STORMTRACK

The Magazine for Storm Spotters and Chasers

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JARRELL, TEXAS TORNADO EXPANDED EDITION

COVER: Picturesque tornadoes on May 27, 1997 west of Lorena, Texas taken by Lon Curtis.

Storm Track is a non-profit publication intended for the scientist and amateur alike who share an avid interest in the acquisition and advancement of knowledge concerning severe or unusual weather phenomena. It is published bi-monthly in Lewisville, Texas. David Hoadley founded the publication in 1977 and STORMTRACK has continued to grow and improve ever since. Gene Rhoden designed the current cover. David Hoadley still contributes drawns and sketches. Current, we have about 675 subscribers!

Anyone can submit an article or letter to STORMTRACK. Articles should be single-spaced and contain proper english. Right justified margins are preferred or the editor can retype the text. High contrast photographs reproduce best. Diagrams should be clear and legible, subject to photo-reduction. All articles will be edited.

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TORNADO FORECASTING?

I. COMMENTARY [unabridged for CD-ROM]

The tornado outbreak in Texas on May 27, 1997, otherwise known as the Jarrell, Texas event, made me once again think about what we know or don't know about forecasting tornadoes. I have looked at this event several times over and I am left scratching my head. Tornado outbreak? No way. Will storm cells discretely develop southwestward along a stationary boundary? No chance. And will the tornadoes that develop move southwest too, last a fairly long time, and be up to wedge status? Don't make me laugh. Once again, mom nature taught me a lesson.

Some may say, "Well at least you chased that day". True, but I wasn't really serious about it. Low level wind fields were weak and any storm that moved east or northeast would have very low storm relative helicities. With all the instability around I figured lots of storms would develop. The slow moving front passed Dallas that morning and I headed southeast around 11 am to keep ahead of it. A line of towering cumulus became visible as I headed southeast of downtown. I stopped and set up my satellite dish and watched The Weather Channel. The first tornado watch box was issued for northeast Texas. The box was placed south and parallel to a pseudo-warm front and extended from Dallas to near Shreveport. I was in the western part of this box in what seemed like the perfect place. At 12:30pm, the radar on The Weather Channel only showed two isolated storms developing near Longview, Texas. These "diversion" storms held my interest for awhile and I continued to monitor them with the false assumption that anything which developed further southwest (i.e. near Waco) would head my way! Hearing that a tornadic storm somehow popped up between Waco and Temple, I headed west only to find Interstate 20 closed due to a major traffic accident. All traffic was at a standstill for about one hour. By the time I got back to Dallas and headed south on 1-35, the storm was passed Belton heading southwestward for Jarrell. It wasn't long before I heard that 1-35 was closed at Salado because a highly visible tornado just off the interstate. Need I say I missed the show.

I have studied tornado outbreak days for more than twenty years. I have seen many "traditional" tornado days with the classic (textbook type) Colorado low and dryline. There also have been many "unique" tornado days (i.e. Plainfield, IL, Jarrell, TX). Over the years, I find myself becoming less confident in my forecasts. This is because more and more "unique" tornado situations are being added to my data base each year. Soon, I will have more "unique" events than "traditional" events. The end result seems to be chaos!! Given this scenario, I see two possibilities for chasing: 1) chase everything on any risk day (which I can't possibly do) or 2) try to pick and choose the best chase days knowing that I'll miss them most of the time. The moral of this story: Don't give up your day job!

II. CHASER NEWS

The Iowa National Weather Association Severe Storms and Doppler Radar Conference will be held 3-5 April 1998 at the Holiday Inn Des Moines Airport (where it was last year) in Des Moines, IA. More than 200 are expected to attend second annual gathering! Reserve your room at the Holiday Inn for the special rate of $65 by calling 1-800-248-4013. The subject will be tornadoes, tornadoes, tornadoes. The conference will include a storm chasers video-fest (show and tell session). Additional conference details posted at: http://www.ecity.net/-iowanwa/ Registration before January 1 is $75.00, $50 for students, and $250 for vendors (includes 10 minute presentation). Registration should be mailed to: Central Iowa NWA, Box 7512, Urbandale, IA 50322. John McLaughlin. his email: johnmc49@ecity.net

The 16th Conference on Weather Forecasting and Analysis will be held January 12-16 at the Phoenix Convention Center in Phoenix, Arizona. Registration for this conference ranges from $120 to $315 depending on the time of registration and whether you are a member of the American Meteorological Society. Sessions on severe weather forecasting will be held on Thursday, January 15th. For more information, contact the AMS at 45 Beacon Street, Boston, MA 02108, phone: 617-227-2426.

David Dowell and Howie "Cb" Bluestein have published a paper entitled: "The Arcadia, Oklahoma Storm of May 17, 1981: Analysis of a Supercell during Tornadogenesis" in the October 1997 issue of Monthly Weather Review.

The 1998 STORM CHASER PARTY will be held at the editor’s house on a Sunday at the end of May or early June. Stay tuned for later details - and possible warnings.

INTERNET DISCUSSIONS ABOUT THE JARRELL, TEXAS EVENT

Rich Thompson (iluvwx@ix.netcom.com) writes: "Jarrell's been discussed quite a bit in the past few months, but not many people have tried to explain why that storm managed to produce multiple, significant tornadoes in that environment. Here's what I've noticed about this event:

1) Vertical shear - 12z soundings from FWD (Fort Worth) and DRT (Del Rio), as well as area vertical wind profiles did not suggest a supercell shear profile (weak Bulk Richardson Number Shear, weak storm relative helicity). The local vertical wind profiles looked pretty sad even near the time of the event...though the profile probably varied more in close to the storms.

2) Temperature/moisture profile - exceptional CAPE (Convective Available Potential Energy) in the 12z soundings (near 5000 J/kg unmodified), with a classic "loaded gun" profile. Boundary layer dewpoints ranged from 74-78 degrees Fahrenheit.

3) Mesoscale boundaries - A north-northeast/south-southwest oriented surface boundary (weak quasi-stationary front?) across central Texas. This boundary was well-defined in surface observations and visible satellite imagery as a narrow line of cumulus. Visible imagery also suggested a gravity wave (from collapsing storms over Arkansas/Mississippi originated in Oklahoma the night before) propagating southwestward and "intersecting" the surface boundary near where the Jarrell storm complex initiated.

4) Event evolution -- It's my best guess that the Jarrell storm(s) did not originate as supercells, certainly not in the classic sense. Perhaps the enhanced baroclinic (horizontal) and vertical vorticity (cyclonic horizontal shear) along the surface boundary provided a source for storm scale rotation through tilting/stretching. Once rotation was established (from the bottom upward to the mid-levels), then supercell processes may have become relevant. The observed CELL motion was very slow to the south (not to be confused with mesoscale convective system motion which was south- southwest at 20-25 knots), so storm-relative flow through the troposphere would have been optimized.

Perhaps the real importance of the storm-relative winds was to keep the new updrafts removed from developing rain cores such that the storm was not undercut by outflow prematurely from the north or northeast. I still don't think you can apply a classic conceptual model to this case, because storm motion didn't result from continuous propagation as with most long-lived, violent-hose-producing supercells (i.e., it was not just a single storm). It seems to me that any pressure perturbation effects would have helped the storm move more south-southeast (off the boundary), while the gravity wave phase speed seemed to agree well with storm motion and may have played an important role in keeping the storms on the surface boundary.

From eyewitness accounts, pictures and video, it is not clear that the storm or individual tornadoes displayed supercell characteristics PRIOR to tornadogenesis (e.g., lowered, rotating wall cloud, clear slot, etc.). The tornadoes had some "landspout" characteristics and appeared to originate from flat updraft bases with no apparent RFD (rear flank downdraft) or precipitation nearby. Since I'm not aware of any 7000 CAPE Denver Cyclone cases, who's to say that these tornadoes weren't largely non-supercellular given the outrageous contribution from vertical stretching? I suppose it's possible that there were some mixed supercell/non-supercell processes going on, which might explain the bizarre evolution of the Jarrell tornado from what looked like a stationary, strong (maybe) landspout to a suddenly south moving multi-vortex tornado more characteristic of high-end supercells. I hope this storm doesn't become another "Plainfield" where everyone and his dog tries to force this event neatly into the same part of the spectrum as, say, the Red Rock/Andover supercells (the Plainfield event brought about an endless search for large storm relative helicity values, since storm relative helicity was thought to be the main player by many people at the time)."

Erik Rasmussen (me@blackbox.mmm.ucar.edu) says: "I had the privilege two weeks ago to give a talk at a conference of National Weather Service forecasters in Dodge City, Kansas, and to COMAP in Boulder. Here are some of the ideas from that talk and other recent discussions regarding what is and is not a supercell and a supercell tornado. First, let me say this: we need to start thinking in terms of the physical processes, and move away from semantics. I think this is true in all areas of severe storms... from spotting and chasing to research. For the sake of discussion, let's define two types of tornadoes: 1. Landspout... the rotation is supplied by concentration (convergence/stretching) of pre-existing vertical vorticity ONLY, and 2. Non-landspout... the rotation is supplied through tilting or downward transport of vorticity, implying nearby-downdrafts are fundamentally important. The landspout tornado requires an updraft to move over a pre-existing meso-circulation in the boundary layer. Not much is required of this updraft except that it be strong enough, and persist long enough, to do the convergence/stretching thing.

The non-landspout tornado requires a bit more. It requires pre-existing rotation aloft, at SOME scale larger than a tornado (as Gene Moore pointed out... this spans a big range of observed circulation's in real storms). It does NOT require the rotation to be pre-existing for a certain period of time; rather, at some moment it exists and is available to be moved to the boundary layer via tilting or downward advection. Further, it requires a downdraft near the initial circulation to do the tilting and/or downward transport. It requires an updraft that is strong enough, and persistent enough, to then concentrate the vorticity that has been brought to the lowest levels into a tornado, and maintain that tornado for a certain period of time. In general, I think it's becoming apparent that this process requires that the updraft not be a single pulse that then gets loaded with precip and collapses; i.e., a certain amount of storm-relative upper flow (a.k.a. deep shear) is required.

Does the non-landspout require a mid-level meso? No. Does it require persistent rotation for 45 minutes? 30 minutes? 20 minutes? No. It requires a source of vorticity to initiate a larger-than-tornado circulation in the lowest few kilometers; a downdraft; and an updraft associated with the circulation that can persist long enough to form and maintain the tornado. All of the foregoing is laced with my opinions, but they are informed opinions (in my opinion !), and are the subject of several investigations and articles. To me, growing understanding of the non-landspout tornado (a.k.a. supercell tornado) may require us to change our notions of what supercells are, or at least their importance to tornado formation. Further, I think that we almost certainly will need to change our operational, chase, and spotter perceptions of what is and isn't important in the tornado formation process. Essentially, any strong low- level rotation in an environment locally supportive of supercells should be viewed as potentially tornadic. On the other hand, in my opinion (!), the presence of a persistent or even long-lived mid-level mesocyclone is not of much significance to the tornado formation problem. My point in the earlier Jarrell post was that, owing to enough storm- relative UT flow in that storm, the precip and updraft were segregated, and the precipitation fell down shear, leading to a forward-flank boundary and an environment locally supportive of a tornadic supercell. This is largely speculation on my part. Many of you have looked at a lot more data. So please prove me wrong.

Rich Thompson responds: "This entire Jarrell discussion focuses on the MECHANISM behind the Jarrell tornadic storm, and how it may have varied from the "classic" violent tornado producing supercell. That's not to say that Jarrell wasn't a supercell, but if the definition gets so large as to be inclusive of almost all storms that rotate (and looking at radar data nationwide MANY do rotate!), then it's of little use. From the perspective of a national forecaster, do I have to assume that a tornadic storm is possible in virtually every combination of shear and instability except for zero? The mechanisms Erik is describing seem to apply most in the run of the mill storm days where something is clearly less than ideal, thus some sort of local augmentation is necessary for tornadoes. However, by nature, these events tend to be VERY localized and affect a relatively small area. Sure, if the Jarrell storm hits a town it's devastating, but what the heck would have happened if the Kellerville/Allison storm had moved over populated areas? It seems to me that a long-lived mid-level meso gives you MORE opportunities for tornadoes, all else being equal. Also, can't the longevity of the mid-level rotation correspond to the longevity of a tornado in some cases? We know there are many environments where long-lived rotating storms fail to produce tornadoes, but many of the most important cases of violent tornado outbreaks DO consist of storms with long-lived mid-level rotation. If you're going to make the claim that mid-level mesocyclones are not terribly relevant, then I would at least like to see some evidence showing that storms with long-lived mid-level mesocyclones are in some way LESS LIKELY to produce tornadoes than other storms encountering similar local environments. Do you really believe that a long-lived supercell (even non-tornadic) that encounters an outflow boundary (just an example) is less likely to produce a significant tornado than a non-supercell storm that encounters the same conditions?

By the way, I've seen a summary version of the article, and the claim is that the extreme damage was a function of the open exposure and time each dwelling experienced the strongest winds. For a time period of 90-150 seconds, the engineers from Tech estimated the damage would result from winds at or below 200 mph. This estimated wind corresponds to F3. I think they may be right, and this just may be a case where Fujita's wind estimates don't account for enough factors to be practically useful."

Erik Rassmussen (me@blackbox.mmm.ucar.edu) responds to Rich Thompson's post: "Once again, our intense focus and debate on the definition of a supercell may be somewhat unproductive. I don't have to issue watches and warnings for a living (fortunately for the public!), but I think it's still fair to say that if it rotates, it's worth some special attention. I.e., if it's a supercell by the definition of "updraft well-correlated with rotation", then it's probably a storm capable of producing some severe weather. I think the tornado production issue is perhaps a somewhat separate issue. I'm having a heck of a time disproving the hypothesis that local augmentation is almost always necessary. I now look back over a couple of decades of chasing and wonder if most/all of those successful chases were the result of local augmentation, and those zillions of crappie chases (on "supercell days") were the result of lack of augmentation. Am I crazy? Don't answer that!

On the brighter side, my climatology work (in agreement with a lot of good work in the past such as Jon Davies') has also shown that significant tornadoes are generally associated with a threshold combination of shear (e.g. SRH) and CAPE, so NO... as a national forecaster, I would think that not much has changed. It's just that if there's a gob'o'CAPE, and there's enough storm-relative upper flow to remove the precip from the updraft, and there's a boundary hanging around or the storm can generate one itself, then a non-landspout tornado is possible. Here, I would have to reiterate my earlier rant about a need to shift focus to the physical process of tornadogenesis, once we begin to understand it, instead of the ingredients for supercells in general. These two things are obviously not mutually exclusive, but maybe not as intimately tied as we once thought (remember when we were all told that > 50% of mesocyclones produce tornadoes?).

I can argue the following: if there are mid-level mesocyclones, this is evidence that the environment is providing some certain threshold level of CAPE and shear (or whatever the relevant parameters are). This means that it is probably that much easier to get the local augmentation. For instance, a boundary could double the SRH locally. Or, deep shear is strong enough that storm-generated forward-flank boundaries could be effective at getting low-level rotation going. With confidence I can point you to a number of cases of NON-LANDSPOUT tornadoes in which the rotation first intensified near the ground, and then built quickly upward through the storm, followed in short order by a tornado. In these cases, I think the mid-level meso was of little significance, being a consequence of low-level processes, not the cause.

Gene Moore (gene42@ix.netcom.com) says: "I remember one of the most important discoveries that came out of early tornado research was the "mid-level mesocyclone". The fact that this circulation we were watching not only extended 25,000 feet into the storm, but it started there. What a revelation that was! Today, I fear the (radar) detection of mid-level rotation is commonly thought of as the "beginning of a tornado". When a radar operator sees mid-level rotation on the monitor, supercell comes to mind....does it not? In reality that mid-level mesocyclone may not be that uncommon for thunderstorms moving in a good current of (mid to upper level) westerlies. An artifact of covering the country with Doppler radar's. We now see what was always there. Mid-level rotation alone, does not make a supercell. Quite a few (isolated) thunderstorms that come off the front range contain rotation. It's probably why outflow boundaries are so important in the high country. It triggers this garden variety (high based) storm to reach below the boundary layer inversion and become a "real supercell". Without the connection to the low level inflow/circulation that cell is nothing more than another "thundershower" (its a good thing Chuck's not on this thread). Can we have a thunderstorm with a mid-level mesocyclone and not call it a supercell? That might be progress. I'm still a fanatic on the subject of boundaries, but since the early days I have made extreme changes to my chase methods. With the exception of my old 200/300 mb rules my whole approach is different. I try to determine where the initial base of the storm will be and make my forecast for that level....that becomes my surface. I ignore what's below that. So I negate all shallow boundaries the cloud base can't "see". It also throws out shallow warm fronts. My favorite boundary remains the downstream outflow boundary from anvil precip. This year I had the joy of watching a cumulus-calvus (A large TCU with a small anvil, but no precip) that moved north and made contact with the forward flank downdraft of an existing cell. In fact it may be further downstream than that...I'm not sure how far the accepted FFD extends. Since that boundary is so beautifully vertical through such a tall column it really works well with an approaching updraft (from another source). Another feature that makes this boundary the best (in my estimation) is that it's hard for it to "pulse" like the outflow from the main convective elements of the storm. I'm talking about pulsing in both wind velocity & temperature. Since it's from the anvil the flow is smoother, more consistent. When the updraft hits that vertical wall of deep down motion a strong mesocyclone winds-up fast. Since this downdraft is not tilted with height like the storm that it originated from the mid-levels of the new updraft are forced to tilt alongside the boundary instead of over it. Sometimes this tilt increases the S-R of the new updraft. This particular case netted a couple of tornadoes.

Ed Calianese (cbtops@flash.net) writes: "I'm happy to see the continued discussion of the Jarrell event - fairly extensive discussion has been occurring intermittently here in North Texas concerning this event, as it struck "close to home". As Lon Curtis mentioned, the storm developed in the WSFO FTW county warning area (CWA), produced several strong tornadoes with significant damage in our CWA, and later devastated several areas south of our CWA. The event stirs up interest due to its occurrence in a non-classic violent tornado setup (marginally sheared environment). While composing Storm Data for our CWA, l had the opportunity to go through the Archive IV 88D data from KGRK (Granger) several times, and discuss the event extensively with one of the individuals who saw the storm first-hand, Lon, in an effort to logically put the event together. Alan Moller and Mike Foster were also involved in some of these discussions. It was concluded that indeed most of the tornadoes that occurred were associated with a supercell thunderstorm. One tornado (a likely landspout) did developed in northern Bell County in association with a small non-rotating storm (per radar data) that formed about five miles south of the supercell. This storm was quickly "eaten up" by the larger complex.

Though I agree with much of what has been stated previously regarding this "non-classic" event (theoretically speaking it was non-classic), I must interject the fact that the radar data was more classic than has been suggested. The storm initially formed south of KACT (Waco) and was not indicating rotation from the onset. Our first severe thunderstorm warning went out quickly after the storm developed when it still appeared to be non-severe. In fact, it had obtained a VIL (vertically integrated liquid) of only about 25 by that time (our warning forecaster warned due to his anticipation of rapid severe weather development due to the ungodly amount of instability present). Within 30 minutes, radar indicated storm-scale rotation and the first tornado warning was issued (Lon was viewing a tornado at about this time). The storm proceeded to strongly indicate supercellular characteristics on radar (very tight reflectivity gradient on the southwest flank, deep storm-scale rotation, and what I like to call a screaming eagle reflectivity appearance. I have yet to see a non-rotating storm exhibit this latter characteristic. In addition, both reflectivity and velocity data indicated the presence of a rear flank downdraft. Lastly, many of the radar indicated tornado signatures were embedded in a weaker and broader circulation. This was especially true of the actual Jarrell circulation that was embedded in a several nautical mile diameter mesocyclone and had at least 50 kt gate-to-gate shears (from KGRK) for three volume scans before Jarrell was hit (the tornado associated with this signature touched down several miles north of Jarrell)."

Alan Moller says: "I see no reason to redefine "supercells" at the present time. It is extremely important that operational forecasters identify mid-level mesocyclonic storms (vertical vorticity of at least 10-2 sec-1 through at least 1/3 of the storm's depth, lasting for tens of minutes) as supercells - tornadoes are not the only threat from these beasts! We at Fort Worth began in 1997 to explain to advanced spotters that the "cascade paradigm" is not the only route (not even the most common route) for tornadogenesis, and that "spotting" low-level conditions under storms is of the utmost importance - especially at distances from the radar. Further, when issuing warnings I want to hear from the most knowledgeable spotters (i.e., chaser-spotters) as far as detecting low-level circulation's outside of radar range. Good chasers are the people who will understand what they are seeing. Dadgum, chasers CAN also be spotters! Lon Curtis proved that at Jarrell. Good spotters always help, but some of this stuff is rough to handle unless one has seen many storms. I support Ed Calienese's view (with some caution pending another look at the data), that Jarrell was a supercell. Mid-level mesocyclones/echo overhang were common, and several times small BWERs (bounded weak echo regions) were identifiable. Tornadoes generally were preceded by very strong low-level convergence along the gust front, occasionally with a low-level meso, and followed by a TVS (tornadic vortex signature) with the tornadoes. "Landspout- like" stretching likely figured into tornadogenesis, but the tubes would not have been so nasty without the parent supercells contributions (whatever THAT is). Granted, the "propagation" was a mixture of continuous/intermittent development, but (I think I recall) so were Browning's 1964 storms. Different supercells in '64 fired from individual flanking line towers associated with the first storm - with each succeeding supercell producing tornadoes. I don't have the Jarrell data at the present time, but I think someone calculated SRH's (storm relative helicities) of 100-200 m2/s2. I must admit that I would have been thinking primarily of wind/hail-filled HP storms, but knowledge of Plainfield and presence of the May 27th boundary should have keyed any forecaster with his/her salt into considering the tornado threat. How many great dry line tornadic storms have we seen - away from areas of favored terrain? I'm also with Gene Moore here. If severe storms go up on boundaries ahead of the dry line, they often have better tornado potential. More examples - the 198O Grand Island storm (thermal gradient area northeast of a sub-synoptic surface low, which was well ahead of the dry line.) The 6-13-76 Jordan Iowa event - (warm front ahead of dry line), etc. Chasers who opted for dry line were slashed by both events. When to be on the dry line?... Big dynamics, dry line bulge, pressures falling rapidly, strongly backed winds, etc.

Gene Rhoden (grhoden@why.net) presents some of his ideas: "After reviewing the incredible sequence of photos taken by Lon, I must say that this event is a little more "classic" than what I had previously thought. Several of his photos show a tornado prior to the Prairie Dell event with what I would consider as a classic RFD (rear flank downdraft) occluding off the updraft (no doubt in my mind), even though the vortex has a cylindrical double/triple end-wall landspout "looking" structure. Lon's latter photos of the Prairie Dell rope show the base of the vortex holding almost stationary while the "top" seems to be pulled into a newly developed updraft core.

The vortex then appears to be stretched until it segments and the new updraft reorganizes the circulation rapidly just north-northeast of the subdivision. This looks like a type of "hand the baton off" possibly not completely unlike what happened with the Wichita/Andover tornado between Haysville and the Hydraulic area of town. Its simply amazing to see how the Prairie Dell "Tight Rope" transitioned into a maxi vortex just as it struck the subdivision (as if that was its only purpose) then rope out just south of the addition. The storm base at the time of the transition showed a rather large bowl lowering or "pregnant appearance" typical of rather large tornadic mesos with latter shots showing evidence of large scale RFD wrapping around the circulation as the tornado reached maximum size. I must also agree with Ed's' post regarding the radar showing mesocyclonic signatures just prior to the first reported tornadoes with the storm taking on a classic "flying eagle" appearance. There are no storms that I know of that have had that appearance and were not classified as "supercells".

I have also just reviewed the damage photos that Tim Marshall shot of the event. I must say that I was IMPRESSED! It is quite likely that with the relatively slow translation coupled with the immediate widening of the vortex over the subdivision, that extreme winds could have lasted for a couple of minutes over any one point which is evidenced by some slabs with peripheral anchor-bolts showing much caked mud on them as well as a concrete stair set in front of a former pier-and-beam house looking more like a ramp due to the amount of caked on tornado "adobe" mixture of hay and mud. While the time the tornado had over any given structure may have been longer than "average" which would have contributed to the reason why the houses were so well cleaned away, I still am quite confident that the winds in this tornado were on the order of 250 mph. I do not feel that an F-3 rating for this storm holds much merit given comparison with other storm damage surveys that I have done.

Back to the Jarrell vortex, since nature works in a continuum of storm "types" without solid boundaries between our devised LP/CL/HP categories, why wouldn't there be a continuum of vortex types and for that matter of vortex development processes and combinations thereof i.e. vortex hybrids? Does all "supercell" tornadogenesis have to occur in the same fashion (whatever that may be) to be considered non-landspout or supercellular? Two events, the Ash Valley KS event, the first several of which most invariably were landspouts, with the "big one" being a "I'm not so sure" and the Lazbuddie Il event two years ago captured in great detail photographically by NWS personnel from upstate NY show side by side transition between typical landspout processes and classic mesocyclonic processes within a short amount of time and space. These aforementioned cases and possibly others would be good initial candidates for trying speculations about vortex "hybrids" (if they exist).

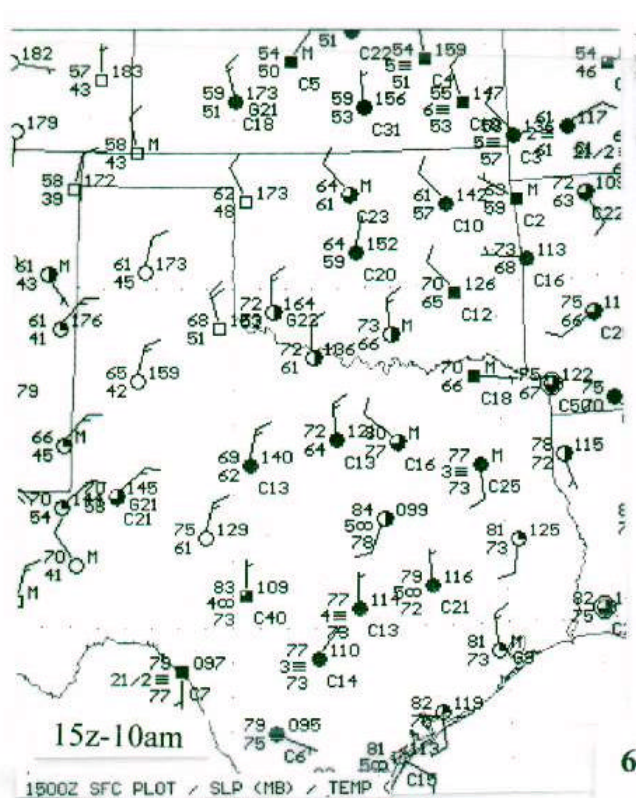
Lon Curtis responds to Gene Rhodens' post. "What a truly fascinating series of posts you guys are making! I've tried to stay "on the sidelines" in the debate over whether the Jarrell tornado produced F5 or F4 or F3 damage ... I think the ultimate resolution of the wind speed issue lies in photogrammetry, but I don't know that anyone is doing that work. With respect to the supercell or not debate, I confess that have assumed the storm was a variation between Classic and HP. After about 1800Z, I was not in a position to see the storm from a distance, I was under the updraft (except for the 1840-1900Z period when I had to cross the precip core to get back ahead of the storm). The rain-free base was huge by the time the storm was south of Belton. The separation between the RFB and precip was on the order of 3-5 miles for most of the period from 1930Z to 2045Z, except that both the Morgans Point-Lake Belton tornado and the Jarrell tornado became rain-wrapped toward the end of their cycles. One of my photos (from 0.4 miles south of the town of Jarrell, looking back north at 2032Z) shows classic supercell features (large, bowl-shaped wall cloud lowering and tail cloud extending from the precip core back toward the RFB/wall cloud), as mentioned by Gene R. I suspect that the demise of the Jarrell tornado was hastened by a fairly strong cell which developed just north and northeast of Georgetown (-12 miles S of Jarrell) as the Jarrell tornado evolved. I think this cell, which was producing +RN and hail by 2045Z, disrupted the juicy air SE of the Jarrell storm and helped cause its early demise. I think we also need to remember that the Jarrell tornado was at least the seventh tornado produced by this system, and it didn't stop producing tornadoes at Jarrell. The Cedar Park tornado was (fortunately) not as intense as either the Jarrell or the Morgans Point-Lake Belton ones, but the Lake Travis tornado was (last time I checked) credited with F4 damage.

MAY 27, 1997 CHASE STRATEGY By Tim Marshall

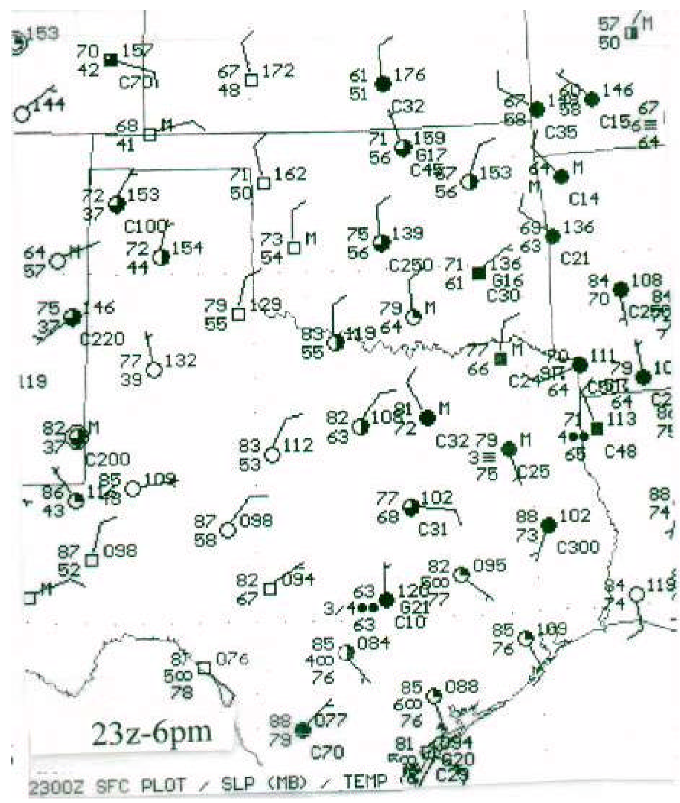
I thought there was a good chance for severe storms today, but I never dreamed a tornado outbreak would occur. The surface features didn't look to bad with all the high dewpoints. At 10am, the front had slipped through Dallas and we were experiencing northwest surface winds. At Waco, their surface winds were southwesterly and there was a low pressure center north of there near Hillsboro. Tyler had south-southeast winds and Paris, Tx had light east winds, thus, the greatest surface convergence was along the boundary east-southeast of Dallas. I figured the surface low would move east-southeasterly along the boundary and I would play the low or just east of there on 1-20 where the best surface convergence would be. I oriented my forecast ellipse east-west along 1-20, centered around Tyler. Yes, I saw the boundary extending southwest of Waco, but I didn't like the disorganized nature of the surface winds there, i.e. light northerly winds at Austin, San Antonio, AND College Station. Besides, if something popped up along the north-south boundary, I figured it would move towards me in Tyler! Winds aloft were terrible and got worse further south. Light westerly winds prevailed aloft, however, the west winds did not get above 20 knots until around 500 mb! I saw no change in the wind profile throughout the day. But it was moderate risk, tisk, tisk and I had the day off.

I left Dallas at 11 am heading southeast on 1-20. A line of towering cumulus became visible southeast of downtown. I stopped and set up my satellite dish and watched The Weather Channel. A tornado watch box was issued for northeast Texas. The box was placed east-west along the front east and southeast of Dallas. "Yes!", I exclaimed with confidence. I was in the western part of this box in what seemed like the perfect place. At 12:30pm, the radar on The Weather Channel only showed two isolated storms developing near Longview, Texas. These storms held my interest for awhile and I continued to monitor them with the false assumption that anything which developed further southwest (i.e. near Waco) would head my way! Hearing that a tornadic storm somehow popped up between Waco and Temple, I headed west only to find westbound Interstate 20 closed due to a major traffic accident. All traffic was at a standstill for about one hour. By the time I got passed this mess, I learned the storm was heading southwestward away from me down l-35. "What!", I exclaimed with embarrassment. Back in Dallas, I headed south on 1-35 and learned the storm was passed Belton heading for Jarrell. It wasn't long before I heard 1-35 was closed at Salado because a highly visible tornado just off the Interstate. Need I say I missed the show, but had two Interstates closed on me for the first time.

May 27, 1997



Surface 15Z (10 am)



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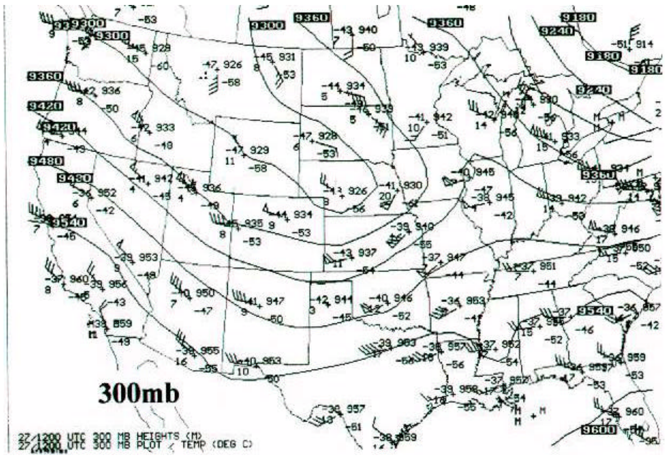
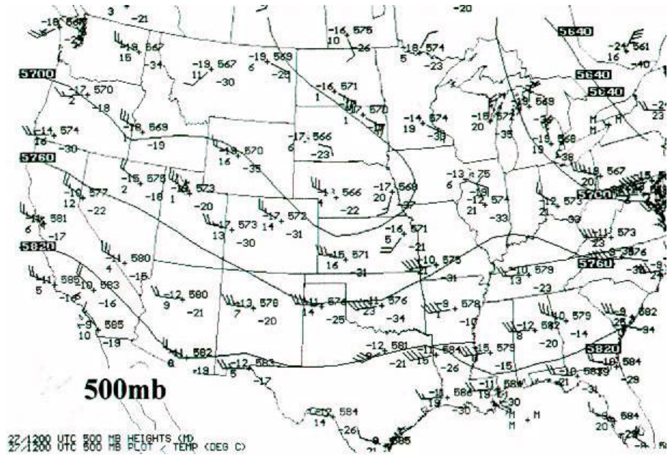
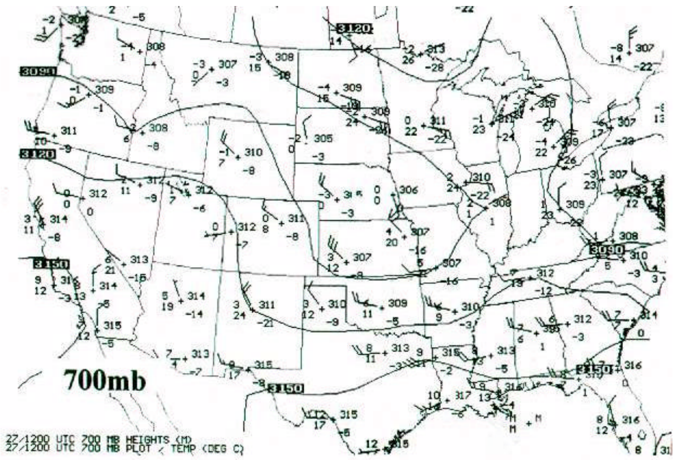


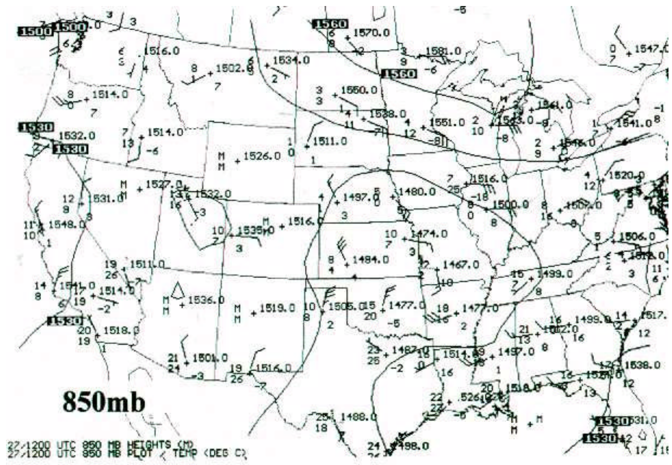
12Z 300 mb



12Z 500 mb



12Z 700 mb



12Z 850 mb

Software program courtesy of Tim Vasquez, Weather Graphics

FOUNDATION SURVEY AT JARRELL, TEXAS By Tim Marshall

Lon Curtis and I conducted a detailed damage survey of the house foundations in the Double Creek subdivision after the Jarrell, Texas tornado. The purpose of our inspection was to determine the type of building construction and thereby infer a lowest bound wind velocity needed to fail the houses. It was already known that all the homes in the subdivision were completely destroyed and an F-5 damage rating was assigned by the NOAA survey team.

A total of 15 house foundations were examined. Eleven of the 15 homes had concrete slab foundations whereas the other four homes were constructed on pier and beam foundations. Wooden bottom plates were attached to the concrete slabs using steel bolts or concrete nails. Two of the 11 concrete slab homes had 2 x 6 inch bottom plates whereas the remaining nine concrete slab homes had conventional 2 x 4 inch bottom plates. Three of the 11 concrete slab homes had bottom plates bolted to their foundations and three more homes had a combination of steel bolts and concrete nails. The remaining five of 11 concrete slab homes had bottom plates only nailed to the slab. Pier and beam homes, by their nature, were not anchored.

Most of the homes did not have brick veneer exteriors. We could infer this from the fact that only three of the 11 concrete slab homes had brick ledges in the foundation -and these ledges were only found on the front side of the house. The remaining homes had no brick ledges and the bottom plates were secured along the very edge of the slab. From our inspection, we found that two of the 15 homes had above average connection strength between the bottom plate and foundation, four additional homes had average foundation connection strength, five additional homes had below average foundation connection strength, and the four remaining (all pier and beam) had no foundation connection strength.. Many connections failed in shear when anchor bolts or nails broke out from the side of the concrete slab. In other instances, the concrete nails themselves were sheared or the studs broke loose from the bottom plate. It was apparent from our inspection that it didn't matter how well the bottom plate/foundation was connected

An interesting comparison between fatality statistics and foundation connection strength revealed that three fatalities occurred in homes with above average foundation connection strength, two fatalities occurred in homes with average foundation connection strength, three fatalities occurred in homes with below average foundation connection strength, and ten fatalities occurred in homes with no foundation connection strength. The best foundation connections (all slab) were found on the Mullins and LaFrances residences while the Smiths, Gowers, and Igos had the worst connections (pier and beam). Two persons did survive in the better built LaFrances residence. The Igos, family of five, had the largest house. The main house was pier and beam and three small room additions were on concrete slabs. Some bolts were noted on the concrete slab portion of this house, however, there were no washers or nuts on the bolt stems. Thus, the Igo house was not anchored and it was swept completely away; all five family members were killed. Relatives indicated the bodies were mangled almost beyond reasonable identification.

The Jarrell tornado was highly visible and most of the victims saw the tornado coming. In fact, some drove several miles to home or other houses to seek shelter. Unfortunately, three members of the Ruizes family left their mobile home and sought refuge in the wood framed house owned by the Moehring family; the Moehring house was leveled but the Ruizes' mobile home remained intact. The Ruizes boys and their mother were killed.

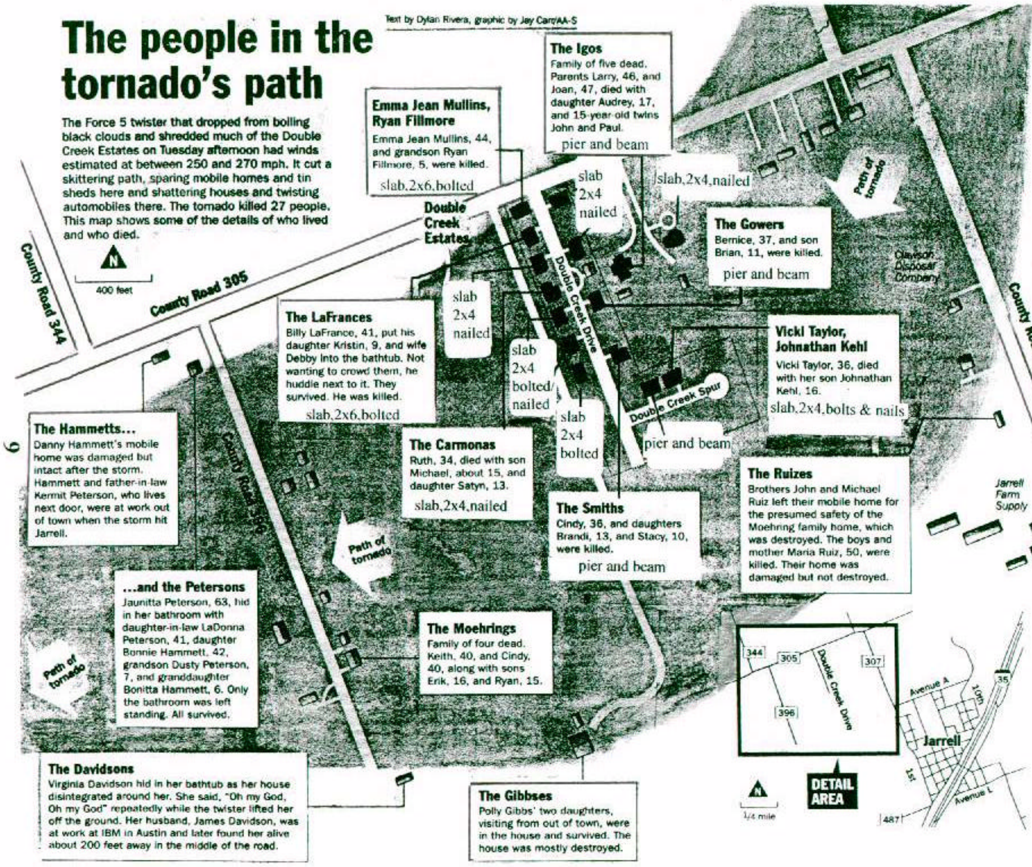
Let us next consider the slow translational movement of the Jarrell tornado. It was reported that the half mile wide tornado traveled between five and ten miles per hour across the subdivision. Thus, the tornado would have taken between THREE AND SIX MINUTES to pass a given house along the center of the path. It appeared that such a slow moving tornado, among houses intermingled with vast differences in construction practices (well anchored adjacent to non anchored), literally shredded every home (like in a blender) regardless of how well it was constructed.

So what were the lower bound winds in the Jarrell, Texas tornado? My best estimate was around 200 mph, or upper F-3. Note that F-5 winds (greater than 260 mph) would have caused the same devastation too. The message learned at Jarrell is that mixing and matching construction techniques within a subdivision (building strong homes next to weak ones) tends to make all houses perform the same, as poorly built homes break apart and throw flying debris into the stronger homes. The moral here is: Your house is only as strong as your neighbors -or- Your house is only as strong as the weakest one in the neighborhood.

The people in the tornado's path

Text by Dylan Rivera, graphic by Jay Carr/AA-S

The Force 5 twister that dropped from boiling black clouds and shredded much of the Double Creek Estates on Tuesday afternoon had winds estimated at between 250 and 270 mph. It cut a skittering path, sparing mobile homes and tin sheds here and shattering houses and twisting automobiles there. The tornado killed 27 people. This map shows some of the details of who lived and who died.



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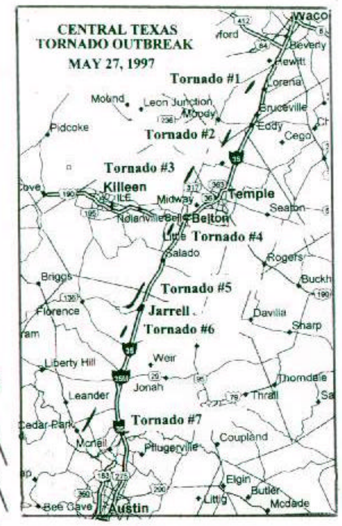
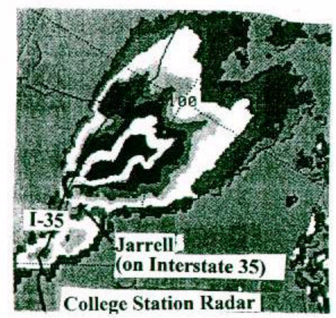





Home swept from concrete slab foundation


Home cleaned from pier and beam foundation


Grass "packing" turned front stairs into a ramp


Gouges in vinyl flooring from flying debris

Bent anchor bolt which secured bottom plate to slab -- grass around bolt shows wind direction


Anchor bolt pulled from side of slab foundation

Concrete nail which secured bottom plate to slab

Nail pulled from side of slab foundation


Asphalt road pavement removed by Jarrell tornado


Apparent truck smashed by Jarrell tornado

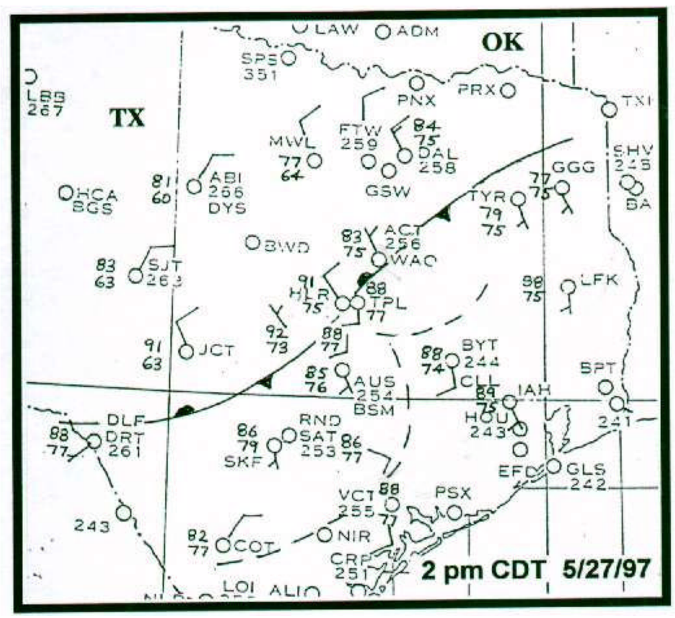

Flattened car from Jarrell tornado


Tire on vehicle was filled with grass

The Jarrell TX Tornado Environment: Landspout or Supercell? By Jon Davies

The Jarrell tornado on May 27 of this year was an unusual and in many respects baffling event... an apparently violent tornado that took place in a synoptic setting that appeared relatively benign for such tornados. Tim Marshall suggested I write something about the wind and instability aspects associated with this event.

A surface map at 2 pm CDT shows a well-defined NE/SW surface boundary through the Waco (ACT)/Temple (TPL) area. At this time tornados were already in progress between Waco and Temple. During the next 3 hours, tornados occurred with three tornadic cells that propagated south or southwestward along the boundary, including the Jarrell tornado between roughly 3:10 and 3:45 pm CDT. Recent discussion and research about the event has suggested that southward propagating gravity waves from the previous night's storms over Oklahoma may have triggered the storms and contributed to their southwestward development and movement.

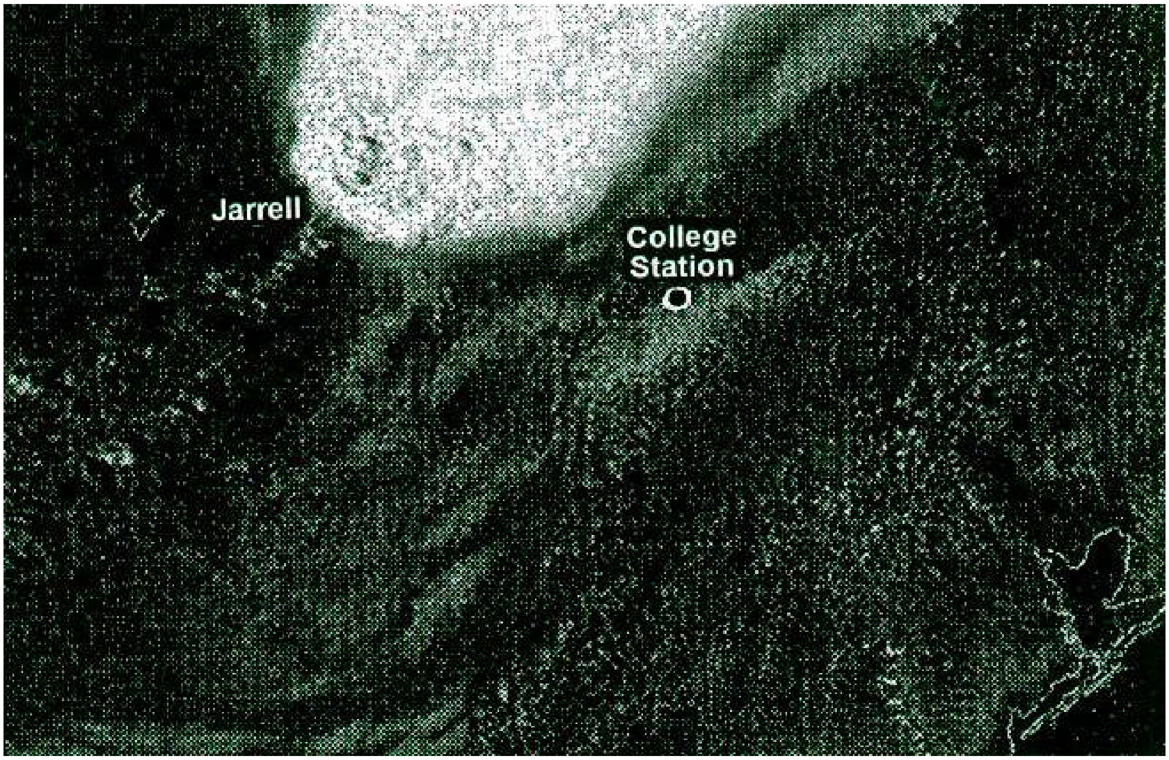


2 pm CDT, 5/27/97

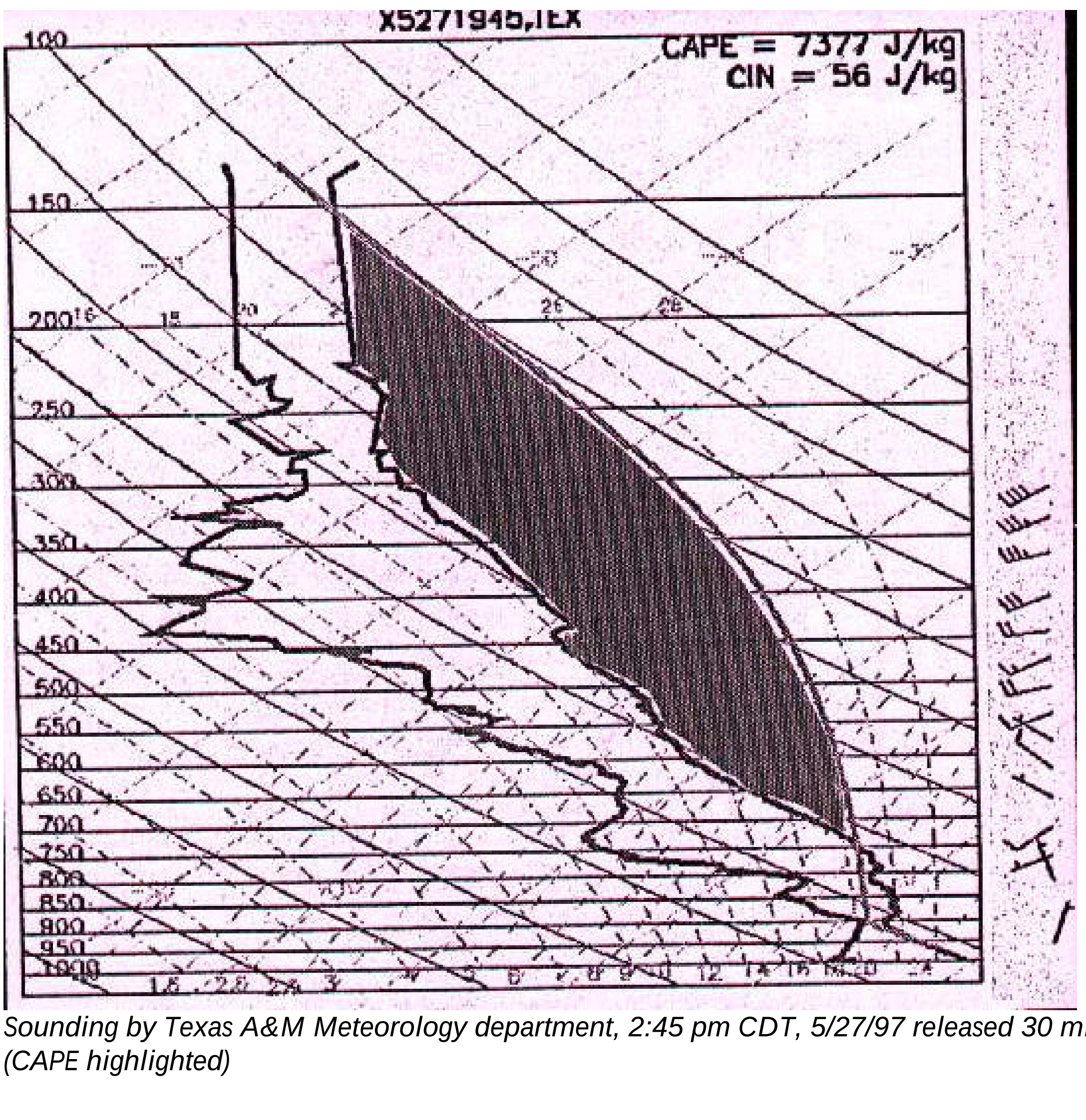
There is certainly a question among researchers and forecasters about whether the Jarrell tornado (and 7 other tornados) were induced by supercell thunderstorm mechanisms, or were more a result of landspout-type formation mechanisms. A "landspout" is a of landspout-type formation tornado that develops along a quasi-stationary windshift boundary under a rapidly developing and relatively new thunderstorm updraft. It is thought that the rapid stretching of the developing updraft can "spin up" a tornado using pockets of vorticity (potential for spin) along the windshift. This is different than supercell tornado formation mechanisms, which are understood to rely more on the interaction of a larger rotating updraft (a radar-detectable mesocyclone) and nearby downdrafts in a supercell storm. While so-called supercell tornados have potential to be strong or violent, landspout tornados have been thought to be typically weak, though there are suggestions that landspouts can leave damage as high as F2 or F3 on the Fujita scale in extreme cases.

Research and modelling have shown that supercells require significant amounts of atmospheric wind strength and shear (changing of wind direction and speed increase with height). In contrast, landspout events seem to occur in environments where atmospheric winds and shear are weak. One thing both types of environments can have in common is strong instability - the potential for a warm moist parcel of air to rise rapidly.

In this context, the Jarrell tornado environment was indeed quite unstable. A sounding (next page) launched by members of the Texas A&M meteorology department 30 miles east of the Jarrell storm at 2:45 pm CDT reveals unusual amounts of CAPE (Convective Available Potential Energy, see Tim Marshall's article, Storm Track Jan/Feb 1995), in



Visible satellite photo taken at 3 pm CDT 5/27/97 showing Jarrell storm



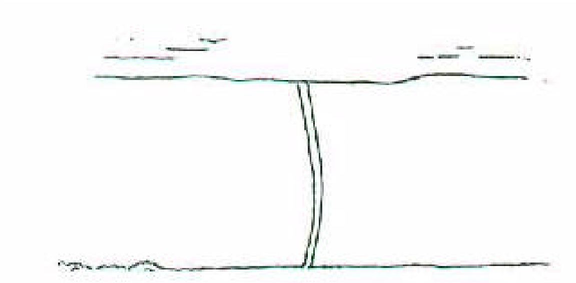
Sounding by Texas A&M Meteorology department, 2:45 pm CDT, 5/27/97 released 30 miles east of Jarrell storm (CAPE highlighted) excess of 7000 J/kg! CAPE values of generally 4000 J/kg or greater are considered strongly unstable in severe weather forecasting, so this is uncommonly large and translates to potential for very strong and rapid updrafts if a warm moist air parcel is lifted past any capping inversion.

In contrast to the instability, the sounding wind fields are weak: only 20 kts at 500 mb or -18,000 ft MSL, and only near 10 kts at 700 mb or -10,000 ft MSL. Storm-relative winds (the winds one would experience if moving along with a storm, due in part to storm motion) are being used increasingly as an indicator of supercell tornado potential in forecasting. As- suming a storm movement 30 degrees right of the average wind through -20,000 ft (a typical forecast assumption for supercells) yields average storm-relative winds of only 8 kts in the 700 to 500 mb layer. Based on Rich Thompson's work at the Storm Prediction Center (SPC), such weak wind speeds are not associated with tornadic supercell environments.

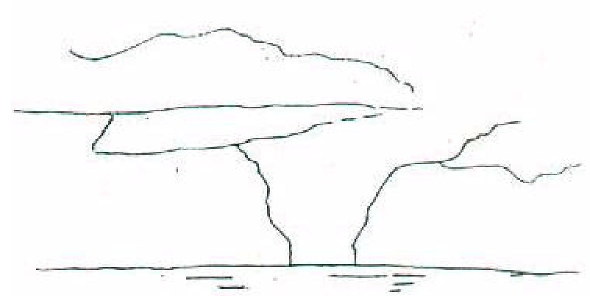
Regarding helicity (another storm-relative parameter, see Storm Track Mar/Apr 1995 for discussion), a smoothing of the bottom part of the Texas A R M sounding using winds ob- served at Temple and Georgetown (Jarrell is between these locations) yields an environment with 0-3 km helicity only around 30 m/s. This is far below "background" values thought to promote significant updraft rotation for supercell development.

So, apart from being unusually unstable, the wind and shear environment of the Jarrell storm does not appear to suggest much in the way of supercells, much less supercells with tornados. But given the combination of huge CAPE values, weak wind profiles, and explosive thunderstorm development along a boundary, this event does appear to fit a classic landspout tornado environment very well. The rope-shaped appearance of some stages of the tornados (including the early stages of the Jarrell tornado) is also suggestive of landspouts.

How then could an environment seemingly more suggestive of landspout development produce a violent tornado like the one that hit Jarrell? As with so many situations in weather, it is hard to say. Based largely on highlights of a detailed radar analysis by Don Burgess, and discussion with a few forecasters at SPC, including Rich Thompson and Roger Edwards, I believe that Jarrell and other tornados that day may have been hybrid events. They seem to be tornados initiated by landspout-type mechanisms, but also tornados that, by virtue of storm motion and maximization of their environment, in some way evolved into tornados and storms having supercell characteristics.



Landspout? (3:21 pm CDT)



Supercell tornado? (3:38 pm CDT)

(Tracings from video, copyright 1997 Rick Igau & Mike Robinson)

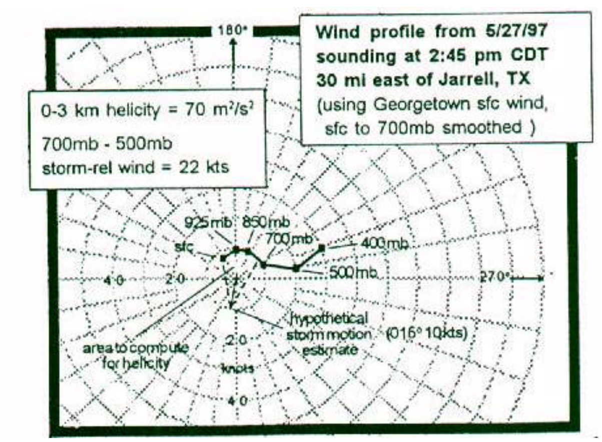
Lon Curtis' photos and observations of the Jarrell tornado, along with video by Rick Igau and Mike Robinson, are quite suggestive. The Jarrell tornado started as an almost station- ary "rope" under a flat rain-free cloud base (visually like a classic landspout), then began moving southward, transforming into a narrow "cone" aloft with dust cloud below. The dust cloud then rose upward as a "sheath" around the cone to form a much larger tornado. By the later part of it's life cycle, the tornado became quite large with a well-defined clear slot wrapping around it, looking very much like a tornado associated with a mesocyclone and supercell storm.

In his analysis, radar expert Don Burgess notes that the Jarrell tornado began as a classic landspout at about 3:07 pm CDT with only a small rotation in the surface layer on radar (good data is available from the Granger, TX WSR-88D radar, which was only a few miles from the Jarrell tornado). Then with time, a mesocyclone signature that had been above 10,000 ft and not associated with the small surface layer rotation, slowly became stronger and estab- lished itself at low-levels, probably absorbing the landspout circulation about the time the tornado became large on video (around 3:25 pm CDT). Don notes that after the landspout phase, the storm on radar appeared as a somewhat normal supercell, and that this transition seemed to occur with several other tornadic storms that day as well. He also notes that local enhancements along an outflow boundary from a dissipating storm further north may have helped this transition with the Jarrell tornado become more pronounced..

From a speculative viewpoint, it is interesting to look at the Texas A R M sounding again from the perspective of a south or south-southwest storm motion. Rough motion of the storm updrafts that day appeared to be toward the south at around 10 kts (not to be confused with the motion of the larger thunderstorm complex, which built and redeveloped more rap- idly southwestward with time). This SSW motion is a strong deviation (more than 90 degrees) from the general wind flow which was from the W or WNW, and was probably influenced in large part by propagation along the NE/SW quasi-stationary surface boundary.

Using a motion from 15 degrees at 10 kts, the storm-relative winds in our sounding become very interesting. The storm-relative flow in the 700 mb to 500 mb layer (10,000- 18,000 ft), which earlier in our discussion was only a meager 8 kts when using a standard storm motion assumption, increases by 270% all the way to 22 kts! From experience at SPC midlevel storm-relative wind flow around 20 kts or greater is characteristic of environments that support supercell tornados, by suggesting significant precipitation separation (blowing downwind and away) from the updraft. The southerly storm motion combined with the Texas A & M sounding certainly produces flow in that range.

Regarding helicity, while still not impressive, the southward motion doubles the value (to around 70 m/s), and in combination with the huge CAPE generates an Energy-Helicity Index (EHI, see article in Storm Track May/June I 995) of around 3.0, somewhat suggestive of support for tornadic supercells. With an outflow boundary in the area potentially enhancing wind flow, temperature gradients, and convergence, it's possible these "background" values could also have been enhanced. And it is certainly graphic the way storm-relative parameters in the Jarrell environment increase when given a storm motion deviation 90 degrees or more to the right of the average wind though midlevels.



These assumptions and computations are, of course, somewhat speculative. But they do suggest that, given the background environment, how it might have been possible for the Jarrell storm to evolve into a supercell given a very deviate storm/updraft motion along the surface boundary. Yet the fact remains that the environment of the Jarrell tornadic storm seems more suggestive of landspouts than supercells, and the mechanisms for the early formation of Jarrell and other tornados that day appear to be more along the lines of landspout formation (rapid stretching of boundary updrafts in a high CAPE environment).

So, to my way of thinking, this event reinforces the idea that there's not a clear delineation between landspout and supercell tornado events... there seems to be a gray area or overlap between the type of tornados where rapid updraft stretching is the dominant mechanism, and tornados where development is a more complex interaction of larger rotating updraft with adjacent downdrafts.

A question then: What might be some knowledge to be gained from the Jarrell event for recognizing similar environments leading to similar events, as uncommon as they may be? To be honest, I think it would be impossible to pick out violent potential for a tornado event like Jarrell from the data I've studied so far. With that said, this case does suggest several clues to a forecaster as red flags for concern and analysis regarding the possibility of significant tornados:

1) extreme surface-based CAPEs around 6000 J/kg and higher (a very key compo- nent), with temperature to dewpoint spreads of 15 deg F or less (this would keep cloud bases relatively low to lessen mixing, evaporative cooling, and resulting CAPE reduction & outflow).

2) a well-defined quasi-stationary surface boundary with cyclonic shear across it (for example, surface winds with a dominant northerly component behind the boundary giving way to south or southeasterly surface winds ahead of it)

3) imminent explosive thunderstorm development along the boundary, suggested by an eroding capping inversion, towering cumulus, or ongoing thunderstorm development south or westward along it.

To suggest the possibility of more significant tornados, one would also look for storm motion in progress that deviates unusually from the mean environmental wind, possibly through propagation along the boundary, enhancing the effect of storm-relative winds. And there is also the possibility of other boundary interactions, such as outflow boundaries.
I 'd also like to note that the Storm Prediction Center did a nice job of recognizing significant tornado potential in this difficult situation, issuing Tornado Watch 338 for central Texas well in advance of the Jarrell tornado.
Many thanks to Don Burgess of OSF, Norman, OK for sharing his analysis of this event.

A Brief Comparison of Tornadic Environments: Plainfield IL and Jarrell TX By Jon Davies

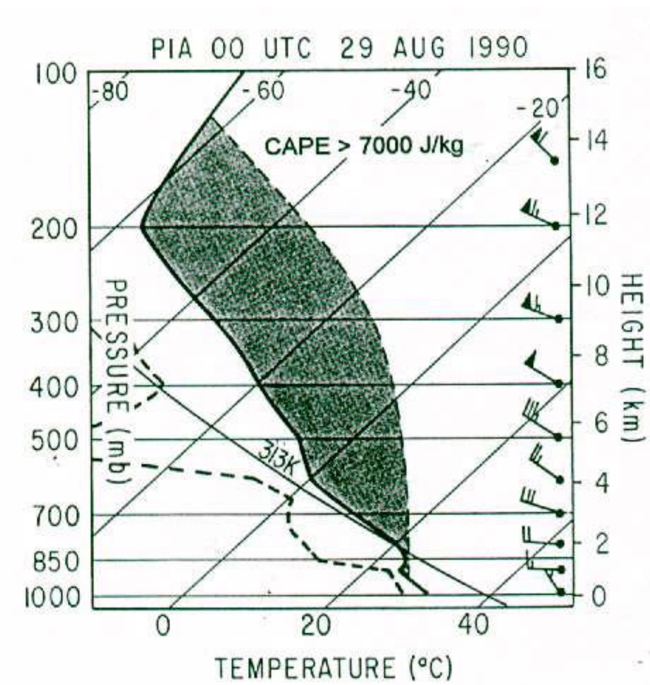
The Plainfield, Illinois tornado in 1990 was another tragic and unexpectedly violent tornado occurring in an environment not readily apparent as supporting supercells, at least according to forecast knowledge at that time. In some ways the Plainfield environment has features in common with the Jarrell environment, and in other ways it is notably different.

The main feature the two events have in common is the unusually strong instability. Using the sounding for Peoria (next page) on the evening of August 28, 1990 as a suggestion of the storm's environment (the violent tornado occurred 3 hours earlier 90 miles northeast), a surface-based CAPE greater than 7000 J/kg is evident, similar to the Jarrell setting. Like the Jarrell storm, the Plainfield storm appeared to interact with boundaries in the area, but it did not develop and move directly along a quasi-stationary as the Jarrell storm did.

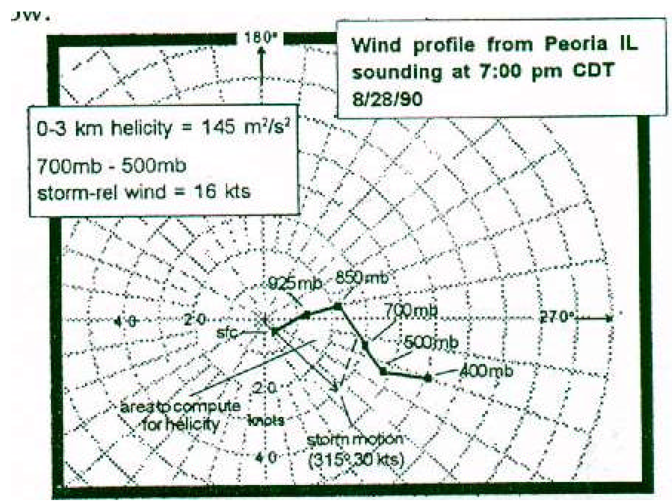
A significant difference between the two events is the general wind fields, which were notably stronger in the Plainfield case, particularly in mid and upper levels. Winds on the Peoria sounding were around 35 knots at 500 mb, and 30 knots at 700 mb, averaging nearly twice as strong as the Jarrell case. As a result, the Plainfield storm moved much faster than the Jarrell storm, from the northwest at around 30 kts. This is three times the speed of the Jarrell storm, and not nearly as deviate in its motion relative to the average wind through 20,000 ft. Unlike Jarrell, the Plainfield storm moved reasonably close a typical supercell motion assump- tion (30 degrees right of the mean wind).

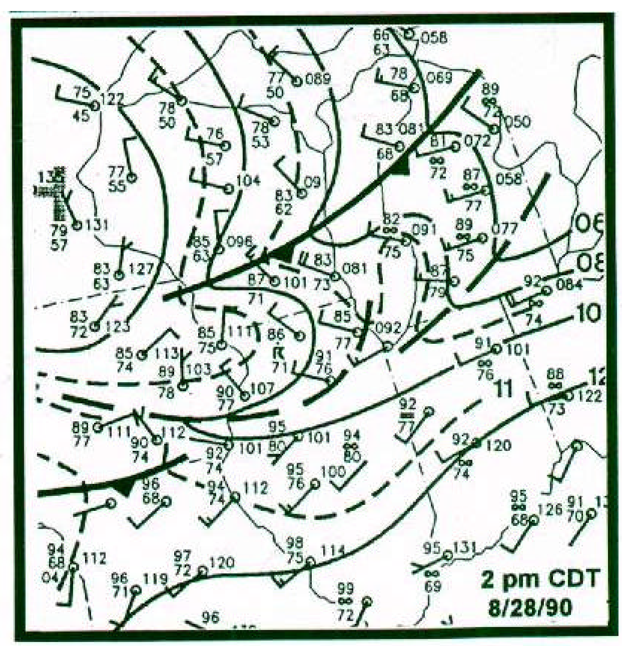
Looking at storm-relative parameters, the midlevel storm-relative flow is around 16 kts for the 700 to 500 mb layer on the Peoria sounding given the Plainfield storm movement. In actuality, the storm-relative Row at this level was probably greater (about 20 kts) because midlevel winds on soundings northeast from Peoria (Green Bay, WI and Flint, MI) were notably stronger. The 0-3 km helicity is near 150 m/s, which combined with the strong CAPE values makes for a large EHI (greater than 6.0). These are all "acceptable" to "good" parameter values when considering environments suggestive of tornadic supercell storms, and, unlike the Jarrell case, they are arrived at without having to assume unusual deviate motions from the general wind flow.

So, while both cases have environments of extreme CAPE (an important "red flag" they share), it can also be seen there are several differences, particularly concerning strength of wind fields and shear. While far from an obvious forecast event, in retrospect the Plainfield tornado environment seems more supportive of supercells than the Jarrell environment by virtue of its stronger wind fields in northwest flow.



Peoria, IL sounding at 7 pm CDT, 8/28/90 (from Siemon, BAMS February 1993)





Williamson County Tornadoes on May 27, 1997 By Craig A. Green, N5WEH

The 27th of May was to be my last day to work before my scheduled vacation which will complete the week. I had to supervise one of my stations to be installed in Austin and was halfway expecting some chance of severe weather after the Red River storms of Monday the 26th. I was surprised to find that the SPC (Storm Prediction Center) had issued a moderate risk for severe weather for central Texas and as Pamela and I packed for the Austin trip, we included our chase gear. The surface dewpoints were in the 70s with lifted indices in the -9 to -12 range for central Texas. With backing 30 to 40 knot mid-level winds from the west, sufficient shear was present for supercell development. The forcing mechanism would most likely be the weak cold front which was moving south toward the region. Additionally, the presence of weak upper troughs moving over the area would add upper air support to an already very dangerous situation!

Pamela and I drove to Austin early in the morning and kept the weather on the back burner. After lunch, the SPC issued a watch box for central Texas which included Williamson county at the extreme western end. At about 1400 local time, I logged in for some weather data on the Internet and found that some storms were beginning to fire north and NE of Austin. Having completed my mission, we started north, thinking that we could monitor NOAA radio and amateur frequencies for guidance. A quick stop at my usual place in Austin, and a quick peek at TWC (The Weather Channel) yielded two storms. One was due north of us in Bell county and the other one was in east Texas. There seemed to be no particular concern for the Bell county storm at about 1500 when we watched TWC, so I decided to head north and decide later, which is often the case. As we drove North on 1-35, we began to hear reports of a tornado in Bell county on the 145.15 machine and decided on the north storm. As we passed the Georgetown exits, Many Texas Department of Safety marked units (Black and Whites) passed us at over 90 MPH. We could see a dark lowering to the north over I 35 about five or six miles away and as we reached the 269 mile marker at 1535, traffic stopped on the interstate due to DPS roadblocks. Pamela began videotaping the Jarrell tornado which was now visible about five miles up the road. Not wanting to get trapped on 1-35 with what was apparently a large wedge tornado headed south towards us, I drove through the grass on the right side of the roadway to get on the northbound access road. We had escape routes to the east and south, so we drove up to a DPS road block at a crossover near the 270 mile marker. I was just about to explain our spotting/chasing posture to the officer when, directly across the highway, in a plowed field next to the southbound service road, large dust whirls began lifting and swirling off the ground at 1540. About 200 yards away a tornado was spinning up on the west side of I 35! The DPS officer glanced at he weak tornado, uttered an expletive as he entered his vehicle, and sped away southbound from his post. This of course eliminated the problem of explaining our actions, but presented another more immediate issue requiring resolution.

We continued up the northbound access road taping the dust tube tornado with a second eye on the big wedge bearing down on us. About 100 yards up the access road a county road slanted off to the ENE and we drove down about 1/4 of a mile out of harms way. We jumped out of the chase truck at 1542 and began our documentation of events. The dust tube was still grinding away to our WSW and I nervously glanced north. No sign of the wedge because a rain area was in the way. Back to our NE was the big rain core with what was most likely gorilla hail. We continued taping and clicking away until Pamela said Its Time To Move CRAIG!. We jumped back into the truck and sped to a 90 degree turn to the south-southeast and after about 1/2 a mile we stopped. Above us, back to the west was the parent cloud of the dust tube which had now narrowed to a skinny rope with a condensation funnel curving away 45 degree from the cloud base, extending halfway to the ground. Debris could still be seen moving on the ground below the tip of the funnel. Looking back to the SW, a new mesocyclone was forming with a growing, rotating lowering. Looking toward the NW, an immense RFD notch was visible which now extended almost to the new lowering.

As we continued taping, with the rain and hail bearing down on us, a large cylindrical tornado became visible from behind the rain area at the right edge of the RFD notch. The radial motion of the dying Jarrell wedge was astounding; somewhat like a white barber pole sped up ten times. The cylinder bent into an elephant trunk and as we continued our observations, a speeding utility vehicle with flashing grille lights was approaching from the NW. The emerging public servant advised us that golf ball size hail was approaching. Pamela perceived his arrival as a portent to move, so we headed down the road to a right turn back to the northbound access road of I 35. We tried to hide under a bridge crossing at mile marker 269 but the DPS officer offered to lodge me at the county caboose if I entered the on ramp. We settled for the crowded underpass at the 268 marker and found fortune with a spot on the wrong side of the road. After a ten minute stay of heavy golf balls, we were evicted by a deputy into 1/2 inch soft hail. Not wanting to join the circus in Austin with the Cedar Park tornado which we heard on the 146.94 Travis County ARES net, we departed North at about 1615.19

Central Texas Twisters - 27 May 1997 By Bruce Haynie

A day that will be remembered by many people for three very different reasons. The first for the destruction of lives and property. The second for those who dedicated enormous resources to the Jarrell relief effort. The third for weather forecasters and storm chasers who have scratched their heads trying to explain this "relatively unexpected" tornado outbreak in Central Texas. Specifically, at least 9 tornadoes (Figure 1) occurred in the Central Texas counties of McLennan, Falls, Bell, Williamson, and Travis.

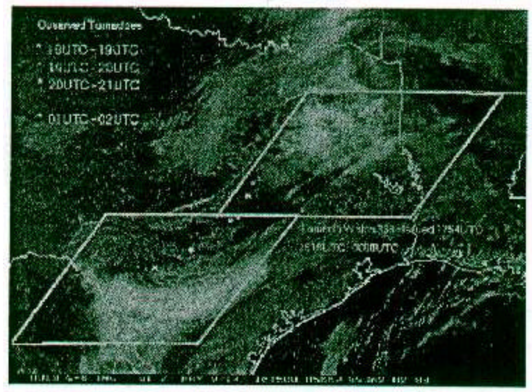


Figure 1. Tornado watches overlaid on a visible satellite imagery from 27 May 1997 at 1615Z. Image courtesy of Don Gray at NOAA/NESDIS.

The most devastating and most covered by the various media was the Jarrell, Texas tornado. Twenty-seven unfortunate people lost their lives. The eighth tornado developed in southwest Williamson County in the Austin, TX. suburb of Cedar Park. This tornado moved across the Albertson's supermarket collapsing the roof and trapping several people inside for a few hours. Although no deaths occurred in Cedar Park, several people were injured in Albertson's and the Buttercup Creek subdivision. The ninth tornado developed in far western Travis County and became a killer tornado when it passed through Happy Hills near Lake Travis.

Synoptic/Mesoscale Conditions

To say that the atmosphere was unstable this day is a gross understatement. Explosive might be a more appropriate description. CAPE's (Convective Available Potential Energy) were exceptionally high; over 5,000 joules per kilogram. LI's (Lifted Index) were quite low; less than -12. Even 12Z soundings at Del Rio and Corpus Christi, TX. were showing extremely high CAPE'S in the absence of daytime heating. Two surface boundaries focused the convection this day. At 11Z a weak surface low was located on a dying/stationary front near Dallas which extended southwest from the surface low to the Del Rio area. An outflow boundary (from overnight convection) was located along a line from Fort Polk, LA., Conroe, and College Station to the low near Dallas creating a "pseudo" triple point. The atmosphere at the surface was very moist with dewpoints in the mid and upper 70's across Central Texas. The upper levels of the atmosphere were less favorable, but good enough. Westerly flow of 20 knots at 700 millibars and 30-35 knots at 500 millibars would be sufficient for supercells given the instabilities. In addition, extremely deviant storm motion would play a significant role during this event. Upper level winds at 300 millibars were also westerly at 40-45 knots.

By 15Z the surface low along with the triple point drifted south-southwest to the Waco vicinity. Convection initiated around 17Z just south of Waco in McLennan County. The storm propagated south-southwest along the dying/stationary front.

The Chase -- See Lon Curtis' article about the Jarrell, TX and earlier tornadoes.

After looking at the early morning discussions, outlooks, and raw data, I decided to take my chase gear to work in the event of a late afternoon or evening chase. This turned out to be one of the most important decisions of the day. I stayed aware of the potential weather situation by checking hourly surface data, radar, and visible satellite images. By 15Z (10am CDT), two surface boundaries, a dying/stationary front and an outflow boundary, become very obvious on the visible satellite image. The outflow boundary intersects the stationary front in the vicinity of Waco creating a "pseudo" triple point. Organized convection begins to fire around 17Z in the same area. At work, I continued to check radar and satellite data (Figure 2), becoming more and more antsy with time knowing that I could not get off work until 3:45pm. Now it's 1830Z and several tornado warnings have been issued by WSFO-FTW for the cell now located in southern McLennan County. The storm is moving radically to the right; south-southwest at approximately 15 knots. It is about 3:20 and I try to call Lon on his cell phone from the office. No answer. I didn't know that he was photographing what would be called the Jarrell, Texas tornado. Finally, it's 3:45 pm and I can get away from the office. Northbound on 1-35, it's 3:55pm and I try Lon on the cell phone again from my chase vehicle. He answers, nearly out of breath, and tells me what he has seen and gives me some much needed information which confirms my suspicions of storm motion and how the mesocylones are evolving over time. Lon says: "Go up US 183 northwest!" I do exactly that and proceed toward a darkening sky. A frantic call on the ham radio exclaims: "Tornado in Cedar Park! I'm turning around!" Approaching the intersection of 620 and 1S3 and looking in the direction of Cedar Park. I didn't see any tornado. I turn back to the east-northeast on 620 to get out of traffic. As I do, I catch a glimpse of what appears to be a loose column of smoke suspended over the north sections of Cedar Park. Uh-oh! My interest is beginning to peak. Lon calls: "Tornado Warning for the Cedar Park area". I make a u-turn at a crossover on 620 and head back toward 183. A small funnel comes into view to the northwest as I make the u-turn. Tornado was at 4:23pm from my perspective. Dust (an unseen debris) is being pulled skyward as the condensation funnel thickens, extends closer to the ground and moves south-southwest. I start looking for a suitable place to take video and stills. After some meandering, I find a place to stop at Lakeline Mall on a small hill. I begin to video and take stills for approximately five minutes as the tornado unfortunately moves through the Buttercup Creek subdivision of Cedar Park. The tornado, with condensation 7/8 to the ground and a very tight debris cloud, veers more to the west and gradually becomes wrapped in rain. I become concerned about getting pounded by the core and try to go south and then west toward Lake Travis only to become stranded in traffic gridlock on Rt. 360. Cringing as the core moves over me, I get lucky some how and miss all but heavy rain and some 1/4 inch diameter hail. That's where the chase ends for me. Unfortunately, another tornado develops and moves through the Hazy Hills area very near Lake Travis and takes the life of a 25 year old man.

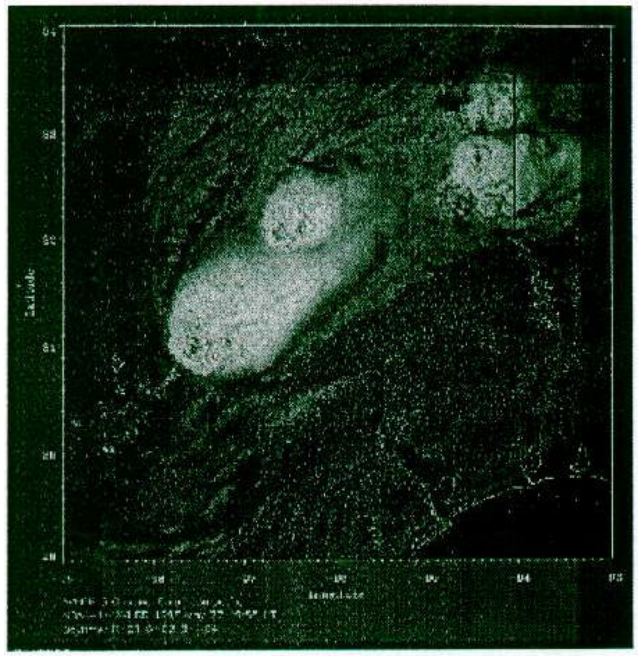


Figure 2. Visible image taken of the Jarrell storm at 1958Z from the polar orbiting satellite NOAA-14. Note the other two non-tornadic supercells above and to the right of the Jarrell storm. Image courtesy of Dr. Steven Babin and Johns Hopkins University Applied Physics Laboratory.

For further information on the 27 May 1997 tornadoes, see the following sites on the World Wide Web:

http://fermi.jhuapl.edu/people/babin/imgallery/tornatx/index.html
http://cimss.ssec.wise.edu/goes/misc/970527.html
http://ftp.cira.colostate.edu/motta/picoday/special.html
http://www.ncdc.noaa.gov/rcsg/txtornadoes/texastornadoes.html#OTHER

Acknowledgements: Dr. Steven M. Babin and John Hopkins University Applied Physics Laboratory.
Mr. Lon Curtis for allowing me to borrow from his chase report.
Mr. Donald G. Gray and NESDIS

CENTRAL TEXAS TORNADOES: MAY 27, 1997 By Lon Curtis

I started the day around 6:30 am with the usual review of model output from 00Z the night before, early morning forecast discussions from Texas offices, and the morning severe weather outlook. The SPC (storms prediction center) had issued a moderate risk for portions of eastern Texas, southern Arkansas and northern Louisiana, but the western edge of the moderate risk extended west into central Texas near Austin and Waco. The forecast soundings for the afternoon looked very unstable and when I ran the 09Z RUC output valid at 21Z through PC-GRIDDS, the results looked promising for deep, intense convection, but forecast winds, both surface and aloft, looked pretty weak. Instability was forecast to be extreme, with CAPES (convective available potential energies) of 4000+ j/kg and Lls (lifted indices) of -10C in central Texas by forecast time.

My 11Z hand-analysis of surface data placed a weak surface low on a dying cold front right at Dallas, with a trough extending southwest to near Del Rio. An outflow boundary from overnight convection in eastern Oklahoma and northeastern Texas had pushed across east Texas and was draped from Fort Polk to Conroe to College Station to the low near Dallas. Ahead of the front, surface winds were light southeasterly except in areas impacted by the outflow boundary. North of the front, winds were northerly with some evidence of a secondary front across central Oklahoma. The most striking feature on the map was an area with dewpoint temperatures 75 degrees F or better which was to the right of a Del Rio-Junction-Waco-Palacios line.

I put on my work clothes (suit, dress shirt, tie, etc.) and went to the office. During the morning, I watched the situation evolve via internet sites. The first significant data to arrive was the 12Z soundings, which I obtained from RAP- UCAR. Del Rio was showing CAPE near 4700 j/kg and LI=-12 C (at 7am CDT!!!) while Fort Worth was CAPE near 3000 j/kg and LI almost -10 C. (I didn't look at Corpus Christi but have been told it was almost 8000 j/kg). Such extreme instability before daytime heating took effect foretold incredible instability for the afternoon hours. The 15Z SPC update of the SWO (severe weather outlook) continued a moderate risk of severe storms for portions of central Texas eastward, but noted that the relatively weak wind fields would mean that the primary threat was hail and damaging winds, with only a chance for an isolated tornado. Experience and many hours of reading research papers from AMS conference preprints told me to watch for evidence of storm deviating in the extreme from the hodograph, which suggested storm motions of -300 degrees at 12 knots.

My 15Z hand-analysis placed the surface low nearer to Waco than Dallas, suggesting that it had drifted southwestward. The outflow boundary to the east was still visible on satellite imagery, as was the trough-cold front to the west. The cooler air east of the outflow boundary appeared to protrude westward to near Corsicana, northeast of Waco, creating something resembling a triple-point at Waco. I left at 11:30am for lunch so I could drop-off film shot in south central Oklahoma Sunday for processing (two tornadoes near Duncan Sunday afternoon), telling the secretary I'd be back by I:00pm. Lunch was from Chick-Fil-A in Temple and a large cumulus tower to the north grabbed my attention and sent me home for a quick look at data. I ate the sandwich as I drove.

The -12:40 SRM products off of KGRK and KFWS (thanks, Freese-Notis!) both indicated strong shear suggestive of a developing mesocyclone in the storm I'd seen visually, now located in southern McLennan County. A quick look at a local television radar showed the storm was developing a reflectivity pendant on the WNW side. I put the SRMs and the pendant each together and went to put on my jeans and then headed for McLennan County. The chase was "on"! Come on along! (All times are CDT.)

About 1:00pm I left my house in far western Temple and traveled north on SH317 to Moody. I called the office to report I'd be a little late getting back. A severe thunderstorm watch was issued for the McLennan Co. storm at 12:50pm ("rapidly developing thunderstorm near Woodway"). Passing Moody, I heard the DPS dispatcher at Waco asking a trooper to check the "back side" of that cell near Woodway. I took FM2113, which took me right into the rear of the storm. The sky darkened. FM2113 passed through farm and ranch land broken by several small streams, and about 5 miles northeast of Moody, I came up out of a valley and around a curve and there, a mile or two in front of me, was tornado #1. After several photographs and a chance to observe the very slow motion of the storm, I crept up toward it. Additional photos are shot from -1/2 mile away. The tornado was undercut by outflow and died. I went down Mackey Ranch Rd to see if help was needed; a mobile home was blown-away but no one was hurt. This tornado moved from ENE to WSW over a distance I would estimate to be a couple of miles. Path width was probably 75 yards or less. Reports were made to NWSFO/FTW when the tornado was spotted and when it dissipated.

At this point, I made one of only two mistakes in the afternoon chase which is about to evolve. Hearing a tornado warning being issued for Falls County, southeast of my location, I continued on to Hewitt and then south on IH35 toward Eddy and Falls Co. In the process, I almost missed seeing tornado #2. Approaching Eddy, it was obvious that to get back south of the storm, I'd have to punch the core, because the storm was not moving southeast, it was going almost due south. Most motorists had abandoned the Interstate as I barreled south at the speed limit or better with golf ball hail everywhere and smaller hail beginning to cover the highway. (Perhaps that explains why I've never worried about repainting the chase truck where the hood is peeling and rusting!)

The scanner was absolutely full of spotter and law enforcement reports of a new tornado between Moody and Troy. Passing through Troy, I took FM1237 back west toward Pendleton and SH317. Topping a hill near Pendleton, I could see tornado #2 off to the northwest. I watch for several minutes as until it became rain-wrapped and disappeared. I'm low on gasoline and I radioed the Belton Fire Dept. to watch the area near Moffat and Morgans Point for new development (southwest of the last tornado) as I stop for fuel near SH317 and SH36 just west of Temple.

I headed on south on SH317 and while crossing from Temple into Belton, hear that a new tornado (#3) is on the ground at Morgans Point. I turn west of FM439 and from the south side of Belton Dam, shoot several photos of the large tornado that is roughly 3 miles away. I declined to cross the dam and approach the tornado for fear that a traffic accident or sightseers will obstruct my only path of escape. Instead, I repositioned to US190 at FM1670, west of Belton, in time to see that #3 is rain-wrapped. I shoot one photo with aid of a telephoto lens as it emerged from the rain and ropes-out. I radioed to the Fire Department that we will need to watch the Lake Stillhouse area for new development, and I head for Stillhouse Hollow Dam on FM1670. While crossing the dam, I glanced left and see a funnel cloud extending earthward; looking down into the valley east of the dam, I see that there was a condensation funnel forming and debris flying; tornado #4 is developing, but soon dissipated. I continued on south on FM1670, and radioed the Belton Fire Department to notify the Salado Fire Department to be particularly alert; 1 expected the next threat to be from near Youngsport (west of Salado on FM2484) to Salado itself.

I passed through Salado southbound on the IH35 west side frontage road. On a hill south of Salado at the FM2268 overpass (one of my favorite 'spotting' locations), I saw a funnel cloud to me southwest. I continued south on the frontage road and about MP282 on the Interstate, just south of a rest area, stop to watch tornado #5, a thin rope-like tornado as it wandered around in a pasture about 3/4-mile away. After several minutes of observing little movement other than 'wandering', I moved-up on the tornado, eventually closing to -0.3 mile, documenting with more photos. I realize maybe I'm getting a little bold, and retreated to the Exit 280 overpass and make several more photos, as the pencil-like tornado suddenly begins to move southward and accelerates. I take the east side service road southbound and turn my back to the tornado for about 2 minutes. Halfway to Jarrell, I stop for another quick series of photos. I am amazed ... my "pencil" is now a multi-vortex tornado and growing rapidly in size. (Later surveys and interviews with residents show that the "pencil' likely dissipated as the multi-vortex tornado formed (tornado #6).

I rush southward to Jarrell (another 2 miles or less) and notice that what looks to be most of the residents are outside watching the tornado grow and move toward their city. Just prior to observing this fact, I radioed the Belton Fire Department to have them notify the Jarrell Fire Department that a large tornado is approaching from the north. I stayed with the east side frontage road through Jarrell and take a position 0.4 mile south of the center of town. (Time 3:30pm) I begin to photograph the tornado again, now a large cone which becomes a wedge, and continue to do so until debris falling from the storm make my position untenable. Turning to "flee" (the chaser is beginning to feel like the chased), I am confronted with the sight of another tornado (#7) on the ground about 3 miles to my southwest. My last view of the Jarrell wedge was as it becomes rain-wrapped. Subsequent survey led me to believe that it was entering the Double Creek subdivision at that time. I moved south on the frontage road and about 3 miles south of Jarrell, stop to 'shoot' the large tornado as it emerged from the rain and slowly begins to rope-out. (#7 turns out to be thankfully brief.) I now began to get south of the parent thunderstorm, which had overtaken me near Jarrell, so that I can stay ahead of it. As I turn northwest on SH195 north of Georgetown, Bruce Haynie called from Austin (it is 3:55pm, give or take a minute) and wanted to know where I was and where he should go. I tell him to head northwest, out US183, toward Cedar Park and Liberty Hill. Bruce gets out in time to catch the next tornado at Cedar Park, but I'll let him tell that story himself. I continue to Cedar Park, hoping perhaps to get on the west side of the storm again, but to no avail. The traffic jam caused by the tornado there and the hail and rain put an end to my chase at roughly 4:30pm. I buy two beers (among the best I've ever had), and visit with the convenience store customers and clerks about the events I've just witnessed.

Tornado west of Lorena, Texas in southern McClellan County (photos by Lon Curtis)

Ropy tornado near Prairie Dell, Texas eventually evolves into the Jarrell, Texas tornado (photos by Lon Curtis)

Large tornado striking Double Creek Estates just north of Jarrell, Texas (photos by Lon Curtis)