

S6E4. Students will understand how the distribution of land and oceans affects climate and weather.

- a. Demonstrate that land and water absorb and lose heat at different rates and explain the resulting effects on weather patterns.
- b. Relate unequal heating of land and water surfaces to form large global wind systems and weather events such as tornados and thunderstorms.
- c. Relate how moisture evaporating from the oceans affects the weather patterns and weather events such as hurricanes.

The earth's atmosphere is fairly invisible until clouds and storms develop. Weather is the state of the atmosphere at a particular time and place. It is composed of a combination of temperature, air pressure, wind and moisture and is caused by the uneven heating of the Earth's surface by the sun. These elements are organized into various weather systems, such as areas of high and low pressure, hurricanes, thunderstorms and tornadoes. All weather systems have defined cycles and structural features and are governed by the laws of heat and motion. These conditions are studied in meteorology which is the study of weather and weather forecasting.

Weather occurs in the lowest layer of the atmosphere called the troposphere. The energy rays of the sun reach the earth by passing through the atmosphere. Some of the energy is lost here from absorption, some reaches the earth's surface and some is reflected back by clouds and particles in the atmosphere. The energy that reaches the earth is absorbed by the land masses and water and is changed into heat. Since water absorbs heat slower and releases this heat more slowly than land does, a heat differential results: during the day, air over land becomes warmer than the air over water.

The air near the ground is heated by conduction which causes the air molecules to move faster and farther apart. This air becomes less dense. Cooler, denser air sinks, which causes the warmer, less dense air to rise producing convection currents. The temperature differences between the equator region and the poles of the earth produce giant convection currents.

All winds are caused by air pressure differences. Air is a fluid and will travel from an area of high pressure to lower pressure. Colder air has higher pressure and, as it moves into areas of lower pressure, wind is produced. Local winds are those produced over a small area by the difference in heating of the earth's surface. Global winds blow consistently from a specific direction over a large distance and are affected by the earth's rotation. This Coriolis effect causes winds in the Northern Hemisphere to turn toward the right; in the Southern Hemisphere winds curve toward the left.

When warm, humid air is forced upwards at a cold front, cumulonimbus clouds form and thunderstorms result. Tornadoes form in much the same way as thunderstorms. The Great Plains region of the United States has the type of weather pattern that favors development of tornadoes and has earned it the name "Tornado Alley."

Hurricanes form as low pressure disturbances over warm water. If it grows in size and strength by gaining energy from the warm water, it becomes a tropical storm which can continue growing into a hurricane. Hurricanes that form in the Atlantic Ocean are steered by the easterly trade winds toward the Caribbean islands and the southeastern coast of the United States.

a. Demonstrate that land and water absorb and lose heat at different rates and explain the resulting effects on weather patterns.

The Earth is covered by an unequal distribution of large masses of land and water which absorb heat at different rates. Oceans have a very large heat capacity as compared to land which means that the heat is lost at a much slower rate. So, during the daytime, air over land is warmer than the air over water. This can be seen at the beach: The warm, less dense air over the sand rises while the cooler, denser air over the water sinks which results in an on-shore breeze. At night, the effect is reversed as the land becomes cooler than the water.

Many differences in local geography affect the annual temperature pattern of a region. Differences in the land and water, distance from large bodies of water and/or mountains, and the ocean currents all have an effect. As an example, think about water mass formation in the high latitudes of the North Atlantic. There is a loss of heat to the atmosphere which lowers the temperature of the ocean's surface and causes the more dense cooler water to sink. Warmer water then moves in from lower latitudes to replace this. This raises the ocean surface temperatures and this water is moved eastward towards Europe. This partially explains the milder European winters as compared to American cities at the same latitude. (ex. New York vs Madrid)

b. Relate unequal heating of land and water surfaces to form large global wind systems (Part I) and weather events such as tornadoes and thunderstorms (Part II).

Part I

Water heats up much more slowly than land with the result that continents are warmer than the oceans, the air above the continents is warmer and the different temperatures lead to wind and weather. Wind is air in motion. If there are differences in air temperature, the warmer air expands, becomes lighter and rises while the cold air sinks. This movement produces winds which are also affected by the rotation of the earth: The Coriolis force causes moving masses of air to be deflected toward the right in the Northern Hemisphere and to the left in the Southern Hemisphere. These winds are what drive every weather system on earth. Temperatures along ocean coasts are moderated by these sea and land breezes while the interior of larger continents will get hotter than a smaller landmass.

Colder air has higher air pressure and will move into areas of lower air pressure also producing wind. Around the Earth there are several major bands where high or low pressure predominates with a general pattern of high pressure air movement to lower pressure areas. The greater the difference in air pressure between any two places at the same altitude, the stronger the wind will be. The boundaries where these high and low pressure areas meet are called fronts and these fronts are usually very active producing precipitation. Weather forecasters track the movement of high and low pressure areas because they affect the patterns of other weather variables such as temperature, cloudiness and wind.

Part II

Thunderstorms form within cumulonimbus clouds when warm air is forced upward at a cold front or on hot, humid summer afternoons. The warm, humid air rises quickly, cools and forms dense thunderheads that produce heavy rain and, sometimes, hail. The transition from a small cloud into a turbulent, electrified storm front can occur in as little as 30 minutes. The sharper, darker and lower the front edge of the cloud, the more severe the storm. The anvil-shaped top of the storm cloud points in the direction that the storm is moving.

When warm ground air rises and meets colder air, it condenses and forms water droplets. Condensation releases energy, which charges the atmosphere, and when the dissimilar charge between the negatively charged surface air and the positively charged highest parts of the cloud gets large enough, an explosion of lightning is created with up to 30,000,000 volts of electricity.

Tornadoes develop in the same type of cumulonimbus cloud. They occur under the same conditions as thunderstorms, in the spring and summer and usually late in the afternoon when the ground is warm. Tornadoes form when the warm, humid air mass meets a cold, dry air mass. The cold air moves under the warm air, which rises. Squall lines of thunderstorms form and can cause numerous tornadoes, although the exact reason for tornado formation is not understood.

c. Relate how moisture evaporating from the oceans affects the weather patterns and weather events such as hurricanes.

Hurricanes form as low pressure areas over large areas of warm tropical waters (about 80 degrees F) between June and November. Warm air can hold more moisture than colder air and a hurricane gains its energy from the warm humid air at the ocean's surface. The warm air rises and forms clouds as it cools. More air is then drawn into the system and the winds spiral inward toward the area of lower pressure. The lower the pressure, the faster the winds spin. When the wind velocity reaches 74 mph, the storm is called a hurricane in the Atlantic and Northeastern Pacific, or a typhoon in the Pacific. Hurricanes can travel long distances over water, gathering energy from the ocean but, since hurricanes are fueled by the water vapor that is drawn up from the surface of the ocean, they cannot travel far over land.

On an average, ten low pressure systems will develop over the Atlantic Ocean, Caribbean Sea, or Gulf of Mexico each year. About 6 of these will strengthen to become hurricanes while approximately 2 will become intense storms and cause extensive damage.