1. (5 points) What is the difference between freezing rain and sleet?

Both freezing rain and sleet occur when a portion of the atmosphere above the surface reaches temperatures above 0°C. The difference between the two is the depth of the atmosphere below the inversion that is below freezing. For sleet to occur, there must be a relatively deep freezing layer below the warm layer, so that the liquid droplets have an opportunity to re-freeze before hitting the ground. For freezing rain to occur, the lowest freezing layer must be very shallow so that the liquid drops do not have an opportunity to re-freeze, thus forming supercooled droplets that freeze upon contact with a surface.

2. (10 points) List and describe the three ways in which ice crystals can grow in a cloud.

Vapor deposition (Diffusional growth) – The vapor pressure over an ice crystal is much lower than that over a liquid droplet. Because atmospheric properties tend to move from regions of higher pressure to regions of lower pressure, water vapor surrounding liquid droplets tends to diffuse towards the ice crystals and deposit on them. This creates a deficit of water vapor above the droplet, which evaporates to make up for it. The newly evaporated water vapor also diffuses to the ice crystal, so that the ice crystal grows at the expense of the water droplet.

Accretion – As ice particles fall through the cloud at a higher velocity than cloud droplets, it collides and collects the supercooled droplets, which freeze upon contact with the crystal. The collected droplets are known as rime.

Aggregation – Ice crystals falling through the cloud can collide with each other and stick together. This process is particularly efficient at temperatures near 0°C, because the thin liquid water coating that forms on the partially melted crystals can act as an adhesive between the crystals.

3. (5 points) Explain why most deserts are located at 30° north and south latitude.

The subsiding branch of the Hadley Cell is located at 30° north and south latitudes. As the air sinks, it warms and compresses. Because warm air has a higher capacity to hold water vapor than cold air, increased evaporation occurs, preventing cloud formation and precipitation, as well as evaporating any moisture that may have existed on the surface.
4. (5 points) Why is a warm, tropical cumulus cloud more likely to produce precipitation than a cold, stratus cloud?

The most efficient way for rain drops to form is through the collision-coalescence process. In this process, larger cloud droplets fall through the cloud at a higher velocity than smaller ones. As the large droplet falls, it collects the smaller drops in its path, increasing in size. A tropical cumulus cloud is well developed in the vertical, so a falling droplet has a long distance to travel to the cloud base, and therefore more opportunities to collect smaller droplets and grow larger. In the cold stratus cloud, a droplet does not have very far to fall, and therefore it is less likely the drop will grow to a size that will be able to overcome the clouds updraft and leave the cloud as precipitation.

5. (5 points) How can snow be falling when the air temperature is above freezing?

If the atmosphere below a cloud that is producing snow is above freezing and dry enough, the precipitation particles can partially evaporate as they are falling through the air. Because latent heat is absorbed as the rain or snowflake evaporates, this can cool the air enough to allow the snowflake to fall to the ground without melting.

6. (5 points) Why do some hailstones have alternating opaque and transparent layers?

As a growing makes its multiple trips through a cloud, it can encounter regions of varying temperature and liquid water content. In the wet growth regime, the hailstone is in a region of high liquid water, and the condensation of water vapor onto the hailstone releases enough heat to keep the surface of the stone very near 0°C. This creates a liquid water coating on the surface of the stone, from which air bubbles can escape before the stone is transported into a colder region of the cloud where the water can freeze, resulting in a clear layer. In the dry growth regime, the stone is in a region of the cloud that is colder and has a lower liquid water content, so that the supercooled water droplets freeze onto the stone so rapidly that air bubbles do not have an opportunity to escape, causing the stone to appear opaque.
7. (5 points) Why is hail more common in the summer than in the winter?

Hailstones form when an ice particle gets carried up and down through a cloud multiple times by up and downdrafts, where it collects a very large number of supercooled droplets. Therefore, hail requires a very deep cumulonimbus cloud to form. These clouds only form in very unstable air, where strong vertical motions allow for deep convective cloud development. In the winter, surface heating is not strong enough to warm temperatures enough to support such growth. In the summer, however, longer days and more direct sunlight results in much stronger surface heating, and therefore the convective energy necessary to form cumulonimbus clouds.

8. (5 points) Explain why regions just to the east of the Rocky Mountains receive less precipitation than the regions to the west.

The lee of the Rockies is found in what is known as a rain shadow. As air is forced up the western slopes of the Rockies, it cools and condenses, resulting in precipitation on this side of the mountains. When the air travels over the peak of the mountain and begins to descend on the other side, it compresses and warms, resulting in evaporation of any moisture remaining in the parcel. The sinking air suppresses any upward motion necessary for cloud development, as well as evaporate any moisture present in the atmosphere, as well as resulting in increased evaporation at the surface.
There is a lake effect snow event occurring on this day. Surface winds to the north of the lake are northwesterly, while winds to the south of the lake are southwesterly. This results in convergence over the center of the lake. Additionally, the darker color of the lake in this picture indicates that the lake surface is not frozen, yet the air temperature of the surface stations around it is well below freezing. As this cold air travels over the warm lake surface, the air becomes unstable, and the warm air from directly above the lake must rise, cool, and condense to form the band of clouds seen in the center of the lake. The westerly component of the winds seen at all stations around the lake pushes the band of clouds to the west over the land, all the while continuing to form more clouds behind it. The combination of these conditions is resulting in a lake effect snow event in the Buffalo area. If the conditions persist, significant snowfall will occur in this region.