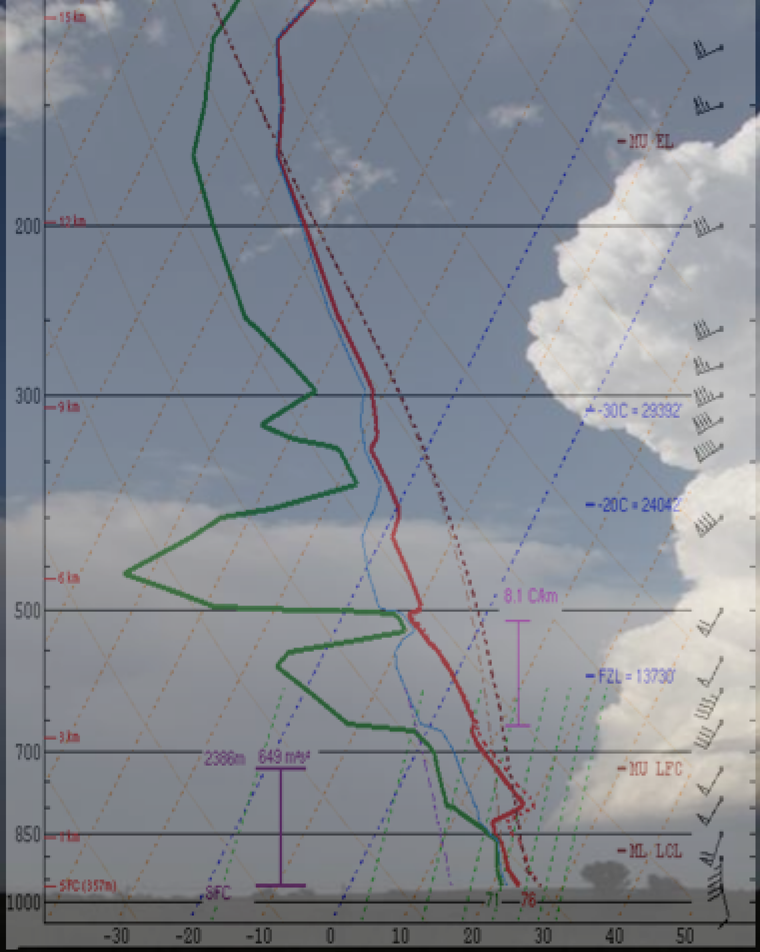


Lapse Rate Tendency

Material by Rich Thompson, Ariel Cohen, Andrew Moore, Tom Galarneau

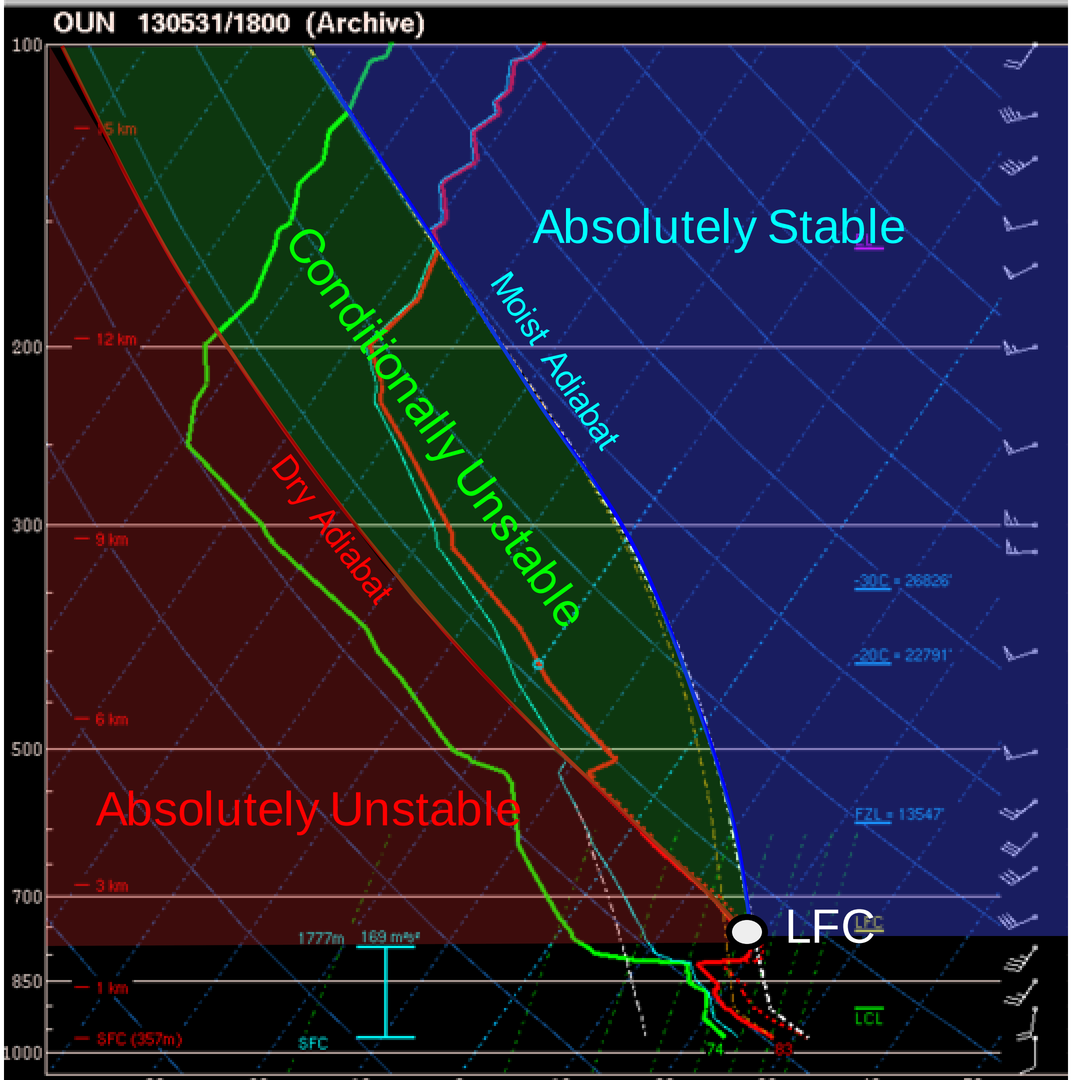
Photo by Andrew Moore

Why do we care about lapse rates?

- Helps generate buoyancy (influences T-storm intensity)
- Influences convective initiation (Houston and Niyogi 2007)
- Influence precipitation intensity (Takemi 2009)

Lapse rates in most T-storm environments will be conditionally unstable…

In other words, between the dry adiabatic lapse rate (9.8 C/km) and the moist adiabatic lapse rate.

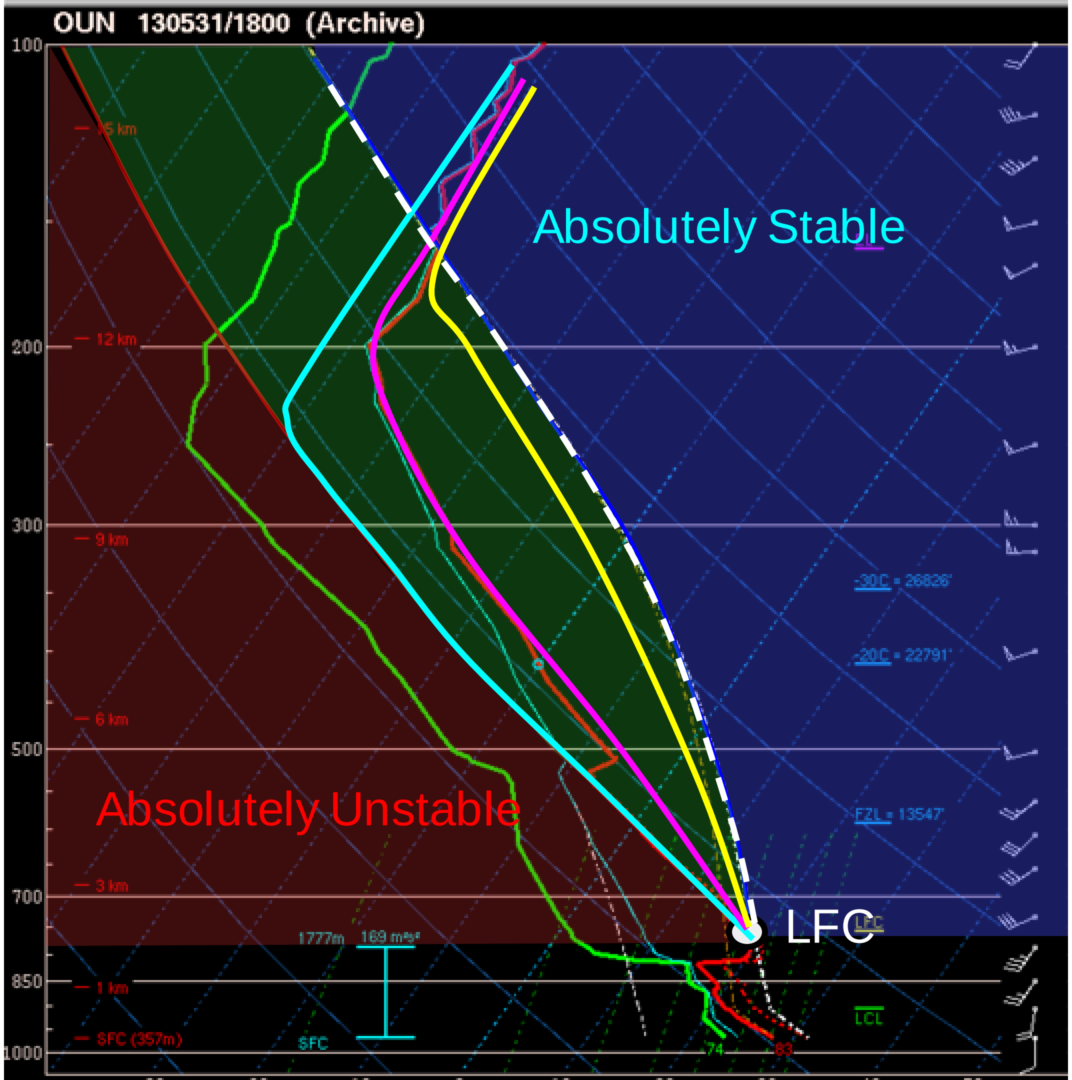


Lapse rates in most T-storm environments will be conditionally unstable…

In other words, between the dry adiabatic lapse rate (9.8 C/km) and the moist adiabatic lapse rate.

Compare the CAPE profiles for these three environmental lapse rates. What are the implications for updraft acceleration?

(Recall: Wmax = sqrt(2*CAPE))



How do lapse rates change?

Local change in lapse rate =

- Horizontal lapse rate advection
- Influence of lift/stretching
- Differential Thermal Advection
- Diabatic Heating

Lapse Rate Tendency

- What physical processes alter the environment lapse rate?

<u>Start with 1st Law of Thermodynamics</u>

temperature

pressure

$$q = C_p \frac{dT}{dt} - \alpha \frac{dp}{dt}$$

heating rate

specific heat

specific volume $(\frac{1}{\rho})$

time

This is an important point!
Our ability to anticipate changes in lapse rate derives directly from the first law of thermodynamics!

Lapse Rate Tendency

- What physical processes alter the environment lapse rate?

Start with 1st Law of Thermodynamics

$$q = C_p \frac{dT}{dt} - \alpha \frac{dp}{dt}$$

temperature
pressure
heating rate
specific heat
specific volume $\left(\frac{1}{\rho}\right)$
time

Expand full derivatives and assume hydrostatic conditions (OK for synoptic and mesoscale)

$$q = C_p\left(\frac{\partial T}{\partial t} + \boldsymbol{v}_h \cdot \boldsymbol{\nabla}_h T + w\frac{\partial T}{\partial z}\right) - \frac{1}{\rho}\left(\frac{\partial p}{\partial t} + \boldsymbol{v}_h \cdot \boldsymbol{\nabla}_h p + w\frac{\partial p}{\partial z}\right)$$

Local change in temperature with time
Horizontal temperature advection
Vertical temperature advection
Local change in pressure
Horizontal pressure advection
Vertical pressure advection

Lapse Rate Tendency

- What physical processes alter the environment lapse rate?

<u>Start with 1st Law of Thermodynamics</u>

temperature

pressure

$$q = C_p \frac{dT}{dt} - \alpha \frac{dp}{dt}$$

heating rate

specific heat

specific volume ($\frac{1}{\rho}$)

time

<u>Expand full derivatives and assume hydrostatic conditions (OK for synoptic and mesoscale)</u>

$$q = C_p\left(\frac{\partial T}{\partial t} + \boldsymbol{v}_h \cdot \boldsymbol{\nabla}_h T + w\frac{\partial T}{\partial z}\right) - \frac{1}{\rho}\left(\cancel{\frac{\partial p}{\partial t}} + \cancel{\boldsymbol{v}_h \cdot \boldsymbol{\nabla}_h p} + w\boxed{\frac{\partial p}{\partial z}}\right) = C_p\left(\frac{\partial T}{\partial t} + \boldsymbol{v}_h \cdot \boldsymbol{\nabla}_h T + w\frac{\partial T}{\partial z}\right) + gw$$

Relatively small

$$= -\rho g$$

Assume that the hydrostatic approx applies

Lapse Rate Tendency

- What physical processes alter the environment lapse rate?

<u>Start with 1st Law of Thermodynamics</u>

temperature   pressure

heating rate

$$q = C_p \frac{dT}{dt} - \alpha \frac{dp}{dt}$$

specific heat   specific volume $\left(\frac{1}{\rho}\right)$ time

<u>Expand full derivatives and assume hydrostatic conditions (OK for synoptic and mesoscale)</u>

$$q = C_p\left(\frac{\partial T}{\partial t} + v_h \cdot \nabla_h T + w\frac{\partial T}{\partial z}\right) - \frac{1}{\rho}\left(\cancel{\frac{\partial p}{\partial t}} + \cancel{v_h \cdot \nabla_h p} + w\underbrace{\boxed{\frac{\partial p}{\partial z}}}_{=-\rho g}\right) = C_p\left(\frac{\partial T}{\partial t} + v_h \cdot \nabla_h T + w\frac{\partial T}{\partial z}\right) + gw$$

Relatively small, assume hydrostatic

<u>Differentiate with respect to $-z$</u>

$$-\frac{\partial q}{\partial z} = C_p\left[\frac{\partial}{\partial t}\left(-\frac{\partial T}{\partial z}\right) + \boldsymbol{v_h} \cdot \boldsymbol{\nabla_h}\left(-\frac{\partial T}{\partial z}\right) + w\frac{\partial}{\partial z}\left(-\frac{\partial T}{\partial z}\right) - \frac{\partial \boldsymbol{v_h}}{\partial z} \cdot \boldsymbol{\nabla_h} T - \frac{\partial w}{\partial z}\frac{\partial T}{\partial z}\right] - g\frac{\partial w}{\partial z}$$

Lapse Rate Tendency

- What physical processes alter the environment lapse rate?

Start with 1st Law of Thermodynamics

temperature

pressure

$$q = C_p \frac{dT}{dt} - \alpha \frac{dp}{dt}$$

heating rate

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Relatively small, assume hydrostatic

Differentiate with respect to $-z$

$$-\frac{\partial q}{\partial z} = C_p\left[\frac{\partial}{\partial t}\left(-\frac{\partial T}{\partial z}\right) + \boldsymbol{v}_h \cdot \boldsymbol{\nabla}_h\left(-\frac{\partial T}{\partial z}\right) + w\frac{\partial}{\partial z}\left(-\frac{\partial T}{\partial z}\right) - \frac{\partial \boldsymbol{v}_h}{\partial z} \cdot \boldsymbol{\nabla}_h T - \frac{\partial w}{\partial z}\frac{\partial T}{\partial z}\right] - g\frac{\partial w}{\partial z}$$

We neglected $\frac{\partial^2 T}{\partial z^2}$ terms

Substitute in definition for environment lapse rate $\gamma = -{}^{\partial T}/_{\partial z}$ and dry adiabatic lapse rate $\Gamma_d = {}^{g}/_{c_p}$

$$\frac{\partial \gamma}{\partial t} = -\boldsymbol{v}_h \cdot \boldsymbol{\nabla}_h \gamma - w\frac{\partial \gamma}{\partial z} + \frac{\partial \boldsymbol{v}_h}{\partial z} \cdot \boldsymbol{\nabla}_h T + \frac{\partial w}{\partial z}(\Gamma_d - \gamma) - \frac{1}{C_p}\frac{\partial q}{\partial z}$$

Lapse Rate Tendency

- What physical processes alter the environment lapse rate?

Start with 1st Law of Thermodynamics

$$\underbrace{q}_{\text{heating rate}} = \underbrace{C_p}_{\text{specific heat}} \frac{d\overbrace{T}^{\text{temperature}}}{\underbrace{dt}_{\text{time}}} - \underbrace{\alpha}_{\text{specific volume } \left(\frac{1}{\rho}\right)} \frac{d\overbrace{p}^{\text{pressure}}}{dt}$$

Expand full derivatives and assume hydrostatic conditions (OK for synoptic and mesoscale)

$$q = C_p\left(\frac{\partial T}{\partial t} + \boldsymbol{v}_h \cdot \boldsymbol{\nabla}_h T + w\frac{\partial T}{\partial z}\right) - \frac{1}{\rho}\left(\cancel{\frac{\partial p}{\partial t}} + \cancel{\boldsymbol{v}_h \cdot \boldsymbol{\nabla}_h p} + w\underbrace{\boxed{\frac{\partial p}{\partial z}}}_{=-\rho g}\right) = C_p\left(\frac{\partial T}{\partial t} + \boldsymbol{v}_h \cdot \boldsymbol{\nabla}_h T + w\frac{\partial T}{\partial z}\right) + gw$$

Relatively small, assume hydrostatic

Differentiate with respect to $-z$

$$-\frac{\partial q}{\partial z} = C_p\left[\frac{\partial}{\partial t}\left(-\frac{\partial T}{\partial z}\right) + \boldsymbol{v}_h \cdot \boldsymbol{\nabla}_h\left(-\frac{\partial T}{\partial z}\right) + w\frac{\partial}{\partial z}\left(-\frac{\partial T}{\partial z}\right) - \frac{\partial \boldsymbol{v}_h}{\partial z}\cdot\boldsymbol{\nabla}_h T - \frac{\partial w}{\partial z}\frac{\partial T}{\partial z}\right] - g\frac{\partial w}{\partial z}$$

Substitute in definition for environment lapse rate $\gamma = -{}^{\partial T}/_{\partial z}$ and dry adiabatic lapse rate $\Gamma_d = {}^{g}/_{c_p}$

$$\boxed{\frac{\partial \gamma}{\partial t} = -\boldsymbol{v}_h \cdot \boldsymbol{\nabla}_h \gamma - w\frac{\partial \gamma}{\partial z} + \frac{\partial \boldsymbol{v}_h}{\partial z}\cdot\boldsymbol{\nabla}_h T + \frac{\partial w}{\partial z}(\Gamma_d - \gamma) - \frac{1}{C_p}\frac{\partial q}{\partial z}}$$

Lapse rate tendency equation

Lapse Rate Tendency Equation

$$\frac{\partial \gamma}{\partial t} = -\boldsymbol{v}_h \cdot \boldsymbol{\nabla}_h \gamma - w\frac{\partial \gamma}{\partial z} + \frac{\partial \boldsymbol{v}_h}{\partial z} \cdot \boldsymbol{\nabla}_h T + \frac{\partial w}{\partial z}(\Gamma_d - \gamma) - \frac{1}{C_p}\frac{\partial q}{\partial z}$$

A B C D E F

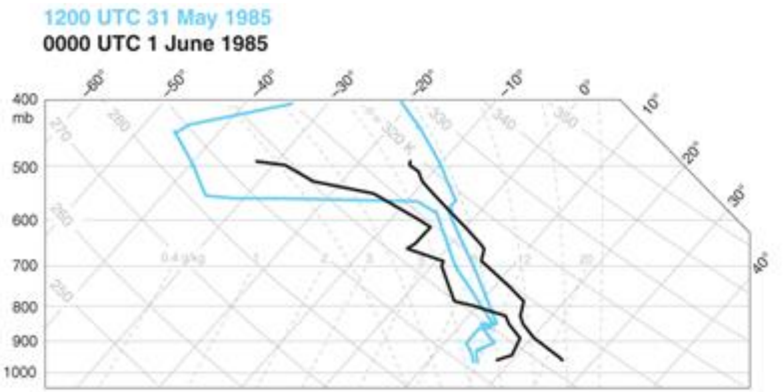
We'll work through each term to understand the physical mechanisms

Lapse Rate Tendency Equation

$$\boxed{\frac{\partial \gamma}{\partial t}} = -\boldsymbol{v}_h \cdot \boldsymbol{\nabla}_h \gamma - w\frac{\partial \gamma}{\partial z} + \frac{\partial \boldsymbol{v}_h}{\partial z} \cdot \boldsymbol{\nabla}_h T + \frac{\partial w}{\partial z}(\Gamma_d - \gamma) - \frac{1}{C_p}\frac{\partial q}{\partial z}$$

A B C D E F

<u>Term A:</u> local time rate of change of environment lapse rate



(Markowski and Richardson 2010, Fig. 7.3)

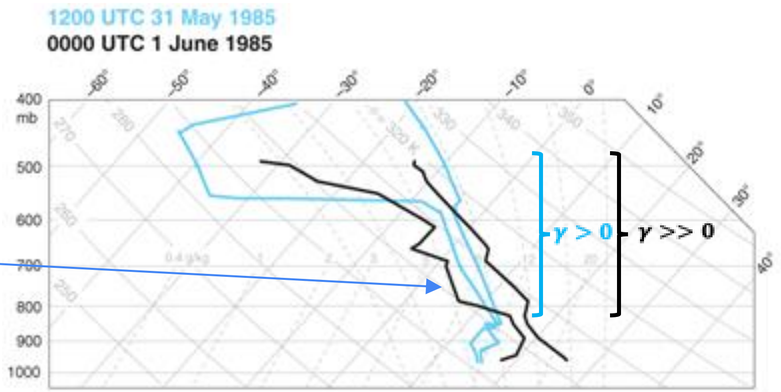
Lapse Rate Tendency Equation

$$\boxed{\frac{\partial \gamma}{\partial t}} = -\boldsymbol{v}_h \cdot \boldsymbol{\nabla}_h \gamma - w\frac{\partial \gamma}{\partial z} + \frac{\partial \boldsymbol{v}_h}{\partial z} \cdot \boldsymbol{\nabla}_h T + \frac{\partial w}{\partial z}(\Gamma_d - \gamma) - \frac{1}{C_p}\frac{\partial q}{\partial z}$$

A B C D E F

<u>Term A:</u> local time rate of change of environment lapse rate

$\frac{\partial \gamma}{\partial t} > 0$ lapse rate increasing at PIT due to warming below 600 mb



(Markowski and Richardson 2010, Fig. 7.3)

Lapse Rate Tendency Equation

$$\frac{\partial \gamma}{\partial t} = \boxed{-\boldsymbol{v}_h \cdot \boldsymbol{\nabla}_h \gamma} - w\frac{\partial \gamma}{\partial z} + \frac{\partial \boldsymbol{v}_h}{\partial z} \cdot \boldsymbol{\nabla}_h T + \frac{\partial w}{\partial z}(\Gamma_d - \gamma) - \frac{1}{C_p}\frac{\partial q}{\partial z}$$

A B C D E F

<u>Term B:</u> horizontal lapse rate advection - this one is very important! Let’s take a closer look!

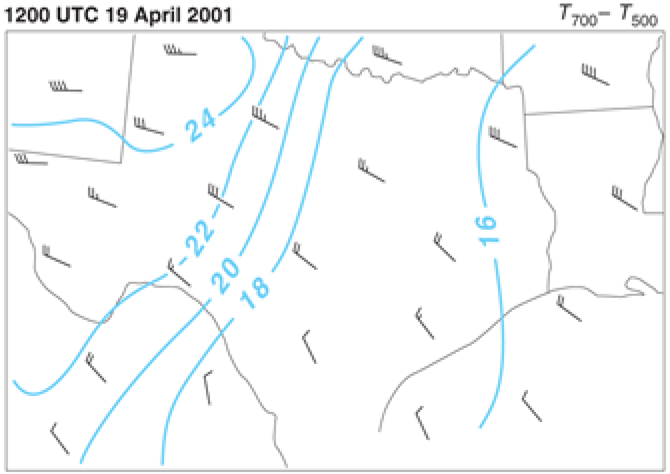
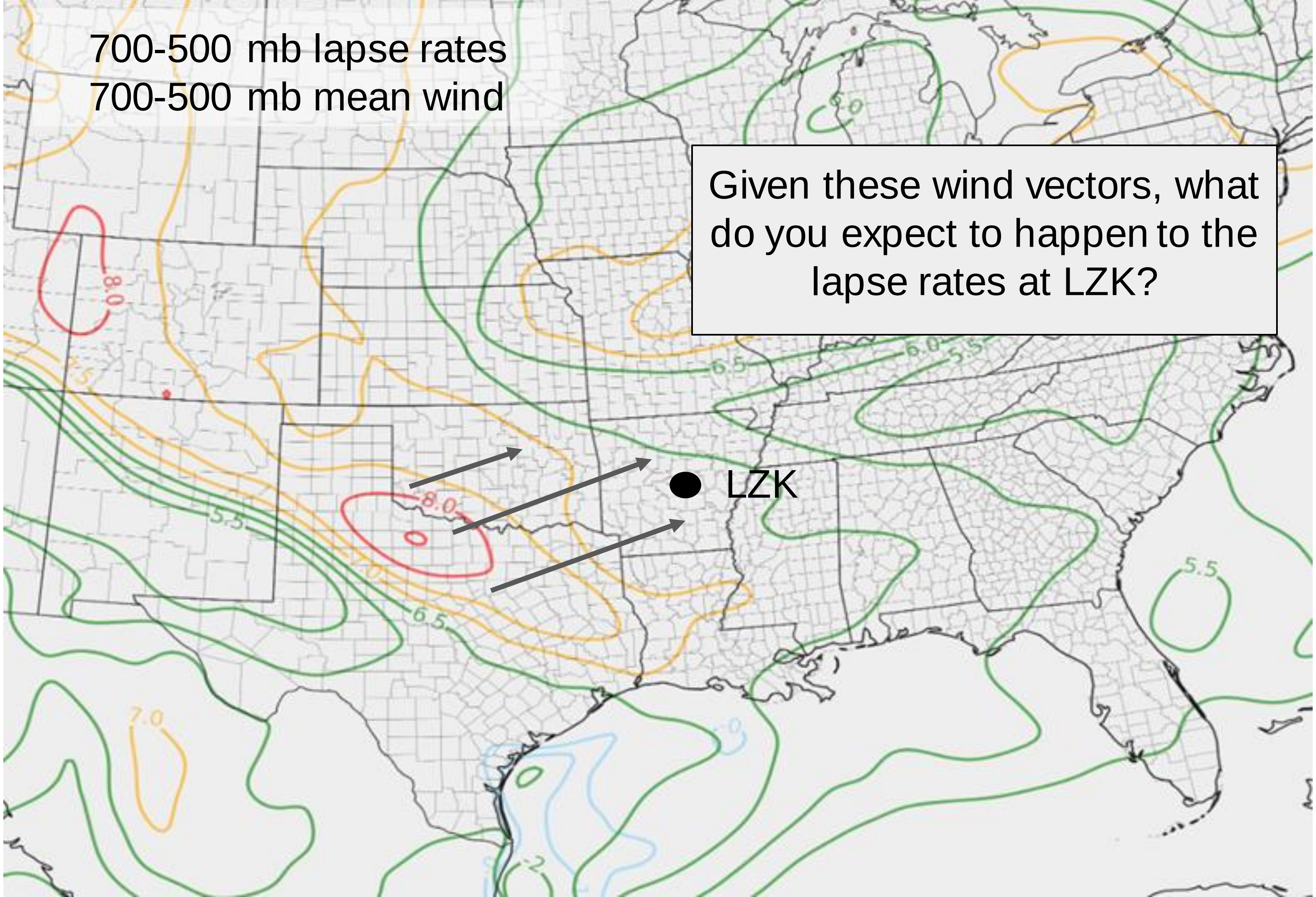


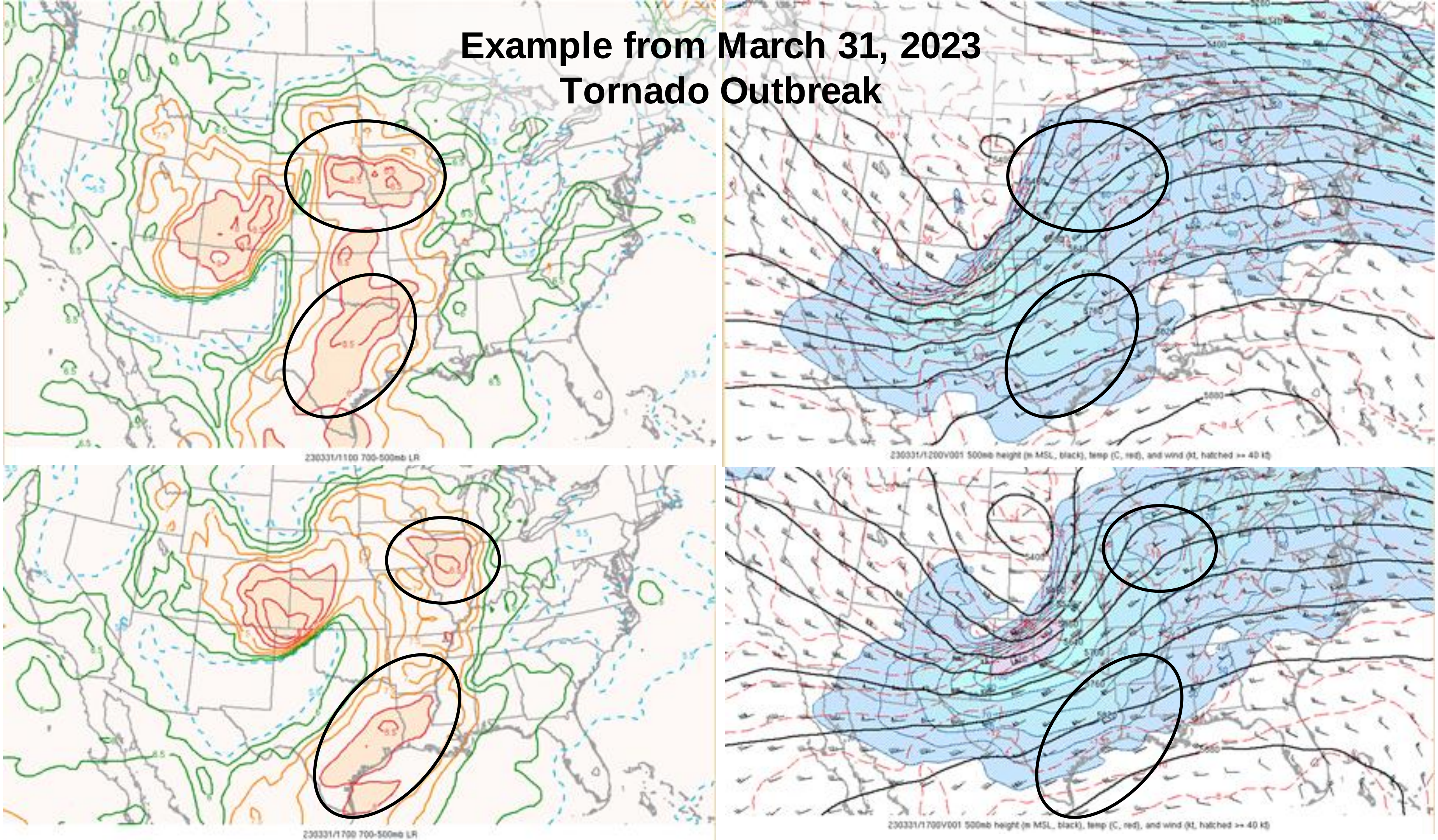
Figure 7.4

Analysis of the environmental temperature difference between 500 and 700 mb (K), which is a bulk measure of the midlevel lapse rate (a temperature difference of 27 K between 500 and 700 mb corresponds to an approximately dry adiabatic environmental temperature profile), revealing the presence of horizontal lapse rate advection. Wind barbs depict the mean wind in the 500–700 mb layer. Large lapse rates from the high terrain of northern Mexico and eastern New Mexico are being advected toward the southern Great Plains of the United States. This common warm season phenomenon leads to the formation of the elevated mixed layer that caps soundings in the Great Plains region.

(Markowski and Richardson 2010, Fig. 7.4)

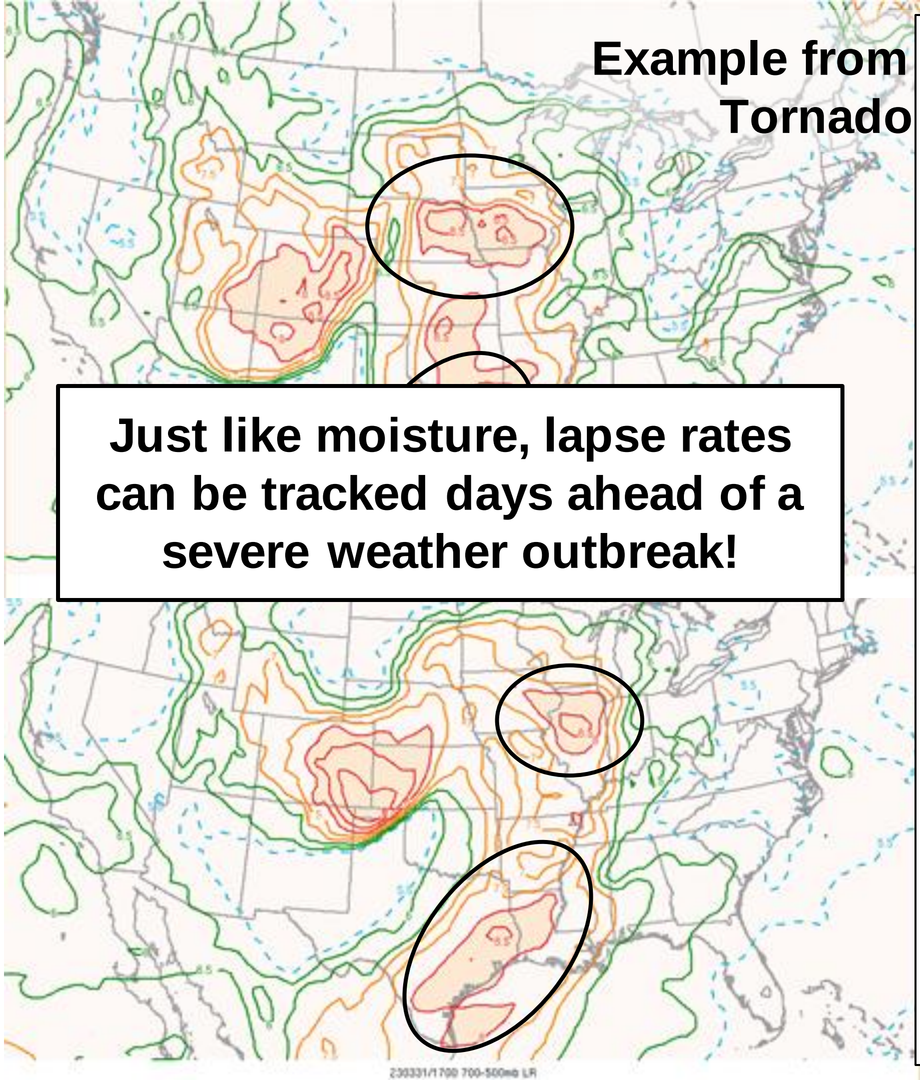

700-500 mb lapse rates
700-500 mb mean wind
Given these wind vectors, what do you expect to happen to the lapse rates at LZK?
LZK
8.0
8.0
6.0
5.5
6.5
5.5
7.0
6.5
5.5
7.0

Example from March 31, 2023 Tornado Outbreak



Example from
Tornado

Just like moisture, lapse rates can be tracked days ahead of a severe weather outbreak!



Revisiting the 3–4 April 1974 Super Outbreak of Tornadoes

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(Manuscript received 27 April 2009, in final form 22 October 2009)

ABSTRACT

The Super Outbreak of tornadoes over the central and eastern United States on 3–4 April 1974 remains the most outstanding severe convective weather episode on record in the continental United States. The outbreak far surpassed previous and succeeding events in severity, longevity, and extent. In this paper, surface, upper air, radar, and satellite data are used to provide an updated synoptic and subsynoptic overview of the event. Emphasis is placed on identifying the major factors that contributed to the development of the three main convective bands associated with the outbreak, and on identifying the conditions that may have contributed to the outstanding number of intense and long lasting tornadoes. Selected output from a 29 km, 50 layer version of the Eta forecast model, a version similar to that available operationally in the mid 1990s, also is presented to help depict the evolution of thermodynamic stability during the event.

1. Introduction

The Super Outbreak of tornadoes of 3–4 April 1974 remains the most outstanding severe convective weather episode on record in the continental United States (Fig. 1). By nearly every metric imaginable, the outbreak far surpassed previous and succeeding events in severity, longevity, and extent. A sampling of statistics only partially conveys its enormity: 148 tornadoes, of which 95 were F2 or stronger and 30 were F4 or F5; 48 killer tornadoes resulting in 335 deaths and more than 6000 injured; pathlengths up to 145 km (90 mi), with a total pathlength >4000 km (2500 mi); F2s or greater present for each three-hour period between 1200 UTC 3 April and 1500 UTC 4 April; 15 tornadoes in progress simultaneously at the height of the event; and 10 states declared federal disaster areas. Further appreciation for the phenomenal nature of the Super Outbreak may be gleaned from Fig. 2, which depicts the maximum, week-long running total of F2 or greater tornadoes from 1915 through 2008. Entire *years* noted for their prominent tornado counts (e.g., 1947, 1953, and 2003) pale in comparison to the 18-h period that began around midday on Wednesday, 3 April 1974. Twenty-five F3 or greater long-track [>40 km (25 mi)] tornadoes occurred during the same period, more than triple the annual average of such events since 1880 (Broyles and Crosbie 2004).

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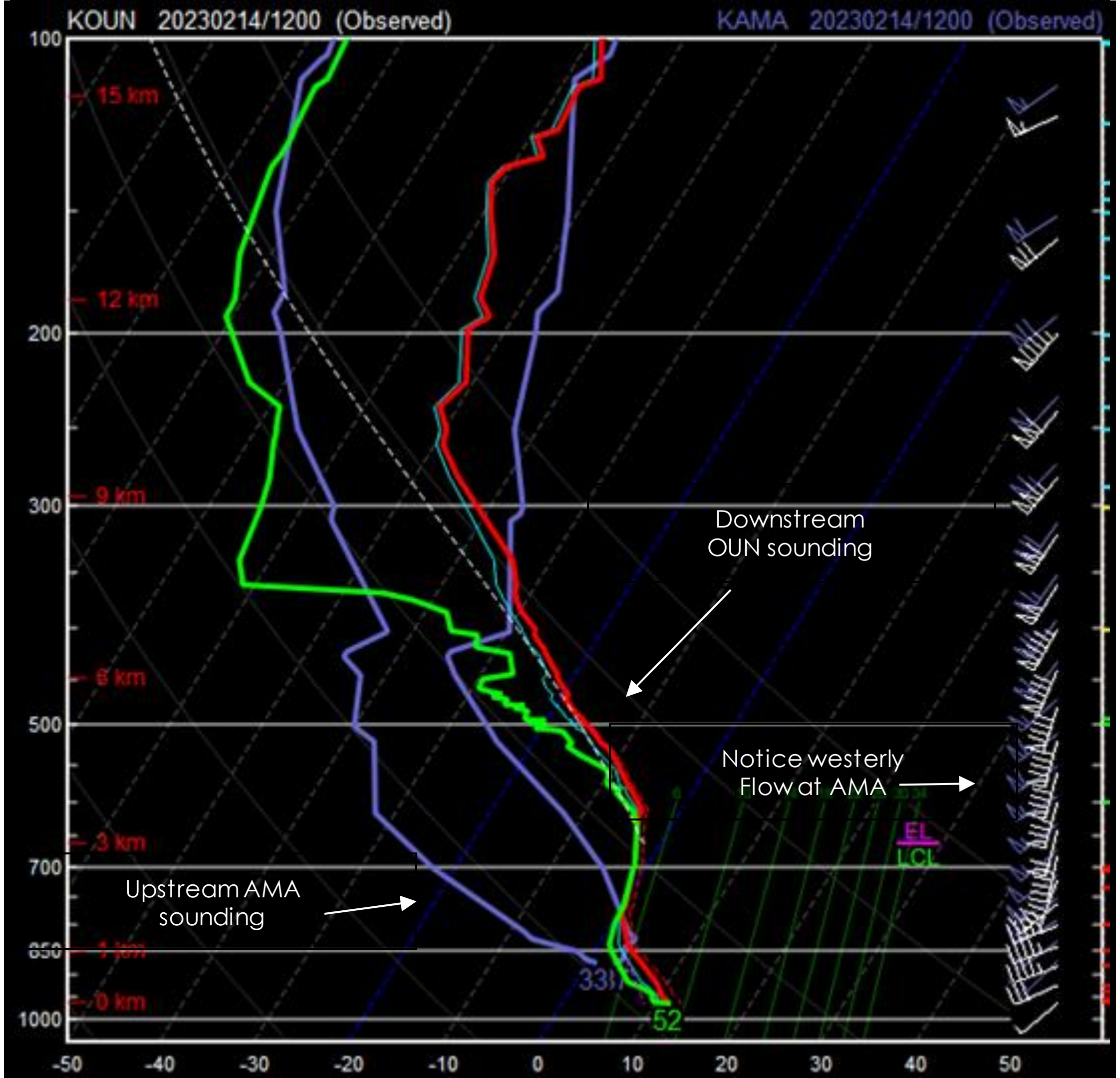
DOI: 10.1175/2009WAF2222297.1



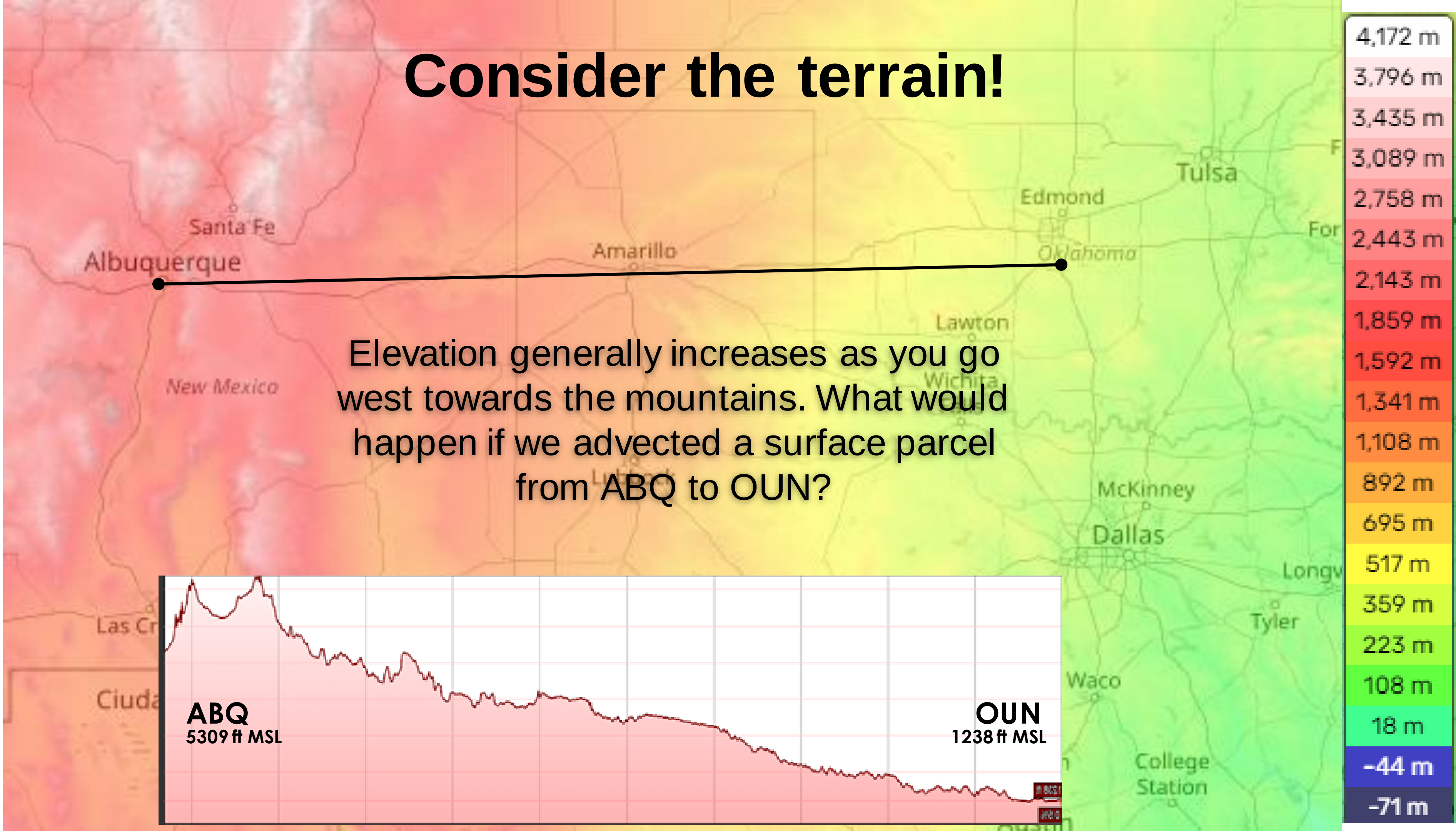
Here's another example.

Notice the steeper lapse rates upstream at AMA.

Given westerly winds, what do you think will happen to the lapse rates at OUN?

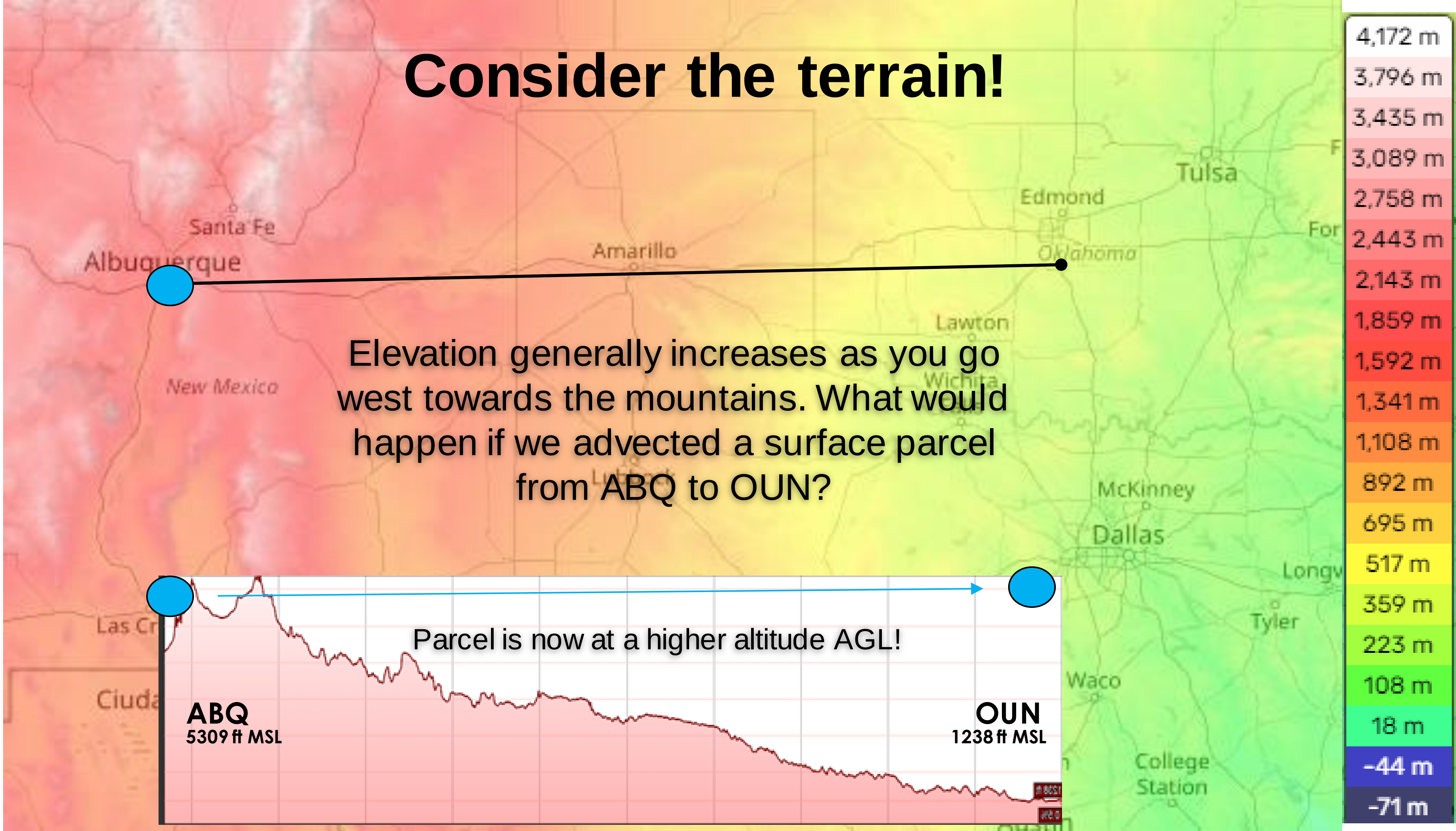
Consider the terrain!

Elevation generally increases as you go west towards the mountains. What would happen if we advected a surface parcel from ABQ to OUN?



Consider the terrain!

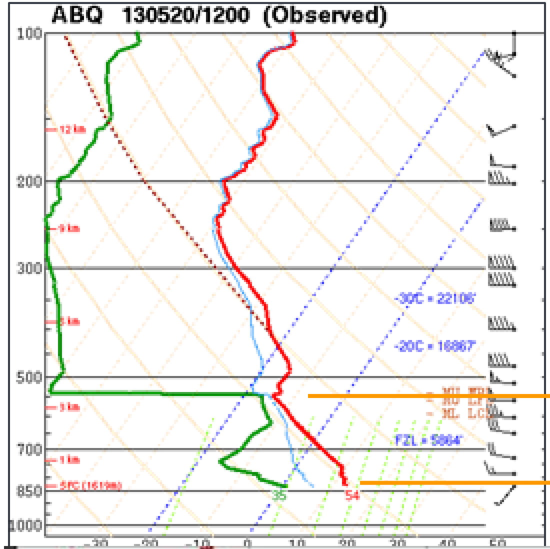
Elevation generally increases as you go west towards the mountains. What would happen if we advected a surface parcel from ABQ to OUN?

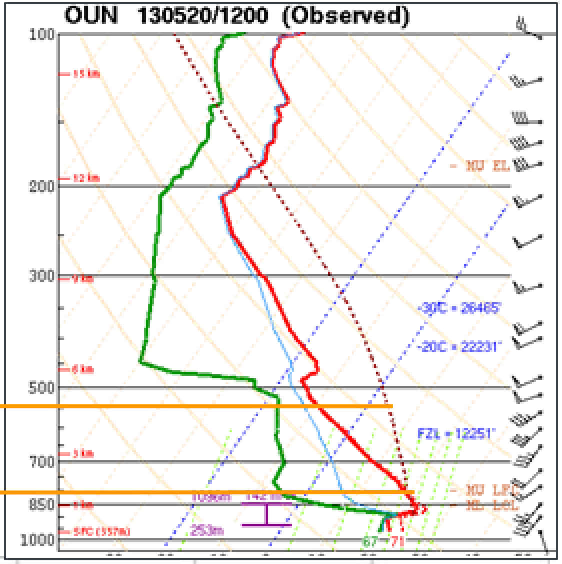


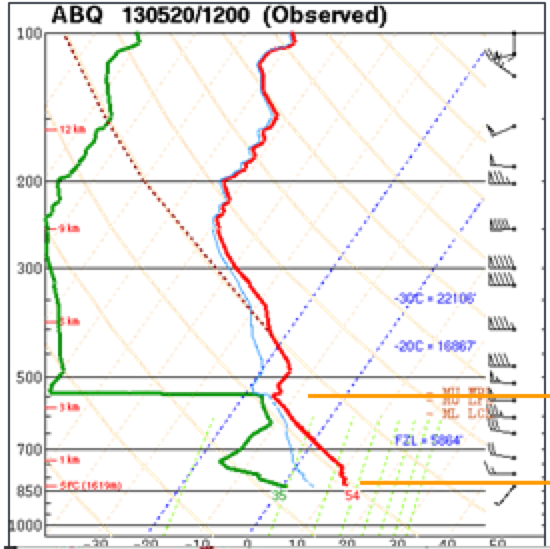
The last slide was a slight exaggeration of what occurs (parcels can descend in altitude), but illustrates an important point.

The deep, well-mixed boundary layer over the southern Rockies can be advected east over the plains…

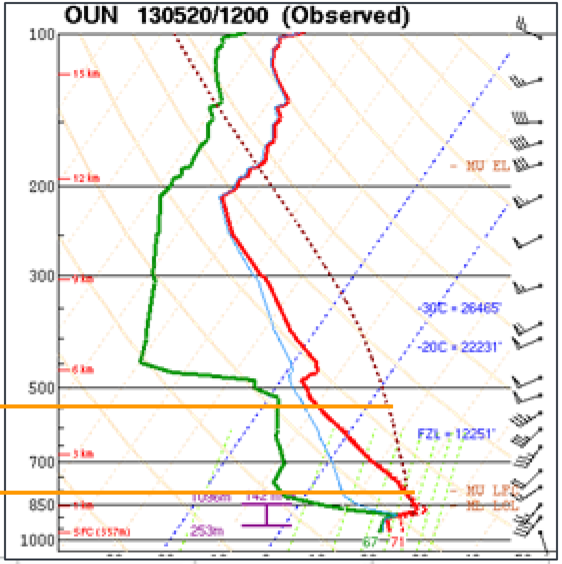
And becomes an **E**levated **M**ixed **L**ayer!

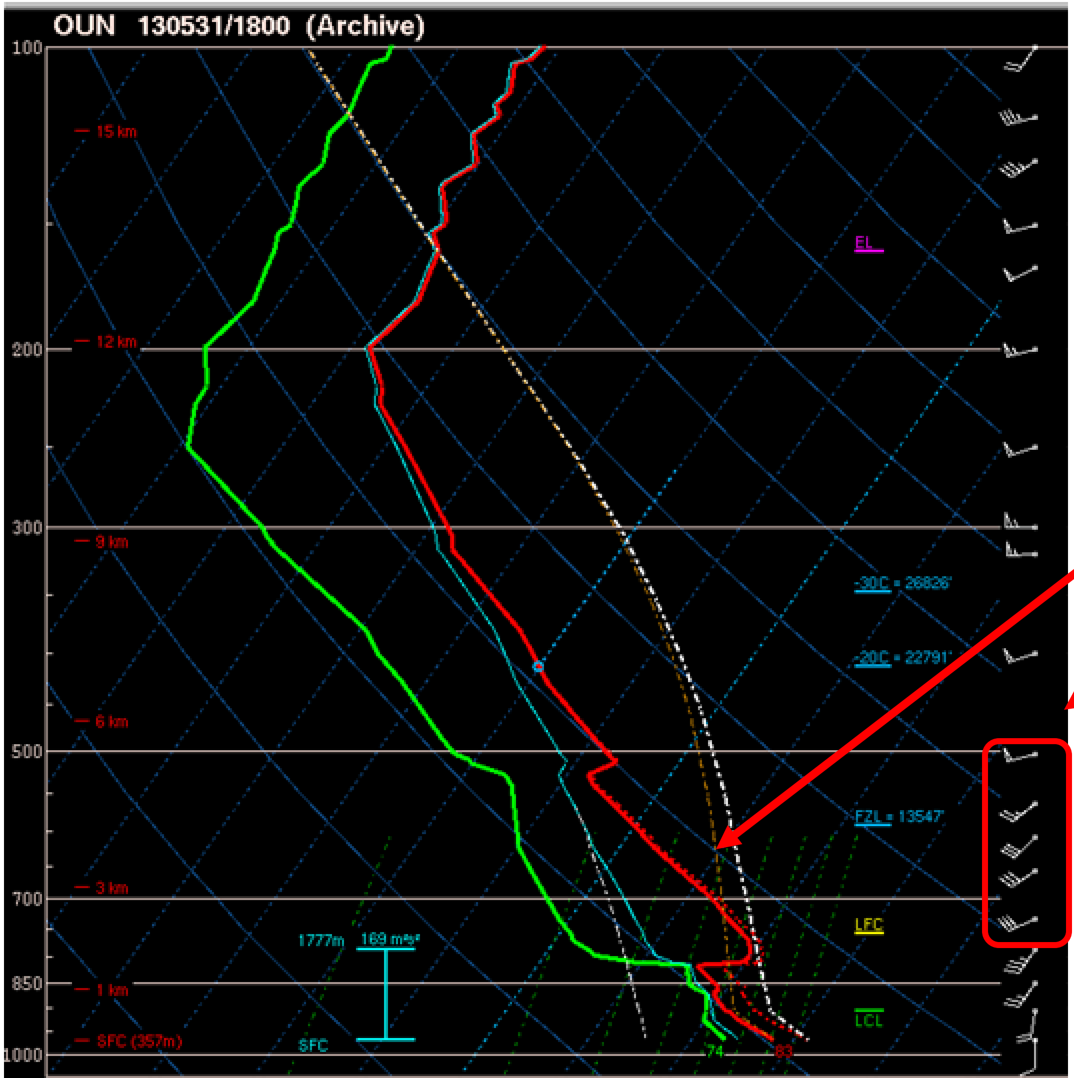






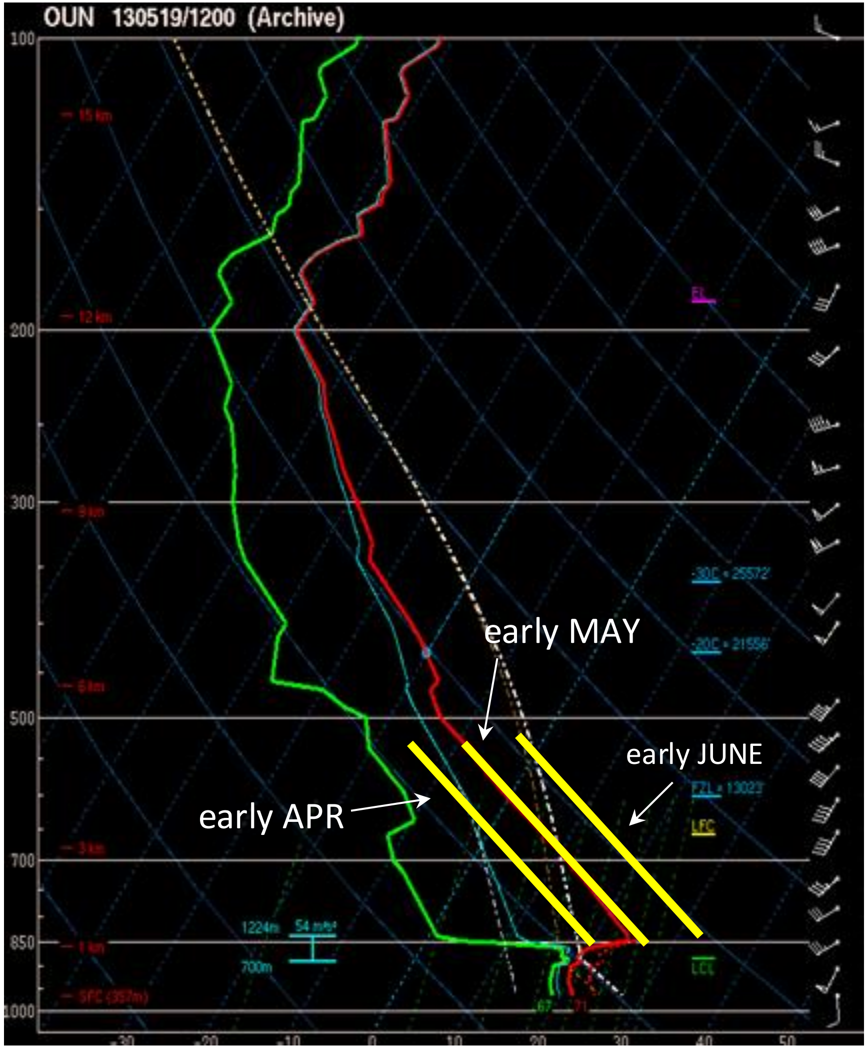
This is an important process for generating steep lapse rates over the Plains, which in turn support large CAPE values.





Nearly neutral layer above boundary layer in Norman noon sounding.

Notice the southwesterly flow in this layer - it likely originated from New Mexico plateau!



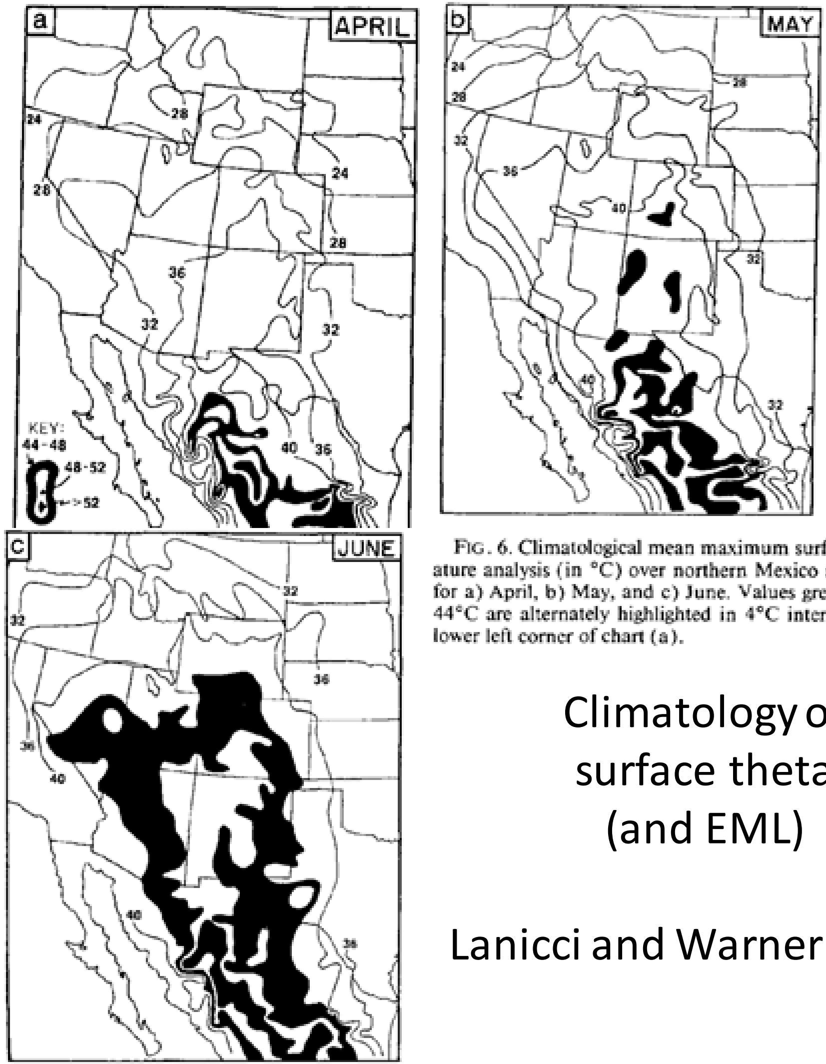


FIG. 6. Climatological mean maximum surface potential temperature analysis (in °C) over northern Mexico and the western U.S. for a) April, b) May, and c) June. Values greater than or equal to 44°C are alternately highlighted in 4°C intervals as shown in the lower left corner of chart (a).

Climatology of surface theta (and EML)

Lanicci and Warner (1991)

Lapse Rate Tendency Equation

$$\frac{\partial \gamma}{\partial t} = -\boldsymbol{v}_h \cdot \boldsymbol{\nabla}_h \gamma \boxed{- w\frac{\partial \gamma}{\partial z}} + \frac{\partial \boldsymbol{v}_h}{\partial z} \cdot \boldsymbol{\nabla}_h T + \frac{\partial w}{\partial z}(\Gamma_d - \gamma) - \frac{1}{C_p}\frac{\partial q}{\partial z}$$

A **B** **C** **D** **E** **F**

<u>Term C:</u> vertical lapse rate advection

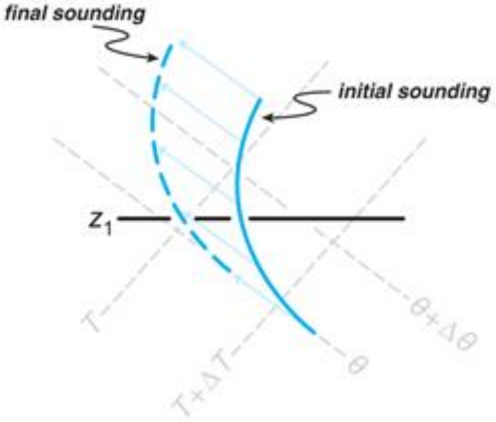


Figure 7.5

Schematic thermodynamic diagram illustrating the effect of vertical lapse rate advection. The light blue arrows indicate dry adiabatic parcel displacements. At level z_1, $\partial\gamma/\partial z < 0$, so when upward motion is imposed ($w > 0$ but $\partial w/\partial z = 0$, so that all of the parcels are displaced upward by the same distance) larger lapse rates are advected from below z_1 upward to z_1, increasing the lapse rate there. Note that this process occurs adiabatically, so that cooling has occurred at z_1 in addition to increasing the lapse rate there. This cooling associated with upward motion is typically more important for cap removal and thunderstorm initiation than just the increasing lapse rate. For example, dry adiabatic large-scale ascent *always* leads to cooling (and cap weakening) when lapse rates are less than dry adiabatic, but lapse rate changes resulting from large-scale ascent may or may not be significant, depending on the initial γ, $\partial\gamma/\partial z$, and $\partial w/\partial z$.

(Markowski and Richardson 2010, Fig. 7.5)

Lapse Rate Tendency Equation

$$\frac{\partial \gamma}{\partial t} = -\boldsymbol{v}_h \cdot \boldsymbol{\nabla}_h \gamma \boxed{- w \frac{\partial \gamma}{\partial z}} + \frac{\partial \boldsymbol{v}_h}{\partial z} \cdot \boldsymbol{\nabla}_h T + \frac{\partial w}{\partial z}(\Gamma_d - \gamma) - \frac{1}{C_p}\frac{\partial q}{\partial z}$$

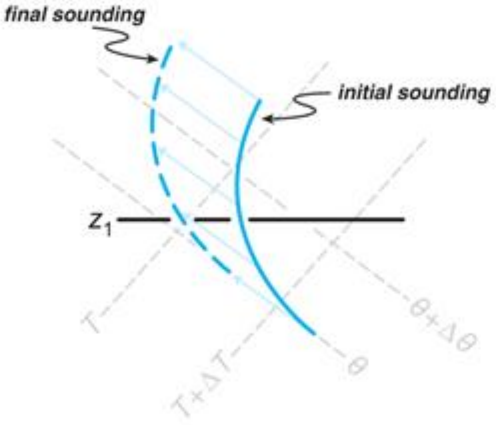
A B C D E F

<u>Term C:</u> vertical lapse rate advection

Positive lapse rate advection will contribute to increasing lapse rates

In this case, lapse rates at level z1 increase as steeper lapse rates from below are advected upward

Can be order of magnitude larger than term B on <u>mesoscale</u>



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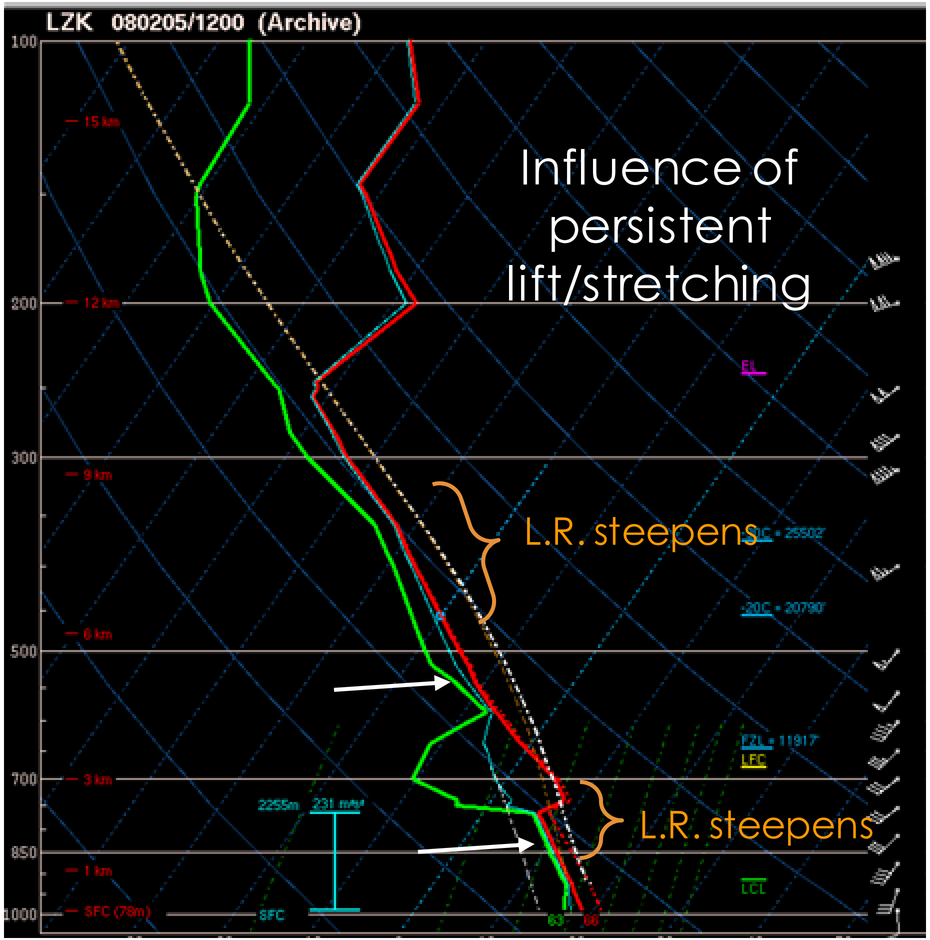
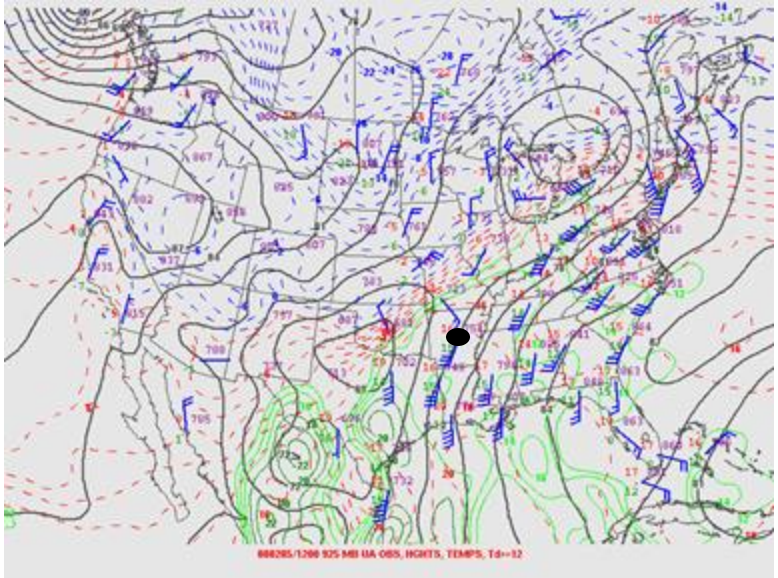
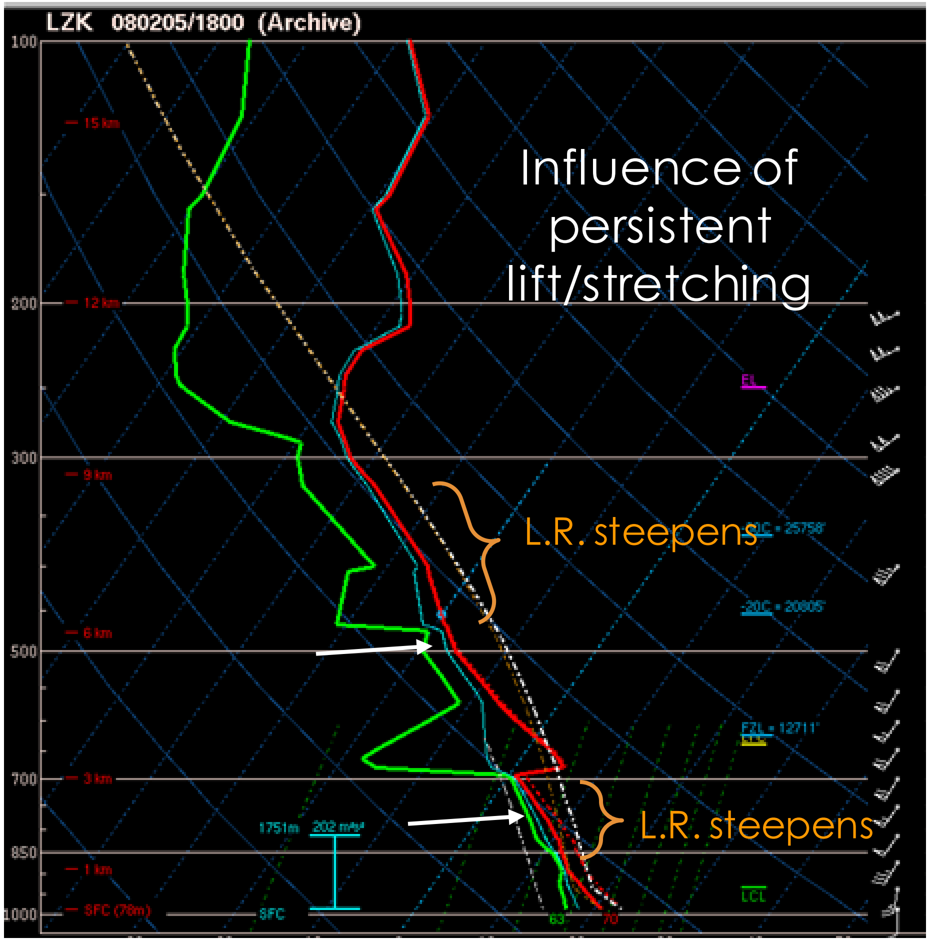
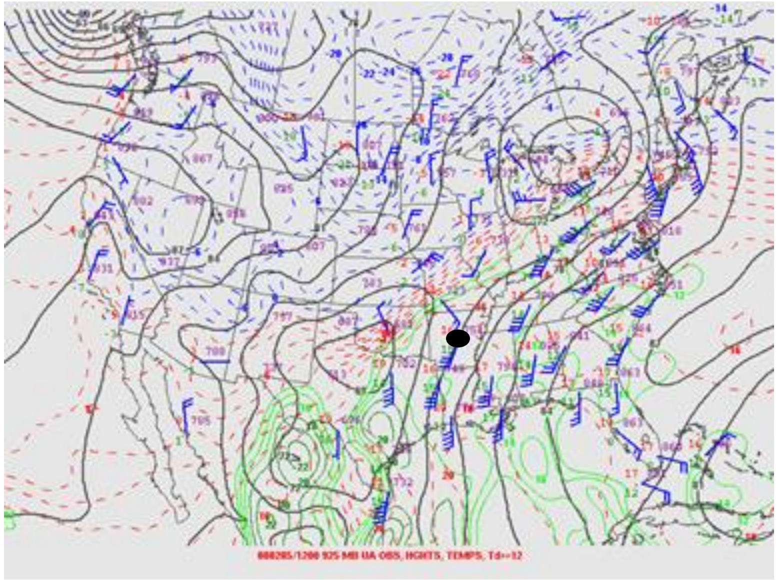


Influence of Lift/Stretching

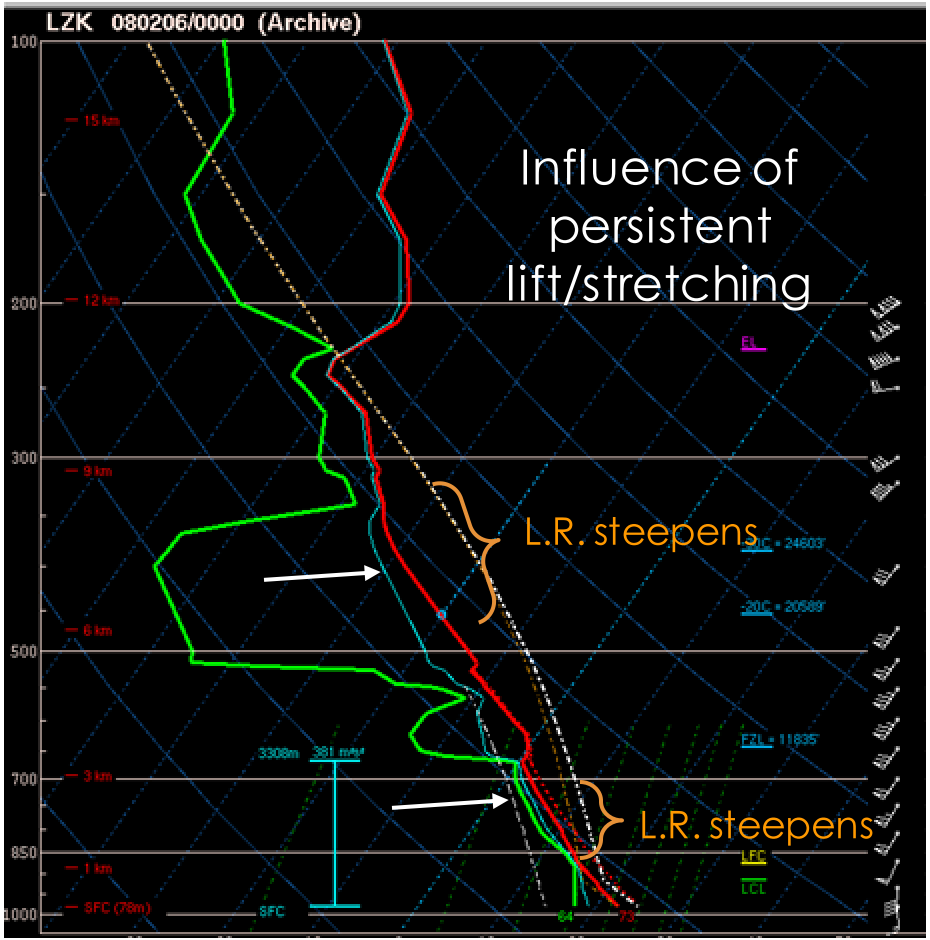


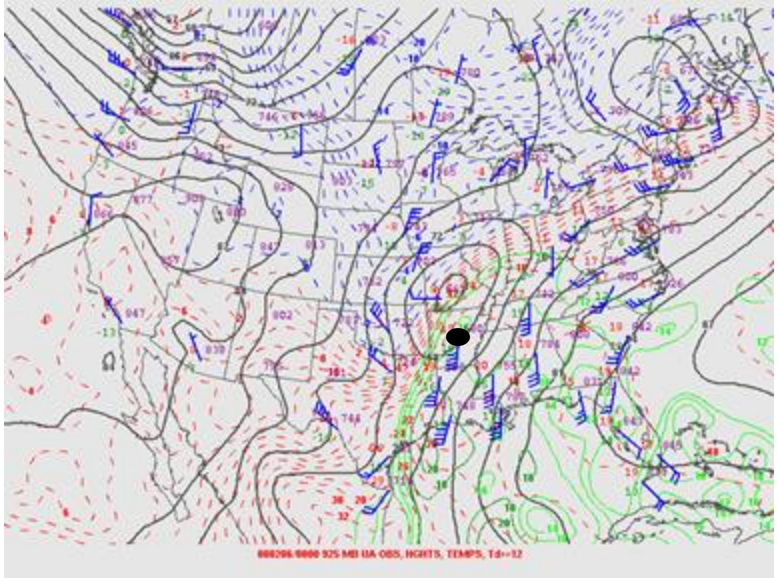
Influence of Lift/Stretching





Influence of Lift/Stretching





Lapse Rate Tendency Equation

$$\frac{\partial \gamma}{\partial t} = -\boldsymbol{v}_h \cdot \boldsymbol{\nabla}_h \gamma - w\frac{\partial \gamma}{\partial z} \boxed{+ \frac{\partial \boldsymbol{v}_h}{\partial z} \cdot \boldsymbol{\nabla}_h T} + \frac{\partial w}{\partial z}(\Gamma_d - \gamma) - \frac{1}{C_p}\frac{\partial q}{\partial z}$$

A B C D E F

Term D: when combined with term B, this term represents differential temperature advection

$$\frac{\partial \boldsymbol{v}_h}{\partial z} \cdot \boldsymbol{\nabla}_h T - \boldsymbol{v}_h \cdot \boldsymbol{\nabla}_h \gamma = \boxed{-\frac{\partial}{\partial z}(-\boldsymbol{v}_h \cdot \boldsymbol{\nabla}_h T)}$$

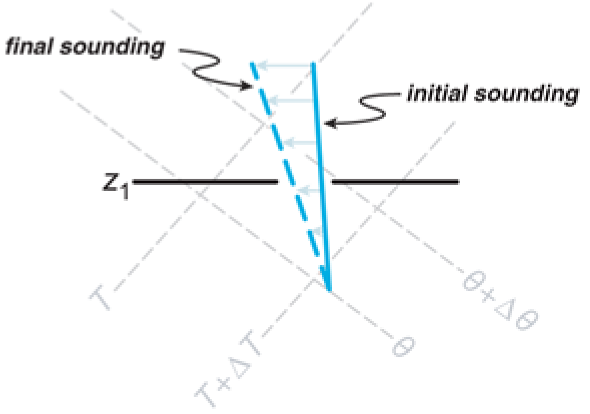


Figure 7.6

Schematic thermodynamic diagram illustrating the effect of differential horizontal temperature advection (by the ageostrophic wind) on the lapse rate (temperature changes are indicated by the light blue arrows). Cold advection increases with height at level z_1, which leads to an increase in the lapse rate at that level. This effect is really the same effect as illustrated in Figure 7.4.

(Markowski and Richardson 2010, Fig. 7.6)

Lapse Rate Tendency Equation

$$\frac{\partial \gamma}{\partial t} = -\boldsymbol{v}_h \cdot \boldsymbol{\nabla}_h \gamma - w\frac{\partial \gamma}{\partial z} \boxed{+\frac{\partial \boldsymbol{v}_h}{\partial z} \cdot \boldsymbol{\nabla}_h T} + \frac{\partial w}{\partial z}(\Gamma_d - \gamma) - \frac{1}{C_p}\frac{\partial q}{\partial z}$$

A B C D E F

Term D: when combined with term B, this term represents differential temperature advection

$$\frac{\partial \boldsymbol{v}_h}{\partial z} \cdot \boldsymbol{\nabla}_h T - \boldsymbol{v}_h \cdot \boldsymbol{\nabla}_h \gamma = \boxed{-\frac{\partial}{\partial z}(-\boldsymbol{v}_h \cdot \boldsymbol{\nabla}_h T)}$$

Lapse rates will increase in situations where cold advection is increasing with height or warm advection is decreasing with height

In this case, lapse rates at level z1 increase in response to cold air advection increasing with height

Can be order of magnitude larger than term B on mesoscale

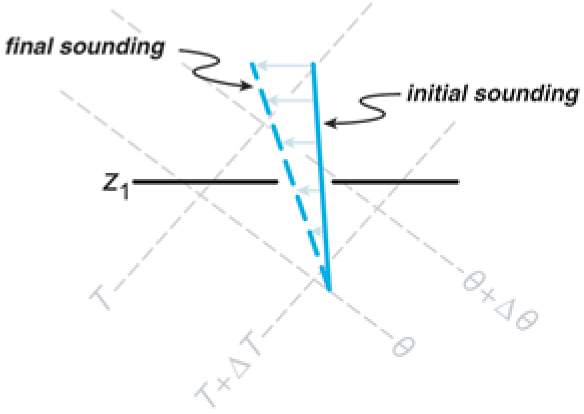
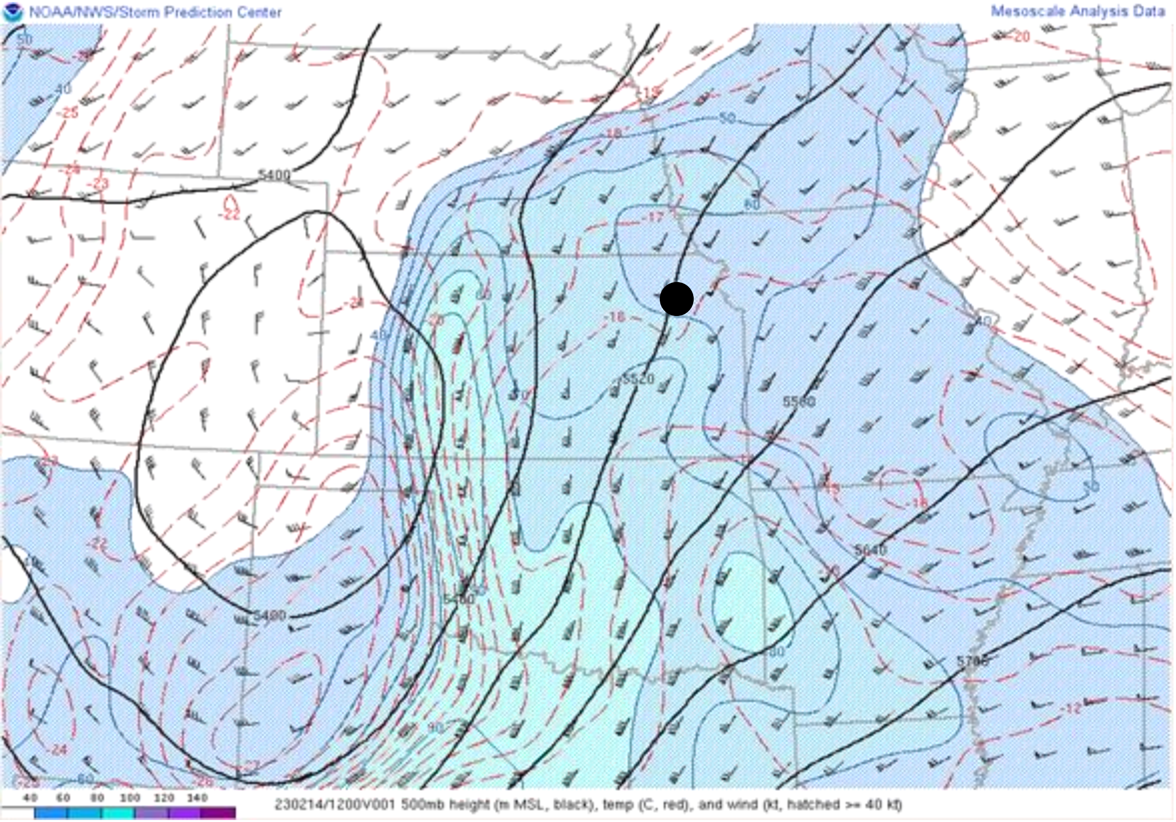


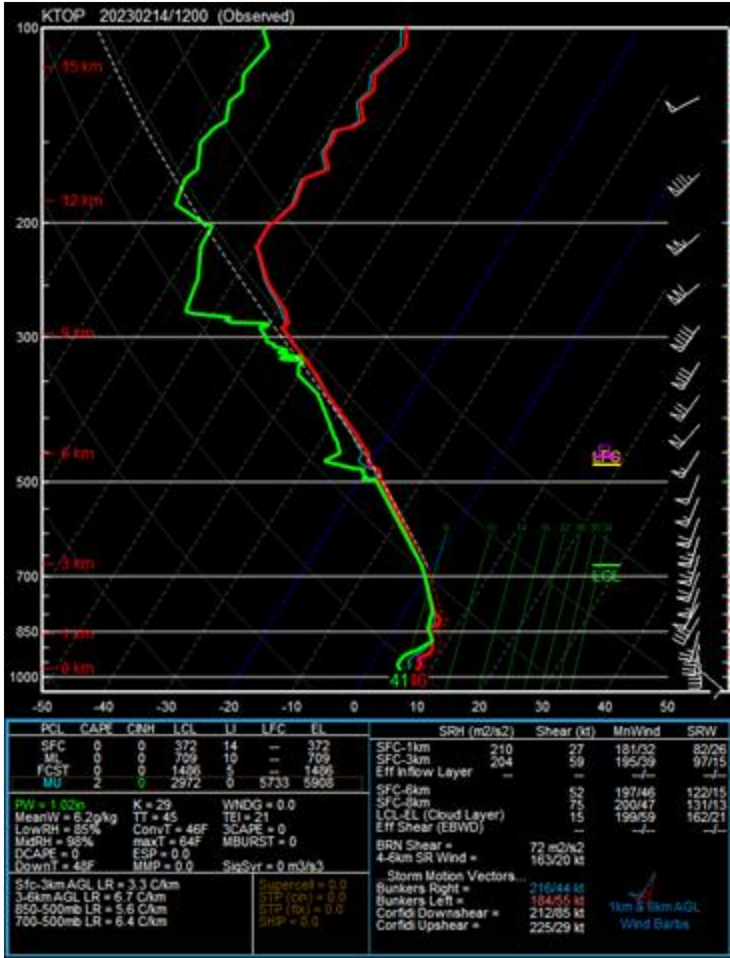
Figure 7.6

Schematic thermodynamic diagram illustrating the effect of differential horizontal temperature advection (by the ageostrophic wind) on the lapse rate (temperature changes are indicated by the light blue arrows). Cold advection increases with height at level z_1, which leads to an increase in the lapse rate at that level. This effect is really the same effect as illustrated in Figure 7.4.

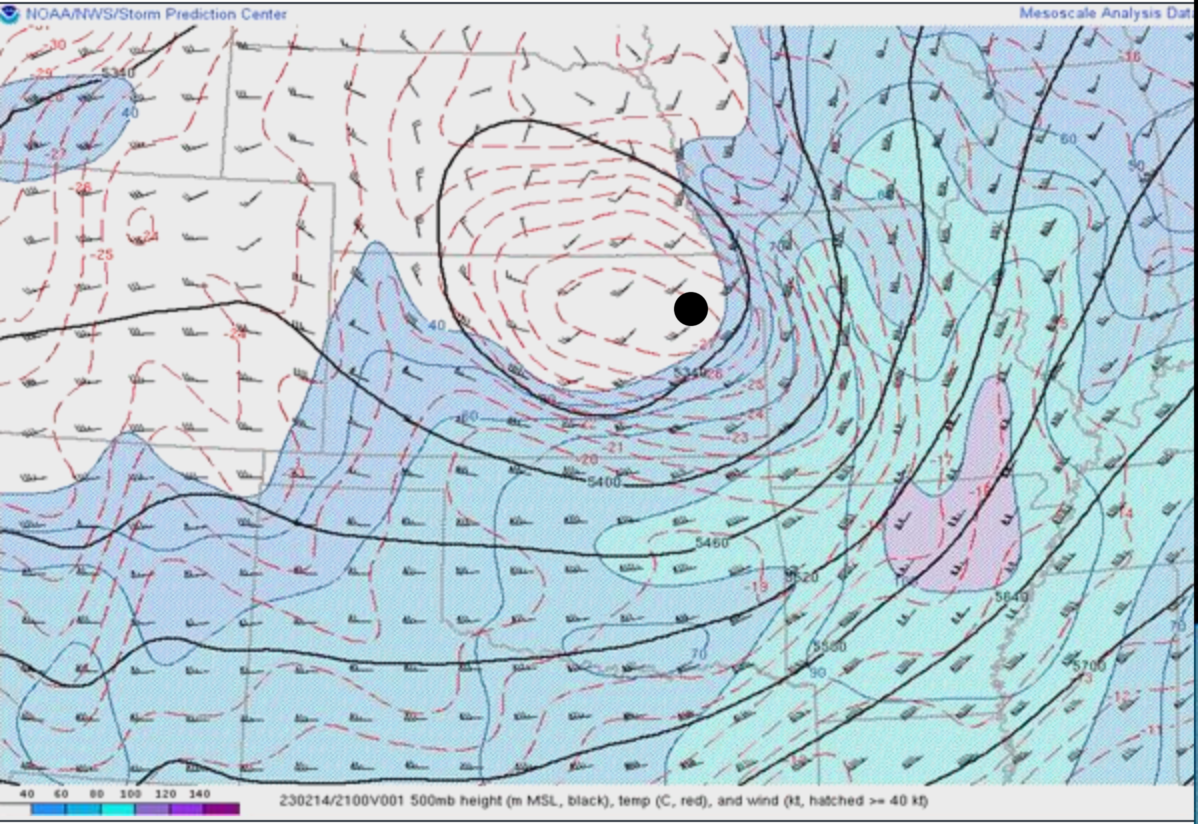
(Markowski and Richardson 2010, Fig. 7.6)

Differential Thermal Advection





Differential Thermal Advection



Lapse Rate Tendency Equation

$$\underset{A}{\frac{\partial \gamma}{\partial t}} = \underset{B}{-\boldsymbol{v}_h \cdot \boldsymbol{\nabla}_h \gamma} \underset{C}{- w\frac{\partial \gamma}{\partial z}} + \underset{D}{\frac{\partial \boldsymbol{v}_h}{\partial z} \cdot \boldsymbol{\nabla}_h T} + \underset{E}{\boxed{\frac{\partial w}{\partial z}(\Gamma_d - \gamma)}} \underset{F}{- \frac{1}{C_p}\frac{\partial q}{\partial z}}$$

Term E: stretching effect on lapse rate

Horizontal convergence increases lapse rate
Horizontal divergence decreases lapse rate
Term = 0 when environment lapse rate is dry adiabatic ($\gamma = \Gamma_d$)

In this case, lapse rates at level z1 increase in response to convergence ($\frac{\partial w}{\partial z} > 0$)

Can be order of magnitude larger than term B on mesoscale

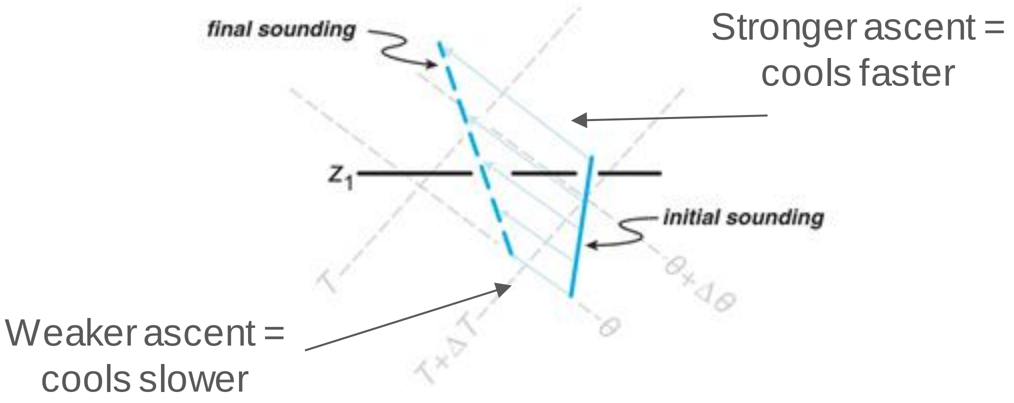
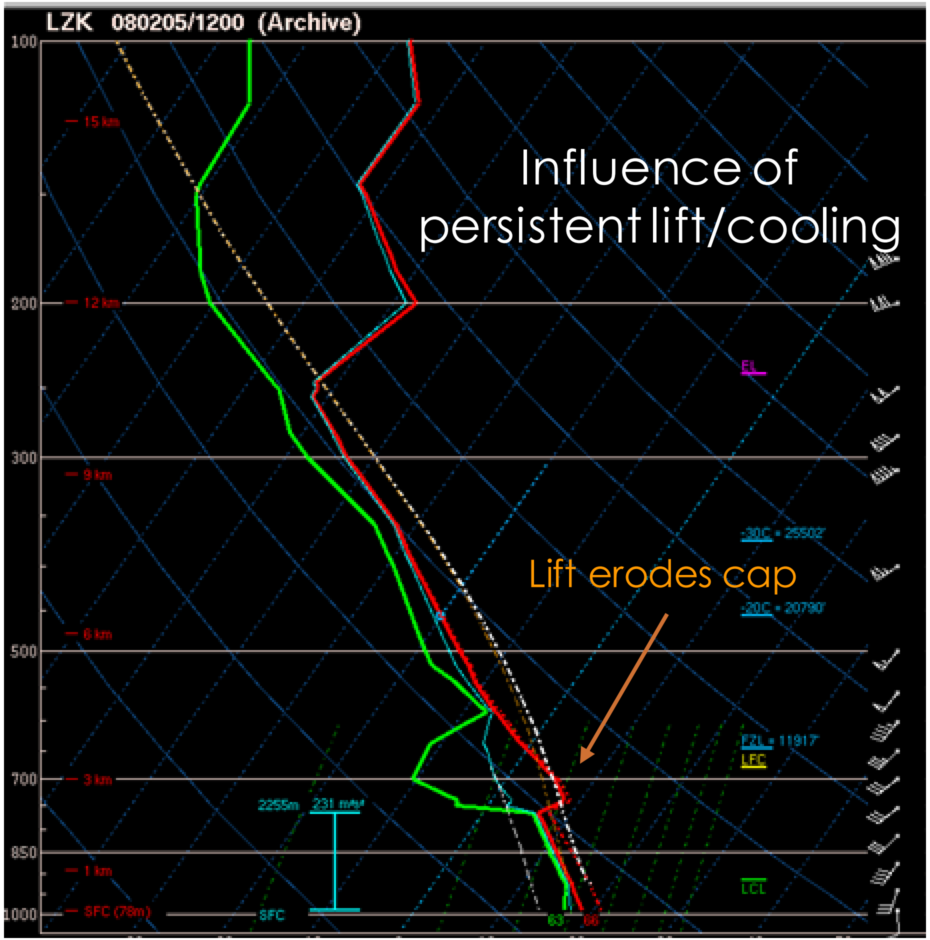


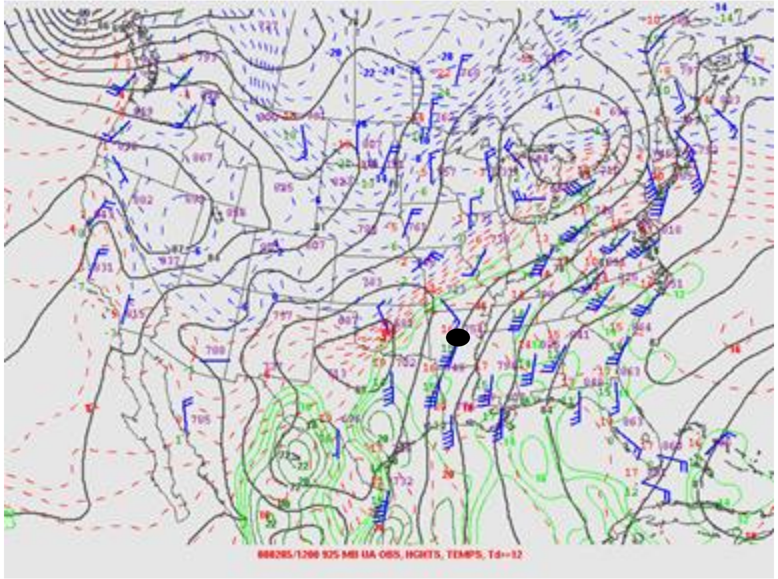
Figure 7.7

Schematic thermodynamic diagram illustrating the stretching effect on lapse rate. In this example, $\Gamma_d > \gamma$ and $\partial w/\partial z > 0$, therefore the lapse rate at level z_1 increases in time. The light blue arrows indicate dry adiabatic upward parcel displacements (because $\partial w/\partial z > 0$, the displacements increase with height).

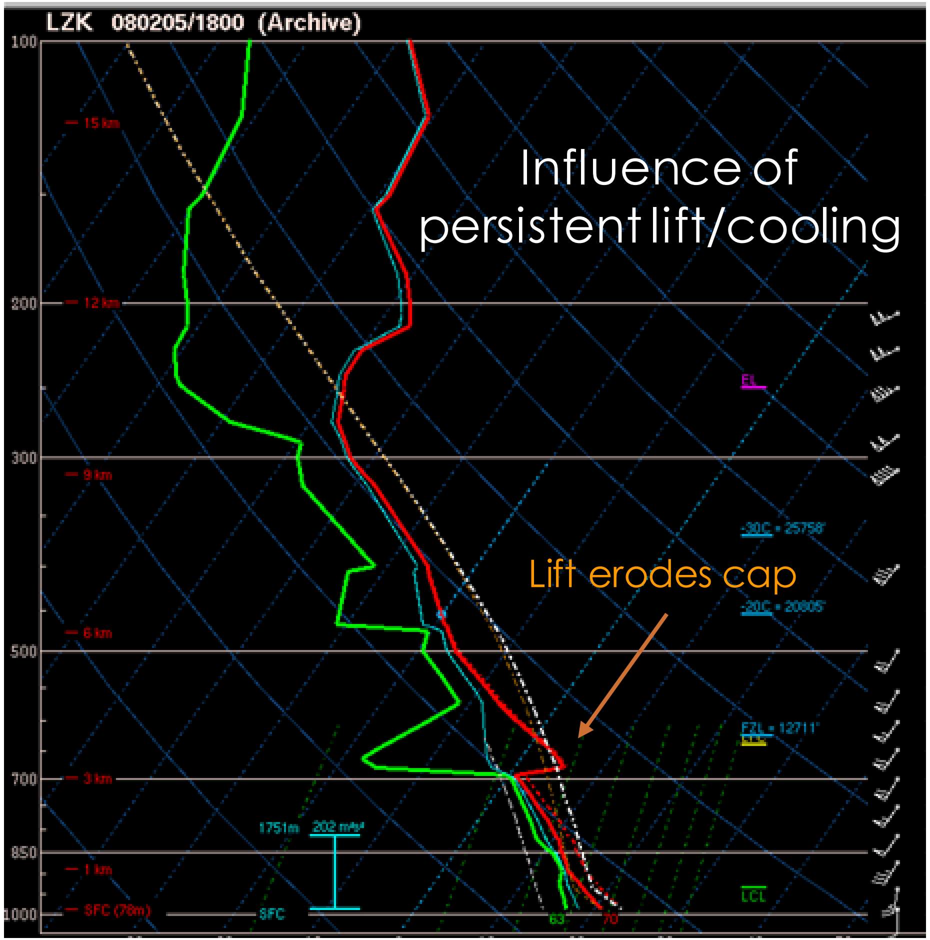
(Markowski and Richardson 2010, Fig. 7.7)

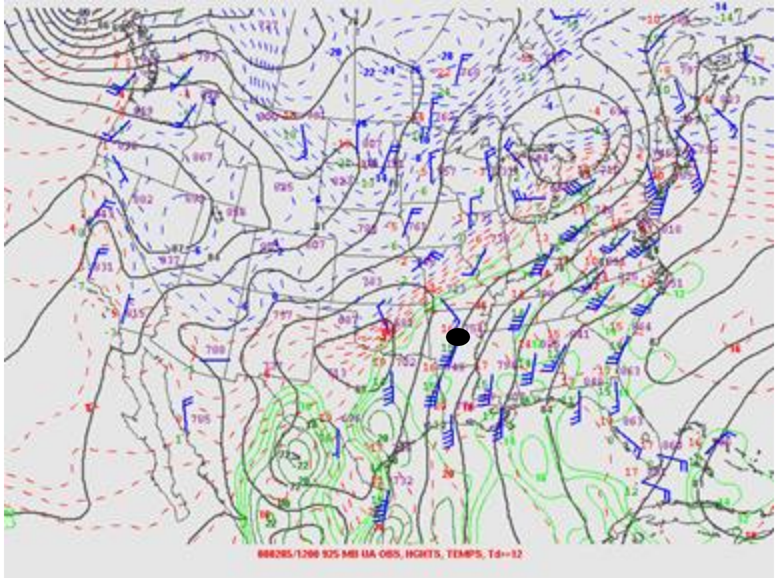


Influence of Lift/Stretching

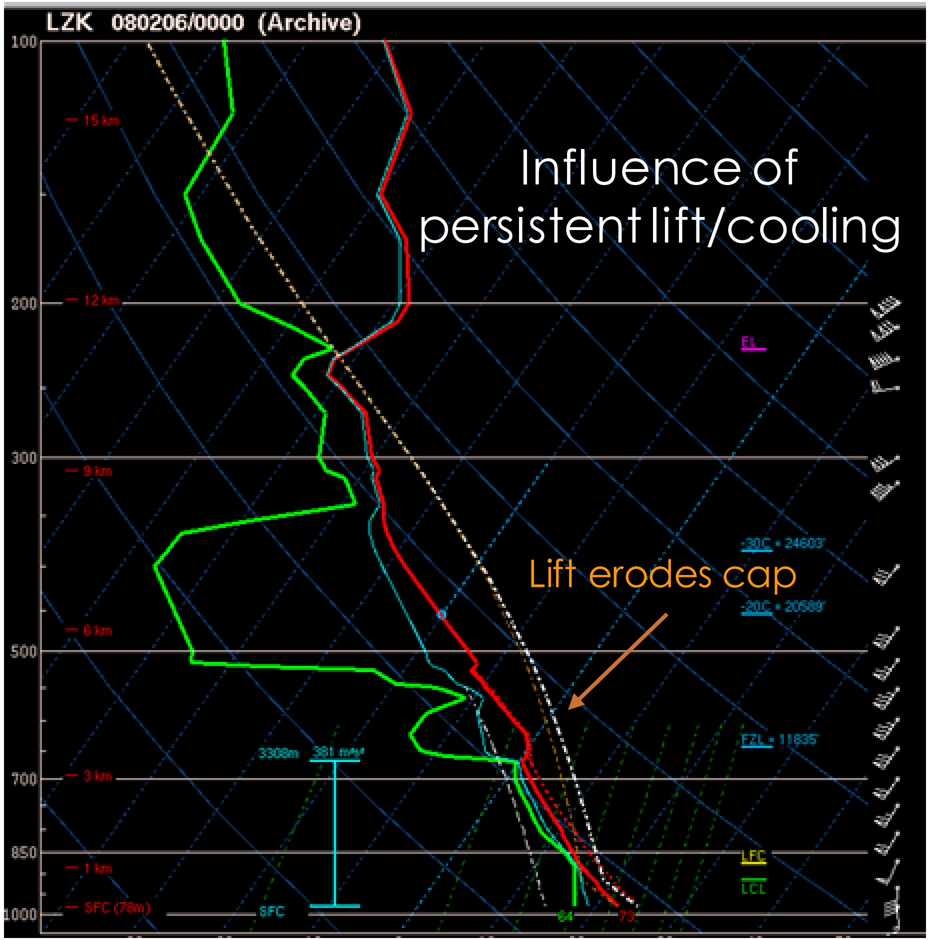


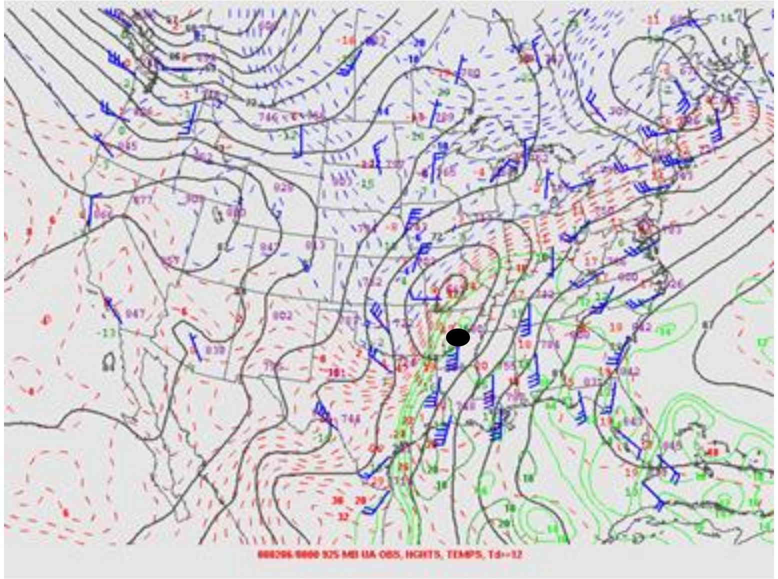
Influence of Lift/Stretching





Influence of Lift/Stretching





Lapse Rate Tendency Equation

$$\frac{\partial \gamma}{\partial t} = -\boldsymbol{v}_h \cdot \boldsymbol{\nabla}_h \gamma - w\frac{\partial \gamma}{\partial z} + \frac{\partial \boldsymbol{v}_h}{\partial z} \cdot \boldsymbol{\nabla}_h T + \frac{\partial w}{\partial z}(\Gamma_d - \gamma) \boxed{- \frac{1}{C_p}\frac{\partial q}{\partial z}}$$

A **B** **C** **D** **E** **F**

<u>Term F:</u> diabatic heating effect on lapse rate

In this case, in response to a diabatic heating maximum at level z1, lapse rates increase above and decrease below level z1.

Can be order of magnitude larger than term B on <u>mesoscale</u>

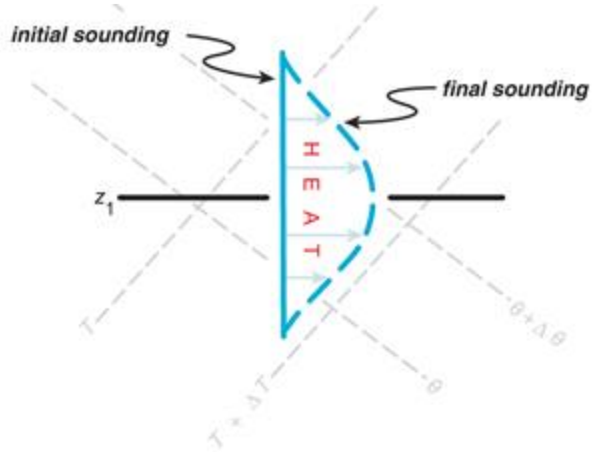
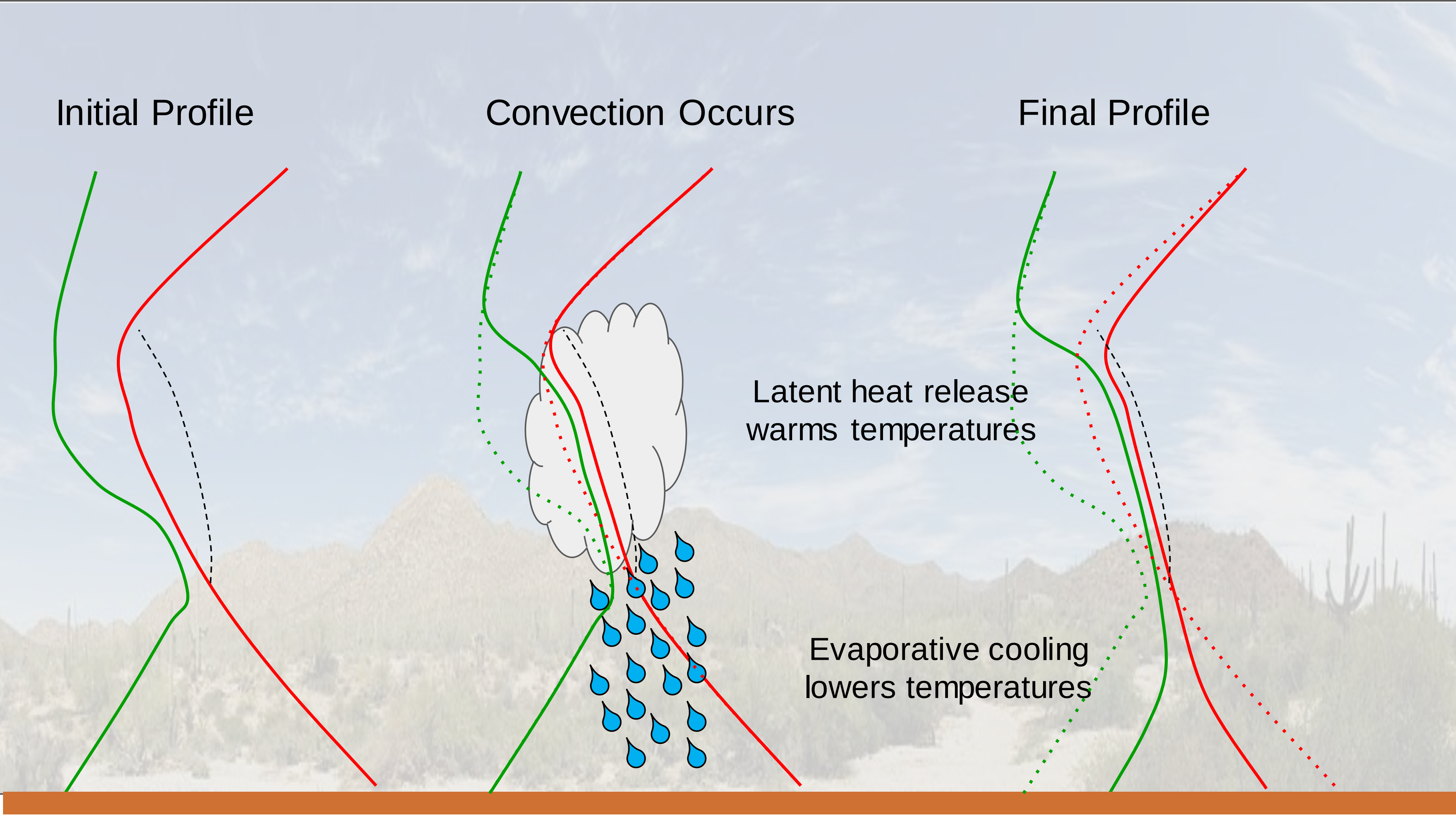


Figure 7.8

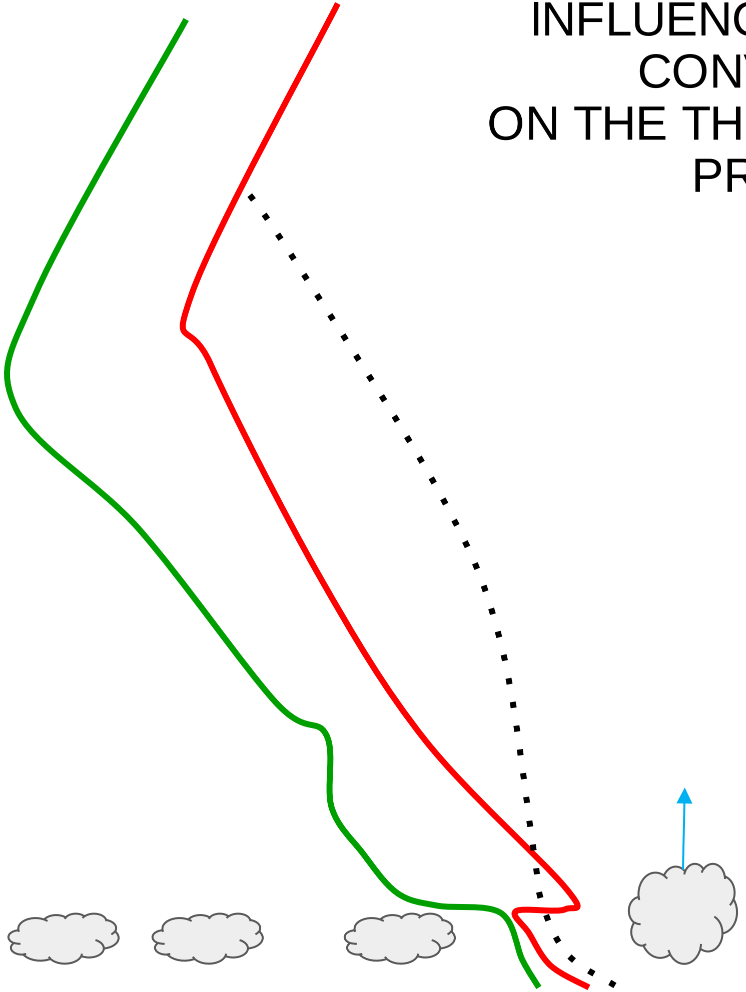
Schematic thermodynamic diagram illustrating the effects of differential diabatic heating on lapse rate (temperature changes are indicated by the light blue arrows). The maximum latent heating occurs at level z_1, where $\partial q/\partial z = 0$ and the lapse rate is unchanged. The lapse rate increases above the level of maximum heating ($z > z_1$) and decreases below the level of maximum heating ($z < z_1$).

(Markowski and Richardson 2010, Fig. 7.8)



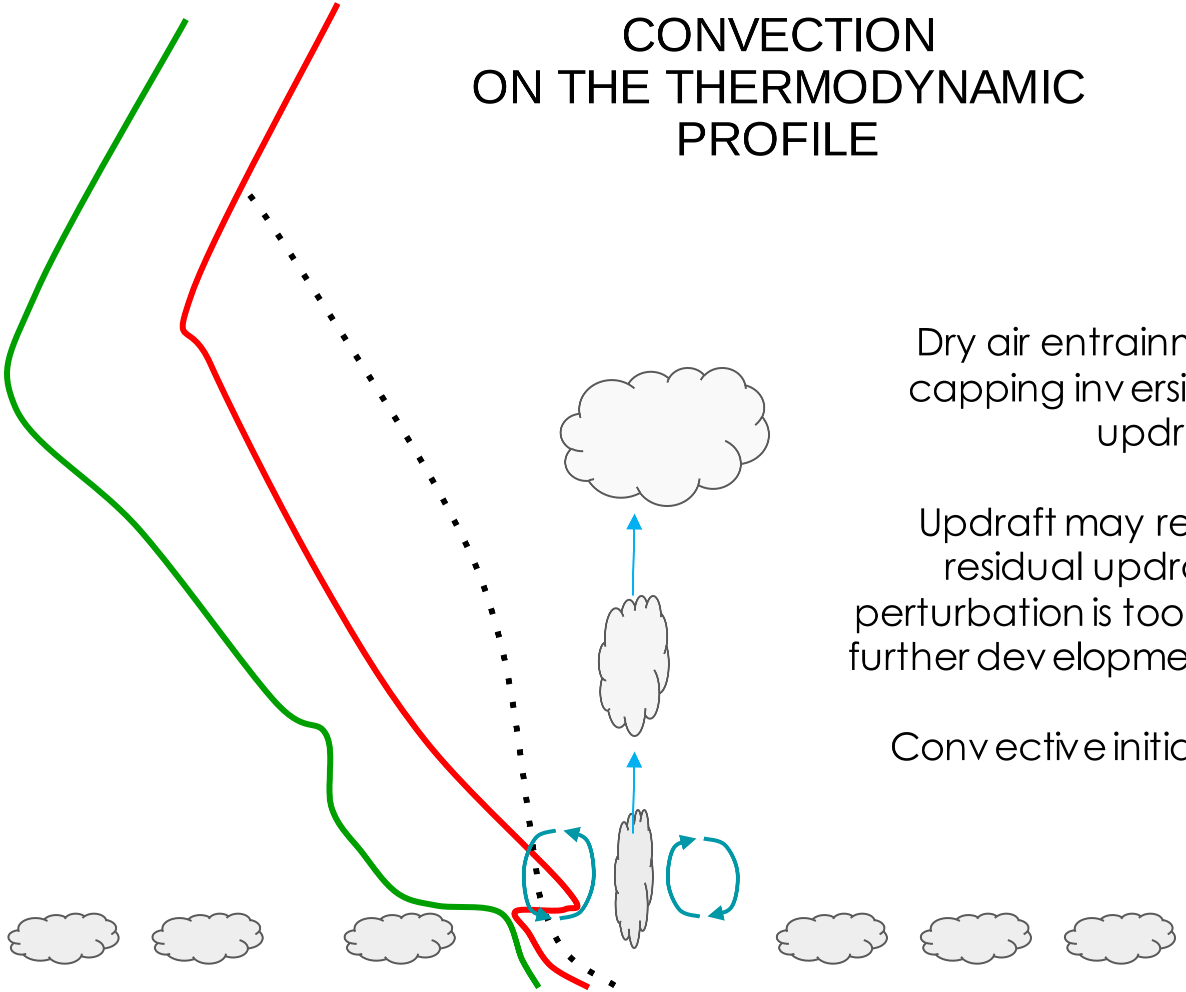
Initial Profile
Convection Occurs
Final Profile
Latent heat release
warms temperatures
Evaporative cooling
lowers temperatures

INFLUENCE OF FAILED CONVECTION ON THE THERMODYNAMIC PROFILE



Weak ascent supports an initial, isolated updraft

INFLUENCE OF FAILED CONVECTION ON THE THERMODYNAMIC PROFILE

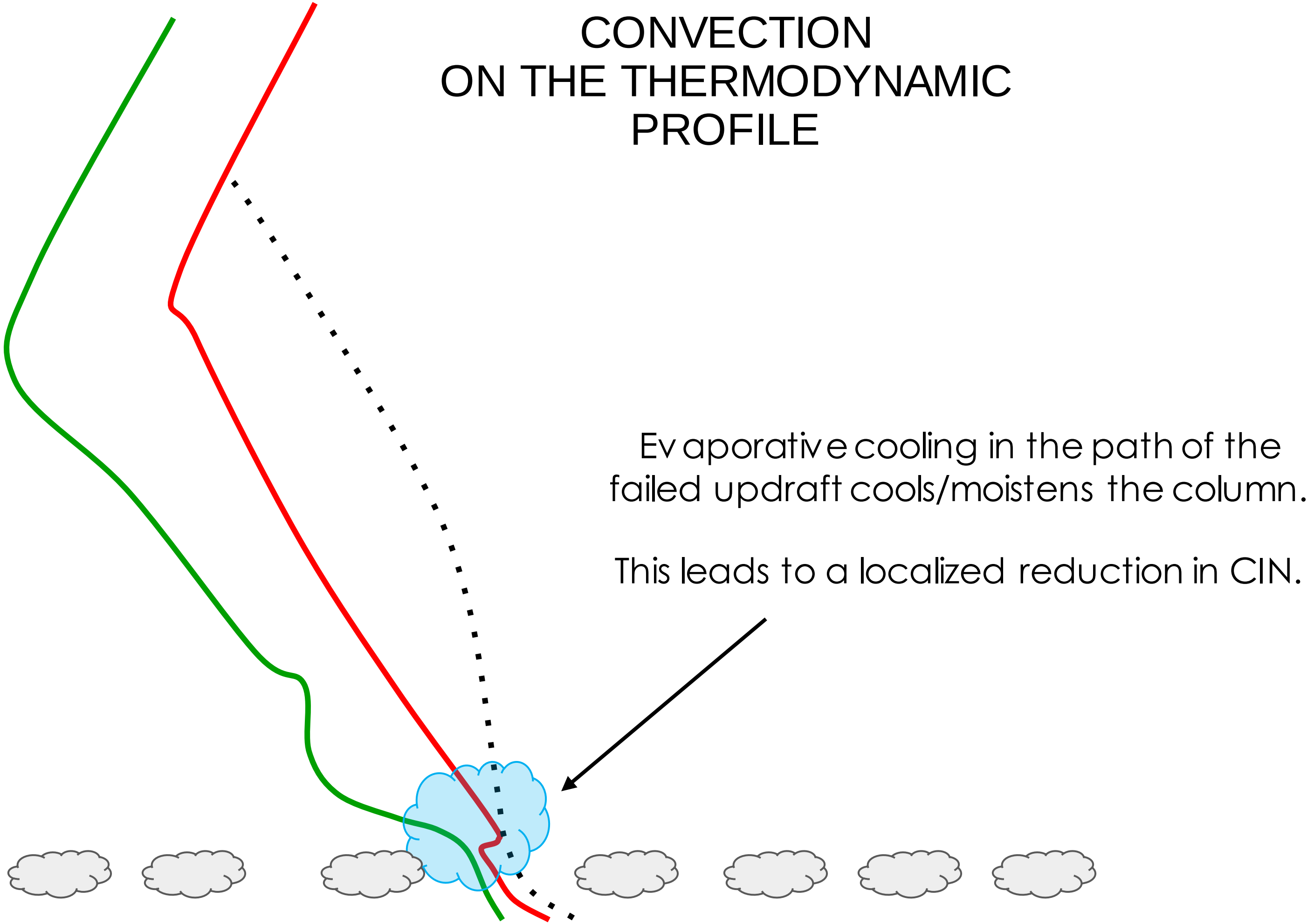


Dry air entrainment near the capping inversion erodes the updraft.

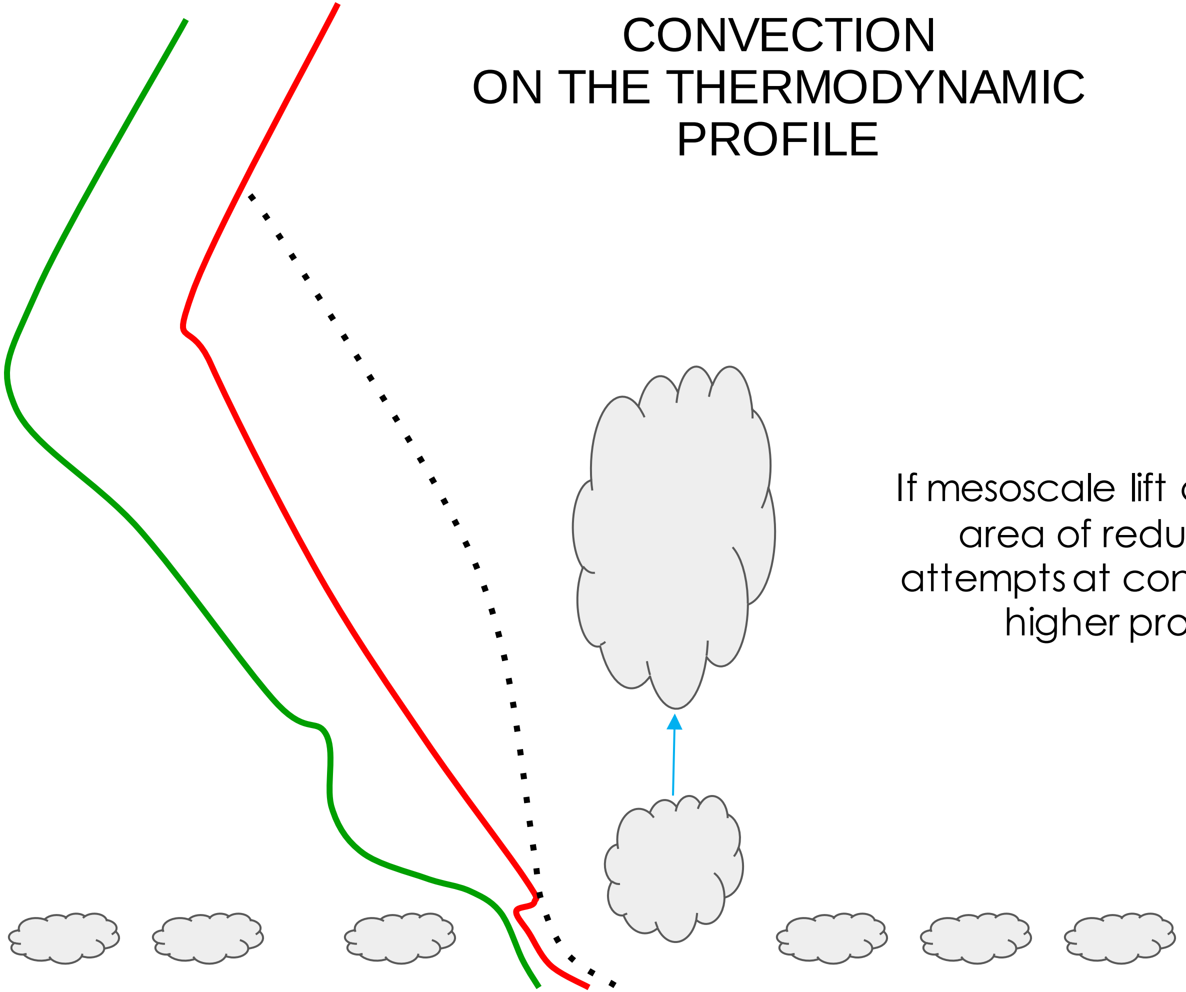
Updraft may reach LFC, but residual updraft/pressure perturbation is too weak to support further development (turkey tower).

Convective initiation has failed.

INFLUENCE OF FAILED CONVECTION ON THE THERMODYNAMIC PROFILE

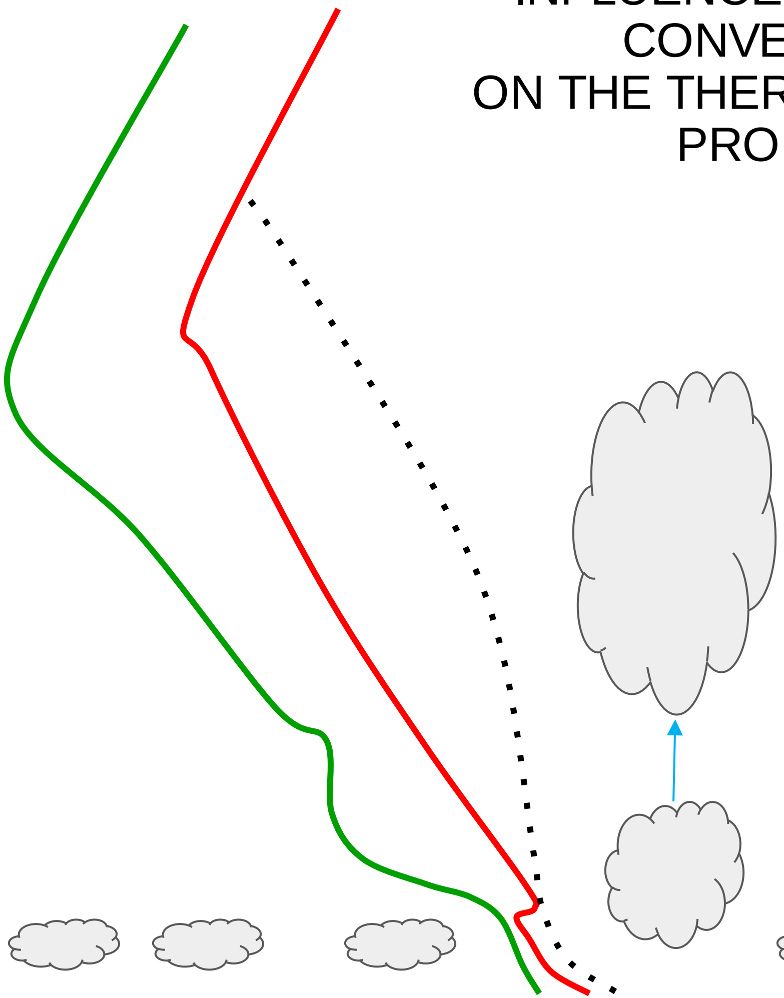


INFLUENCE OF FAILED CONVECTION ON THE THERMODYNAMIC PROFILE



If mesoscale lift continues in this localized area of reduced CIN, subsequent attempts at convective initiation have a higher probability of success!

INFLUENCE OF FAILED CONVECTION ON THE THERMODYNAMIC PROFILE



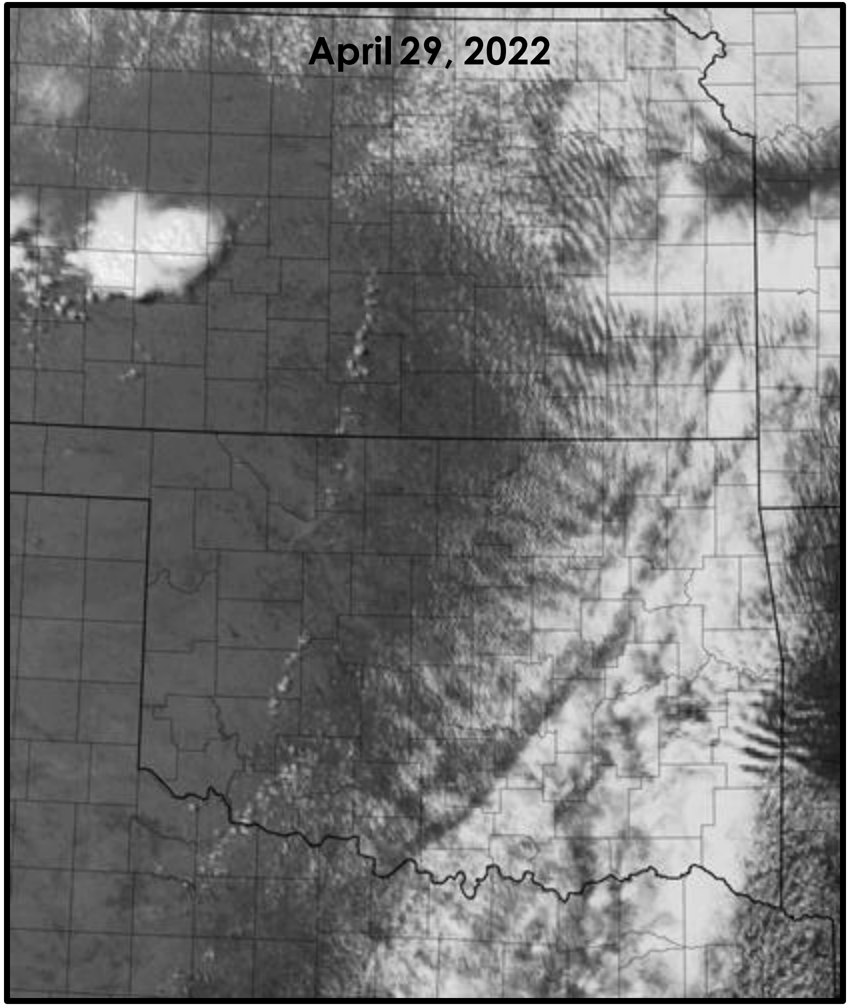
Additional Considerations:

It may take multiple attempts at CI to sufficiently reduce CIN.

Consider time of day (is this occurring at 20 UTC (additional diurnal heating expected) or at 00 UTC (peak diurnal heating)?

Strong forcing for ascent can reduce CIN via lift/cooling and/or overcoming cap by lifting parcels to LFC (i.e. is the depth of the lift greater than the LFC?)

Watching satellite trends is vital!



In this loop, watch for:

- Initial attempts at CI along dryline
- Successful CI following the failed attempts
- Maturation of tornadic supercells

CAPE/CIN Changes Independent of γ Tendency

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

Rising motion **Low-Level Moistening** **Low-Level Warming**

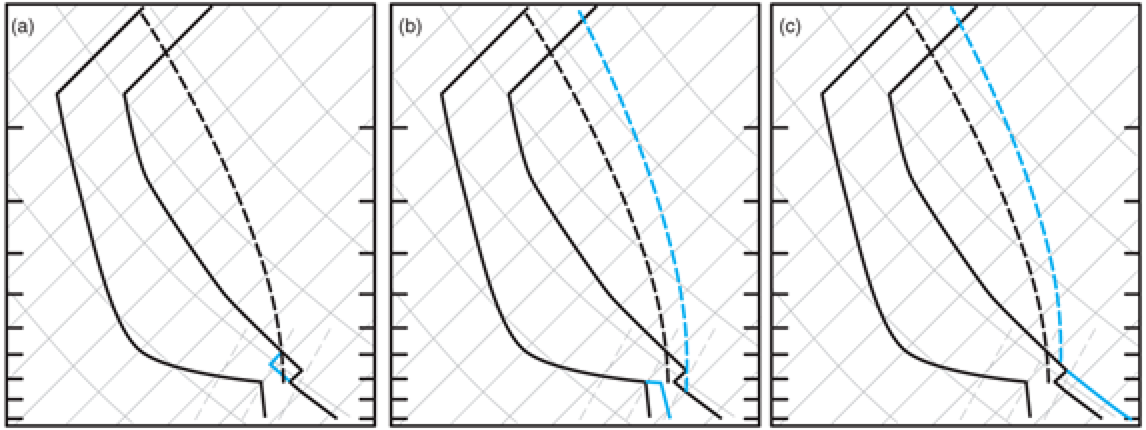


Figure 7.9

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.