A Southern Sierra Nevada Flash Flood Event Resulting from Monsoonal Convection - A WES Case

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Introduction

The southwestern United States monsoon results from tropical and subtropical moisture being drawn north on the backside of upper-level high pressure typically stationed over the high plains and eastern Rockies during the summer months. In combination with sufficient atmospheric instability, the interaction of this moisture with the varied terrain of the West often results in scattered high-based convection in the four-corners region. On occasion, when this high pressure area is situated farther west, or when some weakness in upper level heights develops west of the California coastline, the western edge of higher moisture spills into the Sierra Nevada. Although this occurrence periodically results in wetting rains for isolated portions of the mountain range, heavy rain events are quite unusual. Despite their rarity, substantial water runoff due to the steep terrain exacerbates the potential for flash flooding across this region during periods of intense rainfall. Such an event occurred during the early evening hours of August 20, 2003 near the Kern county mountain community of Lake Isabella.

Synoptic and Mesoscale Description and Processes

A weak closed low aloft was positioned approximately 450 nautical miles west of Point Conception, California, while strong upper level high pressure extended from the central Rocky mountains south into the southern high plains. As illustrated by the ETA 500 mb analysis from 00Z on August 21, 2003 (see Figure 1), the resultant southerly flow aloft provides an effective mechanism for the transport of any meteorological parameter from lower latitudes. The corresponding 700 mb ETA depiction, as shown in Figure 2, confirms a substantial fetch of mid level moisture present across the southeastern portion of the WFO San Joaquin Valley County Warning Forecast Area (CWFA), which includes the southern Sierra Nevada, with the best moisture residing farther south. Much of this moisture, along with embedded vorticity maxima, were the southern remains of a Mesoscale Convective Vortex (MCV) which moved across Arizona the previous day and resulted in significant flooding in portions of the Las Vegas, Nevada metropolitan area. As this increased moisture surges north into the region on southerly winds, the gradually rising terrain forces the air to rise orographically (see Figure 3).

However, several other mechanisms had a probable impact in contributing to significant convection late that day. Figure 4 provides a contour of elevation across the affected area, along with the transport of moisture along this terrain as suggested by high resolution Local Analysis and Prediction System (LAPS) data. The San Joaquin valley, indicated by the purple shaded area extending from just south of Bakersfield north to Porterville, is experiencing an up-valley flow typical of late afternoon in the summer. Quite unusual, however, are the high dew points observed in the valley, with the reading at Bakersfield registering 73 degrees fahrenheit at 01Z. Meanwhile, farther east, surface moisture transport vectors (depicted by the direction and length of arrows) show a weak northwesterly transport of moisture across the deserts and higher terrain of Kern county. The resultant surface moisture convergence area lies east of the highest peaks, or from northwest of Tehachapi to Lake Isabella (see Figure 5). As temperatures across the San Joaquin valley remain very hot (99 degrees fahrenheit at 01Z in Bakersfield) and lapse rates relatively steep, a high buoyancy environment helped provide additional lift to induce showers and thunderstorms. The workstation-ETA model indicated a broad swath of Surface-Based Convective Available Potential Energy (SBCAPE) between 500 and 1,000 joules/kilogram over the area between 00Z and 03Z on August 21. The accompanying forecast sounding at Lake Isabella even registered a 00Z SBCAPE of 1,500 joules/kilogram, along with a boundary layer lifted index of -4.9 Celsius. The model K-index at 00Z stood at 46, substantially above the 35 reading typically associated with heavy rain potential.

Event Chronology

Infrared (Figure 6) and visible (Figure 7) satellite imagery at 01Z on August 21 indicate the cold cloud tops as well as the overshooting top in association with potent thunderstorm development near Lake Isabella. The KHNX 88D radar, located some 90 nautical miles northwest of the most intense cell, north of Tehachapi, reported this cell as having a composite reflectivity of 65 decibels (dbZ) at 0114Z, as shown in Figure 8. Approximately a half-hour earlier, the same cell was estimated to have reflectivity tops approaching 44,000 feet above mean sea level (see Figure 9). Given the high radar reflectivities, radar cross section, as well as the nearly stationary movement of the storm, the obvious short-fuse impact would be flash flooding. The weather forecast office issued a flash flood warning at 0049Z, effective for the following three hours. The KHNX three-hour accumulated precipitation total, ending at 0209Z, indicated between three and four inches of rainfall associated with this cell (see Figure 10). Ground truth confirmed the severity of flooding. Later reports included significant mud and water flows over roads, as well as trees and power lines brought down and swept onto an adjacent highway by the heavy rains. The maximum observed 24-hour precipitation, 1.78 inches, occurred at the Piute fire station, located 17 miles south of Lake Isabella, of which, 1.00 inch fell in a 15-minute period as the primary cell was overhead.

Conclusion

The flash flood warning issued for this event proved to be timely and justified, and this event has since been incorporated as a Weather Event Simulator (WES) case for local office study and training. Although flooding events are fairly uncommon in the Hanford CWFA, this event suggests that forecasters be especially mindful of situations where satellite imagery indicates a weak circulation (the remnant MCV) which serves to enhance not only the transport of monsoonal moisture north, but also dynamically force air to rise. With instability already present and low-mid level moisture abundant, forecasters should also be watchful for additional influx and subsequent convergence of low-level moisture, as forecasted using surface moisture flux depictions and transport vectors. Finally, the use of numerical parameters, such as the K-index and SBCAPE, continue to provide additional information to the meteorologist for the purpose of planning for probable events, as well as justifying the issuance of flood watches before the event develops.

Acknowledgements

I especially wish to thank Dan Gudgel for providing figures and insight necessary for the development of this paper.

Figure 1

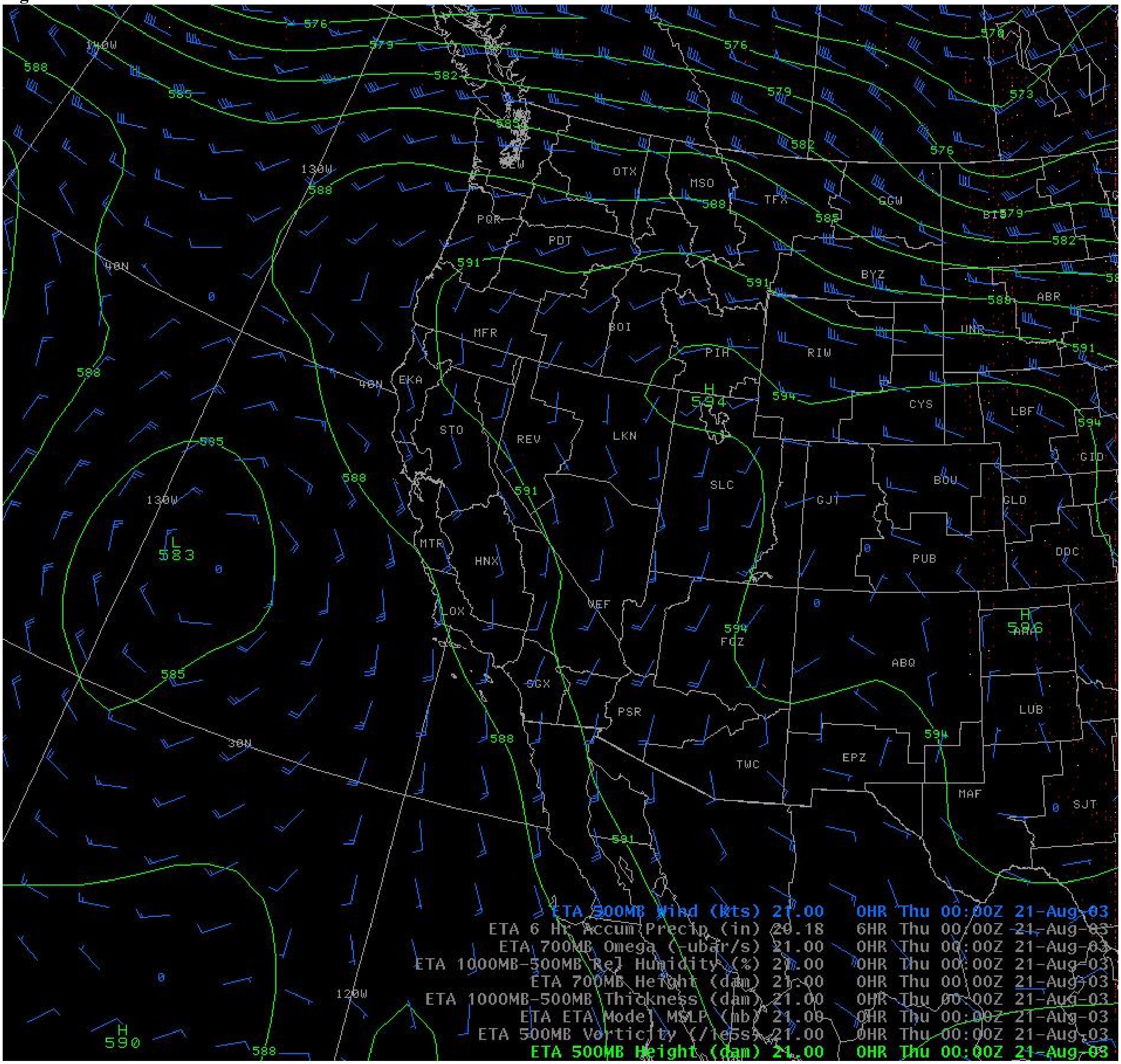
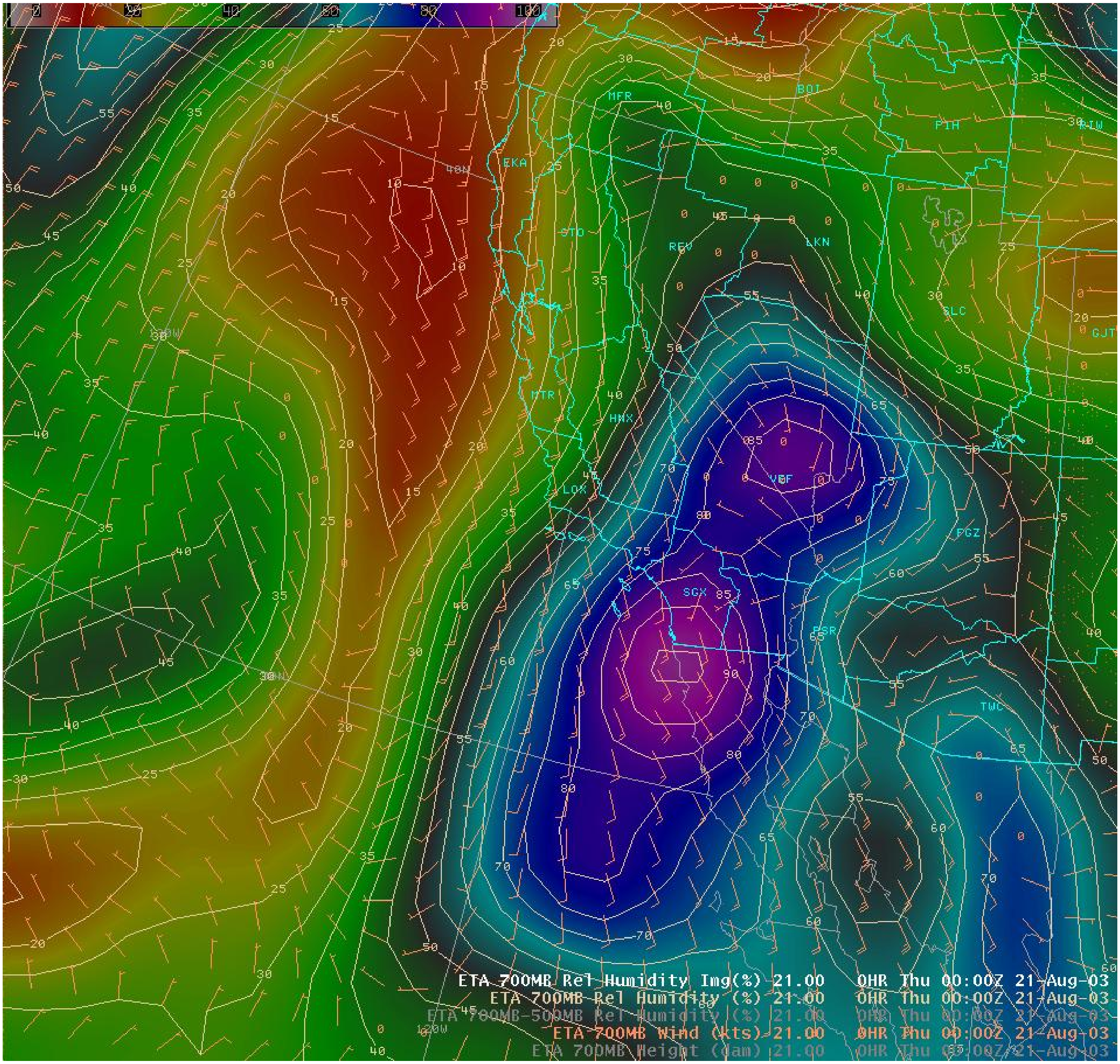


Figure 2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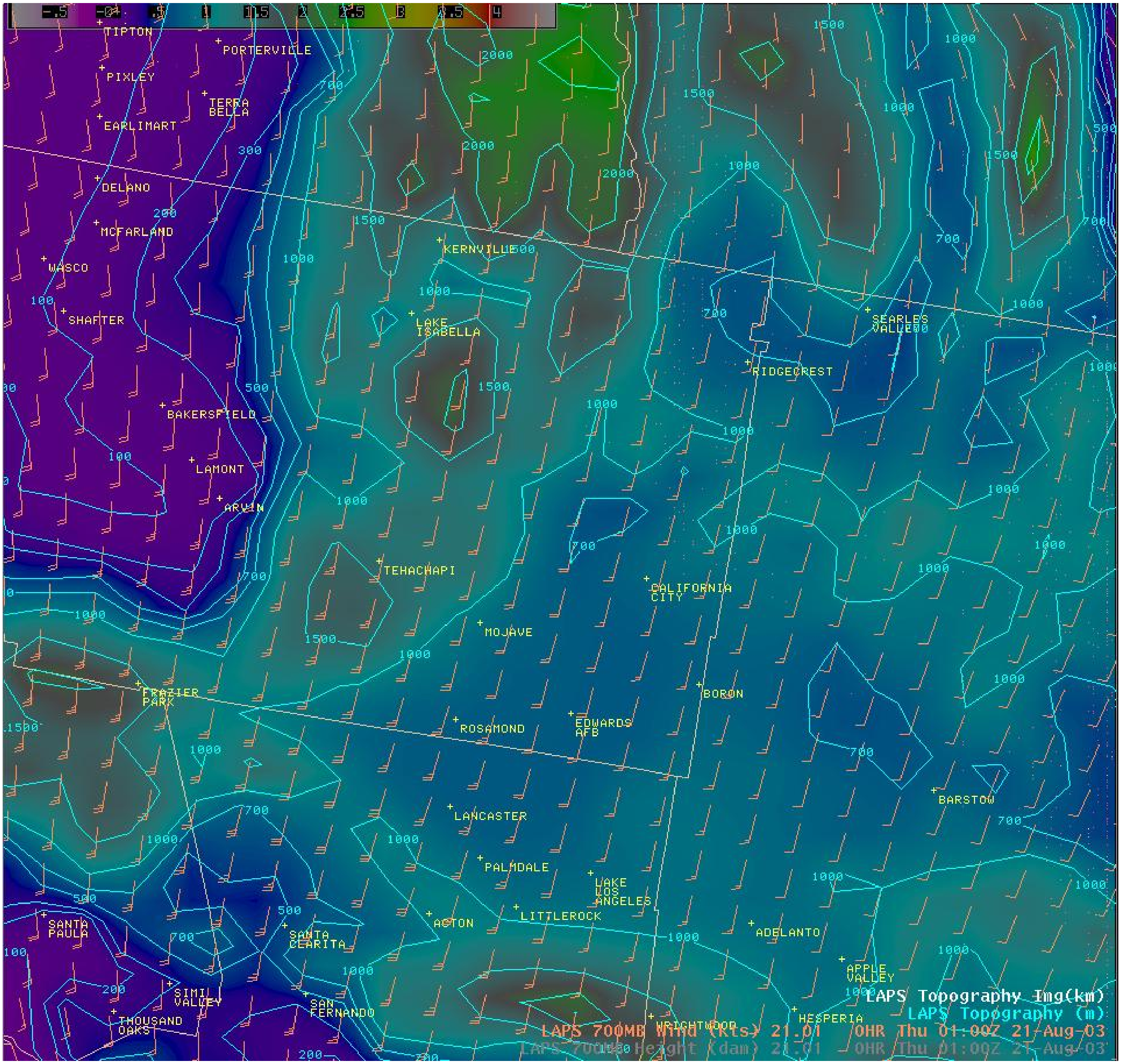
ETA 700MB Rel Humidity (%) 21.00 0HR Thu 00:00Z 21-Aug-03
ETA 700MB-500MB Rel Humidity (%) 21.00 0HR Thu 00:00Z 21-Aug-03
ETA 700MB Wind (kts) 21.00 0HR Thu 00:00Z 21-Aug-03
ETA 700MB Height (dam) 21.00 0HR Thu 00:00Z 21-Aug-03

Figure 3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PIXLEY
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EARLIMART
DELANO
MCFARLAND
WASCO
SHAFTER
BAKERSFIELD
LAMONT
ARVIN
KERNVILLE
LAKE ISABELLA
TEHACHAPI
MOJAVE
FRAZIER PARK
ROSAMOND
EDWARDS AFB
CALIFORNIA CITY
BORON
RIDGECREST
SEARLES VALLEY
BARSTOW
LANCASTER
PALMDALE
LAKE LOS ANGELES
LITTLEROCK
ACTON
ADELANTO
APPLE VALLEY
HESPERIA
WRIGHTWOOD
SANTA PAULA
SANTA CLARITA
SIMI VALLEY
THOUSAND OAKS
SAN FERNANDO
LAPS Topography Img(km)
LAPS Topography (m)
LAPS 700MB Wind (kts) 21.01 0HR Thu 01:00Z 21-Aug-03
LAPS 700MB Height (dam) 21.01 0HR Thu 01:00Z 21-Aug-03

Figure 4

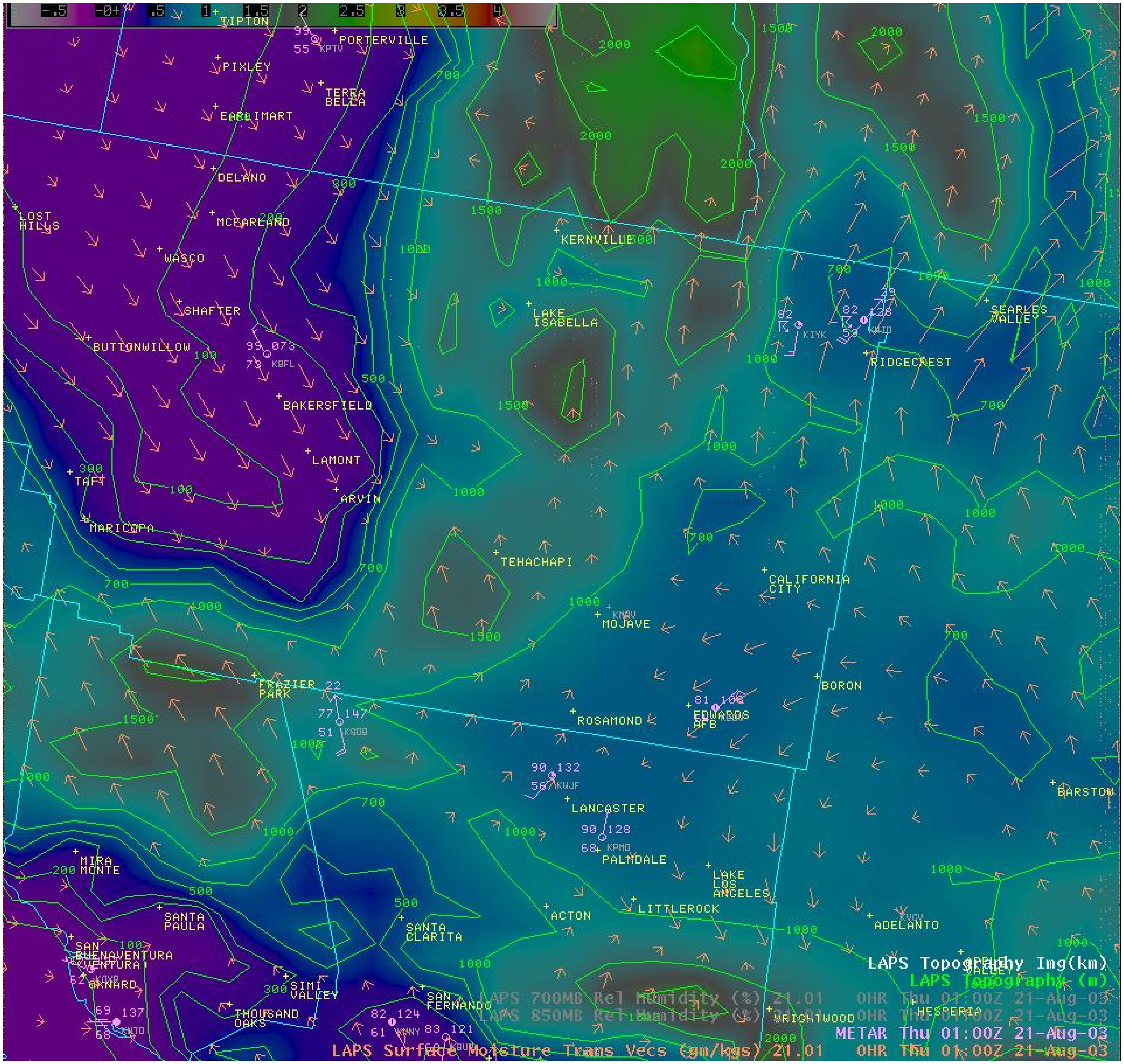
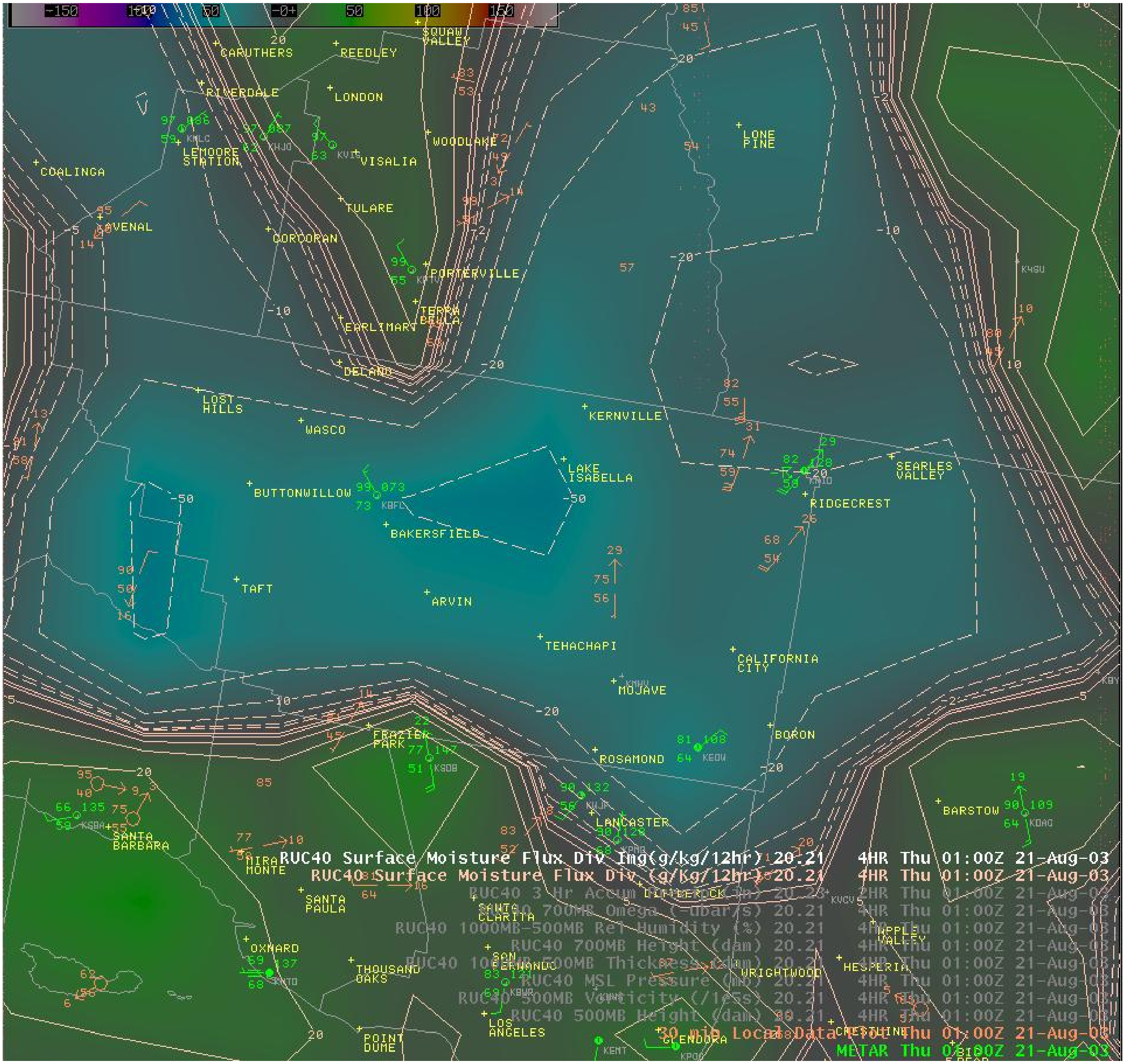

LAPS Topography Img(km)
LAPS Topography (m)
LAPS 700MB Rel Humidity (%) 21.01 OHR Thu 01:00Z 21-Aug-03
LAPS 850MB Rel Humidity (%) 21.01 OHR Thu 01:00Z 21-Aug-03
METAR Thu 01:00Z 21-Aug-03
LAPS Surface Moisture Trans Vecs (gm/kgs) 21.01 OHR Thu 01:00Z 21-Aug-03
TIPTON
PORTERVILLE
PIXLEY
TERRA BELLA
EARLIMART
DELANO
LOST HILLS
MCFARLAND
WASCO
SHAFTER
BUTTONWILLOW
BAKERSFIELD
LAMONT
ARVIN
TAFT
MARICOPA
KERNVILLE
LAKE ISABELLA
RIDGECREST
SEARLES VALLEY
TEHACHAPI
CALIFORNIA CITY
MOJAVE
FRAZIER PARK
ROSAMOND
EDWARDS AFB
BORON
LANCASTER
PALMDALE
LAKE LOS ANGELES
LITTLEROCK
ACTON
ADELANTO
BARSTOW
MIRA MONTE
SANTA PAULA
SANTA CLARITA
SAN BUENAVENTURA (VENTURA)
OXNARD
SIMI VALLEY
THOUSAND OAKS
SAN FERNANDO
WRIGHTWOOD
HESPERIA

Figure 5



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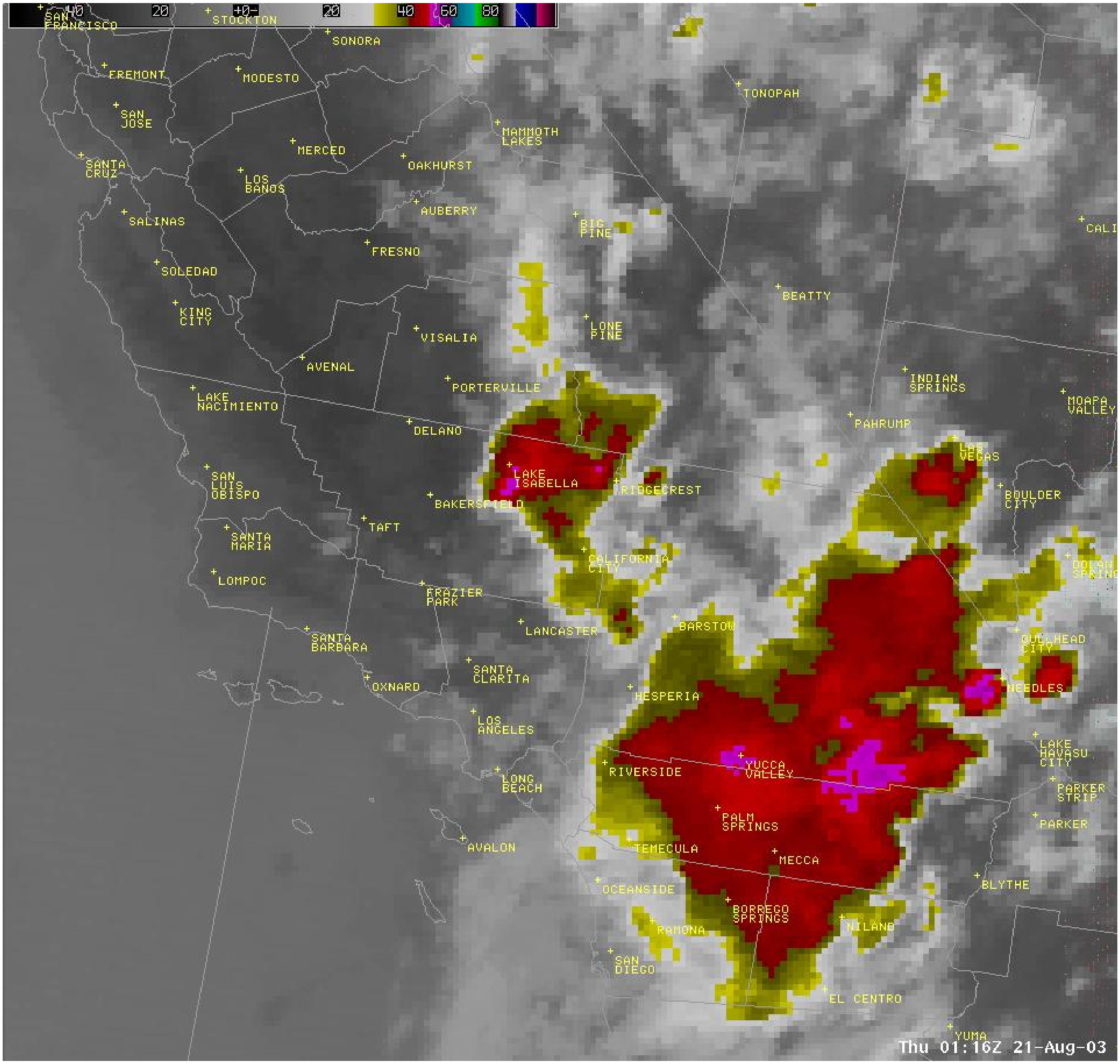
-100
-50
-0+
50
100
150
CARUTHERS
REEDLEY
SQUAW VALLEY
RIVERDALE
LONDON
LEMOORE STATION
VISALIA
WOODLAKE
LONE PINE
COALINGA
AVENAL
TULARE
CORCORAN
PORTERVILLE
TERRA BELLA
EARLIMART
DELANO
LOST HILLS
WASCO
KERNVILLE
LAKE ISABELLA
SEARLES VALLEY
BUTTONWILLOW
RIDGECREST
BAKERSFIELD
TAFT
ARVIN
TEHACHAPI
CALIFORNIA CITY
MOJAVE
FRAZIER PARK
BORON
ROSAMOND
LANCASTER
BARSTOW
SANTA BARBARA
MIRA MONTE
SANTA PAULA
SANTA CLARITA
OXNARD
THOUSAND OAKS
SAN FERNANDO
WRIGHTWOOD
HESPERIA
APPLE VALLEY
LOS ANGELES
POINT DUME
GLENDORA
CRESTLINE
RUC40 Surface Moisture Flux Div Img(g/kg/12hr) 20.21 4HR Thu 01:00Z 21-Aug-03
RUC40 Surface Moisture Flux Div (g/kg/12hr) 20.21 4HR Thu 01:00Z 21-Aug-03
RUC40 3 Hr Accum Difference (in) 20.23 2HR Thu 01:00Z 21-Aug-03
RUC40 700MB Omega (-ubar/s) 20.21 4HR Thu 01:00Z 21-Aug-03
RUC40 1000MB-500MB Rel Humidity (%) 20.21 4HR Thu 01:00Z 21-Aug-03
RUC40 700MB Height (dam) 20.21 4HR Thu 01:00Z 21-Aug-03
RUC40 1000MB-500MB Thickness (dam) 20.21 4HR Thu 01:00Z 21-Aug-03
RUC40 MSL Pressure (mb) 20.21 4HR Thu 01:00Z 21-Aug-03
RUC40 500MB Vorticity (/1e5s) 20.21 4HR Thu 01:00Z 21-Aug-03
RUC40 500MB Height (dam) 20.21 4HR Thu 01:00Z 21-Aug-03
30 min Local Data Plot Thu 01:00Z 21-Aug-03
METAR Thu 01:00Z 21-Aug-03

Figure 6



-40
20
+0-
20
40
60
80
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STOCKTON
SONORA
FREMONT
MODESTO
TONOPAH
SAN JOSE
MAMMOTH LAKES
MERCED
SANTA CRUZ
OAKHURST
LOS BANOS
AUBERRY
SALINAS
BIG PINE
CALI
FRESNO
SOLEDAD
BEATTY
KING CITY
LONE PINE
VISALIA
AVENAL
INDIAN SPRINGS
PORTERVILLE
MOAPA VALLEY
LAKE NACIMIENTO
PAHRUMP
DELANO
LAS VEGAS
LAKE ISABELLA
SAN LUIS OBISPO
RIDGECREST
BOULDER CITY
BAKERSFIELD
TAFT
SANTA MARIA
CALIFORNIA CITY
LOMPOC
FRAZIER PARK
LANCASTER
BARSTOW
SANTA BARBARA
BULLHEAD CITY
SANTA CLARITA
OXNARD
HESPERIA
NEEDLES
LOS ANGELES
LAKE HAVASU CITY
YUCCA VALLEY
RIVERSIDE
LONG BEACH
PARKER STRIP
PALM SPRINGS
PARKER
AVALON
TEMECULA
MECCA
OCEANSIDE
BLYTHE
BORREGO SPRINGS
RAMONA
NILAND
SAN DIEGO
EL CENTRO
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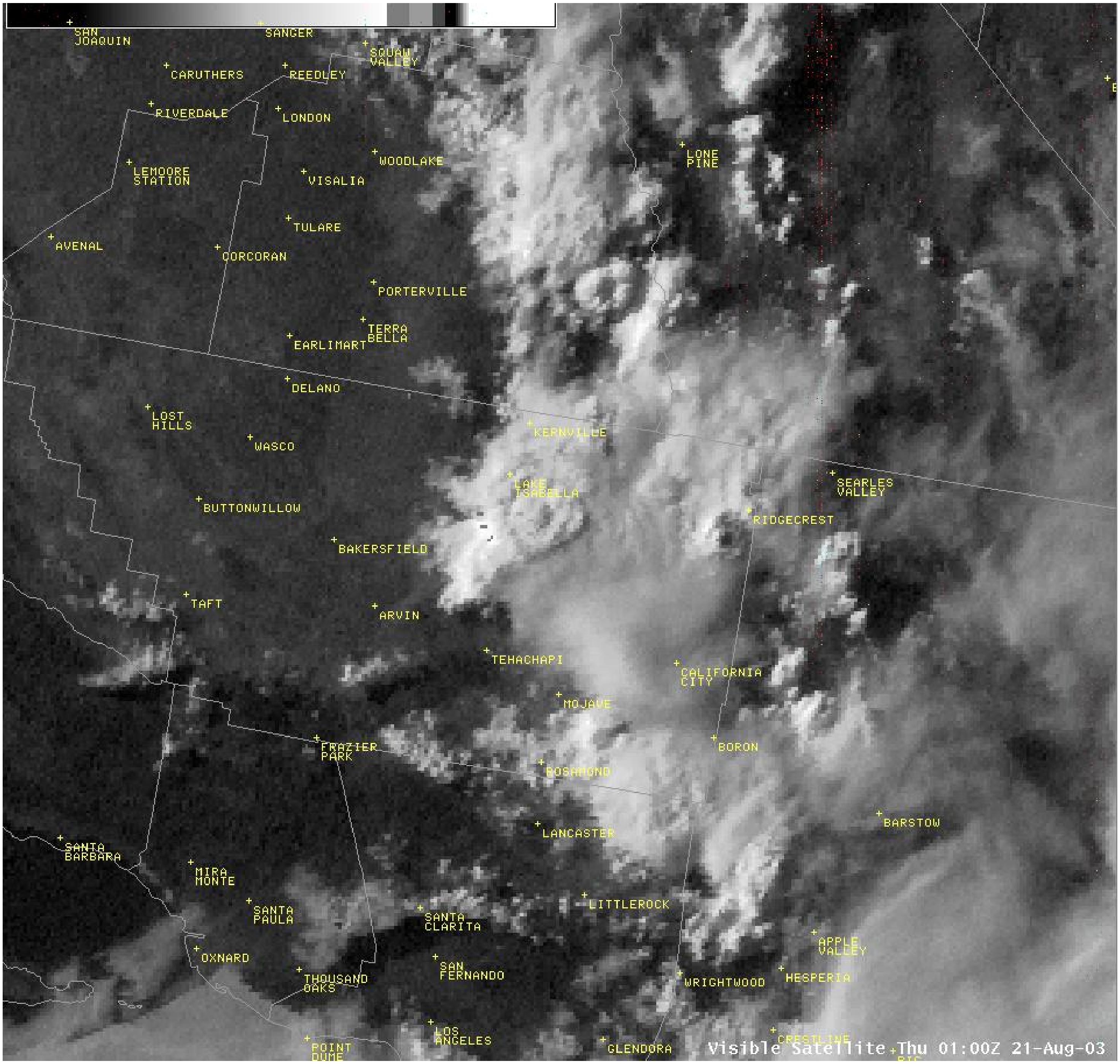
Thu 01:16Z 21-Aug-03

Figure 7



SAN JOAQUIN
SANGER
SQUAW VALLEY
CARUTHERS
REEDLEY
RIVERDALE
LONDON
LONE PINE
WOODLAKE
LEMOORE STATION
VISALIA
TULARE
AVENAL
CORCORAN
PORTERVILLE
TERRA BELLA
EARLIMART
DELANO
KERNVILLE
LOST HILLS
WASCO
LAKE ISABELLA
SEARLES VALLEY
BUTTONWILLOW
RIDGECREST
BAKERSFIELD
TAFT
ARVIN
TEHACHAPI
CALIFORNIA CITY
MOJAVE
FRAZIER PARK
BORON
ROSAMOND
LANCASTER
BARSTOW
SANTA BARBARA
MIRA MONTE
SANTA PAULA
SANTA CLARITA
LITTLEROCK
APPLE VALLEY
OXNARD
THOUSAND OAKS
SAN FERNANDO
WRIGHTWOOD
HESPERIA
LOS ANGELES
POINT DUME
GLENDORA
CRESTLINE
Visible Satellite Thu 01:00Z 21-Aug-03

Figure 8

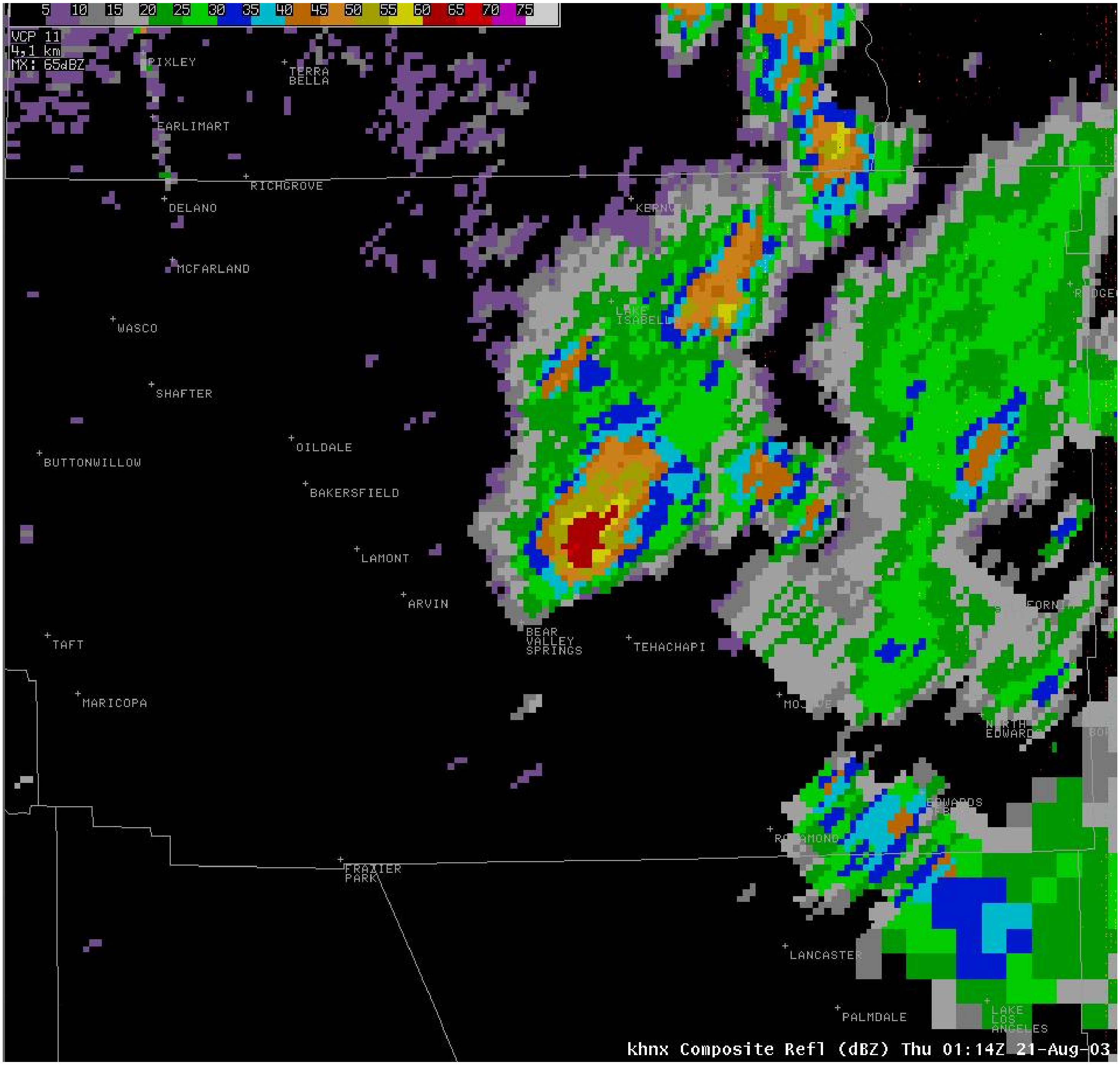
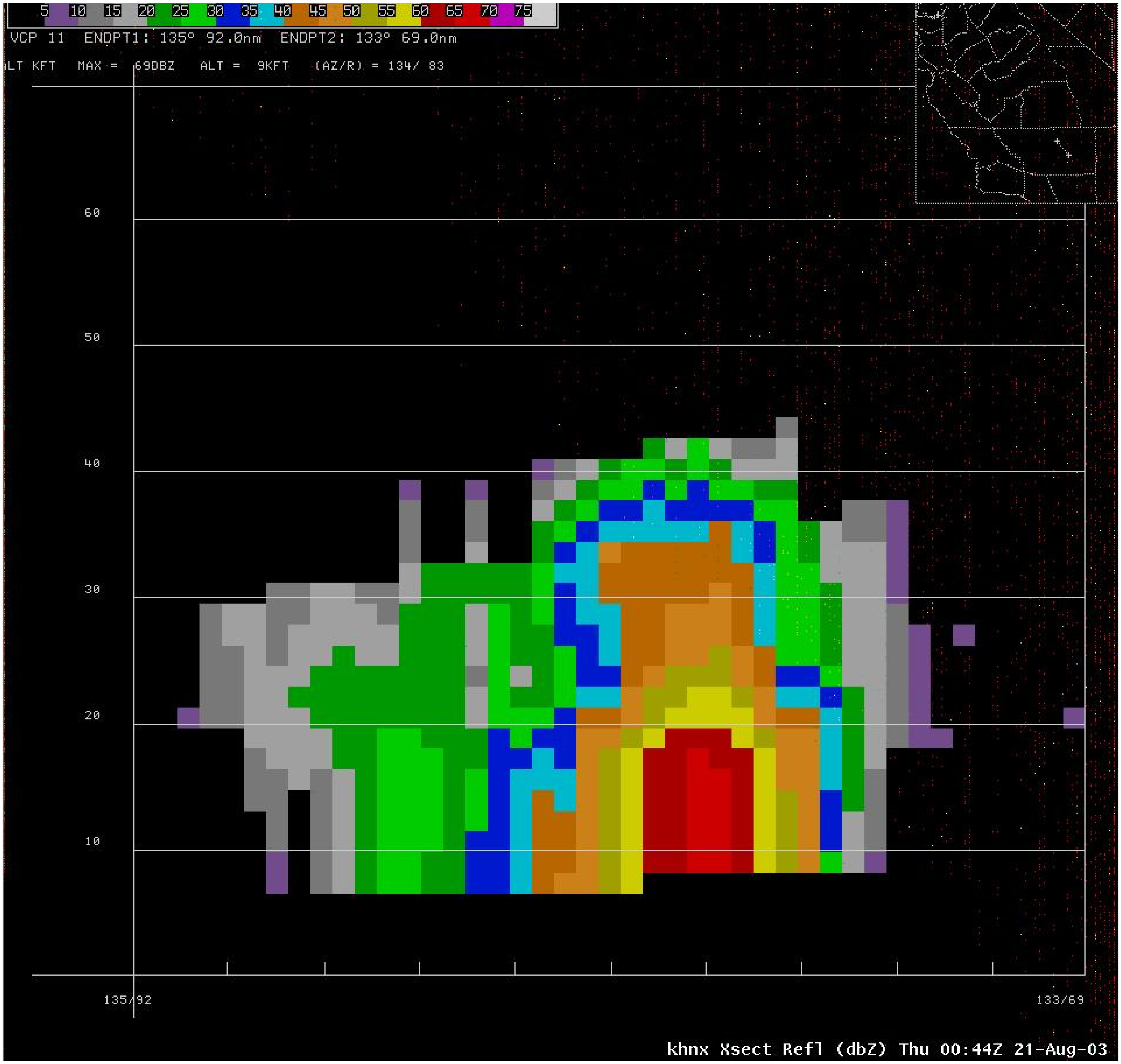

5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
VCP 11
4,1 km
MX: 65dBZ
PIXLEY
TERRA BELLA
EARLIMART
RICHGROVE
DELANO
MCFARLAND
WASCO
SHAFTER
OILDALE
BUTTONWILLOW
BAKERSFIELD
LAMONT
ARVIN
TAFT
MARICOPA
BEAR VALLEY SPRINGS
TEHACHAPI
LAKE ISABELLA
FRAZIER PARK
LANCASTER
PALMDALE
NORTH EDWARDS
LAKE LOS ANGELES
khnx Composite Refl (dBZ) Thu 01:14Z 21-Aug-03

Figure 9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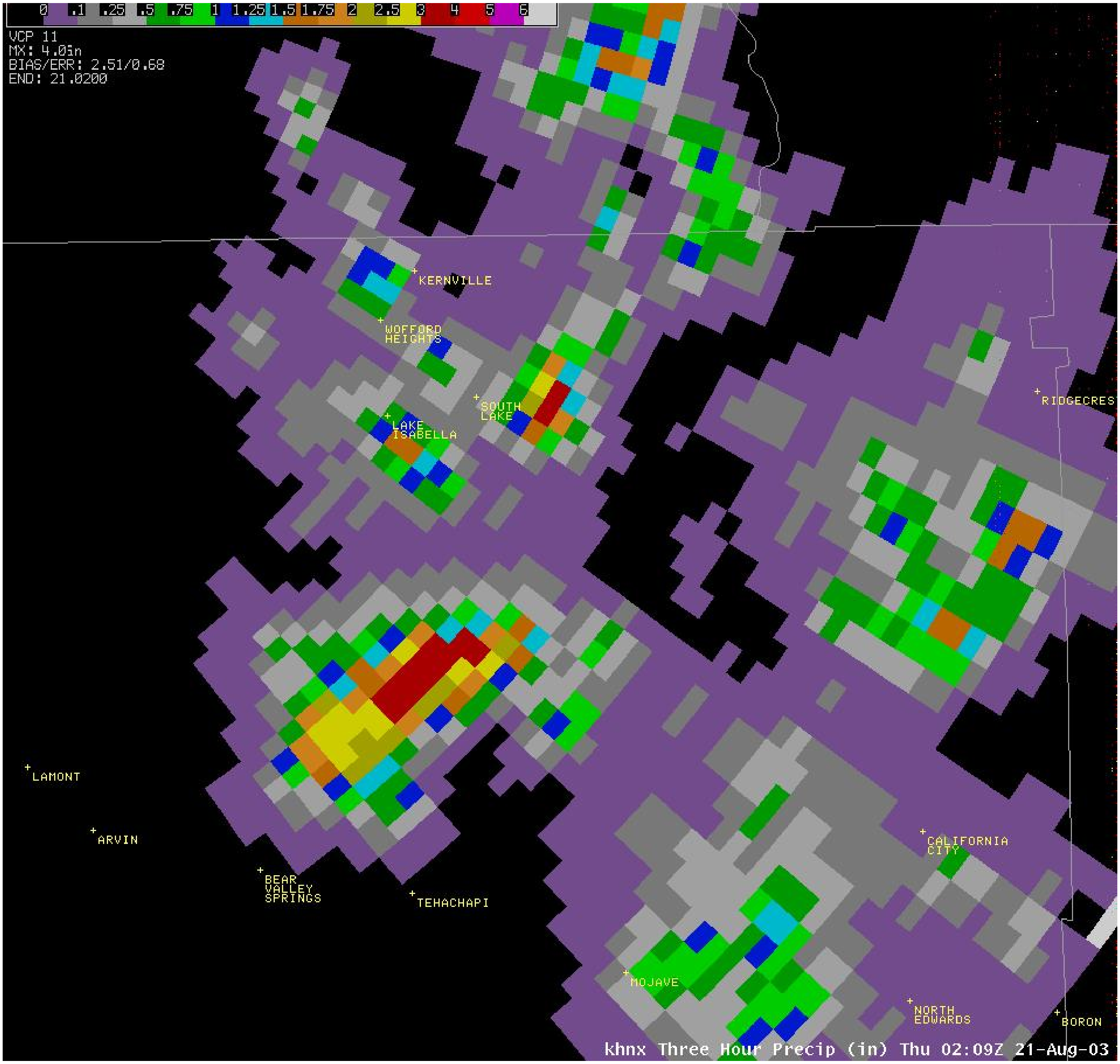
LT KFT MAX = 69DBZ ALT = 9KFT (AZ/R) = 134/ 83
60
50
40
30
20
10
135/92
133/69
khnx Xsect Refl (dbZ) Thu 00:44Z 21-Aug-03

Figure 10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VCP 11
MX: 4.0in
BIAS/ERR: 2.51/0.68
END: 21.0200
KERNVILLE
WOFFORD HEIGHTS
SOUTH LAKE
LAKE ISABELLA
RIDGECREST
LAMONT
ARVIN
BEAR VALLEY SPRINGS
TEHACHAPI
CALIFORNIA CITY
MOJAVE
NORTH EDWARDS
BORON
khnx Three Hour Precip (in) Thu 02:09Z 21-Aug-03