

# THE RESTLESS SEA

Energy from the sun is the engine that drives the major ocean basin circulation patterns. Rising warm air, sinking cold air, and uneven heating of the Earth's surface create wind, the essential energy component necessary to move water in a horizontal manner. Other forces are involved such as the gravitational pull of the sun and moon. They have a particularly profound influence on coastal waters where tidal ranges are large. Whatever the force moving the waters, the ocean is in constant motion.

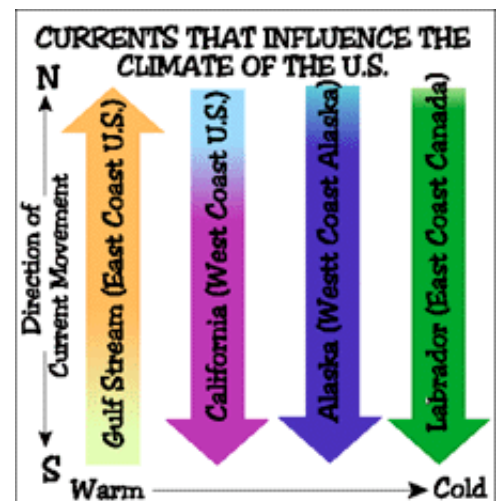


**CURRENTS:** Most currents are persistent global water motions that transport large volumes of surface and subsurface water over vast distances. They may be horizontal or vertical, depending on their forcing mechanism. Horizontal surface currents are propelled by the frictional force of wind dragging the water. The subsurface flow of deep ocean water, called thermohaline circulations, arise from differences in density in seawater. These sea-surface and deep-ocean currents continually keep the oceans in motion.

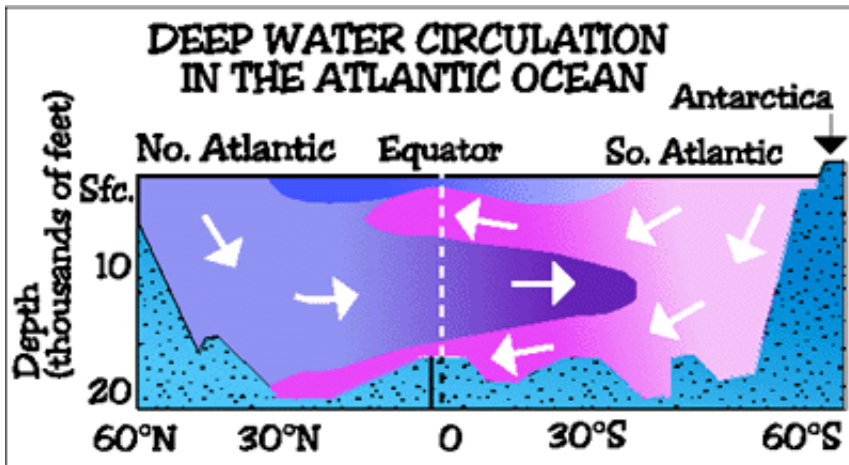
Some surface currents are transient and seasonal, a number of them flow with great persistence, setting up a circulation that continues with relatively little change throughout the year. Because of the influence of wind in creating currents in the surface-layer circulations of the ocean, there is a relationship between oceanic circulation and the general circulation of the atmosphere. A notable feature of the oceanic circulation is that it is clockwise in the northern hemisphere and counterclockwise in the southern hemisphere.

Currents perform a chore that benefits the entire planet. Oceans serve as vast heat reservoirs. They store heat in the summer and release it during the winter. Currents are the mass transit system that moves large amounts of heat, plus suspended solids and dissolved chemicals, between low and high latitudes, effectively moderating the world's climate. Major currents in the Northern Hemisphere include the Gulf Stream in the Atlantic and the Kuroshio Current in the Pacific. These currents, called western boundary currents, are important links in this heat transfer.

In deep ocean circulations, the differences in seawater density are controlled by variations in temperature and salinity. The deeper waters are driven by the formation of new, cold dense water masses in polar and sub-polar regions. The densest (coldest) seawater found in the Southern Hemisphere is formed on the continental shelf around Antarctica. Its water is so cold, and therefore heavier than the surrounding water, that it flows down the continental slopes of Antarctica, displacing less dense water, which is then caught up and carried around the southern oceans by the Antarctic Circumpolar Current.



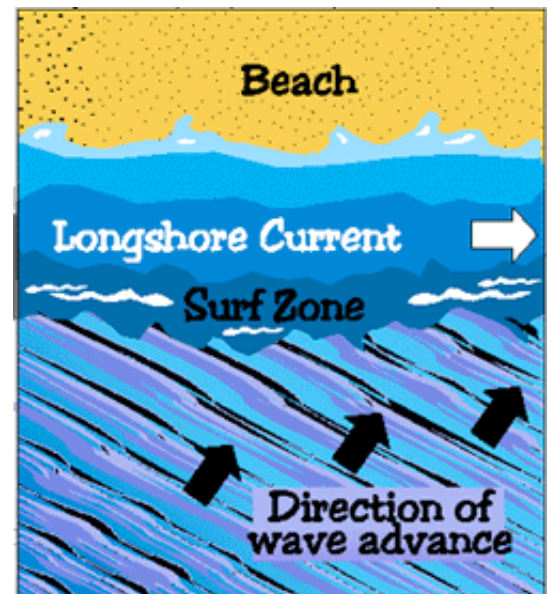
Movement of deep, slow-moving ocean waters can be detected through analyses of temperature and salinity samples drawn from depths that are more than 15,000 feet. These waters can be traced into deep basins of the Atlantic, Pacific, and Indian Oceans because of their unique physical characteristics. It has been estimated that the dense waters move at a daily rate of about 3 to 5 miles.



**LONGSHORE CURRENTS:**

Longshore currents can be found on most beaches, but their strength is seasonally variable (stronger in winter). They form when waves strike a beach at an angle. As the wave front enters shallow water, the

leading edge of the wave hits the shallow water sooner than the rest of the wave front and slows down, bending the wave as it moves ashore. The shoreward movement of the wave thus forms a current whose net flow is parallel to the shore in the surf zone. The speed of the longshore current increases with increasing wave height, decreasing wave period, increasing angle of wave front to beach, and increasing beach slope. Once established, the current moves at a speed of about one knot in the same direction as the advancing wave train. Longshore currents are more prevalent along lengthy straight coastlines. Sandbars often form in areas where longshore currents frequently occur.



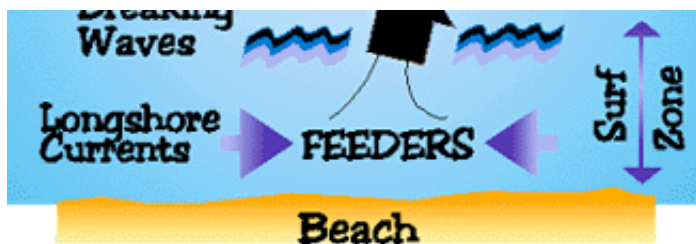
Longshore currents transport significant amounts of sand and sediment suspended by wave action in the surf zone along the shore. When the current enters deeper water, forward momentum diminishes and the sediment settles to the bottom. This can erode the beach in one area and build it in another. Unfortunately a considerable amount of sediment is dumped into shipping channels and harbors, which requires expensive dredging to remove.

**RIP CURRENTS:** Another consideration of longshore currents is the rip current, often called "rip tide". Rip currents are formed when longshore currents, moving parallel to the coastline, are deflected seaward by

bottom irregularities, or meet another current deflecting the flow to seaward. Development depends upon wave conditions. Large incoming waves on a long, straight beach will produce rips.

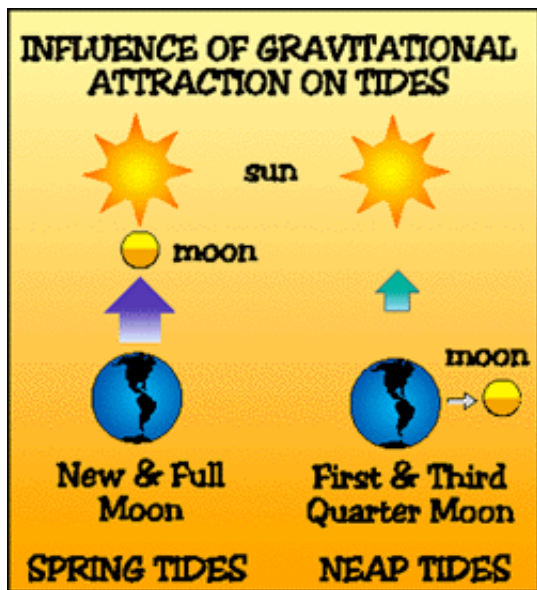
Rip currents consist of feeders, a neck, and a head. The feeder is usually the longshore current that flows parallel to the beach inside the breakers. The neck is the main channel of the rip current where feeder





currents converge and flow outwards at a speed of one to three knots through a weak point in the breakers. The head is where the current widens and slackens outside the breaker line. A number of swimmers are lost every summer when caught up in rips and swept out to sea. If trapped in this situation, swim parallel to the shoreline until out of the rip rather than swimming

directly into the current, then swim back to shore.



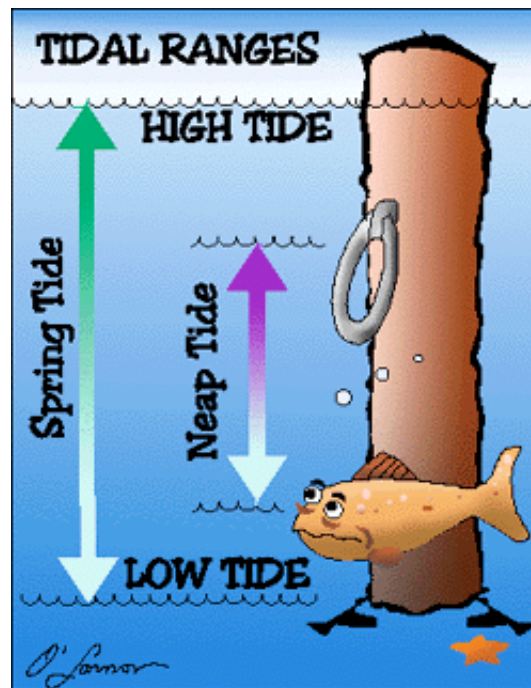
**TIDES:** Tides are the slow, periodic vertical rise and fall of the sea surface. They are usually described as being either diurnal or semi-diurnal. Diurnal tides have one high water and one low water in each lunar day (about 24.8 hours), while semi-diurnal tides have two high and two low waters in the same time period. While these tidal changes are easier to observe where land and water meet, they exist everywhere -- even in the middle of the ocean. Tidal ranges along the shoreline vary by location. For example, the tides in Canada's Bay of Fundy, an Atlantic Ocean inlet west of Nova Scotia, rise and fall as much as 50 feet, while the tidal range in Lake Superior is measured in inches.

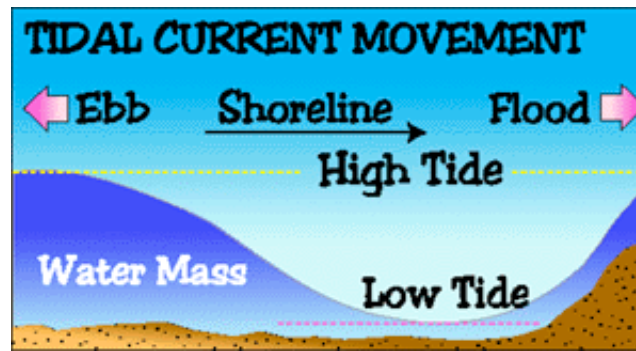
High and low tides are the result of the attractive forces (gravitational pull) of the moon and sun on a rotating Earth. The closeness of the moon to Earth (238,857 miles), and the distance to the

sun (92,955,770 miles), accounts for the moon having a tide-raising force nearly 2.5 times greater than the sun. The position of these celestial bodies results in significant variations in pulling forces causing above or below normal tidal ranges.

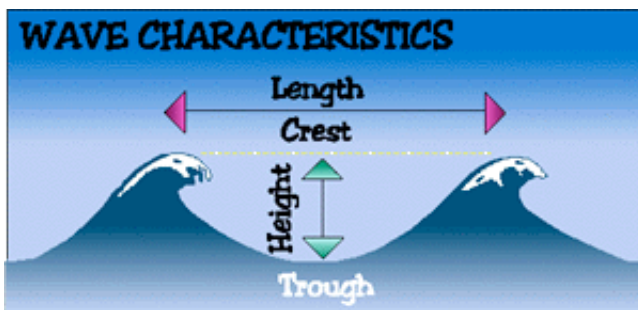
The range between a high and a low tide is greatest when the sun, moon and Earth are in alignment. These are spring tides. When the sun and moon are at right angles to the Earth, their gravitational forces significantly reduce each other. This causes the neap tide, a period of decreased tidal range. The term neap is an acronym for near even as possible.

**TIDAL CURRENTS:** The rise and fall of the tide is accompanied by the horizontal flow of water called a tidal current. The usual terms used to describe the direction of this horizontal movement are ebb and flood. Ebb currents occur when tidal currents are moving away from the coast. Flood currents move toward the coast. In a purely semi-diurnal current, the flood and ebb each last about 6 hours. Speed of tidal currents depends upon the shape and dimensions of the harbor, coastal areas and ocean bottom. The configuration also influences vertical range of the tide itself. Under certain conditions, tidal currents can move more than 10 knots.





**WAVES:** Waves are created principally by wind moving over water although earthquakes or landslides can initiate wave action. Friction between a water surface and moving air piles up water in ridges that become waves. Wave height depends upon wind strength, fetch (distance wind blows over water) and duration (length of time the wind blows). Small wavelets called ripples appear when a breeze of less than two knots blows across a smooth water surface. Whitecaps will form on an ocean or large lake when winds reach 12 to 13 knots. White foam from breaking waves begins to blow in streaks along the direction of the wind at about 30 knots.

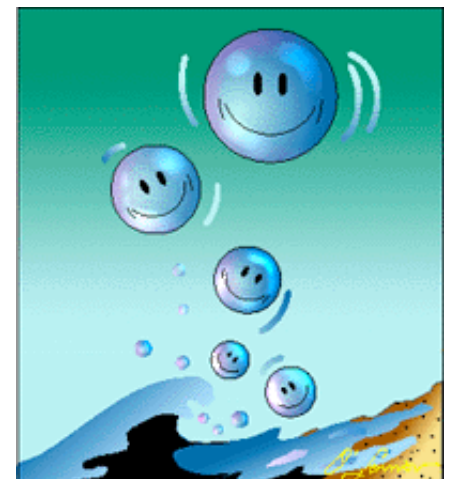


Wind wave characteristics can be depicted by a sine wave. (A sine wave is the simplest type of periodic motion that repeats at regular time intervals.) The crest and trough are the high and low points on the curve. Wave length is the horizontal distance between successive troughs or crests. Wave height is the vertical difference between a trough and a crest. A wave period is the time (in seconds) between passage of successive crests (or troughs) at a stationary point. Waves generated by the wind travel in a

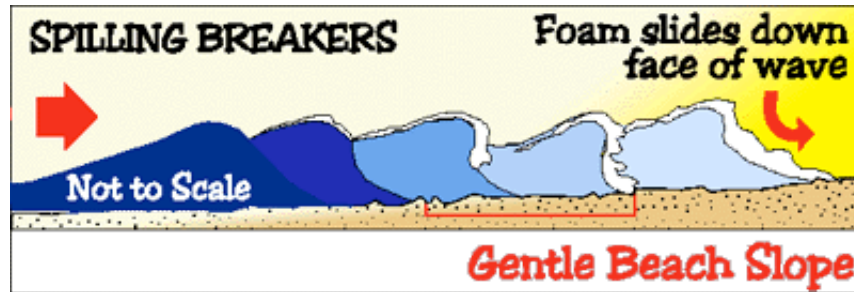
direction just to the right of the wind (Northern Hemisphere) and usually have a period of less than 12 seconds. Wave heights of 15 to 20 feet are not unusual, but there are limits to growth. During very intense winter storms, waves of 40 and 50 feet have been reported by ships. The ocean liner Queen Elizabeth II reported a wave measuring 100 feet in 1996.

**SWELLS:** Swells are long period waves that have traveled a considerable distance from their origin (usually a significant weather event). As the waves move away from the wind field that created them, waves with shorter periods die out and the remaining waves (swell) flatten out and exhibit regular and longer periods than wind waves.

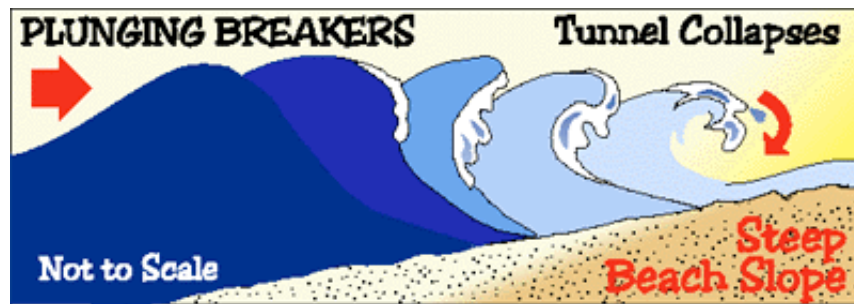
**BREAKERS (SURF):** When waves approach a beach and enter shallow water, there is significant change in wave form. The wave becomes higher with a shorter wave length and a slower speed. As the wave form changes, it becomes steeper with a narrower crest which allows the wave to become unstable. Waves normally break when the forward speed of the crest exceeds the speed of the wave itself. The collapse of the wave creates a frothy surf of foam and air-filled bubbles.



Any serious surfer will tell you that there are three types waves (spilling, plunging and surging). The type of breaker depends on the steepness of the beach and the steepness of the wave before it reaches shallow water. Spilling breakers occur on a gently sloping beach. They gradually break over a considerable distance from the shore. When a crest does break, the surf slides down the face of the wave.



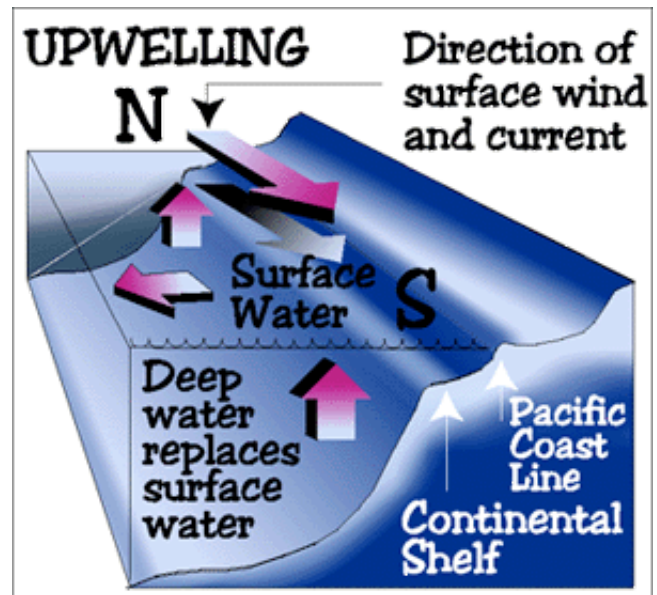
A plunging breaker occurs on moderately steep beaches. This type usually curls over forming the characteristic tunnel along the face of a wave until it breaks. Some of the best surfing conditions occur when long period swells (waves from distant storms move shoreward creating an unbroken train of nearly uniform breakers).



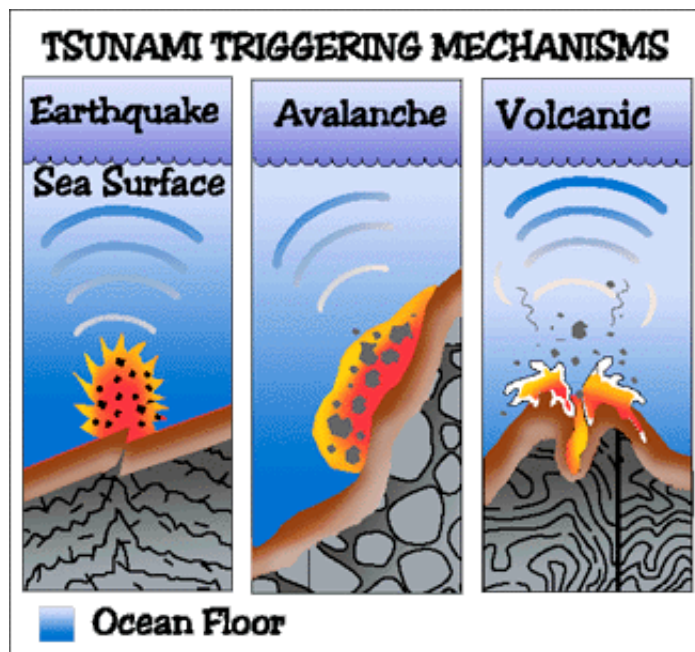
The third type is the surging breaker. It is different in that it doesn't break at all, but rolls up the beach without plunging. It happens on very steep beaches. These breakers can be dangerous and can cause significant structural damage and erosion. Major coastal storms bring stories of tremendous waves, and TV accounts of extensive flooding, beach erosion, and property damage. In even a moderate storm there will be as many as 450 long period waves crashing against the coast every hour. The actual force of wave action on a beach front has been accurately measured by spring dynamometers. This instrument records pressure exerted against a specific area. A seawall dynamometer at Dunbar, Scotland registered a force of 3.5 tons per square foot from 20 foot waves.

While large waves can cause damage, a heavy surf may also contribute to your next rainy day. All raindrops require a nucleus, whether it be a microscopic piece of Nebraska farmland or an infinitesimal particle of Atlantic Ocean salt. When breaking waves finally impact the beach, nothing usually remains but a frothy wash of seawater and foam. Tiny bubbles in the surf, usually less than a half millimeter in diameter, burst as they ascend and release salt spray into the atmosphere. These exploding bubbles propel minute particles of salt to heights estimated up to 1,000 times the diameter of the bubble. As the microscopic particles drift upwards, they gradually begin to attract atmospheric moisture. When they are sufficiently burdened, and depending upon the season, they may return to earth as the nucleus of a raindrop or snowflake.

**UPWELLING:** Cool summers and coastal fog may be attributed to upwelling of adjacent ocean waters. Upwelling is the vertical movement of colder deep water to the surface. In the Northern Hemisphere, it occurs when persistent surface winds blow parallel to a coastal boundary causing surface waters to be transported seaward. The displaced surface water that moves away from the coast is replaced by colder water rising from the depths.



**TSUNAMI WAVES:** The word "tsunami" is Japanese meaning "storm-wave". It is the term used internationally to describe a series of ocean waves created by sudden, large scale submarine disturbances such as a major earthquake, landslide, or underwater volcanic eruption. The size of the wave depends on the nature and intensity of the underwater disturbance. The height and destructiveness of a wave arriving at any place depend on the distance from the epicenter, the topography of the ocean floor and the coastline. The most active generating areas are in the ocean trenches rimming the Pacific Ocean where waves up to 100 feet have been reported.



Tsunamis are described by the same physical characteristics as wind-generated waves (length, period and height) but with dimensions that are vastly different. When a significant underwater event occurs, energy is transmitted upwards in the shape of a dome or mound. This force creates a series of waves as the water settles. In deep ocean, the wave height of a tsunami is normally only a few feet. Since the wave length is usually considerably more than 100 miles, the wave is not really noticeable at sea. Their wave periods in deep water vary between 15 to 60 minutes with a speed of more than 400 knots. When the tsunami enters shallow water, it undergoes changes similar to, but more dramatic than, those experienced by regular waves. Because of its great speed in deep ocean, the forward speed diminishes and the height increases at a much greater rate than in an ordinary wave. It is possible to predict the arrival of a tsunami wave at a

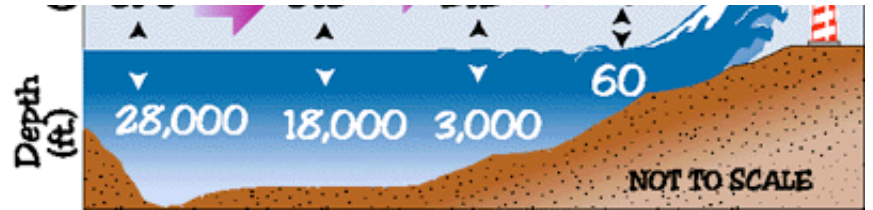
distant beach, because the speed of the advancing wave in shallow water (water depth less than half the tsunami's wave length) is determined by the water depth.

A submarine earthquake on April 1, 1946, with an epicenter in the Aleutian Islands, destroyed the nearby Scotch Cap lighthouse on Unimak Island. The U.S. Coast Guard



facility was located 57 feet above sea level. The tsunami wave encompassed the entire Pacific Ocean Basin. Traveling at an average speed of 425 knots, the wave reached the Hawaiian Islands in 4 hours and 34 minutes, with the tsunami cresting

50 feet above the normal water level. A section of coast more than 1,000 feet wide was flooded. Some of the waves reached North and South America, and Australia - 6,700 miles from the epicenter.



The death toll in Hawaii was 173 with \$25 million in property damage (1946 dollars). The incident was the thirty-sixth tsunami to strike the Hawaiian Islands since 1819 but none were quite as damaging. It ranks as one of the worst natural disasters in the state's history. Shortly after the tsunami of 1946, the Pacific rim nations established an international tsunami warning system.

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