

OCEAN CURRENTS

Ocean Currents-Definition and Features

Definition and Features

1. Ocean Currents are the large scale water movement which occurs everywhere in the ocean. Ocean currents rely on atmospheric circulation for their propulsion.
2. Current tables that give daily predictions of times, speed, and direction of tidal currents.
3. **Ebb current:** Tidal current directed away from shore or down a tidal stream.
4. **Density current flow** caused by density differences or gravity of one current under, or over another current. It retains its unmixed identity from the surrounding water because of density differences.
5. **Ekman spiral:** representation of currents resulting from a steady wind blowing across an ocean having unlimited depth and extent uniform viscosity. The surface layer moves 45° to the right of the wind direction in the Northern Hemisphere. Water at successive depths drifts in directions more to the right until, at some depth, the water moves in a direction opposite to the wind water. Speed decreases with depth throughout the spiral. The net water transport is 90° to the right of the wind in the northern hemisphere.
6. **El Nino** warm surface waters offshore from Peru. It occurs around Christmas time.
7. Geostrophic current resulting from the balance between gravitational force and the Coriolis effect.

Measurement of currents

Measurement of currents: Currents are measured by two methods they are

A. Direct method: Currents can be measured directly by observing the motion of water relative to the solid earth or by observing the motion of the solid earth relative to the water.

Example: A floating device tied to a weight at the ocean bottom by a wire of appropriate length depending on the depth of the current to be measured. The water speed can be measured by the speed with which a propeller is turned, and the current direction might be detected by comparing the direction of a weather vane-type pointer to a compass needle.

An example for larger device would be a float of just the right buoyancy to float at the desired depth. It should be deposited one day and then retrieved several weeks or months later and it should be attached with signal generating device to identify. The ocean current would then be known by how far and in what direction the float had gone.

B. Indirect method:

Geostrophic technique in which the current can be measured by measuring the slope of density contours due to current flow (cf) by knowing the slope of the density gradients and knowing the latitude.

In the second method the principle of electricity and magnetism is involved. When charged particles move through a magnetic field they get deflected, opposite charges in opposite direction. Ocean currents carry many charged particles-the salt ions that are moving through the earth's magnetic field. When two metal plates are put in to this current the positive ions will go toward one plate and the negative ions towards the other. By measuring the electrical voltage thus generated between these two plates, and the orientation of the plates for maximum voltage, we can predict the speed and direction of current. All instruments discussed so far produce information about oceanic property irrespective of the dynamic state of the ocean.

An elementary way of observing oceanic movement is the use of drifters. Drifters are

platforms designed to carry instruments. But all measurements obtained from drifters are of little use unless they can be related to positions in space. A geolocation (GPS) device which transmits the drifter location to a satellite link is therefore an essential instrument on any drifter, and this turns the drifter into an instrument for the measurement of [ocean currents](#).

[Ocean currents](#) can be measured in two ways. An instrument can record the speed and direction of the current, or it can record the east-west and north-south components of the current. Both methods require directional information. All currents meters therefore incorporate a magnetic compass to determine the orientation of the instrument with respect to magnetic north. Four classes of [current meters](#) can be distinguished based on the method used for measuring current magnitude.

Mechanical current: Meters use a propeller-type device. A Savonius rotor or a paddle-wheel rotor to measure the current speed, and a vane to determine current direction. Propeller sensors often measure speed correctly only if they point into the current and have to be oriented to face the current all the time. Such instruments are therefore fitted with a large vane, which turns the entire instrument and with it the propeller into the current.

Propellers can be designed to have response with the angle of incidence of the flow. Two such propellers arranged at 90° will resolve current vectors and do not require an orienting vane.

The advantage of the Savonius rotor is that its rotation rate is independent of the direction of exposure to the current. A Savonius rotor [current meter](#) therefore does not have to face the current in any particular way, and its vane can rotate independently and be quite small, just large enough to follow the current direction reliably.

With the exception of the [current meter](#) that uses two propellers with cosine response set at 90° to each other, mechanical [current meters](#) measure current speed by counting propeller or rotor revolutions per unit time and current direction by determining the vane orientation at fixed intervals. In other words, these [current meters](#) combine a time integral or mean speed over a set time interval (the number of revolutions between recordings) with an instantaneous reading of current direction (the vane orientation at the time of recording). This gives only a reliable recording of the ocean current if the current changes slowly in time. Such mechanical [current meters](#) are therefore not suitable for current measurement in the oceanic surface layer where most of the oceanic movement is due to [waves](#).

The Savonius rotor is particularly problematic in this regard. Suppose that the [current meter](#) is in a situation where the only water movement is from [waves](#). The current that alternates back and forth, but the mean current is zero. A Savonius rotor will pick up the wave current irrespective of its direction, and the rotation count will give the impression of a strong mean current. The paddle-wheel rotor is designed to rectify this; the paddle wheel rotates back and forth with the wave current, so that its count represents the true mean current.

Mechanical [current meters](#) are robust, reliable and comparatively low in cost. They are therefore widely used where conditions are suitable, for example at depths out of reach of surface [waves](#).

Electromagnetic current: Meters exploit the fact that an electrical conductor moving through a magnetic field induces an electrical current. Sea water is a very good conductor, and if it is moved between two electrodes the induced electrical current is proportional to the ocean current velocity between the electrodes. An electromagnetic [current meter](#) has a coil to produce a magnetic field and two sets of electrodes, set at right angle to each other, and determines the rate at which the water passes between both sets. By combining the two components the instrument determines speed and direction of the ocean current.

Acoustic current: Meters are based on the [principle](#) that sound is a compression wave that travels with the medium. Assume an arrangement with a sound transmitter, and let receiver B

located downstream. If a burst of sound is generated at the transmitter it will arrive at receiver B earlier than at receiver A, having been carried by the ocean current.

A typical acoustic [current meter](#) will have two orthogonal sound paths of approximately 100mm length with a receiver/transmitter at each end. A high frequency sound pulse is transmitted simultaneously from each transducer and the difference in arrival time for the sound travelling in opposite directions gives the water velocity along the path.

Electromagnetic and acoustic [current meters](#) have no moving parts and can therefore take measurements at a very high sampling rate (up to tens of readings per second). This makes them useful not only for the measurement of [ocean currents](#) but also for wave current and turbulence measurements.

Forces acting on seawater surface

As in the case with most of the processes on [earth](#) the ultimate source of energy providing the power for the atmospheric circulation is the sun. Unlike liquids, gases are easily compressed, so where the atmospheric pressure is greater, the air is also correspondingly denser. Atmospheric pressure is decreased by half for every 6 km of elevation and it gets thinner at the same rate. For example at an elevation of 6 km, air pressure is only one-half as dense. At 12 km, the pressure and density are both reduced by another factor of half, being quarter of their sea level values.

Our atmosphere blocks the infrared radiation given off by the [earth](#). But at higher altitudes the air is thinner, so it is easier for radiated heat to pass on out into space. Consequently the atmosphere generally gets cooler with altitude up to a height of about 12 km above sea level where it is roughly -60°C .

In equatorial regions, air rises for two reasons, the obvious one is that warmer air is less dense and therefore lighter. The other, more subtle reason is that the water molecules are actually lighter than the nitrogen or oxygen molecules. Since there is a good deal of evaporation from the oceans and rain forests in equatorial regions, the air there contains relatively more water molecules and less of heavier molecules than elsewhere, although only by a fraction of a percent. In polar regions, the high altitude air masses are very cold and therefore dense, so they sink.

If the [earth](#) were not spinning the movement of air masses and the circulation of the atmosphere would be of a simple pattern. Around the equator the air warmed from below, rises. Once aloft, the air flows towards the poles where it is cooled from below and sinks to flow back towards the equator. The surface winds would always blow towards the equator, being prevailing northerlies (coming from the north) in the Northern Hemisphere, and prevailing southerlies in the Southern Hemisphere. It should be noted that winds are named for the direction from which they blow.

The real [earth](#) however, spins and therefore there is a deflection of moving air masses due to Coriolis. The effect of [earth](#)'s rotation on objects moving above it is called the Coriolis effect. It was first described by Gaspard Gustave Coriolis (1792 – 1843), a French engineer. The Coriolis force is maximum at the poles and diminishes towards the equator, where it goes through zero and changes direction.

The atmosphere moves somewhat independent of the Earth's surface, as there is little or low friction between the [earth](#)'s surface and the atmosphere. A parcel of air that appears to be stationary above a point on the equator is actually turning with the [Earth](#) and moving eastward at a speed of about 1700 km/hr (1050 miles/hr). If the south wind blows this parcel of air due north, it moves across circles of latitude with progressively smaller circumferences. At these higher latitudes, points on the [Earth](#)'s surface move eastward more slowly. At 60°N , the eastward speed of a point on the [Earth](#)'s surface due to rotation is

only half of the speed (850km/hr) at the equator. Because of this, a parcel of air that was originally moving only northward relative to the [earth](#) at the equator, carries with its equatorial eastward speed. Therefore the air parcel is displaced to the east, relative to the [earth](#)'s surface, as it moves from low to high latitude. In the northern hemisphere this deflection is to the right of the direction of the air motion. If the same situation occurs in the southern hemisphere with a parcel of air moving southward from the equator, due to a north wind, the deflection is still to the east relative to the [earth](#)'s surface. However this deflection is now to the left of the direction of the air motion.

In the northern hemisphere, the air rising at the equator turns poleward gets deflected towards the right and soon heads eastwards, when it reaches higher altitude and latitude, at about 30° , the air loses much of its heat by radiation to space and the cold heavy air descends. Another factor that contributes to the descent is that the poleward moving air is moving eastward at about 30° latitude and therefore piles up and this contributes to the descent. The descending air is warm by comparison, making this region near 30° latitude, warm, clear, and dry. Many of the warm desert areas are near 30° north and south of the equator.

The descending air divides, some continuing towards the poles, and the rest returns to the equatorial regions. The surface air returning towards the equator is acted on by the coriolis effect that turns it westward producing the easterly trade winds which were used by the sailing ships on their way towards the new world. In the region from the equator to 30° north and south latitudes, the surface winds are easterly and the winds aloft are westerly. These westerly winds aloft move from west to east, commonly at a speed exceeding 160 km/hr (100 miles/hr)

Between 60° N and the north pole, the winds blow from the north and east while between 60° S and the south pole they blow from south and east. In both cases they are called polar easterlies. In the intermediate latitude the third circulation cell is established with the air sinking near 30° N along with that from the tropical cell, and rising near 60° N along with that from the north polar cell. The surface winds in this intermediate cell are deflected and produce winds that blow from the south and west between 30° N and 60° N and from north and west between 30° S and 60° S. In both hemispheres these winds are called westerlies. The air returning aloft to 30° latitude in this intermediate cell is also a westerly wind because it has enough westerly momentum to overcome the coriolis effect. Thus in the region between 30° – 60° latitude the winds are westerlies at all elevation.

The place where the westerly winds of the temperate area meets the cold polar air is called the polar front. Its location changes, especially with season, but it generally varies between 40° - 60° latitude. At the equator and 60° N and S, moist, low-density air rises; these are areas atmospheric pressure zones of clouds and rain. Zone of high density descending air at 30° . And 90° . North and south are areas of high atmospheric pressure zones of low precipitation and clear skies. Air flows over the [Earth](#) surface from regions of high atmospheric pressure to low atmospheric pressure. The area of rising air at the equator is known as the **doldrums**, and high pressure areas at 30° N and S are known as **horse latitudes** In these areas sailing ships could find themselves becalmed for days.

The momentum imparted to the sea by these major wind drive regular patterns of broad, slow, relatively shallow ocean surface currents. Some currents transport more than one hundred times the volume of water carried by all of the [Earth](#)'s rivers combined. Currents of such magnitude greatly affect the distribution of marine organisms and the rate of heat transport from tropical to polar regions. As the surface water is moved horizontally by the wind, momentum is transferred downward. The speed of the deeper water diminishes steadily as momentum is lost to overcome the viscosity of water. Eventually at depths generally less than 200 m, the speed of wind driven currents become negligible. Surface currents set up by

the winds move at about 2% of the speed of the wind that caused them. For instance, a wind blowing at 10m/sec would cause a [surface current](#) of about 20 cm/sec. Wind driven surface water sets the water immediately below it in motion. But due to low friction, this next deeper layer is deflected to the right (Northern Hemisphere) or left (Southern Hemisphere) of the surface layer direction. The same is true for the next layer down and the next.

The result is a spiral in which each deeper layer moves slowly, and with a greater angle of deflection than the layer above. This current spiral is called the [Ekman spiral](#), after the Swedish Physicist V. Walfrid Ekman, who in 1902 demonstrated mathematically that under ideal conditions a systematic decrease in current speed and a change in its direction occurred at increasing depths. (Fig.9).

Under natural conditions however the [Ekman spiral](#) does not operate in its predicted theoretical fashion. Oceans are not in uniform state, and a single wind impact is not so prolonged. The net motion of the entire mass of moving water flows at right angles to the wind direction is called **Ekman transport**. The Ekman layer marks a depth of 100m; their currents and frictional force defining the [Ekman spiral](#) are quite active. Below this depth these forces are virtually non existent.

West Wind Drift Current

The west wind drift current flows across [the indian ocean](#) to the water southwest of australia. Here it splits, one branch continues east along the southern coast, while the other flows northward along the western coast. this branch brings relatively cold water to the western australian coast and contributes to the formation of fog and low stratus clouds over the region.

EKMAN SPIRAL

Surface winds and [ocean currents](#) are intimately related. But how winds drive oceans currents is not so obvious. The process begins when winds blow across the water and drag on the surface. This sets a thin layer in motion which, in turn, drags on the one beneath, setting it too in motion. This process continues downward, transferring momentum. Such transfers of momentum between layers are inefficient, and energy is lost in the process. As a result, Current speed decreases with increasing depth below the surface. In an infinite ocean on a nonrotating [earth](#), the waters would always move in the same direction as the wind that set it in motion.

Since the [earth](#) rotates, movements of surface waters are deflected to the right of the wind in the northern hemisphere as was noted by Fridtjof Nansen while studying the drift of Arctic ice. He found that the ice moved 20° to 40° to the right of the wind. To explain such effects, we assume a simple, uniform oceans with no boundaries. In such oceans, each layer sets in motion the layer beneath, so that the deeper layer moves more slowly than the one above. These movements can be represented by arrows (vectors) whose orientation shows current direction and whose length indicated current speed. The change in current direction and speed with increasing depth form a spiral when viewed from above. This is called the Ekman spiral. A spiral for the Southern Hemisphere exhibits the opposite sense of deflection, but current speeds still decrease with increasing depth.

Water column stability controls the depths to which wind effects penetrate below the sea surface. A strong pycnocline inhibits transfer of momentum from the surface to waters below the pycnocline. The limit for wind effects is usually taken to be the depth at which the subsurface current is exactly opposite to the [surface current](#). Under strong winds, wind-drift currents may be as deep as 100 meters below the surface. Surface currents move at about 2%

of the speed of the wind that caused them. For instance, a wind blowing at 10 meters per second causes a [surface current](#) of about 20 centimeters per second.

[Upwelling](#) and Downwelling

Near the coast, winds blowing parallel to the shoreline cause a layers of surface waters a few tens of meters thick to move either away from or towards the coast. When surface water moves away from the coast, they expose subsurface water, which then move upward towards the surface. This is called [upwelling](#).

The equator is major [upwelling](#) area, which is caused by the winds and by the change in the sign of the Coriolis effect at the equator. Consider the trade winds near the equator. North of the equator, Ekman transport is to the right of the winds (to the northwest) in the northeast trades, and surface waters move away from the equator. South of the equator, the Ekman transport associated with the southeast trades is to the left of the winds (toward the southwest) and again away from the equator. Thus the equator is a divergence zone, where subsurface waters are brought up into the photic zone.

Where surface waters move toward the coast, they cause the surface layer to thicken, a process called [downwelling](#). In this case, the resulting sea surface slopes create currents parallel to the coast.

[Upwelling](#) is especially conspicuous on the eastern side of ocean basins, where the surface layer is relatively thin. Much [upwelling](#) occurs near coasts, usually in areas few tens of kilometers across, often near capes or other irregularities in the coastline. The cells of upwelled water often have plumes of cold waters extending offshore a **current gyre** – a nearly circular current system. The east-west-elongated gyres are centred in the subtropical regions north and south of the equator, In addition to an equatorial current, each current gyre includes a major east-west current at higher latitudes, flowing in the opposite direction to the equatorial currents. These east-west currents are relatively slow.

Boundary currents flow parallel to the continental margins, usually north-south. Boundary currents on the western sides of oceans basins are especially strong. Eastern boundary currents are much weaker.

In the subpolar and polar regions of all ocean basins there are smaller current gyres. These high-latitude gyres circulate in the opposite direction from the subtropical gyres. Because of the positions of the continents, subpolar gyres are well developed in the Northern Hemisphere. These currents flow in a counter clockwise direction.

Gradient current

Gradient current:

Is the current which is defined by assuming that the horizontal pressure gradient in the sea is balanced by the sum of the coriolis and bottom frictional forces. At some distance from the bottom the effect of friction becomes negligible and above this the gradient and geostrophic currents are equivalent which is also known as slope current. These are currents originating in oceans and seas as a result of differences in water column pressure. These differences in pressure are caused by the driving force of winds on the water, the unequal distribution of the waters density in a basin or the atmospheric pressure above it and the influx of continental waters or waters from other sources, and so forth. Under the action of the coriolis force, gradient currents are deflected from the direction of the pressure gradient to the right in the northern hemisphere and to the left in the southern hemisphere.

Chapter 2: Thermohaline circulation , [El-Nino](#) and current types

Thermohaline circulation

[Thermohaline circulation](#) is generated by density differences between water masses and can result in horizontal and vertical flow. Water density increases as water becomes cooler or more saline. If density increases sufficiently, the water sinks to a level such that all water below it is more dense and above it is less dense. The [water mass](#) then flows outward in all unobstructed directions sinking below less dense and rising above more dense water masses it encounters.

Several forms of [thermohaline circulation](#) occur in the ocean. In subpolar to polar regions, cold, dense water descends and slowly flows towards the equator across the basin. These water masses may also be more saline than regular sea water because of the concentration of salts in the remaining water as sea ice forms. As the currents slowly flow, they mix with adjacent water masses and eventually lose their identity.

Excess evaporation in a restricted sea can produce dense, saline water that sinks to the appropriate density level as it flows out into the ocean. Circulation through the Strait of Gibraltar, the entrance to the Mediterranean Sea, is an example of this form of [thermohaline circulation](#).

[Thermohaline circulation](#) also occurs in estuaries. As a river flows into the estuary, or narrow bay, the less dense fresh water forms a wedge that displaces the denser sea water. The wedge thins seaward as the fresh water spreads outward and slowly mixes with the sea water. Friction between the outflowing fresh water and the underlying salt water establishes a form of circulation called **estuarian circulation**.

INTERNAL PROGRESSIVE [WAVES](#)

In contrast to surface [waves](#), [internal waves](#) occur on boundaries (psynoclines) between water masses of different density within the ocean. Surface and [internal waves](#) are similar, but [internal waves](#) tend to be smoother, slower, more stable and can attain greater wave heights than surface [waves](#). This is because the density difference between the water layers is less than that between air and water. [Internal waves](#) display many of the properties shown by surface [waves](#), such as reflection, refraction and interference.

[SEICHES](#)

[Standing waves](#) that occur in natural basins are called [seiches](#). [Seiches](#) appear as a rocking back-and-forth of the water surface or an internal boundary within the water column. The line about which the [seiche](#) rocks is called a node and it experiences no vertical motion. In contrast, the antinode is where the vertical motion is the maximum. A simple [seiche](#) has only one node in the center of the basin and two antinodes. The period of the [seiche](#) is the time required for the water surface to rock back and forth once and is dependent upon the length and depth of the basin.

[Seiches](#) display interference, refraction and reflection, but unlike other progressive [waves](#), they do not move water in circular to elliptical orbits. In a [seiche](#), water flows forward for a given distance, stops and then flows in the reverse direction. Maximum velocity is achieved when the surface is horizontal. No flow occurs when the surface is at a maximum tilt (antinode).

A rotary [seiche](#) is a special type of [seiche](#) in which the position of the antinode rotates about the basin as the surface rocks back and forth. The node and antinodes are reduced to points.

Types of [Ocean currents](#)

Most important [ocean currents](#) are the western boundary currents and eastern boundary currents.

Western boundary currents:

- Gulf Stream
- Kuroshio
- Labrador Current
- Oyashio
- Agulhas Current
- Brazil Current
- East Australia Current

Eastern Boundary currents

- California Current
- Canary Current
- Peru Current
- Benguela Current

INDIAN [OCEAN CURRENTS](#)

The Asiatic Monsoon influences the North Indian Ocean, while the currents of the south Indian Ocean are influenced by the atmosphere's anticyclonic circulation. [The Indian ocean](#) currents are

1. NORTH EQUATORIAL CURRENT

During the Northwest monsoon (February and March), the wind blows from the continent and aids in the development of the North Equatorial Current. The current flows from east to west; and upon reaching the east coast of Africa, a good portion turns southwards, crosses the equator, and becomes the MOZAMBIQUE CURRENT. A strong counter current exists south of North Equatorial Current at this same time of year. In August and September, during the southwest monsoon, the North Equatorial Current reverses the flows west to east as the MON-SOON CURRENT. At the same time, the countercurrent seems to disappear.

2. MOZAMBIQUE CURRENT: The Mozambique Current flows south along the east coast of Africa from the vicinity of the equator to about 35°S, where it becomes known as the ALGULHASSTREAM.

AHULAS STREAM: The Ahulas Stream flows westward along the southern coast of Madagascar and joins the Mozambique Current along the east African coast. From there it flows south to southern tip of Africa (the Cape of Good Hope), where a good portion joins up with the [West Wind Drift Current](#).

3. [WEST WIND DRIFT CURRENT](#): The [West Wind Drift Current](#) flows across [the Indian Ocean](#) to the waters southwest of Australia. Here it splits; one branch continues east along the southern coast, while the other flows northward along the western coast. This branch brings relatively cool water to the western Australian coast and contributes to the formation of fog and low stratus clouds over the region.

In general, the following statements may be made concerning the effects [ocean currents](#) have on weather:

1. West Coast of continents in tropical and subtropical latitudes (except close to the equator) are bordered by cool waters. Their average temperatures are relatively low with small diurnal and annual ranges. There is fog, but generally the areas (southern California, Morocco, etc.) are arid.

2. West coasts of continents in middle and higher latitudes are bordered by warm waters which cause a distinct marine climate. They are characterized by cool summers and relatively mild winters with a small annual range of temperatures (upper west coasts of the United States and Europe).
3. Warm currents parallel to east coasts in tropical and subtropical latitudes. This results in warm and rainy climates. These areas lie in the western margins of the subtropical anti-cyclones and are relatively unstable (Florida, the Philippines, Southeast Asia).
4. East coasts in the lower middle latitudes (leeward side) have adjacent warm waters that produce a modified continental-type climate. The winters are fairly cold, and the summers are warm or hot.
5. East coasts in the higher middle latitudes have adjacent cool [ocean currents](#), with subsequent cool summers.

El Nino

Wind driven reversal of the Pacific equatorial currents resulting in the movement of warm water toward the coasts of the Americas, so called because it generally develops just after Christmas.

On the sheltered or lee side of the tropical landmasses, under the trade winds of the Pacific, the [upwelling](#) of deep oceanic water is nearly constant process. From time to time, this process falters; the trade winds strengthen, and warm tropical surface water accumulates on the west side of the Pacific. This even is followed by the winds losing their driving force; the [upwelling](#) lessens, and the mass of warm western Pacific water moves eastward across the ocean to accumulate along the coast of the Americas. This sequence of events is known as El Nino.

A severe El Nino event affects weather systems over large areas of the [earth](#). In 1982-83 the polar jet stream was displaced far southward over the Pacific Ocean, bringing unusually dry conditions to Hawaii and a strong low pressure system to the Gulf of Alaska that resulted in high winds and high precipitation along the west coast of the United States. Heavy rains occurred in Ecuador, Peru, and Polynesia, while droughts came to Australia, the Sahel of Africa, southern India, and Indonesia. At the same time lower surface temperatures in the North Atlantic made the hurricane season the quietest in over fifty years.

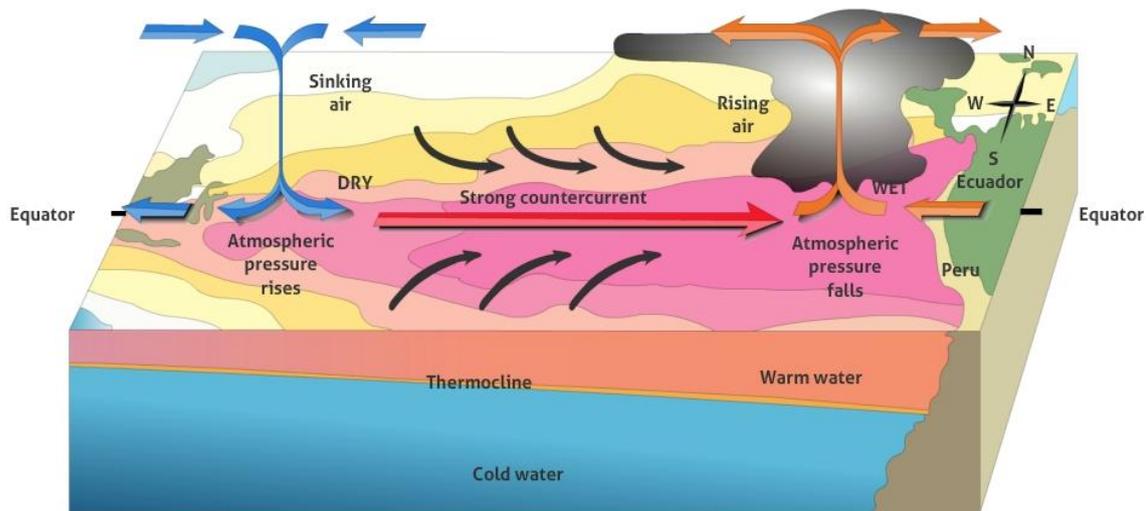
The exact cause of El Nino is still in doubt, but certain processes have been identified with its appearance. One process, in which atmospheric pressure increase on one side of the Pacific, decreases on the other, and then reverses, is known as the Southern Ocean Oscillation. The pressure centers associated with this Oscillation lie over Easter Island in the eastern Pacific and Indonesia in the western Pacific. Under normal conditions, there is a high-pressure system over Easter Island and a low-pressure system over Indonesia, the trade winds are strong and constant and [upwelling](#) occurs along the coast of Peru. When the atmospheric pressure system reverses, the southeast trade winds break down.

A severe El Nino uses the changes in the Southern Ocean Oscillation and the surge in strength of the trade winds, which appears to precede their decline and the development of the westerlies.

The alternation between these two events has been quite regular for the last hundred years, except for the periods between 1880 and 1900 when La Nina conditions prevailed, and the 1975-88 periods of El Ninos. Look carefully at figure 7.23 and notice that the 0 ° C line represents the long-term average sea-surface temperature over the last forty years. If this line were redrawn between 0 ° C on the left and 0.5 ° C on the right, allowing a half-degree rise in ocean surface temperature, the regular alternation between El Nino and La Nina events would appear as a more regular pattern. Recent analyses of surface water temperatures off the

southern California coast during this period (1950-1990) indicate an average water temperature increase of 0.8 ° C. There are at least two possible mechanisms that could lead to such a warming of ocean surface water: (i) the oceans response to global warming or (2) a reduction in [upwelling](#) in the Pacific Ocean associated with changes in North Atlantic circulation.

El Nino



Tidal Currents

Tidal Currents

The [tides](#) horizontal and vertical flow of water is easily noticeable near the coast. The periodical horizontal movements of the sea, in response to the tide generating forces, are called tidal currents. These currents respond to the changes in the tide-generating forces brought about by the changing relative positions of the moon, the sun and the [earth](#), in a manner similar to that [tides](#). High [tides](#) and low [tides](#) can set up currents known as flood currents and ebb currents, particularly in narrow straits and channels. In these areas tidal currents may reach velocities of up to 15km/h. Similar to [tides](#), tidal currents in restricted areas changes their direction due to [earth](#)'s rotation. Some time the flood and ebb currents may even be opposite to each other. The important factors which affect the tidal currents are the shape of the bay, river flow, depth and shape of the channel and friction. Tidal currents in estuaries and restricted channels can be very important. They can move large amount of sediment, which may block harbours located in the estuaries.

Tidal range

[Tidal range](#): Difference in height between consecutive high and low waters.

Tide period: Rise and fall of the ocean, caused by the gravitational attraction of moon and sun acting on the [earth](#).

Tide curve: Presentation of the rise and fall of tide time with [reference](#) to it height of the tide.

Tide producing force slight local difference between the gravitational attraction of two astronomical bodies and the centrifugal force that holds them apart. Gravitational attraction predominates at the surface point nearest to the other body while centrifugal "repulsion"

predominates at the surface point farthest from the other body.

Tide pool: Depression-usually water filled-in the intertidal zone, alternately submerged and exposed by the rise and fall of tide or wave action.

Tide tables: tables that predict the times and heights of tidal phenomena at specified locations.

Tide wave I the long-period gravity wave that has its origin in the tide- producing force. Tide wave itself in the rising and falling of the tide.

Tide winds wind system, in most of the tropics, which blow from the subtropical highs toward the equatorial lows. Trade winds are from the northeast in the northern Hemisphere, from the southeast in the southern hemisphere.

Thermocline marked vertical temperature change in a body of water; also a layer in which such a temperature change occurs.

Thermohaline circulation induced by differences on water density which is controlled primarily by temperature and salinity.

[Spring tide](#) of increased range that occurs about every 2 weeks when the moon is new or full.

Neap tide lowest range of the tide, occurring near the times of the first and last quarters of the moon.