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A COMPARISON OF THE ETA AND THE MESO ETA MODELS DURING THE 11-12 DECEMBER 1995 STORM OF THE DECADE

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Introduction

On 11-12 December 1995, a powerful storm system developed off the West Coast of the United States causing widespread heavy precipitation along with extremely high winds and dangerous surf. The most seriously affected regions were from the central California coast northward to Washington. It was estimated that up to 1.3 million people were without power across portions of central and northern California alone, with more outages across Oregon and Washington. Five people lost their lives in the storm due to trees falling on cars or homes. Rainfall exceeding 10 inches was reported at some locations due to the storm, with many locations reporting three or more inches. Wind gusts of over 100 mph were reported from the central California coast to the Oregon coast with near hurricane force wind gusts commonly reported inland. This Technical Attachment will investigate both the Eta and the Meso Eta models performance of this event to show how the improved resolution, topography and dynamical package in the Meso Eta outperformed the Eta model.

Description of the Models

The Eta model is a hydrostatic model with a horizontal grid spacing of 48 km and a vertical resolution of 38 layers. The Eta model has a comprehensive physical package including parameterizations for radiation, soil, explicit cloud water, and vertical mixing processes. This model is run twice daily at 00Z and 12Z with model forecasts available every 6 hours through 48 hours. More information regarding the Eta model can be found in Black and Messinger (1989).

The Meso Eta model is an enhanced version of the hydrostatic Eta model with a horizontal grid spacing of 29 km and a vertical resolution of 50 layers. The greatest concentration of layers is near sea level and near the mean height of the tropopause. In 1995, the Meso Eta model had a more refined physics package than the 48 km Eta model. This model is run twice daily at 03Z and 15Z. Model forecasts are made at 3 hour intervals and extend out to 33 hours. More detailed information on the Meso Eta can be found in Staudenmaier (1996).

Storm Analysis

The storm of 11-12 December 1995 will be examined in three main areas: precipitation, winds, and its three-dimensional structure. Much of the analysis will be focused on northern California centered around 1200 UTC 12 December, at the height of the storms most widespread damage. Both the 48 km and the 29 km Eta models will be examined to see which model most accurately portrayed the actual environment of the storm. This comparison will show the importance of increased resolution, better model physics, and higher resolvable topography in the 29 km Eta model.

Precipitation

During the period of 0600 to 1200 UTC, 12 December, three main areas of precipitation occurred over northern California. These areas were in the northwest corner of the state, along the Coastal Range Mountains north of San Francisco, and between 3000 and 6000 feet in the Sierra Nevada Mountains (Fig. 1). Figure 2a shows that these areas are also areas of significant topography in northern California. Figures 2b and 2c indicate the model resolvable topography. Clearly one can see that the Meso Eta model has the better representation.

None of the models captured the maximum amounts of precipitation recorded during this period of the storm, when some locations received nearly five inches of rainfall in the six hour period. A comparison of the model solutions showed that the Eta model predicted a broad area of precipitation over the northern portion of the state with the heaviest amounts located along the main gradient of its model topography (Fig. 3a). The Meso Eta, on the other hand, indicated three distinct areas of precipitation which match closely to that which was observed (Fig. 3b). The Meso Eta clearly gave the forecasters a better idea of where heavier precipitation would occur even though amounts were underforecasted.

Wind

By 1200 UTC, strong gusty winds had developed across much of northern California. Along the coast, surface winds were generally from the south-southwest with sustained speeds of 15-25 kt with gusts above 40 kt, however some locations had wind gusts of up to 70 kt. At some of the higher peaks along the coast, winds were gusting to near 90 kt at this time. In the Sacramento Valley, winds were generally from the southeast with sustained winds of 25-30 kt with gusts up 50 kt, however at the northern portion of the valley, the winds were more southerly and stronger with sustained winds of 40-50 kt and gusts of 55-65 kt. In the Sierra Nevada Mountains, winds were generally from the south-southwest with sustained winds of 25-40 kt with some wind gusts near 90 kt.

The Eta model produced near surface (1000 mb) southerly winds of 35-45 kt over much of the northern California coast with slightly weaker winds inland (Fig. 4a). Over the Sierra Nevada Mountains, winds were forecast to be southwesterly at speeds of 35-40 kt. No indication of the strong southeasterly flow over interior portions of California was apparent in the Eta model forecast.

The Meso Eta model produced similar winds along the California coast with speeds of 30-40 kt (Fig. 4b). Winds over the ocean were generally southerly, with winds becoming more southwesterly over the Coastal Range. Inland, southeasterly winds were forecast with speeds of 25-35 kt with some indication of increasing winds at the northern portion of the valley where winds were forecast to be sustained near 45 kt and more southerly in direction. Winds in the Sierra Nevada Mountains were forecast to be southwesterly at 35-45 kt. These winds match the observed surface winds much more closely than those winds forecasted by the Eta model.

Three-dimensional Structure

A cross section of vertical velocities from 39°N 129°W to 39°N 117°W at 1200 UTC in the Eta model indicated a large area of rising motion over much of northern California with a maximum value of 30 microbars/sec centered at around 750 mb (Fig. 5a). Some subsidence was evident over the crest of the Sierra Mountains.

The same cross section in the Meso Eta model indicated much finer detail with two separate vertical velocity centers (Fig. 5b). One center, with a maximum value of 36 microbars/sec, was located over the eastern side of the Coastal Range Mountains at around 840 mb. The other center, with a maximum value of 33 microbars/sec, was located over the western side of the Sierra Nevada Mountains at around 710 mb. Between these two centers of strong vertical motions, an area of subsidence aloft could be seen over the Sacramento Valley. Some indication of stronger vertical velocities along the west side of the Sacramento Valley were also seen. Strong subsidence was occurring over the crest and eastern sides of the Sierra Nevada Mountains with a center of 15 microbars/sec located just above the model surface.

A cross section through the center of the 960 mb low pressure system at 1200 UTC indicated major differences in the depiction of the low in both models. Figure 6a is a north-south oriented cross section through the low center from the Eta model. This figure has little thermodynamic detail associated with the low with just a broad area of unstable air in the theta-e field. The vertical motion field associated with this low is broad and weak with a 4 microbars/sec center of upward motion on the southern end of the storm, and 10 microbars/sec associated with rising motion on the northern side of the low. The model produced some areas of low-level potential vorticity on the northern side of the low pressure system, and a tropopause fold of potential vorticity to the south of the low pressure system. The wind field indicated an upper-level jet near the tropopause fold and a low-level jet of 80 kt could be seen on the southern flank of the storm centered at around 870 mb.

The same cross section in the Meso Eta model showed much more detail in all fields previously mentioned (Fig. 6b). A deep and unstable region over the surface low center could be seen flanked by strong areas of rising motion. Some subsidence could be seen over the surface low, similar to that of a tropical storm. An area of low-level potential vorticity could be seen to the north of the low pressure system, with an additional area located to the south of the storm possibly connected to the tropopause fold aloft. Another tropopause fold could be seen over the surface low, likely contributing to its rapid intensification during the previous 12 hours. The wind field showed somewhat more structure, with the low-level jet of 80 kt located at around 850 mb.

Discussion

Model resolution appeared to play a major role in the correct placement of precipitation and the resolution of wind structure for this case. The Meso Eta predicted the three distinct precipitation maxima much closer to reality than the Eta model, which placed a broad area of precipitation over a large area. Because of a better representation of topography, the Meso Eta was able to make a better precipitation forecast than the Eta model, because of a better representation of the vertical velocity field. The Meso Eta vertical velocity field at 700 mb (Fig. 7b) has much finer structure than the Eta model (Fig. 7a), which can be linked directly to the orographic influence on the vertical velocity pattern. In addition, the Meso Eta also indicated downward vertical motions over the Sacramento Valley (Fig. 5b), likely due to the downward branch of the secondary circulation pattern. It is this subsidence which enhances the minima in precipitation across the Sacramento Valley. The Eta model did not show any indication of this circulation, since it cannot resolve the Central Valley.

The vertical velocity field on this date in the Meso Eta model was enhanced by a low-level convergence zone produced by southeasterly winds in the Sacramento valley impinging on the southwesterly flow located over the Coastal Range. This low-level convergence produced heavier precipitation on the west side of the Sacramento Valley and over the Coastal Range. The development of the southeasterly winds in the Sacramento Valley (Fig. 4b) was enhanced by two processes. Southwesterly flow aloft, blowing over northern California, caused a channeled southerly low-level windflow in the Sacramento Valley to develop. This low-level windflow became southeasterly as a trough of lower pressure formed in the lee of the Coastal Range Mountains, and a ridge of higher pressure developed on the western side of the Sierra Nevada Mountains (Fig. 8b). These sub-synoptic pressure fields were caused by the strong flow aloft over the topography. Because of its lower resolution, the Eta model does not resolve the sub-synoptic pressure features (Fig. 8a) and therefore cannot enhance the winds in the valley, nor make them southeasterly.

The Meso Eta was also far superior to the Eta model in resolving the three-dimensional structure of the cyclone itself. As discussed previously, the Meso Eta was able to resolve finer details in the vertical motion field over the Sacramento Valley, in addition to a much higher details in the moisture and temperature fields. A cross section through the center of the low pressure system over the ocean showed that the Meso Eta had generated a more intense jet around the low center and had a better developed cyclone in terms of the vertical velocity fields, horizontal wind, and theta-e fields. (Figs. 6a,b). In addition, the Meso Eta model was able to generate more low-level potential vorticity than the Eta model. It has been shown that low-level potential vorticity can enhance a cyclone's circulation up to 40 percent (Davis, 1991), which comprises a very important part of the rapid deepening process in a developing cyclone. The Eta model likely cannot generate as much low-level potential vorticity, mainly due to its lower spatial resolution. Because of this lower resolution the model cannot produce strongly packed potential temperature gradients which are important in the development of potential vorticity.

The Eta and the Meso Eta both produced a low-level jet of the same intensity, 80 knots jet at around the 875 mb level, just east of the cyclone over the ocean. However, much more detail was apparent in the Meso Eta in terms of position of the jet and small extensions of the jet along the coastline. Both models tended to have forecast winds of a similar speed and direction over the ocean, but over complex terrain the resolution differences in model terrain made the Meso Eta a much better model to use during this case.

Conclusion

Model output for the 11-12 December 1996 storm over the western United States was examined to investigate the differences between the Eta model and the Meso Eta model. It appears that since the Meso Eta model had better resolution and model physics, it was able to make a better forecast in this case than the Eta model. The Meso Eta was able to resolve the commonly seen lee-side trough over the Coastal Range Mountains, more accurately place precipitation maxima, and create much more realistic low-level wind fields and three-dimensional structure, while the Eta model could not. With its better resolution, it is also possible the Meso Eta may perform better for rapidly developing cyclones since it is better able to generate low-level potential vorticity. In situations where the role of orography is dominant, it appears that the Meso Eta model is a more useful forecasting tool than the lower resolution Eta model. Hopefully this trend will continue with the 10 km Meso Eta model which is currently being developed.

Authors Note

As of January 31, 1996, the Eta model was given the same physical package as the Meso Eta model. However much of the results of this case are likely still valid, as it appears that the higher resolution topography was the most important difference in the models.

Experiments will be run to compare the old Eta physical package with the new and improved package to see just how significant the new physics were during this case.

References

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Davis, C.A., Emanuel, K.A., 1991:Potential Vorticity Diagnostics of Cyclogenesis. *Mon. Wea. Rev.*, **119**, No. 8, 1929-1953.

Staudenmaier, M.J., 1996: A description of the Meso Eta model. WR-Technical Attachment 96-06.

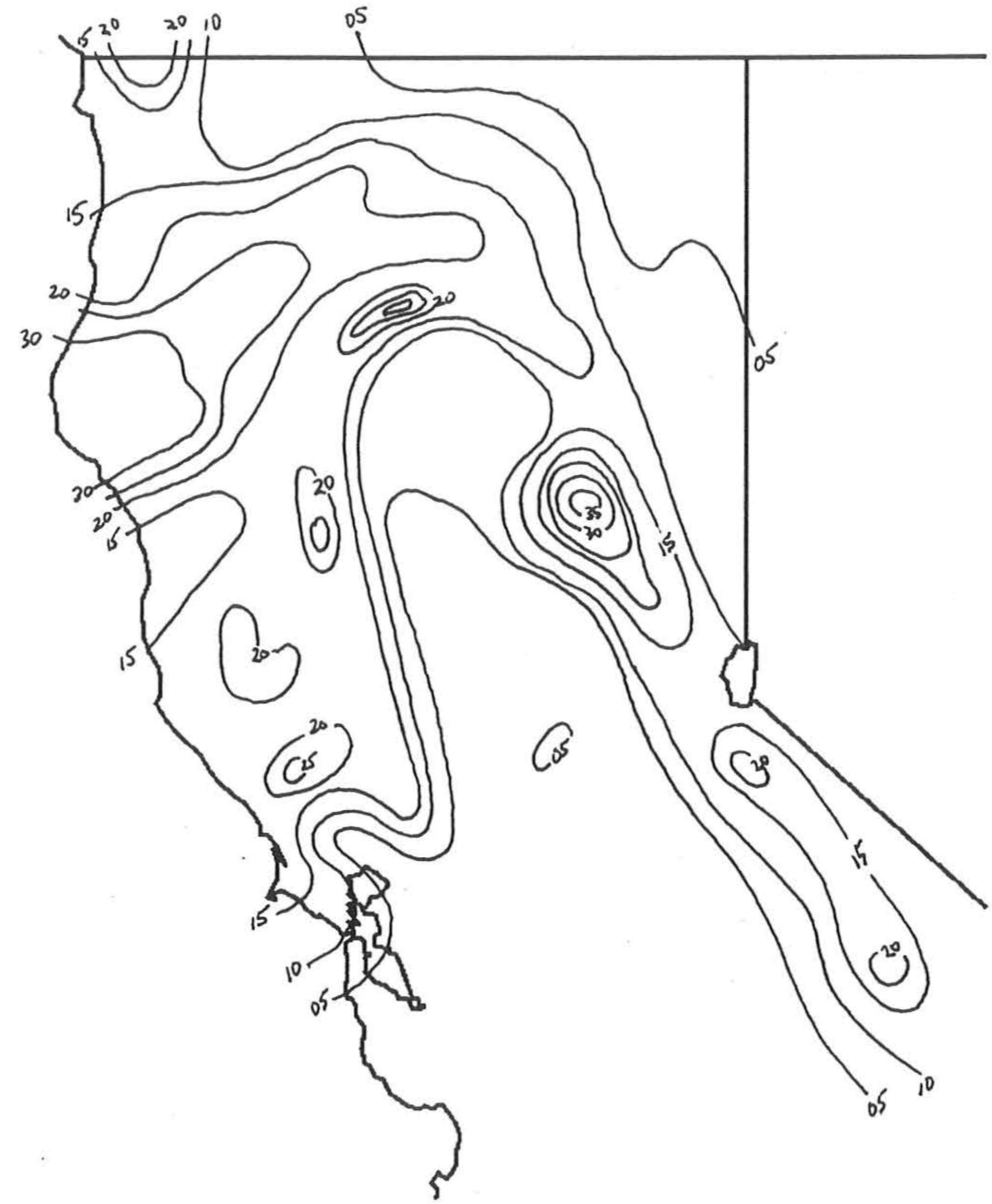

Figure 1. Observed 6 hour accumulated precipitation valid at 1200 UTC 12 December 1995. The contour interval is 0.5 inches.

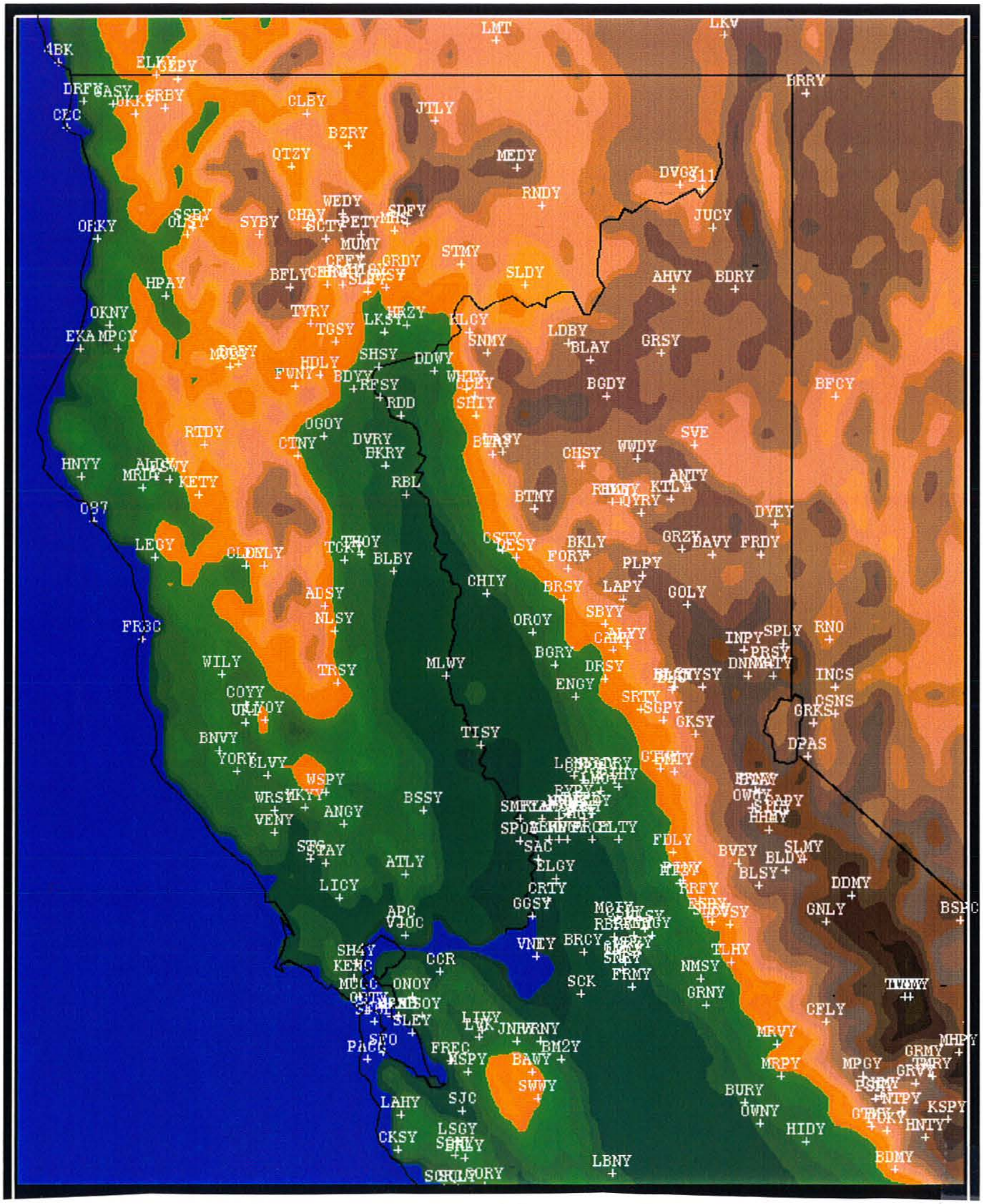

Figure 2a. Topography of Northern California from the University of Utah homepage.

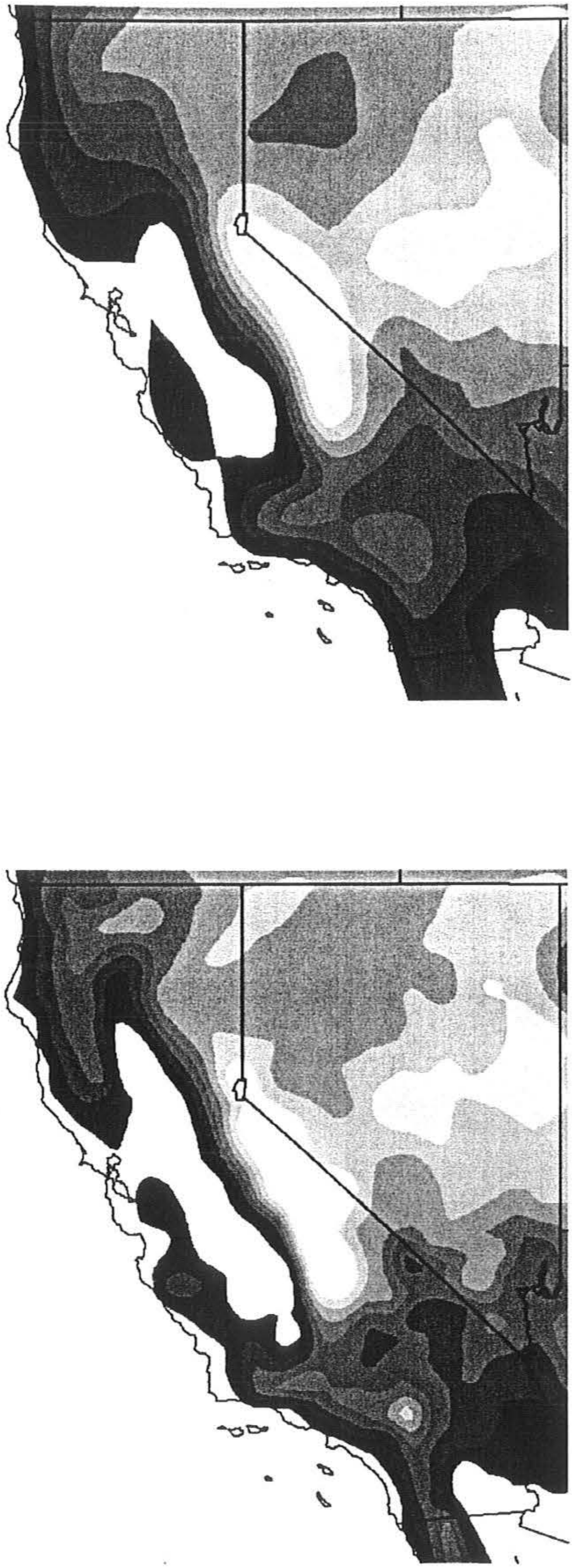

Figure 2b,c. Northern California topography b)Eta model and c)Meso Eta model (in thousands of feet).

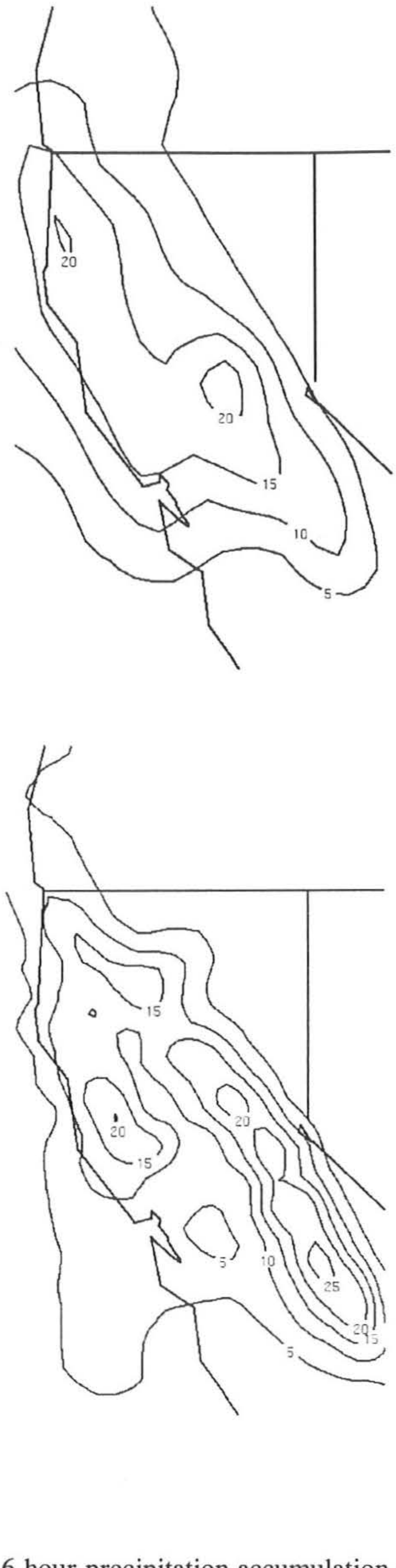

Figure 3. Model predicted 6 hour precipitation accumulation valid at 1200 UTC 12 December 1995 from the a)Eta model and b)Meso Eta model. The contour interval is 0.5 inches (20=2.0 inches).

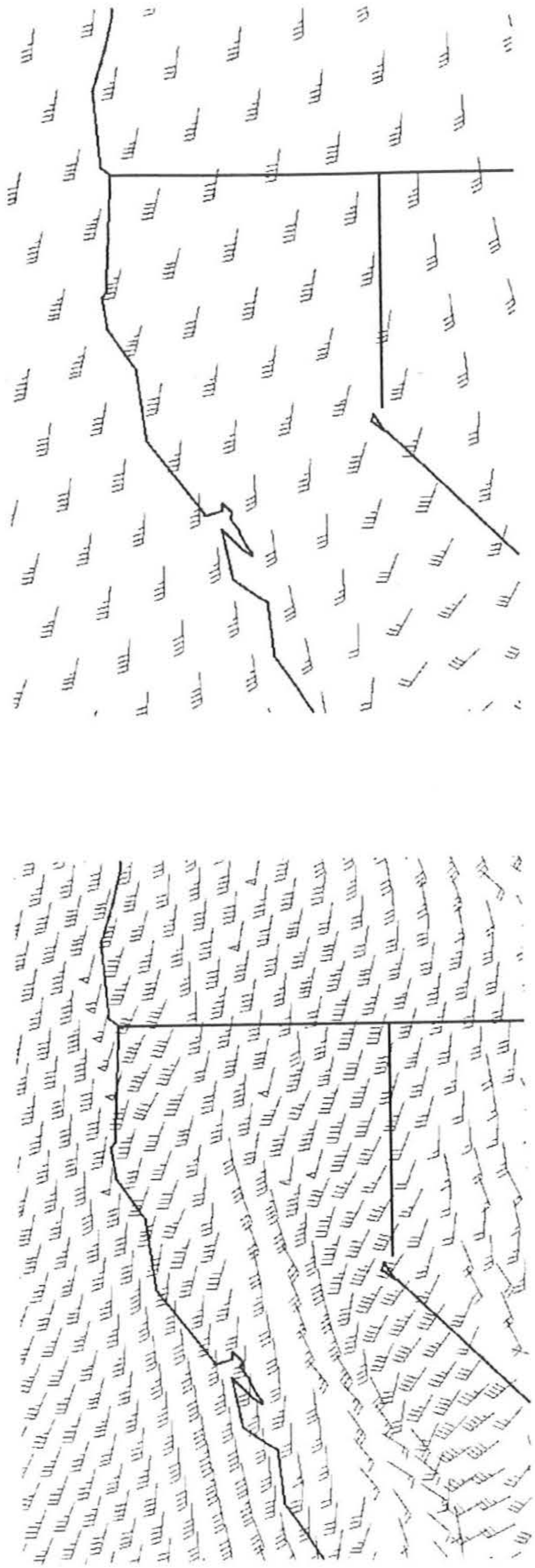

Figure 4. Near surface (1000mb) winds valid at 1200 UTC 12 December 1995 from the a)Eta model and b)Meso Eta model. Wind barbs are in knots.

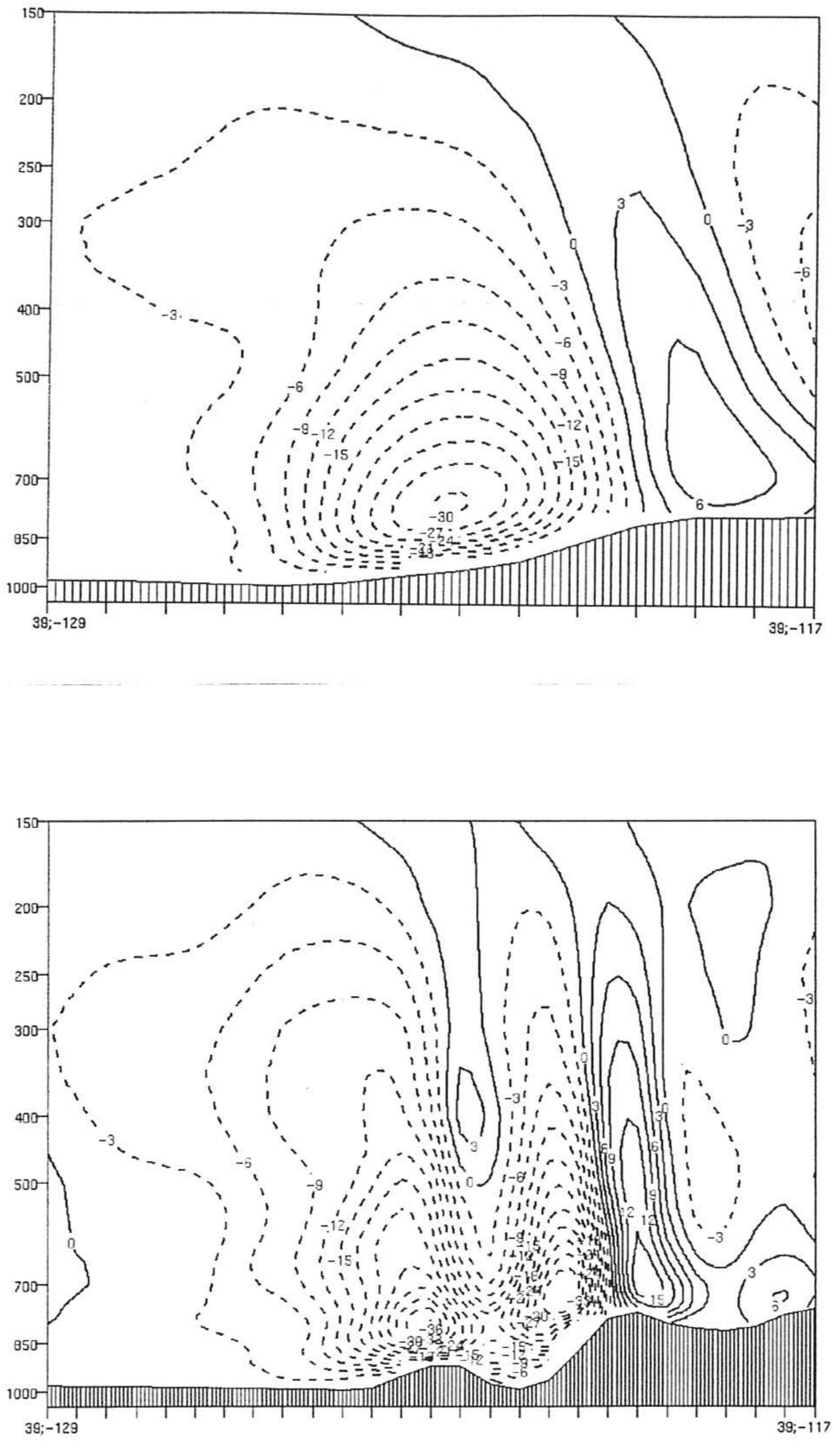

Figure 5. Cross section through the Central Valley of California (39°N, 129°W to 39°N, 117°W) of vertical velocity (microbar/sec) valid at 1200 UTC 12 December 1995 from the a)Eta model and b)Meso Eta model. Dashed contours represent upward vertical motion.

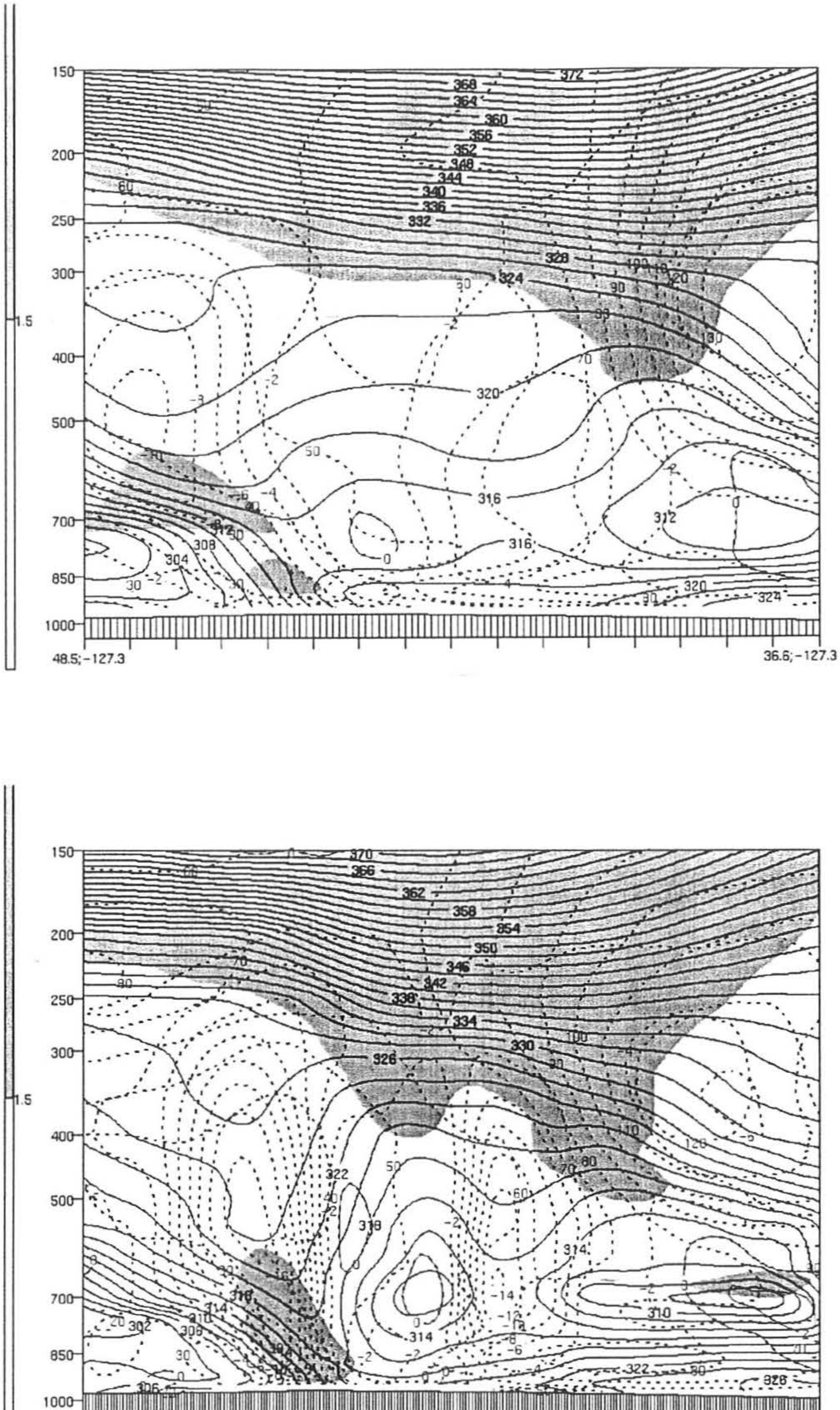

Figure 6.Cross section through the center of the cyclone (48.5°N,127.3°N to 36.6°N, 127.3°N) of potential vorticity greater than 1.5 units (shaded), theta-e (solid black), upward vertical velocity (microbars/sec in dashed blue), and isotachs (kt in dashed pink) valid at 1200 UTC 12 December 1995 from the a)Eta model and b)Meso Eta model.

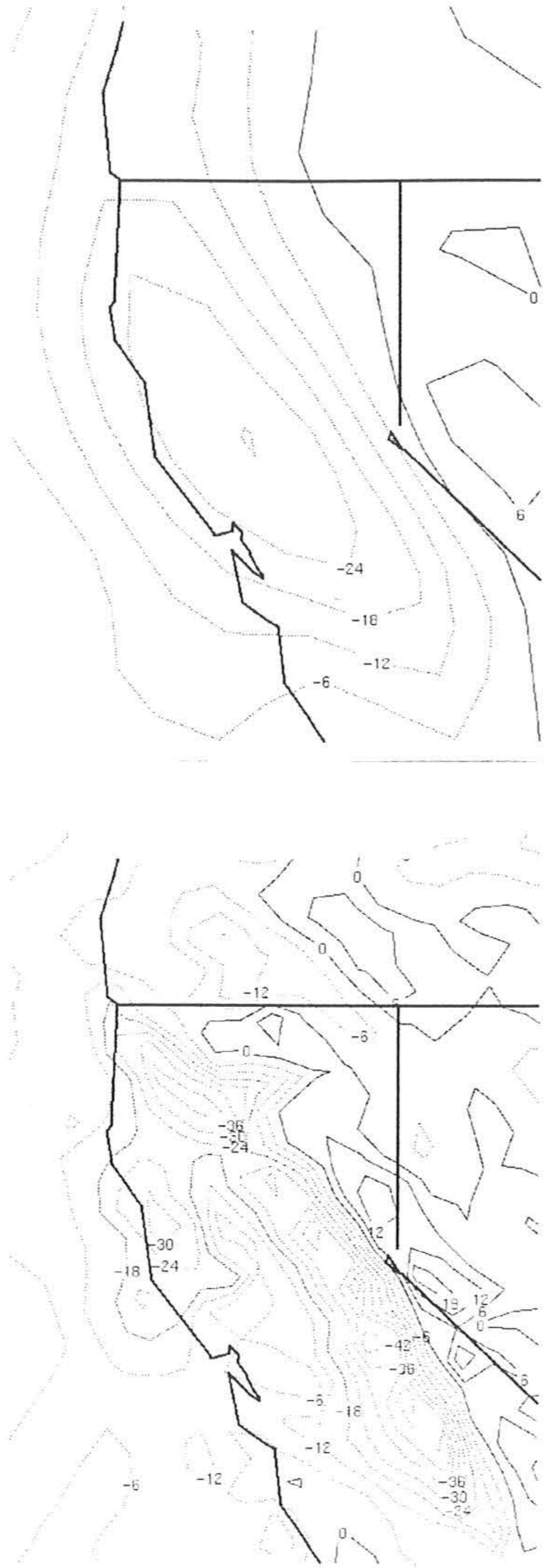

Figure 7. Vertical velocity field (microbars/sec) valid at 1200 UTC 12 December 1995 from the a)Eta model and b)Meso Eta model. Dashed contours represent upward vertical motion.

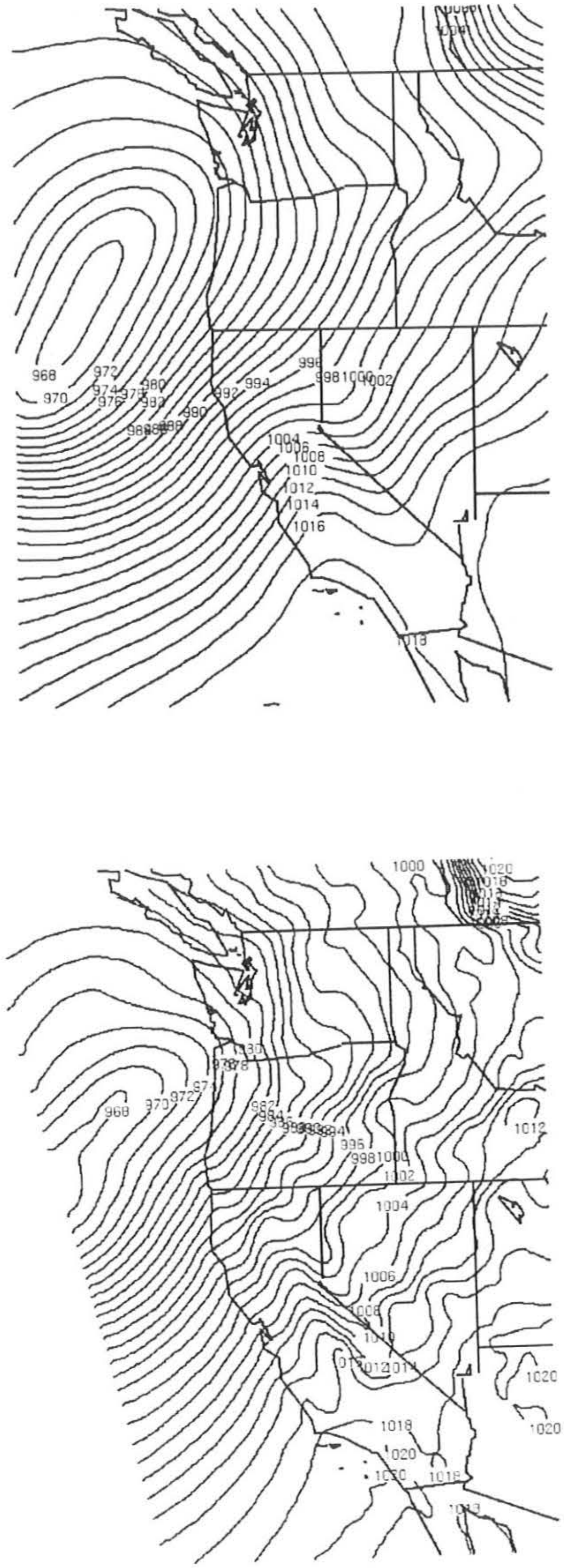

Figure 8.Mean sea-level pressure field valid at 1200 UTC 12 December 1995 from the a)Eta model and b)Meso Eta model. The contour interval is 2 mb.