

ESCI 107/109 – The Atmosphere
Lesson 5 – Stability

Reading: *Meteorology Today*, Chapter 6

ADIABATIC COOLING AND HEATING

- **The first law of thermodynamics**
 - Heat added to the air can either raise the kinetic energy of the air molecules (increase temperature), or perform work on the surrounding air by expanding
 - A process in which no heat is added or removed is called an *adiabatic* process
- **An air parcel is a volume of air surrounded by an imaginary cover, such as by a very thin balloon.**
- ***Adiabatic cooling* - As an air parcel rises in the atmosphere, it encounters less pressure. It therefore expands, which does work on the surrounding air. Since energy is conserved, this work is performed at the expense of the kinetic energy of the air molecules. This results in a lowering of the parcel's temperature.**
- ***Adiabatic heating* - As an air parcel sinks in the atmosphere, it encounters more pressure. It therefore contracts (shrinks), or has work done on it by the surrounding air. This work results in increased kinetic energy of the air molecules and a higher temperature.**
- **The rate at which the temperature of an unsaturated air parcel changes due to rising or sinking is known as the *dry adiabatic lapse rate*. It is approximately 10°C for every 1 km of altitude (5.5°F per 1000 ft).**

CLOUD FORMATION

- **As a parcel is lifted and cooled adiabatically, eventually its temperature will lower to the saturation point, and the water vapor will condense to form a cloud. The altitude at which this occurs is called the *lifting condensation level (LCL)*.**
- **As the parcel continues to be lifted above the LCL, condensation will continue to occur, and the cloud will get thicker. The process of condensation releases heat. This means that the parcel will not cool as fast as it did when it was unsaturated.**

- The rate at which a saturated parcel cools as it is lifted is called the *wet adiabatic lapse rate* or *moist adiabatic lapse rate*.
- The wet adiabatic lapse rate is different depending on how much moisture is in the air. It is smaller for air with lots of moisture.
- The wet adiabatic lapse rate is always less than the dry adiabatic lapse rate.
- The adiabatic cooling of air is the primary means by which clouds are formed in the atmosphere.
 - If you see a cloud (other than some fog or stratus clouds), you can almost bet that it is there due to upward motion.
 - A lack of clouds does not necessarily mean there is no upward motion. It may just mean that the air is too dry to form a cloud.

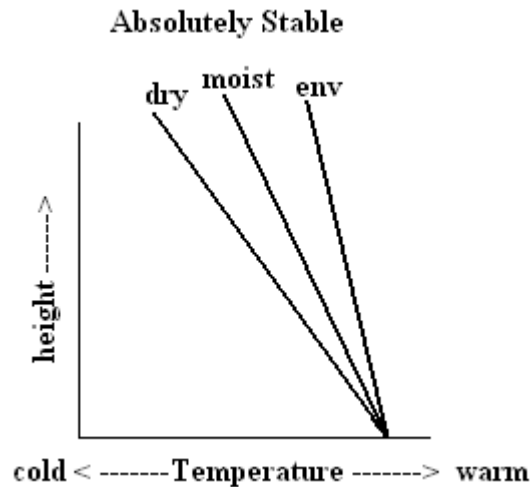
LIFTING PROCESSES

- There are four main processes that lead to lifting of an air parcel.
 - *Orographic lifting* – Lifting caused by air forced to rise a hill or sloping terrain.
 - *Frontal wedging* – Lifting caused by warm air being forced to rise over colder air, such as at a frontal boundary.
 - *Convergence* – Lifting caused by the collision of low-level horizontal air flows. The opposite of convergence is divergence, which results in sinking air.
 - *Convective lifting* – This occurs when a parcel of air becomes less dense than the surrounding air, resulting in it becoming buoyant. Typically this is due to heating, but the addition of moisture can also cause an air parcel to become less dense.

ATMOSPHERIC STABILITY

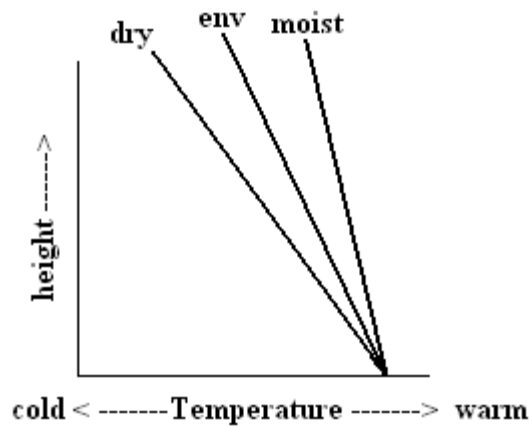
- As an unsaturated air parcel rises it will cool at the dry-adiabatic lapse rate of 10°C per kilometer.
- As a saturated air parcel rises it will cool at the moist-adiabatic lapse rate.

- A saturated air parcel will cool less than an unsaturated air parcel as it rises, because of latent heat release from condensation.
- The moist-adiabatic lapse rate is always less than 10°C per kilometer.
- Stability describes the atmosphere's ability to resist vertical motion.
- Stability is determined by comparing the environmental lapse rate with the dry and moist adiabatic lapse rates.
- Types of stability
 - *Absolutely stable* – The environmental lapse rate is less than both the dry or moist (wet) adiabatic lapse rates. This means that a rising air parcel, either saturated or unsaturated, will be colder than its environment, and will sink back down if bumped upward.



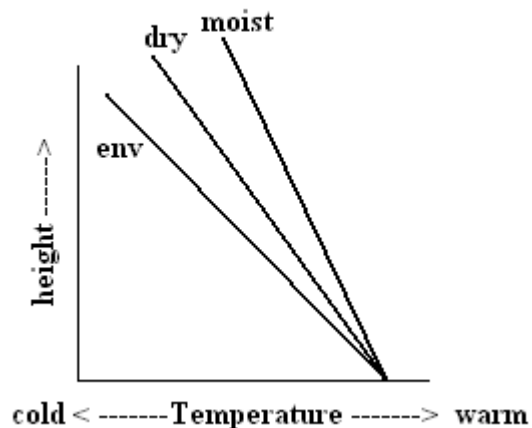
- *Conditionally unstable* (also called *conditionally stable*) – The environmental lapse rate is between the moist and dry adiabatic lapse rates. This means that a rising, unsaturated air parcel will be colder than its environment and sink back down if bumped upward, but a saturated, rising air parcel will be warmer than the environment and continue to rise if bumped upward.

Conditionally Stable/Unstable



- ***Absolutely unstable*** – The environmental lapse rate is greater than both the dry and moist adiabatic lapse rates. This means that a rising air parcel (either saturated or unsaturated) will be warmer than its environment and will continue to rise if bumped upward.

Absolutely Unstable



- You can get an idea of atmospheric stability by just looking at the sky.
 - A stable atmosphere will either have no clouds, or clouds that are spread out horizontally and not very deep (stratiform clouds). If stable air is forced aloft, then the weather will likely be overcast and drizzly.
 - Clouds in an unstable atmosphere will have more vertical development (cumuliform clouds). *Thunderstorms are a sure sign of instability!* Precipitation will usually be more showery, rather than continuous.

- The stability of the atmosphere can change throughout the day.
 - Any process that results in heating the air from below, or cooling it from above, will decrease stability.
 - Lifting of a layer of air will also decrease stability.
 - Any process that results in cooling from below, or heating from above will increase stability.
 - Large-scale downward motion (called *subsidence*) increases stability.

STABILITY AND WIND SPEED AT THE GROUND

- The lowest part of the atmosphere right next to the ground, where friction is important, is called the *planetary boundary layer* or simply *boundary layer*.
- The boundary layer can range from a few 10's of meters to 100's of meters in depth.
- At night and in early morning the coldest temperatures are at the ground. There is therefore a surface inversion in the boundary layer.
- The inversion layer is very stable. This does not allow air from above, where the winds are strong, to reach the ground.
 - This is why the winds often die down at night.
- During the daytime, when the surface warms up, the inversion is mixed away and the boundary layer becomes less stable.
 - This allows high speed air from above to mix down to the ground, causing the wind speeds to increase, and also gusts to occur.