CHAPTER 6 – Lectures 12-15
Atmospheric Moisture and Precipitation

I. Water The Global Perspective: Water plays a key role in the energy flows that shape our planet's climate and weather. Ocean currents act to carry solar energy and latent heat poleward. Precipitation over land also provides water (and ice) that can move under the influence of gravity, carving the landforms and landscapes that provide the Earth's varied surfaces.

A. Three States of Water - Water can exist in three states – solid (ice), liquid (water), and gas (water vapour). Changes of state from solid to liquid, liquid to gas, and solid to gas requires latent heat energy. A change of state from liquid to solid, gas to liquid, or gas to solid releases latent heat.

B. The Hydrosphere and the Hydrologic Cycle - The hydrosphere includes water in all of its forms: 97.2% is ocean saltwater; 2.8% is fresh water; 2.15% is frozen in glaciers and ice sheets. Very small amounts make up ground water, soil water, and the water in the atmosphere. The movement of all of this water makes up the hydrologic cycle. Water moves from land and ocean to the atmosphere and atmospheric water returns to the land and ocean as precipitation.

II. Humidity: The amount of water vapor present in the air varies widely from place to place and time to time. Humidity refers to the amount of water vapour present in the air. Warm air can hold more water vapour than cold air. Air at room temperature (20°C) can hold about three times as much water vapour as air at 0°C.

A. Specific Humidity - The actual quantity of water vapor held by a parcel of air. Specific humidity is the mass of water vapour contained in a given mass of air and is expressed as grams of water vapour per kilogram of air (g/kg). Specific humidity is a measure of the quantity of water in the atmosphere that can be extracted as precipitation.

B. Relative Humidity - This measure compares the amount of water vapour present in air to the maximum amount that the air can hold at a specific temperature. It is expressed as a percentage. A change in relative humidity of the atmosphere can happen in one of two ways, through direct gain or loss of water vapour or through a change of temperature. Relative humidity is measured with a sling psychrometer.

III. The Adiabatic Process: The adiabatic process refers to the heating or cooling of parcels of air that occurs solely as a result of pressure change.

A. Dry Adiabatic Rate - Describes the behavior for a rising air parcel that has not reached saturation. This is a fixed rate of 10°C per 1000 meters of vertical rise. The dry rate refers to the fact that condensation has not occurred.

B. Wet Adiabatic Rate - The cooling rate for saturated air is called the wet adiabatic lapse rate and ranges between 4 and 9°C per 1000m. It is variable because it depends on the temperature and pressure of the air and its moisture content. For most saturation we can use a value of 5°C/1000m. The higher rates apply only to cold, relatively dry air that contains little moisture and therefore little latent heat.

IV. Clouds: A cloud is made up of water droplets or ice particles suspended in air. These particles have a diameter in the range of 20 to 50 μm. Each cloud particle is formed on a tiny centre of solid matter, called a condensation nucleus.

A. Cloud Forms - Clouds are classified into four families, arranged by height; high, middle, and low clouds, and clouds with vertical development. They are grouped into two major classes on the basis of form – stratiform, and cumuliform. Stratiform clouds are blanket-like and cover large areas. Cumuliform clouds are globular masses that are associated with small to large parcels of rising air.

B. Fog - Fog is a cloud layer at or very close to the surface. There are two major types of fog – advection and radiation. Radiation fog forms at night when the temperature of the air layer at the ground level falls below the dew point. It is associated with low-level temperature inversions. Advection fog results when a warm moist layer moves over a cold surface (a common occurrence over oceans) Sea fog, another form, is produced when a cool marine air layer comes into contact with the cold sea. This is common along the west coast of continents.

V. Precipitation: Clouds are the source of precipitation. It forms in two ways. In warm clouds, fine water droplets condense, collide, and coalesce into larger and larger droplets that can fall as rain. In colder clouds, ice crystals form and grow in a cloud that contains a mixture of both ice crystals and water droplets. Precipitation comes in four basic forms: rain, snow, sleet, and hail. Precipitation is measured in units of depth of fall per unit of time – for example, centimeters or inches per hour or per day.

A. Precipitation Processes - These are processes that cause air to move upwards and then cool down to dewpoint. Air can move upward in three ways. First, it can be forced upward as a through-flowing wind. Second, air can be forced up through convection. Third, air can be forced up through the movement of air masses.

B. Orographic Precipitation - Through-flowing winds are carried over mountains. As the air rises on the windward side of the range, it is cooled at the dry adiabatic rate. When cooling is sufficient, condensation sets in and clouds form. Cooling proceeds at the wet adiabatic rate and precipitation begins. After passing over the mountain summit, the air begins to descend the leeward slope. It is compressed and warmed and the cloud droplets and ice crystals evaporate or sublimate.

C. Convectional Precipitation - Strong updrafts occur within convection cells – vertical columns of rising air that are often found above warm land surfaces. As the

cell rises, it is cooled adiabatically and its temperature decreases as it rises. If the cell remains warmer than the surrounding air and uplift continues, adiabatic cooling chills the cell below dewpoint. Condensation occurs, and the rising air column becomes a cumulus cloud. The flat base of the cloud marks the lifting condensation level at which condensation begins.

D. Unstable Air - This is air that continues to lift strongly, developing into dense cumulonimbus masses. Two environmental conditions encourage their development:

1. air that is very warm and moist
2. an environmental temperature lapse rate in which temperature decreases more rapidly with altitude than it does for either the dry of wet adiabatic lapse rates

E. Thunderstorms - Intense local storms associated with a tall, dense cumulonimbus cloud in which there are very strong updrafts of air. These storms can produce extensive damage, including millions of dollars of crop loss, and can generate lightning.

F. Microbursts - The downdraft that accompanies a thunderstorm can sometimes be very intense. This type of intense downdraft is called a microburst. The downward-moving air flows outward in all directions. It is often, but not always, accompanied by rain.

VI. Air Quality: One of the significant human impacts on our planet is air pollution. Industrial processes and fossil fuel combustion release large quantities of unwanted and unhealthy substances into the air.

A. Smog and Haze - Smog is a combination of smoke and fog. It allows hazy sunlight to reach the surface. Smog may reduce as much as twenty percent of visible sunlight from reaching the surface. Ozone is a major component of smog and is generally produced by a photochemical reaction triggered by the sun when nitrogen oxides react with hydrocarbons. Haze is simply a condition resulting when a large quantity of aerosols obscure distant objects.

B. Fallout and Washout - Large particulates in the atmosphere “fallout” over a short period of time due to the influence of gravity. Lighter, smaller particles “washout” with precipitation.

C. Inversion and Smog - Heat inversions are hazardous to urban communities because they trap pollutants in a low layer near the surface. Both low-level and high-level inversions trap many poisonous industrial discharge gases and auto exhausts in the very lowest parts of the environment.

D. Climatic Effects of Urban Air Pollution - Urban air pollution reduces visibility and illumination. Smog layers can cut illumination by 10 percent in the summer and 20 percent in winter. Ultraviolet radiation is absorbed by ozone in smog. Although it

reduces the risk of skin cancer, it permits increased viral and bacterial activity at ground level. Fog is enhanced by the abundance of aerosols and particulates.

E. Acid Deposition - Includes acid rain and dry acidic dust particles. Acid rain simply consists of raindrops that have been acidified by air pollutants. Dry acidic particles are dust particles that are acidic in nature. They fall to Earth and coat the surface in a thin dust layer, and when wet, acidify the water on leaves and soils. A primary effect is the acidification of lakes and streams which injure aquatic plants and animals. A secondary effect is soil damage.

F. Air Pollution Control - The United States and Canada have some of the strictest laws in the world limiting air pollution. Alternative energy sources, emission control of automobiles, and "smokestack" factories, and the trapping and processing of pollutants as they are produced, are all strategies to control air pollution. As the human population continues to grow, these problems will be more difficult to solve.