The Education Program at the
New Jersey Sea Grant Consortium
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UNDERSTANDING STORM SURGE

OVERVIEW

In this climate education module, students will gain an understanding of the term “storm surge” by exploring the meteorological principles that create storms and generate storm surges. Many basics of weather are discussed, including air pressure, air circulation, and the influence of the Coriolis effect on weather.

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OBJECTIVES

Following completion of this module, students will be able to:

- Define storm surge and the factors that influence it
- Learn how temperature affects air density and the formation of high and low pressure systems in the atmosphere
- Explore the effect of gravity on air in the atmosphere
- Discover the role of Earth's rotation on global and localized wind patterns
- Examine the effects that air pressure has on storm surge levels
- Determine how storm surge affects coastal communities
- Explore the impact of shoreline shape and beach slope on storm surge

GRADE LEVEL 5 – 12

NGSS PE'S MS- ESS2-2, MS-ESS 2-4, MS-ESS 2-5, MS-ESS 2-6, MS- ESS 3-2, HS- ESS2-5, HS-ESS3-5.

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BACKGROUND

Storm surge is the abnormal rise of water generated during a storm over and above the expected tides. The rise is caused when an atmospheric low pressure system combines with strong swirling winds in a hurricane or Nor'easter. The resulting surge causes flooding, often severe, along coastal areas. People frequently consider wind to be the most dangerous part of a storm; however, flooding and the fast flow of water that characterizes storm surge often result in more damage and can be far more devastating than any other part of a storm.

Since storm surge is directly related to air movement, we must first consider how air in the atmosphere moves to understand how water levels rise during a storm and lead to a storm surge. Air, like water, is a fluid medium, constantly rising and falling as it warms and cools. When air molecules cool, they lose heat energy and move closer together, becoming denser and heavier. This is the reason cold air sinks. In contrast, warm air molecules are energized and move away from each other. This makes the air less dense and causes it to rise.

As the sun warms the surface of the Earth, such as at the Equator, warm air rises and exerts less atmospheric weight and force onto the area to form *a low pressure system*. When an area of the Earth receives less of the sun's energy, such as near the Earth's poles, the surface cools and the air above it becomes more dense. The dense air falls toward the Earth, and exerts force down onto the area to form a *high pressure system*. Air pressure is a driver of weather. When high and low pressure systems interact, wind is created by the gradients (the differences in temperature and pressure). Areas of high air pressure always move toward areas of low air pressure because air pressure always strives toward equilibrium. Atmospheric pressure systems are dynamic, depending on how much the sun warms different areas of Earth's surface.

Low pressure systems can cause severe storms. The warmed air results in rapid water evaporation and rapid rising of water vapor. As water vapor reaches the cool upper atmosphere, it condenses to form clouds and precipitation. When this occurs, an empty space is created near Earth's surface. Higher pressure air that is denser moves down to take over that space. This movement of air from high pressure to low creates wind.

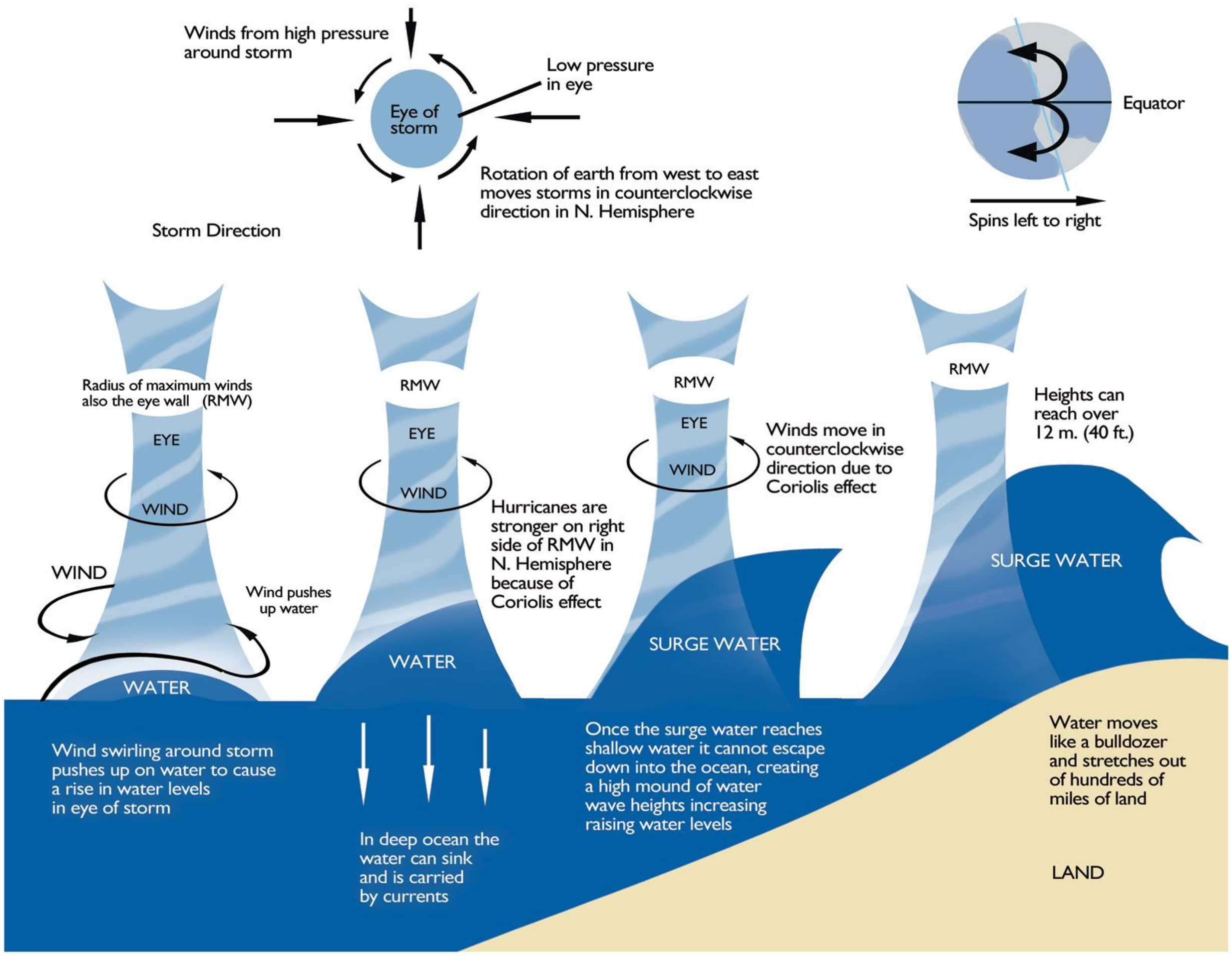
When low pressure is in place over the ocean, less weight (and thus, less force) is exerted downward, causing water levels to rise. A barometer is a meteorological tool used to measure how much atmospheric pressure is exerted down onto Earth's surface in a particular area. It reports measurements in millibars (mb). For every barometric pressure drop of 1 mb, sea levels will rise by 1 cm. Strong storms and hurricanes can have a barometric pressure drop of 30 mb, causing sea levels to rise 30 cm.

Warm ocean water is like fuel for a storm since it warms the air above it quickly. The higher the water temperature, the faster it will warm the air above it and cause the air to rise. This rising warm air creates a void close to the ocean surface that is quickly filled by cooler atmospheric air; as a result, winds grow stronger. As water vapor condenses and precipitates (generally in the form of rain) during a storm, it releases heat energy or *latent heat*. This latent heat warms the air even more, causing additional air to expand and rise. The result is air movement up and away from the center of the storm, which causes the storm to expand in size.

As wind blows over the ocean for extended periods of time, it transfers some of its energy into the water, which results in waves. Waves will increase in size and intensity the longer the winds blow (duration), the faster they blow (speed), and the length of the area they travel (fetch). During a storm all of these factors combine to make strong, large waves. As these waves move into shallow water and push up onto the land, they do so quickly and furiously. As a result, the waves cannot retreat back into the ocean fast enough, so they grow even larger in size and pile up along the shoreline. This pile-up is known as *wave setup*. Wave setup raises mean water level and can cause flooding on the land.

Air pressure changes and wind are not the only reasons for air to move horizontally and/or vertically in the atmosphere. Since Earth also rotates on its axis, there is also planetary air movement. This is known as the *Coriolis* effect. The Coriolis effect is defined as the deflection of air in the atmosphere due to the rotation of the Earth. In the Northern Hemisphere, the rotation deflects air currents to the right (northeast). In the Southern Hemisphere, the rotation deflects air currents to the left (southwest). During strong storms or hurricanes, very low pressure in the center of the storm causes the higher-pressure air that surrounds the storm to try to move in and fill the space created by rising warm air. Air is deflected to the right as the storm spins counter-clockwise north of the Equator (clockwise south of the Equator).

The stronger the storm, the more wind is circulated, creating a large spiral or circular vortex of air similar to a tornado twister. The strong winds spiraling in and around the storm push ocean water up into the middle or eye of the storm, which raises sea levels. When storm winds circulate over the deep ocean, the water level does not rise as much because water can escape down into the deep ocean and move away on currents. However, when the storm reaches land, energy dissipation downward is not possible. At this point water has nowhere to go but up; this is what causes storm surge flooding. Excess precipitation (rainfall) from storms, high tides and breaking waves onto the shore (also known as *wave runup*) can also have an effect on flooding during a storm but are not technically a part of storm surge.



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