Courtesy of Glen Romine

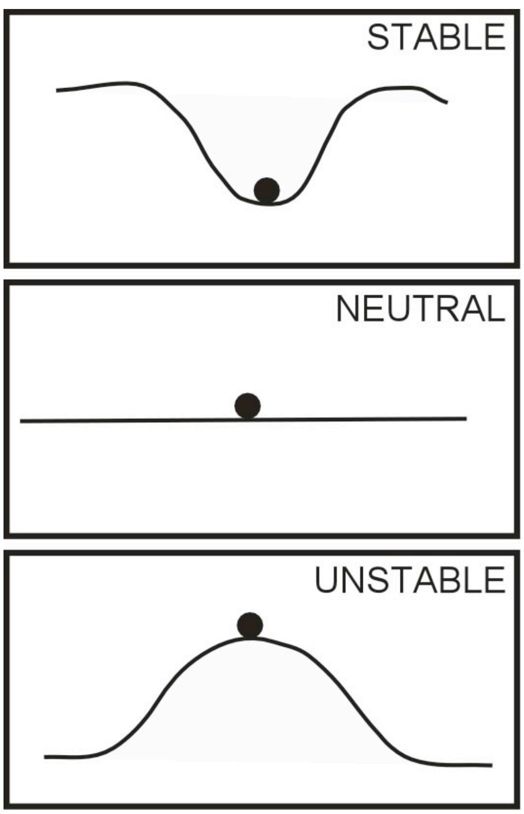
Chapter 6
Atmospheric Stability

The Concept of Stability

Why do we care about atmospheric stability?

A non-atmospheric example of stability:

What happens if we push the ball to the left or right in each figure below?



Air parcel - a distinct blob of air that we will imagine we can identify as it moves through the atmosphere

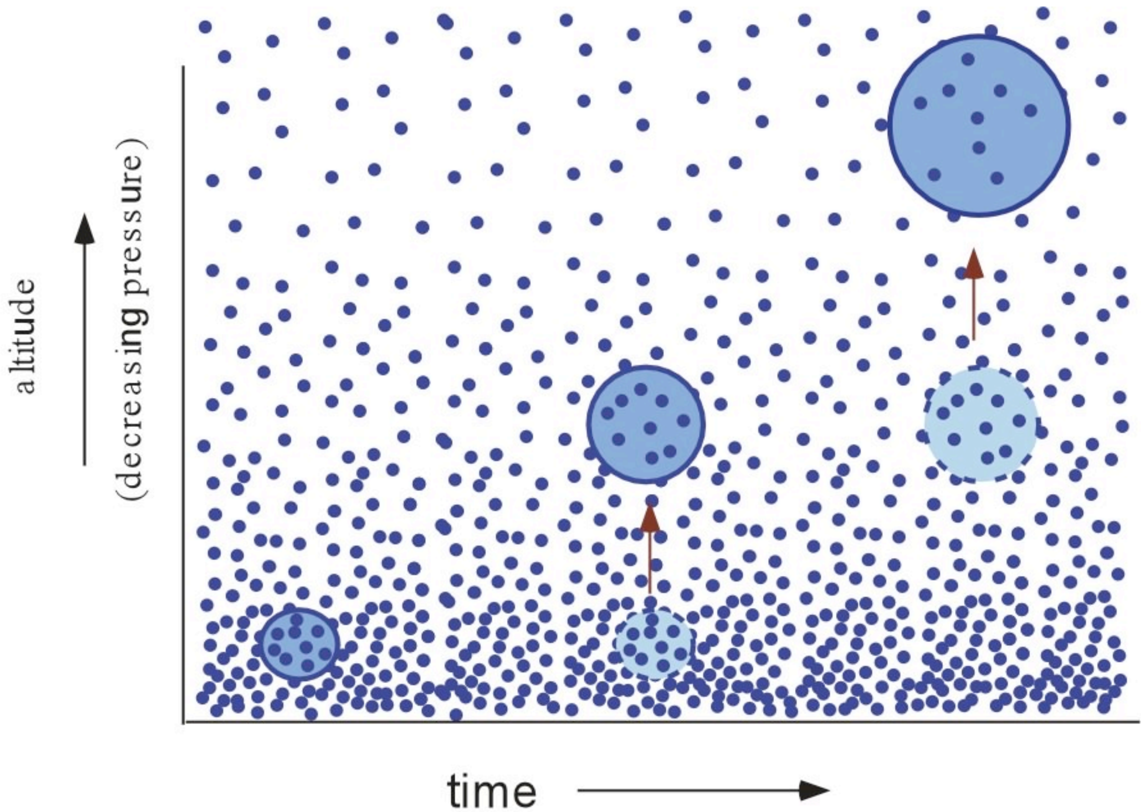
Air parcels and stability:

Stable: if the parcel is displaced vertically, it will return to its original position

Neutral: if the parcel is displaced vertically, it will remain in its new position

Unstable: if the parcel is displaced vertically, it will accelerate away from its original position in the direction of the initial displacement

What happens to the size of an air parcel as it moves vertically in the atmosphere?



An air parcel will expand as it rises because it encounters lower pressure.

An air parcel will compress as it sinks because it encounters higher pressure.

What happens to the temperature of an air parcel as it expands (rises) or compresses (sinks)?

The air parcel cools as it expands (rises).
The air parcel warms as it compresses (sinks).

Adiabatic process – a process in which an air parcel does not mix with its environment or exchange energy with its environment

An air parcel will expand and cool as it rises and will compress and warm as it sinks.

Lapse Rates

Dry adiabatic lapse rate – the rate at which an unsaturated air parcel will cool if it rises or warm as it sinks (applies to an air parcel with a relative humidity of less than 100%)

Dry adiabatic lapse rate = 10 deg C / km

Moist adiabatic lapse rate – the rate at which a saturated air parcel will cool if it rises or warm if it sinks (applies to an air parcel with a relative humidity of 100%)

Moist adiabatic lapse rate = 6 deg C / km (on average in the troposphere)

Why is the moist adiabatic lapse rate different? Why is it less than the dry adiabatic lapse rate?

What happens to a saturated air parcel as it rises?

1. The air parcel will cool as it rises
2. Water vapor will condense as the parcel rises (a cloud forms)
3. As water vapor condenses latent heat is released
4. The latent heat that is released will offset some of the cooling that occurred as the air parcel rose (the amount of latent heat released will vary, but on average will offset about 4 deg C / km of cooling)

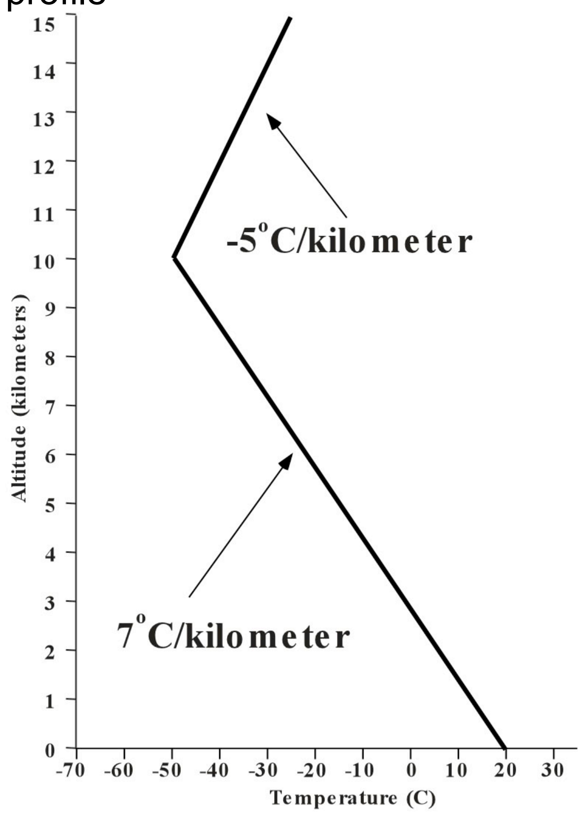
Use the dry adiabatic lapse rate or moist adiabatic lapse rate to determine the temperature of an air parcel as it rises or sinks in the atmosphere.

Environment – the atmosphere outside of an air parcel

Environmental lapse rate – the rate at which the environment's temperature decreases with increasing altitude

Use the environmental lapse rate to determine the temperature of the environment as you move up or down in the atmosphere.

Idealized environmental temperature profile



How do we measure the environmental temperature profile?

Is the environmental temperature profile always the same?

Inversion layer – a layer of the atmosphere where the environmental temperature increases with increasing altitude

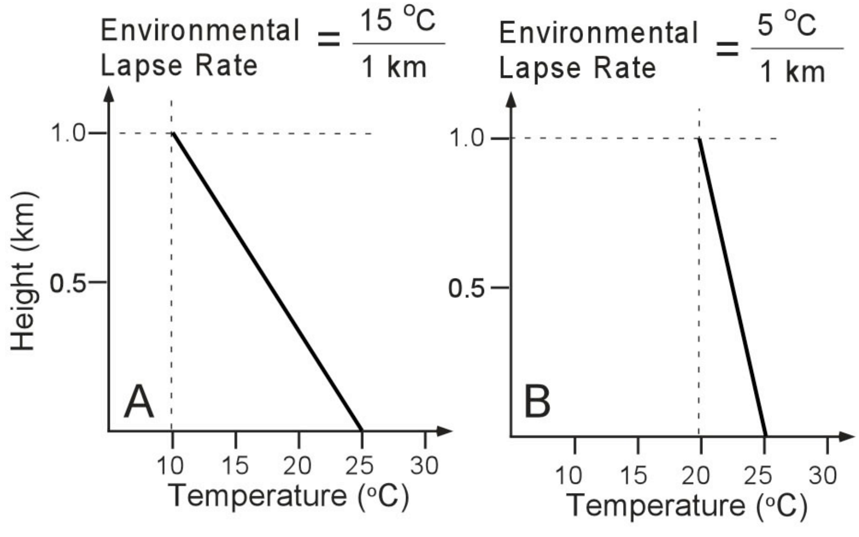
What does a negative environmental lapse rate mean?

Determining Stability

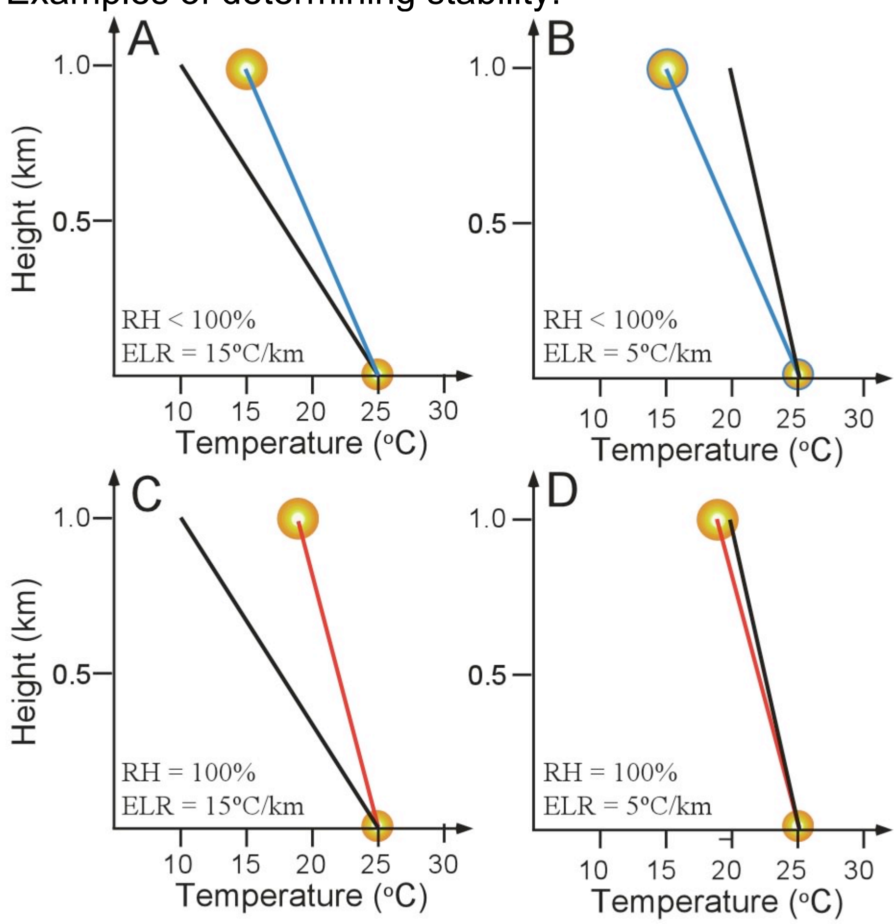
To determine stability we need to compare the temperature of an air parcel to the temperature of its environment.

If an air parcel is warmer than its environment it will rise.
If an air parcel is colder than its environment it will sink.

Two sample environmental temperature profiles:



Examples of determining stability:



For these examples an air parcel starts at the surface, and has the same temperature as the environment at the surface.

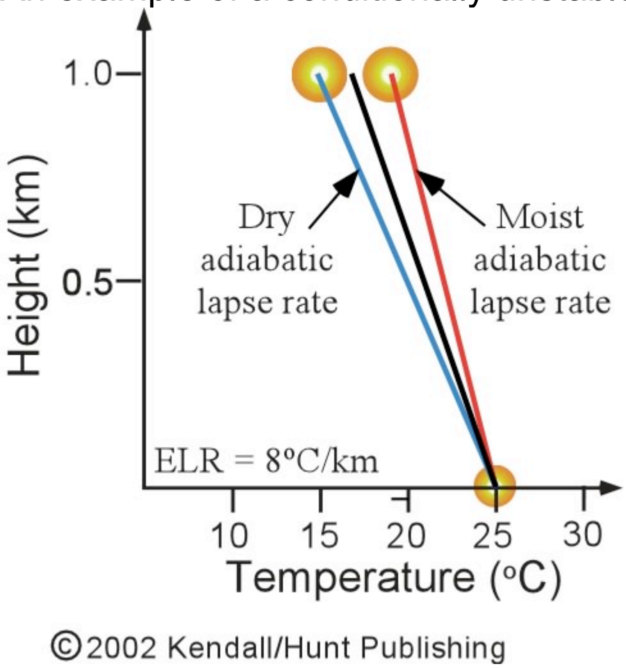
The air parcel is then lifted 1 km.

How does the temperature of the air parcel change as it is lifted?

What is the stability of the air parcel in each panel of this figure?

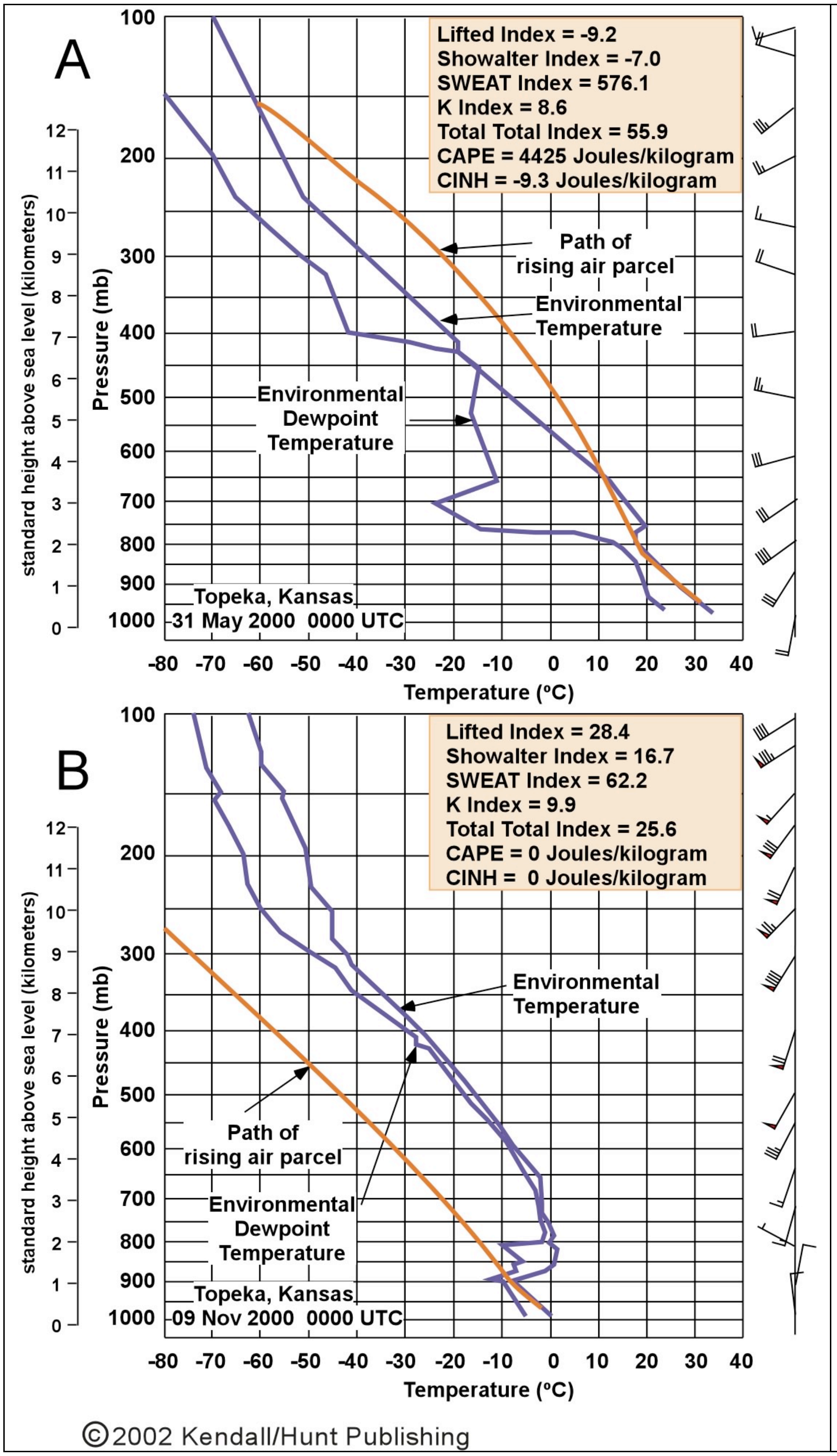
Conditionally unstable – the condition required for instability is that the displaced air parcel is saturated.

An example of a conditionally unstable atmospheric layer:



Summary of Categories of Atmospheric Layer Stability

Environmental Lapse Rate (ELR)	**Stability**
ELR > 10 deg C / km	Unstable
ELR = 10 deg C / km	Neutral if unsaturated Unstable if saturated
6 deg C / km < ELR < 10 deg C / km	Conditionally unstable (see above)
ELR = 6 deg C / km	Neutral if saturated Stable if unsaturated
ELR < 6 deg C	Stable



The environmental temperature profile is often more complex than was shown in the examples above. On the left are two examples of actual environmental temperature profiles and the temperature of an air parcel as it rises through the environment.

What is the stability of the air parcel as it rises through the environmental temperature profile?

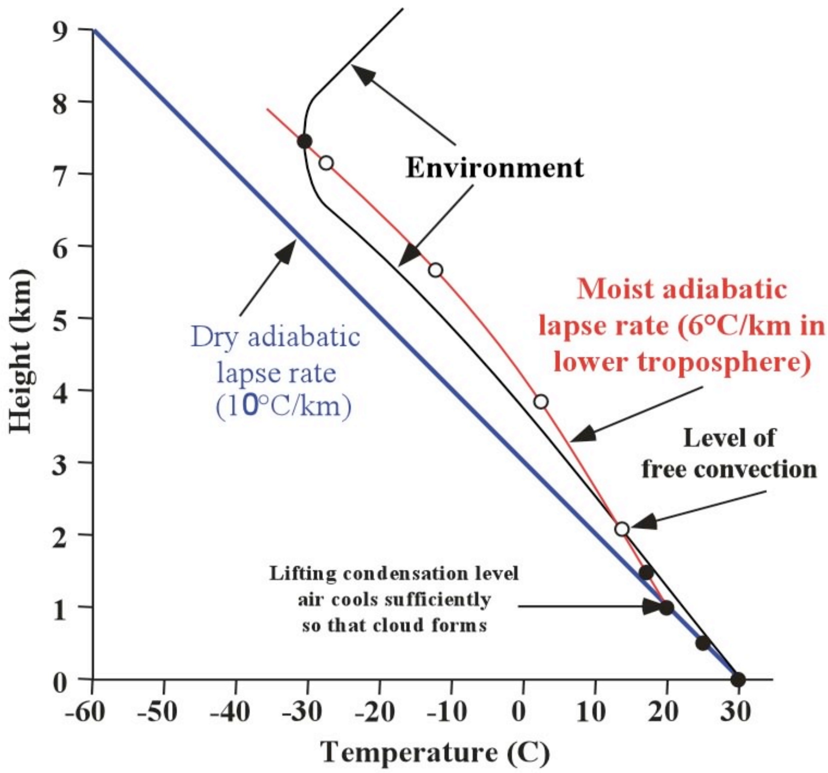
Does the stability change if we look at different levels of the atmosphere?

How can the stability of an atmospheric layer be changed?

What happens to the stability of the lower part of the atmosphere over the course of a day?

Stability and thunderstorm development

Convection – an air parcel rising buoyantly because it is warmer than its environment



What happens to an unsaturated air parcel as it is lifted?

Size
Temperature
Relative humidity

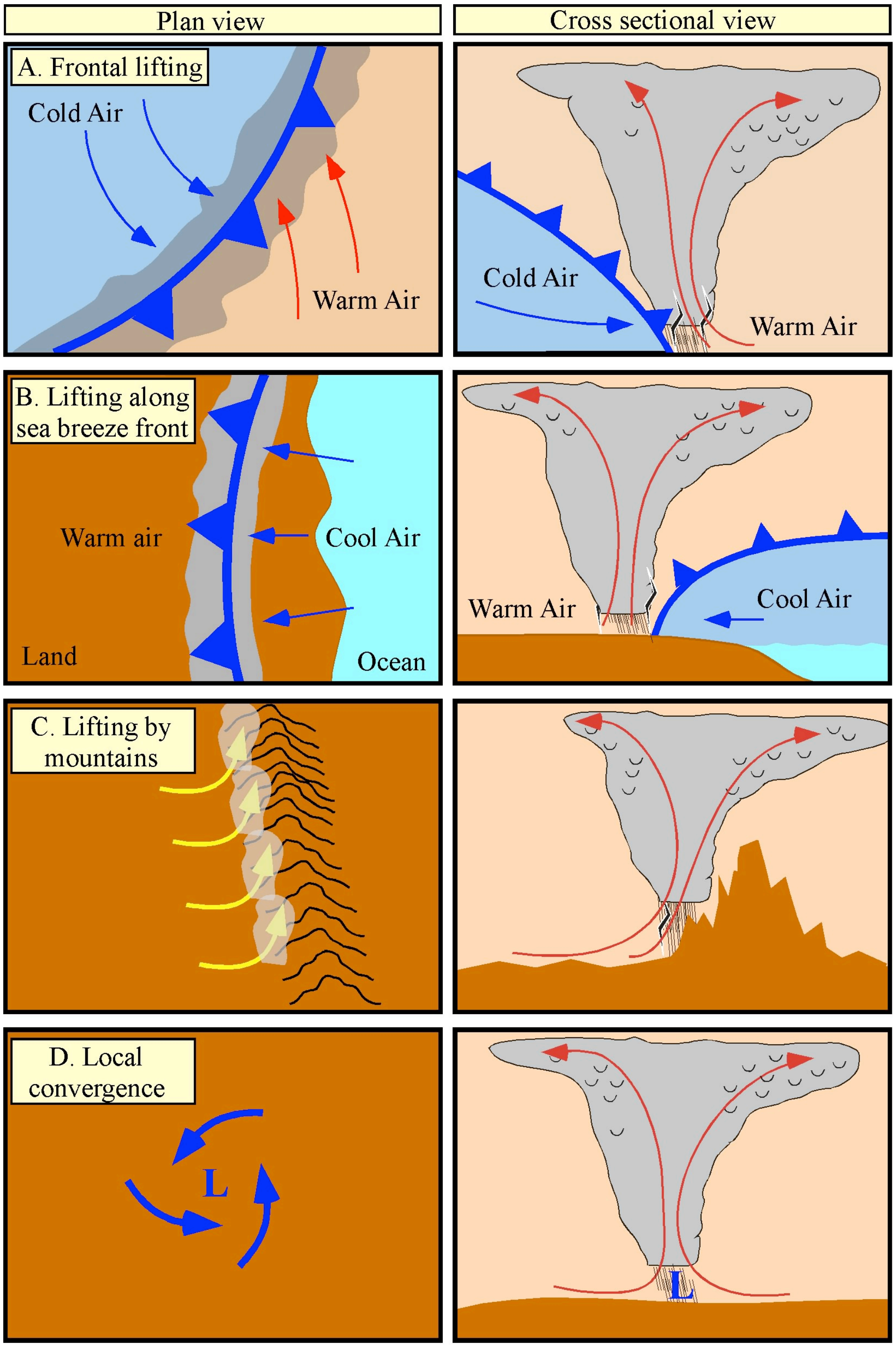
What happens when the relative humidity of the air parcel increases to 100%?

Lifting condensation level – the level where condensation first occurs as an air parcel is lifted (where the relative humidity of the air parcel becomes 100%)

Level of free convection – the level where an air parcel first becomes buoyant (warmer than its environment)

Lifting Mechanisms

How are air parcels lifted in the atmosphere?



Clouds

How do clouds form?

(In class experiment to make a cloud)

Ingredients for a cloud:

1.

2.

How is the 2nd ingredient achieved in the atmosphere?

3.

Do we need a 3rd ingredient? Why?

What serves as the 3rd ingredient?

Clouds form when an air parcel is lifted to the lifting condensation level and condensation occurs

There are four basic types of clouds based on Latin words:

Stratus: “spread out”
layered cloud

Cumulus: “heap”
puffy (cotton ball) cloud

Cirrus: “curl of hair”
wispy cloud

Nimbus: “rain cloud” or “rain storm”
raining cloud

Cloud categories:

There are also four categories based on:
Height/altitude, vertical development, and appearance of the cloud

Low (0-2 km): no special prefix for height
stratus, stratocumulus, nimbostratus

Middle (2-6 km): alto-----
altostratus, altocumulus

High (>6 km): cirrus or cirro-----
cirrus, cirrostratus, cirrocumulus

Vertically developed: cumulus or cumulo----
cumulus, cumulonimbus

Cumuliform clouds occur more in unstable environments when the air parcels undergo a lot of vertical motion

Stratiform clouds occur in more stable environments