Mesoscale Analysis And Forecasting

Bridging the Watch to Warning Gap

Material by:

Andrew Moore

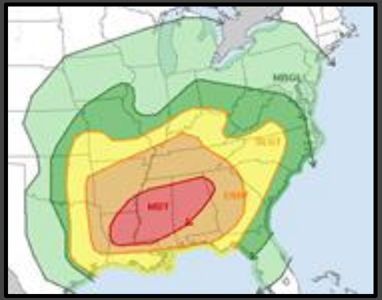
What is Mesoanalysis?

Mesoanalysis:

Utilizing observations, short-range guidance, and meteorological concepts to anticipate convective evolution within meso spatial and temporal scales.

… Or in other words:

Anticipate potential storm hazards prior to the issuance of a warning!



Outlooks

Synoptic Scale

1-8 Days

Watches

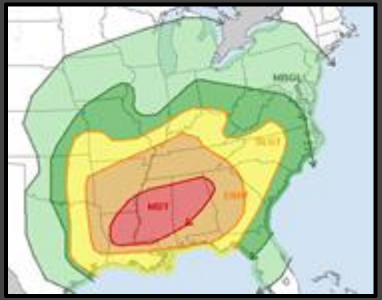
Meso-Alpha Scale

1-4 Hours

Warnings

Storm Scale

30-60 minutes



Outlooks

Synoptic Scale

1-8 Days

Watches

Meso-Alpha Scale

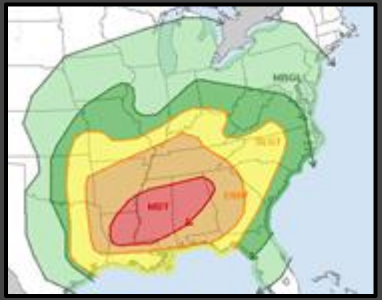
1-4 Hours

Warnings

Storm Scale

30-60 minutes

Watch - Warning Gap!



Outlooks

Synoptic Scale

1-8 Days

Watches

Meso-Alpha Scale

1-4 Hours

Mesoanalysis

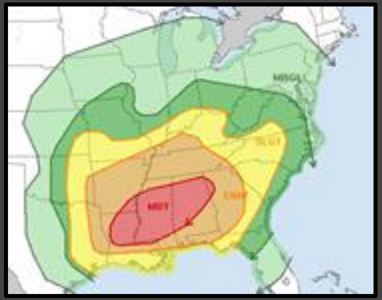
Meso-Alpha to Beta Scale

0-2 Hours

Warnings

Storm Scale

30-60 minutes



Outlooks	Watches	Mesoanalysis	Warnings
Synoptic Scale	Meso-Alpha Scale	Meso-Alpha to Beta Scale	Storm Scale
1-8 Days	1-4 Hours	0-2 Hours	30-60 minutes

Anticipate potential storm local to regional hazards prior to the issuance of a warning!

Why Care About Mesoanalysis?

Changes philosophy from “reactive” to “proactive”!

This can aid in:

- ➔ Enhanced lead time for the public
  - ◆ Done through non-warning methods (such as NWS Chat, phone calls, text messages, social media graphics, etc…)
  - ◆ Consider groups that need extra lead time like hospitals, nursing homes, outdoor events, etc…
- ➔ Warning Type Decisions
- ➔ Polygon (Warning Shape) Decisions
- ➔ Builds trust between NWS, partners, and public

Who Does Mesoanalysis

Everyone can do mesoanalysis!

- ➔ SPC issues Mesoscale Convective Discussions:
  - ◆ Typically ahead of watch issuances
  - ◆ To update ongoing watches
  - ◆ To highlight a corridor of enhanced severe potential
  - ◆ Purpose is to serve as a “heads up” to WFOs and other partners
- ➔ WFOs do mesoanalysis to aid in warning decisions
  - ◆ Will work more closely with local partners, broadcast media, and public.
- ➔ Students can do mesoanalysis to help build their intuition of convective evolution!

How do we do Mesoanalysis?

Get to know your tools:

Radar, Satellite, Surface Obs, RAP Mesoanalysis Fields, VWPs, ACARs, Soundings, etc...

Mesoscale Meteorology, Storm Scale Dynamics, Thermodynamics, etc...

RAP, HRRR, HREF, other experimental guidance...

How do we do Mesoanalysis?

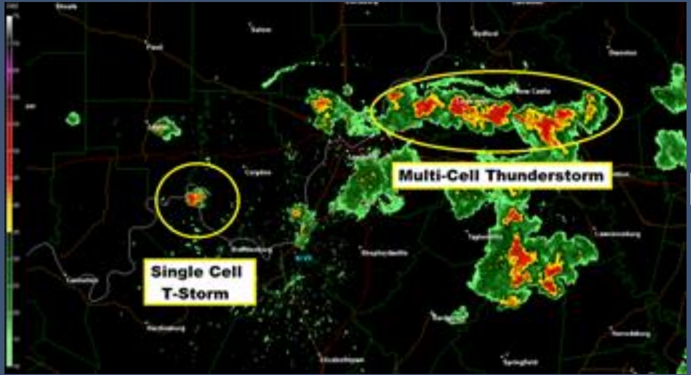
General Methodology

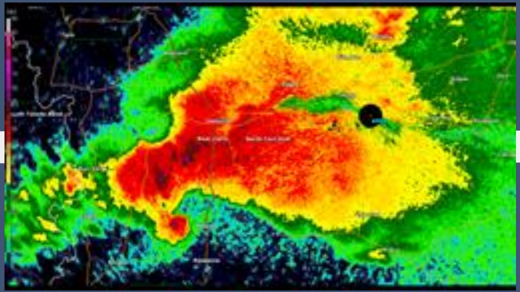
1. Analyze ongoing weather!
    a. Are storms ongoing or imminent?
    b. Characterize the instability/shear
    c. What type of forcing for ascent?
    d. Are there any boundaries?
    e. Is model guidance handling the scenario well?

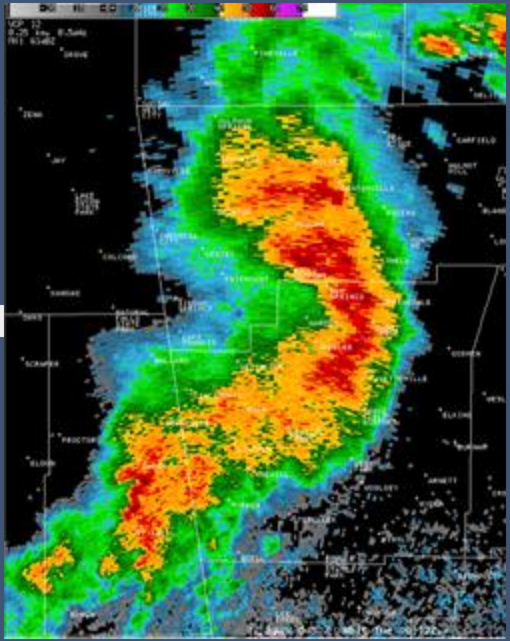
2. Apply Meteorological Concepts
    a. Anticipate storm mode/evolution over the next 0-4 hours
    b. Anticipate potential hazards
    c. Consider a range of possible outcomes

3. Utilize Guidance
    a. Check again to ensure guidance is on the right track.
    b. If so, use it to build confidence that you're anticipating the correct most likely scenario.

Storm Mode Spectrum







How do we anticipate the storm mode?

Storm Mode Basics

Consider each of these:

1) Boundary-relative storm motion
2) Boundary-relative deep-layer shear
3) Storm-relative anvil-level winds
4) Strength of forcing for ascent
5) Strength of capping

All of these must be taken into account to anticipate storm mode for the first few hours after convective initiation.

Numerous combinations are possible!

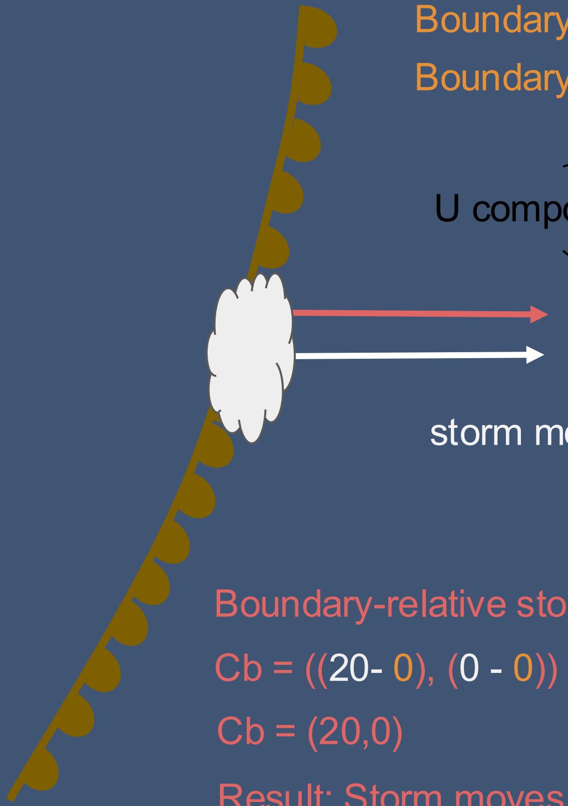
Storm Mode Basics

Consider each of these:

1) Boundary-relative storm motion
2) Boundary-relative deep-layer shear
3) Storm-relative anvil-level winds
4) Strength of forcing for ascent
5) Strength of capping

Boundary = zone of ascent

Boundary Motion (B) = (0,0)



U components

V components

storm motion (c) = (20,0)

Boundary-relative storm motion (Cb) = c - B

Cb = ((20- 0), (0 - 0))

Cb = (20,0)

Result: Storm moves off boundary;
favorable for discrete convection!

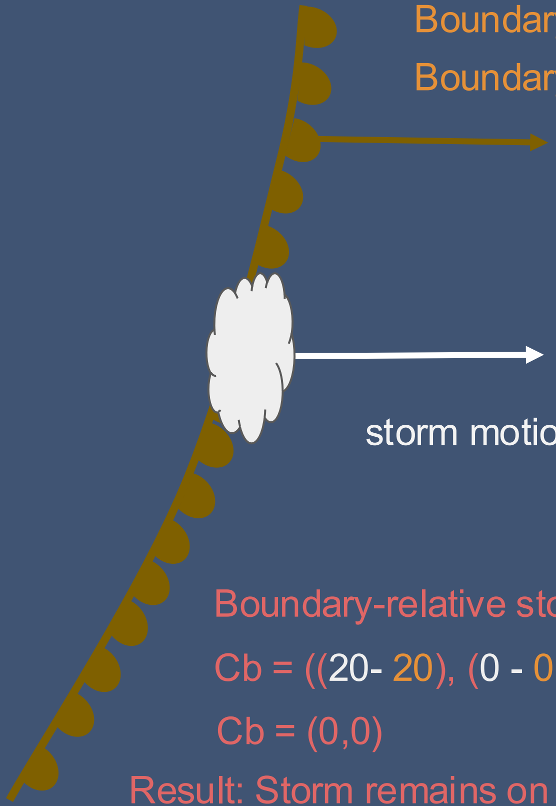
Storm Mode Basics

Consider each of these:

1) Boundary-relative storm motion
2) Boundary-relative deep-layer shear
3) Storm-relative anvil-level winds
4) Strength of forcing for ascent
5) Strength of capping

Boundary = zone of ascent

Boundary Motion (B) = (20,0)



storm motion (c) = (20,0)

Boundary-relative storm motion (Cb) = c - B

Cb = ((20- 20), (0 - 0))

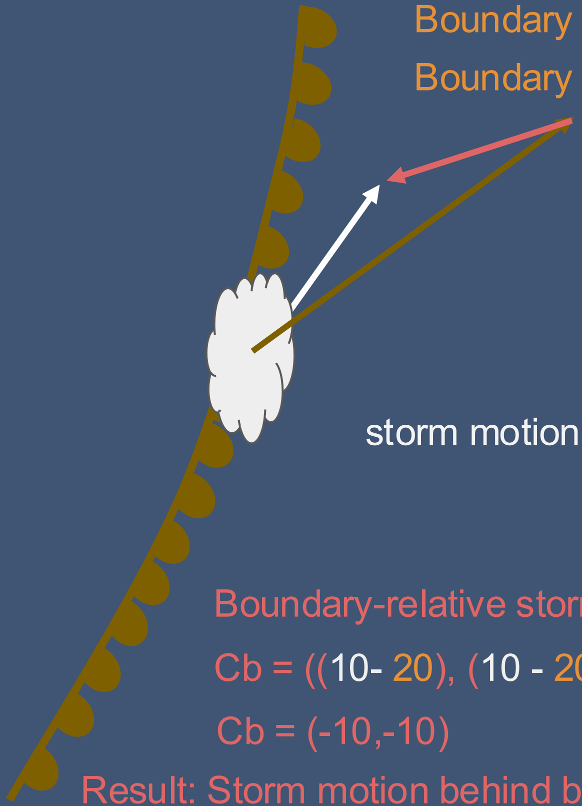
Cb = (0,0)

Result: Storm remains on boundary;
Enhances residence time, promotes <u>upscale growth</u>!

Storm Mode Basics

Consider each of these:

1) Boundary-relative storm motion
2) Boundary-relative deep-layer shear
3) Storm-relative anvil-level winds
4) Strength of forcing for ascent
5) Strength of capping



Boundary-relative storm motion (Cb) = c - B

$Cb = ((10 - 20), (10 - 20))$

$Cb = (-10,-10)$

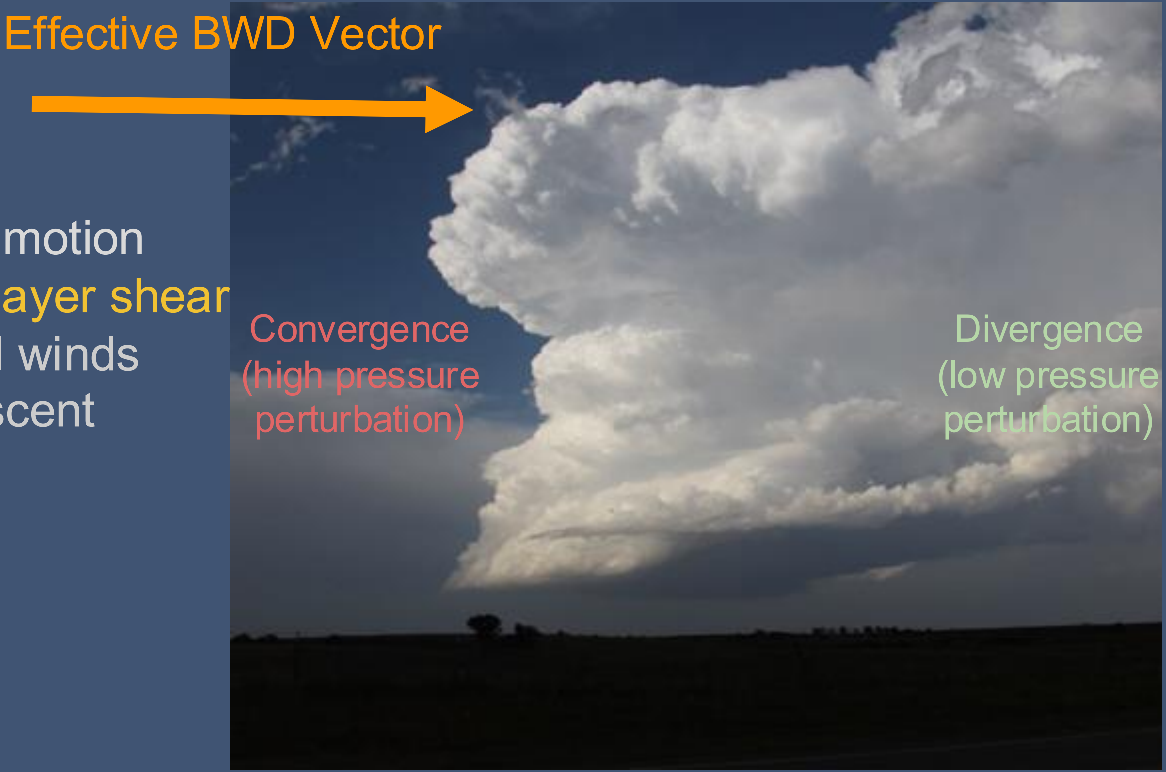
Result: Storm motion behind boundary;
Enhances residence time, promotes <u>upscale growth</u>!

Storm Mode Basics

Downshear Pressure Perturbation

Consider each of these:

1) Boundary-relative storm motion
2) Boundary-relative deep-layer shear
3) Storm-relative anvil-level winds
4) Strength of forcing for ascent
5) Strength of capping



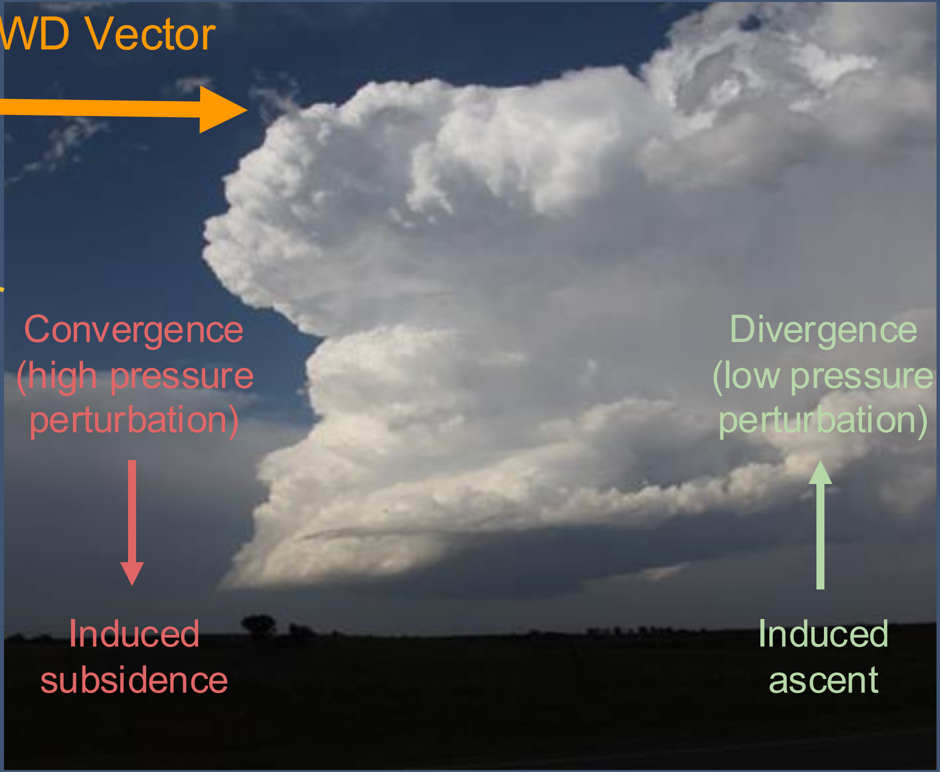
Storm Mode Basics

Downshear Pressure Perturbation

Effective BWD Vector

Consider each of these:

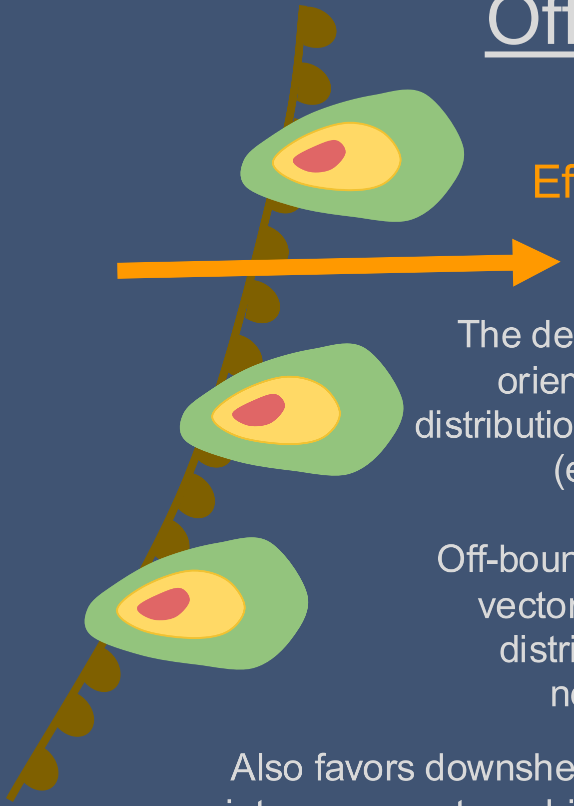
1) Boundary-relative storm motion
2) Boundary-relative deep-layer shear
3) Storm-relative anvil-level winds
4) Strength of forcing for ascent
5) Strength of capping



Storm Mode Basics

Consider each of these:

1) Boundary-relative storm motion
2) Boundary-relative deep-layer shear
3) Storm-relative anvil-level winds
4) Strength of forcing for ascent
5) Strength of capping



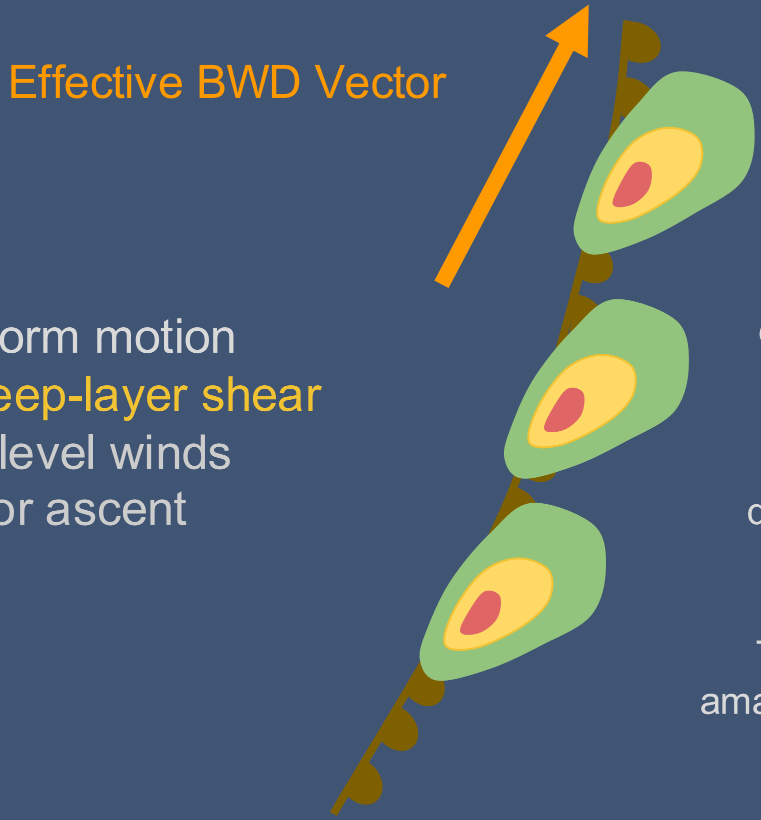
Off Boundary

The deep-layer shear vector orients the precipitation distribution away from the updraft (ex: size sorting)

Off-boundary deep-layer shear vectors favor precipitation distributions away from neighboring cells

Also favors downshear updraft development into warm sector, which favors discrete cells.

Storm Mode Basics



Consider each of these:

1) Boundary-relative storm motion
2) Boundary-relative deep-layer shear
3) Storm-relative anvil-level winds
4) Strength of forcing for ascent
5) Strength of capping

Along Boundary

Deep-layer shear vectors along the boundary favor precipitation (and outflow/cold pool) distributions towards the updraft regions of neighboring storms.

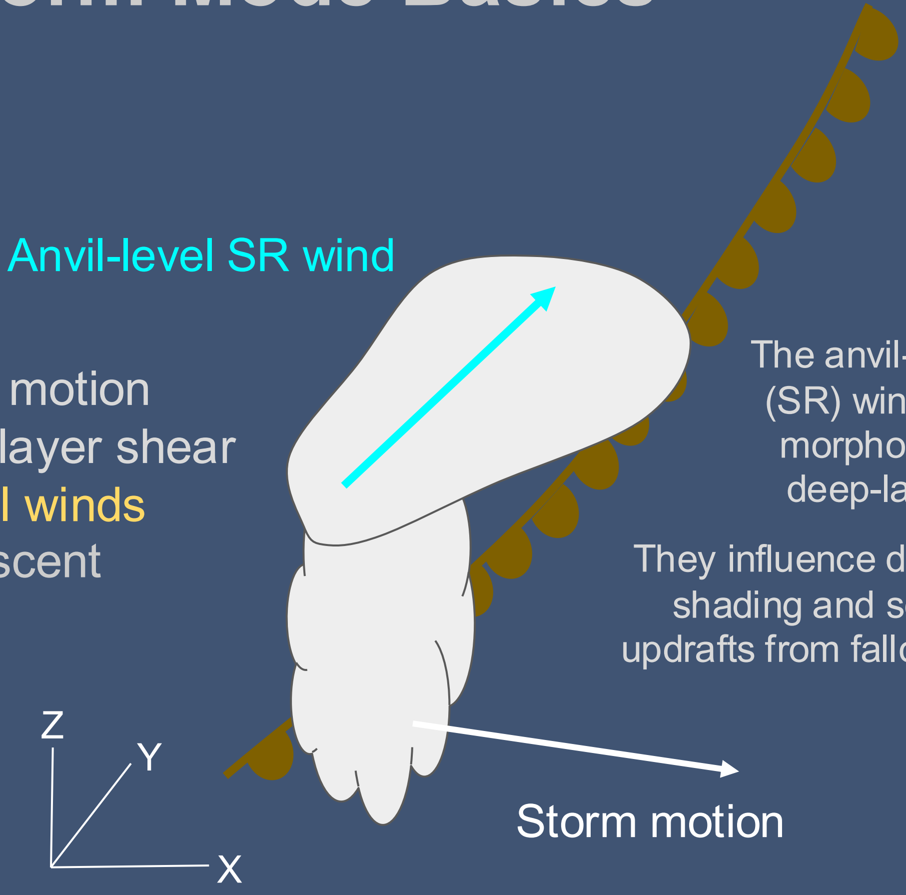
Also favors downshear updraft development in close proximity to neighboring storms.

This tends to favor cold pool amalgamation and upscale growth.

Storm Mode Basics

Consider each of these:

1) Boundary-relative storm motion
2) Boundary-relative deep-layer shear
3) Storm-relative anvil-level winds
4) Strength of forcing for ascent
5) Strength of capping



The anvil-level storm relative (SR) winds influence storm morphology similar to the deep-layer shear vector.

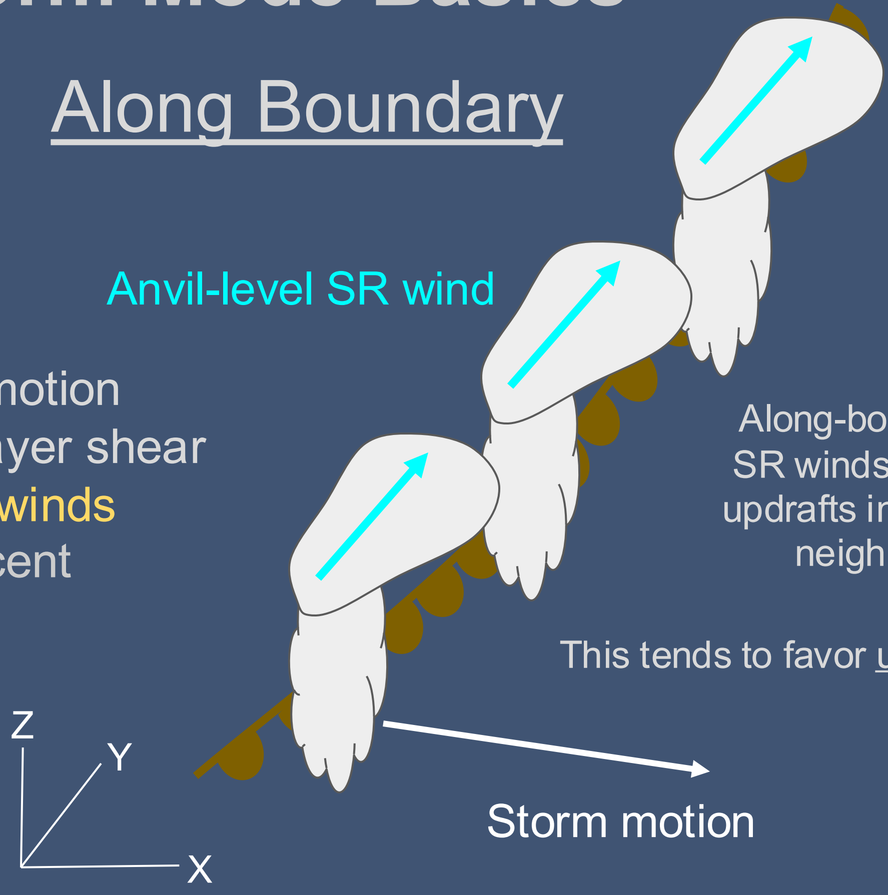
They influence downstream anvil shading and seeding of new updrafts from fallout hydrometeors

Storm Mode Basics

Along Boundary

Consider each of these:

1) Boundary-relative storm motion
2) Boundary-relative deep-layer shear
3) Storm-relative anvil-level winds
4) Strength of forcing for ascent
5) Strength of capping



Along-boundary anvil-level SR winds tend to seed new updrafts in close proximity to neighboring storms.

This tends to favor upscale growth

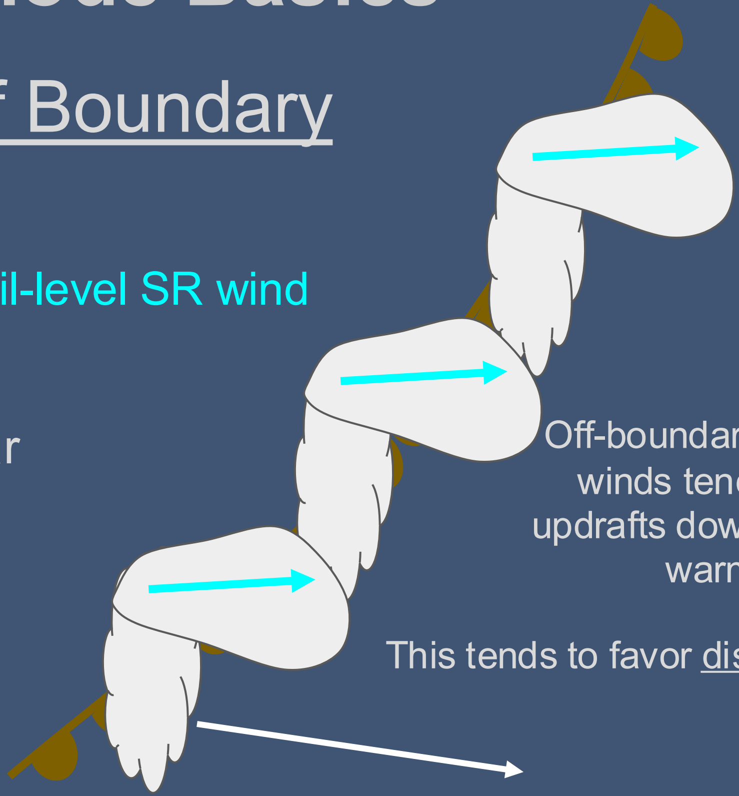
Storm Mode Basics

Off Boundary

Consider each of these:

1) Boundary-relative storm motion
2) Boundary-relative deep-layer shear
3) Storm-relative anvil-level winds
4) Strength of forcing for ascent
5) Strength of capping

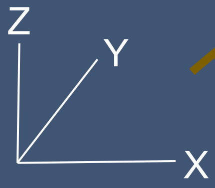
Anvil-level SR wind



Off-boundary anvil-level SR winds tend to seed new updrafts downstream into the warm sector.

This tends to favor discrete cells.

Storm motion



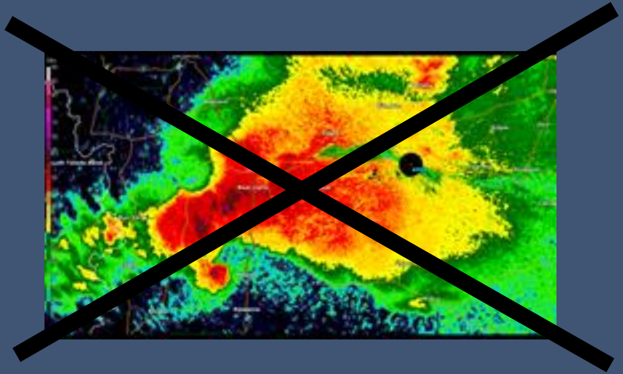
Storm Mode Basics

Consider each of these:

1) Boundary-relative storm motion
2) Boundary-relative deep-layer shear
3) Storm-relative anvil-level winds
4) Strength of forcing for ascent
5) Strength of capping

No Lift?

No storms!

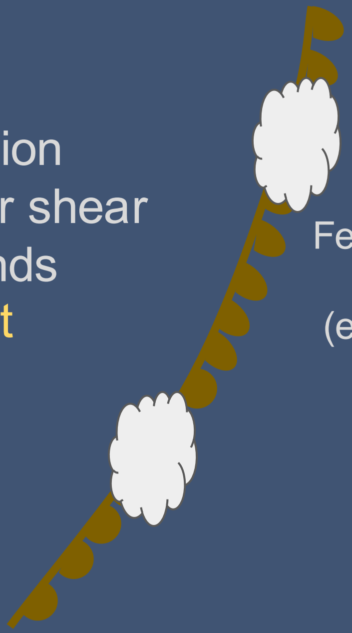


Storm Mode Basics

Weak Ascent

Consider each of these:

1) Boundary-relative storm motion
2) Boundary-relative deep-layer shear
3) Storm-relative anvil-level winds
4) Strength of forcing for ascent
5) Strength of capping



Fewer initial cells, greater spacing between cells, less chance of storm interactions (even if shear/anvil-level winds aren't favorable)

This tends to favor discrete cells.

Weak forcing mechanisms:
Drylines
Weak outflow boundaries
Confluence axes

Storm Mode Basics

Consider each of these:

1) Boundary-relative storm motion
2) Boundary-relative deep-layer shear
3) Storm-relative anvil-level winds
4) Strength of forcing for ascent
5) Strength of capping

Strong Ascent

More initial cells, smaller spacing between cells, higher chance of storm interactions (even if boundary-relative storm motions are favorable for discrete)

This tends to favor <u>upscale growth.</u>

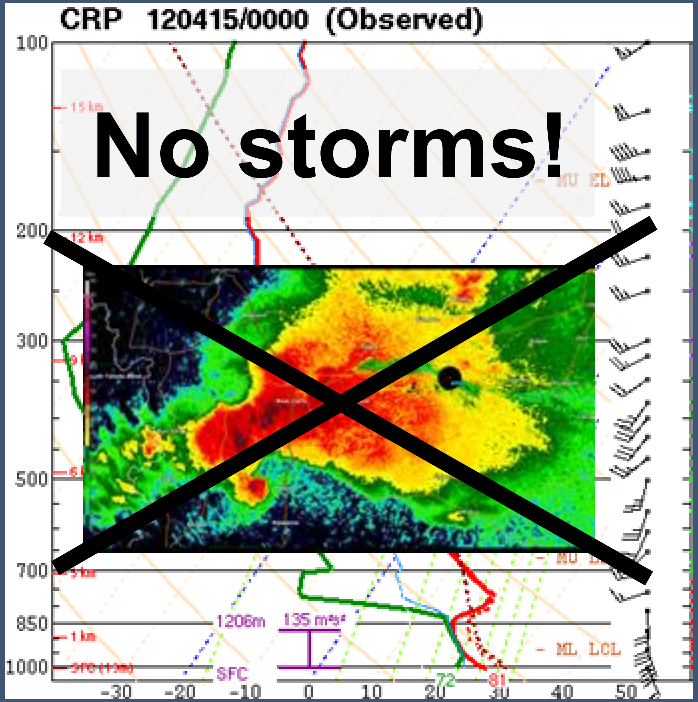
Strong forcing mechanisms:
Surging cold fronts
Strong outflow boundaries

Storm Mode Basics

“Nuclear” cap?

Consider each of these:

1) Boundary-relative storm motion
2) Boundary-relative deep-layer shear
3) Storm-relative anvil-level winds
4) Strength of forcing for ascent
5) Strength of capping

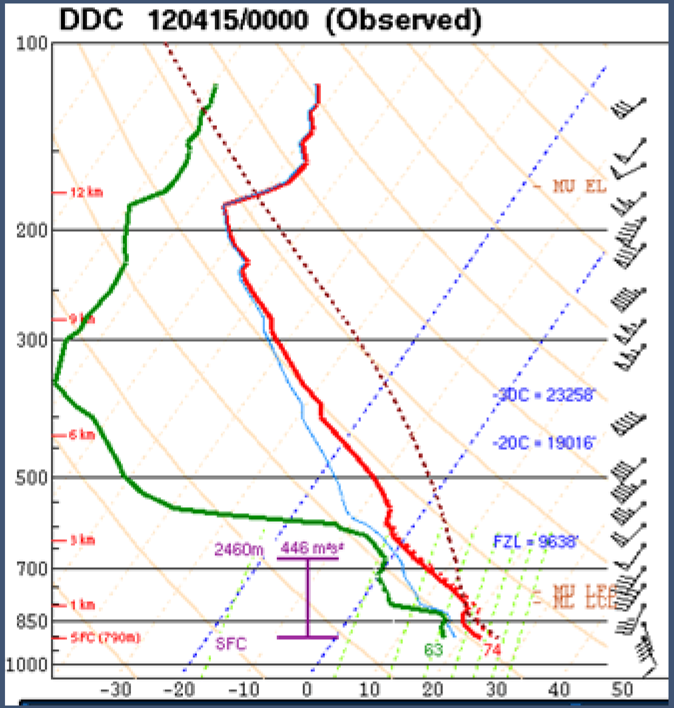


Storm Mode Basics

Consider each of these:

1) Boundary-relative storm motion
2) Boundary-relative deep-layer shear
3) Storm-relative anvil-level winds
4) Strength of forcing for ascent
5) Strength of capping

Weak cap?



Limits number of initial storms: favorable for discrete cells

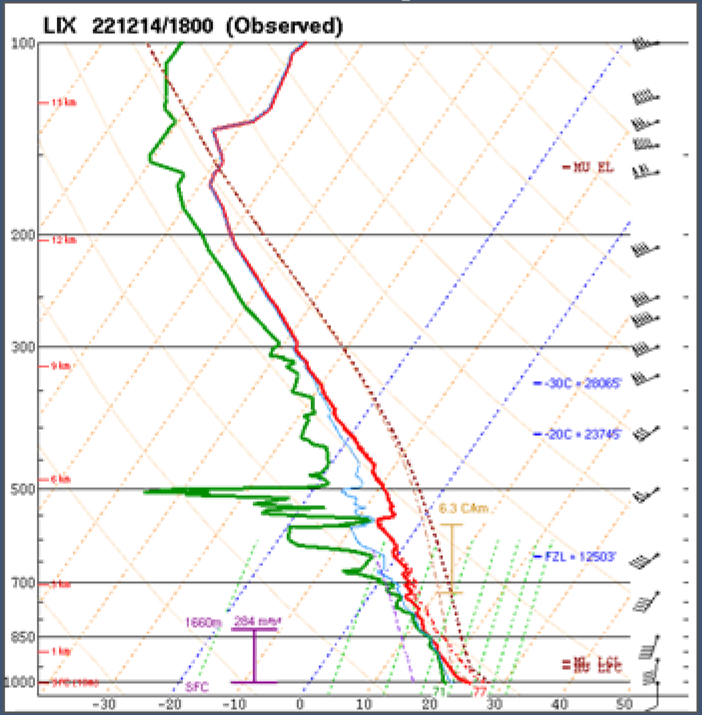
Storm Mode Basics

No cap?

Consider each of these:

1) Boundary-relative storm motion
2) Boundary-relative deep-layer shear
3) Storm-relative anvil-level winds
4) Strength of forcing for ascent
5) Strength of capping

Remember: numerous combinations are possible!



Allows for numerous storms, favors upscale growth

Storm Mode Basics

Consider each of these:

1) Boundary-relative storm motion
2) Boundary-relative deep-layer shear
3) Storm-relative anvil-level winds
4) Strength of forcing for ascent
5) Strength of capping

How do I weight each of these factors?

Storm Mode Basics

Consider each of these:

1) Strength of forcing for ascent
2) Boundary-relative storm motion
3) Boundary-relative deep-layer shear
4) Storm-relative anvil-level winds
5) Strength of capping

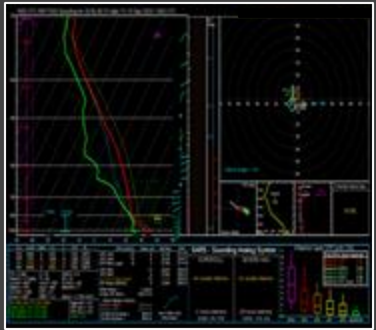
Primary influencing factor

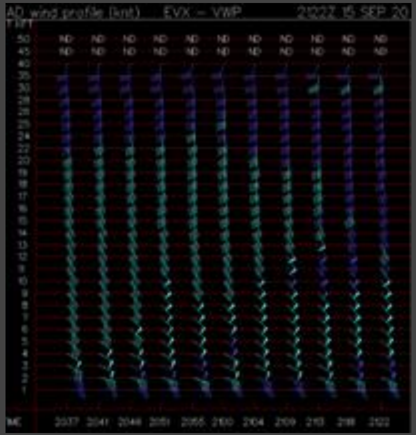
Secondary influencing factors

Modulating factor

Let’s see an example!

In this exercise we will primarily be focusing on the tornado potential, but the concepts apply to other hazards as well.





Storm Mode In a nutshell

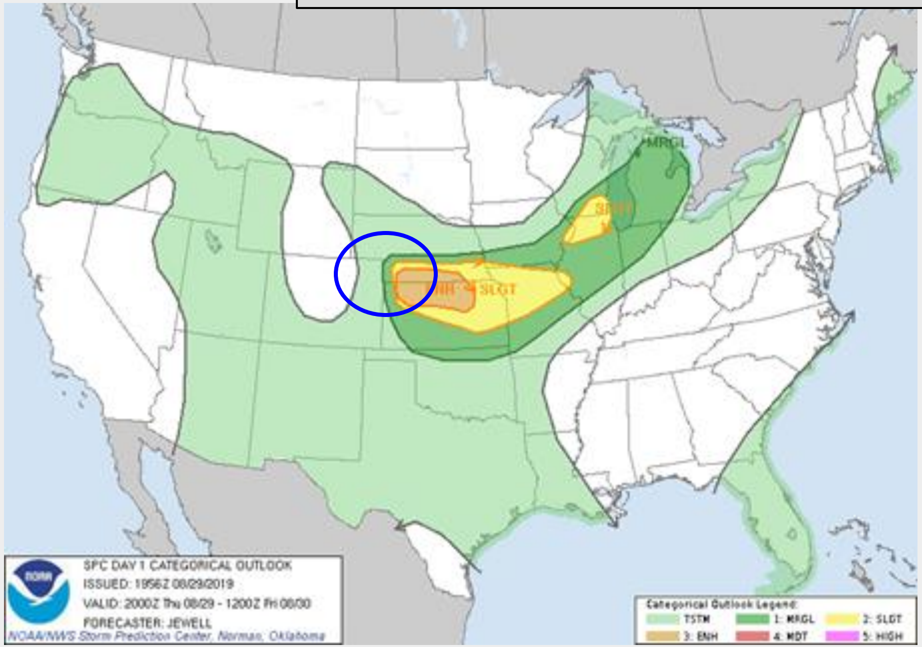
Storm mode is a function of:

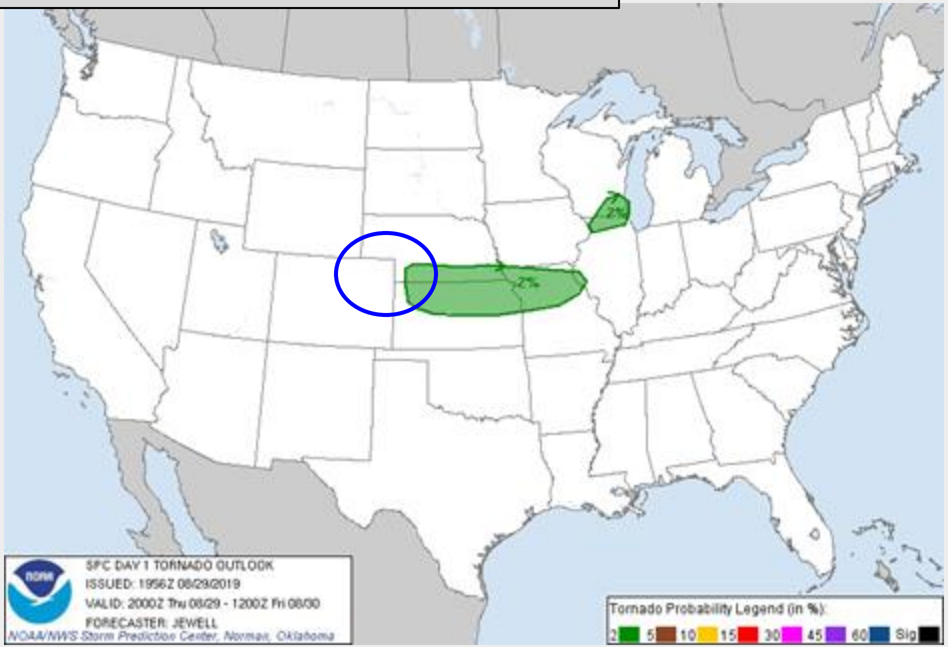
1) Boundary-relative storm motion
   a) Storms move off boundary => favorable for discrete
   b) Storms stay on/move along boundary => favorable for linear
2) Orientation of deep layer shear vector relative to the boundary
   a) Shear vector off boundary => storm orients off-boundary => favorable for discrete
   b) Shear vector along boundary => storm orients along boundary => favorable for linear
3) Anvil level storm-relative winds
   a) Winds off boundary => Anvil debris less likely to “seed” neighboring storms along boundary => discrete
   b) Winds along boundary => Anvil debris more likely to “seed” neighboring storms along boundary => linear
4) Strength of the forcing for ascent
   a) Weak forcing for ascent => fewer storms => favorable for discrete
   b) Strong forcing for ascent => more storms => favorable for linear

For details: Dial et al. 2010, Short-term Convective Mode Evolution along Synoptic Boundaries

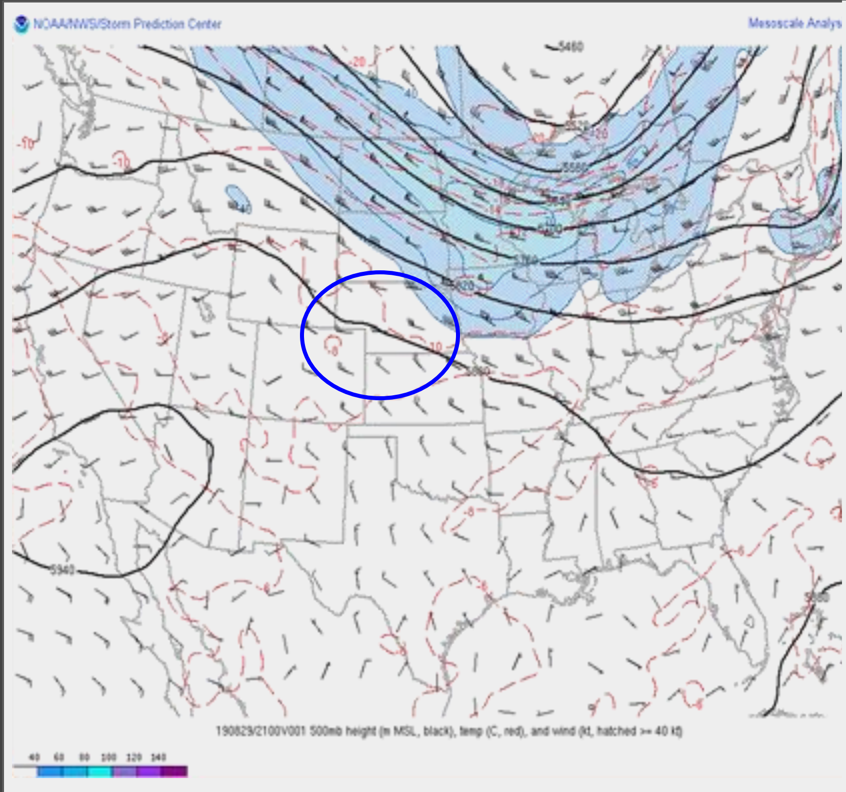
August 29, 2019 21 UTC

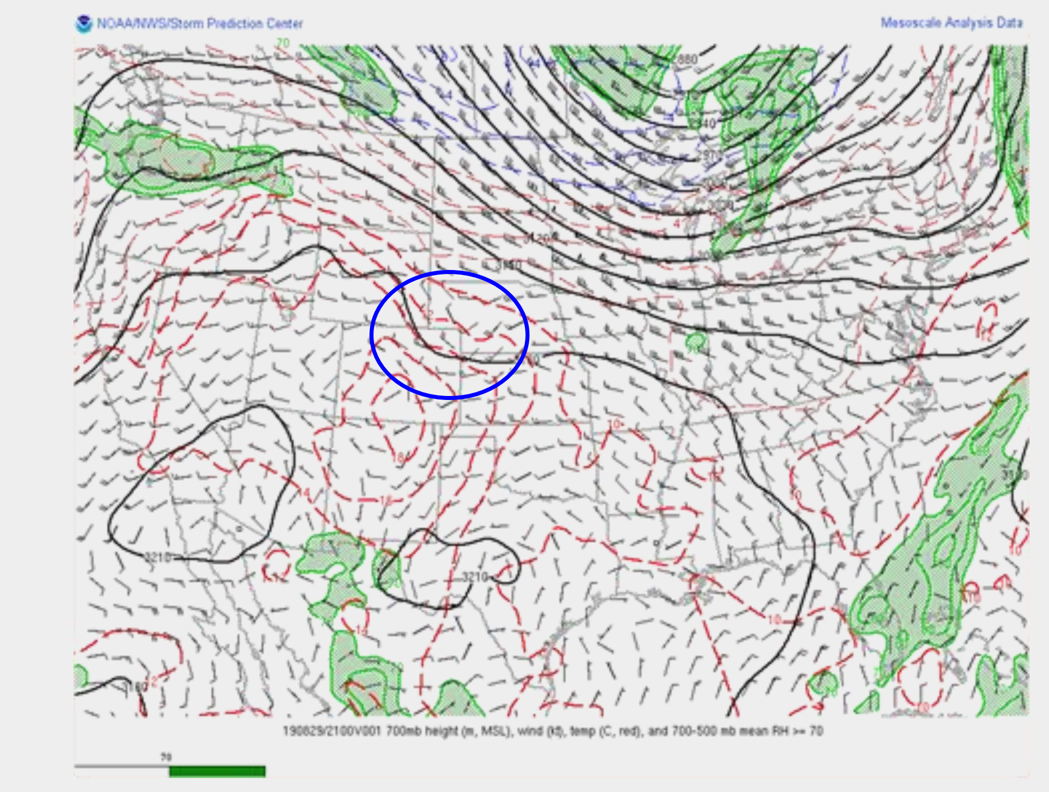
We'll be focusing on southwest NE, northeast CO, and northwest KS



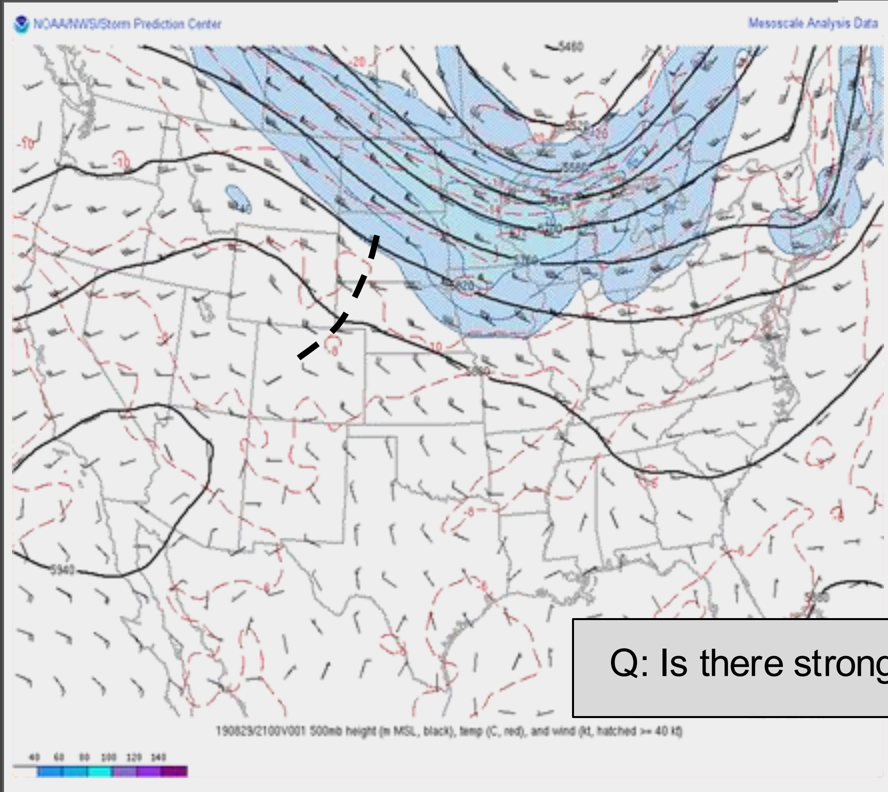


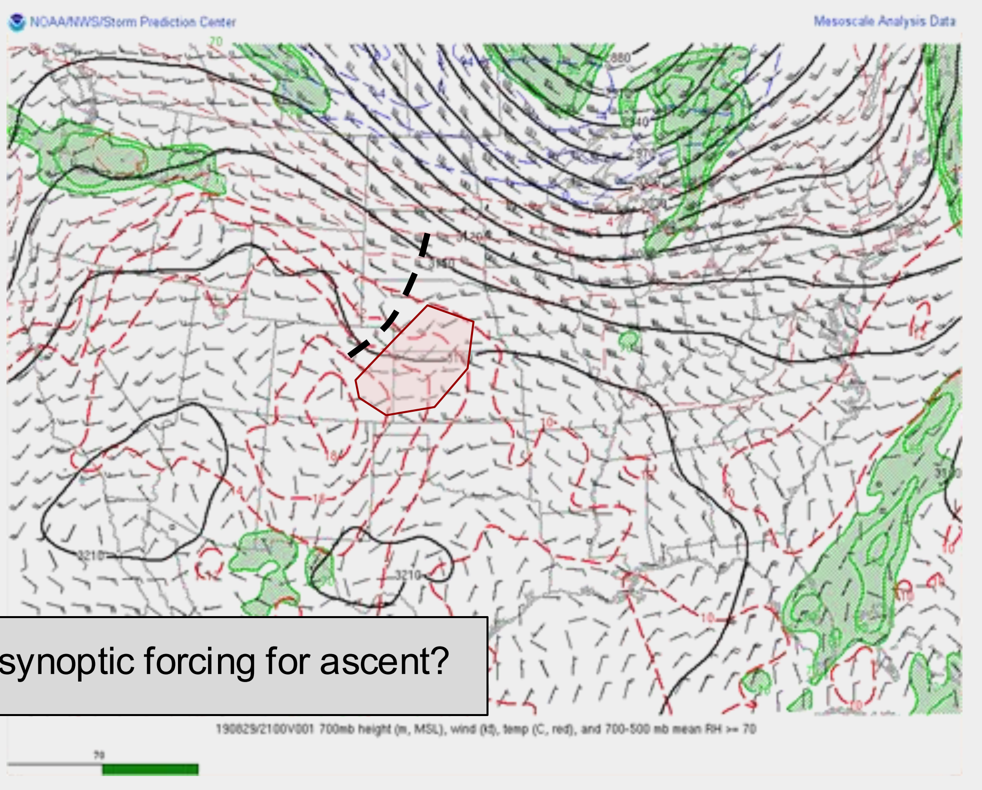
August 29, 2019   21 UTC





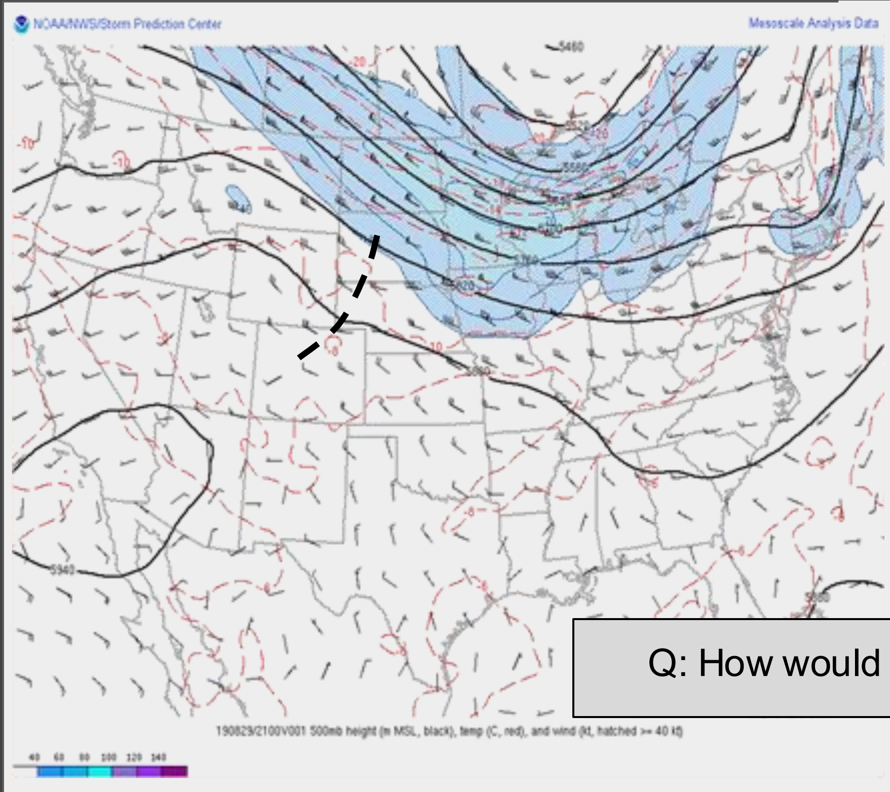
August 29, 2019 21 UTC

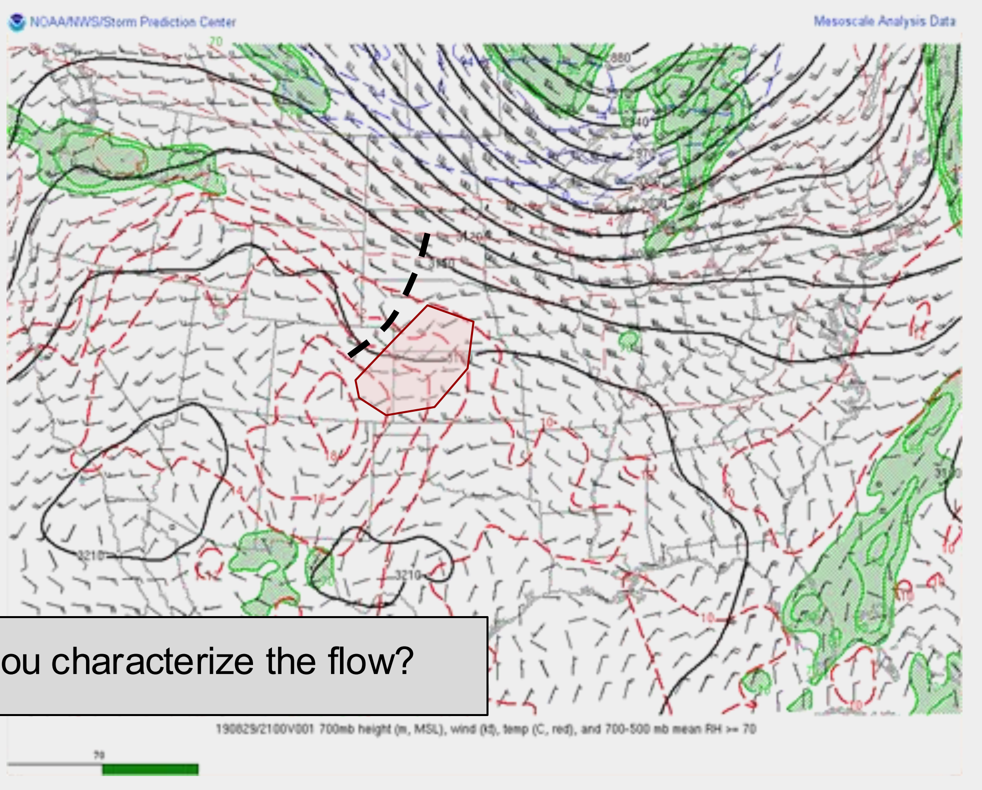




Q: Is there strong synoptic forcing for ascent?

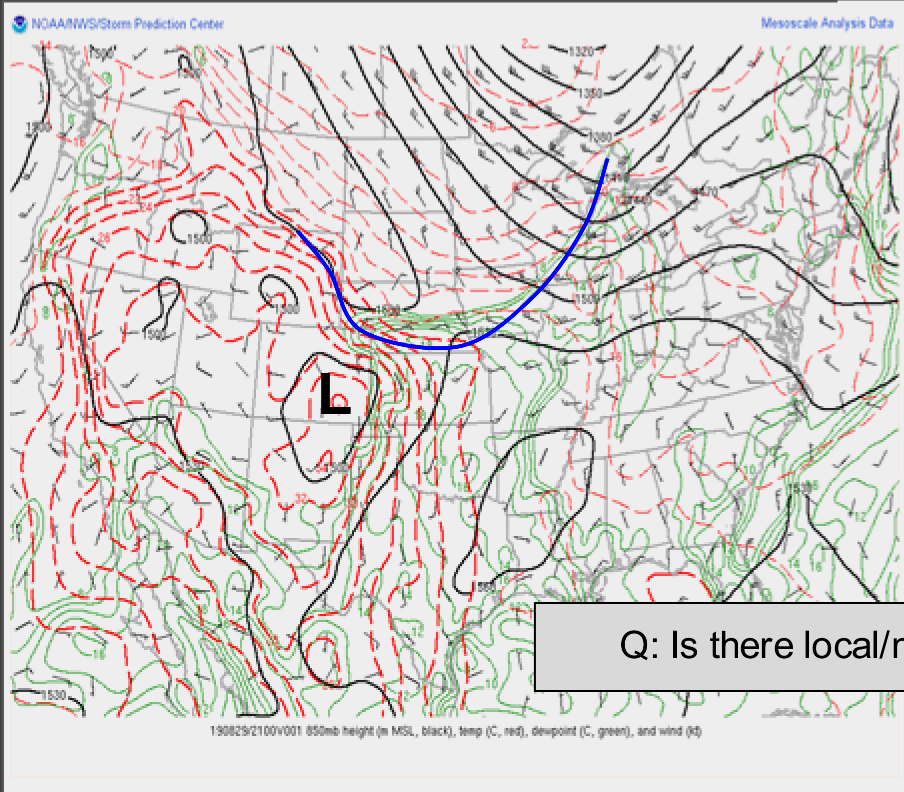
August 29, 2019   21 UTC

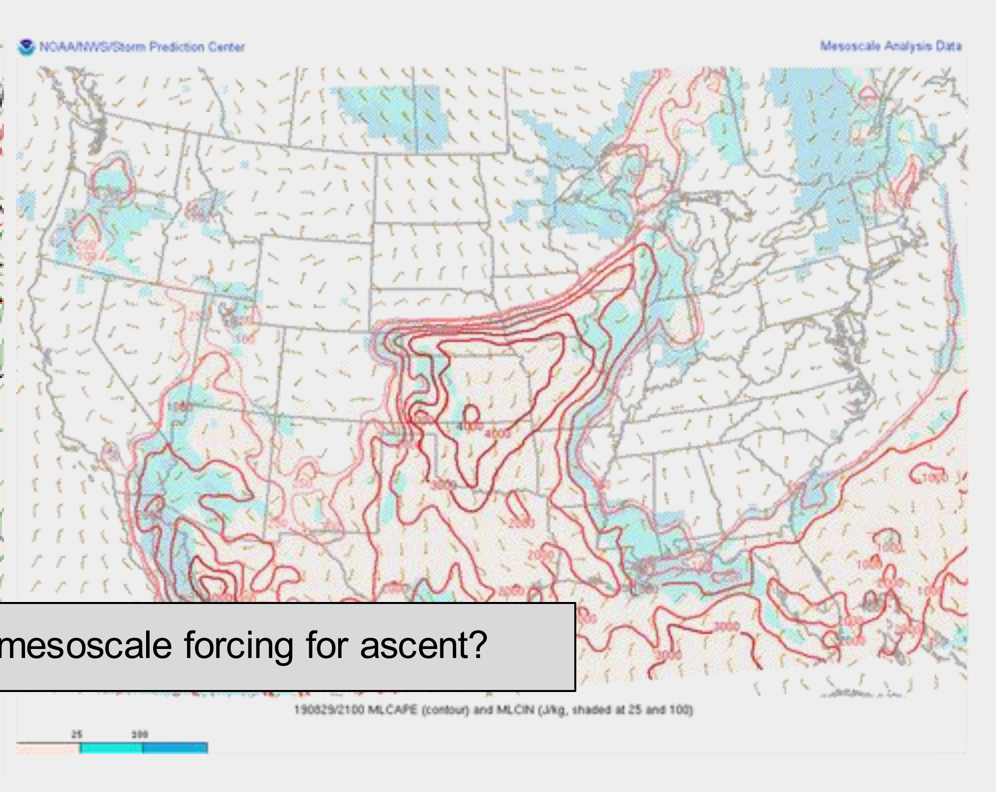




Q: How would you characterize the flow?

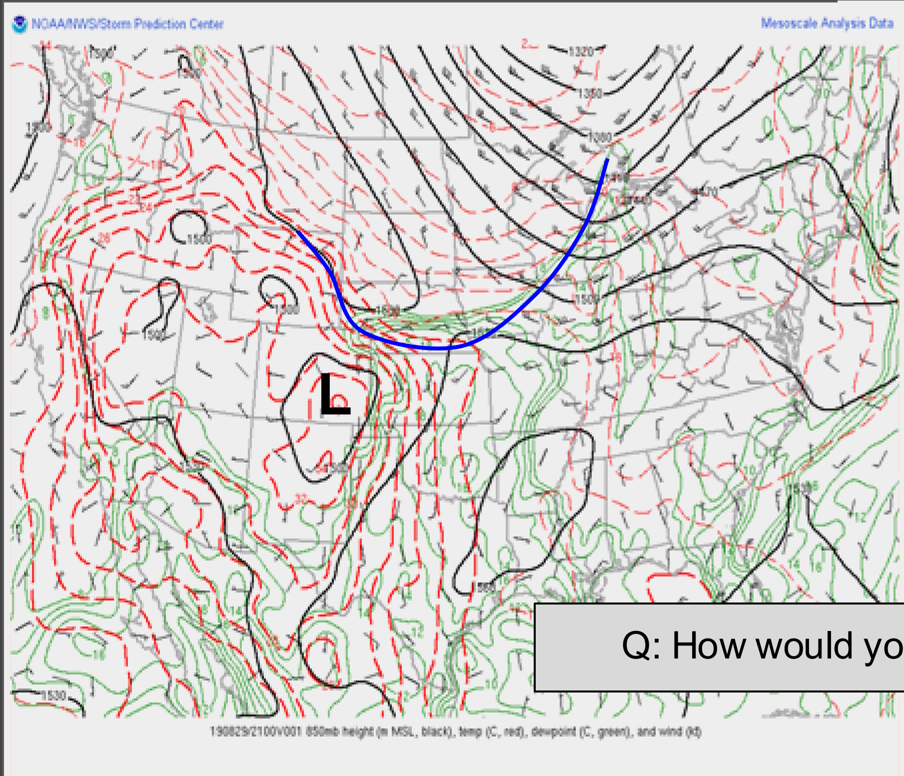
August 29, 2019 21 UTC

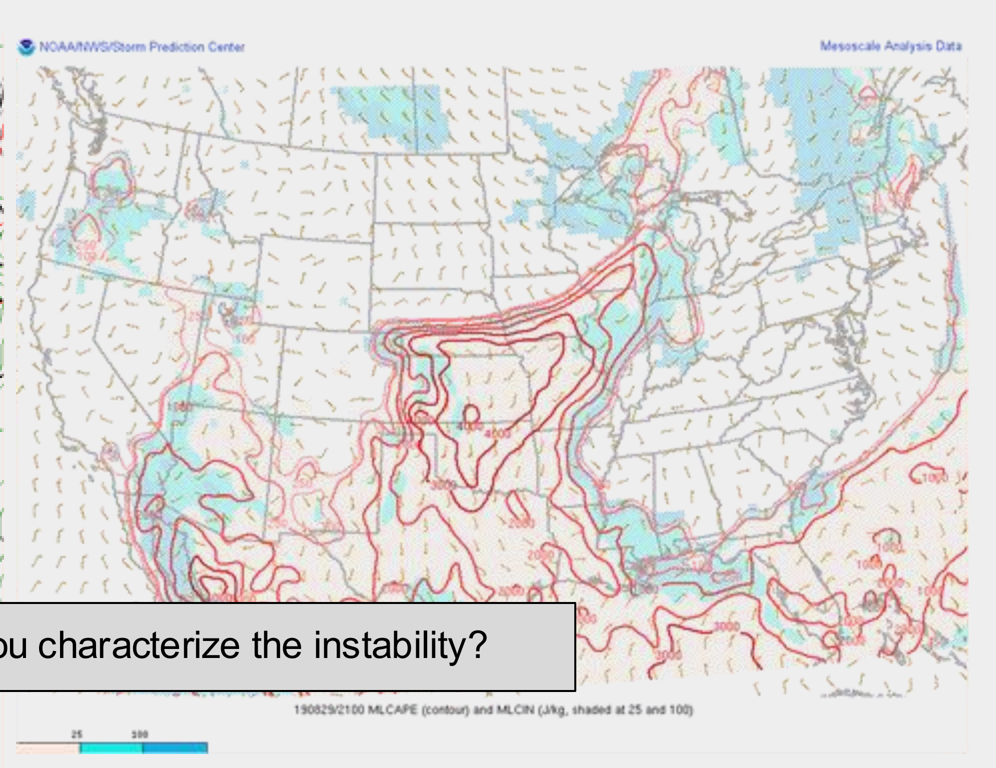




Q: Is there local/mesoscale forcing for ascent?

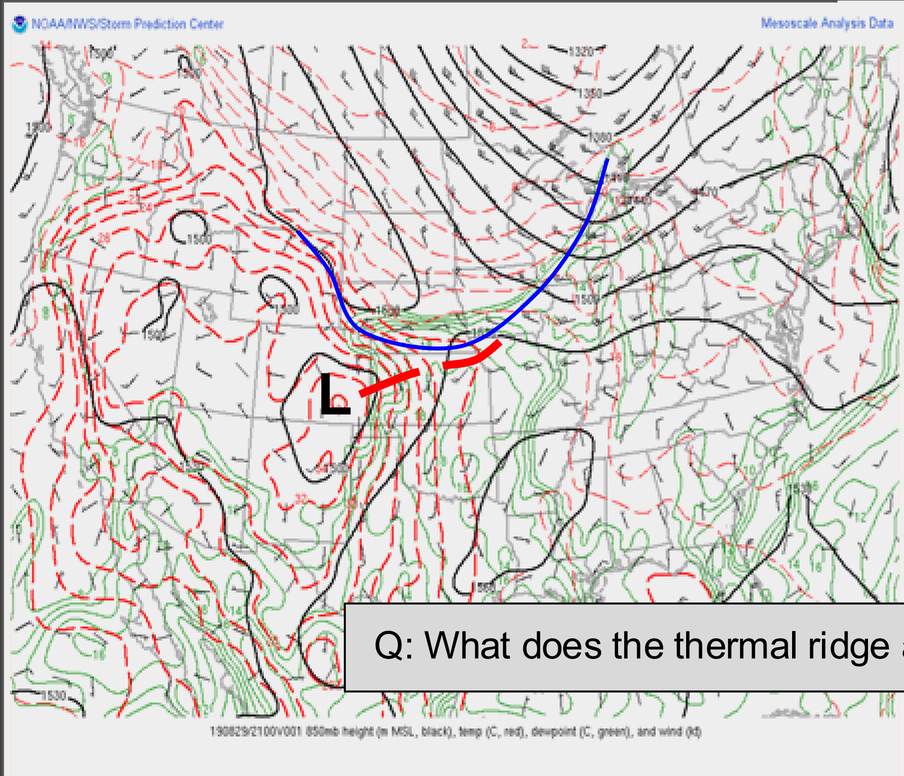
August 29, 2019 21 UTC

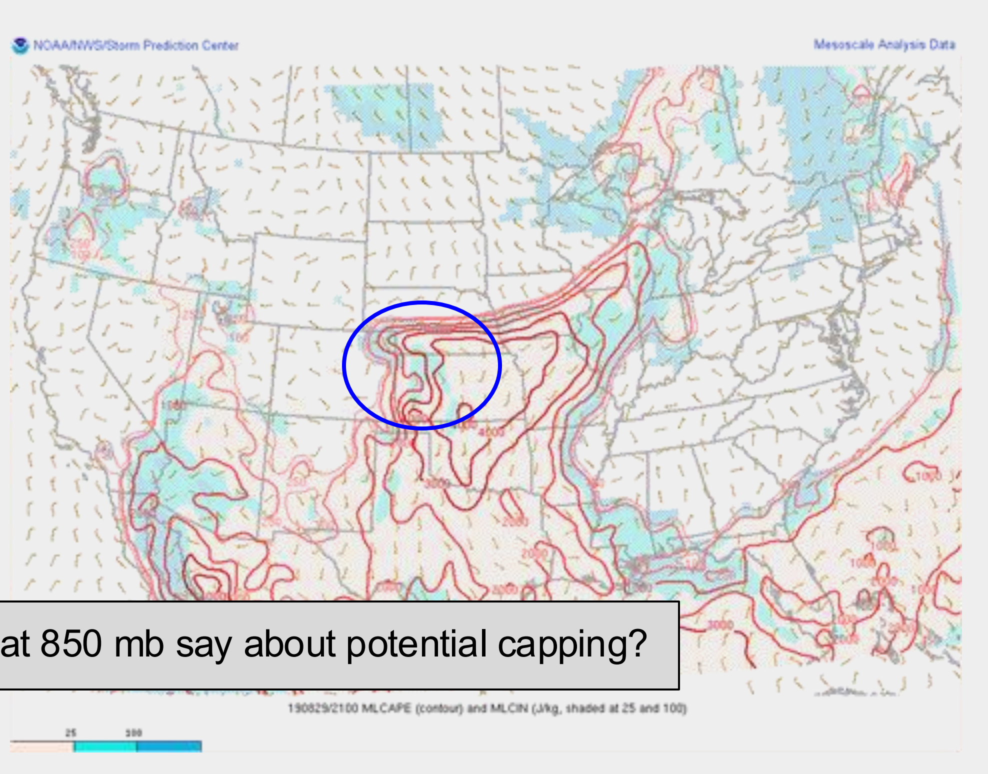




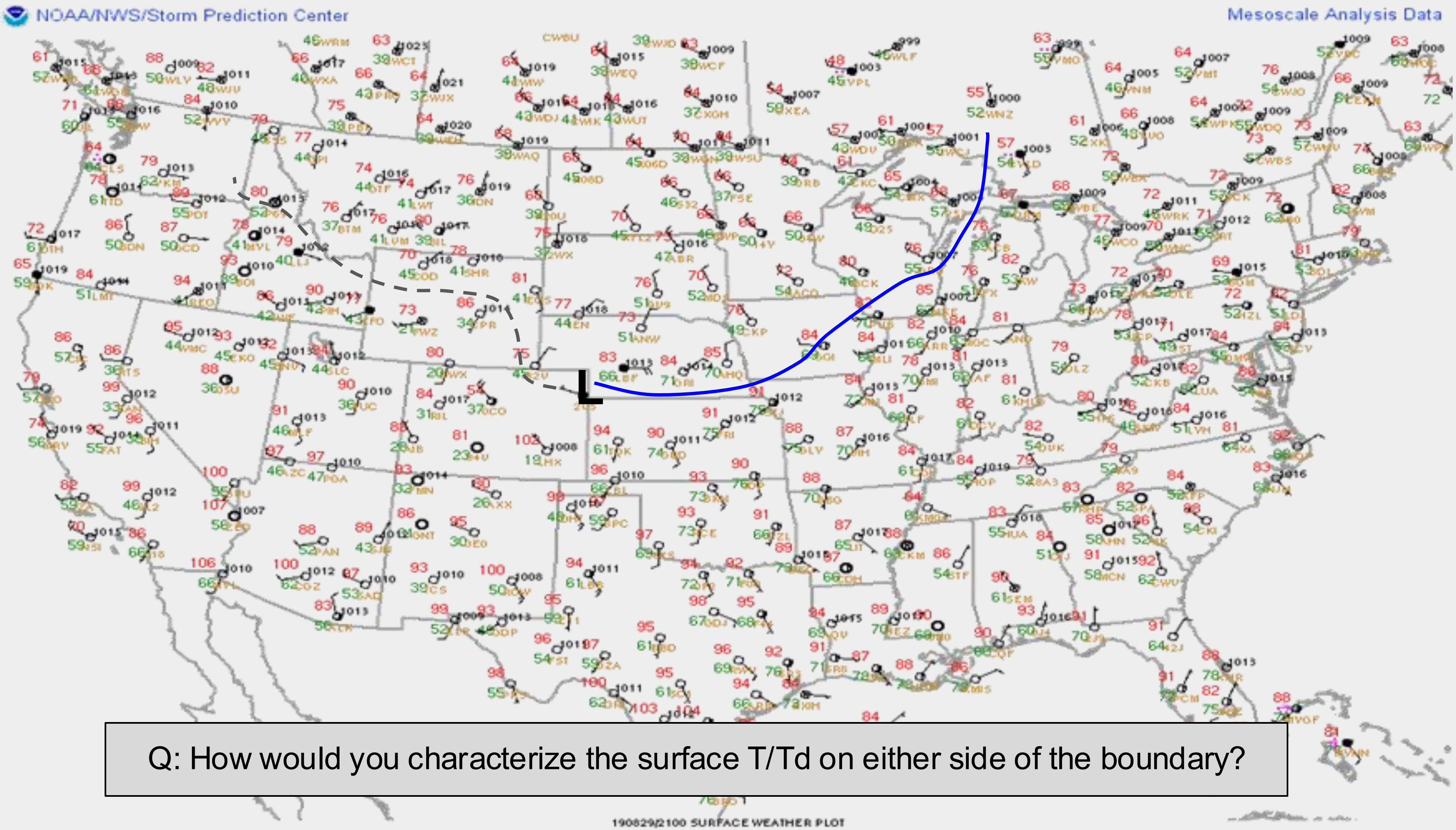
Q: How would you characterize the instability?

August 29, 2019 21 UTC

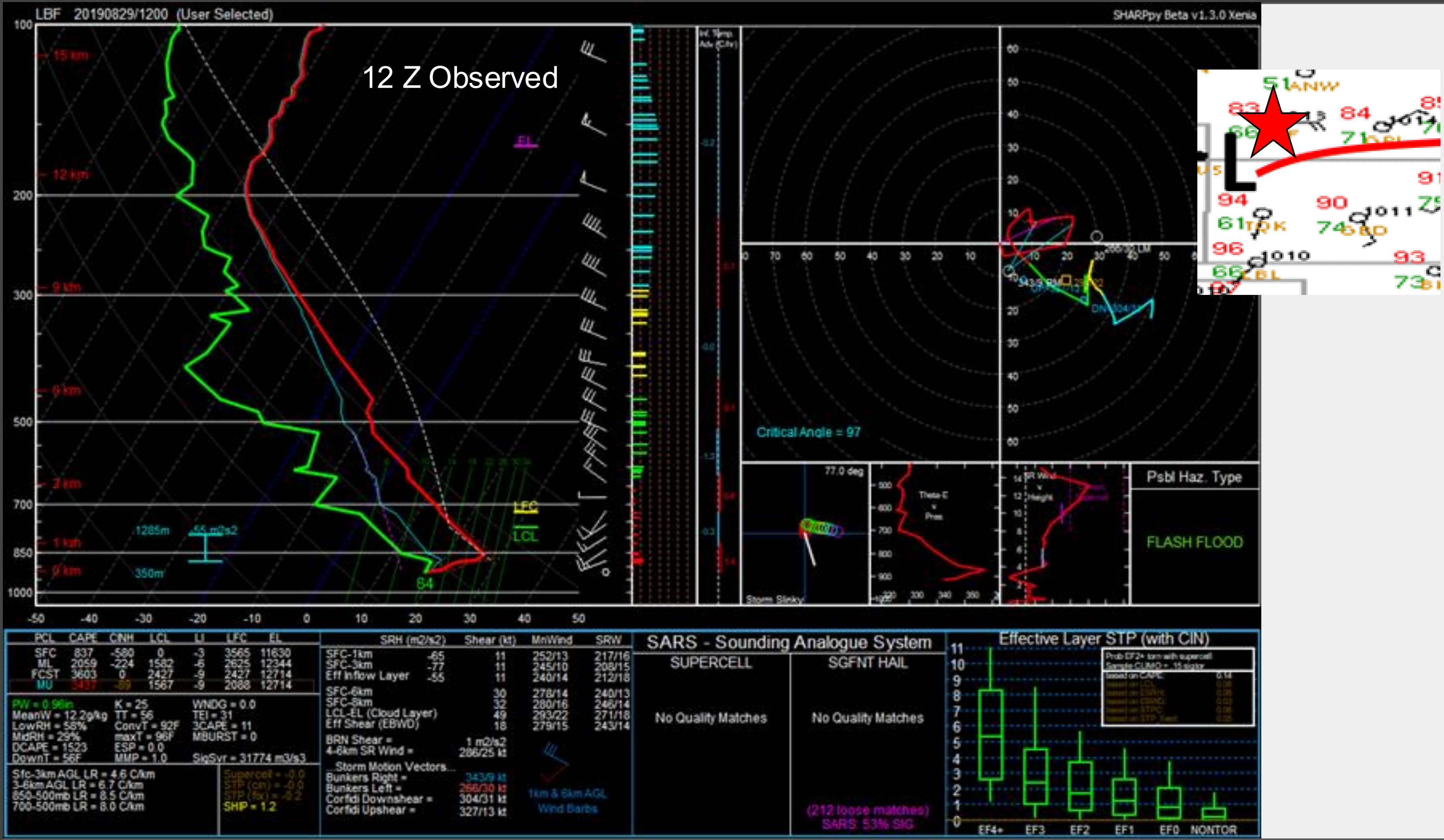




Q: What does the thermal ridge at 850 mb say about potential capping?



Q: How would you characterize the surface T/Td on either side of the boundary?

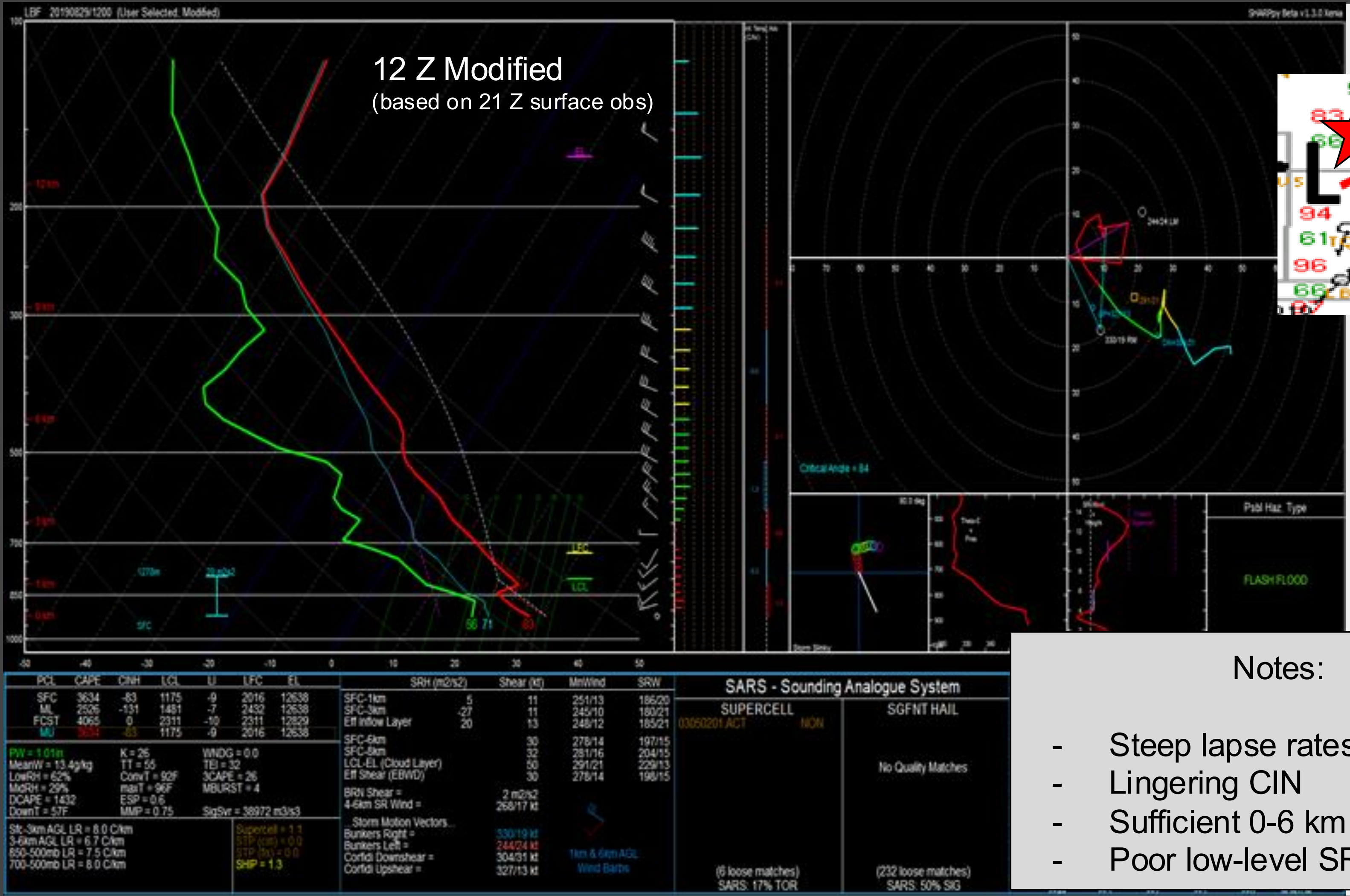


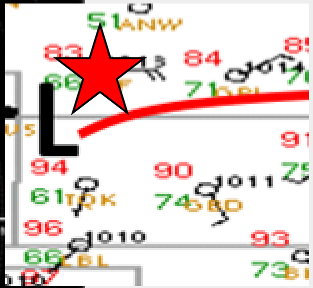
PCL	CAPE	CINH	LCL	LI	LFC	EL
SFC	837	-580	0	-3	3565	11630
ML	2059	-224	1582	-6	2625	12344
FCST	3603	0	2427	-9	2427	12714
MU	3437	-59	1567	-9	2088	12714

	SRH (m2/s2)	Shear (kt)	MnWind	SRW
SFC-1km	-65	11	252/13	217/16
SFC-3km	-77	11	245/10	208/15
Eff Inflow Layer	-55	11	240/14	212/18
SFC-6km		30	278/14	240/13
SFC-8km		32	280/16	246/14
LCL-EL (Cloud Layer)		49	293/22	271/18
Eff Shear (EBWD)		18	279/15	243/14

12 Z Modified

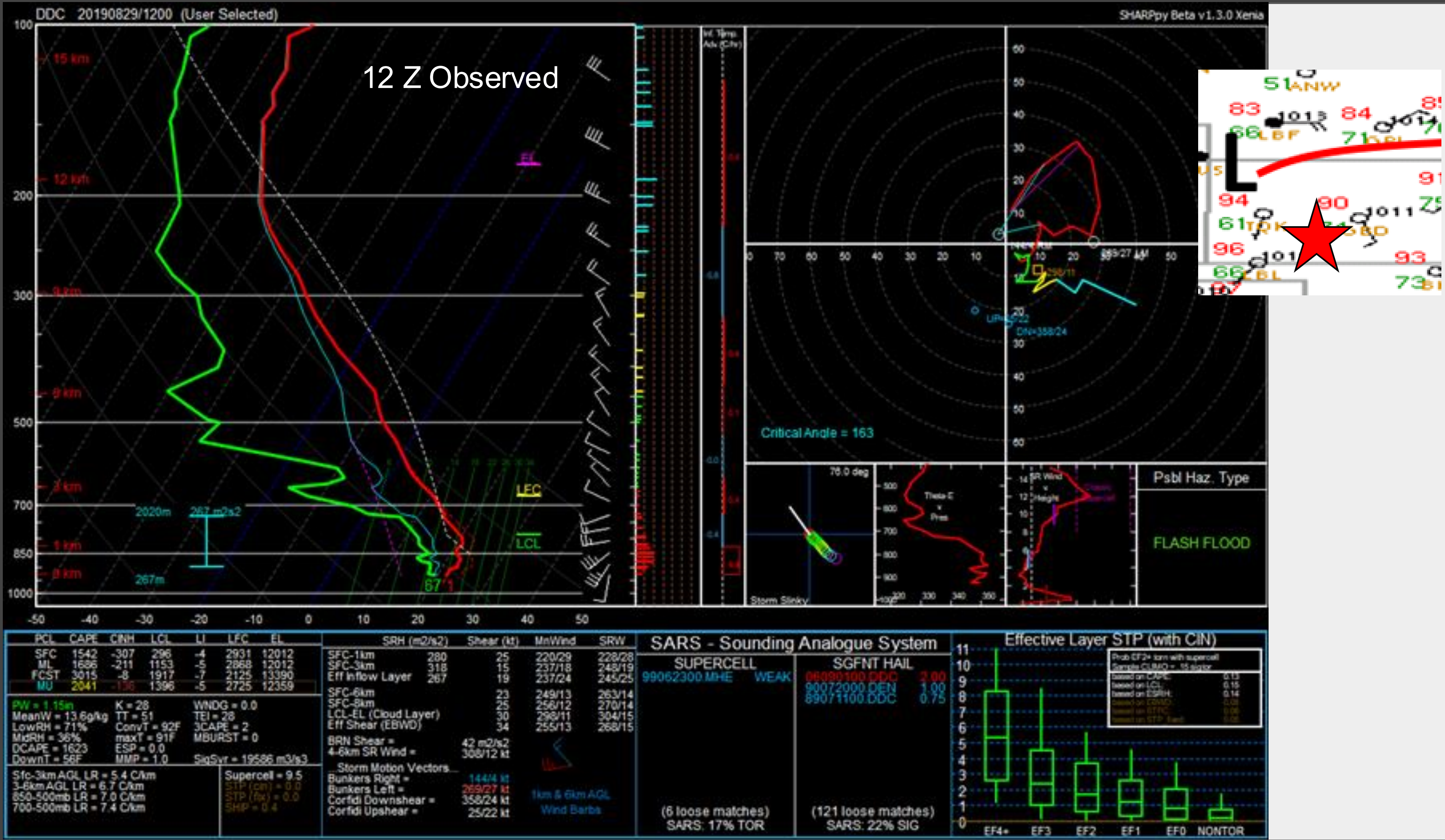
(based on 21 Z surface obs)

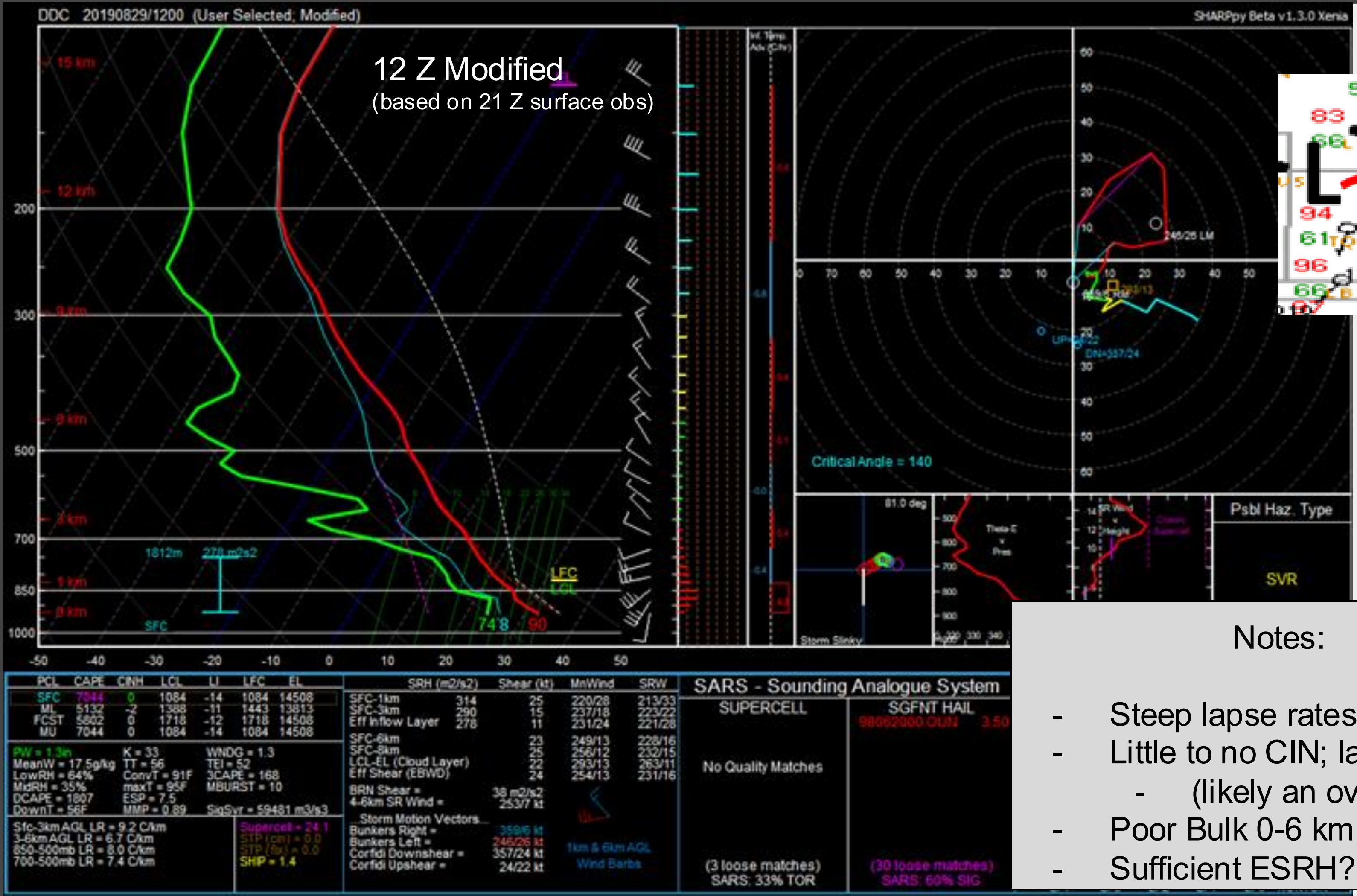


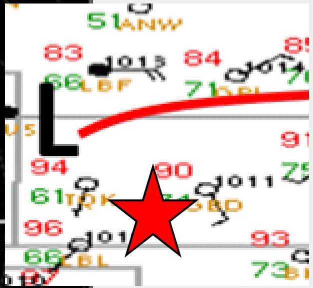


Notes:

- Steep lapse rates
- Lingering CIN
- Sufficient 0-6 km Bulk shear
- Poor low-level SRH


DDC 20190829/1200 (User Selected)
SHARPpy Beta v1.3.0 Xenia
12 Z Observed
LFC
LCL
EL
2020m
267 m2/s2
267m
Critical Angle = 163
Storm Slinky
Psbl Haz. Type
FLASH FLOOD
PCL CAPE CINH LCL LI LFC EL
SFC 1542 -307 296 -4 2931 12012
ML 1686 -211 1153 -5 2868 12012
FCST 3015 -8 1917 -7 2125 13390
MU 2041 -136 1396 -5 2725 12359
PW = 1.15in
MeanW = 13.6g/kg
LowRH = 71%
MidRH = 36%
DCAPE = 1623
DownT = 56F
K = 28
TT = 51
ConvT = 92F
maxT = 91F
ESP = 0.0
MMP = 1.0
WNDG = 0.0
TEI = 28
3CAPE = 2
MBURST = 0
SigSvr = 19586 m3/s3
Sfc-3km AGL LR = 5.4 C/km
3-6km AGL LR = 6.7 C/km
850-500mb LR = 7.0 C/km
700-500mb LR = 7.4 C/km
Supercell = 9.5
STP (cin) = 0.0
STP (fix) = 0.0
SHIP = 0.4
SRH (m2/s2) Shear (kt) MnWind SRW
SFC-1km 280 25 220/29 228/28
SFC-3km 318 15 237/18 248/19
Eff Inflow Layer 267 19 237/24 245/25
SFC-6km 23 249/13 263/14
SFC-8km 25 256/12 270/14
LCL-EL (Cloud Layer) 30 298/11 304/15
Eff Shear (EBWD) 34 255/13 268/15
BRN Shear = 42 m2/s2
4-6km SR Wind = 308/12 kt
Storm Motion Vectors
Bunkers Right = 144/4 kt
Bunkers Left = 269/27 kt
Corfidi Downshear = 358/24 kt
Corfidi Upshear = 25/22 kt
1km & 6km AGL Wind Barbs
SARS - Sounding Analogue System
SUPERCELL
99062300.MHE WEAK
(6 loose matches)
SARS: 17% TOR
SGFNT HAIL
06080100.DDC 2.00
90072000.DEN 1.00
89071100.DDC 0.75
(121 loose matches)
SARS: 22% SIG
Effective Layer STP (with CIN)
EF4+ EF3 EF2 EF1 EF0 NONTOR
51 ANW
83
84
66 LBF
71
91
94
90
1011
61
96
93
66
73

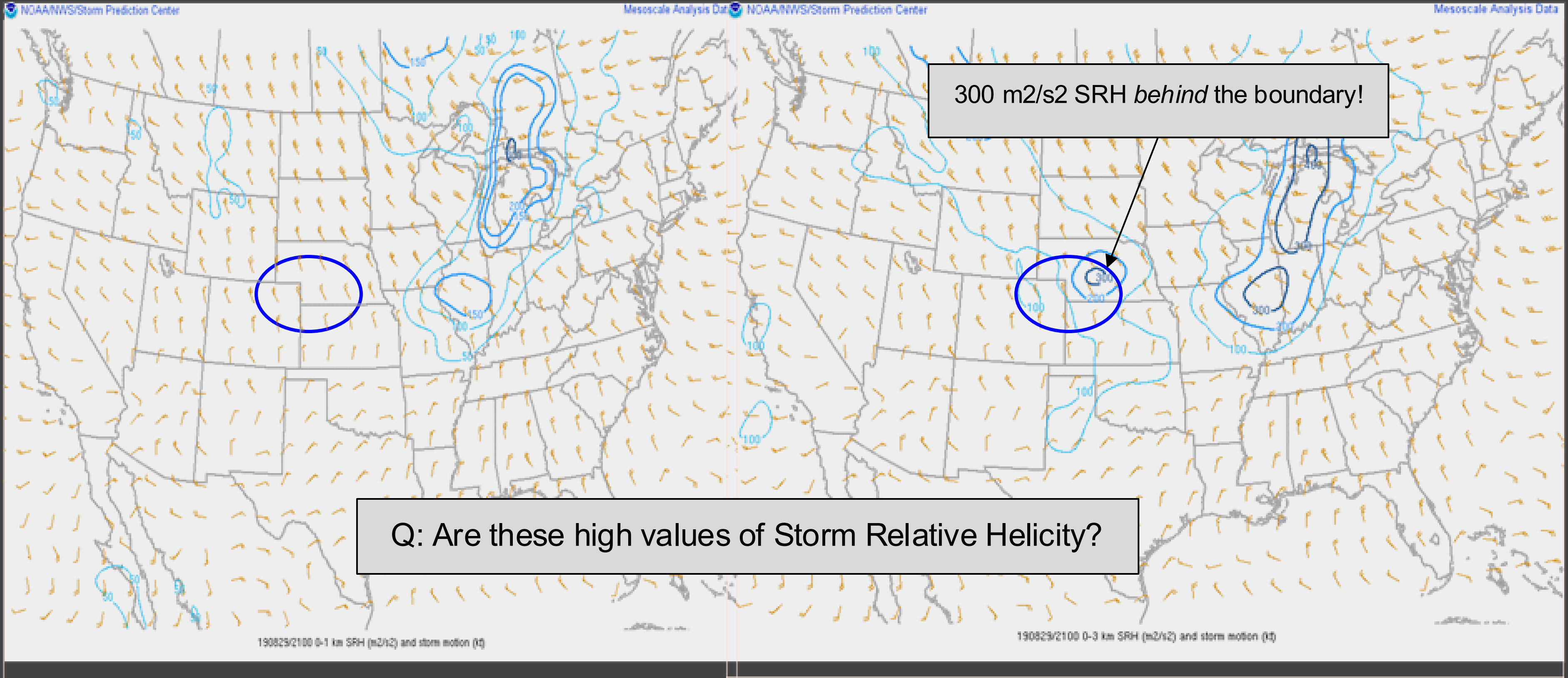




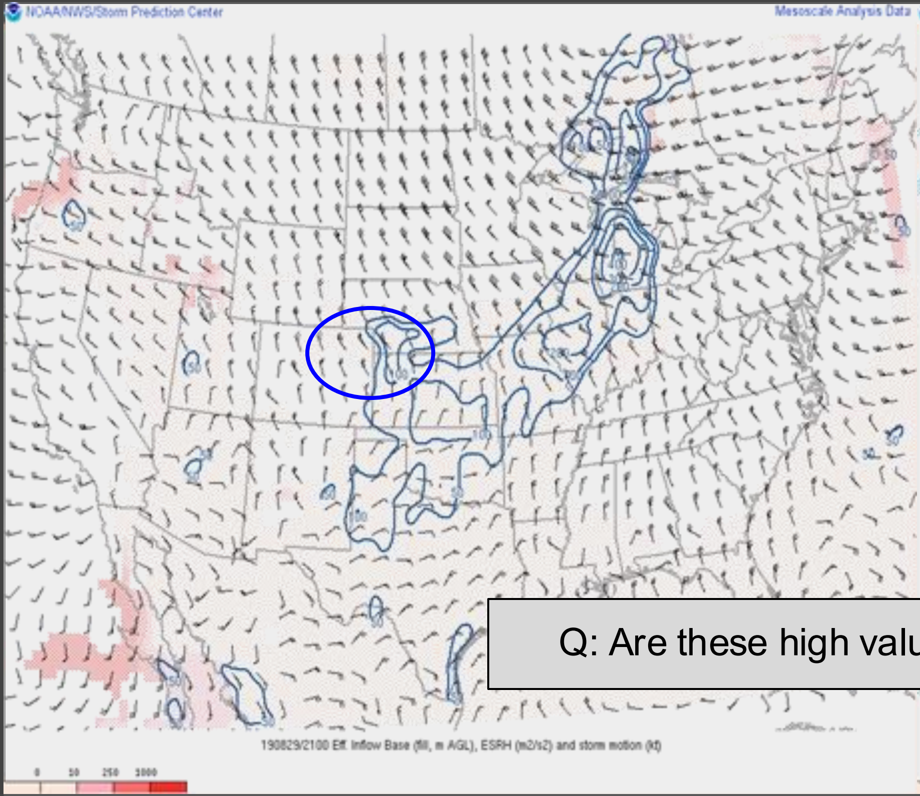
Notes:

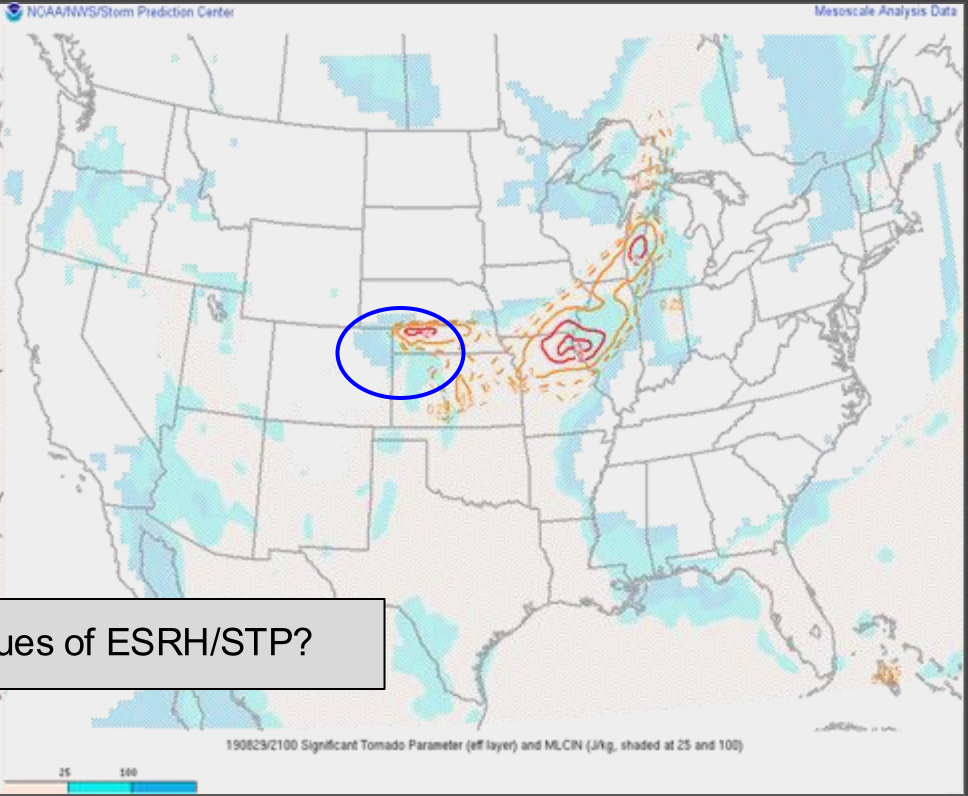
- Steep lapse rates
- Little to no CIN; large CAPE
    - (likely an overestimate!)
- Poor Bulk 0-6 km bulk shear
- Sufficient ESRH?

August 29, 2019   21 UTC



August 29, 2019 21 UTC





Q: Are these high values of ESRH/STP?

How would you rate the tornado threat for our area of concern?

A: Low (10-30%)

B: Medium (40-60%)

C: High (70-90%)

D: Very High (>90%)

Tornado threat so far:

Parameter	**Value**	**Subjective Ranking***

*The subjective ranking is largely based on the parameter's tornado climatology. This is available on the SPC Mesoanalysis website.

Tornado threat so far:

Parameter	Value	Subjective Ranking*
0-1 km SRH	Near 0	Low

*The subjective ranking is largely based on the parameter's tornado climatology. This is available on the SPC Mesoanalysis website.

Tornado threat so far:

Parameter	Value	Subjective Ranking*
0-1 km SRH	Near 0	Low
0-3 km SRH	100-200 m2/s2	Medium

*The subjective ranking is largely based on the parameter's tornado climatology. This is available on the SPC Mesoanalysis website.

Tornado threat so far:

Parameter	Value	Subjective Ranking*
0-1 km SRH	Near 0	Low
0-3 km SRH	100-200 m2/s2	Medium
ESRH	Near 100 m2/s2	Low

*The subjective ranking is largely based on the parameter's tornado climatology. This is available on the SPC Mesoanalysis website.

Tornado threat so far:

Parameter	Value	Subjective Ranking*
0-1 km SRH	Near 0	Low
0-3 km SRH	100-200 m2/s2	Medium
ESRH	Near 100 m2/s2	Low
STP	0-1	Low-Medium

*The subjective ranking is largely based on the parameter's tornado climatology. This is available on the SPC Mesoanalysis website.

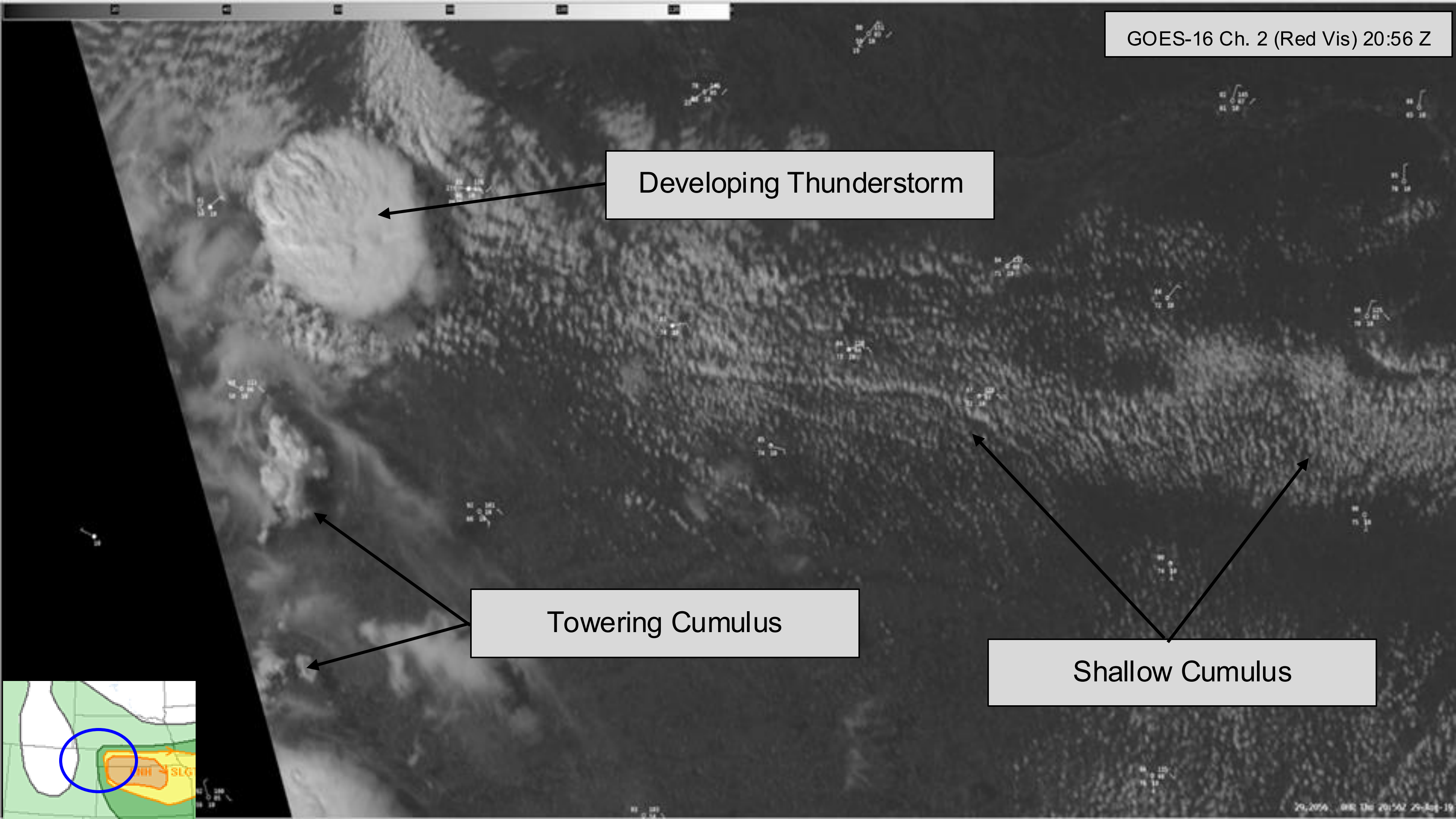
Tornado threat so far:

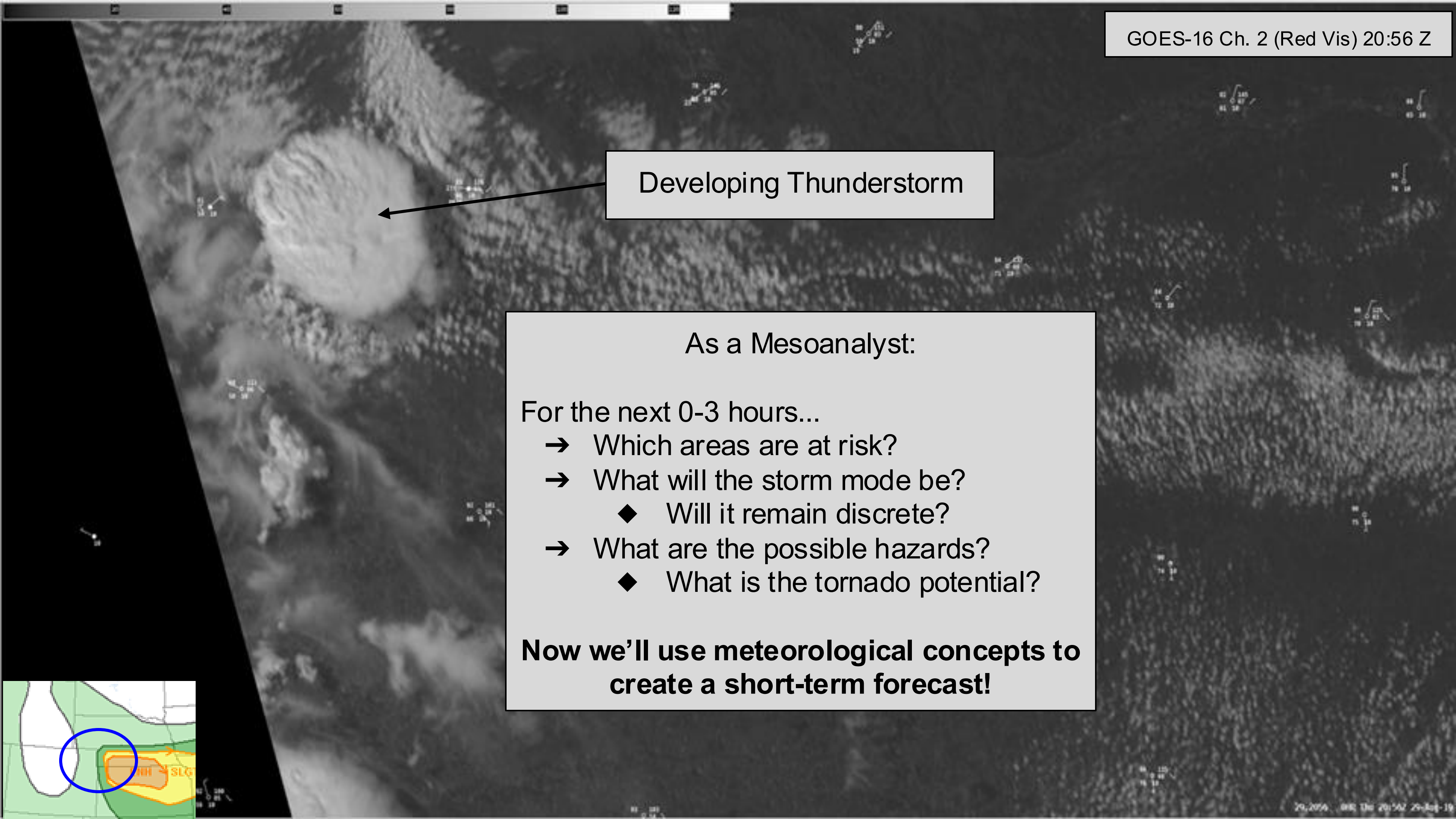
Parameter	**Value**	**Subjective Ranking***
0-1 km SRH	Near 0	Low
0-3 km SRH	100-200 m2/s2	Medium
ESRH	Near 100 m2/s2	Low
STP	0-1	Low-Medium

Overall Environment: High CAPE/Low Shear

Does the SPC tornado risk seem appropriate?

*The subjective ranking is largely based on the parameter's tornado climatology. This is available on the SPC Mesoanalysis website.


GOES-16 Ch. 2 (Red Vis) 20:56 Z
Developing Thunderstorm
Towering Cumulus
Shallow Cumulus



GOES-16 Ch. 2 (Red Vis) 20:56 Z

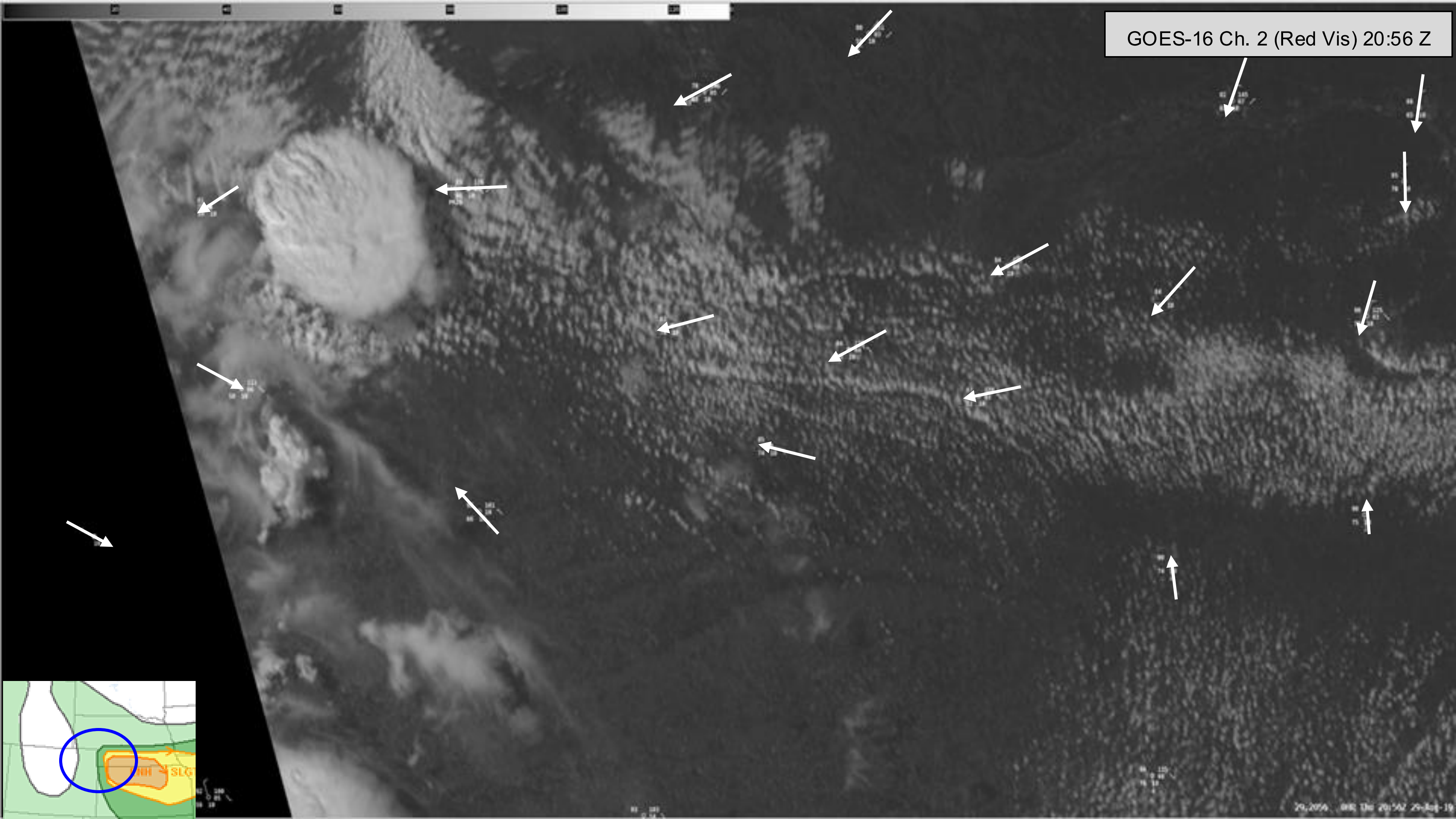
Developing Thunderstorm

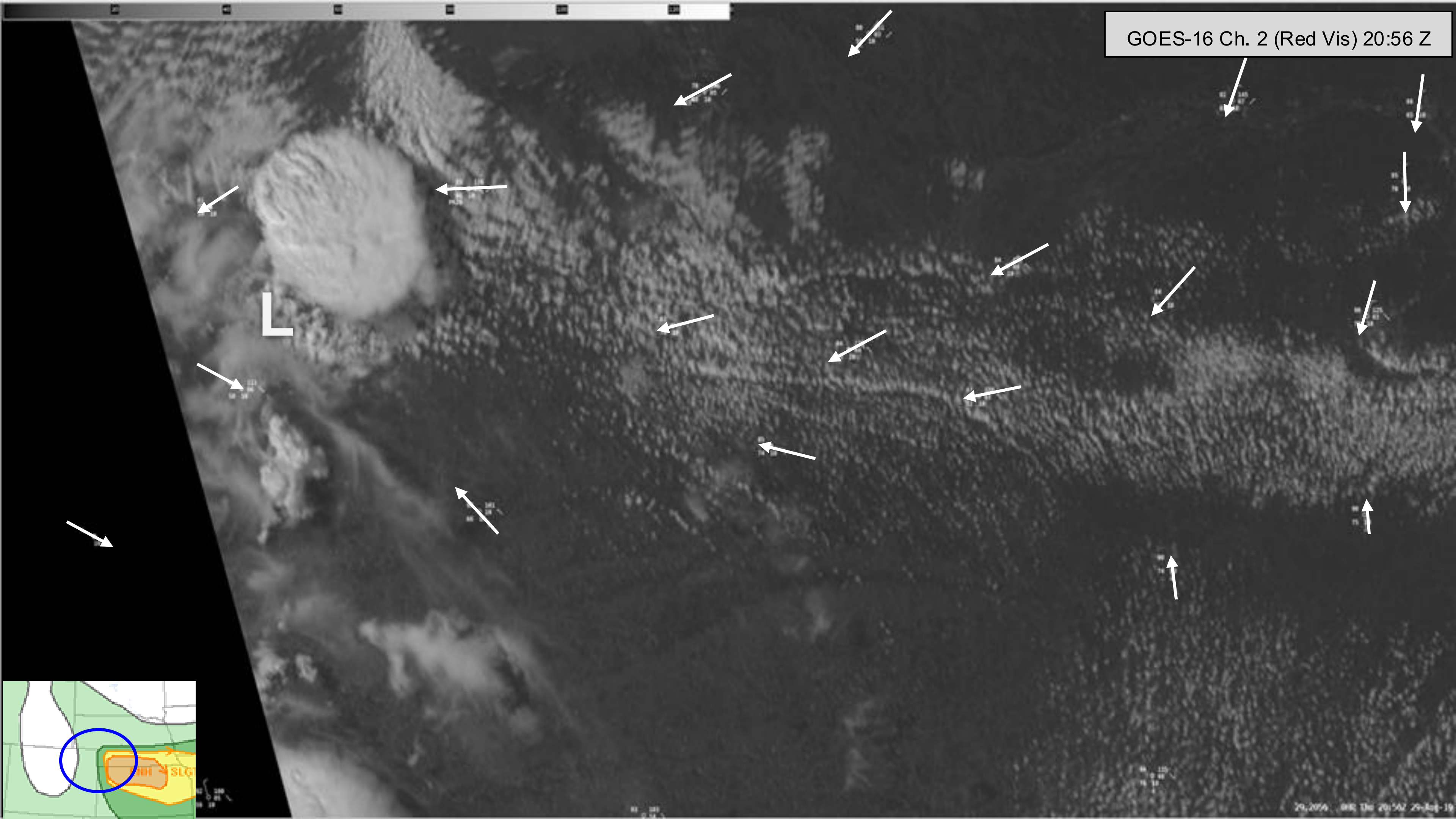
As a Mesoanalyst:

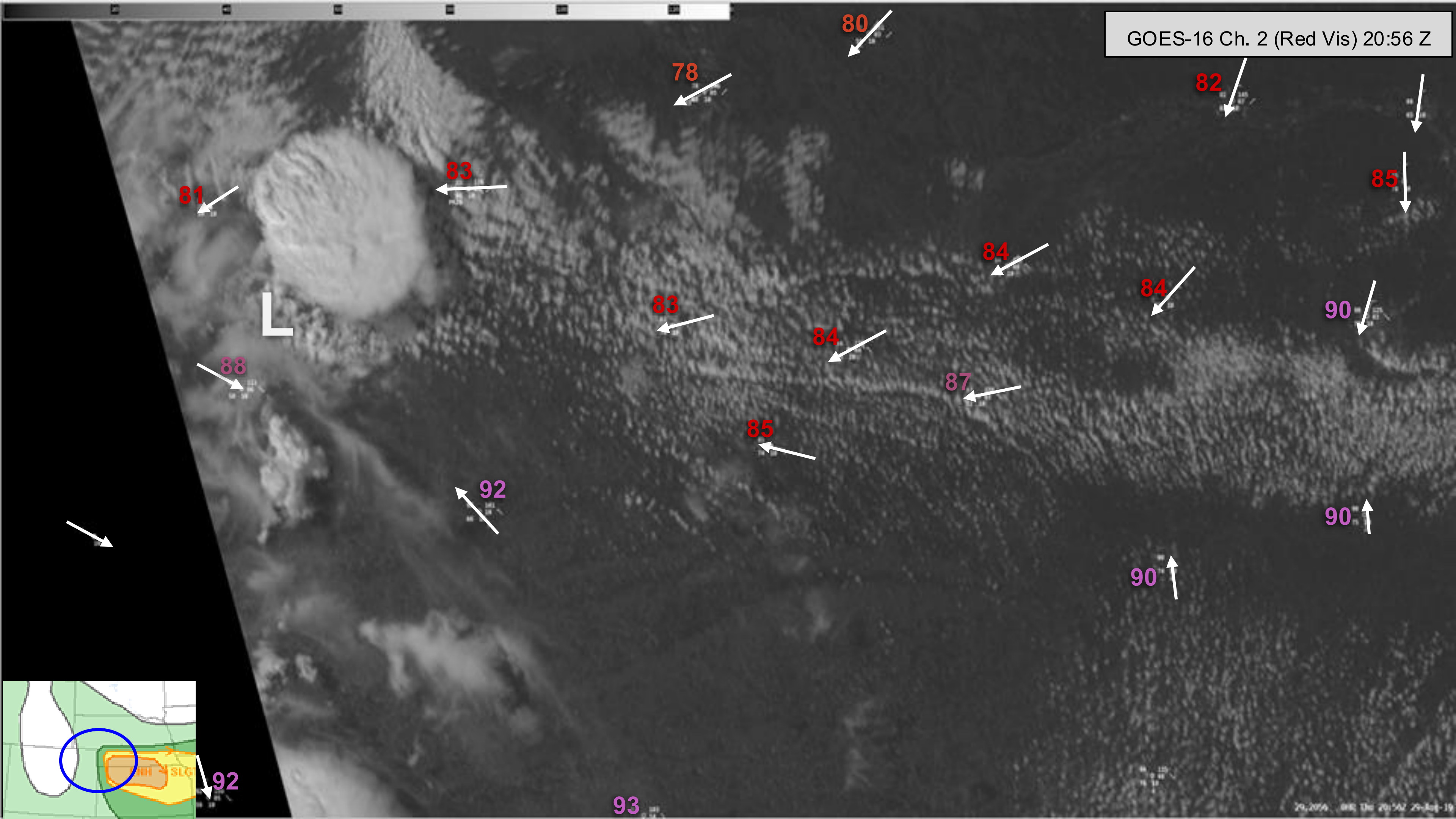
For the next 0-3 hours...

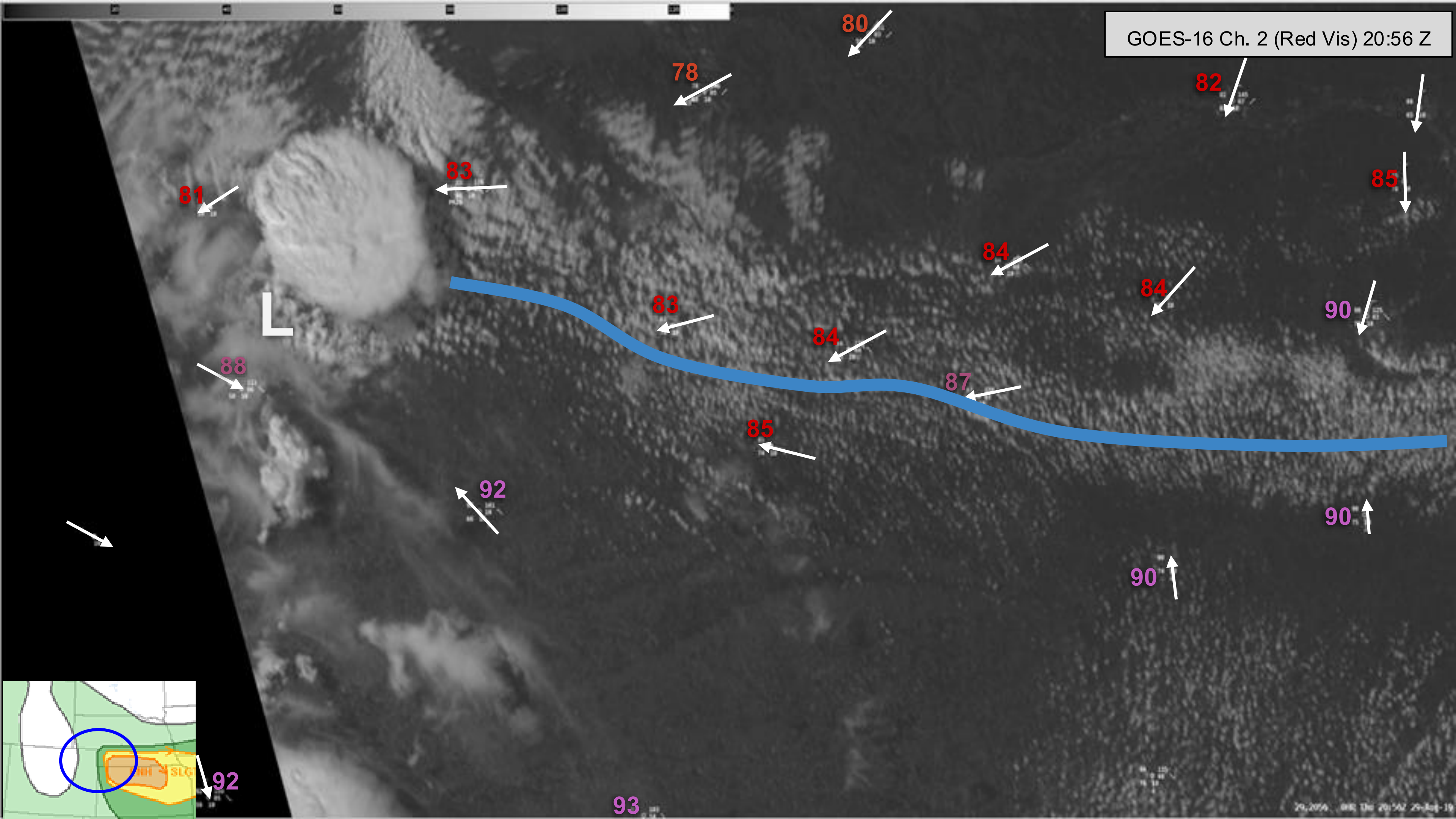
- ➔ Which areas are at risk?
- ➔ What will the storm mode be?
  - ◆ Will it remain discrete?
- ➔ What are the possible hazards?
  - ◆ What is the tornado potential?

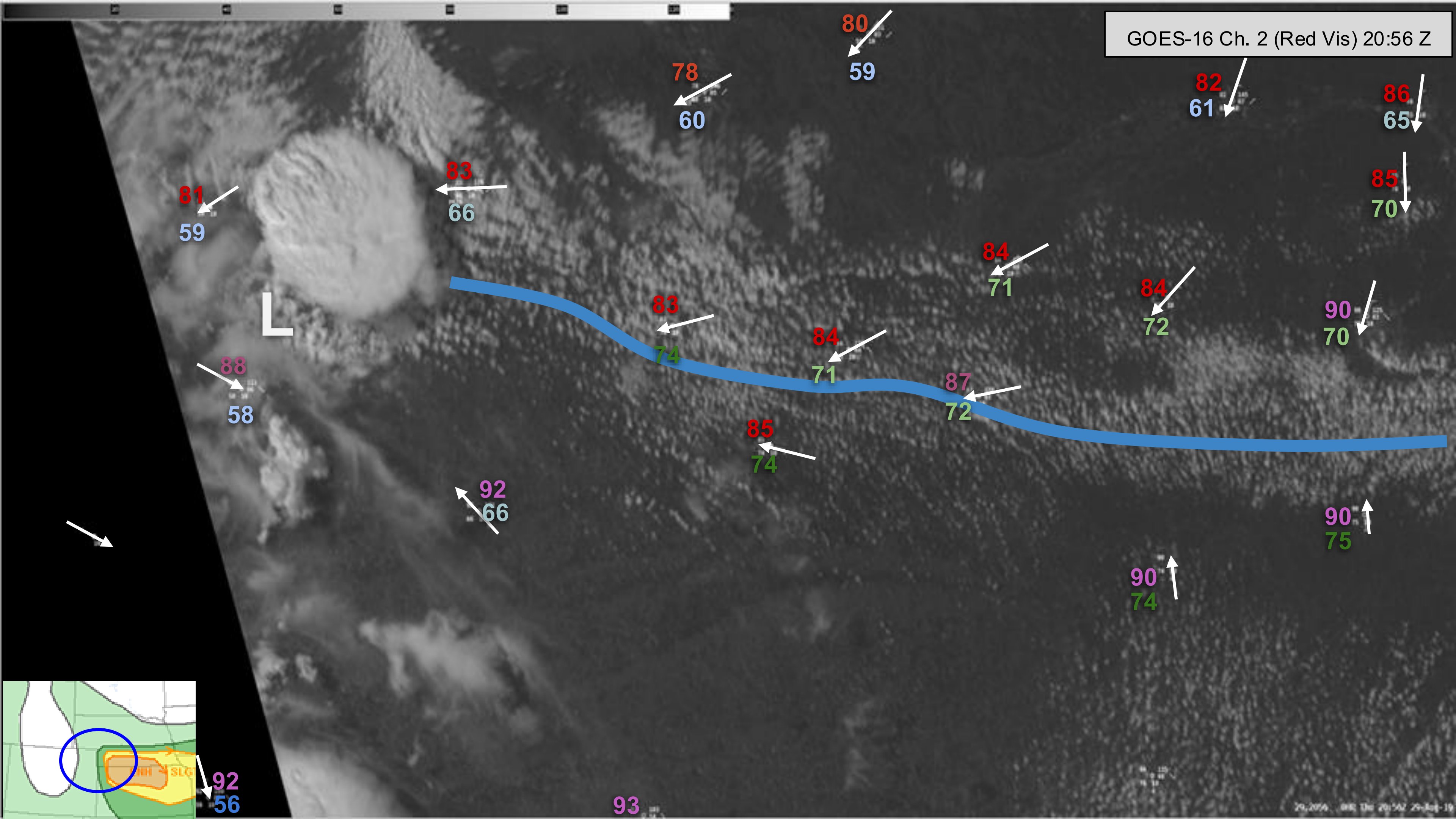
Now we'll use meteorological concepts to create a short-term forecast!

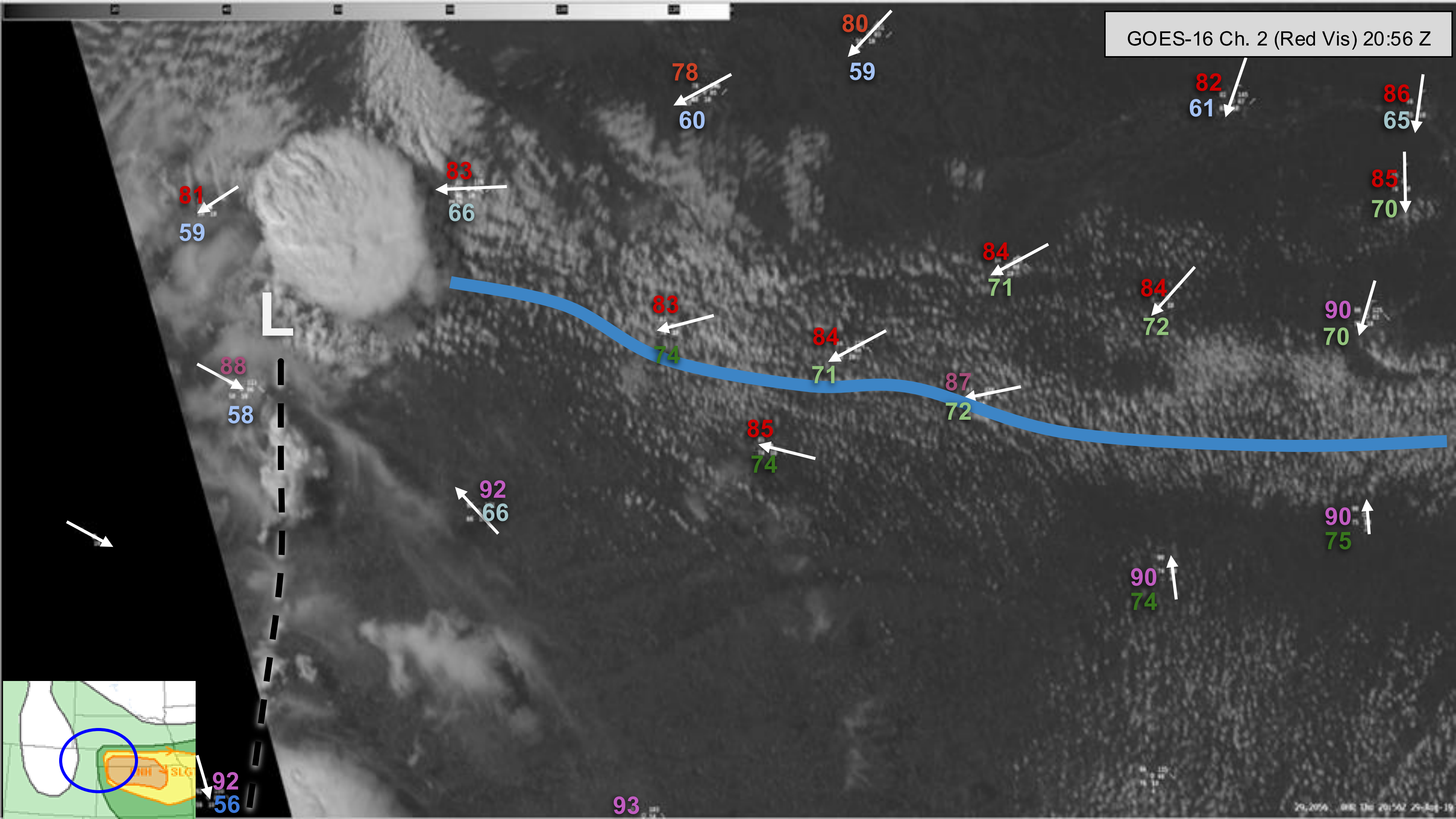

GOES-16 Ch. 2 (Red Vis) 20:56 Z

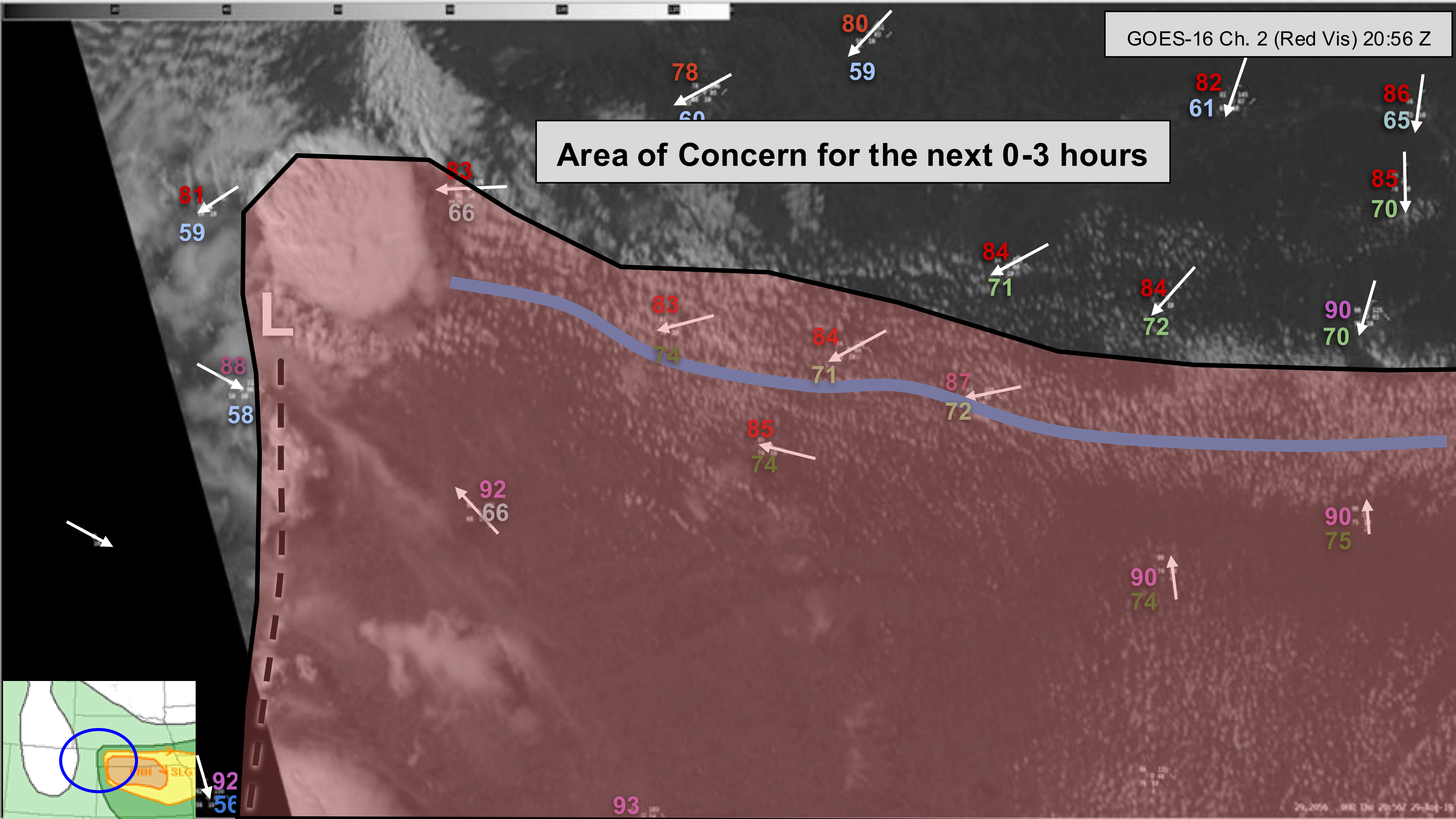

GOES-16 Ch. 2 (Red Vis) 20:56 Z
L


GOES-16 Ch. 2 (Red Vis) 20:56 Z
80
78
82
83
81
85
84
84
83
84
90
L
88
87
85
92
90
90
92
93

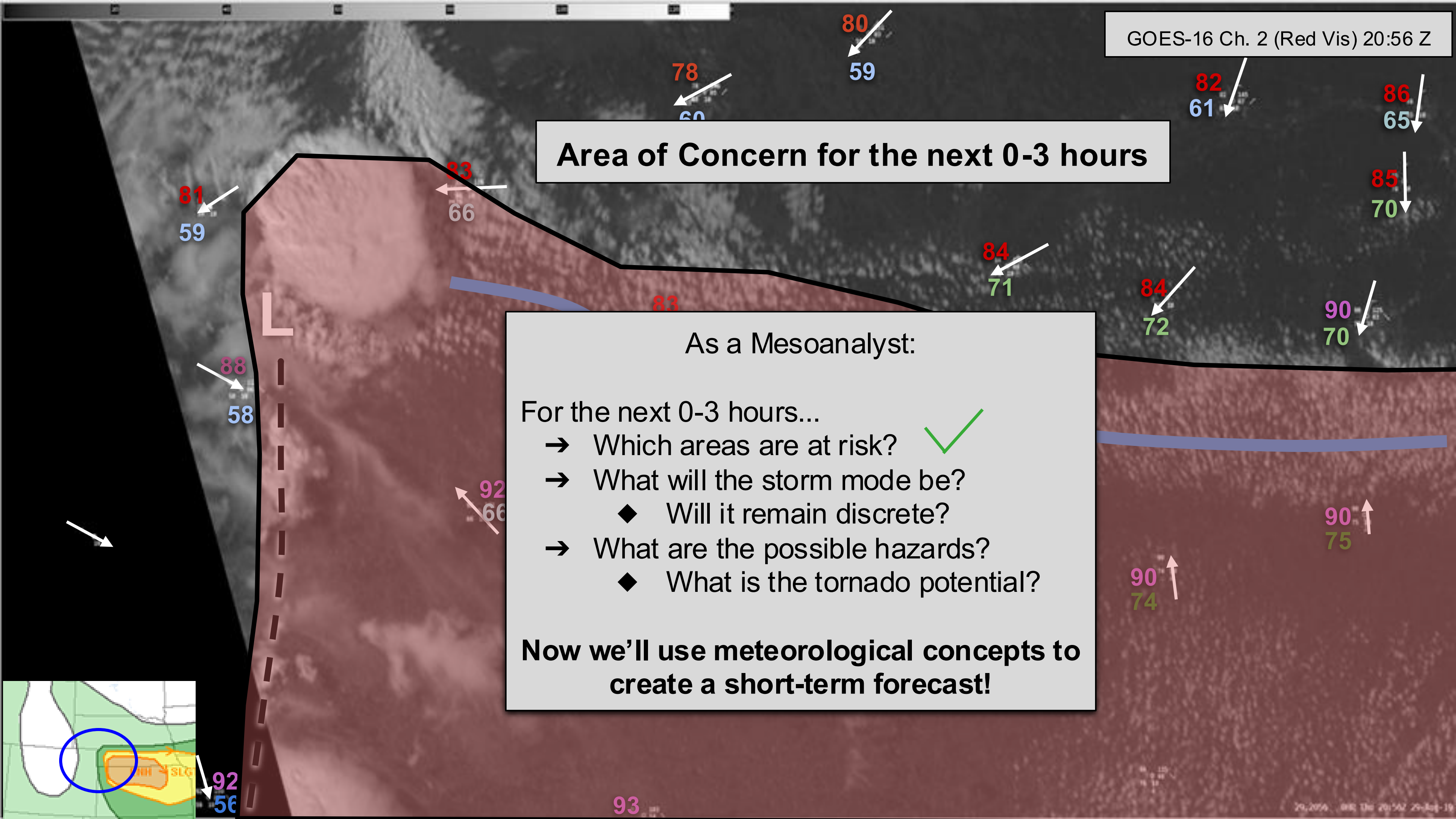

GOES-16 Ch. 2 (Red Vis) 20:56 Z
80
78
82
83
81
85
84
84
83
84
90
L
88
87
85
92
90
90
92
93


GOES-16 Ch. 2 (Red Vis) 20:56 Z
L
80
59
78
60
82
61
86
65
85
70
83
66
81
59
84
71
84
72
90
70
83
74
84
71
87
72
88
58
85
74
92
66
90
75
90
74
92
56
93


GOES-16 Ch. 2 (Red Vis) 20:56 Z
80
59
78
60
82
61
86
65
81
59
83
66
85
70
L
84
71
84
72
83
74
84
71
90
70
88
58
87
72
85
74
92
66
90
75
90
74
92
56
93


GOES-16 Ch. 2 (Red Vis) 20:56 Z
Area of Concern for the next 0-3 hours
L

Area of Concern for the next 0-3 hours



As a Mesoanalyst:

For the next 0-3 hours...

- ➔ Which areas are at risk?
- ➔ What will the storm mode be?
  - ◆ Will it remain discrete?
- ➔ What are the possible hazards?
  - ◆ What is the tornado potential?

Now we'll use meteorological concepts to create a short-term forecast!

Storm Mode In a nutshell

Storm mode is a function of:

1) Boundary-relative storm motion
   a) Storms move off boundary => favorable for discrete
   b) Storms stay on/move along boundary => favorable for linear

For details: Dial et al. 2010, Short-term Convective Mode Evolution along Synoptic Boundaries

Storm Mode In a nutshell

Storm mode is a function of:

1) Boundary-relative storm motion
   a) Storms move off boundary => favorable for discrete
   b) Storms stay on/move along boundary => favorable for linear
2) Orientation of deep layer shear vector relative to the boundary
   a) Shear vector off boundary => storm orients off-boundary => favorable for discrete
   b) Shear vector along boundary => storm orients along boundary => favorable for linear

For details: Dial et al. 2010, Short-term Convective Mode Evolution along Synoptic Boundaries

Storm Mode In a nutshell

Storm mode is a function of:

1) Boundary-relative storm motion
   a) Storms move off boundary => favorable for discrete
   b) Storms stay on/move along boundary => favorable for linear
2) Orientation of deep layer shear vector relative to the boundary
   a) Shear vector off boundary => storm orients off-boundary => favorable for discrete
   b) Shear vector along boundary => storm orients along boundary => favorable for linear
3) Anvil level storm-relative winds
   a) Winds off boundary => Anvil debris less likely to “seed” neighboring storms along boundary => discrete
   b) Winds along boundary => Anvil debris more likely to “seed” neighboring storms along boundary => linear

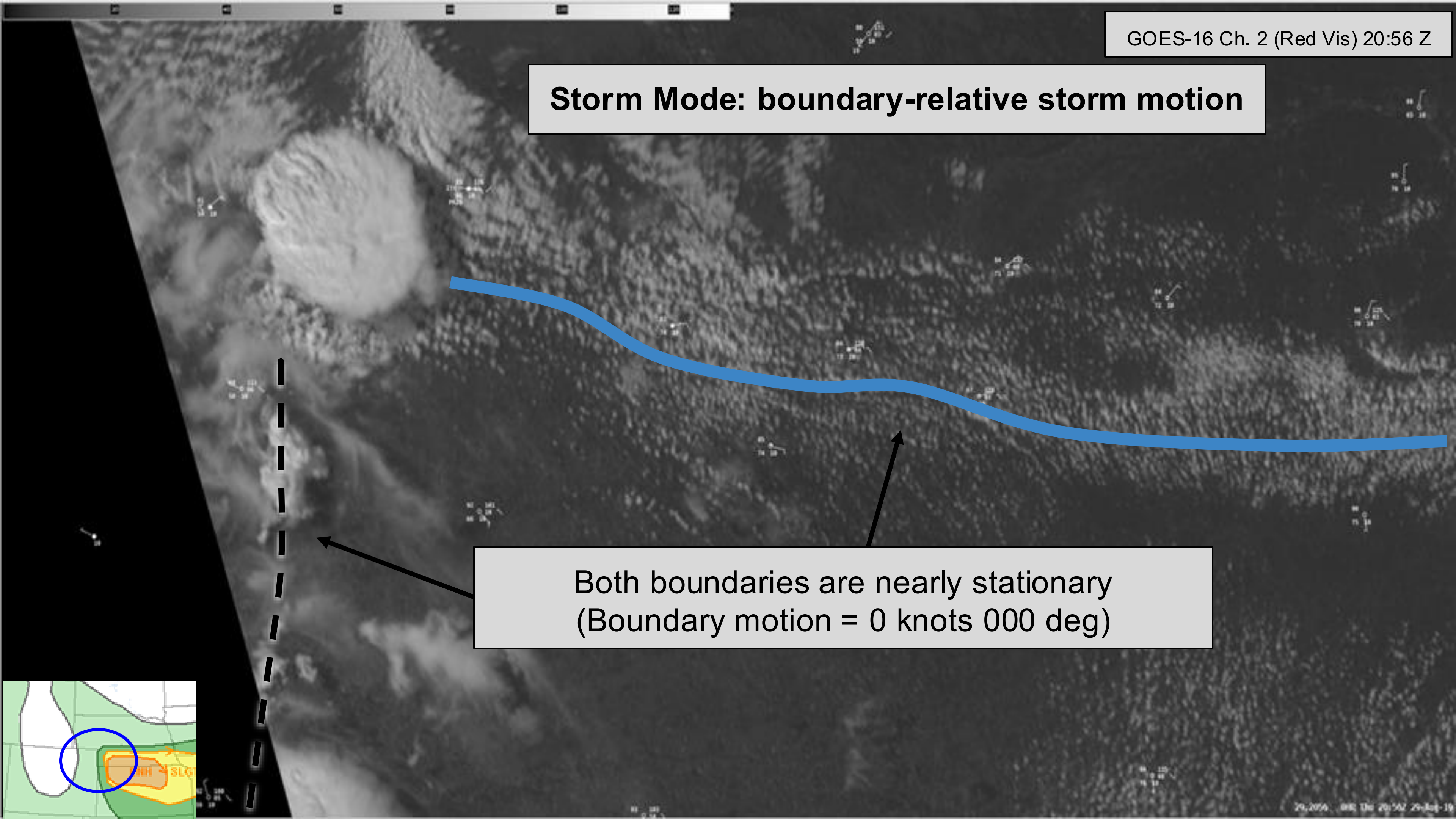
For details: Dial et al. 2010, Short-term Convective Mode Evolution along Synoptic Boundaries

Storm Mode In a nutshell

Storm mode is a function of:

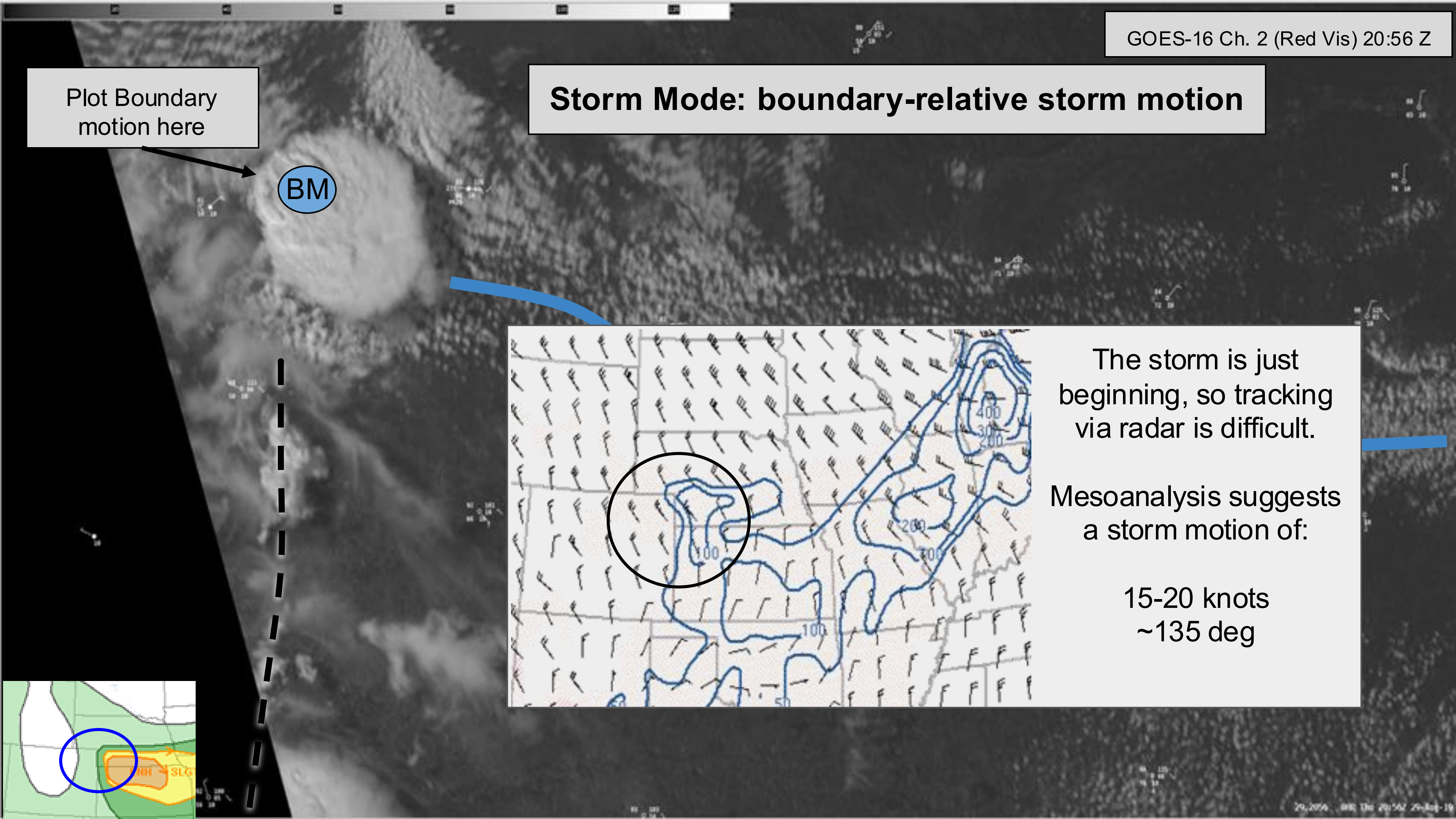
1) Boundary-relative storm motion
   a) Storms move off boundary => favorable for discrete
   b) Storms stay on/move along boundary => favorable for linear
2) Orientation of deep layer shear vector relative to the boundary
   a) Shear vector off boundary => storm orients off-boundary => favorable for discrete
   b) Shear vector along boundary => storm orients along boundary => favorable for linear
3) Anvil level storm-relative winds
   a) Winds off boundary => Anvil debris less likely to “seed” neighboring storms along boundary => discrete
   b) Winds along boundary => Anvil debris more likely to “seed” neighboring storms along boundary => linear
4) Strength of the forcing for ascent
   a) Weak forcing for ascent => fewer storms => favorable for discrete
   b) Strong forcing for ascent => more storms => favorable for linear

For details: Dial et al. 2010, Short-term Convective Mode Evolution along Synoptic Boundaries


GOES-16 Ch. 2 (Red Vis) 20:56 Z
Storm Mode: boundary-relative storm motion
Both boundaries are nearly stationary
(Boundary motion = 0 knots 000 deg)

Storm Mode: boundary-relative storm motion

GOES-16 Ch. 2 (Red Vis) 20:56 Z

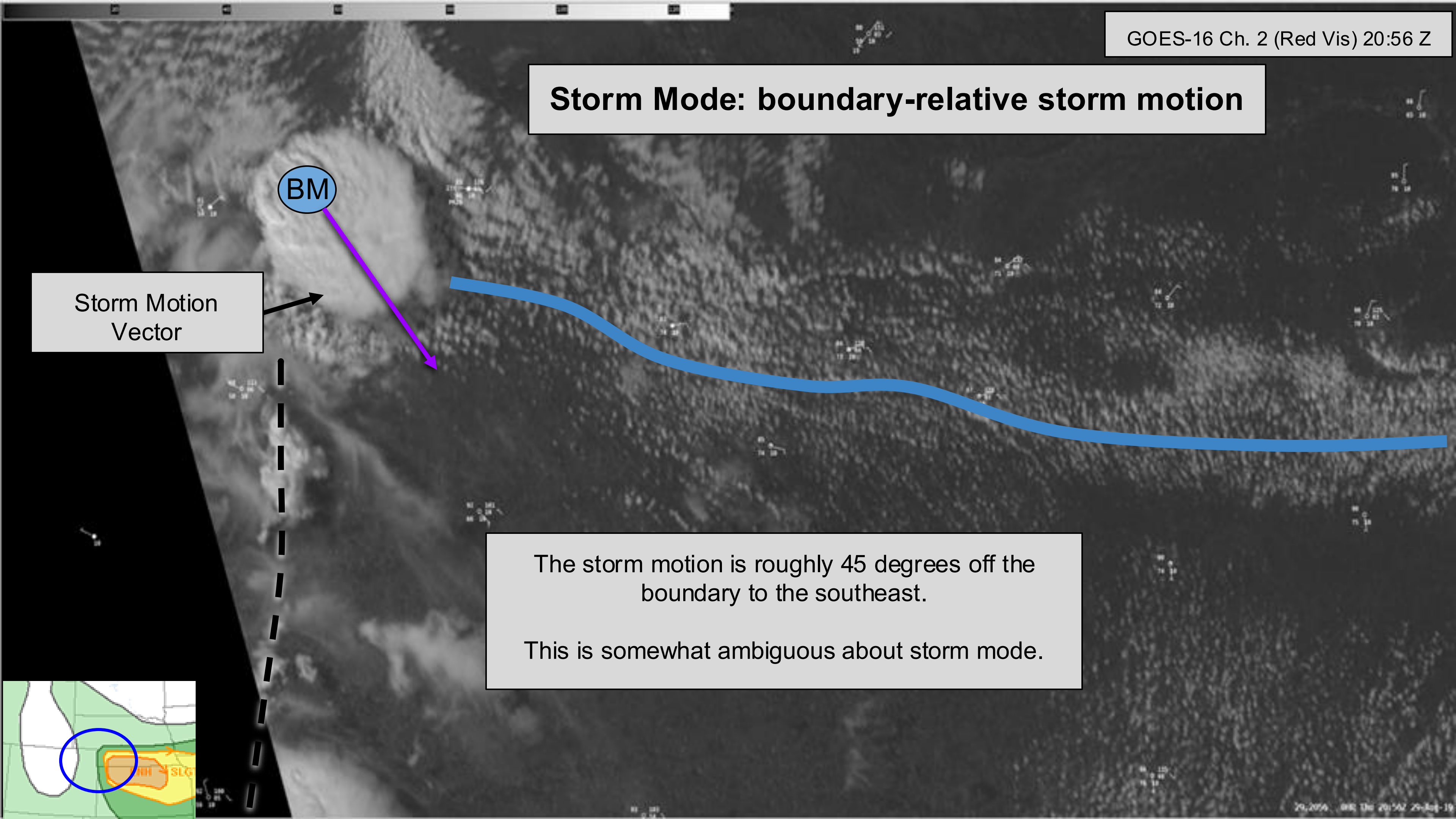


The storm is just beginning, so tracking via radar is difficult.

Mesoanalysis suggests a storm motion of:

15-20 knots
~135 deg

Storm Mode: boundary-relative storm motion



The storm motion is roughly 45 degrees off the boundary to the southeast.

This is somewhat ambiguous about storm mode.

Storm Mode In a nutshell

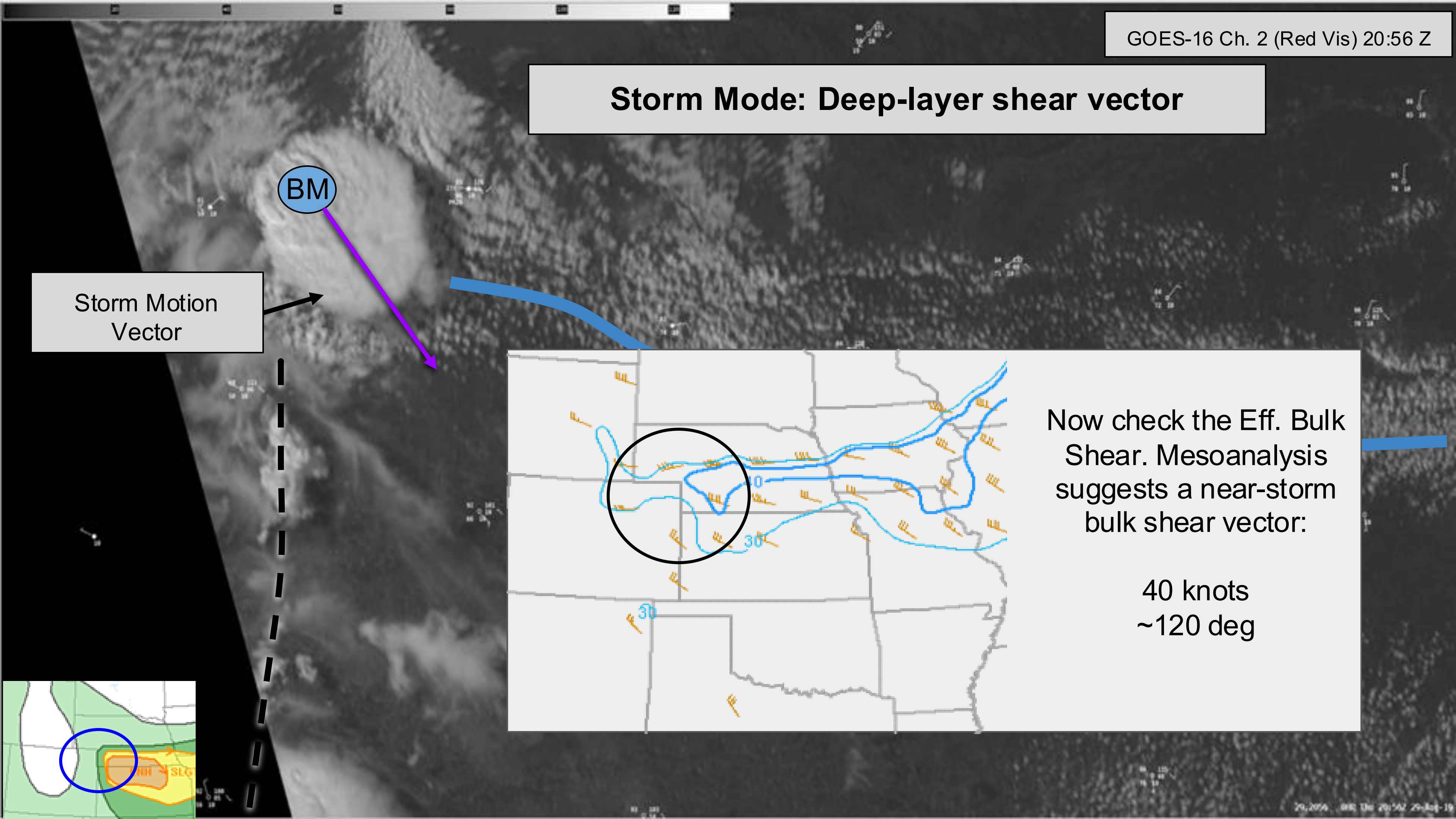
Storm mode is a function of:

1) Boundary-relative storm motion
   a) Storms move off boundary => favorable for discrete
   b) Storms stay on/move along boundary => favorable for linear

?

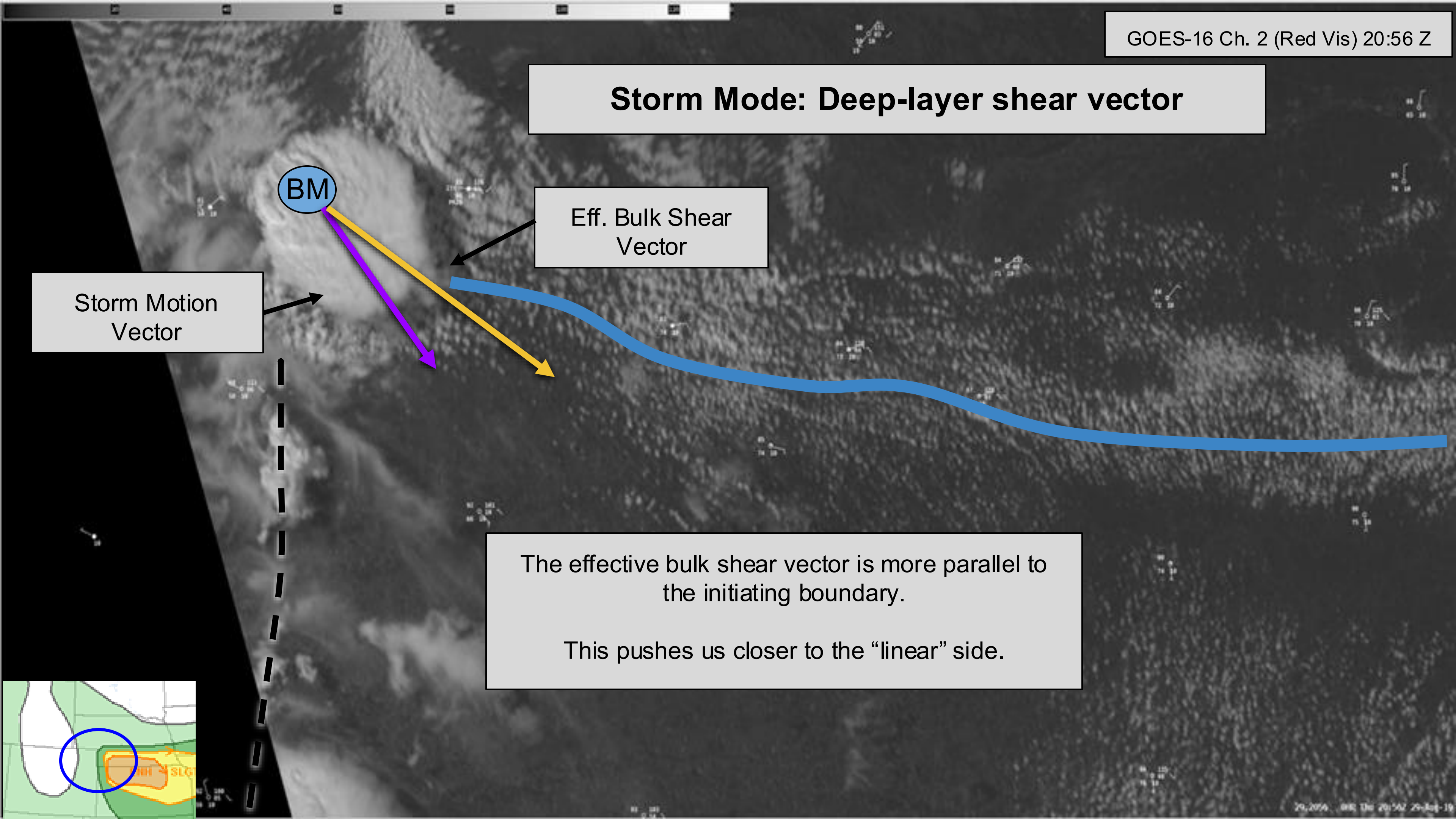
2) Orientation of deep layer shear vector relative to the boundary
   a) Shear vector off boundary => storm orients off-boundary => favorable for discrete
   b) Shear vector along boundary => storm orients along boundary => favorable for linear
3) Anvil level storm-relative winds
   a) Winds off boundary => Anvil debris less likely to “seed” neighboring storms along boundary => discrete
   b) Winds along boundary => Anvil debris more likely to “seed” neighboring storms along boundary => linear
4) Strength of the forcing for ascent
   a) Weak forcing for ascent => fewer storms => favorable for discrete
   b) Strong forcing for ascent => more storms => favorable for linear

For details: Dial et al. 2010, Short-term Convective Mode Evolution along Synoptic Boundaries


GOES-16 Ch. 2 (Red Vis) 20:56 Z
Storm Mode: Deep-layer shear vector
BM
Storm Motion Vector
Now check the Eff. Bulk Shear. Mesoanalysis suggests a near-storm bulk shear vector:
40 knots
~120 deg
40
30
30

Storm Mode: Deep-layer shear vector

GOES-16 Ch. 2 (Red Vis) 20:56 Z



The effective bulk shear vector is more parallel to the initiating boundary.

This pushes us closer to the “linear” side.

Storm Mode In a nutshell

Storm mode is a function of:

1) Boundary-relative storm motion
   a) Storms move off boundary => favorable for discrete
   b) Storms stay on/move along boundary => favorable for linear

?

2) Orientation of deep layer shear vector relative to the boundary
   a) Shear vector off boundary => storm orients off-boundary => favorable for discrete
   b) Shear vector along boundary => storm orients along boundary => favorable for linear
3) Anvil level storm-relative winds
   a) Winds off boundary => Anvil debris less likely to “seed” neighboring storms along boundary => discrete
   b) Winds along boundary => Anvil debris more likely to “seed” neighboring storms along boundary => linear
4) Strength of the forcing for ascent
   a) Weak forcing for ascent => fewer storms => favorable for discrete
   b) Strong forcing for ascent => more storms => favorable for linear

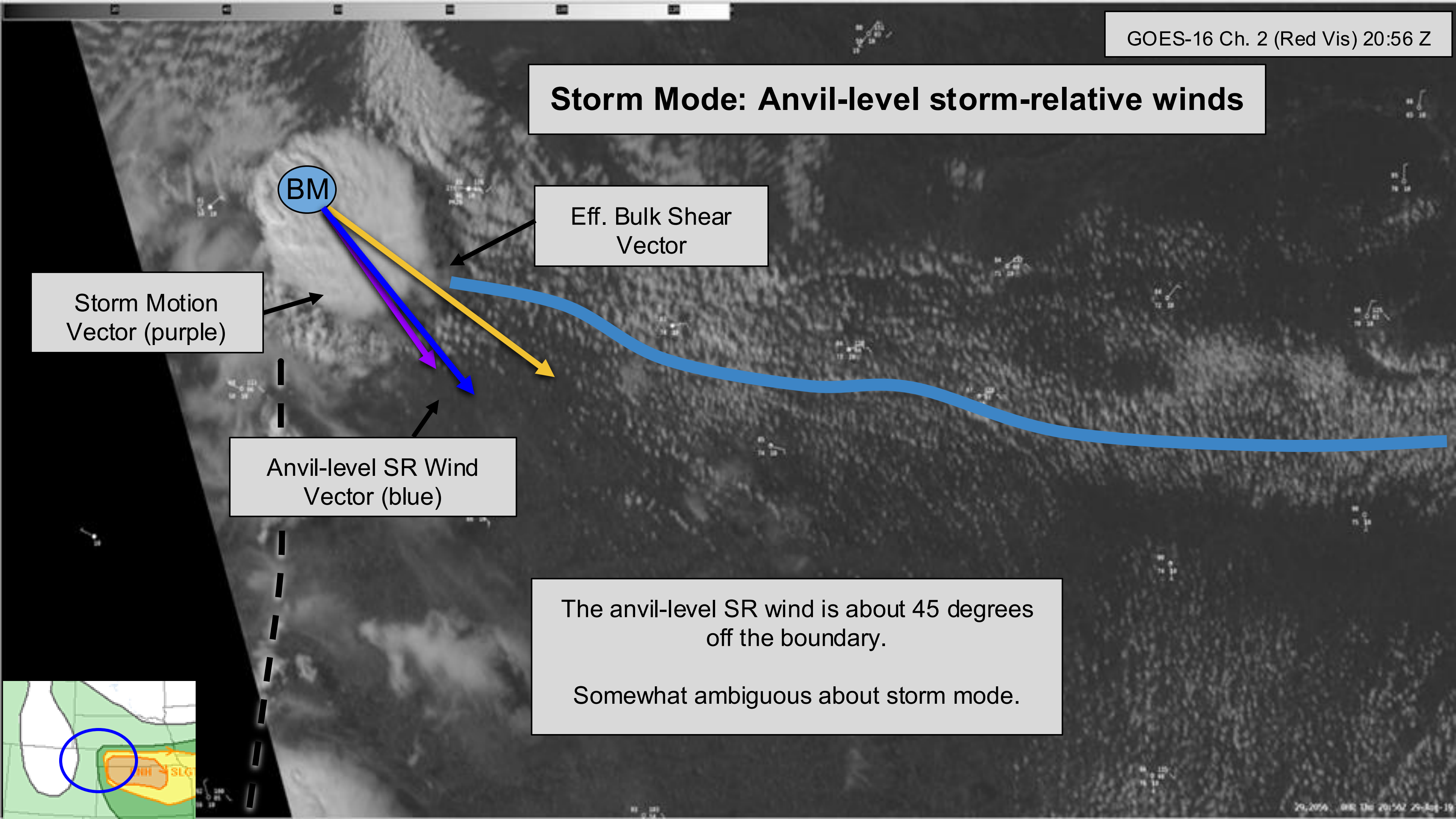
For details: Dial et al. 2010, Short-term Convective Mode Evolution along Synoptic Boundaries

GOES-16 Ch. 2 (Red Vis) 20:56 Z

Storm Mode: Anvil-level storm-relative winds

Use sounding to get an approximation of the anvil-level SR winds:

~25 knots
~ 135 deg


GOES-16 Ch. 2 (Red Vis) 20:56 Z
Storm Mode: Anvil-level storm-relative winds
BM
Eff. Bulk Shear Vector
Storm Motion Vector (purple)
Anvil-level SR Wind Vector (blue)
The anvil-level SR wind is about 45 degrees off the boundary.
Somewhat ambiguous about storm mode.

Storm Mode In a nutshell

Storm mode is a function of:

1) Boundary-relative storm motion
   a) Storms move off boundary => favorable for discrete
   b) Storms stay on/move along boundary => favorable for linear

?

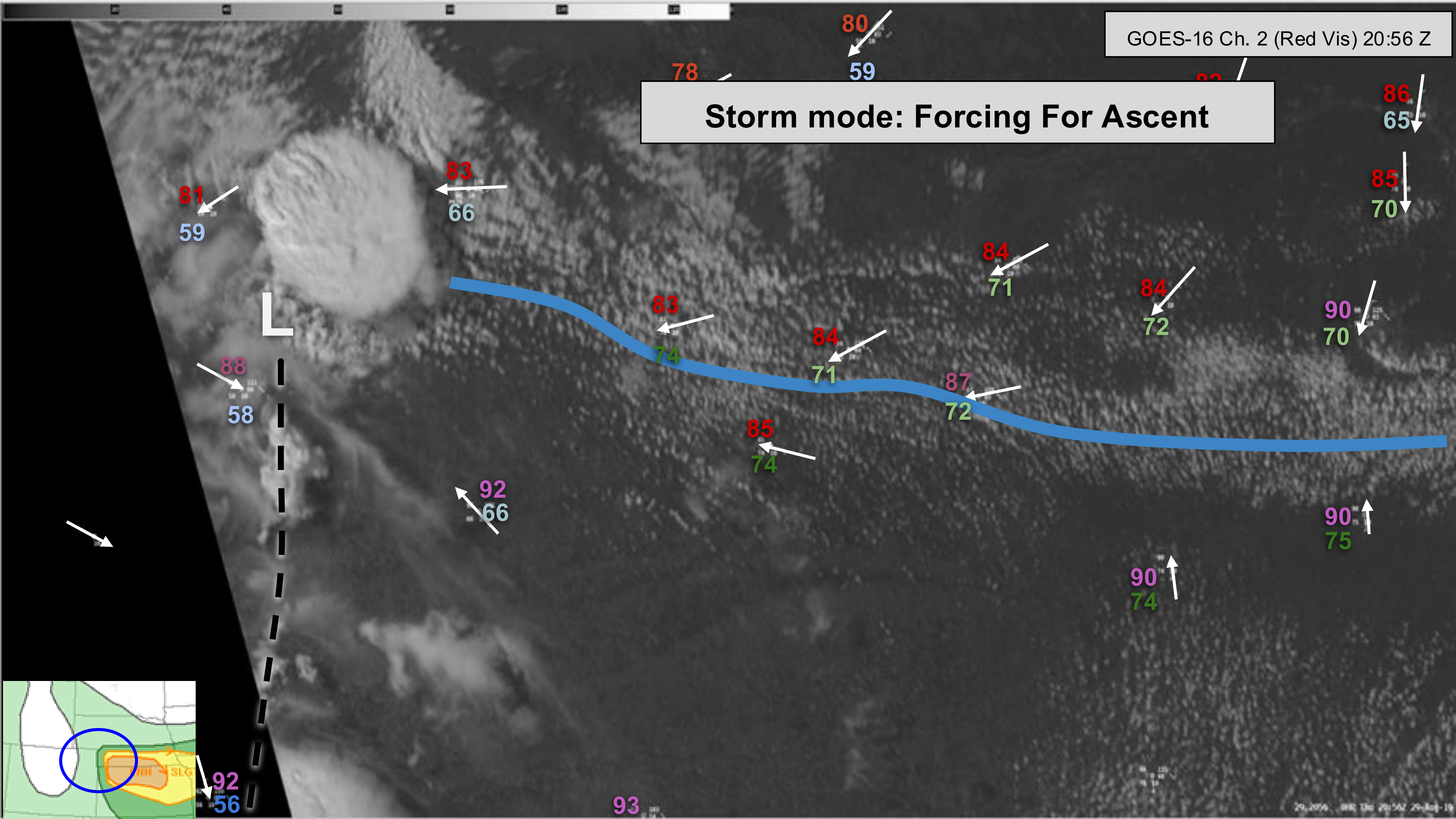
2) Orientation of deep layer shear vector relative to the boundary
   a) Shear vector off boundary => storm orients off-boundary => favorable for discrete
   b) Shear vector along boundary => storm orients along boundary => favorable for linear
3) Anvil level storm-relative winds
   a) Winds off boundary => Anvil debris less likely to “seed” neighboring storms along boundary => discrete
   b) Winds along boundary => Anvil debris more likely to “seed” neighboring storms along boundary => linear

?

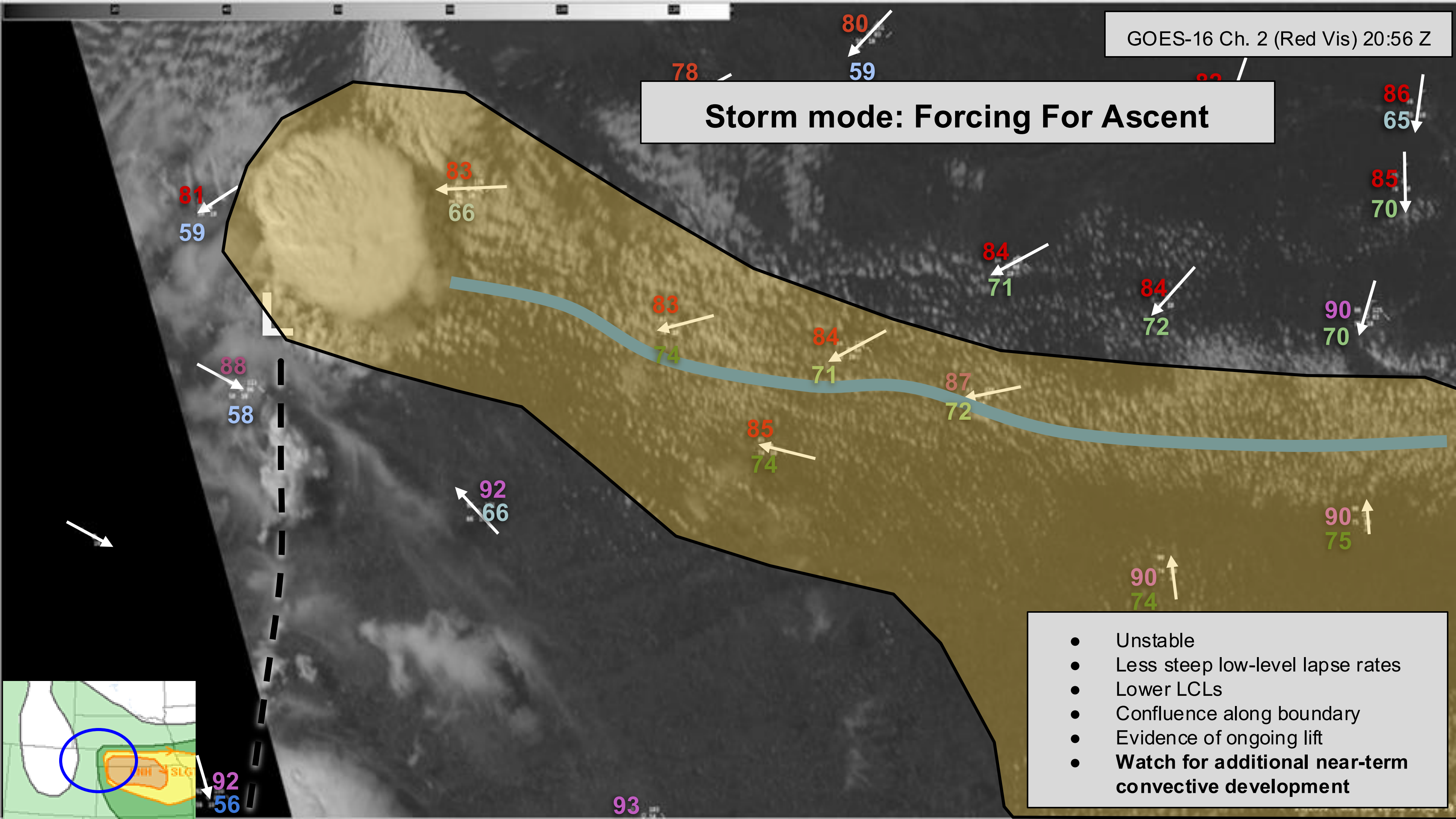
4) Strength of the forcing for ascent
   a) Weak forcing for ascent => fewer storms => favorable for discrete
   b) Strong forcing for ascent => more storms => favorable for linear

For details: Dial et al. 2010, Short-term Convective Mode Evolution along Synoptic Boundaries

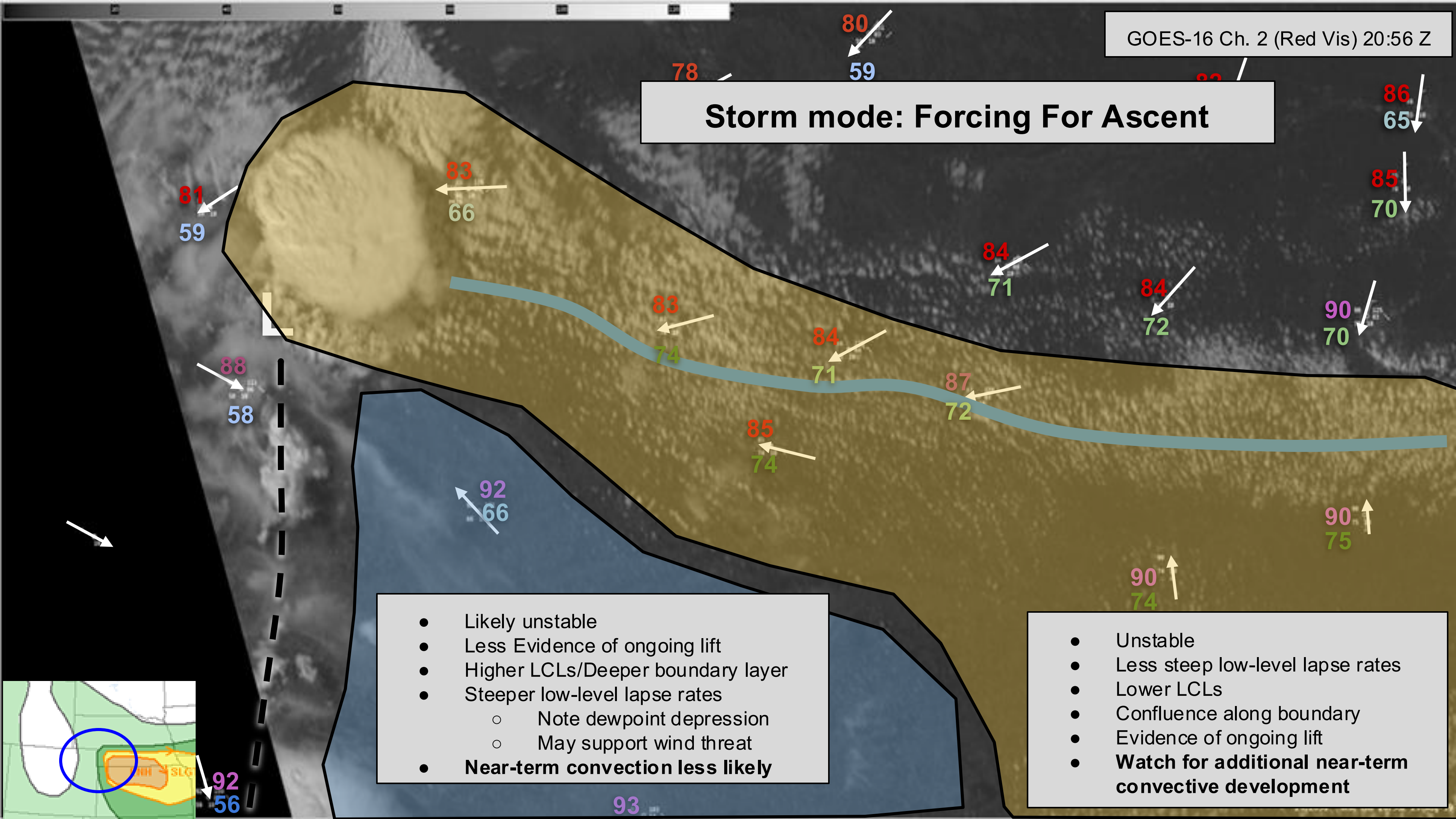
Storm mode: Forcing For Ascent

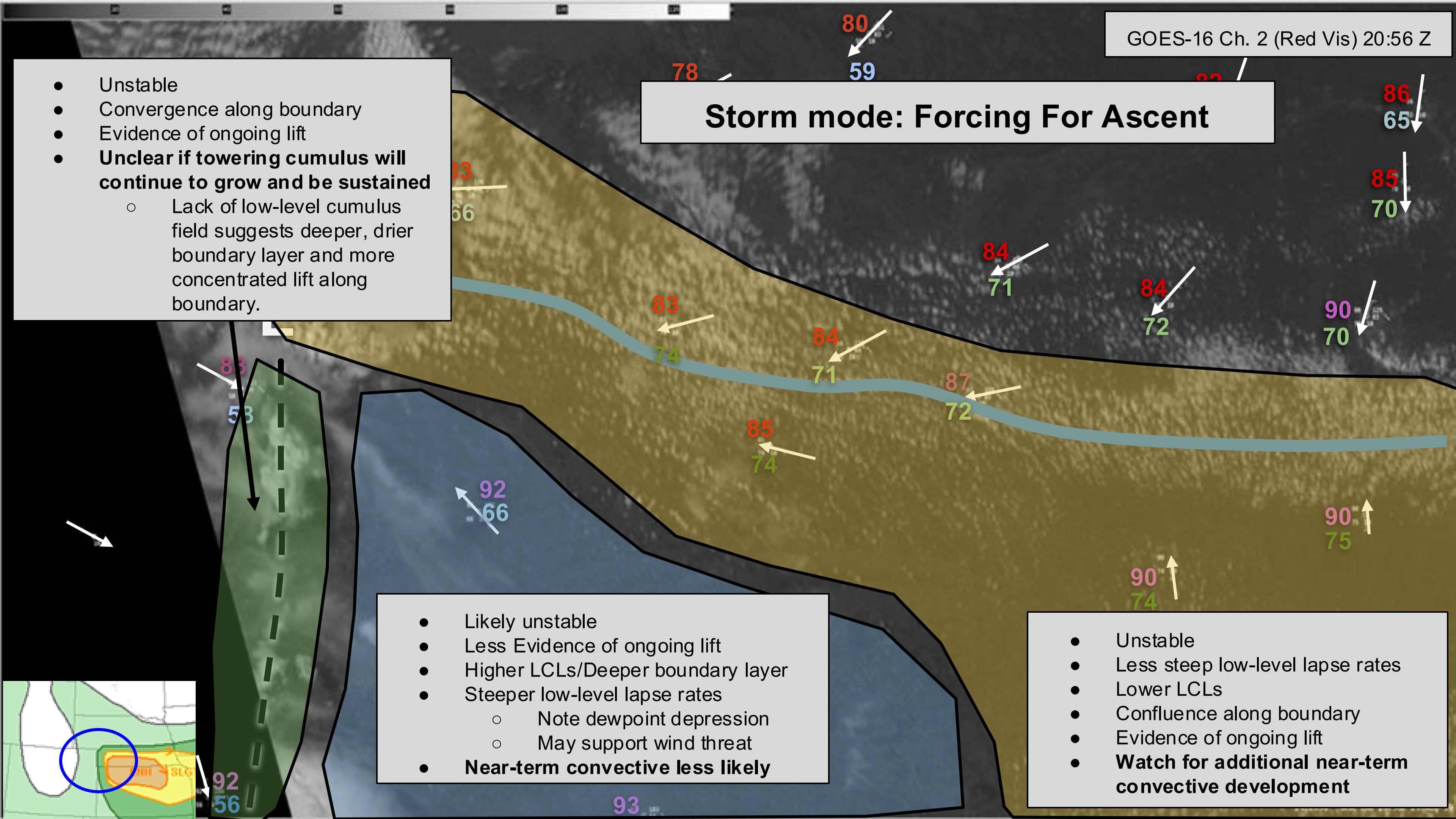


Storm mode: Forcing For Ascent

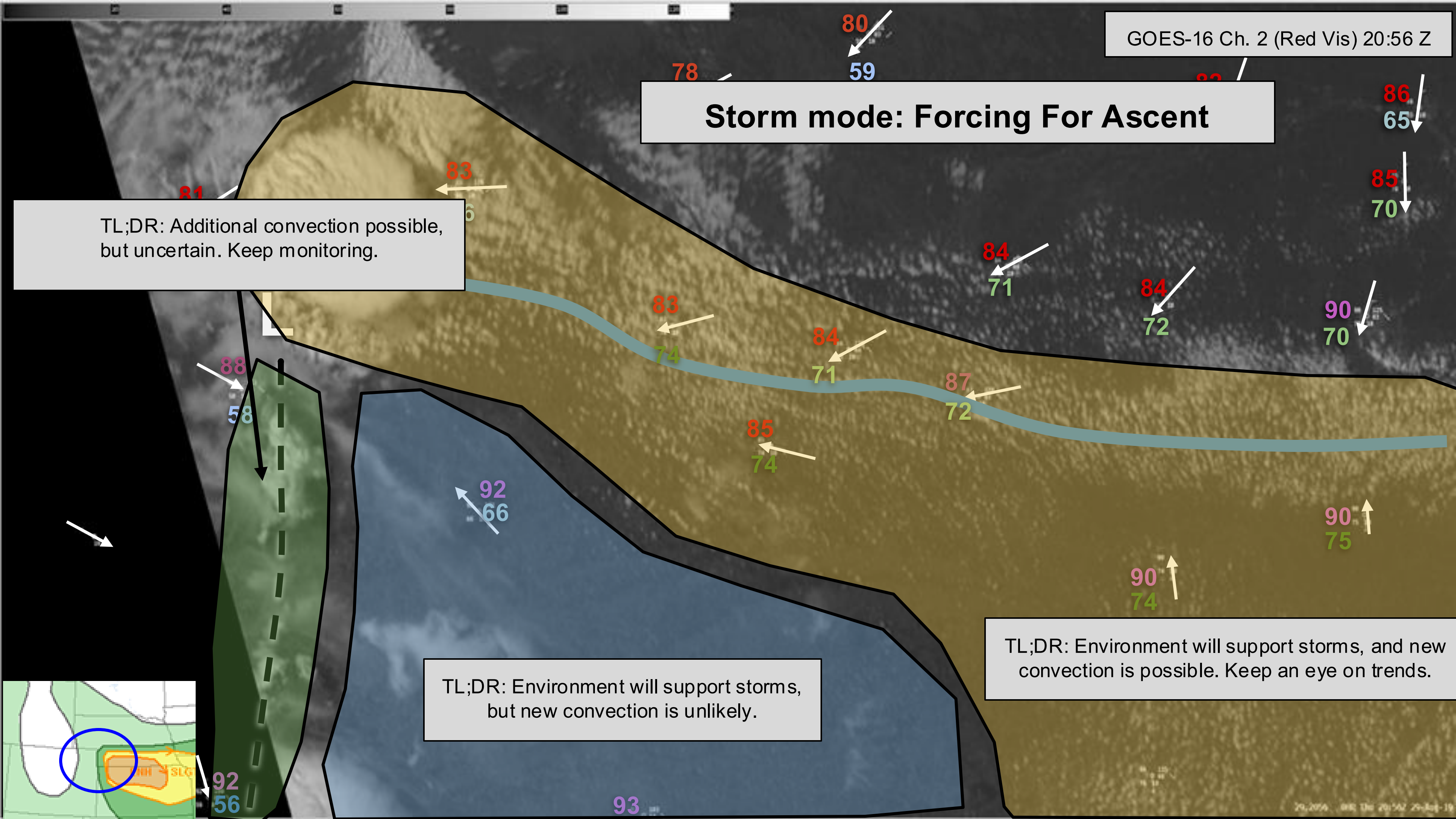


- Unstable
- Less steep low-level lapse rates
- Lower LCLs
- Confluence along boundary
- Evidence of ongoing lift
- **Watch for additional near-term convective development**


GOES-16 Ch. 2 (Red Vis) 20:56 Z
Storm mode: Forcing For Ascent
L
Likely unstable
Less Evidence of ongoing lift
Higher LCLs/Deeper boundary layer
Steeper low-level lapse rates
Note dewpoint depression
May support wind threat
Near-term convection less likely
Unstable
Less steep low-level lapse rates
Lower LCLs
Confluence along boundary
Evidence of ongoing lift
Watch for additional near-term convective development



GOES-16 Ch. 2 (Red Vis) 20:56 Z
Storm mode: Forcing For Ascent
Unstable
Convergence along boundary
Evidence of ongoing lift
Unclear if towering cumulus will continue to grow and be sustained
Lack of low-level cumulus field suggests deeper, drier boundary layer and more concentrated lift along boundary.
Likely unstable
Less Evidence of ongoing lift
Higher LCLs/Deeper boundary layer
Steeper low-level lapse rates
Note dewpoint depression
May support wind threat
Near-term convective less likely
Unstable
Less steep low-level lapse rates
Lower LCLs
Confluence along boundary
Evidence of ongoing lift
Watch for additional near-term convective development


GOES-16 Ch. 2 (Red Vis) 20:56 Z
Storm mode: Forcing For Ascent
TL;DR: Additional convection possible, but uncertain. Keep monitoring.
TL;DR: Environment will support storms, but new convection is unlikely.
TL;DR: Environment will support storms, and new convection is possible. Keep an eye on trends.
80
59
78
86
65
85
70
83
84
71
84
72
90
70
83
74
84
71
87
72
85
74
88
58
92
66
90
75
90
74
92
56
93

Storm Mode In a nutshell

Storm mode is a function of:

1) Boundary-relative storm motion
   a) Storms move off boundary => favorable for discrete
   b) Storms stay on/move along boundary => favorable for linear

?

2) Orientation of deep layer shear vector relative to the boundary
   a) Shear vector off boundary => storm orients off-boundary => favorable for discrete
   b) Shear vector along boundary => storm orients along boundary => favorable for linear
3) Anvil level storm-relative winds
   a) Winds off boundary => Anvil debris less likely to "seed" neighboring storms along boundary => discrete
   b) Winds along boundary => Anvil debris more likely to "seed" neighboring storms along boundary => linear

?

4) Strength of the forcing for ascent
   a) Weak forcing for ascent => fewer storms => favorable for discrete
   b) Strong forcing for ascent => more storms => favorable for linear

For details: Dial et al. 2010, Short-term Convective Mode Evolution along Synoptic Boundaries

Storm Mode In a nutshell

1) Bou
   a)
   b)
2) Orie
   a)
   b)
3) Anvi
   a)
   b)
4) Stre
   a)
   b)

discrete
=> linear
?

End Result?

Inconclusive!

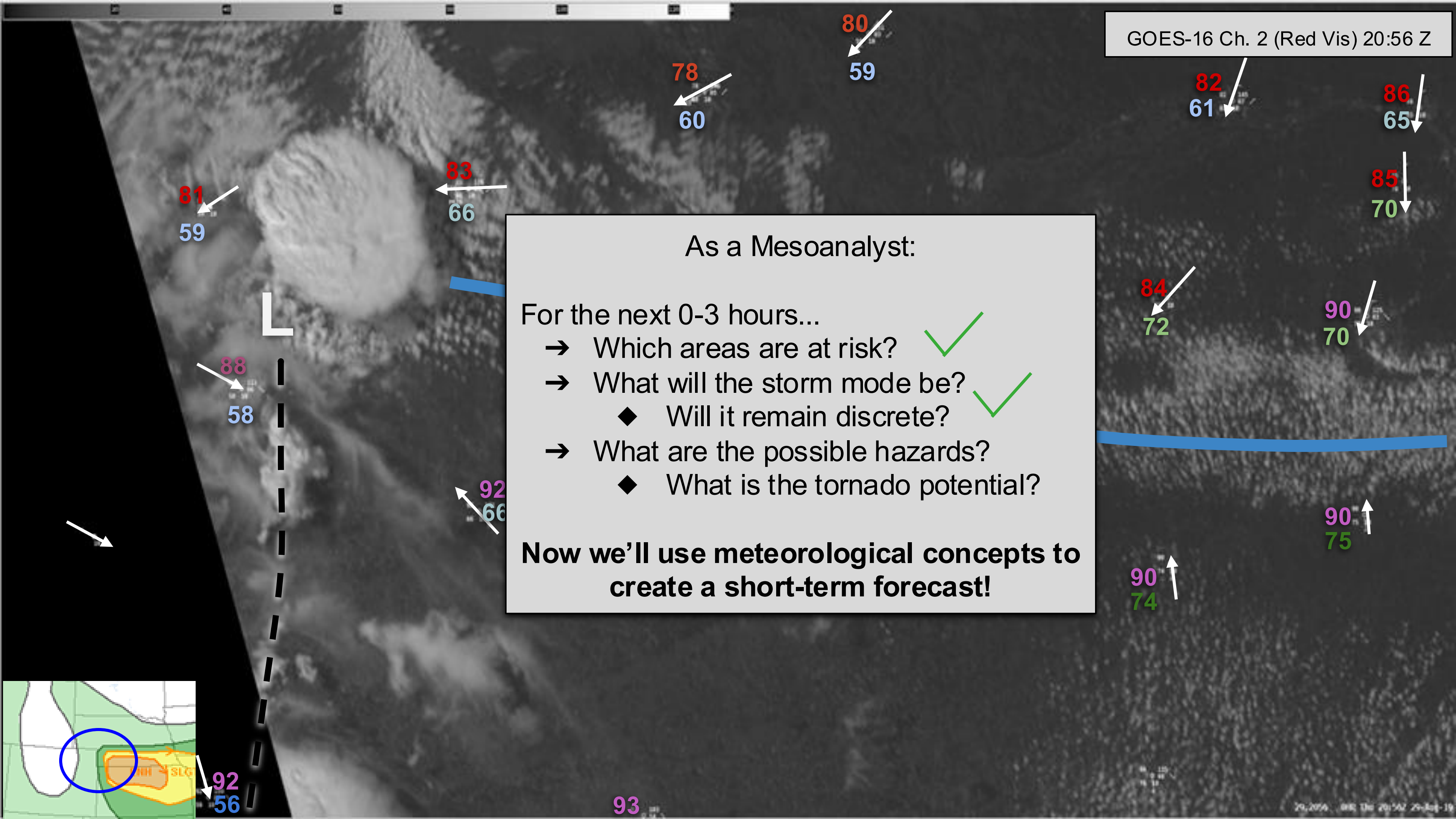
So what to do?
This is where you need to think in terms of a range of possible outcomes.

Best Case Scenario: The ongoing storm is the only storm that initiates, severe threat is limited spatially.

Most Likely Scenario: The ongoing storm remains discrete for the next 1-2 hours before additional storms develop along the boundaries and the cluster grows upscale. Severe threat begins small, then expands with time.

Worst Case Scenario: Rapid upscale growth with a widespread potential for severe weather.

For details: Dial et al. 2010, Short-term Convective Mode Evolution along Synoptic Boundaries

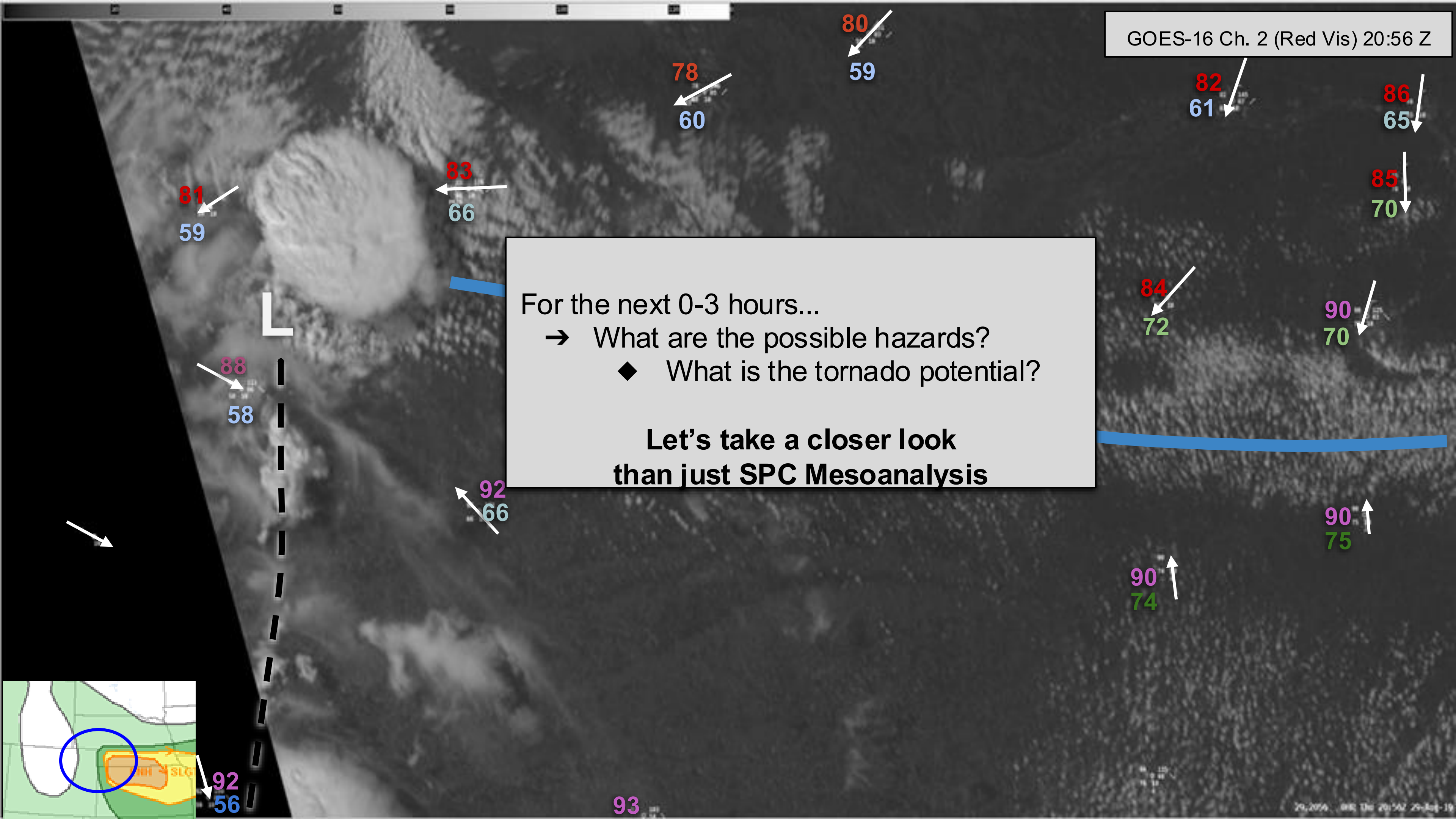


As a Mesoanalyst:

For the next 0-3 hours...

- ➔ Which areas are at risk? ✓
- ➔ What will the storm mode be? ✓
  - ◆ Will it remain discrete?
- ➔ What are the possible hazards?
  - ◆ What is the tornado potential?

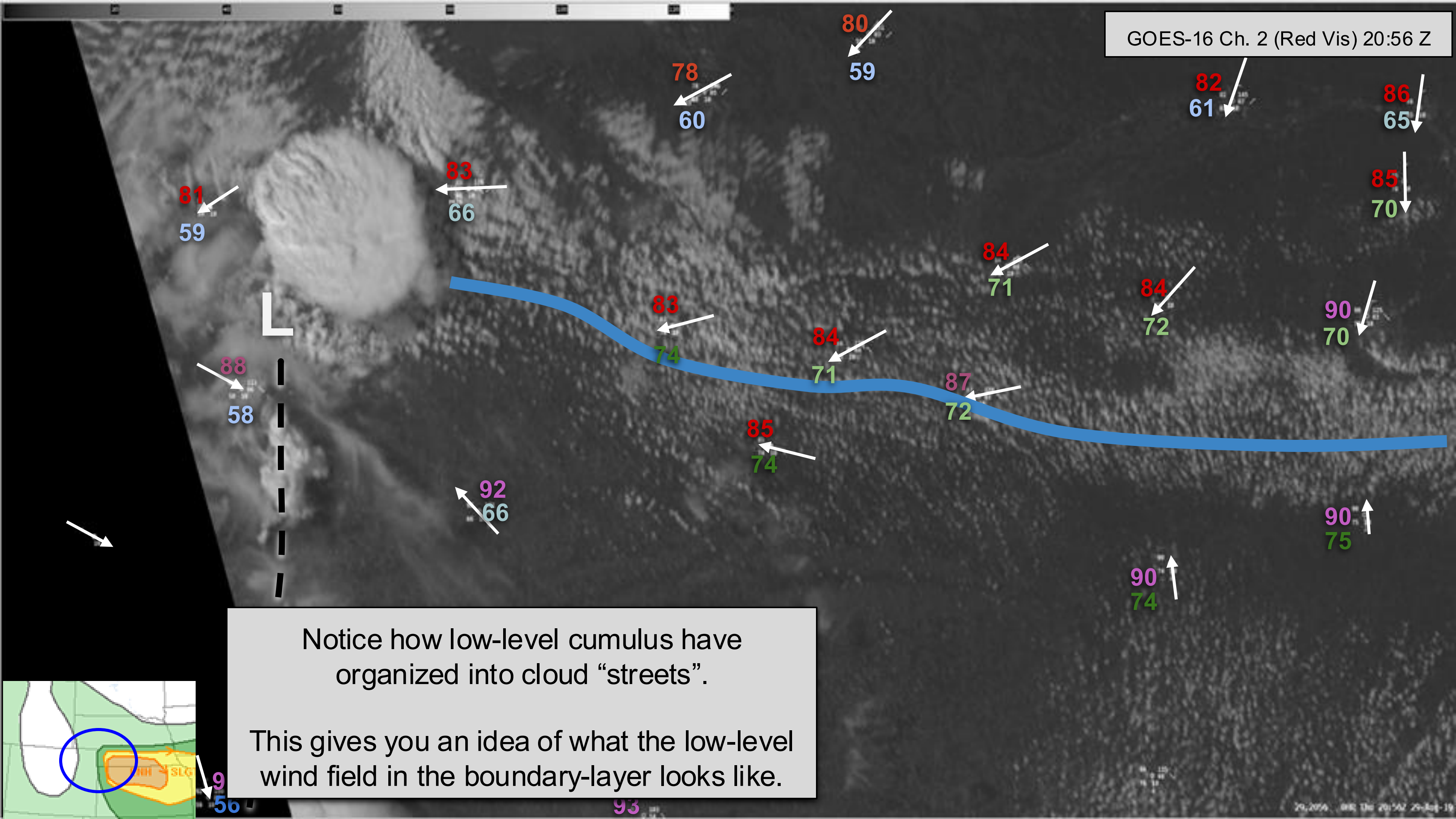
Now we'll use meteorological concepts to create a short-term forecast!

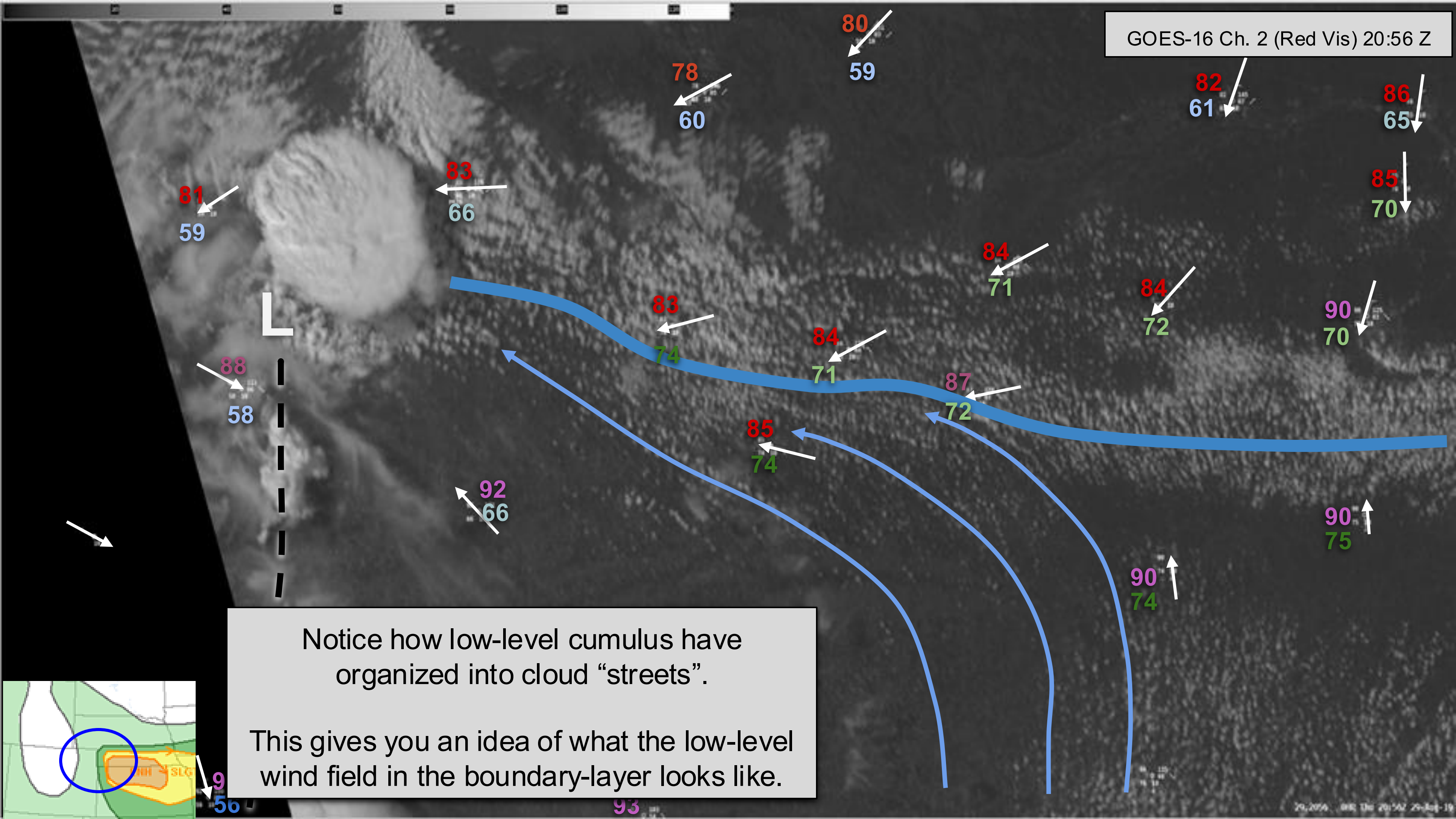


For the next 0-3 hours...

- ➔ What are the possible hazards?
  - ◆ What is the tornado potential?

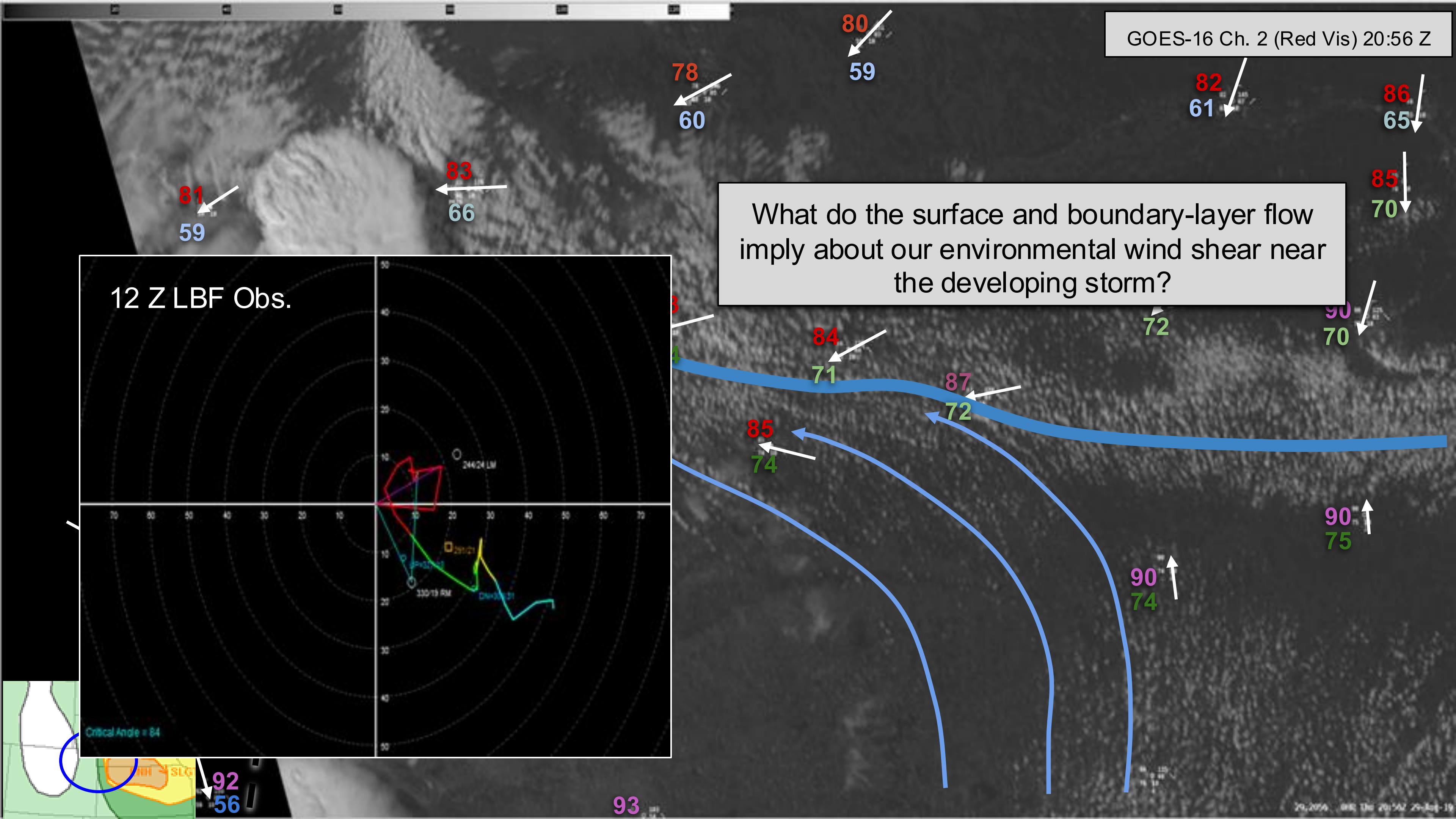
Let's take a closer look than just SPC Mesoanalysis

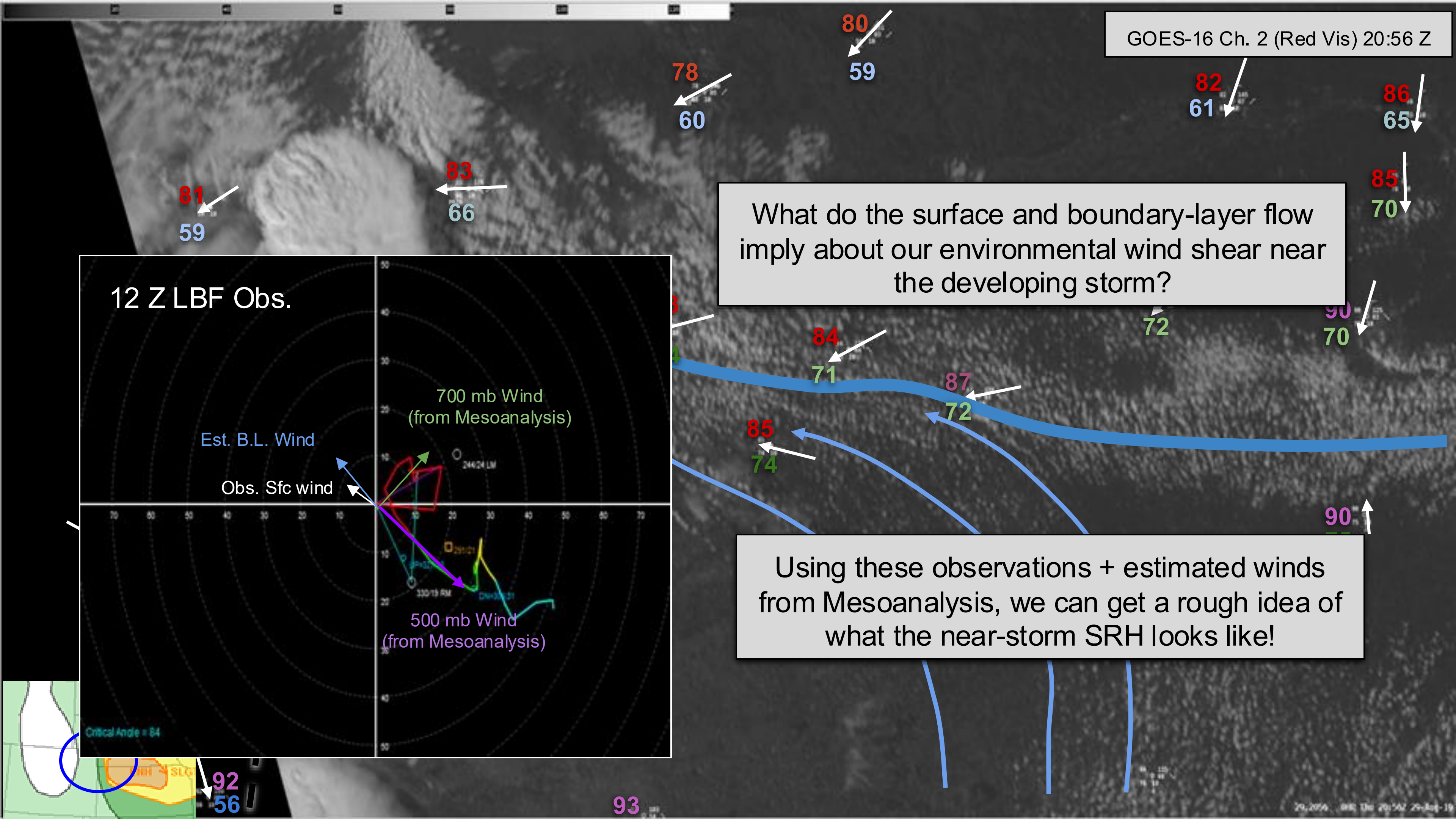

GOES-16 Ch. 2 (Red Vis) 20:56 Z
L
Notice how low-level cumulus have organized into cloud “streets”.
This gives you an idea of what the low-level wind field in the boundary-layer looks like.



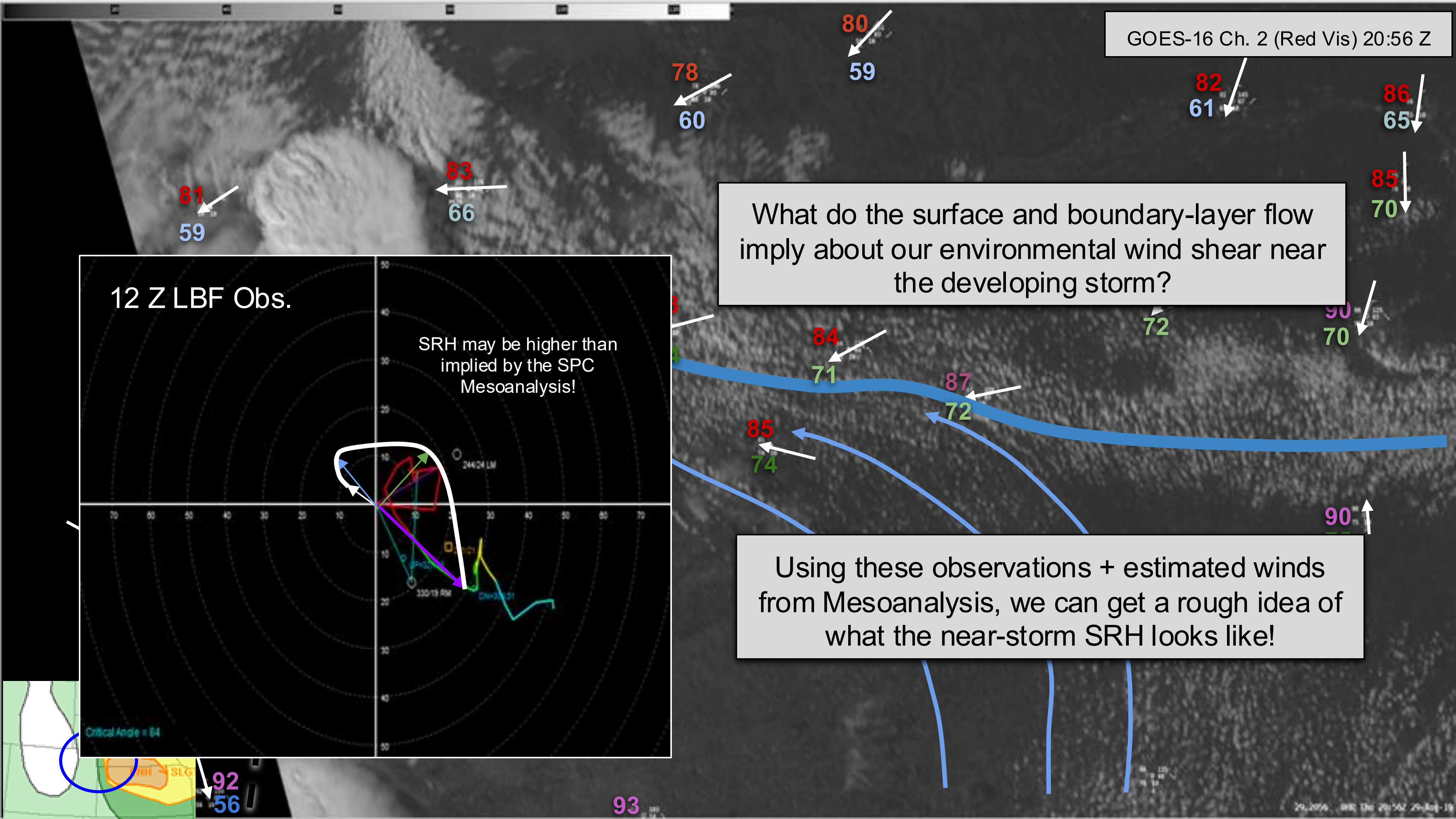
Notice how low-level cumulus have organized into cloud “streets”.

This gives you an idea of what the low-level wind field in the boundary-layer looks like.


GOES-16 Ch. 2 (Red Vis) 20:56 Z
What do the surface and boundary-layer flow imply about our environmental wind shear near the developing storm?
12 Z LBF Obs.
80
59
78
60
82
61
86
65
83
66
81
59
85
70
84
71
87
72
72
90
70
85
74
90
75
90
74
92
56
93
244/24 LM
330/19 RM
Critical Angle = 84



GOES-16 Ch. 2 (Red Vis) 20:56 Z
What do the surface and boundary-layer flow imply about our environmental wind shear near the developing storm?
Using these observations + estimated winds from Mesoanalysis, we can get a rough idea of what the near-storm SRH looks like!
12 Z LBF Obs.
700 mb Wind
(from Mesoanalysis)
Est. B.L. Wind
Obs. Sfc wind
500 mb Wind
(from Mesoanalysis)
Critical Angle = 84
80
59
78
60
82
61
86
65
83
66
81
59
85
70
90
70
72
84
71
87
72
85
74
90
92
56
93


GOES-16 Ch. 2 (Red Vis) 20:56 Z
What do the surface and boundary-layer flow imply about our environmental wind shear near the developing storm?
12 Z LBF Obs.
SRH may be higher than implied by the SPC Mesoanalysis!
Using these observations + estimated winds from Mesoanalysis, we can get a rough idea of what the near-storm SRH looks like!

When poll is active, respond at **pollev.com/andrewmoore925**

Text **ANDREWMOORE925** to **22333** once to join

How would you rate the tornado threat for our area of concern?

A: Low (10-30%)

B: Medium (40-60%)

C: High (70-90%)

D: Very High (>90%)

Powered by Poll Everywhere

Tornado threat so far:

Parameter	**Value**	**Subjective Ranking***
0-1 km SRH	Near 0	Low
0-3 km SRH	100-200 m2/s2	Medium
ESRH	Near 100 m2/s2	Low
STP	0-1	Low-Medium

These values are likely higher than previously anticipated!

Is the 2% tornado risk still appropriate?

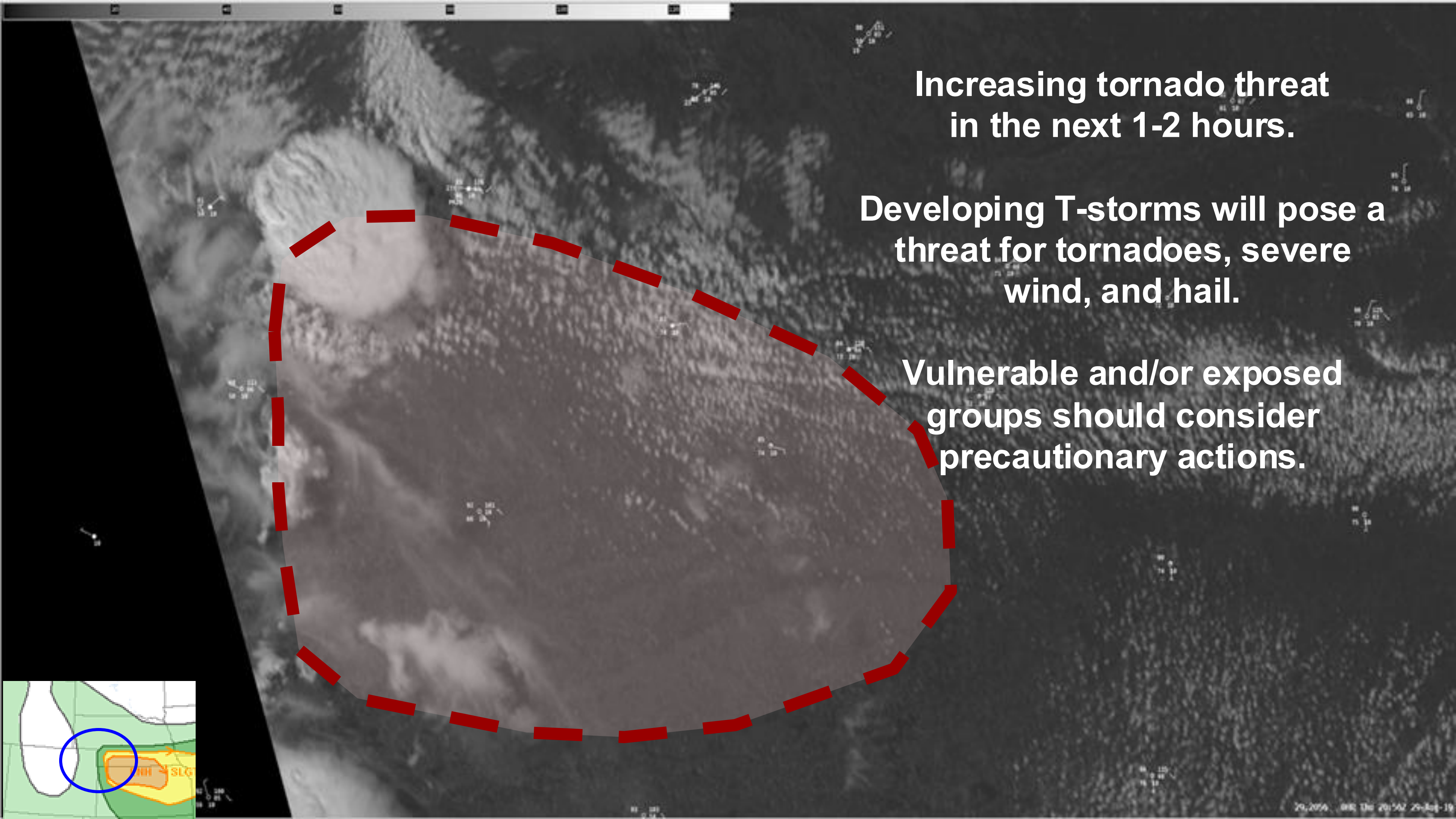
*The subjective ranking is largely based on the parameter’s tornado climatology. This is available on the SPC Mesoanalysis website.

Tornado threat so far:

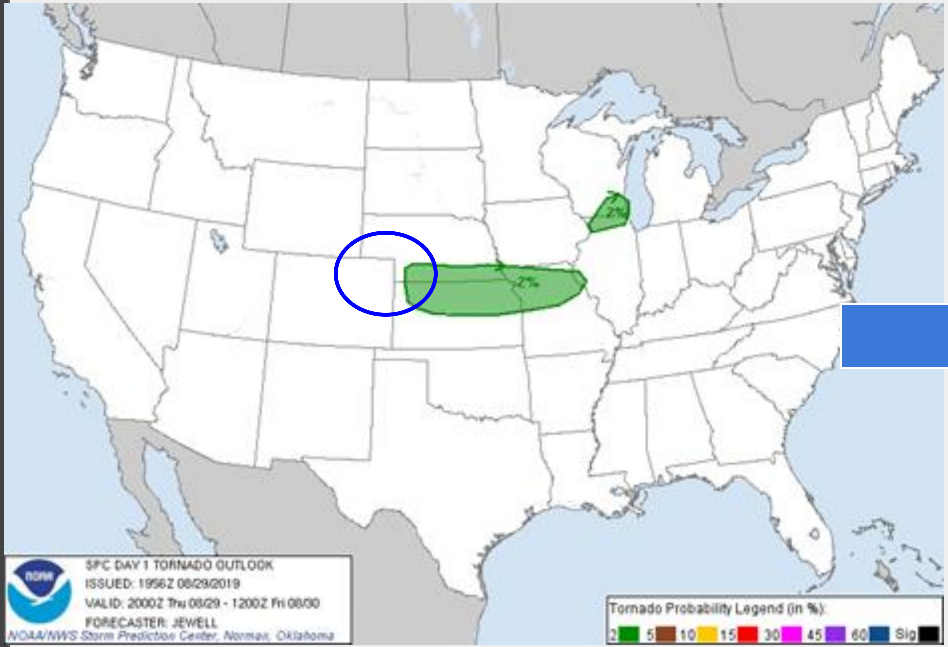
Parameter	**Value**	**Subjective Ranking***
0-1 km SRH	Near 0	Low
0-3 km SRH	100-200 m2/s2	Medium
ESRH	Near 100 m2/s2	Low
STP	0-1	Low-Medium

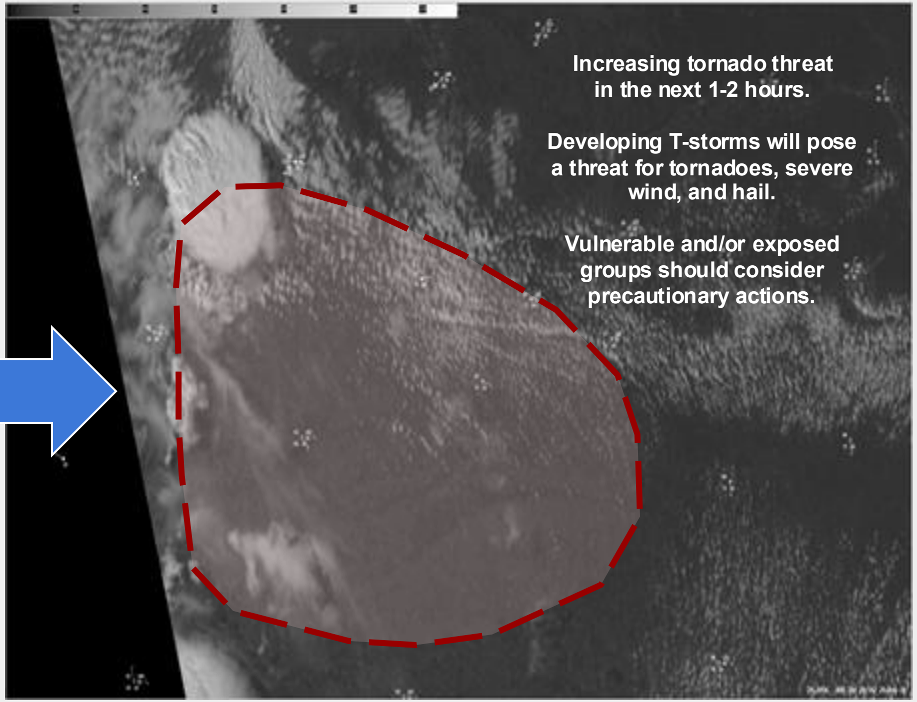
This is valuable information that you can communicate to the radar operator, partners, public, etc...

*The subjective ranking is largely based on the parameter’s tornado climatology. This is available on the SPC Mesoanalysis website.

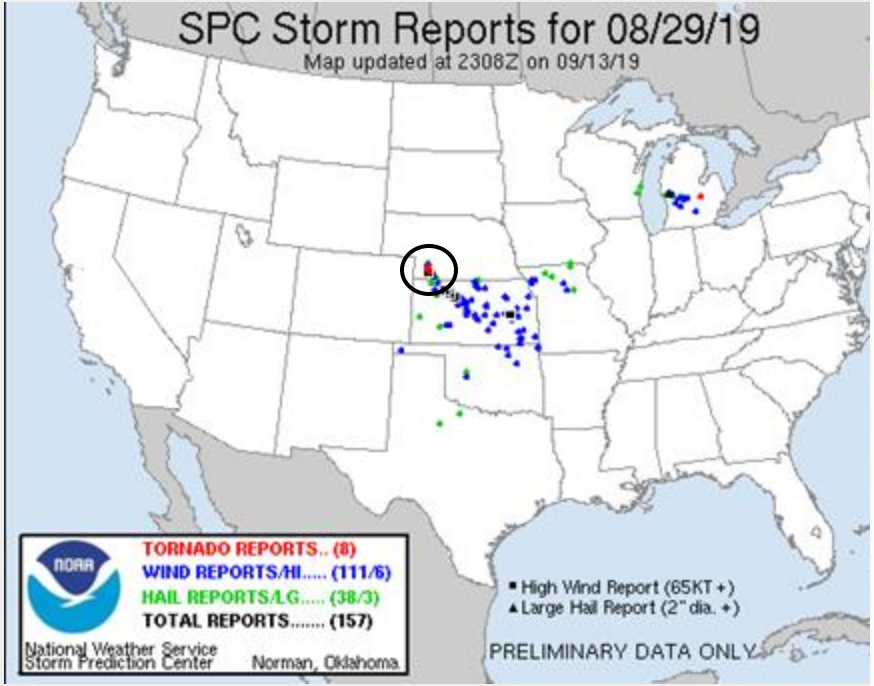

Increasing tornado threat
in the next 1-2 hours.
Developing T-storms will pose a
threat for tornadoes, severe
wind, and hail.
Vulnerable and/or exposed
groups should consider
precautionary actions.

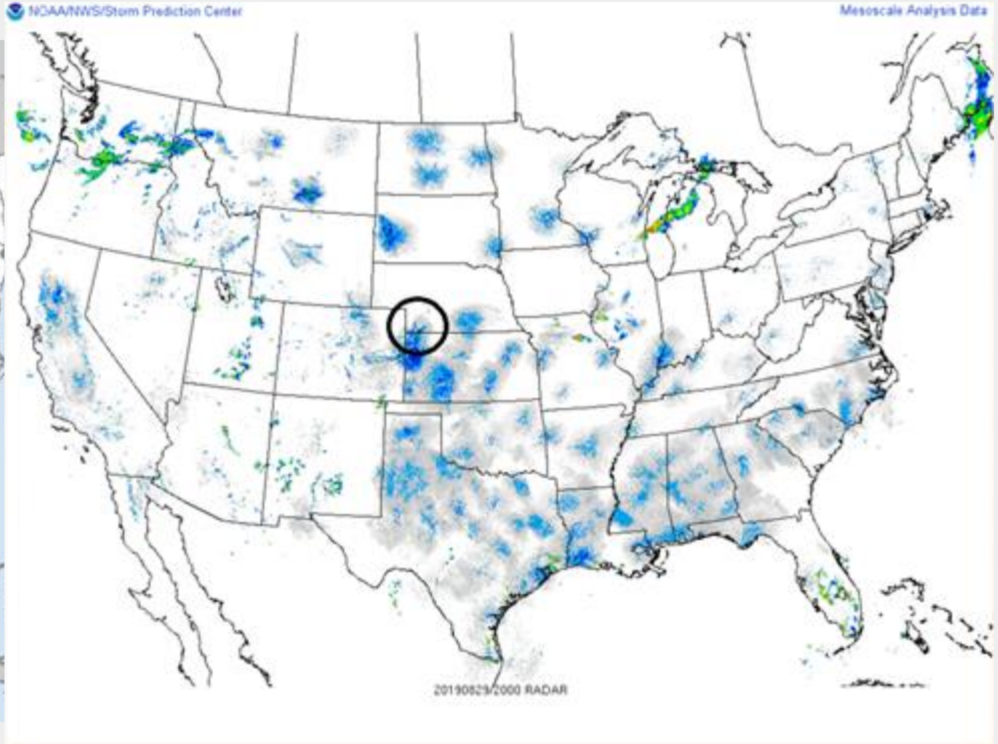
We used Mesoanalysis to add local value to the forecast!





We used Mesoanalysis to add local value to the forecast!

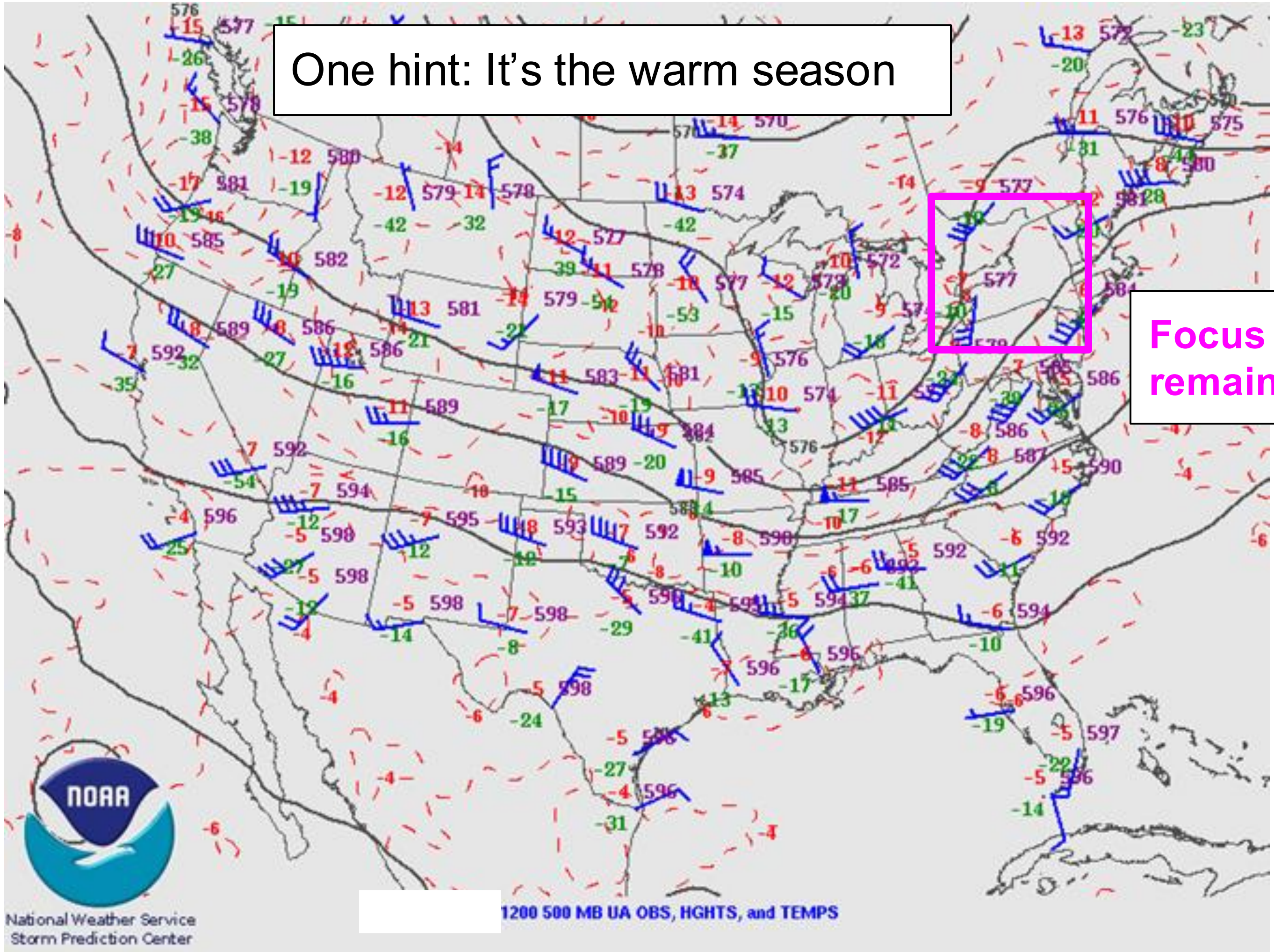




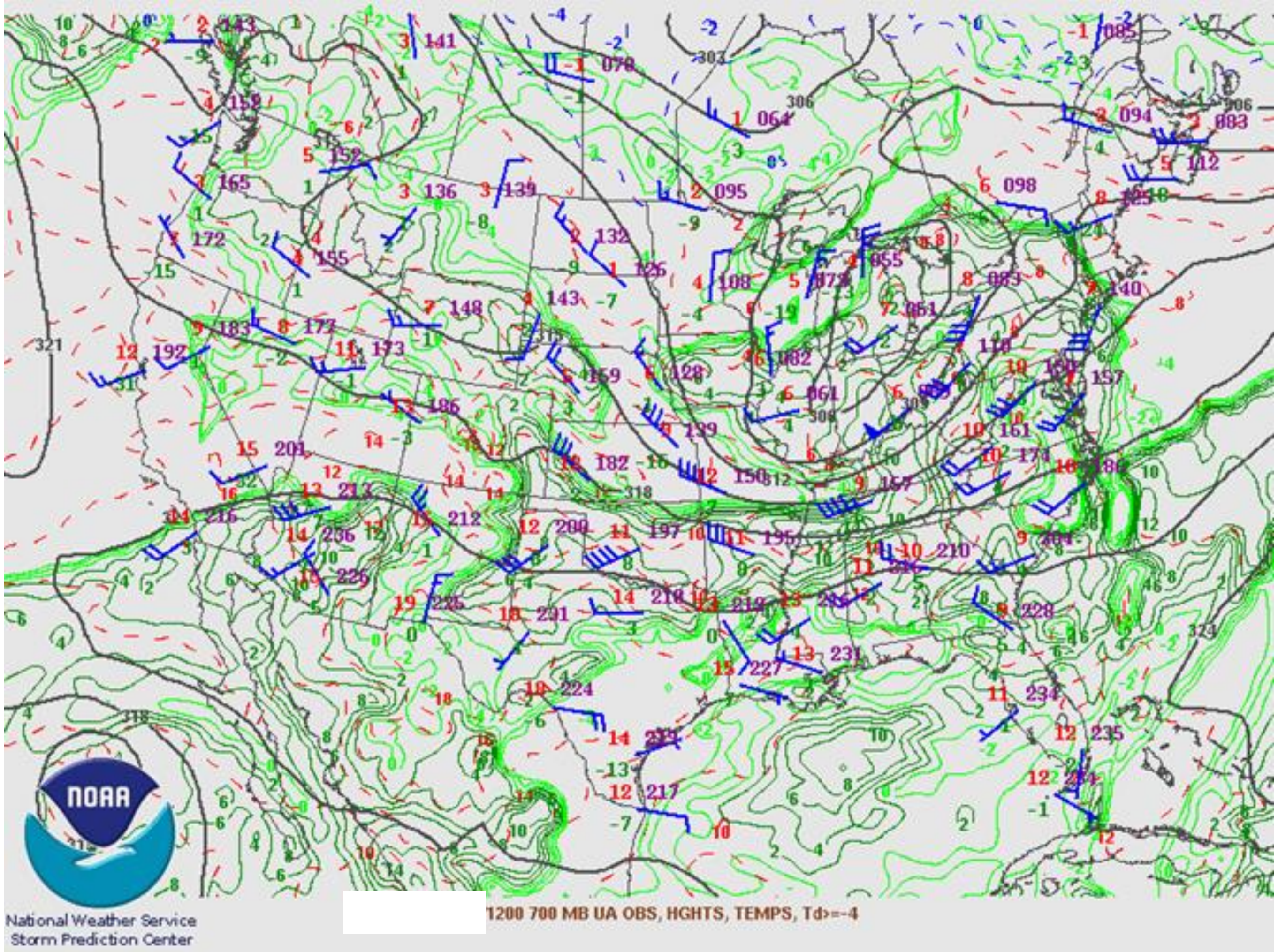
Mesoscale Analysis

Material by:
Harry Weinman

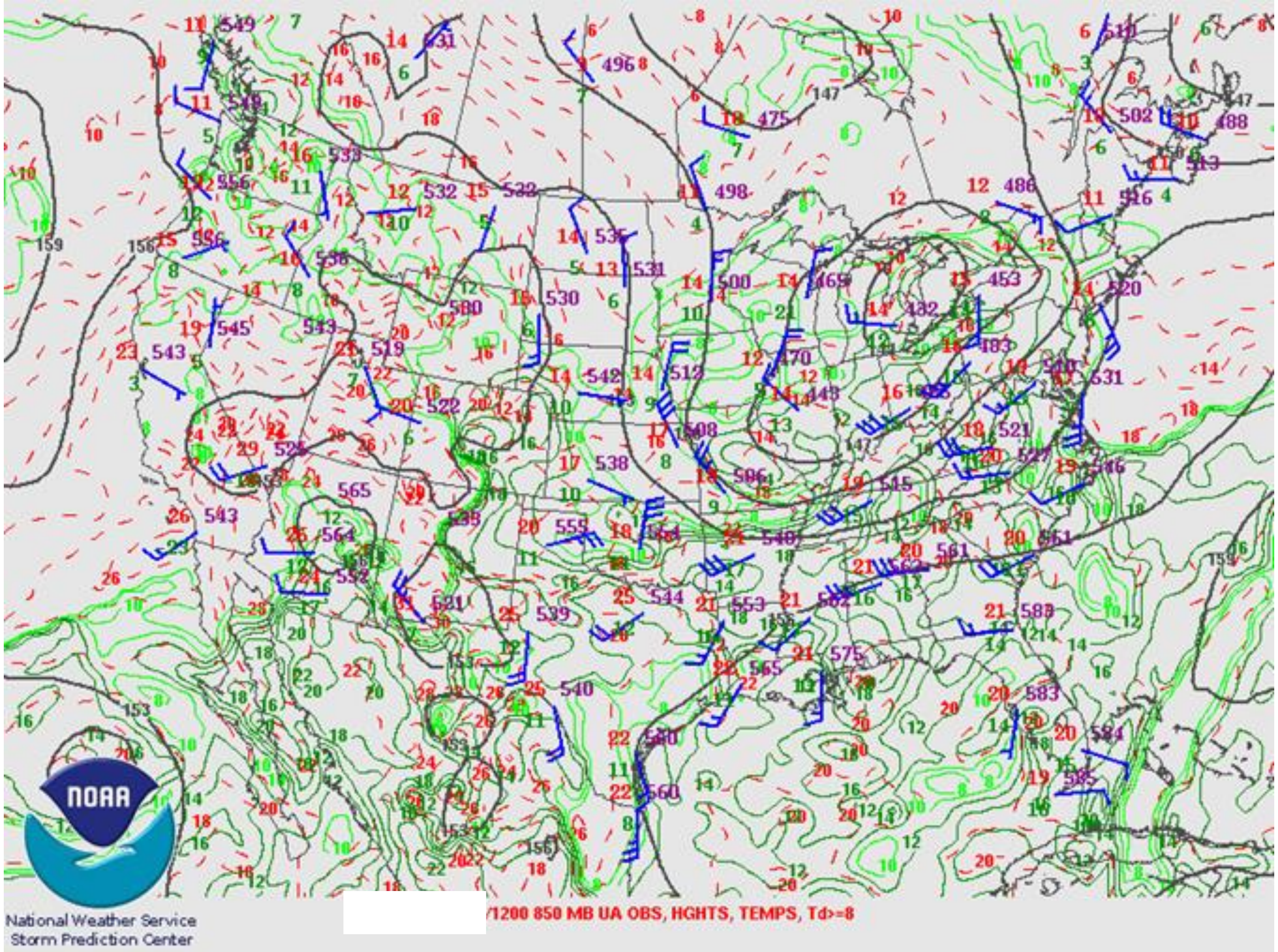
One hint: It’s the warm season

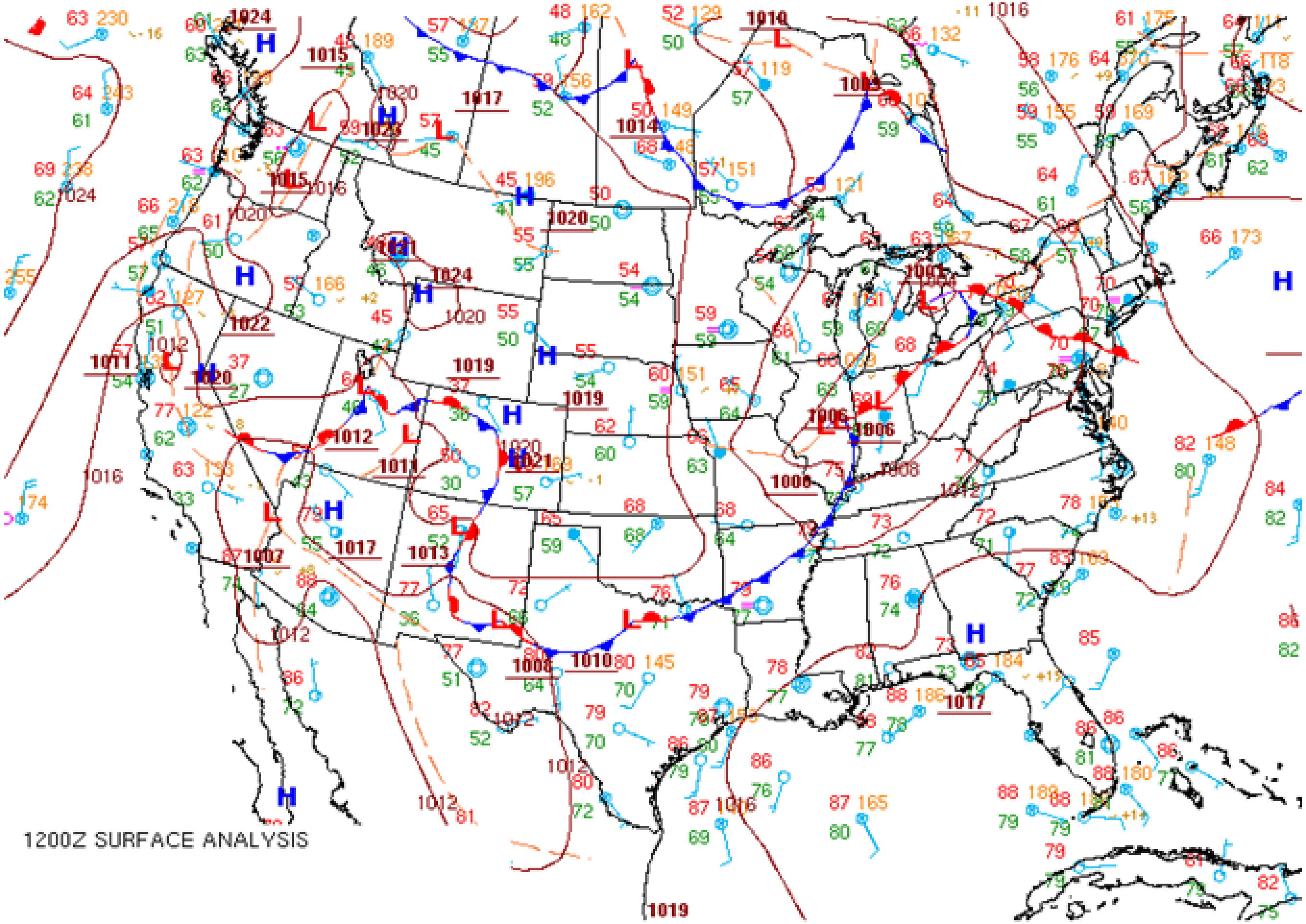


Focus here for remainder of the case



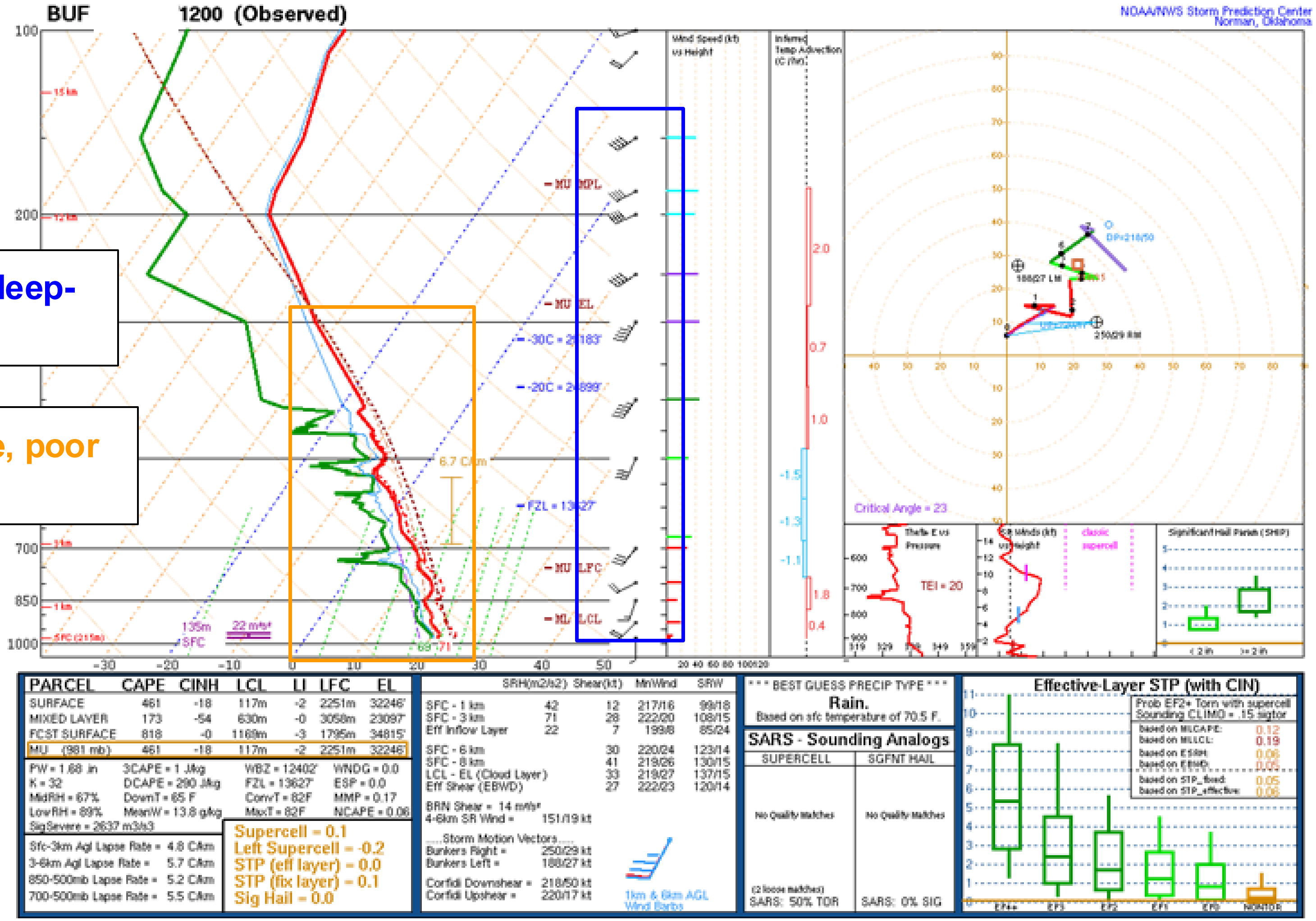
1200 700 MB UA OBS, HGHTS, TEMPS, Td>=-4


/1200 850 MB UA OBS, HGHTS, TEMPS, Td>=8
National Weather Service
Storm Prediction Center


1200Z SURFACE ANALYSIS

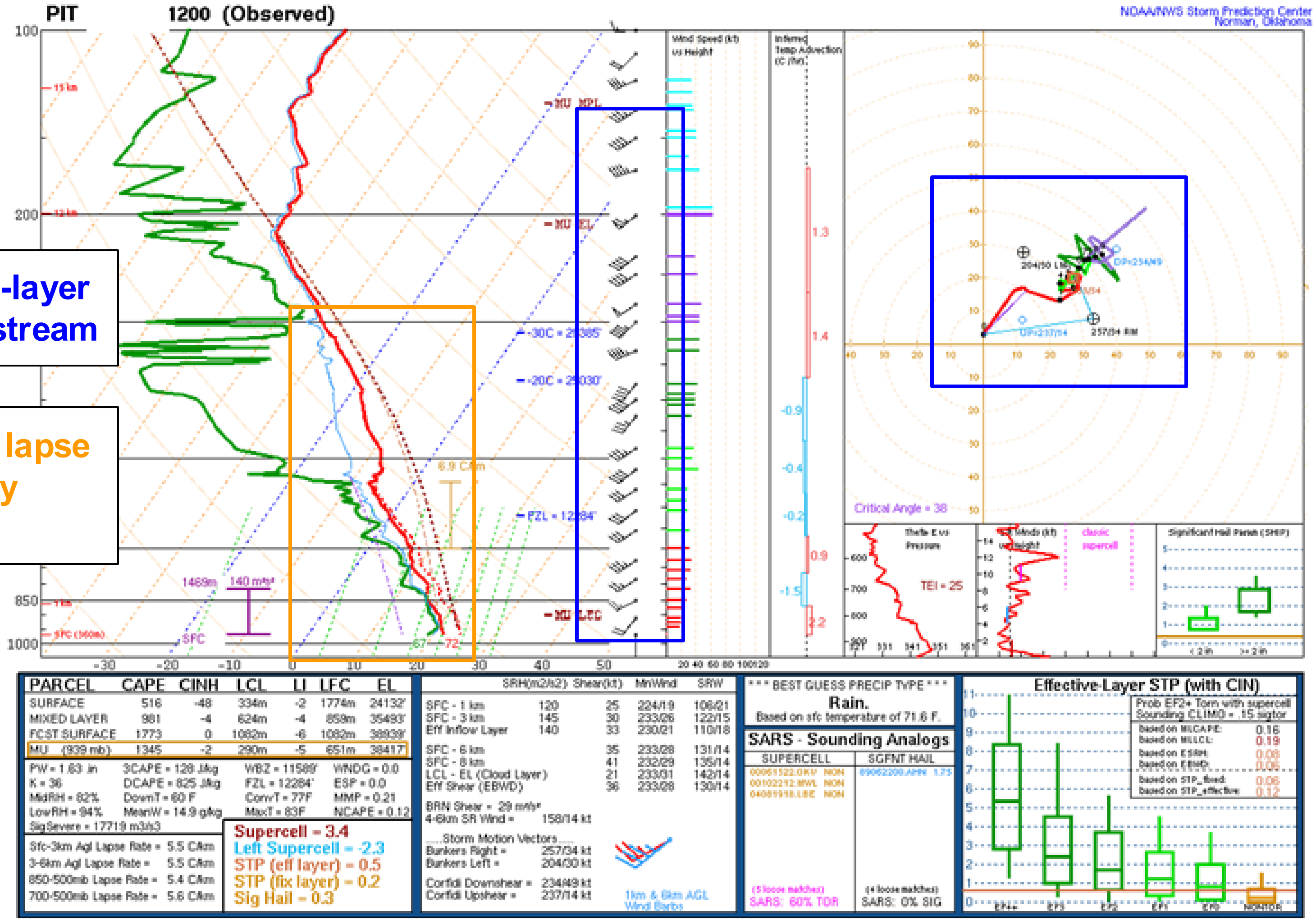
Fairly strong deep-layer flow

Deep moisture, poor lapse rates

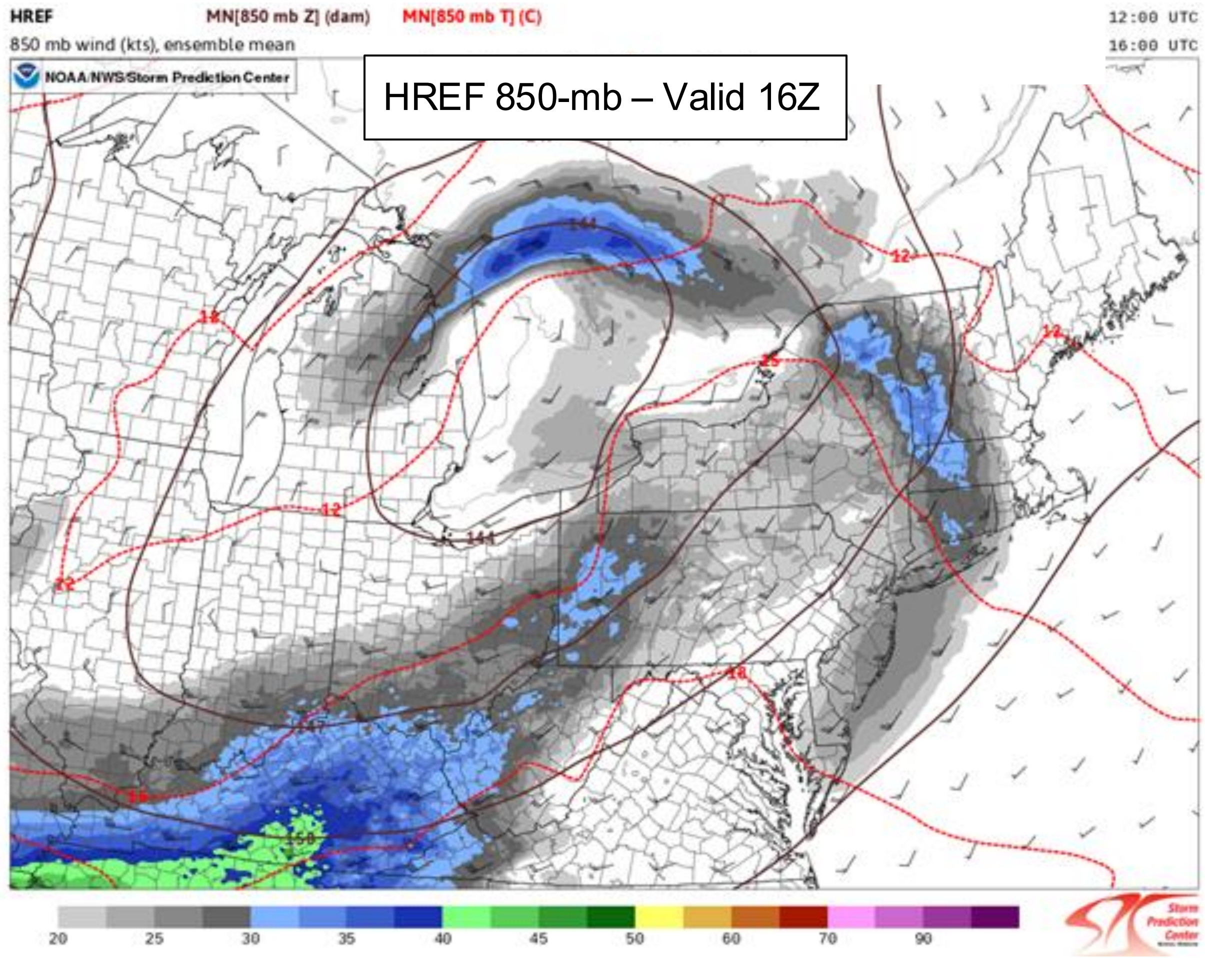


Stronger deep-layer flow/shear upstream

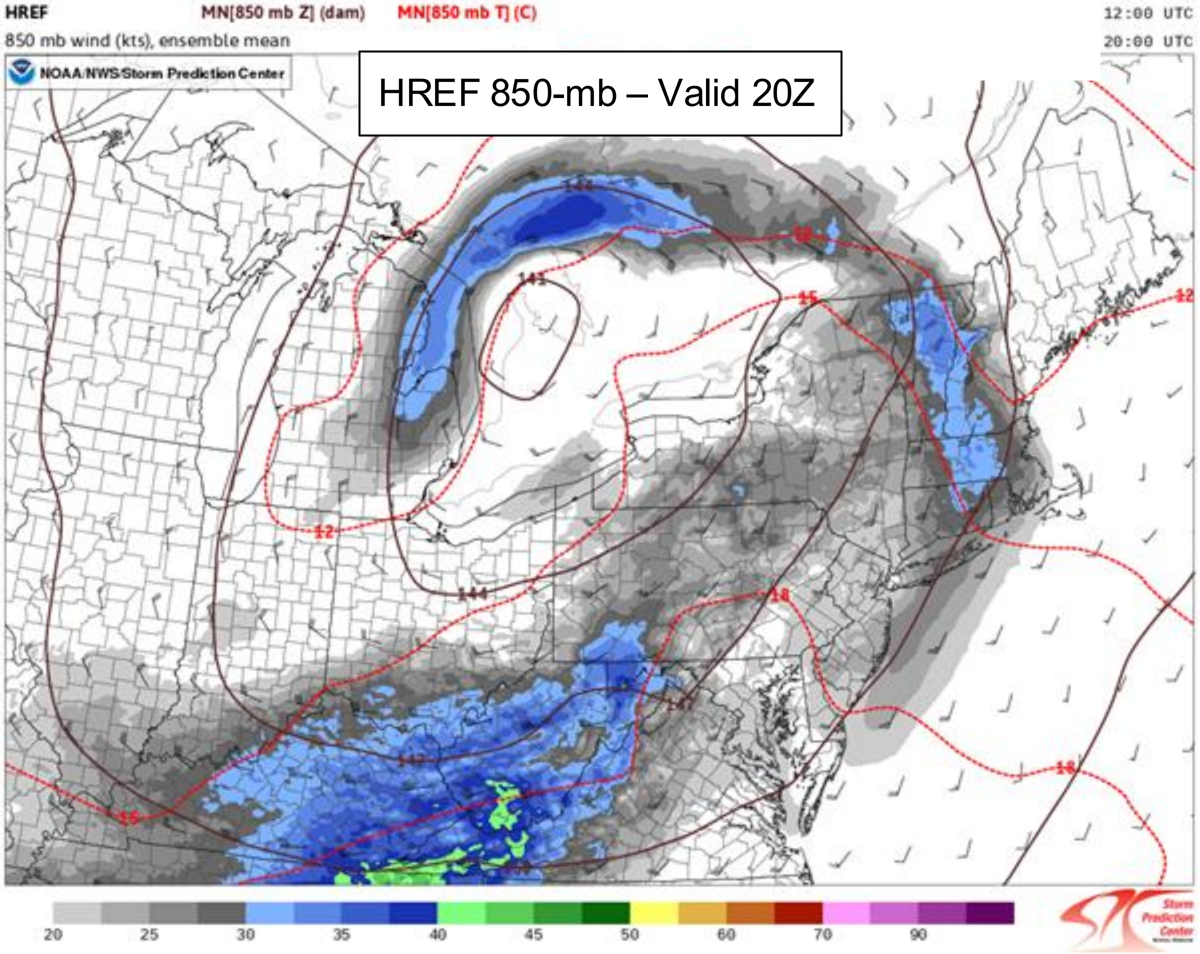
Slightly better lapse rates/buoyancy upstream



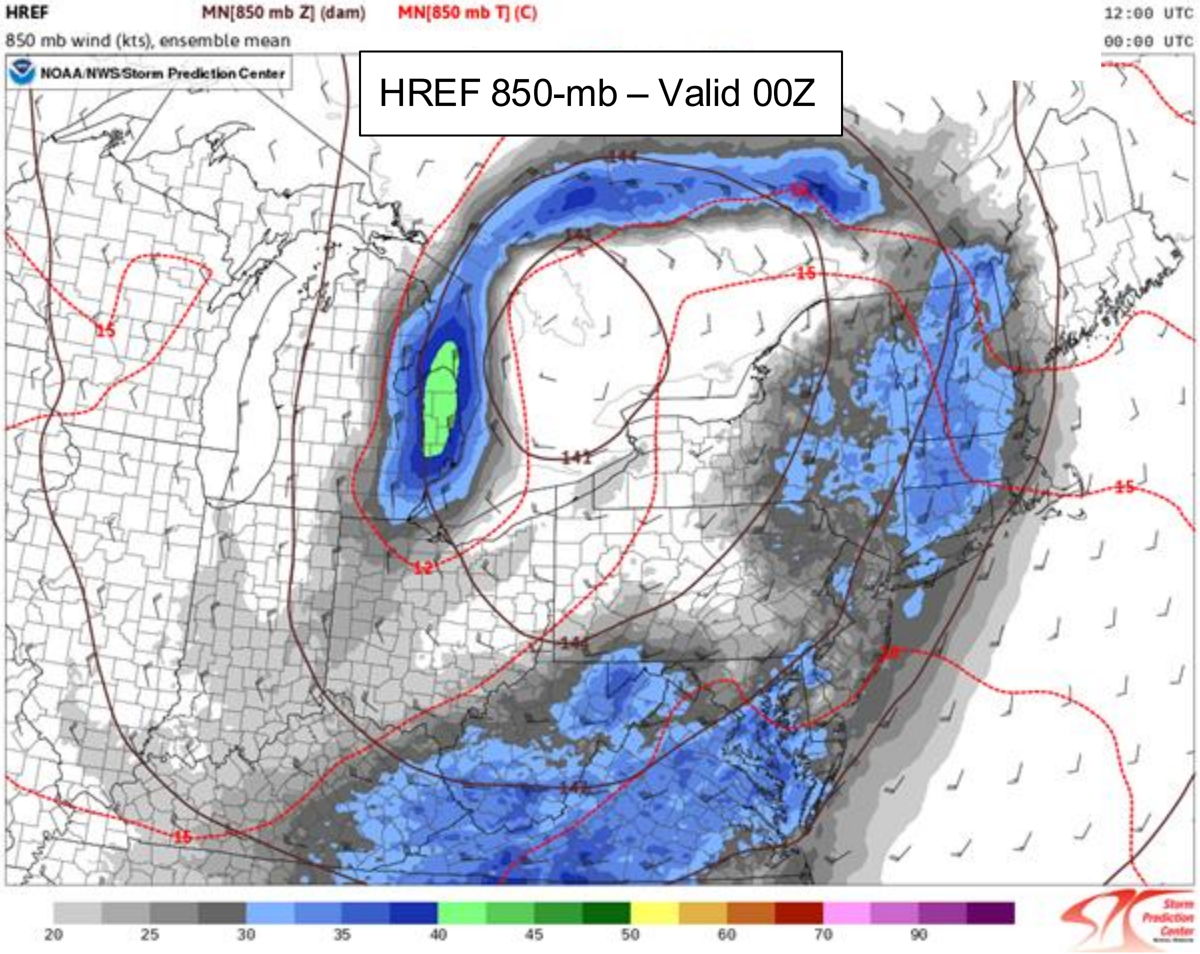
HREF 850-mb – Valid 16Z



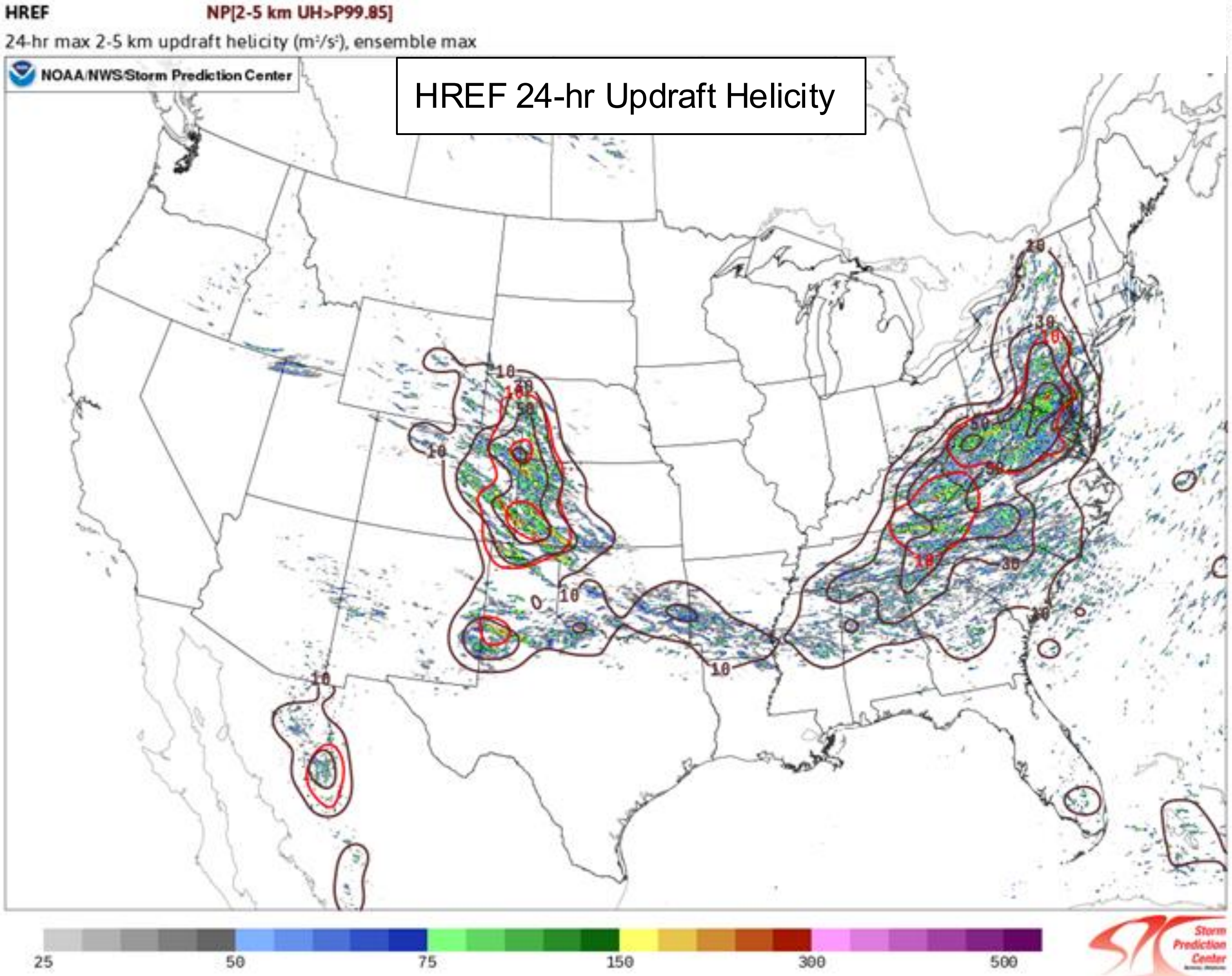
HREF 850-mb – Valid 20Z



HREF 850-mb – Valid 00Z

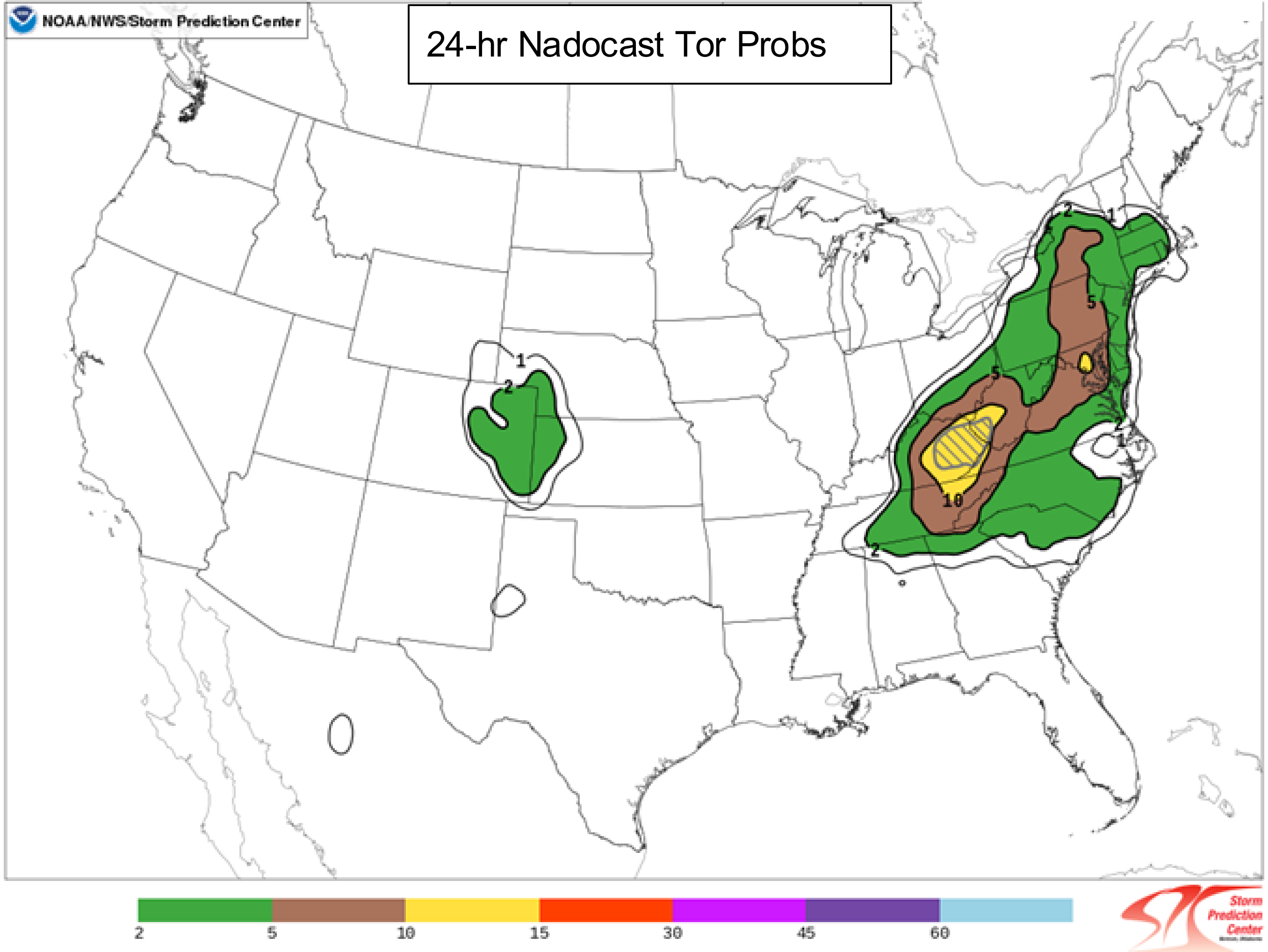


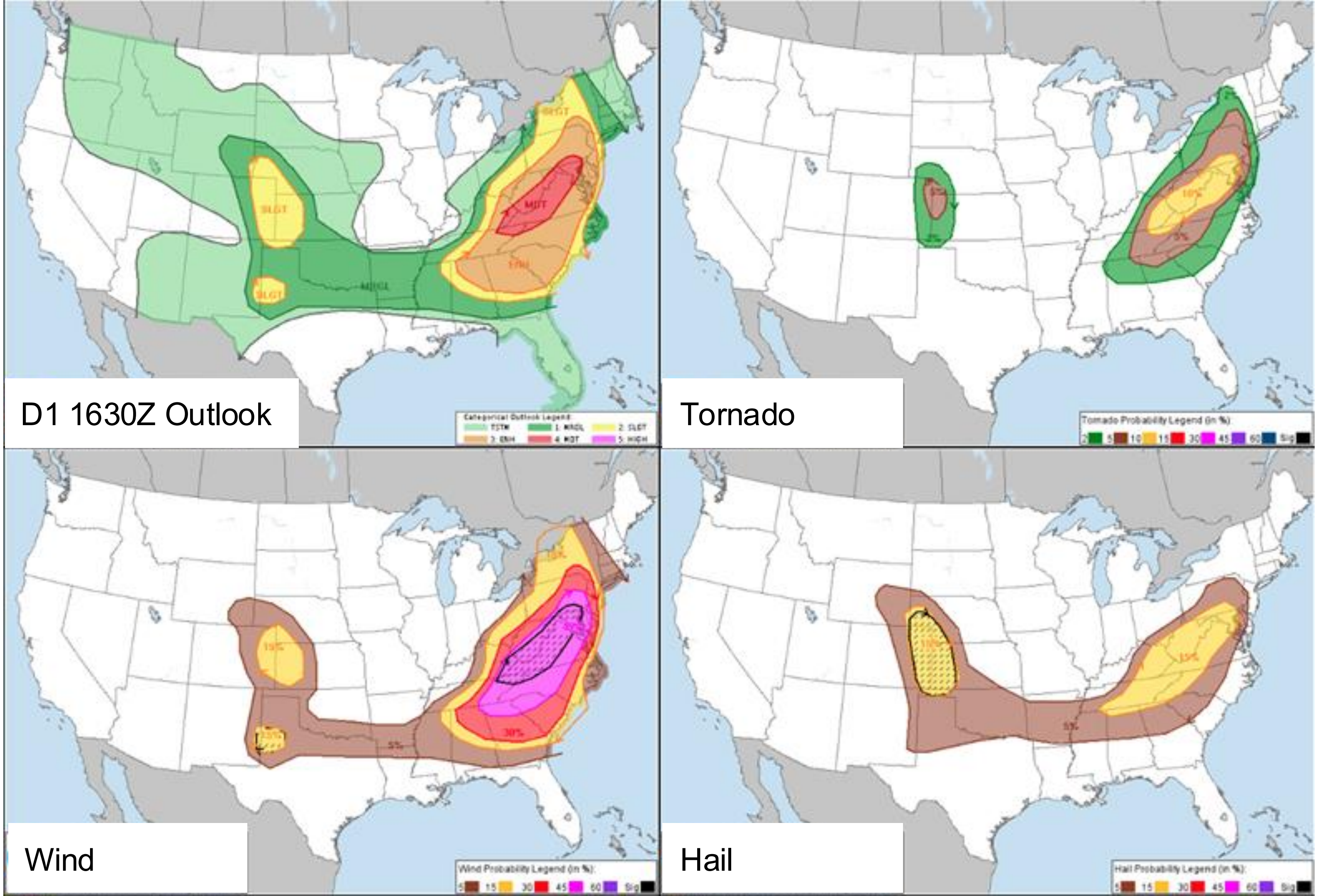
HREF 24-hr Updraft Helicity



HREF

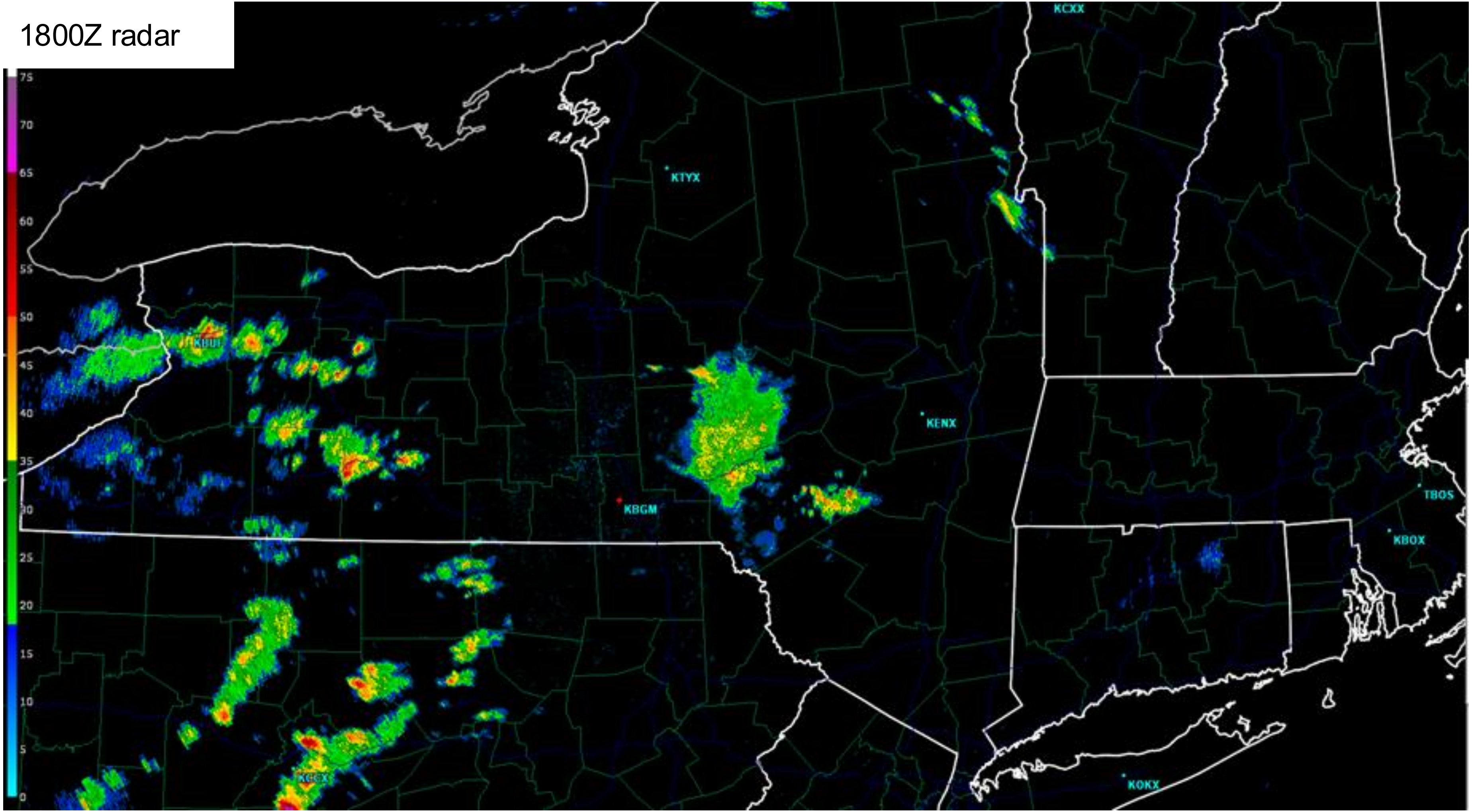
24-hr neighborhood probability of tornado (r=40 km), Nadocast (2022 models)





D1 1630Z Outlook
Categorical Outlook Legend:
TSTM 1: MRGL 2: SLGT
3: ENH 4: MDT 5: HIGH
Tornado
Tornado Probability Legend (in %):
2 5 10 15 30 45 60 Sig
Wind
Wind Probability Legend (in %):
5 15 30 45 60 Sig
Hail
Hail Probability Legend (in %):
5 15 30 45 60 Sig

1800Z radar


75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
KCXX
KTYX
KBUF
KENX
KBGM
TBOS
KBOX
KCCX
KOKX

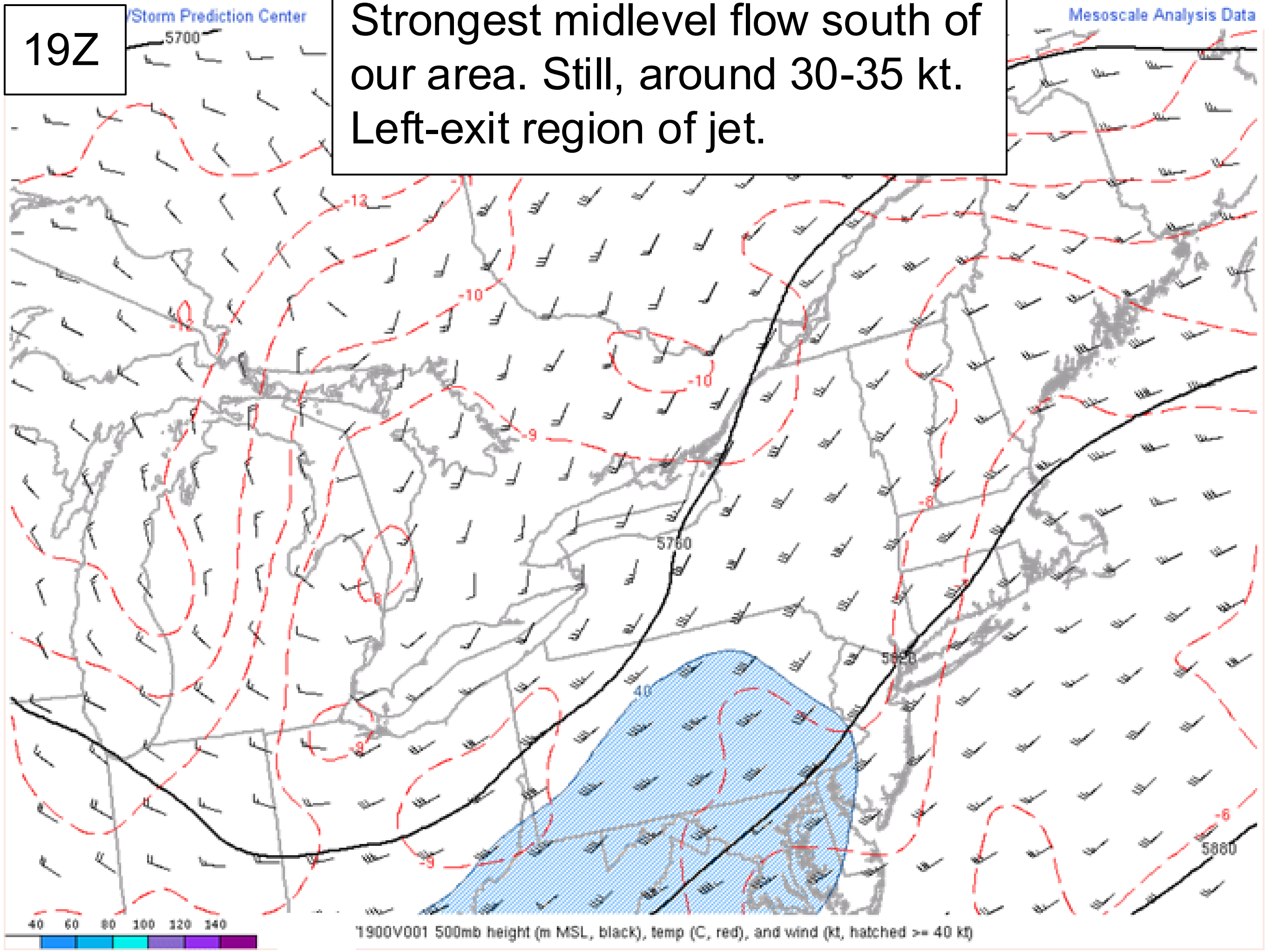
Approaching 19Z – Lets do some Mesoanalysis!

What will the radar look like in the next 1-3 hours?

(Convective Initiation, Mode and Future Evolution)

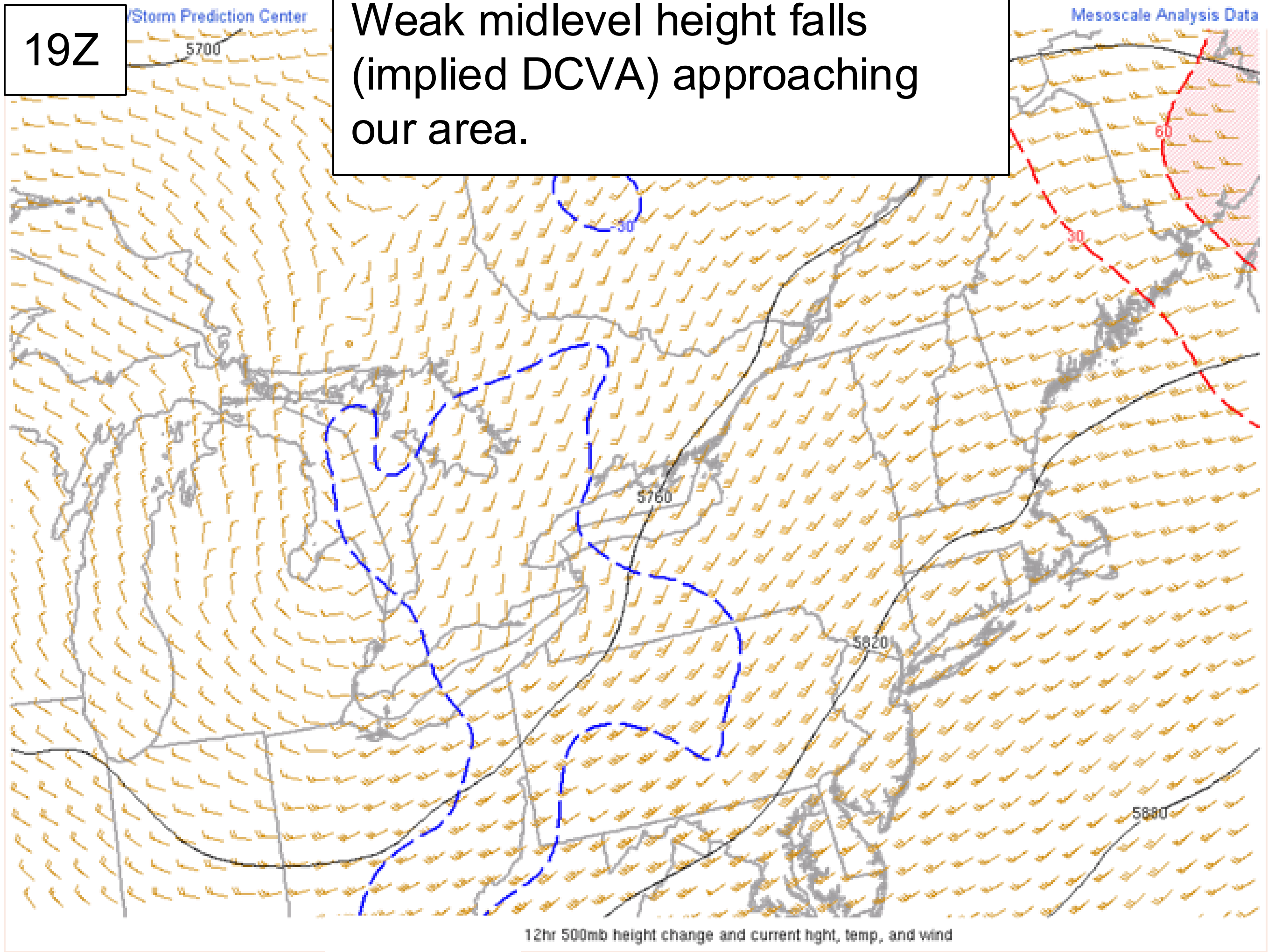
19Z

Strongest midlevel flow south of our area. Still, around 30-35 kt. Left-exit region of jet.



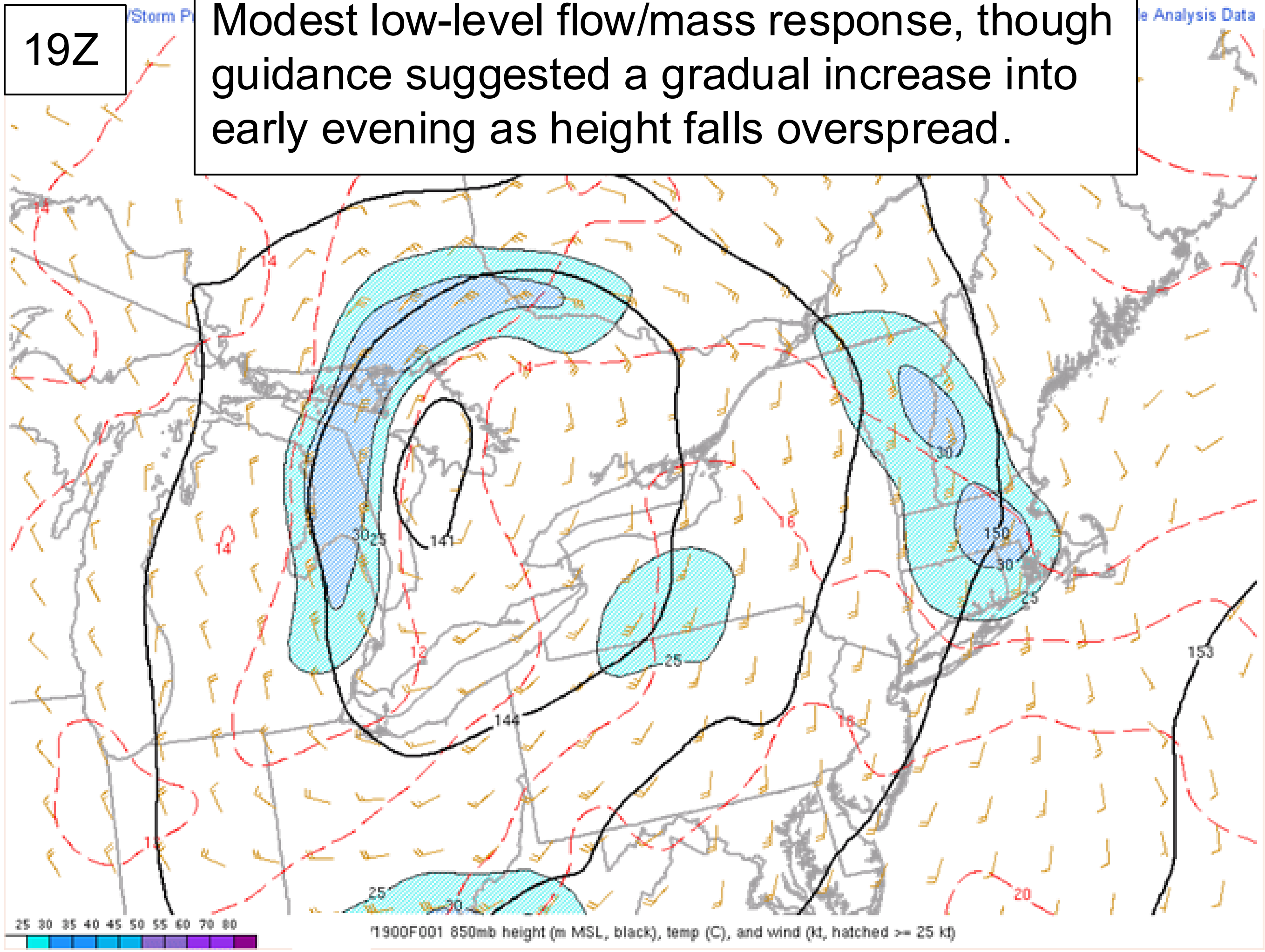
19Z

Weak midlevel height falls (implied DCVA) approaching our area.

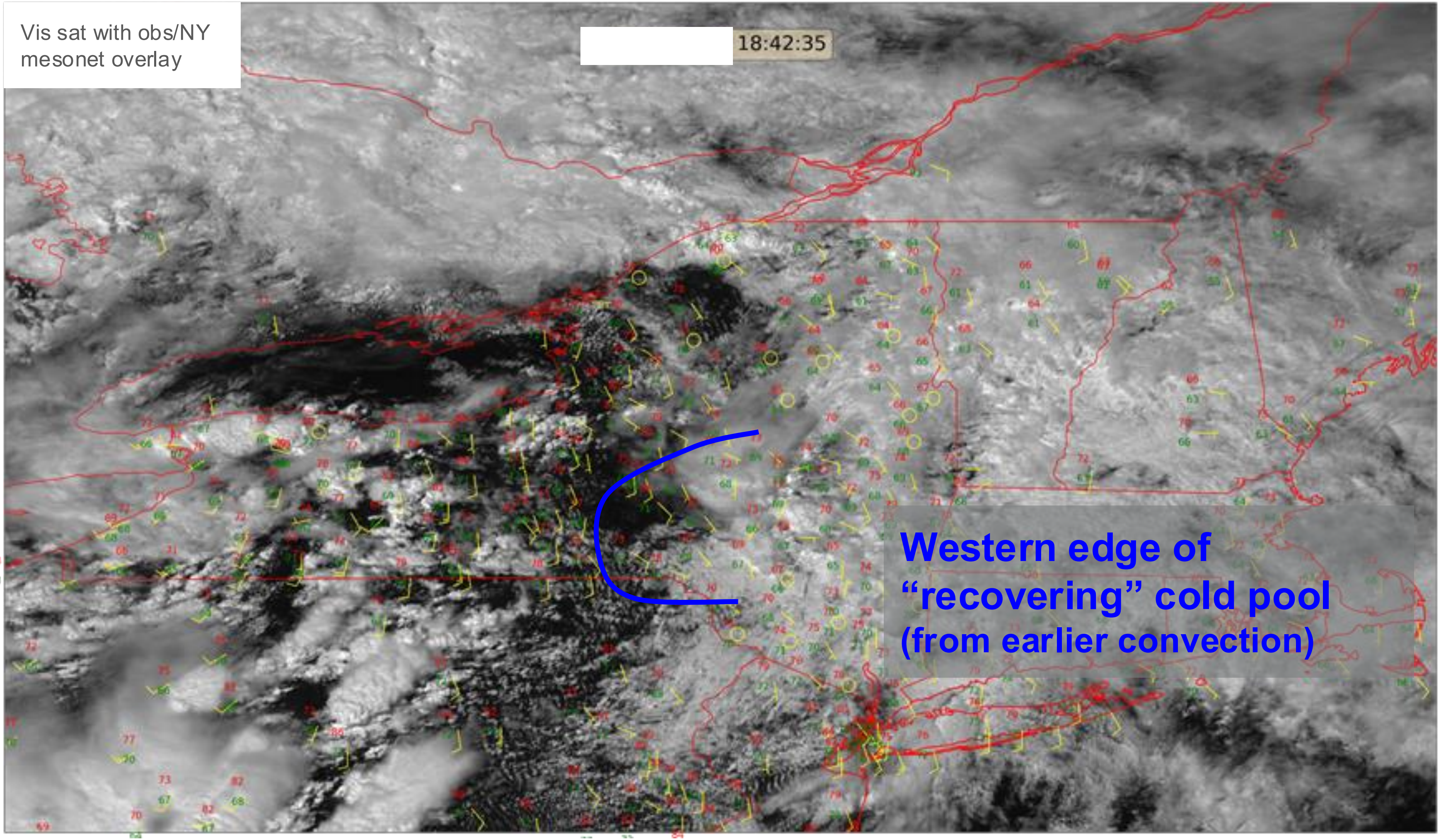


19Z

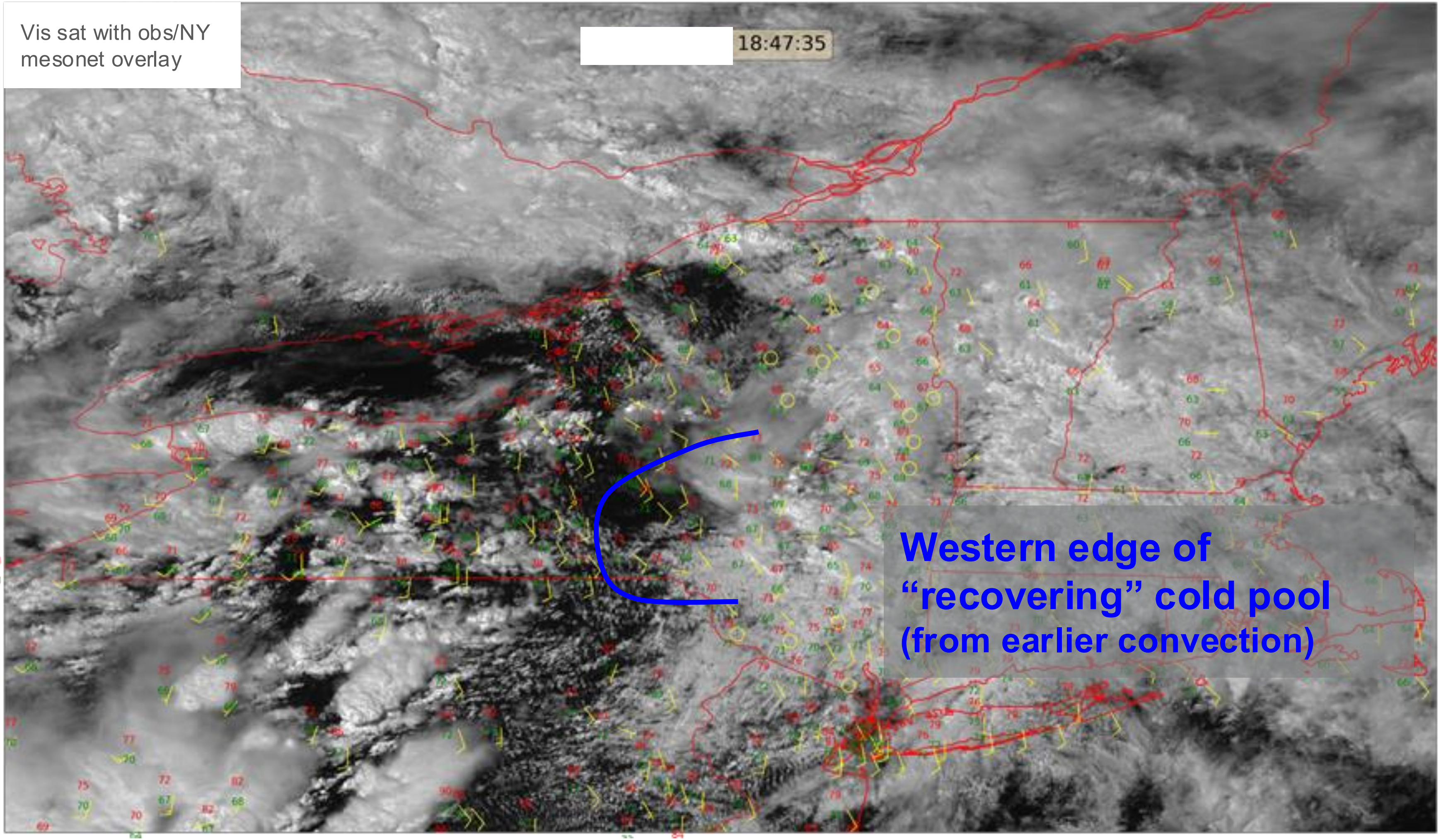
Modest low-level flow/mass response, though guidance suggested a gradual increase into early evening as height falls overspread.



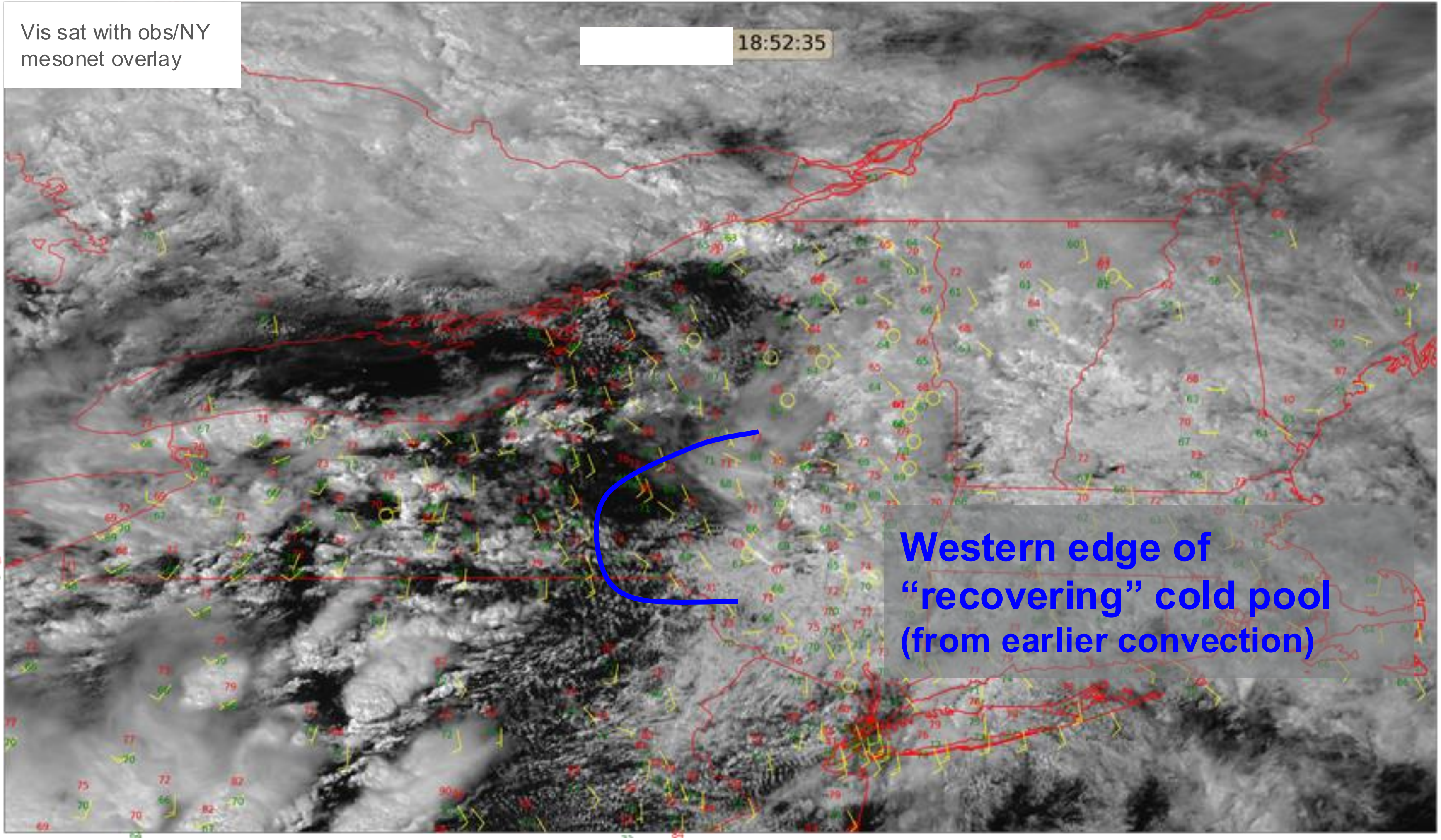
Vis sat with obs/NY mesonet overlay



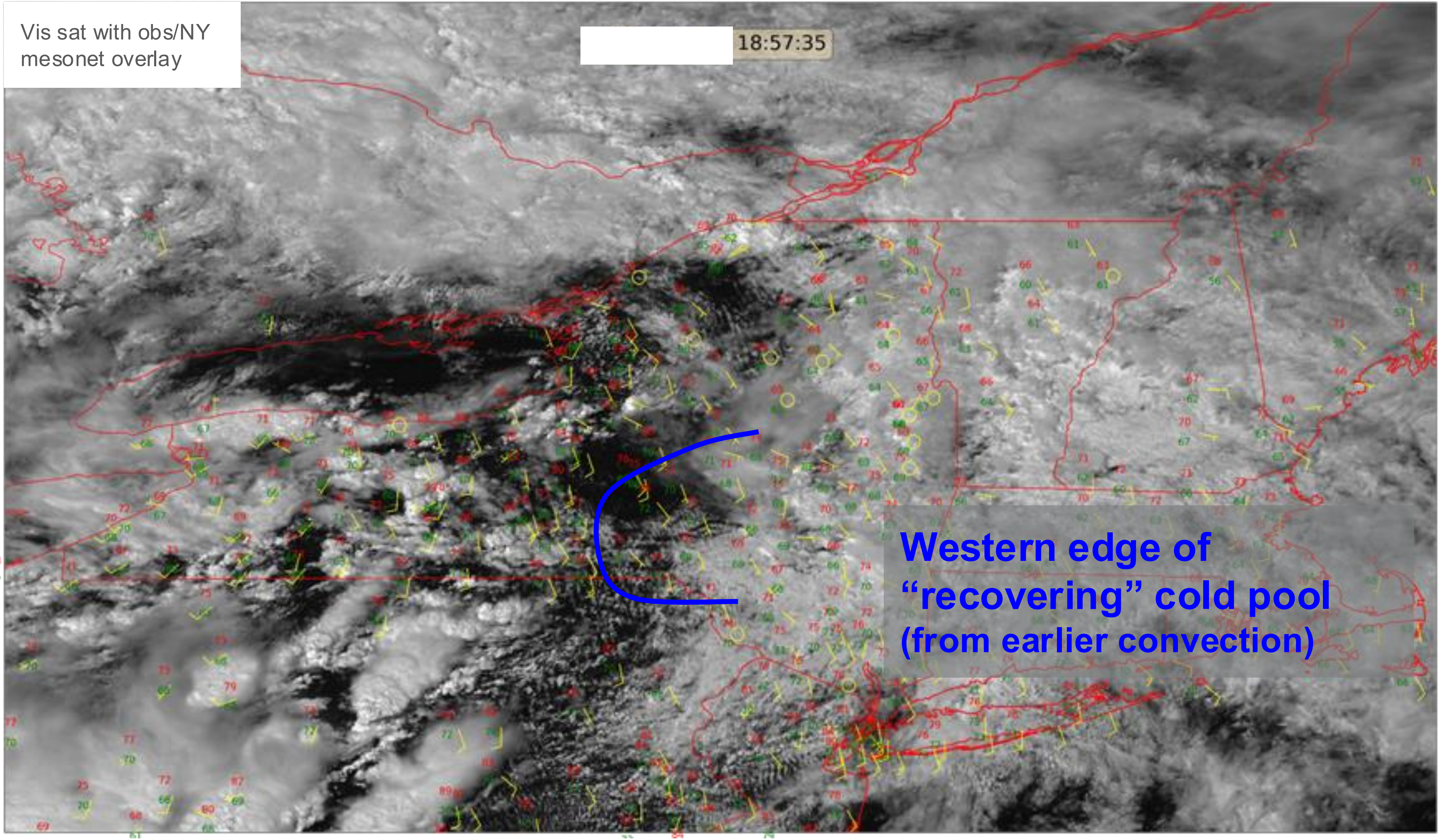
Vis sat with obs/NY mesonet overlay



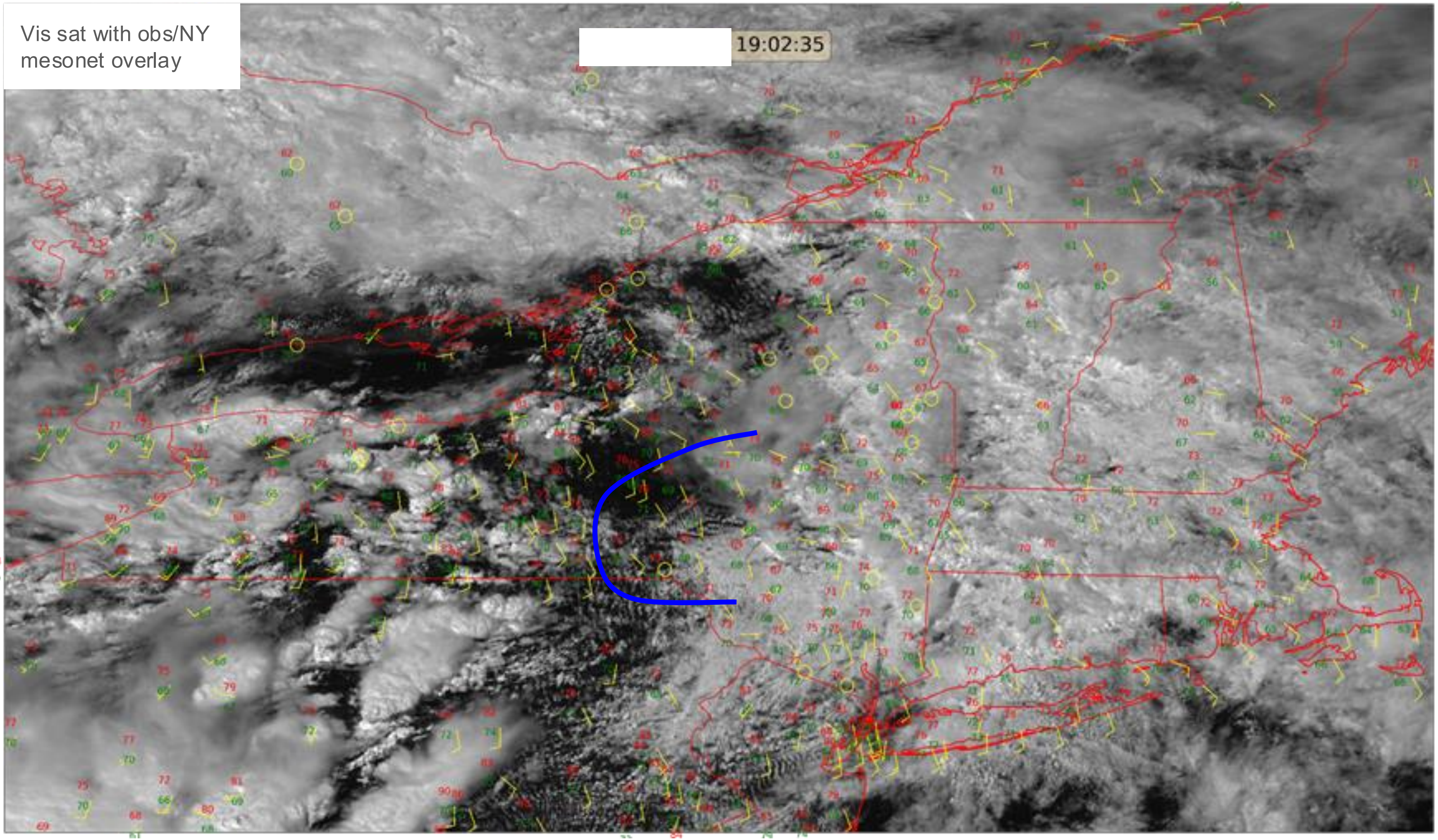
Vis sat with obs/NY mesonet overlay



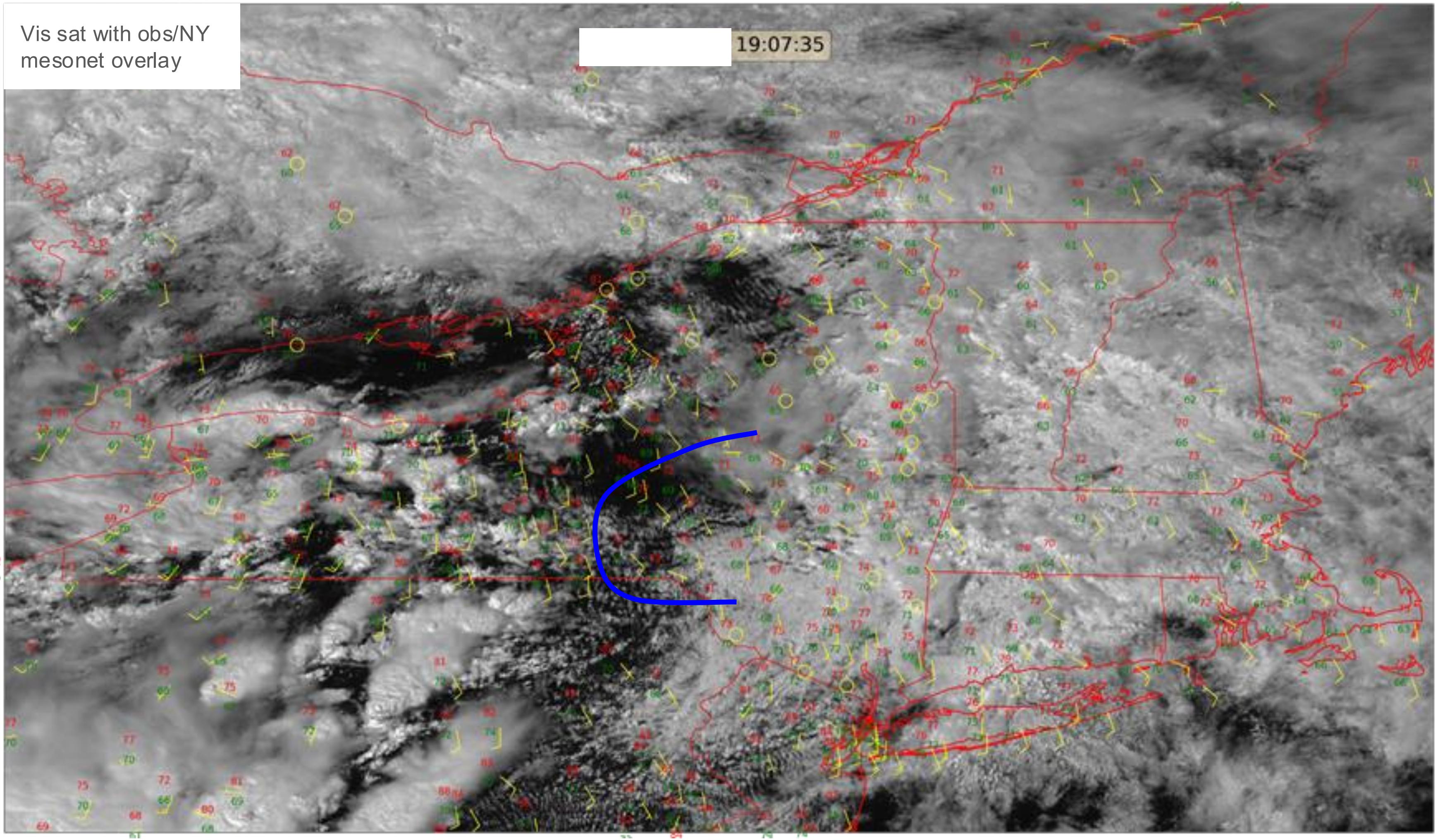
Vis sat with obs/NY mesonet overlay



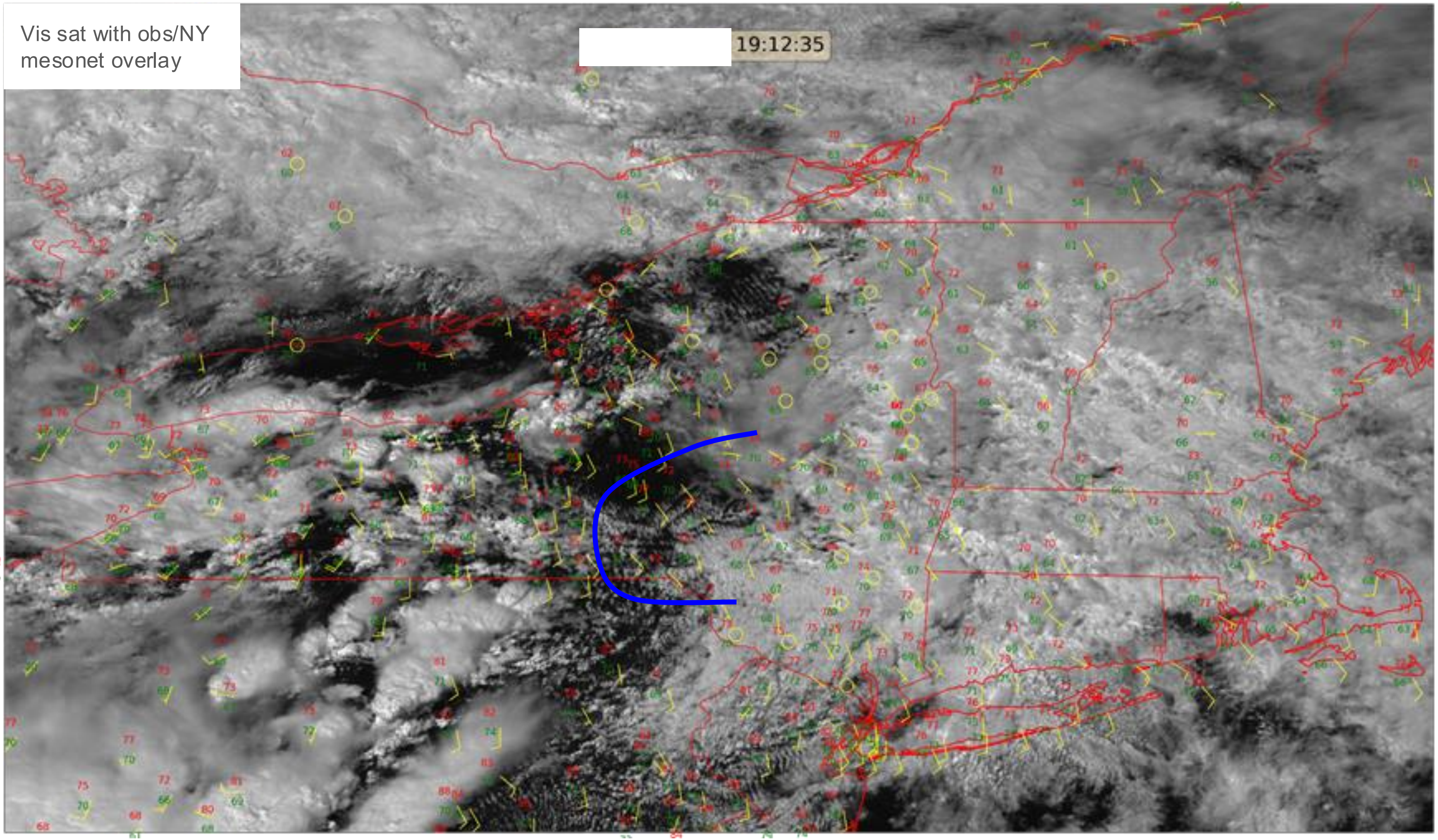
Vis sat with obs/NY mesonet overlay



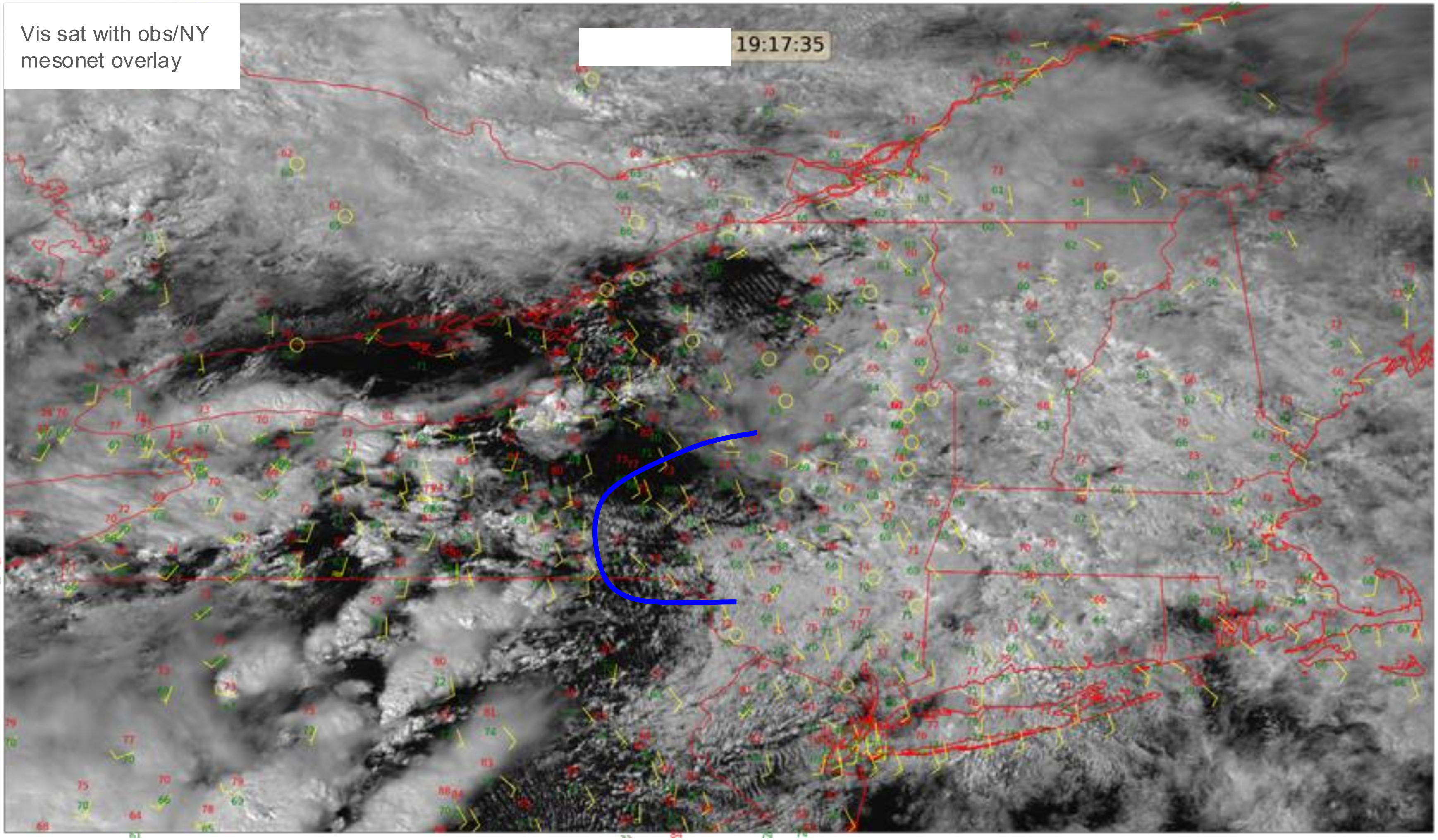
Vis sat with obs/NY mesonet overlay

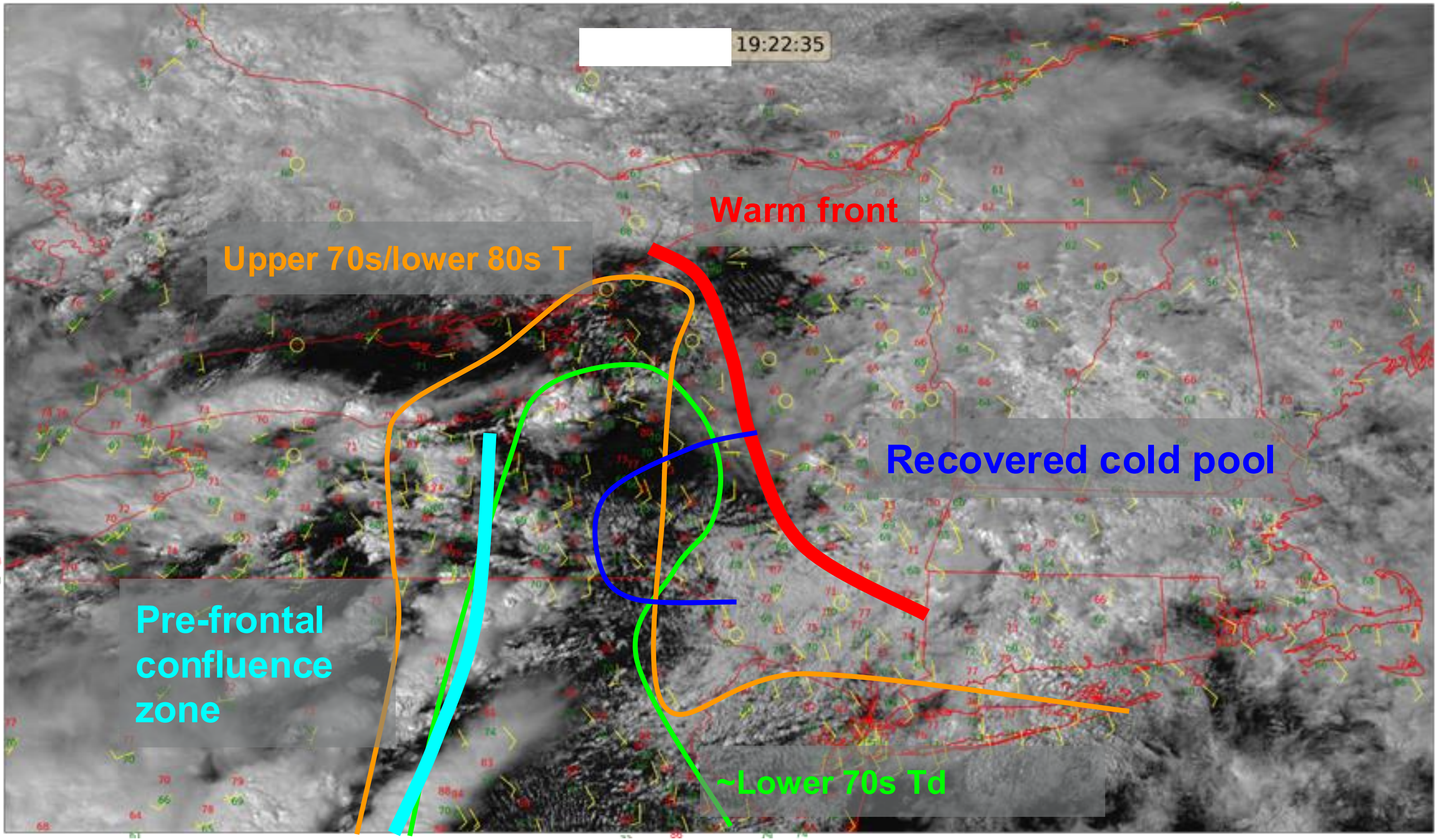


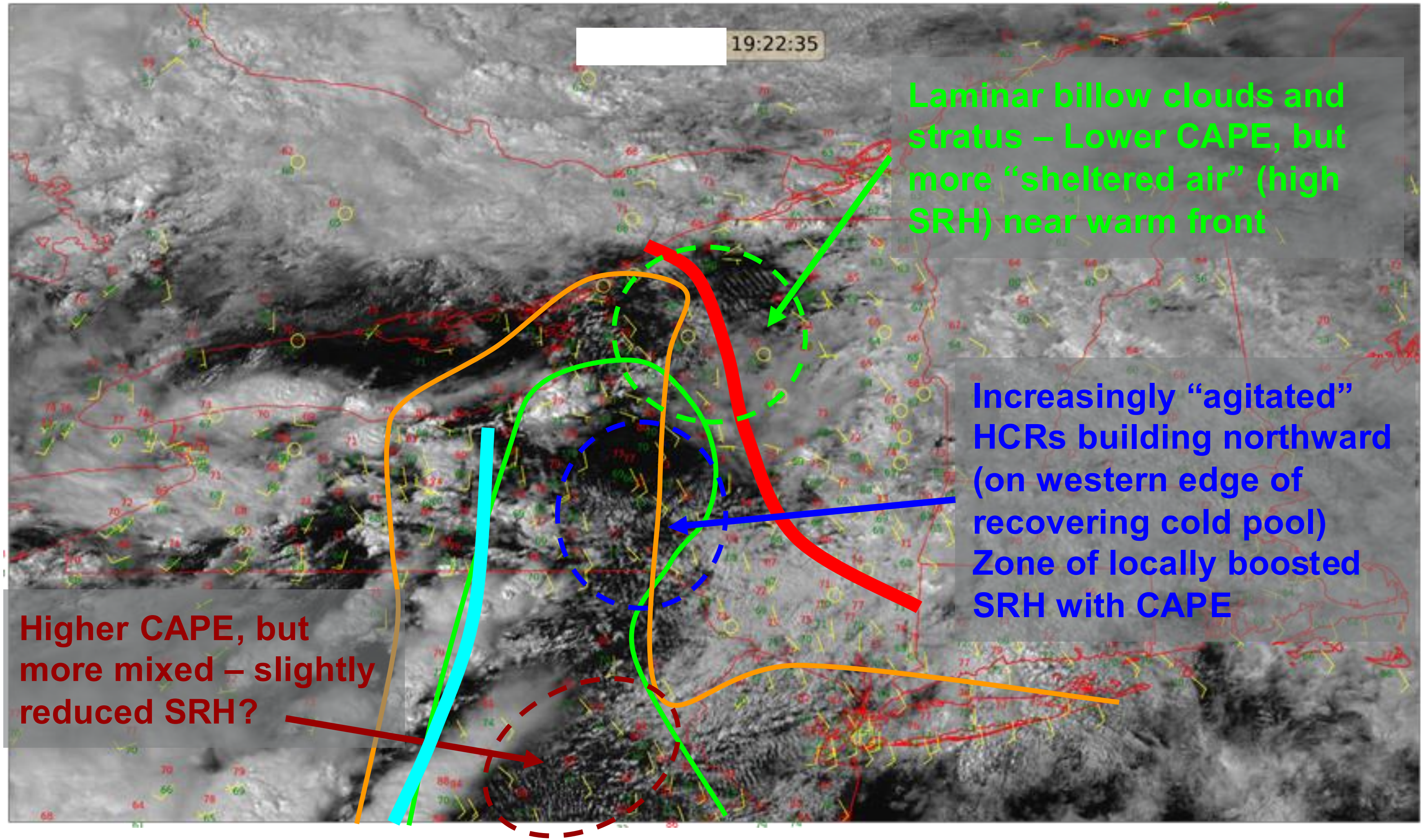
Vis sat with obs/NY mesonet overlay



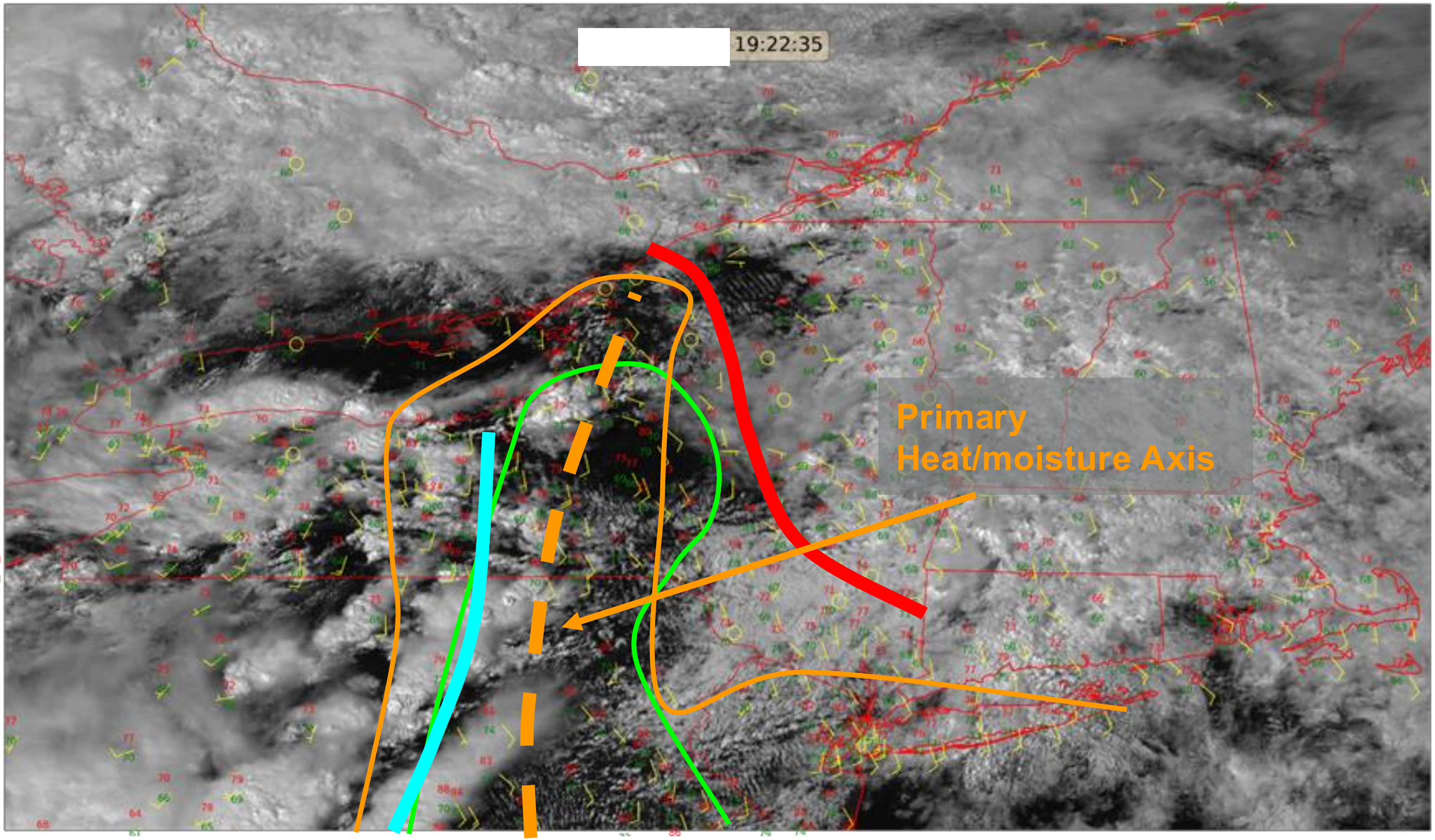
Vis sat with obs/NY mesonet overlay

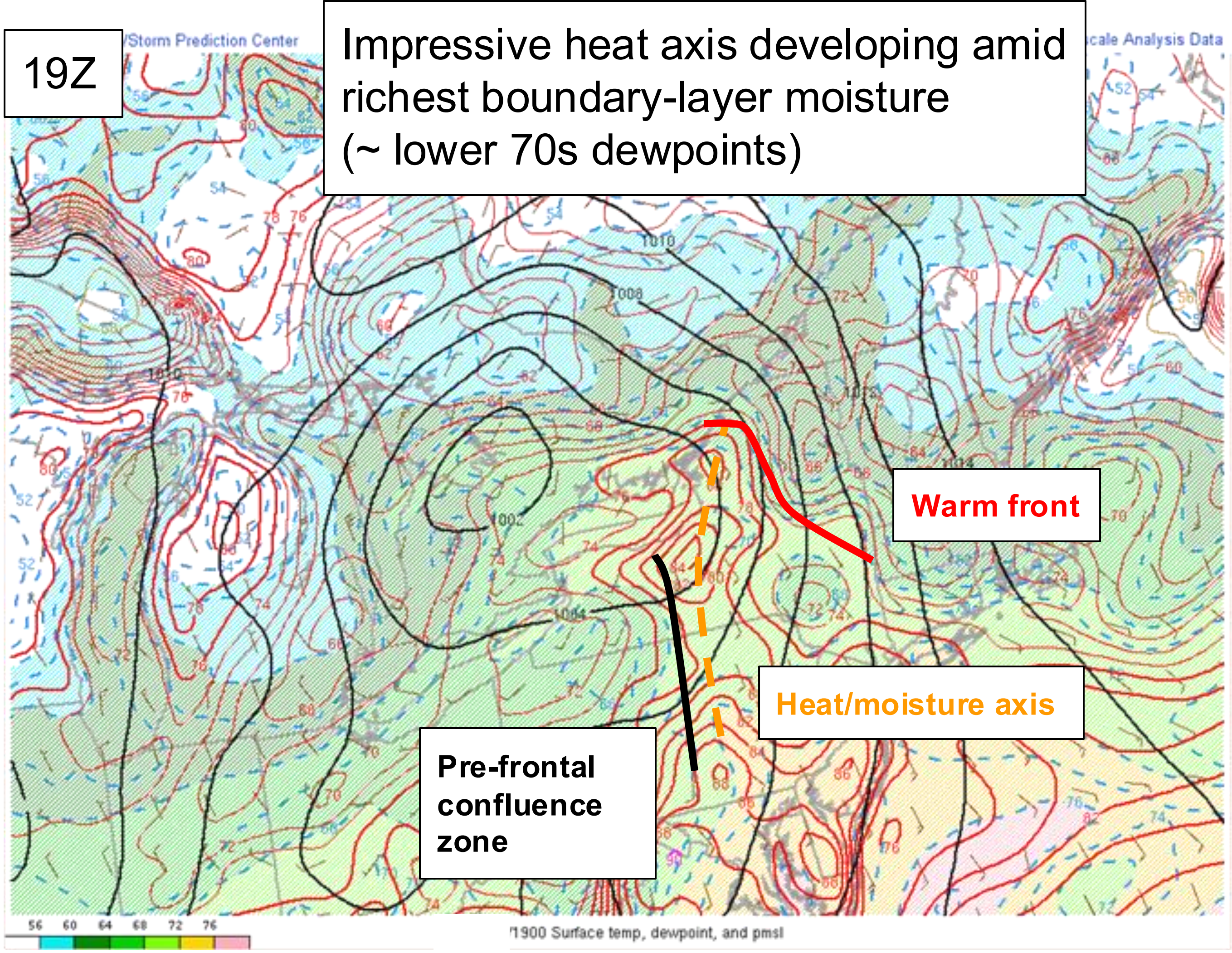



19:22:35
Warm front
Upper 70s/lower 80s T
Recovered cold pool
Pre-frontal confluence zone
~Lower 70s Td

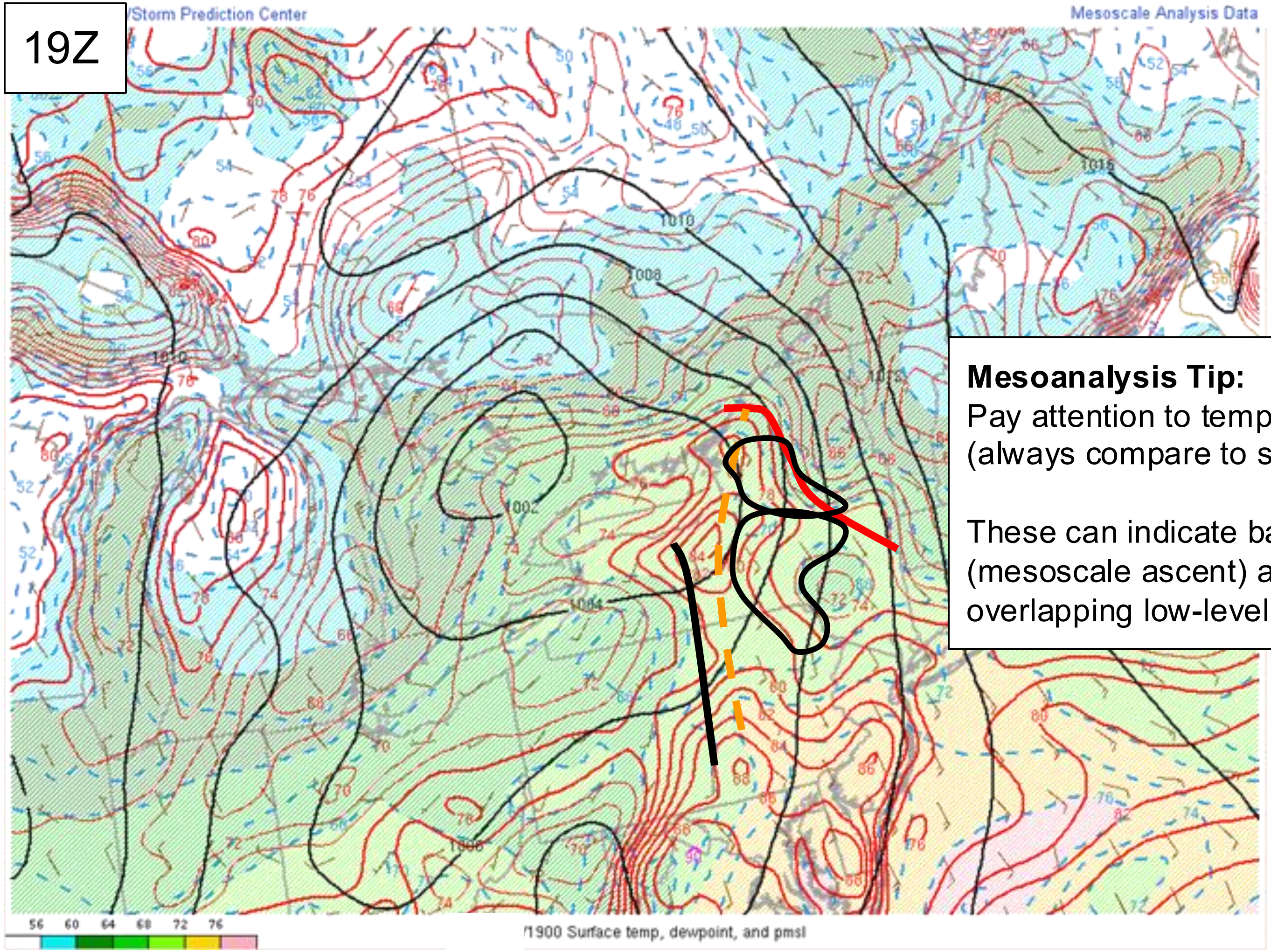


19:22:35
Laminar billow clouds and stratus – Lower CAPE, but more “sheltered air” (high SRH) near warm front
Increasingly “agitated” HCRs building northward (on western edge of recovering cold pool) Zone of locally boosted SRH with CAPE
Higher CAPE, but more mixed – slightly reduced SRH?


19:22:35
Primary
Heat/moisture Axis


19Z
Impressive heat axis developing amid richest boundary-layer moisture
(~ lower 70s dewpoints)
Warm front
Heat/moisture axis
Pre-frontal confluence zone
/Storm Prediction Center
cale Analysis Data
/1900 Surface temp, dewpoint, and pmsl
56 60 64 68 72 76

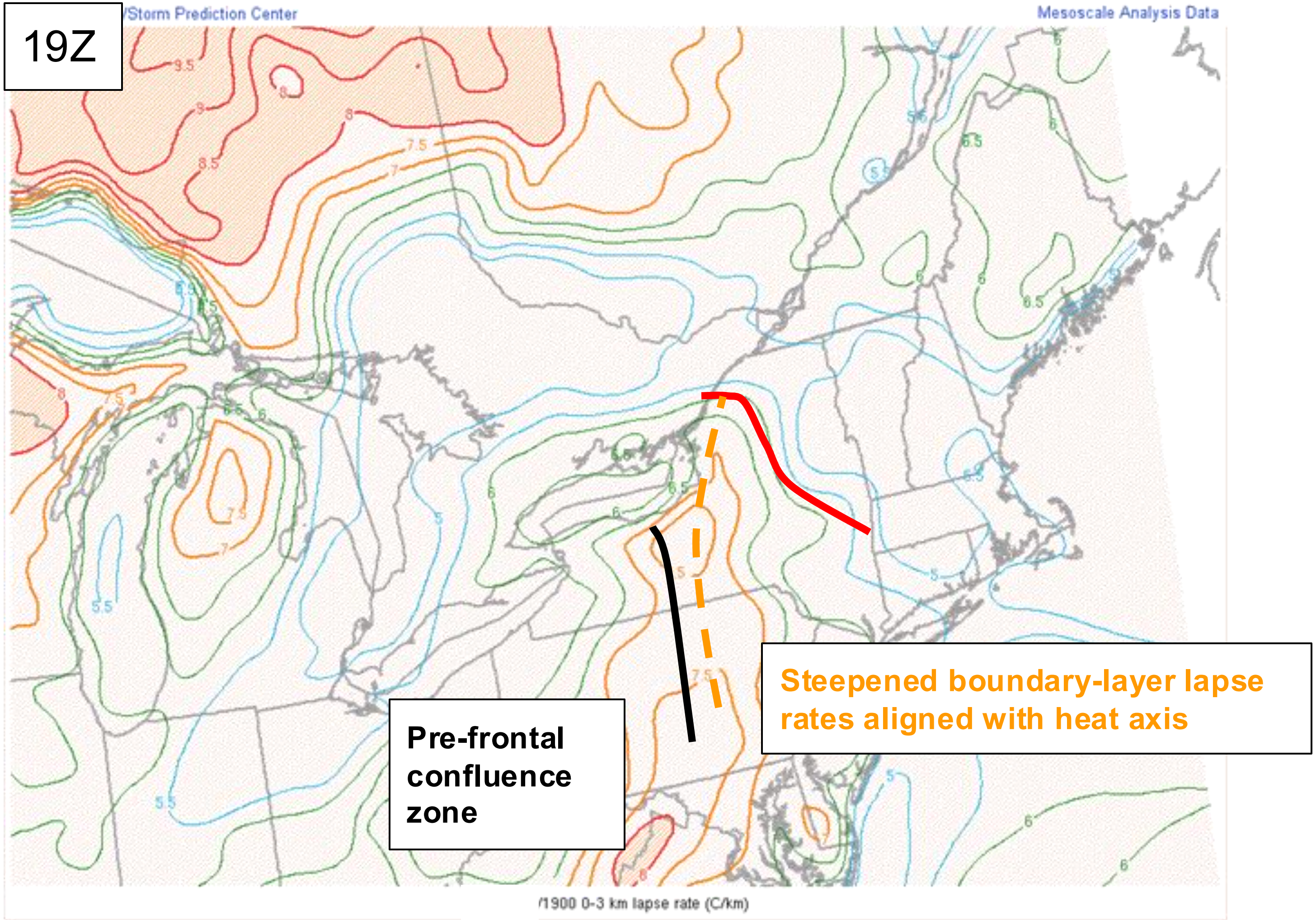
19Z



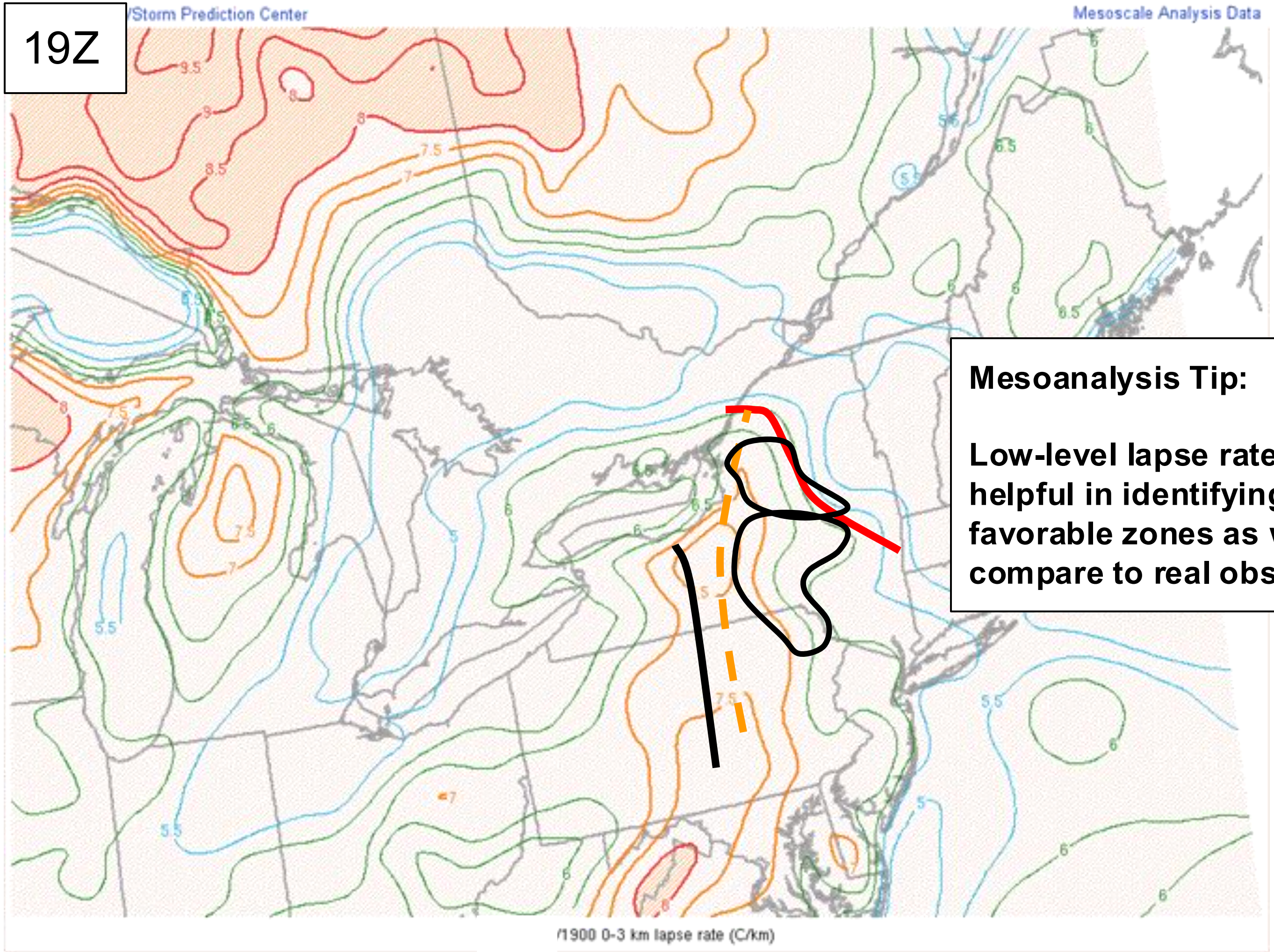
Mesoanalysis Tip:
Pay attention to temp gradients like these (always compare to surface obs)!

These can indicate baroclinic zones (mesoscale ascent) and possibly overlapping low-level shear/CAPE

19Z


Storm Prediction Center
Mesoscale Analysis Data
1900 0-3 km lapse rate (C/km)
Steepened boundary-layer lapse rates aligned with heat axis
Pre-frontal confluence zone

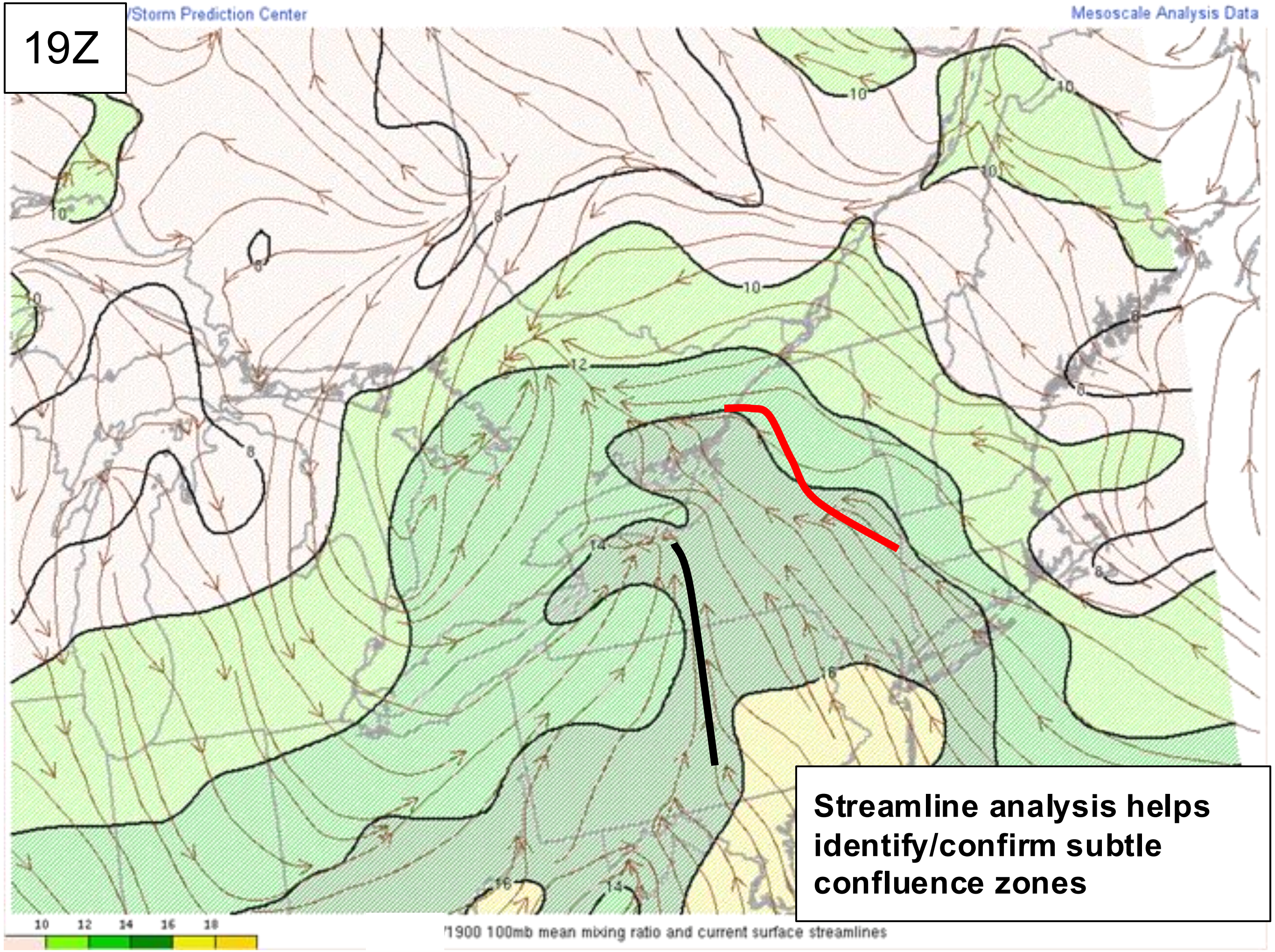
19Z



Mesoanalysis Tip:

Low-level lapse rate gradients can be helpful in identifying these potentially favorable zones as well – always compare to real obs

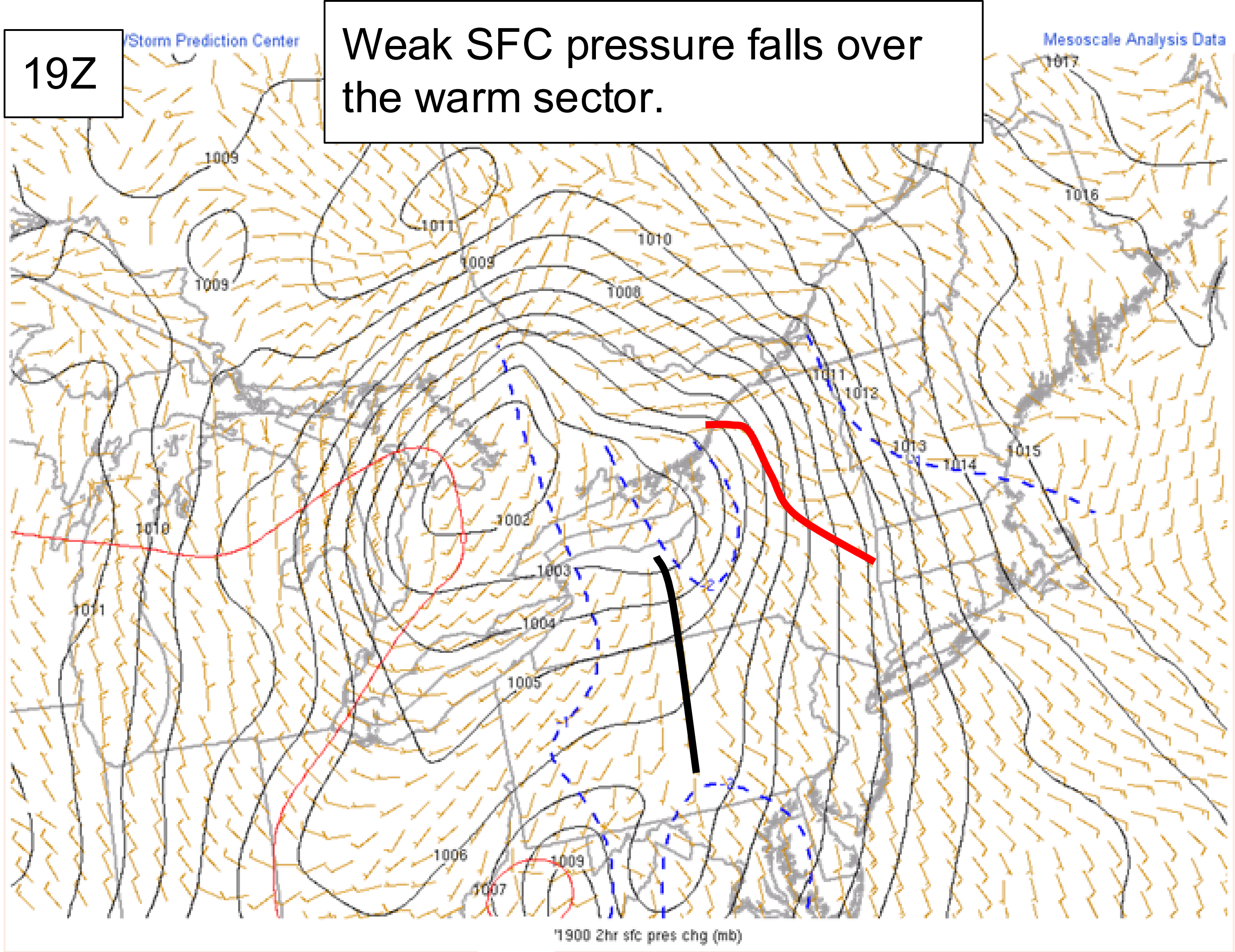
19Z



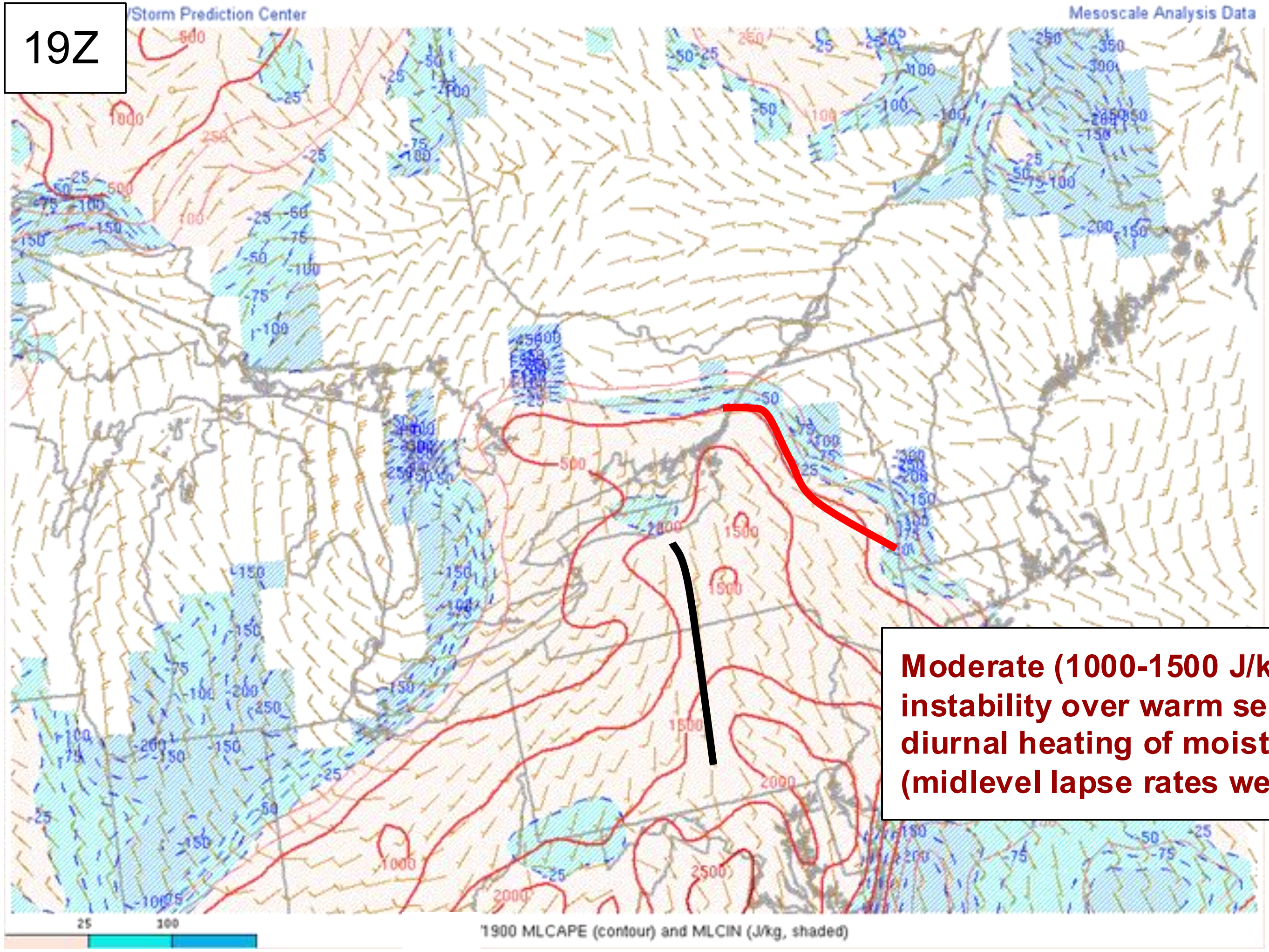
Streamline analysis helps identify/confirm subtle confluence zones

19Z

Weak SFC pressure falls over the warm sector.



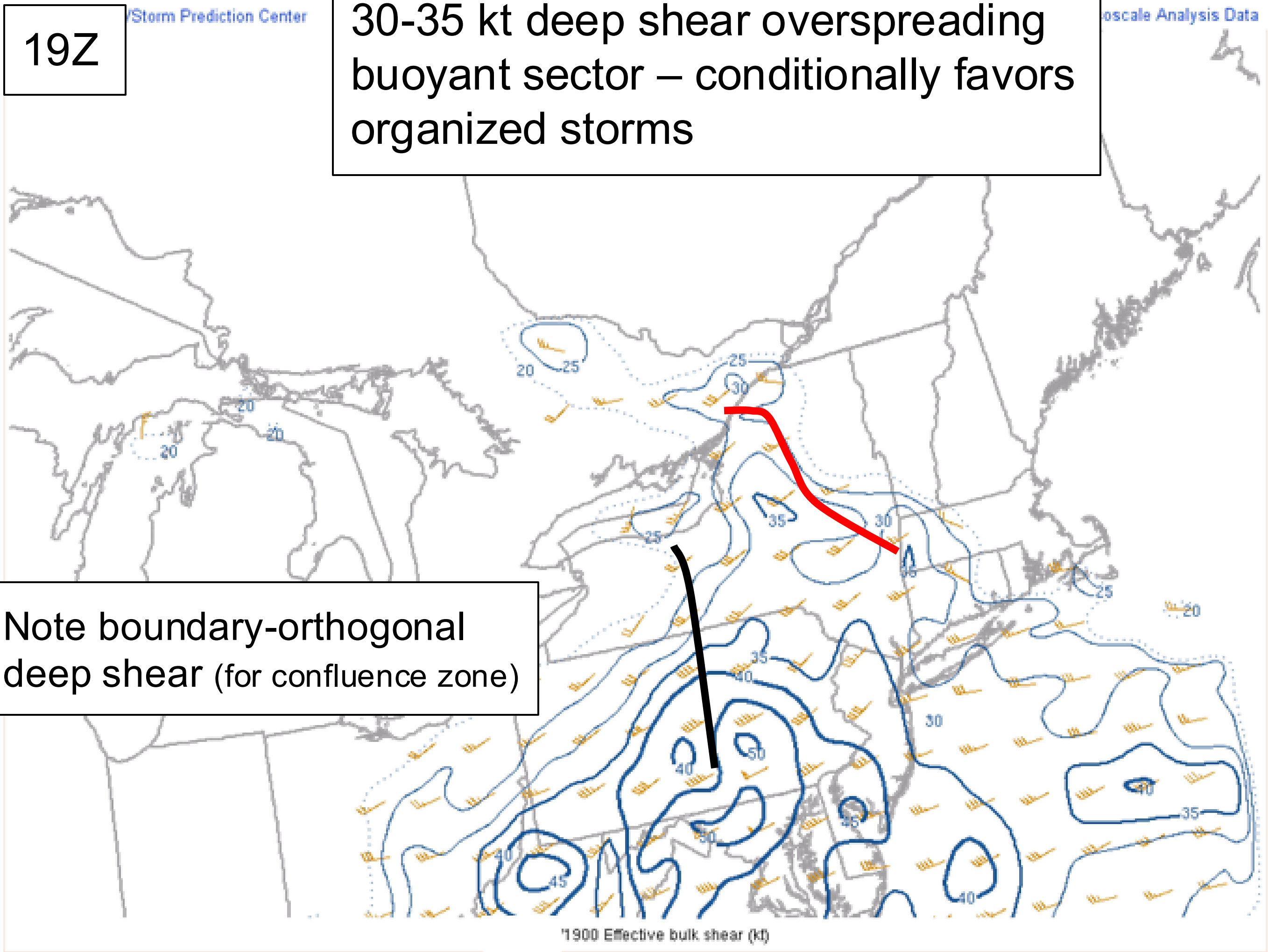
19Z



Moderate (1000-1500 J/kg MLCAPE) instability over warm sector – driven by diurnal heating of moist boundary layer (midlevel lapse rates were generally poor)

19Z

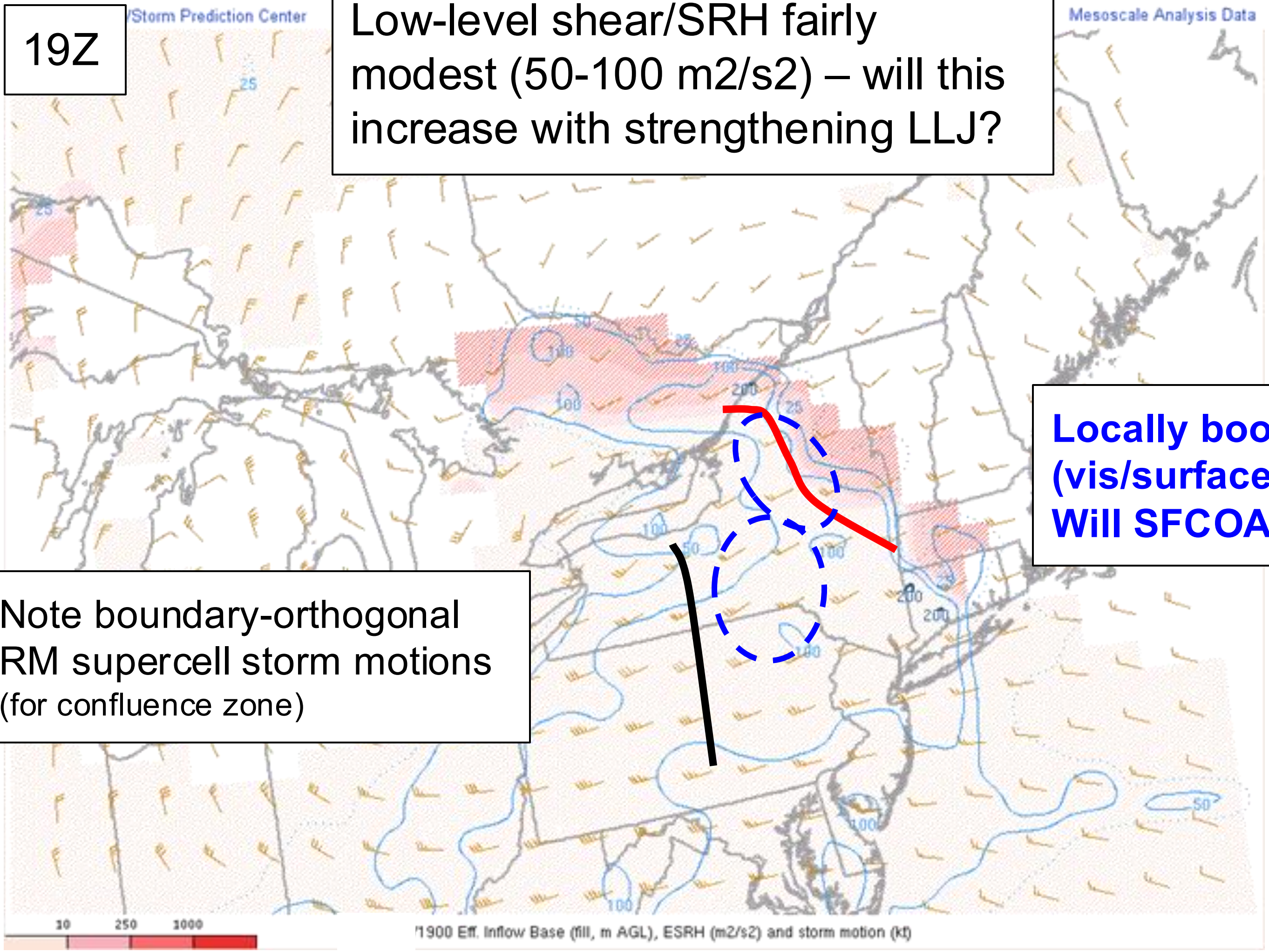
30-35 kt deep shear overspreading buoyant sector – conditionally favors organized storms



Note boundary-orthogonal deep shear (for confluence zone)

19Z

Low-level shear/SRH fairly modest (50-100 m2/s2) – will this increase with strengthening LLJ?

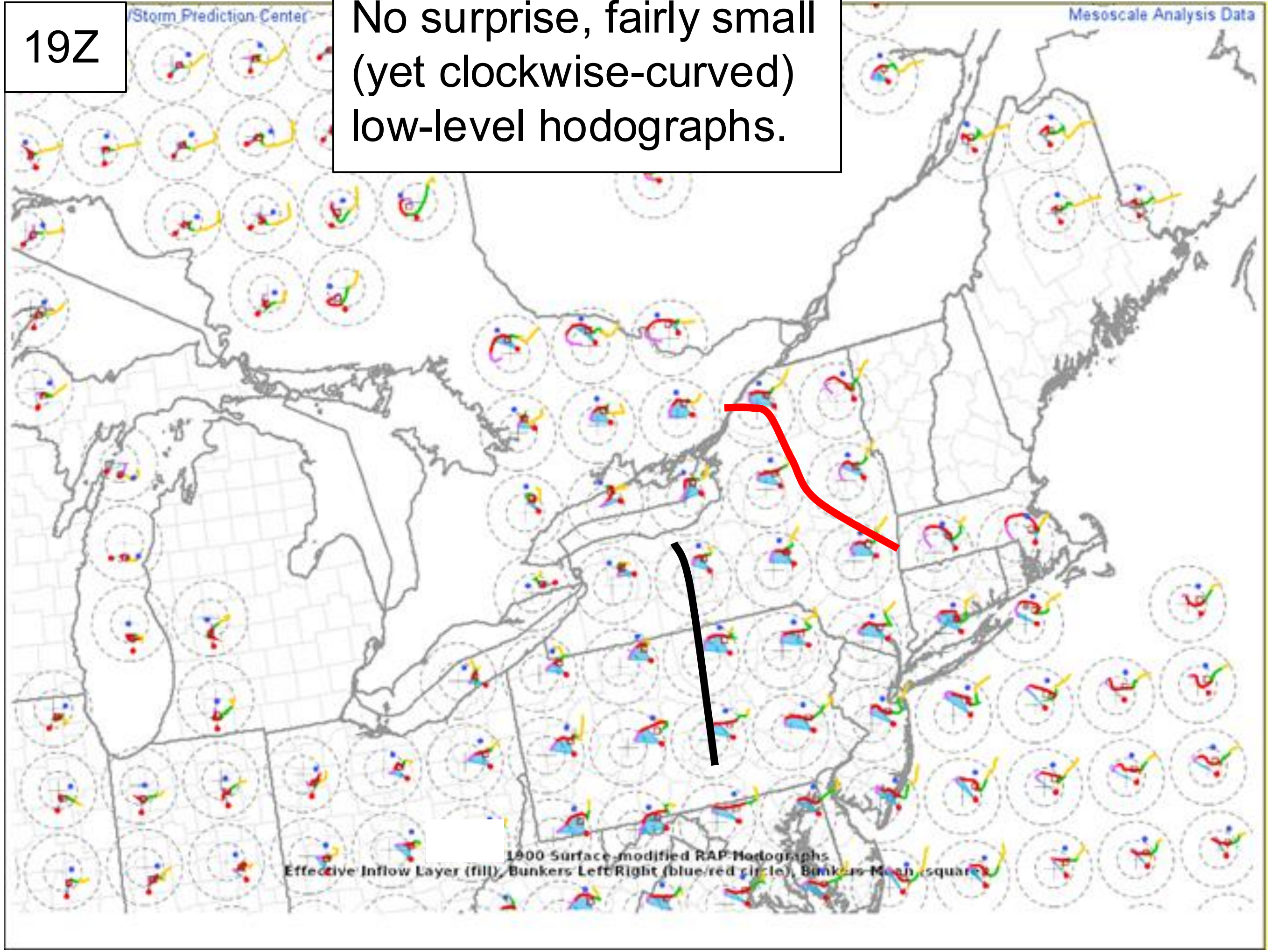


Locally boosted SRH here? (vis/surface analysis). Will SFCOA capture this?

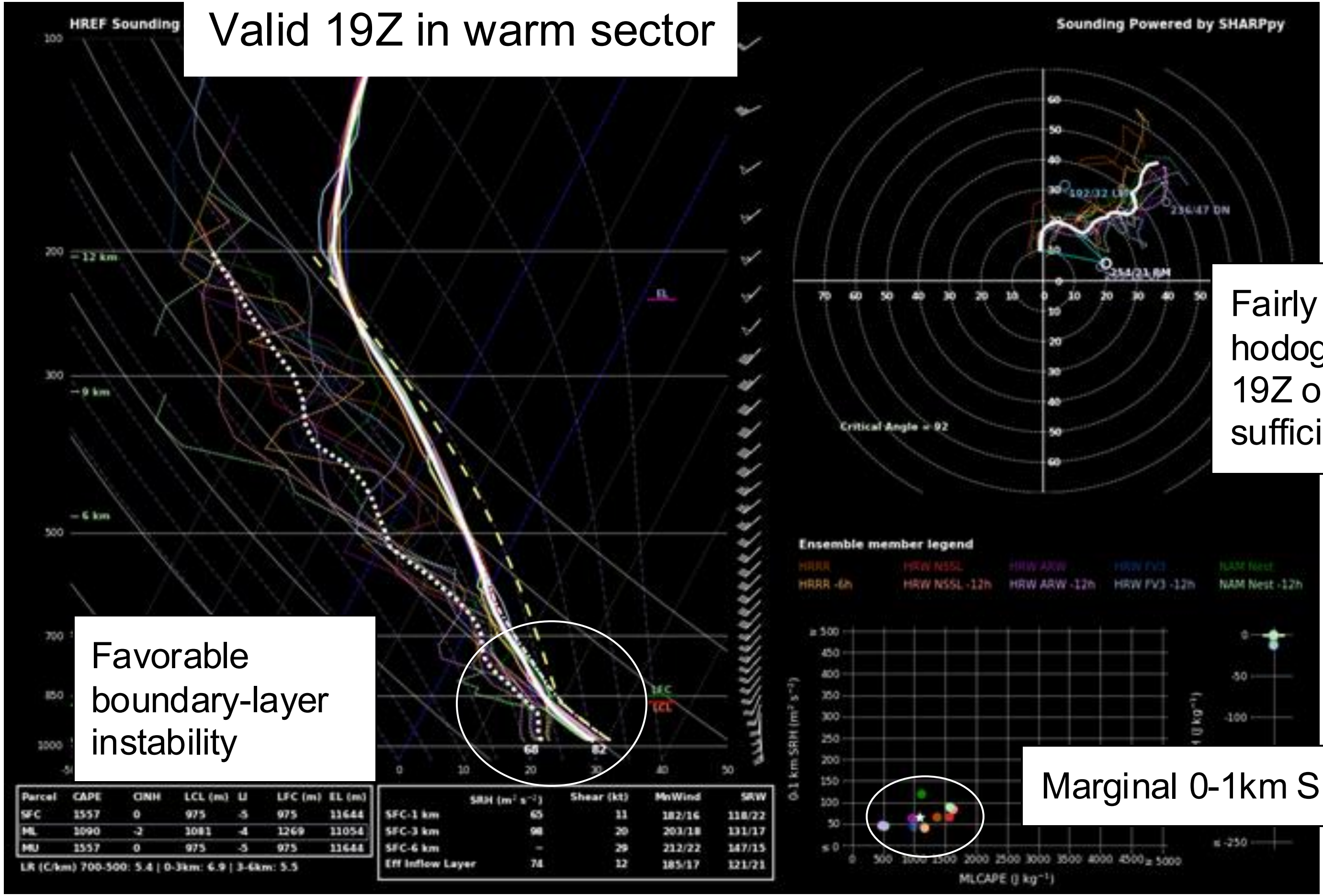
Note boundary-orthogonal RM supercell storm motions (for confluence zone)

19Z

No surprise, fairly small (yet clockwise-curved) low-level hodographs.



<u>Let’s look at some forecast soundings – very helpful!</u>



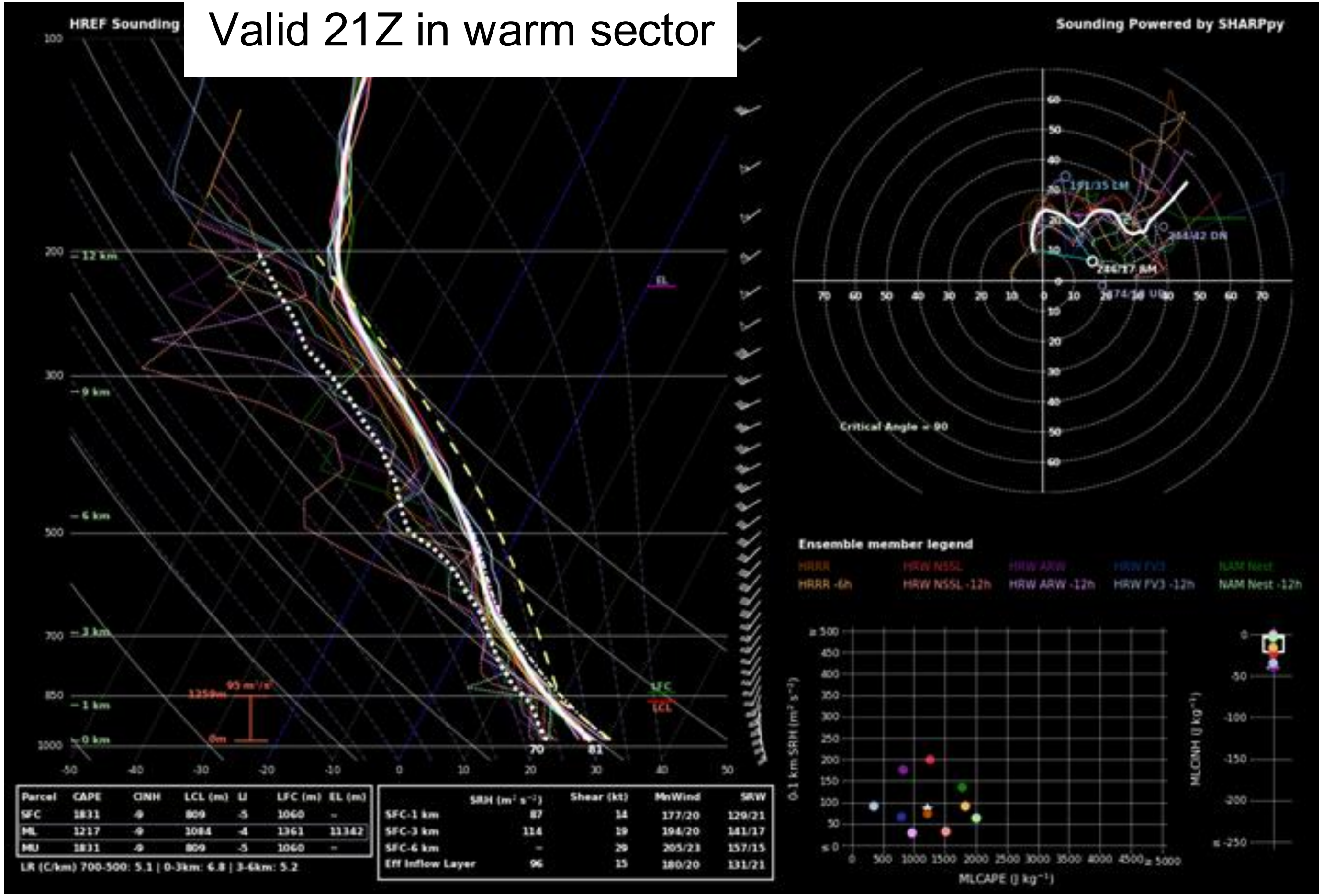
Valid 19Z in warm sector

Fairly small low-level hodograph (as seen in 19Z objective analysis) – sufficient deep shear

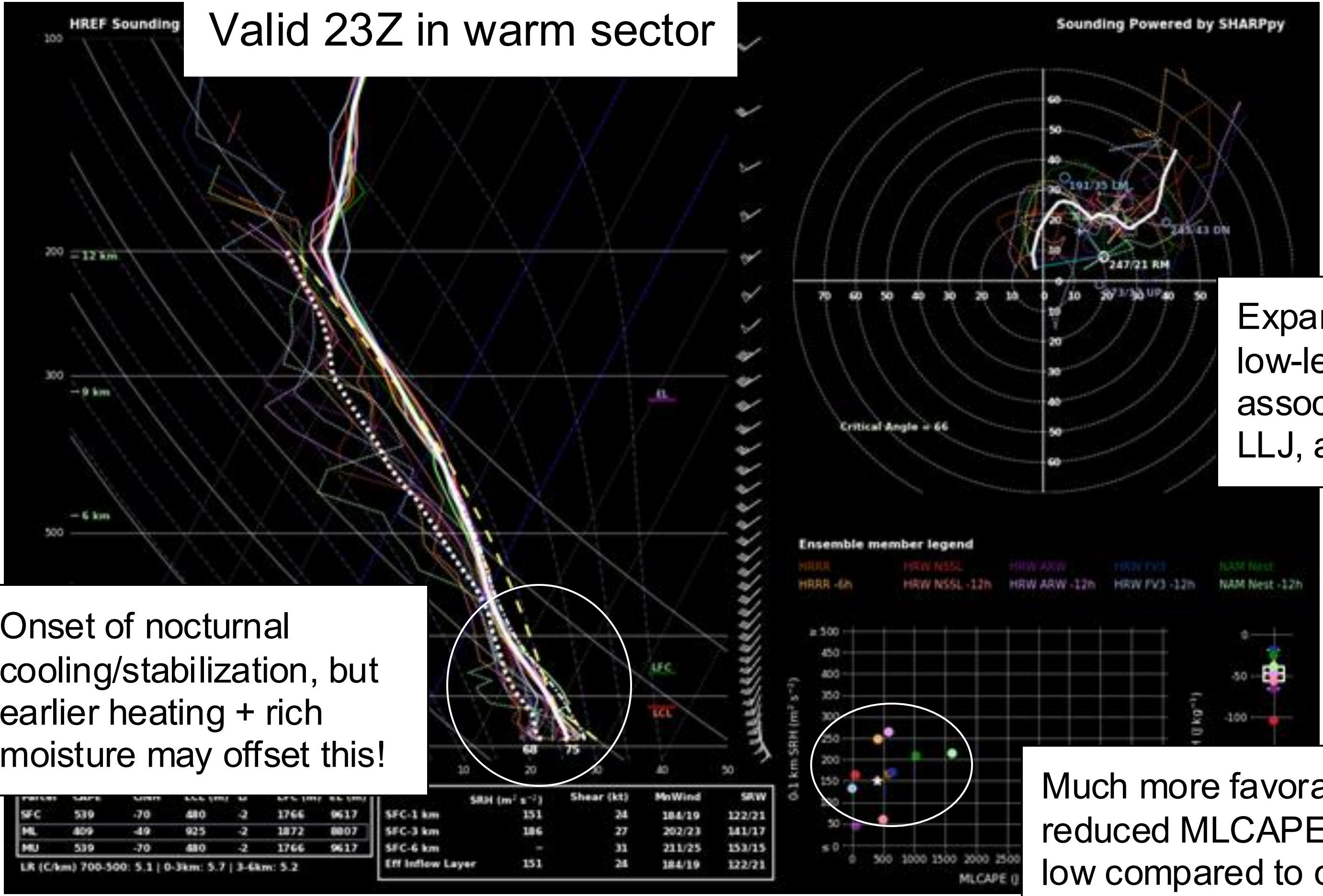
Favorable boundary-layer instability

Marginal 0-1km SRH

Valid 21Z in warm sector



Valid 23Z in warm sector



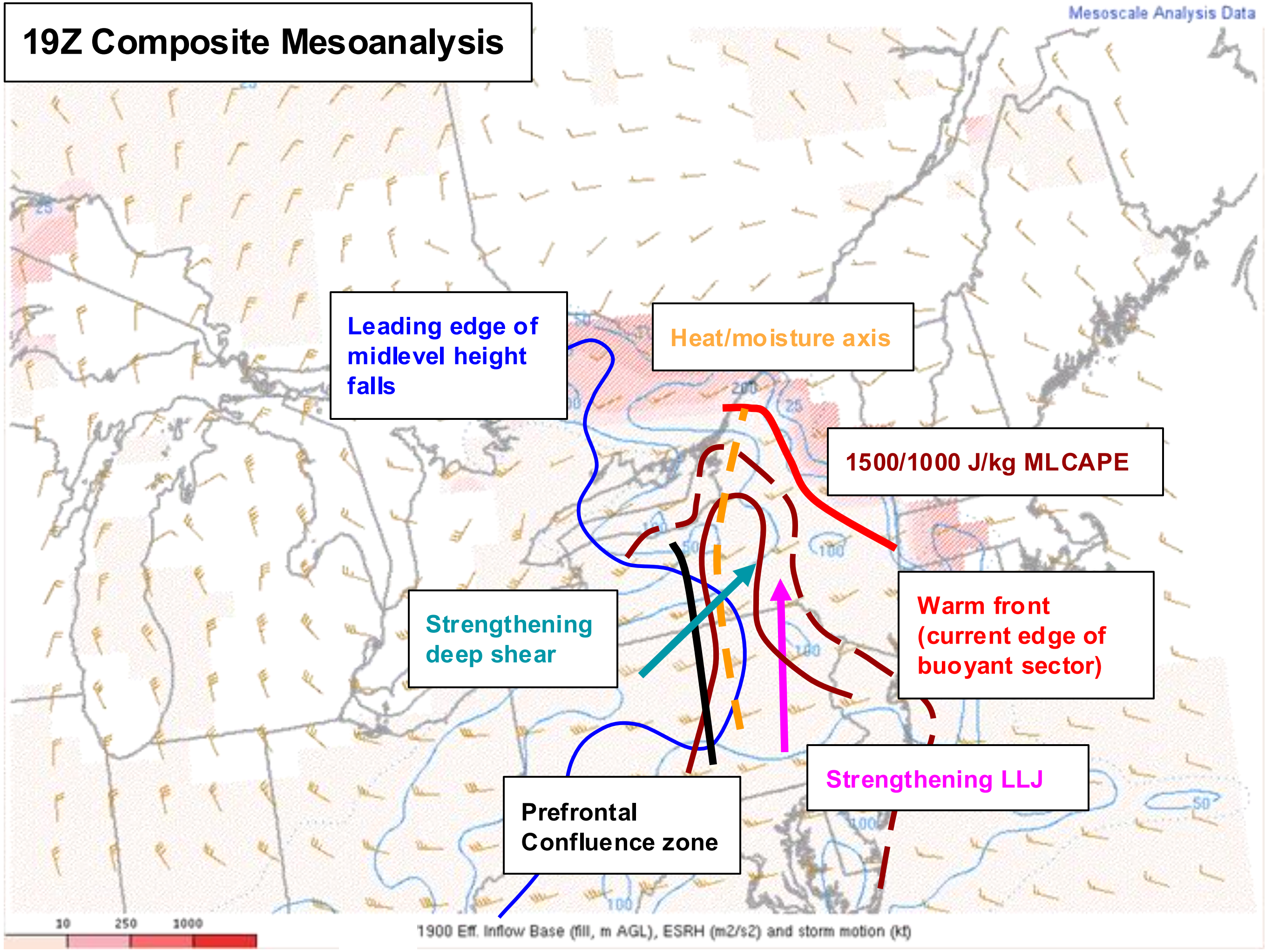
Expanding clockwise-curved low-level hodograph – associated with strengthening LLJ, and stronger deep shear

Onset of nocturnal cooling/stabilization, but earlier heating + rich moisture may offset this!

Much more favorable 0-1km SRH, reduced MLCAPE… (75/68) – too low compared to obs?

Piece it all together into a useful conceptual model!

19Z Composite Mesoanalysis



Weak midlevel height falls/implied DCVA impinging on the warm sector – favors CI AND discrete mode

Prefrontal Confluence zone: Weak density gradient/baroclinic circulation supports separated updrafts/discrete mode

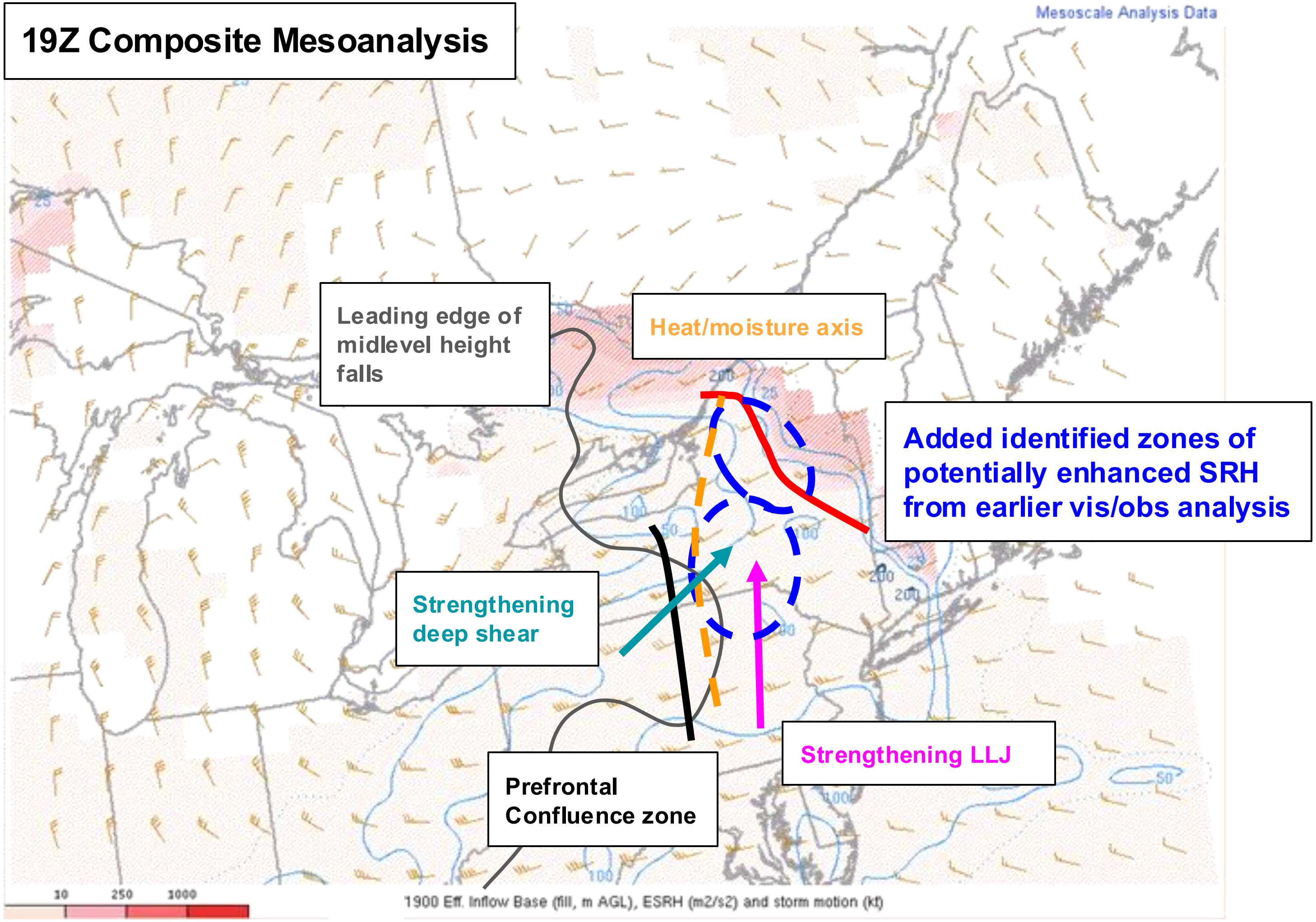
(compare to strongly forced cold front, which would encourage quicker upscale growth)

Strengthening off-boundary deep shear AND storm motions: Storms get OFF the boundary, and given slow-moving boundary, – discrete mode favored

Ample width of buoyant/warm sector – plenty of convective residence time in surface-based buoyancy

Strengthening LLJ yields expanding clockwise-curved low-level hodos – strongly favors RM / sustained discrete mode

19Z Composite Mesoanalysis



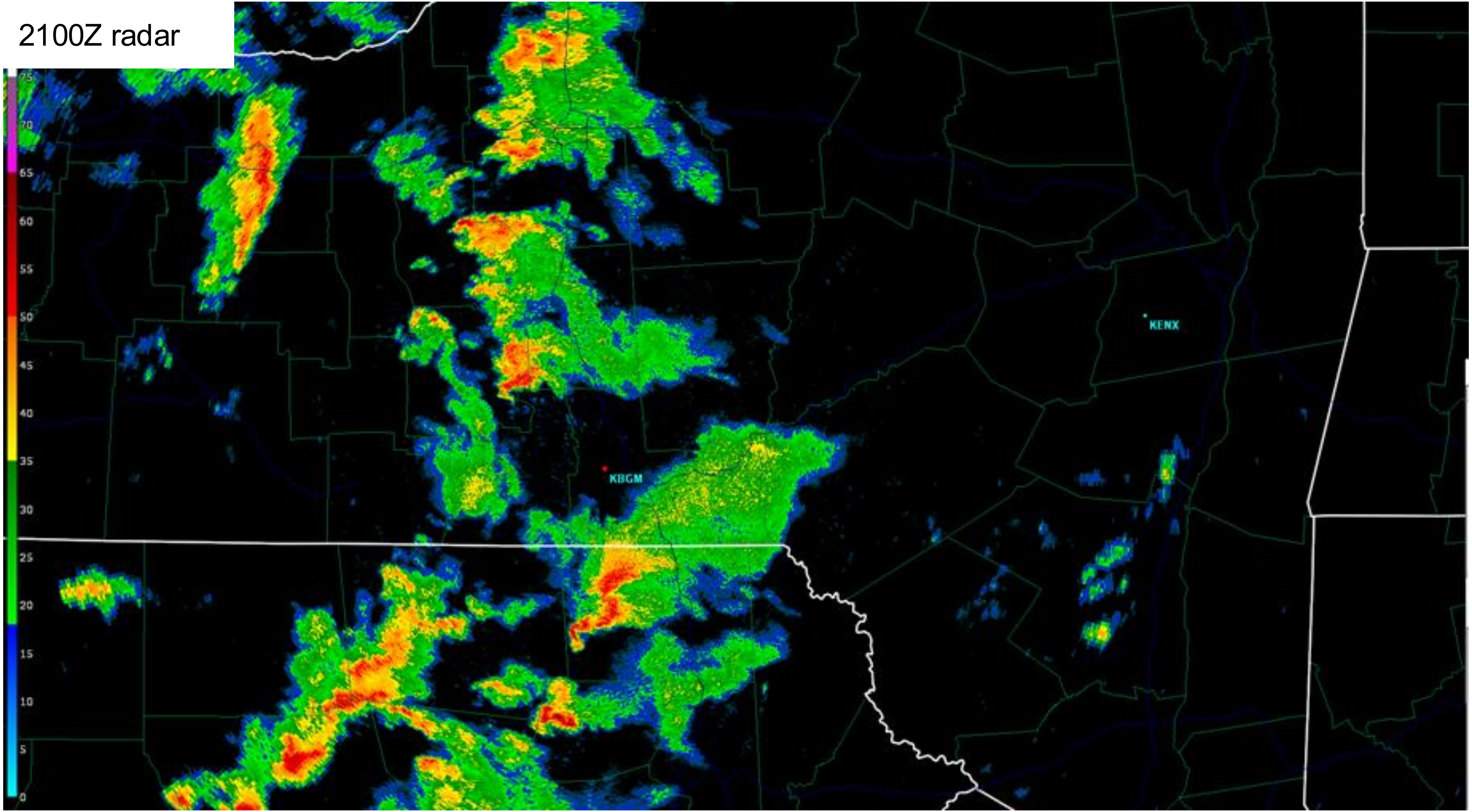
1900Z radar

19Z: Back to our question:

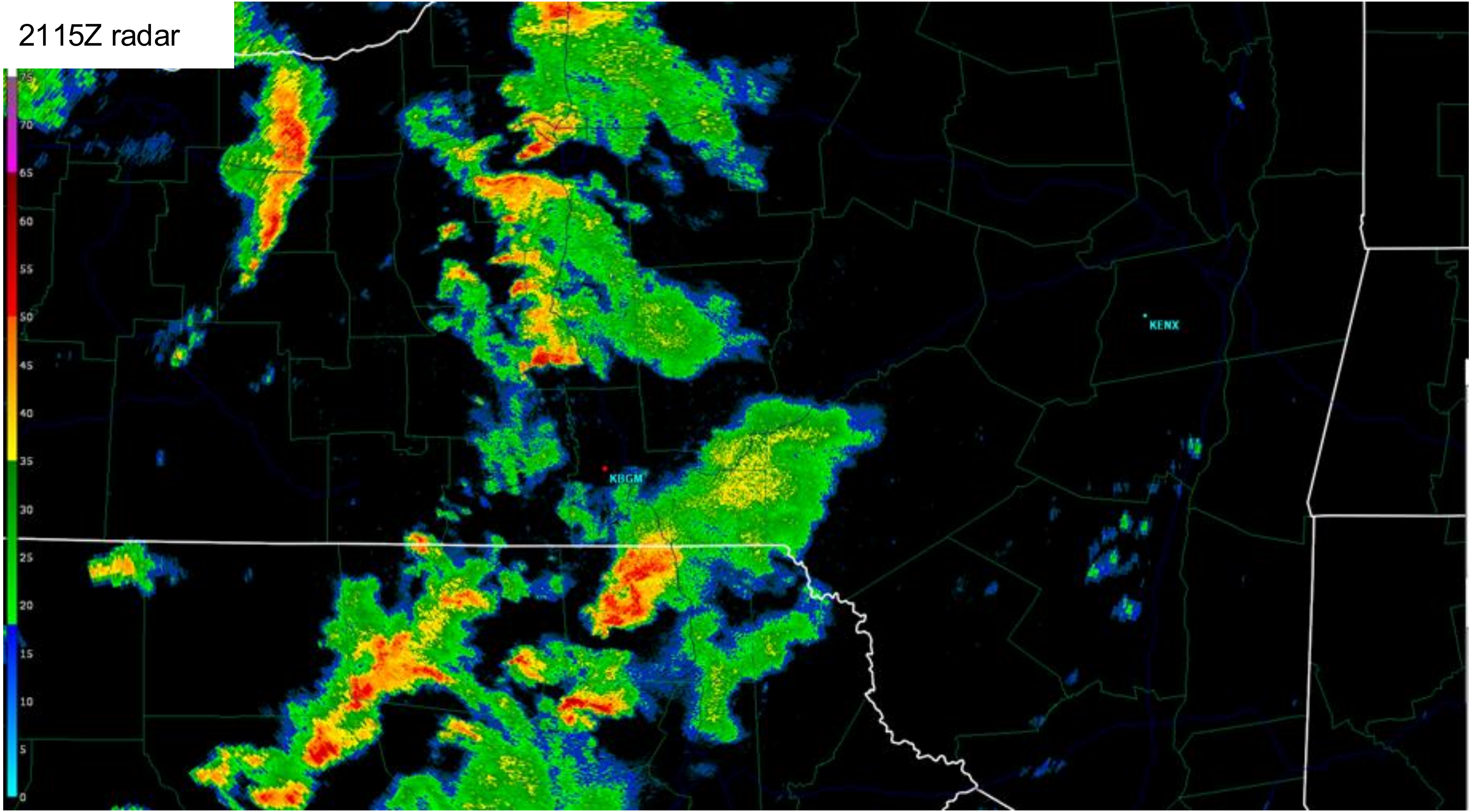
What will the radar look like in the next 1-3 hours?

So what happened?

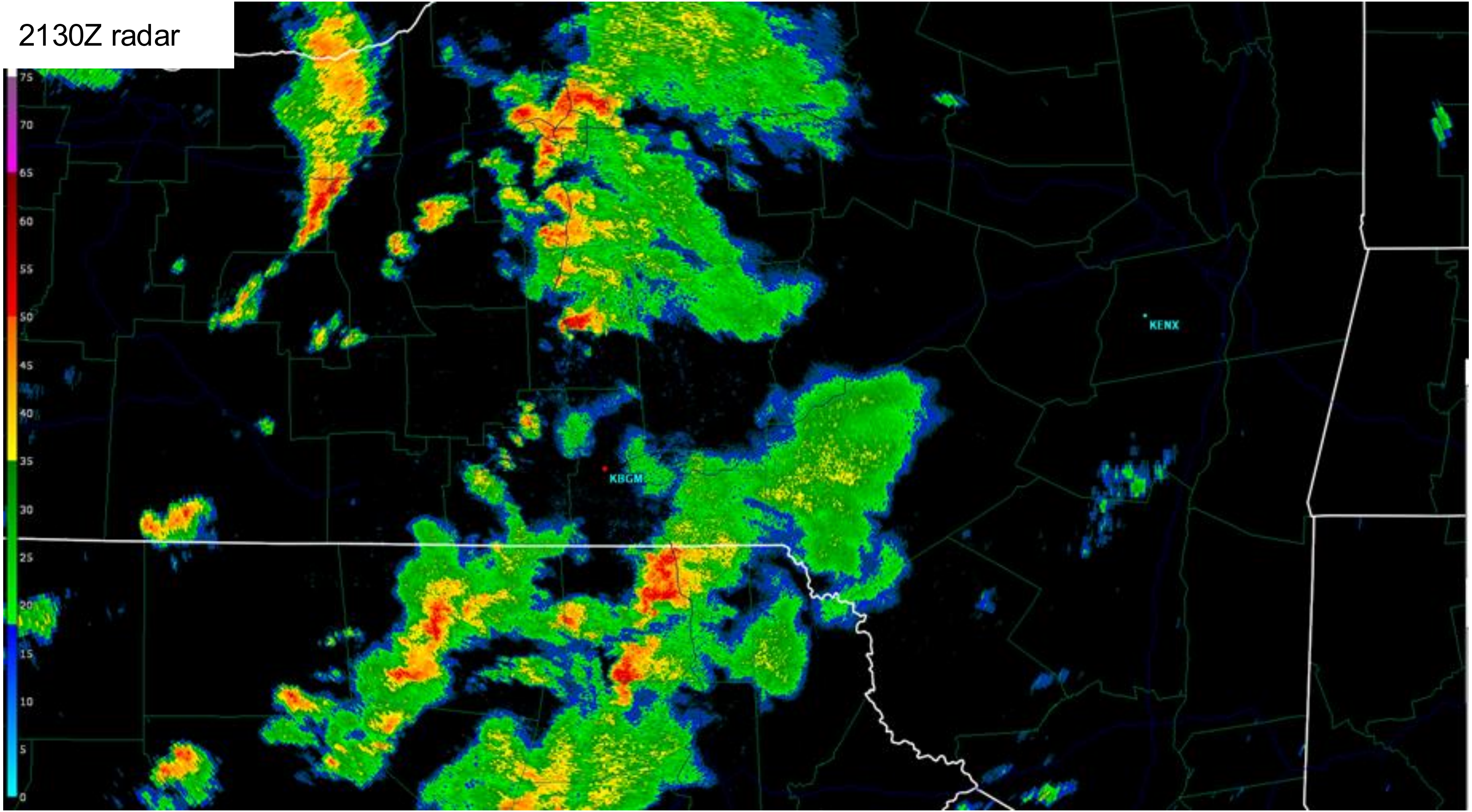
2100Z radar



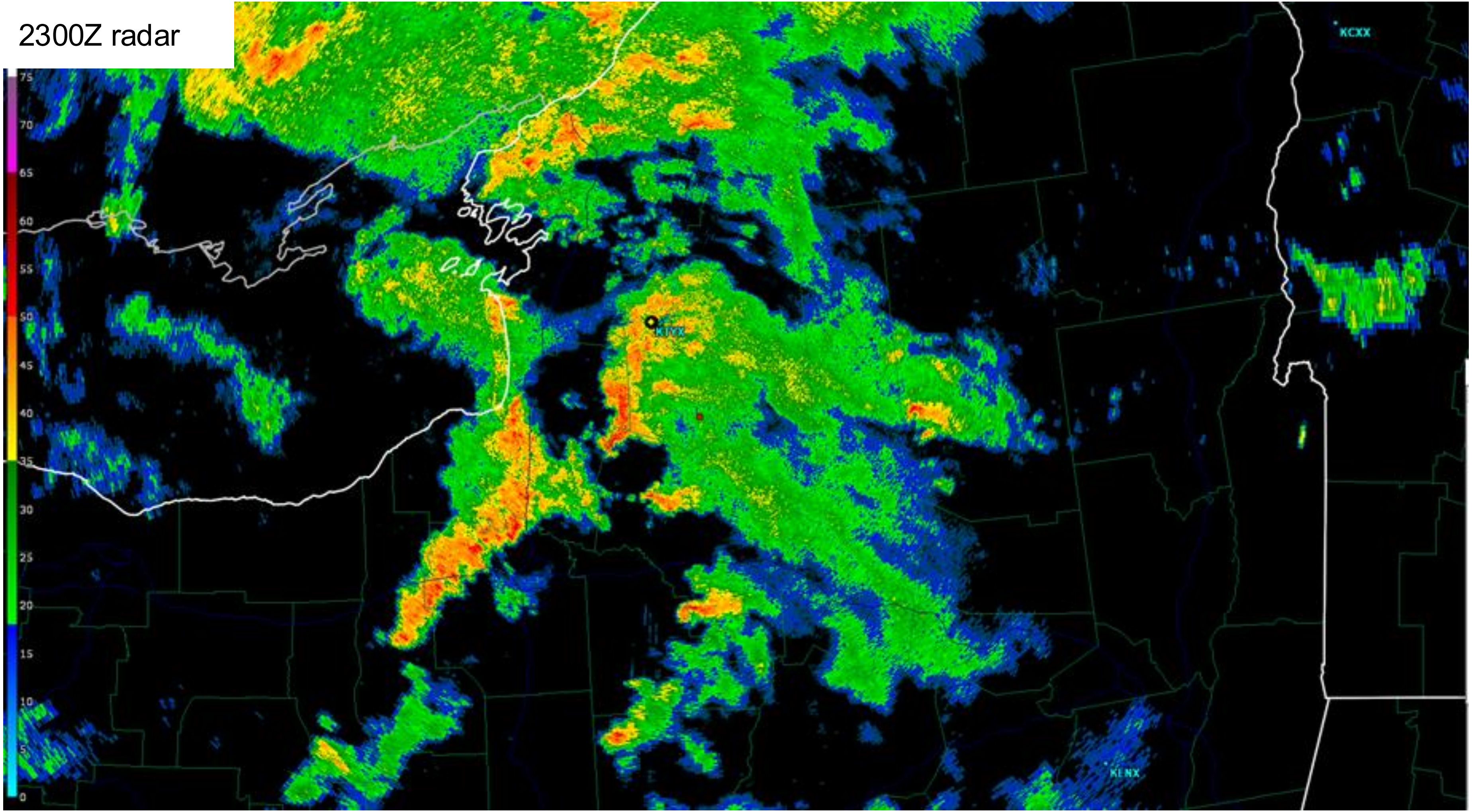
2115Z radar

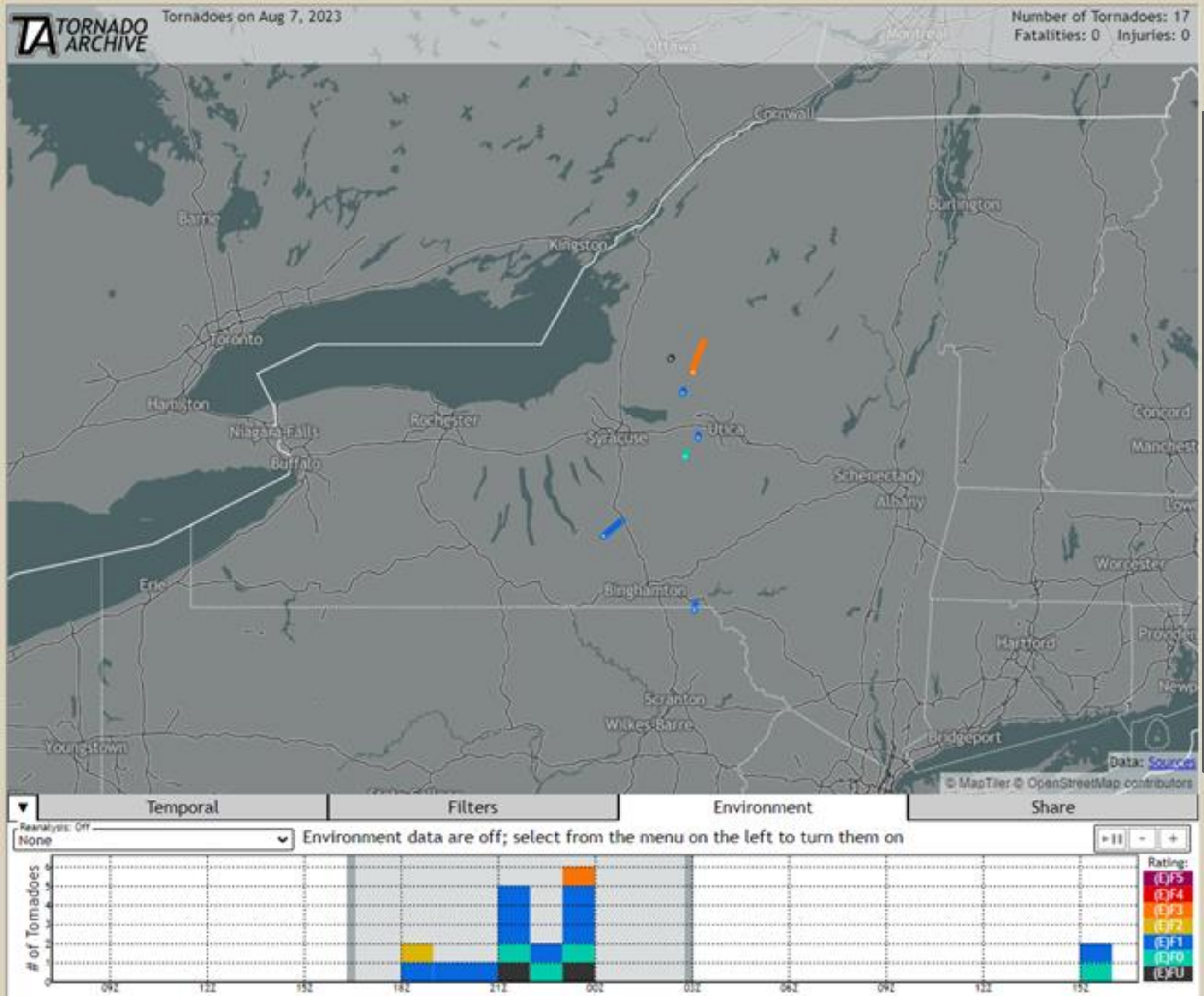


2130Z radar



2300Z radar




TORNADO ARCHIVE
Tornadoes on Aug 7, 2023
Number of Tornadoes: 17
Fatalities: 0 Injuries: 0
Ottawa
Montreal
Cornwall
Burlington
Barrie
Kingston
Toronto
Hamilton
Niagara Falls
Rochester
Syracuse
Utica
Buffalo
Concord
Manchester
Schenectady
Albany
Erie
Binghamton
Worcester
Hartford
Scranton
Wilkes-Barre
Youngstown
Bridgeport
Data: Sources
© MapTiler © OpenStreetMap contributors
Temporal
Filters
Environment
Share
Reanalysis: Off
None
Environment data are off; select from the menu on the left to turn them on
# of Tornadoes
Rating:
(E)F5
(E)F4
(E)F3
(E)F2
(E)F1
(E)F0
(E)FU


Belleville
Kingston
Lake Ontario
NEW YORK
Rochester
Utica
Syracuse
Binghamton
CATSKILL MOUNTAINS
Scranton