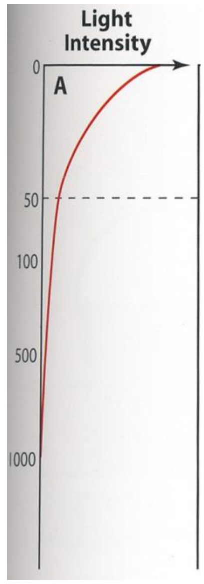
PROBLEMS OF A TWO LAYERED OCEAN

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

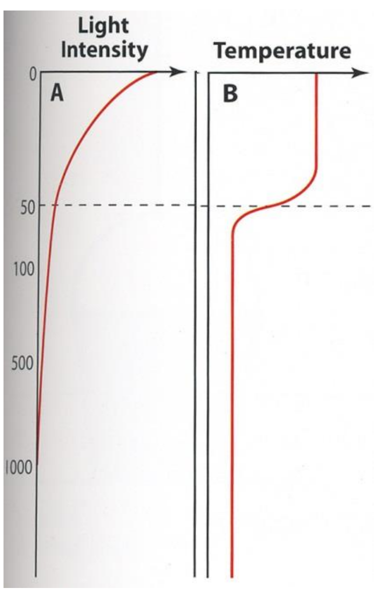
For all life on earth, the point of origin will be the organisms that are able to create their own food from either the sunlight or some chemical source. Most of this takes place through PHOTOSYNTHESIS in which water and carbon dioxide in the presence of sunlight produce sugar which ultimately turn this 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.

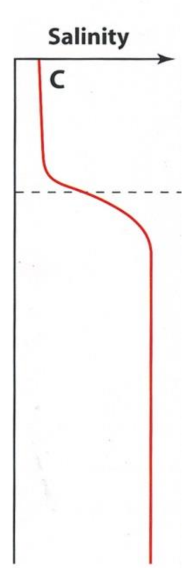
The temperature of the ocean also falls off, but in a slightly different pattern.



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”.

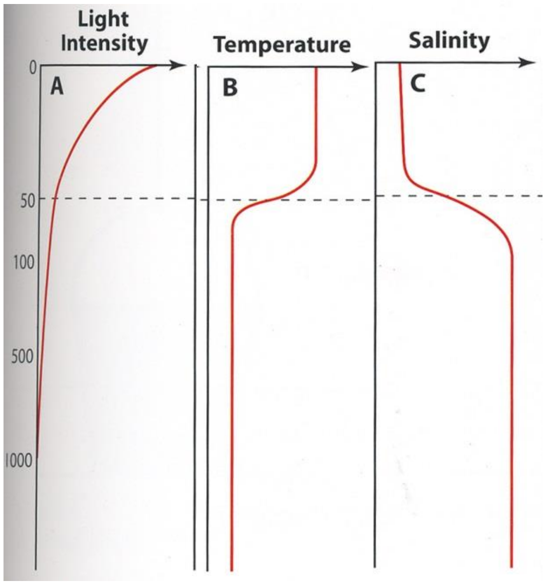
The water near the top of the ocean is heated by the sunlight and there is sufficient water movement from waves and such to keep temperatures up to 50 meters fairly constant, but at the 50 meter mark, things change and the water becomes colder. The polar current, also traveling toward the ocean bottom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

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



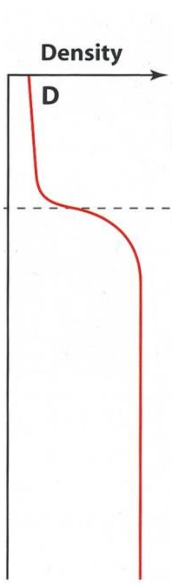
This graph shows the changes in salinity for high latitudes. In low latitudes, it reverses. Most of the processes that have an impact on salinity occur on or near the surface and have little impact on the deep levels of the ocean. In higher latitudes, melting icebergs for example, put fresh water into 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”.

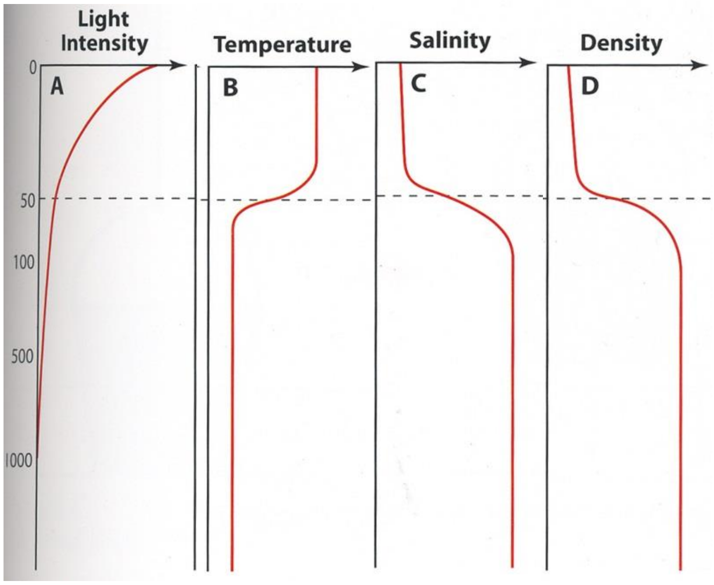


The temperature and a salinity taken together are known as thermohalocline!

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.

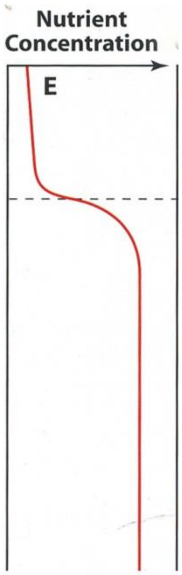


The next two measurements, nutrients and oxygen are especially important if we are considering life forms, since both are necessary for primary producers.

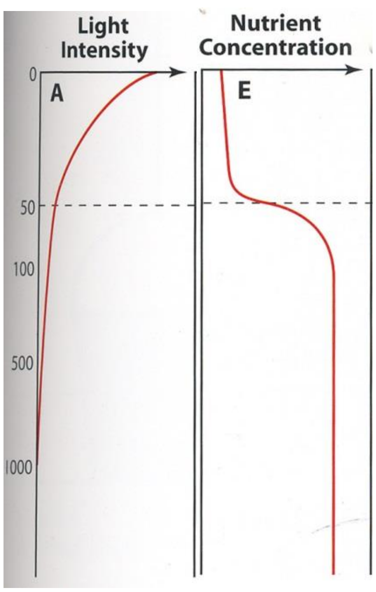
Nutrients may seem an odd inclusion here, because we tend to thlnk that primary producers perform photosynthesis and as a result make all the food they need, but this is not the case. In addition to the sugar produced by photosynthesis, organisms also need mineral nutrients which are defined here as "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.

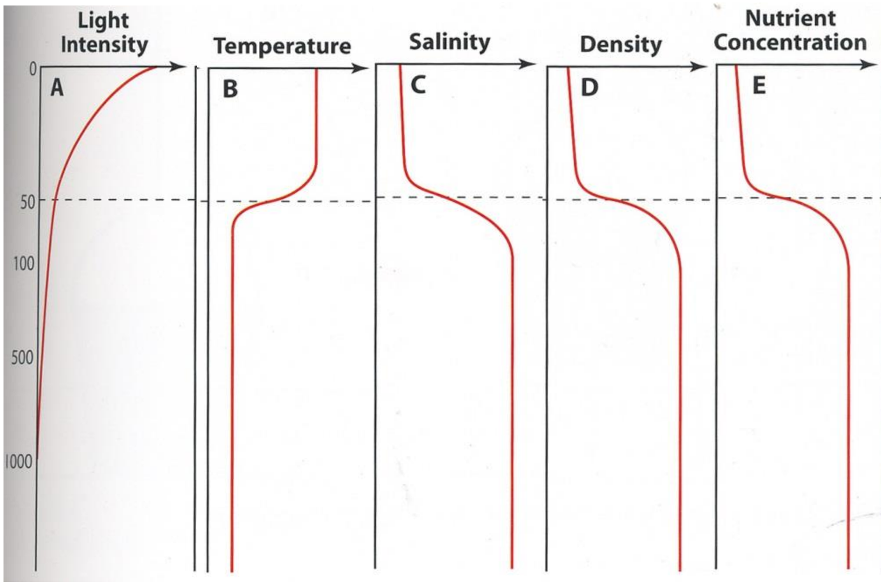
The problems here are with nitrogen which is the "limiting factor" – the one that is least available. The problem is that nitrogen by itself is in great quantities but few organisms can use it in this form. It needs to be "fixed" – that is to be made into a form that is usable. This happens as a result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

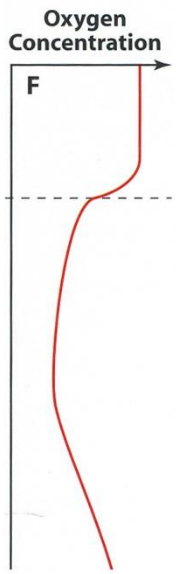


So you can see where you have light, you have little nutrients. Where you have nutrients, you have little light!



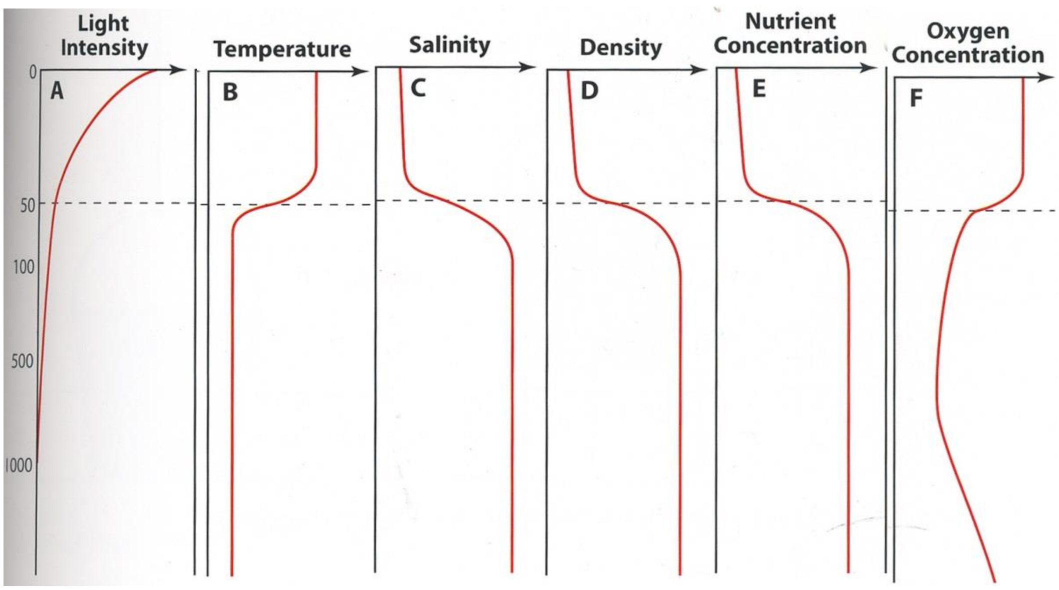
Because the upper levels are low in nutrients, photosynthetic forms have trouble growing here.

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!

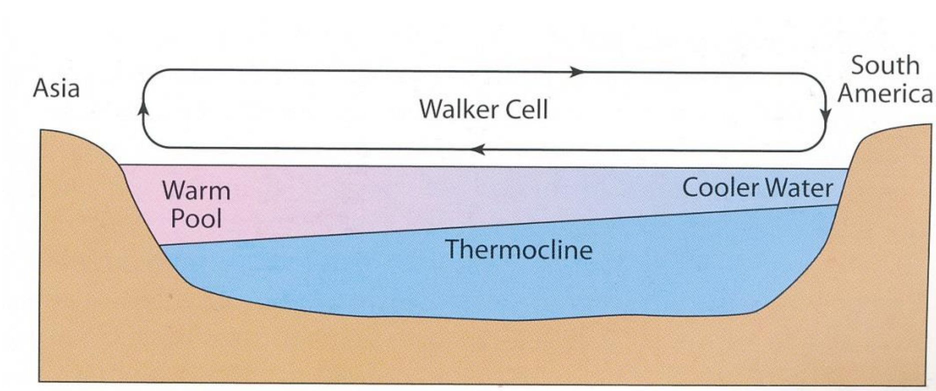
The problem here is that many of the small organisms cannot swim but are plankton. They are also negatively buoyant as adults and tend to sink slowly. As they sink, the move into the dysphotic zone and can no longer produce food and die. (Some reproduce near the surface and the young start the cycle 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.

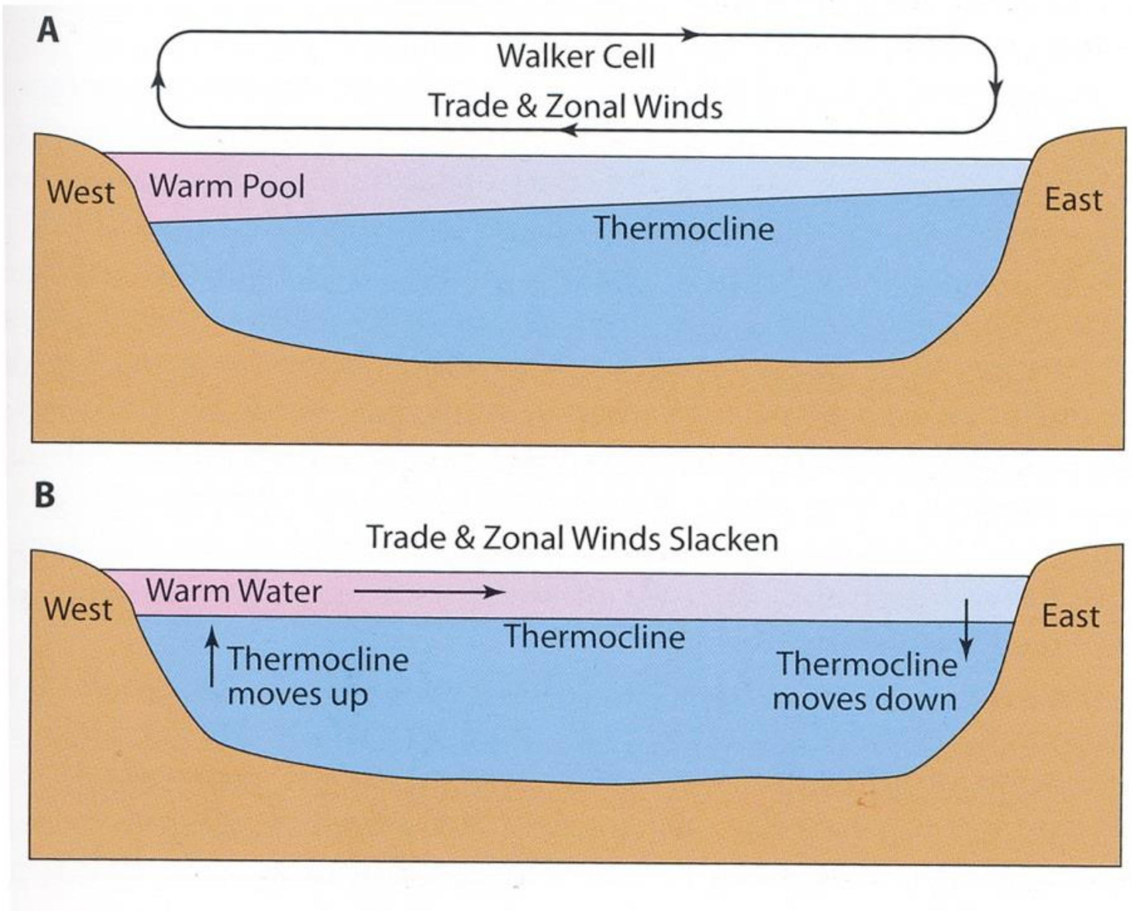
This diagram shows a “tilt” in the thermocline caused by two pressures of air and the Walker Cell (the cell in which the winds move from east to west here) – one low pressure in Asia and one corresponding high pressure in South America. As a result of a pressure differential, air flows from an area of 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.

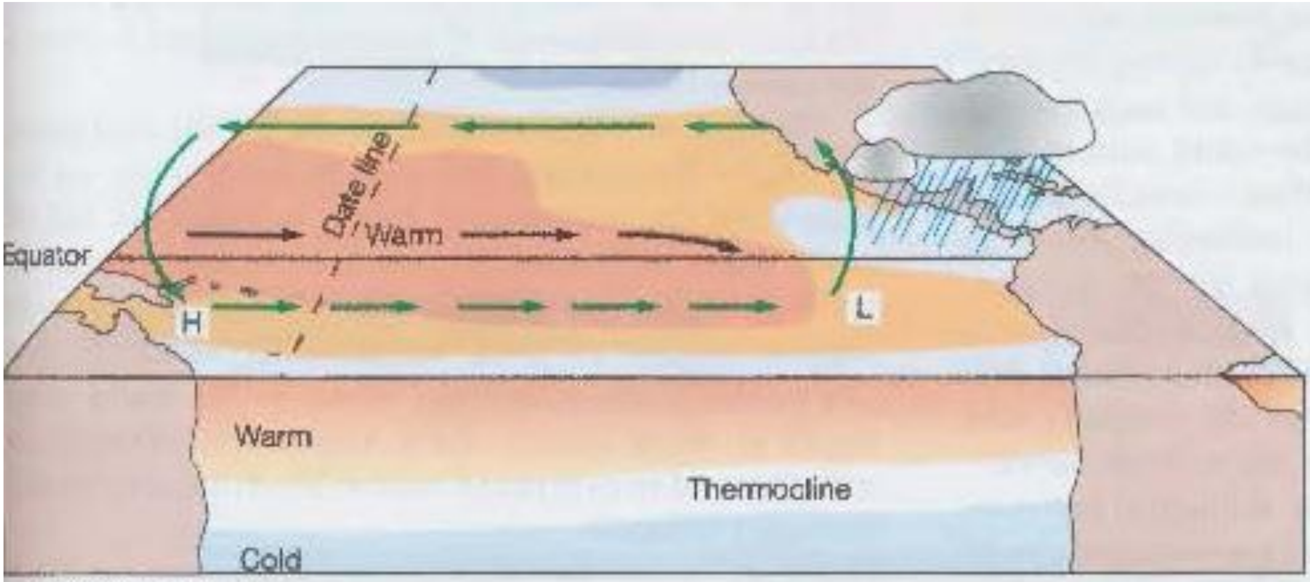
Whether the air or the water is the primary cause is fought about. But the change is not.

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.

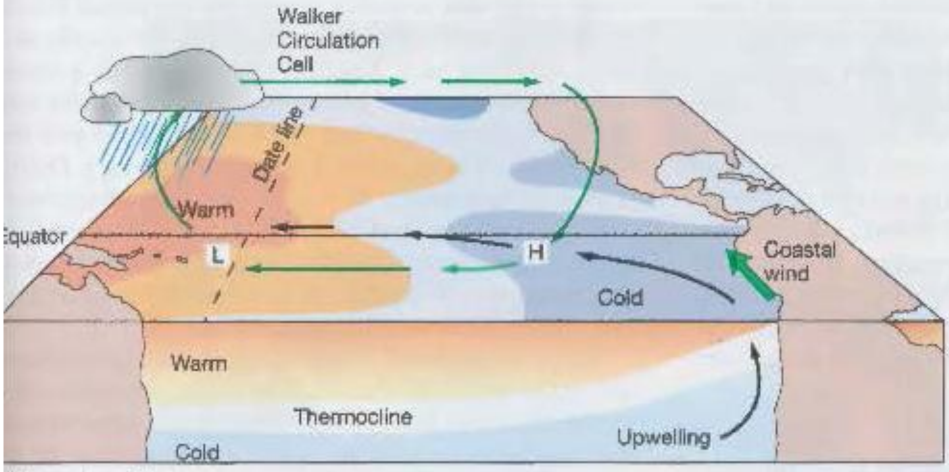
Once the change happens and the winds and water reverse direction, the thermocline that was higher in the east, now begins to descend and the upwelling slows or comes to a halt.



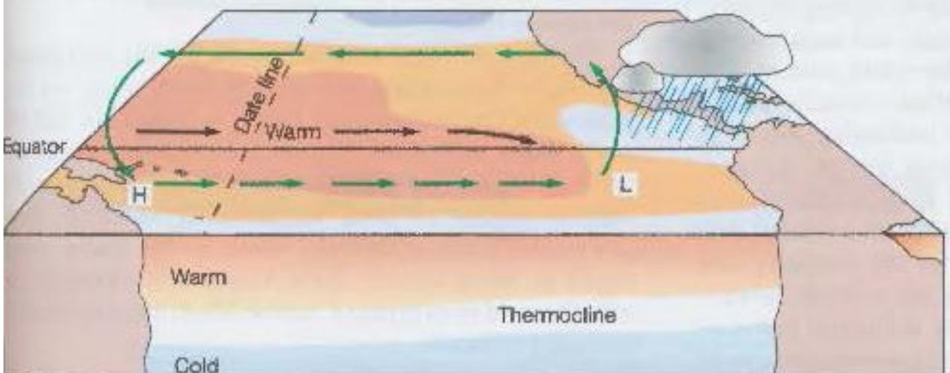
This shift between high and low pressure and rising and falling thermoclines was known to both meteorologists and oceanographers for quite some time. One group referred to it as the "Southern Oscillation" the other as "El Niño". Now that it has been realized this is the same phenomenon it tends to be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



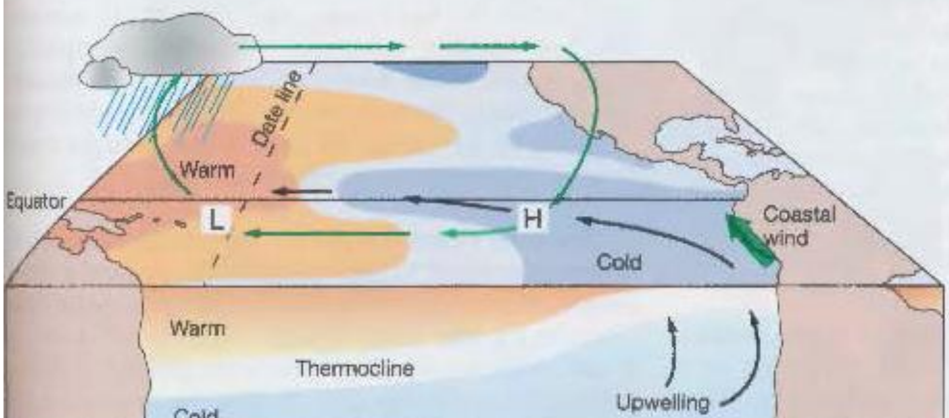
b) El Niño conditions



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.