ATM 10   Severe and Unusual Weather

Prof. Richard Grotjahn

http://atm.ucdavis.edu/~grotjahn/course/atm10/index.html

Lecture topics:

- **What happens when air rises?**
- **Stability**
  - What is it?
  - Why is it important?
  - How is it classified?
  - How do you know what type is present?
  - Use of a chart of temperature in vertical
  - Etc.

Vertical Movement & Temperature

A rising air parcel encounters less pressure so it expands. Expansion uses energy to push out, **adiabatically** cooling the air.

A sinking parcel encounters greater pressure and that higher pressure does work on the parcel thereby heating it up.

Recall: $P = \rho \, R \, T$

2000 — 10°C

Expands and cools

Altitude (m)

1000 — 20°C

Compresses and warms
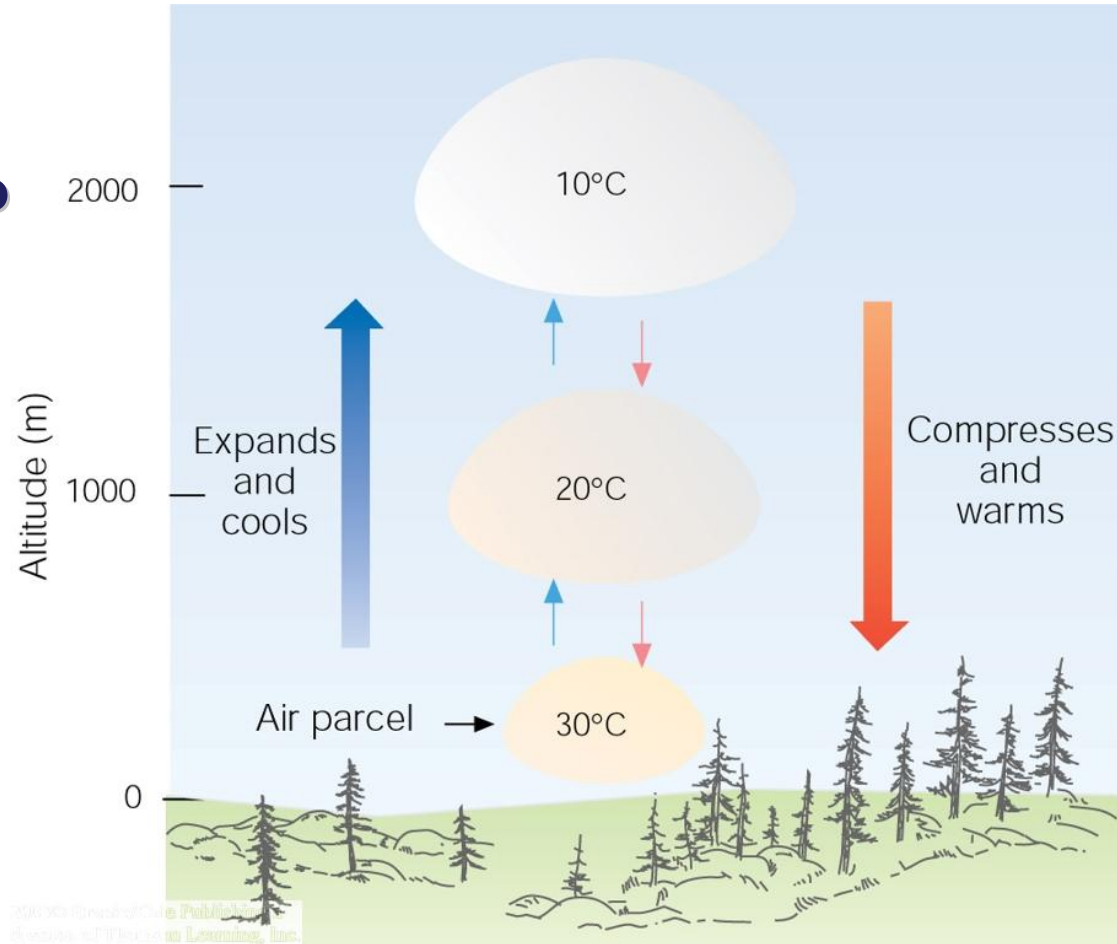
Air parcel → 30°C

0 —

Figure 7.2

Stability & Clouds: Introduction

- Stability is related to weather several ways:

Stability & Clouds: Introduction

- Three examples of weather related to stability:

  - Clouds types linked to stability of the air. Stratus clouds found in stable conditions, cumulus are in unstable conditions. Thunderstorms in very unstable conditions.

  - Lenticular wave clouds form in stable air

  - Downslope winds, like the Santa Ana: stable air

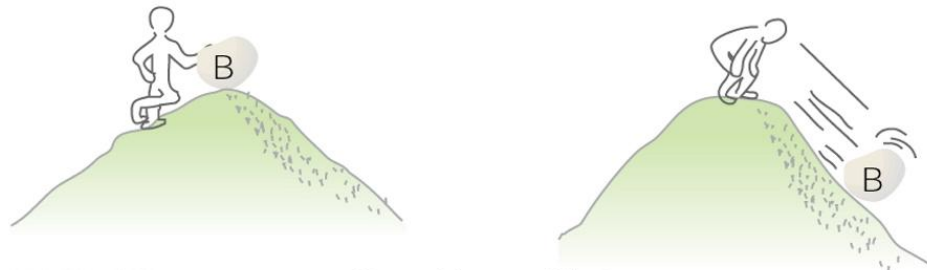- But what is stability?

stratiform

cumuliform

lenticular

What is Stability?

- Stability indicates to what extent the temperature CHANGE IN A LAYER OF AIR resists vertical motion.

- Fig. 7.1 illustrates the concept w/ an analogy.

Stable equilibrium

Unstable equilibrium

Stable – returns to Original position.

Unstable – keeps going In direction of push.

Figure 7.1

Why examine stability?

- Different types of cloud form for different stability conditions

- Most clouds form as air rises -- leading to cooling -- leading to condensation. So, since stability affects the ability of air to rise, stability affects cloud growth.

How is T structure classified?

- Stability related to temperature change in the vertical.

- Temperature change in the vertical is called the lapse rate.

- Lapse rate is: $\Gamma = - \Delta T / \Delta Z$

- ΔT is T at top of layer minus T at bottom of layer.

- ΔZ is the thickness of layer.

- $\Gamma > 0$ usually

Environmental Lapse Rate $= \dfrac{15\ ^{o}C}{1\ km}$
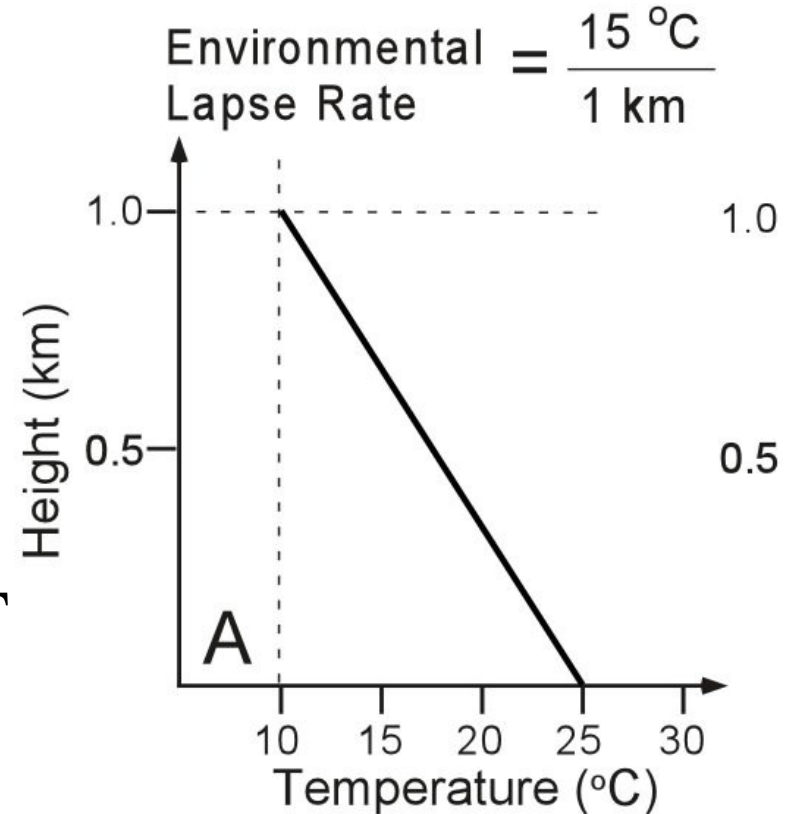
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Fig: $\Delta T = -15$ C, $\Delta Z = 1000$m, $\Gamma = 0.015$ C/m

If I know Γ, then I know the stability?

- Almost
- Stability depends on:

  - Γ value AND on

  - whether the air is saturated or not

- Why saturated? Because if air that is saturated is cooled further, then some vapor must condense. Recall that the condensation adds heat to the air.

How many types of stability are there?

- Three basic types, (plus some special cases given specific names)

1. Absolutely stable
2. Conditionally unstable
3. Absolutely unstable

- Special case of #3 is inversion: T increases with elevation

- Neutral a special case related to saturation

How do you tell them apart?

- Compare the actual change of temperature IN A LAYER with two calculated lapse rates called the dry adiabatic and moist adiabatic lapse rates: Γd & Γm.

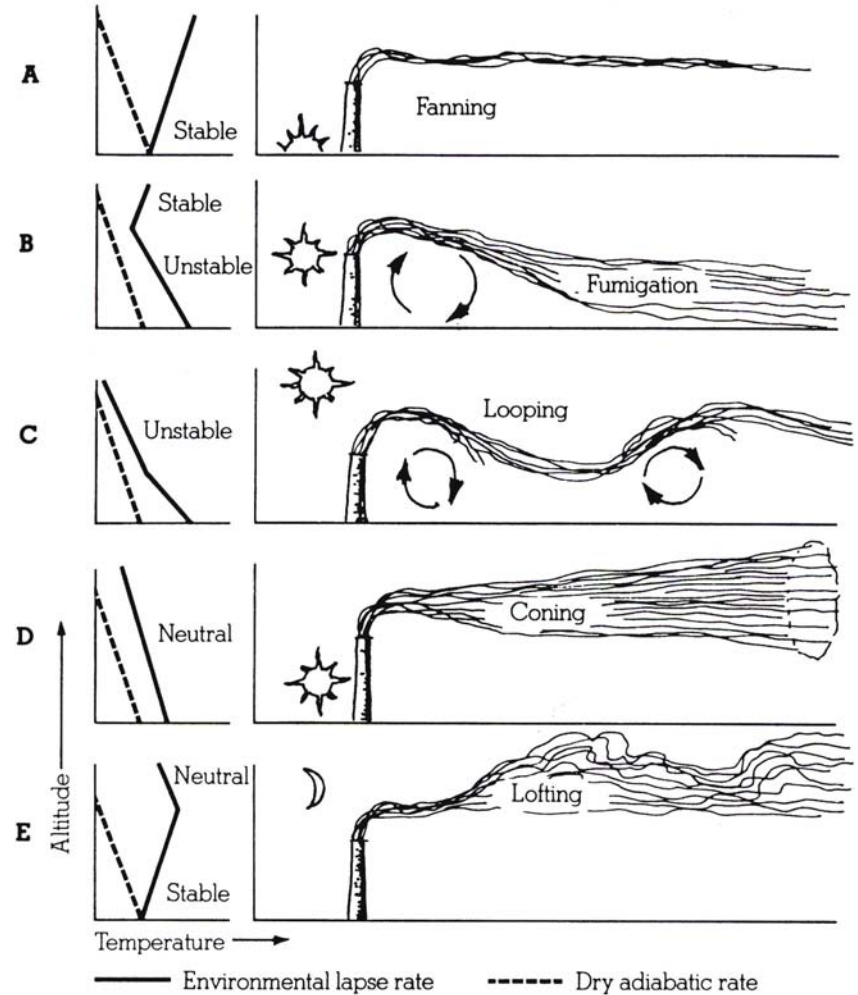- Example: in clear air, deduce stability from smoke plume

FIGURE 1 Smoke-plume patterns that are related to various types of atmospheric stability.
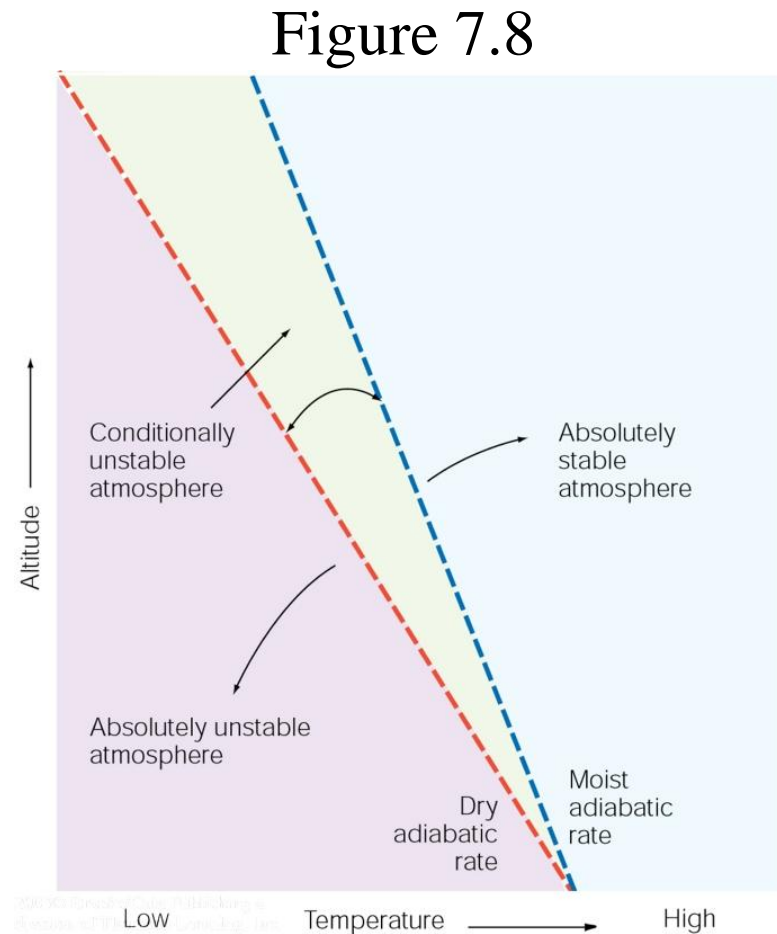
What are Γd and Γm ?

- dry adiabatic lapse rate: $\Gamma d = 10 \ ^{o}C/1000m$ of elevation change

- moist adiabatic lapse rate: $\Gamma m < \Gamma d.$

  – Γm depends on amount of water vapor to dry air which in turn depends on T and P.

  – T change for parcel that is saturated.

Height (km)

Dry adiabatic lapse rate

Moist adiabatic lapse rate

Temperature (°C)
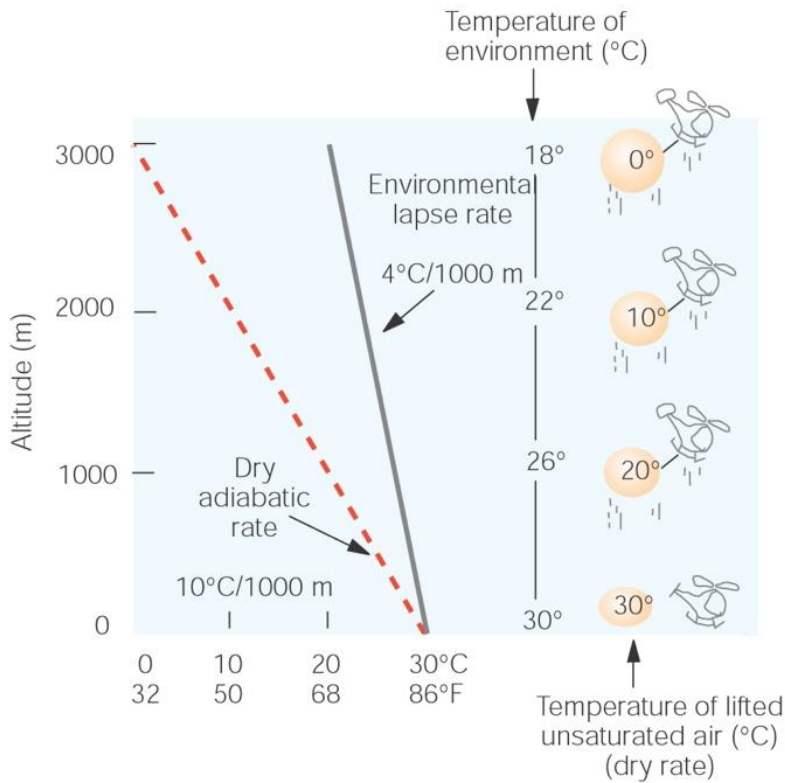
©2002 Kendall/Hunt Publishing
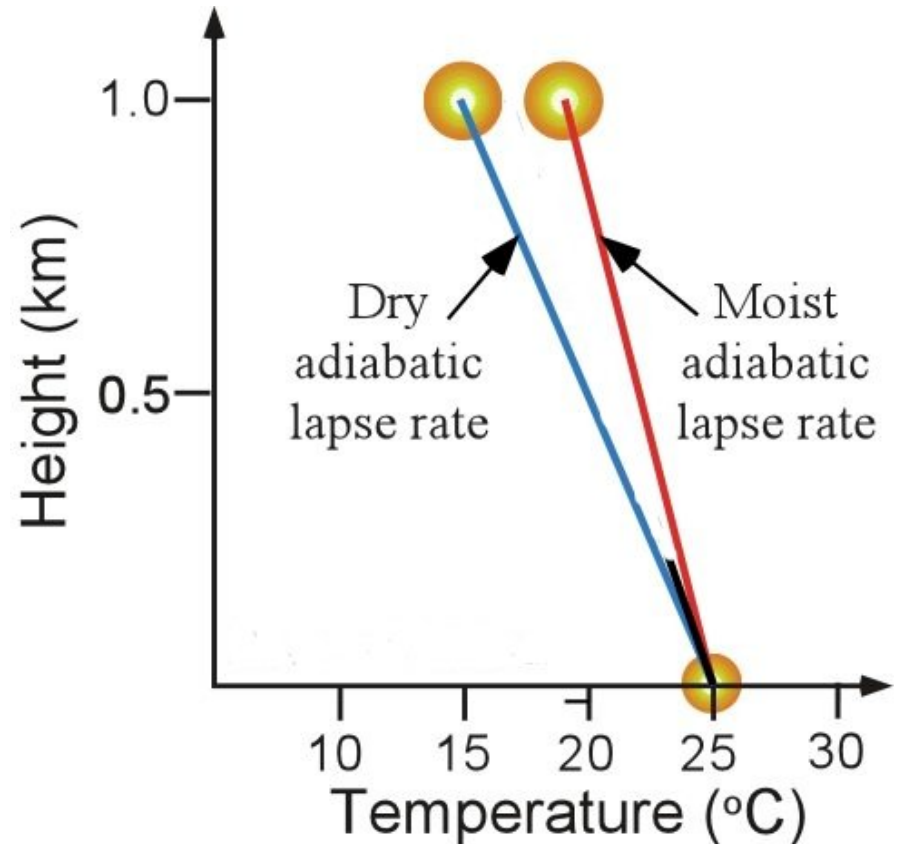
Am I now able to figure out the stability classes?

- Yes! but it is easier to do this using a chart
- Compare the actual T change with height to the lapse rates Γd (red line) and Γm (blue line)
- Figures 7.3, 7.6, and 7.7 work out the three categories.
- Figure 7.8 is a summary:

Figure 7.8

Conditionally unstable atmosphere

Absolutely stable atmosphere

Absolutely unstable atmosphere

Dry adiabatic rate

Moist adiabatic rate

Altitude

Low   Temperature   High

Absolutely Stable

- Γ to the right of Γm
- Unsaturated (left), saturated (right)
- Recall: $P = \rho\, R\, T$
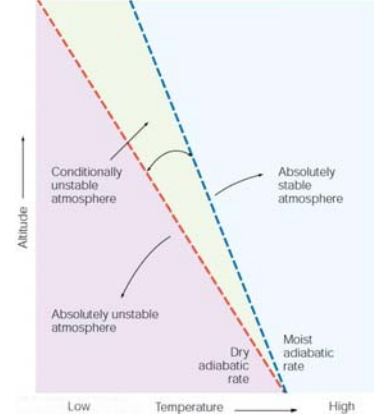
Lifted, unsaturated air at each level is colder and heavier than the air around it. If given the chance, the parcel would return to its original position.

Lifted, saturated air at each position is colder and heavier than the air surrounding it. If released, the parcel would return to its original position.
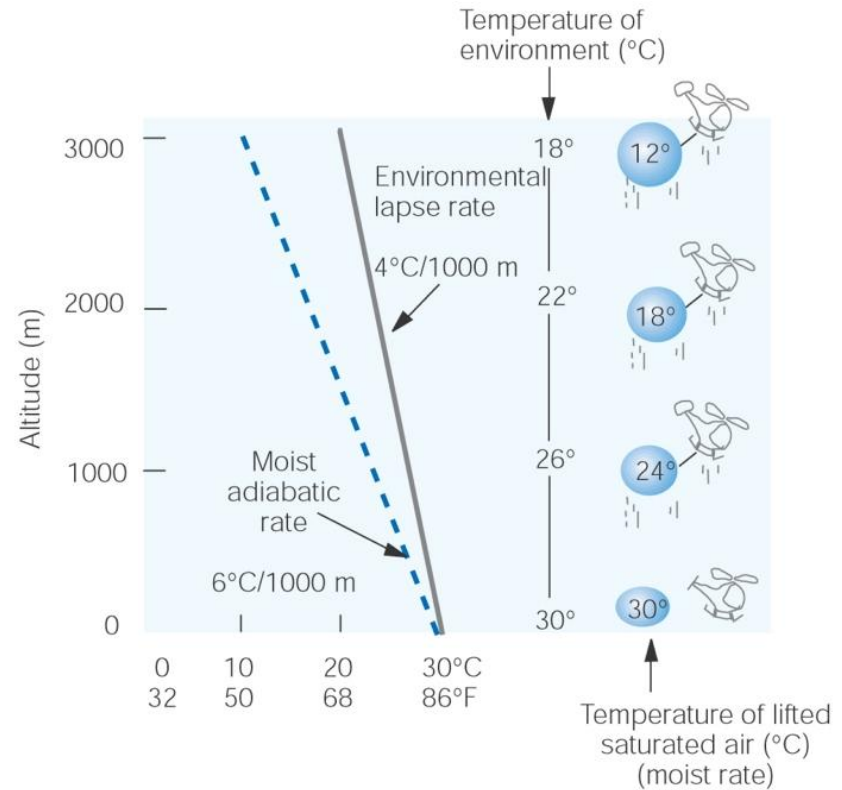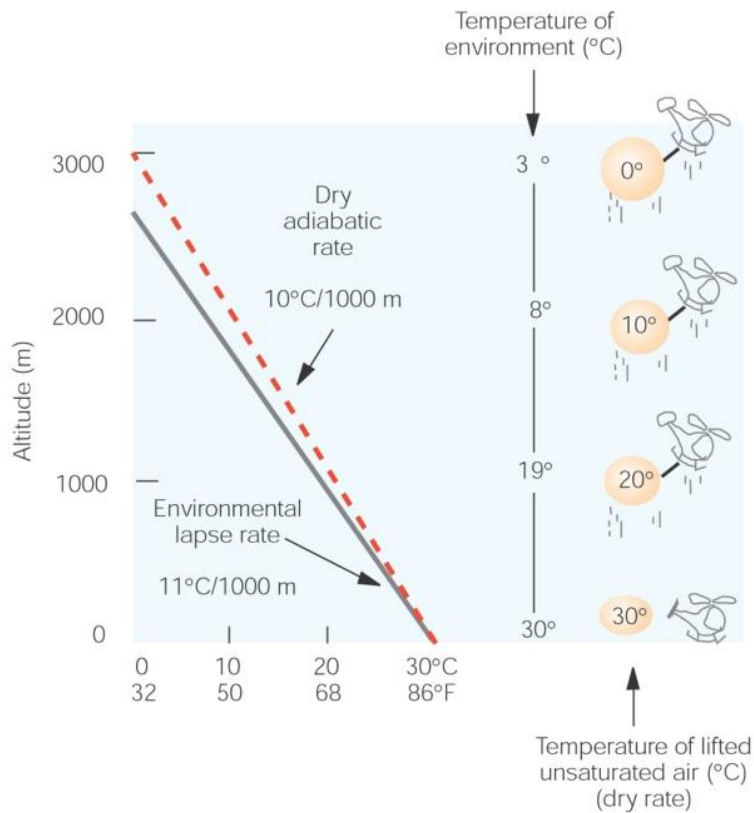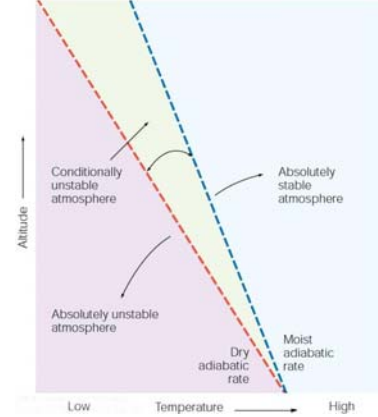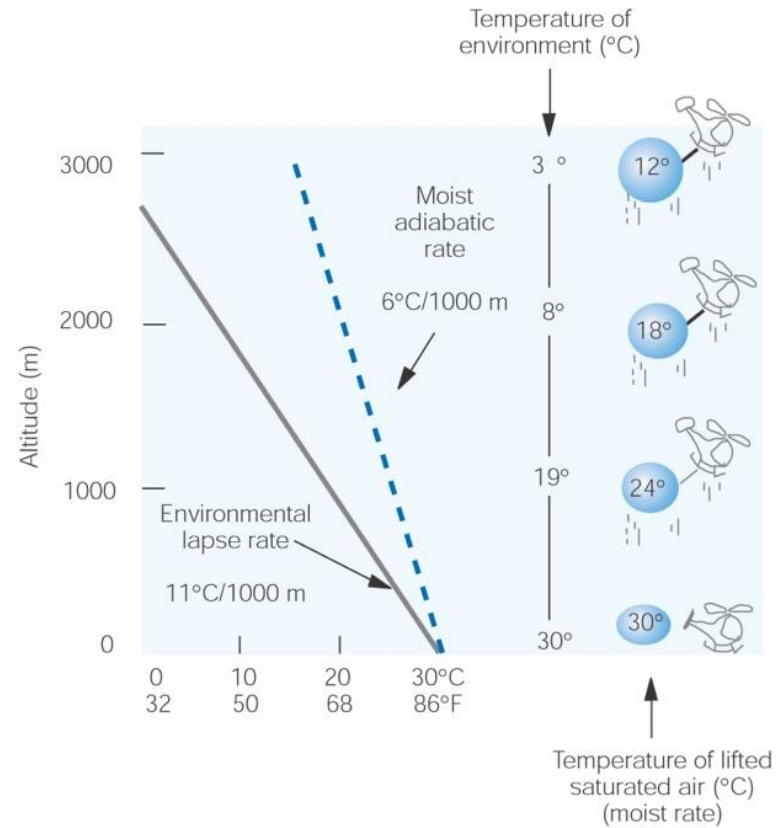
Absolutely Unstable

- Γ to the left of Γd
- Unsaturated (left), saturated (right)
- Recall: $P = \rho\, R\, T$

Conditionally unstable atmosphere

Absolutely stable atmosphere

Absolutely unstable atmosphere

Dry adiabatic rate

Moist adiabatic rate

Altitude

Low — Temperature — High

Temperature of environment (°C)

Dry adiabatic rate
10°C/1000 m

Environmental lapse rate
11°C/1000 m

3°
8°
19°
30°

0°
10°
20°
30°

3000
2000
1000
0

Altitude (m)

0 / 32   10 / 50   20 / 68   30°C / 86°F

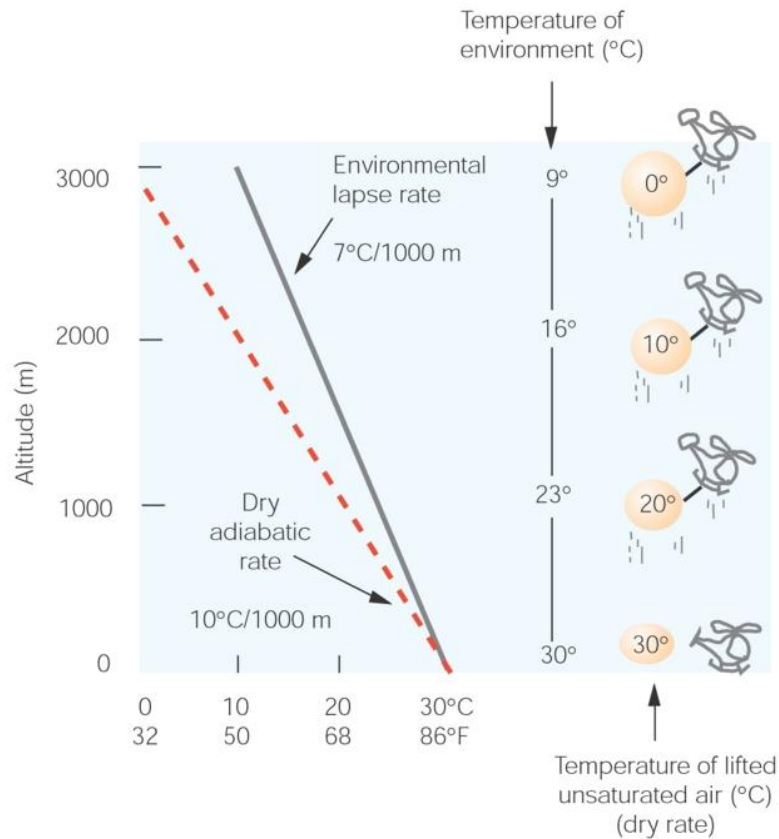Temperature of lifted unsaturated air (°C) (dry rate)

The rising, unsaturated air parcel at each level is warmer and lighter than the air around it. If given the chance, the air parcel would accelerate away from its original position.

Temperature of environment (°C)

Moist adiabatic rate
6°C/1000 m

Environmental lapse rate
11°C/1000 m

3°
8°
19°
30°

12°
18°
24°
30°

3000
2000
1000
0

Altitude (m)

0 / 32   10 / 50   20 / 68   30°C / 86°F

Temperature of lifted saturated air (°C) (moist rate)

The rising, saturated air parcel is warmer than its surroundings. If given the chance, it also would move away from its original position.

Conditionally Unstable

- Γ between Γd and Γm
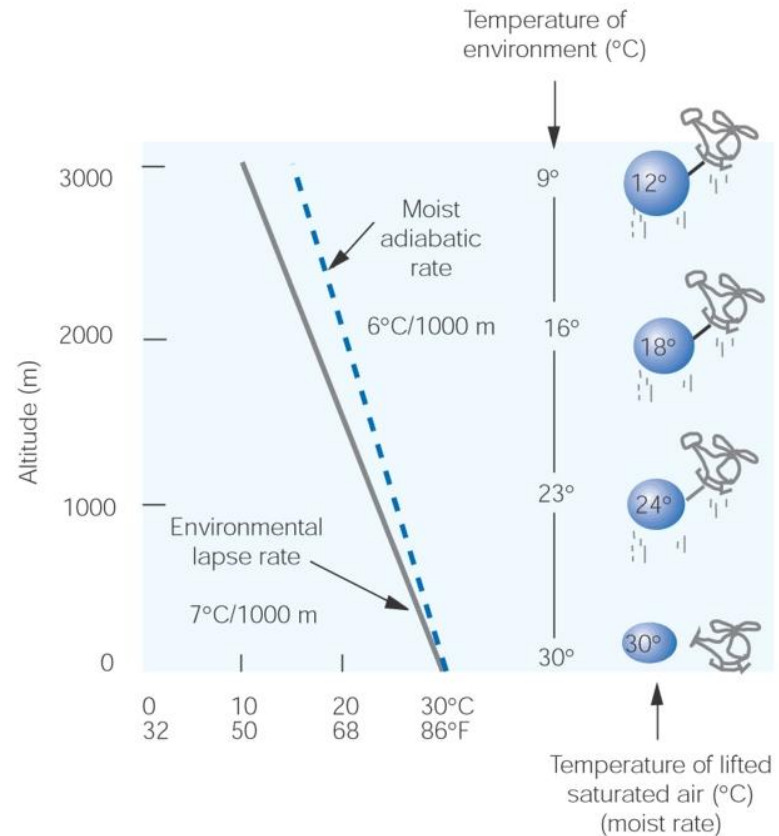- Unsaturated (left), saturated (right)
- Recall: $P = \rho R T$

Conditionally unstable atmosphere
Absolutely stable atmosphere
Absolutely unstable atmosphere
Dry adiabatic rate
Moist adiabatic rate
Low — Temperature — High

Temperature of environment (°C)

3000
Environmental lapse rate
7°C/1000 m
9°   0°

2000
16°   10°

Dry adiabatic rate
23°   20°

1000
10°C/1000 m
30°   30°

0
0   10   20   30°C
32   50   68   86°F

Temperature of lifted unsaturated air (°C) (dry rate)
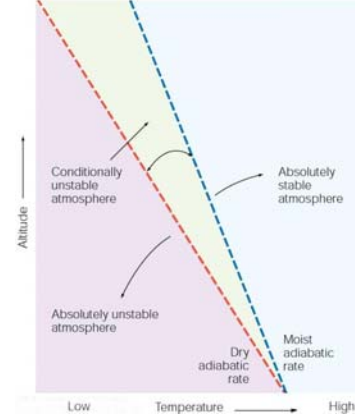
The unsaturated parcel of air at each elevation is colder than its surroundings. The atmosphere is stable with respect to unsaturated, rising air.

Temperature of environment (°C)

3000
Moist adiabatic rate
6°C/1000 m
9°   12°

2000
16°   18°

1000
Environmental lapse rate
7°C/1000 m
23°   24°

0
30°   30°

0   10   20   30°C
32   50   68   86°F

Temperature of lifted saturated air (°C) (moist rate)

The lifted, saturated air parcel is warmer at each elevation than its surroundings. The atmosphere is unstable with respect to saturated, rising air.

Which stability classes are more common?

- Atmosphere is most commonly conditionally unstable

- Atmosphere can be absolutely stable for long periods

- Absolutely unstable conditions can occur but usually are brief

If an absolutely unstable LAYER doesn't last long, why mention it?

- Can facilitate several types of severe weather

- Convection could be "thermals" if the air is unsaturated.

- If saturation occurs, cumulus type clouds form.

How can absolutely unstable air be created? -- 7 ways

1. Bring colder air aloft
2. Radiation cools top of layer
3. Daytime heating
4. Bring warmer air below
5. Air moves over a warmer surface
6. Mixing the air (fig. 7.10)
7. Moving the whole column of air upwards (figs. 7.11 & 7.12)
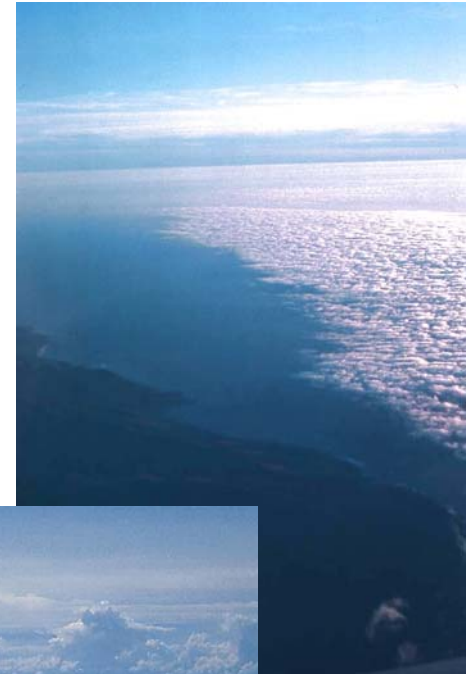
Am I now ready to discuss how clouds form?

- Yes! (finally)

End of lecture 4