https://www.windy.com/?36.880,-97.515,5,i:pressure

Principal Terms

atmosphere: gaseous “envelope” surrounding the earth that contains all gases produced by terrestrial sources

circulation cell: cyclic pattern of air movement within the atmosphere

convection: the vertical transport of atmospheric properties

Coriolis effect: illusion of deflection observed when a body moves through the atmosphere with regard to an individual situated on the moving surface of the earth

magnetosphere: outer region of Earth’s ionosphere where the movement of particles is dominated by Earth’s magnetic field

ozone: form of oxygen containing three joined oxygen atoms responsible for blocking much of the solar radiation that hits Earth’s atmosphere

stratosphere: uppermost region of the atmosphere able to support life; extends from 10 to 50 kilometers (6 to 31 miles) above Earth’s surface

thermosphere: outer region of the atmosphere between 80 and 800 kilometers (50 to 497 miles) from the surface where temperature increases with increasing altitude because of bombardment by solar radiation

topography: the relief features or surface configuration of a certain area

troposphere: the lowest level of Earth’s atmosphere extending to approximately 10 kilometers above sea level

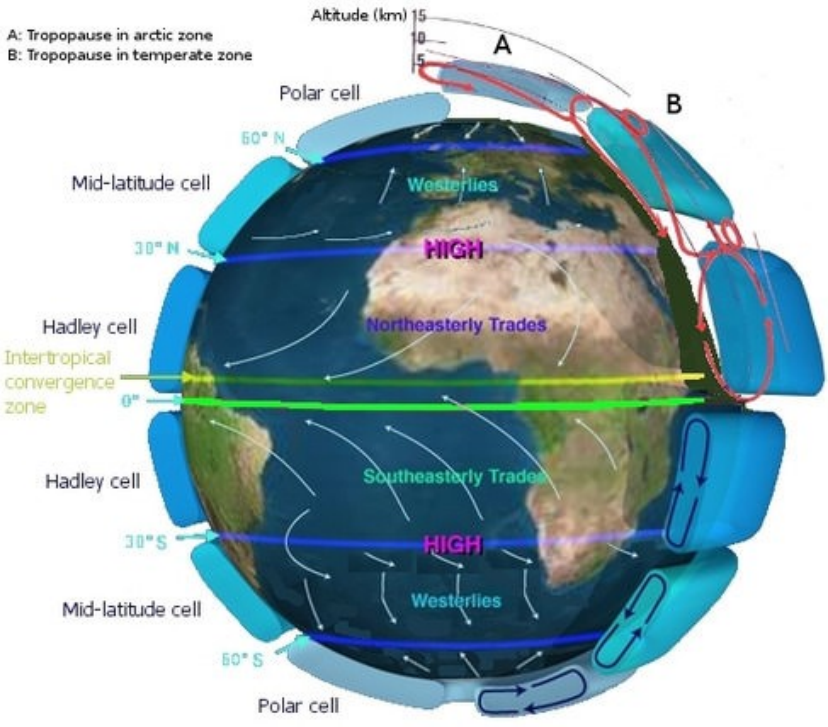
troposphere *contains the greatest density of gases in the atmosphere*

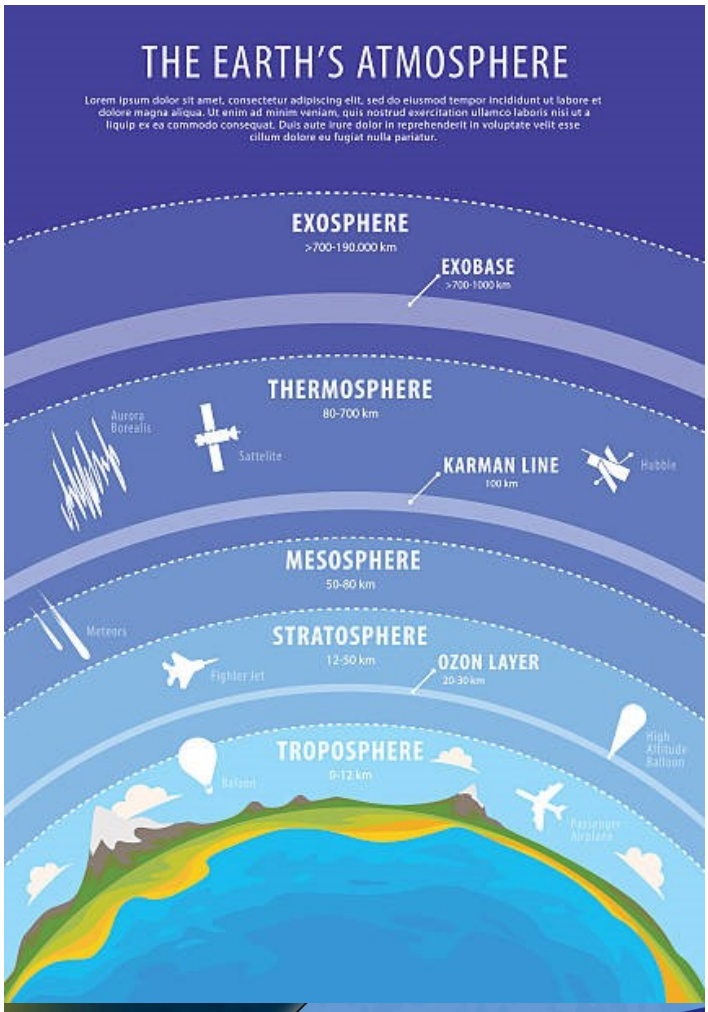
stratosphere *contains the ozone layer, which protects the earth from cosmic radiation.*

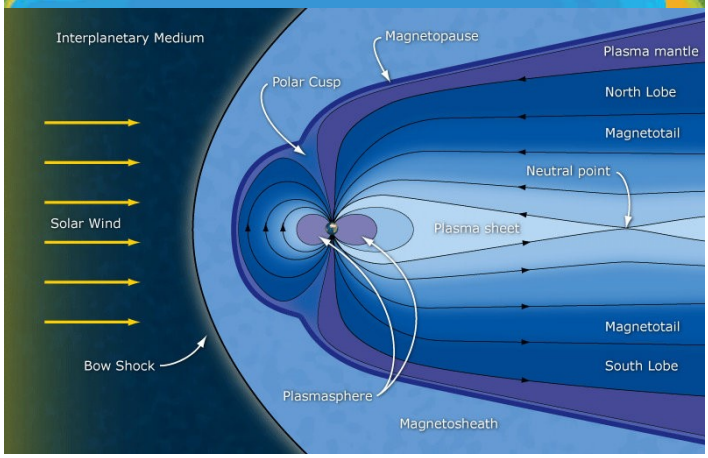
heliosphere, which is the portion of space affected by the sun

magnetosphere, which is a field of charged magnetic particles that surrounds the earth

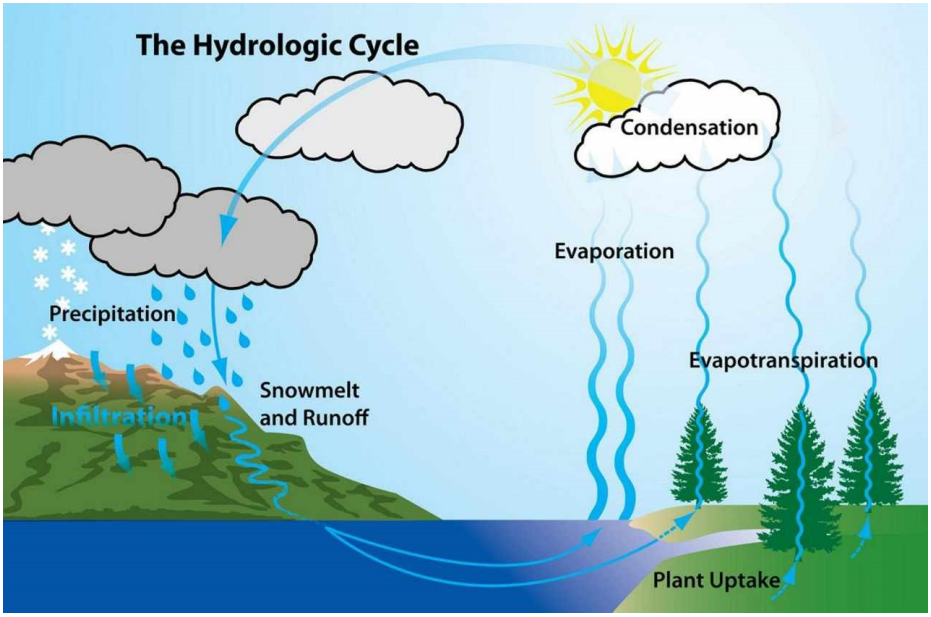
The earth’s atmosphere is largely made up of nitrogen (N_2) Oxygen (O_2) is the next most abundant type of gas, The remaining 1 percent of the atmosphere is composed mostly of argon (Ar) and carbon dioxide (CO_2) The remaining atmosphere consists of minute quantities of trace gases, including hydrogen (H_2), helium (He), neon (Ne), ozone (O_3), and methane (CH_4). Though the trace gases are present only in minute quantities, many of them are essential for life on Earth







Earth generates a magnetic field because of the inherent magnetism, heat, and movement of material in the planet’s core.



1. Understand the significance of the atmosphere.

Indispensable for life on earth, crucial part of the water cycle, ozone layer makes life possible, it moderates earth's temperature.

2. Describe the composition of the atmospheric gasses.

Nitrogen, Oxygen, Argon, Carbon dioxide, other gasses.

3. Explain the major layers of the atmosphere and their importance.

Troposphere

STRATOSPHERE temperature increases with altitude. **ozone layer** is found within the stratosphere The thickness varies by the season and also by latitude , it absorbs most of the Sun's harmful ultraviolet (UV) radiation

MESOSPHERE the heat source is the stratosphere below.

THERMOSPHERE The ionosphere gets its name from the solar radiation that ionizes gas molecules to create a positively charged ion and one or more negatively charged electrons.

The Van Allen radiation belts are two doughnut-shaped zones of highly charged particles that are located beyond the atmosphere in the **magnetosphere**

exosphere, the outermost layer of the atmosphere; the gas molecules finally become so scarce that at some point there are no more

4. Analyze the relationships between energy, temperature, and heat.

High temperature particles vibrate faster than low temperature particles. Rapidly vibrating atoms smash together, which generates heat.

5. Describe how the Sun influences seasonality.

UVC: the highest energy ultraviolet, does not reach the planet's surface at all.

UVB: the second highest energy, is also mostly stopped in the atmosphere.

UVA: the lowest energy, travels through the atmosphere to the ground.

Ozone completely removes UVC, most UVB and some UVA from incoming sunlight. Oxygen, carbon dioxide, and water vapor also filter out some wavelengths.

- Describe how heat is transferred around the planet.

Inversions are very stable and may last for several days or even weeks. They form:
Over land at night or in winter when the ground is cold. The cold ground cools the air that sits above it, making this low layer of air denser than the air above it.

Near the coast where cold seawater cools the air above it. When that denser air moves inland, it slides beneath the warmer air over the land.

We feel infrared energy as heat.

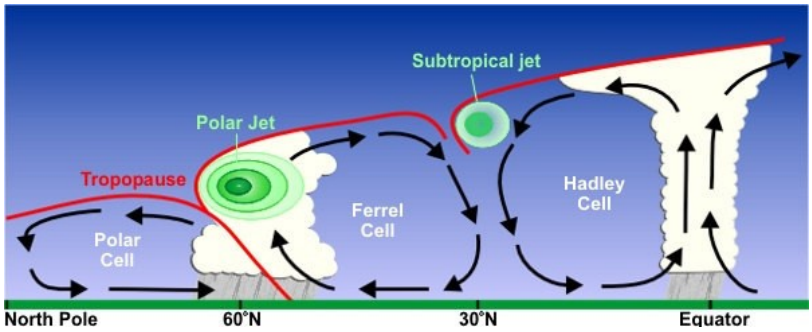
Radiation The transfer of energy from one object to another through electromagnetic waves Heat radiates from the ground into the lower atmosphere.

Albedo is a measure of how well a surface reflects light.

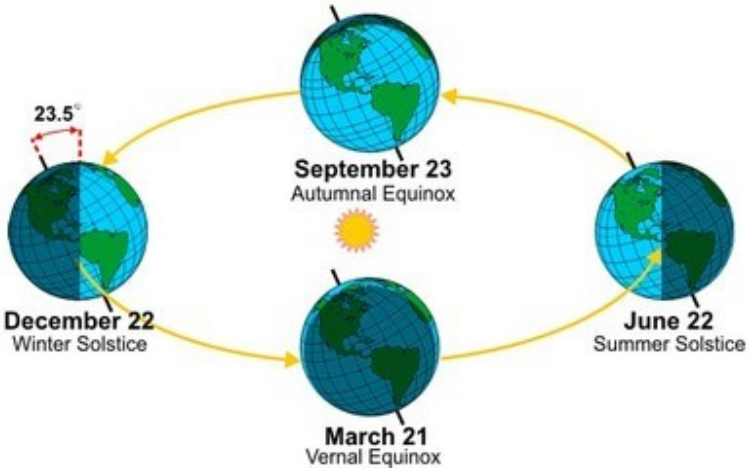
Temperature is a measure of how fast the atoms in a material are vibrating

Heat measures the material's total energy. is taken in or released when an object changes state, or changes from a gas to a liquid, or a liquid to a solid. This heat is called **latent heat**

Warm air rising creates a **low pressure zone** at the ground. Air from the surrounding area is sucked into the space left by the rising air. Air flows horizontally at top of the troposphere; horizontal flow is called **advection**. The air cools until it descends. Where it reaches the ground, it creates a **high pressure zone**. Air flowing from areas of high pressure to low pressure creates winds. Warm air can hold



more moisture than cold air. Air moving at the bases of the three major convection cells in each hemisphere north and south of the equator creates the global wind belts.



Naturally occurring ozone -An oxygen molecule (O2) in the atmosphere is broken into 2 oxygen atoms (O + O) by absorbing ultraviolet light energy from the sun. The oxygen atom (O) is now free to react with an oxygen molecule (O2) to create an ozone molecule (O3).

- Methane: Temperature
- Water Vapor: Precipitation
- Carbon Dioxide: Temperature
- Aerosols: Cloud formation

Methane: Risen and fallen cyclically every 23,000 years Rate of increase accelerated with industrialization Rise cultivation, biomass burning, fossil fuel extraction Residence time 10 years Impacts Climate: Temperature

Aerosols: Not water vapor or precipitation. Small solid particles and liquid droplets. Dust, ash, sea spray, combustion by products. Urban smog. Removed via rain. Impacts Weather: Help create clouds

Electrical properties: Ionosphere: Upper mesosphere to into Thermosphere. Contains many ions. Aurora borealis

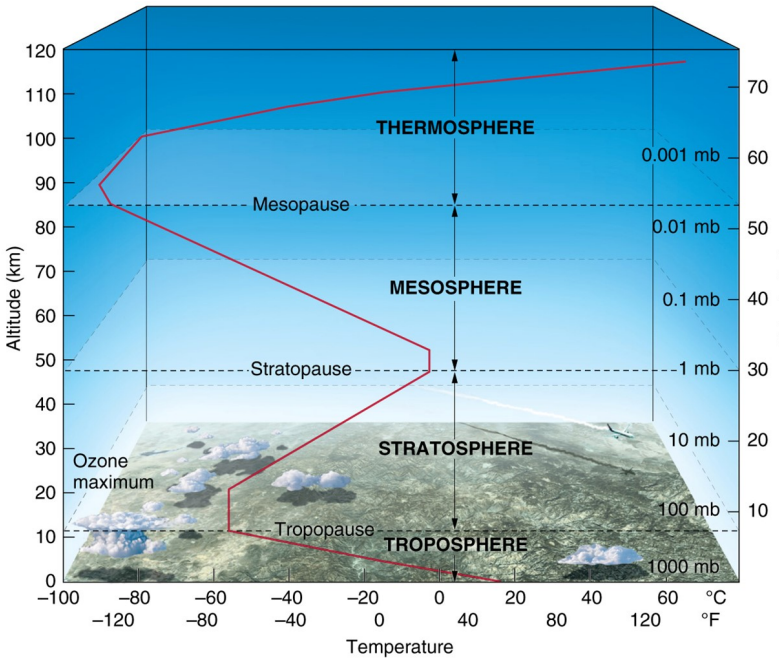
Evolution of Earth's Atmosphere: Atmosphere formed by volcanic gas release, (outgassing), water vapor and CO2, N2. Comets: Water Vapor. Anerobic Bacteria: gave off oxygen. Ozone layer formed from 02. Life outside of ocean possible. Plant life

Water Vapor: Part of Atmosphere-Hydrosphere interaction. Impacts Weather: precipitation, humidity

Carbon Dioxide: Part of Atmosphere-Biosphere interaction

Anthropogenic combustion. Kyoto Agreement in effect Feb 16, 2005, US is only major industrialized nation not to sign on. Impacts Climate: Temperature

1. Video: Atmosphere Layers (Links to an external site.) Links to an external site.



Where are most air molecules concentrated? - In the lower few kilometers of the atmosphere—the Troposphere

What are the 2 main gasses in the atmosphere? - Nitrogen & Oxygen

Which layer protects the Earth from most radiation? Ozone filter located in the Stratosphere

2. Video: Atmospheric Pressure (Links to an external site.)Links to an external site.

What instrument measures Atmospheric pressure? A Mercury Barometer

How does atmospheric pressure vary with altitude? It is one third as strong on top of mount Everest as it is at sea level.

How does atmospheric pressure vary with temperature? The colder the air, the slower the molecules move so they tend to be closer together. Atmospheric pressure rises.

3. Video: The Ozone Layer (Links to an external site.)Links to an external site.

What type of solar rays does Ozone absorb? Ultraviolet rays

What atoms compose Ozone? Three oxygen atoms.

Anticyclones - high pressure zones

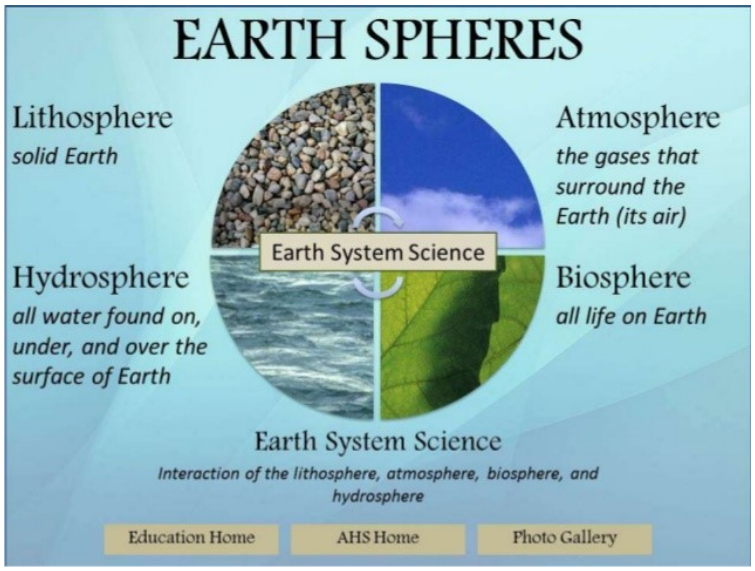
Depressions: low pressure zones.

1. The atmosphere is held in place by: gravity
2. **The heterosphere:** is populated primarily by variable gases.
3. **Compared to the size of the earth, the atmosphere is very thin because it is highly compressed**
4. **This is the most abundant gas in the atmosphere. Nitrogen**
5. **If your ears have** ever "popped" in an airplane, what have you have experienced? (mark all that apply) all
6. In what atmospheric layer are most air molecules concentrated? Troposphere
7. What atoms compose Ozone? 3 oxygen atoms
8. If you were to travel **vertically** upward for one mile, the pressure would be much lower than if you traveled horizontally for one mile.
9. What instrument measures Atmospheric pressure? Barometer
10. In what atmospheric layer are most air molecules concentrated? Troposphere
11. Ozone: absorbs ultra light

Week 2

Seasons, Global Energy Transfer, and Remote Sensing of the Atmosphere

Seasons



Principal Terms

autumnal equinox: the day that the sun passes directly over the equator in the southward direction, producing day and night of equal length and marking the beginning of autumn; in the Northern Hemisphere, the date is about September 21, and in the Southern Hemisphere, it occurs about March 21

equator: the line of latitude on Earth that is exactly halfway between the North and South Poles

monsoon: a wind system that results in an annual cycle of fair weather followed by rainy weather

perihelion: the point in a planet's orbit at which it is closest to the sun

summer solstice: the day when the sun is directly over the Tropic of Cancer in the Northern Hemisphere; in the Southern Hemisphere, the day when the sun is directly over the Tropic of Capricorn

Tropic of Cancer: a line of latitude 23.5 degrees north of the equator; the most northerly latitude on Earth at which the noon sun passes directly overhead

Tropic of Capricorn: a line of latitude 23.5 degrees south of the equator; the most southerly latitude on Earth at which the noon sun passes directly overhead

vernal equinox: the day that the sun passes directly over the equator in the northward direction, producing day and night of equal length and marking the beginning of spring; in the Northern Hemisphere, the date is about March 21, and in the Southern Hemisphere, it is about September 21

winter solstice: the diametric opposite of the summer solstice, occurring in the Northern Hemisphere when the sun passes directly over the Tropic of Capricorn, and in the Southern Hemisphere when it passes over the Tropic of Cancer

The seasons and their weather patterns all result from the variable distribution of energy from the sun according to the relative positions and motions of the sun and Earth.

Earth makes a complete orbit around the sun every 365 days, 5 hours, and 49 minutes

This results in two factors that together cause the warmer weather of summer: The sun is higher in the sky than it is in autumn and winter, and the number of hours of daylight is increased. The higher the sun is in the sky, the more concentrated is its heat and thus the warmer that part of the surface becomes.

The only days on which the sun rises due east and sets due west are the vernal and autumnal equinoxes.

Global Energy Transfer

Principal Terms

albedo: the amount of radiation a surface reflects; higher albedo reflects more incoming radiation

atmospheric greenhouse effect: the result of greenhouse gases in the atmosphere; trapped energy (heat) in the earth's system

electromagnetic radiation: radiation that includes visible light, infrared radiation (heat), radio waves, gamma rays, and X rays

energy budget: an accounting of all the incoming and outgoing energy for Earth as a system

greenhouse gas: an atmospheric gas that contributes to the greenhouse effect by absorbing infrared radiation and reemitting that radiation

infrared radiation: electromagnetic radiation with wavelengths longer than visible light but shorter than radio waves; the type of electromagnetic radiation perceived as heat

irradiance: the power of electromagnetic radiation over a given unit of area, usually in watts per square meter; used to measure the influx of energy through an area such as the earth's surface

radiative equilibrium: a state in which Earth's incoming radiation and outgoing radiation are equal; it results in a generally stable climate as there is no net gain or loss of energy from the planet's system

radiative forcing: the total change in irradiance between different layers in the atmosphere; positive radiative forcing indicates a net increase in energy in the system (warming), whereas negative radiative forcing indicates a net release of energy (cooling)

solar flux: the total energy entering Earth's atmosphere from the sun

specific heat: the amount of heat (energy) it takes to raise the temperature of the unit mass of a given substance by a given amount, usually one degree; functionally, a substance's capacity to store heat

Remote sensing of the atmosphere

Scientists utilize a variety of remote sensory technologies, including passive imaging systems, radar, and lidar (light direction and ranging), to study gases and aerosols in the five layers of Earth's atmosphere. Remote sensors analyze and forecast meteorological phenomena and conditions. The field of remote sensing has particular relevance in light of efforts to assess and reverse global warming caused by human-made greenhouse emissions. Remote sensory technologies are ground-based, airborne, and space-based.

Principal Terms

active sensor: type of remote sensor that emits radiation at a target to study its composition and condition

lidar: type of remote sensor that operates similarly to radar but uses lasers instead of radio waves

lower atmosphere: region of the atmosphere comprising the troposphere and the tropopause, reaching an altitude as high as 19 kilometers, or 12 miles

middle atmosphere: region of the atmosphere comprising the mesosphere, mesopause, stratosphere, and strat-

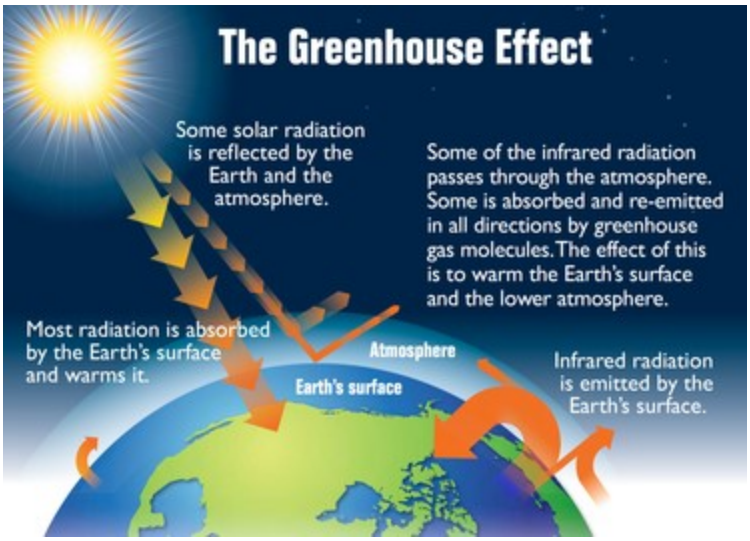
Greenhouse Gas	Where It Comes From
Carbon dioxide	Respiration, volcanic eruptions, decomposition of plant material; burning of fossil fuels
Methane	Decomposition of plant material under some conditions, biochemical reactions in stomachs
Nitrous oxide	Produced by bacteria
Ozone	Atmospheric processes
Chlorofluorocarbons	Not naturally occurring; made by humans

opause

passive sensor: type of remote sensor that detects naturally emitted energy, such as reflected sunlight, from target sources

pulse Doppler: type of radar system that emits waves of electromagnetic energy at an atmospheric target; provides a detailed profile of motion, precipitation, and other conditions and objects

thermosphere: region of the atmosphere marked by thin gases and ultraviolet radiation; also known as the upper atmosphere



Heat Transfer in the Atmosphere

Energy travels through space or material.

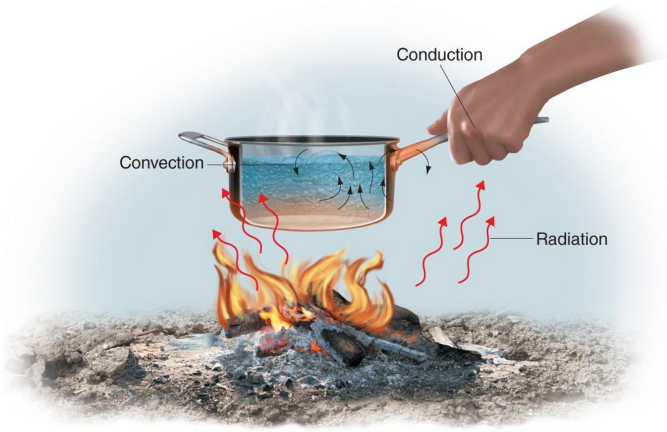
Reflection is when light (or another wave) bounces back from a surface.

Albedo is a measure of how well a surface reflects light

Heat is taken in or released when an object changes state, or changes from a gas to a liquid, or a liquid to a solid

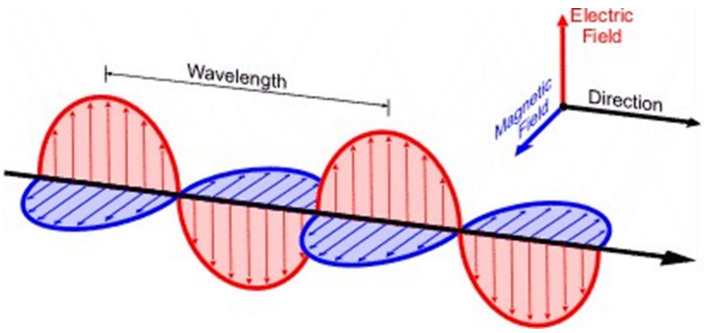
This heat is called **latent heat**

specific heat, the amount of energy needed to raise the temperature of one gram of the material by 1.0 degrees C (1.8 degrees F).



- UVC: the highest energy ultraviolet, does not reach the planet's surface at all.
- UVB: the second highest energy, is also mostly stopped in the atmosphere.
- UVA: the lowest energy, travels through the atmosphere to the ground.

Radiation is the transfer of energy between two objects by electromagnetic waves. Heat radiates from the ground into the lower atmosphere.



	Day Length	Sun Angle	Solar Radiation	Albedo
Equatorial Regon	Nearly same all year	High	High	Low
Polar Regions	Night 6 months	Low	Low	High

conduction, heat moves from areas of more heat to areas of less heat by direct contact.

Heat transfer by movement of heated materials is called **convection**

The warming of the atmosphere because of insulation by greenhouse gases is called the **greenhouse effect**

Energy

•Measured: 1 joule = .239 calories

•2 Types: Kinetic and Potential

•Kinetic: energy of motion: falling raindrops, wind blown dust, molecular vibration = temperature

•Potential: energy hasn't been used: droplets at altitude

Convection: Mixing of a liquid or gas

Characteristics of Radiation

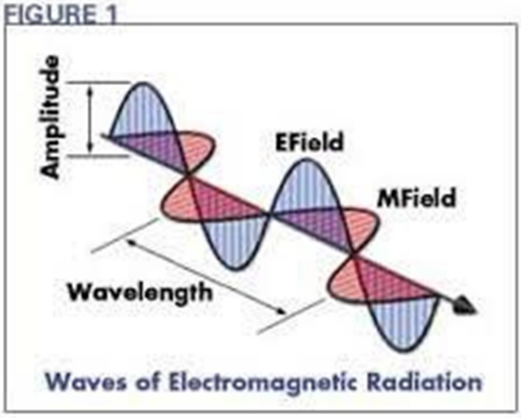
•Transmitted by a sequence of waves

•Waves are both electrical and magnetic waves= electromagnetic radiation

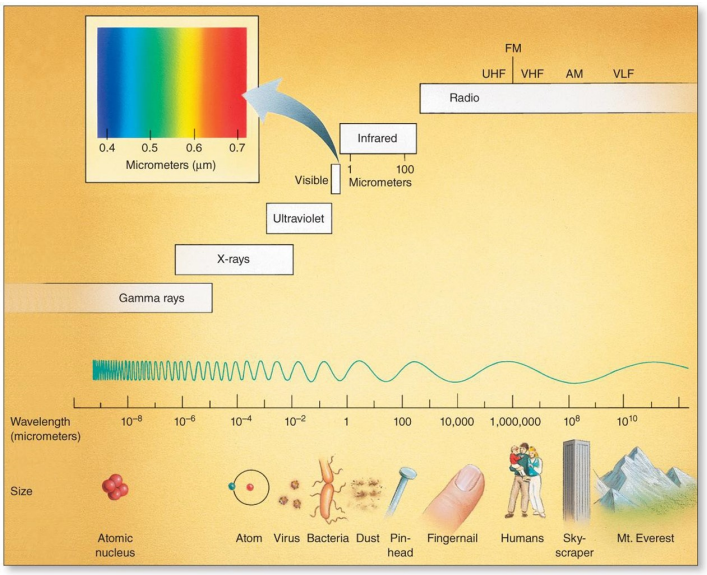
•When an object emits radiation (all objects do) an electrical field and magnetic field are radiated outward

•They are coupled, and rise and fall in unison

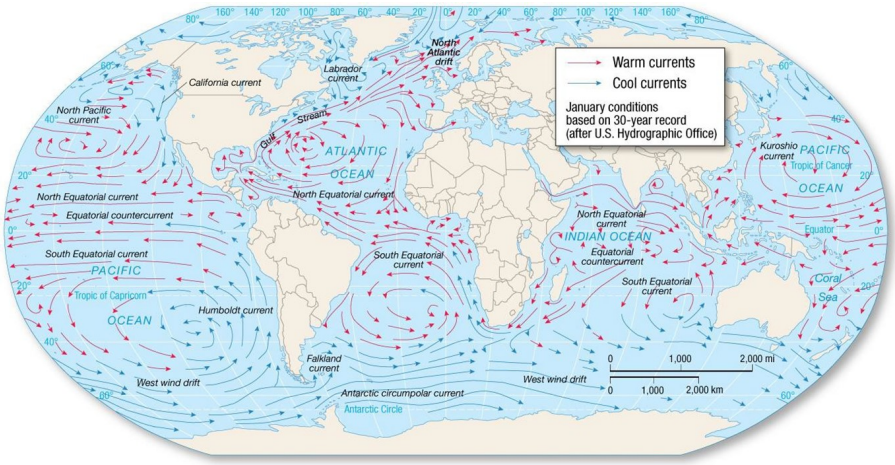
FIGURE 1



•Radiation Quantity = height of wave (amplitude)
•Radiation Quality (type) = distance between wave crests (wavelength)
•Electromagnetic radiation; travels at speed of light 186,000 miles per second
•Nearest star: takes 4.3 years before reaching Earth
•Stephan Boltzmann Law: Intensity of radiation depends on temperature raised to the 4th power
•Wiens Law: hotter object radiates energy at shorter wavelengths than cooler bodies
•Useful Applications: measuring intensity of IR = height of clouds = intensity of precipitation
•Do Seasons change because Earth's tilt changes? NO



Insolation Absorption
•Performed by gases, particulates and droplets
•Absorber gains energy and warms
•Energy delivered to Earth's surface reduced
•UV almost totally absorbed by Ozone layer in Stratosphere
•Near Infrared radiation absorbed by water vapor and CO2
•Reflection: radiation making contact with a surface is completely redirected
•% Reflection = Albedo
•Diffuse reflection = scattering
–Performed by solids, gases, particulates and small droplets
–When it reached Earth it is diffuse radiation as opposed to direct radiation
–Rayleigh scattering, Mie scattering, non selective Scattering



Raylight Scattering
•Performed by individual gas molecules in the atmpohsphere
•Primarily affect shorter wavelengths, particularly visible light
•Esp effective for scattering blue light forward and backward

Mie Scattering
•Performed by suspended aerosols
•Predominantly forward scattering
•Sky appears grey on hazy or polluted days b/c whole range of visible radiation scattered

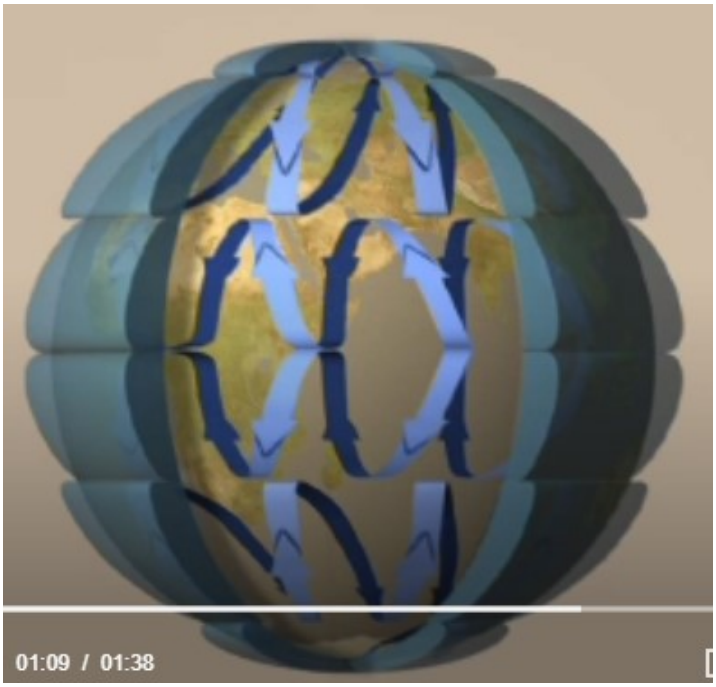
Non Selective Scattering
•Performed by water droplets
•Scatter sunlight like lenses
•Isolated drops create rainbows
•Aggregate drops (clouds) reflect all wavelengths which appear white or grey
•Reflect large amount of energy back to space

Influence on temperature
•Latitude
•Altitude and Elevation
•Atmospheric Circulation Patterns
•Lands Vs. Water

Location of Subsolar Point	**Name**	**Day Length**	**Seasons Begin**
23.5° S Latitude (Tropic of Capricorn)	December Solstice	N.H. Shortest S.H. Longest	**N.H. Winter** S.H. Summer
0° (Equator)	March Equinox	N.H. 12 Hour S.H. 12 Hour	**N.H. Spring** S.H. Fall
23.5° N Latitude (Tropic of Cancer)	June Solstice	N.H. Longest S.H. Shortest	**N.H. Summer** S.H. Winter
0° (Equator)	September Equinox	N.H. 12 Hour S.H. 12 Hour	**N.H. Fall** S.H. Spring

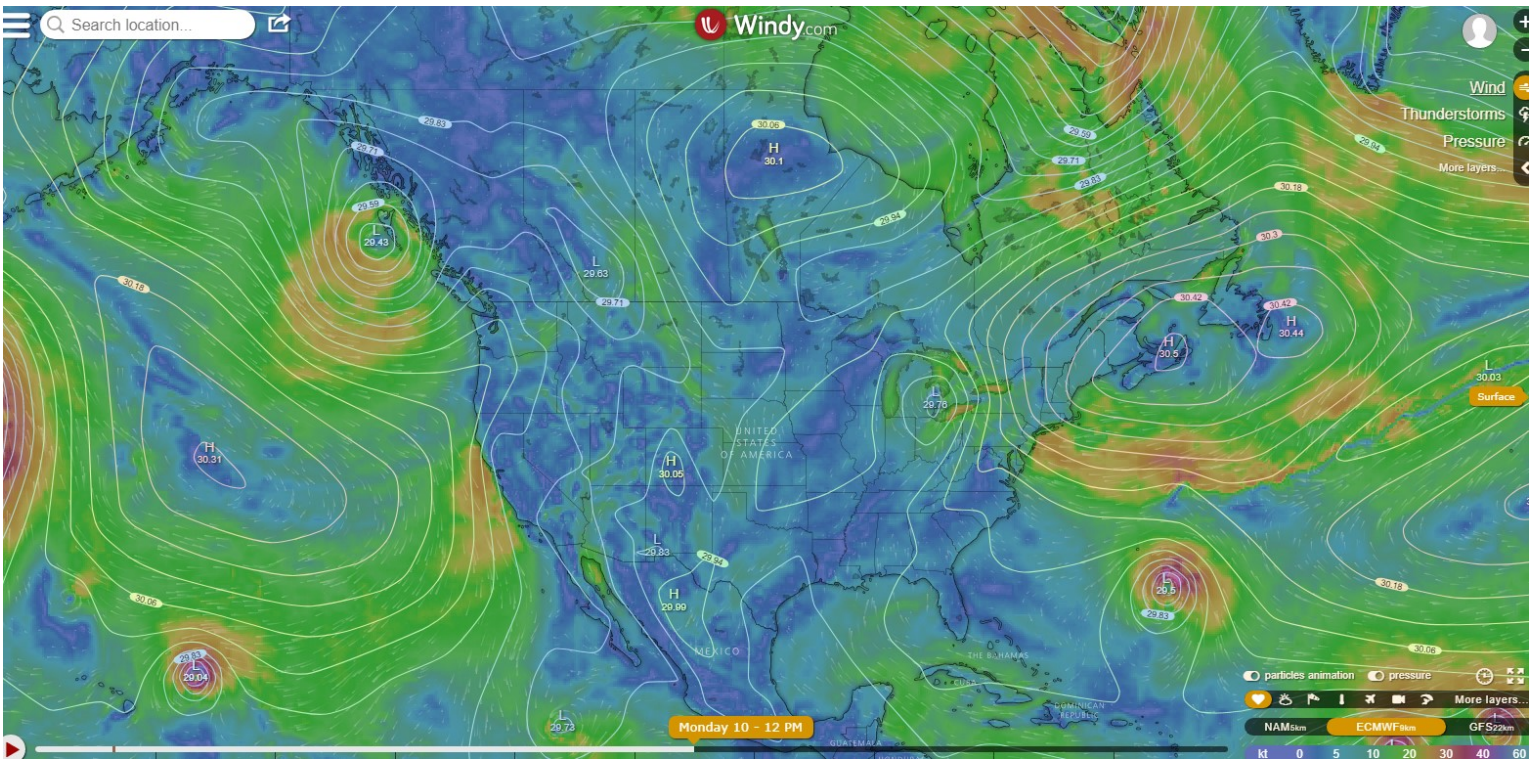
Quiz 2

1. The greatest seasonal change in the period of daylight is experienced at the: North and South Poles
2. Looking at global temperature distributions, it is seen that : temperatures over land are colder than those over water at the same latitude in winter.
3. The sky is blue because : blue light is easily scattered by the atmosphere.
4. The Earth is actually the farthest from the sun on : July 4th
5. The Northern Hemisphere has its maximum tilt toward the Sun on the : June solstice
6. The Antarctic Circle has 24 hours of daylight on the : December solstice
7. In the Northern Hemisphere, south-facing slopes: receive more solar radiation than do north-facing slopes
8. Ultraviolet, visible, and infrared are all types of radiation with different: : Wavelengths
9. Choose the correct listing of radiation from the longest wavelengths to the shortest wavelengths: radio, microwave, infrared, ultraviolet, x rays, gamma rays
10. Temperature is typically determined indirectly by measuring the effect that temperature has on other materials
11. The Tropic of Capricorn is directly under the Sun during the: December solstice
12. The process by which solar energy interacts with the atmosphere is: scattering, absorption, and reflecting



Lines are pressure, colors are winds

Map captured on 9/05/18 3:30pm to compare the day of

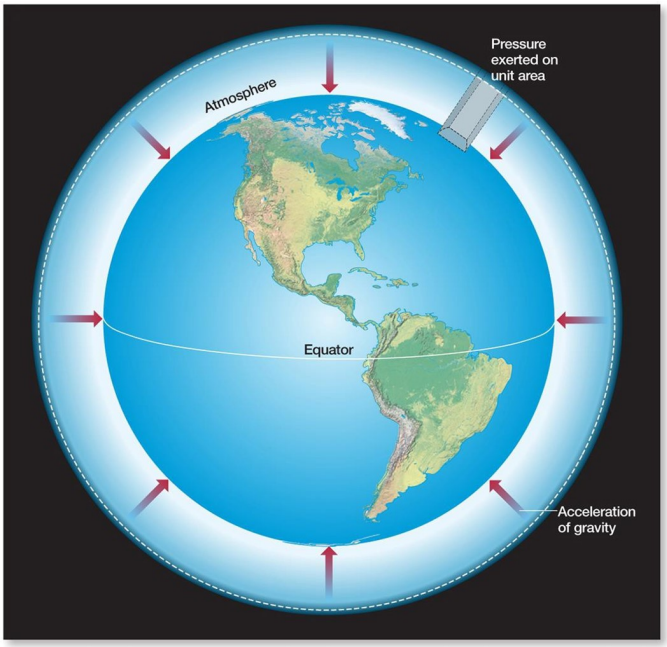


Week 3

Air per pressure—mercury barometer.

Barometric Pressure

Barometric pressure is a measure of atmospheric pressure as recorded by a scientific instrument known as a barometer. Barometric pressure readings have been made since the eighteenth century and remain useful today in forecasting weather. These readings allow meteorologists to identify the areas of high and low pressure that are integral parts of weather events.



Principal Terms

altimeter: scientific instrument that measures the altitude of an object above a fixed level

aneroid barometer: device that uses an aneroid capsule composed of an alloy of beryllium and copper to measure changes in external air pressure

atmospheric pressure: force exerted on a surface by the weight of air above that surface; measured in force per unit area

barograph: a graph that records atmospheric pressure in time

barometer: device for measuring atmospheric pressure; some are water-based, some use mercury or an aneroid cell, and some create a line graph of atmospheric pressure

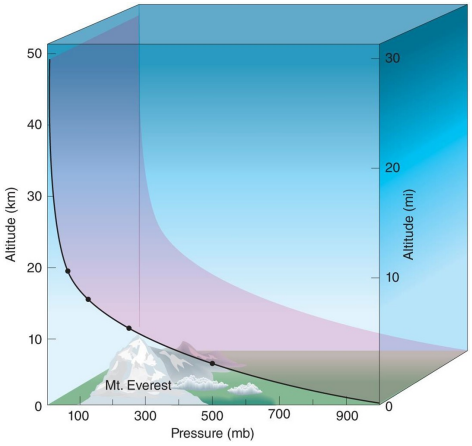
high-pressure area: region in which the atmospheric pressure is greater than that in the areas around it; represented by H on weather maps

low-pressure area: region where the atmospheric pressure is lower than that in surrounding areas; represented by L on weather maps

mercury barometer: glass tube of a minimum of 84 centimeters (33 inches), closed at one end, with a mercury-filled pool at the base; the weight of the mercury creates a vacuum at the top of the tube; mercury adjusts its level to the weight of the mercury in the higher column

meteorology: the study of changes in temperature, air pressure, moisture, and wind direction in the troposphere; the interdisciplinary scientific study of the atmosphere

water-based barometer: also known as a storm glass or Goethe barometer, a device with a glass container and a sealed body half full of water; also has a spout that fills with more or less water depending upon atmospheric conditions and their forces



- •Measured as the pascal, US uses millibar mb
- •Force of air per unit area
- •Each gas has its own pressure (partial pressure), but on earth they are combined (Daltons Law)
- •Pressure always decreases vertically
- •Air pressure is equal in all directions
- •In order to measure surface pressure, the
- affect of elevation has to be separated
- •Sea level pressure: the pressure that would
- exist if a location was at sea level
- •About a 1mb increase for every 10 meters in
- altitude for lower atmosphere
- •Ideal gas law: PV=nRT, temp (t), density (n)
- and pressure (p) are all related.

Wind

Measured:

•Barometer: any instrument that measures pressure

•Mercury barometer (inches or mb)

•Aneroid barometer (without liquid)

Wind is the horizontal movement of air resulting from differences in atmospheric pressure and air densities. Pressure differences may develop on a local or global scale in response to differences in the distribution of solar energy, which affect the density of air masses and, therefore, the pressure they exert relative to each other.

Principal Terms

constant pressure chart: a chart that shows the altitude of a constant pressure, such as 500 millibars

convergence: the movement of different air masses flowing toward a common point

divergence: a net outflow of air in different directions from a specified region

geostrophic wind: an upper-level wind that flows in a straight path in response to a balance between pressure gradient and Coriolis acceleration

hurricane-force wind: a wind with a speed of 64 knots (118 kilometers per hour) or higher

isobar: a line on a meteorological chart delineating points of equal pressure,

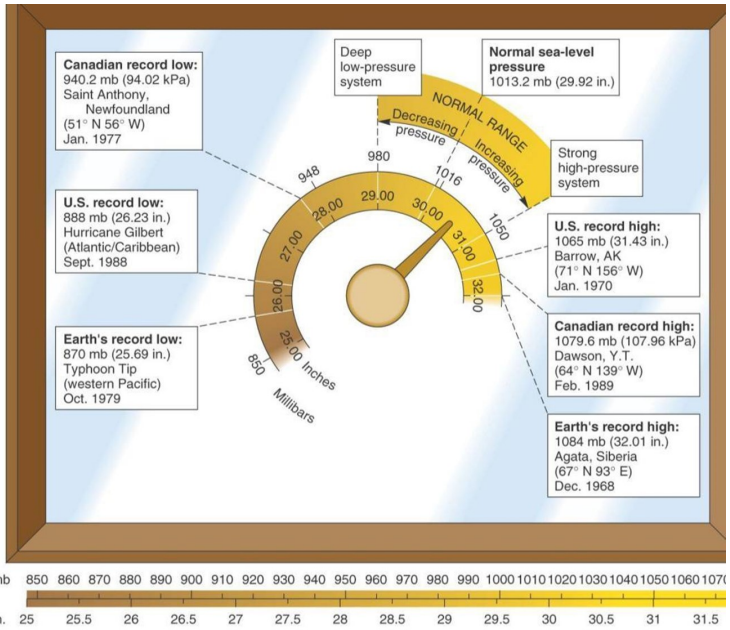
local winds: winds that, over a small area, differ from the general pressure pattern owing to local thermal or orographic effects

pressure gradient: the rate of change of pressure with distance at a given time

rawinsonde: a radiosonde tracked by radar in order to collect wind data in addition to temperature, pressure, and humidity

Wind occurs because:

- Differences in atmospheric pressure between one location and another produce wind
- Wind always blows from high to low pressure
- Winds are named for the direction from which they originate: a wind from the west is a westerly (that blows eastward)



- •ISOBARS: lines connecting places of equal
- pressure
- •Pressure gradient: Spacing of isobars, steep
- (close together) or weak (far apart lines)
- •Pressure gradient force: sets air in motion
- •Measured at a constant altitude: horizontal
- pressure gradient force
- •Greater the pressure gradient force, greater
- the wind

What forces affect the speed and direction of wind?

•Coriolis Force

•Friction

•Gradient flow

•Near surface winds

Pressure Gradient

Isobars indicate continuous air pressure, a pressure gradient is the spacing of isobars close or far apart.

How are vertical and horizontal pressure different?

•Horizontal Pressure: lowest about 990 mb, highest about 1025 mb

•Vertical pressure: mean sea level pressure is 1013.2 mb, decreases to 500 mb at 18,000 ft

•Vertical gradients are much greater than horizontal pressure gradients

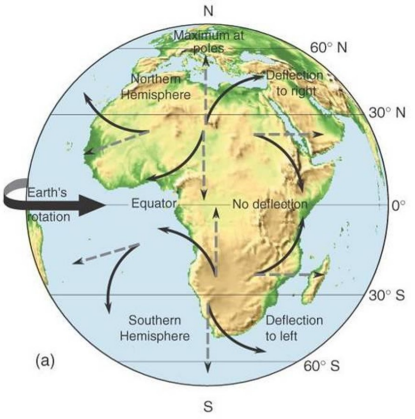
•SO why doesn't air explode out to space along the vertical pressure gradient?

How do near surface and upper atmosphere winds differ?

- •Upper Atmosphere Pressure gradients:
- –Cold, Dense air has stronger vertical pressure
- gradients
- –Pressure heights decrease in a slope toward colder
- air
- –That slope is the pressure gradient force

Coriolis Force

ØAll free moving objects on Earth: Winds, Ocean currents, airplanes...are subject to the Coriolis force because the Earth spins



ØIn the Northern Hemisphere, all motions are deflected to the right of their direction of initial movement

ØIn the Southern Hemisphere, all motions are deflected to the left of their direction of initial movement.

Friction

•Force resisting movement of a fluid or object as it passes along a surface or adjacent gas or liquid

•Friction effect varies with altitude

•Most important in the boundary layer: lower 1 mi

•Friction lowers wind speed and Coriolis force for a given pressure gradient

•Free Atmosphere is above 1 mi, negligible Friction

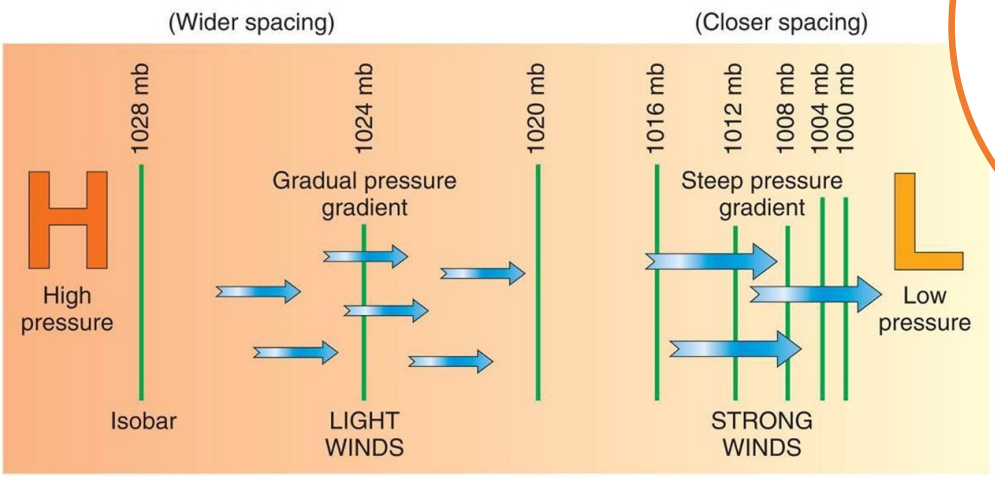
Anticyclonic Flow

•Enclosed high pressure areas with circular isobars

•Clockwise in NH

•Counter clockwise in SH

•Sinking air has clear skies and fair weather



(a)

TABLE 5–4
General Types of Condensation and Deposition

Form	Predominant Processes	Characteristics
Dew	Lowering of temperature to the dew point near the surface. Favored under clear skies and no wind. Diabatic process.	Appears as coating of liquid water on surfaces.
Frost	Lowering of air temperature to saturation point, when the saturation point is below 0 °C (32 °F). Diabatic process.	Appears as large number of small, white crystals on surfaces.
Frozen dew	Formation of dew at temperatures above 0 °C, followed by cooling to temperatures below 0 °C. Diabatic process.	Continuous layer of solid ice on surface.
Fog	Usually by cooling of layer of air with light winds. Sometimes by evaporating water from falling precipitation or by mixing warm, moist air with cold air. Diabatic or adiabatic process.	Large concentration of suspended droplets in layer of air near ground. Under extreme cold, can consist of suspended ice crystals.
Radiation fog	Cooling of air to dew point by longwave radiation loss. Diabatic process.	Same as above.
Advection fog	Cooling of air to dew point as it passes over cool surface. Diabatic process.	Same as above.
Upslope fog	Cooling of air as it flows upslope. Adiabatic process.	Same as above.
Precipitation fog	Increasing the water vapor content of the air by evaporation from falling droplets. Adiabatic process.	Same as above.
Steam fog	Mixing warm, moist air with cold air. Adiabatic process.	Same as above.
Clouds	Usually by lifting of air and adiabatic cooling.	Concentration of suspended droplets and/or ice crystals in air well above the surface.

Cyclones and anticyclones

Cyclones and anticyclones are large-scale weather systems with opposite properties. A cyclone is characterized by a central region of low atmospheric pressure and an anticyclone is characterized by a central region of high atmospheric pressure. Because cyclones are a major cause of stormy weather and anticyclones typically bring good weather, accurate meteorological predictions are greatly informed by an understanding of how these weather systems originate and develop.

Principal Terms

convergence: a tendency of air masses to accumulate in a region where more air is flowing in than is flowing out

Coriolis effect: the illusion of deflection observed when a body moves through the atmosphere with regard to an individual situated on the moving surface of the earth

cyclogenesis: the series of atmospheric events that occur during the formation of a cyclone weather system

divergence: a tendency of air masses to spread in a region where more air is flowing out than is flowing in

front: the boundary between two masses of air with different densities and temperatures; usually named for the mass that is advancing (for example, in a cold front, the mass that is colder is moving toward a warmer mass)

hurricane: a cyclone that is found in the tropics (between 23.5 degrees north and south of the equator) and that has winds that are equal to or exceed 64 knots, or 74 miles per hour

isobar: on a map, a line connecting two or more points that share the same atmospheric pressure, either at a particular time or, on average, in a particular period

mid- latitude cyclone: a synoptic-scale cyclone found in the mid-latitudes (between 30 and 60 degrees north and south of the equator)

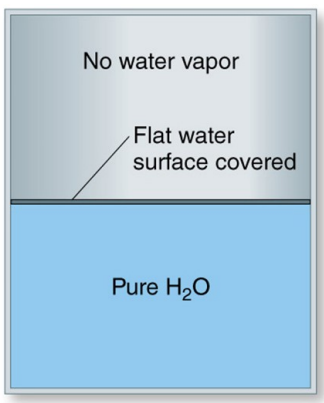
synoptic scale: a scale used to describe high- and low-pressure atmospheric systems that have a horizontal span of 1,000 kilometers (621 miles) or more

1. The pressure at the bottom of the atmosphere is referred to as: Sea level pressure
2. Which of the following is true about the geostrophic flow? Pressure gradient force equals the Coriolis force, it occurs only in the upper atmosphere, and friction is not present.
3. This is the only atmospheric variable that always decreases with distance above the ground: Pressure
4.
5. are less t than vertical pressure changes.
6. If surface pressure readings were plotted on weather maps, they would give a false representation of the atmosphere because: high elevations have lower surface pressures than low elevations, even if the sea-level pressures are the same.
7. Which of the following is not an effect of friction? Increases the Coriolis effect
8. Air pressure is: the sum of the partial pressures of its constituent gases.
9. According to the Ideal Gas Law, the pressure will increase if: the air density increases while the temperature is held constant.

Week 4

Hydrologic Cycle

by Samuel F. Huffman



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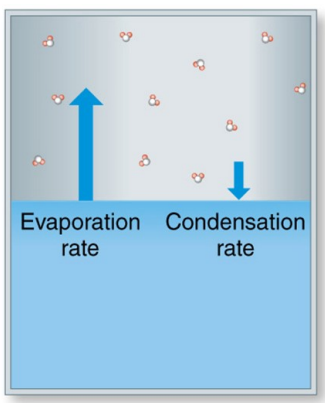

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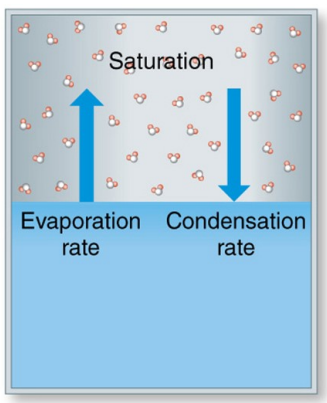
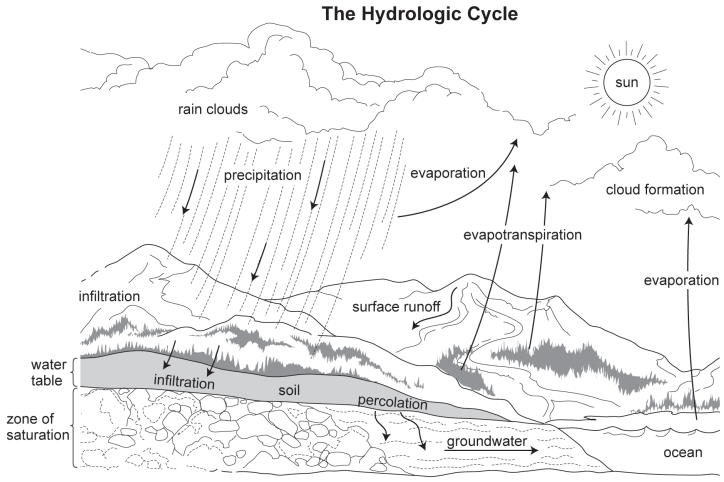


(c)

Water circulates on Earth through a system called the hydrologic cycle. This water cycle functions through vegetation, in the atmosphere, below the ground, and on land, lakes, rivers, and oceans. The sun and the force of gravity provide energy to drive the cycle from ground and surface water to atmospheric moisture that returns to the land and oceans as precipitation.



Principal Terms

base flow: that part of a stream's discharge derived from groundwater and interflow seeping into the stream, representing the normal amount of water in that system

capillary force: a phenomenon in which water moves through tiny pores in rock, soil, and other materials, driven by intermolecular attraction between the water and the porous materials

evaporation: the process by which substances, especially water, change from a liquid into a vapor; when a substance changes directly from solid to gas without an intermediate liquid stage, the process is called sublimation

infiltration: the movement of water into and through the soil

interception: the process by which precipitation is captured on the surfaces of vegetation before it reaches the land surface

overland flow: the flow of water over the land surface caused by direct precipitation

precipitation: atmospheric water in the form of rain, hail, mist, sleet, or snow that falls to the earth's surface

runoff: the total amount of water flowing into a stream, including overland flow, return flow, interflow, and base flow

soil moisture: the water contained in the unsaturated zone above the water table

transpiration: the process by which plants give off water vapor through their leaves

Wind may transport moisture-laden air long distances, and most precipitation events are the result of three causal factors: frontal precipitation, or the lifting of an air mass over a moving weather front; convectional precipitation related to the uneven heating of Earth's surface, causing warm air currents to rise and cool; and orographic precipitation, resulting from a moving air mass being forced to move upward over a mountain range, cooling the air as it rises.

Weather is what is going on in the atmosphere at a particular place at a particular time.

Climate is the average of a region's weather over time.

Humidity is the amount of water vapor in the air in a particular spot.

Clouds have a big influence on weather by preventing solar radiation from reaching the ground; absorbing warmth that is re-emitted from the ground; and as the source of precipitation. conditions needed for clouds to form. First, clouds form when air reaches its dew point. This can happen in two ways: (1) Air temperature stays the same but humidity increases. (2) Humidity can remain the same, but temperature decreases. When the air cools enough to reach 100% humidity, water droplets form. Air cools when it comes into contact with a cold surface or when it rises.

High-level clouds form from ice crystals where the air is extremely cold and can hold little water vapor. **Cirrus**, **cirrostratus**, and **cirrocumulus** are all names of high clouds. Cirrocumulus clouds are small, white puffs that ripple across the sky, often in rows. Cirrus clouds may indicate that a storm is coming.

Middle-level clouds, including **altocumulus** and **altostratus** clouds, may be made of water droplets, ice crystals or both, depending on the air temperatures. Thick and broad altostratus clouds are gray or blue-gray. They often cover the entire sky and usually mean a large storm, bearing a lot of precipitation, is coming.

Low-level clouds are nearly all water droplets. **Stratus**, **stratocumulus** and **nimbostratus** clouds are common low clouds. Nimbostratus clouds are thick and dark that produce precipitation. Clouds with the prefix 'cumulo-' grow vertically instead of horizontally and have their bases at low altitude and their tops at high or middle altitude. Clouds grow vertically when strong unstable air currents are rising upward. Common clouds include **cumulus humilis**, **cumulus mediocris**, **cumulus congestus**, and **cumulonimbus**.

https://www.weather.gov/

Fog is a cloud located at or near the ground . When humid air near the ground cools below its dew point, fog is formed.

Radiation fog forms at night when skies are clear and the relative humidity is high. As the ground cools, the bottom layer of air cools below its dew point.

. Warm, moist Pacific Ocean air blows over the cold California current and cools below its dew point. Sea breezes bring the fog onshore.

Steam fog appears in autumn when cool air moves over a warm lake. Water evaporates from the lake surface and condenses as it cools, appearing like steam.

Warm humid air travels up a hillside and cools below its dew point to create **upslope fog**.

The movement of water between and within the atmosphere and Earth

What processes are a part of the Hydrologic Cycle?

•Evaporation

•Precipitation

•Interception

•Infiltration

•Runoff

•Percolation

•Transpiration

•Evapotranspiration

1. The relative humidity can increase or decrease even though the water vapor content doesn't change because: relative humidity
2. is temperature dependent.
3. Groundwater results mainly from which process in the hydrologic cycle? infiltration
4. How does dew form? when the ground cools to the temperature at which the air is saturated with water vapor
5. Relative humidity: NOT can change substantially during the course of a day.
6. Adiabatic processes: NOT occur with the addition or loss of energy.
7. Which of the following are processes that occur under the Hydrologic Cycle? precipitation, infiltration, and evaporation
8. This is the most common source of condensation nuclei in places like Pittsburgh and Cleveland. : Human Activities
9. Water vapor amounts are generally lower during winter because: colder temperatures reduce the atmosphere's ability to contain water vapor.

Week 5

Clouds

Clouds provide an indication of the current weather and a forecast of weather to come as well as information regarding climate and other aspects of the atmosphere. They are also a resource for the investigation of the dynamic interactions of solid, liquid, and gaseous substances.

Principal Terms

cirrus: trailing or streaky clouds, at altitudes ranging from 5 to 13 kilometers, that are feathery or fibrous in appearance

condensation: the transformation of a substance from the vapor state to the liquid state; atmospheric condensation occurs when droplets of liquid form (or condense) around small particles in the atmosphere

convection: the transmission of heat by cyclic mass transport within a fluid substance; the movement of warmer, less dense material that rises as cooler, denser material sinks

cumulus: clouds with vertical development rising from a seemingly flat base, often appearing as fluffy masses, at altitudes ranging from ground level to 6 kilometers above the ground; sometimes called heap clouds

radiation: the transfer of energy emitted from one body through a transparent medium to another body, as occurs when light and heat energy from the sun impinge on Earth

stratus: sheet or layer clouds, at altitudes ranging from 2 to 6 kilometers above the ground (altostratus, or middle) or from 0 to 2 kilometers above the ground (stratocumulus, or low)

supersaturation: a state in which the air's relative humidity exceeds 100 percent, the condition necessary for vapor to begin transformation to a liquid state

Table 7-6. Snow density.

Density (kg m^{-3})	Characteristics
50 - 100	Fresh falling snow.
100 - 200	New top snow. Uncompacted. Called "**powder**" by skiers.
200 - 300	Settled snow on ground. Self-compacted after several days.
300 - 500	Snow compacted by grooming machines. Some target densities (kg m^{-3}) for groomed ski slopes are: 450 for cross-country (**nordic**) tracks, 530-550 for snowboard and downhill (**alpine**) runs, and 585 - 620 for slalom. Also forms naturally in deep layers of snow, such as during glacier formation.
500 - 550	Called "**névé**". Snow that has been partially melted, refrozen, & compacted.
550 - 830	Called "**firn**". Naturally compacted and aged over 1 year. A form of ice still containing air channels, observed during glacier formation.
830 - 917	Ice with bubbles, typical in the top 1000 m of old glaciers.
917	Solid ice (no bubbles). Typical of glacier ice below 1000 m depth.

Precipitation

Precipitation consists of particles of liquid or frozen water that fall from clouds toward the ground surface. Thus, precipitation links the atmosphere with the other reservoirs of the global hydrologic cycle, replenishing oceanic and terrestrial reservoirs. In addition, precipitation is the ultimate source of freshwater for irrigation, industrial consumption, and supplies of drinking water.

Principal Terms

acid precipitation: rain or snow that is more acidic than normal, usually because of the presence of sulfuric and nitric acid

Bergeron process: precipitation formation in cold clouds whereby ice crystals grow at the expense of supercooled water droplets

cold cloud: a visible suspension of tiny ice crystals, supercooled water droplets, or both at temperatures below the normal freezing point of water

collision-coalescence process: precipitation formation in warm clouds whereby larger droplets grow through the merging of smaller droplets

rain gauge: an instrument for measuring rainfall, usually consisting of a cylindrical container open to the sky

supercooled water droplets: droplets of liquid water at temperatures below the normal freezing point of water

warm cloud: a visible suspension of tiny water droplets at temperatures above freezing

Weather Modification

Weather Modification

Human activities can cause intentional or accidental changes in local weather situations. Many intentional weather modification experiments have focused on creating conditions to benefit agriculture.

Principal Terms

cloud seeding: the injection of nucleating particles into clouds to enhance precipitation formation

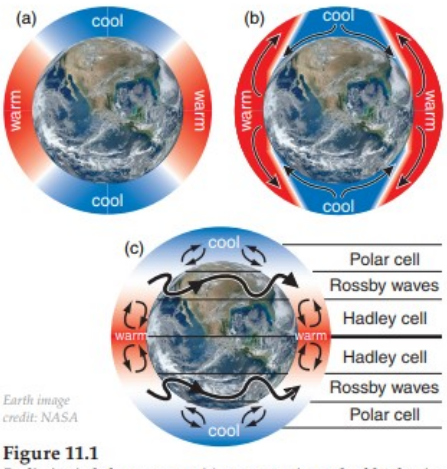


Figure 11.1
Radiative imbalances create (a) warm tropics and cold poles, inducing (b) buoyant circulations. Add Earth's rotation, and (c) three circulation bands form in each hemisphere.

dynamic mode theory: a theory proposing that enhancement of vertical movement in clouds increases precipitation
fog dissipation: removal of fog by artificial means
hail suppression: a technique aimed at lessening crop damage from hailstorms by converting water droplets to snow to prevent hail formation or, alternatively, by reducing hailstone size
hygroscopic particulates: minute particles that readily take up and retain moisture
static mode theory: a theory assuming that natural clouds are deficient in ice nuclei, whereby clouds must be within a particular temperature range and contain a certain amount of supercooled water for cloud seeding to be successful
supercooled: a liquid cooled below its normal freezing point without crystallizing or becoming solid, typically referring to water

Floods

Floods are extreme conditions of flowing water. They generally occur because of inordinate amounts of rainfall or snowmelt, but also result from other causes such as dam failures and volcanic eruptions. Floods exert a major role in shaping river systems, and their occurrence is critical to the human use of riparian lands.

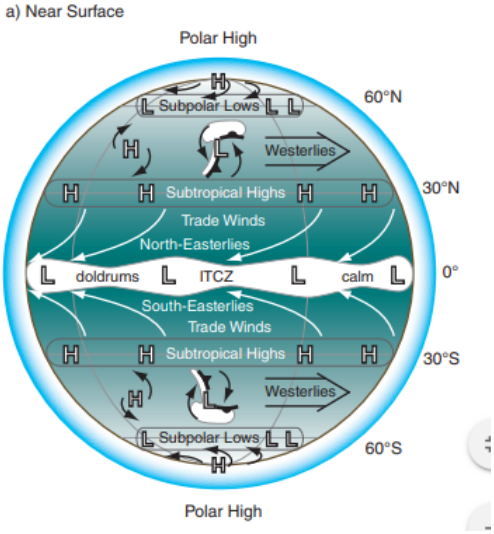
Principal Terms
discharge: the volume of water moving through a given flow cross-section in a given unit of time
flash floods: rises in water level that occur unusually rapidly, generally because of especially intense rainfall
flood: a rising body of water that overtops its usual confines and inundates land not usually covered by water
hydrology: the branch of science dealing with water and its movement in the environment
jökulhlaup: a flood produced by the release of water sequestered by a glacier, most often due to the failure of some type of glacial dam or to subglacial volcanic activity
monsoon: a seasonal, reversing pattern of wind between warm ocean bodies and landmasses
recurrence interval: the average time interval in years between occurrences of a flood of a given magnitude in a measured series of floods
runoff: that part of precipitation that flows across the land and eventually gathers in surface streams

hydrometeors – wet: clouds, rain, snow, fog, dew, frost, etc. • lithometeors – dry: dust, sand, smoke, haze • igneous meteors – lightning, corona • electrometeors – lightning (again), thunder • luminous meteors – rainbows, halos, etc.
Five factors can help make warm-cloud rain: •

- First, by random chance a small number of collisions do occur, which starts to broaden the spectrum of drop sizes
- Second, not all CCN are the same size — some are called giant CCN
- Third, turbulence can entrain outside clear air into the top and sides of a cloud, causing some droplets to partly evaporate,
- Fourth, IR radiation from individual drops near cloud top and sides can cool the drops slightly below the ambient air temperature,
- Fifth, electrical charge build-up in cumuliform clouds

7.7.3 Snowfall Rate & Snow Accumulation
Snowfall rates in the US are classified using the same visibility criterion as drizzle
Blizzard: Low visibility due to heavy snowfall or blowing loose snow, when accompanied by strong winds if it persists for 3-4 hours
White-Out: where the snow makes the ground and sky look uniformly white so you cannot discern any features or landmarks
Liquid-water equivalent: it is the precipitation rate after all precipitation is melted
Metamorphosis: where the tips of the crystals evaporate and redeposit near the crystal centers
Snow grains: d becomes more compact and dense
Pite: a ski run where the snow has been compacted by grooming machines
7.9. REVIEW Cloud droplets that form on cloud condensation nuclei (CCN) overcome a formation barrier caused by the surface tension of the curved surface. However, because there are so many CCN between which the available water is partitioned, the result is a large number of very small droplets. These drops grow slowly by diffusion, and develop a monodisperse droplet-size distribution. Such a distribution reduces droplet collisions, and does not favor droplet growth into precipitation hydrometeors. Hence, we get pretty clouds, but no rain. Warm-cloud (T > 0°C) rain can happen in the tropics, particularly over oceans where there are fewer CCN allow formation of a smaller number of larger drops. Several other processes can cause the droplet sizes to have more diversity, resulting in different terminal velocities for different drops. This encourages collision and coalescence to merge smaller droplets into ones that are large enough to precipitate out. In clouds colder than 0°C, ice nuclei trigger ice crystals to grow. Ice crystals can exist in the air along with supercooled liquid drops. Because of the difference between liquid and ice saturation humidities, the ice can grow at the expense of evaporating liquid droplets. If the ratio of water to ice hydrometeors is about a million to one, then most of the water will be transferred to ice crystals, which are then heavy enough to fall as precipitation. As larger ice particles fall and hit smaller supercooled liquid droplets, the droplets can freeze as rime onto the ice crystals, causing the hydrometeors to grow even faster. This process can create graupel and hail. Also, ice crystals can aggregate (collide and stick together) to make larger clumps of snow. Most rain at midlatitudes results from melted snow that form from this "cold cloud" process.

1. How do layers of frozen ice form in a hailstone? (mark all that apply). A liquid rain drop freezes toward the top of a storm cloud and is released to the ground The hailstone encounters different forms of moisture as it moves, and layers of frozen ice particles accumulate on its surface updrafts of warm air and downdrafts of cool air move the frozen particle up and down through different levels of



the storm cloud a liquid rain drop freezes toward the bottom of a storm cloud
2. The shape of a raindrop flattens out on the bottom as it falls.
3. Which of the following cloud constituents would have the highest terminal velocity? Hailstorms
4. What happens to a raindrop if it gets too large? breaks up into smaller drops
5. Lake-effect snowfall: requires that the lake be relatively warm.
6. Raindrops fall because: they become large enough that gravity can pull them out of the sky.
7. The typical snow to rain water equivalent ratio is: 10:1
8. What chemicals help the cloud seeding process? (mark all that apply) and…

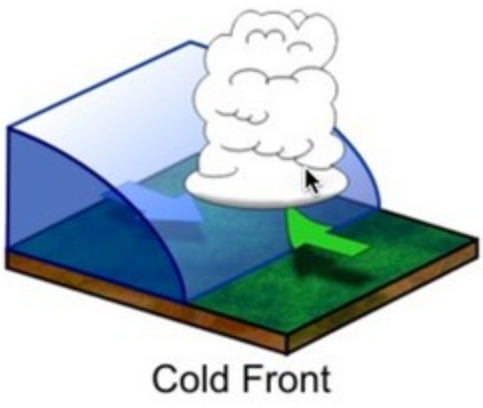
Week 6

Atmospheric Properties

The atmosphere is a layer of gaseous elements that surrounds the earth and differentiates the environment of the earth from outer space. The atmosphere retains gases produced by chemical reactions and protects the surface of the earth from both solar and cosmic radiation, thereby enabling life on Earth. The troposphere contains the greatest density of gases in the atmosphere while the stratosphere contains the ozone layer, which protects the earth from cosmic radiation.

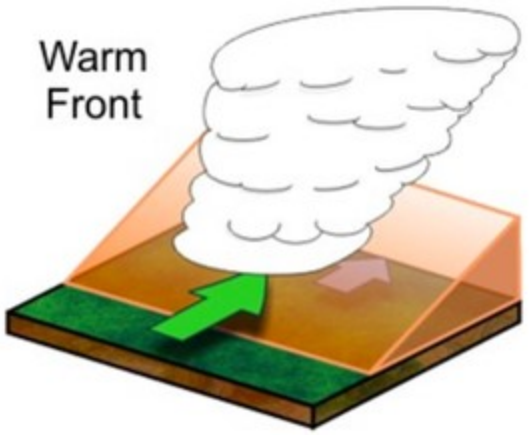
Principal Terms

atmosphere: gaseous "envelope" surrounding the earth that contains all gases produced by terrestrial sources
circulation cell: cyclic pattern of air movement within the atmosphere
convection: the vertical transport of atmospheric properties
Coriolis effect: illusion of deflection observed when a body moves through the atmosphere with regard to an individual situated on the moving surface of the earth
magnetosphere: outer region of Earth's ionosphere where the movement of particles is dominated by Earth's magnetic field
ozone: form of oxygen containing three joined oxygen atoms responsible for blocking much of the solar radiation that hits Earth's atmosphere
stratosphere: uppermost region of the atmosphere able to support life; extends from 10 to 50 kilometers (6 to 31 miles) above Earth's surface
thermosphere: outer region of the atmosphere between 80 and 800 kilometers (50 to 497 miles) from the surface where temperature increases with increasing altitude because of bombardment by solar radiation
topography: the relief features or surface configuration of a certain area
troposphere: the lowest level of Earth's atmosphere extending to approximately 10 kilometers above sea level



Atmosphere's Global Circulation

The general circulation of Earth's atmosphere involves the large-scale movements of significant portions of air in the atmosphere. Variations in surface temperatures produce pressure gradients that combine with the Coriolis force to circulate most of the air in the atmosphere. This involves the Hadley circulation, which moves air in the Northern and Southern Hemispheres in three huge convection cells each, and the Walker circulation along the equatorial belt, which produces the El Niño phenomenon when it oscillates.



Principal Terms

adiabatic: the effect of changing the temperature of a gas or other fluid solely by changing the pressure exerted on it, without the input or removal of heat energy
anticyclone: a general term for a high-pressure weather system that rotates clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere
Coriolis force: a non-Newtonian force acting on a rotating coordinate system; on the Earth, this causes objects moving in the Northern Hemisphere to be deflected toward the right and objects moving in the Southern Hemisphere to be deflected toward the left due to Earth's rotation
cyclone: a general term for a low-pressure weather system that rotates counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere
geostrophic wind: a wind resulting from the balance between a pressure gradient force and Coriolis force; the flow produces jet streams and is perpendicular to the pressure gradient force and the Coriolis force
pressure gradient force: a wind-producing force caused by a difference in pressure between two different locations

Atmospheric and Oceanic Oscillations

The oceans' effect on developing weather patterns has long been known and taken into consideration in weather prediction. Atmospheric and oceanic patterns fluctuate over a one- to twenty-year course. These fluctuations, or oscillations, create major climate change, such as the well-known El Niño Southern Oscillation (ENSO) in the tropical Pacific, which affects weather across the globe.

Principal Terms

conveyor belt current: a large cycle of water movement that carries warm waters from the North Pacific westward across the Indian Ocean, around southern Africa, and into the Atlantic, where it warms the atmosphere, then returns to a deeper ocean level to rise and begin the process again
Ekman spiral: water movement in lower depths that occurs at a slower rate and in a different direction from surface water movement
solar radiation: transfer of energy from the sun to Earth's surface, where it is absorbed and stored
trade winds: winds that blow steadily toward the equator; north of the equator, trade winds blow from the northeast, whereas south of the equator they blow from the southeast
upwelling: the process by which colder, deeper ocean water rises to the surface and displaces surface water

Monsoons

Monsoons are seasonal wind systems that reverse directions biannually and are crucial for the economic stability and agricultural productivity of affected geographic areas.

Principal Terms

austral: referring to an object or occurrence that is of the Southern Hemisphere

boreal: referring to an object or occurrence that is of the Northern Hemisphere
convection: heat transfer by the circulating movement that occurs in fluid materials as warmer, less dense material rises above cooler, denser material
geostrophic: descriptive of wind that occurs when the Coriolis force is in exact balance with the force of a horizontal pressure gradient and therefore blows in a straight line
Intertropical Convergence Zones (ITCZ): low-pressure areas where southern and northern trade winds meet
orography: study of mountains that incorporates assessment of how they influence and are affected by weather and other variables
oscillation: variation of some physical property or condition between two opposing states, much like the rising and falling of a wave between its maximum and minimum heights
troposphere: the level of the atmosphere closest to the ground, extending from the surface to an altitude of 11 kilometers
trough: a long and relatively narrow area of low barometric pressure
vortex: the central locus of a whirling liquid or gas, about which the fluid mass circulates

Long-term weather patterns

Much work in meteorology is dedicated to the accurate prediction of short-term weather patterns. However, an important part of meteorology is the pursuit of information on long-term trends and conditions. This field involves the study of consistent weather conditions that develop and continue through months and years. The field also entails an understanding of certain phenomena that contribute to these extended weather periods. Research on long-term weather patterns can help scientists understand past climate changes and predict future shifts, enabling society to better prepare for such weather changes.

Principal Terms

Arctic oscillation: long-term weather pattern in which the different air pressures in the Arctic and middle latitude regions cause varying weather conditions
El Niño: meteorological condition in which the waters of the tropical, eastern Pacific Ocean are warmed by the atmosphere
La Niña: meteorological condition in which the waters of the eastern, tropical Pacific Ocean are cooled by a lack of radiation from the atmosphere
Madden-Julian oscillation: intraseasonal tropical wave that travels around the globe, causing monsoons and other high-water storms and also suppresses them
trade winds: winds at the level of the ocean surface that blow from the east to the west in the tropical Pacific

Table 12-1. Airmass abbreviations. **Boldface** indicates the most common ones.

Abbr.	Name	Description
c	**continental**	Dry. Formed over land.
m	**maritime**	Humid. Formed over ocean.
A	Arctic	Very cold. Formed in the polar high.
E	Equatorial	Hot. Formed near equator.
M	Monsoon	Similar to tropical.
P	**Polar**	Cold. Formed in subpolar area.
S	Superior	A warm dry airmass having its origin aloft.
T	**Tropical**	Warm. Formed in the subtropical high belt.
k	colder than the underlying surface	
w	warmer than the underlying surface	
Special (regional) abbreviations.		
AA	Antarctic	Exceptionally cold and dry.
r	returning	As in "rPm" returning Polar maritime [Great Britain].

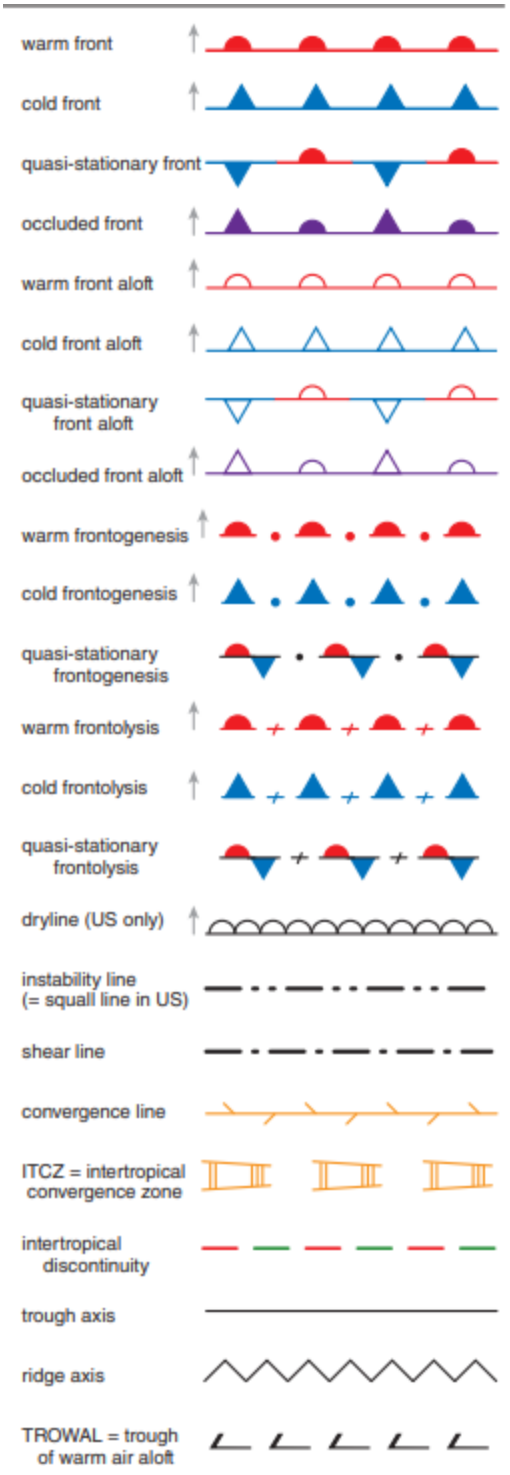
Note: Layered airmasses are written like a fraction, with the airmass aloft written above a horizontal line and the surface airmass written below. For example, just east of a dryline you might have:

$$\frac{cT}{mT}$$

Ch. 10 The Atmosphere: Atmospheric Movements and Flow

Significance of the Atmosphere: INDISPENSABLE FOR LIFE ON EARTH , CRUCIAL PART OF THE WATER CYCLE , OZONE LAYER MAKES LIFE POSSIBLE , MODERATES EARTH'S TEMPERATURE

All **weather** takes place in the atmosphere, virtually all of it in the lower atmosphere.
Ozone is a molecule composed of three oxygen atoms, (O3). Ozone in the upper atmosphere absorbs high-energy **ultraviolet (UV) radiation** coming from the Sun.
Greenhouse gases trap heat in the atmosphere so they help to moderate global temperatures.

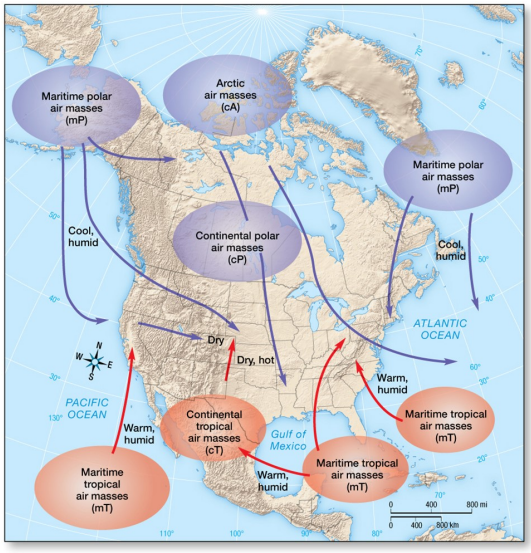


Global Atmospheric Circulations

Because more solar energy hits the equator, the air warms and forms a low pressure zone. At the top of the troposphere, half moves toward the North Pole and half toward the South Pole. As it moves along the top of the troposphere it cools. The cool air is dense and when it reaches a high pressure zone it sinks to the ground. The air is sucked back toward the low pressure at the equator. This describes the convection cells north and south of the equator.
In the **Ferrel cell** air should move south to north, but the winds actually blow from the southwest.
the **Polar cell**, the winds travel from the northeast and are called the polar easterlies The wind belts are named for the directions from which the winds come.
the **Hadley cell** air should move north to south, but it is deflected to the right by Coriolis. So the air blows from northeast to the southwest.

Air masses: uniform temperature and humidity characteristics. Vast areas
Fronts :boundaries between different air masses. Spatially limited and usually linked to midlatitude cyclones.
•Source Regions
–areas of the globe where air masses form.
–Long-term heating or cooling
–air must remain over a source region for a substantial time
–temperature and humidity categorized using lowercase and upper-case letter

•Continental Polar (cP) Air Mass
–Continental polar (cP) air masses form over large, high-latitude landmasses, such as N Canada and Siberia.
–The cold, dry air is typically stable.
•Continental Arctic (cA) Air Mass
–Continental arctic (cA) air masses contains very little water vapor.
–The boundary between cA and cP air is the arctic front.
•Maritime Polar (mP) Air Masses
–Maritime polar (mP) air masses form over the North Pacific migrate to the east
–Impacts N America primarily in winter.
–mP air masses affect the east cost of N America in the form of northeasters,
–bringing cold winds and heavy snowfall to the US northeast.
•Continental Tropical (cT) Air Masses
–Continental tropical (cT) air masses form during the summer over hot, low-latitude areas (southwestern US and Mexico).
–cT air masses are hot and dry.
–air masses are very unstable but low water vapor, do not usually produce precipitation.
–When water vapor is present, thunderstorms form
•Maritime Tropical (mT) Air Masses
–Maritime tropical (mT) air masses form over warm tropical waters
–mT air masses form over the Atlantic and Gulf of Mexico and migrate toward N America.
–High moisture content and instability
–thunderstorms and heavy rains.
–Fronts separate air masses
–four general types of fronts associated with midlatitude cyclones.
•Cold fronts
•Warm fronts
•Stationary fronts
•Occluded fronts



•Stationary Fronts
–Stationary fronts do not move.
–They do not advance.
–two unlike air masses side by side.
•Occluded Fronts
–Occluded fronts: two fronts meet, and the warm air mass is displaced aloft.
–occurs when a cold front meets a warm front as it

Source Regions

TABLE 9–1
Air Masses

Type	Source Regions	Properties at Source
Continental polar (cP)	High-latitude continental interiors	Cold and dry. Very stable. Minimal cloud cover.
Continental arctic (cA)	Highest latitudes of Asia, North America, Greenland, and Antarctica	Extremely cold and very dry. Extremely stable. Minimal cloud cover.
Maritime polar (mP)	High-latitude oceans	Cold, damp, and cloudy. Somewhat unstable.
Continental tropical (cT)	Low-latitude deserts	Hot and dry. Very unstable.
Maritime tropical (mT)	Subtropical oceans	Warm and humid.

circulates the low pressure center of a midlatitude cyclone.
–A cold-type occlusion where a cold front associated with cP air meets a warm front with mP air ahead.
–A warm-type occlusion where the cold front associated with mP air migrates to an area that is occupied by cP.
•Drylines
–Drylines boundaries between humid air and denser dry air.
–favored location for thunderstorm development.
Orographic lift occurs when an air mass is forced from a low elevation to a higher elevation as it moves over rising terrain. As the air mass gains altitude it quickly cools down adiabatically, which can raise the relative humidity to 100% and create clouds and, under the right conditions, precipitation
Lifting by **Convergence** broad **lifting** of an entire layer of air.**Convergence** is an atmospheric condition that exists when there is a horizontal net inflow of air into a region. When air converges along the earth's surface, it is forced to rise since it cannot go downward

_____
http://www.classzone.com/books/earth_science/terc/content/visualizations/es2002/es2002page01.cfm?chapter_no=visualization
http://fod.infobase.com.ezp.pasadena.edu/p_ViewVideo.aspx?xtid=44017&loid=111158
http://fod.infobase.com.ezp.pasadena.edu/p_ViewVideo.aspx?xtid=34726&loid=26107
http://www.mesoscale.iastate.edu/agron206/animations/05_cnWfronts.html

1. There are _____ primary types of fronts. Four
2. This type of front has a mass of warm air cut off from the surface. Occluded front
3. Fronts can cause uplift.
4. The coldest air mass is: Arctic
5. Which of the following are often associated with the passage of a frontal system? ALL
6. When a warm and cold air mass come together _____ lifting occurs. Frontal
7. Warm fronts: typically provide longer periods of precipitation than do cold fronts.
8. An "air mass" is a large body of air that has similar horizontal characteristics of: moisture & temp.

Week 8

Cyclones and Anticyclones.

Cyclones and anticyclones are large-scale weather systems with opposite properties. A cyclone is characterized by a central region of low atmospheric pressure and an anticyclone is characterized by a central region of high atmospheric pressure. Because cyclones are a major cause of stormy weather and anticyclones typically bring good weather, accurate meteorological predictions are greatly informed by an understanding of how these weather systems originate and develop.

Principal Terms

convergence: a tendency of air masses to accumulate in a region where more air is flowing in than is flowing out

Coriolis effect: the illusion of deflection observed when a body moves through the atmosphere with regard to an individual situated on the moving surface of the earth

cyclogenesis: the series of atmospheric events that occur during the formation of a cyclone weather system

divergence: a tendency of air masses to spread in a region where more air is flowing out than is flowing in

front: the boundary between two masses of air with different densities and temperatures; usually named for the mass that is advancing (for example, in a cold front, the mass that is colder is moving toward a warmer mass)

hurricane: a cyclone that is found in the tropics (between 23.5 degrees north and south of the equator) and that has winds that are equal to or exceed 64 knots, or 74 miles per hour

isobar: on a map, a line connecting two or more points that share the same atmospheric pressure, either at a particular time or, on average, in a particular period

mid- latitude cyclone: a synoptic-scale cyclone found in the mid -latitudes (between 30 and 60 degrees north and south of the equator)

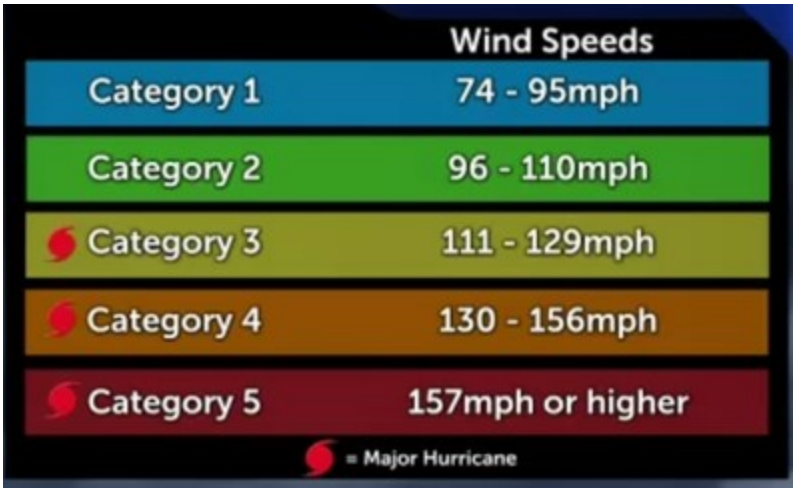
synoptic scale: a scale used to describe high- and low-pressure atmospheric systems that have a horizontal span of 1,000 kilometers (621 miles) or more

in Chapter 11 Weather Processes and Systems: Cyclones.

A **cyclone** is a system of winds rotating counterclockwise in the Northern Hemisphere around a low pressure center. The swirling air rises and cools, creating clouds and precipitation.

Mid-latitude cyclones, sometimes called **extratropical cyclones**, form at the polar front when the temperature difference between two air masses is large. These air masses blow past each other in opposite directions

Common Name in N. Amer.	Formal Name	Other Common Names	T of the Core	Map Symbol
low	extra-tropical cyclone	mid-latitude cyclone low-pressure center storm system* cyclone *(in N. America)*	cold	L
hurricane	tropical cyclone	typhoon *(in W. Pacific)* cyclone *(in Australia)*	warm	



HURRICANES

Tropical cyclones have many names. They are called hurricanes in the North Atlantic and eastern Pacific oceans, typhoons in the western Pacific Ocean, tropical cyclones in the Indian Ocean, and willi-willi's in the waters near Australia.

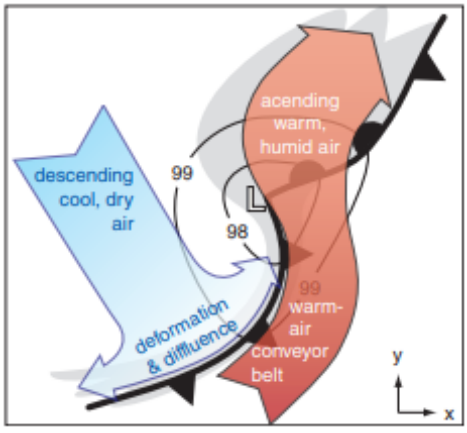
Around the low pressure disturbance is a wall of clouds called an **eye wall**. Within the eye wall, the wind speeds are greatest, the clouds are the tallest, atmospheric pressure is at its lowest, and precipitation is most intense.
At the center or heart of the hurricane is called the **eye**. Within the eye of a hurricane, winds are light, precipitation is minimal, and occasionally the skies above are clear. It is the calm region of the tropical storm

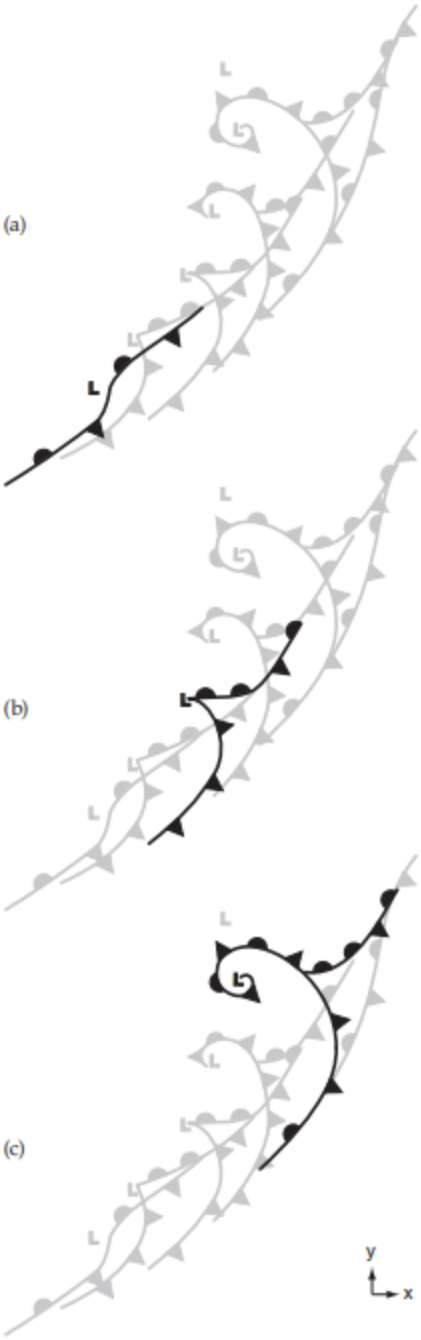
spiral rain bands, that rotate around and toward the storm's eye wall

Hurricanes typically last for 5 to 10 days. Over cooler water or land, the hurricane's latent heat source shut downs and the storm weakens. When a hurricane disintegrates, it is replaced with intense rains and tornadoes.

Page 423- 435 in Chapter 13 Extra Tropical Cyclones.
updrafts over a synoptic-scale region remove air from near the surface, causing the air pressure to decrease. The pressure gradient between this low-pressure center and the surroundings drives horizontal winds, which are forced to turn because of Coriolis force. Frictional drag near the ground causes these winds to spiral in towards the low center, adding more air molecules horizontally to compensate for those being removed vertically. If the updraft weakens, the inward spiral of air molecules fills the low to make it less low (cyclolysis).

baroclinic zone – a long, narrow region of large temperature change





across a short horizontal distance near the surface.

spin-up stage — so named because vorticity is increasing as the cyclone intensifies. The resulting pressure gradient around the surface low starts to generate lower-tropospheric winds that circulate around the low

The kinked front is wave shaped, and is called a frontal wave . The winds begin to advect the warm air poleward on the east side of the low and cold air equatorward on the west side, causing a kink in the former stationary front near the low center

The cool air is often drier, and is visible in satellite images as a dry tongue of relatively cloud-free air that begins to wrap around the low. This marks the beginning of the cyclolysis stage. During this stage, the low is said to occlude as the occluded front wraps around the low center.

http://

fod.infobase.com.ezp.pasadena.edu/p_ViewVideo.aspx?xtid=115861&loid=422118

<mid latitude cyclone .swf>

http://www.classzone.com/books/earth_science/terc/content/investigations/es2003/es2003page03.cfm

- According to the polar front theory, midlatitude cyclones : cover large portions of a continent and bring precipitation to wide areas
- Rising air is usually associated with a(n) **trough** while sinking air is usually associated with a **ridge**
- Mid-latitude cyclones: often bring substantial changes in wind and temperature

The three-dimensional nature of mid-latitude cyclones is depicted best by

the conveyor belt model

- In and during the occlusion process, the mid-latitude cyclone accomplishes its major purpose which is to mix air of different temperatures
- Anticyclones: often bring calm weather
- The surface high and low pressure centers are steered by : Jet streams, Rossby waves and upper level flows
- Of the following steps in classical cyclogenesis of a mid-latitude cyclone, this happens last. occlusion occurs

Midterm:

- Ozone: absorbs ultraviolet light
- This is the most abundant gas in the atmosphere. Nitrogen
- The heterosphere: is populated primarily by variable gases.
- Compared to the size of the earth, the atmosphere is very thin because it is highly compressed
- Albedo: is high for ice, snow and thick clouds.
- Temperatures at any point on the face of the earth are influenced by: latitude, altitude, and proximity to water.
- Which of the following is the tilt of the earth's axis NOT responsible for? Different lengths of day at different latitudes
- This is the only atmospheric variable that always decreases with distance above the ground: pressure
- Air pressure is: the sum of the partial pressures of its constituent gases.
- Which of the following is true about the geostrophic flow? Pressure gradient force equals the Coriolis force, it occurs only in the upper atmosphere, and friction is not present.
- In the northern hemisphere, a low pressure system: TRY has counterclockwise flow in at the surface and out at the top of the system
- Which of the following connects points of equal atmospheric pressure? Isobars
- Air that contains as much water as it can hold: is saturated
- Adiabatic processes: NOT usually not reversible
- How does advection fog form? (mark all that apply) ??
- How do Jet Streams show up on satellite images of water vapor? Jet streams show up as elongated dark regions bordered by lighter regions in the images
- A parcel of rising air is least likely to do this. Contract
- Water vapor amounts are generally lower during winter because: colder temperatures reduce the atmosphere's ability to contain water vapor.
- The most important principle underlying the Bergeron process is this: For a given temperature, the saturation vapor pressure of ice is less than that for supercooled water.
- Which of the following does not compromise the accuracy of rain gauge measurements? different sizes of raindrops entering the gauge
- The process by which supercooled water droplets freeze onto falling ice crystals is called: riming
- Lake-effect snowfall: requires that the lake be relatively warm
- A collector drop will have the highest collision efficiency with this size drop NOT drops that are somewhat smaller
- How do layers of frozen ice form in a hailstone? (mark all that apply) ??
- Cyclones and anticyclones are classified as this scale of phenomena: synoptic scale

- Semi-permanent pressure cells: can change substantially from summer to winter
- Maps of the global distribution of the mean height of the 500 mb surface show a decrease in height at the pole, which is due primarily to: low temperatures at the pole.
- The process where cold ocean waters are circulated to the surface is called upwelling
- The two major jet streams that impact weather in the northern hemisphere are the: polar jet stream and the subtropical jet stream
- The Hadley cell: originates with strong solar heating at the equator.
- The Ferrel Cell is associated with the mid-latitudes
- Which of the following are often associated with the passage of a frontal system? All
- Northern Hemisphere mid-latitude cyclones can typically have all of the following characteristics, except: a high-pressure region at the center.
- The difference between "Rayleigh" scattering and "Mie" scattering is: the wavelength of the incoming radiation and the size of the scattering particulates.
- If the tilt of the earth's axis were to increase from 23.5° to 33.5°: summers would get warmer and winters would get colder.
- Adiabatic processes: often involve changes both in temperature and pressure.
- A collector drop will have the highest collision efficiency with this size drop: drops that are much larger
- What chemicals help the cloud seeding process? (mark all that apply) Calcuim chloride & Silver Iodide
- How do layers of frozen ice form in a hailstone? (mark all that apply). updrafts of warm air and downdrafts of cool air move the frozen particle up and down through different levels of the storm cloud The hailstone encounters different forms of moisture as it moves, and layers of frozen ice particles accumulate on its surface
- Sea breezes: result from the fact that water both warms and cools more slowly than land.
- The ITCZ: receives a lot of rain

Week 9

Lightning and Thunder

Lightning is the discharge of accumulated static electricity from a thundercloud as a gigantic electrical arc between the cloud and the ground or another cloud. It is accompanied by intense heating and explosive expansion of air, producing the sonic boom called thunder. Lightning may cause property damage and death, but it also contributes to the nitrogen absorption in the soil necessary for plant life and may have even helped to start life on Earth.

Principal Terms

ball lightning: a rare form of lightning appearing as luminous balls of charged air

bead lightning: lightning that appears as a series of beads tied to a string

convection: vertical air circulation in which warm air rises and cool air sinks in a cyclic manner

corona discharge: a continuous electric discharge from highly charged, pointed objects that produces the luminous greenish or bluish halo known as St. Elmo's fire

cumulonimbus: thunderstorm clouds that develop vertically by strong convection in the atmosphere and, due to high-altitude wind shear, often form a top shape reminiscent of an anvil

dart leaders: surges of electrons that follow the same intermittent ionized channel taken by the initial stepped leader of a lightning stroke

graupel: ice particles between 2 and 5 millimeters in diameter that form by a process of accretion in a cloud

ionosphere: an electrically active region of the upper atmosphere from about 80 to 800 kilometers above the surface of Earth that contains a relatively high concentration of ions (charged atoms or molecules) and free electrons

return stroke: the luminous lightning stroke that propagates upward from the ground surface toward the base of a cloud as electrons surge downward and a positive current flows to the cloud

stepped leader: an initial discharge of electrons that proceeds in a series of steps from the base of a thundercloud toward the ground

Tornadoes

Tornadoes are small, violent, rotating storms that may produce devastating wind velocities of more than 400 kilometers per hour. The force of the cyclonic wind in a strong tornado can demolish well-built structures, and people in a tornado's path are at severe risk of physical harm and death.

Principal Terms

cold front: the transition zone or zone of contact between two air masses when cold air moves into a region occupied by warmer air

Coriolis effect: a phenomenon in which, because of the planet's rotation, an apparent force is exerted on objects in motion, causing them to deflect from their intended path to the right in the Northern Hemisphere or to the left in the Southern Hemisphere

cumulonimbus cloud: also called "thunderstorm cloud"; a very dense, tall, billowing cloud form that develops an anvil-shaped head due to high-altitude wind shear, and normally accompanied by lightning and heavy precipitation

dust devil: a rotating column of air rising above a hot ground surface, made visible by the dust it contains; it is much smaller than a tornado, having winds of less than 60 kilometers per hour, and causing little or no damage

hurricane: a huge, tropical low-pressure storm system with sustained winds in excess of 118 kilometers per hour, formed over warm ocean surface water and powered by thermodynamic heat transfer from the water

squall line: any line of vigorous thunderstorms created by a cold downdraft that spreads out ahead of a fast-moving cold front

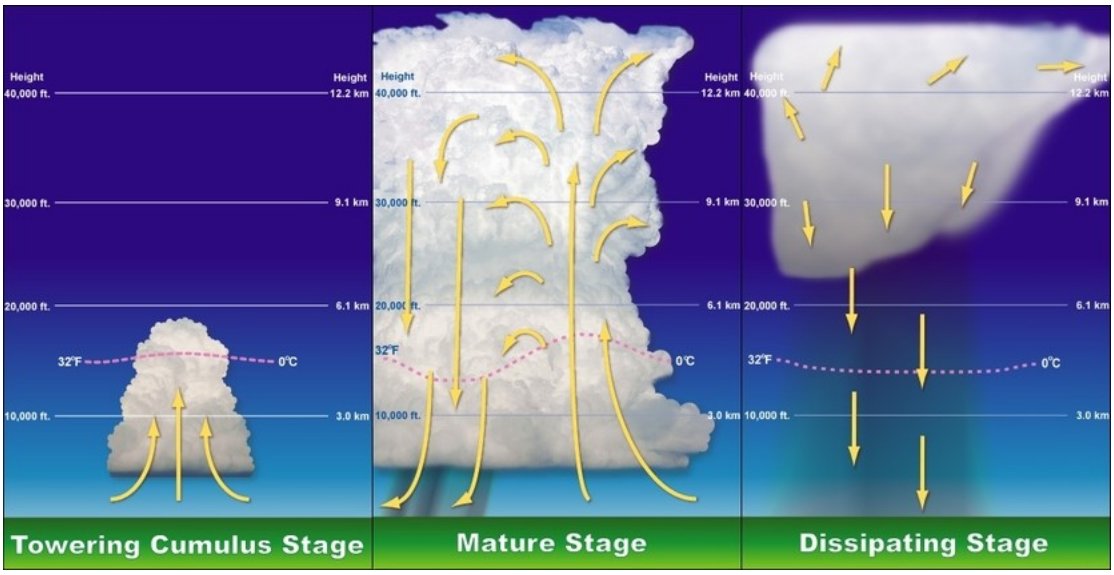
unstable air: a condition that occurs when the air above rising air is unusually cool so that the rising air becomes relatively warmer and accelerates upward

vortex: the central, low-pressure axis of any rotating fluid, as occurs in whirlpools and tornadoes

waterspout: a tornado that exists over water; less violent and smaller waterspouts form in fair weather just as dust devils do over dry land

Thunderstorms are extremely common: They form when ground temperatures are high, ordinarily in the late afternoon or early

evening in spring and summer.



All thunderstorms go through a three-stage life cycle. The first stage is called the **cumulus stage**, where an air parcel is forced to rise, cool, and condense, called the lower condensation level, to develop into a cumulus cloud. The process of water vapor condensing into liquid water releases large quantities of latent heat, which makes the air within the cloud warmer, and unstable causing the cloud continues to grow upward like a hot air balloon. These rising air parcels, called updrafts, prevent precipitation from falling from the cloud. But once the precipitation becomes too heavy for the updrafts to hold up, the moisture begins to fall creating downdrafts within the cloud. The downdrafts also begin to pull cold, dry air from outside the cloud toward the ground in a process called **entrainment**.

Once the precipitation begins to fall from the cloud, the storm has reached the **mature stage**. During this stage, updrafts and downdrafts exist side-by-side and the cumulonimbus is called a **cell**. If the updrafts reach the top of the troposphere, the cumulus cloud will begin to spread outward creating a defined **anvil**. At the same time, the downdrafts spread within the cloud and at first make the cloud become wider, but eventually overtaking the updrafts. Cool downdrafts form when precipitation and the cool air from entrainment are dragged down to the lower regions of a thunderstorm. It is also during the mature stage when the storm is most intense producing strong, gusting winds, heavy precipitation, lightning, and possibly small hail.

Once the downdrafts overtake the updrafts, which also prevents the release of latent heat energy, the thunderstorm will begin to weaken into the third and final stage, called the **dissipating stage**. During this stage, light precipitation and downdrafts become the dominate feature within the cloud as it weakens. In all, only twenty percent of the moisture within the cloud fell as precipitation whereas the other eighty percent evaporates back into the atmosphere.

With severe thunderstorms, the downdrafts are so intense that when they hit the ground it sends warm air from the ground upward into the storm. The warm air gives the convection cells more energy.

The electrical discharge may be between one part of the cloud and another, two clouds, or a cloud and the ground. Click here

Lightning heats the air so that it expands explosively creating a shock wave called **thunder**

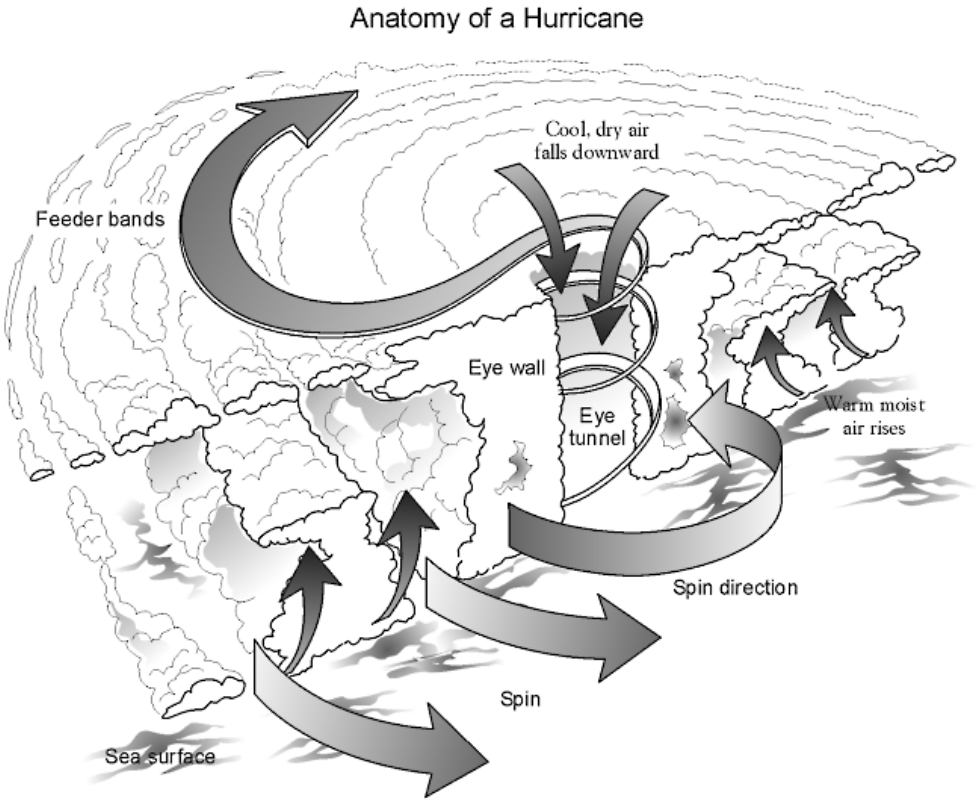
Tornadoes, also called twisters, are fierce products of severe thunderstorms. As air in a thunderstorm rises, the surrounding air races in to fill the gap, forming a funnel

Tornadoes form at the front of severe thunderstorms. Lines of these thunderstorms form in the spring where where maritime tropical (mT) and continental polar (cP) air masses meet.

- Which of the following are correct lightning safety rules? (Mark all that apply) - All
- Which of these can be characteristics of severe thunderstorms? (Mark All that Apply) Try all except None of the answers
- If you are outside in the presence of lightning and cannot take cover indoors, which of the following would be the safest course of action? go to a low-lying area, crouch down and minimize your contact with the ground
- Charge separation: results in lightning only if the cloud extends above the freezing level.
- Thunder: results from the explosive expansion of air
- The sound of thunder caused by a lightning strike reaches your ears after the light from the lightning flash reaches your eyes.
- Most lightning discharges occur within clouds
- A common Doppler radar signature associated with a supercell tornado is the: hook echo

EF-Scale	3 Second Gust (mph)	Damage
EF0 (Gale)	65-85	Light - tree branches fall and chimneys may collapse
EF1 (Weak)	86-110	Moderate - mobile homes, automobiles pushed aside
EF2 (Strong)	111-135	Considerate - roofs torn off houses, large trees uprooted
EF3 (Severe)	136-165	Severe - houses torn apart, trees uprooted, cars lifted
EF4 (Devastating)	166-200	Devastating - houses leveled, cars thrown
EF5 (Incredible)	Over 200	Incredible - structures fly, cars become missiles

Week 10



Hurricanes are cyclonic storms that form over tropical oceans. A single storm can cover hundreds of thousands of square kilometers and have interior wind speeds of 65 to 230 knots (74 to 200 miles) per hour near its eye. Destruction is caused by wind damage, as well as by storm surge and subsequent flooding.

Principal Terms

condensation: the process by which water, or any other substance, changes from a vapor state to a liquid state, releasing heat into the surrounding air; this process is the opposite of evaporation, which requires the input of heat

Coriolis force: an apparent force caused by the rotation of the planet, in which objects moving above Earth's surface (such as the wind) deflect to the right in the Northern Hemisphere and to the left in the Southern Hemisphere

knot: a unit of nautical distance equivalent to 1.86 kilometers or 1.15 miles

tropical cyclone: an area of low pressure that forms over tropical oceans, characterized by extreme amounts of rain, a central area of calm air, and winds that attain speeds of up to 300 kilometers per hour rotating counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere

tropical depression: cyclonic thunderstorms with wind speeds from 36 to 64 kilometers per hour

tropical storm: a thunderstorm with cyclonic winds circulating at speeds of 64 to 118 kilometers per hour

vortex: a mass of air, water, or other fluid that spins about a central axis, capable of reaching high velocities

hurricanes have sustained winds of at least 65 knots (74 miles) per hour with maximum wind speeds of 230 knots (200 miles) per hour. In the Western Hemisphere, these storms are called hurricanes. They are also referred to as typhoons in the western North Pacific, cyclones in the Indian Ocean, and *baguios* in the Philippines. The swirling motion of these storms is counterclockwise, or cyclonic, in the Northern Hemisphere and clockwise, or anticyclonic, in the Southern Hemisphere.

The region around the equator is traditionally called "the doldrums" because there is no consistent direction to wind flow. Hurricanes, needing wind to form, can be found as close as 4 to 5 degrees away from the equator. At these latitudes, the Coriolis effect, an apparent deflecting force associated with Earth's rotation, gives the moving air masses the spin necessary to form hurricanes.

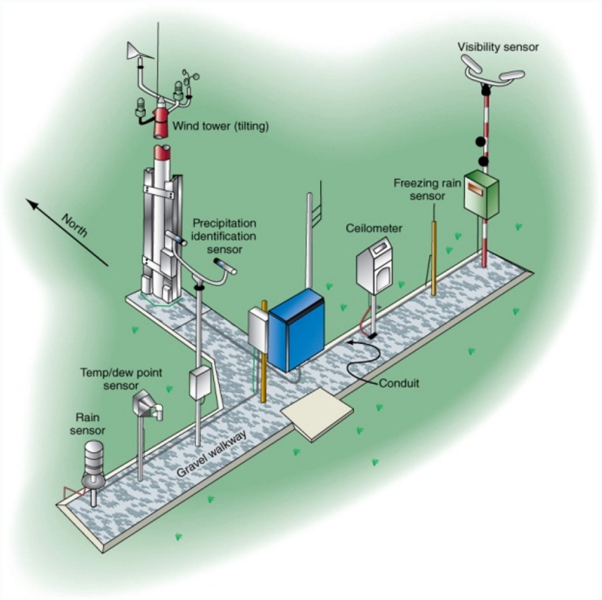
- Sea-level pressure near the center of a typical hurricane is about **50 mb less** than the average sea-level pressure.
- The driving force of all hurricanes is: the release of latent heat
- As one approaches the eye wall of a hurricane, the sea level pressure **falls rapidly** and the surface wind **rises rapidlly**.
- Hurricanes have: no fronts
- Hurricanes: contain numerous thunderstorms arranged in a pinwheel formation.
- Hurricane storm surges are most destructive during : High tide
- An easterly wave is: a favorable area for hurricane development
- Choose the answer that places the hurricane at its proper position with respect to overall storm size. (largest diameter to smallest diameter) mid-latitude cyclone, hurricane, thunderstorm, tornado

Week 11

Weather Forecasting and Analysis

•National Weather Service (NWS) US Weather
–8 hour shifts
– 122 weather offices
– open 24/7
–Use The Advanced Weather Interactive Processing System (AWIPS) current weather conditions, computer forecast models displayed in map form, satellite and radar images, forecast advisories and discussions from other weather facilities, etc.).
•There are four forecasting methods:
–Climatological forecasts: based on long-term averages.
–Persistence forecasts: based on current conditions.
–Analog approach: based on current conditions and similar well-studied patterns from the past.
Numerical weather forecasting: based on computer programs that mimic the behavior of the atmosphere
•There are three types of forecasts:
–Quantitative forecasts: "An inch of rain is expected." "The high is going to be 56ºF today."
–Qualitative forecasts: "Rain/no rain" or "above/below normal"
–Probability (PoP) forecasts: "The rain chance today is 70%." "There is a 60% chance of snow."

The FAA and NWS have installed a network of more than 800 automated sensors, called Automated Surface Observing System, or ASOS, for measuring and recording temperature, humidity, pressure, cloud conditions, wind direction and speed, visibility, presence of fog or rain, and accumulated precipitation readings at ground level.



•Phases in Numerical Modeling
–A variety of numerical models are used to create forecasts.
–Models differ but they all involve three phases: analysis, prediction, and postprocessing.
•Analysis Phase
–Data is used to create a current state of the atmosphere.
–Data is converted into uniform initial values.
–Values for both the horizontal and the vertical conditions over very large areas plotted.
–Prediction Phase
•Based on solving basic governing equations.
•Equations used to obtain new values minutes into the future.
•Equations solved and advanced through various forecasting periods.
•Billions of equations solved at each step.
–**Postprocessing Phase**
•A series of maps of atmospheric conditions constructed.
•Each map centers upon one or a few variables.
•Forecasters use these products as general guidance.
•Combinations of model output are generally used.
•Model output statistics (MOS) are produced, taking into account the effect of topography and other local features.
•Short Term Models (72 hours or less):
–(NAM) North American Mesoscale Forecast Sysatem
–Rapid Refeash model (RAP): Run every hour going out 18 hours
•Medium Range Models:
•Medium range forecasts (MRF) forecasts for 72 hours to a few weeks.
•GFS Global Forecast System: up to 16 days
•Long Range Forecasts: several weeks to several months or more.
–Climate Prediction Center (CPC) produces these forecasts.
CPC also produces a seasonal outlook, or a forecast for the entire season
•Medium-Range Forecasts
–Medium range forecasts (MRF) forecasts for 72 hours to a few weeks.
–Ensemble forecasting predictions from several different computer model forecasts are combined
–Chaos it impossible to precisely predict how a system will appear
•Surface Maps
–Forecasting is performed by experienced meteorologists by examining and analyzing many weather charts and models.
•Surface maps
–Surface maps depict prevailing conditions, pressure distributions, location of fronts, etc.
–Both large-scale features and station models are included in surface maps.
•Station models include well over a dozen elements.
•Upper-Level Maps
–Plotted twice daily, for 0000 and 1200 UTC for all mandatory pressure levels.
•850mb Maps
–850mb level typically found about 1.5km (1mi) above sea level.
–Heights are solid lines, isotherms are dashed lines.
–useful in determining daily maximum surface temps for non-mountainous regions.
–700mb Maps
•700 mb level typically found about 3km (2mi) above sea level.
•Useful for observing short waves and the formation of
midlatitude cyclones, and tracking air mass thunderstorms.

Weather systems are chaotic, which limits the degree of forecasting accuracy. The study of chaos theory and chaotic systems has allowed the development of innovative techniques that give insight into weather predictability.

Principal Terms

aperiodic: describing any phenomenon that occurs at random rather than at regularly occurring intervals, such as found in most weather cycles, rendering them virtually unpredictable

chaos: an emerging scientific discipline that attempts to quantify and describe the properties of seemingly random, aperiodic events

nowcasting: a weather forecast made and disseminated within an hour or less for a specific area for an approaching weather system

weather analogue: an approach that uses the weather behavior of the past to predict what a current weather pattern will do in the future

Most industrialized nations use numerical weather prediction (NWP) techniques to formulate weather forecasts. NWP is based on physical laws that are incorporated into a mathematical model, with solutions determined using computer algorithms. Large amounts of data are used to initialize the numerical models and verification of short-range NWP models shows a considerable improvement over climatology. NWP models require large mainframe supercomputers to formulate each forecast.

Principal Terms

climatology: the scientific study of climate that depends on the statistical database of weather observed over a period of twenty or more years for a specific location

ensemble weather forecasting: repeated use of a single model, run many times using slightly different initial data; the results of the model runs are pooled to create a single “ensemble” weather forecast

forecast verification: comparison of predicted weather to observed weather conditions to assess forecasting accuracy and reliability

global atmospheric model: computational model of global weather patterns based on a spherical coordinate system representing the entire planet

hemispheric model: a numerical model that extends over the whole Northern or Southern Hemisphere, or just one half of the planet

long-range prediction: a weather forecast for a specific region

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hemispheric model: a numerical model that extends over the whole Northern or Southern Hemisphere, or just one half of the planet

long-range prediction: a weather forecast for a specific region for a period greater than one week in advance, often supplemented with climatological information

mesoscale model: a weather forecast for an area of up to several hundred square kilometers in extent on a time scale of between one and twelve hours

nondeterminism: chaotic, random events that cannot be predicted but that have a significant influence on the development of weather systems

nowcasting: a very short-term weather forecast usually for the prediction of rapidly changing, severe weather events within a time of no more than a few hours

Thermometers measure temperature. In an old-style mercury thermometer, mercury is placed in a long, very narrow tube with a bulb. Because mercury is temperature sensitive, it expands when temperatures are high and contracts when they are low.

Meteorologists use **barometers** to measure air pressure. A barometer may contain water, air, or mercury, but like thermometers, barometers are now mostly digital.

According to the WMO, weather information is collected from 15 satellites, 100 stationary buoys, 600 drifting buoys, 3,000 aircraft, 7,300 ships, and some 10,000 land-based stations. The official weather stations used by the National Weather Service is called the **Automated Surface Observing System** (ASOS).

Radiosondes is a balloon that measures atmospheric characteristics, such as temperature, pressure, and humidity as they move through the air. Radiosondes in flight can be tracked to obtain wind speed and direction

Radar stands for Radio Detection and Ranging. A transmitter sends out radio waves that bounce off the nearest object and then return to a receiver. Weather radar can sense many characteristics of precipitation: its location, motion, intensity, and the likelihood of future precipitation.

Doppler radar can also track how fast the precipitation falls. Radar can outline the structure of a storm and can be used to estimate its possible effects.

Weather satellites, a form of remote sensing, have been increasingly important sources of weather data since the first one was launched in 1952 and are the best way to monitor large scale systems, such as storms.

SATELLITES

Weather satellites, a form of remote sensing, have been increasingly important sources of weather data since the first one was launched in 1952 and are the best way to monitor large scale systems, such as storms. Satellites are able to record long-term changes, such as the amount of ice cover over the Arctic Ocean in September each year. They also observe all energy from all wavelengths in the **electromagnetic spectrum**.

The flagship of the National Weather Service is the **Geostationary Operational Environmental Satellites** (GOES). These satellites are the ones you see on the nightly news where it looks like the clouds are moving, but not the planet.

Polar Orbiting Environmental Satellites (POES). These types of satellites fly much lower to the earth, only about 530 miles, and orbit the planet pole-to-pole.

Weather maps, also called **synoptic maps**, simply and graphically depict meteorological conditions in the atmosphere from a spatial perspective.

- **Isotherms**, likes connecting points of equal temperature. They spatially show temperature gradients and can indicate the location of a front. In terms of precipitation, what does the 0oC (32oF) isotherm show?

- **Isobars** are lines of equal average air pressure at sea level. Closed isobars represent the locations of high and low pressure cells.

Isotachs are lines of constant wind speed. Where the minimum values occur high in the atmosphere, tropical cyclones may develop. The highest wind speeds can be used to locate the jet stream

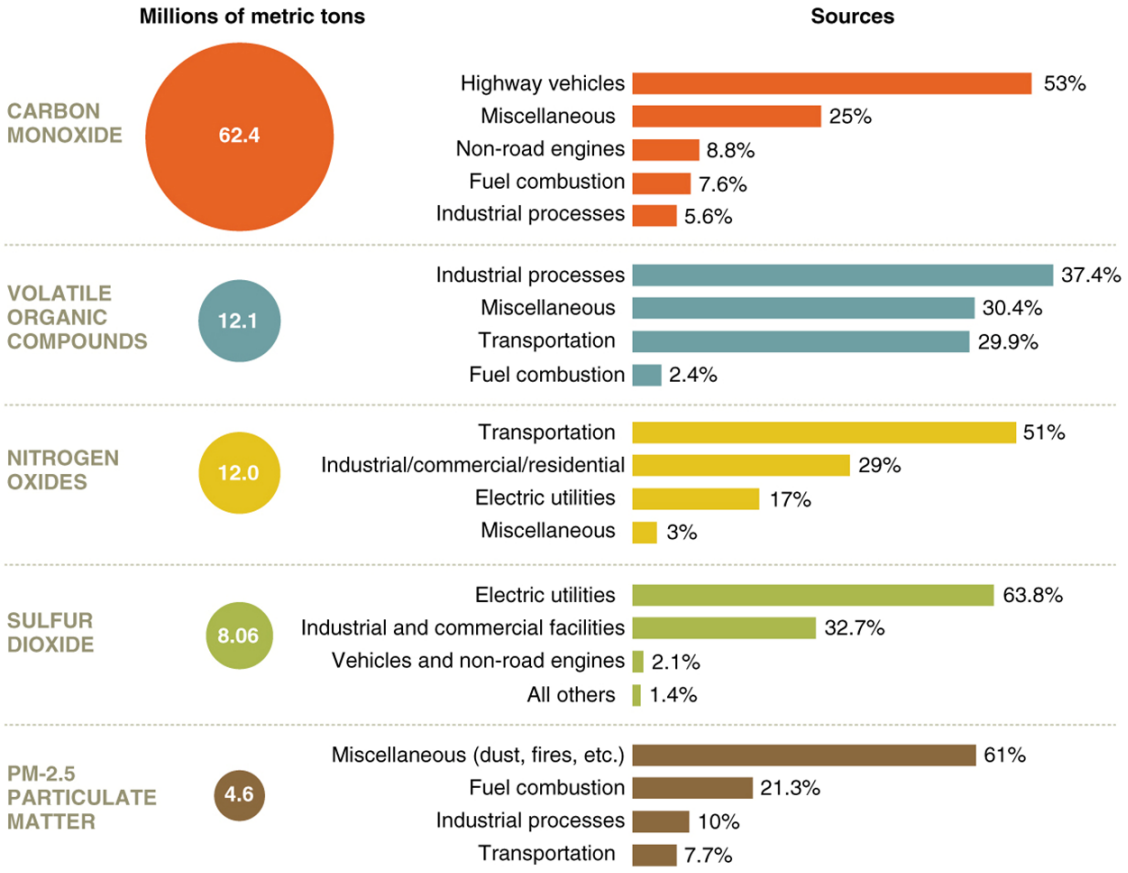
Quiz week 11

- This is the proper order of the forecasting phases: APP
- The meteorologist at your local TV station says "There is a 60% chance of rain tomorrow." This is an example of: probability
- Which of the following is not a consideration when making a weather forecast? nearby seismic activity
- A surface map: depicts the general prevailing weather conditions over an area.
- Computer-based weather forecasts provide important guidance to human forecasters
- Surface maps show all of the following, except: precipitation amounts.
- The drawback of the following images is that their data can only be used from daylight hours visible images
- A central circle on a station model that is 75 percent black and 25 percent white tells you: the cloud cover ranges over 70 to 80 percent of the sky.

Week 12

Air Pollution

Air pollution is generated from both natural and human-made sources. Natural sources include pollen from plants, gases and particulate matter from volcanoes and decomposing organic matter, and windblown dust. Human-made sources include industrial and automobile emissions and airborne particles associated with human-induced abrasion.



Principal Terms

acid rain: precipitation having elevated levels of acidity relative to pure water

atmosphere: the layer of mixed gases that surrounds Earth

carbon dioxide: CO_2, one of many minor gases that are natural components of the atmosphere; the product of the complete oxidation of carbon

greenhouse effect: the environmental process that results when heat energy is absorbed and retained in the atmosphere by various gases and is not radiated out into space

inversion: an unusual atmospheric condition in which temperature increases with altitude

off-gassing: the spontaneous emission of entrained or entrapped gases from within natural and artificial sources

oxides of nitrogen: several gases that are formed when molecular nitrogen is heated with air during combustion, primarily NO and NO_2

oxides of sulfur: gases formed when fuels containing sulfur are burned, primarily SO_2

ozone: a highly reactive compound composed of three atoms of oxygen, as O_3

photochemical oxidants: pollutants formed in air by primary pollutants undergoing a complex series of reactions driven by light energy

photochemical reaction: a type of chemical reaction that can occur in polluted air driven by the interaction of sunlight with various pollutant gases

TABLE 14–1

Threshold Levels of Carbon Monoxide

Carbon Monoxide Concentration (ppm)	Comment
50	Maximum allowable Occupational Safety and Health Administration dose for 8-hour exposure
200	Headache, fatigue, dizziness, nausea in 2–3 hours
400	Headache in 1–2 hours, life threatening after 3 hours
800	Dizziness, nausea, and convulsions within 45 minutes; death in 2–3 hours
1600	Headache, dizziness, nausea in 20 minutes; death in 1 hour
3200	Headache, dizziness, nausea in 5–10 minutes; death in 25–30 minutes
6400	Headache, dizziness, nausea in 1–2 minutes; death in 10–15 minutes
12,800	Death within 1–3 minutes

What are air pollutants?

–gases, liquids, or solids in the air that can adversely affect plant and/or animal life.

Primary pollutants emitted directly by natural or anthropogenic (manmade) processes.

Secondary pollutants arise from chemical reactions of atmospheric gases with gases emitted by natural or anthropogenic processes.

Particulates

–Particulates (aerosols) solid or liquid matter suspended in the air (from 0.1 to 100 μm in size).

–Natural: natural fires, volcanic eruptions, salt spray, pollen.

–Anthropogenic: burning of fossil fuels.

–Can remain in the air long due to their small size, rain removes them.

–PM10 (<10 μm) enters lungs (associated with asthma); PM2.5 even more dangerous (lung cancer).

Carbon Oxides

–Carbon monoxide (CO) colorless, odorless gas from vol-

canic eruptions, forest fires, and other processes.

–Toxic and dangerous to humans and animals.

–Carbon dioxide (CO_2) a important greenhouse gas but is officially considered a pollutant by the U.S. EPA.

Sulfur Compounds

–can occur as gaseous or aerosol forms.

–Natural: steam vents, volcanic eruptions, sea spray.

–Anthropogenic: burning sulfur containing fossil fuels (particularly coal and oil) and ore smelting.

•Sulfur dioxide (SO_2) is a respiratory irritant.

Sulfur trioxide (SO_3) contributes to acid fog and acid rain

Nitrogen Oxides (NOX)

Nitric oxide (NO) nontoxic, colorless, and odorless gas.

Natural: biological processes in soil and water.

Nitrogen dioxide (NO_2) toxic, yellow to reddish-brown gas that is pungent and corrosive.

Gives air yellow to reddish brown color.

Anthropogenic: vehicle traffic.

Can cause pulmonary health problems.

Volatile Organic Compounds (Hydrocarbons)

–made of carbon and hydrogen. Examples: methane, butane, propane, octane, etc.

–Natural: plant and animal emissions and decomposition of organic matter.

–Anthropogenic: primarily combustion from automobiles, trucks, buses, and other fossil fuel motors; also evaporation of gasoline and other chemicals.

Photochemical Smog

–Ozone, NO_2, formaldehyde, and other gases combine with solar radiation to form Los Angeles-type photochemical smog.

–Ozone causes respiratory and heart problems.

–High levels of ozone result in environmental degradation.

Air Quality Index

–EPA created index for air pollution monitoring Air Quality Index (AQI).

–A formula applies to ozone, particulates, carbon monoxide, sulfur dioxide, and nitrogen dioxide by expressing each pollutant on a scale that ranges from 0 to 500.

–The official AQI for any location at a particular time is the highest of the five individual pollutant values.

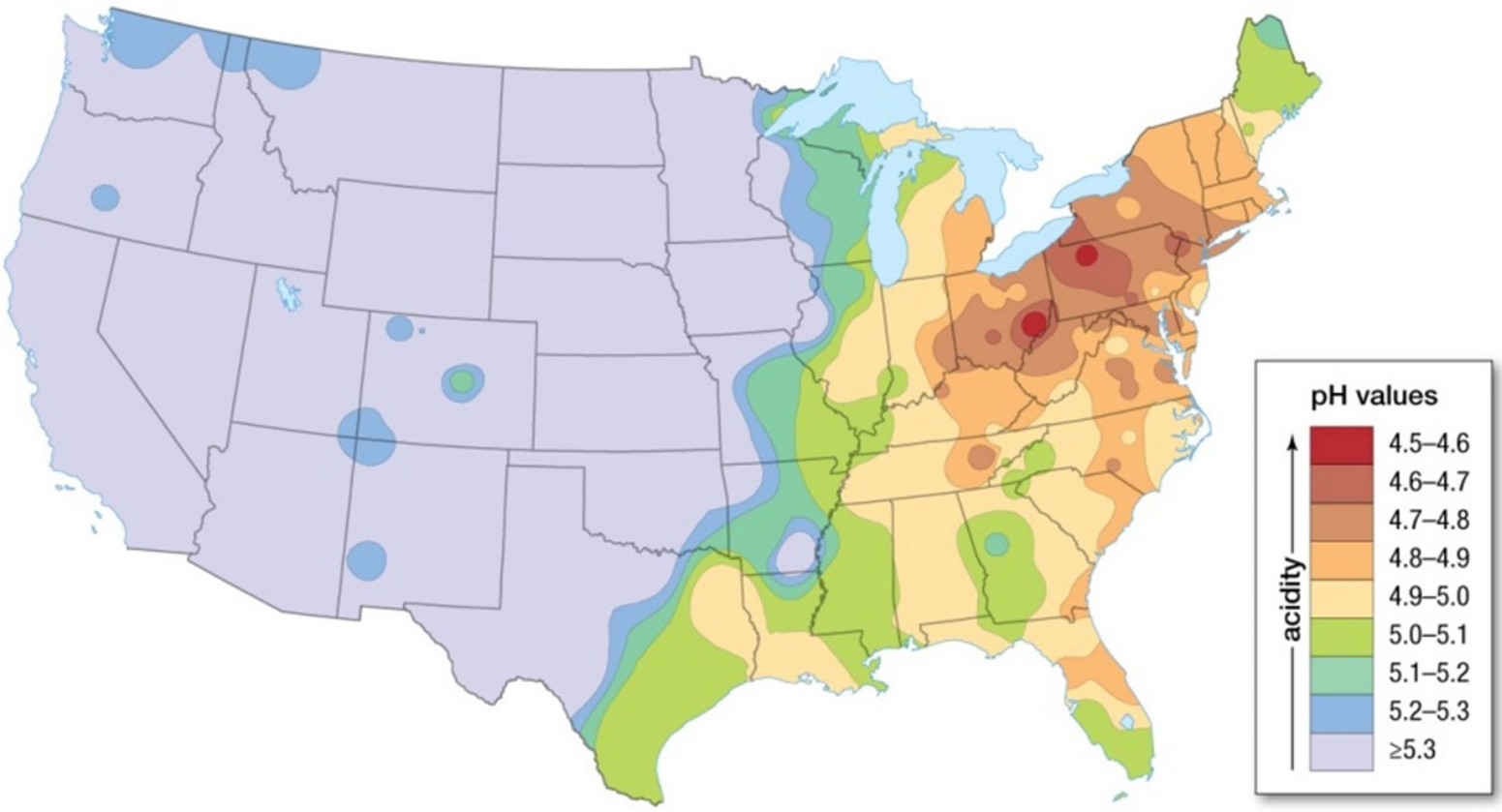
Effect of Winds on Horizontal Transport

–High concentrations of pollutants in a small area (usually due to anthropogenic sources) are the biggest air pollution problems.

–The horizontal and vertical transport of air pollutants by winds help control the local concentrations of pollutants.

–Concentrations are inversely related to wind speed.

–Eddies can mix air vertically.



Effect of Atmospheric Stability

–Inversions can trap pollutants near the Earth's surface.

Effect of Atmospheric Stability

Inversions can trap pollutants near the Earth's surface

Regulations designed to improve air quality have made a substantial impact on the lives of people in the United States and Canada.

–1970 Clean Air Act

–Clean Air Interstate Rule

–Cross-State Air Pollution Rule

Urban Heat Islands

–the increased local temperatures that result from urbanization.

–Occurs when natural surfaces are paved and built upon or when human activities release heat into the environment.

–Several variables influence the magnitude of the heat island: population density, radiation, changes in heat storage, sensible and latent heat transfer.

Radiation Effects

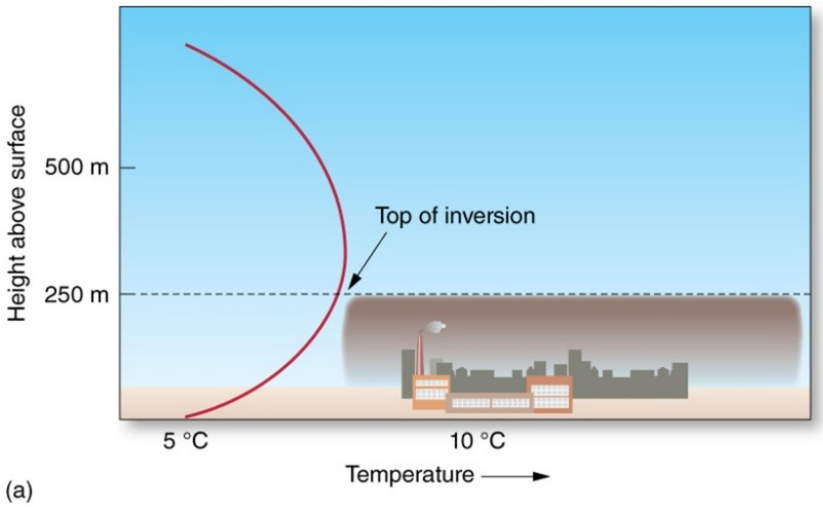
–Increased particulates associated with urban activity absorbs and scatters incoming solar radiation.

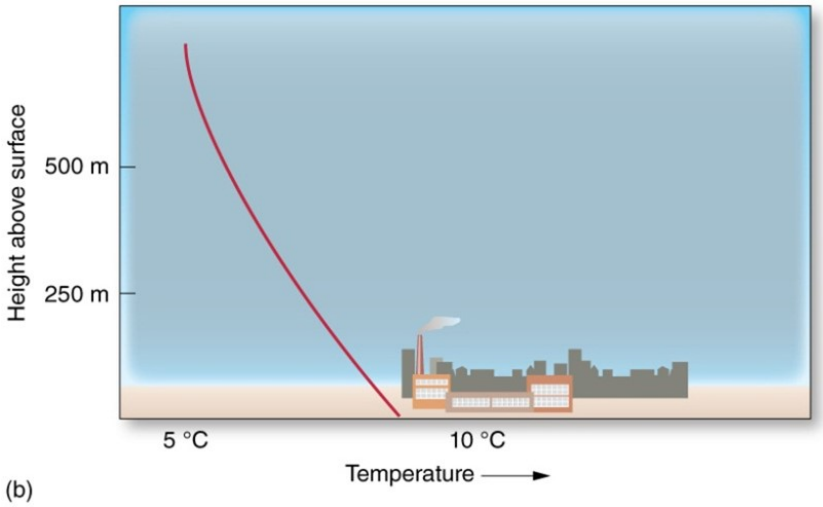
–Buildings, often a part of urbanized areas, impact the radiation balance by albedo and energy transfer.

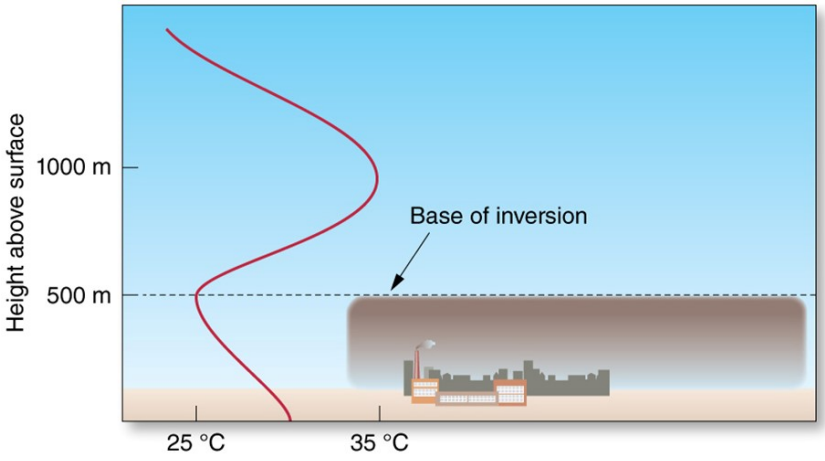
cloud conditions can influence the rate of photochemical reactions taking place.

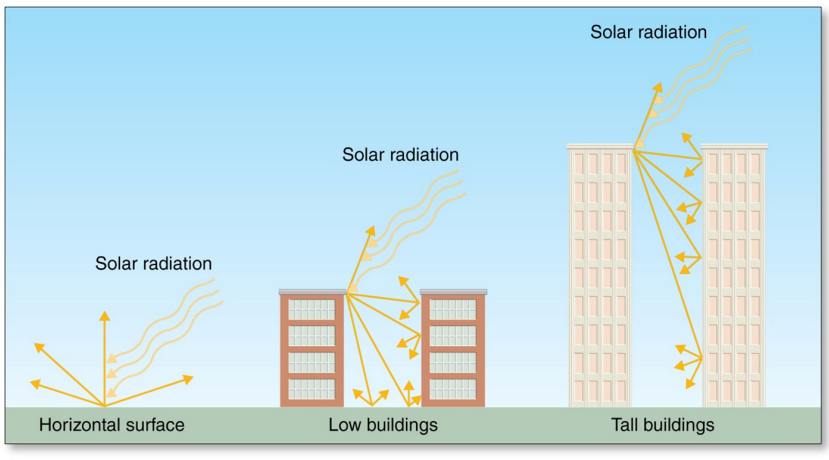
Quiz Ch 12

- The urban heat island effect is typically **stronger closer to downtown**
- An unstable atmosphere: TRY decreases pollutant concentration aloft and increases pollutant concentration near the surface
- Atmospheric stability and wind conditions control **the vertical and horizontal dispersion of pollutants**
- Which of the following is not a contributing factor to the poor air quality in Los Angeles? **Heavy rainfall**
- Buildings: **can affect the surface albedo**
- The "land-sea breeze" is reversible from day to night , shallow, does not reach to great heights , and driven by a thermal differential
- Pollutants that are formed in a manufacturing process or in the combustion process are called primary pollutants
- This is the largest source of atmospheric pollutants **human activities**
- Air pollutants can take the form of: liquids, gasses and particulates









Week 13

Climate is the long-term combined effects of atmospheric variations. Over shorter periods of time, climate is referred to as weather. Climate always refers to a specific geographical location or region and is determined by many factors, including wind belts, topography, elevation, barometric pressure, the movement of air masses, the amount of solar radiation available, proximity to oceanic influences, and planetary and solar cycles.

Principal Terms

air mass: a mass of air in the lower atmosphere that has generally uniform properties of temperature and moisture

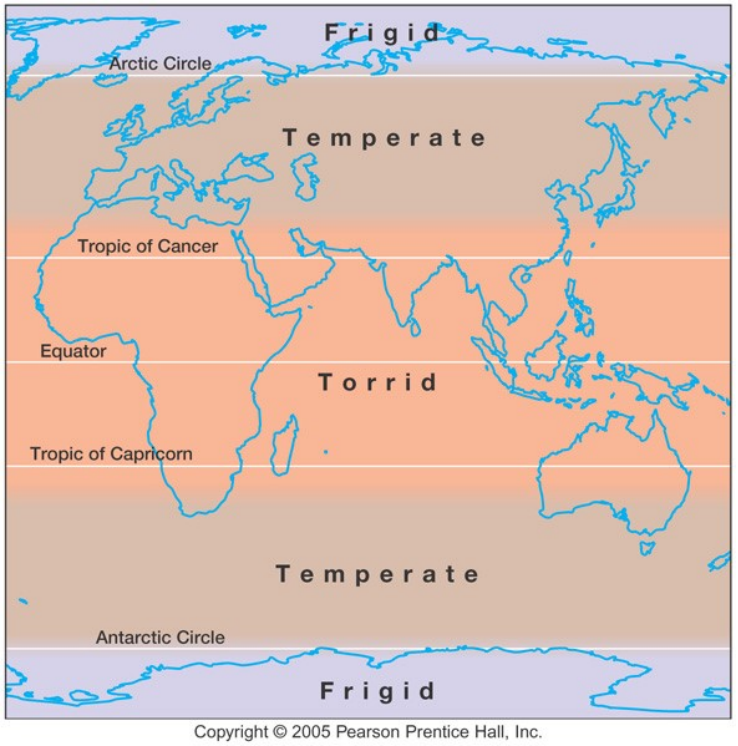
atmosphere: the envelope of gases surrounding Earth, consisting of five clearly defined stratigraphic regions

general circulation models (GCMs): comprehensive, mathematical-numerical formulas in climate studies that attempt to express in equations the basic dynamics thought to govern the large-scale behavior of the atmosphere

greenhouse effect: the enhanced surface heating effect of solar radiation due to the absorption and redirection of infrared radiation by various gases in the atmosphere

parameterization: the arbitrary assignment of a value to physical processes that occur on scales too small to be resolved by a general circulation model

precipitation: phenomena such as rain, snow, and hail that form through condensation of atmospheric water vapor into liquid and solid forms that subsequently fall toward the surface due to gravity



The ancient Greeks in the sixth century b.c.e. visualized Earth as having three temperature zones based on the sun's elevation above the horizon. - three zones torrid, temperate, and frigid

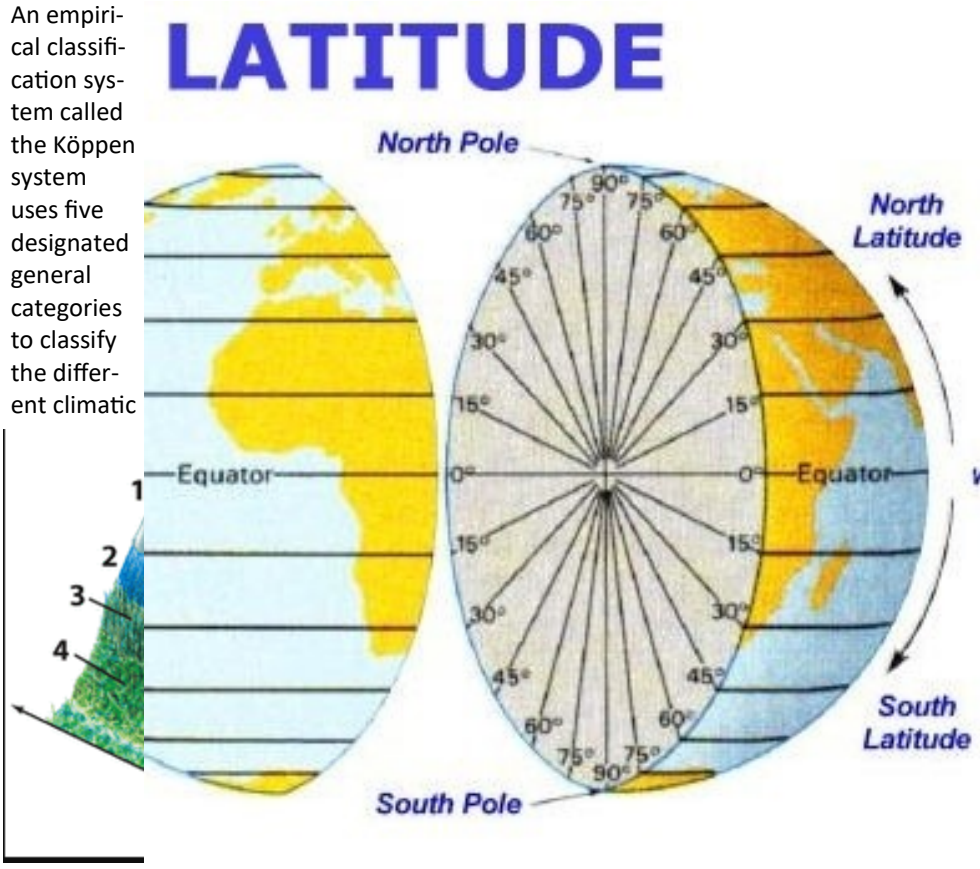
classification of climates genetic and empirical

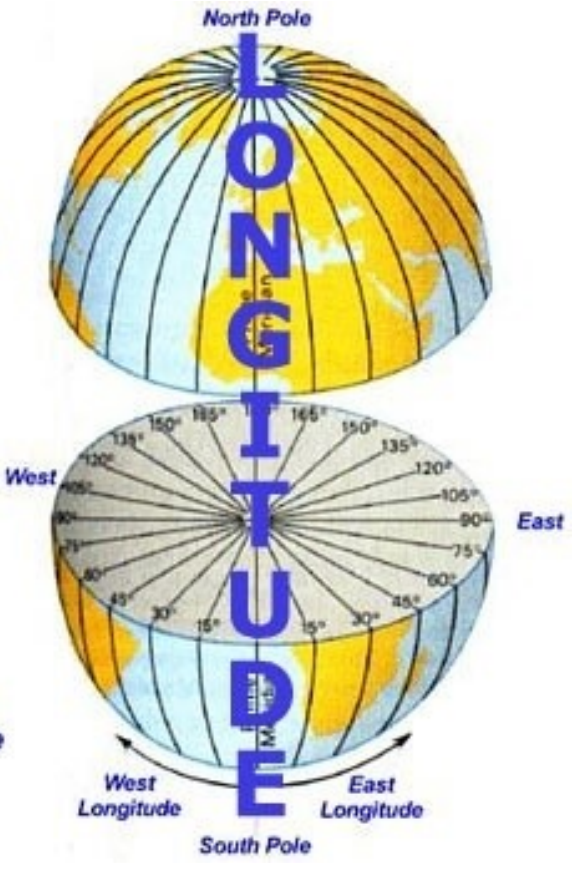
An empirical classification system called the Köppen system uses five designated general categories to classify the different climatic regions of the world by their characteristics: tropical forest climates; dry climates; warm, temperate rainy climates with mild winters; cold forest climates with severe winters; and polar climates

Controls of Climate, Climate Zones and Biomes

LATITUDE

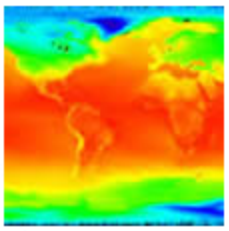
The main factor influencing the climate of a region is latitude because different latitudes receive different amounts of solar radiation.





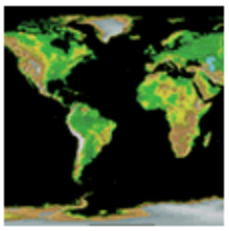
- The equator receives the most solar radiation. Days are equally long year-round and the sun is just about directly overhead at midday.
- The polar regions receive the least solar radiation. The night lasts six months during the winter. Even in summer, the sun never rises very high in the sky. Sunlight filters through a thick wedge of atmosphere, making the sunlight much less intense. The high albedo, because of ice and snow, reflects a good portion of the sun's **light**.

The climate of any particular place is influenced by a host of interacting factors. These include **latitude**, **elevation**, **nearby water**, **ocean currents**, **topography**, **vegetation**, and **prevailing winds**. The global climate system and any changes that occur within it also influence local climate. Consider how each factor illustrated by the thumbnail images might control climate at your location.



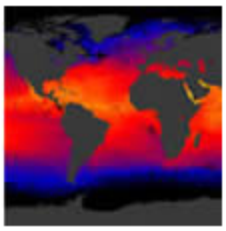
NASA

LATITUDE
Surface temperatures vary with latitude.



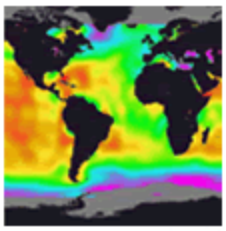
NOAA

ELEVATION
Climate zones coincide roughly with elevation ranges.



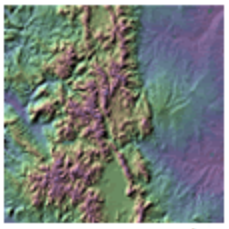
NASA

NEARBY WATER
Sea surface temperatures affect land temperatures.



NASA

OCEAN CURRENTS
Water temperatures indicate transfer of heat energy by currents.

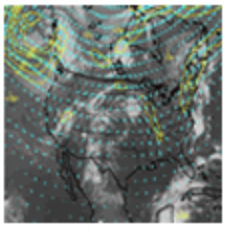


Ray Sterner, Johns Hopkins University Applied Physics Laboratory

TOPOGRAPHY
Local variations in elevation can cause local variations in climate.

Martos Hoffman

VEGETATION
Type of ground cover and seasonal changes affect climate.



San Fransisco State University—Meteorology

PREVAILING WINDS
Winds deliver air masses with specific properties.

Quiz Ch 13

- All of the following are true about tropical climates, except: they often exist above 30 degrees latitude
- The primary parameters of a climatological classification system are temperature and moisture.
- Locations in the center of large, midlatitude continents typically experience large annual temperature ranges
- Severe midlatitude climates occurbetween 40° and 70° latitude
- Which of the following primary climates is most likely to be closest to a pole? severe midlatitude
- Tropical wet and dry climates: owe much of the seasonal changes in precipitation to the shifting of the Hadley cell.
- This climate type has produced the world's highest temperatures. subtropical desert
- Mediterranean climates are characterized by all of the following, except: an average annual rainfall that rarely exceeds 30 inches.
- A severe midlatitude climate features : very cold winters
- This is the only climate zone in which precipitation is the defining characteristic. desert

Week 14

IPCC,

The Intergovernmental Panel on Climate Change (IPCC) is an international group affiliated with the United Nations and charged with reviewing scientific data related to Earth's climate. Every few years, the group releases reports containing its findings and recommendations for possible future action.

Principal Terms

anthropogenic global warming: rises in global temperatures caused by human activity

climate change: change in Earth's climate that persists for roughly ten years or longer

great conveyor belt: a system of ocean circulation in which heat is carried to warm certain parts of the earth; also called great ocean conveyor belt

greenhouse gas: gases within the earth's atmosphere that absorb heat and help maintain the planet's climate

ice core record: ice sheet samples used for chemical analysis of temperature, atmospheric and volcanic activity, and precipitation

radiative forcing: a measurement of how much the greenhouse gas in a given area will affect the level of radiation maintained; measured in watts per square meter

remote-sensing satellites: satellites that carry instruments to monitor and collect climate data while orbiting Earth

solar irradiance: energy from the sun's rays that reach Earth; measured in units of power over time (typically watts per second)

tree-ring data: data gathered from tree rings that reflect climate data from the past; thicker rings indicate the presence of light and nutrients that allow more growth

variability: with respect to climate, refers to small-scale changes, such as those in a few years

volcanic aerosols: volcanic ash released into the atmosphere; can affect the amount of solar radiation reaching Earth through components such as sulfur dioxide

Recent Climate Change Research,

Scientists are studying the effects of greenhouse gases emitted through industrialization and transportation—namely vehicles. Greenhouse gases are believed to be causing an increase in global temperatures and triggering climate change. The technologies and research methods employed toward this end are steadily improving. Climatologists can now analyze prehistoric evidence of periods in which climate change occurred, can analyze current trends, and can create models that can predict future conditions.

Principal Terms

aerosol: a gaseous suspension of fine liquid and solid particles

geographic information system: a network of satellite mapping technologies that can capture detailed images of the land surface

ice core: long, cylindrical sample of ice bored from glaciers that provides evidence of ancient climate conditions

paleoclimatology: study of climate conditions in Earth's ancient and prehistoric past

sedimentary rock: rock that has broken from igneous, metamorphic, or other sedimentary rocks to form new deposits

Climate Change Theories,

Earth's climate is a complex system in constant flux. An understanding of how those changes occur has emerged in recent decades. This insight has allowed for a better understanding of Earth's history and has helped to mitigate the dangers of modern climate change.

Principal Terms

albedo: the reflecting power of a substance

carbon-oxygen cycle: the process by which oxygen and carbon are cycled through Earth's environment

cosmic ray: high-energy subatomic particles that are produced by phenomena in space, such as supernovae

eccentricity: the departure of an ellipse from circularity; less circularity means greater eccentricity

El Niño: an eleven-year weather cycle in the Western Hemisphere that creates alternating wet and dry periods

greenhouse effect: the process by which some gases trap heat on Earth

obliquity: the angle of tilt between the earth's rotational axis and an axis perpendicular to the plane of its orbit

precession: a change of the axis of rotation in a rotating body or system

proxies: traces of ancient environments that reveal details, such as climatic data, about those environments

sedimentary rock: rock formed by the repeated deposition of sediment in a body of water or by the layering of material on land

Ice Ages and Glaciations

Glaciers are layers of ice that form on Earth's lithosphere where the temperature is sufficiently low to support year-round ice and snow. Extended periods when temperatures drop sufficiently low to support large-scale increases in glaciation are called glacial epochs or ice ages. Earth is now in an ice age that began 2.4 million years ago and has involved twenty or more fluctuations between glacial and interglacial periods. Estimates indicate that Earth is undergoing cycles of glaciation that occur every eleven thousand years.

Principal Terms

cryosphere: portion of the earth's surface in which the year-round temperature remains constant enough to support permanent ice and snow

eccentricity: variation in the shape of the earth's orbit around the sun, ranging from circular to elliptical

glacial: short-term period of glaciation, generally lasting for less than 1 million years and alternating with interglacial periods

glacial epoch: an extended period of global temperature reduction and glaciation that generally lasts for millions of years and includes internal glacial and interglacial periods

glacier: buildup of frozen ice on some portion of Earth's lithosphere

interglacials: periods of reduced glacial coverage that alternate with glacials within a global glacial epoch

isostacy: equilibrium between the lithosphere of the earth and the liquid layer of rock in the inner layers of the strata

obliquity: long-term variations in the tilt of the earth relative to the sun; varies through a cycle of 42,000 years

Pleistocene-Quaternary glaciation: current ice age beginning

approximately 2.4 million years ago
precession: variation in the angle of Earth's rotational tilt relative to an astronomical point of reference; shifts through a cycle of 26,000 years

Climate Change in Earth History,

For the past two centuries, climate has been relatively stable. People placed their farms and cities in locations that were in a favorable climate without thinking that the climate could change. But climate has changed throughout Earth history, and a stable climate is not the norm. In recent years, Earth's climate has begun to change again. Most of this change is warming because of human activities that release greenhouse gases into the atmosphere.

Changes in climate have had effects on human civilization.

- The Medieval Warm Period from 900 to 1300 A.D. allowed Vikings to colonize Greenland and Great Britain to grow wine grapes.
- The Little Ice Age, from the 14th to 19th centuries, the Vikings were forced out of Greenland and humans had to plant crops further south.

Short-term Climate Changes

Short-term changes in climate are common. The largest and most important of these is the oscillation between El Niño and La Niña conditions. This cycle is called the ENSO (El Niño southern oscillation). The ENSO drives changes in climate that are felt around the world about every two to seven years.

El Niño events change global climate patterns.

- Some regions receive more than average rainfall, including the west coast of North and South America, the southern United States, and Western Europe.
- Drought occurs in other parts of South America, the western Pacific, southern and northern Africa, and southern Europe.

In a La Niña year, as in a normal year, trade winds moves from east to west and warm water piles up in the western Pacific Ocean

Causes of Long-term Climate Change

Many processes can cause climate to change. These include changes in the amount of energy the Sun produces over years; the positions of the continents over millions of years; in the tilt of Earth's axis; orbit over thousands of years; that are sudden and dramatic because of random catastrophic events, such as a large asteroid impact; in greenhouse gases in the atmosphere, caused naturally or by human activities.

PLATE TECTONICS

Plate tectonic movements may help start an ice age. When continents are located near the poles, ice can accumulate, which may increase albedo and lower global temperature. Low enough temperatures may start a global ice age.

MILANKOVITCH CYCLES

The most extreme climate of recent Earth history was the Pleistocene. Scientists attribute a series of ice ages to variation in the Earth's position relative to the Sun, known as **Milankovitch cycles**. The Earth goes through regular variations in its position relative to the Sun:

- The planet wobbles on its axis of rotation.
- The planet's tilt on its axis varies between 22.1 degrees and 24.5 degrees
- The planet wobbles on its axis of rotation

SUN VARIATION

The amount of energy the Sun radiates is variable. **Sunspots** are magnetic storms on the Sun's surface that increase and decrease over an 11-year cycle.

CHANGES IN ATMOSPHERIC GREENHOUSE GAS LEVELS

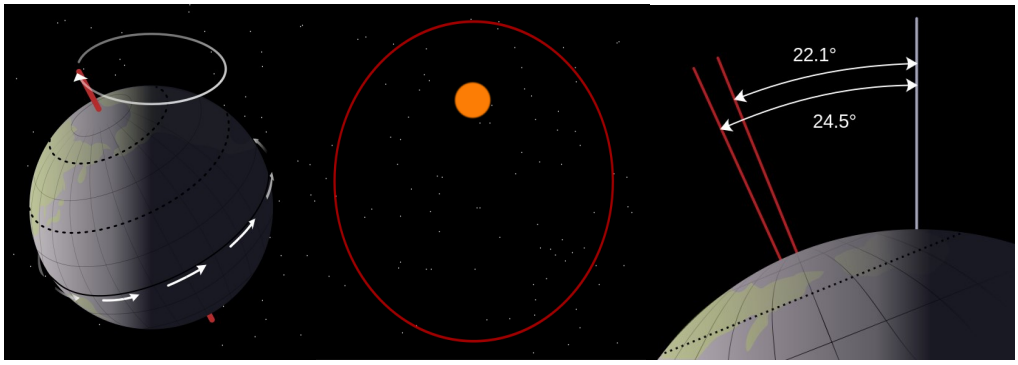
Natural processes add (volcanic eruptions and the decay or burning of organic matter) and remove absorption by plants, animal tissue, and the ocean) CO2 from the atmosphere. When plants are turned into fossil fuels the CO2 in their tissue is stored with them. So CO2 is removed from the atmosphere

Fossil fuel use has skyrocketed in the past few decades more people want more cars and industrial products. This has released CO2 into the atmosphere. Burning tropical rainforests, to clear land for agriculture, a practice called **slash-and-burn agriculture**, also increases atmospheric CO2.

- There is now nearly 40% more CO2 in the atmosphere than there was 200 years ago, before the Industrial Revolution. About 65% of that increase has occurred since the first CO2 measurements were made on Mauna Loa Volcano, Hawaii, in 1958.CO2 is the most important greenhouse gas that human activities affect because it is so abundant. But other greenhouse gases are increasing as well. A few are:

Methane: released from raising livestock, rice production, and the incomplete burning of rainforest plants.

Precession Eccentricity—elliptical Obliquity



- Chlorofluorocarbons (CFCs): human-made chemicals that were invented and used widely in the 20th century.

Tropospheric ozone: from vehicle exhaust, it has more than doubled since 1976.

Defining Climate Change

•Boundary conditions: external factors

•Forcing agents: the external factors driving climatic change

•Climate changes on many different time scales.

Methods for determining past climates

Oceanic Deposits

–deep cores of material

–include the bones and shells of plankton and other animal life.

–info the oxygen in the calcium carbonate is most important

Ice Cores

oxygen ratios for ice cores from Greenland and Antarctic ice sheets, and alpine glaciers

cores are used to obtain temp data from isotope ratios, and past chemistry of the atmosphere and past volcanic eruptions.

Remnant Landforms

eroding and depositing material include the movement of water, the slow-moving ice sheets expanding across the surface, wave action along coastlines, wind, and floating icebergs carrying land debris.

evidence to infer climatic conditions at the time of erosion or deposition.

Past Vegetation

pollen and spores can be deposited and preserved indefinitely in lake beds or bogs.

info extend back for several thousand years from tree rings.

Past Climates

The geologic column uses a hierarchical system dividing time into eras, periods, and epochs.

Segments based on geologic and fossil evidence of past environmental conditions and events.

Warm Intervals and Ice Ages

Brief cold ice ages interrupted a generally warm climate, about 10–20% of time in the last 2.5 billion years.

For most of Earth's history, climate was 5–15°C warmer than present.

The Pleistocene

Pleistocene epoch often referred to as the Ice Age.

It is the most recent ice age, following the Eocene warm episode.

The Earth is now in a warm interglacial

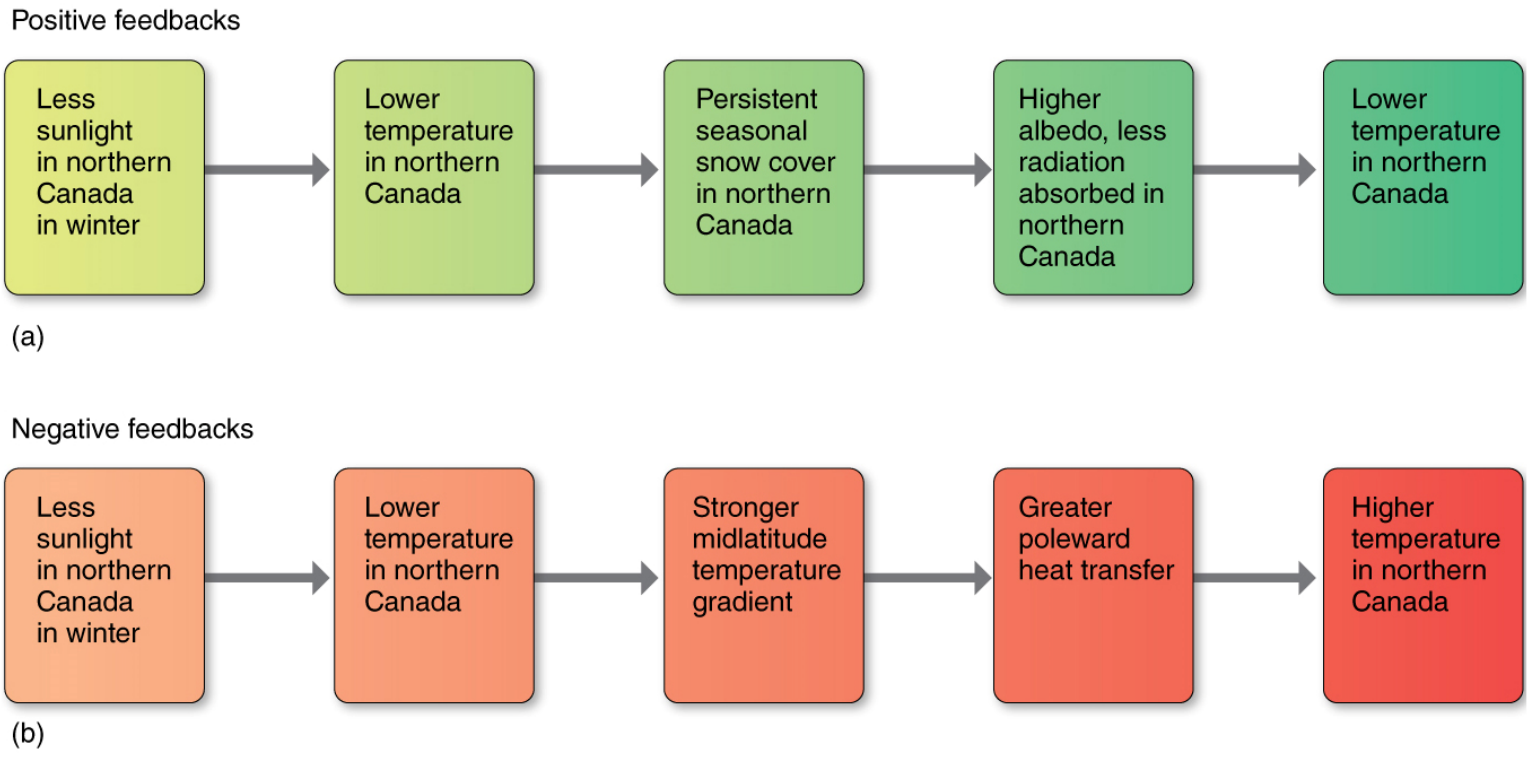
The Last Glacial Maximum

2 main pulses of glaciation, one about 115,000 years ago and another about 75,000 years ago.

ice added to polar caps during the first pulse

ice added to caps in North America and Eurasia during the later pulse.

The Holocene



Holocene is marked by two events:

warmth was interrupted by abrupt and short cooling 8200 years ago.

Temps fell rapidly throughout the N Hem Atlantic, with SSTs in the subtropical Atlantic suppressed by 7°C to 8°C (13°F to 14°F).

Second, severe drought in midcontinental N America. Water tables fell, sand dunes became active, wildfires increased in frequency and/or intensity, and there were widespread changes in forest vegetation

The Last Century

Due to meteorological data/stations on the increase, more climate data is available for the last century.

Global warming is not the only climate trend in the last hundred years.

Precipitation exhibits variability from year to year and from place to place. Long-term changes must be very large.

Effects of Warming on Temperature-Related Variables

# of days with frost has decreased over many parts of the midlatitude regions.

Decrease in extreme cold and extreme warm events have become more frequent.

Snow cover has decreased in most areas and has mostly been driven by increasing temperature.

From 1901 to 2002 the maximum extent of seasonally frozen ground declined by about 7 percent in the Northern Hemisphere.

Factors involved in climate change

Variations in Solar Output

–Solar output changes regularly.

•0.1–0.2% change due to sunspots.

•11-year cycle for sunspots.

–The Maunder minimum was a period of few sunspots and lower solar activity around the year 1600.

•The Little Ice Age occurred during the Maunder minimum.

•Links to the quasi-biennial oscillation (QBO): changes in stratospheric tropical winds associated with changes in sunspots.

Changes in Earth's Orbit

Milankovitch cycles refer to regular natural variations in the Earth's orbit around the sun.

Obliquity—41,000-year period

Eccentricity—100,000-year period

Precession—27,000-ye

Changes in Land Configuration and Surface

Characteristics

Plate tectonics gradually change the configurations of the mountains and oceans.

Mountain building and land erosion affect climate over geologic time.

Land use changes such as deforestation and desertification change albedo, surface temperatures, and water balance.ar period

Changes in Atmospheric Turbidity

Atmospheric turbidity refers to the amount of suspended aerosols contained in the air.

Major volcanic eruptions inject aerosols into the atmosphere over days or weeks, leading to temporary climate cooling.

Changes in atmospheric aerosols affect the amount of solar energy that can reach the Earth's surface (global dimming).

Residence times of tropospheric aerosols is a few years.

Residence times of stratospheric aerosols is a few decades

Changes in Radiation-Absorbing Gases

Anthropogenic contributions of CO_2 has resulted in an exponential increase since the mid-19th century due to fossil-fuel burning.

Increased CO_2 concentrations lead to increased atmospheric absorption of IR radiation.

Increased anthropogenic greenhouse gases in the atmosphere can lead to increased atmospheric water vapor (the most important greenhouse gas).

Feedback mechanisms are systems in which changes in one variable lead to changes in another.

Feedback mechanisms can be:

–Negative: where the feedback acts to inhibit further change in a variable.

–Positive: where the feedback acts to magnify further change in a variable.

Examples of feedbacks

- Ice-albedo feedback (positive feedback)
- Ice cover affects global albedo
- Evaporation of water vapor (positive feedback)
- Water vapor is a greenhouse gas
- Ocean-atmospheric interaction (positive or negative feedback)
- Ocean levels change through thermal expansion and glacial melting

Atmosphere—Ocean Interactions

Identifying the Causes of Climate Change

- Observing changes to particular causes and in making predictions about possible futures, climate science relies heavily on so-called Atmosphere–Ocean General Circulation Models (GCMs).
- GCMs are mathematical representations of the Earth atmosphere–ocean–land system that run on supercomputers.

Projecting Climate Changes

General Circulation Models

- The average amount of warming predicted by the models for three 20-year time periods.
- Research will help to better understand the impact of human activity, and new information will be obtained to help better understand climate change.

Observe how nature records climate change

It's us video

Chapter 14 Quiz

- Humans created the Greenhouse Effect. False
- Large volcanic eruptions : decrease global temperatures due to the increased albedo of volcanic aerosols
- The effects of global warming will not be the same in all places. The smallest changes in temperature are to occur in _____ regions : Tropical
- The current rate at which Earth's temperature is increasing can be explained due to natural Earth processes. False
- Where does the past 150 years of instrumental climate data come from? (Mark all that apply). Thermometers , Barometers
- Milankovitch cycles include all of the following, except: changes in the distance between the earth and the Moon
- Instrumental observations (past 157 yrs) show temperatures at Earth's surface have _____ globally, with important regional variations Risen
- The input of anthropogenic carbon dioxide into the atmosphere comes primarily from the Northern Hemisphere
- A period of minimal sunspot activity between 1645 and 1715 is known as the Maunder Minimum
- We are currently living in the Holocene epoch
- During ice ages, the ice sheets were thickest and most wide spread in the northern hemisphere

Week 15

Clouds provide an indication of the current weather and a forecast of weather to come as well as information regarding climate and other aspects of the atmosphere. They are also a resource for the investigation of the dynamic interactions of solid, liquid, and gaseous substances.

Principal Terms

cirrus: trailing or streaky clouds, at altitudes ranging from 5 to 13 kilometers, that are feathery or fibrous in appearance

condensation: the transformation of a substance from the vapor state to the liquid state; atmospheric condensation occurs when droplets of liquid form (or condense) around small particles in the atmosphere

convection: the transmission of heat by cyclic mass transport within a fluid substance; the movement of warmer, less dense material that rises as cooler, denser material sinks

cumulus: clouds with vertical development rising from a seemingly flat base, often appearing as fluffy masses, at altitudes ranging from ground level to 6 kilometers above the ground; sometimes called heap clouds

radiation: the transfer of energy emitted from one body through a transparent medium to another body, as occurs when light and heat energy from the sun impinge on Earth

stratus: sheet or layer clouds, at altitudes ranging from 2 to 6 kilometers above the ground (altostratus, or middle) or from 0 to 2 kilometers above the ground (stratocumulus, or low)

supersaturation: a state in which the air's relative humidity exceeds 100 percent, the condition necessary for vapor to begin transformation to a liquid state

•Low Pressure: Due to warm ascending air, that cools, condenses, forms clouds and rains.

Cloud formation Processes

•Cloud :an aggregation of tiny moisture droplets and ice crystals suspended in the air, great enough in volume and concentration to be visible

•Fog: is a cloud in contact with the ground

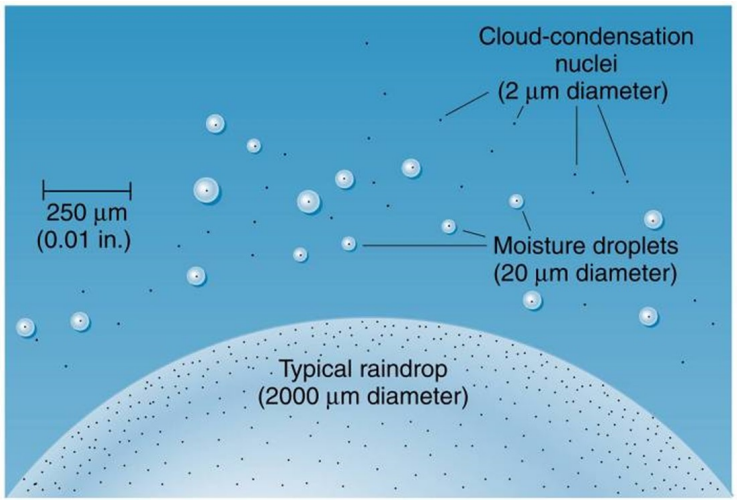
•Cloud-condensation nuclei: microscopic particles always present in the atmosphere, required for cloud formation

Provided by sea salt, dust, soot, and ash

Cloud types and Identification

•Altitude and shape are key to cloud classification

•Clouds occur in three basic forms: flat (stratoform), puffy



(cumuliform), and wispy (cirroform)

•And in four primary altitudes: low, middle, high, and vertically developed

Low Clouds:

•Range from the surface to 2000 m

•Range from the surface to 2000 m

–Stratus: appear dull, gray, and featureless

–Nimbostratus: when stratus clouds yield precipitation, typically falling as drizzling rain

–Stratocumulus: lumpy, grayish, low level clouds often near end of day

Middle Level Clouds

•Range from 2000 m to 6000 m

–Altocumulus: broad category with may different styles

–Altostratus: sun's outline just visible, gray day

High Level Clouds

•Range from 6000 m – 13,000 m

–Cirrus: wispy, featherlike

–Cirrostratus: fused sheets of ice crystals, milky with sun and moon halos

–Cirrocumulus: small white flakes and tufts in lines or groups

Vertically Developed Clouds

•Near surface to 13,000 m

–Cumulus: puffy, billowy, flat based swelling tops, fair weather

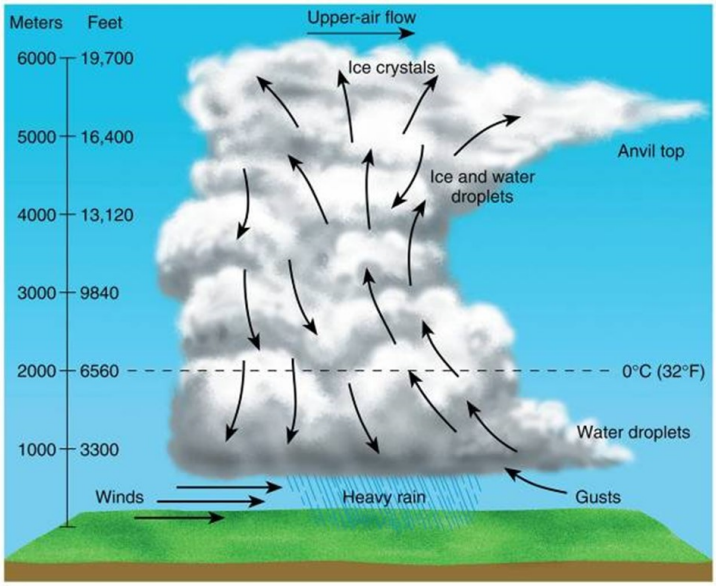
–Cumulonimbus: Dense , heavy, dark thunderstorms, explosive top, towering

Fog

•A cloud layer on the ground

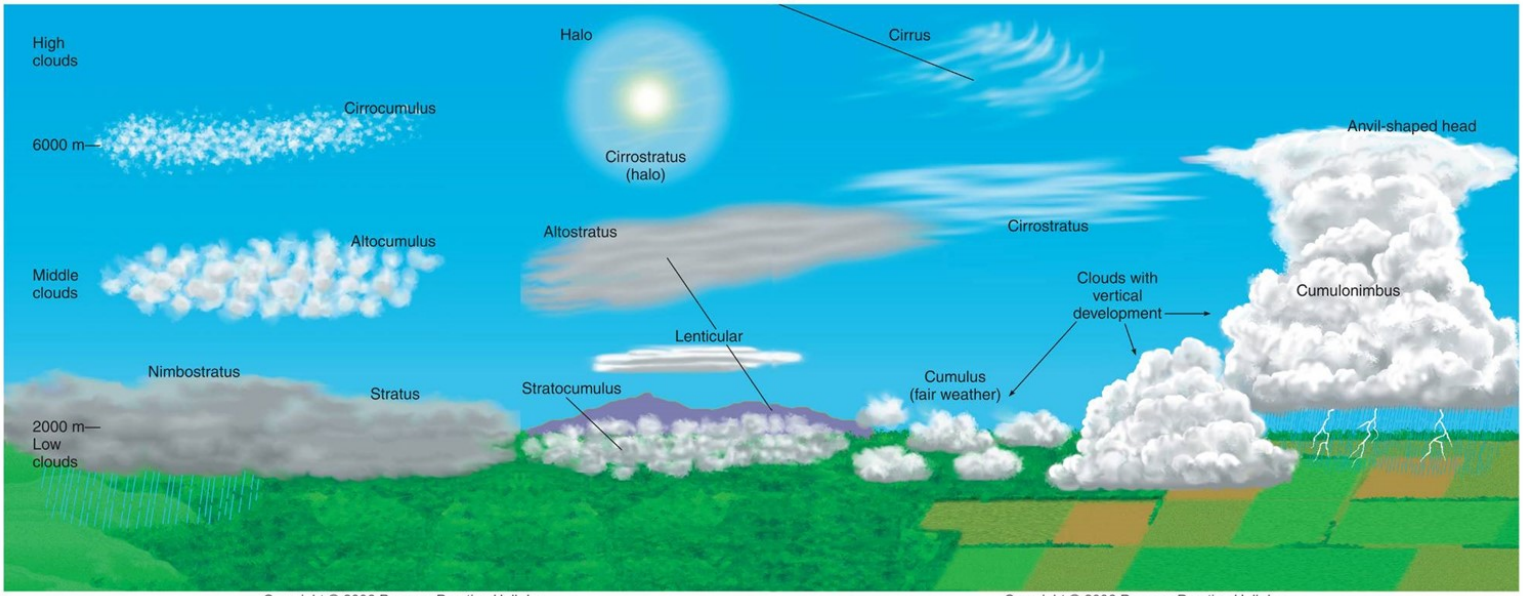
•Visibility restricted to less than 1 km

•Presence indicates air temperature and dew point temperature at ground are nearly identical (saturated conditions)



Chapter 15 Quiz

- The atmosphere is held in place by gravity
- This is not a form of low cloud: nimbocumulus
- Which of the following are not in the High Cloud group? altostratus
- Cumulonimbus can span nearly the entire troposphere.
- Clouds that are high and are always composed entirely of ice crystals are cirrus
- Clouds that form downwind from mountain barriers and have a curved shape are called: lenticularis clouds
- Cirrostratus clouds are responsible for the halo effect around the sun.
- Which of the following pairs of clouds are the primary precipitation-producing ones? nimbostratus and cumulonimbus
-



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Final Questions

- Which of the following are correct lightning safety rules? (Mark all that apply) all
- If you are outside in the presence of lightning and cannot take cover indoors, which of the following would be the safest course of action? go to a low-lying area, crouch down and minimize your contact with the ground
- Lightning can strike : below a thunderstorm cloud, out of the anvil of a thunderstorm cloud, from the side of the cloud
- Which of the following tornado safety rules are correct? (Mark All that Apply) Leave mobile homes, move toward the center of the building you are in, go to the basement, cover yourself with a mattress or other padded item to protect from debris
- The strongest winds within a hurricane occur: in the eyewall
- A prediction of "partly cloudy" is an example of: q qualitative forecast
- Which of the following are sources of particulates? Natural fires, volcanic eruptions, wind-blown pollen
- Carbon dioxide: is a greenhouse gas that may hold the key to important climatic changes
- Evidence for global warming can be found in every part of the Earth system. Besides well documented changes in air temperature, global warming is has also been documented.... (Mark ALL that apply). Causing sea levels to rise, heating the world's oceans, affecting plant and animal distribution
- Which of the following more accurately describes the precipitation patterns of a Mature Cyclone? Intense precipitation
- Which of the following are associated with the formation and intensification of surface mid-latitude cyclones? upper-level divergence and lower-level convergence
- Stratocumulus clouds are considered low clouds

Look carefully at your cloud. Answer the questions below, and follow the instructions. When you reach a cloud name in bold, that is the type of cloud you are observing. Stop at that point.

1. Is it raining?

No- go to number 2.

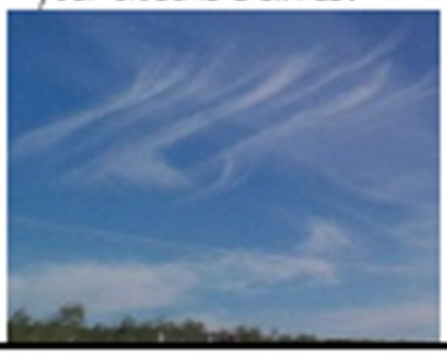
Yes- with thunder, lightning, & heavy rain – your cloud is a **cumulonimbus**.

Yes- but only drizzly, with small raindrops – your cloud is a **nimbostratus**.

2. Is it a high wispy cloud, like a horse's tail?

No- go to number 3.

Yes- your cloud is a **cirrus**.

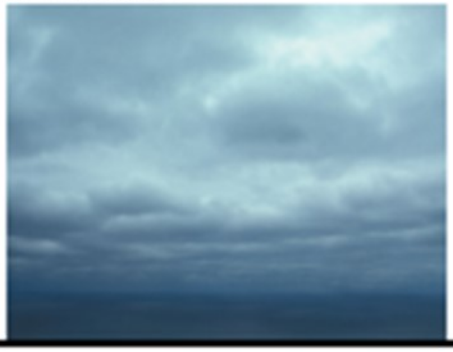


3. Is it flat & layered, puffy & bumpy, or some of both?

Flat & layered-go to number 4

Puffy & bumpy-go to number 5

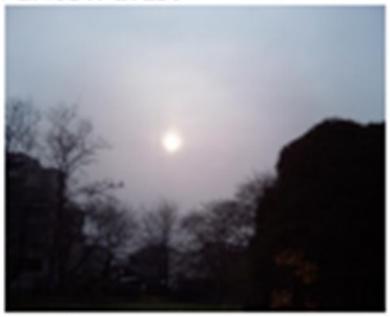
Both- If your cloud is a nearly solid layer of large puffs (the size of your fist or larger), your cloud is a **stratocumulus**.



4. **Determine how high and how thick your flat layered cloud is.**

If your cloud is high, thin, and the sun is shining casting distinct shadows, it is a **cirrostratus.**

If it is thicker, the sun is dimmer, and there are hardly any shadows, it is an **altostratus.**



If it is a low cloud, so low it's hard to see the bottom and it covers most of the sky, it is a **stratus.**

5. Hold your hand up toward your cloud. Look at the size of the puffs. Compare them to your hand.

If the puffs are the size of your fingernail (very small), your cloud is a **cirrocumulus.**

If the puffs are the size of your thumb (medium-sized), your cloud is an **altocumulus.**

If the puffs are the size of your fist (large), your cloud is a **cumulus.**