Western Region Technical Attachment
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WHERE DID THE RAIN COME FROM?

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On Thursday morning, December 21, 1989, rain fell for a few hours across much of western Washington (Olympia northward); it was light, and given the time of year, would be considered insignificant in most cases.

However, several factors separated this event from most others. First, the Pacific Northwest had been under a long-wave ridge for several weeks and an unusual winter dry period prevailed. Second, all forecast model guidance indicated little or no overall change; in fact, on the morning of the 21st, a moderately sharp short-wave ridge was approaching the coast. Guidance indicated little or no precipitation threat and, as a result, the early morning public forecasts followed the trend by omitting the precipitation.

There were several specific indicators that no rain would occur:

1) A moderately sharp ridge of high pressure at 500 mb and a minimum center of vorticity were moving onto the Washington coast (Figure 1).
2) The flow from 700 mb to 500 mb was anticyclonic over western Washington as well as upstream (Figure 2).
3) The analysis indicated that the flow was divergent from 850 mb to at least 500 mb (Figure 3), and at 850 mb divergence of moisture was occurring (Figure 4).
4) Surface features indicated high pressure east of the Cascades and a dry easterly flow through the mountains.
5) In the upper levels, the jetstream remained north and east of western Washington.

Considering these factors alone would lead one to the conclusion that subsidence was occurring over western Washington and, therefore, precipitation would not be likely.

However, a more complete study of the atmosphere that morning explains the light rain. The 1200Z sounding over Quillayute, on the northern Washington coast, indicated an almost saturated column of air from 850 mb to above 500 mb (Figure 5), probably the remnants of a baroclinic zone. Satellite imagery confirms that a blanket of mid- and low-level cloudiness did exist along and a few hundred miles off the Washington coast (Figure 10). With so much moisture (0.87 inches of precipitable water), only small amounts of vertical lift would be needed to produce saturation and light precipitation. The wind direction on the 1200Z Quillayute sounding was veering with height indicating warm advection from approximately 900 mb to 700 mb; computed results for these levels, Figure 6, confirm this. Weak moisture convergence is also apparent at 700 mb in Figure 7.

A very close look at the amount of divergence from the surface to 200 mb indicates divergence increasing with height (Figure 8), and stronger divergence aloft supports the possibility of some net upward motion to balance the column of air.

Weak convergence of Q-Vectors at 700 mb (not shown) is also apparent over the location where the rain fell in western Washington (see Figure 9). Hoskins, et. al. (1978, 1980) demonstrated that divergence of a vector quantity called Q could be used to infer upward or downward vertical motion. Q-vectors take into account vertical motion induced by both differential vorticity advection and thickness advection. Hoskins shows that one can expect upward vertical forcing where Q-vectors converge and downward vertical forcing where Q-vectors diverge.

The surface observations that morning suggest the precipitation probably originated from clouds at 6,000 - 8,000 feet above the surface. This is the same layer of the atmosphere where weak, warm advection was occurring, as well as a net upward lift due to increasing divergence with height. These atmospheric processes alone would not likely produce rain (because they were relatively weak); however, an almost saturated atmosphere needed only a small amount of vertical lift to produce precipitation. Although a ridge of high pressure did build inland later that morning stabilizing and drying the airmass, the atmospheric processes that induced the light rain combined and temporarily overcame the subsistence associated with the anticyclonic flow, and the lack of apparent surface support.

[Editor's Note: This study is a good reminder of how important it is to carefully examine all levels of the atmosphere for mechanisms which may cause upward vertical motion. It is of course particularly important when the atmosphere is completely or nearly saturated since only very weak upward motions can lead to precipitation. When the upward vertical forcing is more significant, then the atmosphere need not be completely saturated initially; strong upward velocities will quickly saturate a column of air that is apparently "lacking in moisture".]

References

Hoskins, B. J., and M. A. Pedder, 1980: The Diagnosis of Middle Latitude Synoptic Development. *Quart. J. Roy. Meteor. Soc.,* 106, 707-719.

______, I. Draghici and H. C. Davis, 1978: A New Look at the Omega Equations, *Quart. J. Roy. Meteor. Soc.,* 104, 31-38.

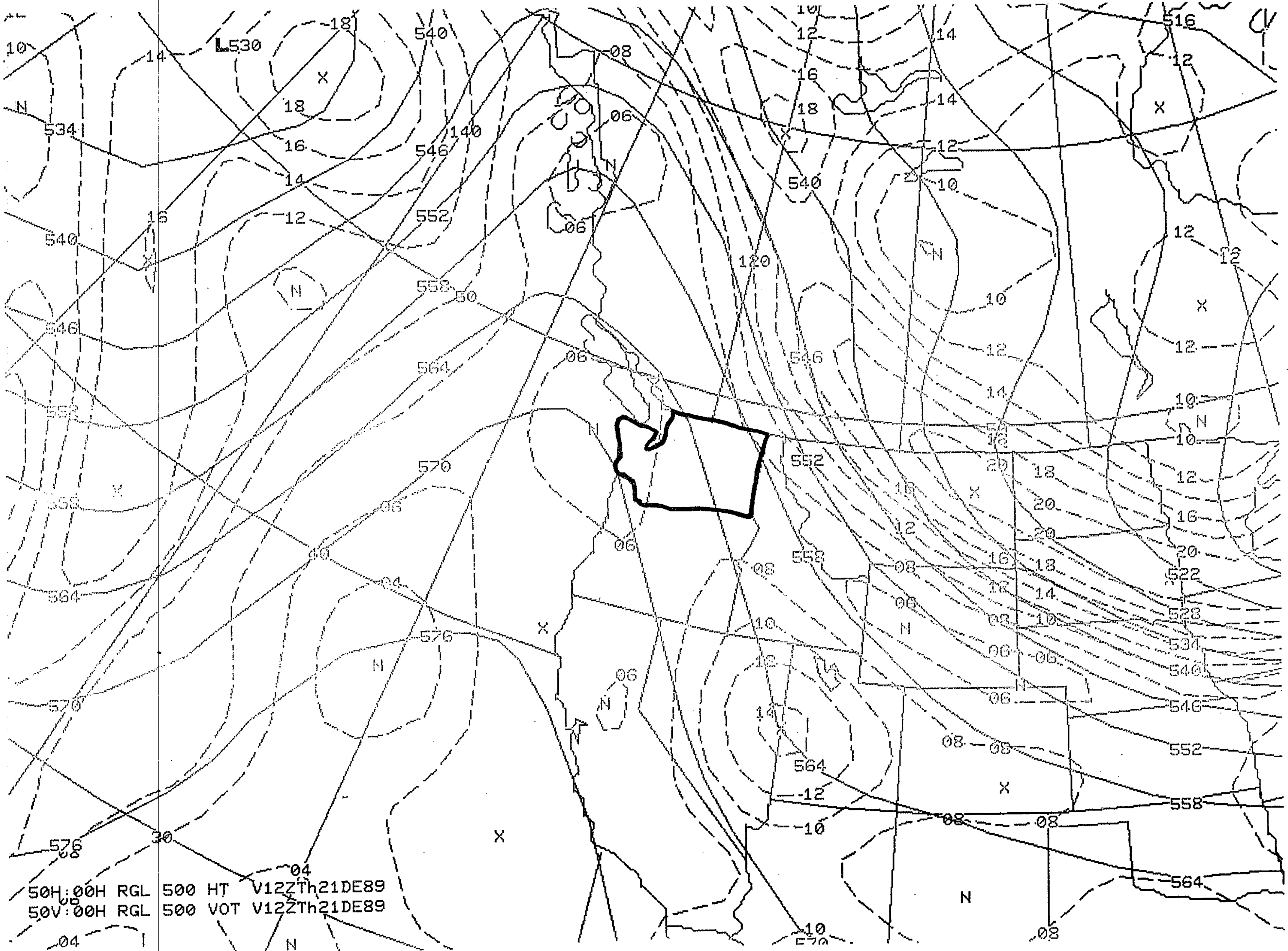


Figure 1. NGM analysis for 12Z Dec 21, 1989. 500 mb height and vorticity.

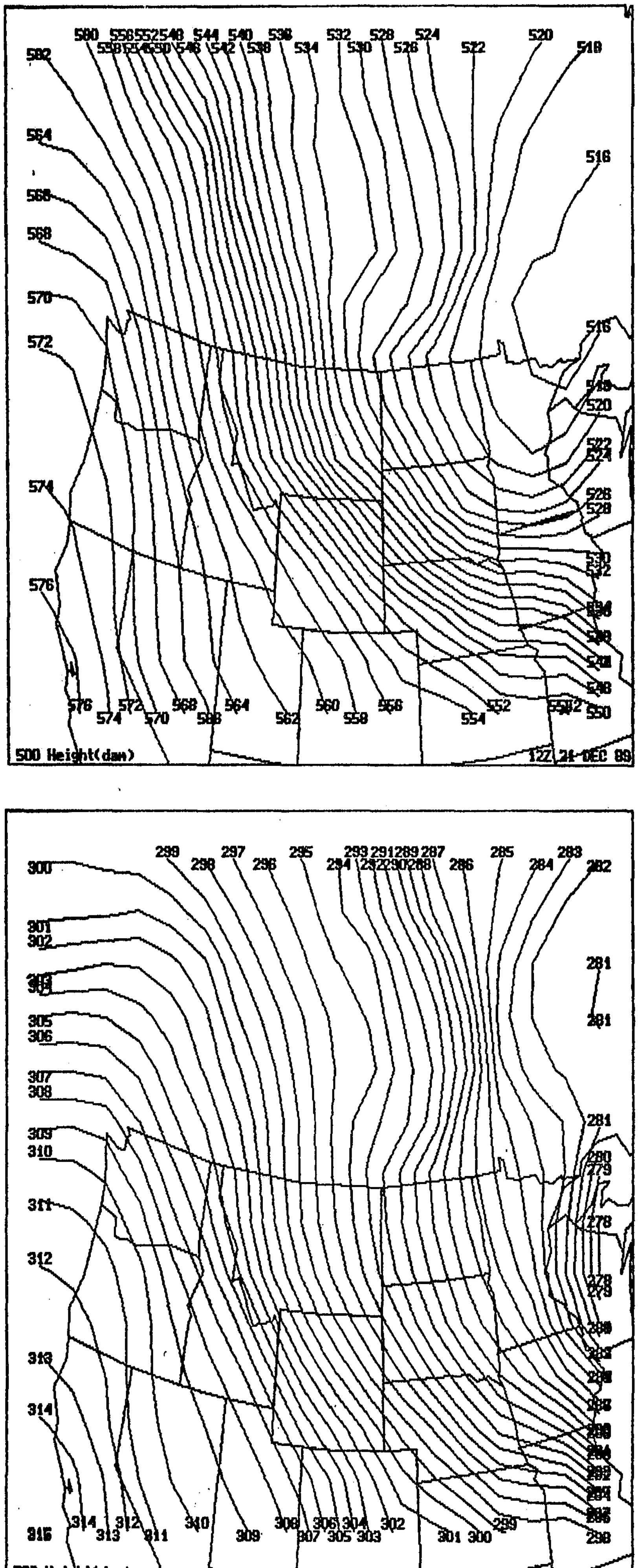
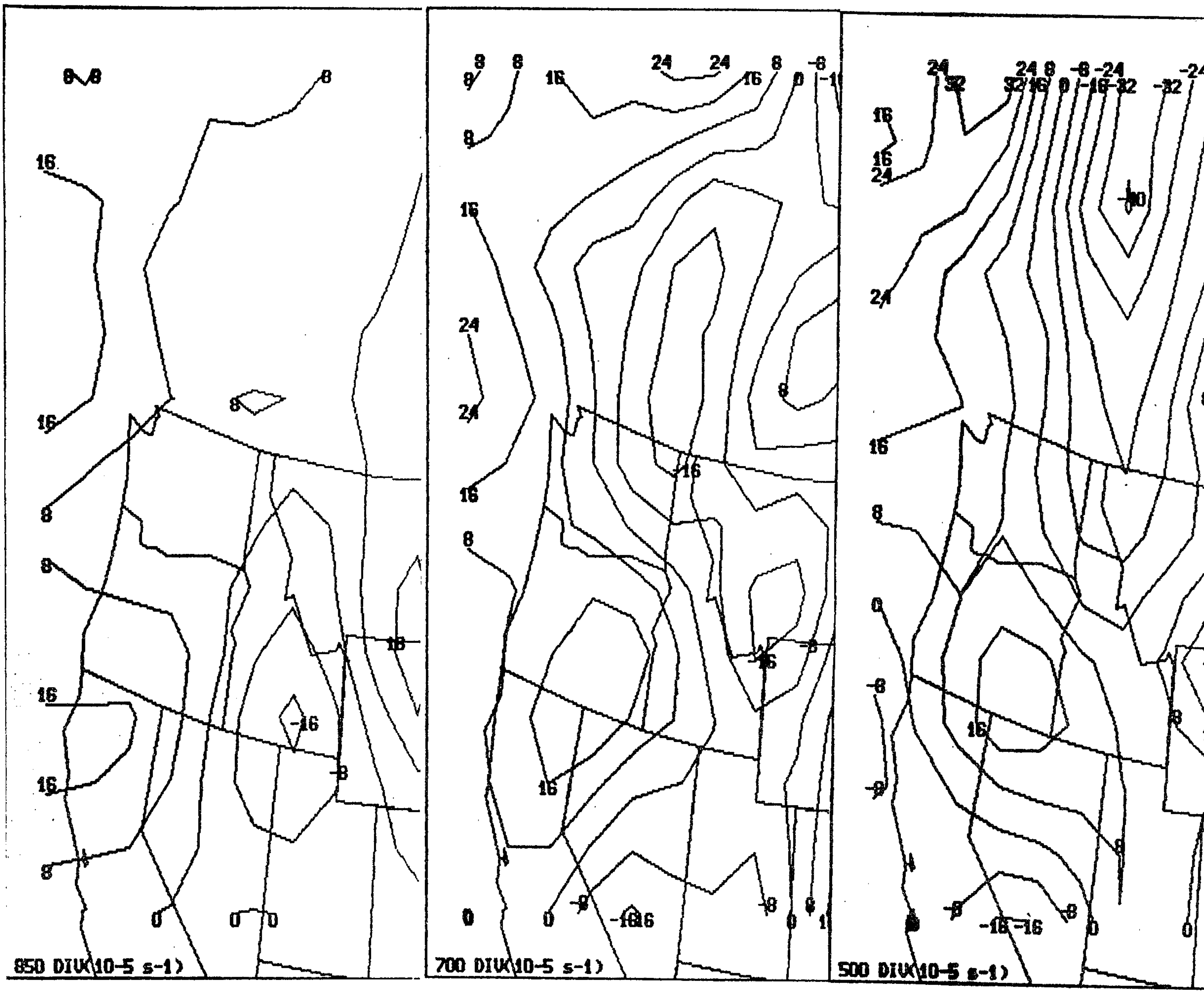


Figure 2.

Note weak anticyclonic flow over Western Washington



12Z 21 DEC 89

Figure 3. Divergence at 850, 700, and 500 mb.

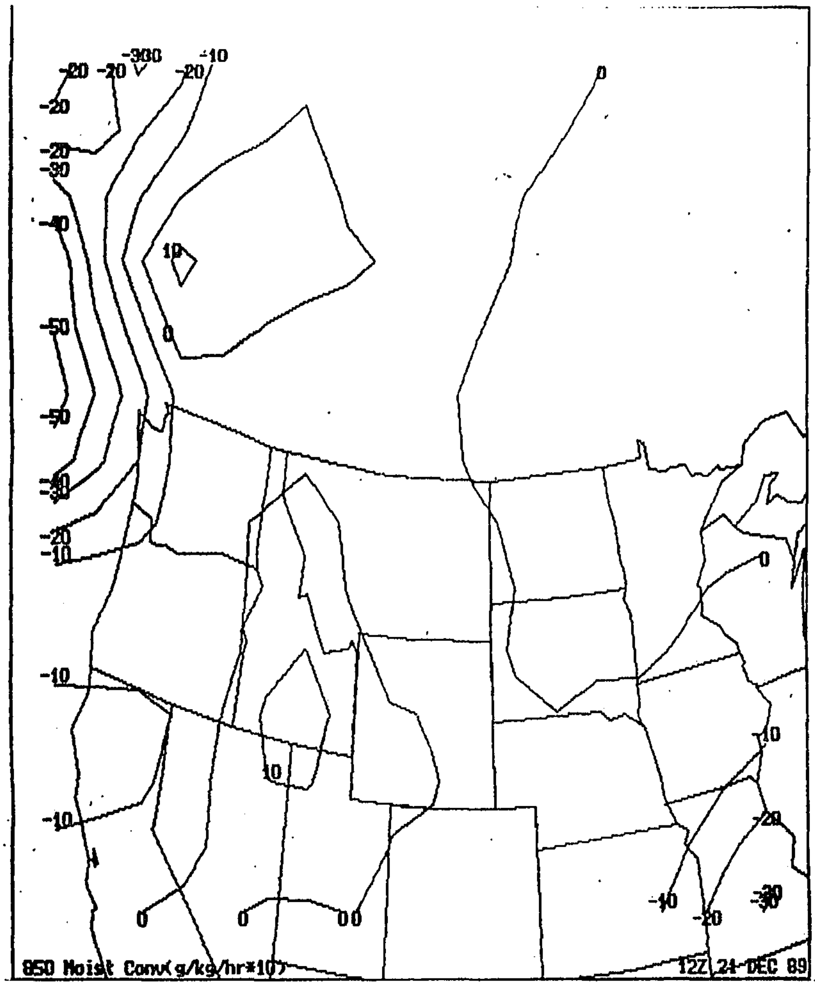


Figure 4.

Moisture convergence at 850 mb. Note negative values depicting divergence of moisture over Western Washington.

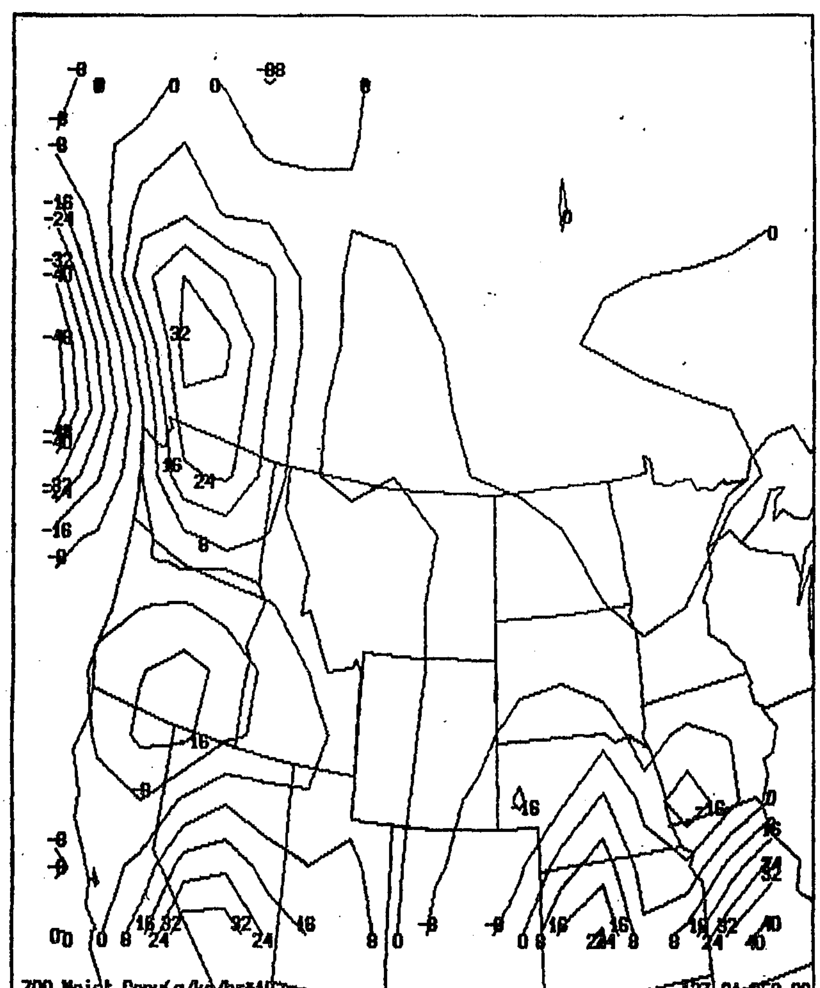


Figure 7.

700 mb moisture convergence.

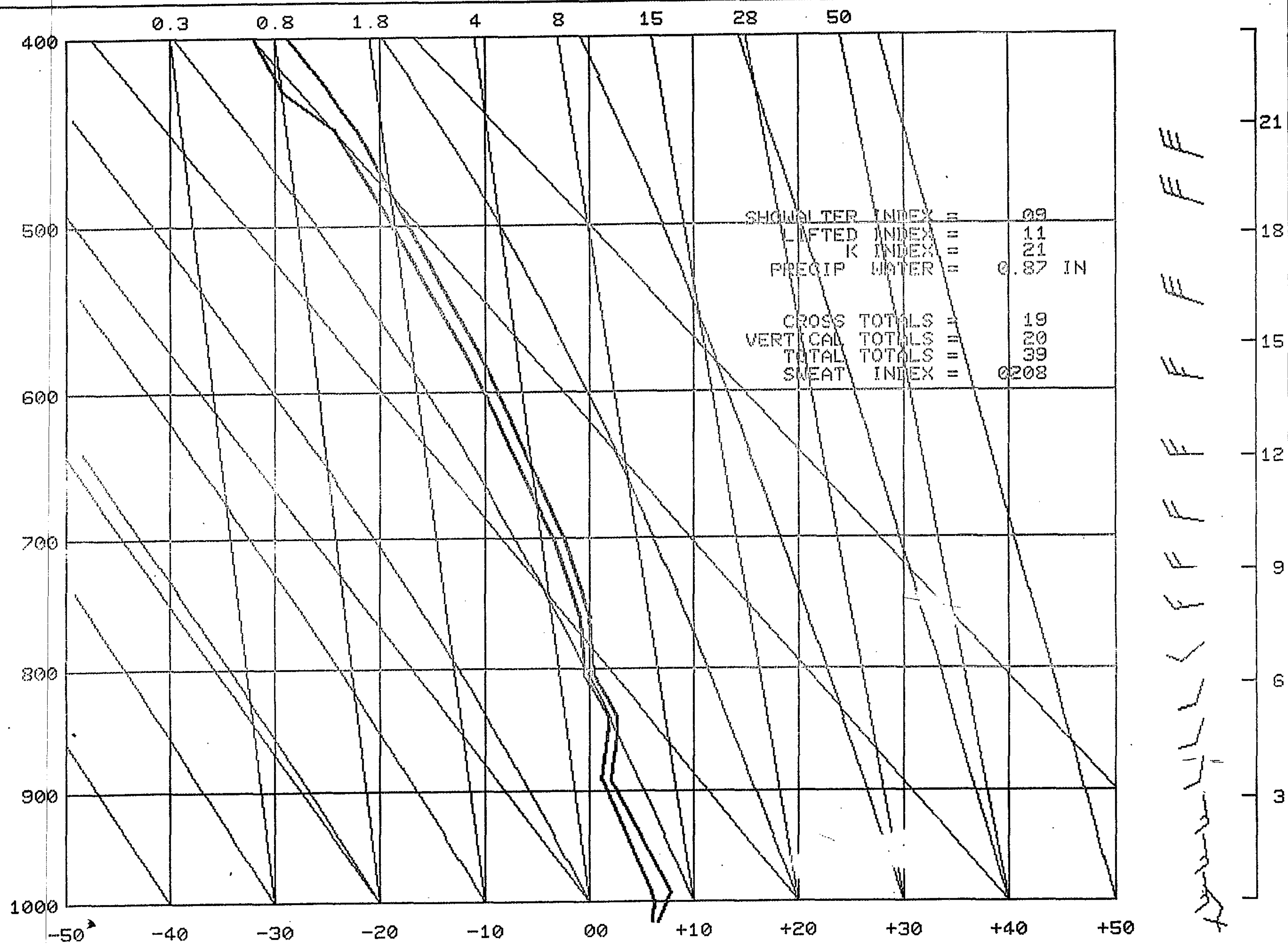


Figure 5. Quillayute 12Z sounding. Wind direction is veering with height at low levels.

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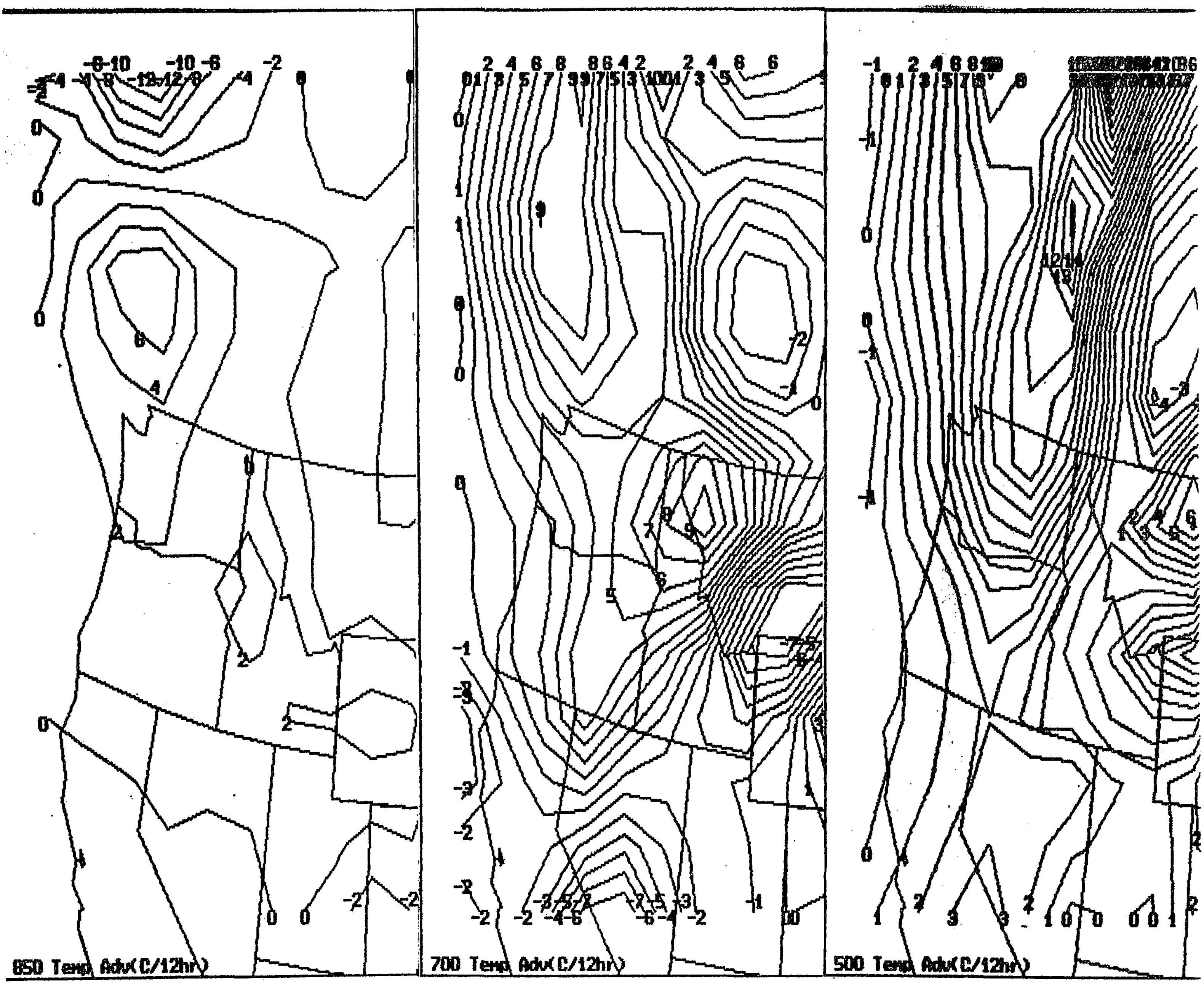

Figure 6. Temperature advection at 850, 700, and 500 mb. Note warm advection over Western Washington.

APPROXIMATE DIVERGENCE OVER WESTERN WASHINGTON

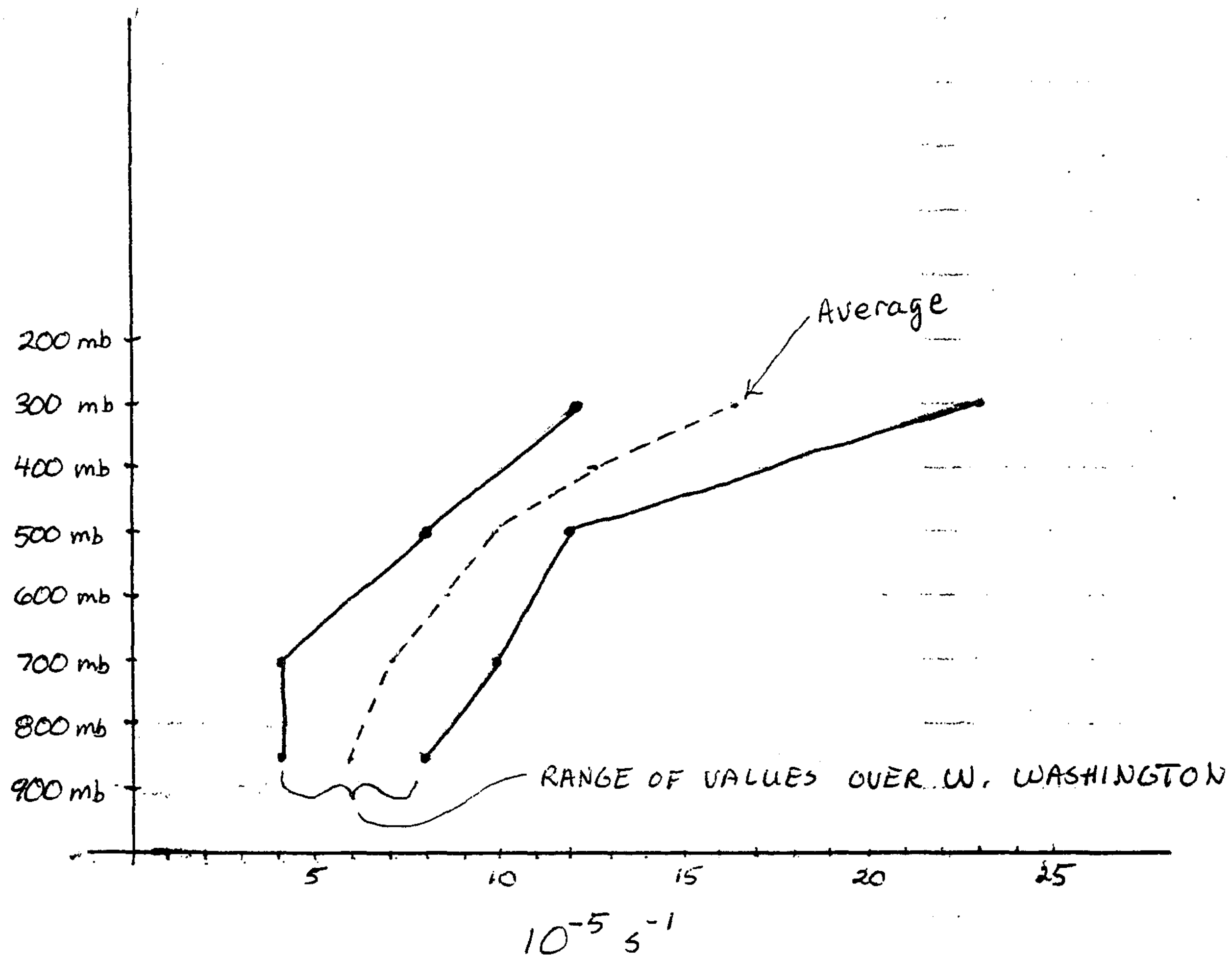

Figure 8.

The average amount of divergence appears to be increasing with height.

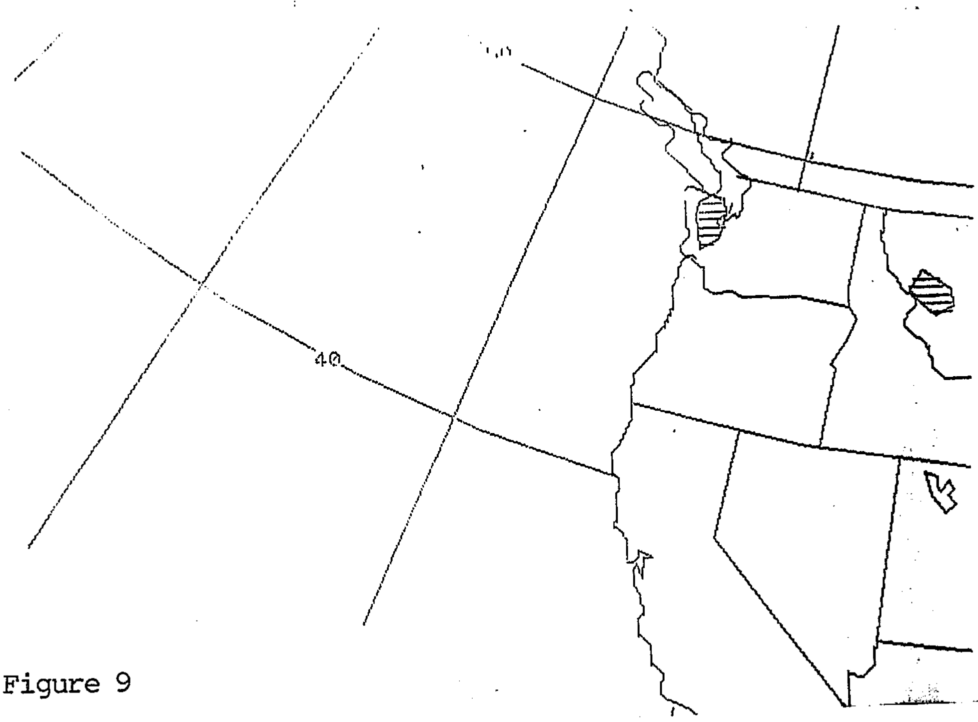

Figure 9

Radar contours around 13Z Thursday December 21, 1989.

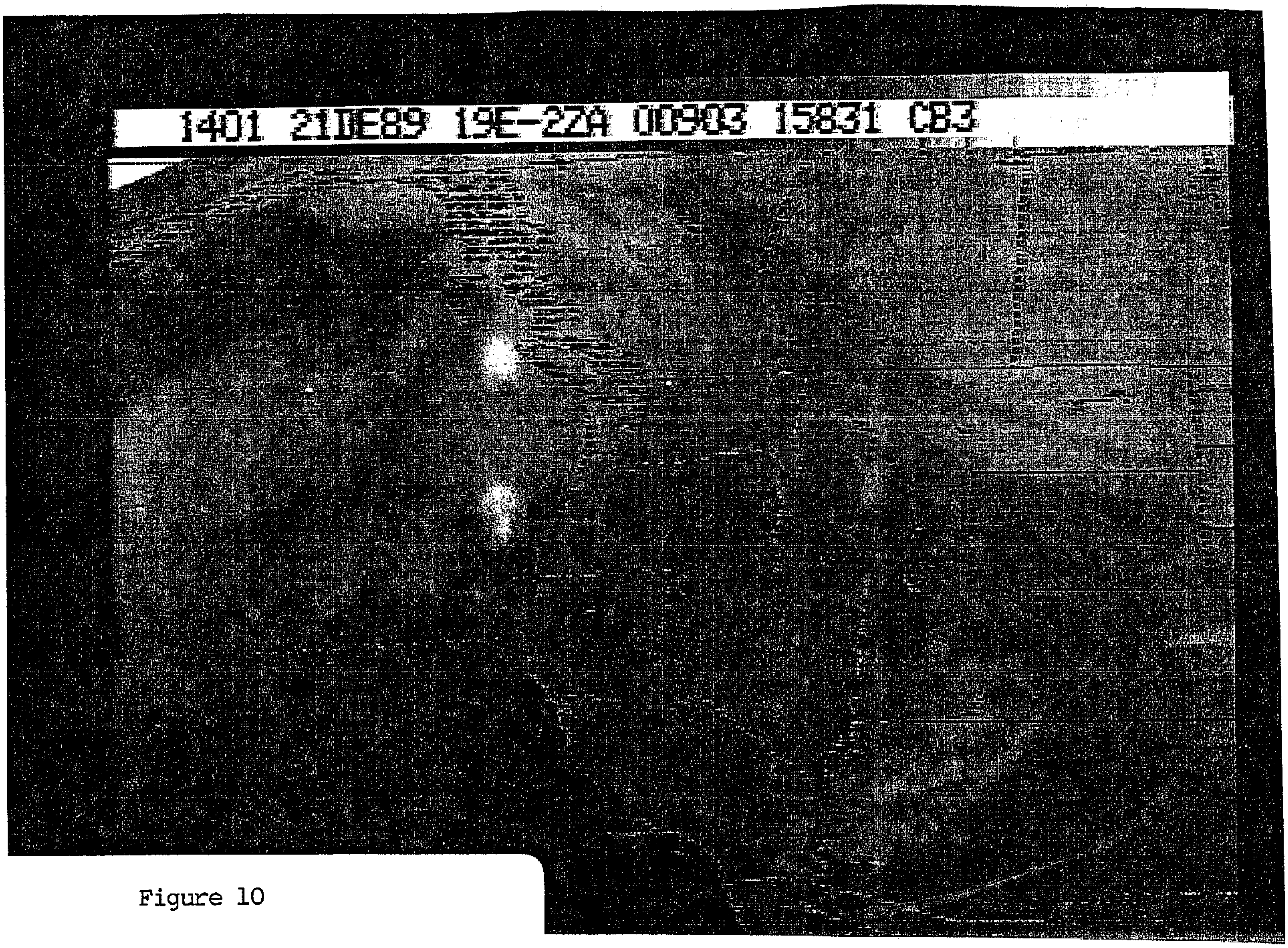

Figure 10