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HEAVY SNOWFALL IN NORTHWEST WYOMING

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ABSTRACT. Heavy snowfall in the northwest part of Wyoming is a significant occurrence to the area. A climatology of heavy snow events for northwest Wyoming is given. Results indicate that the orientation of the flow aloft to the mountains is very important. In heavy snow situations winds at or above 700 mb blow perpendicular to the mountains at speeds of 30 knots or greater. Temperatures typically range from -6 to -8C at 700 mb and -26 to -28C at 500 mb. Saturated vertical ascent due to orographic lift was also noted in most cases.

1. Introduction

Snowfall in northwest Wyoming is often the most significant weather event during the year. For this paper, northwest Wyoming is defined as the Absaroka, Wind River, Teton and Salt Mountain ranges as well as Yellowstone National Park. This area is roughly represented by public forecast zones 1, 7, and 9 in Wyoming. The snowfall in this part of the state can occur almost anytime of the year, with heavy snowfall possible from September through May.

Heavy snowfall can be both hazardous and beneficial to the people of Wyoming. In addition, it poses as one of the most difficult weather events to forecast in the state. Heavy snowfall is defined as snowfall greater than ten inches from a particular storm. This is somewhat different than the Central Region's heavy snowfall definition of six inches in 12 hours or eight inches in 24 hours. In this paper a description of the factors producing heavy snowfall in northwest Wyoming will be given as well as the climatology and possible forecast solutions for these events.

2. Topography

The topography of northwest Wyoming can best be described as mountainous, with some high plateaus. The elevations range from 6,000 feet in the plateaus to over 13,000 feet in the higher mountains. This terrain rises sharply and effectively acts as a barrier to the general westerly flow of winds in the upper atmosphere. The mountain ranges each are oriented differently, adding to the forecast problem (see Fig. 1). The Absaroka Mountains are oriented generally from north to south, with Dead Indian Peak the highest elevation at 12,268 feet. A part of this range extends from northwest to southeast to east of Dubois, Wyoming.

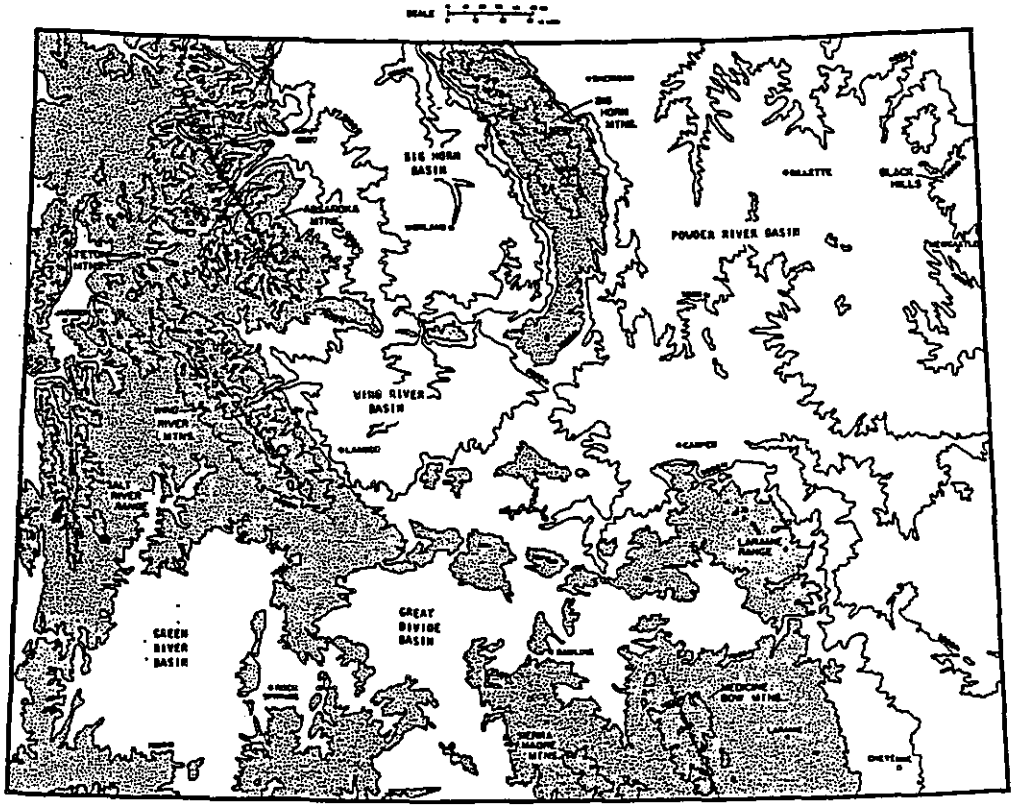

Fig. 1. Topographic map of Wyoming. Regions above 7,000 feet are shaded.

The Wind River range extends from northwest to southeast and the highest peak is Bennett Peak at 13,804 feet. The tallest mountains are in the northwest half of this chain. This range is also more continuous than the Absaroka Mountains.

The Teton mountain range extends from north to south, starting from near southern Yellowstone Park reaching to Alpine Junction, Wyoming. The highest peak in this range is Grand Teton peak at 13,766 feet. Finally, to the south of the Teton range is the Salt range. This range extends from north to south to just southeast of Afton, Wyoming. The highest peaks in this range are just over 10,000 feet. Yellowstone National Park, located in the northwest corner of the state, is lower in elevation, ranging from 6,000 to 10,000 feet and is surrounded by higher mountains to the north, east and south.

3. Climatology

Seasonal snowfall in the northwest part of Wyoming is among the highest in the state. Average seasonal snowfall ranges from 100 to 200 inches in the area (see Fig. 2). As would be expected, the higher amounts fall in the mountain areas. While much of the snow falls in January, the Wind River and part of the Absaroka ranges experience a maximum snowfall in April. This is due to large topographic differences across regions which create strong orographic affects in the predominant westerly flow in the winter months.

The differences in the month of maximum snowfall is also due, in part, to differences in orientation of the mean flow aloft. For December to February, the mean flow aloft is from the west to northwest, affecting the north to south oriented ranges. In the late winter through early spring, the mean flow aloft becomes more from the southwest, affecting the northwest to southeast mountain ranges. It is also interesting to note that the large amounts of snowfall in the northwest to southeast oriented ranges. This may be due, in part, to the increased moisture available in the warmer southwest flow aloft in the spring (see Fig. 3).

A heavy snow event in northwest Wyoming typically lasts from two to four days, with a moderate to heavy snowfall occurring from time to time. It appears that during any given season, four to ten of these significant events will occur. Snowfall of a lighter variety is very common and occurs almost daily in that part of the state.

The climate of northwest Wyoming can be classified as either Alpine or Tundra. This climate has very cold and wet winters and cool summers. In northwest Wyoming, nearly 40 percent of the annual precipitation falls from December through February (see Fig. 5).

4. Methodology

This paper looks at widespread, significant snowfalls of greater than 10 inches in northwest Wyoming from fall of 1986 through early spring of 1987. Snowfall information was obtained from reports received at WSFO Cheyenne,

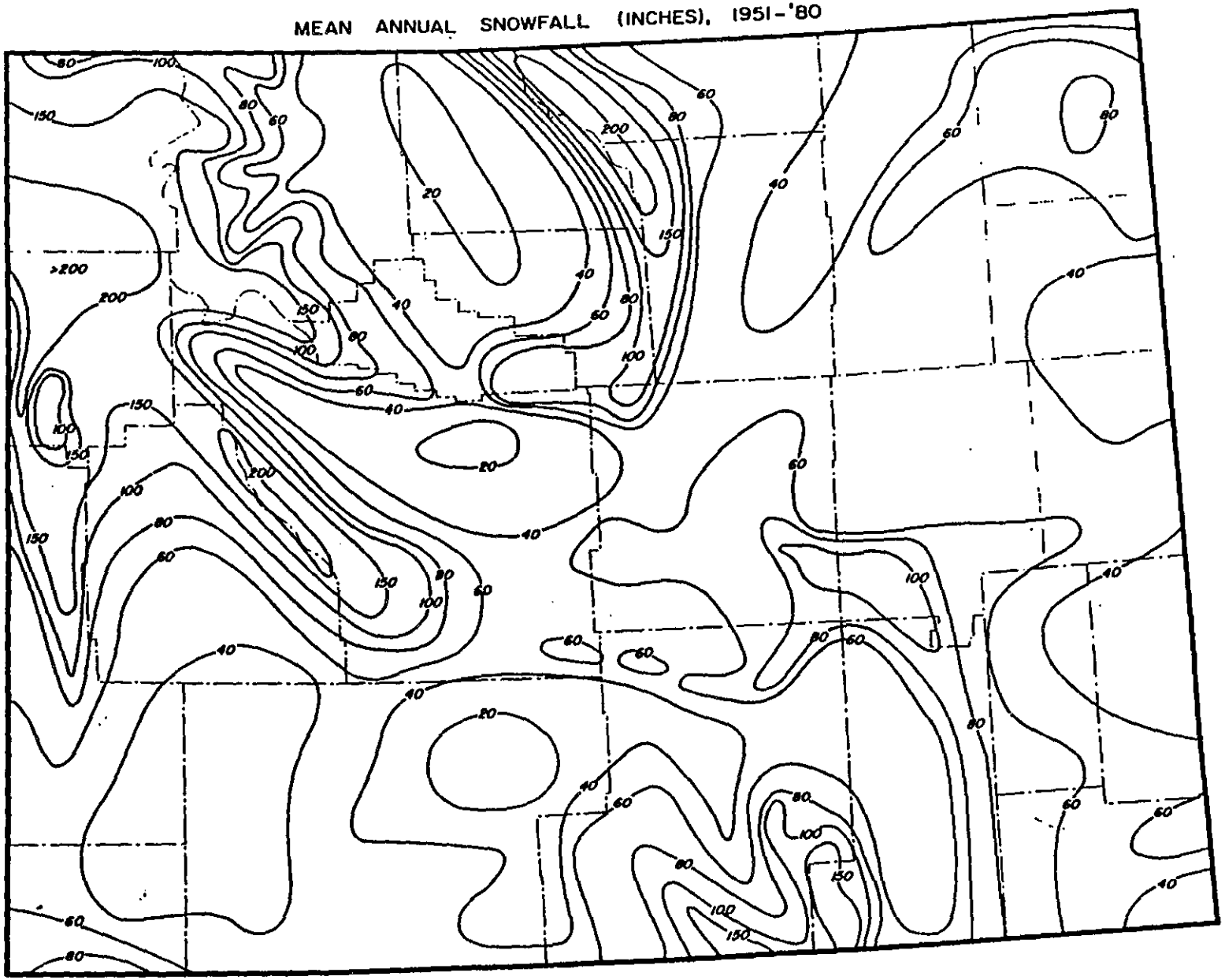

Fig. 2. Mean annual snowfall (inches).

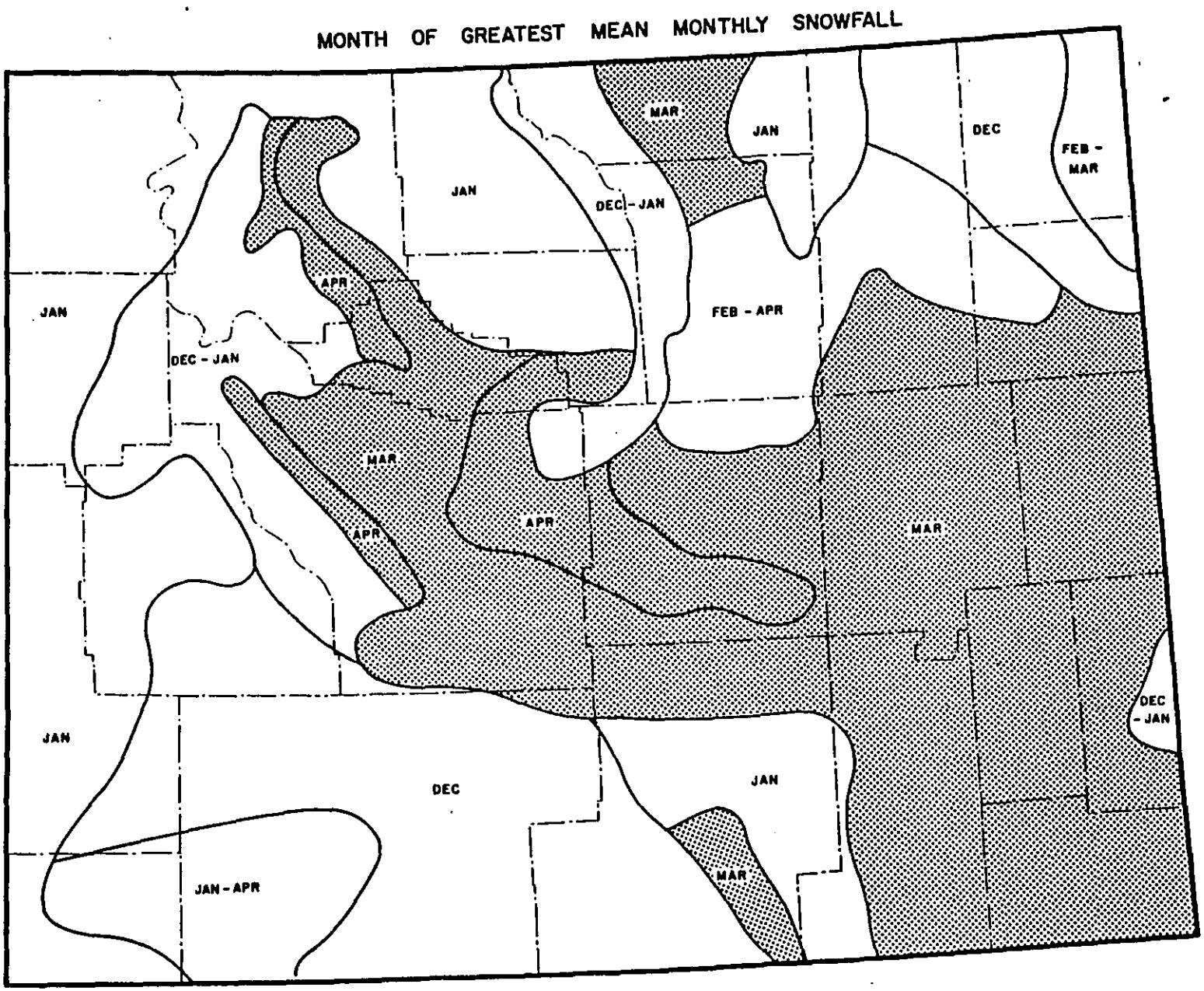

Fig. 3. Month of greatest mean monthly snowfall.

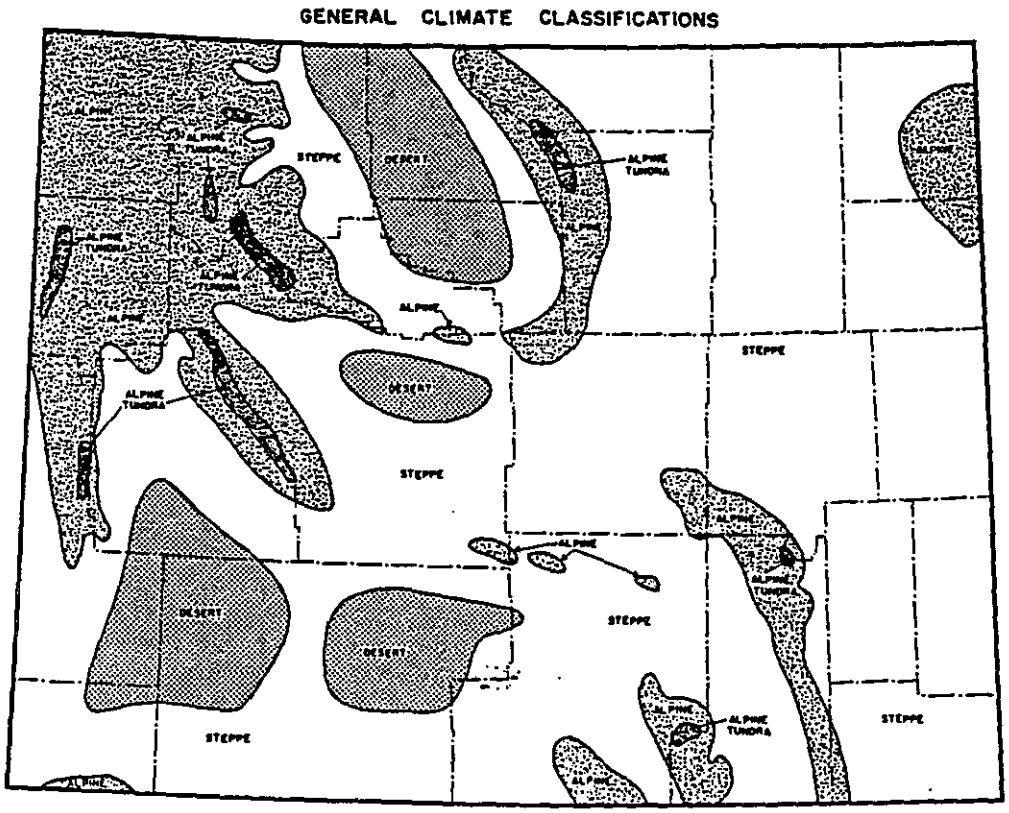

Fig. 4. General climate classifications.

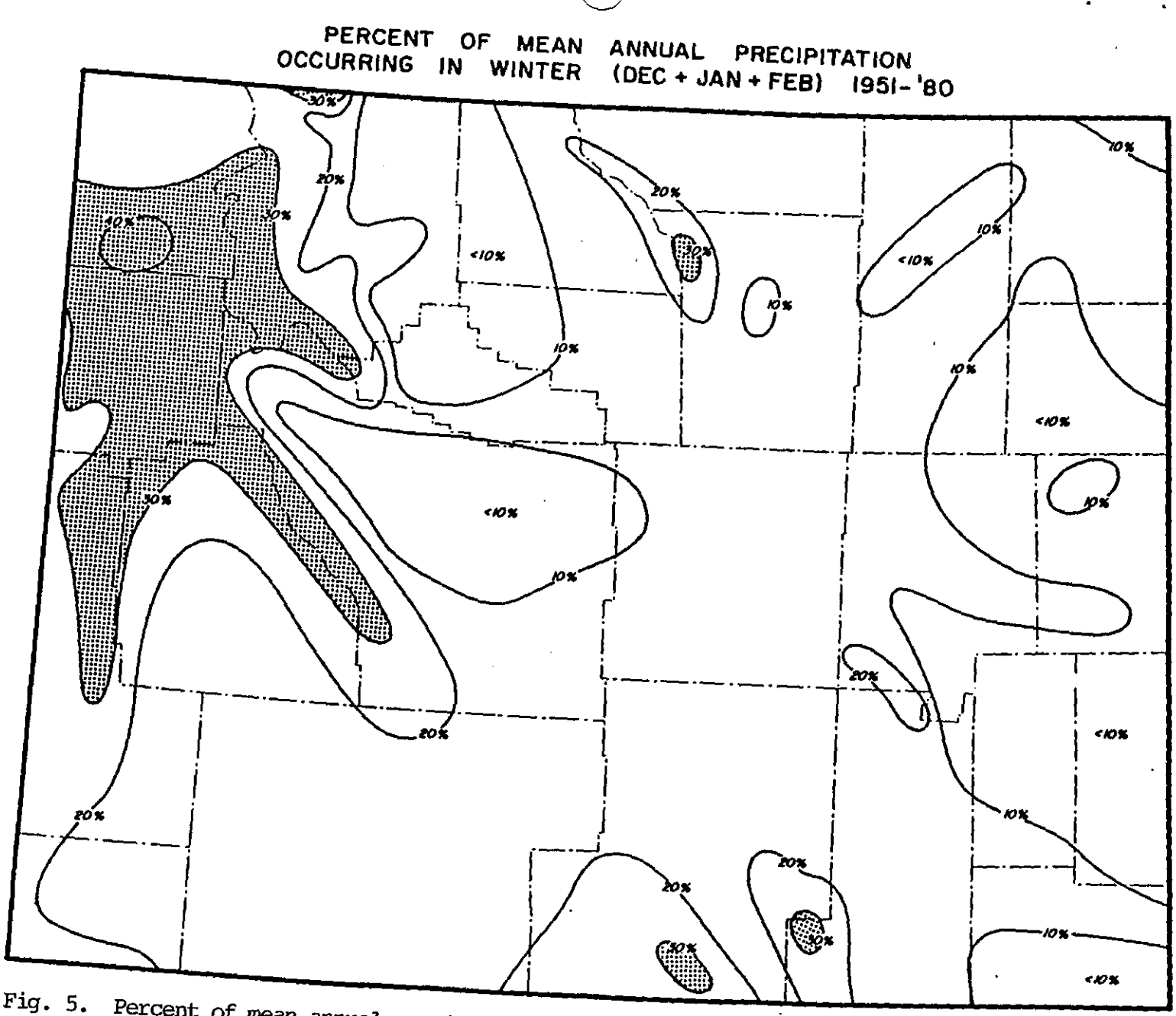

Fig. 5. Percent of mean annual precipitation occurring in winter.

cooperative station reports and SNOTEL (Snow Telemetry system)1 sites (Fig. 6). There were four significant events during the 1986-1987 season. Weather data to examine these cases were obtained from WSFO Cheyenne and the National Climatic Data Center (NCDC) in Asheville. The dates include: November 5 and 6, 1986; January 1 and 2, 1987; January 4, 5, and 6, 1987; and January 24, 25, and 26, 1987.

5. Case Studies

Four heavy snow cases were examined and data were analyzed at the 300, 500, and 700 millibar (mb) levels. RAOB soundings and some other data such as surface charts, precipitable water, and lifted index charts were also studied. For each case study the appropriate 300, 500, and 700 mb charts will be provided.

A. November 5-6, 1986

Snowfall amounts and patterns are shown in Fig. 7. Heavy snowfall of 10 inches or more fell in Yellowstone Park, the Absaroka mountain range, including that portion of the range which extends from the northwest to the southeast; the Wind River range and parts of the Salt range. The largest snowfall amount reported was 20 inches at Slyvan Lake in the Absaroka range.

The synoptic situation for this case can be seen in Figs. 8, 9, and 10 which are for 00Z on November 6. A 500 mb trough was developing over the Pacific Northwest at 12Z on November 5 (not shown). By 00Z on November 6 it extended from California to southwest Montana. A 300 mb 90 kt jet was positioned from Oregon to southwest North Dakota at 00Z on November 6 and by 12Z on November 6 a 70 kt jet was from Utah to North Dakota. Northwest flow aloft developed behind the trough. Height falls at 500 mb for 00Z on November 6 were from -6 to -14 dm over the area.

Cold air advection and backing flow occurred aloft over northwest Wyoming during this period. Temperatures at 500 mb went from -20C at 00Z on November 6 to -23C to -26C at 12Z on November 6. Strong 700 mb cold air advection also moved over the area on the 5th and 6th with temperatures ranging from around -5C at 00Z on November 6 to -6C to -9C at 12Z on November 6. There was strong baroclinicity over northwest Wyoming.

Moisture at 700 mb increased through the period with the dew points -3C to -9C by 12Z on November 6. Moisture at 500 mb increased dramatically as well. The main precipitation came in the southwest flow aloft as shown by the snowfall chart.

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1 SNOTEL can be defined as an automatic snow depth and snowfall observing station set up in mountain locations where snowfall is a critical element. These stations are operated by the U.S. Soil and Conservation Service and report to satellite once a day.

SNOTEL SITES

STATION	ELEVATION
Togwotee Pass	9580
Spring Creek Divide	9000
Two Ocean Plateau	9160
Gros Ventre Summit	8750
Willow Creek	8450
Phillips Bench	8200
Lewis Lake Divide	7850
Cottonwood Creek	7600
Salt River Summit	7700
Grassy Lake	7265
Base Camp	7030
Coulter Creek	7020
Parkers Peak	9400
Beartooth Lake	9275
Sylvan Lake	8420
Canyon	7940
Dinwoody	10160
Hobbs Park	10100
Christina Lake	9980
Little Warm	9620
South Pass	9040
Burroughs Creek	8750
Townsend Creek	8700
St. Lawrence	8960
Irish Rock	9600
Blackwater	9780
Kirwin	9550
Evening Star	9200
Owl Creek	8975
Marquette Creek	8760
Trout Creek	8400
Younts Peak	8350
Elkhart Park GS	9400
Big Sandy Opening	9080
Blind Bull Summit	8650
Triple Peaks	8500
Loomis Park	8240
East Rim Divide	7930
Kendall RS	7740

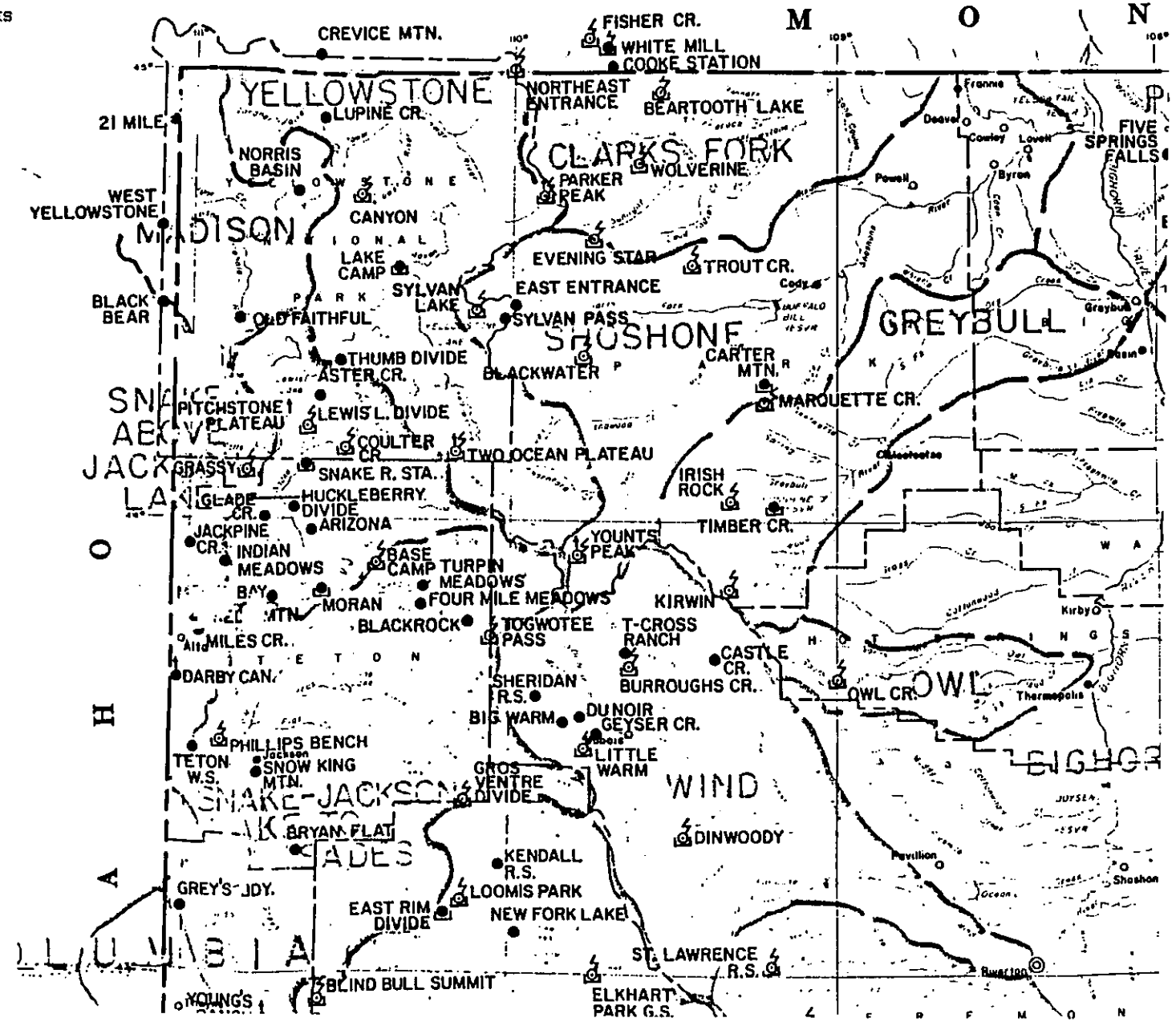

Fig. 6. Map and listing of SNOTEL sites in northwest Wyoming.

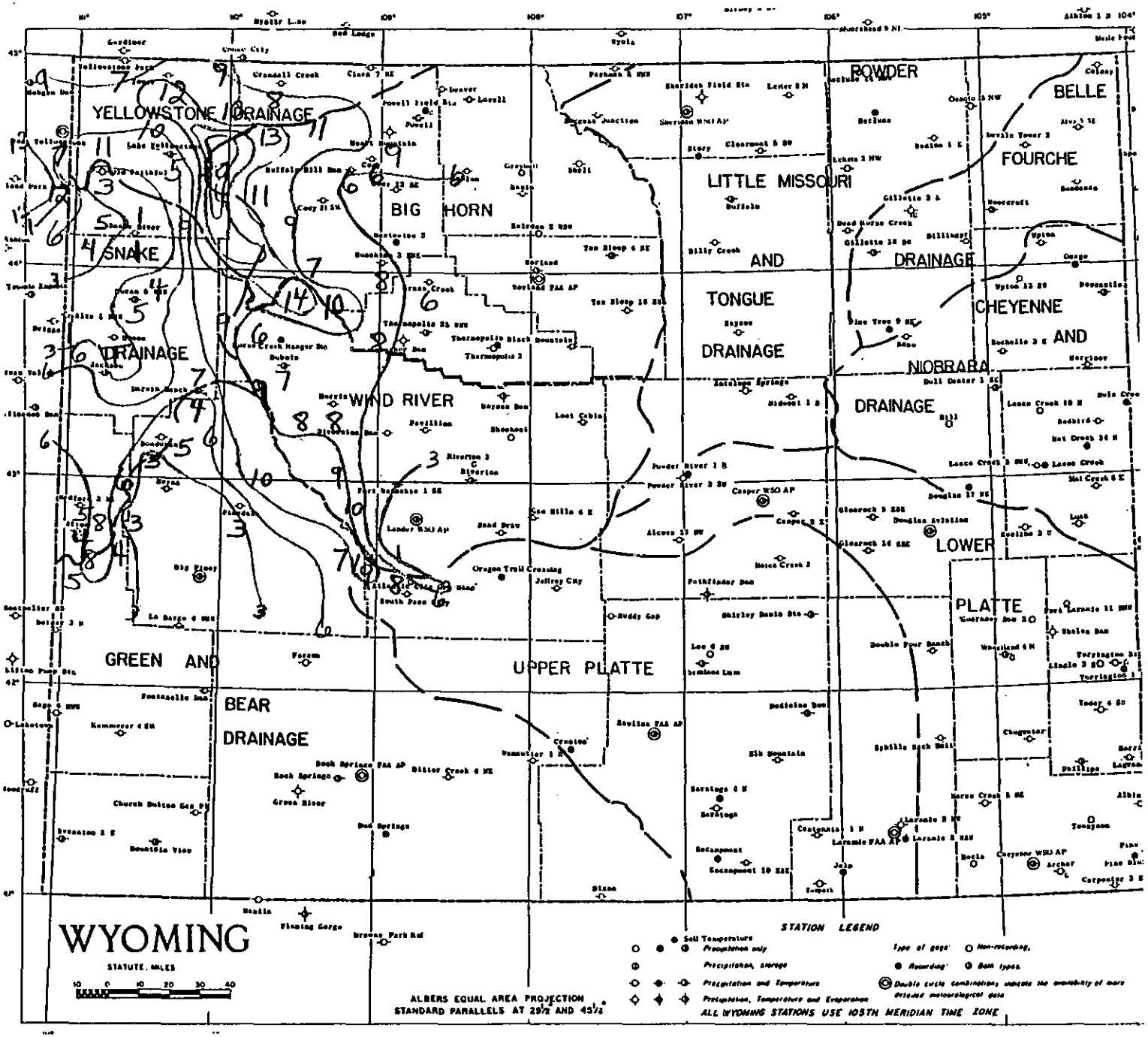

Fig. 7. Snowfall (inches) for November 5-6, 1986.

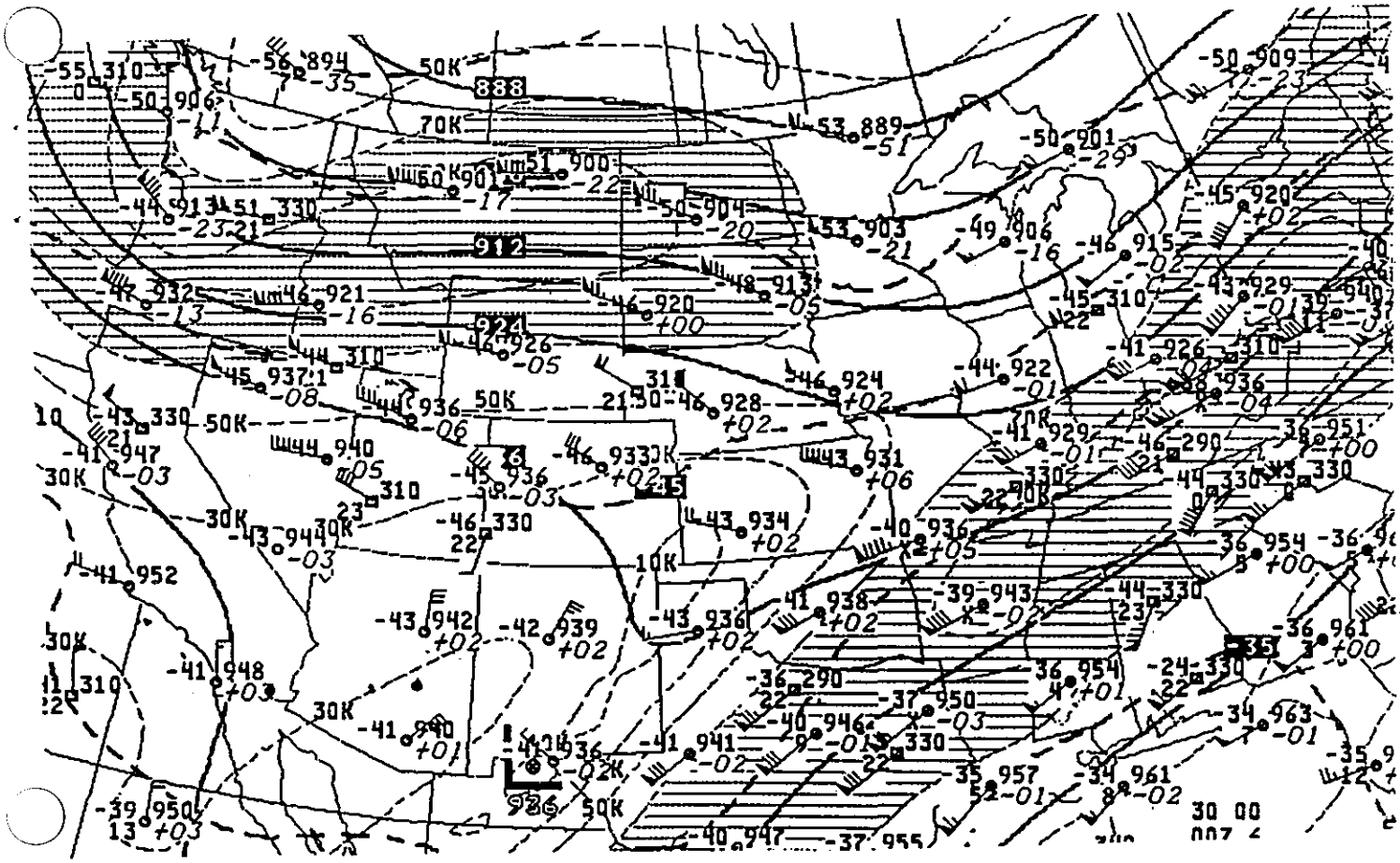

Fig. 8. 300 mb Chart for 00Z, November 6, 1986. Heights in decameters (solid lines), wind speeds in knots (dashed lines), wind barbs in knots.

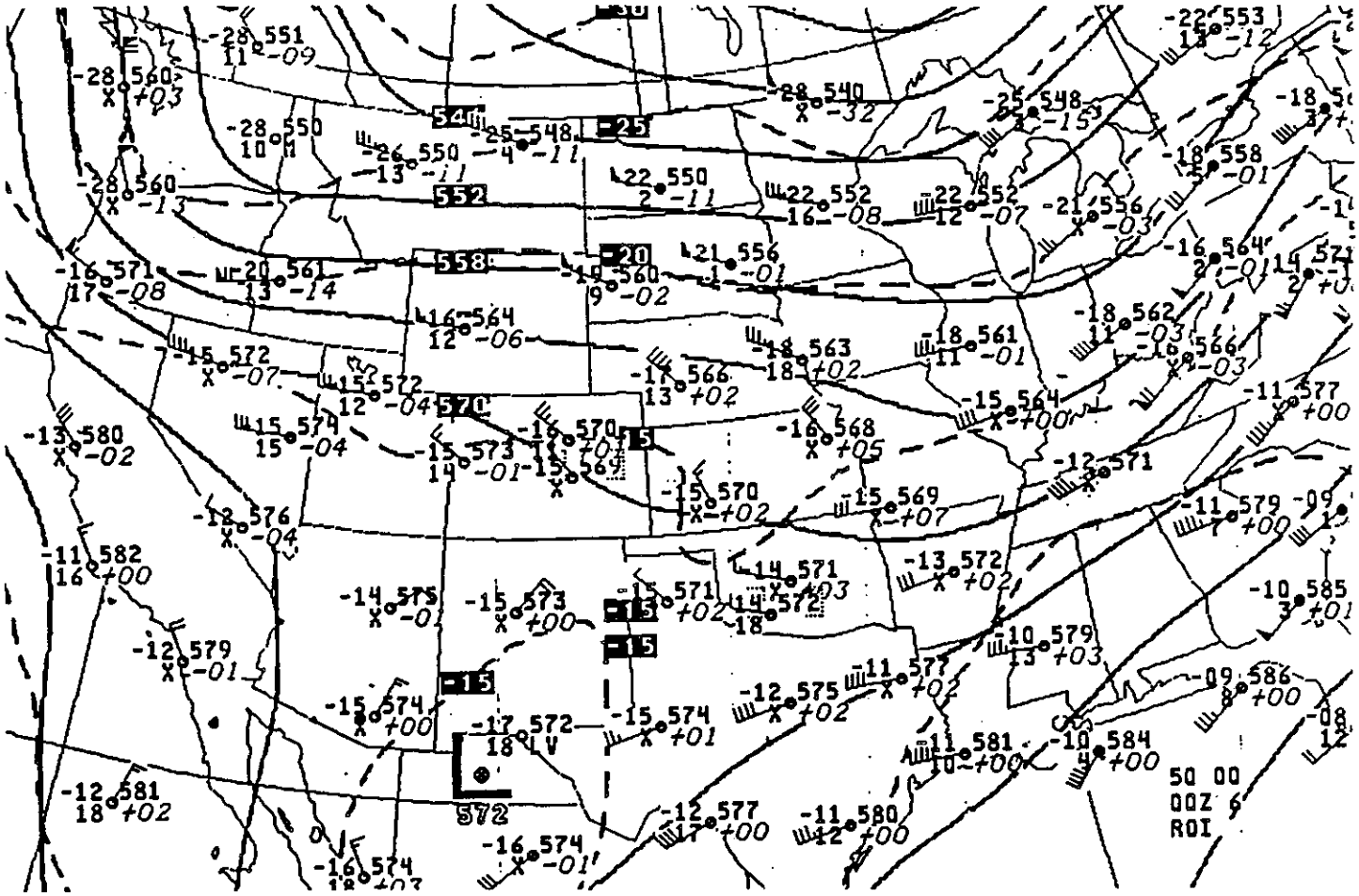

Fig. 9. 500 mb Chart for 00Z, November 6, 1986. Heights in decameters (solid lines), temperatures in degrees Celcius (dashed lines), wind barbs in knots. Solid circle indicates temperature dew point spread less than five degrees.

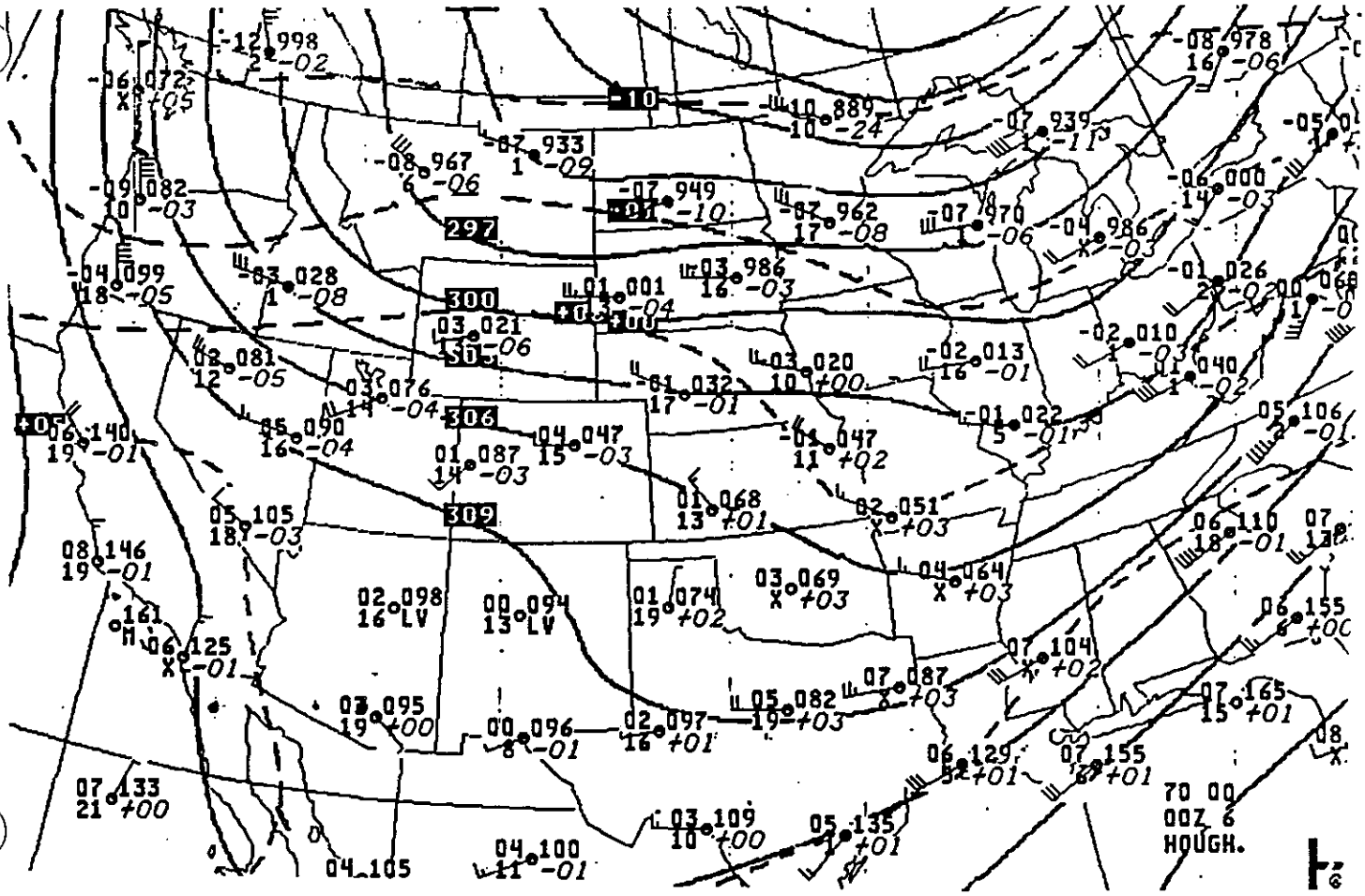

Fig. 10. 700 mb Chart for 00Z, November 6, 1986. Heights in decameters (solid lines), temperatures in degrees Celcius (dashed lines), wind barbs in knots. Solid circle indicates temperature dew point spread less than five degrees.

B. January 1-2, 1987

Snowfall amounts were 10 inches or more in the Teton and Salt mountain ranges, with very little in the northwest to southeast oriented ranges. The largest amount reported was 14 inches at Triple Peaks and Grassy Lake (see Fig. 11).

In this case, please refer to Figs. 12, 13, and 14. At 300 mb a 90 kt jet was positioned over eastern Oregon at 12Z on January 1. By 00Z on January 2, the jet had moved into southwest Idaho and northwest Nevada with diffluent flow over southwest Wyoming. A short wave trough was situated along the West Coast. At 12Z on January 2, the 300 mb short wave deepened and extended from western North Dakota to eastern Utah. A 110 kt jet was now into southwest Utah and a 90 kt jet into central Idaho.

The mean 500 mb trough for 12Z, January 1, was off the Pacific Northwest coast. Seven to 11 dm height falls were occurring in northwest U.S. and southwest Canada. There was high moisture with 500 mb. By 00Z the short wave trough was off the West Coast, and eight to 13 dm height 500 mb falls were evident in the Pacific Northwest. The height falls moved over southwest Wyoming, northern Utah and northern Colorado by 12Z, January 2. Most of the moisture at this time was over Utah and Colorado. Strong cold air advection pushed into the region with northwest flow at 25 kts behind the trough.

At 700 mb, a strong westerly flow of 30 kts existed over northwest Wyoming which increased the cold air advection at 12Z on January 2. A Pacific cold front moved through northwest Wyoming between 03Z and 06Z on January 2.

Temperatures at 500 mb on 00Z January 2 were -20C, with -25C at 12Z on January 2. Temperatures at 700 mb were from -4C to -8C at 00Z January 2 and around -7C at 12Z January 2. The dew point at 700 mb was -8C to -12C at 12Z on January 2.

C. January 4-6, 1987

Snowfall amounts of 10 inches or more occurred over the Wind River range, Salt range, and the Tetons. The greatest snowfall reported was 24 inches at Darwin Ranch. This snow fell during three days from the 4th through the 6th (see Fig. 15).

Please refer to Figs. 16, 17, 18, 19 and 20 for upper air data on 00Z January 5. In this case, a deep trough was over the West Coast at 00Z January 5 with strong southwest flow aloft over Wyoming through January 6. At 300 mb, a 110 kt jet extended from southern California to central Utah.

Temperatures at 500 mb ranged from -22C to -26C, while temperatures at 700 mb were from -5C to -9C. Precipitable water values were over 100 percent of normal to the southwest of the region, with lifted indices from four to seven. Even with the southwest flow aloft over the region, there was slight cold air advection occurring during the snowfall period. Colder surface temperatures worked into the area on January 6.

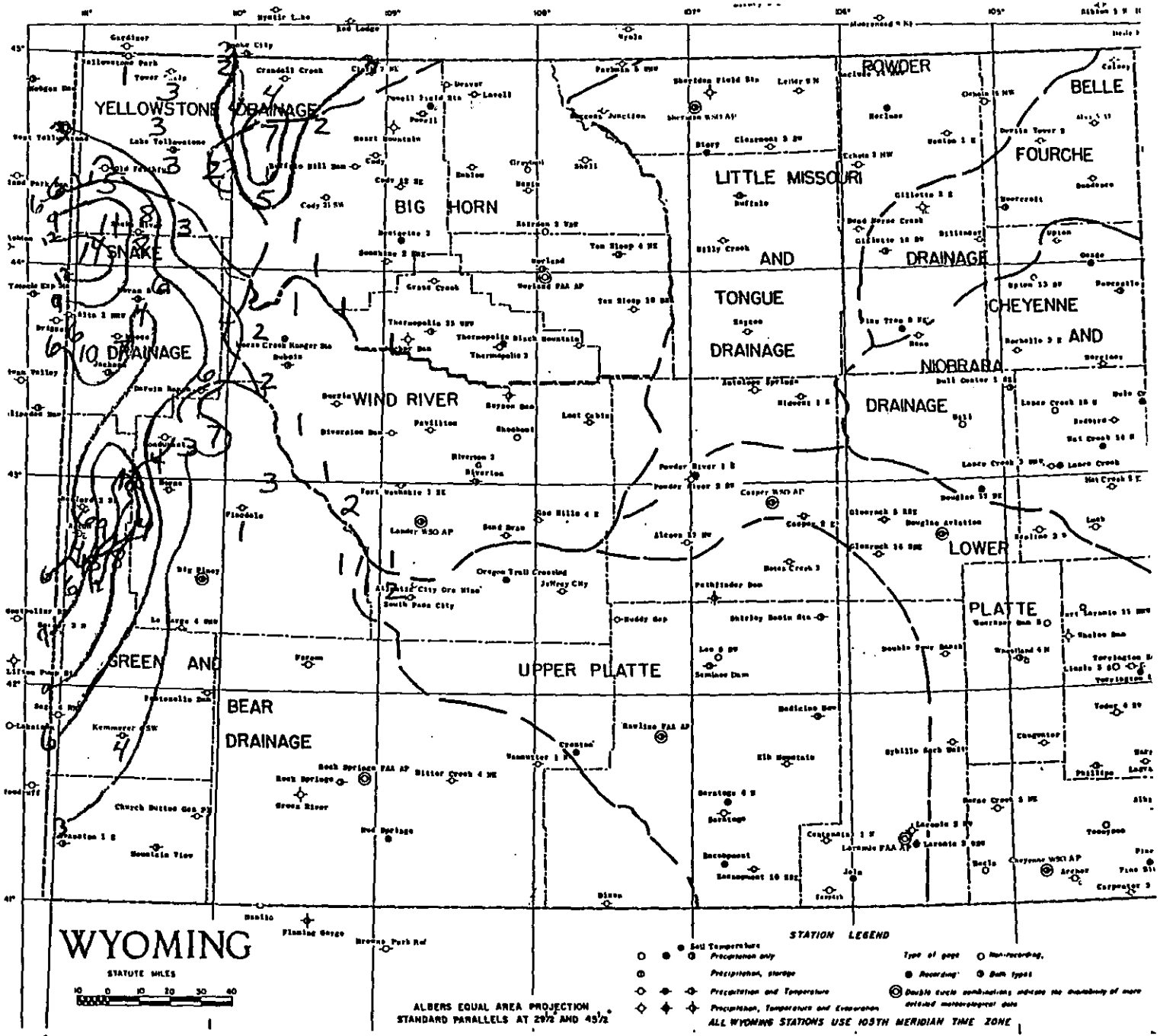

Fig. 11. Snowfall (inches) for January 1-2, 1987.

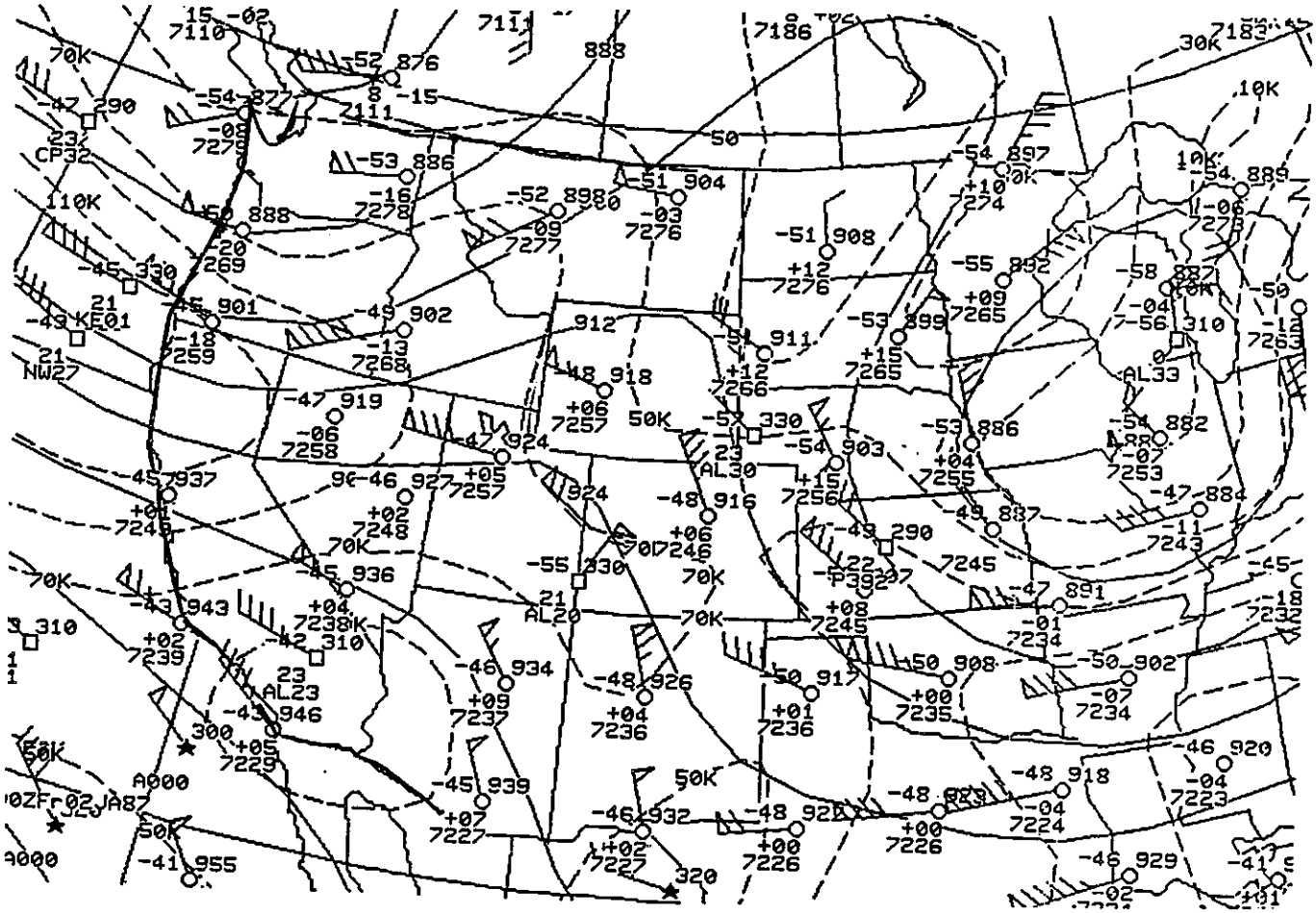

Fig. 12. 300 mb Chart for 00Z, January 2, 1987. Heights in decameters (solid lines), wind speeds in knots (dashed lines), wind barbs in knots.

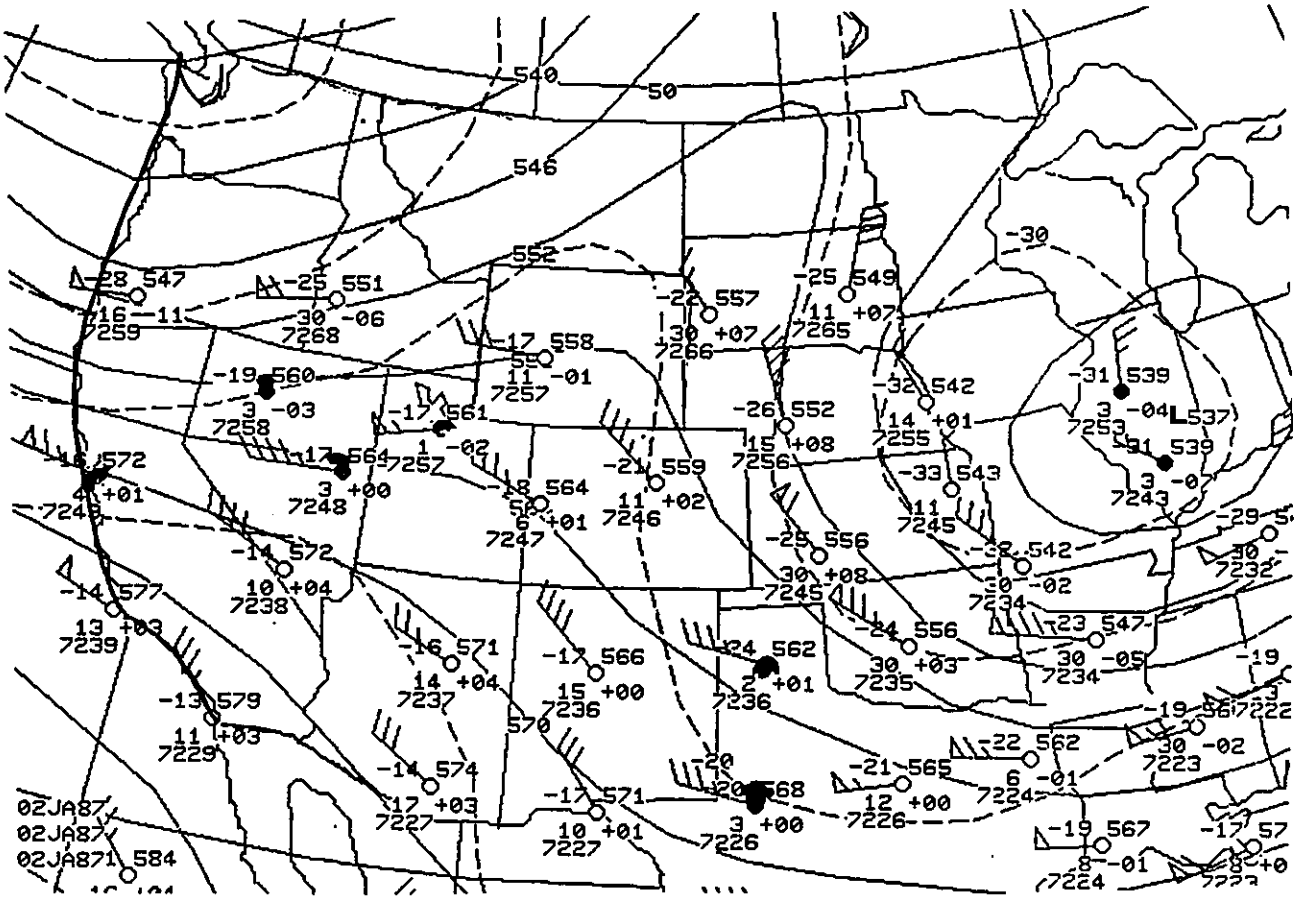

Fig. 13. 500 mb Chart for 00Z, January 2, 1987. Heights in decameters (solid lines), temperatures in degrees Celcius (dashed lines), wind barbs in knots. Solid circle indicates temperature dew point spread less than five degrees.

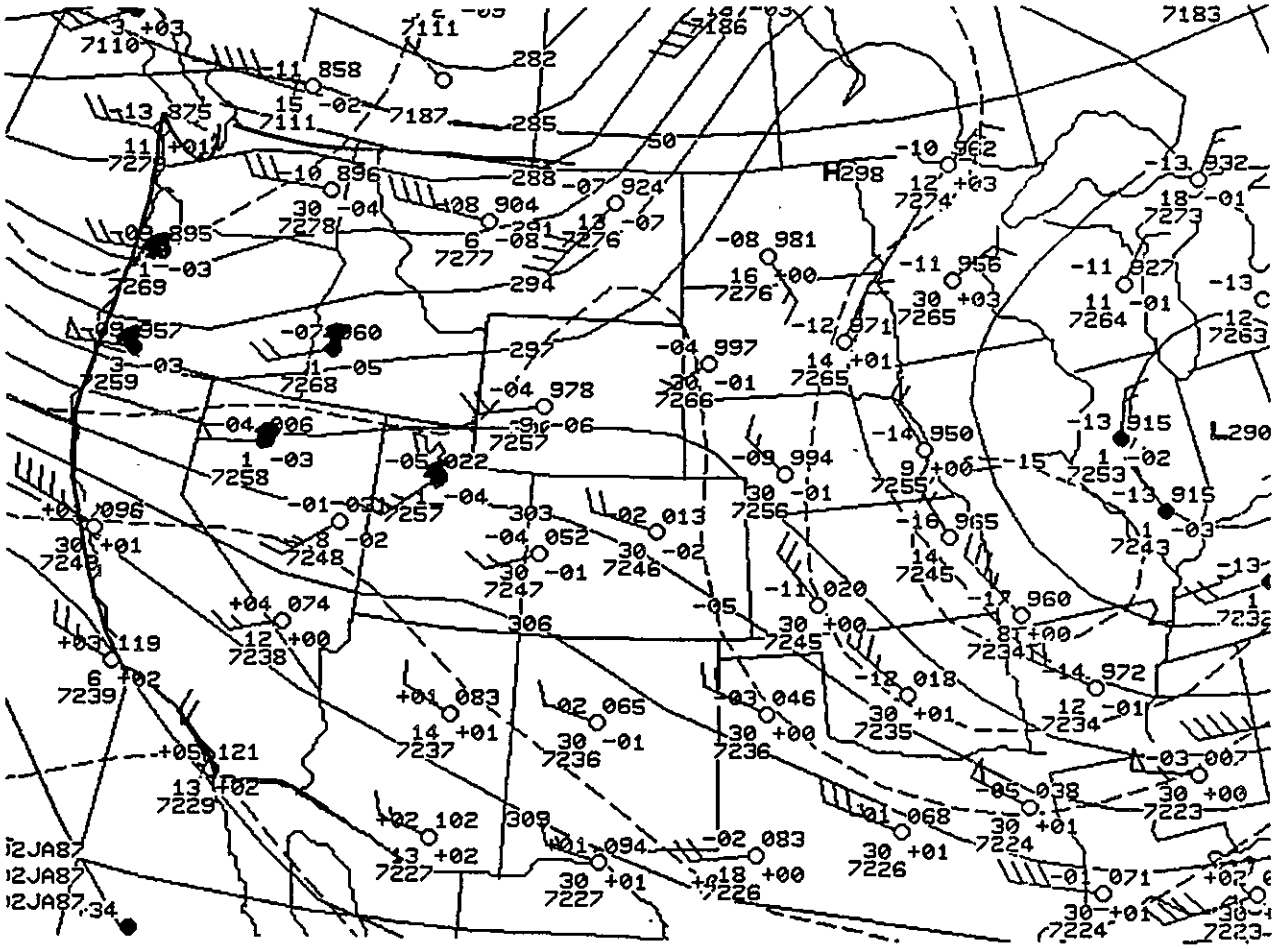

Fig. 14. 700 mb Chart for 00Z, January 2, 1987. Heights in decameters (solid lines), temperatures in degrees Celcius (dashed lines), wind barbs in knots. Solid circle indicates temperature dew point spread less than five degrees.

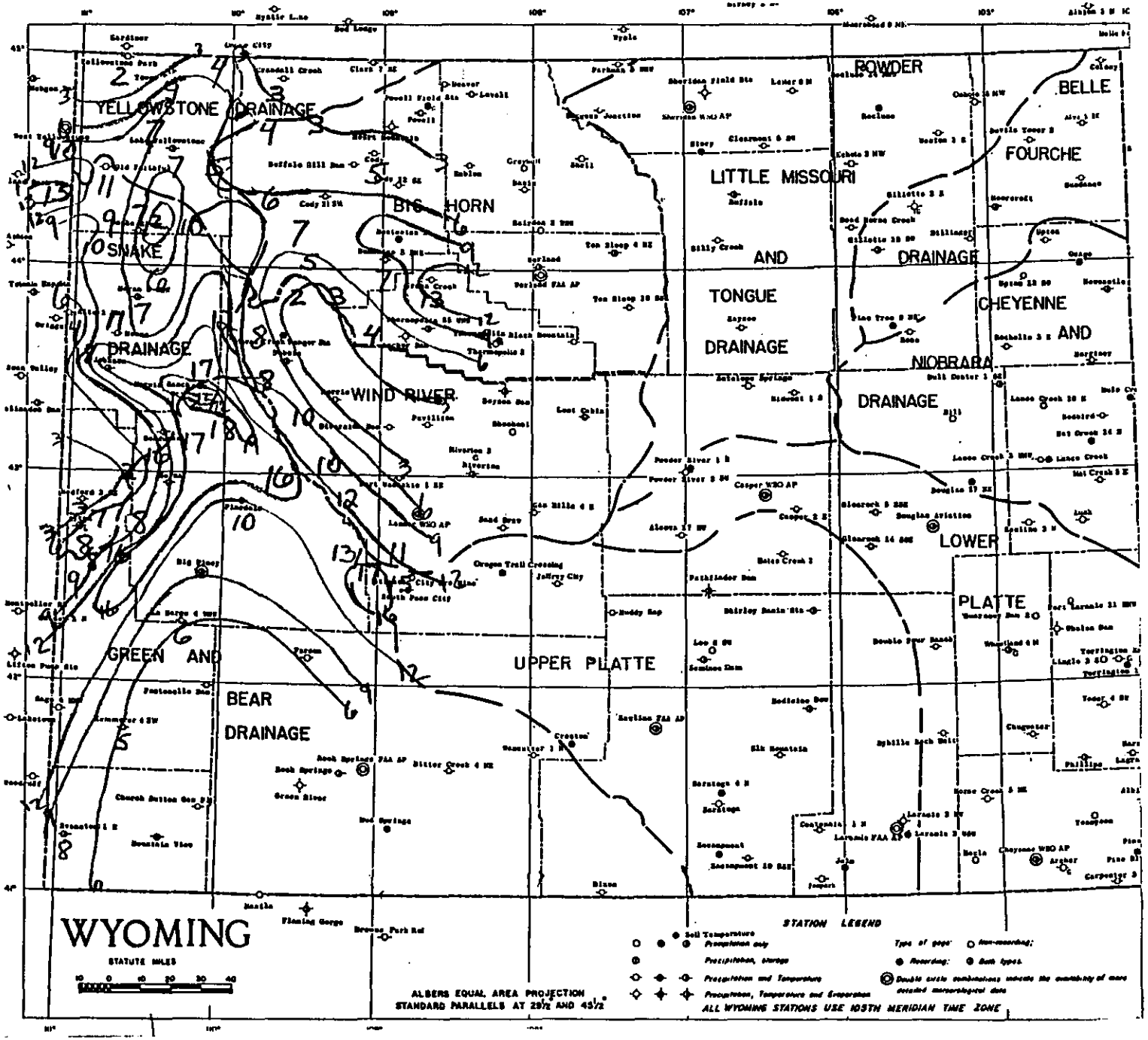

Fig. 15. Snowfall (inches) for January 4-6, 1987.

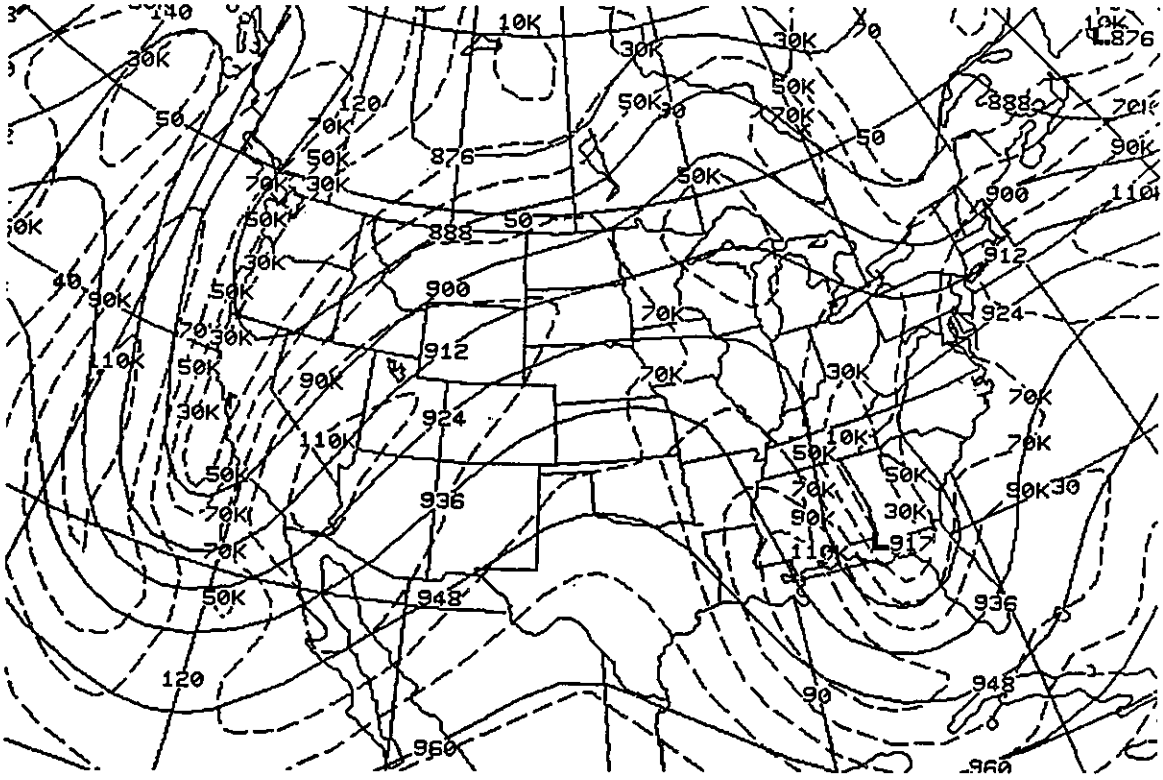

Fig. 16. 300 mb Chart for 00Z, January 5, 1987. Heights in decameters (solid lines), wind speeds in knots (dashed lines), wind barbs in knots.

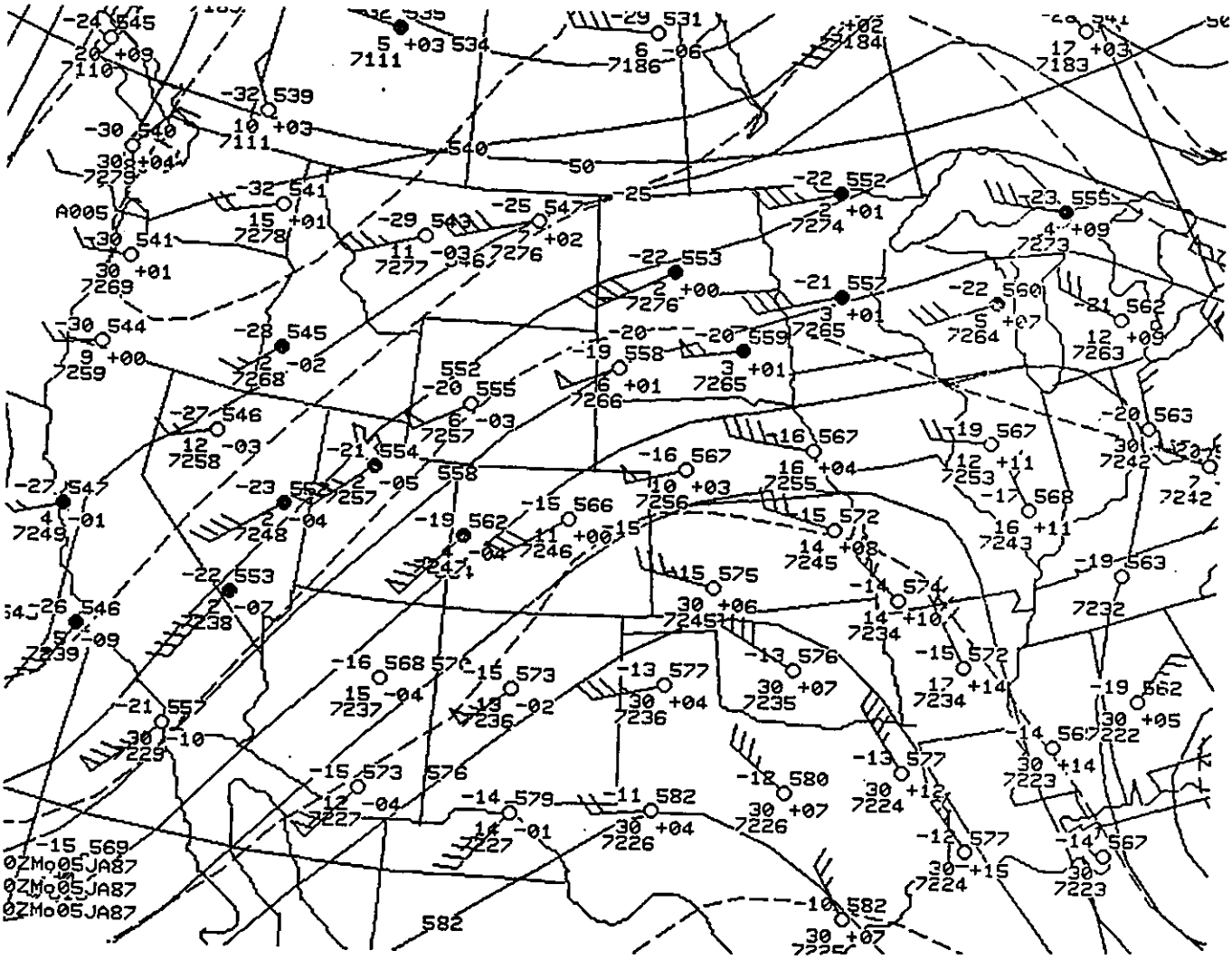

Fig. 17. 500 mb Chart for 00Z, January 5, 1987. Heights in decameters (solid lines), temperatures in degrees Celcius (dashed lines), wind barbs in knots. Solid circle indicates temperature dew point spread less than five degrees.

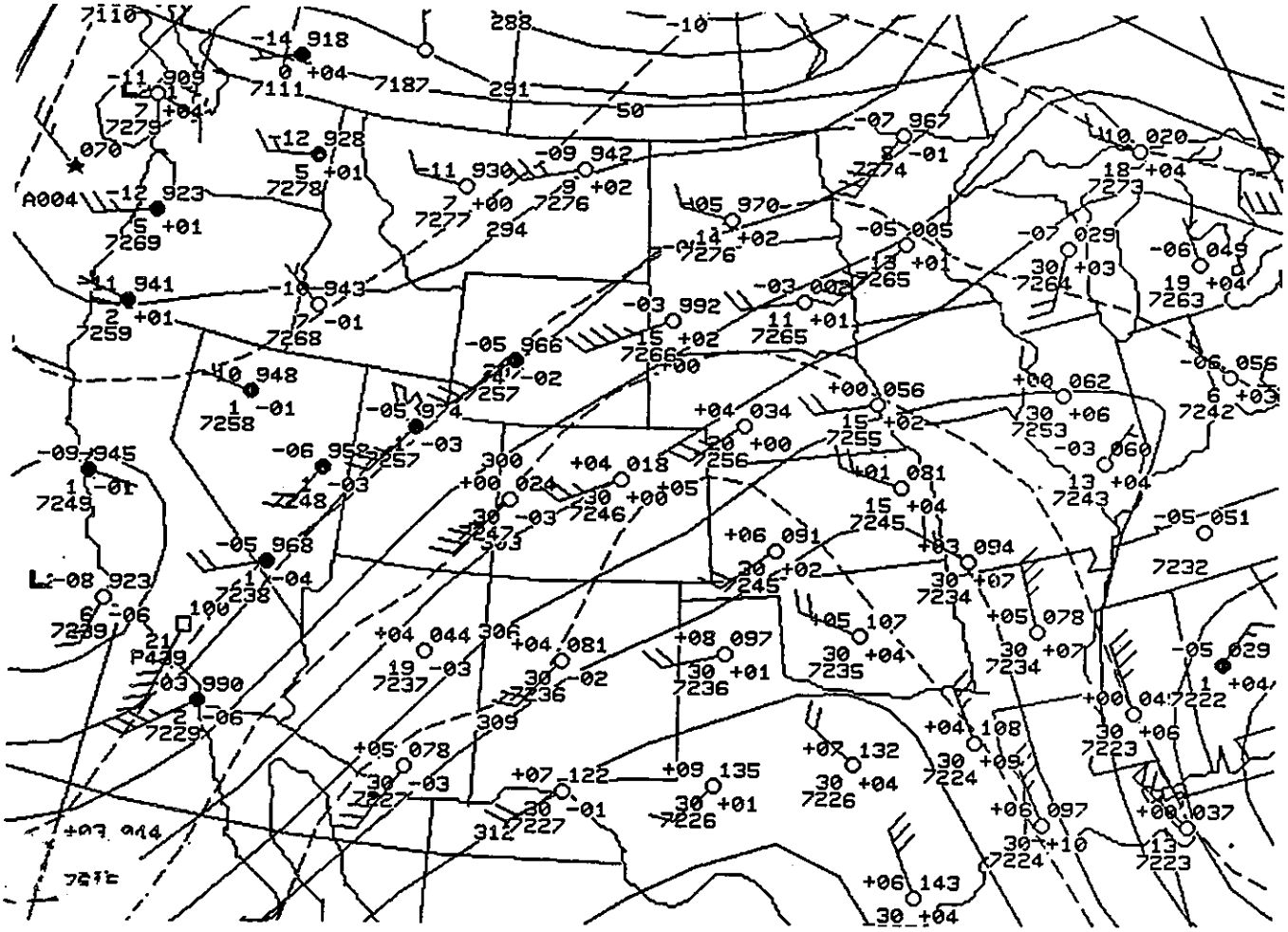

Fig. 18. 700 mb Chart for 00Z, January 5, 1987. Heights in decameters (solid lines), temperatures in degrees Celcius (dashed lines), wind barbs in knots. Solid circle indicates temperature dew point spread less than five degrees.

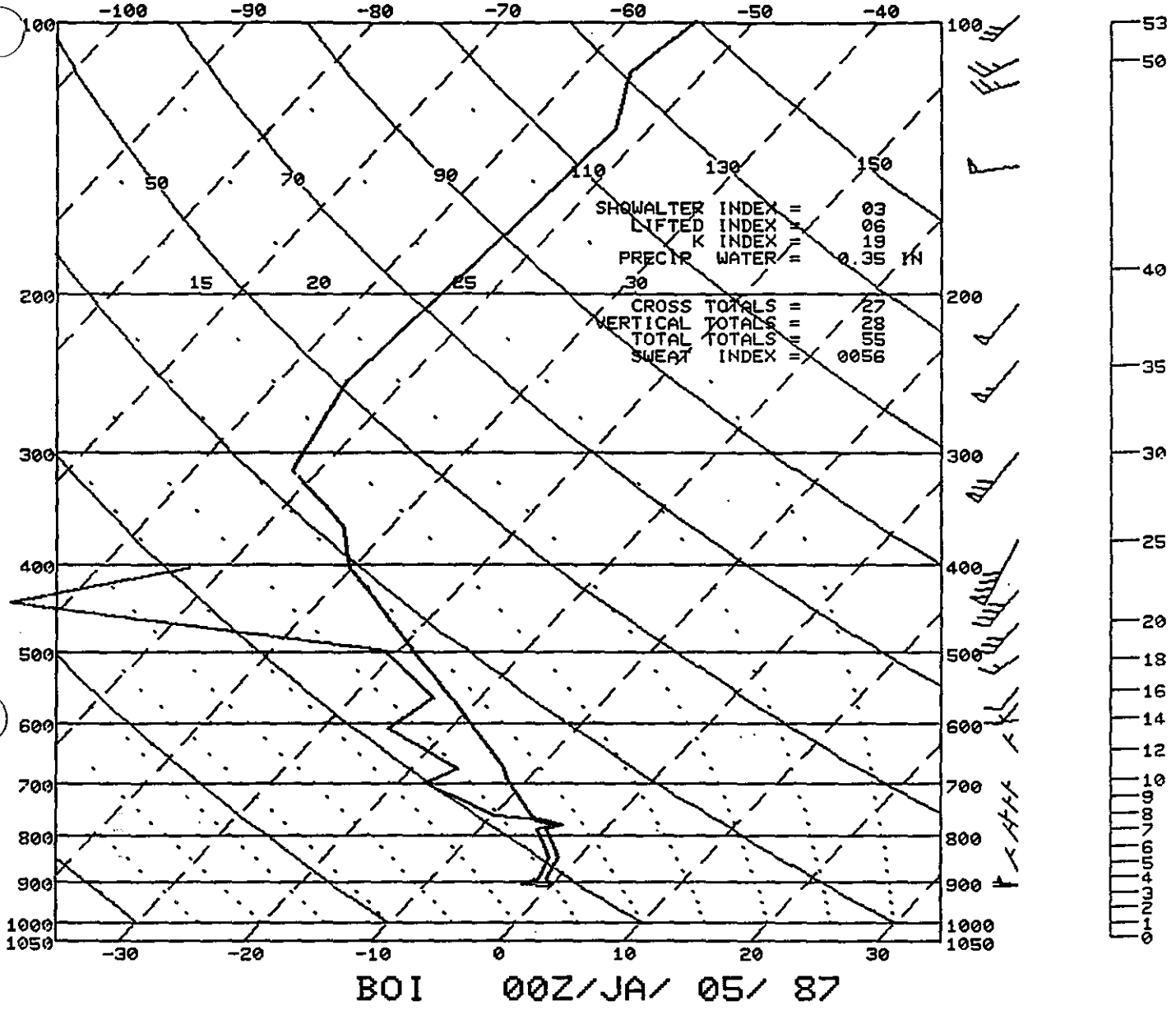

Fig. 19. RAOB from Boise at 00Z, January 5, 1987.

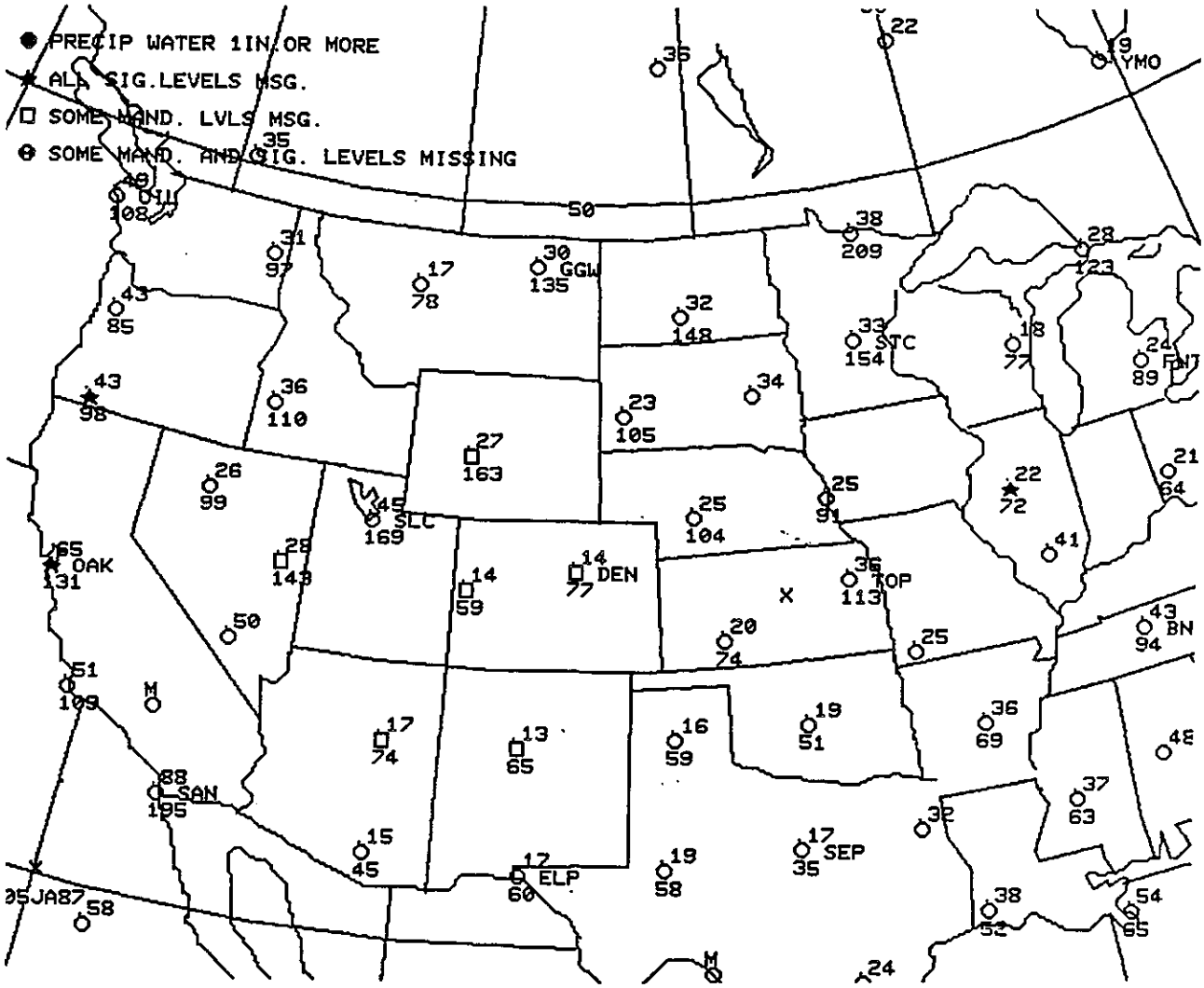

Fig. 20. Precipitable water (inches) for 00Z, January 5, 1987. Bottom number is percent of normal.

D. January 24-27, 1987

Snowfall amounts of greater than eight inches were observed over most of the area with the greater amounts in the Salt range, northern Wind River range and the northern Tetons. The greatest amount reported was 26 inches at Triple Peaks in the Salt range (see Fig. 21).

Refer to Figs. 22, 23 and 24 for analysis of the upper air data for 12Z January 25. At 300 mb, diffluent flow was indicated over northwest Wyoming with a 90 kt jet over Salt Lake City. At 500 mb at 00Z, a 40 kt westerly wind was over the area and heights were rising. A 500 mb ridge was extending from northern Utah with weak cold air advection into northwest Wyoming. At 700 mb westerly flow dominated the region. By 12Z on January 25 a 130 kt, 300 mb jet was over northwest Wyoming and a weak ridge was located along the West Coast. The flow aloft was from the west-northwest over Wyoming. At 500 mb the flow was 40 to 70 kts, while at 700 mb it was 40 to 50 kts.

A surface Pacific cold front moved through northwest Wyoming between 03Z and 06Z on January 25. The air mass stabilized from 00Z to 12Z on January 25, and temperatures cooled at 700 mb and warm at 500 mb.

Temperatures at 500 mb at 00Z were between -22C and -25C and at 12Z between -25C to -26C. At 700 mb, the temperatures were from -5C to -7C at 00Z and at 12Z were from -6C to -9C. The dew points were from -3C to -7C at 700 mb at 00Z and -10C to -18C at 12Z. The temperature-dew point spread was less than 10C.

E. Case Studies Summary

These case studies that have been discussed have several similarities. In most of the heavy snow events in northwest Wyoming were produced by a combination of a moist westerly flow orographic lift, and supporting dynamic lift produced by synoptic features. Please refer back to the upper air charts for this discussion.

As was mentioned earlier, direction and speed of the flow aloft is very important. If this flow is moist to at least 500 mb and saturated ascent is occurring then clouds and precipitation will form. For Wyoming, if the flow above 750 mb is from 230 to 250 over the Wind River range and the northwest to southeast part of the Absaroka range it will be perpendicular and produce strong orographic lift. If the flow above 750 mb is from 250 to 300, then the north to south oriented ranges will be the greatest affected.

The stronger the boundary layer wind perpendicular to the mountain range, the greater the orographic lift effect will be in producing precipitation. However, moisture needs to be widespread over the region to produce considerable snowfall. Precipitable water data shows an average of .3 to .5 inches of water upstream of northwest Wyoming. It appears that at 700 mb and

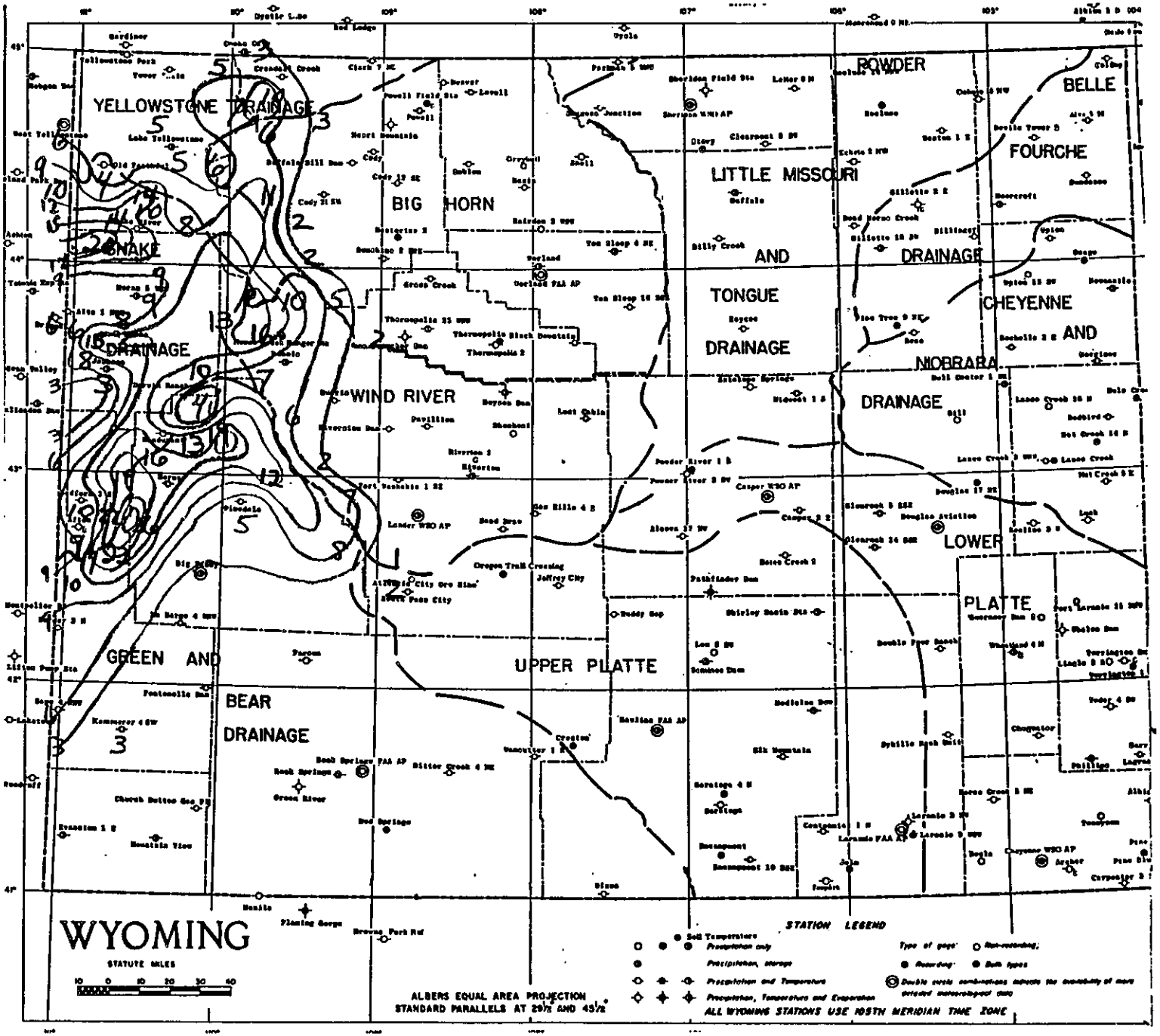

Fig. 21. Snowfall (inches) for January 24-26, 1987.

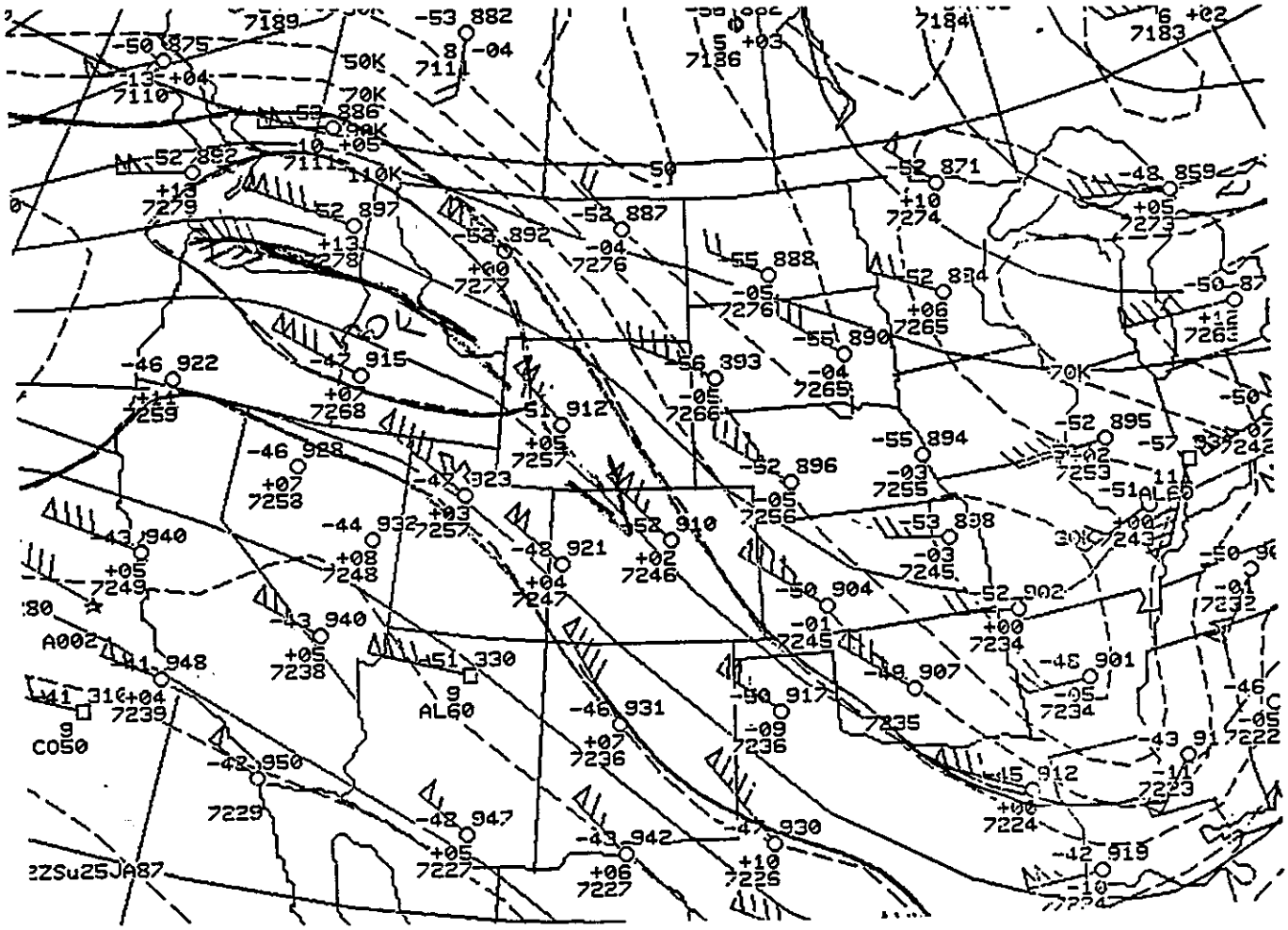

Fig. 22. 300 mb Chart for 12Z, January 25, 1987. Heights in decameters (solid lines), wind speeds in knots (dashed lines), wind barbs in knots.

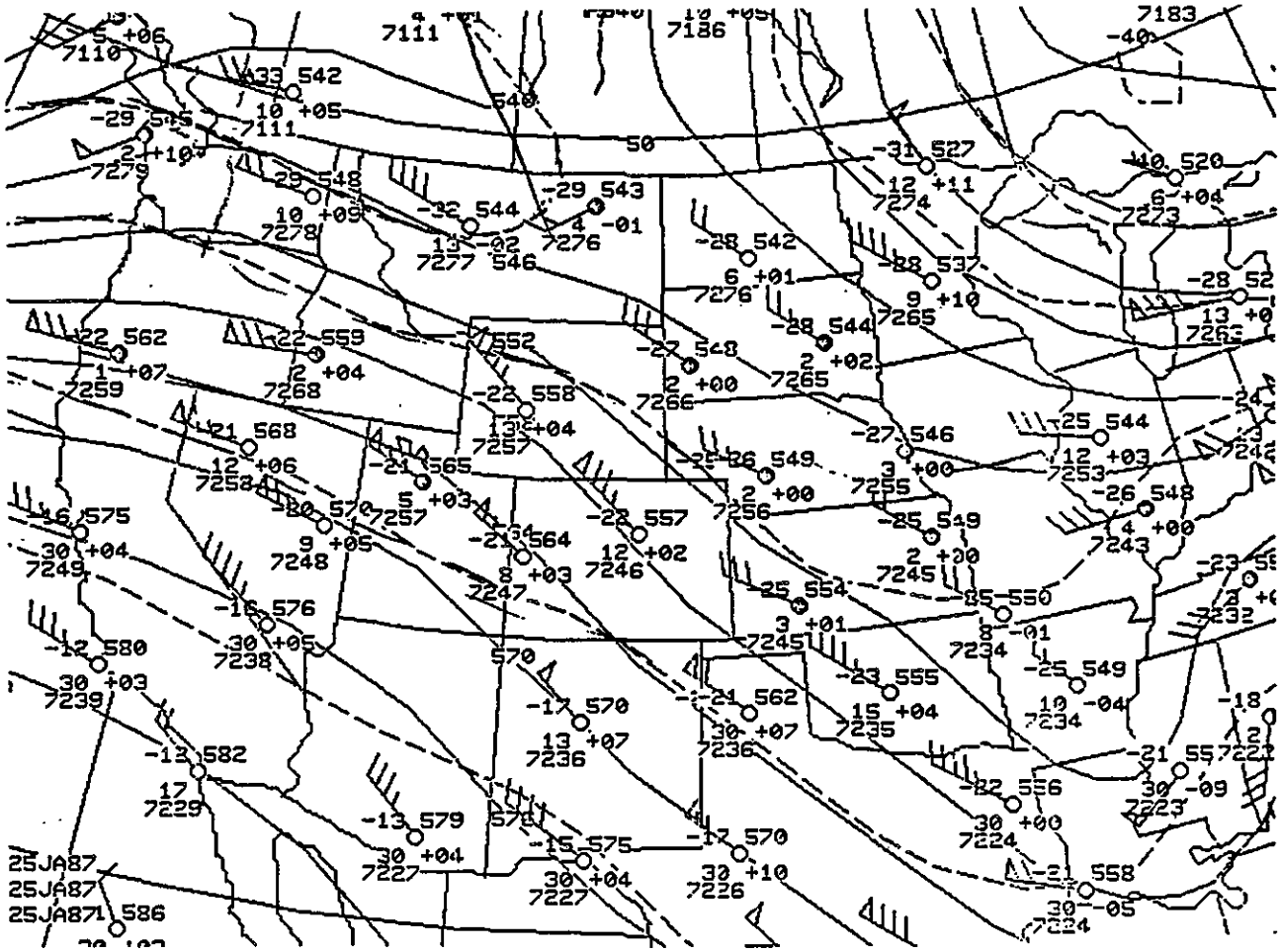

Fig. 23. 500 mb Chart for 12Z, January 25, 1987. Heights in decameters (solid lines), temperatures in degrees Celcius (dashed lines), wind barbs in knots. Solid circle indicates temperature dew point spread less than five degrees.

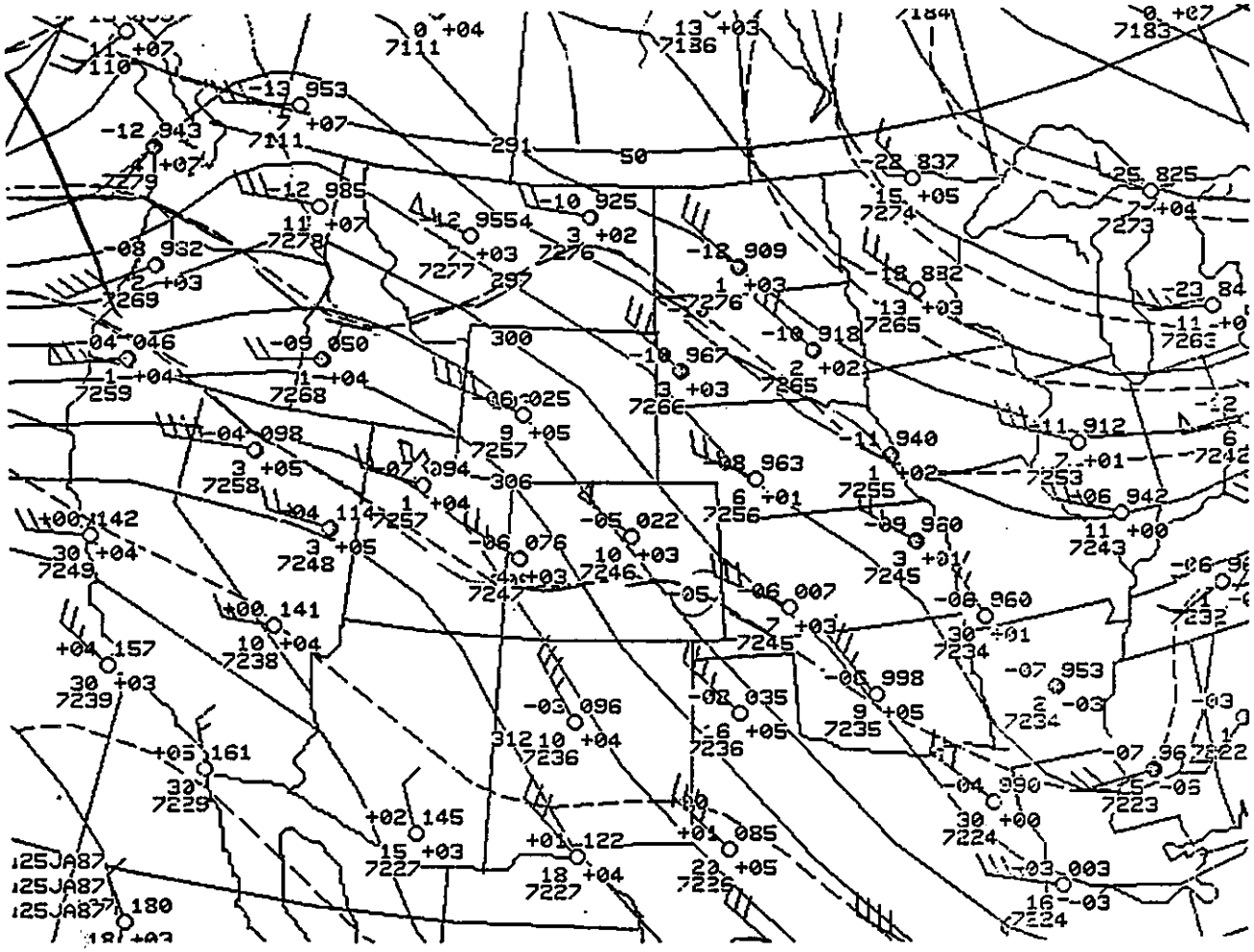

Fig. 24. 700 mb Chart for 12Z, January 25, 1987. Heights in decameters (solid lines), temperatures in degrees Celcius (dashed lines), wind barbs in knots. Solid circle indicates temperature dew point spread less than five degrees.

500 mb the temperature and dew point spread is in the 0 to 5C range. For two of the storms, FRH data showed over 90 percent relative humidity throughout the air mass.

Maximum vertical velocity in orographic lifting is at the mountain top levels. This is around 650 mb in northwest Wyoming. Most of the significant snowfall in northwest Wyoming is due to orographics, but with dynamics aloft involved as well. Auer (1) showed that at 700 mb temperatures need to be between -5 to -8C and at 500 mb -25 to -28C in a dynamic snowfall situation. This would appear to make the favorable temperatures at 700 mb -8 to -10C and at 500 mb from -28 to -30C. The examples from the 1986-1987 season showed us that the dynamic temperatures seem to fit fairly well. It is important to remember that this favorable temperature must be in an area of saturated vertical ascent. So at the temperatures mentioned the air must be saturated.

From the case studies, it appeared that the onset of heavy snowfall in northwest Wyoming started when proper boundary layer flow and correct temperatures aloft were coincident over the region. The heavier snowfall ended with trough passage or an end to the saturation of the air mass.

In summary, the things that appear to be needed to produce heavy snowfall in northwest Wyoming are:

(1) 700 mb temperature -6 to -8C

(2) 500 mb temperature -26 to -29C

(3) 30 kt or greater wind flow above 700 mb and perpendicular to range

(4) T-Td less than 10C

(5) Saturated ascent due to 300 mb jet or short wave trough.

Snowfall amounts from the storms are more difficult to determine. The longer the mentioned conditions effect the region, the heavier the snow. Forecasters can estimate probable heavy snow occurrences by considering wind, temperatures aloft, and available moisture.

FRH data for Pocatello, Idaho from the January 1-4, 1987 storm and the January 24-27, 1987 storm have been obtained from the LFM and the NGM and compared to actual snowfall. The NGM and LFM with both storms had relative humidity over 90 percent and both showed small amounts of precipitation. Actual precipitation from Pocatello on January 4-7, 1987 was .19 with 2.5 inches of snow, while on January 24-27 .04 precipitation fell with .4 inches of snow. Pocatello is at an elevation of 4,464 feet.

For the first storm the LFM showed about .25 to .35 precipitation with the NGM having .2 to .3. For the second storm, the LFM had between .1 and .2

and the NGM had between .15 and .4 (both were fairly close). With this precipitation forecast consistent for both storms and both models a fair correlation can be obtained for northwest Wyoming. Pocatello received .4 inches on January 24-27, 1987, with amounts in the north to south oriented ranges from 8 to 12 inches above 8,000 feet. On the January 4-7 storm, a southwesterly storm, the Wind River range picked up from 8 to 24 inches. The models forecast precipitation at Pocatello better in the southwest track storm. On January 4-6, 1987 Pocatello had 2.5 inches of snow and this works out to an average of 3.2 to six times the Pocatello snowfall forecast. The annual snowfall at Pocatello is 43 inches and this works out to the northwest Wyoming mountains receiving normally 4.6 times as much snow as Pocatello.

In summary, by analyzing the synoptic features around northwest Wyoming with particular attention to the temperatures aloft and the wind direction and speed, a better forecast of snowfall for northwest Wyoming can be made. My hope for this paper was to show the patterns and climatology of heavy snowfall in the northwest part of Wyoming and to show that it is significant. Close attention should be made to the area in the winter. This snowfall affects water resources, travelers and fire possibilities for the upcoming season.

6. References

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