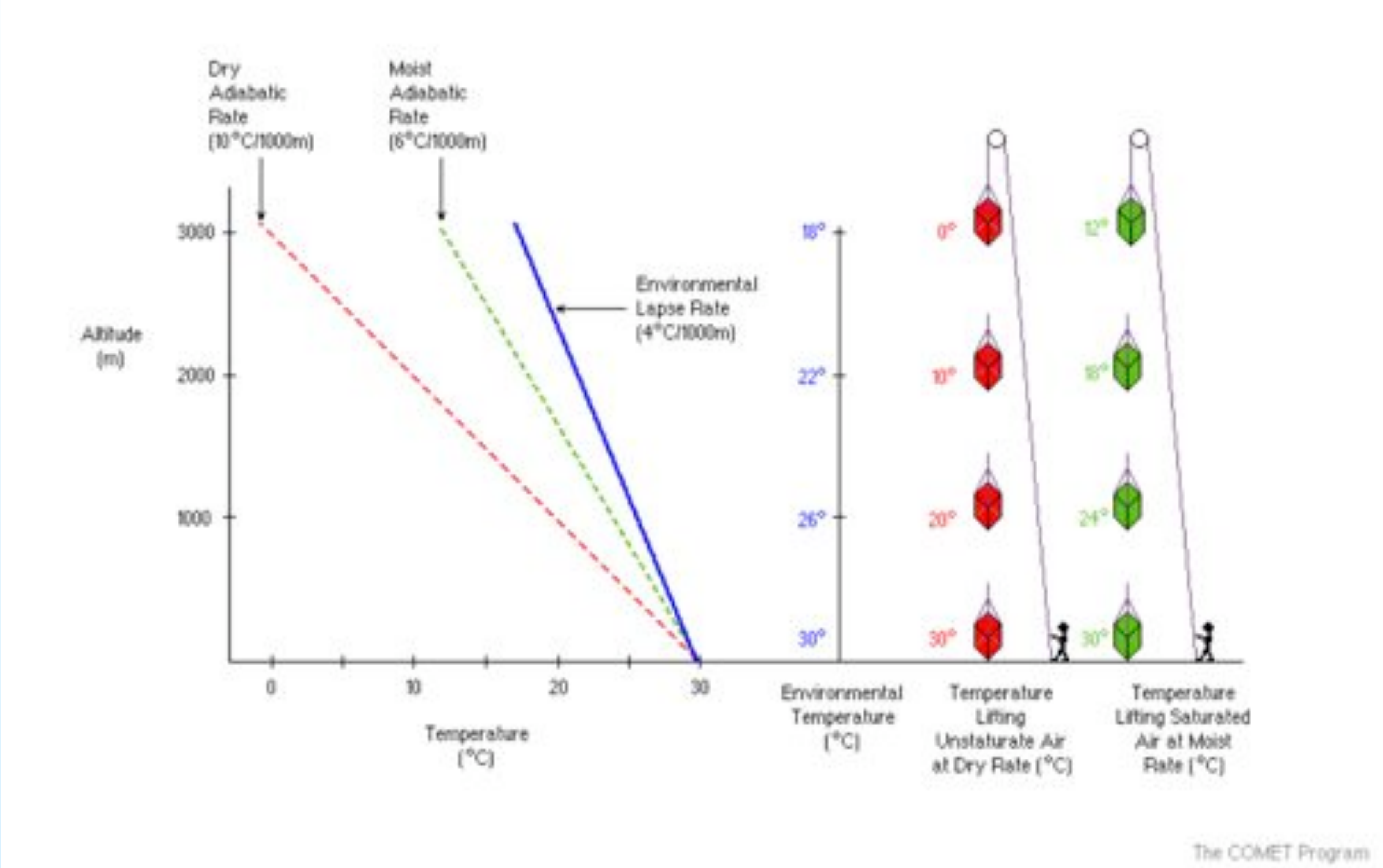
Warm season forecasting

Some material adapted from Material Produced
at COMET for their Residence
Course in Hydrometeorology

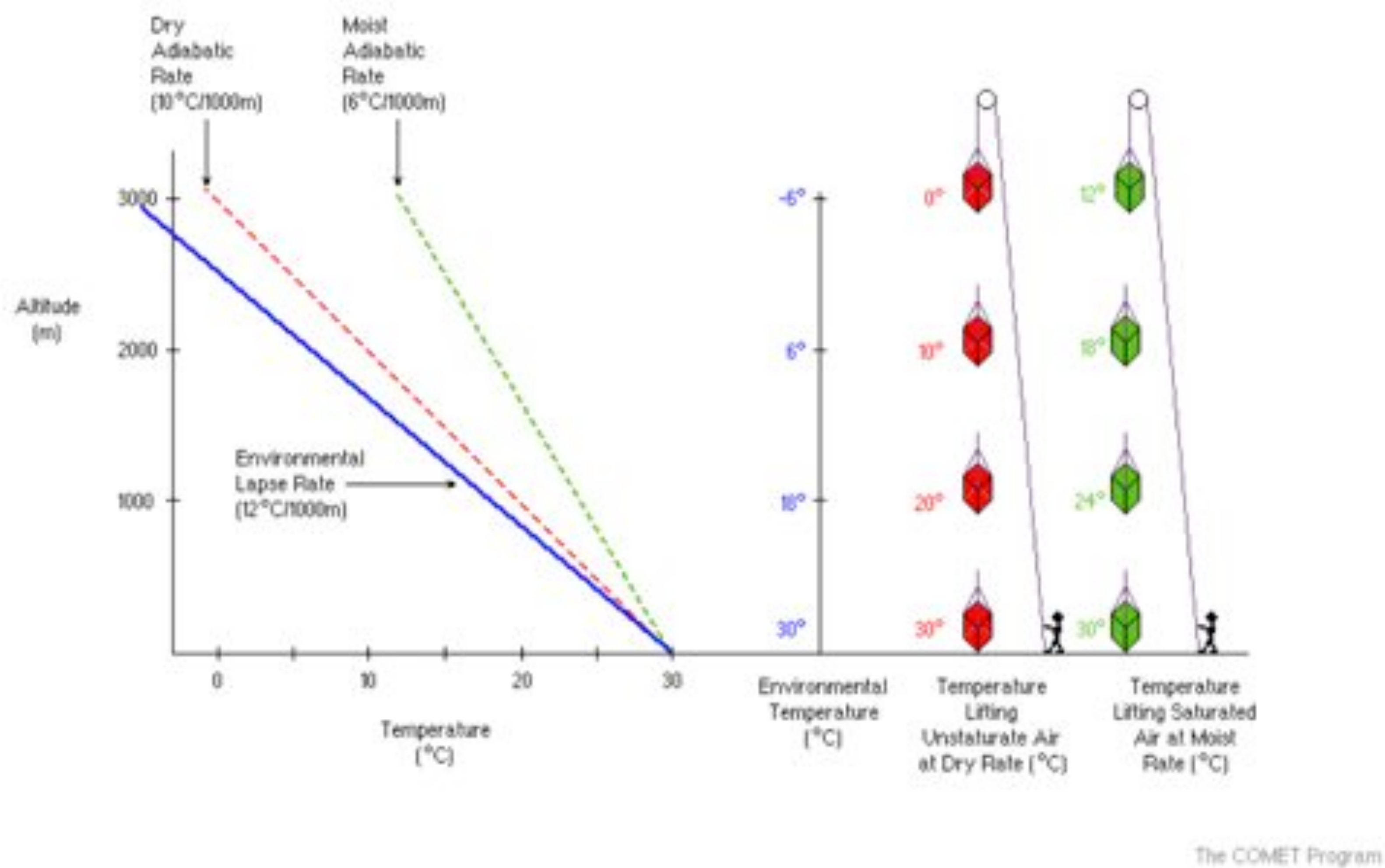
Outline

- Types of stability and application to forecasting
- Dry and moist adiabatic processes
- Skew-T Log-P diagrams, instability diagnostics
- Types of hazards and techniques to forecast them

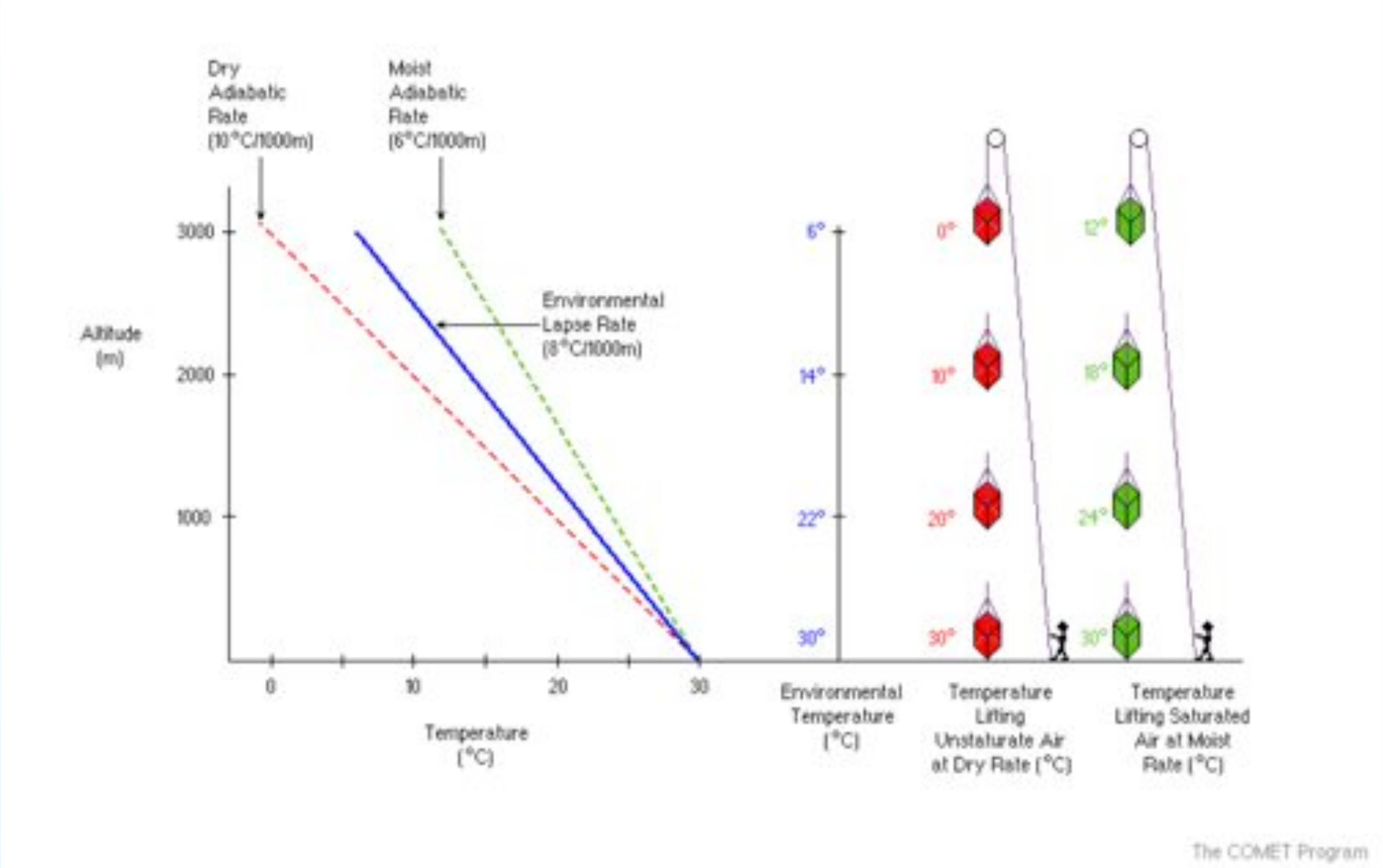
Absolutely Stable



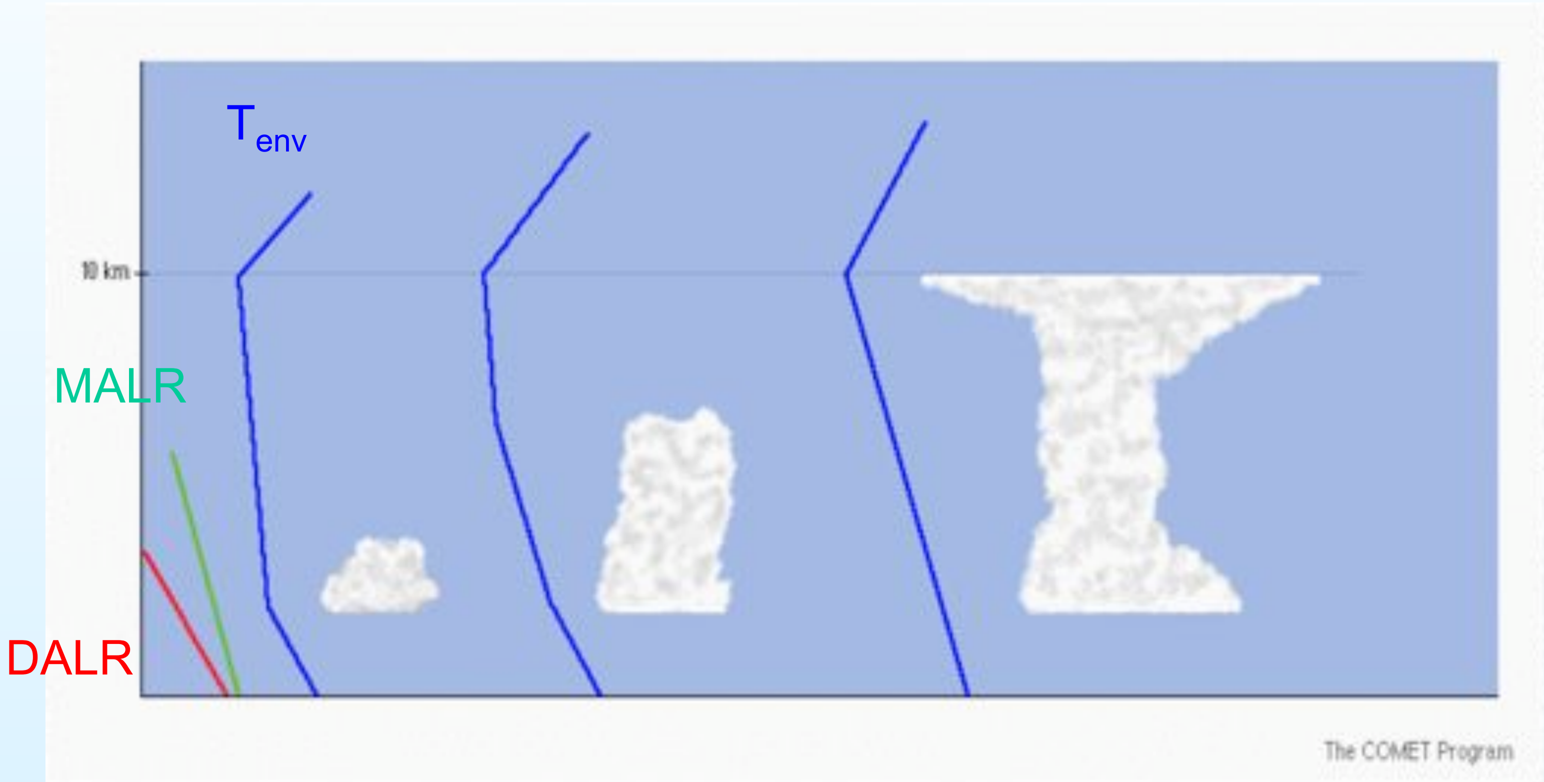
Absolutely Unstable



Conditionally Unstable

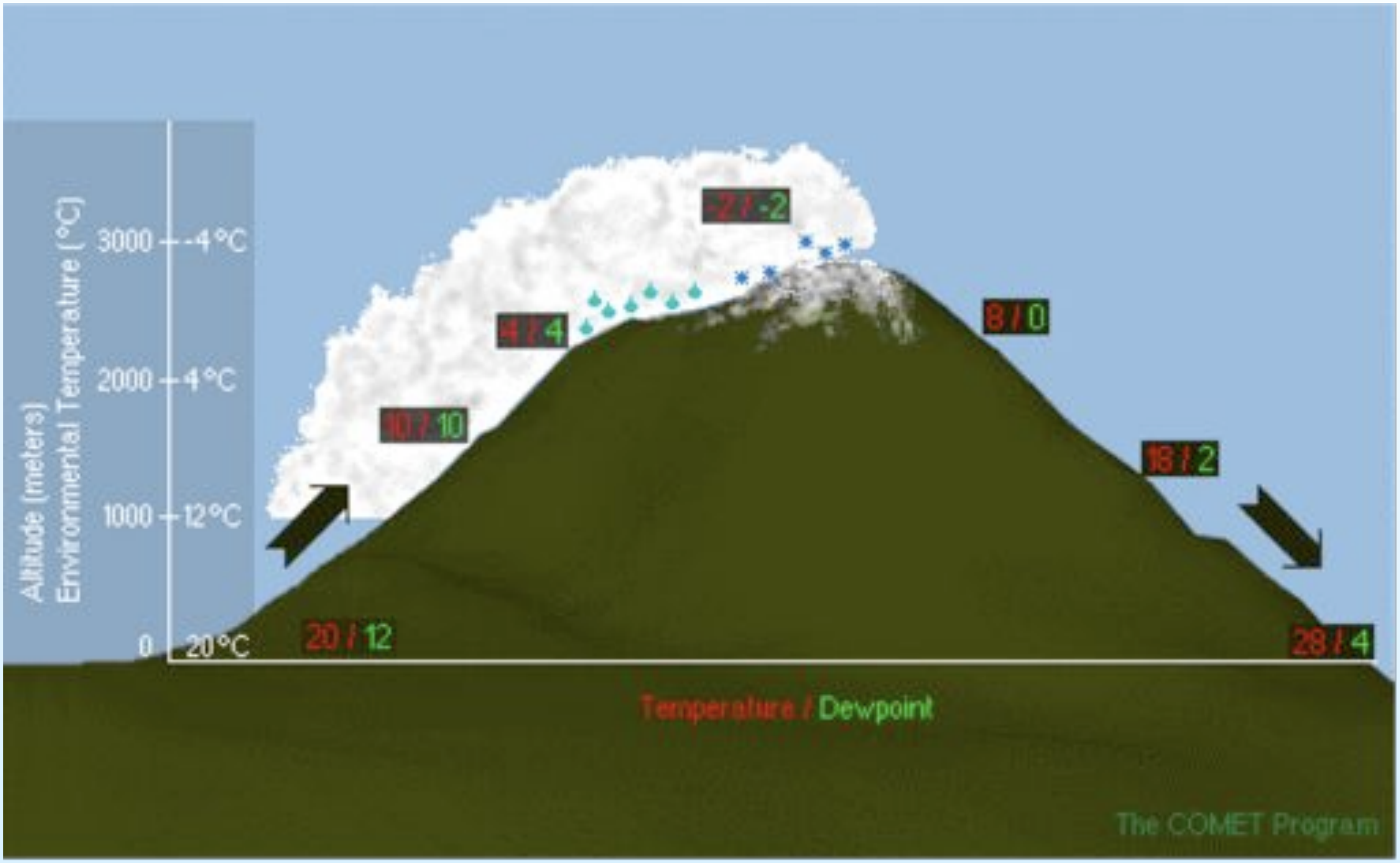


Growth of a Thunderstorm



Towards a moist adiabatic profile

Effects of Orography



Thermodynamic Diagrams

A thermodynamic diagram is a graph that shows the relationship between five atmospheric properties:

- Pressure (millibars)
- Temperature (C)
- Potential temperature (C – must be converted to K)
- Equivalent Potential Temperature (C – must be converted to K)
- Saturation Mixing Ratio (g/kg)

Since pressure rapidly decreases with altitude, thermodynamic diagrams are used most commonly to display vertical profiles of atmospheric properties, as measured with rawinsondes.

Wind speed and direction are also displayed as separate variables

Thermodynamic diagrams

Allow meteorologists to determine and quantify:

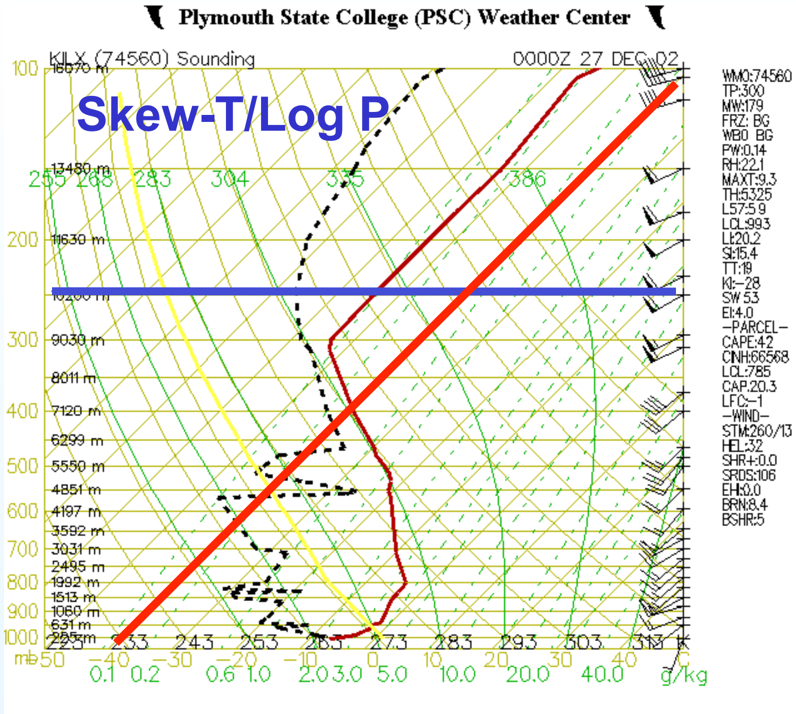
1) Atmospheric Stability
2) Cloud layers
3) Height of the tropopause
4) Cloud top temperatures
5) Frontal zones
6) Vertical wind shear
7) Helicity
8) Location of inversions
9) Precipitation type
10) Height of the freezing level
11) Locations of upper level fronts

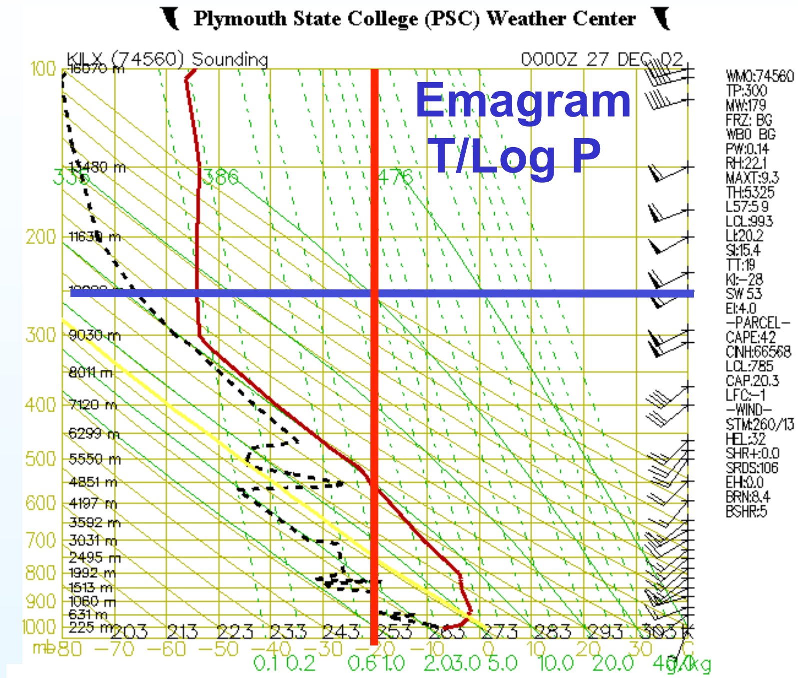
Thermodynamic diagrams

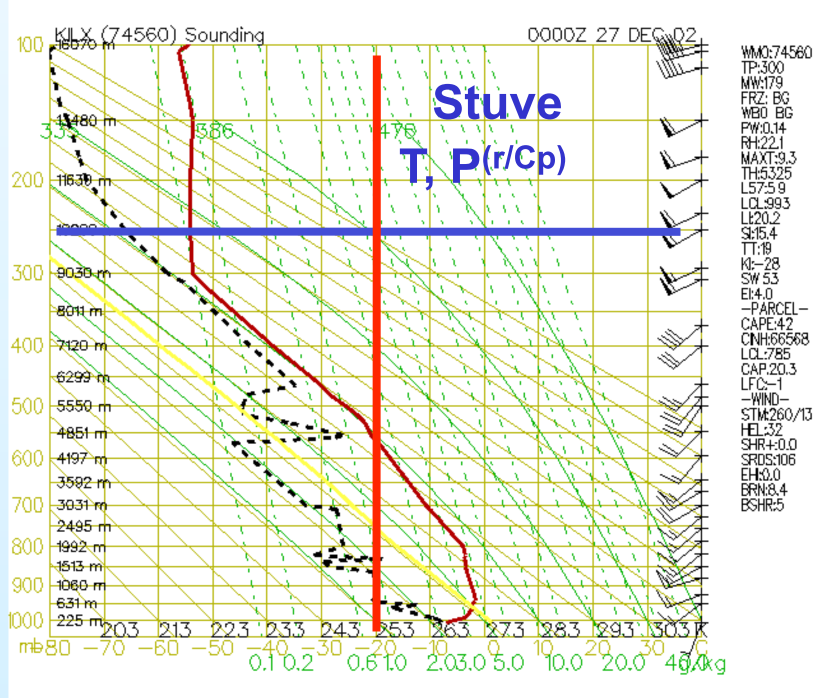
Emagram
Tephigram
Stuve Diagram
Skew-T Log P diagram

- All express the same physical (thermodynamic) relationships
- All show isobars, isotherms, saturation mixing ratio lines dry adiabats, and saturation adiabats.

Difference between these diagrams is the choice and orientation of the two fundamental coordinates, which can be any of the five variables or variants of them.







Three common diagrams used in the United States are:

The Skew-T/Log-P
The Emagram
The Stuve Diagram

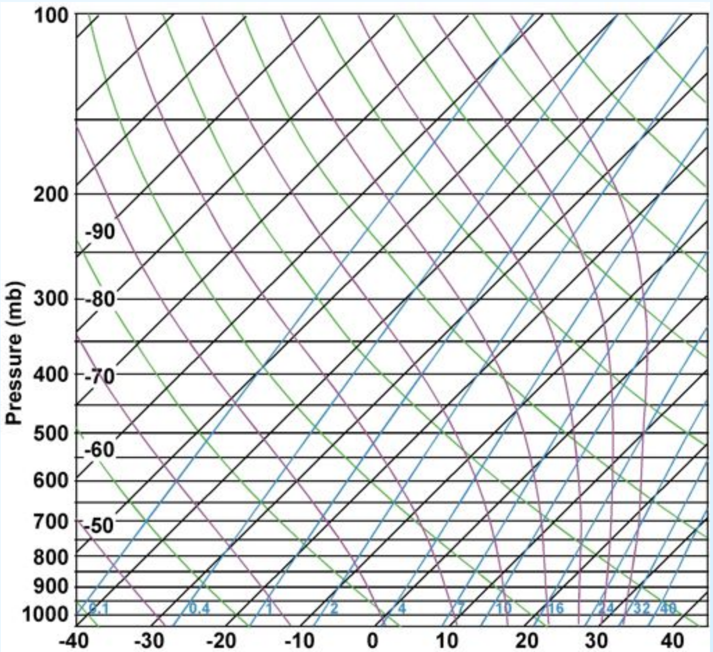
Desirable Properties of a thermodynamic diagram:

- Area on diagram proportional to energy
- As many lines representing basic processes should be ~straight
- Vertical coordinate proportional to height
- Dry adiabats should be at near right angles to isotherms
- Saturation adiabats should be at large angle to dry
- adiabats in lower atmosphere

•The Skew T-Log P diagram was selected by the Air Weather Service as the most convenient thermodynamic diagram for general use.

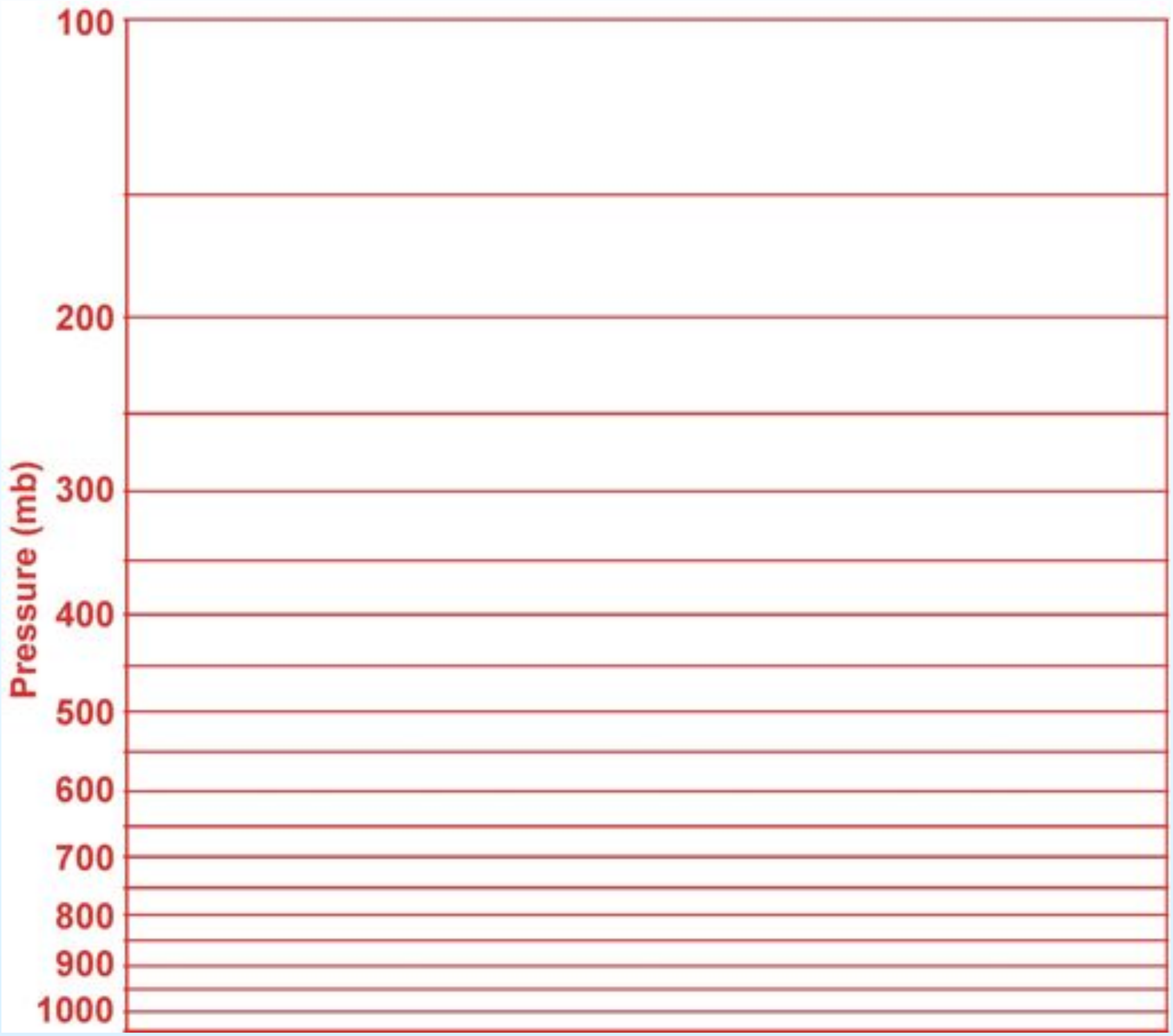
• The most commonly used diagram in the United States.

• Current soundings, model soundings, and archived soundings are available in Skew-T Log-P form at several websites and in analysis programs such as GARP.

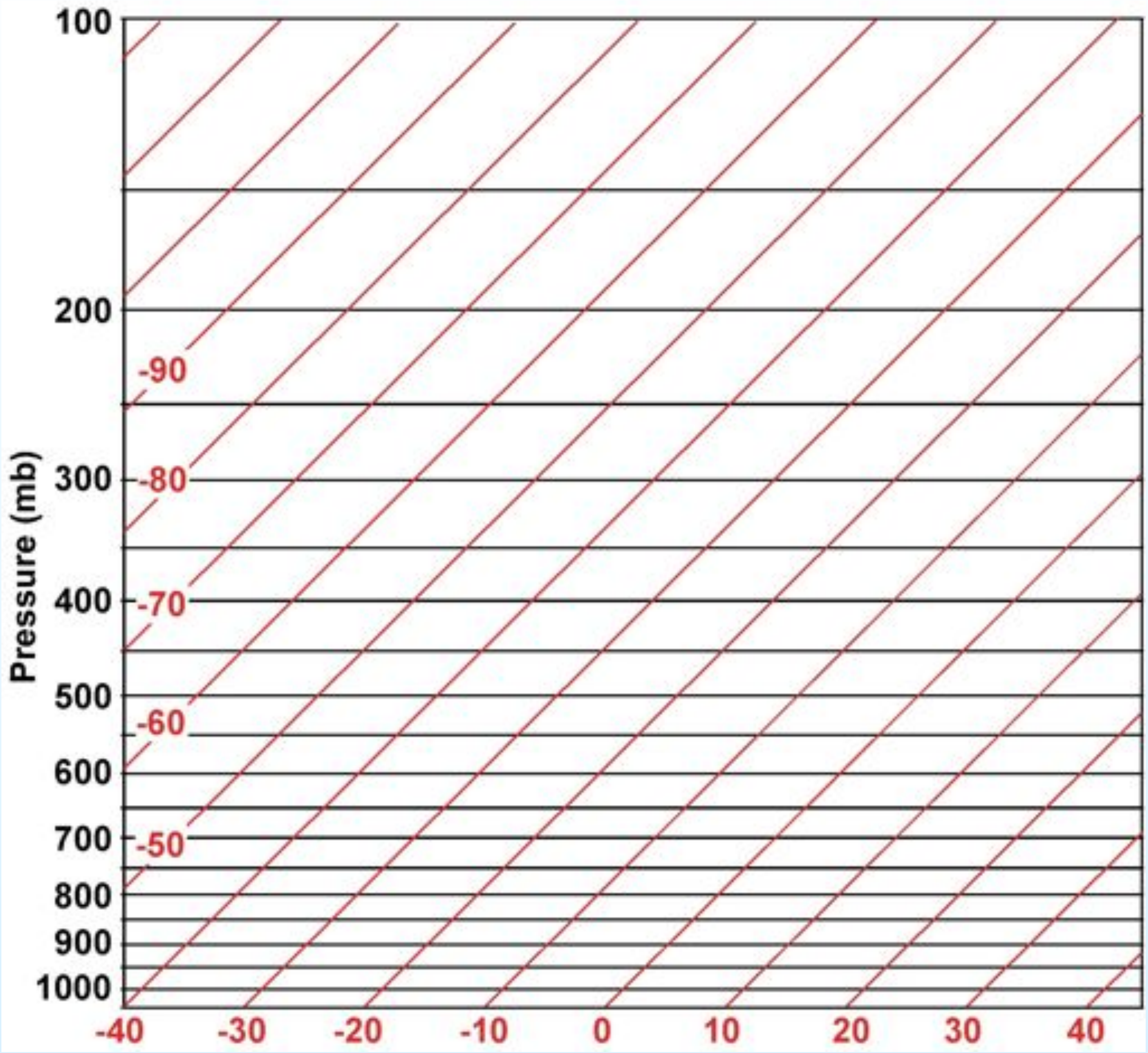


Pressure (mb) is the vertical coordinate on a Skew T-Log P

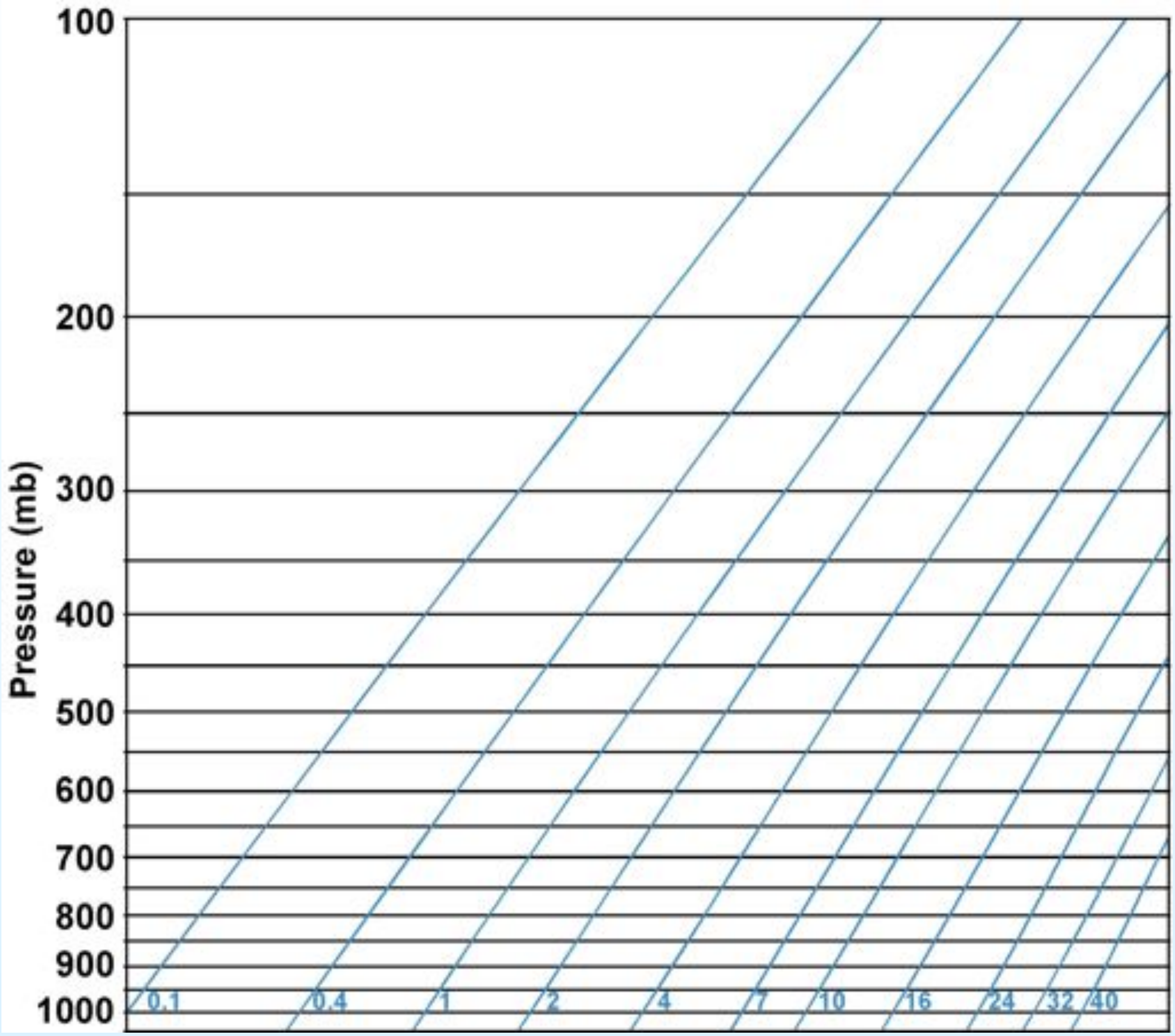
Note that pressure is scaled logarithmically – making the diagram correspond to the atmosphere

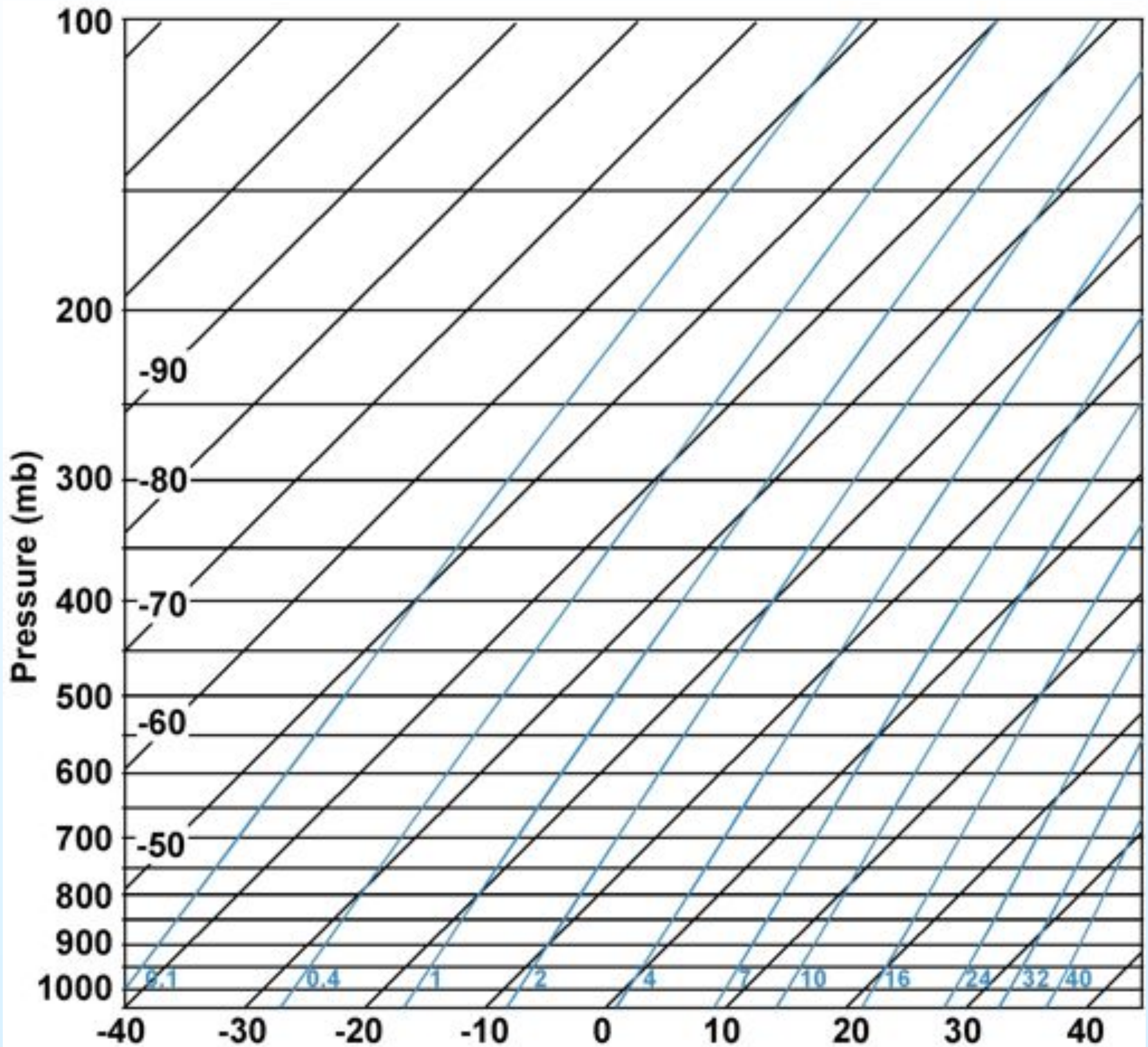


Temperature lines are skewed and labeled in Celsius

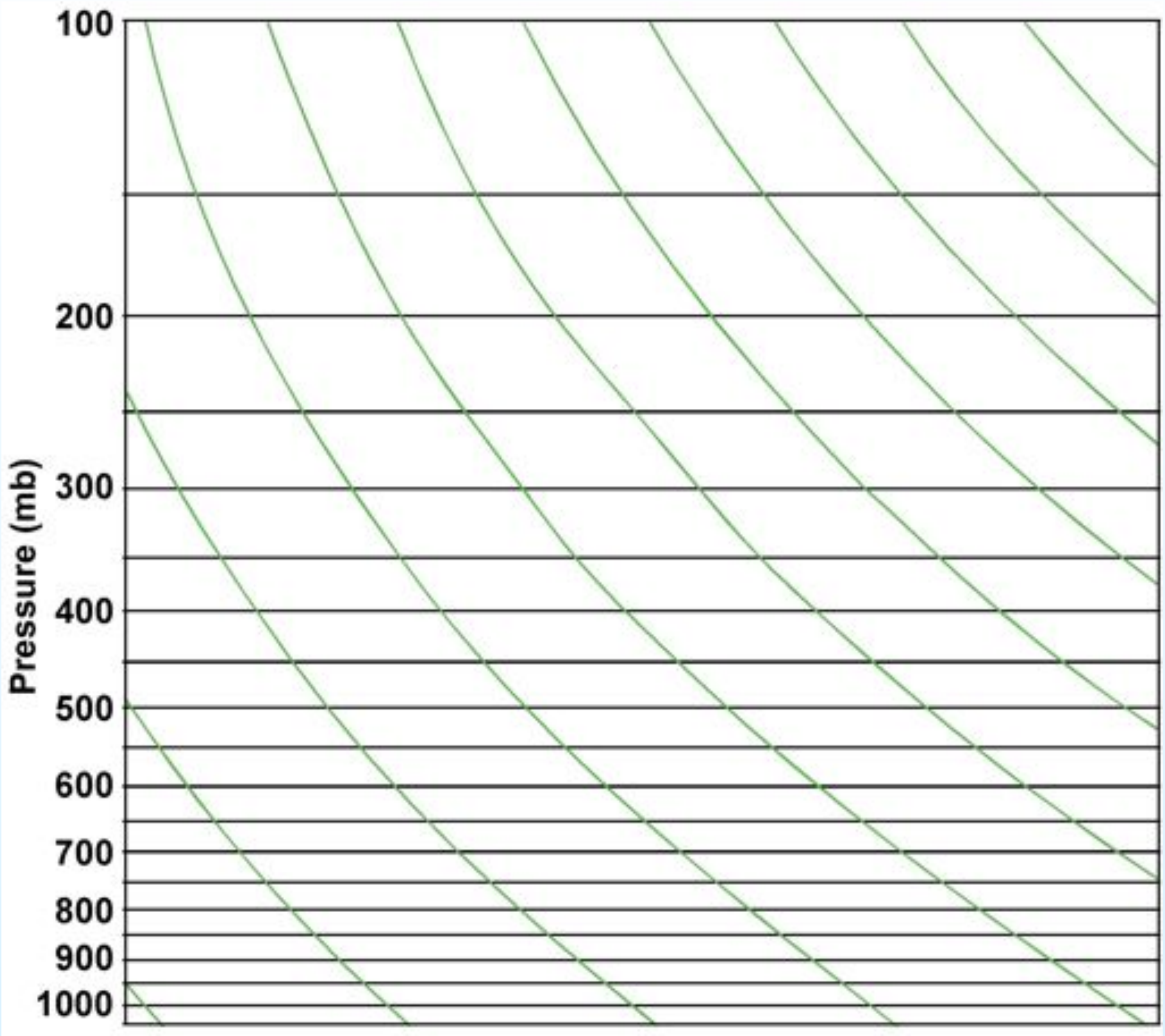


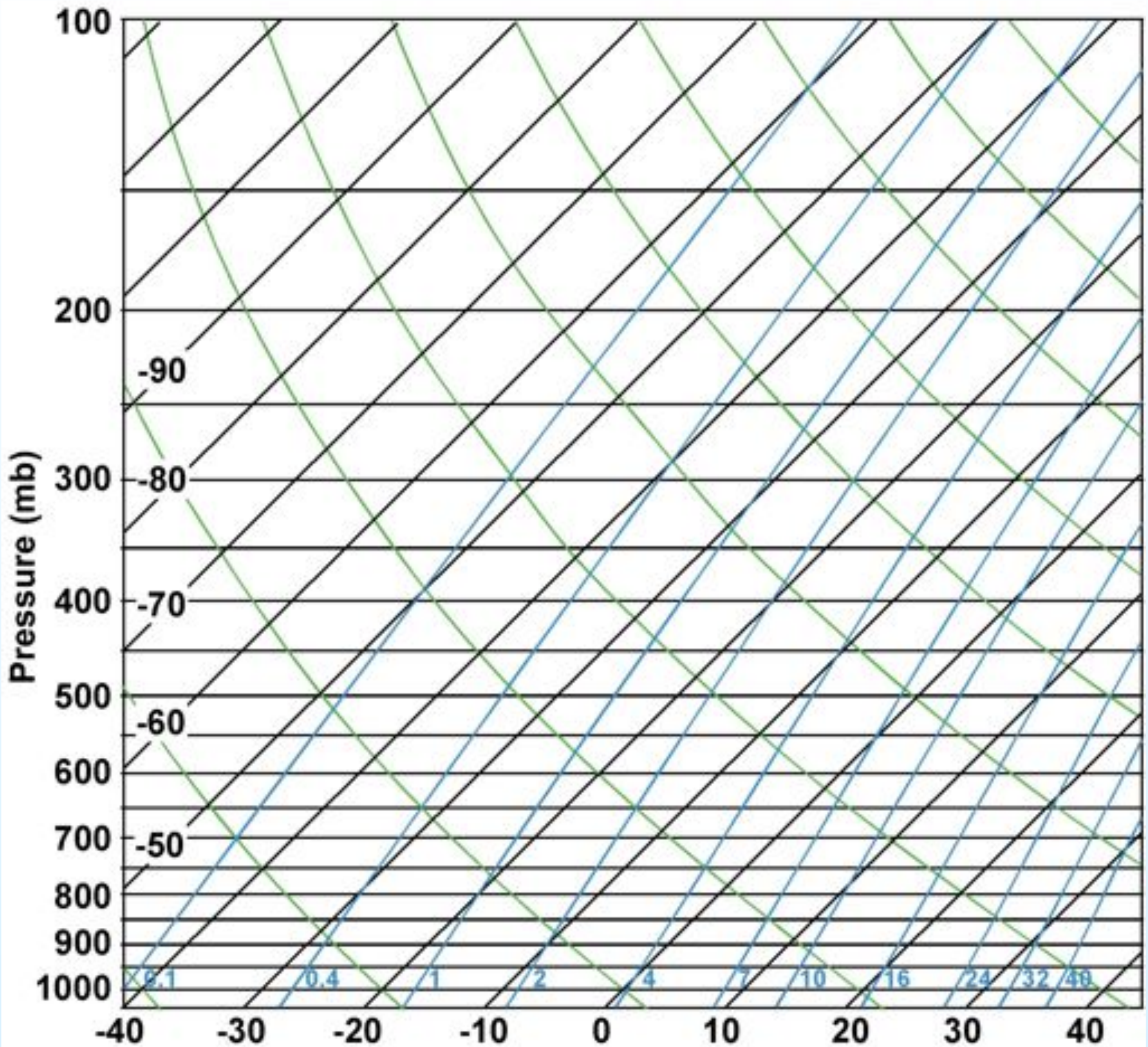
Saturation mixing ratio lines, labeled in g/kg




100
200
300
400
500
600
700
800
900
1000
Pressure (mb)
-90
-80
-70
-60
-50
0.1
0.4
1
2
4
7
10
16
24
32
40
-40
-30
-20
-10
0
10
20
30
40

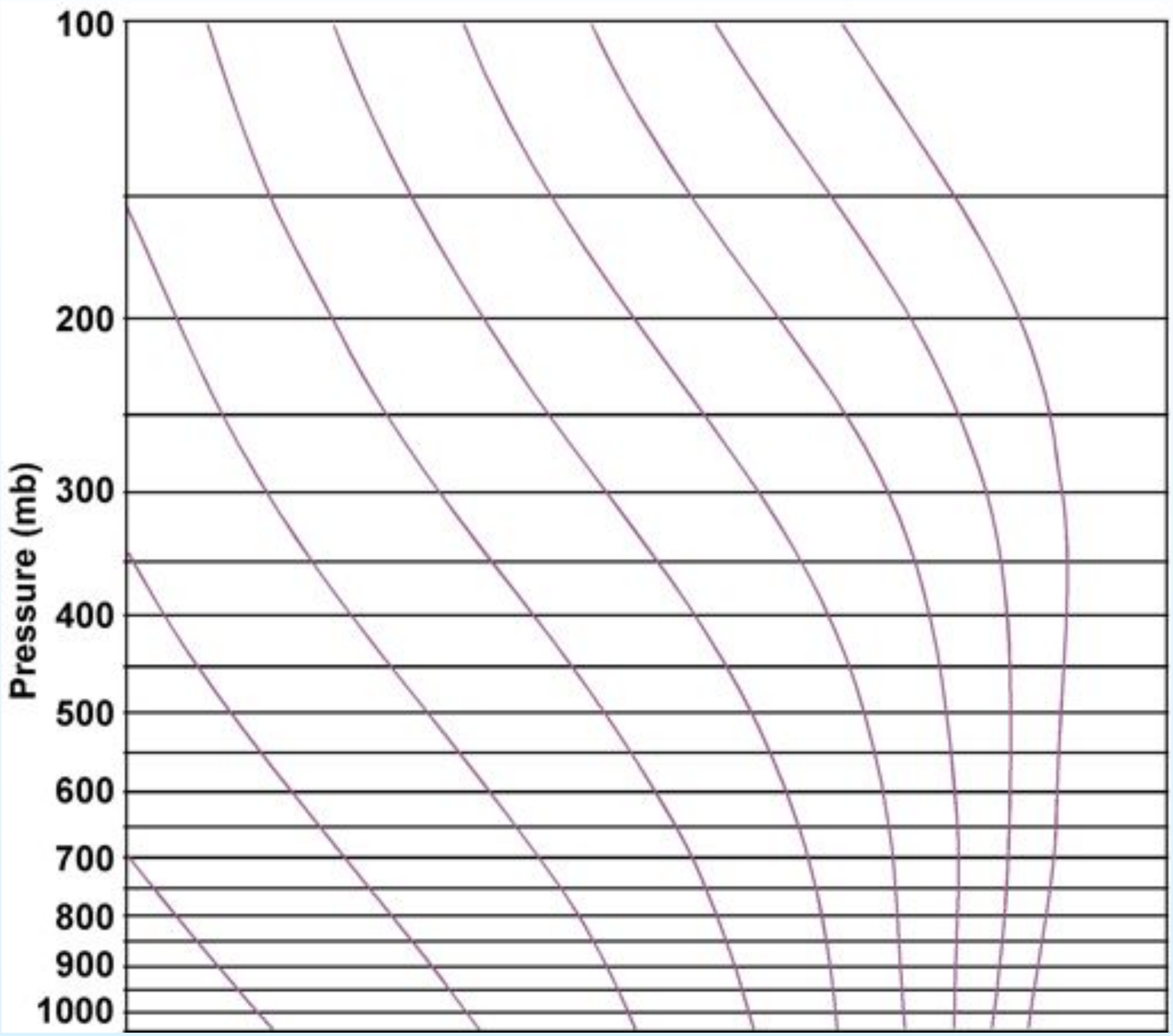
Dry adiabats: indicate rate of change of temperature of a parcel of air ascending or descending dry adiabatically



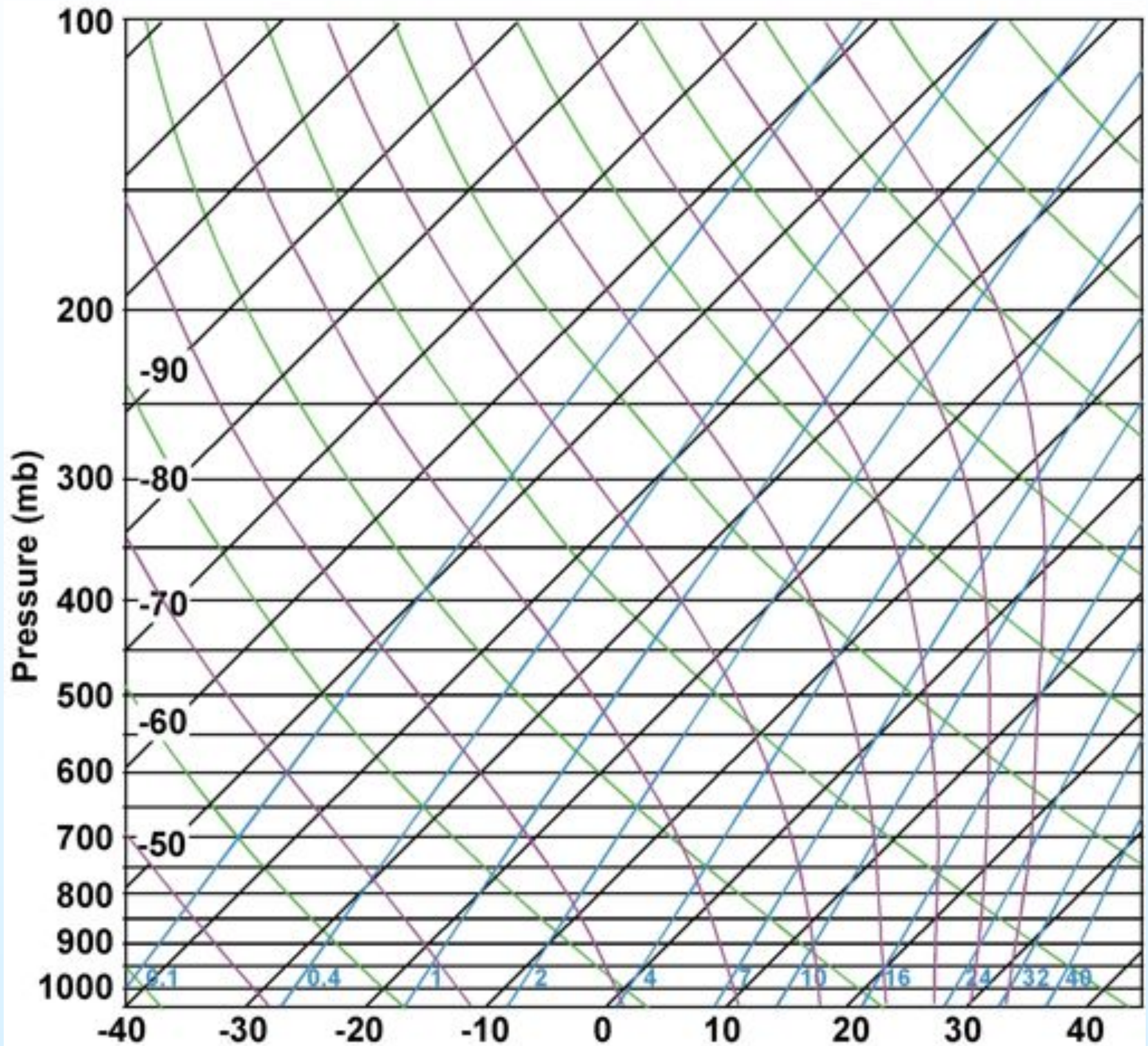


Pressure (mb)
100
200
300
400
500
600
700
800
900
1000
-90
-80
-70
-60
-50
0.1
0.4
1
2
4
7
10
16
24
32
40
-40
-30
-20
-10
0
10
20
30
40

Saturation Adiabats: the path that a saturated air parcel follows as it rises pseudo-moist-adiabatically through the atmosphere.

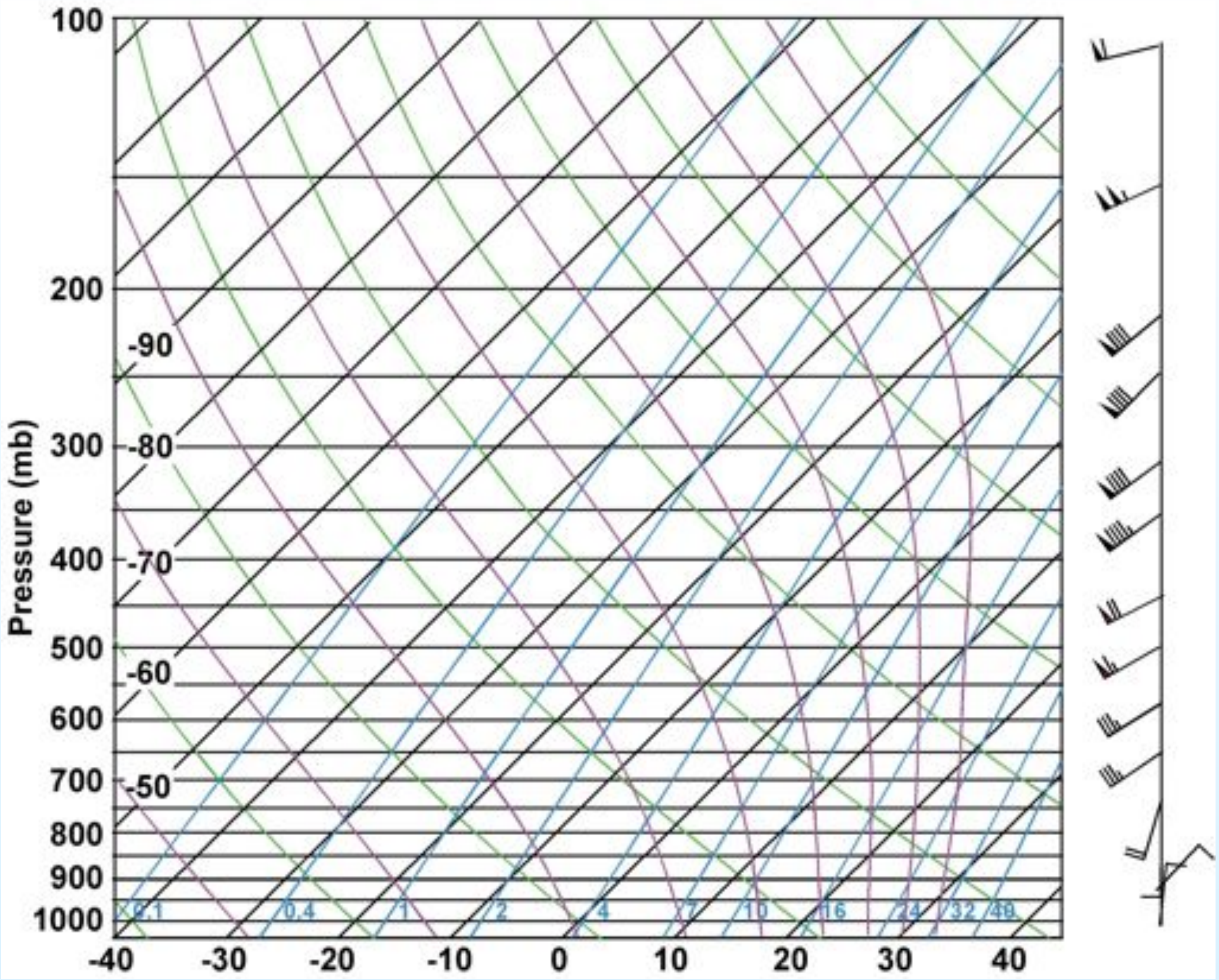


Pseudo-moist-adiabatically: All condensed moisture immediately precipitates from parcel.
Moist adiabatically: All condensed moisture remains in parcel.

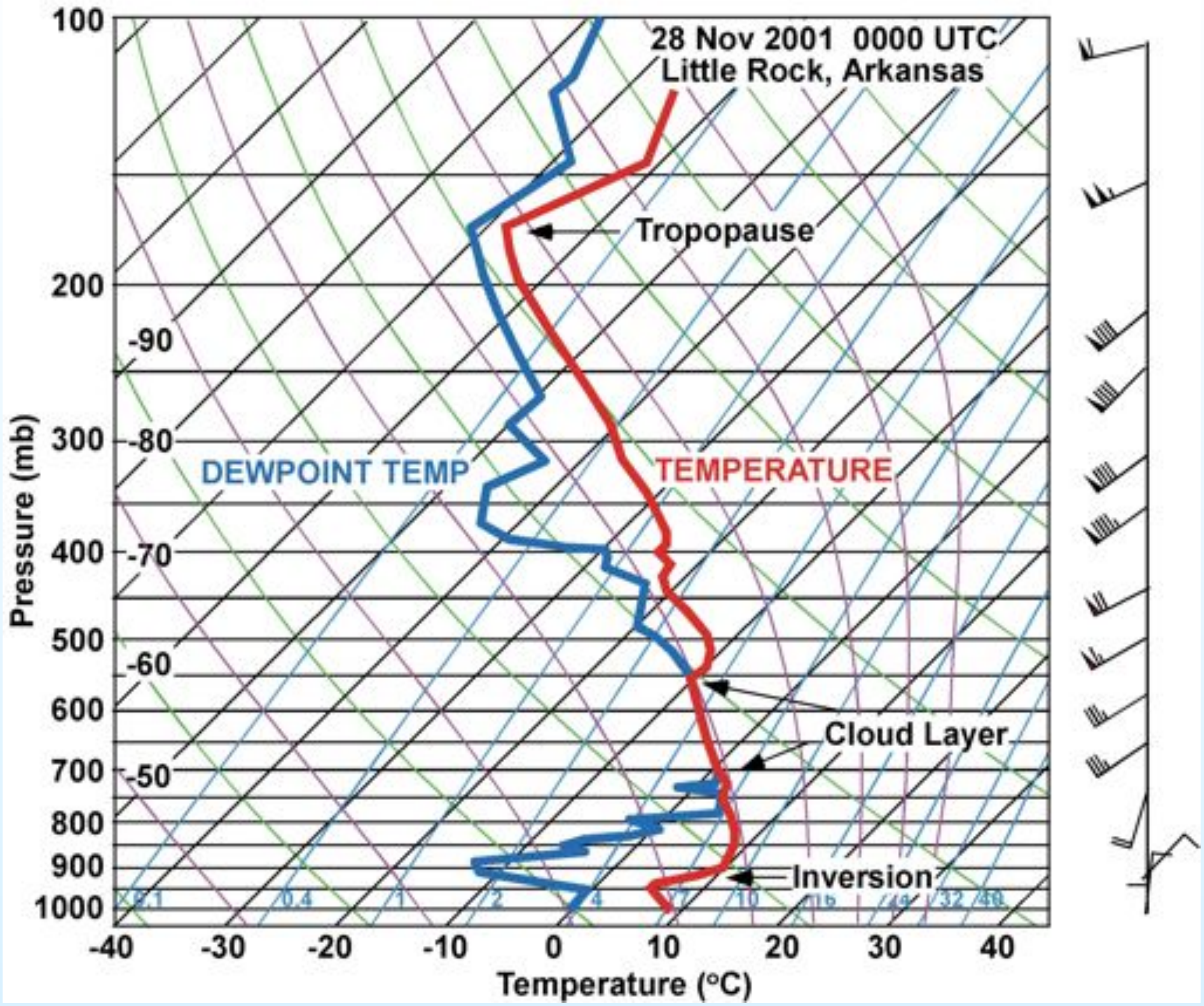


100
200
300
400
500
600
700
800
900
1000
Pressure (mb)
-90
-80
-70
-60
-50
0.1
0.4
1
2
4
7
10
16
24
32
40
-40
-30
-20
-10
0
10
20
30
40

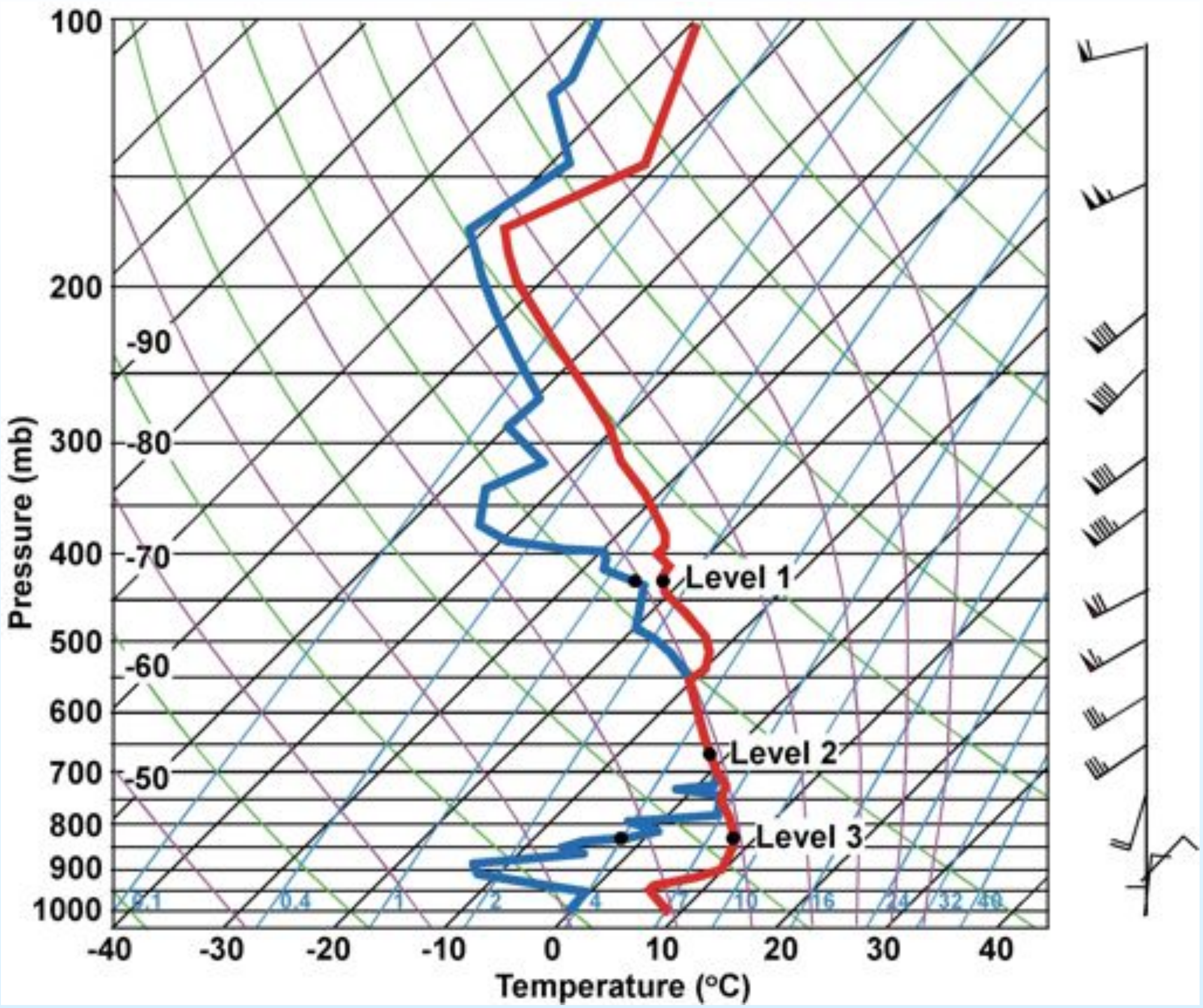
Winds are plotted in standard staff/barb format on the line to the right of the diagram



Temperature/Dewpoint temperature from a sounding are plotted as two lines on a Skew-T



Many other thermodynamic properties of the atmosphere can be determined from a Skew-T Log-P diagram



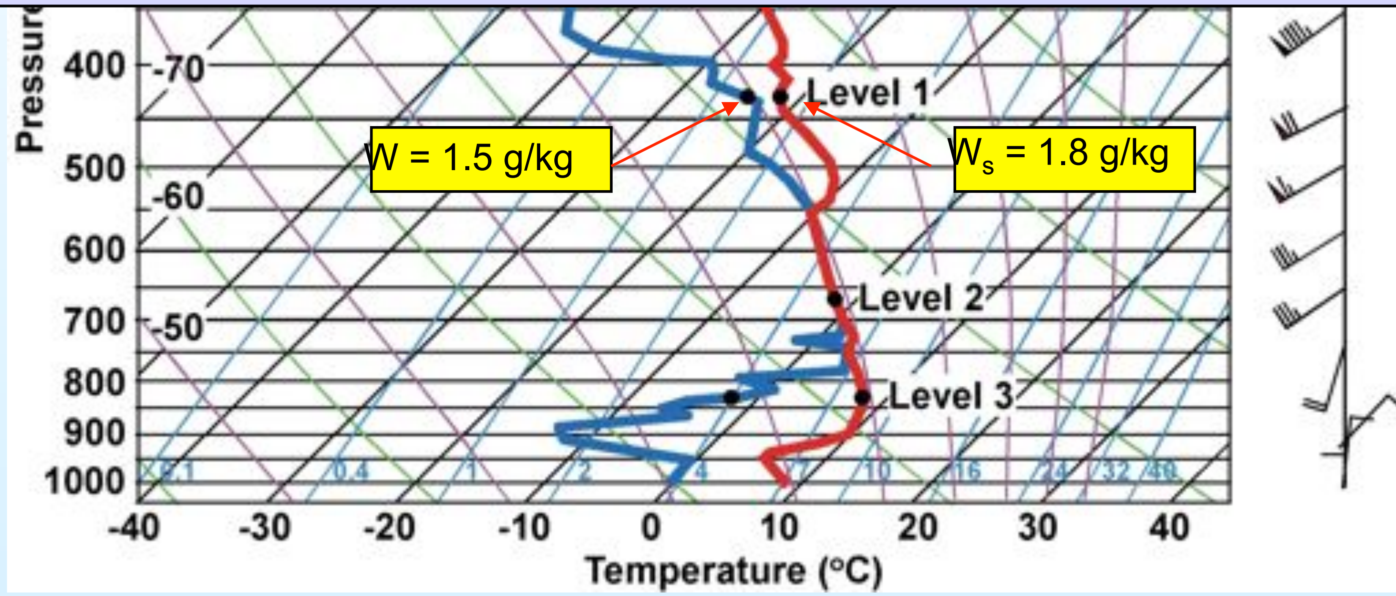
100
200
300
400
500
600
700
800
900
1000
-90
-80
-70
-60
-50
Pressure (mb)
Level 1
Level 2
Level 3
-40
-30
-20
-10
0
10
20
30
40
Temperature (°C)

Mixing ratio (w): ratio of the mass of water (M_v) to the mass of dry air (M_d) in a sample of air.

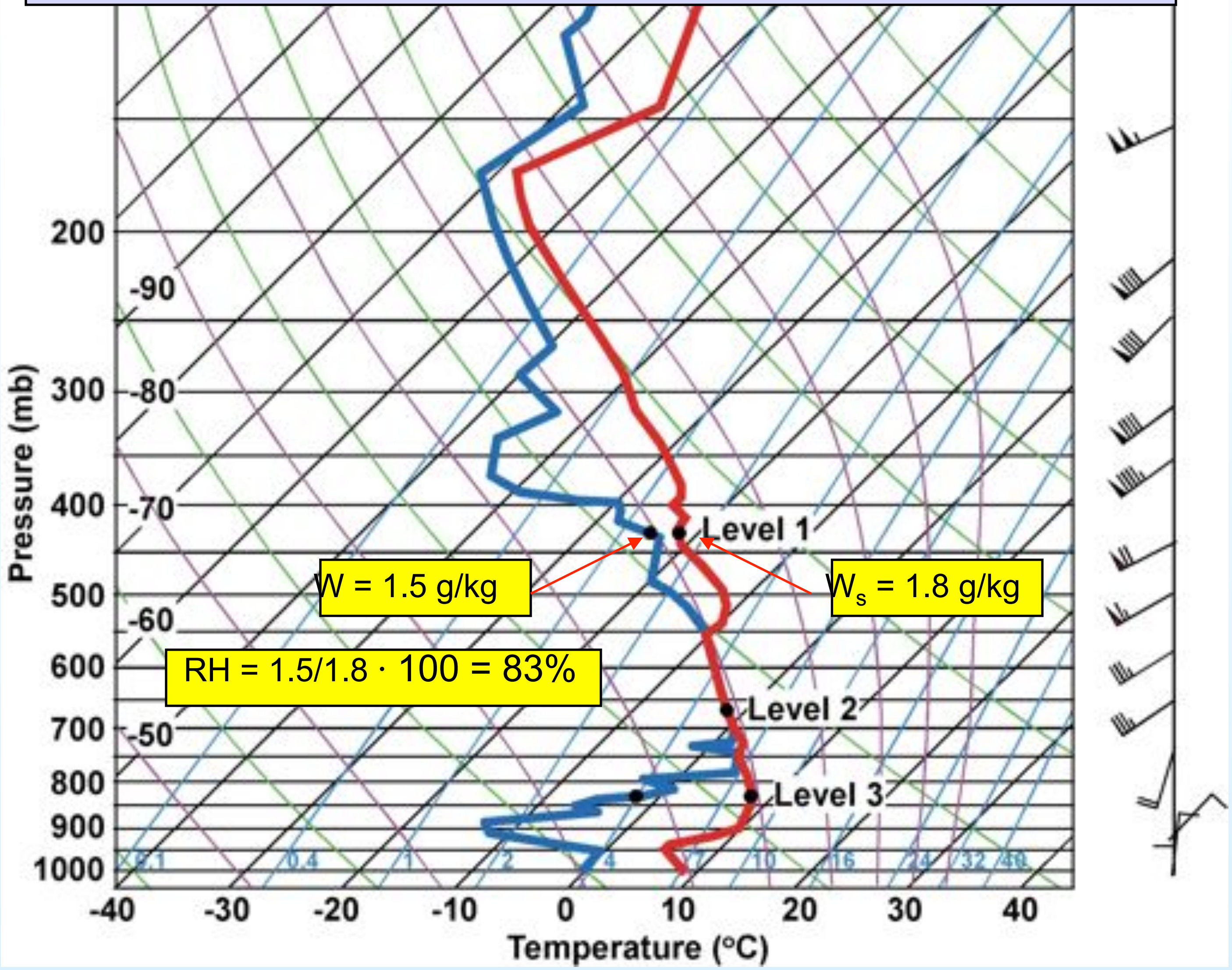
ON THE SKEW-T: READ VALUE, EITHER DIRECTLY OR BY INTERPOLATION, OF THE SATURATION MIXING RATIO LINE THAT CROSSES T_D CURVE.

Saturation mixing ratio (w_s): The mixing ratio a sample of air would have if it were saturated

ON THE SKEW-T: READ VALUE, EITHER DIRECTLY OR BY INTERPOLATION, OF THE SATURATION MIXING RATIO LINE THAT CROSSES T CURVE.



Relative Humidity (RH): ratio of the mixing ratio to the saturation mixing ratio · 100% (RH = $w/w_s \cdot 100$).

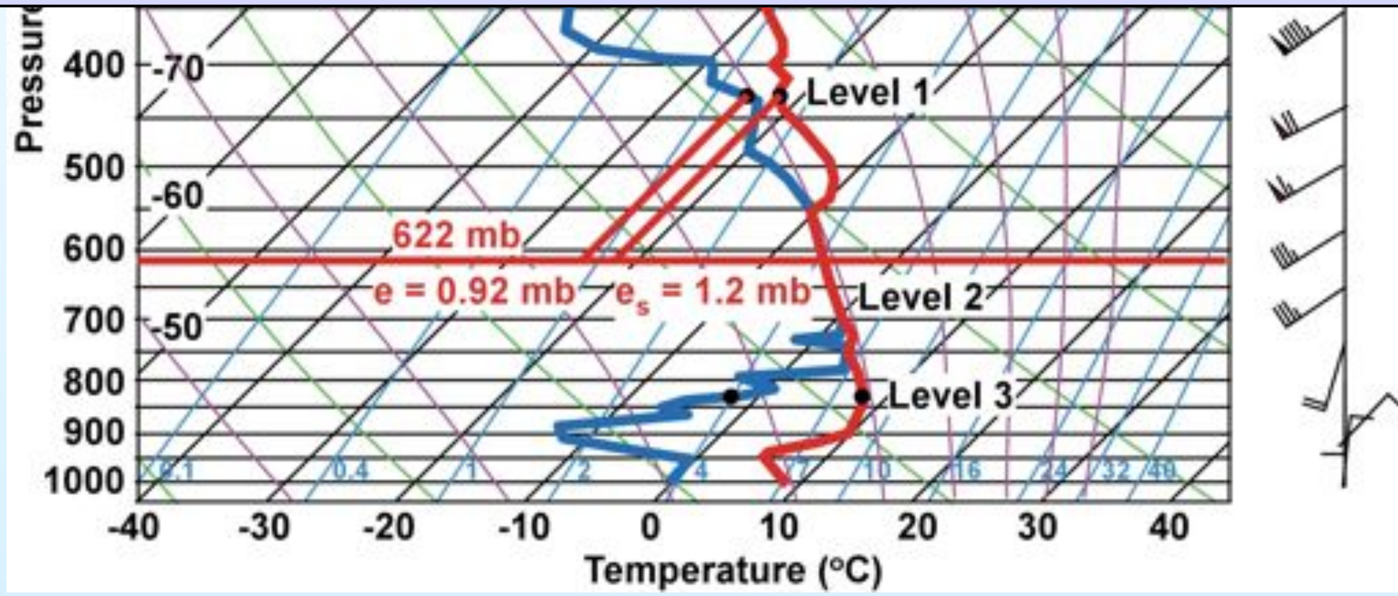


Vapor pressure (e): That part of the total atmospheric pressure Contributed by water vapor molecules.

ON THE SKEW-T: FOLLOW THE ISOTHERM THROUGH THE DEWPOINT OF INTEREST TO THE 622 MB LEVEL. VALUE OF WS LINE IS VAPOR PRESSURE IN MB.

Saturation vapor pressure (e_s): The vapor pressure a sample of air would have if it were saturated.

ON THE SKEW-T: FOLLOW THE ISOTHERM THROUGH THE TEMPERATURE OF INTEREST TO THE 622 MB LEVEL. VALUE OF WS LINE IS VAPOR PRESSURE IN MB.



WHY DOES THIS WORK?

From Basic Thermodynamics….

$$w = \frac{0.622e}{P - e} \approx \frac{0.622e}{P}$$

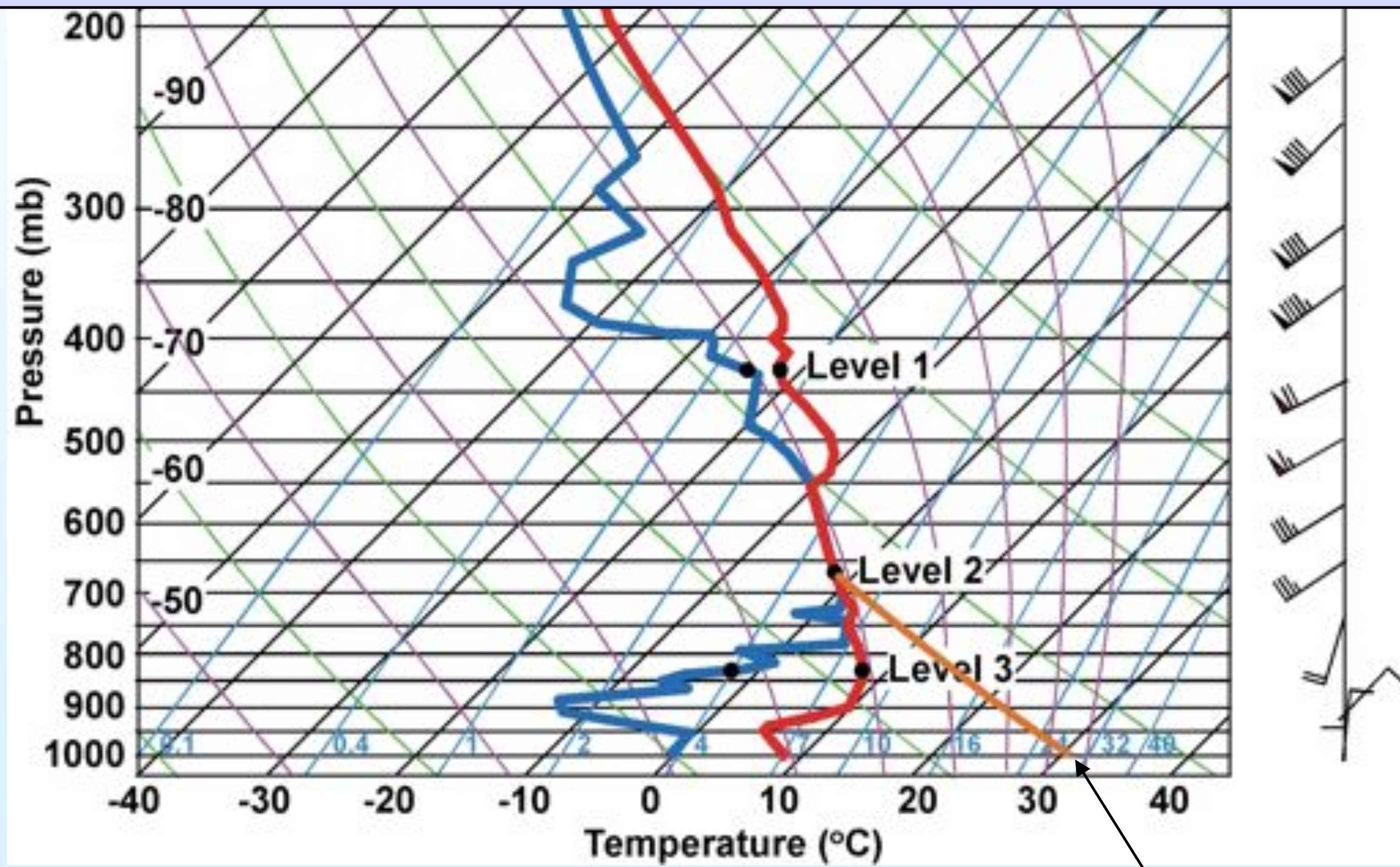
Use P = 622 mb

$$w = \frac{0.622e}{622} \approx 0.001e \qquad \text{in kg/kg}$$

$$w = e \qquad \text{in g/kg}$$

Potential Temperature (θ): The temperature a parcel of air would have If it were brought dry adiabatically to a pressure of 1000 mb.

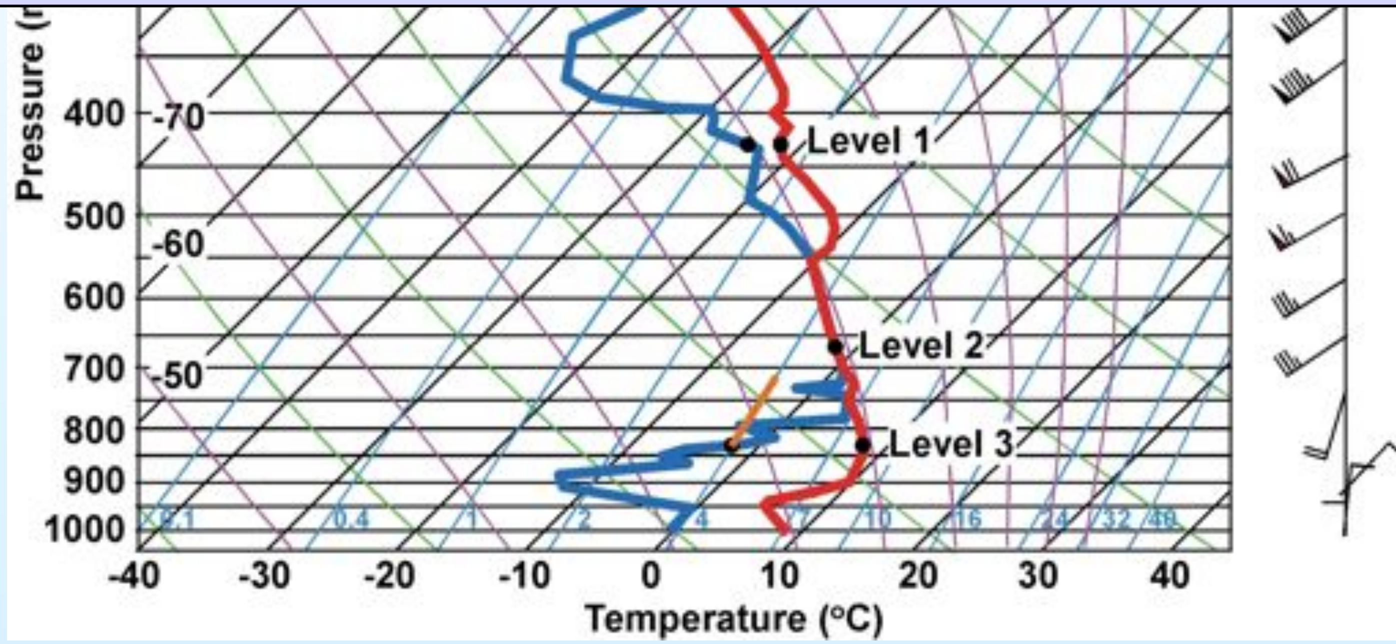
ON THE SKEW-T: FOLLOW THE DRY ADIABAT TO THE 1000 MB LEVEL. VALUE OF TEMPERATURE AT 1000 MB (CONVERT TO K) IS POTENTIAL TEMPERATURE.



θ = 273.1 + 30.5 = 303.6 K

Wet Bulb Temperature (T_w): The lowest temperature to which a volume of air can be cooled at constant pressure by evaporating water into it.

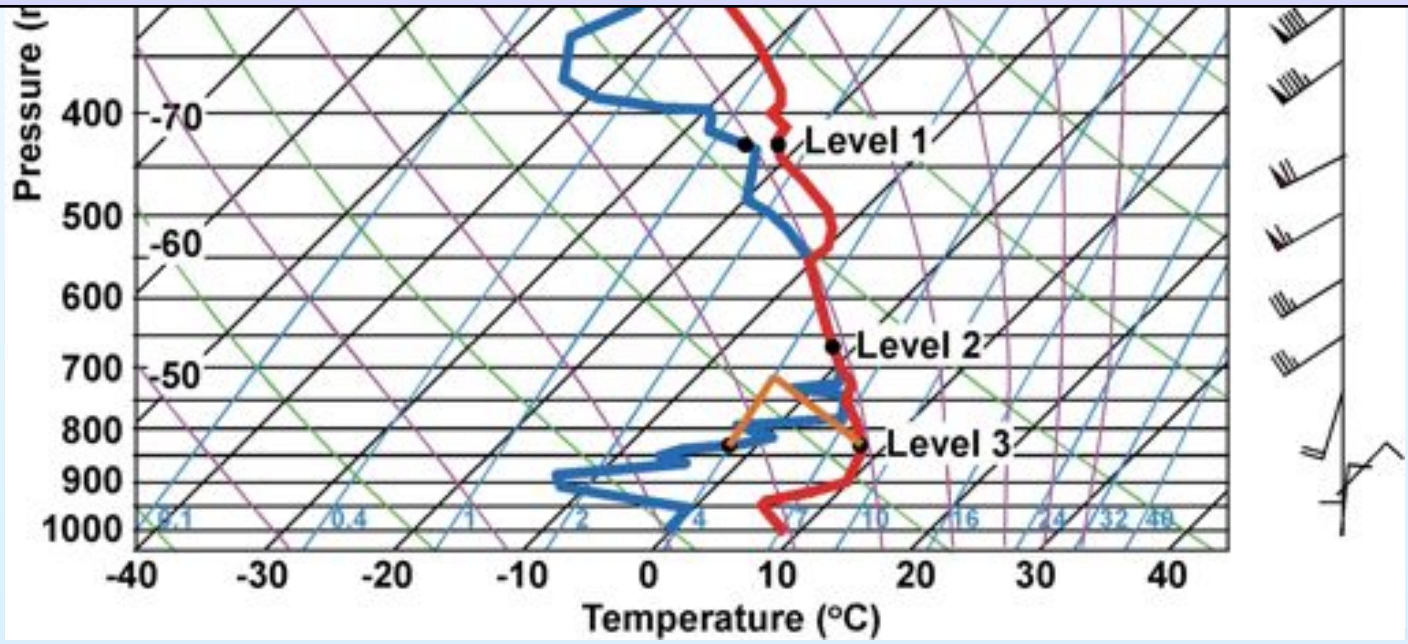
ON THE SKEW-T: 1) FOLLOW THE SATURATION MIXING RATIO LINE UPWARD FROM THE DEWPOINT TEMPERATURE



Wet Bulb Temperature (T_w): The lowest temperature to which a volume of air can be cooled at constant pressure by evaporating water into it.

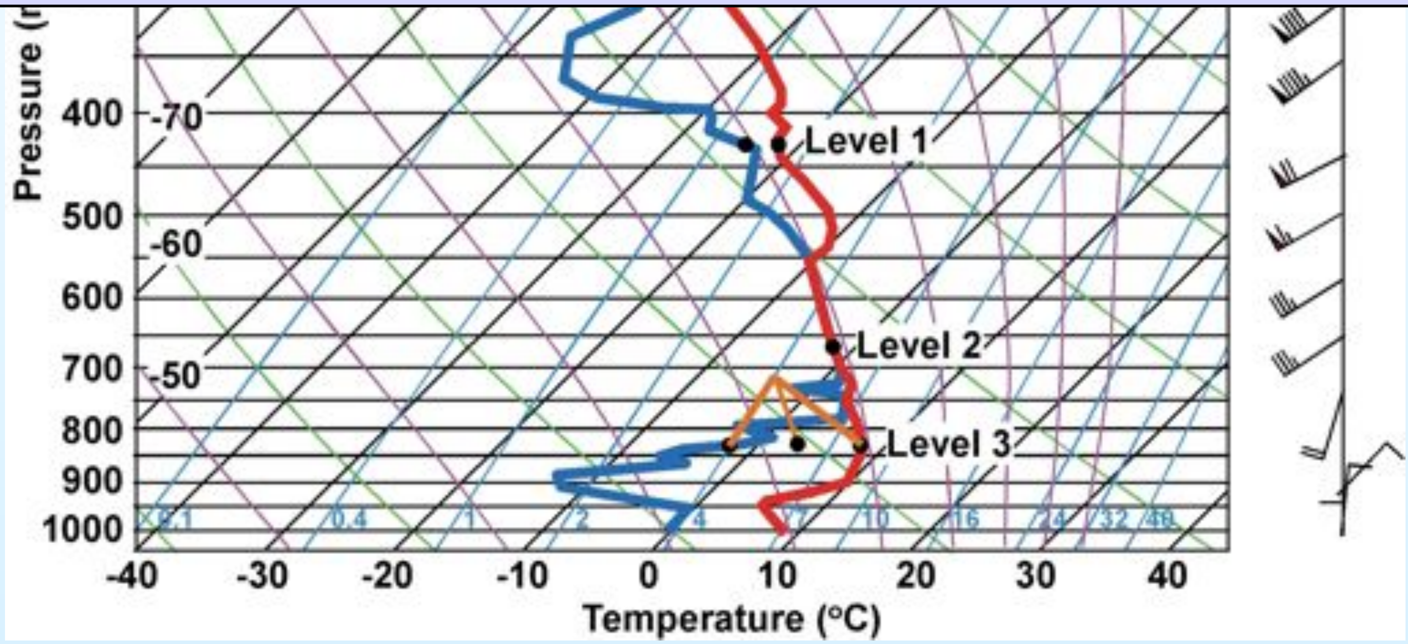
ON THE SKEW-T: 1) FOLLOW THE SATURATION MIXING RATIO LINE UPWARD FROM THE DEWPOINT TEMPERATURE

2) FOLLOW THE DRY ADIABAT UPWARD FROM THE TEMPERATURE UNTIL IT CROSSES THE FIRST LINE



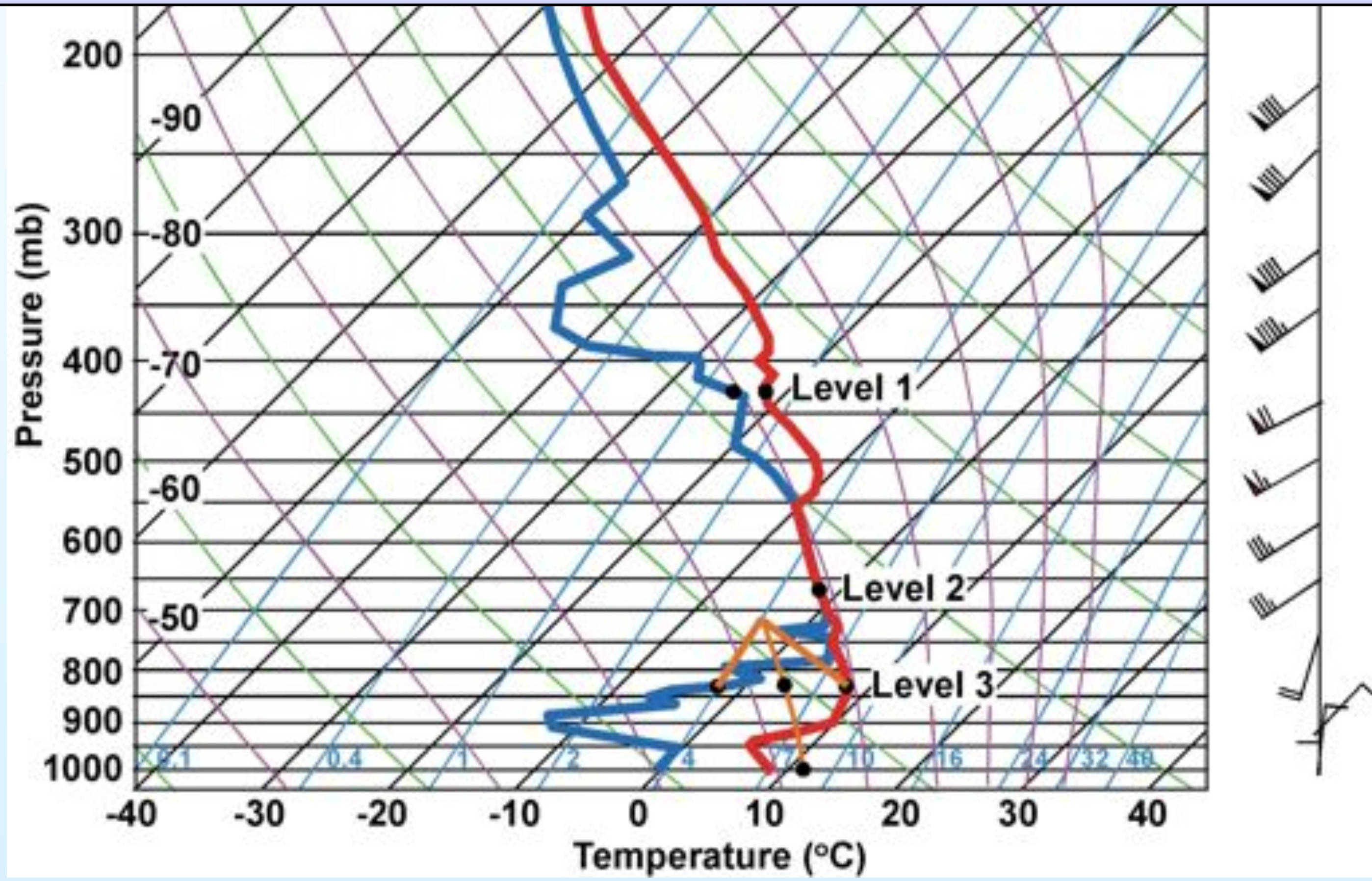
Wet Bulb Temperature (T_w): The lowest temperature to which a volume of air can be cooled at constant pressure by evaporating water into it.

ON THE SKEW-T: 1) FOLLOW THE SATURATION MIXING RATIO LINE UPWARD FROM THE DEWPOINT TEMPERATURE
2) FOLLOW THE DRY ADIABAT UPWARD FROM THE TEMPERATURE UNTIL IT CROSSES THE FIRST LINE
3) FOLLOW THE SATURATION ADIABAT DOWN TO THE ORIGINAL LEVEL. TEMPERATURE AT THIS POINT IS THE WET-BULB TEMPERATURE

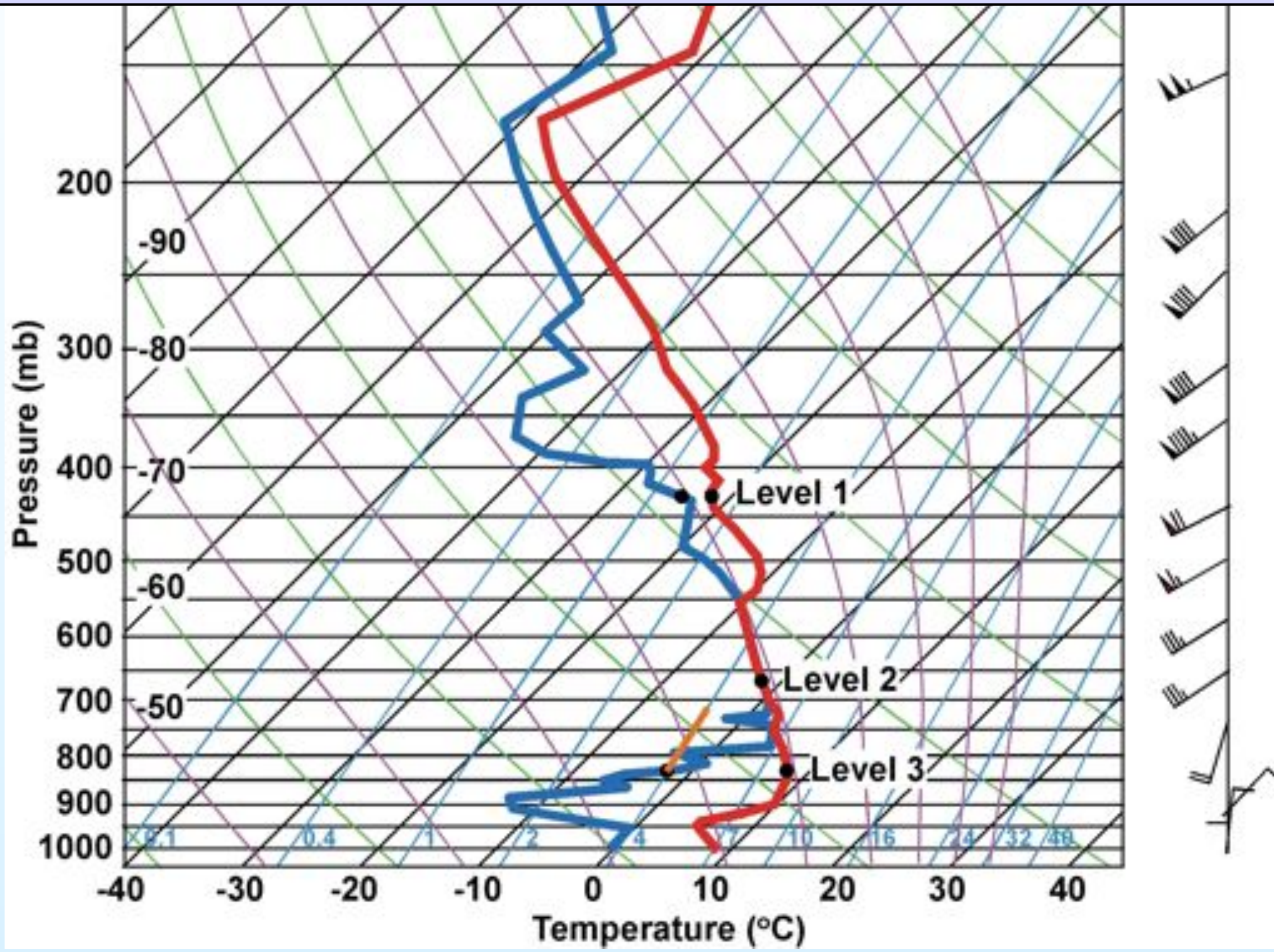


Wet Bulb Potential Temperature (θ_w): The wet bulb temperature a parcel of air would have if it were brought saturation adiabatically to a pressure of 1000 mb.

ON THE SKEW-T: 1) FOLLOW THE SATURATION ADIABAT FROM THE WET BULB TEMPERATURE TO 1000 MB.

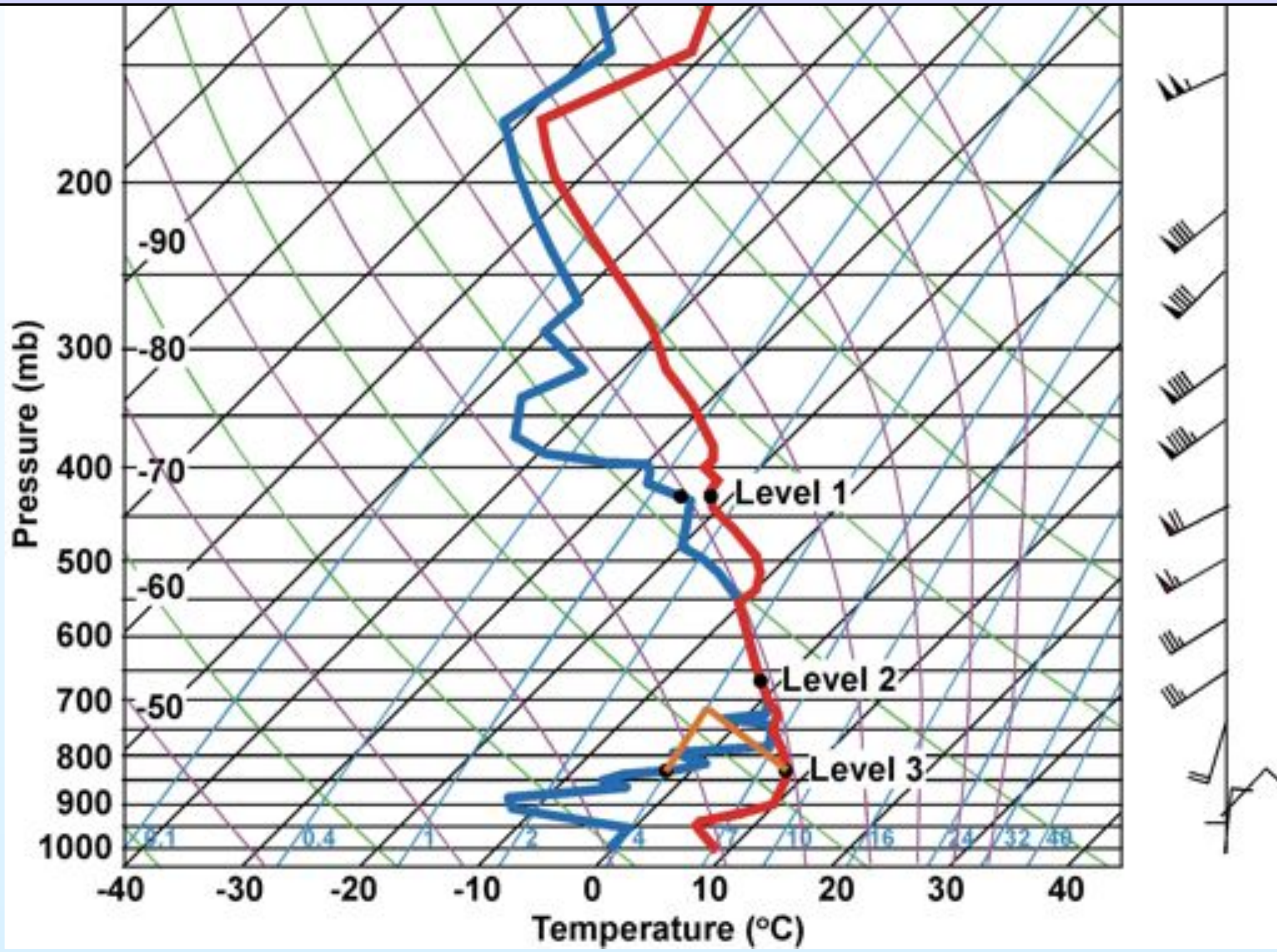


Equivalent Temperature (T_e): The temperature a sample of air would have if all its moisture were condensed out by a pseudo-adiabatic process (with the Latent heat of condensation heating the air sample), and the sample then brought Dry adiabatically to its original pressure.



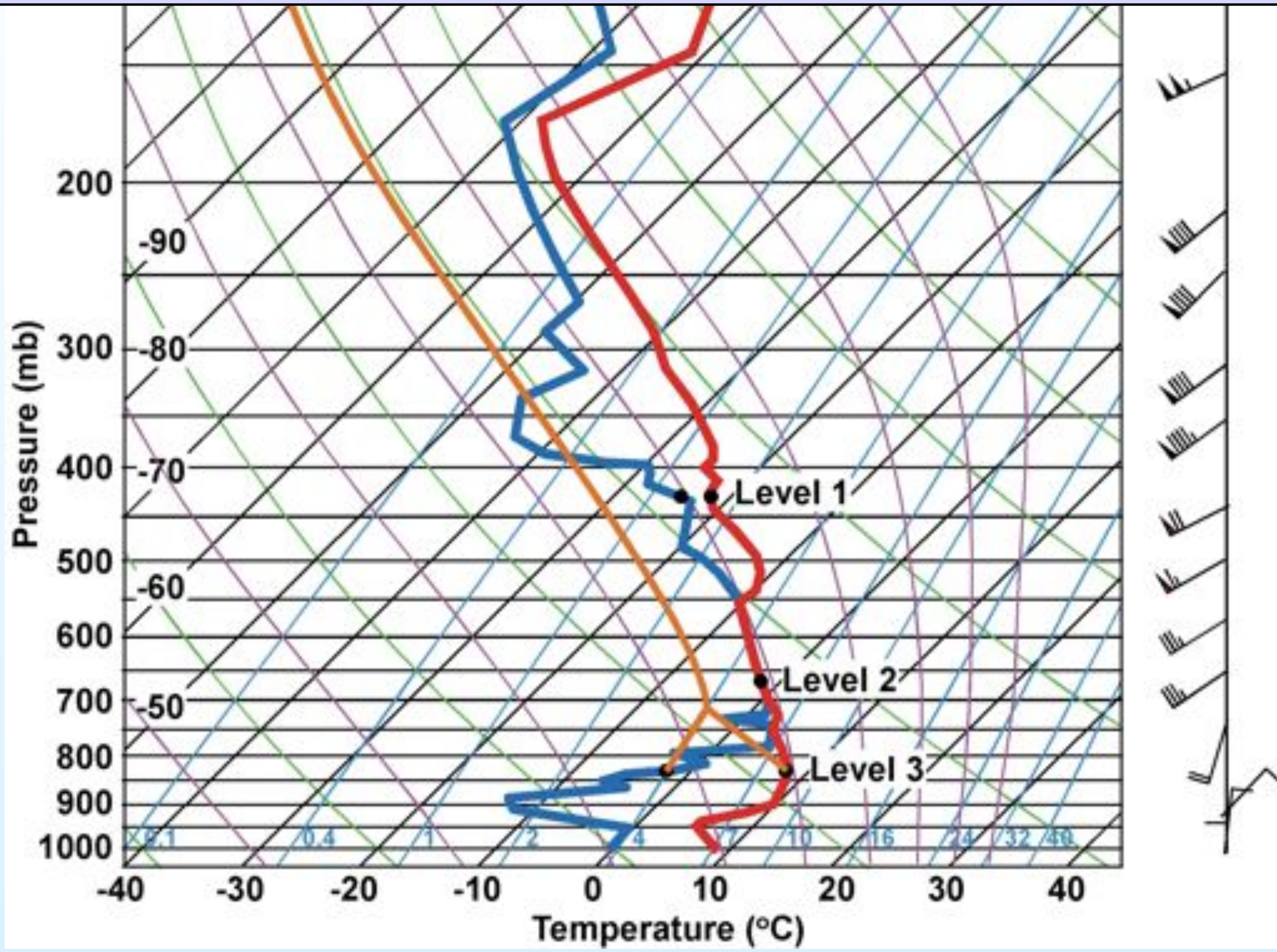
ON THE SKEW-T: 1) FOLLOW THE SATURATION MIXING RATIO LINE UPWARD FROM THE DEWPOINT TEMPERATURE

Equivalent Temperature (T_e): The temperature a sample of air would have if all its moisture were condensed out by a pseudo-adiabatic process (with the Latent heat of condensation heating the air sample), and the sample then brought Dry adiabatically to its original pressure.



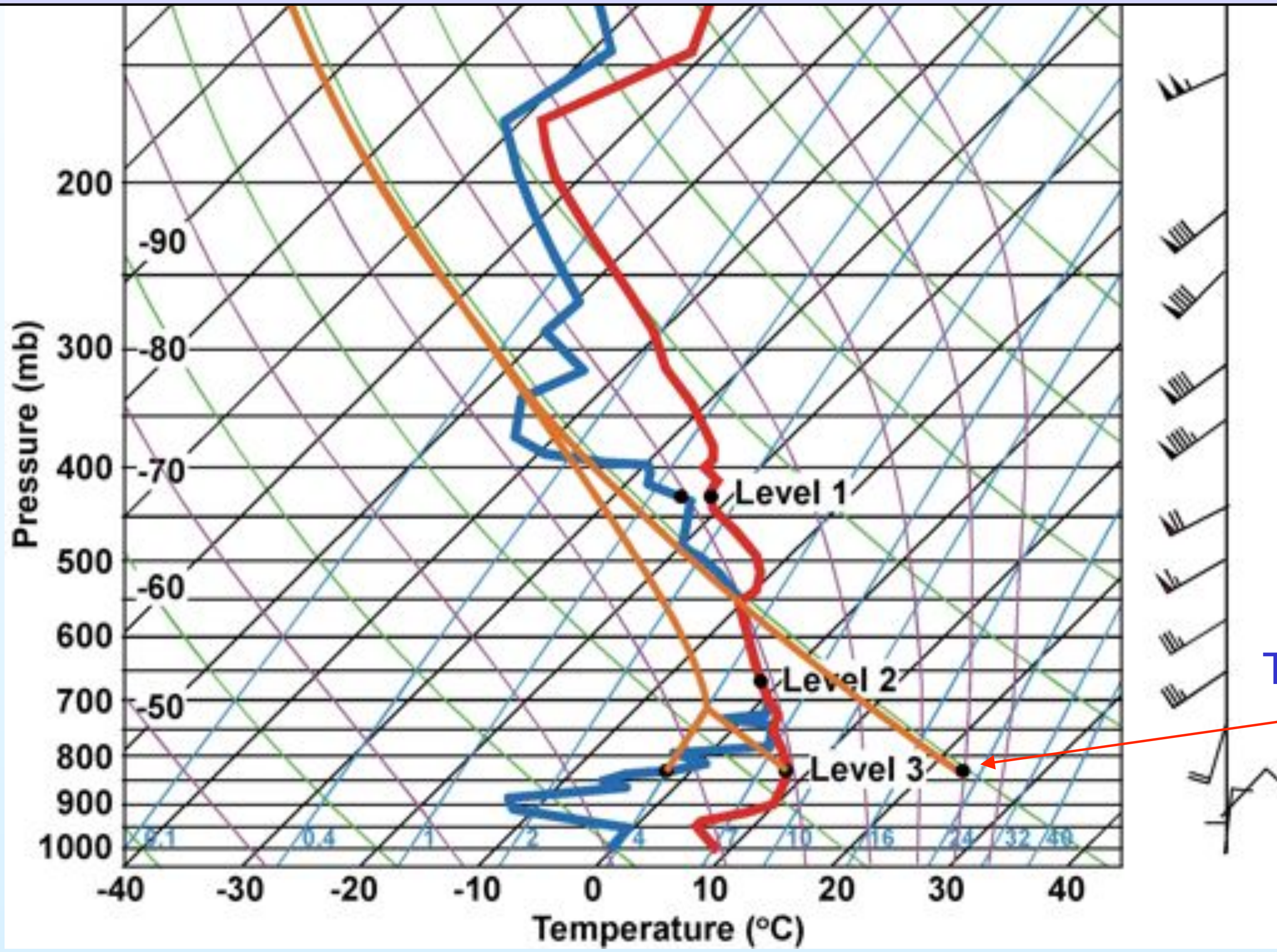
2) FOLLOW THE DRY ADIABAT UPWARD FROM THE TEMPERATURE UNTIL IT CROSSES THE FIRST LINE

Equivalent Temperature (T_e): The temperature a sample of air would have if all its moisture were condensed out by a pseudo-adiabatic process (with the Latent heat of condensation heating the air sample), and the sample then brought Dry adiabatically to its original pressure.



3) FOLLOW THE SATURATION ADIABAT UPWARD UNTIL IT PARALLELS A DRY ADIABAT

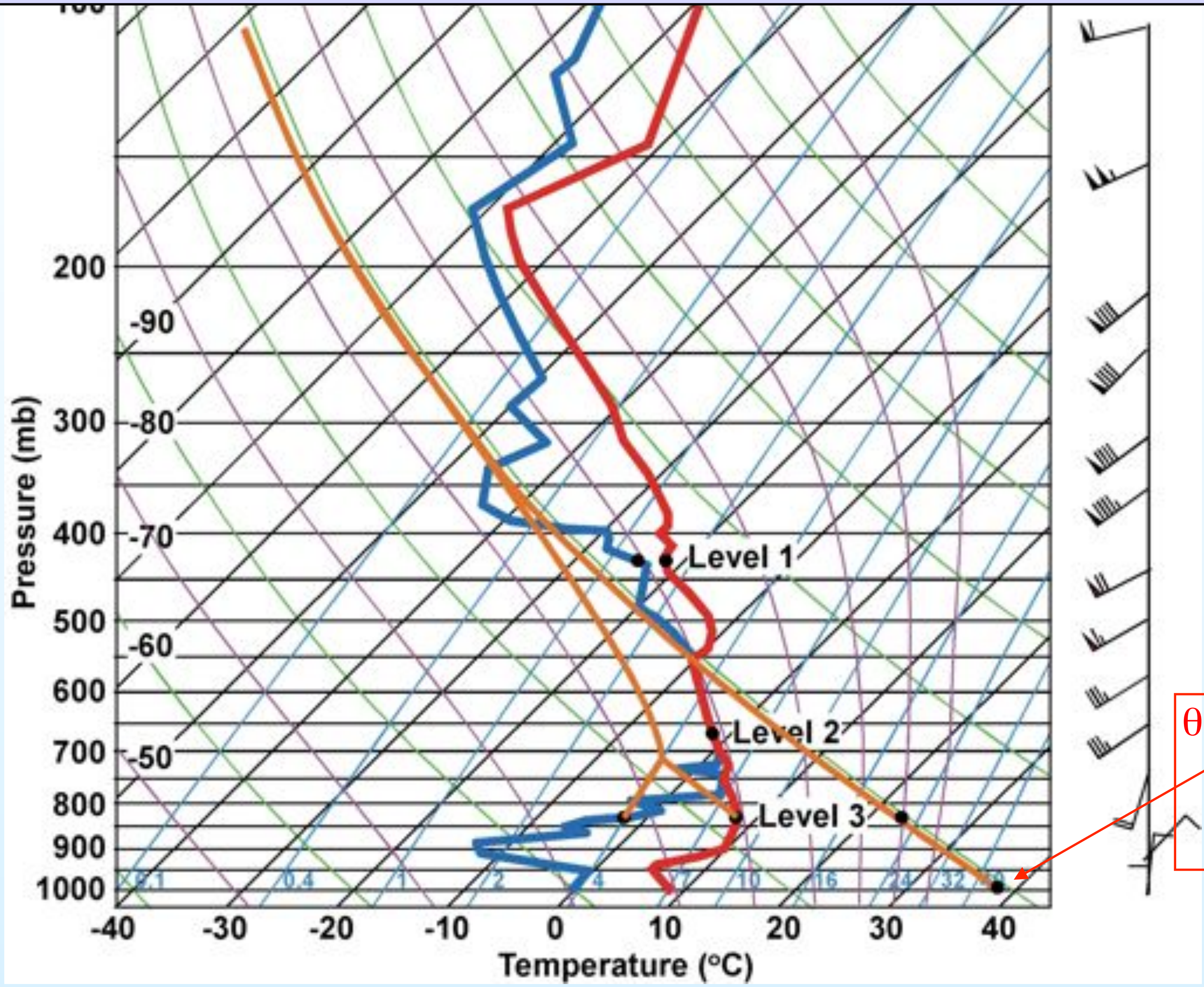
Equivalent Temperature (T_e): The temperature a sample of air would have if all its moisture were condensed out by a pseudo-adiabatic process (with the Latent heat of condensation heating the air sample), and the sample then brought Dry adiabatically to its original pressure.



T_e = 273.1 + 23.0 = 296.1 K

3) FOLLOW THE DRY ADIABAT DOWN TO THE ORIGINAL LEVEL AND READ THE TEMPERATURE AT THAT LEVEL.

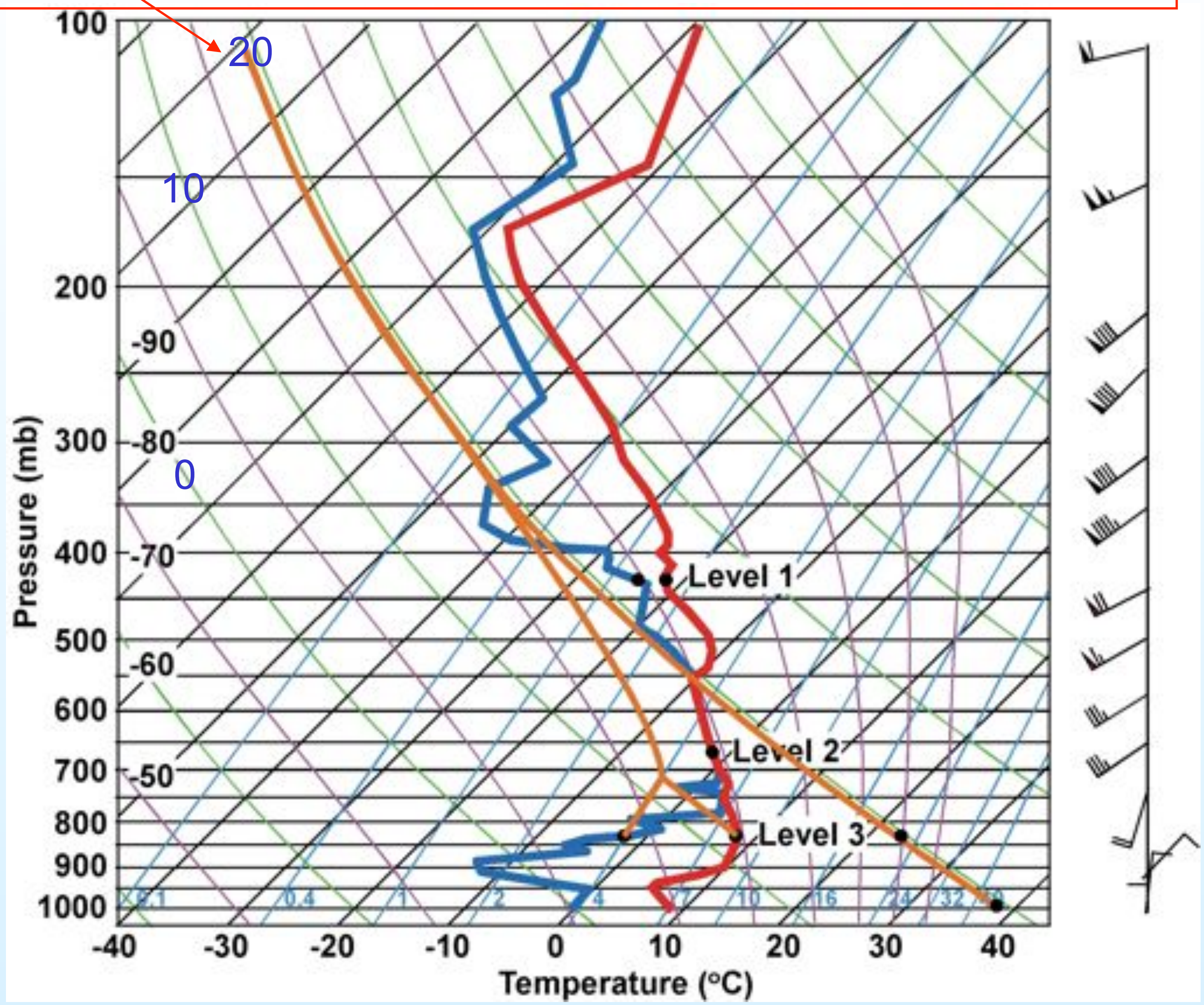
Equivalent Potential Temperature (θ_e): The equivalent temperature a sample of air would have if it were compressed adiabatically to 1000 mb.



θ_e = 273.1 + 39.0 = 312.1 K

4) FOLLOW THE DRY ADIABAT DOWN FROM EQUIVALENT TEMPERATURE TO THE 1000 MB LEVEL.

For high levels, read the value of the dry adiabat to determine θ_e

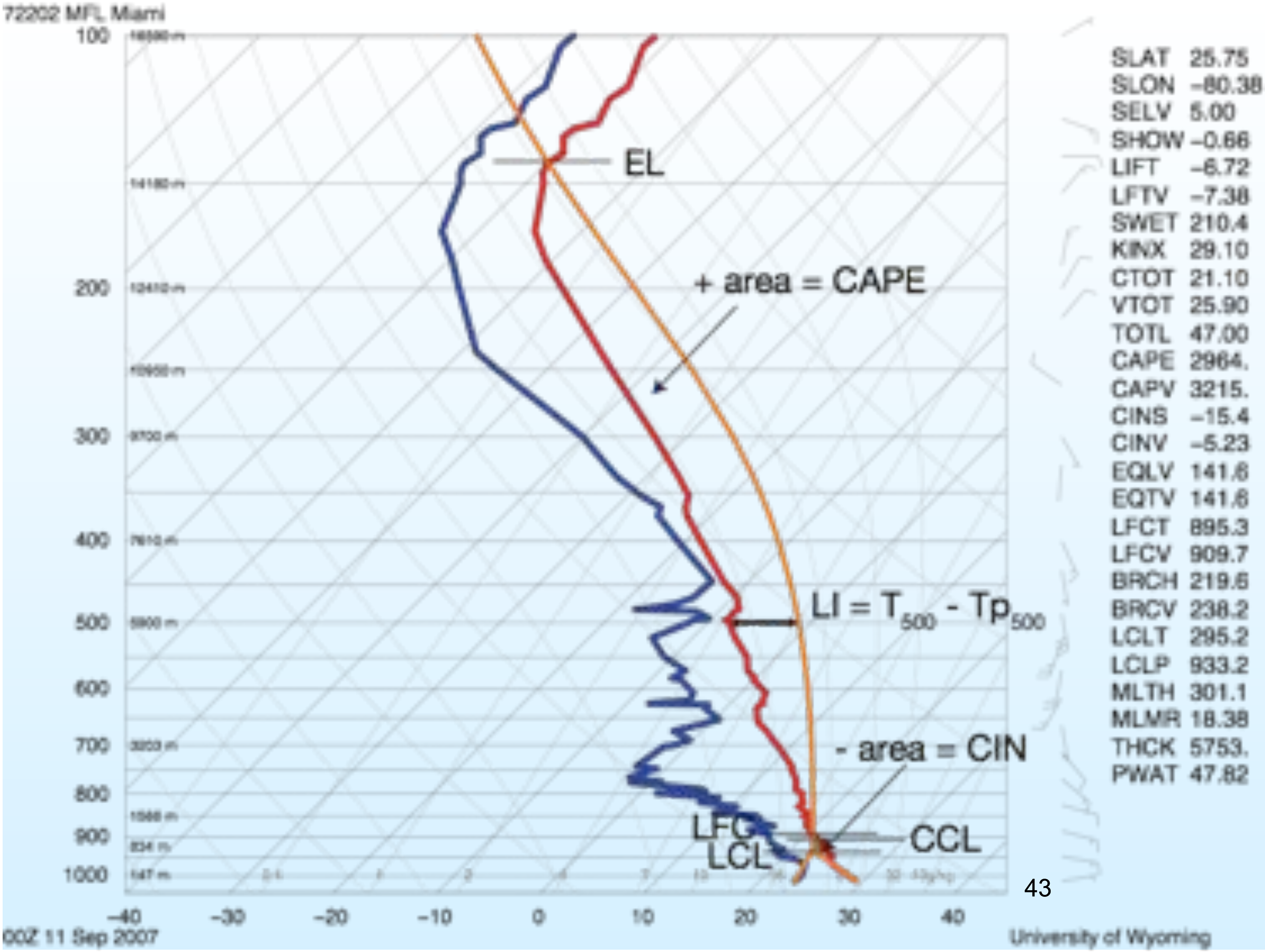


Skew-T Log-P Diagram (cont.)

- Basic Definitions
  - ***Convective condensation level*** (CCL)
    - Height where rising parcel just becomes saturated (condensation starts) when heated to the convective temperature
  - ***Convective temperature*** (T_c)
    - T that must be reached for a surface parcel to rise to CCL
  - ***Lifting condensation level*** (LCL)
    - Height where parcel becomes saturated by lifting dry-adiabatically
  - ***Level of free convection*** (LFC)
    - Height where parcel lifted dry-adiabatically until saturated, then moist-adiabatically, first becomes warmer than the surrounding air
  - ***Lifted index*** (LI)
    - A measure of bulk stability of the atmosphere LI = T

Skew-T Log-P Diagram (cont.)

- Basic Definitions (cont.)
  - ***Positive area*** (or CAPE)
    - Area between the sounding and the moist adiabat that intersects the LFC, above the LFC. Proportional to the amount of energy the parcel gains from the environment.
  - ***Negative area*** (or CIN)
    - Area between the sounding and the dry adiabat that intersects the CCL, below the CCL. Proportional to the energy needed to move the parcel.
  - ***Equilibrium level*** (EL)
    - Height where the temperature of a buoyant parcel again becomes equal to the temperature of the environment.
  - ***Wet bulb zero***
    - Height above ground where the wet bulb first reaches zero degrees Celsius. This is the level where hail will begin to melt.


72202 MFL Miami
EL
+ area = CAPE
LI = T500 - Tp500
- area = CIN
LFC
LCL
CCL
SLAT 25.75
SLON -80.38
SELV 5.00
SHOW -0.66
LIFT -6.72
LFTV -7.38
SWET 210.4
KINX 29.10
CTOT 21.10
VTOT 25.90
TOTL 47.00
CAPE 2964.
CAPV 3215.
CINS -15.4
CINV -5.23
EQLV 141.6
EQTV 141.6
LFCT 895.3
LFCV 909.7
BRCH 219.6
BRCV 238.2
LCLT 295.2
LCLP 933.2
MLTH 301.1
MLMR 18.38
THCK 5753.
PWAT 47.82
00Z 11 Sep 2007
University of Wyoming

A Warm Season Forecasting Handbook

Courtesy of Bruce Lee

THUNDERSTORMS
TORNADOES
STRAIGHT-LINE WINDS

HAIL
LIGHTNING
DOWNBURSTS

In the first part of the course, we learned about forecasting winter weather, which is organized on the synoptic scale (with important details in the forecast on the mesoscale, and not much variation occurring on the convective scale).

Now, we will focus on warm season forecasting, which often occurs on the mesoscale and convective scale, yet has the ‘stage set’ by the synoptic scale.

This has many important implications for forecasting:

• Diabatic processes become more important - diurnal cycle of radiation very strong

• Convection is parameterized in models, however recent increases in model resolution (i.e. WRF) helps resolve mesoscale convection. However, 11 km resolution (currently used in WRF) is still not going to resolve the convective scale (1 km or less). Also, the fact remains that even perfect models require good initialization data on the mesoscale (and that doesn’t exist today). Thus, looking at the observations is key for good warm-season forecasting.

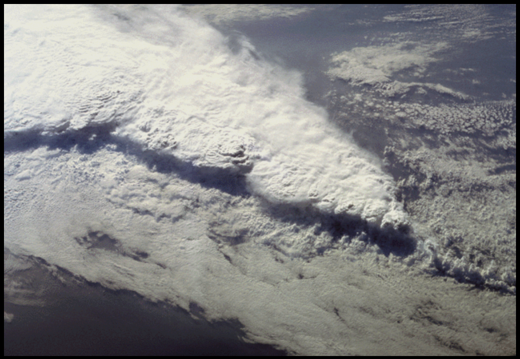
• Limits of predictability greatly decrease

• Forecasts become more probabilistic, especially beyond nowcasting (e.g. mostly sunny with a 30% chance of thunderstorms, some which may become severe and destroy your house…)

ORGANIZATION OF THUNDERSTORMS

Airmass Thunderstorms

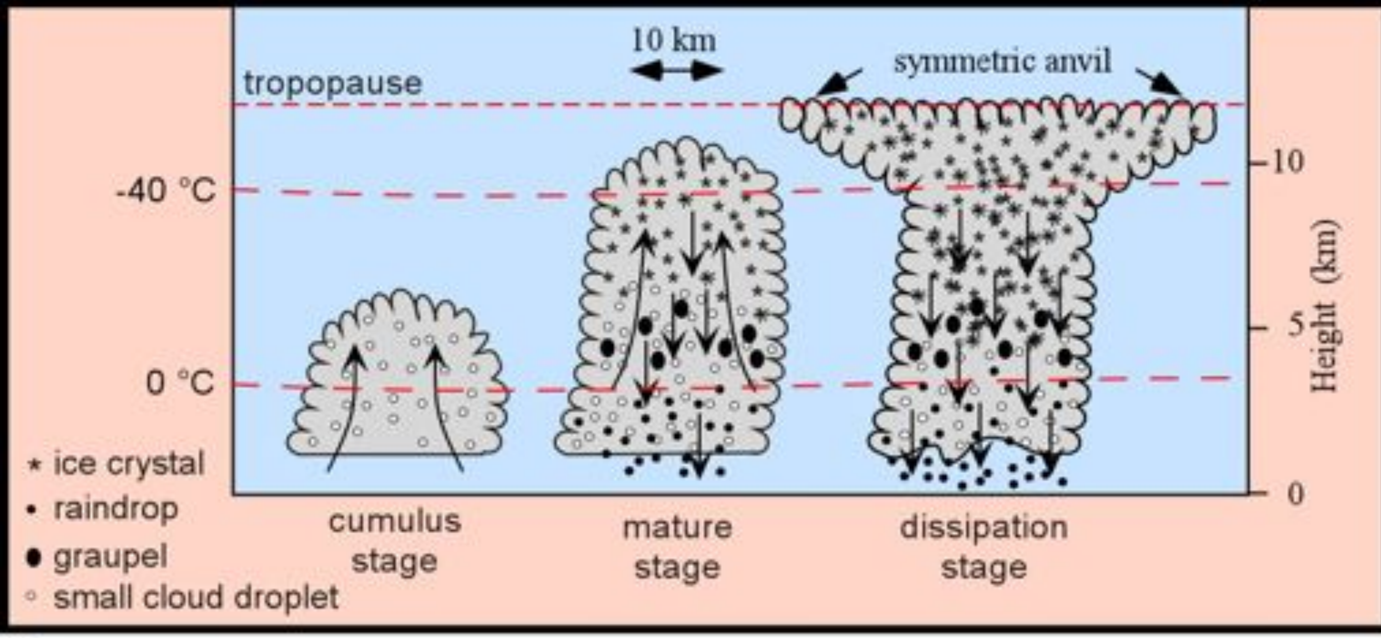
Cool season squall Lines



Mesoscale convective systems (MCSs)

Supercell Thunderstorms

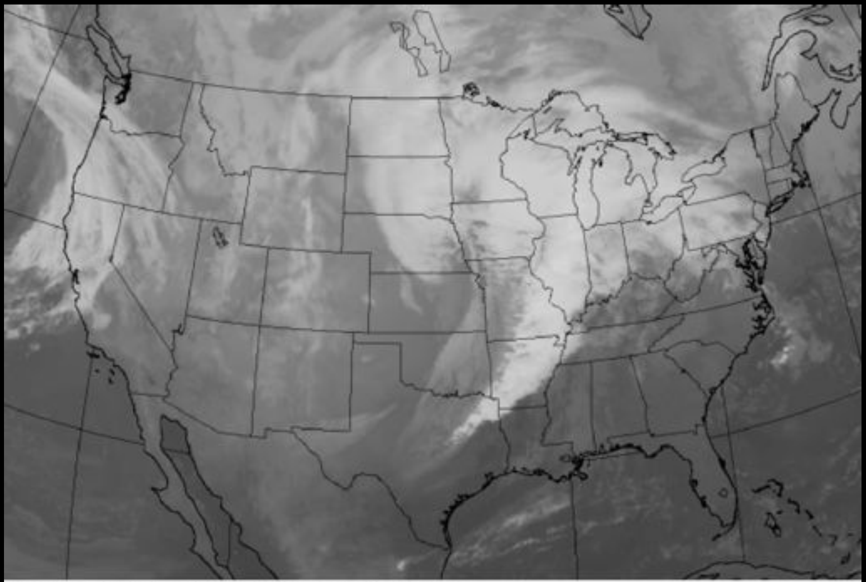
Airmass Thunderstorms



-Form within airmasses far from frontal boundaries
-Low wind shear environment
-Precipitation forming in upper part of storm falls into updraft. Evaporation and precipitation drag retard and eventually eliminate updraft.
- Storm rains out and dissipates.

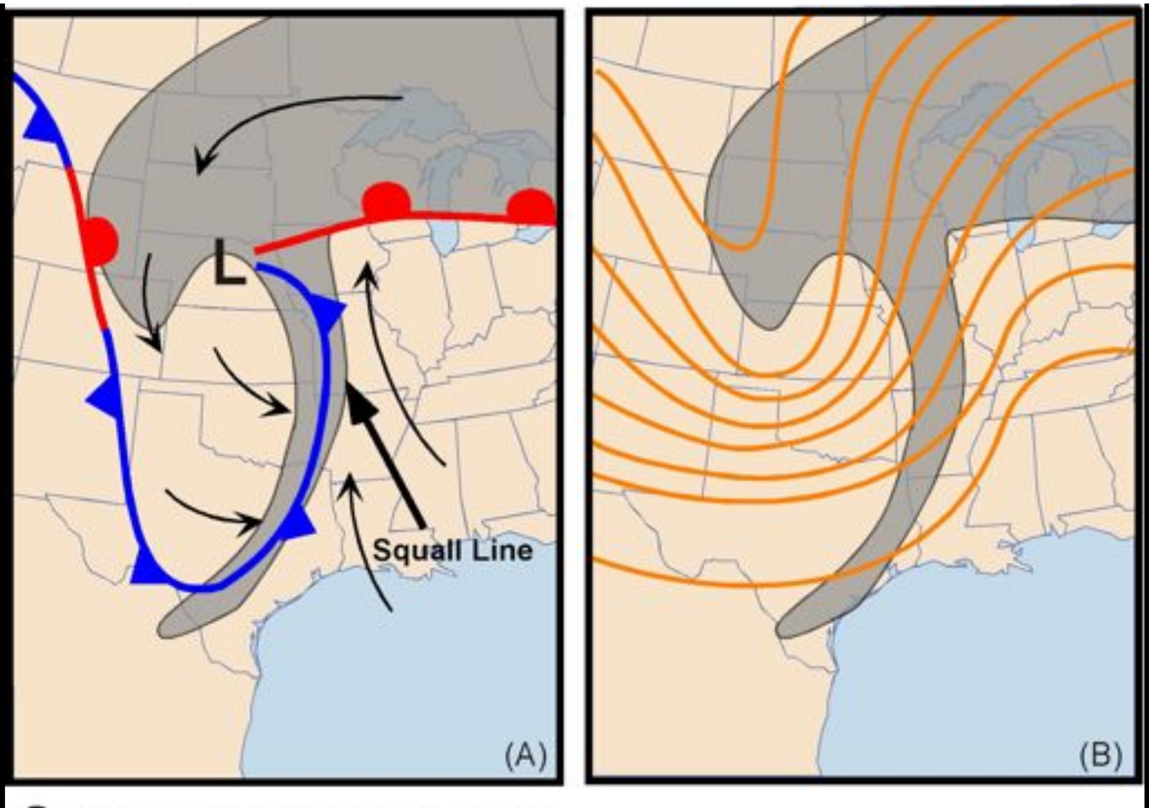
COOL SEASON SQUALL LINES

Courtesy of Weather Services International Corporation

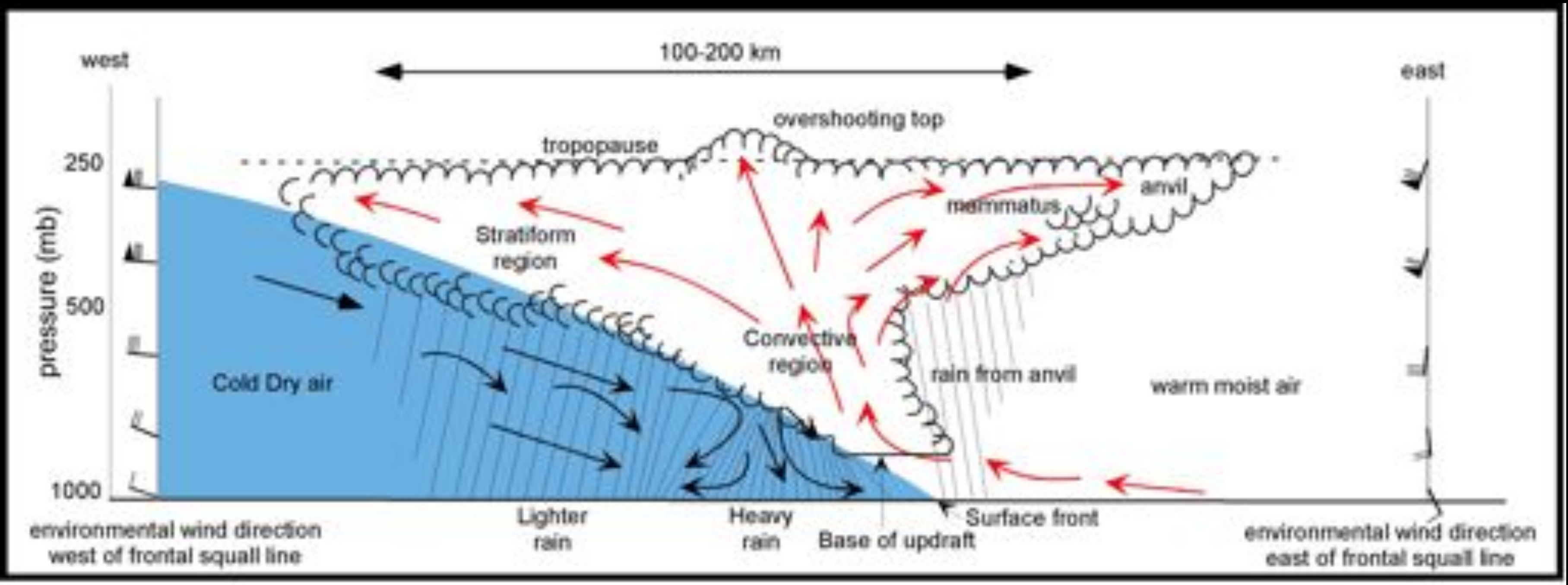


Courtesy of the Department of Atmospheric Sciences
University of Illinois at Urbana-Champaign

A cool season squall line is a long line of thunderstorms in which adjacent thunderstorm cells are so close together that the heavy precipitation from the cells falls in a long continuous line. The line forms along, and remains along a synoptic scale frontal boundary, such as a cold front, upper level front, or dry line.



Cool season squall lines form along cold fronts, dry lines and upper level fronts and often form the “tail” of a cyclone’s comma cloud

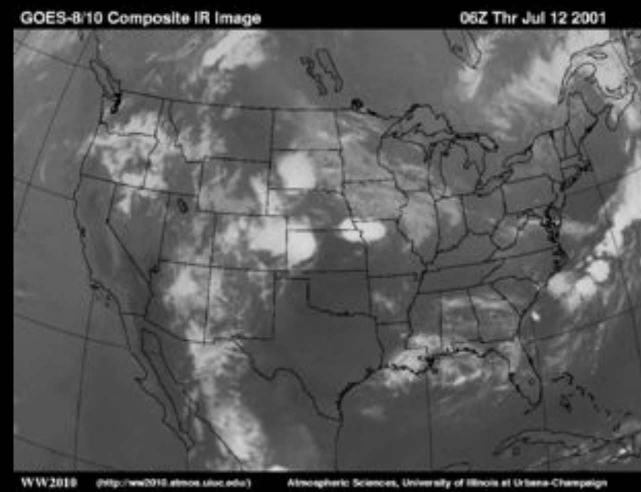


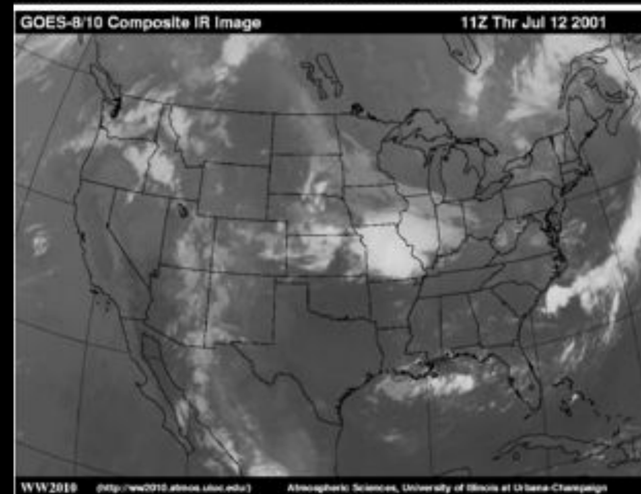
Vertical structure of a cool season squall line along a front

Mesoscale Convective Systems (or MCSs)

Thunderstorms develop along weak boundaries, appear first as clusters or along a line, and then organize to become a system with a leading line of convection and a large trailing stratiform region.

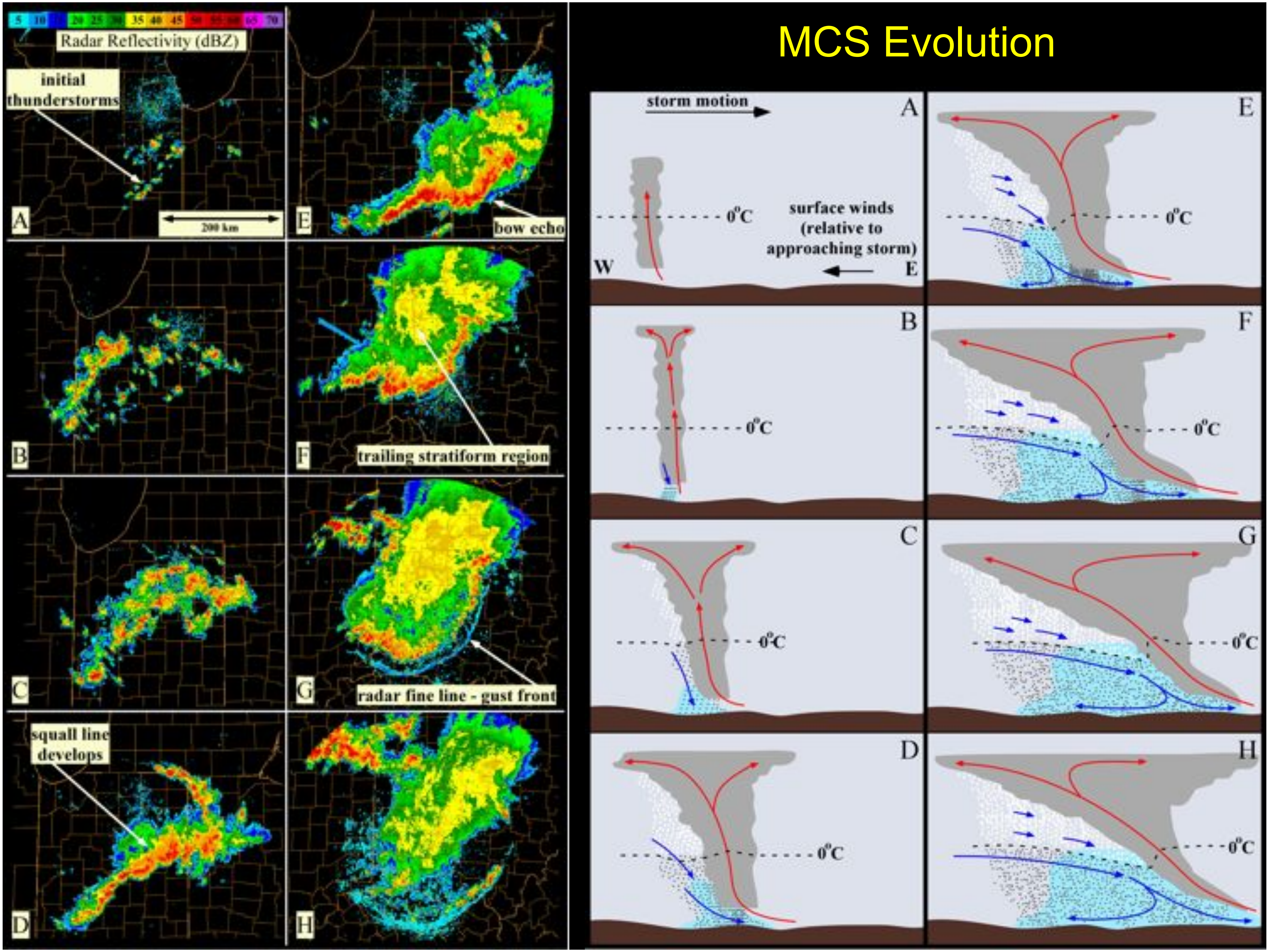
Courtesy of the Department of Atmospheric Sciences, University of Illinois at Urbana-Champaign

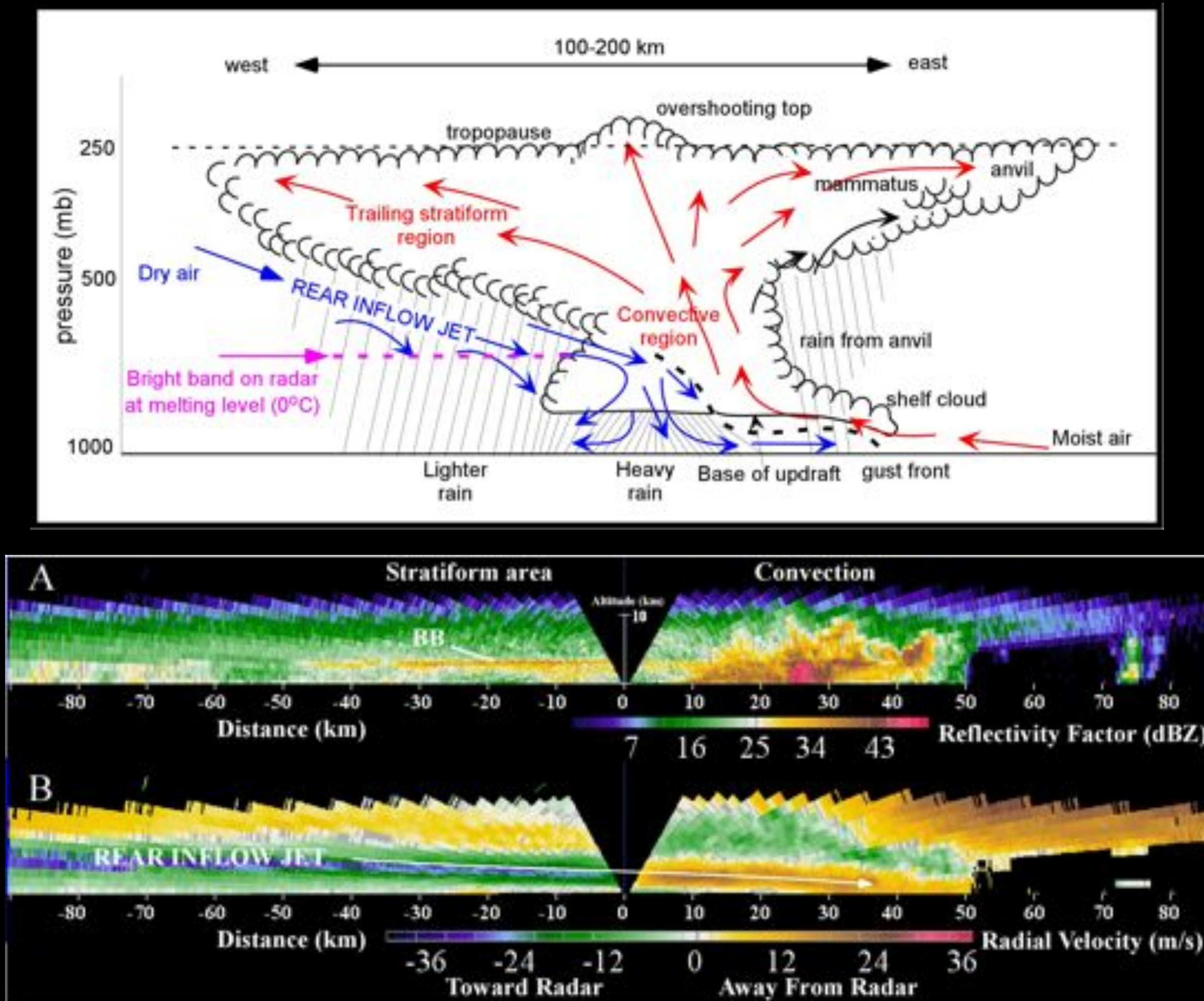




Courtesy of the Department of Atmospheric Sciences University of Illinois at Urbana-Champaign

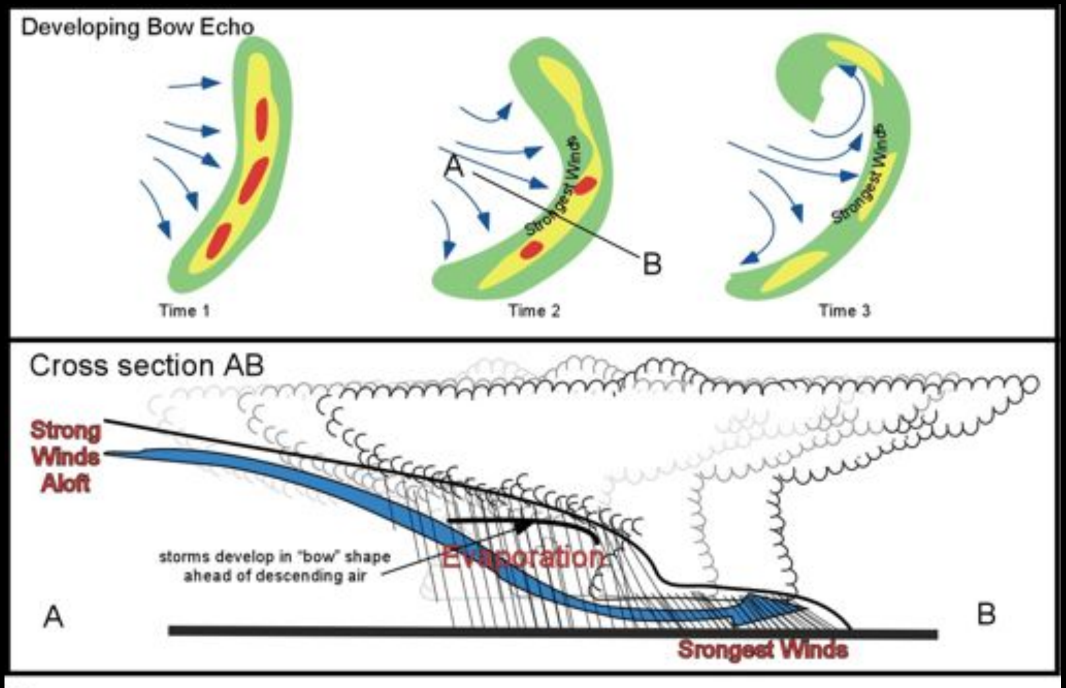
MCS Evolution

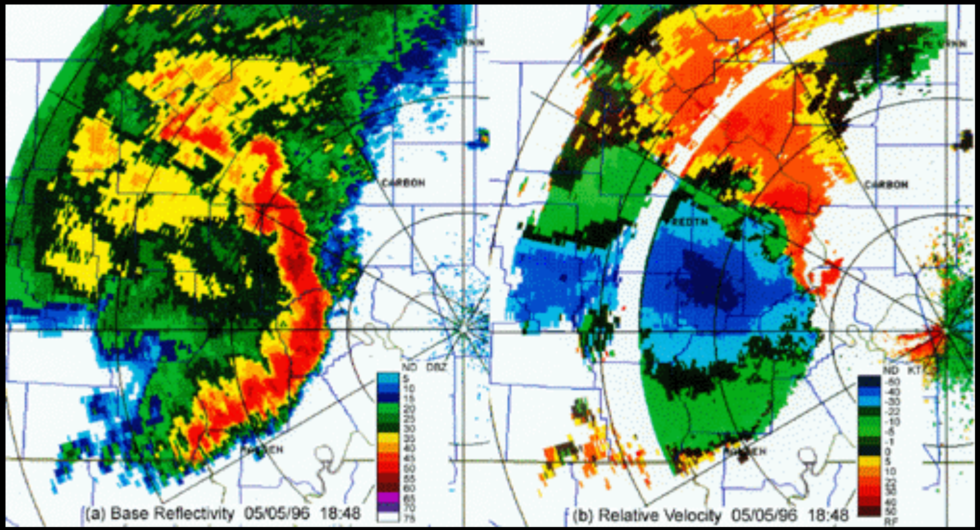




Courtesy of Michael Biggerstaff, Texas A&M University

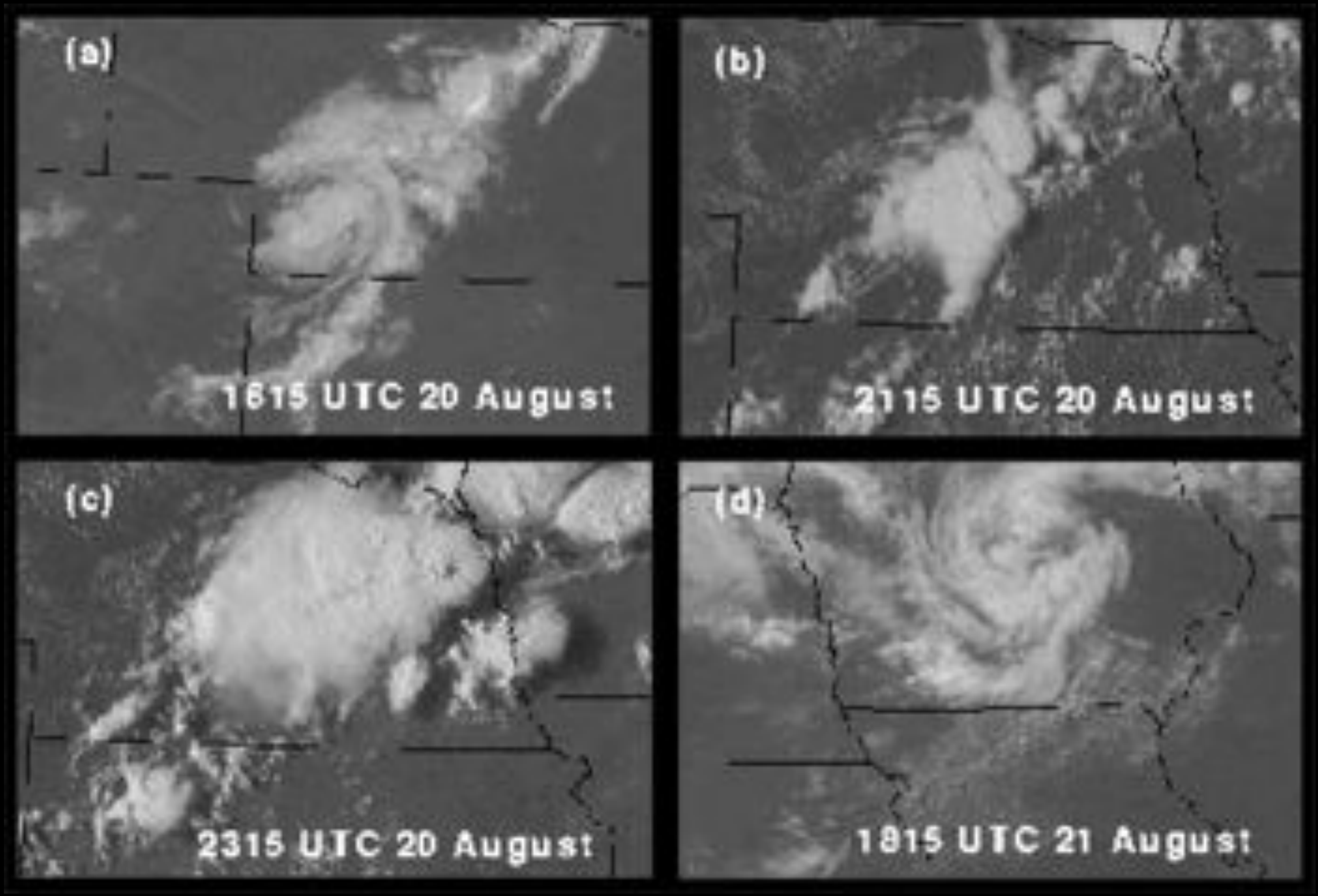
The bow-echo on radar is an indicator of strong straight-line winds





Courtesy of NOAA/NSSL Photo Library

Mesoscale Convective Vortices: Long-lasting vortices aloft that result from the heating associated with a mesoscale convective system. Vortex circulations often trigger new convection the following day



Supercell thunderstorms:

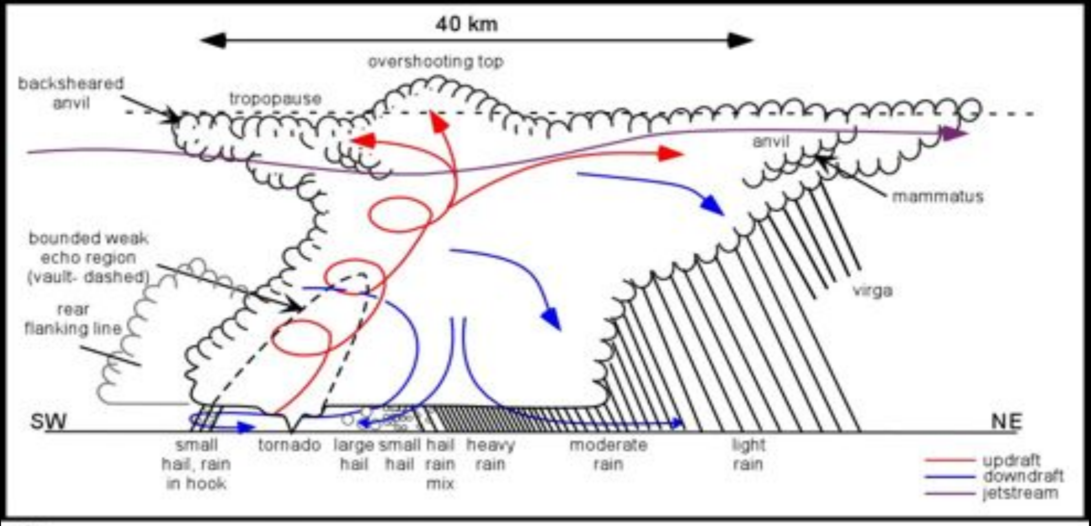
-The most intense thunderstorms in Earth's atmosphere.

-Always rotate.

-Account for most tornadoes, virtually all severe tornadoes, damaging straight-line winds, and most large hail.

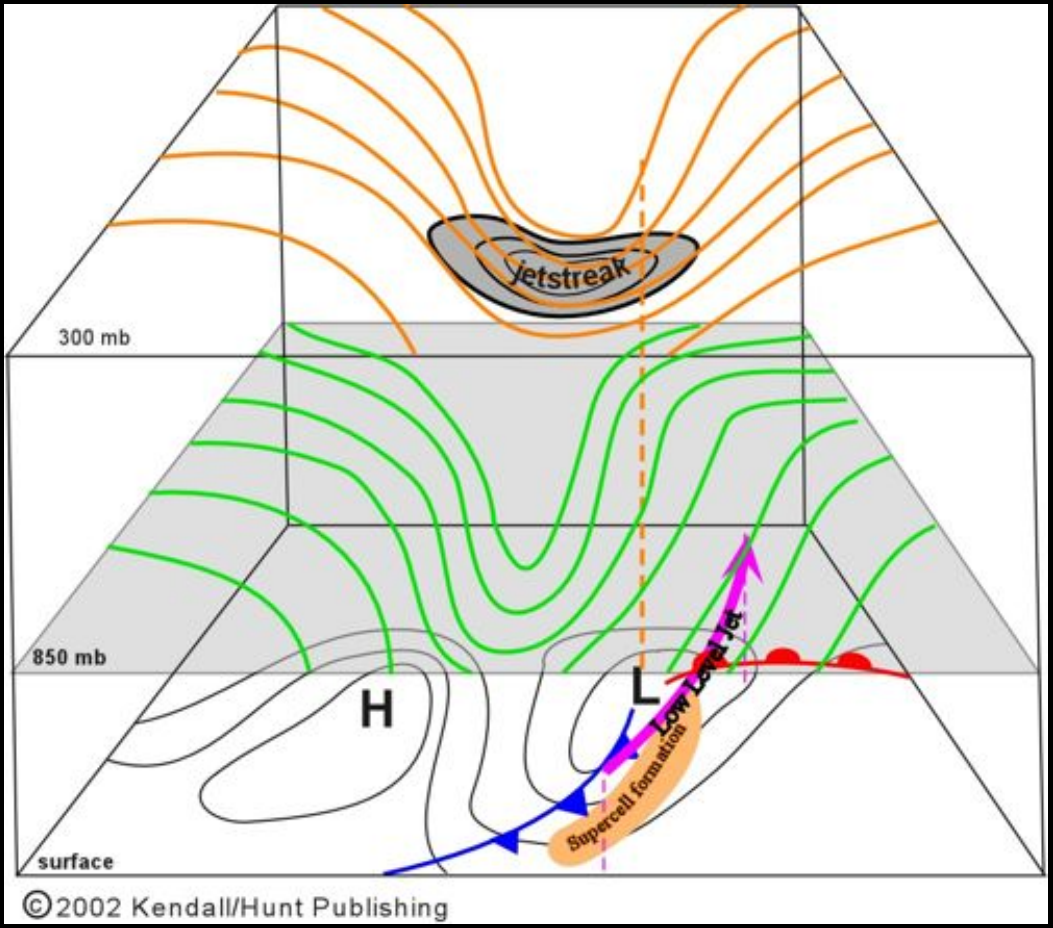
-Updrafts typically 20 to 40 meters/sec, but have been estimated to approach 50 meters/sec.

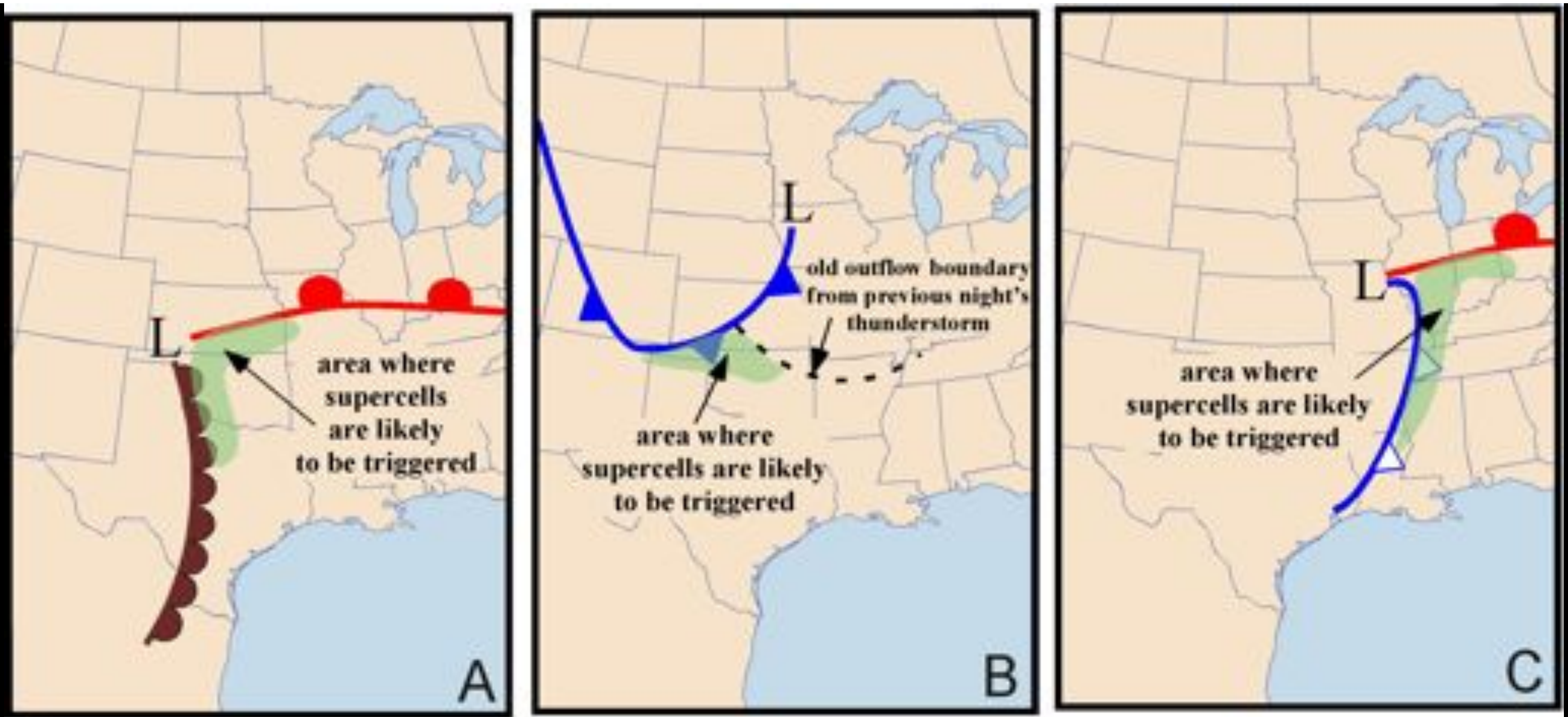
Supercell Thunderstorms -structure



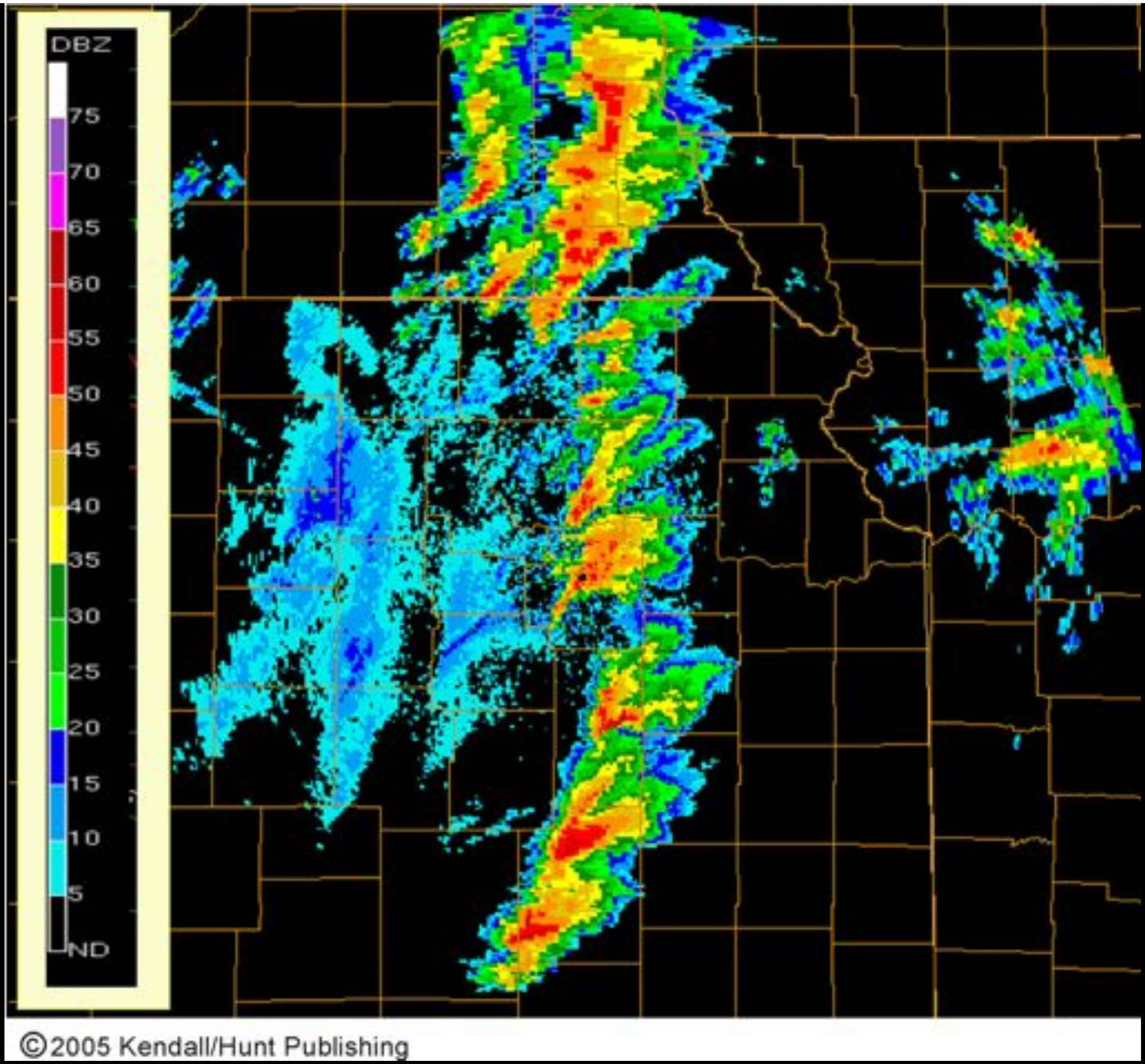
Key components of supercell environment

1. Warm, moist air at in lower atmosphere.
2. Strong vertical wind shear in lowest 2-3 km, typically associated with low level jet
3. Dry air aloft, typically with a near dry-adiabatic lapse rate in the middle troposphere
4. Strong southwesterly jetstream aloft, flowing over southerly low level jet. A jetstreak is often present.
5. Frontal boundary to trigger updraft, can be dry line, cold front, upper level front, or outflow boundary from another storm.

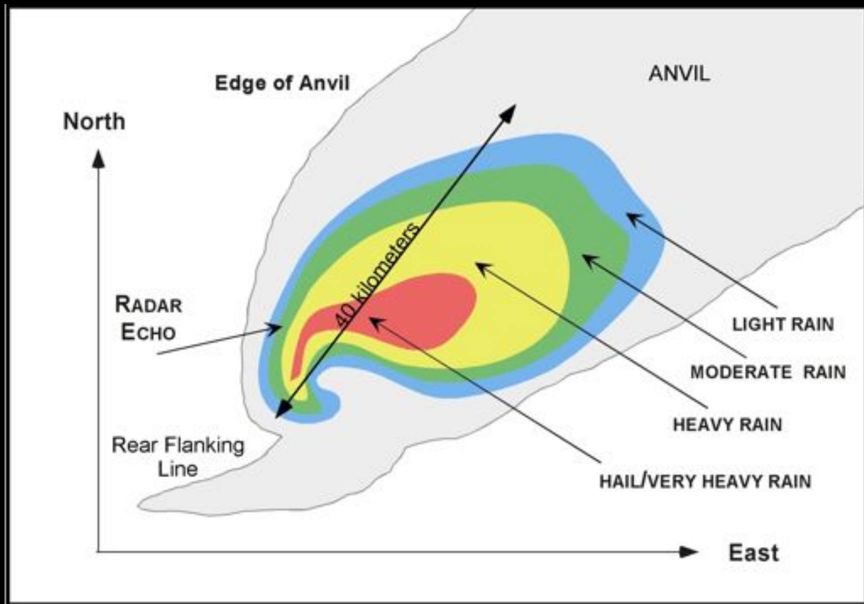


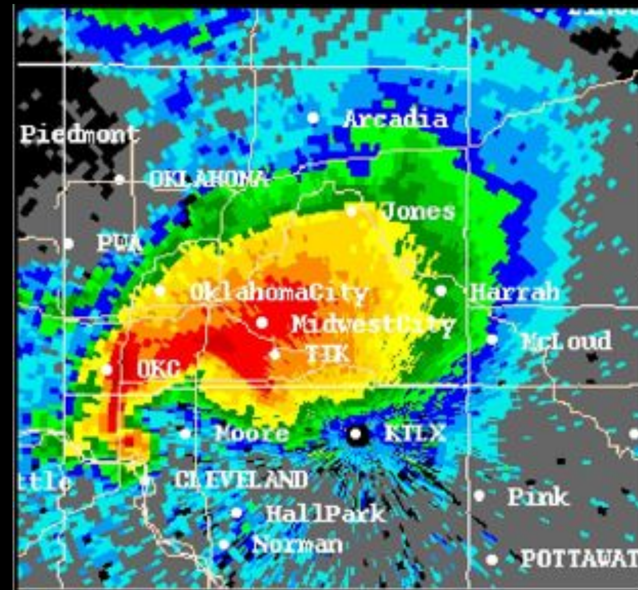


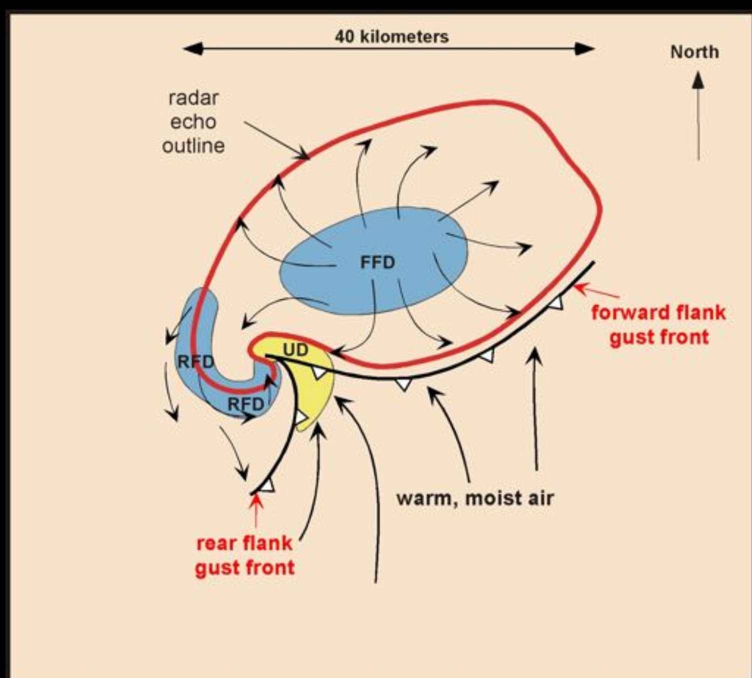
Environments conducive to supercell development



Supercells often form along a line

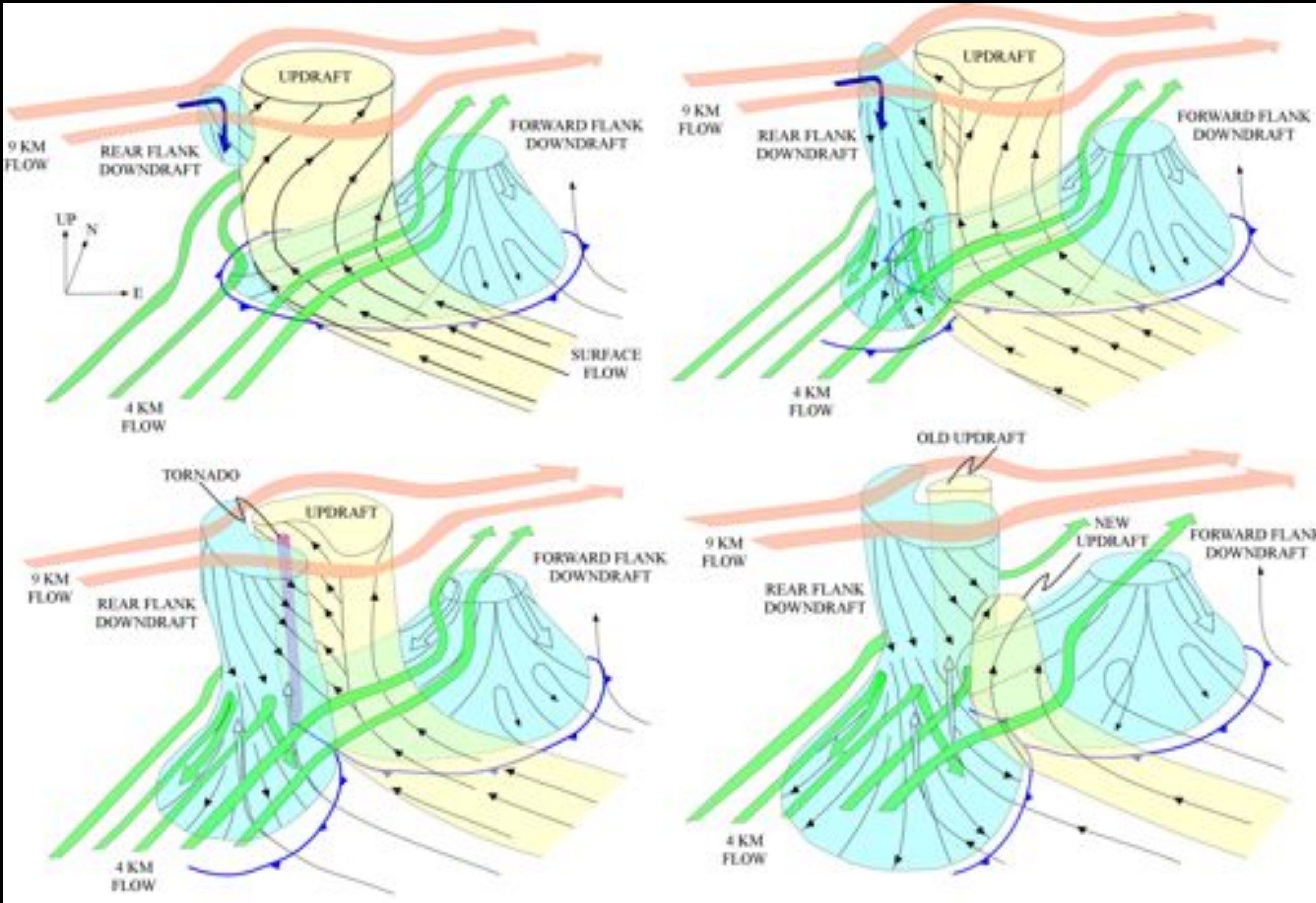






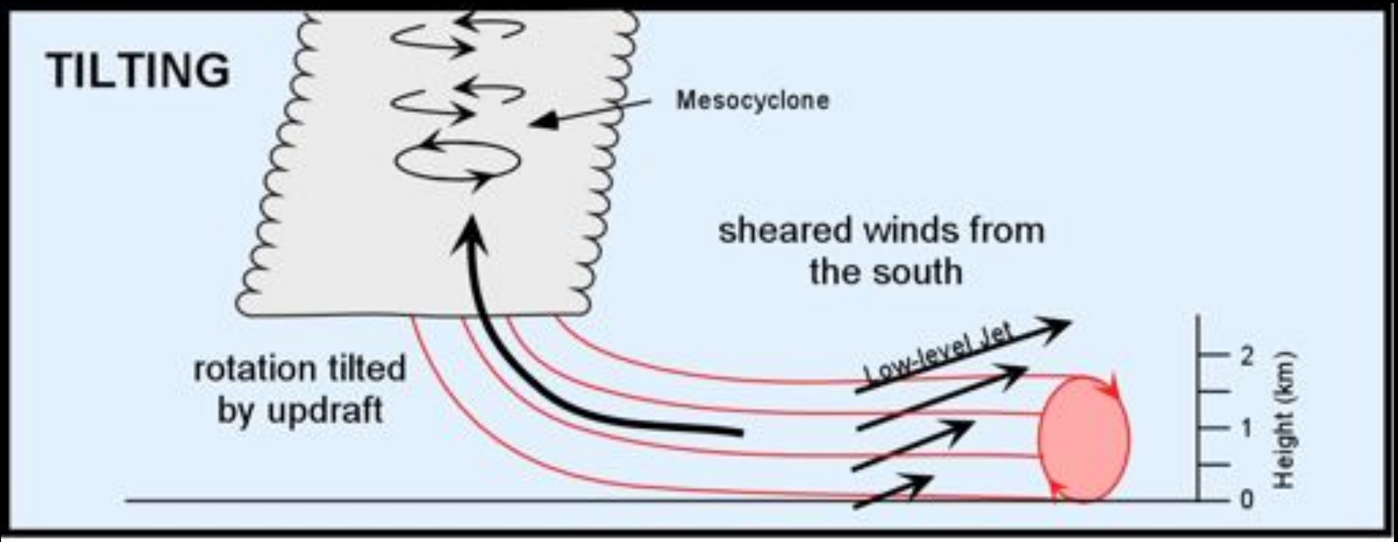
STRUCTURAL FEATURES OF A SUPERCELL THUNDERSTORM

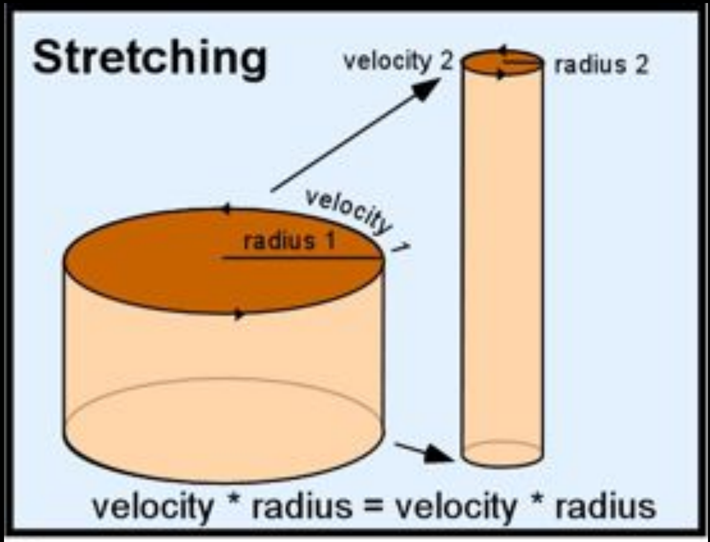
Evolution of a Supercell Thunderstorm

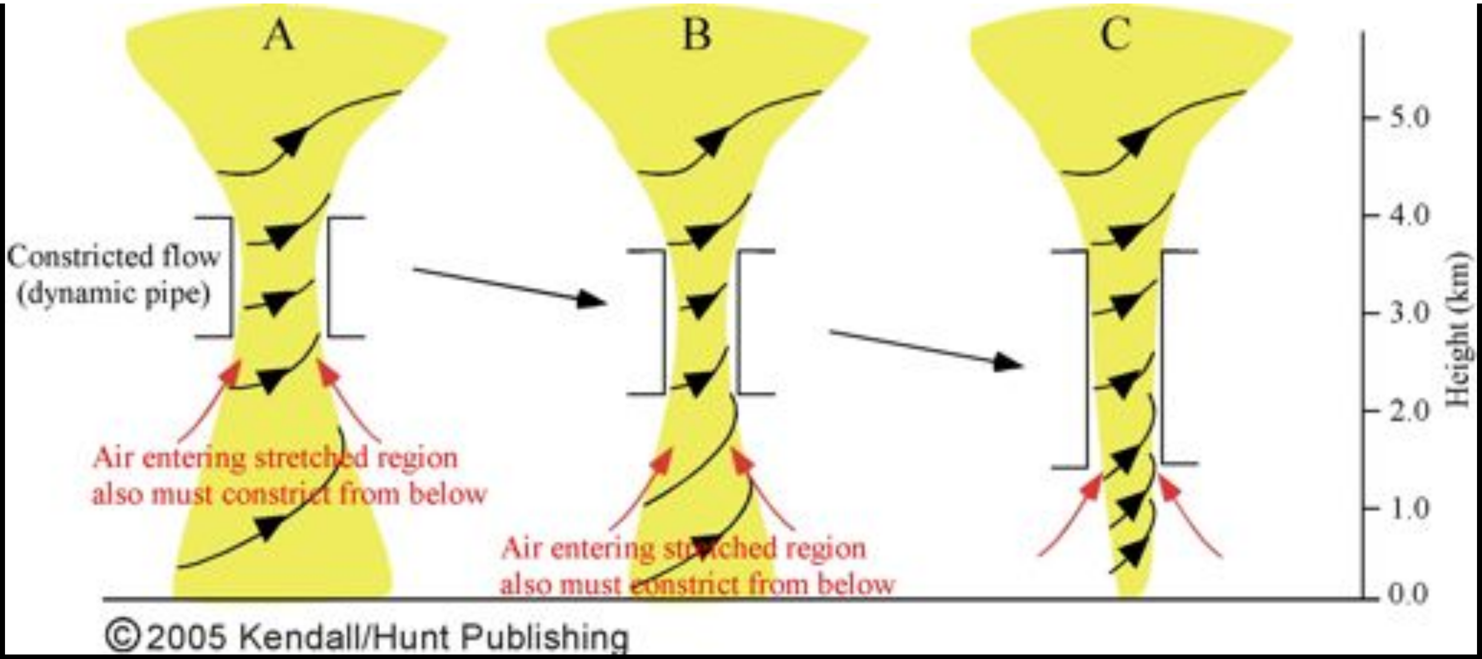


Courtesy of the American Meteorological Society

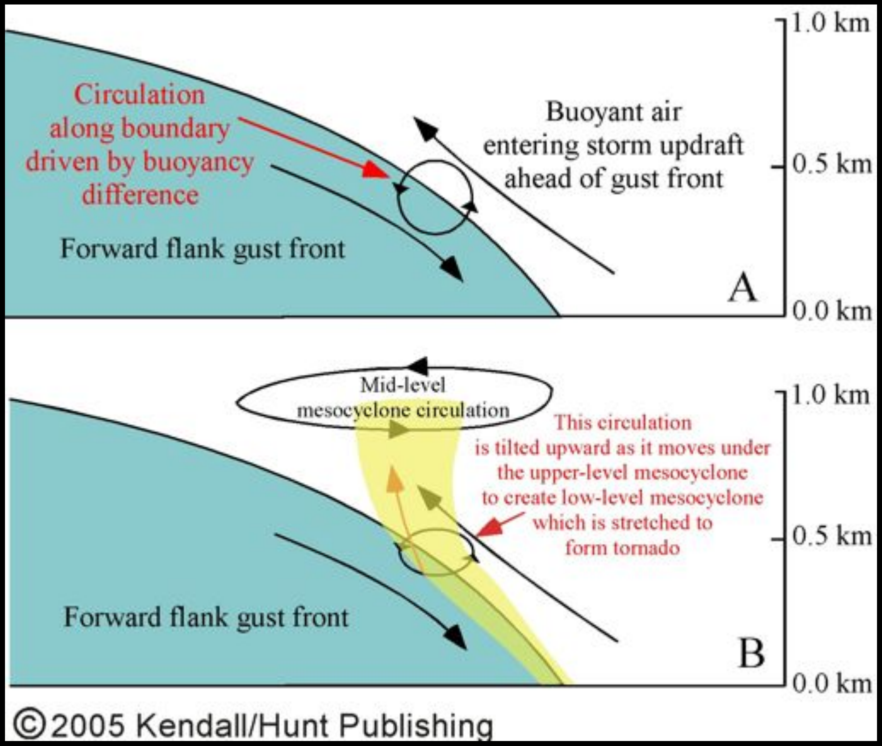
Tornado formation mechanisms in supercells





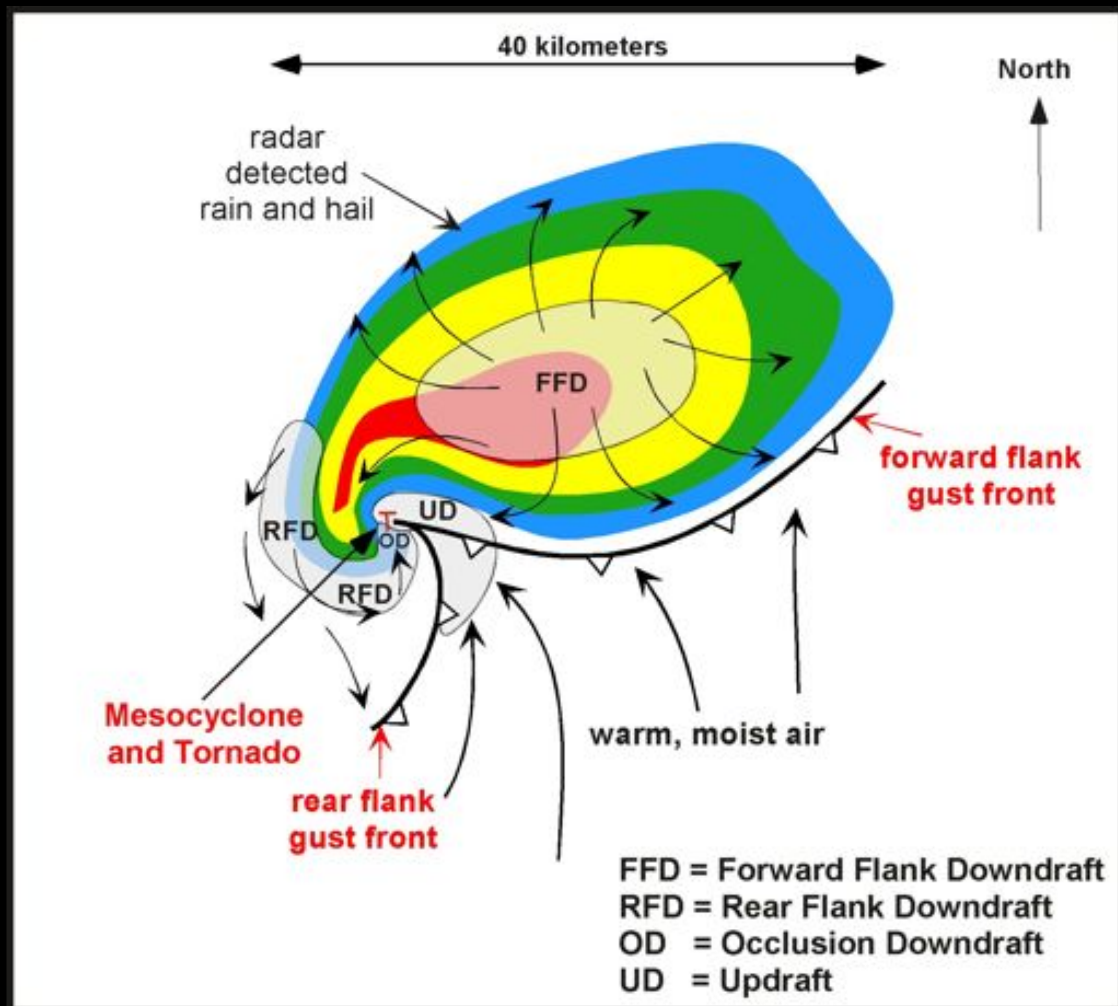


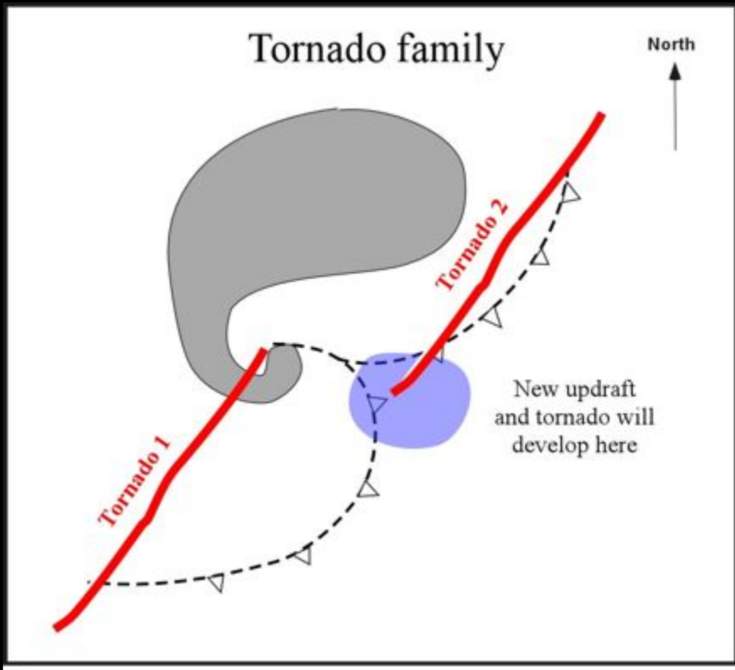
Dynamic pipe effect



"Baroclinic generation"

The mesocyclone and occlusion downdraft associated with a Supercell thunderstorm





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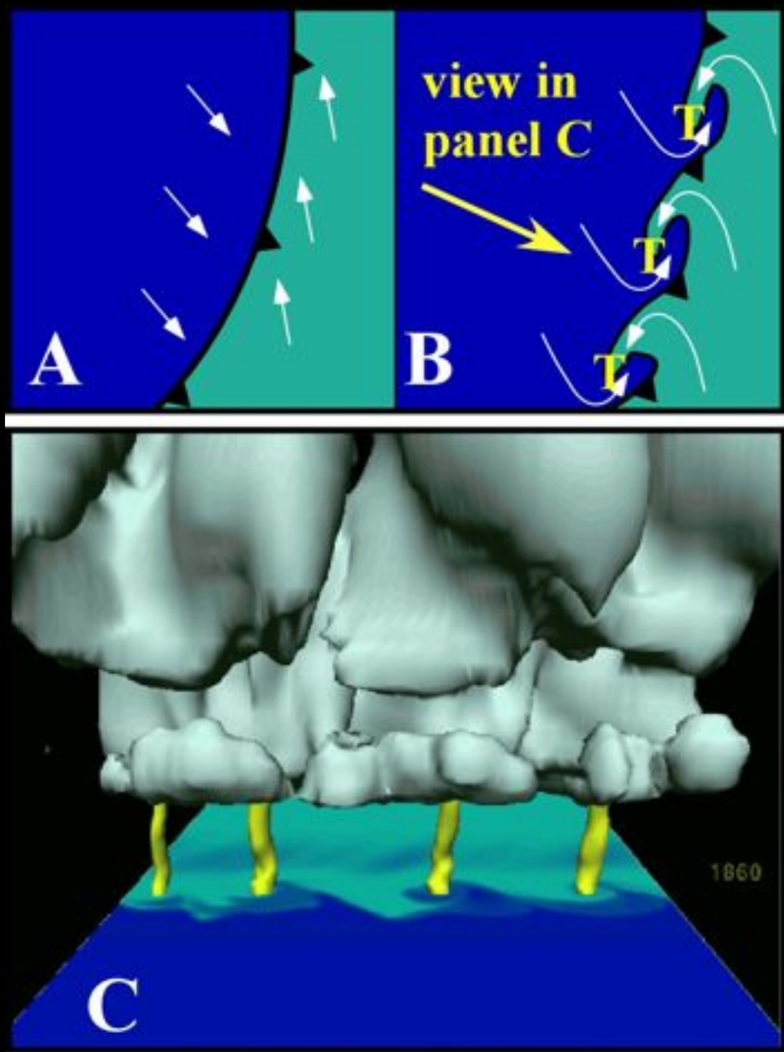
Courtesy of the University of Oklahoma Press

Supercell tornadoes often occur in families, the next forming
About the time that the previous tornado is dissipating

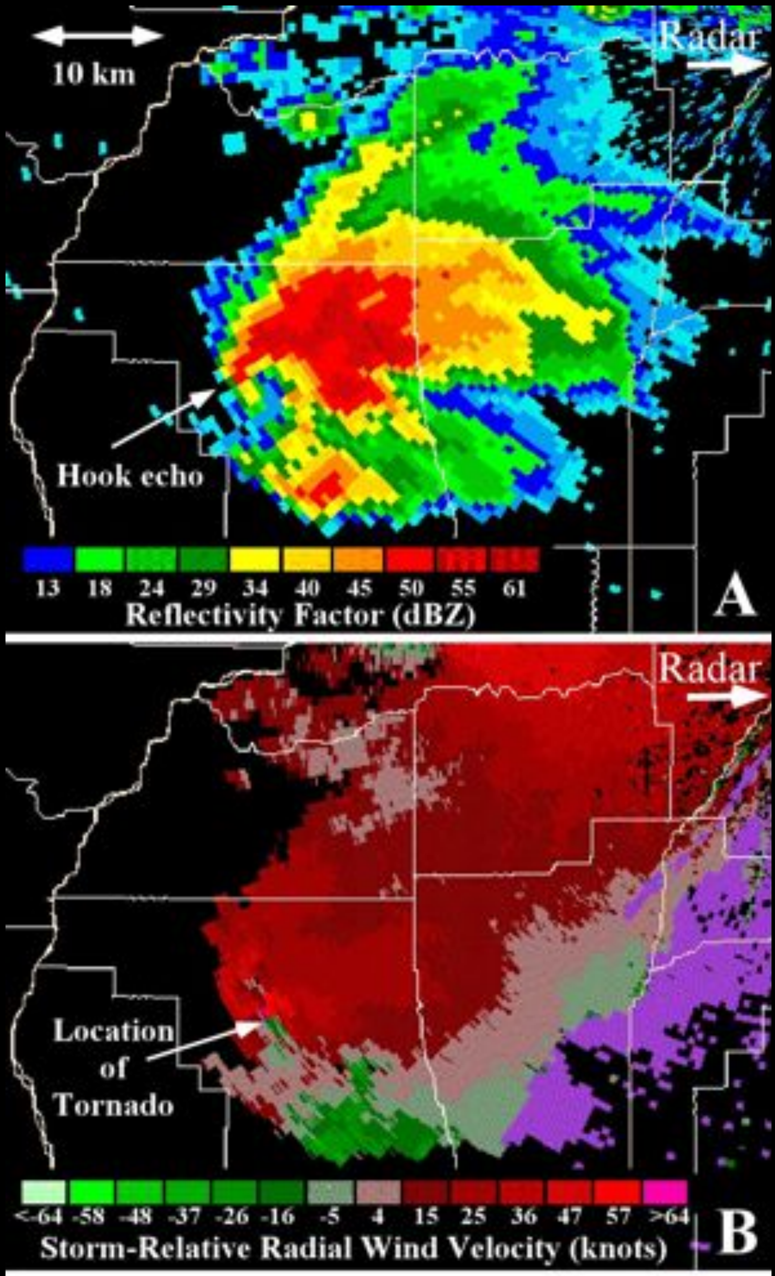
Non-supercell tornadoes form along squall lines characterized by strong horizontal shear



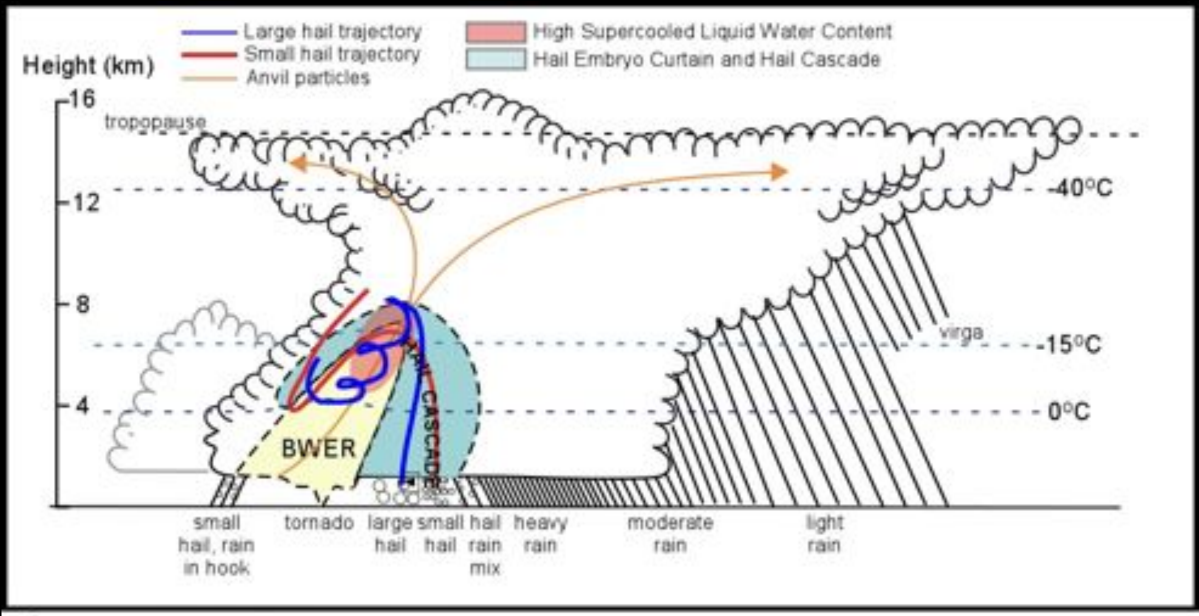
Detection of tornadoes with Radar:

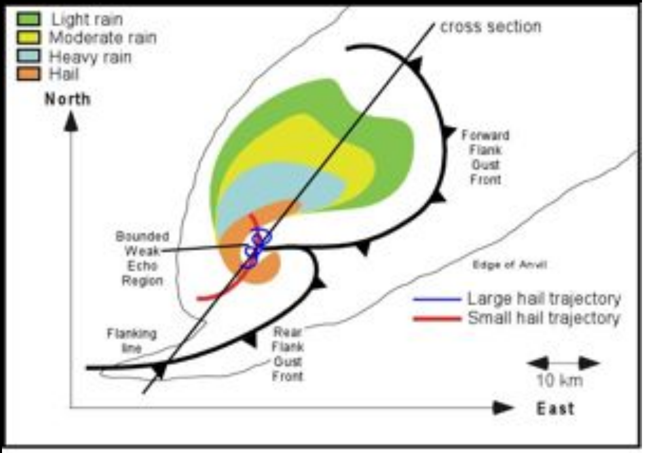
Hook Echo

Radial velocity couplet in Storm relative radial velocity Field.



Hail in supercells falls primarily to the northeast of the rain free base associated with the updraft and along the hook echo associated with the rear flank downdraft.





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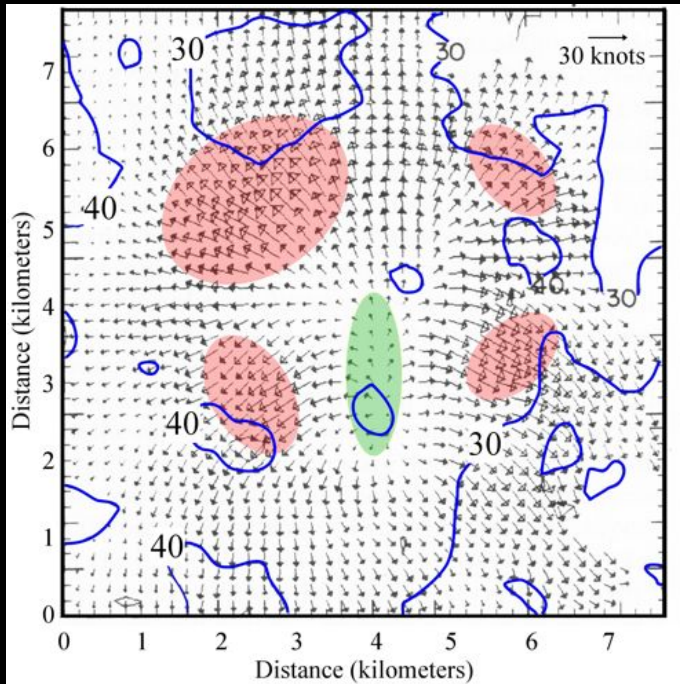
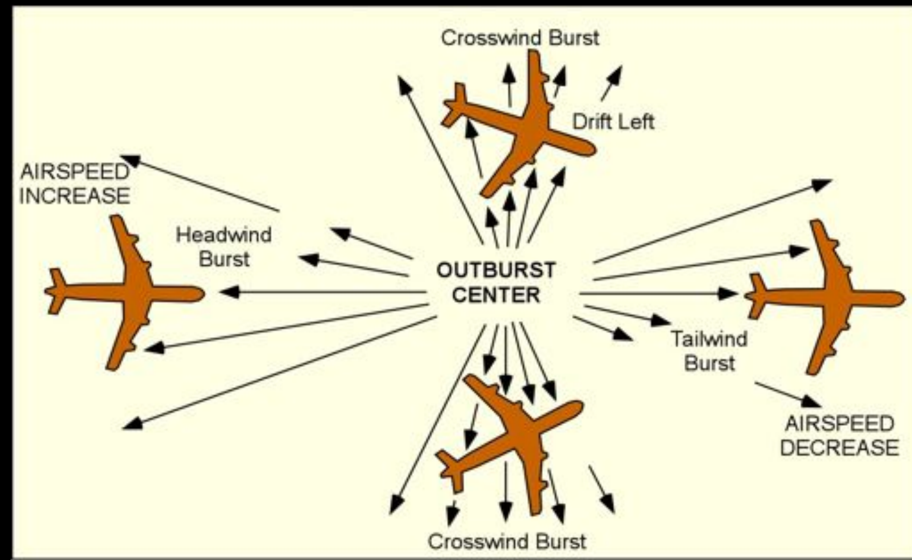
Courtesy of NOAA/NSSL Photo Library

Microbursts: Outbursts of strong wind associated with downdrafts from cumulus congestus and cumulonimbus clouds.

Driven by evaporative cooling of rain below cloud base and precipitation drag.



Courtesy of Jim Wilson and the American Meteorological Society



Courtesy of the Theodore Fujita Family

Microbursts can cause damage equivalent to a weak tornado and are a hazard to aircraft during takeoff and landing

Forecasting and nowcasting severe convective storms

NWS definition of a "severe" thunderstorm: Any thunderstorm that produces one or more of the following elements:

1) A tornado

Courtesy of NOAA/NSSL Photo Library

2) Damaging winds, or winds in excess of 50 knots (58 mph)

3) Hail 1 inch* in diameter or larger.

*Updated 1/5/10

Severe convection (generally) requires the following elements:

- A high degree of instability
- Strong vertical wind shear
- Sufficient moisture in the lower atmosphere
- A lifting mechanism, such a front, an outflow boundary, a gravity wave, or topography, to lift air to its level of free convection

The key to predicting the time and location of the onset of severe convection is determining where and when these four elements will phase together most effectively.

Once the convective storms have erupted, the focus shifts to short term forecasting and nowcasting – determining where severe conditions exist or are likely to exist in the near future.

Assessing Instability

1. Maps of stability indices can be used to initially assess where the atmosphere is conditionally or potentially unstable.

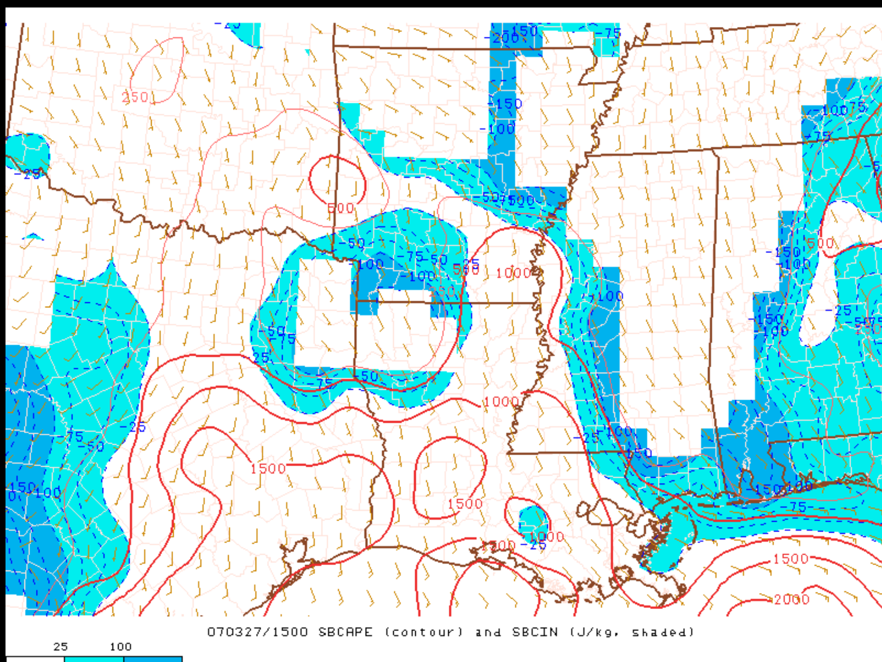
   Examples: CAPE
   Lifted index
   K Index
   Showalter Index
   SWEAT Index
   Total-Totals Index

2. Once the key areas are identified, current and model soundings should be used to examine the current state and evolution of the atmosphere in the locations where instability is expected.

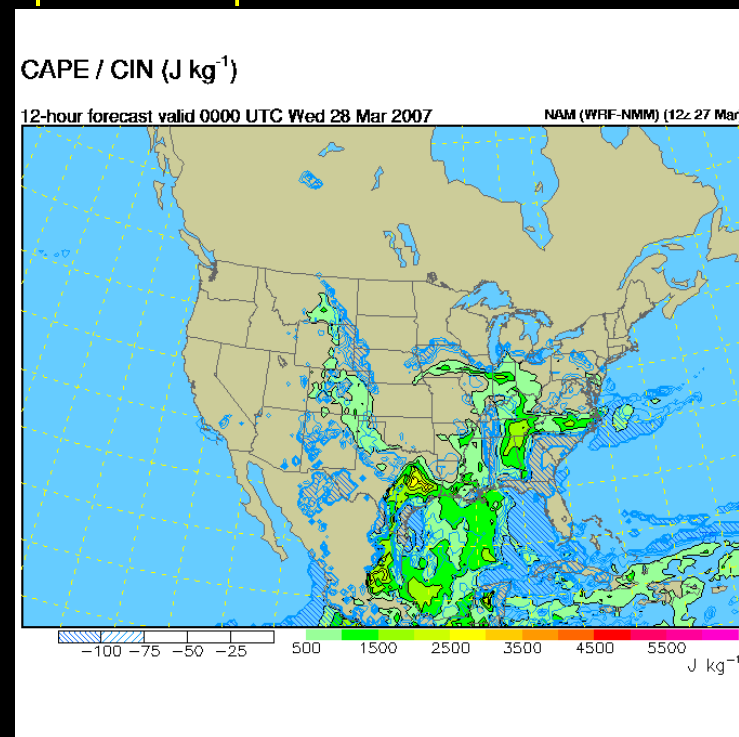
GOAL: IDENTIFY THE REGIONS OF GREATEST THREAT

Examples of products available on the web: CAPE

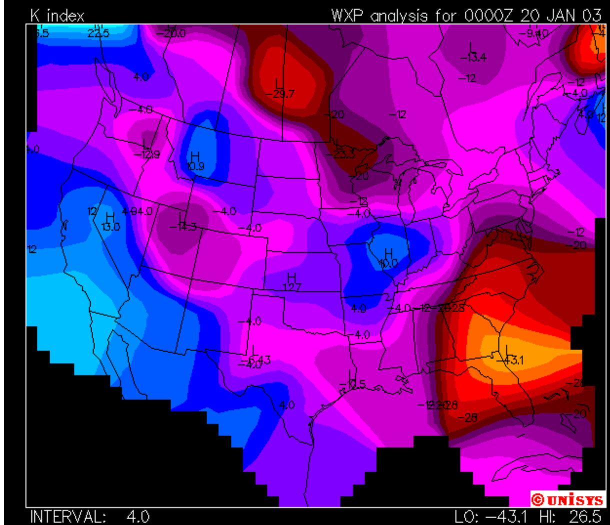
http://www.spc.noaa.gov/exper/mesoanalysis/



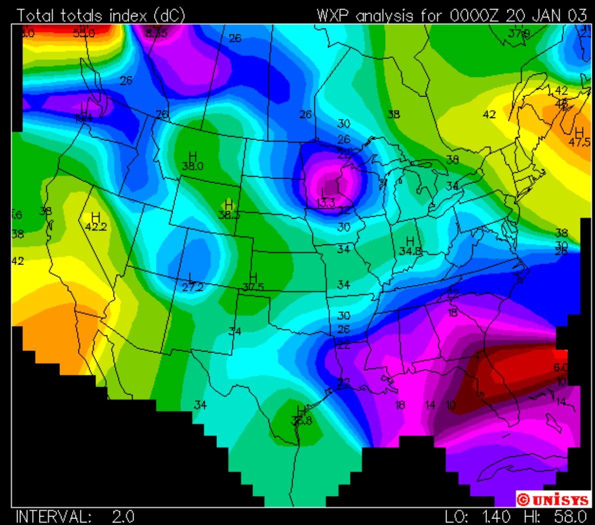
http://www.rap.ucar.edu/weather/model/



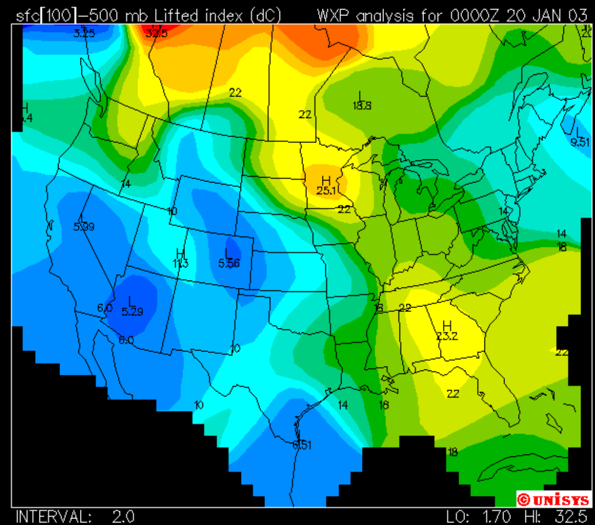
A site with all the indices in convenient form is Unisys: http://weather.unisys.com/upper_air/ua_con_ki.html



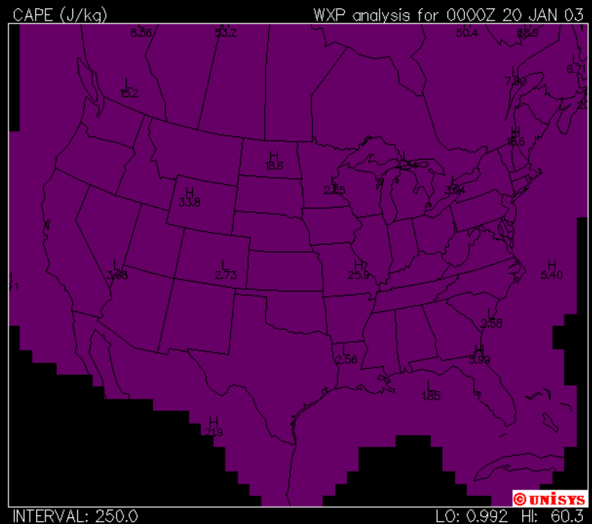
K Index



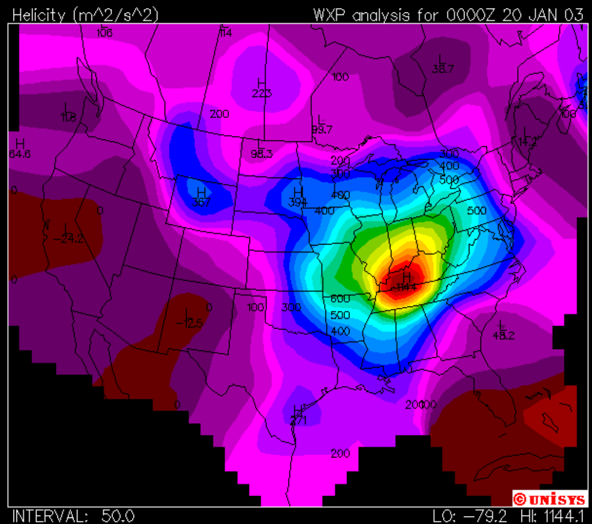
Total-totals Index



Lifted Index



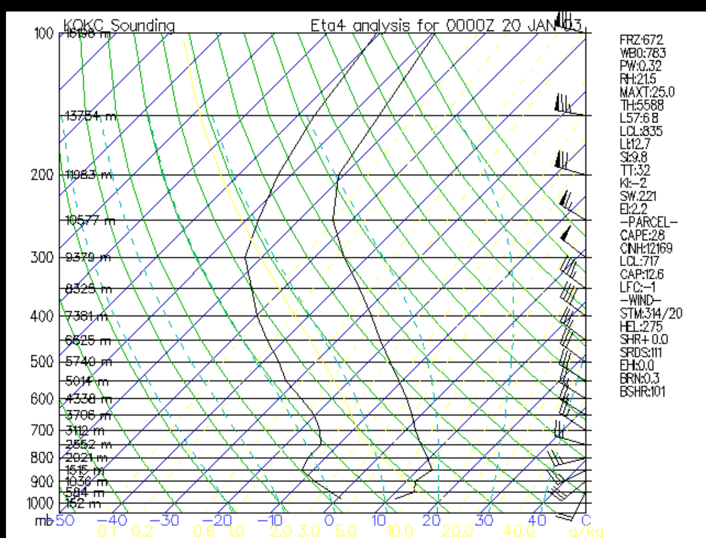
CAPE



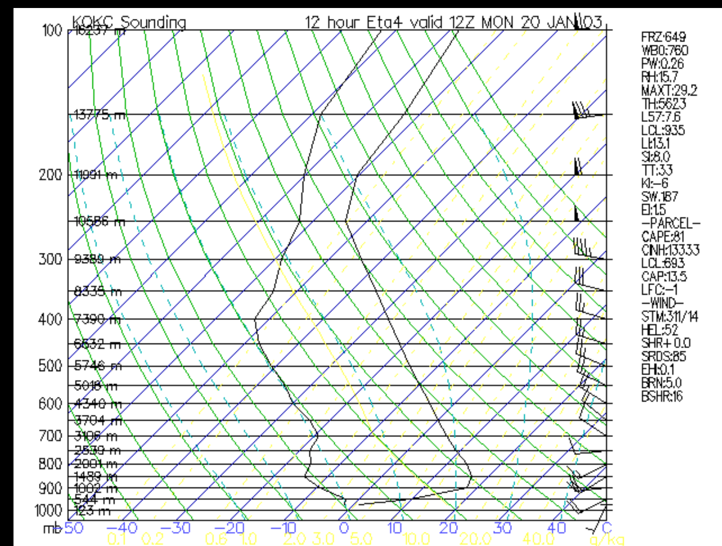
Helicity

Model current and forecast soundings available at NIU site

http://www.stormchaser.niu.edu/machine/fcstsound.html



0 hr

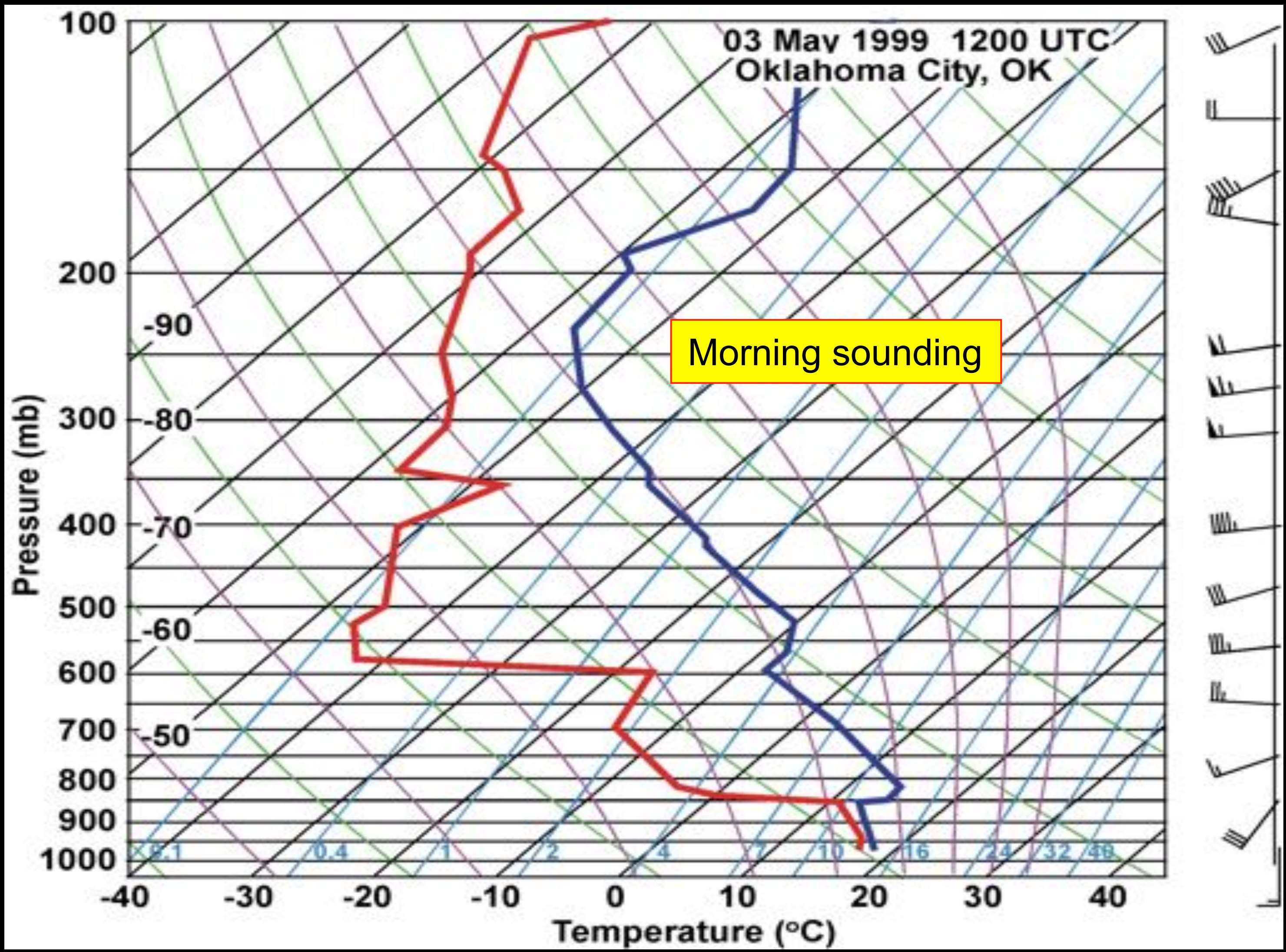


12 hr

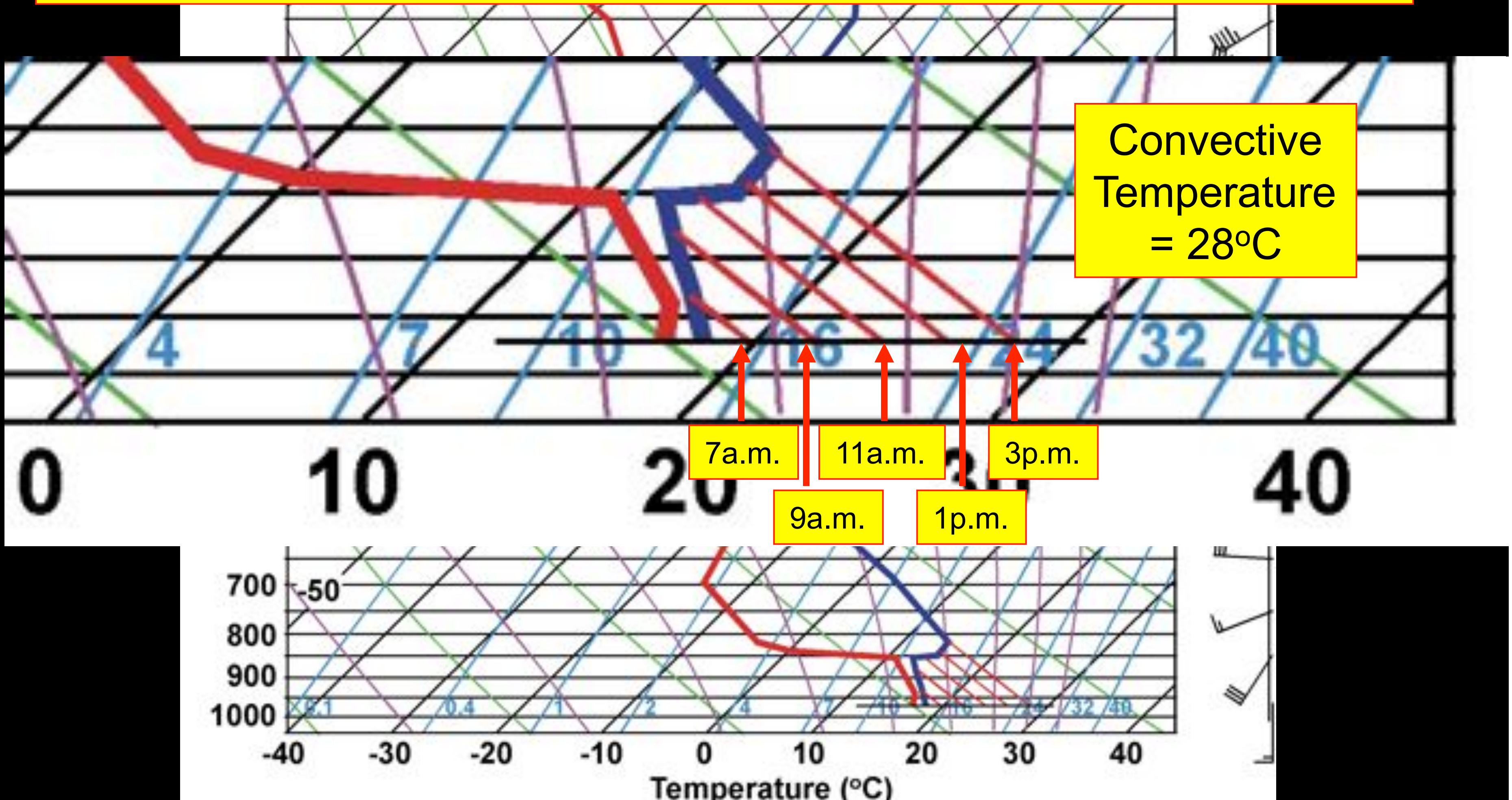
IDV and GARP plot forecast soundings. BUFKIT, which is a Windows program for analyzing soundings, is also useful for sounding analysis.

http://wdtb.noaa.gov/tools/BUFKIT/index.html

Instability estimated from morning (1200 UTC) soundings will be an underestimate of the actual instability that will be realized later in the day when the surface is heated by solar radiation.

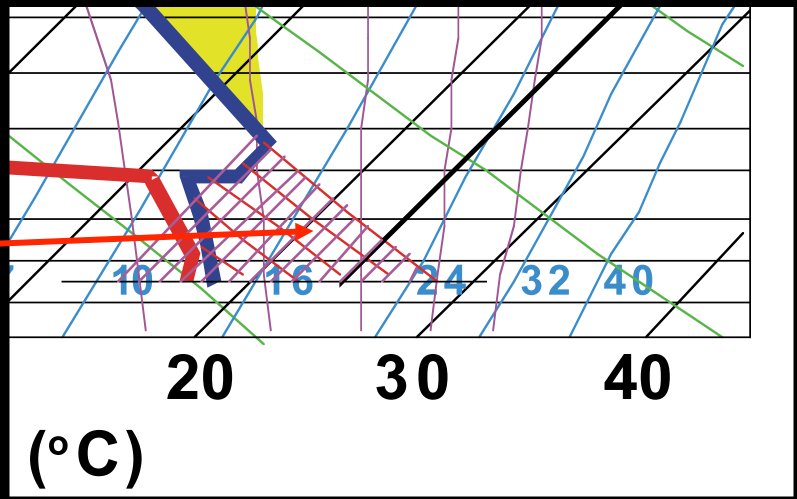


As surface heats during the day, air in contact with the surface rises in thermals whenever the lapse rate exceeds the dry adiabatic lapse rate. Small cumulus may form if the air in the thermals saturate. When air heats sufficiently to trigger deep convection the surface temperature is will reach the "Convective Temperature."



On the Skew-T, each box defined by the intersection of dry adiabats with temperature = 7 Joules/kg of energy.

Note boxes defined by temperature and dry adiabats



Ideal clear sky solar input of energy (J cm^{-2} day^{-1}):

	Incident	Ground heating	Boxes
Jan	925	167	23.8
Feb	1238	223	31.8
Mar	1628	293	41.8
Apr	1897	341	48.7
May	2152	387	55.3
Jun	2341	421	60.1
Jul	2286	411	58.7
Aug	2110	380	54.3
Sep	1645	296	42.2
Oct	1381	249	35.6
Nov	1017	183	26.1
Dec	837	150	21.4

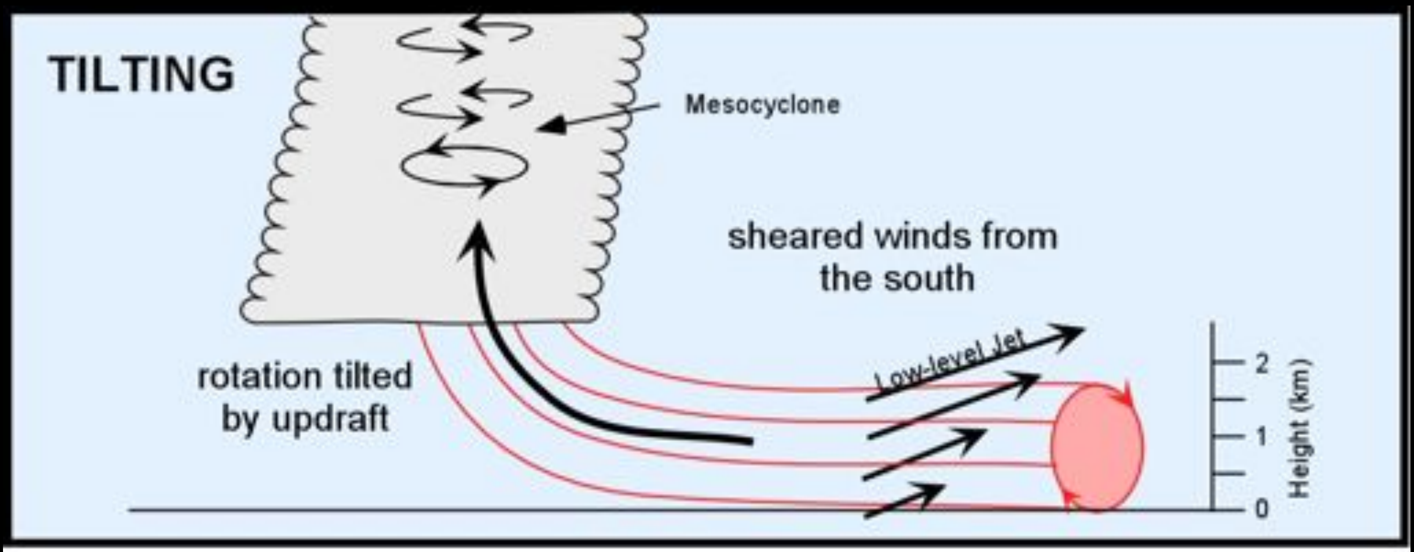
Modifications to number of boxes For PBL heating:

Overcast skies:	0.5
Broken clouds:	0.7
Scattered clouds:	0.9
Haze or moist air:	0.8
Surface moisture or water:	0.7
Ice or snow cover	0.2
Snow and overcast:	0.1
Scattered clouds, surf moist	0.6

Vertical Wind Shear

Shear plays two important roles in severe thunderstorm generation

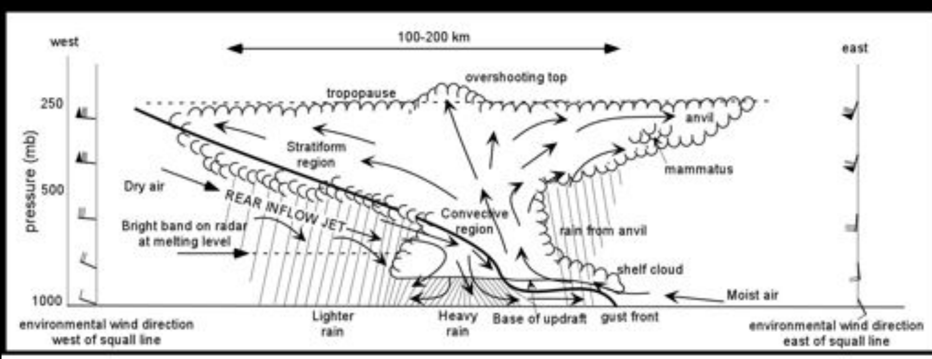
1. Vertical shear provides a source of horizontal vorticity that can be tilted into the vertical to produce rotating thunderstorms.

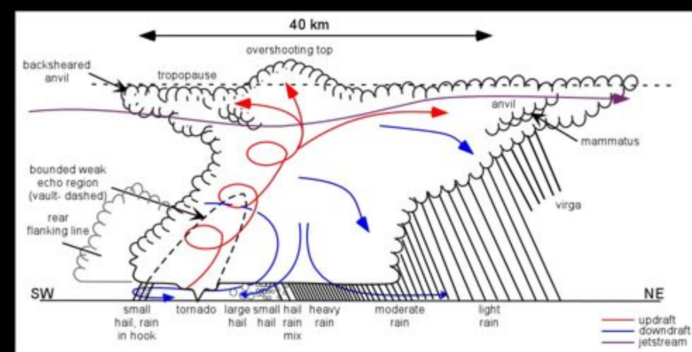


Vertical Wind Shear

Shear plays two important roles in severe thunderstorm generation

2. Vertical shear tilts the updraft, allowing the precipitation to fall outside the updraft. Shear decouples the updraft and downdraft and allows these circulations to reinforce one-another.

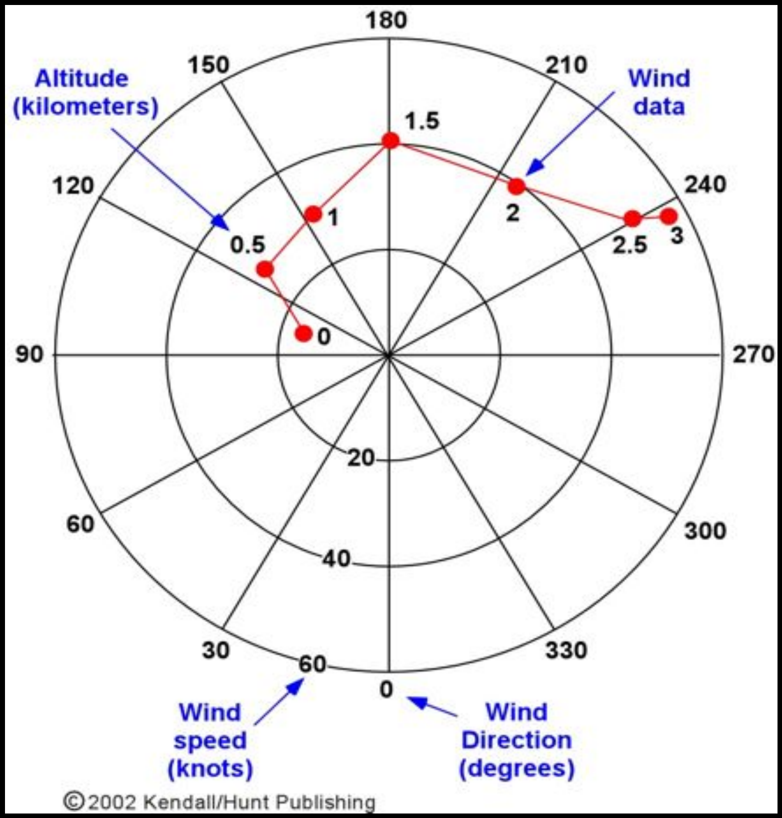




Evaluating Wind Shear

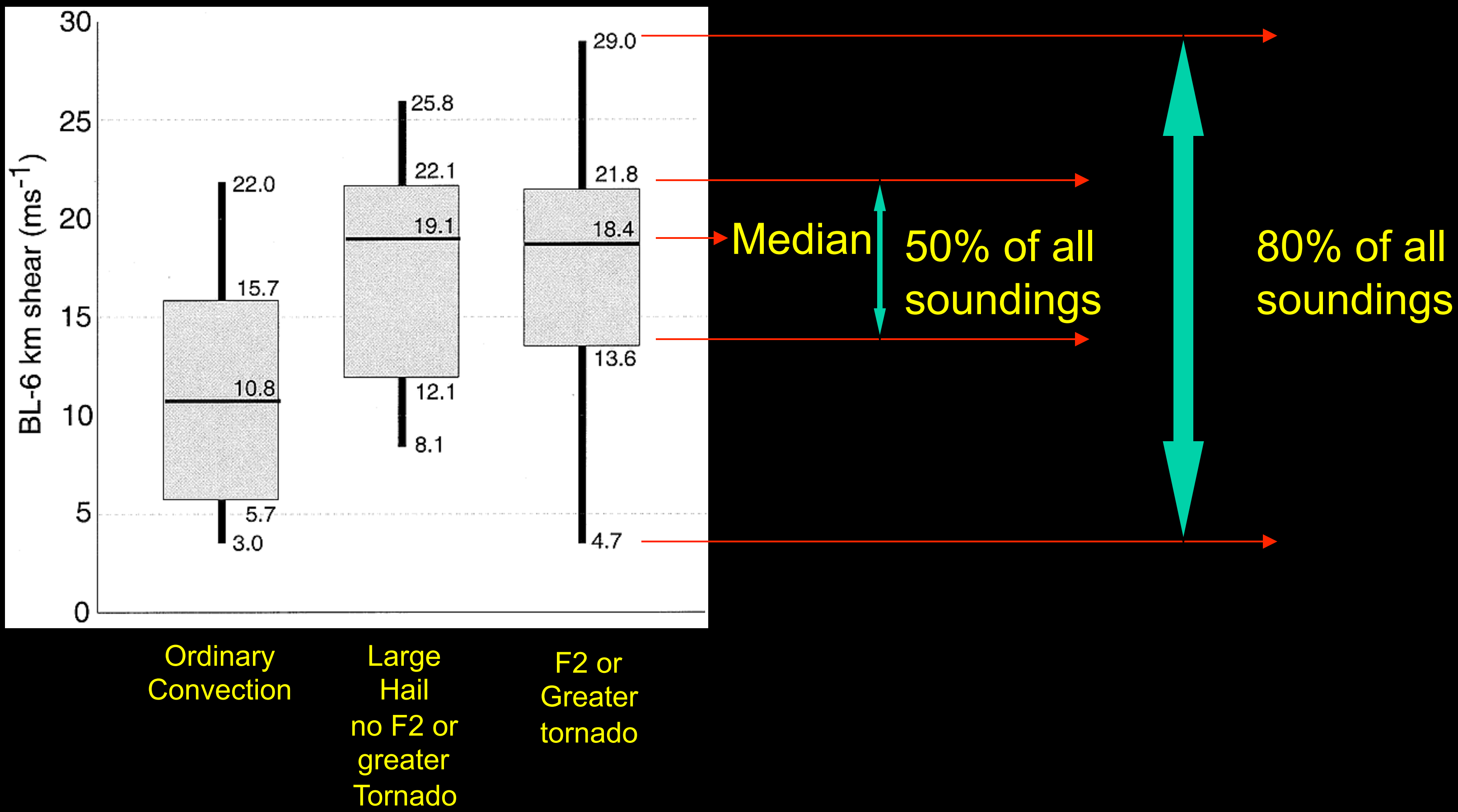
1.Hodographs:

-Polar diagram conventionally designed with north (0°) at the bottom, south (180°) at the top, east (90°) to the left and west (180°) to the right.
-Distance from the center of the hodograph denotes wind speed, with rings about the center of the hodograph marking specific speeds.
- Wind data from soundings are normally plotted on a hodograph at evenly spaced altitudes, for example, at 1, 2, 3 kilometers, etc.
-A point is placed on the hodograph denoting the wind speed and direction at each altitude



Directional shear appears as a turning line, speed shear as a long line
Magnitude of shear vector = length of line segment between two altitudes/altitude difference
Direction of shear vector = direction of line segment transposed to origin.

Boundary layer (0-500 m average) to 6 km shear vector magnitude measured in inflow air: (1992 climatology)



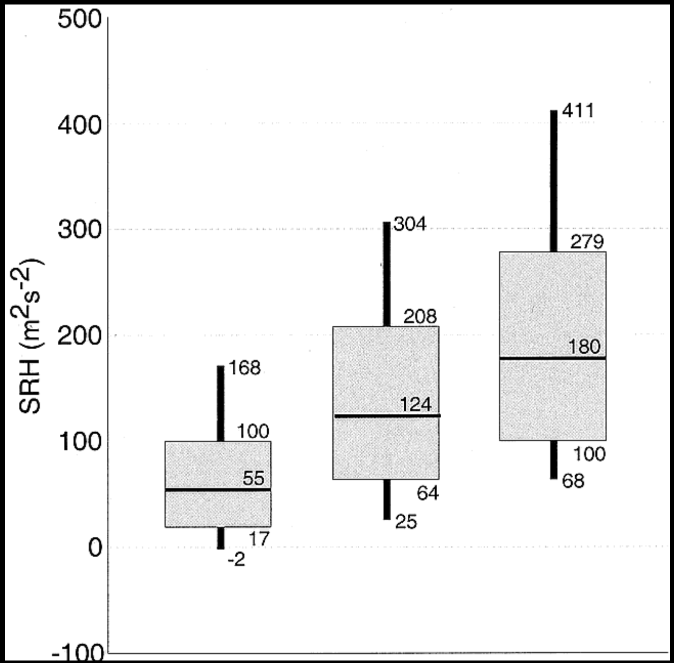
High shear environments distinguish ordinary convection from supercells producing hail or tornadoes, but does not distinguish between supercells that produce tornadoes and those that do not.

From Rasmussen and Blanchard (1998, WAF)

Storm-Relative Helicity:

(measure of inflow of horizontal vorticity into a storm updraft -- where it can be tilted to produce rotation)

$$SRH = \int_0^h k \bullet \left(\vec{V}_h - \vec{c}\right) \times \frac{\partial \vec{V}_h}{\partial z}\, dz$$



Ordinary Convection

Large Hail no F2 or greater Tornado

F2 or Greater tornado

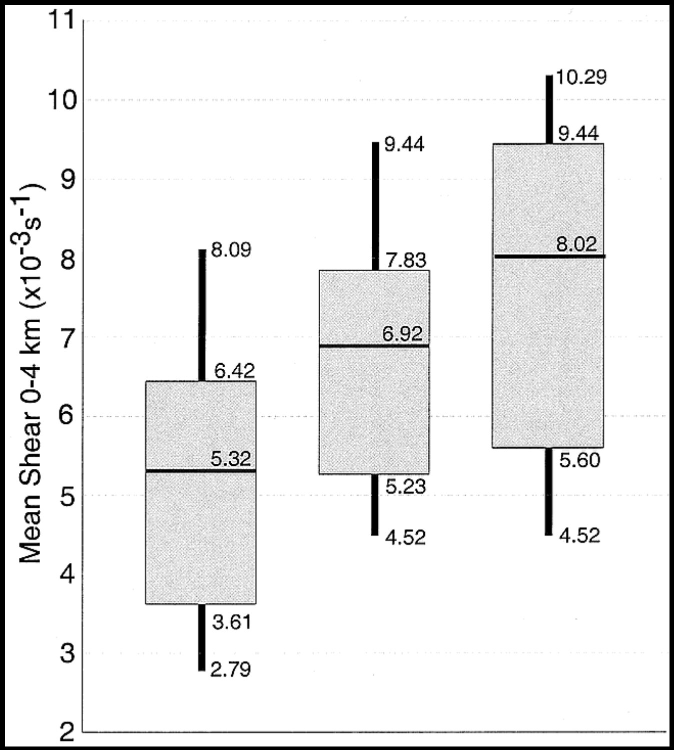
Note that values > 200 are very likely to be associated with tornadic storms

Note that values < 70 are unlikely to be associated with tornadic storms

From Rasmussen and Blanchard (1998, WAF)

Mean Shear (lowest 4 km)

$$S = \frac{\int_0^h \frac{\partial V}{\partial z} dz}{\int_0^h dz}$$

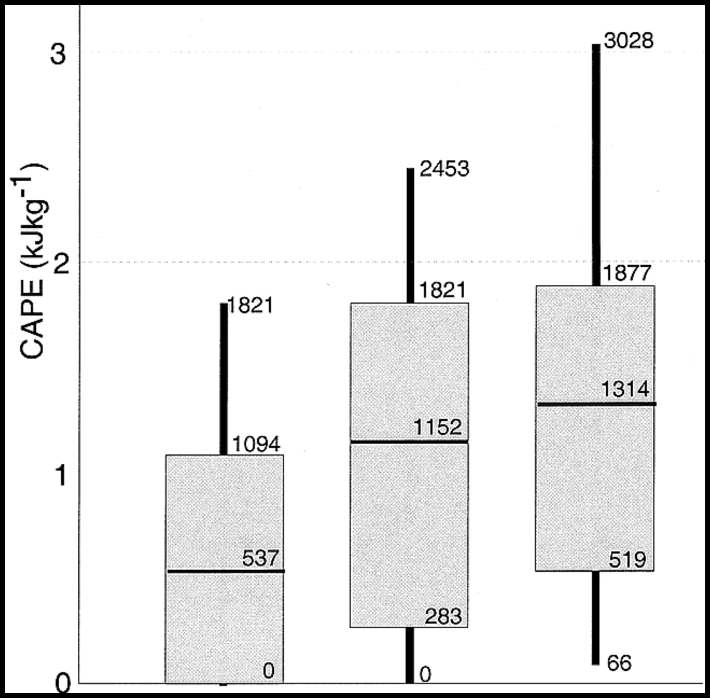


Ordinary Convection | Large Hail no F2 or greater Tornado | F2 or Greater tornado

Mean shear also distinguishes between the categories, but with a lot of overlap.

From Rasmussen and Blanchard (1998, WAF)

CAPE



Ordinary Convection

Large Hail no F2 or greater Tornado

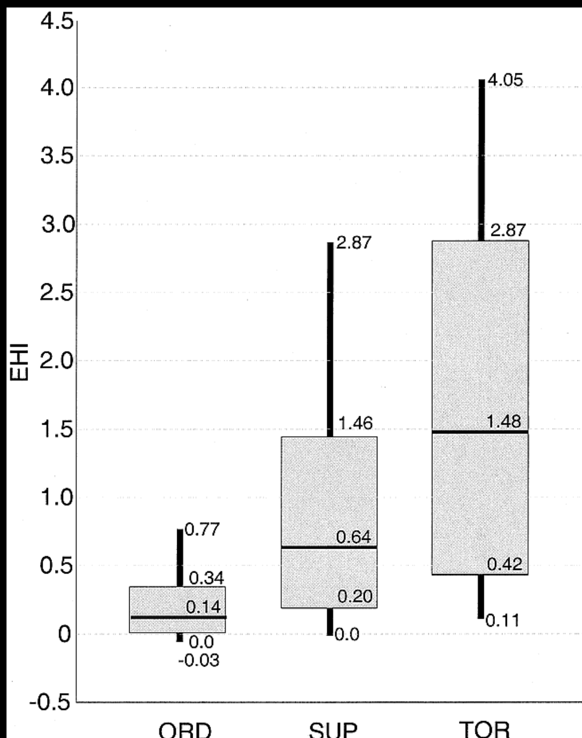
F2 or Greater tornado

CAPE is a reasonable predictor to separate hail producing or tornado producing supercells from ordinary thunderstorms, and with very high values (>2500), has predictive value for separating supercells that produce tornadoes from those that do not.

From Rasmussen and Blanchard (1998, WAF)

Energy-Helicity Index (EHI)

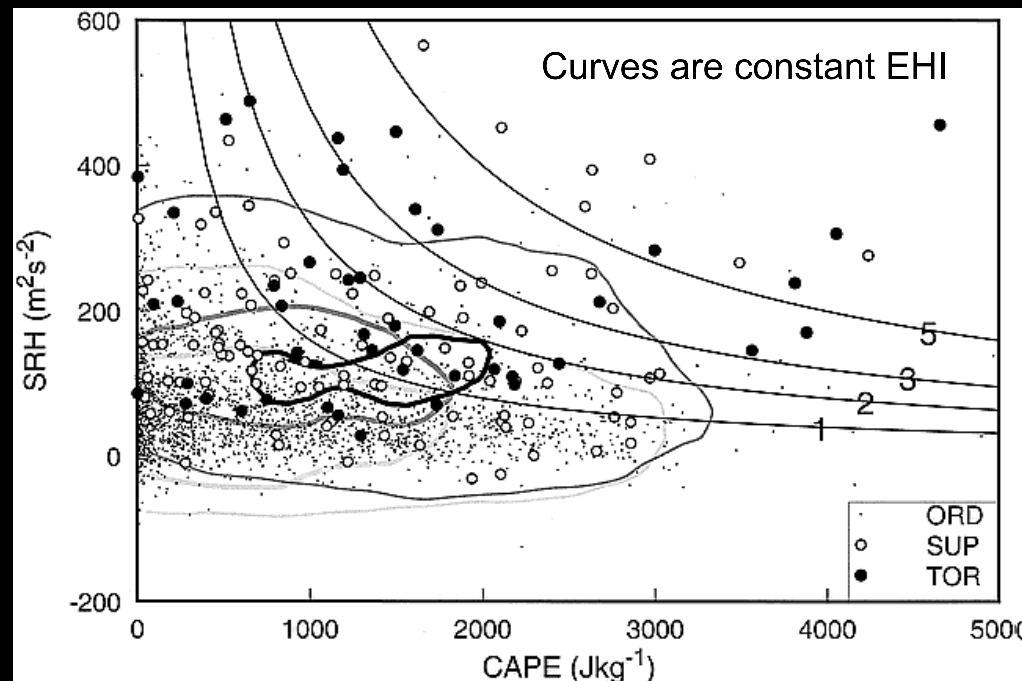
$$EHI = \frac{[CAPE][SRH]}{1.6 \times 10^5}$$



Ordinary Convection

Large Hail no F2 or greater Tornado

F2 or Greater tornado



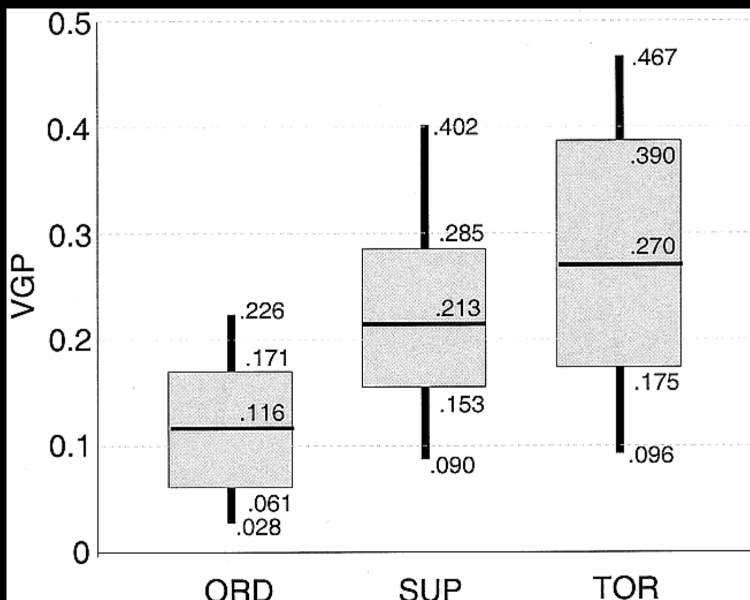
The EHI is an good discriminator of ordinary convection, and large tornadic vs weak or non-tornadic supercells

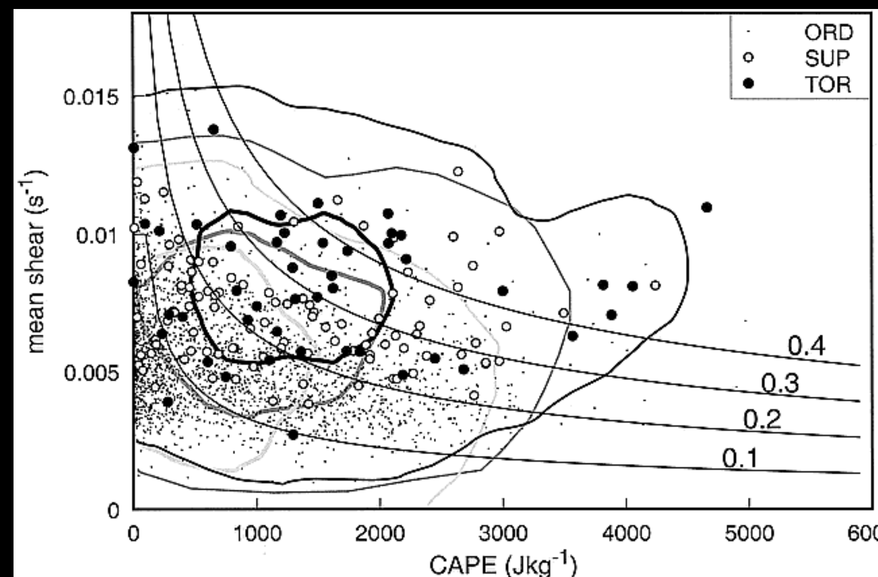
From Rasmussen and Blanchard (1998, WAF)

Vorticity Generation Parameter

$$VGP = S\sqrt{CAPE}$$

Called “vorticity generation parameter” because S, the mean shear, is related to the horizontal vorticity and $(CAPE)^{1/2}$ is related to updraft speed (which tilts the horizontal vorticity into the vertical).





Ordinary Convection

Large Hail no F2 or greater Tornado

F2 or Greater tornado

Predictive capability similar to EHI

From Rasmussen and Blanchard (1998, WAF)

The shear/CAPE combinations are useful for forecasting severe convection, but still result in a high false alarm rate.

Nevertheless, these represent one way to determine the areas that are more likely to experience severe storms.

Boundaries – focal points for storm initiation

Boundaries between airmasses, both on the synoptic and mesoscale, are nearly always associated with triggering of convection.

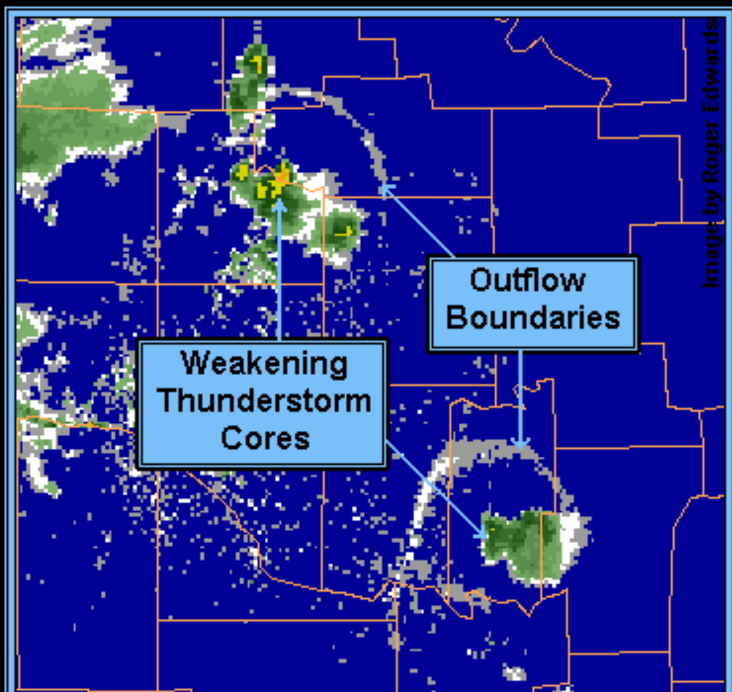
Detection and monitoring boundaries, in conjunction with CAPE, Shear and other parameters, allows a forecaster to focus on the most threatened regions for severe storms to develop

Surface-based frontal boundaries can be tracked using surface data

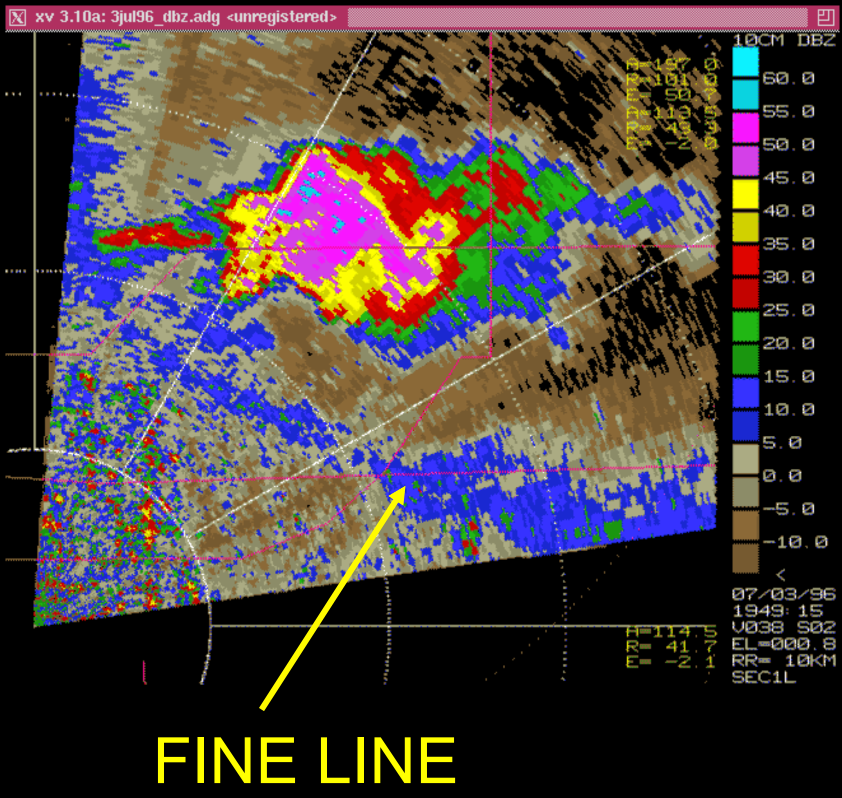
Look for strong gradients in temperature and dewpoint, a trough in the pressure field, and wind shifts.

Advanced techniques for identifying boundaries:

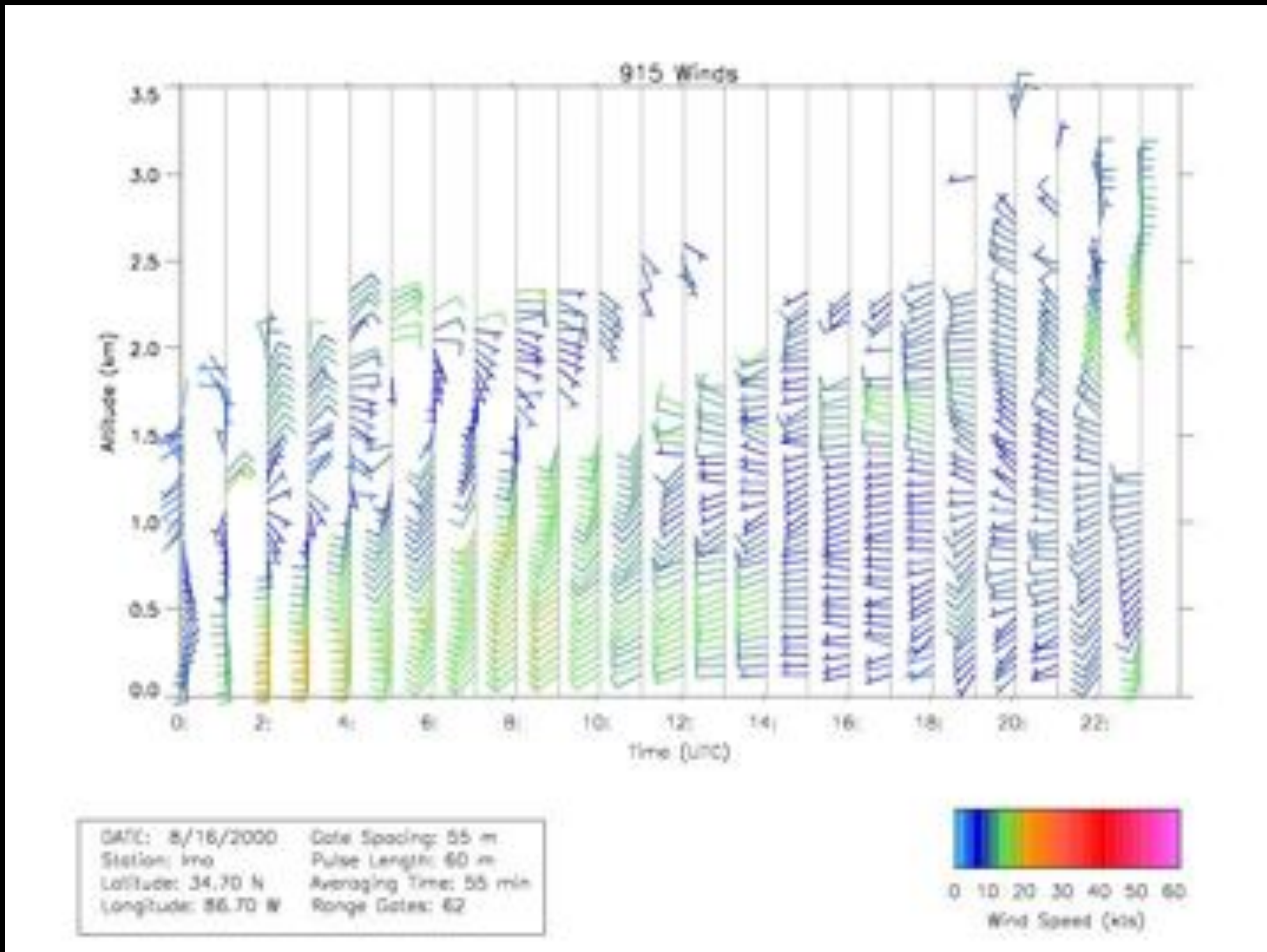
NEXRAD RADAR: Look for a “fine line” of higher reflectivity
In the clear air echo, or fine lines ahead of existing thunderstorms
That indicate a gust front.



Radar Depiction of Central Oklahoma Outflows
27 Jun 97 / 1943 CDT SPC Reflectivity Composite

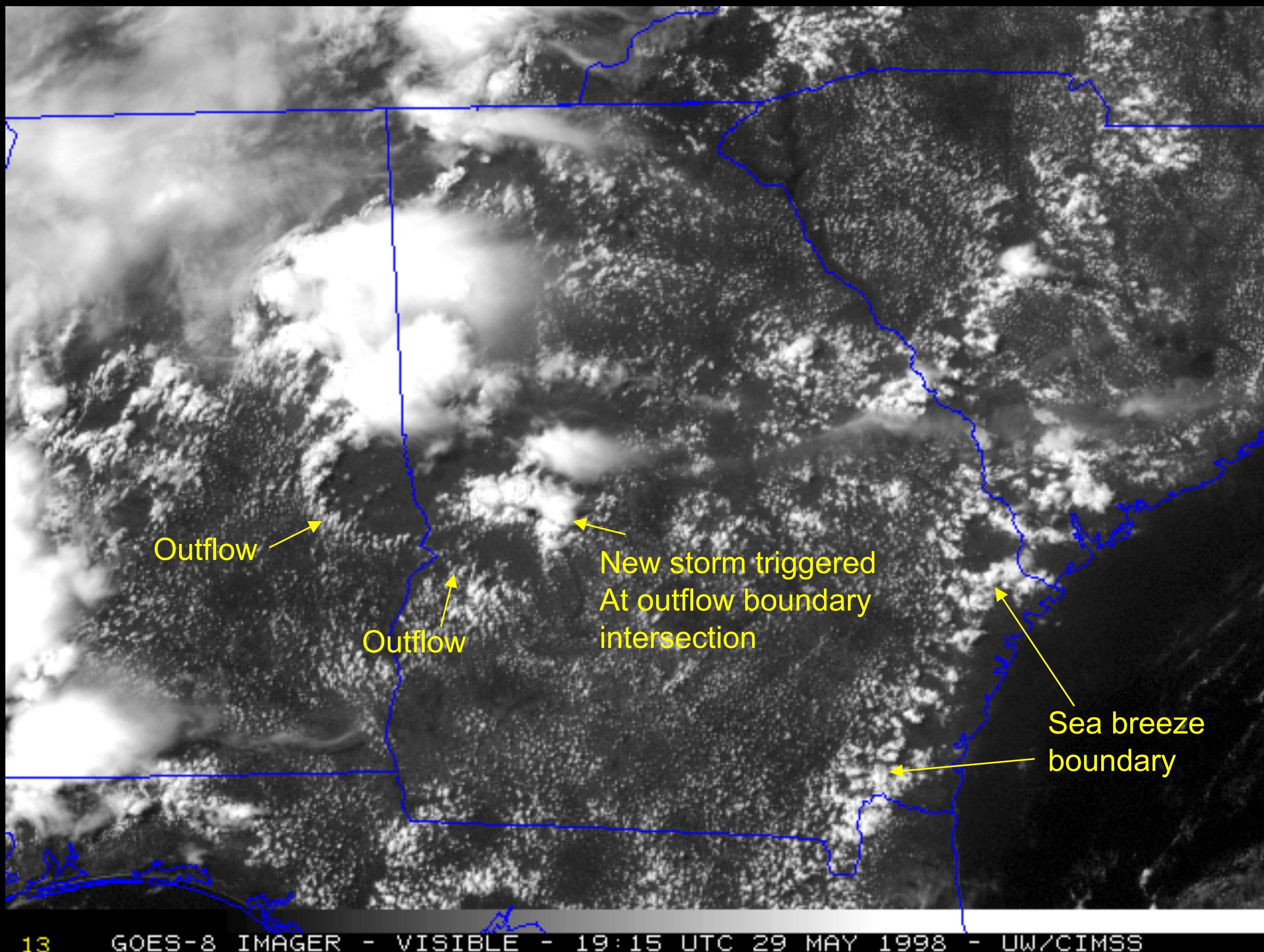


Profiler winds: Look for wind shifts associated with passing boundaries

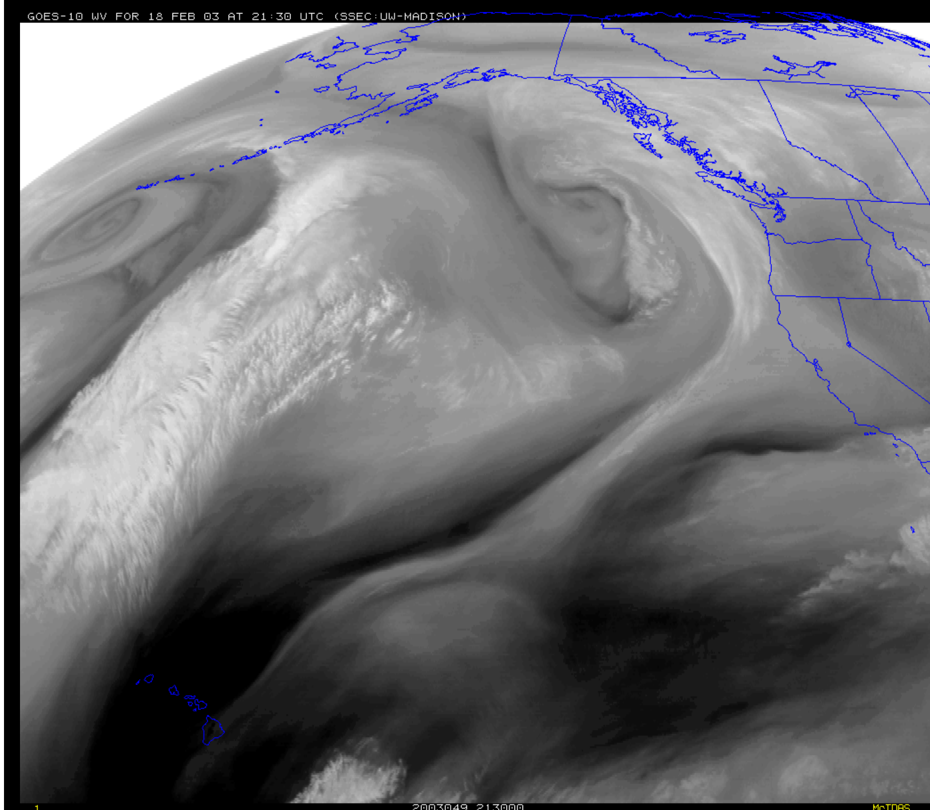


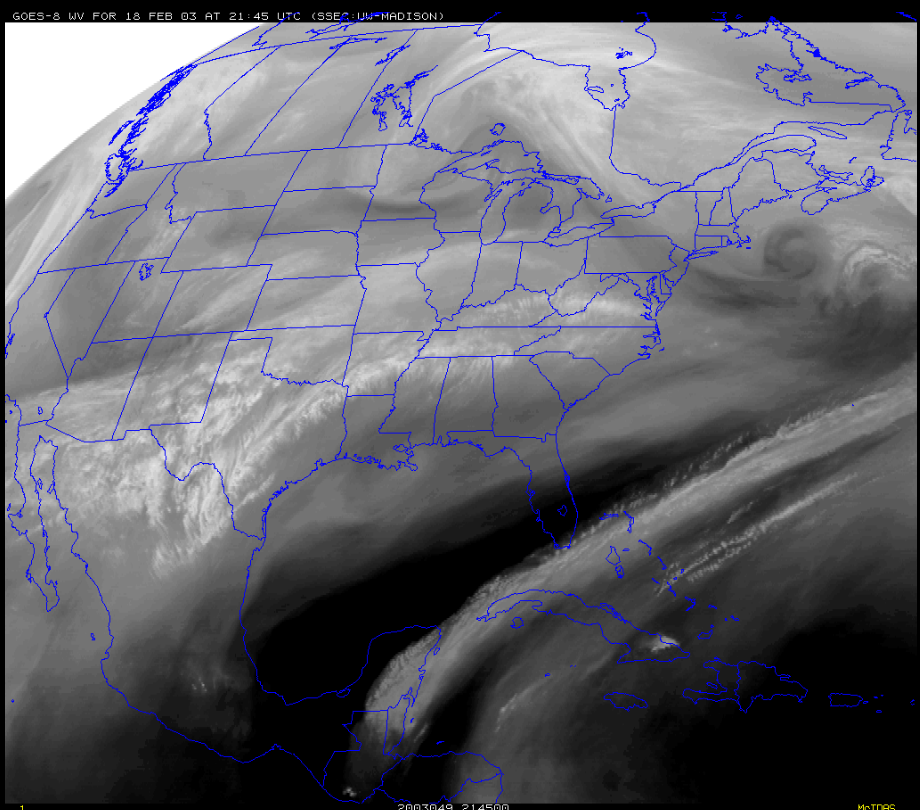
Courtesy of Kevin Knupp

Intersecting Boundaries: Focal points for convection (see loop)



Look for dark filaments on water vapor images. The leading edge of these filaments are often associated with middle or upper tropospheric fronts. When filament moves over a potentially unstable region, convection may trigger.

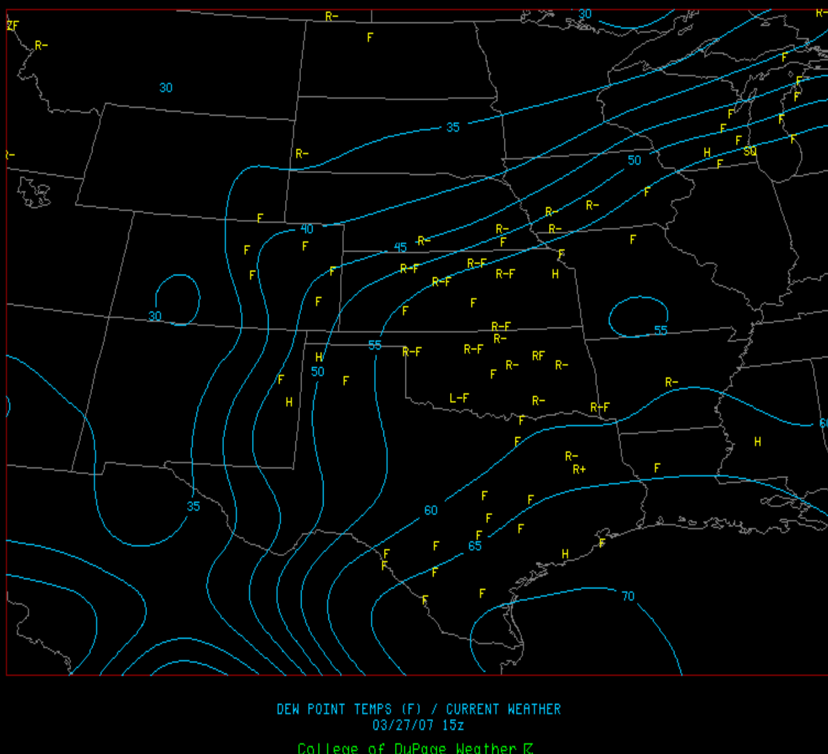




Moisture

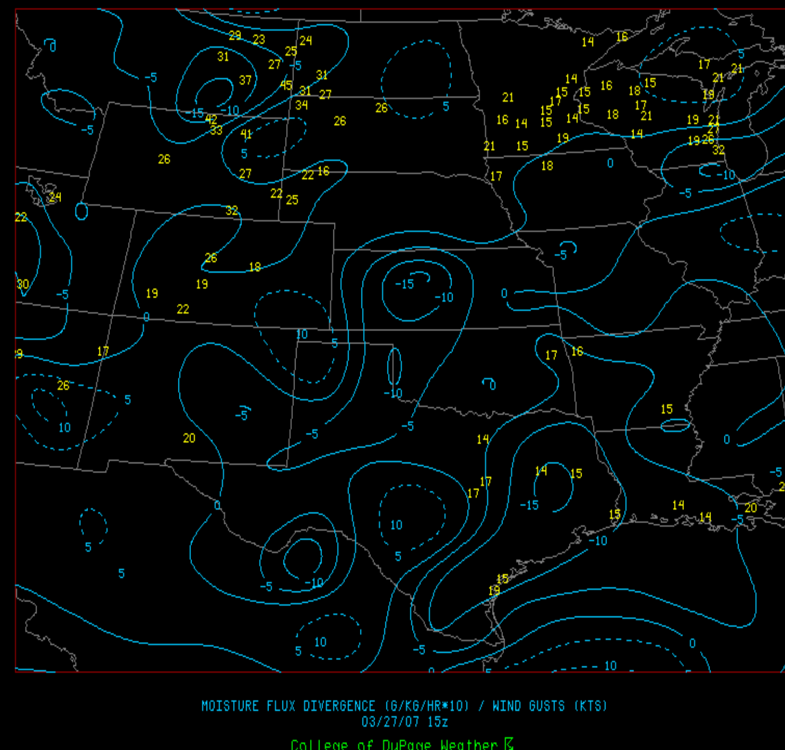
http://weather.cod.edu/analysis/analysis.sfccon.html

Moisture



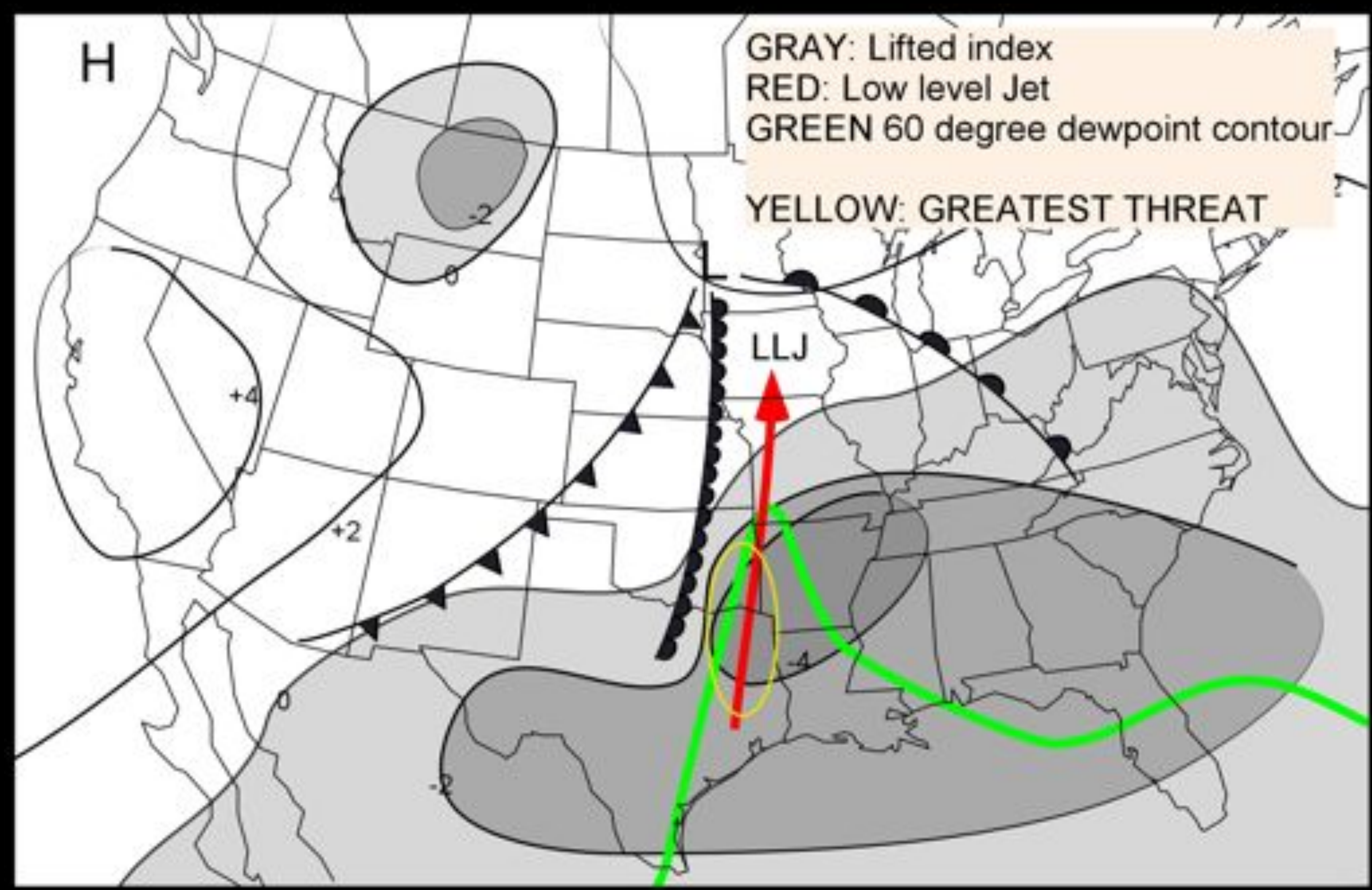
High dewpoint temperatures

Moisture Convergence



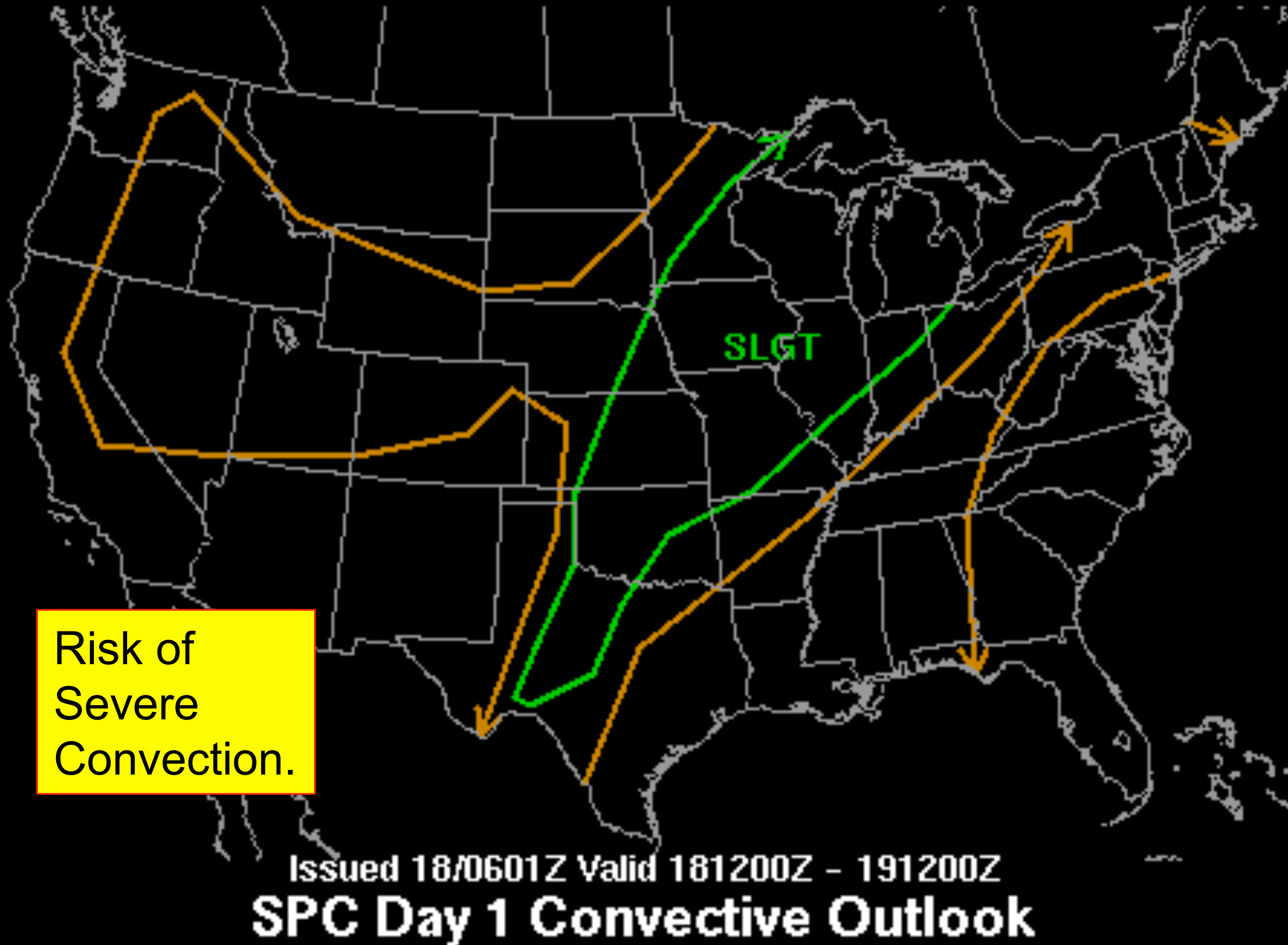
$\left(\nabla \bullet q_v \vec{V}\right) \times 10^5$ (approximately g/kg/day)

The key to forecasting convection is to determine where these four important quantities converge



SPC PRODUCTS (Day 1, Day 2, Day 3 outlooks for severe weather)

http://www.spc.noaa.gov/products/outlook/day1otlk.html

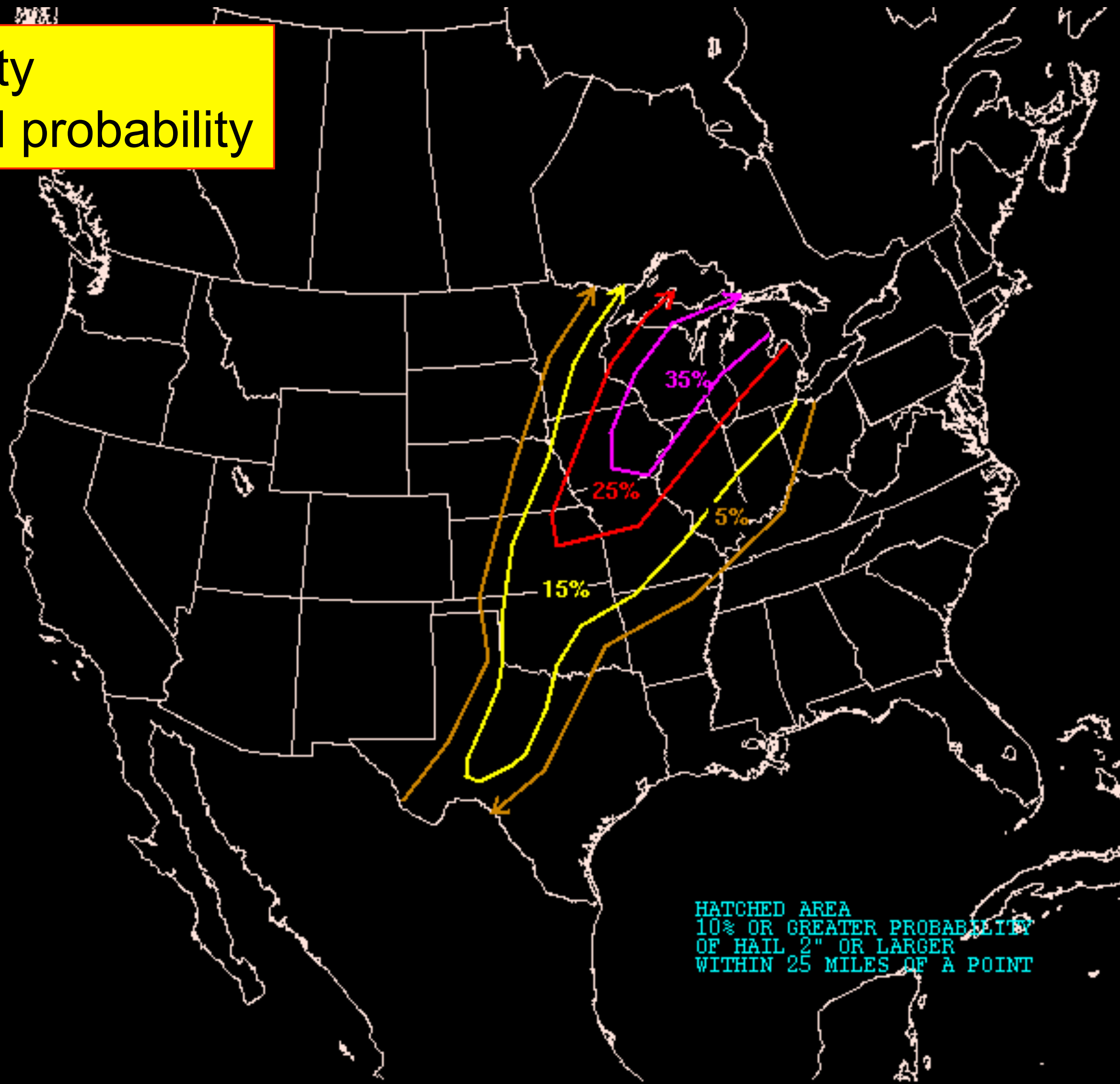


Risk of Severe Convection.

SPC PRODUCTS (Day 1, Day 2, Day 3 outlooks for severe weather)

http://www.spc.noaa.gov/products/outlook/day1probotlk_2000_hail.gif

Hail probability
and large hail probability



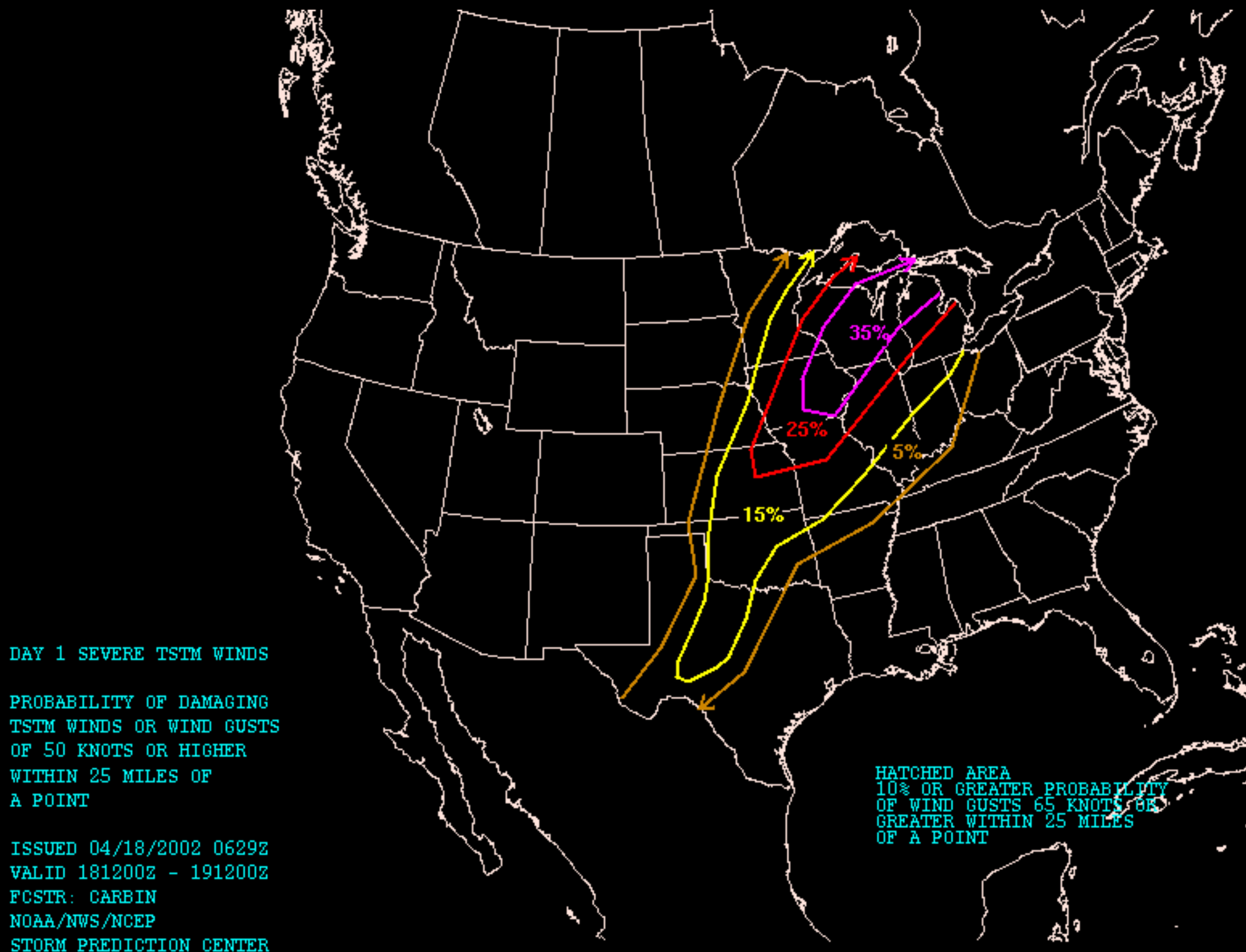
DAY 1 SEVERE HAIL

PROBABILITY OF HAIL
3/4" OR LARGER WITHIN
25 MILES OF A POINT

ISSUED 04/18/2002 0629Z
VALID 181200Z - 191200Z
FCSTR: CARBIN
NOAA/NWS/NCEP
STORM PREDICTION CENTER

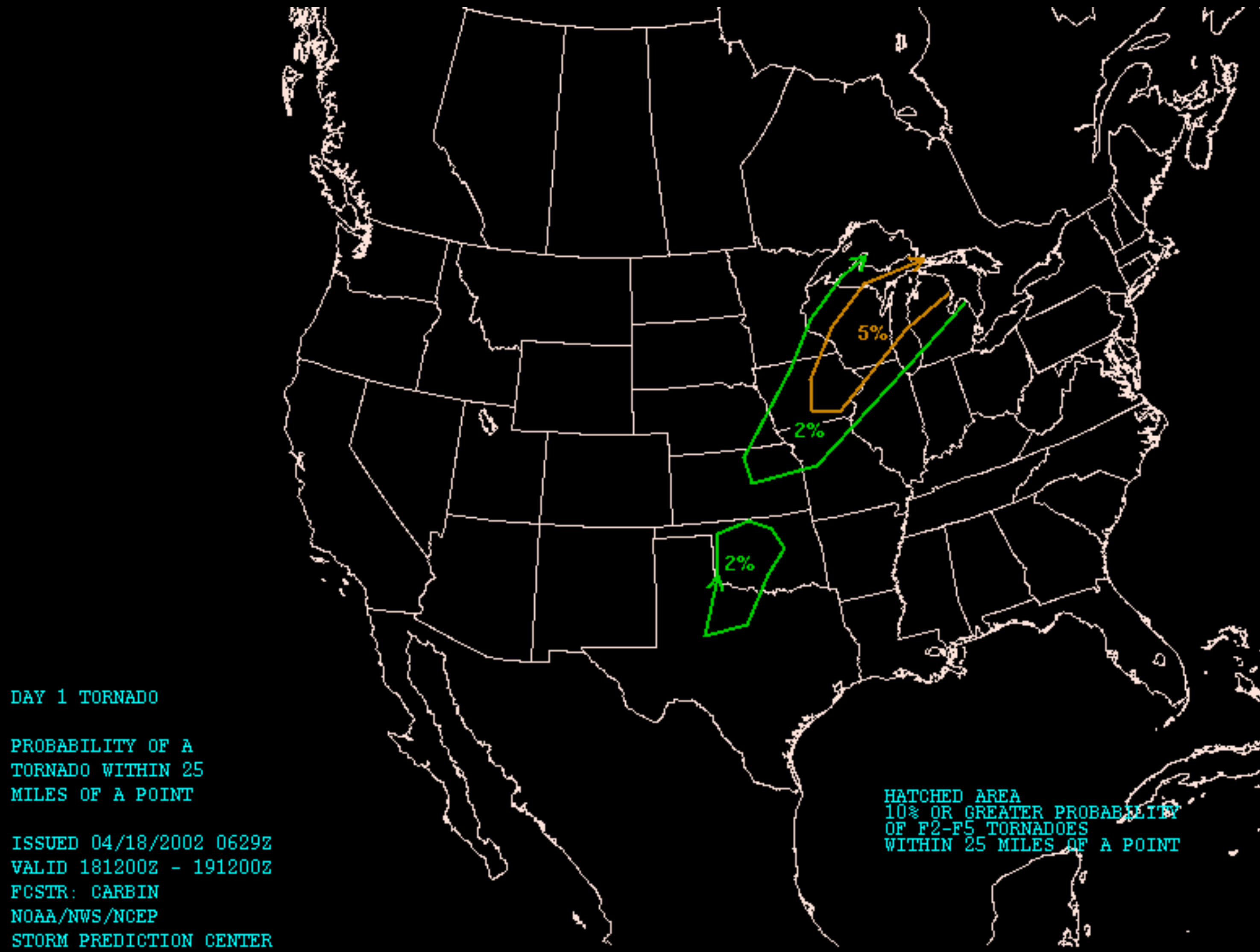
SPC PRODUCTS (Day 1, Day 2, Day 3 outlooks for severe weather)

http://www.spc.noaa.gov/products/outlook/day1probotlk_2000_wind.gif

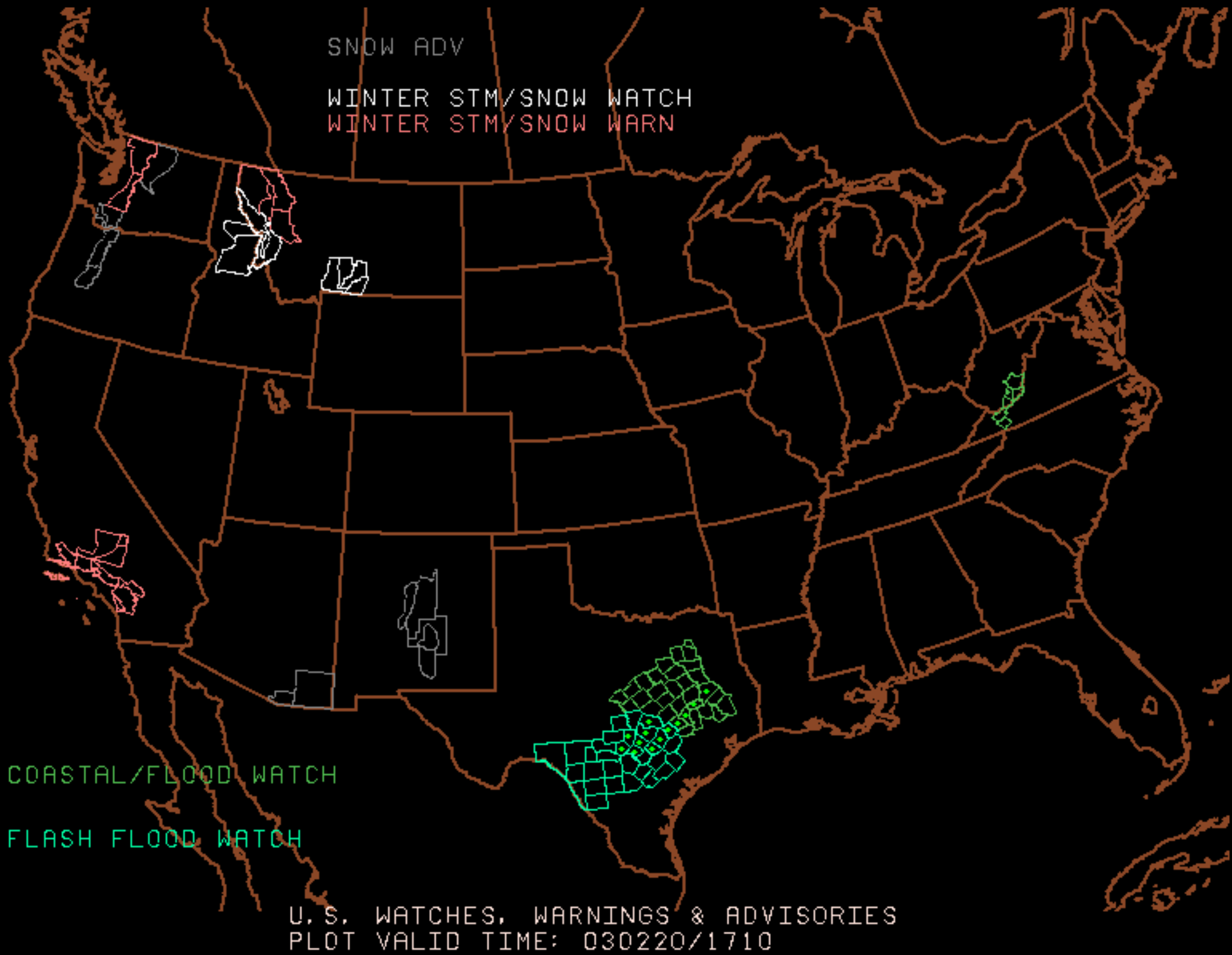


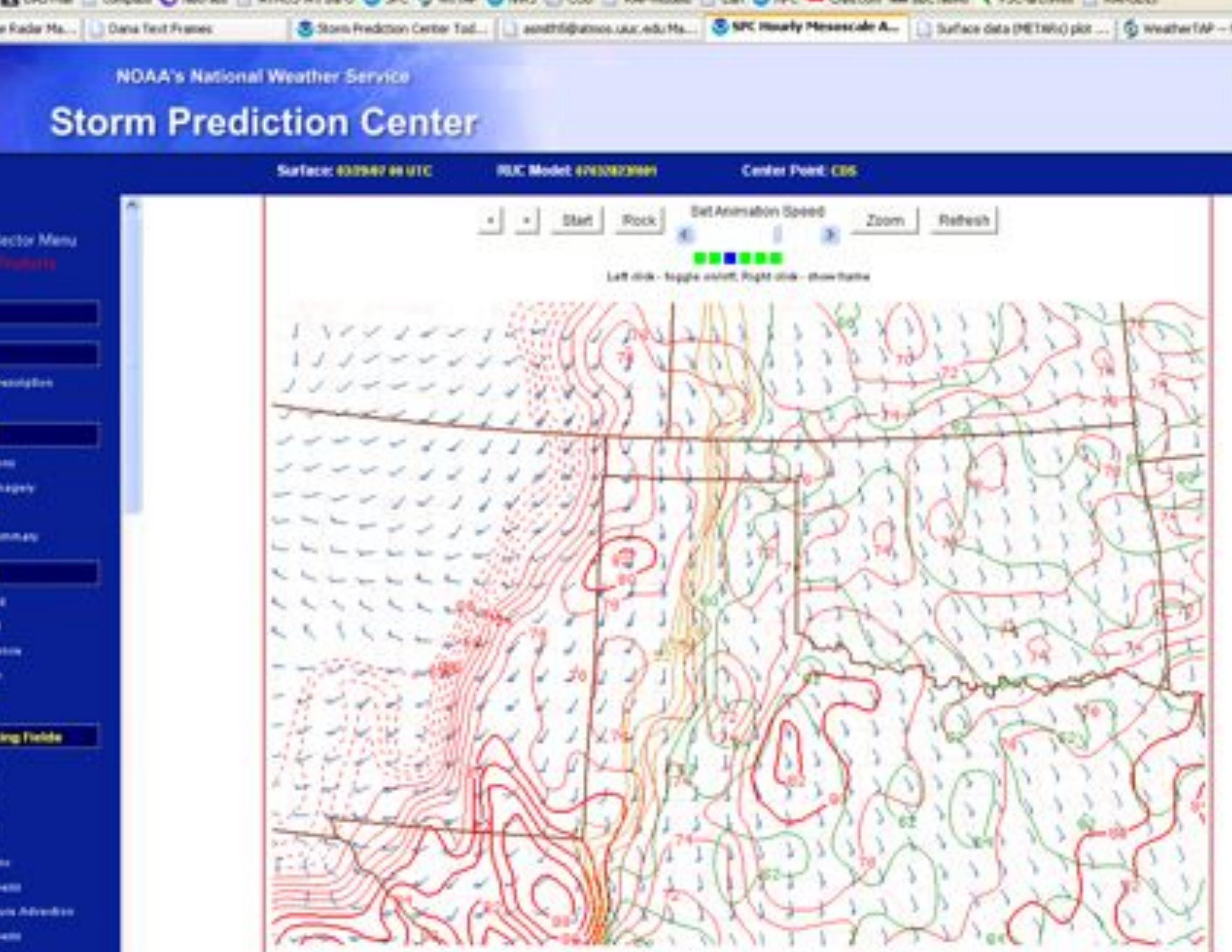
SPC PRODUCTS (Day 1, Day 2, Day 3 outlooks for severe weather)

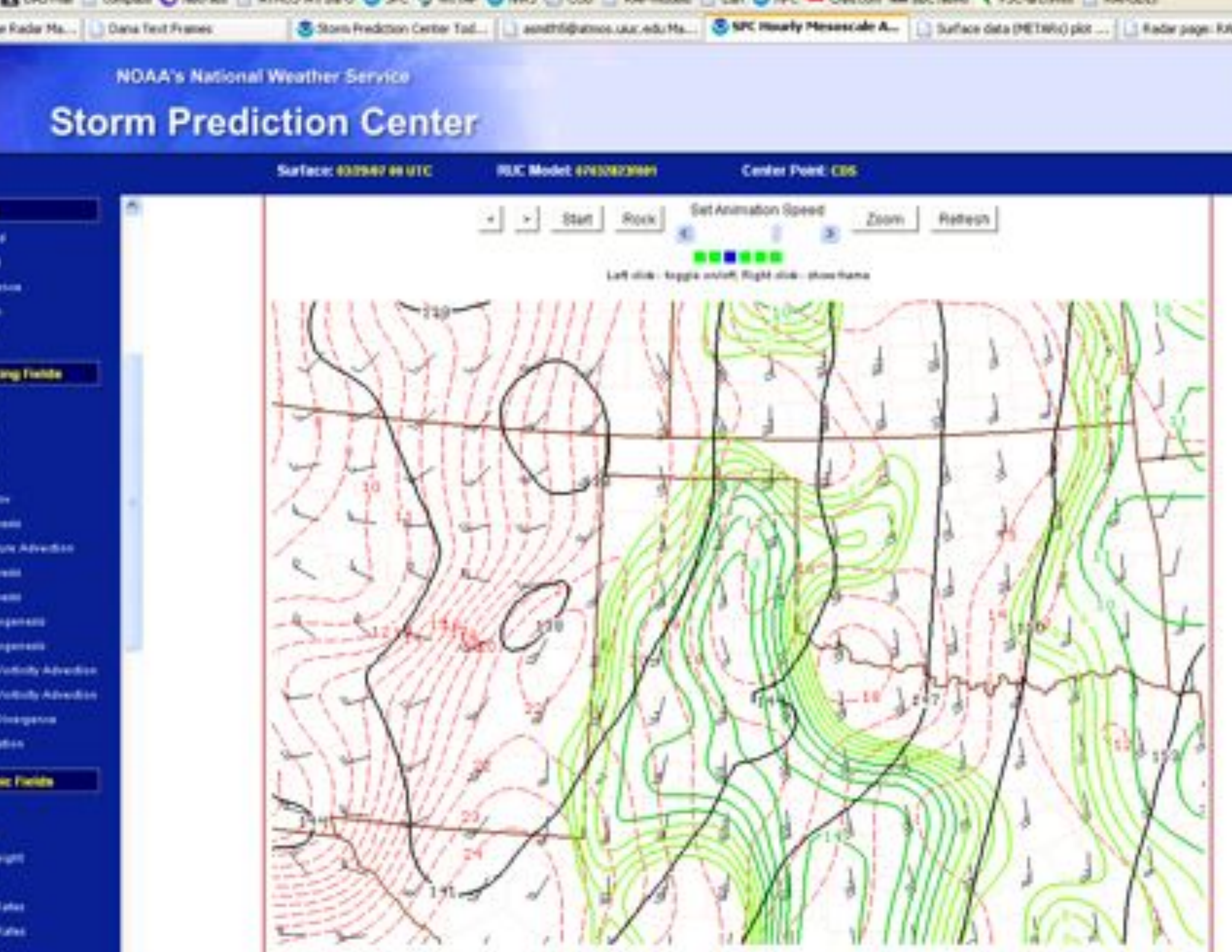
http://www.spc.noaa.gov/products/outlook/day1probotlk_2000_torn.gif



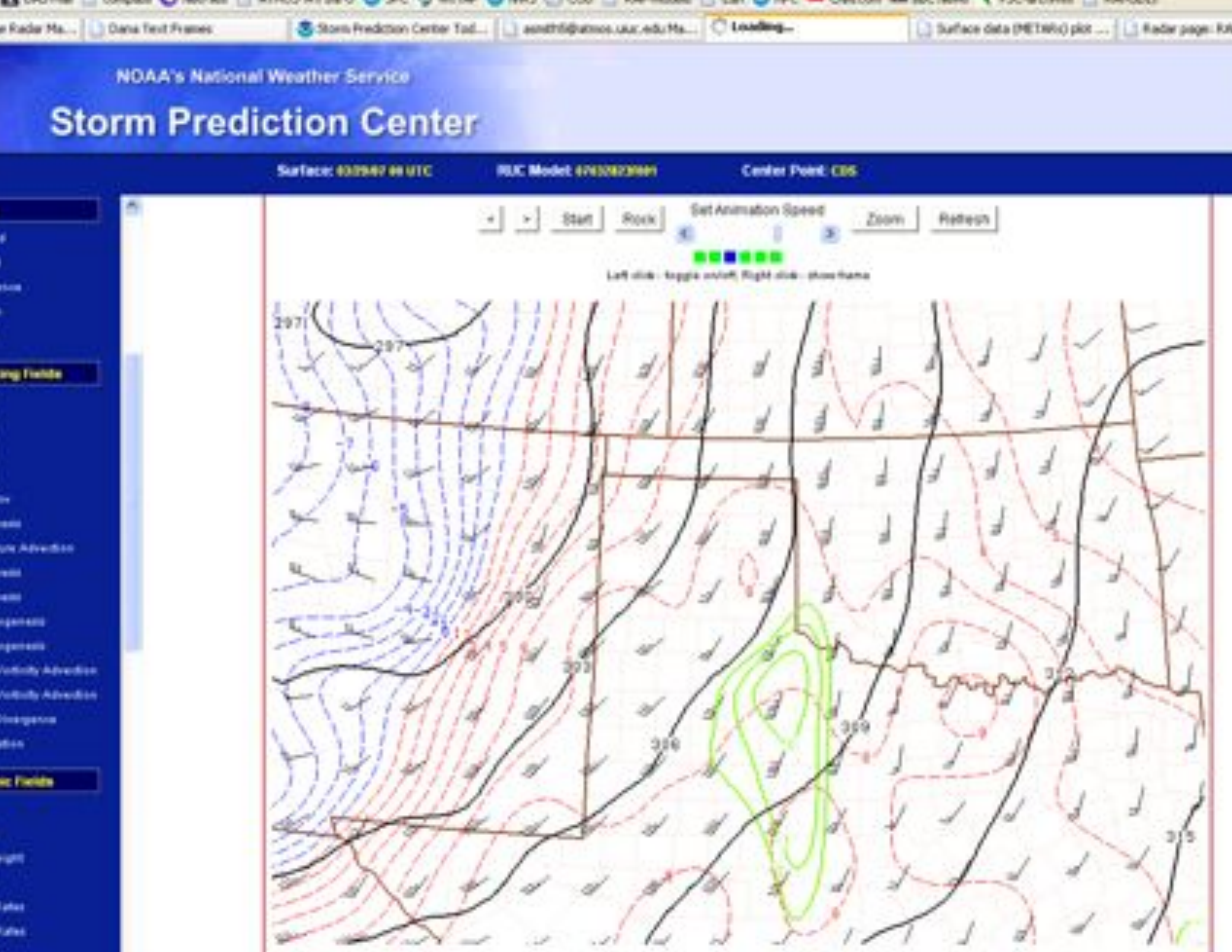
SPC: Watches and warnings
http://www.spc.noaa.gov/products/wwa/



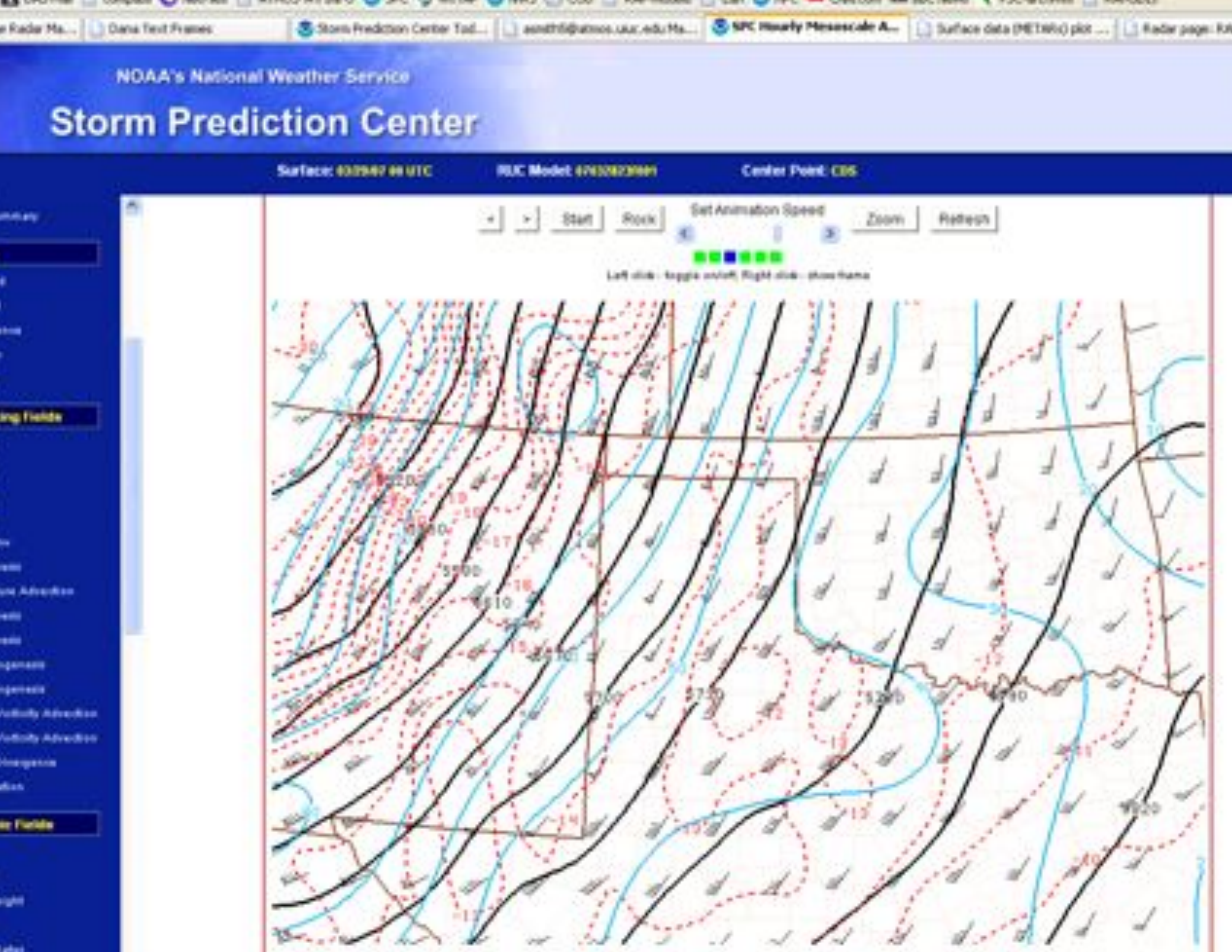

NOAA's National Weather Service
Storm Prediction Center
Surface:
RUC Model:
Center Point:
Start
Rock
Set Animation Speed
Zoom
Refresh



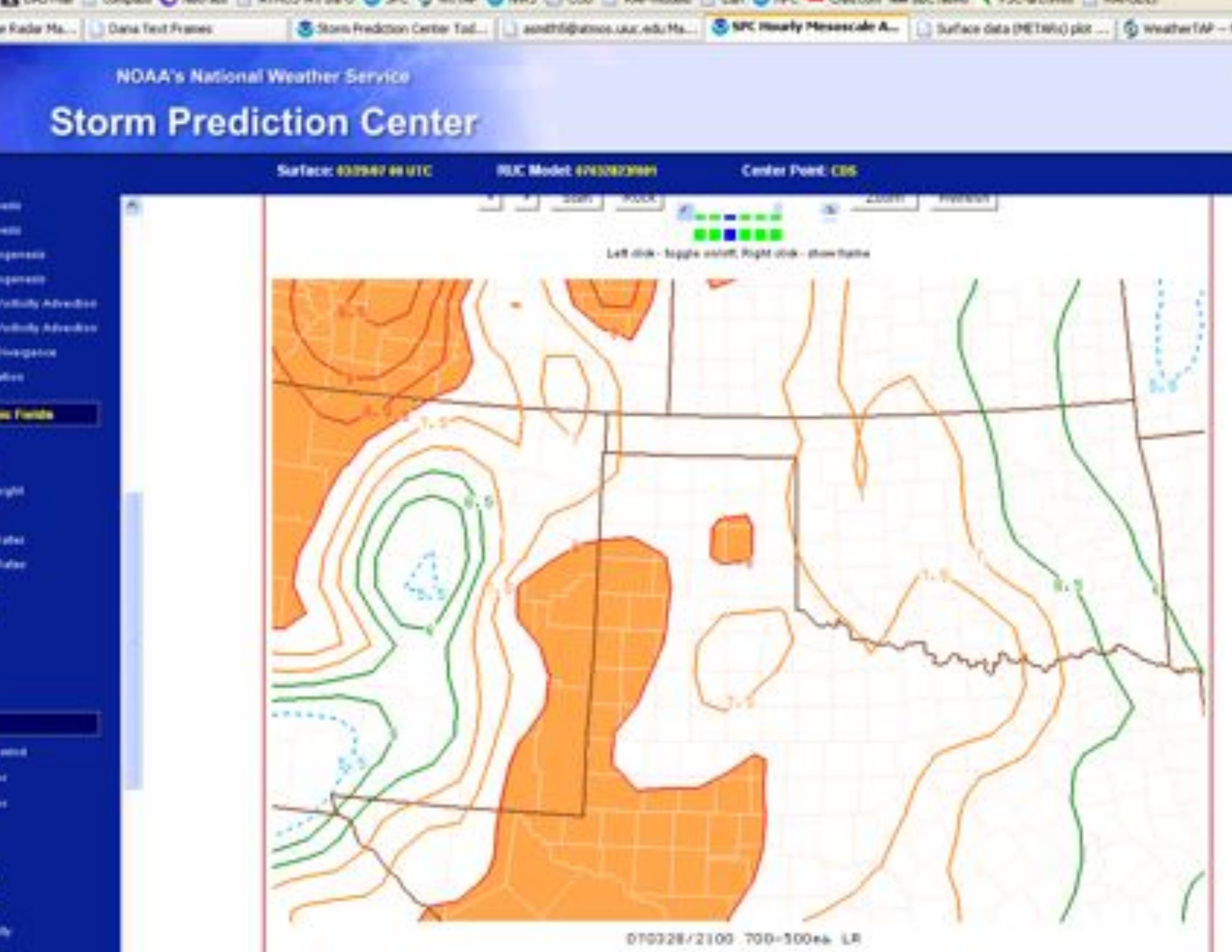
Dana Text Frames
Storm Prediction Center Tod...
SPC Hourly Mesoscale A...
Surface data (METARs) plot ...
NOAA's National Weather Service
Storm Prediction Center
Surface:
RUC Model:
Center Point:
Start
Rock
Set Animation Speed
Zoom
Refresh

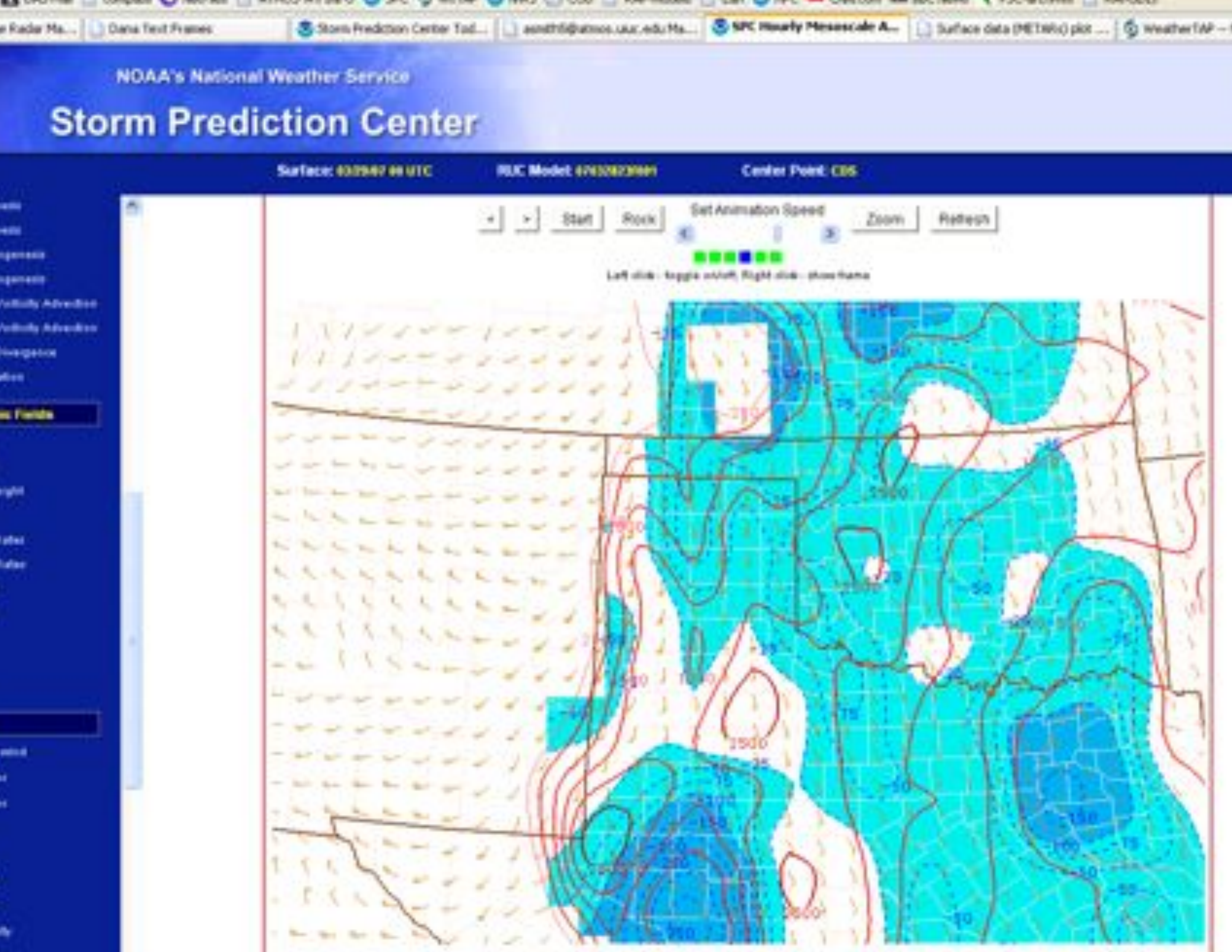


NOAA's National Weather Service
Storm Prediction Center
Surface:
RUC Model:
Center Point:
Start
Rock
Set Animation Speed
Zoom
Refresh
297
297
303
306
309
312
315



Dana Text Frames
NOAA's National Weather Service
Storm Prediction Center
Surface:
RUC Model:
Center Point: CDS
Start
Rock
Set Animation Speed
Zoom
Refresh


NOAA's National Weather Service
Storm Prediction Center
Surface:
RUC Model:
Center Point:
Left click - toggle on/off; Right click - show frame
070328/2100 700-500mb LR


NOAA's National Weather Service
Storm Prediction Center
Surface:
RUC Model:
Center Point:
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Rock
Set Animation Speed
Zoom
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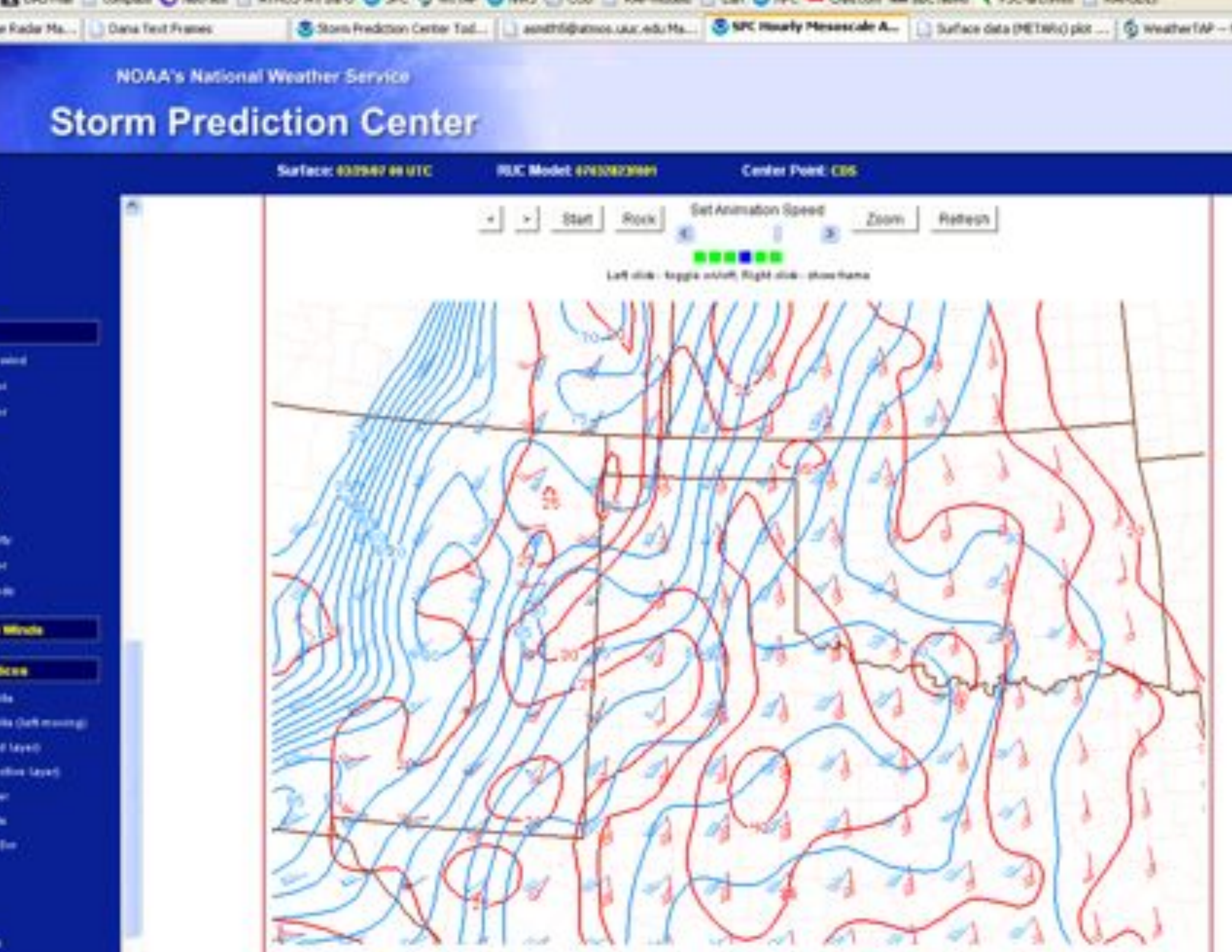
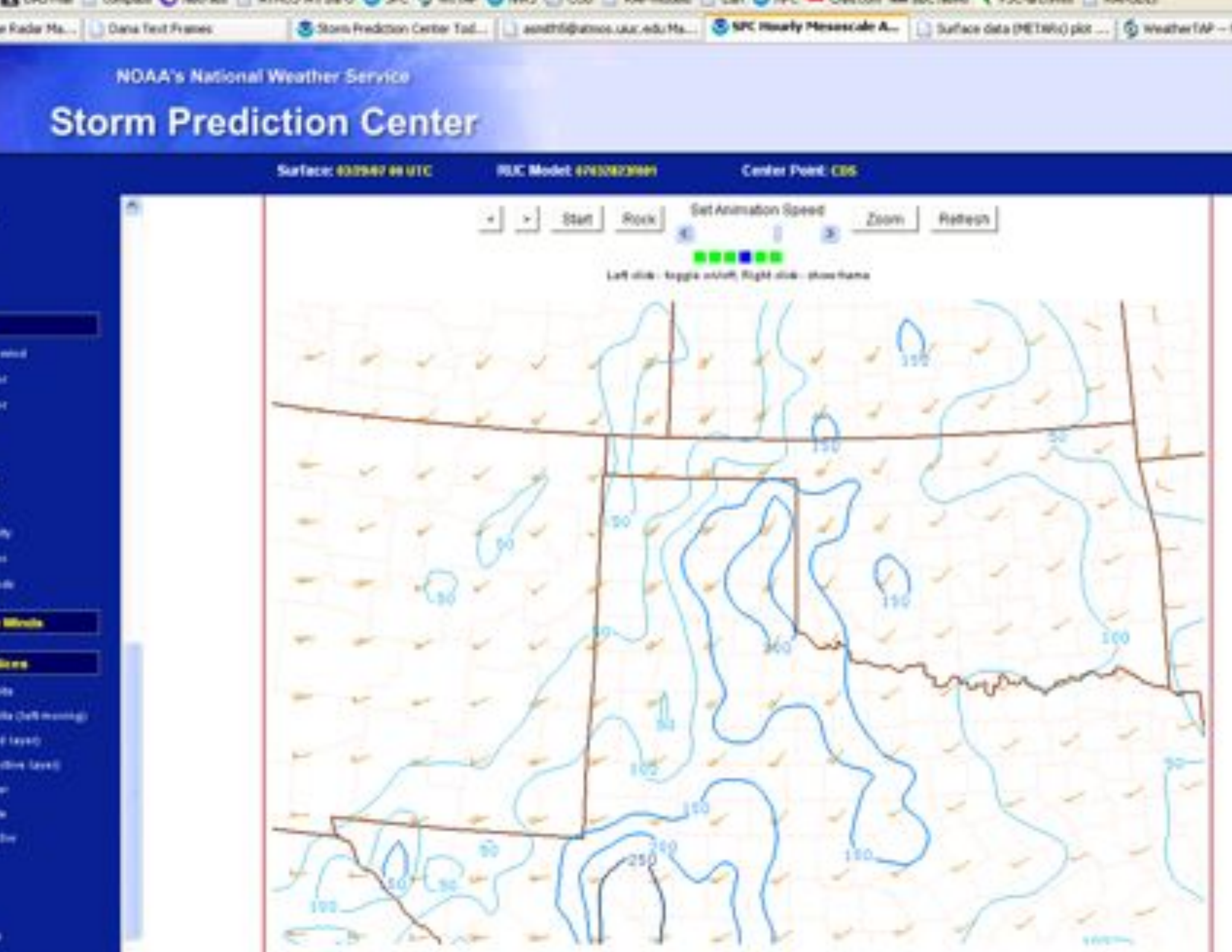
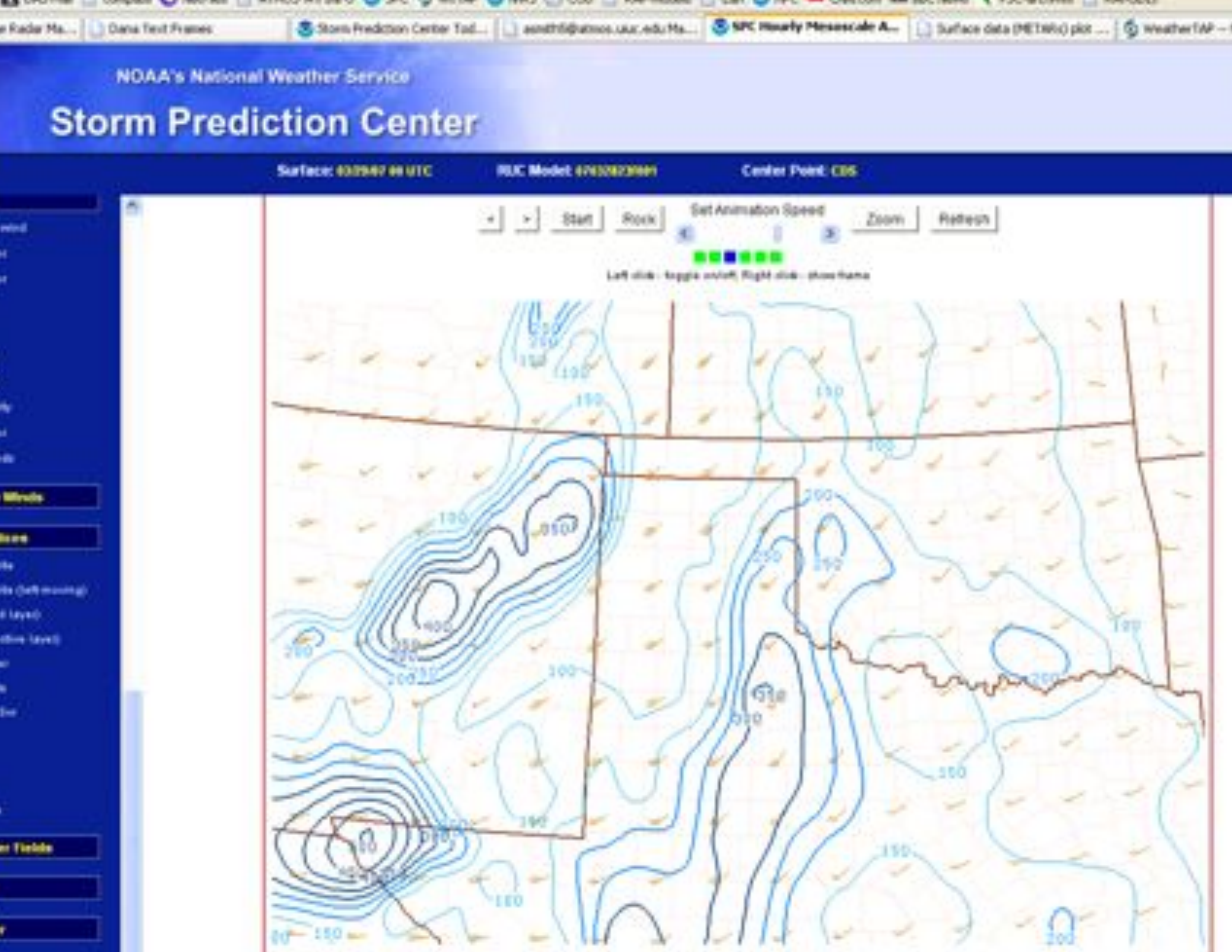

NOAA's National Weather Service
Storm Prediction Center
Surface:
RUC Model:
Center Point:
Start
Rock
Set Animation Speed
Zoom
Refresh


NOAA's National Weather Service
Storm Prediction Center
Surface:
RUC Model:
Center Point:
Start
Rock
Set Animation Speed
Zoom
Refresh


NOAA's National Weather Service
Storm Prediction Center
Surface:
RUC Model:
Center Point:
Start
Rock
Set Animation Speed
Zoom
Refresh
150
100
200
250
350
400