SCP & STP

The Parameters of all Parameters!*

*If used correctly under the conditions outlined herein. Users assume full responsibility when utilizing these (and all) convective parameters.

Material created by Rich Thompson

Arranged by Andrew Moore/Lyons

What is a composite parameter?

What is a parameter?

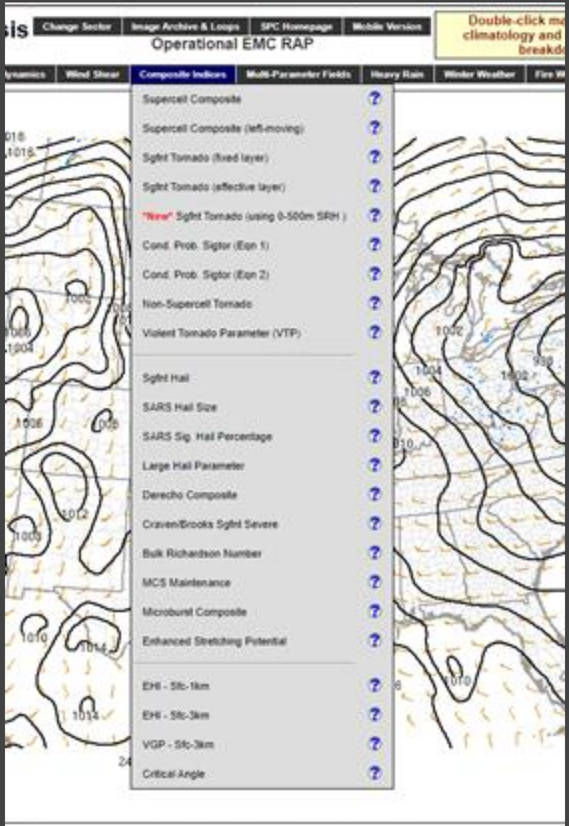
A numerical or other measurable factor forming one of a set that defines a system or sets the conditions of its operation.

In meteorology:

An equation or multiple sets of equations that produce a scaled numerical output based on one or more numerical inputs. Usually produced by mixing forecast inputs to get a useful output.

Examples:

- Significant Hail parameter
- Derecho Composite
- Non-Supercell Tornado
- SHERBE
- EHI (Energy Helicity Index)
- Numerous other forecast examples.



SCP & STP

What are they?

Supercell **C**omposite **P**arameter

Significant **T**ornado **P**arameter

Thompson et al. 2004

Thompson et al. 2012

SCP & STP

What are they?

Convective parameters that try to discriminate between environments that can support right-moving supercells (SCP) and the associated threat for significant (EF-2+) tornadoes (STP).

(i.e. the most impactful convection!)

SCP & STP

In general, these parameters work well when used appropriately, but let's take a closer look at:

- How they're derived
- When to use them
- Nuances

SCP

Recall what is needed for a supercell:

- An initial updraft (buoyancy)
- Vertical wind shear

↓

- The updraft tilts and stretches ambient environmental horizontal vorticity
- Leads to mesocyclone development and supports a stronger, longer-lived storm.

SCP

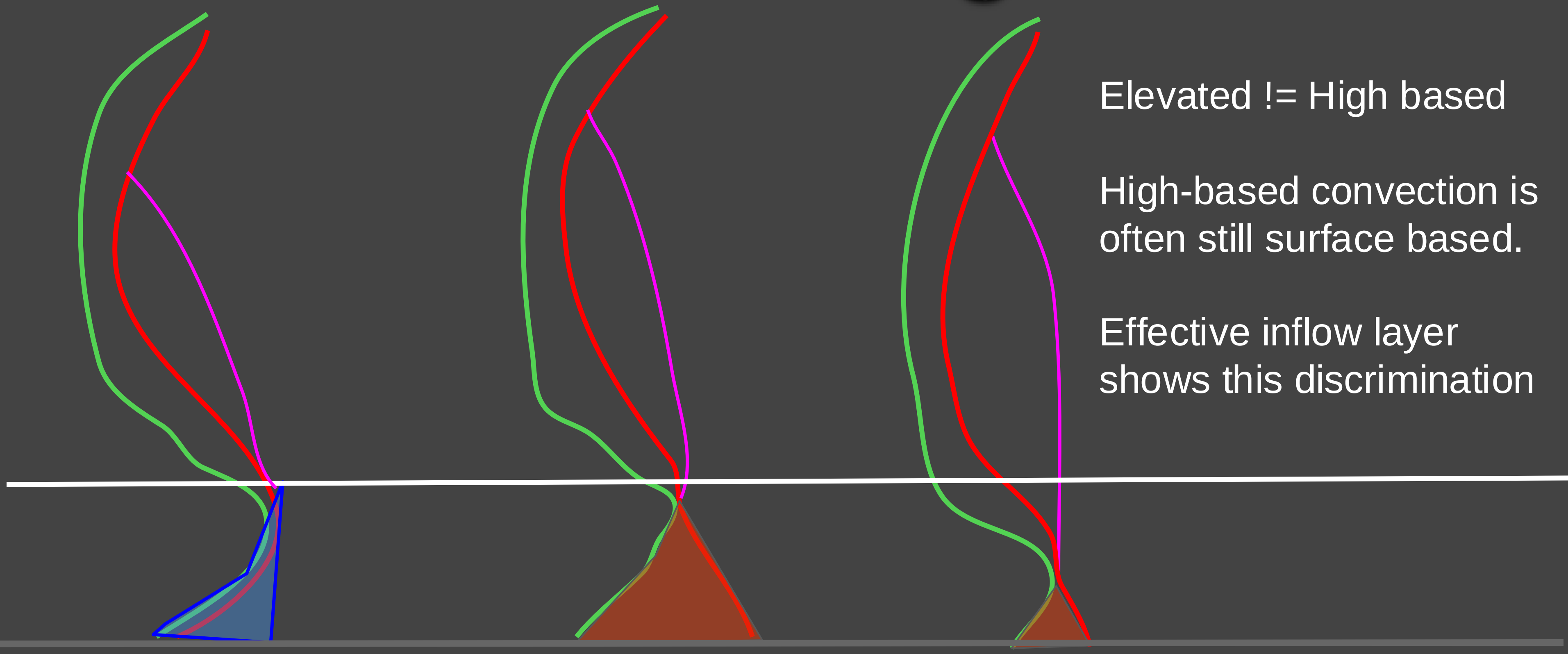
Let’s consider each:

Buoyancy - Easy! We already know how to calculate that!

SBCAPE **MLCAPE** **MUCAPE**

But which one to use?

Elevated vs. high based



Elevated != High based

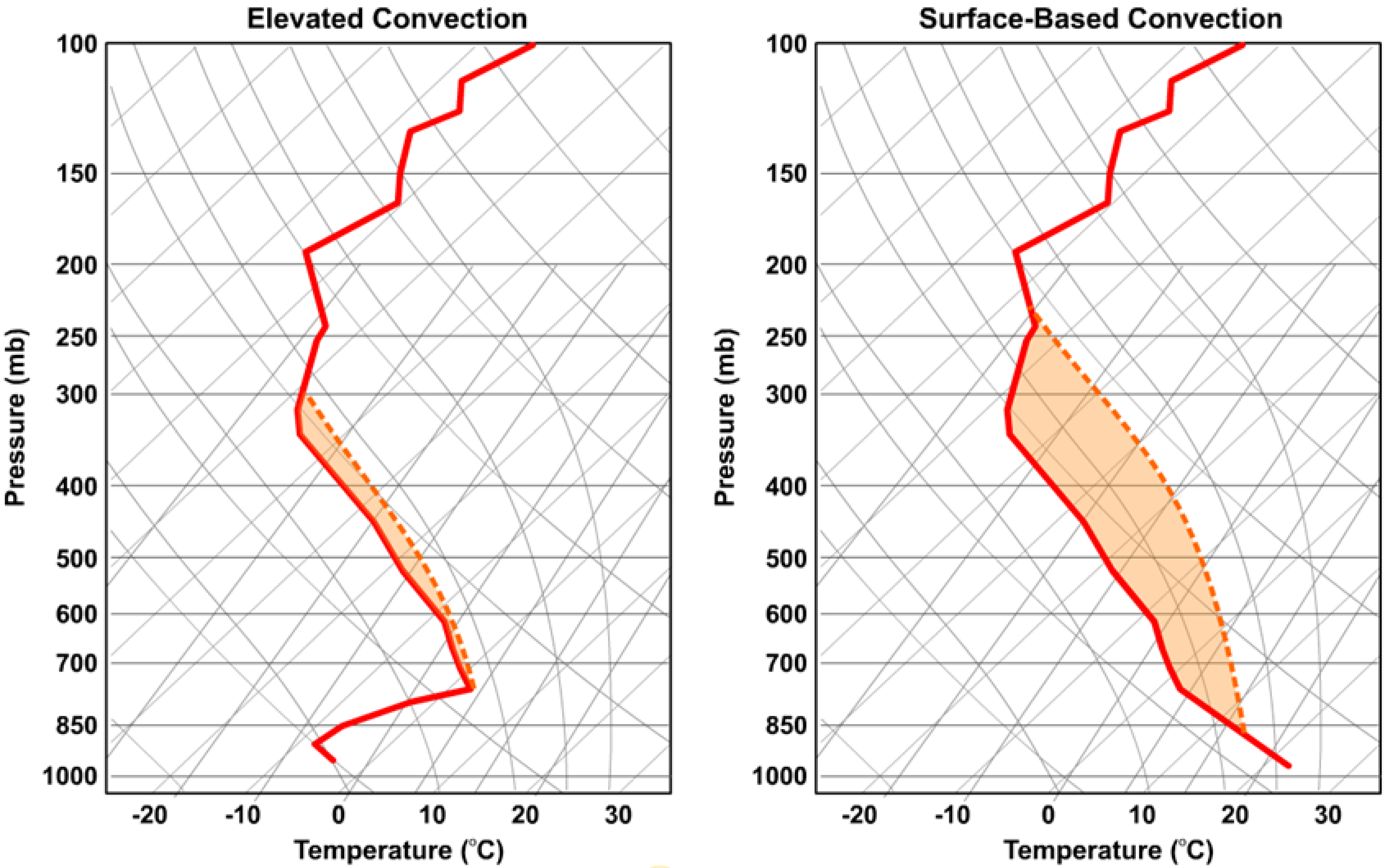
High-based convection is often still surface based.

Effective inflow layer shows this discrimination

Cold stable layer
<u>Elevated Convection</u>

<u>Surface High-based</u>
mixed PBL High LCL

Surface based
mixed PBL Low LCL


Elevated Convection
Surface-Based Convection
Pressure (mb)
100
150
200
250
300
400
500
600
700
850
1000
-20
-10
0
10
20
30
Temperature (°C)

SCP

Let’s consider each:

Buoyancy - Easy! We already know how to calculate that!

SBCAPE **MLCAPE** **MUCAPE**

We’ll use MUCAPE to capture all thunderstorm environments

SCP

Let's consider each:

Vertical wind shear - Also easy!

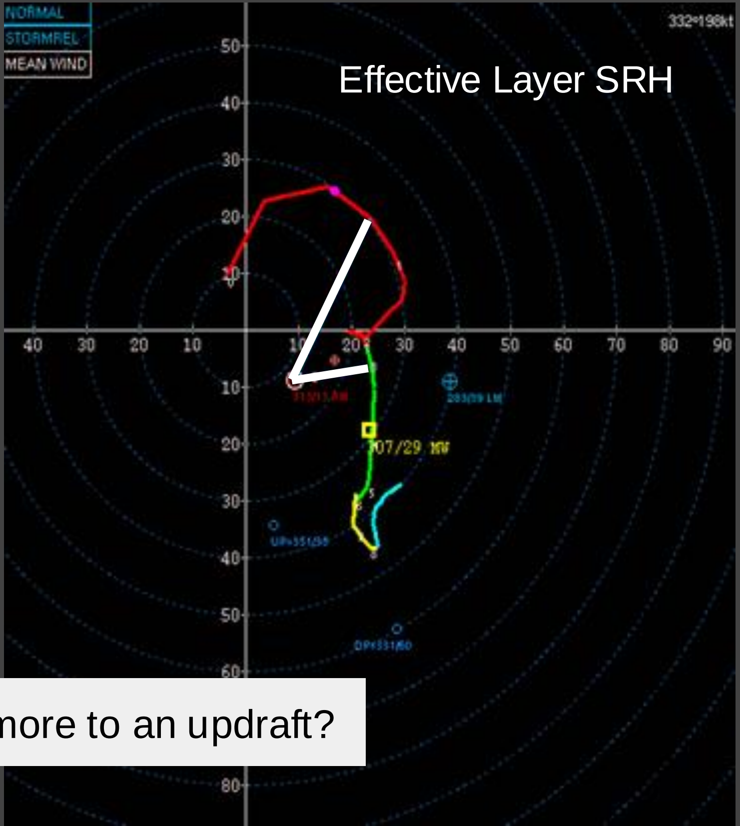
0-6 km BWD | Effective BWD | 0-1 km SRH | 0-3 km SRH | Effective SRH

Favorable for organized convection (0-6 km BWD, Effective BWD)

Favorable for supercells (target phenomenon) (0-1 km SRH, 0-3 km SRH, Effective SRH)

We'll use Effective BWD and Effective SRH since they capture shallow and deep buoyancy environments as well as elevated thunderstorm environments.

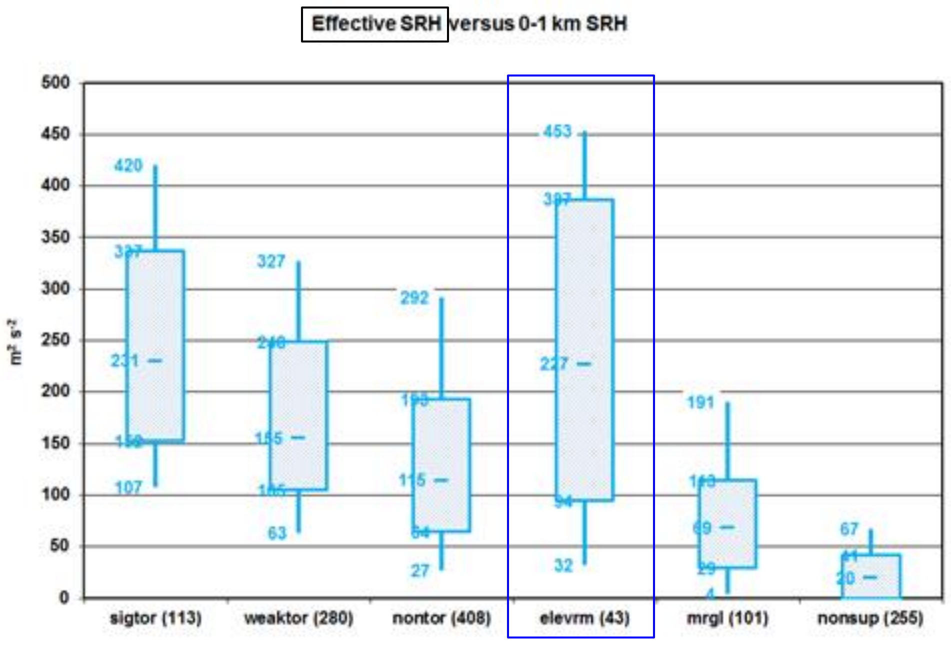
Low-level shear



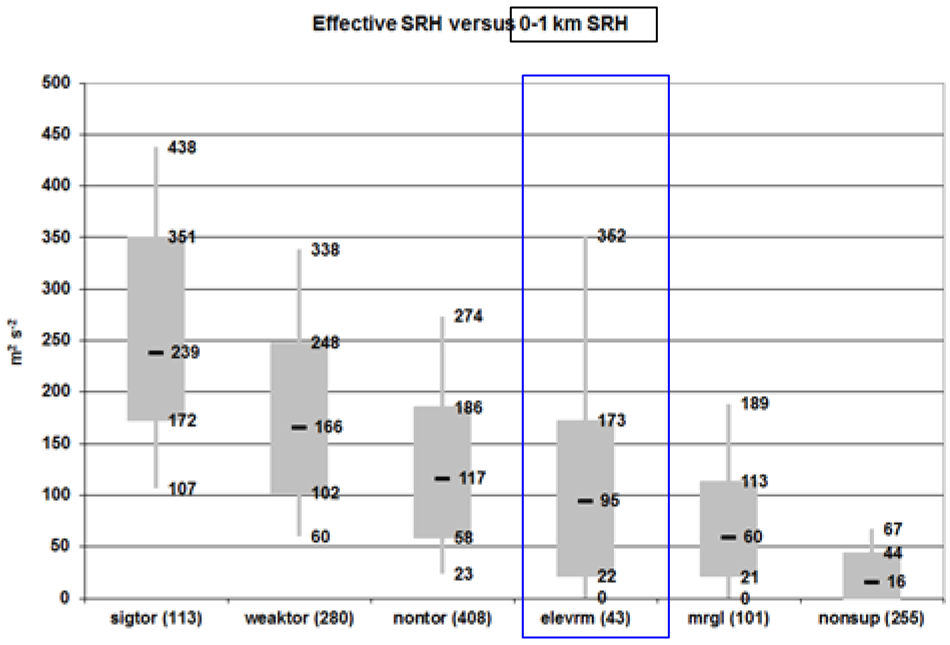
Which is going to matter more to an updraft?

Low-level shear

0-1 km SRH



Effective Layer SRH



SCP

Three steps involved:

- Combine terms of buoyancy and shear that are relevant to supercell formation.

- Normalize these terms to climatological distributions

- Combine the terms for a final product

SCP

Three steps involved:

- Combine terms of buoyancy and shear that are relevant to supercell formation.
- Normalize these terms to climatological distributions
- Combine the terms for a final product

SCP

SCP = f(MUCAPE, MUCIN, EBWD, ESRH)

Measure of instability

Measure of inhibition

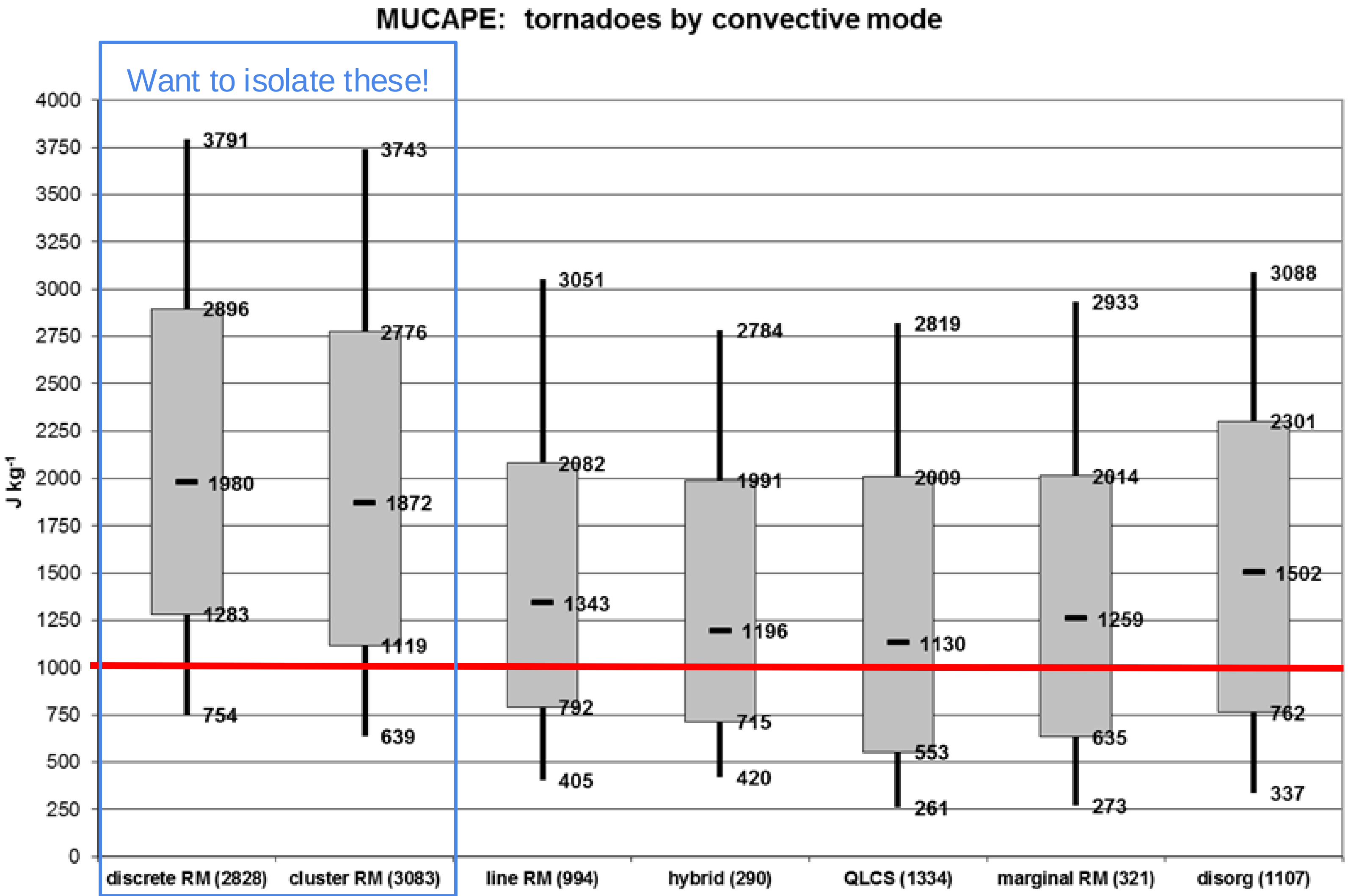
Deep-layer shear

Low-level shear

SCP

Three steps involved:

- Combine terms of buoyancy and shear that are relevant to supercell formation.
- Normalize these terms to climatological distributions
- Combine the terms for a final product


MUCAPE: tornadoes by convective mode
Want to isolate these!
J kg-1
4000
3750
3500
3250
3000
2750
2500
2250
2000
1750
1500
1250
1000
750
500
250
0
3791
2896
1980
1283
754
3743
2776
1872
1119
639
3051
2082
1343
792
405
2784
1991
1196
715
420
2819
2009
1130
553
261
2933
2014
1259
635
273
3088
2301
1502
762
337
discrete RM (2828)
cluster RM (3083)
line RM (994)
hybrid (290)
QLCS (1334)
marginal RM (321)
disorg (1107)

SCP

$$SCP = f\left(\frac{MUCAPE}{1000}, MUCIN, EBWD, ESRH\right)$$

MUCAPE <= 1000: term = 0 to 1.0

MCAPE > 1000: term = 1.0+

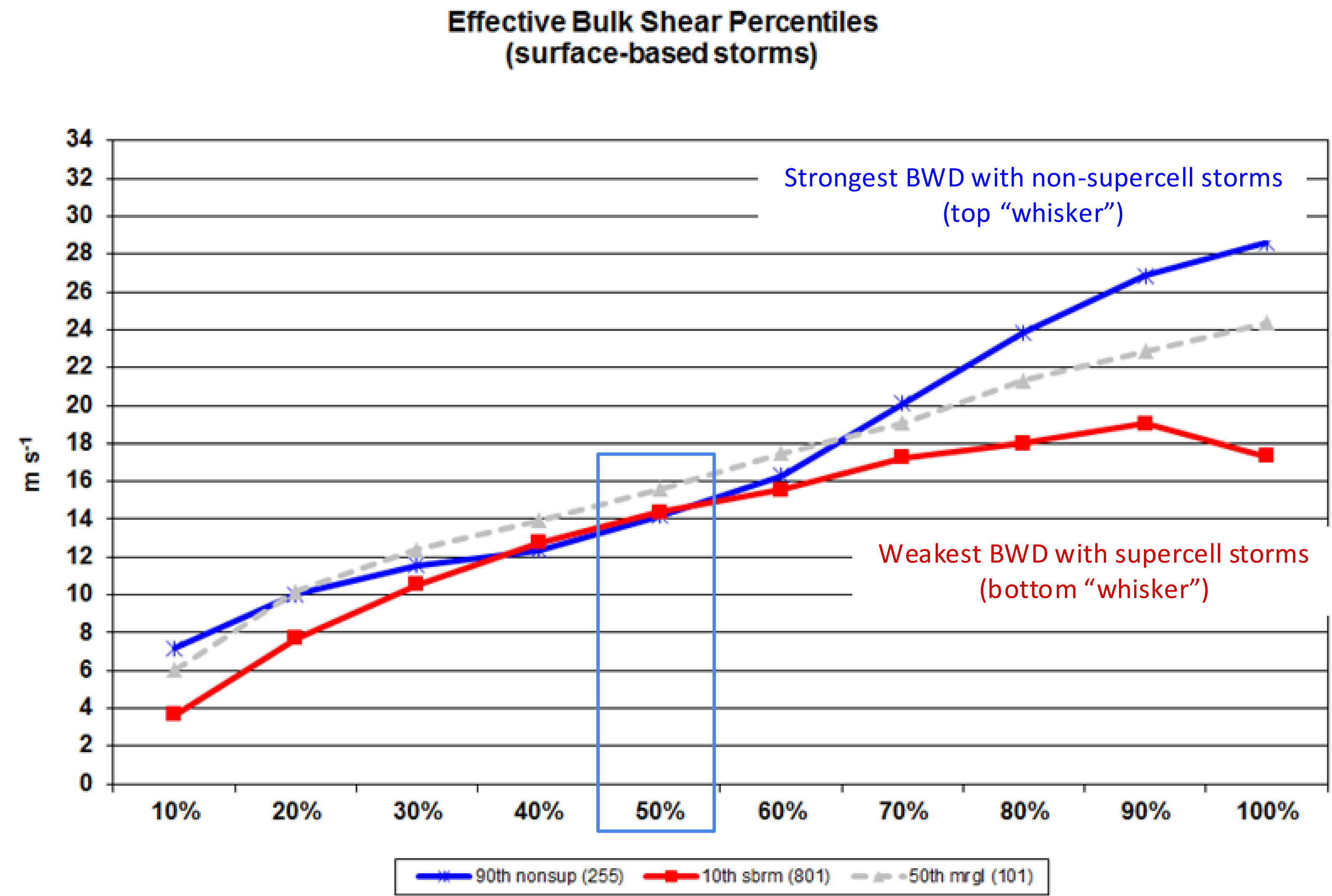
SCP

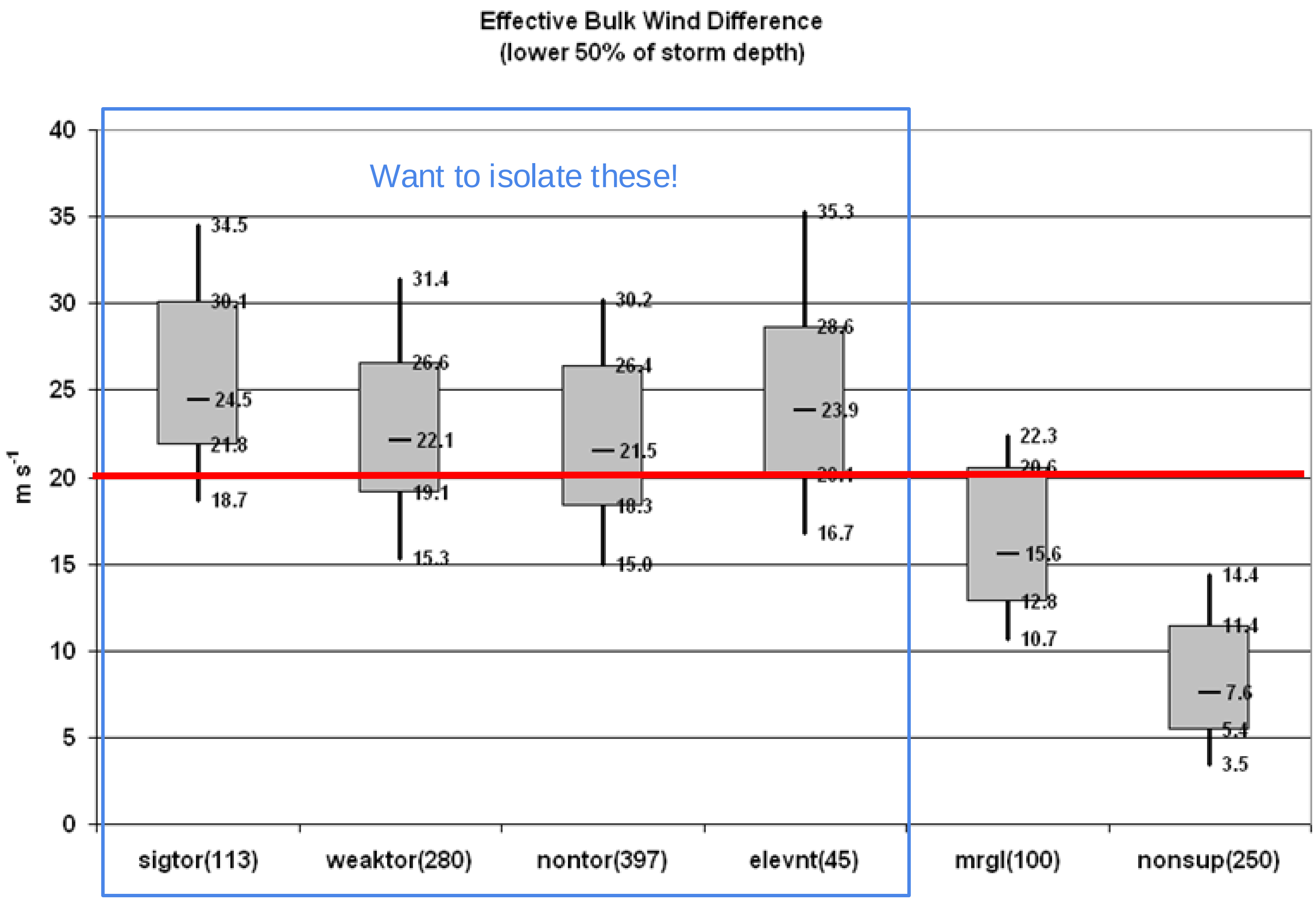
$$SCP = f\left(\frac{MUCAPE}{1000}, \frac{-40}{MUCIN}, EBWD, ESRH\right)$$

MUCIN > -40: term = 1.0

MUCIN <= -40: term 0.0 to 1.0

(term decreases with increasing MUCIN)


Effective Bulk Shear Percentiles
(surface-based storms)
Strongest BWD with non-supercell storms
(top "whisker")
Weakest BWD with supercell storms
(bottom "whisker")
m s-1
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
90th nonsup (255)
10th sbrm (801)
50th mrgl (101)



Effective Bulk Wind Difference
(lower 50% of storm depth)
Want to isolate these!
m s-1
40
35
30
25
20
15
10
5
0
34.5
30.1
24.5
21.8
18.7
31.4
26.6
22.1
19.1
15.3
30.2
26.4
21.5
18.3
15.0
35.3
28.6
23.9
20.1
16.7
22.3
20.6
15.6
12.8
10.7
14.4
11.4
7.6
5.4
3.5
sigtor(113)
weaktor(280)
nontor(397)
elevnt(45)
mrgl(100)
nonsup(250)

SCP

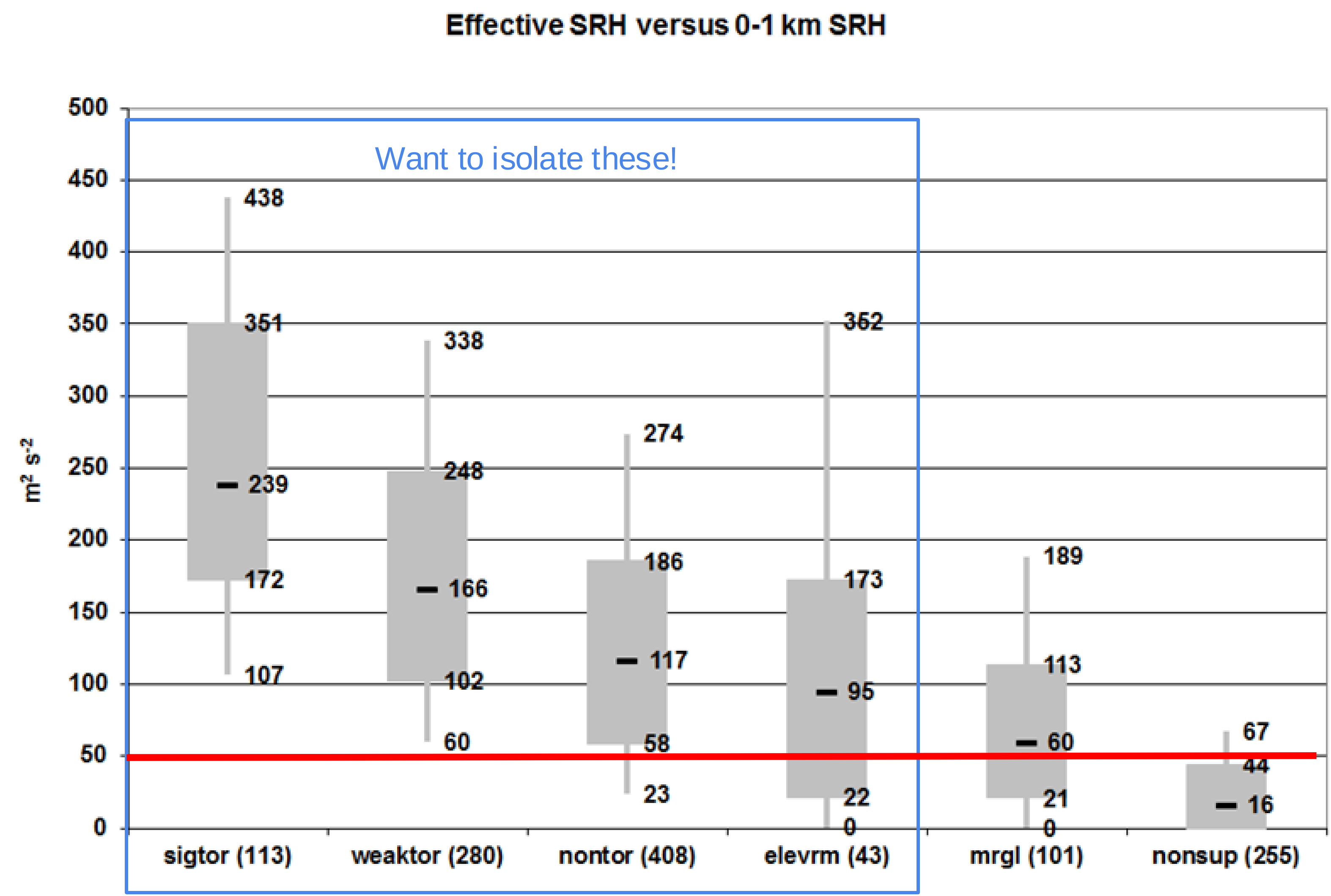
$$SCP = f\left(\frac{MUCAPE}{1000}, \frac{-40}{MUCIN}, \frac{EBWD}{20}, ESRH\right)$$

EBWD >= 20: term = 1.0

10 < EBWD < 20: term 0.0 to 1.0

EBWD < 10: term = 0.0

Note:
This is done so that environments with very high shear/very low CAPE don't give false alarms (think bulk Richardson #).



Effective SRH versus 0-1 km SRH
Want to isolate these!
m² s⁻²
500
450
400
350
300
250
200
150
100
50
0
438
351
239
172
107
338
248
166
102
60
274
186
117
58
23
352
173
95
22
0
189
113
60
21
0
67
44
16
sigtor (113)
weaktor (280)
nontor (408)
elevrm (43)
mrgl (101)
nonsup (255)

SCP

$$SCP = f\left(\frac{MUCAPE}{1000}, \frac{-40}{MUCIN}, \frac{EBWD}{20}, \frac{ESRH}{50}\right)$$

ESRH <= 50: term = 0.0 to 1.0

ESRH > 50: term = 1.0+

SCP

Three steps involved:

- Combine terms of buoyancy and shear that are relevant to supercell formation.

- Normalize these terms to climatological distributions

- Combine the terms for a final product

SCP

$$SCP = \frac{MUCAPE}{1000} * \frac{-40}{MUCIN} * \frac{EBWD}{20} * \frac{ESRH}{50}$$

Multiplying the terms allows for:

- One (or more) terms to compensate for a weakness

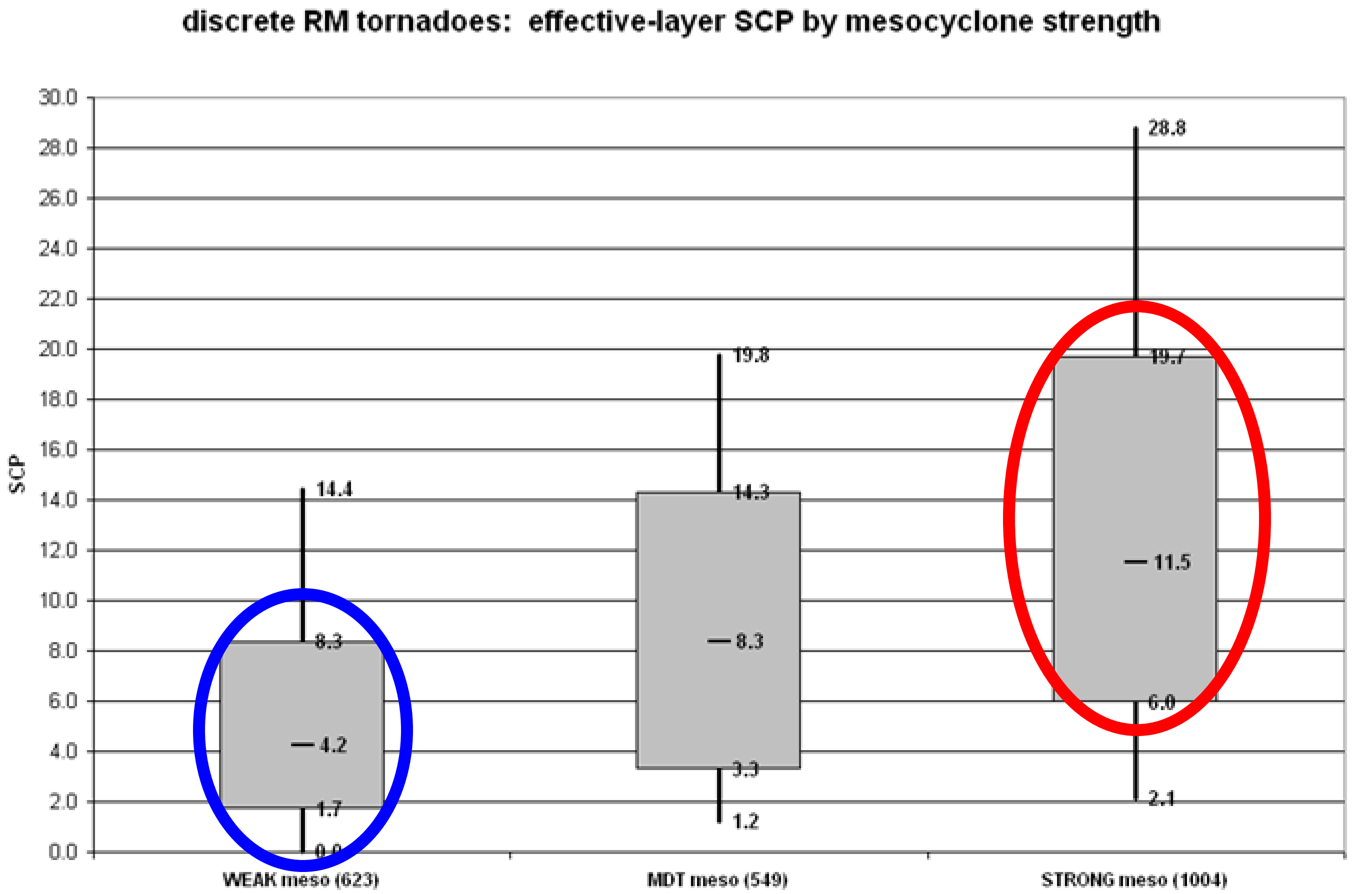
- The parameter to go to zero if one term is not in place
  - (ex: no CAPE)

SCP

$$SCP = \frac{MUCAPE}{1000} * \frac{-40}{MUCIN} * \frac{EBWD}{20} * \frac{ESRH}{50}$$

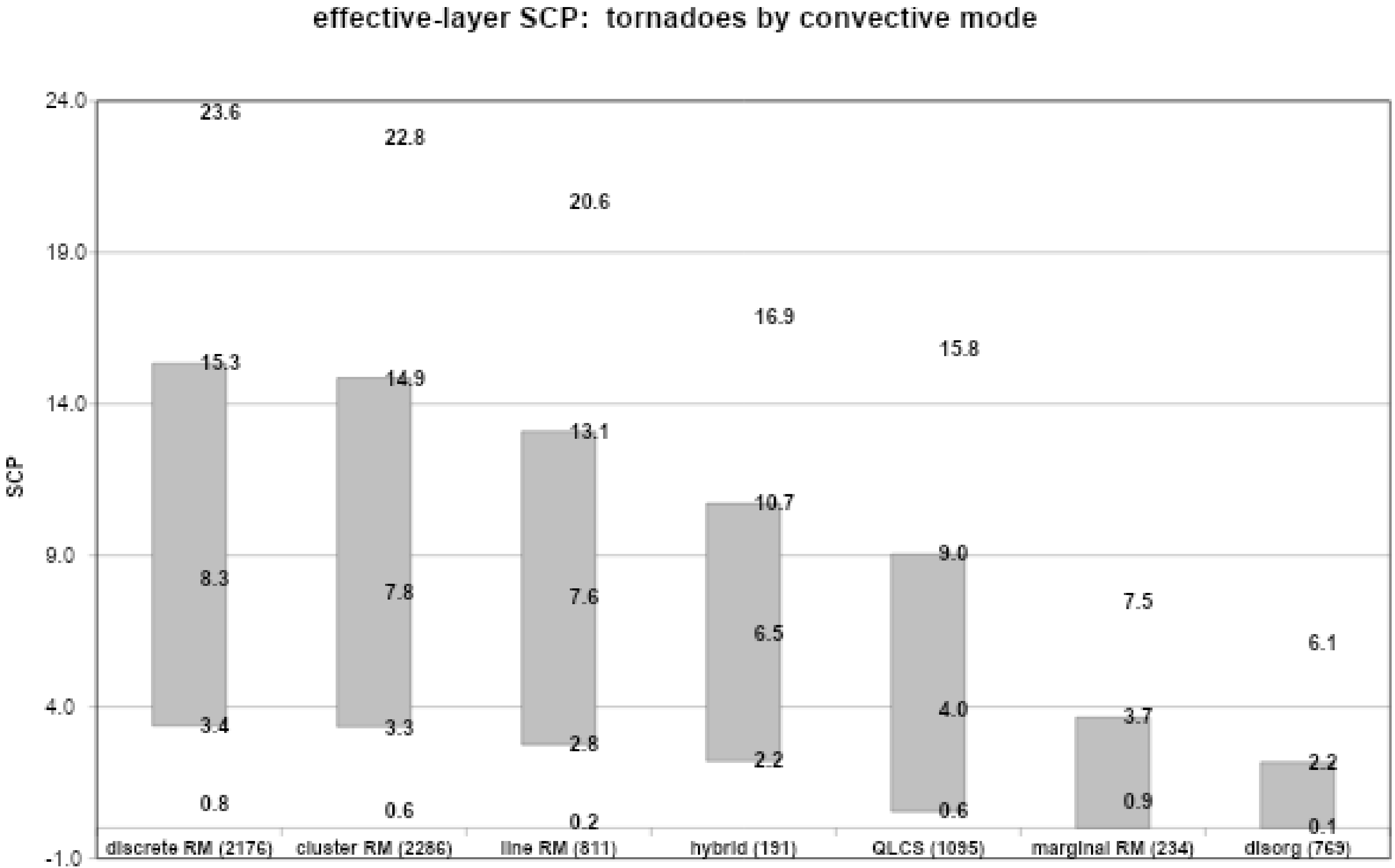
Also note:

MUCAPE and ESRH are the two main drivers of high SCP values!



Weaker rotation – smaller SCP

Stronger rotation – larger SCP



effective-layer SCP: tornadoes by convective mode
SCP
24.0
19.0
14.0
9.0
4.0
-1.0
23.6
15.3
8.3
3.4
0.8
22.8
14.9
7.8
3.3
0.6
20.6
13.1
7.6
2.8
0.2
16.9
10.7
6.5
2.2
15.8
9.0
4.0
0.6
7.5
3.7
0.9
6.1
2.2
0.1
discrete RM (2176)
cluster RM (2286)
line RM (811)
hybrid (191)
QLCS (1095)
marginal RM (234)
disorg (769)

SCP Strengths

- Simple estimate of conditional supercell potential
- Covers a wide range of environments (surface-based and elevated)
- Has a physical basis in relevant processes for supercells

SCP Weaknesses

- Conditional on having a right-moving supercell!
    - Does not consider:
        - Convective initiation
        - Storm mode

- Sensitive to storm-motion estimate
    - Uses Bunker's right-moving storm motion estimate.
    - Storm motion will influence ESRH, which will influence SCP.
    - Assumes you have a right-moving supercell, so may not be relevant for the early stages of storm development.

STP

- Utilizes the same “philosophy” as SCP

- Goal is to discriminate between environments that can/can’t support significant tornadoes

STP Considerations Pt. 1

- Want to prioritize mesocyclonic tornado production

- Utilize some concepts from SCP
  - Looking for right-moving, long-lived supercell
  - The need for buoyancy & deep-layer shear are still relevant

- But need to adjust our focus to buoyancy, inhibition, and vertical shear near the ground
  - Need to estimate the potential for strong mesocyclone and low-level stretching
  - Need to estimate the potential for evaporative cooling in the RFD
    - recall low-level horizontal vorticity production from tornado lecture
    - This gives us an idea of the low-level resistance to stretching

STP Considerations Pt. 2

- Need sustained, (near) surface-based supercell environments
  - Requires buoyancy/shear (MLCAPE, MLCIN, EBWD)

- Need strong, low-level source of stretching
  - Generally comes in the form of a strong negative pressure perturbation associated with the mesocyclone (ESRH)

- Need to estimate the resistance to stretching
  - MLCAPE, MLCIN, MLLCL

STP

STP = f(MLCAPE, MLCIN, EBWD, ESRH, MLLCL)

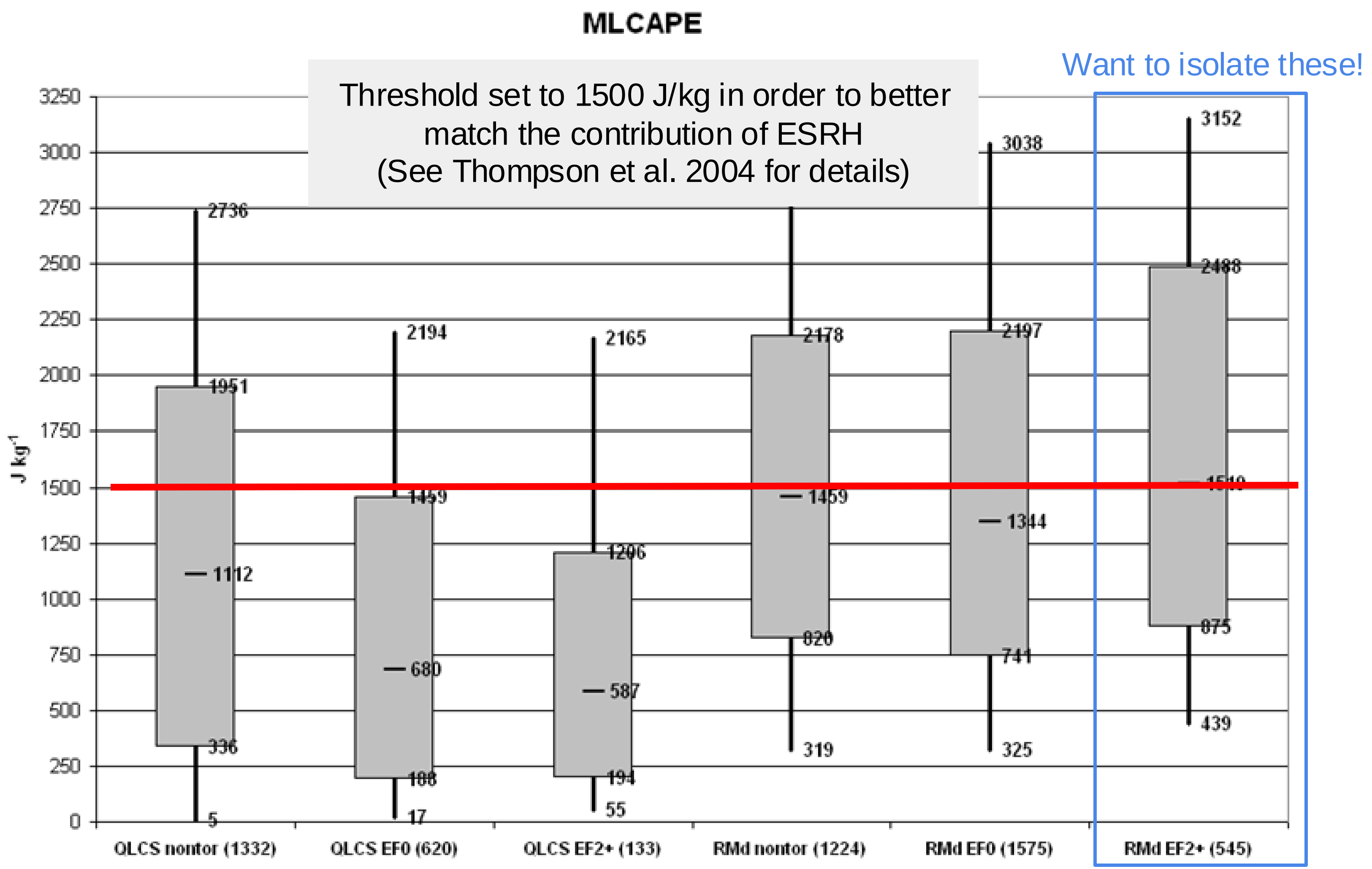
MLCAPE: Measure of surface (or near-surface) based instability — Driving factor

MLCIN: Measure of surface (or near-surface) based inhibition — Limiting factor

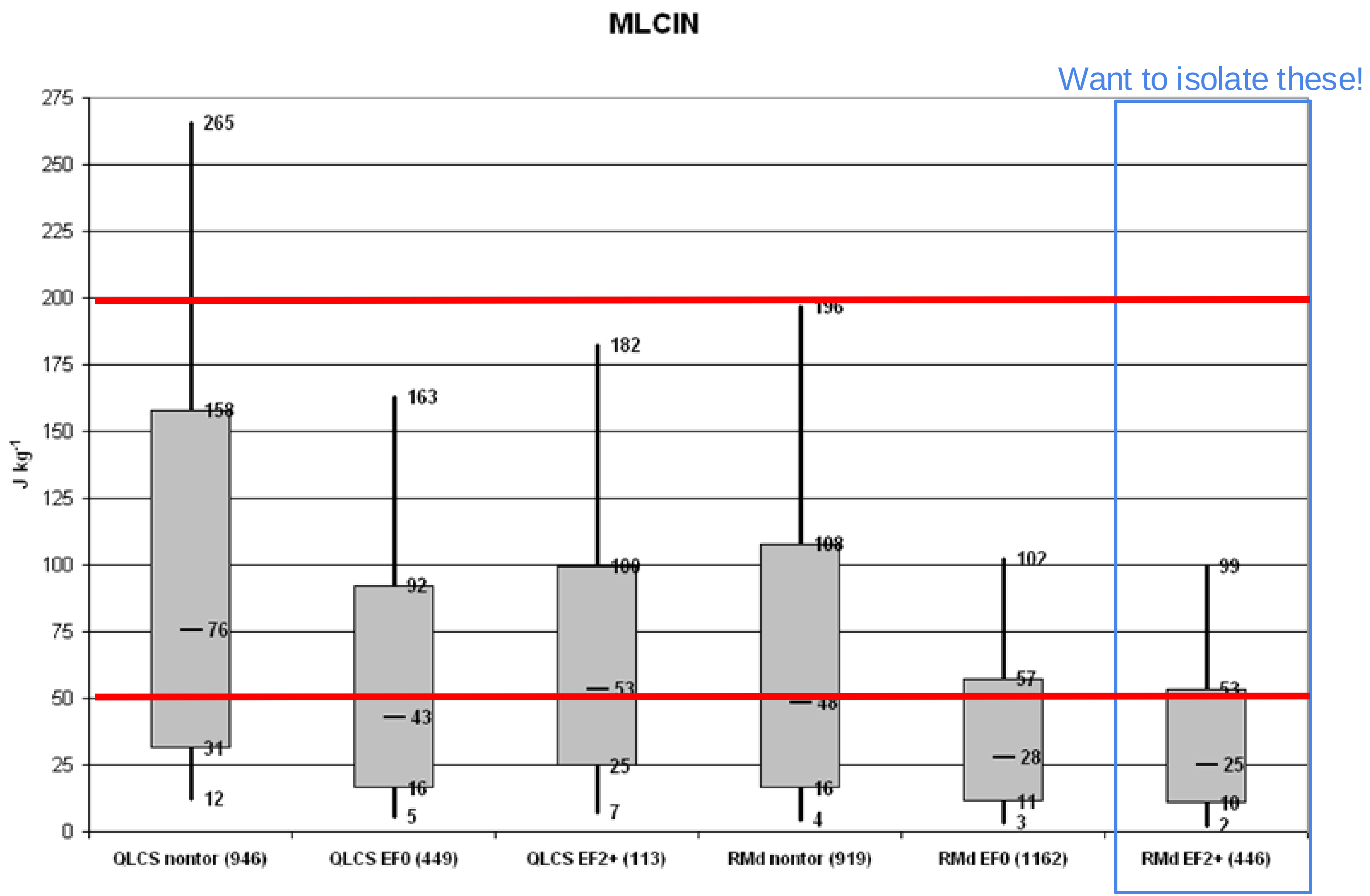
EBWD: Deep-layer Shear — Necessary Factor

ESRH: Low-level Shear — Driving factor

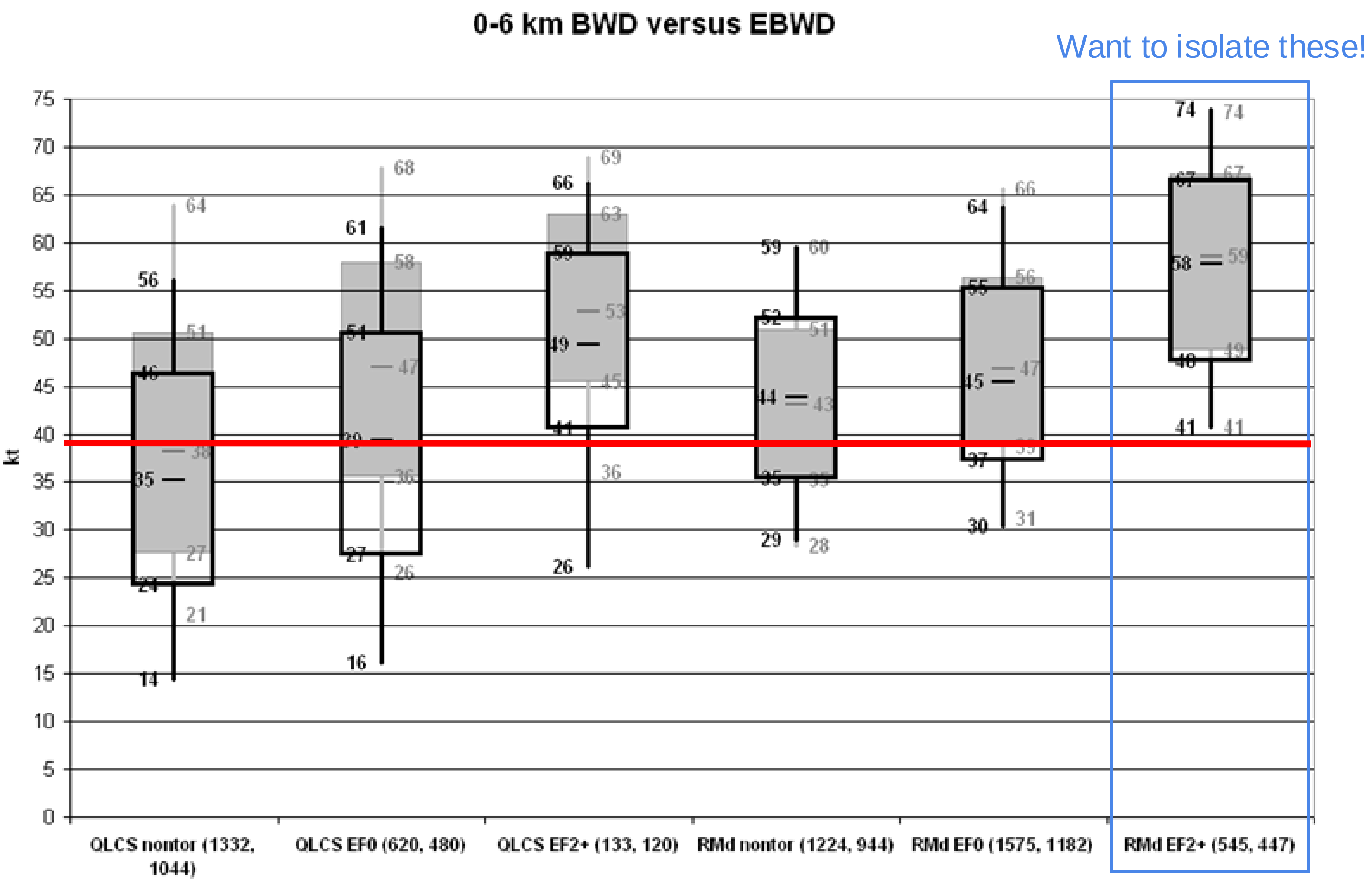
MLLCL: Measure of near-surface downdraft air buoyancy/stretching potential — Limiting factor



MLCAPE
Threshold set to 1500 J/kg in order to better match the contribution of ESRH
(See Thompson et al. 2004 for details)
Want to isolate these!
J kg-1
3250
3000
2750
2500
2250
2000
1750
1500
1250
1000
750
500
250
0
2736
1951
1112
336
5
2194
1459
680
17
2165
1206
587
194
55
2178
1459
319
3038
2197
1344
741
325
3152
2488
875
439
QLCS nontor (1332)
QLCS EF0 (620)
QLCS EF2+ (133)
RMd nontor (1224)
RMd EF0 (1575)
RMd EF2+ (545)



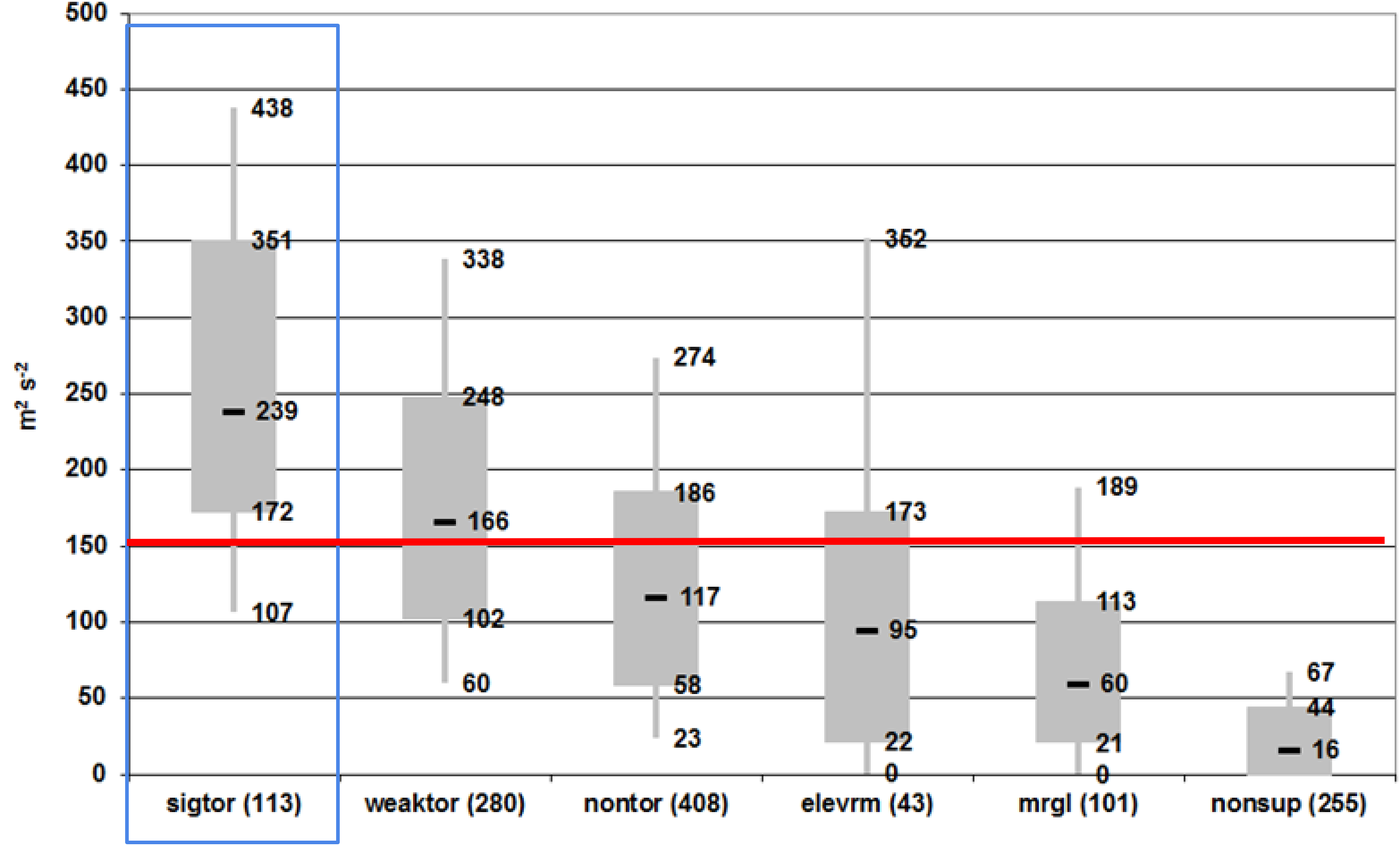
MLCIN
Want to isolate these!
J kg-1
275
250
225
200
175
150
125
100
75
50
25
0
265
158
76
31
12
163
92
43
16
5
182
100
53
25
7
196
108
48
16
4
102
57
28
11
3
99
53
25
10
2
QLCS nontor (946)
QLCS EF0 (449)
QLCS EF2+ (113)
RMd nontor (919)
RMd EF0 (1162)
RMd EF2+ (446)

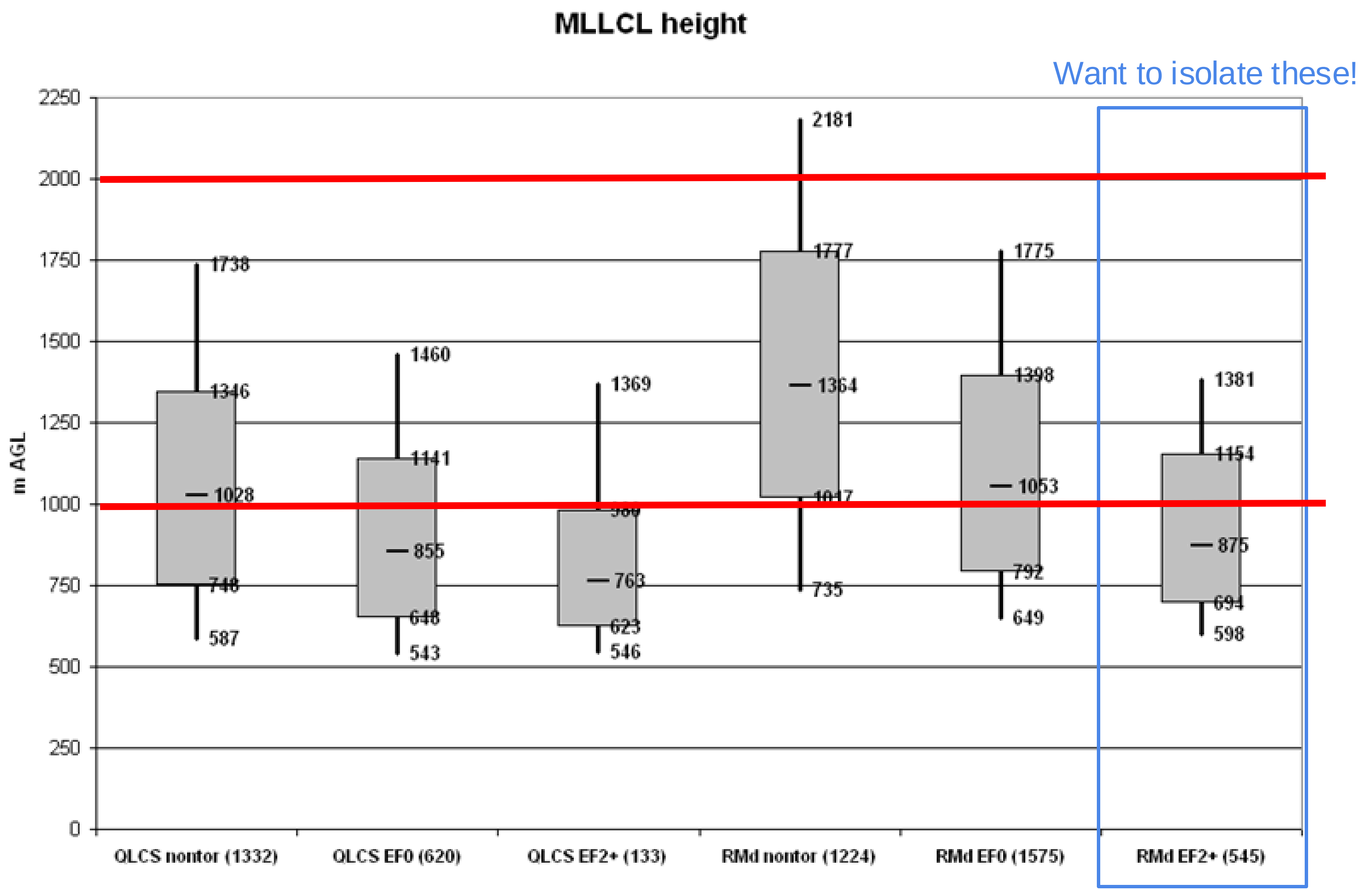


0-6 km BWD versus EBWD
Want to isolate these!
kt
QLCS nontor (1332, 1044)
QLCS EF0 (620, 480)
QLCS EF2+ (133, 120)
RMd nontor (1224, 944)
RMd EF0 (1575, 1182)
RMd EF2+ (545, 447)

Effective SRH versus 0-1 km SRH

Want to isolate these!




MLLCL height
Want to isolate these!
m AGL
2250
2000
1750
1500
1250
1000
750
500
250
0
1738
1346
1028
748
587
1460
1141
855
648
543
1369
763
623
546
2181
1777
1364
1017
735
1775
1398
1053
792
649
1381
1154
875
694
598
QLCS nontor (1332)
QLCS EF0 (620)
QLCS EF2+ (133)
RMd nontor (1224)
RMd EF0 (1575)
RMd EF2+ (545)

$$STP = \frac{MLCAPE}{1500} * \frac{(200+MLCIN)}{150} * \frac{EBWD}{20} * \frac{ESRH}{150} * \frac{(2000 - MLLCL)}{1000}$$

Goes to 0 as MLCIN decreases (magnitude increases)

Set to 1 if MLCIN > -50

Goes to 0 as ESRH decreases

Set to zero if the bottom of the Eff. Inflow Layer is above the surface

$$\frac{\text{MLCAPE}}{1500} * \frac{(200+\text{MLCIN})}{150} * \frac{\text{EBWD}}{20} * \frac{\text{ESRH}}{150} * \frac{(2000 - \text{MLLCL})}{1000}$$

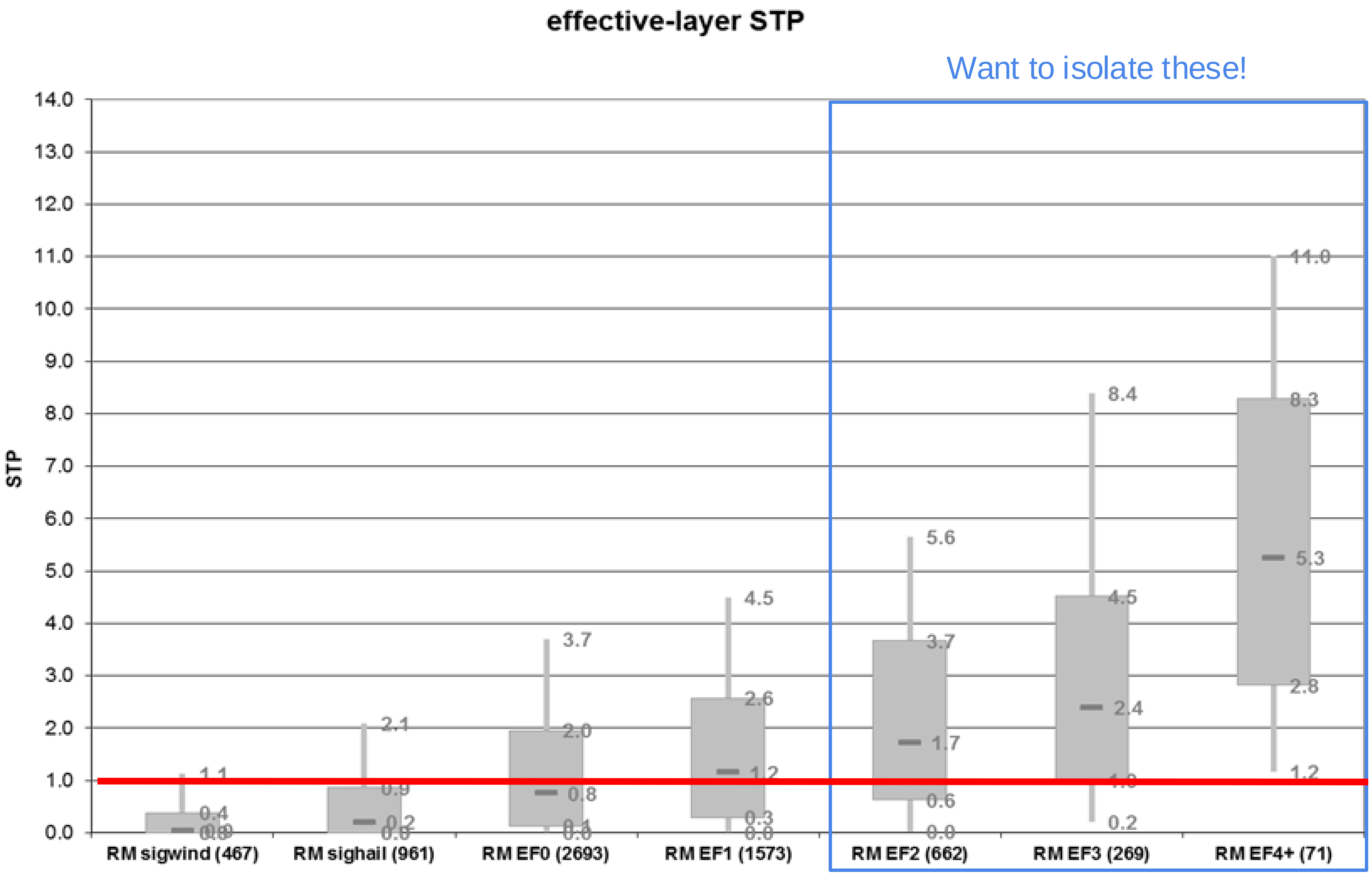
Goes to 0 as MLCAPE decreases.

Set to 0 if EBWD < 12.5 m/s

Set to 1.5 if EBWD > 30 m/s

Set to 0 if MLLCL > 2000 m

Set to 1.0 if MLLCL < 1000 m



effective-layer STP
Want to isolate these!
STP
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
RM sigwind (467)
RM sighail (961)
RM EF0 (2693)
RM EF1 (1573)
RM EF2 (662)
RM EF3 (269)
RM EF4+ (71)
1.1
0.4
2.1
0.9
0.2
3.7
2.0
0.8
4.5
2.6
1.2
0.3
5.6
3.7
1.7
0.6
0.0
8.4
4.5
2.4
0.2
11.0
8.3
5.3
2.8
1.2

Fixed-Layer STP

MLCAPE → SBCAPE

MLCIN → SBCIN

EBWD → 0-6 km BWD

ESRH → 0-1 km SRH

MLLCL → SBLCL

Otherwise, uses the same formulation!

Effective vs. Fixed Layer STP

- SBCAPE is less dependent on RAP moisture profile above the surface & is more responsive in SPC Mesoanalysis

- Fixed-layer terms aren't as sensitive to errors in the thermo profile or storm-motion estimates

- No replication of Eff. layer terms

- Examine closely when the two vary substantially!

STP Strengths

- Gives single parameter to characterize the potential for significant tornadoes

- Is rooted in physical processes relevant to tornadogenesis

- Recent studies show combining STP with observed tornado vortex signatures in WSR-88D data can give a reliable estimate of tornado strength in real-time

STP Strengths

Other studies have shown that STP correlates well with tornado occurrence:

“..we conclude that STP is statistically significant covariate to U.S. tornado frequency”

- Gensini and Bravo de Guenni (2019)
when analyzing a 30-year climatology of STP and tornado occurrence

STP Weaknesses Pt. 1

- Conditional on the existence of a right-moving, surface-based supercell

- Simplified estimate of environments favoring both supercell initiation and sustenance
  - which are not the same - easier to sustain a supercell in a higher CIN environment than to initiate!

- Currently no reliable way to measure/estimate near-surface vorticity generation

STP Weaknesses Pt. 2

- Different environments may give the same STP value!
    - Always look into the environment to see if the parameter value is reasonable!

- Different environments may give the same STP value!
    - Always look into the environment to see if the parameter value is reasonable!

$$STP = \frac{MLCAPE}{1500} * \frac{(200+MLCIN)}{150} * \frac{EBWD}{20} * \frac{ESRH}{150} * \frac{(2000 - MLLCL)}{1000}$$

MLCAPE = 500 J/kg

ESRH = 500 m2/s2

EBWD = 20 m/s

MLCIN = -150 J/kg

MLLCL = 1000 m

STP = 1.1

Low CAPE/High Shear Environment

- Different environments may give the same STP value!
  - Always look into the environment to see if the parameter value is reasonable!

$$STP = \frac{MLCAPE}{1500} * \frac{(200+MLCIN)}{150} * \frac{EBWD}{20} * \frac{ESRH}{150} * \frac{(2000 - MLLCL)}{1000}$$

MLCAPE = 5000 J/kg

ESRH = 50 m2/s2

EBWD = 20 m/s

MLCIN = -150 J/kg

MLLCL = 1000 m

STP = 1.1

High CAPE/Low Shear Environment

- Different environments may give the same STP value!
    - Always look into the environment to see if the parameter value is reasonable!

$$STP = \frac{MLCAPE}{1500} * \frac{(200+MLCIN)}{150} * \frac{EBWD}{20} * \frac{ESRH}{150} * \frac{(2000 - MLLCL)}{1000}$$

MLCAPE = 5000 J/kg

ESRH =

1.1

EBWD =

ow Shear

ment

MLCIN = -150 J/kg

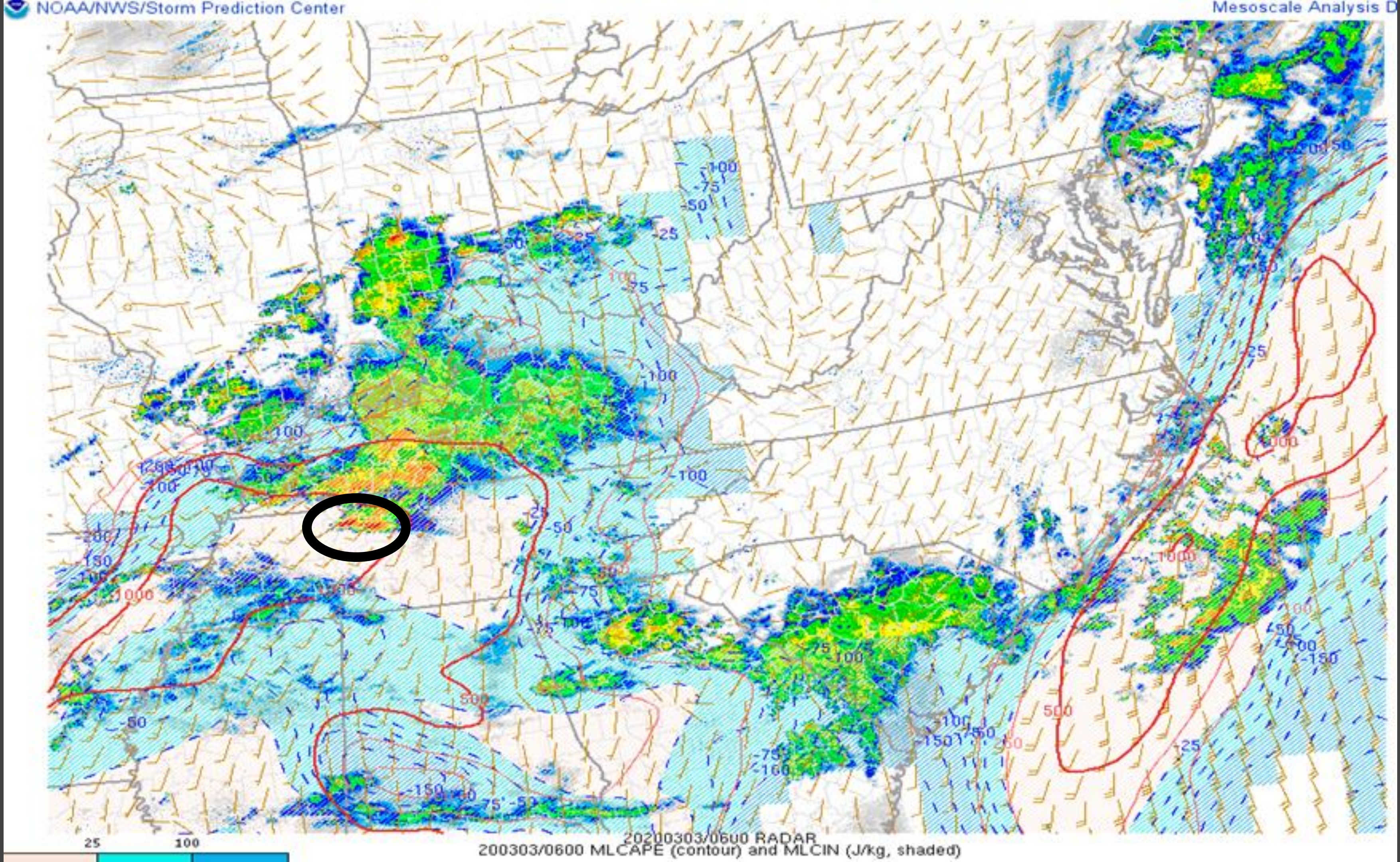
MLLCL = 1000 m

Same STP value, but which environment is more favorable for tornadoes?

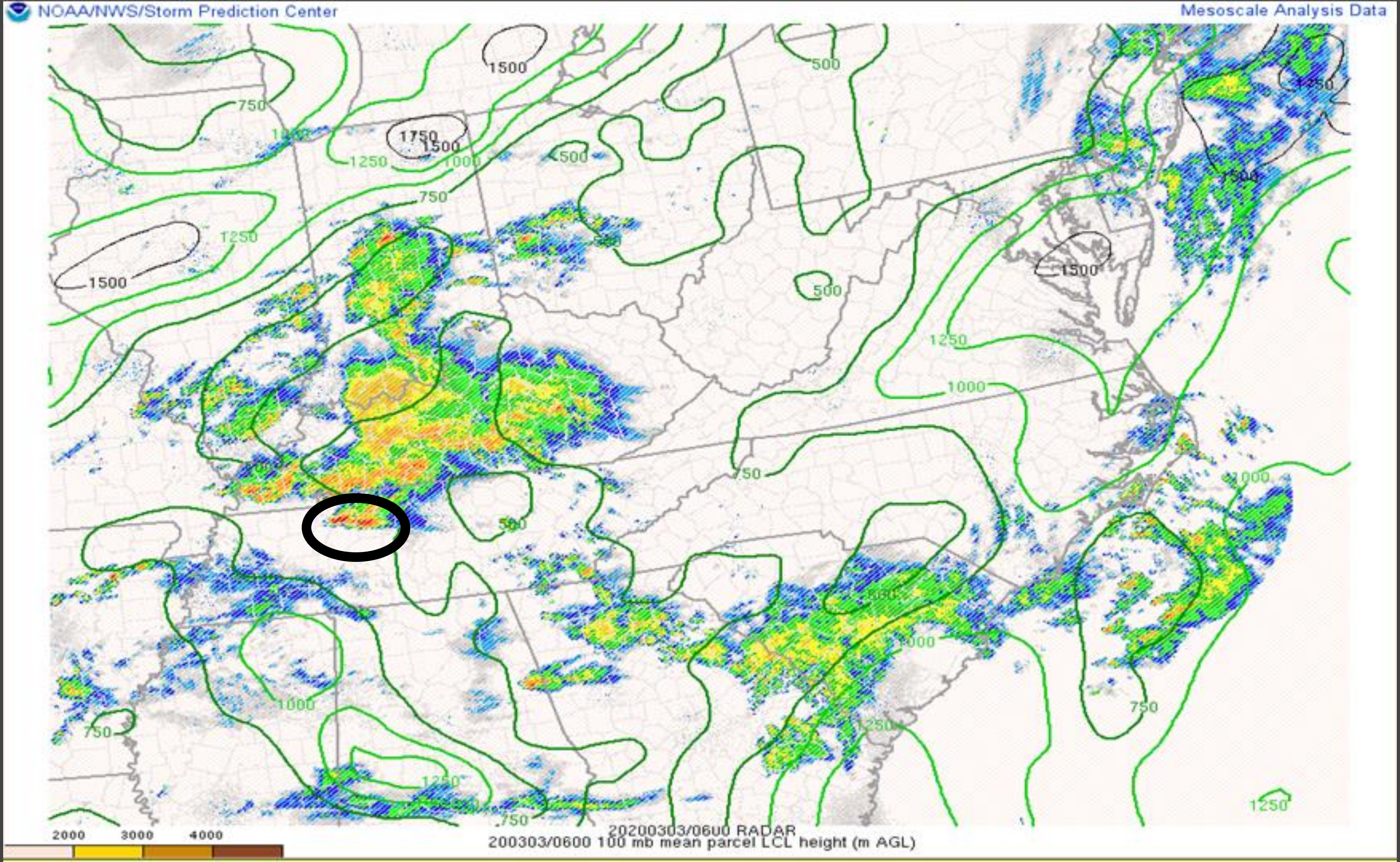
The Main Point

Spend time understanding how each parameter works

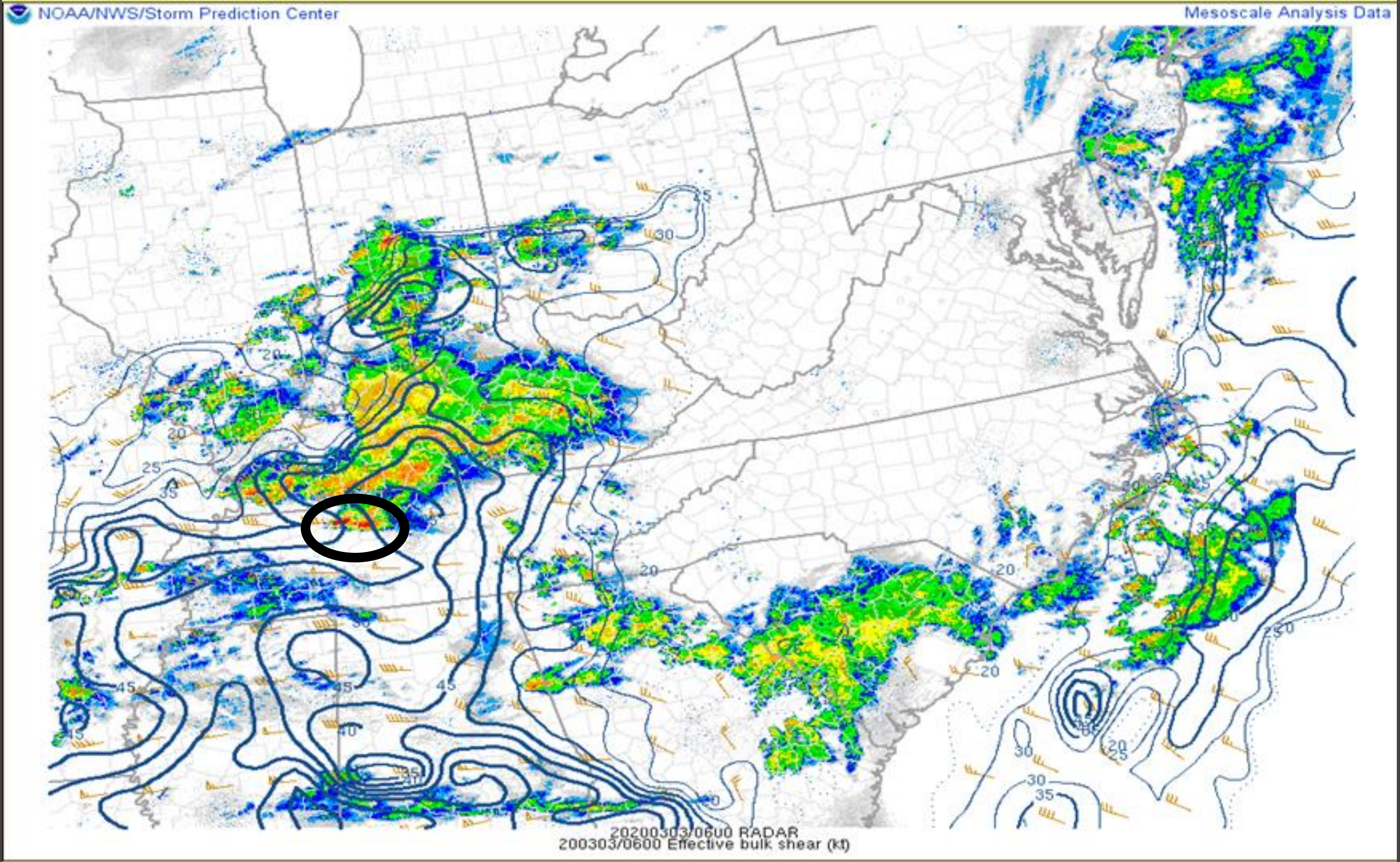
It can save you from making incorrect assumptions about the environment!

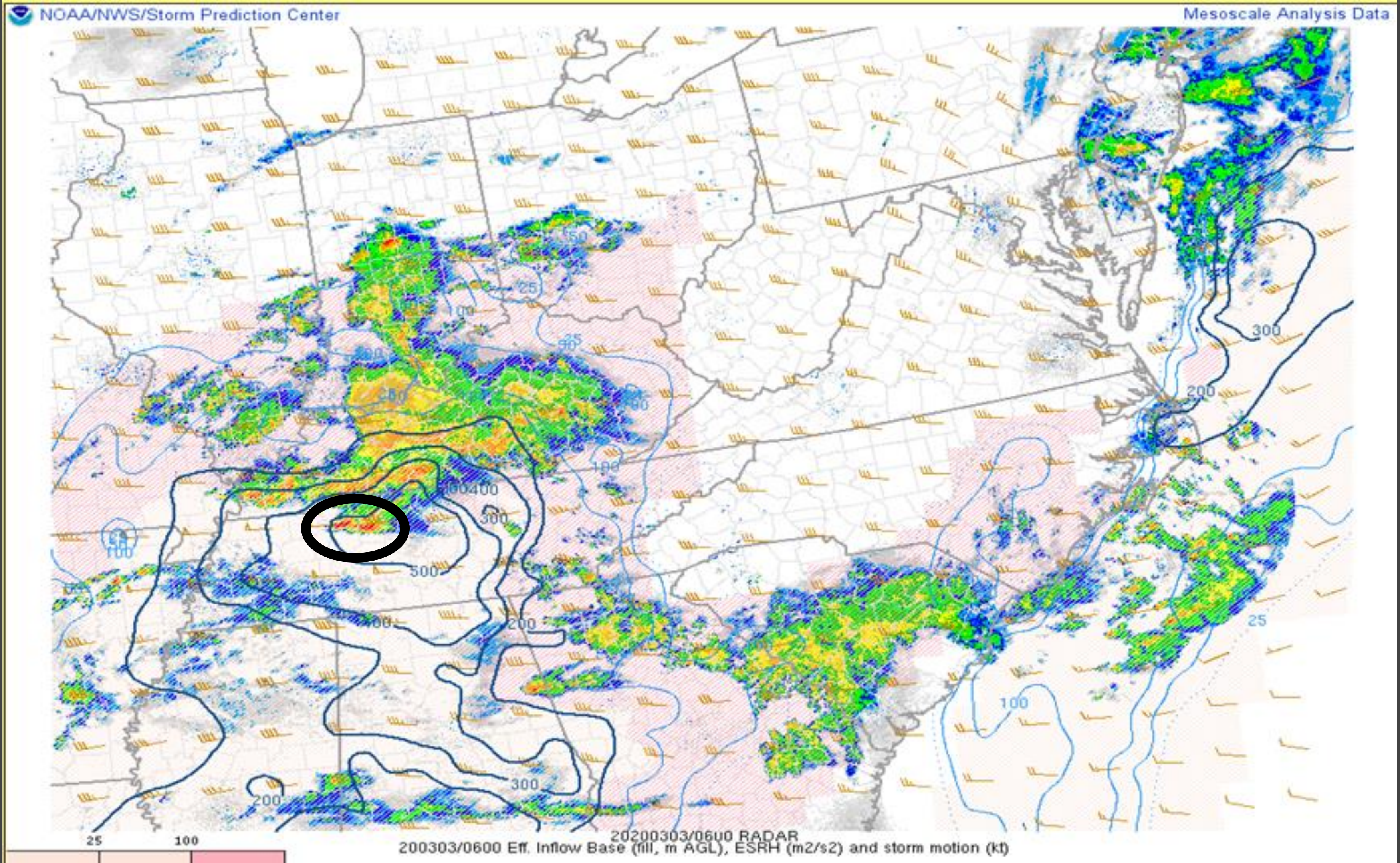


NOAA/NWS/Storm Prediction Center
Mesoscale Analysis D
25
100
20200303/0600 RADAR
200303/0600 MLCAPE (contour) and MLCIN (J/kg, shaded)

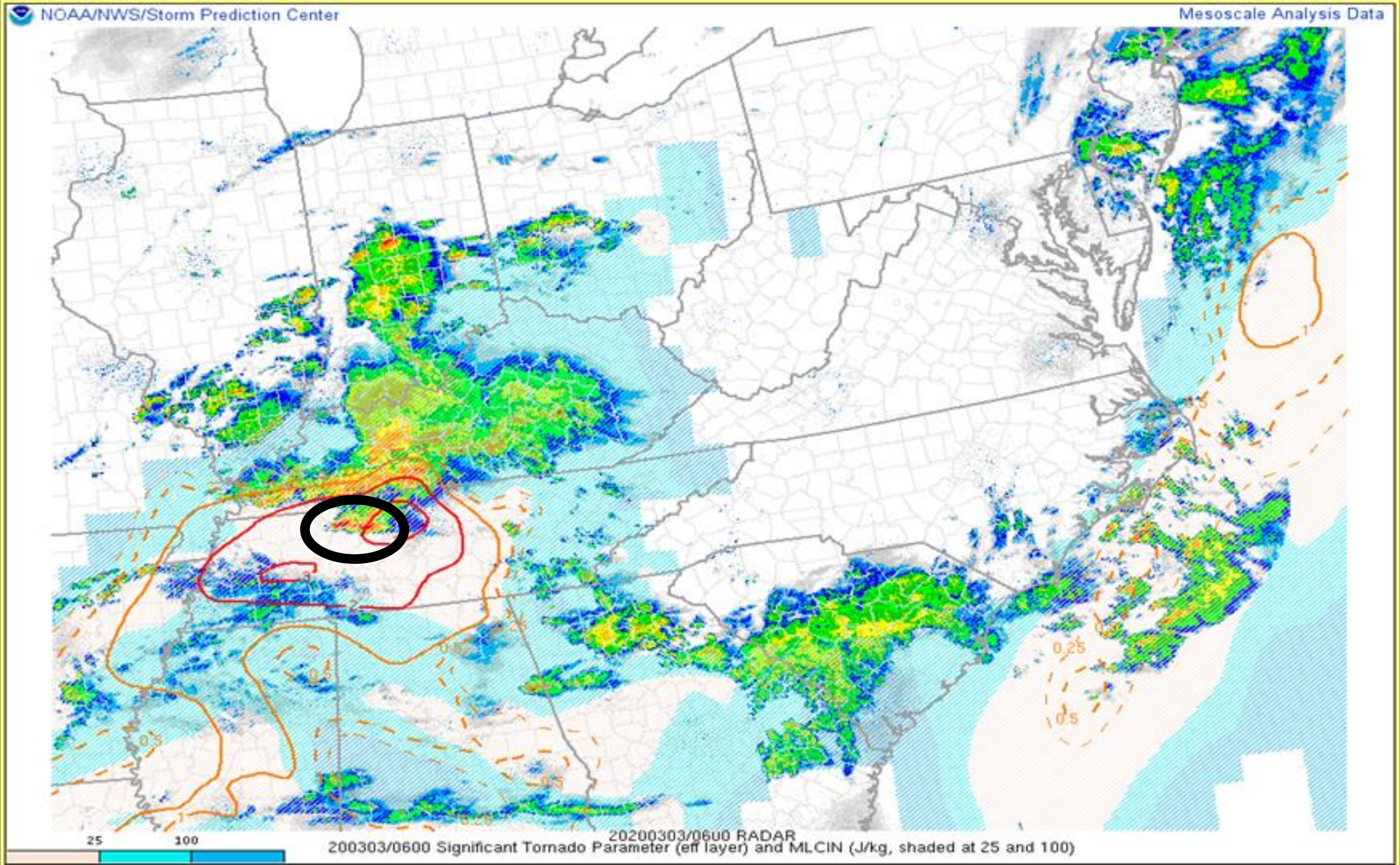


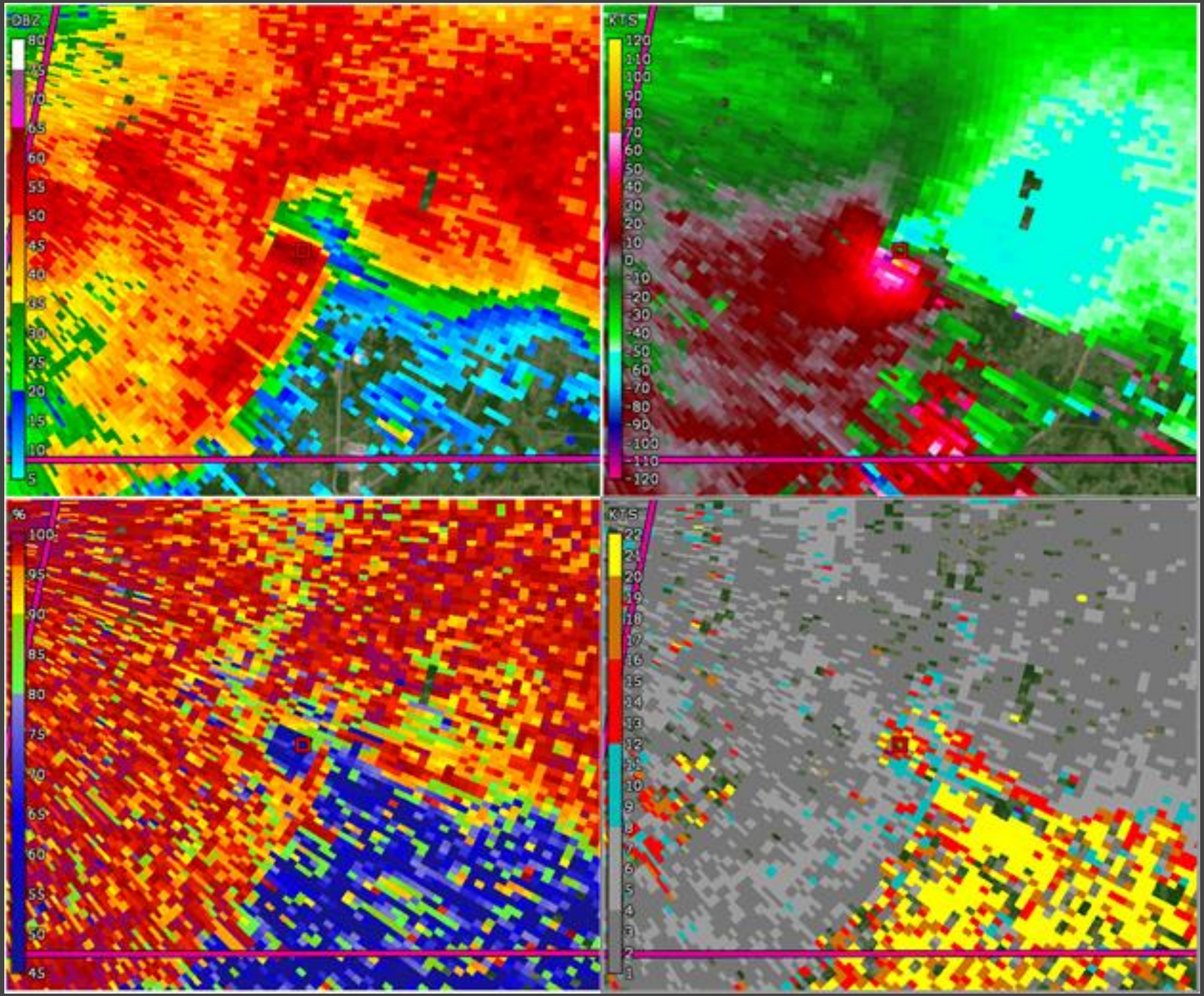
NOAA/NWS/Storm Prediction Center
Mesoscale Analysis Data
20200303/0600 RADAR
200303/0600 100 mb mean parcel LCL height (m AGL)
2000
3000
4000
1500
1750
1250
1000
750
500


NOAA/NWS/Storm Prediction Center
Mesoscale Analysis Data
20200303/0600 RADAR
200303/0600 Effective bulk shear (kt)



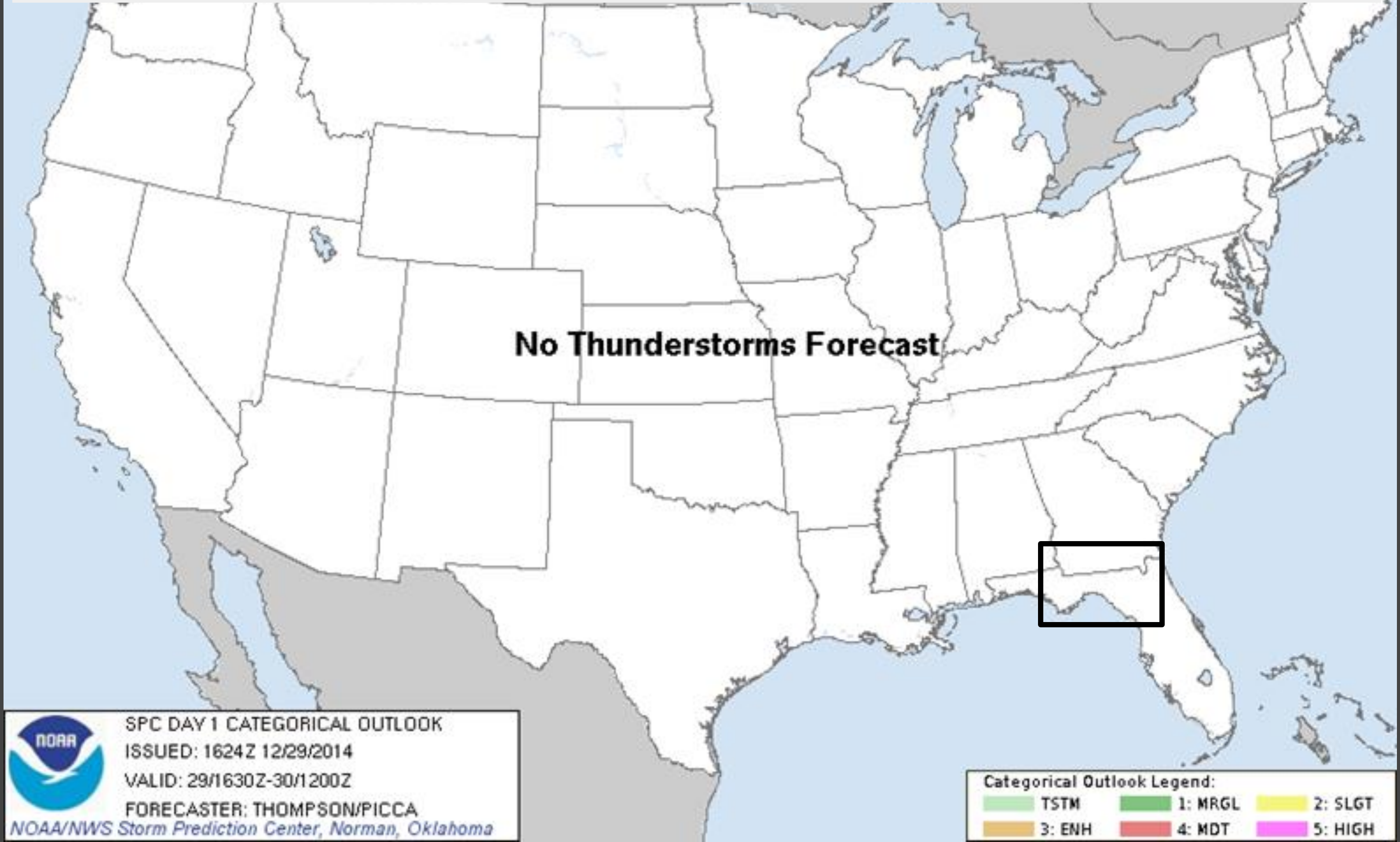
NOAA/NWS/Storm Prediction Center
Mesoscale Analysis Data
20200303/0600 RADAR
200303/0600 Eff. Inflow Base (fill, m AGL), ESRH (m2/s2) and storm motion (kt)

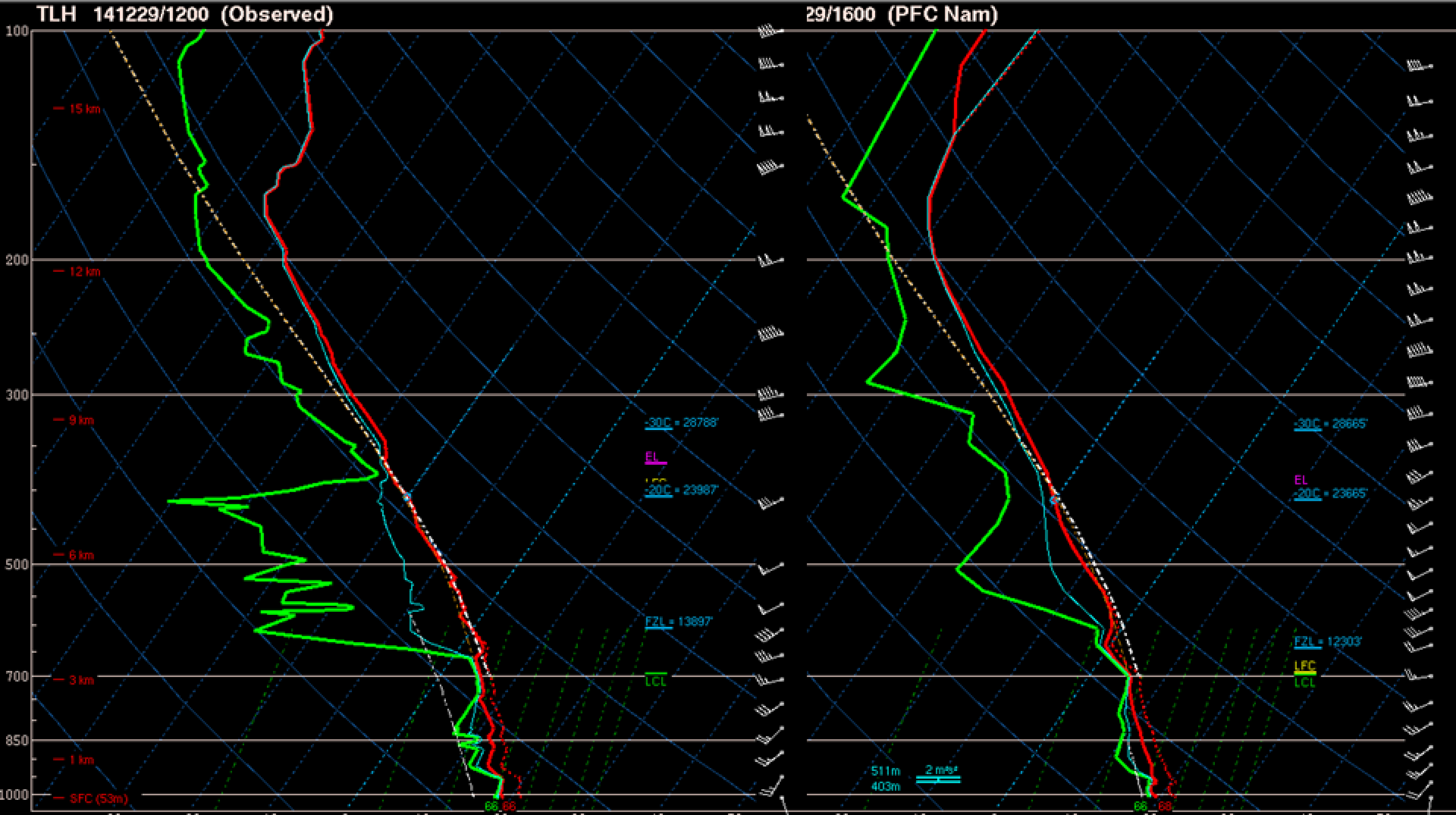

NOAA/NWS/Storm Prediction Center
Mesoscale Analysis Data
20200303/0600 RADAR
200303/0600 Significant Tornado Parameter (eff layer) and MLCIN (J/kg, shaded at 25 and 100)
25
100



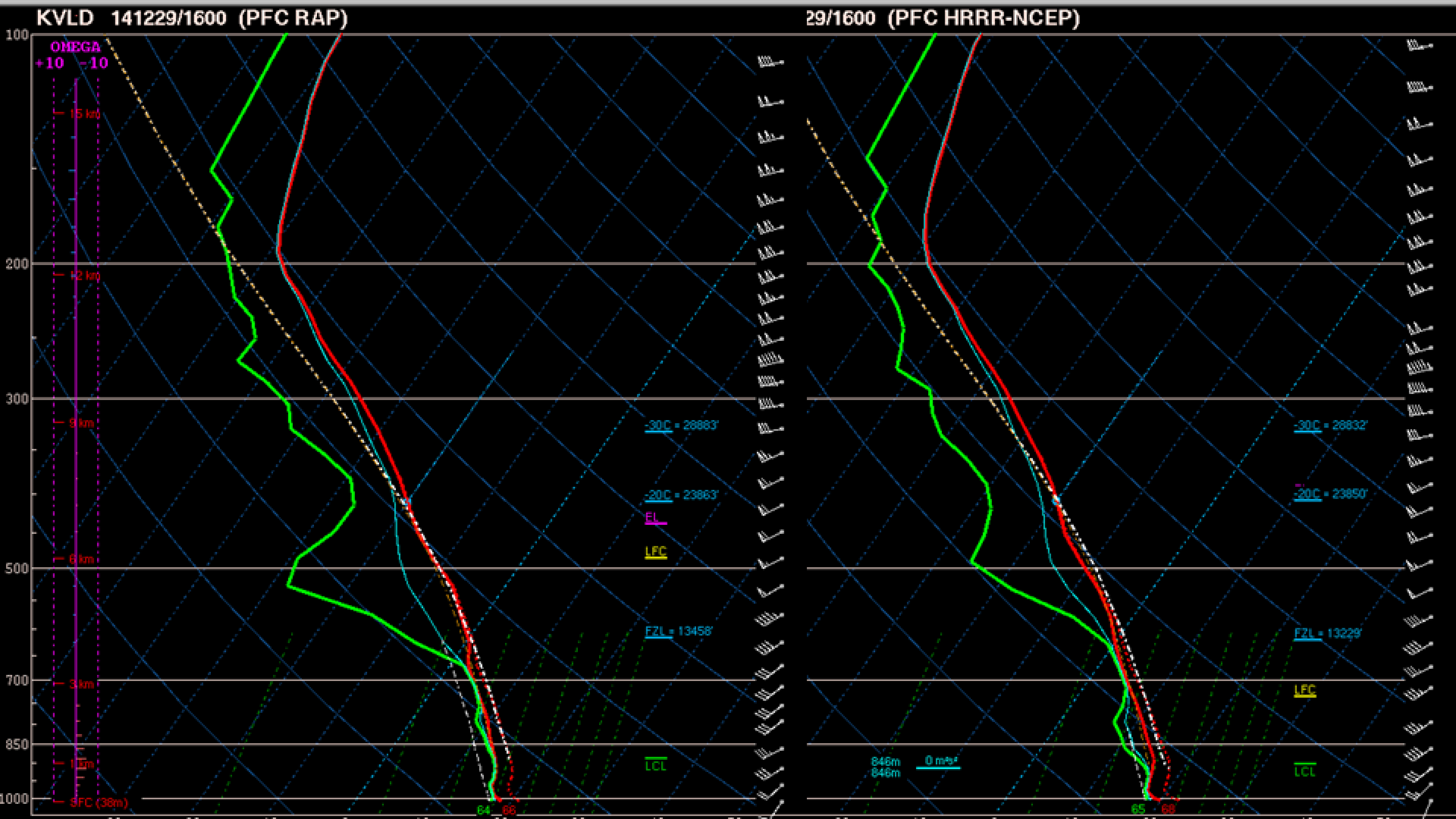
March 2nd, 2020
Cookville, TN
EF-4

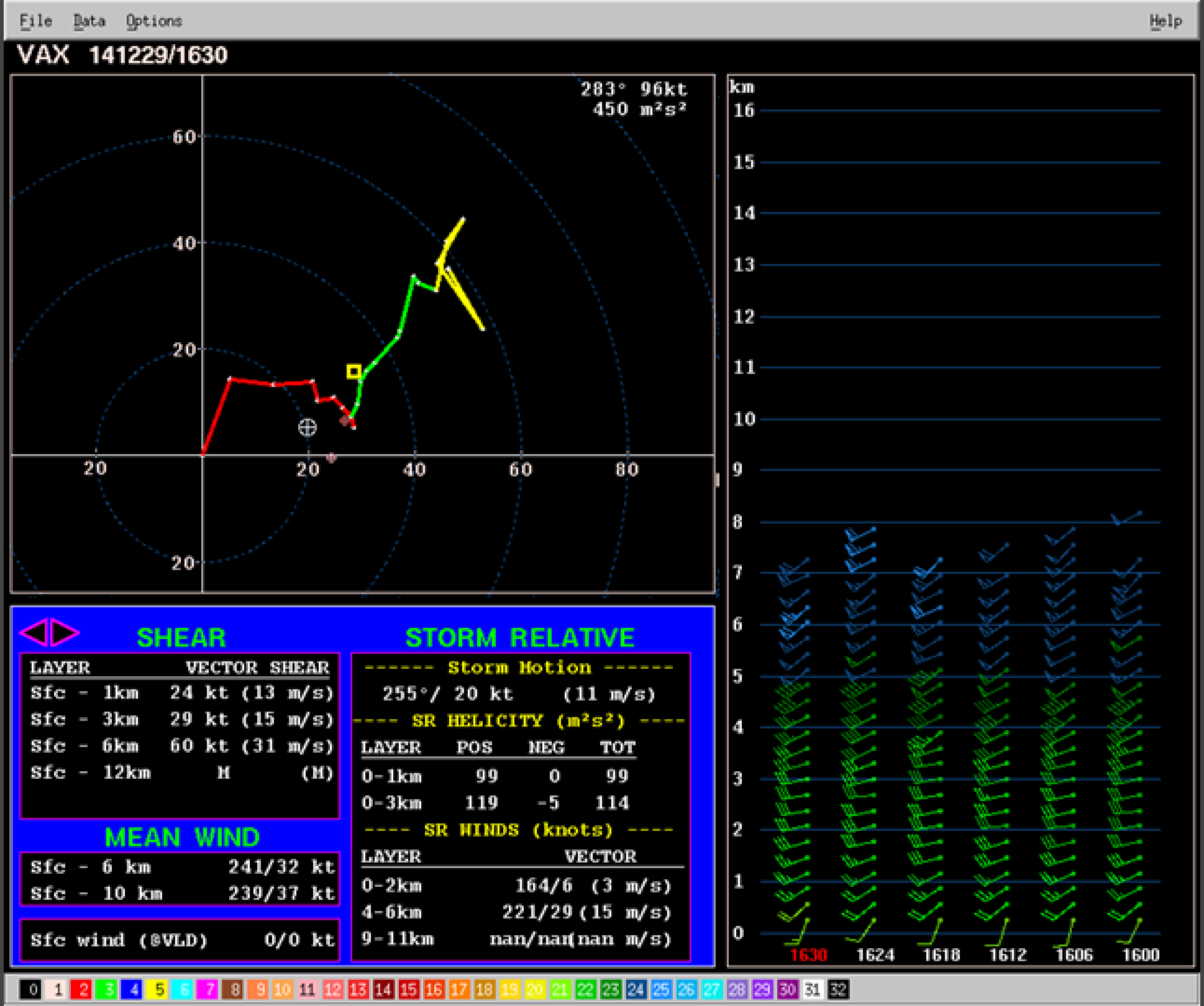
29 December 2014 supercell





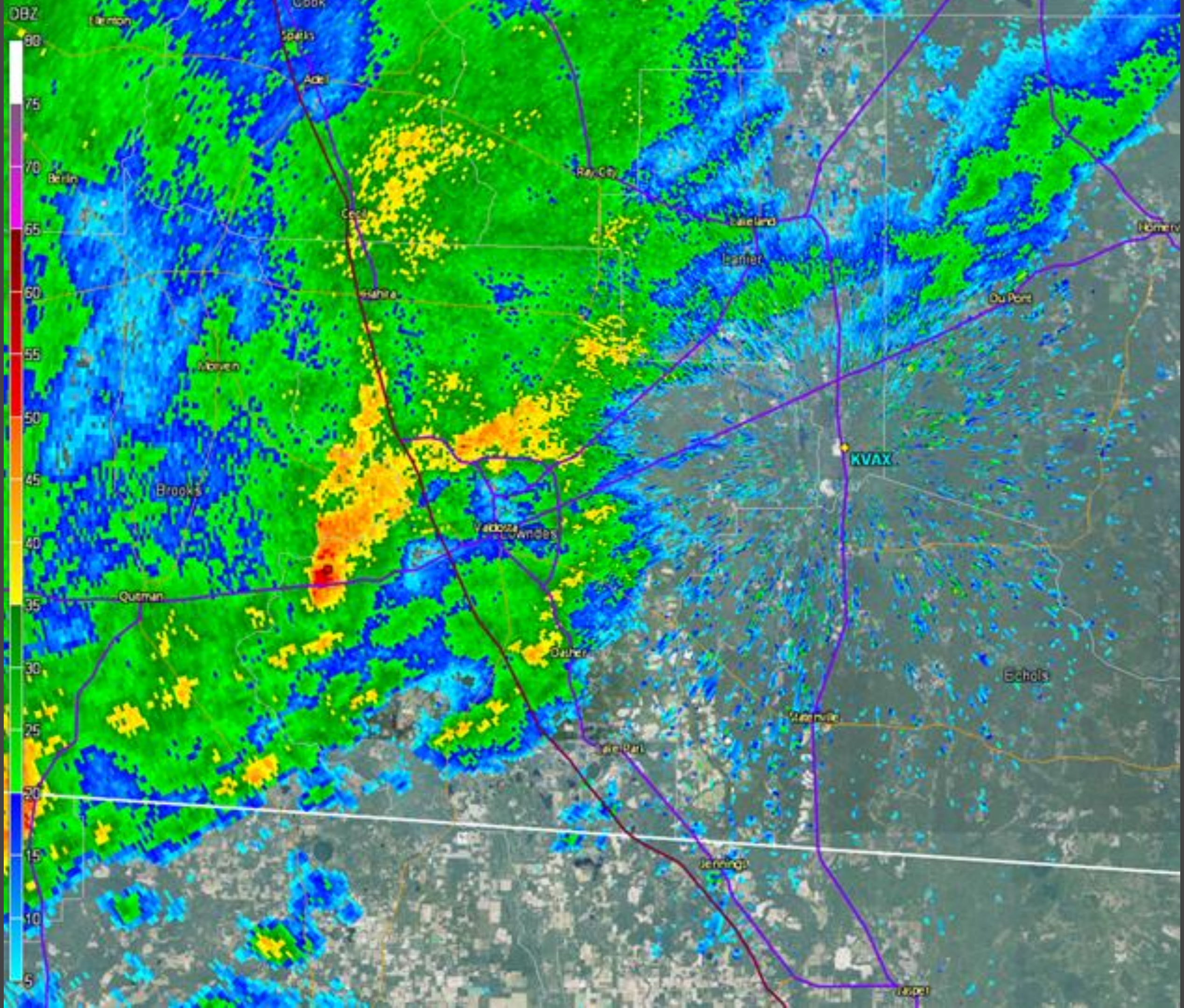
TLH 141229/1200 (Observed)
29/1600 (PFC Nam)
100
200
300
500
700
850
1000
15 km
12 km
9 km
6 km
3 km
1 km
SFC (53m)
-30C = 28788'
EL
LFC
-20C = 23987'
FZL = 13897'
LCL
66
66
-30C = 28665'
EL
-20C = 23665'
FZL = 12303'
LFC
LCL
511m
403m
2 m/s²
66
68


KVLD 141229/1600 (PFC RAP)
29/1600 (PFC HRRR-NCEP)
OMEGA
+10 -10
15 km
12 km
9 km
6 km
3 km
1 km
SFC (38m)
100
200
300
500
700
850
1000
-30C = 28883'
-20C = 23863'
EL
LFC
FZL = 13458'
LCL
64
66
-30C = 28832'
-20C = 23850'
FZL = 13229'
LFC
LCL
846m
846m
0 m²/s²
65
68



Given the previous forecast soundings and the observed VWP profile on the left…

what value of STP would you expect?



DBZ
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Cook
Ellenton
Sparks
Adel
Berlin
Cecil
Ray City
Lakeland
Lanier
Hahira
Du Pont
Morven
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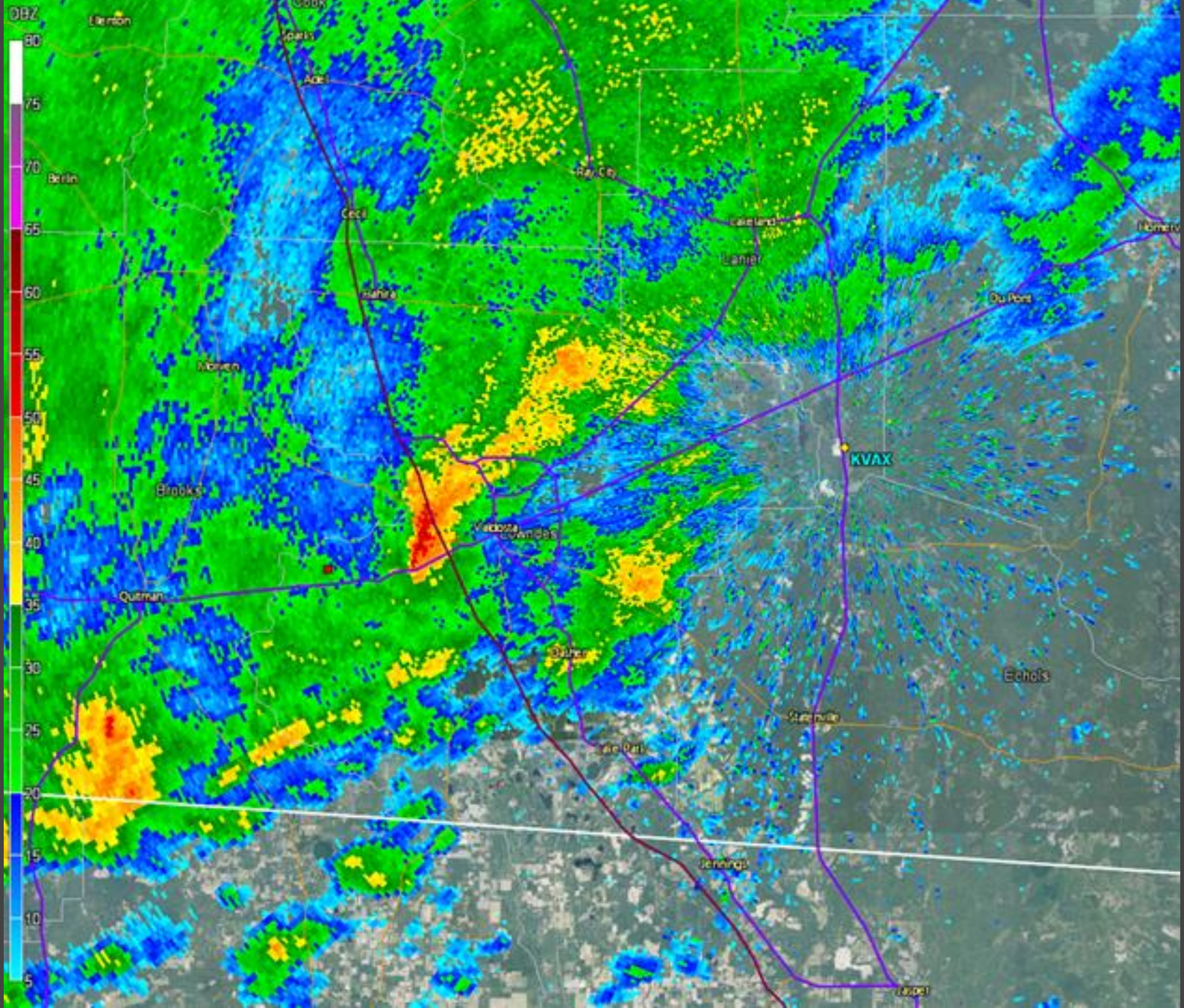
Valdosta
Lowndes
Quitman
Dasher
Echols
Statenville
Lake Park
Jennings
Jasper



DBZ
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Echols
Statenville
Lake Park
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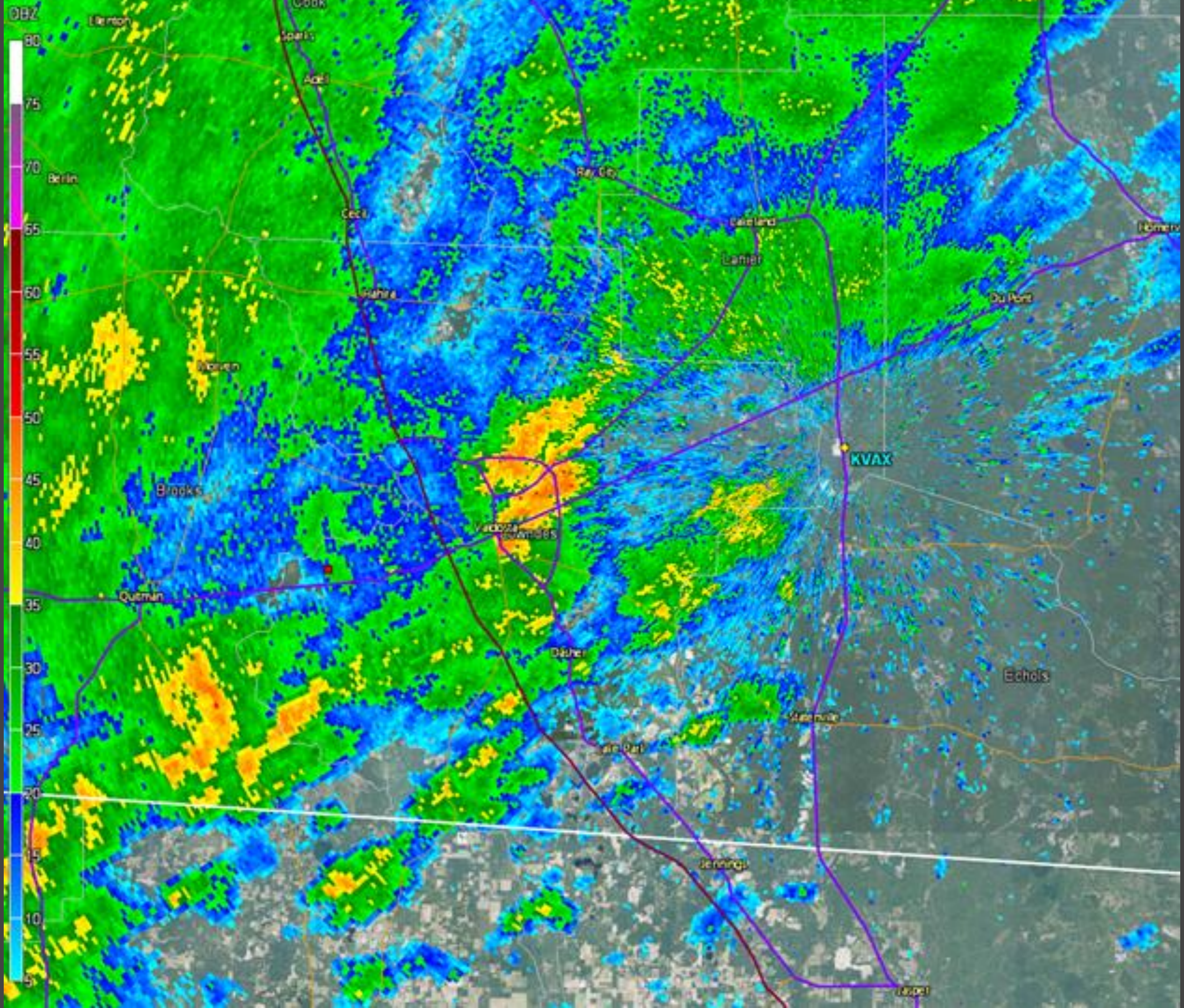
DBZ
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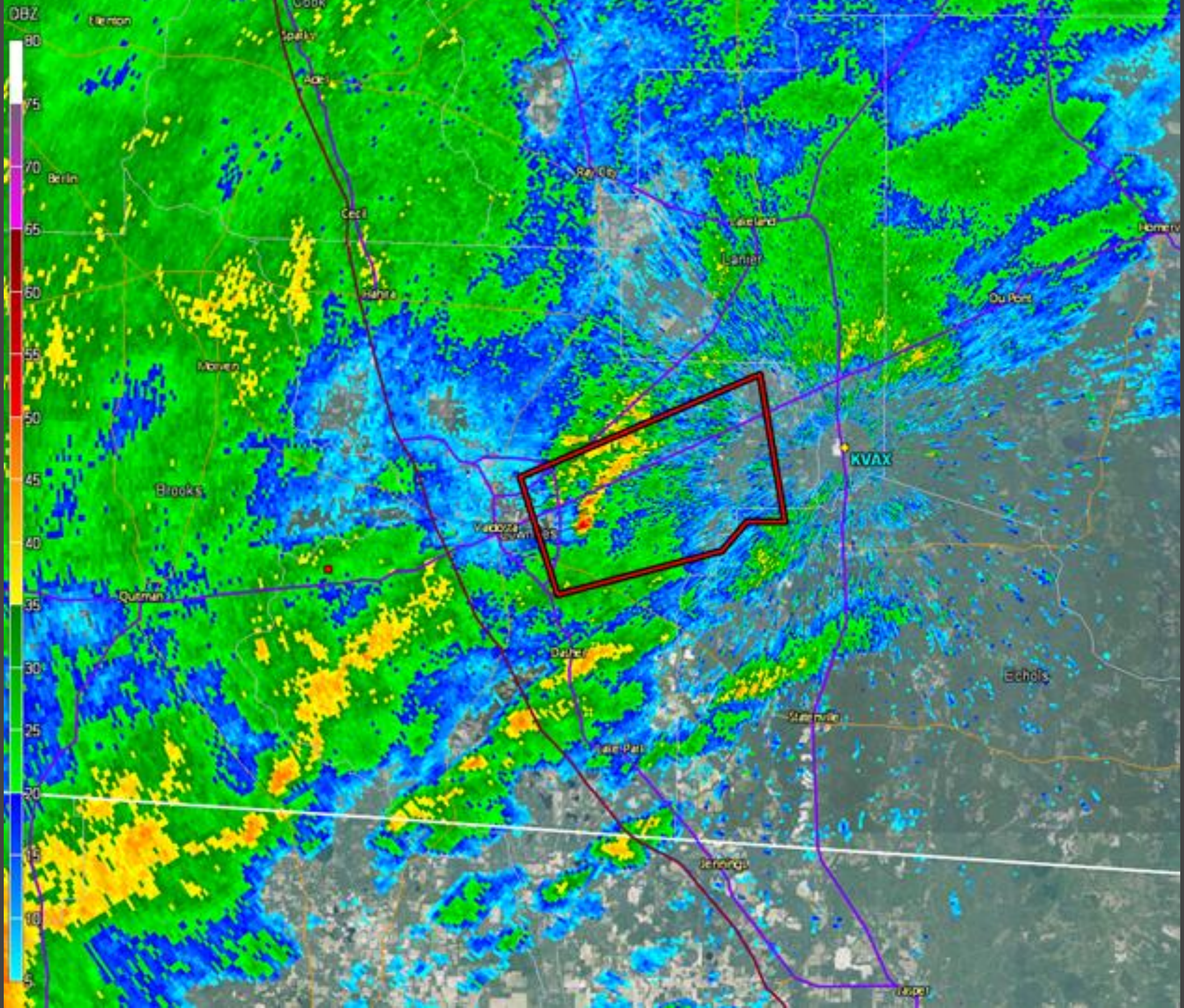
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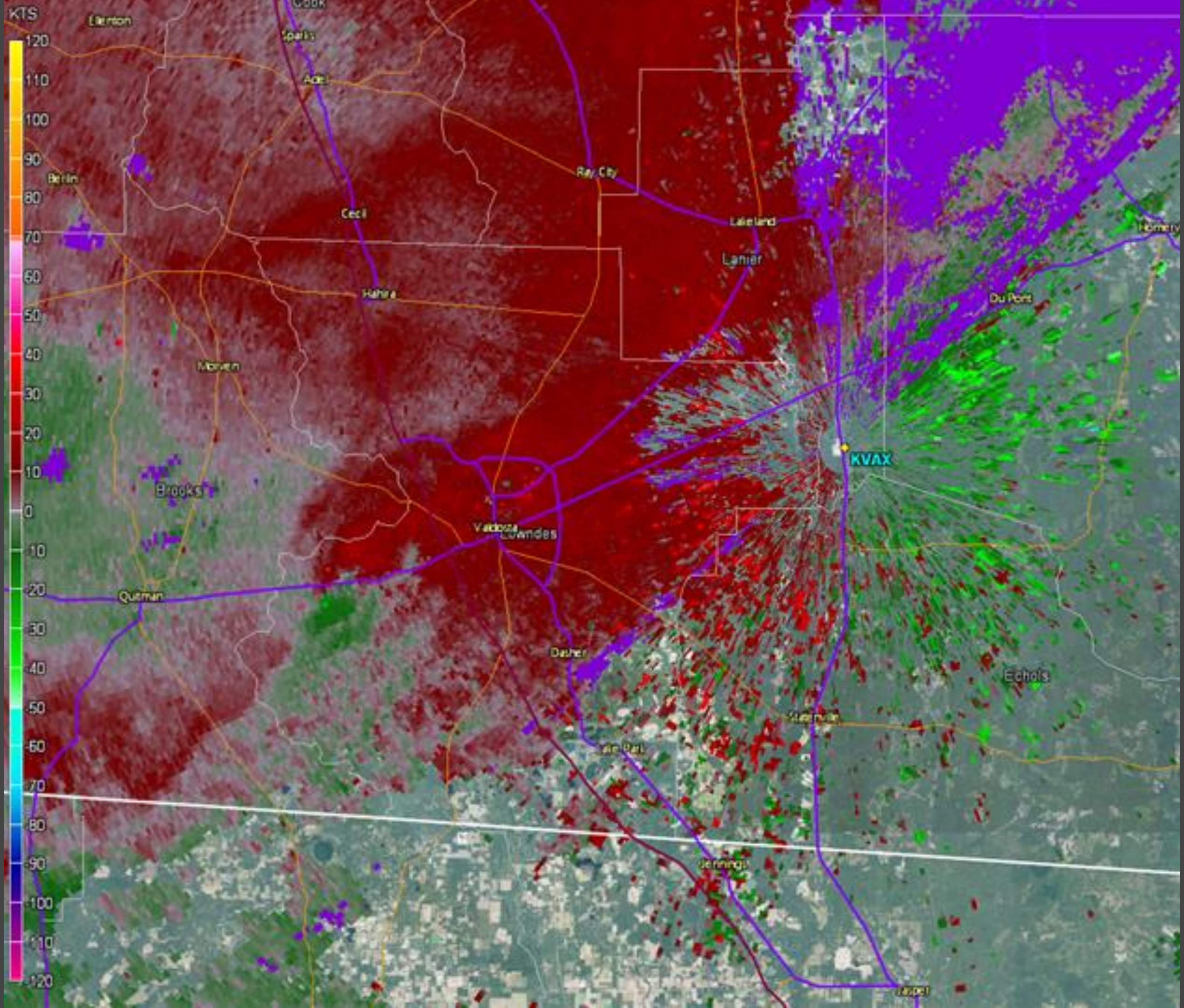

KTS
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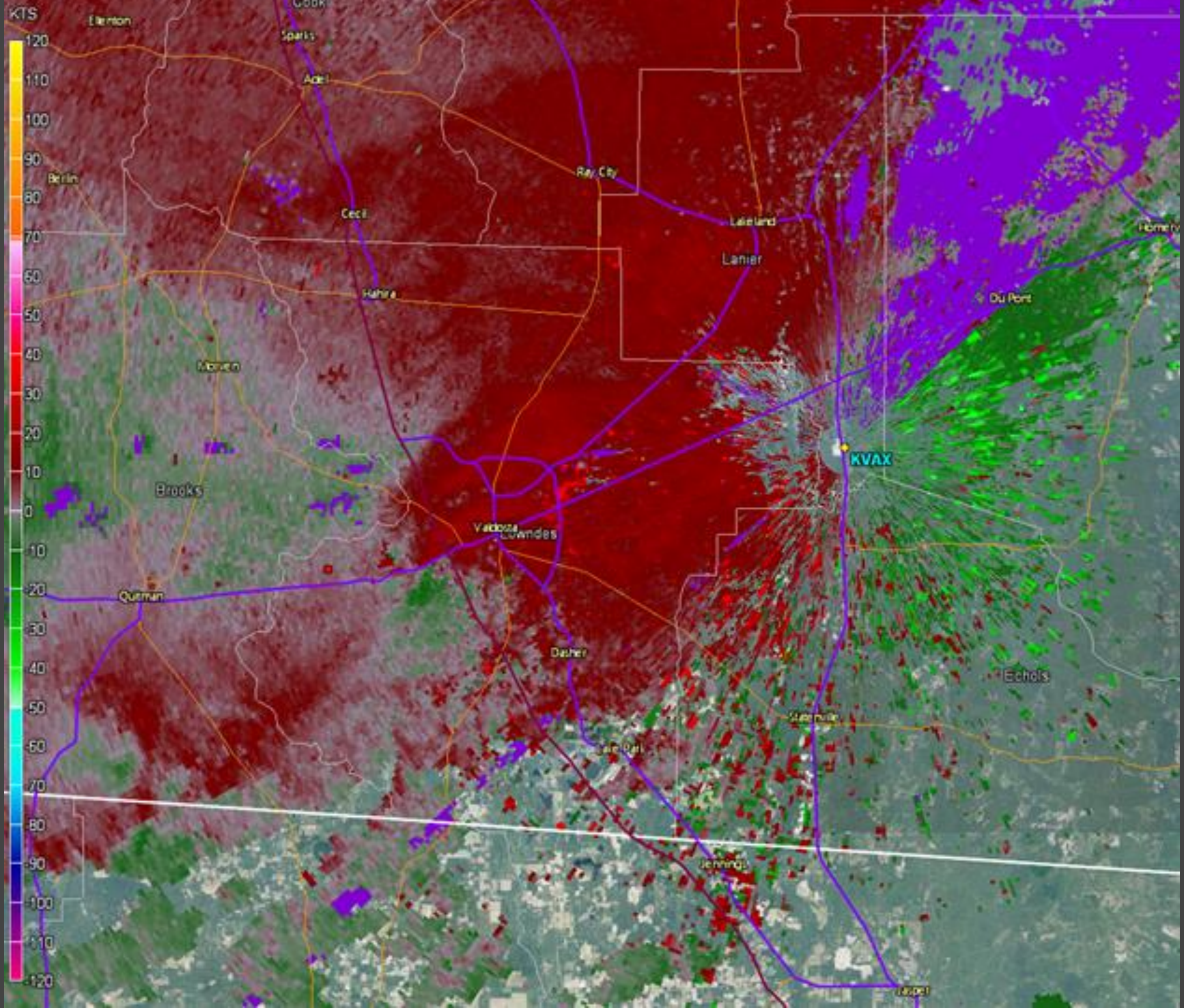
KTS
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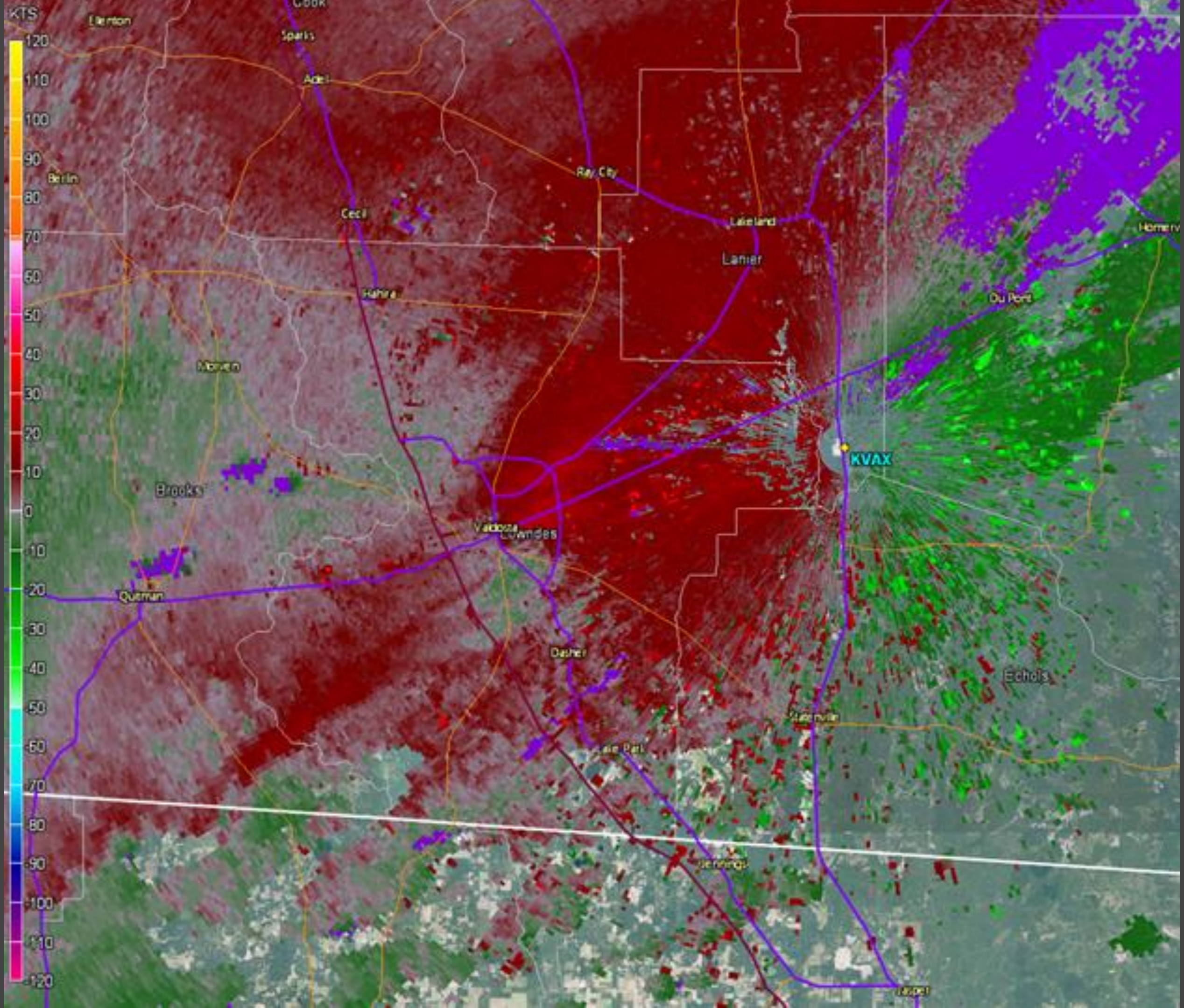
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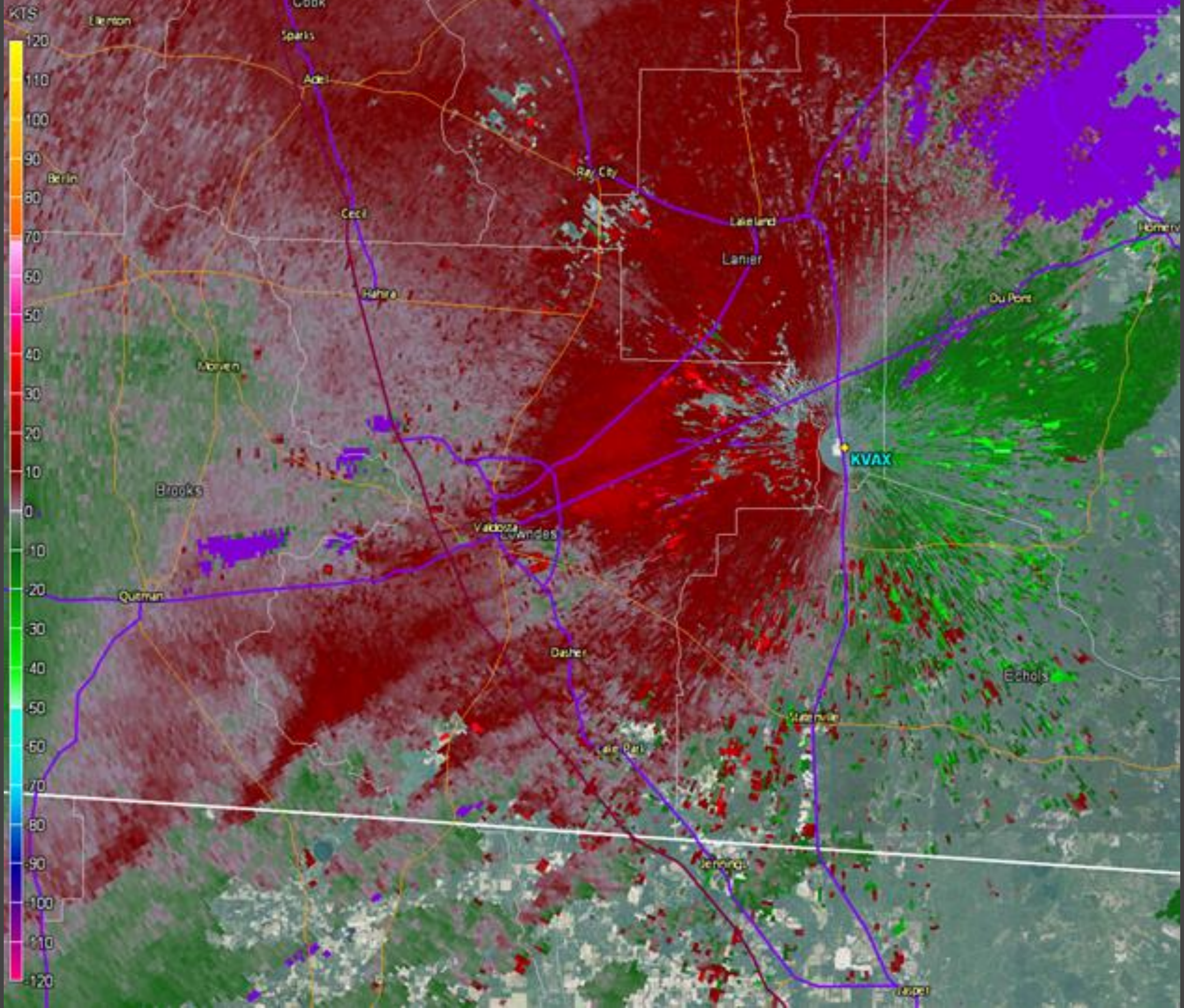
KTS
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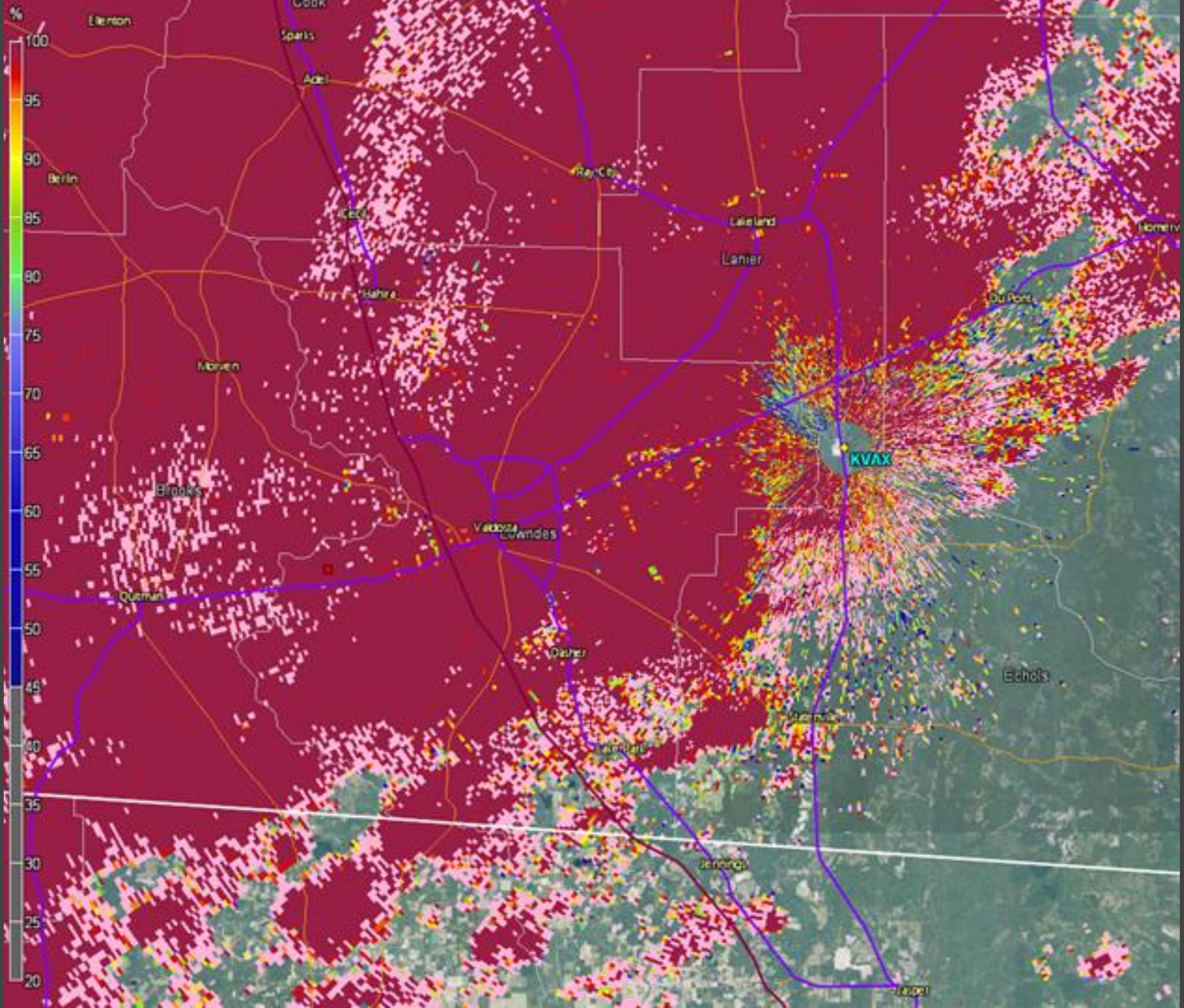
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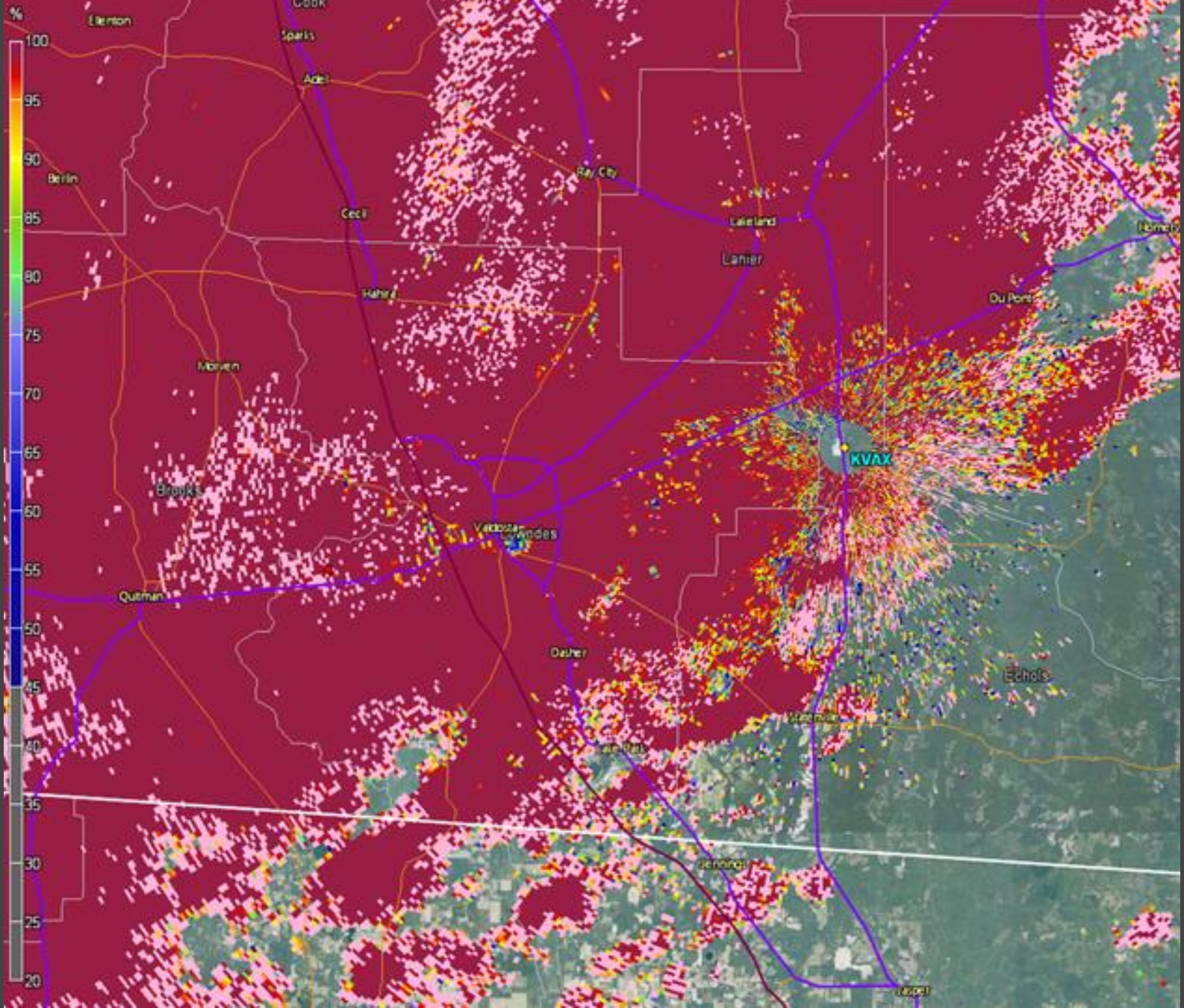
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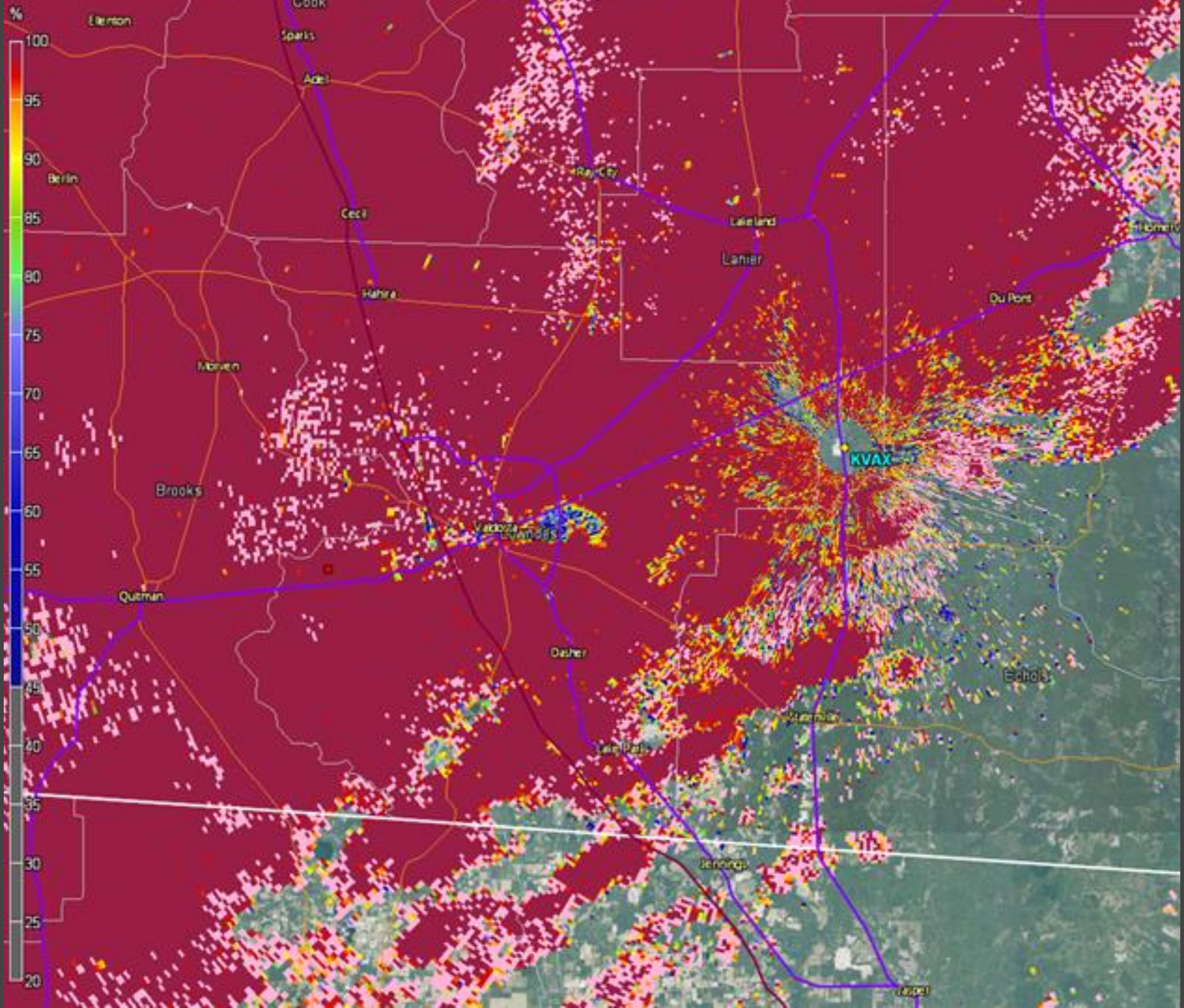
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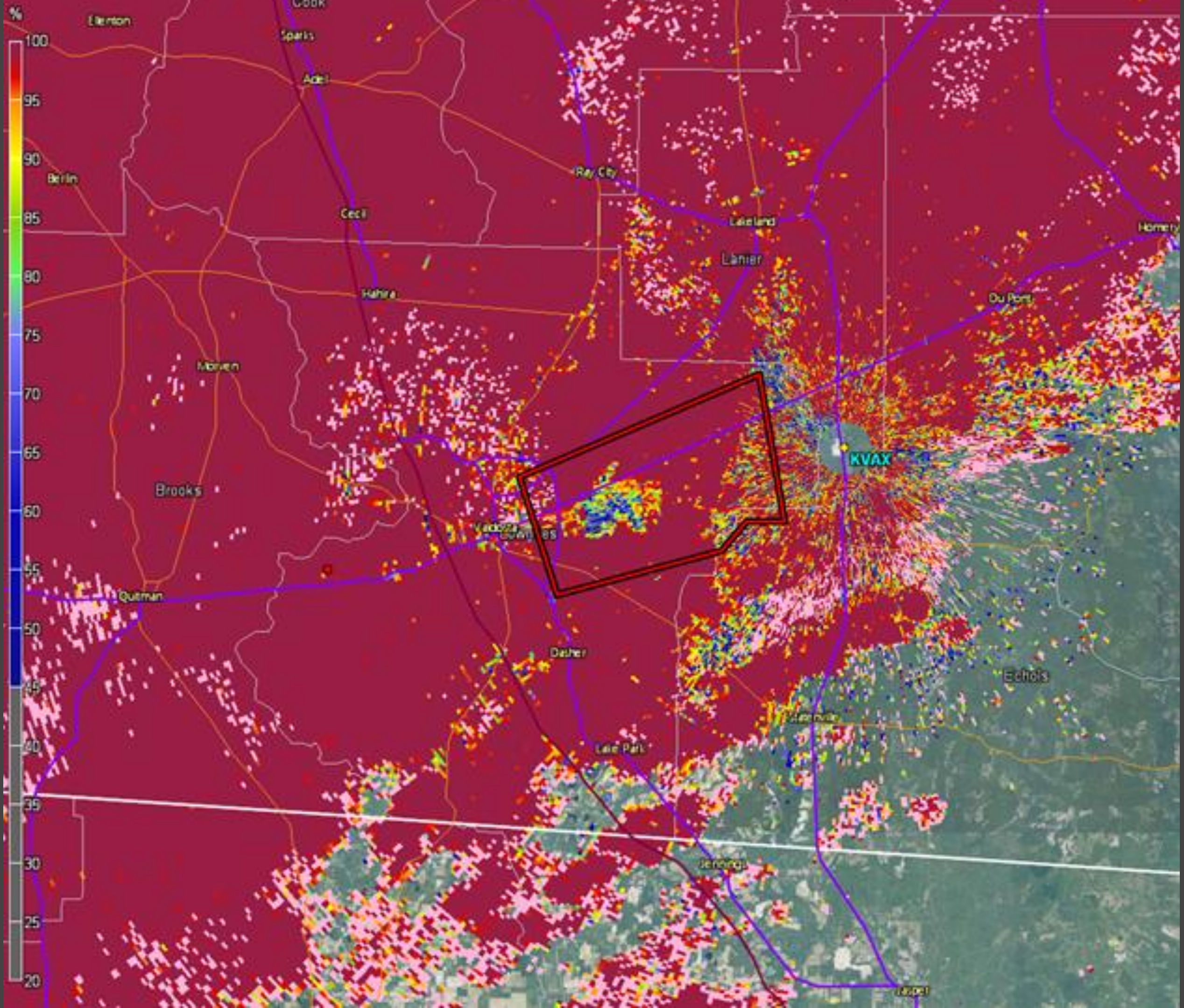

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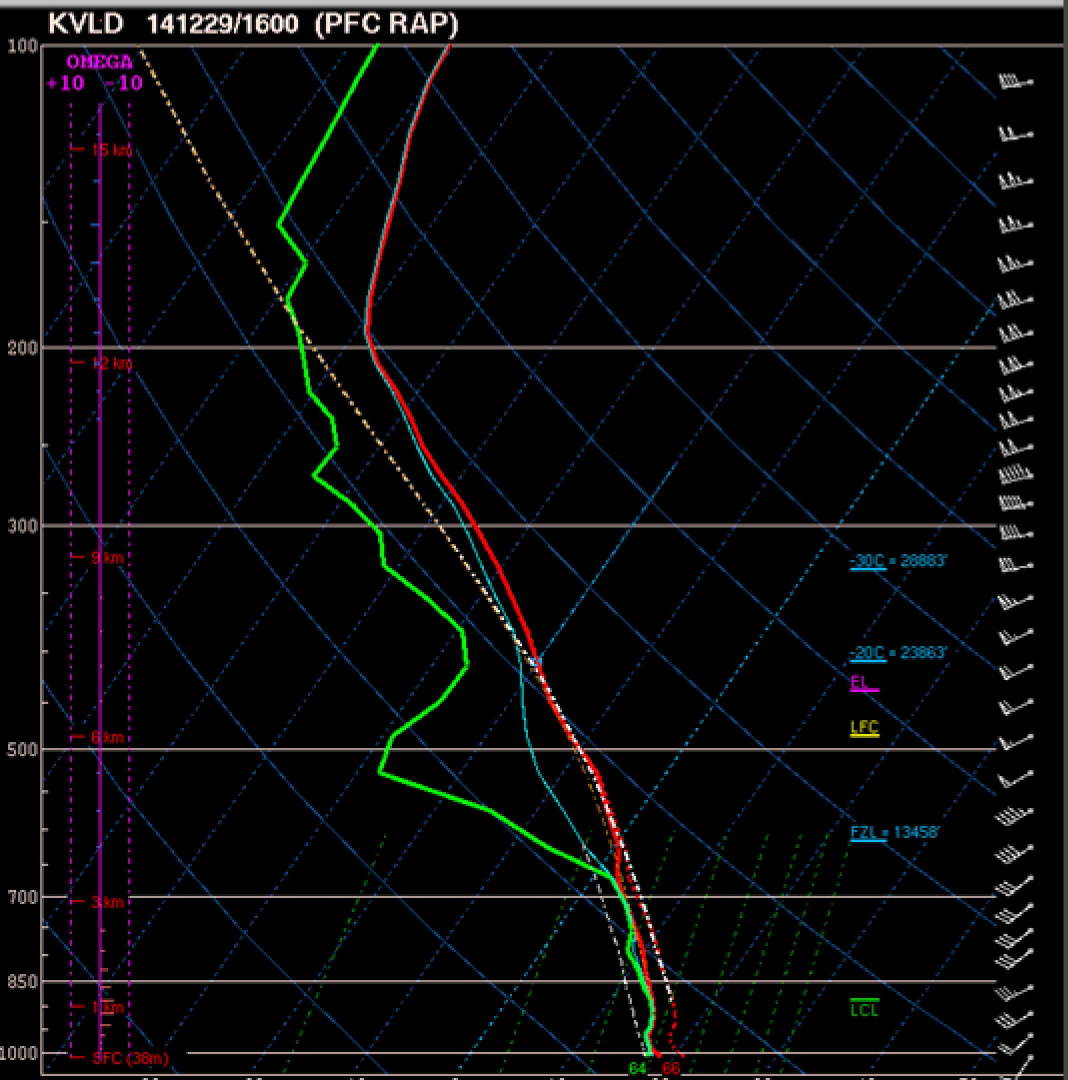
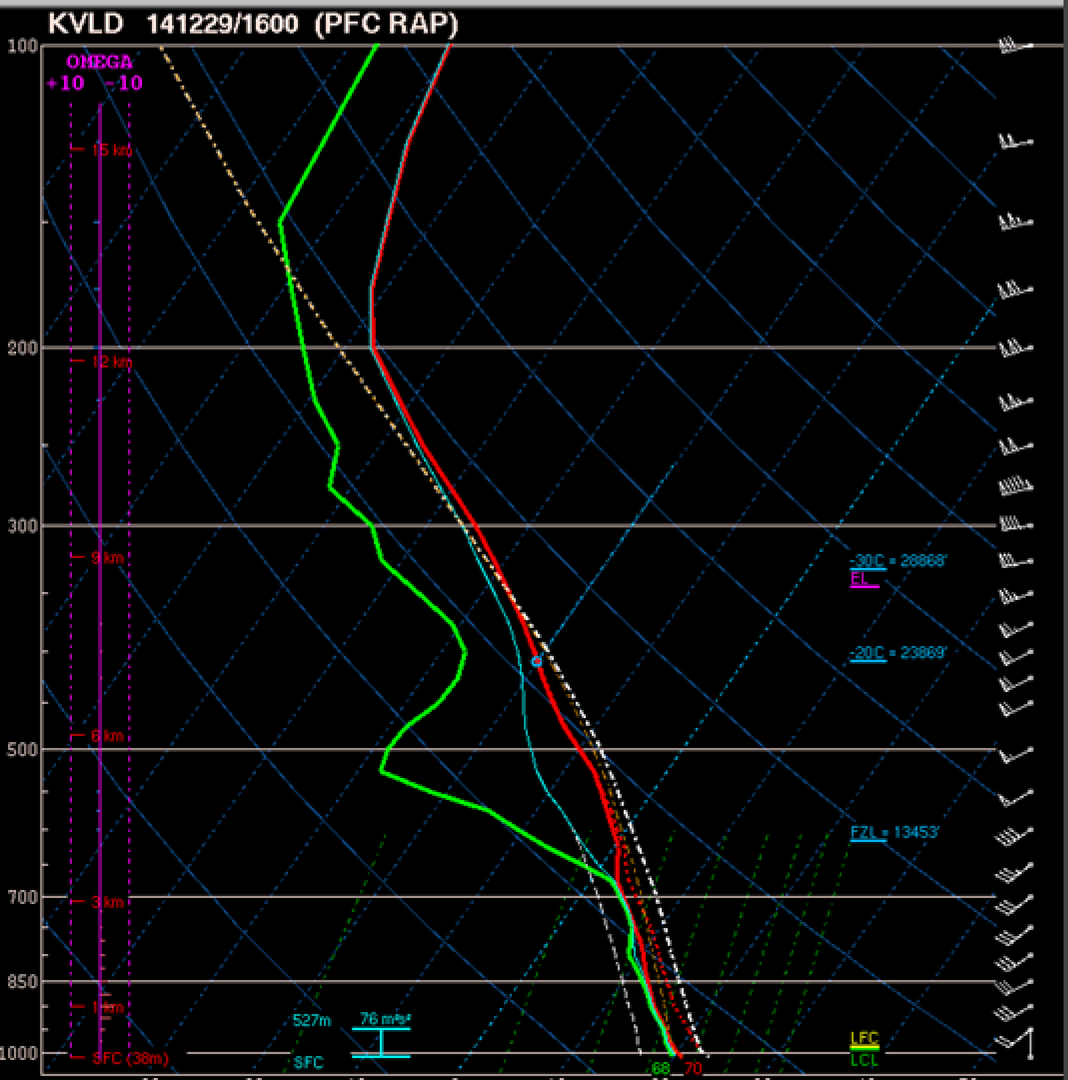
Valdosta, GA
Dec. 29, 2014
EF-2



What if we adjusted the soundings based on nearby surface observations?

This gives a little more MLCAPE, which would increase the STP value to a degree.

But analyses and models may not catch this!



What if we adjusted the soundings based on nearby surface observations?

This gives a little more MLCAPE, which would increase the STP value to a degree.

But analyses and models may not catch this!

No approach is foolproof!

Parameters are useful tools, but should not substitute a thorough analysis of the environment.