Funding provided by NOAA
Sectoral Applications Research Project

THE ATMOSPHERE

Basic Climatology

Oklahoma Climatological Survey

What we are going to cover

1. Composition of the Atmosphere
2. State Variables
3. Measuring the Weather
4. Climate Patterns
5. Global Weather Patterns
6. Clouds
7. Pressure Systems, Air Masses & Fronts
8. Thunderstorms
9. Other Weather Hazards
10. Climate Change

First, Some Definitions…

- **Meteorology** - a science that deals with the atmosphere and its phenomena and especially with weather and weather forecasting
- **Weather** - the state of the atmosphere with respect to heat or cold, wetness or dryness, calm or storm, clearness or cloudiness
- **Climate** - the statistical collection of weather conditions at a place over a period of years

Weather vs. Climate

- **Weather**
  - Condition of the atmosphere at any particular time and place, day-to-day state of the atmosphere
- **Climate**
  - Accumulation of daily and seasonal weather events over a long period of time (weeks, months, years and longer)
  - Includes weather and weather extremes (heat waves, cold spells)
  - Long-term averages of weather variables (e.g., temperature, precipitation amount and type, air pressure, humidity, cloudiness, sunshine, wind speed and direction), departures of weather variables from *normals* (more about normals later!)

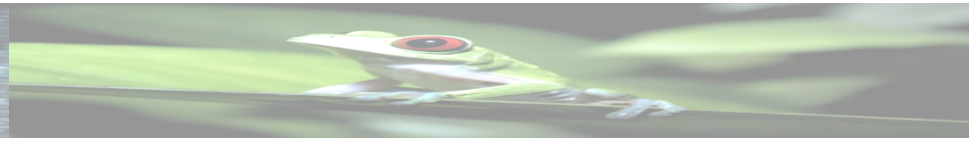
Weather vs. Climate

What *weather* determines

- Type of clothing we wear today
- Windows open or closed today? This week?
- If a crop will reach maturity: hail can destroy a crop in a day!
- Warm and rainy for a day: raincoa*t*

What *climate* determines

- Type of clothing we buy and keep
- Housing: straw hut vs. brick house
- Crop selection (timing and species): Mangoes are not a good crop in Oklahoma
- Warm and wet for MANY years: rain*forest*



Composition & Structure of the atmosphere

What gasses make up the atmosphere?

Gas	Symbol	Content
Nitrogen	N_2	78.084%
Oxygen	O_2	20.947%
Argon	Ar	0.934%
Carbon Dioxide	CO_2	0.033%
Neon	Ne	18.20 parts per million
Helium	He	5.20 parts per million
Krypton	Kr	1.10 parts per million
Sulfur dioxide	SO_2	1.00 parts per million
Methane	CH_4	2.00 parts per million
Hydrogen	H_2	0.50 parts per million
Nitrous Oxide	N_2O	0.50 parts per million
Xenon	Xe	0.09 parts per million
Ozone	O_3	0.07 parts per million
Nitrogen dioxide	NO_2	0.02 parts per million
Iodine	I_2	0.01 parts per million
Carbon monoxide	CO	trace
Ammonia	NH_3	trace

Source: NOAA National Weather Service Jetstream

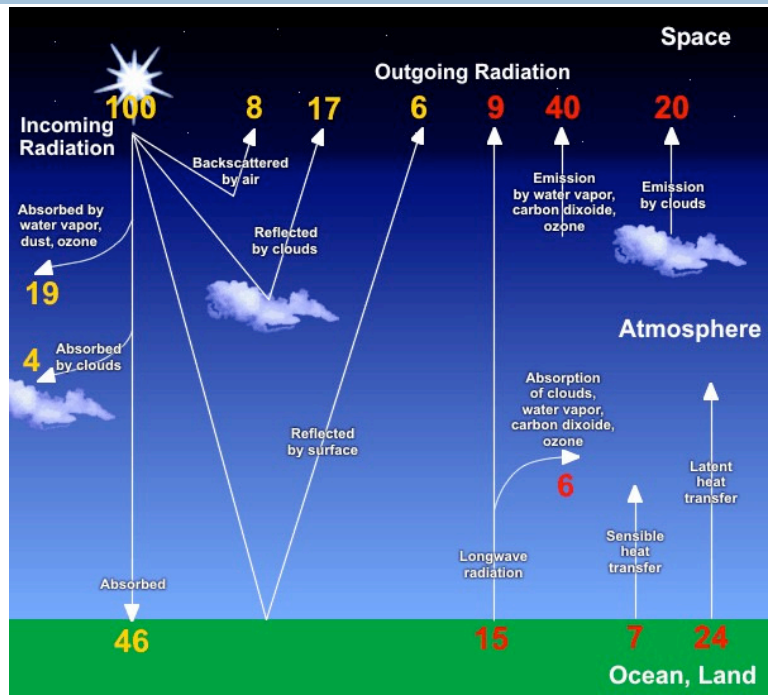
Layers of the Atmosphere

- *Exosphere* (up to 6,200 miles)
- *Thermosphere* (up to 430 miles)
  - Very few particles, but highly energized
  - Ionosphere (37-190 miles): highly energized particles reflect radio waves
- *Mesosphere* (up to 53 miles)
  - Gasses become very thin
  - Temperature decreases with height (less absorption)
- *Stratosphere* (up to 31 miles)
  - Virtually no vertical motion
  - Temperature warms with height (absorption of radiation)
- *Troposphere* (ground to 4-12 miles)
  - Most human activities occur in the troposphere
  - Density and pressure decrease with height
  - Temperature decreases with height

Source: NOAA National Weather Service Jetstream

The Earth's Energy Balance

- Incoming energy from the sun (solar radiation) heats the Earth
- Some of the energy is reflected by clouds or the atmosphere back into space
- Some of the energy is absorbed by the Earth and re-emitted
  - Incoming solar radiation is shorter wavelengths (higher energy) than what is emitted by the Earth
- Atmospheric gasses trap some of the longer-wave radiation
  - The atmosphere keeps Earth at an average temperature of about 58°F

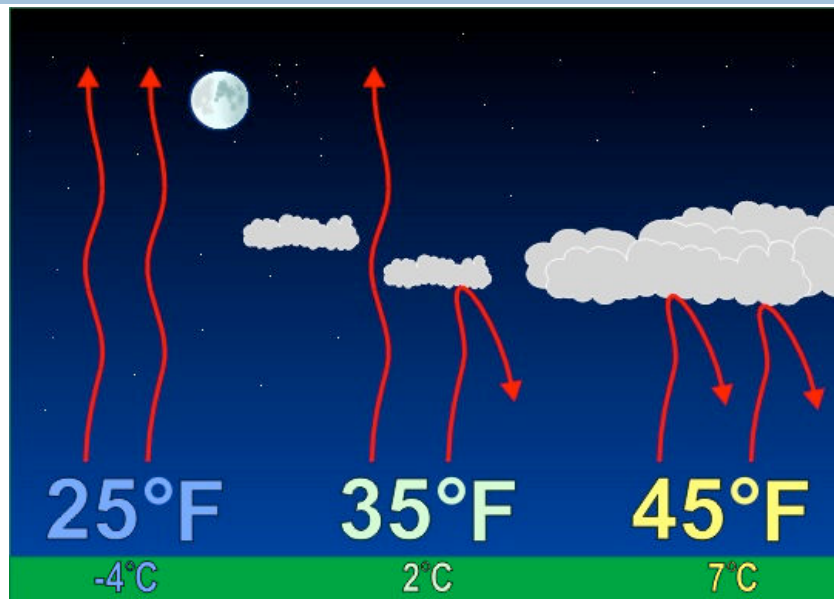


Source: NOAA National Weather Service Jetstream

Without atmospheric gasses, the Earth's average temperature would be about 0°F!

The Earth's Energy Balance

- Water vapor is very good at absorbing and re-radiating the longer-wavelength energy from the Earth
- During the day, the Earth stores more energy than it releases
- At night, without incoming solar radiation, the energy is released
- Without clouds, most of the energy escapes back into space
- With clouds, more energy is captured and re-radiated back toward the ground, keeping surface temperatures higher

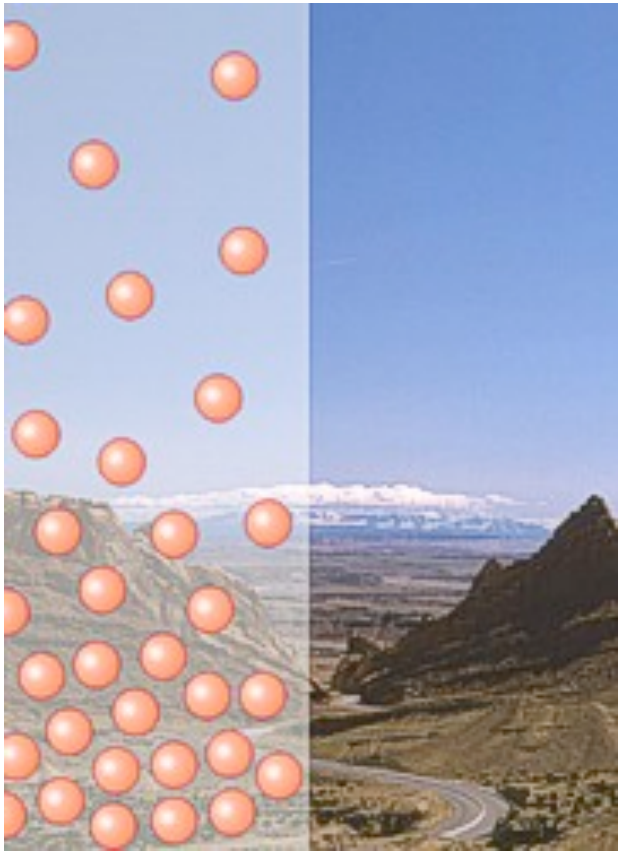


Source: NOAA National Weather Service Jetstream

STATE VARIABLES

PRESSSURE

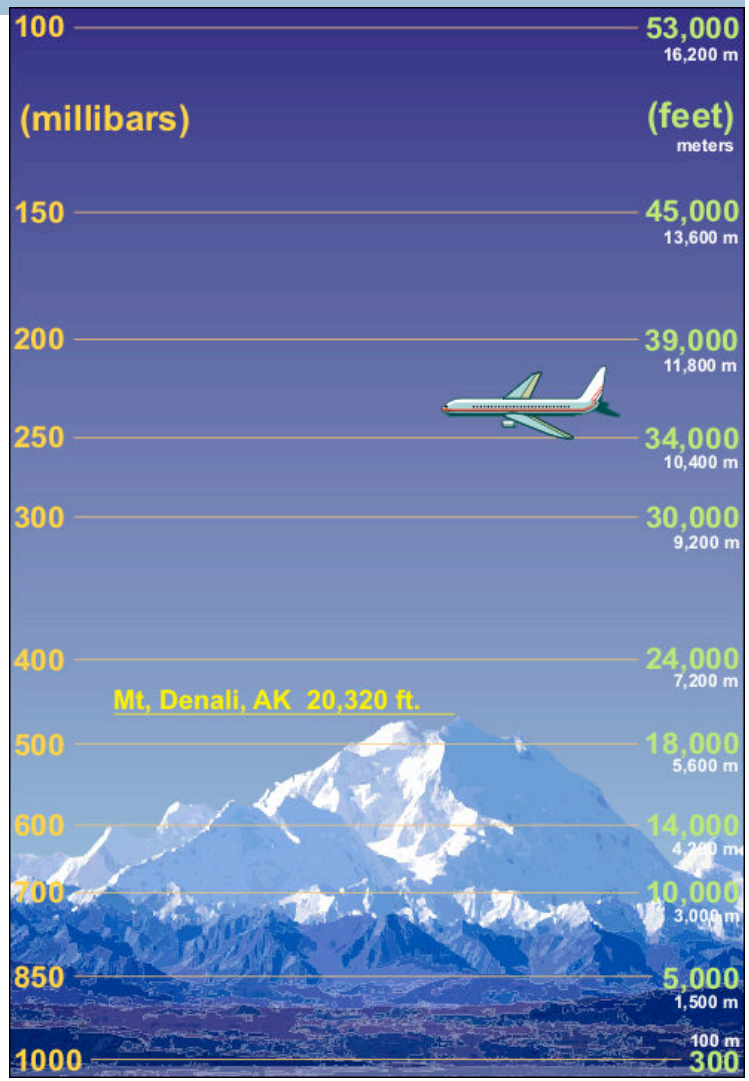
- The motion of molecules creates a force, pressure, as they strike a surface (you)
- The number of molecules packed into a volume determines its *density*
  - Often thought of as weight but not quite the same; you weigh less on the moon than on earth because the effects of gravity are less, but you have the same density
- The more molecules, the more pressure
  - At sea level, this force is about 14 pounds per square inch, or about 1 ton per square foot
  - This force raises a column of mercury 29.92 inches



Source: NOAA National Weather Service Jetstream

PRESSSURE

- The number of molecules are greater near the surface of the earth than at higher elevations
  - Thus, pressure (force) decreases with elevation
  - Half of the atmosphere's molecules are below ~18,000 feet (the *500 millibar* level)
- Warm air is less dense than cold air
  - Higher energy moves molecules farther apart
  - 'Pushes' the 500 mb level upward



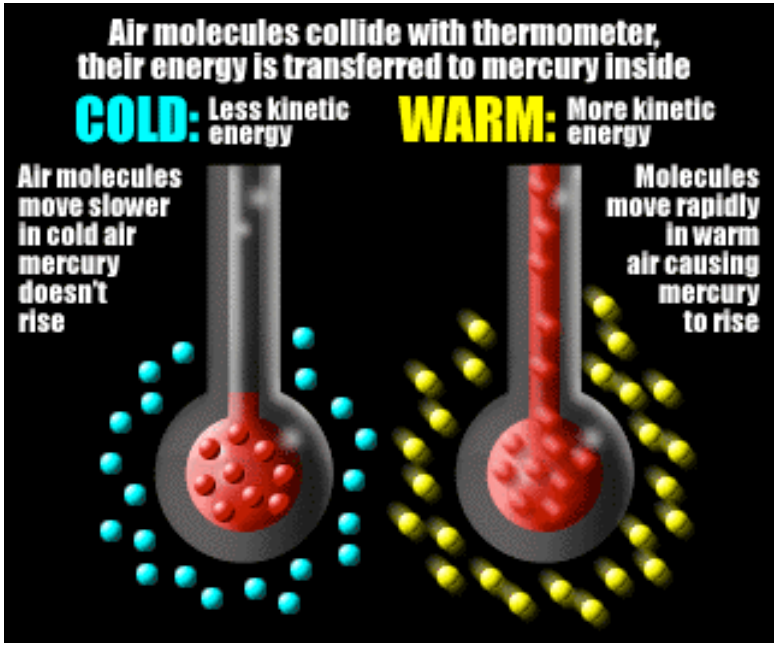
Source: NOAA National Weather Service Jetstream

TEMPERATURE

- Temperature is a measure of the energy of a 'parcel' of molecules
- Temperature scales
  - Fahrenheit: freezing point = 32 degrees; boiling point = 212 deg.
  - Celsius: freezing point = 0 degrees; boiling point = 100 degrees

    F = 1.8 * C + 32
  - Kelvin: zero = point at which all motion ceases

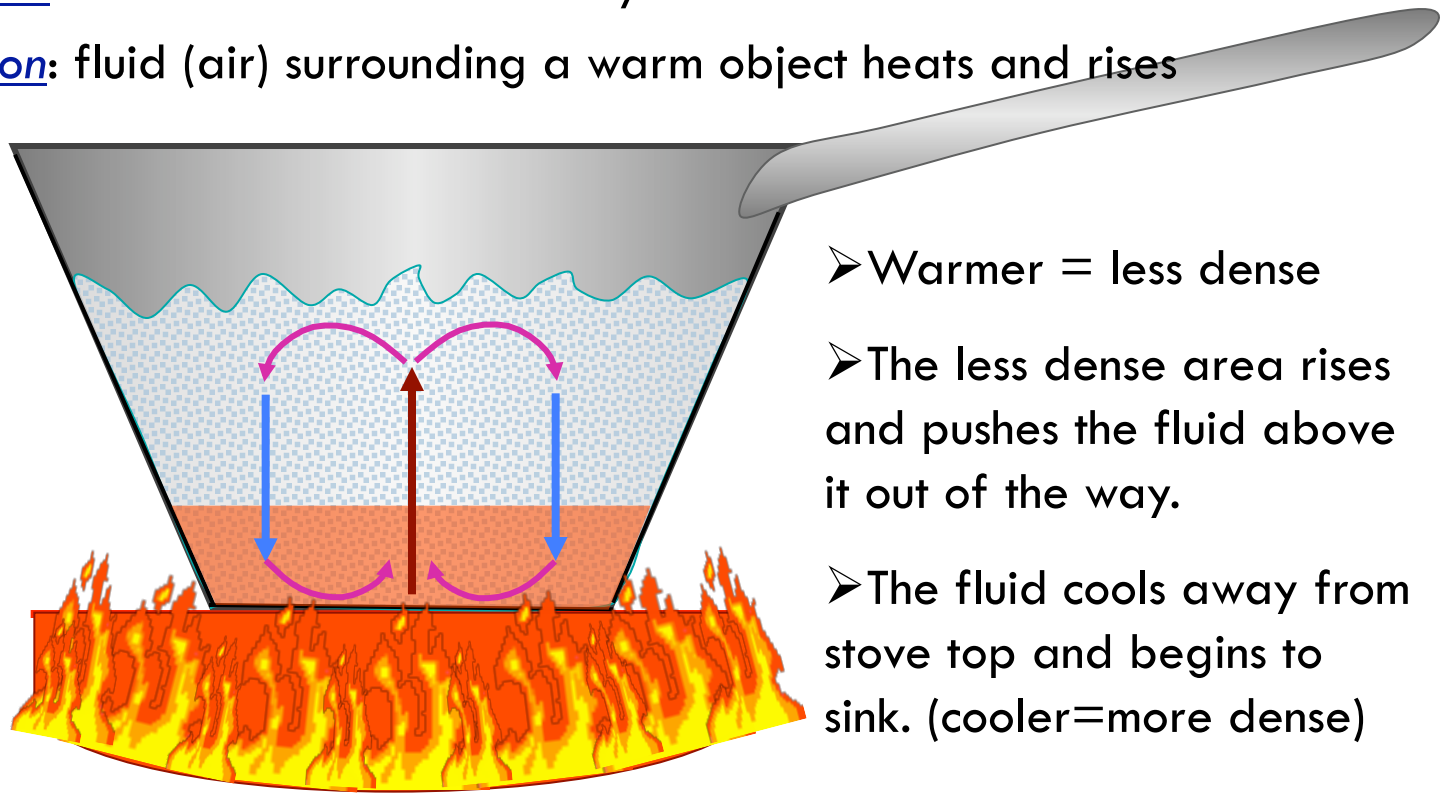
    K = C + 273.16
- Energy from the sun warms the planet, which we experience as heat
- Dark colors absorb more radiant energy than light colors
  - Measure of reflectivity: *albedo*



Source: Oklahoma Climatological Survey

TEMPERATURE

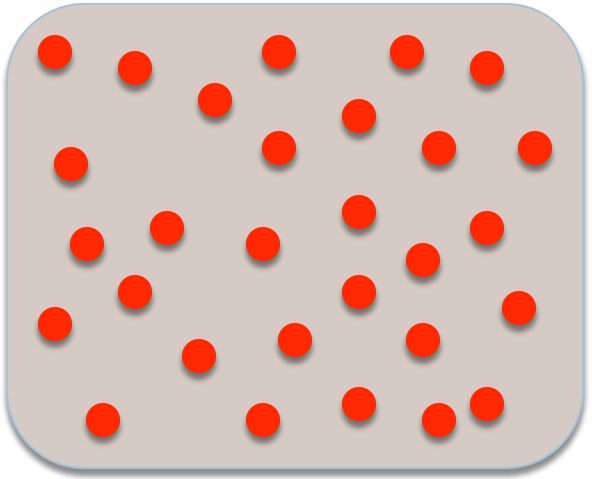
- Heat is transferred one of 3 ways:
  - *Radiation*: molecules absorb electromagnetic radiation, increasing their energy (heat)
  - *Conduction*: heat is transferred directly from one molecule to another
  - *Convection*: fluid (air) surrounding a warm object heats and rises

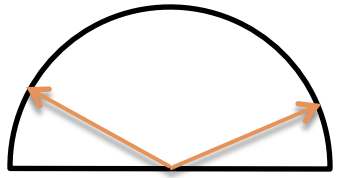


- Warmer = less dense
- The less dense area rises and pushes the fluid above it out of the way.
- The fluid cools away from stove top and begins to sink. (cooler=more dense)

MOISTURE

- Plays a big role in the atmosphere
- Water vapor can be from 1-4% of total atmospheric mass
- Converting moisture between vapor (gas), liquid (water), and solid (ice) absorbs / releases energy
- Amount of moisture expressed as:
  - *Relative humidity* (%): the proportion of moisture that the air is capable of holding
  - *Dew Point* (degrees): the temperature at which the air would become saturated, for a given amount of moisture

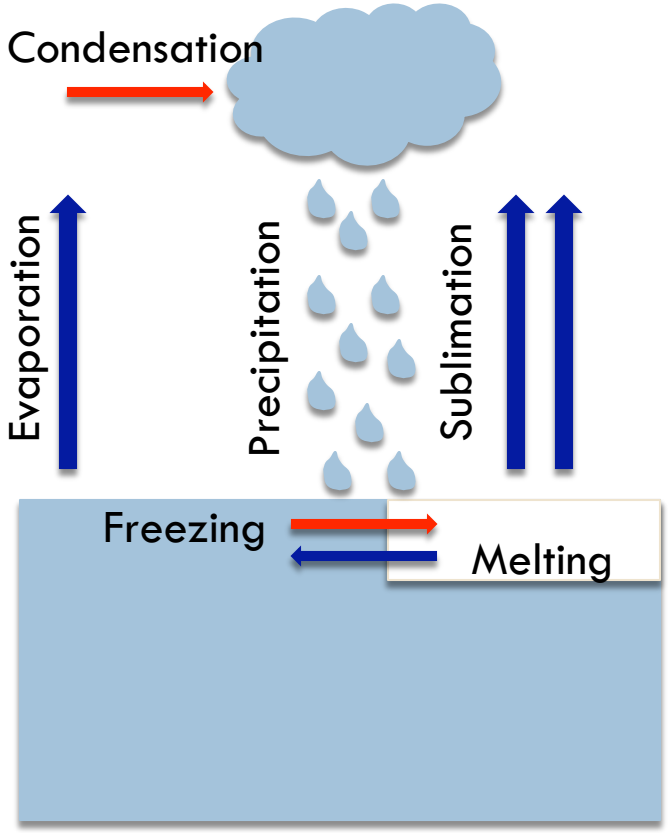


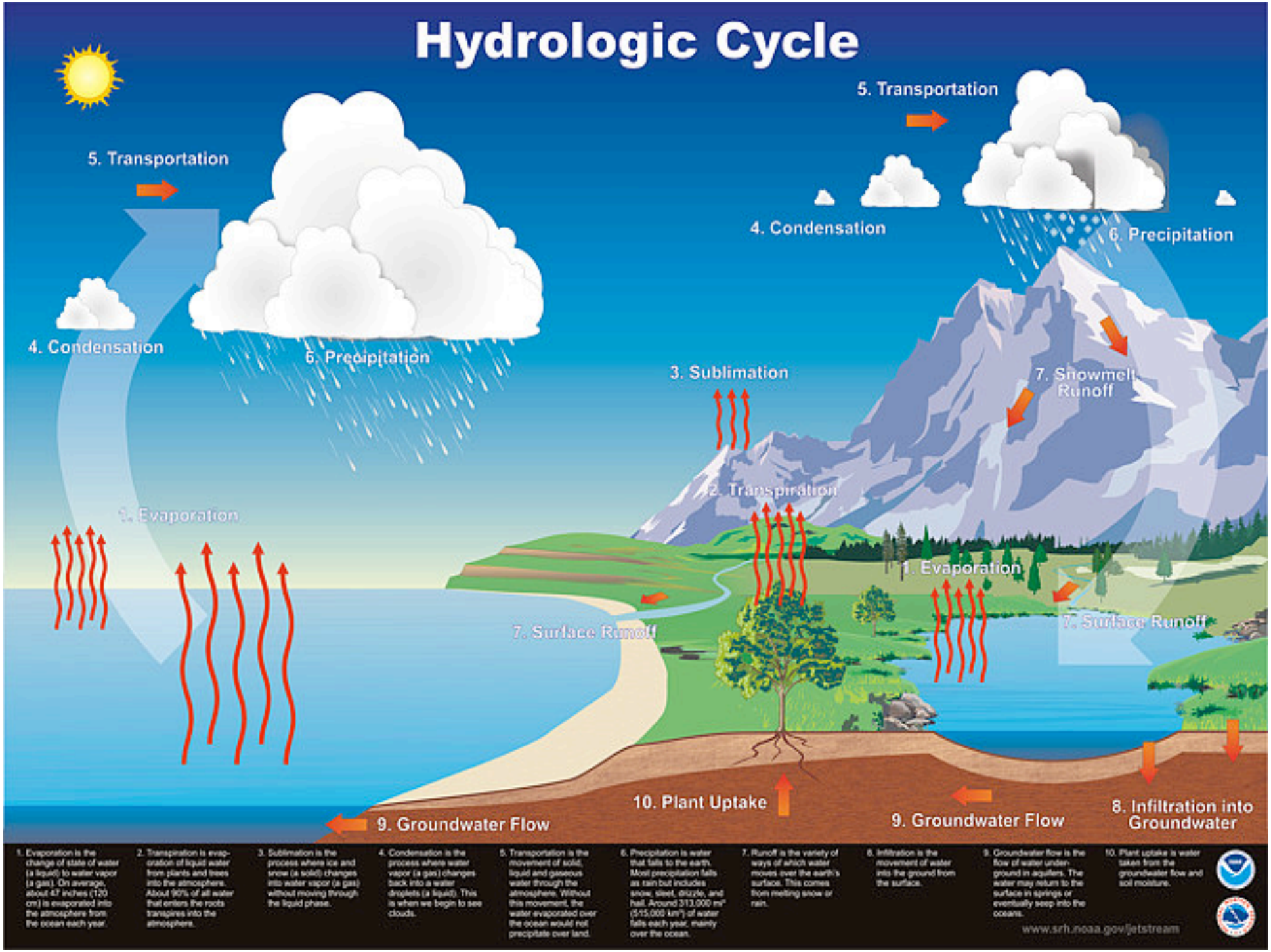


Relative Humidity

TEMPERATURE & MOISTURE

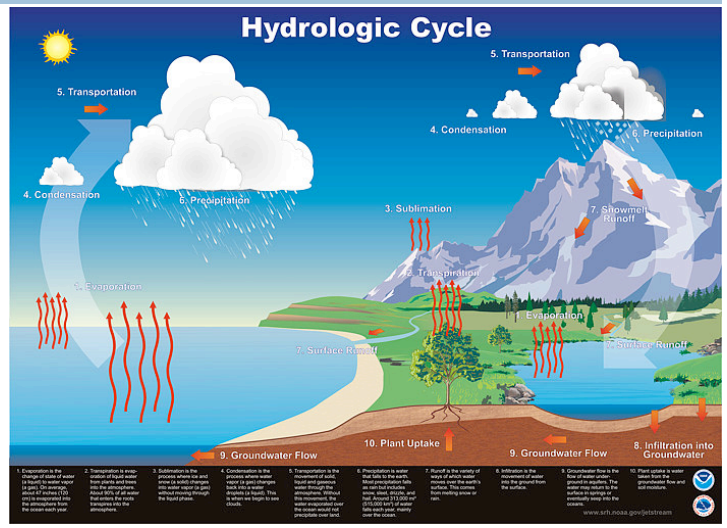
- *Evaporation* - the process by which a liquid is transformed into a gas. The process uses heat, leaving the surroundings cooler than before the process.
- *Condensation* - the process by which a gas becomes a liquid; the opposite of evaporation. The process releases heat.
- *Freezing* – the process by which a liquid is transformed into a solid. This process releases heat.
- *Melting* – the process by which a solid is transformed into a liquid. This process uses heat.
- *Sublimation* - the process by which a solid directly changes into a gas. This uses heat.
- *Precipitation* - any form of liquid or solid water, which falls from the atmosphere and reaches the ground.




Hydrologic Cycle
5. Transportation
4. Condensation
6. Precipitation
3. Sublimation
7. Snowmelt Runoff
2. Transpiration
1. Evaporation
7. Surface Runoff
10. Plant Uptake
9. Groundwater Flow
8. Infiltration into Groundwater
1. Evaporation is the change of state of water (a liquid) to water vapor (a gas). On average, about 47 inches (120 cm) is evaporated into the atmosphere from the ocean each year.
2. Transpiration is evaporation of liquid water from plants and trees into the atmosphere. About 90% of all water that enters the roots transpires into the atmosphere.
3. Sublimation is the process where ice and snow (a solid) changes into water vapor (a gas) without moving through the liquid phase.
4. Condensation is the process where water vapor (a gas) changes back into a water droplets (a liquid). This is when we begin to see clouds.
5. Transportation is the movement of solid, liquid and gaseous water through the atmosphere. Without this movement, the water evaporated over the ocean would not precipitate over land.
6. Precipitation is water that falls to the earth. Most precipitation falls as rain but includes snow, sleet, drizzle, and hail. Around 313,000 mi³ ($\sim$15,000 km³) of water falls each year, mainly over the ocean.
7. Runoff is the variety of ways of which water moves over the earth's surface. This comes from melting snow or rain.
8. Infiltration is the movement of water into the ground from the surface.
9. Groundwater flow is the flow of water underground in aquifers. The water may return to the surface in springs or eventually seep into the oceans.
10. Plant uptake is water taken from the groundwater flow and soil moisture.
www.srh.noaa.gov/jetstream

The Hydrologic Cycle

- *Evaporation* - transformation of a liquid into a gas, in this case water into water vapor
  - recall *sublimation* is the process where solids (snow) are converted directly to gas (water vapor)
- *Transpiration* – evaporation of water secreted by the leaves of plants
  - 99% of water taken up by plants is *transpired* into the atmosphere
- *Condensation* – conversion of water vapor into water droplets, seen as clouds, fog, mist, dew, or frost
- *Precipitation* – *coalescence* (sticking together) of tiny water droplets create larger drops which fall to Earth
- *Infiltration* – Some of the precipitation is absorbed into the ground and *filters* down through layers of soil and rock
- *Runoff* – precipitation that cannot be absorbed by the ground *runs off* into streams, lakes, and rivers, and eventually to the ocean



Source: NOAA National Weather Service Jetstream

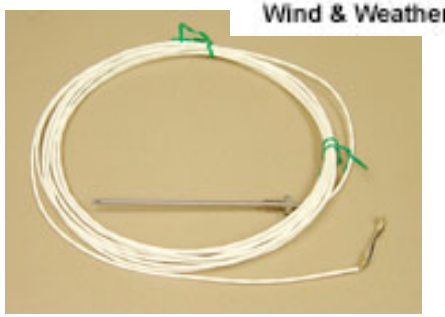
MEASURING THE WEATHER

Measuring Temperature

- A *thermometer* measures the heat content of the air
- Thermometers often use alcohol, which has a lower freezing point than water
  - The fluid expands as temperature increases
- Electronic *thermistors* are often used in automated weather systems

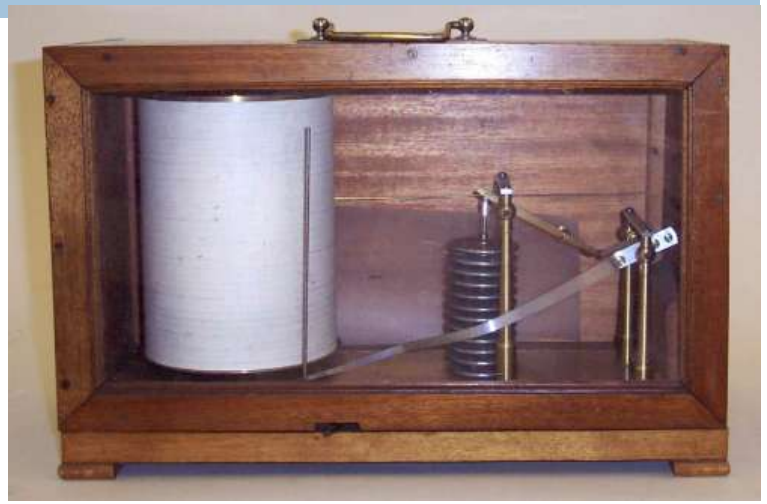
Bulb Thermometer
Note reservoir at bottom.
Photo courtesy:
Wind & Weather

Spring Thermometer
Photo Courtesy:
Wind & Weather



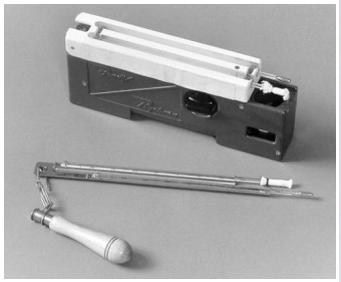
Measuring Pressure

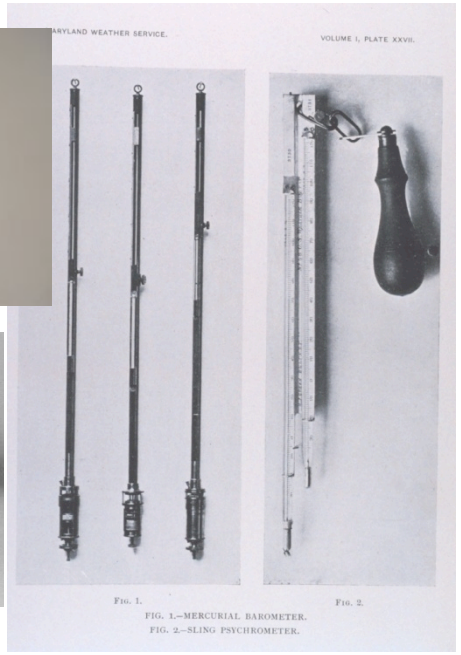
- A *barometer* operates much like a scale, responding to the 'weight' of the air above it
- Pressure readings are shown by a needle that moves upward or downward as pressure changes
- Some barometers record pressure on a *strip chart*
- Many barometers today are automated with digital readouts



Measuring Moisture

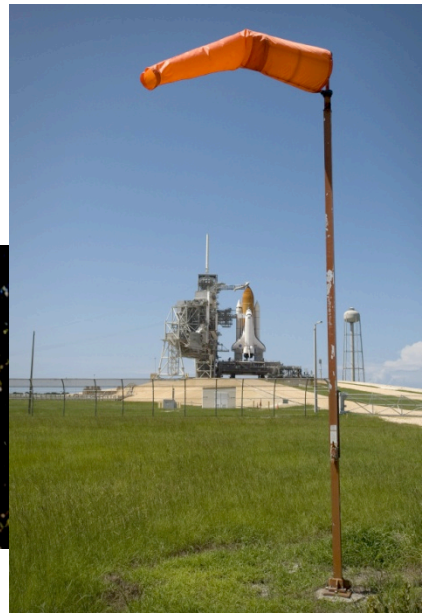
- A *hygrometer* is an instrument used to measure the water content of the atmosphere
  - Calculates either *relative humidity* or *dewpoint*
- A *psychrometer* is a type of hygrometer consisting of pair of thermometers
  - One is a regular thermometer that measures the actual temperature of the air, called the *dry bulb* temperature
  - The other has a moistened wick; water is evaporated cooling the thermometer to a moisture equilibrium temperature called the *wet bulb* temperature
  - The amount of water vapor the air is able to hold at each temperature is determined; the ratio of these determines the relative humidity
- Materials that lengthen or shorten based on the moisture content of the air are also used in hygrometers
  - Hair is a great measuring device!





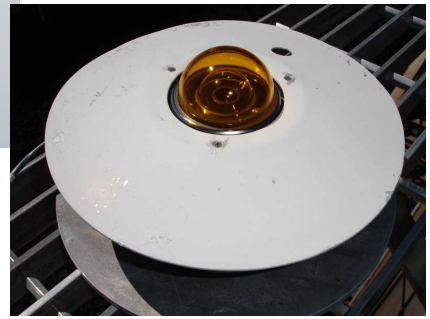
Measuring Wind

- Wind speed is directly measured with an *anemometer*
  - Wind turns a propeller; faster wind speeds make the propeller spin faster
  - A magnet is attached to the propeller shaft; each revolution is counted to calculate speed
- Wind direction is measured with a *wind vane*
  - Air blows against a flat surface, aligning the axis in the direction of the wind
  - An arrow points into the wind
- Wind speed can be estimated with a *wind sock*
  - Often used at airports for a quick visual of wind direction and approximate speed
- *Sonic anemometers* measure the speed with which particles pass between their sensors



Measuring Sunshine

- A pyranometer is a radiation sensor that measures solar radiation
  - Solar radiation may be direct (incoming from the sun) and reflected from the surface
  - Solar radiation is needed to calculate energy balance
- A *Celiometer* uses light to measure the height of clouds
  - From this, sky cover can be recorded



Measuring Rainfall

- Rainfall is measured with a *rain gauge*
- *Direct read* rain gauges simply collect rainfall and are read manually
  - A smaller inner tube allows finer resolution
- *Tipping bucket* rain gauges have a small bucket that tips (and empties) whenever a certain amount of rain fills the bucket
  - A magnetic switch counts the number of tips, which is converted to rainfall accumulation
- *Weighing gauges* collect rainfall on a scale; the weight of the water determines how much rain fell
  - Water may be lost through evaporation
- Some rain gauges are heated to melt and measure winter precipitation