Rotated Supercell Structure in a Severe Weather Event over Northern Arizona on 14 August 2003

Michael Staudenmaier, WFO Flagstaff, Arizona

Introduction

An infusion of enhanced deep layer shear, interacting with abundant moisture and instability associated with the North American Monsoon, produced a severe weather outbreak over northern Arizona during the afternoon and evening hours of 14 August 2003. This enhanced deep layer shear was associated with an unusual baroclinic mid-summer cyclone, which had originated in the Ohio Valley and was propagating southwestward around the periphery of a large high pressure cell over the western United States. Due to the westward movement of the cyclone, the vertical structure of the wind field was unusual, supporting a rotated supercell structure with the "hook" echo located on the northern flank of the storms as they moved westward. This case served to illustrate that with a solid conceptual understanding of supercell environments and internal storm circulations, forecasters could anticipate the behavior of these storms given a representative hodograph, in this highly unusual mid-monsoon situation.

Synoptic Overview

The low pressure system that enhanced the severe weather potential over Arizona had its origins over the midwestern United States several days earlier. Strong high pressure over the western United States resulted in the low pressure system slowly moving to the south toward the Gulf of Mexico, then westward across Texas and into New Mexico (Fig 1 and Fig 2). The thermal structure of this system was more typical of a summer continental low than the more typical tropical lows that move across Mexico and then northward into Arizona. This thermal structure resulted in more CAPE than is often observed in northern Arizona. Additionally, stronger dynamics were associated with this system than typically observed during the monsoon season (Fig 3).

Examination of the KFGZ sounding from 1200 UTC 14 August showed a classic "onion" shape sounding signifying the sounding had been taken in the wake of deep convection (Fig 4). However, with the approach of the low pressure system from the east, the sounding was likely to dry aloft with the approach of the dry sector of the storm as shown in the water vapor, cool in the mid-levels due to the approach of the cooler core of the low pressure system, yet still retain the low-level moisture shown in the morning sounding. This meant that the airmass could be expected to destabilize during the day.

Of more importance was the vertical structure of the wind field. The hodograph indicated a clockwise turning of the winds with height, supporting the development of supercells during the afternoon hours when the atmosphere destabilized (Fig 5). However these winds were rotated almost 135 degrees from the classical supercell hodograph. Because of this, it also meant that a similar rotation of the important features of any supercells that might develop should be expected, so that the hook echo, while still being located in the right rear quadrant of the supercell, would be on the northern flank of the supercell.

Model data appeared to capture the synoptic evolution well during the event. Examination of the model forecasts for the afternoon and evening of 14 August identified an environment supportive of organized convection. A four panel of convective indices valid at 2100 UTC (Fig 6) indicated that the eastern portion of the CWA would have values of CAPE over 1000 J/kg (well above the climatological values typical of the monsoon season) and 0-6 km Bulk Shear magnitudes greater than 30 kt (again exceeding the climatological values typical of monsoon season). Energy Helicity Index (EHI) and Vorticity Generation Potential (VGP) values were also high for the region, and identified the potential for possible tornadogenesis. By 0300 UTC 15 August, these high values were predicted to shift into the western portion of the CWA resulting in a continued threat even into the evening hours (Fig 7). Model wind data indicated that the vertical wind fields would remain similar to those sampled in the morning sounding, such that supercells rotated from the classic orientation could be expected.

Event Discussion

Convection began during the morning hours and became widespread across the eastern portions of the CWA by early afternoon. As indicated by the model forecasts, embedded supercells first developed over portions of the eastern CWA. An example of one of the supercells is shown in Figure 8, with a four panel vertical slice of the storm at 2354 UTC illustrating many of the classic signatures associated with supercells, although rotated almost 135 degrees from normal. This storm was one of two supercells that developed in the same general area. A combined reflectivity/velocity image at 2158 UTC illustrates both of these storms (Fig 9). Over the next several volume scans, the rear flank downdraft (located on the north side of the storm) accelerated rapidly toward the west and was associated with another rapid spin-up of the storm with an even more classic supercellular appearance (Fig 10). In the SRM image on the right, 30-40 kt of outbound velocity are adjacent to 40-50 kt of inbound velocities. This particular storm produced five separate TVS alarms between 2349 and 0034 UTC as it underwent this evolution. An important feature illustrated by Figure 10 is that due to the more course resolution of the reflectivity data, small thin hook echoes may be difficult to identify. However, the higher resolution velocity data showed this area more clearly. This is an important consideration during the warning process for placement of the potential tornado.

Additional embedded supercells developed during the remainder of the afternoon and into the evening hours. As indicated by the Eta model, convection lingered long into the evening hours, and additional storms developed tornadic signatures over the western portions of the CWA between 0000 and 0400 UTC. Reports of funnel clouds and tornadoes were received by the office with several of these supercells, validating the radar indicated signatures. In addition to the tornadic activity, hail up to two inches in diameter was also reported during this severe weather outbreak.

Summary

By conducting a careful examination of the winds aloft and the shape of the hodograph, an educated assessment of potential supercell evolution can be accomplished. Too often, forecasters think all supercells will attain the "classic" appearance, even though this can only occur with the proper curvature and orientation of the hodograph. By properly determining, in advance, the most likely shape and orientation of the supercell, the radar meteorologist can focus his attention on the relevant portion of the storm looking for classic structures such as rotation aloft, hook echoes, and weak echo regions. This severe weather outbreak serves as an excellent example of a modified environment that led to 'rotated' supercells along with isolated large hail and tornadoes.

Figure 1

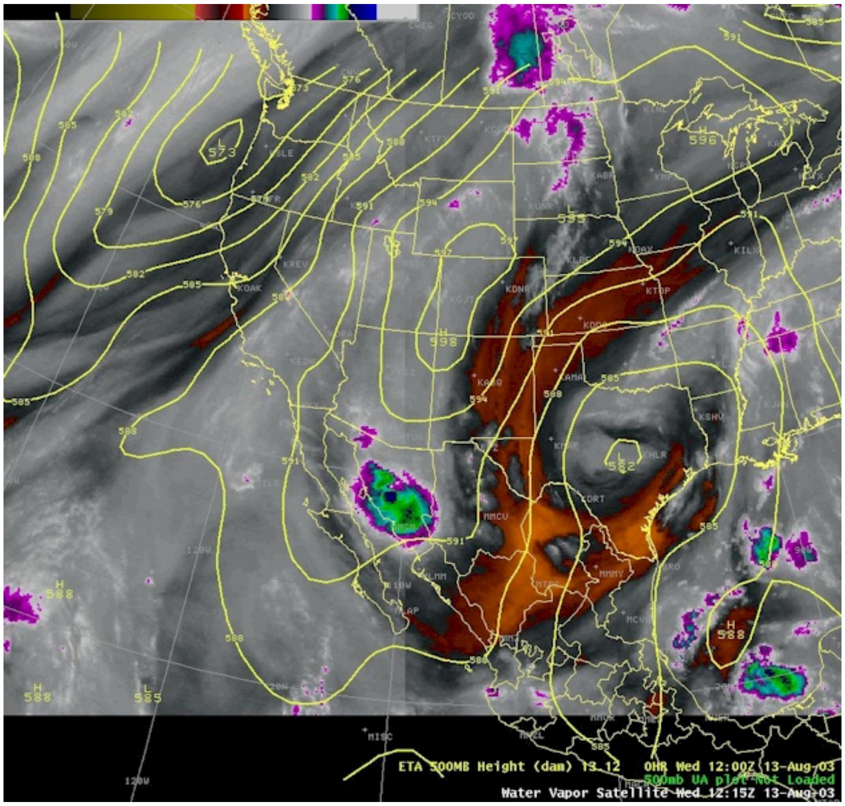


Figure 2

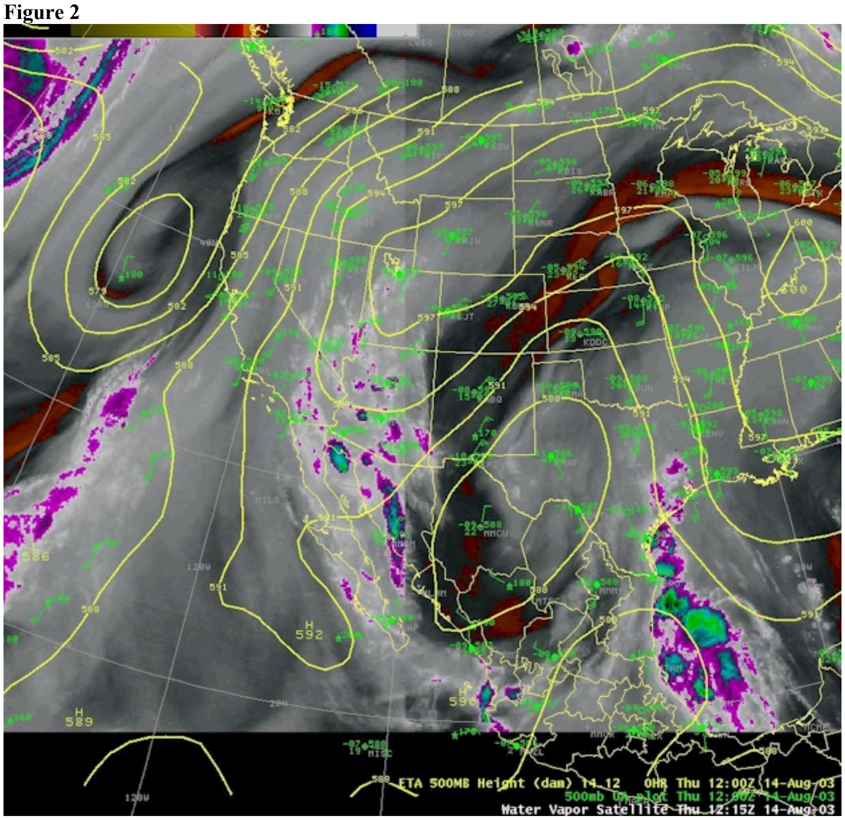
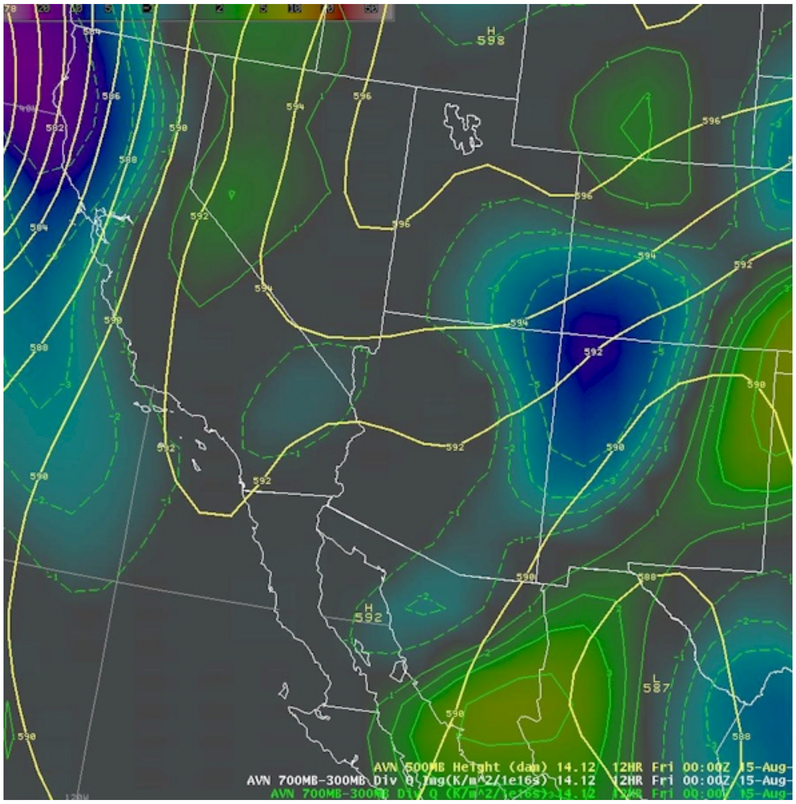


Figure 3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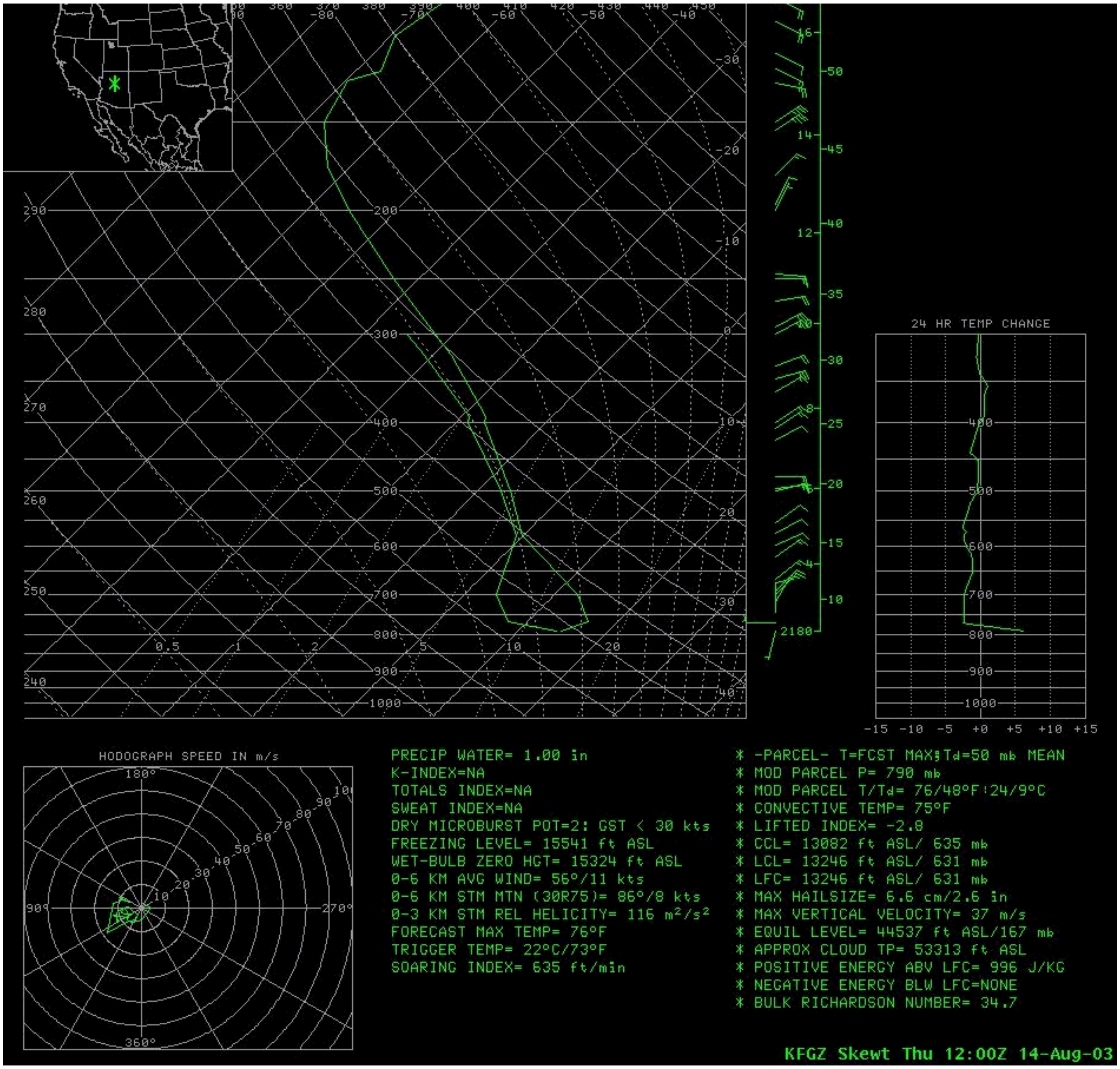
AVN 700MB-300MB Div Q Img(K/m^2/1e16s) 14.12 12HR Fri 00:00Z 15-Aug-
AVN 700MB-300MB Div Q (K/m^2/1e16s) 14.12 12HR Fri 00:00Z 15-Aug-

Figure 4



HODOGRAPH SPEED IN m/s
24 HR TEMP CHANGE
PRECIP WATER= 1.00 in
K-INDEX=NA
TOTALS INDEX=NA
SWEAT INDEX=NA
DRY MICROBURST POT=2: GST < 30 kts
FREEZING LEVEL= 15541 ft ASL
WET-BULB ZERO HGT= 15324 ft ASL
0-6 KM AVG WIND= 56°/11 kts
0-6 KM STM MTN (30R75)= 86°/8 kts
0-3 KM STM REL HELICITY= 116 m²/s²
FORECAST MAX TEMP= 76°F
TRIGGER TEMP= 22°C/73°F
SOARING INDEX= 635 ft/min
* -PARCEL- T=FCST MAX;Td=50 mb MEAN
* MOD PARCEL P= 790 mb
* MOD PARCEL T/Td= 76/48°F:24/9°C
* CONVECTIVE TEMP= 75°F
* LIFTED INDEX= -2.8
* CCL= 13082 ft ASL/ 635 mb
* LCL= 13246 ft ASL/ 631 mb
* LFC= 13246 ft ASL/ 631 mb
* MAX HAILSIZE= 6.6 cm/2.6 in
* MAX VERTICAL VELOCITY= 37 m/s
* EQUIL LEVEL= 44537 ft ASL/167 mb
* APPROX CLOUD TP= 53313 ft ASL
* POSITIVE ENERGY ABV LFC= 996 J/KG
* NEGATIVE ENERGY BLW LFC=NONE
* BULK RICHARDSON NUMBER= 34.7
KFGZ Skewt Thu 12:00Z 14-Aug-03

Figure 5

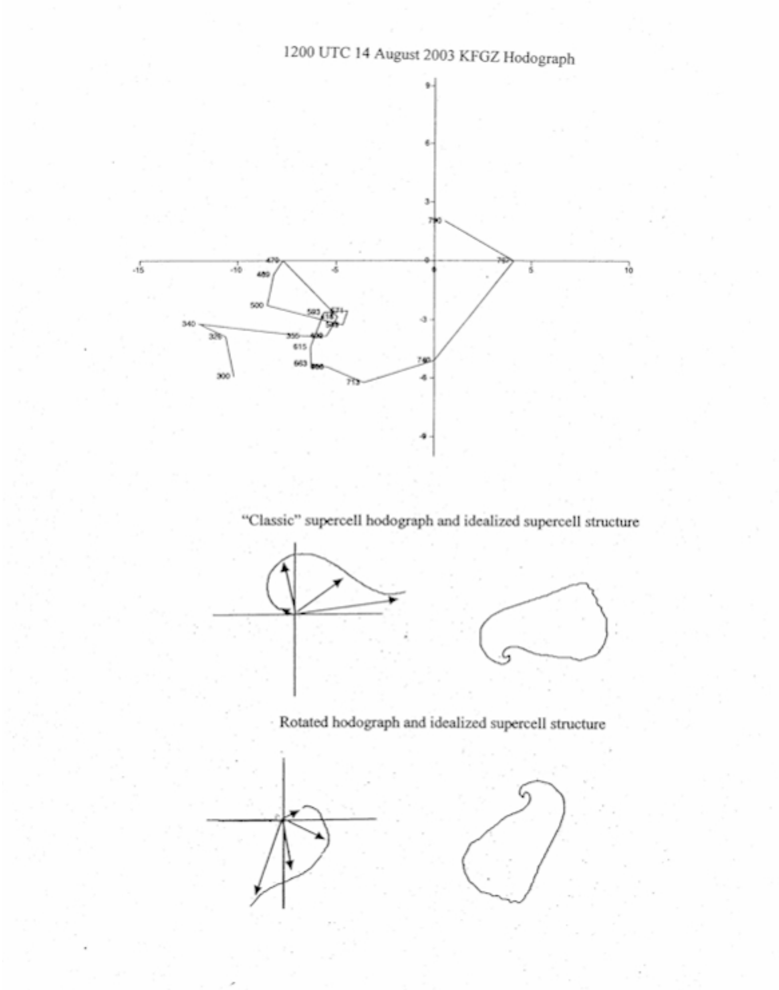


Figure 6

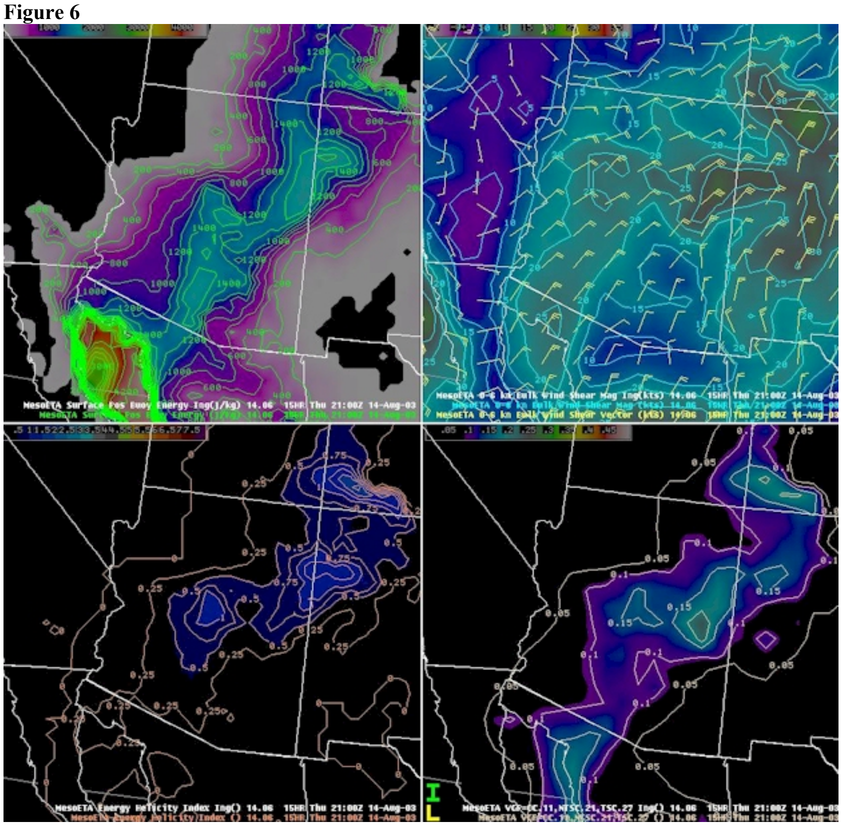


Figure 7

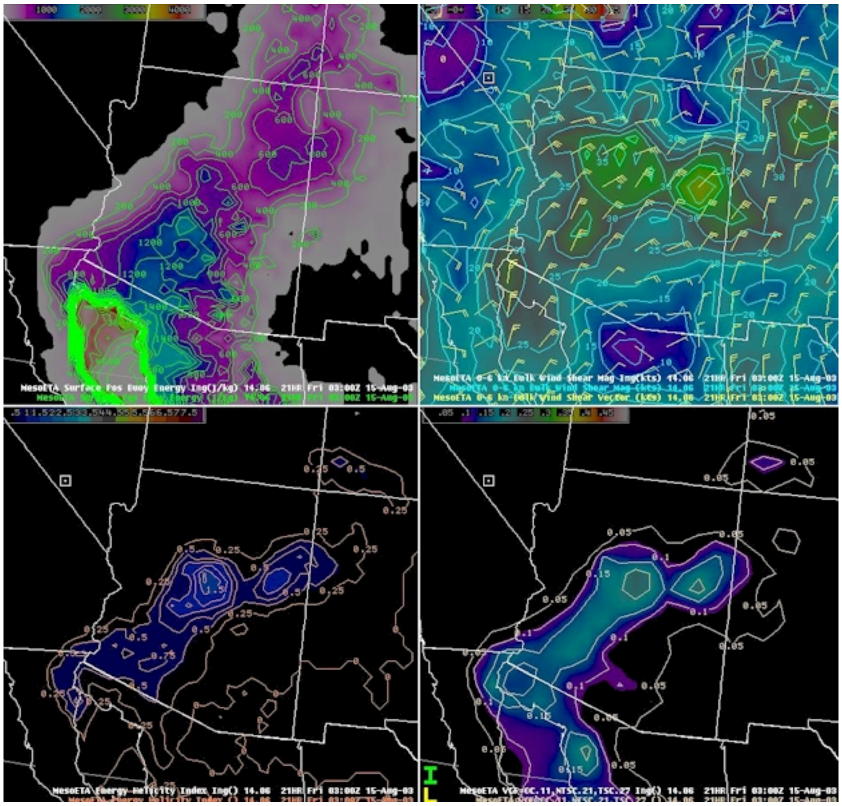


Figure 8

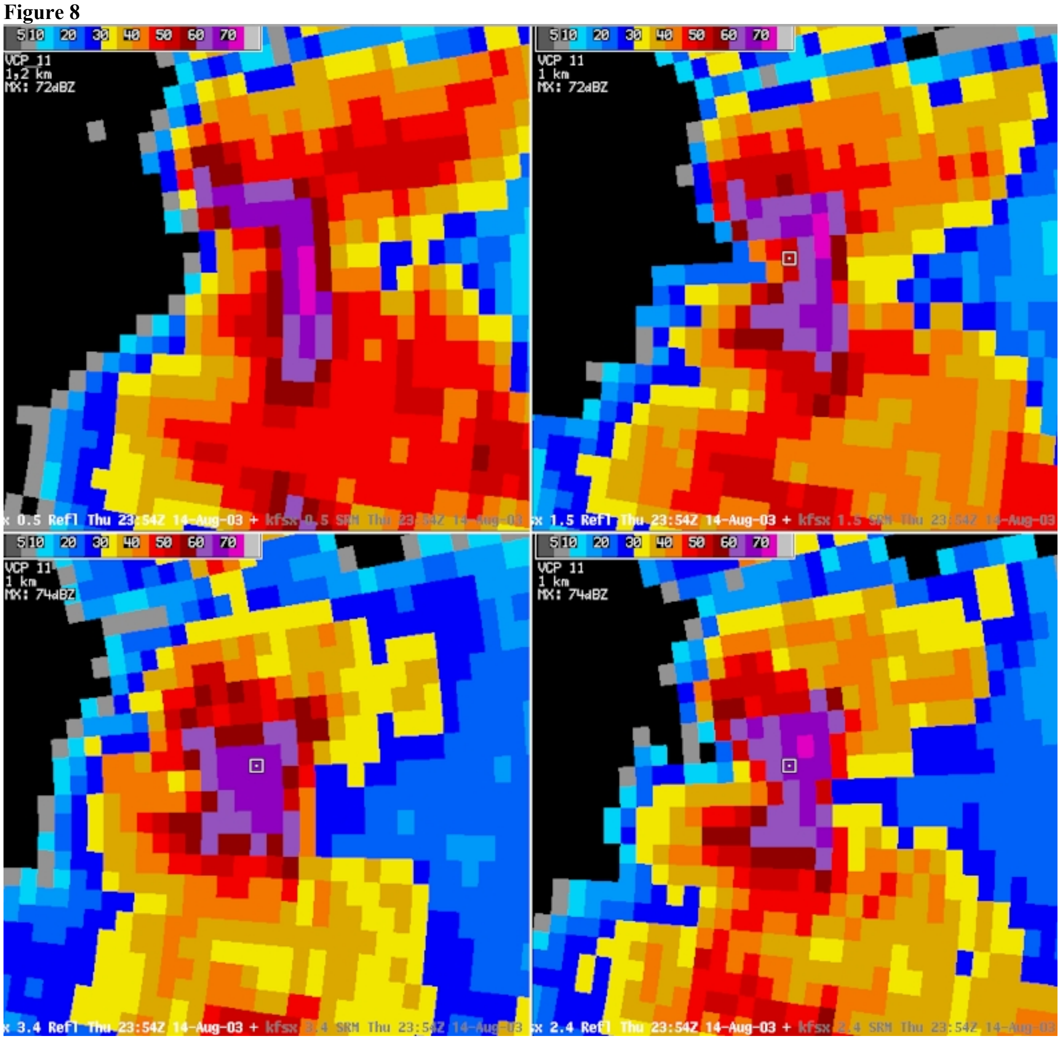
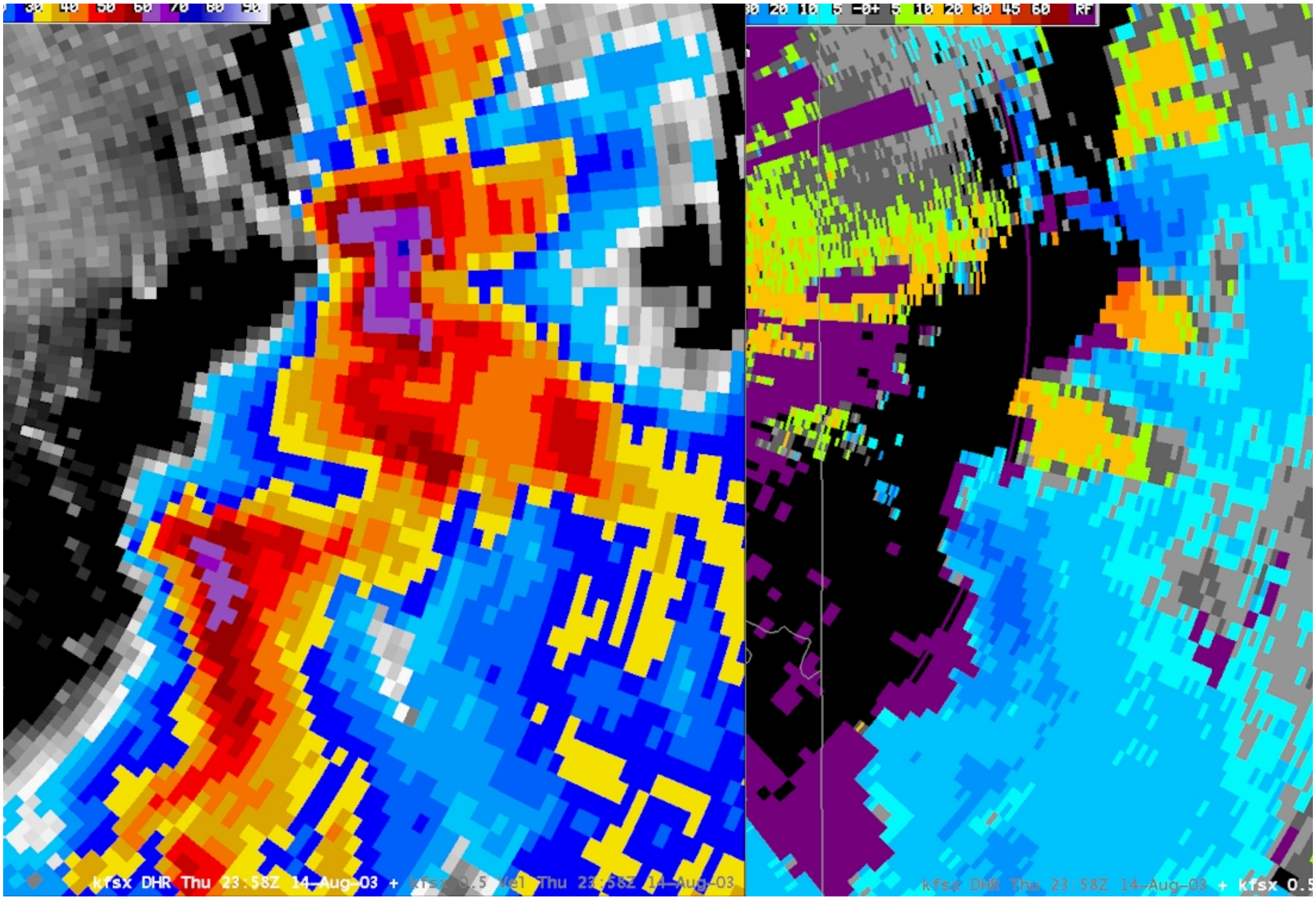


Figure 9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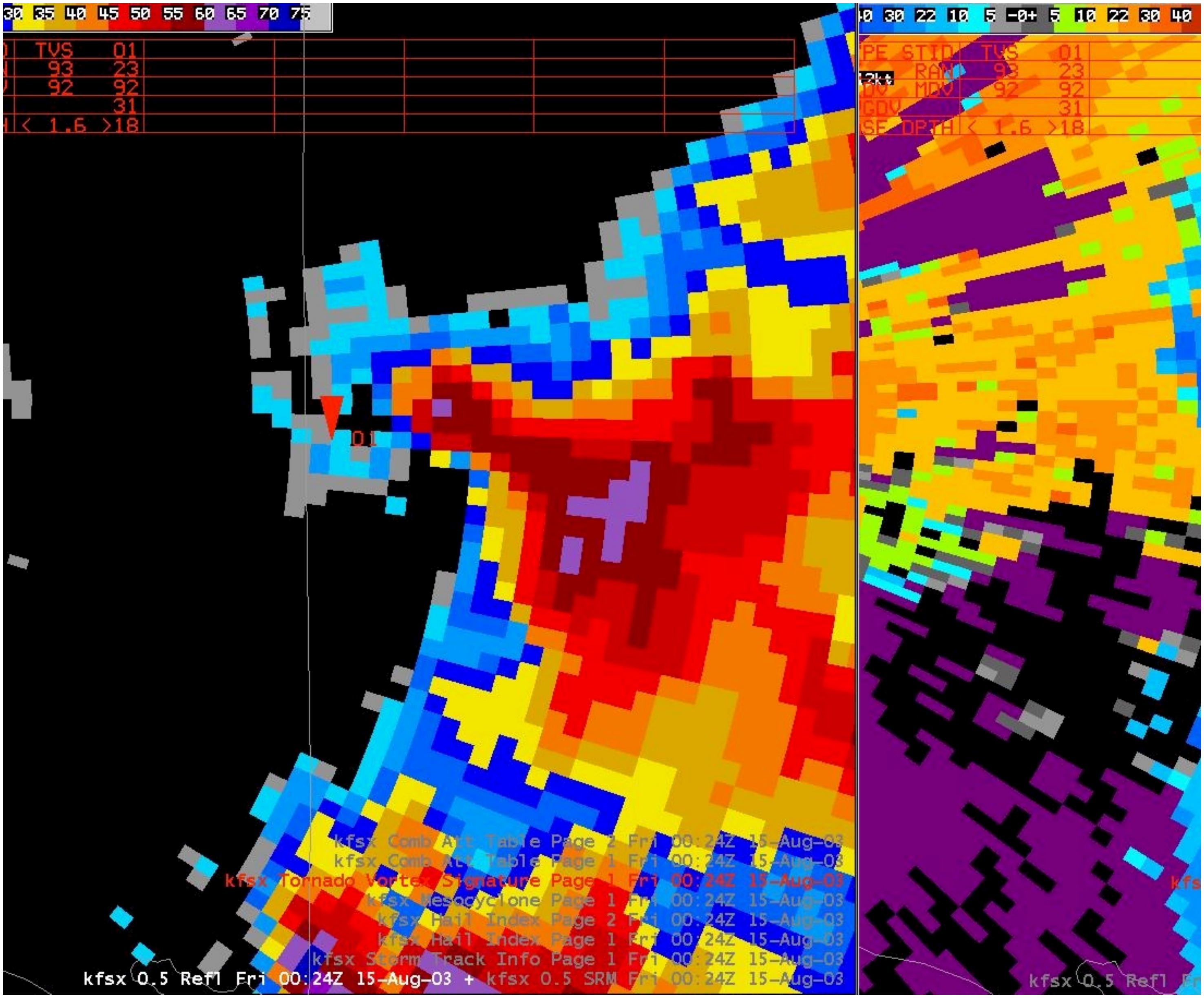
kfsx DHR Thu 23:58Z 14-Aug-03 +
kfsx DHR Thu 23:58Z 14-Aug-03 + kfsx 0.5

Figure 10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STID TVS 01
RAN 93 23
MDV 92 92
GDV 31
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kfsx 0.5 Refl