WESTERN REGION TECHNICAL ATTACHMENT
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AN OUTSTANDING PERFORMANCE BY THE ETA-10 FOR THE SOUTHERN CALIFORNIA STORM OF 23 FEBRUARY 1998

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ABSTRACT

Numerical models have tended to underforecast amounts and mislocate maxima of winter season precipitation in areas of complex terrain due to poor representation of terrain. For the operational versions of the Eta model, gradual increases in resolution have resulted in steady, but mostly unspectacular improvements in quantitative precipitation forecasts (QPF) for Southern California. This has been due to the failure of the models to adequately depict the detail present in the terrain of Southern California. The Eta-10 is the first version of the Eta model to come close to capturing the detail evident in the terrain of Southern California. This much improved representation of terrain has allowed the Eta-10 to make dramatic improvements in winter season model QPF in Southern California.

Introduction

Increases in the vertical and horizontal resolution of the operational Eta model have resulted in steady improvement in both amounts forecast and location of maxima for winter-season precipitation in Southern California. The storm on the 23rd and 24th of February 1998 produced peak rainfall exceeding 14 inches in 30 hours in the mountains of Southern California (Fig. 1) with peak 6-hourly amounts exceeding 5 inches. For this event, model QPF will be compared for the AVN and Eta-32 runs from 00Z on the 23rd and for the Eta-29 and nested Eta-10 runs from 03Z on the 23rd. Table 2 contains a comparison of the details of each model. It should be noted that the domain of the Eta-10 for the period of this study was smaller than the domain used during the Western Region evaluation of the Eta-10 in 1997.

Model	Vertical Resolution	Horizontal Resolution	Domain
AVN	26 layers	T126	Global
Eta-32	45 layers	32 km	North America
Eta-29	50 layers	29 km	Reduced North America
Eta-10	60 layers	10 km	Nested California

Table 2 - Overview of model characteristics

Synoptic Overview

A closed upper low over the eastern Pacific Ocean, off the northern California coast at 12Z on the 23rd, progressed slowly southeastward with the upper low passing across Southern California on the 24th (Fig. 3). A subtropical moisture connection, with values exceeding 0.75 inch, was directed into Southern California from the southwest. Divergence associated with the right rear entrance region to a 120 knot upper jet streak helped to enhance large-scale lift over Southern California from 12Z on the 23rd through 00Z on the 24th. From 00Z to 12Z on the 24th, the axis of subtropical moisture and zone of enhanced large-scale lift associated with the jet streak moved eastward to a position along the lower Colorado River Valley. This synoptic pattern resulted in strong orographic upslope flow along the south-facing slopes in Southern California. This was well depicted by the Eta-10 forecasts of 1000 mb wind, orographic vertical motion computed from the flow of the 1000 mb wind along the model terrain field, and 850 mb relative humidity for 12Z on the 23rd through 00Z on the 24th . Maximum orographic uplift exceeded 100 $\mu b\, s^{-1}$ along the coastal slopes of the San Gabriel Mountains in eastern Los Angeles County from 18Z on the 23rd through 00Z on the 24th (Fig. 4).

Observed Rainfall

For the 30-hour period from 06Z on the 23rd to 12Z on the 24th, all of Los Angeles and Ventura Counties and all but northwest Santa Barbara County received more than one inch of rainfall (Fig. 1). A large axis of rainfall exceeding 5 inches for the 30-hour period extended eastward from southeastern Santa Barbara County across the mountains of Ventura County into the eastern San Gabriel Mountains of Los Angeles County. During this 30-hour period, peak amounts exceeded 8 inches in Santa Barbara and Ventura Counties and 14 inches in Los Angeles County.

Amounts for two 6-hour periods were examined in greater detail. For the period from 12Z to 18Z on the 23rd (Fig. 5), peak amounts exceeding 4.5 inches were observed in the Santa Ynez Valley of Santa Barbara County, immediately downwind of the Santa Ynez Mountains, and in the mountains of Ventura and Los Angeles Counties. For the period from 18Z on the 23rd to 00Z on the 24th (Fig. 6), peak amounts exceeding 5 inches were observed in the San Gabriel Mountains of Los Angeles County with peak amounts exceeding 3 inches in the mountains of Ventura County.

Model QPF

Model QPF for the 30-hour period from 06Z on the 23rd to 12Z on the 24th varied widely. The AVN (Fig. 7) had a single circular maximum of 1.50 to 1.75 inches over central California. This maximum extended into the northern two-thirds of Los Angeles and Ventura Counties and northeastern Santa Barbara County. The Eta-32 (Fig. 8) had an elongated west-east maxima across Southern California from Santa Barbara County eastward across Ventura and Los Angeles Counties to southwestern San Bernardino County. Peak forecast amounts in this axis were 3.0 to 3.25 inches across the southern third of Los Angeles County. The Eta-29 (Fig. 9) was similar to the Eta-32, except with forecast maxima of 4 to 4.5 inches in southern Ventura County and 3.5 to 4 inches in southern Los Angeles County. Terrain contours for the Eta-29 interpolated to a 40 km display grid were overlayed on this image.

For the Eta-10, the last three hours of the 30-hour period - from 09Z to 12Z on the 24th - were not available. The Eta-10 QPF (Fig. 10) for the 27-hour period from 06Z on the 23rd to 09Z on the 24th had greater amounts and more detail than any of the other models. Terrain contours for the Eta-10 were overlayed on this image. The Eta-10 had an elongated west-east maxima of amounts greater than 3.5 inches from southeastern Santa Barbara County eastward across the mountains of Ventura and Los Angeles Counties, into the mountains of southwestern San Bernardino County. Peak forecast amounts in this axis exceeded 5 inches in Santa Barbara County, 5.5 inches in Ventura County, and 8 inches in Los Angeles County. Though the peak amounts were still underforecast by the Eta-10 by about 30 percent, the Eta-10 was able to accurately forecast the locations of precipitation maxima. This was a substantial improvement over the next best forecast, the forecast of the Eta-29. The corresponding 27-hour forecast for the Eta-29 (Fig. 11) is shown for comparison.

Model QPF for Two 6-Hour Periods

Six-hourly QPF for the Eta-29 and Eta-10 were compared for the two 6-hour periods of peak precipitation, 12Z to 18Z on the 23rd (Fig. 5) and 18Z on the 23rd to 00Z on the 24th (Fig. 6). For the period from 12Z to 18Z on the 23rd, maxima exceeding 2.5 inches were observed over southeastern Santa Barbara County, across the mountains of Ventura County, and across the San Gabriel Mountains in eastern Los Angeles County. During this period, peak amounts exceeded 4.5 inches were observed in each of the three counties. The Eta-10 (Fig. 12) accurately delineated these two maxima with forecast peak amounts in the western maxima of 1.75 to 2 inches in western Ventura County and 1 to 1.25 inches in the eastern maxima in Los Angeles County. The corresponding Eta-29 forecast (Fig. 13) had a single maxima with peak amounts of 1 to 1.25 inches across the Ventura County coastal plain.

For the period from 18Z on the 23rd to 00Z on the 24th, maxima exceeding 5 inches (Fig. 6) were observed over the San Gabriel Mountains of Los Angeles County with smaller maxima exceeding 2.5 inches in the mountains of Ventura County and in the Santa Monica Mountains of Los Angeles County. The Eta-10 (Fig. 14) once again accurately forecast the location of the maxima with peak amounts of 3 to 3.25 inches in the mountains of Ventura County and 3.25 to 3.5 inches in the San Gabriel Mountains in eastern Los Angeles County. Amounts were slightly overforecast in southeastern Santa Barbara County, possibly attributable to slight timing errors in the model. Amounts were also underforecast by the Eta-10 in the Santa Monica Mountains due to the weak reflection of the Santa Monica Mountains in the terrain of the Eta-10. The Eta-29 (Fig. 15) had a single elongated west-east maximum with peak amounts for this period of 2 to 2.25 inches, once again mislocated over the Ventura County coastal plain.

Comparison of Results with Previous Studies

Results for this event are consistent with previous studies (Martin, 1996a, Martin, 1996b, Martin, 1998, and McDonald and Horel, 1998) in showing improvements in model QPF performance in the complex terrain of the West with increases in model resolution. Regional, seasonal, and national QPF verification of the Eta-48 and Eta-29 by Gartner, et. Al. (1998) showed little difference in the performance of these two models. However, in that study verification was performed for 24-hour time periods on an 80 km grid for threshold amounts up to 2 inches. Such a large grid spacing would tend to mask the benefits provided by increased resolution, especially in areas of complex terrain. Such a large grid spacing would also tend to underestimate the skill provided by higher resolution models for 24-hour threshold amounts greater than 2 inches -- amounts that are common in most Southern California winter season storms of moderate or greater intensity.

Conclusions

The model QPF for this event varied widely. Since the model synoptic forecasts were similar, the differences in the forecasts were mostly due to factors inherent to each model, most notably the representation of terrain by each model. While the QPF of the Eta-29 was better than the lower-resolution AVN, the additional terrain resolution provided by the Eta-10 was necessary in order to generate QPF with amounts close to the proper magnitude and maxima close to the proper location across Southern California. Further enhancements in horizontal resolution, to around 5 km, might well have allowed for depiction of the smaller maximum associated with the Santa Monica Mountains and for magnitudes of the maxima to be closer to the observed amounts.

Recommendations

This study provides another example of the substantial benefit to be gained in areas of complex terrain from greater model resolution, such as that provided by the Eta-10. However, additional resolution improvements may still be needed in order to capture the full level of detail experienced in regions of complex terrain. A modeling study (Cairns and Corey, 1998) of a high wind event in the complex terrain near Reno, NV found that a horizontal resolution of around 3 km was required to resolve the finer terrain and related atmospheric phenomena. That study suggested the need to further increase the horizontal resolution of the experimental Eta from 10 km to around 5 km.

While each incremental improvement in the resolution of the operational Eta model has resulted in improvements in model QPF in Southern California, none of these improvements has resulted in the kind of dramatic improvement shown by the Eta-10. Until resources allow for increases in the horizontal resolution of the operational Eta model to at least 10 km, there is a substantial benefit to be gained in regions of complex terrain from a nested run of much higher resolution than that of the operational Eta. In fact, no number of lower resolution model runs is capable of showing the level of detail routinely experienced in Southern California.

Acknowledgments

Special thanks to NCEP for providing a daily nested run of the Eta-10 for a period during the 1998 winter season. The Eta-10 run from 23 February 1998 was useful not only in evaluating the performance of the Eta-10, but more importantly in providing more accurate, detailed forecasts of a major storm (Fig. 16). Thanks also to David Bright and Ivory Small for their reviews of this Technical Attachment.

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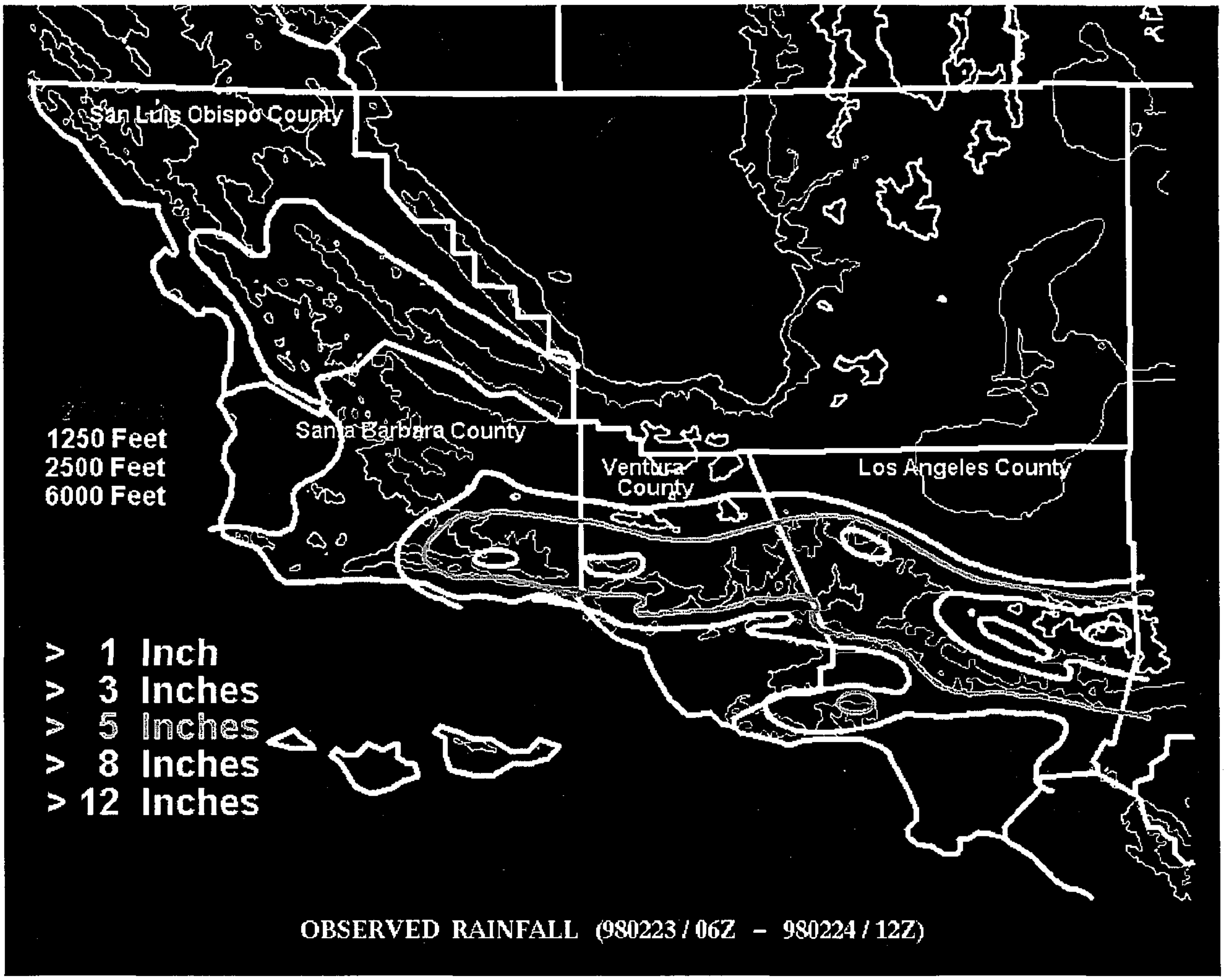
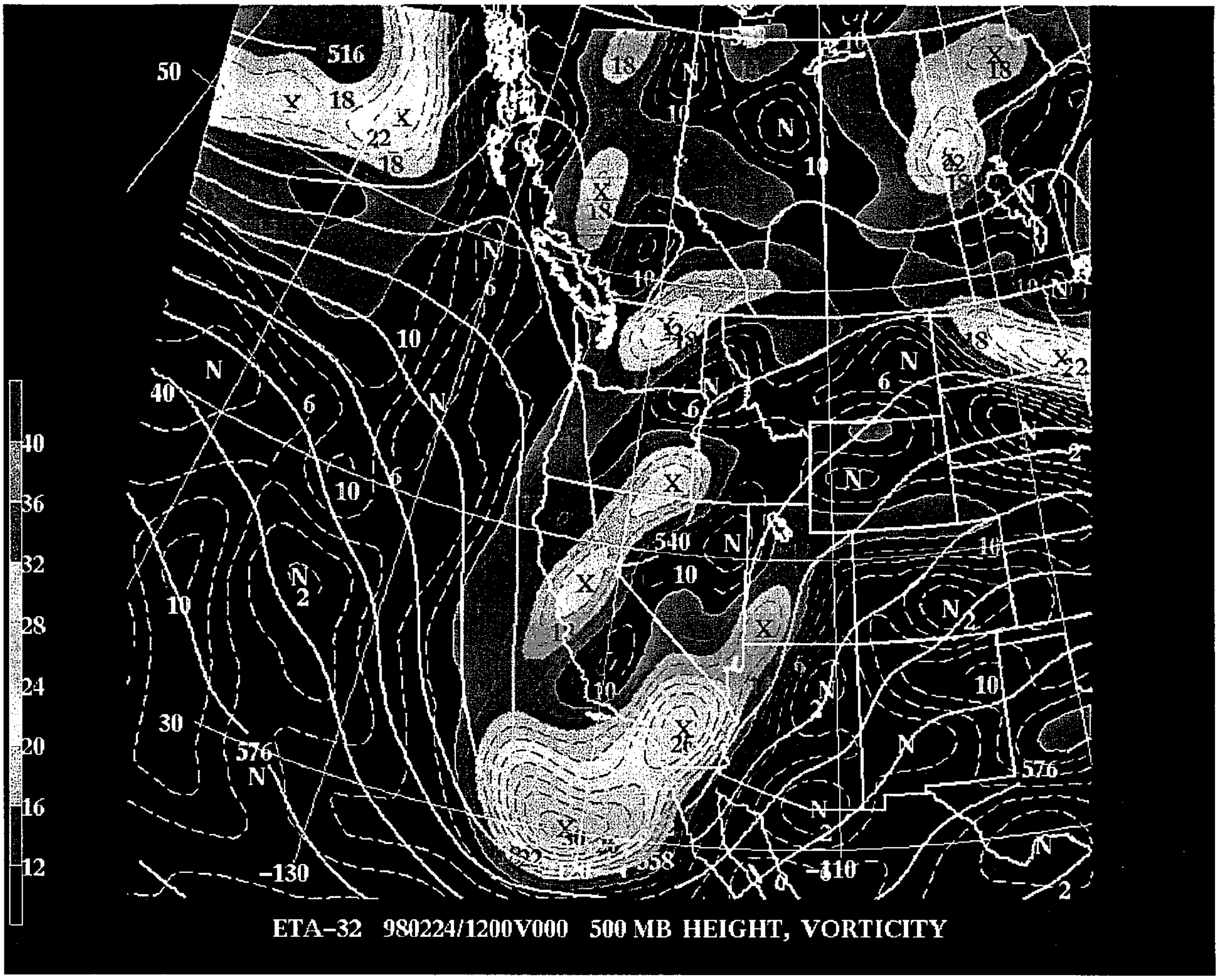

San Luis Obispo County
Santa Barbara County
Ventura County
Los Angeles County
1250 Feet
2500 Feet
6000 Feet
> 1 Inch
> 3 Inches
> 5 Inches
> 8 Inches
> 12 Inches
OBSERVED RAINFALL (980223 / 06Z – 980224 / 12Z)

Fig. 1



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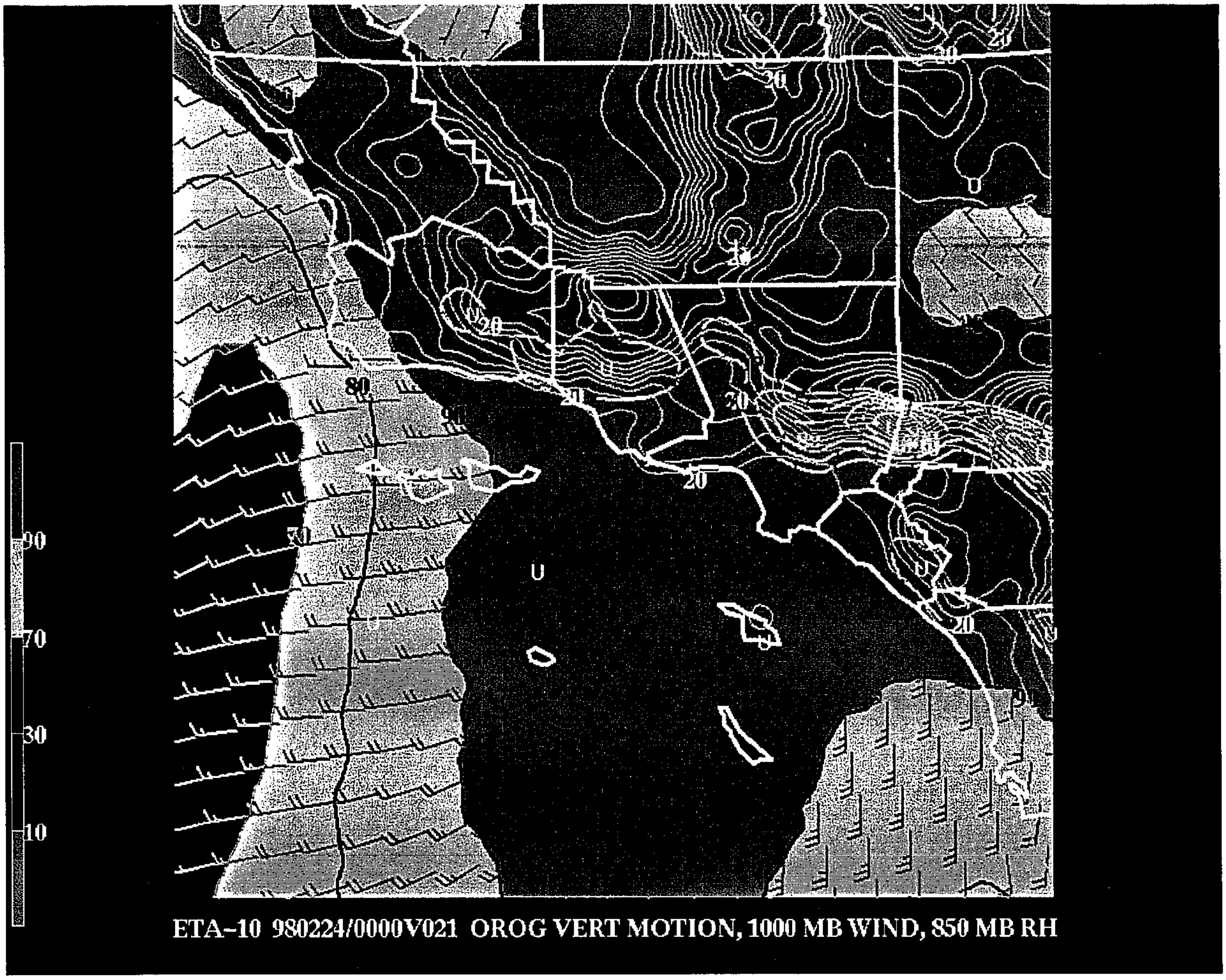
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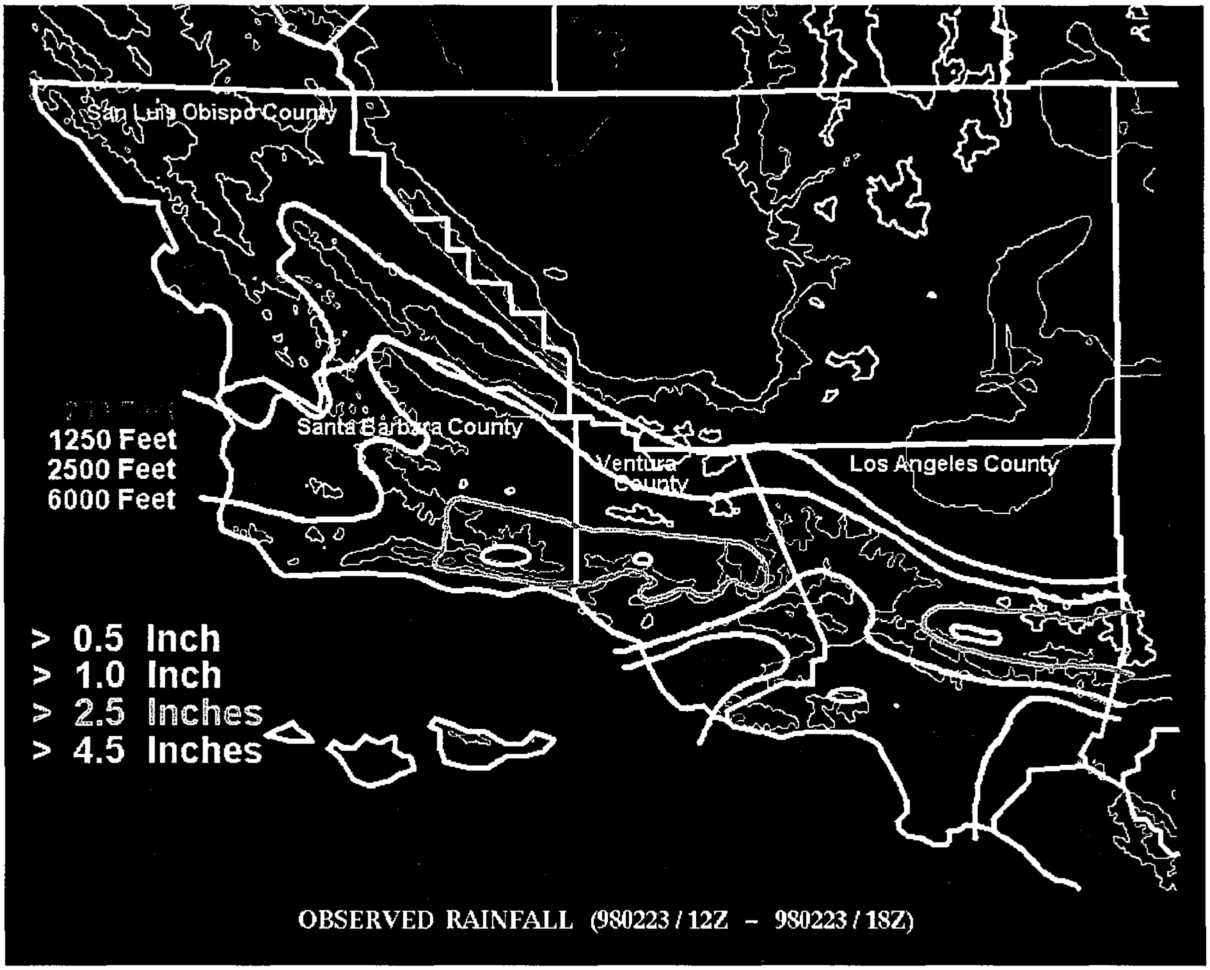
70
30
10
ETA-10 980224/0000V021 OROG VERT MOTION, 1000 MB WIND, 850 MB RH

Fig. 4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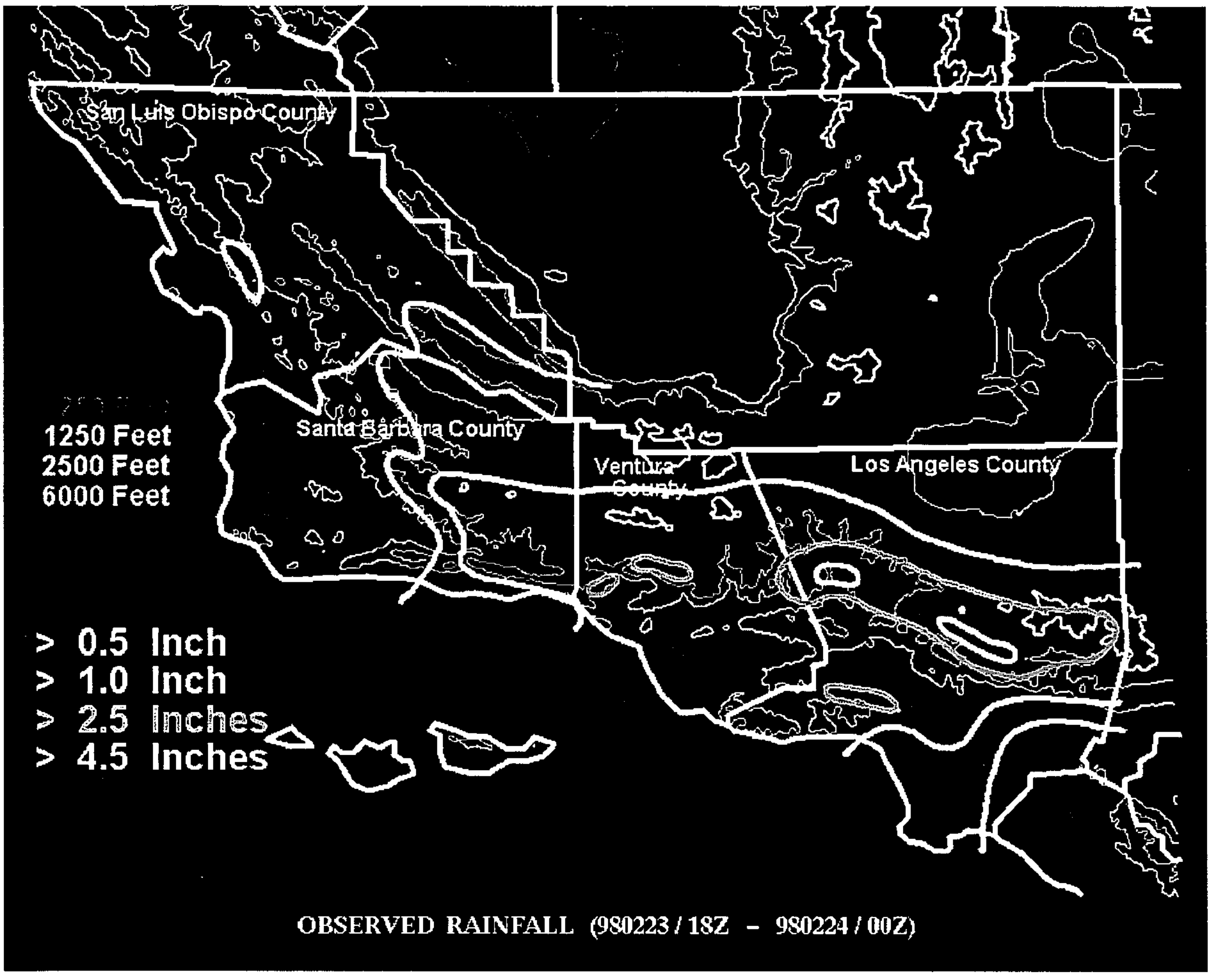
Santa Barbara County
Ventura County
Los Angeles County
1250 Feet
2500 Feet
6000 Feet
> 0.5 Inch
> 1.0 Inch
> 2.5 Inches
> 4.5 Inches
OBSERVED RAINFALL (980223 / 12Z - 980223 / 18Z)

Fig. 5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Ventura County
Los Angeles County
1250 Feet
2500 Feet
6000 Feet
> 0.5 Inch
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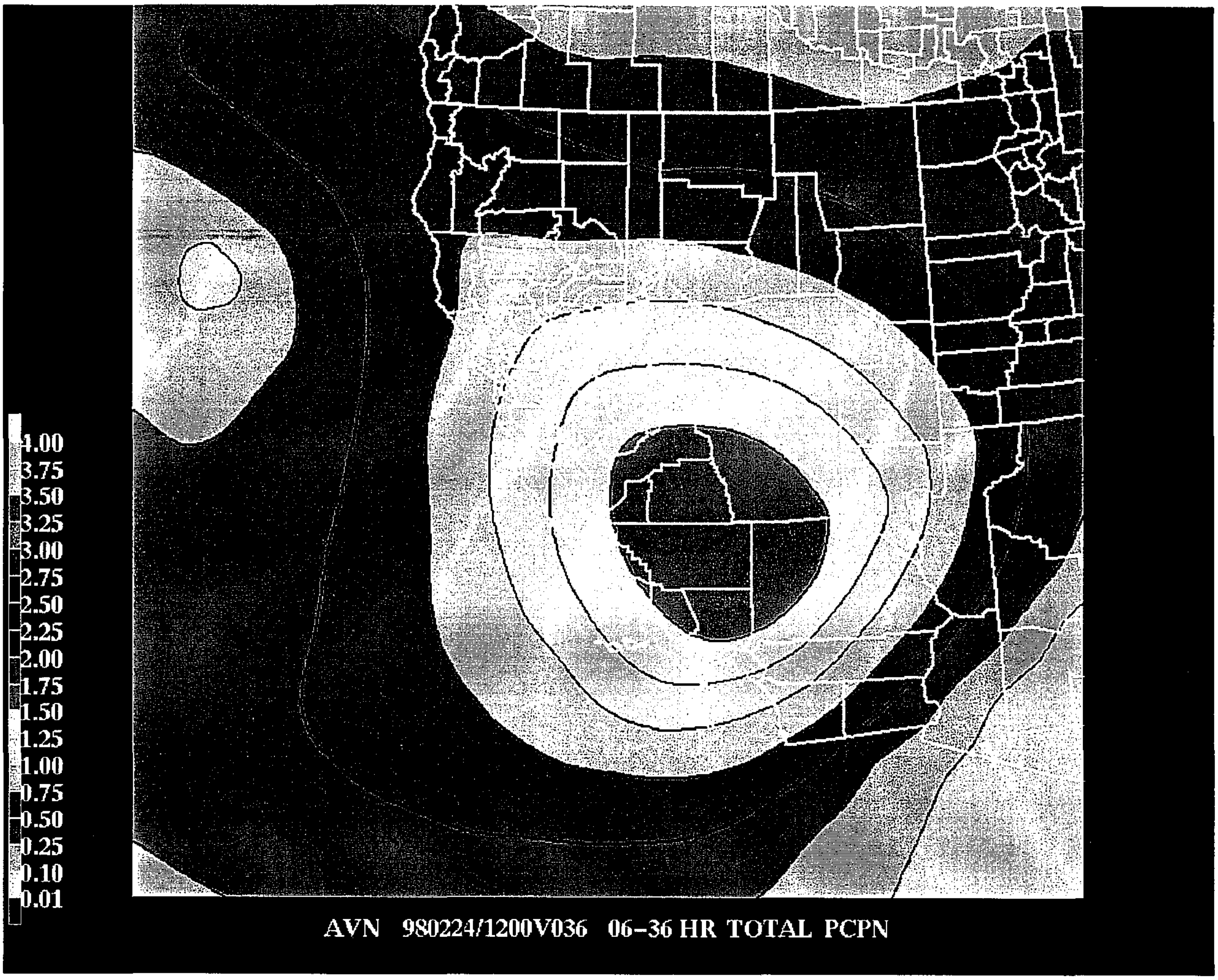
> 4.5 Inches
OBSERVED RAINFALL (980223 / 18Z - 980224 / 00Z)

Fig. 6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3.25
3.00
2.75
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2.25
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1.50
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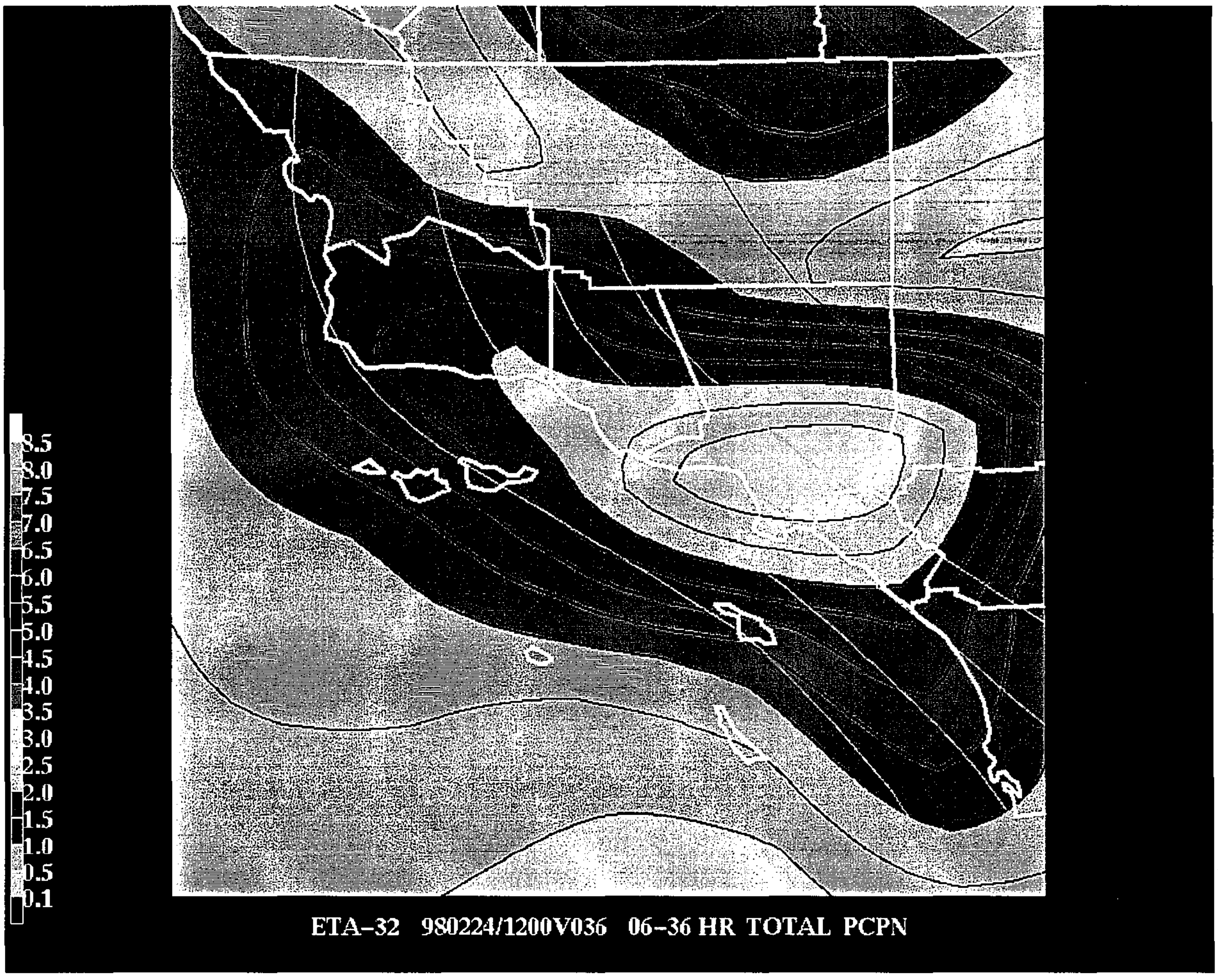
0.25
0.10
0.01
AVN 980224/1200V036 06-36 HR TOTAL PCPN

Fig. 7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8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.1
ETA-32 980224/1200V036 06-36 HR TOTAL PCPN

Fig. 8

8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.1
ETA-29 980224/1200V033 03-33 HR TOTAL PCPN

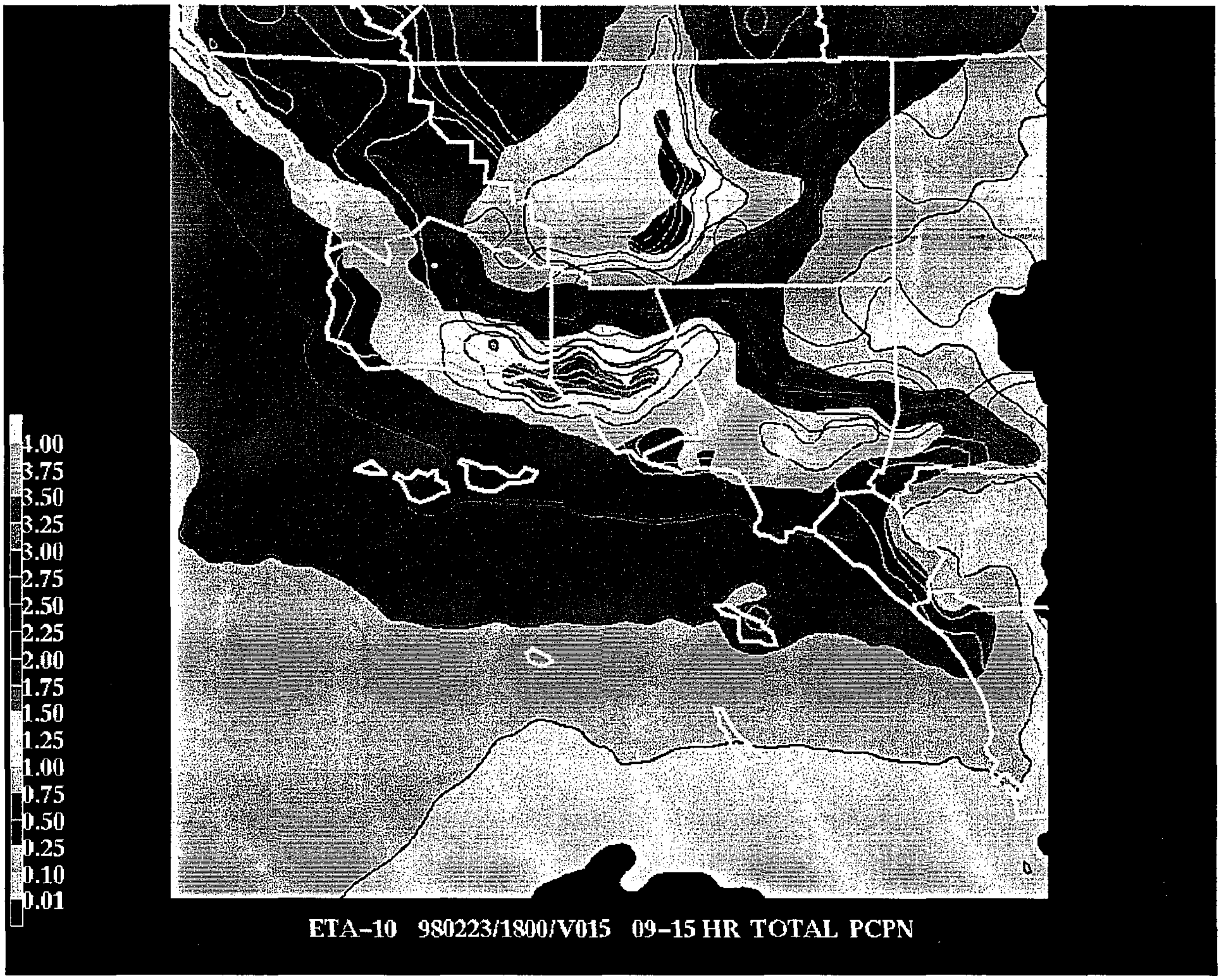
Fig. 9

8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.1
ETA-10 980224/0900V030 03-30 HR TOTAL PCPN

Fig. 10


8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.1
ETA-29 980224/0900V030 03-30 HR TOTAL PCPN

Fig. 11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3.75
3.50
3.25
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.10
0.01
ETA-10 980223/1800/V015 09-15 HR TOTAL PCPN

Fig. 12


4.00
3.75
3.50
3.25
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
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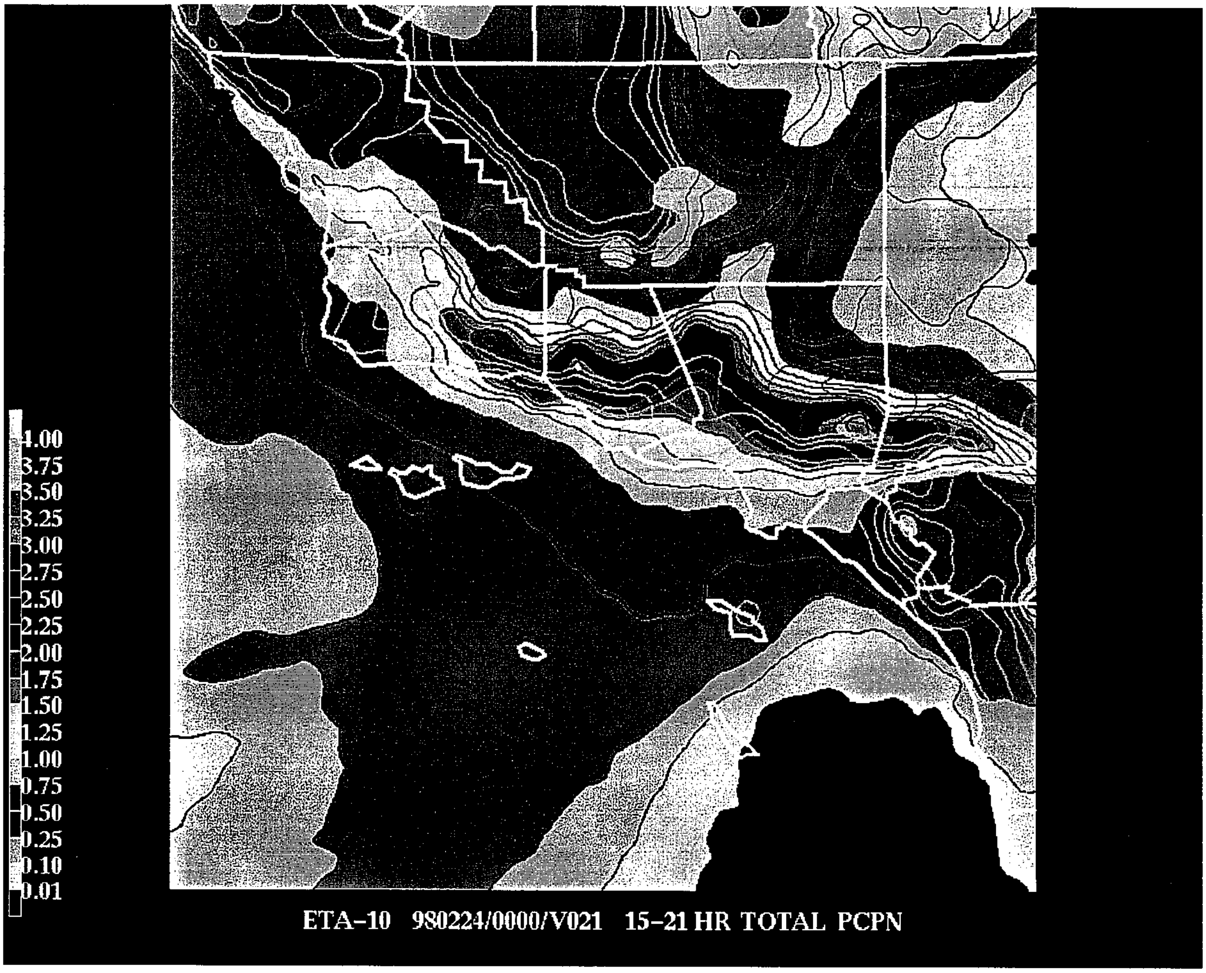
0.10
0.01
ETA-29 980223/1800/V015 09-15 HR TOTAL PCPN

Fig. 13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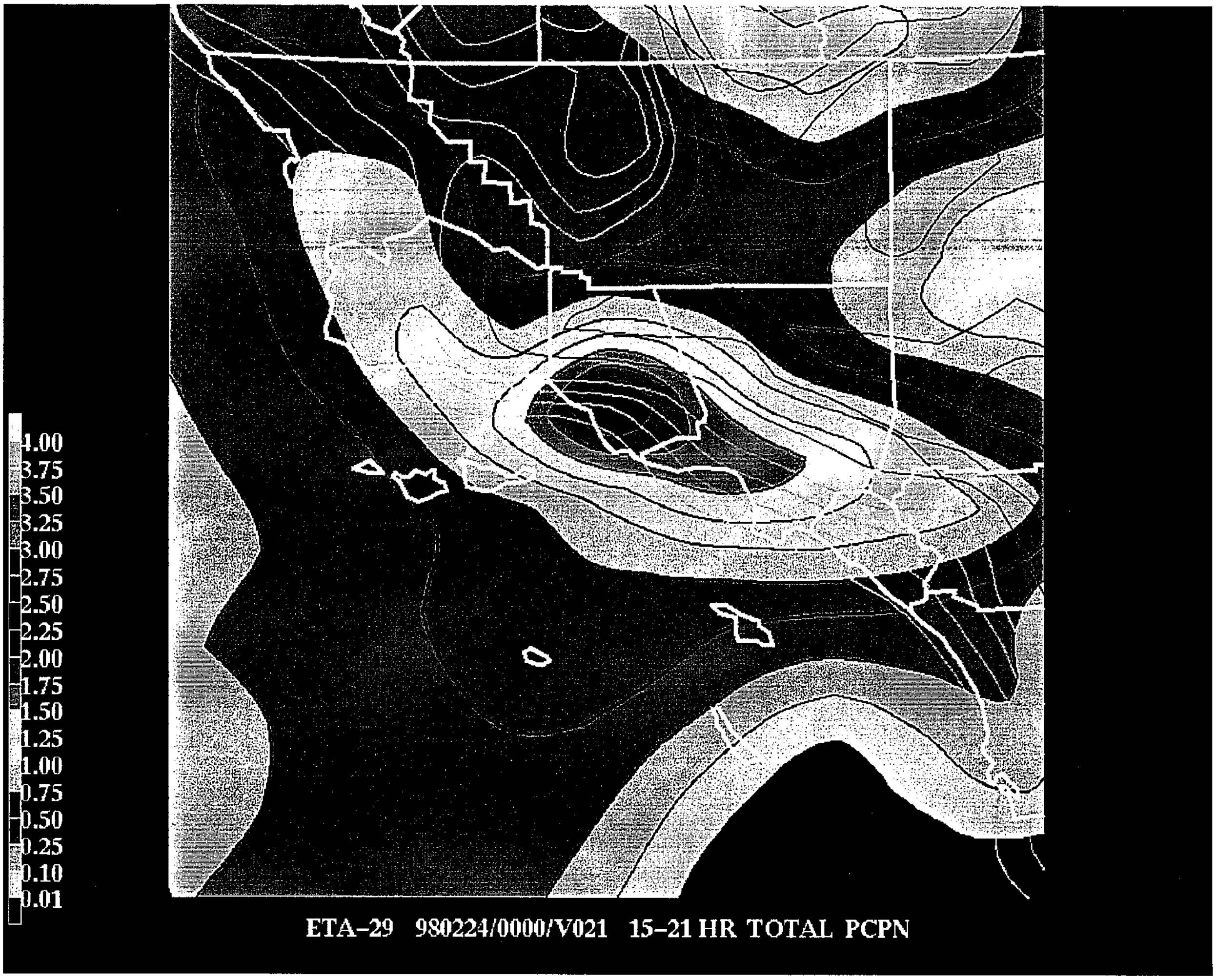
ETA-10 980224/0000/V021 15-21 HR TOTAL PCPN

Fig. 14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3.25
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2.25
2.00
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1.50
1.25
1.00
0.75
0.50
0.25
0.10
0.01
ETA-29 980224/0000/V021 15-21 HR TOTAL PCPN

Fig. 15

CAZ034>041-044>047-051>054-059-231800-

SPECIAL WEATHER STATEMENT
NATIONAL WEATHER SERVICE OXNARD CA
500 AM PST MON FEB 23 1998

...FORECAST RAINFALL TOTALS FOR THE STORM TODAY...

A STRONG PACIFIC STORM WILL MOVE INTO CENTRAL AND SOUTHERN CALIFORNIA TODAY AND ACROSS SOUTHERN CALIFORNIA TONIGHT.

THE FOLLOWING ARE FORECAST RAINFALL TOTALS FOR 4 AM TODAY THROUGH 4 AM TUESDAY.

...SAN LUIS OBISPO COUNTY...
CENTRAL COAST.................1.5 to 2.5 INCHES.
INTERIOR VALLEYS..................1 to 2 INCHES.
MOUNTAINS.....................2.5 to 3.5 INCHES.

...SANTA BARBARA COUNTY...
CENTRAL COAST.....................2 to 4 INCHES.
SOUTH COAST.......................3 to 5 INCHES.
SANTA YNEZ VALLEY.................5 to 9 INCHES.
SANTA YNEZ MOUNTAINS..............5 to 9 INCHES.
SIERRA MADRE MOUNTAINS............4 to 8 INCHES.
CUYAMA VALLEY.................1.5 to 2.5 INCHES.

...VENTURA COUNTY...
COAST AND VALLEYS.................3 to 6 INCHES.
MOUNTAINS.........................5 to 9 INCHES.

...LOS ANGELES COUNTY...
COASTAL PLAIN.....................2 to 4 INCHES.
SANTA MONICA MOUNTAINS............4 to 7 INCHES.
COASTAL VALLEYS...................3 to 6 INCHES.
SAN GABRIEL MOUNTAINS.............5 to 9 INCHES.
ANTELOPE VALLEY...................1 to 3 INCHES.

Fig. 16