February 21, 2005 Hail Storms

An in-depth meteorological review of the hail storms from February 21, 2005, along with analysis of new techniques for utilization in the warning-decision making

by

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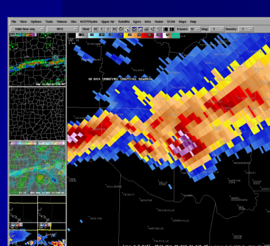
Andy Kula and Matt Zika

Photo courtesy Tom Crow (Mentone) (relayed by WHNT TV)

Mesoanalysis, Parameters and Storm Types of 2/21/05



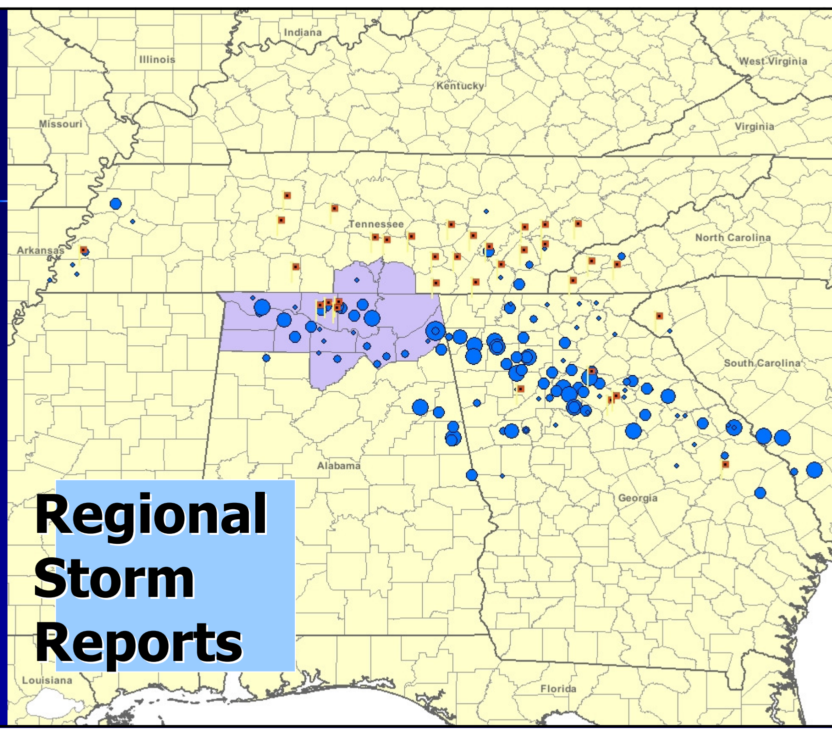
Andy Kula

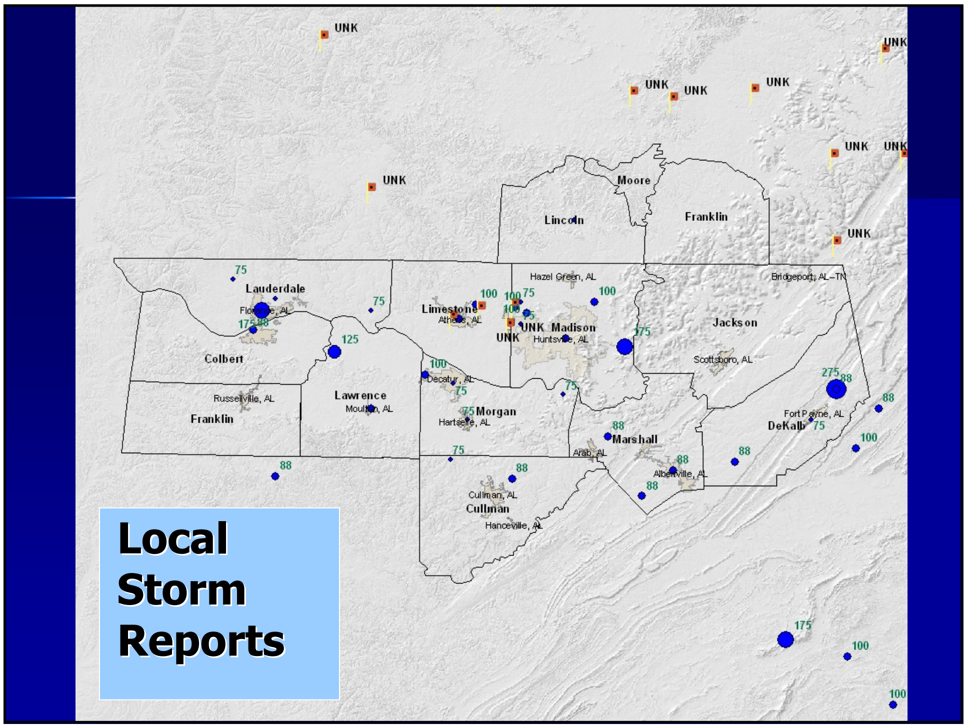
Hail Photos

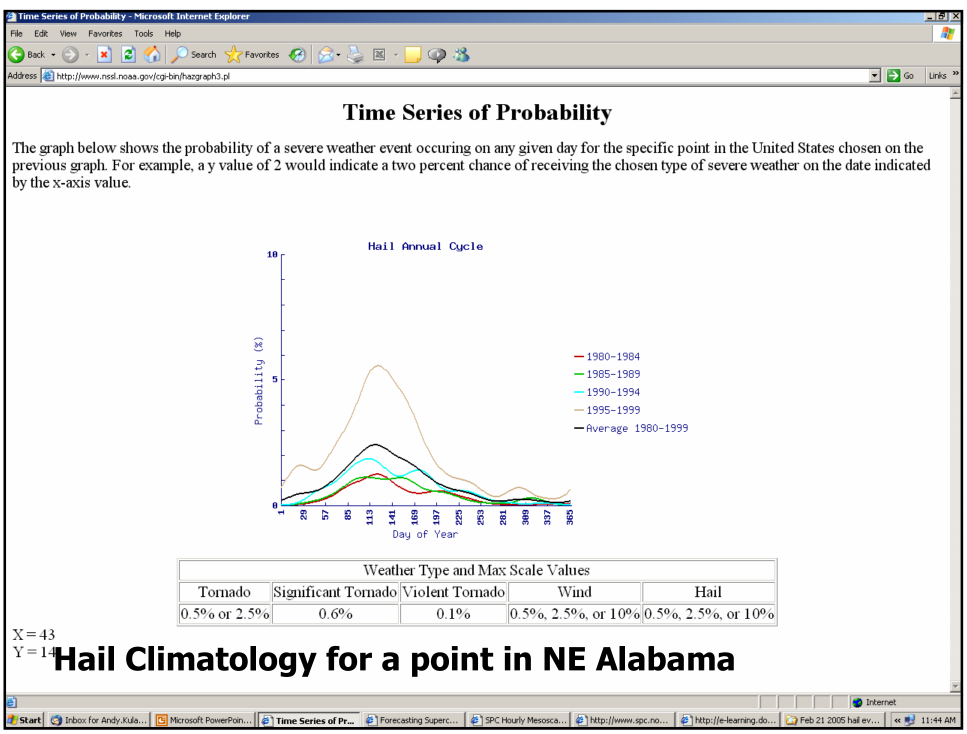
- Debbie Summerville in Henagar AL (up to Golf Ball sized)

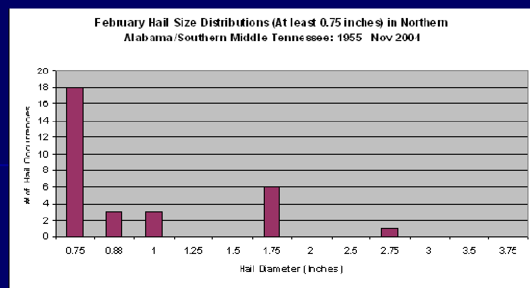
- Carson Clark in Arab AL just before 7 pm (size not given)

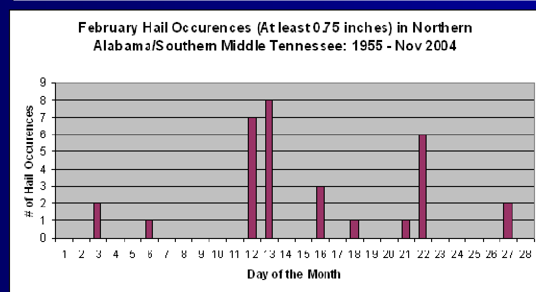
Regional Storm Reports




Local Storm Reports
Lauderdale
Colbert
Franklin
Lawrence
Limestone
Madison
Morgan
Marshall
Cullman
Jackson
DeKalb
Lincoln
Moore
Franklin
UNK


Time Series of Probability - Microsoft Internet Explorer
http://www.nssl.noaa.gov/cgi-bin/hazgraph3.pl
Time Series of Probability
The graph below shows the probability of a severe weather event occuring on any given day for the specific point in the United States chosen on the previous graph. For example, a y value of 2 would indicate a two percent chance of receiving the chosen type of severe weather on the date indicated by the x-axis value.
Hail Annual Cycle
Probability (%)
Day of Year
1980-1984
1985-1989
1990-1994
1995-1999
Average 1980-1999
Weather Type and Max Scale Values
Tornado | Significant Tornado | Violent Tornado | Wind | Hail
0.5% or 2.5% | 0.6% | 0.1% | 0.5%, 2.5%, or 10% | 0.5%, 2.5%, or 10%
X = 43
Y = 14
Hail Climatology for a point in NE Alabama

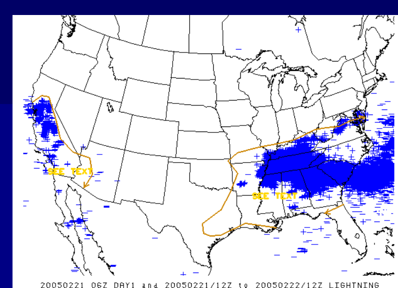




February Hail Climatology for the HUNs (courtesy Kurt Weber)

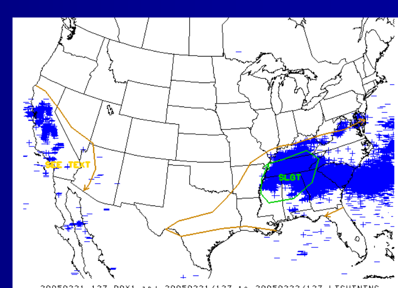
SPC Outlook

- 13Z Day 1 upgraded to Slight Risk
- Supercell threat mentioned in warm sector in AL and GA



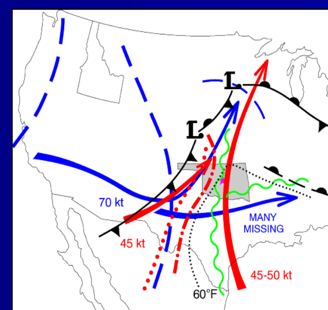
...THERE IS A SLGT RISK OF SVR TSTMS OVER PARTS OF THE GULF COAST STATES AND TN VALLEY...

...SOUTHEAST STATES...
MORNING WATER VAPOR IMAGERY SHOWS WELL-DEFINED UPPER VORT MAX OVER SOUTHEAST KS. STRONG UVVS AHEAD OF THIS SYSTEM HAVE AIDED IN THE ORGANIZATION OF A LINE OF SEVERE STORMS OVER WESTERN TN. THIS ACTIVITY WILL LIKELY PERSIST MUCH OF THE DAY AND TRACK ACROSS MUCH OF TN AND NORTHERN MS/AL. A RELATIVELY WEAK CAPPING INVERSION AND AMPLE DAYTIME HEATING ALSO SUGGEST THE RISK OF ISOLATED THUNDERSTORM DEVELOPMENT SOUTHWARD INTO THE WARM SECTOR OVER CENTRAL MS/AL/GA. STRONG WESTERLY WIND FIELDS ALOFT AND MODERATE DEEP LAYER VERTICAL SHEAR VALUES WILL PROMOTE A RISK OF SUPERCELLS. COMBINATION OF STEEP MID LEVEL LAPSE RATES...COOL TEMPERATURES ALOFT...AND RATHER STRONG DAYTIME HEATING WILL AID IN THE POTENTIAL OF LARGE HAIL AND DAMAGING WINDS.



Mesoscale Analysis

- Pre-afternoon storm environment
- Test "thresholds" provided by Craven (2005), Davies (2004) and SPC
- LAPS/RUC soundings
- Focus on risks of hail and tornadoes
- Address why there were few wind reports, no tornadoes and mostly hail.
- NOTE: SPC graphics and descriptions used heavily.

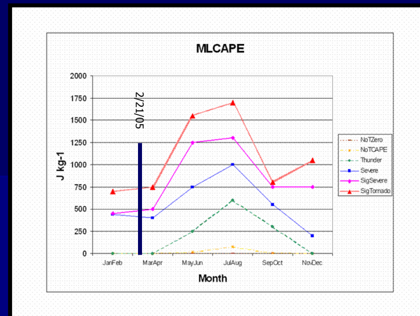


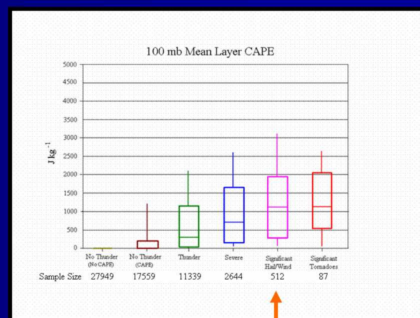
Composite Chart 26/0000 Z March 1948 (Maddox and Crisp 1999)

Supercell / Tornado Parameters

100mb MLCAPE (Craven, 2005)

SigSvr	~ 400-500 J/kg
SigTor	~ 600-750 J/kg
Svr	~ 300-450 J/kg

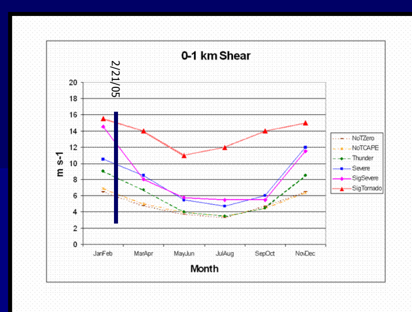


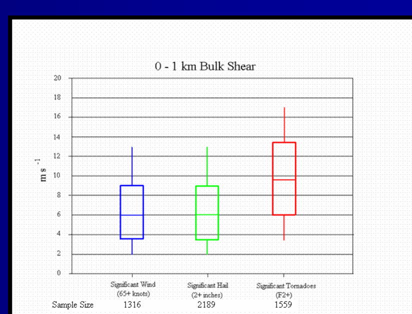


2/21/05

0-1 km Shear (Craven, 2005)

SigSvr	~ 12-14 m/s
SigTor	~ 14-16 m/s
Svr	~ 9-11 m/s

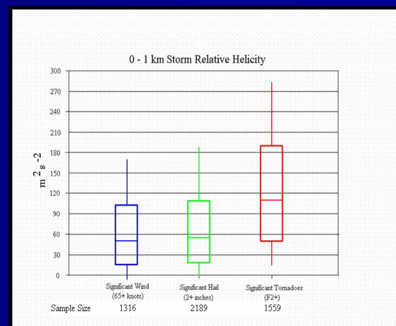




2/21/05

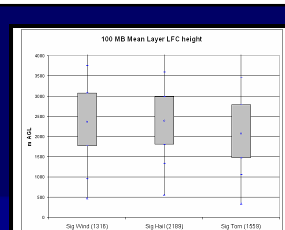
0-1 km SRH (Craven, 2005)

- Note the marked discrimination between SigTor vs. SigWind and SigHail
- Remember to use 0-3 km SRH for supercell hail forecasting (updraft rotation needed)



2/21/05

100 mb ML LFC Height



Craven (2005)

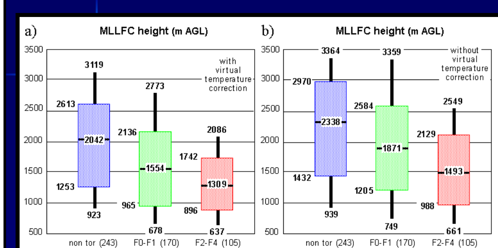


Figure 3. As in Fig. 2, except MLLFC height (m AGL) for profiles in the D03 database.

Davies (2004)

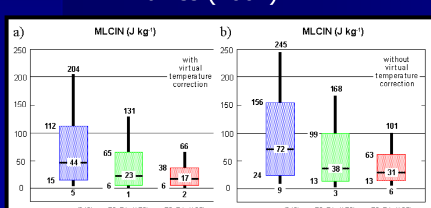


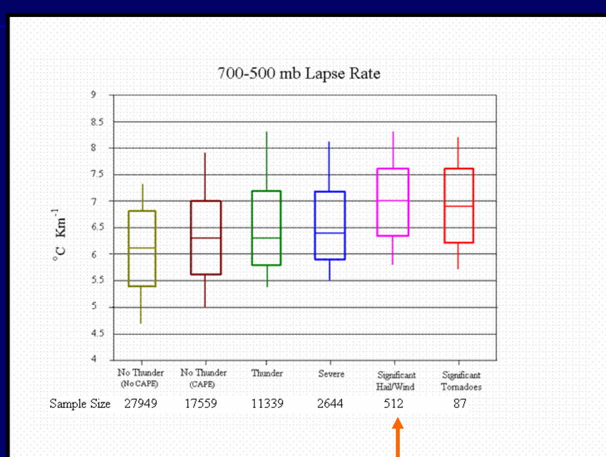
Figure 2. Box and whisker plots of MLCIN (J kg⁻¹) for profiles in the D03 database computed (a) with and (b) without the virtual temperature correction. Data is grouped as cases with no tornadoes ("non tor", left), weak tornadoes ("F0-F1", middle), and significant tornadoes ("F2-F4", right). Numbers in parentheses give total cases in each category. Boxes denote 25th to 75th percentiles, with horizontal bar showing median value. Whiskers extend to the 10th and 90th percentiles.

- Note the importance in LFC as a discriminator to tornadic storms in most cases.
- Davies used RUC soundings
- Craven used 00 UTC RAOBs

SPC 3-km CAPE (J/kg) & Surface Vorticity
(direct from SPC mesoanalysis page)

- CAPE in the lowest 3-km above ground level, and surface relative vorticity. Areas of large 0-3-km CAPE tend to favor strong low-level stretching, and can support tornado formation when co-located with significant vertical vorticity near the ground.

700-500 mb Lapse Rate



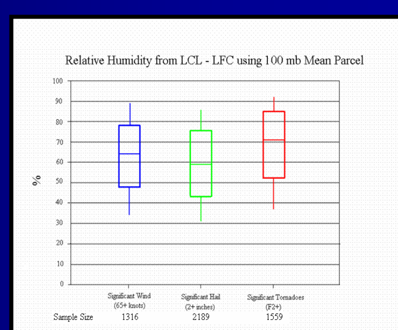
2/21/05

SPC Hail Forecast Parameters (direct from SPC mesoanalysis page)

- This image depicts three forecasting parameters used to predict hail. They are CAPE in the layer from -20 C to -40 C, 0-6-km shear vector, and the freezing level height. Large CAPE in the layer from -20 C to -40 C favors rapid hail growth. 0-6-km shear in excess of 30-40 knots supports supercells with persistent updrafts that contribute to large hail production. Finally, lower freezing level heights suggest a greater probability of hail reaching the surface prior to melting, though melting impacts small hail much more than very large hailstones.

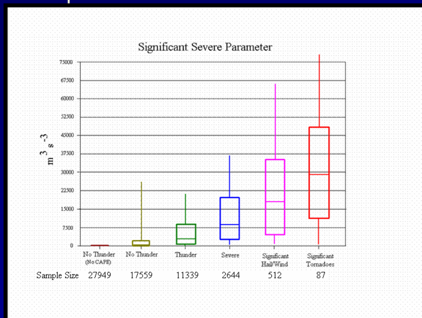
SPC LCL-LFC Relative Humidity (%) (direct from SPC mesoanalysis page)

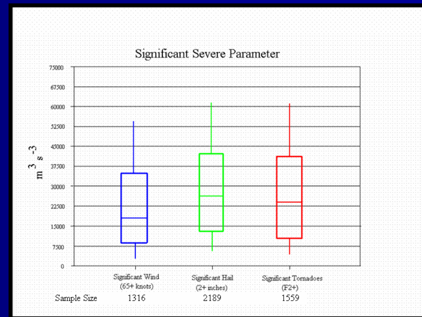
- This is the mean relative humidity in the layer between the LCL (<u>L</u>ifting <u>C</u>ondensation <u>L</u>evel) and the LFC (<u>L</u>evel of <u>F</u>ree <u>C</u>onvection). Near saturation (RH=100%), from the LCL to the LFC, suggests that the LFC is near the LCL. When this occurs, a parcel experiencing forced ascent above the LCL may not be diluted with dry environmental air prior to reaching the LFC.



2/21/05

Significant Severe Parameter Craven (2005)





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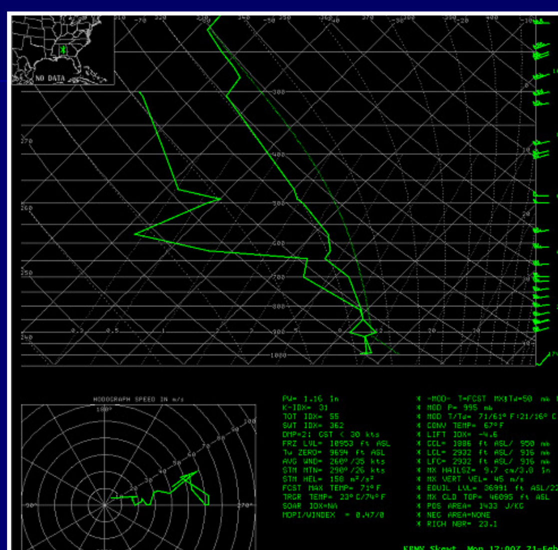
2/21/05

- Product of ML CAPE and 0-6km Shear (m3/s3)

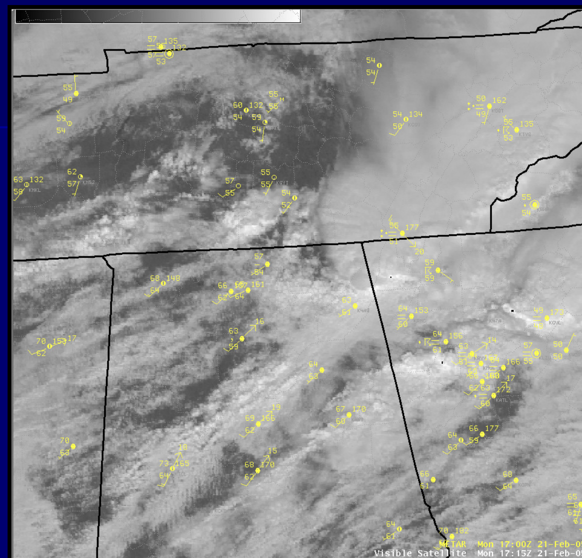
12 UTC KBMX Sounding

- Limited elevated CAPE noted.
- Forecast SBCAPE of 1433 J/kg
- Generally straight line hodograph noted above lowest 1km.
- Lack of mid level dry layer.



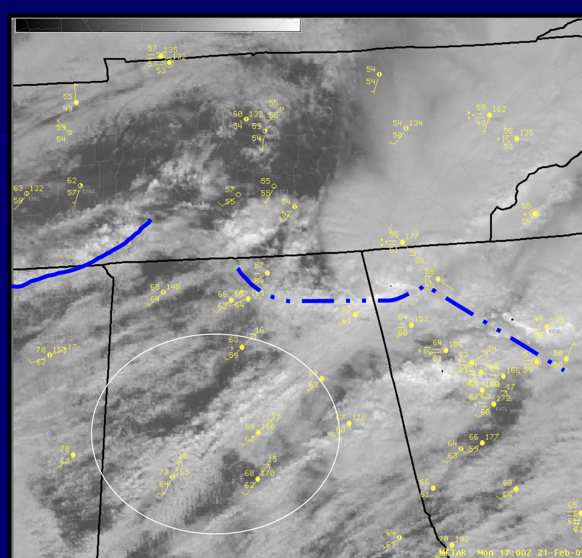
17 UTC VIS

- Do you see boundaries of concern for the afternoon?
- How about areas of surface convergence?

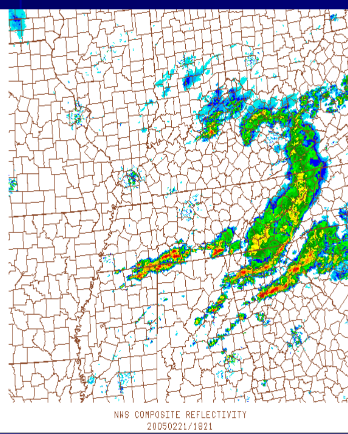


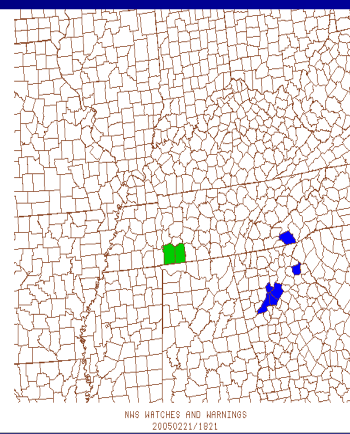
17 UTC VIS

- Note the gust front spreading into NW Georgia and the arcus cloud extending into NE Alabama.
- Note another area of cumulus congestus bubbling across central AL along another convergent zone.
- Pre-frontal convective line.



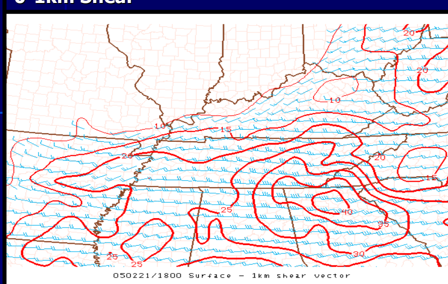
18 UTC Radar and Warnings



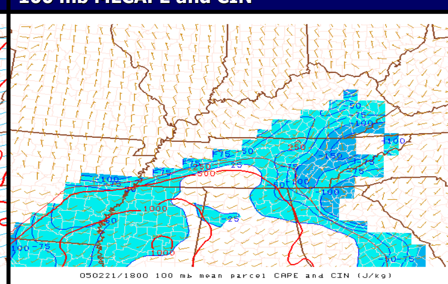


18 UTC Tornado Parameters

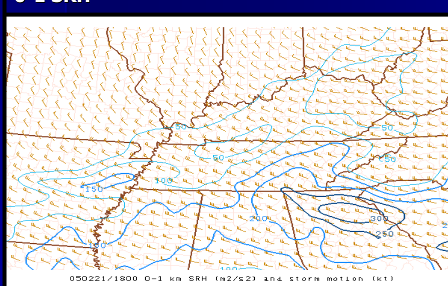
0-1km Shear



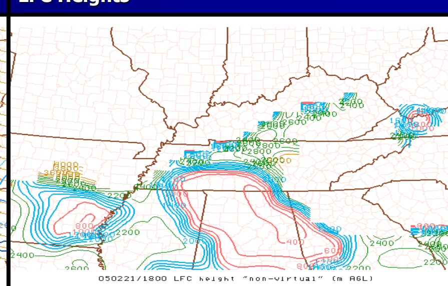
100 mb MLCAPE and CIN



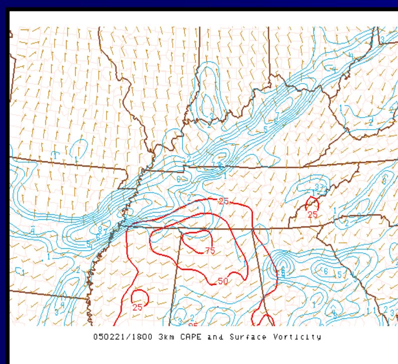
0-1 SRH

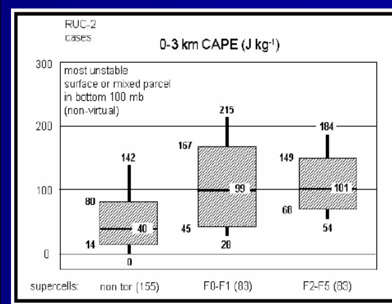


LFC Heights



18 UTC
Low Level CAPE

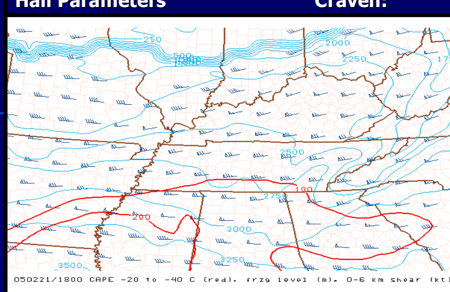




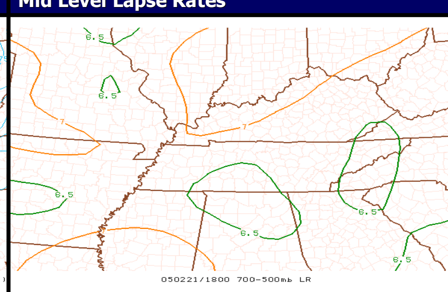
Davies (2002)

18 UTC Hail Parameters

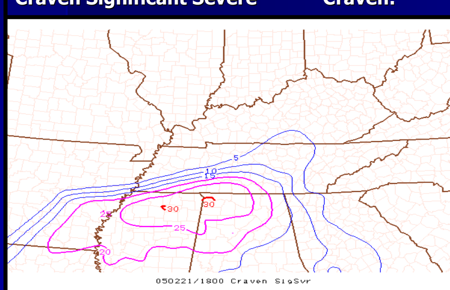
Hail Parameters **Craven:**



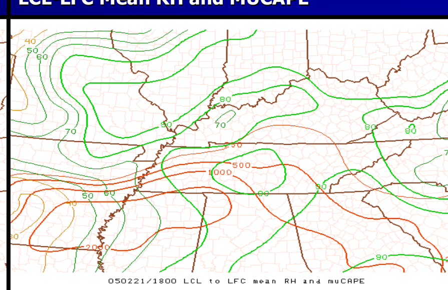
Mid Level Lapse Rates



Craven Significant Severe **Craven:**

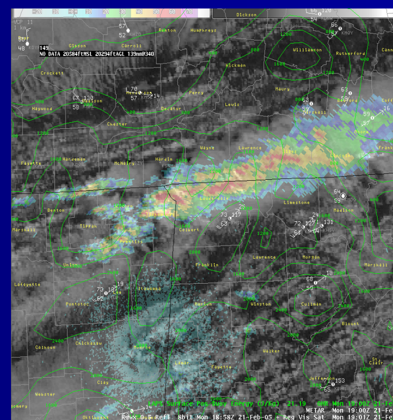


LCL-LFC Mean RH and MUCAPE

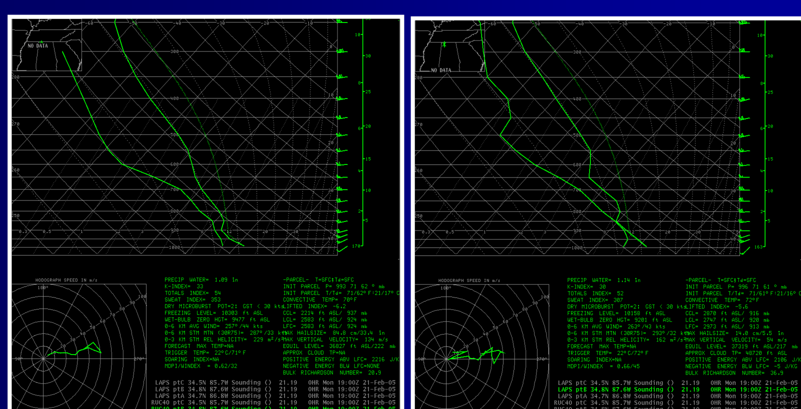


19Z Vis/Refl

- Pre-frontal line explodes in NW Alabama and NE Mississippi
- Inflow SBCAPEs are impressive
- "Gusty" surface inflow obs noted at KMSL and KDCU

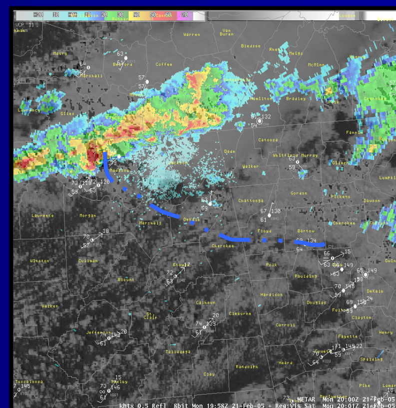


KMSL NSE soundings

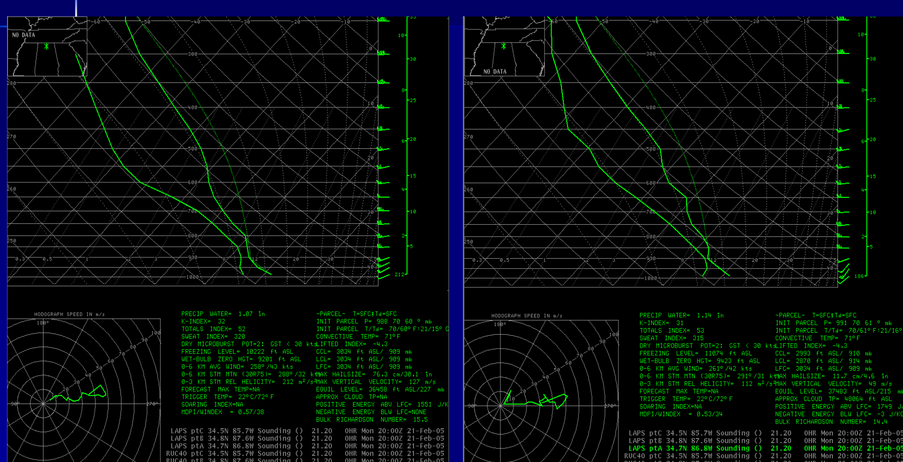


20Z Vis/Refl

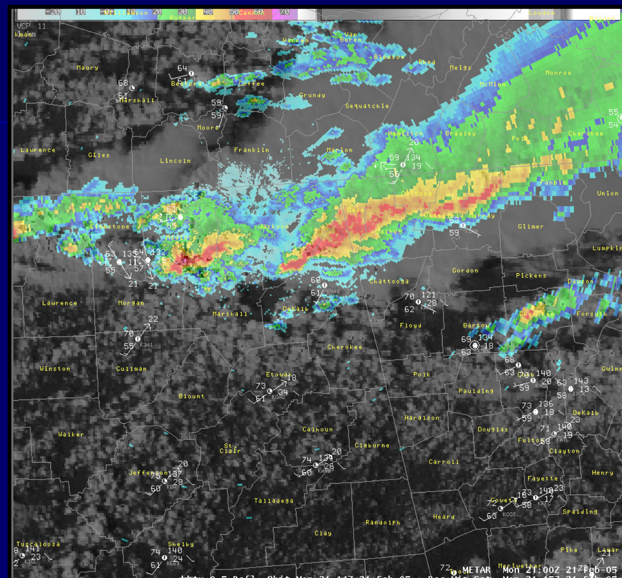
- Well-defined supercell enters Madison County
- Good SW surface inflow (not SE, so 0-1km directional shear is weak)
- Note cumulus cloud streets flowing SW-NE toward the outflow boundary in NE Alabama.



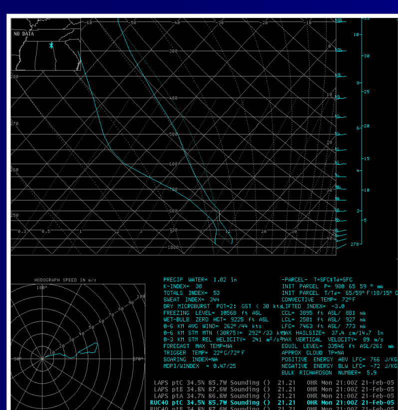
KHSV NSE soundings

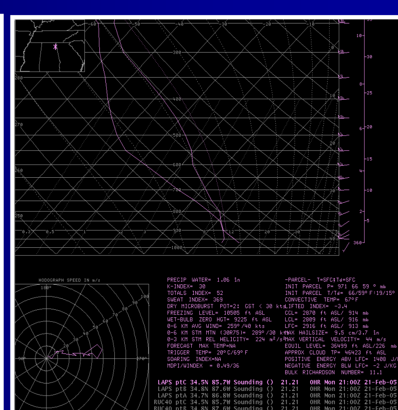


2115Z Vis/Refl

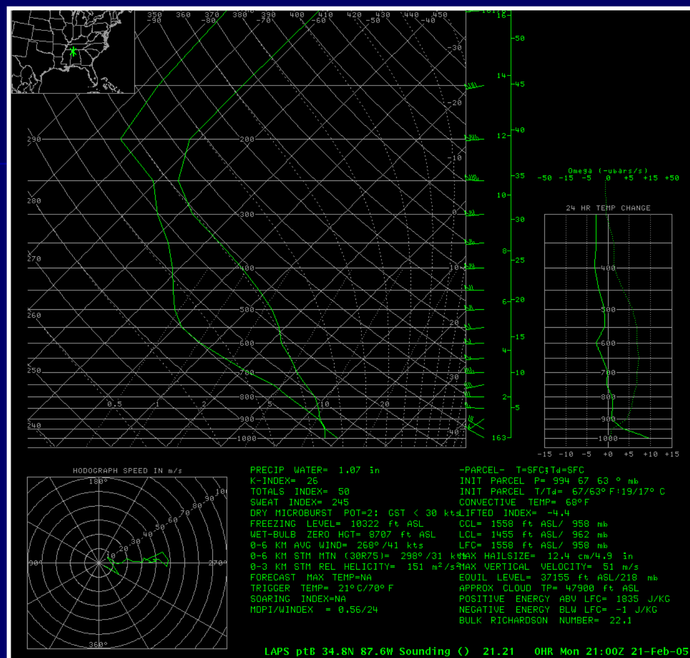


21 UTC K4A9 NSE soundings



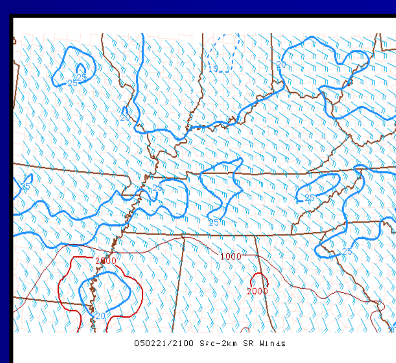


21 UTC "Warm Sector" Sounding KMSL



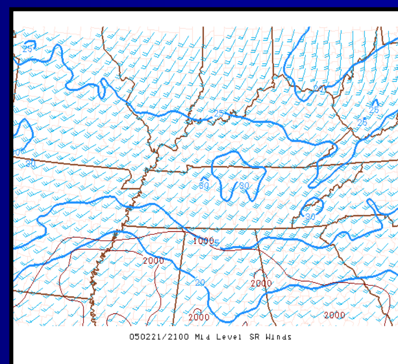
SPC SR-Winds

- Surface-2-km Storm Relative Winds (kts)
- Low-Level SR (Storm Relative) winds (0-2-km) are meant to represent low-level storm inflow. The majority of sustained supercells have 0-2-km storm inflow values of 15-20 knots or greater.



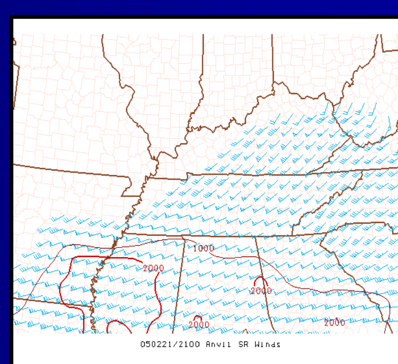
SPC SR-Winds

- 4-6-km Storm Relative Winds (kts)
- Mid-Level SR (Storm Relative) winds (4-6-km) are of some use in discriminating between tornadic and non-tornadic supercells. Tornadic supercells tend to have 4-6-km SR wind speeds in excess of 15 knots, while non-tornadic supercells tend to have weaker mid-level storm-relative winds.

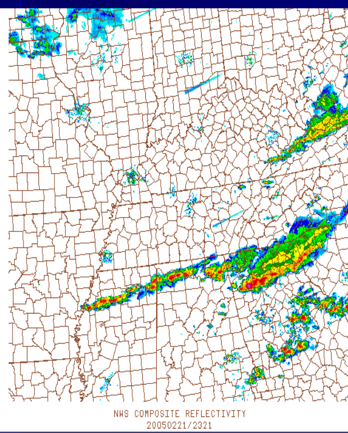


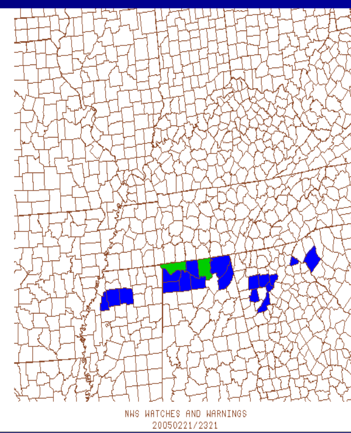
SPC SR-Winds

- Anvil Level/9-11-km SR Winds (kts)
- The Anvil Level SR (Storm Relative) winds and SR winds from 9-11-km are meant to discriminate supercell type. In general, upper-level SR winds less than 40 knots correspond to "high precipitation" supercells, 40-60 knots SR winds denote "classic" supercells, while SR winds greater than 60 knots correspond to "low precipitation" supercells.



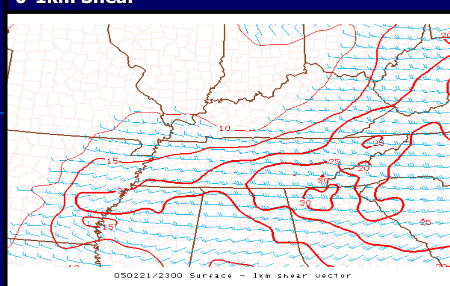
23 UTC Radar and Warnings



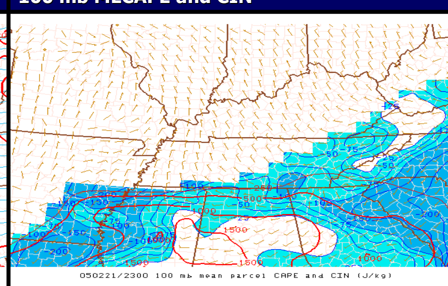


23 UTC Tornado Parameters

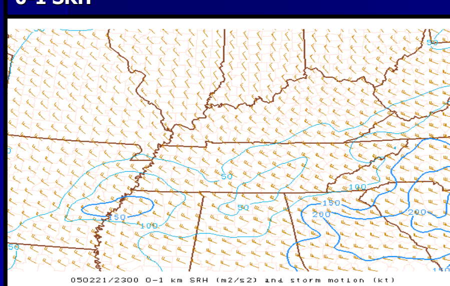
0-1km Shear



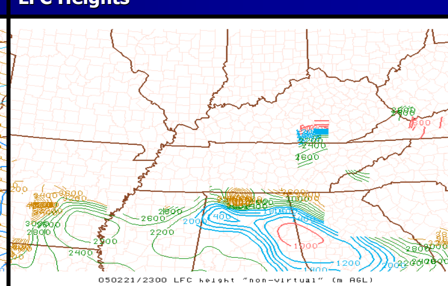
100 mb MLCAPE and CIN



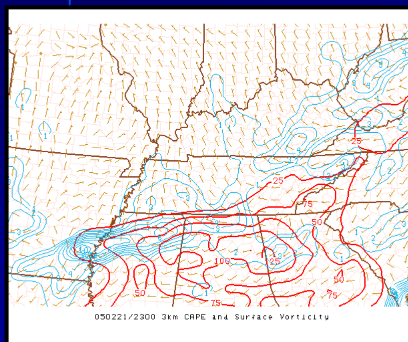
0-1 SRH

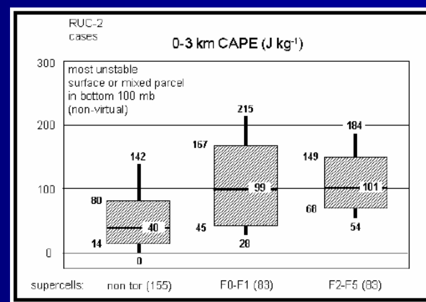


LFC Heights



23 UTC
Low Level CAPE

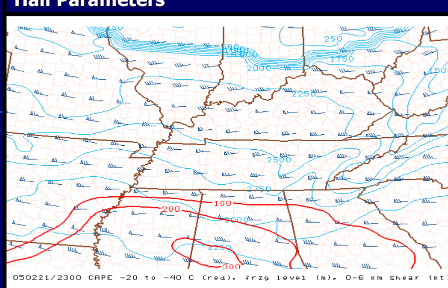




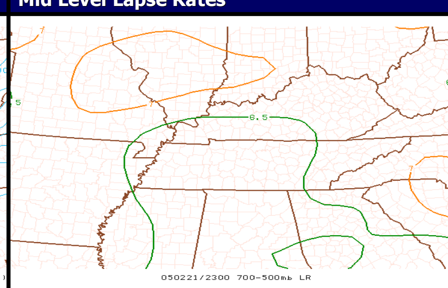
Davies (2002)

23 UTC Hail Parameters

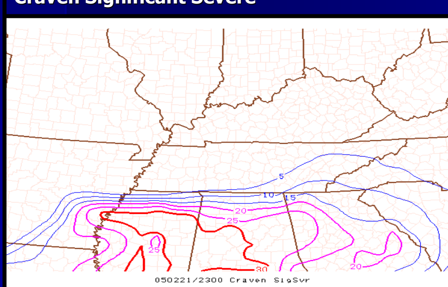
Hail Parameters



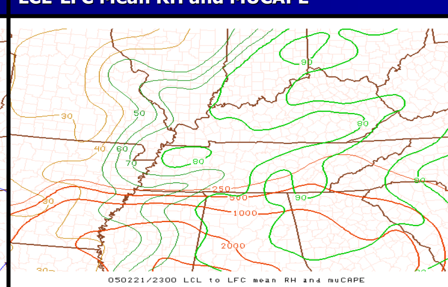
Mid Level Lapse Rates



Craven Significant Severe



LCL-LFC Mean RH and MUCAPE



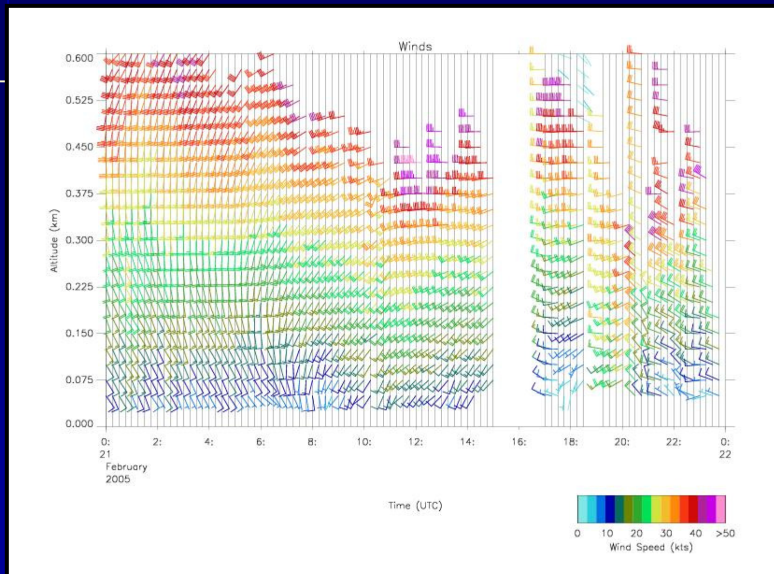
Selected Parameter Checklist for SigHail and SigTornadoes (F2-F5)

Parameter	15Z	17Z	23Z	Suggested (Craven), (Davies), SPC
				TORNADO
0-1 km shear	X	X	X	9-14 m/s (Feb-Mar)
0-1 km SRH	X	X		>=100 m2/s2
100 mb MLCAPE	X	X	X	~ 300-750 J/kg (Feb-Mar)
SR Winds (21Z)	-	-	X	0-2km: 15kt sustained supercell Anvil Level: < 40kt HP 40-60kt CL > 60kt LP 4-6km: 20kt tornadic
LCL-LFC RH	X	X	X	> 75 % for tornadoes
0-3 km CAPE	X	X	X	>50-60 J/kg (low end, not a "threshold")
LFC heights	X	X	X	< 2200 m
				HAIL
Hail Parameter	X	X	X	0-6km Shear: 60-80 kt, Large -20 to -40C CAPE, Low FZL,
Mid LR	X	X	X	> 6 C/km
SigSvr	X	X	X	> 7500 m3/s3 very low end, ~22000 for sig events

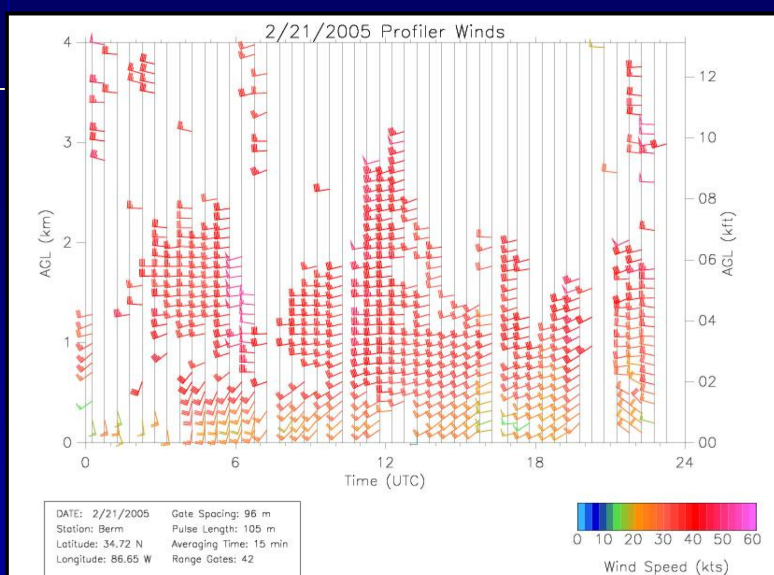
Some MIPS data

- Good low level wind data to show shear / implied SRH
- Meteograms show the multiple storms in the local area

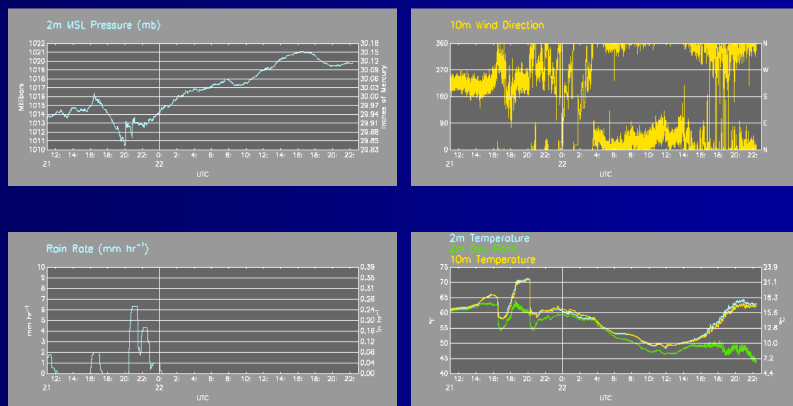
MIPS Sodar



MIPS Profiler

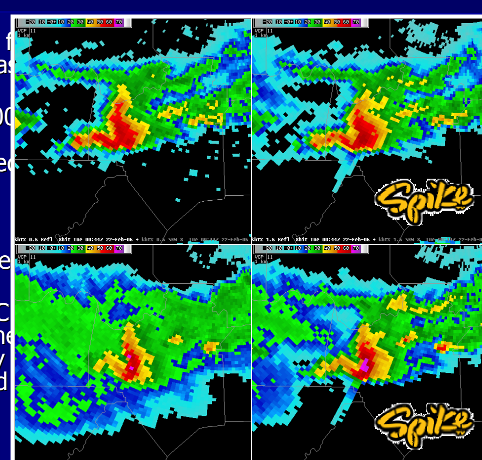


MIPS Surface Data (at UAH)

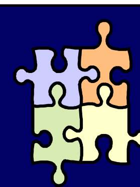


T'was A Favorable Hail Day

- Deep layer shear sufficient f classic supercells and at leas mid level mesocyclones
- 100mb MLCAPES 1000-150(J/kg created strong initial updrafts that were sustaine by deep layer shear
- Sufficient low level convergence initiated development and maintaine westward expansion
- Low LFCs and high LCL-LFC made for quick redevelopme of new storms and possibly retarded wider spread wind damage.

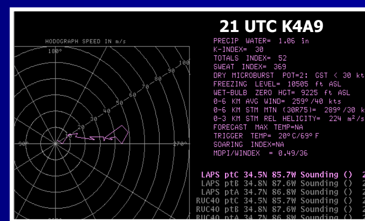


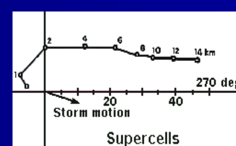
Why the Lack of Tornadoes?



(hypotheses of course)

- Lack of low-level wind turning (SRH), especially in the lowest 1km for most of the area with southwest surface winds.
- Lack of streamwise vorticity throughout most of the area, SR winds were good predictors of supercells, but not tornadoes.
- Conditions were more favorable in NE Alabama for tornadoes with an outflow boundary in place. This boundary enabled higher 0-1km shear and SRH where LFC heights were persistently low.

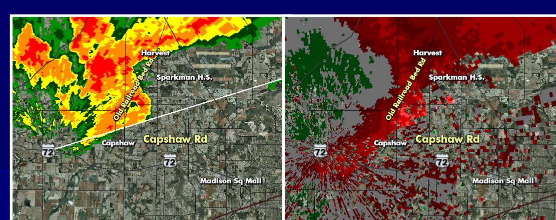




From WFO Louisville (SOO) web page

Possible reasoning for few damaging wind reports

- Lack of "dry air" in mid levels to support downdraft cooling and acceleration.
- Storm mode was not as linear as in the morning
- Local wet microburst Harvest could possibly have been a strong RFD based on radar (88D and WAFF TV) and visual evidence of WAFF photo.



And just downstream in Georgia

- http://www.srh.noaa.gov/ffc/html/hail22105.shtml
- Supercells appeared to gain rotation and updraft strength.
- Storm Tops over 50,000 FT on strongest supercells

Radar Analysis

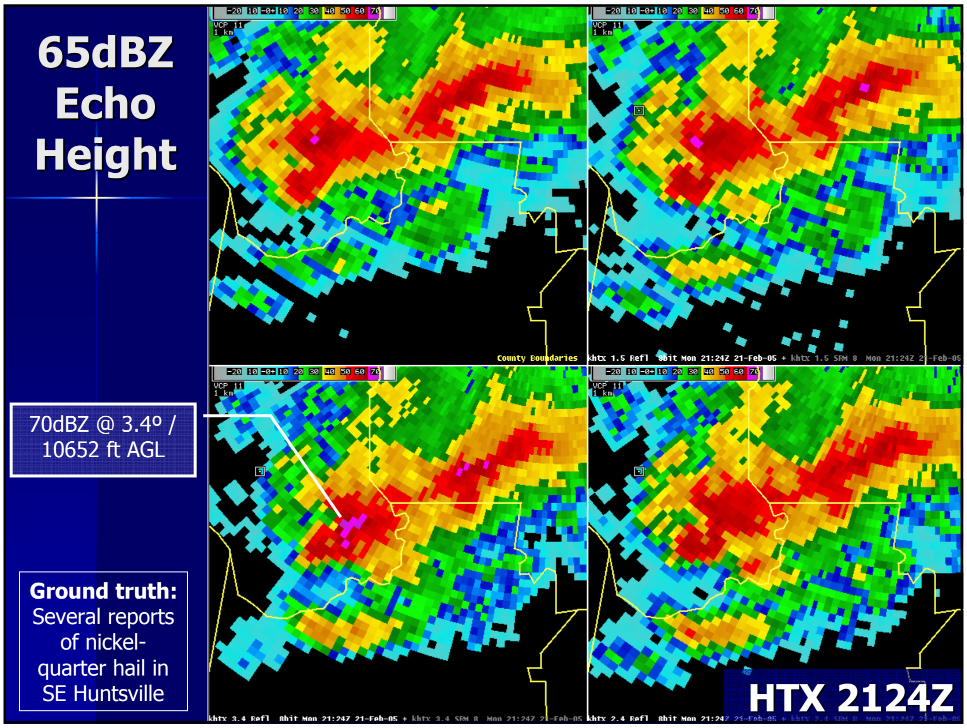
- A review of radar data and analysis of the warning-decision making process.

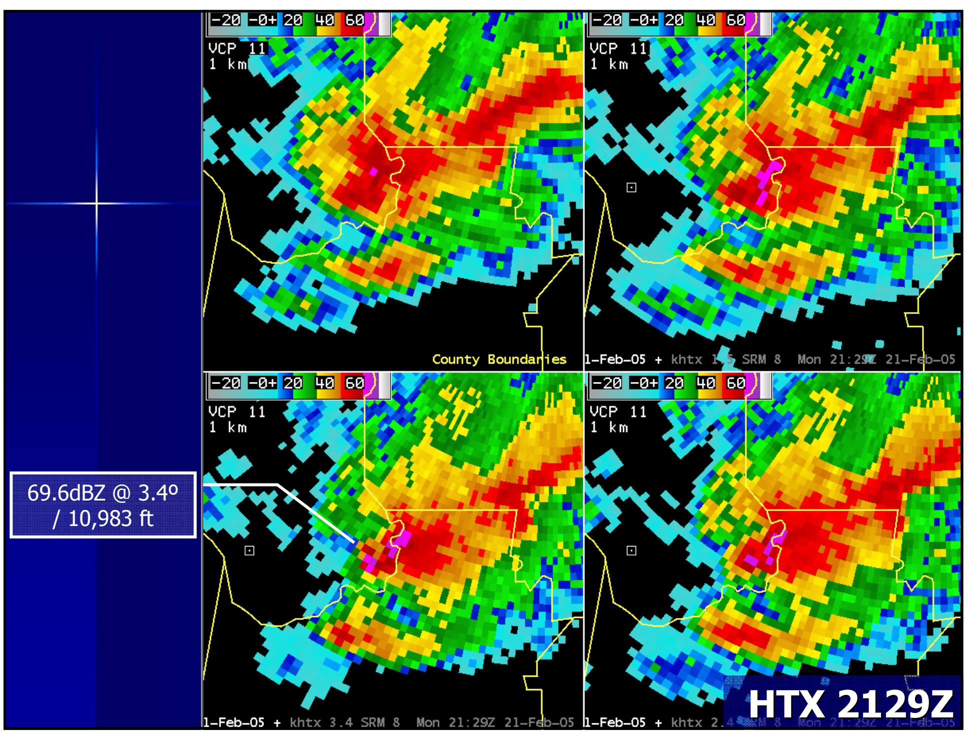
WDM for Afternoon/Evening Storms

- Quick review/application of existing hail detection methods
- Applying Donovan's (2004) 50dBZ Echo Height Thresholds
- "Polygonology" as an aspect of WDM

Standard Techniques

- 65dBZ echo height ≥ freezing level
  - Better suited to stronger shear and tilted updrafts (what we saw in this event)
- Three-body scatter spike
- "VIL of the Day"

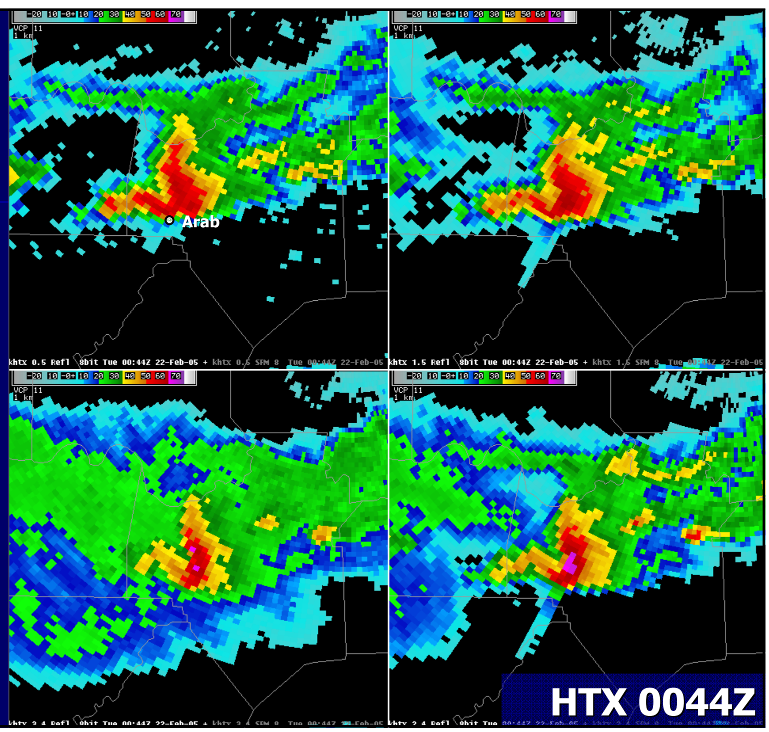

65dBZ Echo Height
70dBZ @ 3.4º / 10652 ft AGL
Ground truth: Several reports of nickel-quarter hail in SE Huntsville
HTX 2124Z


VCP 11
1 km
County Boundaries
69.6dBZ @ 3.4º / 10,983 ft
HTX 2129Z

65dBZ Echo Height

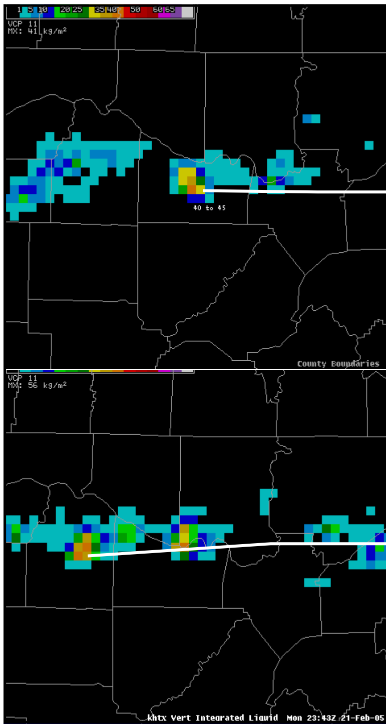
- Informal survey of storms producing nickel-size hail or greater on the 21st revealed that many of these storms met the 65dBZ criteria

TBSS



Ground truth:
Nickel-sized hail in Scant City (5 NE Arab)

"VIL of the Day": 30-35



40-45 VIL

Ground truth:

Penny-sized hail in Hartselle

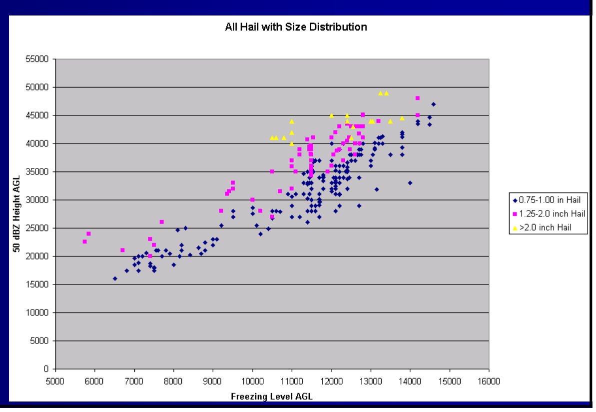
40-45 VIL

Ground truth:

Dime & quarter-sized hail in and around Moulton

Donovan's 50dBZ Echo Height Technique

- Donovan (2004) plotted freezing level vs. height of 50dBZ echo for severe hail cases



Source: Donovan teletraining 2004

- Correlation found between height of 50dBZ echo (compared to freezing level) and severe hail

Frzg Level	50dBZ EH
6000	15000
6500	16000
7000	17000
7500	18000
8000	19000
8500	20000
9000	21000
9500	22000
10000	23000
10500	24500
11000	26000
11500	28000
12000	30000
12500	32000
13000	34000
13500	36000
14000	38000
14500	40000
15000	42000

"Donovan Technique" (cont'd)

- Best used with pulse-type, weakly-tilted updrafts with minimal shear
- Tough to find storms from 21 Feb that did not meet other criteria but came close to meeting 50dBZ criteria
- Samples from Colbert, Cullman, Marshall counties

“Donovan” Limitations

- Environment supported rotating storms with strongly tilted updrafts, but technique best suited for pulse-type storms with minimal shear
- Study conducted for Great Plains / DMX CWA
- Elevation angles may miss the **true** 50dBZ echo height depending on the distance from the RDA

Limitations (cont’d)

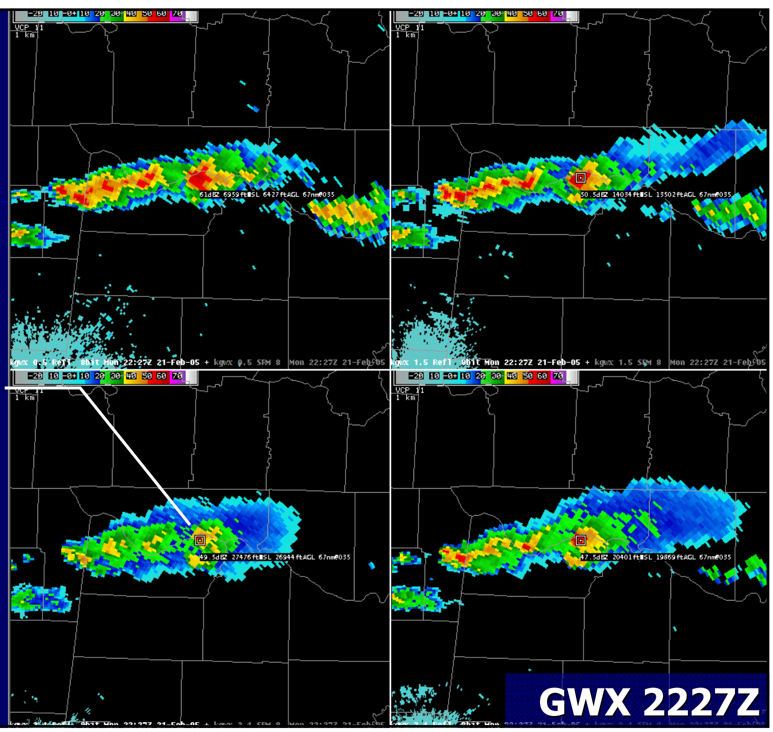
- Some difficulty determining an accurate value for freezing level during this event
- There was a 500-750’ variation at times among the LAPS, EtaBufr, and RUC soundings, which translates to a 2000’+ variation in the 50dBZ criteria

MSL Storm (21/2227Z)

- As mentioned, 500-750′ variation in freezing level depending on sounding (EtaBufr lowest to LAPS highest)
- Used average of ~10000′
- Corresponds to 50dBZ echo height of 23000′

Frzg Level	50dBZ EH
6000	15000
6500	16000
7000	17000
7500	18000
8000	19000
8500	20000
9000	21000
9500	22000
10000	23000
10500	24500
11000	26000
11500	28000
12000	30000
12500	32000
13000	34000
13500	36000
14000	38000
14500	40000
15000	42000

0.5 - 3.4º



49.5dBZ at 26,944 ft

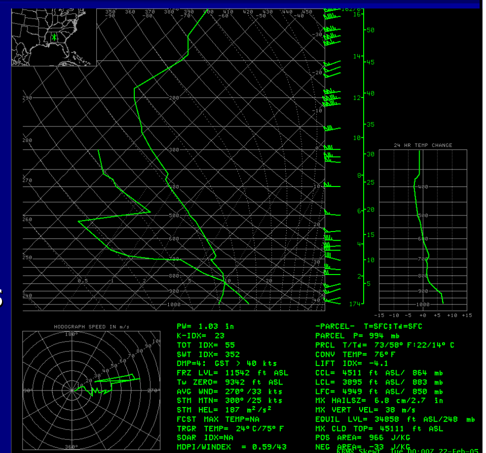
(borderline)

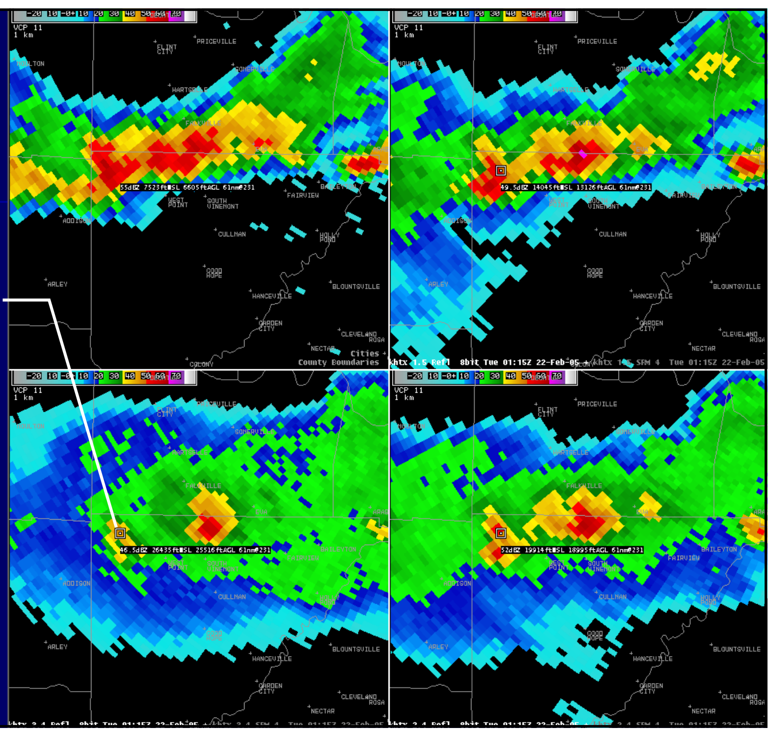
Ground truth:

Dime-sized hail @ 2232Z

Battleground Storm

- Storm in far NW Cullman Co.
- Occurring at 0115Z
- 00Z BMX sounding
  - Freezing level: 11542′
  - 50dBZ level: 28000′
- Slightly lower numbers from 02Z LAPS sounding at 3A1 (10531′ → 24500′)

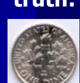




46.5dBZ at 25,516 ft

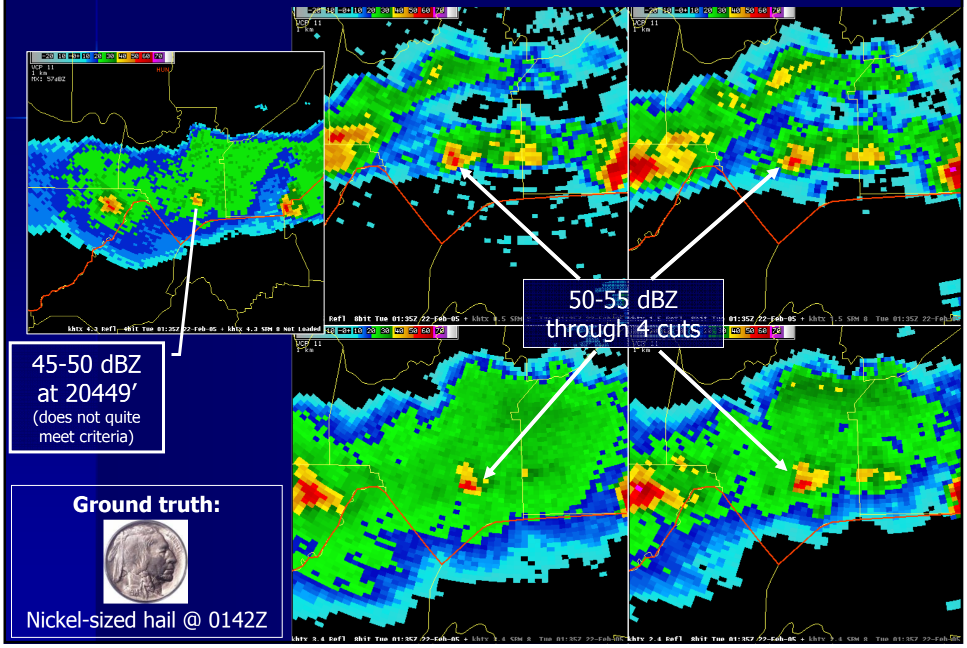
Close to 50dBZ criteria (but not quite)

Ground truth:



Dime-sized Hail @ 0115Z

Albertville Storm – 0135Z



“Donovan Technique” Conclusions

- 50dBZ echo height was not an exact predictor of severe hail, but was close
- Reasonably effective at diagnosing storms with marginally/borderline severe hail (e.g., dimes/pennies)
- Needed some leeway in criteria, which was already based on a mean value with large variation

"Donovan Technique": The Bottom Line

- With such leeway required in the criteria, and such marginal verification, it likely would have been very difficult to base warnings solely on this technique in real time.

Technique Has Promise!

- Effectiveness likely hurt by more highly sheared environment, perhaps not-yet-identified regional differences
- In similar events, technique may be more effective as a situational awareness tool for the warning forecaster—a sign to look for additional clues or additional scans
- Bears further study

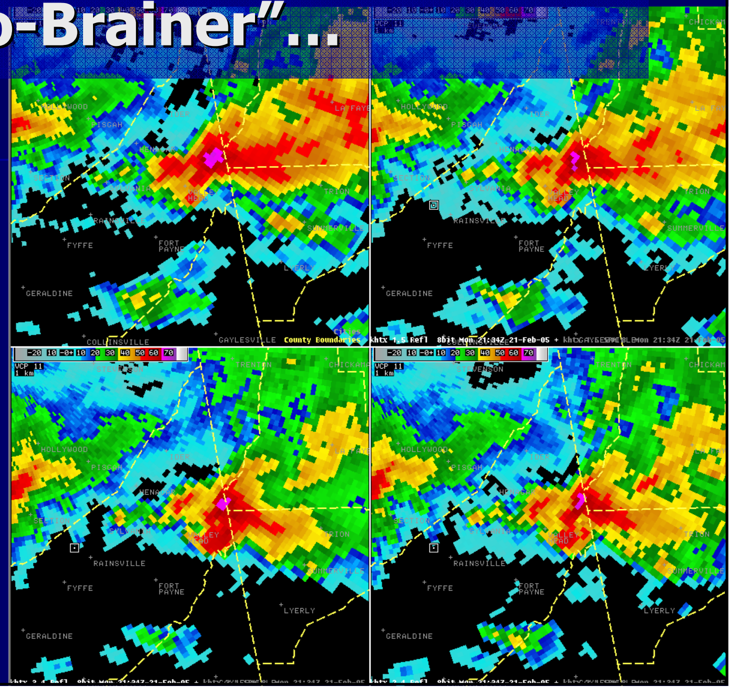
General Conclusions

- 65dBZ echo height was especially useful with the larger hail events (nickel-size or greater)
- "Donovan Technique" was a reasonable predictor of marginally severe hail, but limitations would have made its use difficult in real time

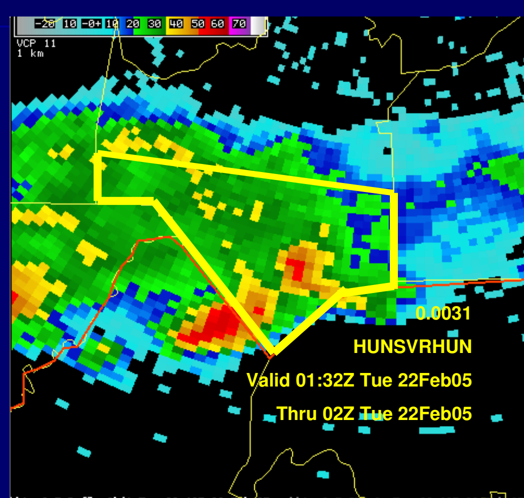
Related Thoughts

- Important to have freezing height in mind for hail WDM
- More easily-referenced 50dBZ height chart/table could be helpful depending on the environment
- Echo height techniques particularly useful with all-tilts or cross-section products

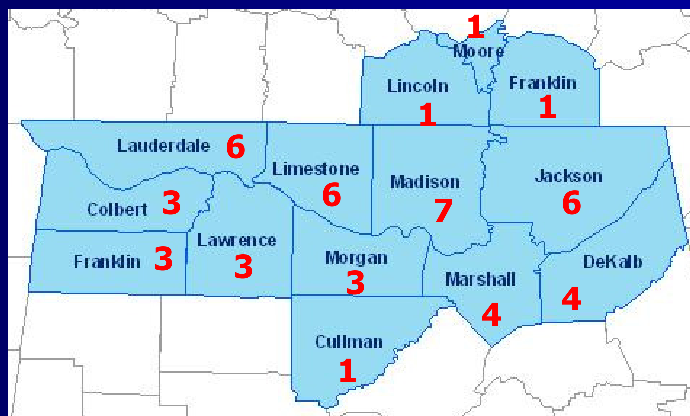
The "No-Brainer"…



"Polygonology"



Number of Warnings per County



32 SVR's issued, many for multiple counties, totaling 49 warnings

Why so many warnings?

- Storm motion averaged 270-280º @ 35-45kt
- WarnGen distance/speed tool was effective at determining when storms would exit counties
- However, sometimes needed multiple warnings over a short period

Complicating Factors

- Inconsistent storm redevelopment upstream
- Very slow-moving front, nearly stationary during early afternoon
- Storms moving west to east along the front; frontal motion added a southward component

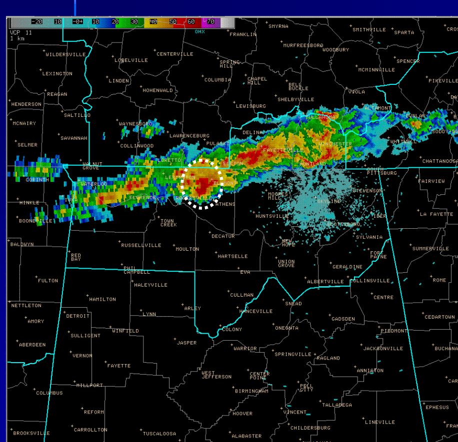
Food for Thought

- Warning forecasters should keep some things in mind before issuing:
  - Is WarnGen storm motion accurate or consistent?
  - Is a warning already in effect? Can I simply update with an SVS? (As of 3/1/05 no longer as much of an issue since “Rule 2” for SVR/TOR verification no longer exists – VTEC ETN allows for individual tracking for multiple warnings in a county)
  - If the storm is already on its way out of the county, is it worth yet another warning?
  - Are there more storms just upstream that could intensify? (Therefore, should I keep the warning going longer and update as needed?)

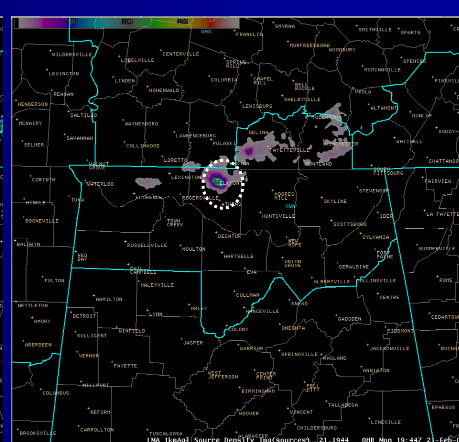
LMA Data

- A review of the usefulness of the data provided by the North Alabama Lightning Mapping Array.

Storm #1
Lauderdale to Jackson County
1846 – 2115 UTC



1943 UTC

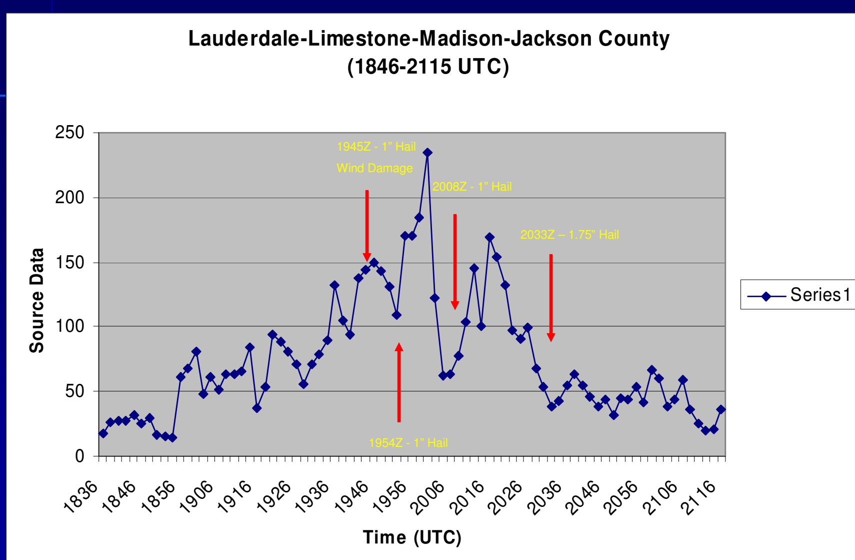


1944 UTC

Lauderdale–Limestone-Madison-Jackson County Storm (1846-2115 UTC)

- Storm #1 developed during the afternoon and tracked from western Lauderdale county into Jackson/De Kalb counties between 1830 and 2130 UTC.
- This storm first produced severe weather at 1945 UTC as it began to bow out over eastern Limestone county. Wind damage and 1.00 inch hail was reported 5 ENE of Athens.
- The storm moved into western Madison county at 1958 UTC and continued to produce wind damage in the Capshaw and Harvest areas.
- 1.75 inch hail was reported in Gurley at approx. 2025 UTC.
- No reports of severe weather were received from Jackson county.

Lauderdale–Limestone-Madison-Jackson County Storm (1846-2115 UTC) *



* = Valid Time of Warning

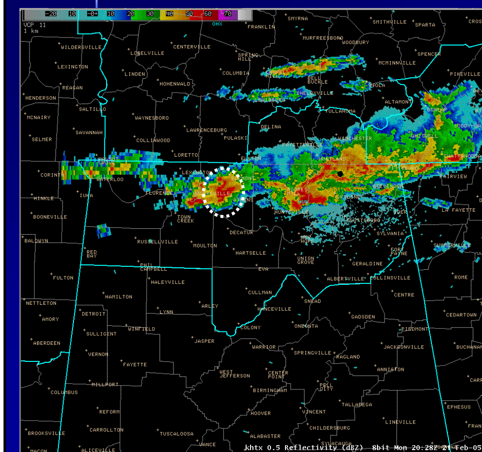
Lauderdale–Limestone-Madison-Jackson County Storm (1846-2115 UTC)

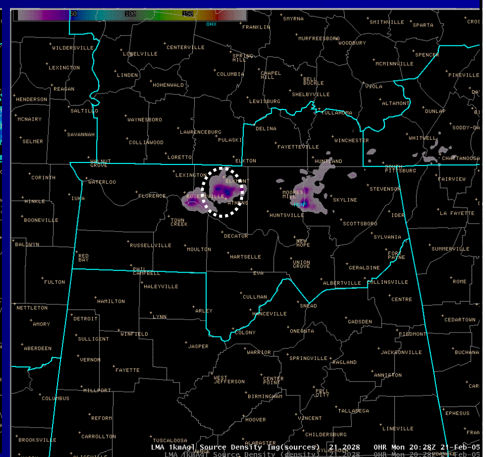
TIME (Z)	REPORT	LMA DETAILS	LEAD TIME
1944	Wind damage 1.00 inch hail	Occurred near peak of lightning jump	None
1954	1.00 inch hail	Occurred at ***relative*** lightning minimum	~6 minutes
2008	1.00 inch hail	Occurred at lightning minimum	~ 8 minutes
2033	1.75 inch hail	Lighting was already on downward trend and hail occurred during this time.	13 minutes from highest peak 3 minutes from secondary peak

Lauderdale–Limestone-Madison-Jackson County Storm (1846-2115 UTC)

- **Usefulness of LMA Data**
  - Wind damage and first hail report occurred as the lightning peaked. LMA data was not useful in this instance (possibly because storm transformed into bow and microphysics in cloud were not being captured in this structure).
  - Without a trending feature available, it would have been very hard to see some of the more subtle jumps that occurred before the 1954 UTC hail report.
  - Definite lightning jump noted before the hail occurred at 2008 UTC, with a significant minimum coinciding with instance of hail.
  - Subtle jump just prior to 2033 UTC hail. Lightning was on a downward trend and it is unclear whether minor jump was indicative of hail or larger spike at 2000 UTC was. Even subtle jumps may play key role in warning-decision making.
  - Plan view of lightning for this storm may not have been extremely useful, with the exception of the hail that occurred at 2008 UTC.

Storm #2
Lauderdale and Limestone County
2015 – 2100 UTC

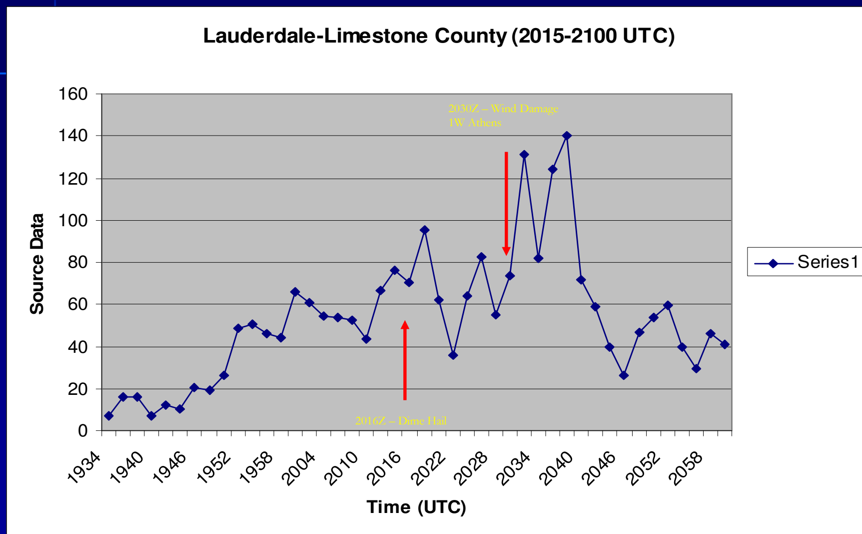

2028 UTC


2028 UTC

Lauderdale – Limestone County Storm (2015-2100 UTC)

- Storm #2 developed and followed almost same track across Lauderdale and Limestone counties. It developed just east of Waterloo at 1930 UTC. The storm began to develop strong core just east of Killen around 1958 UTC.
- The first report of hail came from Rogersville at 2016 UTC with 0.50 inch hail.
- Moved into Limestone county at 2018 UTC and produced wind damage 1 W of Athens at 2030 UTC.
- Storm developed mid-level rotation across eastern Lauderdale, persisting into eastern Madison county before dissipating.
- Rotation remained aloft, with strongest rotation noted over Athens at approx. 2028 UTC.

Lauderdale – Limestone County Storm (2015-2100 UTC)*



* = Valid Time of Warning

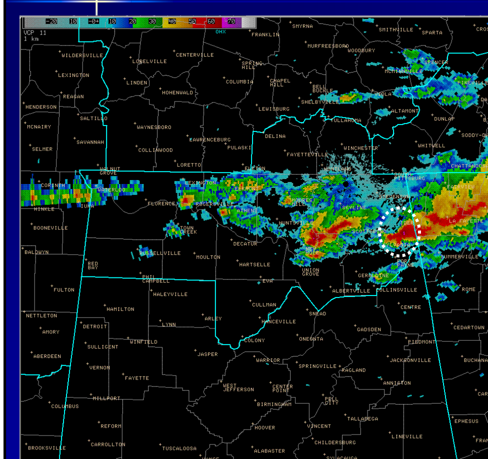
Lauderdale – Limestone County Storm (2015-2100 UTC)

TIME (Z)	REPORT	LMA DETAILS	LEAD TIME
2016	0.75 inch hail	Hail occurred as lightning activity was increasing.	None
2030	Wind damage	Lightning very "jumpy" during this time. Hail occurred near min. in activity, but lightning was increasing when hail reported.	4 minutes

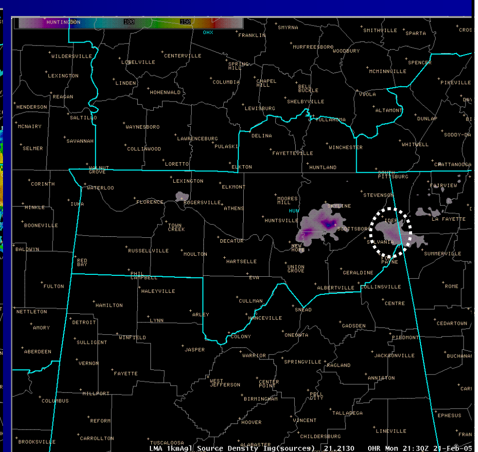
Lauderdale – Limestone County Storm (2015-2100 UTC)

- **Usefulness of LMA Data**
  - Dime hail from 2016 UTC occurred as lightning activity was on the increase. A very subtle decrease was at the time of the report. However, the sources only dropped between 5 and 10 sources during this two-minute period. This would not have been sufficient for warning operators to key in on, considering the overall trend was a lightning increase.
  - Lightning data was very "jumpy" prior to the wind damage report at 2030 UTC. The lightning did spike approximately 4 minutes to the damage occurring, before dropping off. However, this decrease was not as notable as the one which occurred several minutes prior.

Storm #3 Jackson and Dekalb County 2101 – 2145 UTC



2129 UTC

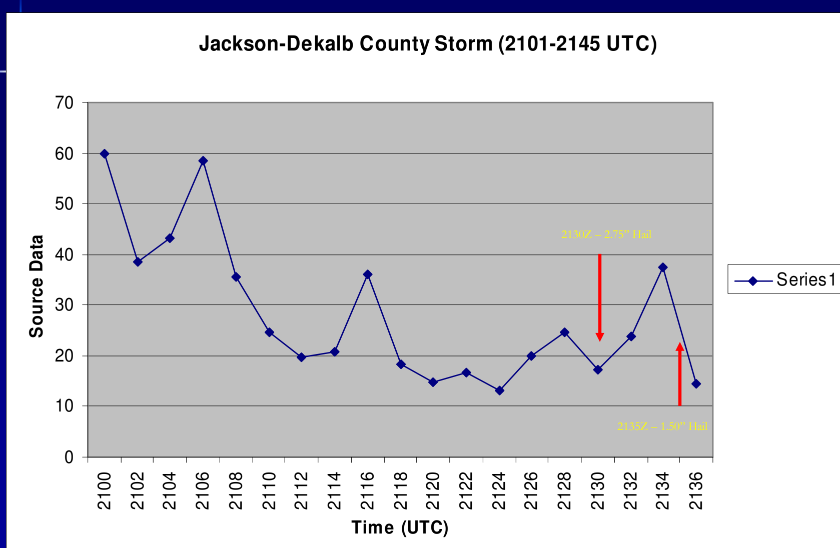


2130 UTC

Jackson-Dekalb County Storm (2101-2145 UTC)

- Storm moved across from Madison county where it produced 1.75 inch hail in Gurley.
- No hail reports received in Jackson county.
- Mid-level rotation developed just south of Pisgah at approx 2109 UTC. Rotation remained broad throughout the storm's life-cycle.
- BWER develops at ~ 2129 UTC.
- Storm moved into De Kalb County and produced 2.75 inch hail in Valley Head at 2130 UTC and 1.50 inch hail near Valley Head at 2134 UTC.
- Storm moved into Georgia at 2036 UTC.

Jackson-Dekalb County Storm (2101-2145 UTC)*



* = Valid Time of Warning

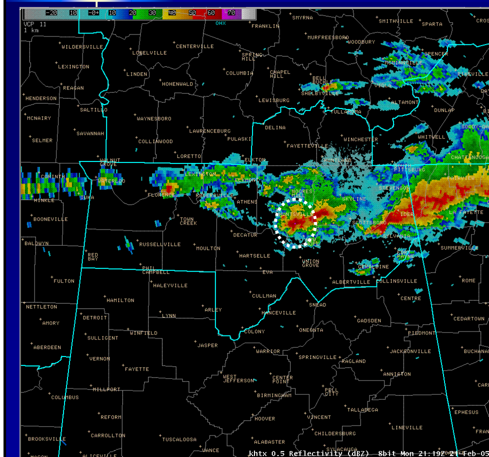
Jackson-Dekalb County Storm (2101-2145 UTC)

TIME (Z)	REPORT	LMA DETAILS	LEAD TIME
2130	2.75 inch hail	Hail occurred at lightning minimum, following a very minor jump.	2 minutes
2135	1.50 inch hail	Hail occurred as lightning decreased.	1-2 minutes

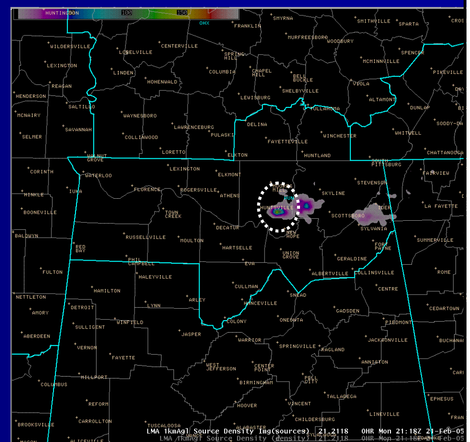
Jackson-Dekalb County Storm (2101-2145 UTC)

- **Usefulness of LMA Data**
  - Jackson and De Kalb counties are a significant distance from the sensors that make up the Lightning Mapping Array.
  - An overall decrease in the lightning can be noted after 2105 UTC, as the storms move farther away from the network.
  - Several spikes were picked up just prior to the storm moving into Georgia.
  - Each hail report occurred after a lightning jump, and near a minimum in the lightning activity.
  - Lightning activity was weak because of the distance from the network, and signatures in the LMA data are very subtle. Relative to lightning activity noted earlier, these storms would have appeared to be weaker.
  - ***Always keep in mind the distance the storms are from Huntsville.***
  - Info on the efficiency of the sensors to detect sources from various distances will prove useful in determining how much the lightning activity is being affected by distance vs. actual storm strength.

Storm #4
Limestone and Madison County
2059 – 2145 UTC



2119 UTC

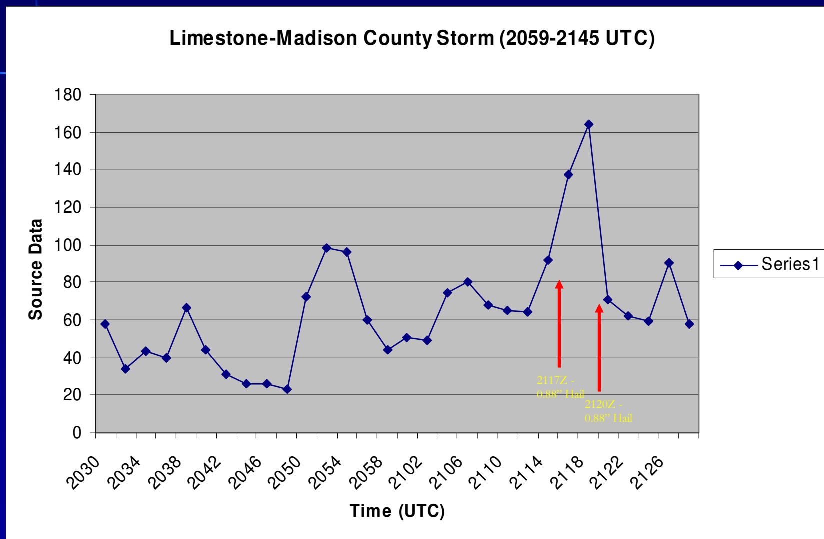


2118 UTC

Limestone-Madison County Storm (2059-2145 UTC)

- Storm #3 developed over northern Colbert county at 2000 UTC. It followed almost similar path as first and second storms across Limestone and Madison counties.
- Was several miles south of storm which produced wind damage just west of Athens, and affected southeast Limestone and southern Madison county.
- Intensified over southwest Limestone county with the 2038 UTC KHTX reflectivity volume scan.
- No reports received from Limestone county.
- Produced 0.88 inch hail at Mountain Gap School in Huntsville at 2117, with subsequent report at 2120 UTC on Mtn. Gap Road.

Limestone-Madison County Storm (2059-2145 UTC)*



* = Valid Time of Warning

Limestone-Madison County Storm (2059-2145 UTC)

TIME (Z)	REPORT	LMA DETAILS	LEAD TIME
2117	0.88 inch hail	Hail occurred as lightning activity was increasing.	None
2120	0.88 inch hail	Hail occurred as lightning decreased following a large spike.	2 minutes

Limestone-Madison County Storm (2059-2145 UTC)

- **Usefulness of LMA Data**
  - Initial report of hail (2117 UTC) was received as lightning activity was beginning to significantly increase.
  - Lightning was fairly uniform 10-15 minutes prior to hail report, with just a small variance in the number of sources.
  - Second hail report was received at 2120 UTC. Hail fell shortly after a significant spike in the lightning activity, and near minimum in activity. However, first report of hail had already been received and, more than likely, LMA data would not have added much additional benefit to warning-decision.

Findings on LMA Data

- Only a few instances found where the LMA data would have proved useful.
- Several severe reports occurred as the lightning was increasing. This is in contrast to research that suggests a lightning jump, then severe weather occurrences. Very little lead time would have been provided using the LMA data.
- Two instances stand out in which a significant jump occurred, followed by hail reports.
- Most severe weather occurred with a very minimal jump. During warning operations, it would have been extremely difficult to determine whether the lightning activity was peaking or not. A trend feature may, or may not, help in this case.

Findings on LMA Data (cont'd)

- LMA data was not useful for storm that began to bow out over Limestone county. Storm structure and evolution not conducive to capturing micro-physics associated with pulse in updraft/lightning activity.
- Lightning data questionable for storms across far western and eastern portions of CWA as distance from sensor increased. Efficiency chart will prove useful in determining how much signal diminishes with given distance.
- LMA data in support of warning-decision making in this type of environment (strongly tilted updrafts) is questionable. Storms were of supercell nature (hybrids) while others did not show signs of rotation.
- Further data needed to specify how useful data is with classic supercells vs. those that are not.
- Drawback to investigating hail reports is inability to confirm each occurrence. Many storms may have been producing hail their entire life cycle but this cannot (and probably never will be) confirmed.