Hewitt/Lyons/Suchocki/Yeh

# *Conceptual Integrated Science*

Chapter 26

WEATHER



## Weather and Climate

Weather is defined as the state of the atmosphere at a particular time and place.

Climate is the general pattern of weather that occurs in a region over a period of years.

Weather is short term, climate is long term.



## Weather and Climate

The six weather elements include:

- Atmospheric pressure
- Temperature
- Wind
- Precipitation
- Cloudiness
- Humidity



## Atmospheric Pressure

Atmospheric pressure = force the atmosphere exerts on an area of surface.

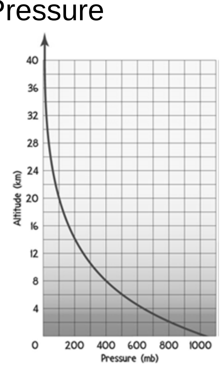
- Force = weight of air molecules above that surface.
- At any level in the atmosphere, force = total weight of air above that level.
- At higher elevations, fewer air molecules above—atmospheric pressure is less.



## Atmospheric Pressure

**Table 25.1** Equivalent Measurements for Atmospheric Pressure

| |
|---|
| 1 standard atmosphere (1 atm) |
| 101,325 pascals |
| 1.013 bars |
| 14.7 pounds per square inch (14.7 psi or 14.7 lb/in$^2$.) |
| 760 torr |
| 760 millimeters of mercury (760 mm Hg) |






## Composition of Atmosphere

**Table 25.2** Composition of the Atmosphere

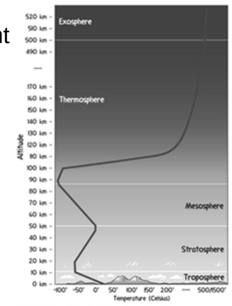
| Gas | Symbol | Percentage by Volume | Gas | Symbol | Percentage by Volume |
|---|---|---|---|---|---|
| *Permanent Gases* | | | *Variable Gases and Particulates* | | |
| Nitrogen | $N_2$ | 78 | Water vapor | $H_2O$ | 0 to 4 |
| Oxygen | $O_2$ | 21 | Carbon dioxide | $CO_2$ | 0.038 |
| Argon | Ar | 0.9 | Ozone | $O_3$ | 0.000004* |
| Neon | Ne | 0.0018 | Carbon monoxide | CO | 0.00002* |
| Helium | He | 0.0005 | Sulfur dioxide | $SO_2$ | 0.000001* |
| Methane | $CH_4$ | 0.0001 | Nitrogen dioxide | $NO_2$ | 0.000001* |
| Hydrogen | $H_2$ | 0.00005 | Particles (dust, pollen) | | 0.00001* |

*Average value in polluted air

## Structure of Atmosphere

Earth's atmosphere is divided into layers, each with different characteristics:

- Troposphere
- Stratosphere
- Mesosphere
- Thermosphere
- Ionosphere
- Exosphere






## Structure of Atmosphere

Troposphere:

- Lowest and thinnest layer; 16 km at equator, 8 km at poles
- 90% of the atmosphere's mass
- Where weather occurs - water vapor and clouds
- Temperature decreases with altitude: 6°C per kilometer; Top of troposphere averages –50°C



## Structure of Atmosphere

Stratosphere:

- Top of troposphere to 50 km above surface
- Ozone layer - Absorbs harmful UV radiation
- Temperature increases because of ozone absorption of UV radiation. Ranges from –50°C at base to 0°C at top



## Structure of Atmosphere

Mesosphere:

- Extends from stratosphere to altitude of 80 km
- Temperature decreases with altitude - 0°C at bottom to –90°C at top
- Gases in this layer absorb very little UV radiation.



## Structure of Atmosphere

Thermosphere:

- No well-defined upper limit
- Temperature increases with altitude – gas molecules move fast for high temps.
- Very low density of gas molecules means very little heat absorption - low thermometer reading.



## Structure of Atmosphere

Ionosphere:

- Not a true layer but an electrified region within the thermosphere and upper mesosphere (Auroras)

Exosphere:

- The interface between Earth and space
- Beyond 500 km, atoms and molecules can escape to space

## Structure of Atmosphere

Ozone is both good and bad:

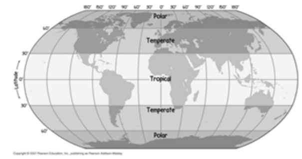
- Stratospheric ozone is good ozone
  - — It facilitated emergence of life on Earth.
  - — It protects Earth from harmful UV radiation.
  - — Stratospheric ozone depletion is detrimental to life.
  - — CFCs react with ozone and deplete it.
- Tropospheric ozone is bad ozone
  - — In the troposphere, ozone is a pollutant.



## Climate

The world is divided into different climate zones. Temperatures are:

- Highest in the tropics, near the equator
- Lower nearer the poles
- Moderate and variable in the temperate zone






## Solar and Terrestrial Radiation

Solar radiation is electromagnetic energy emitted by the Sun.

- Visible, short-wavelength radiation

Terrestrial radiation is reemitted solar radiation from Earth's surface.

- Infrared, longer-wavelength radiation



## Solar and Terrestrial Radiation

The Sun warms Earth's ground, and the ground, in turn, warms Earth's  atmosphere.

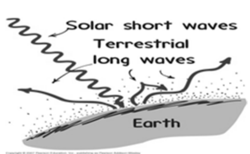
- Earth's temperature varies according to the degree of solar intensity—the amount of solar radiation per area.
- Where solar intensity is higher, temperatures are higher.



## Solar and Terrestrial Radiation

Solar intensity is stronger where the Sun's rays strike Earth's surface straight on (equatorial regions)

Solar intensity is weaker where the Sun's rays strike Earth's surface at an angle (higher latitudes)



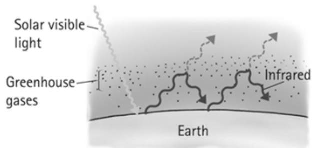



## Global Climate Change

- There have been many different climatic transitions over geologic time.
- Today, Earth is experiencing a warming trend, part of which may be connected to human activities: "anthropogenic" climate change.
- Humans have an impact on climate change by burning fossil fuels and deforestation.
- Both produce an increase in greenhouse gases.

## Global Climate Change

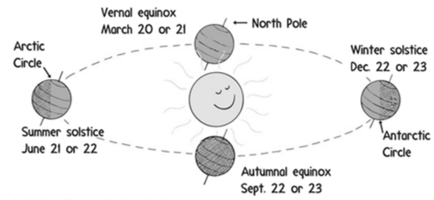
- The greenhouse effect is the warming of the atmosphere as terrestrial radiation is trapped by "greenhouse gases."
- Scientists agree that Earth is warming. The effects of that warming are still being investigated. Some effects can be predicted with more certainty than others.






## Solar Radiation

Variation in solar intensity with latitude and the tilt of the Earth's axis helps to explain the different seasons.



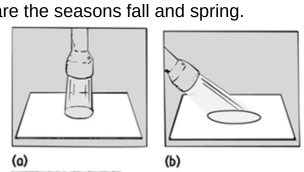



## Solar Radiation

When the Sun's rays are closest to perpendicular at any spot on the Earth, that region's season is summer.

Six months later, as the rays fall upon the same region more obliquely, the season is winter.

In between are the seasons fall and spring.






## Solar Radiation

Earth's revolution (orbit) around the Sun determines the length of a year (365 days).

- Earth's rotation on its axis determines day length—24 hours in each day.
- The number of daylight hours varies during the year depending on latitude.



## Solar Radiation

At the summer solstice (June 21st), locations north of the Arctic Circle in the Northern Hemisphere have ~24 hours of daylight.

At the winter solstice (December 22nd), locations north of the Arctic Circle have ~24 hours of night.

In the Southern Hemisphere, it is the Antarctic Circle, and the seasons are reversed (summer solstice is in December).



## Solar Radiation

Halfway between the summer and winter solstices are the equinoxes.

- Mid-September is the Autumnal (fall) equinox.
- Mid-March is the Vernal (spring) equinox.

The equal hours of day and night are not restricted to high latitudes but occur all over the world.

## Circulation of the Atmosphere

Wind is air that flows horizontally from higher pressure to lower pressure.

- Isobars connect areas with similar pressure.
- Pressure gradient is represented by the spacing between isobars:
  - —Closely spaced isobars indicate abrupt change in pressure.
  - —Widely spaced isobars indicate gradual change in pressure.
- The greater the pressure gradient, the stronger the wind.



## Circulation of the Atmosphere

Air pressure differences are caused by uneven heating of the Earth's surface.

- Local differences in heating contribute to small-scale local winds.
- Planet-scale differences occur because of solar intensity variations; equatorial regions have greater solar intensity than polar regions.
  - —Differences contribute to global wind patterns—prevailing winds.



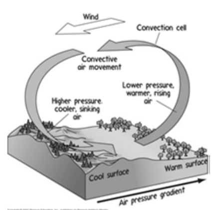
## Circulation of the Atmosphere

Warm air characteristics:

- Warm air expands
- Warm air rises
- Warm air has lower density and lower pressure

Cool air characteristics:

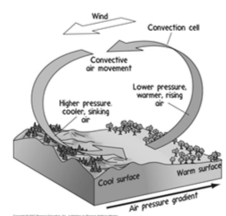
- Cool air contracts
- Cool air sinks
- Cool air has higher density and higher pressure






## Circulation of the Atmosphere

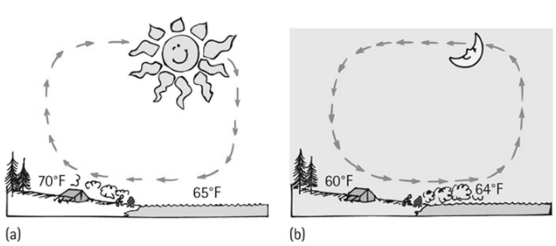
Movement of warm and cool air occurs in convection cycles in the lower atmosphere. Air is warmed at Earth's surface, rises, cools, and then sinks to be warmed near the surface again.






## Circulation of the Atmosphere

Water has a high specific heat capacity, making it heat up more slowly in the daytime and cool more slowly at night as water will hold onto its heat better than the land surface.






## Circulation of the Atmosphere

Local winds:

- Not all surfaces are heated equally. *Example*: Land heats and cools more rapidly than water.
- Unequal heating results in pressure differences. And pressure differences result in wind.

Remember: Wind is air that flows horizontally from higher pressure to lower pressure.

## Circulation of the Atmosphere

Prevailing Winds: high solar intensity at equatorial latitudes generates powerful, worldwide convection cells (heat redistribution).

Convection cells that move heat from the equator to the poles are *Hadley cells.*

- Named after George Hadley, an 18th-century English lawyer and amateur meteorologist.



## Circulation of the Atmosphere

At the equator, rising warm, moist air, low pressure - doldrums

- Trade winds (0°–30°)

At 30° N and S latitude, air cools and sinks—dry air, high pressure - horse latitudes, deserts

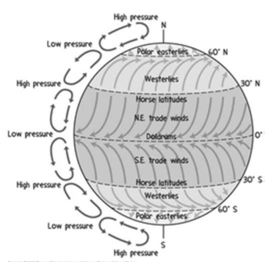
- Westerlies (30°–60°)

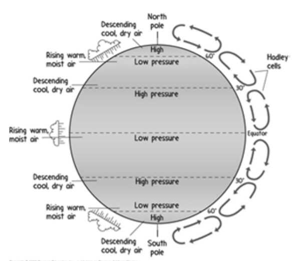
At 60° N and S latitude, cool, dry air meets warm, moist air—low pressure (Polar Front)

- Polar easterlies (60°–90°)



## Circulation of the Atmosphere






## Circulation of the Atmosphere

Earth's rotation greatly affects the path of moving air

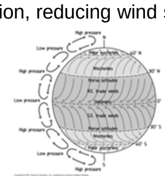
- *Coriolis effect*: moving bodies (such as air) deflect to the right in the Northern Hemisphere, to the left in the Southern Hemisphere.
- Deflection of wind varies according to speed and latitude.
  - Faster wind, greater deflection
  - Deflection greatest at poles, decreases to zero at equator



## Circulation of the Atmosphere

Factors that affect wind:

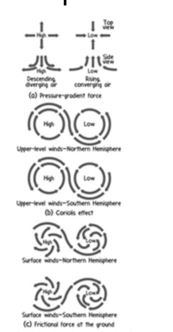
- The pressure gradient force: air moves from high pressure to low pressure
- The Coriolis effect: apparent deflection of winds due to Earth's rotation
- Frictional force: air moving close to ground encounters friction, reducing wind speed and the Coriolis affect





## Circulation of the Atmosphere

High and Low Pressure centers behave differently in the Northern and Southern hemispheres due to the Coriolis effect.



## Oceanic Circulation: Currents

Ocean currents are streams of water that move, relative to the larger ocean.

Surface currents are created by wind.

Surface ocean currents correspond to the directions of the prevailing winds.



## Oceanic Circulation: Currents

Factors that influence ocean currents:

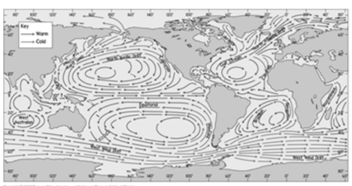
- For short distances, wind is strongest factor
- For longer distances, Coriolis effect comes into play:
  - Coriolis causes surface currents to turn and twist into semicircular whirls called gyres.
  - Northern Hemisphere gyres rotate clockwise.
  - Southern Hemisphere gyres rotate counterclockwise.



## Oceanic Circulation: Currents

Surface currents redistribute Earth's heat.

The Gulf Stream current carries vast quantities of warm tropical water into higher latitudes.





## Humidity

*Humidity* is the mass of water vapor a given volume of air contains.

*Relative humidity* is the ratio:

$$\frac{\text{amount of water vapor in air}}{\text{amount of water vapor air can hold at that temperature}}$$



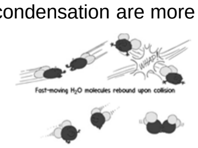
## Humidity

Air that contains as much water vapor as it possibly can is *saturated*.

- Warm air holds more water vapor than cold air.
- As air cools, it holds less and less water vapor.

Saturation can occur when air temperature drops, causing water vapor to condense.

Saturation and condensation are more likely in cold air.






## Humidity

Dew point is the temperature at which saturation occurs.

Condensation occurs when the dew point is reached.

- Water vapor condenses high in the atmosphere and forms clouds.
- Water vapor condenses close to the ground surface to form dew, frost, and/or fog.

## Clouds and Precipitation

**Table 25.4** The Four Major Cloud Groups

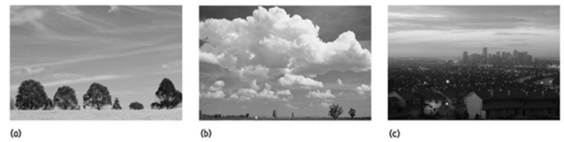
| 1. High Clouds (above 6000 m) | 2. Middle Clouds (2000–6000 m) | 3. Low Clouds (below 2000 m) | 4. Clouds of Vertical Development |
|---|---|---|---|
| Cirrus | Altostratus | Stratus | Cumulus |
| Cirrostratus | Altocumulus | Stratocumulus | Cumulonimbus |
| Cirrocumulus | Nimbostratus | | |





## Clouds and Precipitation

Cirrus Cumulus Stratus



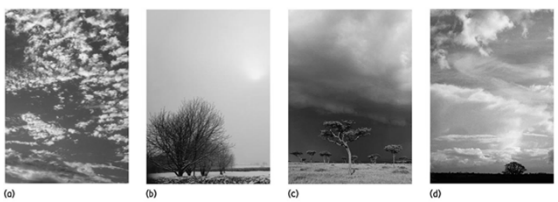
(a) (b) (c)





## Clouds and Precipitation

Cirrocumulus Altostratus Nimbostratus Cumulonimbus



(a) (b) (c) (d)

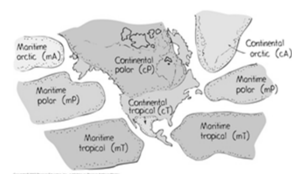




## Changing Weather: Air Masses

An air mass is a volume of air that has a characteristic temperature and humidity throughout and tends to remain intact as it travels.

Air masses acquire the temperature and moisture characteristics of its source region.






## Changing Weather: Air Masses

**Table 25.5** Classification of Air Masses and Their Characteristics

| Typical Source Region | Classification | Symbol | Characteristics |
|---|---|---|---|
| Arctic | maritime arctic | mA | cool, moist, unstable |
| Greenland | continental arctic | cA | cool, dry, stable |
| North Atlantic, Pacific Ocean | maritime polar | mP | cool, moist, unstable |
| Alaska, Canada | continental polar | cP | cold, dry, stable |
| Caribbean Sea, Gulf of Mexico | maritime tropical | mT | warm, moist, usually unstable |
| Mexico, Southwestern U.S. | continental tropical | cT | hot, dry, stable aloft; unstable at surface |

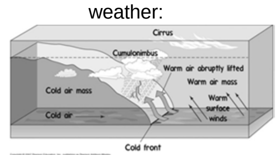


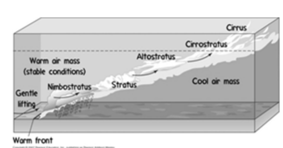


## Changing Weather: Fronts

A front is the boundary where air masses meet.

- When two air masses meet, differences in temperature, moisture, and pressure can cause one air mass to ride over the other. This is frontal lifting.
- Fronts are associated with rapid changes in weather:



## Changing Weather: Cyclones and Anticyclones

A cyclone is an area of low pressure around which winds flow.

Due to the Coriolis effect, winds in a cyclone move:

- Counterclockwise in the Northern Hemisphere
- Clockwise in the Southern Hemisphere

Air converges in the center (lowest pressure) and is forced to rise upward.



## Changing Weather: Cyclones and Anticyclones

An anticyclone is an area of high pressure around which winds flow.

Due to Coriolis, winds in a cyclone move:

- Clockwise in the Northern Hemisphere
- Counterclockwise in the Southern Hemisphere

Air moves downward (high pressure) and outward from an anticyclone.



## Storms

Storms are defined as violent and rapid changes in the weather.

Three major types of severe storms:

Thunderstorms, Tornadoes, Hurricanes



## Storms

Thunderstorms begin with humid air rising, cooling, and condensing into a single cumulus cloud.

When fed by unstable, moist air , a cumulus cloud grows into a thundercloud.

Thunderstorms contain immense amounts of energy.



## Storms

Tornado: a column of air rotating around a low-pressure core that reaches from a thundercloud to the ground.

A funnel cloud is similar to a tornado, but it does not touch the ground.



## Storms

Hurricanes are the greatest storms on Earth—energy comes from latent heat released from condensing water vapor.

- Rising warm air creates low pressure near the surface, drawing in more moist air.
- Winds rotate around a central low-pressure area—the eye of the storm.
- There is a continuous supply of energy from tropical waters. A hurricane weakens as fuel is cut off (land fall or cooler water).

## Formation of a Hurricane

- A hurricane begins to form over warm, moist water, generally in the tropical zone.
- Water evaporates then condenses to form thunderclouds.
- Warm, moist air is continually sucked into the low-pressure zone below the clouds. Huge collections of thunderclouds develop.
- The system gains energy as water vapor condenses to form clouds.
- The energy released by the water vapor when it condenses is called *latent heat*.



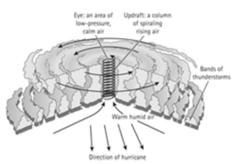
## Formation of a Hurricane

- The Coriolis effect turns the spiral-shaped weather system around its low-pressure center.
- The hurricane dies soon after it leaves the open ocean because it no longer can absorb large quantities of warm, moist air.



## Anatomy of a Hurricane

- The low-pressure center of a hurricane is its "eye." Moist air spirals around the eye and is sucked upward across a pressure gradient. The extent of bands of thunderstorms, rain, and wind determines the size of the hurricane.






## Hurricane Facts

- Most of the deaths that occur during hurricanes result from drowning in floods.
- The intensity of a hurricane is measured on the Saffir-Simpson Scale.



## Classification of Hurricanes

TABLE 27.4 SAFFIR–SIMPSON HURRICANE SCALE

| Category | Wind Speed (miles per hour) | Effects |
|---|---|---|
| No. 1 | 74–95 | *Very dangerous winds produce some damage.* Examples: roofs damaged or destroyed; large tree branches snap; shallow-rooted trees topple; power lines and poles fall or break |
| No. 2 | 96–110 | *Extremely dangerous winds cause extensive damage.* Examples: older mobile homes destroyed; some roofs removed; shallow-rooted trees uprooted blocking roads; long-term power loss |
| No. 3 | 111–130 | *Devastating damage occurs.* Examples: electricity and water unavailable; extensive roof and siding damage; windows broken; high risk of injury or death due to flying and falling debris |
| No. 4 | 131–155 | *Catastrophic damage occurs.* Examples: extensive structural damage to top floors; collapse of some masonry buildings; fallen trees and power poles isolate residential areas; long-term water shortages |
| No. 5 | Greater than 155 | *Catastrophic damage occurs.* Examples: people, livestock, and pets at very high risk of injury or death from falling or flying debris, even inside homes; many homes destroyed; nearly all trees uprooted; most of the area uninhabitable for weeks or months |