Today (Mon. 24 Oct. 2016) let's start by going over the question posed in file Ch7-B

TABLE 7.1 | Saturation vapour pressure at different air temperatures, or vapour pressure at different dew-point temperatures,[a] over flat surfaces of pure liquid water or ice.[b]

Air Temperature/Dew-Point Temperature (°C)	Saturation Vapour Pressure/Vapour Pressure (kPa) over water (ice)
−14	0.181 (0.208)
−13	0.198 (0.225)
−12	0.217 (0.244)
−11	0.238 (0.264)
−10	0.260 (0.286)
−9	0.284 (0.310)
−8	0.310 (0.335)
−7	0.338 (0.362)
−6	0.369 (0.391)
−5	0.402 (0.421)
−4	0.437 (0.455)
−3	0.476 (0.490)
−2	0.517 (0.528)
−1	0.562 (0.568)
0	0.611 (0.611)

Air Temperature/Dew-Point Temperature (°C)	Saturation Vapour Pressure/Vapour Pressure (kPa)
0	0.611
1	0.657
2	0.705
3	0.758
4	0.813
5	0.872
6	0.935
7	1.001
8	1.072
9	1.147
10	1.227
11	1.312
12	1.401
13	1.497
14	1.598
15	1.704

If T=10, what is the equilib.v.p.? $e_*(10) = 1.23$ kPa

If T_d=10, what is the v.p.? $e = 1.23$ kPa

If T=10, what is the v.p.? can't do

If T_d=10, what is the equilib.v.p.? can't do

If e=13.12 hPa, what is T_d? $T_d = e_*^{-1}(e) = 11$ °C

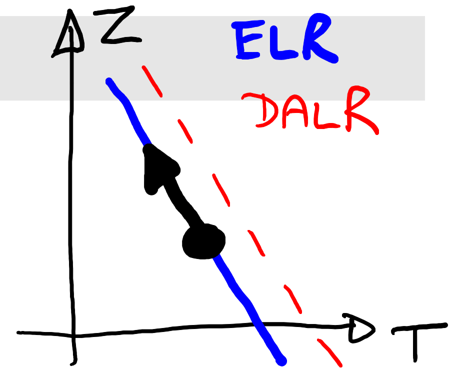
If e*=13.12 hPa, what is T_d? can't do

If e*=13.12 hPa, what is T? $T = e_*^{-1}(e_*) = 11$ °C

Chapter 8 (ctd). Adiabatic lapse rates and atmospheric stability

"Neutral (static) stability" of an unsaturated layer

- ELR is equal to the dry adiabatic lapse rate (10K per kilometer)
- such a layer is termed "neutral with respect to dry adiabatic motion"
- an unsaturated parcel, displaced up or down from its starting point, remains at the same temperature as its environment, and so experiences no buoyancy force: no work by/against gravity is done when the parcel rises or descends



What does it imply if a layer is "neutrally stratified"?

"Neutral stability" of a saturated layer

- ELR is equal to the saturated adiabatic lapse rate
- such a layer is "neutral with respect to saturated adiabatic motion"
- a saturated parcel, displaced up or down from its starting point, remains at the same temperature as its environment, and so experiences no buoyancy force: no work by/against gravity is done when the parcel rises or descends

How to find the LCL? By the formula below – or (on the skew-T diagram) by Normand's Rule.

Recall $\Gamma_d = -0.0098\,\mathrm{K\,m^{-1}}$

$\Gamma_{T_d} \approx -0.0018\,\mathrm{K\,m^{-1}}$ dewpoint lapse rate

$$\frac{\Delta(T-T_d)}{\Delta z} = \Gamma_d - \Gamma_{T_d} = -0.008\,\frac{K}{m}$$

$$0-(T-T_d)_{sfc} = -0.008 \times (z_{LCL} - 0)$$

So

$$z_{LCL} = 125\,(T-T_d)_{sfc}$$

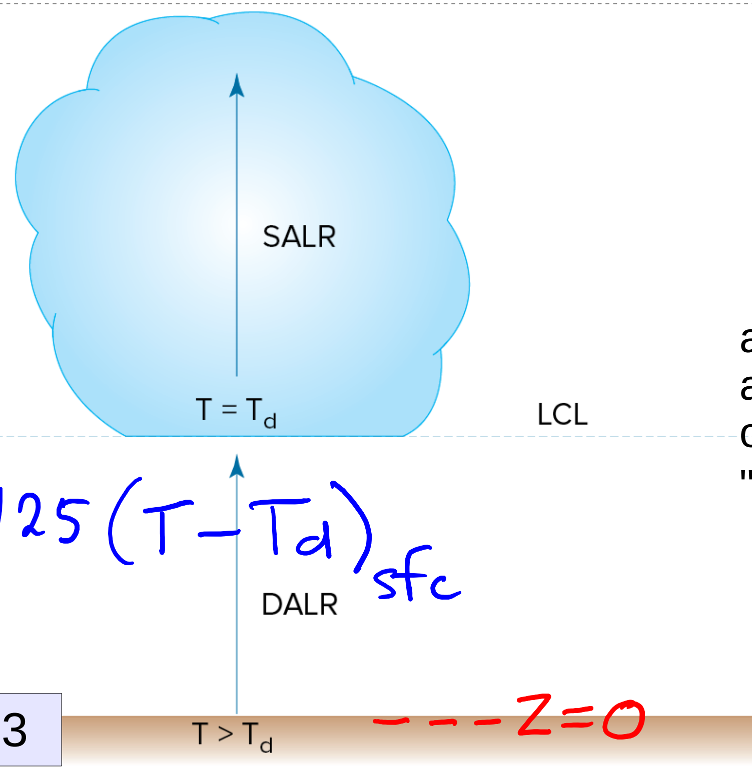


Figure 8.3

Suppose surface temperature and dewpoint are T=29°C, T_d=17°C. How high is the LCL for a rising parcel? What is the parcel's temperature at the LCL?

$$z_{LCL} = 125\,(29-17) = 125 \times 12 = 1500\,m$$

$$T_{LCL} = 29 + \Gamma_d\,(1500) = 29 - 15 = 14^\circ C$$

Suppose the SALR is $\Gamma_s = -0.004\,\mathrm{K\,m^{-1}}$. If the parcel continues to rise above the LCL, what is its temperature at a height of 2000 above the surface?

$$T_{2000} = 14 - (.004) \times (2000 - 1500) = 12^\circ C$$

a) restoring force accentuates original change: "unstable"

b) restoring force opposes original change: "stable"

c) no restoring force: "neutral"

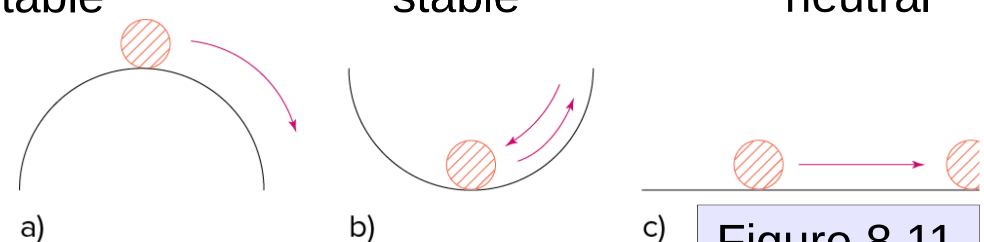


Figure 8.11

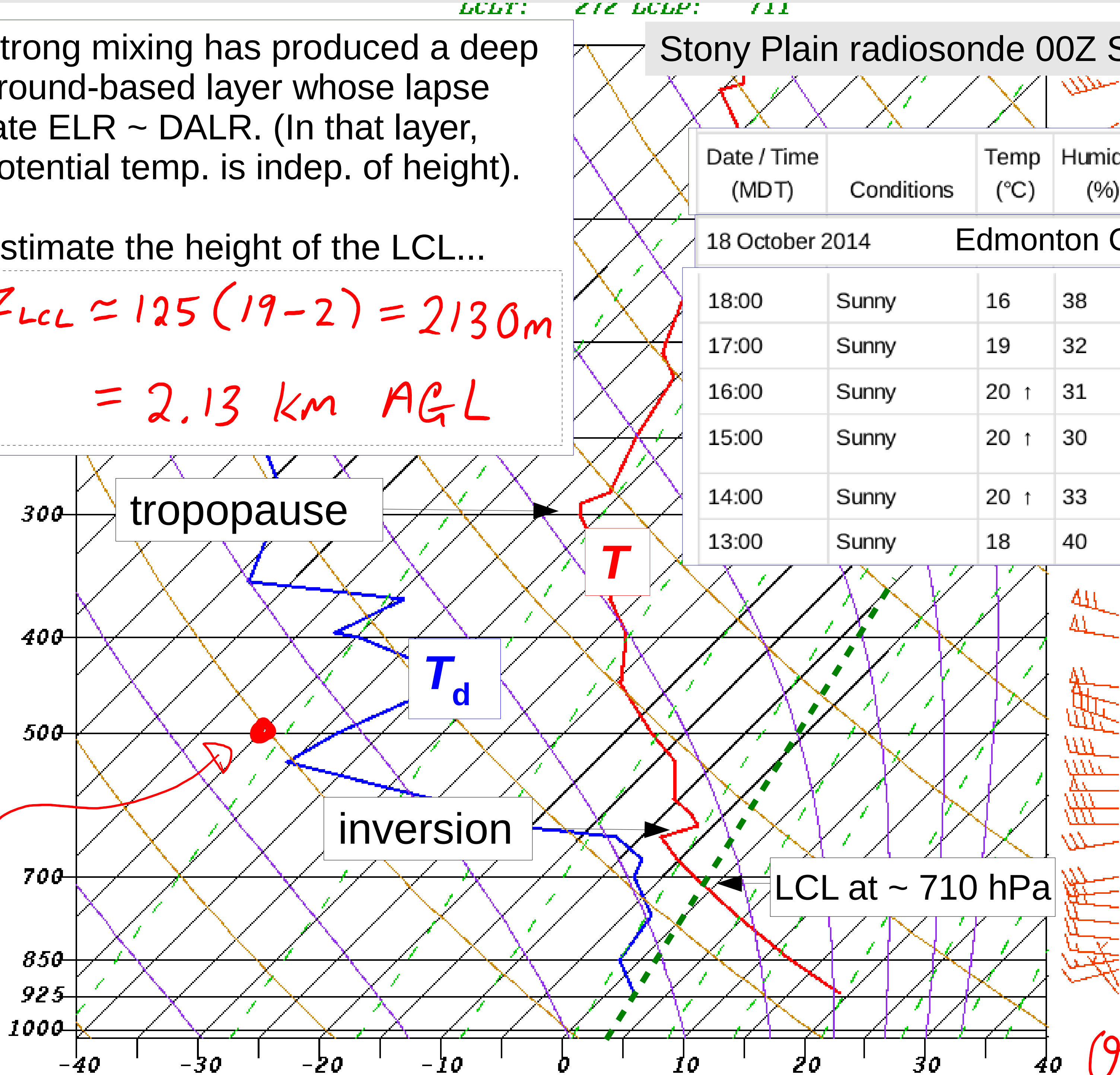
Strong mixing has produced a deep ground-based layer whose lapse rate ELR ~ DALR. (In that layer, potential temp. is indep. of height).

Estimate the height of the LCL...

$Z_{LCL} \simeq 125\,(19-2) = 2130\,m$

$= 2.13$ km AGL

Stony Plain radiosonde 00Z Sun 19 Oct. 2014



Date / Time (MDT)	Conditions	Temp (°C)	Humidity (%)	Dew Point (°C)	Wind (km/h)
18 October 2014	Edmonton City Centre Airport				
18:00	Sunny	16	38	2	N 6
17:00	Sunny	19	32	2	NW 11
16:00	Sunny	20 ↑	31	2	WNW 17
15:00	Sunny	20 ↑	30	2	NW 13 gust 33
14:00	Sunny	20 ↑	33	3	WNW 28
13:00	Sunny	18	40	4	W 15

The green dashed lines ("isohumes") give the dewpoint lapse rate for unsaturated adiabatic ascent

Deduce the ptl. temp. θ of air whose $(p,T) = (500,-50)$

$$\theta = T\left(\frac{p_{ref}}{p}\right)^{0.286}$$

71119 WSE Edmonton Stony Plain Observations at 00Z 19 Oct 2014

Height of the 710 hPa level ~ (2998+2743)/2 ~ 2.87 km ASL or **2.17 km AGL**

PRES hPa	HGHT m	TEMP C	DWPT C	RELH %	MIXR g/kg	DRCT deg	SKNT knot	THTA K
1000.0	22							
925.0	696							
918.0	766	19.2	2.2	32	4.91	320	3	299.6
902.0	914	17.6	1.3	33	4.69	335	5	299.5
869.8	1219	14.4	-0.5	36	4.27	255	12	299.3
850.0	1413	12.4	-1.6	38	4.02	260	13	299.1
838.7	1524	11.3	-1.8	40	4.03	275	13	299.2
808.3	1829	8.5	-2.2	47	4.05	275	18	299.3
779.0	2134	5.6	-2.6	56	4.08	275	21	299.4
765.0	2284	4.2	-2.8	60	4.09	275	23	299.4
750.5	2438	2.8	-3.8	62	3.87	275	25	299.5
722.5	2743	0.0	-5.7	65	3.48	265	26	299.8
700.0	2998	-2.3	-7.3	69	3.17	260	29	299.9
671.0	3333	-5.3	-8.1	81	3.11	260	31	300.2
643.7	3658	-7.8	-11.3	76	2.52	260	32	301.0
636.0	3752	-8.5	-12.2	75	2.37	263	34	301.2
627.0	3863	-7.3	-17.3	45	1.58	267	36	303.8
620.0	3951	-6.3	-22.3	27	1.04	270	38	305.9
619.1	3962	-6.4	-22.6	27	1.02	270	38	305.9
605.0	4143	-7.7	-26.7	20	0.72	270	39	306.4
595.4	4267	-8.9	-28.4	19	0.62	270	39	306.4
583.0	4430	-10.5	-30.5	18	0.52	270	46	306.4
572.3	4572	-11.1	-33.7	14	0.39	270	53	307.3
550.0	4877	-12.5	-40.5	8	0.20	270	47	309.2
534.0	5103	-13.5	-45.5	5	0.12	274	41	310.6
528.4	5182	-14.2	-45.2	5	0.13	275	39	310.8
500.0	5600	-17.7	-43.7	8	0.16	280	43	311.4

Stony Plain 696 m ASL

note θ is const. in the layer in which ELR=DALR

Normand's rule:

Find the LCL graphically as the intersection of the isohume that runs through surface dewpoint with the dry adiabat that runs through surface temperature

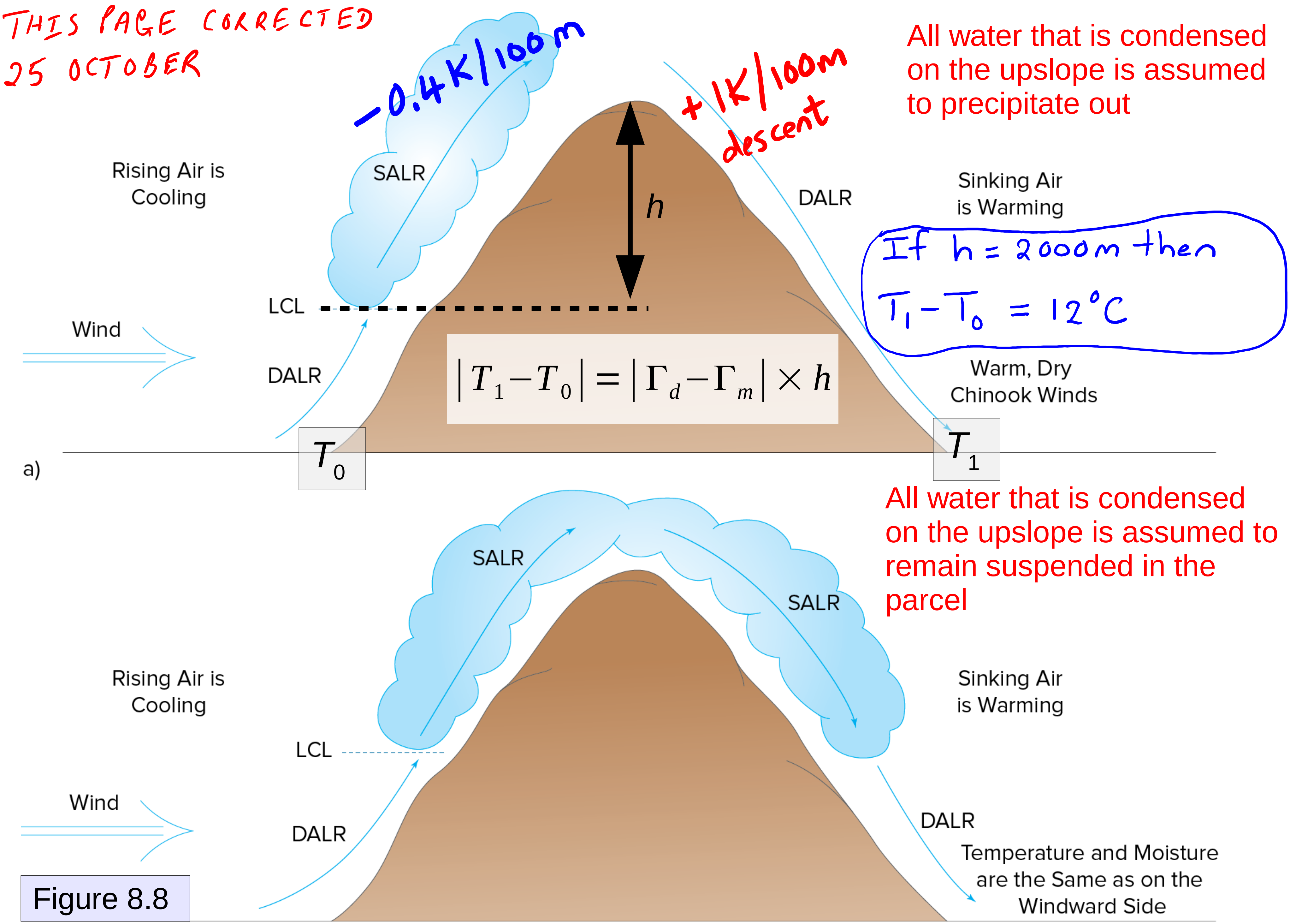
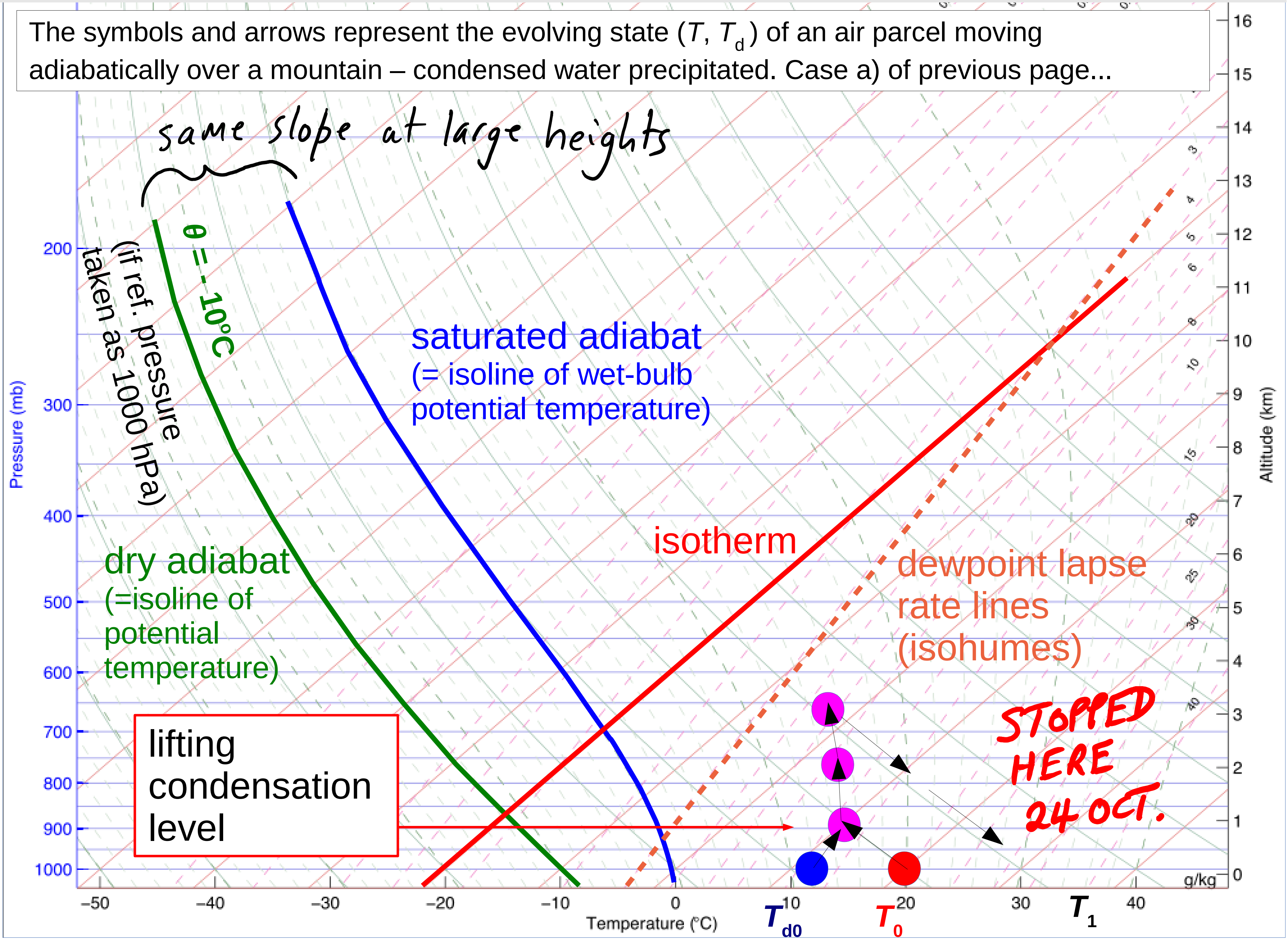

THIS PAGE CORRECTED
25 OCTOBER
All water that is condensed on the upslope is assumed to precipitate out
−0.4K/100m
+1K/100m descent
Rising Air is Cooling
SALR
h
DALR
Sinking Air is Warming
If h = 2000m then
$T_1 - T_0 = 12°C$
LCL
Wind
DALR
$|T_1 - T_0| = |\Gamma_d - \Gamma_m| \times h$
Warm, Dry Chinook Winds
a)
T_0
T_1
All water that is condensed on the upslope is assumed to remain suspended in the parcel
SALR
SALR
Rising Air is Cooling
Sinking Air is Warming
LCL
Wind
DALR
DALR
Temperature and Moisture are the Same as on the Windward Side

Figure 8.8

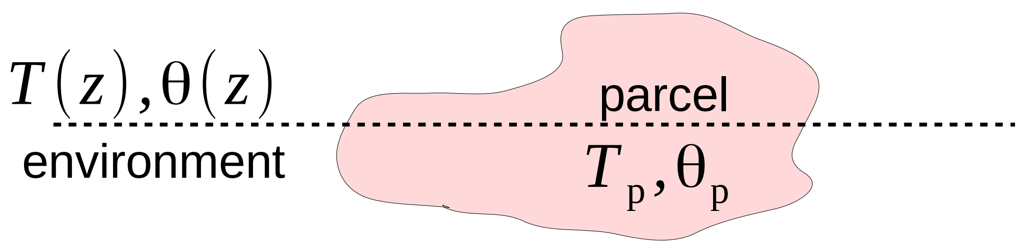
The symbols and arrows represent the evolving state (T, T_d) of an air parcel moving adiabatically over a mountain – condensed water precipitated. Case a) of previous page...



Atmospheric stability [strictly, static stability] quantifies the tendency for an air parcel, once having been vertically displaced for whatever reason, to continue to move vertically

runaway

- Unstable layer – if displaced upward, parcel experiences an upward buoyancy force
  – if displaced downward, parcel experiences a downward buoyancy force
- Stable layer – if displaced upward, parcel experiences a downward buoyancy force
  – if displaced downward, parcel experiences an upward buoyancy force
- Neutral layer – whether displaced upward or downward, parcel experiences **no** buoyancy force



The buoyancy force per unit mass is given by the "reduced gravity"

$$F_B = g\,\frac{T_p - T}{T} = g\,\frac{\theta_p - \theta}{\theta}$$

Kelvin unit on denom.

In general the sensible heat flux Q_H is proportional to (minus) the vertical gradient in potential temperature,

$$Q_H \propto -\frac{\Delta \theta}{\Delta z}$$

The ELR – alone – determines the static stability of a layer... not the actual temperature $T(z)$, but the lapse rate dT/dz

Neutral case

$F_B = 0$

$Q_H = 0$

Figure 8.13

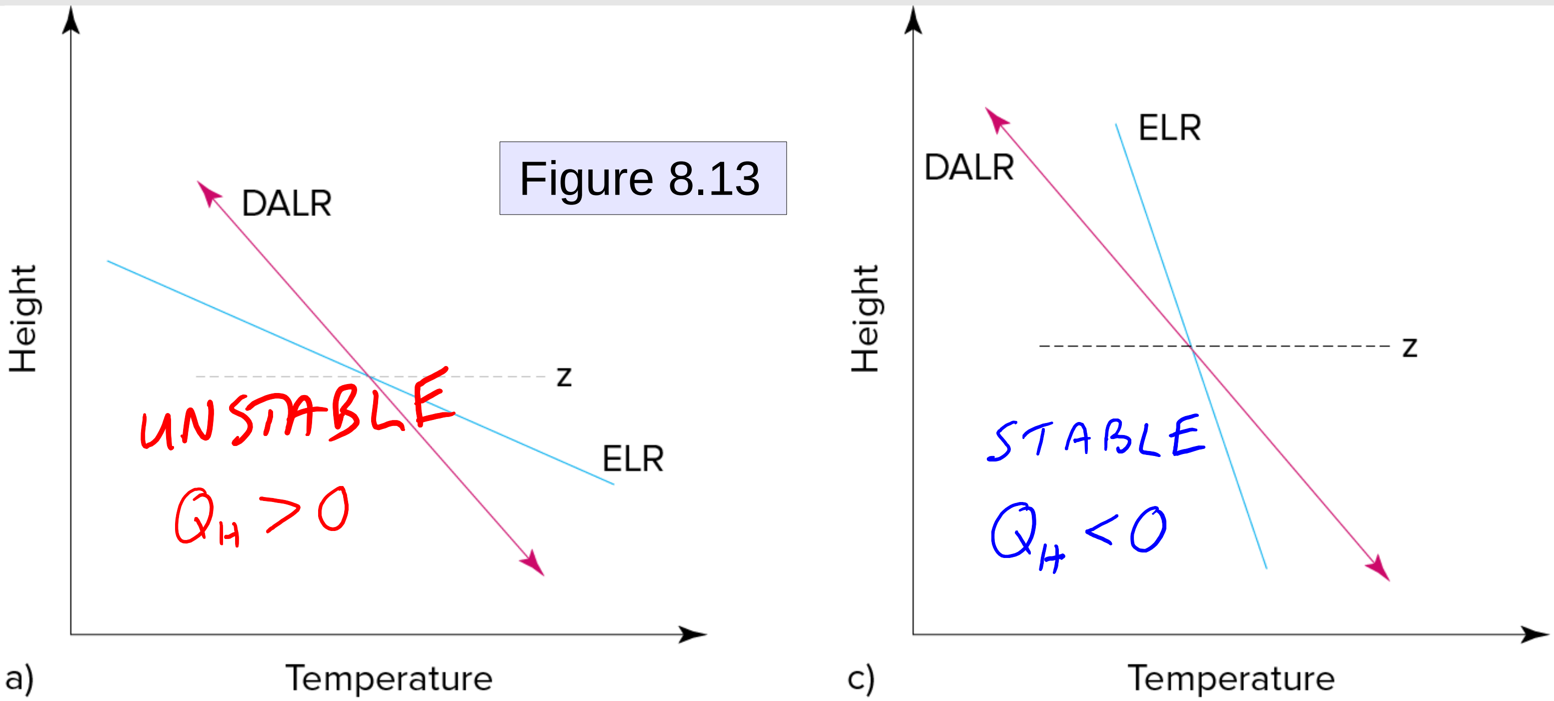
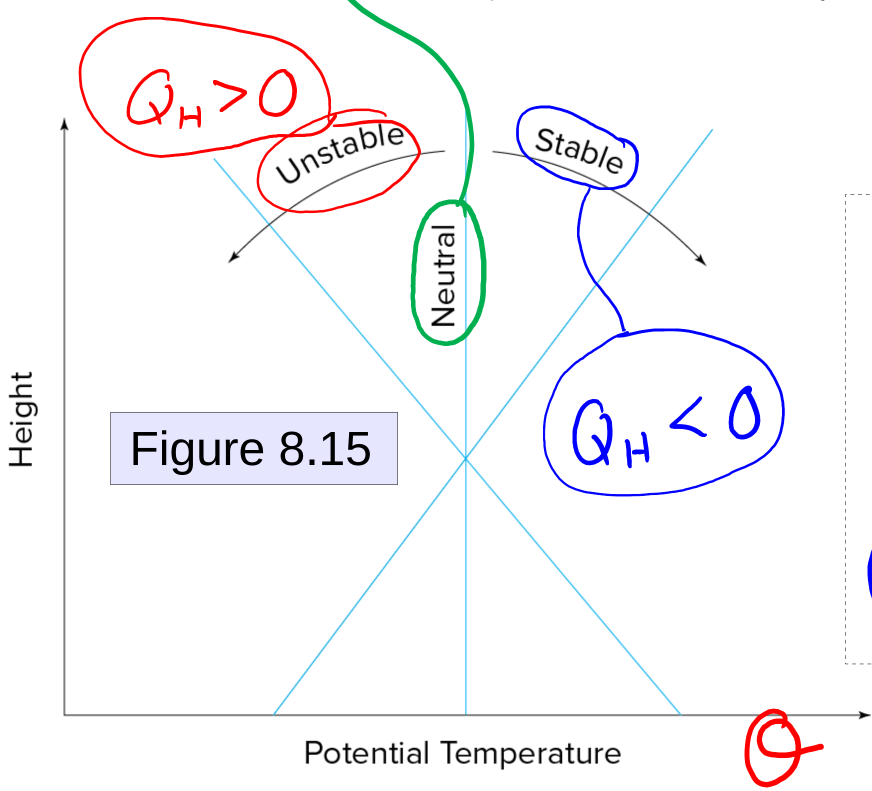


Figure 8.15



What stability classification would you assign to cases (a), (b) above?

(a) unstable, results in unstable buoyancy force and upward heat transfer

(b) stable, buoyancy force opposes motion and heat transferred down

ELR ≡ SALR "neutral w.r.t. moist...

ELR ≡ DALR "neutral w.r.t. unsaturated adiabatic motion"

The ELR of a layer classifies it as "conditionally unstable" (same as "conditionally stable") on the condition that:

- an unsaturated parcel, once dislodged, experiences a restoring buoyancy force
- **BUT**, a saturated parcel, once dislodged, experiences a buoyancy force in the direction of the original motion

The criterion for conditional instability is:

$$|\Gamma_s| < |ELR| < |\Gamma_d|$$

$$|SALR| < |ELR| < |DALR|$$

i.e. ELR lies between the two benchmarks

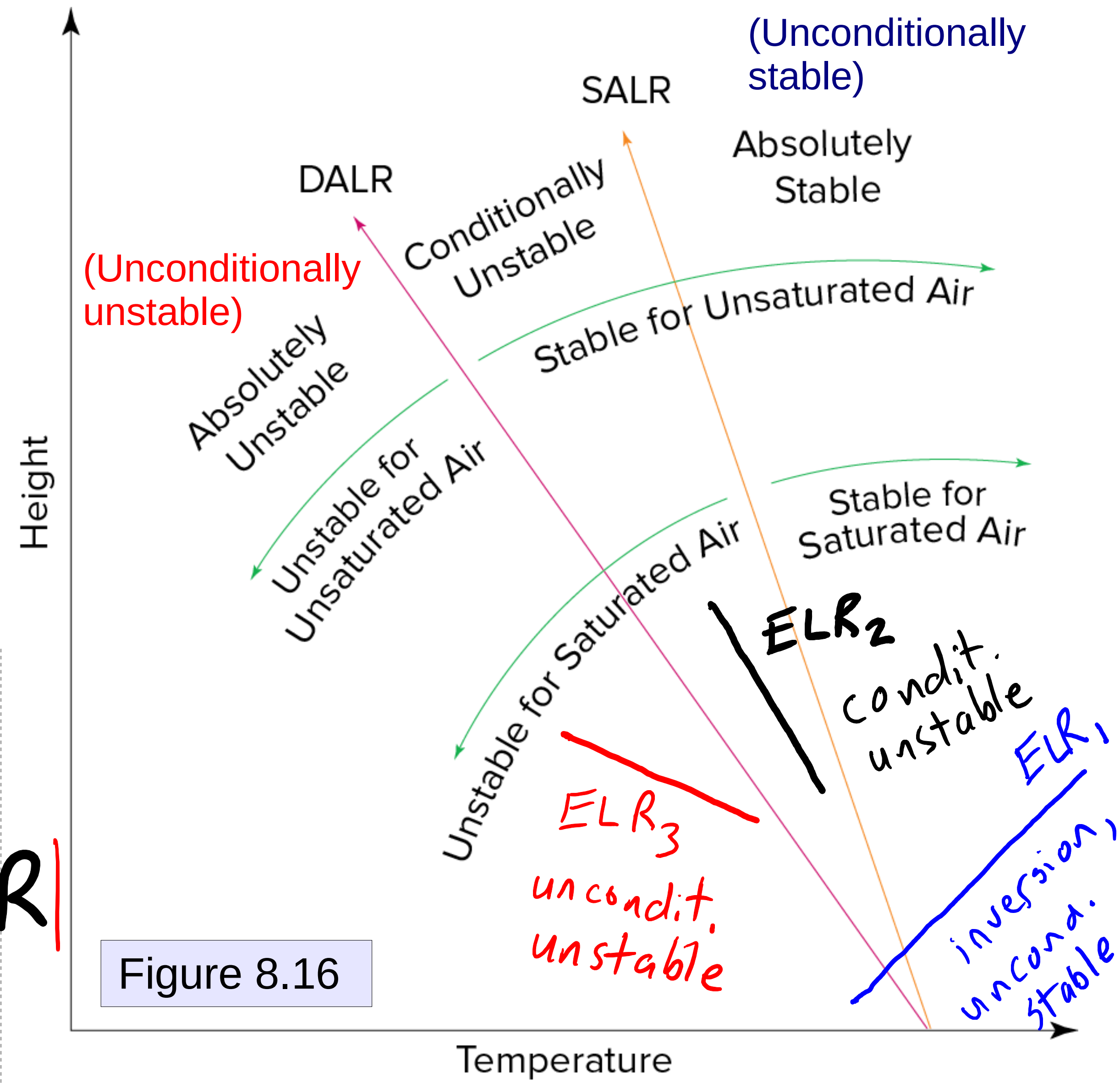
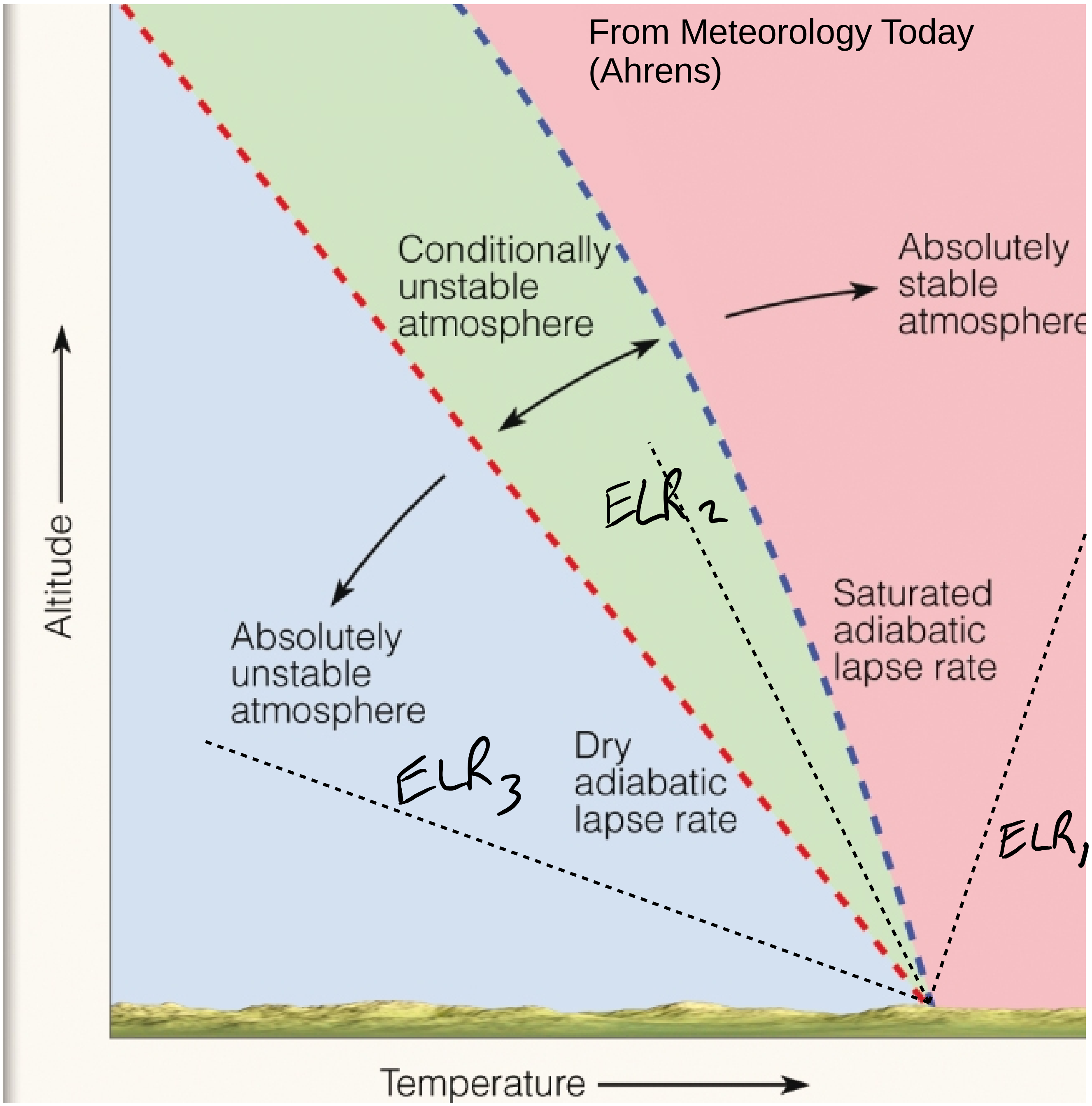
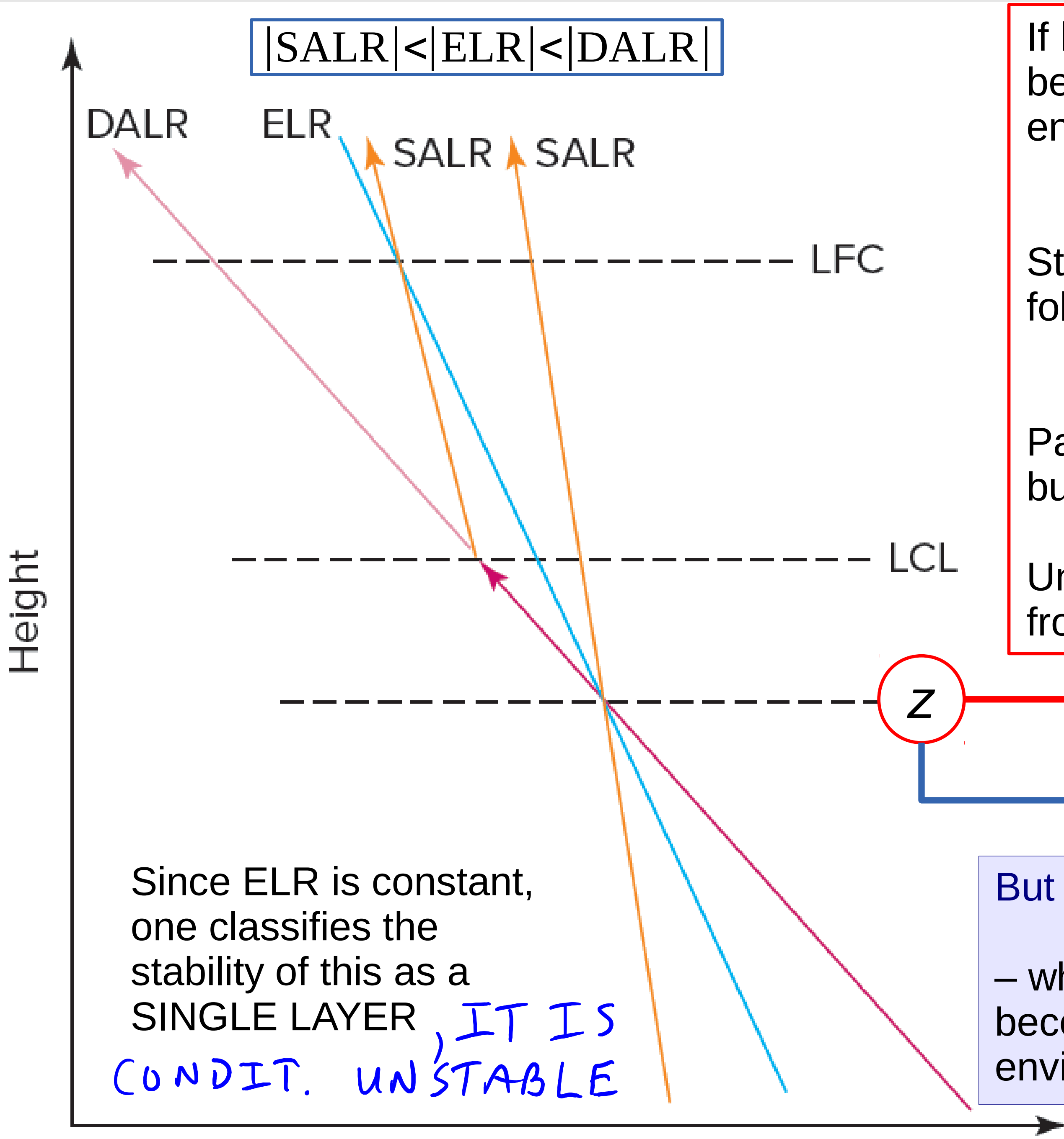


Figure 8.16



- only the *slope* of the environmental temperature profile matters
- the black dashed lines are idealized, simplified environmental profiles (constant ELR, i.e. slope)



(note: dewpoint not given)

Since ELR is constant, one classifies the stability of this as a SINGLE LAYER, IT IS CONDIT. UNSTABLE

If lifted above the LFC, parcel becomes warmer than the environment

Still lifted against buoyancy force, follows saturated adiabat

Parcel arrives at LCL with negative buoyancy

Unsaturated parcel pushed up from *z* follows dry adiabat

But for a parcel saturated at *z*:

– when lifted from *z* it immediately becomes warmer than its environment, so layer is unstable

Figure 8.19

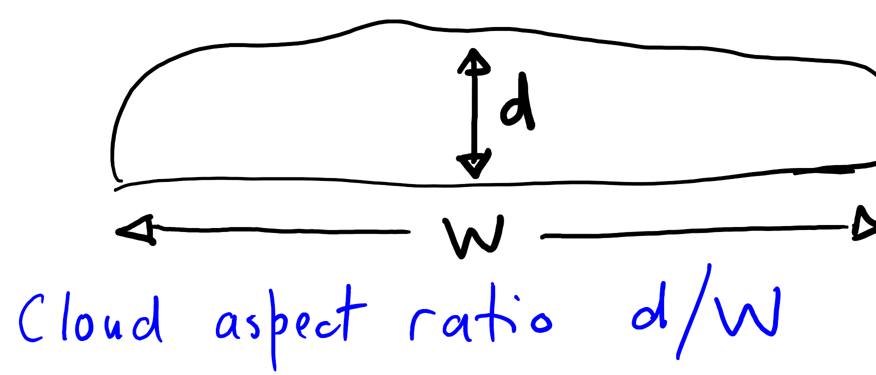
Air forced to rise in an absolutely stable layer will tend to spread laterally and produce ***stratiform*** ("layer") clouds

- flat tops and bases
- small-moderate vertical development (thin cloud layer)

In a conditionally unstable layer** of sufficient depth, rising air may produce ***cumuliform*** ("heapy") clouds with strong vertical development...

… provided parcels are lifted above the "level of free convection" (LFC)

Fair weather Cu (David Adams; used with permission; http://www.davidadamsonline.com/)



** a deep <u>and</u> absolutely unstable layer almost never occurs in the atmosphere. In general, the only location where absolute instability can occur is in the Atmospheric Surface Layer (ASL), roughly the lowest 50 m

Topics/concepts covered

- Families of curves on the skew-T chart
- Deducing the LCL by formula, and using Norman's rule on a skew-T diagram
- Confirmation of the consistency of the two methods using Stony Plain sounding of 00Z 19 Oct. 2014
- Buoyancy force on a parcel determined by its temperature difference relative to the environment at the same level ("reduced gravity")
- On the basis of their ELR, recognizing layers that are:
    - Unstable (also named “unconditionally unstable” or “absolutely unstable”)
    - Stable (also named “unconditionally stable” or “absolutely stable”)
    - Conditionally unstable
    - Neutral