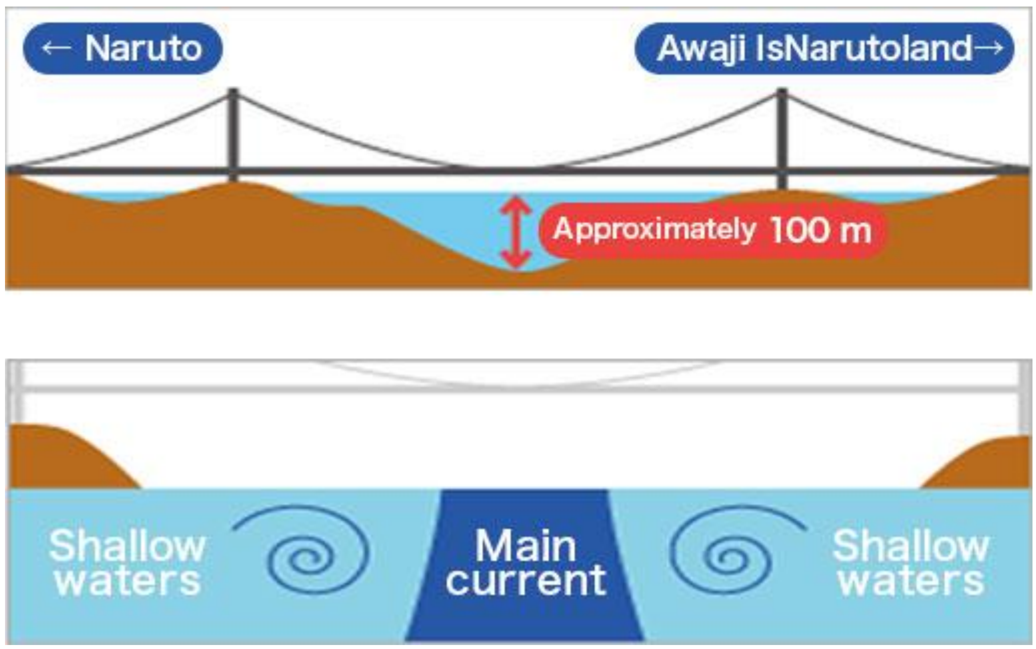
Whirlpools In addition, the changing of the tides can create another hazard known as a “whirlpool”. These are created when the water from two opposing currents meet and form a vortex. (This is NOT what happens in the sink or bathtub).



whirlpool_narutao_formation

Whirlpools become columns of circulating water, but without an “exit” so boats and ships are not “sucked down into them. Large ships can plow through them and small boats may be spun around by them. For a small boat this is very dangerous in that it can become swamped – that is water may flood into the boat and cause it to sink.

Whether or not the whirlpool appears and how rapidly it spins are a function of the tides. High tides and especially spring tides produce the most intense whirlpools. The figures given below are "highs". In some cases, these have become tourist attractions with boats taking passengers out to see the whirlpool "up close"

whirlpool_narutao_tourists

The largest whirlpools are Saltstraumen (23 mph) in Norway,

Whirlpool_Saltstraumen_Norway

Moskstraumen (17.3) also in Norway, although there are those who think this is more an “eddy” than a whirl pool

and Corryvreckan in Scotland found off the west coast between Jura and Scarpa. It has speeds of about 12 mph

Whirlpool_Corryvreckan

A dramatic encounter with Corryvreckan can be seen in the film I Know Where I’m Going. On the US/Canadian border lies Old Sow (17.1 mph) between Deer Island in New Brunswick and Moose Island, Eastport Maine. The US Coast Guard Station in Eastport regularly rescues boats that have gotten too close and do not have enough power to move them out of the current.

whirlpool_Oldsow

Near Awaji Island in Japan lie the Naruto whirlpools which have speeds of up to 12 mph.

Whirlpool_Naruto

Edgar Allen Poe’s Descent Into the Maelstrom and other fictional works have boats being sucked down into the whirlpool, but this is just fiction.

STORM SURGE

Storm winds cause storm surge by pushing the ocean up onto the shore. These are most intense with hurricanes. The speed and intensity of hurricane winds is measure by a scale called the SAFFIR SIMPSON HURRICANE SCALE

Scale Number (Category)	Sustained Winds (MPH)	Damage	Storm Surge
1	74-95	**Minimal:** Unanchored mobile homes, vegetation and signs.	4-5 feet
2	96-110	**Moderate:** All mobile homes, roofs, small crafts, flooding.	6-8 feet
3	111-130	**Extensive:** Small buildings, low-lying roads cut off.	9-12 feet
4	131-155	**Extreme:** Roofs destroyed, trees down, roads cut off, mobile homes destroyed. Beach homes flooded.	13-18 feet
5	More than 155	**Catastrophic:** Most buildings destroyed. Vegetation destroyed. Major roads cut off. Homes flooded.	Greater than 18 feet

There is a separate scale for tornados called the Fujita scale that has been enhanced.

Fujita Scale	
F–0	40–72 mph winds
F–1	73–112 mph
F–2	113–157 mph
F–3	158–206 mph
F–4	207–260 mph
F–5	261–318 mph

fujita-tornado-scale

Enhanced Fujita Scale	
EF–0	65–85 mph winds
EF–1	86–110 mph
EF–2	111–135 mph
EF–3	136–165 mph
EF–4	166–200 mph
EF–5	>200 mph

enhanced-fujita-tornado-scale

These are more intense, but more localized and can occur on the water where they form “water spouts”.

Water spouts

Hurricanes are winds around an extreme low-pressure area. The air being warmed and rising causes a low pressure. Winds then move into the low-pressure area moving to the right (counterclockwise) in the Northern hemisphere and the reverse in the Southern. This is the result of the Coriolis force or effect. Winds in the northern hemisphere veer to the right, in the southern hemisphere to the left.

This is caused by the fact that a sphere which is rotating moves faster near the "equator" than at the poles. At one foot from the pole, one can walk 360 degrees in a few steps, but at the equator the person would have to walk 24,000 miles or so. Since the world rotates on its axis once in approximately 24 hours, the part near the equator must cover about 1000 miles an hour, whereas at the poles it travels only a few feet in 24 hours.

If you imagine a line of skaters or dancers that is revolving around the center of the line, you realize the people toward then center move much slower than those at the outside. The people at the ends of the line must travel very fast while the people in the center go rather slowly. If the line rotates counter-clockwise (as the Earth does if you were to look down at the North Pole from space) the line of dancers/skaters would curve to the right as they try to catch up.

VIDEO OF SKATERS

If you looked at the Earth from outer space from over the South Pole, it would appear to rotate clockwise. A line of dancers/skaters rotating clockwise would bend to the left.

So hurricanes in the North rotate counterclockwise, since the air moving into the low pressure center begins to veer to the right.

Hurricanes season lasts officially from June 1 to Nov. 30. September is the generally to most active month. This because these are the times when the ocean temperature is higher. The hurricanes in the Atlantic begin as low pressure centers coming off the coast of Africa and then they move out over the ocean where they gain energy from the warm water. The air heats and rises causing the low pressure to drop even lower. Because of the pressure gradient (the difference in pressure horizontally in the air) the air moves into the lower pressure areas (air moves from higher to lower pressure). As it move in, the Coriolis effect causes the air moving in moves to the right, and the low pressure center has a counter clockwise turn. The water produces moisture as well and the low pressure area may intensify and when winds reach 74 miles an hour, the event is labeled a hurricane.

The eye is center of the rotation and the area immediately around it is the eye wall. On land, the eye is rather calm, but on the ocean it is an area of violent wave activity since the waves are formed by wind direction and the winds are blowing from all directions around it.

For ships at sea, being in the eye of the hurricane is the worst place to be. Waves are large and come from all directions.

On September 30th of 2015, the 791-foot long freighter, El Faro, at 791 feet long, left Jacksonville Florida en route to Puerto Rico with 391 shipping containers. AT the time, a tropical storm Joaquin in the Atlantic was building and expected to become a hurricane by the next day. The ships course would have taken it into the path of the hurricane which was rapidly intensifying. The ship took on water, began listing and then lost propulsion. The Emergency Position Indicating Beacon (EPRIRB) sent messages as to where the ships was. Two databases indicted slightly different positions, and one put the vessel in the eye wall just before all contact was lost.

Hurricane Hunters and the US Coast Guard aircraft began a search for El Faro and later they were joined by a Coast Guard vessel and a Coast Guard helicopter, but no trace of the ship was found. On October 3rd while flying in hurricane force winds, a life ring was recovered. Debris and some bodies and a damaged life boat were found. On Oct 7th the search was discontinued. On Oct 31 soundings located a vessel at 15,000 feet deep which turned out ot be the ship.

There were 33 people on the ship 28 Americans and 5 Poles. All hands were lost.

When hurricanes come on shore, they often produce large storm surges in which the water level rises dramatically. If the coast is steep, the water may not move far inland, but if the shore is gently sloping the water may move quite a distance inland. Current thoughts are that under the "right" circumstances, storm surge could raise the water level in Brooklyn so that there would be water as far inland as Ave. I.

Since the hurricane is rotating in a counterclockwise direction being on the NE corner is the worst part of the storm. At that point the water is pushing higher into the land. On the NW side, the winds are pushing away from the land. In addition to the shape of the shore line, and which part of the storm is arriving (NE or NW quadrant), there are other factors to consider. Among these is the forward speed of the storm, the speed of the wind, the nature of the land where the hurricane comes ashore (rocky, sandy etc.) and the amount of rain. Clearly a slow moving storm stays longer and hence dumps more rain. Attempts to block incoming seas imitate some natural phenomena like sand bars by building breakwaters - a kind of wall in the water. Some hurricanes have overtopped the walls, or destroyed the walls. Such walls however have an effect on beach erosion. Some of the land has plant life which has long roots and help stabilize the ground and keep it from washing away. In some cases the building of houses on the shore line leads to the loss of such plants and the destruction of sand dunes which may also help control water movement.

On Sept. 8th 1900 Galveston was struck by a hurricane struck causing incredible damage.

The city of Galveston was a hub of businesses with a population of about 36,000 people. It has a natural harbor which helped its growth. It was built basically on a sandbar, with highest point being some 8.7 feet above sea level. Some concerned citizens had suggested the building of a seawall (a wall on the beach basically) to protect the city but the majority of the population thought it unnecessary and so one was not built. There had been a good deal of building going on in the city which led to the destruction of sand dunes to fill in low areas of the city and in this way what protection there was destroyed. There had been storms before which the city had survived which led to some complacency. Isaac Cline of the weather bureau thought it would not be possible for the city to be struck by a hurricane. The weather service at that time had little information about weather at sea and relied on reports from ships.

Cuba forecasters were predicting the storm that they were experiencing, would head toward San Antonio, but the US weather bureau argued that the storm would curve and strike Florida. Isaac Cline's role and that of his meteorologist brother Joseph have been a bone of contention with some people crediting them with giving a hurricane warning before the central office approved it, while others claim their role was negative in that they resisted the idea of building the sea wall.

When the storm surge hit, the waters rose over 15 feet - almost twice the depth of the highest piece of land. The entire island was submerged and over 3,600 hundred buildings were destroyed. Estimates of the death toll rose to somewhere between 6,000 and 12,000 people (official reports claim 8,000) making it the greatest natural disaster to strike the U.S.

Disposing of the dead was a major problem and bodies were weighted and placed on barges and dumped at sea. The currents brought many of the bodies back to shore and the survivors were reduced to building funeral pyres and burning the bodies. This went on day and night for weeks after the storm.

It is reported that there were more people killed in this storm than in all the other cyclones to have struck the US.

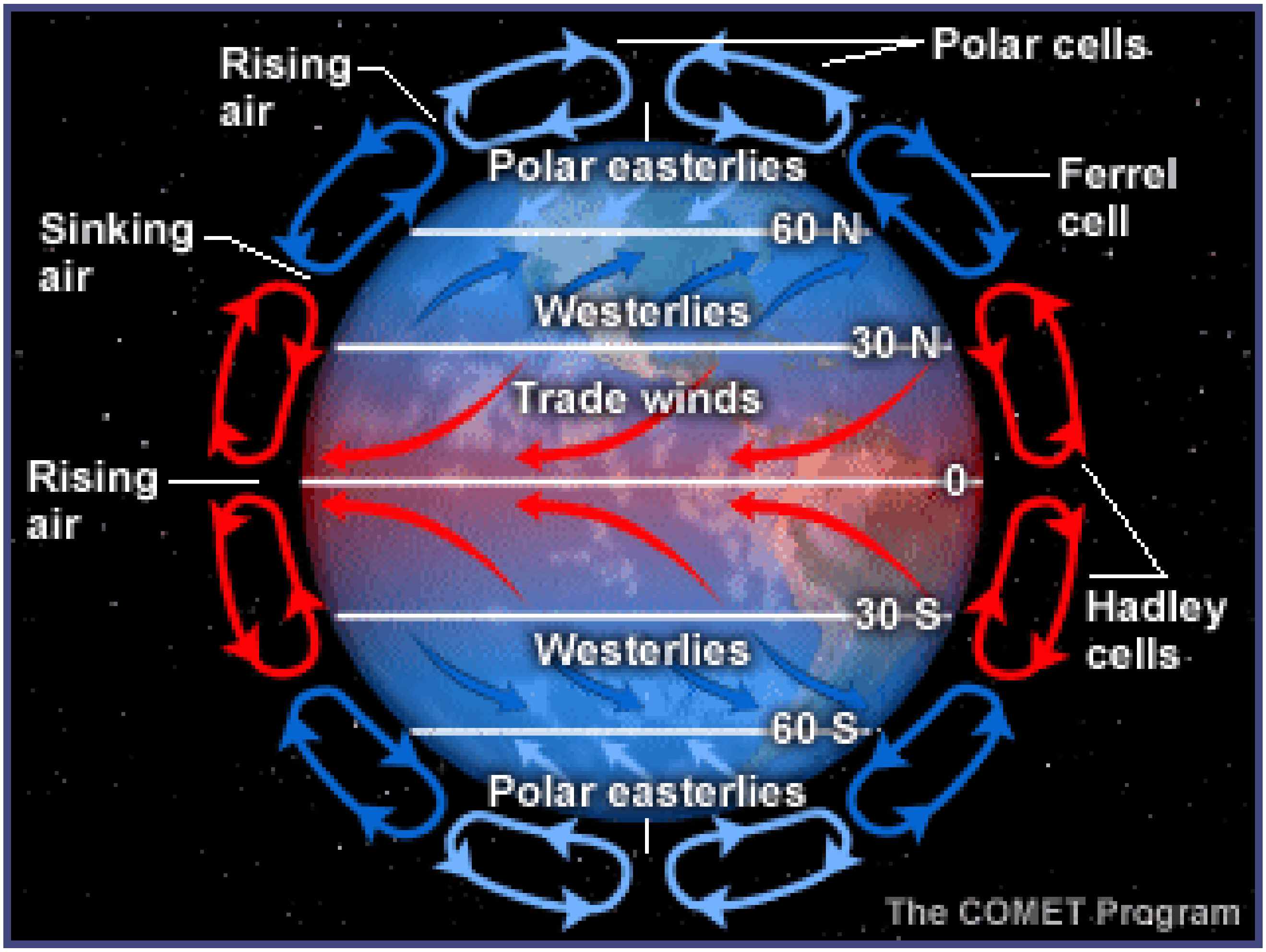
CURRENTS:

Currents are moving water. Major currents are driven by wind and tides and differences in density. As a result currents can be on the surface or under water

So how does the wind operate? Hot air at the equator rises and starts to move north in the N. hemisphere and south in the southern hemisphere. At about 30 degrees from the equator, the air has cooled enough and become dense enough to sink down to the ground. Since the cool air is denser than the warm air toward the equator, the pressure gradient moves the air south.

Currents also operate as heat transport.

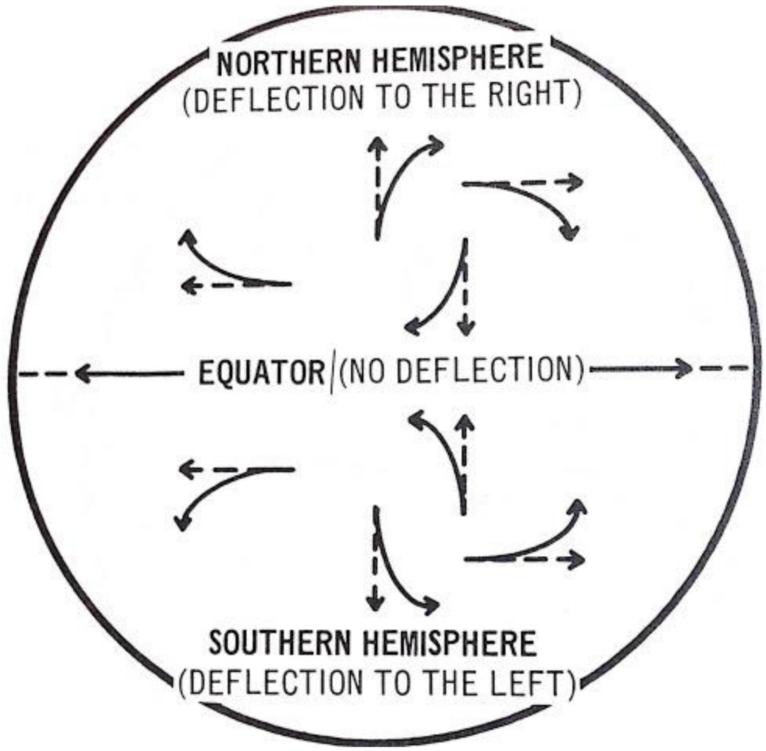
So how does the wind operate? Hot air at the equator rises and starts to move north in the N. hemisphere and south in the southern hemisphere. At about 30 degrees from the equator, the air has cooled enough and become dense enough to sink down to the ground. Since the cool air is denser than the warm air toward the equator, the pressure gradient moves the air south.



At the poles, the cold air over the poles sinks and moves south towards the warmer air. As it moves south it heats and rises at about 60 degrees from the equator. The air between the Hadley Cell and the Polar cell is moved like a gear between the two.

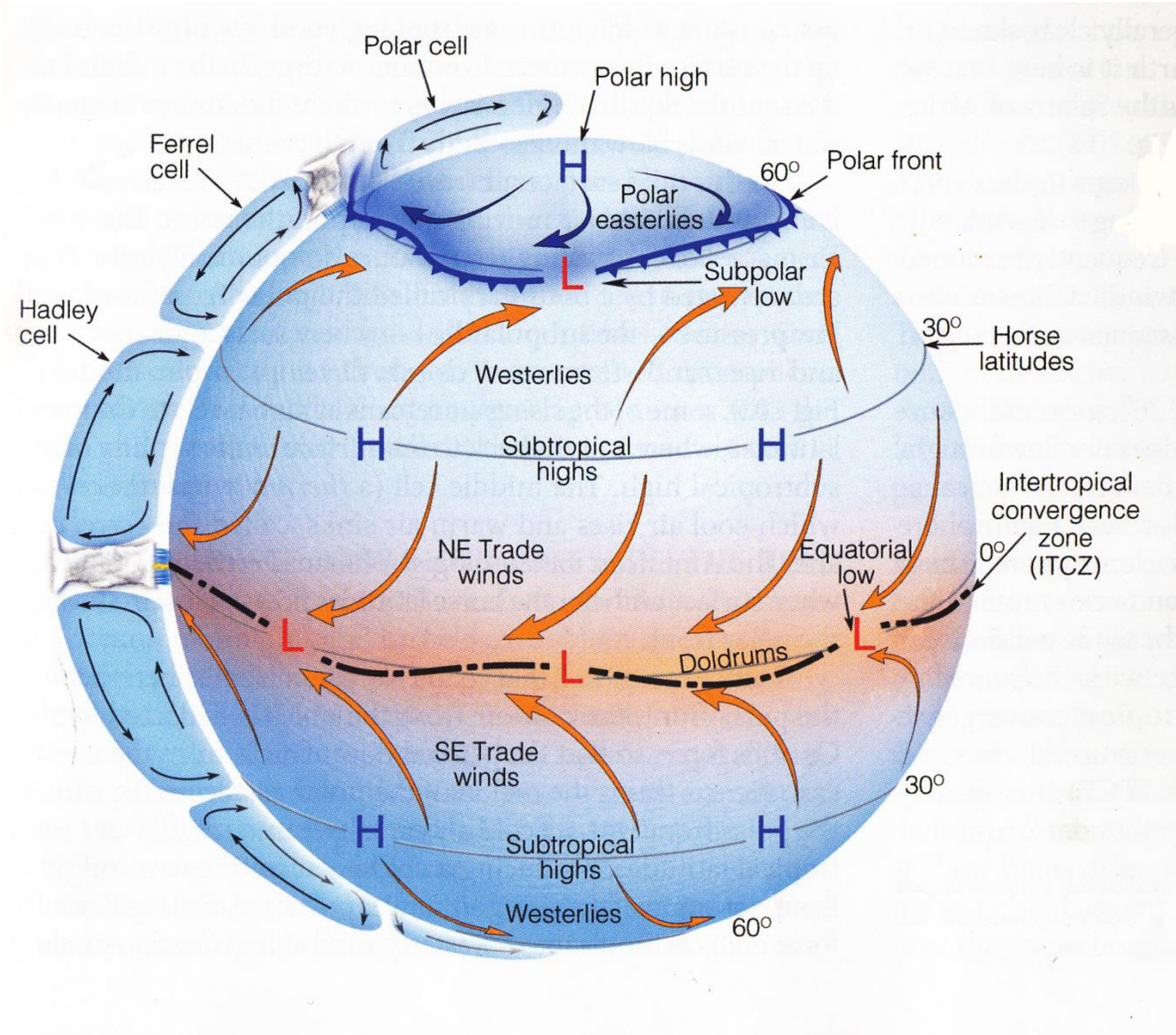
As the air on the surface of the earth moves north and south, the Coriolis Effect takes over and the winds in both directions veer off to the right.

Diagram 2



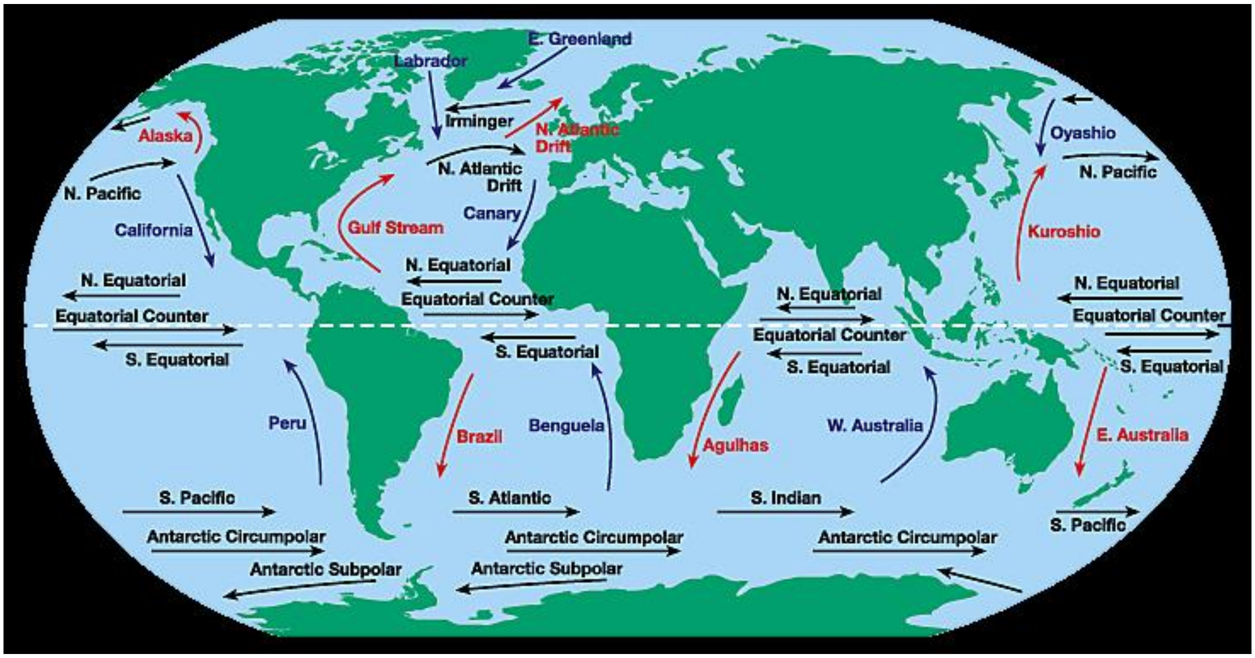
coriolis

This gives the general global wind patterns.



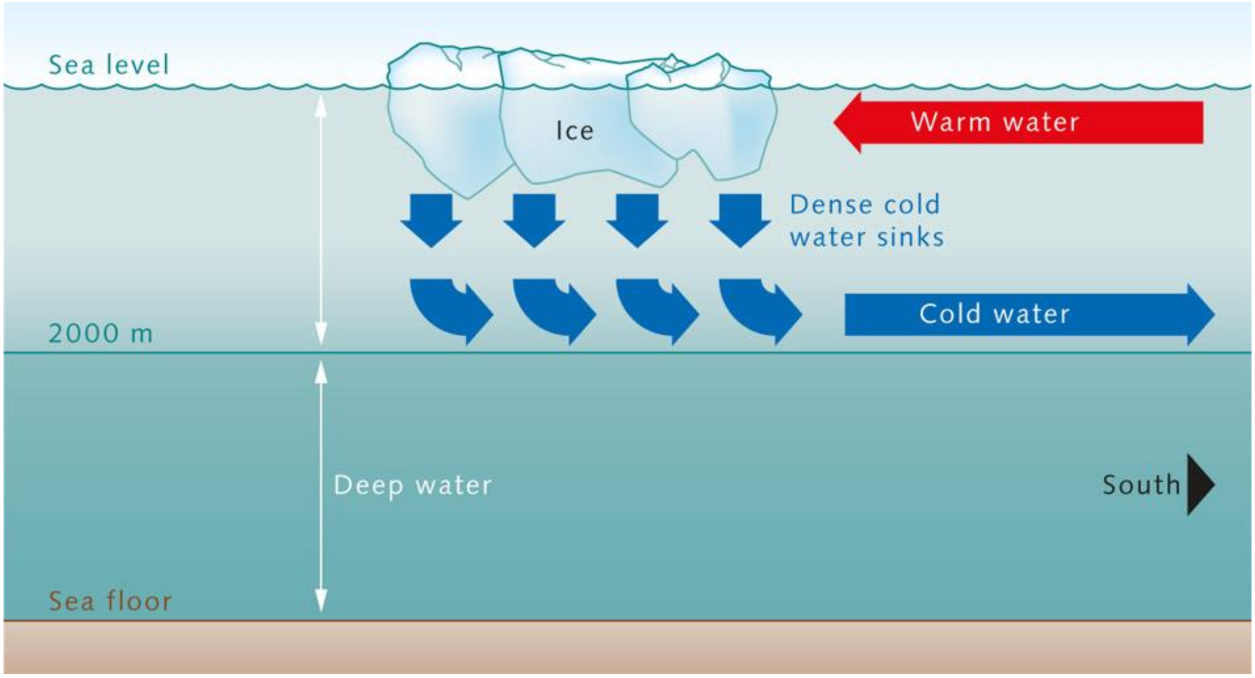
Hadley cells

As a result, ocean currents follow the pattern of the winds

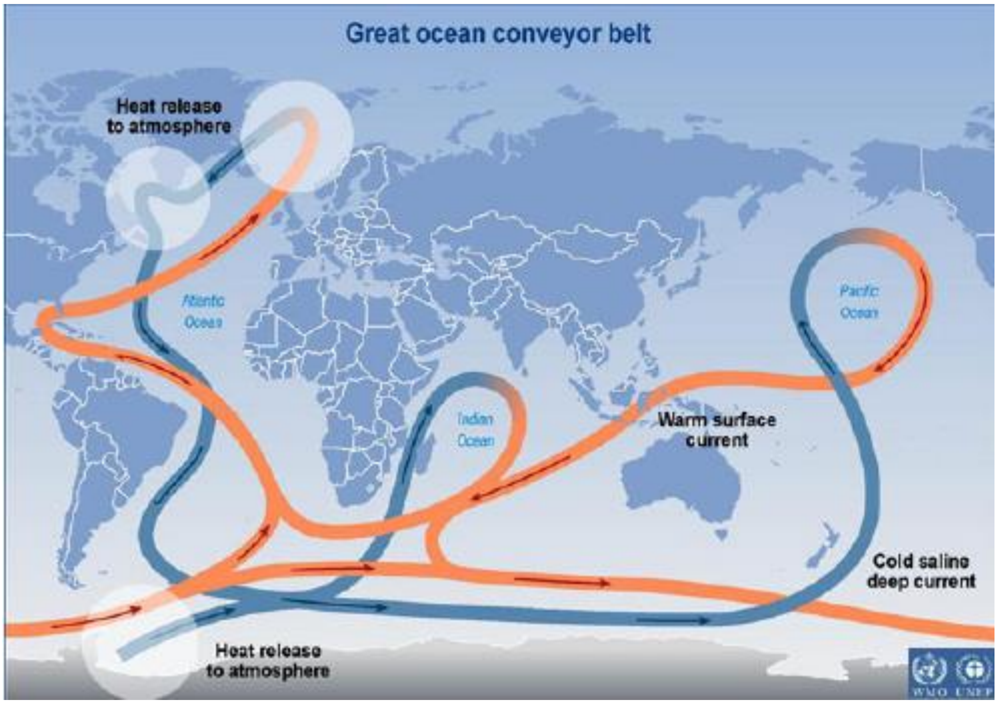


surface_currents_lg

Gulf Stream (surface) and Polar conveyer belt transport (under water) You should note at this point that there are currents that run on the surface of the ocean and those that run deep in the ocean. These have great importance in weather



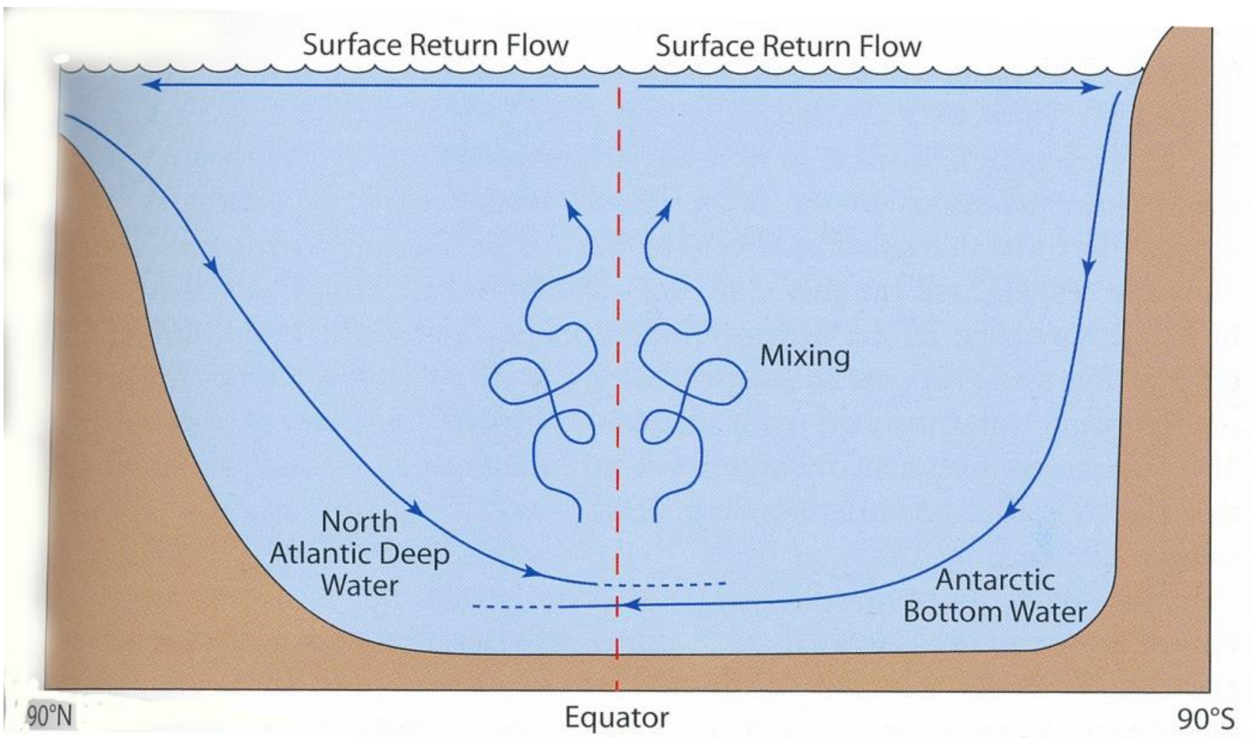
convection-current



conveyor belt

In the polar regions, the water starts to freeze and sheds salts and also becomes denser and sinks. The cold water moves along the bottom of the ocean where it ultimately meets more cold water coming from the Antarctic. Some of this is pushed upwards and mixes with the warmer water above. At the surface, this water is pushed in a northerly direction in the north and a southerly direction in the south. The north moving waters, affected by Coriolis move to the right and bring warm tropical waters across toward Europe in the Gulf Stream.

This accounts for relatively warmer climates in Europe at the same latitudes where it is colder in the US and Canada.



Polar currents

RIP CURRENTS (are not tides) Danger to swimmers who do not understand them

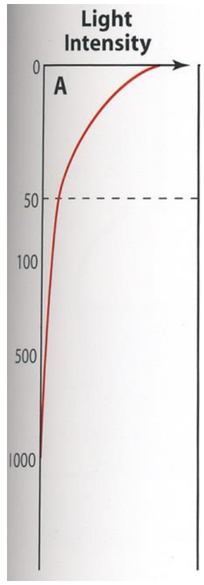
LECTURE FIVE PROBLEMS OF A TWO LAYERED OCEAN

While we have looked at how the ocean is divided into zones going out from the shore- littoral or intertidal, neritic (over the continental shelf) and pelagic (deep ocean) as well as in depth – epipelagic (Euphotic), mesopelagic (Dysphotic) Bathypelagic (aphotic) and Hadalpelagic, we have not discussed many of the changes which occur that are important in understanding how the ocean works.

WHY THIS IS IMPORTANT

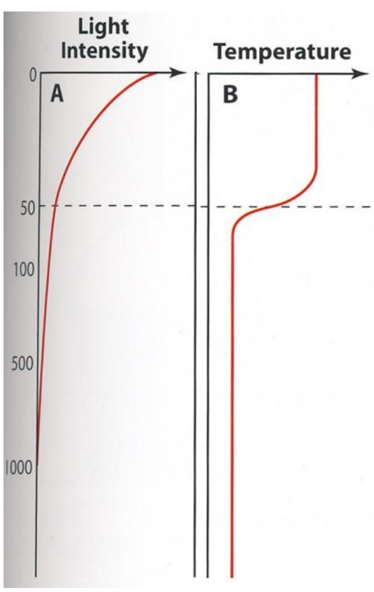
For all life on earth, the point of origin will be the organisms that are able to create their own food from either the sunlight or some chemical source. Most of this takes place through PHOTOSYNTHESIS in which water and carbon dioxide in the presence of sunlight produce sugar which ultimately turn this into energy. However nutrients are needed to move the results of the photosynthesis around the organism. There are nutrients. How this happens in the ocean needs to be understood so that it is possible to see where problems develop and how some of them are solved.

We identified the layers of light because of the ability of autotrophs that need sunlight to photosynthesize. Words like euphotic and dysphotic are based on questions of photosynthesis. Obviously the actual depth at which light fades away is a function of turbidity – how much sediment is mixed in the water. The more sediment, the less the depth to which the light can penetrate. Light clearly penetrated air much more easily that it penetrates water.



From the diagram, it is clear that light (in general) will start to fall off immediately and at about a depth pf 50 meters it is close to gone. By 1000 meters it is gone altogether.

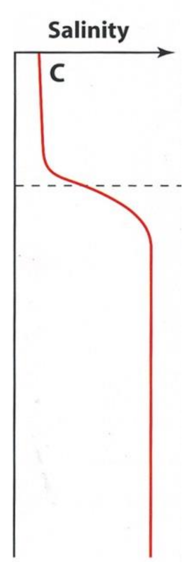
The temperature of the ocean also falls off, but in a slightly different pattern.



The temperature in the ocean from the surface to about 50 meters remains pretty constant and then suddenly becomes colder. Any place where there is this kind of "sudden" change is called a "cline". So where the temperature drops off suddenly, it is called a "thermocline".

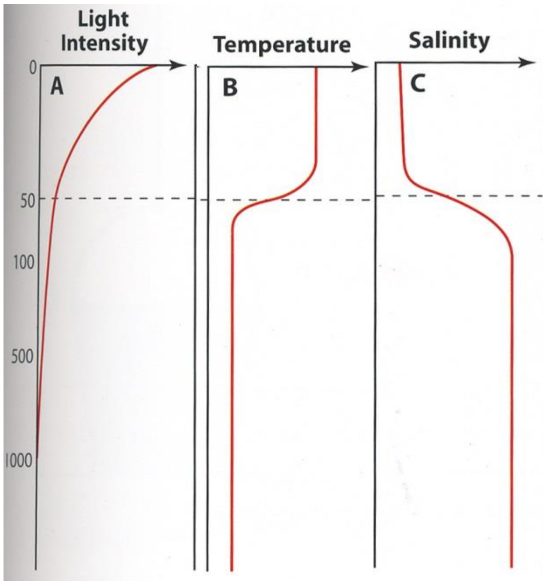
The water near the top of the ocean is heated by the sunlight and there is sufficient water movement from waves and such to keep temperatures up to 50 meters fairly constant, but at the 50 meter mark, things change and the water becomes colder. The polar current, also traveling toward the ocean bottom helps in this as well.

Salinity, or salt content is another variable to be considered.



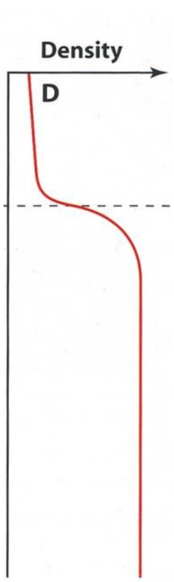
This graph shows the changes in salinity for high latitudes. In low latitudes, it reverses. Most of the processes that have an impact on salinity occur on or near the surface and have little impact on the deep levels of the ocean. In higher latitudes, melting icebergs for example, put fresh water into the ocean at the surface keeping the salinity lower. Precipitation, run off from the land, melting sea ice, sea ice forming, evaporation, all contribute to the lessening of salt in the higher latitudes and the decreasing salinity in the lower latitudes.

This "cline" is called the "halocline".

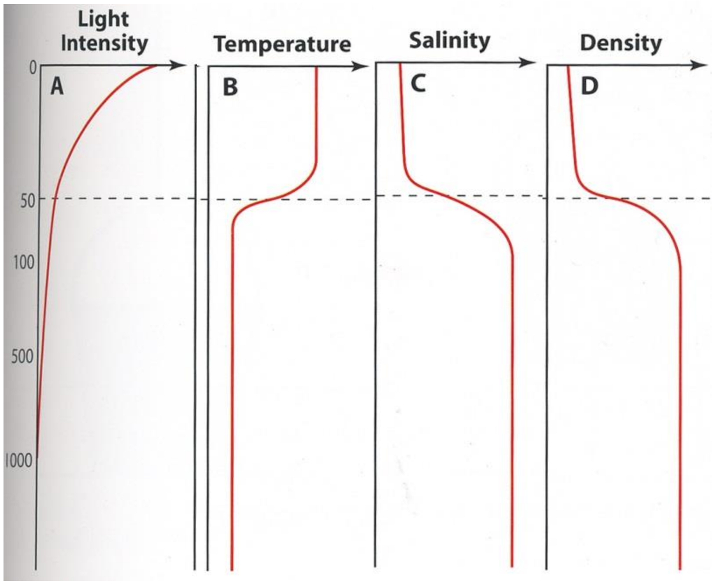


The temperature and a salinity taken together are known as thermohalocline!

Density is next and as one might expect, the deeper one does the more dense the water becomes.



The change matches quite nicely with the thermocline – colder water becomes denser.



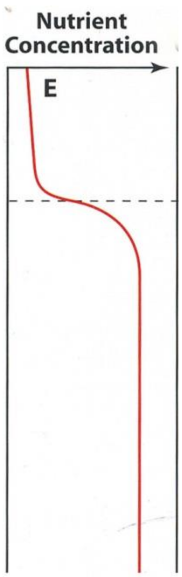
The next two measurements, nutrients and oxygen are especially important if we are considering life forms, since both are necessary for primary producers.

Nutrients may seem an odd inclusion here, because we tend to thlnk that primary producers perform photosynthesis and as a result make all the food they need, but this is not the case. In addition to the sugar produced by photosynthesis, organisms also need mineral nutrients which are defined here as "any small inorganic molecule needed for growth of phytoplankton that is not itself a reactant in photosynthesis". Since water and carbon dioxide are involved in photosynthesis, they are excluded from the definition whereas iron, nitrogen, phosphorous and silicon are not excluded.

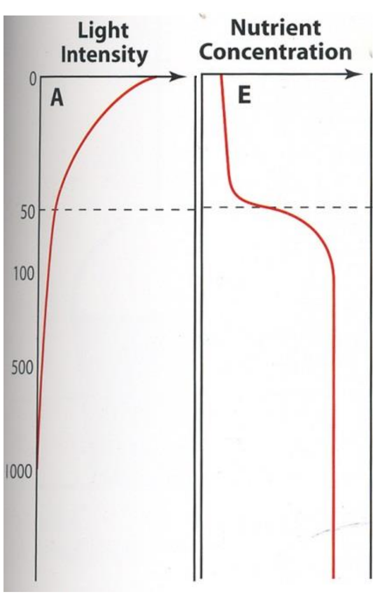
Sea water contains (a) Ammonia in the form of ammonium ion HN^{4+} a source of nitrogen; (b) Nitrate NO_3 - also a source of nitrogen; (c) Phosphate PO_4^{3-} (a source of phosphorous) (d) Silicic acid ($Si(OH)_4$. Iron is also found in the ocean.

The problems here are with nitrogen which is the "limiting factor" – the one that is least available. The problem is that nitrogen by itself is in great quantities but few organisms can use it in this form. It needs to be "fixed" – that is to be made into a form that is usable. This happens as a result of

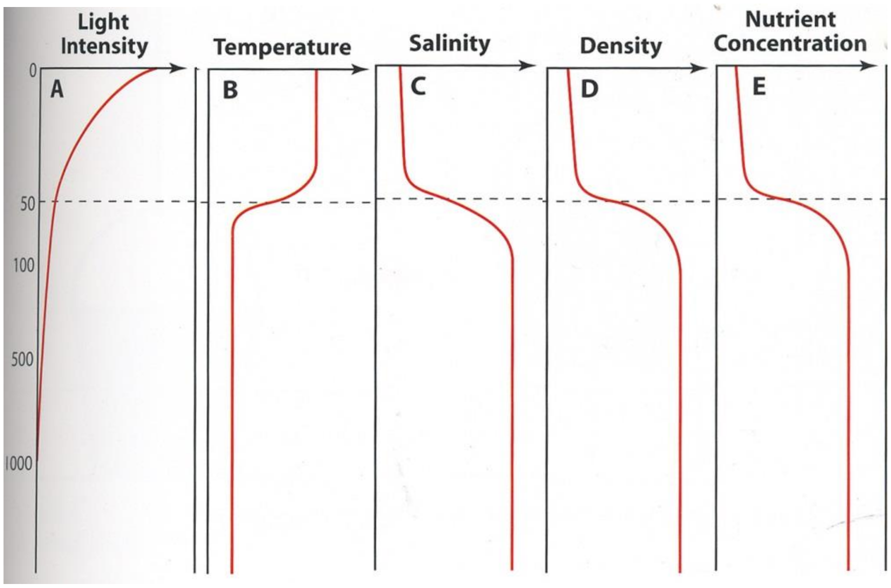
CYNOBACTERIA – a form of bacteria that is able to “fix” nitrogen so it can be used. It does this by making ammonia. What is important here is the recognition that the production of fixed nitrogen is on the ocean floor.



While some nitrogen fixing does go on, on coral reefs closer to the surface, about 85% happens in deep water.

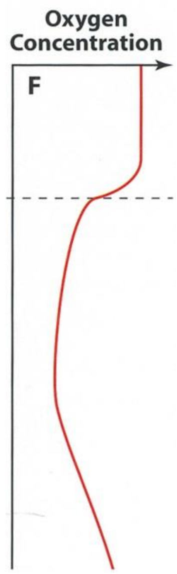


So you can see where you have light, you have little nutrients. Where you have nutrients, you have little light!



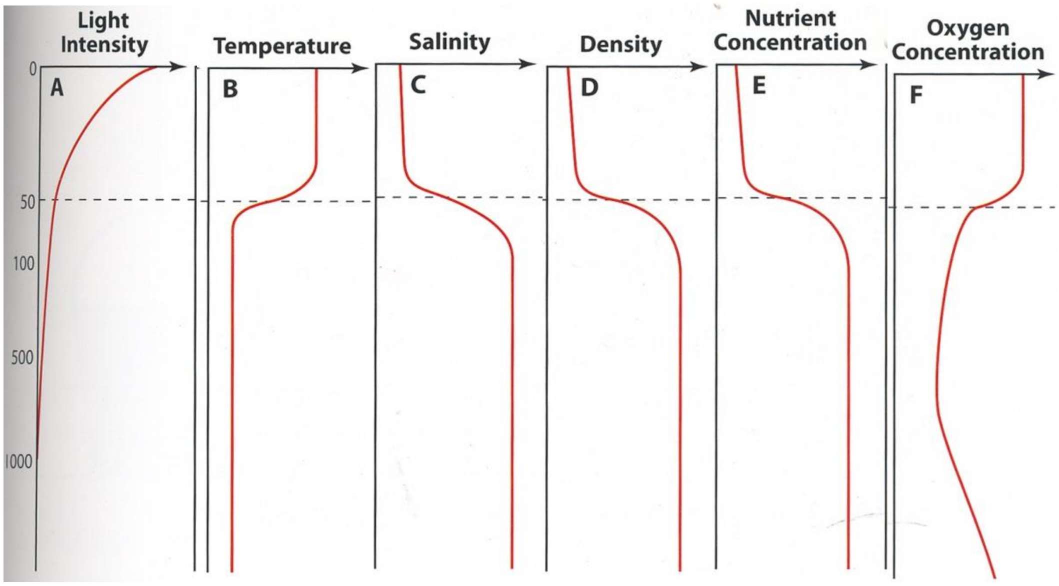
Because the upper levels are low in nutrients, photosynthetic forms have trouble growing here.

The lower level, which has the nutrients doesn't have the light needed for photosynthesis so there seems to be a real problem here. Photosynthesis requires carbon dioxide, but respiration requires oxygen. Photosynthetic organisms usually produce enough oxygen for respiration. Heterotrophs require oxygen which they do not produce. Hence it is only with the appearance of photosynthetic organisms that much life as we know it is possible. There was a time in the history of the earth where life forms did not use oxygen and there was little to no free oxygen in the world. When organisms began to produce oxygen it was lethal to many organisms and is believed in part responsible for a major extinction event. In effect, oxygen was a lethal pollutant. It is still in large quantities dangerous to animals and can be fatal. It is something divers have to worry about because in commercial diving, the amount of oxygen is changed upward from 21% (mixed gasses)



So what happens with the oxygen levels start out fairly constant, then drop off and then rebound!

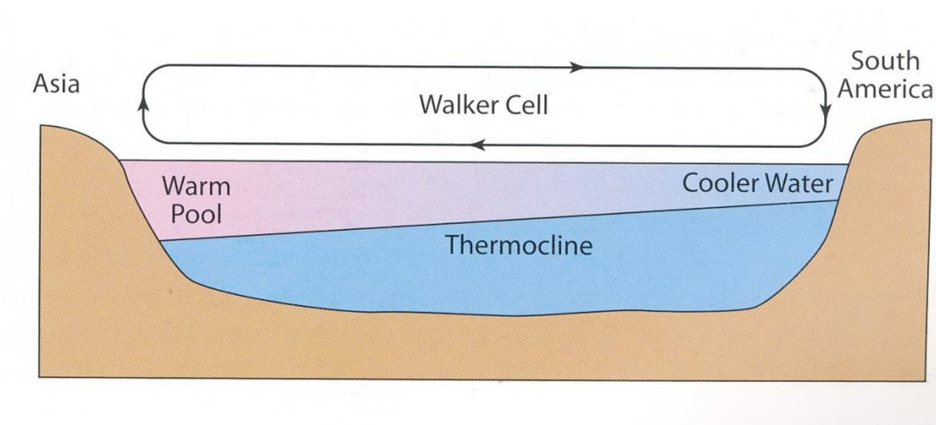
The problem here is that many of the small organisms cannot swim but are plankton. They are also negatively buoyant as adults and tend to sink slowly. As they sink, the move into the dysphotic zone and can no longer produce food and die. (Some reproduce near the surface and the young start the cycle all over again). As they (and other organisms die) they begin to decay and the bacteria that do that respire and use up the oxygen in the water. So the oxygen levels fall off. Finally we reach a level where all that can decay has basically done so. Below this level is the thermocline circulation – the cold water (aerated) moving along the bottom of the ocean. It brings more oxygen with it, raising the level of oxygen.



So the graphs all show, how there are serious changes, starting at about 50 meters and continuing down about another 50. These changes are referred to as the "thermocline" and refers to the changes in all these forms not just temperature.

Remember though, that the actual depth of the thermocline changes both seasonally and in different areas.

So how is it the oceans work at all in terms of life forms? The answer is part "upwelling". Upwelling occurs when minerals are brought up from the bottom, usually caused by a "tilt" in the thermocline.



The Walker cell of zonal winds.

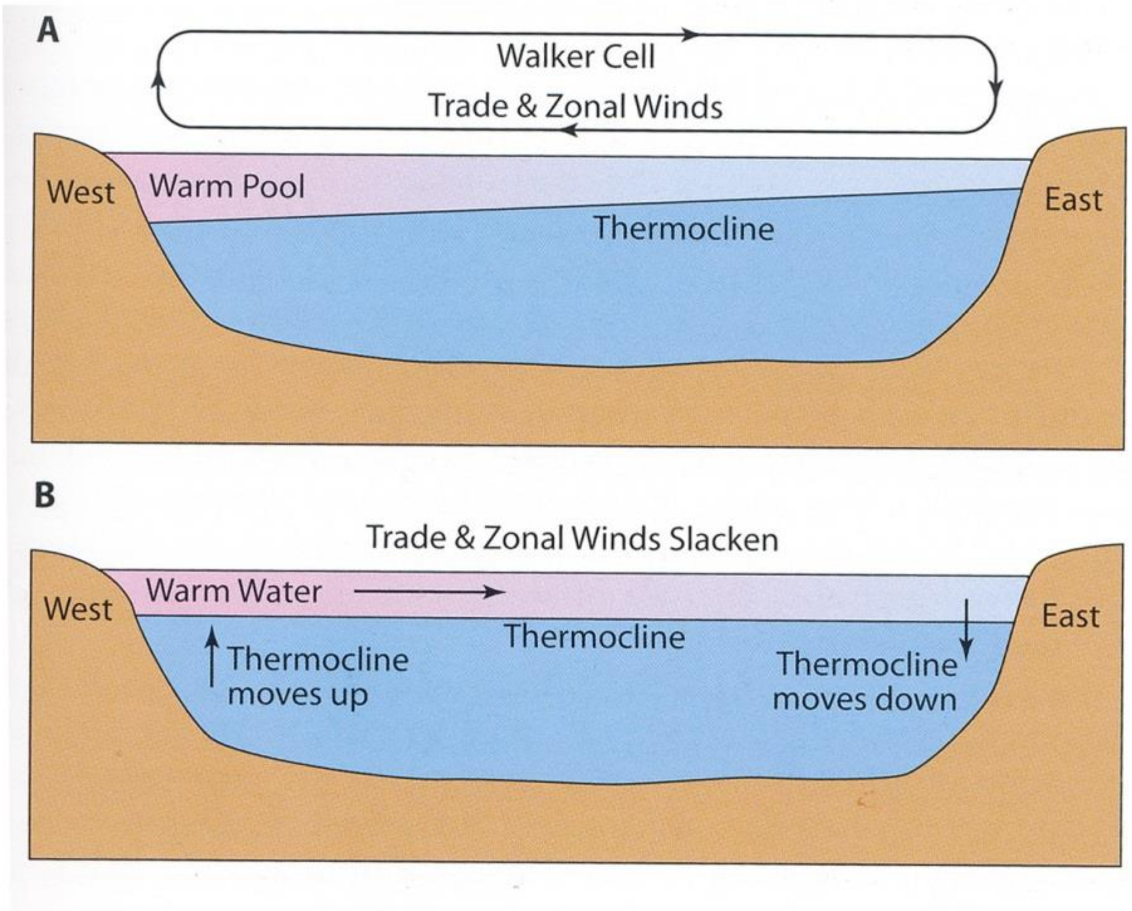
This diagram shows a “tilt” in the thermocline caused by two pressures of air and the Walker Cell (the cell in which the winds move from east to west here) – one low pressure in Asia and one corresponding high pressure in South America. As a result of a pressure differential, air flows from an area of high pressure (over South America) towards one of low pressure (over Asia). This flow of air moves water from the eastern Pacific (SA) towards the western Pacific causing water to begin to “pile up” in the western part. This depresses the thermocline so there is a “tilt” in which the thermocline is deeper in the west than the east.

The warm water in the west heats the air and causes it to rise, whereas cooling air descends over SA and cools the water. Ultimately, the temperatures will start to even off and more and more cool water moves west. This will ultimately cause a stoppage in the Walker cell circulation and a reversal of direction.

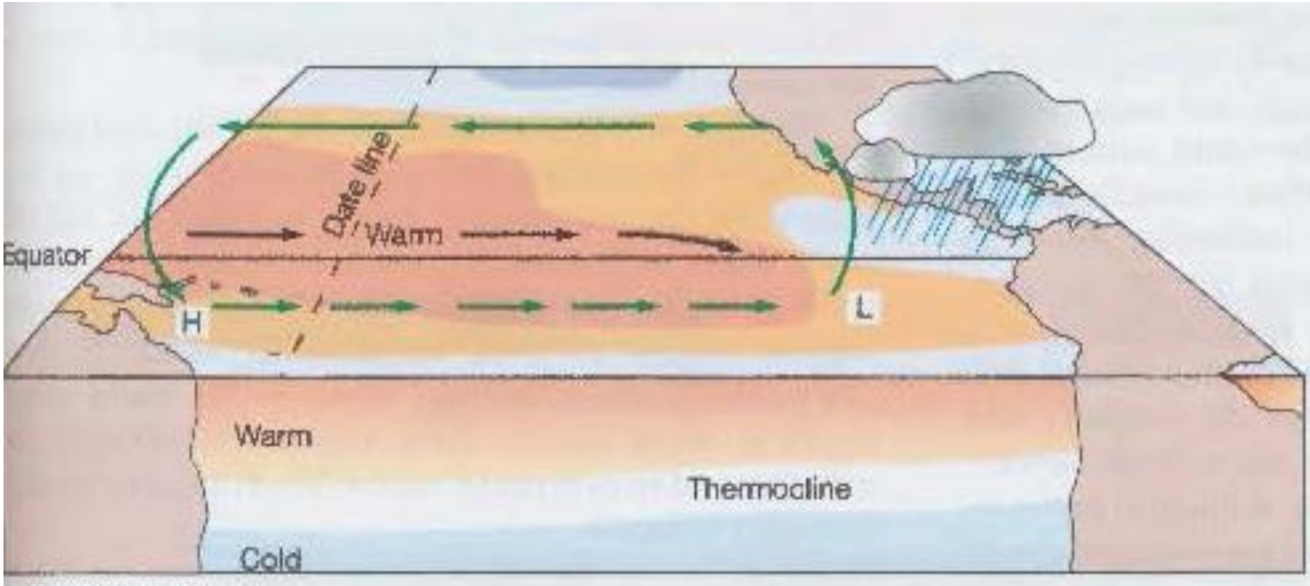
Whether the air or the water is the primary cause is fought about. But the change is not.

When the water moved along the bottom from west to east it finally encounters the shore of SA and must move both up and then north and south (along with the thermocline), which is what it does. The movement up, brings nutrients up from the bottom to the surface and all is well. We now have nutrients and sunlight both at the surface.

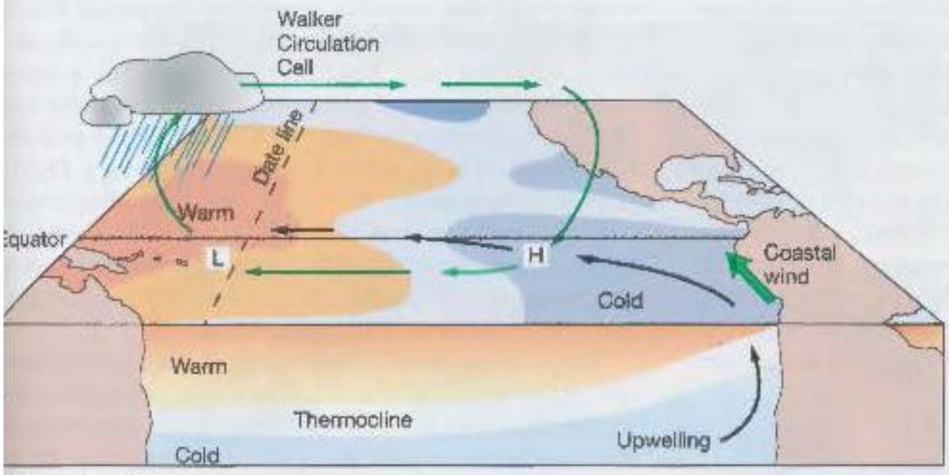
Once the change happens and the winds and water reverse direction, the thermocline that was higher in the east, now begins to descend and the upwelling slows or comes to a halt.



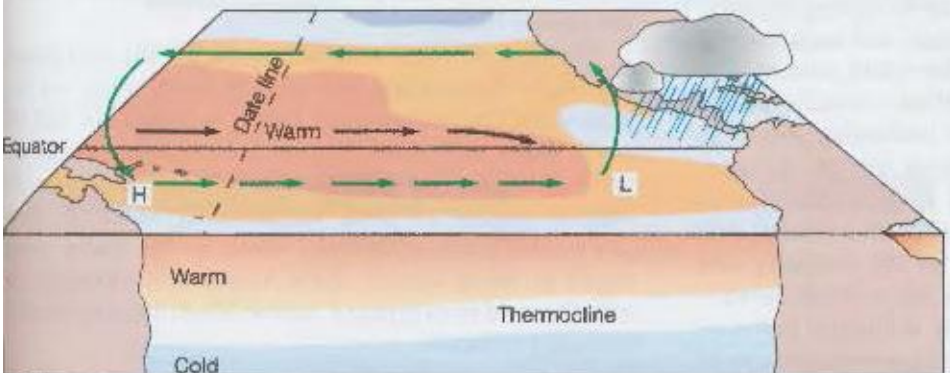
This shift between high and low pressure and rising and falling thermoclines was known to both meteorologists and oceanographers for quite some time. One group referred to it as the "Southern Oscillation" the other as "El Niño". Now that it has been realized this is the same phenomenon it tends to be referred to as "ENSO" (short for "**E**l **N**iño **S**outhern **O**scillation")



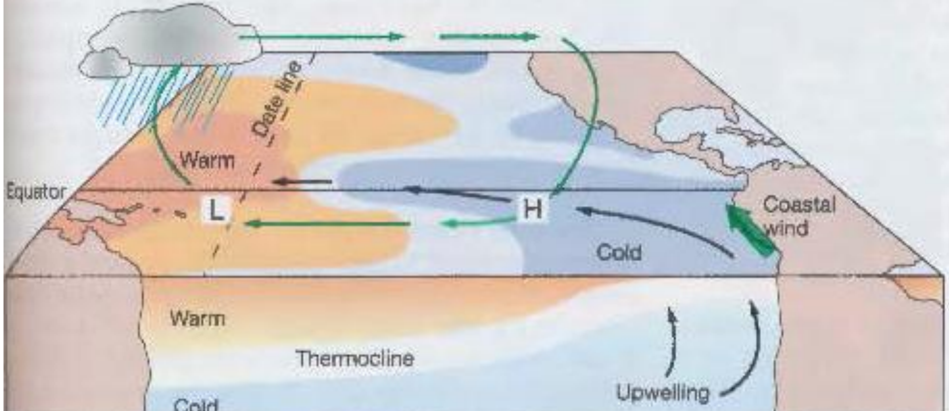
b) El Niño conditions



a) Normal conditions



b) El Niño conditions



(c) La Niña conditions

Similar oscillations happen in the Atlantic as well. The most well known perhaps is the one in the Indian Ocean which causes the Monsoons, although the processes here is a bit different.

The Indian Ocean lies largely in the Southern hemisphere, unlike the Atlantic and Pacific both of which are divided into a Northern and Southern half. This is largely because the currents in the Northern and Southern parts of the ocean have differing currents, thanks to the Coriolis Effect.

In the Indian Ocean, there is a huge land mass sitting in the Northern hemisphere. This heats and cools at a different rate than the waters of the Indian Ocean. In winter, (October to April) cold heavy air sits over the continent and lighter warm moist air rises over the ocean. The pressure gradient brings the winds from Northeast the land onto the ocean. This is sometimes called “the dry monsoon”.As summer appears (from May until Sept.) and the land mass begins to warm, the air from the Southwest over the land begins to rise and the air now moves in from the ocean bringing the heavily water laden air which produces tremendous rainfall as it moves over the continent. This is the “wet monsoon” or more frequently just called “the monsoon”

So as we can see, the ocean and the atmosphere operate together to bring very different kinds of weather around the world at different times of the year.