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AN UPSLOPE SNOW EVENT IN THE NORTHERN SIERRA NEVADA MOUNTAINS

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Introduction

On 8-9 December 1992, a classic overrunning event occurred in the northern Sierra Nevada Mountains. During the preceding days, a deep fetch of moisture developed in the Pacific, stretching from west of Hawaii to northern California (Fig. 1). By 8 December, a low pressure system that moved into the Pacific Northwest produced strong westerly winds across northern California. Though an overrunning situation was apparent, heavy snow amounts were not forecast since most of the supporting dynamics appeared to be passing far to the north with the jet stream.

Observations

Snow began falling along the western slopes of the northern Sierra Nevadas around 2200 UTC 8 December (1400 PST). By 0000 UTC 9 December (1600 PST), snow had started to fall in the Lake Tahoe Basin. The intrusion of subtropical moisture and subsequent warm air advection helped raise snow levels in the Sierra Nevadas to around 6000 feet. In some areas, snow fell at a rate of four inches per hour for several hours. Eighteen hour snowfall amounts generally ranged from two to three feet.

The snow continued to fall through the evening before tapering off early on the morning of 9 December. The heaviest snow fell during a six-hour period, from around 0200 UTC (1800 PST) until about 0800 UTC. Based on intermittent snowfall reports (generally received every three to four hours) from reliable weather spotters and ski areas, hourly snowfall was estimated (Table 1).

Analysis

PCGRIDS was used to analyze both the NGM and Eta gridded data from 1200 UTC 8 December, to determine the type of dynamics that were present. The main focus was the 12 hour forecast since this was about the time that precipitation began to fall in the Sierra Nevadas. Both the NGM and Eta models were in fairly good agreement. The only significant difference was in the 850 mb moisture field in which the Eta model was somewhat more moist.

The 12 hour NGM forecast indicated a 130 kt jet at 300 mb off the southern Oregon coast (Fig. 2), with an associated vorticity maximum at 500 mb along the Washington-Oregon coast (Fig. 3). Additional analysis (not shown) of upper-level divergence and Q-vectors also showed most of the upper-level support and quasi-geostrophic (Q-G) forcing passing well north of the Sierra Nevadas.

Analysis of the 850 and 700 mb fields showed little in the way of lower-level dynamics. However, abundant low-level moisture was apparent (Fig. 4), especially at 700 mb. Also at that level, the 12 hour forecast indicated an area of 40 to 50 kt winds oriented nearly perpendicular to the northern Sierra Nevadas. Although the wind speeds had decreased slightly by 24 hours, the wind direction had turned slightly more southerly and became more perpendicular to the northern Sierra Nevadas.

In addition to the obvious overrunning signatures, the event was depicted well in the Θ_e fields. Initially, the low-level moisture and warm air advection made for a strong 700 mb Θ_e ridge along the California coast, while the Θ_e trough identified colder, dryer air in the lee of the Sierra Nevadas. With the westerly flow, the initial Θ_e advection chart showed a large positive area over northern California (Fig. 5) suggesting an eastward movement, which was observed by 12 hours.

The overrunning stood out best on the 295K isentropic analysis. This initially indicated a broad area of moisture (mixing ratio) advection into northern California. By 12 hours, the magnitude of the moisture advection had decreased significantly, but the main focus had shifted to directly over the northern Sierra Nevadas (Fig. 6).

A comparison of the initial 0000 UTC 9 December PCGRIDS data to the 12 hour forecast from the 1200 UTC 8 December data verified nicely. For additional verification, the SHARP Workstation was used to examine the 0000 UTC 9 December sounding from Oakland, California. The surface to 700 mb data showed a mean wind direction of 240° and wind speeds ranging from 20 kts near the surface to 40 kts at 700 mb. The low-level moisture was also present in the Oakland sounding with the mean surface to 700 mb relative humidity over 90 percent.

Discussion

Since this case was a good example of upslope precipitation, it allowed an opportunity to examine possible contributions of upslope effects on precipitation in the Sierra Nevadas. Obviously, perfect upslope conditions would occur when the lower atmosphere is saturated and strong winds are blowing perpendicular to the mountain range. Although that was not exactly the case in this event, snowfall rates were still on the order of four inches per hour. During a perfect upslope event, snowfall rates of five to six inches per hour could probably be expected.

Of course, snowfall rates are also highly dependent on the water content of the falling snow. During this event, Blue Canyon, California, which was just below the snow line, picked up 4.58 inches of rain through an 18 hour period starting at 1800 UTC 8 December. This would suggest that the water content of the snow was rather high, probably about 15 percent, and with colder temperatures, several more inches of snow could be expected. However, the upslope precipitation amounts would generally be less. Therefore, maximum snowfall rates would still be around five to six inches per hour.

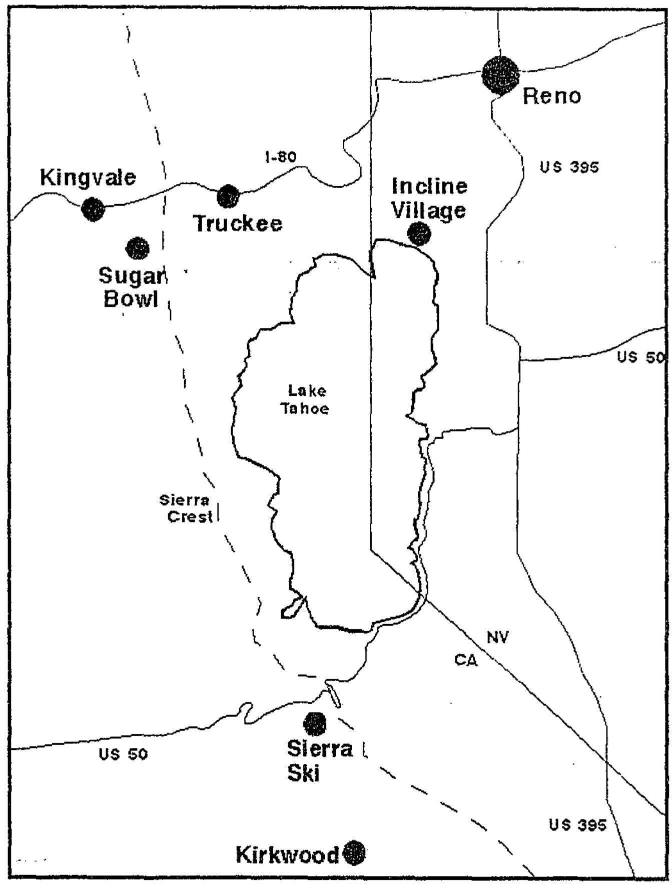
Although very few of the dynamic forcing charts from PCGRIDS were helpful in this study, PCGRIDS can still play an important role in the analysis of upslope precipitation. Specifically, the ability of PCGRIDS to analyze both the moisture and wind fields from the surface to 700 mb represents a major advantage over traditional AFOS graphics. Furthermore, isentropic surfaces and Θ_e fields, typically helpful for an overrunning event, can easily be analyzed through PCGRIDS.

Conclusion

While upslope precipitation is fairly common in the Sierra Nevadas, seldom does it occur without any additional upper-level support. This case represented a rare opportunity to isolate the upslope conditions. Based on a maximum snowfall rate of six inches per hour, a local numerical equation could be developed to try and estimate upslope precipitation amounts using moisture, wind speed, and wind direction in the lower atmosphere. If it turned out to be a reliable way of forecasting upslope precipitation, perhaps during large-scale synoptic events it could be used in conjunction with other predictors, such as model QPF, to predict total snowfall accumulations.

Acknowledgements

I would like to thank Tom Cylke and Ray Collins for their helpful contributions to this paper.



December 8-9, 1992
Estimated Hourly Snowfall

Local Time	Sugar Bowl	King-vale	Sierra Ski	Kirk-wood	Incline Village	TRK Ag Station
1300	0"	0"				0"
1400	2"	1"	0"	0"		1"
1500	4"	2"	2"	2"		2"
1600	6"	4"	4"	4"	0"	3"
1700	8"	6"	7"	6"	2"	4"
1800	12"	8"	8"	8"	4"	6"
1900	16"	10"	9"	12"	6"	8"
2000	20"	12"	11"	16"	8"	10"
2100	23"	--	15"	18"	10"	12"
2200	25"	--	18"	22"	14"	13"
2300	27"	--	20"	26"	17"	15"
0000	29"	--	22"	29"	19"	16"
0100	31"	--	24"	31"	21"	18"
0200	33"	--	26"	33"	23"	--
0300	35"	--	28"	35"	25"	--
0400	36"	--	29"	37"	26"	--
0500	--	--	30"	38"	27"	--
0600	--	--	31"	39"	28"	--
0700	--	--	--	40"	29"	--
0800	--	--	--	42"	30"	--

Table 1. Hourly snowfall data based on reports received from ski areas and weather spotters.

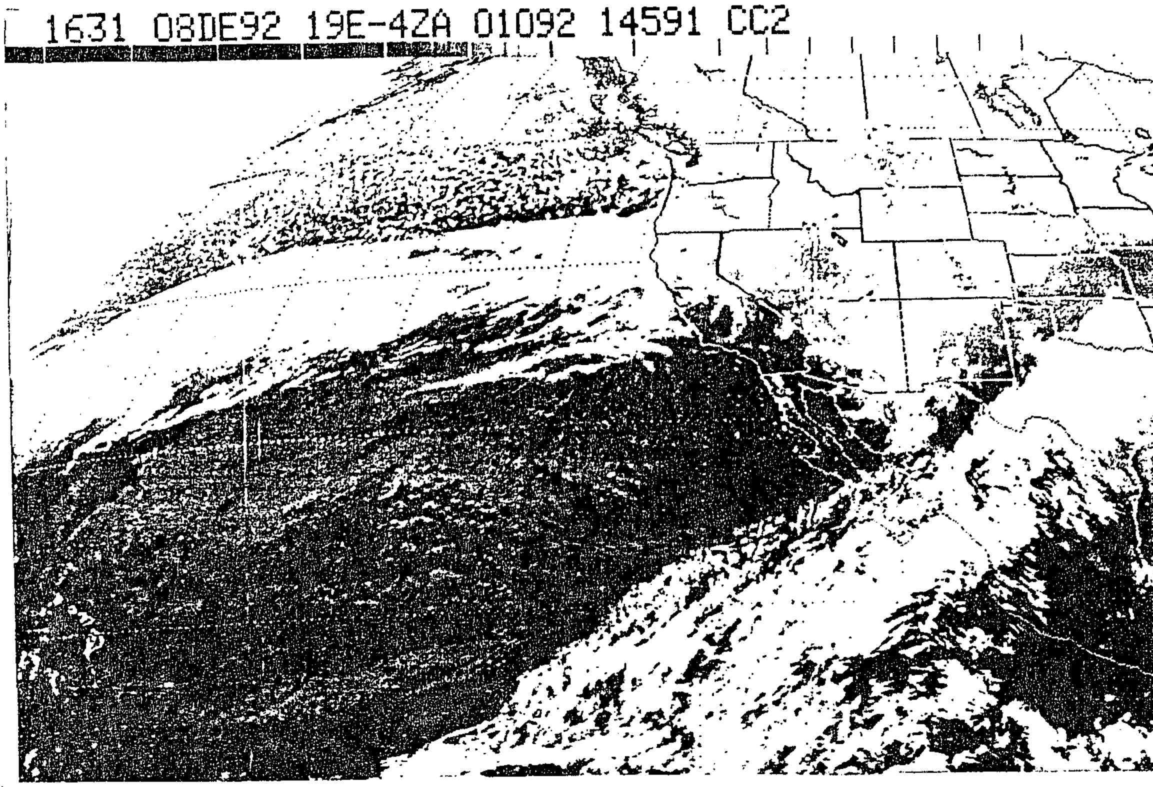


Figure 1. IR Satellite Image. Valid 1631 UTC 8 DEC 92.

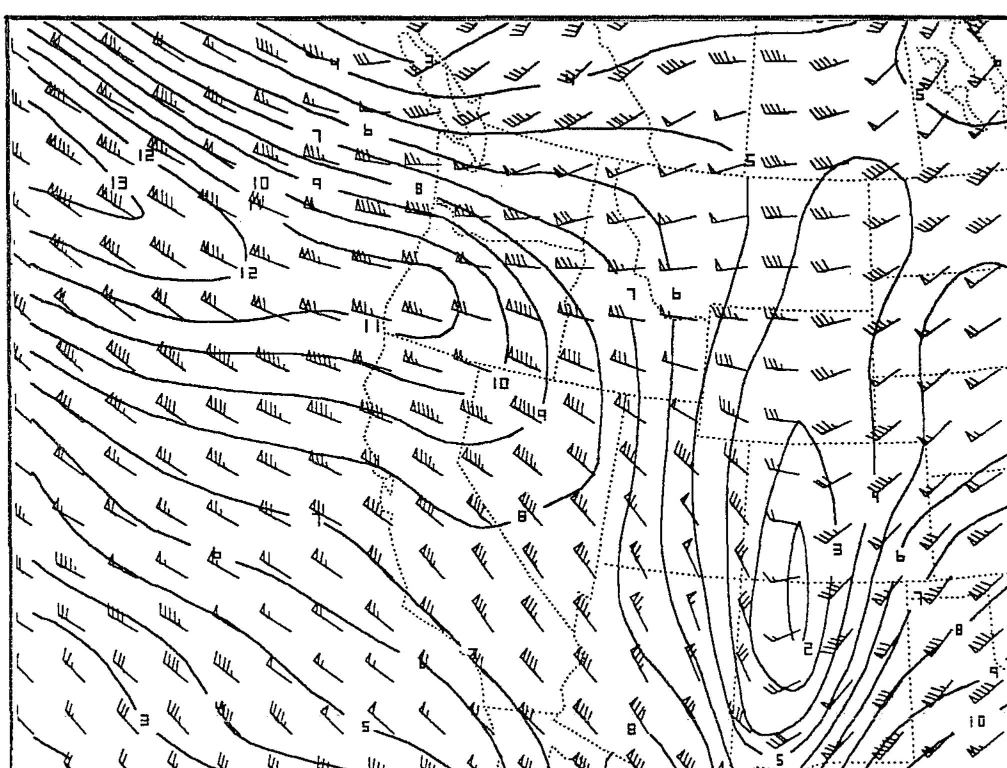


Figure 2. 300 mb wind from the NGM. Valid 0000 UTC 9 DEC 92.

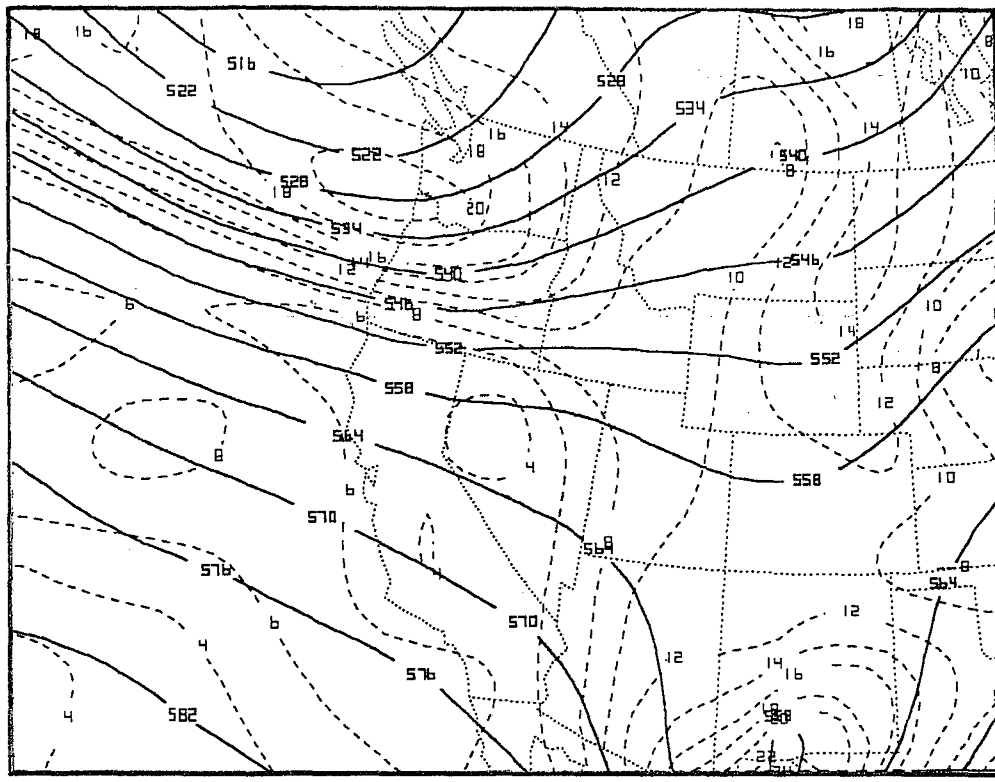


Figure 3. 500 mb heights and voticity from the NGM. Valid 0000 UTC 9 DEC 92.

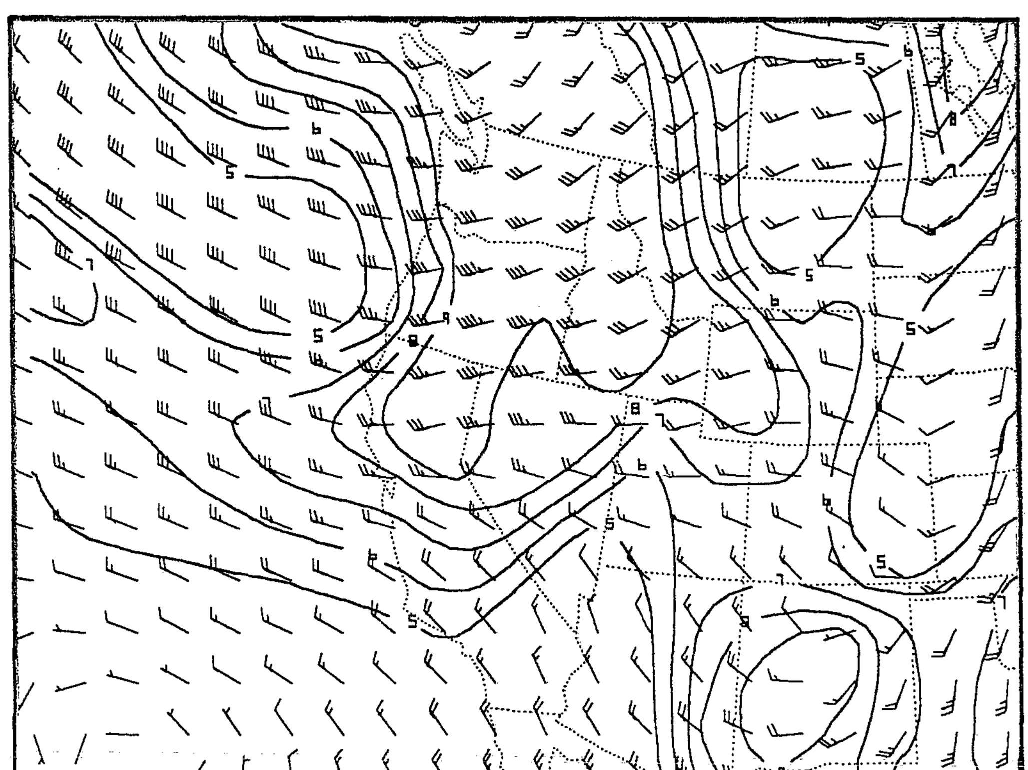


Figure 4. 700 mb to 1000 mb layer average winds and relative humidity from the NGM. Valid 0000 UTC 9 DEC 92.

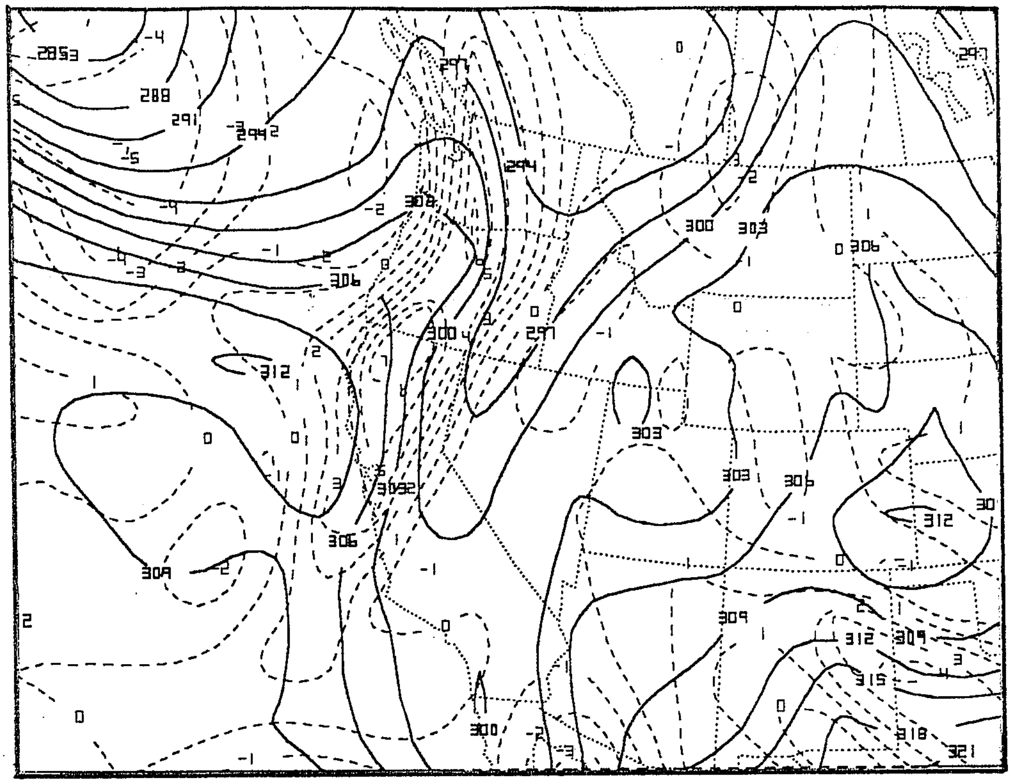


Figure 5. 700 mb theta-e and 12 hour 700 mb theta-e advection from the NGM. Valid 1200 UTC 8 DEC 92.

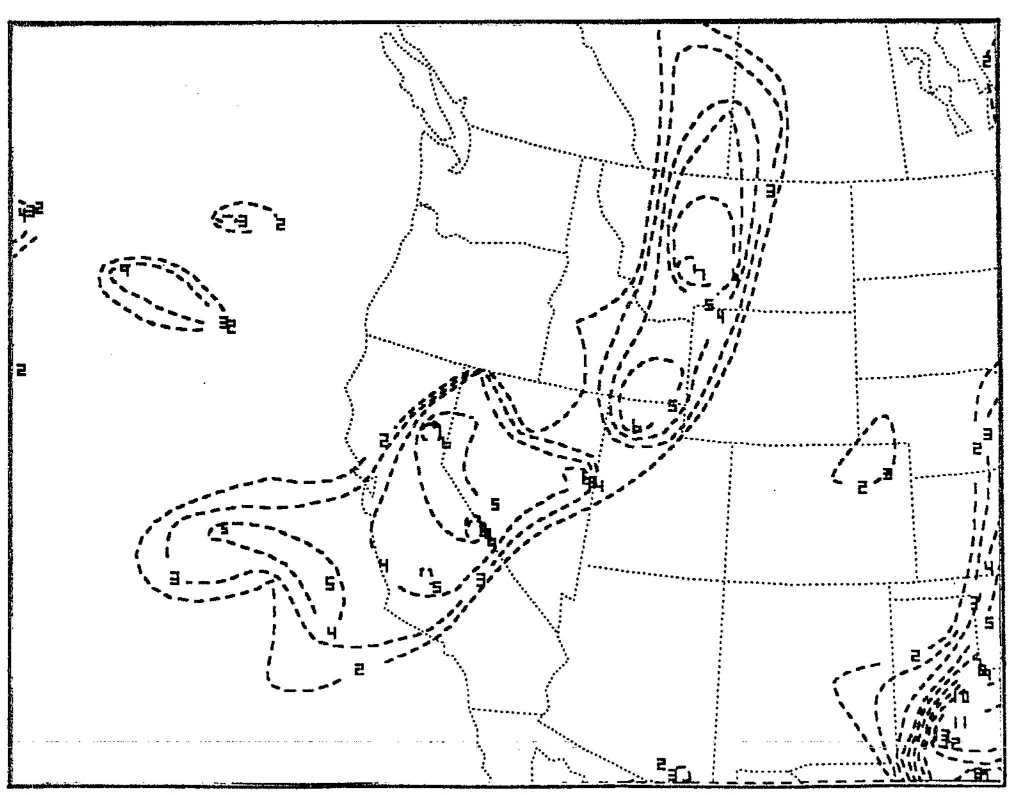


Figure 6. 295K isentropic surface mixing ratio advection from the NGM. Valid 0000 UTC 9 DEC 92.