Moisture, Clouds, and Precipitation

Learning Objectives

After reading, studying, and discussing the chapter, students should be able to:

- List the processes that cause water to change from one of state of matter to another.
- Explain saturation, vapor pressure, mixing ratio, relative humidity, and dew point.
- Describe how relative humidity is determined.
- Explain the basic cloud-forming process.
- List the processes that initiate the vertical movement of air.
- Describe stable and unstable air.
- Discuss the conditions necessary for condensation.
- List the criteria used to classify clouds.
- Describe the formation of fog.
- Discuss the formation and forms of precipitation.

Chapter Outline_____

I. Changes of state of water
    A. Heat energy
        1. Measured in calories —1 calorie is the heat necessary to raise the temperature of 1 gram of water 1 degree Celsius
        2. Latent heat
            a. Stored or hidden heat
            b. Not derived from temperature change
            c. Important in atmospheric processes
    B. Three states of matter
        1. Solid
        2. Liquid
        3. Gas
    C. For substance to change state, heat must be
        1. Absorbed or
        2. Released
    D. D. Processes
        1. Evaporation
            a. Liquid is changed to gas
            b. 600 calories per gram of water are added—called latent heat of vaporization
        2. Condensation
            a. Water vapor (gas) is changed to a liquid
            b. Heat energy is released—called latent heat of condensation
        3. Melting
            a. Solid is changed to a liquid

b. 80 calories per gram of water are added—called latent heat of melting

4. Freezing
    a. Liquid is changed to a solid
    b. Heat is released—called latent heat of fusion
5. Sublimation
    a. Solid is changed directly to a gas (example: ice cubes shrinking in a freezer)
    b. 680 calories per gram of water are added
6. Deposition
    a. Water vapor (gas) changed to a solid (example: frost in a freezer compartment)
    b. Heat is released

II. II. Humidity

A. Amount of water vapor in the air
    1. Saturated air is air that is filled with water vapor to capacity
    2. Capacity is temperature dependent— warm air has a much greater capacity than cold air
    3. Water vapor adds pressure (called vapor pressure) to the air

B. Measuring humidity
    1. Mixing ratio
        a. Mass of water vapor in a unit of air compared with the remaining mass of dry air
        b. Often measured in grams per kilogram
    2. Relative humidity
        a. Ratio of the air's actual water vapor content compared with the amount of water vapor required for saturation at that temperature (and pressure)
        b. Expressed as a percent
        c. Saturated air
            1. Content equals capacity
            2. Has a 100 percent relative humidity
        d. Relative humidity can be changed in two ways
            1. Add to or subtract moisture from the air
                i. Adding moisture raises the relative humidity
                ii. Removing moisture lowers the relative humidity
            2. Changing the air temperature
                i. Lowering the temperature raises the relative humidity
                ii. Raising the temperature lowers the relative humidity
        e. Dew point temperature
            1. Temperature to which a parcel of air would need to be cooled to reach saturation
            2. Cooling the air below the dew point causes condensation
                i. Examples: dew, fog, or cloud formation
                ii. Water vapor requires a surface on which to condense
        f. Two types of hygrometers are used to measure humidity

1. Psychrometer
    i. Compares temperatures of Wet-bulb thermometer and Dry-bulb thermometer
    ii. If the air is saturated (100% relative humidity) then both thermometers read the same temperature
    iii. The greater the difference between the thermometer readings, the lower the relative humidity
2. Hair hygrometer reads the humidity directly

III. Adiabatic heating/cooling
- A. Adiabatic temperature changes occur when
    1. Air is compressed
        a. Motion of air molecules increases
        b. Air becomes warmer
        c. Descending air is compressed owing to increasing air pressure
    2. Air expands
        a. Air parcel does work on the surrounding air
        b. Air becomes cooler
        c. Rising air expands owing to decreasing air pressure
- B. Adiabatic rates
    1. Dry adiabatic rate
        a. Unsaturated air
        b. Rising air expands and cools at 1°C per 100 meters (5.5°F per 1000 feet)
        c. Descending air is compressed and warms at 1°C per 100 meters
    2. Wet adiabatic rate
        a. Commences at condensation level
        b. Air has reached the dew point
        c. Condensation is occurring and latent heat is being liberated
        d. Heat released by the condensing water reduces the rate of cooling
        e. Rate varies from 0.5°C to 0.9°C per 100 meters

IV. Processes that lift air
- A. A. Orographic lifting
    1. Elevated terrains act as barriers
    2. Result can be a rainshadow desert
- B. Frontal wedging
    1. Cool air acts as a barrier to warm air
    2. Fronts are part of the storm systems called middle-latitude cyclones
- C. Convergence occurs where the air is flowing together and rising
- D. Localized convective lifting occurs where unequal surface heating causes localized pockets of air to rise because of their buoyancy

V. V. Stability of air
- A. Types of stability
    1. Stable air

a. Resists vertical displacement
    1. Cooler than surrounding air
    2. Denser than surrounding air
    3. Wants to sink
b. No adiabatic cooling
c. Absolute stability occurs when the environmental lapse rate is less than the wet adiabatic rate
d. Often results in widespread clouds with little vertical thickness
e. Precipitation, if any, is light to moderate

2. Absolute instability
a. Acts like a hot-air balloon
b. Rising air
    1. Warmer than surrounding air
    2. Less dense than surrounding air
    3. Continues to rise until it reaches an altitude with the same temperature
c. Adiabatic cooling
d. Environmental lapse rate is greater than the dry adiabatic rate
e. Clouds are often towering
f. Conditional instability occurs when the atmosphere is stable for an unsaturated parcel of air but unstable for a saturated parcel

B. Determines to a large degree
1. Type of clouds that develop
2. Intensity of the precipitation

VI. Condensation and cloud formation

A. Condensation
1. Water vapor in the air changes to a liquid and forms dew, fog, or clouds
2. Water vapor requires a surface on which to condense
a. Possible condensation surfaces on the ground can be the grass, a car window, and so forth
b. Possible condensation surfaces in the atmosphere are tiny bits of particulate matter
    1. Called condensation nuclei
    2. Dust, smoke, and similar particles
    3. Ocean salt crystals that serve as hygroscopic (“water seeking”) nuclei

B. Clouds
1. Composition
a. Millions of minute water droplets or
b. Millions of tiny crystals of ice
2. Classification
a. Form (three basic forms)
    1. Cirrus—high, white, thin
    2. Cumulus

i. Globular cloud masses
ii. Often associated with fair weather

3. Stratus
   i. Sheets or layers
   ii. Cover much or all of the sky

b. Height

1. High clouds
   i. Above 6000 meters
   ii. Types
      1. Cirrus
      2. Cirrostratus
      3. Cirrocumulus

2. Middle clouds
   i. 2000 to 6000 meters
   ii. Types (alto is part of the name)
      1. Altocumulus
      2. Altostratus

3. Low clouds
   i. Below 2000 meters
   ii. Types
      1. Stratus
      2. Stratocumulus
      3. Nimbostratus (nimbus means "rainy")
      4. Clouds of vertical development
         a. Extend from low to high altitudes
         b. Called cumulonimbus
         c. Often produce Rain showers and Thunderstorms

VII. Fog

A. Considered an atmospheric hazard
B. Cloud with its base at or near the ground
C. Formation
   1. Radiation cooling or
   2. Movement of air over a cold surface
D. Types of fog
   1. Fogs caused by cooling
      a. Advection fog—warm, moist air moves over a cool surface
      b. Radiation fog
         1. Earth's surface cools rapidly
         2. Forms during cool, clear, calm nights
      c. Upslope fog
         1. Humid air moves up a slope
         2. Adiabatic cooling occurs 2
   2. Evaporation fogs
      a. Steam fog

1. Cool air moves over warm water and moisture is added to the air
2. Water has a steaming appearance

b. Frontal, or precipitation, fog
1. Forms during frontal wedging when warm air is lifted over colder air
2. Rain evaporates to form fog

VIII. Precipitation

A. Cloud droplets
1. Less than 20 micrometers (0.02 millimeter) in diameter
2. Fall incredibly slowly

B. Formation of precipitation
1. Bergeron process
a. Temperature in the cloud is below freezing
b. Ice crystals collect water vapor
c. Large snowflakes form and 1
1. Fall to the ground as snow or
2. Melt on their descent and form rain
d. Dominant in the middle latitudes
2. Collision–coalescence process
a. Warm clouds
b. Large hygroscopic condensation nuclei
c. Large droplets form
d. Droplets collide with other droplets during their descent
e. Common in the tropics

C. Forms of precipitation
1. Rain and drizzle
a. Rain—droplets have at least a 0.5- mm diameter
b. Drizzle—droplets have less than a 0.5-mm diameter
2. Snow—ice crystals or aggregates of ice crystals
3. Sleet and glaze
a. Sleet
1. Wintertime phenomenon
2. Small particles of ice
3. Occurrence
i. Warmer air overlies colder air
ii. Rain freezes as it falls
b. Glaze, or freezing rain—impact with a solid causes freezing
c. Hail
1. Hard rounded pellets
i. Concentric shells
ii. Most diameters range from 1 to 5 cm
2. Formation
i. Occurs in large cumulonimbus clouds with violent up- and downdrafts

ii. Layers of freezing rain are caught in up- and downdrafts in the cloud
iii. Pellets fall to the ground when they become too heavy

d. Rime
1. Forms on cold surfaces
2. Freezing of
i. Supercooled fog or
ii. Cloud droplets

D. Measuring precipitation
1. Rain
a. Easiest form to measure
b. Measuring instruments
1. Standard rain gauge . Funnel collects and conducts rain
2. Cylindrical measuring tube measures rainfall in centimeters or inches
2. Snow
a. Depth
b. Water equivalent
1. General ratio is 10 snow units to 1 water unit
2. Varies widely
3. Radar is also used to measure the rate of rainfall