduction to Dynamic Meteorology, 1956: Pennsylvania State University, page 118.

(3) Petterssen, Sverre, Weather Analysis and Forecasting, Vol. 1, pp. 330-339.

(4) Saucier, Walter J., Principles of Meteorological Analysis, 1965: The University of Chicago Press, pp. 344-347.

(5) Sutcliffe, R. C. and Forsdyke, A. G., The Theory and Use of Upper Air Thickness Patterns in Forecasting, Quarterly Journal of the Royal Meteorological Society, April 1950, Vol. 76.

APPENDIX

CHECK LIST FOR CONDITIONS 12 HR PRIOR TO THE BEGINNING OF COLD ADVECTION-TYPE SNOW

The composite charts (pages 33 through 38) offer a visual pattern that should be used as an analog to the cold advection-type snow case. These charts should be used with the check list.

At 500mb:

1. Trough or closed low over western Alaska with the lowest heights between McGrath and Kotzebue.

2. A weak diffluent zone in the northwest Gulf of Alaska and/or over south-central Alaska.

3. Warm or neutral advection into the southeast Bering Sea while the western Alaska low or trough deepens.

4. Ridge over Southeast Alaska, or western British Columbia, northward into the Yukon Territory of Canada.

5. 500mb contours normal to the 850mb isotherms from the Chukchi Sea southward to Bristol Bay.

At 850mb:

1. Cold thermal trough from the vicinity of the Chukchi Sea south along the west coast of Alaska or into the southwest interior.

2. McGrath cooling faster than Fairbanks.

3. Anchorage either warming or showing little temperature change.

4. The McGrath-Anchorage temperature gradient increasing, with McGrath expected to be at least 7 deg C colder than Anchorage within the next 12 hr.

5. Moisture either present at Anchorage at this level or being advected into the area.

6. Weakening trough or low in the northwest Gulf of Alaska and/or in the vicinity of Kodiak Island

If the forecaster feels the above conditions are satisfied and will lead to the 500mb and 850mb patterns of time t, forecast 4-8 in of snow in a 24 hr period. Additional snow will depend on the dynamics of the 500mb trough.

If the LFM forecasts strong positive vorticity advection into Cook Inlet from the northwest and develops precipitation to the east of Anchorage, the forecaster should seriously consider snow or rain for the Anchorage area.

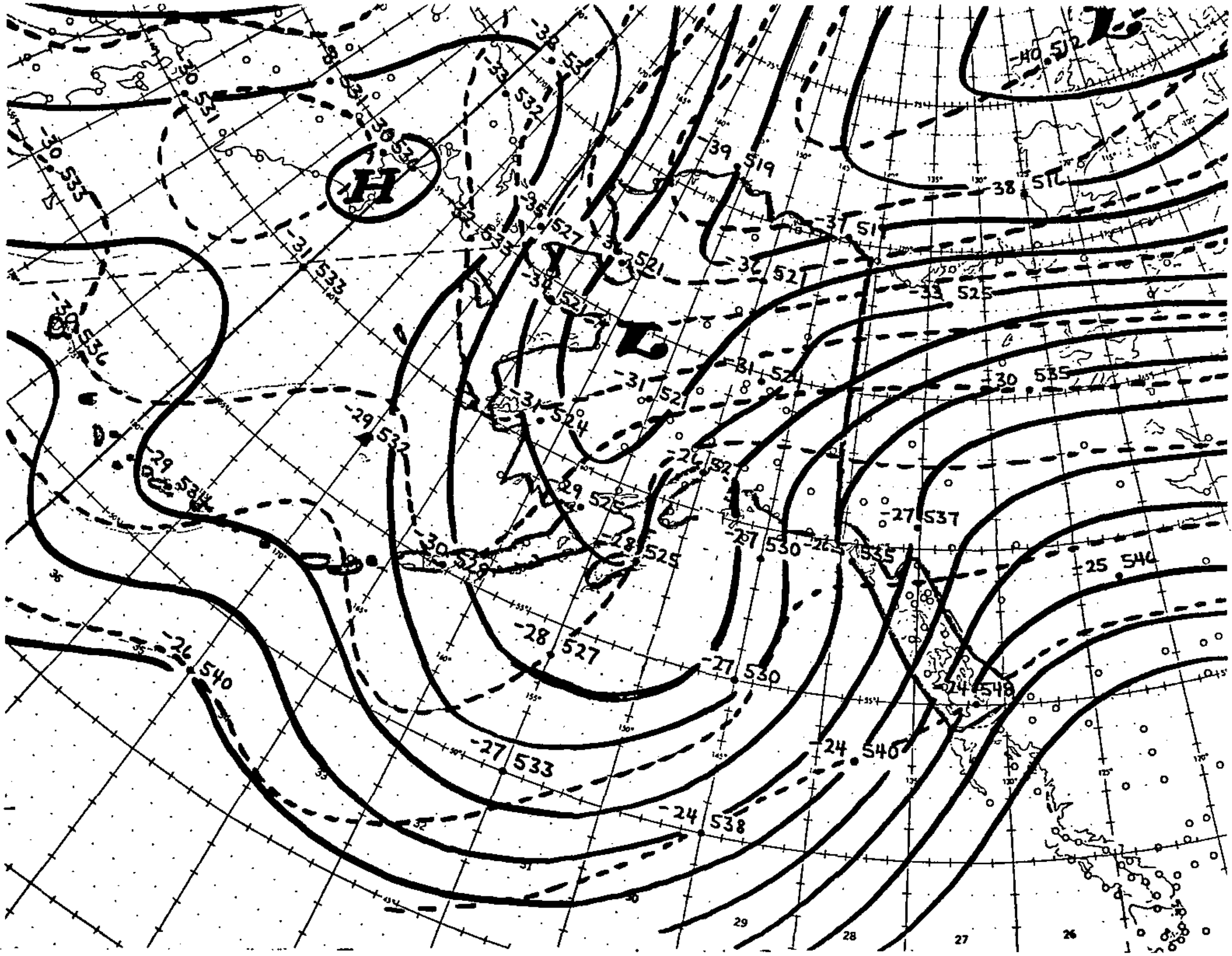


Figure 26. 500mb composite at time t-12 (12 hr prior to the beginning of snow at Anchorage). Contours are at 30 m intervals and isotherms are at intervals of 2 deg C.

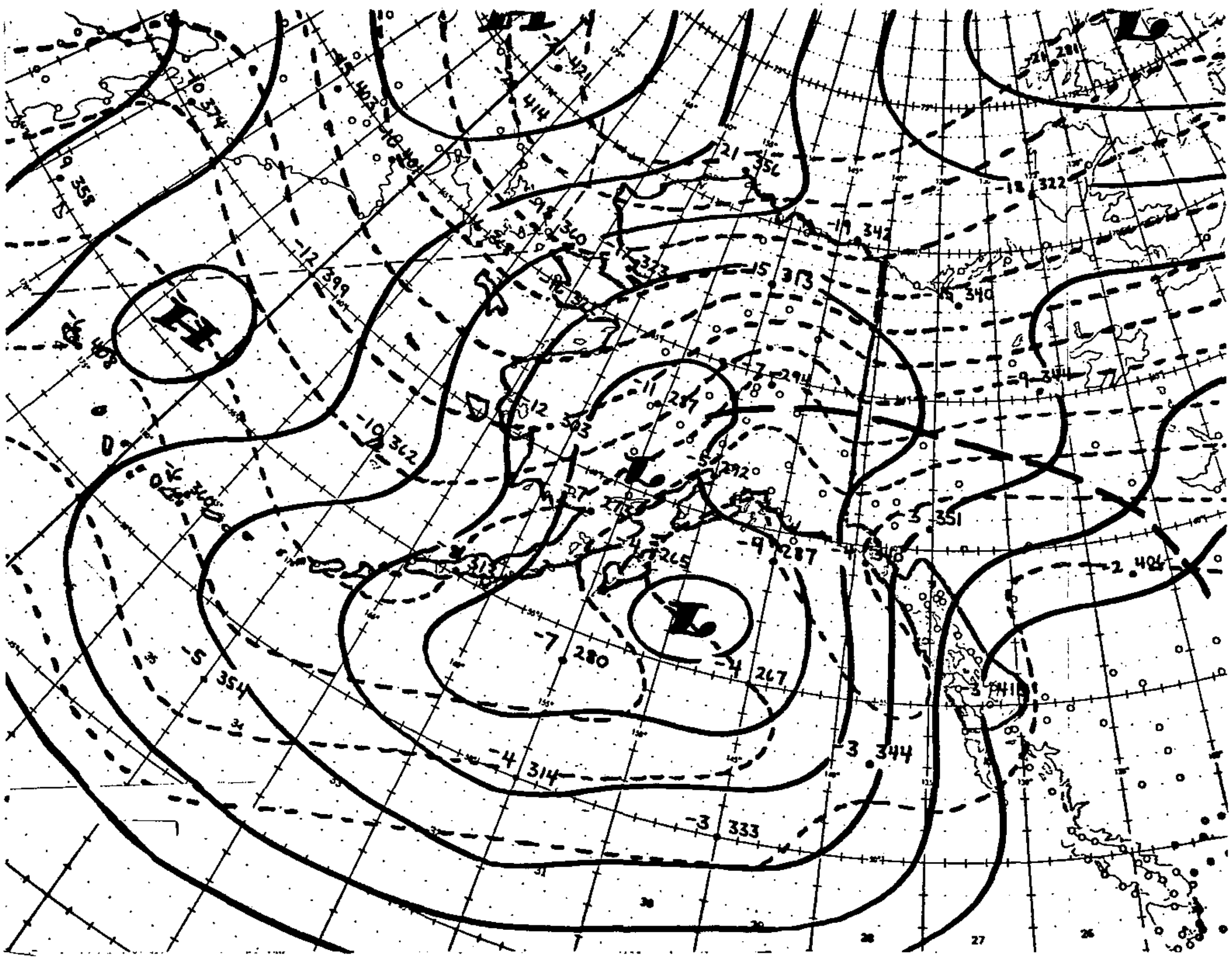


Figure 27. 850mb composite at time t-12 (12 hr prior to the beginning of snow at Anchorage). Contours are at 30 m intervals and isotherms are at intervals of 2 deg C.

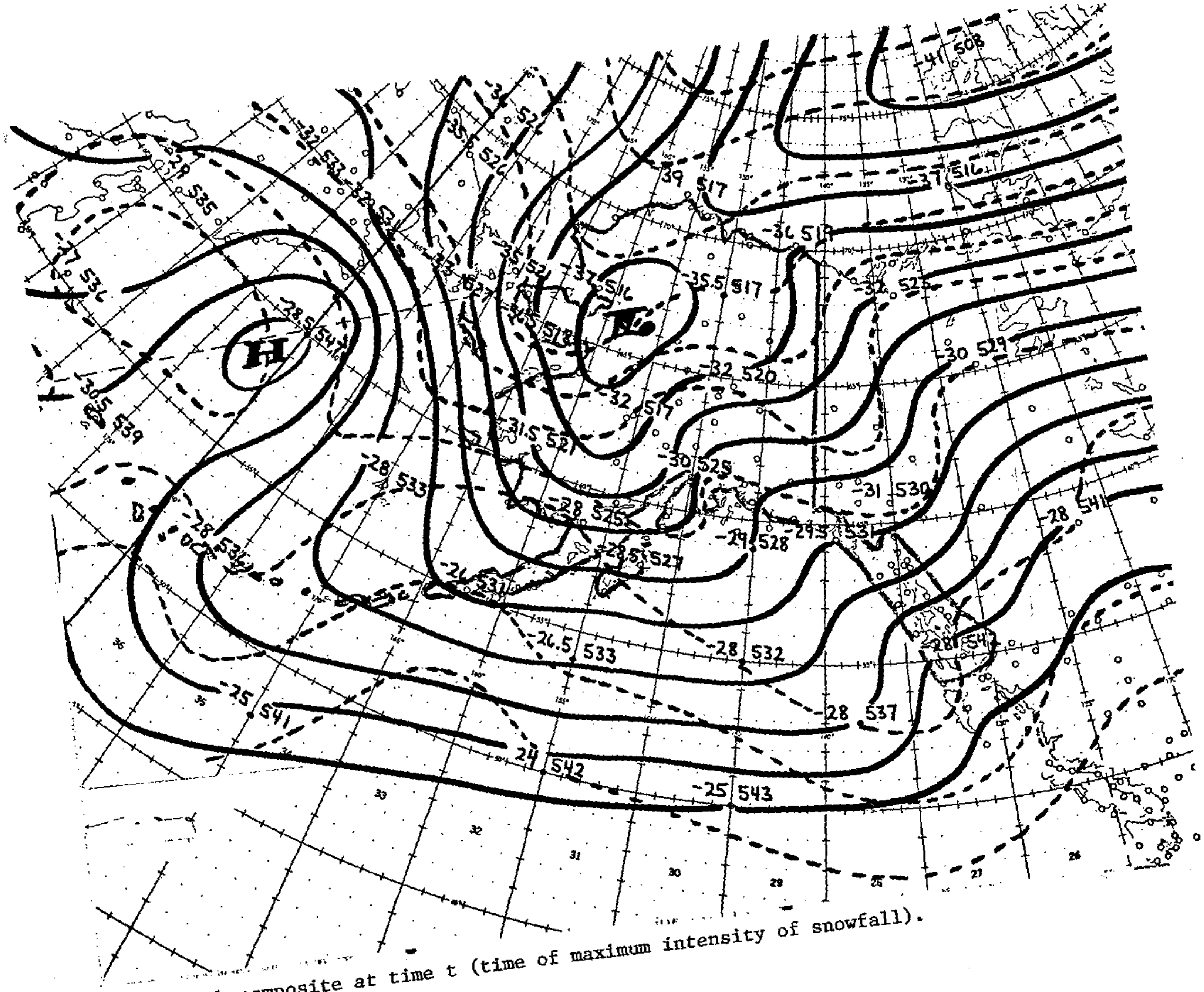


Figure 28. 500mb composite at time t (time of maximum intensity of snowfall).

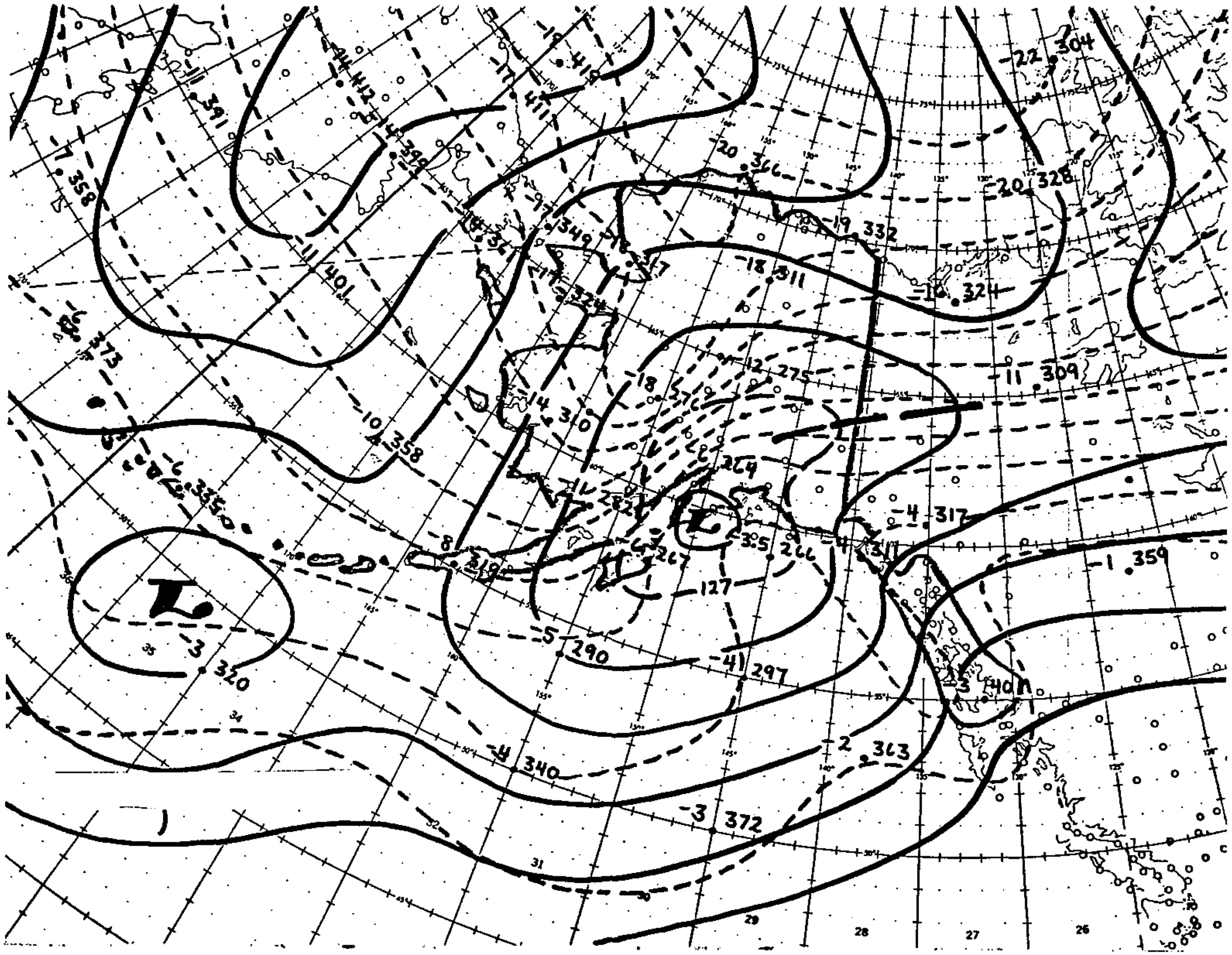


Figure 29. 850mb composite at time t (time of maximum intensity of snowfall).

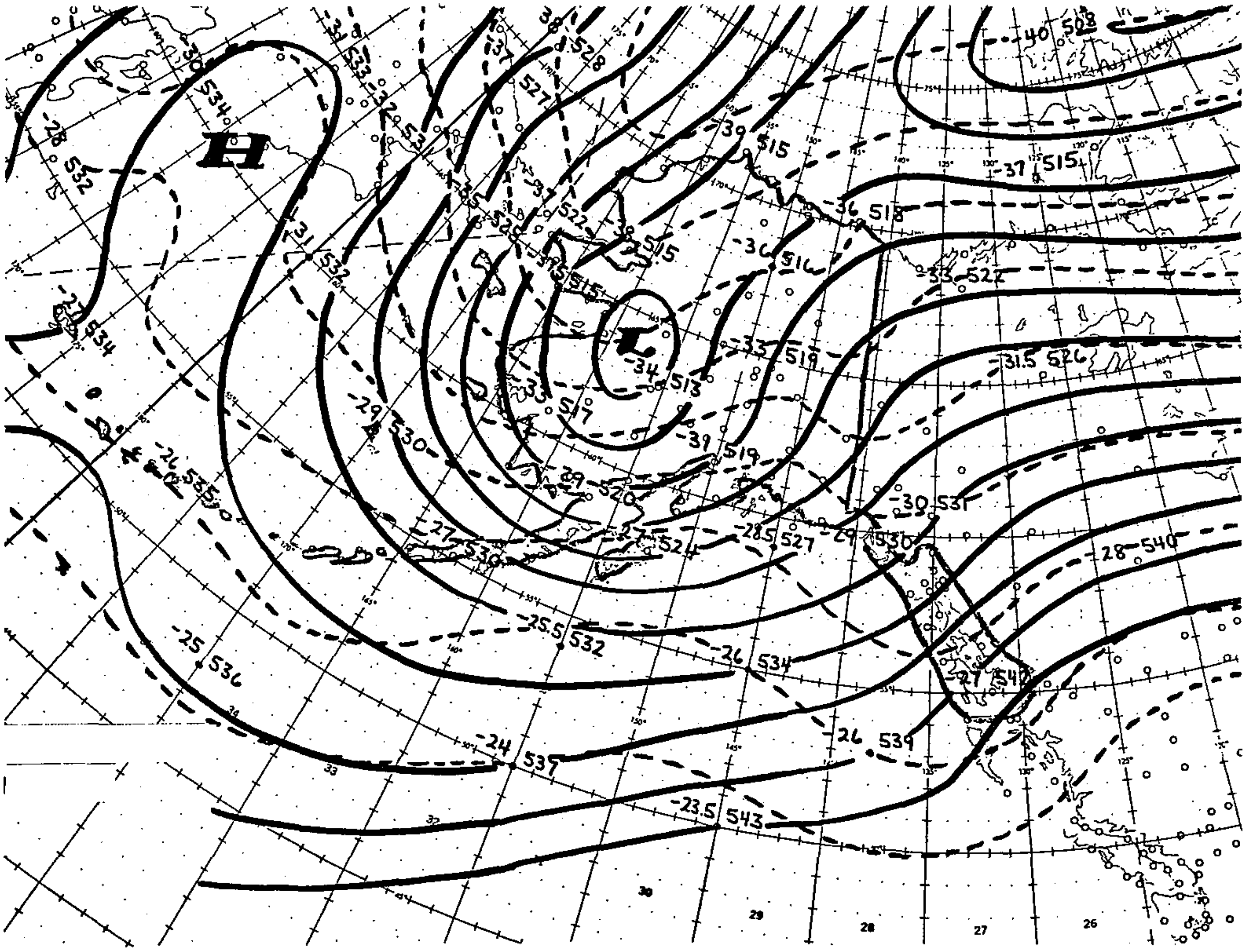


Figure 30. 500mb composite at time t+12 (12 hr after the time of peak snowfall).

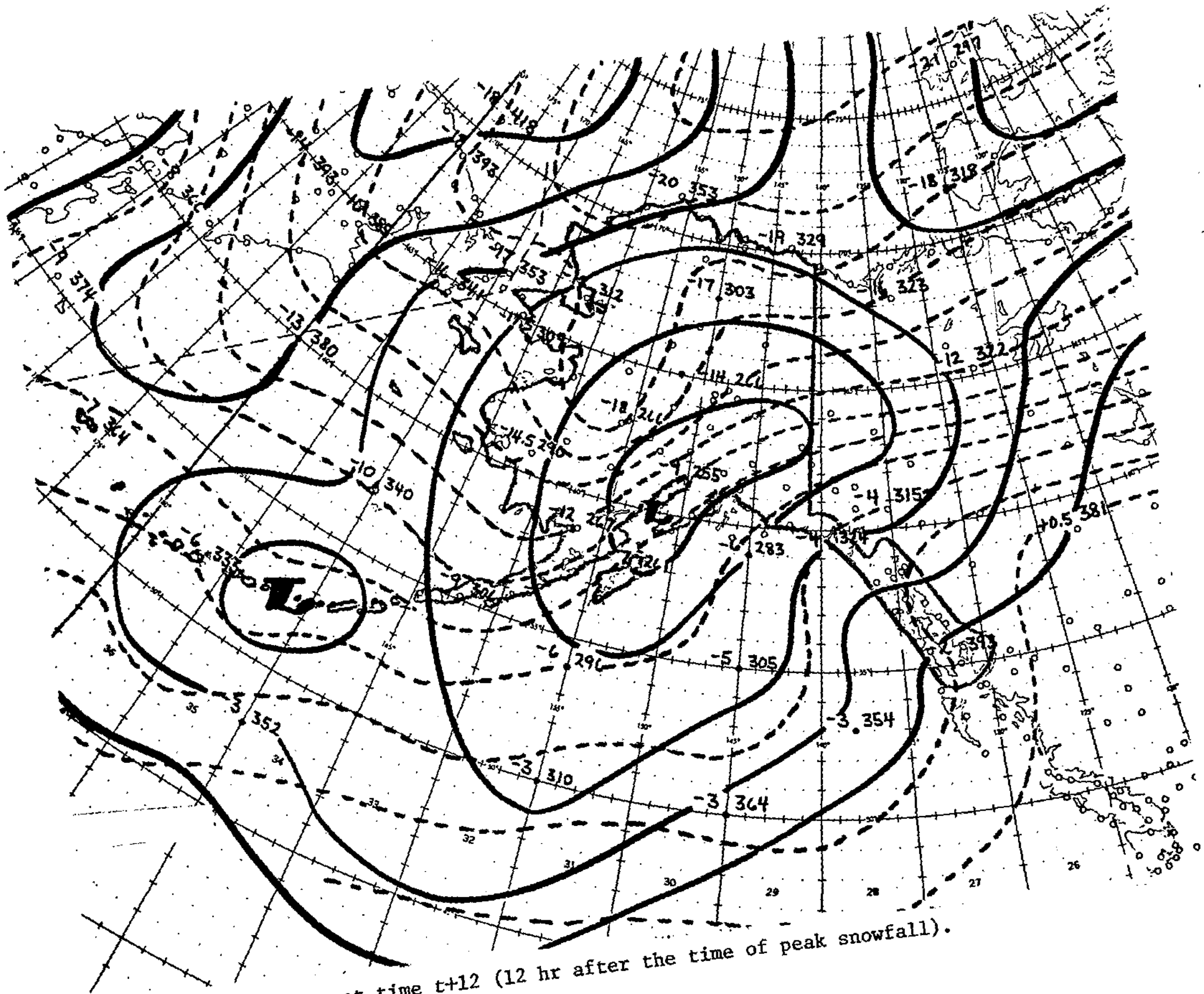


Figure 31. 850mb composite at time t+12 (12 hr after the time of peak snowfall).