Key ideas -- Weather and Climate
General background
Weather is the condition in the atmosphere at a given place and time. The study of weather is called **meteorology**.
Climate describes the long-term pattern of weather at a given location.
Weather and climate are key components of Earth's **energy flow** and cycles of matter, especially water, oxygen and carbon dioxide.
Energy can be transferred three ways:
Radiation travels as **electromagnetic waves** and can even pass through empty space.
Convection occurs in fluids (liquids and gases) and involves density-driven currents. Warmer, less-dense fluids rise and cooler, more-dense fluids sink. **Convection currents** are most important in creating weather and moving tectonic plates.
Conduction involves heat energy moving between substances that are touching, such as your hand and a hot pot.
The **electromagnetic spectrum** describes all of the various types of radiant energy, each of which covers a specific range of **wavelengths**. *(ESRT p. 14)*
The Sun's energy reaches Earth as **incoming solar radiation** ("i**nsolation**). Most of the insolation is **visible light**, with lesser amounts of **infrared** (**heat**) and **ultraviolet** waves.
Energy always travels from the **heat source** (warm place) to the **heat sink** (cold place).
Radiant energy encountering a substance may be **transmitted**, **absorbed**, **reflected**, or **refracted**.
Dark-colored objects are good absorbers and radiators of heat, and poor reflectors. Light-colored objects are good reflectors, but poor absorbers or radiators.
Smooth surfaces are good reflectors and dark surfaces are good absorbers.
Kinetic energy is energy of moving things. The faster they move, the more KE they use.
Temperature is the "average kinetic energy" of an object.
Potential energy is stored energy. It increases with mass and as the object gets higher.
Radiative balance (**equilibrium**) occur when the energy emitted by an object is equal to that absorbed by the object.
The amount of insolation reaching Earth is balanced by the amount reflected back to space (**albedo**) and the **terrestrial re-radiation**, mostly as infrared waves.
Observing and Measuring Weather
Important **weather variable**s include: air temperature, air pressure, wind direction, wind speed, relative humidity, dew point, clouds, and precipitation.
Air temperature is measured with a **thermometer** in **degrees** (Celsius/centigrade or Fahrenheit). *(**ESRT p. 13**)*
Air pressure is measured with a **barometer** in **millibars** or inches of mercury. ***(ESRT p. 13)***
Wind is measured in both direction and magnitude (vector).
Wind direction is measured with a **wind vane**. Winds are named by the direction they blow from.
Wind speed (velocity) is measured with an **anemometer**. Units used include miles per hour, km/hr, and knots (nautical miles per hour.)
Psychrometers made of wet- and dry-bulb thermometers measure relative humidity and dew point.
Relative humidity is a measure of how much water vapor is contained in the air compared with how much it could hold at that temperature. When air holds all the moisture is can, it is said to be at 100% relative humidity and **saturated**.
Dew point temperature is the temperature to which air must be cooled to reach saturation, at which drops of **dew** will form. If the dew point temperature is below freezing, **frost** crystals will form.

Clouds will form when air cools and saturation occurs above the surface. Water or ice attach to invisible **condensation nuclei**.
Meteorologists measure the **amount of cloud cover**.
Clouds can be classified into three basic shapes: **stratus** (flat), **cumulus** (fluffy), and **cirrus** (feathery). The term **"nimbo"** is used to indicate a storm cloud, as in nimbostratus or cumulonimbus.
Precipitation includes all forms of water coming out of the atmosphere, and includes **rain**, **snow**, **sleet**, **hail**, and **drizzle**.
Precipitation cleans the air of pollution by washing dust and other air-borne **particulates**.
Weather at a location can be symbolically represented by a **station model**. ***(ESRT p. 13)***
Many weather variables exhibit relationships with each other.
As air temperature increases, air pressure decreases (inverse relationship).
As air humidity increases, air pressure decreases (inverse relationship). This occurs because water molecules, which have less mass, displace heavier nitrogen and oxygen molecules as humidity increases.
Modern weather observation systems also use **weather radar**, **weather satellites**, and other instrument systems, such as **radiosondes** sent aloft on weather balloons.
Global and Regional Weather and Climate Systems
Local weather is a small part of **global** and **regional weather patterns.**
Global wind, pressure, and precipitation patterns result from differences in the amount of energy received at different latitudes and Earth's rotation.
The **Coriolis effect** causes winds in the northern hemisphere to turn to the right of their direction of movement, and winds in the southern hemisphere to turn to their left. This produces **clockwise** patterns in the northern hemisphere and **counterclockwise** patterns in the southern hemisphere.
Global climate patterns ***(ESRT p. 14)*** include: wet conditions and calm winds centered around the equator (**doldrums**); east-to-west winds **trade winds** in the tropics; zones of calm centered around 30 degrees north and south (**"horse latitudes"**); west-to-east winds in the mid-latitudes (**"prevailing westerly"**); and east-to-west winds at high latitudes (**"polar easterlies"**).
Wind blows from areas of higher pressure to areas of lower pressure. The stronger the **pressure gradient** (difference from one location to another), the faster the wind speed.
Regional weather (on the scale of several states) results from the movement of air masses, weather fronts, and pressure systems.
In the United States, most weather systems move from west to east under the influence of the prevailing westerly.
Air masses are large bodies of air that display similar temperature and moisture characteristics. They are named after the type of geography over which they form.
Continental Polar (cP) air masses are generally dry and cool/cold. They form over central Canada and move southeastward across the United States.
Continental Tropical (cT) air masses are dry and warm/hot. They form over Mexico and the Southwest.
Maritime Polar (mP) air masses are humid and cool. They mostly affect weather in the Pacific Northwest and New England.
Maritime Tropical (mT) air masses are humid and warm. They may form over the Gulf of Mexico and move northeastward across the U.S.
Weather predictions are based largely on air mass movements.
When air masses meet, their boundaries are **weather fronts.**
A **cold front** occurs when cooler air (such as cP) moves faster than warmer air (such as mT.) The warmer air is forced upward. Cold fronts often bring a brief period of heavy rain or even thunderstorms, followed by rapid clearing and cooler temperatures. On a weather map, cold fronts are indicated by triangles pointing in the direction the front moves.

A **warm front** occurs when a warmer air mass pushes colder air ahead of it. Warm fronts extend over a much wider region than cold fronts. Cirrus clouds at the leading edge of the front may be seen a day or two before the front arrives. As the front passes, there may be steady rain, then gradual clearing and warming. Half-circles indicate a warm front on a weather map.

A **stationary front** develops when neither air mass can move the other. Weather is usually cloudy with occasional showers. It is represented on a weather map by triangles and half-circles on opposite sides of the line.

An **occluded front** forms when a second cold air mass overtakes a warm front and lifts it above the ground. Weather is similar to that in a warm front. The map symbol involves triangles and half-circles on the same side of the line.

Movements of air masses and fronts are also influenced by large-scale pressure systems.

Cyclones are low-pressure systems that usually bring unsettled weather. Air circulates counterclockwise and inward to the center of the cyclone. Many cyclones are associated with cold and occluded fronts.

Anticyclones are high-pressure systems that often occur within an air mass They generally bring fair weather. Air circulates outward in a clockwise direction around an anticyclone. (Note: In the southern hemisphere, high circulate in a counterclockwise direction and lows in a clockwise direction.)

If the barometric pressure is rapidly falling it probably means a storm is approaching. Rising air pressure often indicates fair weather will follow.

Additional Climate and Weather Factors

Adiabatic Cooling: As air rises, it cools because it expands and the pressure decreases.

Adiabatic Heating: As air sinks, it warms as it contracts and the pressure increases.

Orographic effect: As air rises up the **windward side** of a mountain, adiabatic cooling occurs, and as it sinks down the **leeward side**, adiabatic warming occurs. So the windward side has greater cloud cover and precipitation, and the leeward side often has a **rain-shadow desert.**

Water has a higher **specific heat** value than minerals and rocks, so when the same amount of insolation strikes materials at a shoreline, the water will remain cooler and the beach will warm up more rapidly.

These heating rate differences produce on-shore **sea breezes** during the day and off-shore **land breezes** at night.

Large bodies of water make cooler summers and warmer winters.

On a regional scale, similar factors create the **monsoons**, with wet-seasons in summer and dry-seasons in winter.

Because warming and cooling take time, generally the hottest part of the day occurs in mid-afternoon, even though insolation is greatest at solar noon. Similarly, the warmest days of the year usually occur in July or August, even though maximum insolation occurs in late June, and the coldest days are in January or February, even though insolation minimum values occur in late December. These patterns are called "**temperature lags"**

Without certain atmospheric gases that absorb infrared energy in terrestrial re-radiation, Earth would have a frozen surface, given its distance from the Sun. These **greenhouse gases** include **carbon dioxide**, **water vapor**, and **methane**.

There is increasing evidence that human releases of carbon dioxide and other greenhouses gases has contributed greatly to **global warming** during the past few decades, which will have significant impact on climate systems in the next few decades. Possible effects include stronger hurricanes and rising sea level, which will especially affect coastal regions.