

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 Composite Parameter



Significant Tornado Parameter



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

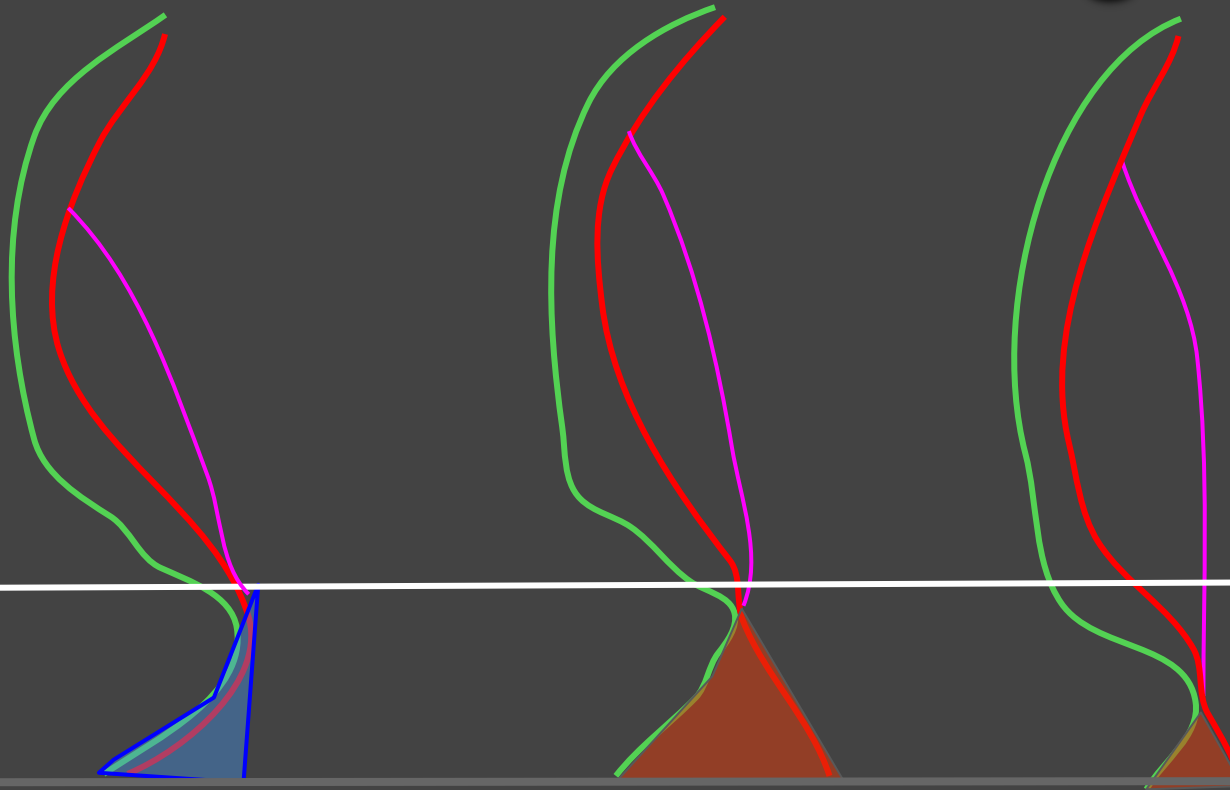
Let's consider each:

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



But which one to use?

Elevated vs. high based



Elevated != High based

High-based convection is often still surface based.

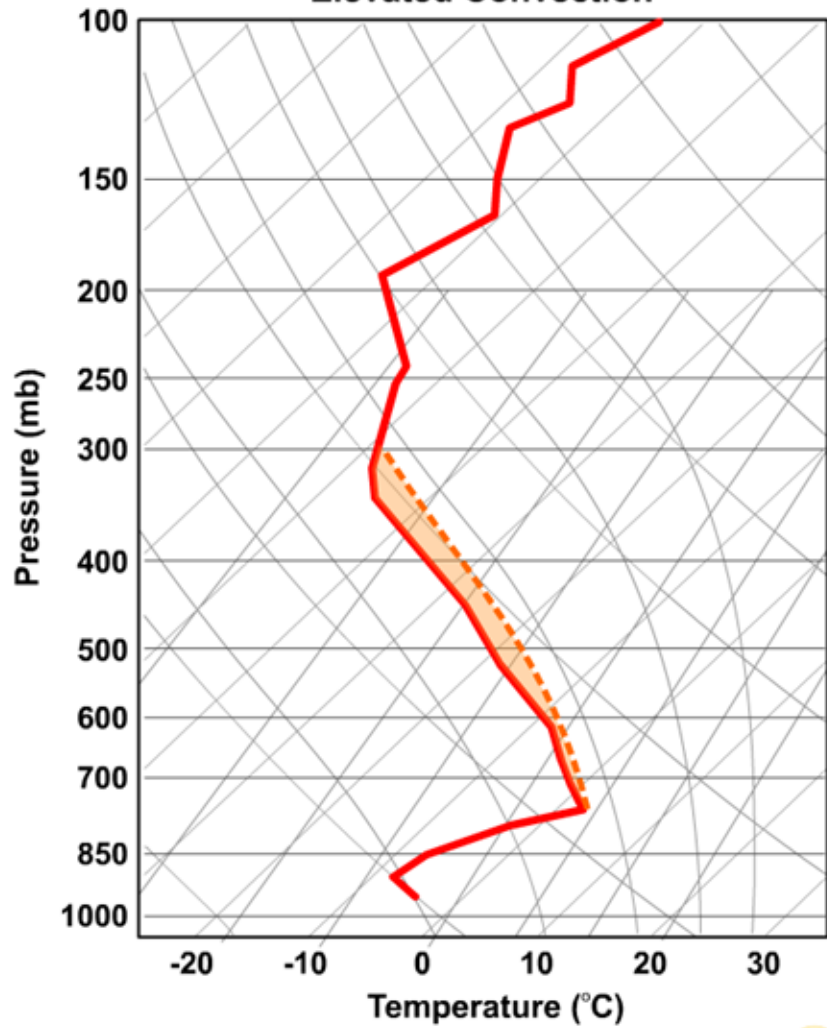
Effective inflow layer shows this discrimination

Cold stable layer
Elevated Convection

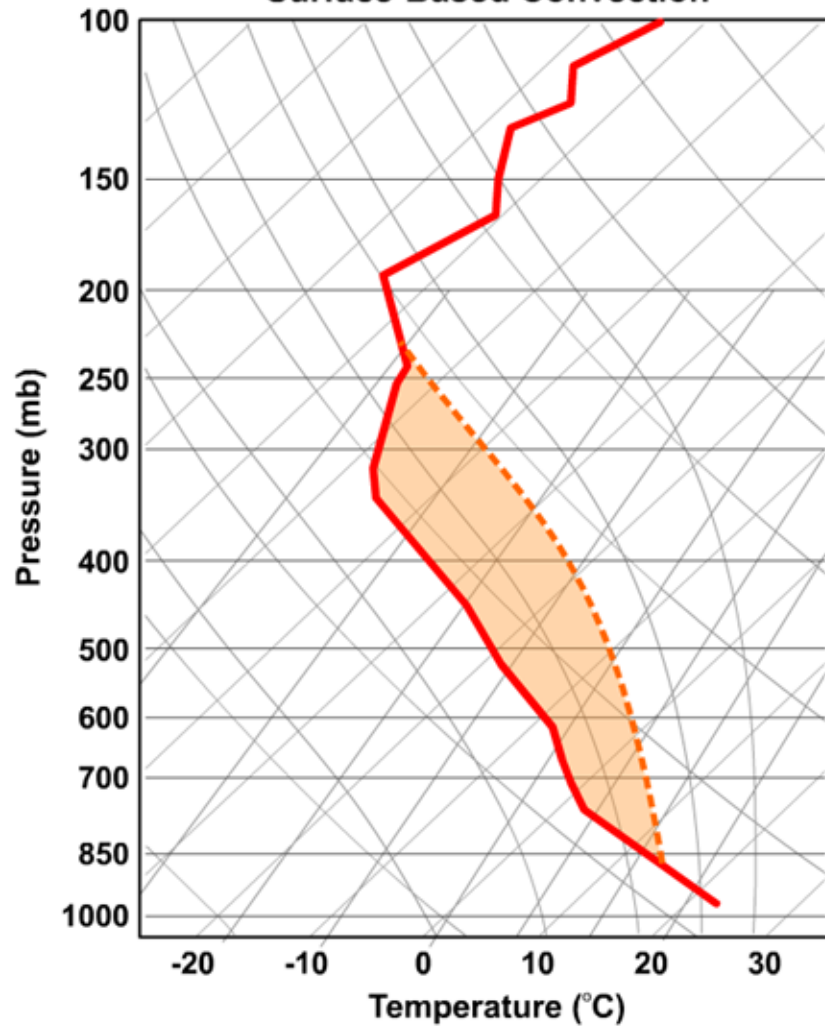
Surface High-based
mixed PBL High LCL

Surface based
mixed PBL Low LCL

Elevated Convection



Surface-Based Convection



SCP

Let's consider each:

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

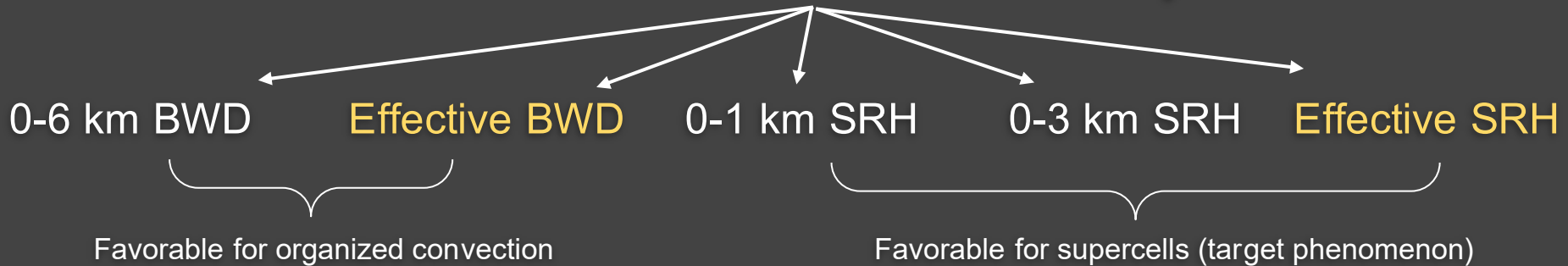


We'll use MUCAPE to capture all thunderstorm environments

SCP

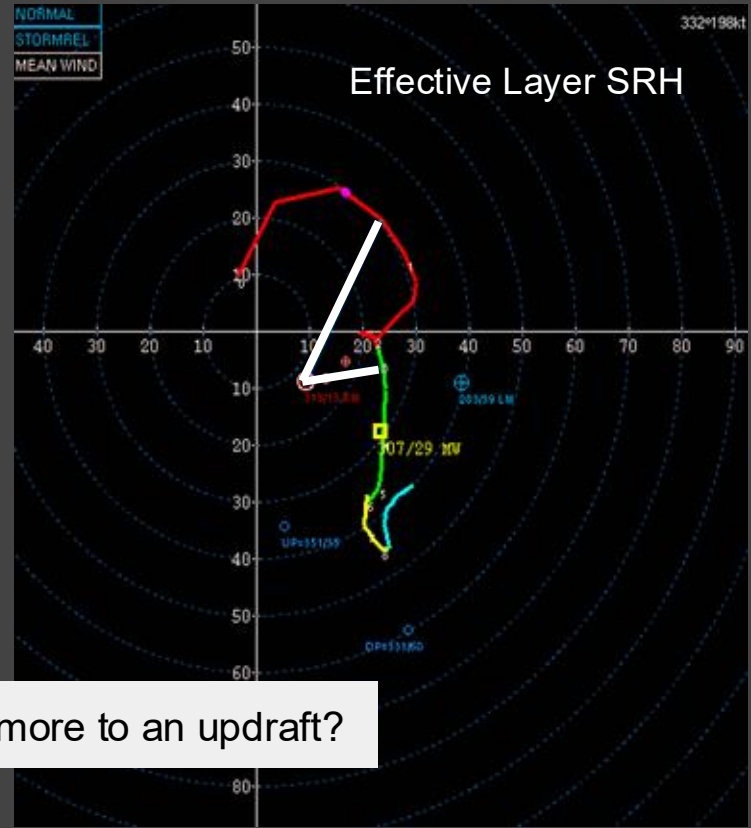
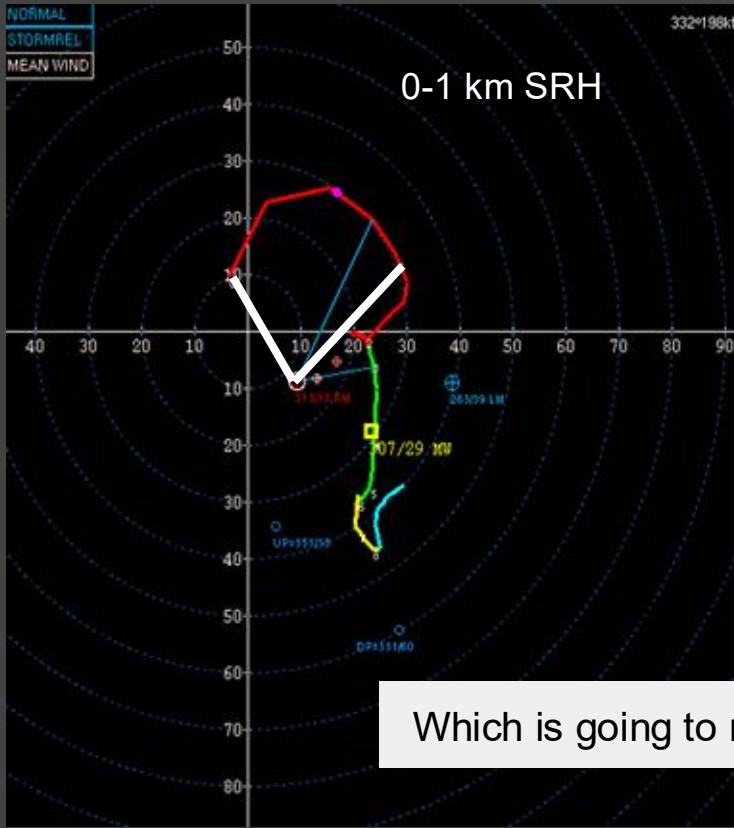
Let's consider each:

Vertical wind shear - Also easy!



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



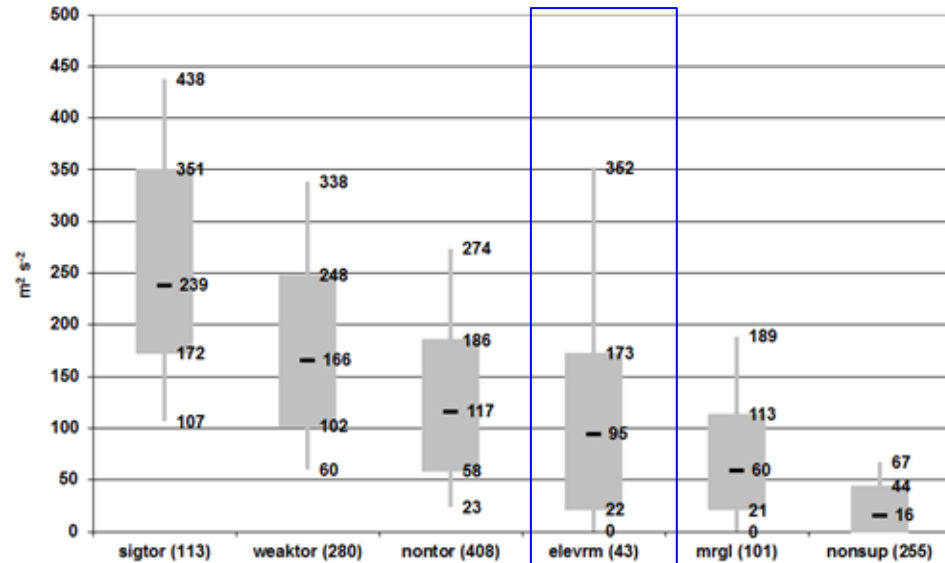
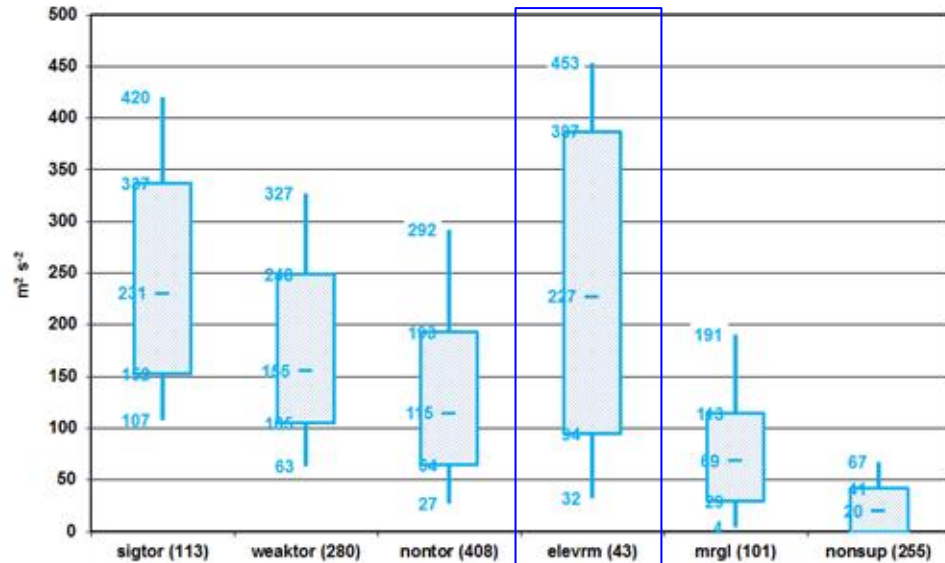
Which is going to matter more to an updraft?

Low-level shear



Effective SRH versus 0-1 km SRH

Effective SRH versus 0-1 km 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

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SCP

$$\text{SCP} = f(\text{MUCAPE}, \text{MUCIN}, \text{EBWD}, \text{ESRH})$$

Measure of
instability

Measure of
inhibition

Deep-layer
shear

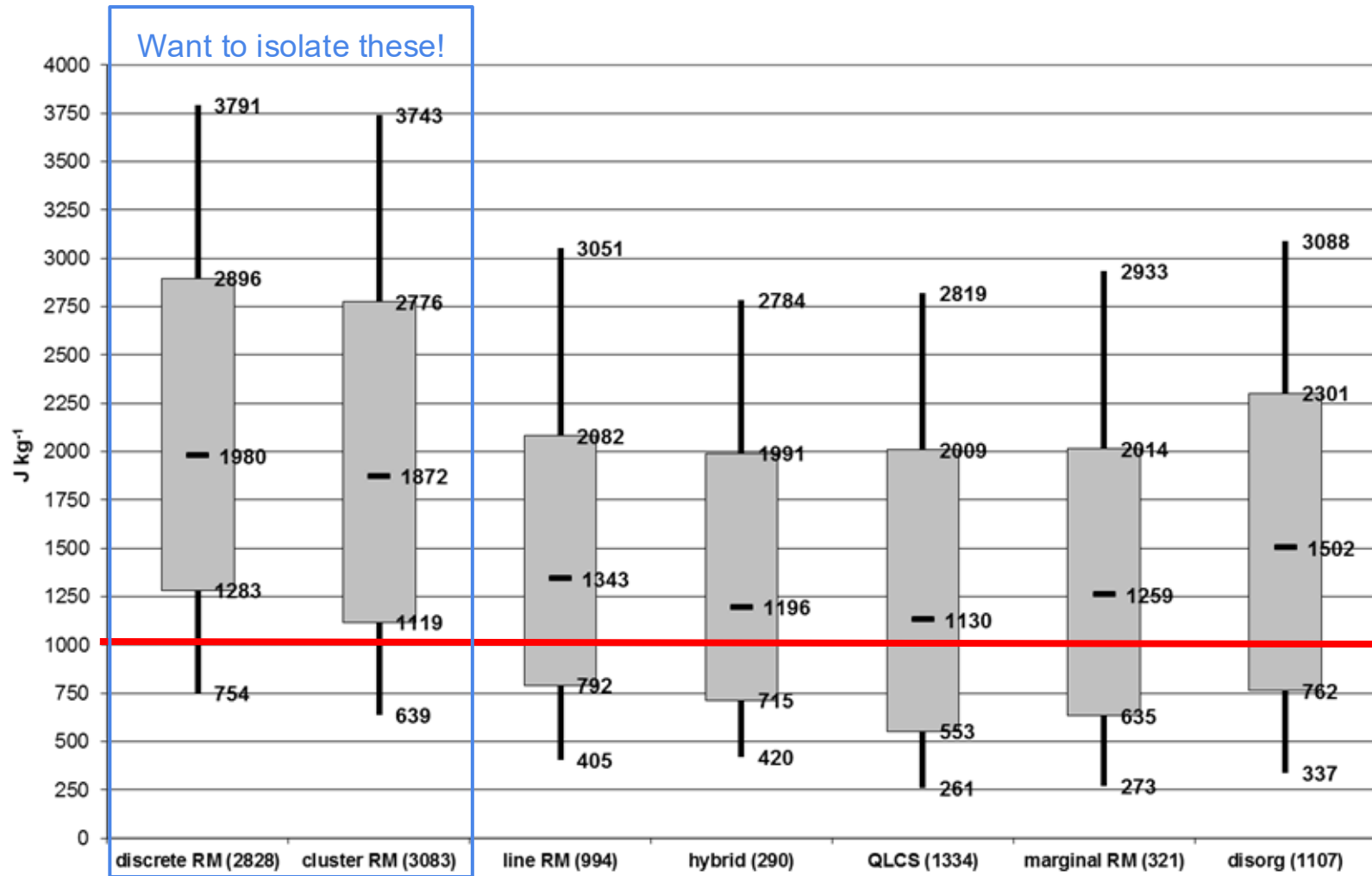
Low-level
shear

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



SCP

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



MUCAPE \leq 1000: term = 0 to 1.0

MCAPE $>$ 1000: term = 1.0+

SCP

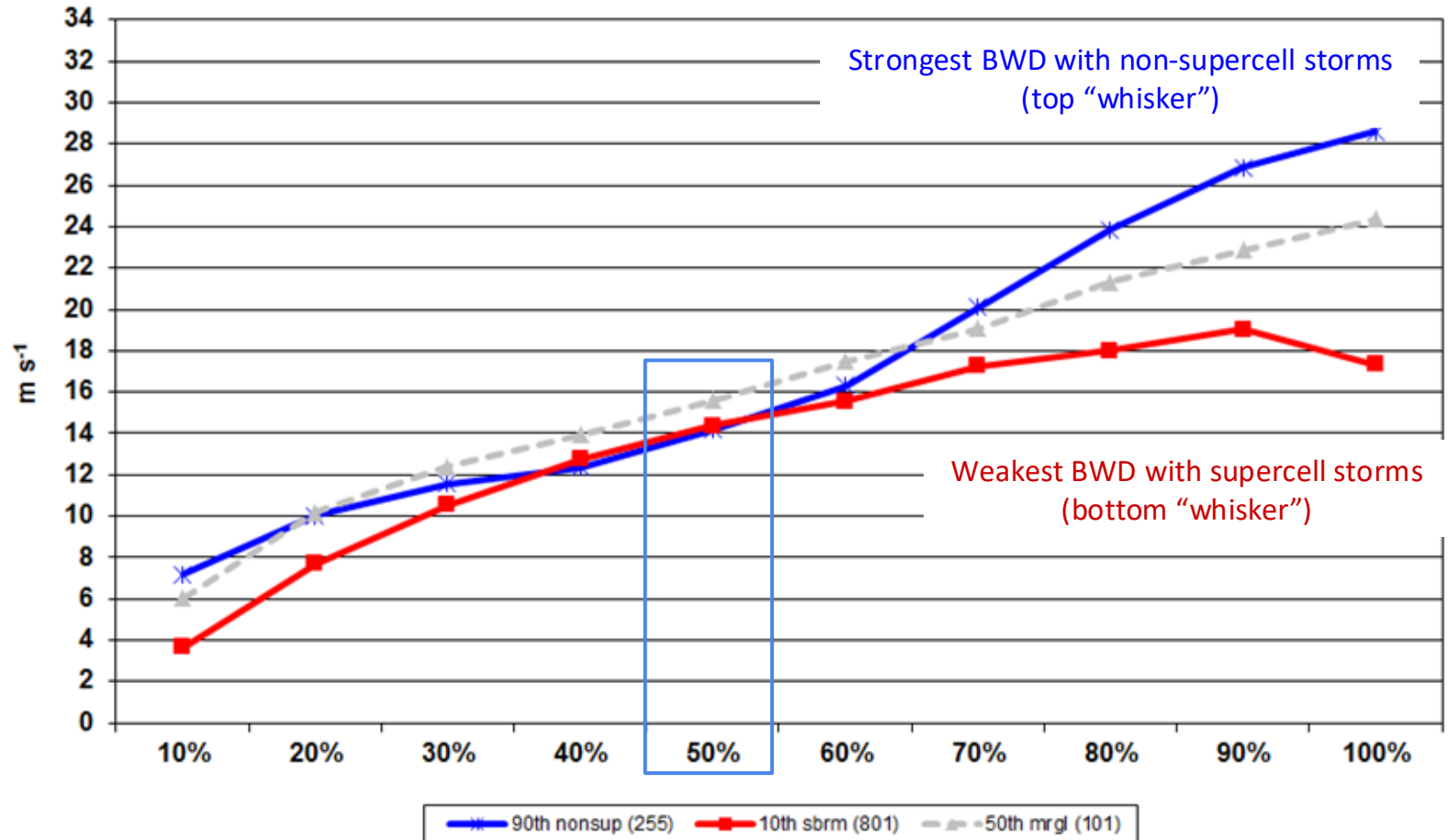
$$\text{SCP} = f\left(\frac{\text{MUCAPE}}{1000}, \frac{-40}{\text{MUCIN}}, \text{EBWD}, \text{ESRH}\right)$$



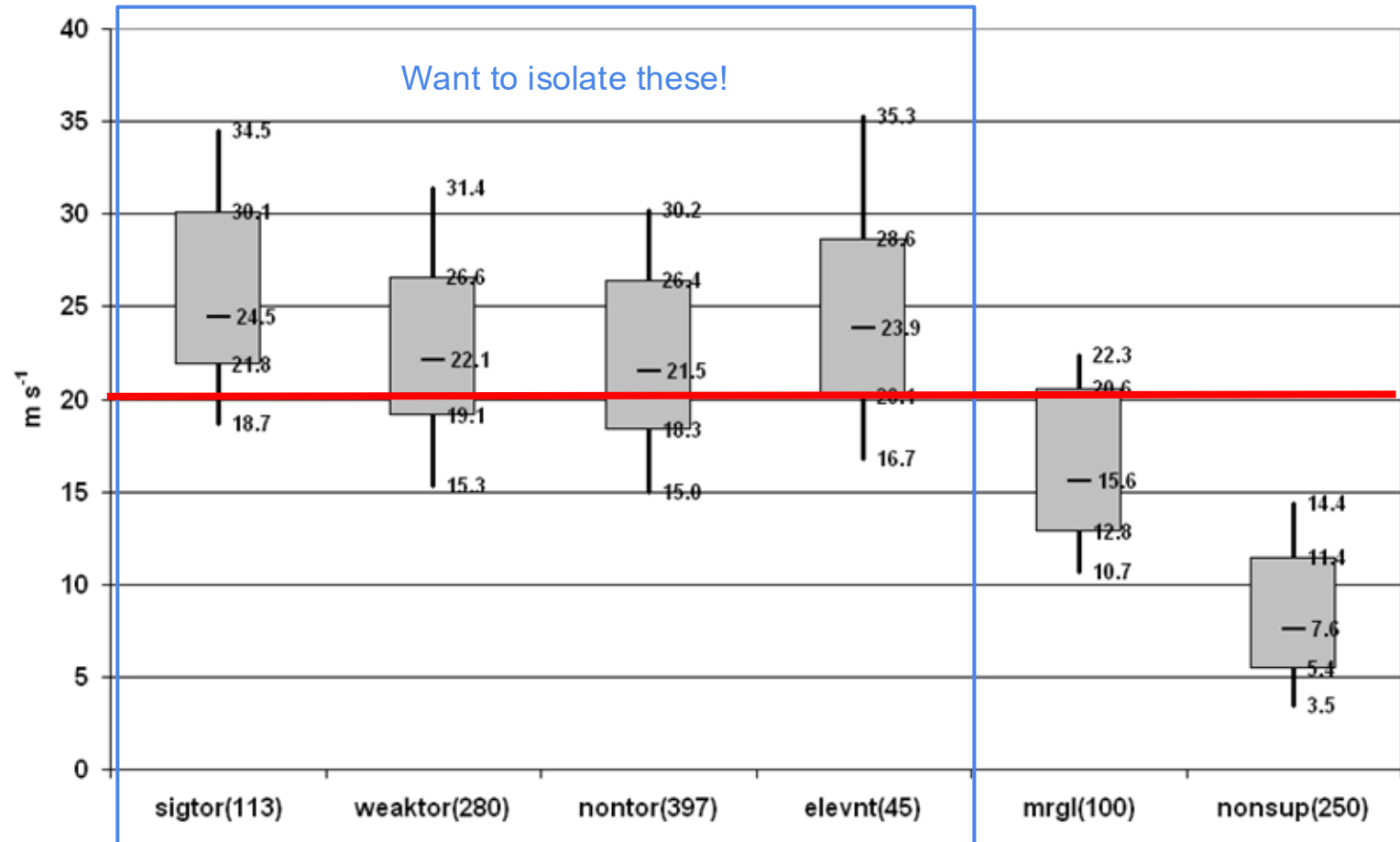
MUCIN > -40: term = 1.0

MUCIN <= -40: term 0.0 to 1.0
(term decreases with increasing MUCIN)

Effective Bulk Shear Percentiles (surface-based storms)



Effective Bulk Wind Difference
(lower 50% of storm depth)



SCP

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

EBWD \geq 20: term = 1.0 \longrightarrow

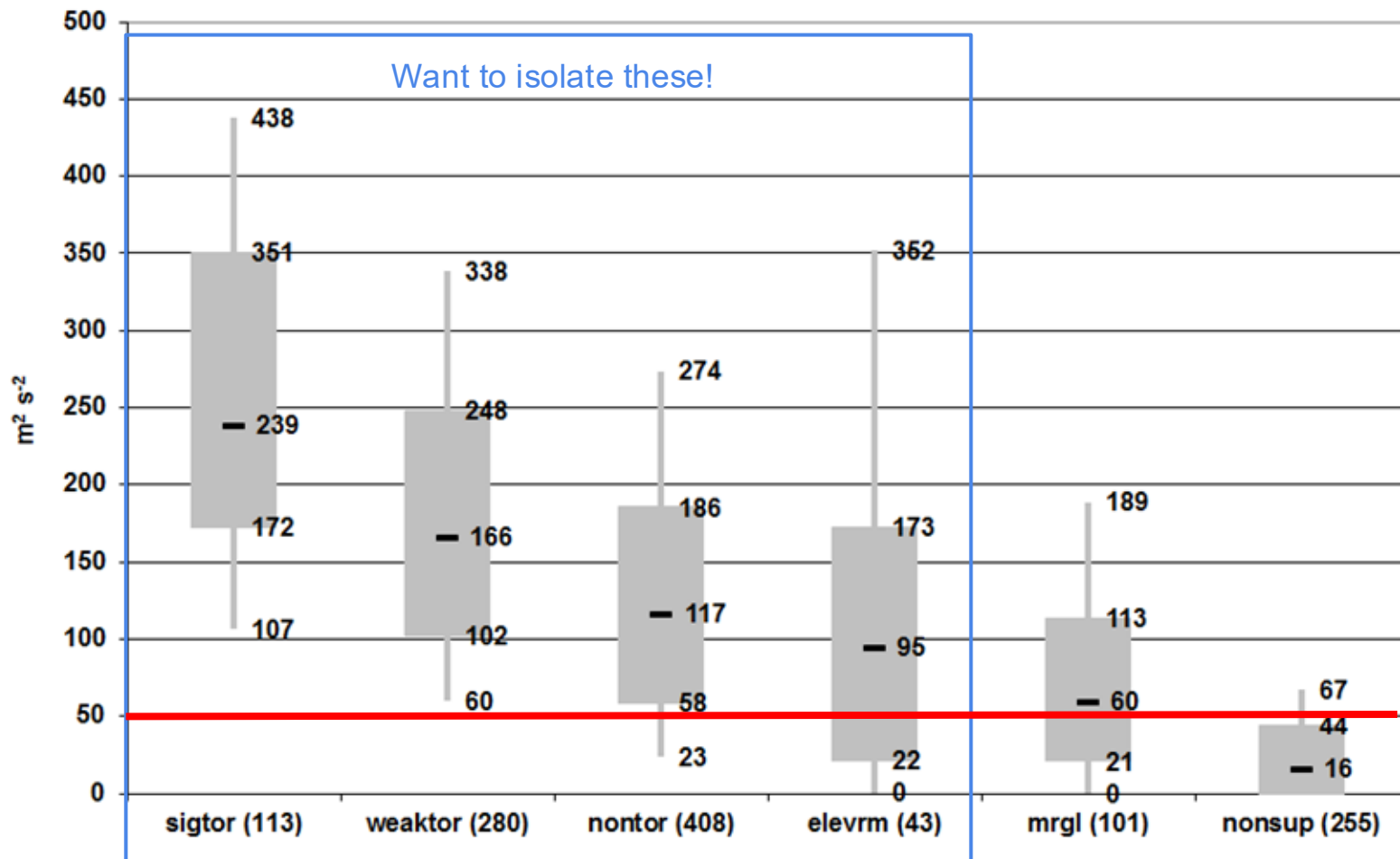
10 < EBWD < 20: term 0.0 to 1.0

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



SCP

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

ESRH \leq 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

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

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)

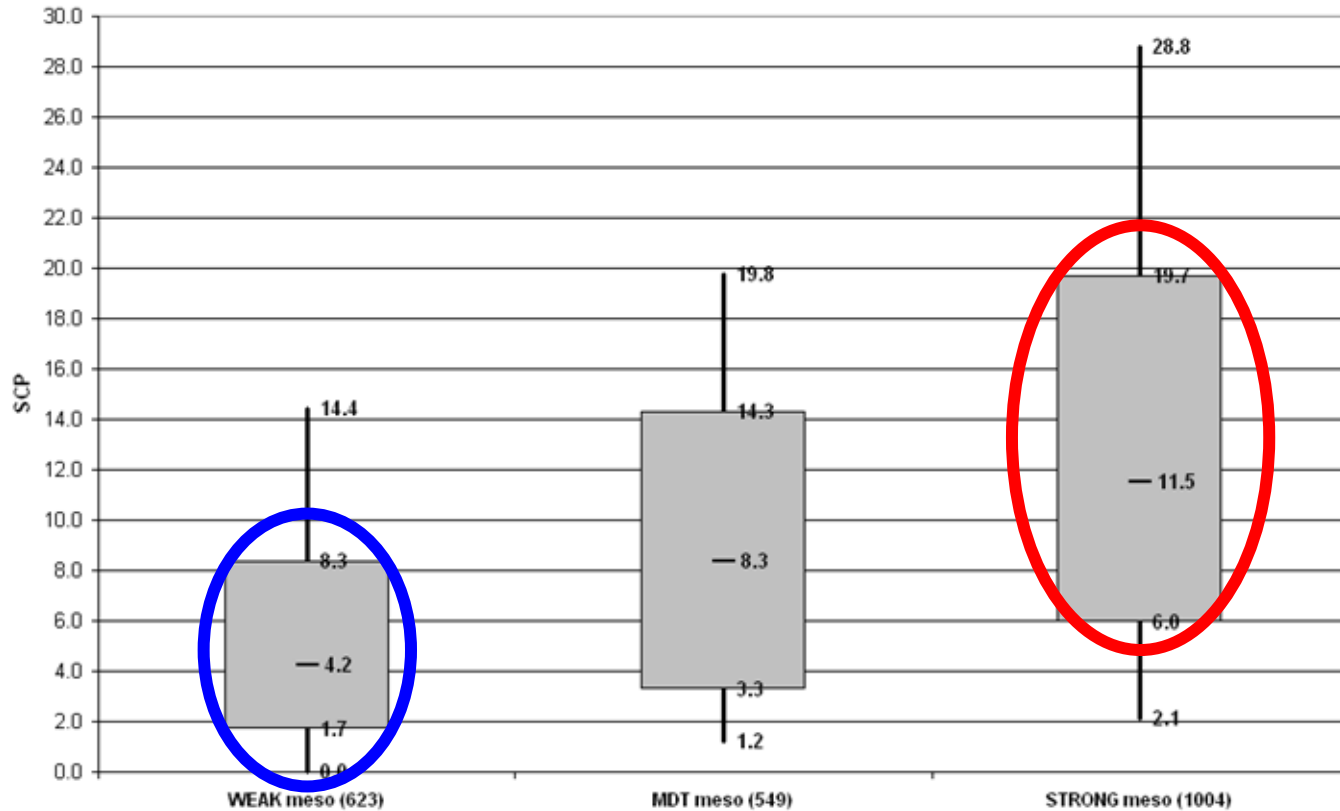
SCP

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

Also note:

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

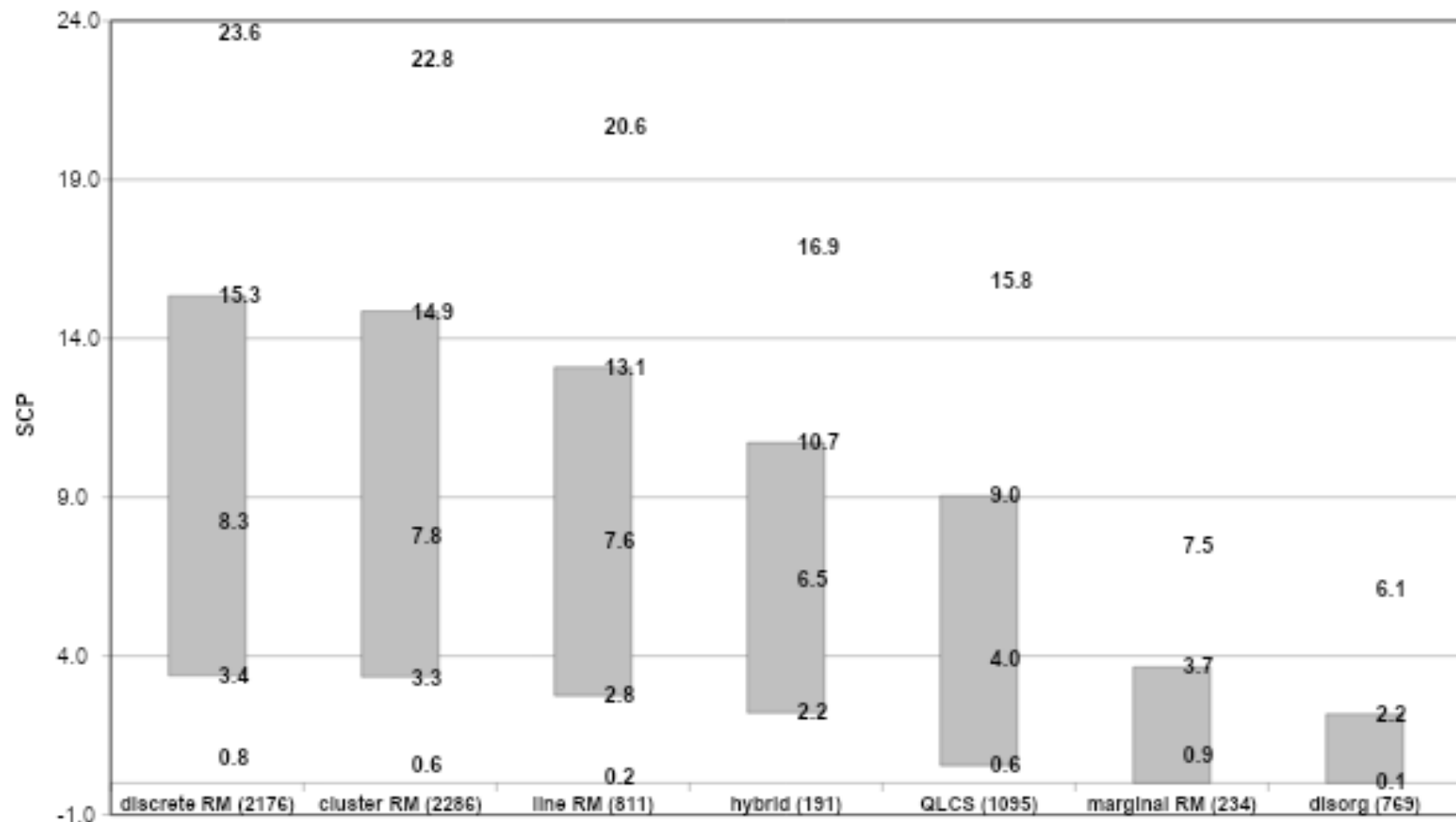
discrete RM tornadoes: effective-layer SCP by mesocyclone strength



Weaker rotation – smaller SCP

Stronger rotation – larger SCP

effective-layer SCP: tornadoes by convective mode



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

$$\text{STP} = f(\text{MLCAPE}, \text{MLCIN}, \text{EBWD}, \text{ESRH}, \text{MLLCL})$$

Measure of surface
(or near-surface)
based instability

Driving factor

Measure of surface
(or near-surface)
based inhibition

Limiting factor

Deep-layer
Shear

Necessary
Factor

Low-level
Shear

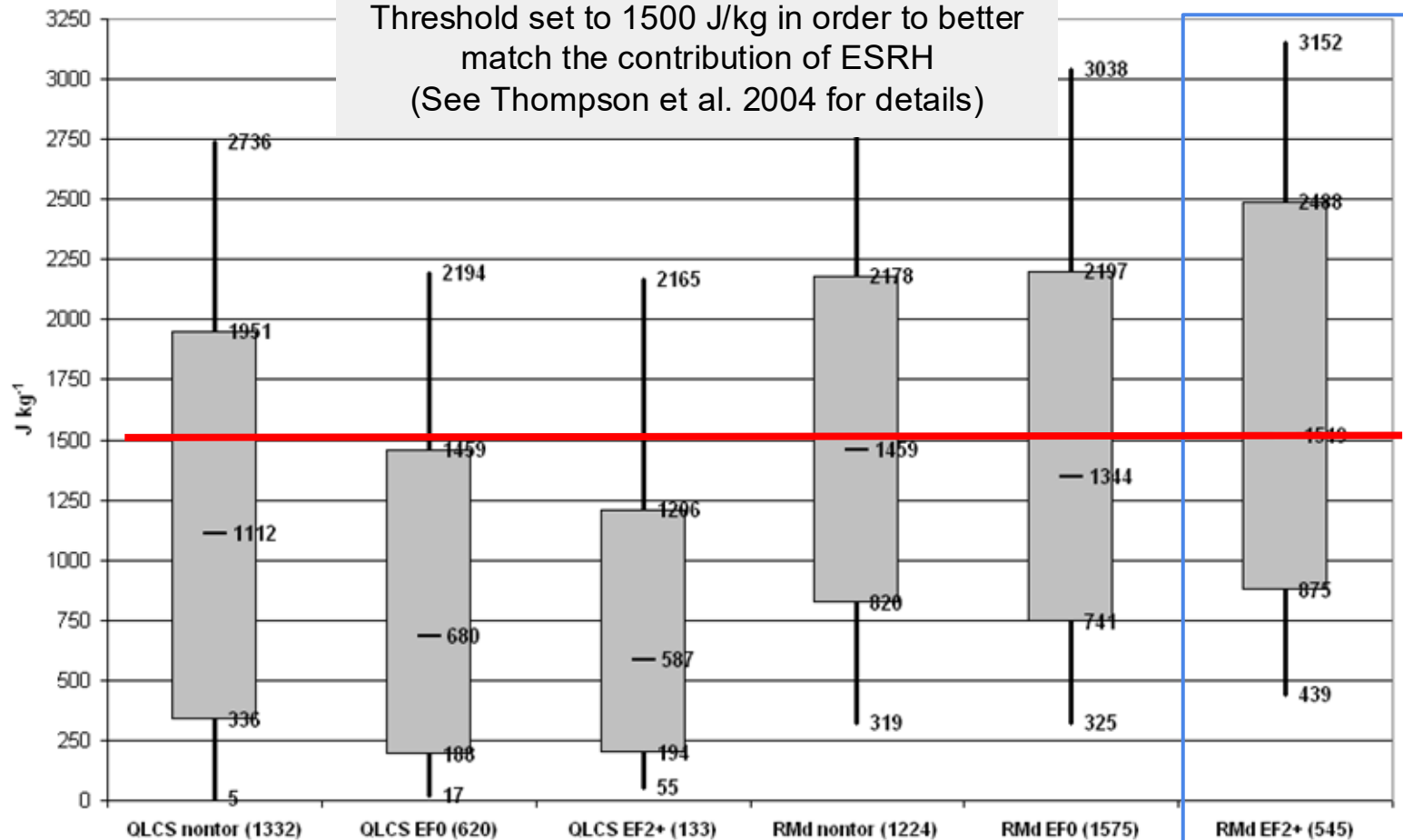
Driving factor

Measure of near-surface
downdraft air
buoyancy/stretching
potential

Limiting factor

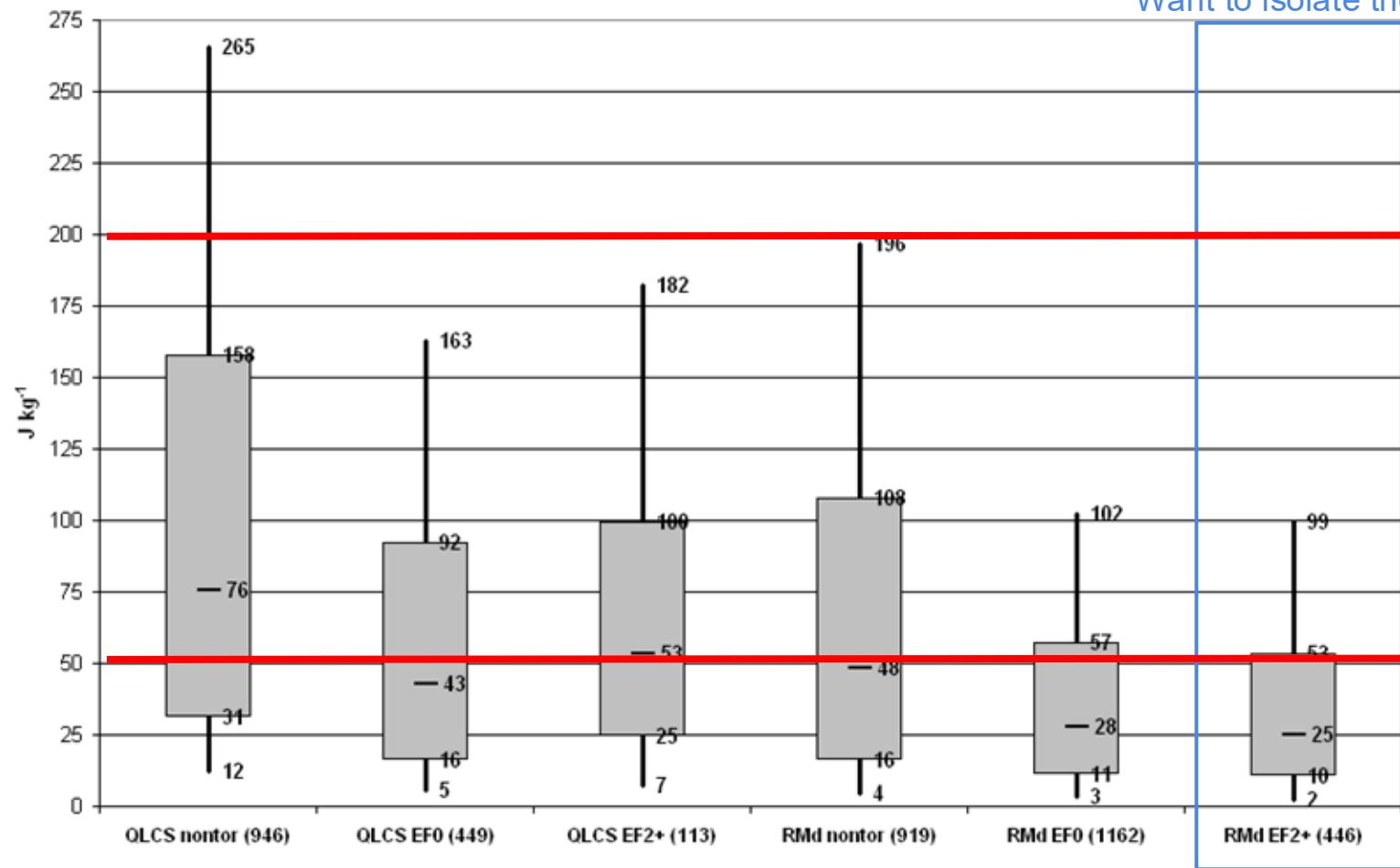
MLCAPE

Want to isolate these!



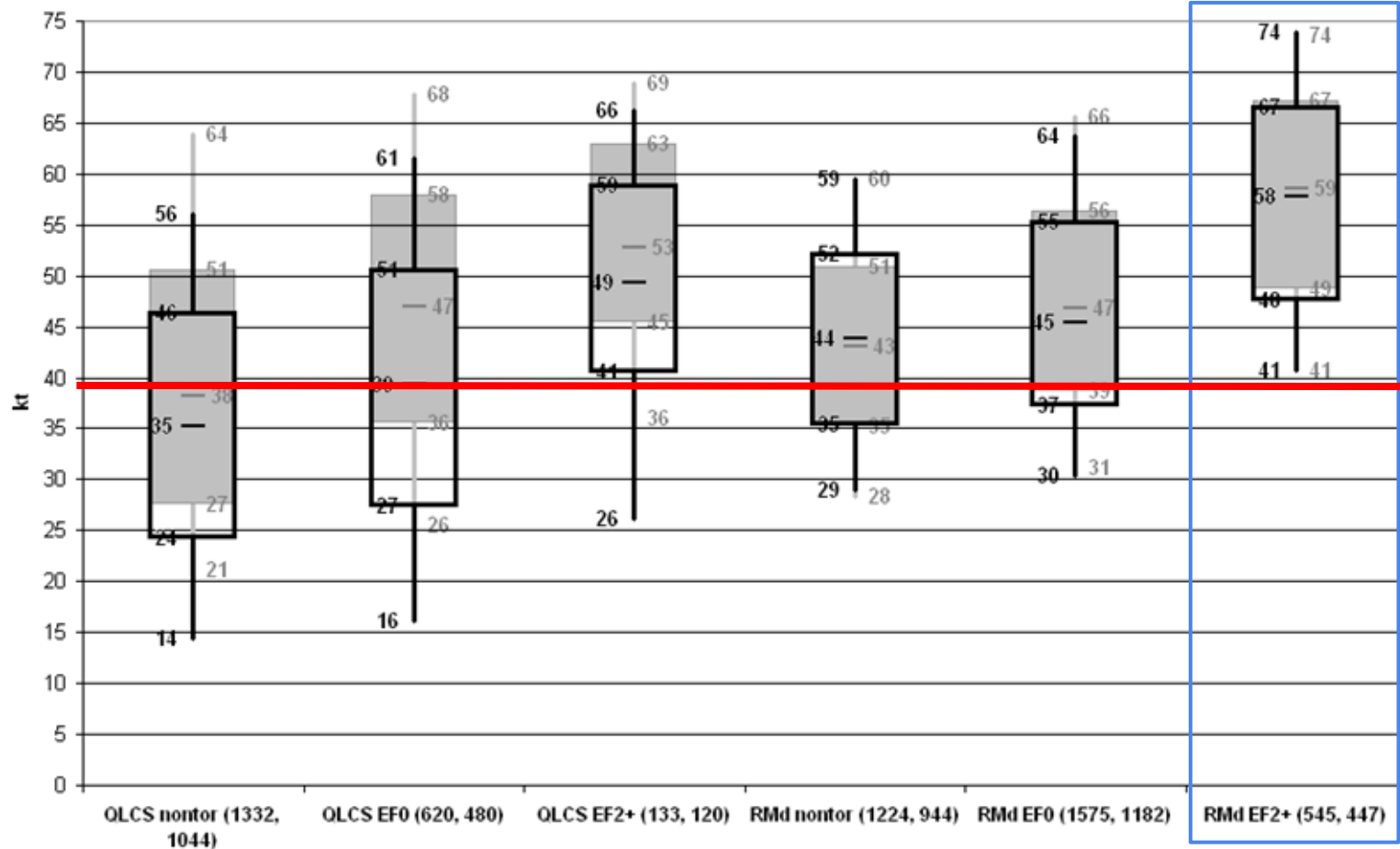
MLCIN

Want to isolate these!



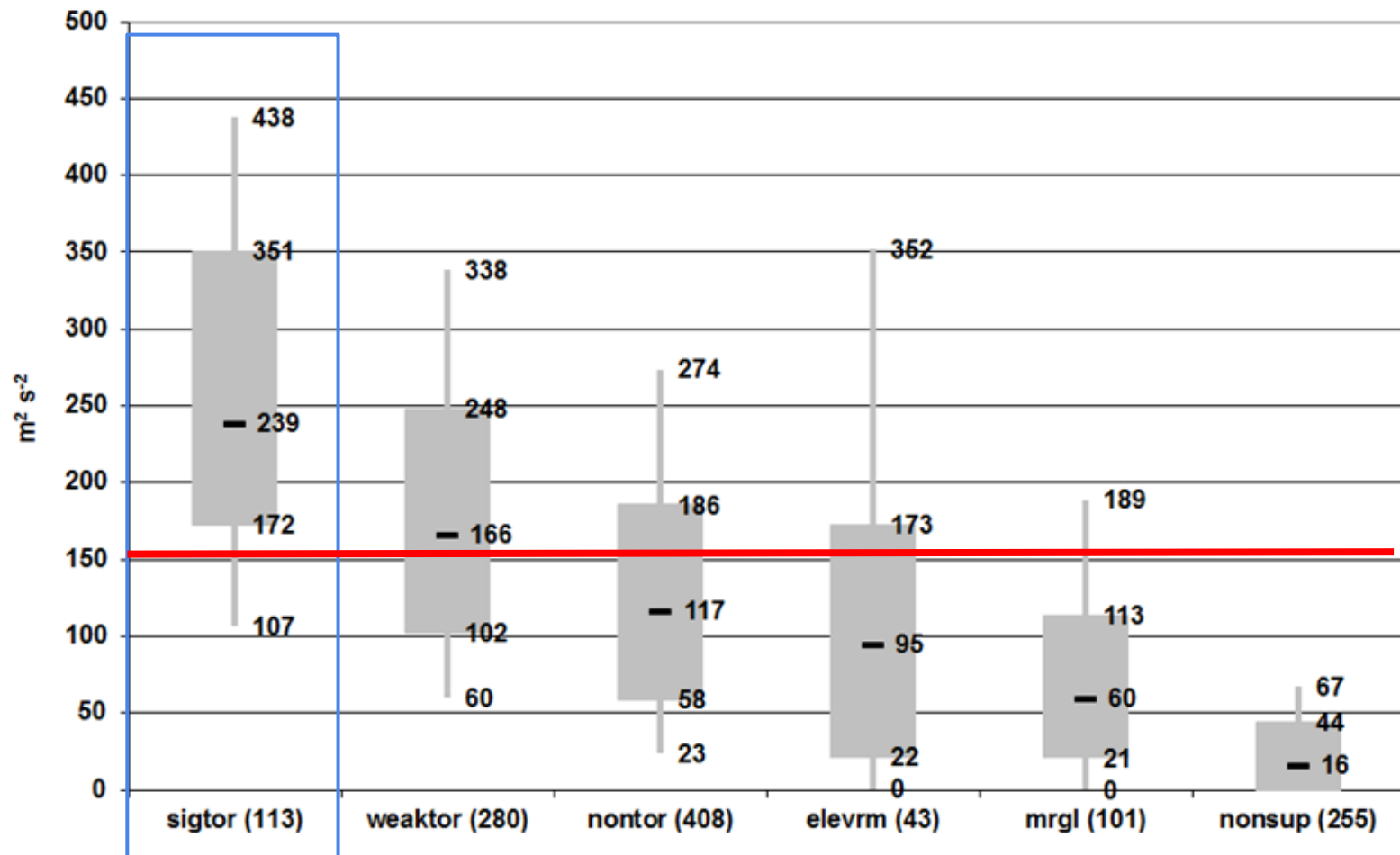
0-6 km BWD versus EBWD

Want to isolate these!



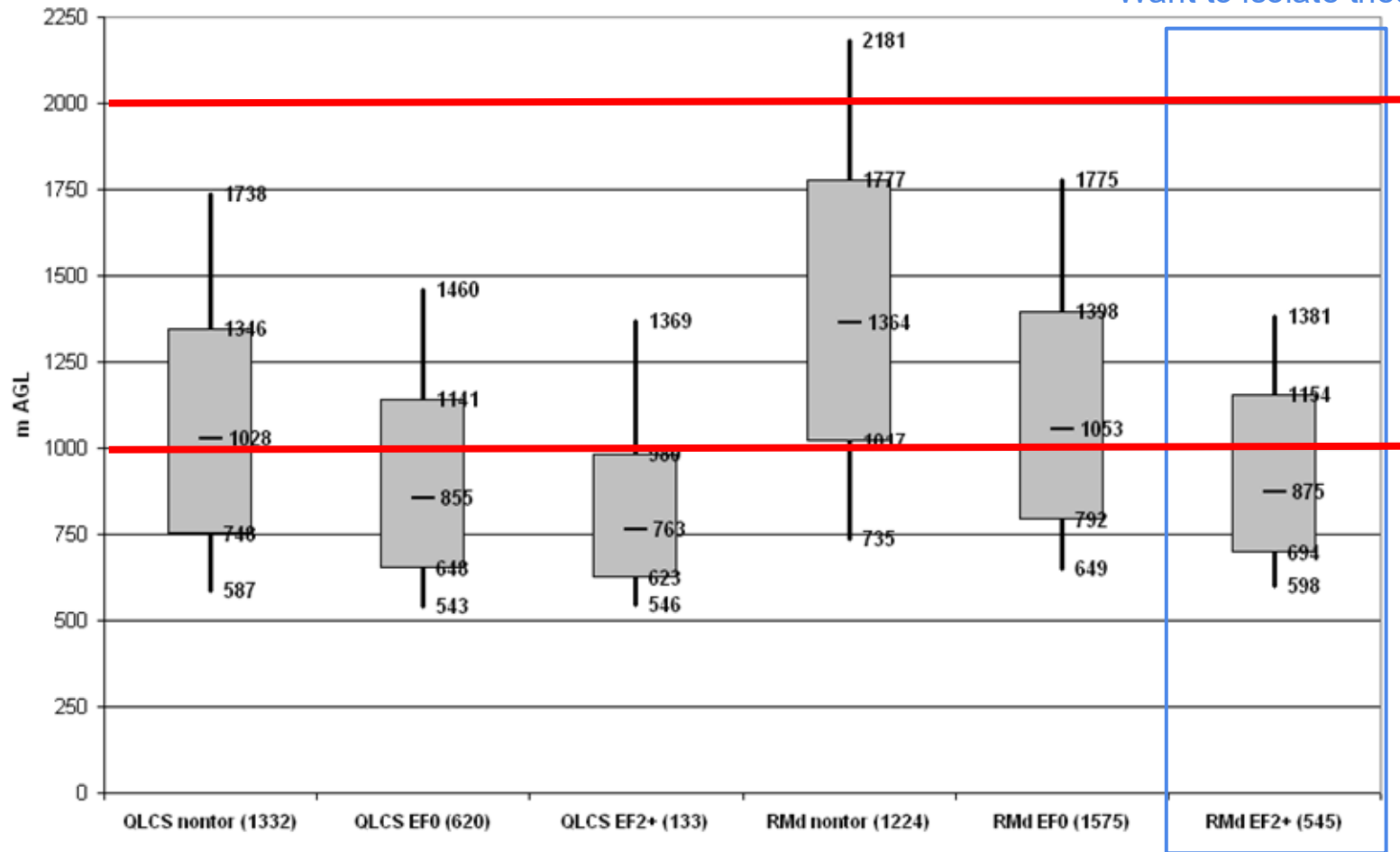
Effective SRH versus 0-1 km SRH

Want to isolate these!



MLLCL height

Want to isolate these!



STP =

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

Goes to 0 as 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

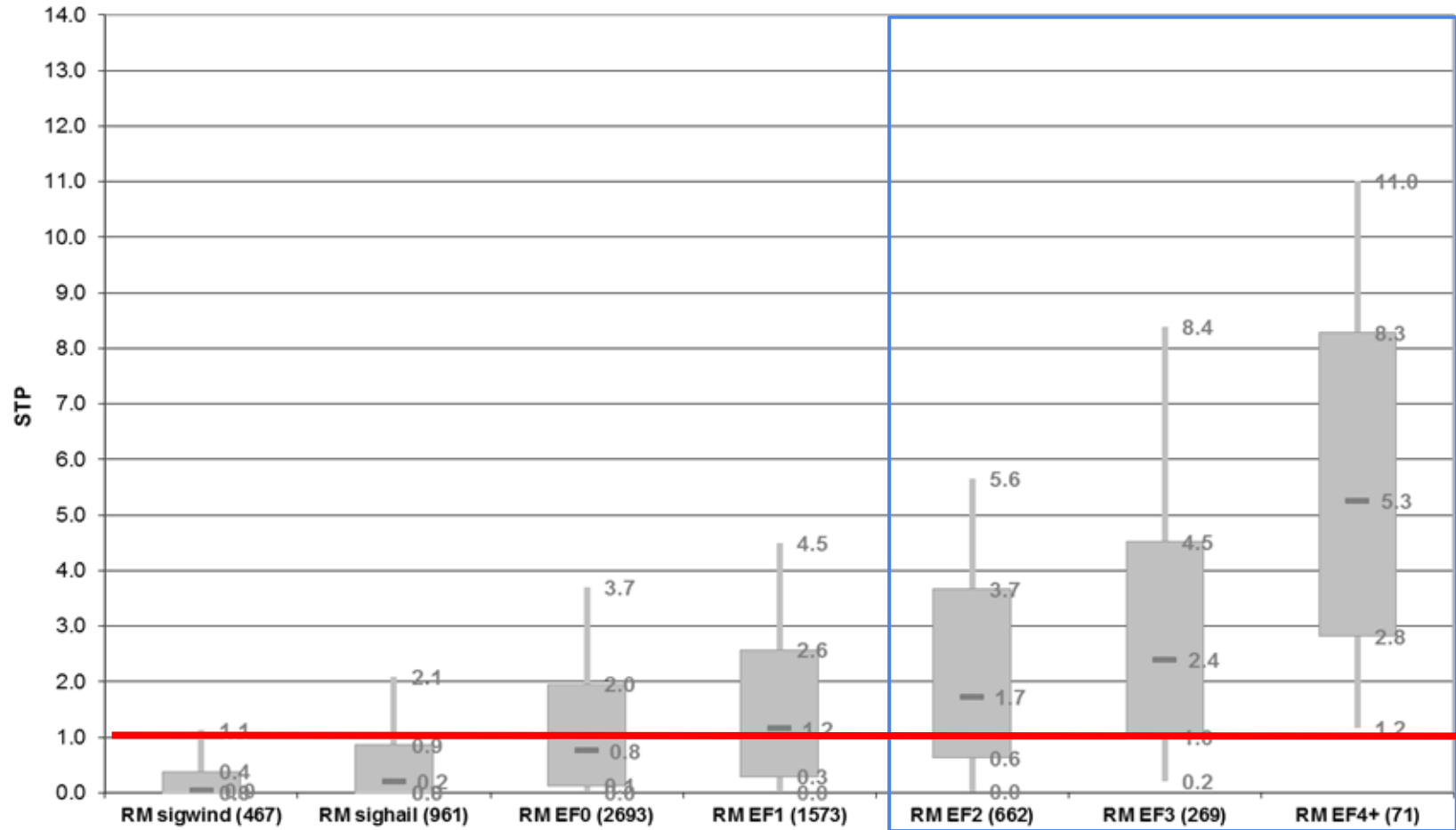
Set to 1.5 if EBWD > 30 m/s

Set to 0 if MLLCL > 2000 m

Set to 1.0 if MLLCL < 1000 m

effective-layer STP

Want to isolate these!



Fixed-Layer STP

MLCAPE \longrightarrow SBCAPE

MLCIN \longrightarrow SBCIN

EBWD \longrightarrow 0-6 km BWD

ESRH \longrightarrow 0-1 km SRH

MLLCL \longrightarrow 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!

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 - Always look into the environment to see if the parameter value is reasonable!

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

$$MLCAPE = 500 \text{ J/kg}$$

$$ESRH = 500 \text{ m}^2/\text{s}^2$$

$$EBWD = 20 \text{ m/s}$$

$$MLCIN = -150 \text{ J/kg}$$

$$MLLCL = 1000 \text{ m}$$

$$STP = 1.1$$

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!

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

$$MLCAPE = 5000 \text{ J/kg}$$

$$ESRH = 50 \text{ m}^2/\text{s}^2$$

$$EBWD = 20 \text{ m/s}$$

$$MLCIN = -150 \text{ J/kg}$$

$$MLLCL = 1000 \text{ m}$$

$$STP = 1.1$$

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 =

EBWD =

MLCIN = 150 J/kg

MLLCL = 1000 m

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

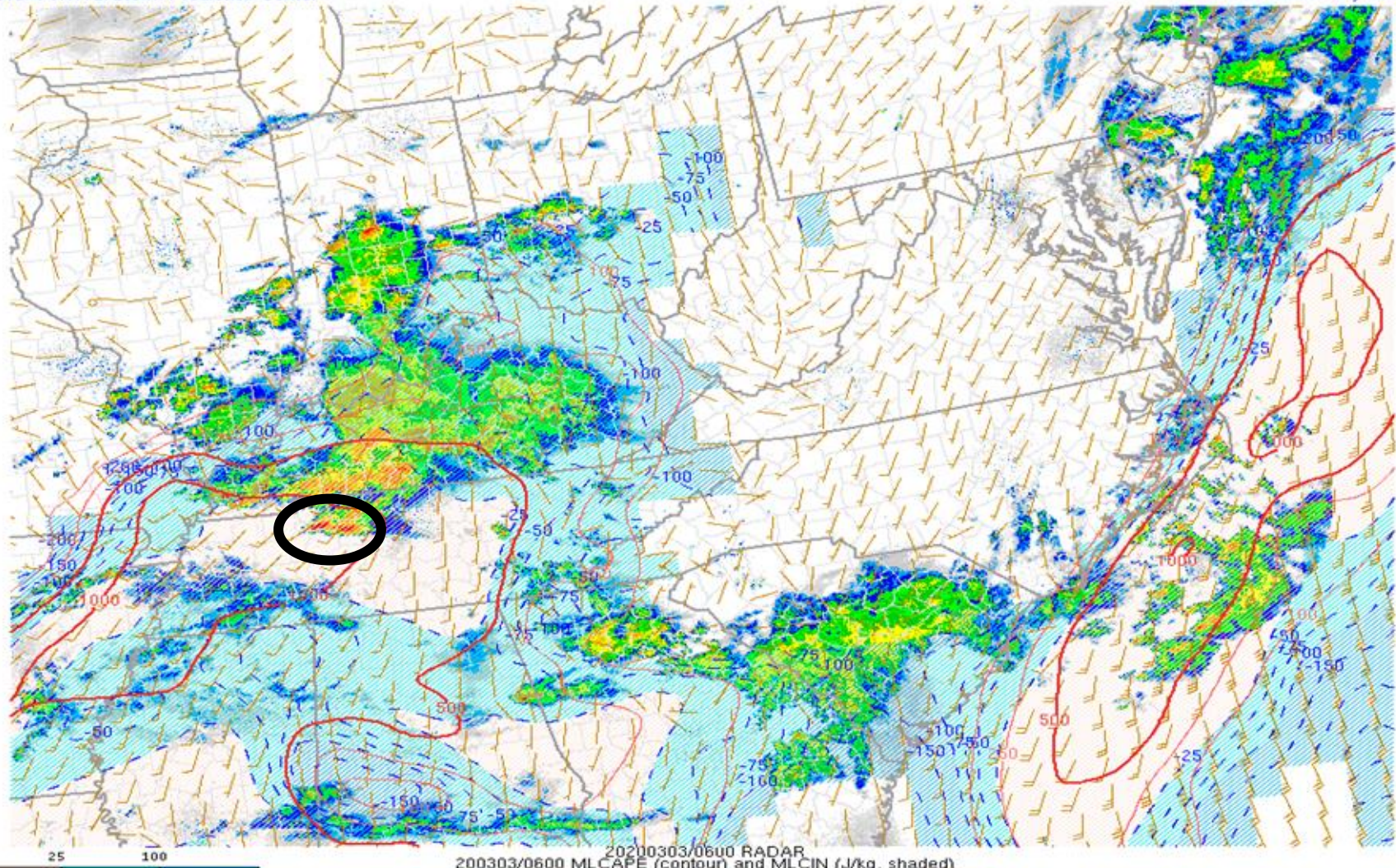
1.1

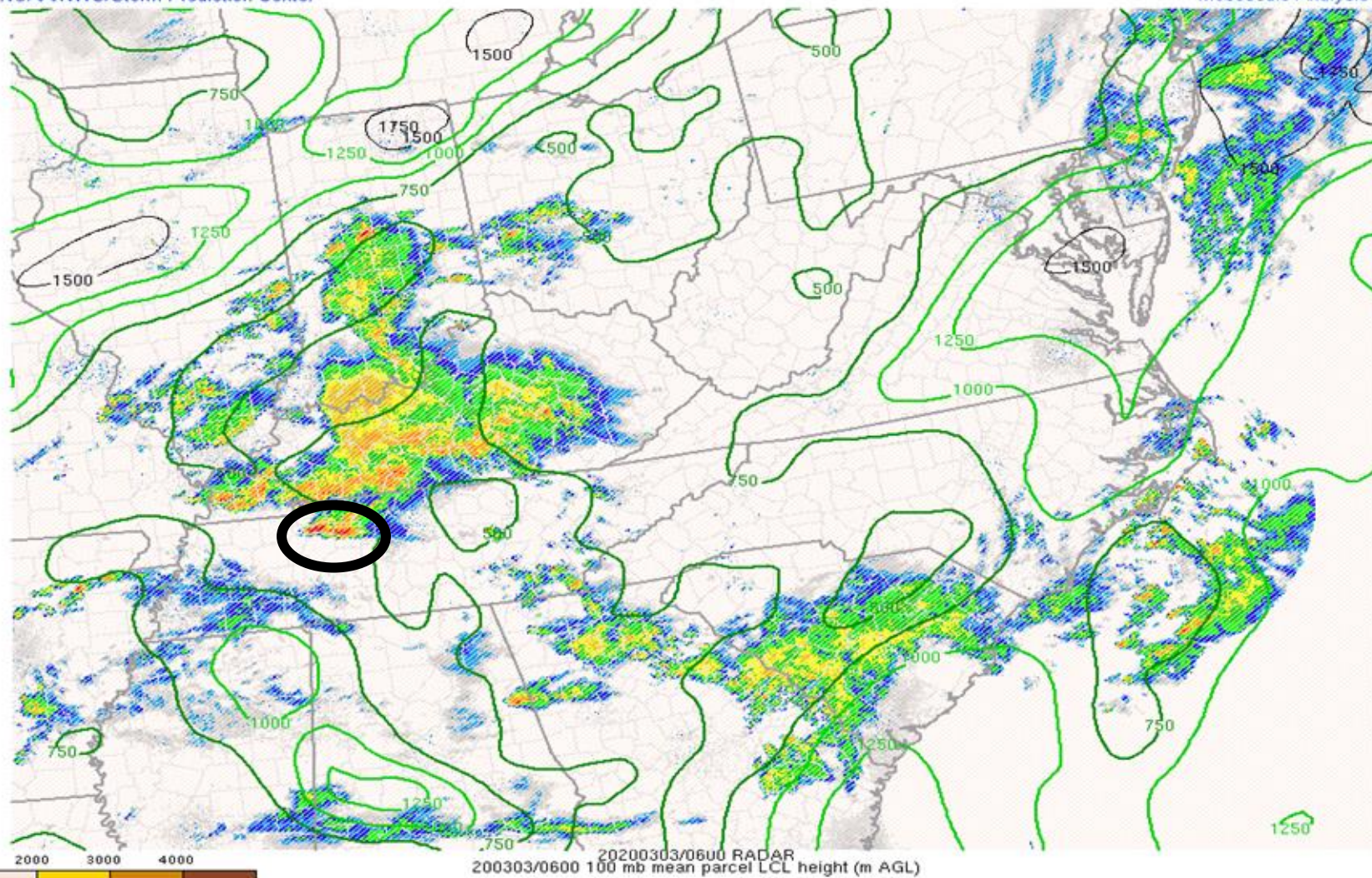
Low Shear
ment

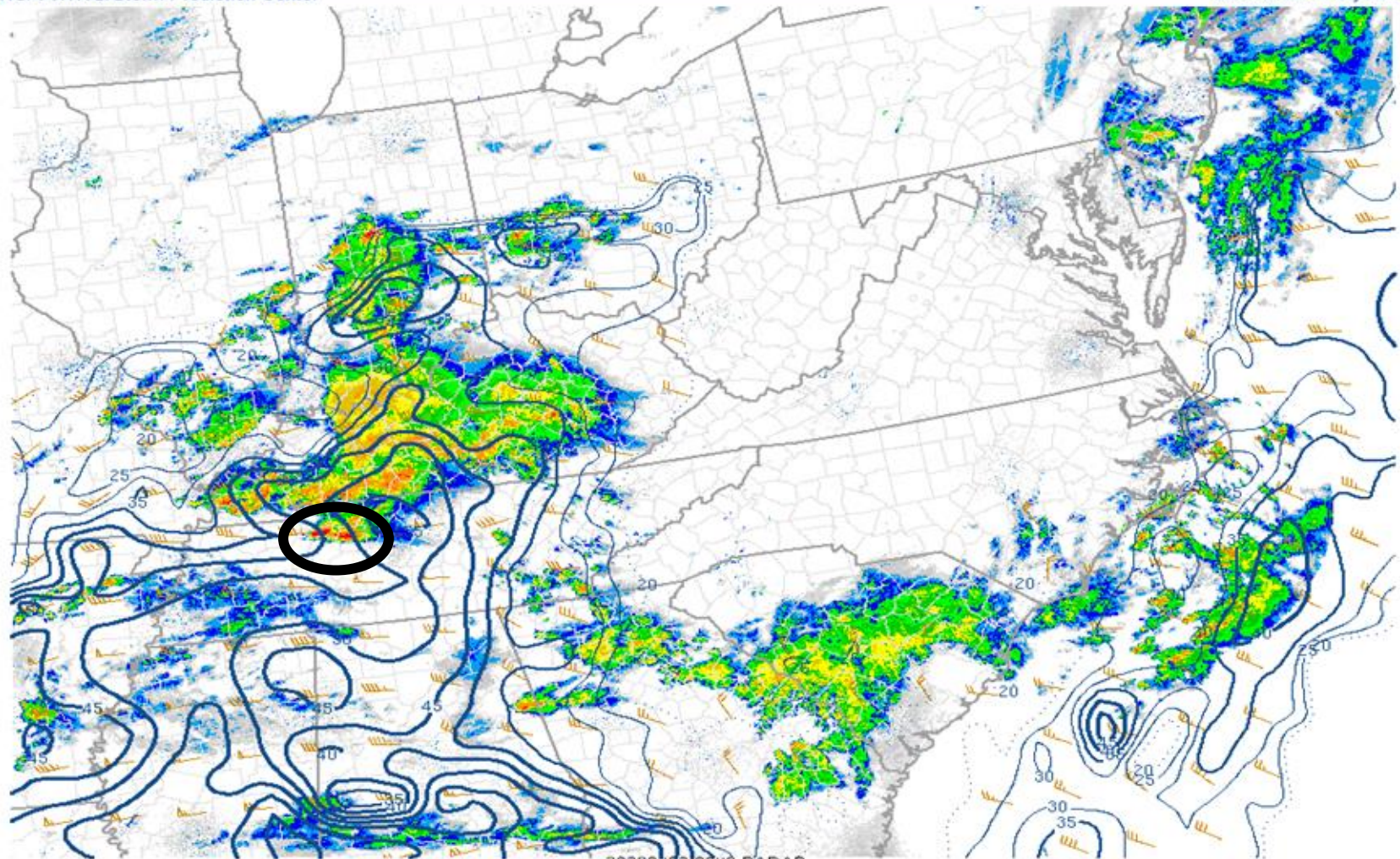
The Main Point

Spend time understanding how each parameter works

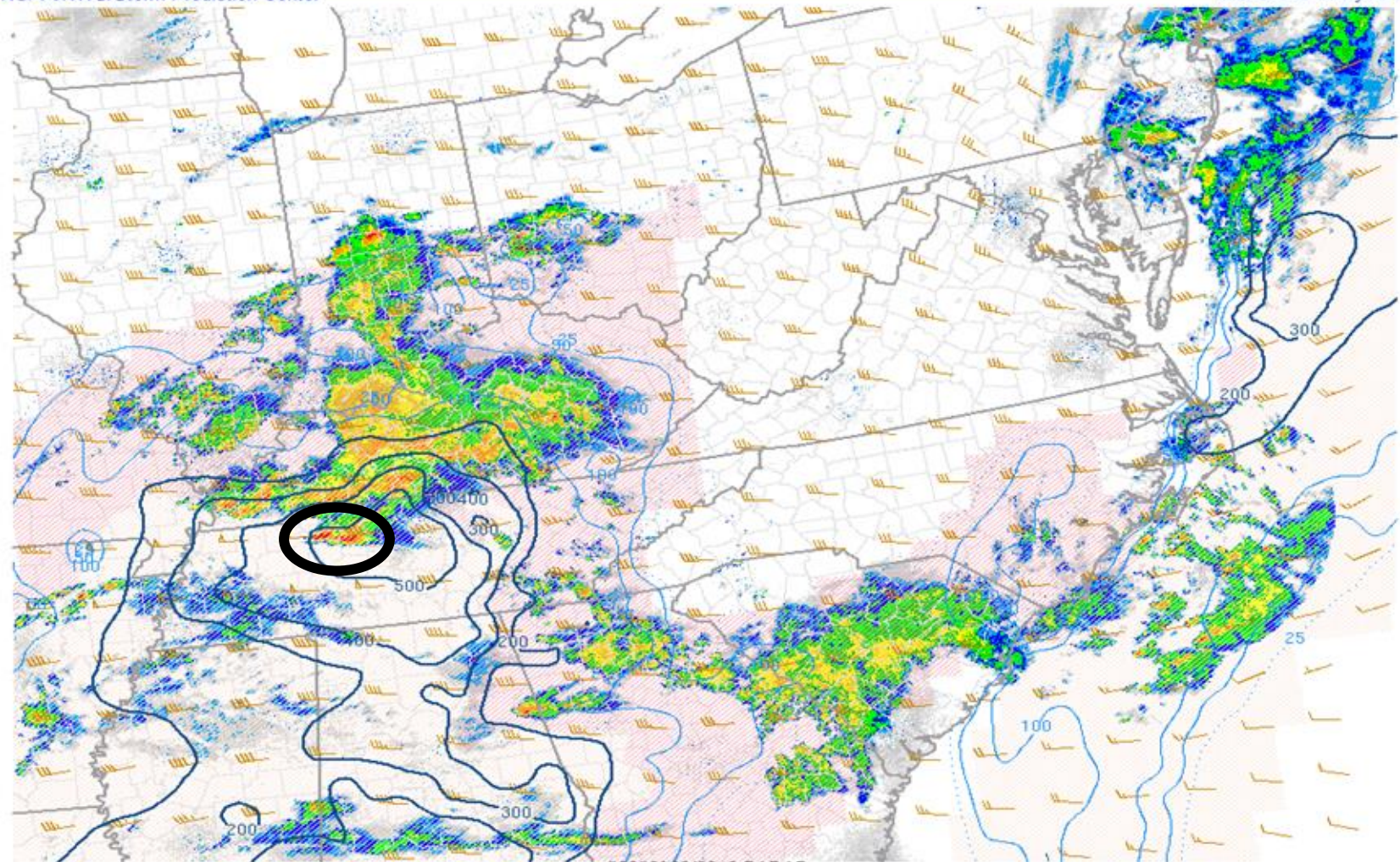
It can save you from making incorrect assumptions about the environment!





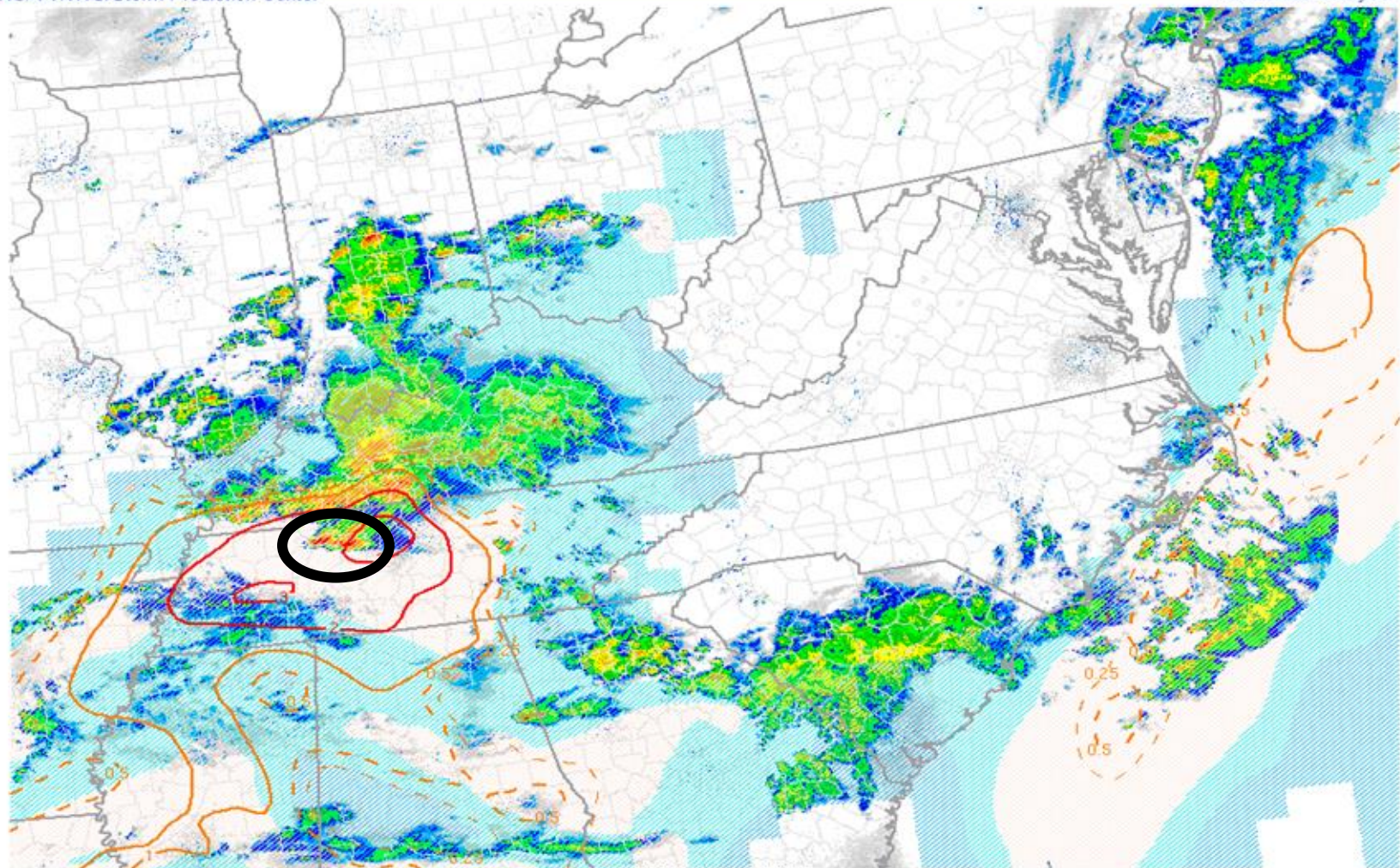


20200303/0600 RADAR
200303/0600 Effective bulk shear (kt)

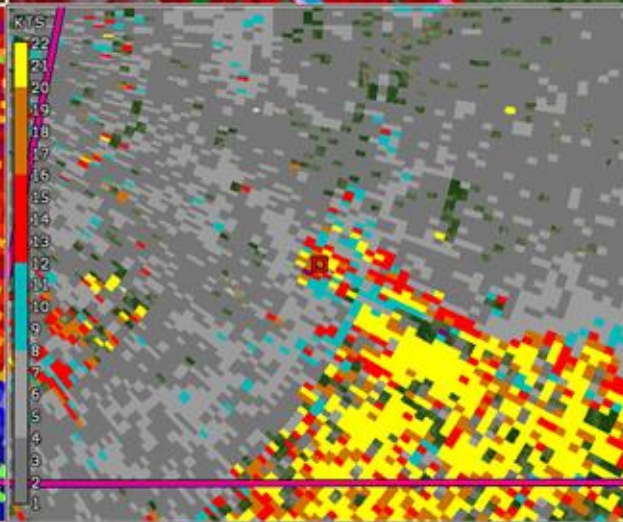
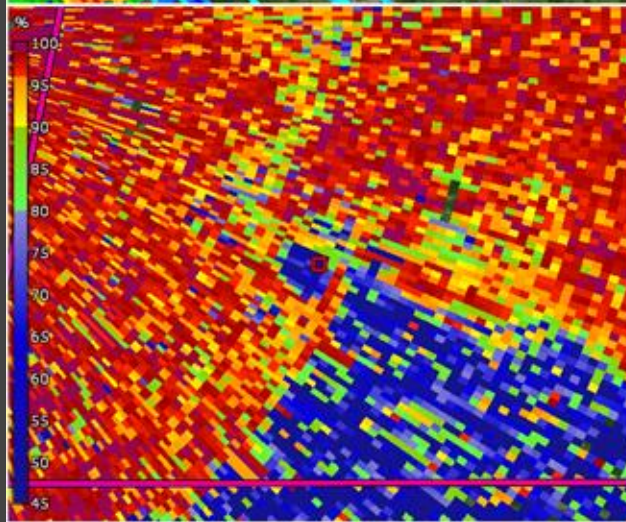
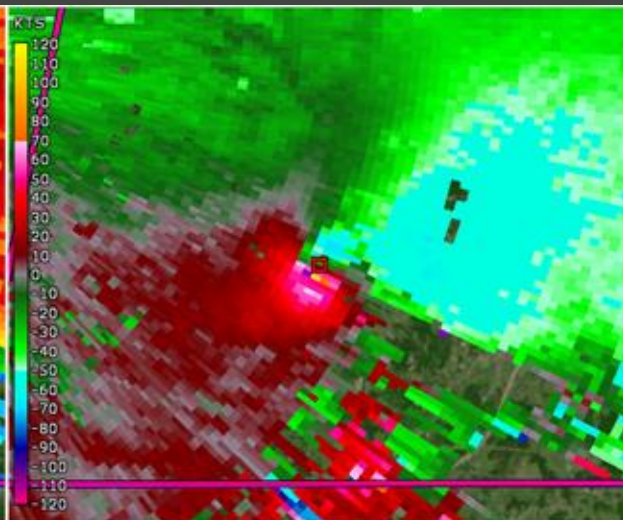
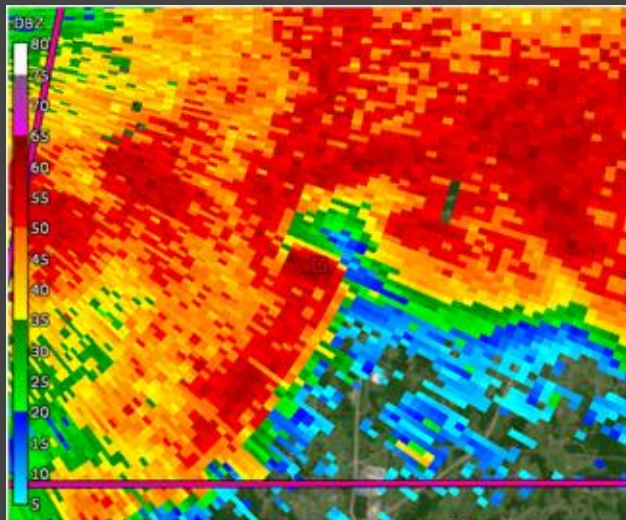


25 100

20200303/0600 RADAR
 200303/0600 Eff. Inflow Base (ft, m AGL), ESRH (m2/s2) and storm motion (kt)



20200303/0600 RADAR
200303/0600 Significant Tornado Parameter (eff layer) and MLCIN (J/kg, shaded at 25 and 100)



March 2nd, 2020
Cookville, TN
EF-4

29 December 2014 supercell



SPC DAY 1 CATEGORICAL OUTLOOK

ISSUED: 1624Z 12/29/2014

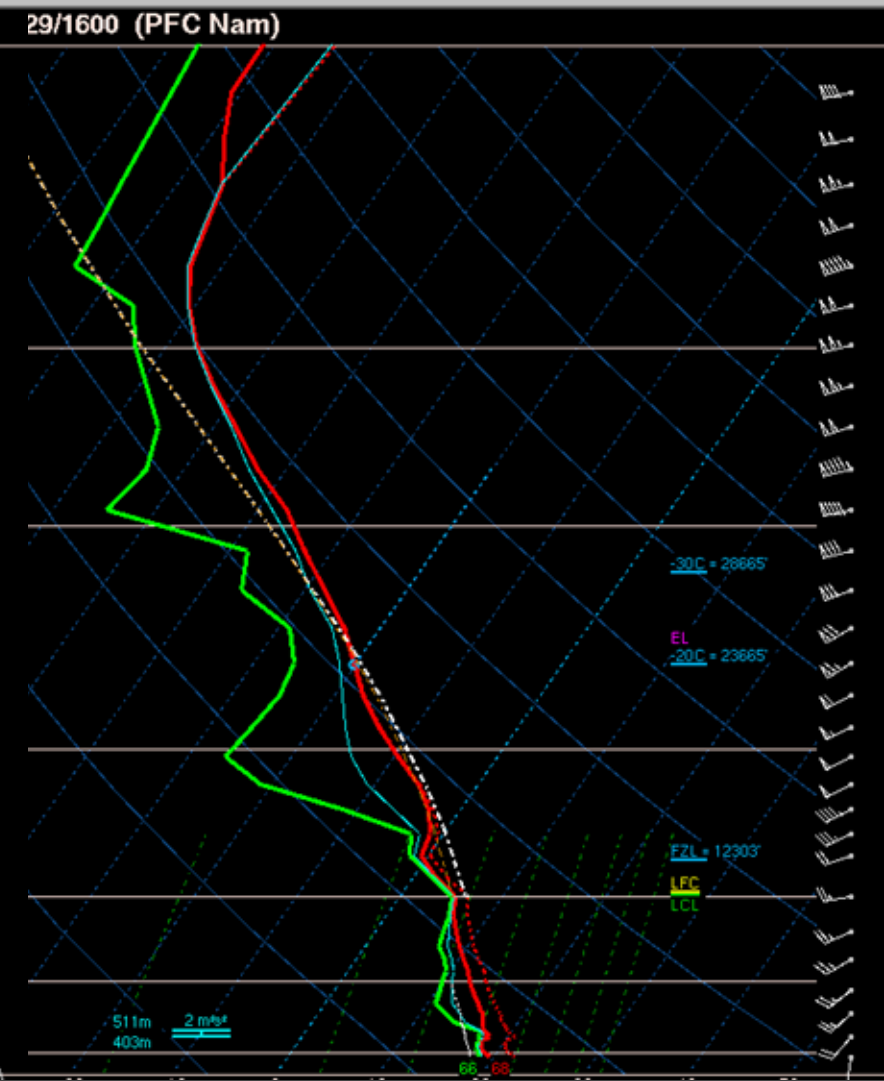
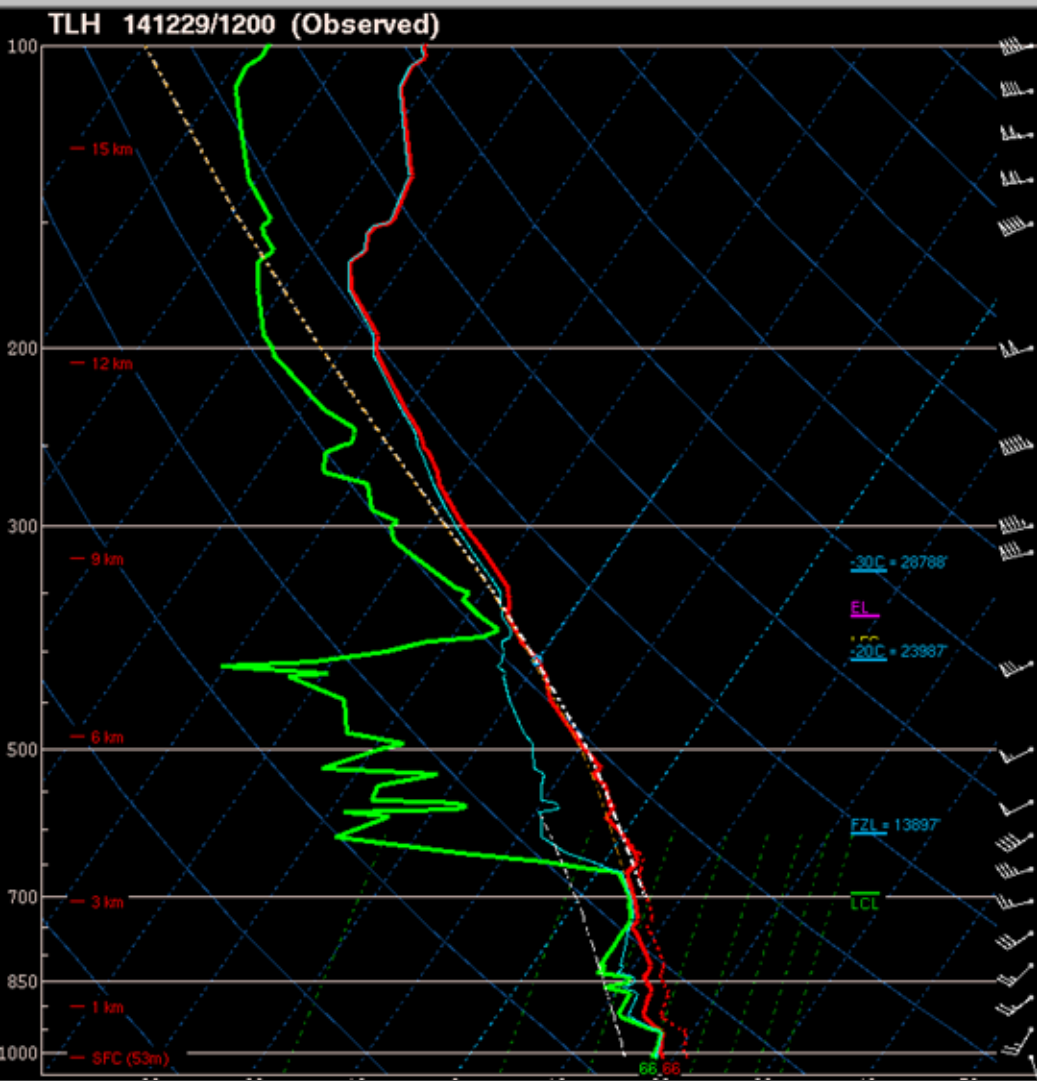
VALID: 29/1630Z-30/1200Z

FORECASTER: THOMPSON/PICCA

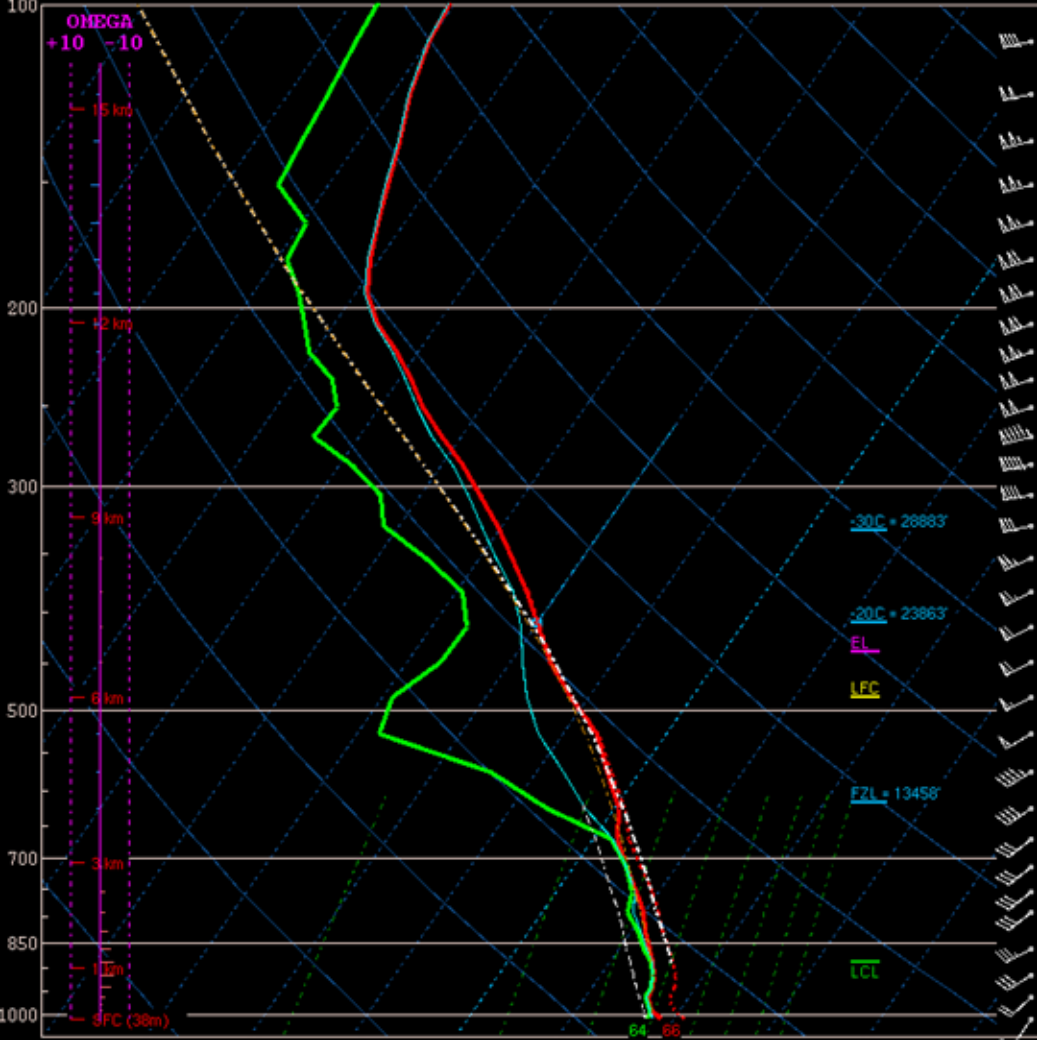
NOAA/NWS Storm Prediction Center, Norman, Oklahoma

Categorical Outlook Legend:

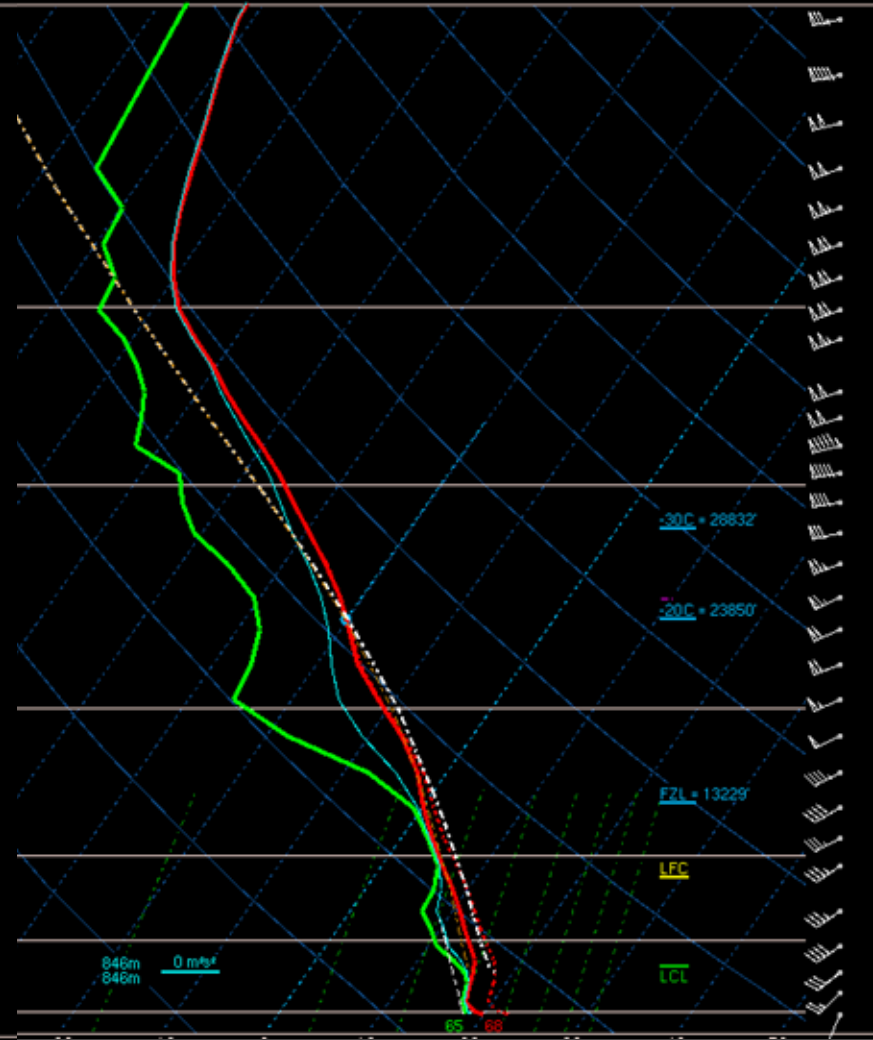
TSTM	1: MRGL	2: SLGT
3: ENH	4: MDT	5: HIGH



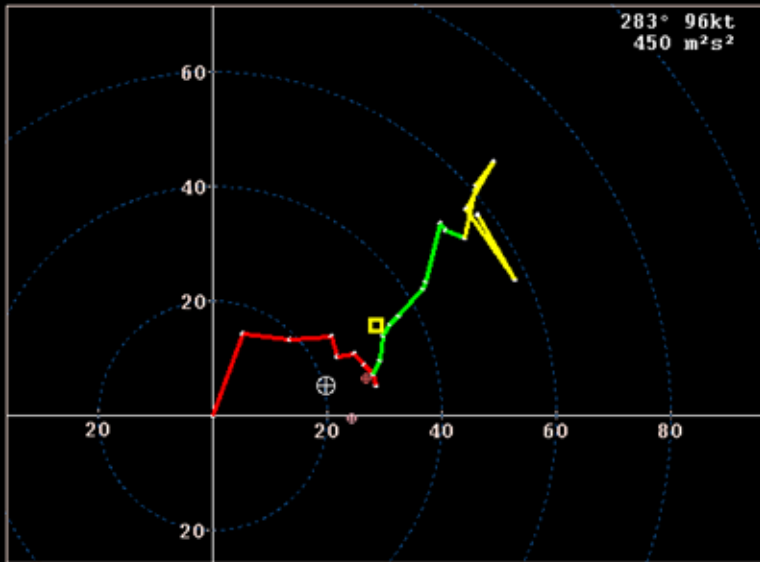
KVLD 141229/1600 (PFC RAP)



29/1600 (PFC HRRR-NCEP)



VAX 141229/1630



SHEAR

STORM RELATIVE

LAYER	VECTOR	SHEAR
Sfc - 1km	24 kt (13 m/s)	
Sfc - 3km	29 kt (15 m/s)	
Sfc - 6km	60 kt (31 m/s)	
Sfc - 12km	M	(M)

----- Storm Motion -----

255° / 20 kt (11 m/s)

----- SR HELICITY (m²s²) -----

LAYER	POS	NEG	TOT
0-1km	99	0	99
0-3km	119	-5	114

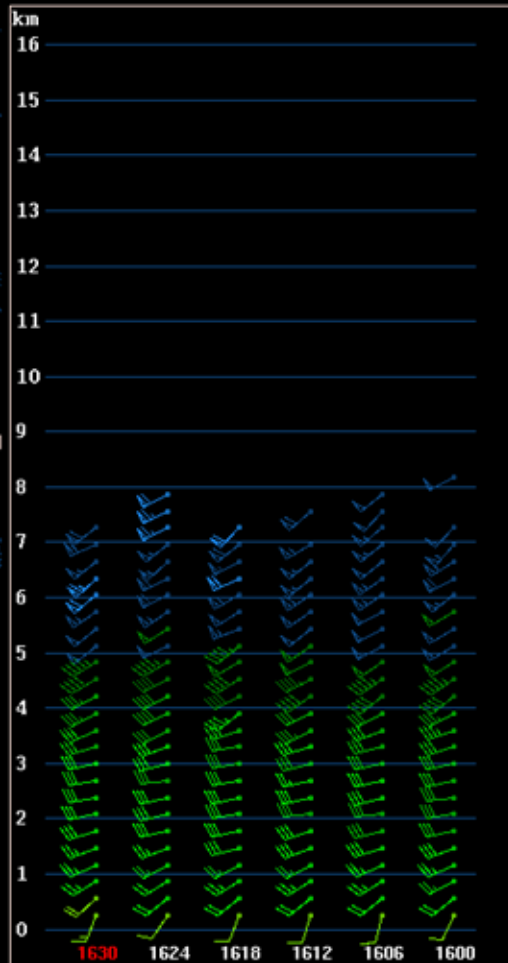
----- SR WINDS (knots) -----

LAYER	VECTOR
0-2km	164/6 (3 m/s)
4-6km	221/29 (15 m/s)
9-11km	nan/nan(nan m/s)

MEAN WIND

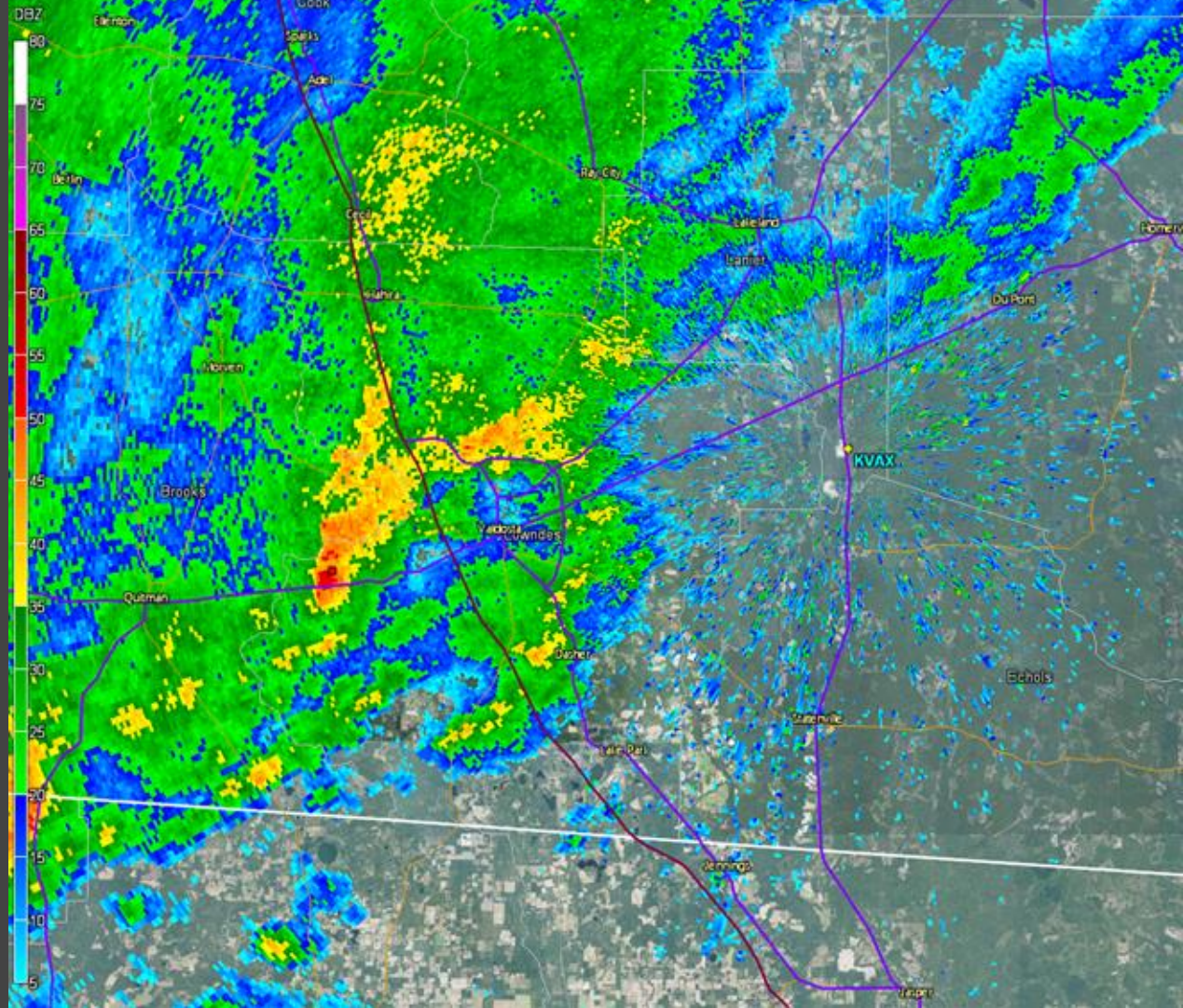
Sfc - 6 km	241/32 kt
Sfc - 10 km	239/37 kt

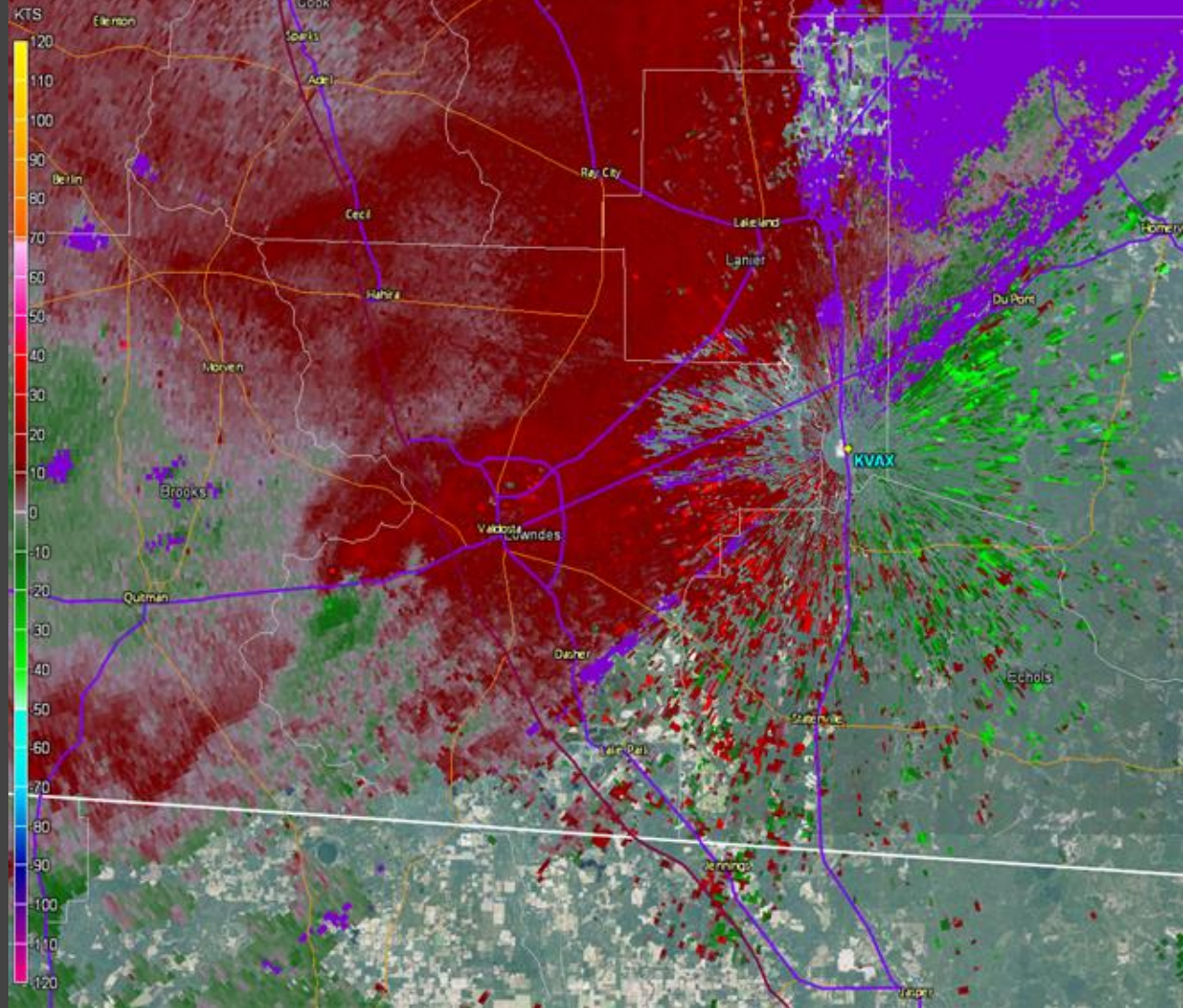
Sfc wind (@VLD) 0/0 kt

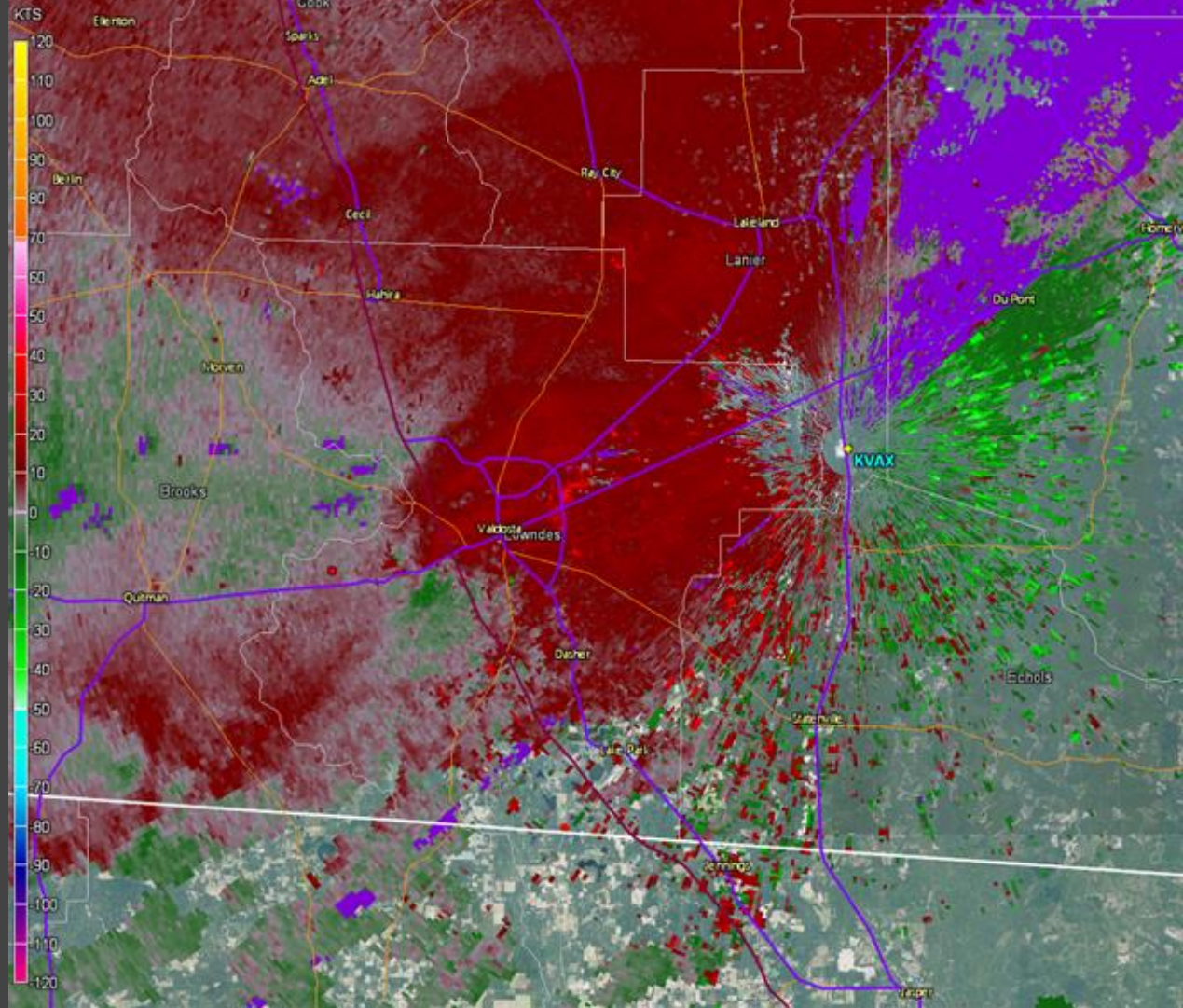


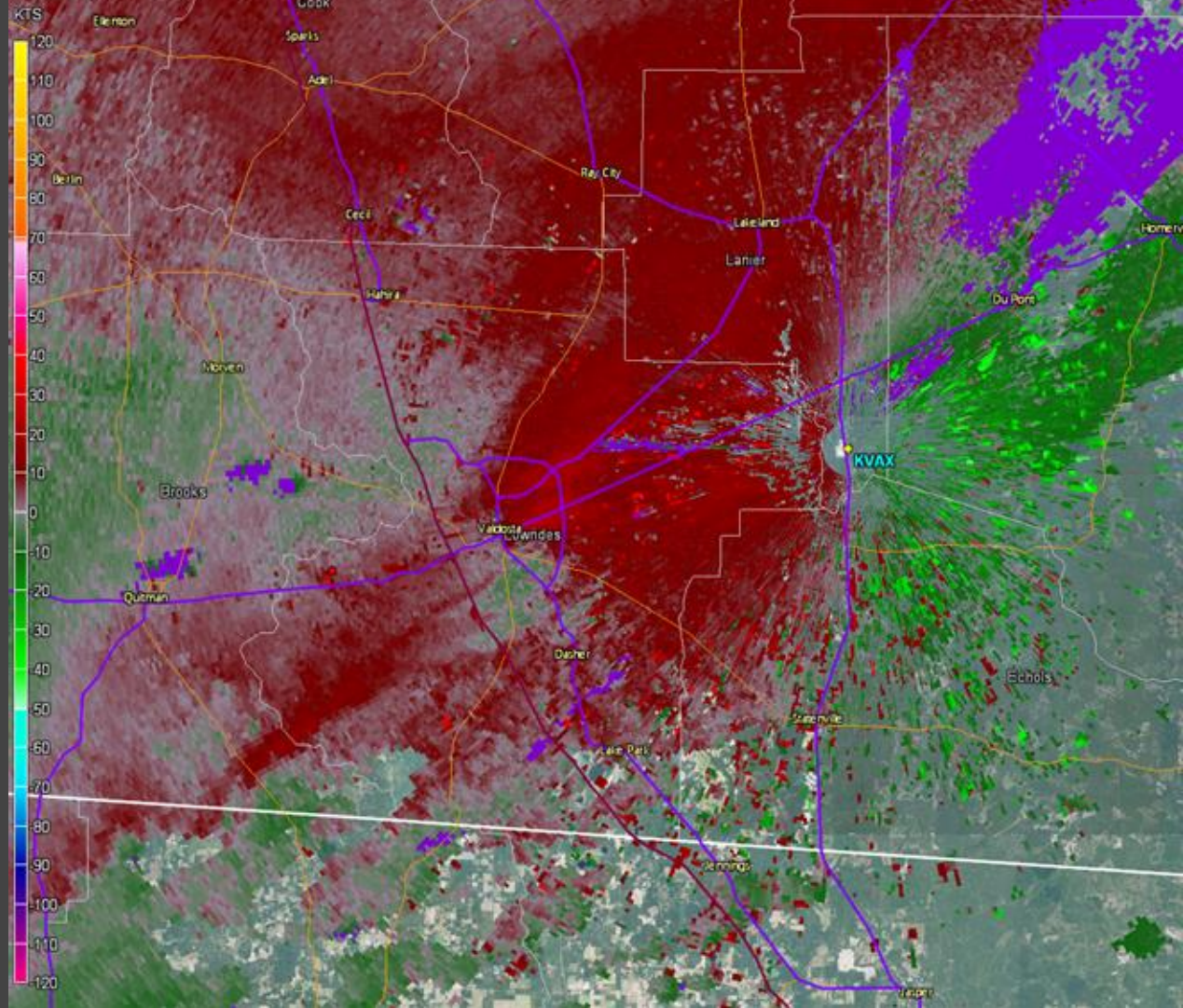
Given the previous forecast soundings and the observed VWP profile on the left...

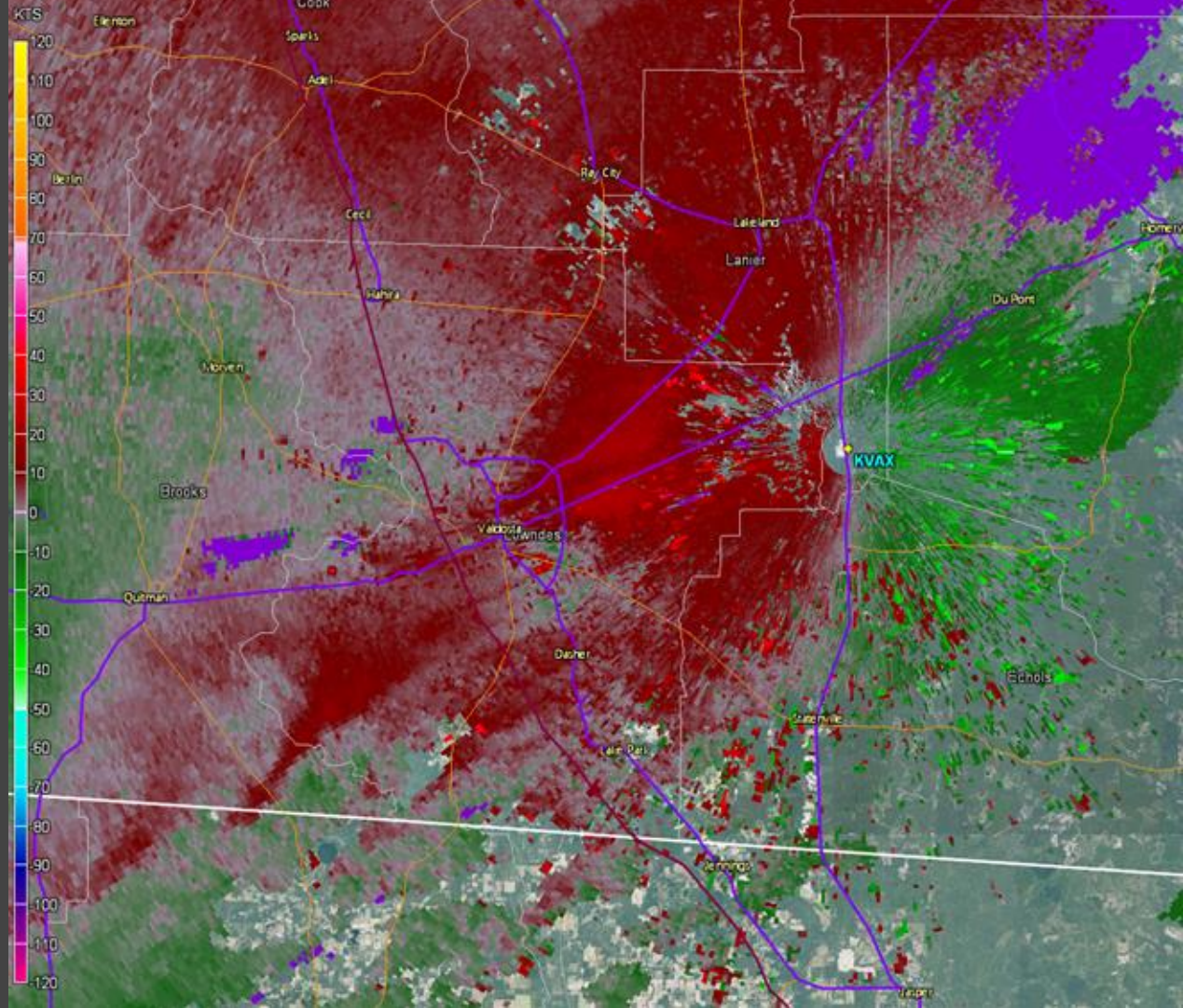
what value of STP would you expect?

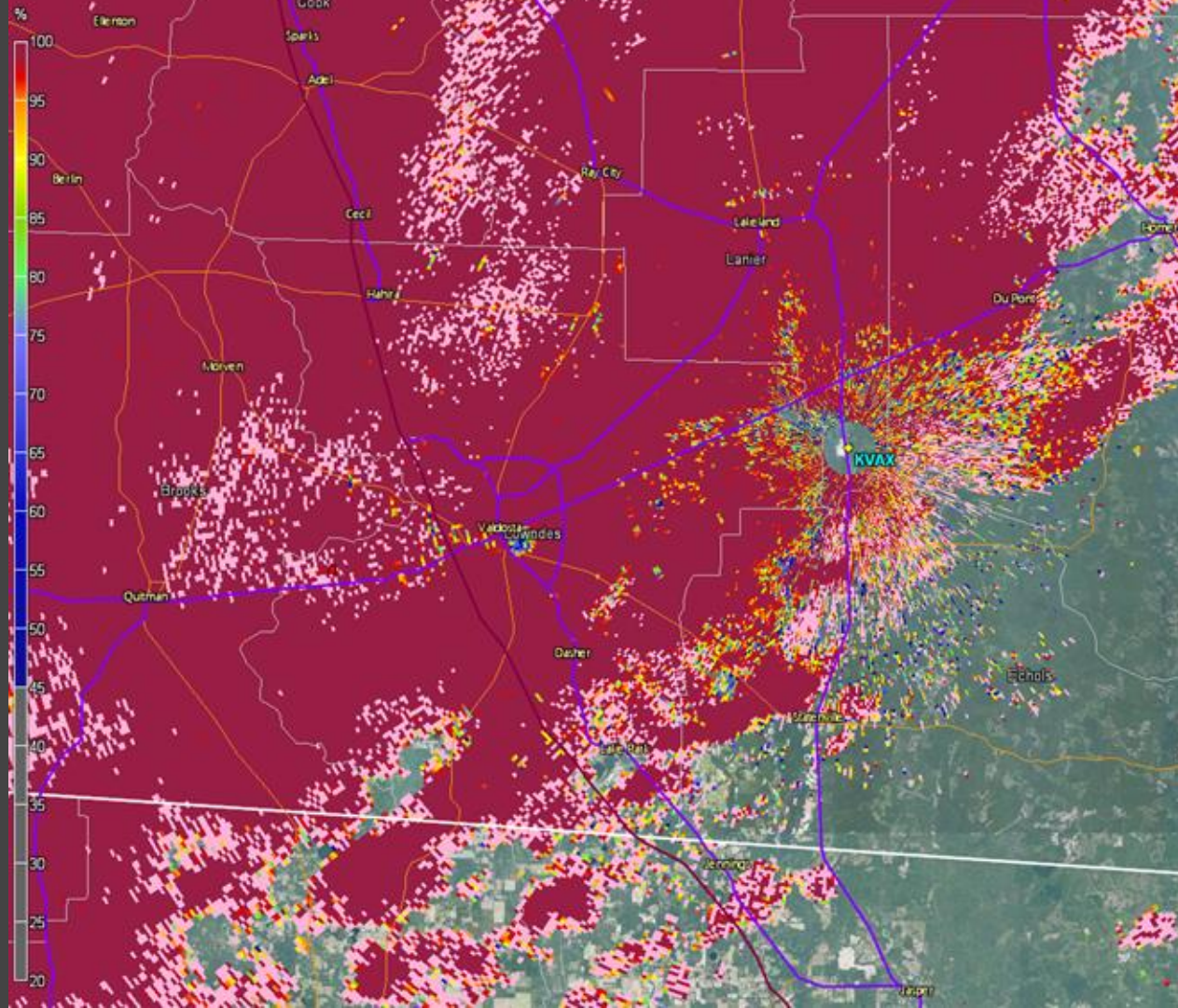


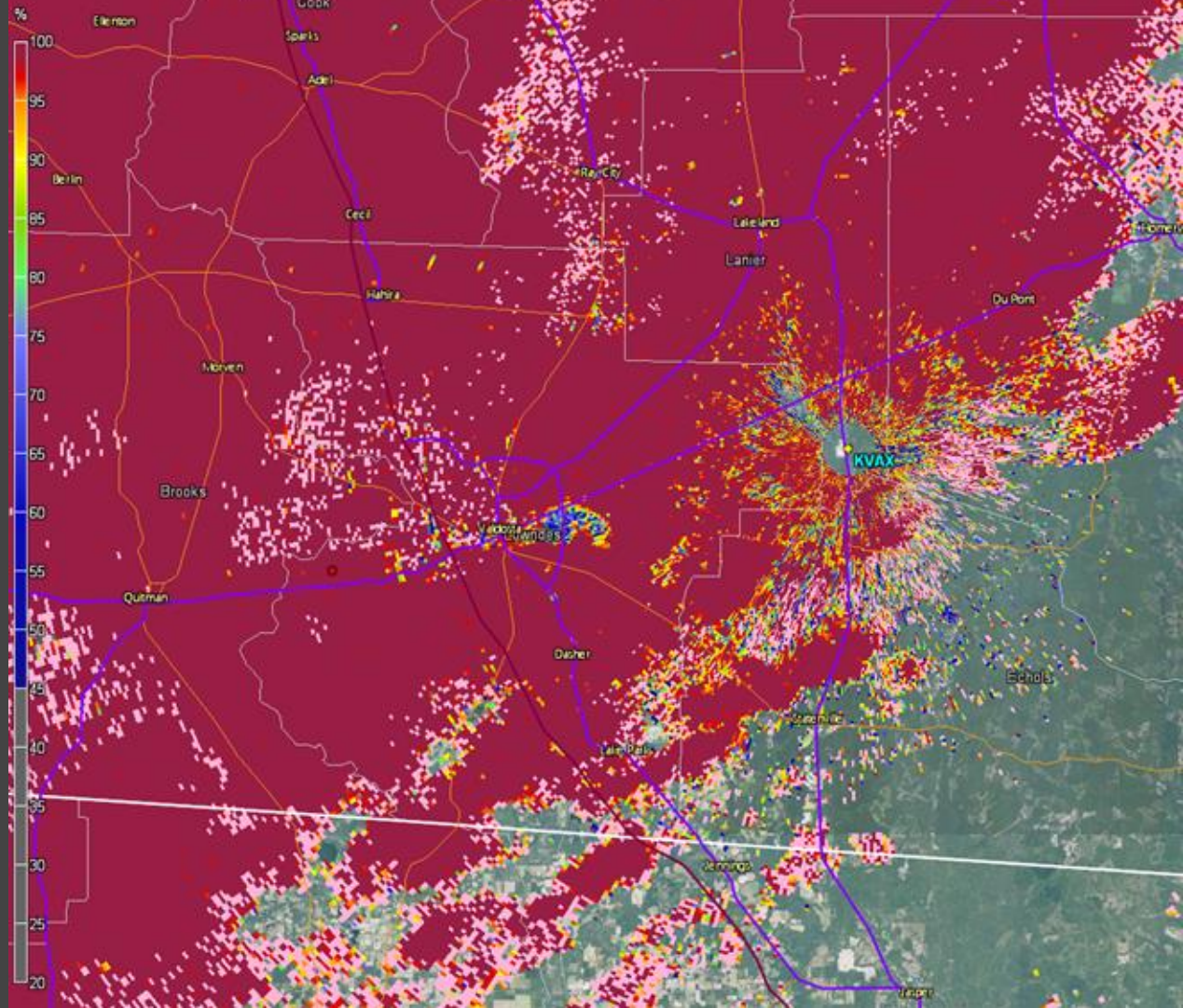


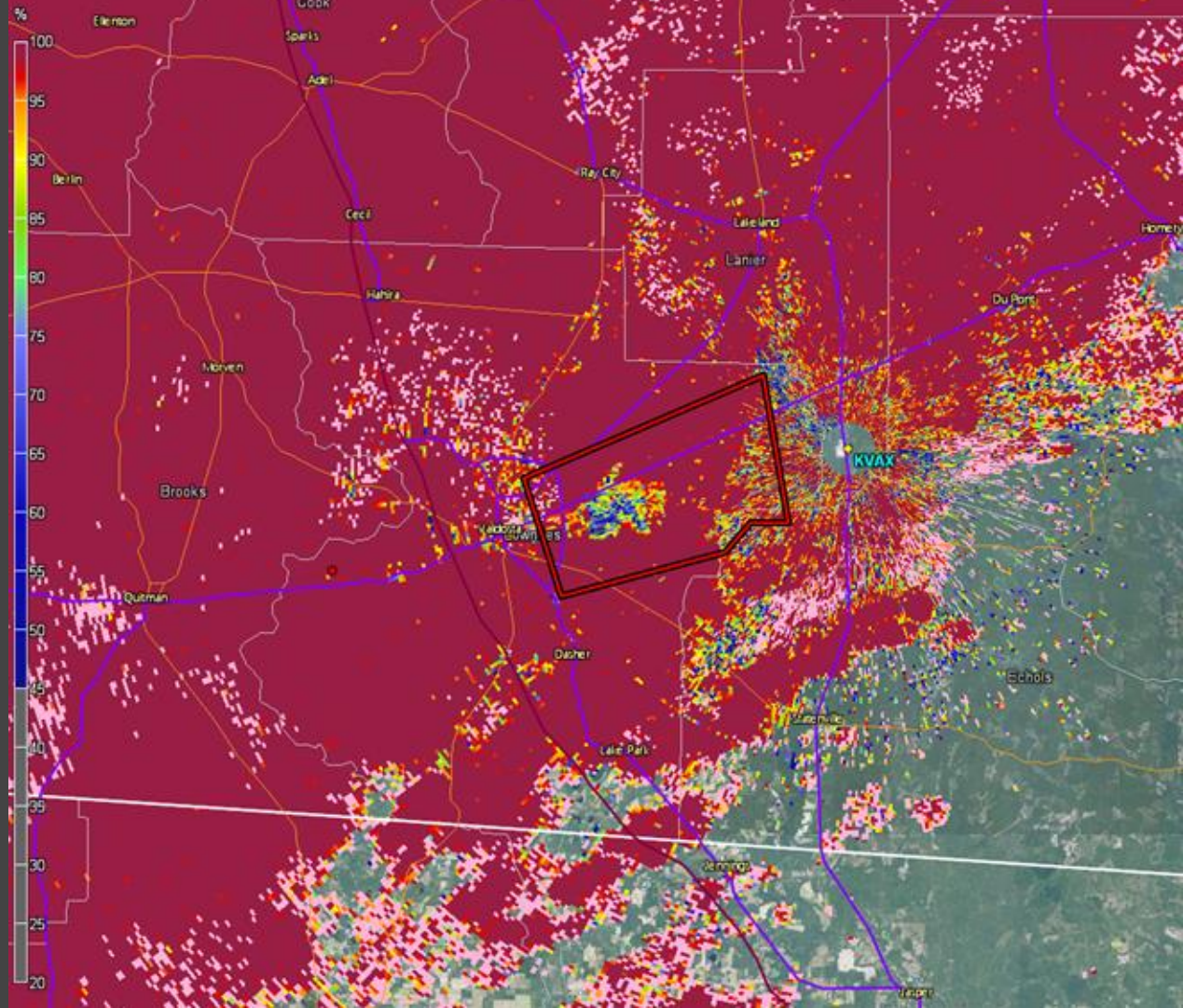






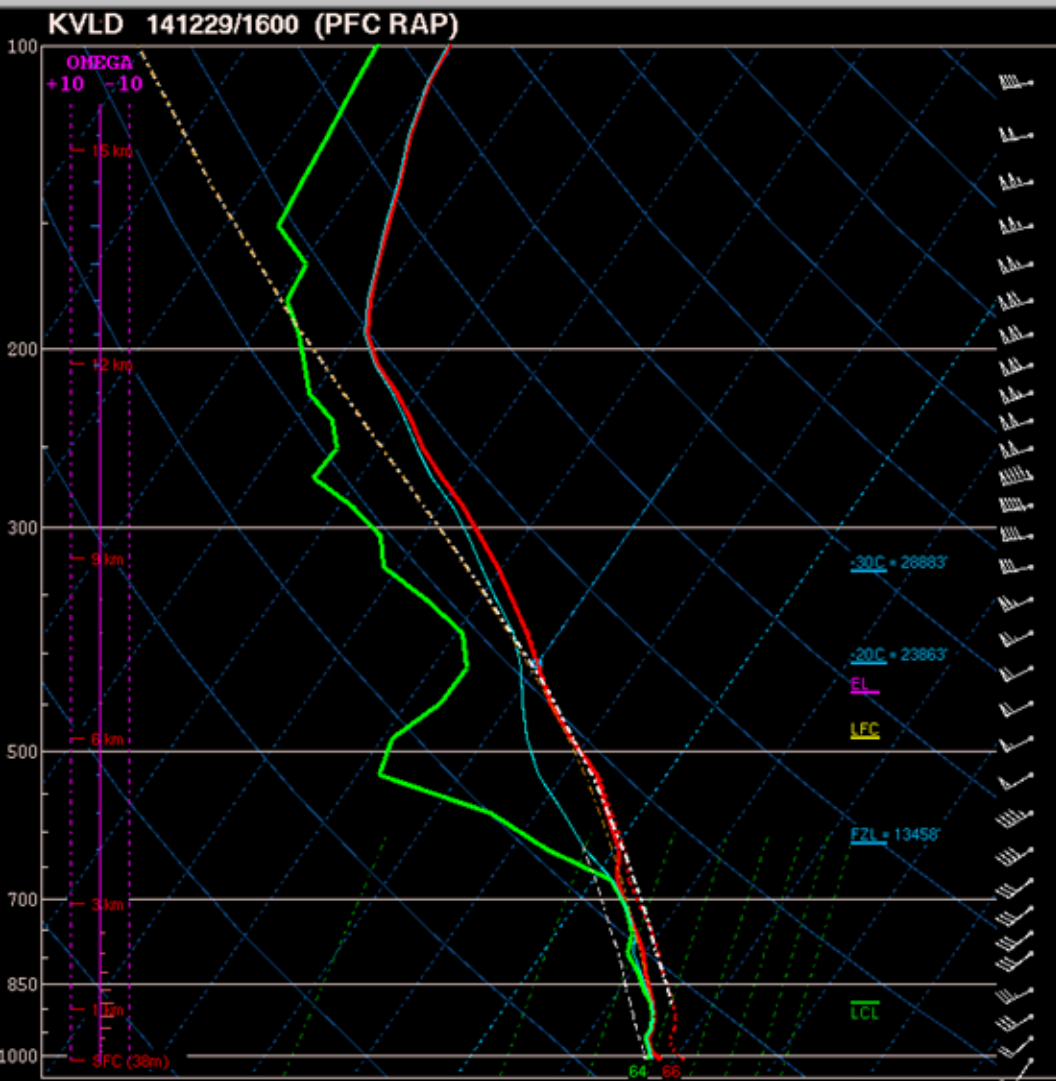






Valdosta, GA
Dec. 29, 2014
EF-2

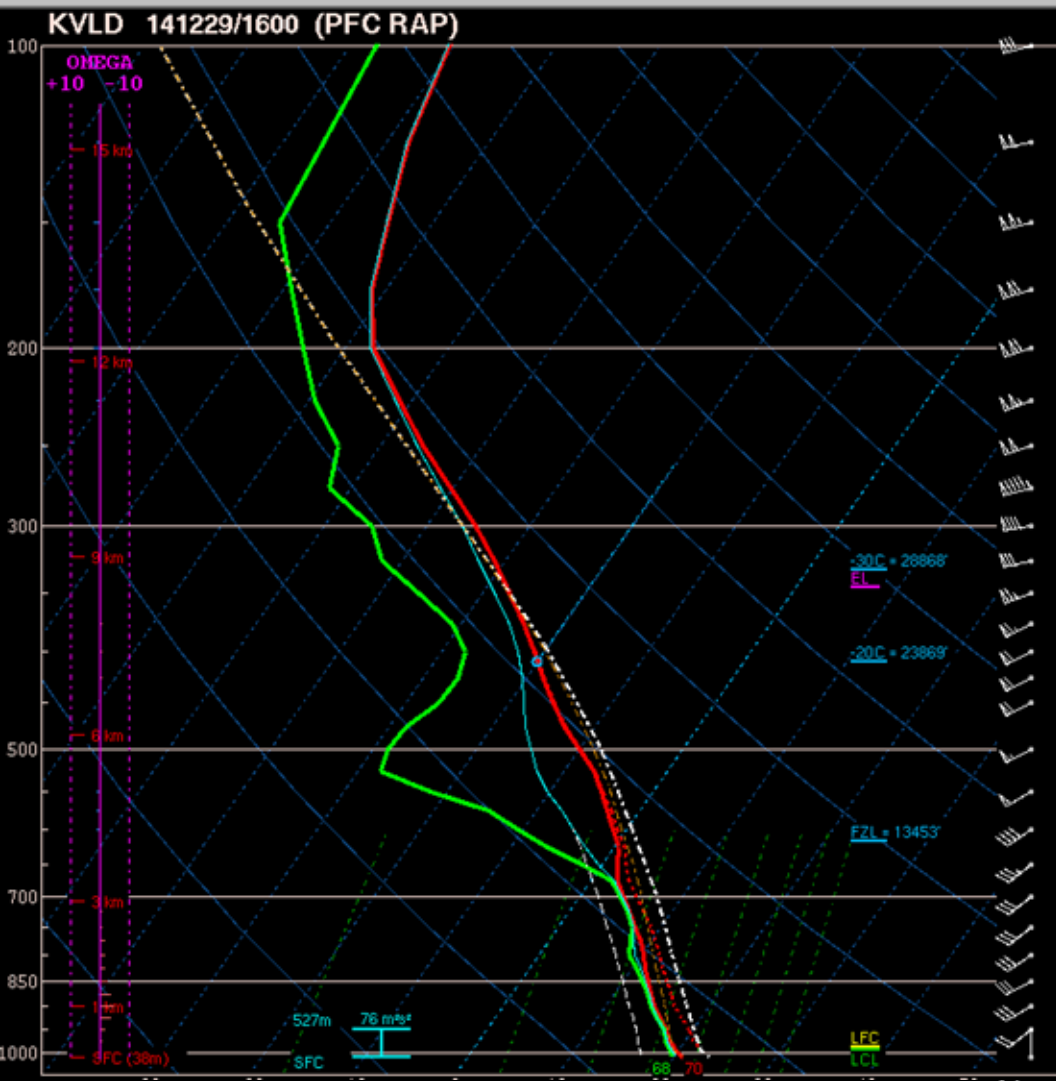




What if we adjusted the soundings based on nearby surface observations?

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.