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FREEZING RAIN EVENT ACROSS EASTERN WASHINGTON AND NORTHERN IDAHO ON 9-11 DECEMBER 1995

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Abstract

Freezing rain is not an uncommon event in the Columbia River Basin of eastern Washington and northern Idaho. The topography of this region is ideal for trapping cold low-level air while warmer air from the Pacific Ocean overruns it. Typically, freezing precipitation is brief in duration and is observed during the transition from snow to rain. However, the freezing rain event of 9-11 December 1995 was notable because of its duration. Some locations in this area received intermittent freezing precipitation for more than two days.

This study provides a synoptic overview of the event and investigates the operational numerical model performance. In general, it was found that the AVN and NGM models did not possess the necessary resolution to predict this event. The Eta and Meso-Eta models did much better at correctly holding the cold air in place at low levels and, thus, successfully predicting freezing rain. It was also found that while previous techniques for forecasting precipitation type often focused on temperatures at mandatory pressure levels or geopotential thicknesses between pressure levels, today's numerical models do possess sufficient skill and resolution to explicitly forecast freezing precipitation. Model derived vertical soundings proved to be very effective for determining forecast precipitation type.

Introduction

A significant freezing rain event occurred across eastern Washington and northern Idaho during the period of 9-11 December 1995. Computer models and forecasts suggested a possibility of freezing rain, but the areal and temporal extent was far more widespread than anticipated. Several NWS watches/warnings/advisories alerted the public of an impending weather system bringing snow, but understated the possibility of freezing rain. Hence, the public anticipated significant snow in the warning/advisory areas, but may not have been prepared for the extensive freezing rain.

This event was particularly notable because of its duration. Freezing rain is not uncommon in this region, with Spokane averaging about 12 hours of freezing rain per year. Cold air is easily trapped in the Columbia River Basin (Fig. 1) allowing warm, moist Pacific air to overrun it. However, typically freezing rain is observed for an hour or two as the transition from snow to rain occurs. In this event, however, intermittent freezing rain was reported for 24 hours at Spokane. Some locations in eastern Washington received freezing precipitation for more than two days.

Guidance from computer models did a reasonable job in handling trends in the weather pattern; however, they performed poorly with respect to the boundary layer and the depth of a strong inversion. The NGM and AVN models gave the least accurate results. It is suspected that this is largely due to the poor resolution of topography in these models. The Eta and Meso-Eta models, with better topographical resolution, produced the best forecast with regards to freezing rain.

Synopsis

On 7 December 1995, a modified arctic cold front swept across eastern Washington and northern Idaho leaving below freezing surface temperatures in its wake. The upper-air pattern was in a state of transition as a low pressure trough was forming off the West Coast. At 500 mb, the flow was backing from northwesterly to westerly at the beginning of the freezing rain event. Southwest flow at 700 mb allowed for increasing moisture to spread across the Pacific Northwest. During the period, surface low pressure remained offshore, creating an easterly gradient at low levels; this kept cold air trapped in the Columbia River Basin and mountain valleys of north central Washington. The warm air advection at midlevels intensified the surface based inversion with surface temperatures in the teens and 20s on the morning of 9 December. The 1200 UTC 9 December 700 mb analysis showed an overrunning pattern setting up with strong warm air advection over Washington (Fig. 2). The ridge axis just off the Pacific Northwest coast was progressing eastward. The upper- air sounding at Spokane for 1200 UTC 9 December (Fig. 3) showed the deep layer of cold air extending from the surface to above 700 mb.

The first of two upper-level short wave troughs moved onshore during the evening of the 8th. Freezing rain was first observed in the Columbia River Gorge at Portland and The Dalles. Light snow spread into the Columbia River Basin of Oregon and Washington overnight. Snow began to fall in the Spokane area by 1800 UTC with a 2-inch accumulation by late afternoon. The warm air advection from this system eroded the cold air dome from aloft. The 1200 UTC 10 December sounding depicted moist warm air overrunning a cold surface (Fig. 4). The depth of the cold air had decreased to nearly 800 mb. As this process continued, the air aloft eventually warmed to above freezing. Snow changed to light freezing rain in Pendleton by 1800 UTC, in Walla Walla by 2100 UTC, and in the Spokane area around 0700 UTC as surface temperatures remained in the mid-teens and lower 20s.

After the warm front passed to the north of the area, the associated cold front remained to the west of the Cascade Mountains. Occasional light freezing rain continued in the area through the night and into 10 December. Along the Oregon coast, a secondary wave developed along the front, setting up a second warm advection overrunning pattern. The 0000 UTC 11 December sounding (Fig.5) showed the presence of an above freezing layer of air at low levels while surface temperatures remained well below freezing. Precipitation increased on Sunday evening with total of 0.29 inches of freezing rain falling at Spokane between 0300 UTC and 0600 UTC. As the second warm front moved through, surface temperatures finally warmed to above freezing around midnight, bringing an end to the freezing rain in the Spokane area. However, sections along the east slopes of the Cascades and the Columbia River Basin still did not mix out. These areas continued to observe intermittent freezing precipitation until Tuesday as additional disturbances continued to move across the area in the southwesterly flow.

Operational Model Analysis

Model data showed good run-to-run continuity during the freezing rain event. All models were similar in their depiction of the synoptic scale events. Additionally, the timing and precipitation amounts from all models were generally in agreement. As previously mentioned, the resulting NWS forecasts called for heavy snow with appropriate warnings/advisories. The main difference between the models was how each model forecast boundary layer temperatures. The 1200 UTC 9 December model runs were examined in detail.

a. NGM - 1200 UTC 9 December Model Run

The 1200 UTC 9 December NGM showed warm air advection and overrunning precipitation beginning to move into eastern Washington. Upper-level dynamics were still offshore with the 500 mb ridge axis just off the Pacific Northwest coast. A northwesterly 300 mb jet was diving into the upper Midwest, but the best jet dynamics stayed in Alberta with minimal upward vertical velocities in eastern Washington.

The 850 mb temperature forecast showed cooler air retreating northward with the 0° C isotherm north of Spokane by 0600 UTC 10 December, and out of northeast Washington and the Idaho Panhandle by 0000 UTC 11 December (Fig. 6). This implied that frozen or freezing precipitation would change to rain with the leading short wave. The time-height cross section for Spokane showed the air mass mixing out when the 90% RH would be moving in (Fig. 7). The NGM forecast position of the 850 mb warm front across southern British Columbia by 36 hours (0000 UTC 11 December) was accurate, but it failed to keep the low- level subfreezing air in eastern Washington. Thus, the NGM model forecast snow during the day on Saturday, changing to rain during Saturday evening, and continued rain for the remainder of the event.

b. AVN - 1200 UTC 9 December Model Run

The initial analysis was comparable with the NGM, with overrunning precipitation beginning to move into eastern Washington. The model forecast the 850 mb warm front to be north of Spokane by 0600 UTC 10 December, and out of Washington and the Idaho Panhandle by 0000 UTC 11 December (Fig. 8). Like the NGM, the leading short wave would push cold air into Canada, with frozen and freezing precipitation changing to rain across the area. This implied that the second short wave would only produce rain across the area. Even though the gridded data for the AVN model did not go below 850 mb, the time-height cross section did show temperatures at that level staying above freezing after 0000 UTC 10 December (Fig. 9). The main difference between the AVN and NGM models was the timing of the short waves, with the NGM model being the faster model. But these differences were inconsequential to the forecast of precipitation type.

c. Eta -1200 UTC 9 December Model Run

Like the NGM and AVN models, the Eta model showed warm air advection and overrunning precipitation moving into eastern Washington on 9 December. The forecast indicated there would be two short waves moving across the region, the first at 0000 UTC 10 December and the second 0900 UTC 11 December. The forecasted movement of the 850 mb warm front was similar to the other models, located over Spokane at 0600 UTC 10 December and progressing into Canada by 0000 UTC 11 December. However, one big difference between the Eta model and the other model solutions was that a pocket of cold air was being left behind over northeast Washington at 0000 UTC 11 December (Fig.10). The NGM and AVN models showed 850 mb temperatures mixing to above freezing across the region (Fig. 6 and 8, respectively). Even by 1200 UTC 11 December, the Eta model clearly showed a portion of northeast Washington below freezing at 850 mb. Obviously, this has implications when forecasting precipitation type. The time-height cross section showed surface temperatures remaining below freezing until 0000 UTC 11 December (Fig. 11), about 21 hours later than either the NGM or AVN model. The Eta model time-height field also showed above freezing air advecting just above the 850 mb level by 1200 UTC 10 December, implying the precipitation threat would be freezing rain between 1200 UTC 10 December and 0000 UTC 11 December.

The 1200 UTC 9 December Eta model run was correct in holding the colder air mass in the Columbia River Basin longer than the NGM and AVN models. However, freezing rain was observed in the vicinity of Spokane by 0600 UTC 10 December, sooner than any model suggested. With its finer topographical resolution, the Eta model performed better than the NGM and AVN models with regard to boundary layer temperatures.

d. Meso-Eta - 1500 UTC 9 December Model Run

The first short wave with high 700 mb relative humidity was forecast to move into the Spokane region at 2100 UTC 9 December, followed by drier air advecting from the southwest at 0900 UTC 10 December. The 850 mb temperatures showed a below freezing air mass across eastern Washington and beginning to retreat at 0600 UTC 10 December with slow moderation. The Meso-Eta model time-height at Spokane denoted freezing rain by 0500 UTC 10 December, and kept Spokane below freezing until 2100 UTC 10 December (Fig. 12). By 33 hours (0000 UTC 11 December), the model output clearly showed there would be cold pools (i.e., less than 0°C) along the north central and portions of the northeast eastern slopes of the Cascades (Fig. 13).

A comparison of Figs. 10 and 13 shows that minor differences occurred between the Eta and Meso-Eta models 850 mb temperature forecasts. Forecast vertical soundings for the Eta and Meso-Eta models valid at 0000 UTC 11 December are shown in Figs. 14 and 15, respectively. Although the Meso-Eta model has an even higher grid resolution than the Eta model, thus possessing a better depiction of the topography, the Eta model actually performed a little better with cooler surface temperatures. In addition to the difference in resolution, the Eta and Meso-Eta models also had differences in physics at this time. The Meso-Eta model allowed for variability of surface land types and soil moisture, while the Eta model made no allowance for this variability. Additionally, the Meso-Eta model was using the higher Mellor-Yamada 2.5 turbulence closure scheme whereas the Eta model was still using version 2.0. It is difficult to pinpoint the exact cause of the differences between the two forecasts. Since this time, however, the Eta model has incorporated all of the improvements in the Meso-Eta model.

Later Model Runs

Model forecasts following the 1200 UTC 9 December runs showed no major changes from previous forecast ideas. The 0000 UTC and 1200 UTC 10 December NGM and AVN models indicated that the 850 mb 0° C isotherm would move north of the Canadian border by 1800 UTC 10 December. The Eta model, like before, differed from the other models in that the 850 mb temperatures would stay below freezing. But the 0000 UTC and 1200 UTC 10 December, Eta model runs were a little quicker mixing the boundary layer air mass compared to the 1200 UTC 9 December run.

A comparison of the 0000 UTC 11 December initialization model soundings at Spokane and the verifying observation (Fig. 5) showed that the models could not resolve the extremely shallow cold air near the surface. The surface temperature at the Spokane airport was modifying, but remained in the 20s with strong warm air advection above the surface. Shallow inversions such as these are "ignored" by the model initializations due to the differences between the model terrain and the actual terrain.

Summary

A significant freezing rain event occurred in eastern Washington and northern Idaho between the 9-12 December 1995. While freezing rain is not uncommon, this event was unusual in its duration. The main cause of this was found to be two short wave disturbances in southwesterly flow, riding over a cold low-level dome of air. The first short wave removed the upper portion of the cold dome allowing snow to change to freezing rain. However, this system was not strong enough to completely mix out the cold air near the surface. Thus, the second system also produced freezing precipitation before finally mixing out most locations. The cold air persisted along the east slopes of the Cascade Mountains, allowing additional freezing rain to occur over the next 48 hours.

While all of the numerical models were similar in their treatment of the large-scale features of this event, there were significant differences in their handling of the low-level cold air. The coarse resolution of the NGM and AVN models caused them to mix out the cold air with the first system, giving little or no indication of freezing rain. The Eta and Meso-Eta models, with their higher resolution, were able to hold the cold air in place over the Columbia River Basin. This resulted in good freezing rain forecasts from these models. Still, the Eta and Meso-Eta models eventually mixed out the cold air, being about 12 hours too fast in doing so.

The operational implications of this event are encouraging. While the coarser resolution models, such as the NGM and AVN, could not correctly forecast this event, the Eta and Meso-Eta models made very good forecasts. The reason for this is likely the higher resolution of the Eta and Meso-Eta models, allowing for a better depiction of the varied topography in this region. As operational models continue to improve in resolution, better forecasts of freezing precipitation are anticipated in this region.

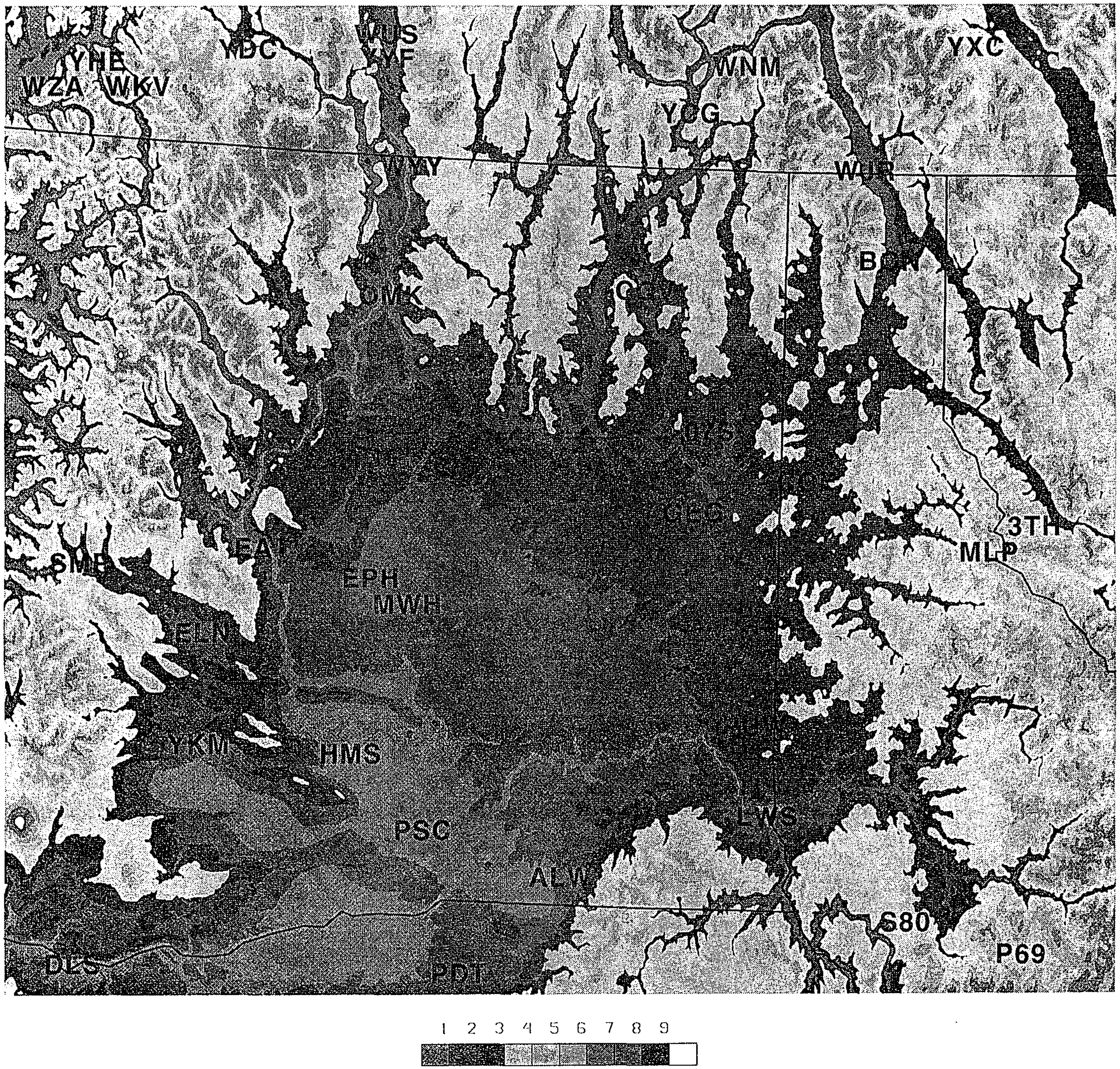

Fig. 1 Topography of the Columbia Basin in Eastern Washington and Northern Idaho.

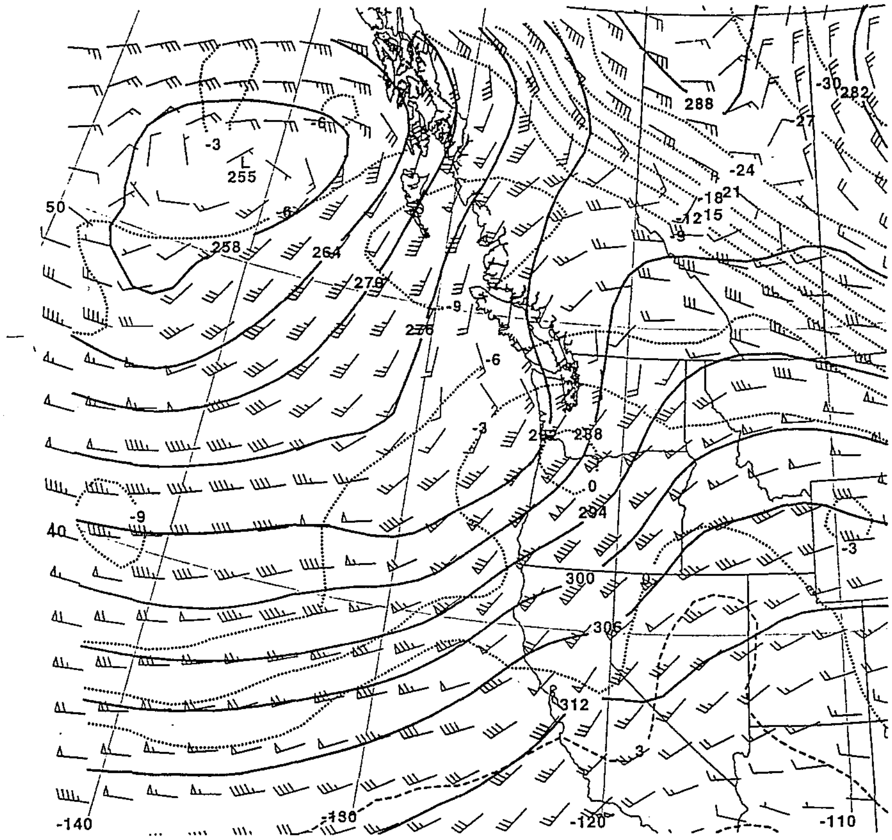

Fig. 2 700 mb heights (thick solid lines), temperatures (thin sold lines, shaded below 0°C), and winds from the Eta model analysis at 1200 UTC 09 Dec 1995.

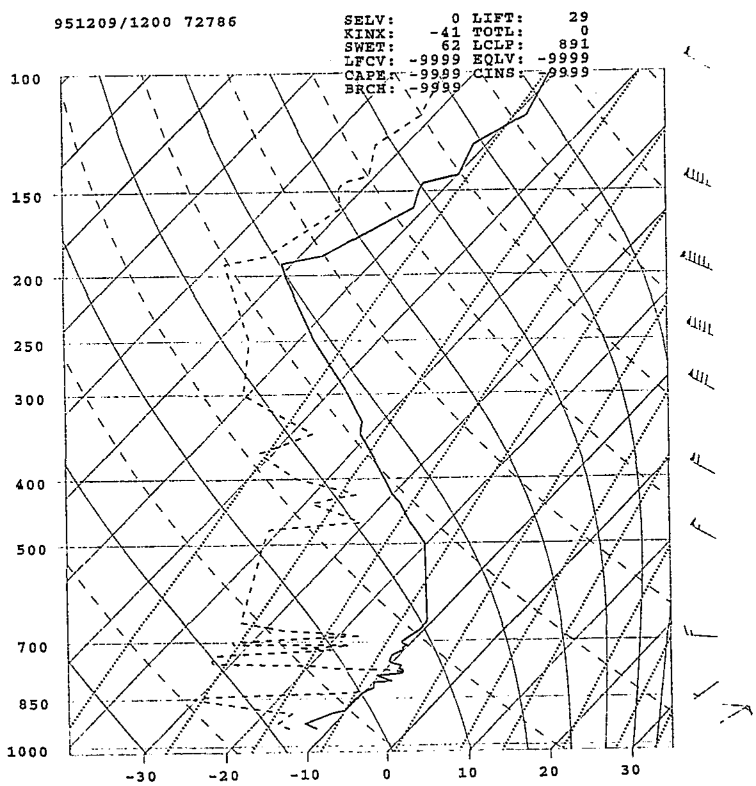

Fig. 3 Rawindsonde sounding at Spokane WA of 1200 UTC 09 Dec 1995.

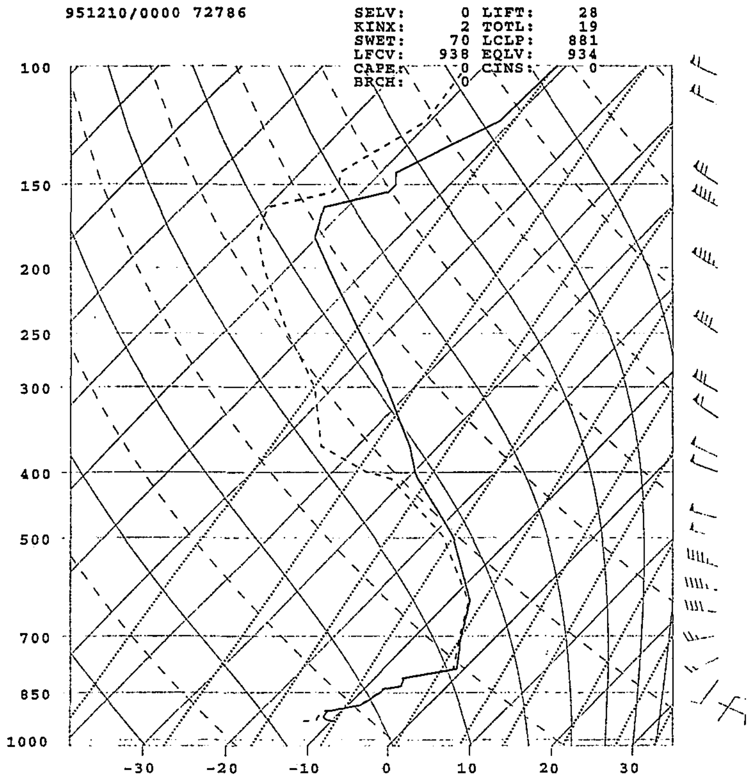

Fig. 4 Rawindsonde sounding at Spokane WA of 1200 UTC 10 Dec 1995.

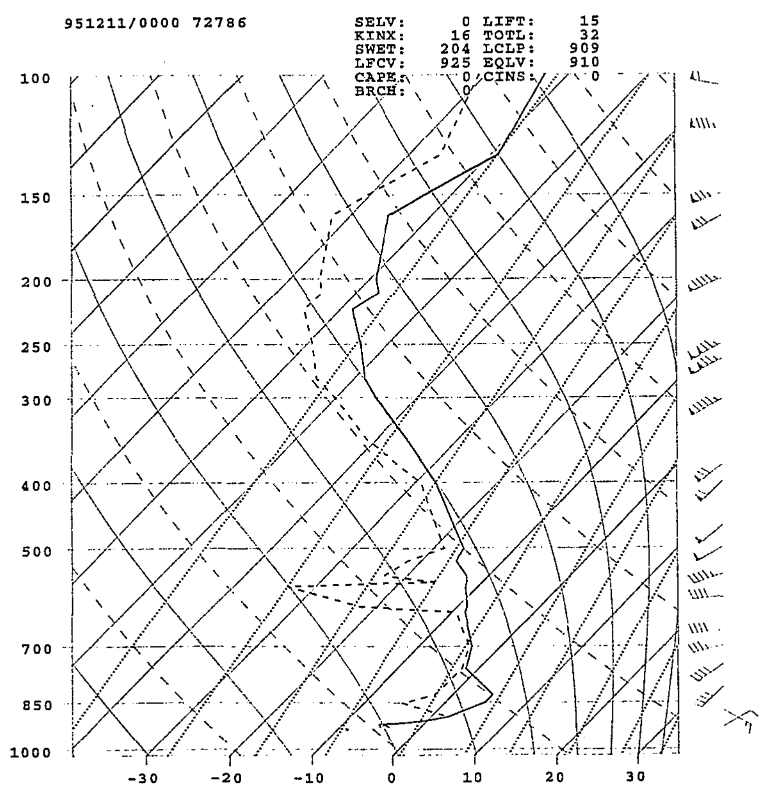

Fig 5. Rawindsonde sounding at Spokane WA of 0000 UTC 11 Dec 1995.

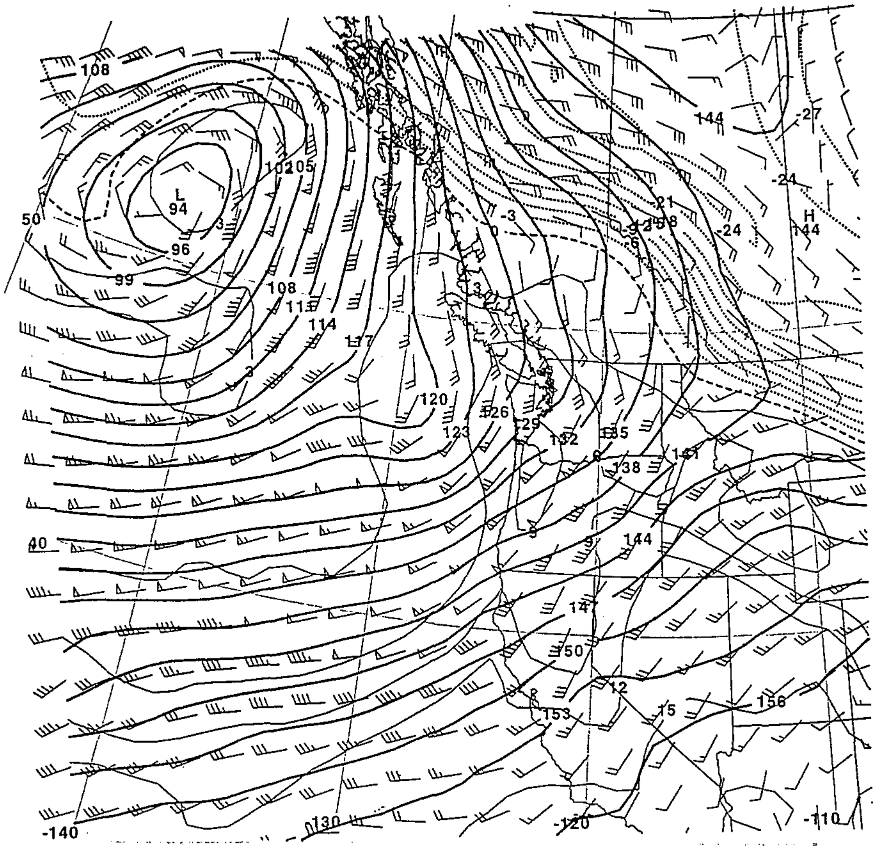

Fig. 6 850 mb heights (thick solid lines), temperatures (thin lines, dot-dashed = 0°C, dotted < 0°C), and winds from the 36 h NGM forecast valid at 0000 UTC 11 Dec 1995.

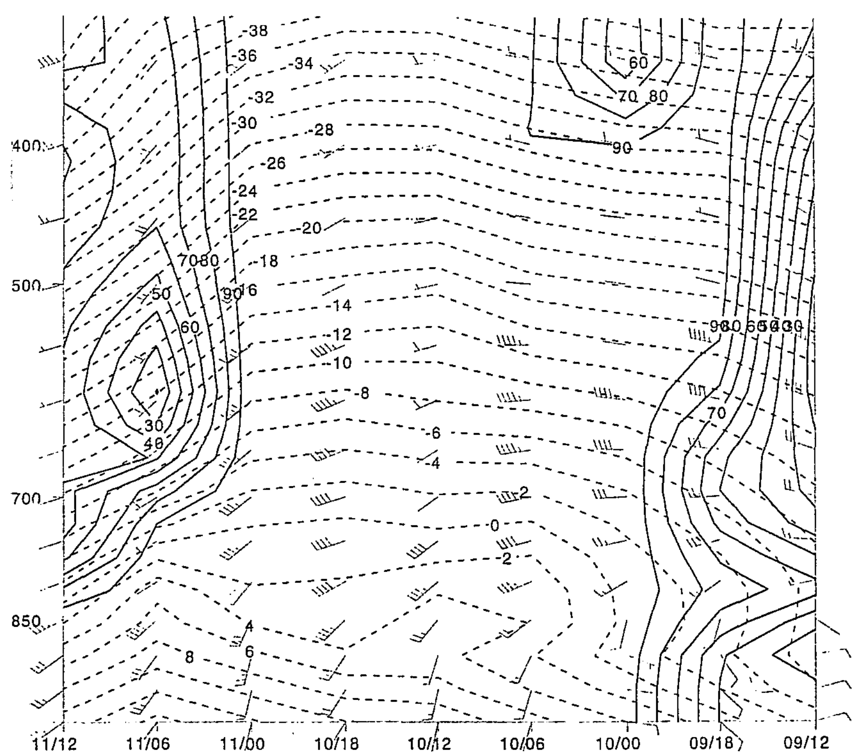

Fig. 7 Time-height section of relative humidity (solid lines), temperature (°C, dashed lines), and winds from the NGM forecast initialized at 1200 UTC 09 Dec 1995.

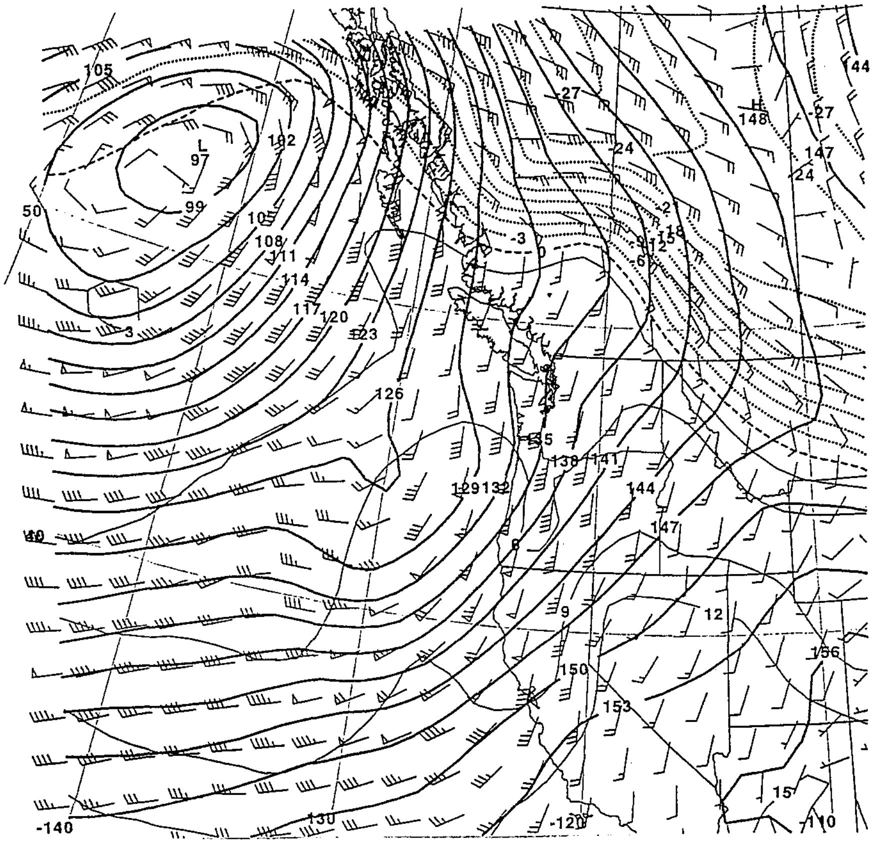

Fig. 8 Same as Fig. 6 except for the AVN model.

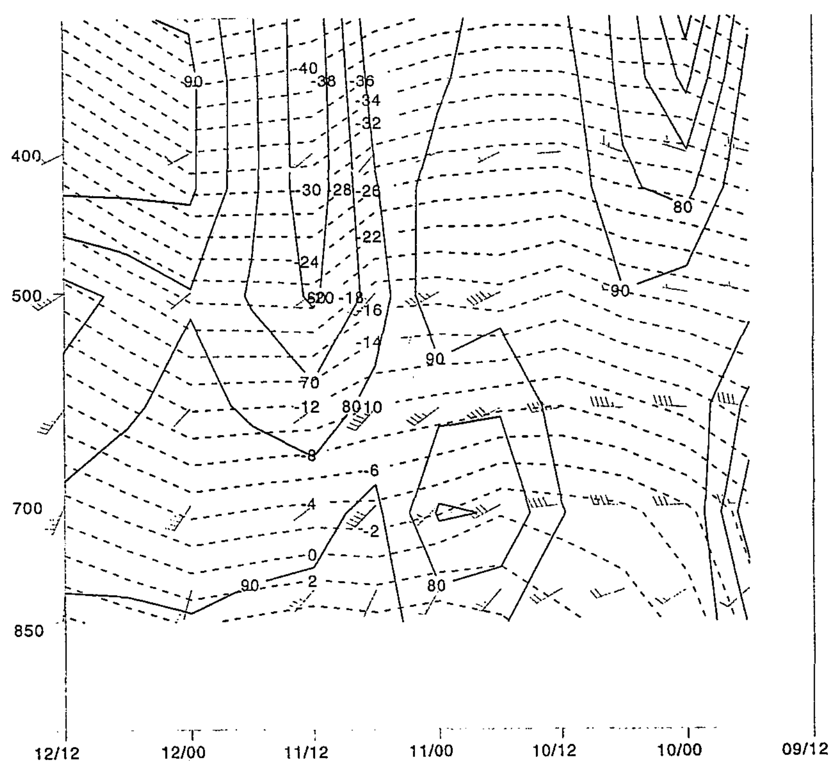

Fig. 9 Same as Fig. 7 except for the AVN model.

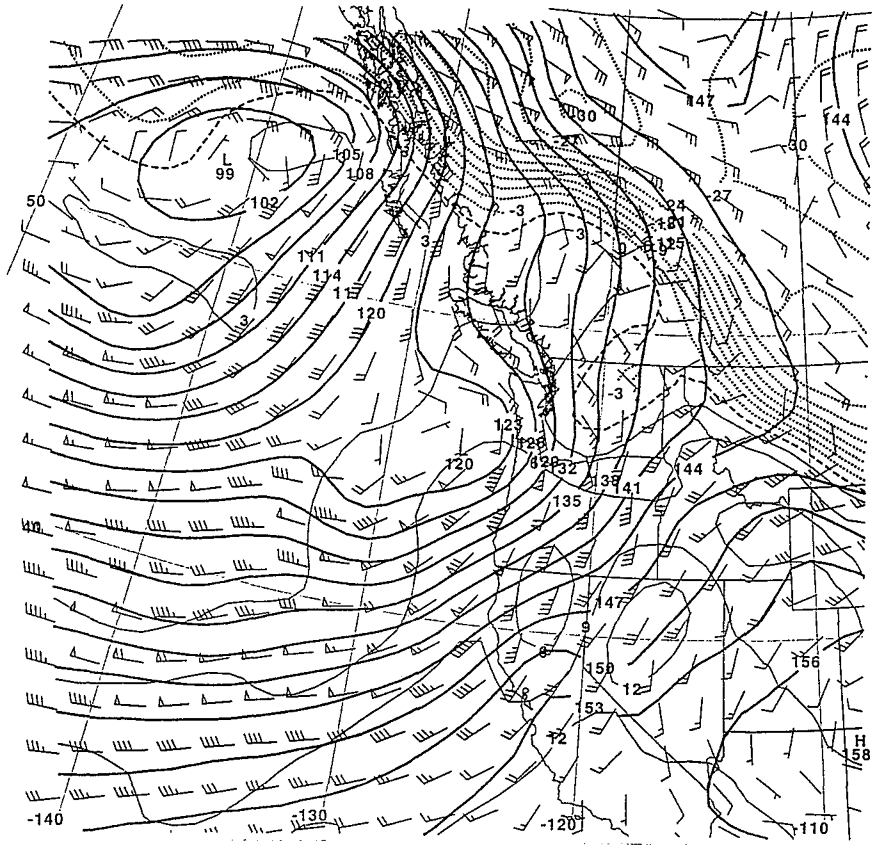

Fig. 10 Same as Fig. 6 except for the 48-km Eta model.

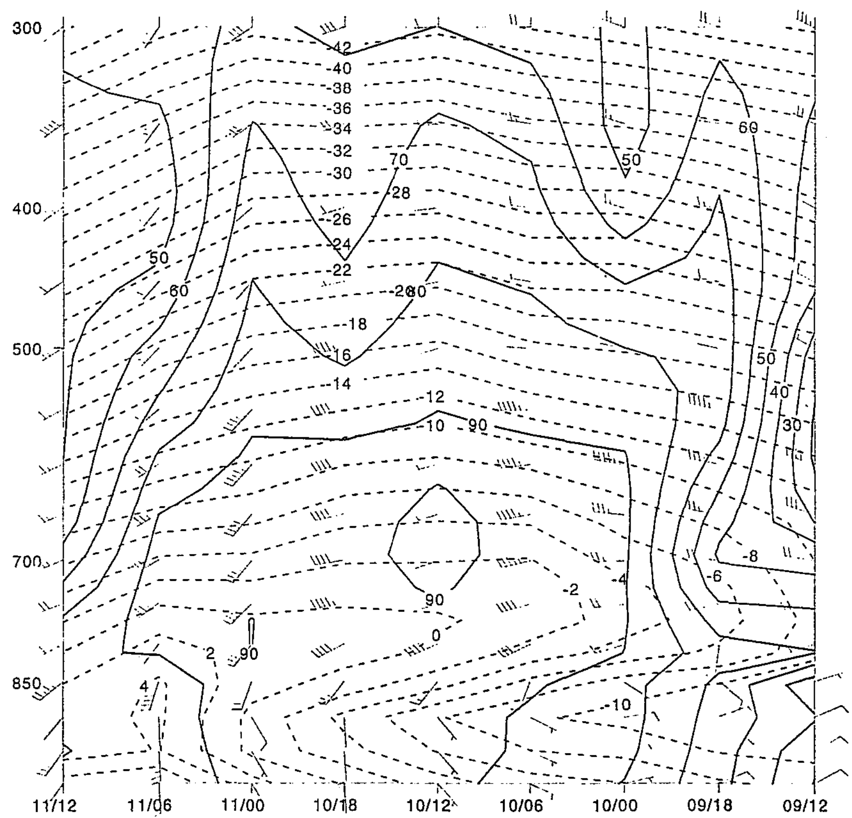

Fig. 11 Same as Fig. 7 except for the 48-km Eta model.

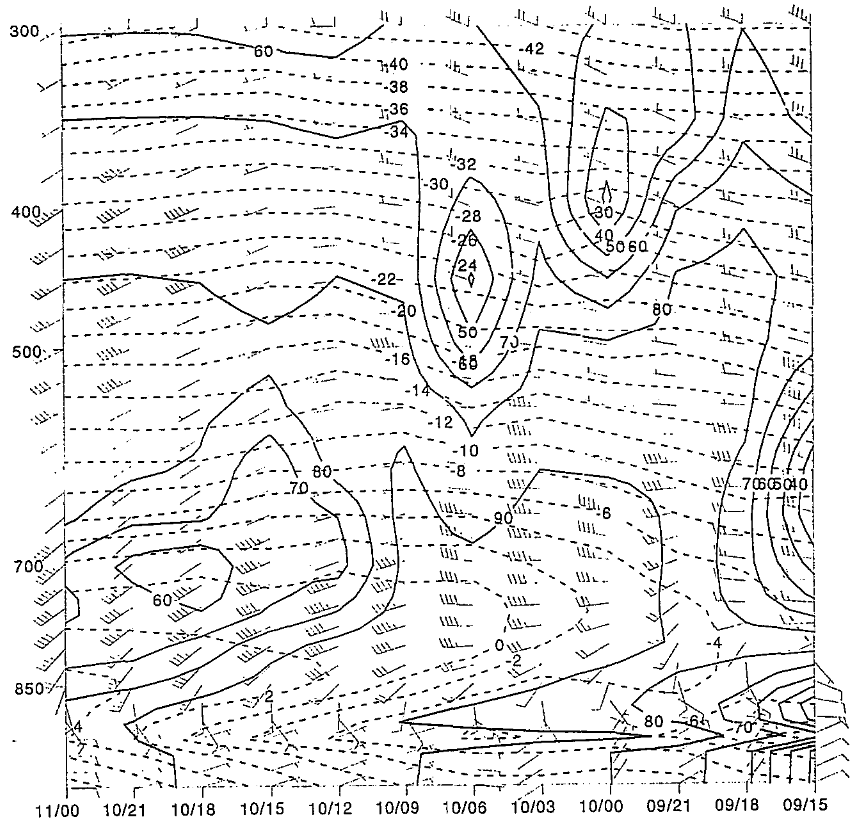

Fig. 12 Same as Fig. 7 except for the 29-km Meso-Eta model.

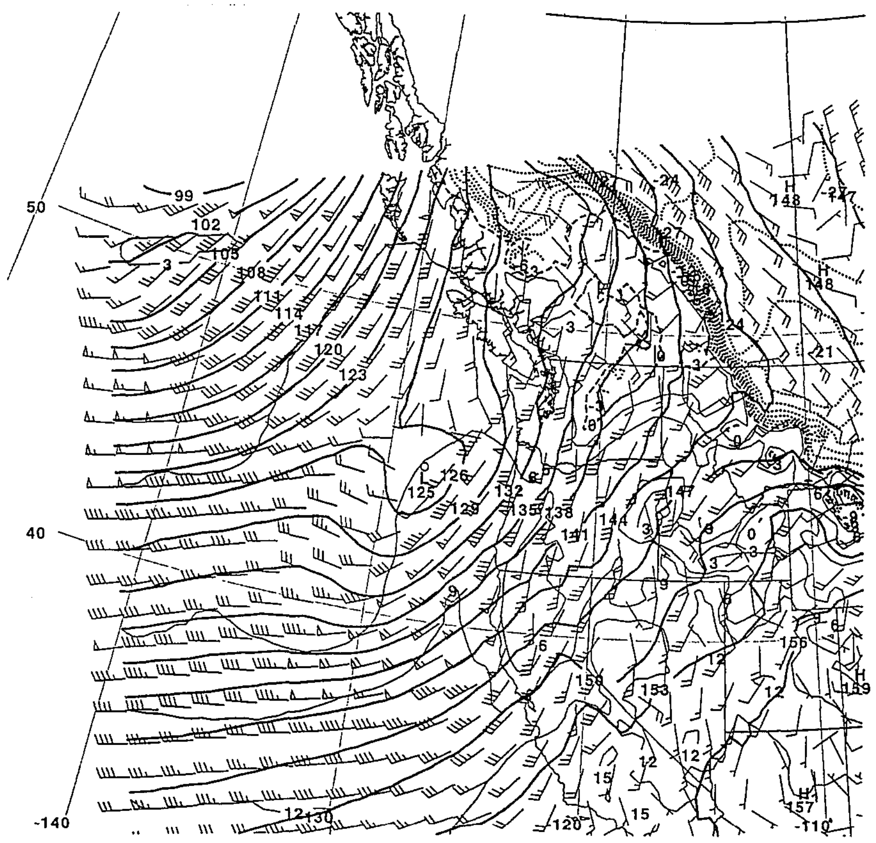

Fig. 13 Same as Fig. 6 except for the 29-km Meso-Eta model.

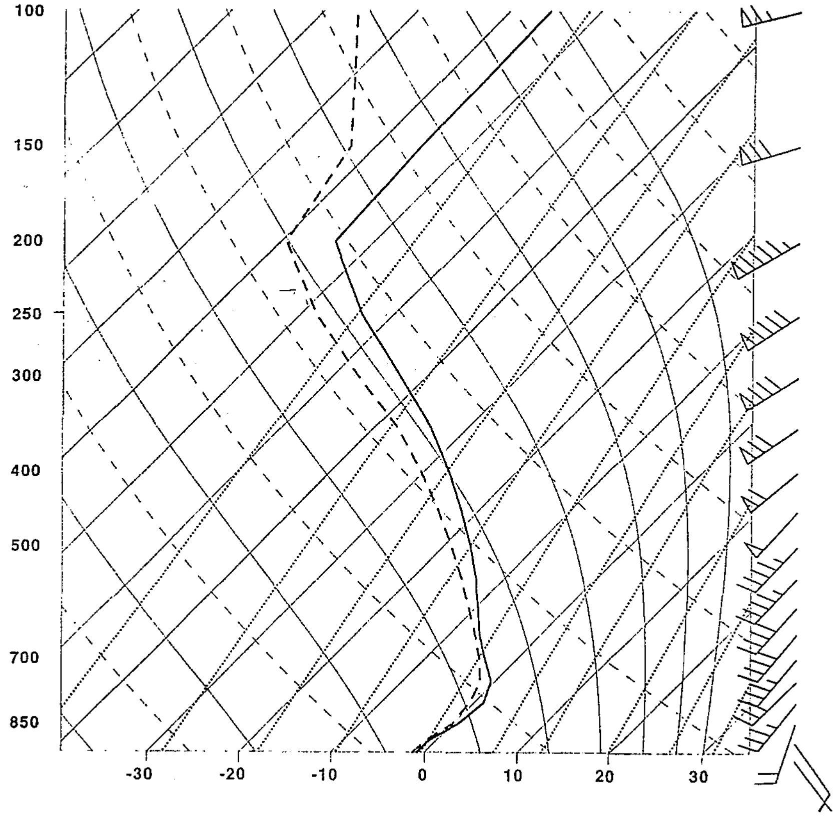

Fig. 14 48-km Eta 36 h forecast sounding of temperature (thick solid line), dew point (thick dashed line), and winds at Spokane, WA valid at 0000 UTC 11 Dec 1995.

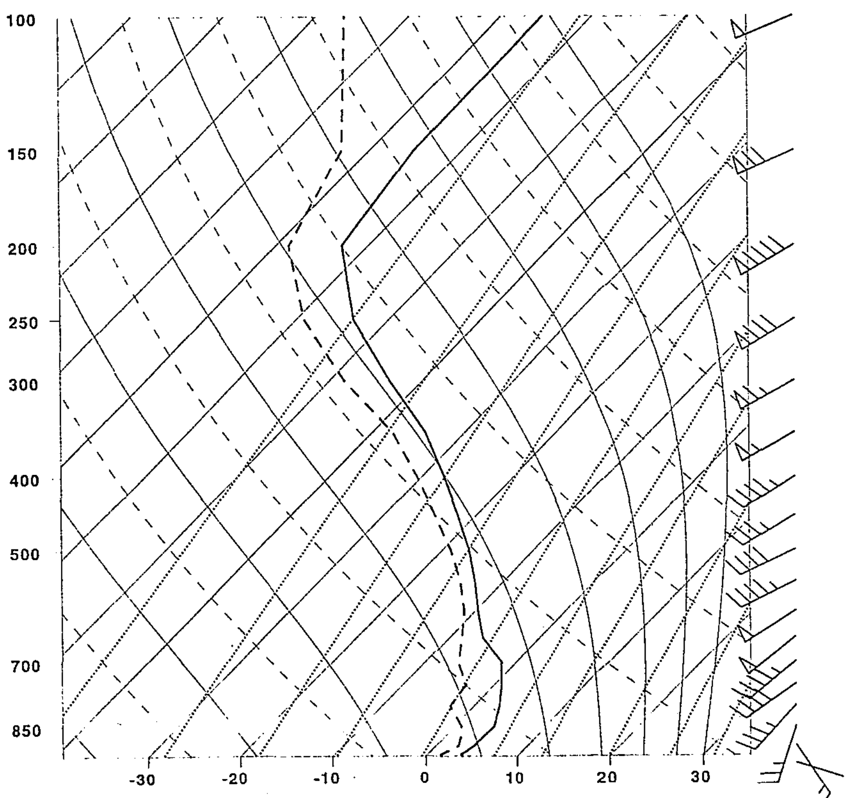

Fig. 15 Same as Fig. 14 except for 33 h forecast from the 29-km Meso-Eta model.