Severe Weather Ingredients

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Rich Thompson and Harry Weinman

Ingredients for Organized Severe Thunderstorms

- **Instability (Lapse Rates)**
- **Lift (QG, mesoscale, convective scale)**
- **Moisture (return flow, soil moisture, evapotranspiration)**
- **Vertical wind shear**

Ingredients for Organized Severe Thunderstorms

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- Moisture (return flow, soil moisture, evapotranspiration)

} This lecture

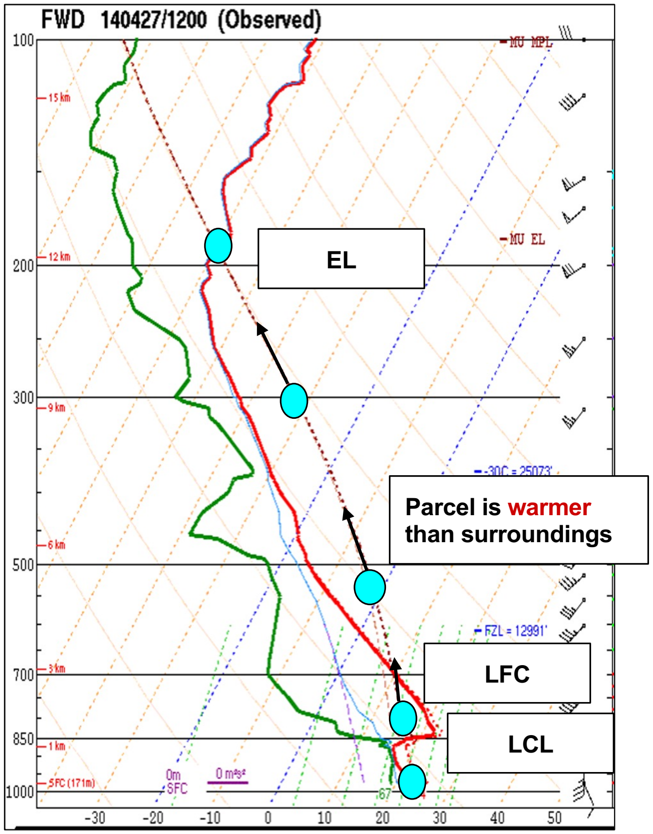
- Vertical wind shear - a separate lecture

Key ingredient for **organized** severe storms

Instability: The Basics

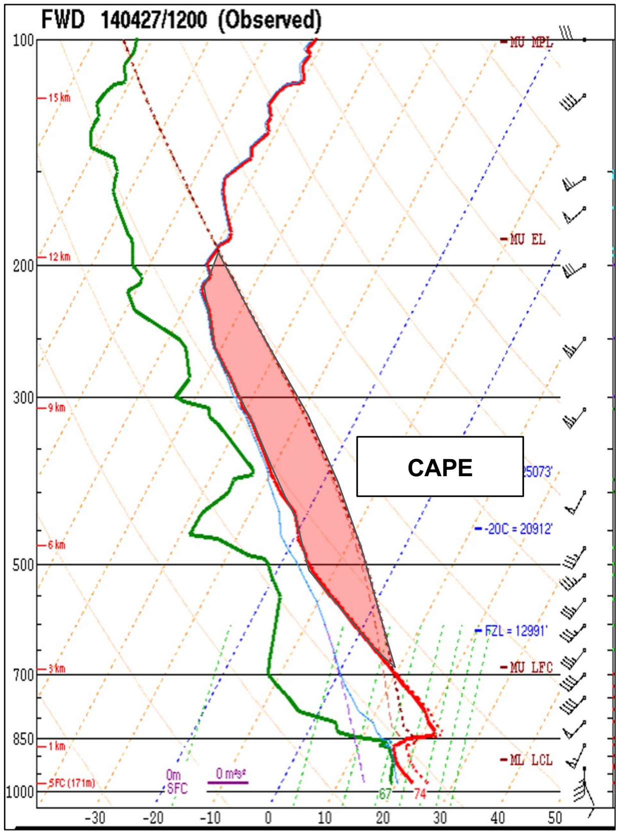
- **Give a parcel a nudge and see what happens!**

- **We determine an environments stability by its <u>lapse rate</u> (Change of environmental temperature with height)**



Instability: The Basics

- **Integrate the depth where parcel is warmer/less dense than its surrounding**
- **CAPE (Convective Available Potential Energy)**



$$CAPE = \int_{LFC}^{EL} g\,\frac{T_{v\_p} - T_{v\_env}}{T_{v\_env}}\,dz = \left[\frac{kg\,m^2}{s^2}\,\frac{1}{kg}\right] = \left[\frac{m^2}{s^2}\right]$$

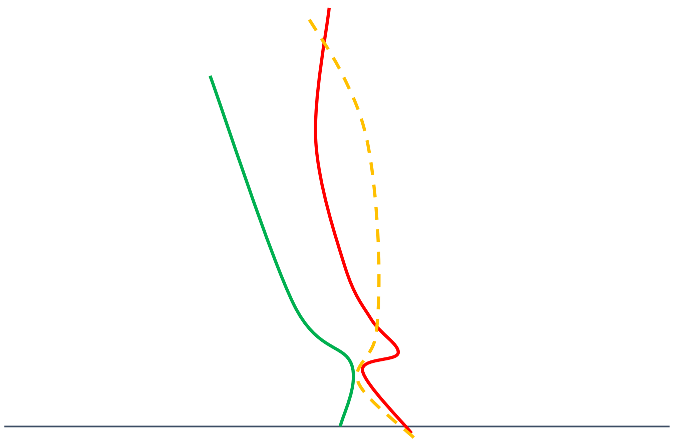
$$= \left[\frac{J}{kg}\right]$$

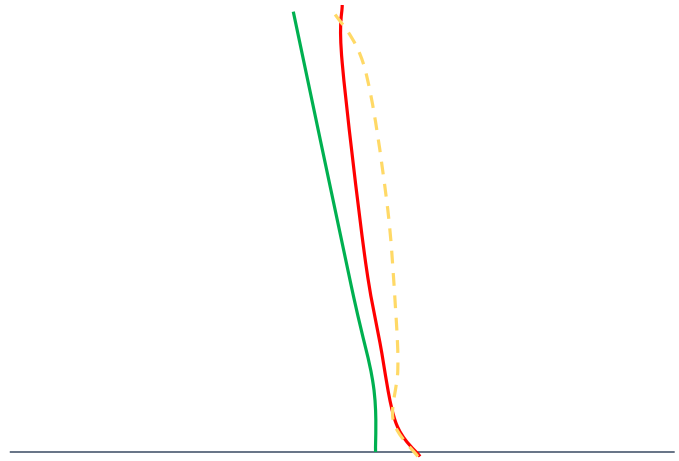
Instability: The Basics

Take a small finite layer depth within CAPE profile

$$\frac{CAPE}{\Delta Z} = \left[\frac{m^2}{s^2}\right]\left[\frac{1}{m}\right] = \left[\frac{m}{s^2}\right] \longrightarrow$$

Upward Acceleration!





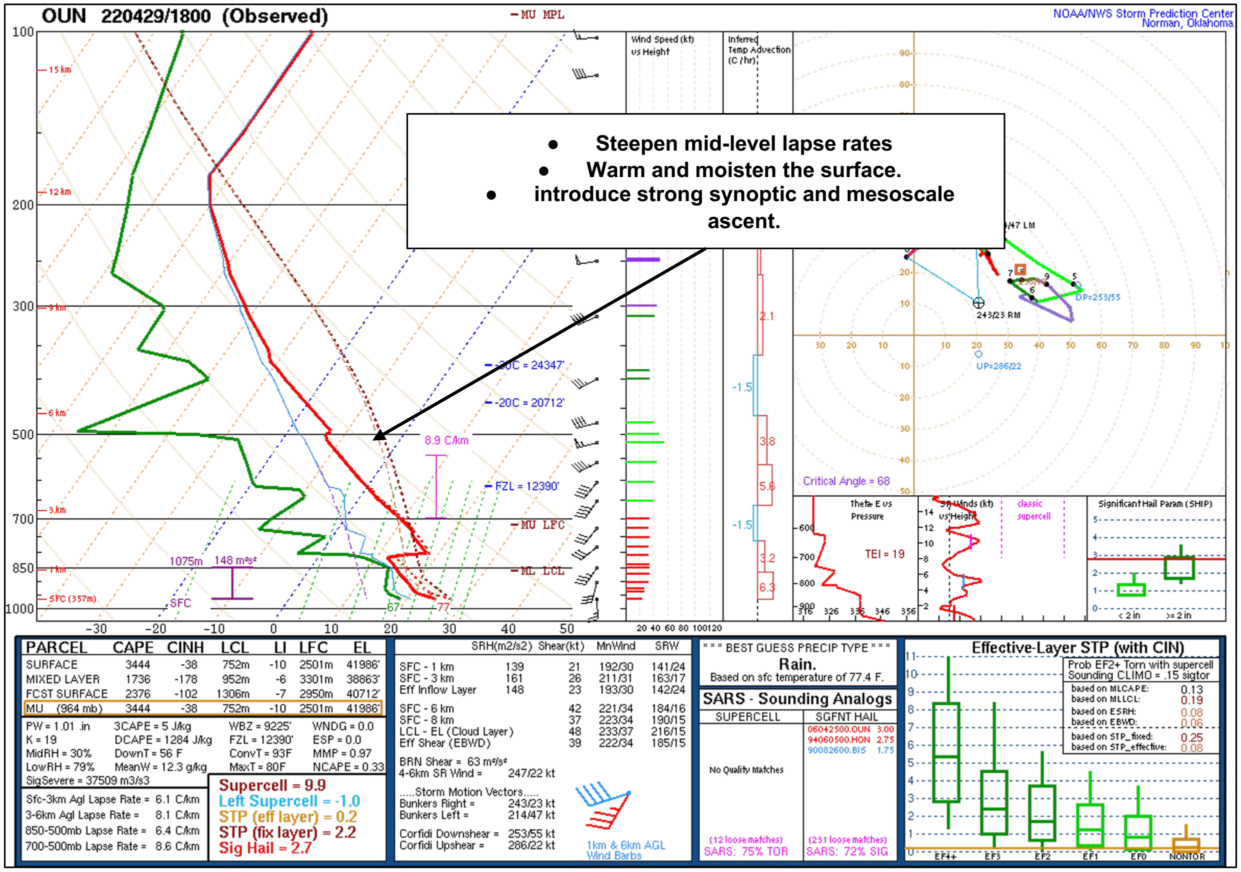
Short/thick CAPE:
Drives larger upward acceleration

1. Offsets negative effects of dry air entrainment into updraft
2. Mitigates effects of precipitation drag on updraft

Tall/narrow CAPE:
Smaller upward acceleration

Water loading and entrainment more substantially weaken updraft

So, how do we get wider CAPE?



- Steepen mid-level lapse rates
- Warm and moisten the surface.
- introduce strong synoptic and mesoscale ascent.

CAPE/CIN Changes Independent of γ Tendency

- CIN can be reduced and/or CAPE increased by:

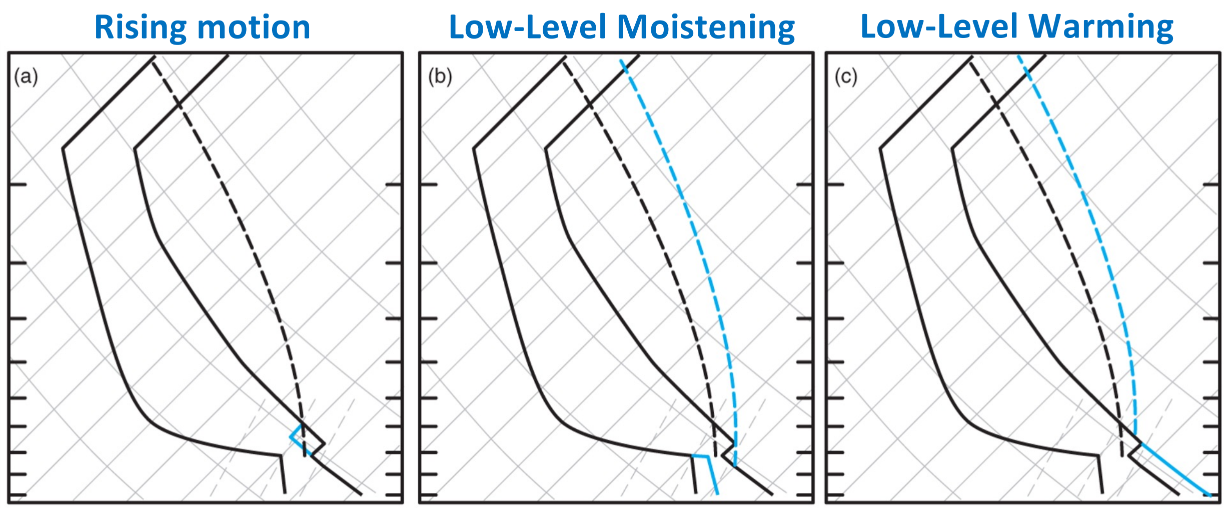


Figure 7.9

CIN can be reduced by (a) large-scale rising motion, (b) low-level moistening (e.g., moisture advection), and (c) low-level warming (e.g., insolation), despite the fact that the CIN modifications may not be accompanied by lapse rate changes, at least not over a significant depth. In (a)–(c), the isotherms and isentropes are solid gray lines, the constant mixing ratio lines are gray dashed lines, the sounding and trajectory taken by an air parcel lifted from the surface are solid and dashed black curves, respectively, and the modified sounding and parcel trajectory are blue solid and dashed curves, respectively. In (a), for clarity, only the temperature profile has been modified (the moisture profile has not been modified in accordance with the vertical motion that has been imposed in the layer of the capping inversion). Note that (b) and (c) are also accompanied by increases in CAPE. Conversely, CIN is augmented by large-scale descent, boundary layer cooling (although this would typically not occur without a concurrent stabilization of the lapse rate), and boundary layer drying (not shown). (Markowski and Richardson 2010, Fig. 7.9)

Instability: Elevated Mixed Layer (EML)

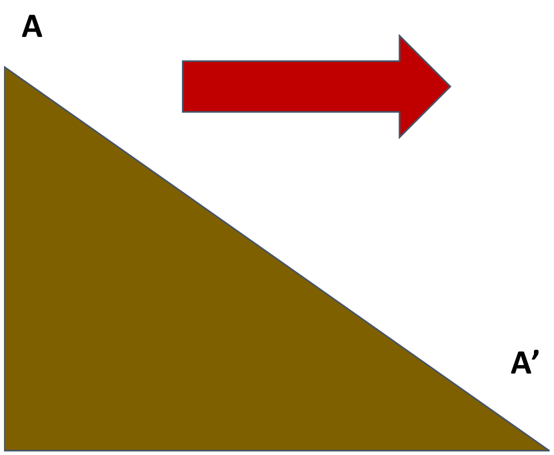
- **Deep mixed layer forms over Rockies and Sierra Madre in response to surface heating**

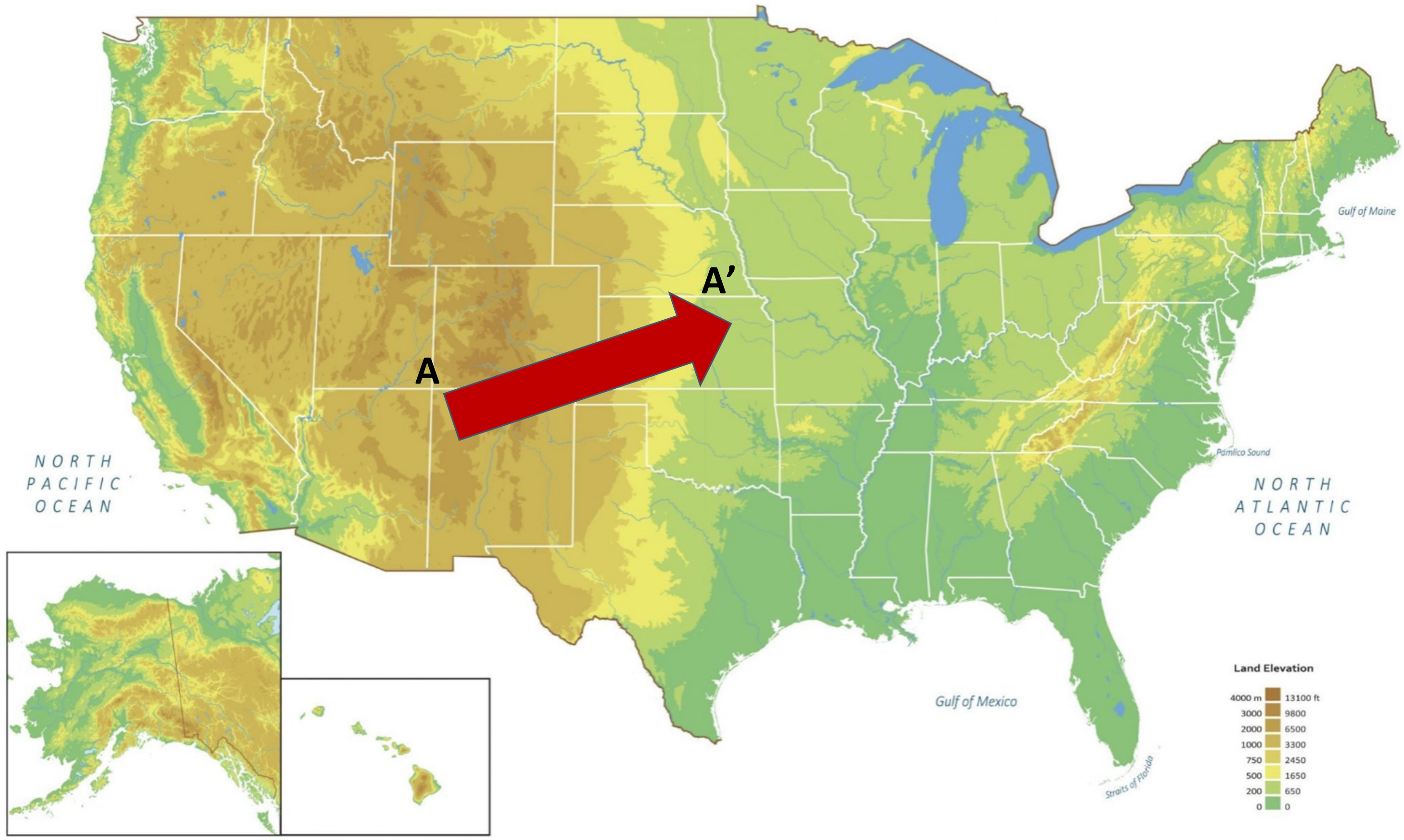
- **Stronger heating and/or cooler temperatures aloft results in deeper mixed layer**

- **Mixed layer is advected eastward and becomes elevated east of the Rockies and Sierra Madre (really, east of the dryline)**

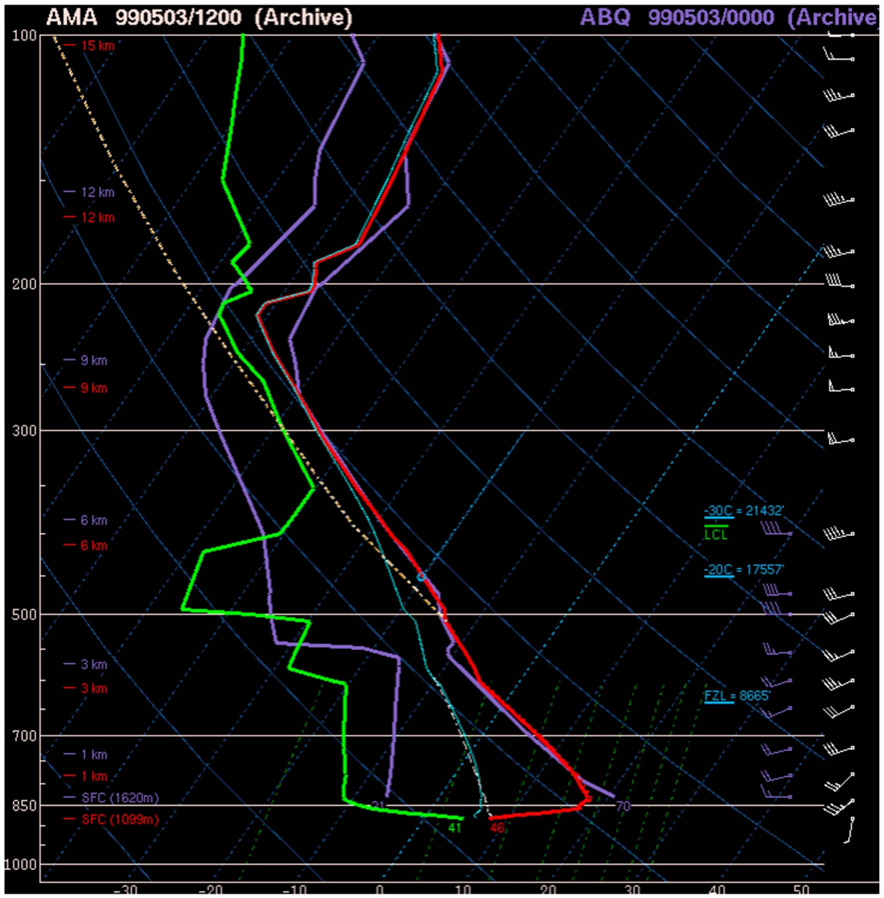
- **Differential advection (eastward advection of EML above northward advection of moisture from GoM) created "loaded gun" profile**

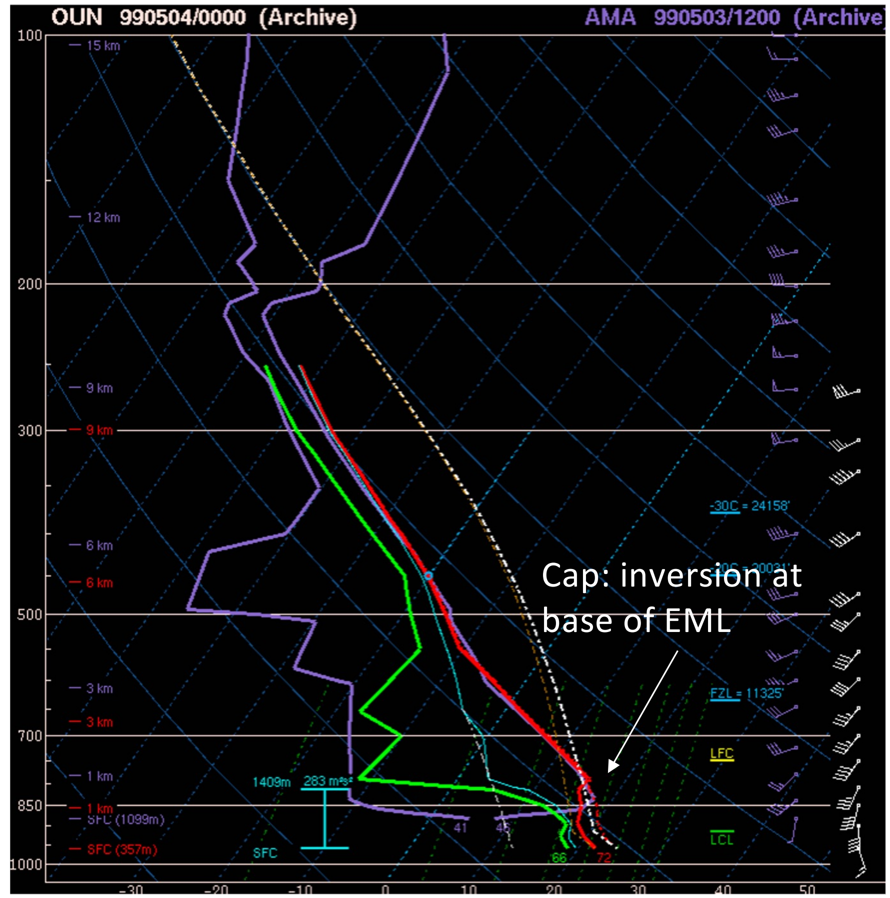
Elevated Mixed Layer (EML) Differential Advection

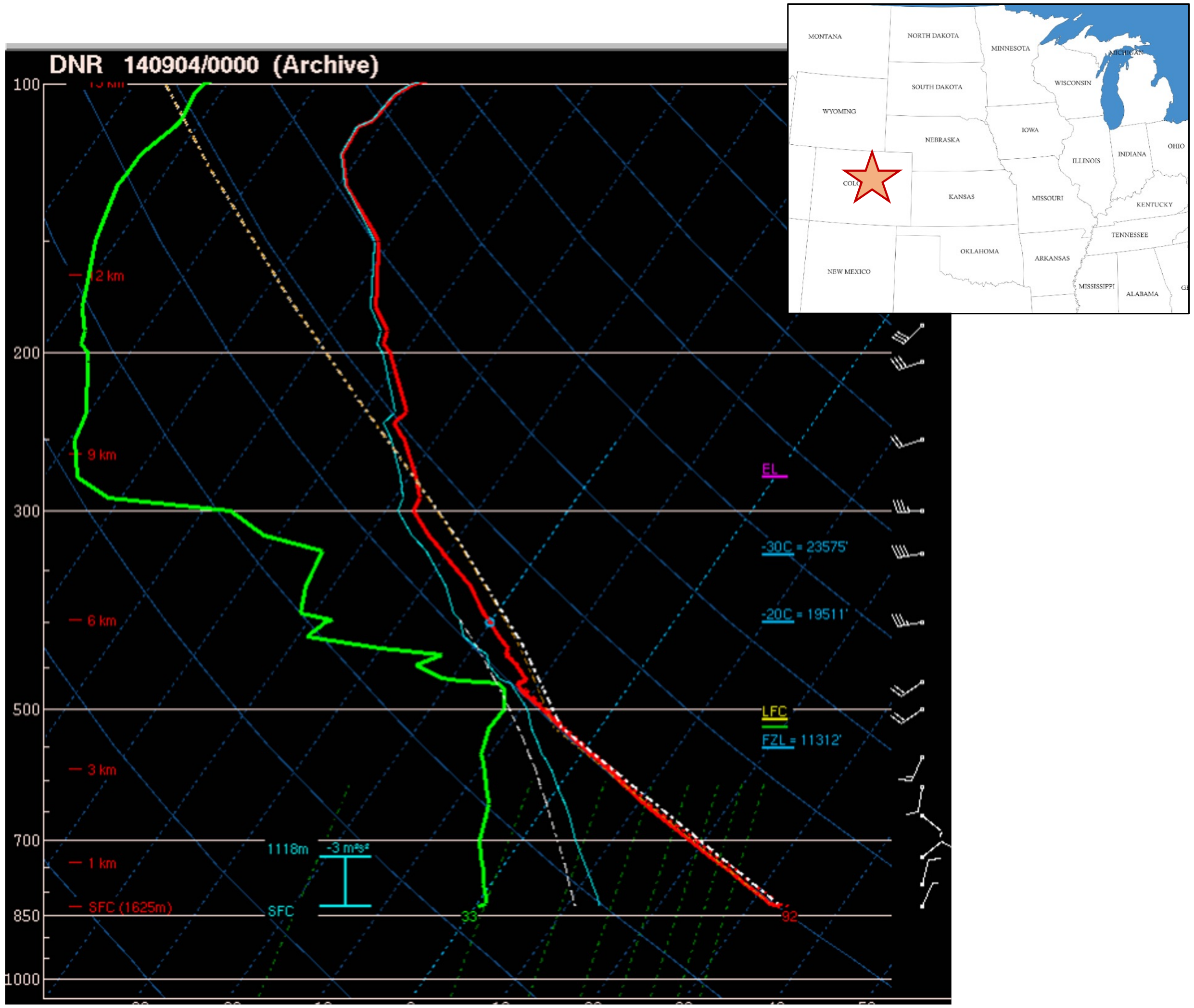


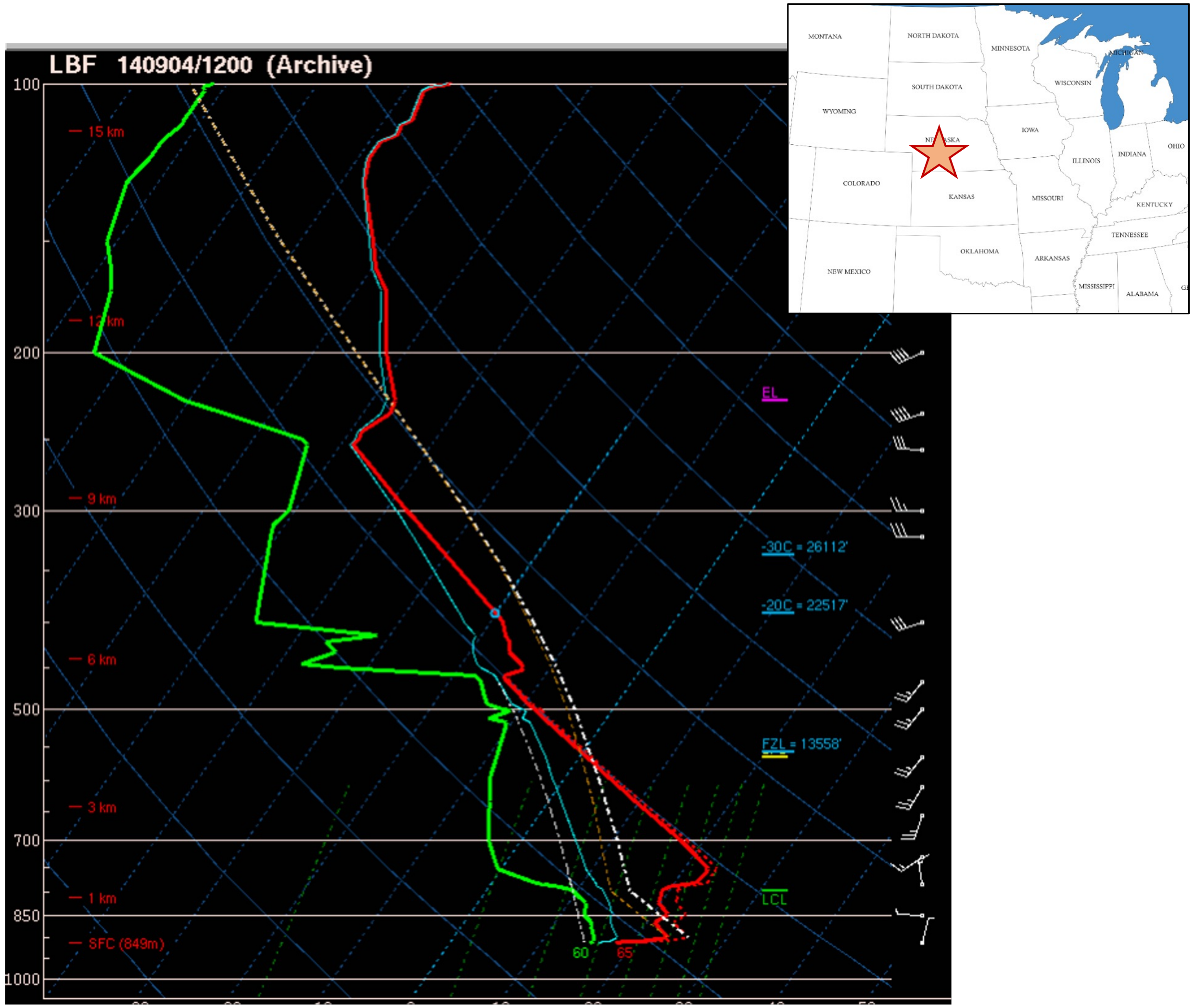


EML at OUN (0000 UTC 4 May 1999)



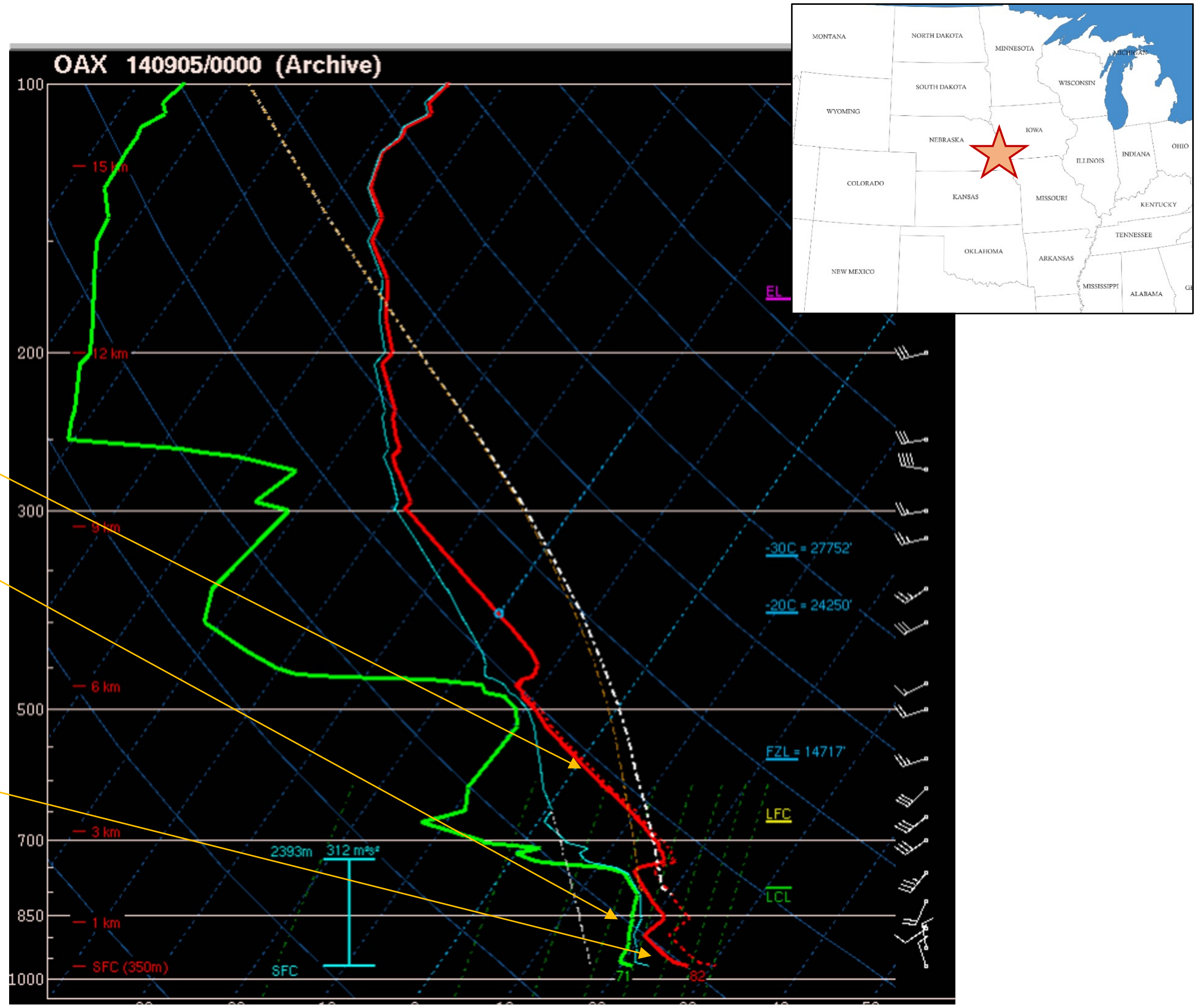



DNR 140904/0000 (Archive)
100
200
300
500
700
850
1000
12 km
9 km
6 km
3 km
1 km
SFC (1625m)
1118m
-3 m²s²
SFC
33
92
EL
-30C = 23575'
-20C = 19511'
LFC
FZL = 11312'
MONTANA
NORTH DAKOTA
MINNESOTA
SOUTH DAKOTA
WISCONSIN
WYOMING
NEBRASKA
IOWA
ILLINOIS
INDIANA
OHIO
KANSAS
MISSOURI
KENTUCKY
TENNESSEE
OKLAHOMA
ARKANSAS
NEW MEXICO
MISSISSIPPI
ALABAMA


LBF 140904/1200 (Archive)
100
15 km
12 km
200
EL
9 km
300
-30C = 26112'
-20C = 22517'
6 km
500
FZL = 13558'
3 km
700
1 km
LCL
850
SFC (849m)
60
65
1000
MONTANA
NORTH DAKOTA
MINNESOTA
SOUTH DAKOTA
WISCONSIN
WYOMING
IOWA
ILLINOIS
INDIANA
OHIO
COLORADO
KANSAS
MISSOURI
KENTUCKY
TENNESSEE
OKLAHOMA
ARKANSAS
NEW MEXICO
MISSISSIPPI
ALABAMA

Cap strength is related to:

- **EML θ**
- **Depth/quality of moisture**
- **Surface heating and mixing in moist sector**



Lift

- **Synoptic-scale lift**
  - 1-10 cm/s for many hours (6 hours ~2 km ascent (SFC-800 hPa))
  - 6 hours to reach LFC
  - Conditions environment for deep, moist convection over broad area
    - Lapse rate stretching
    - Removal of inhibition
  - Layered clouds in regions of isentropic lift; some elevated storms can form

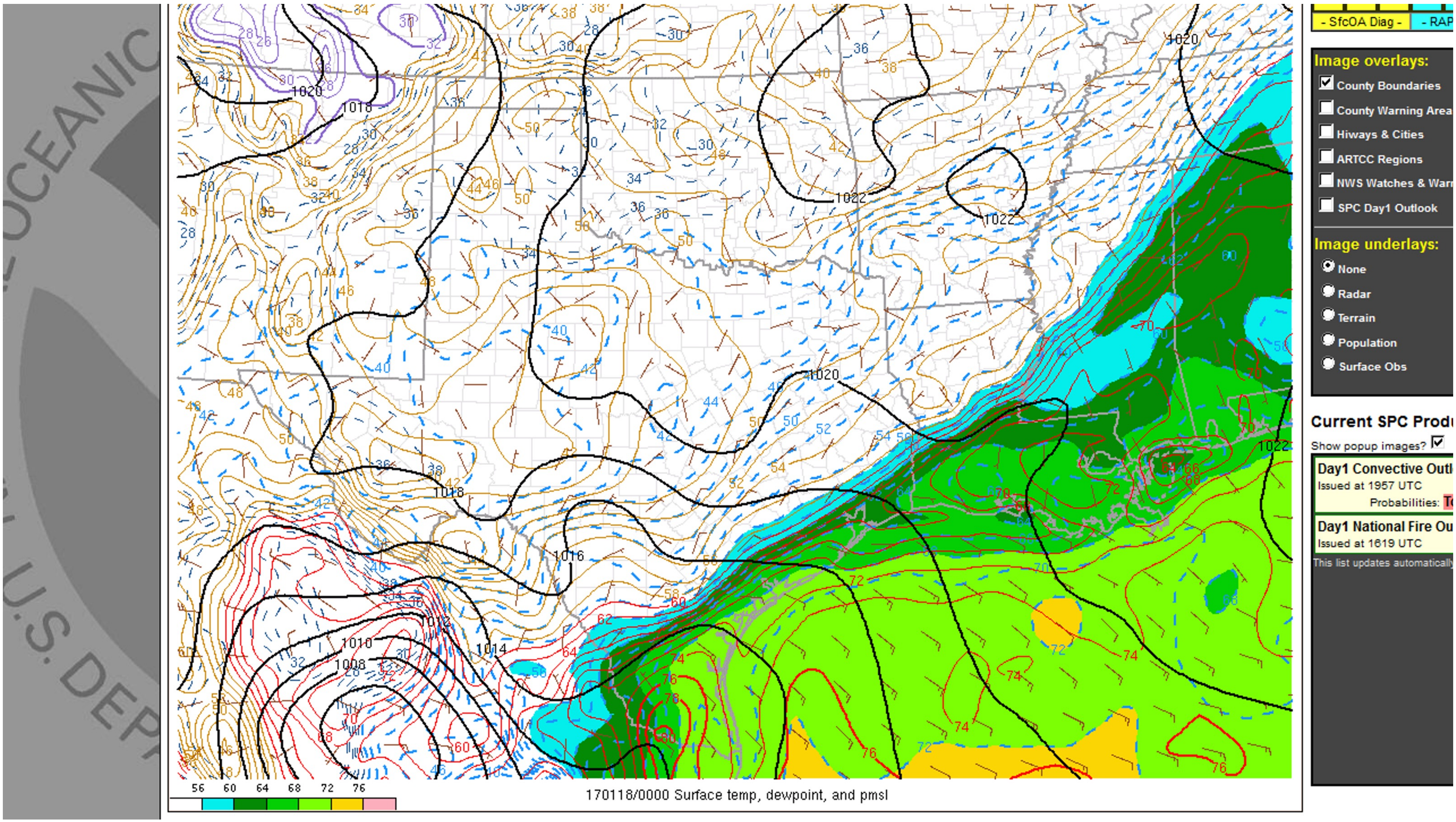
- **Mesoscale lift**
  - 1 m/s for minutes to hours (1 hour ~3.6 km ascent (SFC-650 hPa))
  - < 1 hour to reach LFC
  - Narrow zones of ascent along boundaries and terrain features
  - Direct initiation of thunderstorms

- **Storm-scale lift**
  - 10 m/s for minutes (15 mins ~9 km of ascent (SFC-300 hPa))
  - 5 minutes to reach LFC
  - Storm maintenance and propagation (supercells, MCSs, squall lines, etc.)

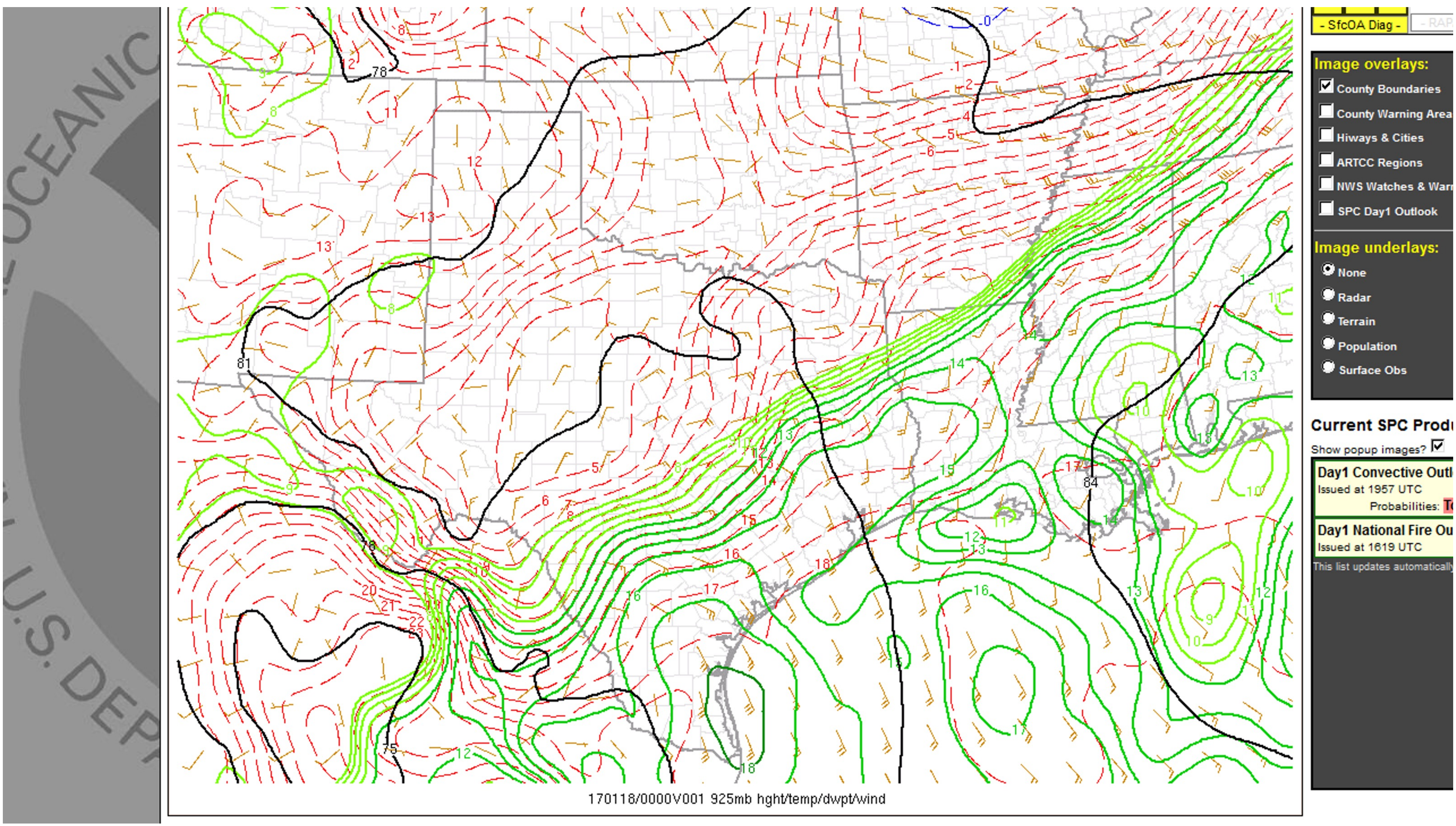
Synoptic-Scale Lift

- **QG sources**
  - **Warm advection/isentropic lift and differential vorticity advection**

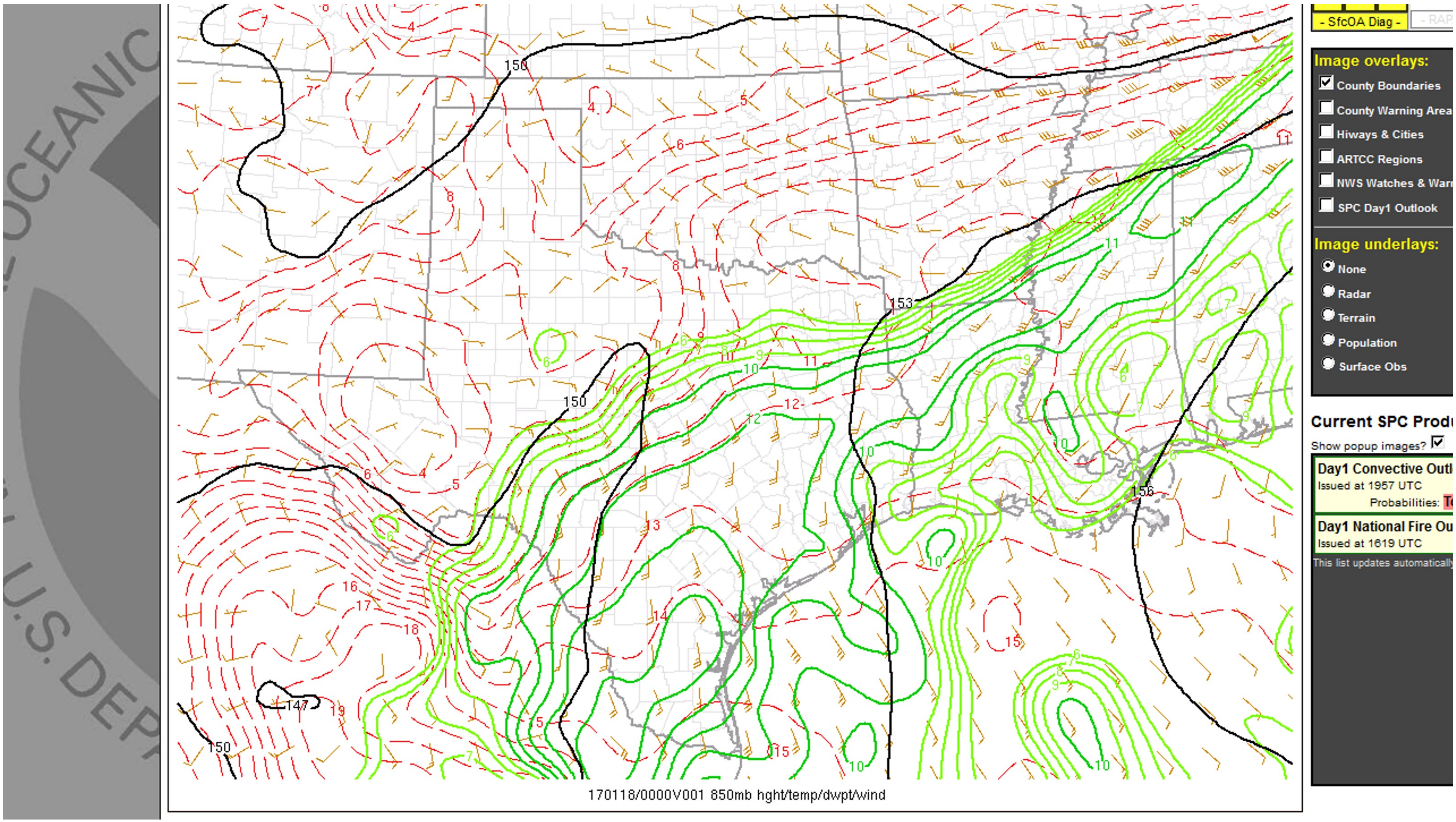
- **Jet streaks (also QG)**
  - **Straight jet: ascent in right entrance and left exit regions**
  - **Curved jet: ascent downstream and along jet core**



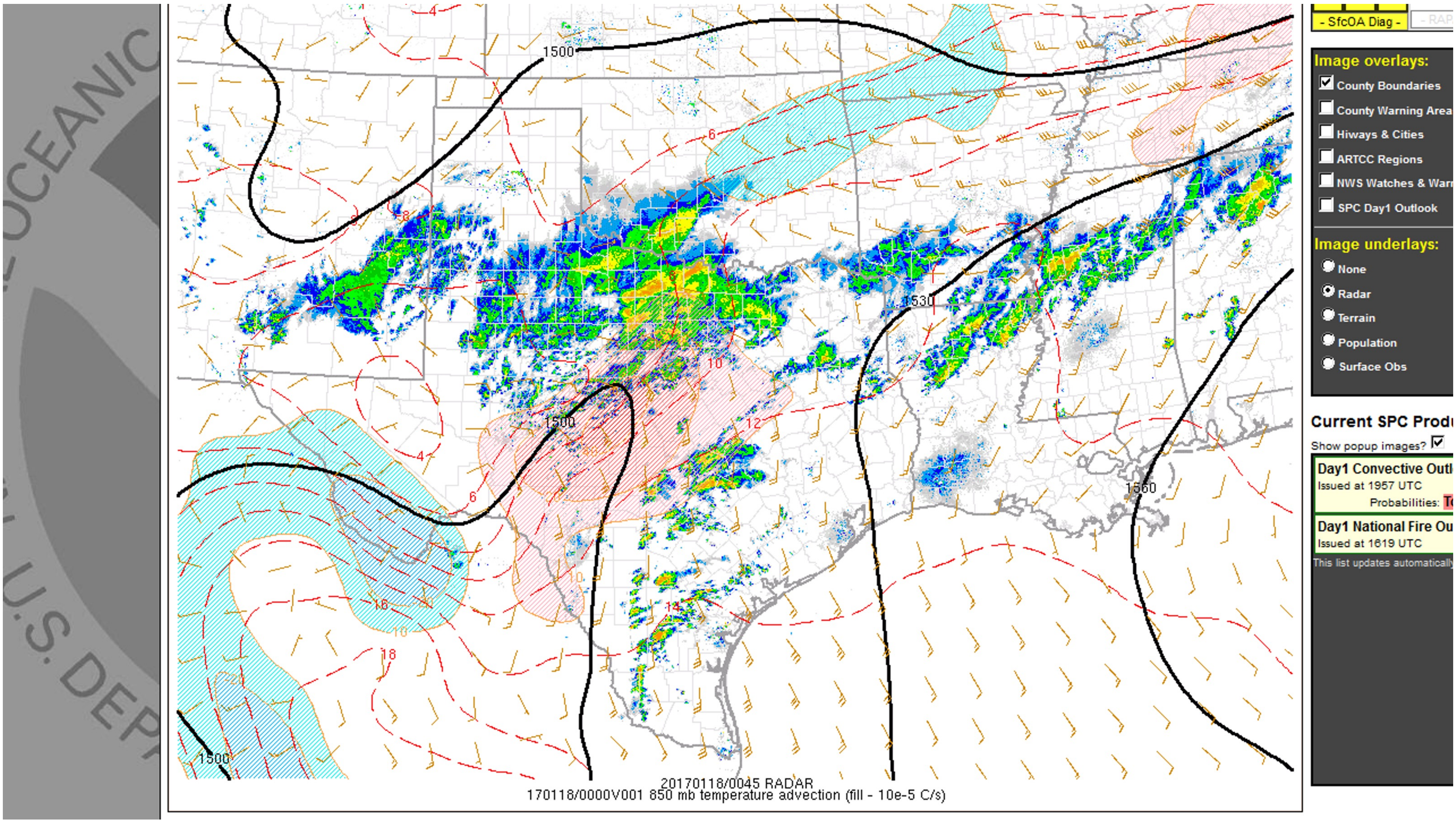
- SfcOA Diag -
- RAP
Image overlays:
County Boundaries
County Warning Area
Hiways & Cities
ARTCC Regions
NWS Watches & Warn
SPC Day1 Outlook
Image underlays:
None
Radar
Terrain
Population
Surface Obs
Current SPC Produ
Show popup images?
Day1 Convective Outl
Issued at 1957 UTC
Probabilities:
Day1 National Fire Ou
Issued at 1619 UTC
This list updates automatically
56 60 64 68 72 76
170118/0000 Surface temp, dewpoint, and pmsl

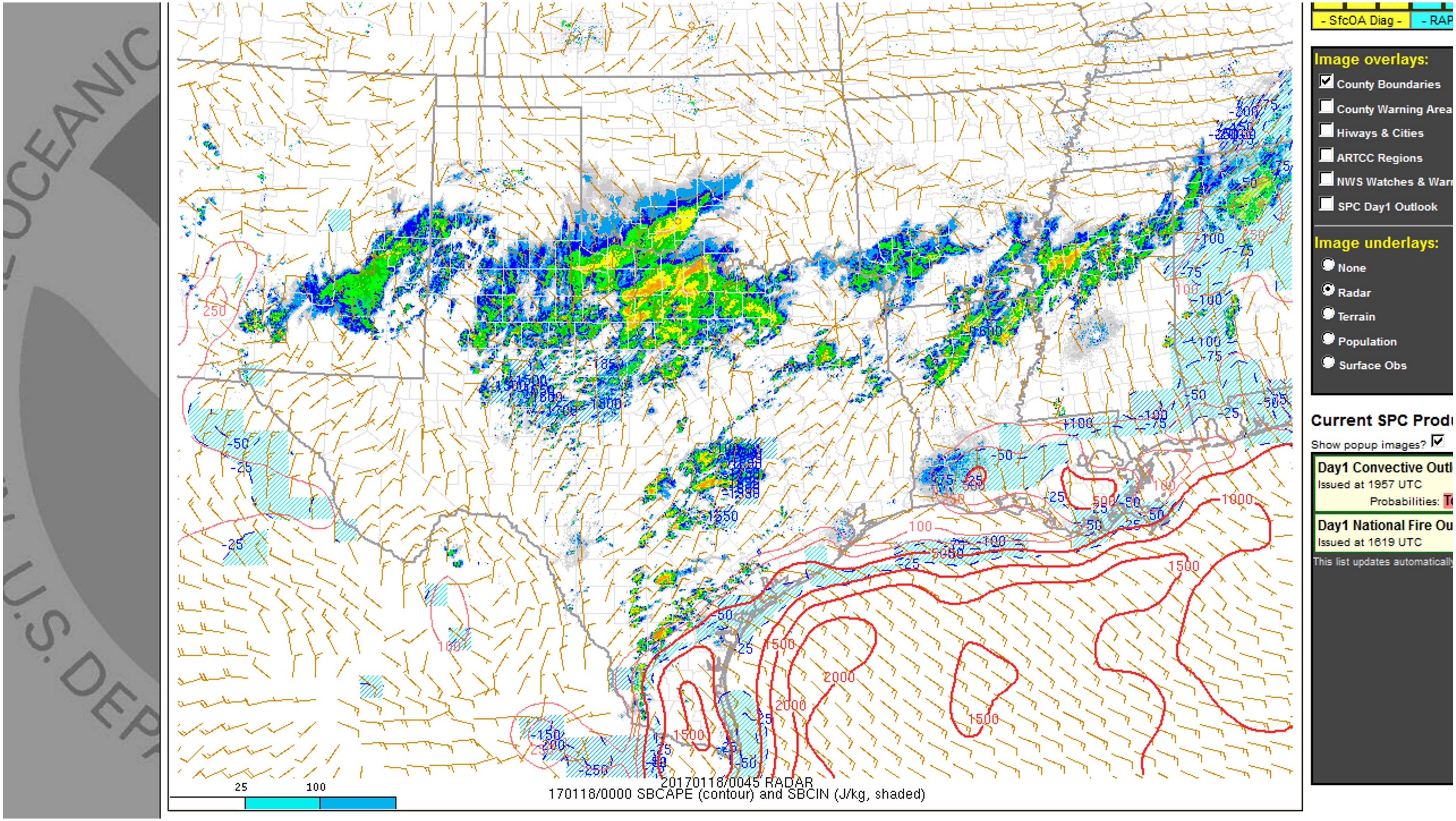


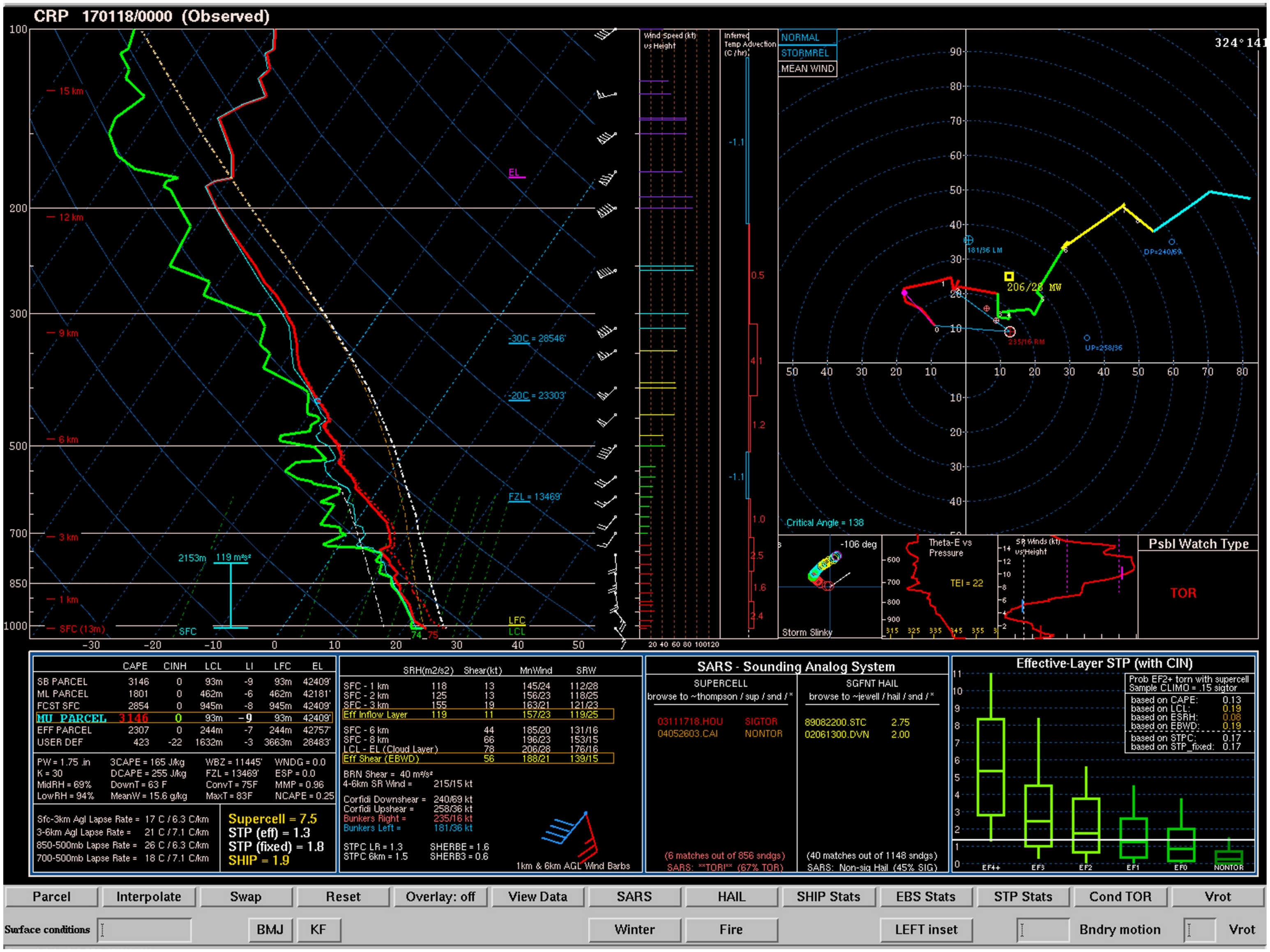
OCEANIC
U.S. DEP
170118/0000V001 925mb hght/temp/dwpt/wind
- SfcOA Diag -
Image overlays:
County Boundaries
County Warning Area
Hiways & Cities
ARTCC Regions
NWS Watches & Warn
SPC Day1 Outlook
Image underlays:
None
Radar
Terrain
Population
Surface Obs
Current SPC Produ
Show popup images?
Day1 Convective Outl
Issued at 1957 UTC
Probabilities:
Day1 National Fire Ou
Issued at 1619 UTC
This list updates automatically



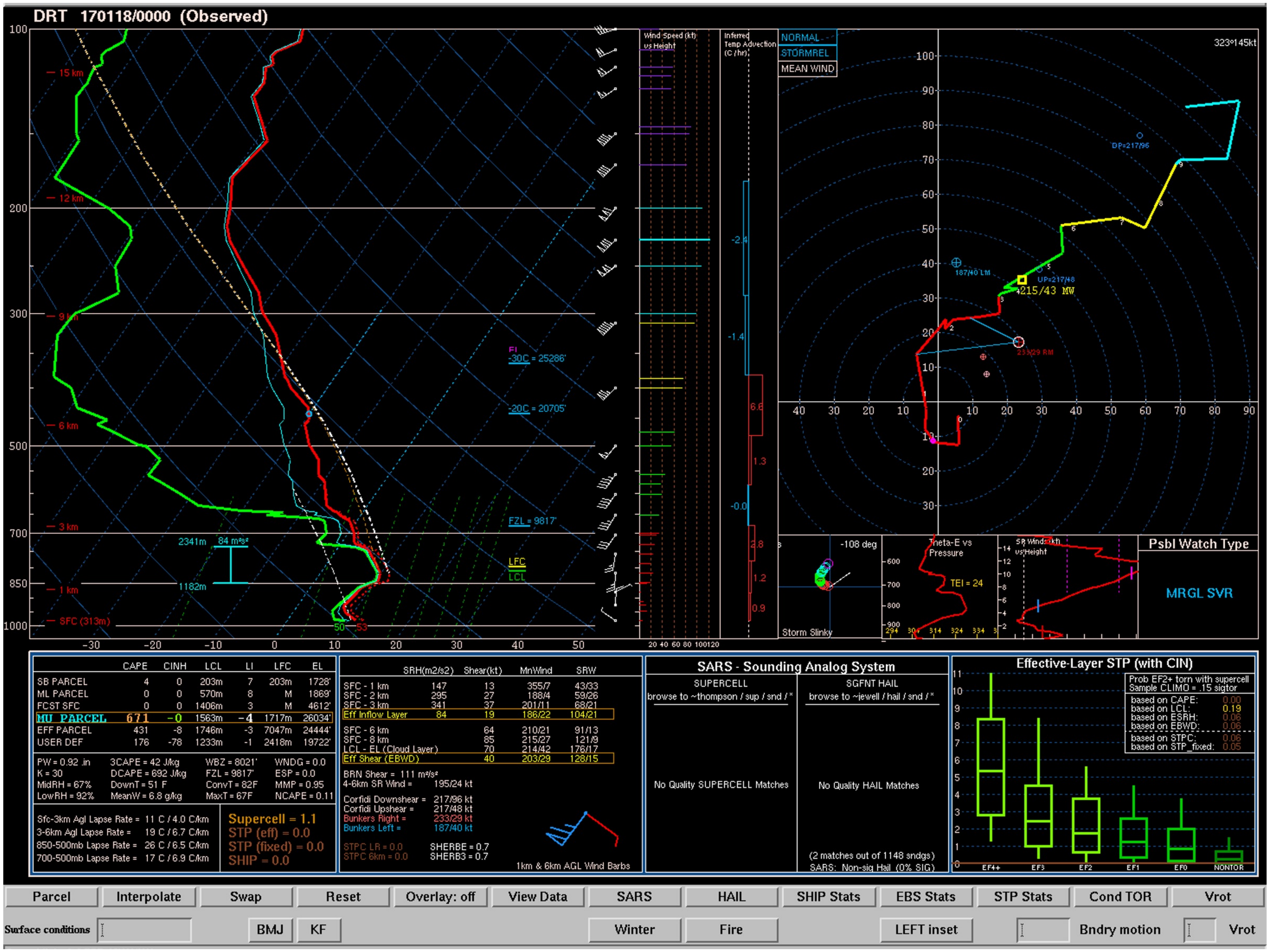
- SfcOA Diag -
Image overlays:
County Boundaries
County Warning Area
Hiways & Cities
ARTCC Regions
NWS Watches & Warn
SPC Day1 Outlook
Image underlays:
None
Radar
Terrain
Population
Surface Obs
Current SPC Produ
Show popup images?
Day1 Convective Outl
Issued at 1957 UTC
Probabilities:
Day1 National Fire Ou
Issued at 1619 UTC
This list updates automatically
150
153
156
147
170118/0000V001 850mb hght/temp/dwpt/wind


20170118/0045 RADAR
170118/0000V001 850 mb temperature advection (fill - 10e-5 C/s)
- SfcOA Diag -
Image overlays:
County Boundaries
County Warning Area
Hiways & Cities
ARTCC Regions
NWS Watches & Warr
SPC Day1 Outlook
Image underlays:
None
Radar
Terrain
Population
Surface Obs
Current SPC Produ
Show popup images?
Day1 Convective Outl
Issued at 1957 UTC
Probabilities:
Day1 National Fire Ou
Issued at 1619 UTC
This list updates automatically


- SfcOA Diag -
- RAP
Image overlays:
County Boundaries
County Warning Area
Hiways & Cities
ARTCC Regions
NWS Watches & Warn
SPC Day1 Outlook
Image underlays:
None
Radar
Terrain
Population
Surface Obs
Current SPC Produ
Show popup images?
Day1 Convective Outl
Issued at 1957 UTC
Probabilities:
Day1 National Fire Ou
Issued at 1619 UTC
This list updates automatically
25
100
20170118/0045 RADAR
170118/0000 SBCAPE (contour) and SBCIN (J/kg, shaded)



CRP 170118/0000 (Observed)
EL
-30C = 28546'
-20C = 23303'
FZL = 13469'
LFC
LCL
2153m 119 m²/s²
SFC
SFC (13m)
Critical Angle = 138
Storm Slinky
Theta-E vs Pressure
TEI = 22
Psbl Watch Type
TOR
206/28 MW
NORMAL
STORMREL
MEAN WIND
CAPE CINH LCL LI LFC EL
SB PARCEL 3146 0 93m -9 93m 42409'
ML PARCEL 1801 0 462m -6 462m 42181'
FCST SFC 2854 0 945m -8 945m 42409'
MU PARCEL 3146 0 93m -9 93m 42409'
EFF PARCEL 2307 0 244m -7 244m 42757'
USER DEF 423 -22 1632m -3 3663m 28483'
PW = 1.75 in 3CAPE = 165 J/kg WBZ = 11445' WNDG = 0.0
K = 30 DCAPE = 255 J/kg FZL = 13469' ESP = 0.0
MidRH = 69% DownT = 63 F ConvT = 75F MMP = 0.96
LowRH = 94% MeanW = 15.6 g/kg MaxT = 83F NCAPE = 0.25
Sfc-3km Agl Lapse Rate = 17 C / 6.3 C/km
3-6km Agl Lapse Rate = 21 C / 7.1 C/km
850-500mb Lapse Rate = 26 C / 6.3 C/km
700-500mb Lapse Rate = 18 C / 7.1 C/km
Supercell = 7.5
STP (eff) = 1.3
STP (fixed) = 1.8
SHIP = 1.9
SRH(m2/s2) Shear(kt) MnWind SRW
SFC - 1 km 118 13 145/24 112/28
SFC - 2 km 125 13 156/23 118/25
SFC - 3 km 155 19 163/21 121/23
Eff Inflow Layer 119 11 157/23 119/25
SFC - 6 km 44 185/20 131/16
SFC - 8 km 66 196/23 153/15
LCL - EL (Cloud Layer) 78 206/28 176/16
Eff Shear (EBWD) 56 188/21 139/15
BRN Shear = 40 m²/s²
4-6km SR Wind = 215/15 kt
Corfidi Downshear = 240/69 kt
Corfidi Upshear = 258/36 kt
Bunkers Right = 235/16 kt
Bunkers Left = 181/36 kt
STPC LR = 1.3 SHERBE = 1.6
STPC 6km = 1.5 SHERB3 = 0.6
1km & 6km AGL Wind Barbs
SARS - Sounding Analog System
SUPERCELL
browse to ~thompson / sup / snd / *
03111718.HOU SIGTOR
04052603.CAI NONTOR
(6 matches out of 856 sndgs)
SARS: **TOR!** (67% TOR)
SGFNT HAIL
browse to ~jewell / hail / snd / *
89082200.STC 2.75
02061300.DVN 2.00
(40 matches out of 1148 sndgs)
SARS: Non-sig Hail (45% SIG)
Effective-Layer STP (with CIN)
Prob EF2+ torn with supercell
Sample CLIMO = .15 sigtor
based on CAPE: 0.13
based on LCL: 0.19
based on ESRH: 0.08
based on EBWD: 0.19
based on STPC: 0.17
based on STP_fixed: 0.17
EF4+ EF3 EF2 EF1 EF0 NONTOR
Parcel
Interpolate
Swap
Reset
Overlay: off
View Data
SARS
HAIL
SHIP Stats
EBS Stats
STP Stats
Cond TOR
Vrot
Surface conditions
BMJ
KF
Winter
Fire
LEFT inset
Bndry motion
Vrot


DRT 170118/0000 (Observed)
NORMAL
STORMREL
MEAN WIND
323°/145kt
Psbl Watch Type
MRGL SVR
Storm Slinky
-108 deg
Theta-E vs Pressure
TEI = 24
SR Wind vs Height
Inferred Temp Advection (C / hr)
Wind Speed (kt) vs Height
FZL = 9817'
-20C = 20705'
-30C = 25286'
LFC
LCL
2341m 84 m²/s²
1182m
SFC (313m)
215/43 MW
DP=217/96
UP=217/48
187/40 LM
233/29 RM
CAPE CINH LCL LI LFC EL
SB PARCEL 4 0 203m 7 203m 1728'
ML PARCEL 0 0 570m 8 M 1869'
FCST SFC 0 0 1406m 3 M 4612'
MU PARCEL 671 -0 1563m -4 1717m 26034'
EFF PARCEL 431 -8 1746m -3 7047m 24444'
USER DEF 176 -78 1233m -1 2418m 19722'
PW = 0.92 in 3CAPE = 42 J/kg WBZ = 8021' WNDG = 0.0
K = 30 DCAPE = 692 J/kg FZL = 9817' ESP = 0.0
MidRH = 67% DownT = 51 F ConvT = 82F MMP = 0.95
LowRH = 92% MeanW = 6.8 g/kg MaxT = 67F NCAPE = 0.11
Sfc-3km Agl Lapse Rate = 11 C / 4.0 C/km
3-6km Agl Lapse Rate = 19 C / 6.7 C/km
850-500mb Lapse Rate = 26 C / 6.5 C/km
700-500mb Lapse Rate = 17 C / 6.9 C/km
Supercell = 1.1
STP (eff) = 0.0
STP (fixed) = 0.0
SHIP = 0.0
SRH(m2/s2) Shear(kt) MnWind SRW
SFC - 1 km 147 13 355/7 43/33
SFC - 2 km 295 27 188/4 59/26
SFC - 3 km 341 37 201/11 68/21
Eff Inflow Layer 84 19 186/22 104/21
SFC - 6 km 64 210/21 91/13
SFC - 8 km 85 215/27 121/9
LCL - EL (Cloud Layer) 70 214/42 176/17
Eff Shear (EBWD) 40 203/29 128/15
BRN Shear = 111 m²/s²
4-6km SR Wind = 195/24 kt
Corfidi Downshear = 217/96 kt
Corfidi Upshear = 217/48 kt
Bunkers Right = 233/29 kt
Bunkers Left = 187/40 kt
STPC LR = 0.0 SHERBE = 0.7
STPC 6km = 0.0 SHERB3 = 0.7
1km & 6km AGL Wind Barbs
SARS - Sounding Analog System
SUPERCELL
browse to ~thompson / sup / snd / *
SGFNT HAIL
browse to ~jewell / hail / snd / *
No Quality SUPERCELL Matches
No Quality HAIL Matches
(2 matches out of 1148 sndgs)
SARS: Non-sig Hail (0% SIG)
Effective-Layer STP (with CIN)
Prob EF2+ torn with supercell
Sample CLIMO = .15 sigtor
based on CAPE: 0.00
based on LCL: 0.19
based on ESRH: 0.06
based on EBWD: 0.06
based on STPC: 0.06
based on STP_fixed: 0.05
EF4+ EF3 EF2 EF1 EF0 NONTOR
Parcel Interpolate Swap Reset Overlay: off View Data SARS HAIL SHIP Stats EBS Stats STP Stats Cond TOR Vrot
Surface conditions BMJ KF Winter Fire LEFT inset Bndry motion Vrot

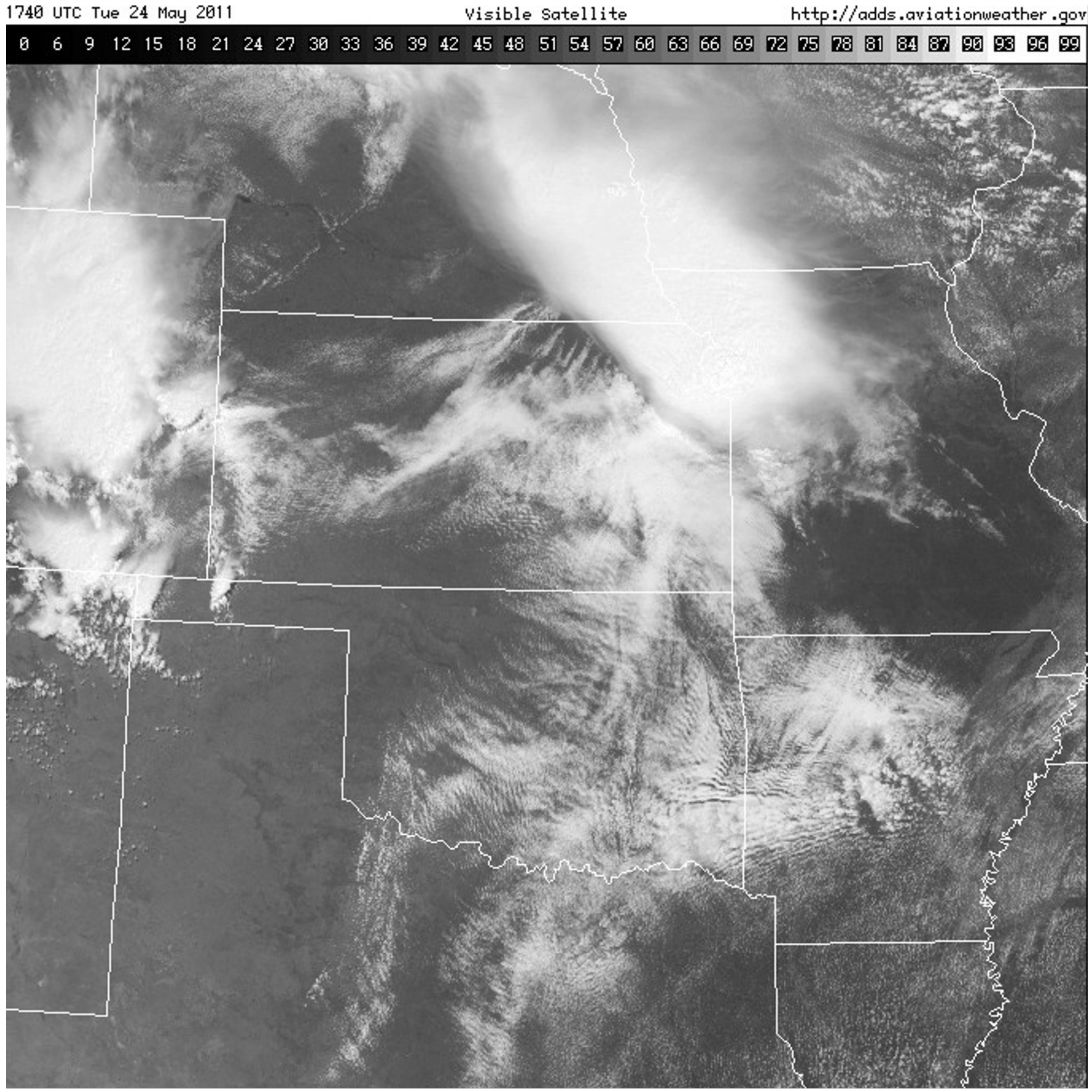
Synoptic-Scale Lift Summary

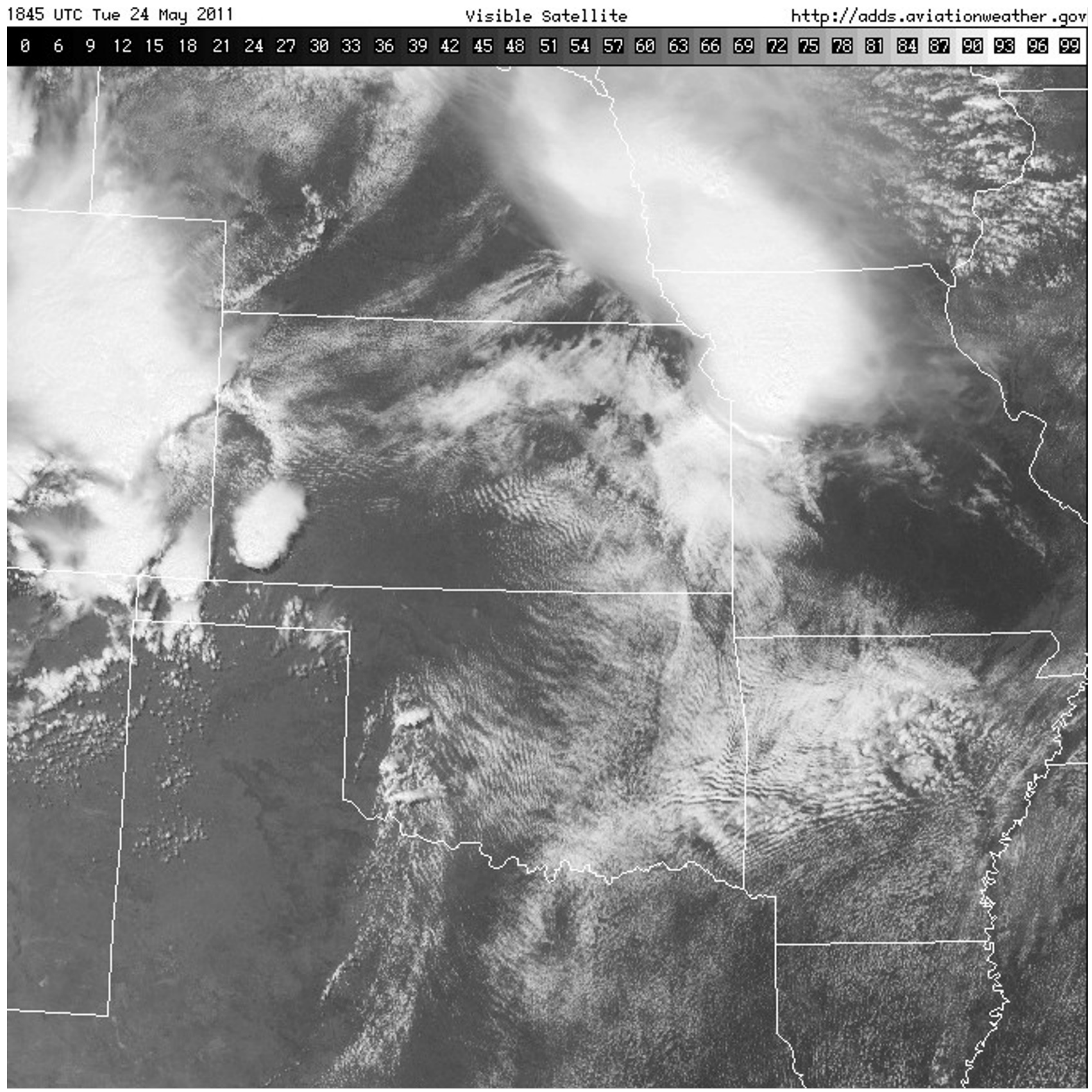
- **Gradual ascent over many hours**
  - **Warm advection and differential vorticity advection are primary drivers**

- **Primary role of QG ascent is to precondition environment for convection**
  - **Can also initiate elevated storms in regions of warm advection**
  - **Most surface-based storms are triggered by mesoscale ascent**

Mesoscale Lift

- Focused and narrow zones of lift for minutes to hours
- Fronts
  - Rising on warm side with frontogenesis
  - Isentropic ascent on sloped warm front
- Outflow boundary
  - Lift is governed by depth/strength of cold pool and low-level vertical wind shear [Rotunno-Klemp-Weisman (RKW) Theory]
- Dryline
  - Lift on dry/hot side (lower density air)
  - Lift governed by depth of mixing west of dryline and depth of moist layer east of dryline


1740 UTC Tue 24 May 2011
Visible Satellite
http://adds.aviationweather.gov
0 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60 63 66 69 72 75 78 81 84 87 90 93 96 99

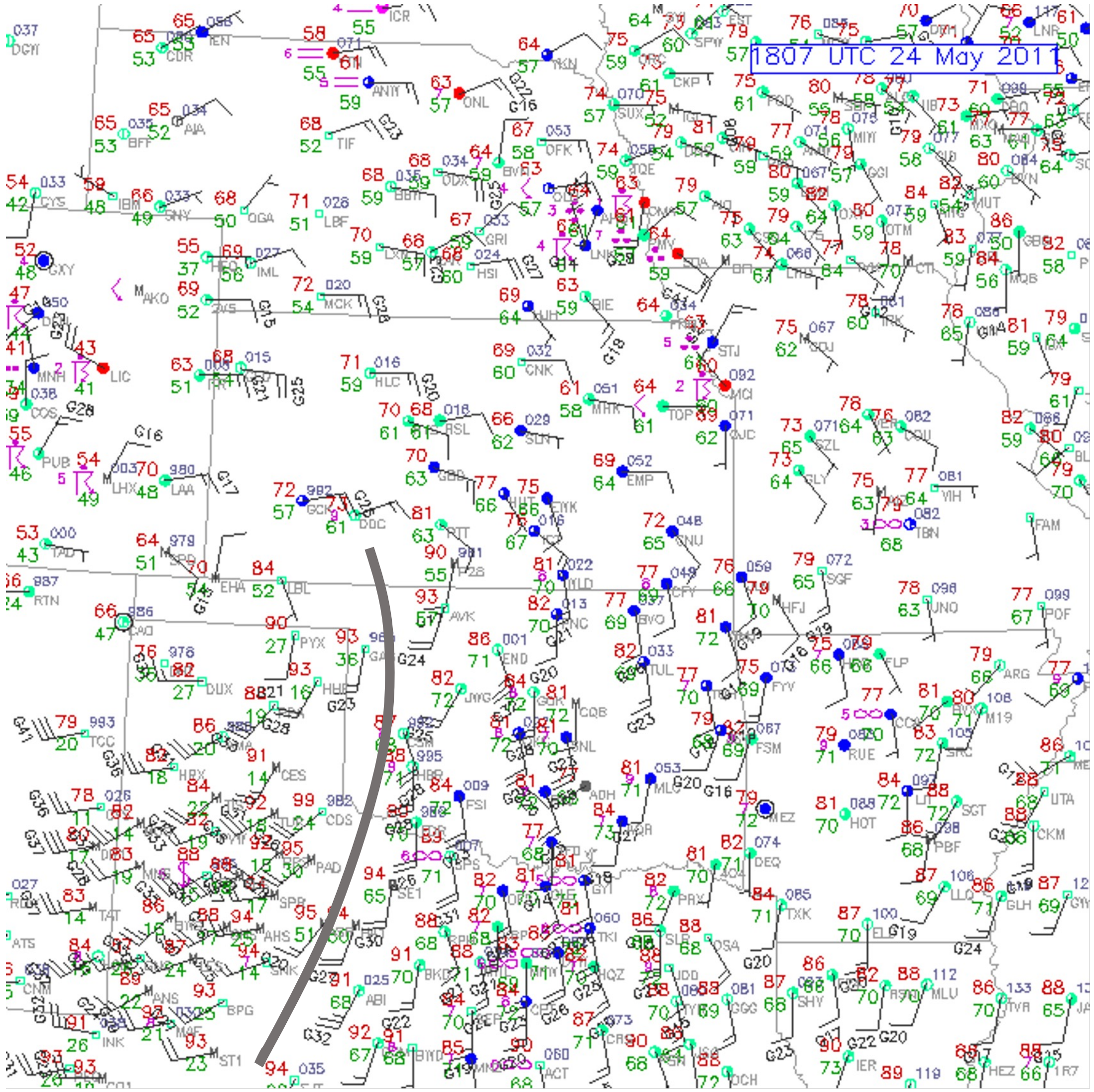

1845 UTC Tue 24 May 2011
Visible Satellite
http://adds.aviationweather.gov
0 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60 63 66 69 72 75 78 81 84 87 90 93 96 99

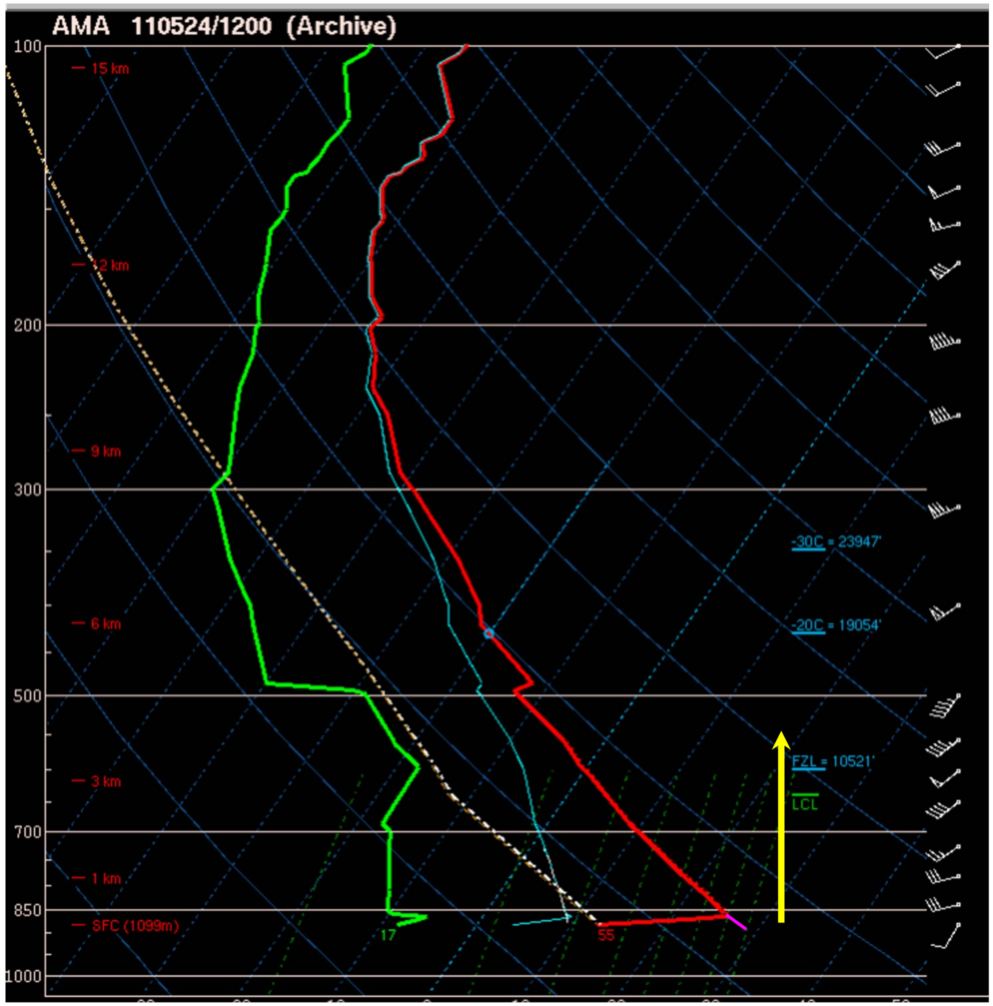
Dryline

- **Focused ascent along dryline can be ~1 m/s (~1 hour to reach LFC)**
  - **Lift depends on depth of mixing west of dryline and depth of moist layer ahead of dryline**
  - **Maximum vertical motion along dryline scales with height of moist layer**

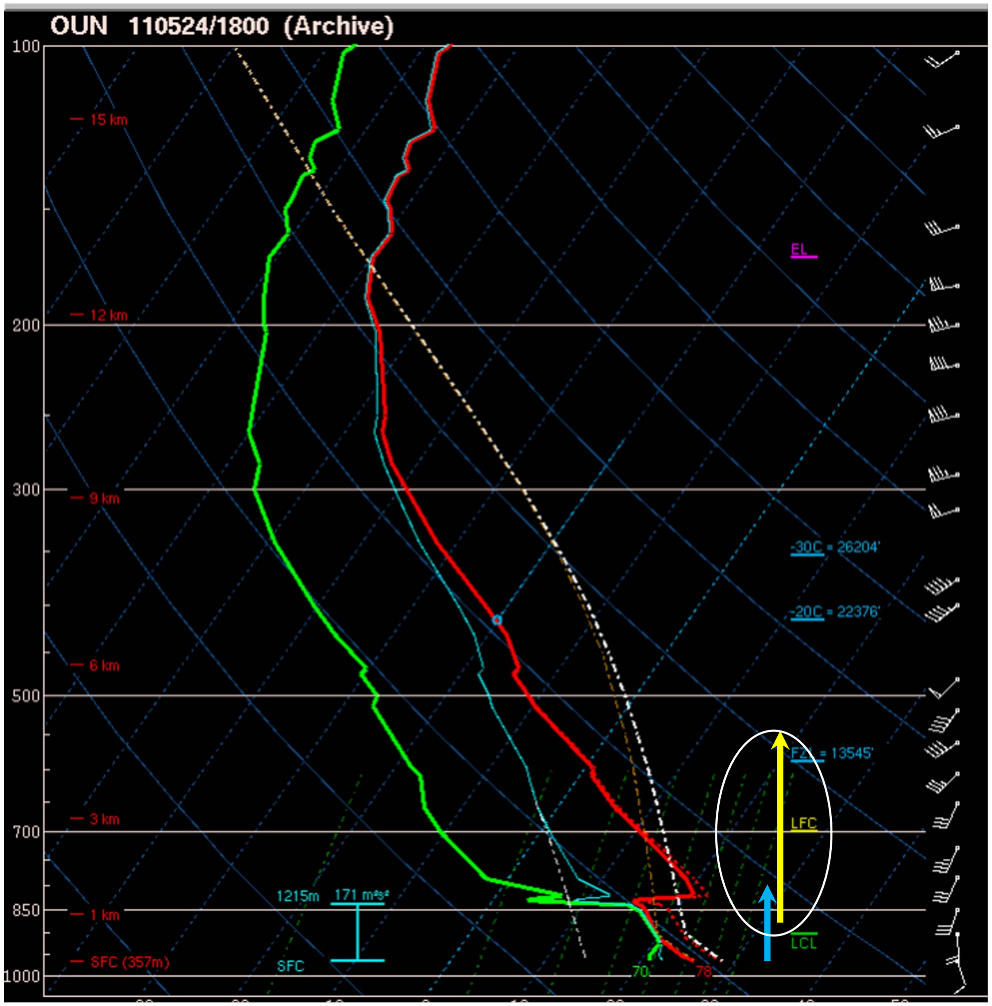
- **Convection initiation linked to the residence time of air in the zone of ascent**
  - **Winds above the surface parallel to dryline keeps air in zone of lift longer**

- **Convection will initiate in points or bands**
  - **Usually the mode of initiation for surface-based supercells in central/southern Plains**


1807 UTC 24 May 2011

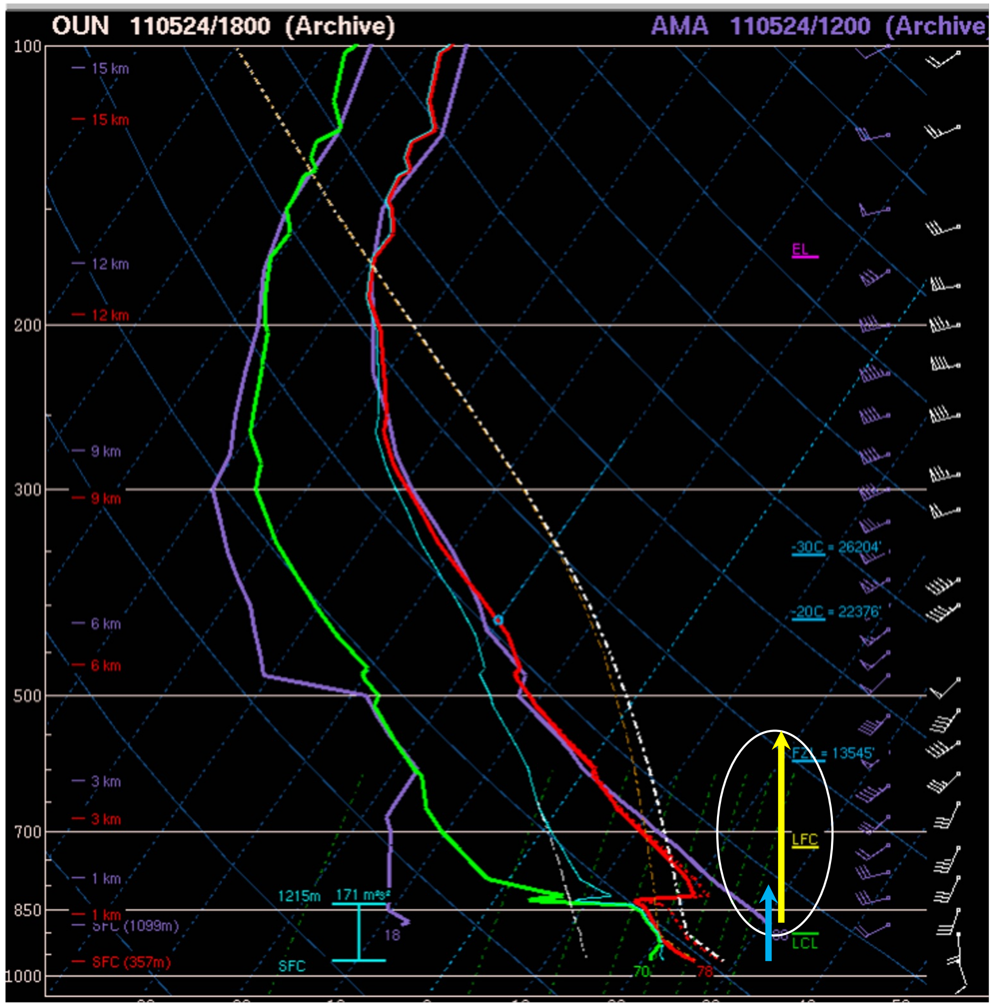


AMA 110524/1200 (Archive)
100
200
300
500
700
850
1000
15 km
12 km
9 km
6 km
3 km
1 km
SFC (1099m)
17
55
-30C = 23947'
-20C = 19054'
FZL = 10521'
LCL

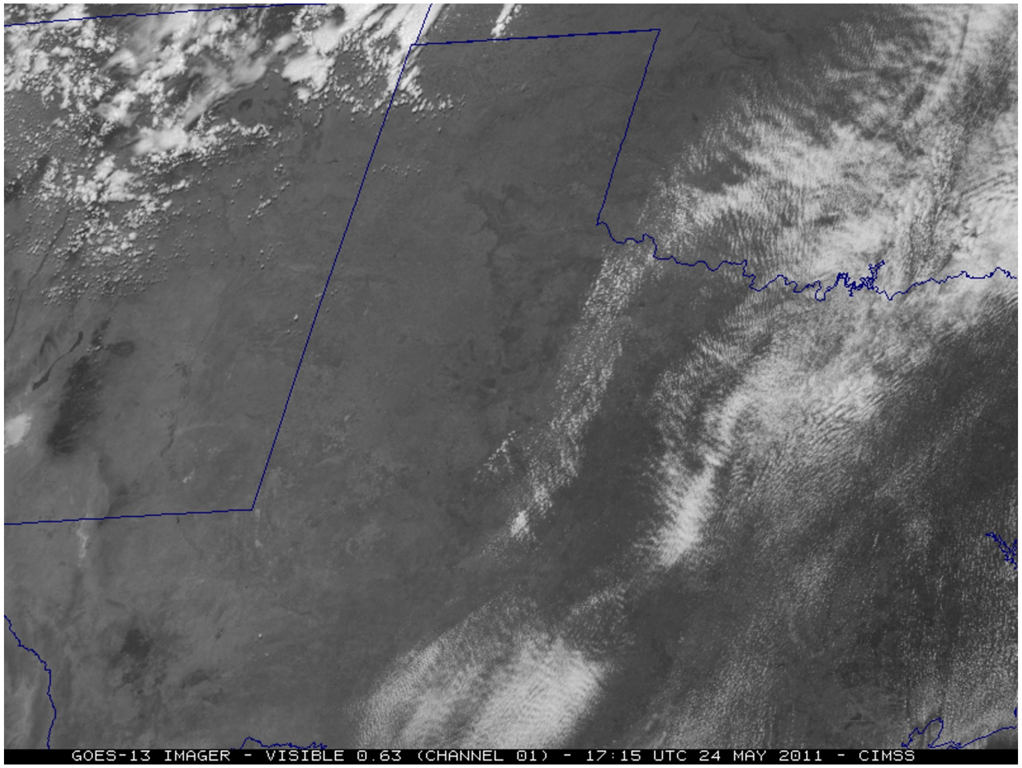


LFC is within the deep dryline circulation

Keep parcels in the zone of ascent – winds within circulation SSW (parallel to dryline)



OUN 110524/1800 (Archive)
AMA 110524/1200 (Archive)
100
200
300
500
700
850
1000
15 km
12 km
9 km
6 km
3 km
1 km
SFC (1099m)
SFC (357m)
EL
-30C = 26204'
-20C = 22376'
FZL = 13545'
LFC
LCL
1215m
171 m²/s²
SFC
18
70
78

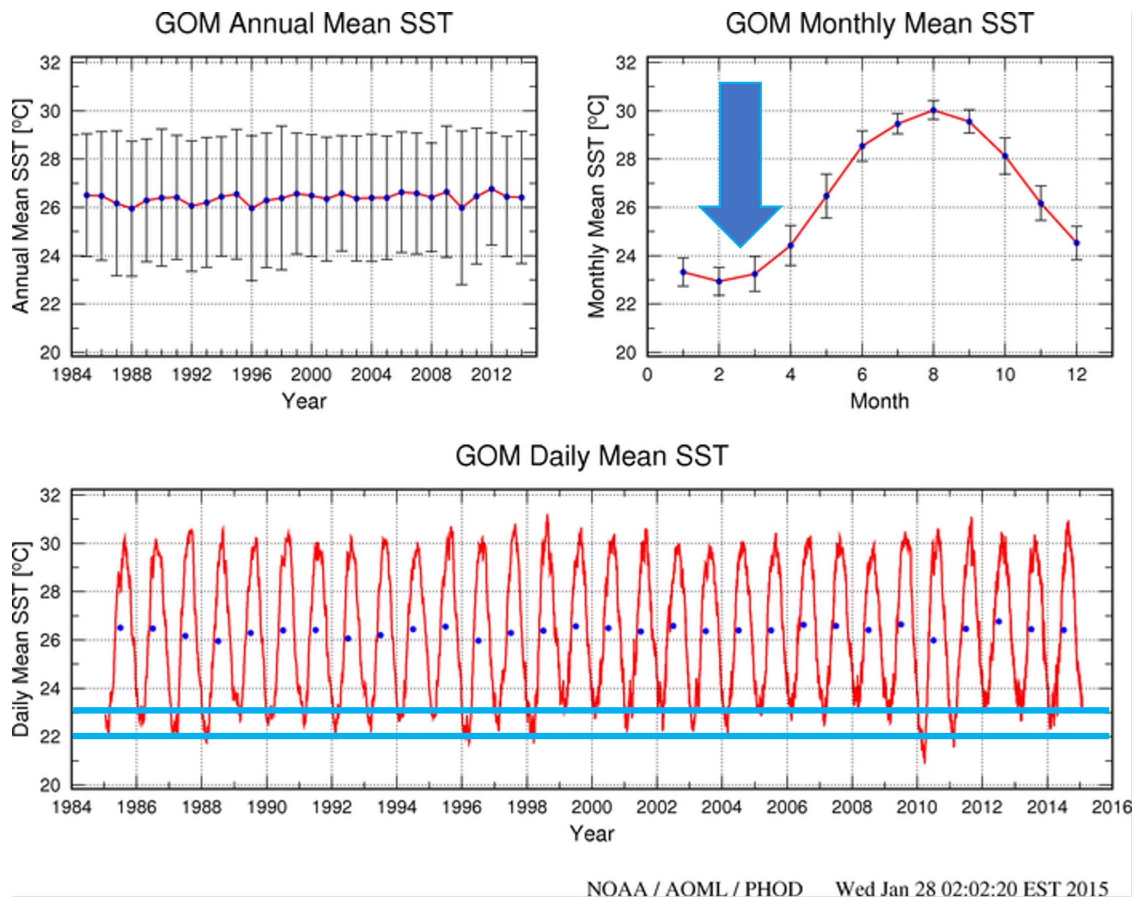

GOES-13 IMAGER - VISIBLE 0.63 (CHANNEL 01) - 17:15 UTC 24 MAY 2011 - CIMSS

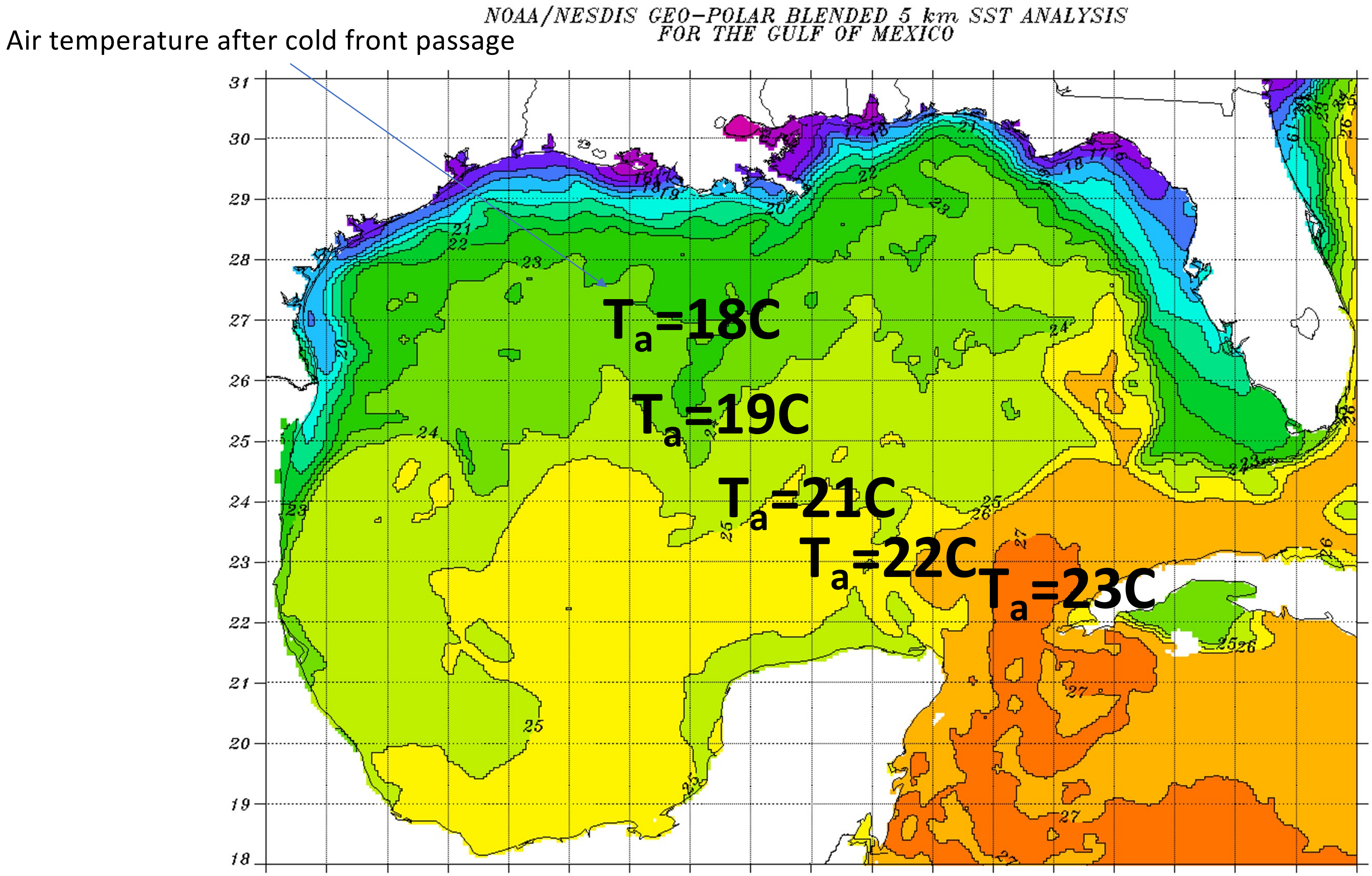
Moisture

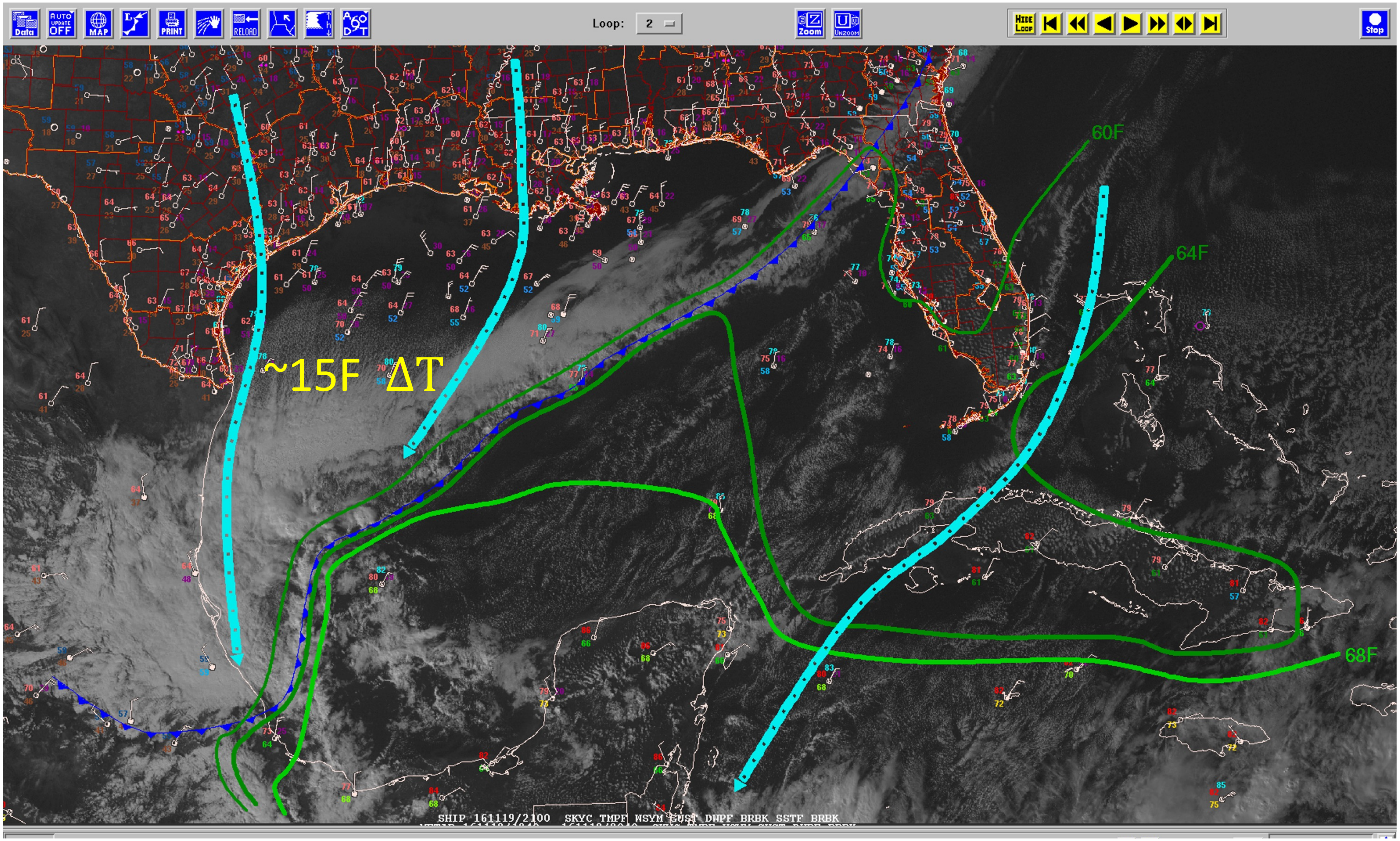
- **Moisture in PBL needs to be large and deep enough for convection**
- **Return flow**
- **Inland vertical mixing/diurnal processes**
- **Evapotranspiration**

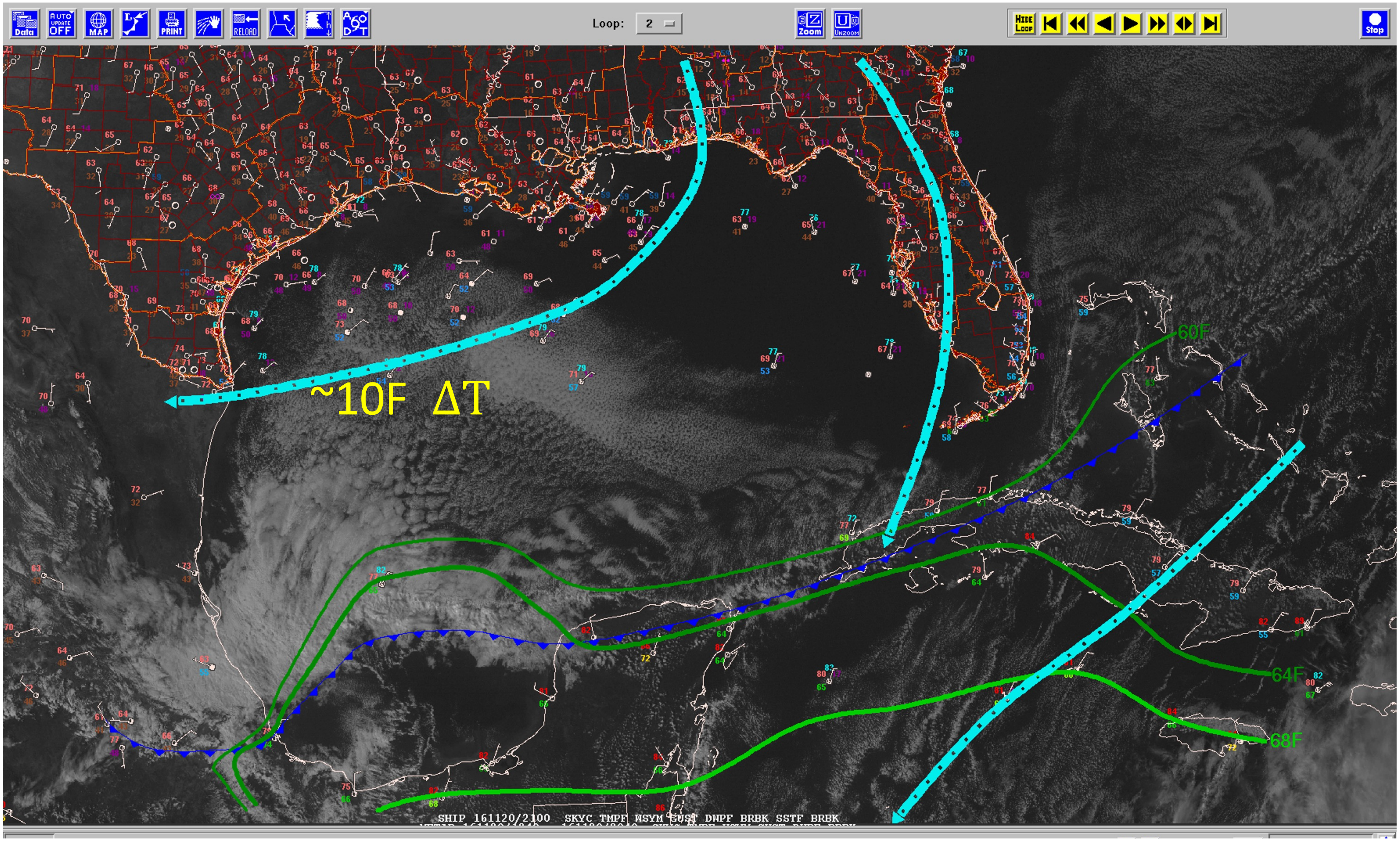
Low-level Moisture Return Flow

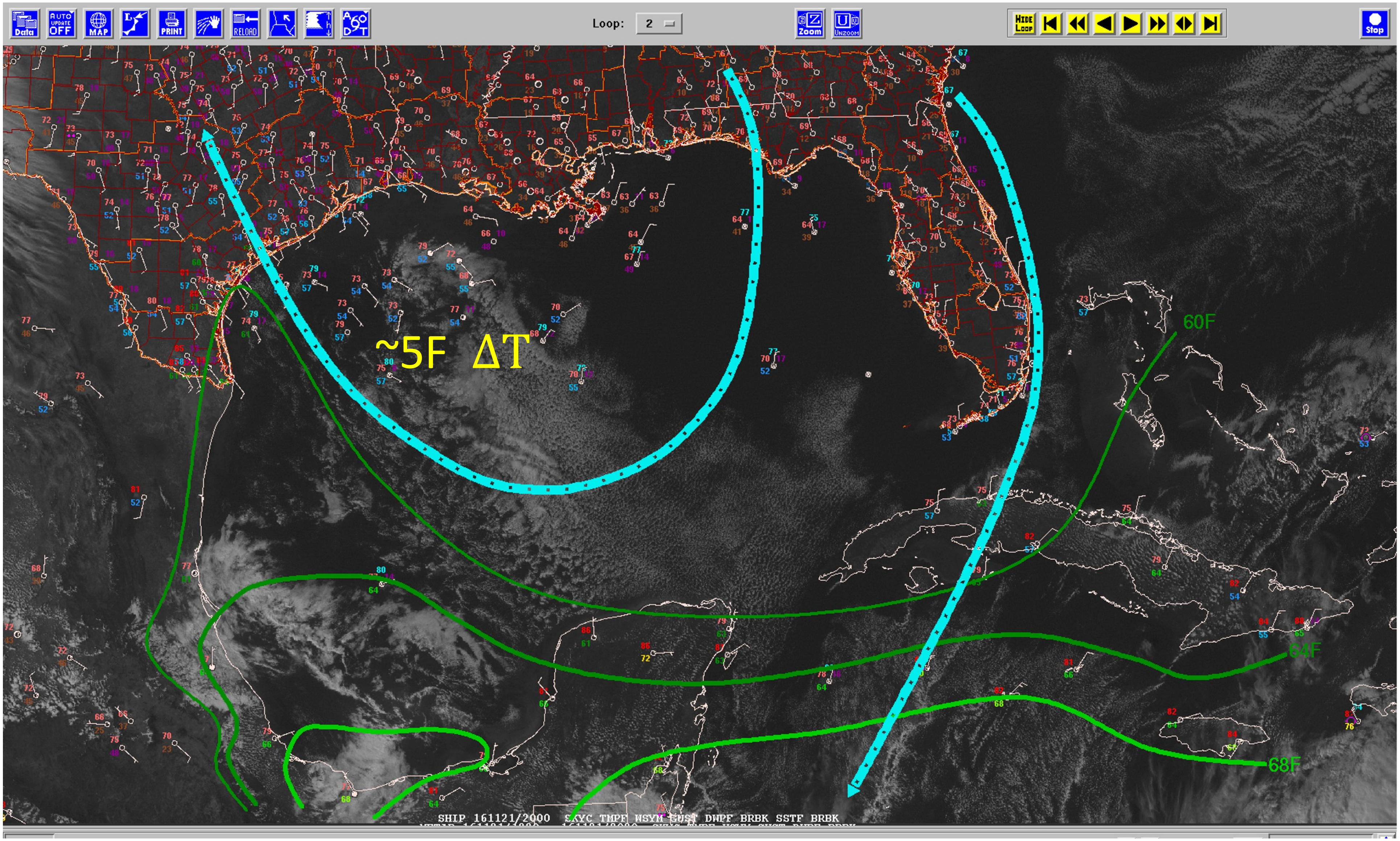
- Key elements include air mass modifications over warmer water and return flow trajectories
- Air mass modification is a multi-date process
- Ask yourself the following:
  - Where is the air coming from?
  - What are the underlying ocean characteristics?
  - What is the character of the returning moist layer?

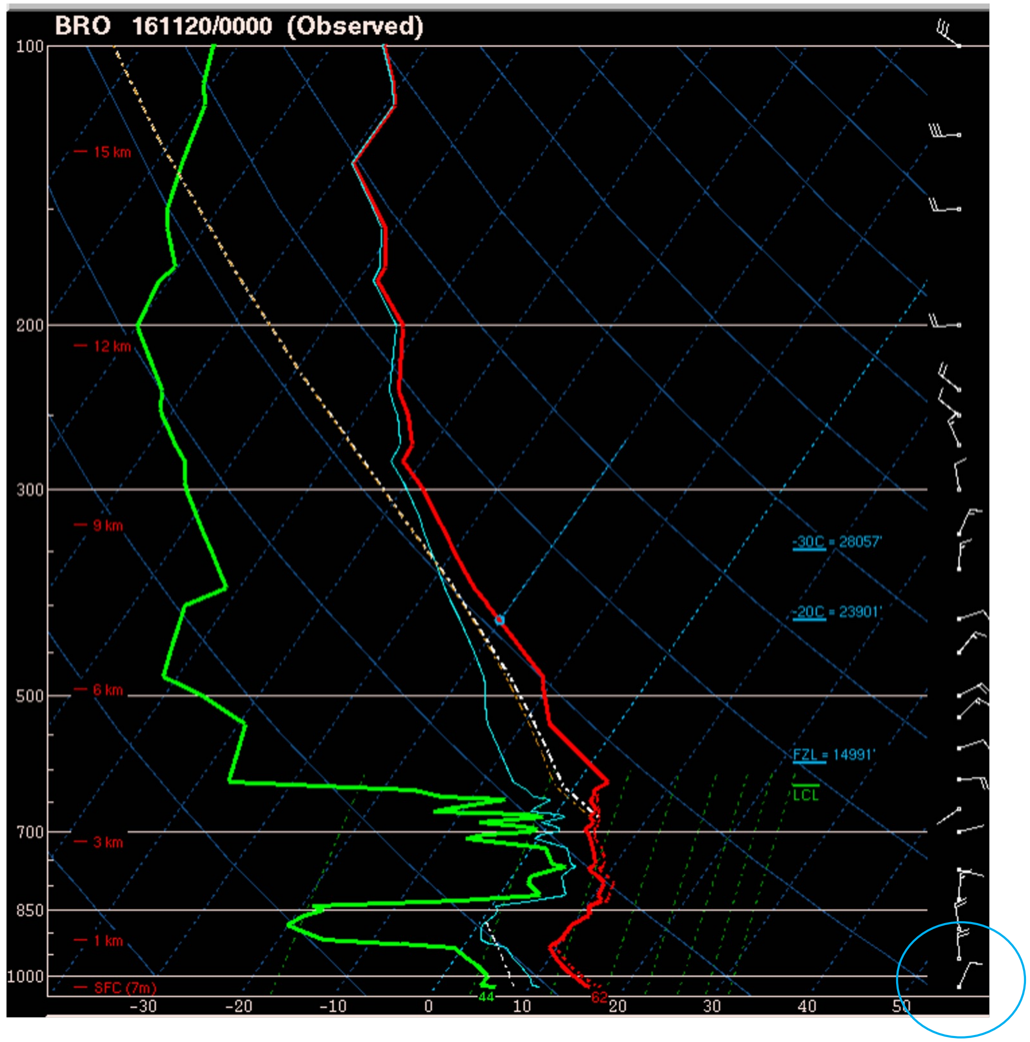

GOM Annual Mean SST
Annual Mean SST [ºC]
Year
1984
1988
1992
1996
2000
2004
2008
2012
32
30
28
26
24
22
20
GOM Monthly Mean SST
Monthly Mean SST [ºC]
Month
0
2
4
6
8
10
12
GOM Daily Mean SST
Daily Mean SST [ºC]
Year
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
NOAA / AOML / PHOD
Wed Jan 28 02:02:20 EST 2015


NOAA/NESDIS GEO-POLAR BLENDED 5 km SST ANALYSIS
FOR THE GULF OF MEXICO
Air temperature after cold front passage
T_a=18C
T_a=19C
T_a=21C
T_a=22C
T_a=23C

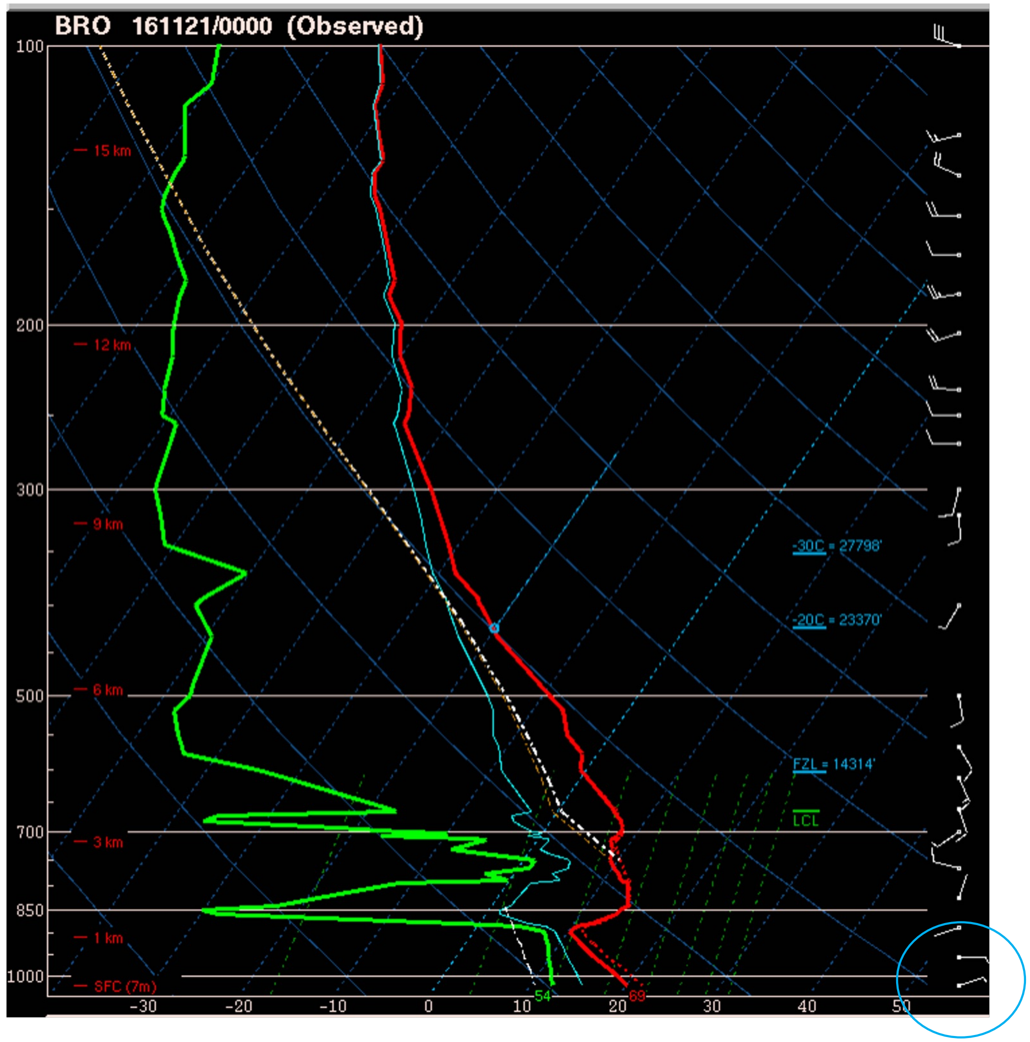

Data
AUTO UPDATE OFF
MAP
PRINT
RELOAD
Loop:
2
Zoom
Unzoom
HIDE LOOP
Stop
60F
64F
68F
~15F ΔT
SHIP 161119/2100 SKYC TMPF WSYM GUST DWPF BRBK SSTF BRBK

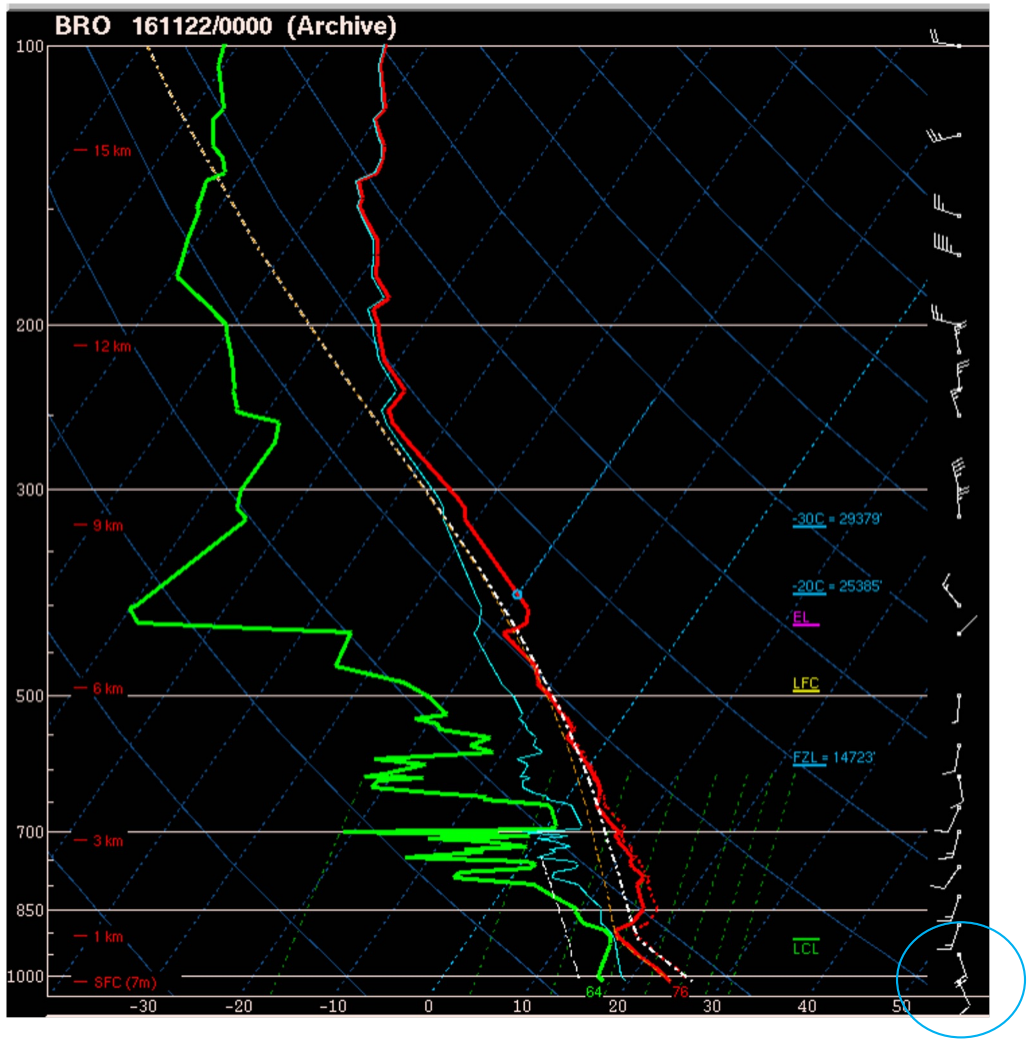

Loop: 2
Data
AUTO UPDATE OFF
MAP
PRINT
RELOAD
Zoom
Unzoom
Stop
~10F ΔT
60F
64F
68F
SHIP 161120/2100 SKYC TMPF WSYM GUST DWPF BRBK SSTF BRBK


Data
AUTO UPDATE OFF
MAP
PRINT
RELOAD
Loop: 2
Zoom
Unzoom
HIDE LOOP
Stop
~5F ΔT
60F
64F
68F
SHIP 161121/2000 SKYC TMPF WSYM GUST DWPF BRBK SSTF BRBK

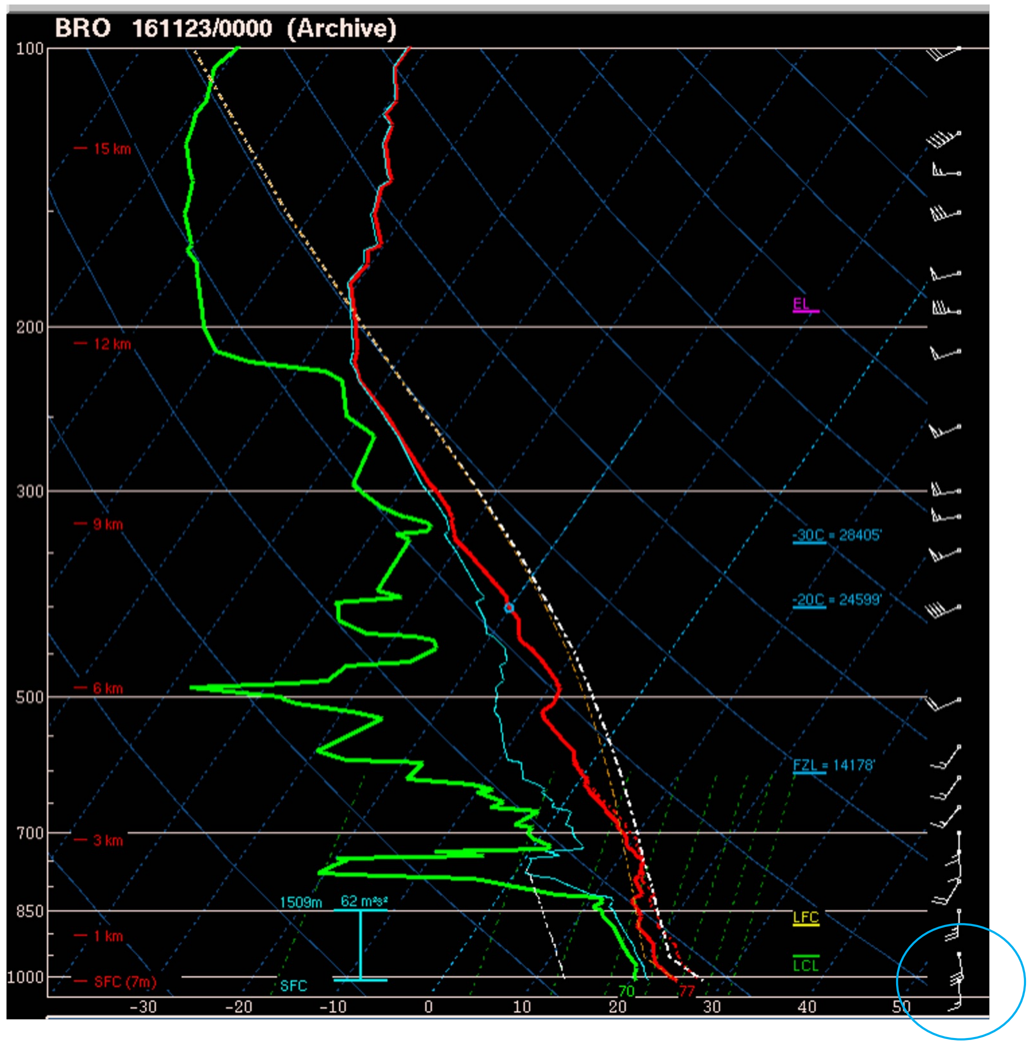


BRO 161120/0000 (Observed)
100
200
300
500
700
850
1000
15 km
12 km
9 km
6 km
3 km
1 km
SFC (7m)
-30C = 28057'
-20C = 23901'
FZL = 14991'
LCL
-30
-20
-10
0
10
20
30
40
50
44
62


BRO 161121/0000 (Observed)
100
200
300
500
700
850
1000
15 km
12 km
9 km
6 km
3 km
1 km
SFC (7m)
-30C = 27798'
-20C = 23370'
FZL = 14314'
LCL
54
68
-30
-20
-10
0
10
20
30
40
50



BRO 161122/0000 (Archive)
100
200
300
500
700
850
1000
15 km
12 km
9 km
6 km
3 km
1 km
SFC (7m)
-30
-20
-10
0
10
20
30
40
50
64
76
-30C = 29379'
-20C = 25385'
EL
LFC
FZL = 14723'
LCL

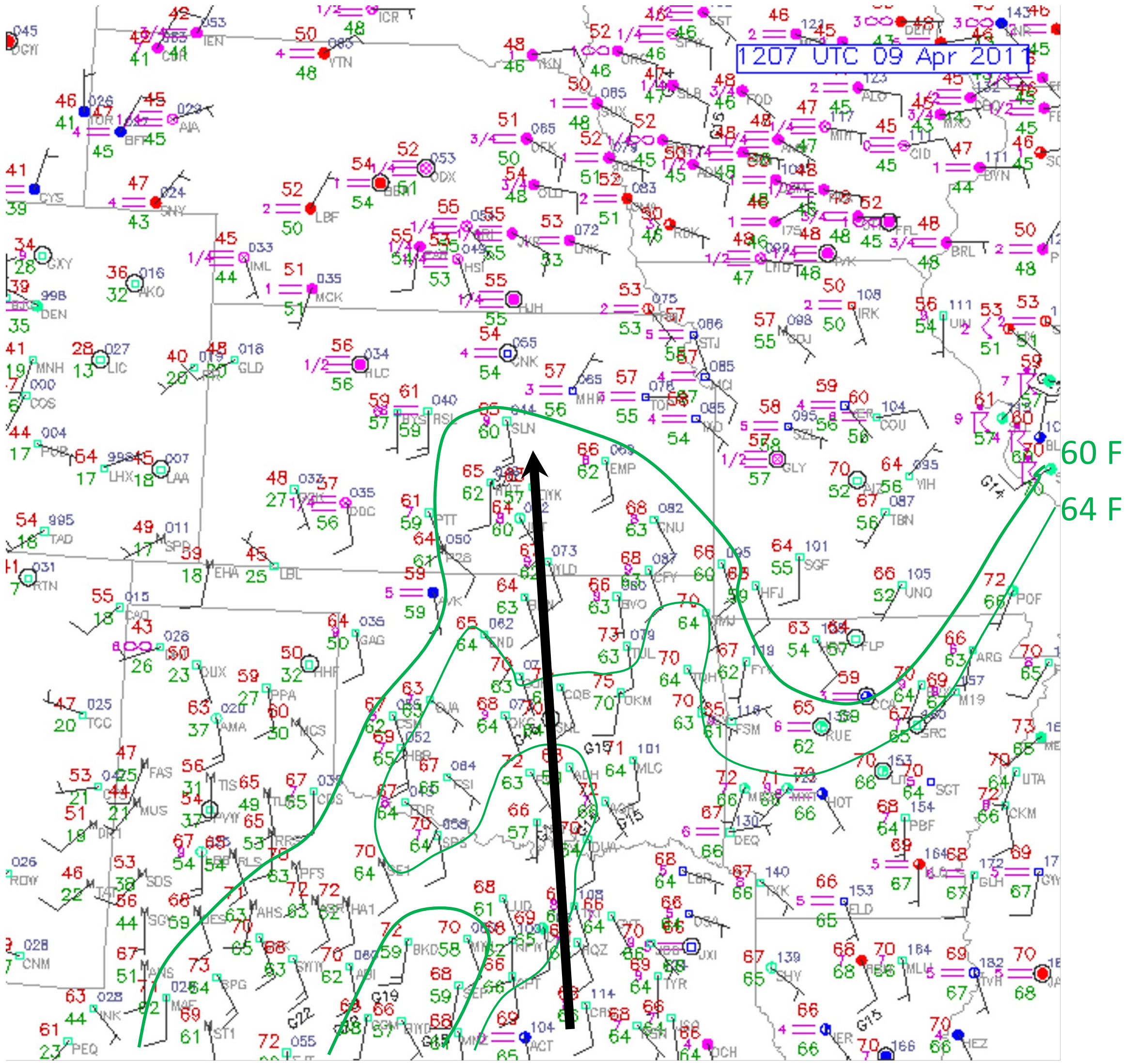


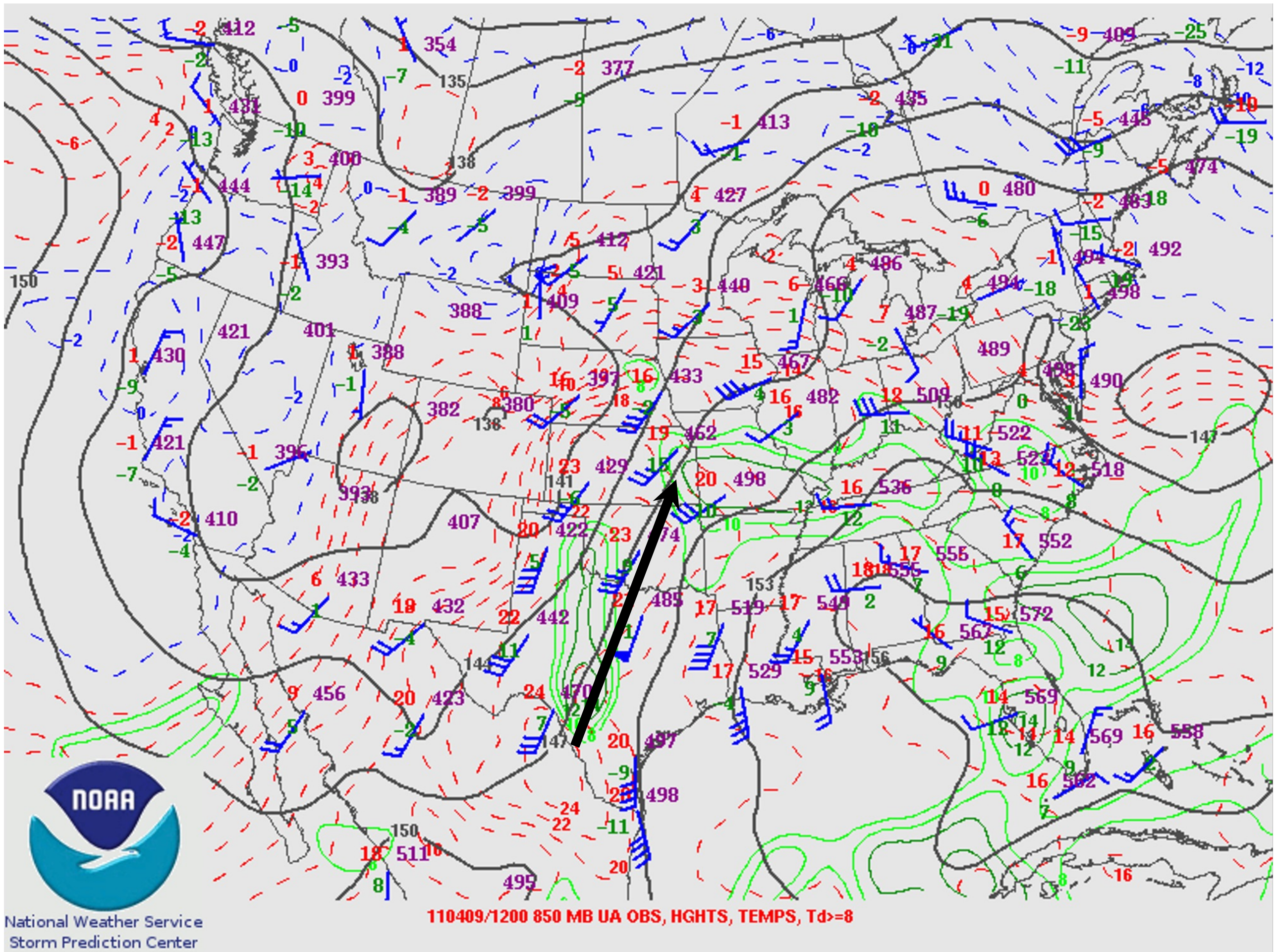
BRO 161123/0000 (Archive)
100
200
300
500
700
850
1000
15 km
12 km
9 km
6 km
3 km
1 km
SFC (7m)
EL
-30C = 28405'
-20C = 24599'
FZL = 14178'
LFC
LCL
1509m
62 m²/s²
SFC
70
77
-30
-20
-10
0
10
20
30
40
50

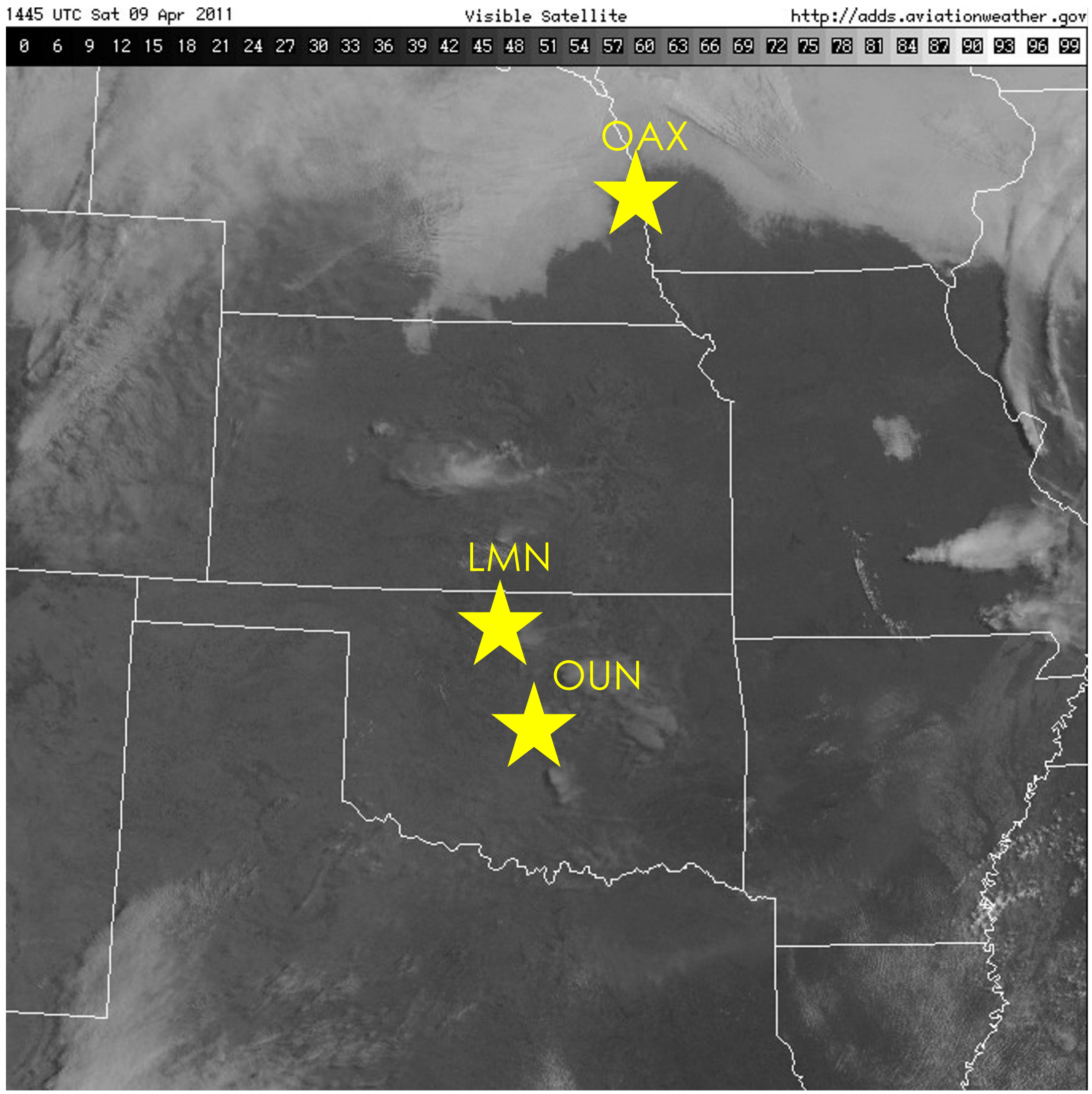
Inland Vertical Mixing

- **Surface moisture can decrease during the daytime when:**
  - **Daytime heating/mixing extends deeper than original moist layer depth**
  - **Moisture advection is not enough to offset mixing**
  - **Compounded by dry soil, little green vegetation, and ongoing drought**

- **Daytime mixing is governed by:**
  - **Vertical moisture structure**
  - **Height and strength of lid/cap**
  - **Upstream moisture sources**
  - **Local moisture sources**


1207 UTC 09 Apr 2011
60 F
64 F


NOAA
National Weather Service
Storm Prediction Center
110409/1200 850 MB UA OBS, HGHTS, TEMPS, Td>=8


1445 UTC Sat 09 Apr 2011
Visible Satellite
http://adds.aviationweather.gov
0 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54 57 60 63 66 69 72 75 78 81 84 87 90 93 96 99
OAX
LMN
OUN

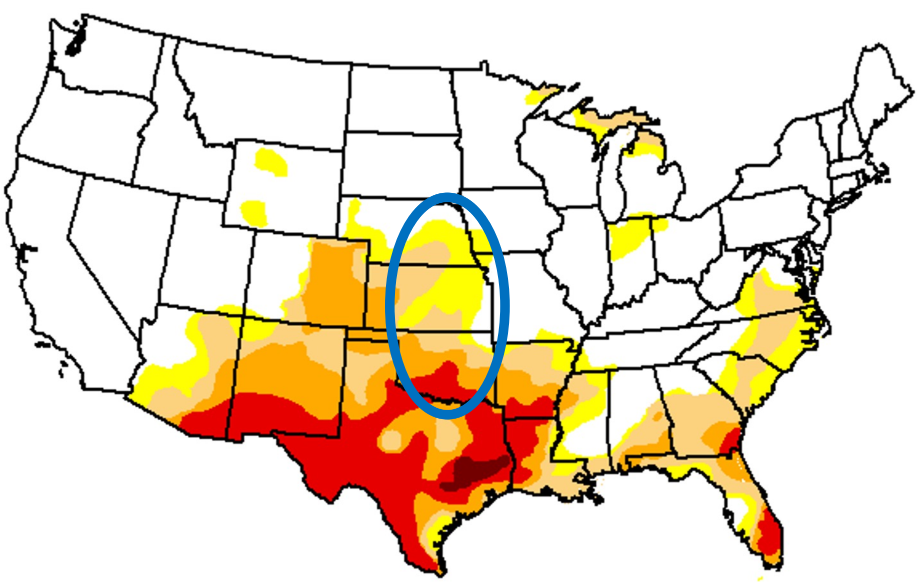
U.S. Drought Monitor

CONUS

April 5, 2011

(Released Thursday, Apr. 7, 2011)

Valid 7 a.m. EST



Drought Conditions (Percent Area)

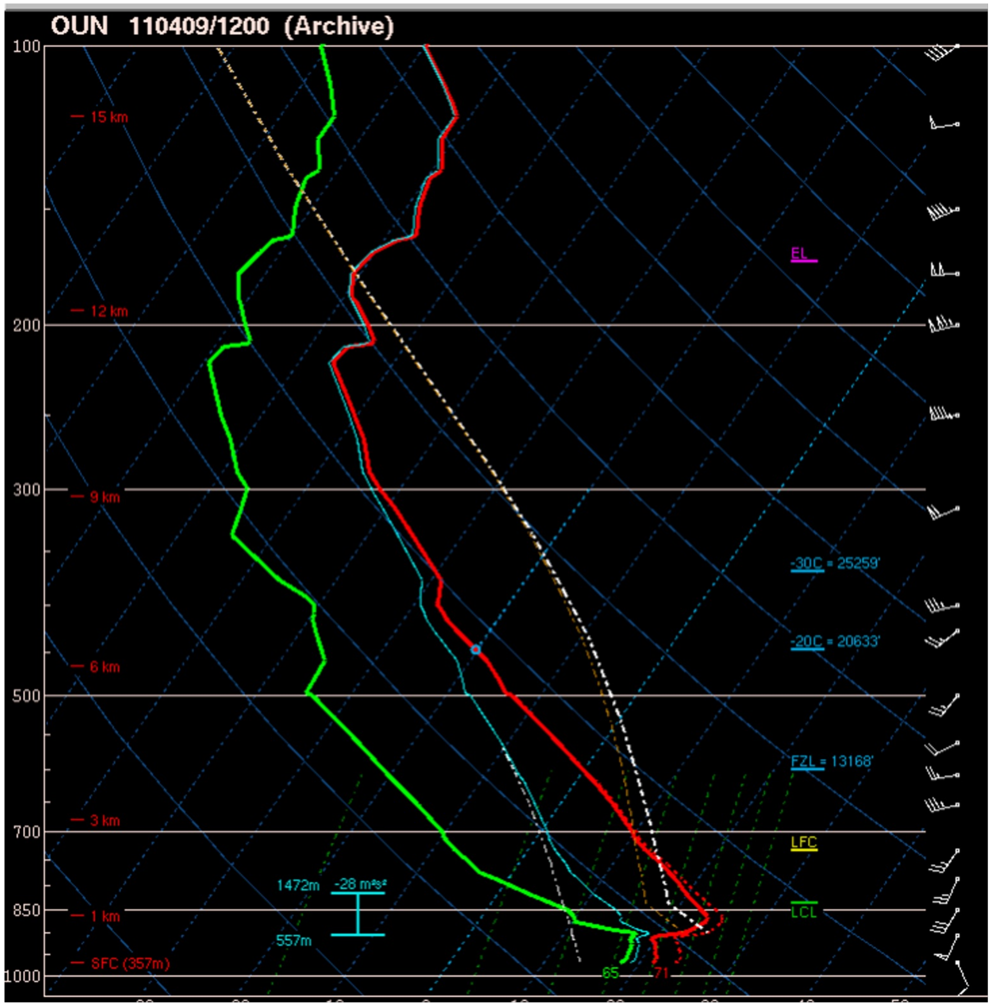
	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	62.46	37.54	28.75	18.17	8.75	0.42
Last Week *3/29/2011*	61.76	38.24	28.14	18.22	6.41	0.00
3 Months Ago *1/4/2011*	60.50	39.50	21.74	8.50	2.60	0.00
Start of Calendar Year *1/4/2011*	60.50	39.50	21.74	8.50	2.60	0.00
Start of Water Year *9/28/2010*	60.05	39.95	13.16	3.09	0.30	0.00
One Year Ago *4/6/2010*	71.57	28.43	9.10	2.00	0.00	0.00

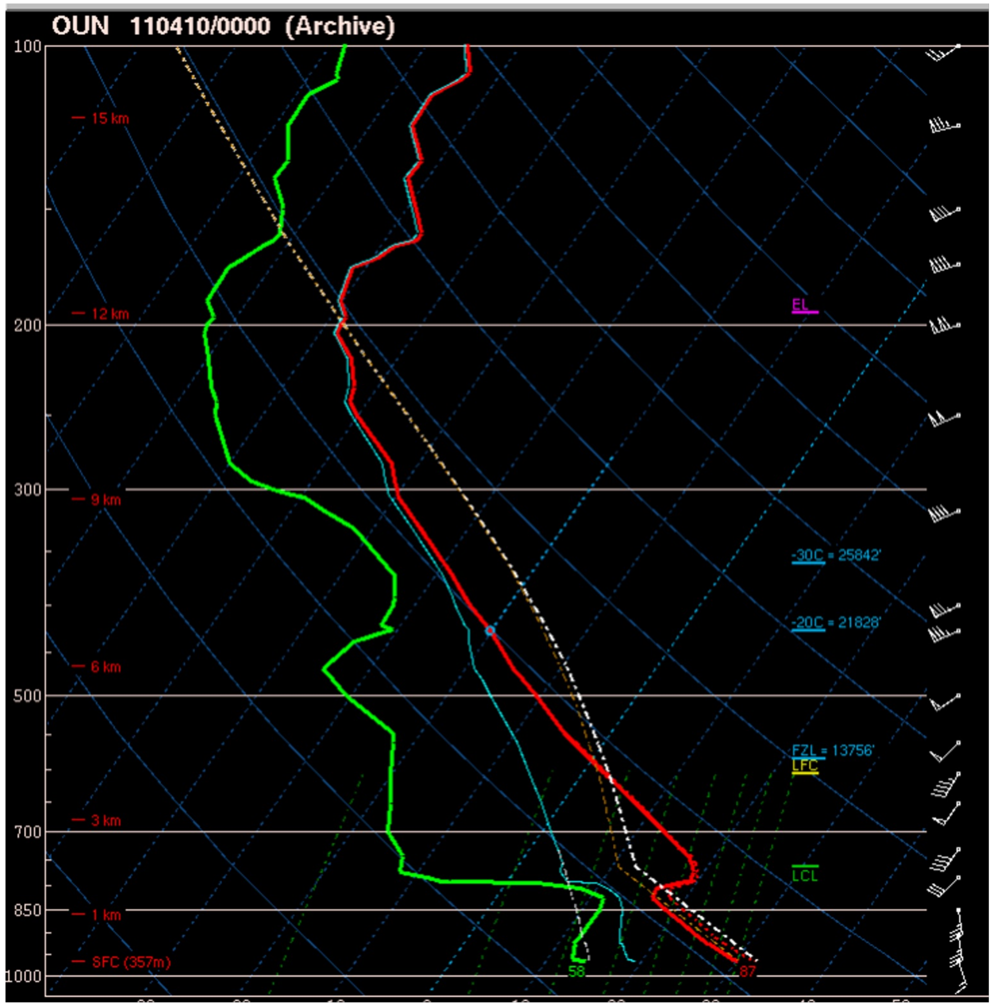
Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

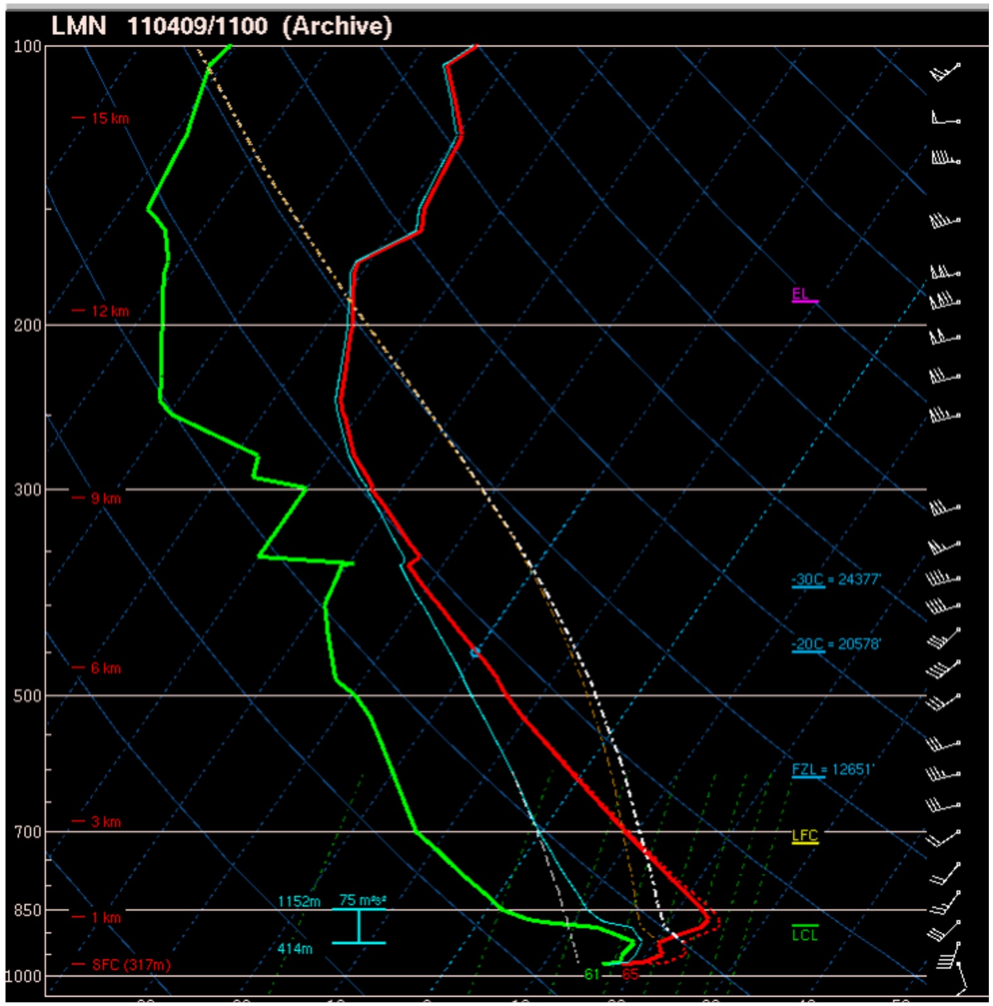
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

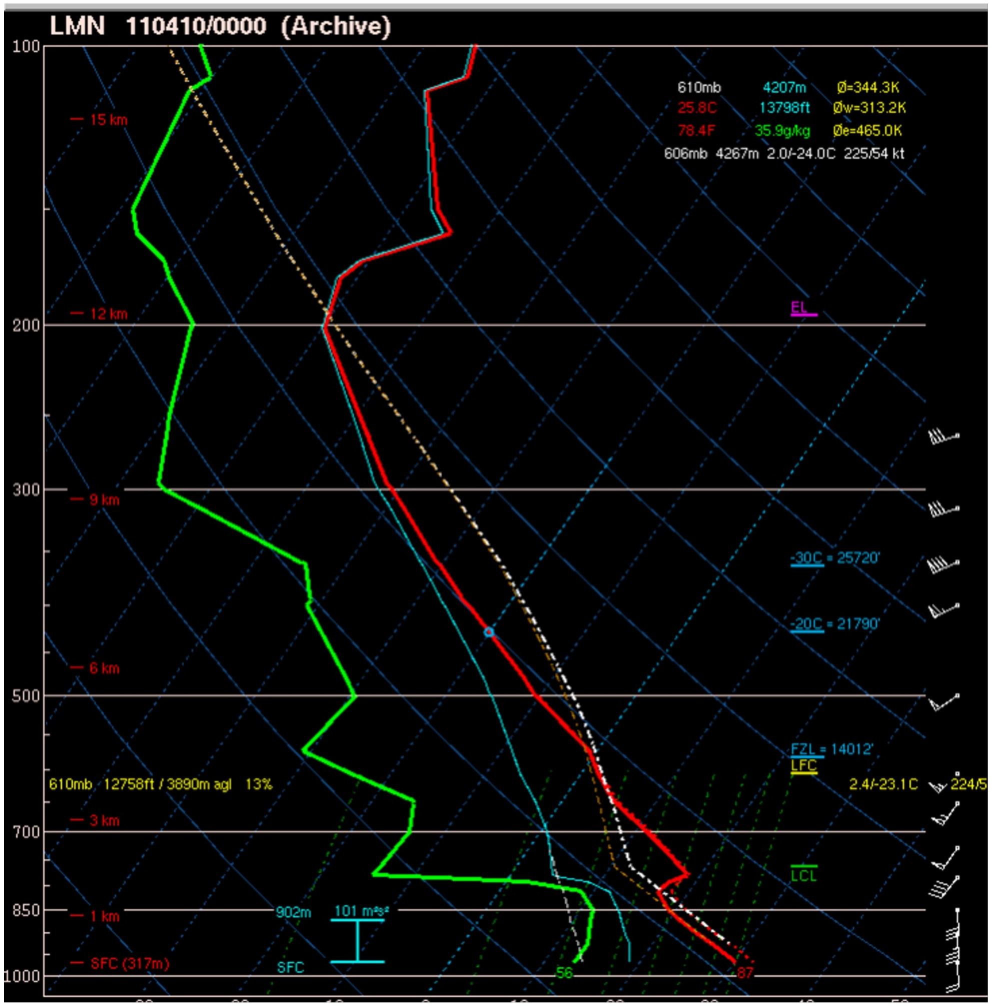
Author(s):
Mark Svoboda
National Drought Mitigation Center


OUN 110409/1200 (Archive)
100
200
300
500
700
850
1000
15 km
12 km
9 km
6 km
3 km
1 km
SFC (357m)
EL
-30C = 25259'
-20C = 20633'
FZL = 13168'
LFC
LCL
1472m
-28 m²s²
557m
65
71

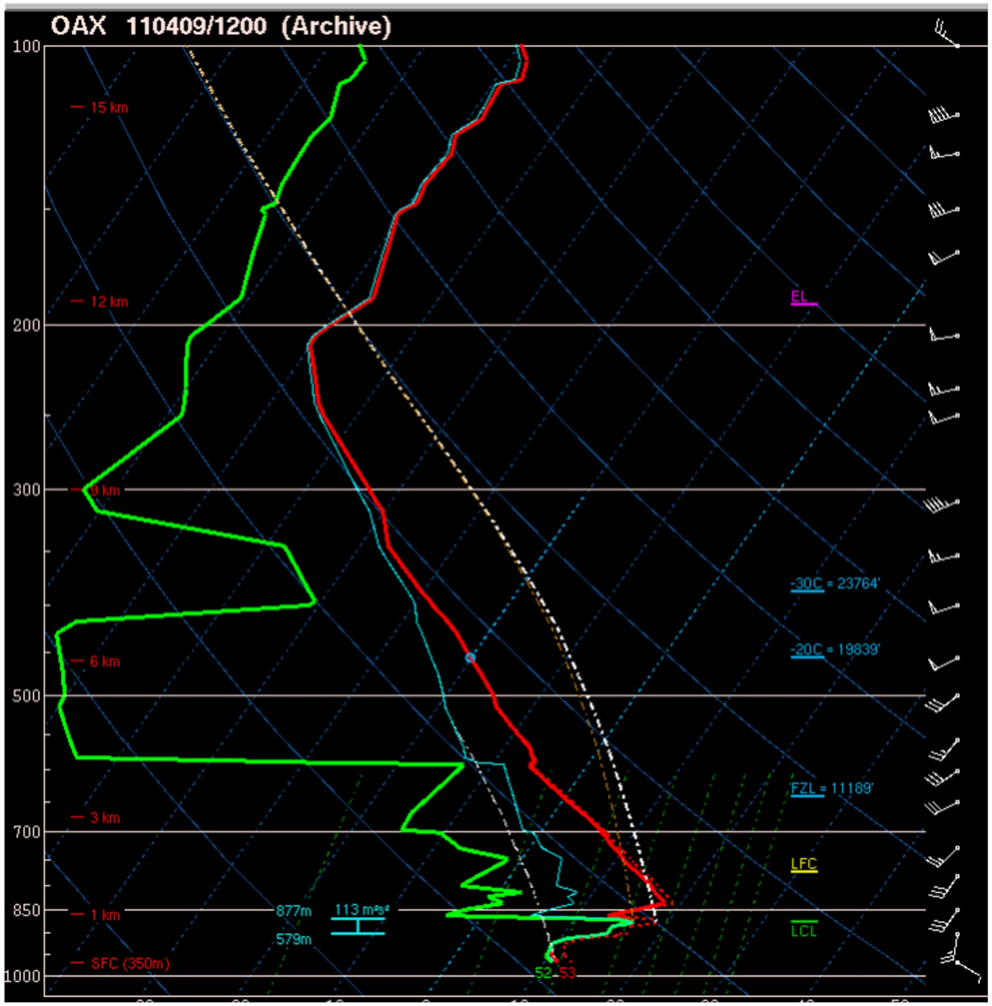


OUN 110410/0000 (Archive)
100
200
300
500
700
850
1000
15 km
12 km
9 km
6 km
3 km
1 km
SFC (357m)
EL
-30C = 25842'
-20C = 21828'
FZL = 13756'
LFC
LCL
58
87

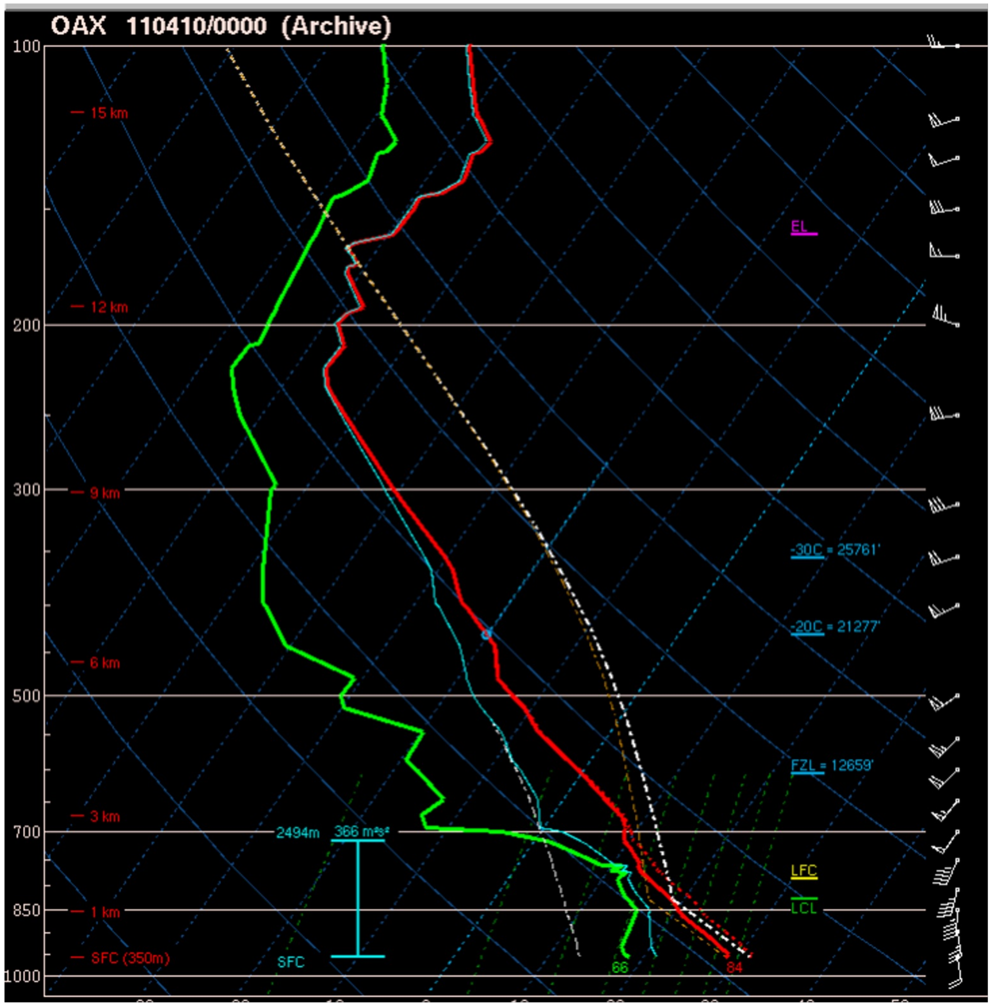

LMN 110409/1100 (Archive)
100
200
300
500
700
850
1000
15 km
12 km
9 km
6 km
3 km
1 km
SFC (317m)
1152m
414m
EL
-30C = 24377'
-20C = 20578'
FZL = 12651'
LFC
LCL
61
65



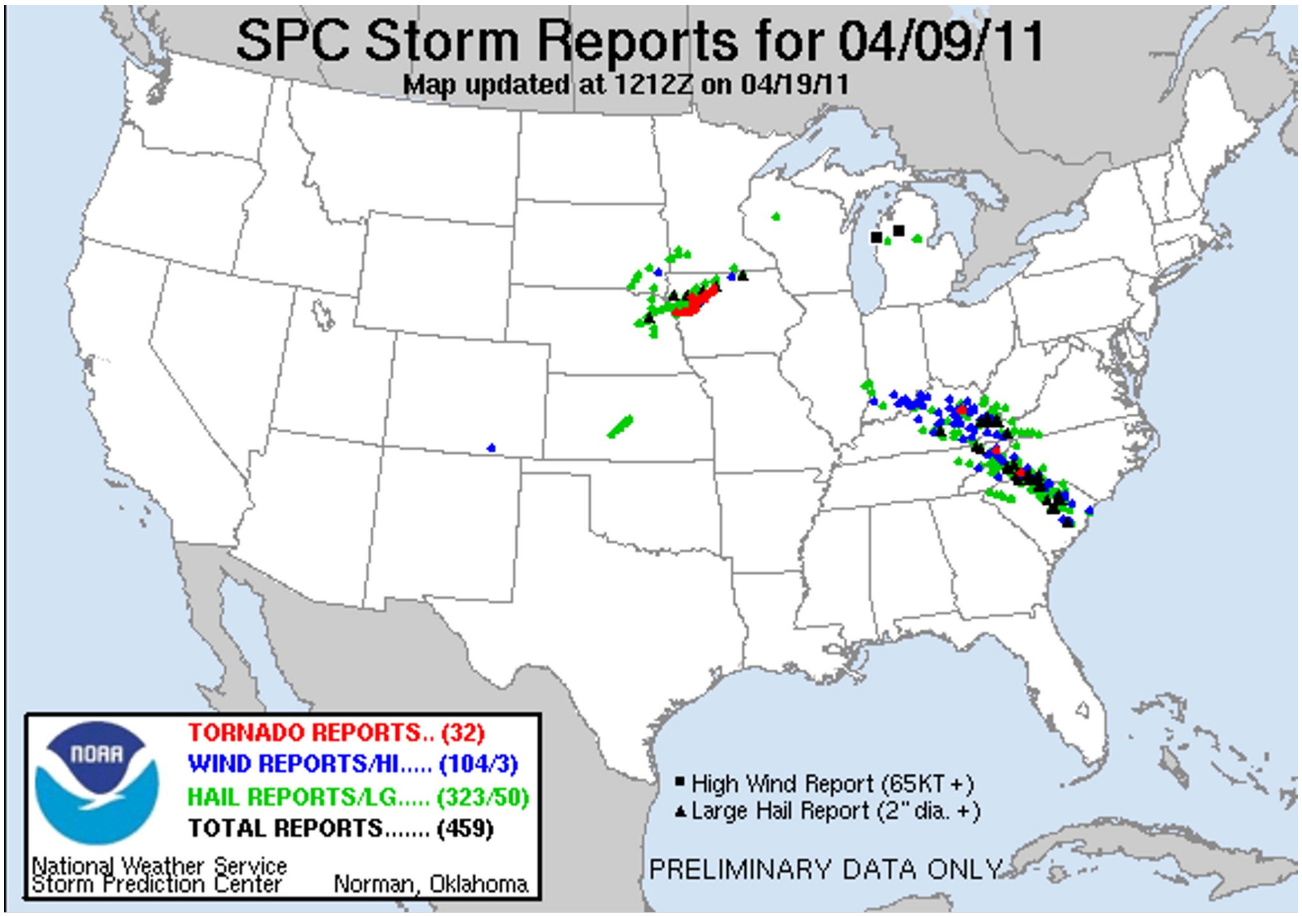
LMN 110410/0000 (Archive)
610mb 4207m Ø=344.3K
25.8C 13798ft Øw=313.2K
78.4F 35.9g/kg Øe=465.0K
606mb 4267m 2.0/-24.0C 225/54 kt
EL
-30C = 25720'
-20C = 21790'
FZL = 14012'
LFC
LCL
610mb 12758ft / 3890m agl 13%
2.4/-23.1C 224/5
15 km
12 km
9 km
6 km
3 km
1 km
SFC (317m)
902m
101 m²/s²
SFC
56
87
100
200
300
500
700
850
1000



OAX 110409/1200 (Archive)
100
200
300
500
700
850
1000
15 km
12 km
9 km
6 km
3 km
1 km
SFC (350m)
877m
579m
113 m²/s²
EL
-30C = 23764'
-20C = 19839'
FZL = 11189'
LFC
LCL
52
53



OAX 110410/0000 (Archive)
100
200
300
500
700
850
1000
15 km
12 km
9 km
6 km
3 km
1 km
SFC (350m)
EL
-30C = 25761'
-20C = 21277'
FZL = 12659'
LFC
LCL
2494m
366 m²/s²
SFC
66
84

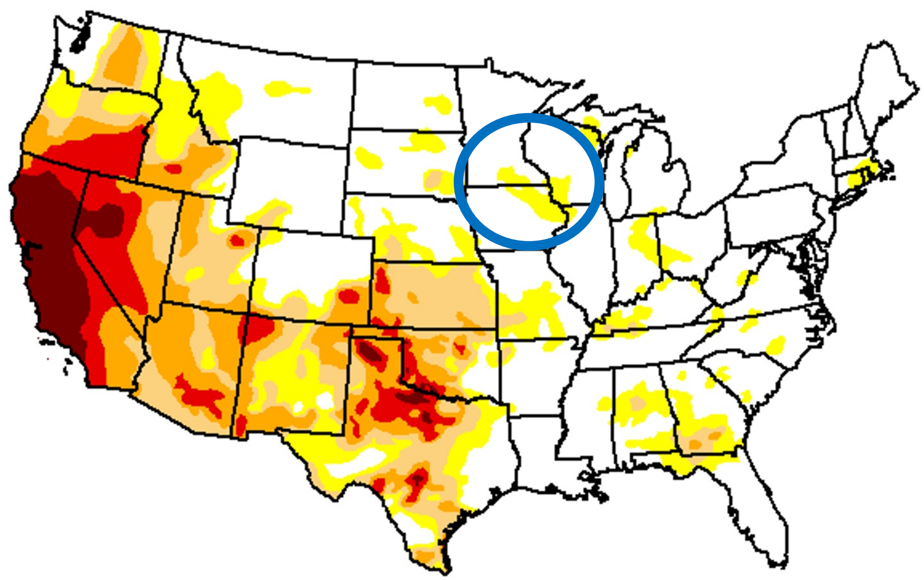

SPC Storm Reports for 04/09/11
Map updated at 1212Z on 04/19/11
NOAA
TORNADO REPORTS.. (32)
WIND REPORTS/HI..... (104/3)
HAIL REPORTS/LG..... (323/50)
TOTAL REPORTS....... (459)
National Weather Service
Storm Prediction Center
Norman, Oklahoma
High Wind Report (65KT+)
Large Hail Report (2" dia. +)
PRELIMINARY DATA ONLY

Evapotranspiration

- **Need moist soil and growing vegetation**
- **Plentiful rain previous 1-2 weeks**
- **Maturing crops (wheat, corn, or canola)**
- **Capped boundary layer to trap moisture; relatively weak winds**
- **Almost always a significant return flow contribution (in addition)**

U.S. Drought Monitor

CONUS



August 19, 2014

(Released Thursday, Aug. 21, 2014)

Valid 8 a.m. EDT

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	51.93	48.07	33.56	21.62	10.12	3.80
Last Week 8/12/2014	52.81	47.19	33.61	22.03	10.24	3.79
3 Months Ago 5/20/2014	52.36	47.64	38.12	28.30	14.47	4.99
Start of Calendar Year 12/31/2013	48.24	51.76	30.95	16.67	3.96	0.37
Start of Water Year 10/1/2013	39.57	60.43	41.21	20.70	3.06	0.29
One Year Ago 8/20/2013	40.02	59.98	45.61	32.23	10.54	1.32

Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

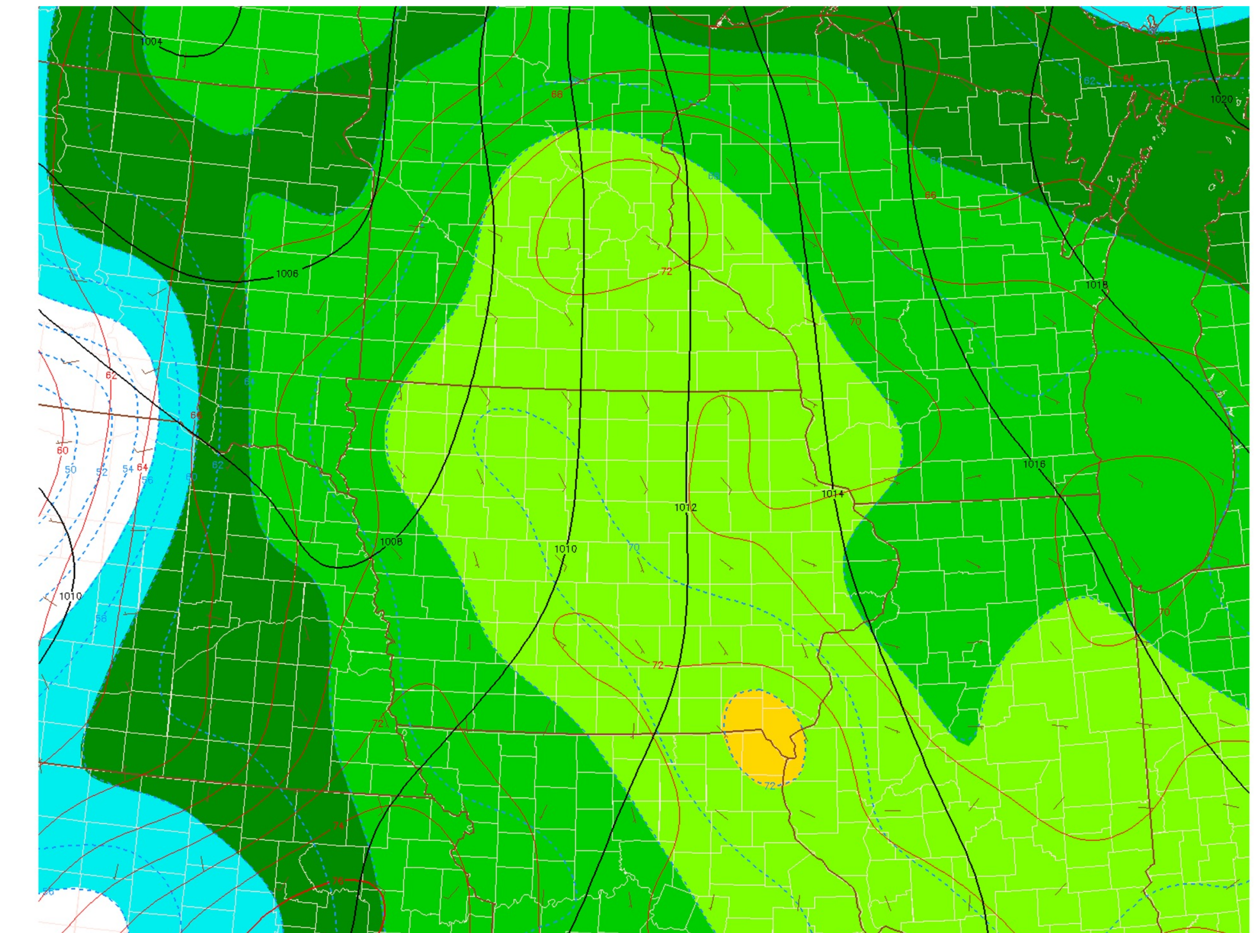
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author(s):

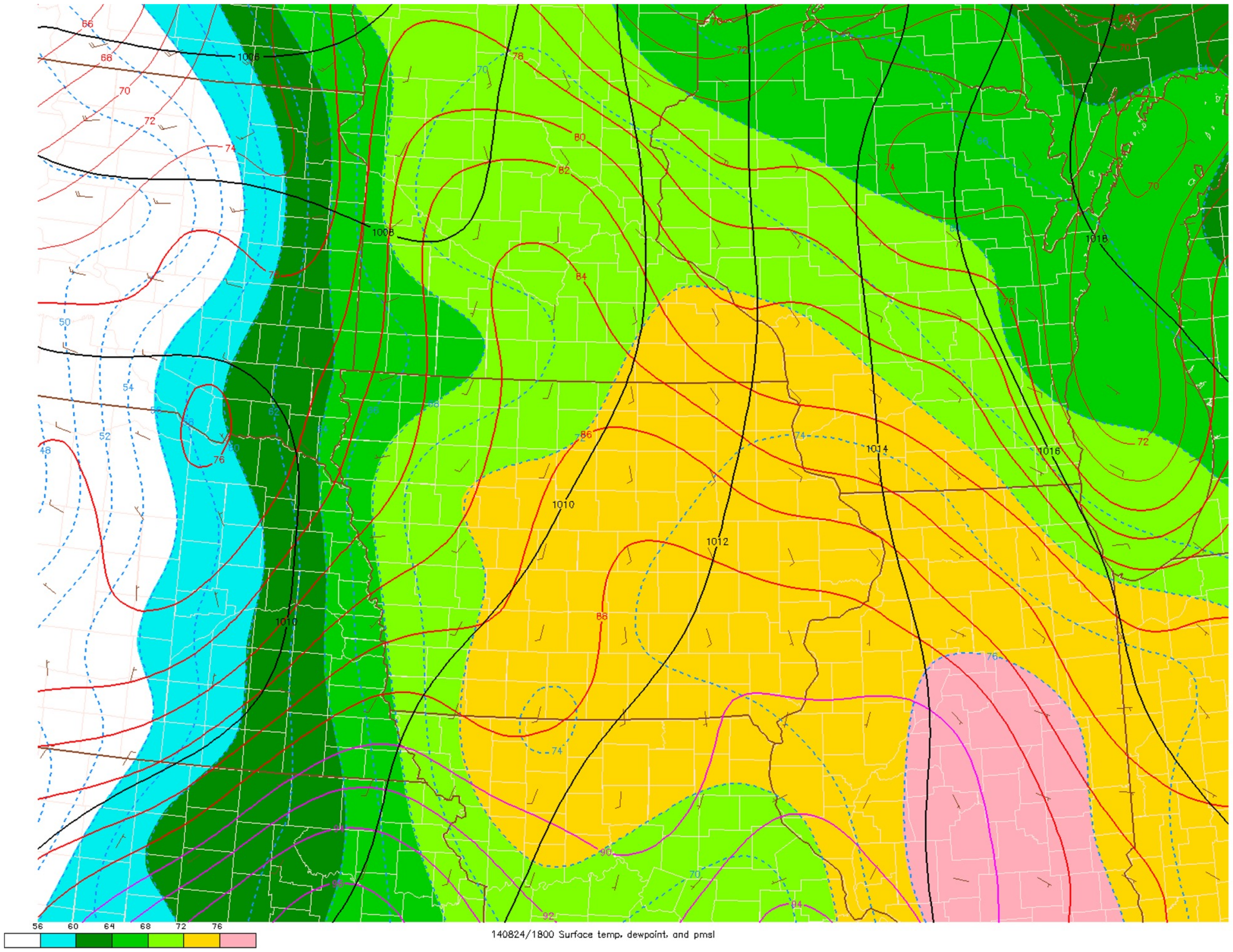
Richard Tinker

CPC/NOAA/NWS/NCEP

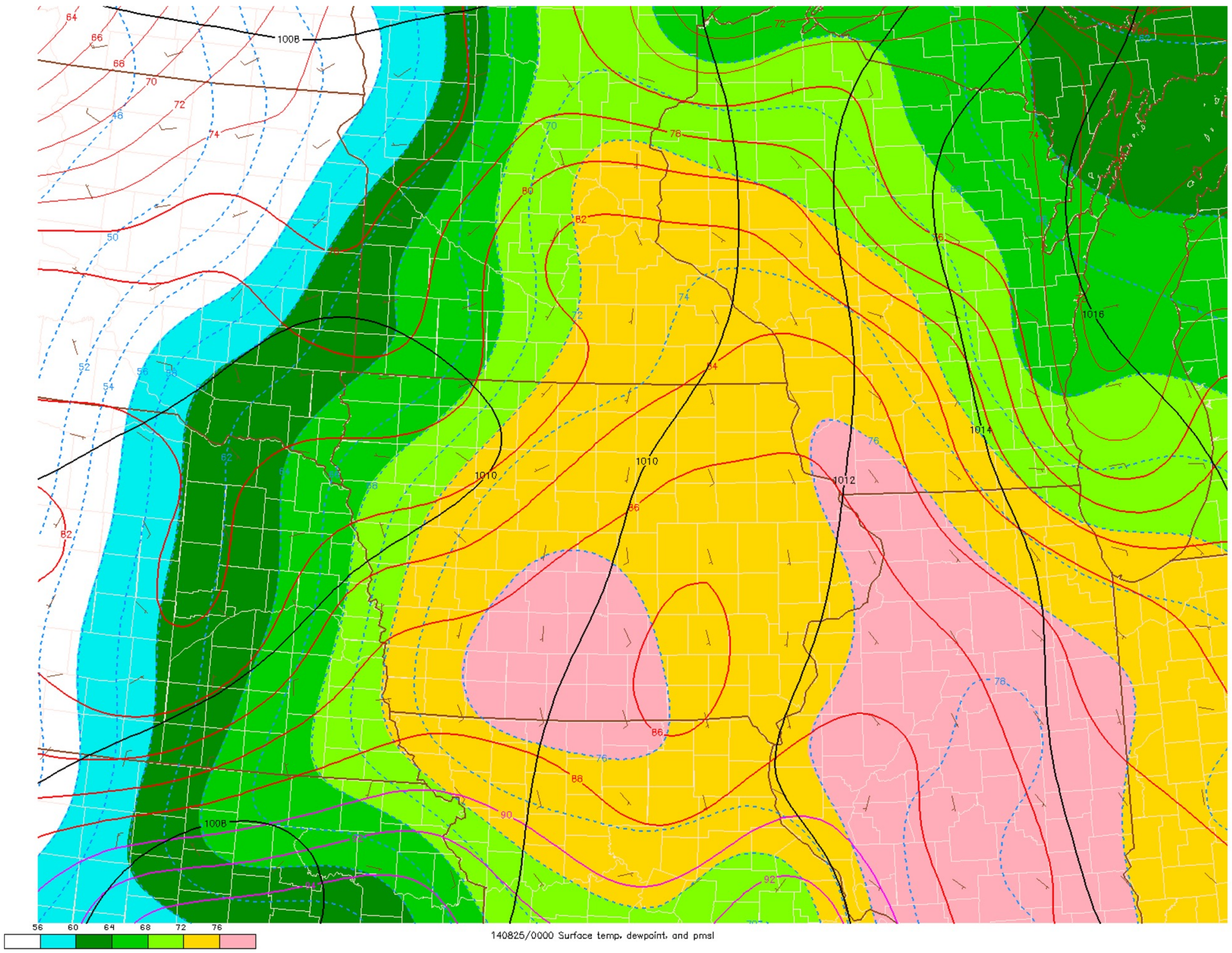
USDA



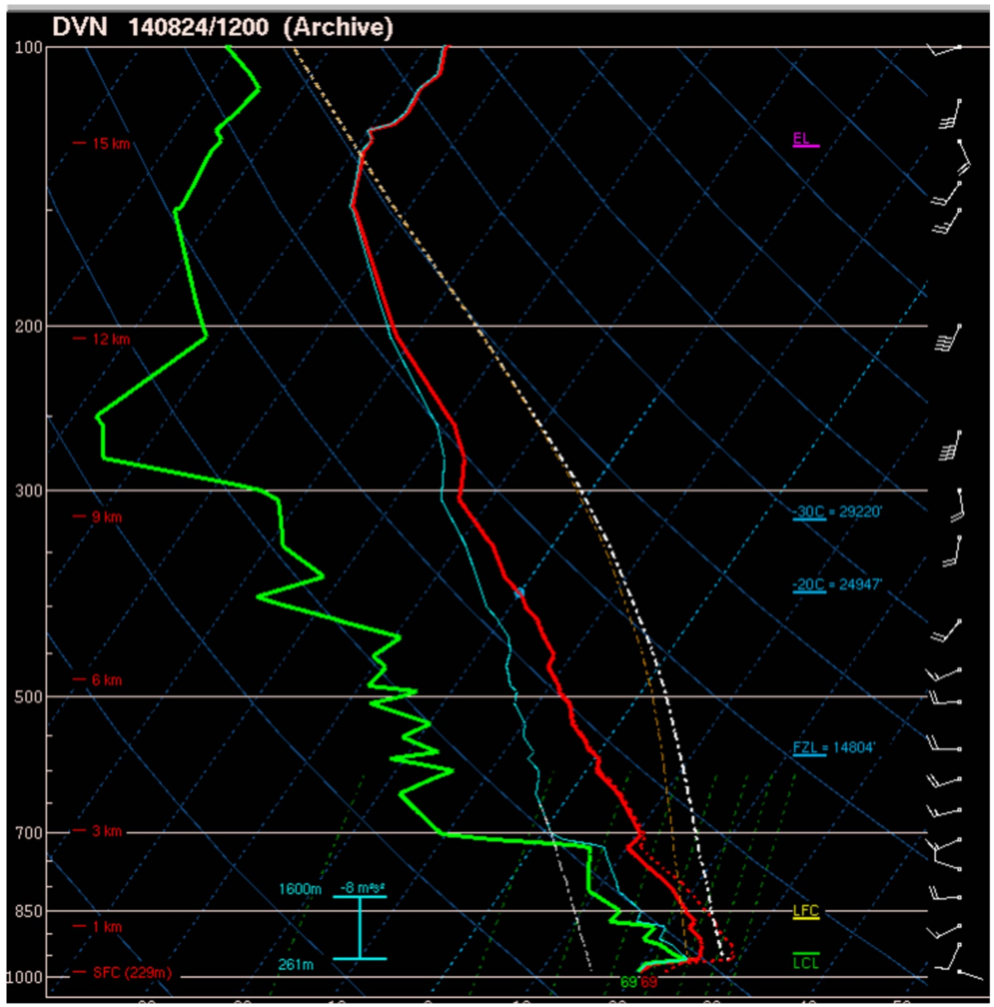
140824/1200 Surface temp, dewpoint, and pmsl

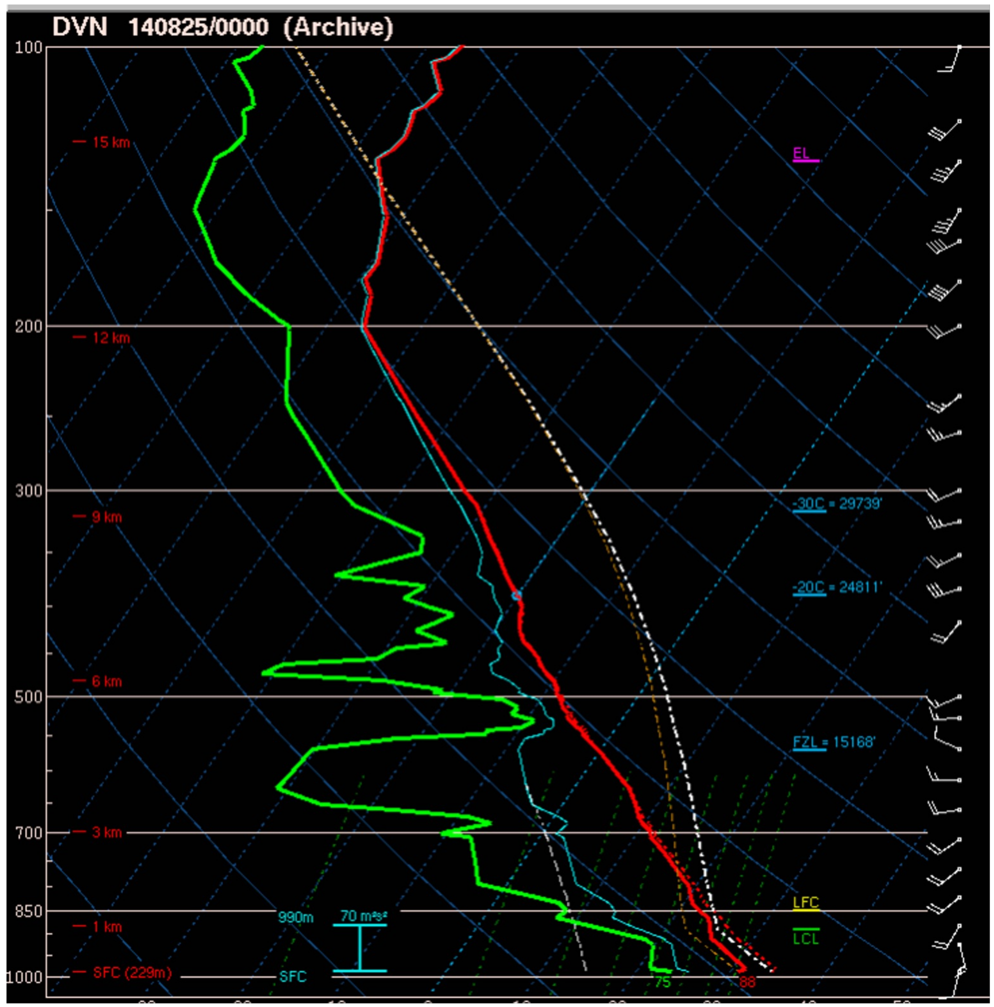


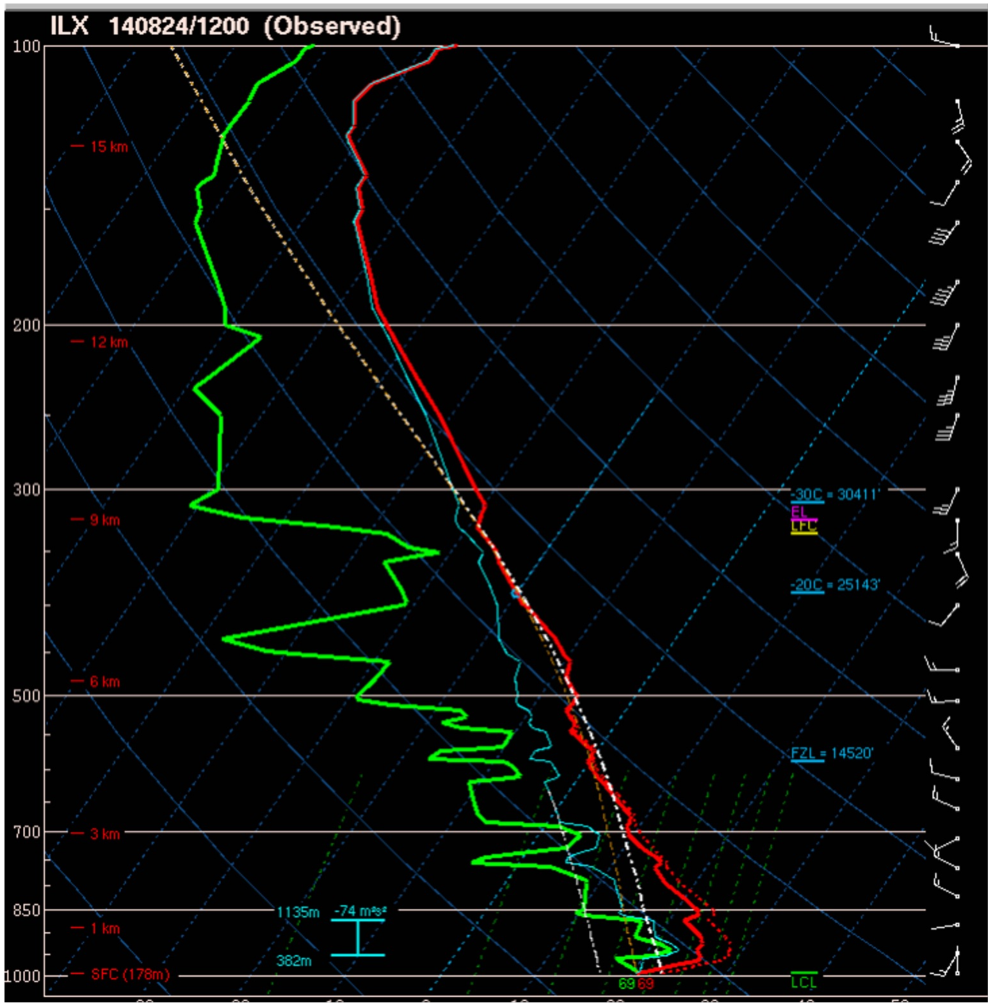
140824/1800 Surface temp, dewpoint, and pmsl



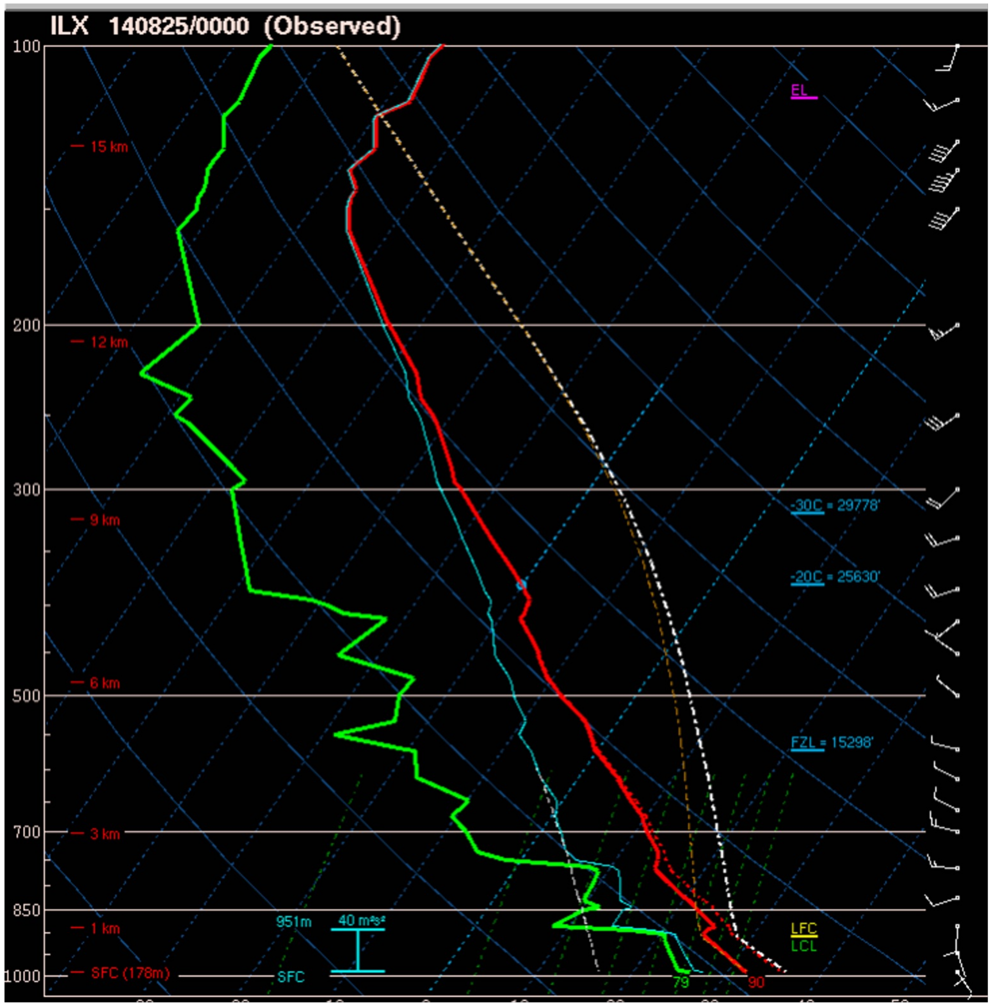
140825/0000 Surface temp, dewpoint, and pmsl


DVN 140824/1200 (Archive)
100
200
300
500
700
850
1000
15 km
12 km
9 km
6 km
3 km
1 km
SFC (229m)
EL
-30C = 29220'
-20C = 24947'
FZL = 14804'
LFC
LCL
1600m
-8 m²s²
261m
69
69


DVN 140825/0000 (Archive)
100
200
300
500
700
850
1000
15 km
12 km
9 km
6 km
3 km
1 km
SFC (229m)
990m
70 m²s²
SFC
EL
-30C = 29739'
-20C = 24811'
FZL = 15168'
LFC
LCL
75
88



ILX 140824/1200 (Observed)
100
200
300
500
700
850
1000
15 km
12 km
9 km
6 km
3 km
1 km
SFC (178m)
1135m
-74 m²s²
382m
-30C = 30411'
EL
LFC
-20C = 25143'
FZL = 14520'
LCL
69
69

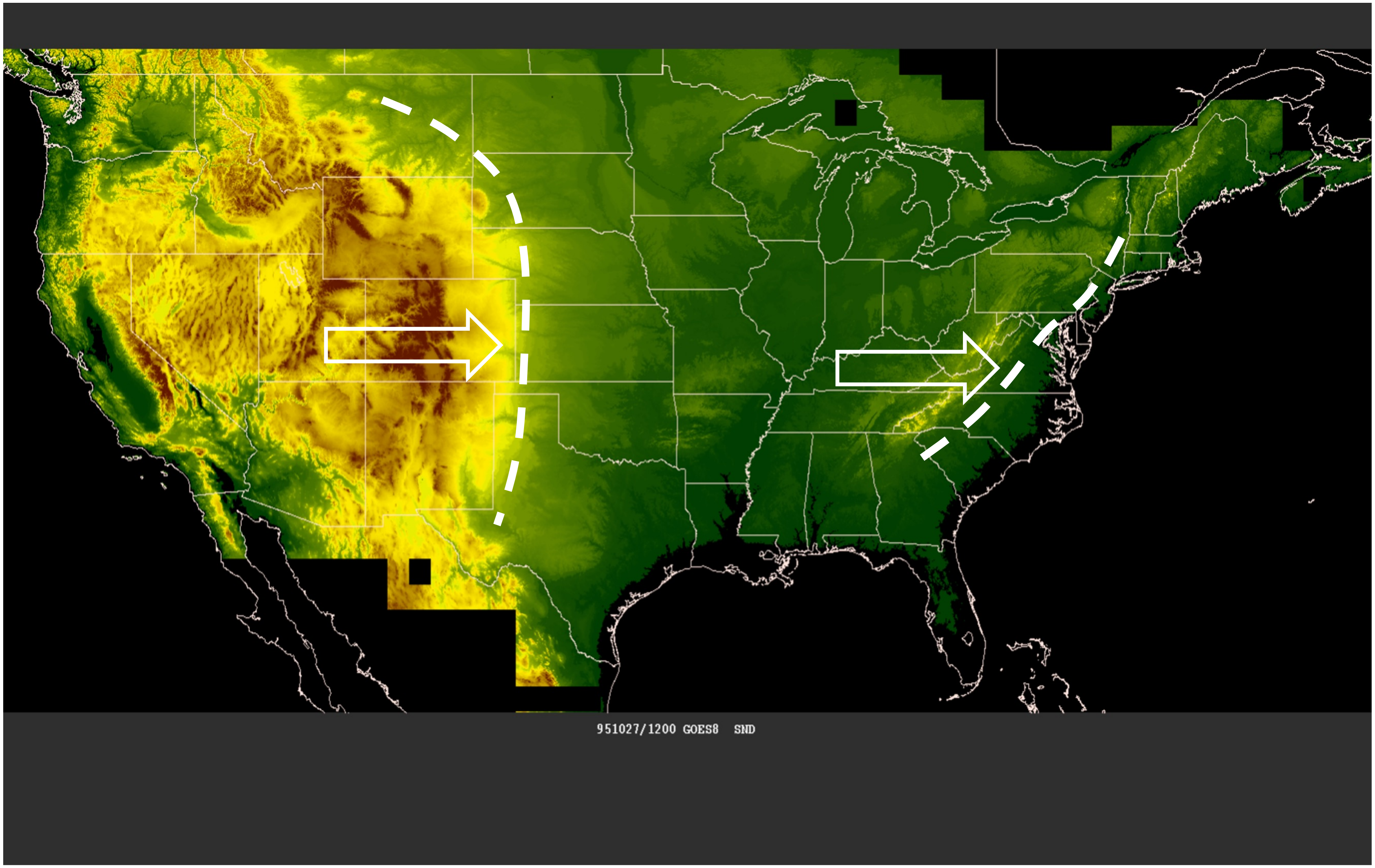


ILX 140825/0000 (Observed)
100
200
300
500
700
850
1000
15 km
12 km
9 km
6 km
3 km
1 km
SFC (178m)
951m
40 m²/s²
SFC
79
90
EL
-30C = 29778'
-20C = 25630'
FZL = 15298'
LFC
LCL

Lee Cyclogenesis

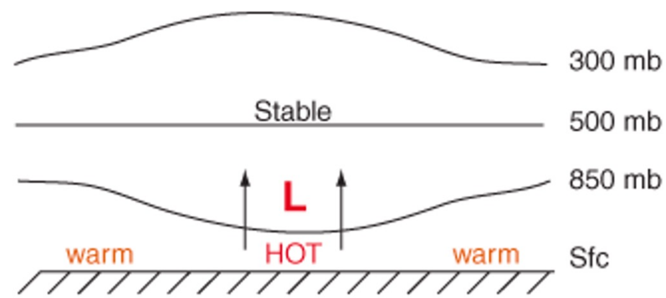
- **Midlevel flow crosses high terrain:**
  - **Subsidence and warming E of mountains**
  - **Warming of column leads to "warm core" low formation**
  - **Strongest pressure falls with strongest flow crosses highest terrain**

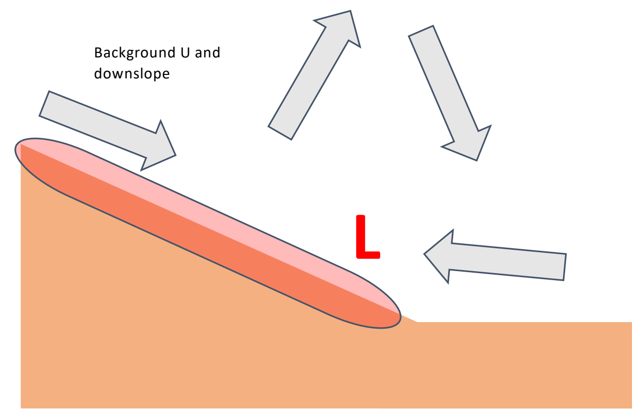
- **The lee trough/cyclone deepens before arrival of strongest Q-G forcing for ascent:**
  - **Head start on differential advection, "loaded gun" sounding, and veering winds with height**


951027/1200 GOES8 SND

Lee Cyclogenesis

- **Mid-level flow crosses high terrain:**
  - Subsidence and warming E of mountains
  - Stronger diabatic heating across slope results in rising motion from induced katabatic flow. (Frontogenesis)
  - Warming of column and rising motion leads to "warm core" low formation
  - Strongest pressure falls with strongest flow crosses highest terrain





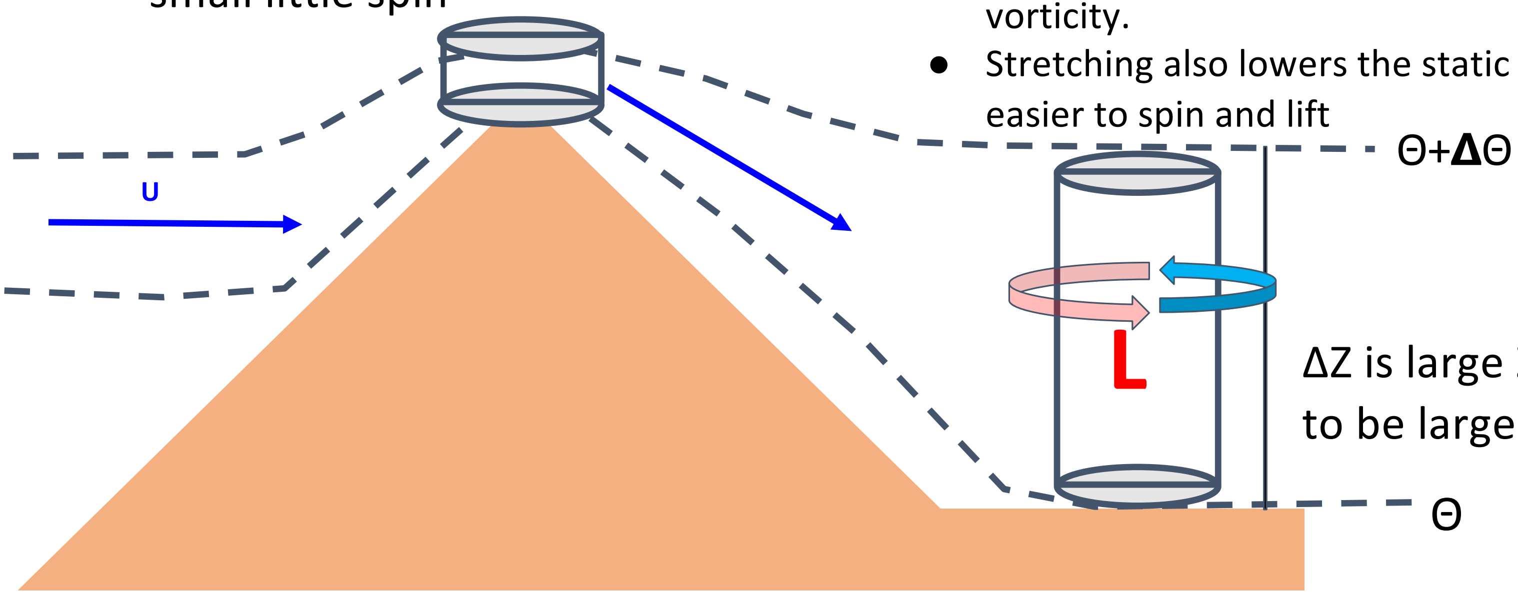
- **The lee trough/cyclone deepens before arrival of strongest Q-G forcing for ascent: (More QG Later)**
  - Head start on differential advection, "loaded gun" sounding, and veering winds with height

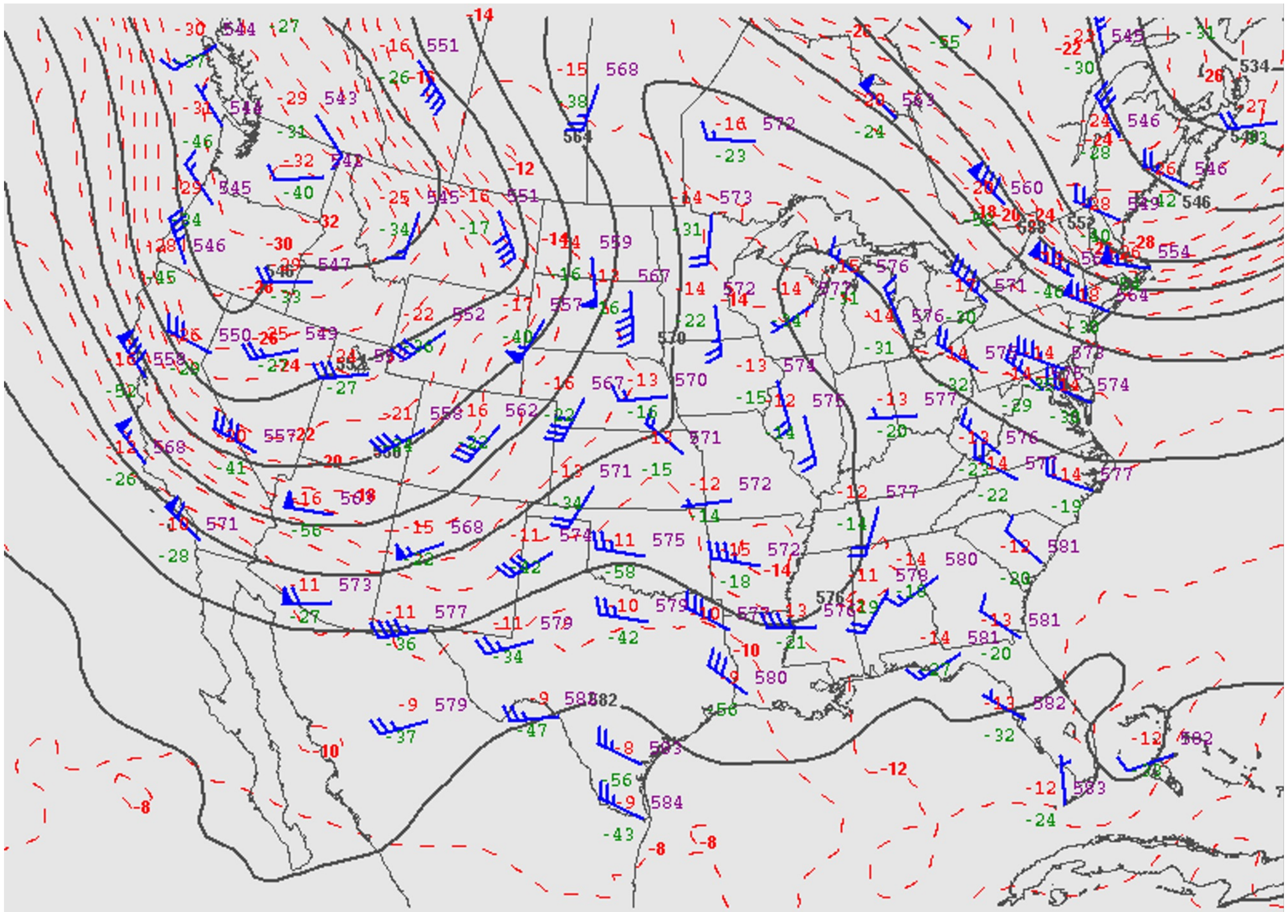
Lee Cyclogenesis PV Framework

$$Pv = \frac{\zeta_{\Theta} + f}{\Delta Z} = \text{const}$$

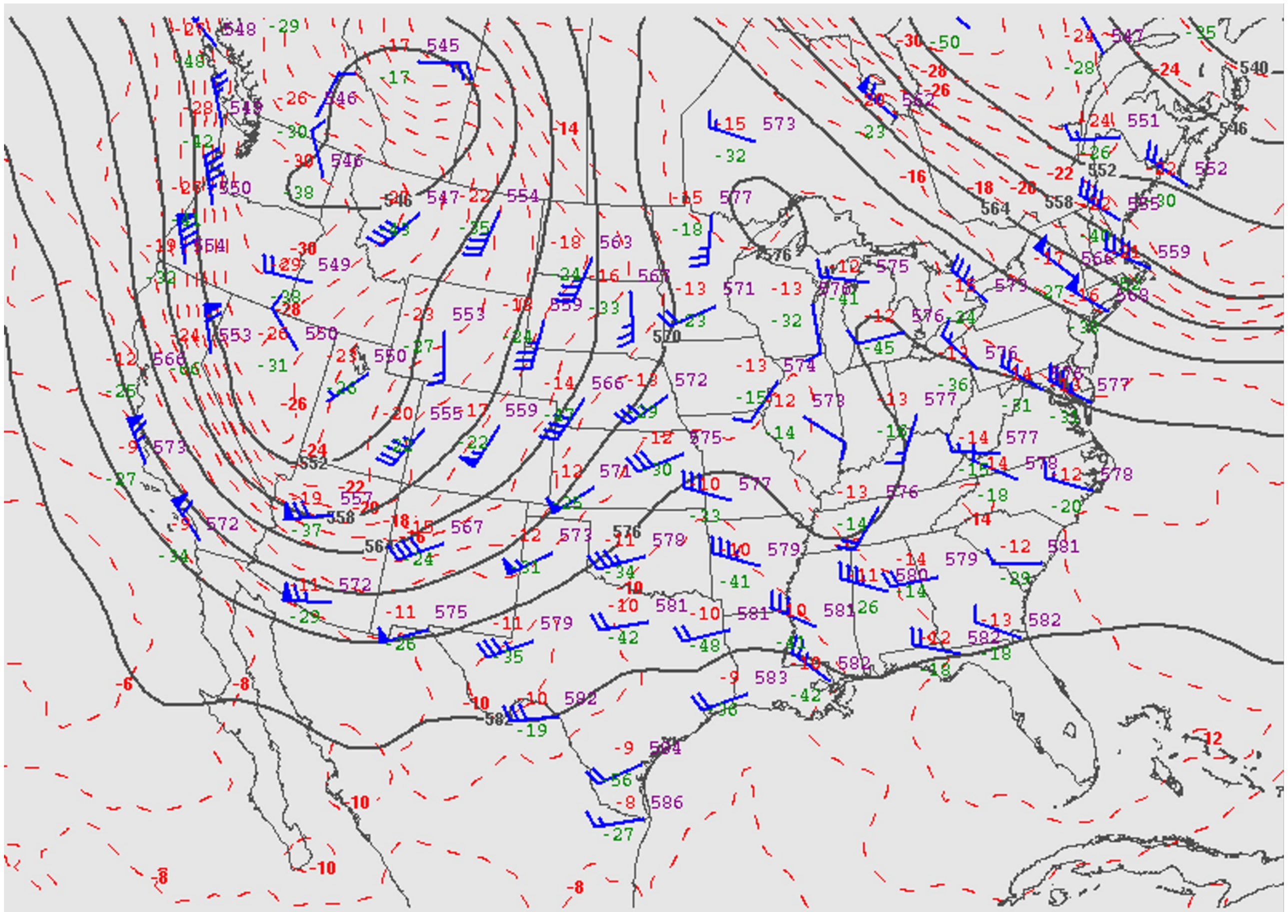
ΔZ small Zeta is also small little spin

- Conservation of Potential Vorticity
  - Assumptions:
    - Constant density/stable
    - Adiabatic
    - Frictionless
- Stretching of the column vertically requires an increase in relative vorticity between the theta surfaces inducing positive vorticity.
- Stretching also lowers the static stability of the atmosphere. easier to spin and lift

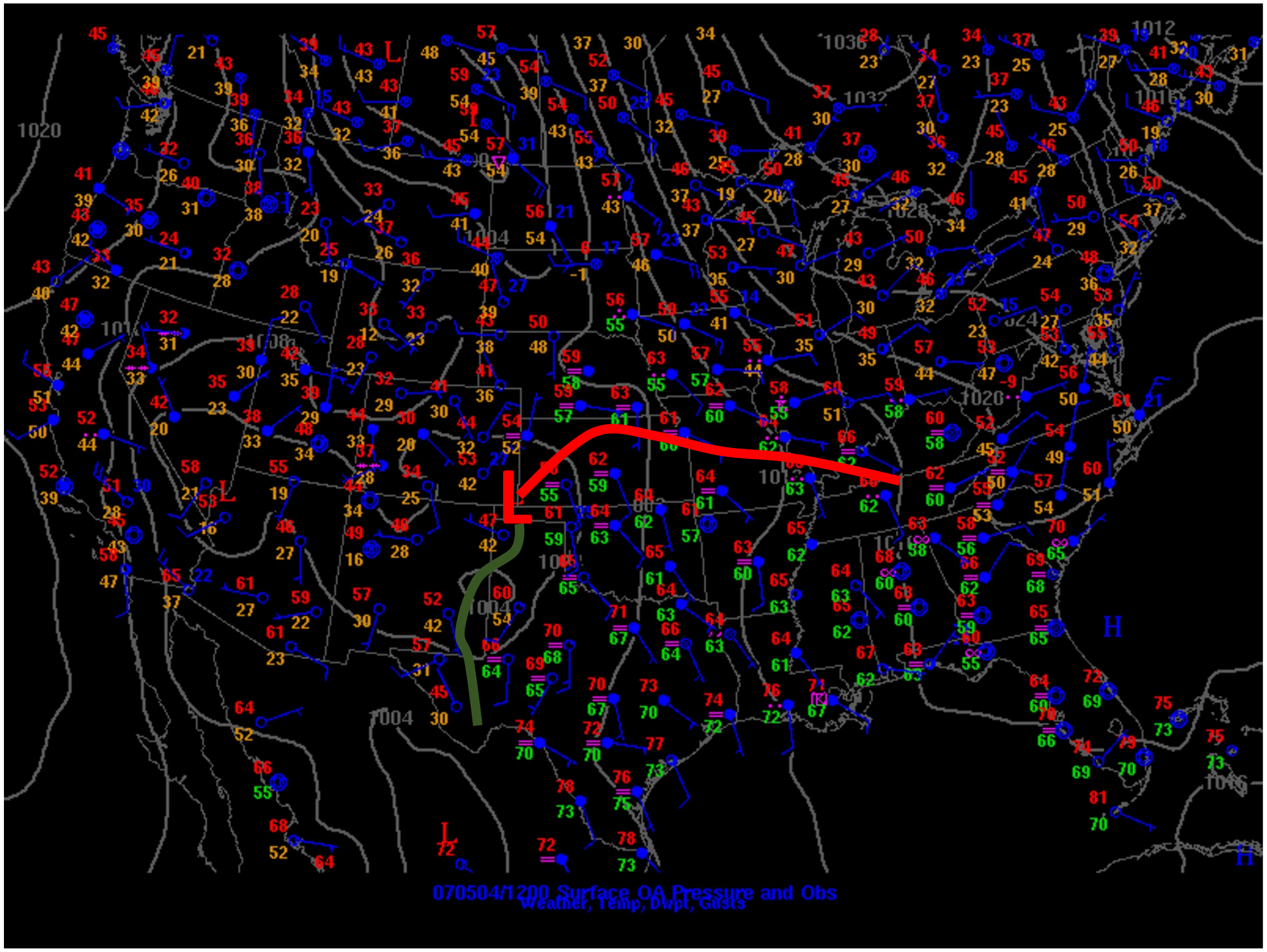


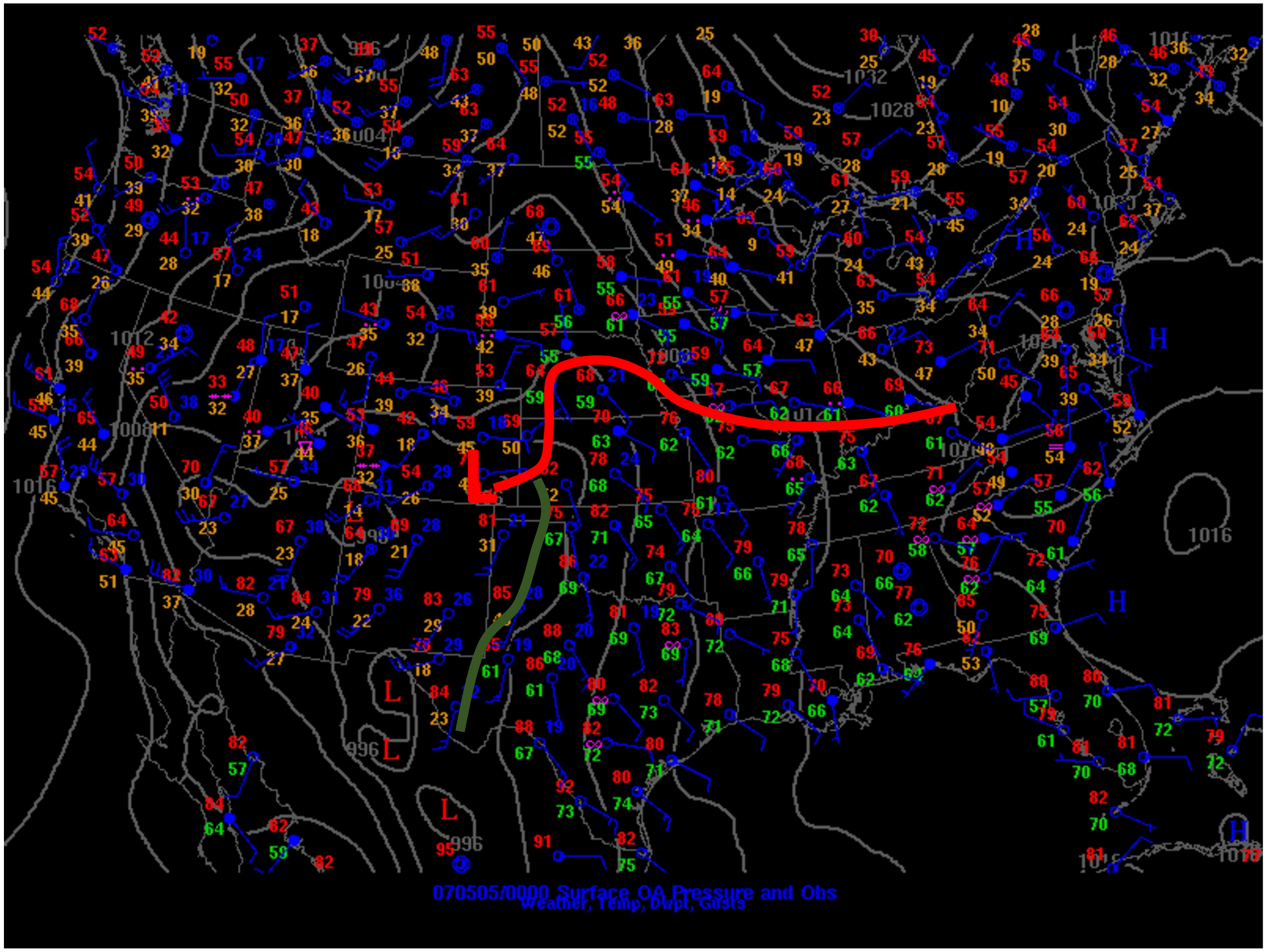


070504/1200 500 MB UA OBS, HGHTS, and TEMPS



070505/0000 500 MB UA OBS, HGHTS, and TEMPS


070504/1200 Surface OA Pressure and Obs
Weather, Temp, Dwpt, Gusts


070505/0000 Surface OA Pressure and Obs
Weather, Temp, Dwpt, Gusts

Nocturnal Low-Level Jet (LLJ)

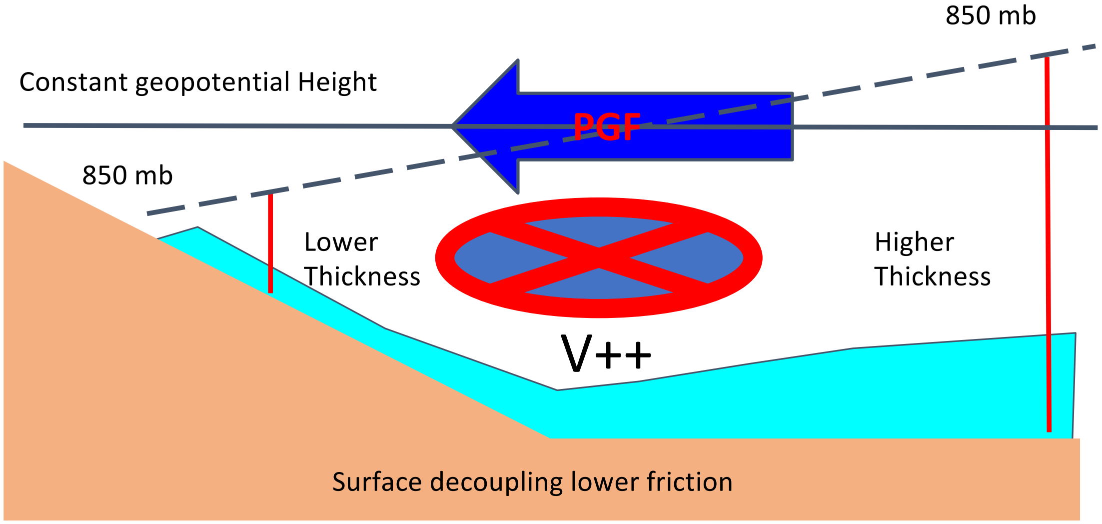
- **Plains often see early nocturnal low-level jet (LLJ) ramp up with lee cyclogenesis**

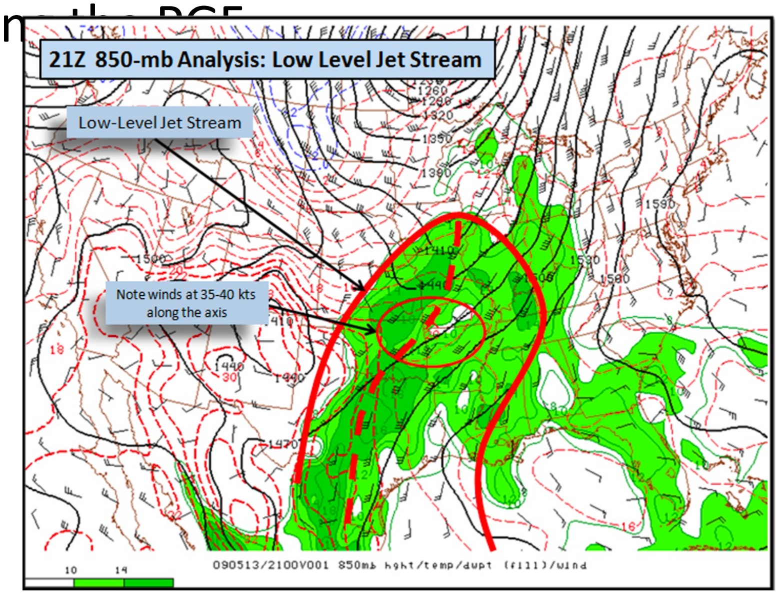
- **Related to two primary factors:**
  - **Boundary-layer decoupling and loss of surface friction (“inertial oscillation”)**
  - **Diurnal temperature variations over sloped terrain (thermal wind)**

- **Part of the process that can favor late evening/early overnight tornadoes (with favorable moisture/CAPE)**

Nocturnal Low-Level Jet (LLJ) Formation

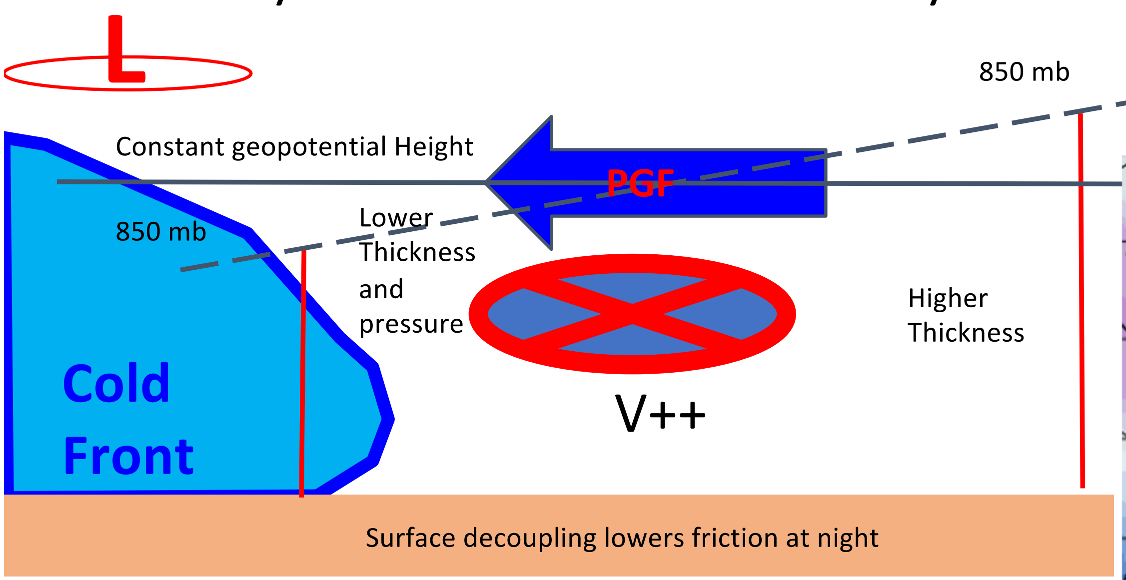
- LLJs form in response to difference in terrain heights, heat fluxes and thickness across pressure surfaces that induces a horizontal Pressure Gradient Force.
- Coriolis forcing turns the momentum northward resulting in an enhanced southerly flow.
- Surface decoupling favors lower friction and acceleration of the jet above the surface
- Lee Cyclones can also enhance it by increasing the PGF.

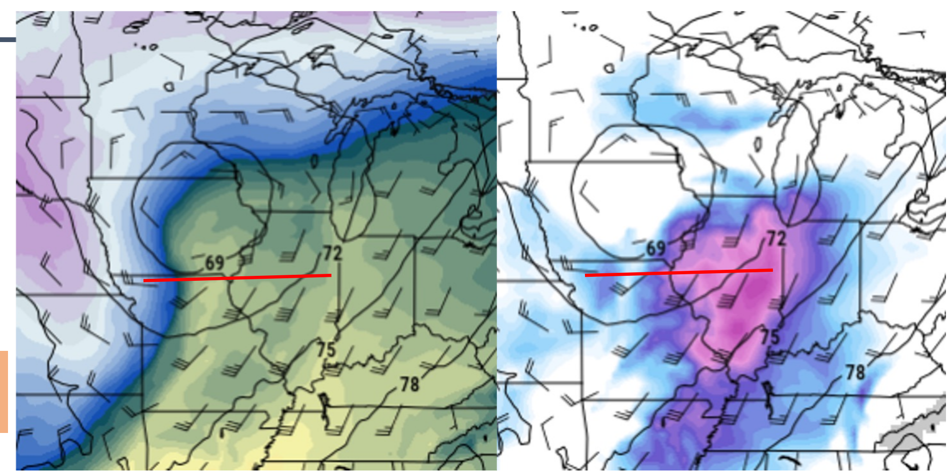




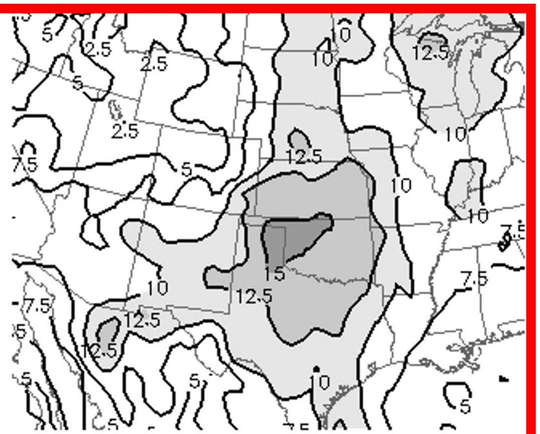
Cyclone induced Low-Level Jet (LLJ) Formation

- LLJs form in response to difference in heat fluxes and thickness across pressure surfaces that induces a horizontal Pressure Gradient Force.
- Coriolis forcing turns the momentum northward resulting in an enhanced southerly flow.
- Surface decoupling favors lower friction and acceleration of the jet above the surface
- Lee Cyclones can also enhance it by increasing the PGF.

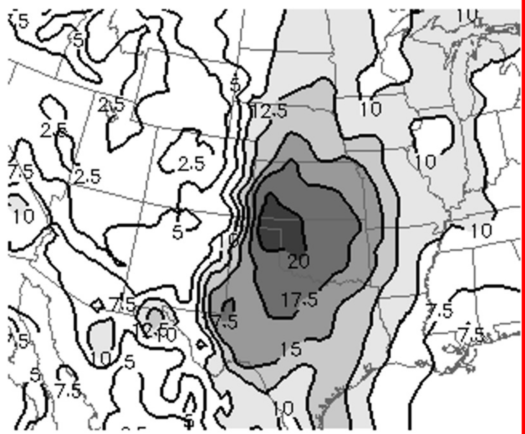




EF2+ supercell events

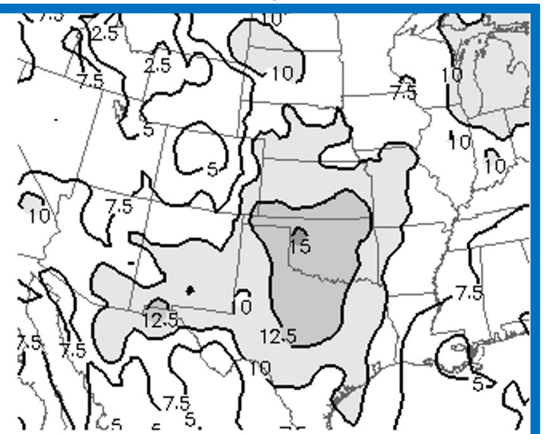


850 hPa isotachs at 0000 UTC (m s-1 SIGTOR)

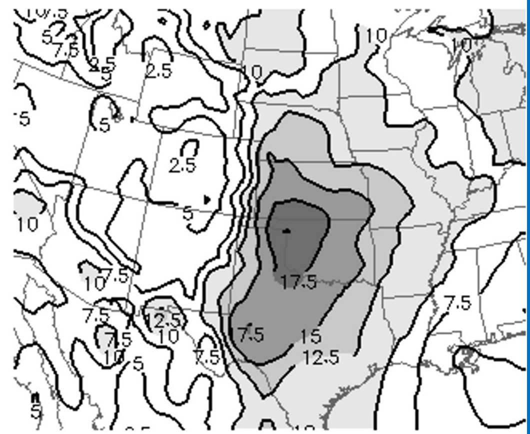


850 hPa isotachs at 0300 UTC (m s-1 SIGTOR)

Nontornadic supercell events



850 hPa isotachs at 0000 UTC (m s-1 NONTOR)



850 hPa isotachs at 0300 UTC (m s-1 NONTOR)

Lee Cyclogenesis Summary

- **Lee cyclogenesis occurs where upper-level flow is perpendicular to terrain features (westerly flow for Rockies)**
- **Lee cyclogenesis more robust with lower static stability**
- **Lee cyclone helps drive low-level moisture return AND vertical windshear (more later)**
- **Nocturnal low-level jet associated with lee cyclone is driven by inertial oscillation and thermal wind → increased low-level shear and tornado threat in evening and after dark if adequate CAPE**