COLORADO CLIMATE WORKSHOP

Basic Climatology
Colorado Climate Center
What we are going to cover

1. The Basics: What we measure and how
2. The Atmosphere in Motion
3. Climate Patterns
4. Clouds and Thunderstorms
5. Pressure Systems, Air Masses & Fronts
6. Other Weather Hazards
7. Climate Change
8. Climate Products
9. Drought
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!)
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: raincoat

What weather 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: rainforest

What climate determines
# What gases make up the atmosphere?

*Source: NOAA National Weather Service Jetstream*

<table>
<thead>
<tr>
<th>Gas</th>
<th>Symbol</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>N₂</td>
<td>78.084%</td>
</tr>
<tr>
<td>Oxygen</td>
<td>O₂</td>
<td>20.947%</td>
</tr>
<tr>
<td>Argon</td>
<td>Ar</td>
<td>0.934%</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>CO₂</td>
<td>0.033%</td>
</tr>
<tr>
<td>Neon</td>
<td>Ne</td>
<td>18.20 parts per million</td>
</tr>
<tr>
<td>Helium</td>
<td>He</td>
<td>5.20 parts per million</td>
</tr>
<tr>
<td>Krypton</td>
<td>Kr</td>
<td>1.10 parts per million</td>
</tr>
<tr>
<td>Sulfur dioxide</td>
<td>SO₂</td>
<td>1.00 parts per million</td>
</tr>
<tr>
<td>Methane</td>
<td>CH₄</td>
<td>2.00 parts per million</td>
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<tr>
<td>Hydrogen</td>
<td>H₂</td>
<td>0.50 parts per million</td>
</tr>
<tr>
<td>Nitrous Oxide</td>
<td>N₂O</td>
<td>0.50 parts per million</td>
</tr>
<tr>
<td>Xenon</td>
<td>Xe</td>
<td>0.09 parts per million</td>
</tr>
<tr>
<td>Ozone</td>
<td>O₃</td>
<td>0.07 parts per million</td>
</tr>
<tr>
<td>Nitrogen dioxide</td>
<td>NO₂</td>
<td>0.02 parts per million</td>
</tr>
<tr>
<td>Iodine</td>
<td>I₂</td>
<td>0.01 parts per million</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>CO</td>
<td>trace</td>
</tr>
<tr>
<td>Ammonia</td>
<td>NH₃</td>
<td>trace</td>
</tr>
</tbody>
</table>
Layers of the Atmosphere

- **Exosphere** (up to 6,200 miles)
  - Very few particles, but highly energized
  - Ionosphere (37-190 miles): highly energized particles reflect radio waves

- **Thermosphere** (up to 430 miles)
  - Gasses become very thin
  - Temperature decreases with height (less absorption)

- **Mesosphere** (up to 53 miles)
  - Virtually no vertical motion
  - Temperature warms with height (absorption of radiation)

- **Stratosphere** (up to 31 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
PRESSURE

- 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 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
  \[ F = 1.8 \times C + 32 \]
- 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: \textit{albedo}
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
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.
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
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