Evolution of Lapse Rate, CAPE, and CIN

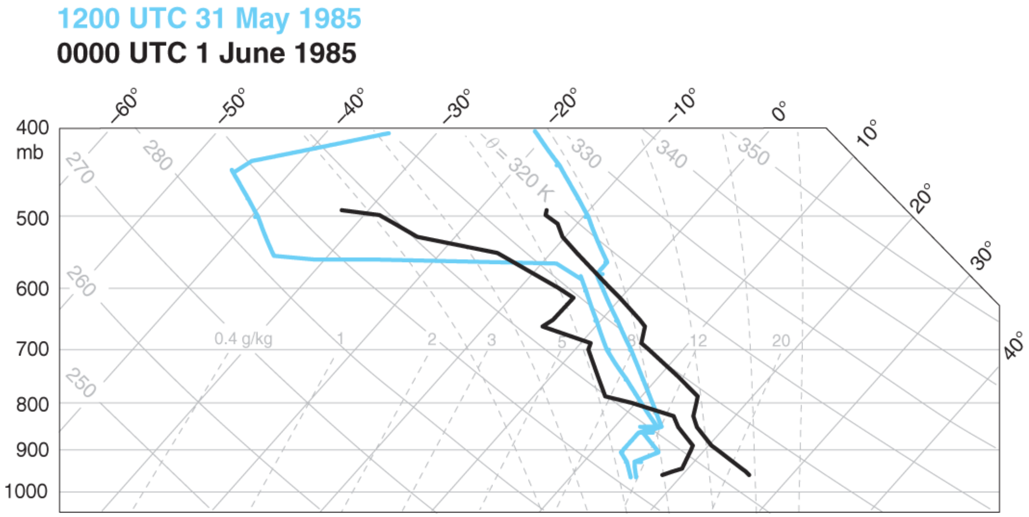
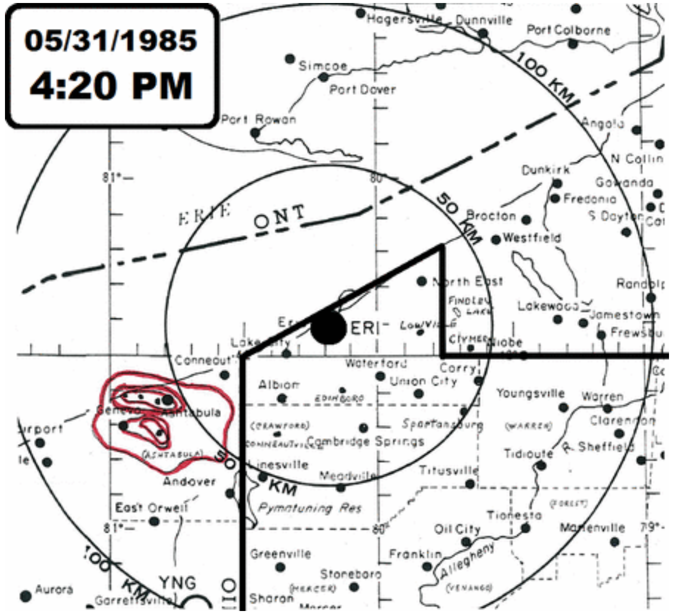


Figure 7.3

Soundings from Pittsburgh, PA, at 1200 UTC 31 May 1985 (blue) and 0000 UTC 1 June 1985 (black). Between 1200 and 0000 UTC, the mean tropospheric lapse rate has undergone significant changes, probably as the result of a number of large-scale processes acting in unison (e.g., insolation, lapse rate advection/differential temperature advection, stretching effect, etc.). The low-level moisture also increased by several g kg $^{-1}$ during the same 12 h period, primarily as a result of moisture advection. The increase in lapse rate and low-level moisture between 1200 and 0000 UTC led to the development of large CAPE (the lifted index decreased from +3 to –7; the lifted index is the temperature difference between the environmental 500 mb temperature and the temperature of an air parcel that has been lifted to 500 mb from the surface, with negative indices indicating that the lifted parcel is warmer than the environment at 500 mb). (Large vertical wind shear also accompanied the large instability; the worst tornado outbreak in the history of Pennsylvania was in progress not far from Pittsburgh at 0000 UTC.)

(Markowski and Richardson 2010, Fig. 7.3)



Radar summary maps from WSR-74 at Erie, PA

“This image, courtesy Greg Forbes via Paul Markowski, is from the radar that was atop the Walker Building, home of Penn State Meteorology Department, around 8pm EST. It shows a pronounced hook echo (center of photo) within the storm moving through Moshannon State Forest about 20 miles north of State College, Centre County.”

What physical processes drive changes in lapse rate, CAPE, and CIN?

Source: https://www.weather.gov/ctp/TornadoOutbreak_May311985

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

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

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

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

Lapse Rate Tendency

- What physical processes alter the environment lapse rate?

Start with 1st Law of Thermodynamics

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

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

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

Lapse Rate Tendency

- What physical processes alter the environment lapse rate?

Start with 1st Law of Thermodynamics

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

heating rate

specific heat

temperature

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

pressure

time

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

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

Relatively small, assume hydrostatic

Differentiate with respect to $-z$

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

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

specific heat

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

time

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

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

Relatively small, assume hydrostatic

Differentiate with respect to $-z$

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

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

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

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

Lapse Rate Tendency

- What physical processes alter the environment lapse rate?

<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 $\left(\frac{1}{\rho}\right)$

time

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

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

Relatively small, assume hydrostatic

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

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

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

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

Lapse rate tendency equation

Lapse Rate Tendency Equation

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

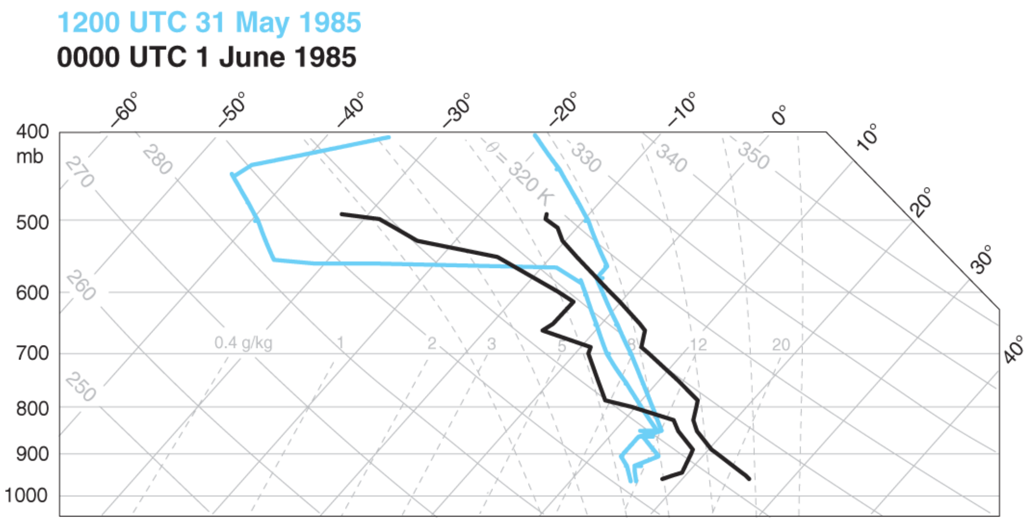
A **B** **C** **D** **E** **F**

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

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



(Markowski and Richardson 2010, Fig. 7.3)

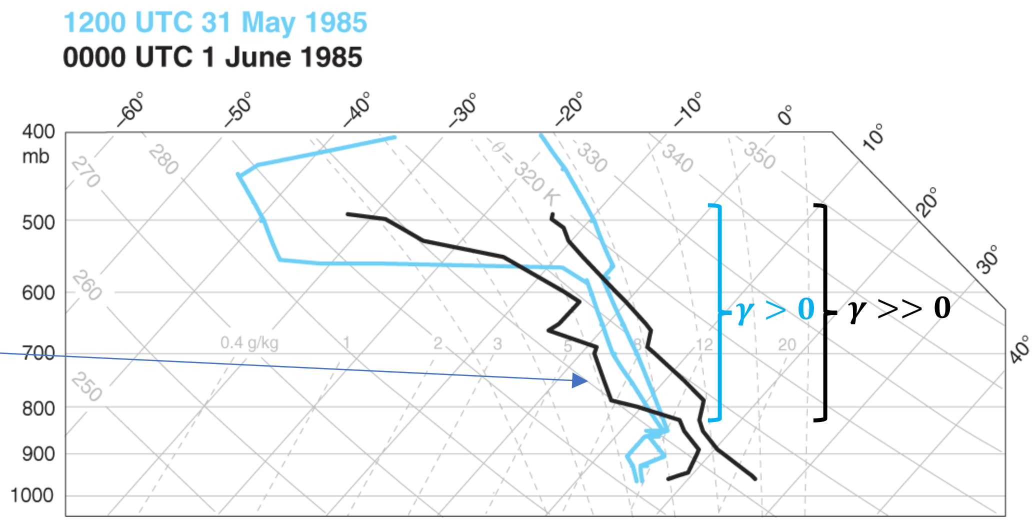
Lapse Rate Tendency Equation

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

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



(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

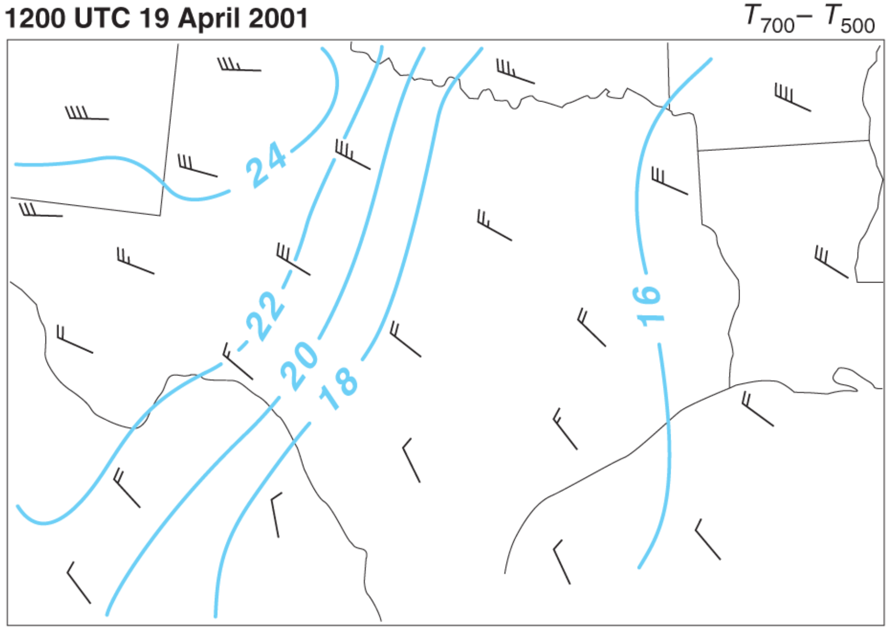


Figure 7.4

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)

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

<ins>Term B:</ins> horizontal lapse rate advection

Positive lapse rate advection will contribute to increasing lapse rates

Typically the dominant term on <ins>synoptic scales</ins>

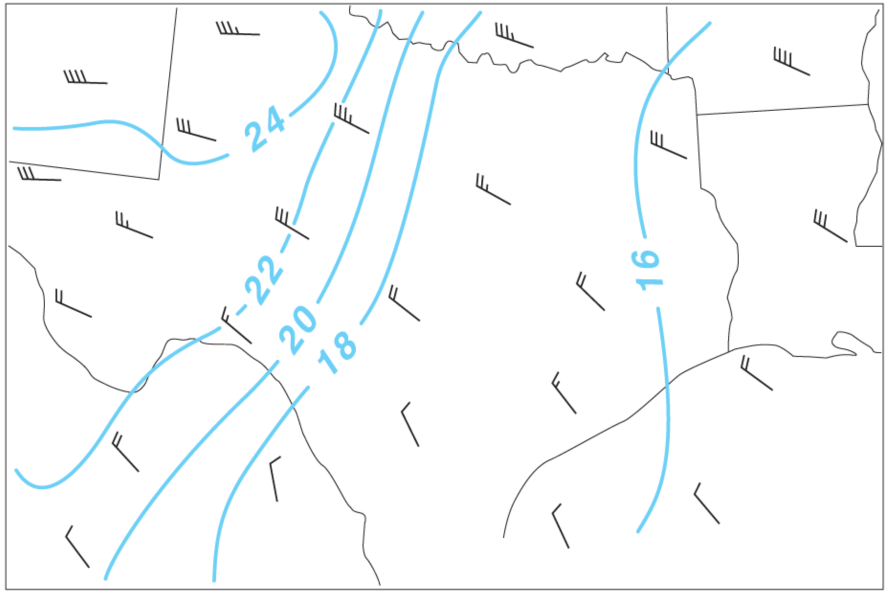
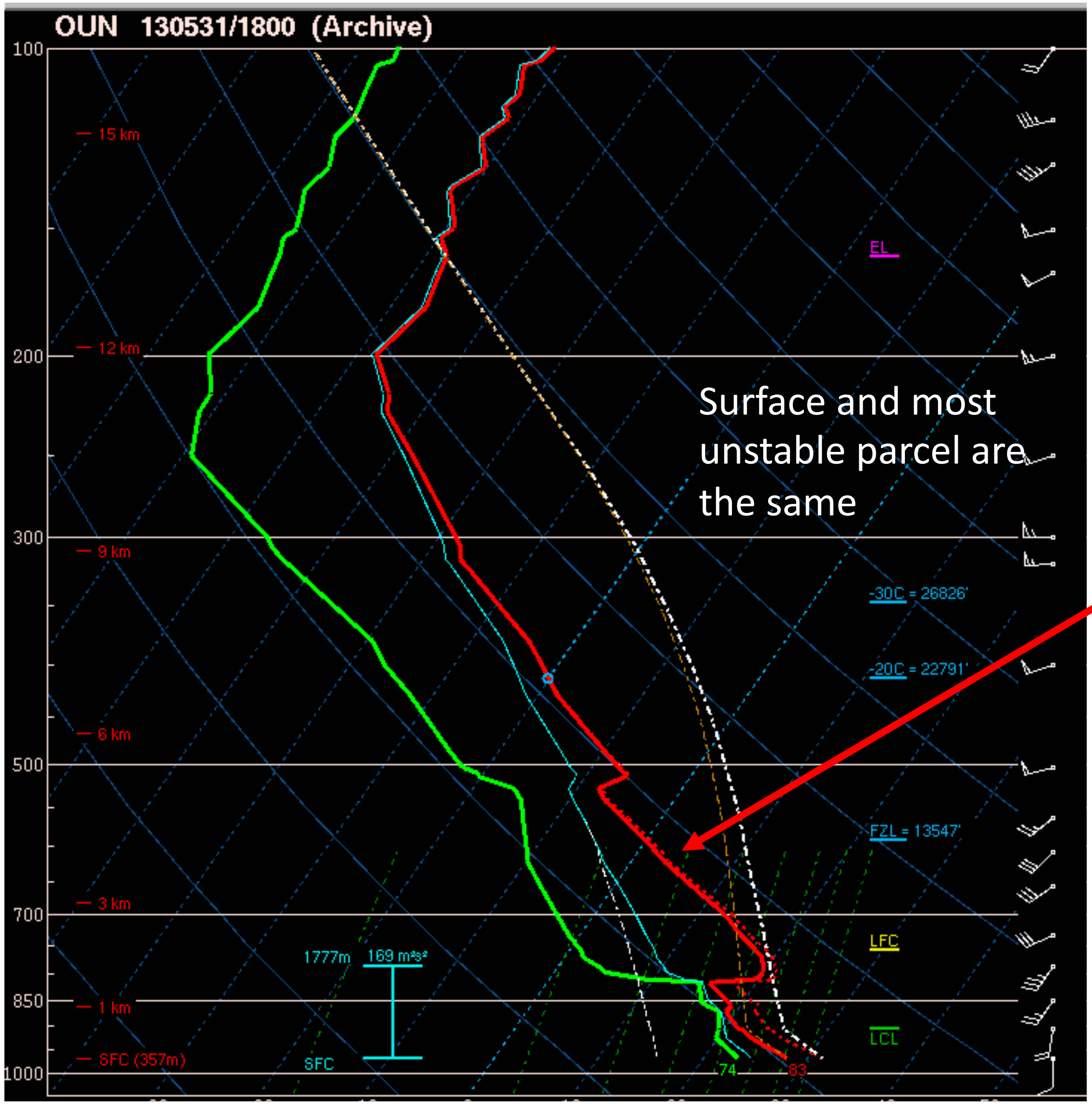


Figure 7.4

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)



Nearly neutral layer above boundary layer in Norman noon sounding – The layer originated from New Mexico plateau

Lapse Rate Tendency Equation

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

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

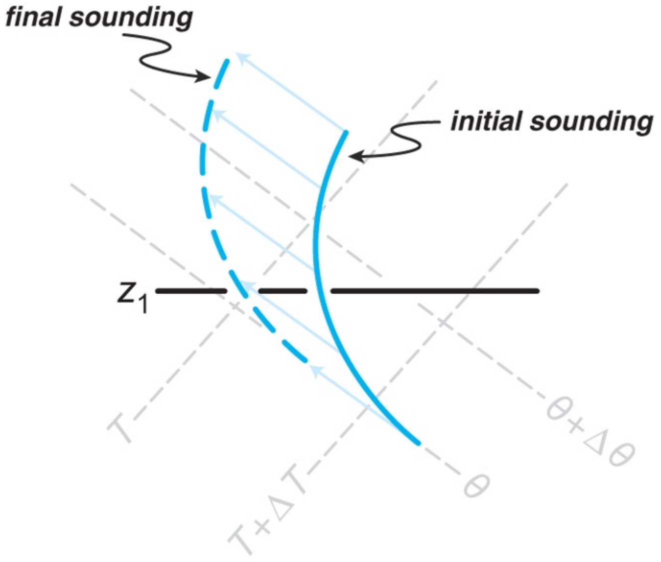


Figure 7.5

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

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

<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>

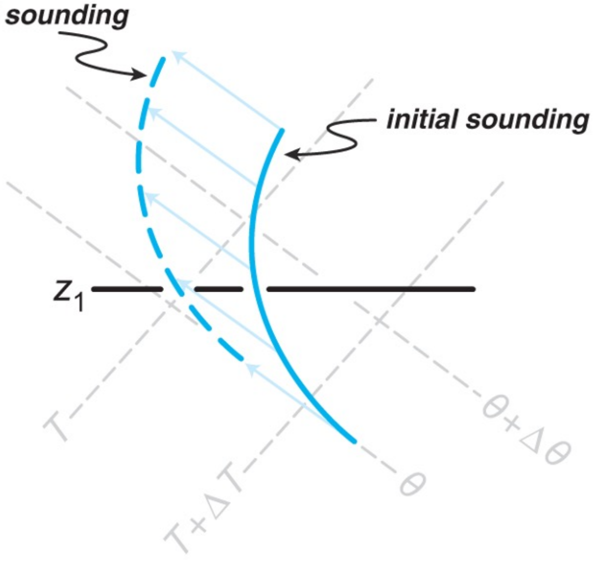


Figure 7.5

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

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

A B C D E F

<u>Term D:</u> when combined with term B, this term represents differential temperature advection

$$\frac{\partial \boldsymbol{v_h}}{\partial z} \cdot \boldsymbol{\nabla_h} T - \boldsymbol{v_h} \cdot \boldsymbol{\nabla_h} \gamma = \boxed{-\frac{\partial}{\partial z}(-\boldsymbol{v_h} \cdot \boldsymbol{\nabla_h} T)}$$

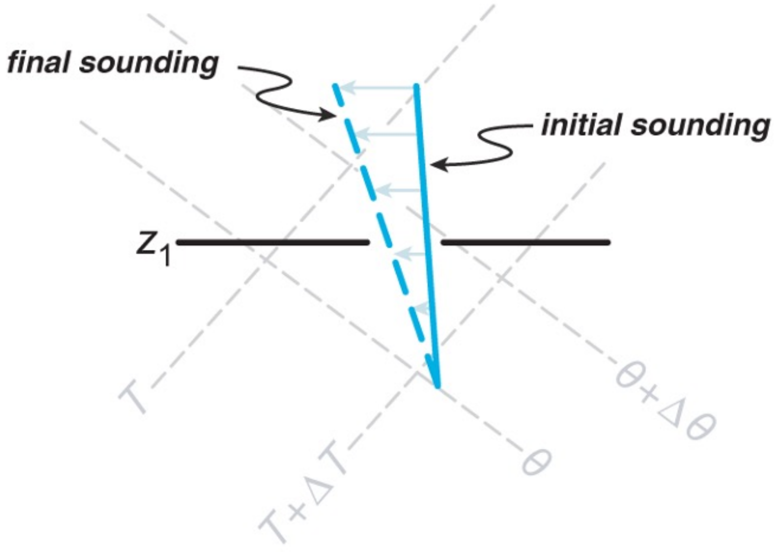


Figure 7.6

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

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

<u>Term D:</u> 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 <u>mesoscale</u>

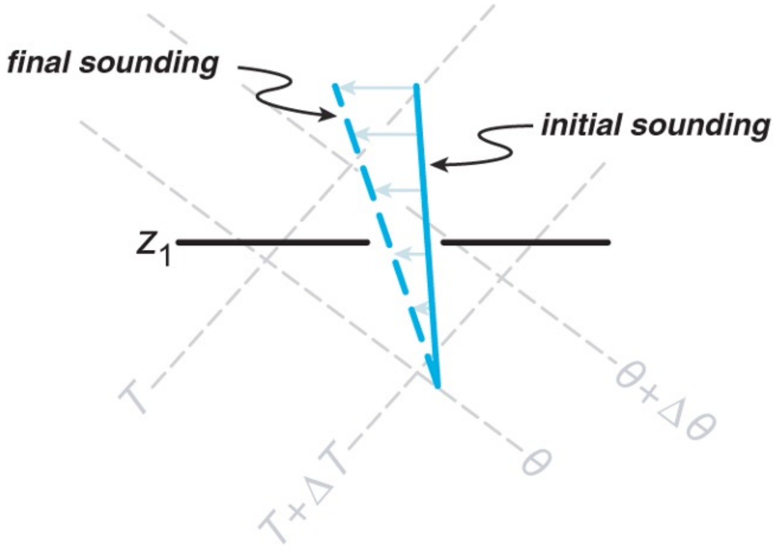


Figure 7.6

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

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

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

<u>Term E:</u> 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 <u>mesoscale</u>

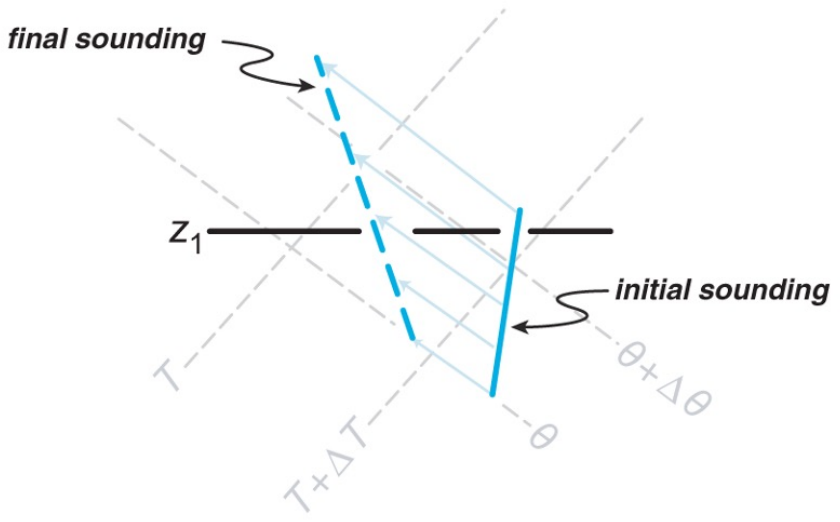


Figure 7.7

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)

Lapse Rate Tendency Equation

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

<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>

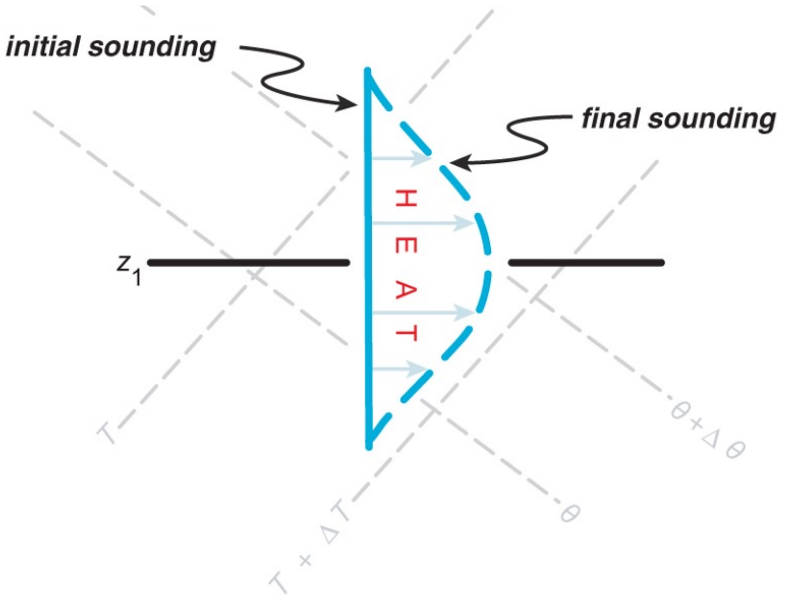


Figure 7.8

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)

CAPE/CIN Changes Independent of γ Tendency

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

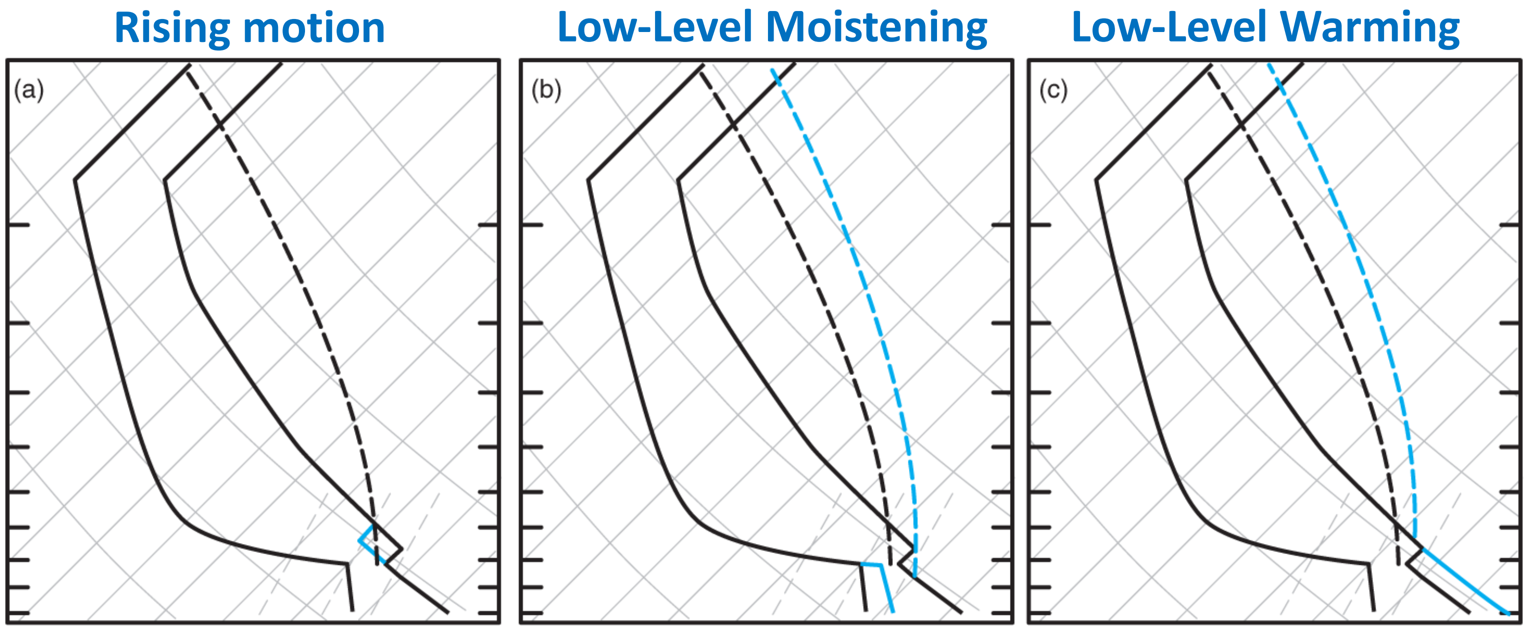
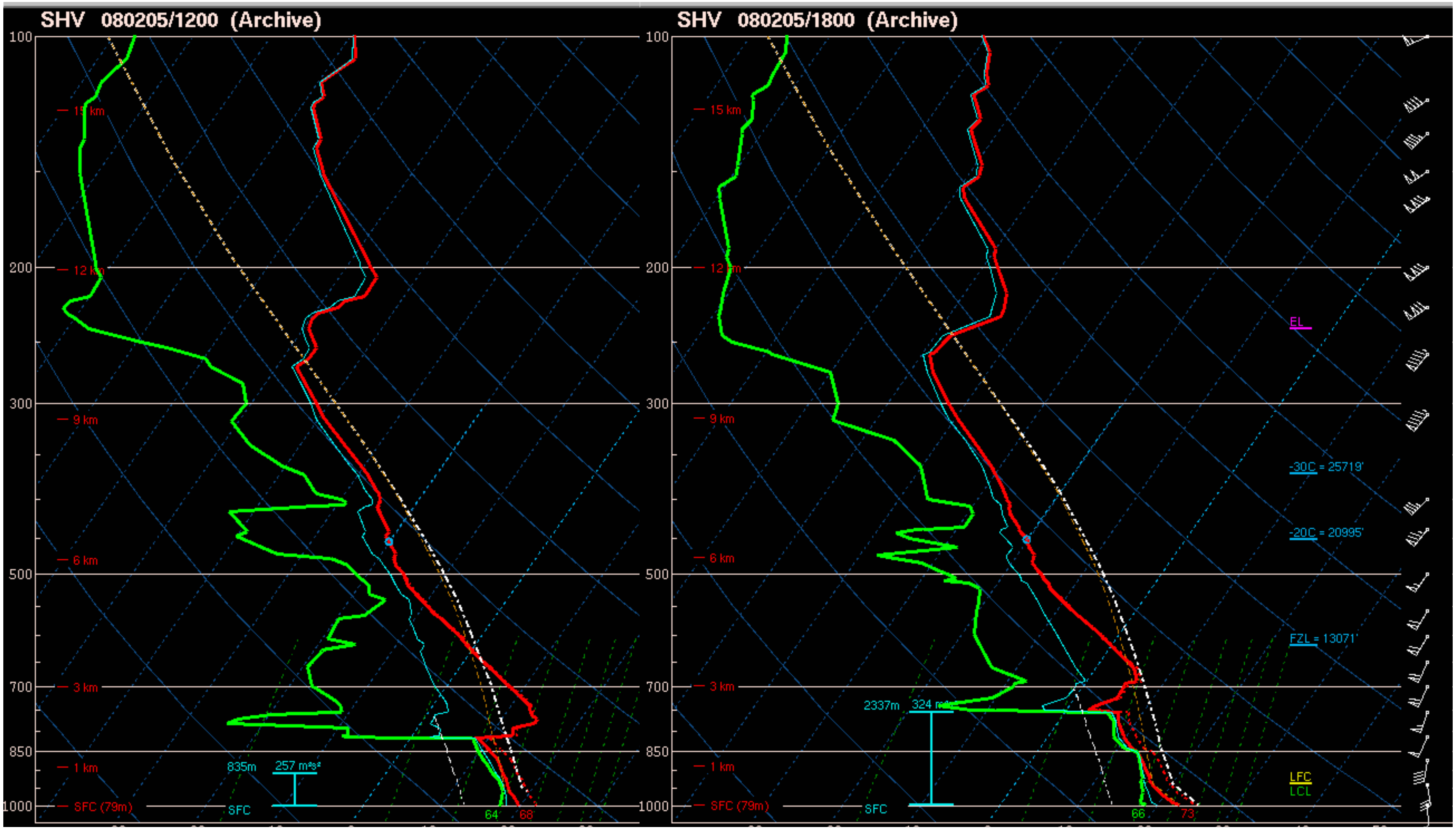


Figure 7.9

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)

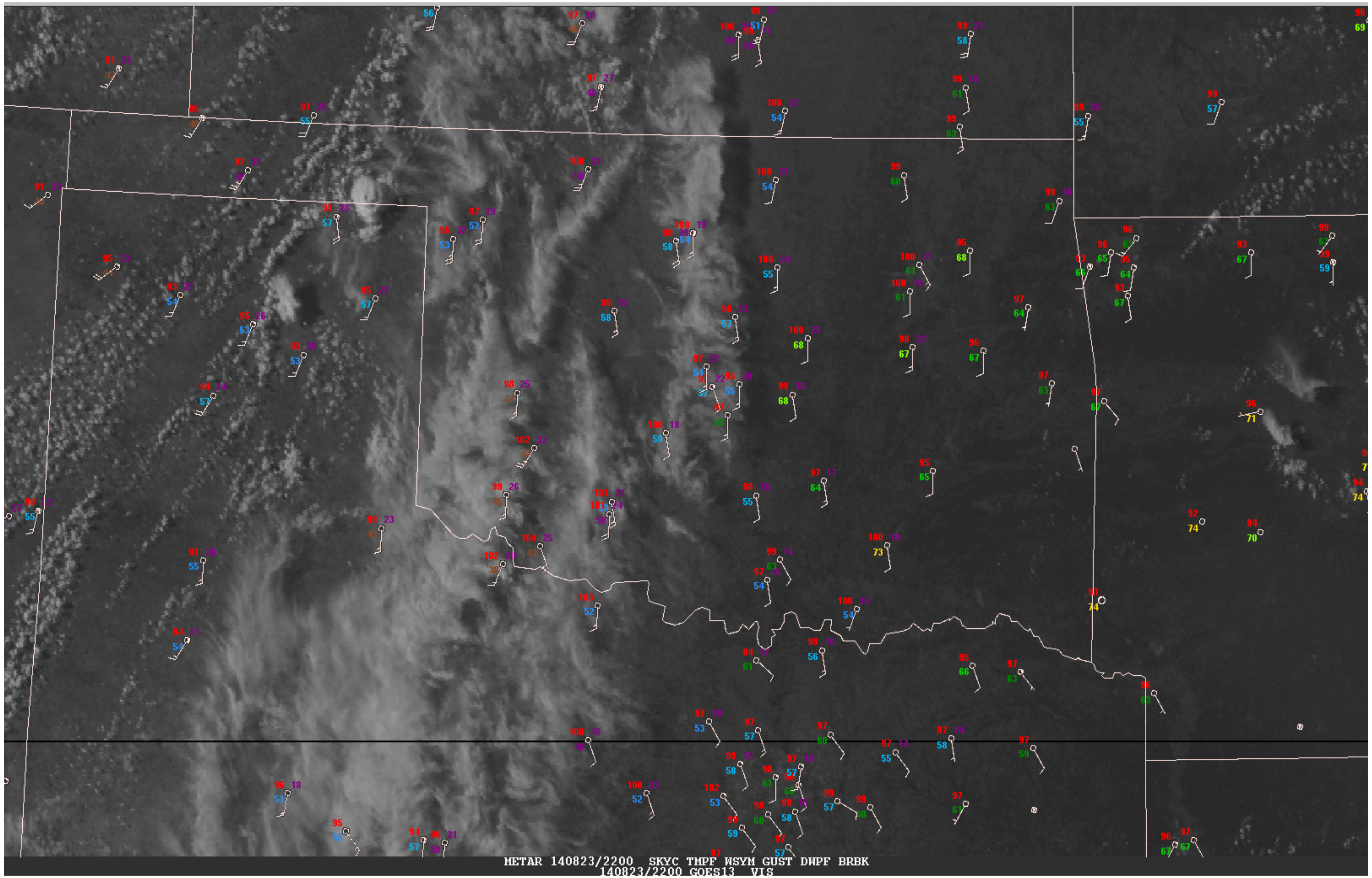
Shreveport soundings



Quality of Surface Observations?

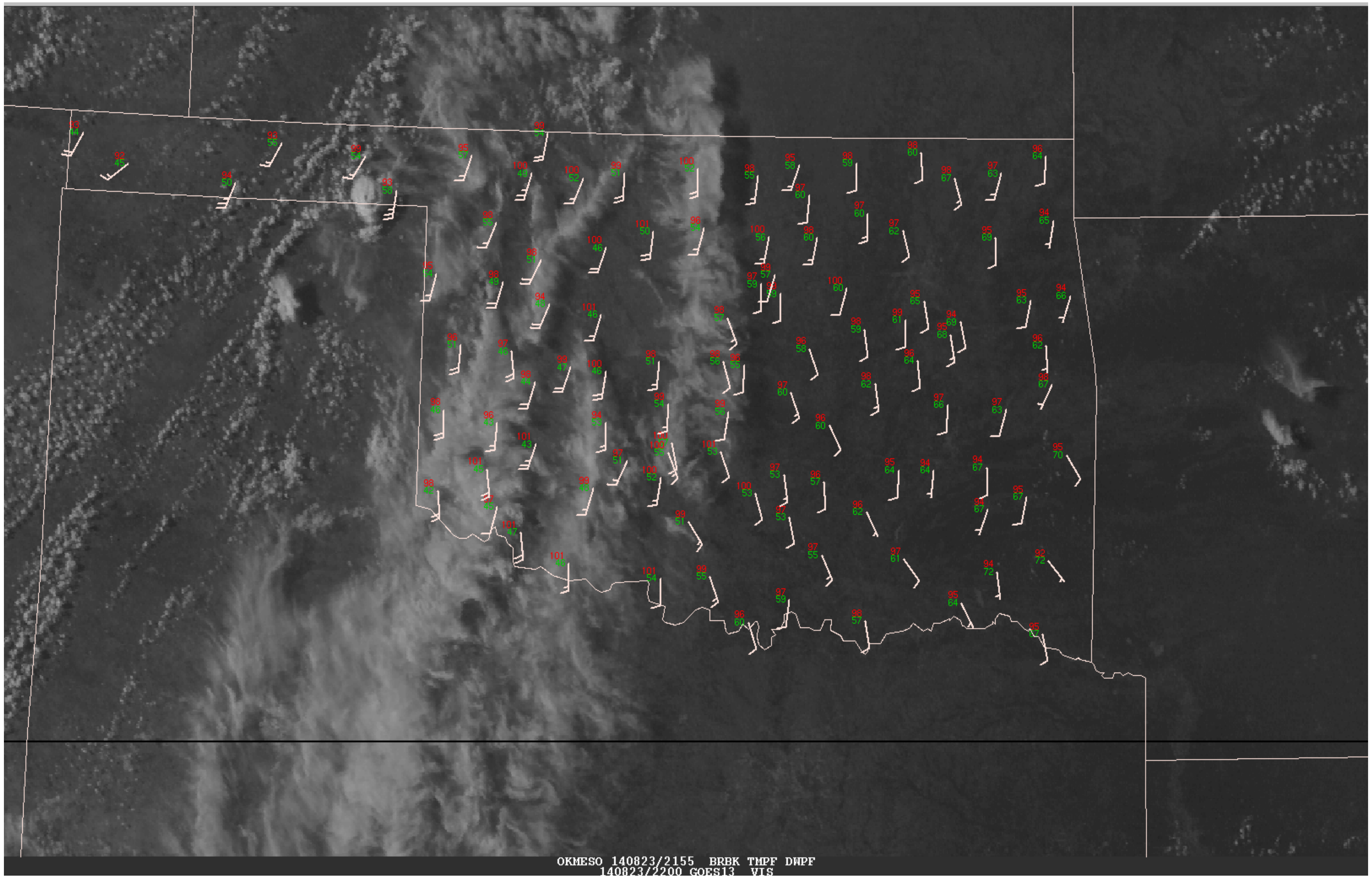
Courtesy of Oklahoma Mesonet

Standard surface observations

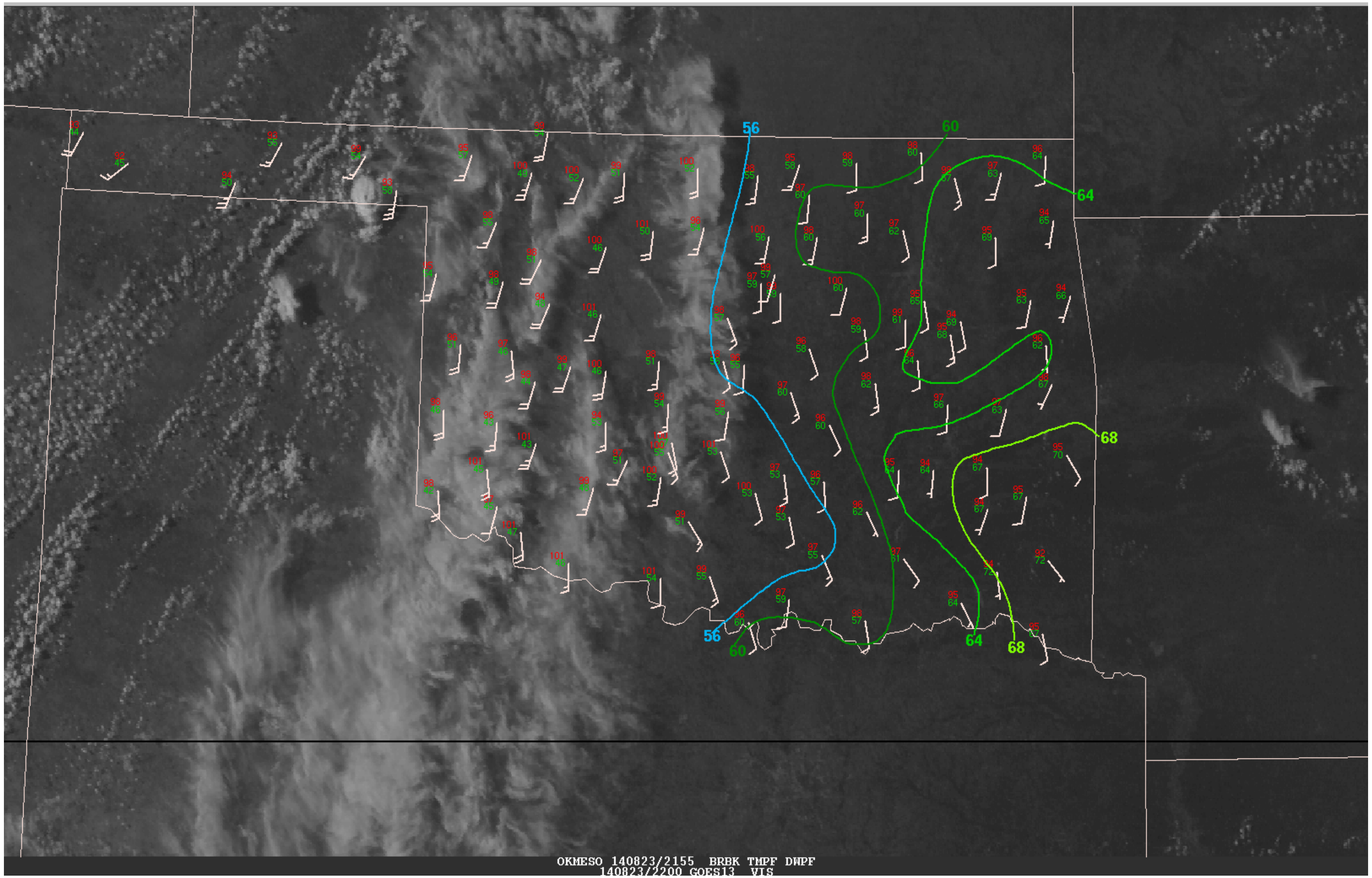


[Automated Surface/Weather Observing Systems (ASOS/AWOS)]

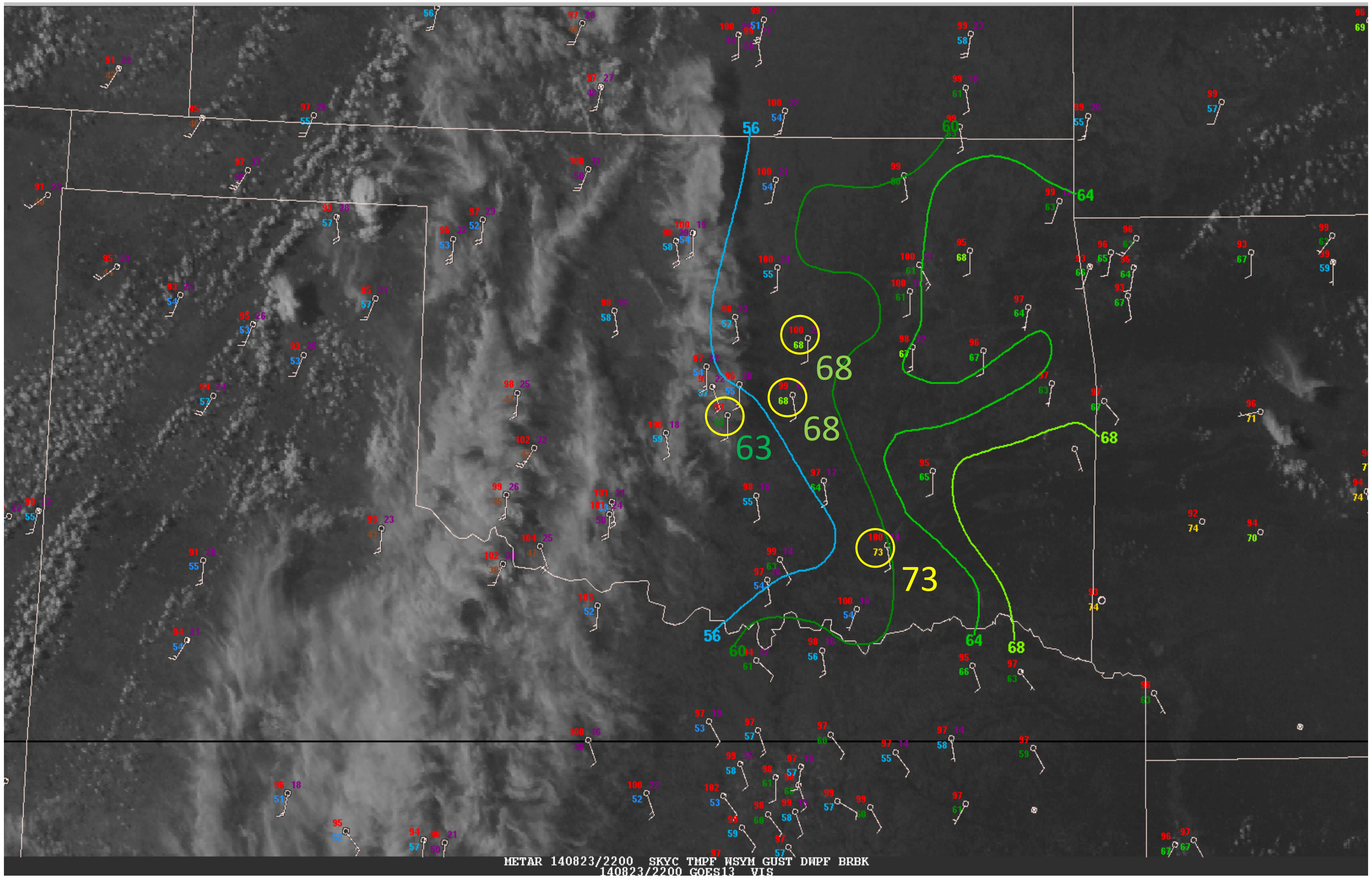
OK mesonet observations at the same time



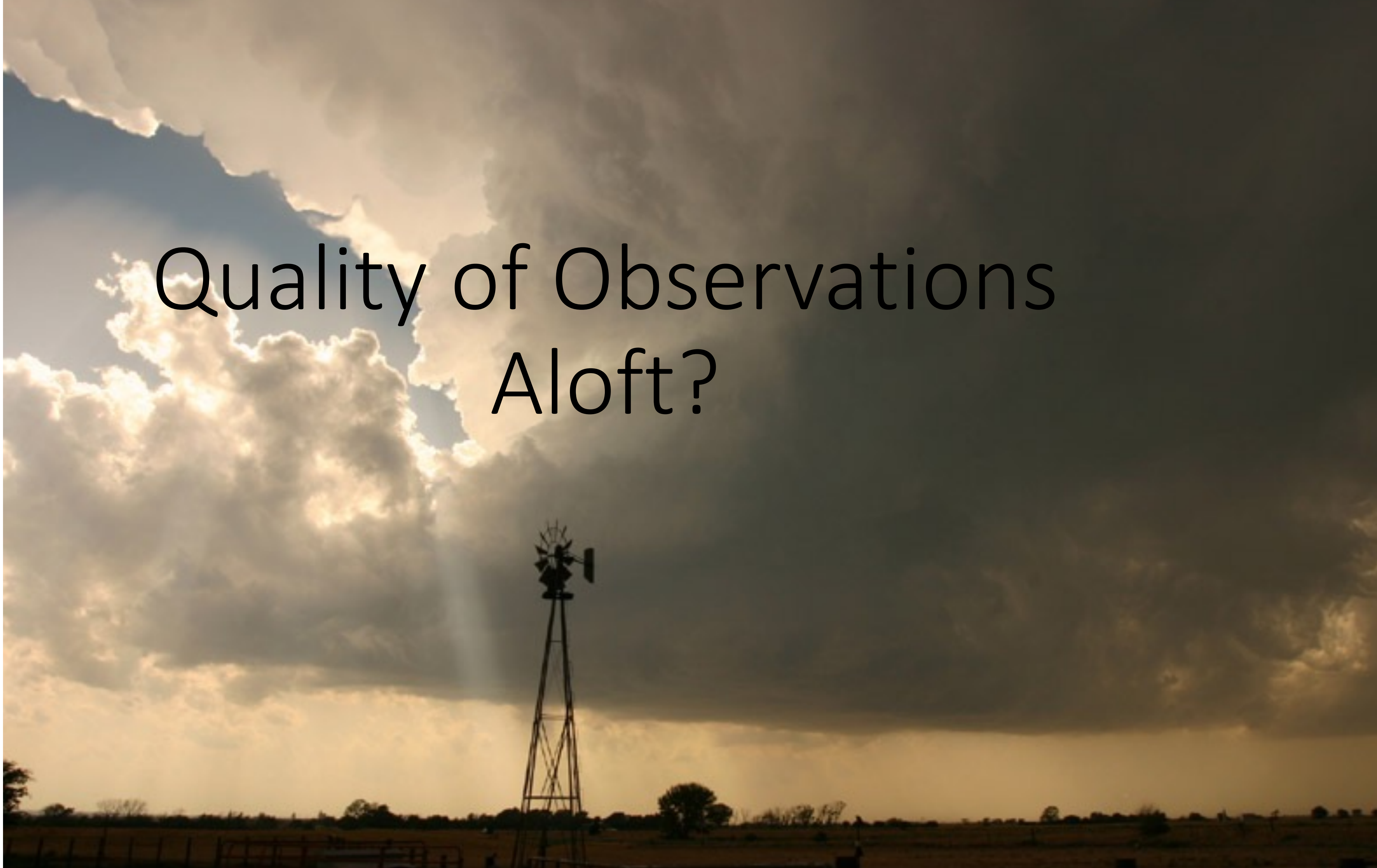
Dew point analysis for OK mesonet observations

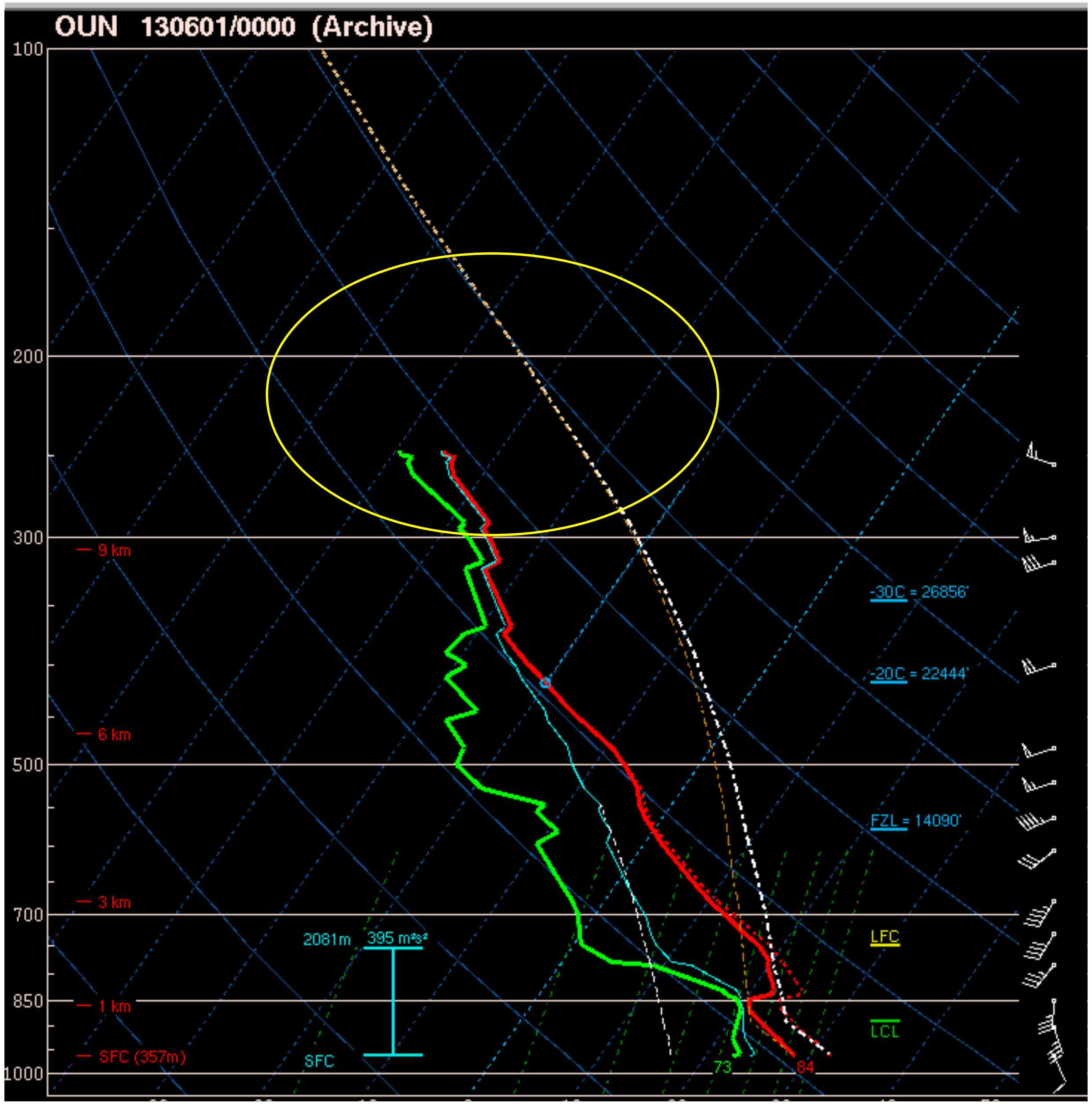


What do these sites have in common?

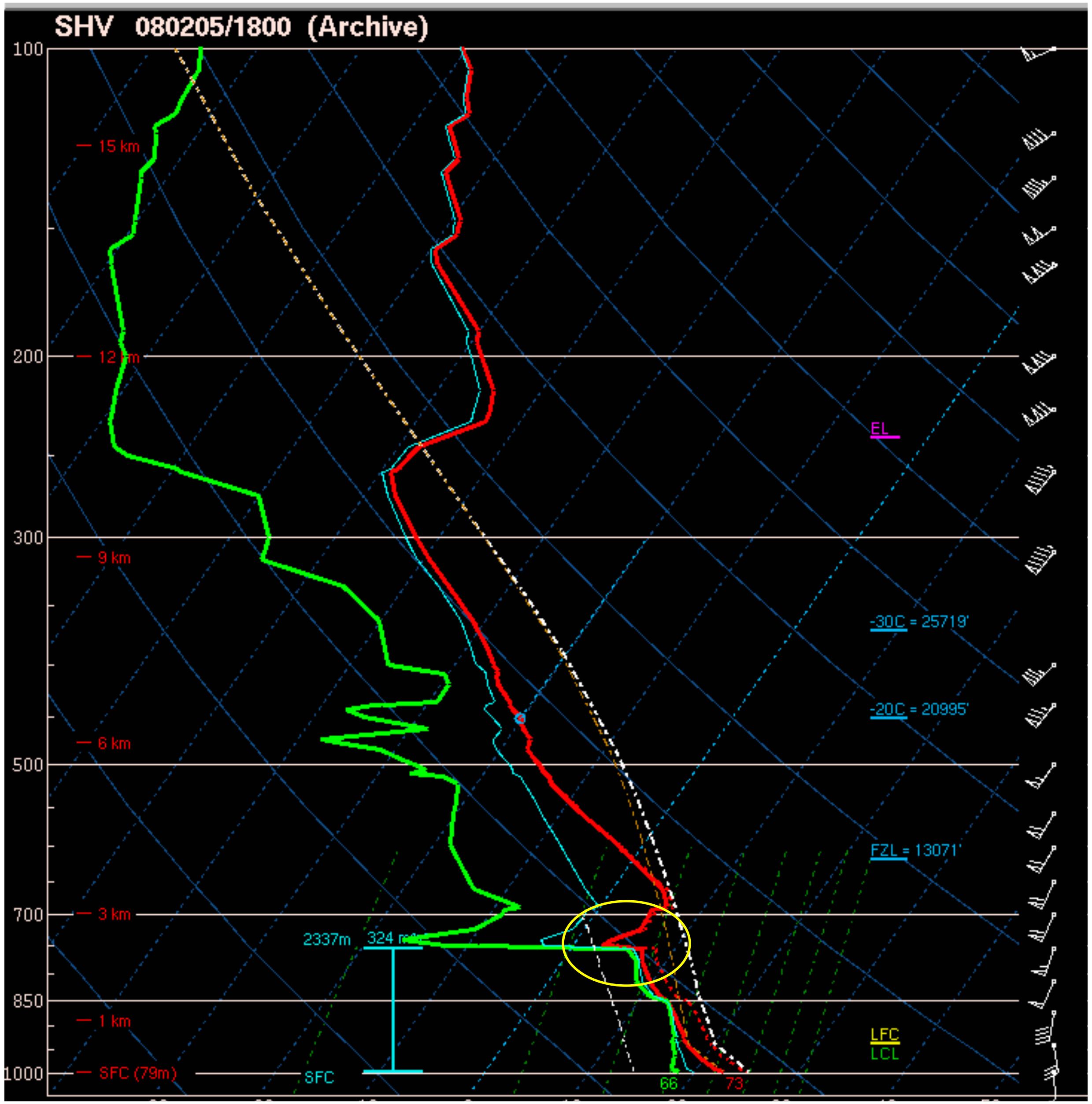


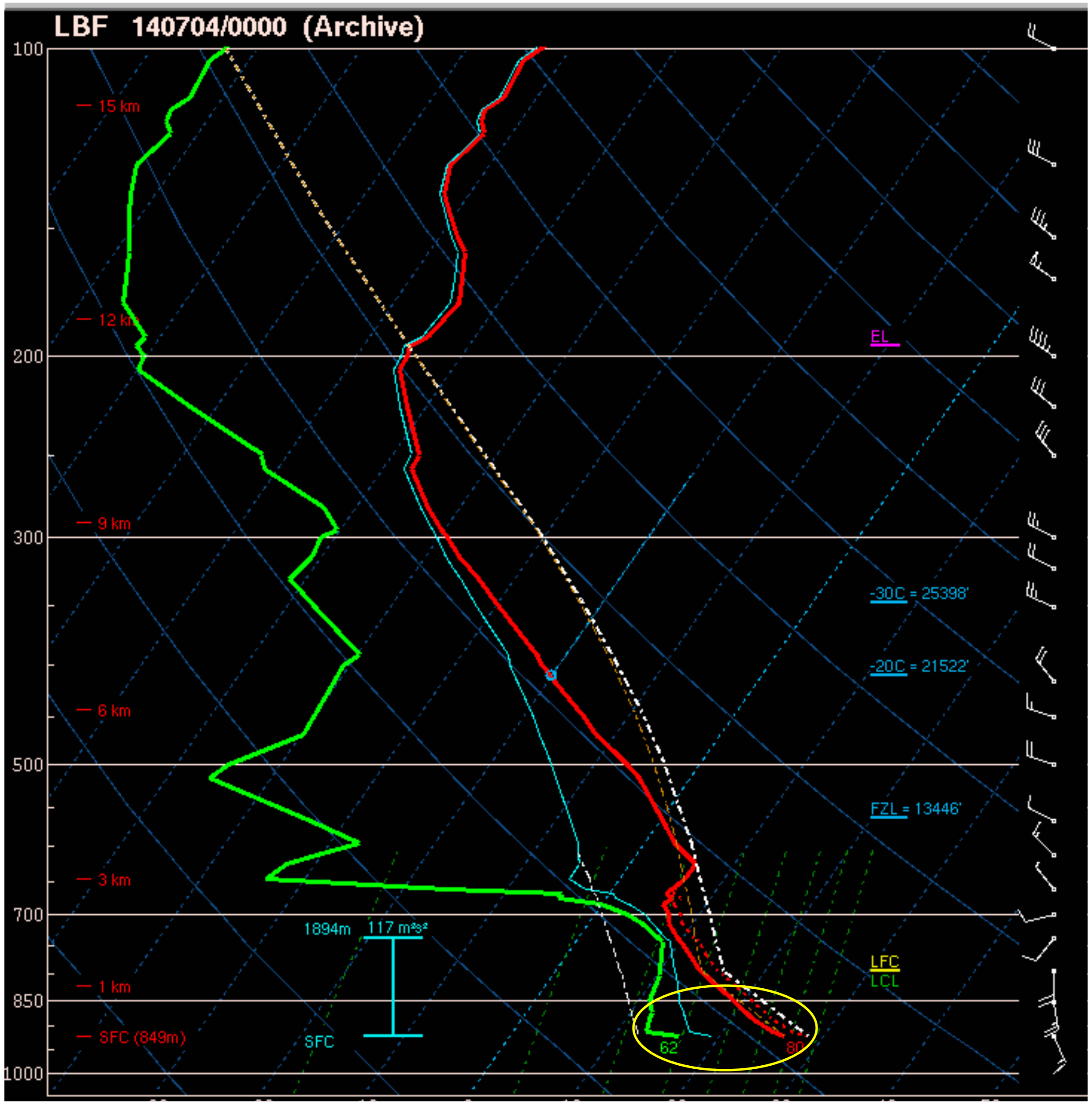
Quality of Observations Aloft?





OUN 130601/0000 (Archive)
100
200
300
500
700
850
1000
9 km
6 km
3 km
1 km
SFC (357m)
2081m
395 m²s²
SFC
-30C = 26856'
-20C = 22444'
FZL = 14090'
LFC
LCL
73
84


SHV 080205/1800 (Archive)
100
200
300
500
700
850
1000
15 km
12 km
9 km
6 km
3 km
1 km
SFC (79m)
SFC
2337m
324 m/s
EL
-30C = 25719'
-20C = 20995'
FZL = 13071'
LFC
LCL
66
73



LBF 140704/0000 (Archive)
100
200
300
500
700
850
1000
15 km
12 km
9 km
6 km
3 km
1 km
SFC (849m)
1894m 117 m²/s²
SFC
EL
-30C = 25398'
-20C = 21522'
FZL = 13446'
LFC
LCL
62
80

Understand the Data and Processes!

- Understanding the processes gives you a sound way to interpret weather data, and recognize errors
- If you don’t know what you’re using, how do you know if you’re using it correctly?
  - Must consider data quality
- Focus on observations!