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SOME THOUGHTS ON THE ROLE MESOSCALE FEATURES PLAYED IN THE 27 MAY 1997 CENTRAL TEXAS TORNADO OUTBREAK

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1. INTRODUCTION

Supercell thunderstorms spawned an outbreak of intense tornadoes over central Texas on the afternoon of 27 May 1997. Hardest hit was the area from just south of Waco to near Austin, where storms took nearly 30 lives and caused more than $125 million in damage (Storm Data 1997). An F5 tornado devastated the Double Creek subdivision near Jarrell, killing 27. Other storms with large hail and damaging winds extended east into Louisiana and south into the Lower Rio Grande Valley.

The 27 May event was unusual in that it occurred in an environment of comparatively weak vertical shear. The most significant upper-level feature of interest over the central United States was a 500 mb low centered well to the north over Nebraska (not shown). Mid-level westerly winds on the south side of the low decreased from around 30 kts over far northern Texas to less than 15 kts over the central and southern parts of the state. Boundary layer winds were quite light, reflecting the absence of a well-defined low-level jet. At the jet stream level, considerable divergence was present, enhanced perhaps by coupling between 250 mb speed maxima over northern Mexico and the mid Mississippi valley.

While the kinematic support for severe convection over central Texas appeared somewhat weak, thermodynamically conditions were quite favorable for intense thunderstorm development. The 1200 UTC radiosonde data at both Corpus Christi and Fort Worth exhibited a very deep elevated mixed layer, with nearly dry adiabatic lapse rates present between 900 and 400 mb (not shown). After several days of onshore flow and the suppression of deep convection (due to the elevated mixed layer "cap"), boundary layer dewpoints were in the mid 70s (F), with the mean mixing ratio above 15 g/kg. These conditions yielded surface-based cape in excess of 5500 J/kg across nearly all of central and east Texas.

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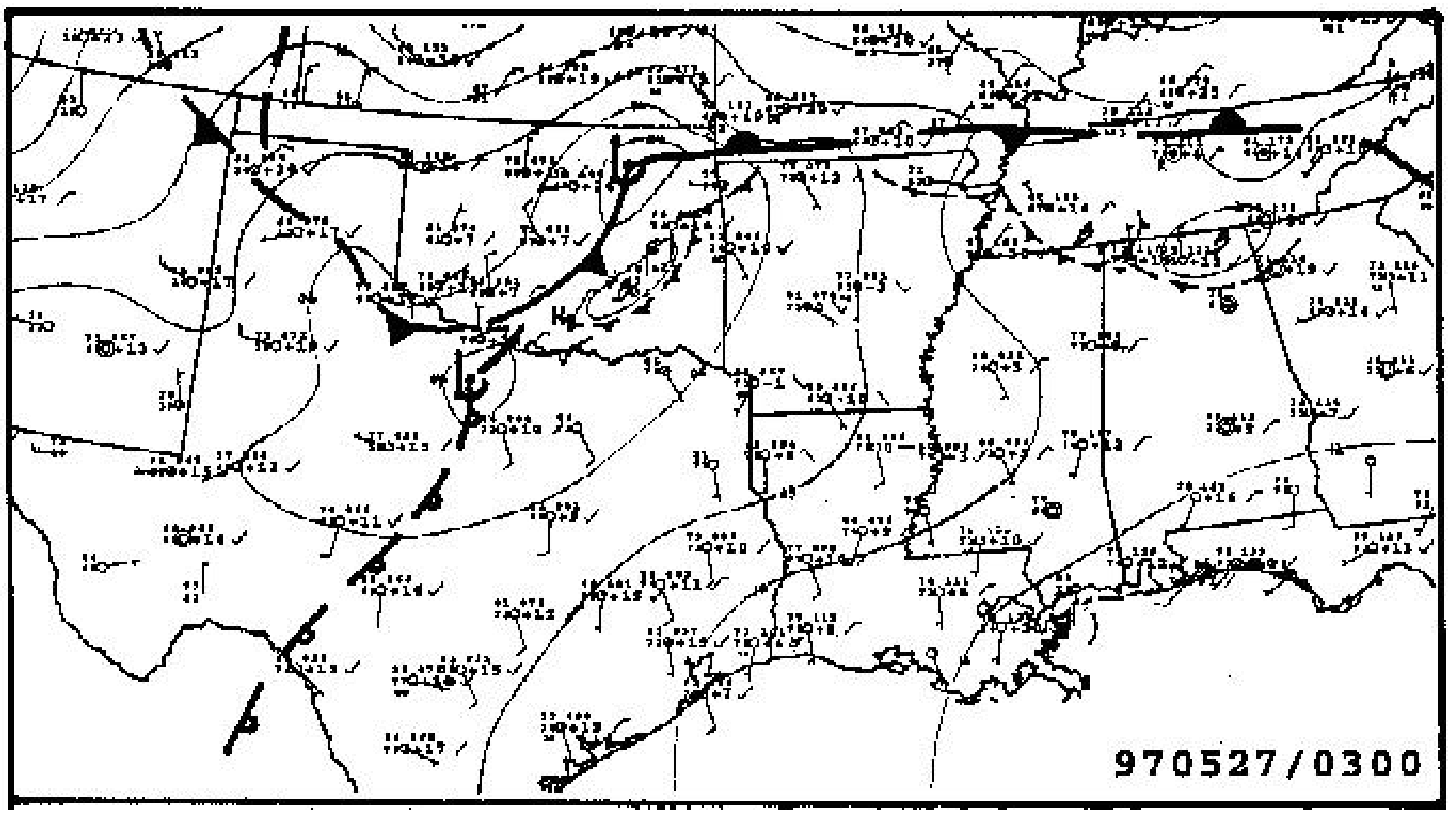
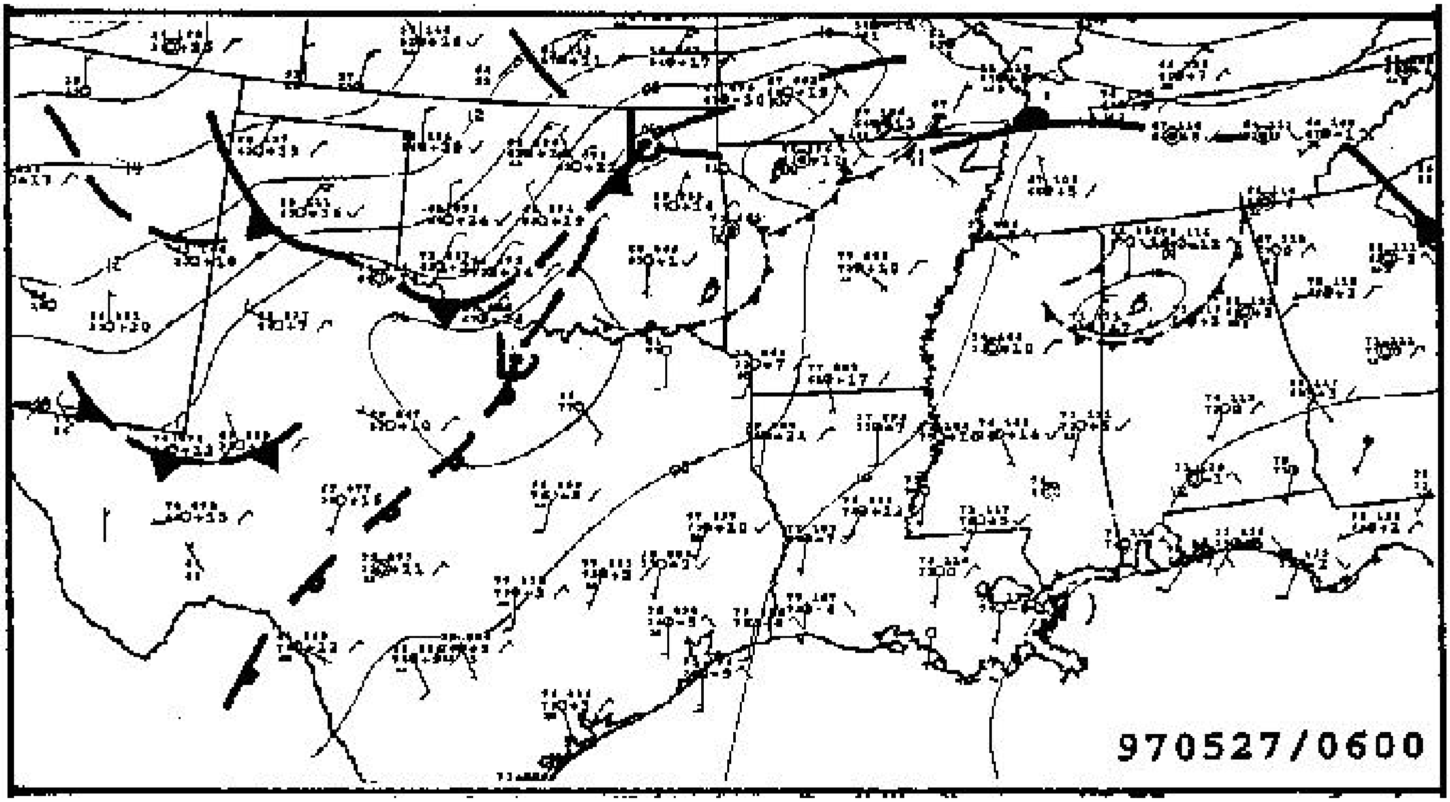
2. MESOSCALE SETUP

Although the thermodynamic environment on 27 May was very unstable, such conditions are not uncommon over central and east Texas in late spring. And, while the setup was certainly supportive of storms with both large hail and damaging winds, the threat for supercells was not obvious. The remainder of this discussion will focus on some aspects of the mesoscale environment, as revealed in the surface and upper air data, which may have played a role in fostering the development of supercellular convection.

The hand analyses below show the evolution of surface features leading to the onset of severe convection on 27 May. Isobars are in two millibar intervals on the 0300, 0600 and 0900 UTC panels, and in one millibar increments on the succeeding charts. Synoptic and mesoscale features are depicted using a modified form of the convention suggested by Young and Fritsch (1989). The dry line is indicated by a series of open warm-front pips, and thunderstorm mesohighs by a "B" (for "bubble"). On the 1600, 1700 and 1800 UTC charts, developing convective cells are shown schematically as dark-colored blobs.

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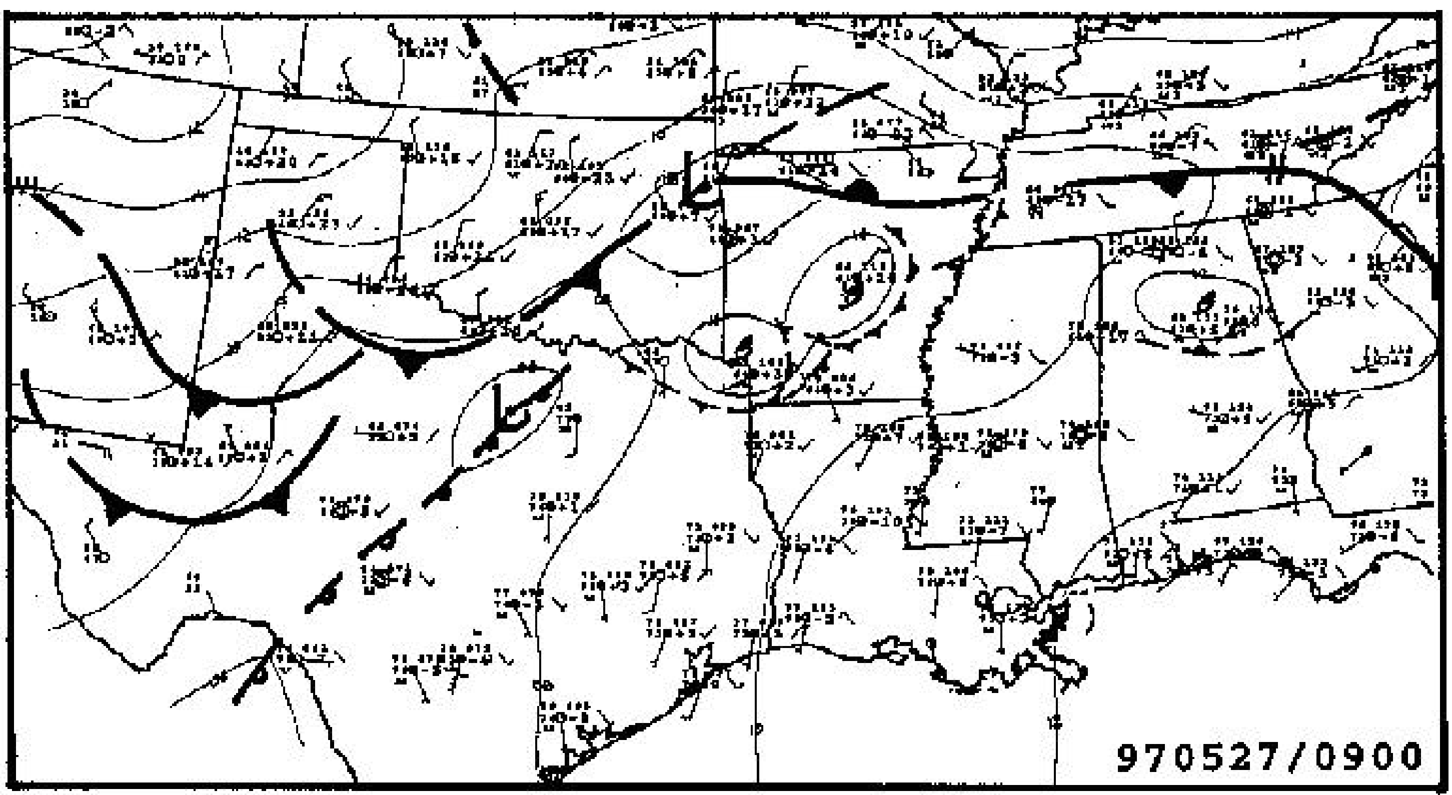
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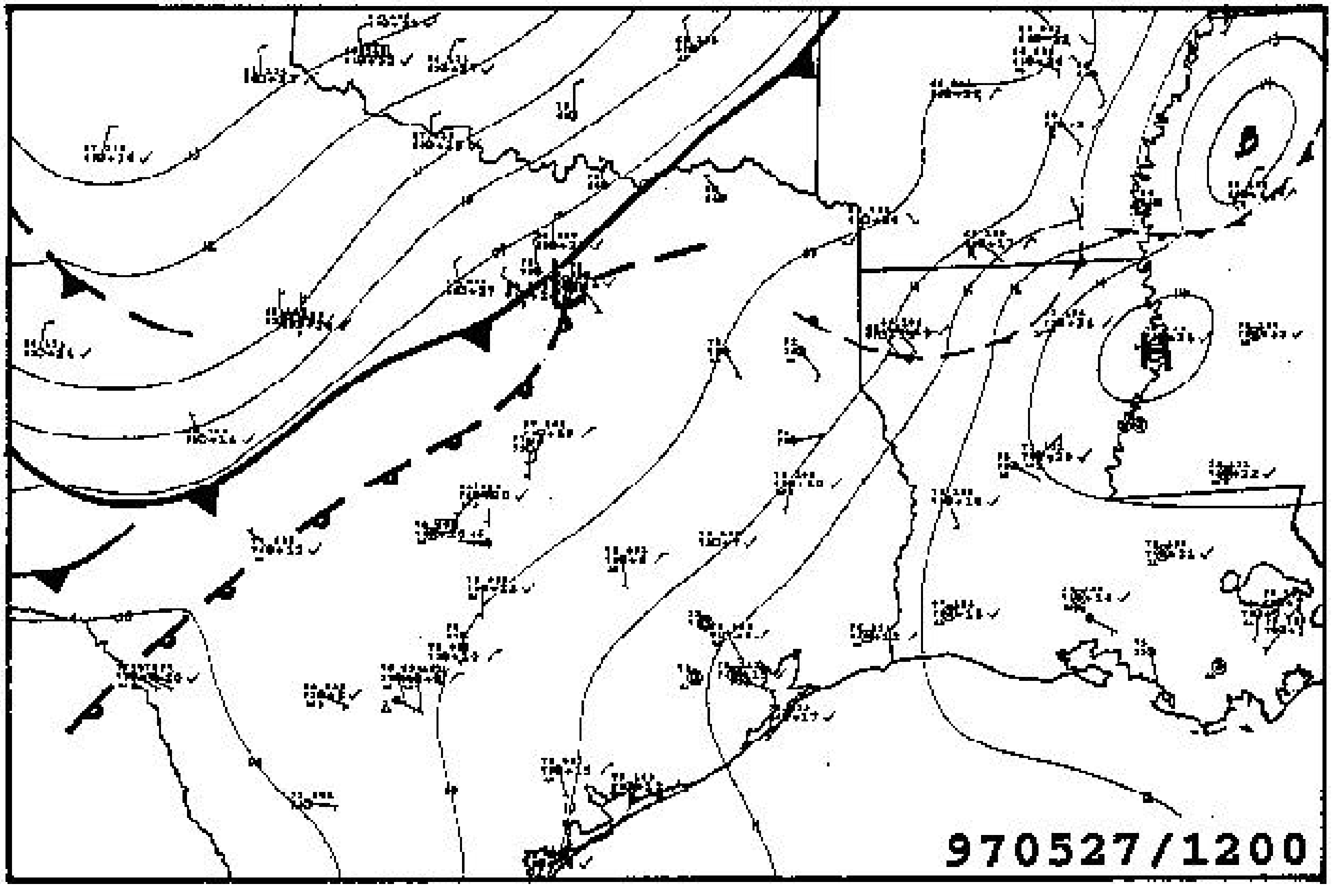
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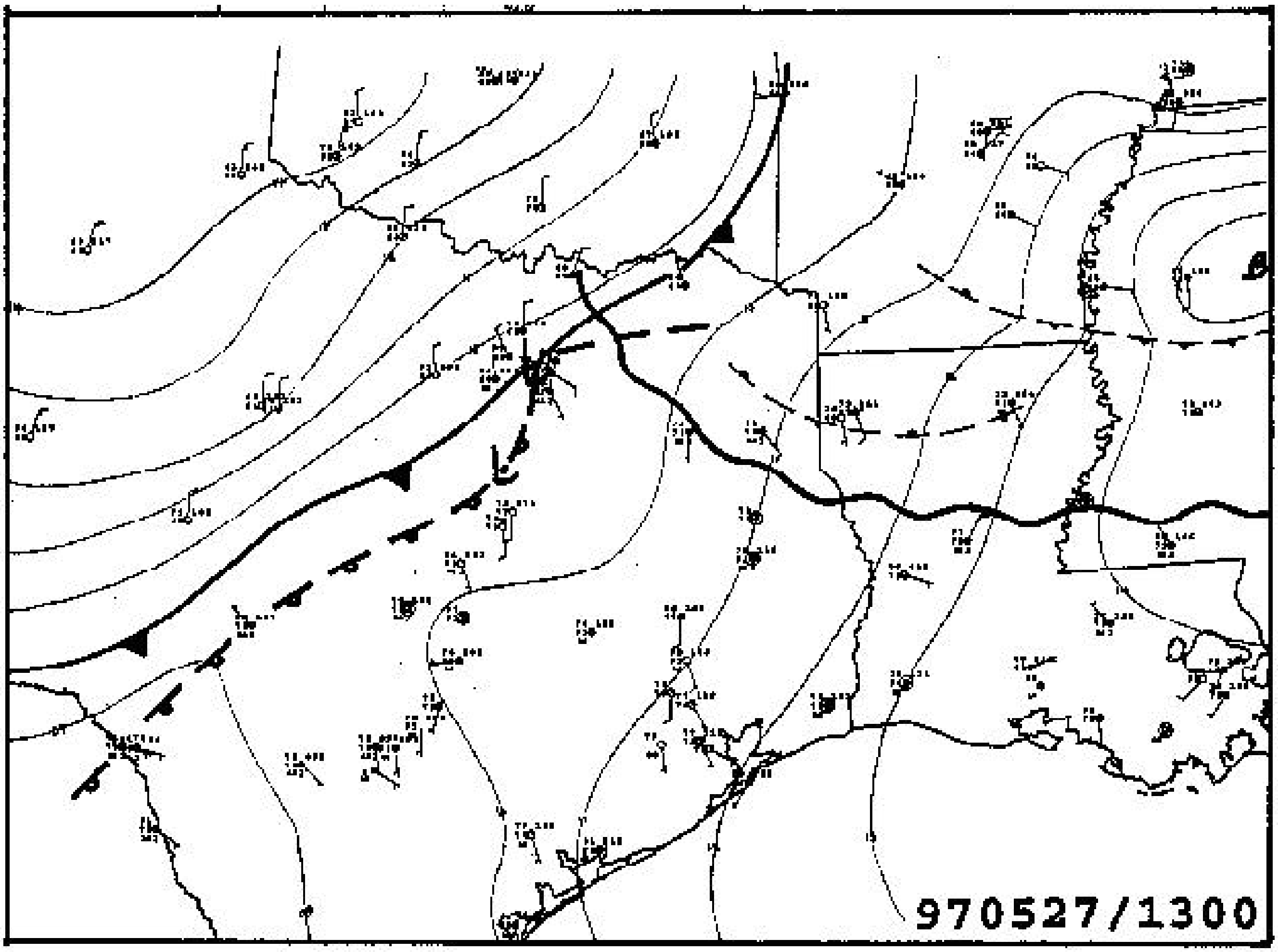

Central TX manual surface analyses, 27 May 1997.

The central Texas supercells all developed in the vicinity of a cold front. This boundary was associated with the Nebraska upper low and had moved slowly southeast across the central plains during the previous two days. The western part of the front accelerated south in a series of "surges" across west Texas during the pre-dawn hours of the 27th, as shown in the 0300, 0600 and 0900 analyses. This acceleration likely reflected the advance of an upper level speed max from the central plains toward the mid Mississippi valley, and channeling of the low-level flow along the east slopes of the Rockies. By 1200 UTC, the cold front extended from southeast Oklahoma across northwest side of the Dallas-Fort Worth region to near the Texas Big Bend.

In advance of the cold front, a dry line oriented along a NE/SW axis separated very moist boundary layer air over east Texas from drier air of continental origin farther west. As the light and variable winds on both sides of this feature would suggest, the dry line was nearly stationary on the morning of the 27th. Thunderstorms which initiated along the dry line over eastern Oklahoma the previous evening evolved into a large mesoscale convective system (MCS) that continued east across Arkansas later in the night. In addition to producing a series of strong mesohighs, the MCS generated a well-defined gravity wave that propagated southwest across the eastern half of Texas beginning around dawn on the 27th. The progress of the wave could be readily tracked via satellite as the capped mixed-layer cloudiness east of the dry line alternatingly thickened and thinned upon passage of the wave (not shown).

The cold front continued to move south across central Texas through the remainder of the morning. Because its movement was greatest over the high plains, the front soon came to parallel the dry line to its south and east. At the same time, a weak dry line low which had been located over the Dallas area at 1200 UTC began to move southwest along the boundary. This movement appeared to occur at least partly in response to diabatic effects as maximum surface heating occurred in the narrowing wedge of clear air lying between the dry line and cold front.

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3. WHY SUPERCELLS

Thunderstorms formed near Waco, TX in the vicinity of the dry line low around 1730 UTC. Objective analyses (not shown) indicate that regional maxima of both surface heating and surface moisture flux convergence were present near the low. In addition, as the 1500-1800 UTC analyses show, the low's southwestward track also marked the locus of points where the cold front overtook and merged with the more slowly-moving dry line. Both boundaries could be observed for a brief time in the base reflectivity data taken by the Fort Hood/Granger, TX Doppler radar (not shown).

Coincidental with the onset of deep convection near Waco was the passage of the MCS-generated gravity wave. Having originated in Arkansas, the central Texas portion of this feature moved southwestward in-step with the surface wave until around 2100 UTC, at which time the cold front overtook the dry line near Austin (not shown).

As already noted, while the lower tropospheric environment over central Texas on 27 May 1997 was very unstable, such instability is certainly not unprecedented. The arrangement and behavior of mesoscale surface features was also not especially noteworthy: dry line/frontal mergers of the type observed might be expected to occur there several times a year. Readily apparent gravity waves are also not uncommon in this region. Nevertheless, the fact that supercells continued to form over central Texas through much of the afternoon despite the presence of weak vertical shear suggests that some unusual circumstances were indeed coming into play. While a final answer must await careful model study, it is the author's opinion that the fortuitous orientation and timing of the MCS-induced gravity wave relative to both the merging surface boundaries and to the diurnal heating cycle were critical in realizing and maintaining supercellular convection over central Texas on 27 May 1997.

Although the lower tropospheric kinematic field appeared too weak to support "classical" supercell evolution, considerable vertically-oriented vorticity was in fact present in the vicinity of the merging cold front and dry line by the afternoon of the 27th (compare, for example, post-frontal and pre-dry line surface winds near Waco at 1200 and 1700 UTC). At the same time, the NE/SW orientation of the merging boundaries between Waco and Austin was, coincidentally, directly orthogonal to the southwest motion of the MCS-induced gravity wave.

Once surface heating and persistent convergence initiated convection near the surface low, the combination of strong updrafts (supported by the presence of very steep mid-level lapse rates), and increasing vertical vorticity in the vicinity of the front/dry line merger could conceivably have supported mid-level storm rotation. This is consistent with Magsig et al. (1998), who found that the mesocyclones on this day "grew from areas of deep convergence within large weak echo regions." What remains to be explained, however, is why the storms did not quickly "gust out" given (1) the limited degree of vertical shear and (2) the presence of a thermodynamic environment favorable for the production of strong downdrafts at the surface.

Since the support for "conventional" supercell propagation was weak, storm persistence was dependent upon the generation of new updrafts at a rate and in a direction such that the cells were not undercut by their own outflow. Because the merging cold front and dry line were oriented perpendicular to the gravity wave between Waco and Austin, it is speculated that the motion of the low-level pressure perturbation field associated with the wave was timed so as to favor new updraft development on the southwest side of existing cells just before these older updrafts began to "gust out." Coupled with the moderate westerly flow present at high levels (observed 300 mb winds were westerly at about 35 kts), southwesterly storm "motion" allowed precipitation from maturing updrafts to descend toward the east northeast and therefore away from the direction of new updraft development. As a result, instead of falling victim to its own outflow, the original updraft near Waco was, in a sense, able to replicate itself southwest along the dry line in a nearly continuous fashion.

To the west of Austin, both the cold front and dry line curved westward (see, for example, the 1800 UTC analysis). As a result, in this region the gravity wave was oriented nearly parallel to the merging boundaries. Instead of fostering new updraft development in a limited area, approach of the wave enhanced uplift almost simultaneously from near Austin to the Texas Big Bend after 2000 UTC (not shown). In addition, because of the wave's delayed arrival in south Texas relative to points farther north, surface heating initiated scattered convection along the boundaries prior to the arrival of the wave (not shown). This activity, while intense, quickly evolved into a non-supercellular mode since (1) outflow from adjacent cells joined to form a large mesohigh, and (2) new updraft development was no longer focused in a direction away from storm outflow.

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4. CONCLUSION

As has been shown, the evolution of the 27 May 1997 central Texas tornado outbreak was unusual in several respects. Given the fortuitous nature of several of the variables involved, it is probably safe to say that another event of this type will not occur for some time to come. However, the case is instructive in illustrating a strikingly unconventional "boot strap" approach to the development of supercellular convection.

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5. ACKNOWLEDGMENTS

The author would like to thank Richard Thompson and his other SPC colleagues for their instructive comments on this event.

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6. REFERENCES

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