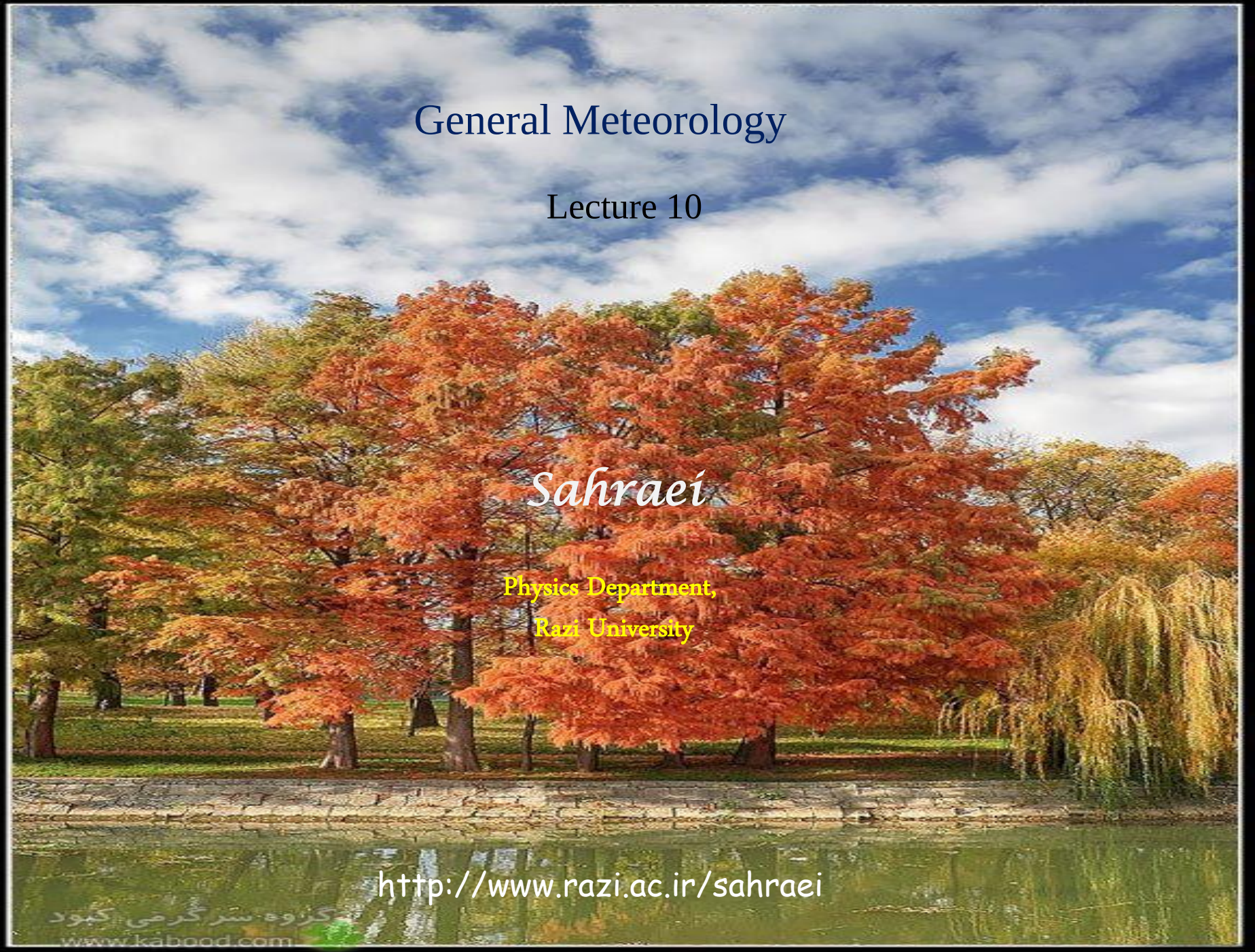
General Meteorology

Lecture 10



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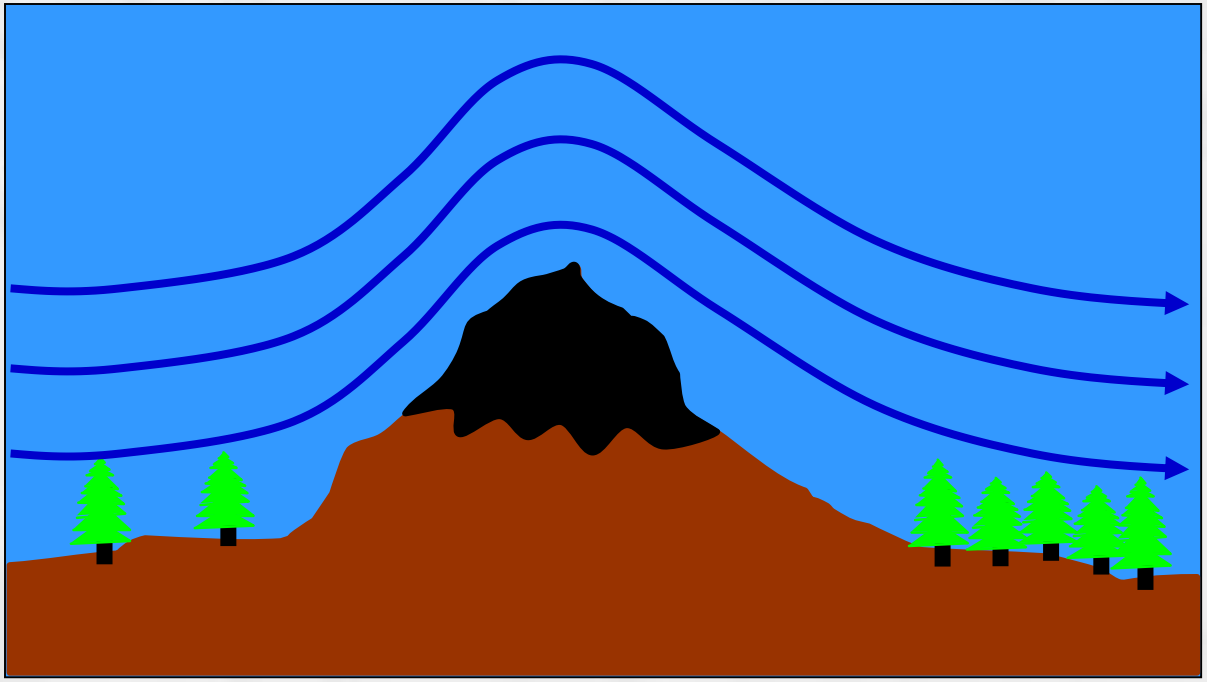
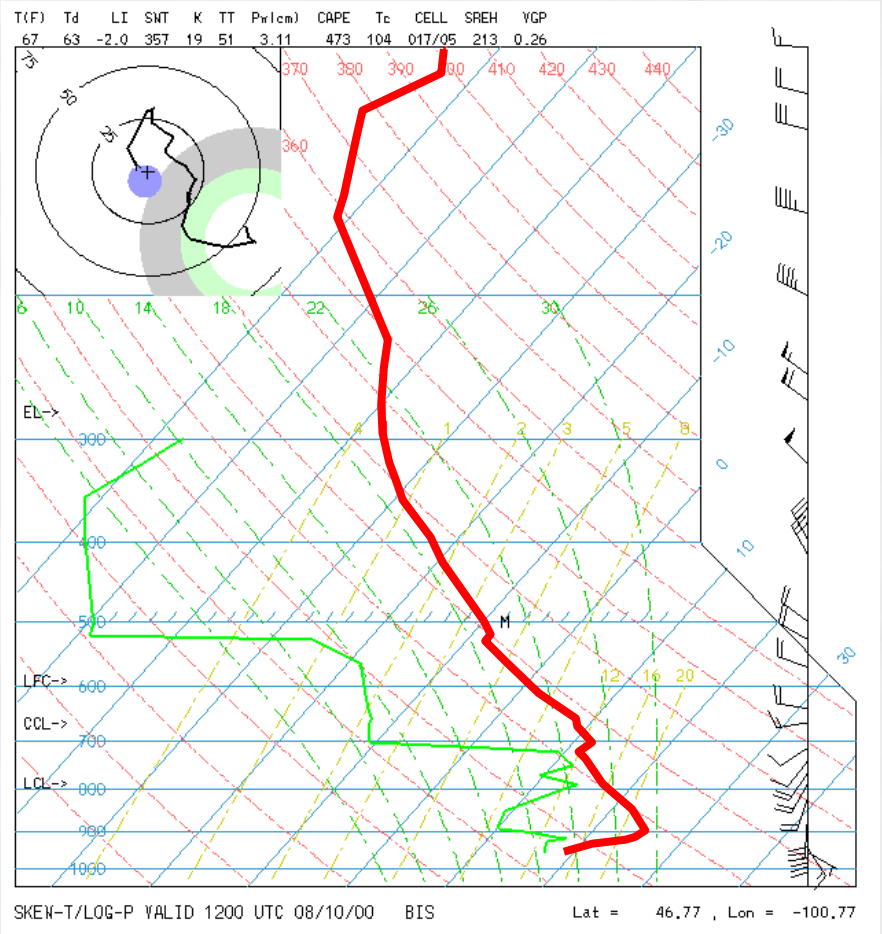
Meteorological Stability

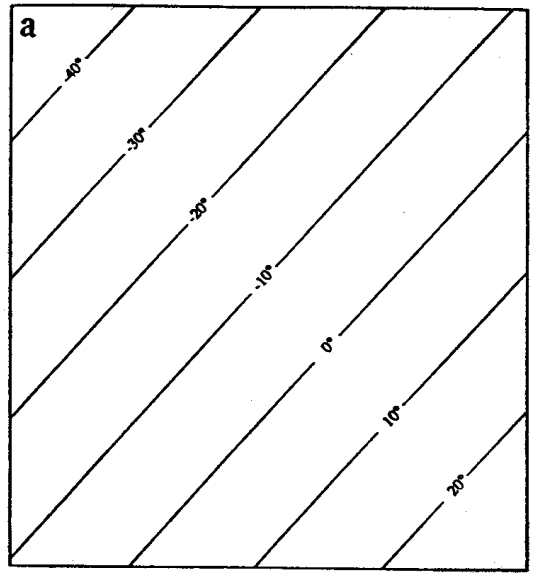
The ability of the air to return to its origin after displacement



Stability

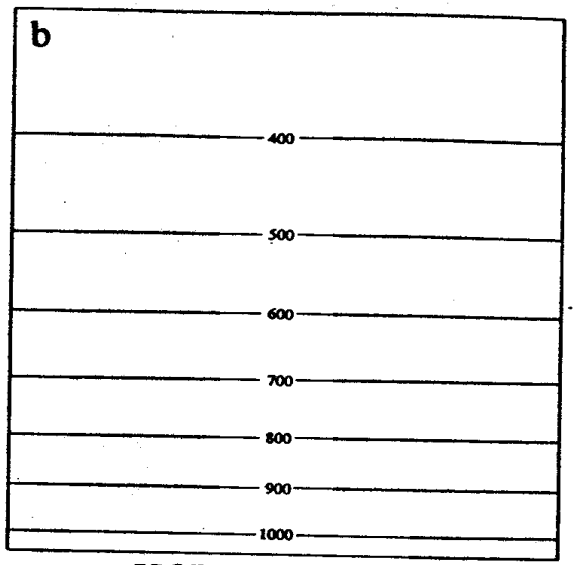
Depends on the thermal structure of the atmosphere





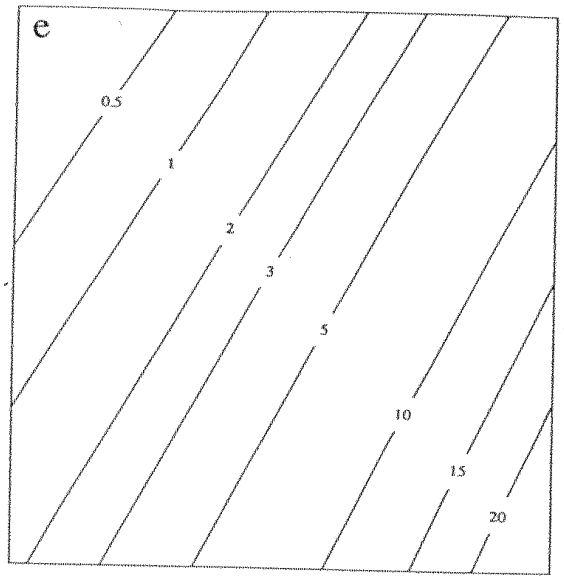
ISOTHERMS (°C)

r

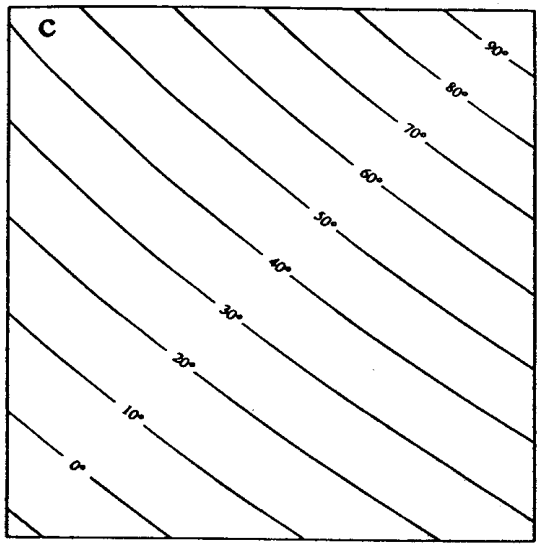


ISOBARS (hPa)

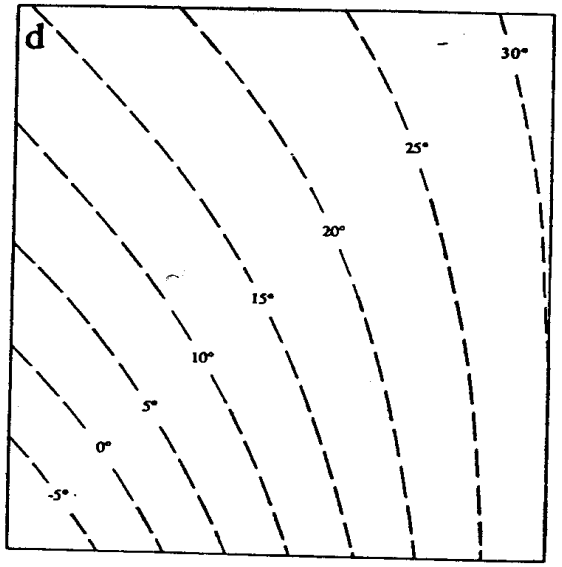
S



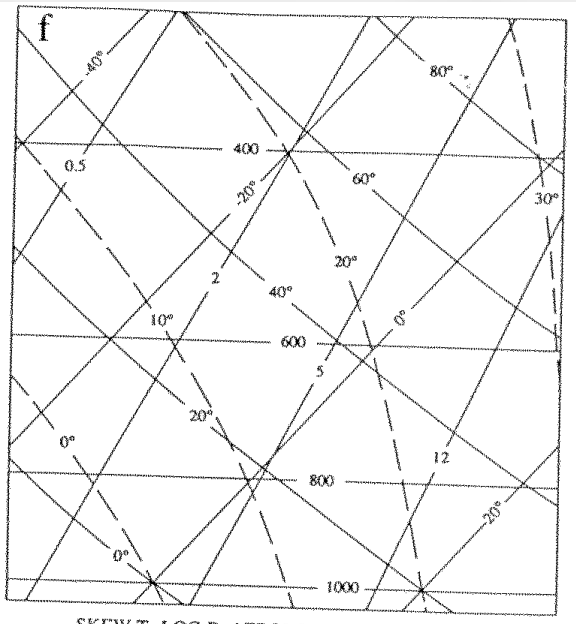
SATURATION MIXING RATIO LINES (g/kg)



DRY ADIABATS (°C)

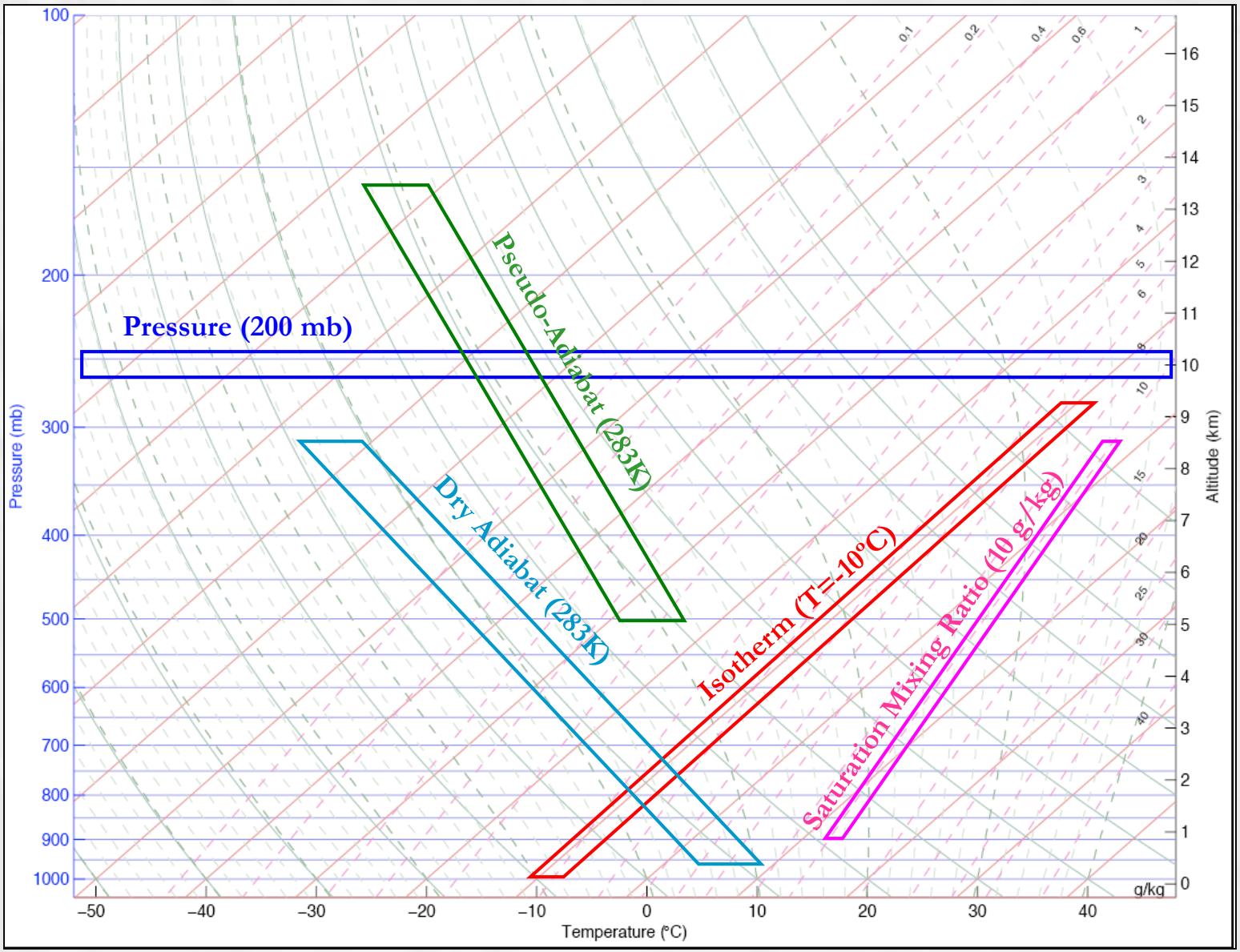


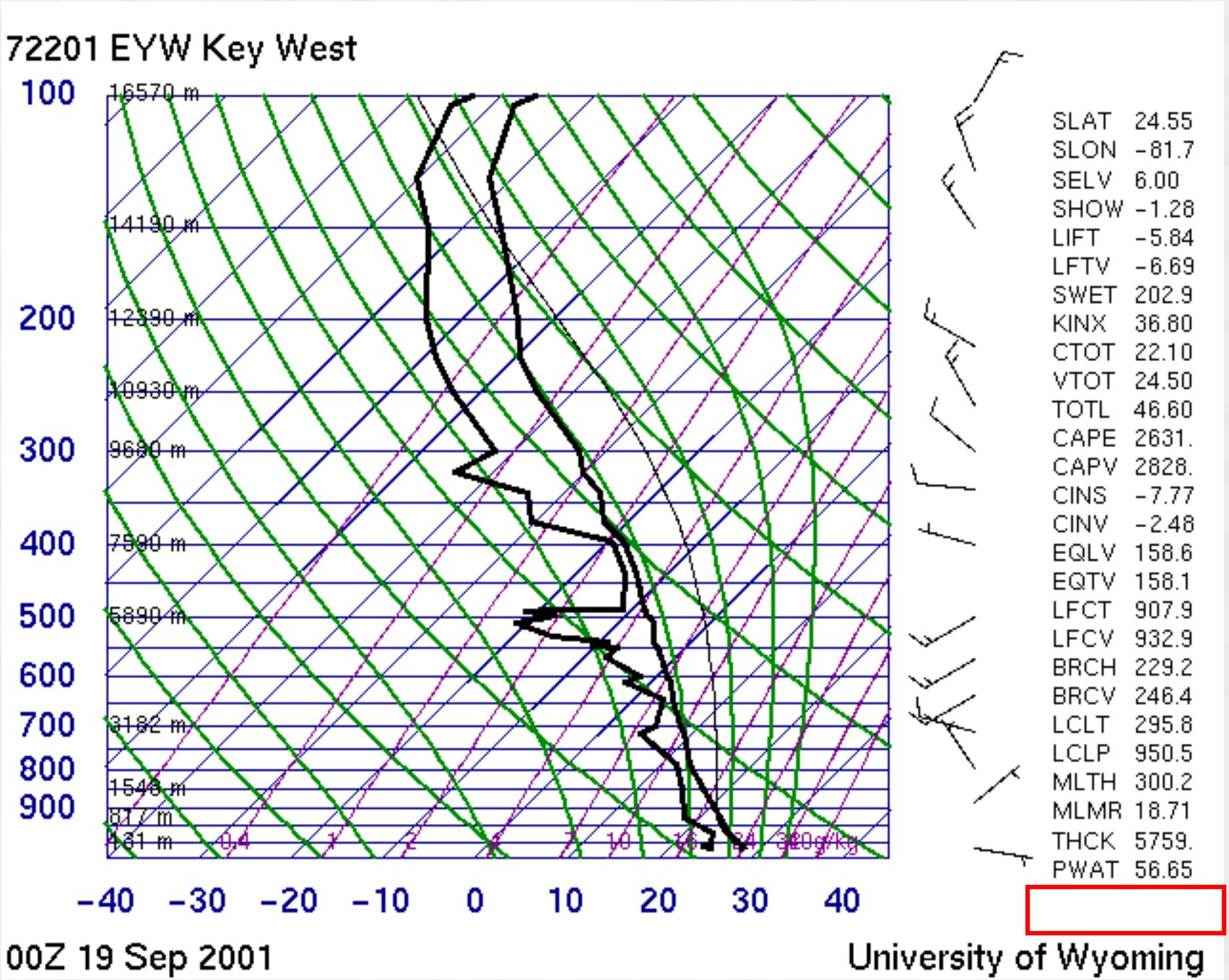
SATURATED ADIABATS θ_w (°C)



SKEW T- LOG P AEROLOGICAL DIAGRAM

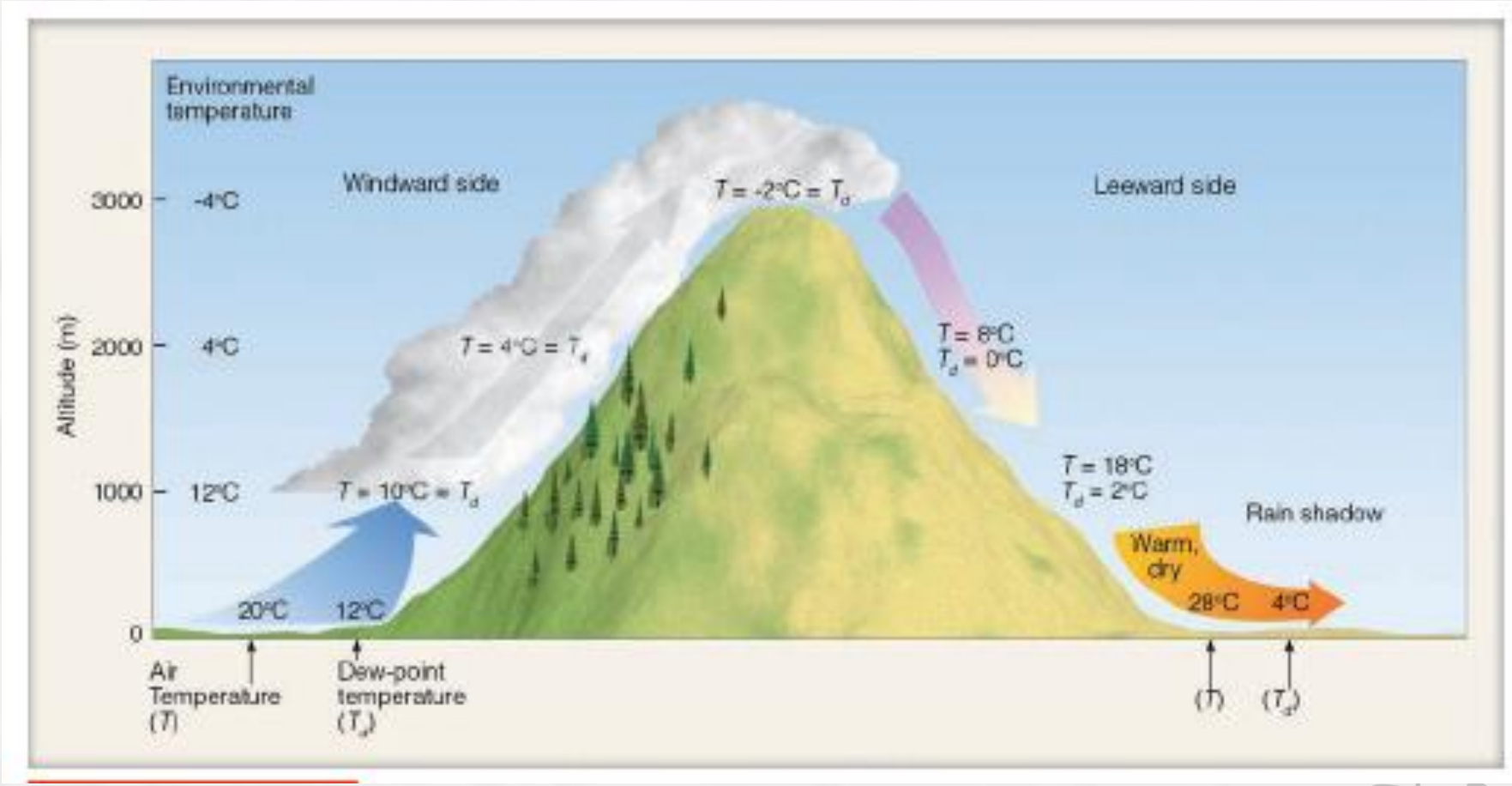
Skew-T Log-P Diagram




72201 EYW Key West
100
200
300
400
500
600
700
800
900
16570 m
14190 m
12390 m
10930 m
9680 m
7590 m
5890 m
3182 m
1546 m
817 m
431 m
0.4
1
2
4
7
10
16
24
32
40g/kg
-40
-30
-20
-10
0
10
20
30
40
SLAT 24.55
SLON -81.7
SELV 6.00
SHOW -1.28
LIFT -5.84
LFTV -6.69
SWET 202.9
KINX 36.80
CTOT 22.10
VTOT 24.50
TOTL 46.60
CAPE 2631.
CAPV 2828.
CINS -7.77
CINV -2.48
EQLV 158.6
EQTV 158.1
LFCT 907.9
LFCV 932.9
BRCH 229.2
BRCV 246.4
LCLT 295.8
LCLP 950.5
MLTH 300.2
MLMR 18.71
THCK 5759.
PWAT 56.65
00Z 19 Sep 2001
University of Wyoming

Orographic Lifting

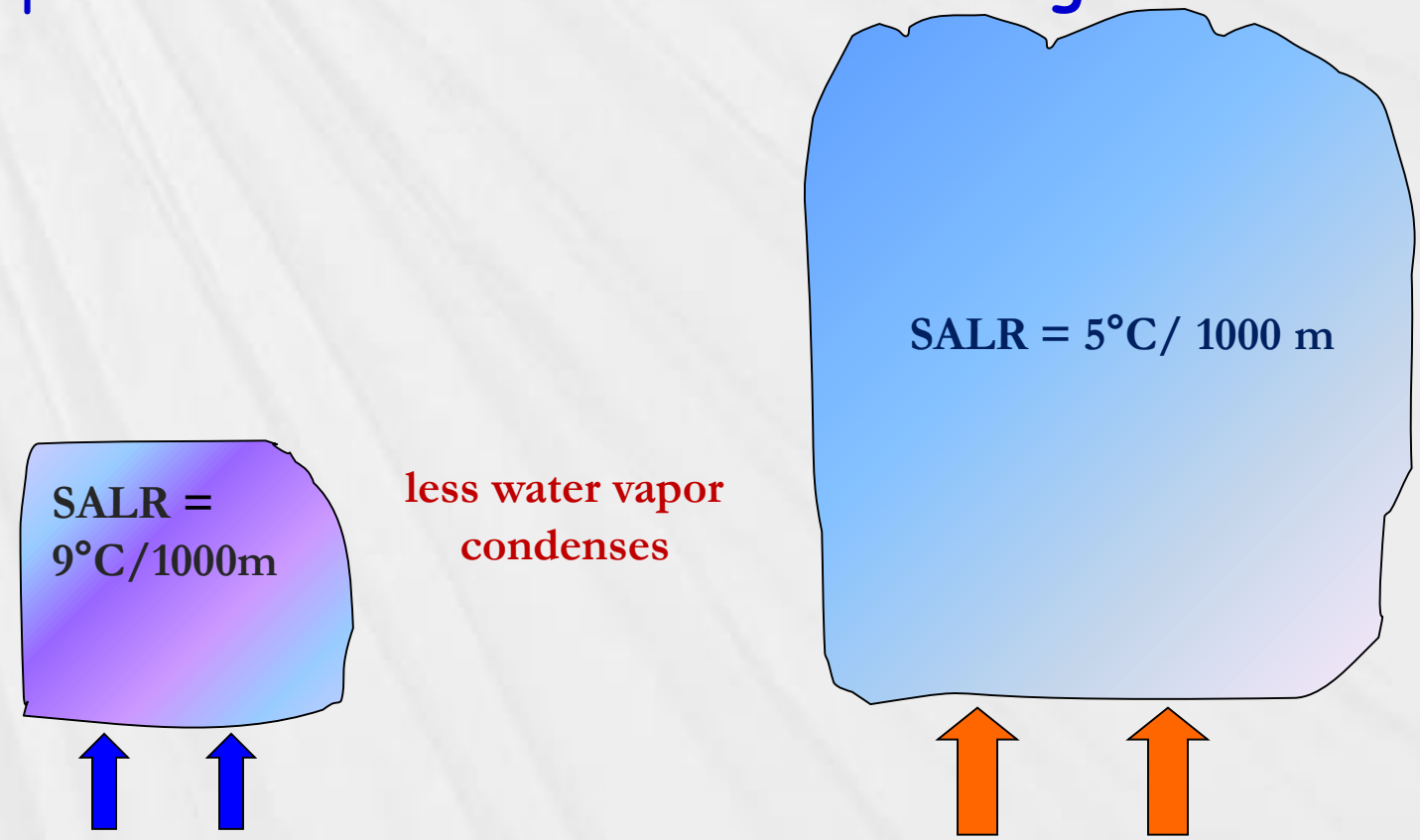
The process where air is forced to rise up the side of a mountain is sometimes called **orographic lifting**.



The Effect of Topography on Precipitation Patterns

When warm moist air rises in a cloud, more water vapor condenses and the **SALR is smaller**.

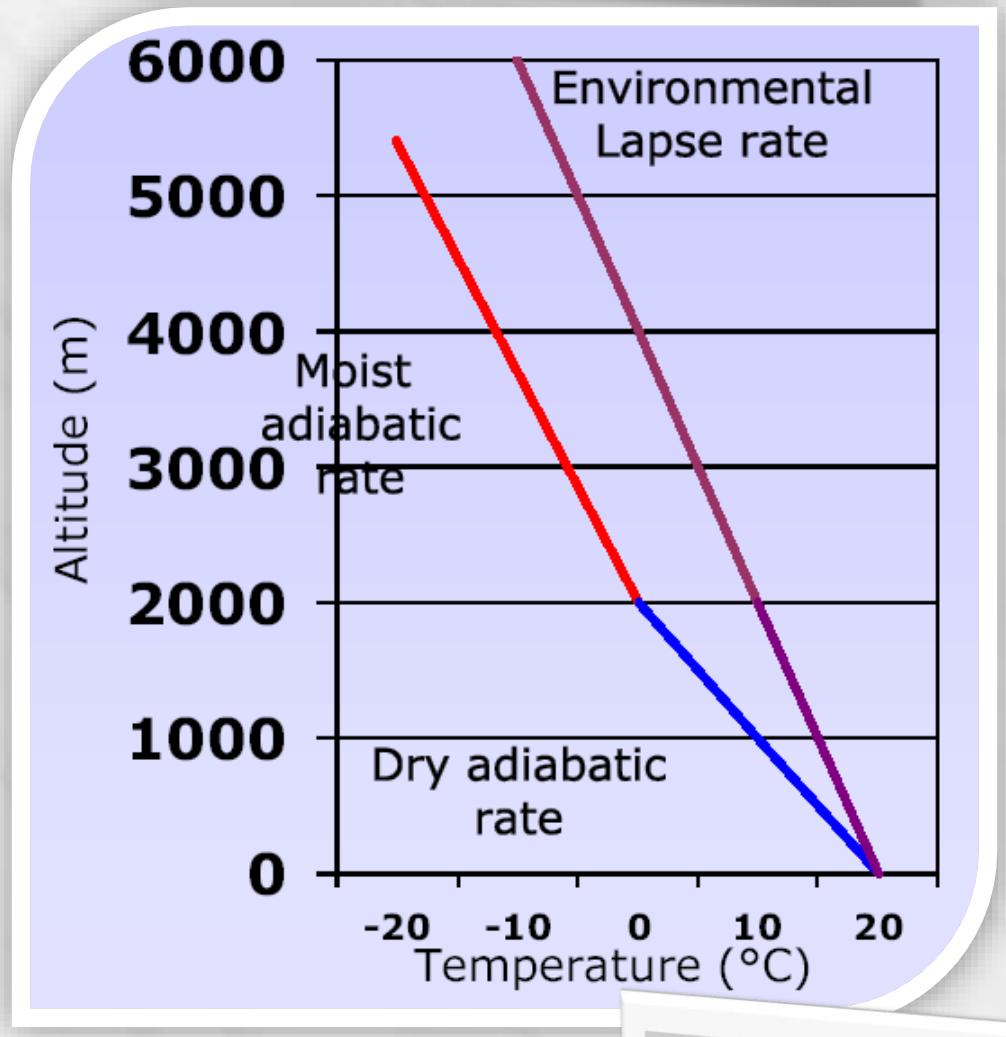
When cooler, drier air rises inside a cloud, less water vapor condenses and the **SALR is larger**.



There is much less vertical motion when air is neutral or stable. Thus, when air inside the clouds is neutral or stable, the **clouds tend to have a flat, layered appearance**.

These types of layered clouds are called **stratus clouds**.

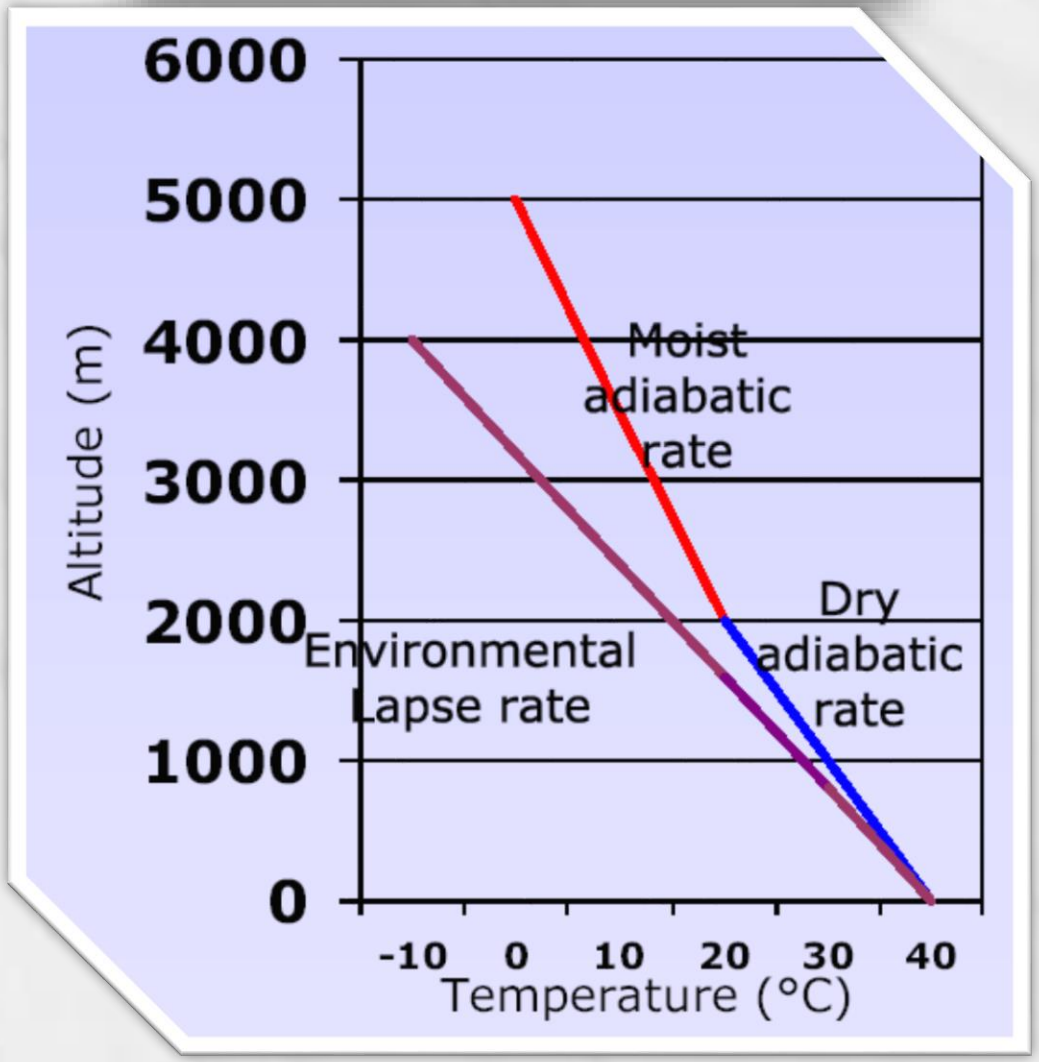
Absolute Stability



When the environmental lapse rate is less than the wet adiabatic lapse rate (~6°C / km)

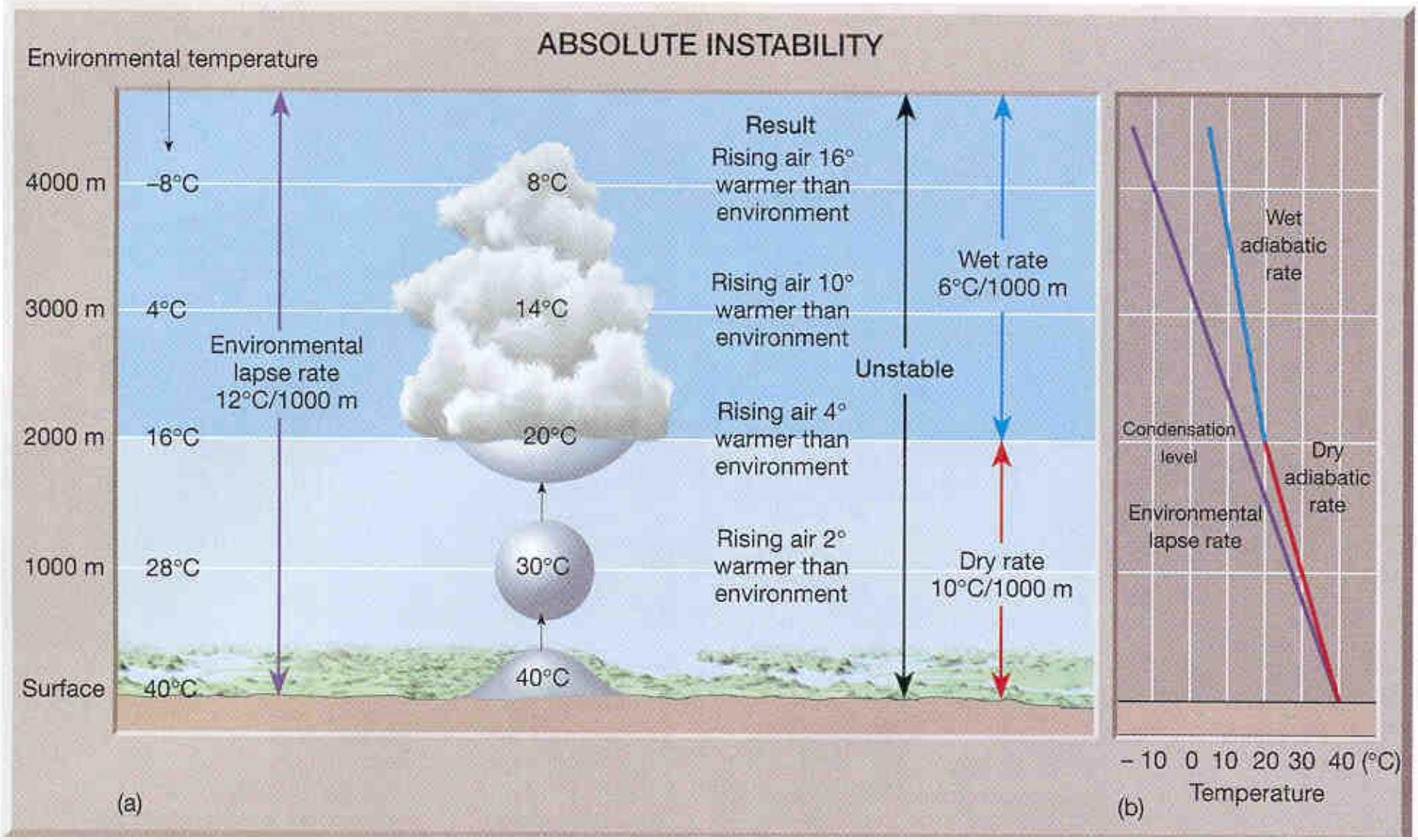
Absolute Instability

The environmental lapse rate is greater than the dry adiabatic lapse rate



Ascending parcel always less dense than surrounding air, will always rise.

Warm month / clear day with lots of surface heating


ABSOLUTE INSTABILITY
Environmental temperature
4000 m
3000 m
2000 m
1000 m
Surface
–8°C
4°C
16°C
28°C
40°C
8°C
14°C
20°C
30°C
40°C
Environmental lapse rate 12°C/1000 m
Result
Rising air 16° warmer than environment
Rising air 10° warmer than environment
Rising air 4° warmer than environment
Rising air 2° warmer than environment
Unstable
Wet rate 6°C/1000 m
Dry rate 10°C/1000 m
(a)
Wet adiabatic rate
Condensation level
Dry adiabatic rate
Environmental lapse rate
– 10 0 10 20 30 40 (°C)
Temperature
(b)

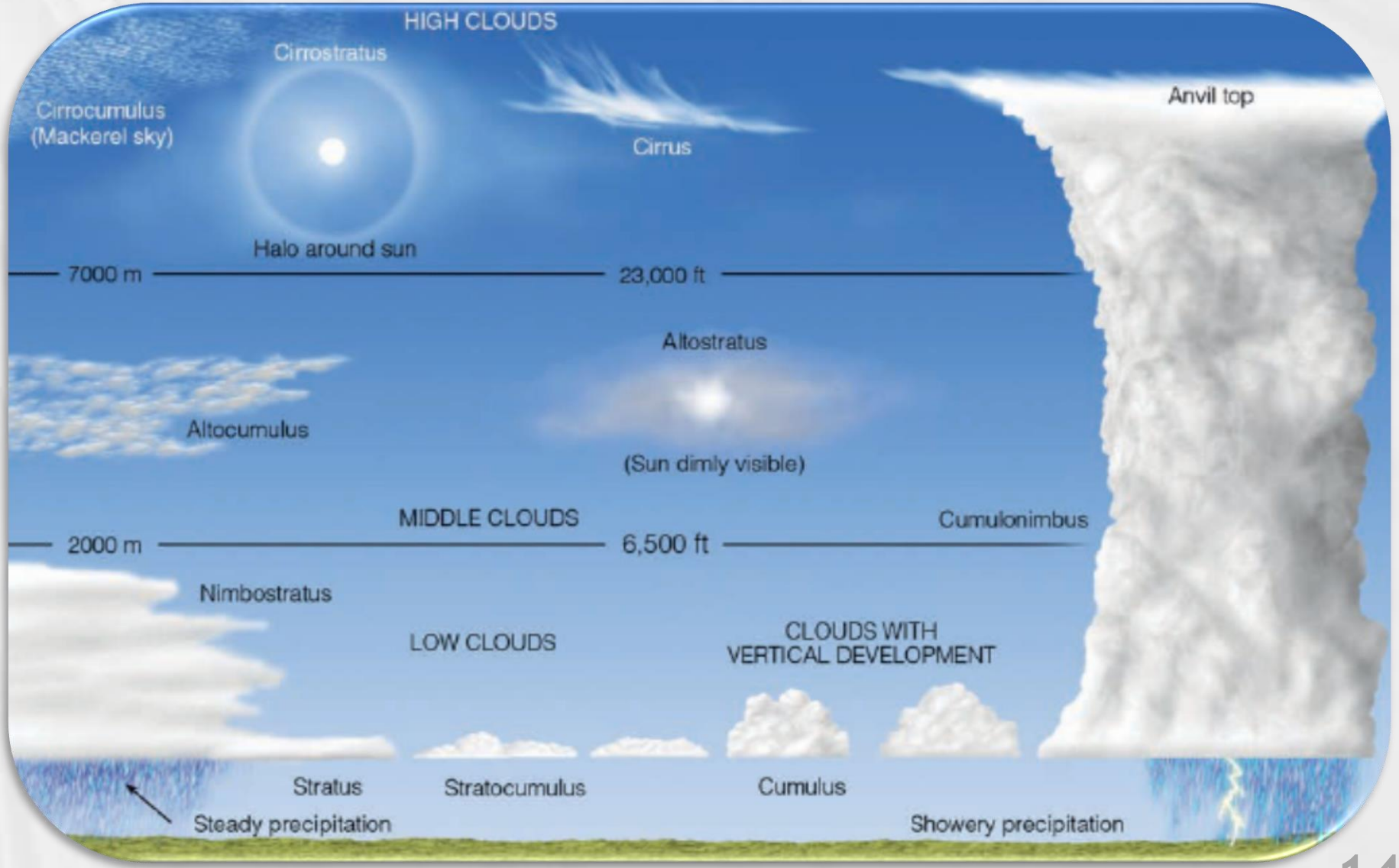
Instability Cases for Clouds

Unstable air moves vertically and we tend to get tall, vertical clouds like **cumulus** and **cumulonimbus**.

Cumulus congestus.

A cumulonimbus cloud (thunderstorm). Strong upper-level winds blowing from right to left produce a well defined anvil.

A generalized illustration of basic cloud types based on height above the surface and vertical development.



Cloud Types

Clouds are classified into broad categories

High level:

- cirrus clouds
- Altitudes above 7,000 meter.
- Composed primarily of ice crystals
- Typically thin and white in appearance

Mid level:

- altocumulus, altostratus
- Altitudes between 2000 to 7,000 meter.
- composed primarily of water drops, sometimes ice crystals

Low level: Stratus,

- nimbostratus
- Altitudes below 2000 meter
- Usually composed of water drops
- Uniform, covers entire sky

Vertically Developed:

- cumulus and cumulonimbus (thunderstorms)
- Cloud top heights in excess of 11,000 meter
- Composed of water and ice together, often producing hail

Other cloud types that are uncommon

Noctilucent clouds (NLCs)

occur in the mesosphere at polar latitudes

Polar stratospheric clouds (PSCs)

occur in the stratosphere at polar latitudes

There is a special stability case that occurs when the Environmental Lapse Rate is between the Dry Adiabatic Lapse Rate and the Saturated Adiabatic Lapse Rate.

For example, what if

DALR = 10°C/1000 m

ELR = 7.5°C/1000 m

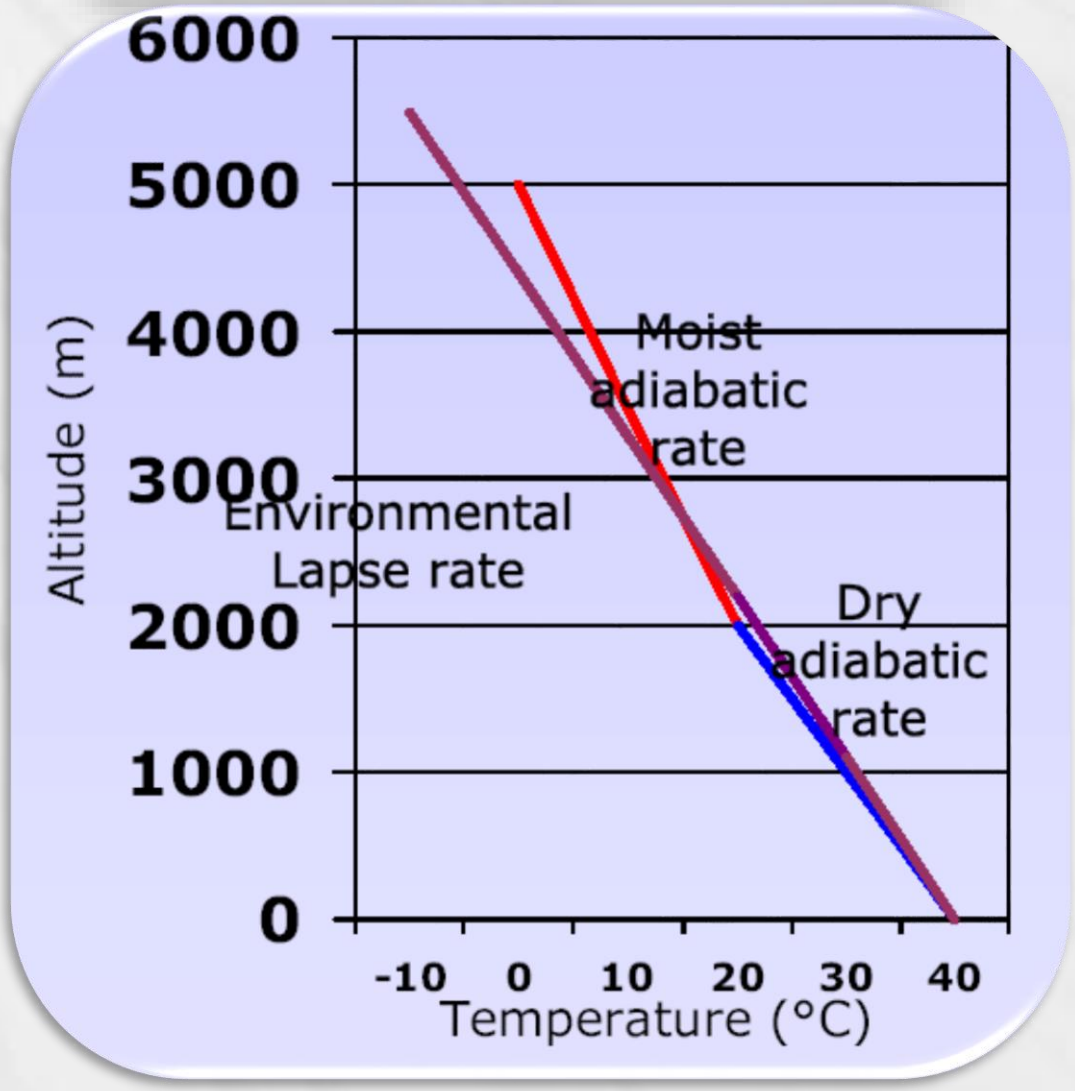
SALR = 5°C/1000 m

If the air is unsaturated **ELR < DALR** and the air is stable, but if the air is saturated, then **ELR > SALR** and the air is unstable.

This special case is called **conditionally unstable**, because the air must be lifted until it becomes saturated in order for it to become unstable

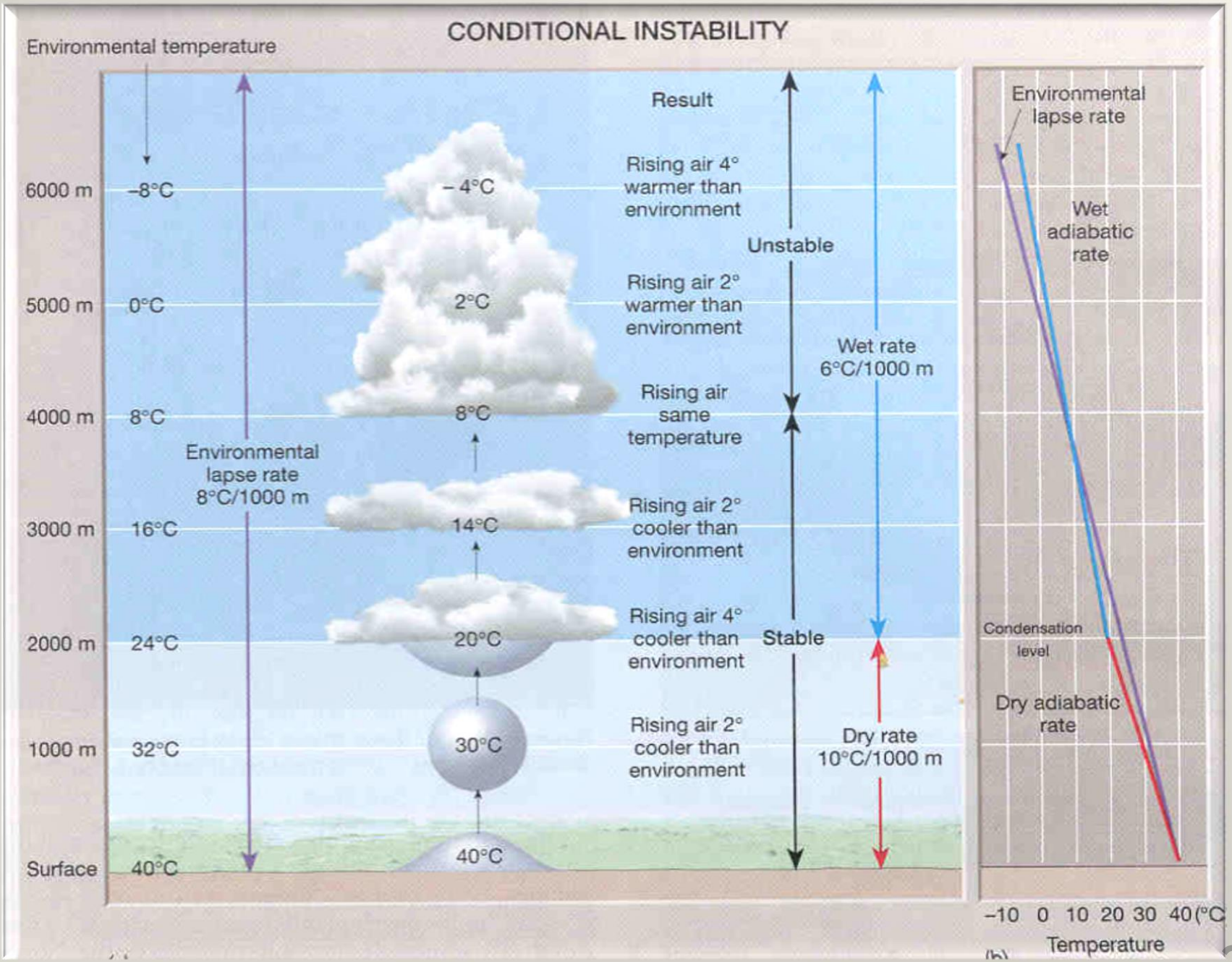
Conditional Instability

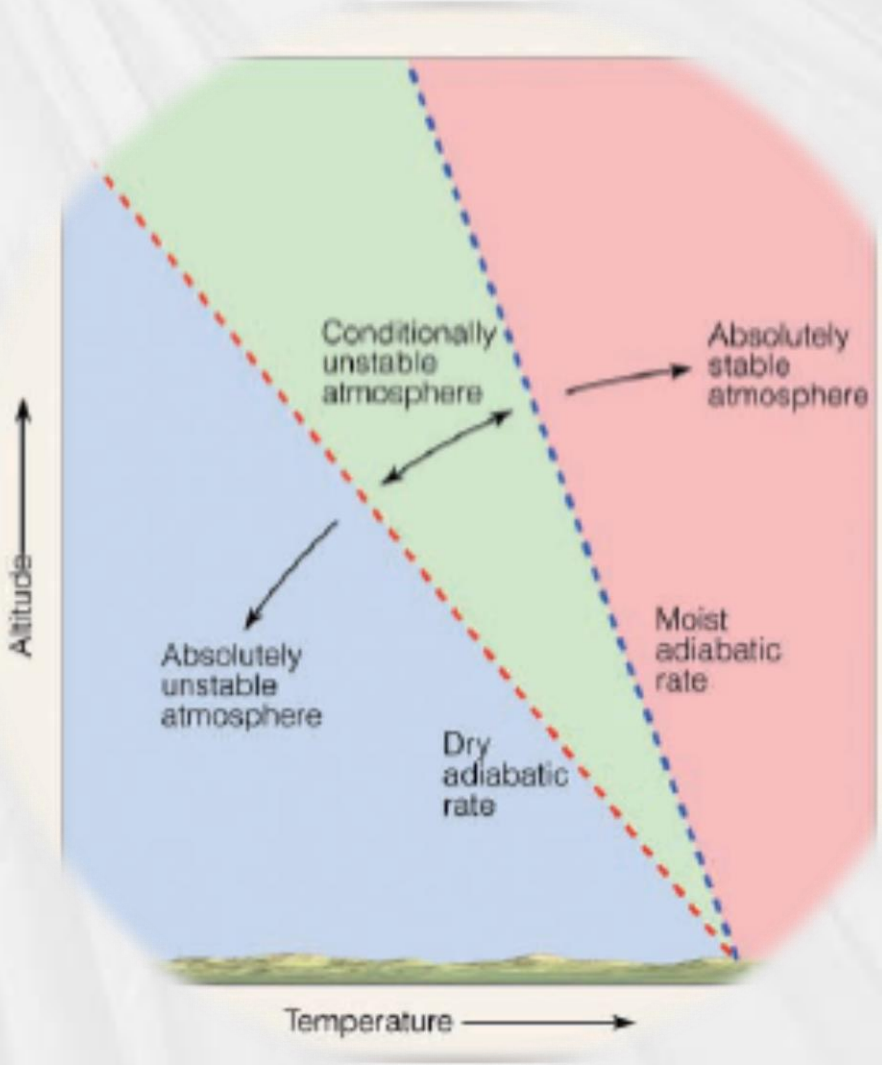
Saturated parcel is unstable



Unsaturated parcel is stable

Depends on whether or not the rising air is saturated


CONDITIONAL INSTABILITY
Environmental temperature
Result
6000 m
5000 m
4000 m
3000 m
2000 m
1000 m
Surface
–8°C
0°C
8°C
16°C
24°C
32°C
40°C
– 4°C
2°C
8°C
14°C
20°C
30°C
40°C
Rising air 4° warmer than environment
Rising air 2° warmer than environment
Rising air same temperature
Rising air 2° cooler than environment
Rising air 4° cooler than environment
Rising air 2° cooler than environment
Unstable
Stable
Environmental lapse rate 8°C/1000 m
Wet rate 6°C/1000 m
Dry rate 10°C/1000 m
Environmental lapse rate
Wet adiabatic rate
Condensation level
Dry adiabatic rate
–10 0 10 20 30 40 (°C
Temperature
(b)



• FIGURE 6.11 The warmth from this forest fire in the northern Sierra Nevada foothills heats the air, causing instability near the surface. Warm, less-dense air (and smoke) bubbles upward, expanding and cooling as it rises. Eventually the rising air cools to its dew point, condensation begins, and a cumulus cloud forms.

How Stability Changes - Instability

Any factor causing the air at the surface to warm compared with air overhead:

1. Intense solar heating of surface
2. Heating of air mass from below as it passes over a warm surface
3. Lifting air processes (orographic lifting, frontal wedging, convergence)
4. Radiation cooling of cloud tops

How Stability Changes: Stability

Any process that causes the surface air to chill compared to air overhead:

1. Nighttime radiation cooling
2. Cooling of air mass from below as it moves over a cold surface
3. Subsidence (sinking) within an air column