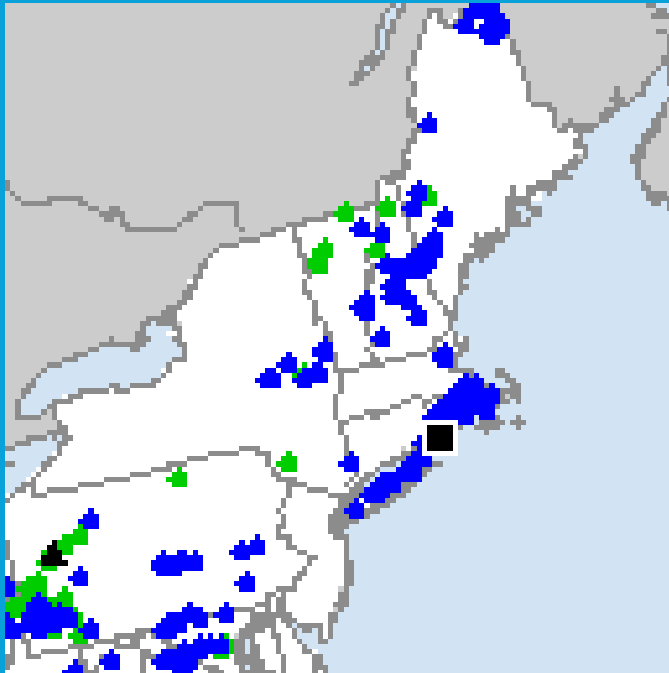


August 4, 2015:
Two Rare High End Severe Weather Events
Inside 12 Hours In
Southern New England

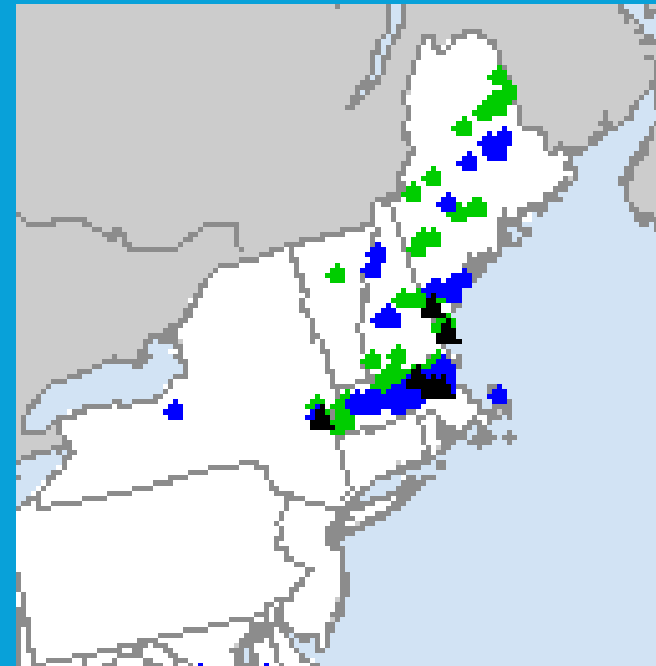
Hayden Frank and Joe DelliCarpini
NOAA/National Weather Service
Taunton, MA



Storm Reports: August 4, 2015



**Round 1
(Morning)**



**Round 2
(Afternoon)**

Overview

First Event:

Rhode Island and Southeast MA 6:00-8:30 am

- Widespread damaging wind gusts of 60 to 80 mph
- Rhode Island hardest hit, including Cranston and Providence
 - Roads/rail blocked by fallen trees making for a horrific rush hour
 - 25 percent of Rhode Island lost power (over 121,000 people)
 - *More power outages in RI than Hurricane Sandy!*
 - 10 minor injuries at Burlingame Campground in Charlestown, RI

Second Event:

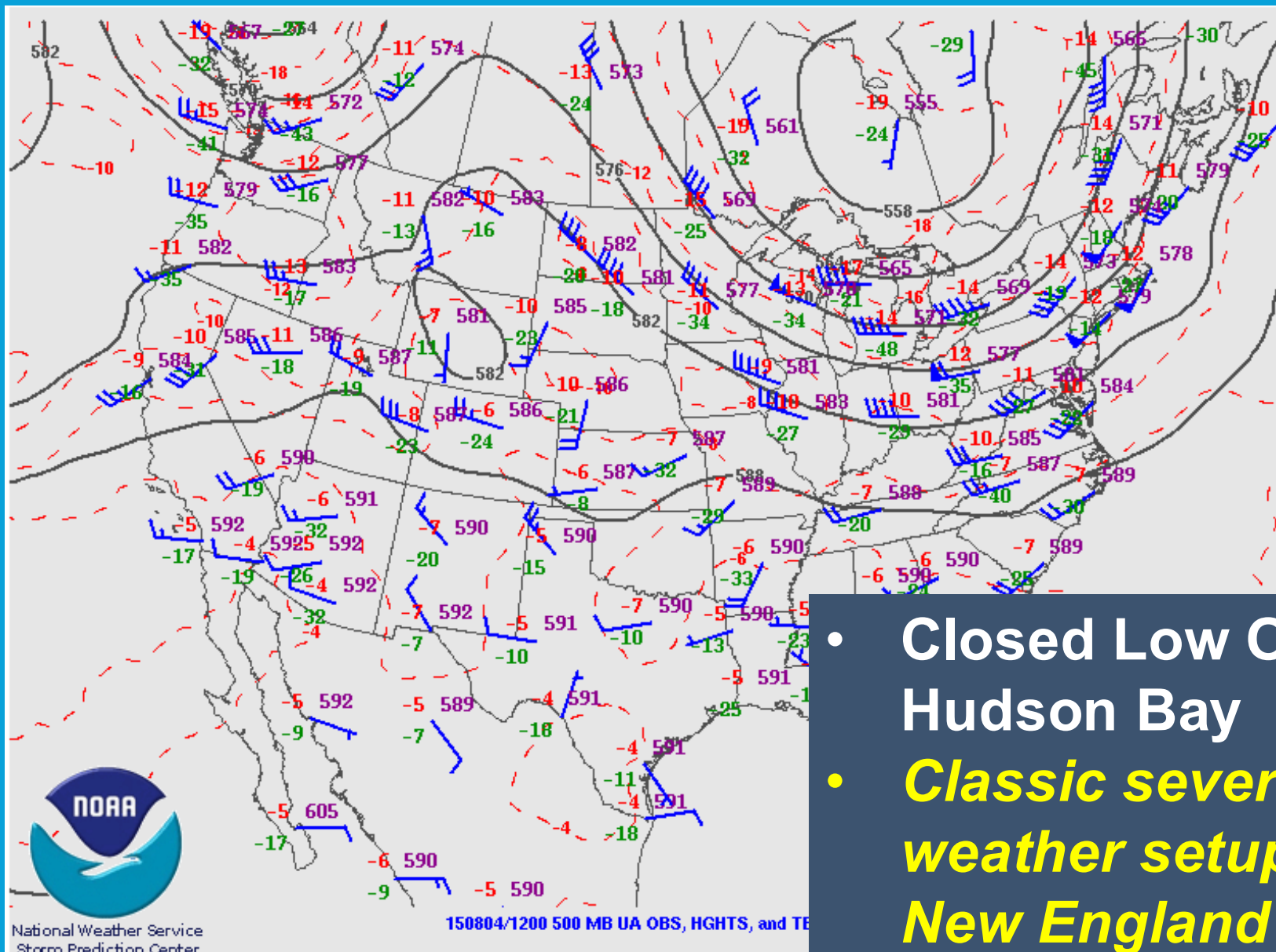
Massachusetts (along/north of Mass Pike) 12:30-4:30 pm

- Reports of golf ball to 2 inch diameter hail
 - 2 inch diameter hail in Boston (Suffolk County: largest recorded)
- Wind gusts of 50-60 mph
 - Some tree damage and isolated power outages
- No injuries reported

Damage in Rhode Island

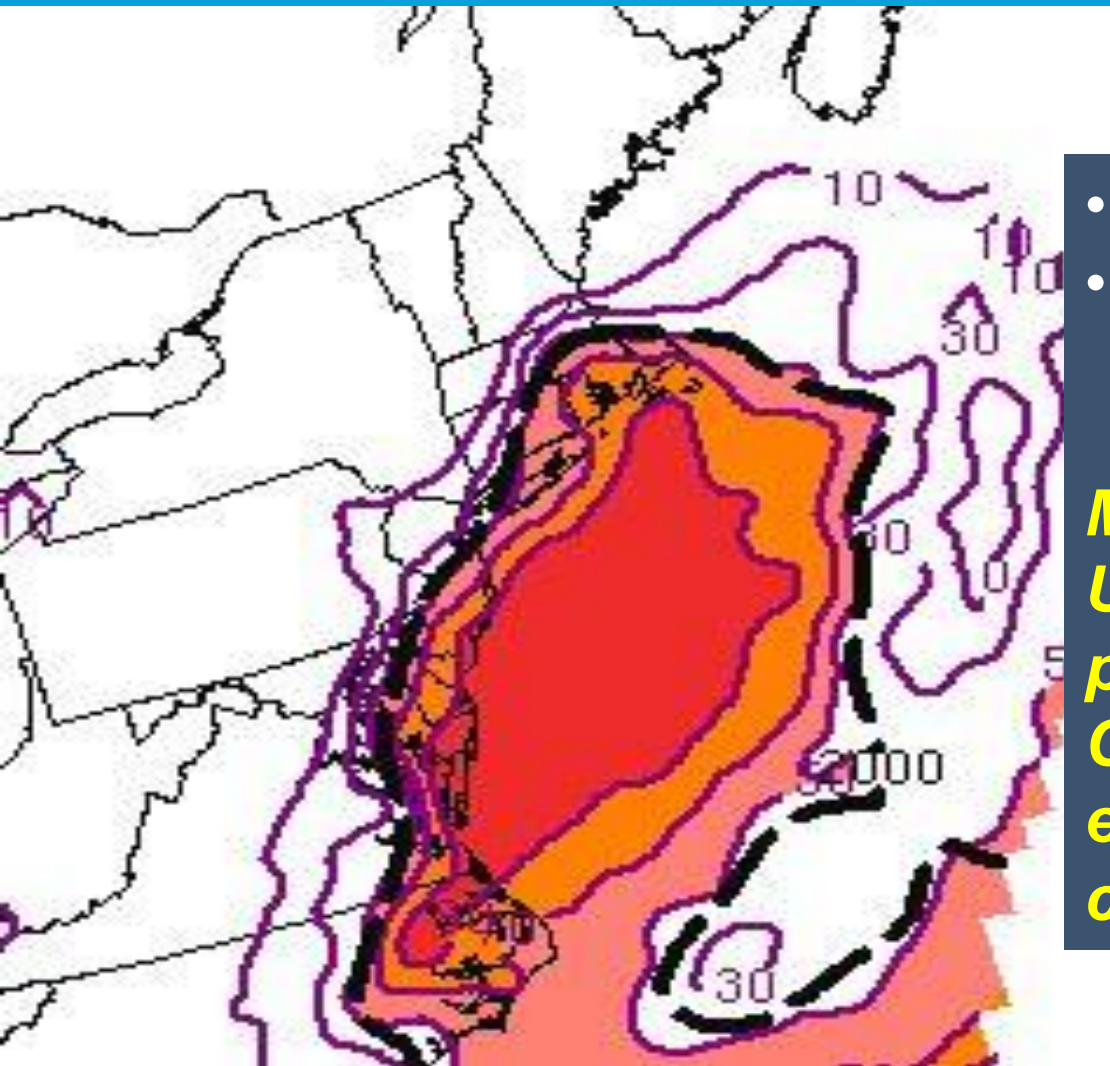


500 mb Analysis: 12z August 4th 2015



- Closed Low Over Hudson Bay
- **Classic severe weather setup for New England**

SPC SREF: Mean Probabilities of MUCAPE Exceeding 2000 J/KG



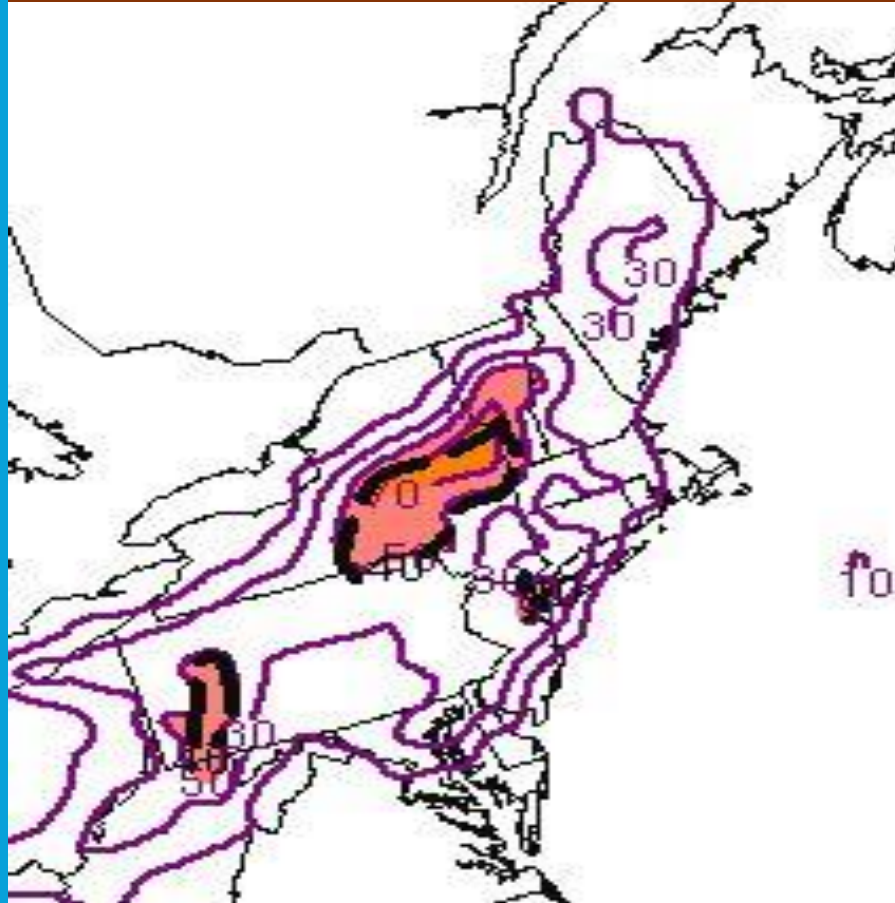
- Valid 09z August 4
- 70 to 90 percent in RI and southeast MA

MUCAPE (Most Unstable CAPE) better predictor than surface CAPE for nighttime/early morning convection

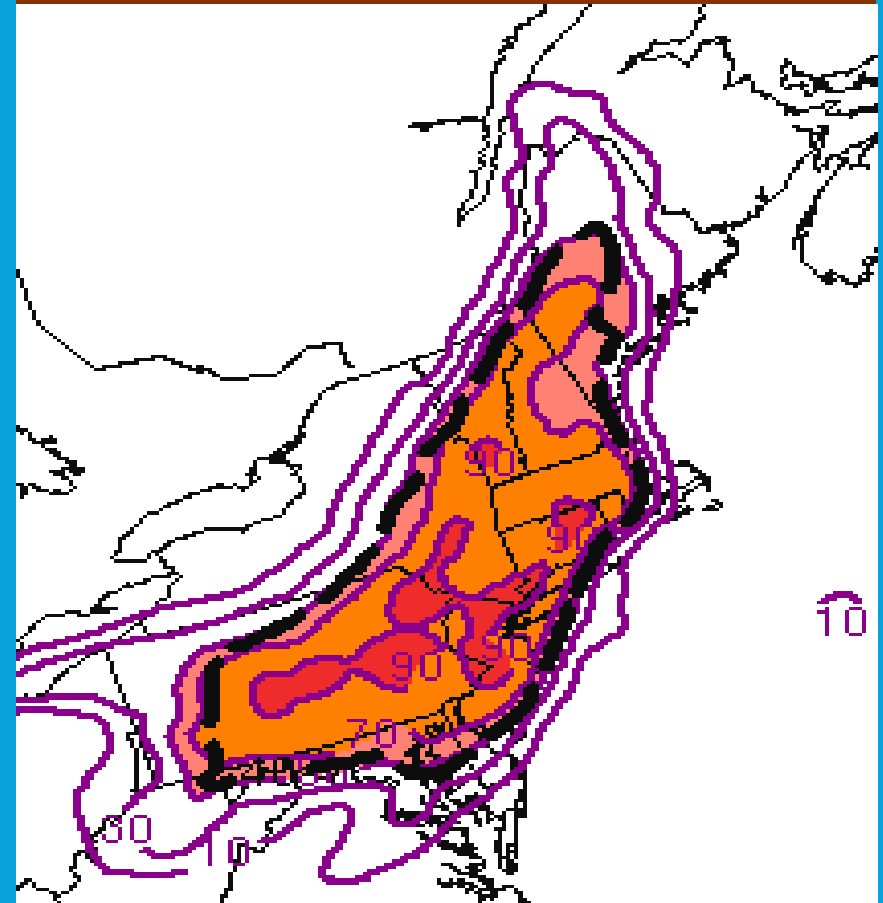
15 Hour Forecast from SREF

SPC SREF: Mean Probabilities of 0-6 km Bulk Effective Shear Exceeding 40 Knots

09z August 4th 2015

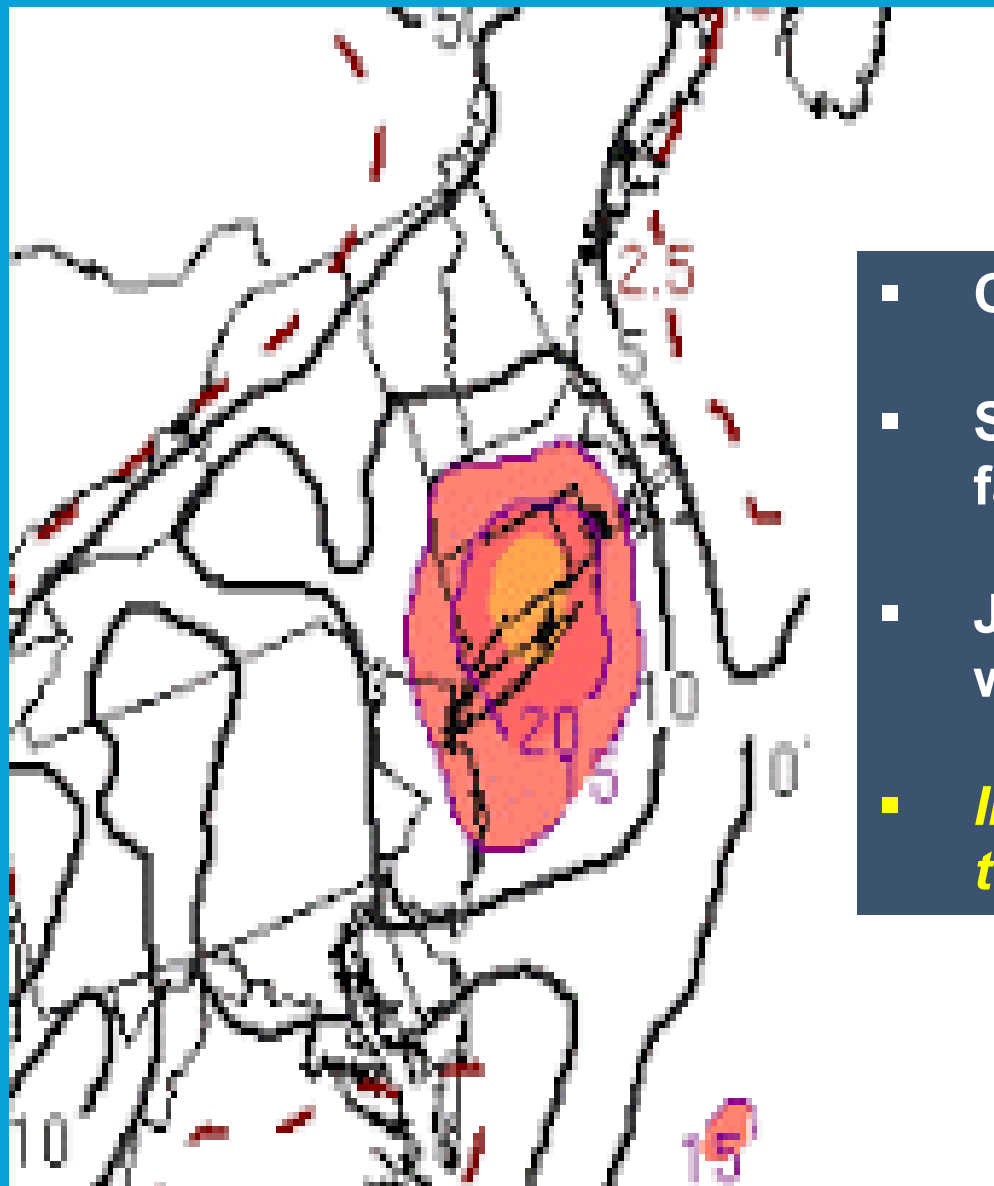


12z August 4th 2015



Probabilities rapidly increase
in response to approaching shortwave

SPC SREF: Severe Probability Through 15z

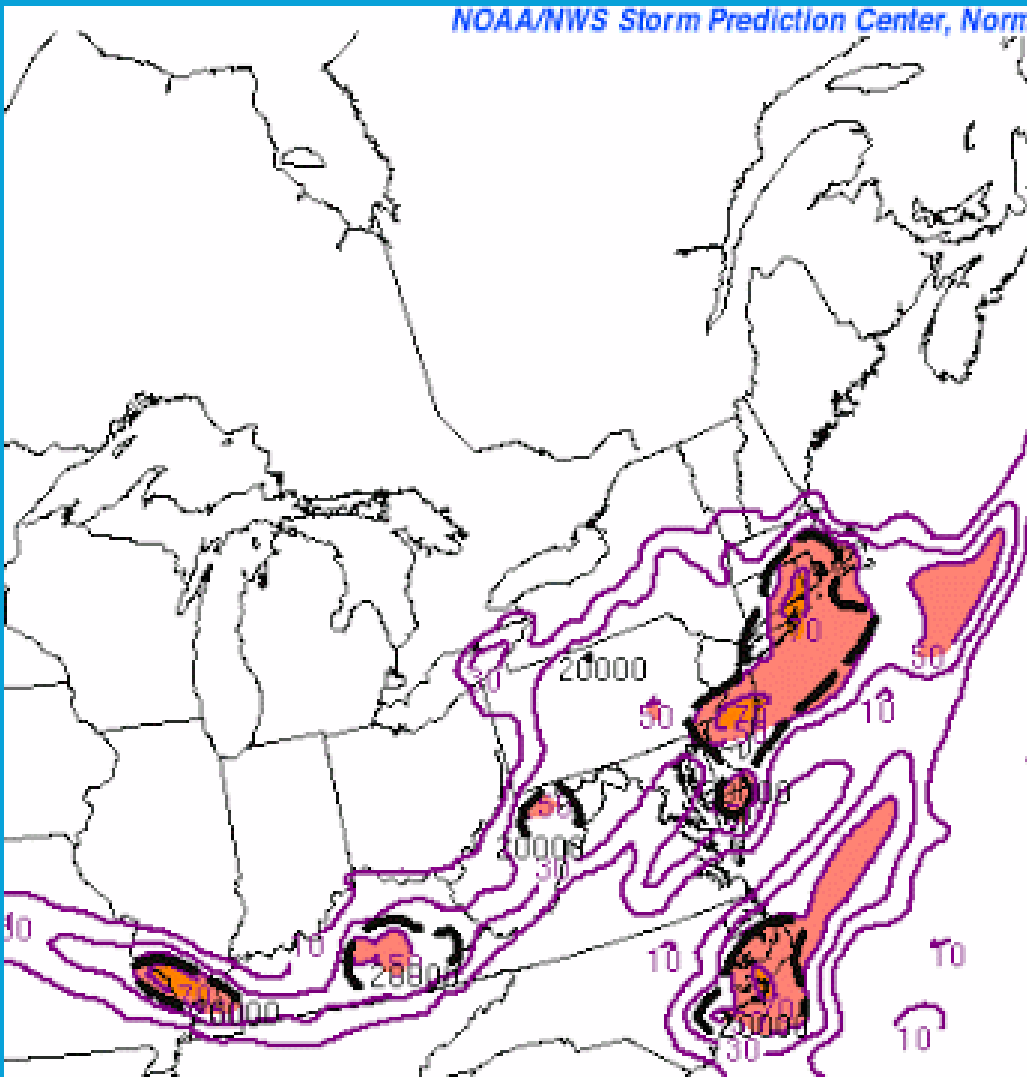


- Combines CAPE and shear
- Shaded regions > 15% are favorable for severe weather
- Just a tool - in this case focus was too far west
- ***Important!!! Still need a trigger to activate CAPE and shear!***

21 Hour Forecast: SREF

SPC SREF: Mean Craven-Brooks Sig Severe Probabilities > 20,000

NOAA/NWS Storm Prediction Center, Norman, OK

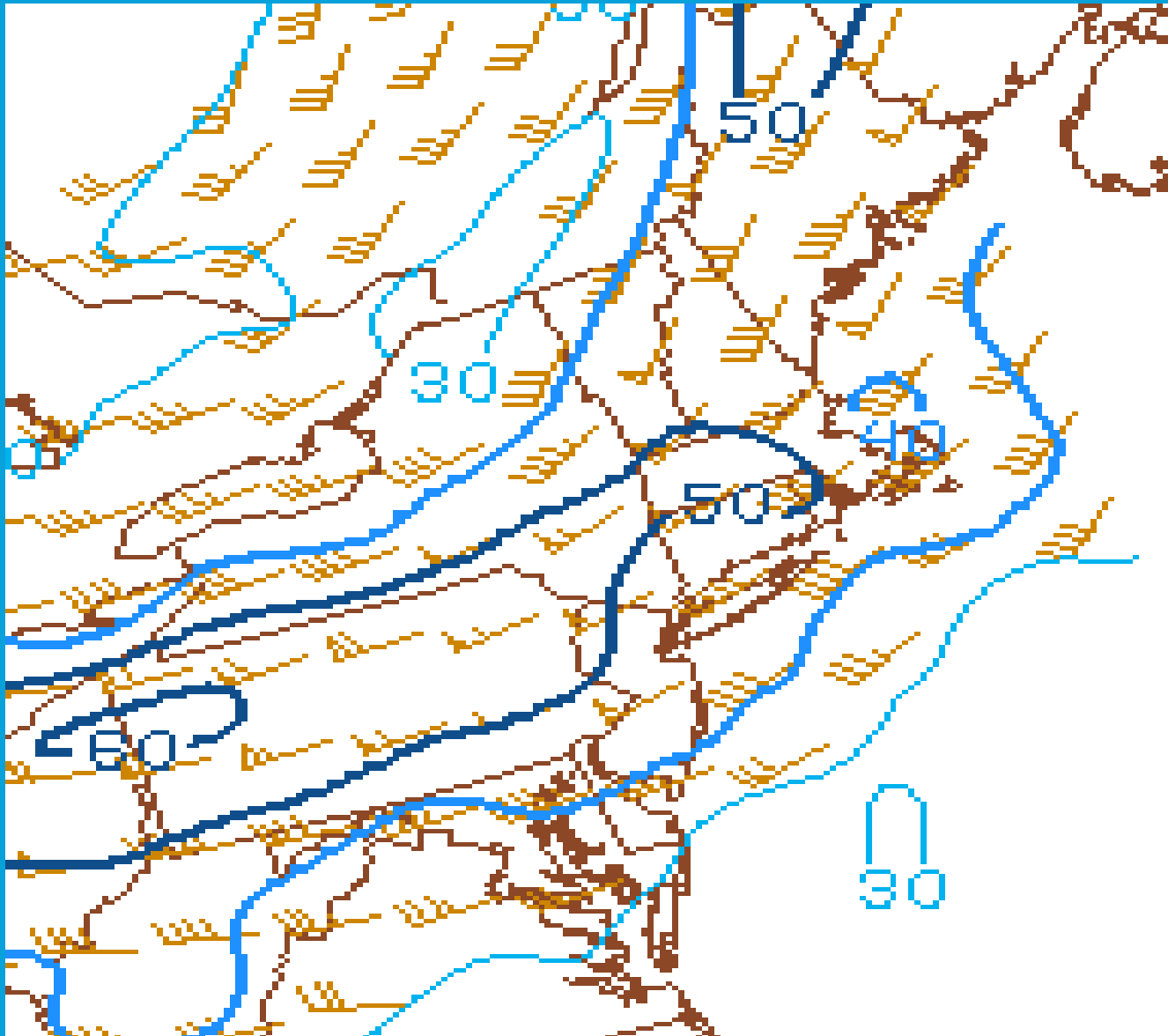


- Combines 100 mb Mean Layer CAPE and 0 to 6 KM Deep Layer Shear
- Majority of events with 2"+ hail, 65+ kt wind gusts, and EF2+ tornadoes occur with values over 20,000.
- Over 50 percent for much of southeast New England by 09z.
- *Very unusual for the Northeast, especially early in the morning!*

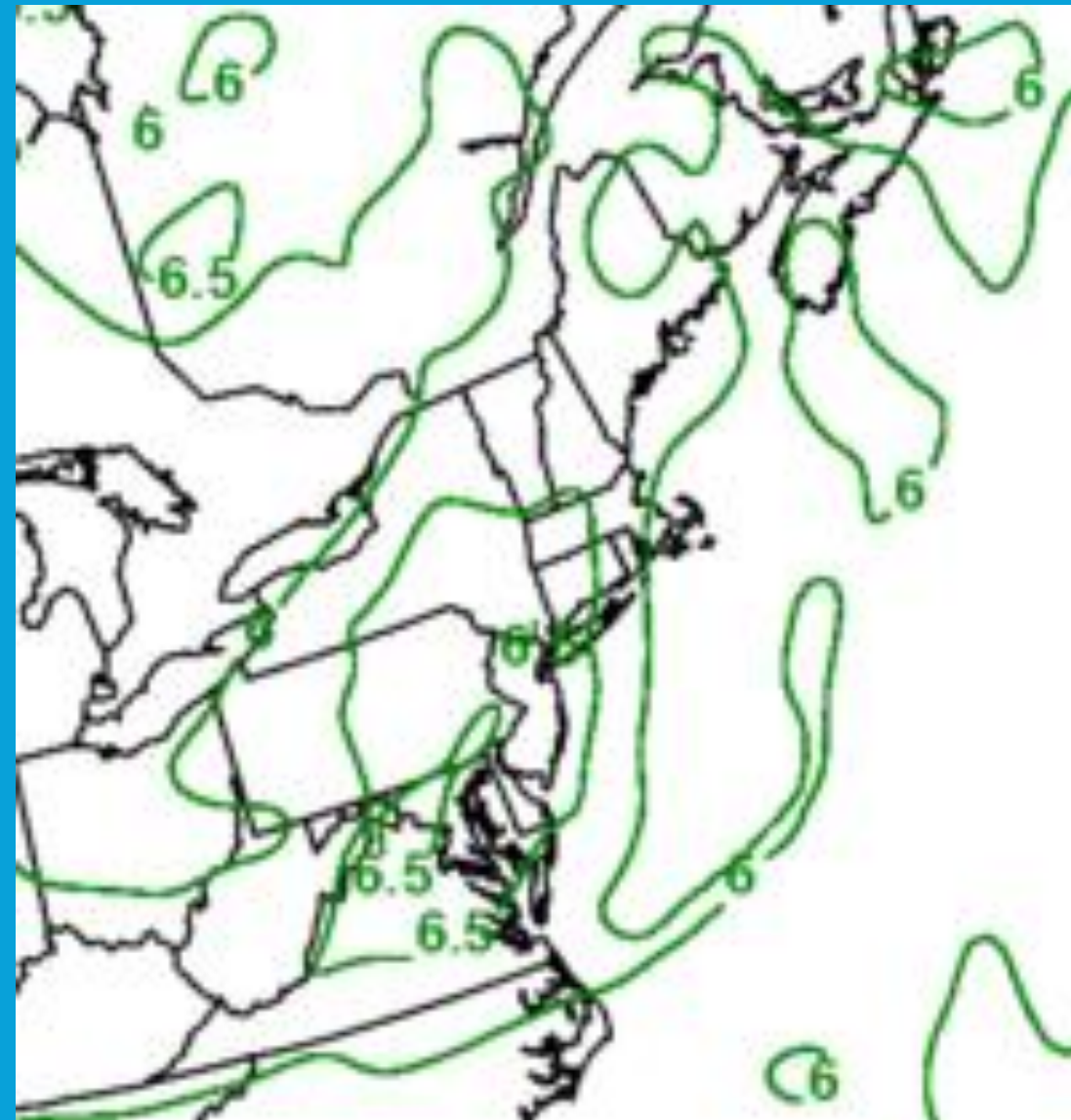
15 Hour SREF Valid 09z: Shaded > 50% Probabilities

SPC Mesoanalysis: 11z

Strong 0-6 km Shear Present



700-500 MB Mid Level Lapse Rates at 12z



Lapse Rates near 6.5C/km working into southern New England.

Not a classic EML, but with lower 70 dewpoints and high shear/CAPE, it was enough to produce a high end severe weather event.

6 Hour GFS Forecast Valid at 12z on August 4th 2015

Forecast Uncertainty: Early Morning on August 4th, 2015

- Anomalous instability co-located with deep shear/moisture across southern New England.**
- Potential for rare high end severe weather event across Southeast New England.**
- Still need a trigger, otherwise all the above parameters will not be utilized.**

BOX Area Forecast Discussion (4 AM August 3rd – Day Before)

TRAILING SHORT WAVE TROUGH APPROACHES SOUTHERN NEW ENGLAND FROM THE WEST. THIS IS QUITE EVIDENT IN WIND FIELDS ALOFT WHERE 500 MB SPEEDS APPROACH 50 KTS! THIS SHORT WAVE TROUGH COOLS H5 TEMPS TO -11C/-12C.

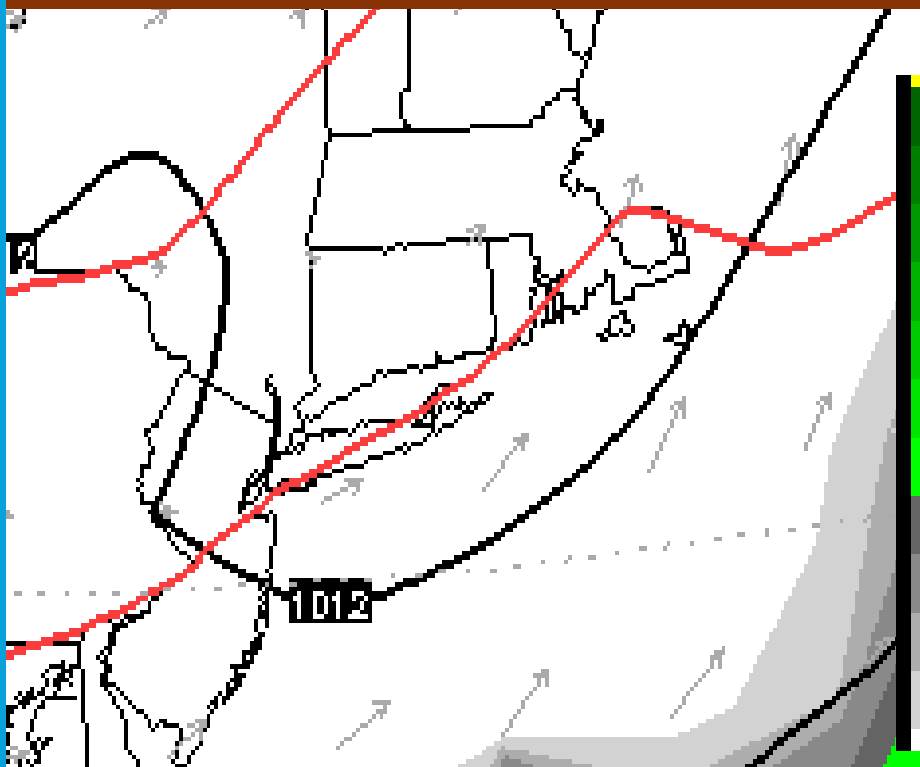
THIS COMBINED WITH SURFACE DEW PTS INCREASING INTO THE U60S AND L70S PROVIDES MUCAPES GREATER THAN 2000J/KG AND MID LEVEL LAPSE RATES BETWEEN 6.5 AND 7.0C/KM BY 12Z TUE ACROSS RI AND EASTERN MA PER 00Z EC AND 00Z GFS.

ONLY UNCERTAINTY IS WILL THERE BE ENOUGH FORCING FOR ASCENT TO UNLEASH THIS STRONG INSTABILITY.

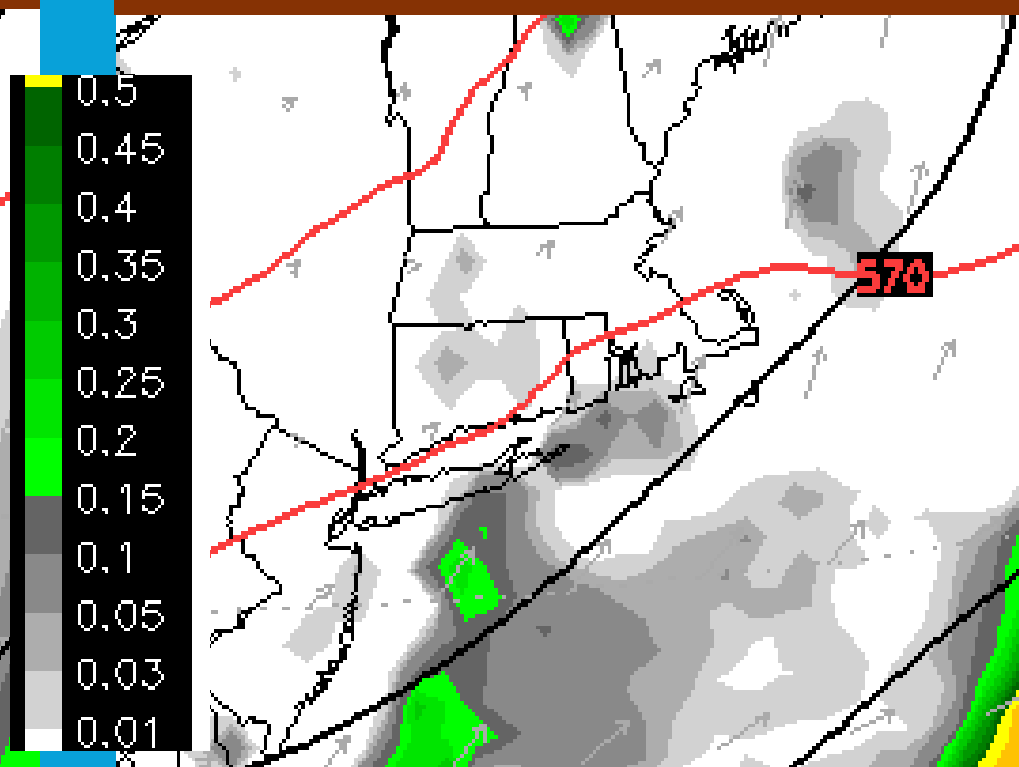
MIXED SIGNALS WITHIN THE GUIDANCE WITH THE GFS AND ECMWF NOT GENERATING MUCH QPF TONIGHT WHILE THE HI RES GUID NMM AND ARW HAVE CONVECTION BUT WEAKENING AS IT CROSSES THE AREA FROM WEST TO EAST.

Dealing With Uncertainty: Several Models Forecasting a “Shutout” Inside 36 Hours

ECMWF QPF 06z to 12z



GFS QPF 06z to 12z

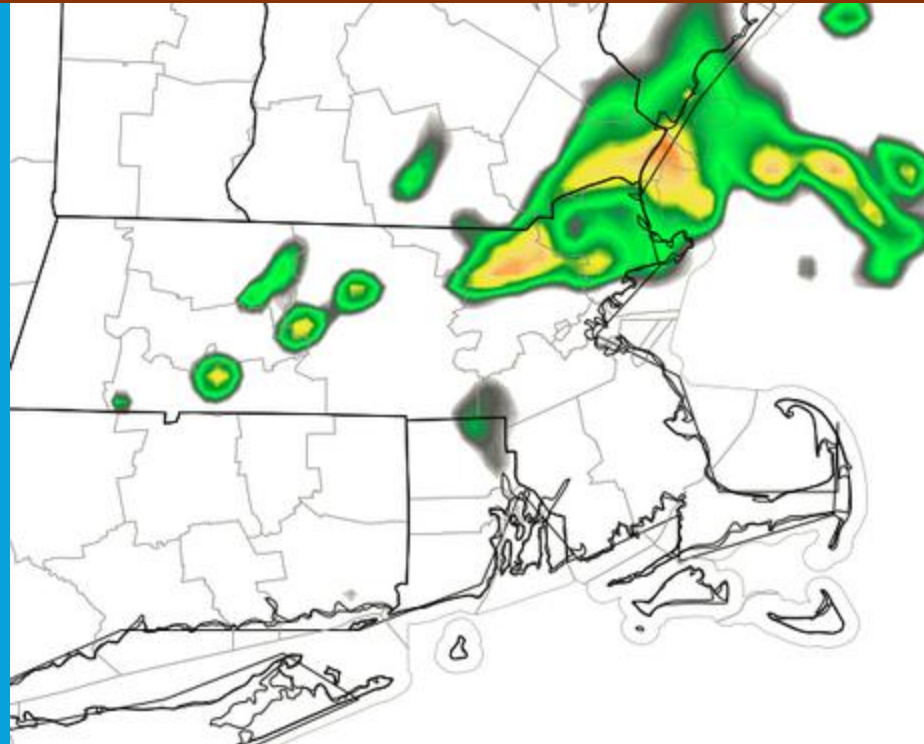


0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0.03
0.01

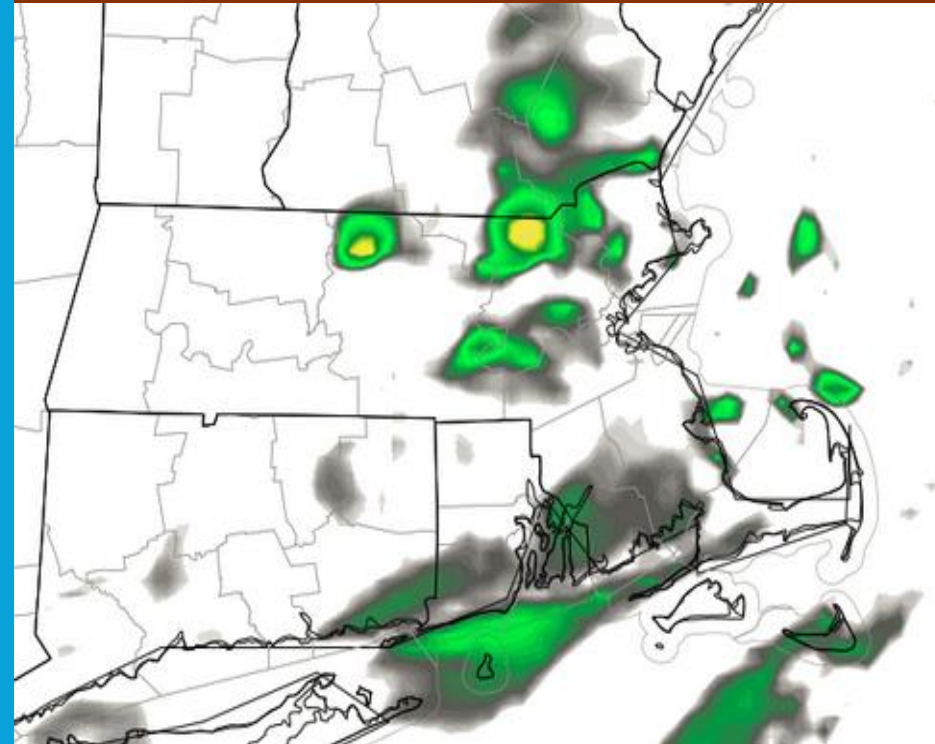
- Need some type of forcing to ignite potentially potent environment.
- GFS/ECMWF suggest there is not enough of a trigger.
- *How do you handle this as a forecaster?*
- *How do you brief EMs?*

High Resolution Guidance

12z Aug 3 ARW Valid 10z Aug 4



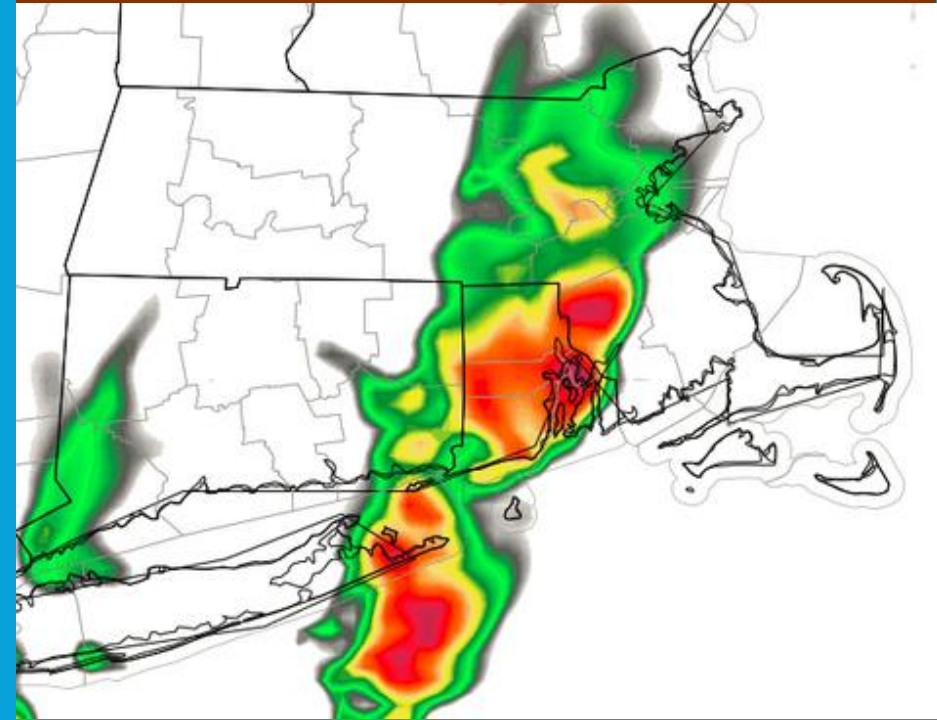
12z Aug 3 NMM Valid 10z Aug 4



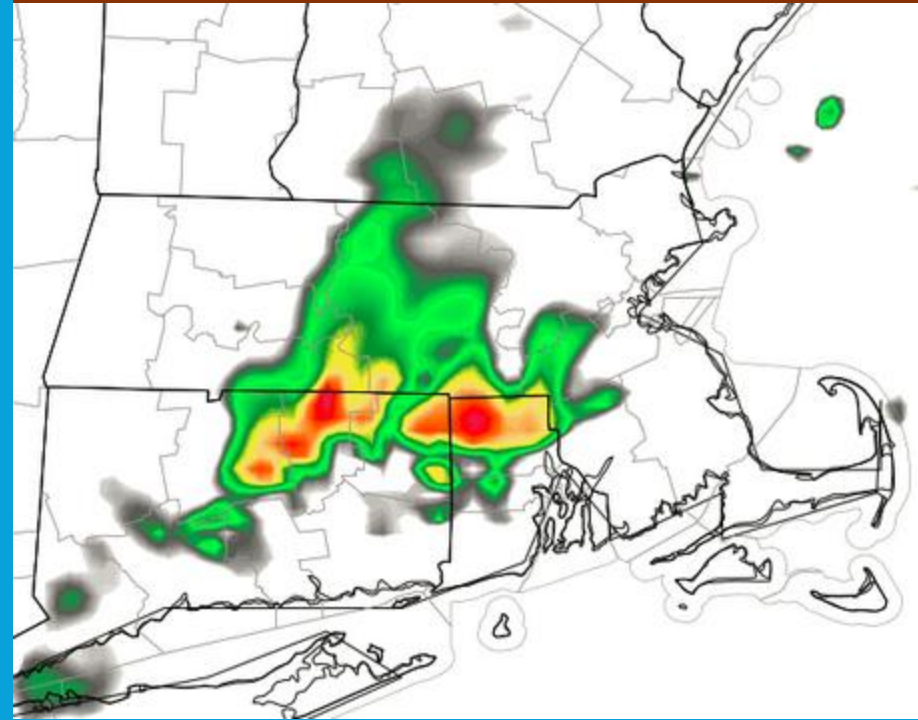
- 22-Hour Forecast from 4 km ARW/NMM not impressive
- Few showers/isolated thunderstorm in Northeast MA
- Little if anything farther to the south

High Resolution Guidance 12 Hours Later

00z Aug 4 ARW Valid 09z



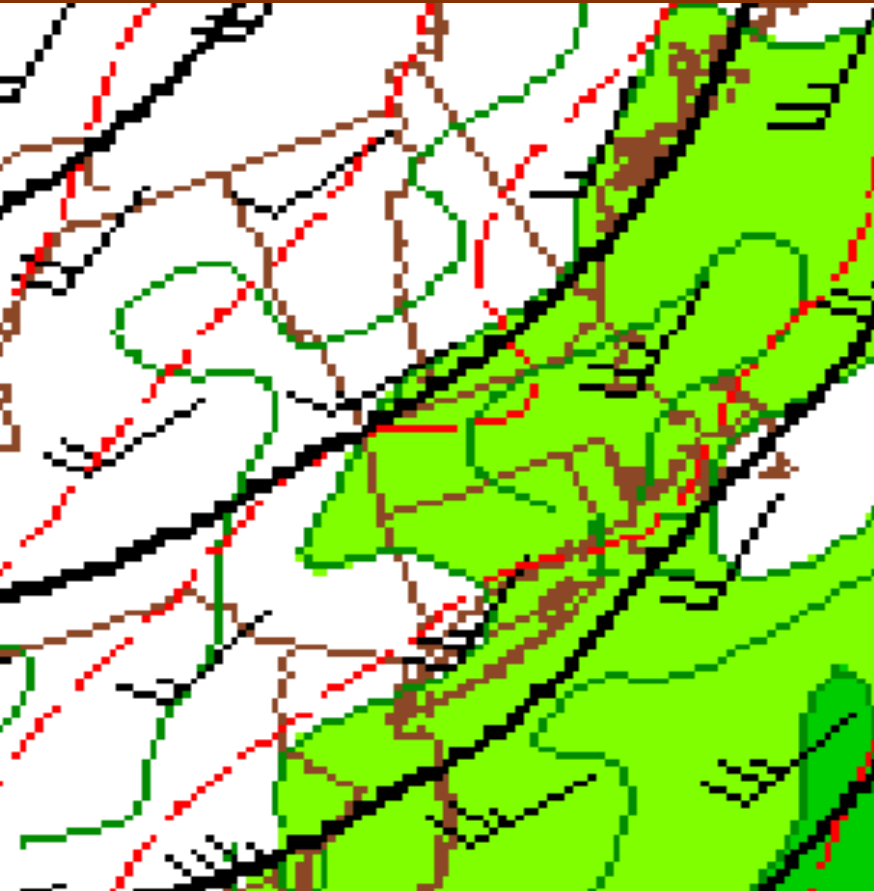
00z Aug 4 NMM Valid 09z



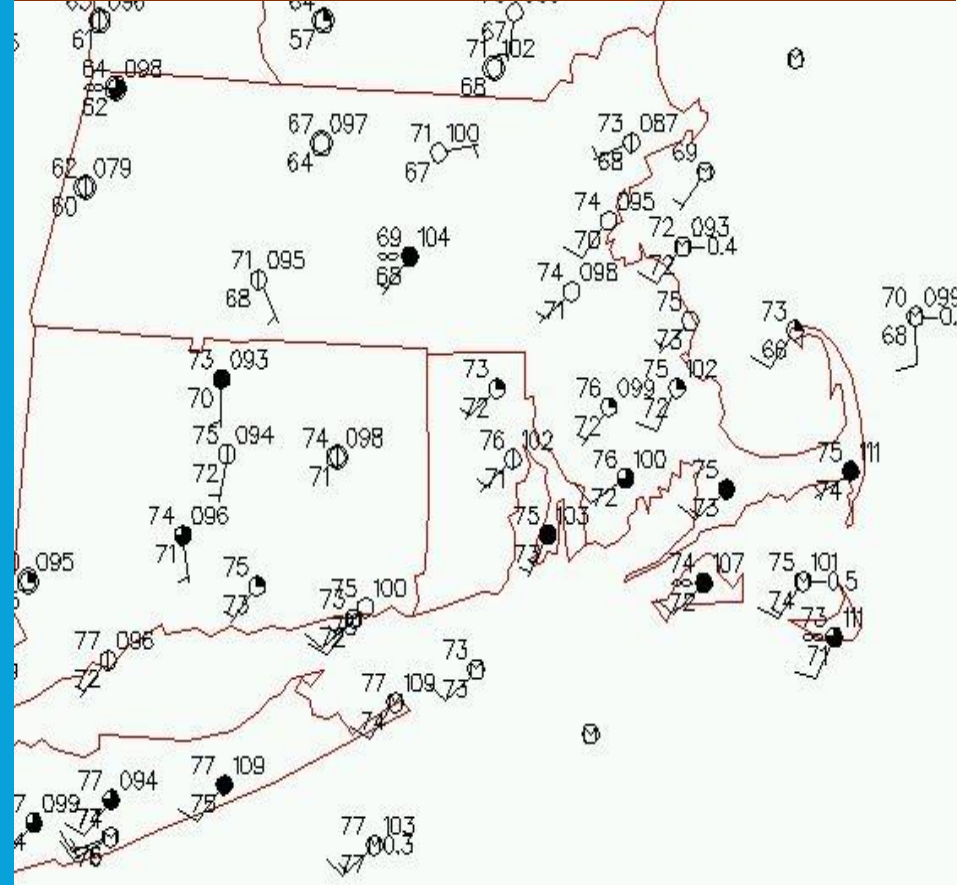
- 9 Hour Forecast shows more convection than before
- 4km NMM better, but not as impressive as the ARW.
- What is causing this change in the high resolution models?

Low Level Jet and Decoupled Boundary Layer

850mb LLJ of 25 Knots at 08z



Much Weaker Surface Winds at 08z

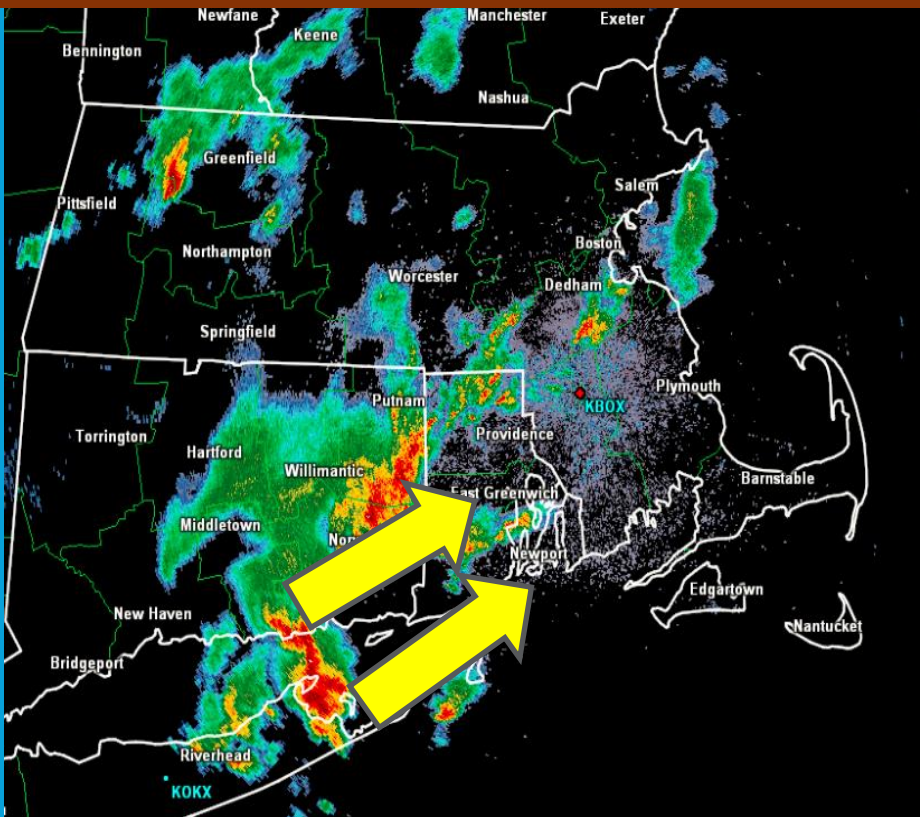


- Low level jet overruns cooler decoupled boundary
 - ***Sets up mesoscale boundary***
- Models often struggle with this setup and we can see a “Sunrise Surprise.”

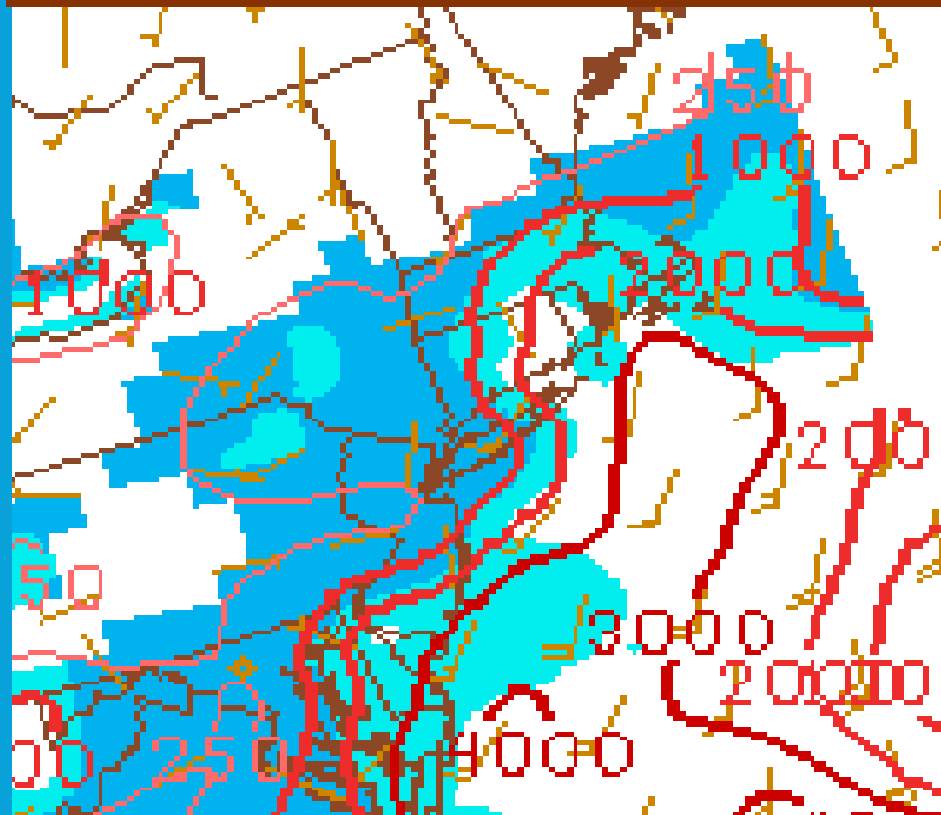
▪ But MUCARE and cheer usually, not as impressive

Radar Imagery

Radar Imagery at 0958z



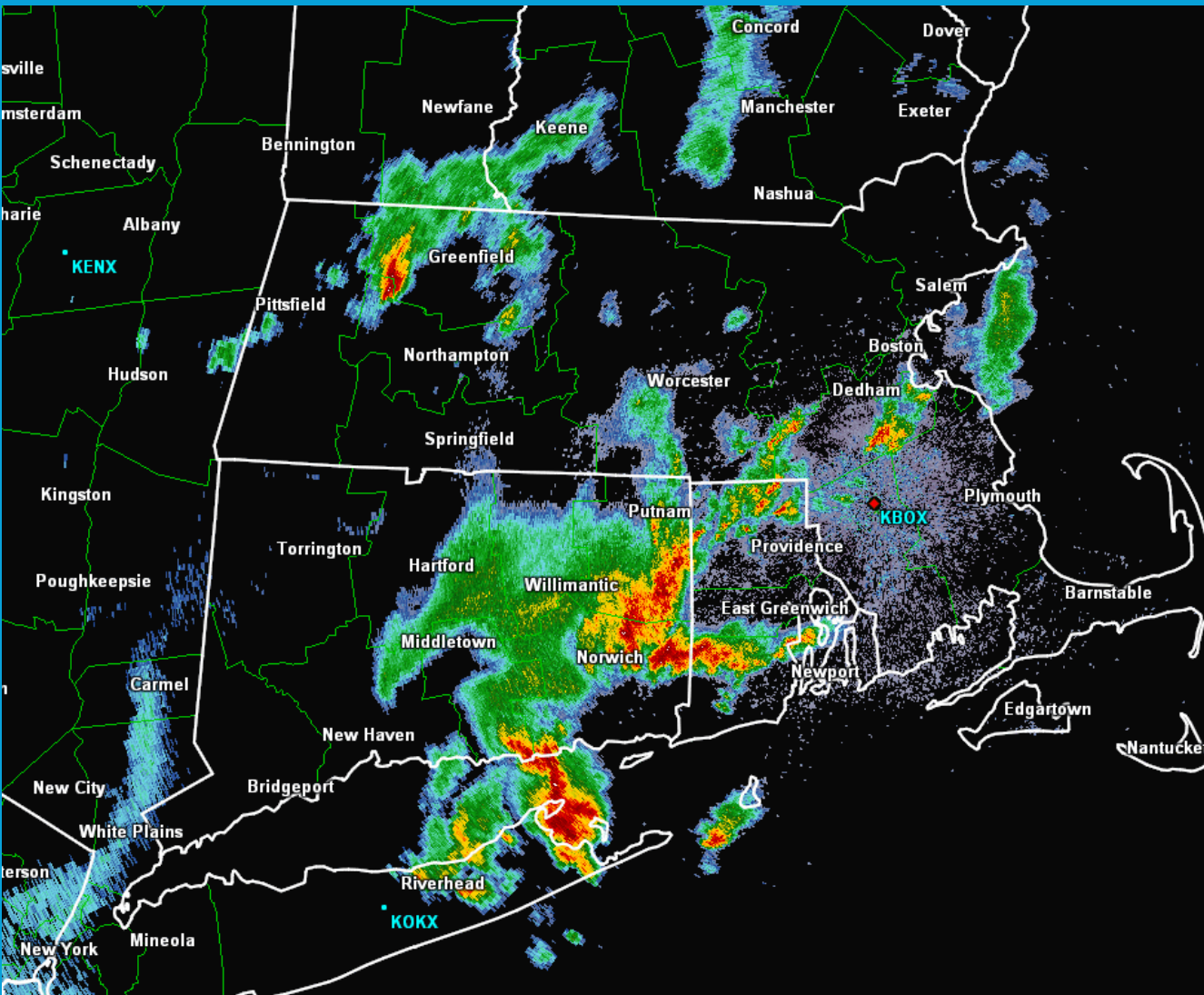
Storms moving into 2-3K of MUCAPE



- Storms formed on LLJ and moved into a more favorable environment.
- 2000 to 3000 J/KG of CAPE across southeast New England
- Deep surface moisture and increasing deep layer shear allows storms to become surface-based.

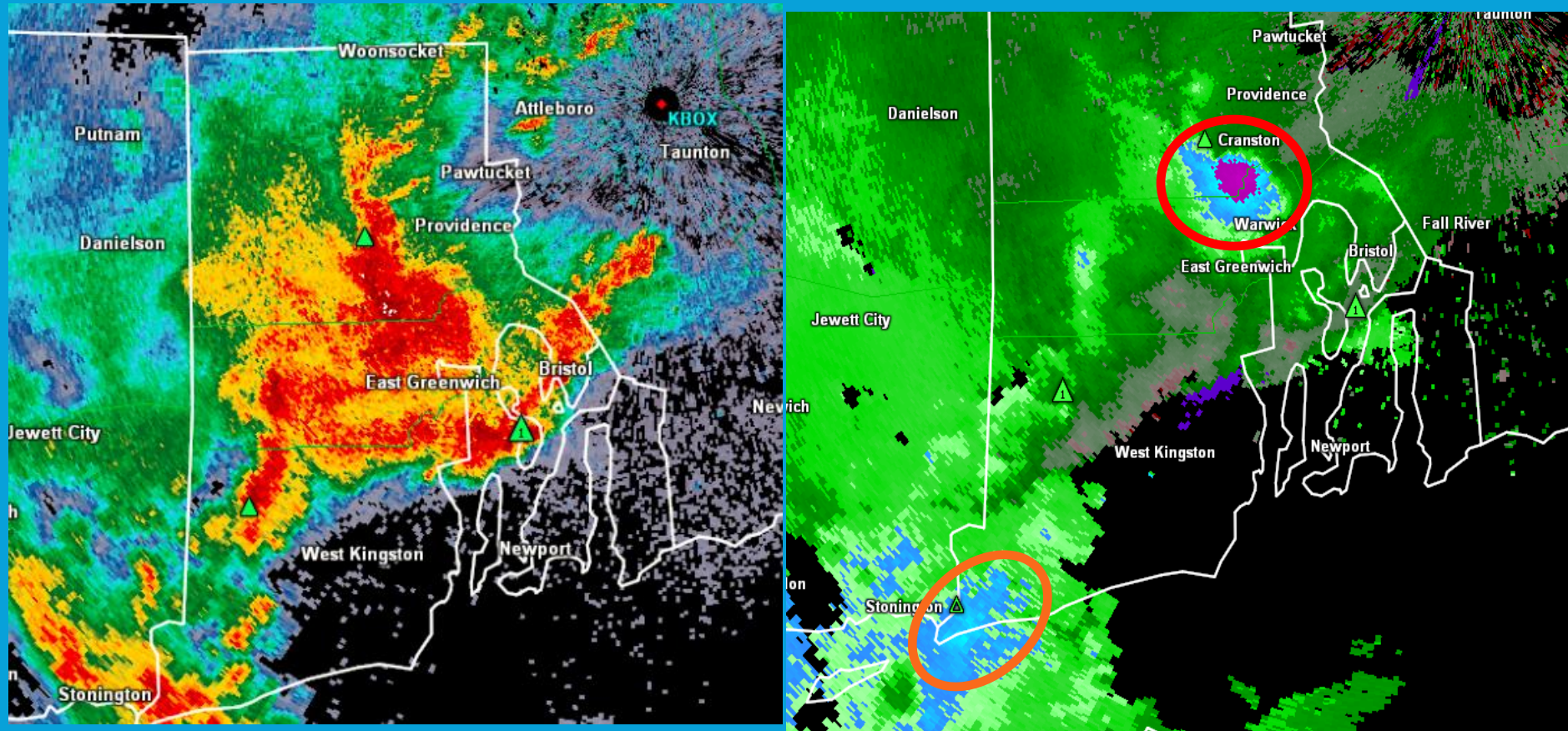
Radar Loop: 10z - 12z

Severe Thunderstorms with 60 to 80 mph Winds
Cross Rhode Island and Southeast Massachusetts



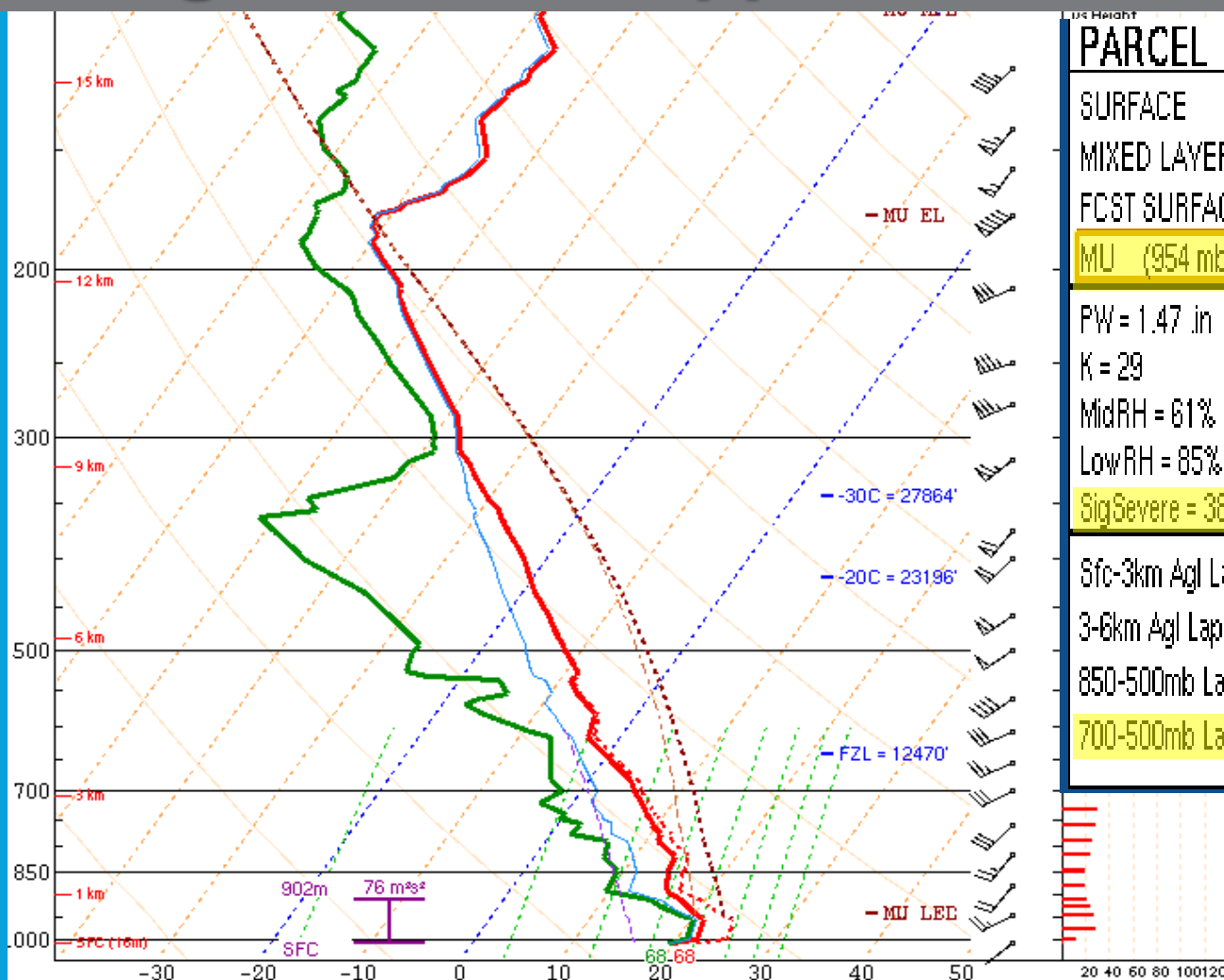
0.5 REF 1124 Z

0.5 VEL 1124 Z



- 70 to 80 knots just off the ground in Cranston, RI
- 60 to 70 knots across Southwest RI
 - Produced 83 mph gust at Charlestown, RI injuring 10 campers.

August 4th 12z Upper Air Sounding Chatham



PARCEL	CAPE	CINH	LCL	LI	LFC	EL
SURFACE	446	-157	24m	-3	2688m	30938'
MIXED LAYER	1494	-19	604m	-6	398m	38116'
FCST SURFACE	2450	0	1084m	-8	1084m	42205'
MU (954 mb)	2712	0	634m	-8	634m	42549'

PW = 1.47 in 3CAPE = 107 J/kg WBZ = 11067' WNDG = 0.0
 K = 29 DCAPE = 744 J/kg FZL = 12470' ESP = 0.0
 MidRH = 61% DownT = 61 F ConvT = 80F MMP = 0.90
 LowRH = 85% MeanW = 14.7 g/kg MaxT = 84F NCAPE = 0.2

Sig Severe = 38657 m3/s3

Sfc-3km Agl Lapse Rate = 5.2 C/km
 3-6km Agl Lapse Rate = 6.6 C/km
 650-500mb Lapse Rate = 6.4 C/km
 700-500mb Lapse Rate = 6.6 C/km

Supercell = 4.1
Left Supercell = -3.8
STP (eff layer) = 0.7
STP (fix layer) = 0.2
Sig Hail = 1.7

Quite an Anomalous Sounding at CHH!

- MUCape: **2712 J/kg**
- 700 to 500 MB Lapse Rate: **6.6C/km**
- 0 to 6 KM Shear: **50 Knots**

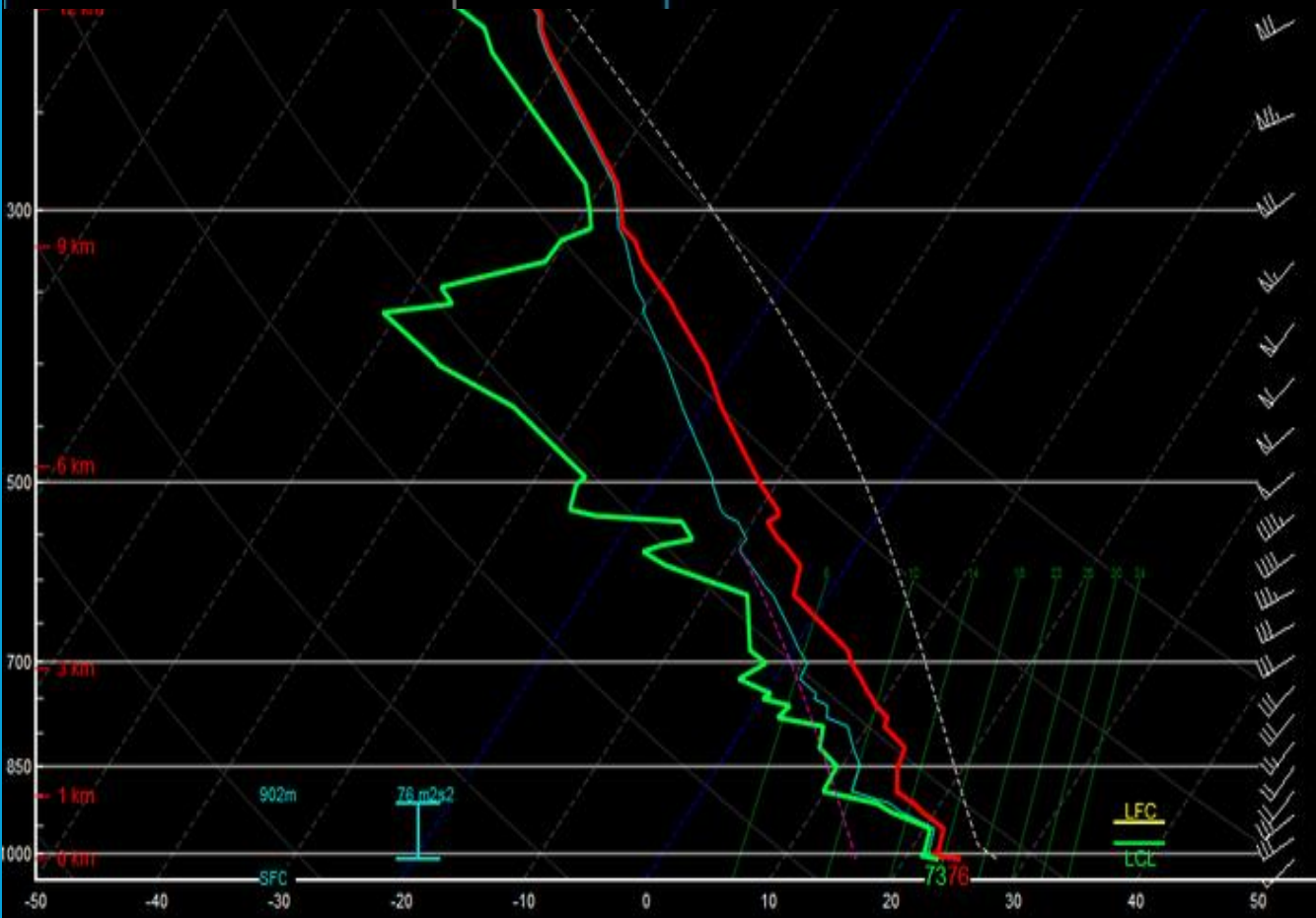
August 4th 12z CHH Sounding Modified for PVD

PCL	CAPE	CINH	LCL	LI	LFC	EL	SRH (m2/s2)	Shear (kt)	MnWind	SRW	
SFC	2882	-2	227	-8	594	13152	SFC-1km	77	19	236/23	101/17
ML	1639	-15	615	-6	855	11771	SFC-3km	119	26	228/24	111/19
FCST	2545	0	1064	-8	1064	13008	Eff Inflow Layer	76	19	237/23	101/17
MU	2882	-2	227	-8	594	13152	SFC-6km		50	233/28	120/15
							SFC-8km		58	232/31	132/14
							LCL-EL (Cloud Layer)		62	233/37	154/14
							Eff Shear (EBWD)		56	233/29	124/15
PW = 1.47in							BRN Shear =		6 m2/s2		
MeanW = 15.2g/kg							4-6km SR Wind =		153/9 kt		
LowRH = 91%							... Storm Motion Vectors...				
MidRH = 61%							Bunkers Right =		255/37 kt		
DCAPE = 885							Bunkers Left =		206/33 kt		
DownT = 61F							Corfidi Downshear =		231/62 kt		
							Corfidi Upshear =		230/20 kt		
K = 29							WINDG = 0.0				
TT = 47							TEI = 26				
ConvT = 80F							3CAPE = 124				
maxT = 84F											
ESP = 0.0											
MMP = 0.86							SigSvr = 42367 m3/s3				
Sfc-3km AGL LR = 6.9 C/km							Supercell = 4.4				
3-6km AGL LR = 6.6 C/km							STP (cin) = 0.8				
850-500mb LR = 6.4 C/km							STP (fix) = 1.3				
700-500mb LR = 6.6 C/km							SHIP = 1.8				

Modified using PVD temperature (76) and dewpoint (73) at time of the event

Courtesy of Ryan Hanrahan

- Surface CAPE: 2882 J/kg
- Effective Deep Layer Shear: 56 knots
- SigSVR: 42,367



Lessons Learned from the Early Morning Event

Highly anomalous environment *may* result in a highly anomalous event, but a trigger is still needed.

- In this case, mesoscale boundary formed from low level jet and decoupled boundary layer

Utilize SPC SREF guidance

- Craven-Brooks Probabilities greater than 20,000 for potential of high end severe weather.
- 12 and 24 Hour Severe Weather Probabilities may show reasonable potential where values are contoured (above 15 percent).

Model QPF should be considered

- Not always the determining factor on what will unfold.

Handle these events probabilistically

- Important to express uncertainty in these situations

Getting the Word Out

- Severe Thunderstorm Warnings provided an average of 31 minutes of lead time
- Strong wording used to let people know these were no “ordinary” severe storms
 - ***“This is a very dangerous situation”***
 - ***“Widespread damage”***
 - ***“Winds in excess of 80 mph”***
- NWSChat and social media used as time allows

Round 2: Unusually Large Hail and Damaging Winds

- All storms stayed to the north of the Connecticut and Rhode Island border.
- Hardest hit area was along and north of the Massachusetts Turnpike
 - Several reports of golf ball sized hail
 - 50 to 60 mph wind gusts.
- Bulk of the area that was hit earlier in the morning was not affected by the afternoon activity.
- No tornadoes occurred during the afternoon, despite impressive radar signatures.

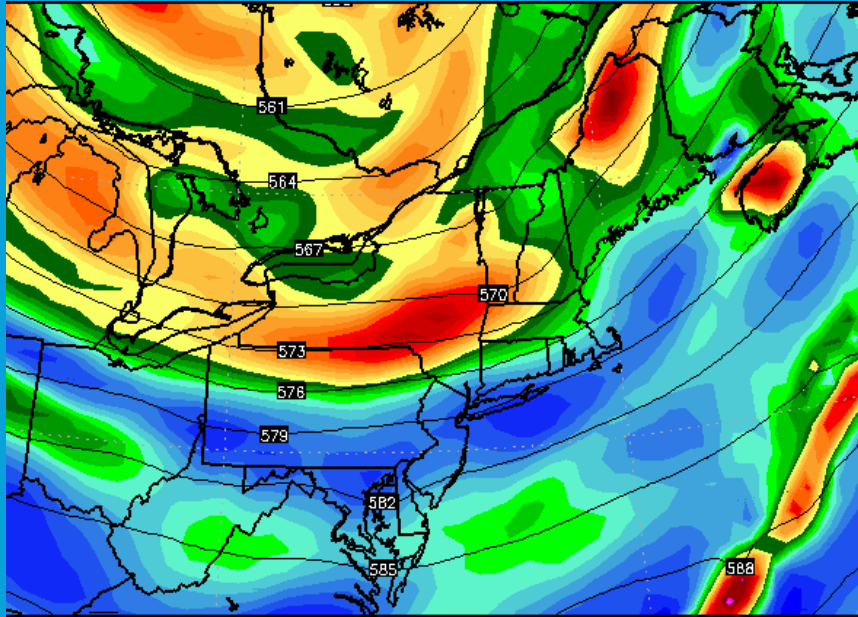
Pictures from Boston Hail Event



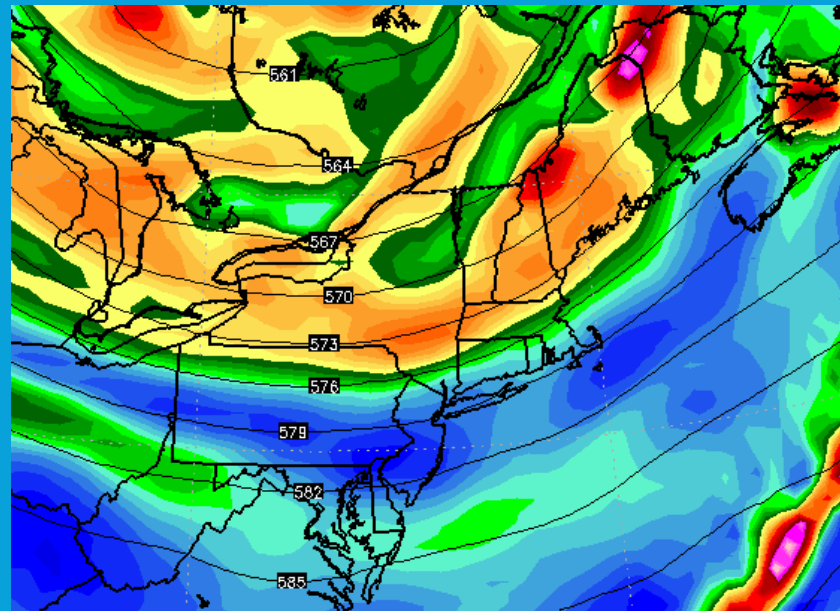
These pictures were taken in Brighton, MA courtesy of Rachel Rumely

500 mb Height/Vorticity from NAM

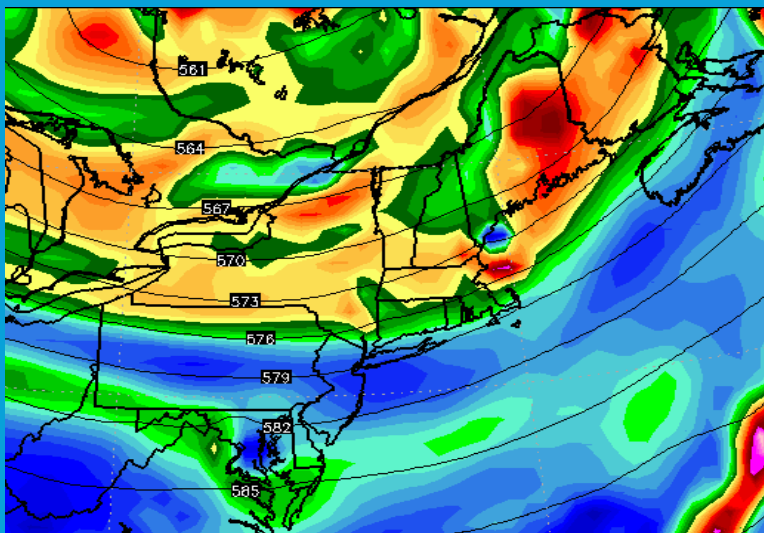
Valid at 18z on August 4, 2015



Valid at 21z on August 4, 2015

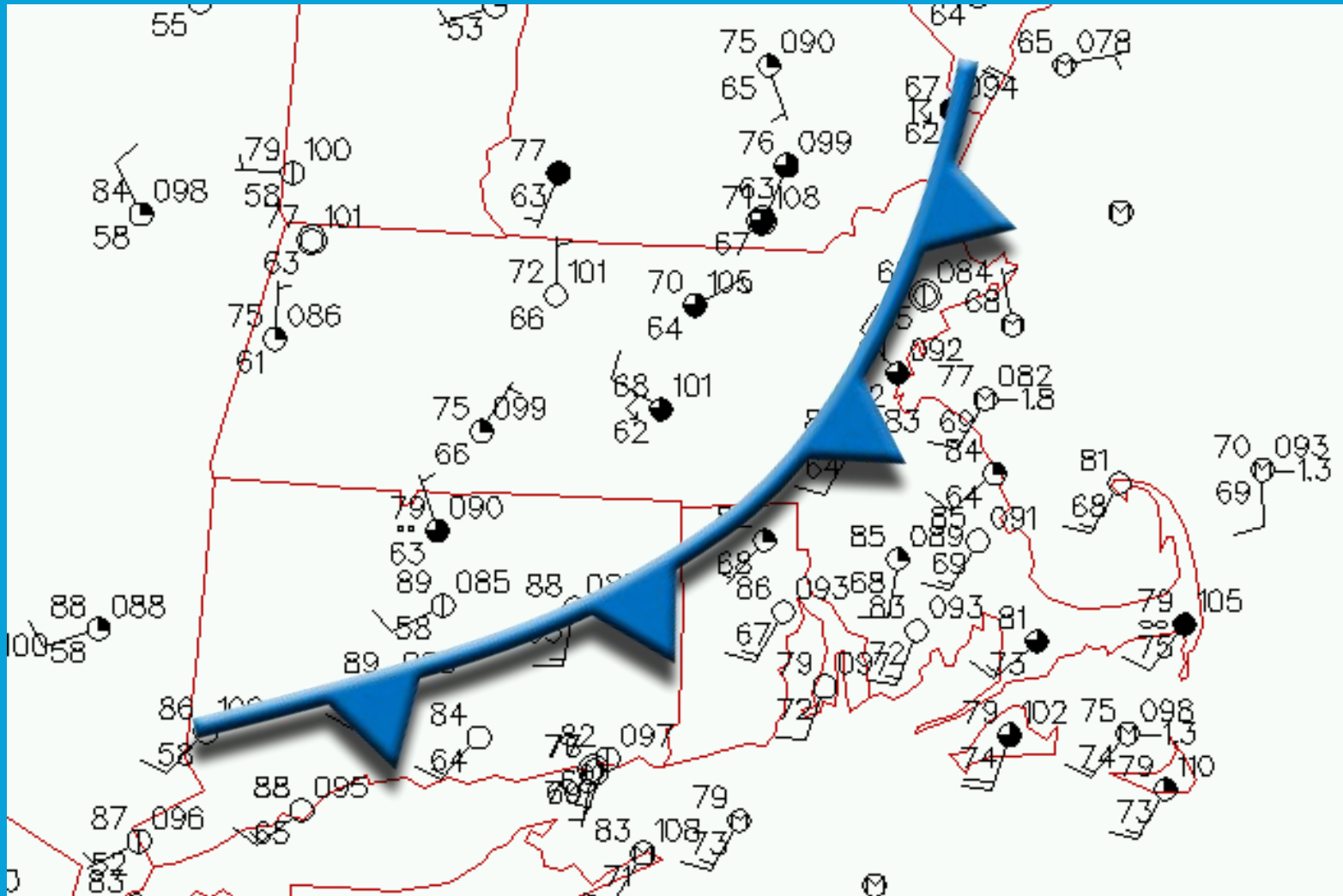


Valid at 00z on August 5, 2015



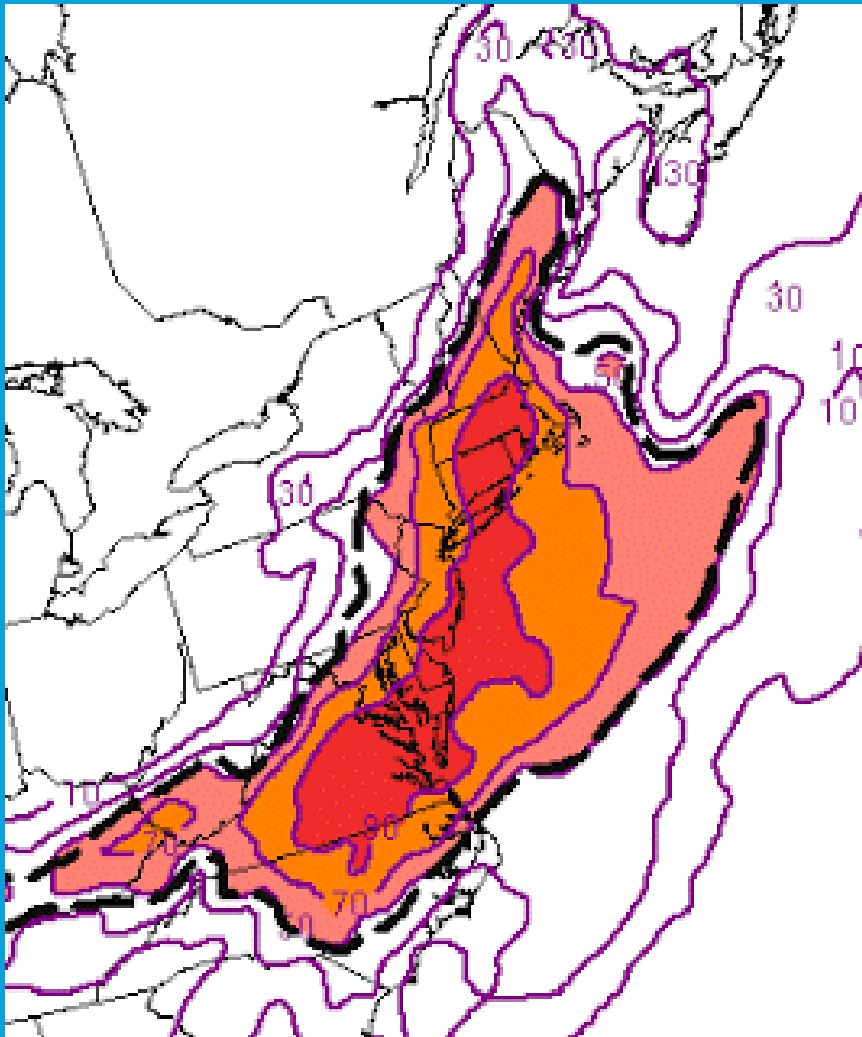
- Next shortwave moving across Central & Northern New England
- Indicates better forcing for convection will be to the north of the Massachusetts Turnpike

Surface Map Valid at 20z on August 4, 2015



Strong Cold Front Crossing the Region

SPC SREF: Mean Craven-Brooks Sig Severe Probabilities > 20,000 For the Afternoon

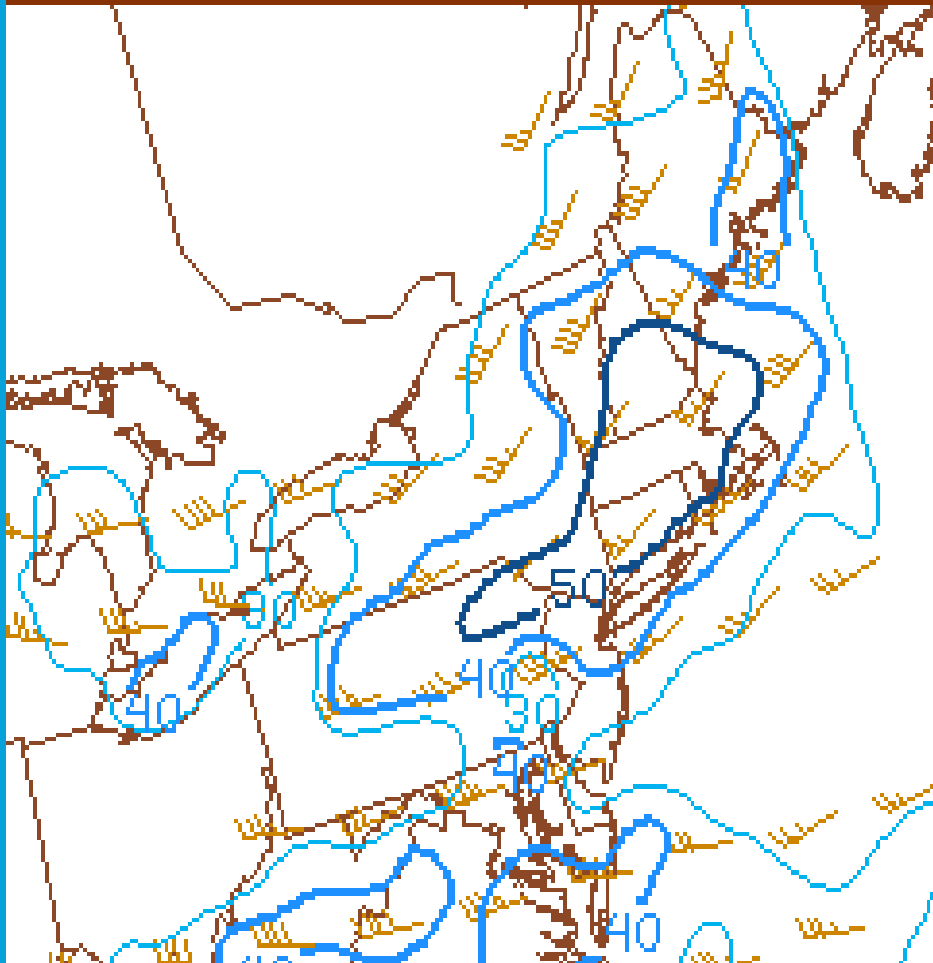


- Over 90 percent for much of southern New England. *Extremely unusual for the Northeast!*
- Keep in mind: Nothing happened in Connecticut in morning or afternoon events. Still need a trigger.

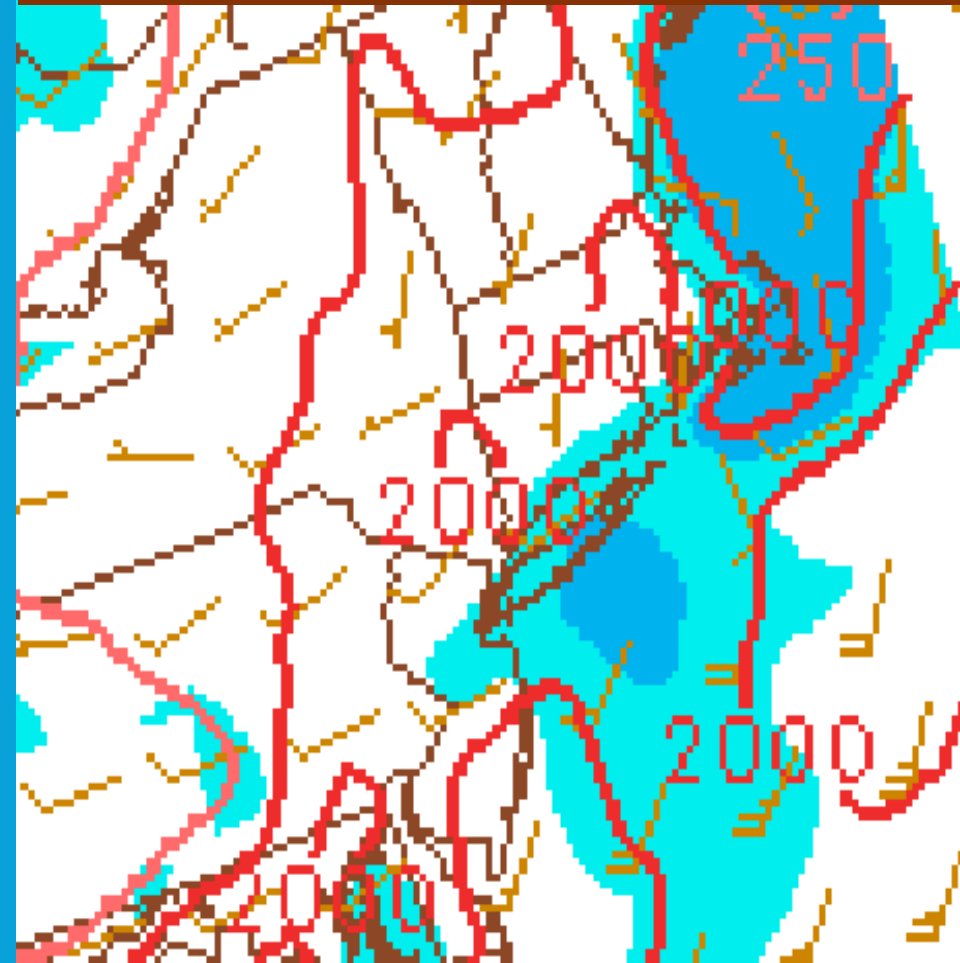
21 Hour SREF Valid 18z: Red Shade > 90% Probabilities

SPC Meso-Analysis: Effective Bulk Shear and MLCAPE at 19z

Bulk Shear Values 50 to 60 Knots

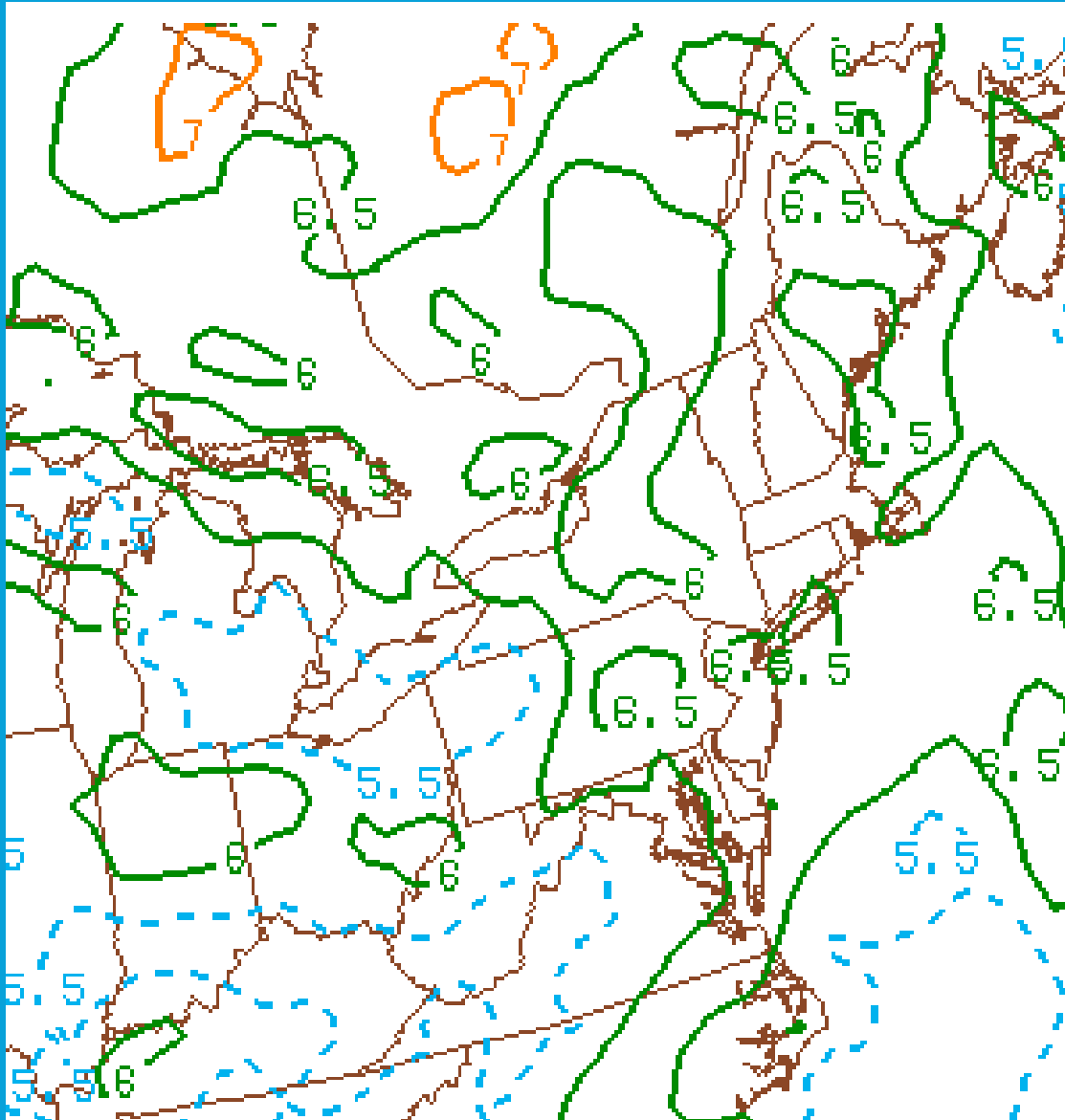


MLCAPE 1500 to 2500 J/kg



High CAPE and High Shear in Place

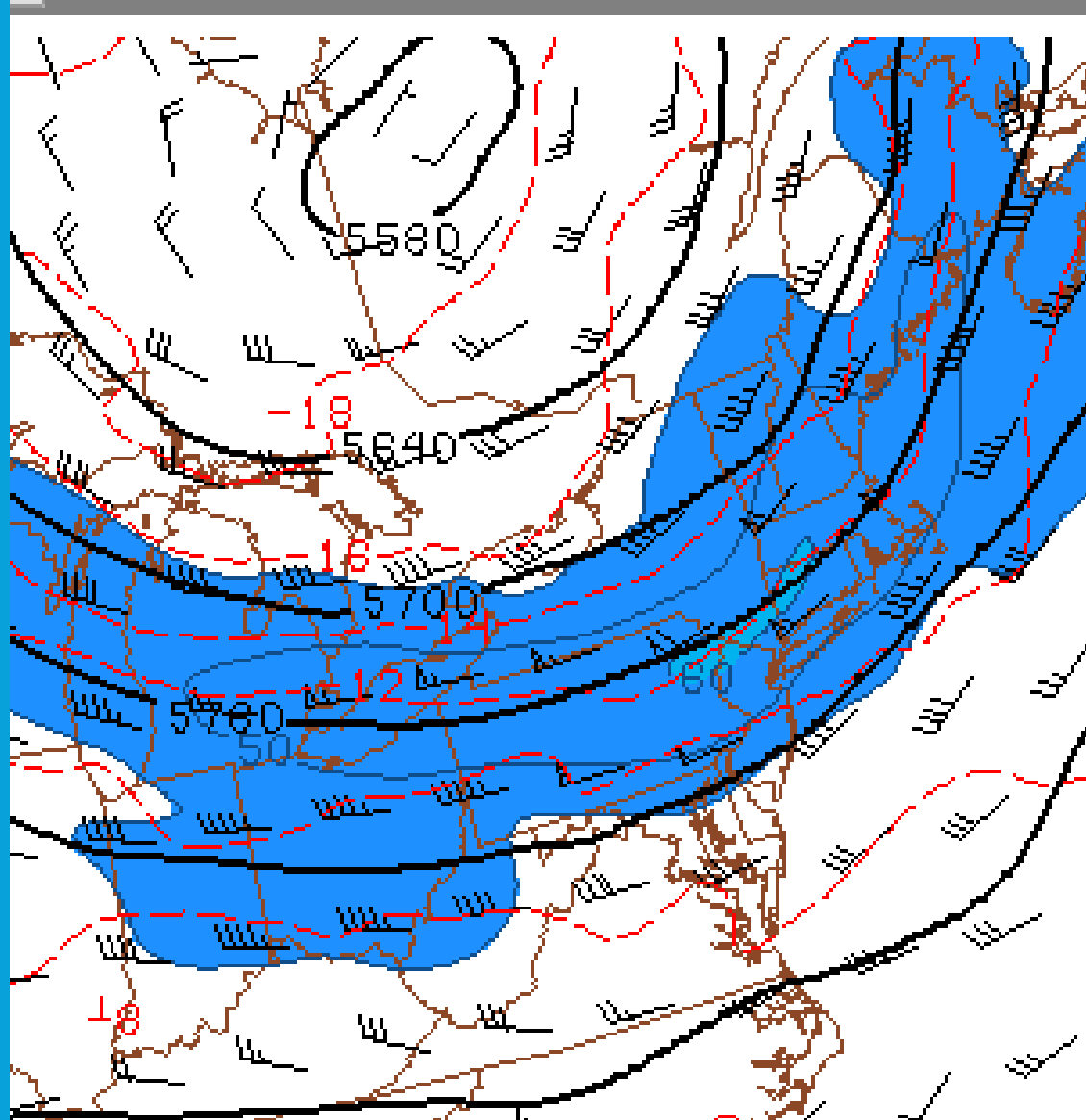
SPC Meso-Analysis: 700-500 mb Mid Level Lapse Rates at 19z



Near 6.5C/km for most of the region.

Potential for high-end severe weather when considering high CAPE and high shear

SPC Meso-Analysis: 20z August 4th

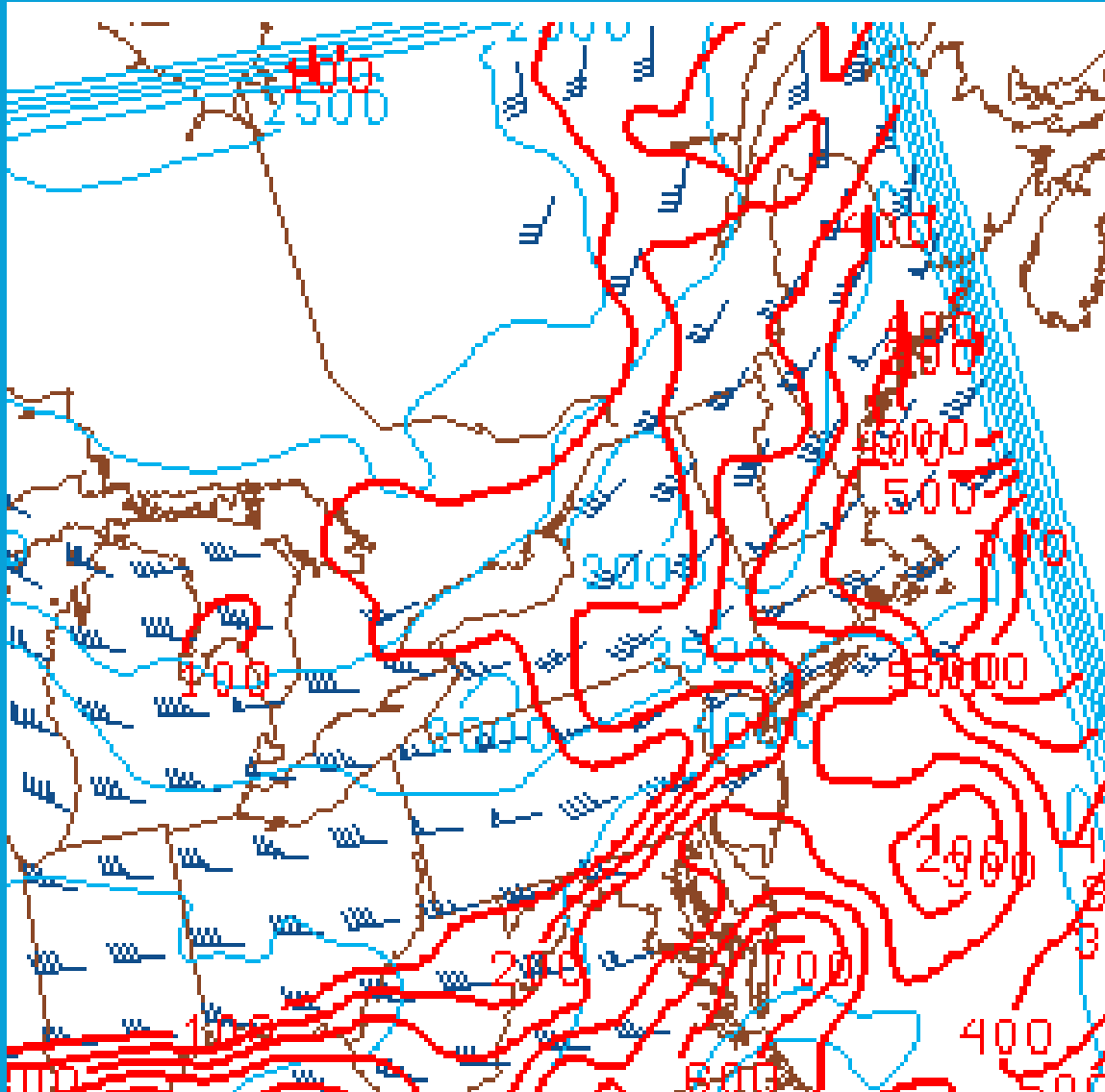


500 mb temps
-12 to -13C

Quite cold aloft
given deep low
level moisture
and highs in the
upper 80s to
near 90

*Favorable for
large hail*

SPC Meso-Analysis: “Hail CAPE” at 19z



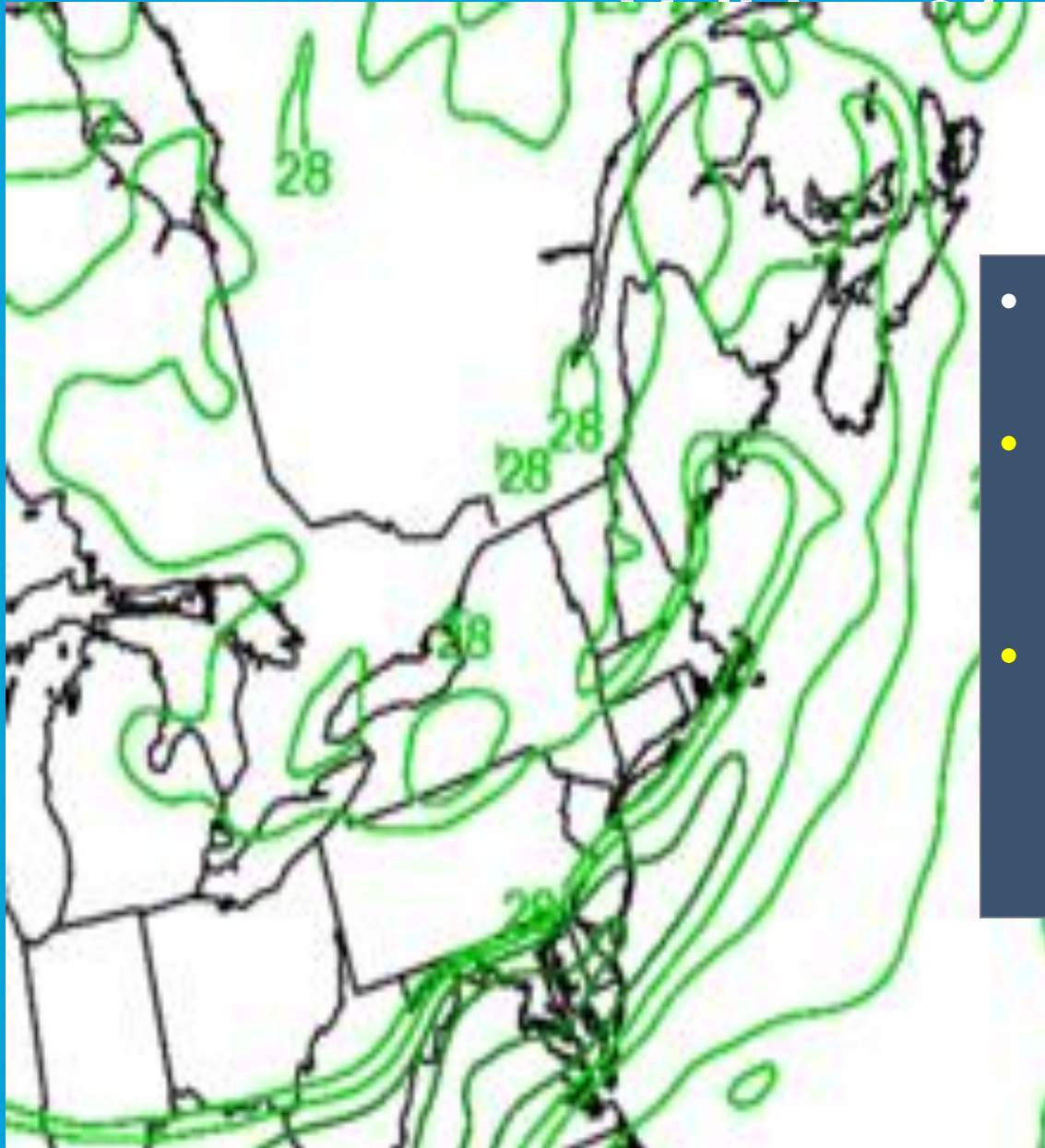
Values > 400 J/kg
in the -10 to -30 C
layer bring the
potential for very
large hail

In this case,
values were
between 400 and
550 J/kg!

Forecast Uncertainty During the Afternoon

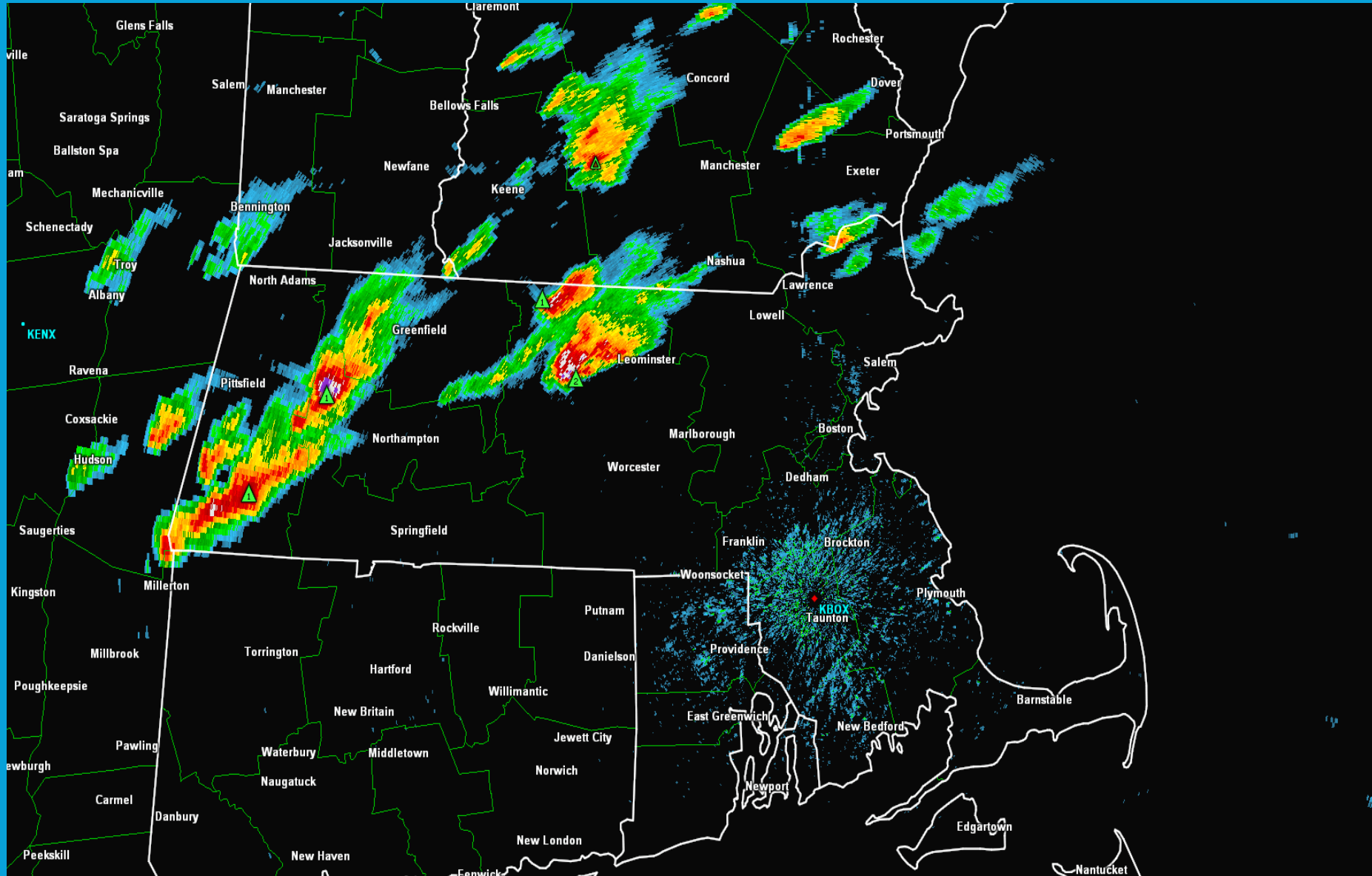
- Anomalously High CAPE/High Shear in place during the afternoon with 6.5C/KM mid level lapse rates
 - **Very cold aloft with >400 J/kg of Hail CAPE**
- High Probabilities of Craven-Brooks Significant Severe Weather Exceeding 20,000.
- Approaching Shortwave/Cold Front would be the potential trigger for another round of high end severe weather
- Biggest uncertainty was amount of mid level dry air that would work into the region behind earlier convection.
 - **Some mid level dry air can increase lapse rates and promote risk for severe wind and hail.**
 - **Too much mid level dry air will cutoff thunderstorm updrafts and prevent severe weather.**
 - **It's a very delicate balance!**

Another Look at Moisture: K Index



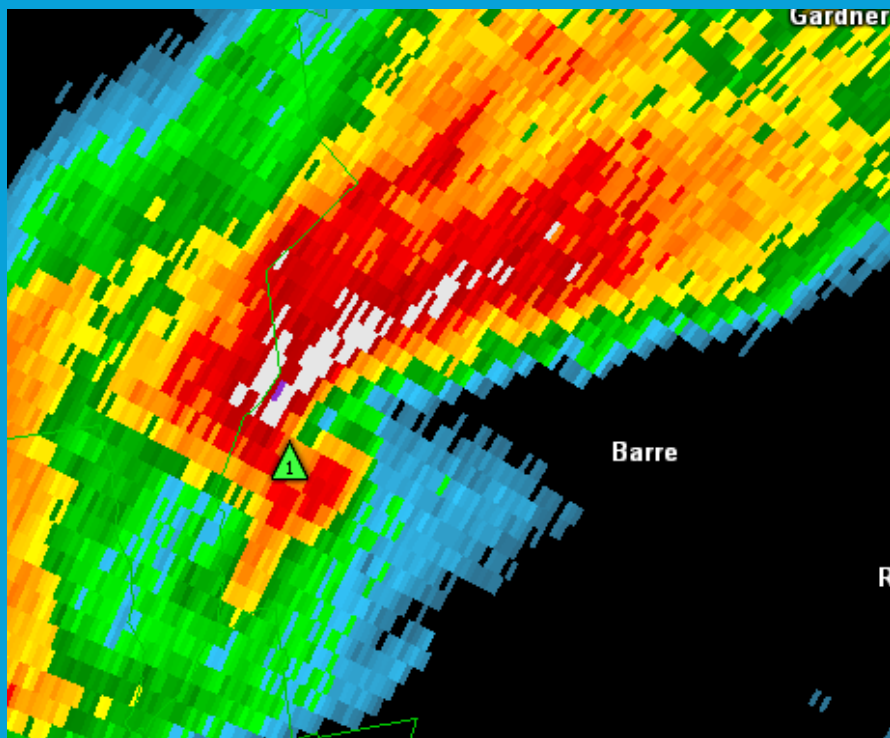
- “Best” moisture near & north of the MA Pike
- ***Just enough mid level dry air prevented storms to the south***
- ***Helped in large hail and strong wind production across Northern MA***

Radar Loop from the Afternoon Storms

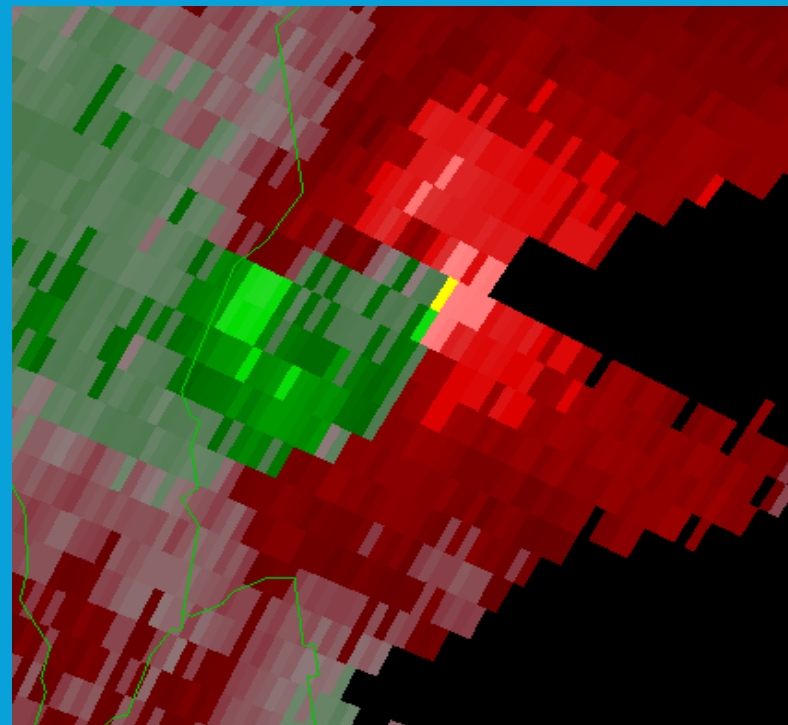


A Few Storms in Northern Massachusetts Prompt Tornado Warnings

0.5 REF: 1937 Z



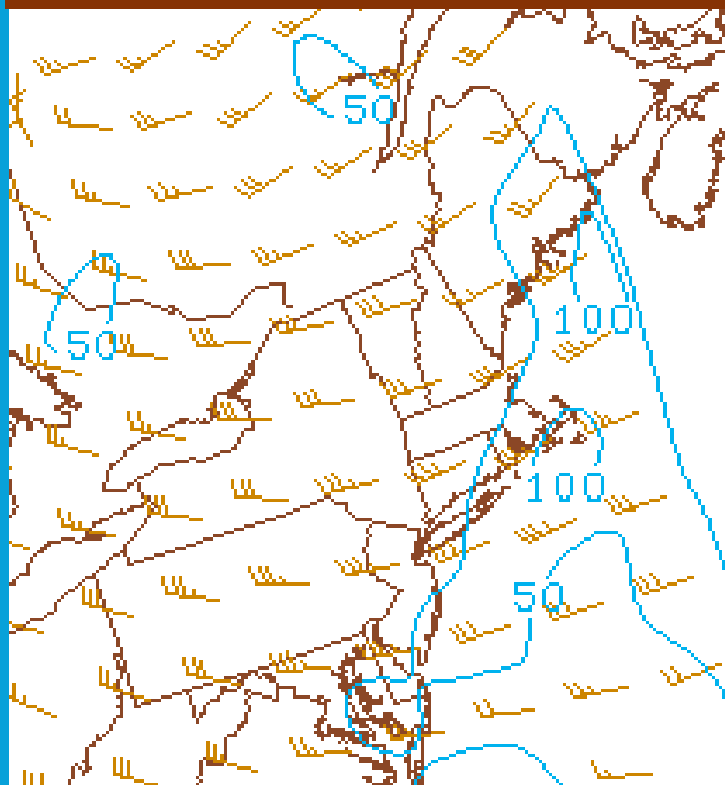
0.5 SRM: 1937 Z



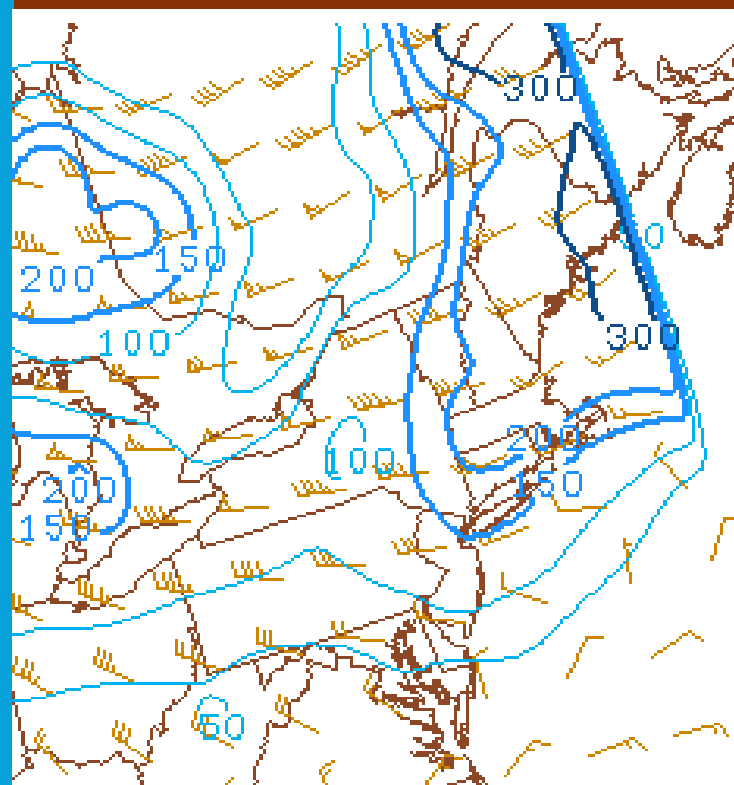
- Classic Hook Echo
- Gate-to-gate shear: 67 knots (7K feet from radar)
- Tornado Warning was issued but no tornadoes confirmed on damage survey

No Confirmed Tornadoes in Southern New England

8/4/15: Values < 50



6/1/11: Values >200



- Comparison of 0-1 km Helicity: Aug 4, 2015 and June 1, 2011
- Low level helicity less than 100, likely prevented this event from producing tornadoes.
- Dry air at low levels may have also been a factor

Summary of Two High End Severe Weather Events

Favorable Environment in Place

- Anomalous instability
- Deep shear/moisture
- Mid level lapse rates near 6.5C/km.

Round 1

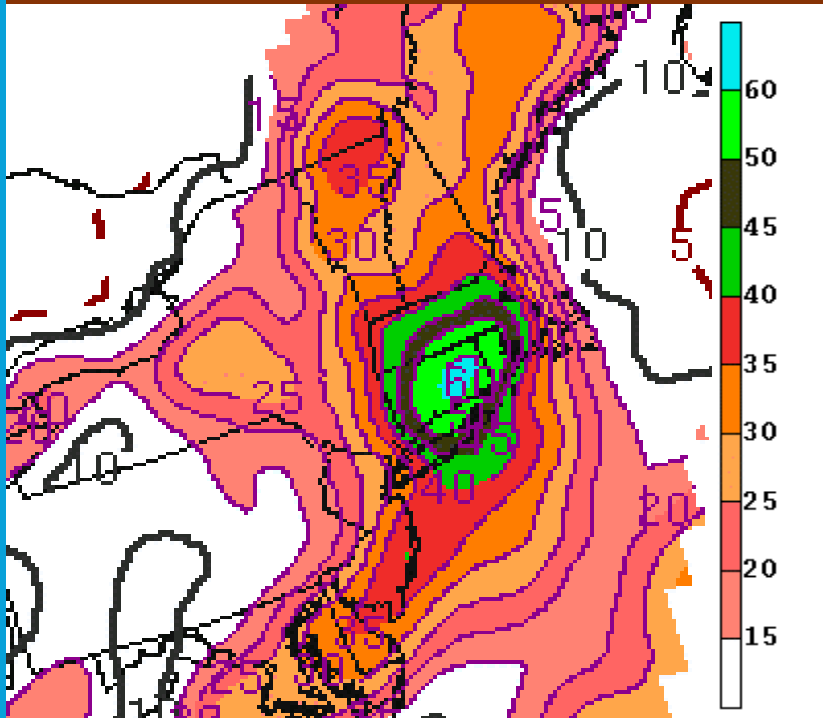
- *Trigger: Mesoscale boundary from increasing shear/low level jet across southeast New England*
- Widespread 60 to 80 mph wind gusts

Round 2

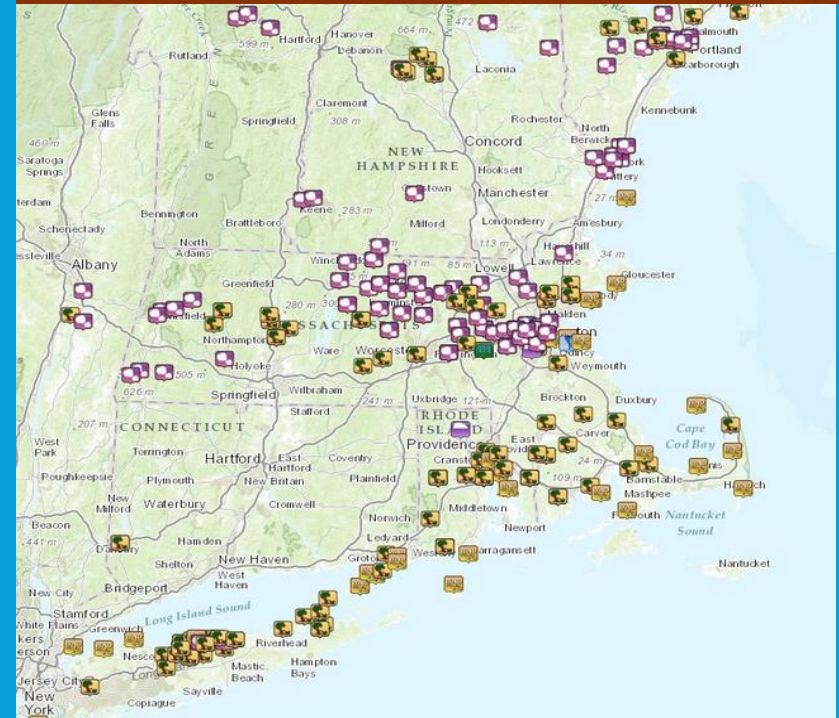
- *Trigger: Shortwave/cold front which brought very large hail to Northern MA*
- Mid levels dried out across CT/RI, not affected
- Lack of 0 to 1 KM helicity and dry air at lower levels were probably the reasons we did not have any confirmed tornadoes

24 Hour Severe Weather Probabilities from SPC SREF VS. Hail/Wind Damage Reports

SPC SREF – 24hr Svr Prob



Storm Reports on 8-4-15



- Incorporates both events
- Probabilities >35 percent unusually high
- Not perfect! Highest probabilities in CT