# Important topics for Test #4

**Direct Thermal Circulations** - A direct thermal circulation develops from a heating imbalance (differential heating). This heating leads to a pressure difference (and a PGF). The air moves/circulates in response to the PGF but the Coriolis force does not act because distances are too short. The resulting circulation flows from cold to warm at the surface with rising motion in the warm air.

All of the circulations discussed in this chapter are examples of the direct thermal circulation. The only differences are the methods for creating a warm side and cold side of the circulation.

**Land/Sea Breeze** - A direct thermal circulation which occurs because of the differences in heat capacity between the land and sea. The sea breeze occurs in the daylight hours when the solar radiation heats up the land faster than the ocean. Thus the sea/water is the cold side of the sea breeze. The mountain breeze occurs overnight when the land cools faster than the sea. The land becomes the cold side of the circulation and a land breeze develops.

**Mountain/Valley Breeze** - A direct thermal circulation occurs because of the different warming/cooling rates between the valley and the mountain. The mountain breeze typically occurs overnight when the mountain tops cool faster than the valley. (The additional air in the valley has a greater greenhouse effect.) The flow is down the mountain (cool to warm). For the land breeze, solar radiation at a low solar altitude warms the side of the mountain faster than the valley and the flow is up the mountain.

**Monsoons** - A large scale seasonal version of a direct thermal circulation. Instead of looking at daily heating, monsoons are associated with seasonal heating. The monsoon examine in class is the Indian monsoon where the "sea breeze" circulation which develops in the summer months brings moisture on shore and intense precipitation. This is known as the wet monsoon. During the winter the "land breeze" keeps the moisture away and little rain falls. This is known as the dry monsoon. Note that the actual air temperature differences between summer and winter are quite small, the change in moisture is the dominant seasonal effect.

**Chinook and Katabatic Winds** - Some mountain breezes are quite extreme. The two basic types of strong mountain breezes are the Chinook and Katabatic winds. The Chinook winds are force down the mountain by upper level flow and are warmer than the air in valley (also drier). Consequently they melt and evaporate snow quickly. This wind has regional names (e.g. Santa Anna wind in California). The katabatic winds are very cold and heavy. They flow down the mountain forced by gravity and are colder than the air in the valley. They can exceed 70 mph.

**Thunderstorm Life Cycle** - The thunderstorm development is a three stage process:

**Cumulus Stage** - the beginning stage of a thunderstorm. Lifting mechanism and an unstable atmosphere produce an updraft and a cumulus cloud. Evaporative cooling on the top of the cloud helps to further destabilize the air leading to further development.

**Mature Stage** - the stage which begins with the formation of the downdraft also assumed to begin when precipitation falls. Here evaporative cooling has created a pocket of cold air which falls toward the earth as the downdraft. When the downdraft hits the surface it spreads out forming a mini-cold front known as the gust front. The continued supply of moisture into the storm allows the precipitation to continue. As the gust front expands it will cut off the updraft leading to the death of the thunderstorm.

**Dissipation Stage** - This stage has no updrafts only downdrafts. The storm is "raining out" at this point.

Additional components of the thunderstorm are: the shelf cloud, over shooting tops, and the anvil. Note that the life cycle of an individual cell is typically less than one hour. Often new cells are forming as the old cells are dissipating. These cells normally form where there is lifting, unstable air, and a supply of moisture (often to the southeast of an existing cell in the midwest).

**Storm and Cell Motion** - The movement of individual cells of a storm and the overall motion of the storm are often different. Most of the time the storm moves to the right of the cell motion (known as right moving storms). In heavy rain cases, we often find the storm motion is nearly zero but the cells move across the storm (e.g. a cell develops on the western edge of the storm and moves to the eastern edge, another cell develops where the first one did and also move to the east).

**Types of Thunderstorms** - Thunderstorms are classified as: 1) Single cell thunderstorms, 2) Squall lines, or 3) Supercells 4) Mesoscale convective systems. The last three are special types that result in the storms lasting a long time. See notes for discussion of each type.

**Ingredients for Development** - Thunderstorms require:

- Warm and moist air (i.e. mT air mass)
- Lifting
- Unstable conditions or destabilizing conditions.
- A supply of moisture
- Dry air aloft (enhancing evaporative cooling)

and severe thunderstorms develop with the addition of:

- Inversions (lid on atmosphere)
- Low level jet (pipeline of moisture)
- Interactions with the jet stream flow (See homework).

**Lightning** - An electrical discharge which is essentially the flow of current. The electrical potential (volts) is the charge separation and the current (amps) is the flow of charge particles. Lightning typical has large voltages (1-3 million volts) but low current (less than 1 amp). This is different than typical electrical current in your house where we have 110 volts and 15 amps from a given outlet. Lightning proceeds in a series of steps until the path for the current is established once the current is established the return stroke is the bright flash we see as the bolt of lightning.

**Funnel cloud** - A tornado which is not in contact with the ground.

**Mesoscyclone** - A rotating circulation within the storm from which the tornado forms. Below the cloud base and around the mesocyclone a wall cloud is often found. Once thought 50% of all mesocyclones generate a tornado (but more like 10-20%). Note mesocyclones are large enough to be detected by doppler radar.

**Fujita Scale** - The ranking of tornados is based on the Fujita scale with F0 being the weakest and most common tornados while F5 being the strongest and rarest tornados. This ranking is based upon damage!

**Formation** - Tornadoes tend to form from mesocyclones which develop from severe thunderstorms which have rotation. This rotation can be horizontal (i.e. flow around a low) or through vertical wind sheer.

**Hurricane Stages** - The hurricane stages are: 1) easterly wave, 2) tropical depression, 3) tropical storm, and 4) hurricane. The storm receives a name once it becomes a tropical storm.

**Hurricane Formation** - Hurricanes form:

- over warm ocean waters,
- with low level convergence and upper level divergence,
- at least $5^\circ$ away from the equator.

Hurricanes get their initial rotation from the Coriolis force. They use latent heating to heat the center of the storm, lowering the pressure and increasing the hurricane's strength. After developing the initial rotation the Coriolis force is not as important and the major balance is the PGF against the Ce force. The strongest winds are in the eye wall and the eye develops as the hurricane increases in strength. Rainfall is found in spiraling bands with the heaviest rainfall in the eye wall. Tornadoes are formed from the "spin down" after the hurricane makes landfall. The damage is caused by 1) winds, 2) tornados, 3) flooding, 4) lightning and 5) the storm surge.