Forecasting Mesoscale Convective Systems

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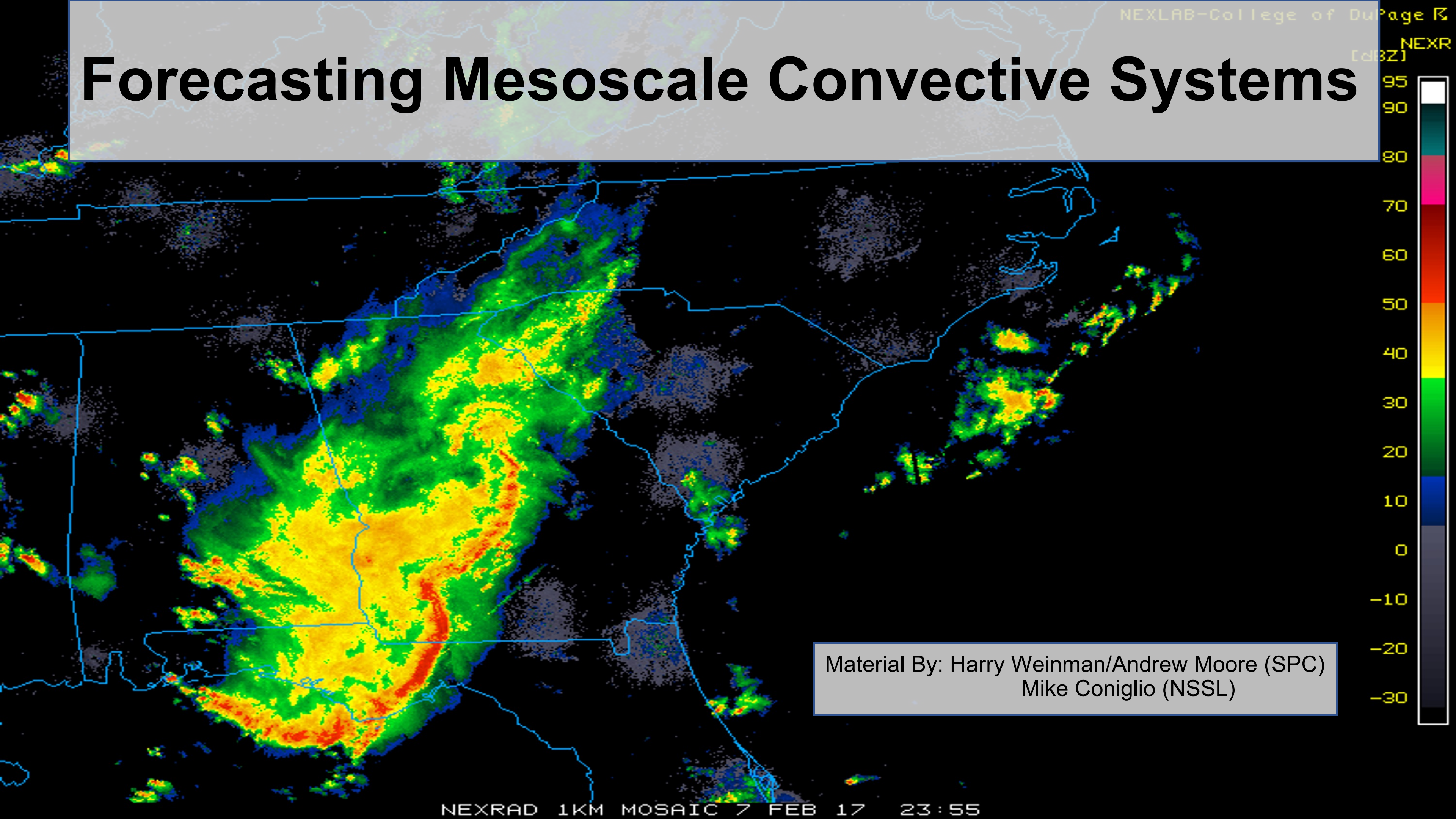


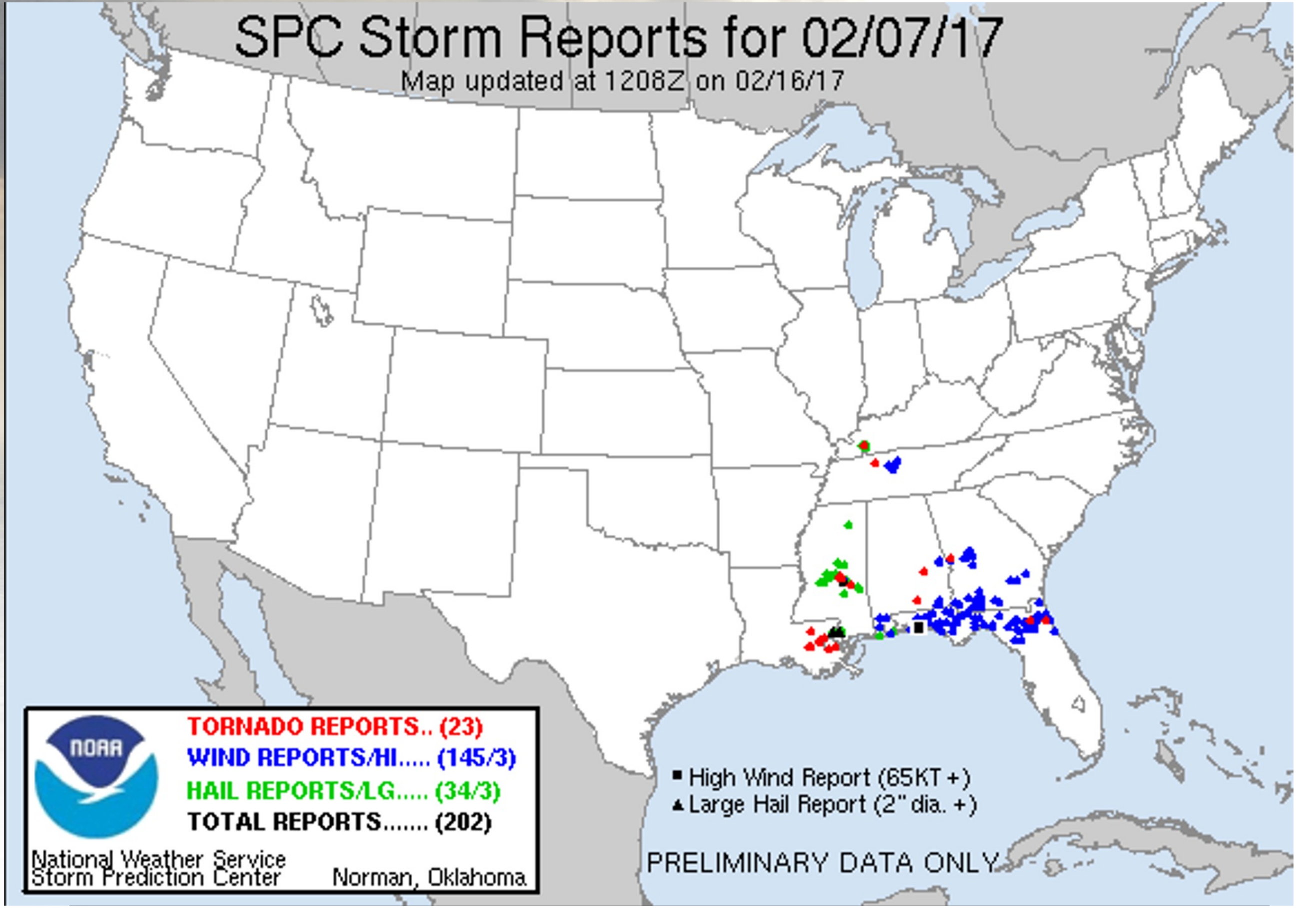
Mesoscale **C**onvective **S**ystem

"A cloud system that occurs in connection with an ensemble of thunderstorms and produces a contiguous precipitation area on the order of 100 km or more in horizontal scale in at least one direction.

An MCS exhibits deep, moist convective overturning contiguous with or embedded within a mesoscale vertical circulation that is at least partially driven by the convective overturning."

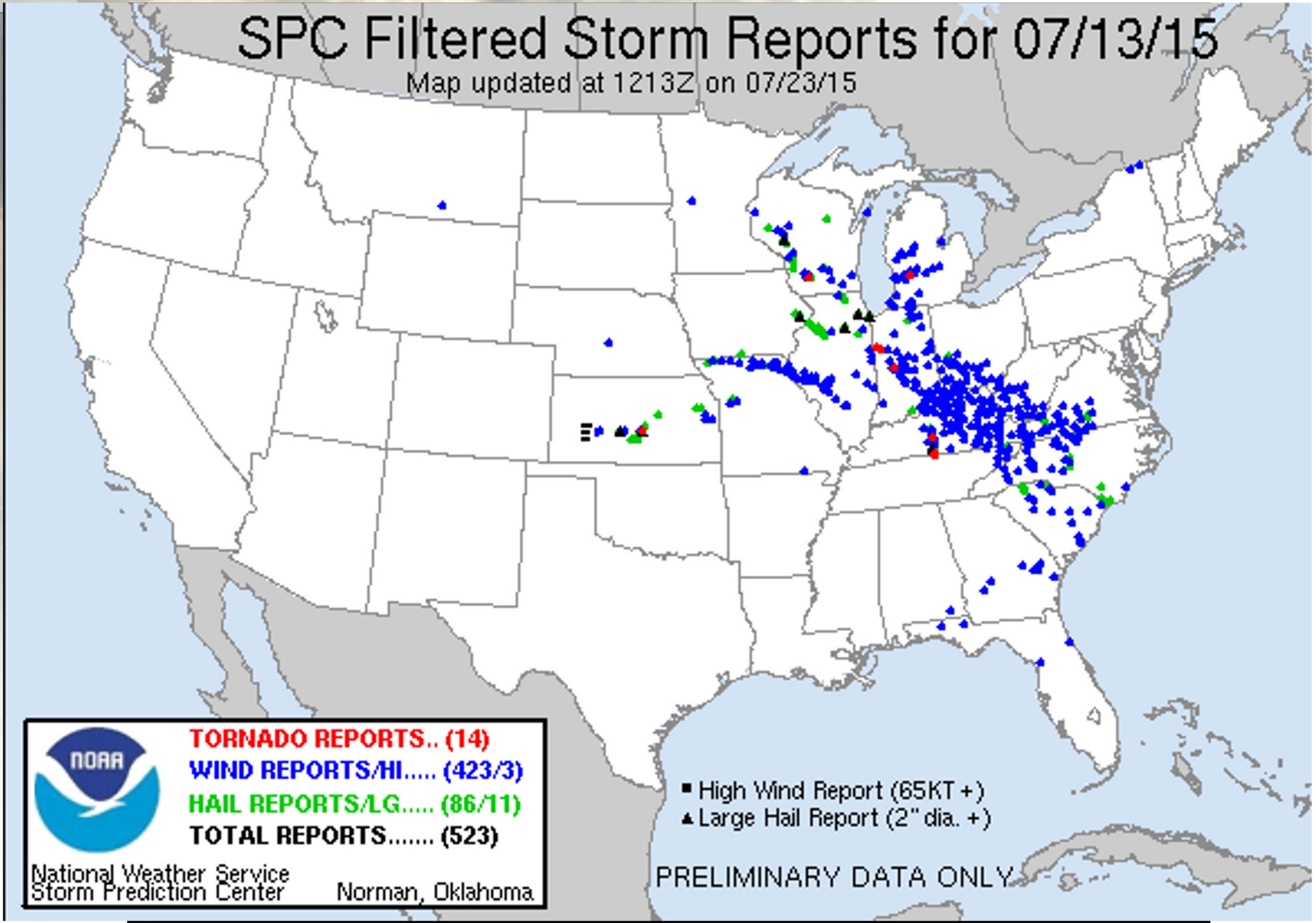
-- AMS Glossary

February 7, 2017



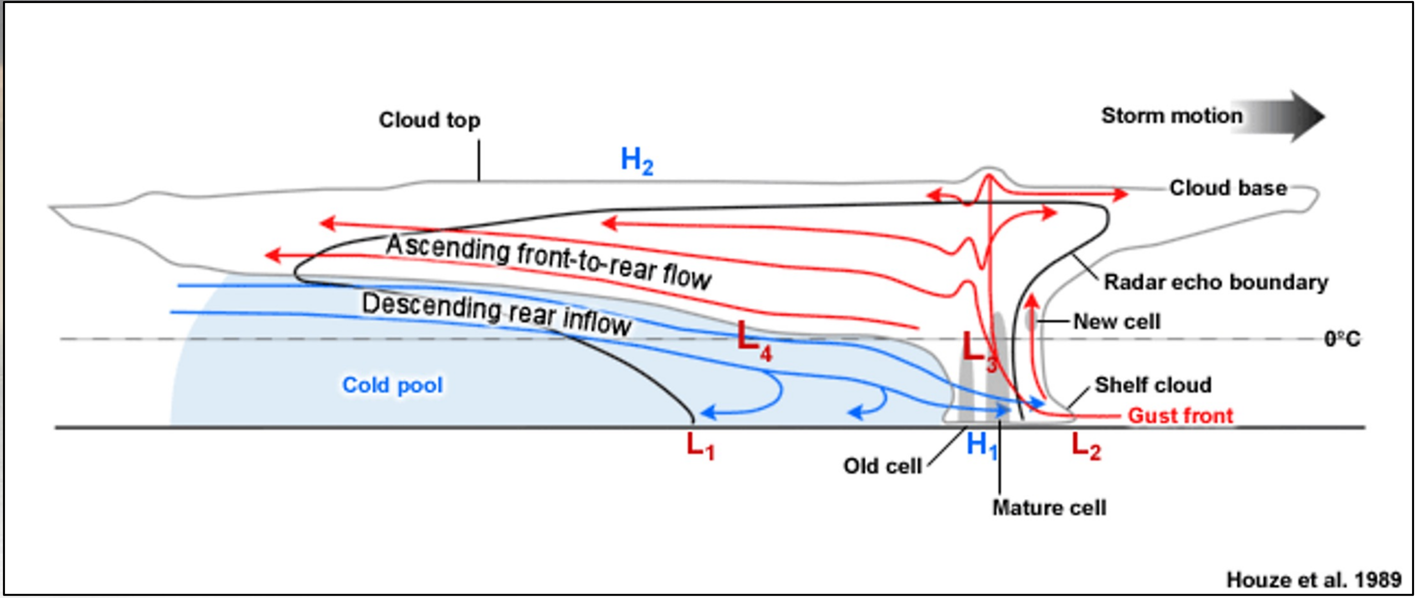
SPC (2017)

July 13, 2015



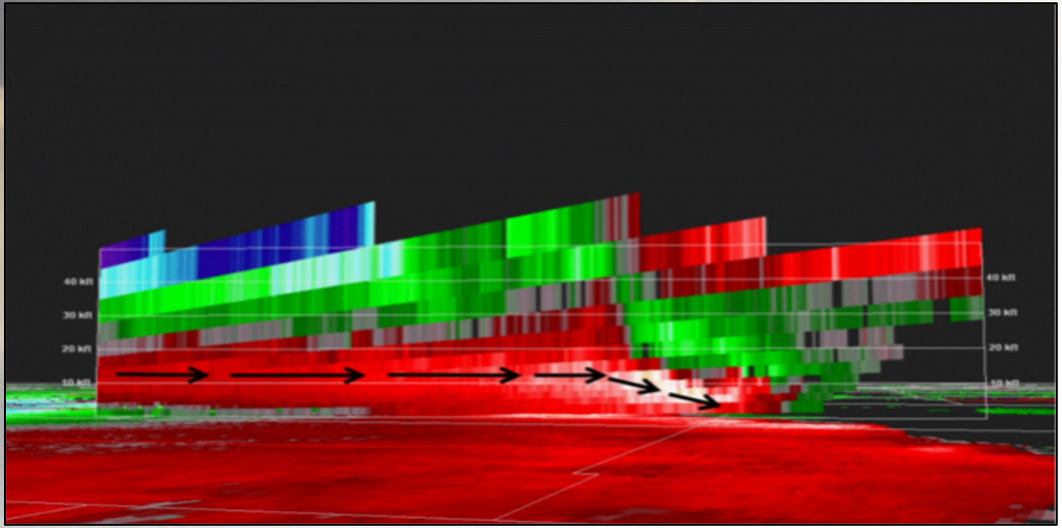
SPC (2015)

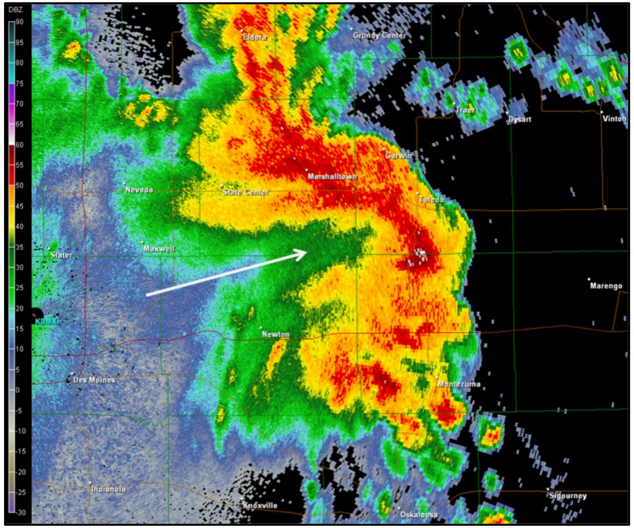
MCS Characteristics



Cross section of a classic MCS (trailing stratiform)

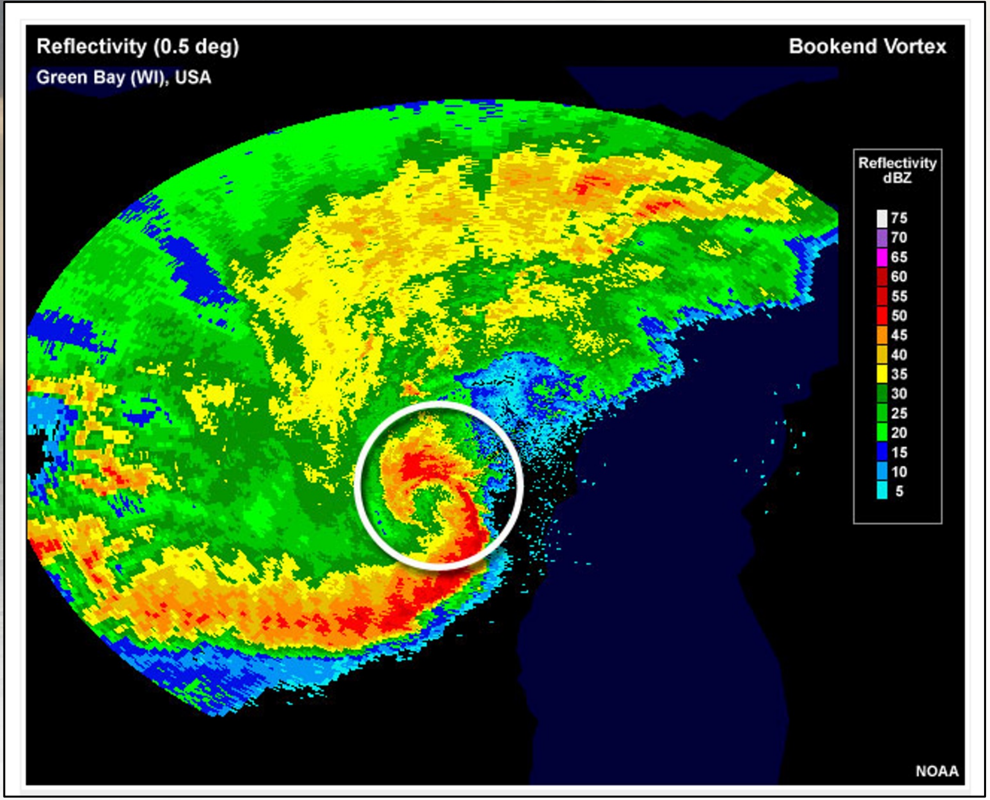
MCS Characteristics





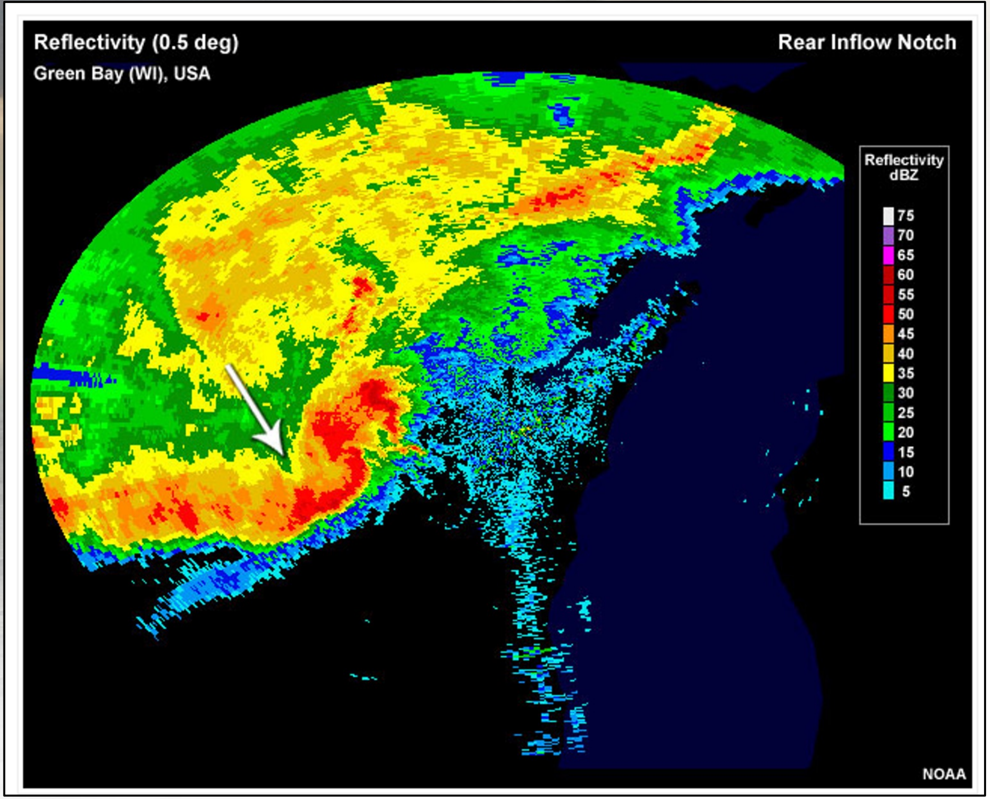
Strong cold pools, mesoscale rear-inflow jets, and organized bow echoes are common features in severe MCSs

MCS Characteristics



Bookend Vortices common with mature bow echoes. Region of enhanced downdraft potential.

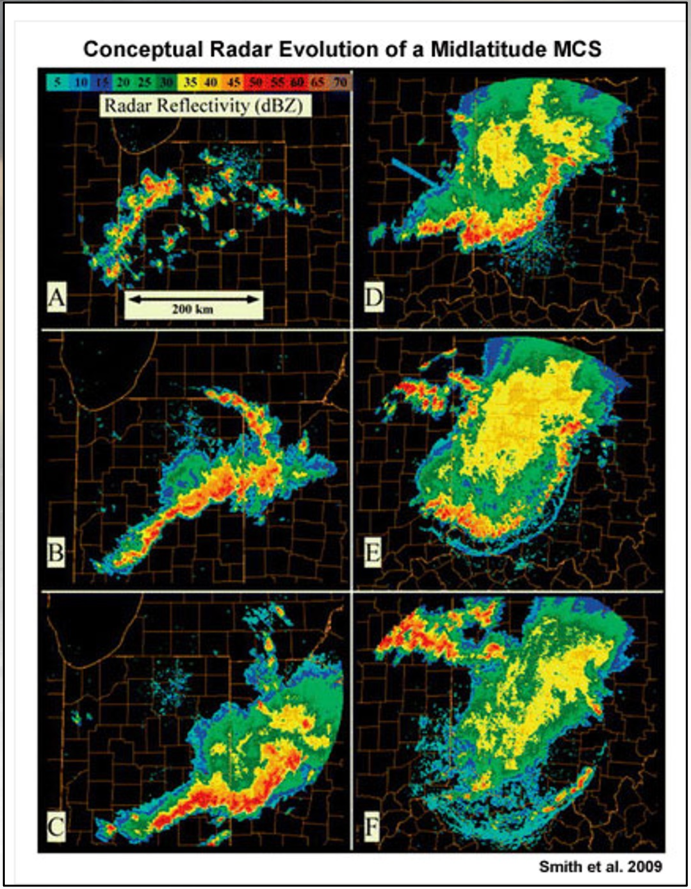
MCS Characteristics



Rear-Inflow Notch (RIN) marks evaporatively cooled, rear-inflow jet

Often evident just before and during leading-line transition into a bow echo

MCS Characteristics



Typical radar evolution of a linear, trailing stratiform MCS

MCS Characteristics

Environmental and Storm Characteristics of MCS Archetypes			
	Leading Stratiform (LS)	**Parallel Stratiform (PS)**	**Trailing Tratiform (TS)**
Upper-level system-relative flow	Rear-to-front	Strongly line-parallel	Front-to-rear
Lower-level system-relative flow	Front-to-rear and parallel	Strongly front-to-rear	Strongly front to rear
Cold Pool Strength	Weak	Moderate	Strong
CAPE (J/kg)	1009	813	1605
Propagation Speed (m/s)	7.1	11.4	13.0
Mean Duration (h)	6.5	6.3	12.2
Occurrence (% of all MCSs)	20%	20%	60%

Table 1: Outline of various attributes of linear MCSs. Adapted from Parker and Johnson (2000).

MCS Characteristics

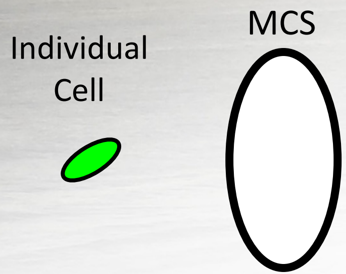
Severe MCS forecasting:

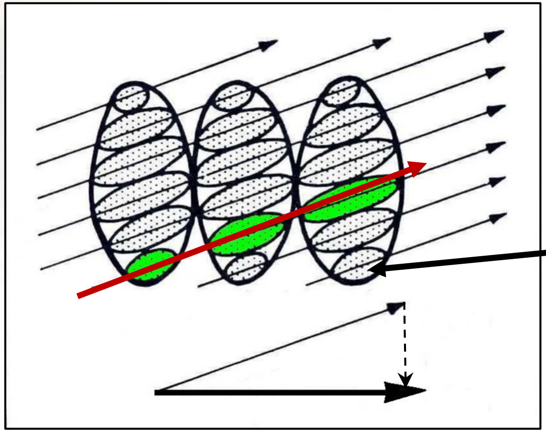
- Need standard ingredients: Moisture, Instability, Lift, and Vertical Wind Shear
- BUT, lots of overlap in the parameter space between convective modes (e.g., MCS vs supercell)
- Parameter space alone will not suffice, need to focus on typical/favorable large-scale patterns that support organized MCS development
- CAMs can help (especially during the cool season), but often struggle with MCS development/evolution in the warm season

MCS Motion

While there is no true steering level, MCS motion can be broken down into two main components:

1. **Advection** of individual cells by the mean wind
2. **Propagation** of the development of new cells





Individual Storm Cells are moving to the northeast

While new cells are developing on the southern end of the line

Net Motion is to the east!

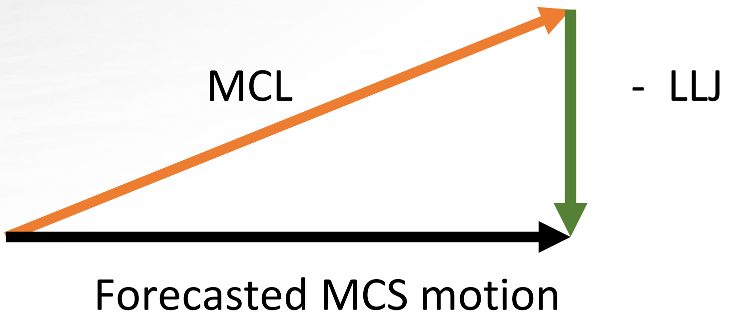
Based on graphics from Corfidi and Browning and Ludlam (1960)

MCS Motion - How to estimate these vectors?

"Vector Method" Developed by Corfidi, Merritt, and Fritsch (1996):

- The negative Low Level Jet (LLJ) wind vector is used as an estimate for the speed and direction of cell propagation

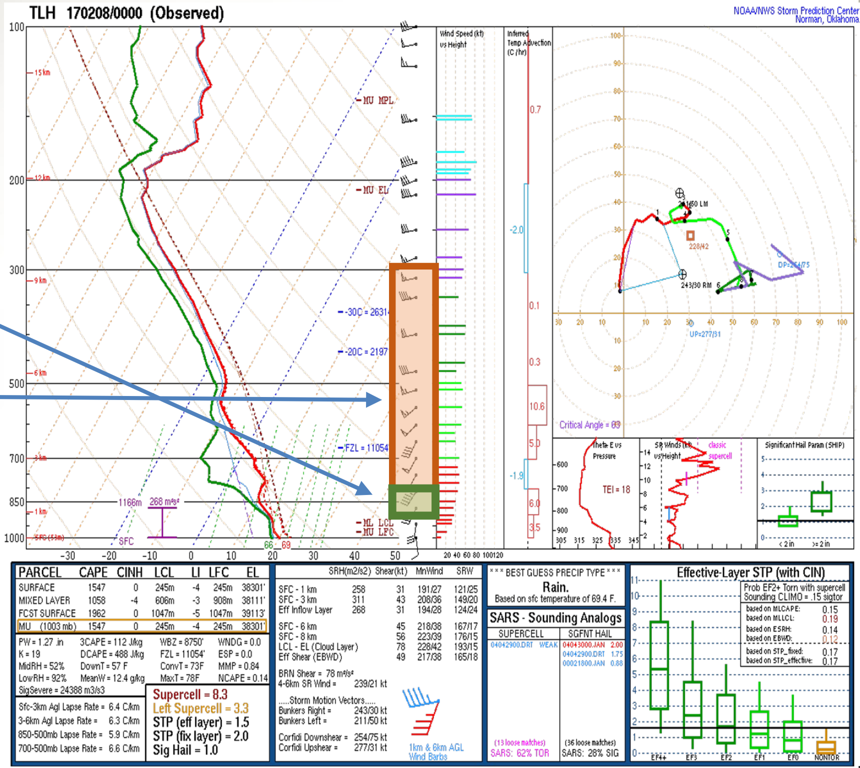
- The mean cloud layer wind (MCL wind) is used to account for the individual cell advection



<u>MCS Motion</u> - How to estimate these vectors?

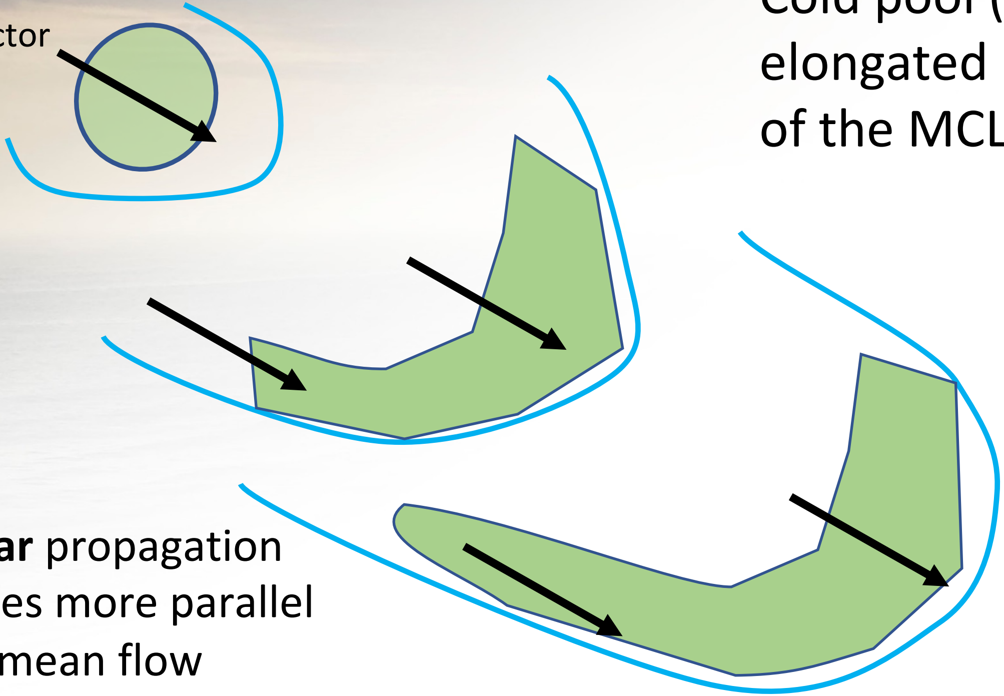
Low Level Jet –
Usually taken as the 850mb wind vector (though this may not always be the case!)

Mean Cloud Layer Wind –
Usually an average wind vector from the 850 to 300 mb layer



MCS Motion – Upwind and Downwind

Cold pool (blue line) is elongated in the direction of the MCL flow.

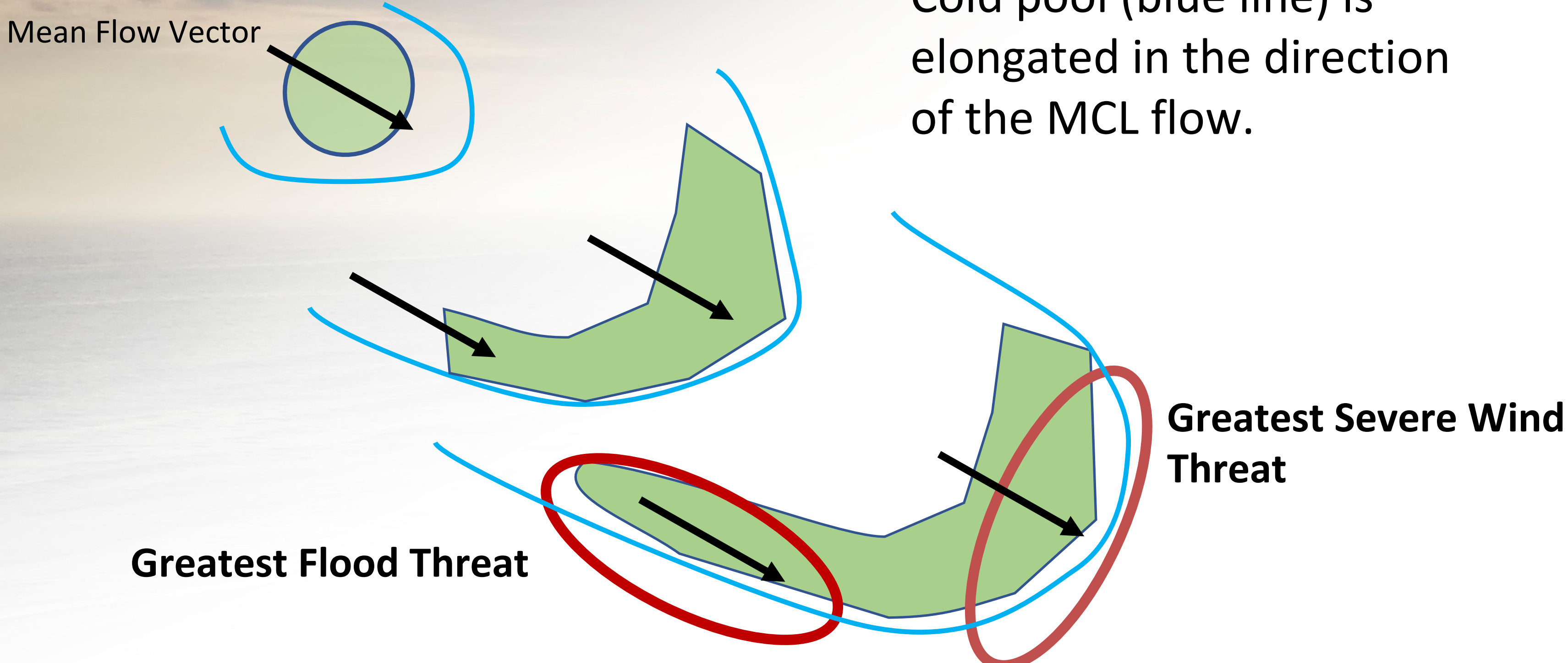


Upshear propagation becomes more parallel to the mean flow

Downshear propagation of the MCS remains perpendicular to the mean flow

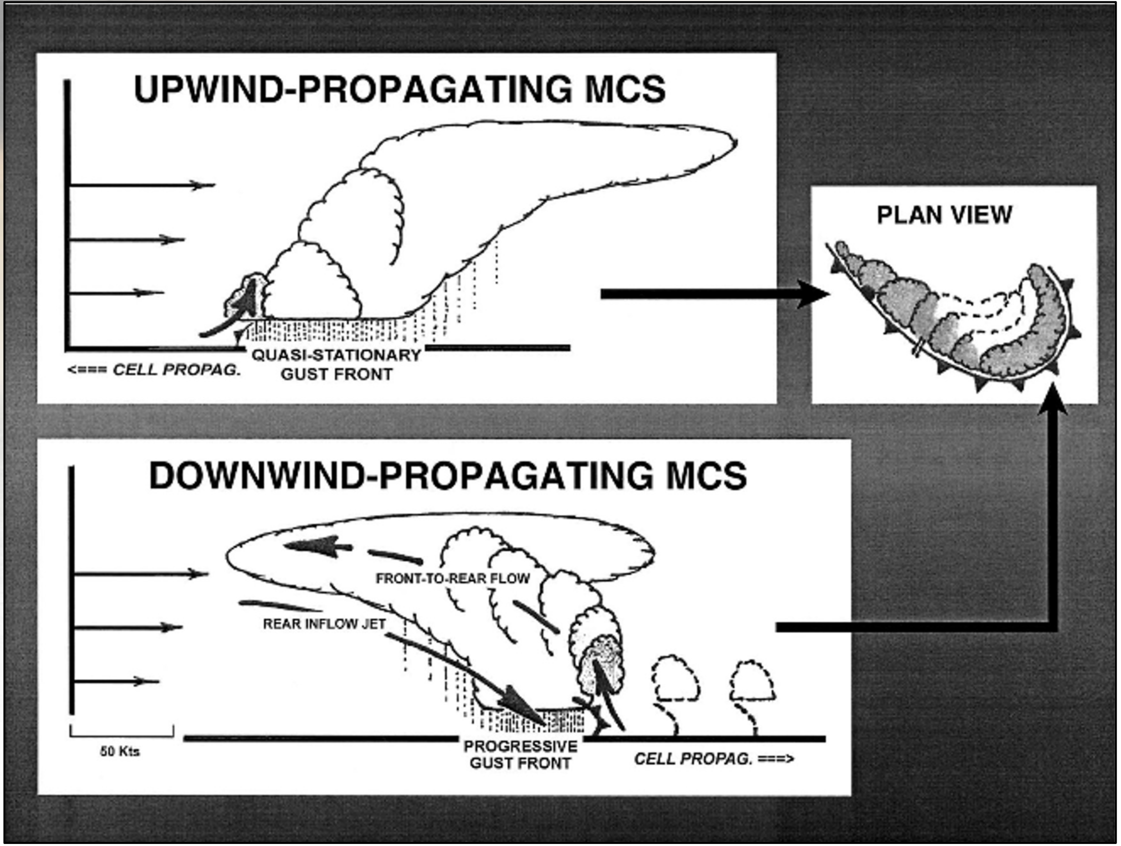
MCS Motion – Upwind and Downwind

Cold pool (blue line) is elongated in the direction of the MCL flow.

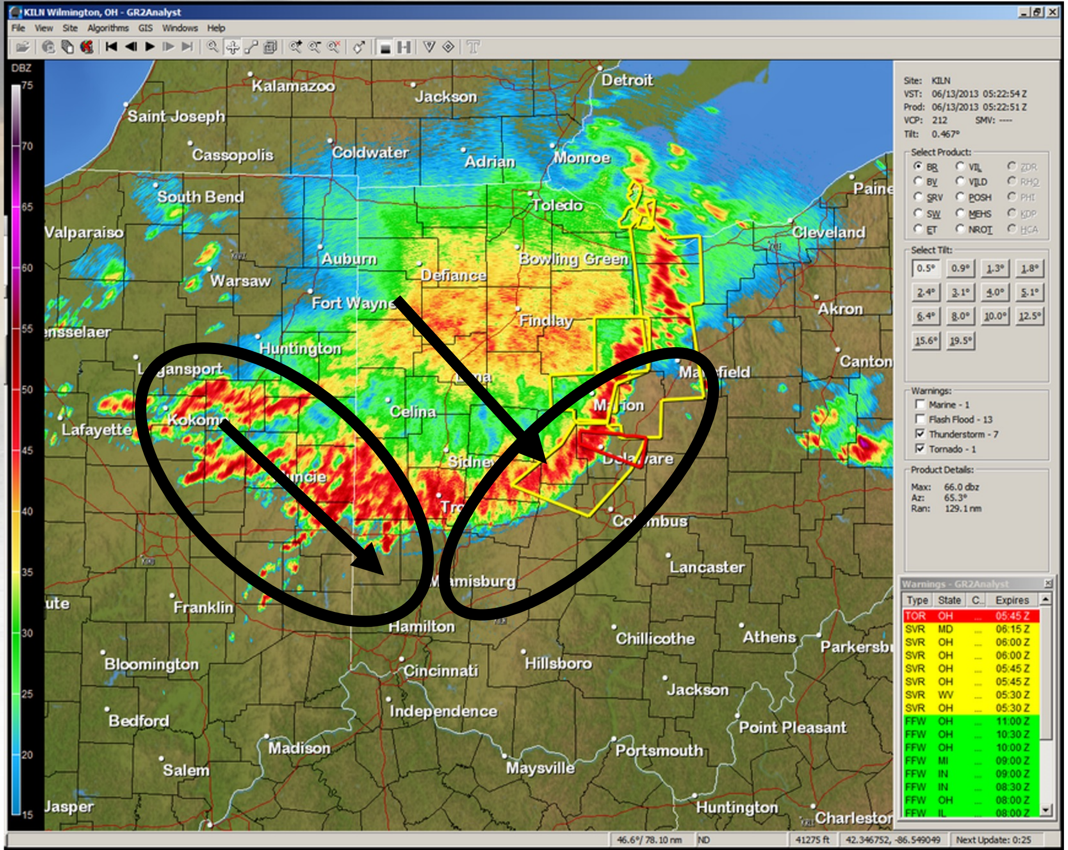


MCS Motion – Upwind and Downwind

From Corfidi 2003:



MCS Motion – Upwind and Downwind



MCS Motion – Upshear and Downshear

How to account for the Upshear and Downshear components?

Upshear: Use the same vector method as described before

- It is assumed that the MCS will continue to propagate along this vector
- However, Keep in mind that "training" cell development can cause a flash flood risk

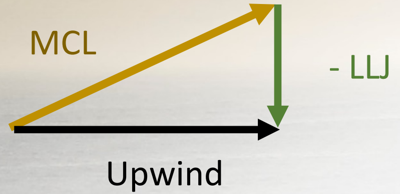
Downshear: Need to account for the role of the cold pool

- Assume the cold pool moves at the same velocity as the MCL wind
- Beginning with the upwind motion vector, simply add the MCL vector again!

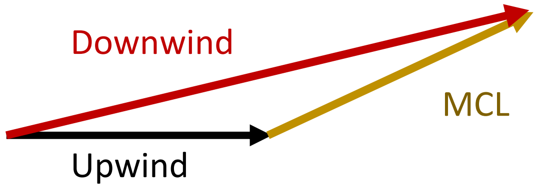
MCS Motion – Downshear Example 1

For the downshear MCS motion vector:

1) Find the Upshear Vector



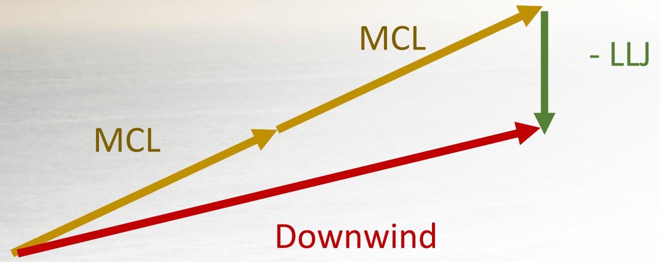
2) Add the MCL vector to the Upshear Vector



MCS Motion – Downshear Example 2

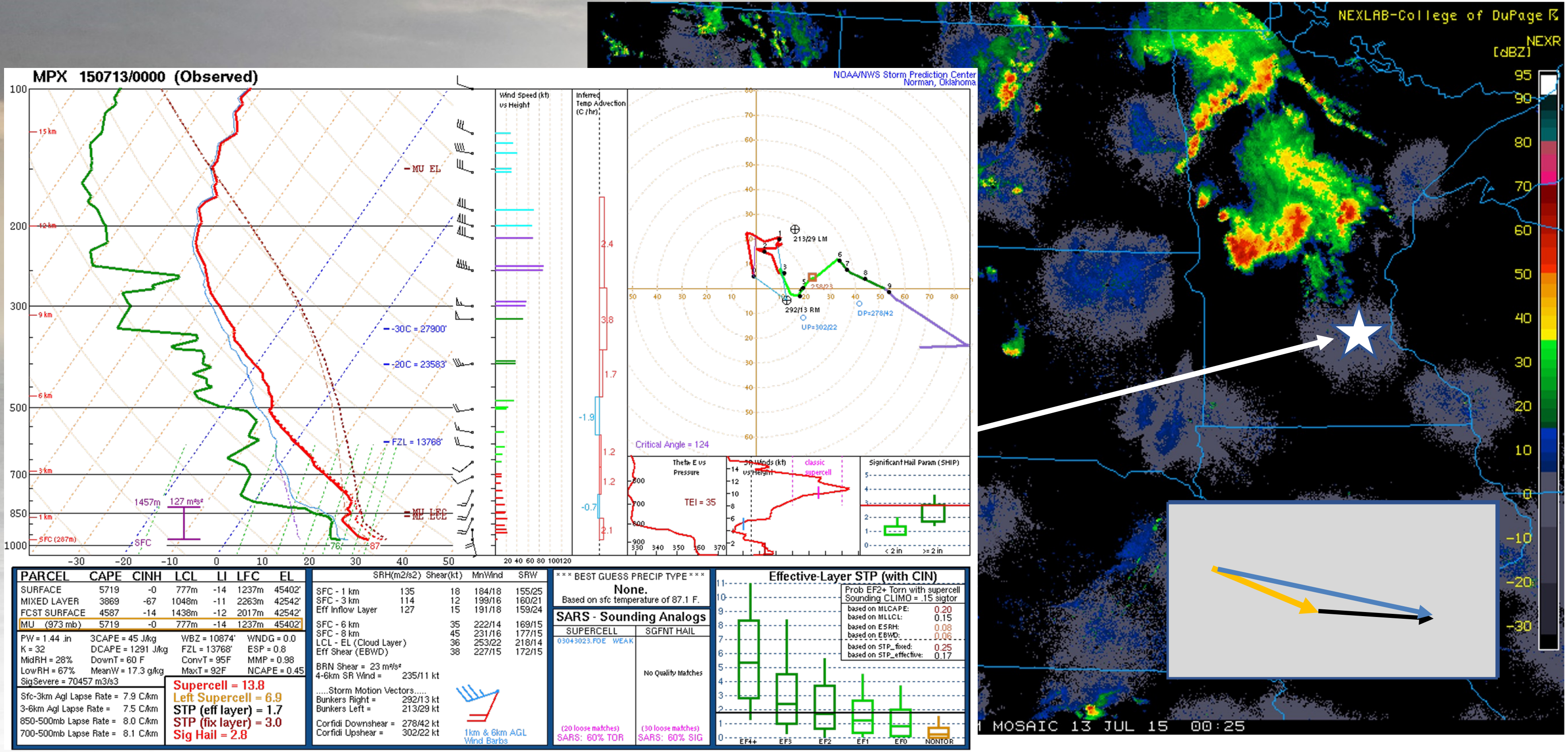
For the downshear MCS motion vector:

1) Add 2 MCL vectors to the –LLJ vector

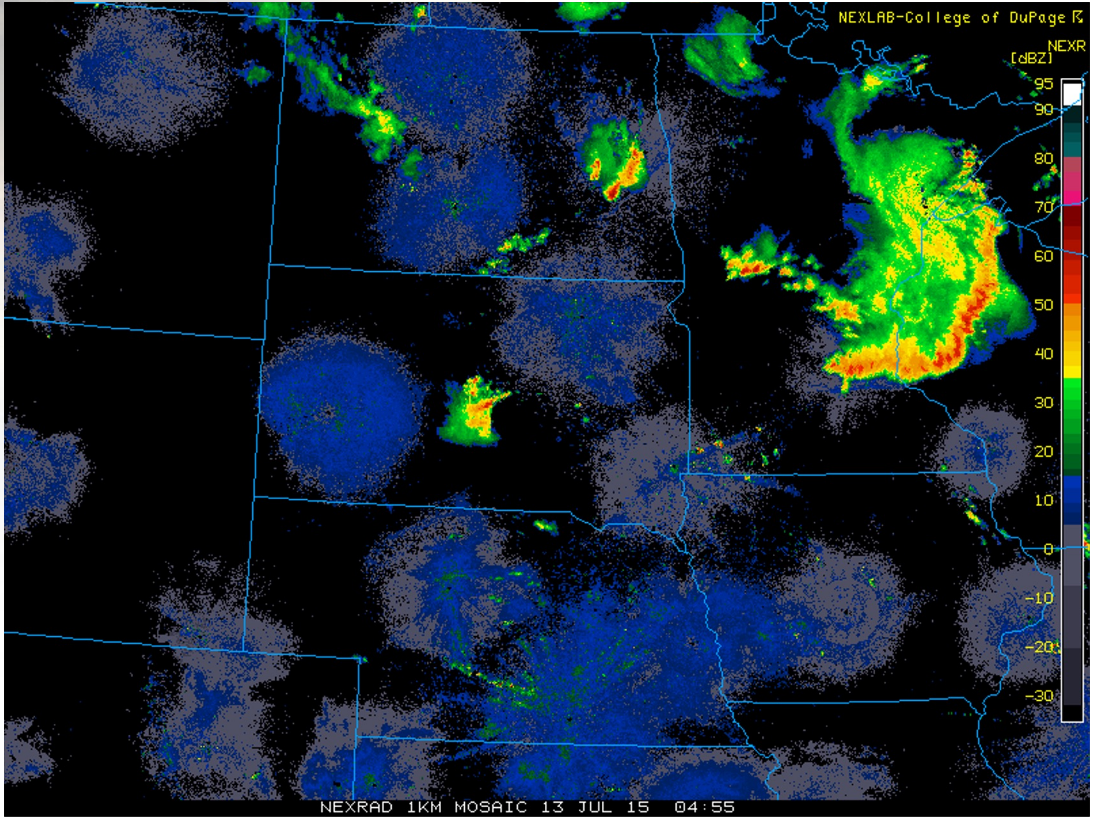


Both Methods give the same result!

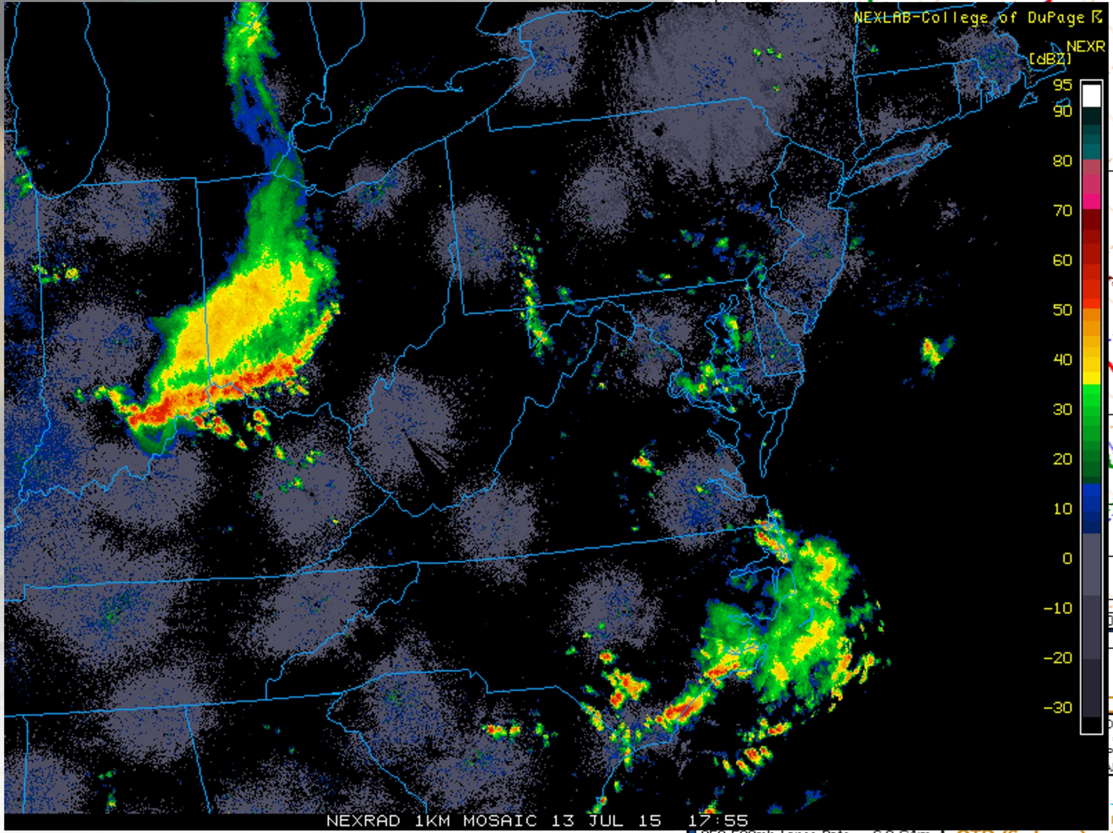
Example: July 13, 2015

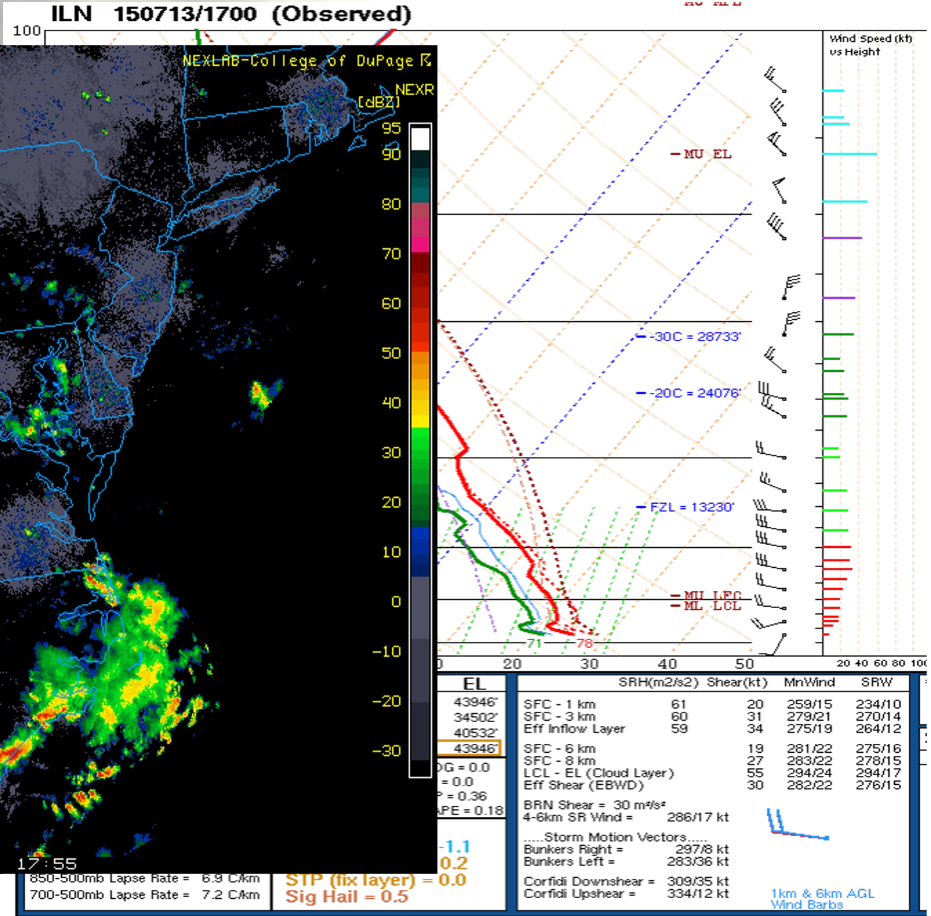


Example: July 13, 2015



Example: July 13, 2015





Other Factors Influencing MCS Motion: **MCVs**

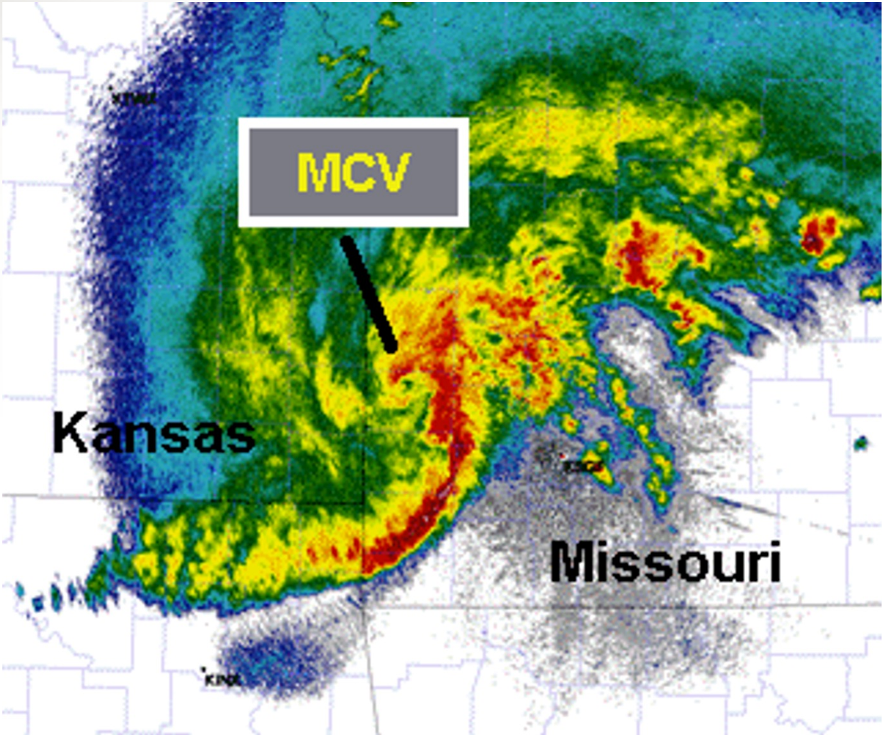
MCV – <u>M</u>esoscale <u>C</u>onvective <u>V</u>ortex

MCVs are mesoscale lows that can persist for several hours.

The track of a MCV can influence the overall motion of a MCS over time.

MCVs can also lead to destabilization ahead of the downwind portion of a MCS and stabilization of the upwind portion.

For more details see Trier and Davis (2007)



Other Factors Influencing MCS Motion:

"Bow and Arrow" Radar Signature

Results from confluent flow behind the MCS.

Can lead to flash flooding and large hail.

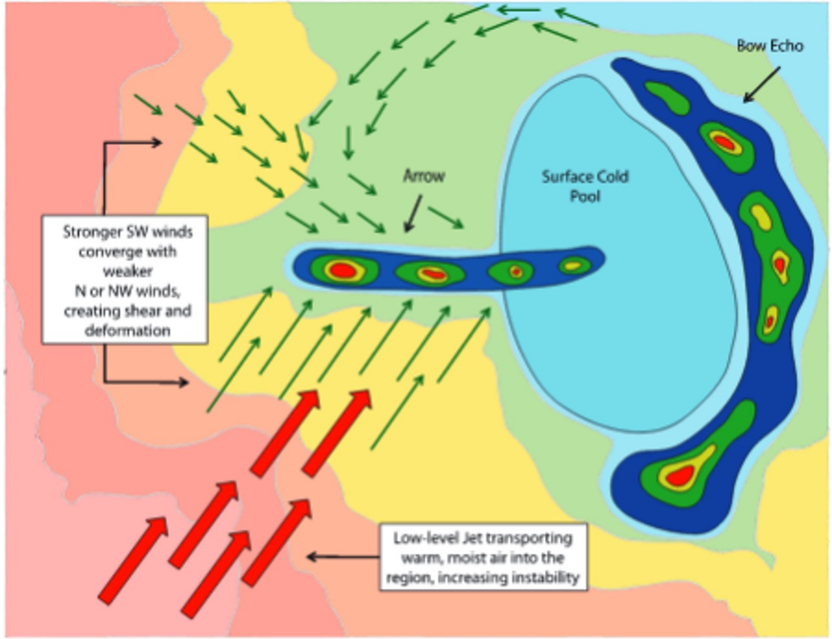
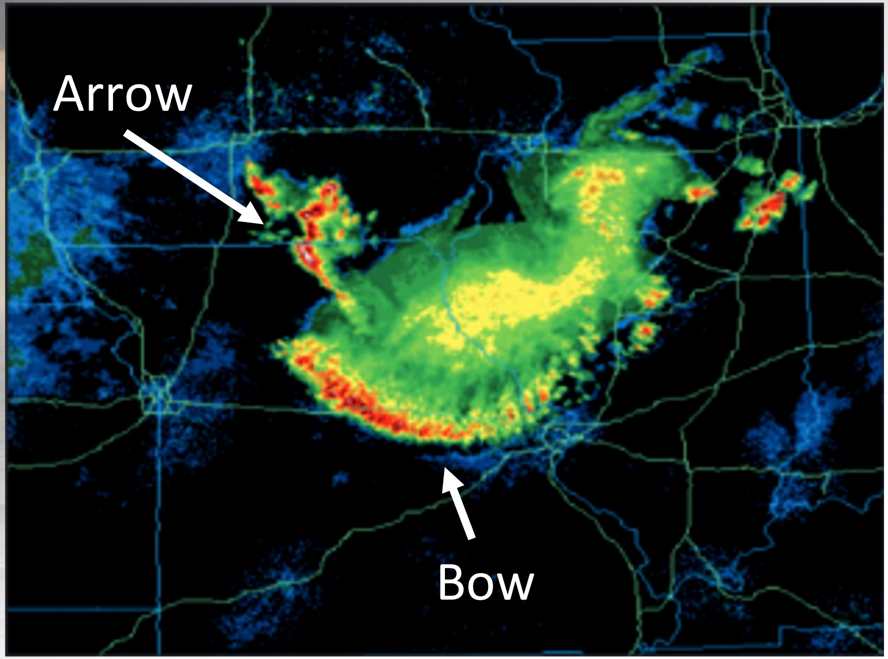
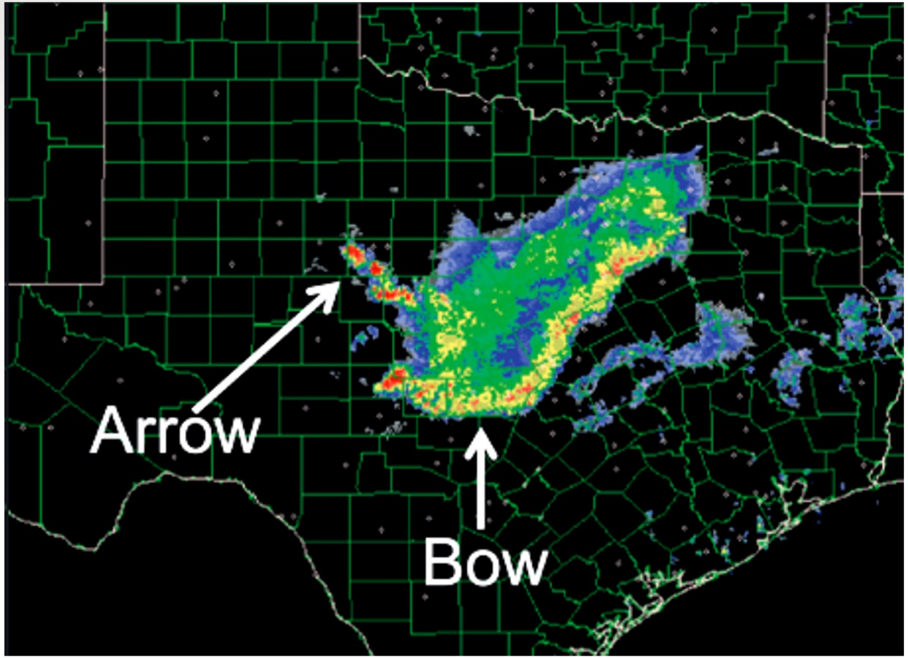


FIG. 25. A schematic diagram showing all the important components of the bow and arrow system. The thick red arrows represent the LLJ, while the thin green arrows represent wind direction and speed (the longer the arrow, the faster the speed) for all pressure levels. The colored contours represent isotherms, where hotter temperatures are in shades of red, and cooling to blue.

From Keene and Schumacher (2013)

“Bow and Arrow” Example



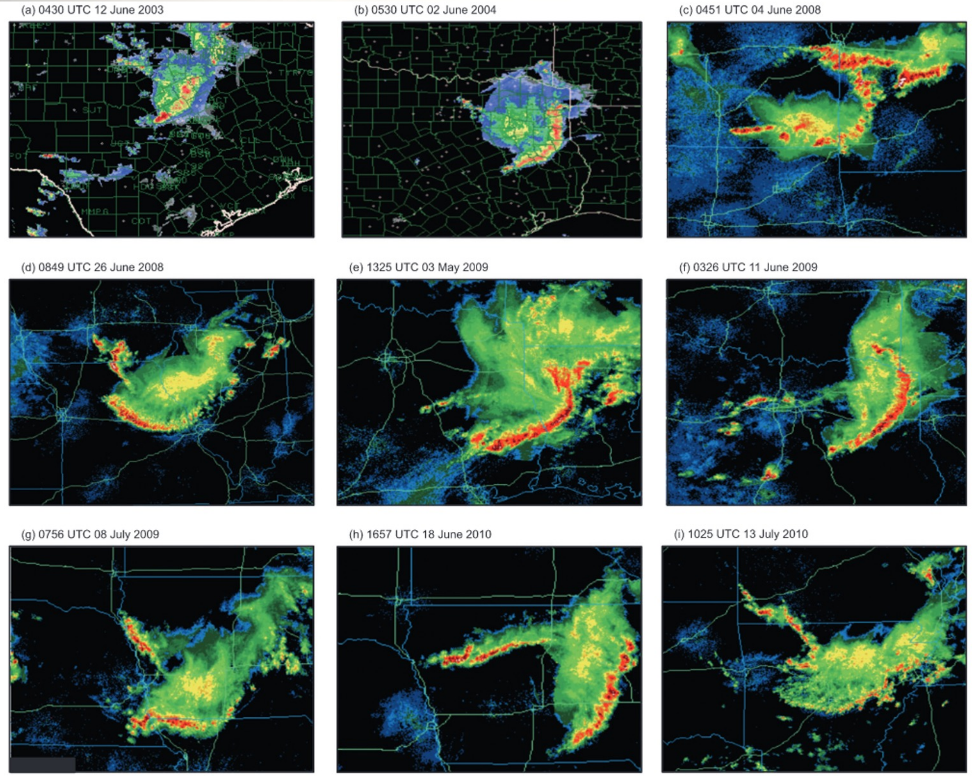


Other Factors Influencing MCS Motion

Other Factors Include:

- Synoptic Fronts
- Spatial and Temporal changes in gradients of shear and CAPE
- Mesoscale Gravity Waves
- Changes in direction and strength of the Low level Jet

(From Corfidi 2003)



MCS Motion Summary (conclusions from Corfidi (2003)

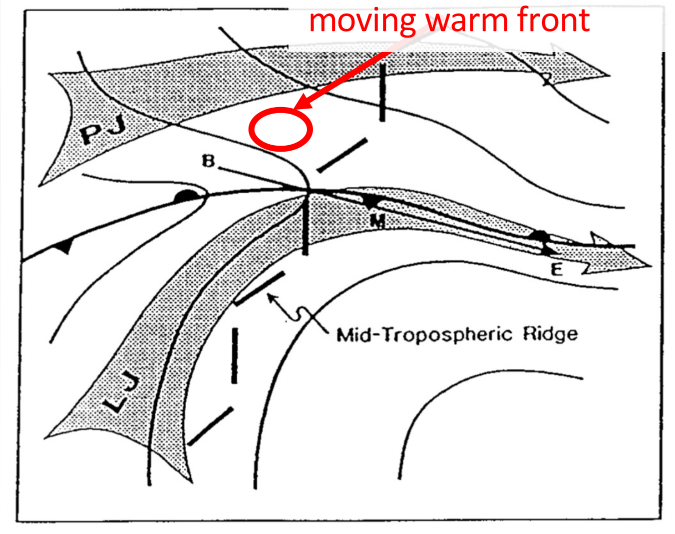
MCS motion is governed by a **propagation** and an **advection** component

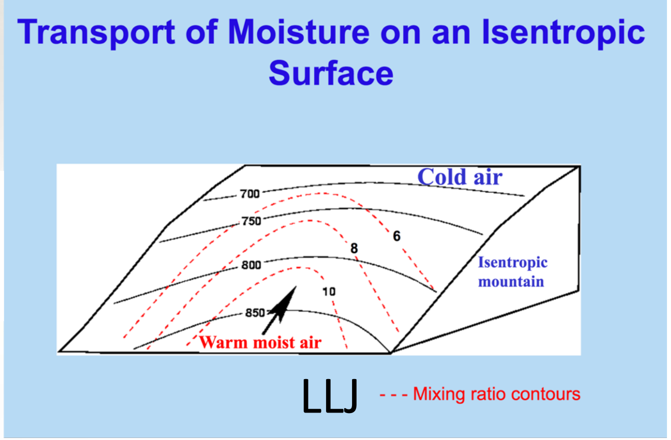
- The Advective component can be approximated by the MCL vector
- The Propagation component can be approximated by the negative LLJ vector
- MCS also have **Upshear** and **Downshear** propagating components
- The Dowshear component takes into account the motion of the cold pool that is elongated by the MCL vector
  - This is the region where severe wind threat is the greatest
- The Upshear propagating component is usually slower due to orientation parallel to MCL wind
  - This is the region where flash flooding threat is the greatest
- Other factors can influence MCS motion and behavior such as MCVs, dry air aloft, synoptic features, changes in shear, CAPE, and LLJ with time and space.

Common & important types of forcing for MCSs: Strong synoptic-scale WAA (isentropic lift) in low levels (sfc – 700 mb), often augmented greatly by low-level jets (Bonner 1968, Maddox 1980 & 1983, McNider and Pielke 1981, Cotton et al. 1989, Jirak and Cotton 2007, etc.)

Composite synoptic pattern for progressive derechos (Johns 1993)

Derechos (and MCSs in general) often begin north of a quasi-stationary or slow-moving warm front

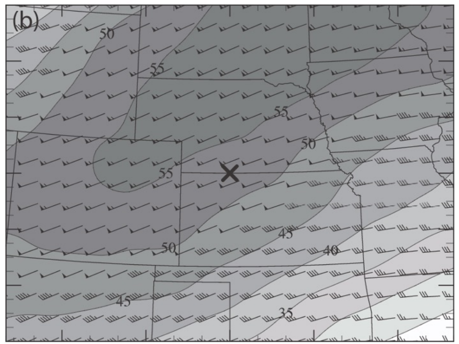




Can produce widespread destabilization over a short time period (although surface-based parcels may be stable)

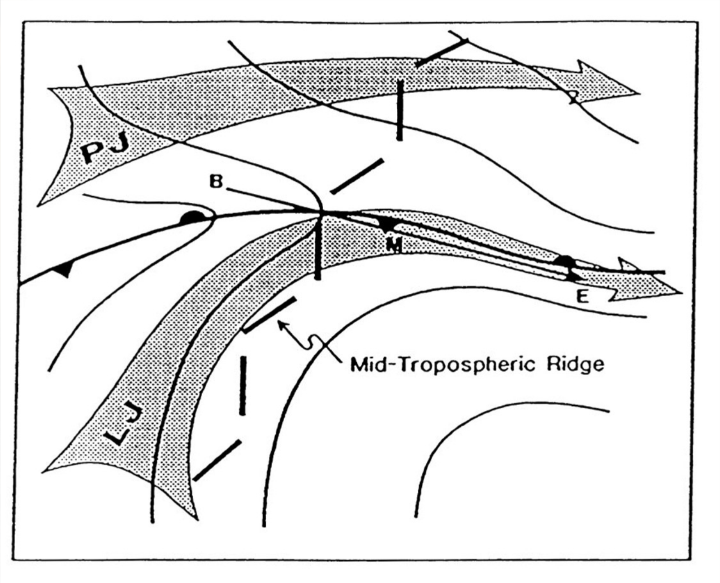
Generate more favorable thermodynamic environment over widespread area → more initial storms → faster cold pool consolidation

250-mb isotachs 1-h before first storms (N=94 MCSs)



Warm-season MCS development in right-entrance region of upper-level jet ubiquitous in every composite analysis out there

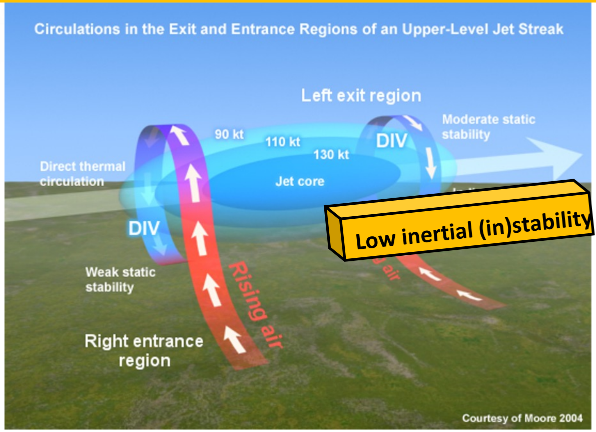
Progressive derecho pattern



Johns (1993)

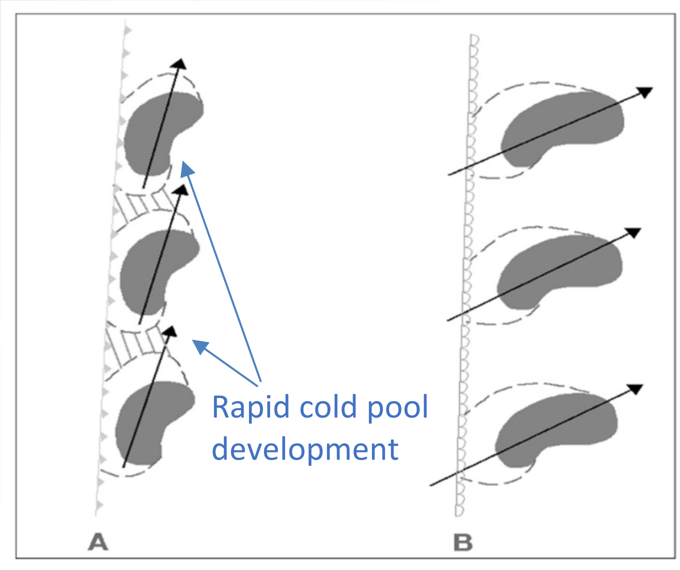
Mesoscale ascent in right-entrance region the primary factor,

but initial convection moving into a region of low inertial (in)stability also plays a role



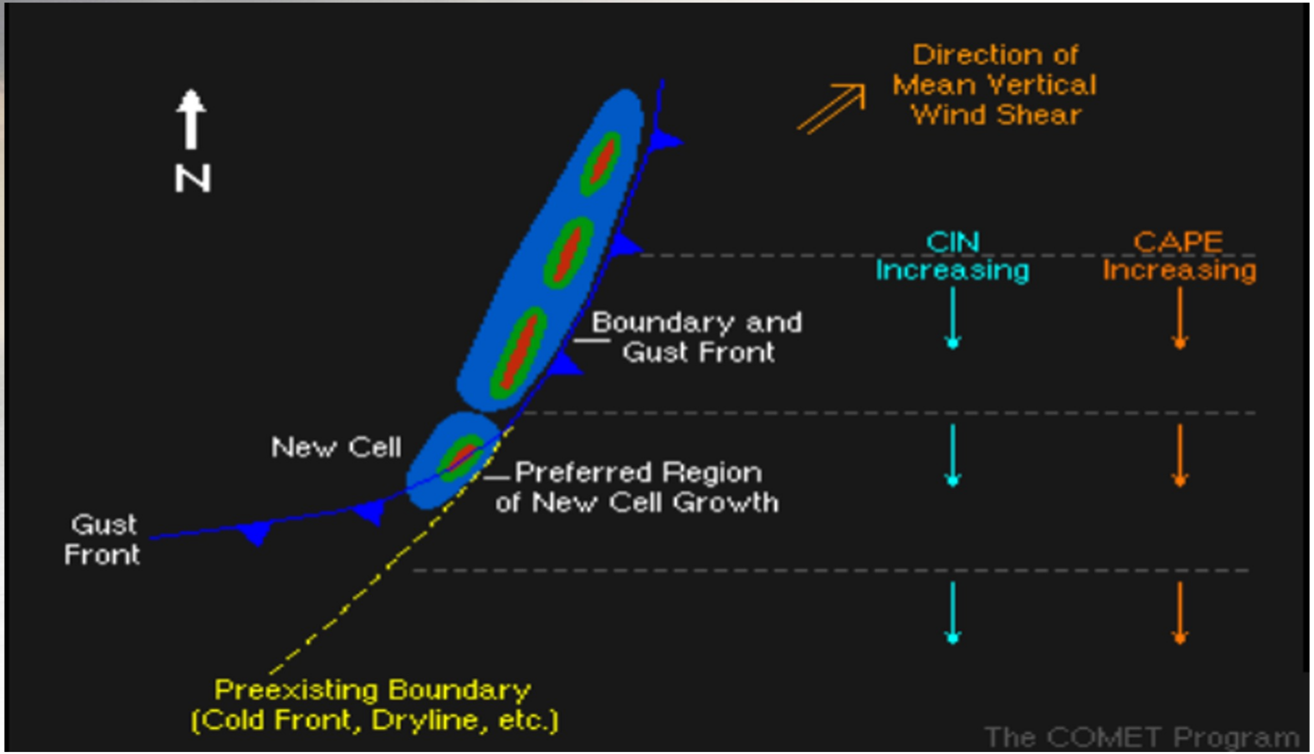
Coniglio et al. (2010)

Dial et al. (2010): Short-term (0 – 3 h) convective mode evolution along initiating boundaries in relation to shear and *mean wind* orientation.



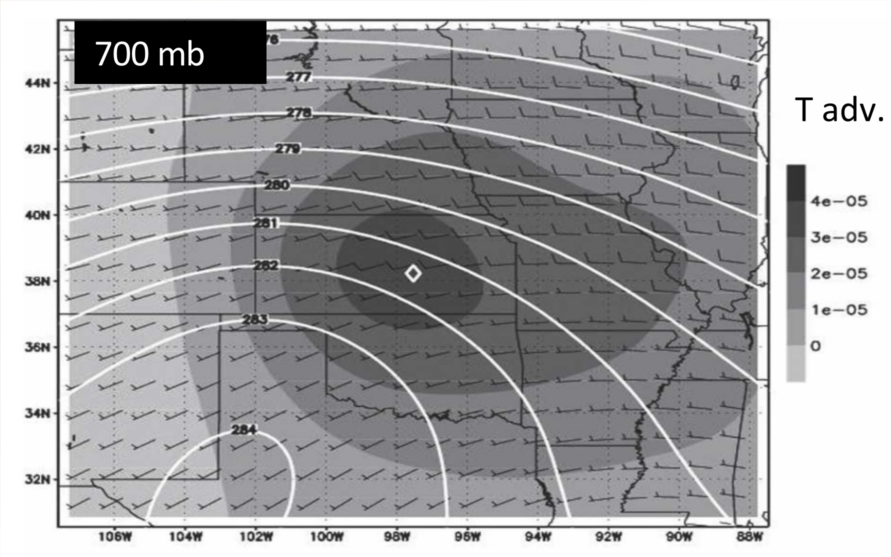
Emphasized that mean wind orientation has a large control over cold pool development when ~parallel to initiating boundary by depositing hydrometeors along the line of cells.

Dial et al. (2010): Strong external forcing can promote rapid upscale growth, through rapid and numerous cell development, regardless of how shear/mean wind is oriented to initiating boundary (e.g. Jewett and Wilhelmson 2006)

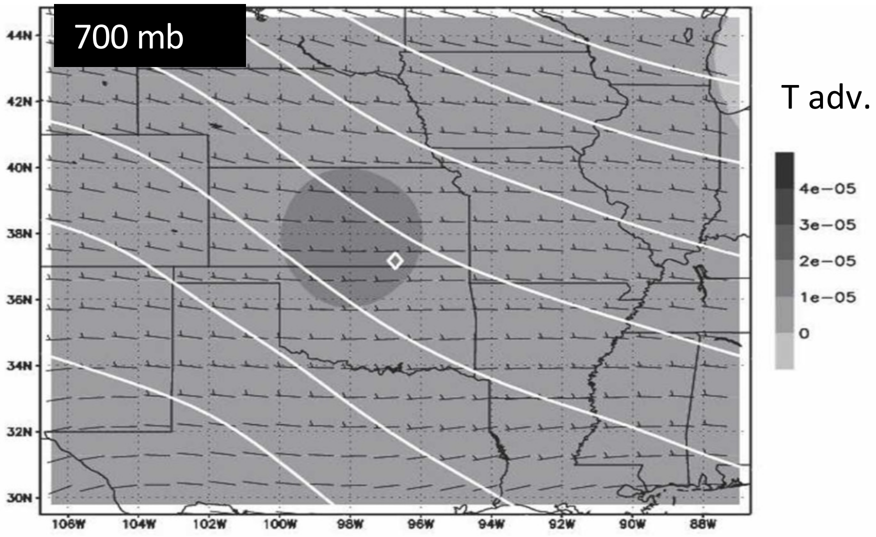


Jirak and Cotton (2007): Differences in precursor MCS environments versus environments that support widespread convection but no MCS in NARR data composites

MCS – 6 h (N = 387)

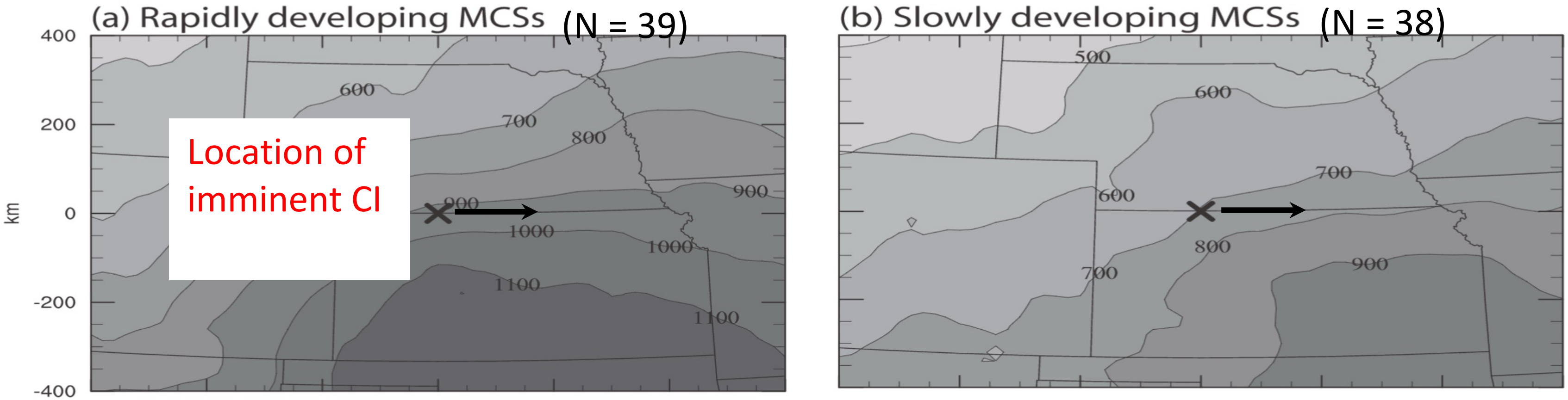


Widespread convection but no MCS (N = 300)

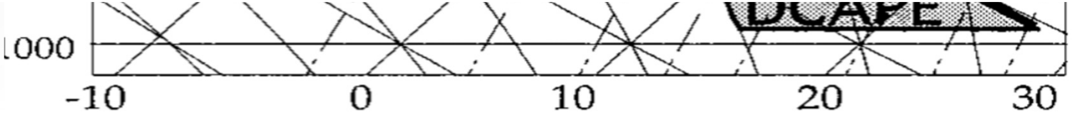


Coniglio et al. (2010): Differences between rapidly-developing (< 4 h) and slowly-developing (> 8 h) MCSs in RUC analysis composites at ~time/location of CI

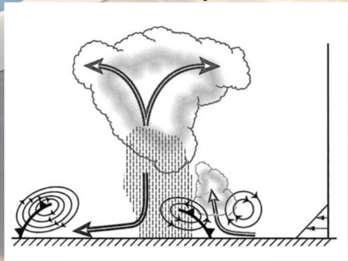
Find significantly larger CAPE (99% confidence) both from larger mid-level lapse rates and higher PW for rapidly-developing MCSs and stronger low-level jet, but some other differences…….one with downdraft CAPE (DCAPE)



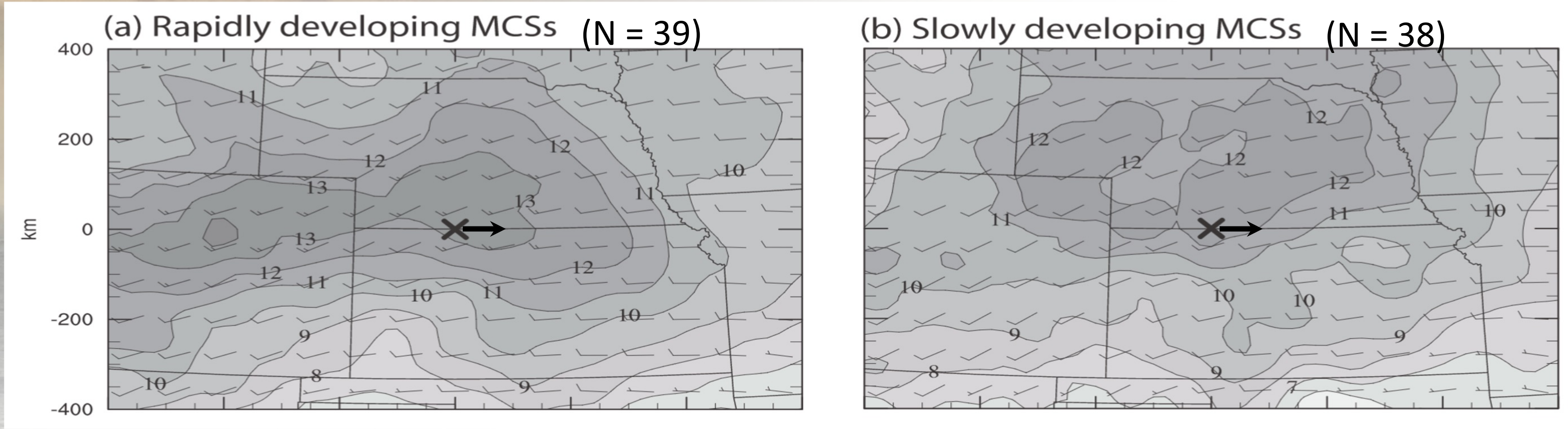
Shading is DCAPE (J/kg)



Rotunno, Klemp, Weisman (1988)

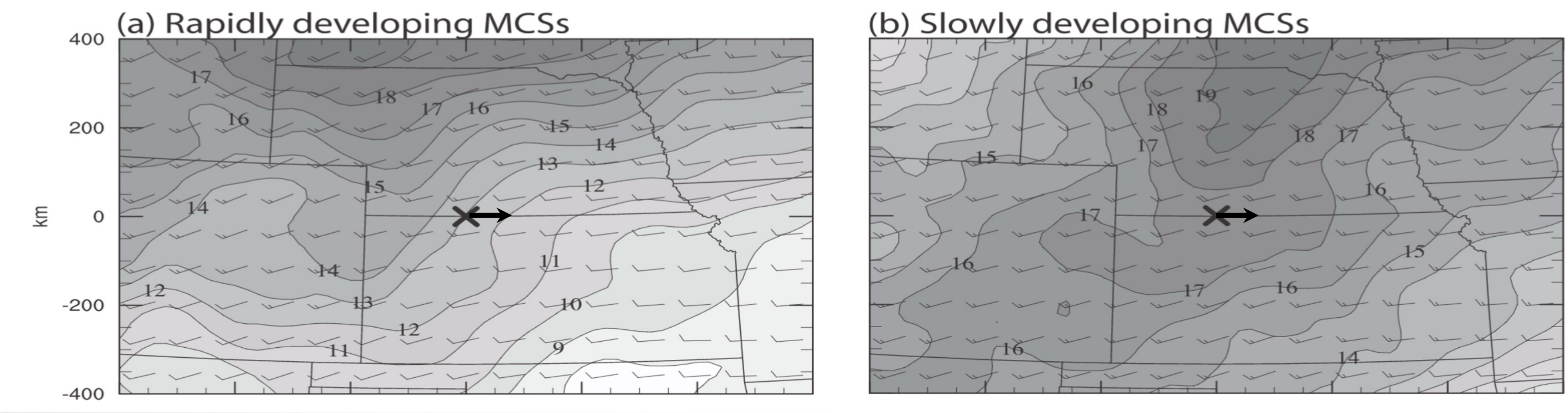


0 - 3 km vertical wind shear (m s^{-1})



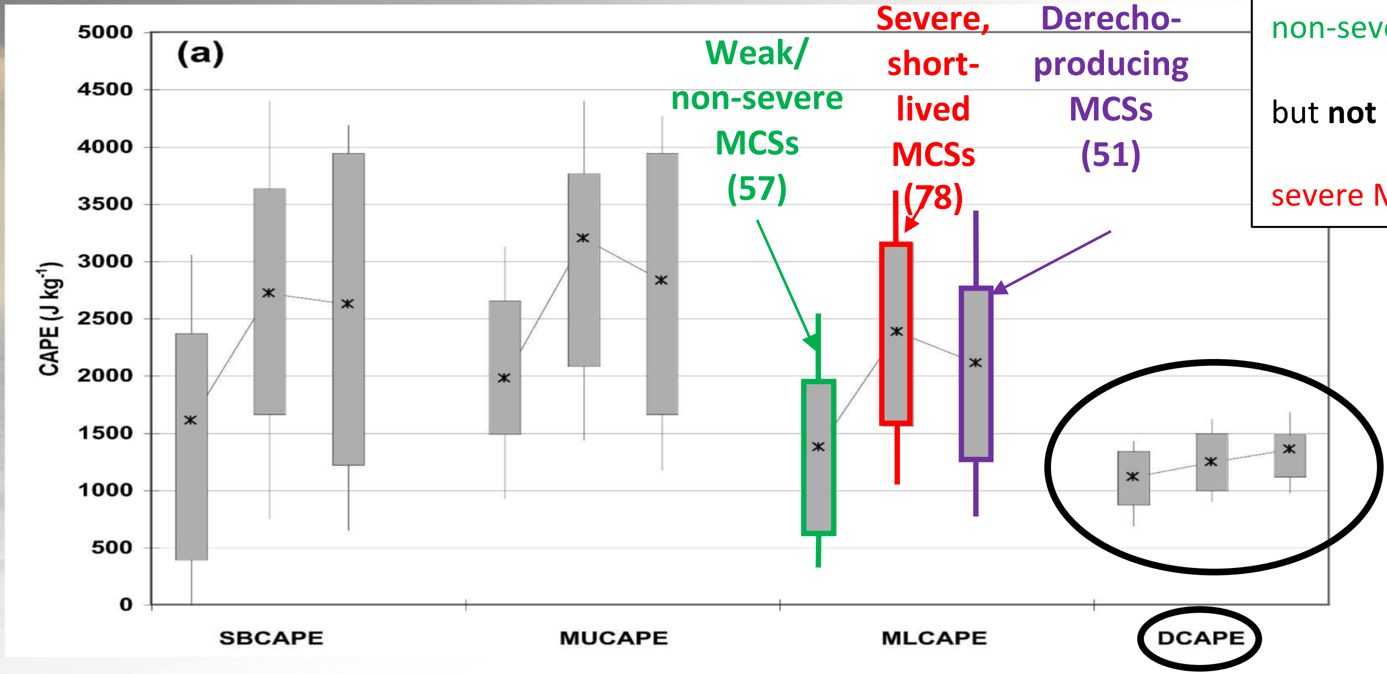
Not seeing a strong signal from RKW effects from low-level shear

3 - 10 km vertical wind shear (m s^{-1})



Larger mid-upper-level shear for slowly-developing MCSs….a reflection of the persistence of supercell modes in the line (Bluestein and Weisman 2000).

Cohen et al. (2007): Examine proximity soundings to 1) weak/non-severe MCSs, 2) Severe, short-lived MCSs, and 3) Derecho-producing MCSs



<u>Point values of CAPE a big factor in:</u>

non-severe vs. severe MCS

but **not** in:

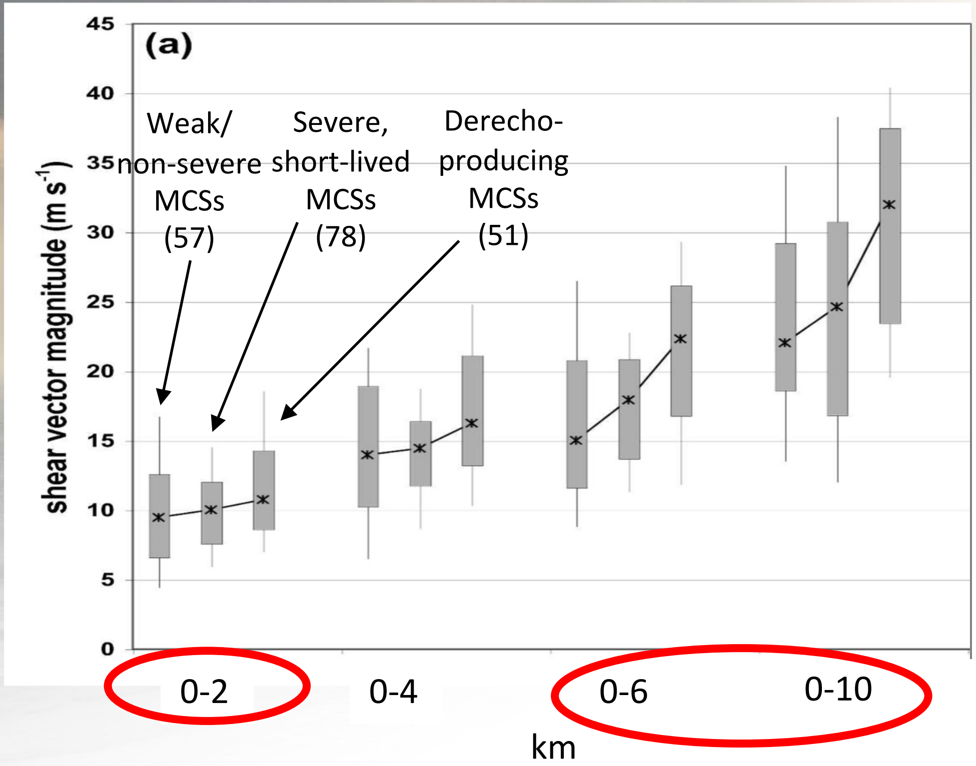
severe MCS vs. derecho

Saw DCAPE important for speed of MCS developments, but

Not much of a DCAPE increase from weak MCSs to derechos

Mixed signal from competing physical processes?

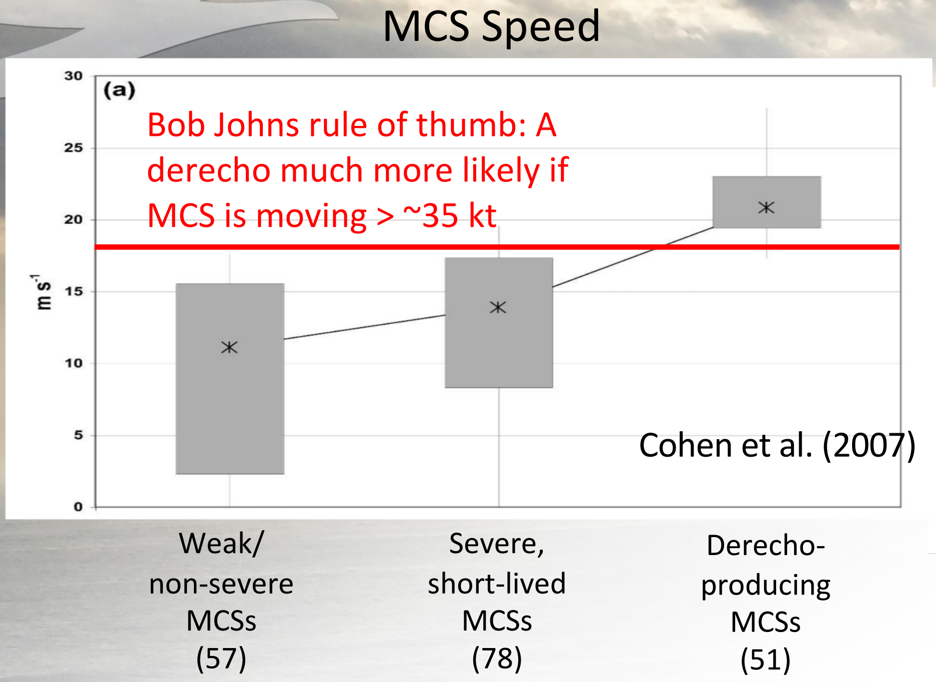
Vertical Wind Shear Magnitude (m s-1)

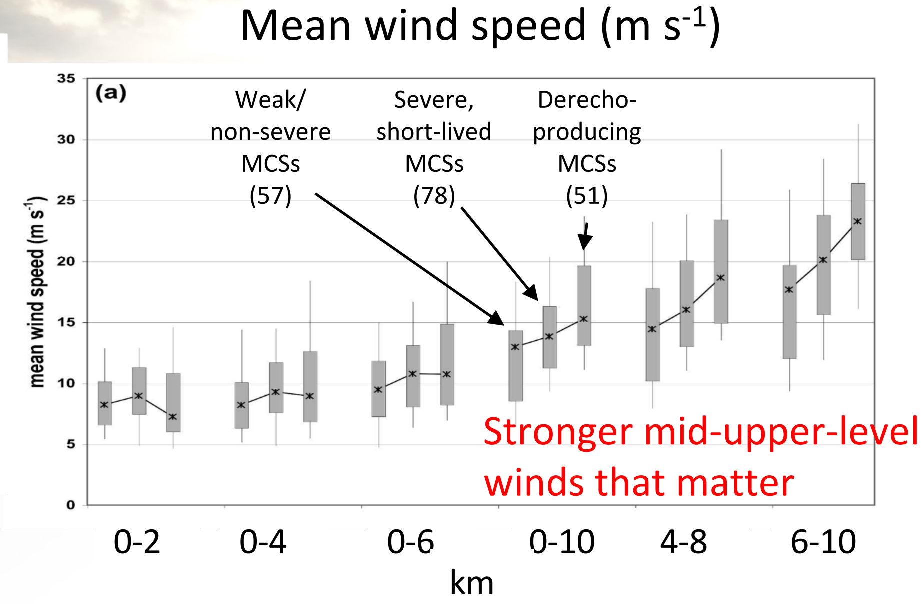


Cohen et al. (2007)

Examining the **low-level shear** only…**somewhat weak discriminator** of MCS strength (at least in terms of severe wind production……fits with SPC experience)

The deep-layer shear provides better discrimination….reflects accumulation of the favorable shear processes over the troposphere…



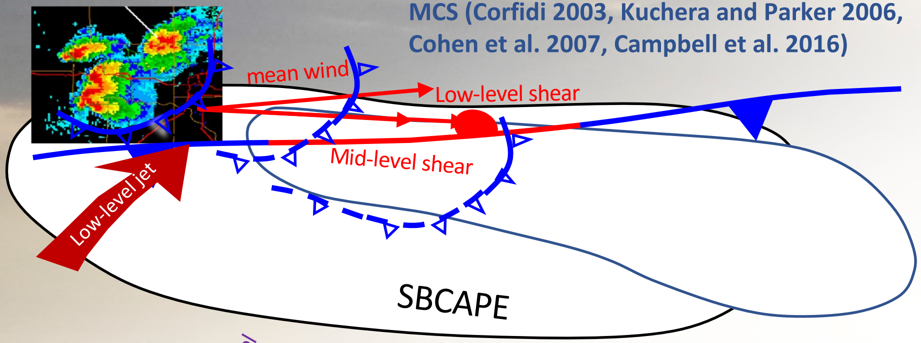


Reflection of both strong cold pools and strong mean winds

Higher mean winds a reflection of stronger **advection** of convective cells that translates to faster MCS motion, and chance for stronger ground-relative wind speeds

Angle of mean wind and shear relative to cold pool (convective line) is important for MCS mode:

Potential for fast-forward propagating severe MCS (Corfidi 2003, Kuchera and Parker 2006, Cohen et al. 2007, Campbell et al. 2016)

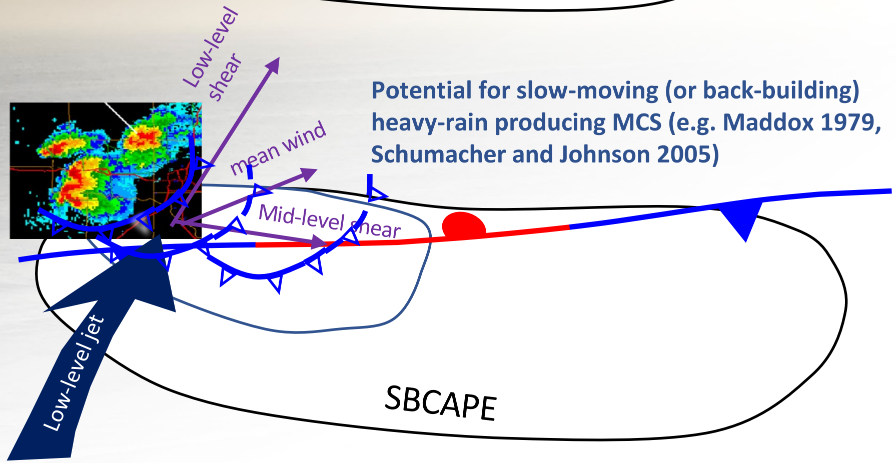


Strong westerly mean wind: Fast cold pool from advection and strong downward CMT

At least moderate westerly low AND mid-level shear at large angle from cold pool: New cells can be maintained on downwind side of cold pool despite fast cold pool motion (cold pool doesn't undercut the convection), acts to replenish cold pool on downwind side.

Moderate LLJ: oriented SW to NE

Potential for slow-moving (or back-building) heavy-rain producing MCS (e.g. Maddox 1979, Schumacher and Johnson 2005)



Weaker southwesterly mean wind: Slower (stronger?) cold pool from weaker advection & downward CMT

Strong low-level shear but directed parallel to northern/eastern part of cold pool, and toward the southern/western part of the cold pool: New cells not favored from effects of shear. Only mid-level shear may support new cells on northern/eastern part of the cold pool, but it's weak.

Strong LLJ more backed….key for new cells is isentropic lift atop the front & cold pool...more cells favored on the upshear side of the cold pool than the downshear side in this configuration.

Derecho:

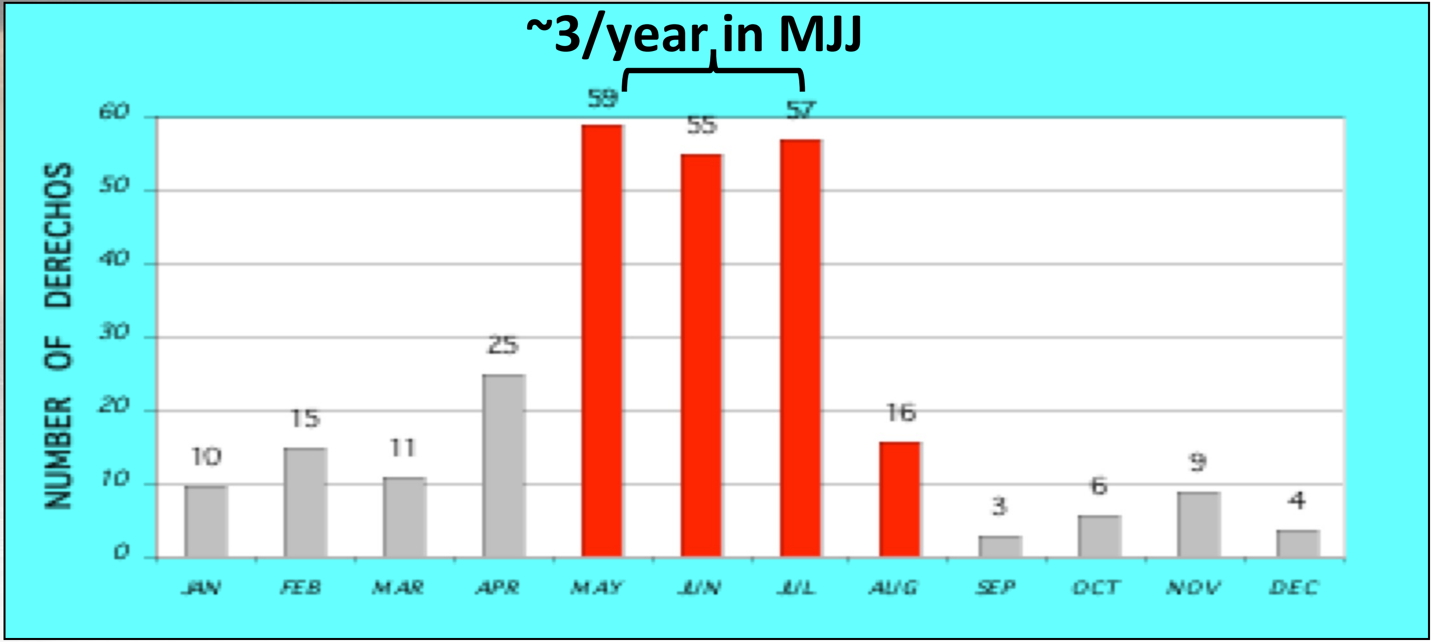
"Any family of particularly damaging downburst clusters produced by a mesoscale convective system. Such systems have sustained bow echoes with book-end vortices and/or rear-inflow jets and can generate considerable damage from straight-line winds. Damage must be incurred either continuously or intermittently over a swat of at least 650 km (~400 mi) and a width of approximately 100 km (~60 mi) or more.

-AMS Glossary

Corfidi et al. (2016)
Johns and Hirt (1987)

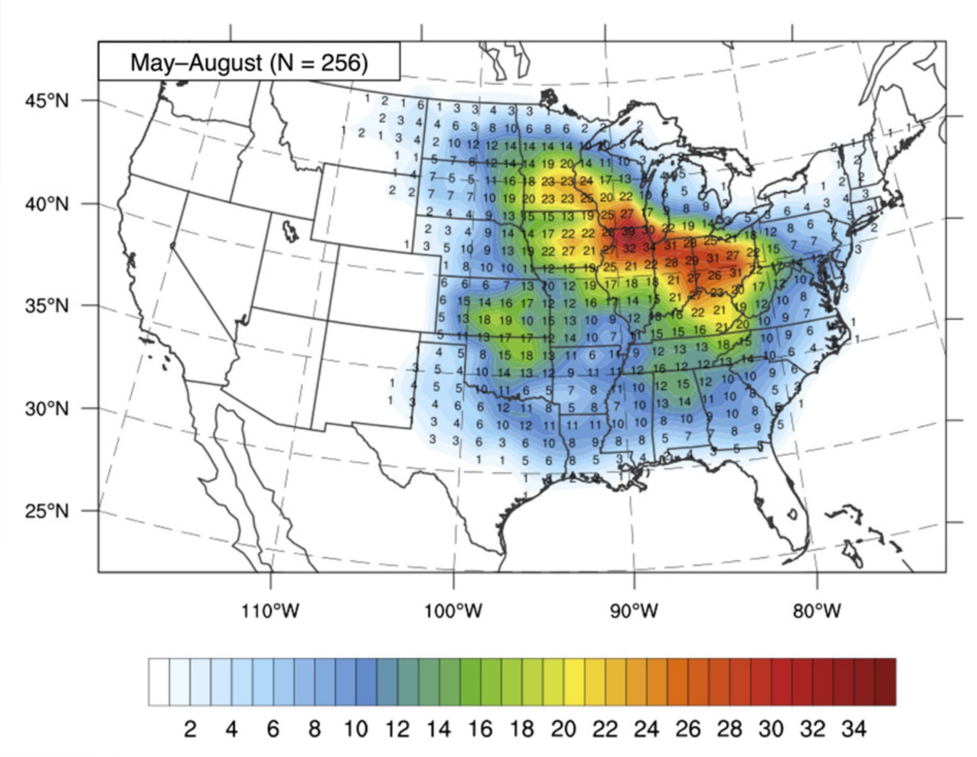
Derecho Climatology

1986-2001 monthly distribution of 270 events



Coniglio and Stensrud (2004)

Derecho Climatology: May – August



Guastini and Bosart (2016)
1996-2013

Next situation to consider: A severe, bowing MCS just formed and we want to know how long it will last?

Revisiting **Coniglio et al. (2010)** RUC analysis composites:

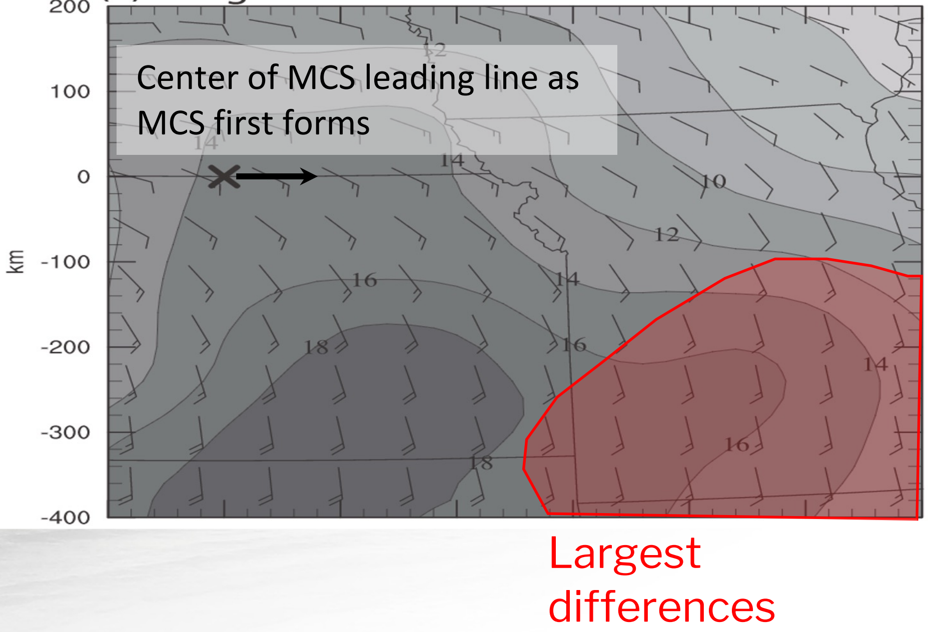
Many of the same environmental fields discussed earlier for helping to determine an MCS from isolated cells and discriminating weak/strong MCSs also discriminate short-/long-lived severe MCSs --

- MLCAPE
- LLJ
- Deep-layer shear versus only low-level shear
- Deeper lifting along stationary front (deeper WAA)

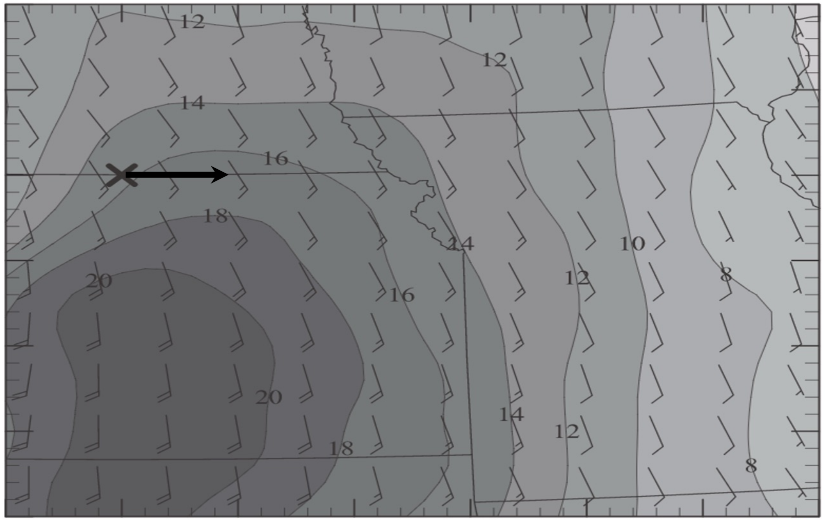
-- but the fields have longer eastward extensions at the time the MCS matures, e.g.…

500 m AGL winds/isotachs

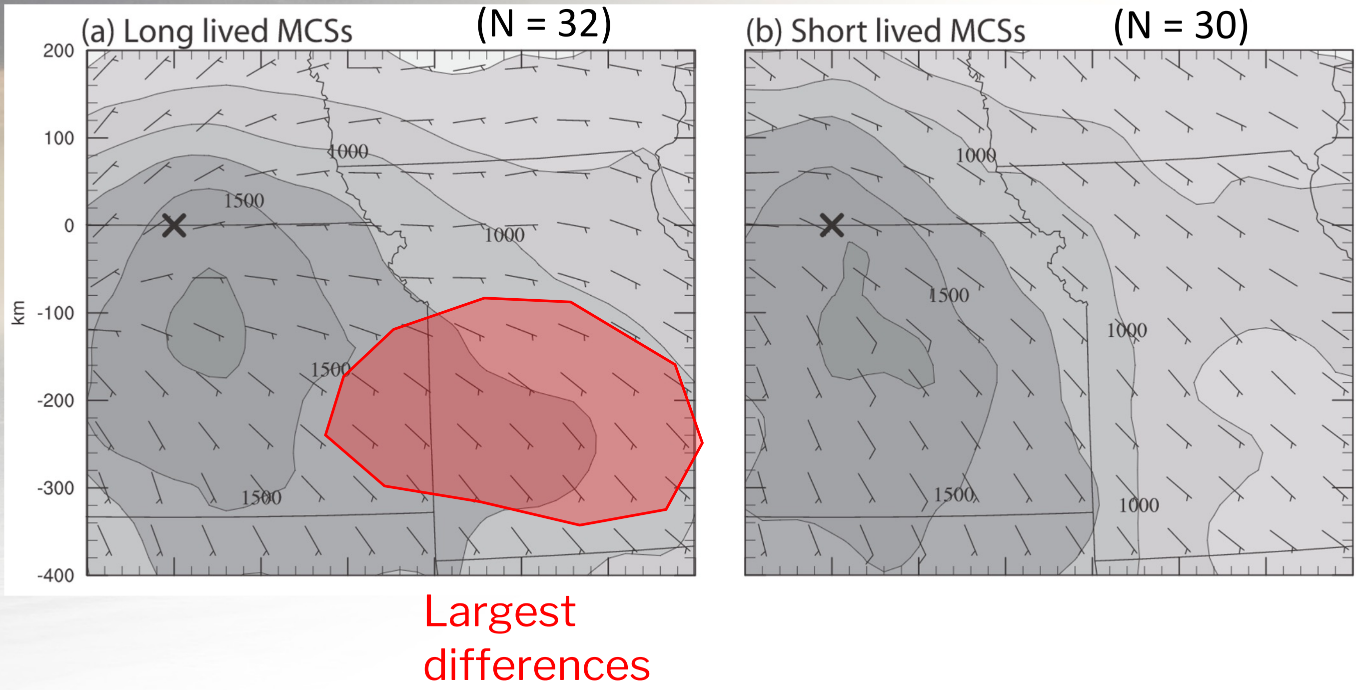
(a) Long lived MCSs (N = 32)



(b) Short lived MCSs (N = 30)



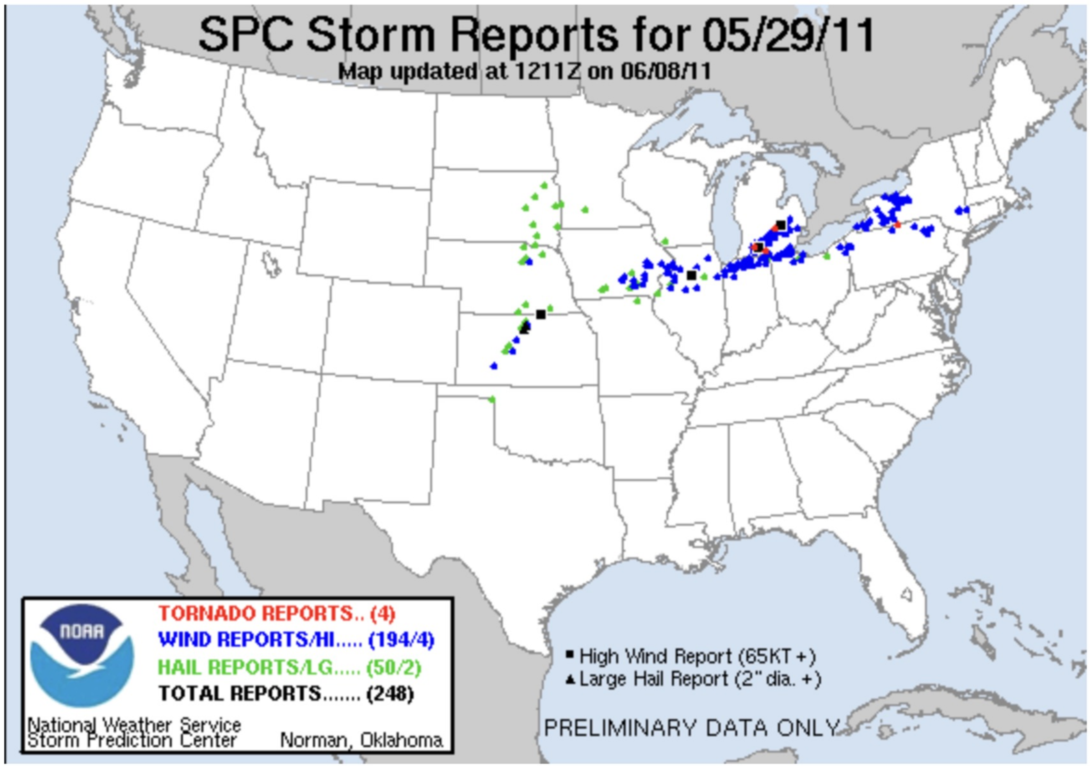
MLCAPE

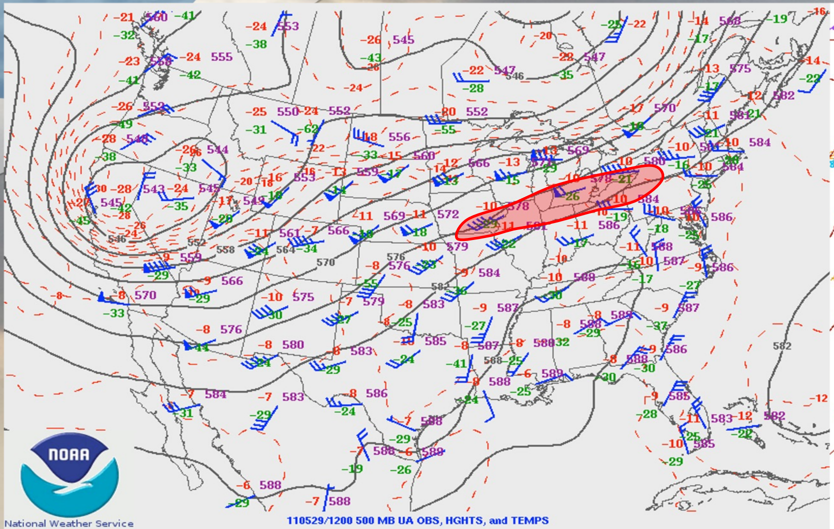

(a) Long lived MCSs
(N = 32)
(b) Short lived MCSs
(N = 30)
200
100
0
-100
-200
-300
-400
km
1000
1500
1000
1500
1500
1000
1500
1000
1500
1000
Largest differences

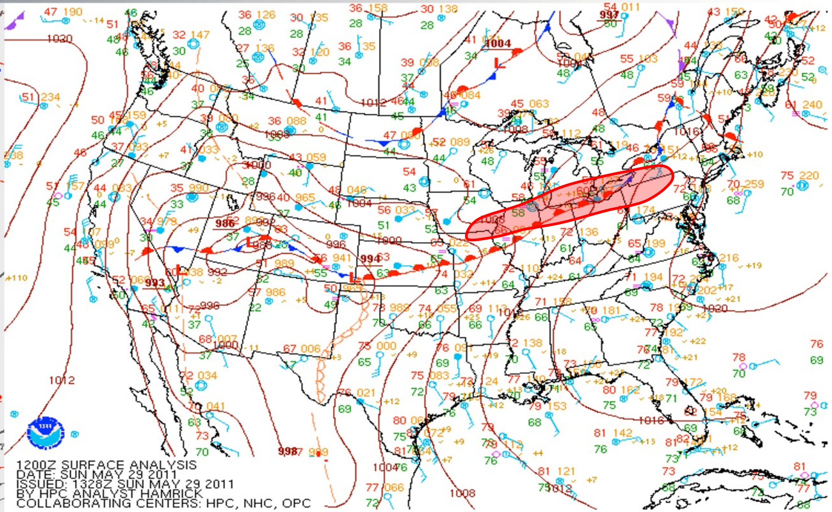
Important takeaway is the corridors of **favorable instability, vertical wind shear, and mean wind are more or less in place as the MCS first matures**….

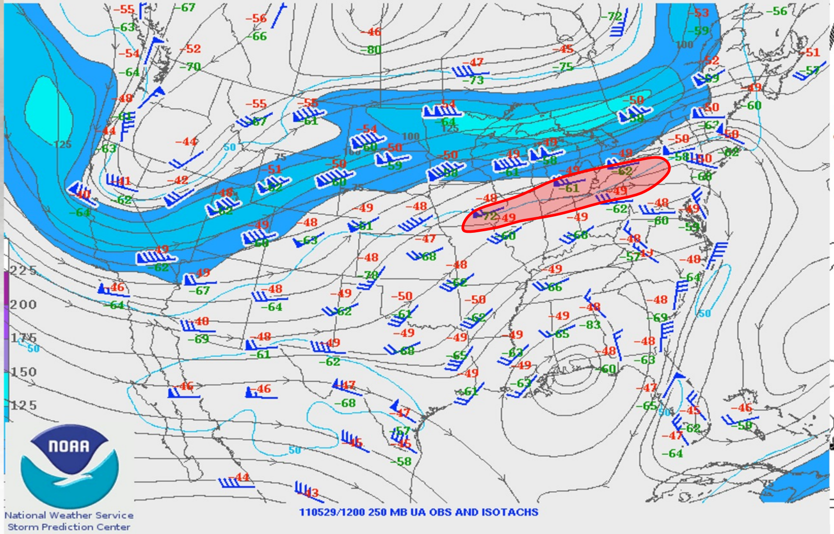
…can look at current analyses to assess short-term (1 - 6 h) MCS evolution and don't need to rely solely on short-term forecasts of the environment (although it's still a good idea to do so).

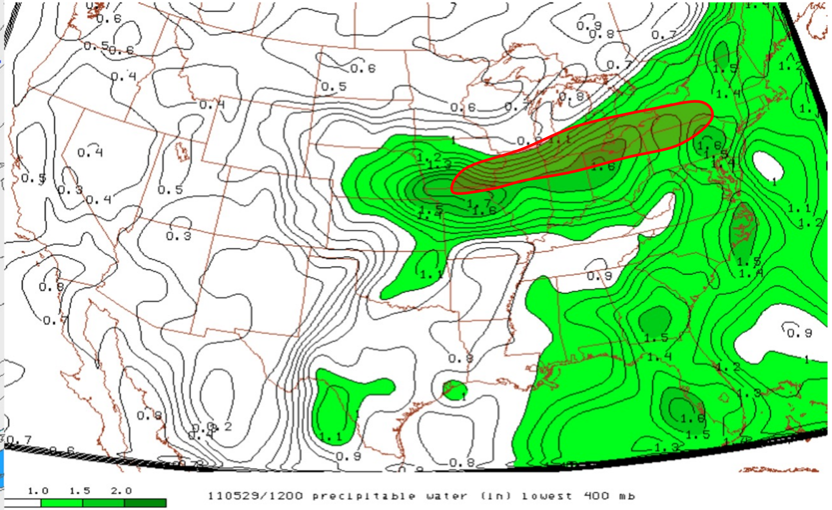
Example: 29 May 2011



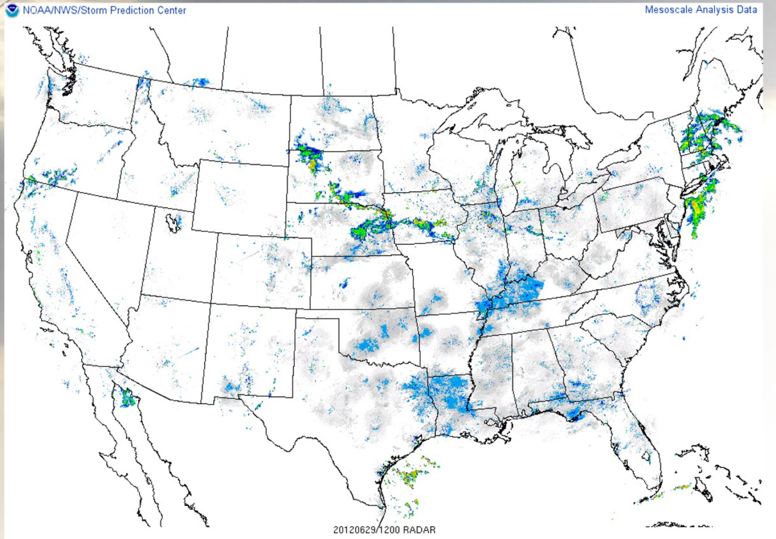

National Weather Service
110529/1200 500 MB UA OBS, HGHTS, and TEMPS

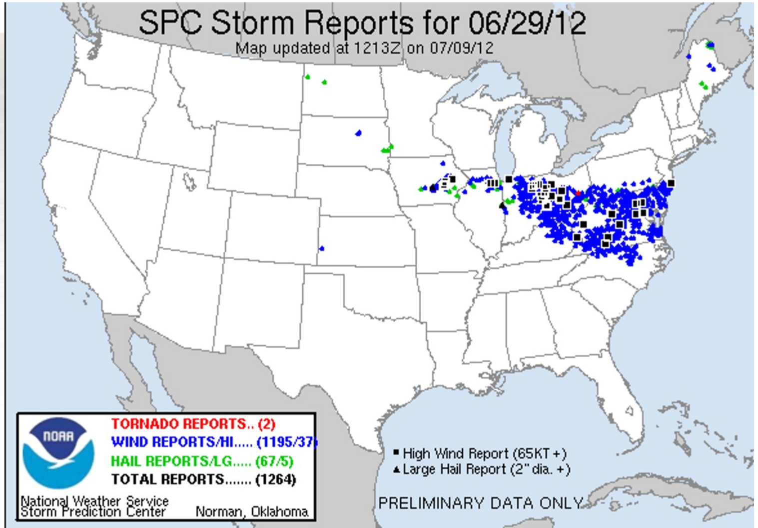

1200Z SURFACE ANALYSIS
DATE: SUN MAY 29 2011
ISSUED: 1328Z SUN MAY 29 2011
BY HPC ANALYST HAMRICK
COLLABORATING CENTERS: HPC, NHC, OPC

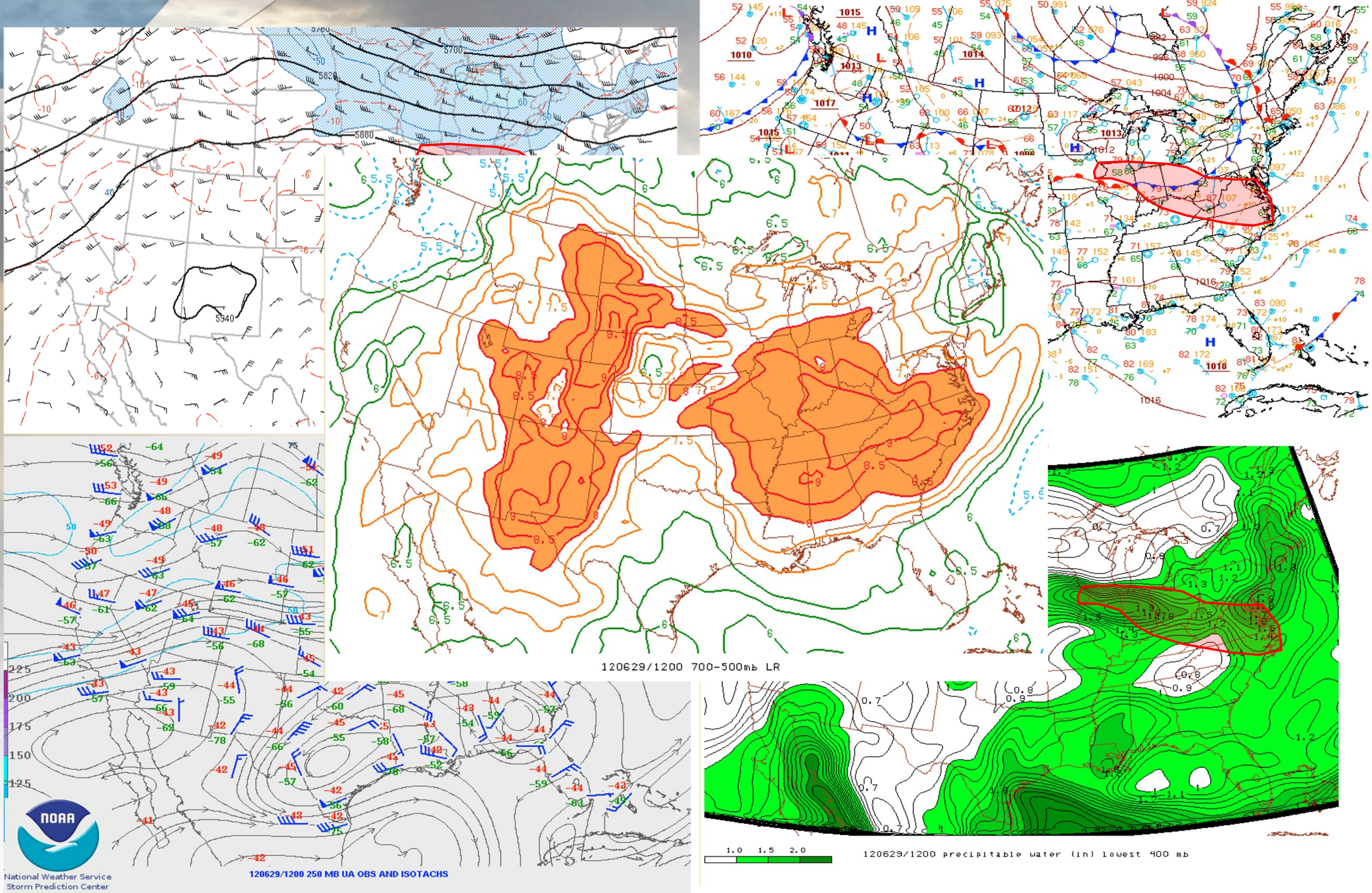

National Weather Service
Storm Prediction Center
110529/1200 250 MB UA OBS AND ISOTACHS


1.0 1.5 2.0
110529/1200 precipitable water (in) lowest 400 mb

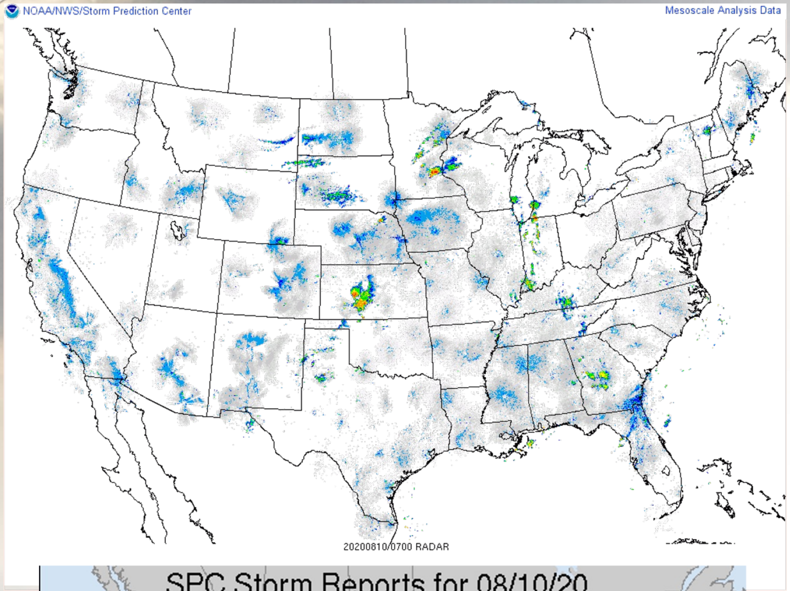
Example: 29 June 2012

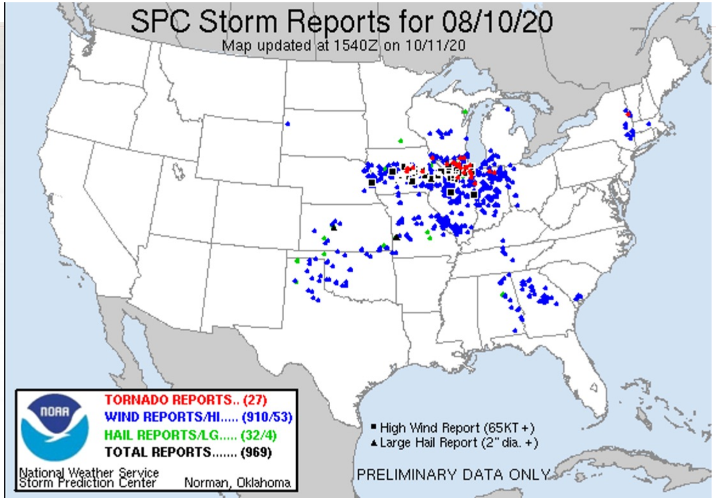




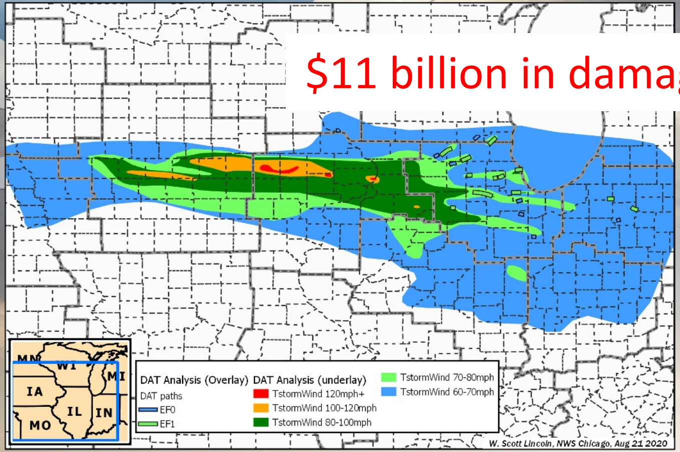

120629/1200 700-500mb LR
120629/1200 250 MB UA OBS AND ISOTACHS
120629/1200 precipitable water (in) lowest 400 mb
1.0 1.5 2.0
NOAA
National Weather Service
Storm Prediction Center

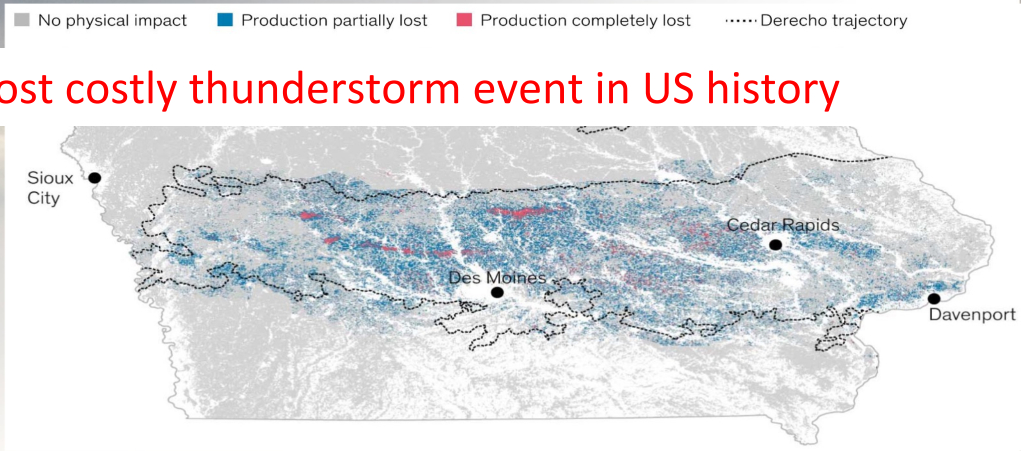
Example: 10 August 2020



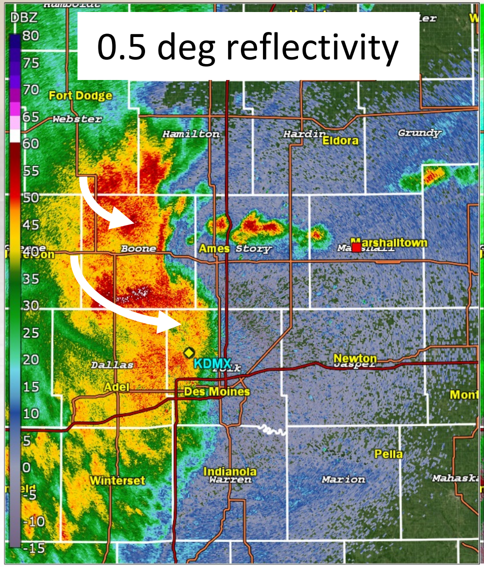


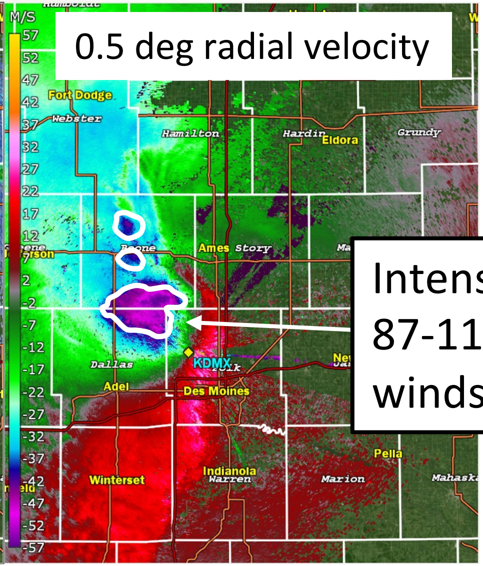
$11 billion in damages…the most costly thunderstorm event in US history



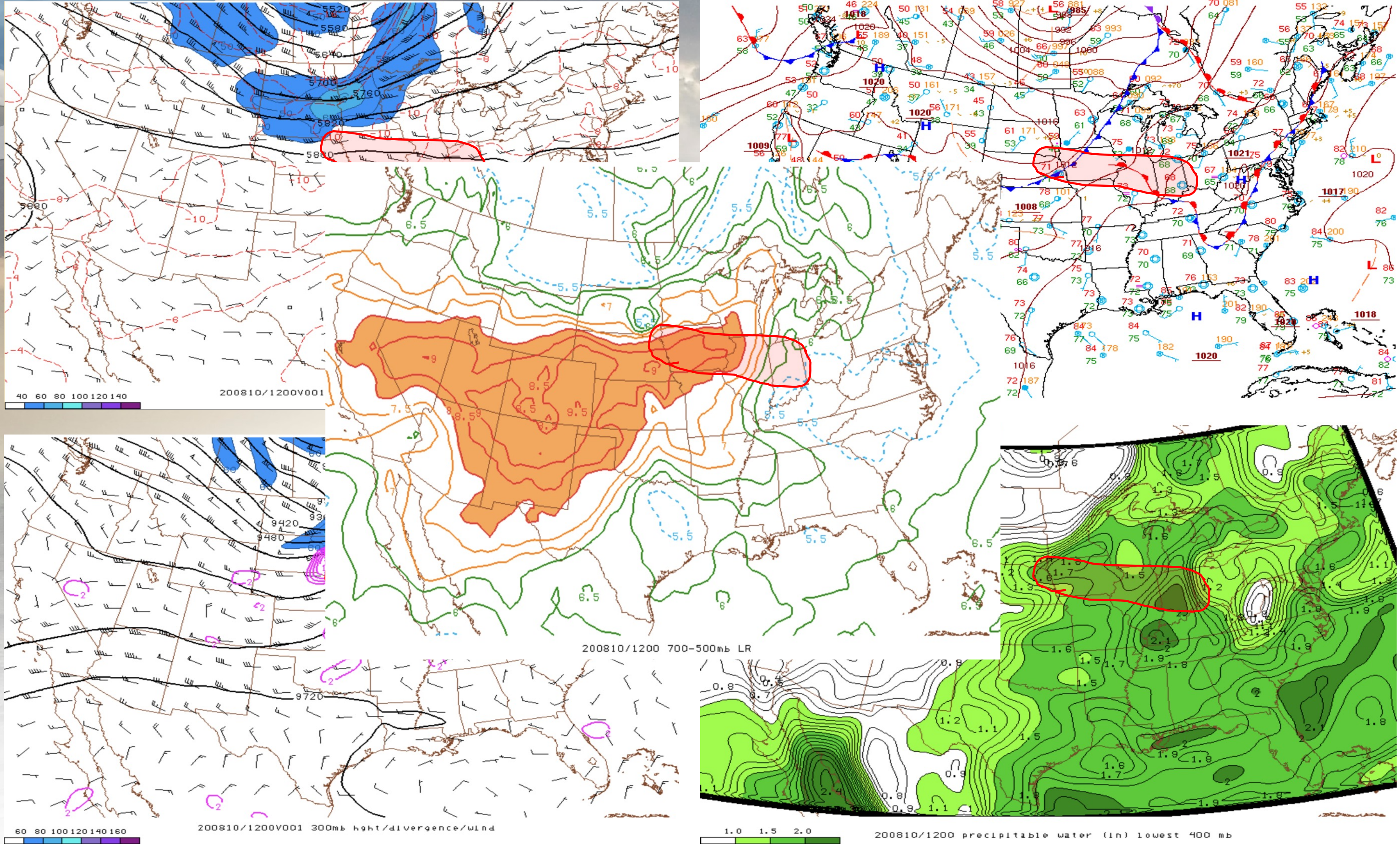


Source: McKinsey 2020

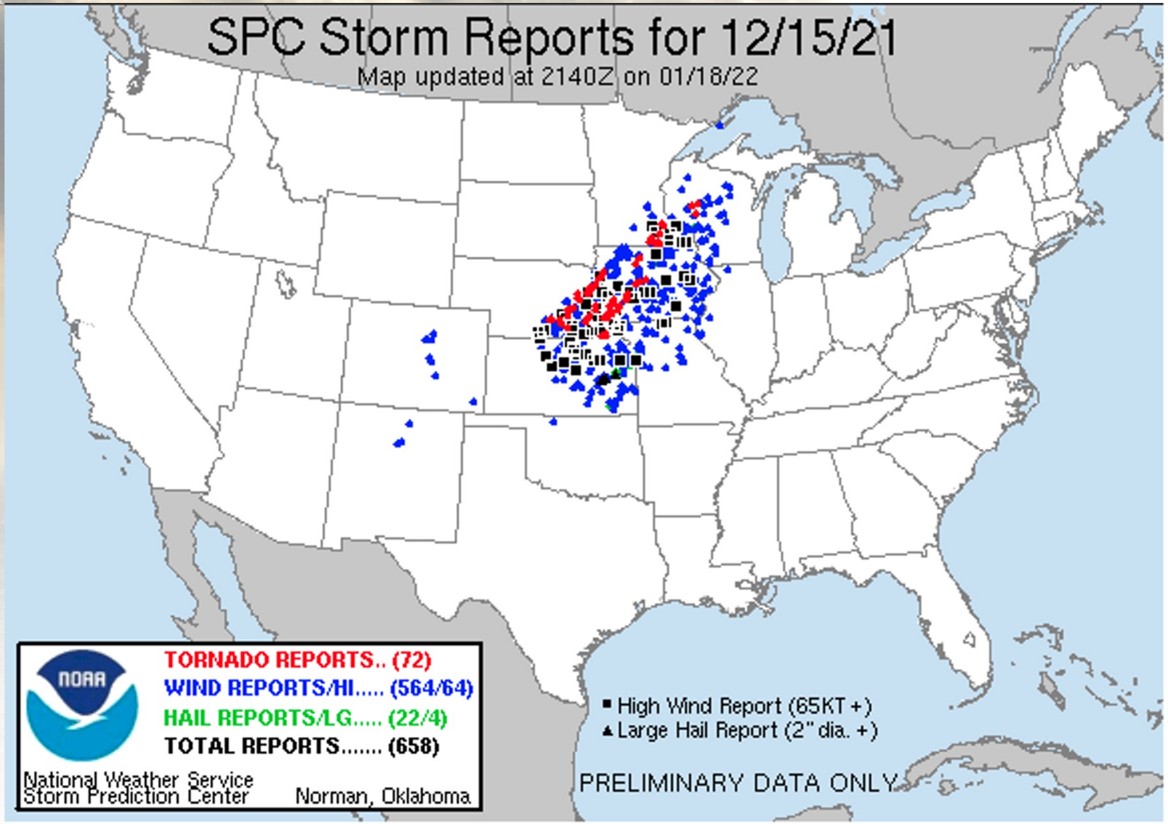


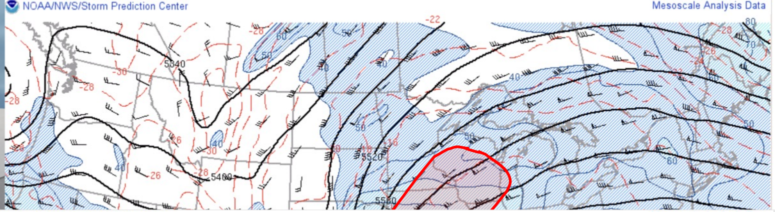


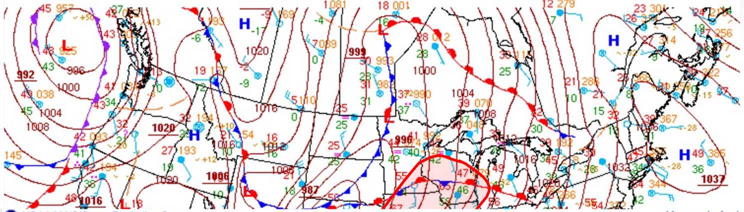
Intense rear-inflow: 87-117 kt inbound winds 100-250 m ARL

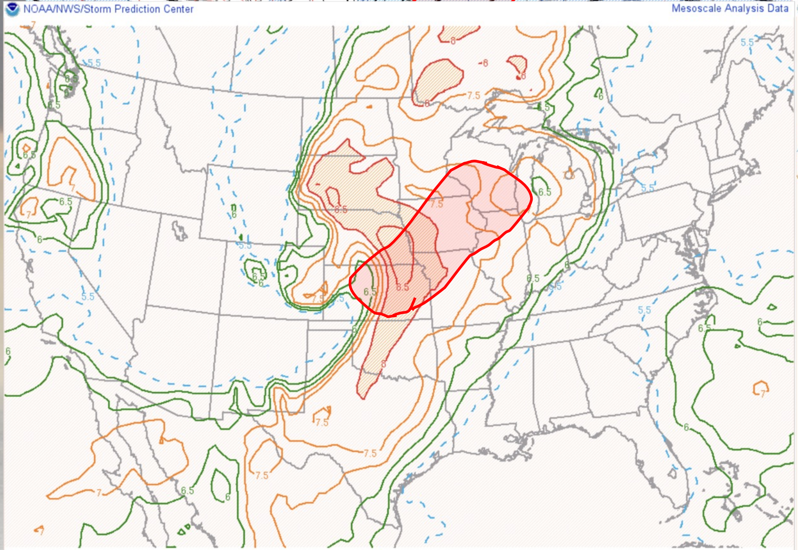

40 60 80 100 120 140
200810/1200V001
200810/1200 700-500mb LR
60 80 100 120 140 160
200810/1200V001 300mb hght/divergence/wind
1.0 1.5 2.0
200810/1200 precipitable water (in) lowest 400 mb

Example: 15 December 2021

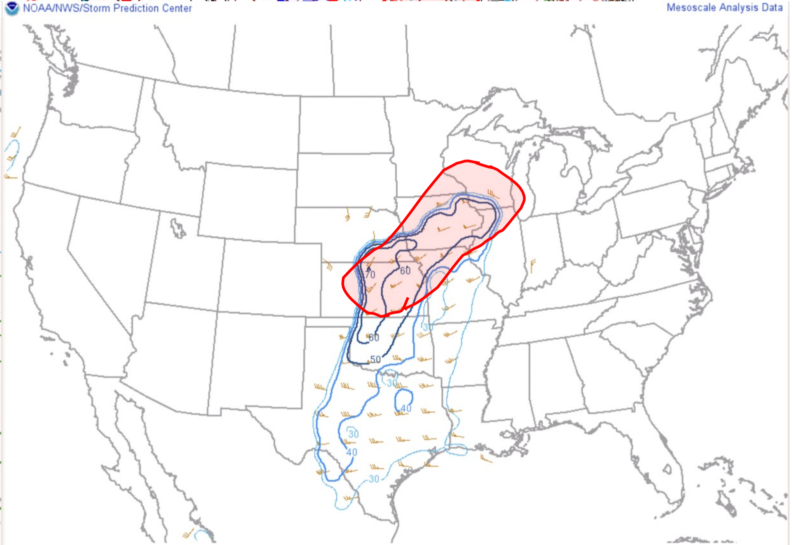




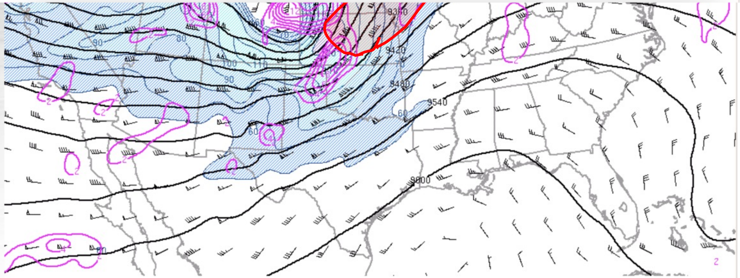




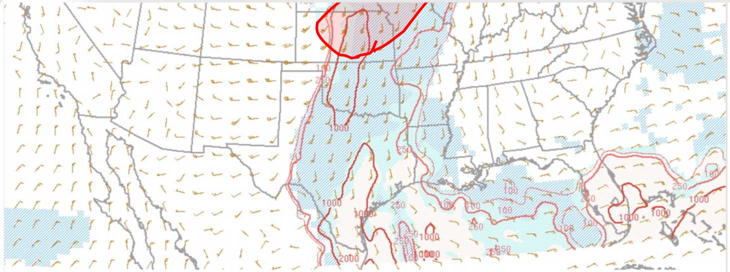
211215/1900 700-500mb LR



211215/1900 Effective bulk shear (kt)



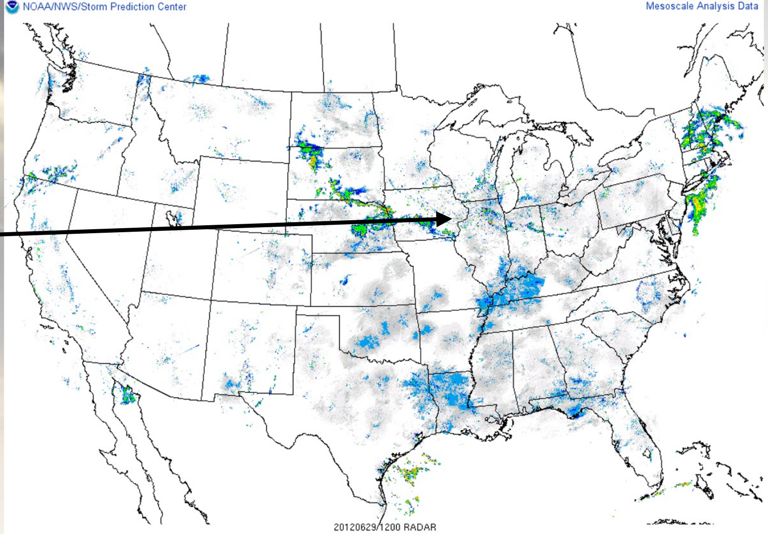
211215/1900V001 300mb height (m MSL, black), divergence (10**-5/s, magenta), and wind (kt, hatched >= 60 kt)



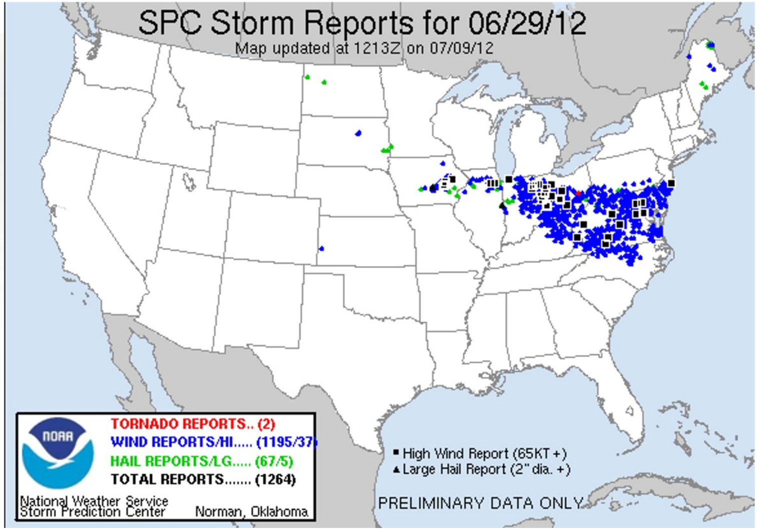
211215/1900 MLCAPE (contour) and MLCIN (J/kg, shaded at 25 and 100)

Final situation to consider: A favorable environment for derechos is in place. Will one occur, i.e. what are possible **failure modes**?

Elevated convection (likely forced by LLJ & thermally-direct circulation) suddenly becomes surface-based after sunrise….very difficult to anticipate this (Aug 10, 2020 was similar)



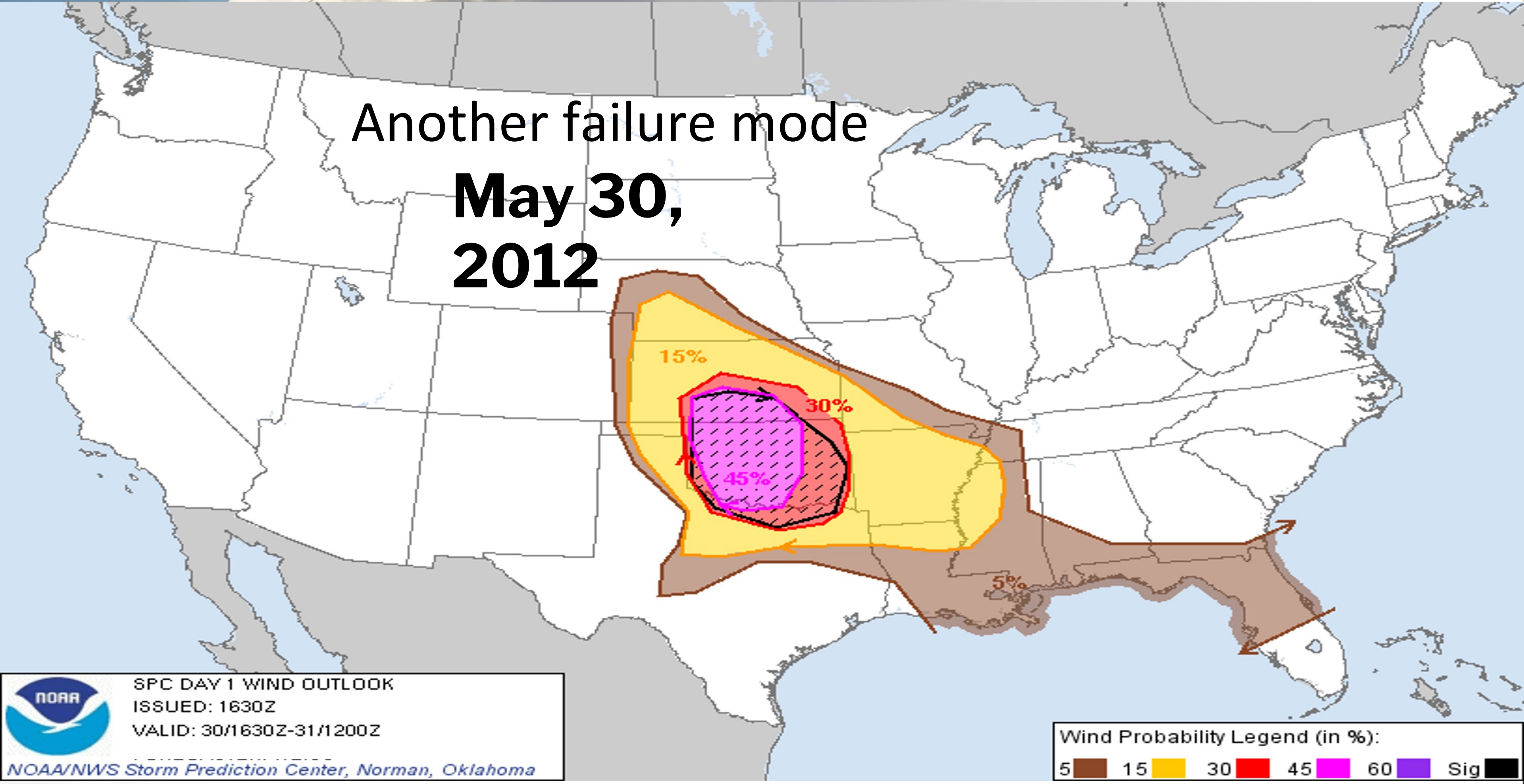
….many derecho setups are wasted by either **lack of CI in the right place (EML too strong) or lack of elevated to surface-based transition**

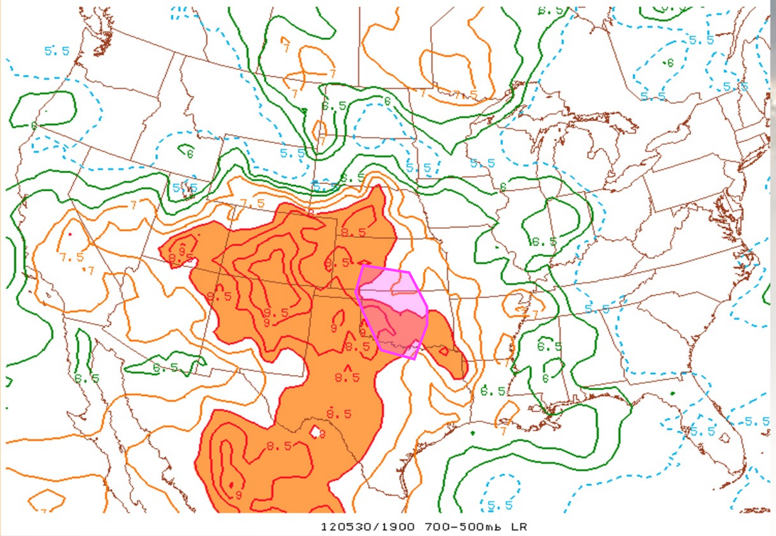


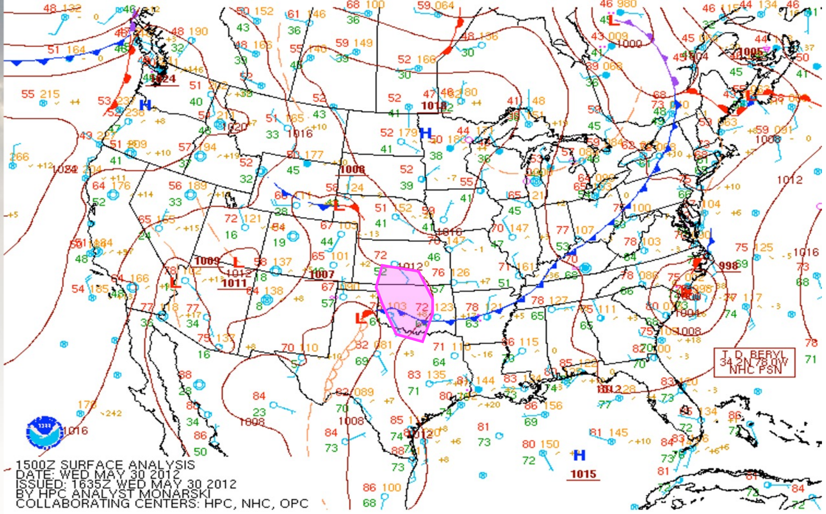
NWP improvements are sorely needed here….convection-allowing guidance is still very inconsistent for summertime MCSs (Warn-on-Forecast system promising!)

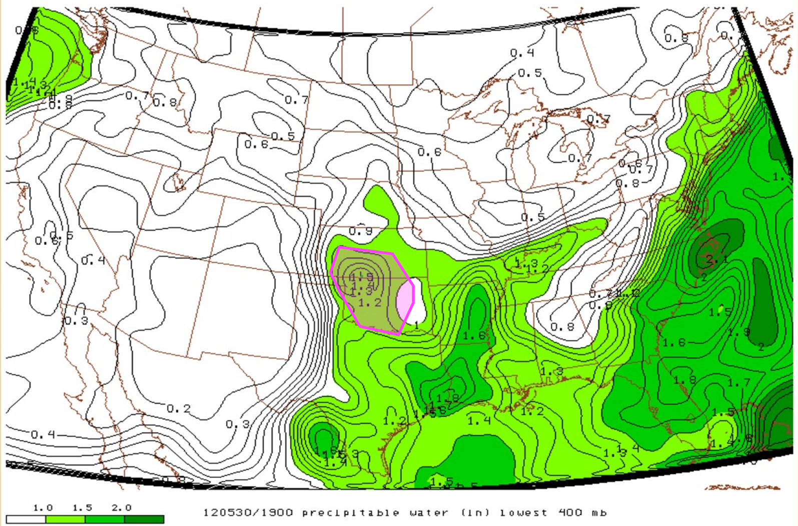
Another failure mode

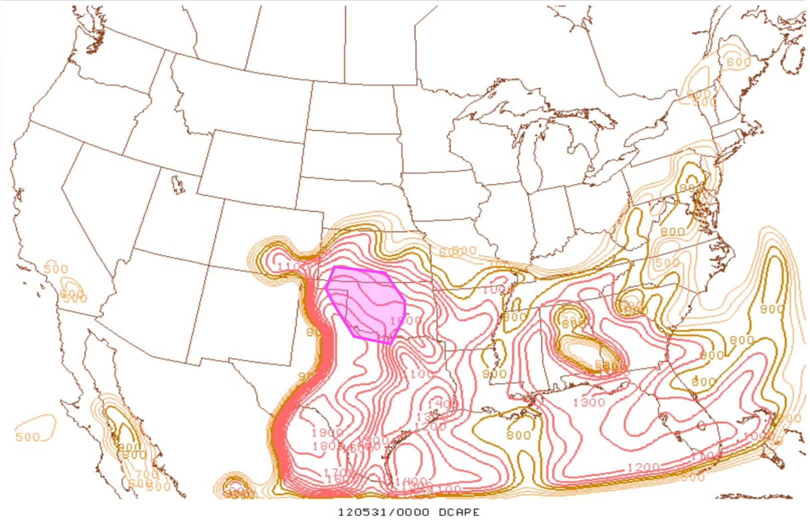
May 30, 2012

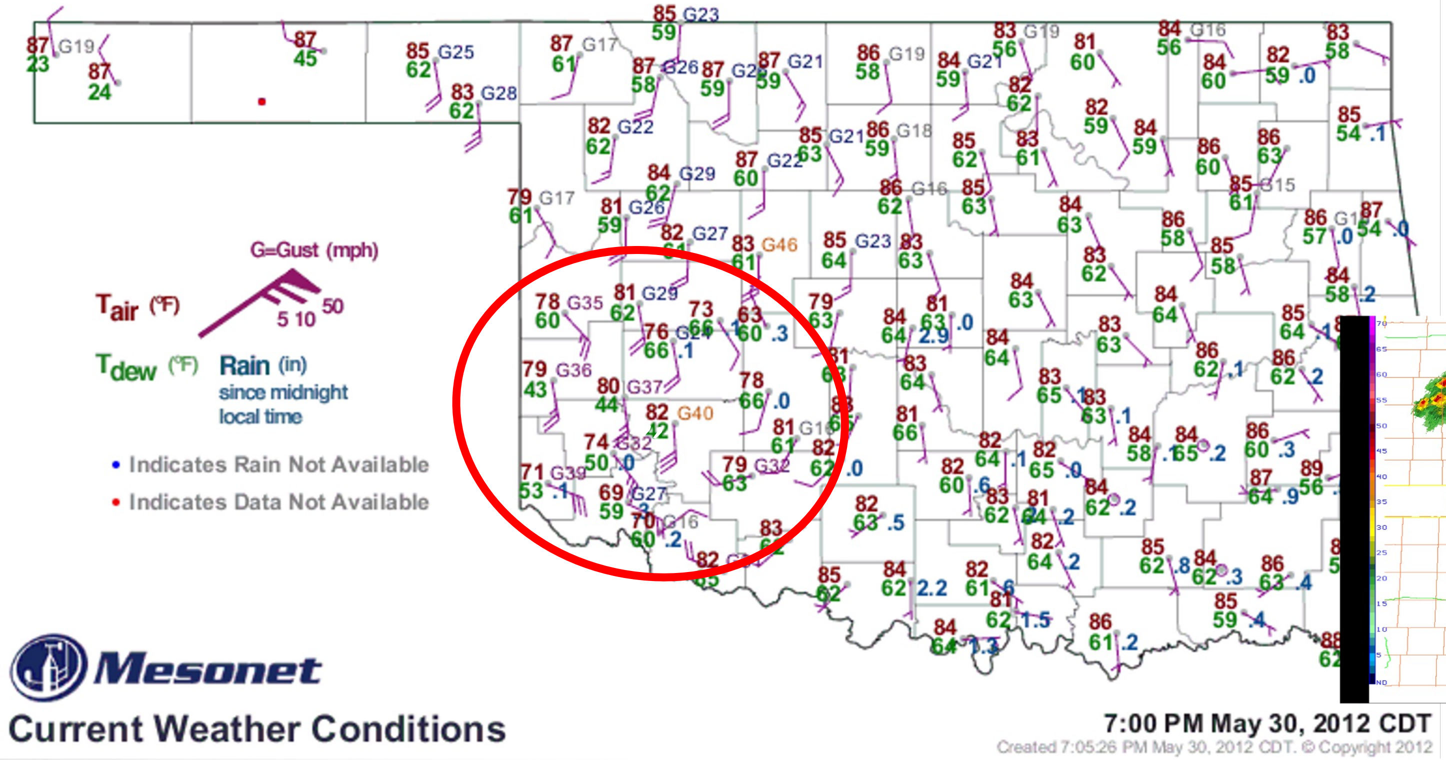


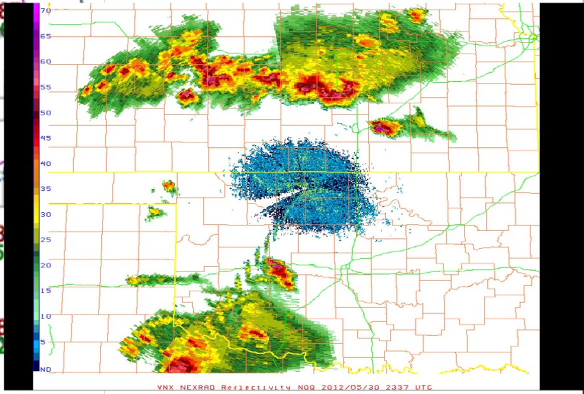

120530/1900 700-500mb LR

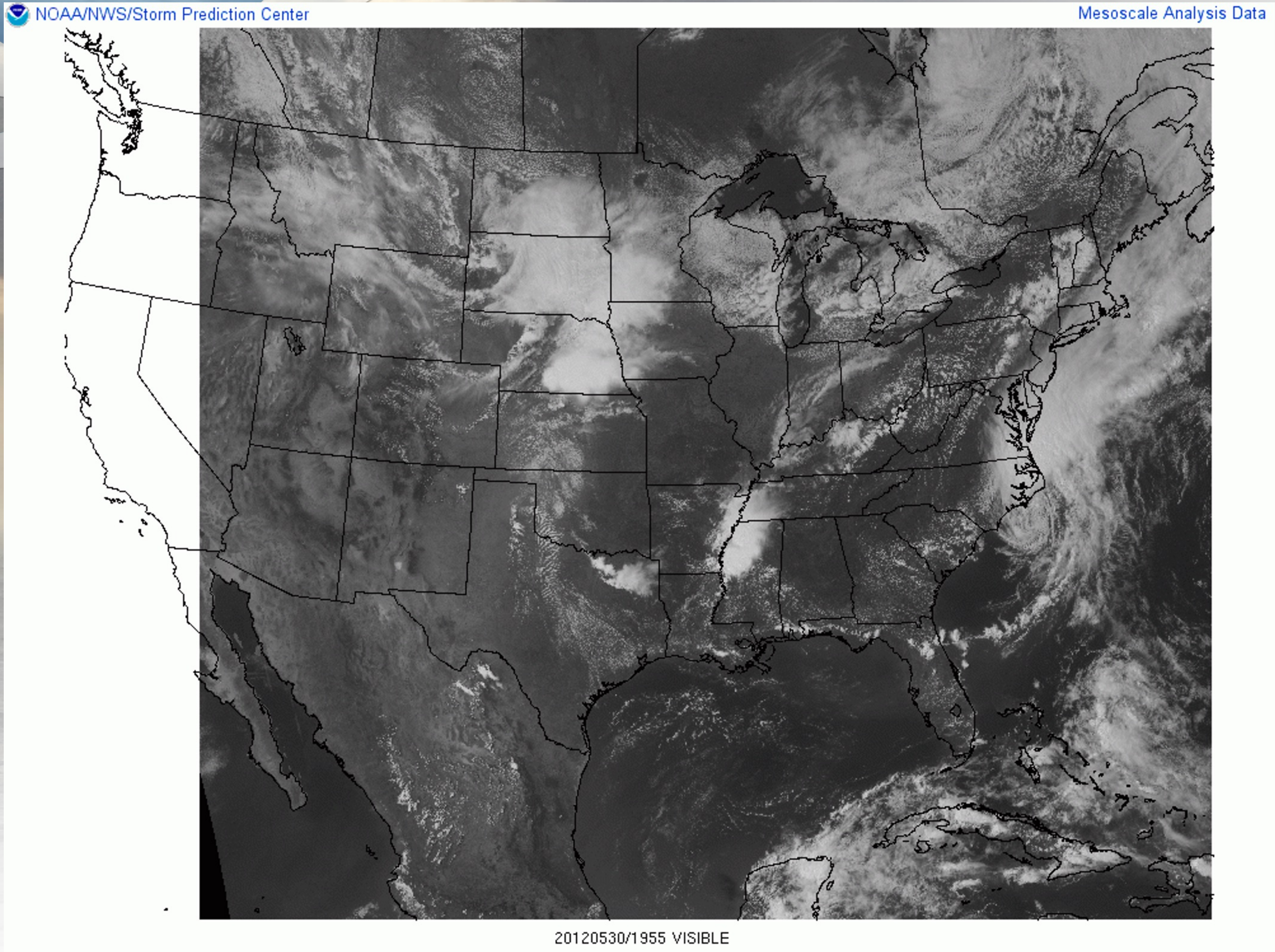

1500Z SURFACE ANALYSIS
DATE: WED MAY 30 2012
ISSUED: 1635Z WED MAY 30 2012
BY HPC ANALYST MONARSKI
COLLABORATING CENTERS: HPC, NHC, OPC
T. D. BERYL
34.2N 78.0W
NHC PSN

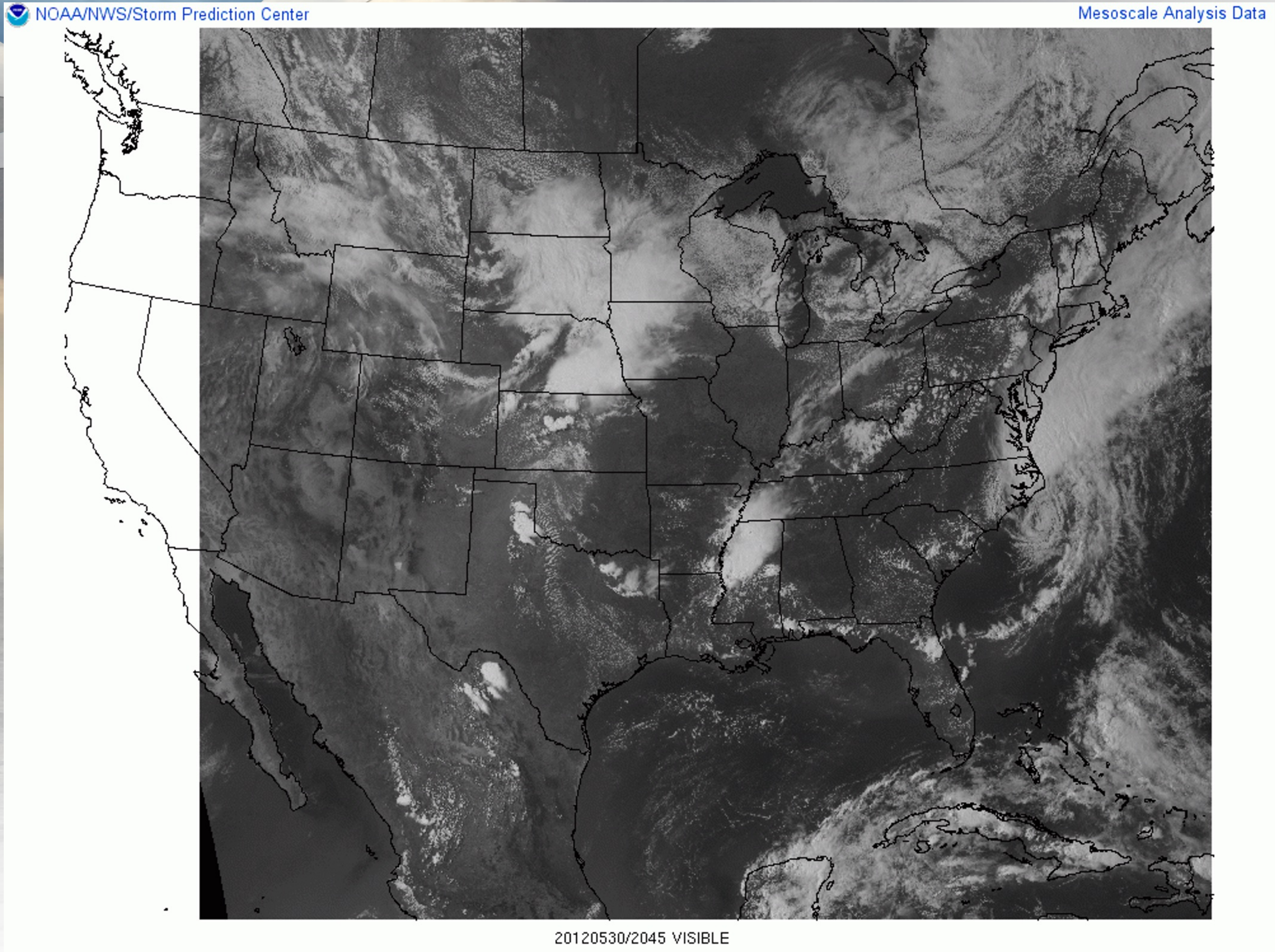

1.0 1.5 2.0
120530/1900 precipitable water (in) lowest 400 mb

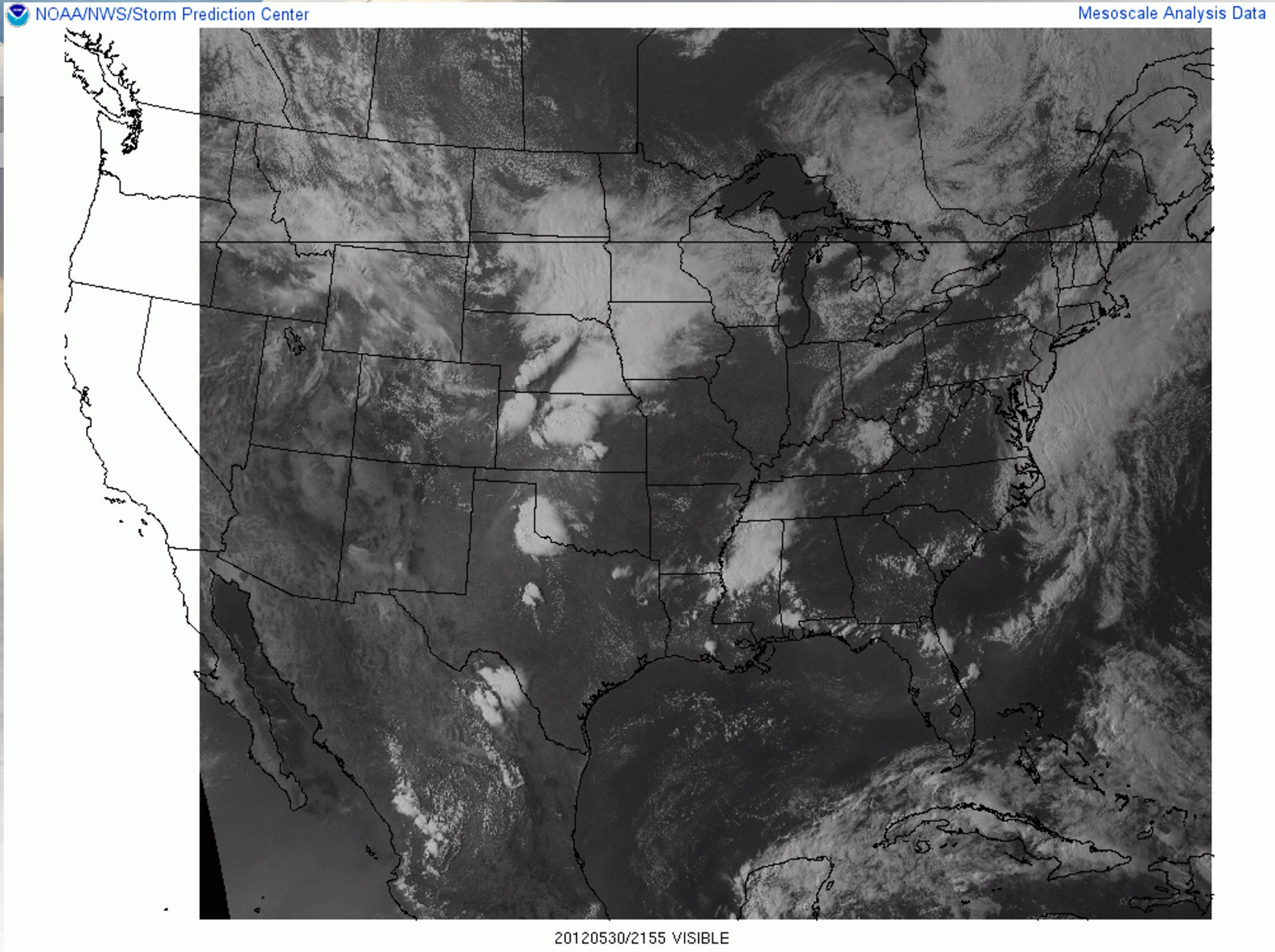

120531/0000 DCAPE

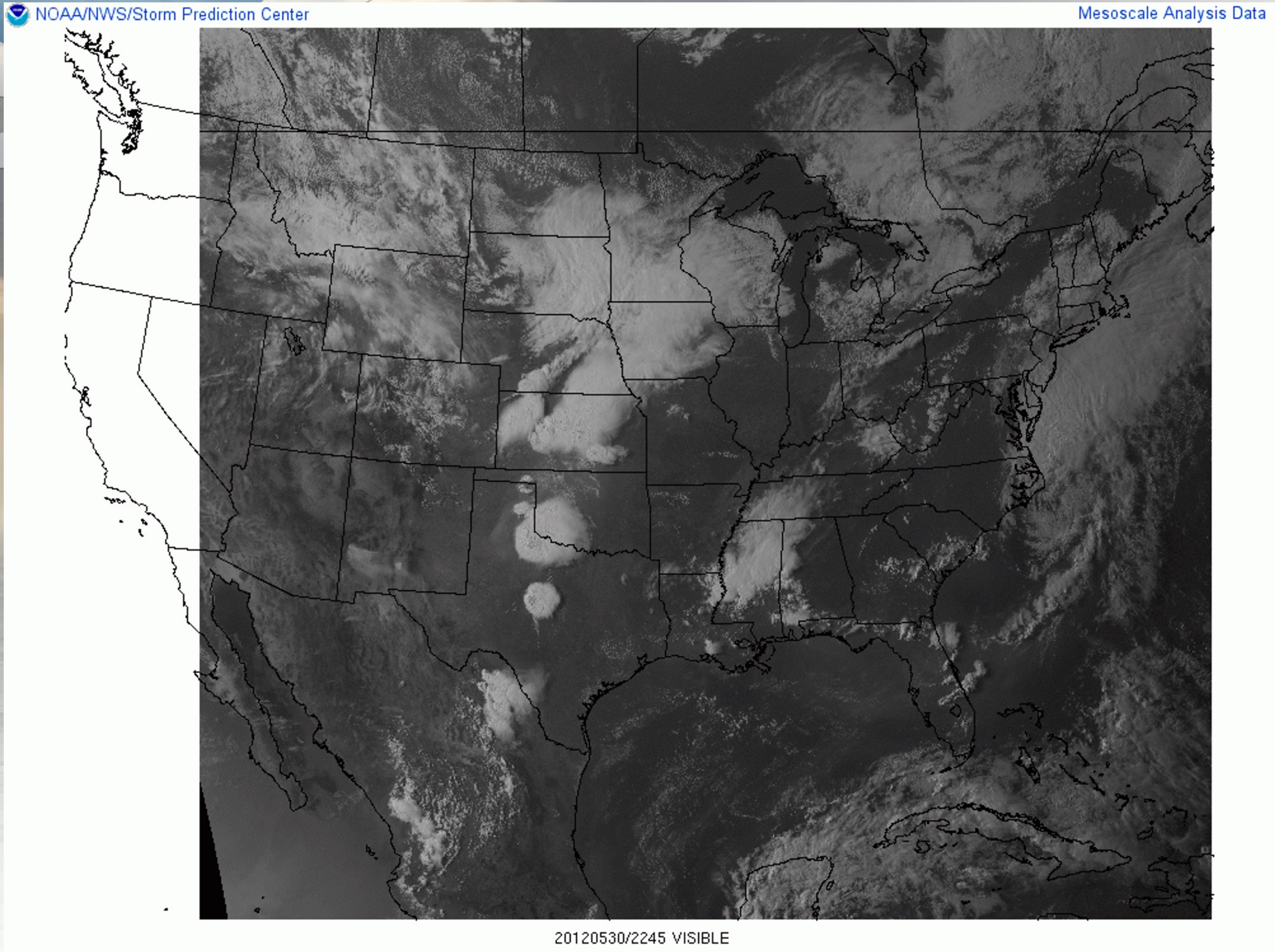

G=Gust (mph)
Tair (°F)
5 10 50
Tdew (°F)
Rain (in) since midnight local time
• Indicates Rain Not Available
• Indicates Data Not Available
Mesonet
Current Weather Conditions
7:00 PM May 30, 2012 CDT
Created 7:05:26 PM May 30, 2012 CDT. © Copyright 2012




NOAA/NWS/Storm Prediction Center
Mesoscale Analysis Data
20120530/1955 VISIBLE


NOAA/NWS/Storm Prediction Center
Mesoscale Analysis Data
20120530/2045 VISIBLE


NOAA/NWS/Storm Prediction Center
Mesoscale Analysis Data
20120530/2155 VISIBLE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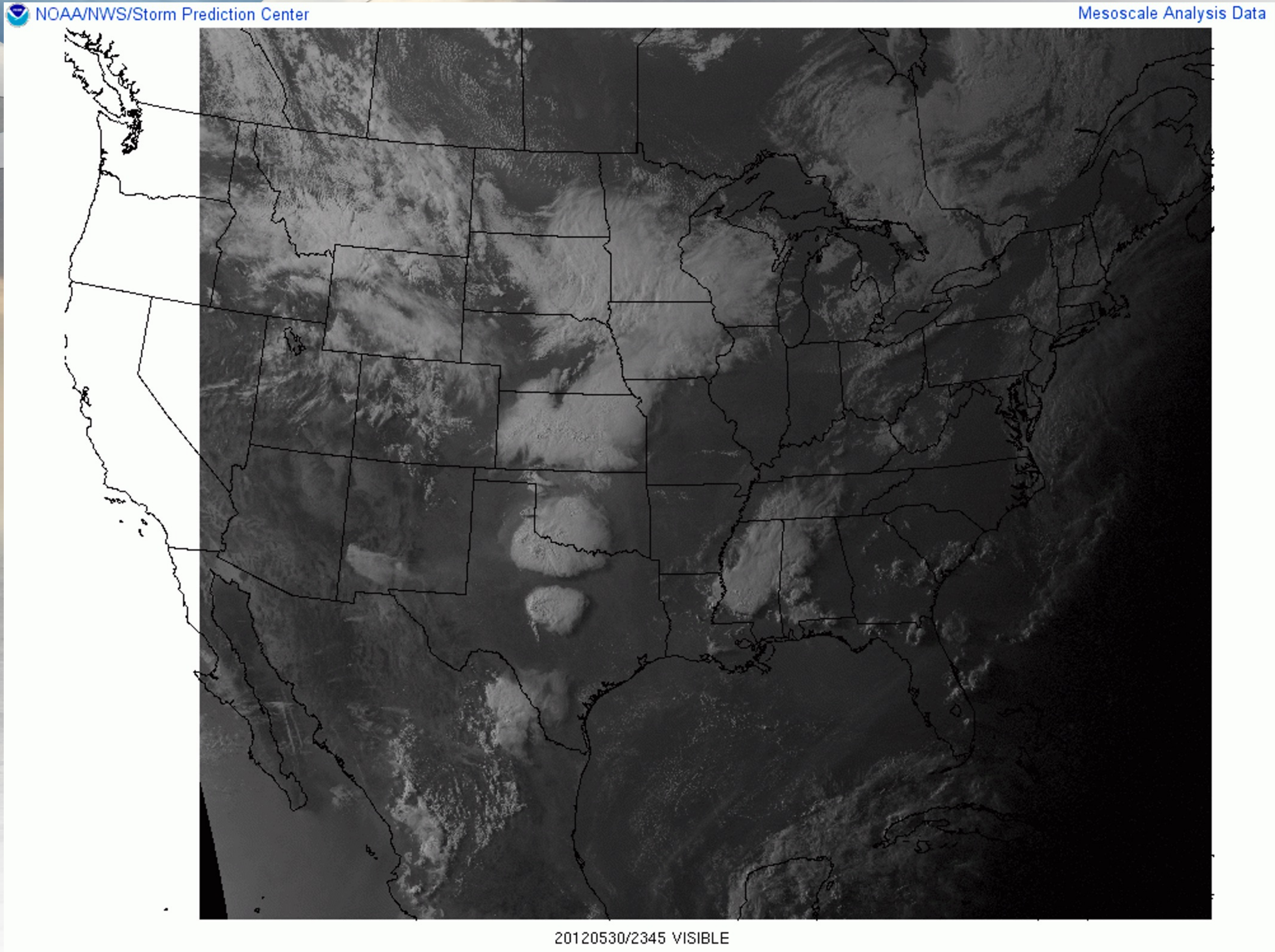
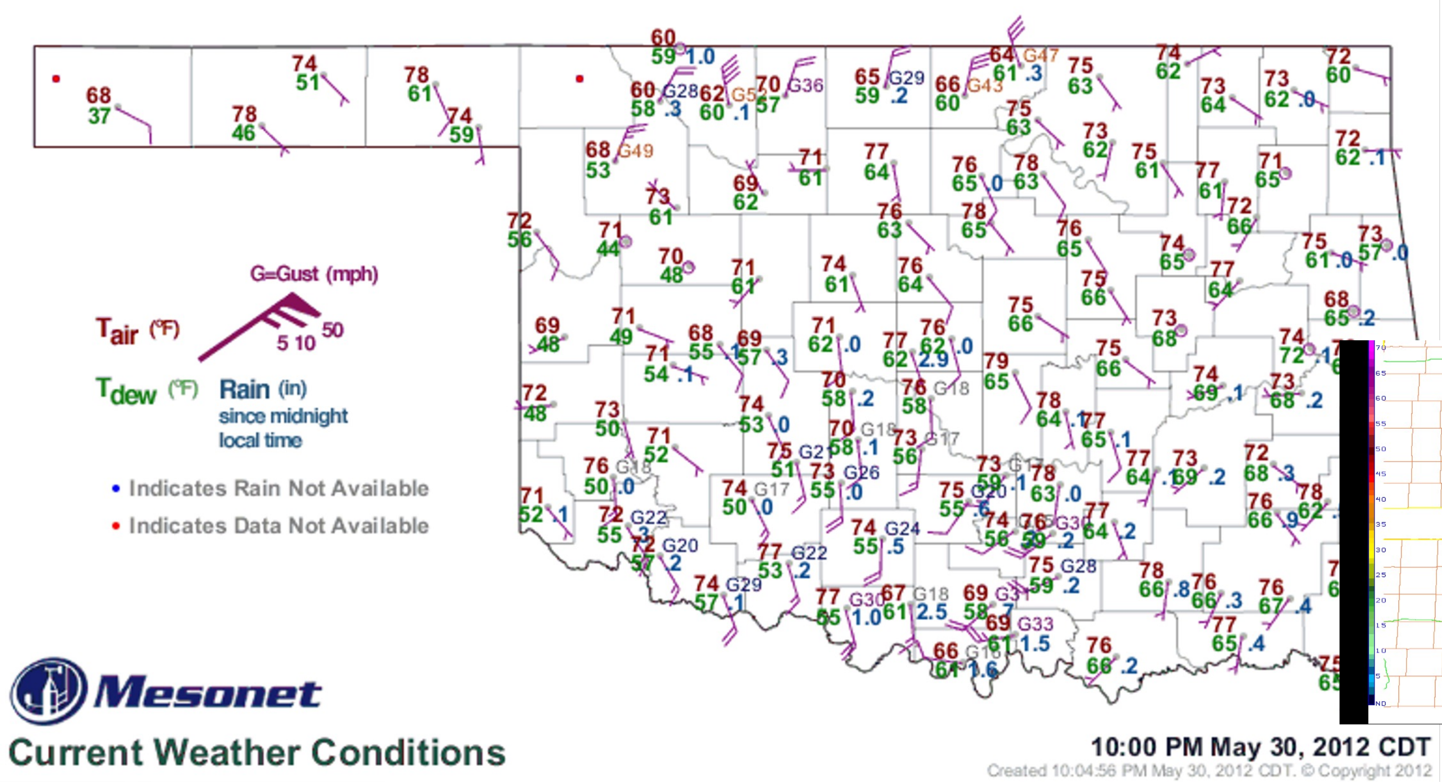
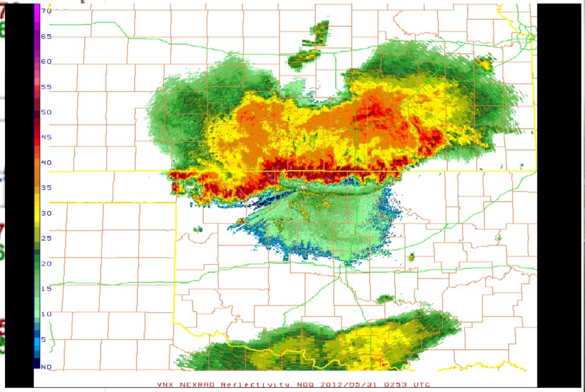
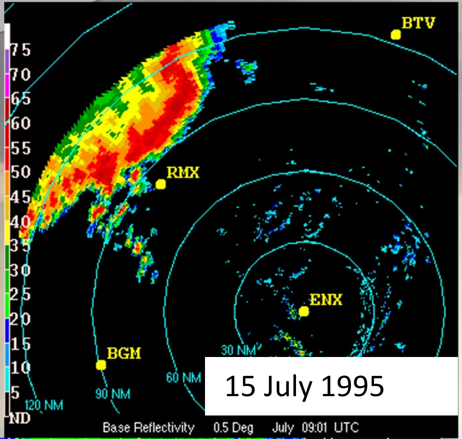
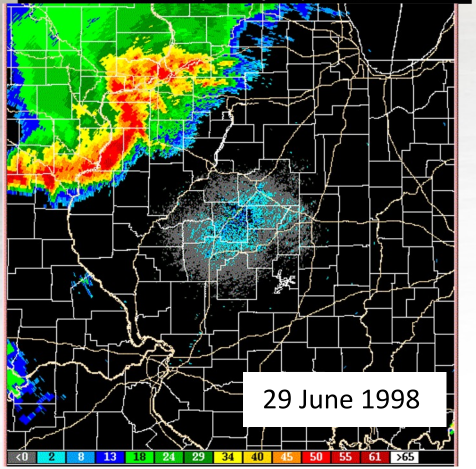

NOAA/NWS/Storm Prediction Center
Mesoscale Analysis Data
20120530/2345 VISIBLE

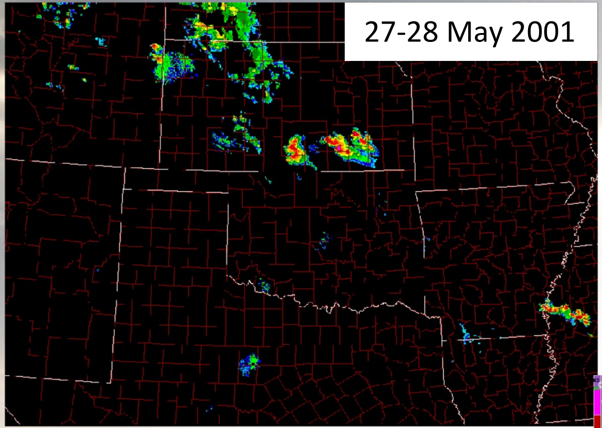

G=Gust (mph)
Tair (°F)
5 10 50
Tdew (°F)
Rain (in) since midnight local time
• Indicates Rain Not Available
• Indicates Data Not Available
Mesonet
Current Weather Conditions
10:00 PM May 30, 2012 CDT
Created 10:04:56 PM May 30, 2012 CDT. © Copyright 2012

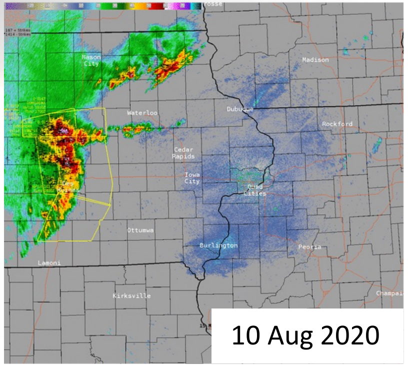

VNX NEXRAD Reflectivity N0Q 2012/05/31 0253 UTC

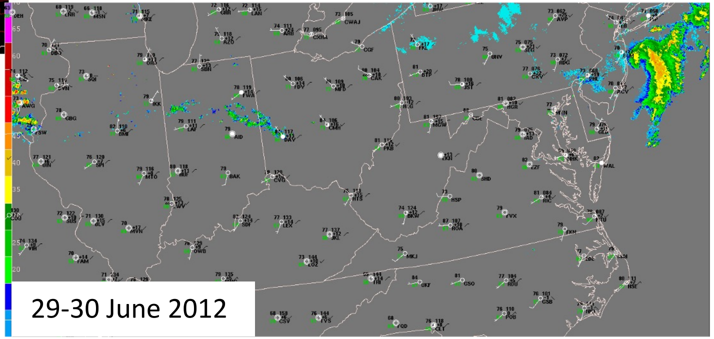
Famous derechos

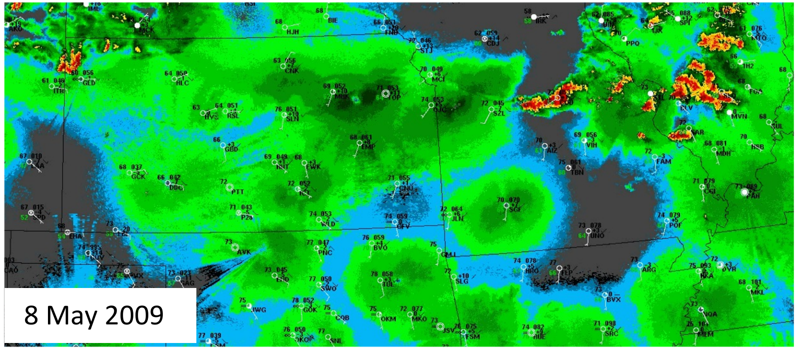






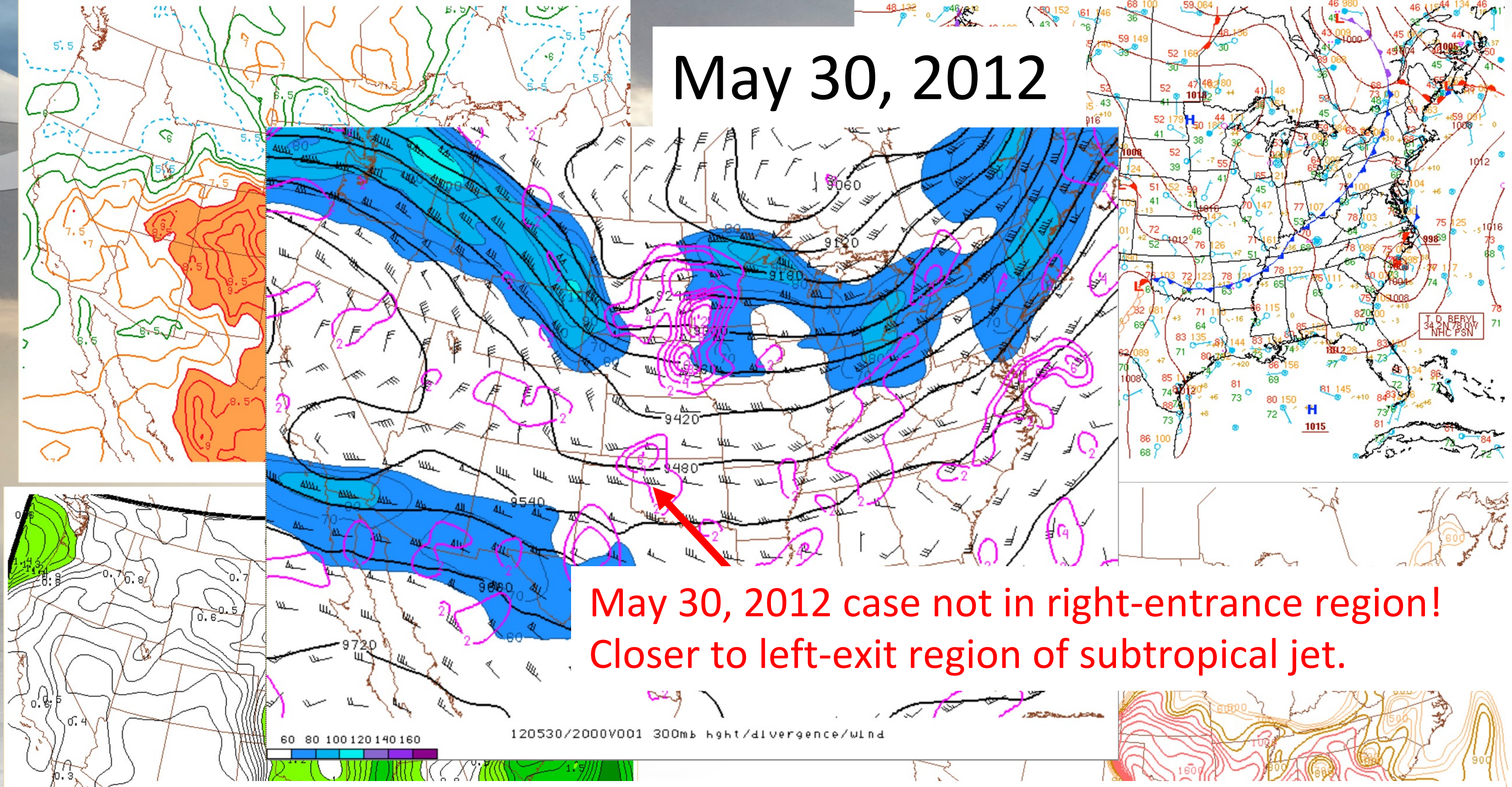






Little to no convection ahead of the main MCS prior to arrival of the cold pool

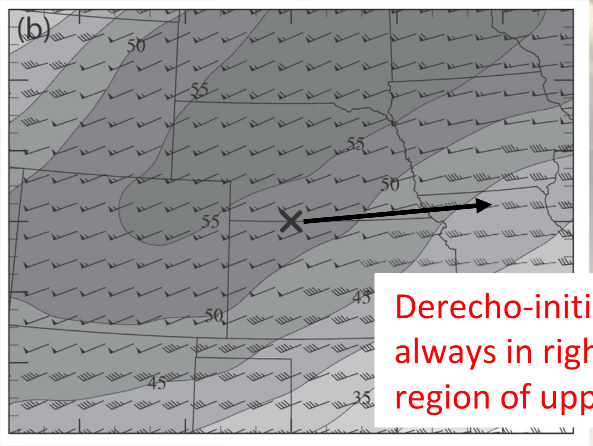
May 30, 2012



May 30, 2012 case not in right-entrance region!
Closer to left-exit region of subtropical jet.

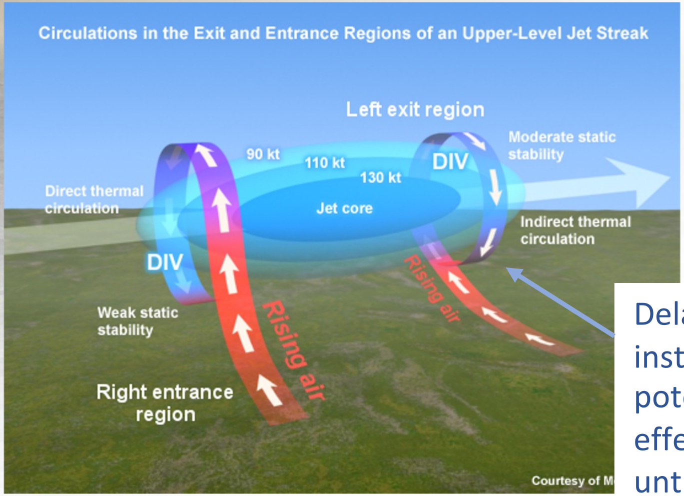
Derechos in left exit regions of upper-level jets are rare and are always associated with a significant mid-to-upper-level short-wave trough (Coniglio et al. 2004)

250-mb isotachs 1-h before first storms (N=94 MCSs)

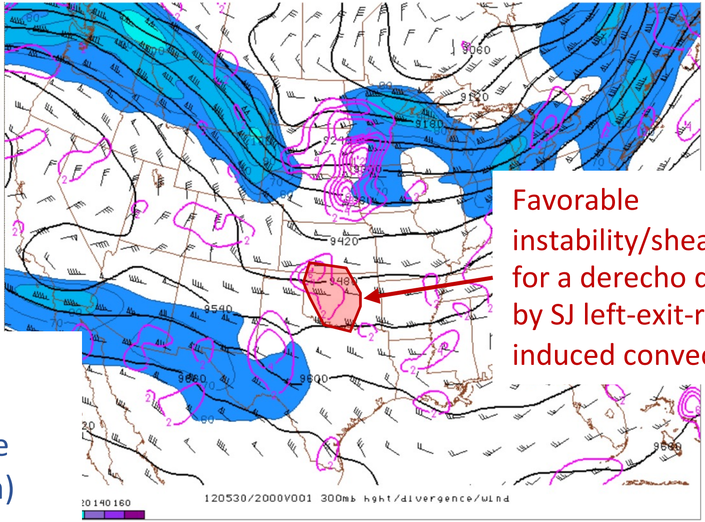


Derecho-initiation almost always in right-entrance region of upper jet

Hypothesis: Derecho initiation in right-entrance region is important not just for lift associated with thermally-direct circulation, but also for subsidence from downward branch of thermally indirect circulation in *right-exit* region that ***suppresses convection ahead of developing derecho***



Delays release of instability (and potentially disruptive effects of convection) until cold pool arrives.



Favorable instability/shear corridor for a derecho disrupted by SJ left-exit-region induced convection

Summary

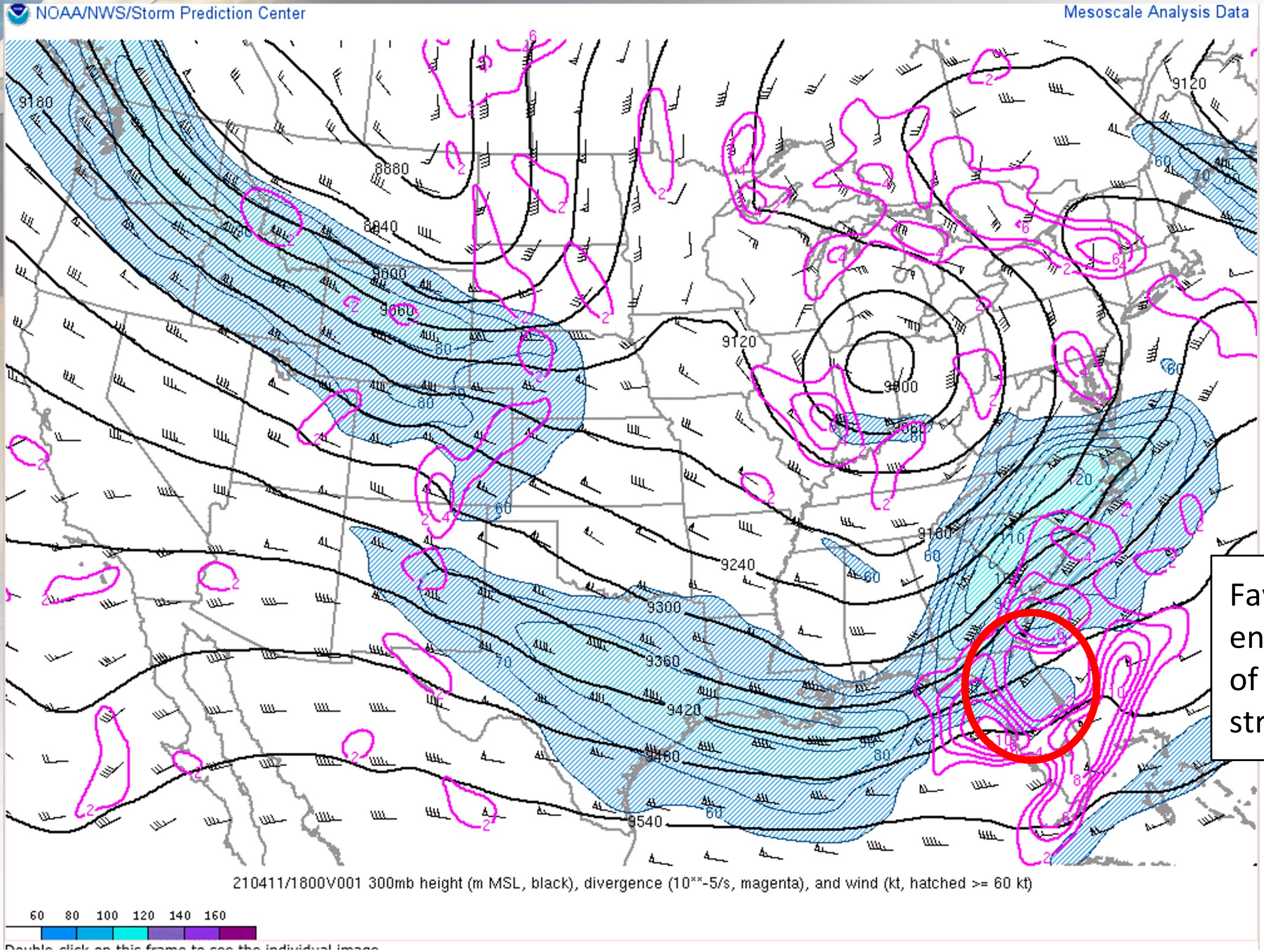
- **Environments favoring forward-propagating and longer-lived, severe MCSs**
  - Higher CAPE (both lapse rates and PW/CAPE) in elongated corridor
  - Stronger mean wind and moderate low and mid-level shear oriented at large angle to the cold pool (downshear cold pool advancement and favorable cold pool/shear setup for new cells)
  - Favorable environments are often in place when MCS first develops
- **But, be careful of failure modes!**
  - Lack of CI in the right place or lack of sfc-based cold pool development from ongoing elevated convection
  - Too much convection develops ahead of main cold pool that disrupts downstream environment
  - More systematic study of derecho failure modes is needed (harder to do)

April 11th, 2021 MCS Event Review
South Florida

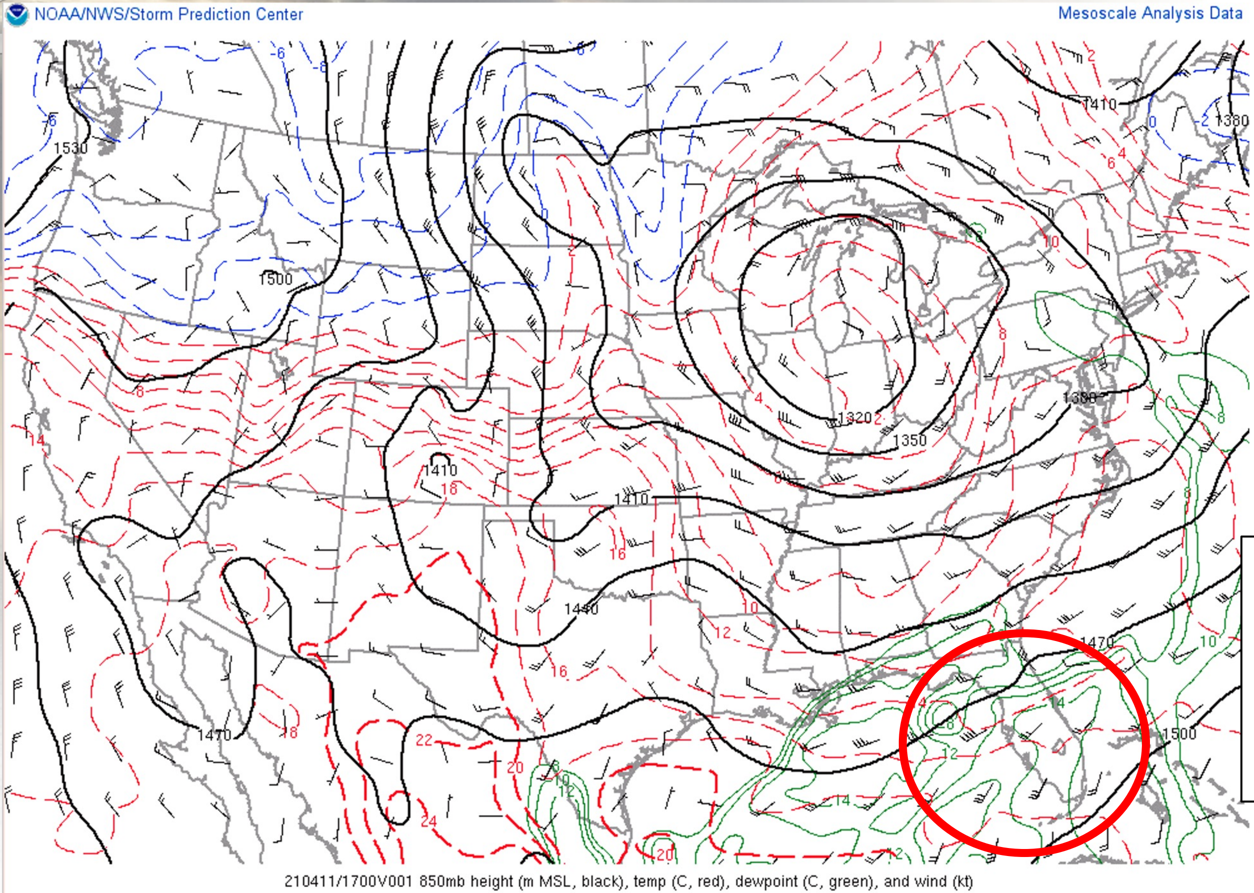
Harry Weinman

Overview: A fairly rare severe weather event unfolded on April 11th, 2021, when a large swath of wind damage occurred across the NWS Miami CWA in association with a backbuilding MCS which moved southward across the region.

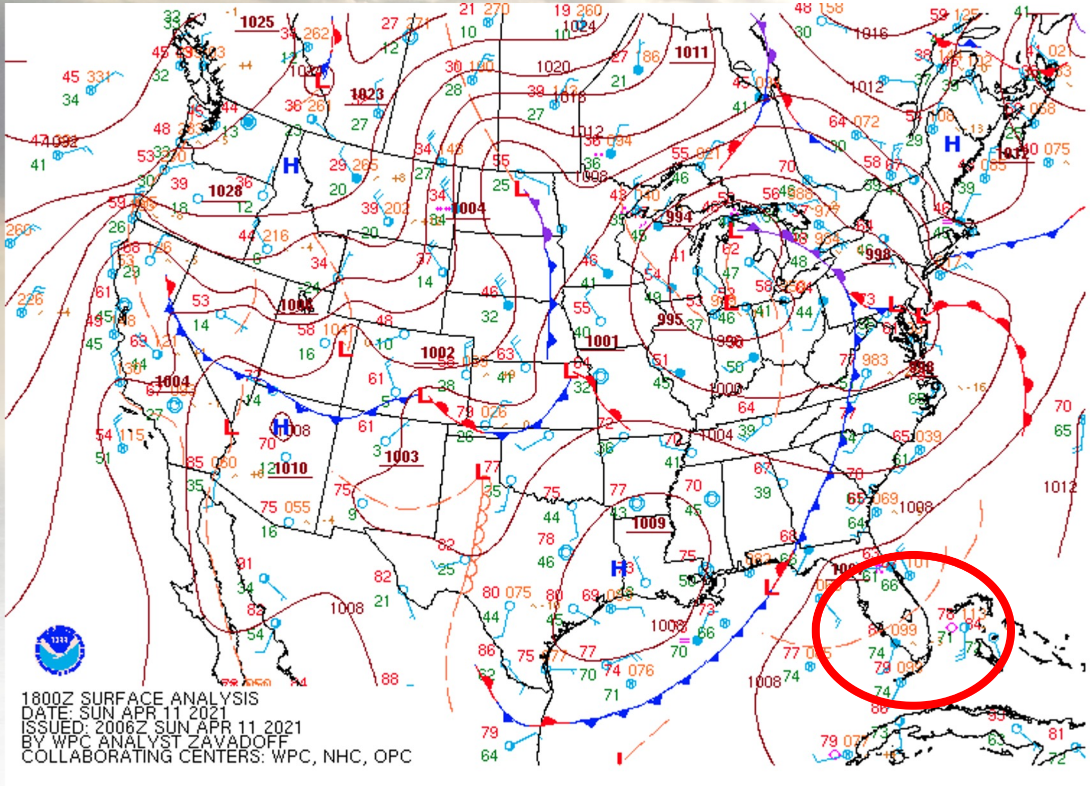
SPC issued a Severe Thunderstorm Watch highlighting 70 mph wind potential for the entire South Florida CWA leading up to the MCS event.



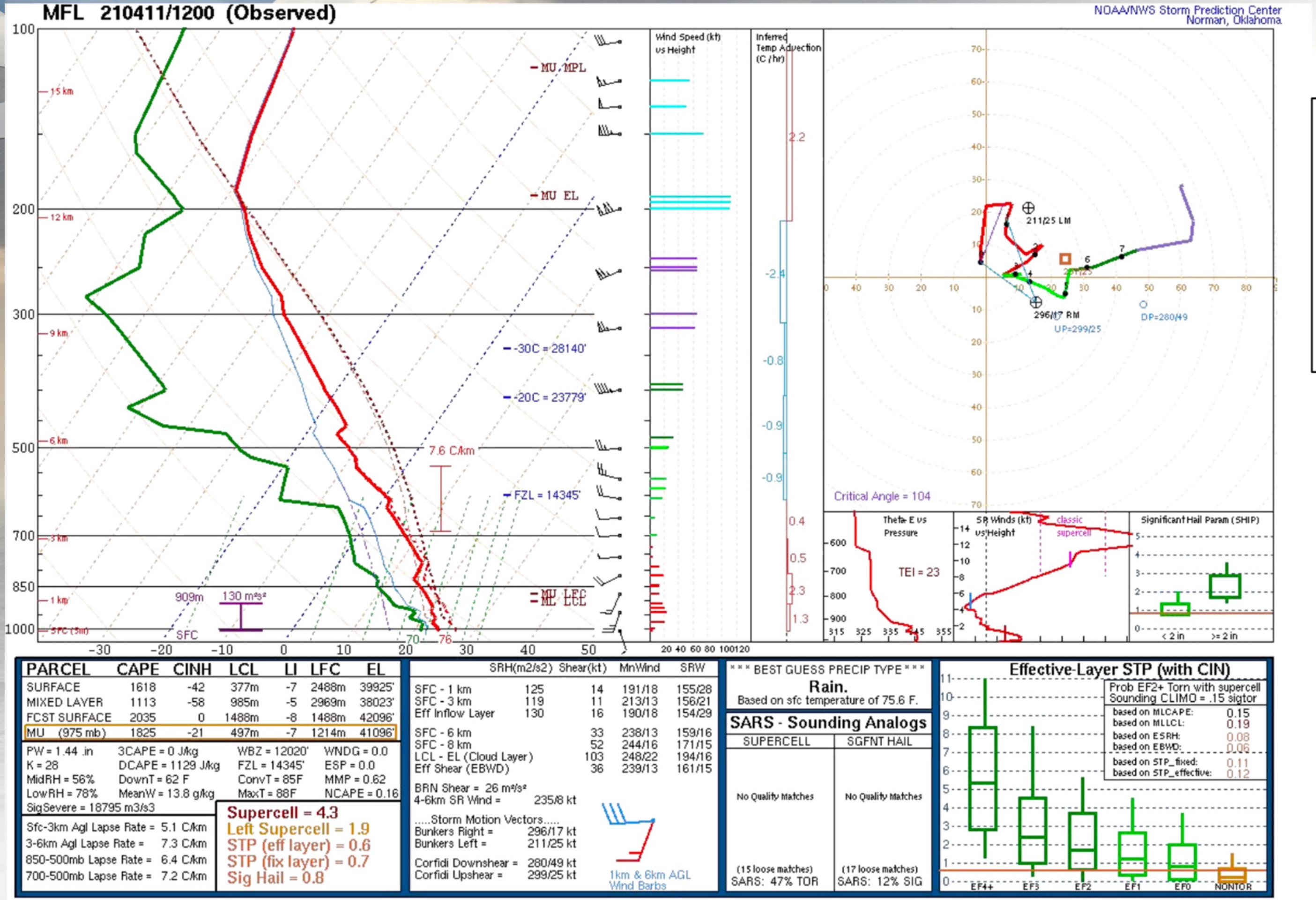
Favorable right-entrance region of strong jet streak



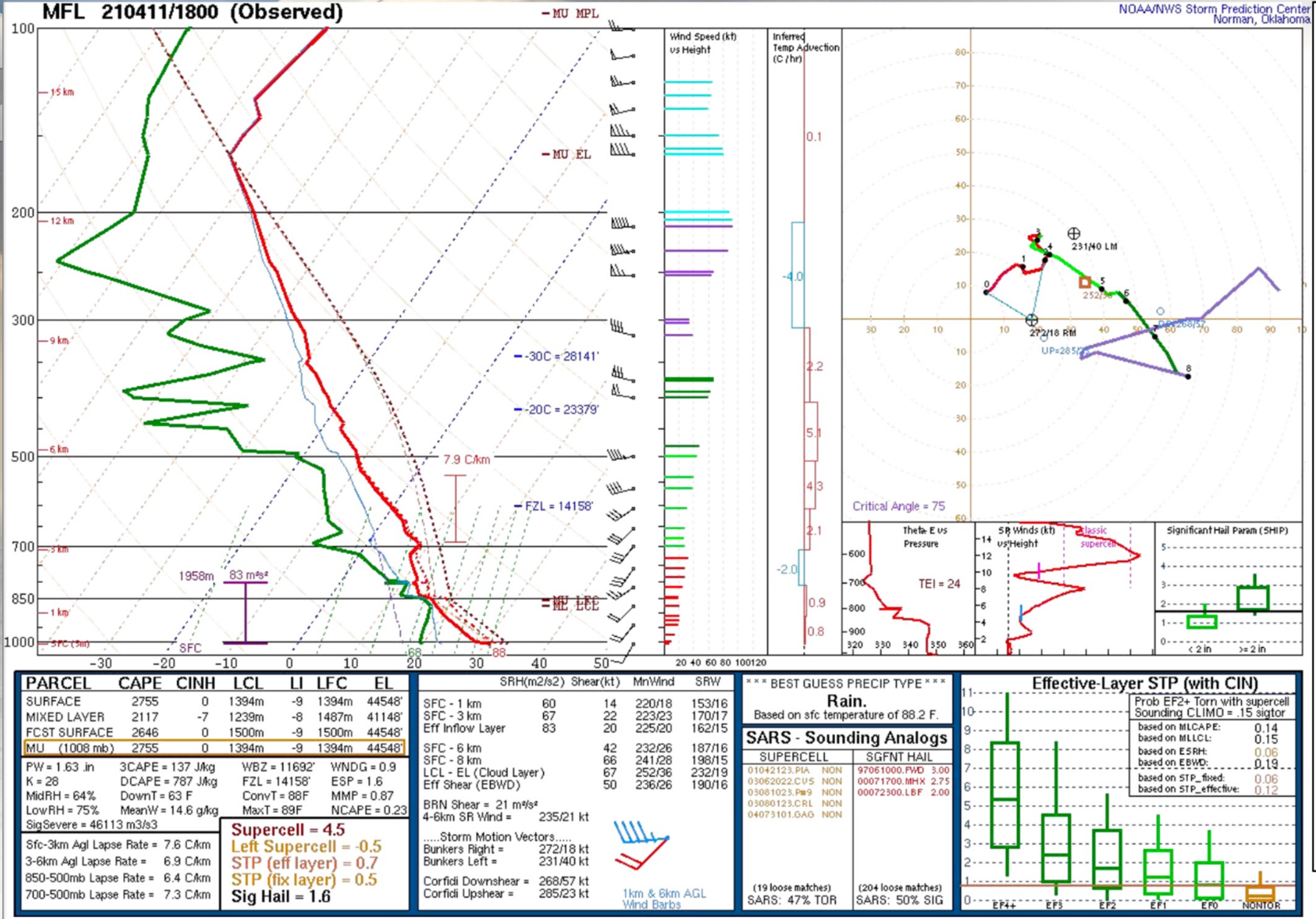
Low-level mass response (30-35–kt LLJ) and related WAA overspreading FL



No significant boundaries (i.e., warm front/cold front) for S FL



12Z MFL sounding shows a modestly favorable environment for strong convection, though a lot will change in the next 6 hours



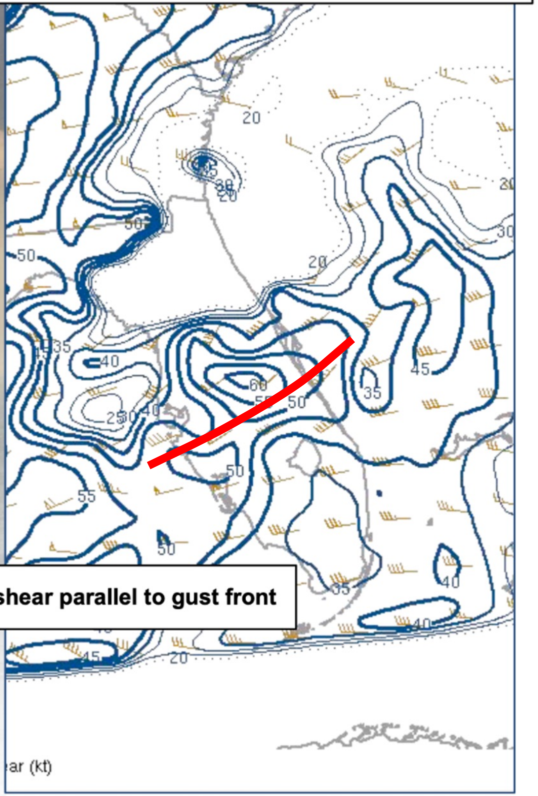
The 18Z MFL special sounding showed a favorable deep shear profile for organized convection along with strong buoyancy resulting from steep low/mid-level lapse rates and ample low-level moisture.

Veered low-level wind profile and associated lack of SRH (unidirectional wind profile).

The thermodynamic/kinematic environment supported severe wind and hail generation, though the hail threat was largely limited due to a predominantly linear convective mode.

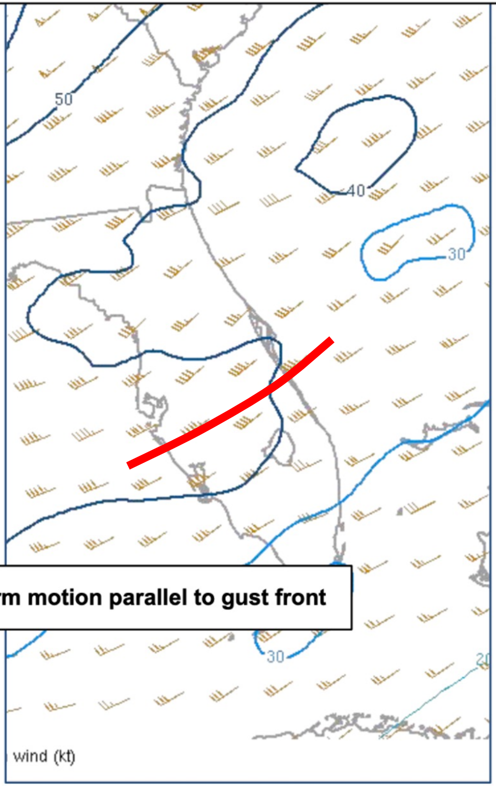
The dynamical influence addressed on previous four slides resulted in significantly more favorable sounding for severe weather at 18Z compared to 12Z.

17Z Mesoanalysis Effective Bulk Shear



Deep shear parallel to gust front

17Z Mesoanalysis 850-300 mb mean wind



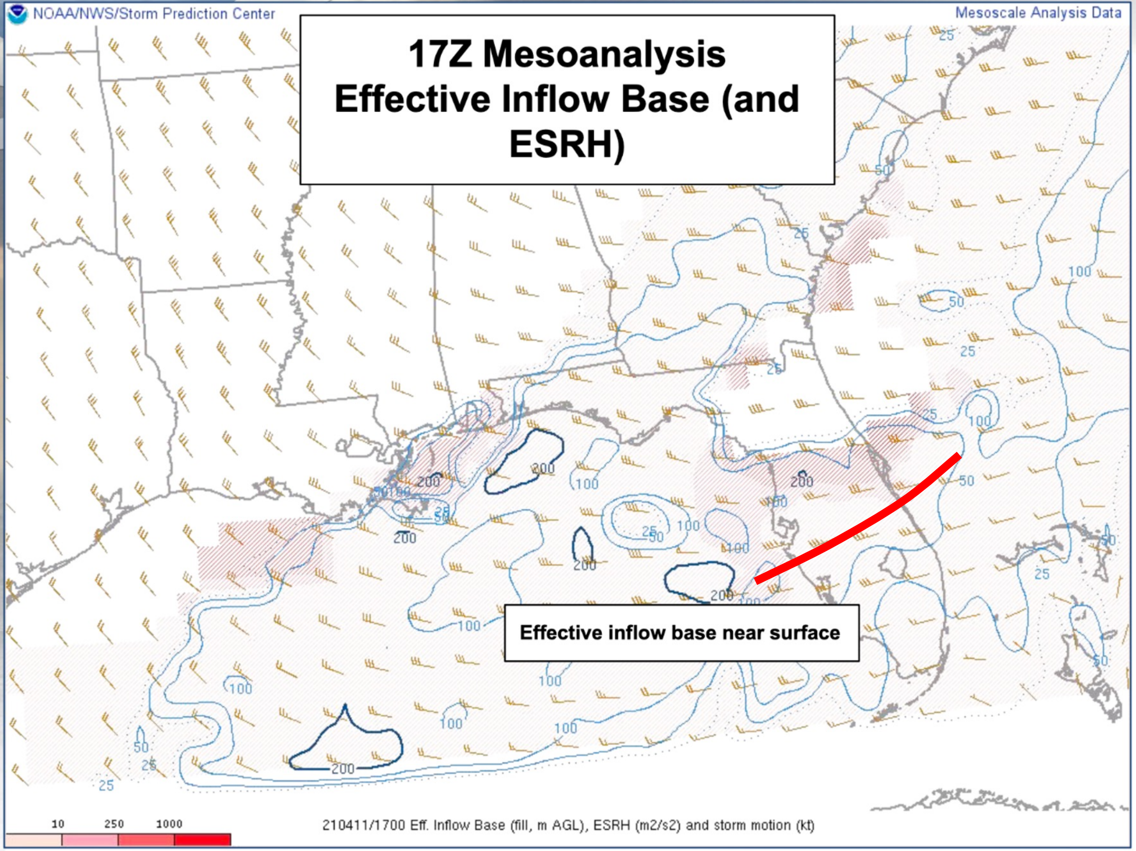
Storm motion parallel to gust front

Deep shear magnitudes of 35 to 40 kt (which increased with time) supported the maintenance of organized convection as it spread southward into the Miami CWA.

Deep shear and storm motion vectors largely oriented parallel to leading-edge gust front promoted continued linear convective mode with southward extent.

Linear mode also supported by strong forcing for ascent regime (discussed in synoptic-scale section) and ample moisture amid minimal convective inhibition.

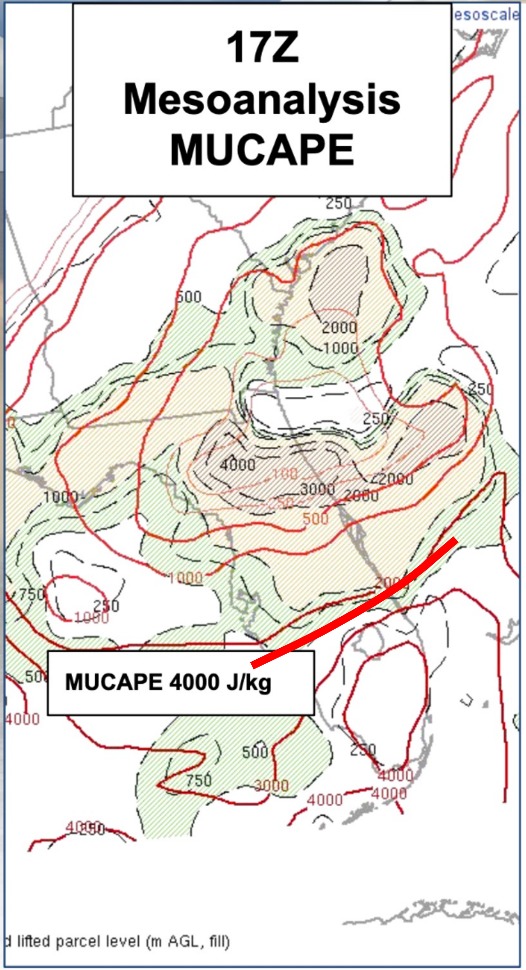
17Z Mesoanalysis Effective Inflow Base (and ESRH)

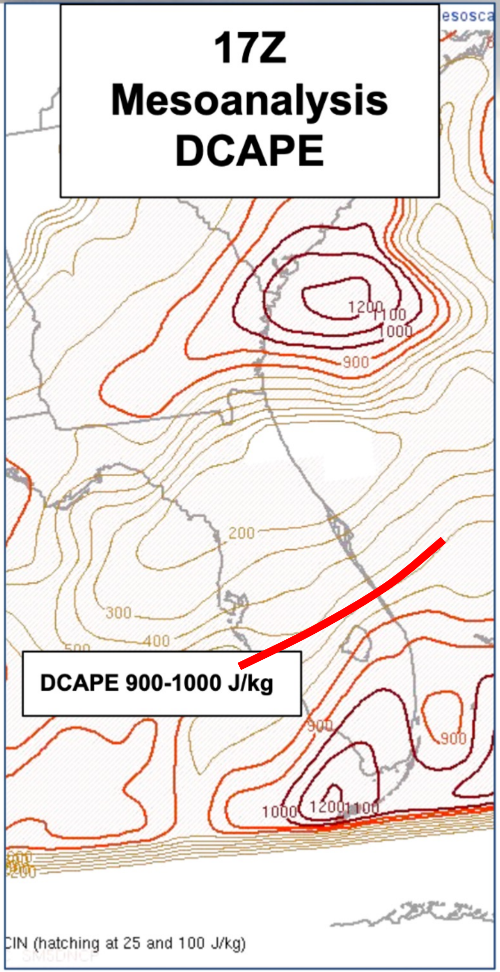


Effective inflow layer was based at the surface (considering the presence sufficient buoyancy), with minimal effective SRH (less than 100 J/kg) present.

Sloped ascent of inflow air over cold pool (pancake batter) originated at the surface, regardless of separation existed between the leading-edge gust front and parent convection.

Ingestion of favorably buoyant surface-based parcels enhances downdraft strength / pancake batter density.



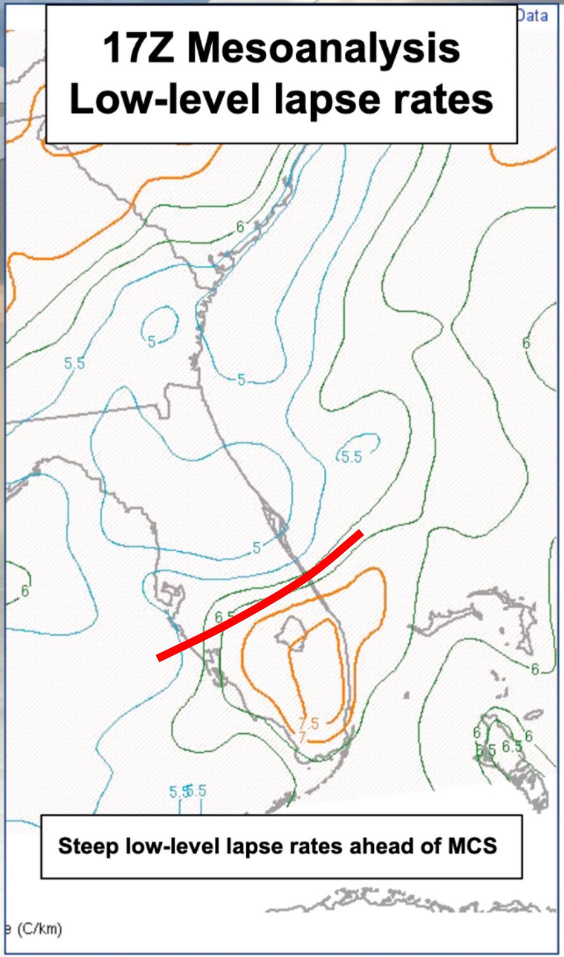


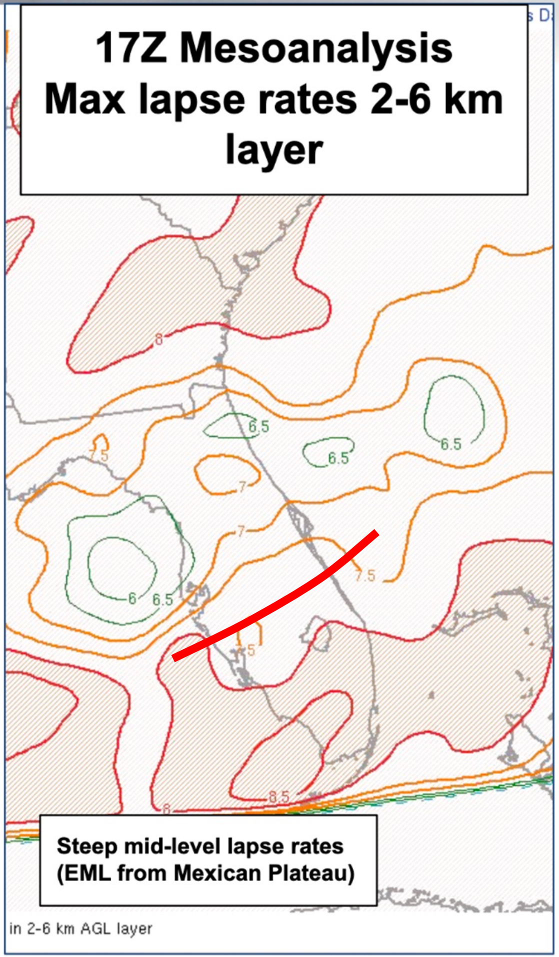
The inflow air feeding the MCS (within the pre-convective environment) supported intense updrafts/downdrafts (strong MUCAPE and strong DCAPE) that reinforced the cold pool.

Strong to severe-wind potential existed behind the leading-edge gust front.

- Can't assume that MCS downdraft air won't reach the surface due to elevated or undercut convection behind the gust front
- The tendency for the downdraft air to reach the surface is greatly influenced by the thermodynamic profile of the inflow air (surface based here, favoring more intense updrafts/downdrafts even over rearward-displaced convection) -- not just degree of separation between the gust front and parent convection.

High DCAPE and large MUCAPE suggested more potential for the pancake batter (high-density downdraft air) to descend faster anywhere within the cold pool.

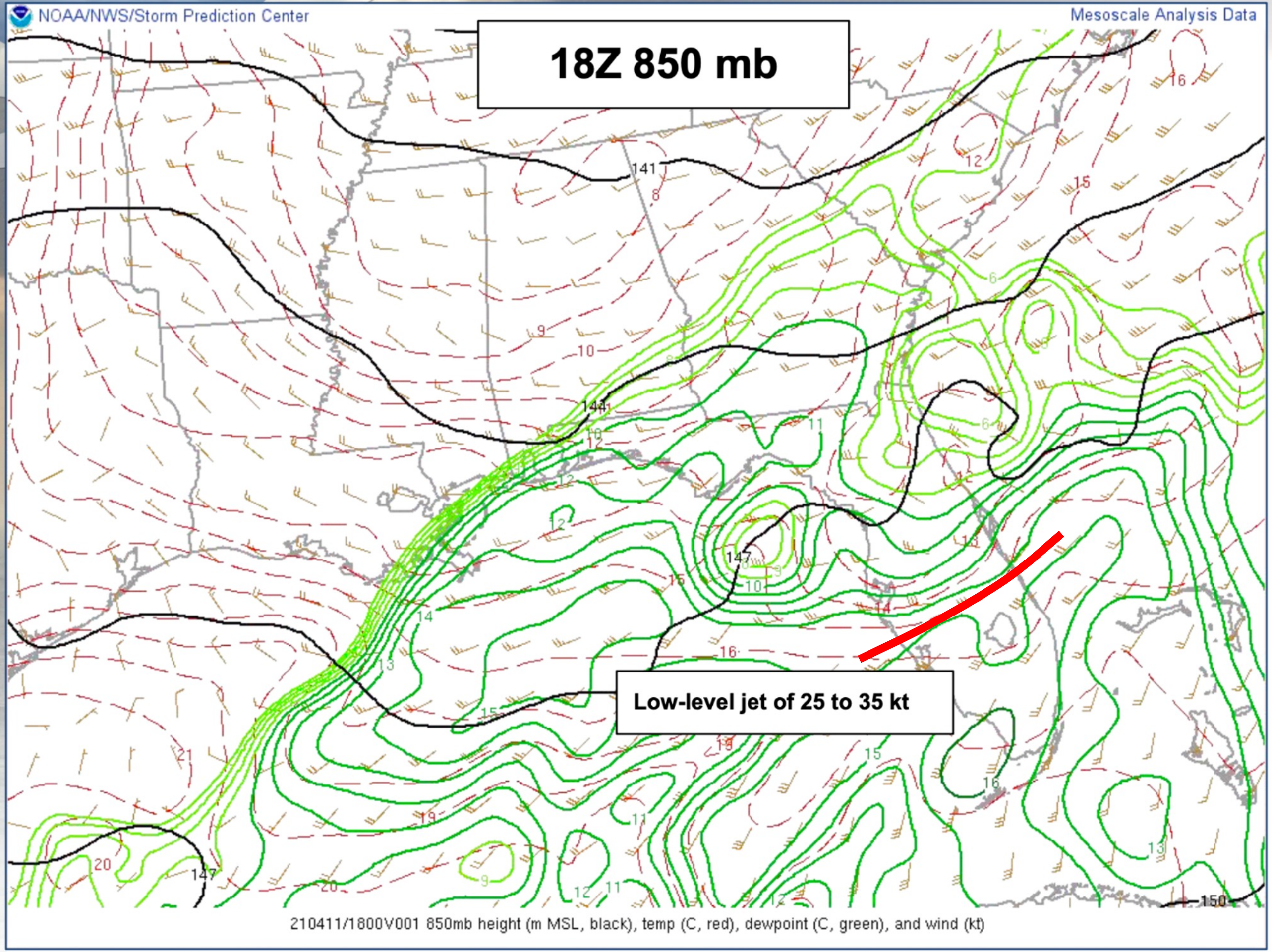




Diurnally steepened low-level lapse rates ahead of the MCS also supported efficient downward transport of higher momentum air to the surface.

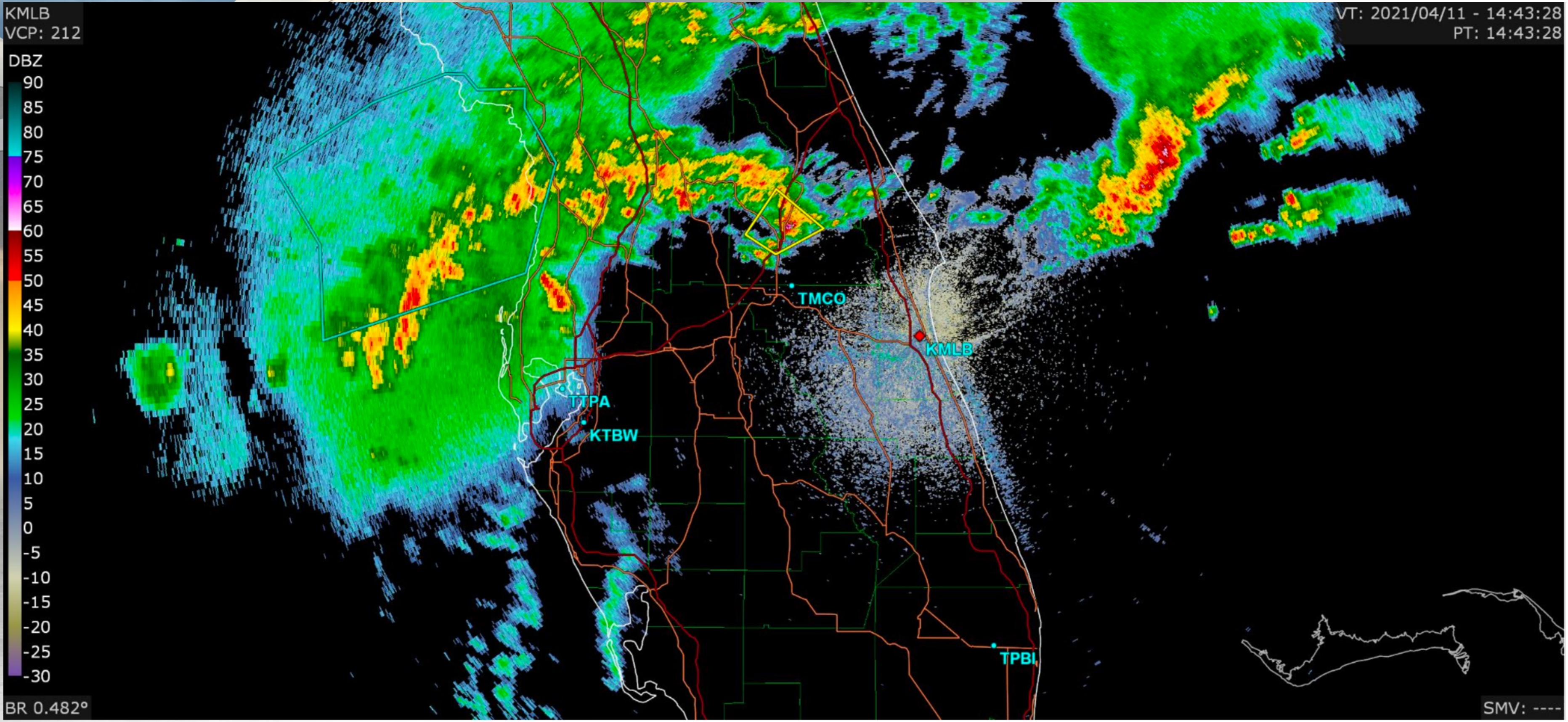
Steep mid-level lapse rates supported large normalized CAPE values and associated strong upward parcel accelerations within convective updrafts.

- **The stronger individual convective updrafts and associated strong downdrafts assisted in reinforcing the larger-scale cold pool with continuous generation of high-density air spreading outward at the ground.**



South-southwesterly low-level jet favored enhanced gust-front convergence along west-to-east-oriented outflow boundary, and isentropic ascent over cold pool -- supporting new cell development upshear.

This process was facilitated by the 25 to 35 kt LLJ, enhancing the convergence / isentropic ascent, efficient backbuilding convective development, cold pool reinforcement, and severe-wind potential (post-gust-front convective regeneration) -- A POSITIVE FEEDBACK PROCESS (more cold pool, sustained ascent, more cells, more cold pool…)!



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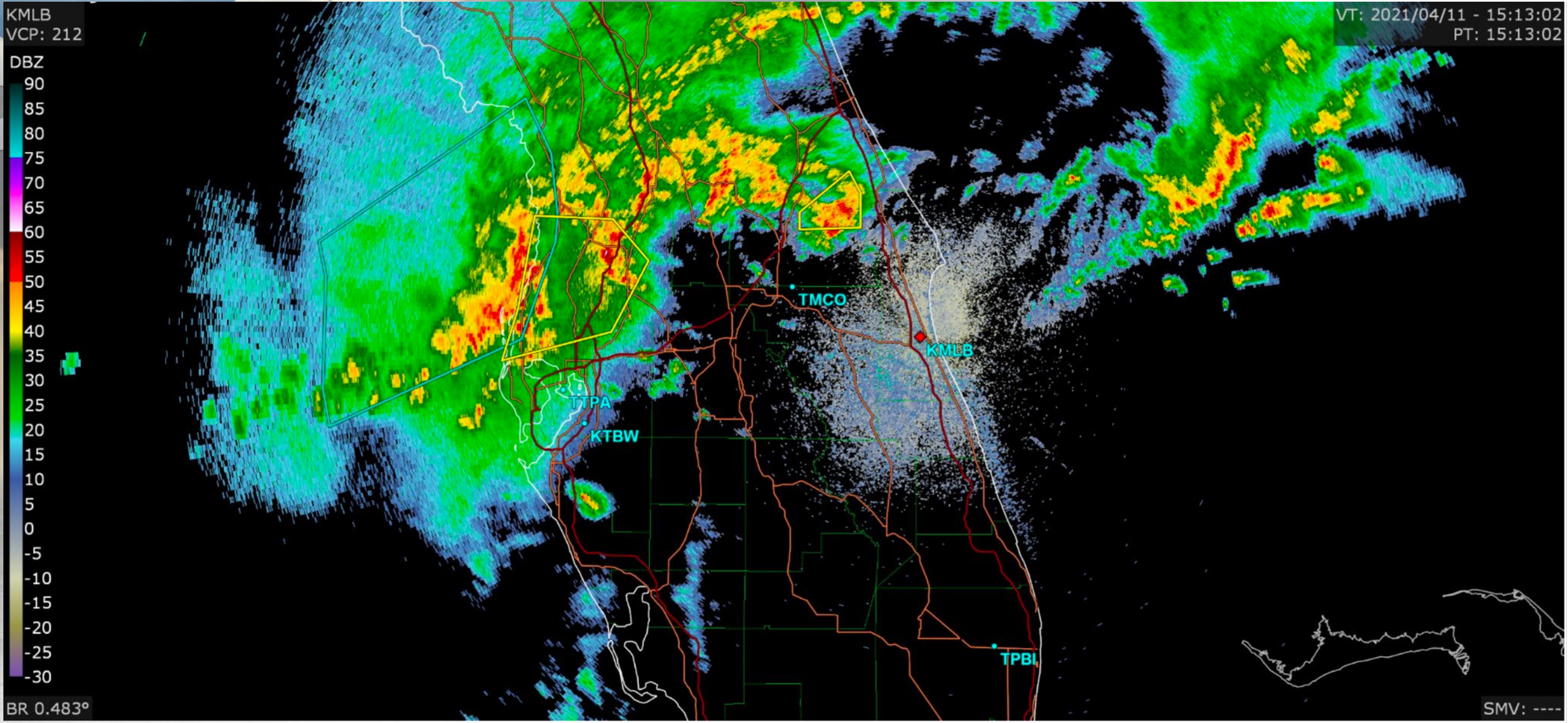
SMV: ----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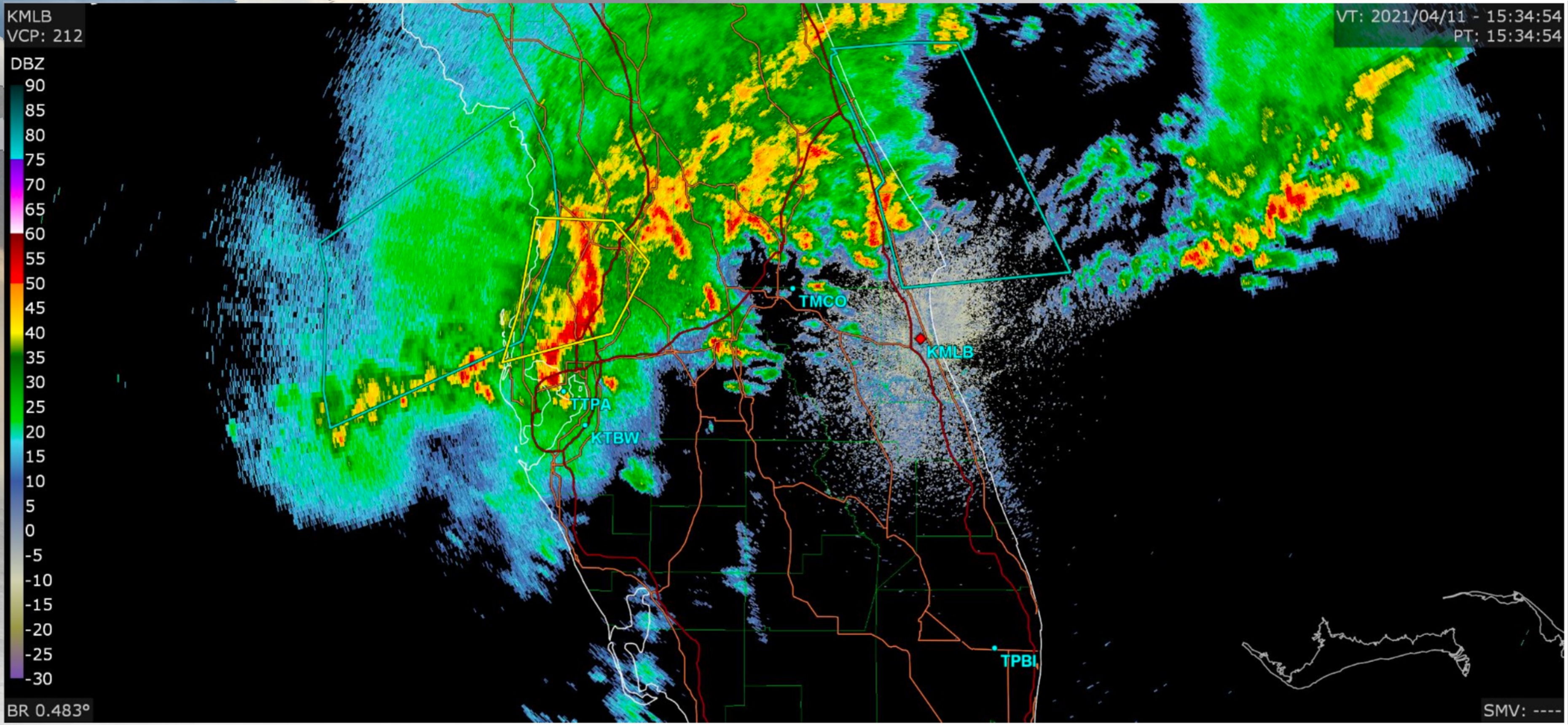
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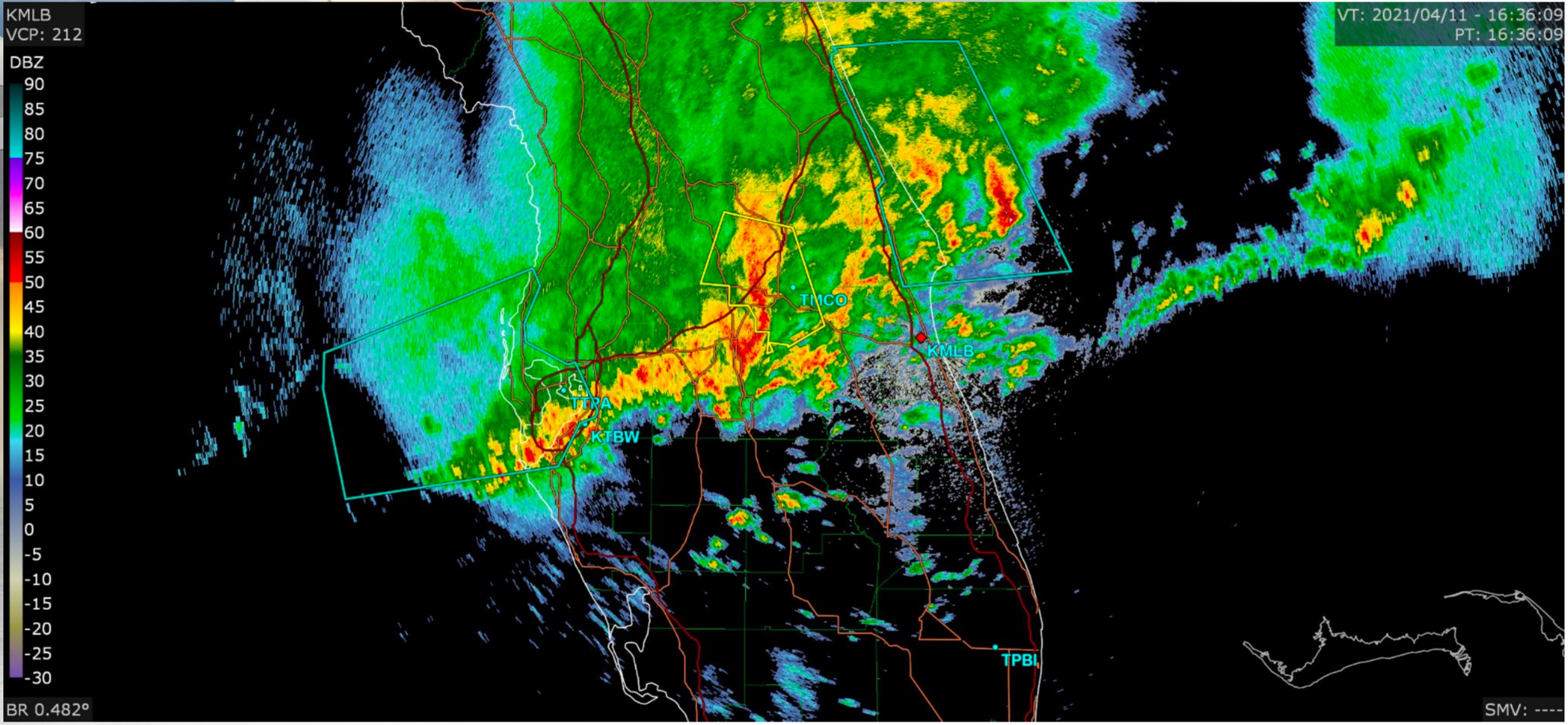
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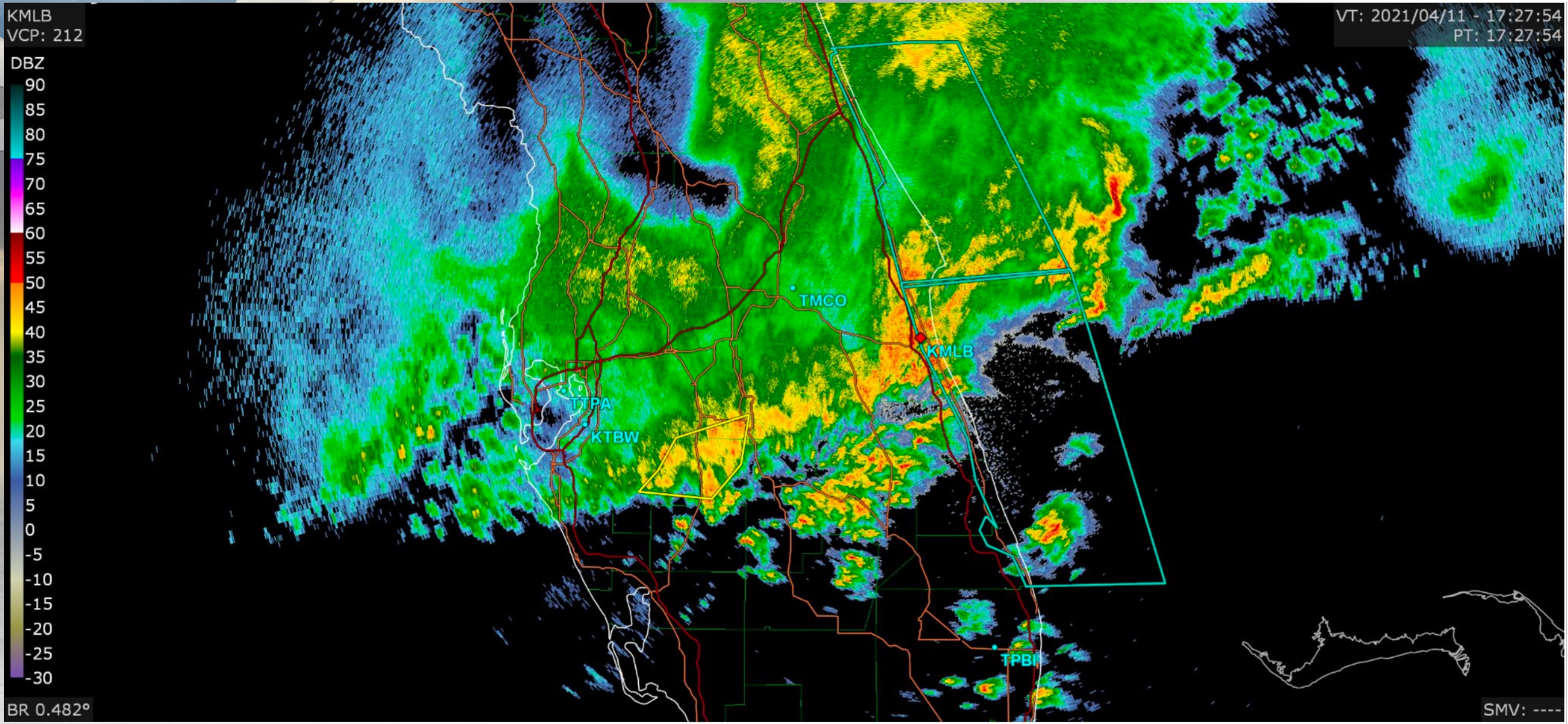
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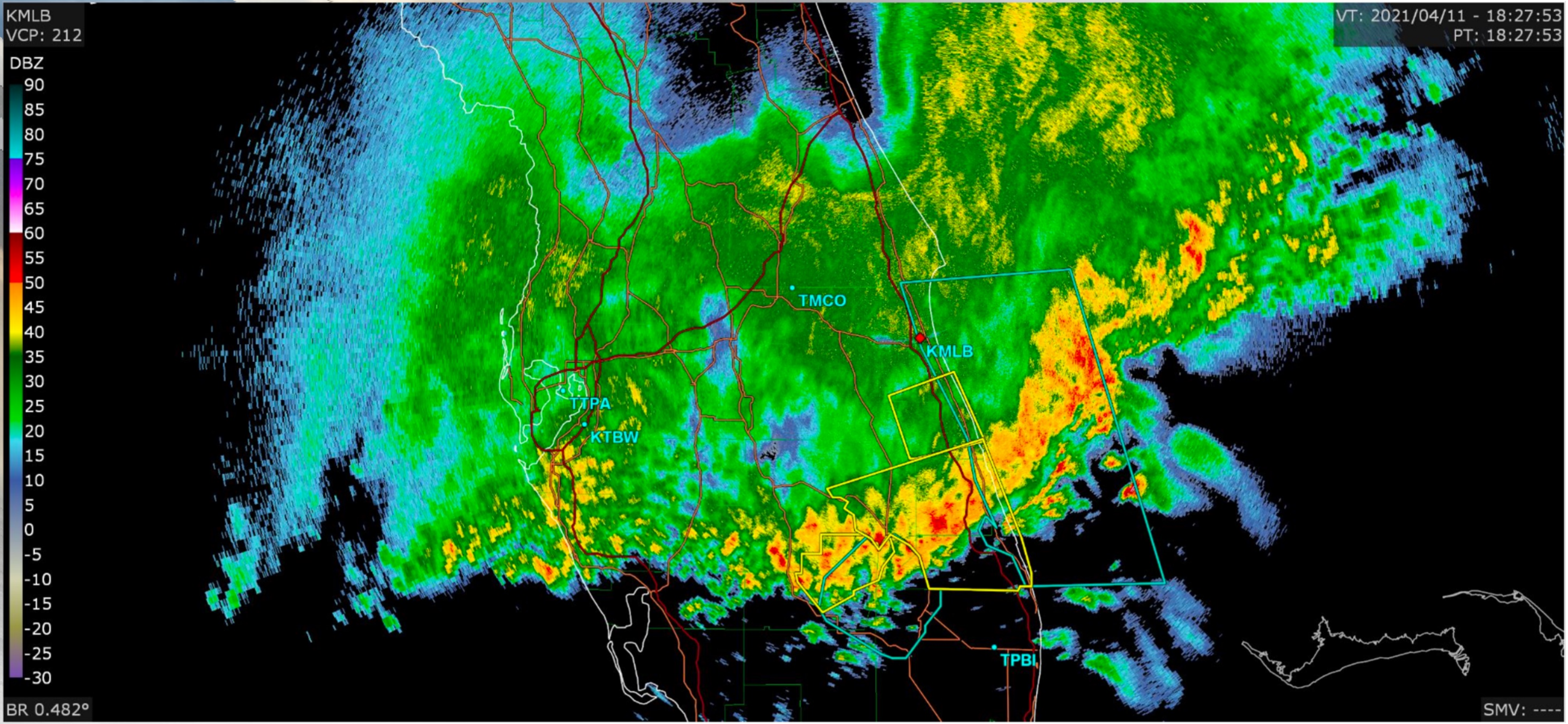
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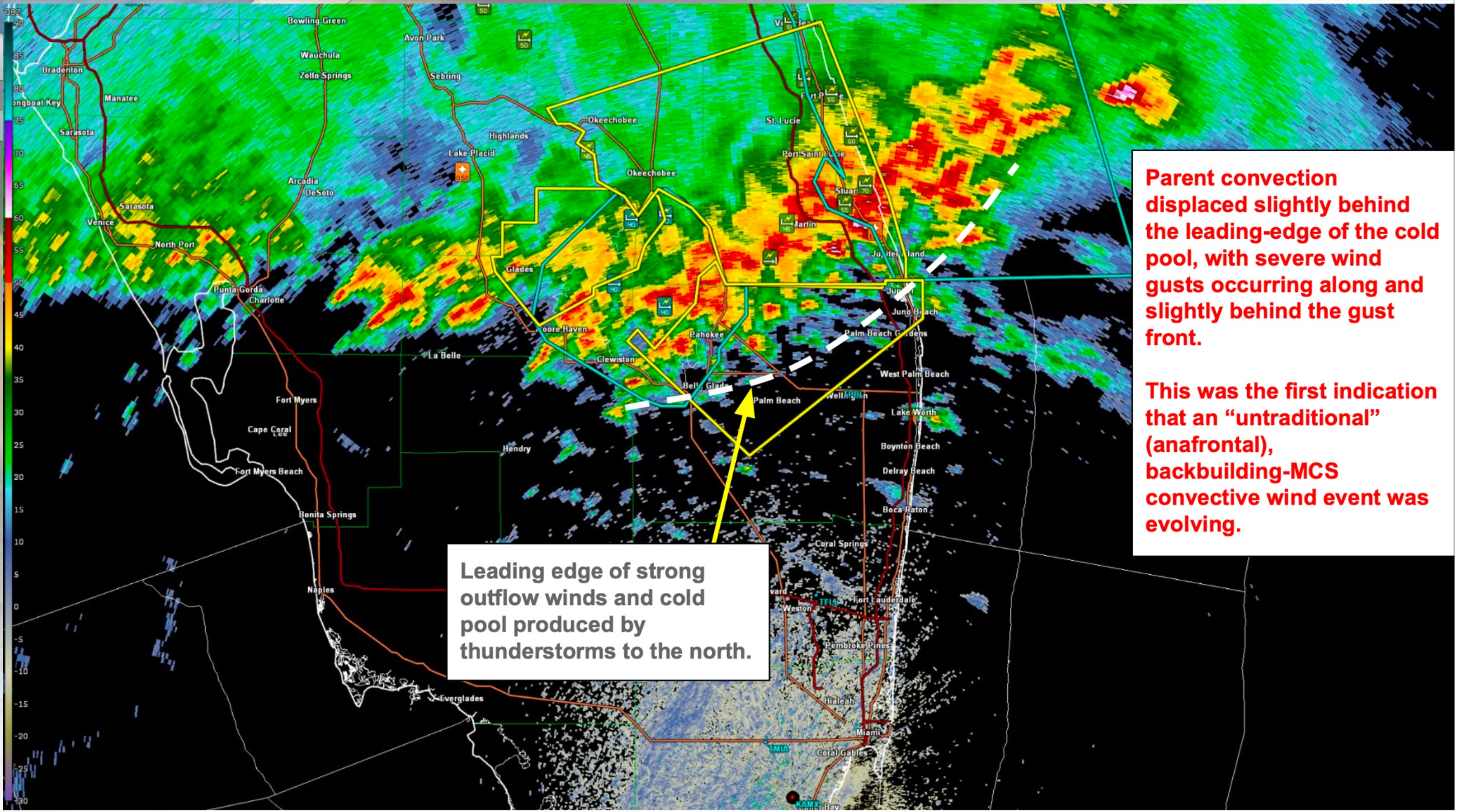
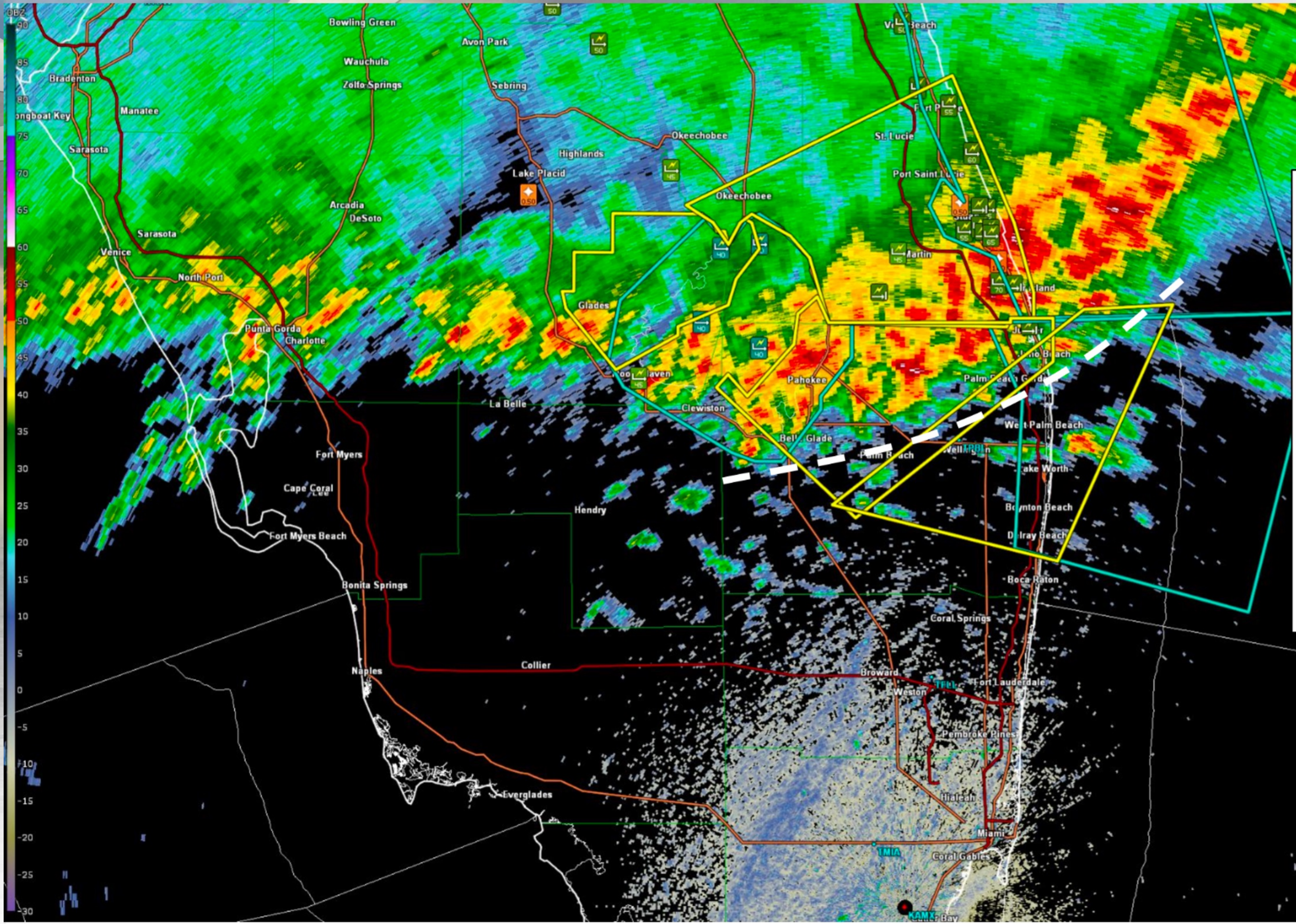

Parent convection displaced slightly behind the leading-edge of the cold pool, with severe wind gusts occurring along and slightly behind the gust front.
This was the first indication that an “untraditional” (anafrontal), backbuilding-MCS convective wind event was evolving.
Leading edge of strong outflow winds and cold pool produced by thunderstorms to the north.
Bowling Green
Avon Park
Wauchula
Zolfo Springs
Sebring
Bradenton
Manatee
Sarasota
Okeechobee
Highlands
Lake Placid
St. Lucie
Port Saint Lucie
Arcadia
DeSoto
Venice
North Port
Glades
Punta Gorda
Charlotte
Pahokee
Clewiston
La Belle
Juno Beach
Palm Beach Gardens
West Palm Beach
Lake Worth
Palm Beach
Fort Myers
Cape Coral
Hendry
Boynton Beach
Delray Beach
Fort Myers Beach
Bonita Springs
Boca Raton
Coral Springs
Naples
Fort Lauderdale
Weston
Pembroke Pines
Everglades
Hialeah
Miami
Coral Gables



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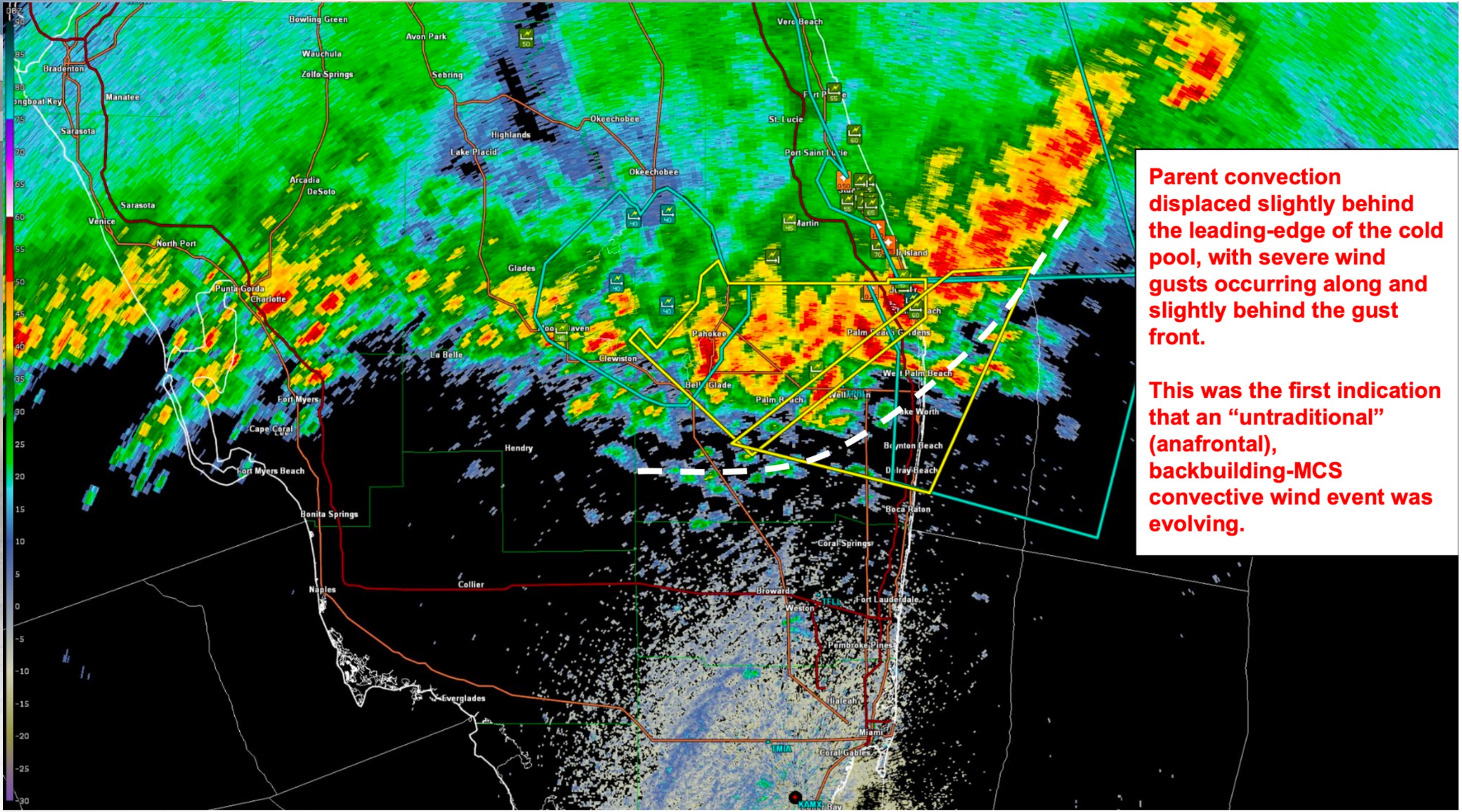

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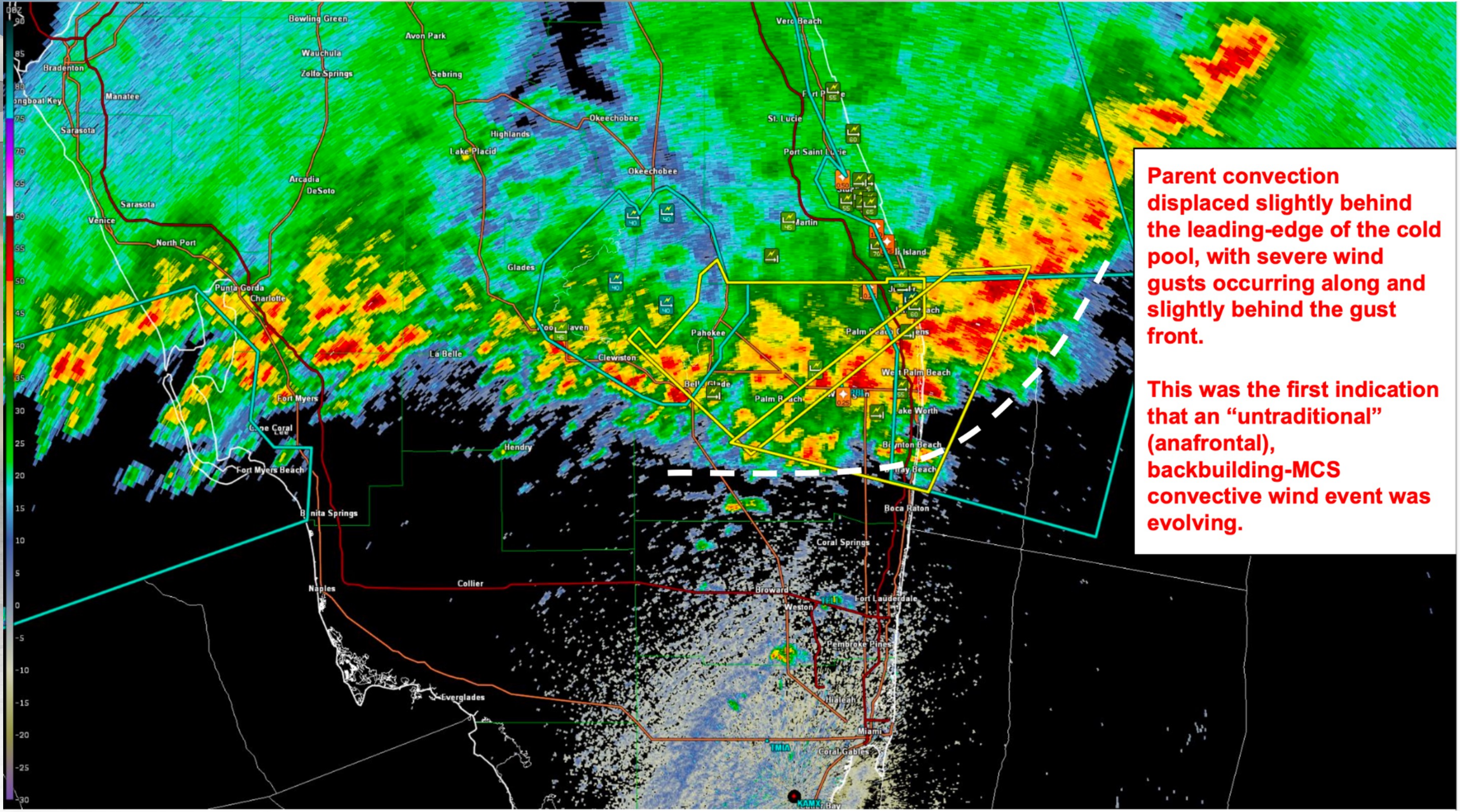

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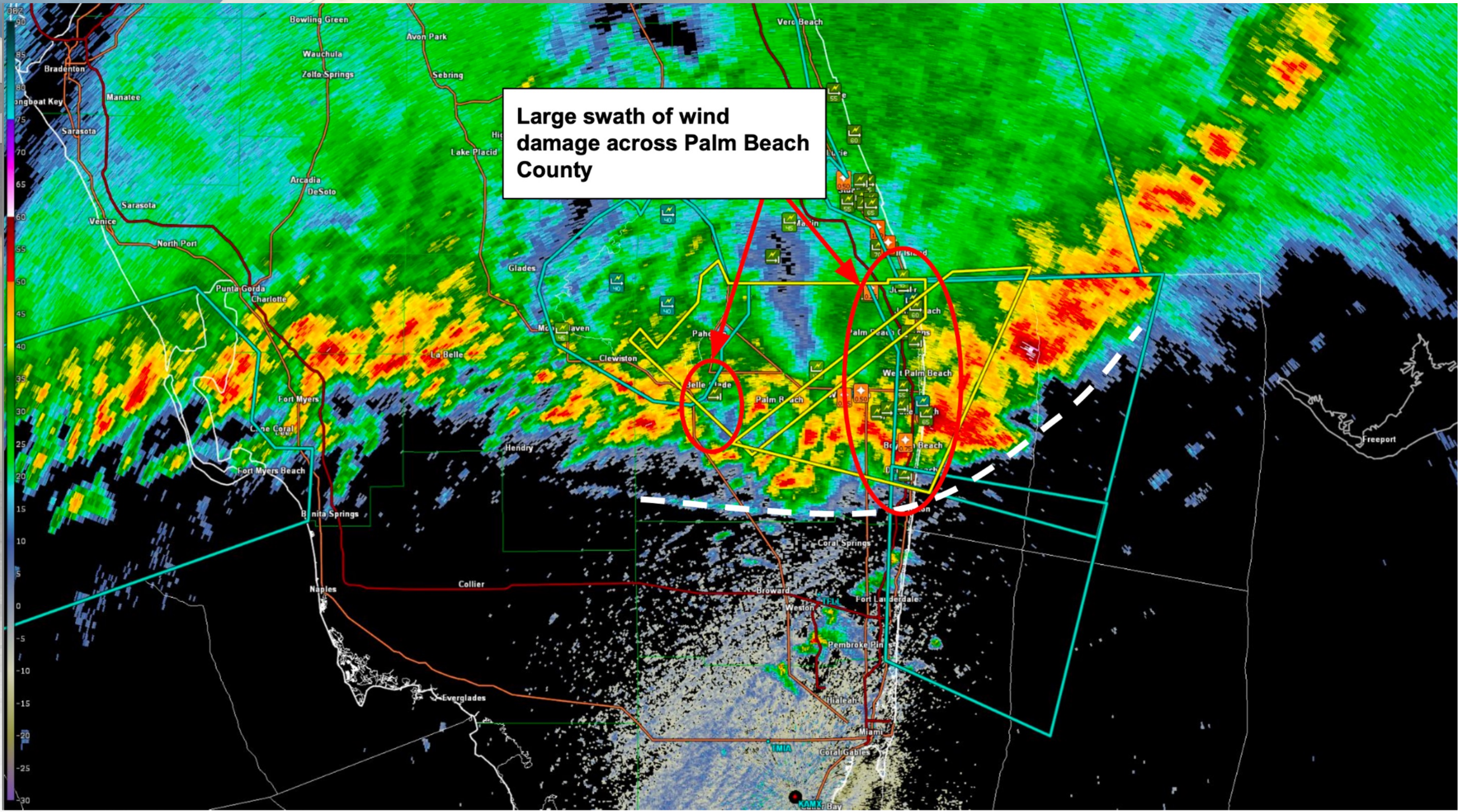
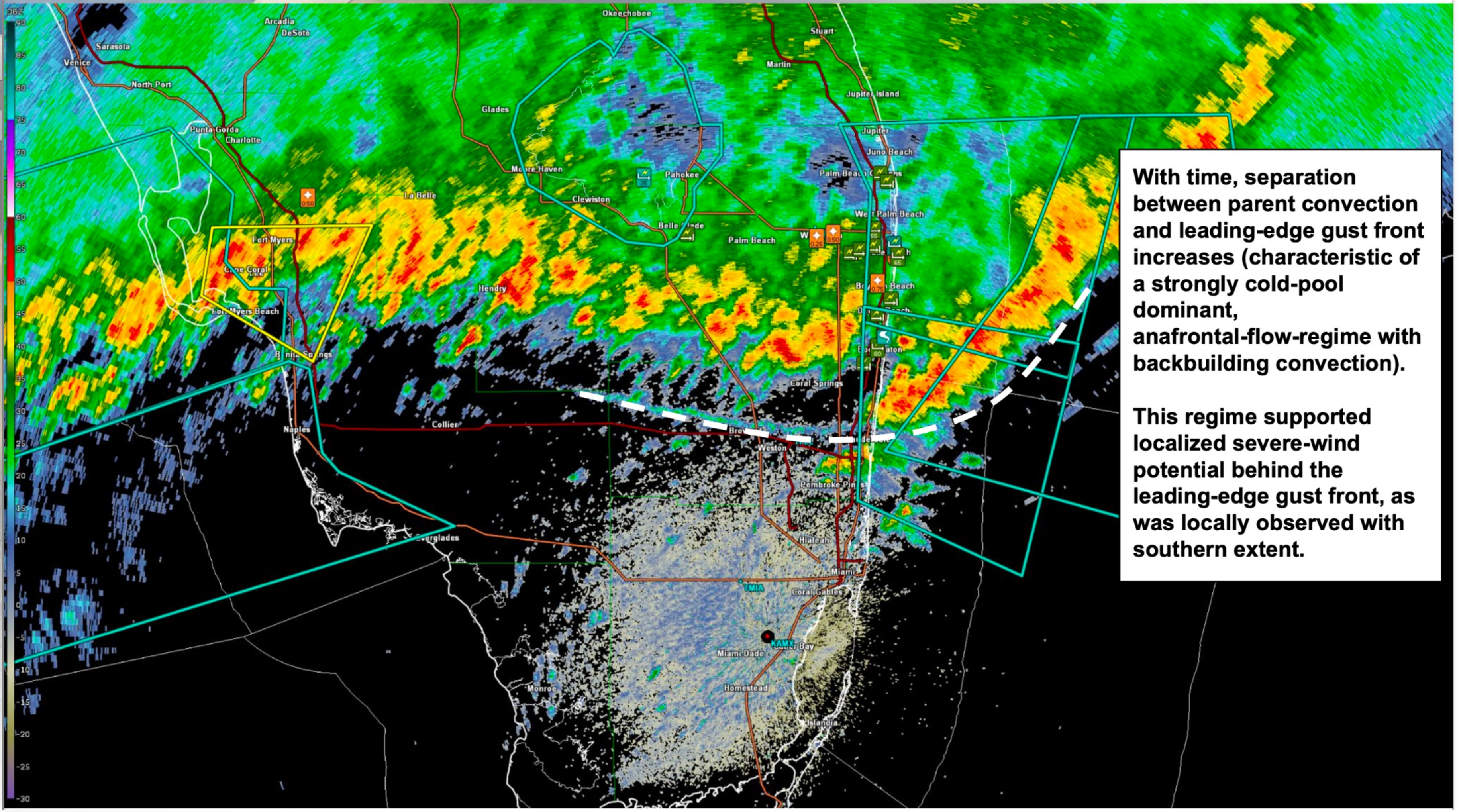
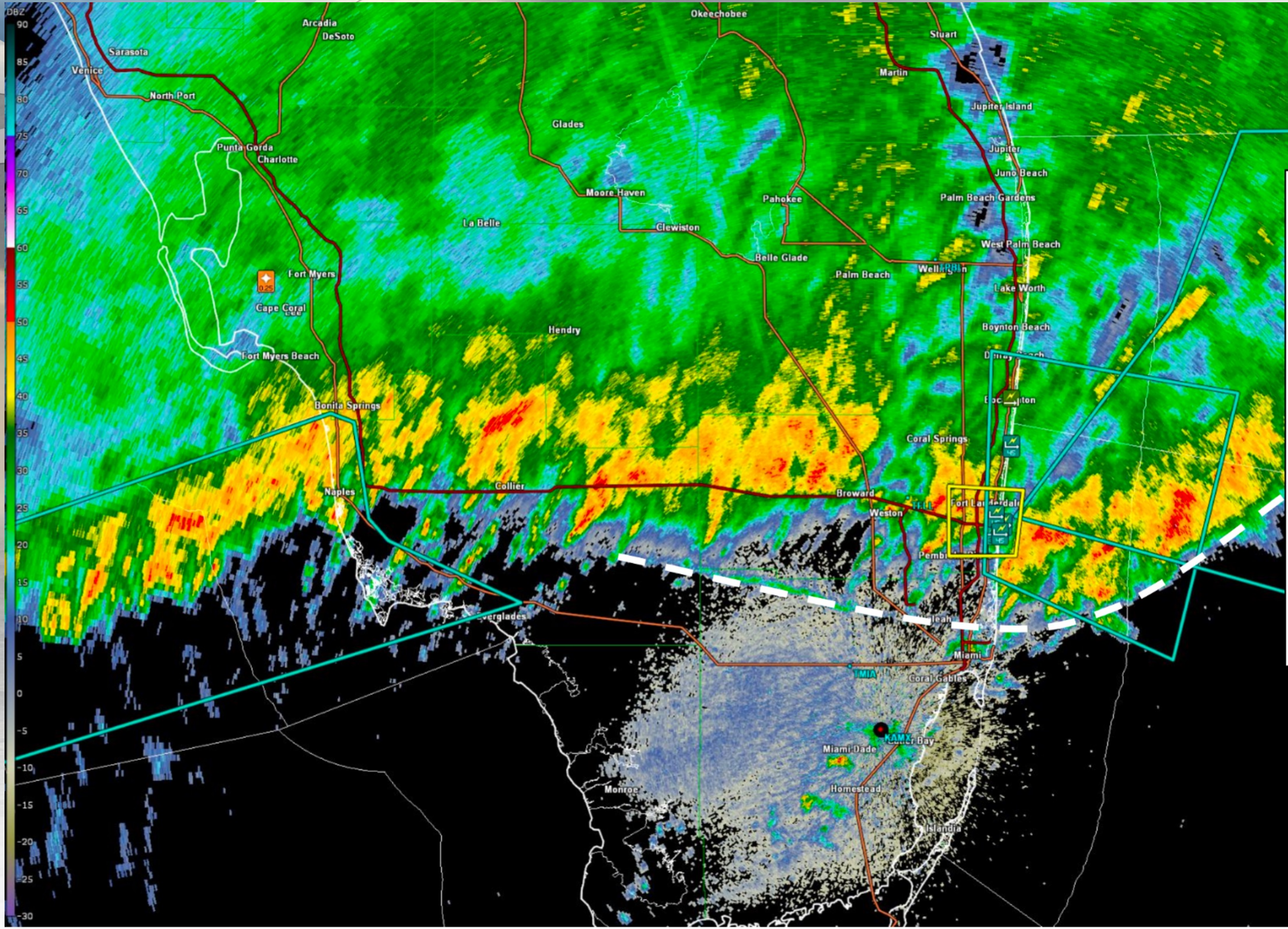


Large swath of wind damage across Palm Beach County
Bowling Green
Avon Park
Vero Beach
Wauchula
Zolfo Springs
Sebring
Bradenton
Manatee
Sarasota
Lake Placid
Arcadia
DeSoto
Venice
North Port
Glades
Punta Gorda
Charlotte
La Belle
Clewiston
Fort Myers
Cape Coral
Fort Myers Beach
Bonita Springs
Hendry
West Palm Beach
Palm Beach
Coral Springs
Naples
Collier
Broward
Weston
Fort Lauderdale
Pembroke Pin
Hialeah
Everglades
Miami
TMIA
Coral Gables
KAMX
Freeport



With time, separation between parent convection and leading-edge gust front increases (characteristic of a strongly cold-pool dominant, anafrontal-flow-regime with backbuilding convection).

This regime supported localized severe-wind potential behind the leading-edge gust front, as was locally observed with southern extent.



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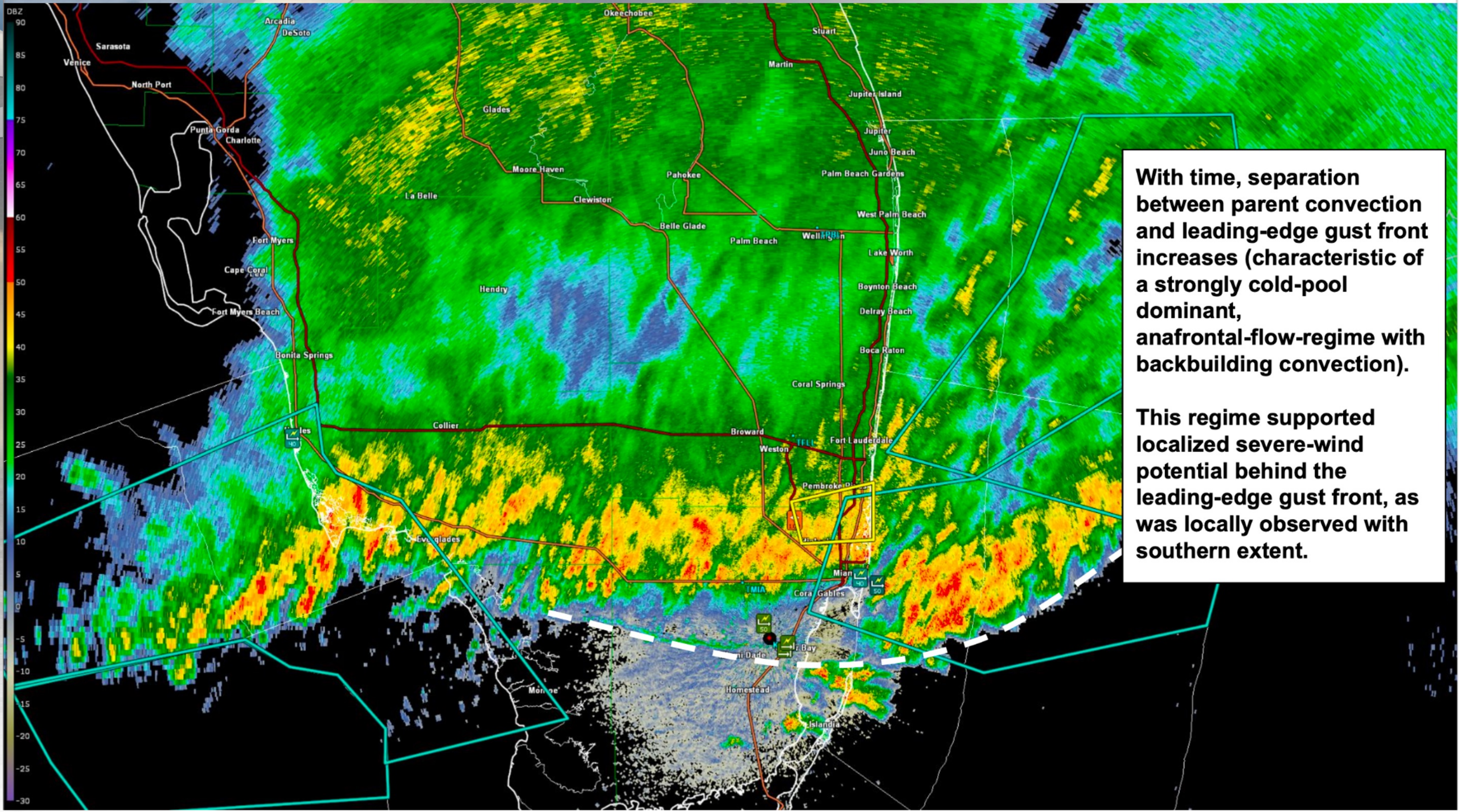

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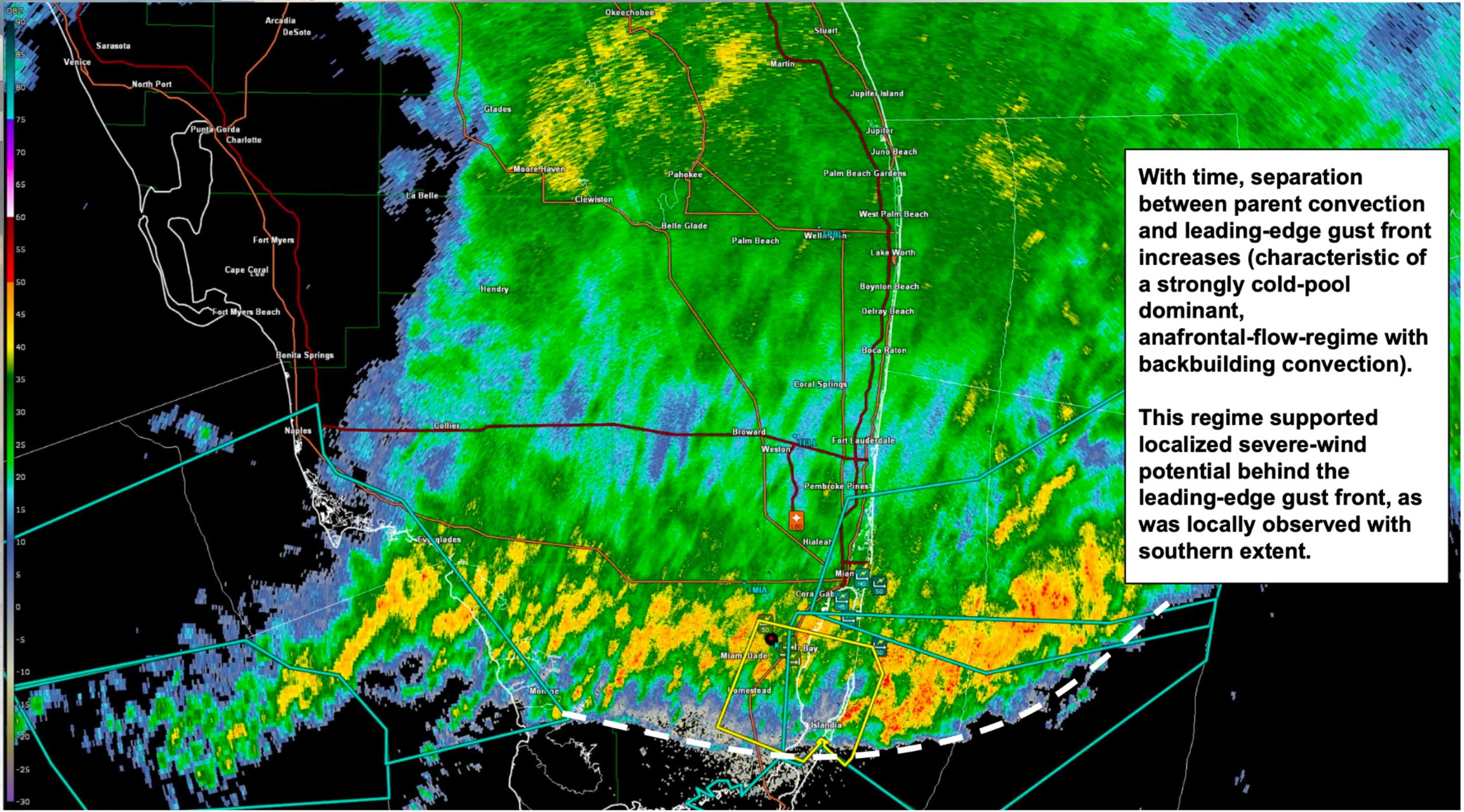

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Isr	Valid	Lead Time:	County	City	Type	Magnitude	Remarks			
H: 1" W: 60	04/11/2021 18:25	04/11/2021 19:00	Glades FL		CON	1241 sq km	2057 sq km	40 %	49% Visual	0%
SV.8 H: 1" W: 70	04/11/2021 18:39	04/11/2021 19:45	Palm Beach FL		CON	2481 sq km	5142 sq km	52 %	30% Visual	63%
	04/11/2021 18:58	19 minutes	PALM BEACH,FL	TEQUESTA	Tstm Wnd Dmg		DELAYED REPORT. MULTIPLE REPORTS FROM THE TEQUESTA AREA INCLUDING DOWNED TREES AND POWER LINES AND DAMAGE TO A RAILROAD C SOCIAL MEDIA REPORTS AND PICTURES. TIME ESTIMATED FROM RADAR.			
	04/11/2021 19:00	21 minutes	PALM BEACH,FL	2 NNE LION COUNTRY SAFA	Tstm Wnd Dmg		TRAINED SPOTTER CALLED IN AND REPORTED SEVERAL DOWNED TREE BRANCHES. BRANCHES WERE ESTIMATED TO BE APPROXIMATELY 5 TO 6 IN			
	04/11/2021 19:00	21 minutes	PALM BEACH,FL	2 SSW PHILO FARMS	Tstm Wnd Dmg		DELAYED REPORT. SMALL HARDWOOD TREE DOWNED IN JUPITER FARMS. SOCIAL MEDIA REPORT. TIME ESTIMATED FROM RADAR.			
	04/11/2021 19:05	26 minutes	AMZ650,FL	1 N JUNO BEACH	Wind Gust	63	MESONET STATION XJUP JUNO BEACH PIER RECORDED A 63 MPH (55 KT) WIND GUST ASSOCIATED WITH A SEVERE THUNDERSTORM OVER PALM BE ELEVATION: 20 FT.			
	04/11/2021 19:15	36 minutes	PALM BEACH,FL	1 E PALM BEACH GARDENS	Tstm Wnd Dmg		LARGE HARDWOOD TREE BRANCH DOWNED. WOODEN FENCE KNOCKED DOWN. OFF BURNS RD NEAR PALM BEACH GARDENS MEDICAL CENTER. T VIA SOCIAL MEDIA.			
	04/11/2021 19:15	36 minutes	PALM BEACH,FL	2 SE BELLE GLADE	Tstm Wnd Dmg		CALLER REPORTED ROOF DAMAGE AT RESIDENCE LOCATED AT SE AVE K PL ASSOCIATED WITH A SEVERE THUNDERSTORM.			
SV.9 H: 1" W: 70	04/11/2021 18:56	04/11/2021 20:00	Palm Beach FL		CON	2642 sq km	5142 sq km	49 %	4% Visual	62%
	04/11/2021 19:22	26 minutes	PALM BEACH,FL	FLORIDA GARDENS	Tstm Wnd Dmg		DELAYED REPORT. LARGE HARDWOOD TREE UPROOTED. ALSO LARGE BRANCHES BROKEN ON HARDWOOD TREES ALONG FLORIDAS TURNPIKE WE PICTURE AND REPORT FROM SOCIAL MEDIA. TIME ESTIMATED FROM RADAR.			
	04/11/2021 19:28	32 minutes	PALM BEACH,FL	PALM SPRINGS	Tstm Wnd Dmg		LARGE TREE DOWN IN PALM SPRINGS. VIA SOCIAL MEDIA REPORT. TIME ESTIMATED FROM RADAR.			
	04/11/2021 19:30	34 minutes	PALM BEACH,FL	2 NNE RIVIERA BEACH	Tstm Wnd Dmg		TRAINED SPOTTER REPORTED DOWNED TREES ON TOP OF VEHICLES ALONG NORTH PALM BEACH NORTHLAKE AND US1.			
	04/11/2021 19:30	34 minutes	PALM BEACH,FL	GREENACRES CITY	Tstm Wnd Dmg		MEMBER OF PUBLIC REPORTED SEVERAL DOWNED TREES ASSOCIATED WITH A SEVERE THUNDERSTORM.			
	04/11/2021 19:36	40 minutes	AMZ650,FL	2 ESE LAKE WORTH	Wind Gust	67	BUOY STATION LKWF1 LAKE WORTH PIER, FL RECORDED A WIND GUST OF 67 MPH (58 KT) ASSOCIATED WITH A SEVERE THUNDERSTORM OVER THE			
	04/11/2021 19:40	44 minutes	PALM BEACH,FL	DELRAY BEACH	Tstm Wnd Dmg		DELAYED REPORT. LARGE HARDWOOD TREE DOWNED IN DELRAY BEACH. TIME IS RADAR ESTIMATED. RELAYED VIA SOCIAL MEDIA.			
	04/11/2021 19:42	46 minutes	PALM BEACH,FL	2 S OCEAN RIDGE	Tstm Wnd Dmg		DELAYED REPORT. LARGE BRANCHES DOWN NEAR GULF STREAM SCHOOL. VIA MULTIPLE SOCIAL MEDIA REPORTS. TIME ESTIMATED FROM RADAR.			
H: 1" W: 60	04/11/2021 20:18	04/11/2021 20:58	Broward FL		CAN	310 sq km	3162 sq km	90 %	14% Visual	0%
SV.11 H: 1" W: 60	04/11/2021 21:24	04/11/2021 22:00	Broward FL, Miami-Dade FL		NEW	330 sq km	8256 sq km	96 %	31% Visual	57%
	04/11/2021 21:35	11 minutes	MIAMI-DADE,FL	2 WNW MIAMI LAKES	Hail	1	QUARTER SIZED HAIL REPORTED NEAR THE INTERSECTION OF 164TH ST AND 87TH AVE. TIME ESTIMATED BASED ON REPORT TIME AND RADAR.			
H: 1" W: 60	04/11/2021 22:09	04/11/2021 22:45	Miami-Dade FL		NEW	1354 sq km	5095 sq km	73 %	7% Visual	0%

Questions?