**Western Region Technical Attachment**
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# THE WALNUT GROVE TORNADO OF 23 MARCH 1995: AN EXAMPLE OF A MINI-SUPERCELL

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*During the late afternoon of 23 March 1995, an F0 tornado touched down in the community of Walnut Grove. The storm which produced this short-lived tornado exhibited radar signatures of a mesocyclone and a front- and rear-flanking downdraft couplet. Although the rotation was not deep or strong by midwestern standards, this storm is typical of the short-lived mini-supercells which develop in the California Central Valley.*

## Introduction

At 16:10 PST (0010 UTC) 23 March 1995, a weak tornado touched down in the town of Walnut Grove, which is located 20 miles south of Sacramento. Damage from this storm was confined to a narrow, well-defined corridor which lined up well with the path of the weak mesocyclone found in the storm. This damage was not coincident with any other wind-related damage, thus ruling out the possibility of the damage being created by a microburst. Shortly after the initial development of the tornado, the path of the storm took it across the Georgeianna Slough of the Sacramento River. On the opposite side of the river, eye witnesses at the scene report that a young girl was lifted off the ground by the tornado, and then deposited back down unharmed. Some buildings in the path of the tornado suffered structural damage, with one building having parts of its roof torn off. The tornado lifted back into the storm a few minutes after touching down.

## Discussion

The synoptic situation during the afternoon of 23 March 1995 was the classic severe weather pattern for northern California. A cold core closed low was located off the coast of Oregon with weak diffluence occurring over the northern half of the state of California (Fig. 1). An 80 kt jet streak at 300 mb was located along the eastern side of the low-pressure system, putting northern California under the left entrance region of the jet, which is a preferred location for upward vertical motion. At the surface, a frontal system had moved through the region on 22 March with another weak trough moving across the state during the afternoon of 23 March. The 1200 UTC sounding from OAK indicated that the atmosphere was stable with a lifted index of +10 and a total totals index of 33.

By early afternoon, towering cumulus began to develop along the weak trough as it began moving into the Sacramento Valley. Soon afterwards, the Davis, CA WSR-88D began to indicate shower activity along the trough. Ahead of this weak front, winds were generally from the south-southeast with speeds near 10 kt and dew points in the mid 40s. Behind this weak front, winds shifted to northwesterly at less than 10 mph. Thus, some low-level moisture convergence was occurring along this front as it moved to the southeast.

Thunderstorms developed by mid-afternoon along the front as it approached the Sacramento metropolitan area. Reflectivities along the line at this time were generally 40-45 dBZ, with imbedded areas of 55-65 dBZ, however some intensification was occurring. As the line of thunderstorms moved through the Sacramento area, moderate rains fell with 0.23 inches being reported at downtown Sacramento. By 2330 UTC, rapid intensification began to occur along the southern portion of the line about 15 miles west of Walnut Grove.

By 2359 UTC, the southernmost cell along the line had intensified with a core of 66 dBZ surrounded by a larger area exceeding 50 dBZ (Fig. 2). (Color Figs. 2-6 appear only on Home Page.) Extensions of the higher reflectivities were occurring out ahead of the thunderstorm and on the southern flank. These likely represented the development of the forward and rear flanking downdrafts and their associated mesoscale boundaries.

The 0006 UTC base reflectivity scans indicated that the core of highest reflectivities had retreated to the back edge of the storm, likely due to the mesoscale occlusion process occurring at the surface (Fig. 3). A second higher core of reflectivity appeared to be developing along the southern appendage of the storm. This matched well with the cyclonic rotation apparent on the storm relative velocity products (Fig. 4). This rotation was moderately deep extending through a depth of about 6000 feet. A weak echo region was observable in the southwest flank of the storm on the 1.5 degree base reflectivity scan, indicating the area of the strong (rotating) updraft in the storm. Strong storm relative inflow could also be seen in this figure with inbound values of 40-50 kt indicated north of Walnut Grove, which was indicative of inflow into the entire thunderstorm line. The 3.4 degree scan indicated that the strong updraft was carrying high reflectivities of over 55 dBZ cyclonically up and around the storm to the southeast producing the observed mid-level overhang used for years by radar operators in severe thunderstorm detection. The storm top associated with this storm was near 19,000 feet.

By 0011 UTC, the tornado had touched down in the town of Walnut Grove. The base reflectivity scans indicated that the highest reflectivities in the lowest scans were occurring along the low-level convergence zone and were bowing out to the southeast along the rear flank downdraft (Fig. 5). An appendage of the storm, located along the eastern end of the storm, was likely the front flank downdraft reflectivity signature. Reflectivities throughout the storm had decreased from the previous scan at all levels except the lowest scan indicating that the high reflectivity core was descending to the ground in the downdraft. As this downdraft descended to the ground it likely enhanced the convergence occurring along the helical storm inflow causing the weak tornado to form and descend to the ground. A bounded weak echo region was located over the town of Walnut Grove, associated with the updraft and tornado. This mesocyclone could be easily determined in the storm relative velocity products with 26 kt of outbound adjacent to 35 kt of inbound at 1.5 degrees (Fig. 6). This 30 kt of rotational velocity at a distance of 16 nm from the radar indicated the presence of a weak mesocyclone, according to research by Burgess. This rotation signature could be seen through the 4.3 degree scan, or a depth of about 6600 feet. With a storm top near 19,000 feet, this represented rotation through 35 percent of the storm.

The new Vr/shear function of the WSR-88D was used with the storm relative velocity data to re-analyze rotational velocity and calculate the shear for the mesocyclone. A shear value of .047/s was calculated at the 0.5° scan with a rotational diameter of 0.3 nm and a rotational velocity of 25 kt at a range of 16 nm. At 1.5°, a shear value of .021/s was found with a rotational couplet diameter of 0.8 nm at a range of 16 nm. The rotational velocity was 30 kts, which agreed with the manual calculations from the same storm relative velocity product. Further aloft, at the 2.4° scan, a shear value of .008/s with a diameter of 1.6 nm was found. A shear value of .005/s represents a minimal mesocyclone while values approaching .020/s may signify a strong mesocyclone according to Don Burgess (NEXRAD Operational Support Facility). Thus, shear calculations indicated a "minimal" mesocyclone circulation at mid levels *increasing* to "strong" mesocyclone strength in the lower levels of the storm due to the tightening of the circulation toward the ground. Rotational velocity calculations indicate the opposite trend - with "weak" mesocyclone rotational velocities observed at the 1.5° elevation scan *decreasing* to "minimal" mesocyclone strength at the lowest slice. This suggests an advantage of using the shear calculation in diagnosing rotating thunderstorms. The apparent decrease in strength of the mesocyclone as one looks lower in the storm using the rotational velocity values alone may lead one to believe that the mesocyclone has or is not lowering toward the ground. Actually, it seems that one is simply seeing an increase in frictional effects, that are in reality being offset by a tightening of the rotation.

## Post-Analysis of Storm Environment

The environment in which the Walnut Grove mini-supercell developed was one which was dominated by moderate values of instability and low-level convergence, upper level diffluence, enhanced secondary circulations associated with the exiting jet streak, along with moderately high values of environmental helicity. An estimated sounding which was created for this time used the 0000 UTC OAK sounding, modifying data from 850 mb to the surface in order to represent conditions located ahead of the southeastward moving front. A surface temperature of 58 F with a dew point temperature of 44 F was used in the sounding and mixed dry adiabatically to 850 mb. This resulted in a sounding which had modest instability (CAPE = 768 J/kg) with an equilibrium level near 22000 feet (Fig. 7). These values are typical of storm environments in the Sacramento Valley in March.

Of greater importance was the hodograph (Fig. 8). This hodograph clearly indicates a supercell environment with surface winds of 150 degrees at 8 kt veering to 260 degrees at 39 kt at 3 km. With a storm movement of 268 degrees at 24 kt, this veering wind field results in a storm-relative helicity value of 352 m2/s2 in the 0-3 km layer. Davies-Jones et al. (1990) found that a 0-3 km storm-relative helicity value approaching 300 m2/s2 supported weak to moderate tornadoes. McCaul (1991) found that supercellular convection can occur in low-buoyancy environments if significant low-level wind shear is present. This environment is quite typical during the spring months in the Sacramento Valley. An observed Bulk Richardson number of 7 further supports the supercellular environment which was located over the southern Sacramento Valley on 23 March 1995.

## Conclusions

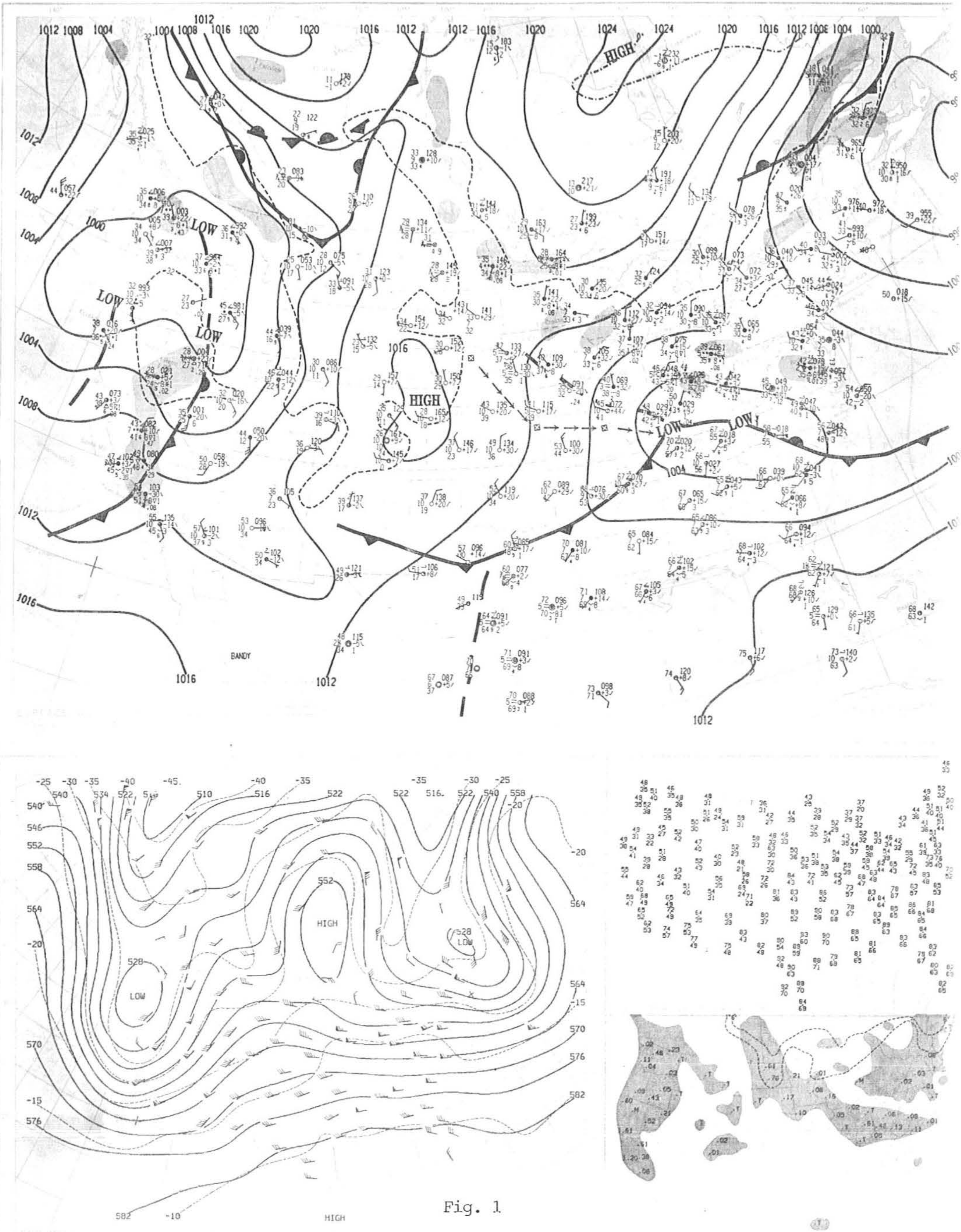
An F0 tornado touched down in the town of Walnut Grove during the afternoon of 23 March 1995. This tornado was short-lived, with rapid development of the parent thunderstorm, and rapid dissipation soon after the development of the tornado. The WSR-88D captured the rotation which was located within the storm, along with indications of other features associated with supercellular convection, such as a rear and forward flanking downdraft couplet and a bounded weak echo region near a region of mid-level overhang. This storm is representative of the mini-supercells which occur in the Sacramento Valley during the spring months. The rapid development and dissipation of these storms creates one of the most challenging and difficult aspects of severe weather forecasting in California.

## References

Davies-Jones, R.D., Burgress and M. Foster, 1990: Test of helicity as a tornado forecast parameter. *16th AMS Conference on Severe Local Storms*, Kananaskis Park, Alberta. 588-592.

McCaul, E.W., Jr., 1991: Buoyancy and shear characteristics of hurricane-tornado environments. *Mon. Wea. Rev.*, **119**, 1954-1978.

Note: Color Figs. 2-6 appear only on the Home Page.


1012
1008
1004
1016
1020
1024
1000
HIGH
LOW
LOW
LOW
LOW
LOW
1016
HIGH
1004
BANDY
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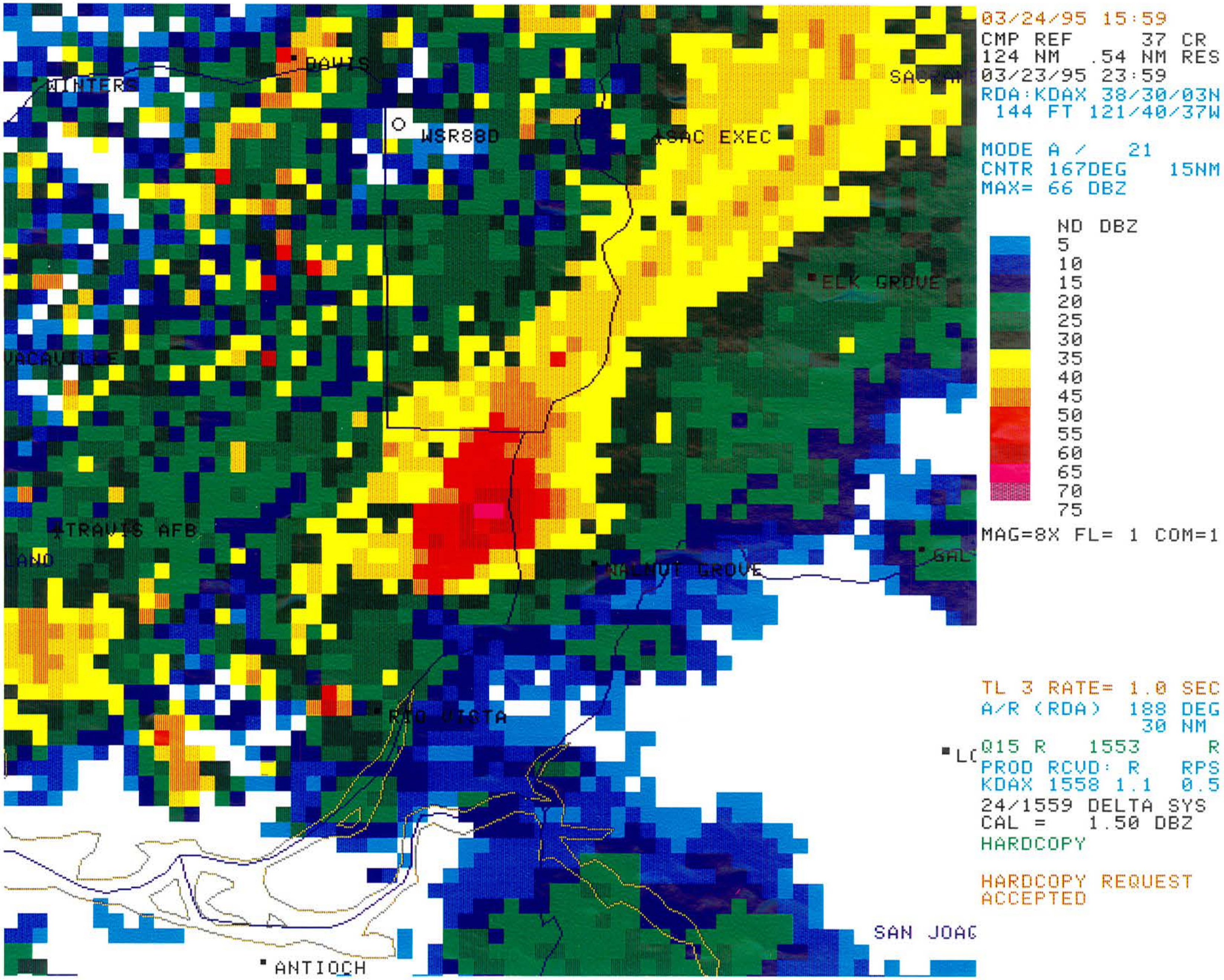
1012
1012
540
534
522
510
516
546
552
558
564
570
576
582
-25
-30
-35
-40
-45
-20
-15
-10
552
HIGH
528
LOW
528
LOW
HIGH

Fig. 1

Fig. 2



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CMP REF      37 CR
124 NM  .54 NM RES
03/23/95 23:59
RDA:KDAX 38/30/03N
 144 FT 121/40/37W

MODE A /   21
CNTR 167DEG   15NM
MAX= 66 DBZ

MAG=8X FL= 1 COM=1

TL 3 RATE= 1.0 SEC
A/R (RDA)  188 DEG
            30 NM
Q15 R   1553     R
PROD RCVD: R   RPS
KDAX 1558 1.1  0.5
24/1559 DELTA SYS
CAL =   1.50 DBZ
HARDCOPY

HARDCOPY REQUEST
ACCEPTED
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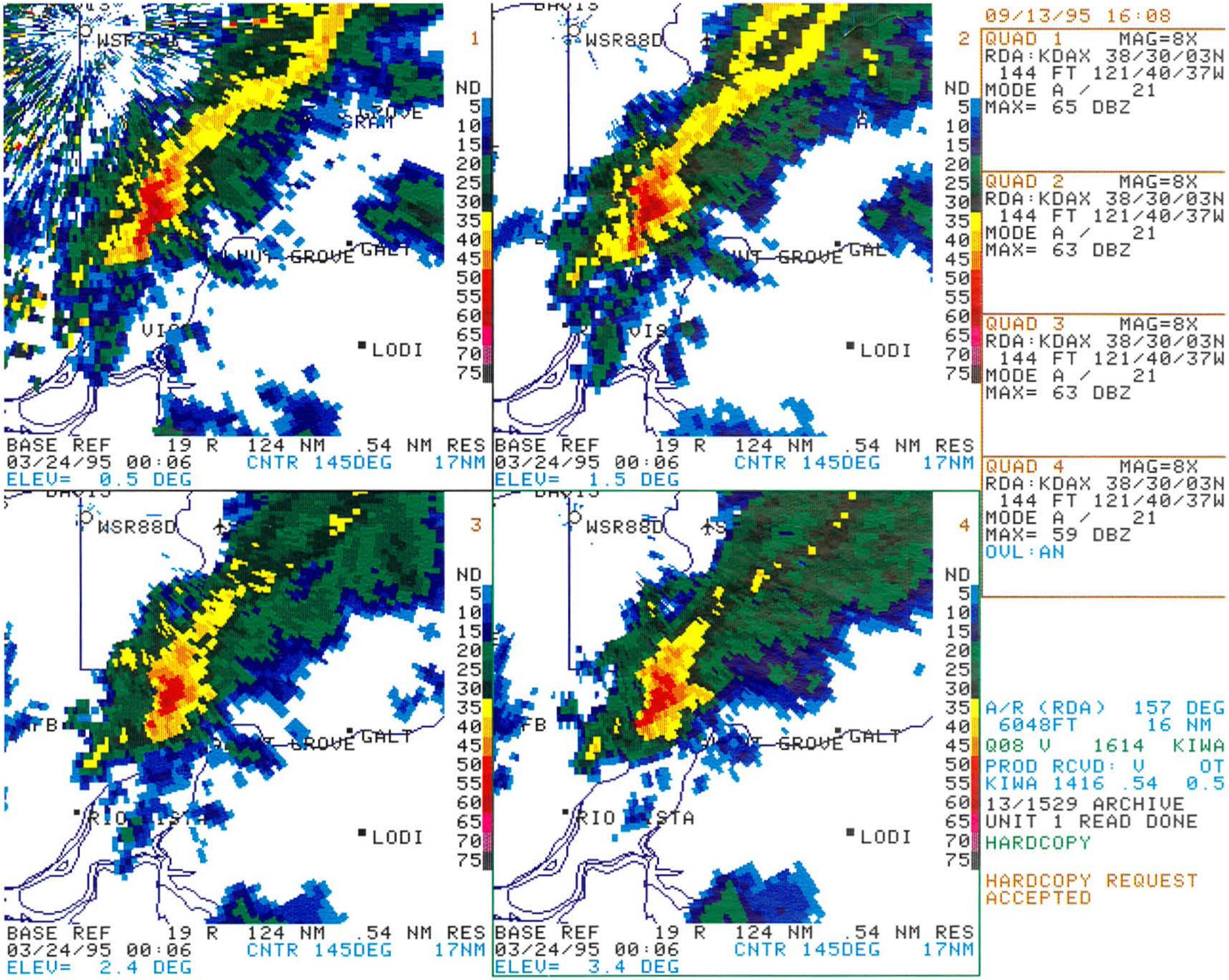
Fig. 3



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BASE REF      19 R   124 NM   .54 NM RES
03/24/95 00:06    CNTR 145DEG      17NM
ELEV=  0.5 DEG

BASE REF      19 R   124 NM   .54 NM RES
03/24/95 00:06    CNTR 145DEG      17NM
ELEV=  1.5 DEG

BASE REF      19 R   124 NM   .54 NM RES
03/24/95 00:06    CNTR 145DEG      17NM
ELEV=  2.4 DEG

BASE REF      19 R   124 NM   .54 NM RES
03/24/95 00:06    CNTR 145DEG      17NM
ELEV=  3.4 DEG
```

```
09/13/95 16:08
QUAD 1      MAG=8X
RDA:KDAX 38/30/03N
 144 FT 121/40/37W
MODE A /    21
MAX= 65 DBZ

QUAD 2      MAG=8X
RDA:KDAX 38/30/03N
 144 FT 121/40/37W
MODE A /    21
MAX= 63 DBZ

QUAD 3      MAG=8X
RDA:KDAX 38/30/03N
 144 FT 121/40/37W
MODE A /    21
MAX= 63 DBZ

QUAD 4      MAG=8X
RDA:KDAX 38/30/03N
 144 FT 121/40/37W
MODE A /    21
MAX= 59 DBZ
OVL:AN

A/R (RDA)   157 DEG
 6048FT      16 NM
Q08 V    1614  KIWA
PROD RCVD: V     OT
KIWA 1416 .54   0.5
13/1529 ARCHIVE
UNIT 1 READ DONE
HARDCOPY

HARDCOPY REQUEST
ACCEPTED
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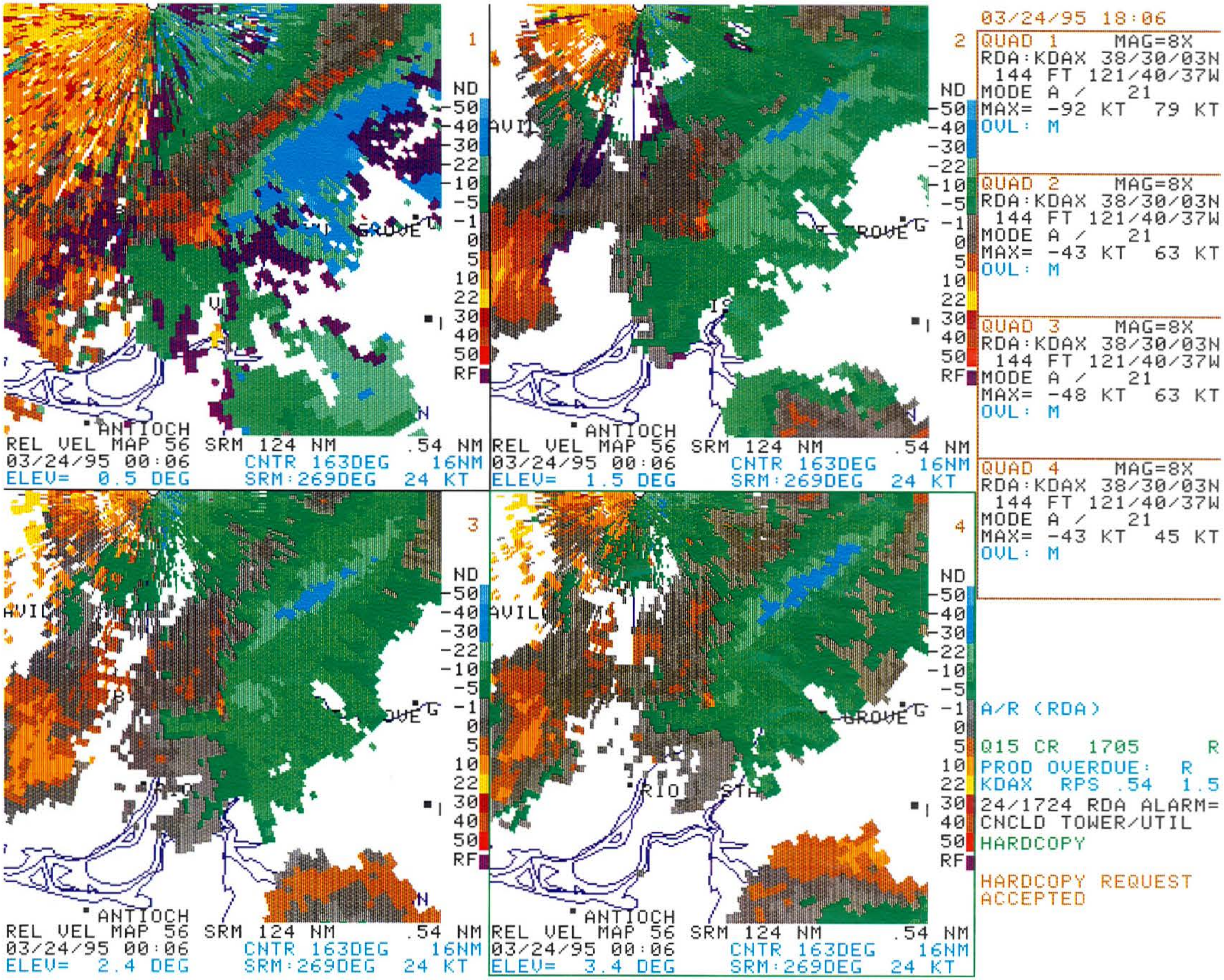
Fig. 4



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REL VEL MAP 56 SRM 124 NM      .54 NM
03/24/95 00:06     CNTR 163DEG    16NM
ELEV=  0.5 DEG     SRM:269DEG   24 KT

REL VEL MAP 56 SRM 124 NM      .54 NM
03/24/95 00:06     CNTR 163DEG    16NM
ELEV=  1.5 DEG     SRM:269DEG   24 KT

REL VEL MAP 56 SRM 124 NM      .54 NM
03/24/95 00:06     CNTR 163DEG    16NM
ELEV=  2.4 DEG     SRM:269DEG   24 KT

REL VEL MAP 56 SRM 124 NM      .54 NM
03/24/95 00:06     CNTR 163DEG    16NM
ELEV=  3.4 DEG     SRM:269DEG   24 KT
```

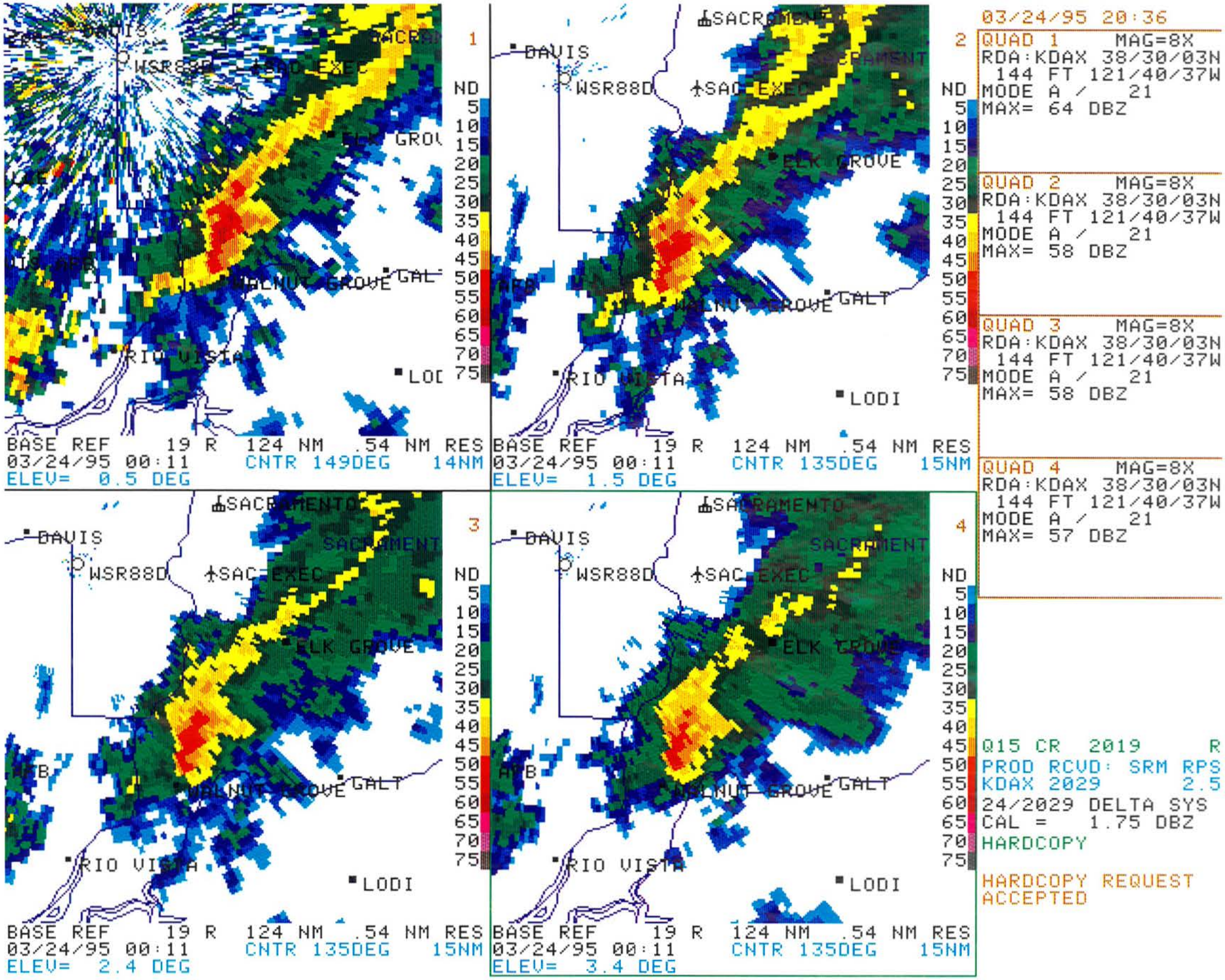
```
03/24/95 18:06
QUAD 1      MAG=8X
RDA:KDAX 38/30/03N
 144 FT 121/40/37W
MODE A /     21
MAX= -92 KT   79 KT
OVL: M
QUAD 2      MAG=8X
RDA:KDAX 38/30/03N
 144 FT 121/40/37W
MODE A /     21
MAX= -43 KT   63 KT
OVL: M
QUAD 3      MAG=8X
RDA:KDAX 38/30/03N
 144 FT 121/40/37W
MODE A /     21
MAX= -48 KT   63 KT
OVL: M
QUAD 4      MAG=8X
RDA:KDAX 38/30/03N
 144 FT 121/40/37W
MODE A /     21
MAX= -43 KT   45 KT
OVL: M

A/R (RDA)

Q15 CR  1705       R
PROD OVERDUE:   R
KDAX  RPS .54   1.5
24/1724 RDA ALARM=
CNCLD TOWER/UTIL
HARDCOPY

HARDCOPY REQUEST
ACCEPTED
```

Fig. 5



BASE REF 19 R 124 NM .54 NM RES
03/24/95 00:11 CNTR 149DEG 14NM
ELEV= 0.5 DEG

BASE REF 19 R 124 NM .54 NM RES
03/24/95 00:11 CNTR 135DEG 15NM
ELEV= 1.5 DEG

BASE REF 19 R 124 NM .54 NM RES
03/24/95 00:11 CNTR 135DEG 15NM
ELEV= 2.4 DEG

BASE REF 19 R 124 NM .54 NM RES
03/24/95 00:11 CNTR 135DEG 15NM
ELEV= 3.4 DEG

03/24/95 20:36

QUAD 1 MAG=8X
RDA:KDAX 38/30/03N
144 FT 121/40/37W
MODE A / 21
MAX= 64 DBZ

QUAD 2 MAG=8X
RDA:KDAX 38/30/03N
144 FT 121/40/37W
MODE A / 21
MAX= 58 DBZ

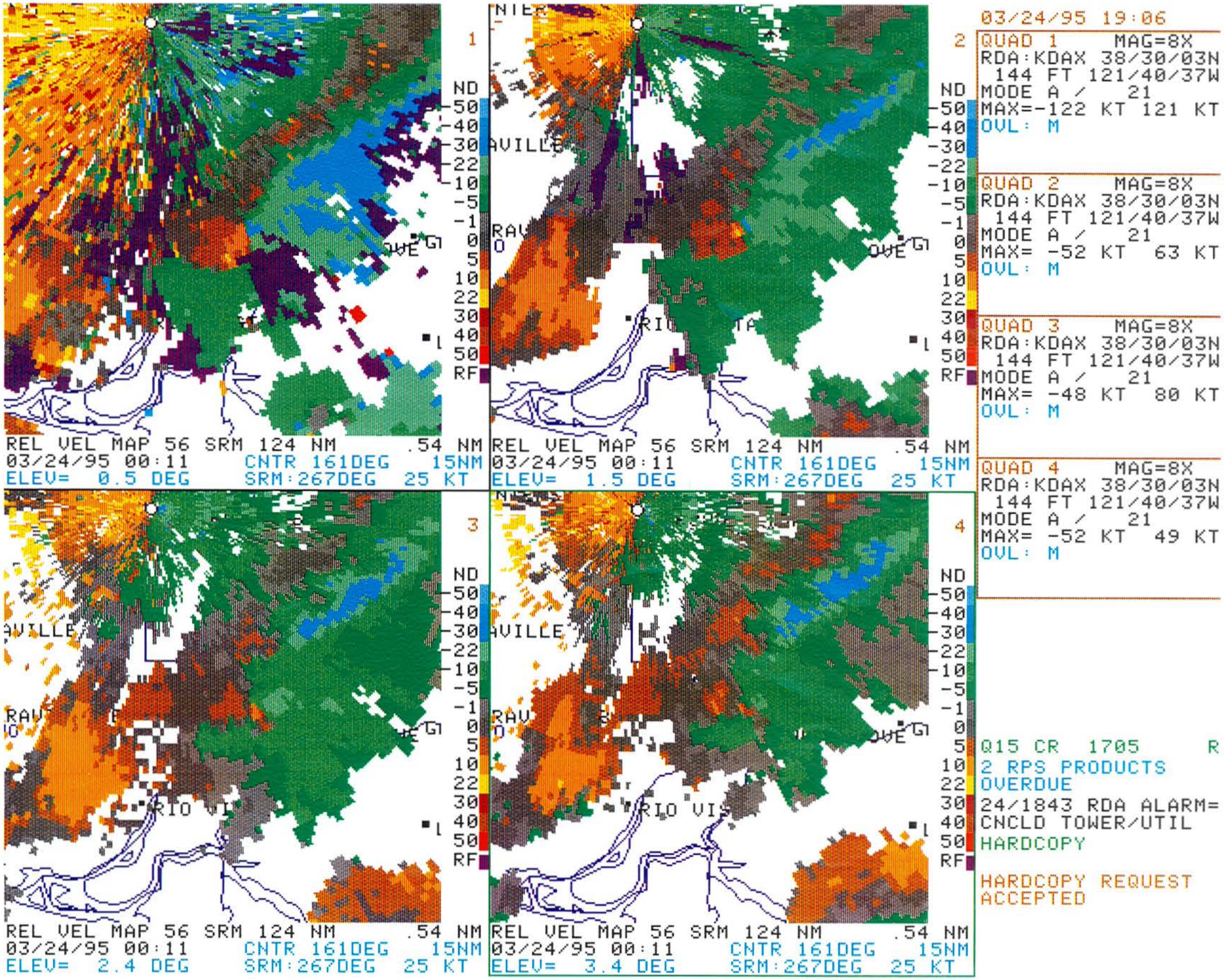
QUAD 3 MAG=8X
RDA:KDAX 38/30/03N
144 FT 121/40/37W
MODE A / 21
MAX= 58 DBZ

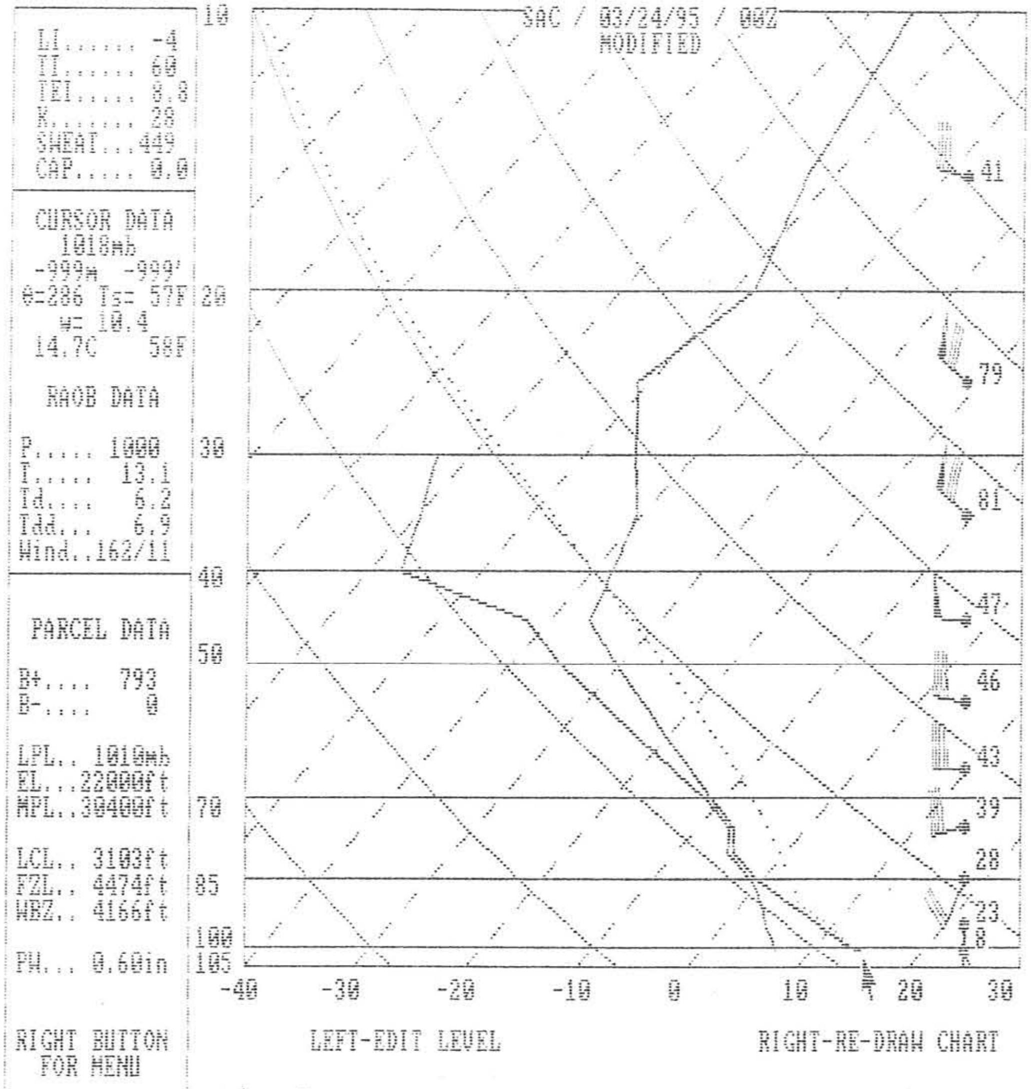
QUAD 4 MAG=8X
RDA:KDAX 38/30/03N
144 FT 121/40/37W
MODE A / 21
MAX= 57 DBZ

Q15 CR 2019 R
PROD RCVD: SRM RPS
KDAX 2029 2.5
24/2029 DELTA SYS
CAL = 1.75 DBZ
HARDCOPY

HARDCOPY REQUEST
ACCEPTED

Fig. 6


03/24/95 19:06
QUAD 1 MAG=8X
RDA:KDAX 38/30/03N
144 FT 121/40/37W
MODE A / 21
MAX=-122 KT 121 KT
OVL: M
QUAD 2 MAG=8X
RDA:KDAX 38/30/03N
144 FT 121/40/37W
MODE A / 21
MAX= -52 KT 63 KT
OVL: M
QUAD 3 MAG=8X
RDA:KDAX 38/30/03N
144 FT 121/40/37W
MODE A / 21
MAX= -48 KT 80 KT
OVL: M
QUAD 4 MAG=8X
RDA:KDAX 38/30/03N
144 FT 121/40/37W
MODE A / 21
MAX= -52 KT 49 KT
OVL: M
1
2
3
4
ND
50
40
30
22
10
5
1
0
-1
-5
-10
-22
-30
-40
-50
RF
AVILLE
RAV
RIO VI
OVE
GT
REL VEL MAP 56 SRM 124 NM .54 NM
03/24/95 00:11 CNTR 161DEG 15NM
ELEV= 0.5 DEG SRM:267DEG 25 KT
REL VEL MAP 56 SRM 124 NM .54 NM
03/24/95 00:11 CNTR 161DEG 15NM
ELEV= 1.5 DEG SRM:267DEG 25 KT
REL VEL MAP 56 SRM 124 NM .54 NM
03/24/95 00:11 CNTR 161DEG 15NM
ELEV= 2.4 DEG SRM:267DEG 25 KT
REL VEL MAP 56 SRM 124 NM .54 NM
03/24/95 00:11 CNTR 161DEG 15NM
ELEV= 3.4 DEG SRM:267DEG 25 KT
Q15 CR 1705 R
2 RPS PRODUCTS
OVERDUE
24/1843 RDA ALARM=
CNCLD TOWER/UTIL
HARDCOPY
HARDCOPY REQUEST
ACCEPTED



```
LI...... -4
TI...... 60
TEI..... 8.8
K....... 28
SWEAT...449
CAP..... 0.0

CURSOR DATA
  1018mb
-999m  -999'
θ=286 Ts= 57F
   w= 10.4
14.7C    58F

 RAOB DATA

P..... 1000
T.....  13.1
Td....   6.2
Tdd...   6.9
Wind..162/11

 PARCEL DATA

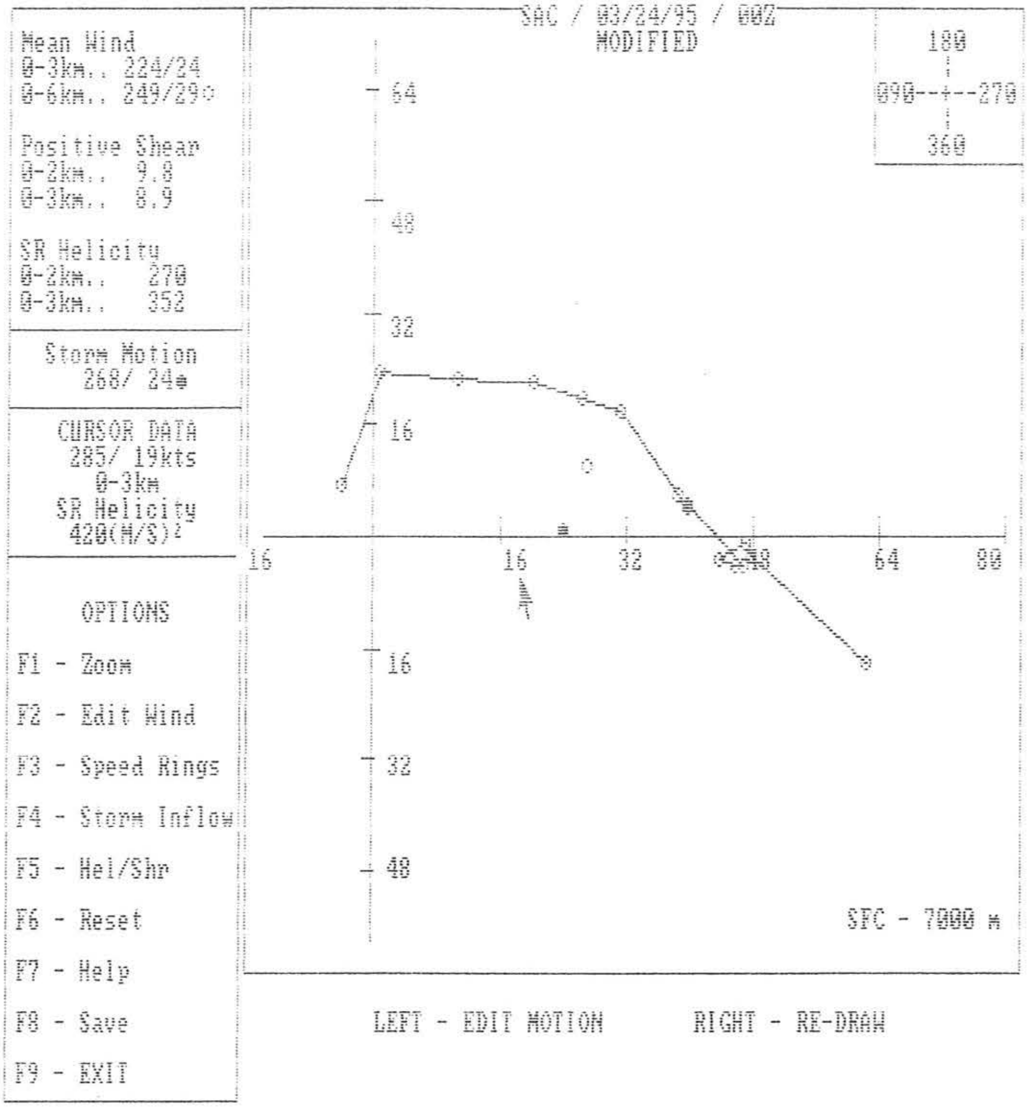
B+....  793
B-....    0

LPL.. 1010mb
EL...22000ft
MPL..30400ft

LCL.. 3103ft
FZL.. 4474ft
WBZ.. 4166ft

PW... 0.60in
```

Fig. 7



SAC / 03/24/95 / 00Z
MODIFIED

Mean Wind
0-3km.. 224/24
0-6km.. 249/29◇

Positive Shear
0-2km.. 9.8
0-3km.. 8.9

SR Helicity
0-2km.. 270
0-3km.. 352

Storm Motion
268/ 24●

CURSOR DATA
285/ 19kts
0-3km
SR Helicity
$420 (M/S)^2$

Fig. 8