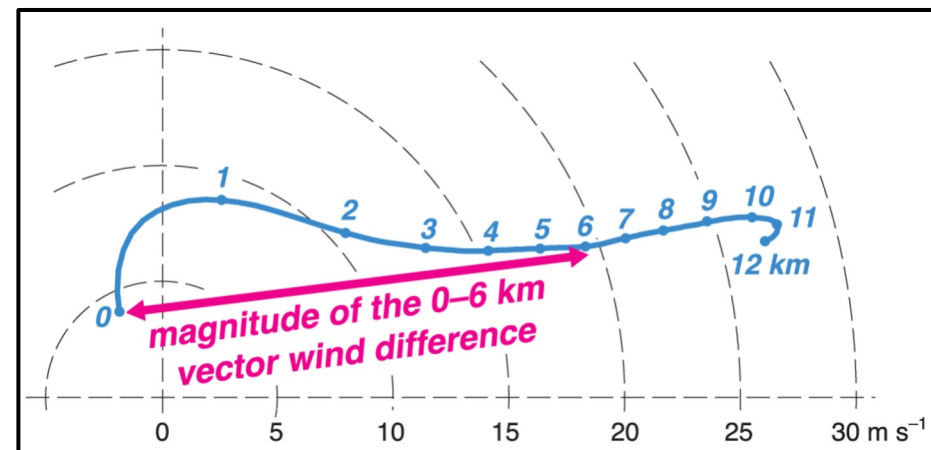


Mode of Convection

METR 4403/5403 – Spring 2023

Mode and Environment Conditions

- Ordinary thunderstorm, multicell storms, and supercells
- Environment conditions (CAPE and shear) influence convective mode
- Vertical wind shear:
 - has greatest influence on thunderstorm structure and behavior (mode)
 - acts to promote longevity and organization of thunderstorms
- 0–6 km bulk shear is most common measure (but it neglects details in hodograph that matter!)
 - $< 10 \text{ m s}^{-1}$ weak
 - $10\text{--}20 \text{ m s}^{-1}$ moderate
 - $> 20 \text{ m s}^{-1}$ strong



MR (2010), Fig. 8.1

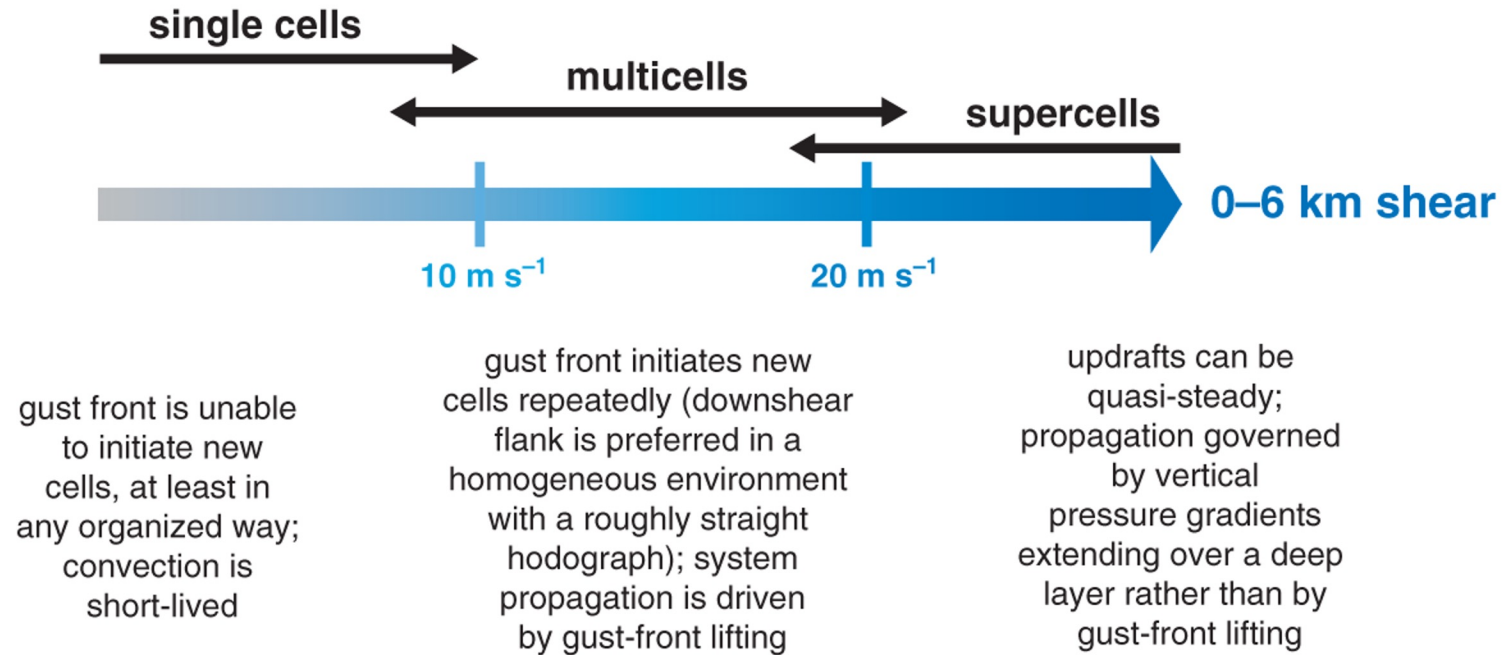
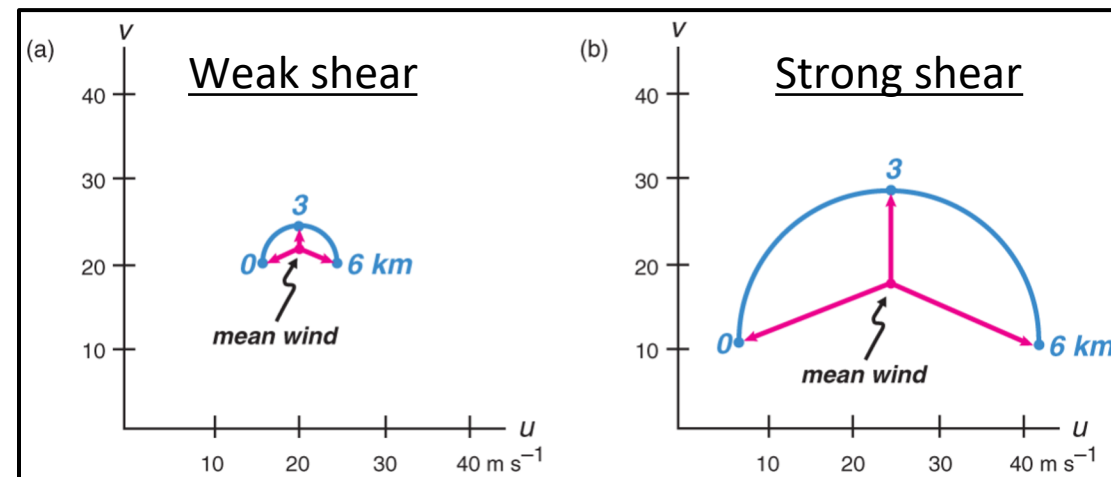


Figure 8.5

Spectrum of storm types as a function of vertical wind shear. Although the vertical shear exerts the greatest influence on storm type, other secondary factors can also affect the mode of convection (e.g., vertical distribution of buoyancy, moisture, and shear, as well as the means by which storms are initiated); thus, some overlap among storm types exists in this simple single-parameter depiction. The relationship between vertical wind shear magnitudes and the nature of cell regeneration/propagation is also shown. MR (2010)

Importance of Vertical Shear

- Interference between precipitation and updraft is reduced as vertical shear increases
- Precipitation falls downwind of updraft
 - Strong storm-relative winds aloft blows precipitation away from updraft core
- Storm-relative inflow at low-levels can slow speed of gust front, limiting its ability to undercut updraft
- Dynamic pressure effects via vertical PGF in shear can produce strong lifting



MR (2010), Fig. 8.2

Ordinary Thunderstorm (single cell)

- Consists of one updraft, outflow gust front spreads in all directions
- Forms in weak shear and modest CAPE, in weak synoptic forcing and typically occur just after max daytime heating

- Pulse severe possible (wind, hail)

- Lifetime approximated as $\tau = \frac{H}{w_0} + \frac{H}{v_t}$
 - Time for precipitation produced by ascent to fall to ground
 - Time for air to ascend from surface to EL

$$\tau = \frac{10^4 \text{ m}}{10 \text{ m s}^{-1}} + \frac{10^4 \text{ m}}{10 \text{ m s}^{-1}} = 10^3 \text{ s} + 10^3 \text{ s} = 2000 \text{ s} = 30 \text{ min}$$

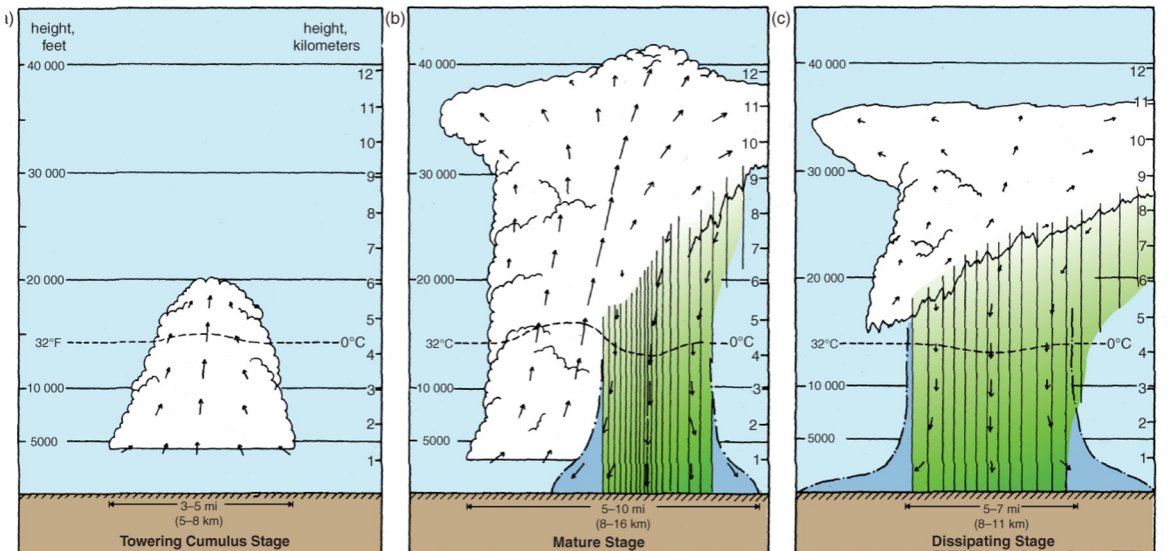
- Life cycle:

- Towering cumulus (only updraft)
- Mature (precipitation falls into updraft, downdraft and gust front forms, anvil forms)
- Dissipating stage (downdraft cuts off updraft; orphan anvil)

H=scale height

w_0 =average updraft speed

v_t =terminal velocity of precipitation



MR (2010), Fig. 8.8

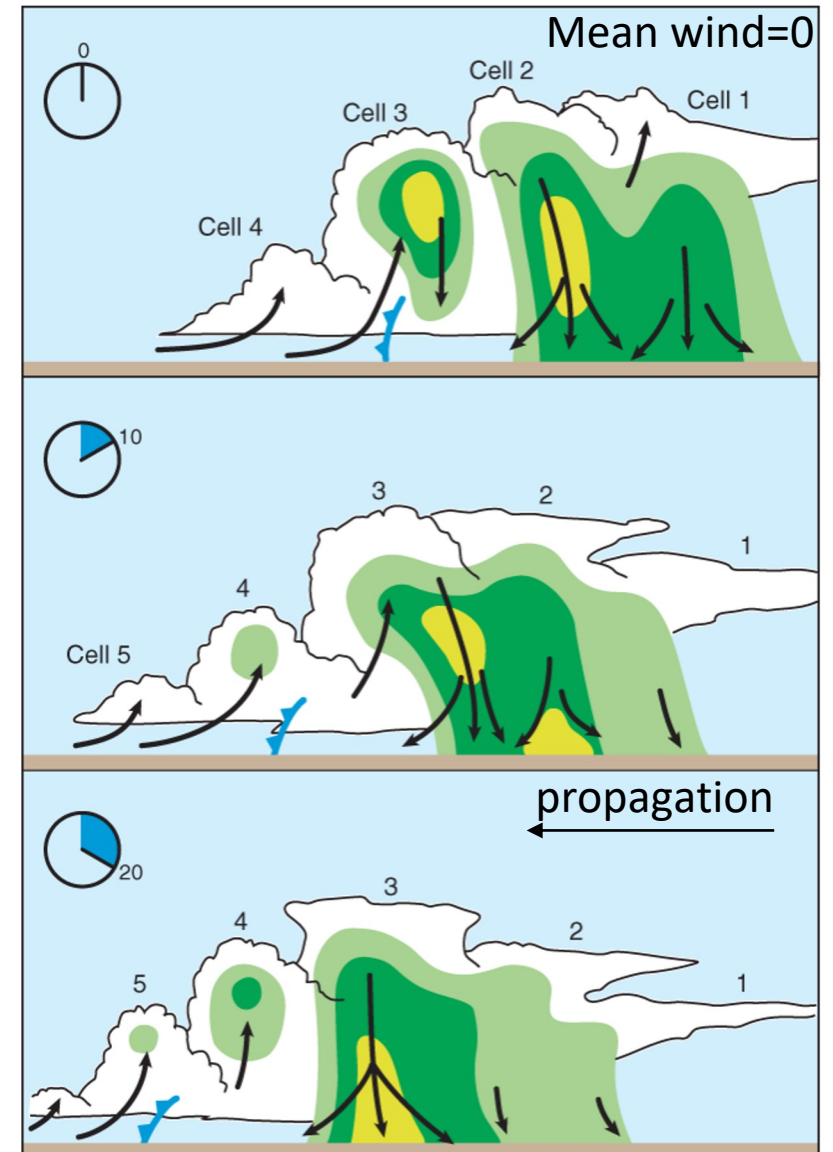
Multicell Convection

- Characterized by repeated development of new cells along the gust front
- Longer-lived cluster of storms in moderate vertical shear and small to large CAPE
- Individual storms in cluster may be ordinary, lasting 30-60 mins
- In high CAPE moderate shear, multicell convection can produce swaths of damaging winds and hail



Evolution of Multicell Convection

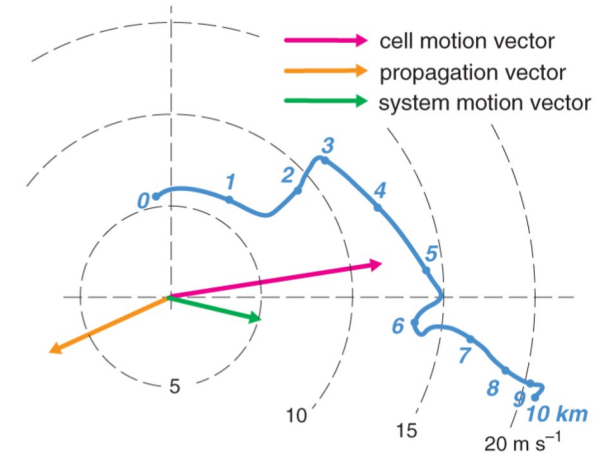
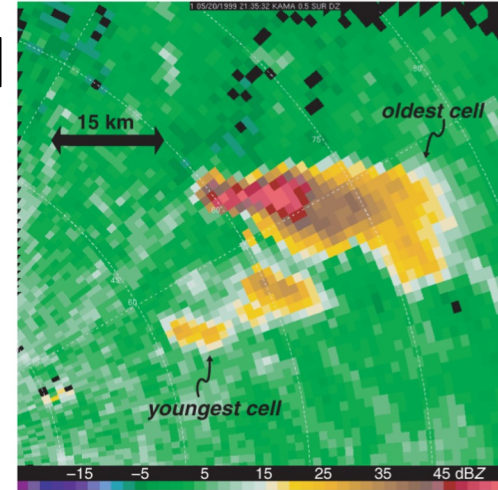
- Individual cells move with the mean wind averaged over their depth
- New cells initiate along gust front
- @ Time 0:
 - Cell 1 – dissipative stage
 - Cell 2 – mature stage
 - Cell 3 – precipitation beginning to form
 - Cell 4 – towering cumulus stage
- @ Time 10:
 - Cell 1 – orphan anvil
 - Cell 2 – dissipative stage
 - Cell 3 – mature stage
 - Cell 4 – precipitation beginning to form
 - Cell 5 – towering cumulus stage
- @ Time 20: ...and so on.



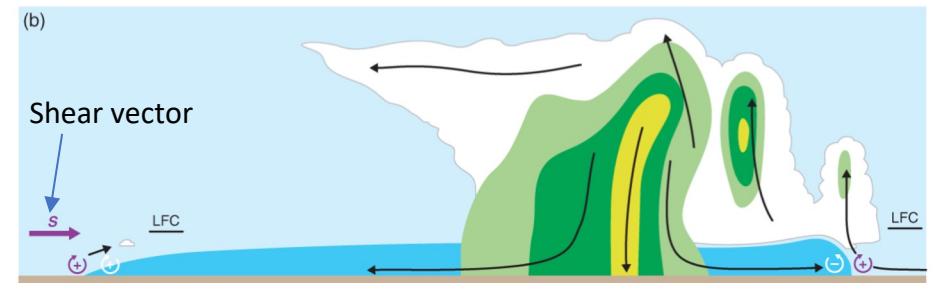
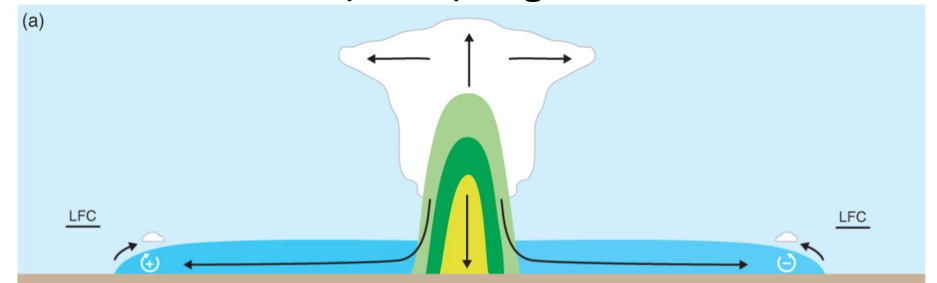
MR (2010), Fig. 8.11

Movement versus propagation

- Individual cells move with the mean wind
- Repeated development of new cells on flank of system leads to propagation of system
- Total motion is cell motion+propagation
- New cells develop on gust front on downshear side of cold pool



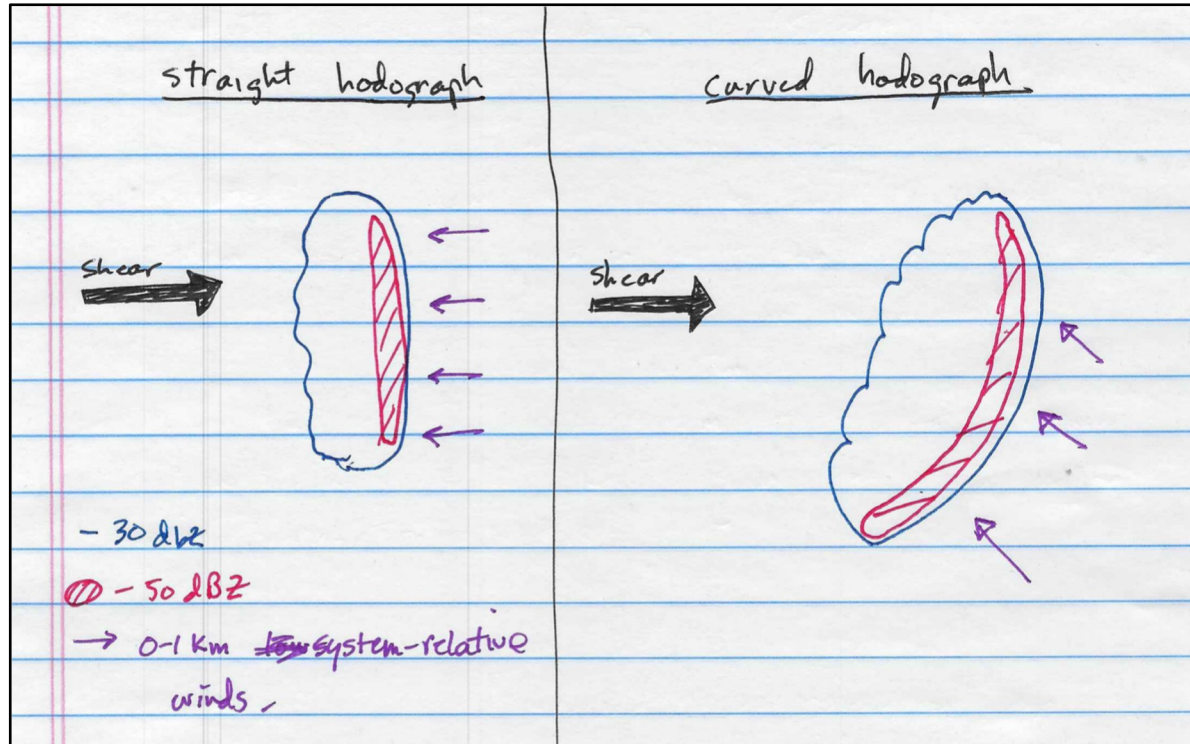
MR (2010), Fig. 8.10



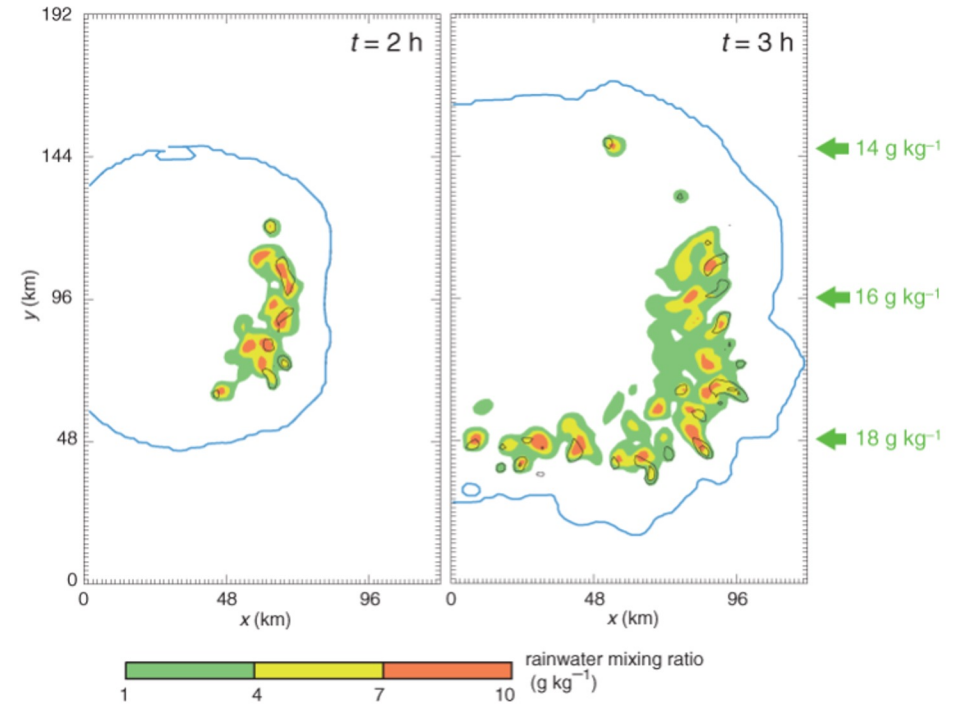
MR (2010), Fig. 8.12

Movement versus propagation

System-relative head winds



Environment moisture gradients

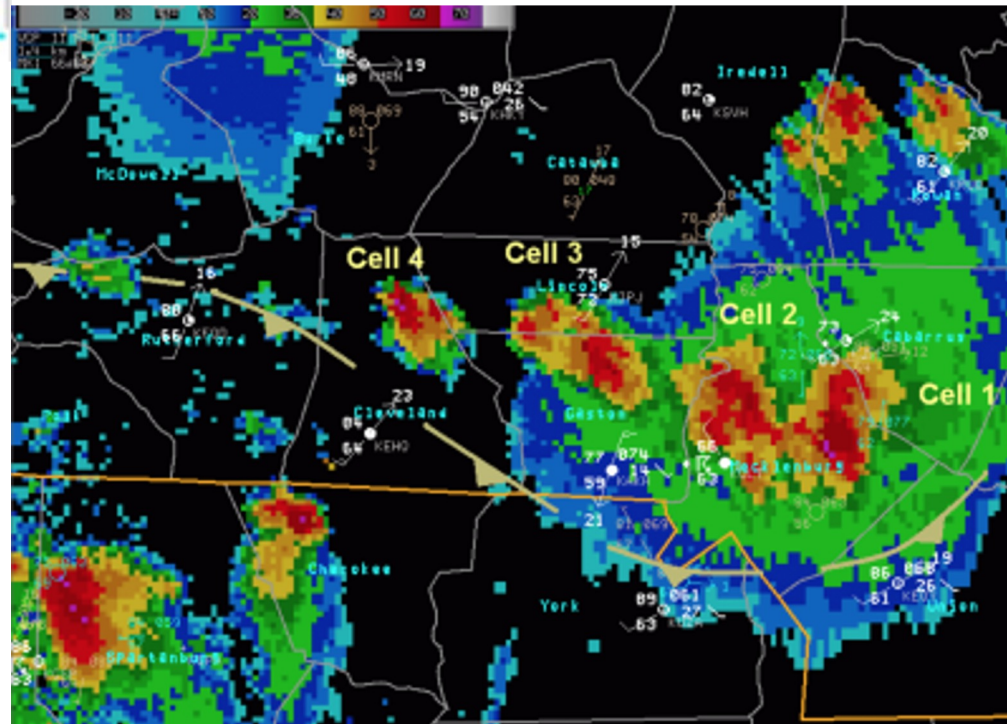
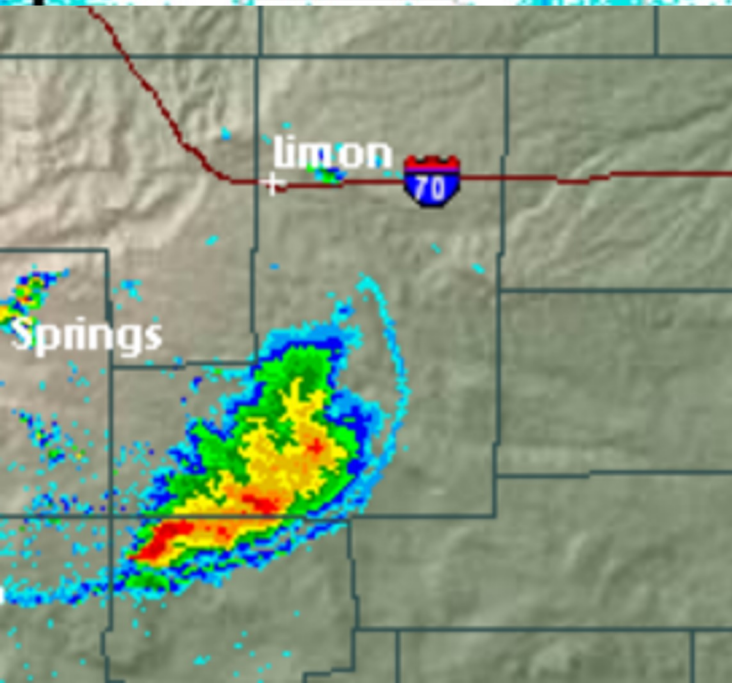
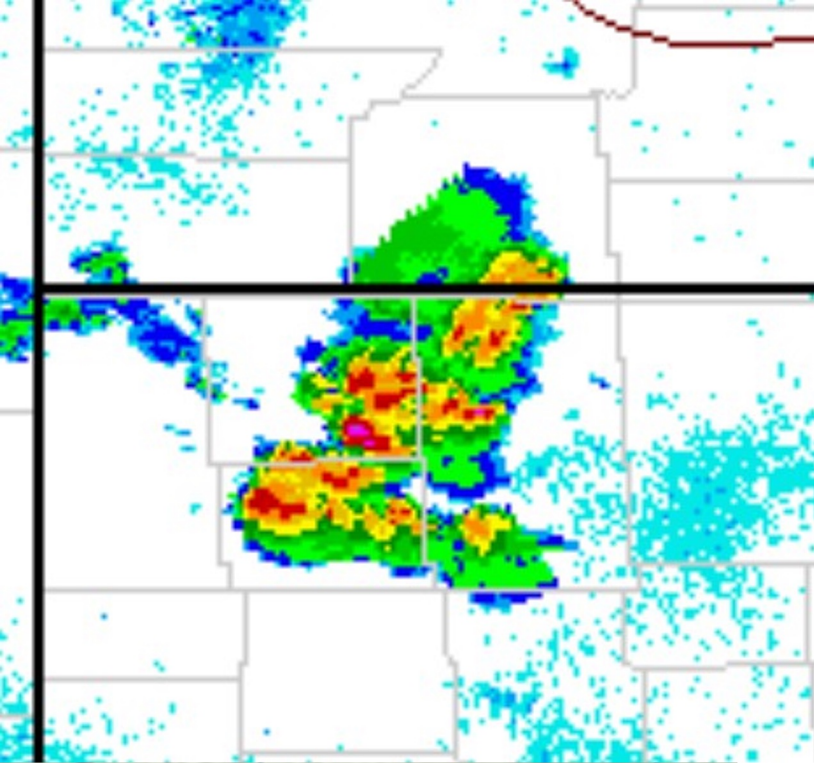


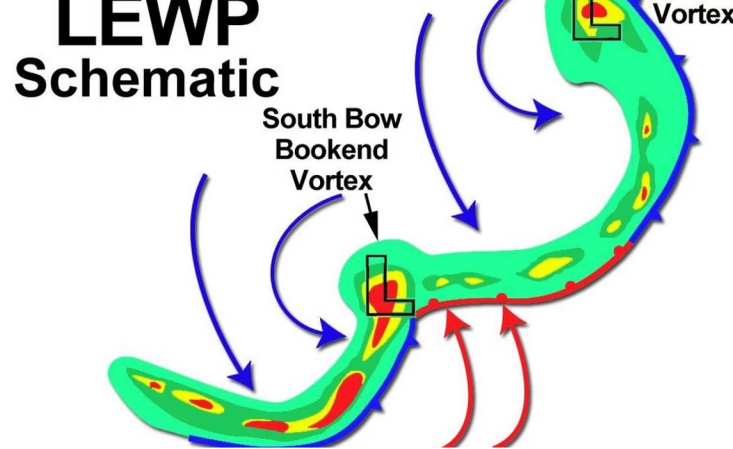
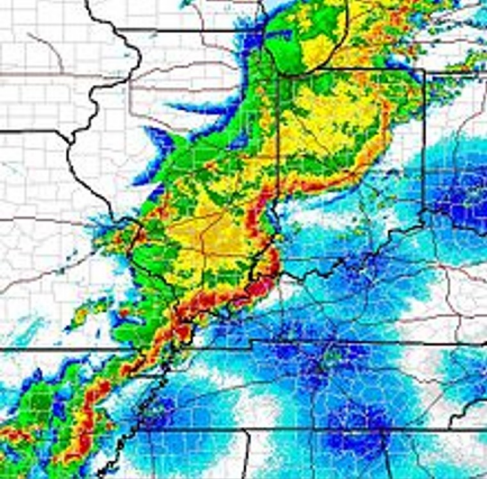
MR (2010), Fig. 8.14

- Formation of new cells along the gust front is also influenced by the low-level system-relative winds (left) and moisture heterogeneities (right)

Multi Cell Clusters

- Aggregates of multi-cell storms are common over parts of the Southeast in the summer. Each storm can be in a different phase of the life cycle.
- Can act as a loosely organized MCS or as vague as a large convective blob.
- Forcing is usually weak and the primary risk is damaging outflow winds from collapsing storms but can also produce hail.

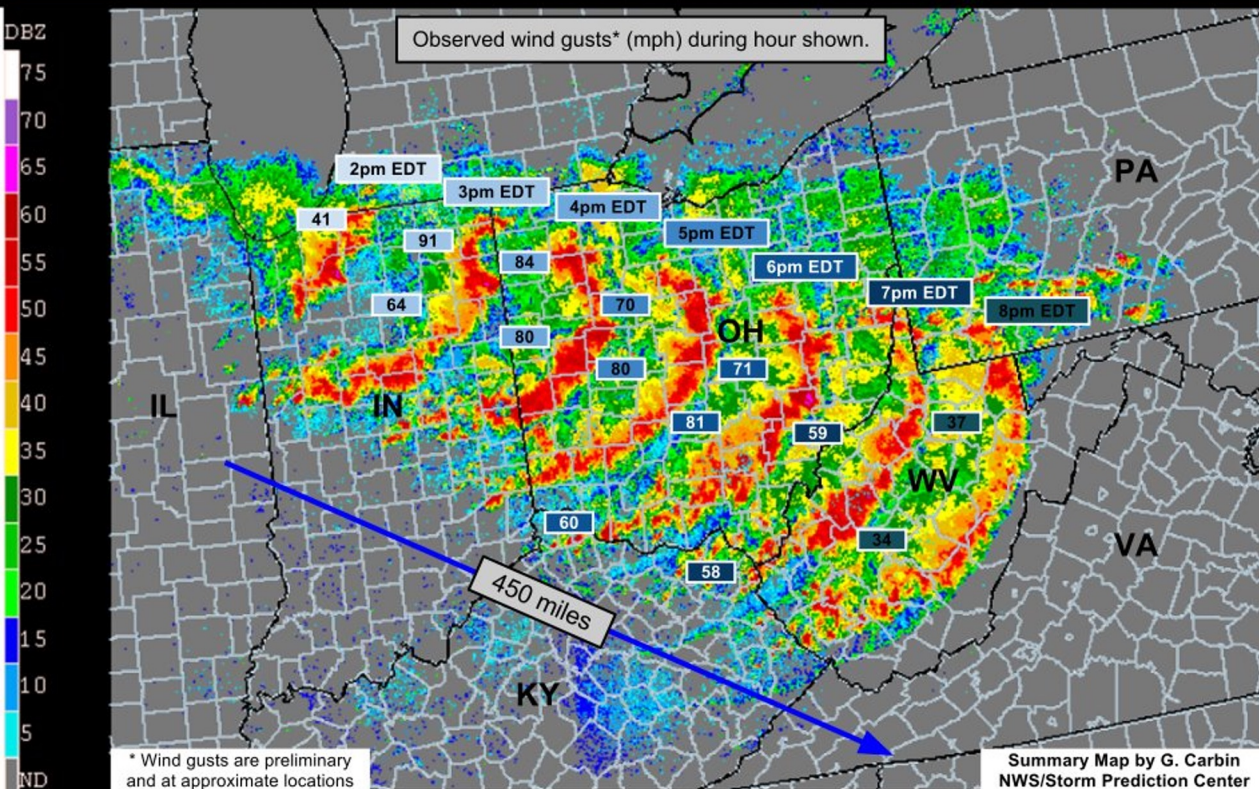




Multi Cell Lines

- Collections of multicell storms along a line with a large length to width ratio.
- Can take multiple forms
 - Serial MCS
 - Progressive MCS
 - LEWPs (line echo wave patterns)
 - Bow echos
 - Derechos
- Usually more organized than clusters with stronger vertical shear.
- Can produce Damaging wind gusts tornadoes and some hail.

June 29, 2012 Midwest/Ohio Valley Derecho
 Radar Imagery Composite Summary 18-00 UTC
 ~450 miles in 6 hours / Average Speed ~75 mph



Supercells

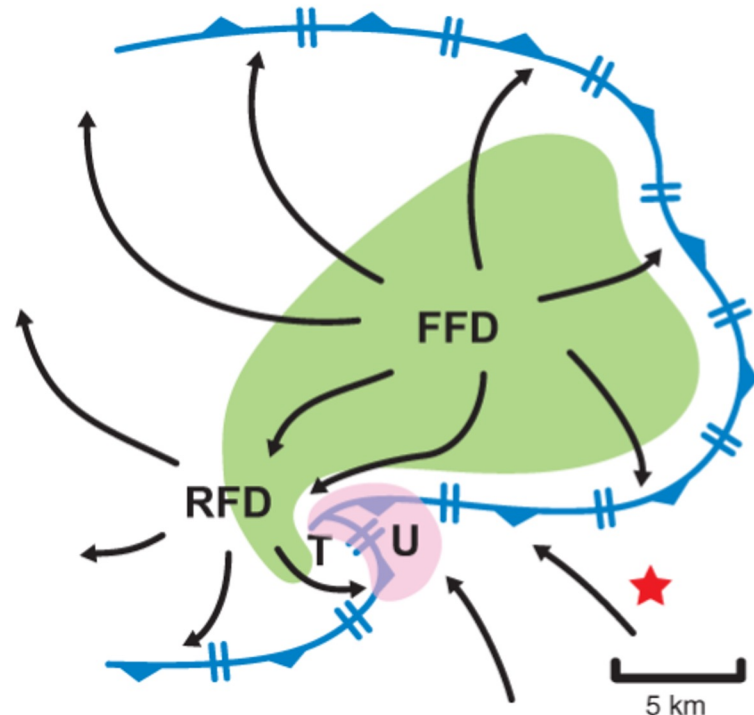
- **Characterized by a thunderstorm with a sustained, deep, rotating updraft \square mesocyclone**
- **Occur in strong vertical shear through a deep layer (big storm-relative winds), but high CAPE not necessary**
- **Motion deviates significantly from mean wind**
- **Vertical PGF enhances updraft, a special property of supercells**



MR (2010), Fig. 8.17

Supercell Features

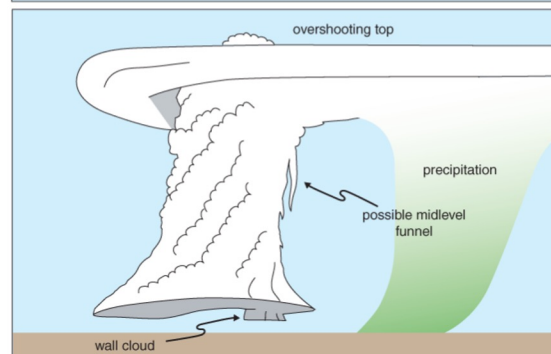
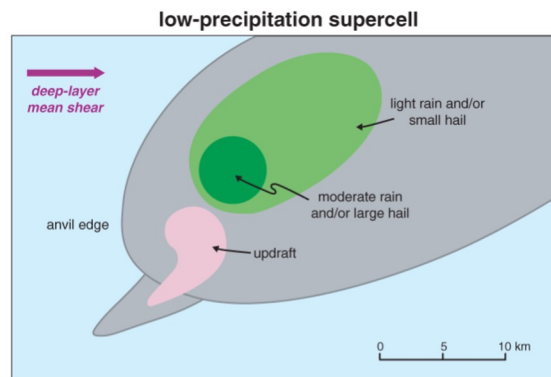
- Single, long-lived, quasi-steady, rotating, precipitation free, updraft
- Wall cloud at updraft base where humid, rain-cooled air drawn upward
- Two downdraft regions: rear flank downdraft (RFD) and forward flank downdraft (FFD)



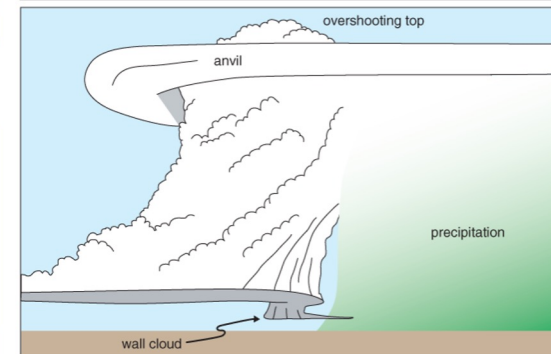
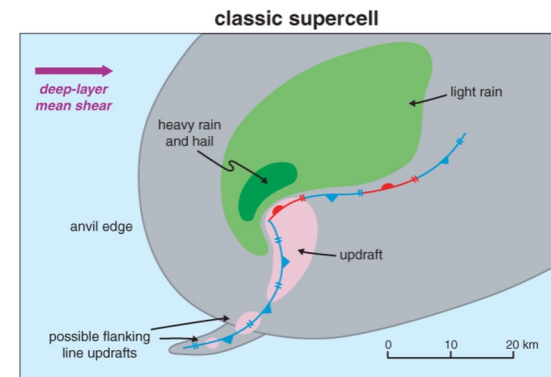
MR (2010), Fig. 8.22

Supercell Types

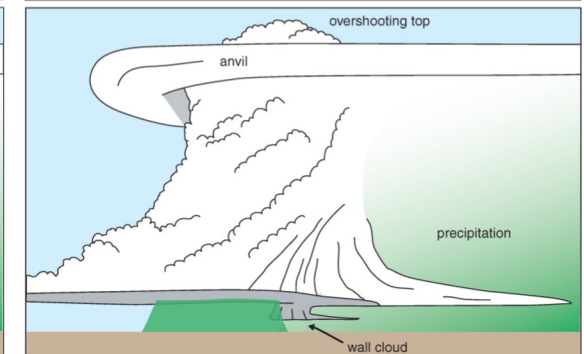
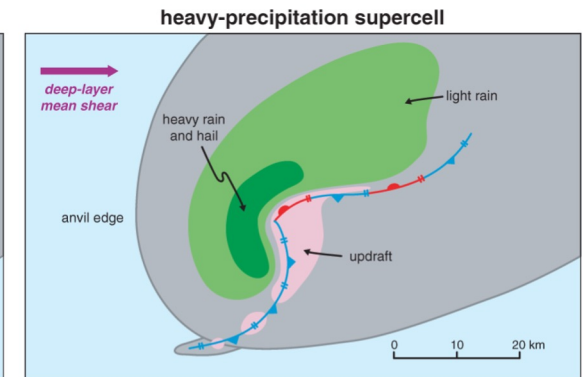
- For isolated storms, supercell type is a function of storm-relative winds (SRW) at level of anvil (9–12 km AGL)
- Weak upper-level storm-relative winds (<18 m/s): **HP**; moderate (18-28 m/s): **classic**; strong (>28 m/s): **LP**
- For multiple storms in close proximity, precipitation from one storm may seed another storm, favoring **HP** types
- Weaker SRW favors larger updrafts resistant to entrainment.



MR (2010), Fig. 8.24

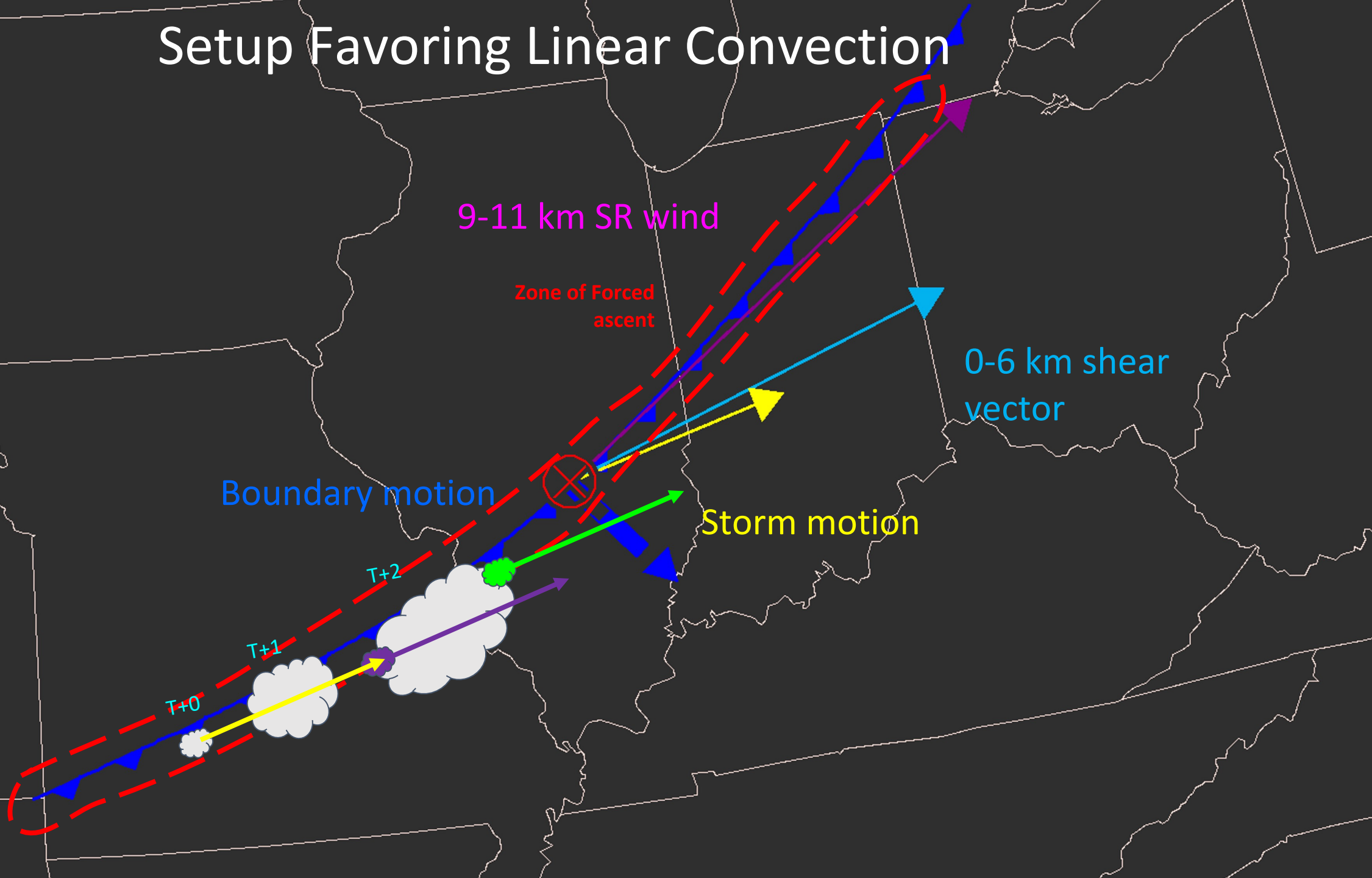


MR (2010), Fig. 8.16



MR (2010), Fig. 8.26

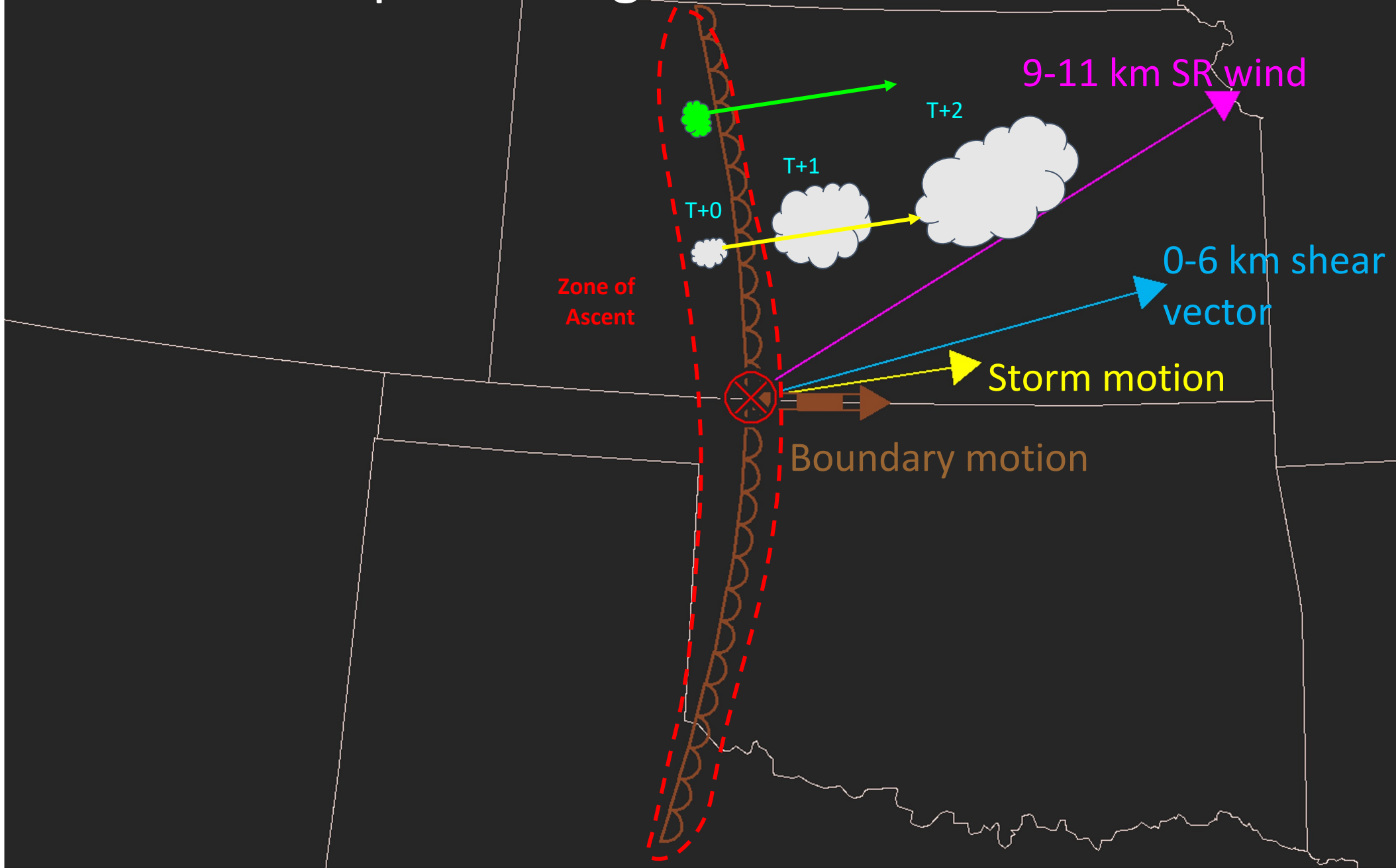
Setup Favoring Linear Convection



Recipe for a Squall Line

- **Deep-Layer flow, shear vectors, and SR winds largely parallel to boundary**
 - **Overlapping and interacting storms**
- **Strong linear convergence (ascent) along the boundary**
 - **Form lots of storms close to one another**
- **Storms do not move away from the zone of ascent**
 - **Longer residence time in the zone of ascent leads to more updrafts and more mature updrafts interacting with each other.**

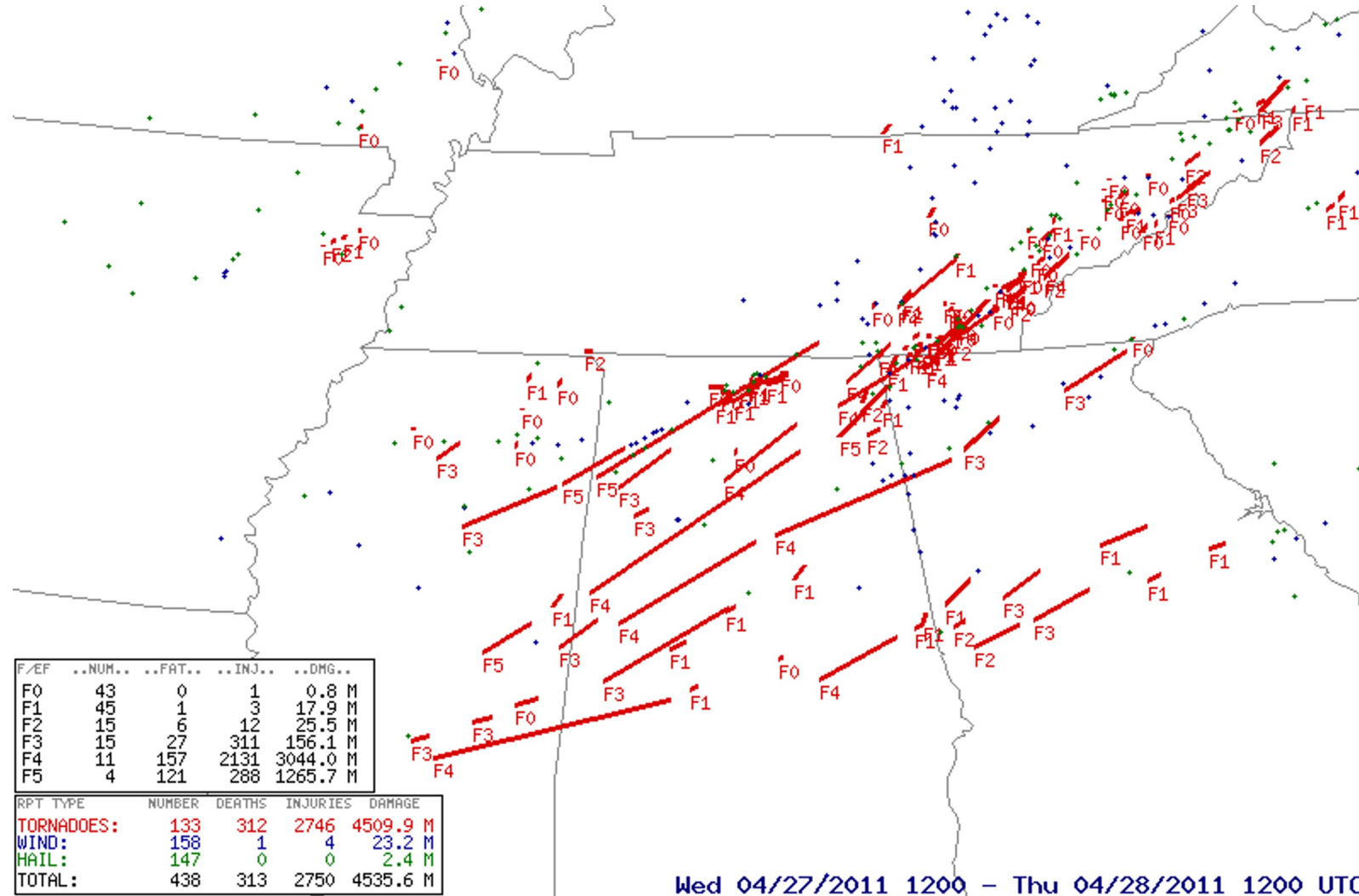
Setup Favoring Discrete Convection

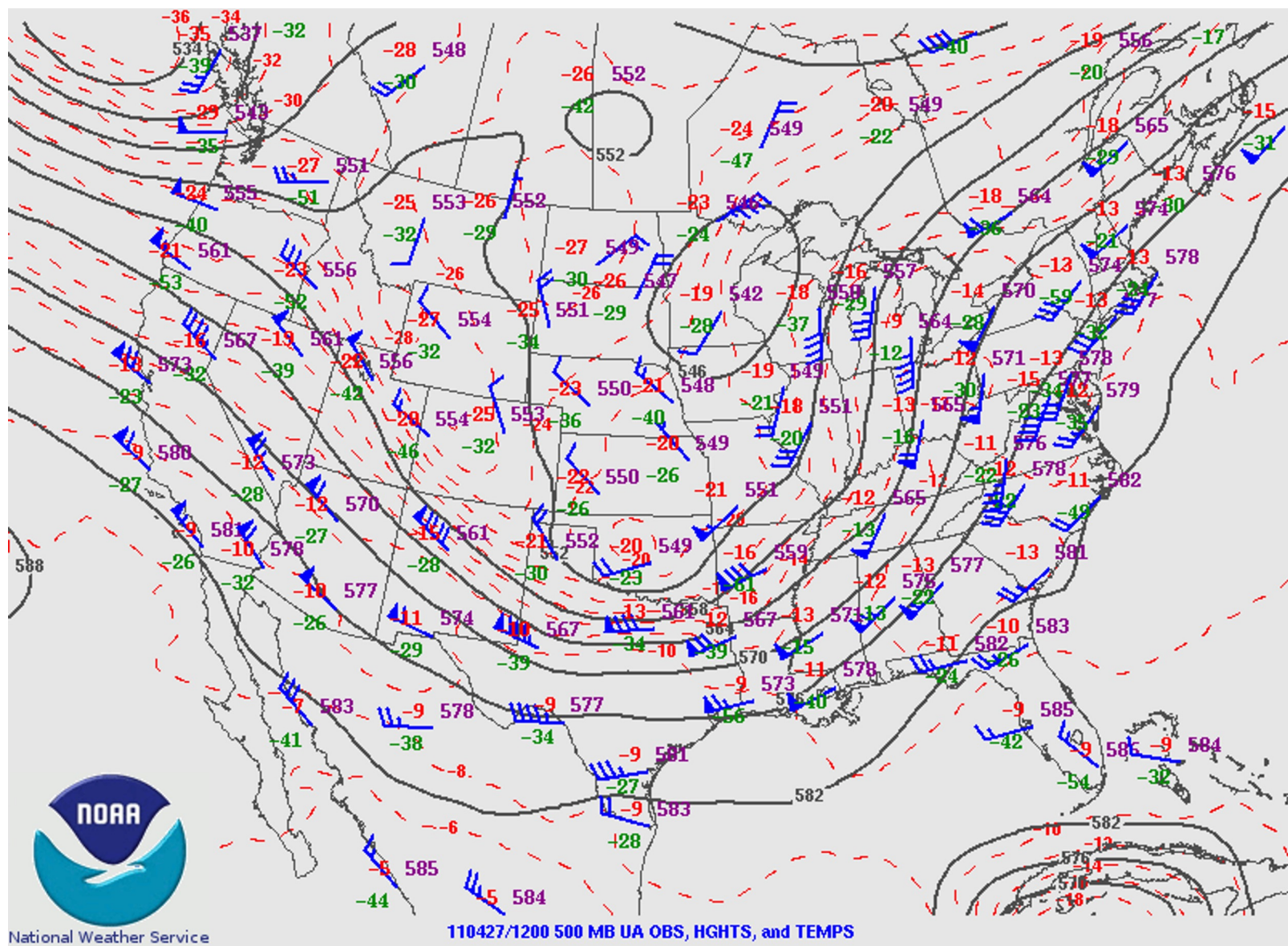


Recipe for Discrete Storms

- **Deep-Layer flow, shear vectors, and SR winds oriented across a boundary**
 - Storms tend to not interact (need to also consider storm splitting)
- **Weaker convergence (ascent) along the boundary**
 - Fewer storms form
- **Storms move away from the zone of ascent faster**
 - Less chance for upscale growth into a line

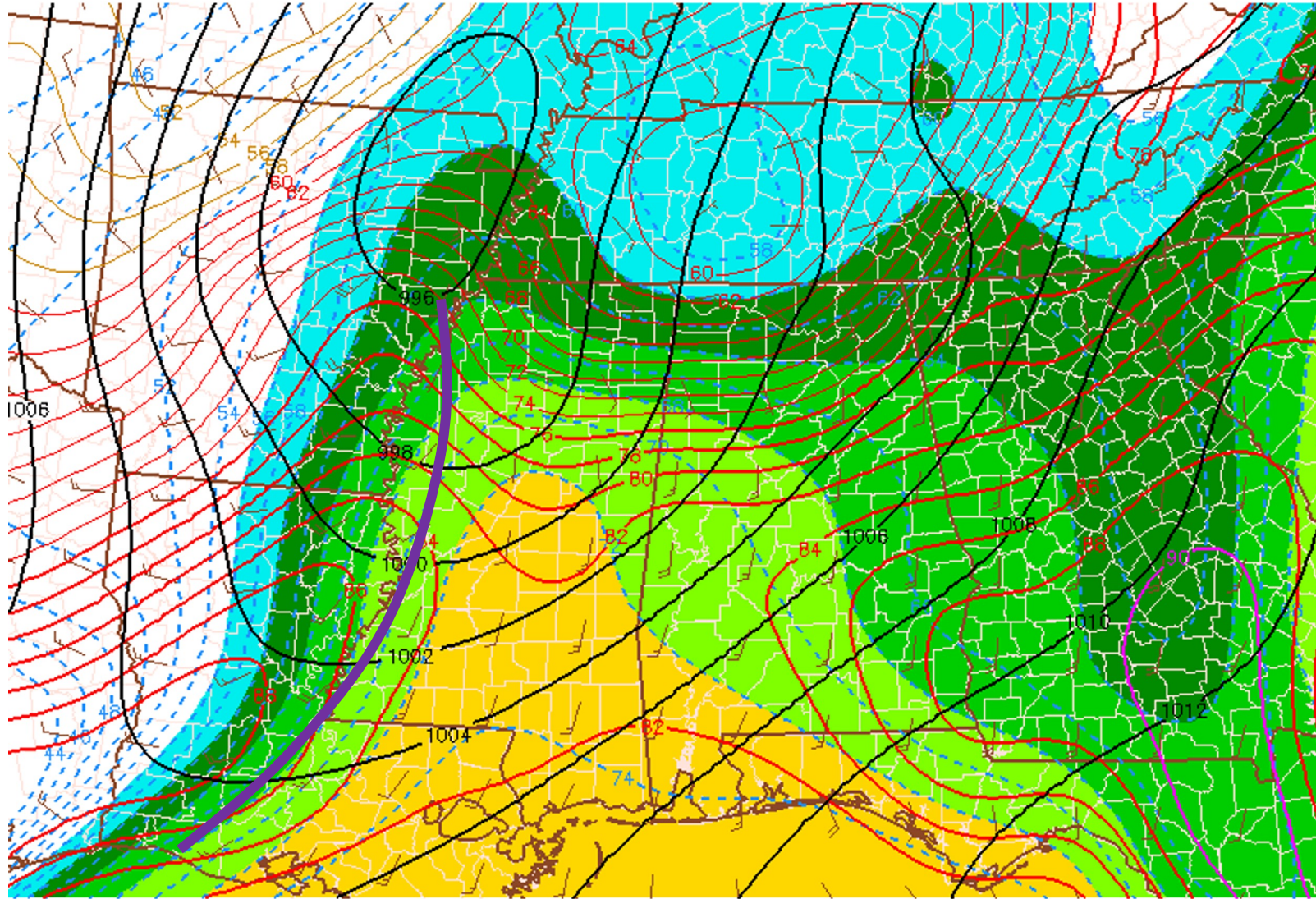
27 April 2011 Supercell Mode Case





27 APR 2011 12z

Surface T, Td, and PMSL

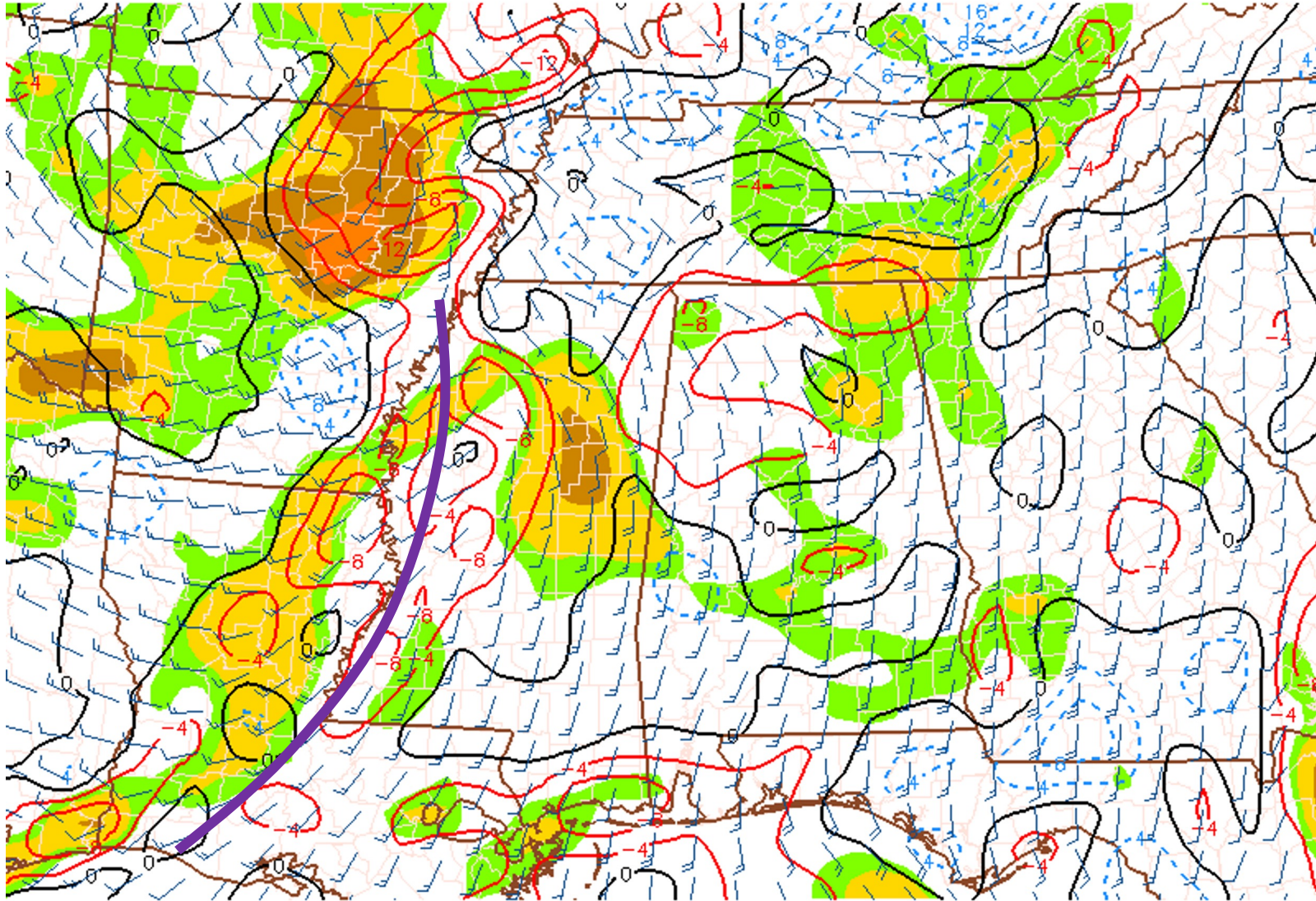


56 60 64 68 72 76

110427/1900 Surface temp, dewpoint, and pmsl

27 APR 19z

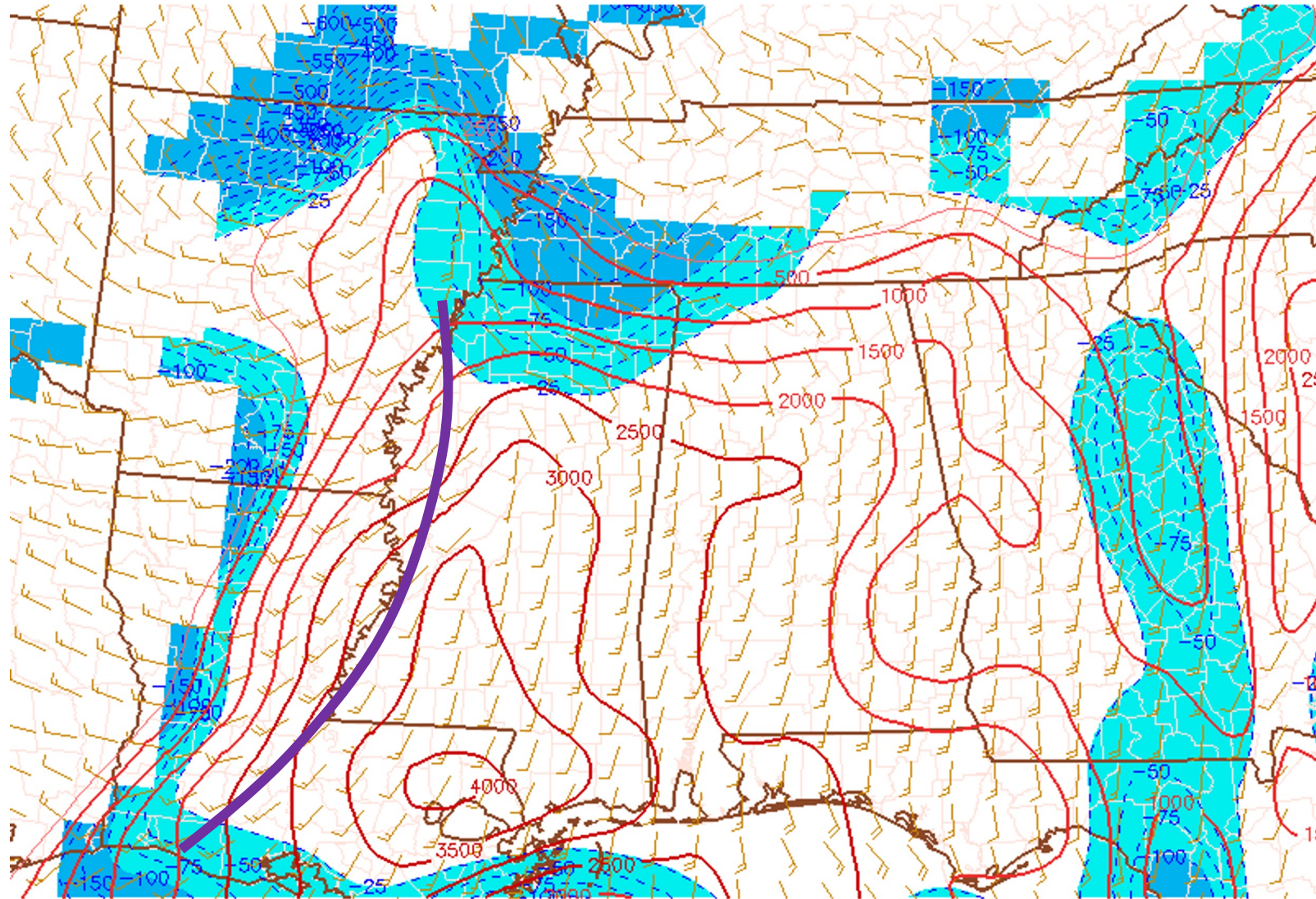
Surface convergence and vorticity



110427/1900 Surface Vorticity (fill) and Divergence (conv=solid RED, divg=dashed blue)
2 4 8 12 16 20 24

27 APR 19z

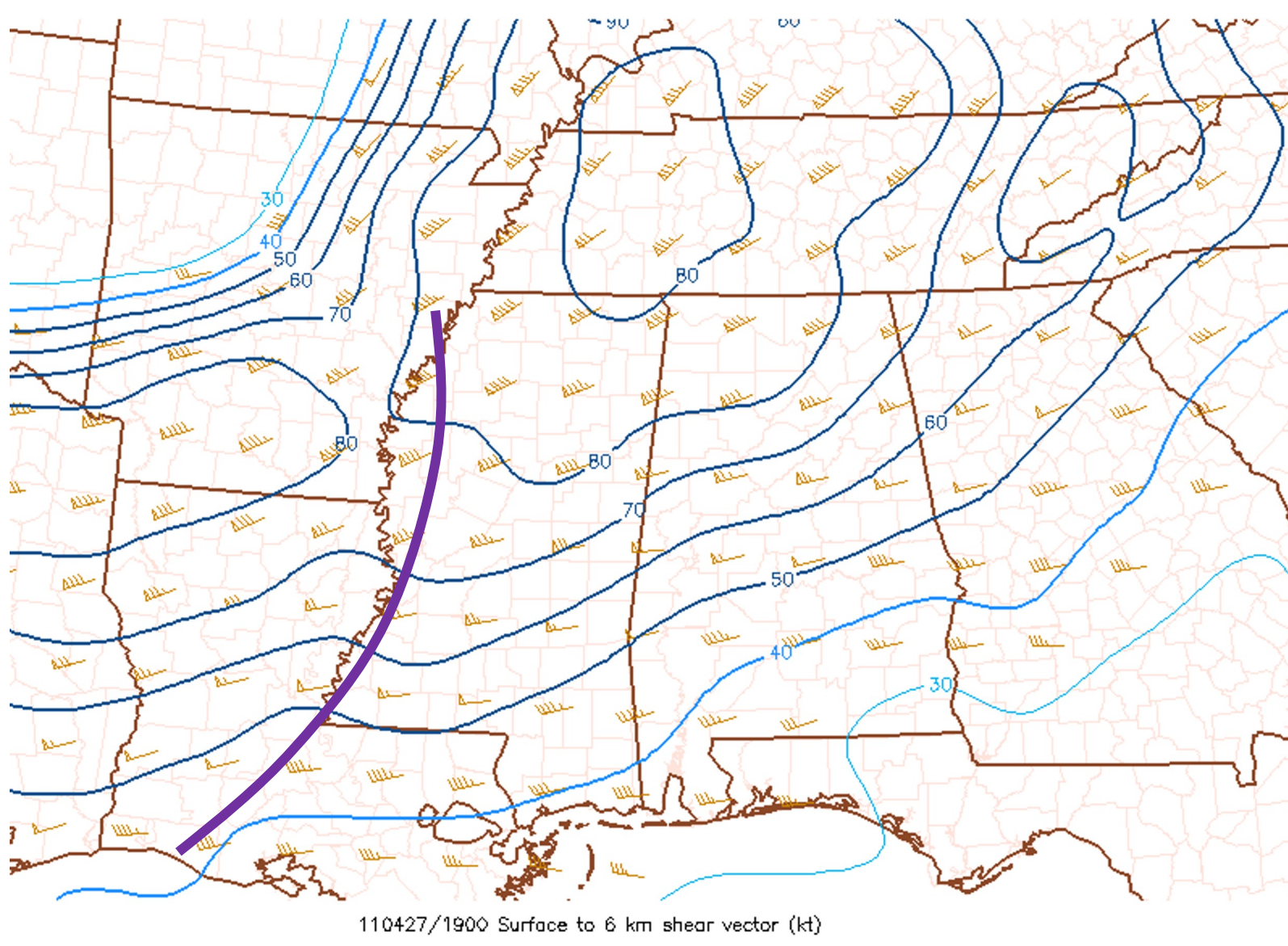
MLCAPE and MLCIN



110427/1900 MLCAPE (contour) and MLCIN (J/kg, shaded)
25 100

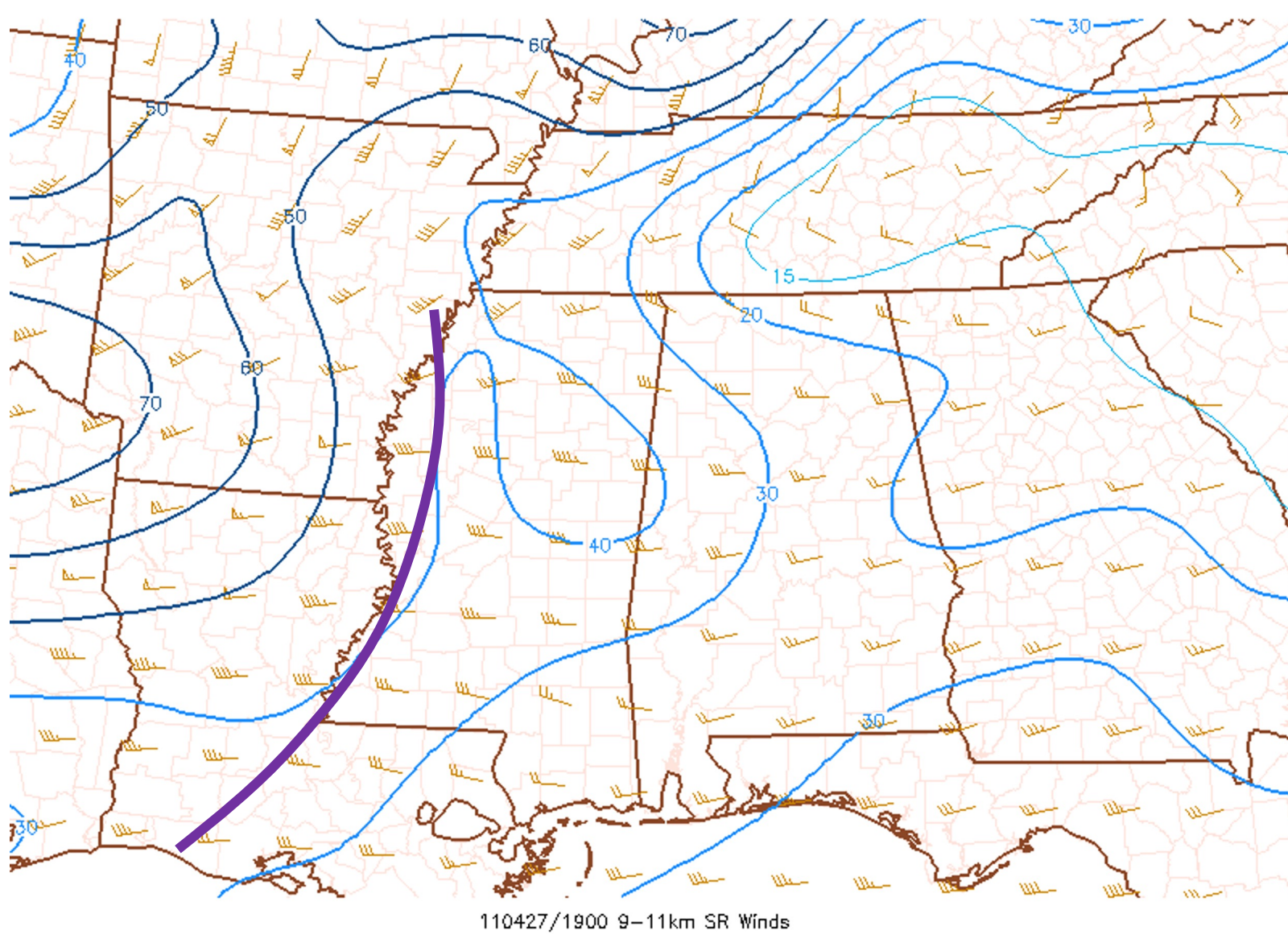
27 APR 19z

0-6 km shear vectors



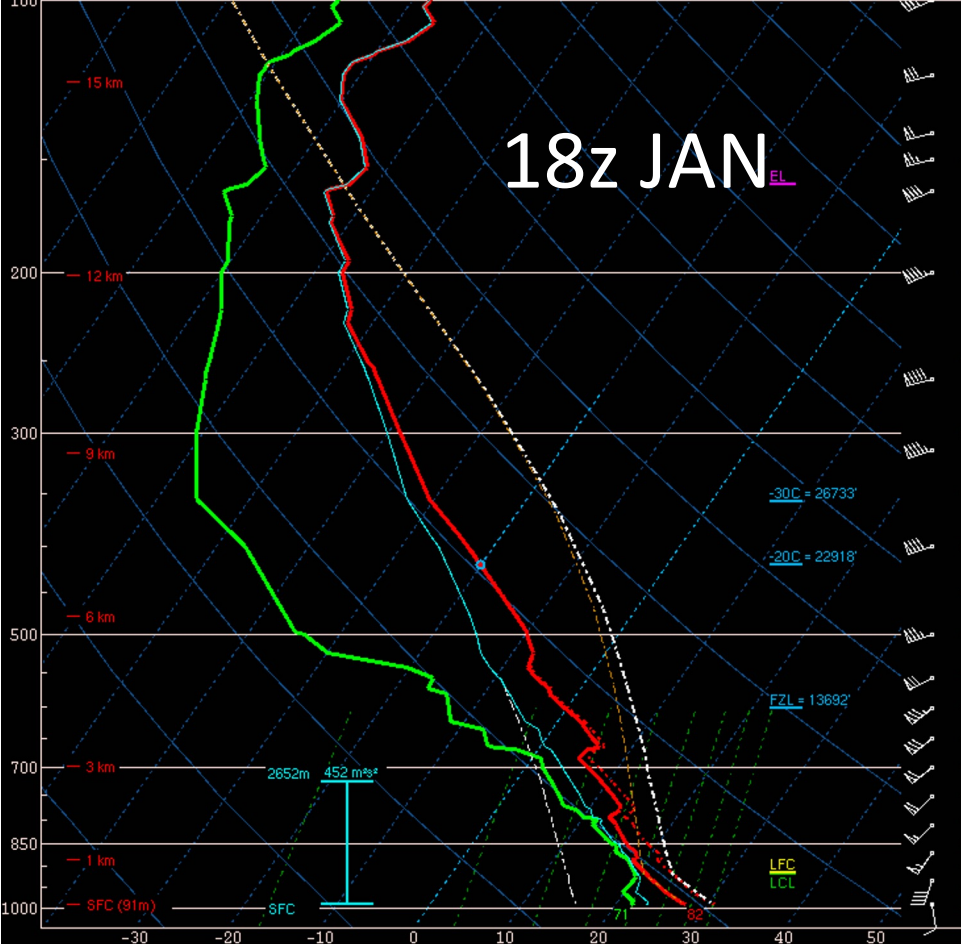
27 APR 19z

9-11 km storm-relative winds

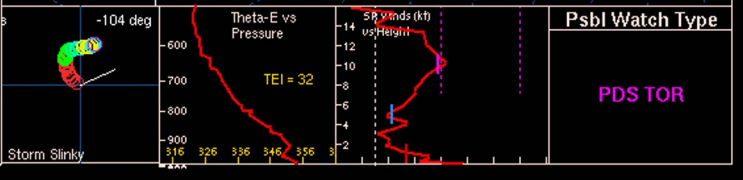
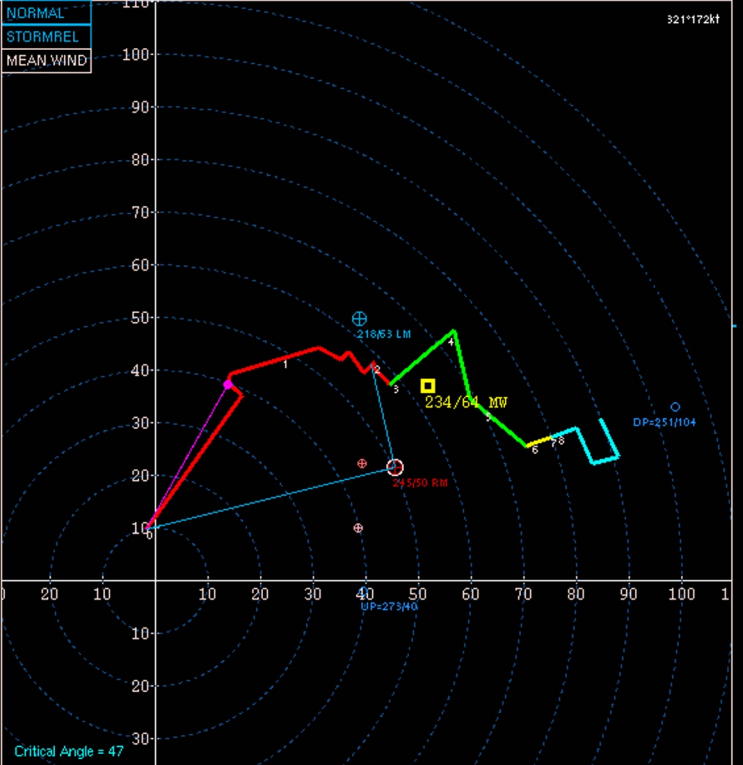
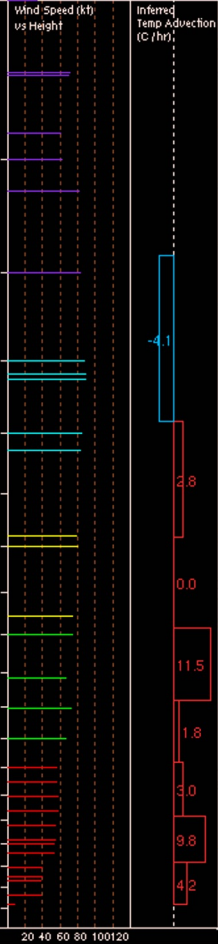


27 APR 19z

JAN 110427/1800 (Archive)



18z JAN



Psbl Watch Type

PDS TOR

	CAPE	CINH	LCL	LI	LFC	EL
SB PARCEL	3804	0	766m	-9	766m	44014'
ML PARCEL	3451	-1	806m	-8	871m	44398'
FCST SFC	4155	0	1128m	-9	1128m	44014'
MU PARCEL 4012	0	0	867m	-9	714m	44014'
EFF PARCEL	1836	-7	1611m	-5	2402m	39979'
USER DEF	1910	-7	1525m	-5	2347m	40086'

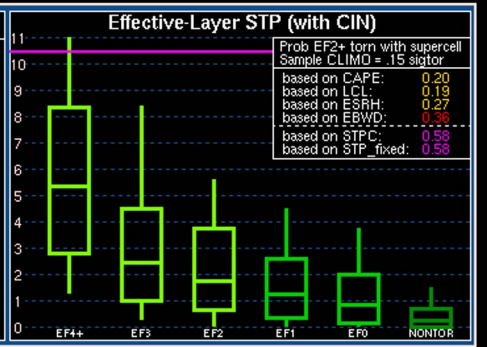
	SRH(m2/s2)	Shear(kt)	MnWind	SRW
SFC - 1 km	356	41	202/37	112/34
SFC - 2 km	455	53	212/44	125/27
SFC - 3 km	468	54	216/47	133/24
Eff Inflow Layer	452	53	215/46	131/25
SFC - 6 km	75	75	225/53	152/18
SFC - 8 km	80	80	229/55	161/16
LCL - EL (Cloud Layer)	58	58	234/63	199/17
Eff Shear (EBWD)	78	227/54	158/16	

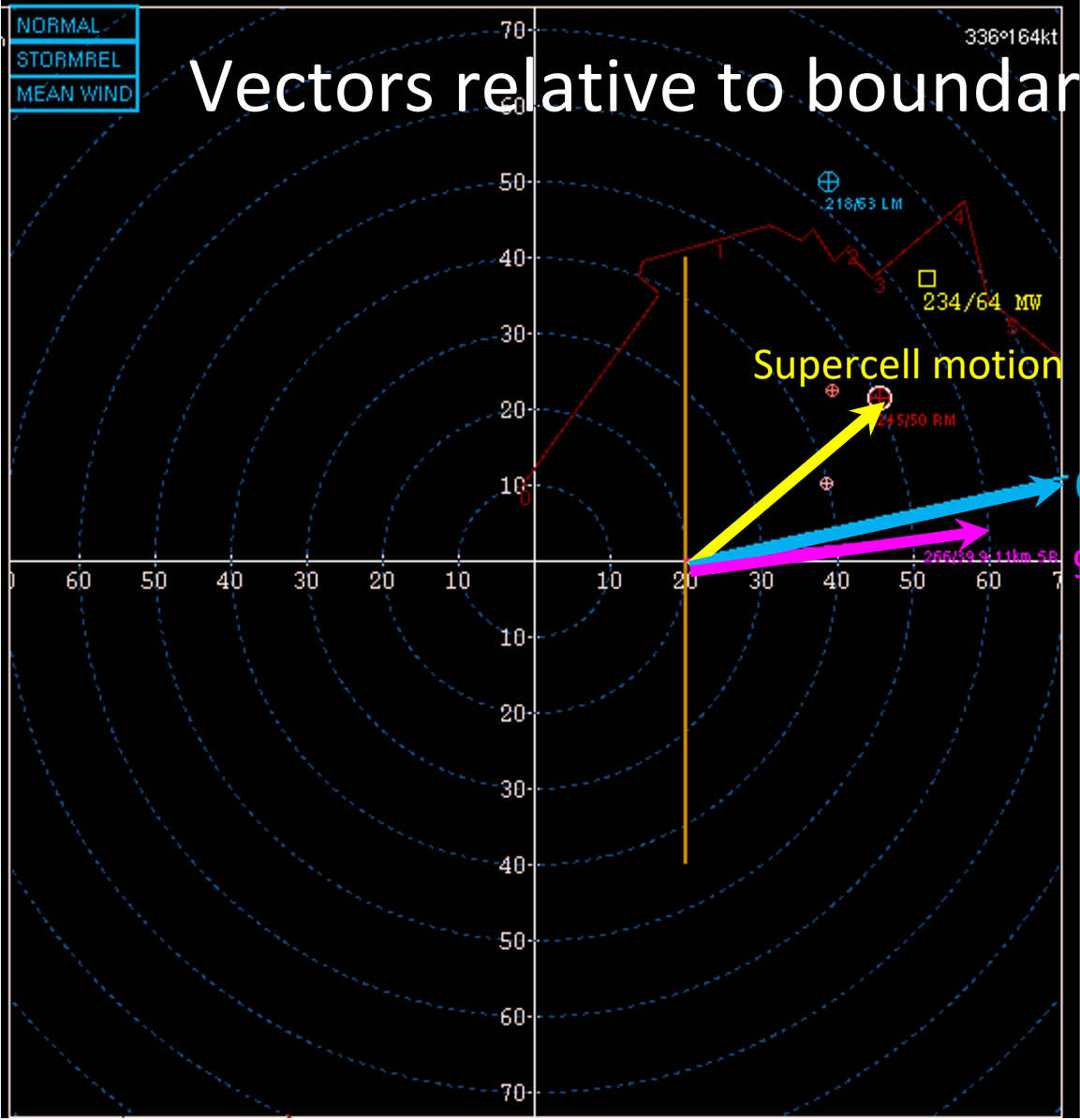
	BRN Shear	4-6km SR Wind	Corridl Downshear	Corridl Upshear	Bunkers Right	Bunkers Left
	99 m/s	230/22 kt	251/104 kt	273/40 kt	245/50 kt	218/63 kt

	STPC LR	SHERBE
	10.4	2.6
	STPC 6km	SHERB3
	7.9	1.9

Supercell = 36.3
STP (eff) = 10.4
STP (fixed) = 9.0
SHIP = 2.2

SARS - Sounding Analog System	
SUPERCCELL	SGFNT HAIL
browse to ~thompson / sup / snd / *	browse to ~jewell / hail / snd / *
03050823_C34 SIGTOR	
(1 matches out of 856 sndgs)	(18 matches out of 1148 sndgs)
SARS: **TOR!** (100% TOR)	SARS: **SIG HAIL** (94% SIG)





Vectors relative to boundary

NORMAL
STORMREL
MEAN WIND

Supercell motion

0-6 km shear

9-11 SR wind

338°164kt

218/63 LM

234/64 MW

245/50 RM

265/59.9/11km 58

1815 UTC Wed 27 Apr 2011

Visible Satellite

<http://adds.aviationweather.gov>

0 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60 63 66 69 72 75 78 81 84 87 90 93 96 99



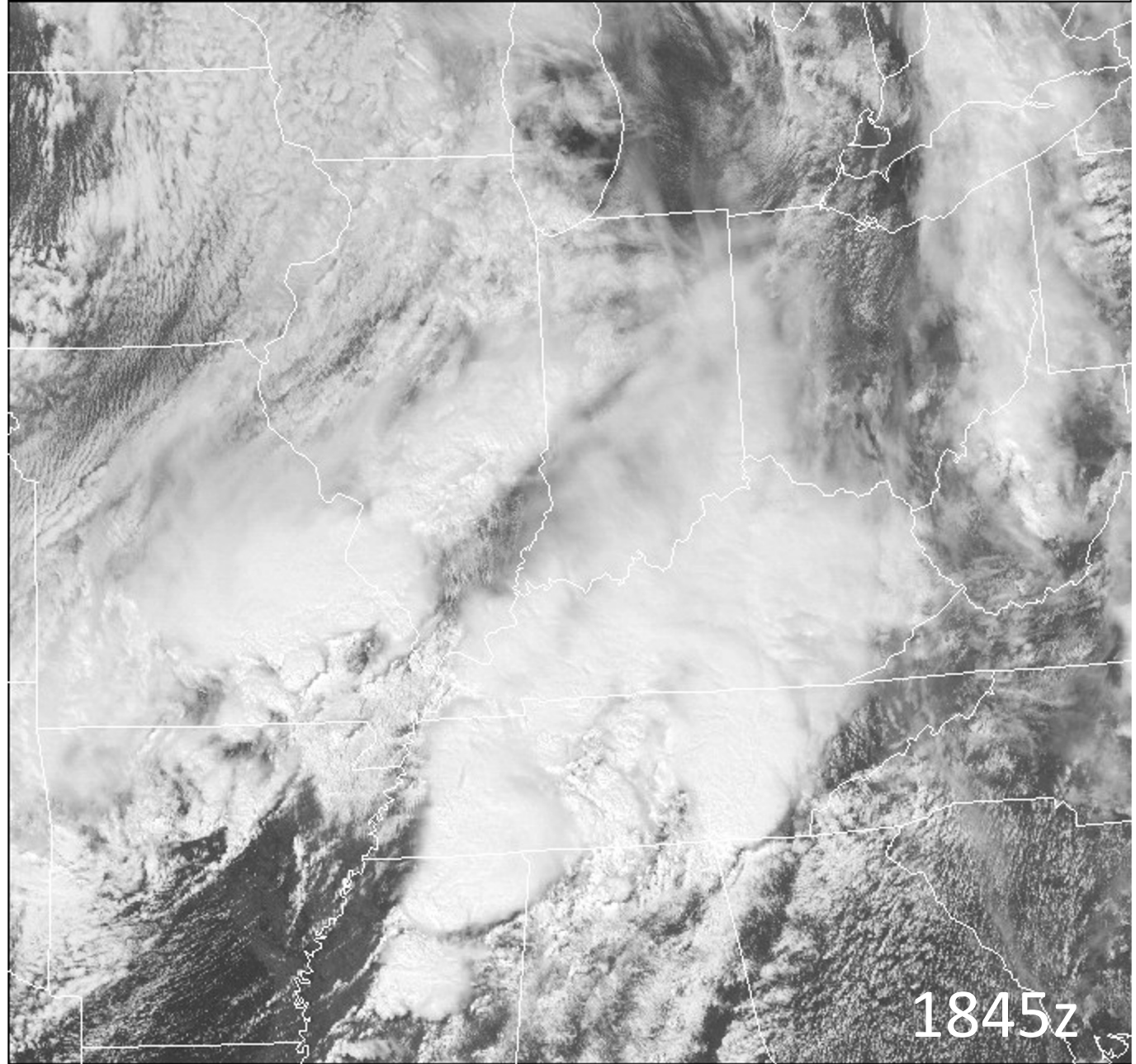
1815z

1845 UTC Wed 27 Apr 2011

Visible Satellite

<http://adds.aviationweather.gov>

0 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60 63 66 69 72 75 78 81 84 87 90 93 96 99



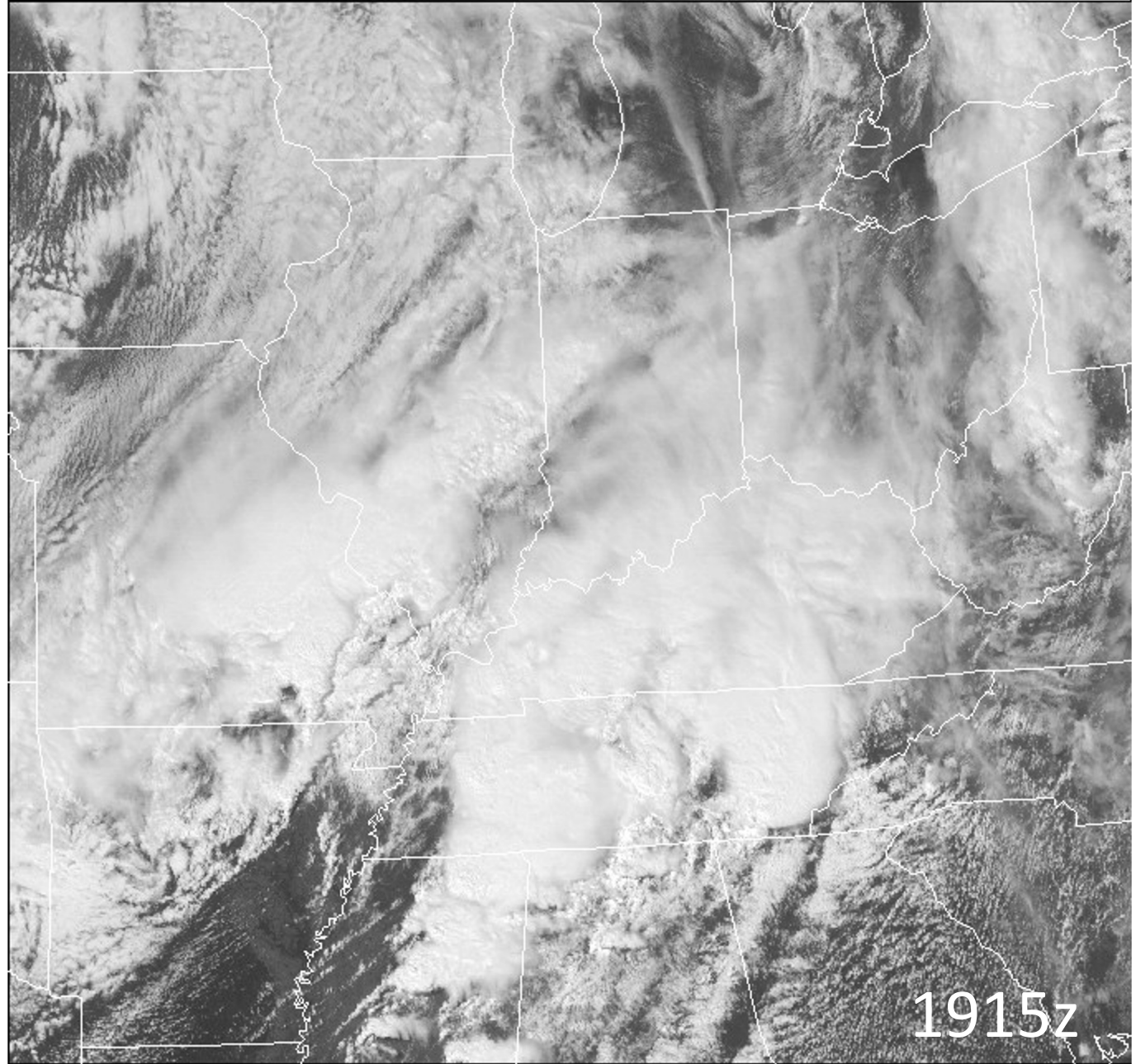
1845z

1915 UTC Wed 27 Apr 2011

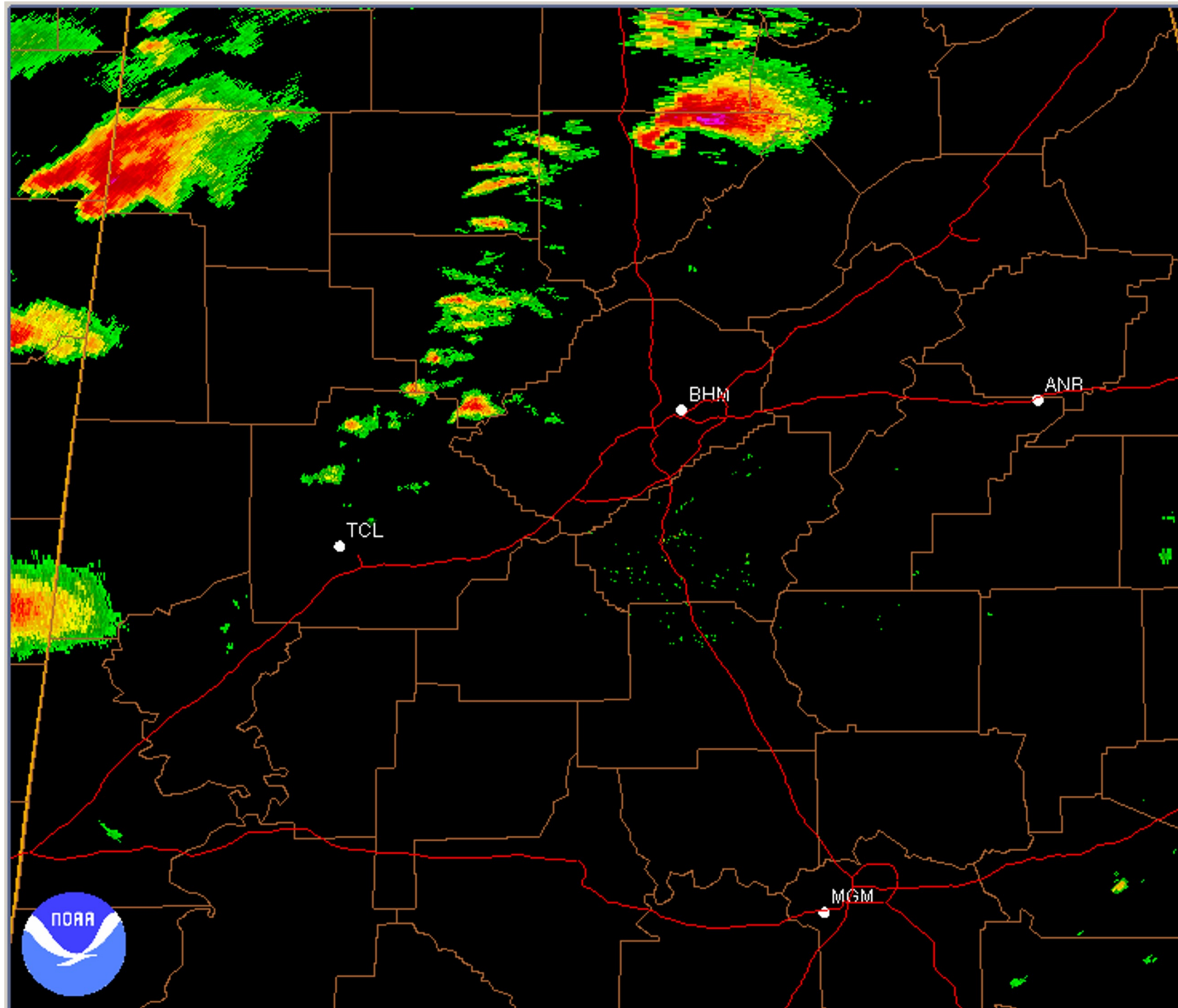
Visible Satellite

<http://adds.aviationweather.gov>

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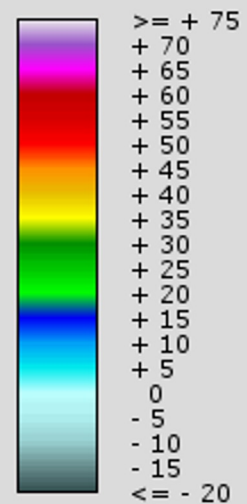
1915z



NEXRAD LEVEL-II
KBMX - BIRMINGHAM, AL
04/27/2011 20:01:13 GMT
LAT: 33/10/19 N
LON: 86/46/11 W
ELEV: 646 FT
VCP: 212

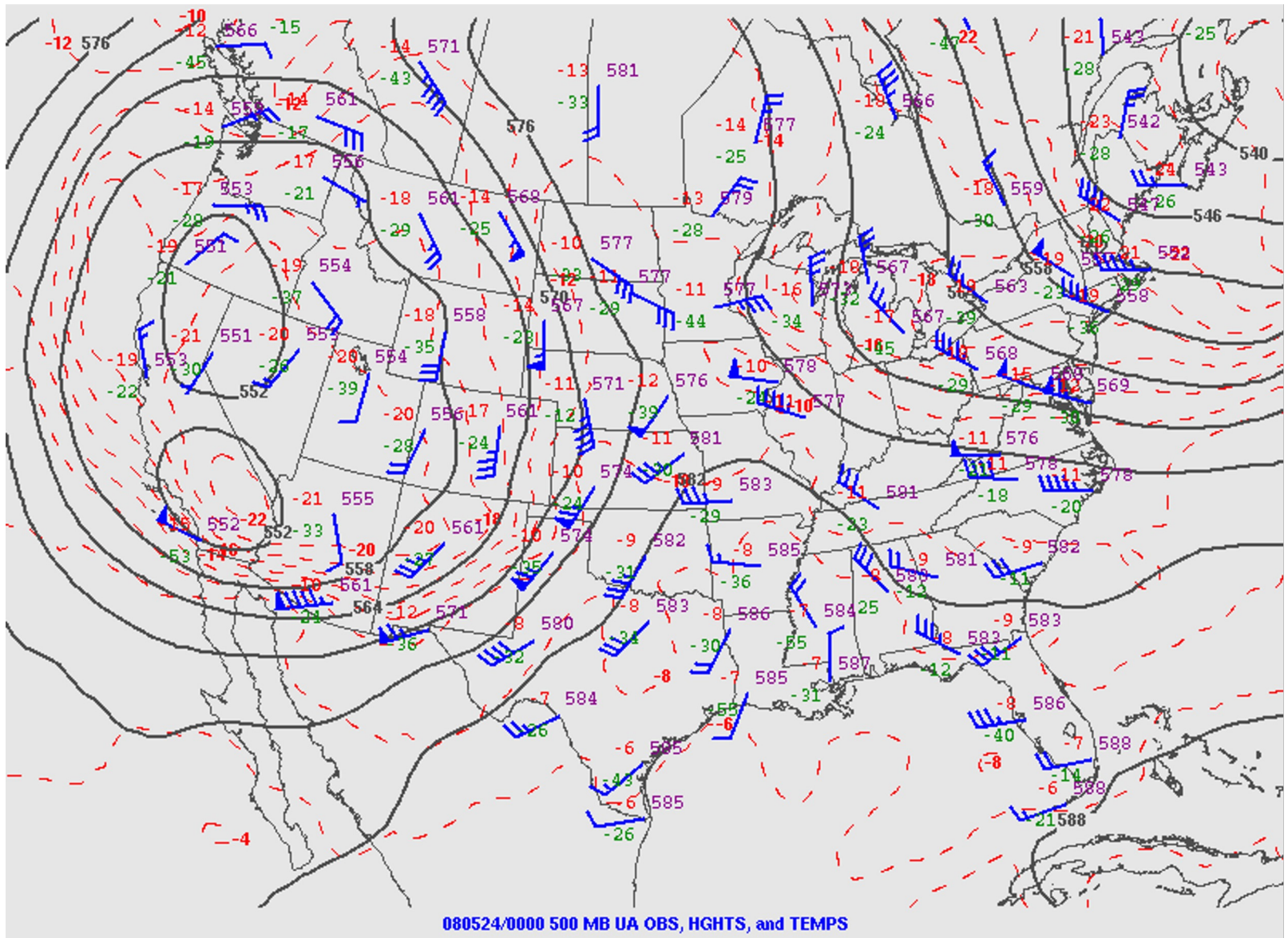
REFLECTIVITY
ELEV ANGLE: 0.53

Legend: dBZ



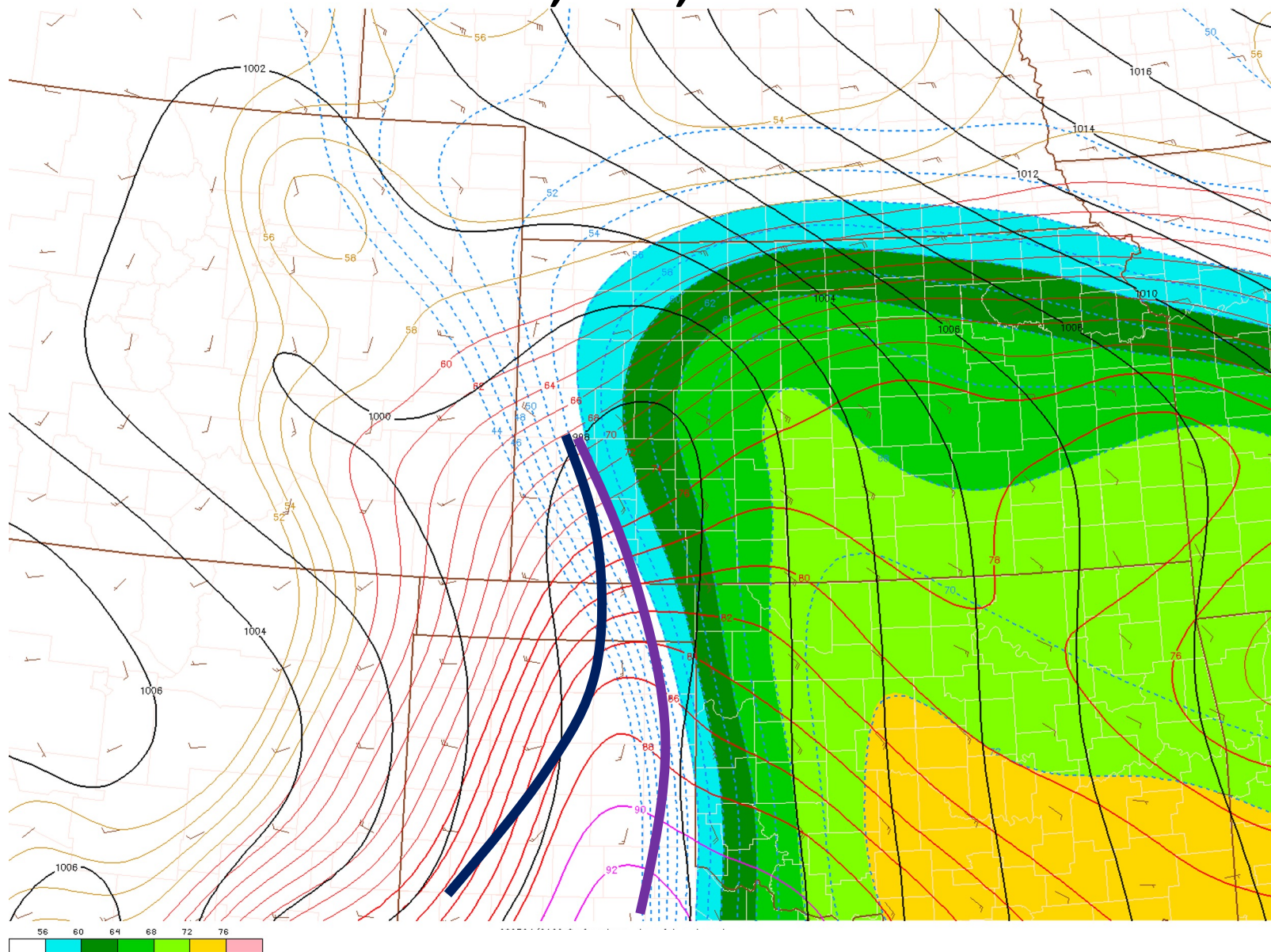
Forced Squall Line Case

- **Still some cross-boundary flow and shear vectors**
- **Stronger cap and moderate buoyancy**
- **Much stronger low-level convergence**
- **Front moved as fast as the storms**
 - **Relative speed is often overlooked. A surging front may travel as fast if not faster than the storms that form on it.**



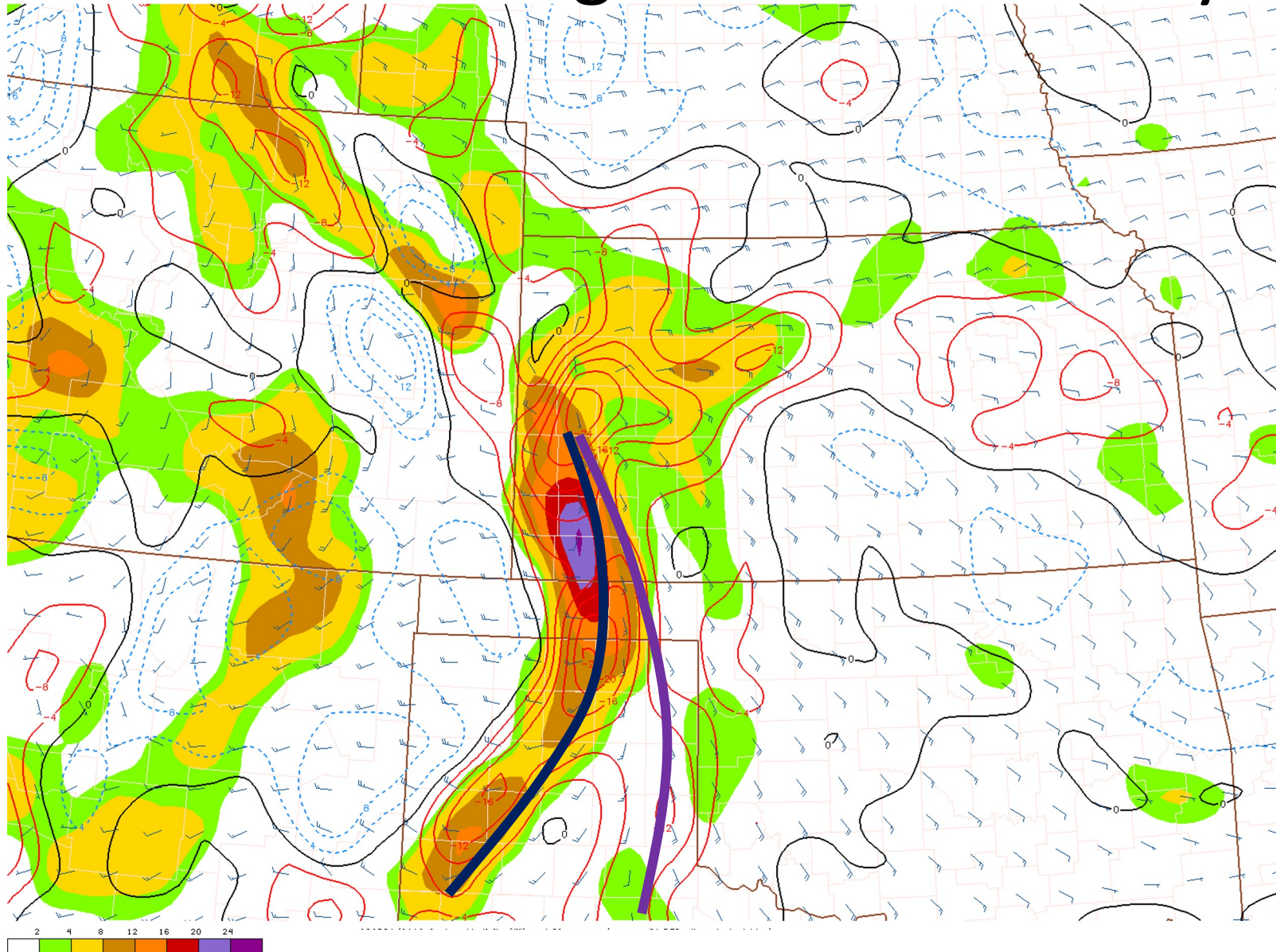
24 MAY 2008 00z

Surface T, Td, and PMSL



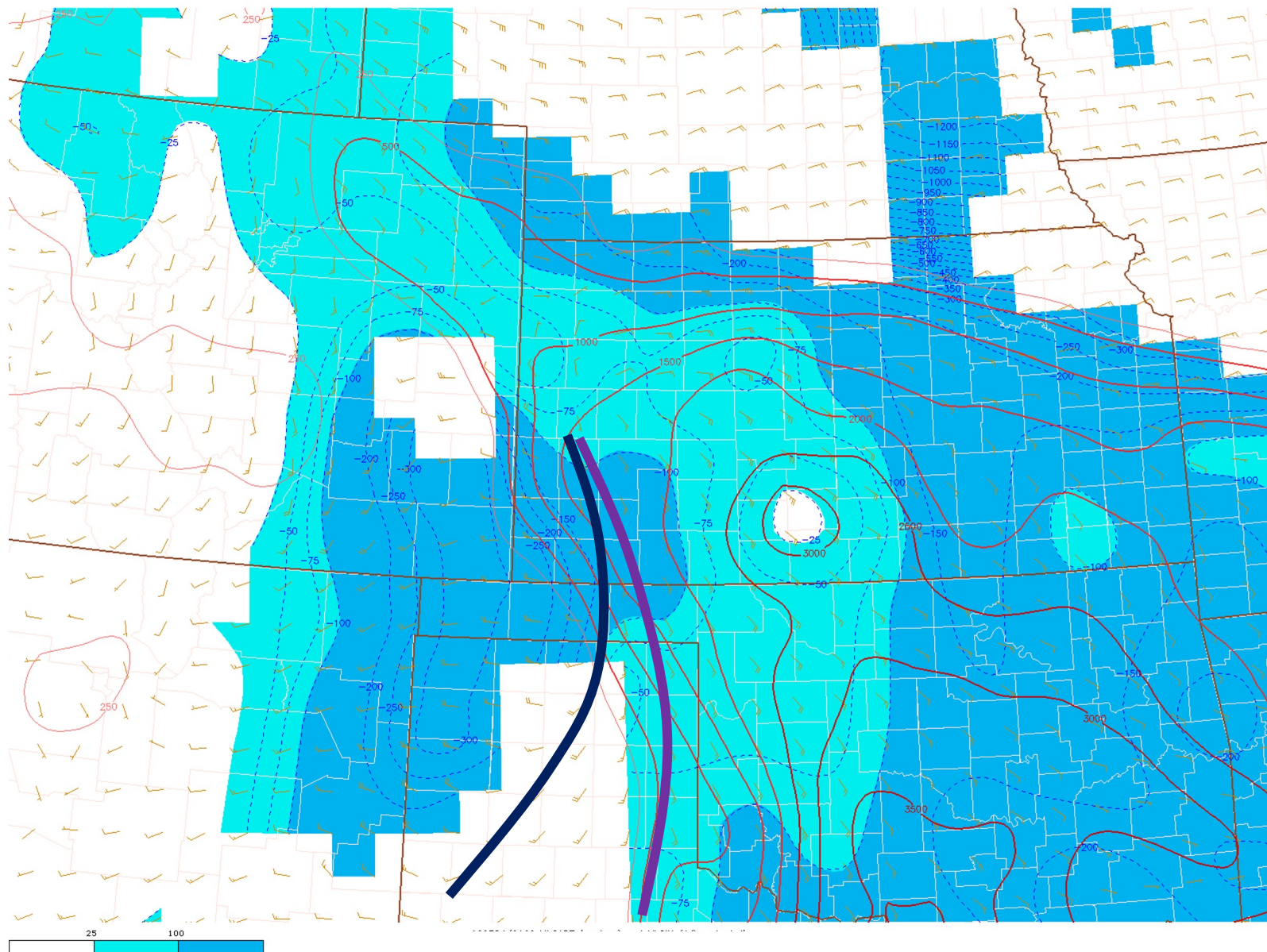
24 MAY 01z

Surface convergence and vorticity



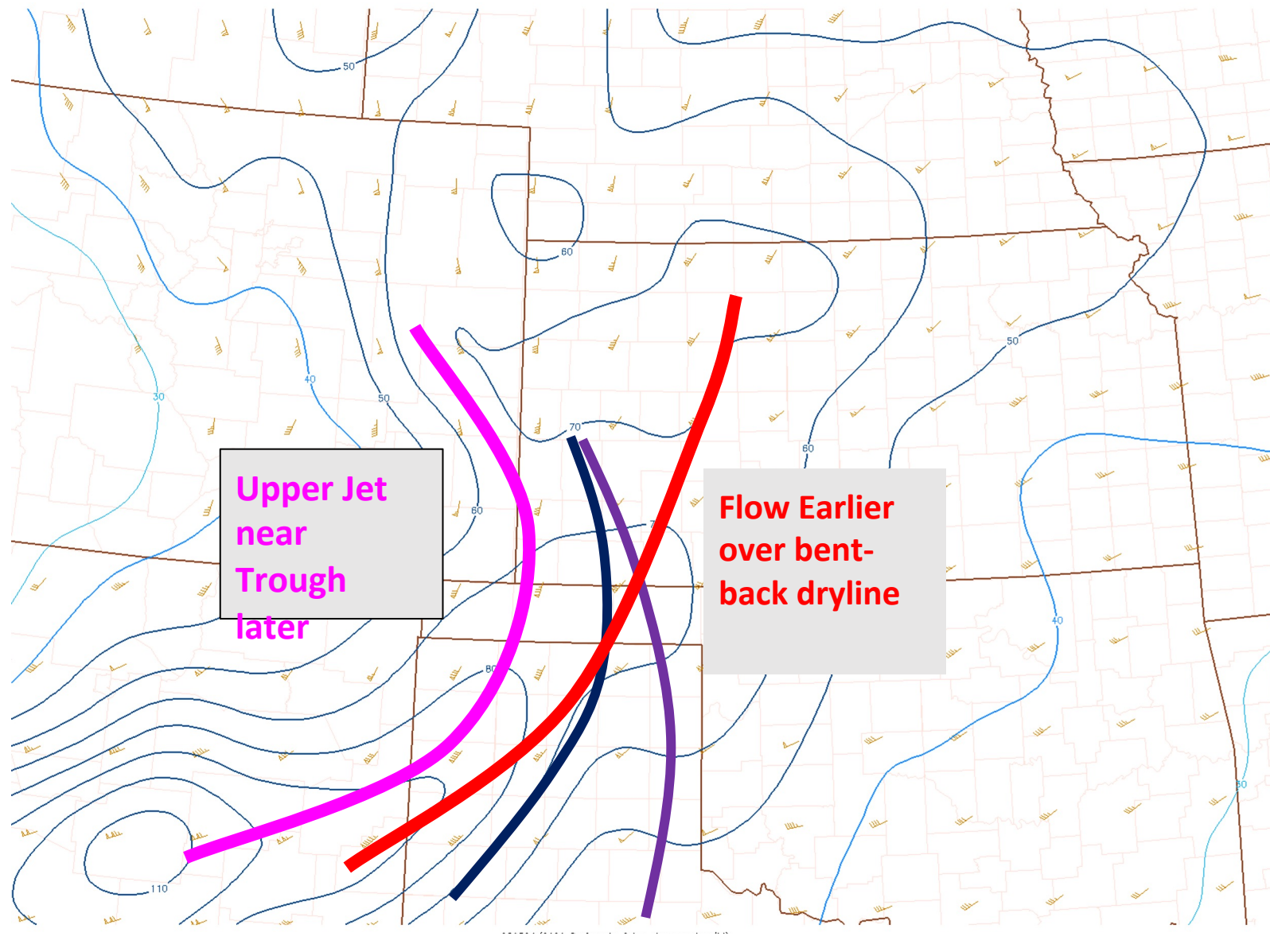
24 MAY 01z

MLCAPE and MLCIN



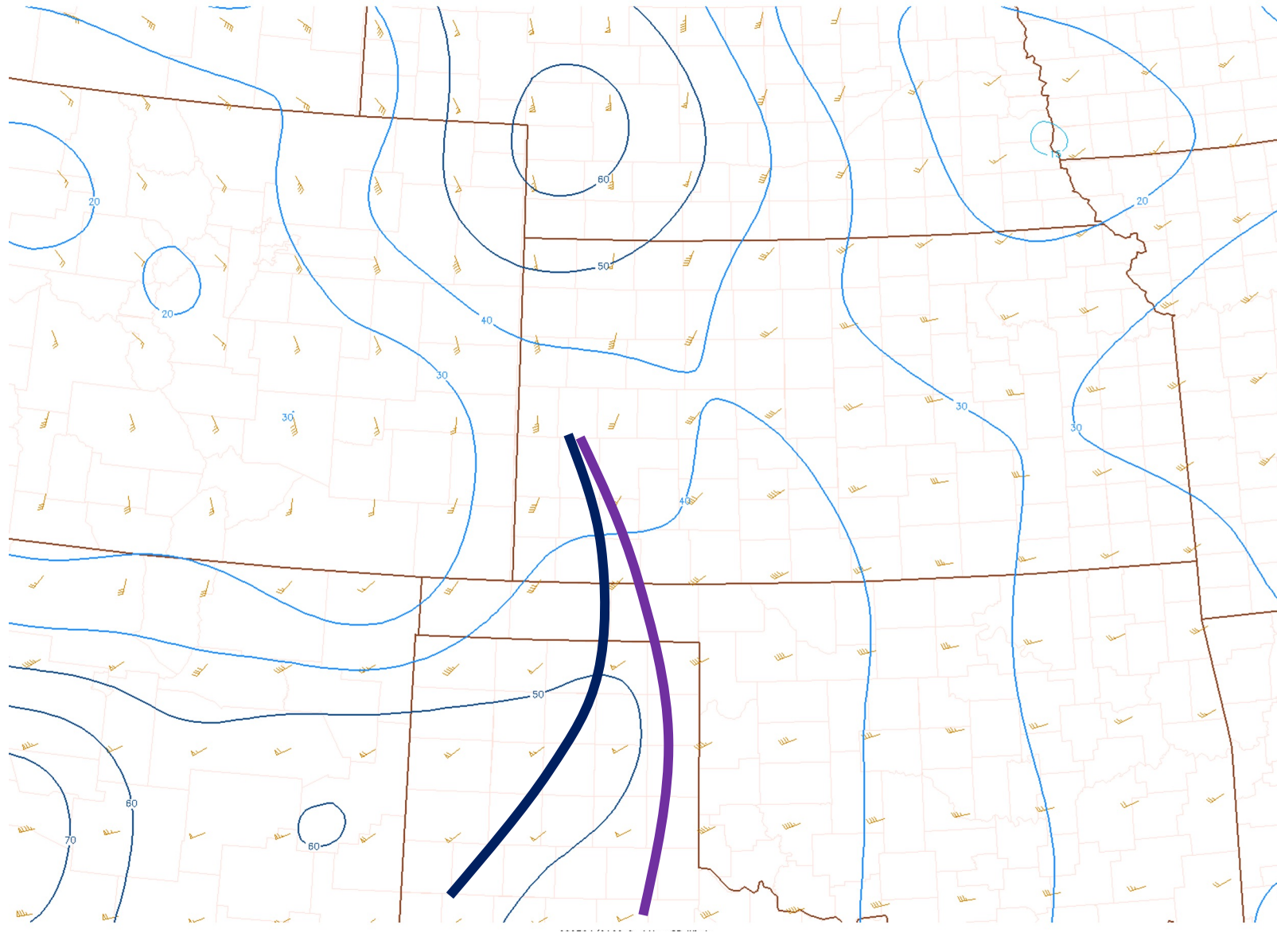
24 MAY 01z

0-6 km shear vectors



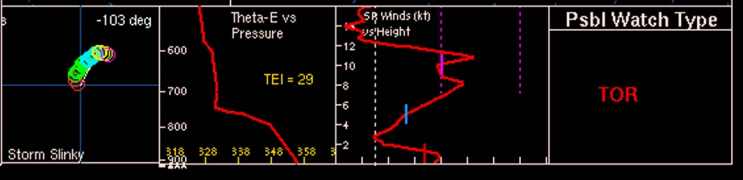
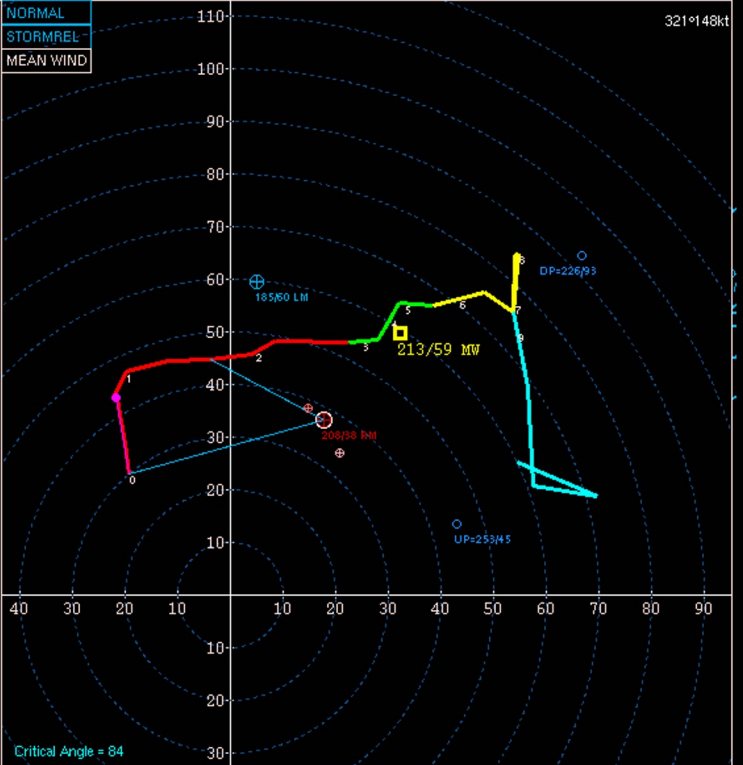
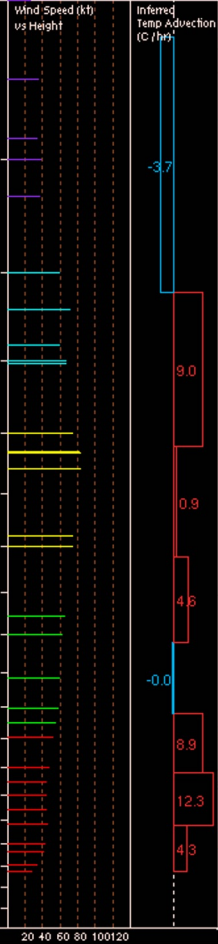
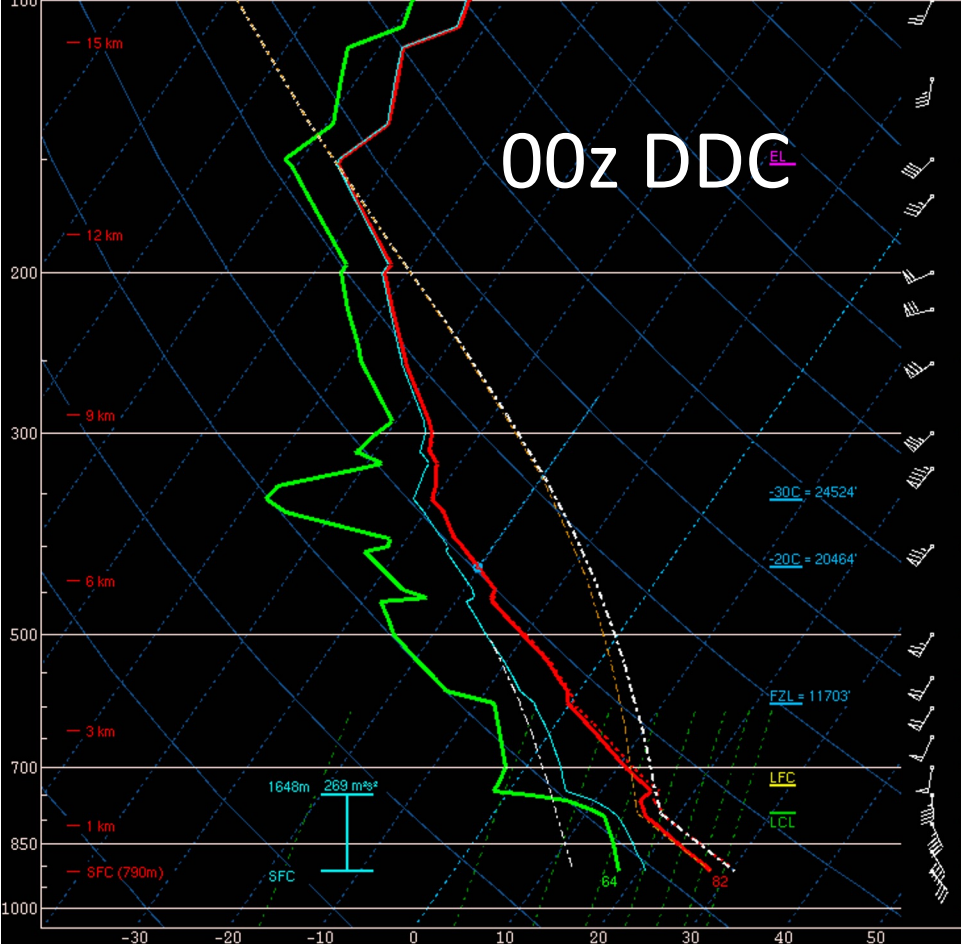
24 MAY 01z

9-11 km storm-relative winds



24 MAY 01z

DDC 080524/0000 (Archive)



	CAPE	CINH	LCL	LI	LFC	EL
SB PARCEL	3110	-2	1270m	-10	1852m	43028'
ML PARCEL	2632	-15	1415m	-9	2011m	38319'
FCST SFC	3171	-0	1706m	-10	1852m	43028'
MU PARCEL	3110	-2	1270m	-10	1852m	43028'
EFF PARCEL	1688	-44	1816m	-7	2488m	35395'
USER DEF	2391	-23	1487m	-8	2251m	37891'

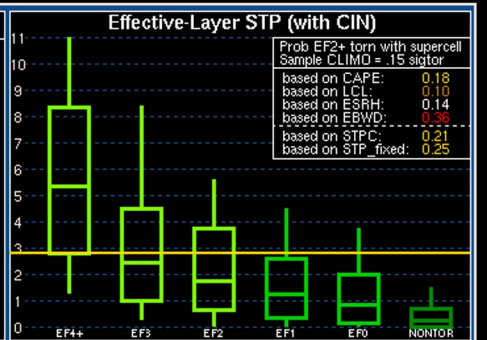
	SRH(m2/s2)	Shear(kt)	MnWind	SRW
SFC - 1 km	200	19	149/41	93/39
SFC - 2 km	303	33	159/42	99/34
SFC - 3 km	387	51	170/42	106/27
Eff Inflow Layer	269	27	155/42	96/36
SFC - 6 km	71	188/45	131/17	
SFC - 8 km	85	193/47	151/15	
LCL - EL (Cloud Layer)	44	208/56	209/18	
Eff Shear (EBWD)	75	189/46	135/16	

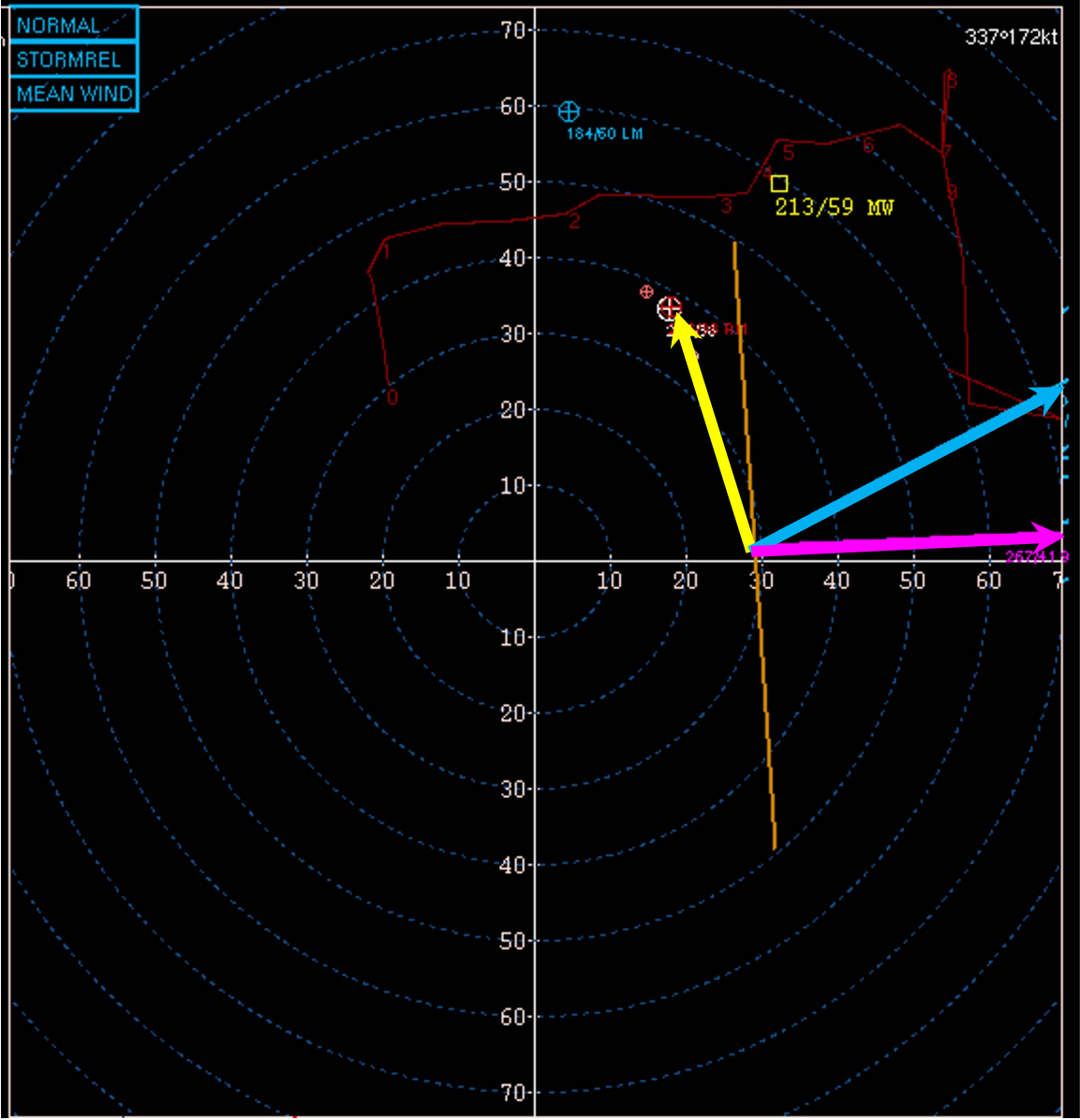
	3-CAPE = 67 J/kg	WBZ = 9690'	WINDG = 1.7
PW = 1.15 in			
K = 35	DCAPE = 1396 J/kg	FZL = 11703'	ESP = 1.9
MidRH = 42%	DownT = 55 F	ConvT = 87F	MMP = 0.99
LowRH = 64%	MeanW = 13.5 g/kg	MaxT = 87F	NCAPE = 0.28

	3-6km Agl Lapse Rate = 23 C / 8.4 C/km
Sfc-3km Agl Lapse Rate = 23 C / 7.8 C/km	
850-500mb Lapse Rate = 32 C / 8.0 C/km	
700-500mb Lapse Rate = 21 C / 8.1 C/km	

SARS - Sounding Analog System	
SUPERCELL	SGFNT HAIL
browse to ~thompson / sup / snd / *	browse to ~jewell / hail / snd / *
No Quality SUPERCELL Matches	
(1 matches out of 856 sndgs)	(82 matches out of 1148 sndgs)
SARS: NONTOR (0% TOR)	SARS: **SIG HAIL** (8% SIG)

Effective-Layer STP (with CIN)	
EF4+	EF3
EF2	EF1
EF0	NONTOR



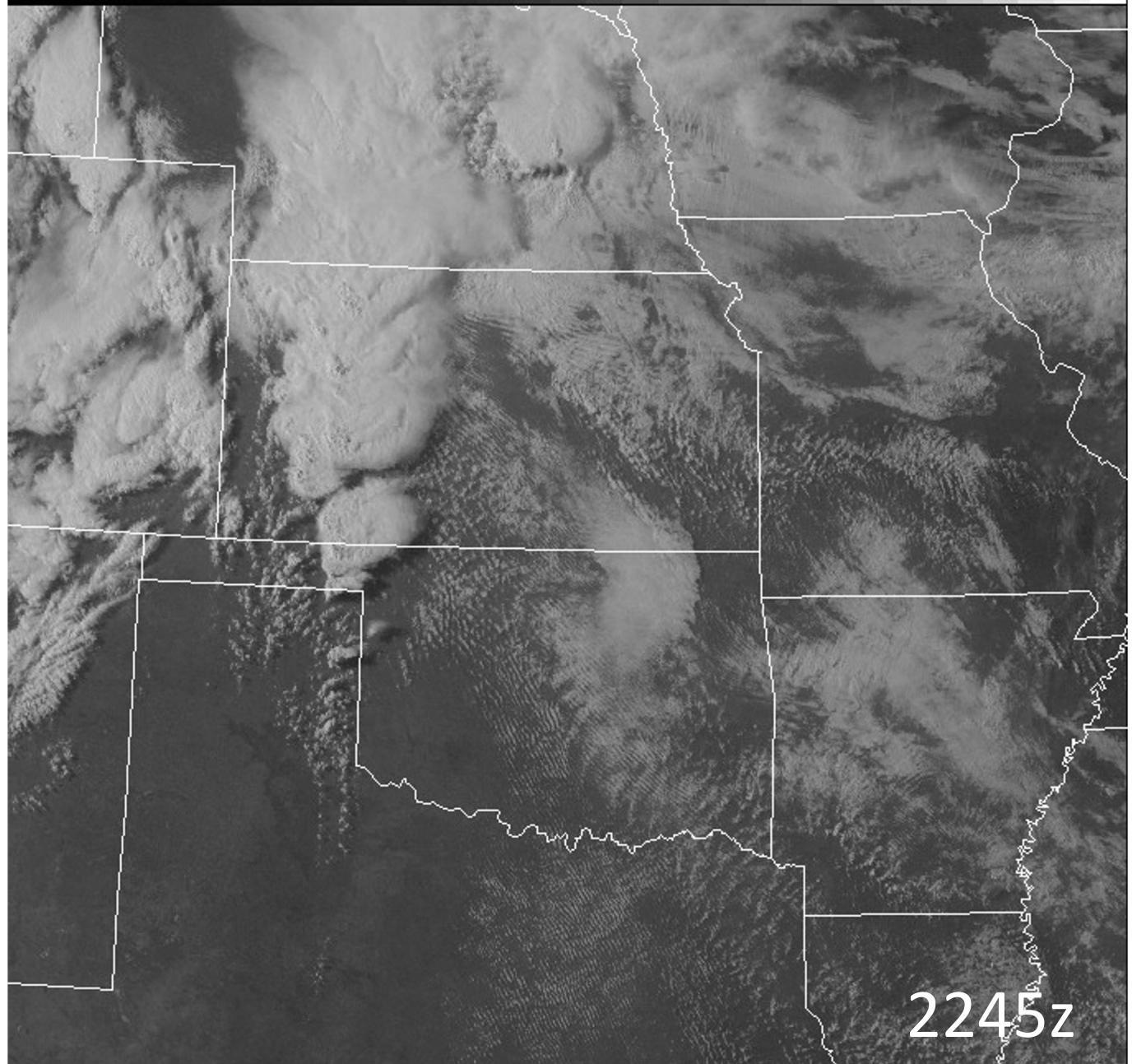


2245 UTC Fri 23 May 2008

Visible Satellite

<http://adds.aviationweather.gov>

0 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60 63 66 69 72 75 78 81 84 87 90 93



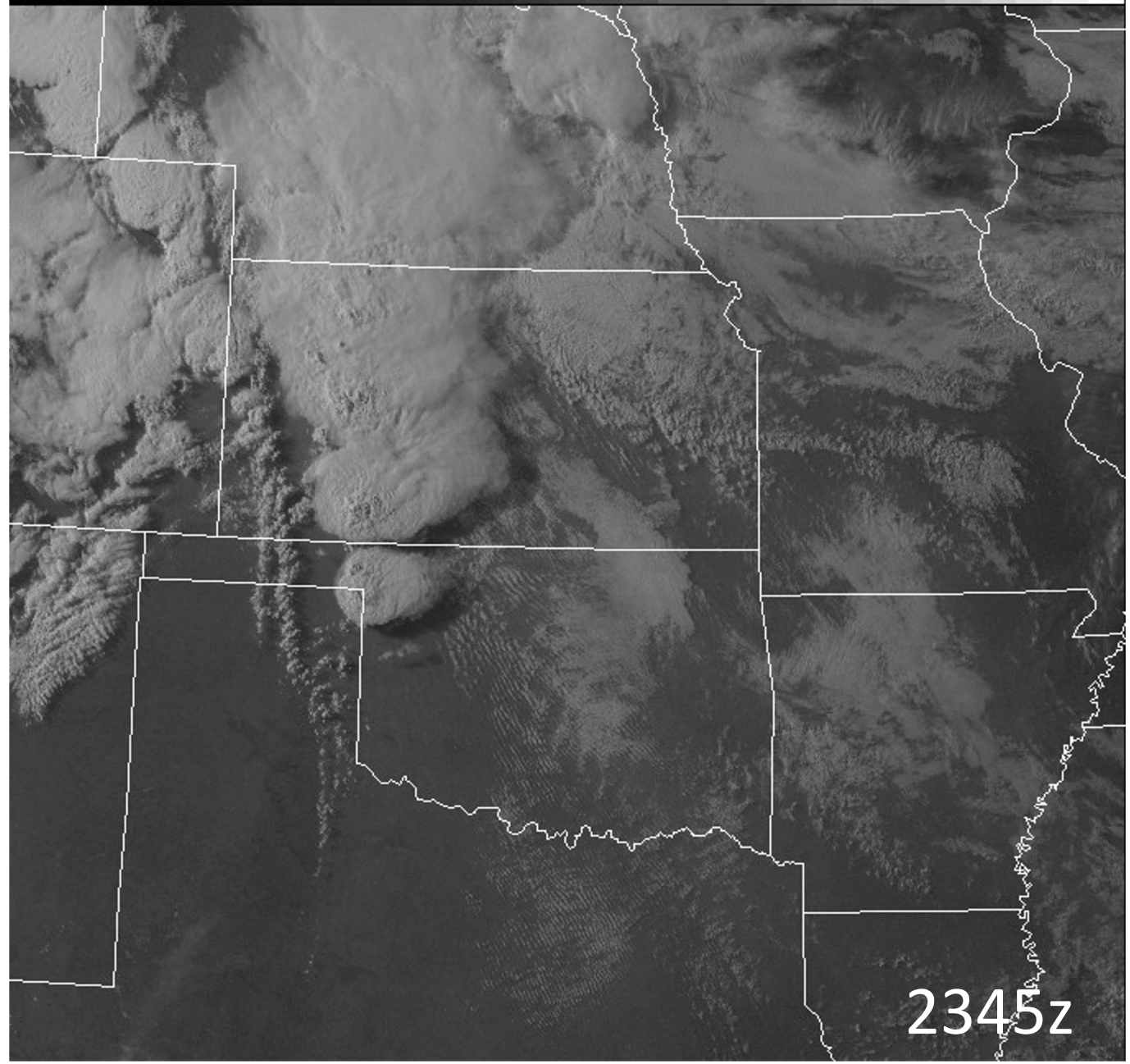
2245z

2345 UTC Fri 23 May 2008

Visible Satellite

<http://adds.aviationweather.gov>

0 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60 63 66 69 72 75 78 81 84 87 90 93



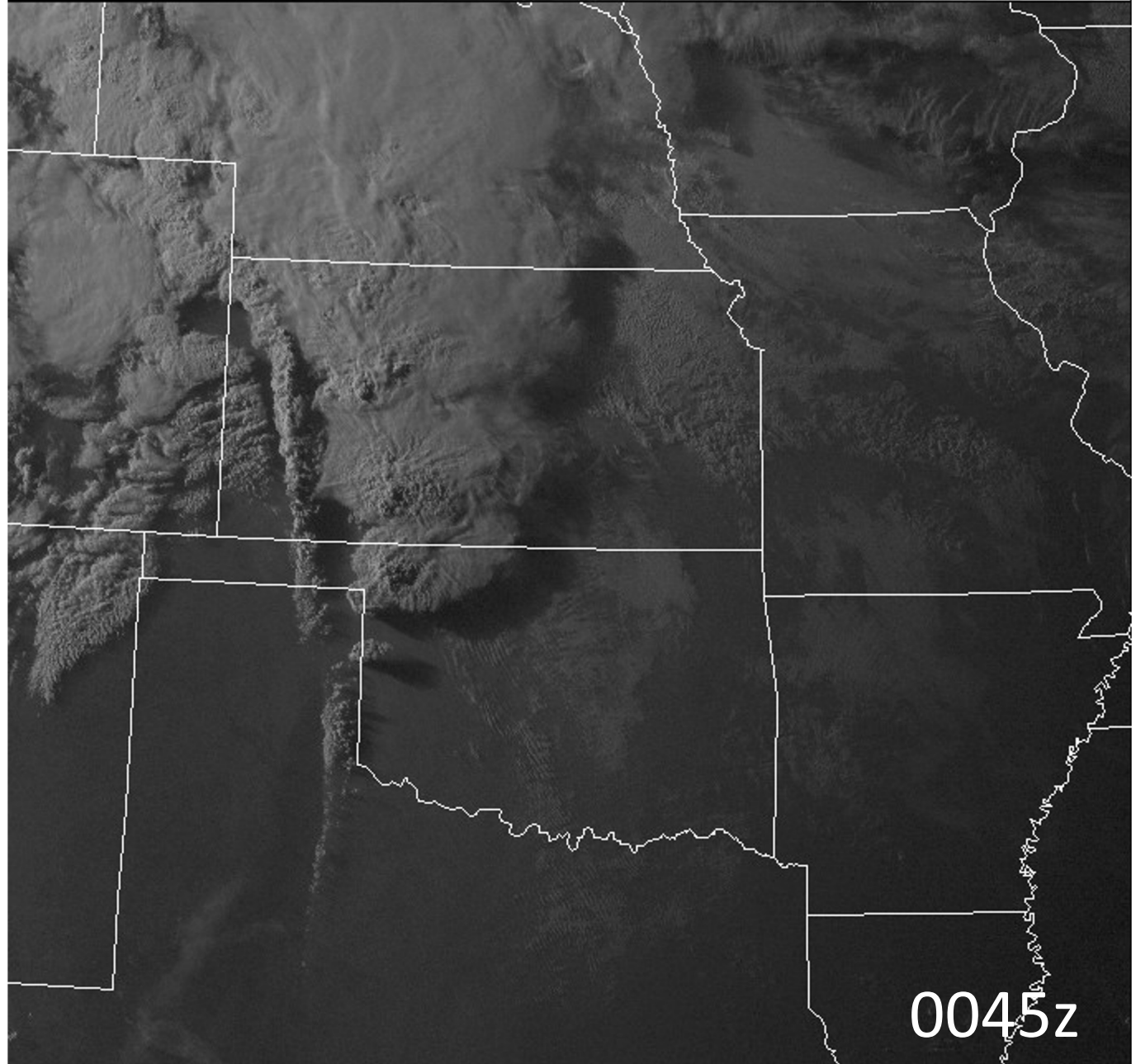
2345z

0045 UTC Sat 24 May 2008

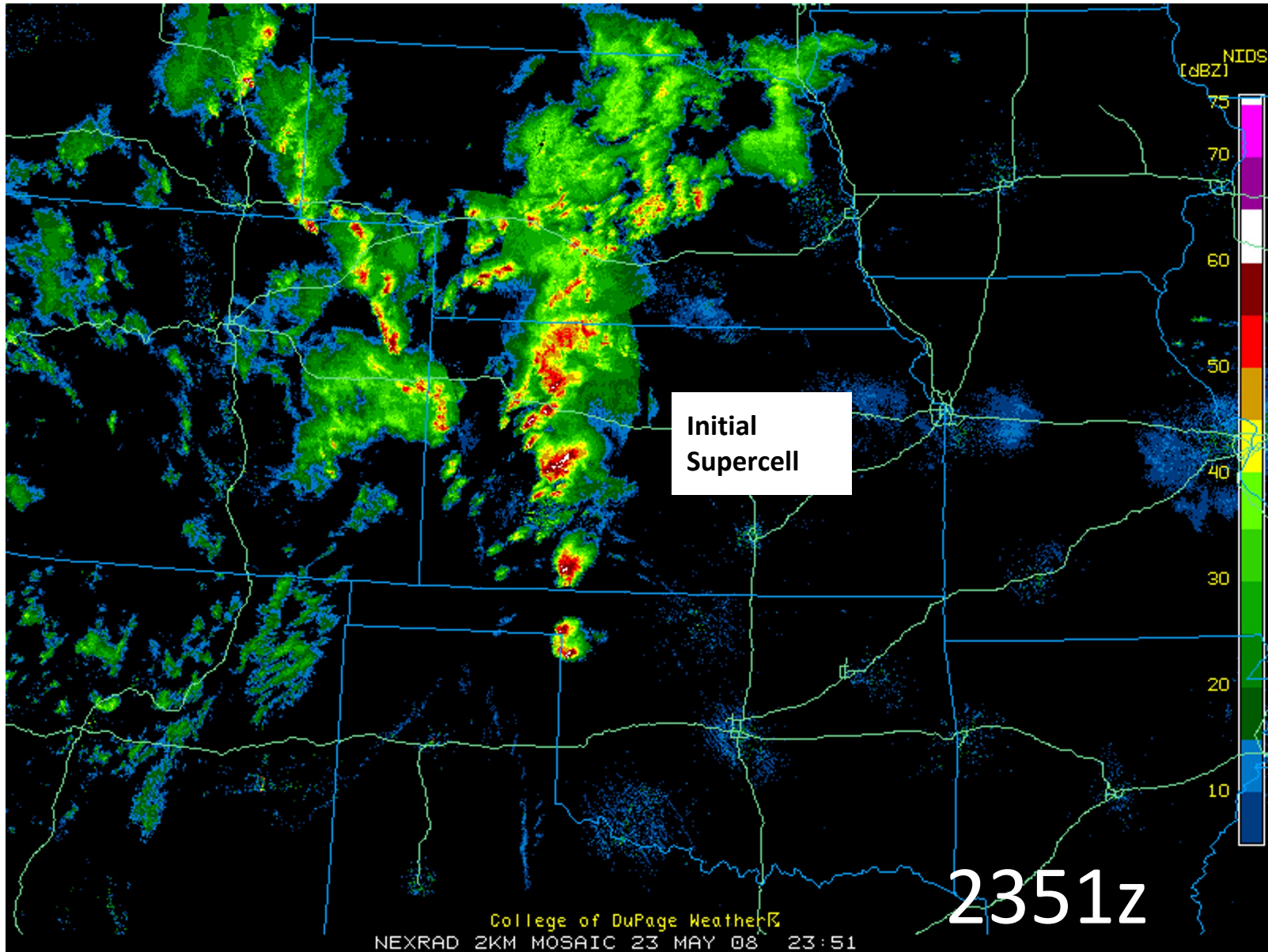
Visible Satellite

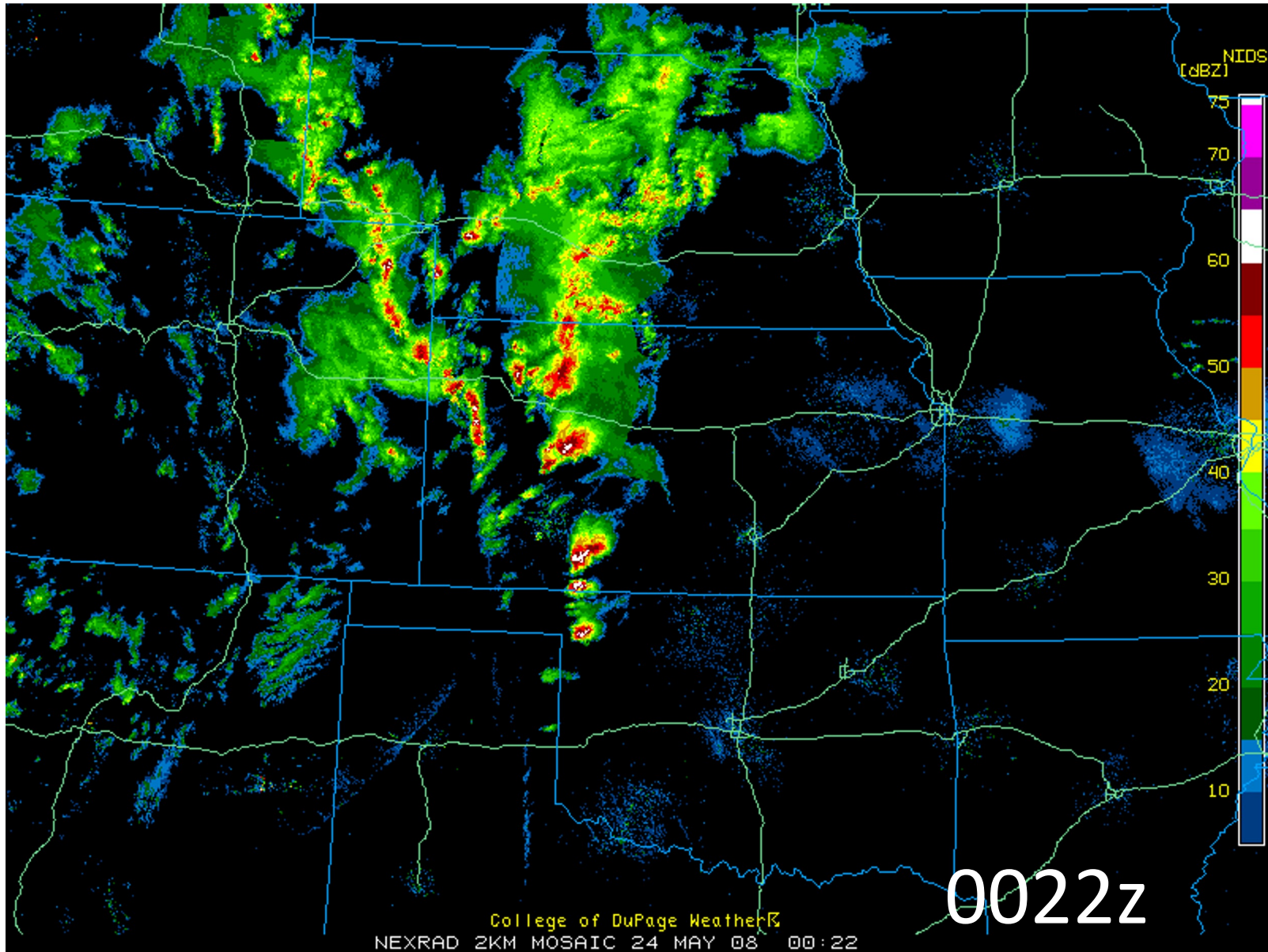
<http://adds.aviationweather.gov>

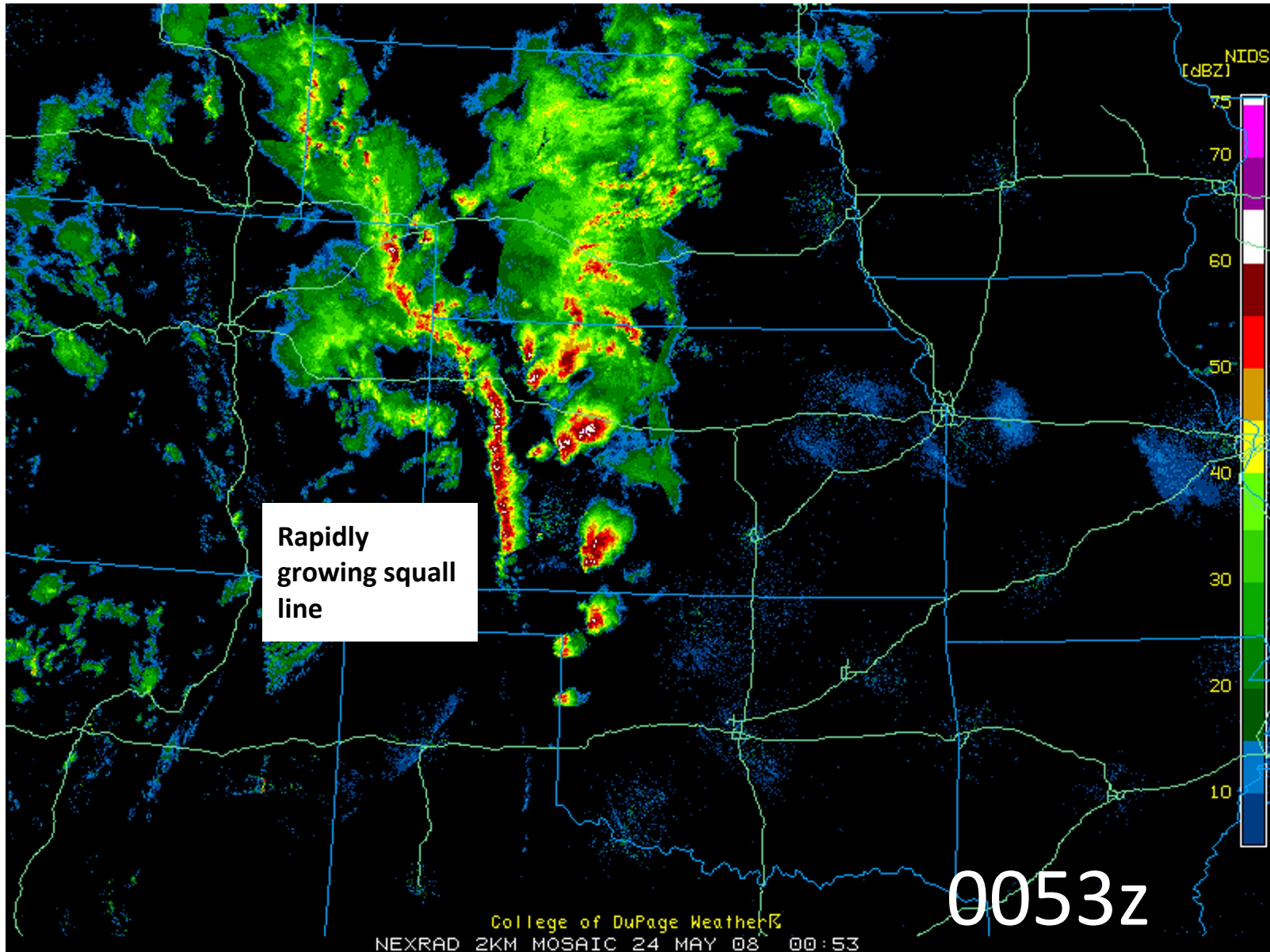
0 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60 63 66 69 72 75 78 81 84 87 90 93



0045z



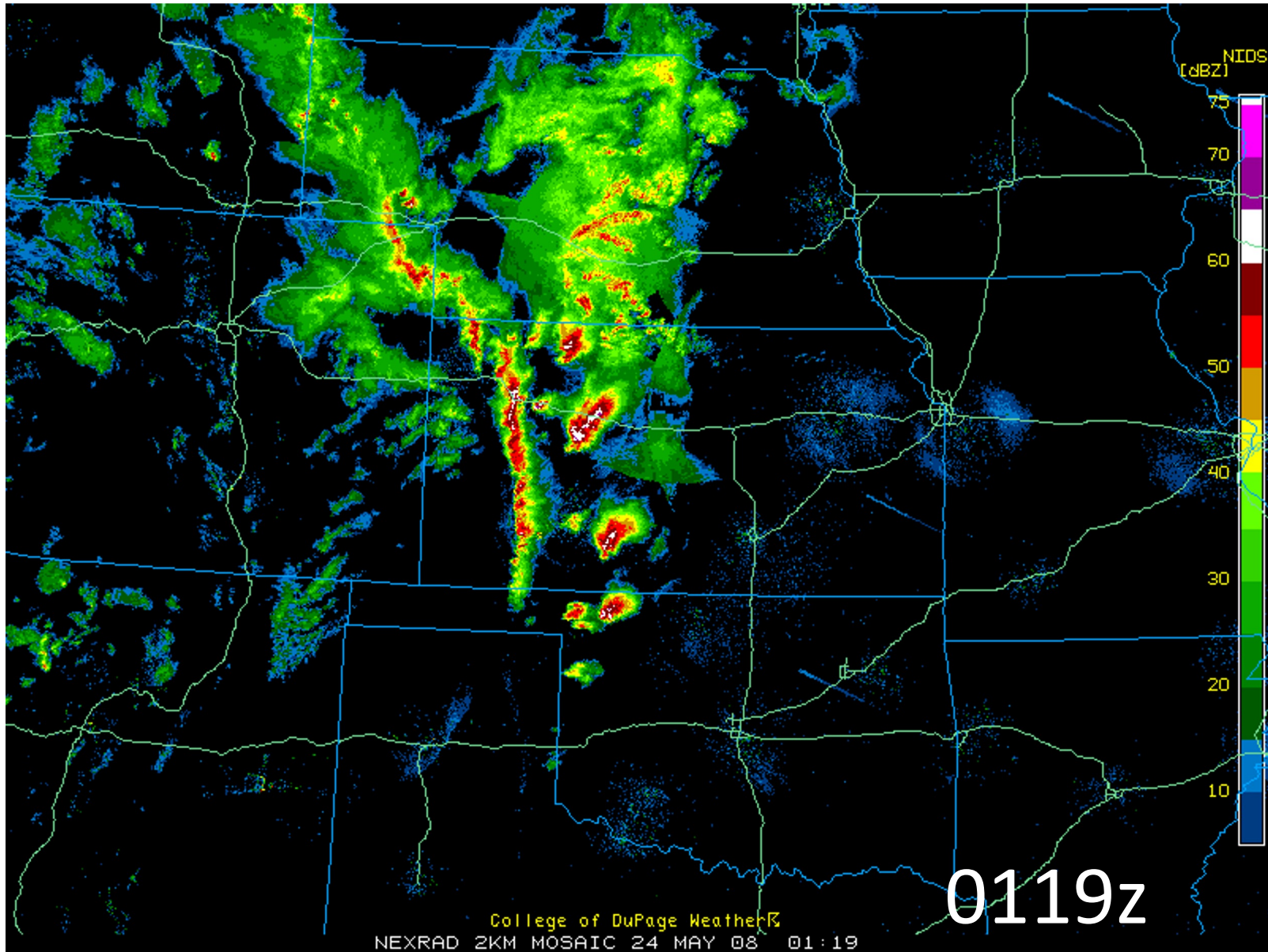


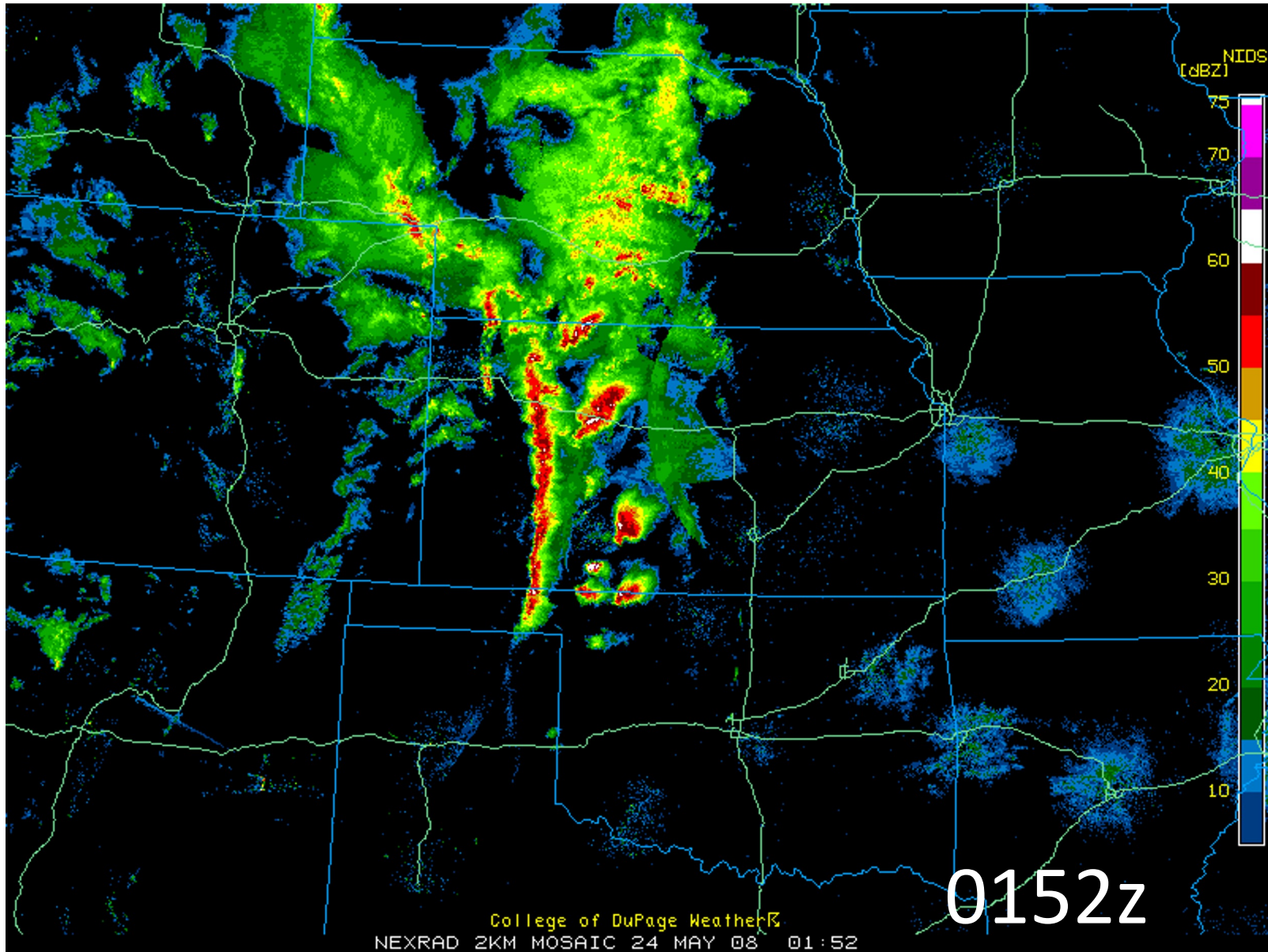


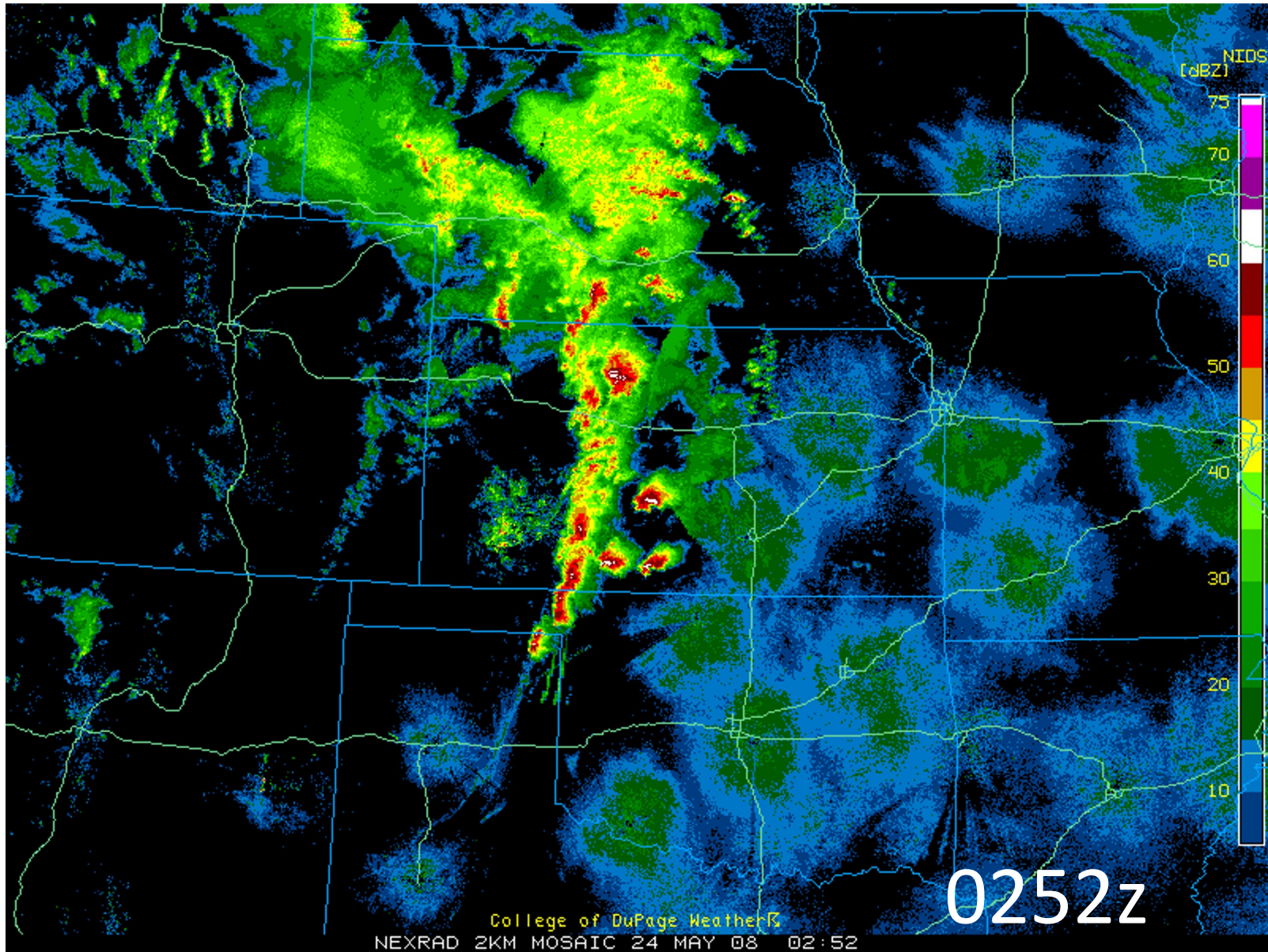
Rapidly
growing squall
line

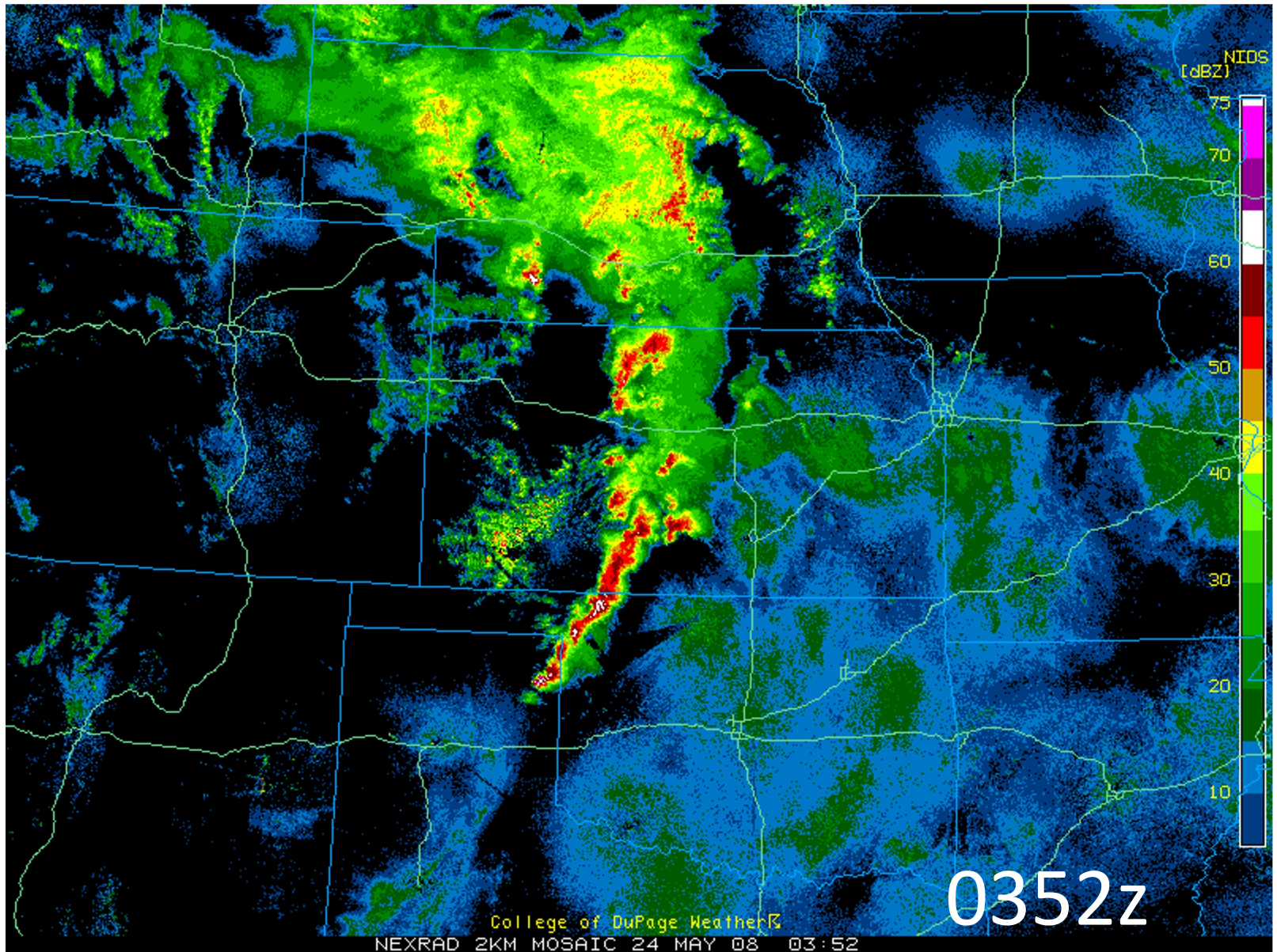
0053z

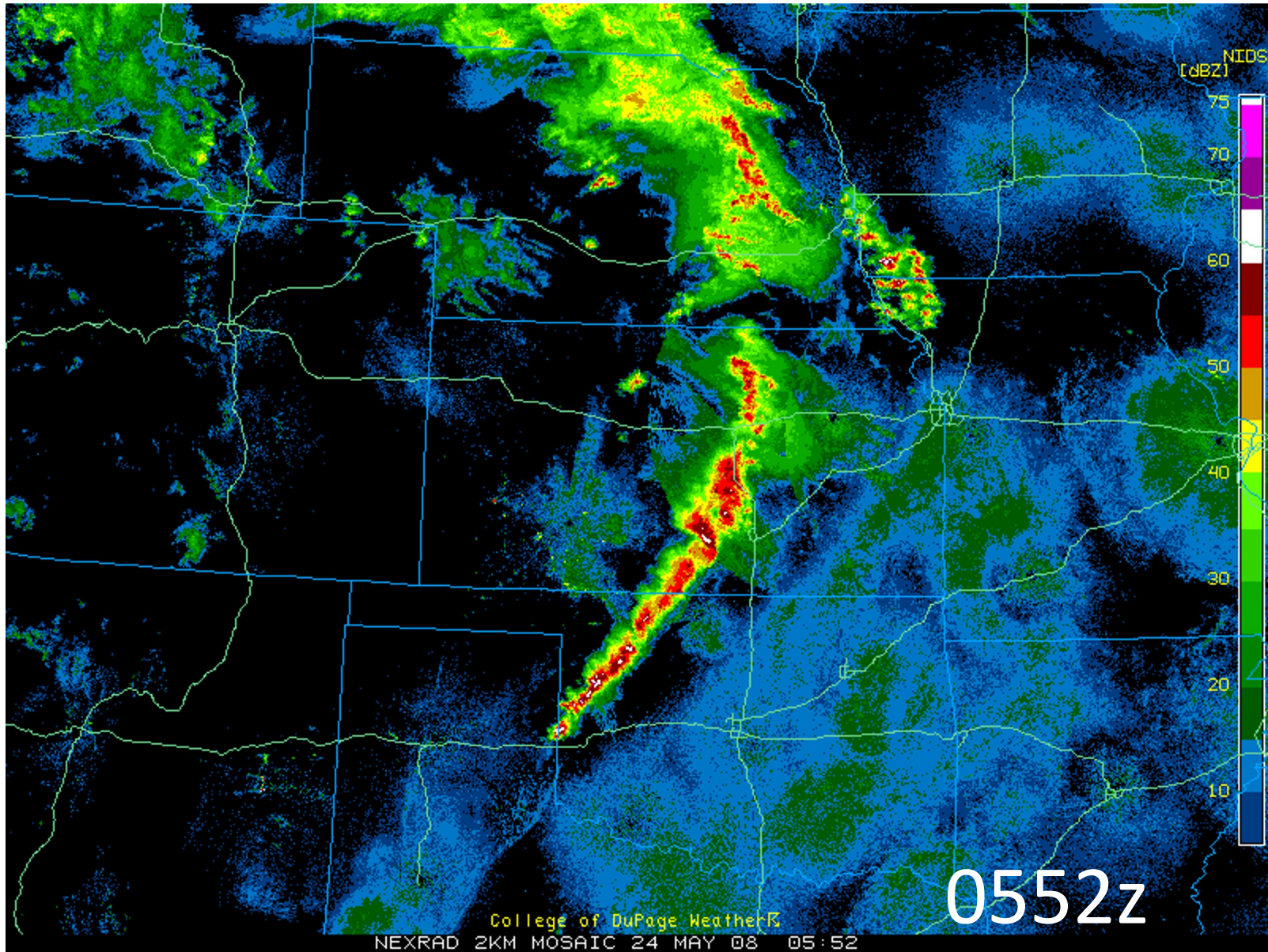
College of DuPage Weather
NEXRAD 2KM MOSAIC 24 MAY 08 00:53











Summary

- **Convective mode and storm organization are primarily modulated by vertical shear.**
- **Strength of forcing for ascent is likely the most important factor, along with whether or not storms will move off a boundary.**
- **Shear Vector orientation and storm relative flow determine residence time within zones of ascent along boundaries.**
- **Shear vector orientation is more important in cases with weaker forcing for ascent, where storm interactions could lead to upscale growth**

What is the approximate life time of a single cell thunderstorm?

1 hour

30 min

3 hours

10 min



What are the three main types of thudnerstorms?

Single Cell, Multi Cells
and Supercells

Single Cells Squall Lines
and Clusters

Supercells Multi Cell
Clusters and Single Cells.



What is the best combination of flow aloft and lift to get linear storms?

Strong forcing for ascent and flow across the initiating boundary.

Weak forcing for ascent and flow parallel to the initiating boundary.

Strong forcing for ascent and flow parallel to the initiating boundary.

Weak forcing for ascent and flow across the initiating boundary.

