Earth Systems, Structures and Processes
Earth Systems, Structures and Processes

7.E.1 Understand how the cycling of matter (water and gases) in and out of the atmosphere relates to Earth’s atmosphere, weather and climate and the effects of the atmosphere on humans.

7.E.1.1 Compare the composition, properties and structure of Earth's atmosphere to include mixtures of gases and differences in temperature and pressure within layers.

7.E.1.2 Explain how the cycling of water in and out of the atmosphere and atmospheric conditions relate to the weather patterns on earth.

7.E.1.3 Explain the relationship between the movement of air masses, high and low pressure systems, and frontal boundaries to storms (including thunderstorms, hurricanes, and tornadoes) and other weather conditions that may result.

7.E.1.4 Predict weather conditions and patterns based on information obtained from: • Weather data collected from direct observations and measurement (wind speed and direction, air temperature, humidity and air pressure). • Weather maps, satellites and radar • Cloud shapes and types and associated elevation

7.E.1.5 Explain the influence of convection, global winds and the jet stream on weather and climatic conditions.

7.E.1.6 Conclude that the good health of humans requires: monitoring the atmosphere, maintaining air quality and stewardship.
Up and Away!

What is Earth’s atmosphere?
• The atmosphere is the mixture of gases that surrounds Earth.

• The functions of the atmosphere include protecting organisms from the sun’s damaging rays and maintaining the right temperature range for life.

• The atmosphere also supplies gases necessary for breathing.
What is Earth’s atmosphere?

• The atmosphere is made up of 78 percent nitrogen gas, 21 percent oxygen gas, and 1 percent other gases.

• The atmosphere also contains small particles of dust, volcanic ash, sea salt, smoke, skin, bacteria, and pollen.

• The atmosphere also has clouds that contain liquid water droplets and solid water in the form of snow and ice crystals.

• Most water in the atmosphere is in the form of water vapor, which is an invisible gas.
How do pressure and temperature change in the atmosphere?

• Gravity pulls gas molecules in the atmosphere toward Earth, causing air pressure.

• **Air pressure** is the measure of the force with which air molecules push on an area of a surface.

• Air pressure decreases as altitude, or distance from Earth’s surface, increases.
How do pressure and temperature change in the atmosphere?

• As altitude increases, air temperature also changes.

• Some parts of the atmosphere are warmer because they contain a high percentage of gases that absorb solar energy.

• Other parts of the atmosphere contain less of these gases and are cooler.
Look Way Up

What are the layers of the atmosphere?

• The atmosphere is divided into four layers, based on temperature and other properties.

• The **thermosphere** is the uppermost layer, with temperatures that increase as altitude increases.

• The thermosphere feels cold because particles are so far apart.
What are the layers of the atmosphere?

• The **mesosphere** is between the thermosphere and stratosphere.

• In the mesosphere, the temperature decreases as altitude increases.

• Meteoroids begin to burn up in the mesosphere.
What are the layers of the atmosphere?

• The stratosphere is between the mesosphere and troposphere.

• In the stratosphere, temperatures generally increase as altitude increases.

• Ozone in the stratosphere absorbs ultraviolet radiation from the sun, which warms the air.
What are the layers of the atmosphere?

- The **troposphere** is the lowest layer of the atmosphere.

- Temperature generally decreases as altitude increases. Temperatures near the surface vary greatly.

- The troposphere contains 80 percent of the atmosphere’s total mass.
Atmosphere Layers

Troposphere
- 6 - 20 km
- Mount Everest

Stratosphere
- 50 km
- Weather balloon

Mesosphere
- 85 km
- Meteors

Thermosphere
- 690 km
- Shuttle
What are the layers of the atmosphere?

• How do temperatures differ with altitude in the atmosphere?
Here Comes the Sun …

How does the atmosphere protect life on Earth?

• Earth’s atmosphere reflects or absorbs most of the radiation from the sun.

• The **ozone layer** is an area in the stratosphere that contains a high concentration of ozone. It absorbs most of the sun’s radiation.
How does the atmosphere protect life on Earth?

• Ozone-layer thickness changes by season and location.

• Scientists have discovered a steady decrease in the volume of ozone over time, attributed to the use of certain chemicals by people.

• An area over the South Pole with a very thin ozone layer is often called the “ozone hole.”
How does the atmosphere protect life on Earth?

• The **greenhouse effect** is the process by which certain gases in the atmosphere absorb and give off infrared radiation.

• Radiation from the sun warms Earth’s surface, which then gives off infrared radiation.

• Greenhouse gases in the atmosphere absorb some of this infrared radiation and reradiate it. In this manner, they keep the Earth warm.
How does the atmosphere protect life on Earth?

• How is the heat inside of a closed car in the summer similar to the greenhouse effect?
Blow It Out!

What causes wind?
• The uneven heating of Earth’s surface by the sun causes temperature differences in the air.

• Warm air rises, creating areas of low pressure. Cool air sinks, creating areas of high pressure.

• Air moves from areas of higher pressure toward areas of lower pressure.
What causes wind?

• **Wind** is the movement of air caused by differences in air pressure.

• Cold air at the poles creates areas of high pressure there. Warm air at the equator creates an area of lower pressure.

• Globally, air moves in circular patterns called *convection cells*. Convection cells occur at about every 30° of latitude, producing pressure belts.
What causes wind?

• How does the sun contribute to global wind patterns?
How does Earth’s rotation affect wind?

• Earth rotates, causing winds to be deflected, or curved.

• The apparent curving of the path of a moving object from an otherwise straight path due to Earth’s rotation is called the Coriolis effect.
How does Earth’s rotation affect wind?

• Points on Earth closer to the equator must travel faster than points close to the poles to make one complete rotation each day.

• In the Northern Hemisphere, air moving to the north curves to the east, and air moving to the south curves to the west.
How does Earth’s rotation affect wind?

• How would the appearance of the purple arrows (curved paths) in the diagram below change if Earth rotated twice as fast?
Blowin’ Around

What are examples of global winds?

- **Global winds** are wind systems that occur at or near Earth’s surface.
- The major global wind systems are the *polar easterlies*, the *westerlies*, and the *trade winds*.
What are examples of global winds?

• The trade winds blow between 30° latitude and the equator in both hemispheres and curve west.

• The westerlies blow between 30° and 60° latitudes in both hemispheres and curve east.

• The polar easterlies blow between the poles and 60° latitudes in both hemispheres and curve west.
What are examples of global winds?

• The trade winds of both hemispheres meet in a calm area around the equator called the doldrums. Very little wind blows in the doldrums.

• The horse latitudes are calm areas at about 30° latitude in both hemispheres. Air stops moving and sinks in the horse latitudes.
What are examples of global winds?

• Identify the major global wind systems in the image below.
What are examples of global winds?

- **Jet streams** are narrow belts of high-speed winds that blow from west to east, between 7 km and 16 km above Earth’s surface.

- Jet streams follow boundaries between hot and cold air and can shift north and south.

- The two main jet streams are the subtropical jet stream and the polar jet stream.
What are examples of global winds?

• Identify the two main jet streams in the image below.
Desert Trades

• Trade winds carry dust from the Sahara across the Atlantic Ocean.

• The Sahara is the world’s largest hot desert.

• Dust in Florida can come from the Sahara.
What are examples of local winds?

• **Local winds** are the movement of air over short distances. They can blow from any direction.

  - A sea breeze forms during the day, as cooler air over the ocean flows toward the land.

  - A land breeze forms at night, as cooler air from the land blows toward the water.
What are examples of local winds?

• During the day, the sun warms the air on mountain slopes faster than it warms the air in a valley. This results in areas of lower pressure near the mountain tops.

• The pressure difference causes a valley breeze, which flows from the valley up the slopes of mountains during the day.

• At night, as air along the mountain slopes cools, it flows down into the valley, creating a mountain breeze.
Weather & Climate
Wonder About Weather?

What is weather?

• **Weather** is the condition of Earth’s atmosphere at a certain time and place.

• Weather conditions in the atmosphere can be recognized through direct observation.

• Weather is described by factors such as temperature, humidity, precipitation, air pressure, wind, and visibility.
What is temperature and how is it measured?

• Temperature is a measure of how hot or cold something is. An instrument that measures and displays temperature is called a thermometer.

• Some thermometers use the thermal expansion of a liquid to determine temperature.

• Electrical thermometers use the strength of an electric current to determine temperature.
What is humidity and how is it measured?

• **Humidity** is the amount of water vapor in the air. As more water evaporates, humidity of the air increases.

• **Relative humidity** is the amount of water vapor in the air compared to the amount of water vapor needed to reach saturation. It is measured with a psychrometer.

• When air is saturated, the rates of evaporation and condensation are equal.
What is humidity and how is it measured?

- **Dew point** is the temperature at which more condensation than evaporation occurs.

- When air temperature drops below the dew point, water vapor condenses to form dew, fog, and clouds.
What is precipitation and how is it measured?

• **Precipitation** is any form of water that falls to Earth’s surface from the clouds. It includes rain, snow, hail, and sleet.

• Inside a cloud, water droplets can collide to form larger droplets, and when they become heavy enough, they fall as rain.

• Rain is measured with a rain gauge.
What is precipitation and how is it measured?

• Snow forms when air temperatures are low enough to turn water vapor into a solid. Fallen snow may be measured with a meter stick.

• When balls or lumps of ice fall from clouds during thunderstorms, it is called *hail*.

• Sleet forms when rain falls through a layer of freezing air, producing falling ice.
Watching Clouds

• Cirrus clouds are made of ice and appear feathery or wispy.

• Cumulus clouds appear as heaps or piles. They form in fair weather but can produce thunderstorms.

• Stratus clouds form flat layers that can block out the sun and produce steady rain.
What is air pressure and how is it measured?

- **Air pressure** is the force of air molecules pushing on an area.

- A barometer is used to measure air pressure.

- Air pressure and density decrease with altitude.
What is air pressure and how is it measured?

- Why do mountain climbers sometimes need extra oxygen to breathe at the top of a mountain?
What is wind and how is it measured?

- **Wind** is air that moves horizontally, or parallel to the ground.

- Over a short distance, air moves from higher pressure to lower pressure.

- An anemometer is used to measure wind speed.

- A wind vane or wind sock is used to measure wind direction.
What is visibility and how is it measured?

- **Visibility** is a measure of the distance at which an object or a light can be clearly seen.

- Visibility is measured by using three to four known landmarks at different distances.

- Air pollution or fog can cause poor visibility.
What are some ways to collect weather data?

• Weather data can be collected at ground stations, by weather buoys, by ships, by airplanes, and by satellites.
Clouds & Cloud Formation
Head in the Clouds

What are clouds?

• A cloud is a collection of small water droplets or ice crystals that are suspended in the air.

• Clouds are visible because water droplets and ice crystals reflect light.

• Clouds are usually associated with precipitation, but most cloud types do not produce precipitation.
How do clouds affect climate?

• The pattern of precipitation from clouds in an area will determine the climate of that area.

• Thick, low-altitude clouds reflect more sunlight back into space and help to cool Earth.

• Thin, high-altitude clouds absorb some energy that radiates from Earth and reradiate some of it back to Earth’s surface. This warms Earth.
How do clouds form?

• Clouds form when water vapor condenses, or changes from a gas to a liquid.

• For water vapor to condense, moist air must be cooled to a certain temperature, and the air must be holding the maximum amount of water vapor possible.

• If air rises high enough into the atmosphere, it cools to its dew point.
How do clouds form?

• **Dew point** is defined as the temperature at which the rate of condensation equals the rate of saturation.

• **Saturation** means that the air is holding the maximum quantity of water vapor possible at a given temperature or pressure.

• Dew point is the temperature at which water vapor in saturated air can condense and form water droplets or ice crystals.
How do clouds form?

- In clouds, tiny solid particles called *cloud condensation nuclei* are the surfaces on which water droplets condense.

- Clouds are most commonly made of numerous small water droplets.

- However, at high altitudes, where temperatures are very cold, clouds are composed of ice crystals.
What is the role of solar energy in cloud formation?

• Solar energy drives the water cycle and thus provides the energy for cloud formation.

• Water on the surface of the land and the oceans absorbs solar energy and becomes water vapor, in a process called evaporation.

• Cloud formation takes place when water droplets or ice crystals condense on solid particles in the air.
What processes cool air enough to form clouds?

• Air can be cooled to its dew point in several ways, including frontal and orographic lifting.

• Frontal lifting can occur when a warm air mass rises over a cold air mass, or when a mass of cold air slides under a mass of warm air.

• Orographic lifting occurs when an obstacle, such as a mountain range, forces a mass of air upward.
What are three cloud shapes?

• The three classes of clouds based on shape are stratus, cumulus, and cirrus clouds.

• **Stratus clouds** are thin and flat, and their edges are not clearly defined.

• **Stratus** is a Latin word that means “layer.” Stratus clouds often merge into one another and may look like a single layer that covers the entire sky.
What are three cloud shapes?

• *Cumulus* is a Latin word that means “heap.”

• *Cumulus clouds* are thick and puffy on top and generally flat on the bottom.

• These clouds have well-defined edges and can change shape rapidly. They can be bright or dark, and they can produce severe weather.
What are three cloud shapes?

• *Cirrus* is a Latin word that means “curl.”

• *Cirrus clouds* look white and feathery, and their ends curl.

• They are made of ice crystals rather than liquid water droplets. They do not produce precipitation that reaches Earth’s surface.
What are the types of clouds based on altitude?

- The four classes of clouds based on altitude are low clouds, middle clouds, high clouds, and clouds of vertical development.

- These four classes are made up of 10 cloud types.

- Prefixes are used to name the clouds that belong to some of these classes.
What are the types of clouds based on altitude?

• Low clouds form between Earth’s surface and 2,000 m altitude. They are commonly made up of water droplets.

• The three types of low clouds are stratus, stratocumulus, and nimbostratus.

• There is no special prefix for naming low clouds. However, *nimbus* means “rain,” so *nimbostratus* clouds are rain clouds.
What are the types of clouds based on altitude?

• Middle clouds form between 2,000 m and 6,000 m altitude. They are commonly made up of water droplets, but may be made up of ice crystals.

• The prefix *alto-* is used to name middle clouds.

• The two types of middle clouds are altocumulus and altostratus.
What are the types of clouds based on altitude?

• High clouds form above 6,000 m altitude, where air temperature is below freezing. Therefore, high clouds are made up of ice crystals.

• The prefix *cirro*- is used to name high clouds.

• Cirrus, cirrocumulus, and cirrostratus are the types of high clouds.
What are the types of clouds based on altitude?

• A cloud of vertical development can have its base at low altitude, but its top can reach higher than 12,000 m.

• The two types of clouds of vertical development are cumulus and cumulonimbus.

• Cumulonimbus clouds are linked to severe weather and can produce rain, hail, lightning, tornadoes, and rapidly sinking columns of air.
What are the types of clouds based on altitude?

• Identify the various types of clouds shown here.
How does fog form?

• Water vapor that condenses very near Earth’s surface is called fog. It forms when moist air near Earth’s surface or moving across cold water cools to its dew point.

• Ground fog, or radiation fog, generally forms in low-lying areas on clear, calm nights. Sea fog, or advection fog, occurs at all times of day.

• Steam fog forms when evaporation takes place into cold air that is lying over warmer water.
Clouds on Other Worlds

• Like Earth, other bodies in the solar system have clouds in their atmosphere.

• There are clouds on Venus, Mars, Jupiter, and Saturn. The clouds of Jupiter and Saturn are arranged in bands that circle the planets.

• Saturn’s moon Titan has clouds in a thick, planet-like atmosphere.
What Influences Weather?
How does the water cycle affect weather?

• Weather is the short-term state of the atmosphere.

• The water cycle is the continuous movement of water among the atmosphere, land, oceans, and living things.

• Evaporation, condensation, and precipitation in the water cycle are also parts of weather.
How does the water cycle affect weather?

• How are weather and the water cycle related?
Putting Up a Front

How do air masses affect weather?

• An air mass is a large volume of air in which temperature and moisture content are nearly the same throughout.

• An air mass forms when air remains over a region for many days and takes on the temperature and humidity of the land below it.
Where do fronts form?

• A boundary, called a **front**, forms between air masses with differing densities.

• Fronts cause a change in weather as they pass.

• The temperature and moisture content of the air masses that meet and their movement relative to each other determine the type of front formed.
Where do fronts form?

- Cold fronts form as a cold air mass pushes an existing warm air mass up.
Where do fronts form?

- Warm fronts form as a warm air mass slides up over a retreating cold air mass.
Where do fronts form?

- Stationary fronts form when a cold air mass and a warm air mass remain in one place.
Feeling the Pressure!

What are pressure systems and how do they interact?

• Areas of different air pressure cause changes in the weather.

• In a high-pressure system, air slowly sinks down and spreads outward.

• In a low-pressure system, air rises and cools.
What are pressure systems and how do they interact?

- A high-pressure system can form a low-pressure system.
How do different pressure systems affect us?

• Sinking air in a high-pressure system generally produces clear skies and calm air or gentle breezes.

• Rising air in a low-pressure system generally produces clouds and rain.
Windy Weather

How do global wind patterns affect local weather?
• Winds are caused by changes in pressure, which is due to unequal heating.

• Wind speed and direction are affected by local winds. Globally, there is an overall movement of surface air from the poles toward the equator.

• Winds bring different air masses to a region, which affects the weather.
How do jet streams affect weather?

• Jet streams are long-distance winds that travel above global winds for thousands of kilometers.

• A jet stream affects temperatures and precipitation patterns.

• The polar jet stream travels further south in the winter and further north in the summer.
How do jet streams affect weather?

• Each hemisphere usually has two main jet streams.
Ocean Effects

How do ocean currents influence weather?

• Surface currents in the ocean are caused by wind.

• Energy is transferred to the atmosphere by the movement of warm and cold currents.

• Hurricanes and monsoons are affected by ocean currents.
How do ocean currents influence weather?

- As currents flow, they warm or cool the atmosphere above, affecting local temperatures.

- Coastal areas may have lower summer temperatures than inland areas because of cold-water currents.

- Coastal areas may have higher winter temperatures than inland areas because of warm-water currents.
How do ocean currents influence weather?

• Why is San Diego cooler than El Centro in the summer?
How do ocean currents influence weather?

• Why is Lillehammer colder than Bergen in the winter months?
Weather Maps & Weather Prediction
Cloudy with a Chance of ...

What is weather forecasting?

- **Weather forecasting** is the analysis of scientific data to predict future weather conditions.

- Checking the weather forecast helps determine what the weather is and how it might change.
What elements of weather are forecast?

• The study of weather and Earth’s atmosphere is called meteorology.

• Scientists who study meteorology are called meteorologists.

• They observe eight elements of weather: air temperature, humidity, wind direction, wind speed, clouds, precipitation, atmospheric pressure, and visibility.
The Hurricane Hunters

• The Hurricane Hunters of the National Oceanic and Atmospheric Administration (NOAA) fly into the eye of tropical storms and hurricanes.

• Their planes are equipped to collect data with special instruments such as radar and radiometers.
The Hurricane Hunters

• Hurricane Hunters also launch a small instrument package called a dropsonde to measure temperature, humidity, wind speed, and air pressure.
What’s Going on up There?

How are weather data collected?

• Meteorologists gather data using advanced technologies at ground stations and in balloons, aircraft, and satellites.

• Land-based ground stations, called *automated surface stations*, collect weather data from the lower atmosphere 24 hours a day.

• Many stations are located near airports and transmit computer-generated voice observations to aircraft regularly.
How are weather data collected?

• Weather radar is useful for finding the location, movement, and intensity of storms. Radar works by bouncing radio waves off precipitation.

• The stronger the returning signal, the heavier the precipitation is. The longer it takes for the signal to return, the farther away the precipitation is.

• Doppler radar is important for detecting and tracking severe storms and tornadoes.
How are weather data collected?

• Aircraft can carry a variety of weather-sensing instruments and collect data in places far from ground stations, such as over oceans.

• Weather balloons carry a small instrument package called a **radiosonde**.

• Radiosondes measure atmospheric pressure, air temperature, humidity, and wind speed and direction, up to about 32 km.
How are weather data collected?

• Orbiting weather satellites provide data on water vapor, cloud-top temperatures, and the movement of weather systems.

• Geostationary weather satellites monitor Earth from a fixed position thousands of kilometers above Earth.

• Polar-orbiting satellites circle Earth and provide global information from hundreds of kilometers above Earth’s surface.
What kinds of symbols and maps are used to analyze the weather?

- **Station model** is a set of meteorological symbols that represent the weather at a particular observing station.

- A station model is a small circle surrounded by a set of symbols and numbers that represent current weather data at a specific site.

- Placing many station models on a map makes it possible to see large weather patterns, such as fronts.
What kinds of symbols and maps are used to analyze the weather?

• How would this station model change if the sky became completely overcast and winds blew from the south at 10 knots?
What kinds of symbols and maps are used to analyze the weather?

• Meteorologists commonly use surface weather maps to show forecasts. The map displays air pressure and the locations of fronts.

• Air pressure is shown by using isobars, which are lines that connect points of equal air pressure, marked in units called millibars.

• Cold fronts are shown using blue lines and blue triangles. Warm fronts are shown using red lines and red half-circles.
What kinds of symbols and maps are used to analyze the weather?

• What can you conclude from this weather map about the weather happening in different parts of the United States?
What kinds of symbols and maps are used to analyze the weather?

• Another type of weather map used to analyze weather is the upper-air chart, based on data collected by weather balloons.

• Upper-air charts show wind and air pressure at middle and upper levels of Earth’s atmosphere.

• Information from these charts indicates if and where weather systems will form, and if they will move, remain stationary, or fall apart.
The National Weather Service has Issued a Severe Storm Warning...

What are some types of weather forecasts?

• Short-range weather forecasts make predictions 0 to 3 days into the future. Medium-range forecasts predict conditions 3 to 7 days into the future.

• Temperature, wind, cloud cover, and precipitation are predicted with different degrees of accuracy.

• Weather forecasting is an imperfect science. Many variables affect weather, all of which are changing constantly.
What are some types of weather forecasts?

• Long-range forecasts can range from weeks to months into the future.

• Using sea surface temperatures and high-level winds, forecasters can make general predictions about the future.

• They can predict if the weather will be warmer or colder or wetter or drier than average, but not the temperature or rainfall on a particular day.
What are some types of weather forecasts?

• Hazardous weather forecasts include weather advisories, weather watches, and weather warnings.

• A weather advisory is issued when the expected weather conditions will not be a serious hazard but may cause inconvenience.

• A weather watch is issued when severe weather conditions are possible over a large area. People should have a plan of action in case of a storm.
What are some types of weather forecasts?

• A weather warning is issued when weather conditions that pose a threat to life and property are happening or are about to happen.

• Those who live in the path of the storm need to take immediate action.
Think Clean and Green
Stewardship

OUR WORLD

...TO CARE FOR
Think Clean and Green

How can people reduce their impact on climate change?

• The Kyoto Protocol, adopted in 1997, is the only existing international treaty in which nations have agreed to reduce CO$_2$ emissions.

• Individuals can reduce greenhouse gas emissions by conserving energy, increasing energy efficiency, and reducing their use of fossil fuels.

• One can take steps such as driving less, using non polluting energy sources, turning off lights, and recycling products.
How can people reduce their impact on climate change?

• Deforestation contributes up to 20 percent of carbon emissions globally.

• Planting trees and supporting reforestation programs are ways to balance carbon sources with carbon sinks.

• Another solution is to educate people about the importance of the carbon that is stored in forests for stabilizing climate.
How can people reduce their impact on climate change?

• Clean-energy technologies are being researched and used in different parts of the world.

• New biofuels, solar power, wind power, and water power reduce the need to burn fossil fuels.

• However, many new technologies are currently more expensive than fossil fuels.
What factors make climate change a global issue?

• Greenhouse gases enter Earth’s atmosphere wherever they are produced.

• Consequently, the economic, political, and social factors related to climate change make it a global issue.

• However, the need to reduce greenhouse gas emissions is more often seen as a problem that affects people locally.
What factors make climate change a global issue?

• The cost of climate change includes the costs of crop failure, storm damage, and human disease.

• However, developing countries may not be able to afford technologies needed to reduce human impact on climate.
What factors make climate change a global issue?

• Political action can lead to regulations that reduce greenhouse gas emissions.

• However, these laws may be challenged by groups who disagree with the need for change or object to the proposed solutions.

• No matter what choices are made to handle the challenges of climate change, it will take groups of people working together to make a difference.