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SEVERE THUNDERSTORMS OF 3 APRIL 2004: AN EXAMINATION OF A DRY-SEASON SEVERE WEATHER EVENT IN THE BORDERLAND

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1. INTRODUCTION

During the afternoon of 3 April 2004, a rare severe thunderstorm event occurred in south-central New Mexico and far west Texas. Hail up to 2.50 inches in diameter accumulated to a depth of four inches on US Highway 62/180 six mi. west of the township of Cornudas, TX, resulting in damage to vehicles. Golf ball-sized hail fell over the northern edge of Chaparral, NM, accumulating over 12 inches in places, resulting in extensive damage to homes.

This event was highly unusual for the region in April, which is typically characterized by dry conditions and frequent wind storms with blowing dust. Normal April rainfall in El Paso is 0.26 inches, making up only 3% of the normal annual precipitation. Since 1955, there have only been six days in April with severe-criteria hail (diameter ≥ 3/4 inch) reported in the current Santa Teresa/El Paso (EPZ) NWS County Warning Area (Reynolds 1999).

This case study will examine the synoptic and mesoscale environment on 3 April and present a detailed analysis of storm initiation and evolution.

2. SYNOPTIC ENVIRONMENT

The synoptic pattern on 3 April featured an eastward drifting middle and upper-tropospheric low centered over southern Arizona. At 250 mb a diffluence axis was oriented southwest to northeast over northern Chihuahua, through south-central New Mexico, and into southeastern Colorado. A 70+ kt jet streak was oriented south-north across the region, as analyzed by various forecast models and as evidenced by a band of cirrus forming on the leeward side of mountain ranges in northern Chihuahua (Fig. 1).

In the mid-levels, the cut-off low induced strong southerly winds, with a 55 kt jet streak cutting through New Mexico. The profiler at White Sands Missile Range (WSMR) Headquarters, about 19 mi. east of Las Cruces, NM, measured 55 kt winds at 6500 meters AGL at 0000 UTC on 4 April. This strong southerly mid-level flow allowed moisture transport from the Gulf of California into New Mexico and Arizona, a process often referred to as the “Baja Tap.” This mid-level moisture is evident at 500 mb, with dew point depressions of 8°C at Santa Teresa, NM, and 3°C at Albuquerque, NM and Tucson, AZ (Fig. 2). Unseasonably cold temperatures aloft associated with the cut-off low were also evident over Arizona. The 500 mb temperature at Tucson was -23°C at 0000 UTC 4 April, 7°C below normal.

In the low-levels, a cold front was banked up against the higher terrain of eastern New Mexico and west Texas. Southeast winds ahead of this front resulted in weak moisture advection from the surface to 700 mb.

3. MESOSCALE FEATURES

Analysis of surface data at 1800 UTC 3 April revealed a 1007 mb low over northeastern Durango, Mexico with a surface trough extending northward through Chihuahua and southwestern New Mexico. The backdoor cold front was banked up against high terrain in eastern New Mexico, but remained east of Guadalupe Pass, TX (GDP). A weak thermal moisture boundary [hereafter, TMB] was analyzed west of GDP, paralleling the cold front. West of the TMB, winds were primarily SSE with dewpoints in the 40s (°F), while east of the boundary dewpoints were in the 50s with ESE winds. Visible satellite imagery revealed a thin line of cumulus clouds in the vicinity of the analyzed TMB. The sparse surface network in west Texas made this feature particularly difficult to analyze.

Daily COOP observations indicated that the high temperature on 3 April reached 81°F in Dell City, TX, which by late afternoon was east of the TMB. Meanwhile, to the west of the TMB, daily high temperatures reached only 73°F at El Paso, TX (ELP) and Santa Teresa, NM (EPZ). Dewpoints at ELP dropped to the upper 30s (°F) by mid-afternoon and did not recover until rain began falling at the station. No official or supplemental dewpoint data was available for the area east of the TMB, with the exception of GDP, which is considered unrepresentative due to the unique topographic location of the observing station. RUC forecast surface dewpoint fields clearly indicated the TMB, with surface dewpoints in the low 50s (°F) to the east of the boundary in the central Hudspeth County, TX where convection initiated (Fig. 3).

The 0000 UTC 4 April sounding from EPZ was modified with the 81°F high temperature at Dell City, TX, and RUC forecast dewpoint of 51°F in central Hudspeth County. This modified sounding (Fig. 4) reveals a pre-storm environment possessing very high instability due primarily to the unusually high amounts of low level moisture. Surface dewpoints in the low 50s east of the TMB were over 20 degrees above normal for early April. This factor, combined with surface temperatures in the upper 70s and lower 80s contributed to most unstable CAPEs of 3600 J kg^{-1} indicating the air mass was very unstable. Winds exhibited little change in direction or

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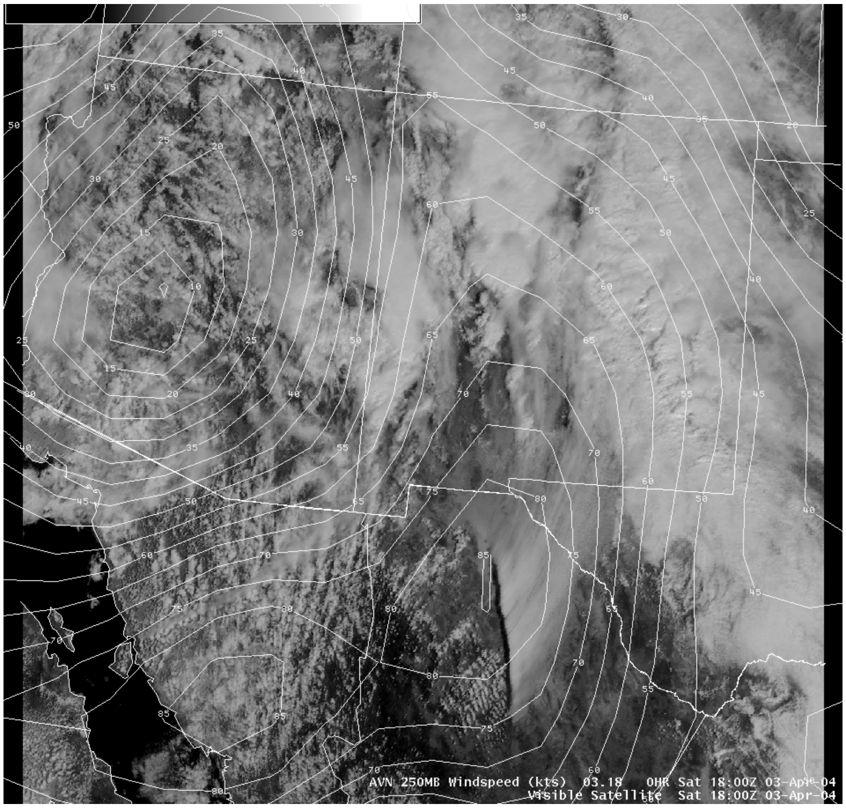


Figure 1. Vis. Sat. image and GFS 250 mb wind speed analysis for 1800 UTC 3 April 2004 indicating 85 kt jet streak.

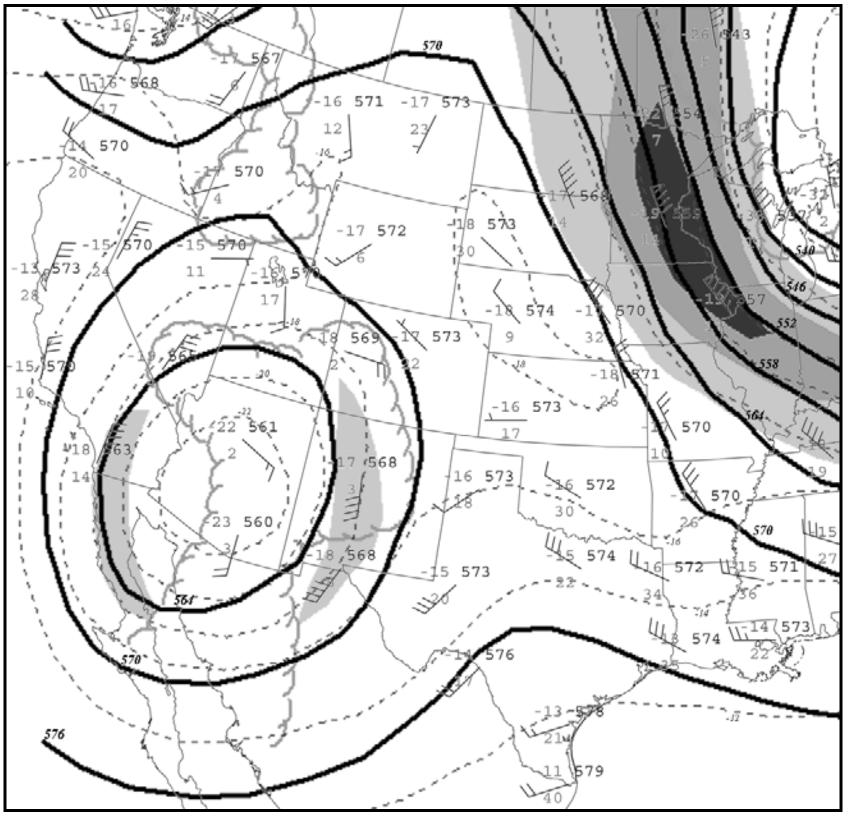


Figure 2. 500 mb analysis for 0000 UTC 4 April 2004.

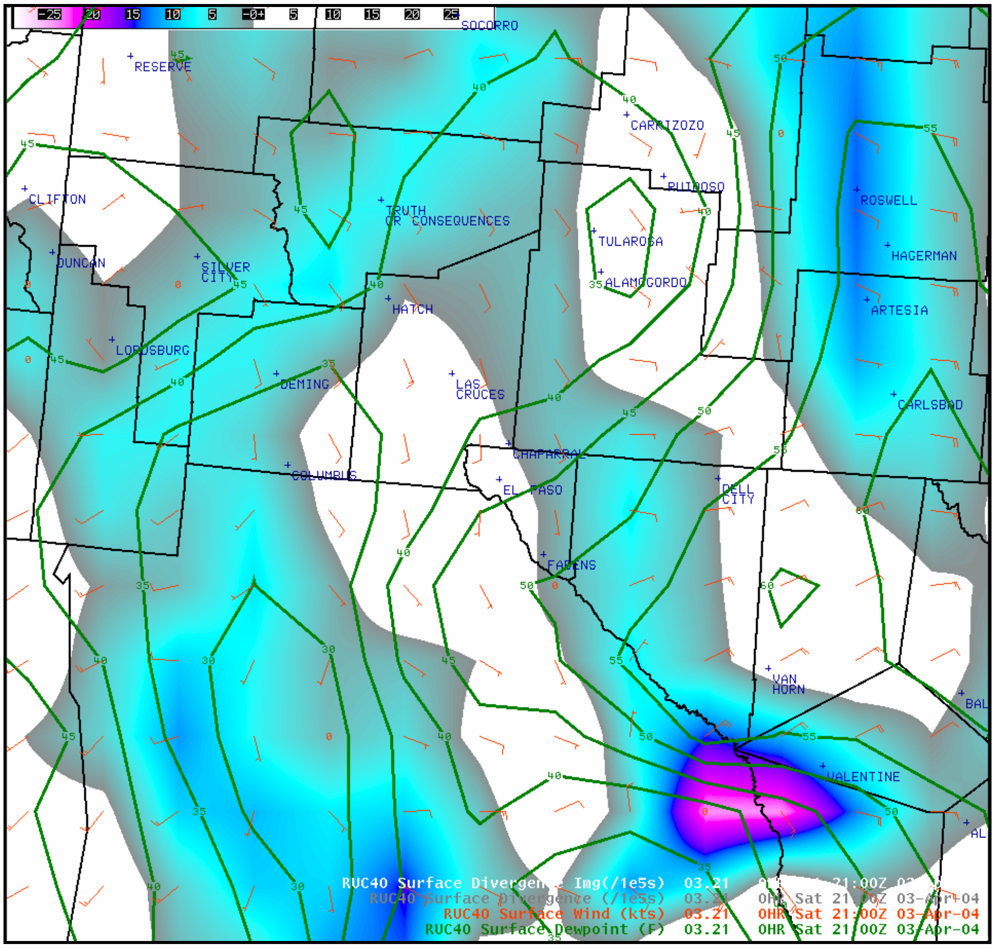


Figure 3. 40km-Rapid Update Cycle analysis of surface dewpoints (solid lines), winds (barbs), and convergence (shaded) for 2100 UTC 3 April.

speed through the lowest 6000 ft AGL; however wind speeds increased from 15 kts to 45 kts between 700 and 500 mb with modest veering. This results in a surface to 3 km storm relative helicity of 74 $m^2 s^{-2}$, suggesting the lower tropospheric shear was only marginally favorable for tornadoes. However the wind speed shear between the surface and middle troposphere was rather intense with a 0-6km shear value of 27 $m s^{-1}$, suggesting a favorable shear for supercell development (Thompson et al. 2003). The level of free convection was rather high, located at 8900 ft AGL while conversely the wet bulb zero height was low at 5900 ft AGL. Thus the available data indicated a strong potential for supercells to produce hail but with tornadoes unlikely due to the higher cloud bases (Thompson et al. 2002).

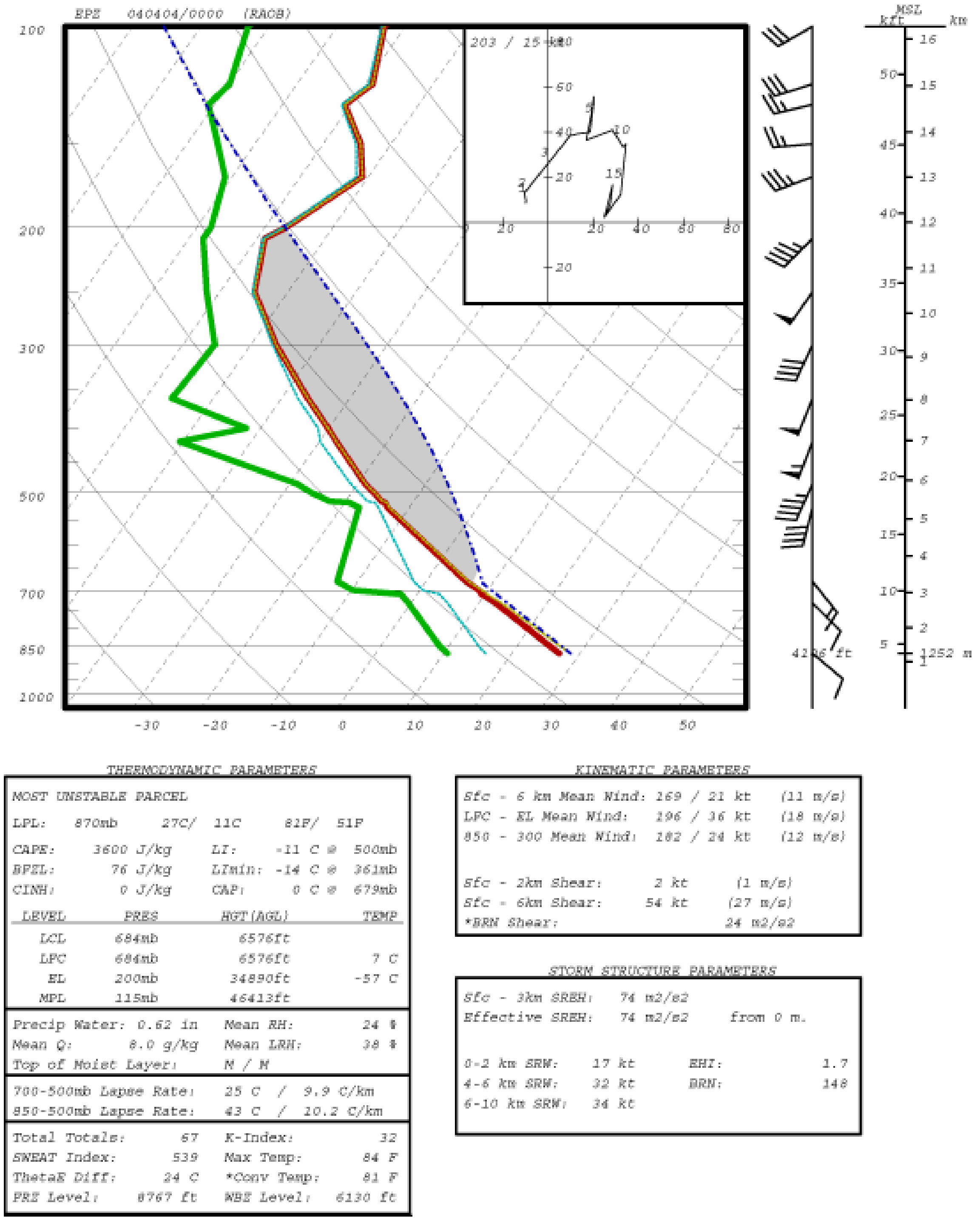
4. STORM EVOLUTION

At 1830 UTC 3 April, the WSR-88D radar in Santa Teresa, NM indicated the TMB on the 2.5-degree reflectivity scan in northeastern El Paso County, arcing southeast into Hudspeth County (Fig. 5). Beam-blockage from the Franklin Mountains prevents lower-level scan analysis over much of eastern El Paso and Hudspeth Counties.

By 1900 UTC weak showers and thunderstorms developed along the nearly-stationary TMB and propagated northward in extreme southwestern Otero County, NM. Outflow from this weak convection may have initiated a westward push to the TMB, which by 2100 UTC had moved into central El Paso County. At this time the northern edge of the TMB became lost in the ground clutter pattern just east of Chaparral, NM. However, a line of cumulus clouds on visible satellite imagery confirmed the location of the TMB which remained nearly stationary after 2100 UTC. Showers and thunderstorms began to develop just east of the boundary in the vicinity of the Sierra Blanca and Finlay Mountains in south-central Hudspeth County, TX after 2100 UTC.

4.1 *"The Cornudas Storm"*

The first severe storm of the day initiated around 2115 UTC just northwest of Sierra Blanca, TX and just east of the TMB, likely aided by low-level upslope flow along the Finlay Mountains. The storm followed the mean flow northward, and by 2230 UTC was located over unpopulated ranchland about 10 mi. southwest of Cornudas, TX while exhibiting echo tops of 30,000 ft. RHI cross sections of KEPZ Level II data as well as 1.5-



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THERMODYNAMIC PARAMETERS

MOST UNSTABLE PARCEL

LPL:    870mb      27C/  11C      81F/   51F

CAPE:     3600 J/kg      LI:      -11 C @   500mb
BFZL:       76 J/kg      LImin:  -14 C @   361mb
CINH:        0 J/kg      CAP:      0 C @   679mb

 LEVEL        PRES         HGT(AGL)          TEMP
   LCL        684mb         6576ft
   LPC        684mb         6576ft            7 C
    EL        200mb        34890ft          -57 C
   MPL        115mb        46413ft

Precip Water: 0.62 in    Mean RH:            24 %
Mean Q:        8.0 g/kg  Mean LRH:           38 %
Top of Moist Layer:      M / M

700-500mb Lapse Rate:    25 C  /  9.9 C/km
850-500mb Lapse Rate:    43 C  /  10.2 C/km

Total Totals:        67  K-Index:            32
SWEAT Index:        539  Max Temp:         84 F
ThetaE Diff:       24 C  *Conv Temp:       81 F
FRZ Level:      8767 ft  WBZ Level:     6130 ft
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KINEMATIC PARAMETERS

Sfc - 6 km Mean Wind: 169 / 21 kt    (11 m/s)
LFC - EL Mean Wind:   196 / 36 kt    (18 m/s)
850 - 300 Mean Wind:  182 / 24 kt    (12 m/s)


Sfc - 2km Shear:       2 kt      (1 m/s)
Sfc - 6km Shear:      54 kt     (27 m/s)
*BRN Shear:                     24 m2/s2
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STORM STRUCTURE PARAMETERS

Sfc - 3km SREH:   74 m2/s2
Effective SREH:   74 m2/s2     from 0 m.


0-2 km SRW:     17 kt      EHI:             1.7
4-6 km SRW:     32 kt      BRN:             148
6-10 km SRW:    34 kt
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Figure 4: Sounding for 0000 UTC 4 April from Santa Teresa, NM (KEPZ), modified for surface high temperature in Dell City, TX and RUC forecast dewpoint east of the thermal-moisture boundary.

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degree reflectivity scans show the beginnings of a cell-split at 2233 UTC, with a clear splitting-cell signature by 2245 UTC (Fig. 6). By 2250 UTC, the left split began to rapidly dissipate, while the right split exhibited echo tops of 40,000 ft with a VIL of 35 kg m^{-2} as it moved east, normal to the mean steering flow.

The Cornudas storm appeared to pulse, with two periods of intensity maxima at 2300 UTC while only a few miles south of US 62/180, and at 2325 UTC, while the storm was located over the highway. At 2300 UTC, the cell exhibited an elevated core of 65 dBZ reflectivity, echo tops of 40,000 ft, and a VIL of 50 kg m^{-2}. This resulted in a VIL density value of 4.10 g m^{-3}. Previous studies (Edwards and Thompson 1998) have question-

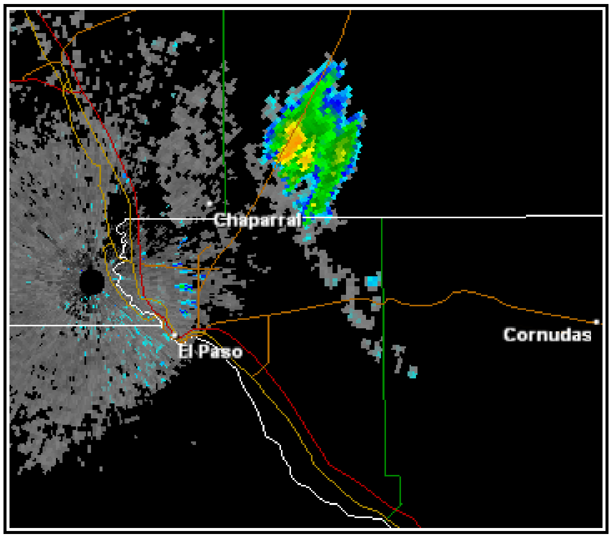

Figure 5: KEPZ WSR-88d 2.4-degree reflectivity image from 1904 UTC 3 April 2004 indicating thermal-moisture boundary moving west into central El Paso County.

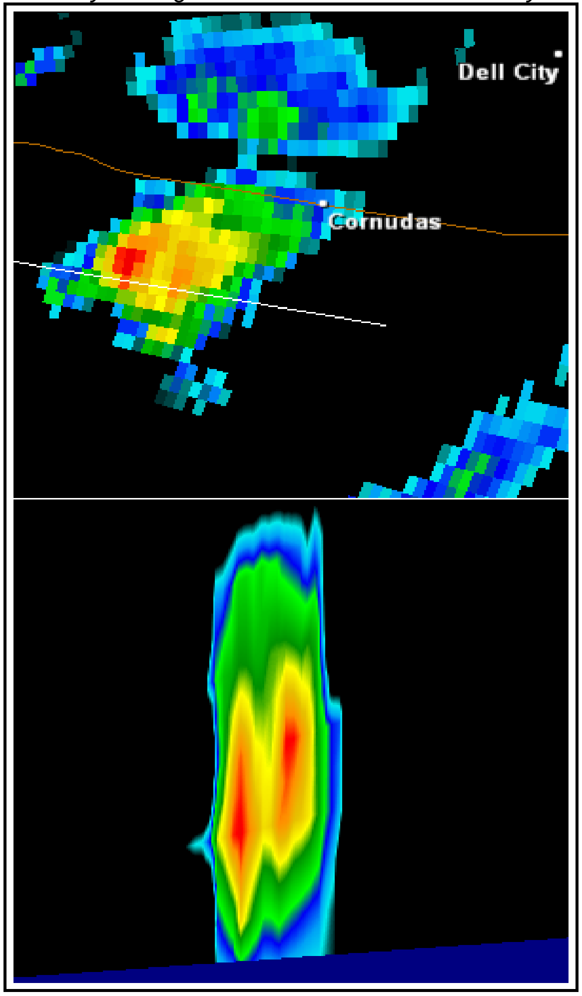

Figure 6: Nexrad Level II 1.5-degree reflectivity image (left) and RHI cross-section at 2245 UTC 3 April. Cross section slice indicated by black line on left image.

ed the skill of VIL density values in predicting actual hail size. However, many regional studies (Amburn and Wolf 1997, Blaes, et al 1998, etc) have shown that VIL density values ≥ 3.70 g m^{-3} reliably indicate severe-criteria hail with a high probability of detection and very low false alarm ratio. At 2325 UTC the storm exhibited an elevated reflectivity core of 70+ dBZ, echo tops of 45,000 ft, and a VIL of 50 kg m^{-2} resulting in a VIL density of 3.6 g m^{-3}.

At this time, the storm was dumping over 4 inches of quarter-sized hail on US highway 62/180, about 6 mi. west of Cornudas, with reports of larger hail up to the size of tennis balls causing damage to vehicles navigating through the severe storm. The cell continued to pulse while moving to the northwest of Cornudas over unpopulated areas before dissipating by 0100 UTC 4 April just west of Dell City, TX

4.2 *"The Chaparral Storm"*

An outflow boundary originating from a disorganized area of showers and storms over Chihuahua was indicated on radar at 0018 UTC, moving north. The Chaparral storm appeared to initiate at 0030 UTC as this outflow boundary interacted with the pre-existing TMB which was stalled over central El Paso County. At 0042 UTC the storm exhibited echo tops of 35,000 ft with a VIL of 30 kg m^{-2} resulting in a VIL density of 2.80 g m^{-3}. The storm strengthened rapidly as it moved NNW towards Chaparral, NM. By 0059 UTC the storm was located over Chaparral while radar indicated echo tops of 40,000 ft and a max VIL of 45 kg m^{-2}, resulting in a VIL density value of 3.69 gm^{-3}. RHI cross-sections of Level II data indicate an elevated core of 72 dBZ at 6000 ft AGL over southern Chaparral at 0053 UTC (Fig. 7a). By 0059 UTC this 72 dBZ core had descended to near the ground (Fig. 7b) and was apparent over the northern edge of Chaparral on the 1.5-degree elevation scan (Fig. 7c). The 0.5-degree scan indicated 69 dBZ over the same area, but appeared to be attenuated by the Franklin Mountains. This low-level attenuation may have affected VIL and VIL density values, resulting in lower figures.

The location of highest reflectivity values corresponds with the area of greatest hail accumulation and damage. Many homes on the north side of Chaparral suffered broken windows, shattered siding, and roof damage. After passing over Chaparral, the storm moved north and weakened over WSMR.

5. CONCLUSIONS

The occurrence of severe-criteria hail in the El Paso CWA during the dry season is rare event however, lower wet bulb zero heights during the early Spring allow for the possibility of large hail should other necessary factors come into place. We have presented a case study detailing one such collusion of factors. A cut-off mid-tropospheric low and cold pool over Arizona and attendant southerly flow allowed for mid-level moisture transport from the Gulf of California. Low-level southeasterly flow ahead of a quasi-stationary "back-

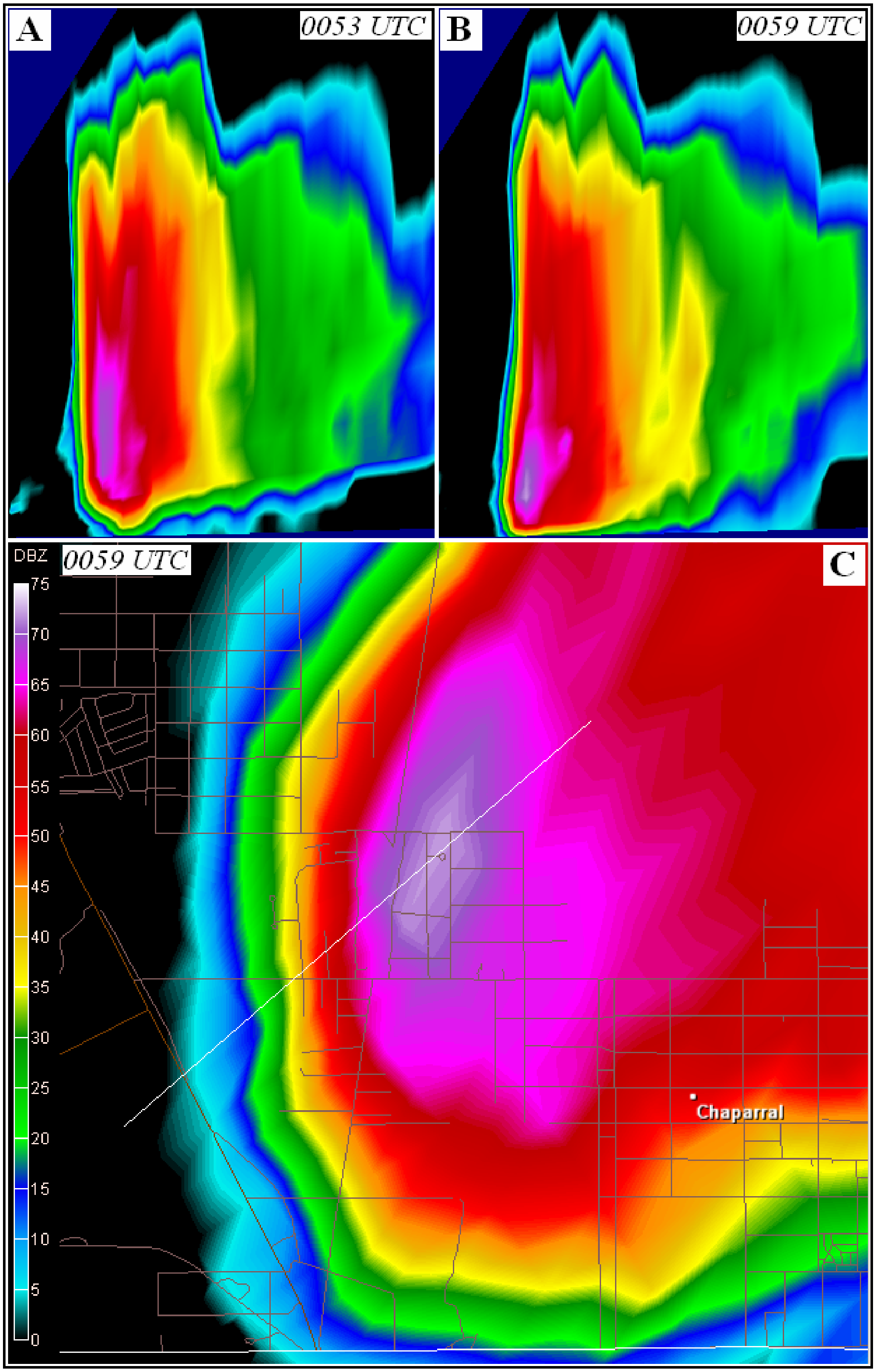

Figure 7: Nexrad Level II RHI cross-section at 0053 UTC 4 April 2004 (a), RHI cross-section at 0059 UTC (b) and 1.5-degree reflectivity image (c) with white line indicating location of cross-section slice shown in (b).

door" front advected moisture into west Texas from the Gulf of Mexico, resulting in a thermodynamic and wind profile featuring sufficient instability, deep moisture, and shear for non-tornadic supercells. Finally, a thermal moisture boundary appeared to act as a trigger for two severe hail-producing thunderstorms.

It is believed by the authors that similar synoptic patterns may be responsible for many other severe weather events in the borderland region. Key features appear to be a cut-off low over the southwestern United States allowing for mid-level moisture transport from the Gulf of California and low-level southeasterly flow combining to establish an unseasonably moist and unstable thermodynamic profile conducive to severe weather. Further examination of dry-season extreme weather events and their associated synoptic patterns will be the focus of a future study.

6. ACKNOWLEDGEMENTS

Level II Nexrad data was examined and presented using the 'GRW88Level2' freeware program from Gibson Ridge Software, available on-line from: (http://www.gibsonridgesoftware.com/grw88level2/).

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