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RESULTS OF THE WESTERN REGION EVALUATION OF THE ETA-10 MODEL

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Introduction

During the period of January through April 1997, Western Region National Weather Service (WR NWS) participated in a formal evaluation of the experimental Eta-10 model. This model is a higher resolution version of the currently operational Eta-29 model, with similar physics and parameterizations. More information regarding these physics and parameterizations can be found in Staudenmaier, 1996. This evaluation was an important step in preparing for high resolution numerical modeling in the National Weather Service. The National Centers for Environmental Prediction (NCEP) plans to make higher resolution versions of the Eta model operational in the future. In order for the Eta model to run at higher resolution over a national domain, a next generation supercomputer is required. This Technical Attachment summarizes the results which were discovered by the field and relayed to the model developers at the NCEP.

Basis Of The Evaluation

In December of 1996, an evaluation form was designed and sent out to Western Region field offices, in preparation of the evaluation which would begin in early January. The form was designed so that the 'forecast problem of the day' could be investigated to see if the Eta-10 model added any value to the forecast process. The evaluator would write down the investigated phenomena, whether he/she thought the Eta-10 should capture the event and why, and then verified what impact the model output had on the overall forecast of the event. Through the four months of the evaluation, 104 distinct phenomena were investigated by Western Region.

Summary Of The Results

As with any evaluation, results were mixed, with some evaluations showing significant skill with the Eta-10 model, and other results showing potential problems with the model. This section will discuss the main points of the evaluations, broken down into positive and negative results. The Eta-10 model was compared only against other operational numerical guidance, not against any locally run mesoscale models.

Positive Results

The Eta-10 model appears to do better than the operational numerical models with arctic air masses, delineating which valleys they will move into and the timing of their movement. This is likely due to the better representation of topography and the increased vertical resolution. For example, Fig. 1a shows an arctic front that was correctly blocked from entering western Montana in the Eta-10 simulation. This blockage did not occur in the Eta-29 (Fig. 1b), nor in any other NCEP model.

Rainfall is better delineated, especially in areas with orography. Rain shadows now occur due to downslope flow over single mountains, as opposed to only occurring in the lee of entire mountain ranges. Bull's-eyes of precipitation are much better placed on mountain slopes when compared with reality. Figure 2 compares Eta-10 three-hour accumulated precipitation with observed six-hour accumulated precipitation valid over northern California. Note that many of the Eta-10 maxima line up with locations of heaviest observed precipitation.

The Eta-10 model generally does a better job delineating winds in larger valleys and near the coastline, where the better resolved topography plays an important role. Some of this improvement near the coastline may be due to the higher vertical resolution of the model near sea level.

The Eta-10 model does well with moisture which tends to get trapped on mountain slopes by mountain ranges. This shows up best in the explicit cloud scheme which is incorporated in the model. The Eta models are the only models with an explicit cloud scheme, so only direct comparisons between differing resolutions of the Eta models are possible. However, based on relative humidity from other numerical models, it can be seen that the Eta-10 is the only model to consistently trap moisture against mountain ranges. With the explicit cloud scheme in the Eta model, forecasters have, for the first time, the opportunity to see model-derived clouds, as opposed to inferring them from planer views of relative humidity. Figure 3 shows a low-level cloud fraction field derived from the explicit Eta-10 forecast of cloud water and ice. Low clouds are trapped against the model terrain in northern Arizona.

The 2-meter temperatures in the Eta-10 model are generally more accurate than at 29 km resolution. This is especially true near coastal areas, where the higher vertical resolution has much more impact on the derivation of 2-meter fields. However, the cold bias over the Intermountain Region, which was noted in the Eta-29 model, continues in the Eta-10 model.

The Eta-10 model often shows precipitation in much more realistic looking structures, like banding, than is seen in other operational numerical models. This may be due to the higher horizontal/vertical resolutions, and a better representation of topographical influences on the synoptic pattern.

The Eta-10 model develops accurate looking lee-side pressure troughs (and windward pressure ridges) along mountain ranges, as demonstrated by Fig. 4. Mesoscale detail can be seen in the ridge-trough patterns located over the Coastal Range Mountains and the Sierra Nevada Mountains (terrain not shown). These types of features have a positive impact on low-level wind fields, and the location of orographically forced precipitation maxima and minima. Additionally, some field stations have noted that pressure gradients appear to be much more realistic, and are now useful for forecasting such phenomena as gap flow through the Columbia River Basin, Sundowner Winds, and Santa Ana events.

The Eta-10 model has much more detail in convectively significant fields, like low-level helicity, and CAPE. The convective parameterization, with the new changes made a few months ago, seems to be working better, with convection now occurring over higher topography. This change will be made in the other versions of the Eta model in the future.

Additionally, the Eta-10 model is showing forecasters many more 'mesoscale' details than previously possible. Some examples are:

1) The Catalina Eddy off the coast of Los Angeles (Fig. 5)
2) The Snake River Valley Convergence Zone
3) Mountain-valley wind regimes (upslope/downslope)
4) Coastal stratus near Los Angeles

Overall, the Eta-10 model appears to have made a positive impact on the overall forecast process at many offices in the Western Region. This was especially true after the model, which originally ran in the 0900 UTC time frame, was moved to a more convenient 0300 UTC time frame. This allowed output to reach the field forecasters before the early morning forecast package was complete, giving them an additional look at mesoscale detail for day 1. However, based on the evaluations, some problems with the Eta-10 model also appeared. These will be discussed in the following section.

Negative Results

It appears that precipitation falls too far down on mountain slopes, or over mountain valleys, as opposed to reality. In some extreme cases, no precipitation falls on or near the mountain crests, and 'holes' appear in the 3-hour precipitation output fields where significant topography exists. In Fig. 6b, several precipitation maxima are evident along mountain slopes adjacent to precipitation minima over mountain peaks, .e.g. over the Uintah Mountains of northeast Utah.

The Eta-10, along with the Eta model in general, appears to be too aggressive in producing precipitation in warm-air advection cases. This appears to be even more of a problem with the higher resolution and the better representation of topography in the Eta-10 model.

The low-level winds are typically too light, especially inland. This could be due to the fact that as one goes higher in the model atmosphere, the vertical layers thicken. The calculation of the low-level winds, especially the 10-meter winds, is dependent on the thickness of the model layer at that point.

Although the 2-meter temperatures are generally more accurate in the Eta-10 model, they are still too cold on average, especially inland. Again, this appears to be due to the thicker model layers which occur as one goes higher in the atmosphere, and the way that 2-meter variables are defined.

Due to the way the cloud model is initialized (with zero values in the Eta-29), the clouds can be inconsistent with resolution of the Eta-10, allowing for a major shift in the 'look' of the field by three hours into the integration. This is probably true with many fields in the model, but is most apparent in the cloud field, as entire shields of clouds may disappear as the model adjusts to the new topography and vertical motions.

There seems to be some discrepancy between the cloud model and the location of precipitation. On some occasions, moderate to heavy precipitation falls with cloud model percentages below 50%. An example is evident in Fig. 6 along the Utah/Nevada border. Also, since the cloud model is not tied to the convective parameterization, you can have heavy convective precipitation, with little or no clouds apparent.

There appears to be a problem with momentum transfer along mountain slopes in the model. High winds associated with mountain waves do not occur in the model. Figure 7 compares Eta-10 and MM5 simulations for a mountain wave event west of the Wasatch Front in northern Utah. The Eta-10 model produces strong subsidence, yet little momentum is transferred downward, and theta surfaces remain flat. MM5 simulations of similar resolution clearly developed classic mountain waves in the two cases which were rerun (for example, Fig. 7b).

Land-sea interactions around the Great Salt Lake are not modeled correctly by the model. Even though a tight gradient of temperature can develop around the Great Salt Lake, the wind field does not respond to it. The expected convergence at night and divergence during the daytime, that is seen in reality, is not evident in the model.

Conclusions

Based on four months of input from Western Region, through a formal evaluation period which ran from January through April 1997, it was found that the Eta-10 model in general did add detail to the forecast process. Some problems were discovered with the Eta-10 model, especially in boundary layer processes. Many of these problems are likely occurring in the other courser resolutions of the Eta model, but have only been discovered now that higher resolution makes looking at the boundary layer fields a viable option. Clearly, even with these problems, the Eta-10 model has lived up to its expectation to produce superior forecasts with sub-synoptic detail. Perhaps it doesn't capture all the mesoscale events that one could expect from a model of its resolution, but it still represents a huge step forward in numerical modeling--to generate operational mesoscale forecasts across a large domain on a daily basis. This experiment has demonstrated the ability of the NWS to produce quality numerical guidance at higher resolutions. These results underscore the need for a next generation supercomputer that will allow higher resolution model runs to become operational across the United States.

Acknowledgments

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References

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

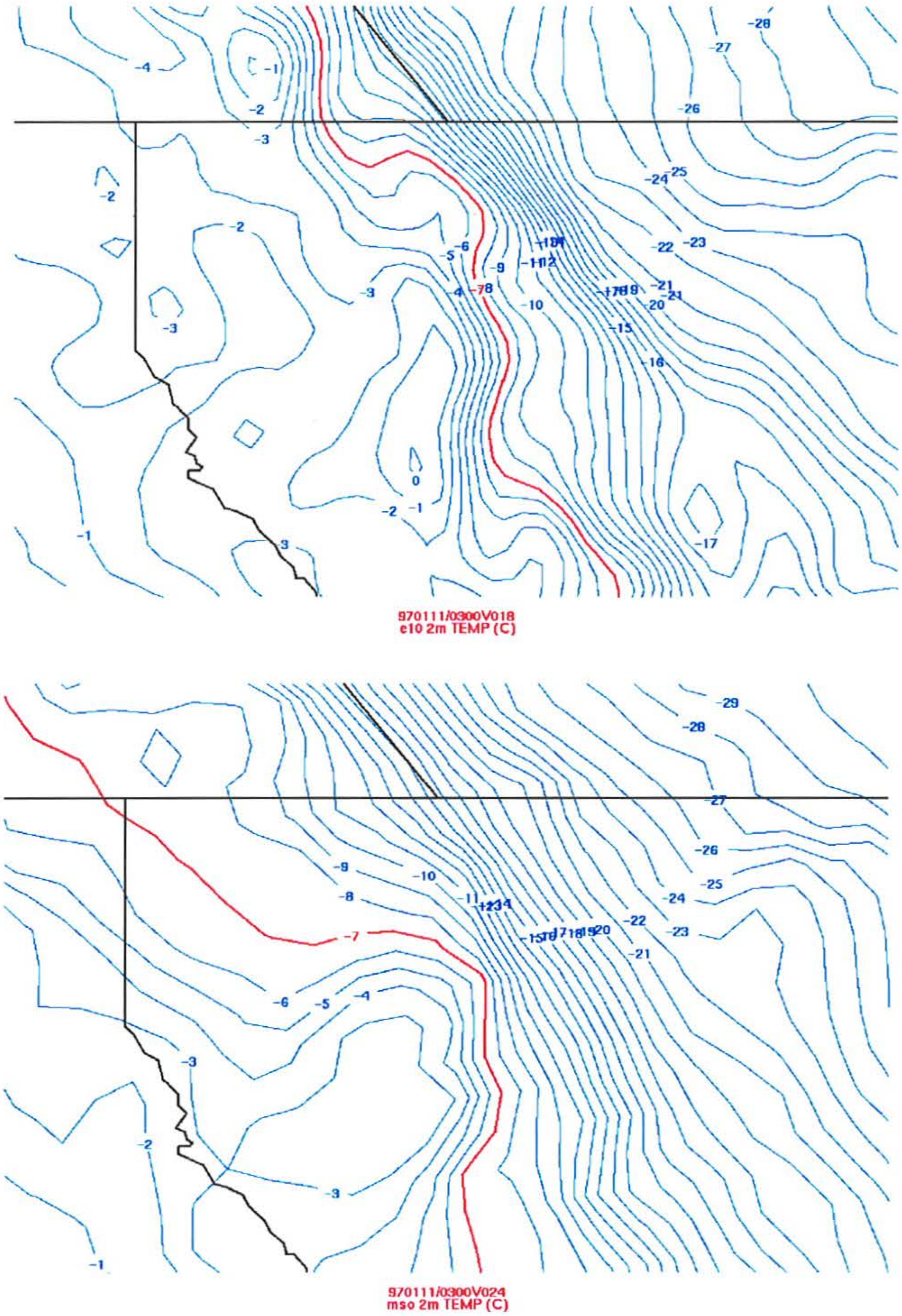

Figure 1.
Two meter Temperature from the Eta-10 (upper panel) and Eta-29 (lower panel). The contour interval is 1°C. The -7°C isotherm is colored red. State outlines are black. The area shown is northern Idaho and northern Montana.

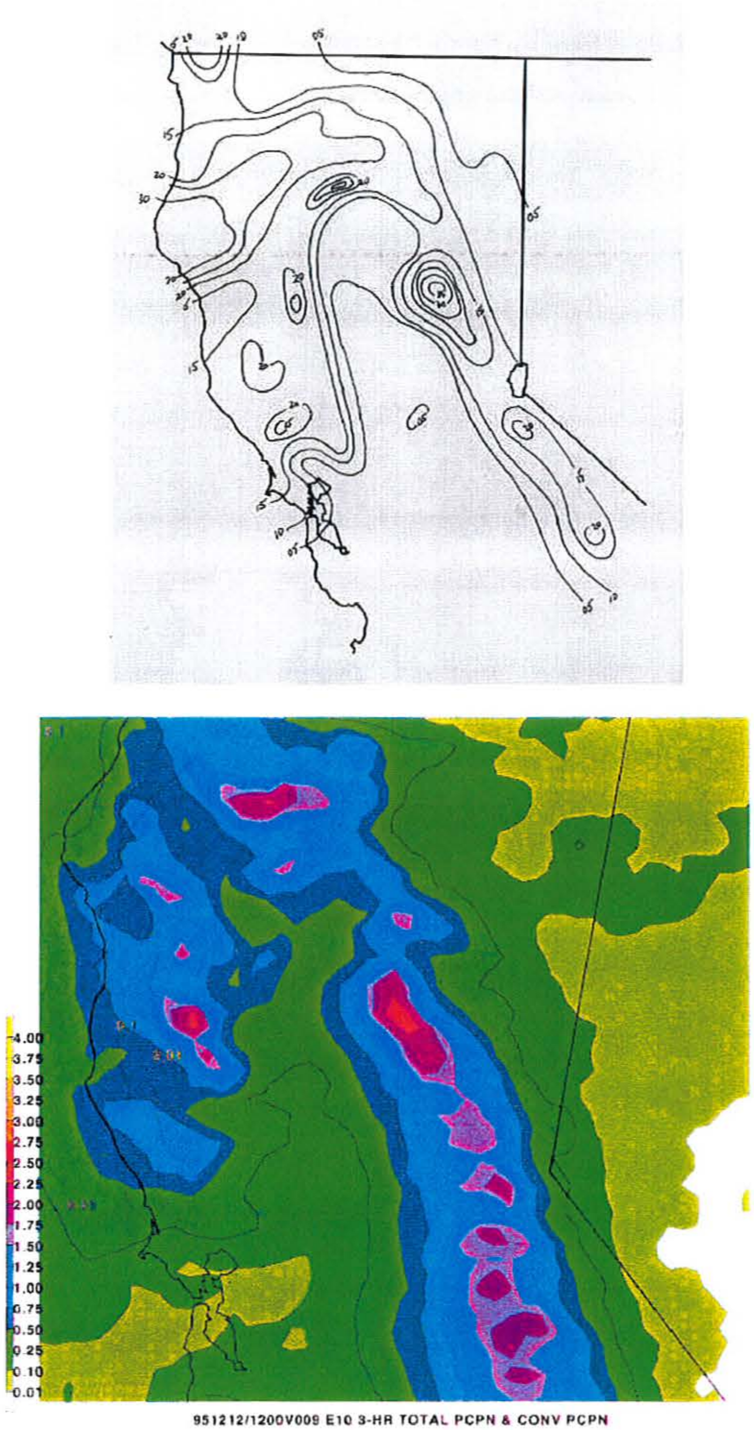

Figure 2.
Accumulated precipitation values for northern California valid 12 December 95 1200 UTC. Upper panel shows observed six-hour precipitation amounts with a contour interval of 0.5 inches. Lower panel shows the three-hour precipitation forecast from the Eta-10 model with fill intervals shown by the color scale.

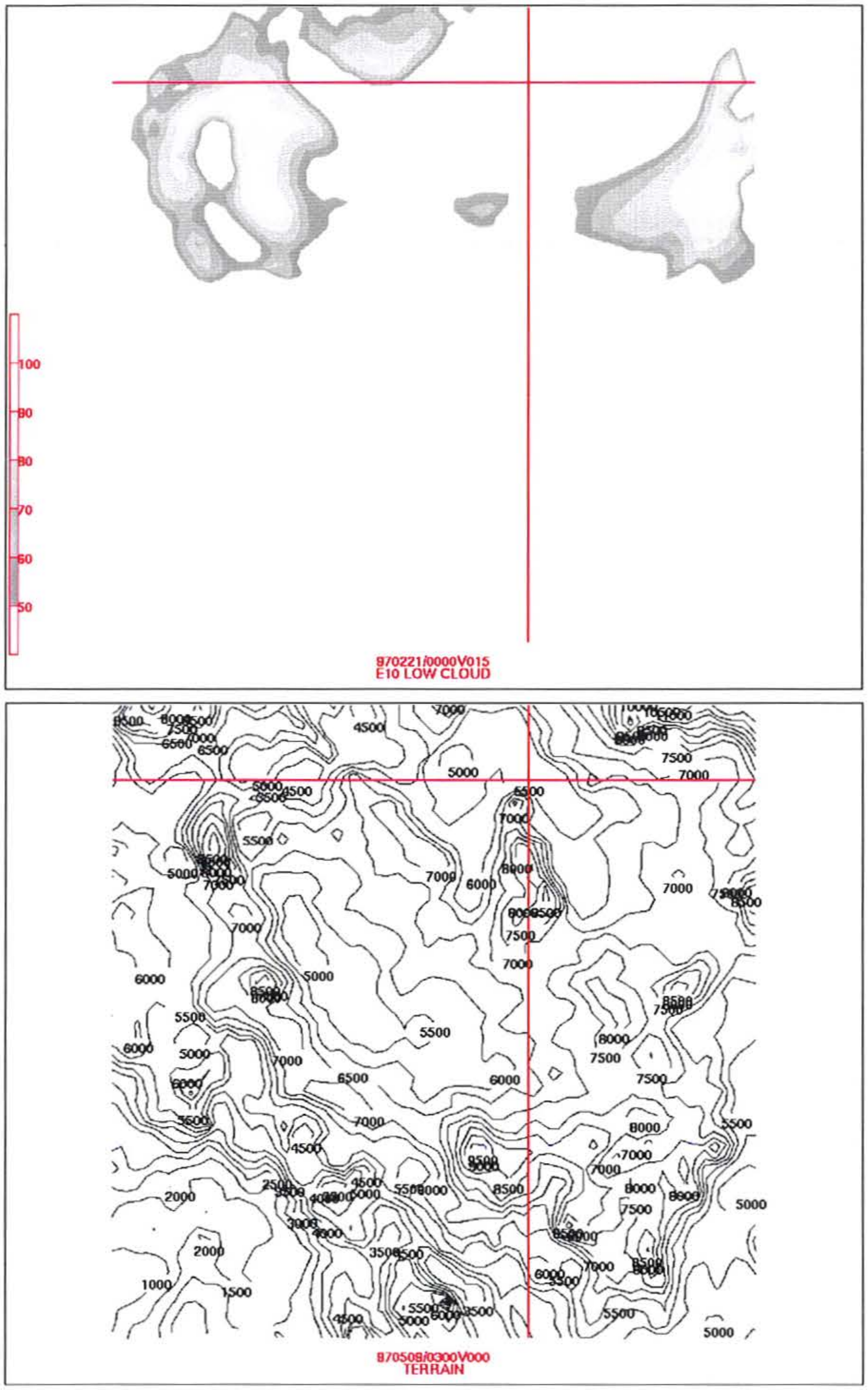

Figure 3.
Upper panel is Eta-10 low-level cloud fraction field. Values represent percentages of sky obscuration. Fill values are indicated by the color scale. Lower panel is Eta-10 terrain for the same area. The contour interval is 500 feet. The red lines are state boundaries and cross at the Four Corners.

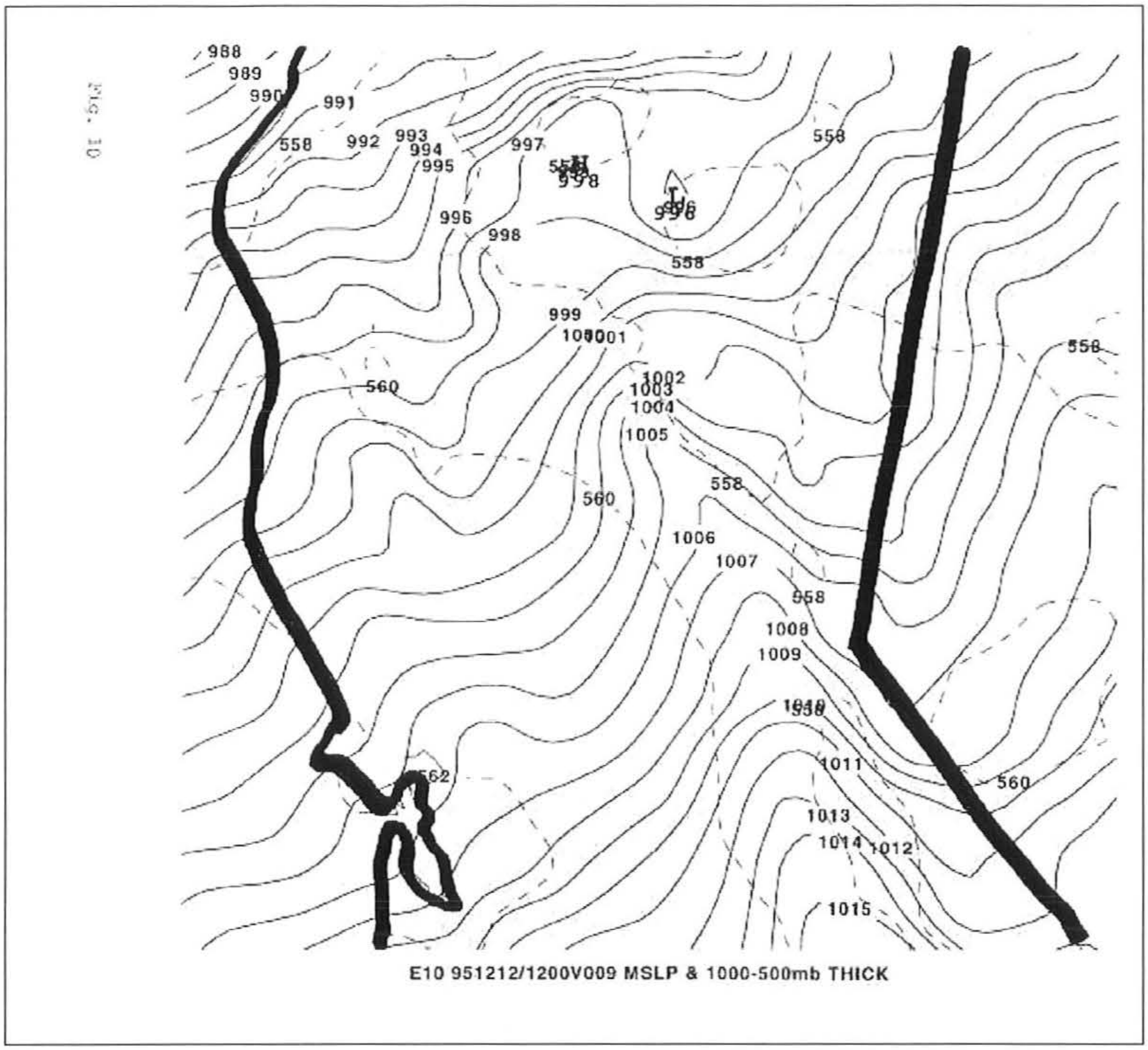

Figure 4.
Solid contours show Eta-10 Mean Sea-Level Pressure over northern California. The contour interval is 1 mb. Dashed lines show 1000-500 mb Thickness with contour interval 20 meters.

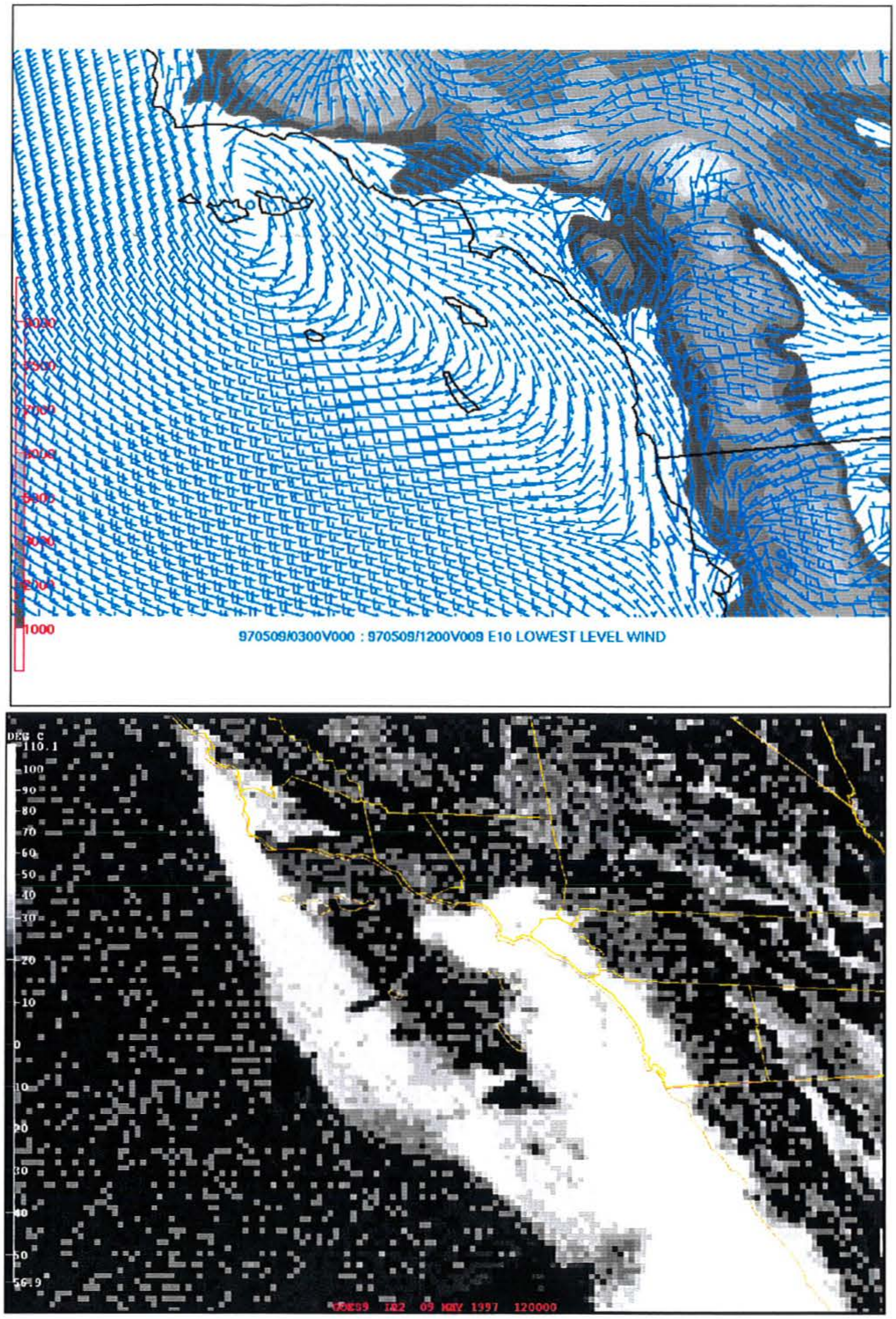

Figure 5.
(a) Upper Panel: Eta-10 Terrain and 9-hour forecast of Low-level Wind valid at 1200 UTC 09 May 97. (b) Lower Panel: GOES-9 Fog/Stratus Product valid at the same time. White shading indicates fog and/or low-level stratus.

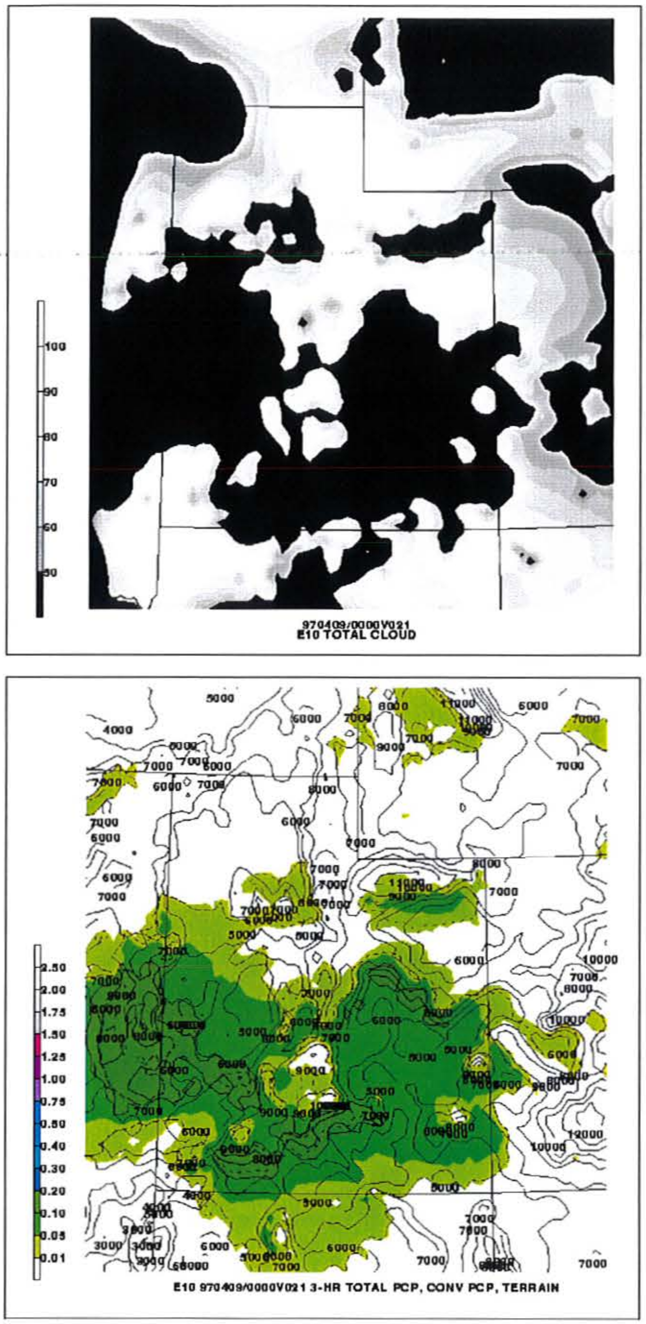

Figure 6.
Eta-10 21-hour forecasts valid at 0000 UTC 09 Apr 97.
(a) Upper Panel. Total Cloud-Fraction Field. Values represent percentage of sky obscuration as indicated by color scale. (b) Lower Panel. Eta-10 3-hour accumulated precipitation and terrain. Dashed lines show convective precipitation (1st contour is .01 inches, 2nd is .1 inches). Solid lines show model terrain with contour interval 1,000 ft. Filled areas indicate grid-scale precipitation with values in inches as indicated by color scale.

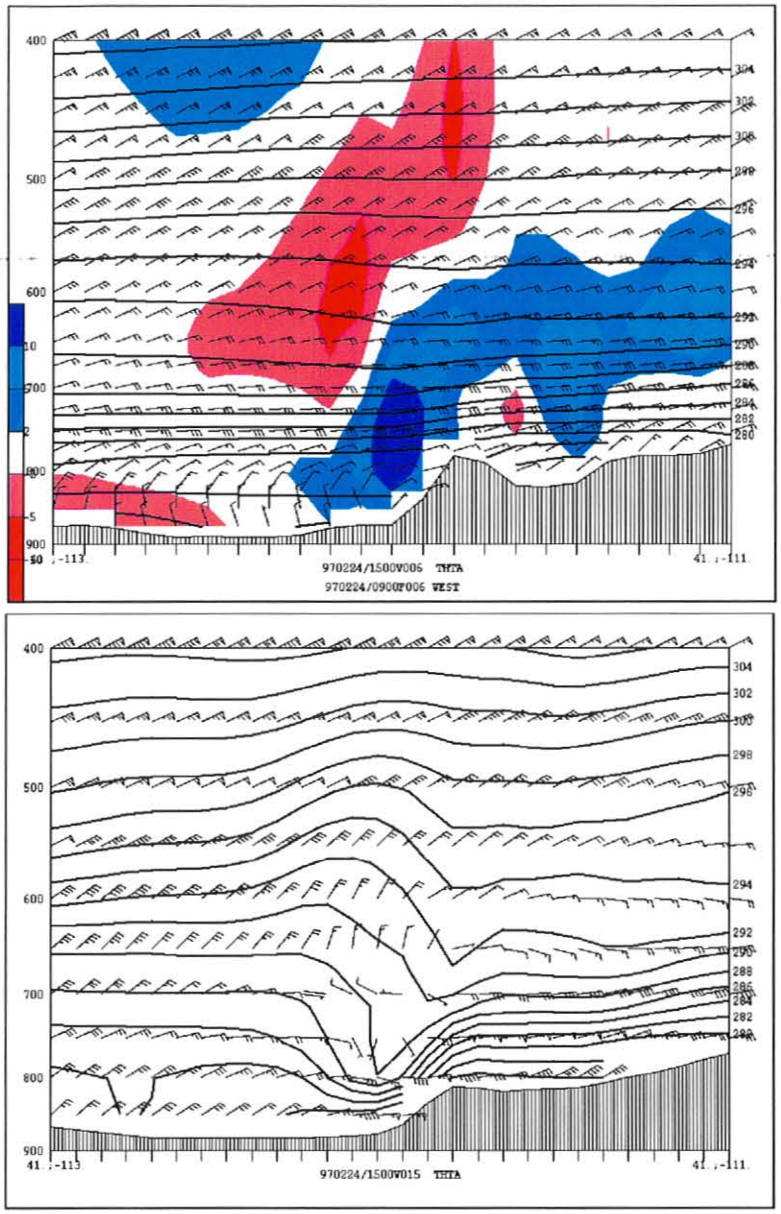

Figure 7.
Cross Sections along 41N cutting across the Wasatch Front of northern Utah valid at 1500 UTC 24 Feb 97. Black lines are Potential Temperature. Wind barbs indicate speed in knots. (a) upper panel: Eta-10. Also shown are filled values of omega as indicated by color scale. (b) lower panel: hydrostatic 6km MM5 run at the University of Utah by Jim Steenburgh.