Western Region Technical Attachment
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AUGUST 1992 MONTANA SNOWSTORM

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An unprecedented weather event occurred in north-central and southwestern Montana in August 1992. An early season arctic surface airmass moved southward along the Continental Divide, resulting in record cold temperatures throughout Montana for nearly a week. Even more impressive was the ability of this air mass to push southward under moist southwesterly flow aloft, a typical snow producer for north-central and southwestern portions of Montana, but not in August. Over 8 inches of snow fell at Great Falls during this storm, making it a significant event considering no snow had ever been measured in August at Great Falls in 100 years of record keeping.

The combination of the performance of the numerical models in this developing situation and that it was mid-August provided a challenging forecast. The numerical models exhibited biases in placing the developing surface low pressure system too far north into the cold air. Also, the models were unable to distinguish the arctic airmass from the northern Pacific high pressure system (northern Pacific referring to the source region as being the northern Pacific, which is classified as maritime polar). Even though a cool, wet trend had been correctly forecast 3 to 5 days in advance, snow was not forecast for the plains of Montana until 24 hours before it fell.

Storm Overview

Extended model runs early in the week had indicated a strong trough moving into the Pacific Northwest by 21 August 1992. On 20 August, forecasts were for cool weather and showers, with snow for elevations above 6500 feet. This forecast changed the afternoon of 21 August, when surface reports from central Alberta indicated an arctic front, not depicted in the models, was moving southward. In fact, the Limited Fine Mesh (LFM) Model Output Statistics (MOS) forecast a high of 67°F for Great Falls on 22 August, while the actual high that day was 38°F! (The previous minimum maximum for the date was 52°F). By looking at the progression of systems through the area, the evolution of this event may be understood.

Synoptic Situation

Around 0000 UTC 20 August 1992 (20/00Z), a strong cold front moved into the northwest section of Montana east of the Continental Divide (Fig. 1). The cold high pressure system behind this front over western Alberta, had originated over the Gulf of Alaska, classifying this front as a northern Pacific cold front. At the same time, moist southwesterly flow aloft developed over Montana in advance of a deep trough and associated pool of cold air aloft.

By 21/12Z, surface pressures were falling across Montana in response to the upper-level trough moving closer to Montana (Fig. 2). At the surface, another cold front in northern Alberta began moving southward as indicated by mild pressure rises and northerly winds at Whitecourt and Edson (Fig. 3). The approaching upper-level trough allowed cyclogenesis to begin over east central Idaho between 21/12Z and 22/00Z along the old northern Pacific frontal boundary. The surface low pressure over this region developed upslope pressure gradients which aided in reinforcing the southward push of arctic air over Montana. By 22/00Z (Fig. 4), the front had passed through Cut Bank, dropping the temperature from the mid-60s°F to the mid-40s°F in just two hours. By the morning of 22 August, 2 inches of snow were reported at Cut Bank and Browning, with even heavier amounts in Glacier National Park. The cold air had reached southwest Montana and the distinctive surface high pressure wedge had set up against the Rocky Mountains (Fig. 5).

During Saturday evening (23/00Z), the main area of upper-level dynamics associated with the trough (Fig. 6) was over southwest Montana with a strong jet maximum in the flow at 300 mb (Fig. 7). As this shortwave rotated through the long-wave trough into the northern portions of southwest Montana, thunder snow showers developed over the Helena area, causing rapid accumulations (4 inches in a little over 2 hours). Snow had developed in the Great Falls area near 23/06Z and became heavy by 23/12Z (Fig. 8), with 8.3 inches of snow (0.92 inches of precipitation) received at Great Falls by early afternoon.

By 24/00Z, most significant precipitation across Montana had already fallen as the favorable upper-level dynamics moved eastward. However, the unseasonably cool airmass remained over Montana for the next 5 days, as record low temperatures occurred across the state (Table 1). The previous all-time record low for August was set in 1910, which had many similar characteristics to this arctic air outbreak.

Historical Analogies

Historical precedents are helpful in studying this storm and associated cold weather outbreak. In Great Falls, only August 1910 has had an outbreak of record low temperatures like 1992. Because of the lack of August snow events, this event is also compared to the most recent late summer heavy snow event in central Montana (September 1988) due to seasonal and atmospheric proximity to August climatologically.

August 1910 correlates with August 1992 because the surface high pressure that came southward was from the north Pacific, as opposed to the Arctic. However, in both cases a sharp blocking ridge of high pressure aloft forced cold air from Alaska. Low surface pressures developed over Idaho, along the old northern Pacific frontal boundary, in both cases. Despite the similarities, the 1910 cold air outbreak was not as extreme as the 1992 event and did not produce as much snow. Also, the record cold temperatures in 1910 were aided by a lack of vegetation and low dewpoint temperatures as a result of massive forest fires during the summer. (With little or no vegetation, less moisture was present in the local atmosphere due to the decrease in evapotranspiration, aiding in low dewpoint temperatures.)

High pressure moving southward along the east slopes of the Rocky Mountains is a common weather producing feature for north-central Montana due to the upslope conditions. In this respect, the August 1992 storm actually compared well with September cold air outbreaks. However, looking at September snowfall records in Great Falls, August 1992 exceeds all Septembers except for 1934, 1984, and 1988.

For example, in September 1988, the northern Pacific high pressure system was already in place before the arctic air moved into the region (Fig. 9). Like the August 1910 event, the September 1988 event saw surface low pressure develop over southeastern Idaho along the old northern Pacific frontal boundary (Fig. 10). In the three cases (August 1992, August 1910, and September 1988), an arctic cold front moved into Montana soon after a northern Pacific cold front had passed through the area.

Numerical Model Performance and Bias

Analysis of the Nested Grid Model (NGM), LFM, and Aviation model (AVN) revealed that each model had problems in the placement and strength of the central pressure of both the high and low pressure systems, as well as the 500 mb low. Comparison of these three models, over the time period 1200 UTC 21 August to 1200 UTC 23 August, determined the model with the least bias and error.

The area of low pressure was consistently too far north and too deep (Table 2) by all three models, which has been a NGM bias. Among the three models, the AVN model generally provided a closer placement and strength compared to the observed, especially over the NGM (Tables 2 and 3).

The identity of the surface high pressure was also handled poorly. The NGM model indicated the source region of the high pressure as the north Pacific, but the 36 hour forecast of the 22/12Z NGM run began to show two distinct areas of high pressure: one associated with an arctic airmass over Canada and the other well off the Pacific coast. Although the NGM had difficulty in identifying this high pressure source region, the 1000-500 mb thickness pattern showed cold air filtering south from Canada. The surface high pressure wedge along the lee of the Rockies, almost absent from the NGM, was handled considerably better by the LFM and AVN, with the most pronounced wedging in the AVN model. The identity of the high pressure was clearly defined by the AVN for the period of the storm, August 20-24, with the origins of the high pressure area nearly to the North Pole.

A similar problem existed at 500 mb. The forecast strength and location of the 500 mb low showed variance from the observed (Table 4). Although the NGM showed considerable error in placement, the 12 and 24 hour forecasts were generally more accurate. The 36 and 48 hour forecasts deteriorated drastically until half way through the period of the storm, when the model apparently become closer to the observed. Again, the LFM and AVN proved to be more accurate in placement, with the LFM slightly better. However, throughout the model runs, the LFM suggested a cold bias, whereas the NGM and AVN showed a slight warm bias. The height lines of the AVN model tended to be quite accurate but, in some instances, showed a cold bias.

Conclusions

The staff at WSFO Great Falls handled this storm well considering it was an unprecedented event. The synoptic situation brought cool wet weather to Montana, with record snowfall amounts and low temperatures for August. Forecaster focus was placed on severe weather in strong southwesterly flow aloft, not snow. Had it been mid-September, this storm would have been a 1 in 10 year event, instead of an all-time record storm.

This storm was typical of spring and fall snow storms for north-central Montana for two reasons: 1) A warm southwesterly flow aloft overran an arctic airmass; and 2) NGM model biases carried the surface low pressure system too far west and north of the observed position. Model performance varied, but the AVN generally was better than the NGM and LFM. The AVN's placement and strength were better at both the surface and 500 mb while placing the surface low too far northwest in the cold air. The identity of the high pressure source region in the AVN was better than the other models.

The source region of the high pressure was an important forecast tool and difficult to identify in this storm. In a similar case, when a northern Pacific high pressure is present, identification of a possible arctic high moving in behind may be a valuable advance clue. Historical comparisons show that one indication an arctic airmass may possibly move into the region is the development of low surface pressures over the Great Basin. In addition, a short-wave trough rotating southeastward through the long-wave pattern can help to reinforce the push of arctic air southward, eventually replacing the north Pacific high.

Despite the fact that many stations in Montana recorded the first measurable August snowfall, it was the record cold temperatures that were the most outstanding features. For example, only twice in 100 years of record keeping at Great Falls had the temperature dropped to 34°F in August. In an eight day span in August 1992, the temperature reached or fell below 34°F five times. Many crops were damaged or destroyed by the storm in the shortest growing season ever in Great Falls. Also affected was tourism at Glacier Park, where travelers were forced from the back country due to the snow. The growing and recreation seasons in Montana are typically short, but snowfall occurring a month earlier than expected makes this a memorable storm.

Table 1 Summary of Records

I. Record Low Temperatures (Montana WSFOs/WSOs only)

Date	City	Old Record/Year		New Record
21	Great Falls	40/1966		38
22	Billings	40/(unknown)	tied	40 (all time August low)***
	Great Falls	40/1927		32 (all time August low)
	Havre	38/1883		35
	Helena	38/1933		33
	Kalispell	36/1963		35 *
23	Billings	42/1934		39 (all time August low)
	Butte	32/1943		30
	Great Falls	40/1893		32
	Havre	36/1928		35
	Helena	37/1910		33
	Missoula	37/1962	tied	37 **
24	Billings	44/1934		36 (all time August low)
	Butte	31/1910	tied	31
	Great Falls	34/1910		30 (all time august low)
	Helena	33/1910	tied	33
	Kalispell	34/1910		33
25	Billings			35 (all time August low)
	Butte	27/1910		23 (all time August low)
	Great Falls	35/1910		31
	Helena	29/1910		28 (all time August low)
26	Billings			40
	Butte	31/1960		26
	Helena	37/1960		35
29	Billings			44
	Great Falls	38/1927		34
30	Billings			42
	Glasgow	38/1935	tied	38 (also in 1925)

* Kalispell set a record high of 96°F on the 14th.

** On the 25th, the low in Missoula was 30°F, 1°F from the all time monthly low of 29°F set in 1910. Also a record high of 100°F was set on the 14th.

*** Billings set a record high of 98°F on the 19th

II. Monthly Snowfall Records for August

Anaconda	4.0 inches	old record 2.5 inches in 1939
Great Falls	8.3 inches	
Havre	trace	
Helena	6.2 inches	

Table 2 Surface Low

Model	Distance (nautical miles)	Direction	Difference (Millibars)
LFM	240		-1
NGM	225	NW	-4
AVN	186	NW	-2

Table 3 Surface High

Model	Distance (nautical miles)	Direction	Difference (Millibars)
LFM	120	NW/SW	3
NGM	172	NW	-1
AVN	192	NW	0

Table 4 500 mb Low

Model	Distance (nautical miles)	Direction	Difference (Meters)
LFM	116	NW	-20
NGM	259	SW	10
AVN	176	SW	10

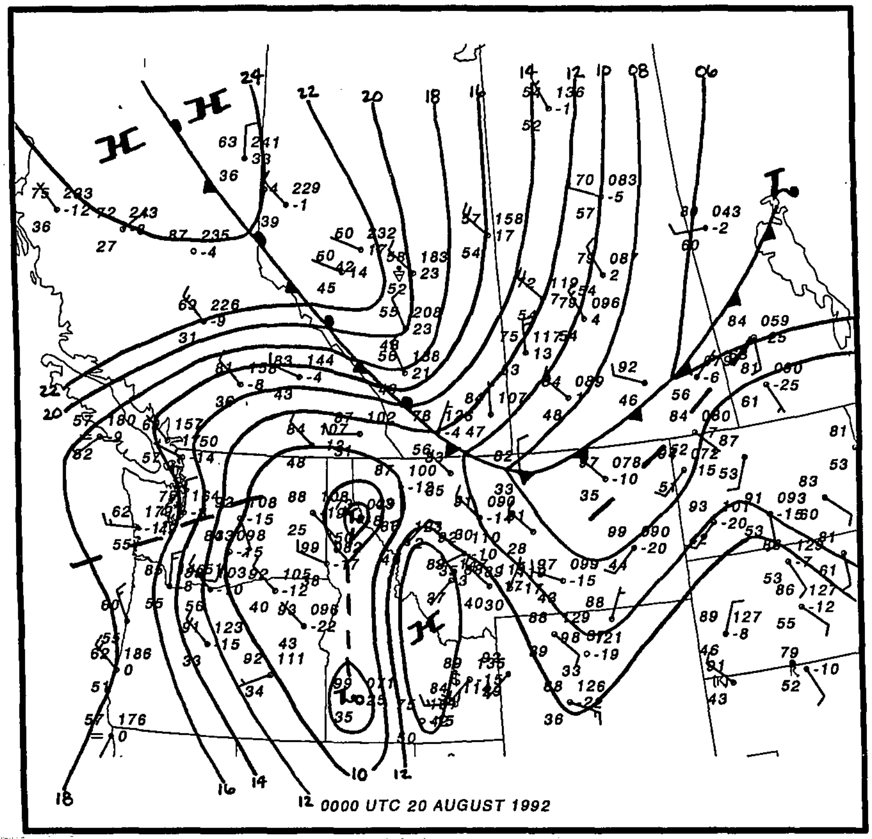

Fig. 1

Surface map at 0000 UTC 20 August 1992. Isobars contoured every 2 mb.

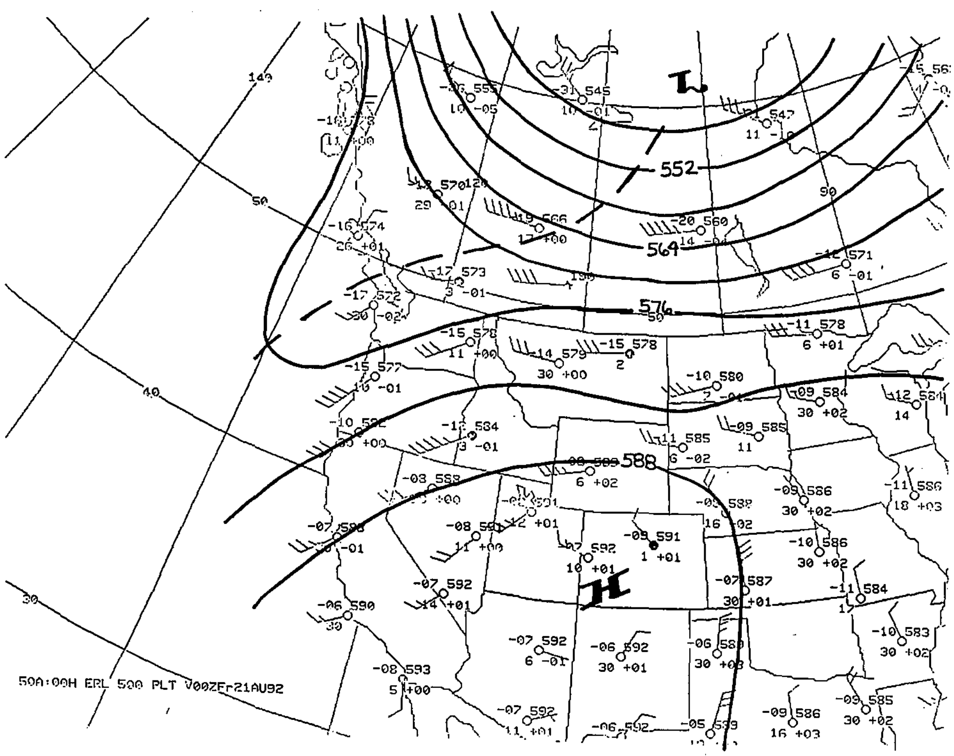

Fig. 2

500 mb chart at 0000 UTC 21 August 1992. Heights contoured every 6 dam.

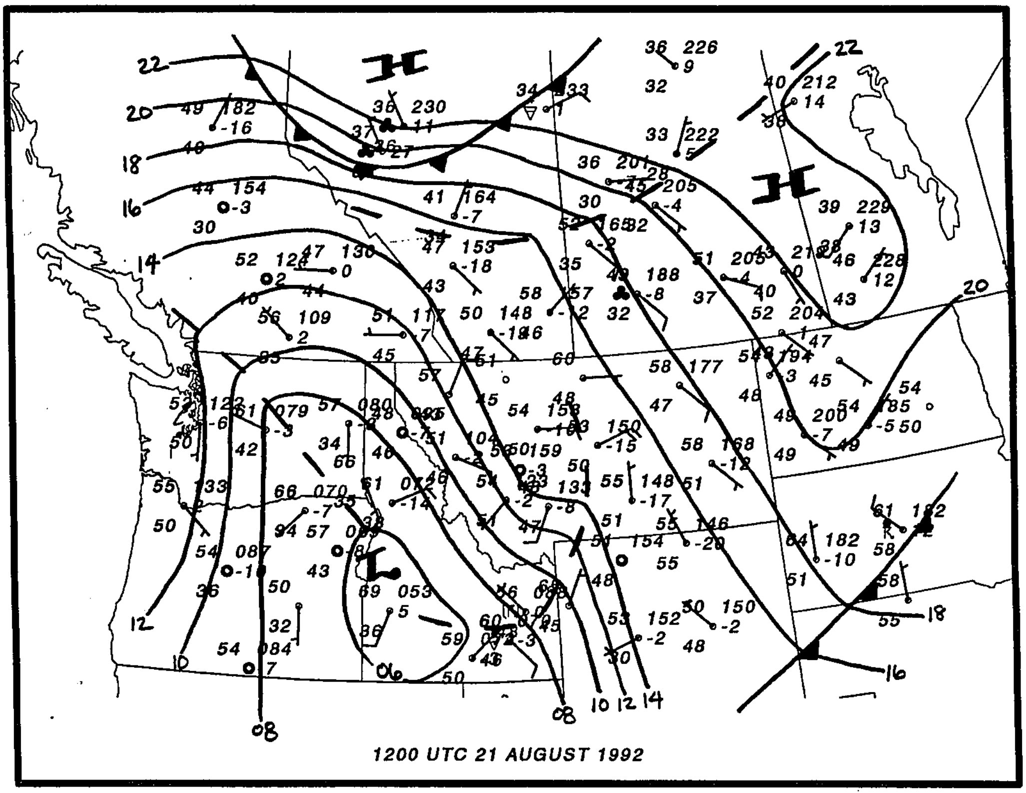

Fig. 3

Surface map at 1200 UTC 21 August 1992. Isobars contoured every 2 mb.

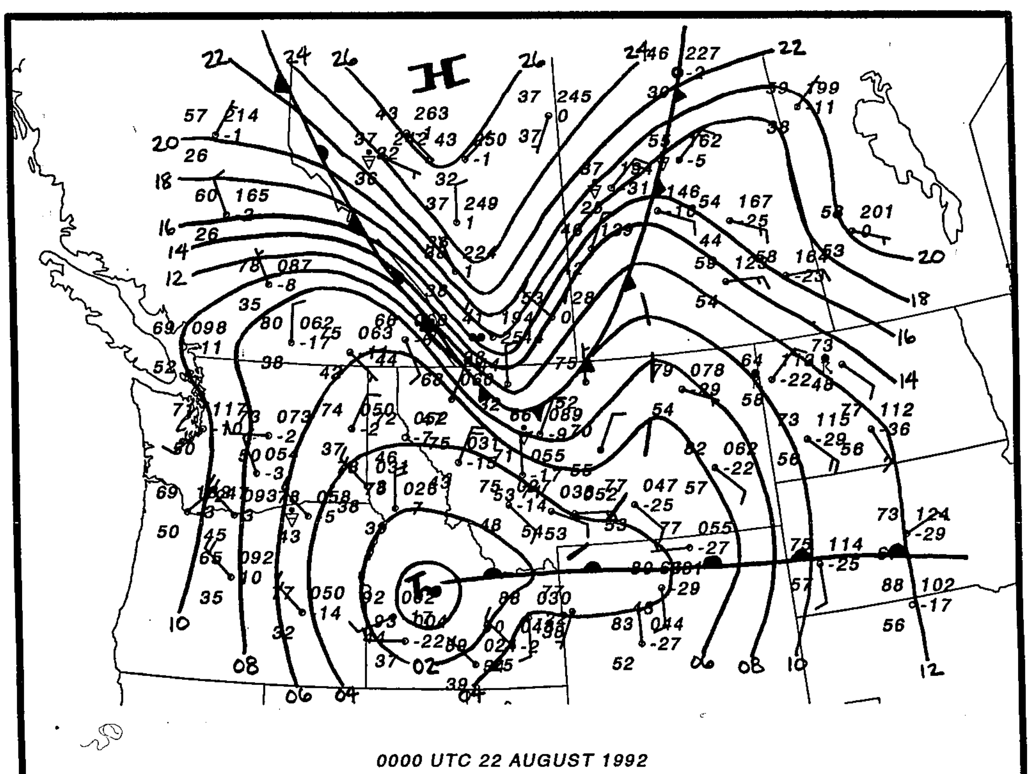

Fig. 4

Surface map at 0000 UTC 22 August 1992. Isobars contoured every 2 mb.

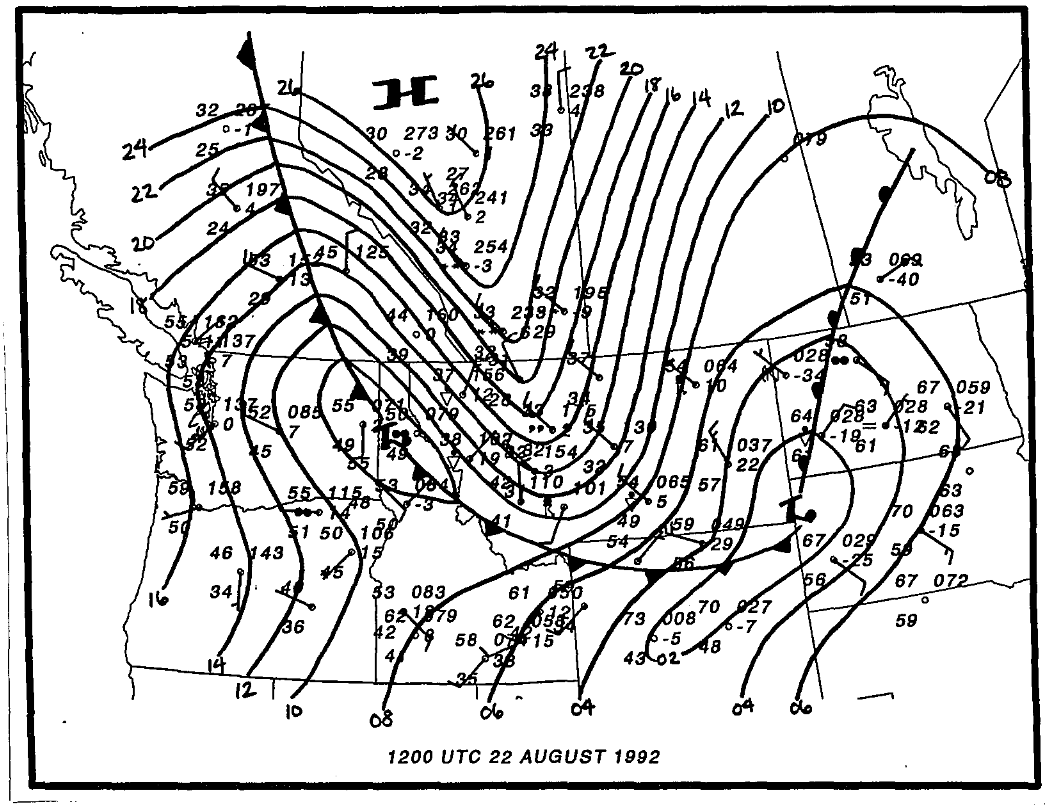

Fig. 5

Surface map at 1200 UTC 22 August 1992. Isobars contoured every 2 mb.

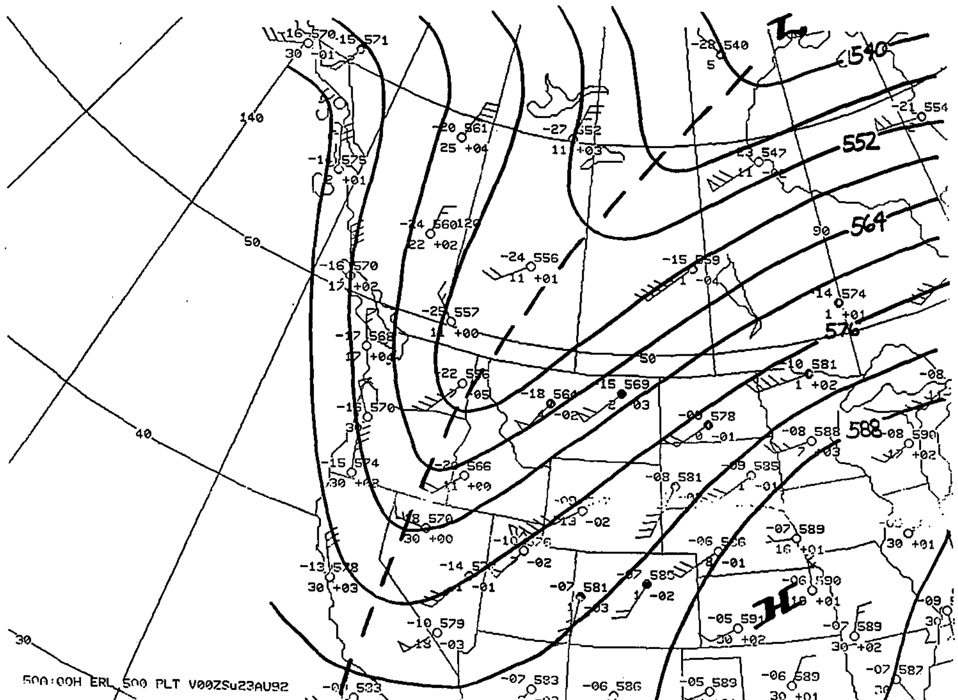

Fig. 6

500 mb chart at 0000 UTC 23 August 1992. Heights contoured every 6 dam.

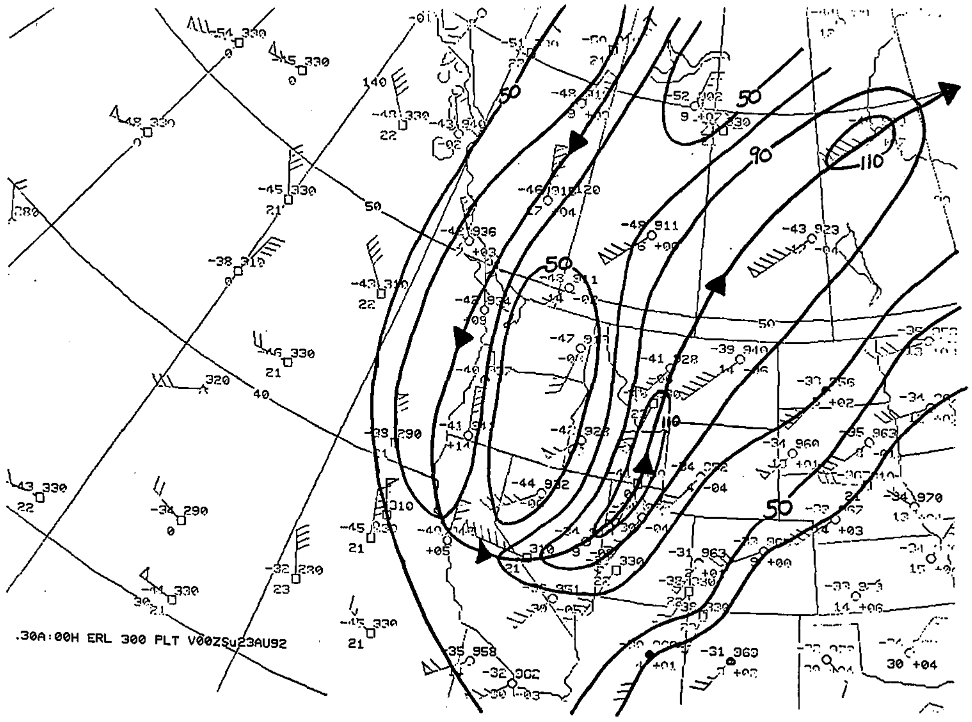

Fig. 7

300 mb chart at 0000 UTC 23 August 1992. Isotachs contoured every 20 knots.

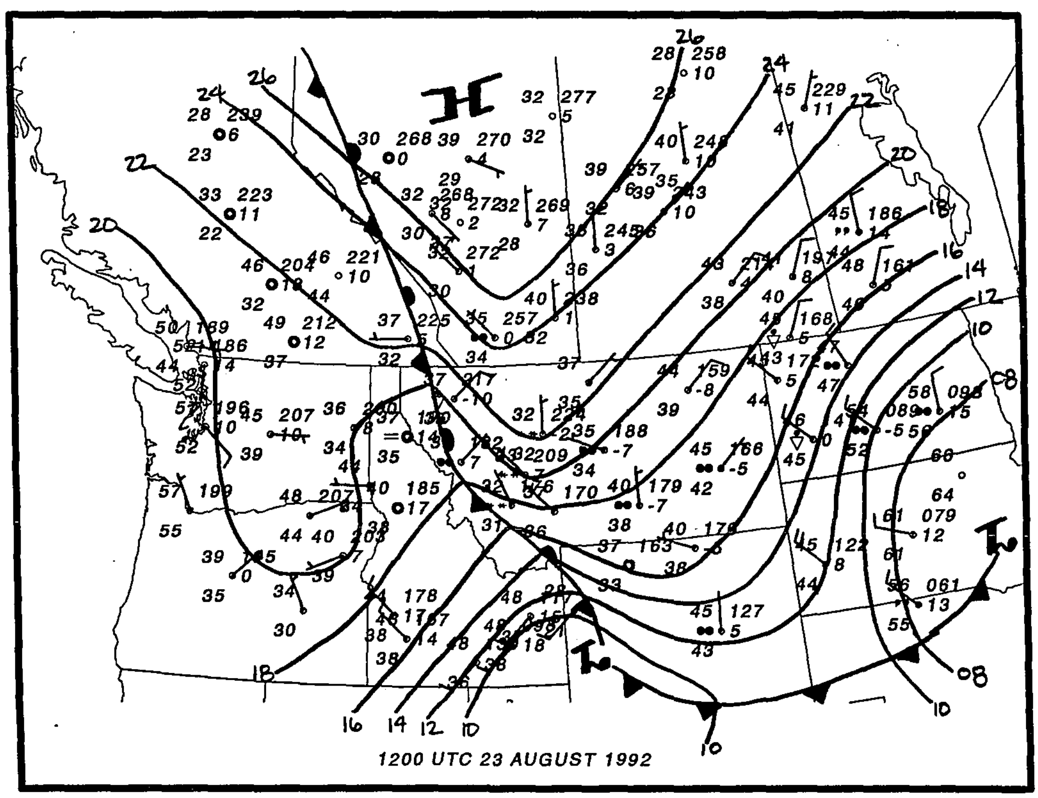

Fig. 8

Surface map at 1200 UTC 23 August 1992. Isobars contoured every 2 mb.

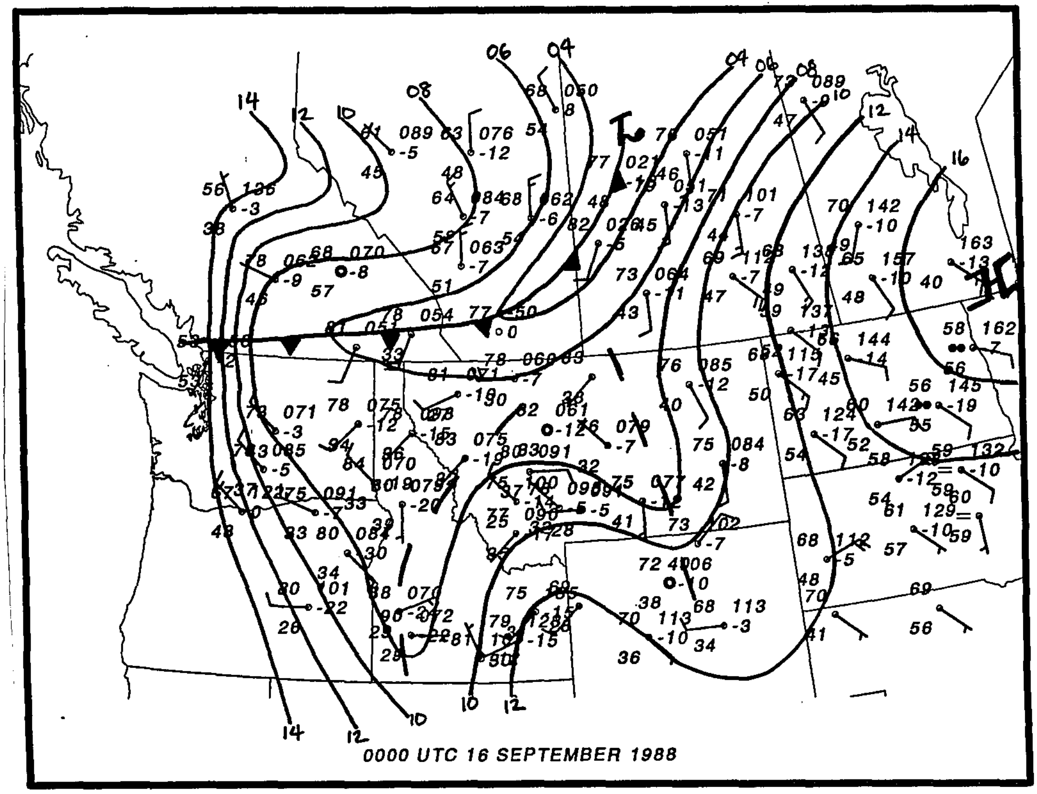

Fig. 9

Surface map at 0000 UTC 16 September 1988. Isobars contoured every 2 mb.

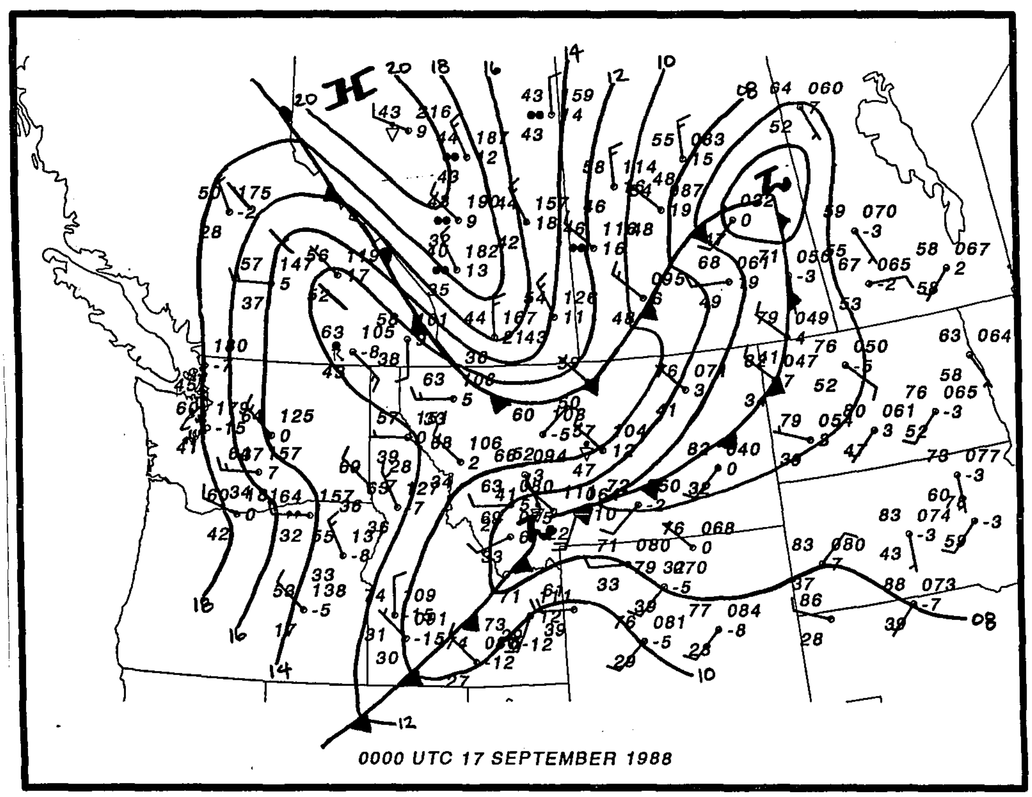

Fig. 10

Surface map at 0000 UTC 17 September 1988. Isobars contoured every 2 mb.