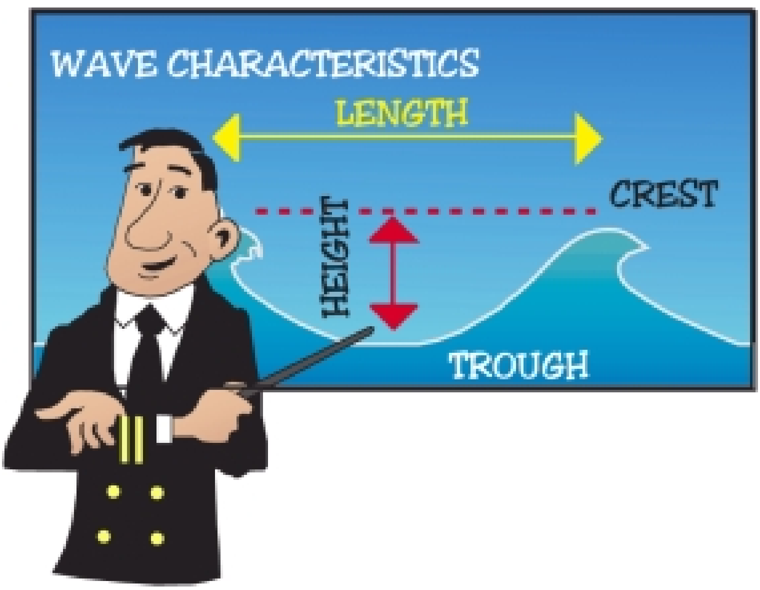
ocean talk

from the Naval Meteorology and Oceanography Command

ocean talk



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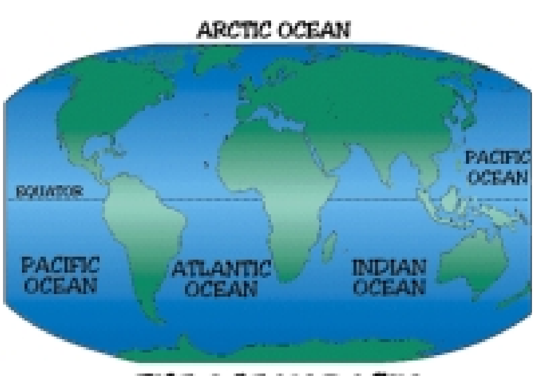
INTRODUCTION

On October 13, 1775, Congress established the U. S. Navy. With that measure the Navy, along with its responsibility to protect our shores and international trade routes, discovered the need to understand the watery precinct it was charged to patrol. Then, there was little oceanographic expertise available to assist the new Navy.

In today's Navy it is the responsibility of the highly trained men and women of the Naval Meteorology and Oceanography Command to obtain and provide global oceanographic information to support the fleet. With the oceans of the world covering 70.8 % of the Earth's surface, the task is immense.

The purpose of this booklet is to provide the reader a glimpse of a few aspects of oceanography, and bring an awareness of the importance of the sea to our environment and our own well-being.



THE OCEAN BASIN

LURE OF THE SEA

From the earliest times, people of the world have used the oceans as a source of food, a path for travel and a highway for trading. The scientific study of the oceans is oceanography. It involves many fields such as biology, geology, chemistry, and meteorology.

ANCIENT MARINERS: It is not possible to state when and where men first put to sea. Accounts of ocean voyages go deep into antiquity. The Egyptians had regular trade with Crete as far back as 2500 BC. The Phoenicians sailed much of the Mediterranean and beyond into the Atlantic. The Greeks and Romans put to sea. All shared a major problem, one that would plague seaman for thousands of years — that of accurate navigation. The first navigators kept land in sight as they traveled and became skilled in recognizing and recording significant land marks. Later they used the position of the Sun and stars. Meteorological phenomena were also used, specifically the winds. Mediterranean sailors noted that steady cold winds came from certain directions, and warm winds from others. About the 6th century BC, the Etruscans developed the eight point wind rose with north at the top, south at the bottom and three uniformly spaced divisions on each side.

During the Middle Ages, accounts of voyages beyond the horizon abounded. The Irish, Welsh, the Scandinavians and others, found lands to the West of Europe.

THE AGE OF EXPLORATION: At the beginning of the 15th century, Portugal was unquestionably the prime Atlantic seapower. Her sturdy caravels sailed up and down the African coast and to the Cape Verde Islands, Madeira, later to the Indies. A visionary member of the royal family, Prince Henry, known as The Navigator, established a center for exploration and hydrography at Sagres in 1420. It was the first institution of its type. Adopting the astrolabe for marine use, the Portuguese were able to calculate the position of the sun and major stars, becoming highly skilled at establishing latitude. Longitude was quite another matter.

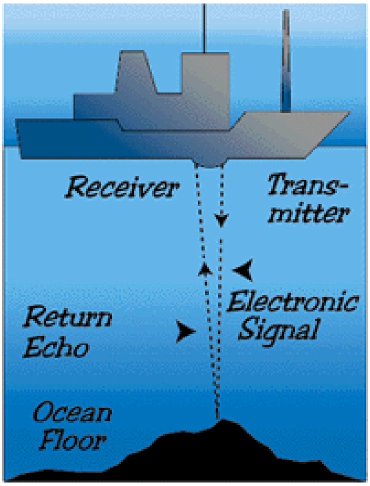
ACCURATE NAVIGATION AT LAST: It had been known for some time that longitude was related to time. The Earth revolves through 360 degrees in 24 hours. Thus each degree of longitude represents 15 minutes. The difference between local time and that of a fixed position elsewhere provides the longitude — provided the clocks are precise. As late as the 18th century, there were no clocks that could maintain accuracy in ever-changing marine environment. Pressure, temperature, corrosion all affected the delicate clock works. John Harrison, after nearly a lifetime's work, developed such an instrument. His chronometer made accurate navigation possible and opened the door to serious scientific study of the oceans. Expeditions such as that of H.M.S. Endeavour and H.M.S. Beagle and the United States Exploring Expedition under Lieutenant Charles Wilkes in the late 18th and early 19th centuries measured and charted the oceans of the world.

H.M.S. CHALLENGER: The first truly scientific survey started in December 1872 when Challenger began her three and a half year voyage. The results of this cruise serve as a benchmark to this day. A vast number of seawater and bottom sediment samples were taken. Ocean currents were measured and recorded, and depths plumbed for data on organic life. Bottom samples, some to depths of 26,000 feet, mapped the seafloor according to sediment types. (one foot is equal to 0.3048 meters.) The Challenger's scientific observations filled fifty volumes. Later oceanographic explorations supplemented the findings but did not alter them.

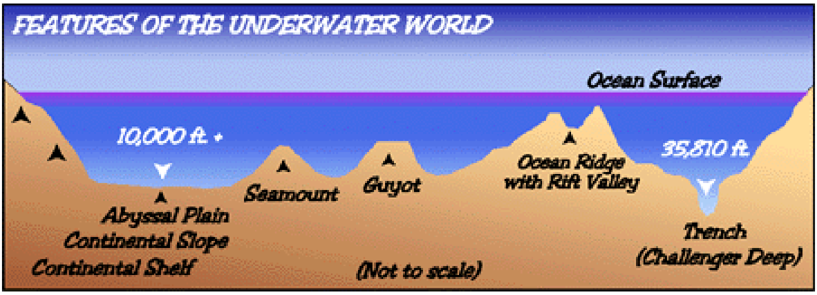
MODERN SHIPS AND EQUIPMENT: Today's oceanographic ships are fast, and capable of obtaining volumes of ocean data. They use satellite communications and navigation systems, towed instruments, expendable probes, electronic and acoustical devices.

THE UNDERWATER WORLD

Most ocean bottom features are large in comparison to those found on land. The introduction of the echo sounder early this century provided the ability to compare these features. The echo sounder calculates water depth by measuring time between emission of a sound signal directed toward the ocean floor and the return echo. From echo-sounder data and bottom samples, marine geologists and hydrographers have gathered sufficient information to produce charts of the ocean bottom features.

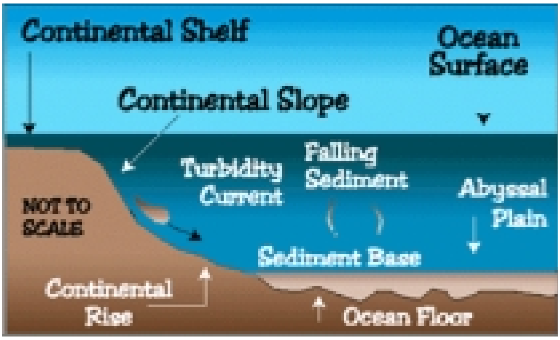


Terms used to describe features of the underwater world are very similar to terms used to identify features on land. Oceanic ridges are similar to mountain ranges, and oceanic trenches are the Grand Canyons of the seabed. The abyssal plain (the term abyssal refers to the large, deep parts of the ocean) is the feature that constitutes the largest portion of the ocean floor. It has been compared to the great flat prairie lands of mid America.



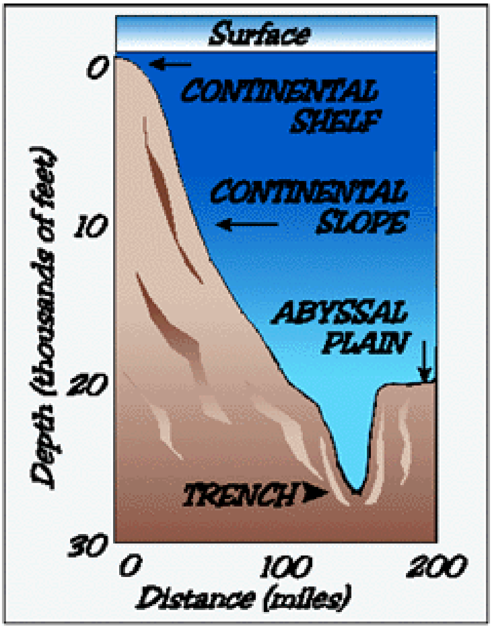
ABYSSAL PLAINS: Abyssal plains are found next to the continental slopes at depths greater than 9-10,00 feet.

They are areas of near freezing water temperatures where there is no season or sunlight. The Abyssal plain is regarded as the true ocean floor. The few marine inhabitants found in the region survive only because they have adapted to the hostile environment of bitter cold and immense pressure. Abyssal plains are among the smoothest surfaces on the planet, with less than five feet of vertical variation for every mile. These level plains are the result of a constant rain of sediments. These sediments, ranging from the remains of marine life to fine, clay-sized particles, drift slowly downward filling in depressions on the irregular rocky ocean floor. Often, coastal sediments are washed down the continental slope as turbidity currents. (A turbidity current is a downward flow of suspended mud-like sediments. The descent is caused by gravity.) Sediments from large rivers reach the ocean floor primarily by way of submarine canyons.

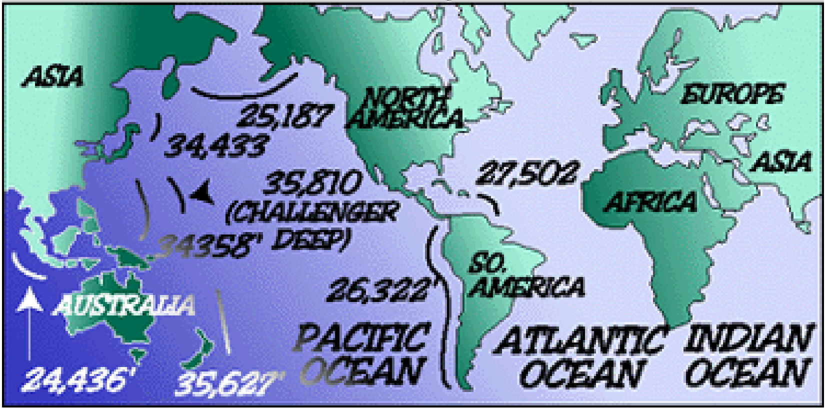


MID-OCEAN RIDGES: Several mid-ocean ridges are longer than the longest mountain ranges on Earth. They are tall, as well, rising to 12,000 feet above the ocean floor, and their peaks penetrate the ocean's surface to form islands, such as Iceland and the Azores in the Atlantic Ocean and the Galapagos Islands in the Pacific Ocean. Most of the ridges crest at a depth of about 8,000 feet and their width varies from 500 to 1,500 miles. Unlike typical continental mountain ranges that have a singular pronounced line of peaks, oceanic ridges have two, separated by a prominent depression known as a *rift valley*. The valley ranges from 15 to 30 miles in width and cradles an active seismic belt.

TRENCHES: Trenches are found adjacent and parallel to continents and island chains. At least 22 trenches have been identified although not all are classified as major. Of this number, 18 are in the Pacific Ocean, three in the Atlantic Ocean, and one (the Java Trench) in the Indian Ocean. Depths of major trenches exceed 18,00 feet, and vary from 10 to 22 miles in width. The deepest is the Challenger Deep, 35,810 feet deep, in the Marianas Trench. The depths of many trenches are greater than the elevation of the world's highest mountain. Mount Everest (29,028 feet) would be less imposing if dropped into the Challenger Deep. Trenches are not uniform in depth or width. The Peru-Chile Trench off the west coast of South America is nearly 1,100 miles long.

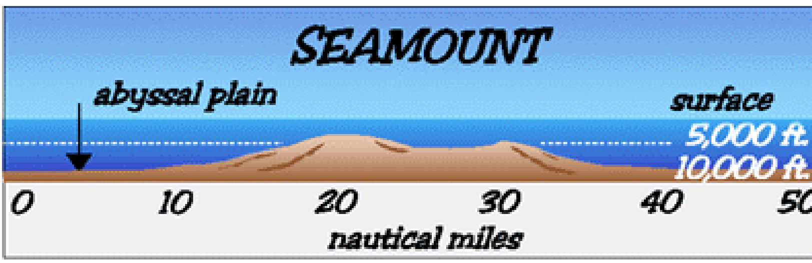


MAJOR OCEAN TRENCHES (Depth in feet)



The Japan Trench is 150 miles long and is the shortest. The Tonga Trench, located between New Zealand and Samoa, is the narrowest and straightest. The Kurile Trench between Japan and Kamchatka is the widest.

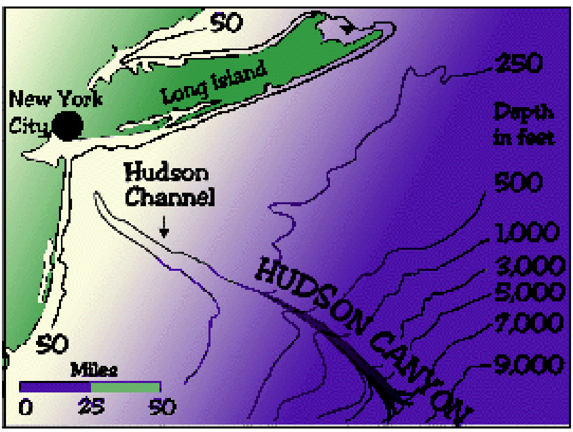
SEAMOUNTS: Seamounts are isolated mountains rising from 3,000 to 10,000 feet above the surrounding seabed. Shaped like a cone, they have a characteristic depression similar to a crater at the summit. Samplings gathered from over 50 seamounts found evidence that indicates they are of volcanic origin. Seamounts are found in all oceans, but are more numerous in the Pacific Ocean, with over 2,000 identified. They are especially abundant in the Gulf of Alaska.



The Cobb Seamount, discovered in 1950, is in a chain of seamounts that extend into the Gulf of Alaska. Located just 270 miles off the coast of Washington, it is one of the most thoroughly explored of all seamounts. Cobb rises from a depth of nearly 9,000 feet to within 124 feet of the surface. Because of relatively shallow depth and good lighting conditions, divers have explored and mapped most of the 23 acre flat top. The closest land feature similar to the seamount is a volcano that rises upwards from surrounding flatlands.

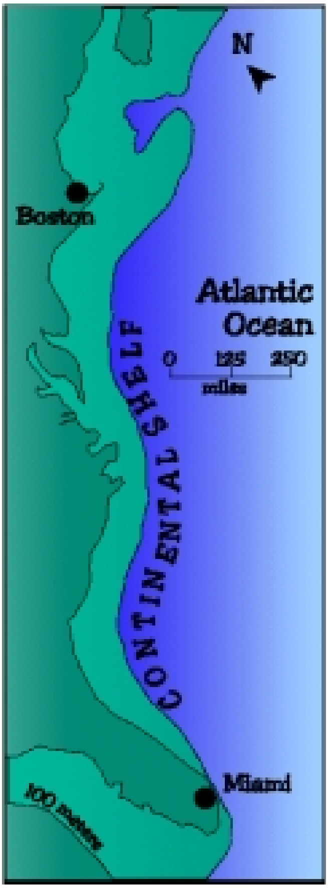
CONTINENTAL SLOPES AND CANYONS: The continental slope gradually rises from the abyssal plains but climbs as much as 45 degrees as it approaches land. In some areas the slope is interrupted by broad wedges of sediment deposits called a *continental rise*. Slopes are often gouged by deep valleys or submarine canyons, many with the same proportions as the

Grand Canyon. While most canyons were originally formed during the last Ice Age, some are the result of earthquakes. Canyons found off the East and West coasts of the United States are similar in one respect, they both have the classic "V" profile with steep walls and rock outcropping. East Coast canyons of the United States begin at the very edge of the landward side of the continental slope and extend to seaward in an almost straight line. The Hudson Canyon off Long Island, New York, is the best known and studied canyon on the East Coast. It was first identified in 1864. The canyon begins as a shallow valley crossing the continental shelf. The axis of the canyon then trails down the continental slope for a distance of about 50 miles. The greatest wall height is about 4,000 feet at a depth of 6,000 feet.



West Coast submarine canyons are noticeably different from those on the East Coast. They are extremely rugged, twisted and begin less than 1,000 feet offshore. This is due to the exceedingly narrow continental shelf. Monterey Canyon is the deepest, largest and most thoroughly studied canyon on the West Coast. It starts near Moss Landing, California at a depth of 50 feet. The canyon, with walls up to 6,000 feet, extends seaward for more than 60 miles. It terminates at a depth of about 10,000 feet.

CONTINENTAL SHELF: The continental shelf, the region from the coastline to the edge of the continental slope, covers about eight percent of the global seafloor area. The continental shelf is a national asset for most nations. It is a source of fish, both commercial and sport, and in some areas, oil and natural gas. Shelves are not of uniform width. They vary considerably in size off the coasts of the United States. They are almost negligible along Southern California and Florida's southeast coast. Off Florida's west coast however, the shelf extends 200 miles into the Gulf of Mexico. The average width worldwide is about 40 miles.



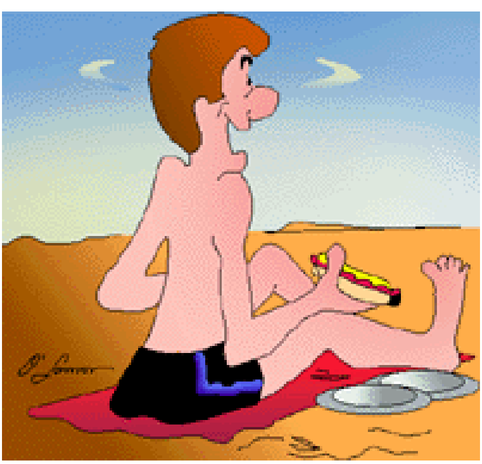
Shelves look like the adjacent land. Coastal areas that are mountainous will have a continental shelf with similar features, which is the case off Southern California. Coastal areas dominated by low hills or plains are likely to have a shelf of nearly flat plains or low hills. This is observed along most of the U.S. Atlantic and Gulf Coasts. Shelves off the mouths of larger rivers such as the Mississippi, are usually broad with a large mud base of continental sediments.

Continental shelves along the coasts of the United States cover an area of about 891,000 square miles. Alaska's continental shelf alone occupies over 1.54 million square kilometers. The Atlantic Coast continental shelf covers 591,000 square miles, about equal to the land mass areas of New York, New Jersey, Ohio, and Pennsylvania. The shelf covers 135,000 square miles in the Gulf of Mexico, nearly the same area as Nebraska and Iowa combined. It covers 25,000 square miles off the coasts of California, Oregon and Washington.

BEACHES: A beach is an expanse of sand or pebbles along a seashore, that is washed by the tide and waves. They are divided into three zones: Offshore, foreshore and back shore. Summer time residents of each zone usually include surfers, waders, and sun bathers.

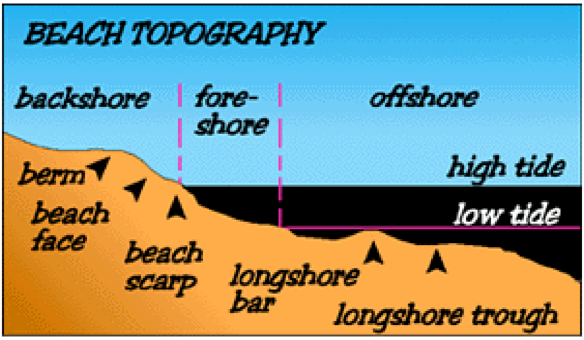
It is in the offshore zone that incoming waves feel bottom and curl over as breakers or surf. The foreshore zone is regularly exposed to high and low tides. On the landward edge of the foreshore is the beach scarp, usually a rise of a few meters caused by the eroding action of stronger waves. The backshore zone extends from the water line to the inland area where the sea does not influence vegetation. The principal feature of the backshore is the berm that marks the ordinary limit of a high tide. Action of the sea creates the berm. Usually there is one, but depending on beach topography there may be two. The width is dependent on surf conditions.

Erosion often reduces beach width in winter when wind and wave action are more powerful and frequent. In summer, gentle wave action transports sediments that replenish the beach with sand and create a wider berm. Most beach sand consists of light-colored quartz and feldspar sand grains, the result of weathering and erosion of rocks such as granite.



Some beach sand comes directly from shoreline erosion, but much is created by the action of rivers flowing to the sea. Most beach sand contains fragments of smoothed and rounded clam shells, and the shells of other marine creatures.

Tropical beaches often consist entirely of shell and coral fragments. Beaches in areas of volcanic activity can be black, its sand created by erosion of volcanic rock.

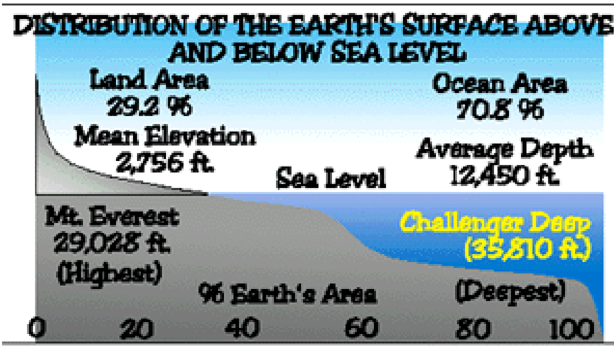


There are several types of beaches found along the coasts of the United States. Common to Northern California and Oregon is the narrow stretch of sand bounded by rolling surf and a rocky cliff mainland. These beaches are located where waves break upon a coast of hard bedrock with little available sediment. The swash (wave uprush) and return backwash carry pebble size fragments ashore, while finer sand is washed to sea. Numerous beaches on the Atlantic Coast are of the *spit type*, such as New York's Coney Island where a narrow shoal extends seaward. This type of beach is created by wave action over a lengthy period.

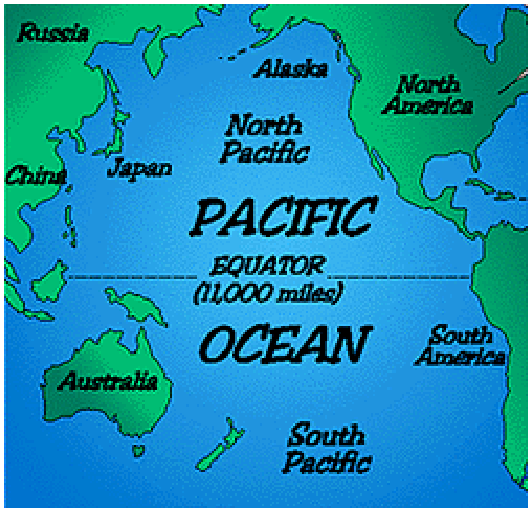
Beaches are a major attraction for coastal living. About two-thirds of the world's population lives within a narrow coastal belt that extends landward from the ocean's edge. In the United States, many large cities are located near or on an ocean shoreline or alongside one of the Great Lakes.

OCEANS OF THE WORLD

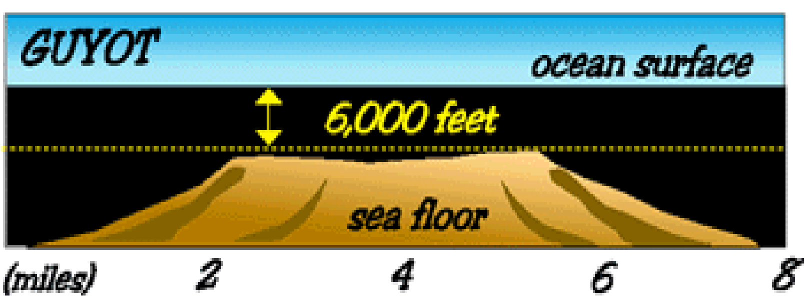
The oceans cover 70.8 percent of planet Earth. Distinct boundaries of oceans occur only where they border on continents, such as the Arctic Ocean. Ocean boundaries in the Southern Hemisphere were arbitrarily established. In that region the Atlantic is separated from the Pacific by a man-drawn line from Cape Horn across Drake Passage to Antarctica. Similarly the Pacific is separated from the Indian Ocean by a string of islands extending from the Straits of Malacca to Australia, and southward from Tasmania to Antarctica. The four oceans contain various seas and gulfs, although common usage has made the terms "seas" and "ocean" interchangeable. Technically, a "sea" is a subdivision of an ocean. The International Hydrographic Bureau, in the Principality of Monaco, the agency responsible for world standardization and cooperation in the measurement and description of the physical features of the ocean, identifies fifty-four different seas.



PACIFIC OCEAN: By far the largest of the four oceans, the Pacific covers nearly one-third of the globe, an area approximately 64 million square miles. The land area of the United States, Alaska and Hawaii covers less than 4 million square miles. The Pacific Ocean is immense. All the continents could be placed into it, and there would still be room left over. Even with the many topographic features found on the sea floor, such as plateaus, ridges, trenches, and seamounts, it has an average depth of 13,000 feet. The Pacific is approximately 11,000 miles wide at the equator.



Not only is it the largest and deepest, it is probably the most violent of all oceans. The Pacific Ocean has typhoons in the equatorial regions, nearly 300 active volcanoes which vent steam and smoke on her borders, and tidal waves are periodically unleashed.



Unlike the basin floors of the Atlantic and Indian Oceans, the Pacific is characterized by the Central Pacific Trough.

This feature extends from the Aleutian Islands southward to Antarctica and from Japan to the west coast of North America. The basin floors are not completely flat and ridges and seamounts abound. Along with a number of deep ocean trenches, the Pacific has many flat-topped seamounts: Guyots. These are rarely found in other oceans.

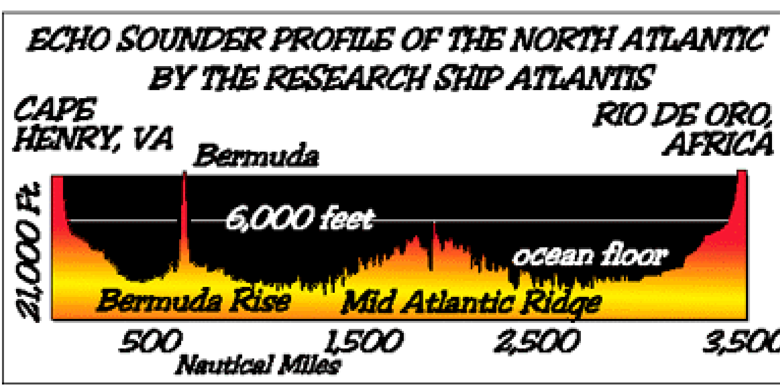
ATLANTIC OCEAN: The hourglass shaped Atlantic covers approximately 20 percent of the Earth's surface and is the second largest of the four oceans. It extends from the North Pole southward for 18,500 kilometers to the Antarctic continent, and covers 106 million square kilometers. Width of the Atlantic varies from 3,273 kilometers between Brazil and Liberia and approximately 5,500 kilometers between Norfolk, VA, and Gibraltar.

THE NORTH ATLANTIC OCEAN BASIN

More is known of the Atlantic than any other ocean because of heavy commercial and military ship traffic connecting Europe and North America. Average depth is 3,650 meters and the greatest depth is 8,654 meters in the Puerto Rico Trench. If Alaska's Mount McKinley (6,198 meters) was to rise from the floor of the Puerto Rico trench, its peak would still be about 2,456 meters below the surface of the Atlantic.

The Mid-Atlantic Ridge divides the sea floor nearly through the center and stretches from the polar regions of the North to Antarctica in the South. The Mid Atlantic Ridge was created by the splitting apart of the super continent of Pangaea 190 million years ago. The ridge lies about 3,000 meters below water level except in a few areas where it surfaces as islands. This mountain range is as much as 800 kilometers wide. Rugged valleys extend outward from the ridge line to the abyssal plains.

The Mid Atlantic Ridge is a continuous feature of the basin floor with one exception. There is a significant break in the ridge near the equator at the Romanche furrow where the crest of the ridge dips 4,500 meters below the surface. This break in the mountain chain allows deep water to flow freely between the Atlantic's east and west sides. The unrestricted movement provides a thorough circulation of the ocean basin that has a pronounced effect on deep water currents, density and temperature.

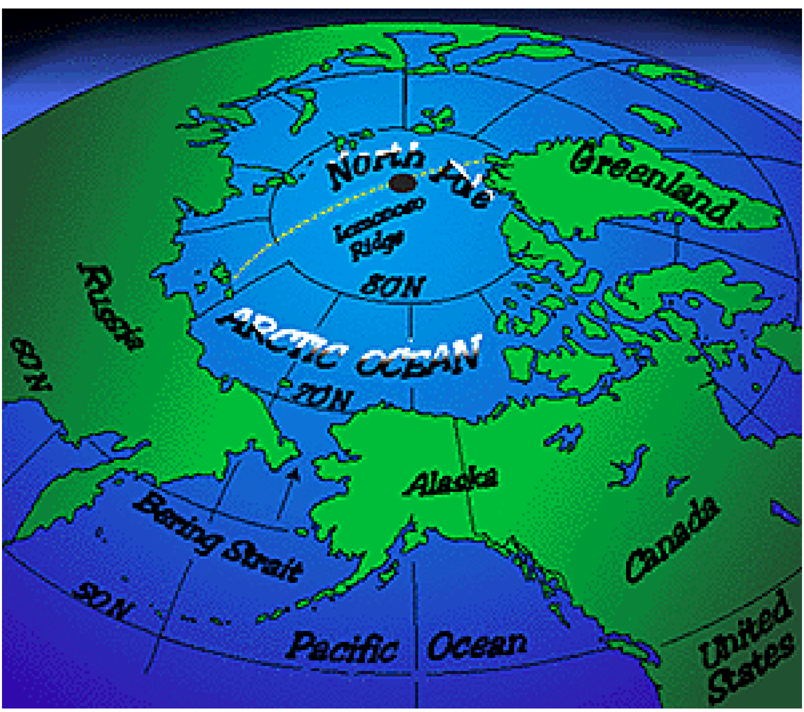


INDIAN OCEAN: The Indian Ocean is often thought of incorrectly as a tropical ocean. Check your map! It stretches southward to Antarctica. It is triangular and bordered by Africa, Asia, Antarctica, and, Australia. Although it covers about 28.5 million square miles, it is smaller than the Atlantic and less than half the size of the Pacific Ocean. The maximum width is 6,200 miles between the southernmost portions of Africa and Australia. The Indian Ocean contains about 20 percent of the earth's water surface. Many island nations are found within the boundaries of this ocean - Madagascar, which is the world's fourth largest island, the Seychelles, Maldives, Mauritius, and Sri Lanka.

The average depth of the Indian Ocean is about 12,750 feet. The deepest is 24,440 feetin the Java Trench in the extreme northeast corner of the basin. The Indian Ocean, like the Atlantic Ocean is divided by a mid-ocean ridge that separates the basin into nearly equal portions. The ocean's continental shelves are narrow, averaging 125 miles in width except off Australia's western coast where it broadens to 600 miles.

ARCTIC OCEAN: Centered approximately on the North Pole, it is the smallest of the world's oceans, covering about 4,732,000 square miles. Maximum depth is 18,050 feet. The ocean is divided into two nearly equal basins: The Eurasia and the Amerasia. The Lomonosov Ridge extends from northeastern Greenland to Central Siberia and separates the basins. The Arctic Ocean is surrounded by landmasses of Eurasia, North America, and Greenland, and is unlike the other three oceans because of the perennial ice cover. The extent of sea ice is seasonal between 60°N and 75°N latitude, but above 75°N it is relatively permanent. Ice cover reduces energy exchange with the atmosphere resulting in reduced precipitation and cold temperatures.

A unique feature of the ice fields of the Arctic Ocean was the discovery in 1946 of large sized ice islands. One of the first major ice islands covered an area of more than 300 square miles. In later years ice islands were extensively tracked to determine current movement. They were also used as scientific research sites for the study of polar meteorology and oceanography.



SEAWATER, SOUND & ICE

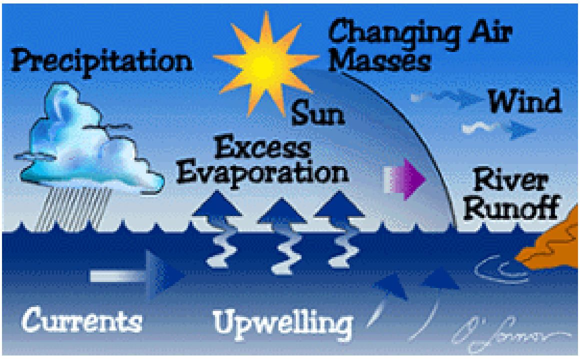
The amount of water occupying the ocean basins of the world is best illustrated when compared with the global supply of fresh water. Of the 3 percent of the earth's water that is fresh, two-thirds is frozen solid in icecaps and glaciers. The remaining 1 percent of the world's water is found in clouds, precipitation (rain and snow), rivers, lakes and ground water.

Seawater is a complex solution with trace amounts of nearly 60 chemical elements including gold. Common salt is the most abundant ingredient, making up approximately 78 percent of the total dissolved solids in seawater.

SEAWATER SALINITY: The first thing that comes to mind about seawater is that it is salty. Salt content, or salinity is the total amount of dissolved solids contained in one kilogram of seawater. In that there are one thousand grams in a kilogram, salinity is numerically expressed in parts per thousand (ppt), or symbolically as °/oo. Salinity in the oceans varies from about 32°/oo to 37°/oo except in the polar regions and near shore where it may be less than 30°/oo.

The average salinity of the world's oceans is 35°/oo, which is the same as 35 grams of salt in each kilogram of water. (One kilogram is equal to 2.205 pounds or 35.27 ounces.)

Sodium chloride, common table salt, is the most abundant of the many salts found in seawater. Other salts come from the leaching process of the Earth's crust. Fresh river water runoff entering coastal waters will dilute salt water making it less saline. Weather also has an influence on salinity. In the North Pacific rainfall is greater than evaporation, resulting in lower salinity than in parts of the Indian Ocean, where evaporation exceeds precipitation. An isolated salt water body is frequently more saline than an open sea. The Mediterranean is an example where waters are more saline due to evaporation than those in the adjacent Atlantic.



In comparison with the Pacific and the Indian Oceans, the Atlantic is the saltiest. The Pacific Ocean is less salty because of meteorological conditions. Salinity in the deeper waters of the Pacific averages about 34.65°/oo. Waters of the Arctic and Antarctic are the least salty.

It has been calculated that if all the salts in the oceans of the world were dried up they would yield approximately 4.4 million cubic miles of rock salt. That's enough salt to cover all the landmasses of the world to a depth of 150 feet.

AVERAGE SALINITY

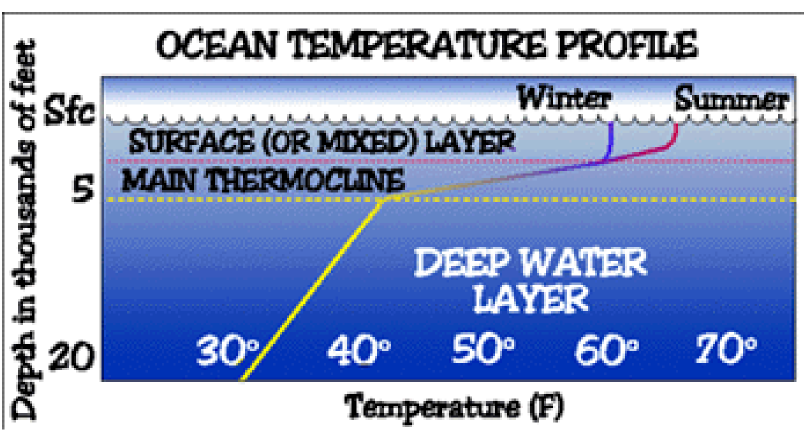
Open Ocean Areas	Range (ppt)
Atlantic	34 to 37
Pacific	32 to 36
Indian	32 to 35
Arctic	30 to 33

SEAWATER PRESSURE: A major problem in working at great depths is the tremendous weight of water. Oceans, like the atmosphere, exert pressure on the surface upon which they rest. For example, a one inch by one inch column of the earth's atmosphere resting on Earth's surface weighs 14.7 pounds. Weight of the atmosphere, like the weight of the sea, is of little concern to the native inhabitants immersed in one or the other of the environments.

Pressure at various ocean depths is usually expressed in units of *atmosphere*. Pressure in the ocean increases one atmosphere with about every 33 feet of depth. For example, at a depth of

99 feet, the absolute pressure would be about four atmospheres, or four times greater than on the surface. (Absolute pressure is the sum of the atmospheric pressure plus the water pressure.) Absolute pressure at a depth of 6,000 feet is more than 2,687 pounds per square inch. In the Challenger Deep (35,810 feet) pressure would be more than 15,966 pounds per square inch. or the equivalent of about 1,080 atmospheres.

SEAWATER TEMPERATURE: The temperature of water is of interest to fishermen, swimmers and people who work in the oceans (like navies). Considered globally, seawater, has a relatively large temperature range that depends upon location and time of year. Warm or cold ocean currents can also influence water temperature. Water temperature in the open ocean varies from a low of 28.4°F (the temperature of sea water) to about 86°F. (The formula used to convert Fahrenheit temperature to Centigrade is: C=5/9 (F-32). The temperature can reach nearly 100°F in shallow coastal waters. The usual thermal structure of the ocean consists of three zones. First is the surface layer where temperatures are almost uniform with depth. The next zone is the thermocline where the temperature decreases rapidly with depth. The third zone is the deep layer where tem-

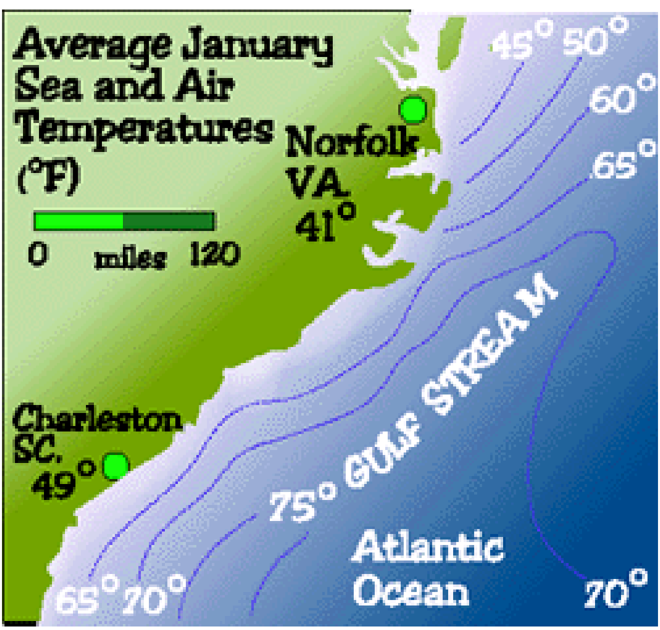


perature decreases very slowly with depth.

The surface layer, frequently called the mixed layer, varies in depth according to location and season. During the winter months it becomes more defined at all latitudes, and may extend to depths of a 1,000 feet or more in mid-latitudes during heavy weather. In polar regions, water can also be thoroughly mixed from surface to bottom during the winter months, so that it is nearly the same temperature from top to bottom.

The daily temperature of the surface layer of the ocean changes less than 5°F under normal conditions. Withsignificant changes in the weather however, sea water temperature can vary as much as 5°F in a 24-hour period.

Warm water of the Gulf Stream just off the East Coast of the U. S. is a classic example of ocean influence on climate. Easterly surface winds passing over the Gulf Stream in the winter are warmed from below and bring milder air to a chilled landmass. The Gulf Stream extends to near the British Isles, which ac-



counts for their milder and less snowy climate than areas considerably to the south.

UNDERWATER SOUND: Light and radio waves are highly absorbed by the oceans, but sound waves are not. Sound waves are used to probe the oceans' depth, locate objects in the ocean, measure bottom sediment thickness and communicate underwater.

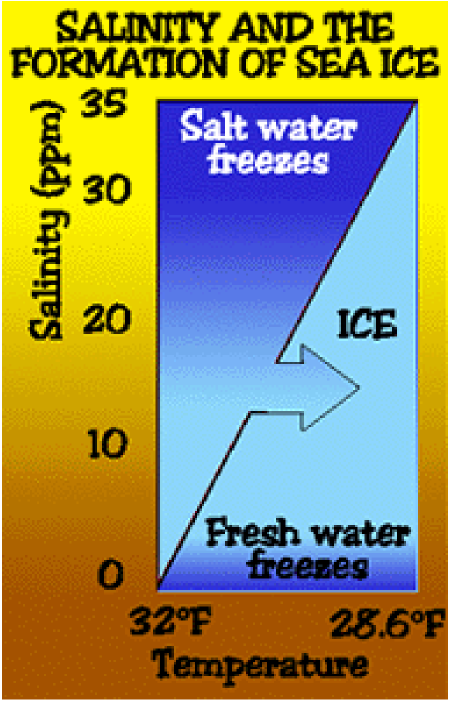
The speed that sound travels underwater varies from about 4,750 - 5,150 feet per second. It increases with temperature at a rate of about 4.3 ft per second per degree Fahrenheit; it increases with salinity at 4.3 ft./sec per one thousandth part increase in salinity; and it increases in depth at 1 ft./sec/60 ft. The sound velocity profile for a particular part of the ocean is often determined by lowering or towing an instrument called a sound velocimeter.

ICEBERGS: Glaciers that end at an ocean's edge create icebergs when large chunks of the glacier break off (calving). Approximately 7,500 icebergs are formed by this process each year. Portions of an iceberg may have hues of blue or green depending upon the age of the ice. Blue ice is old ice, while green ice usually contains algae.

Glaciers on the west coast of Greenland produce most of the icebergs found in the Northern Hemisphere. The icebergs vary in size, but are typically irregular with pinnacles. About seven-eighths of an iceberg is submerged. Thus iceberg drift is affected more by ocean currents than by wind. When they drift into shipping lanes, they become a serious hazard. On April 15, 1912 the Titanic, on her maiden voyage from England, collided with an iceberg off Newfoundland. More than 1,500 passengers and crew perished. Icebergs are rare in the Arctic Ocean although extensive sea ice exists year-round. In Antarctica, they are common and gigantic. Due to their size and the cold temperatures of Antarctica, they can survive up to ten years.

A mammoth iceberg the size of Rhode Island was sighted off the coast of Antarctica during the summer of 1996. It had apparently split from the coast of East Antarctica a few months earlier. The iceberg, with sheer walls rising 100 to 160 feet above the water line, extends into the water to a depth of 1,000 feet. The huge iceberg, covering more than 1,400 square miles, was first observed by a research ship working with the Antarctic Cooperative Research Center.

SEA ICE: Sea ice, formed in saltwater, accounts for about 95 percent of ice found in the oceans. Ice covers about three percent of the world's water surface. It persists in the Arctic Ocean and around the Antarctica continent throughout the year. New ice growth is greatest during the first year of formation, and attains a thickness of5 to 6 feet, but has been observed to grow as much as 3 meters in one year. Ice growth depends upon weather and sea conditions.



Above normal temperatures, strong winds, or powerful wave action will significantly retard ice formation.

Pure water normally freezes at 32°F, but the freezing point of sea water varies considerably. The freezing point of seawater decreases approximately a 0.5°F for each 5 °/oo increase in salinity. At 35°/oo sea water will begin to freeze at 28.6°F. Shallow bodies of water freeze more rapidly than deep basins because there is less volume to be cooled. This is why the first ice of winter usually appears at river mouths, where the water is shallower and fresher.

Sea ice first forms as salt-free crystals near the surface. The resulting formation of crystals is one of nature's better engineering jobs. The newly produced ice is flexible against the rolling action of the sea.

Pack ice consists of pieces of sea ice that drift under the influence of winds and ocean currents. An individual piece of sea ice in the pack is called a floe and can vary from several meters to several hundred meters in length. The size of the pack depends upon temperature and surface wind. If wind pushes pack ice together or onto shore, it piles up until pressure causes the ice to buckle, forming mounds, hummocks, and ridges up to 8 meters or higher. Ice packs grow to their largest sizes in areas of extreme cold and survive longer during periods of light wind. The two largest areas of pack ice are in and near the Arctic Ocean and in the region of coastal Antarctica.

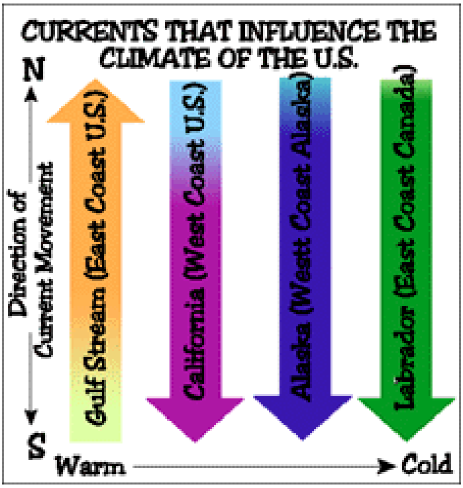
THE RESTLESS SEA

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.

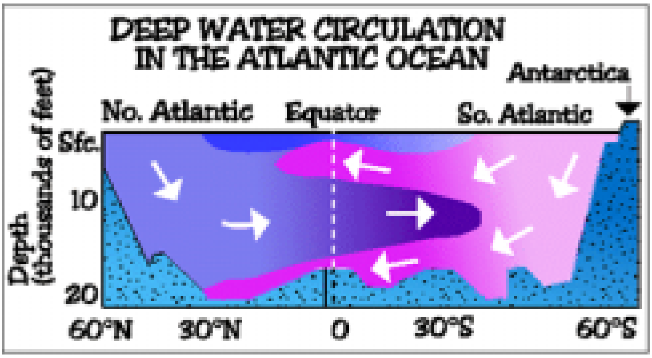
Some surface currents are transient and seasonal, a number of them flow with great persistence, setting up a circulation that continues with relatively little change throughout the year. Because of the influence of wind in creating currents in the surface-layer circulations of the ocean, there is a relationship 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.



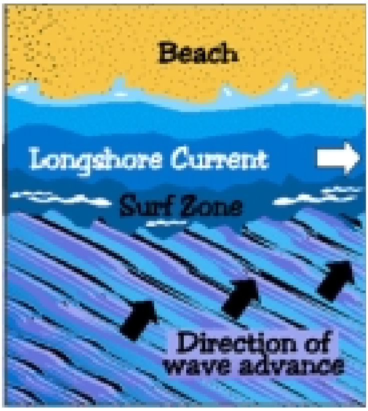
In deep ocean circulations, the differences in seawater density are controlled by variations in temperature and salinity. The deeper waters are driven by the formation of new, cold dense water masses in polar and sub-polar regions. The densest (coldest) seawater found in the Southern Hemisphere is formed 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.



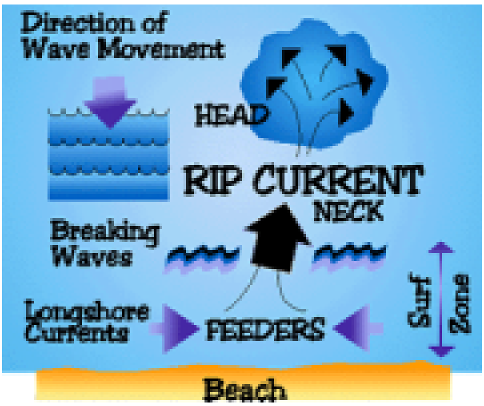
These waters can be traced into deep basins of the Atlantic, Pacific, and Indian Oceans because of their unique physical characteristics. It has been estimated that the dense waters move at a daily rate of about 3 to 5 miles.

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.



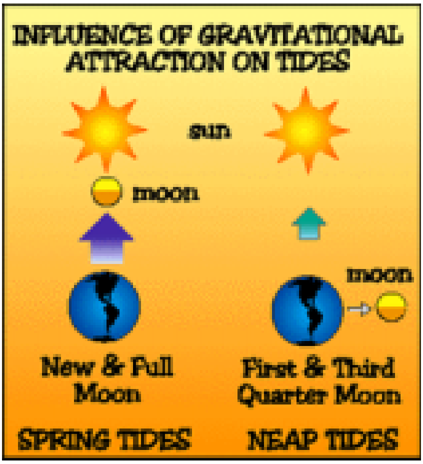
Longshore currents transport significant amounts of sand and sediment suspended by wave action in the surf zone along the shore. When the current enters deeper water, forward momentum diminishes and the sediment settles to the bottom. This can erode the beach in one area and build it in another. Unfortunately 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.

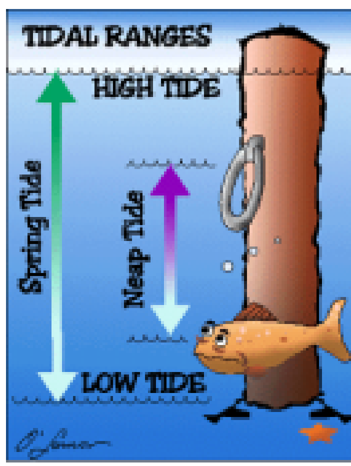


Rip currents consist of feeders, a neck, and a head. The feeder is usually the longshore current that flows parallel to the beach inside the breakers. The neck is the main channel of the rip current where feeder currents converge and flow outwards at a speed of one to three knots through a weak point 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.

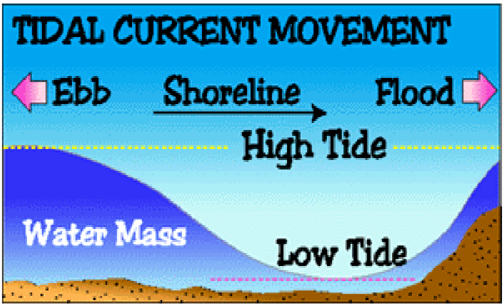


TIDES: Tides are the slow, periodic vertical rise and fall of the sea surface. They are usually described as being either diurnal or semi-diurnal. Diurnal tides have one high water and one low water in each lunar day (about 24.8 hours), while semi-diurnal tides have two high and two low waters in the 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 15 meters, while the tidal range in Lake Superior is measured in centimeters.



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 (384,404 kilometers), and the distance to the sun (149,669,292 kilometers), 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



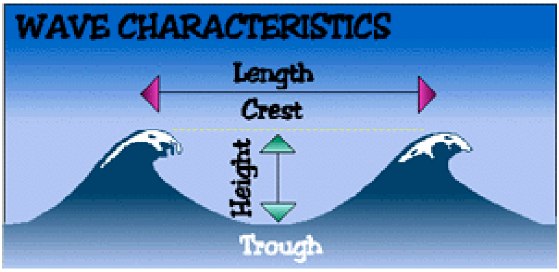
gravitational forces significantly reduce each other. This causes the neap tide, a period of decreased tidal range. The term neap is an acronym for near even as possible.

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.

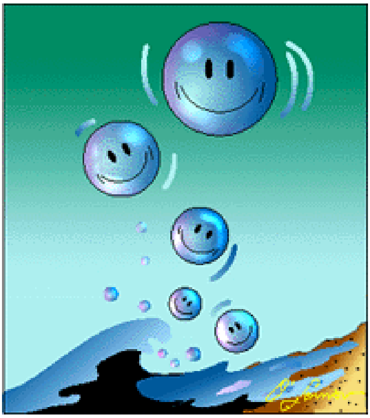
WAVES: Waves are created principally by wind moving over water although earthquakes or landslides can initiate wave action. Friction between a water surface and moving air piles up water in ridges that become waves. Wave height depends upon wind strength, fetch (distance wind blows over water) and duration (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 to 50 feet have been reported by ships. The ocean liner Queen Elizabeth II reported a wave measuring 100 feet in 1996.



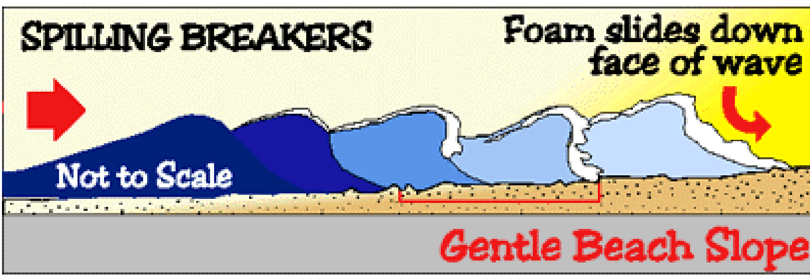
SWELLS: Swells are long period waves that have traveled a considerable distance from their origin (usually a significant weather event). As the waves move away from the wind field that created them, waves with shorter periods die out and the remaining waves (swell) flatten out and exhibit regular and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

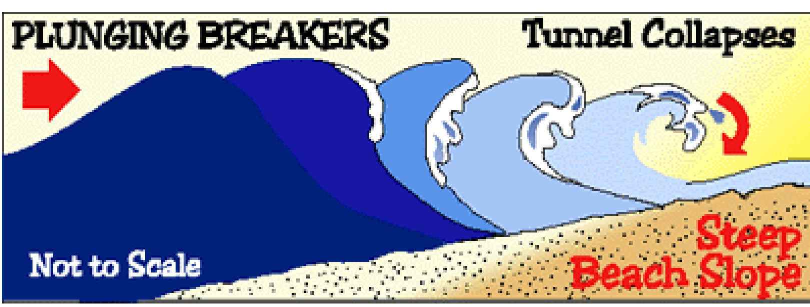


become unstable. Waves normally break when the forward speed of the crest exceeds the speed of the wave itself. The collapse of the wave creates a frothy surf of foam and air-filled bubbles.

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.



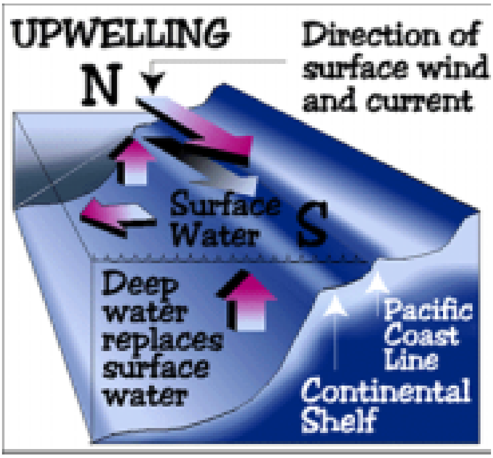
A plunging breaker occurs on moderately steep beaches. This type usually curls over forming the characteristic tunnel along the face of a wave until it breaks. Some of the best surfing conditions occur when long period swells (waves from distant storms move shoreward creating an unbroken train of nearly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

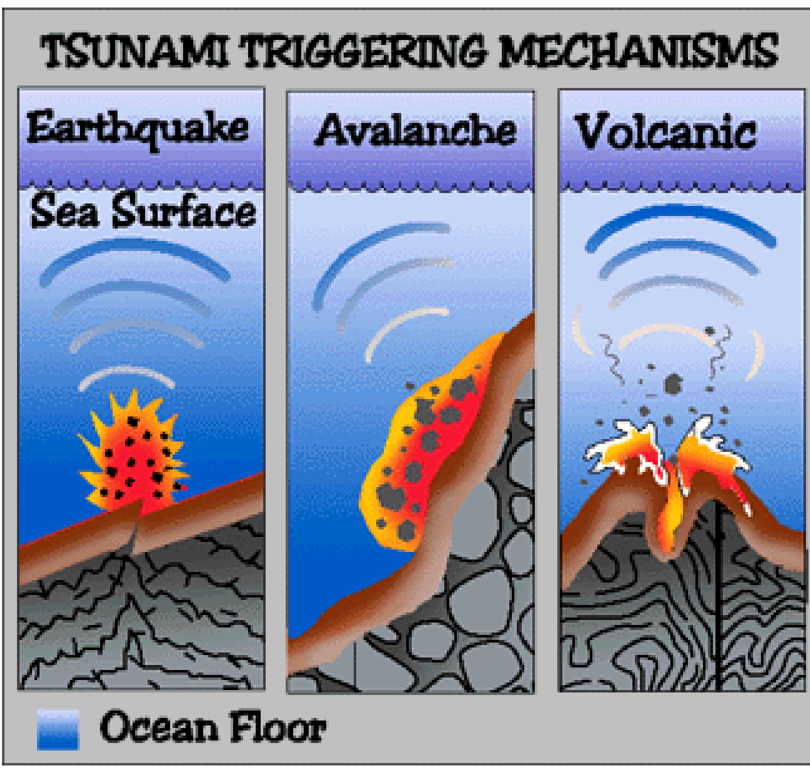
UPWELLING: Cool summers and coastal fog may be attributed to upwelling of adjacent ocean waters. Upwelling is the vertical movement of colder deep water to the surface. In the Northern Hemisphere, it occurs when persistent surface winds blow parallel to a coastal boundary causing surface waters to be 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 feethave 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 about one meter. 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 four 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.