EENS 3050	Natural Disasters
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The Ocean-Atmosphere System

This document last updated on 14-Nov-2016

The Ocean-Atmosphere System

The oceans and the atmosphere are the two large reservoirs of water in the Earth's hydrologic cycle. The two systems are complexly linked to one another and are responsible for Earth's weather and climate. The oceans help to regulate temperature in the lower part of the atmosphere. The atmosphere is in large part responsible for the circulation of ocean water through waves and currents. In this section we first look at how the atmosphere controls weather and climate, and we will explore some the introductory material necessary to understand our upcoming lectures on severe weather.

Weather and Climate

Weather is the condition of the atmosphere at a particular time and place. It refers to such conditions of the local atmosphere as temperature, atmospheric pressure, humidity (the amount of water contained in the atmosphere), precipitation (rain, snow, sleet, & hail), and wind velocity. Because the amount of heat in the atmosphere varies with location above the Earth's surface, and because differing amounts of heat in different parts of the atmosphere control atmospheric circulation, the atmosphere is in constant motion. Thus, weather is continually changing in a complex and dynamic manner.

Climate refers to the average weather characteristics of a given region. Climate, although it does change over longer periods of geologic time, is more stable over short periods of time like years and centuries. The fact that the Earth has undergone fluctuation between ice ages and warmer periods in the recent past (the last ice age ended about 10,000 years ago) is testament to the fact that climate throughout the world as has been changing through time.

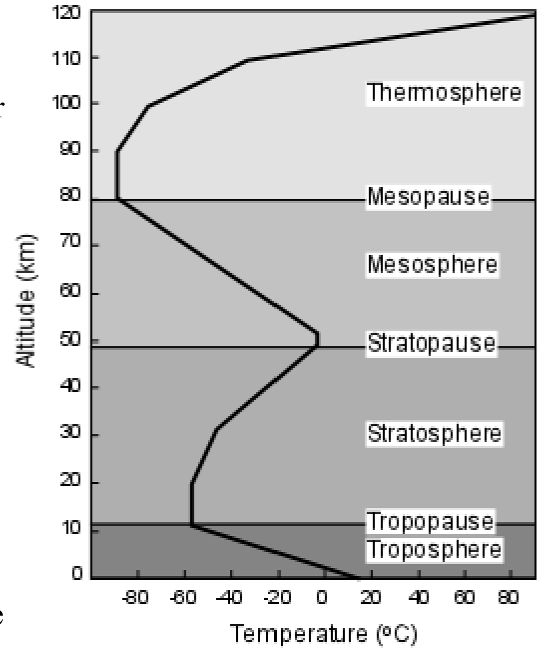
The Earth's weather and climate system represent complex interactions between the oceans, the land, the sun, and the atmosphere. That these interactions are complex is evidence by the difficulty meteorologists have in predicting weather on a daily basis. Understanding climate change is even more difficult because humans have not been around long enough to record data on the long term effects of these processes. Still, we do know that the main energy source for changing weather patterns and climate is solar energy from the Sun.

The Atmosphere

Earth's atmosphere consists of a mixture of Nitrogen (N_2) and Oxygen (O_2). At the Earth's surface, dry air is composed of about 79% Nitrogen, 20% Oxygen, and 1% Argon. It can also contain up to 4% water vapor at saturation, but saturation depends on temperature.

Relative humidity is the term used to describe saturation with water vapor. When the relative humidity is 100%, the atmosphere is saturated with respect to water vapor, and precipitation results. Other gases occur in the atmosphere in small amounts. Among the most important of these other gases is Carbon Dioxide (CO_2).

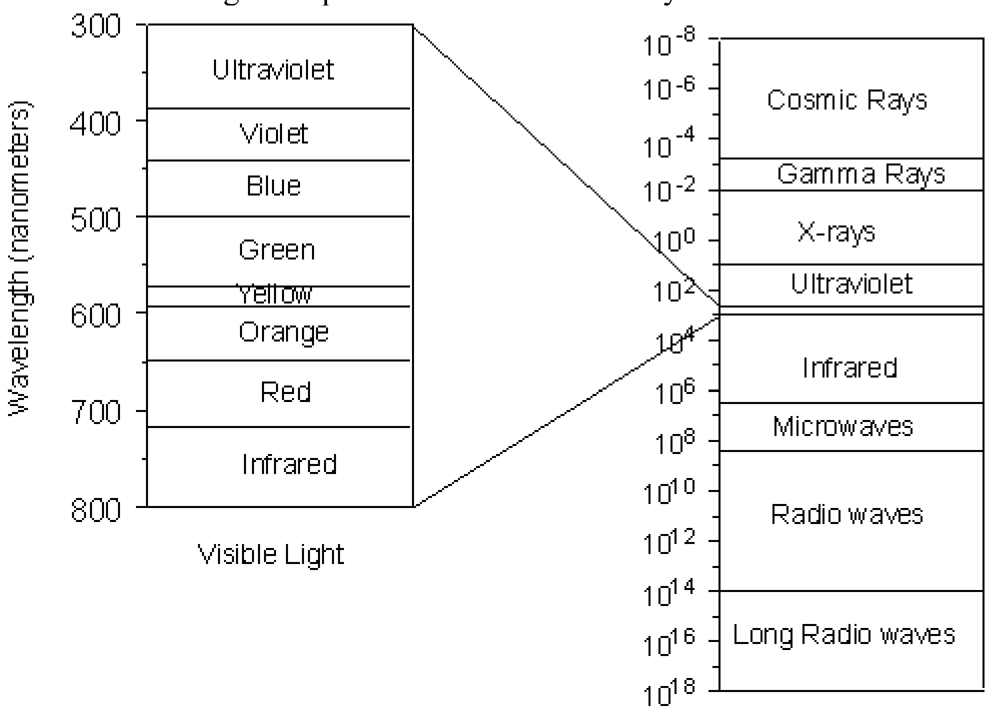
The atmosphere has a layered structure, as shown here. Each layer is defined on the basis of properties such as pressure, temperature, and chemical composition. The layer closest to the surface is called the troposphere, which extends to an altitude of 10 to 15 km. Temperature decreases upward in the troposphere to the tropopause (the boundary between the troposphere and the next layer up, the stratosphere). The troposphere contains about 90% of the mass of the atmosphere, including nearly all of the water vapor. Weather is controlled mostly in the troposphere.



After Murck et al. (1997)

Solar Radiation and the Atmosphere

Radiation reaching the Earth from the Sun is electromagnetic radiation. Electromagnetic radiation can be divided into different regions depending on wavelength. Note that visible light is the part of the electromagnetic spectrum to which human eyes are sensitive.



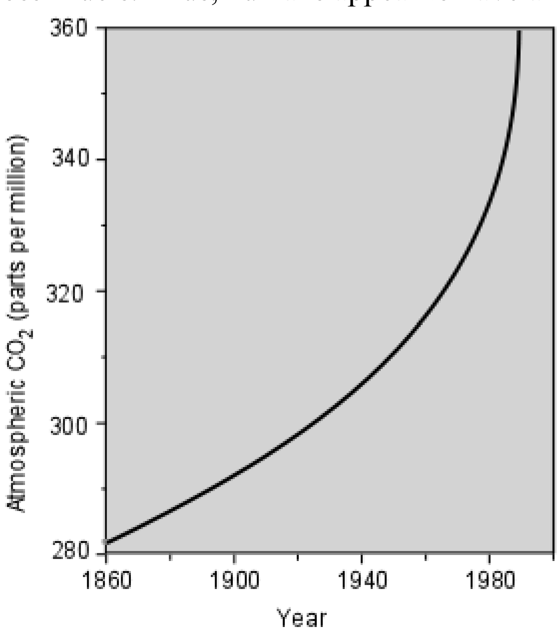
- Earth receives all wavelengths of solar radiation. But certain gases and other contaminants in the atmosphere have different effects on different wavelengths of radiation.

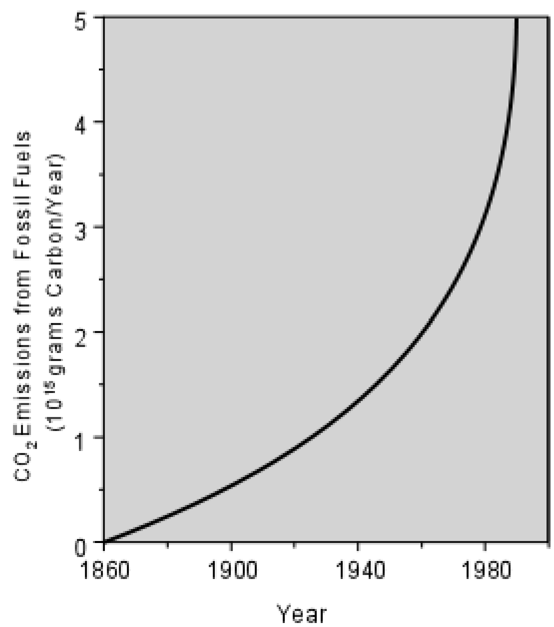
- Dry air is composed of about 79% Nitrogen, 20% oxygen, and 1% Argon. It also contains water, 4% at saturation, but saturation depends on temperature. In addition trace gases have an effect, the most important of which are the greenhouse gases.

Greenhouse Gases

Energy coming from the Sun is carried by electromagnetic radiation. Some of this radiation is reflected back into space by clouds and dust in the atmosphere. The rest reaches the surface of the Earth, where again it is reflected by water and ice or absorbed by the atmosphere. Greenhouse gases in the atmosphere absorb some of the longer wavelength (infrared) radiation and keep some of it in the atmosphere. This keeps the atmospheric temperature relatively stable so long as the concentration of greenhouse gases remains relatively stable, and thus, the greenhouse gases are necessary for life to exist on Earth.

The most important green house gases are H_2O (water vapor), CO_2 (Carbon Dioxide), CH_4 (methane), and Ozone. H_2O is the most abundant greenhouse gas, but its concentration in the atmosphere varies with temperature. Venus, which has mostly CO_2 in its atmosphere, has temperature of about 500^{o}C (also partly due to nearness to Sun). The CO_2 concentration in the atmosphere has been increasing since the mid 1800s. The increase correlates well with burning of fossil fuels. Thus, humans appear to have an effect.





Methane concentration in the atmosphere has also been increasing. Naturally this occurs due to decay of organic matter, the digestive processes of organisms, and leaks from petroleum reservoirs. Humans have contributed through domestication of animals, increased production of rice, and leaks from gas pipelines and gasoline.

Volcanic Effects

Volcanoes produce several things that result in changing atmosphere and atmospheric temperatures.

1. CO_2 produced by volcanoes adds to the greenhouse gases and may result in warming of the atmosphere.

2. Sulfur gases produced by volcanoes reflect low wavelength radiation back into space, and thus result in cooling of the atmosphere.

3. Dust particles injected into the atmosphere by volcanoes reflect low wavelength radiation back into space, and thus can result in cooling of the atmosphere.

4. Chlorine gases produced by volcanoes can contribute to ozone depletion in the upper atmosphere.

The Mt. Pinatubo eruption in 1991 and El Chichón eruption in 1981 released large quantities of dust and sulfur gases - resulted in short term cooling of atmosphere.

Volcanism in the middle Cretaceous produced large quantities of basalt on the seafloor and released large amounts of CO_2. The middle Cretaceous was much warmer than present, resulting in much higher sea level.

The Carbon Cycle

In order to understand whether or not humans are having an effect on atmospheric carbon concentrations, we must look at how carbon moves through the environment. Carbon is stored in four main reservoirs.

1. In the atmosphere as CO_2 gas. From here it exchanges with seawater or water in the atmosphere to return to the oceans, or exchanges with the biosphere by photosynthesis, where it is extracted from the atmosphere by plants. CO_2 returns to the atmosphere by respiration from living organisms, from decay of dead organisms, from weathering of rocks, from leakage of petroleum reservoirs, and from burning of fossil fuels by humans.

2. In the hydrosphere (oceans and surface waters) as dissolved CO_2. From here it precipitates to form chemical sedimentary rocks, or is taken up by organisms to enter the biosphere. CO_2 returns to the hydrosphere by dissolution of carbonate minerals in rocks and shells, by respiration of living organisms, by reaction with the atmosphere, and by input from streams and groundwater.

3. In the biosphere where it occurs as organic compounds in organisms. CO_2 enters the biosphere mainly through photosynthesis. From organisms it can return to the atmosphere by respiration and by decay when organisms die, or it can become buried in the Earth.

4. In the Earth's lithosphere as carbonate minerals, graphite, coal, petroleum. From here it can return to the atmosphere by weathering, volcanic eruptions, hot springs, or by human extraction and burning to produce energy.

Cycling between the atmosphere and the biosphere occurs about every 4.5 years. Cycling between the other reservoirs probably occurs on an average of millions of years.

For example, carbon stored in the lithosphere in sedimentary rocks or as fossil fuels only reenters the atmosphere naturally when weathering and erosion expose these materials to the Earth's surface. When humans extract and burn fossil fuels the process occurs much more rapidly than it would occur by natural processes. With an increased rate of cycling between the lithosphere and the atmosphere, extraction from the atmosphere by increased interaction with the oceans, or by increased extraction by organisms must occur to balance the input. If this does not occur, it may result in global warming.

Global Warming

Average global temperatures vary with time as a result of many processes interacting with each other. These interactions and the resulting variation in temperature can occur on a variety of time scales ranging from yearly cycles to those with times measured in millions of years. Such variation in global temperatures is difficult to understand because of the complexity of the interactions and because accurate records of global temperature do not go back more than 100 years. But, even if we look at the record for the past 100 years, we see that overall, there is an increase in average global temperatures, with minor setbacks that may have been controlled by random events such as volcanic eruptions. Records for the past 100 years indicate that average global temperatures have increased by about 0.8^{o}C. While this may not seem like much, the difference in global temperature between the coldest period of the last glaciation and the present was only about 5^{o}C.

In order to predict future temperature changes we first need to understand what has caused past temperature changes. Computer models have been constructed to attempt this. Although there is still some uncertainty, most of these models agree that if the greenhouse gases continue to accumulate in the atmosphere until they have doubled over their pre-1860 values, the average global temperature increase will be between 1 and 5^{o}C by the year 2100.

This is not a uniform temperature increase. Most models show that the effect will be greatest at high latitudes (near the poles) where yearly temperatures could be as much as 16^{o}C warmer than present.

Effects of Global Warming

Among the effects of global warming are:

- Global Precipitation changes - A warmer atmosphere leads to increased evaporation from surface waters and results in higher amounts of precipitation. Equatorial regions will be wetter than present, while interior portions of continents will become warmer and drier than present.

- Changes in vegetation patterns - because rainfall is distributed differently, vegetation will have to adjust to the new conditions. Mid latitude regions become more drought prone, while higher latitude regions become wetter and warmer, resulting in a shift in agricultural patterns.

- Increased storminess - A warmer, wetter atmosphere favors tropical storm development. Tropical Cyclones will be stronger and more frequent.

- Changes in Ice patterns - Due to higher temperatures, ice in mountain glaciers will melt. This is now being observed. But, because more water will be evaporated from the oceans, more precipitation will reach the polar ice sheets causing them to grow.

- Reduction of sea ice - Sea ice is greatly reduced due to higher temperatures at the high latitudes, particularly in the northern hemisphere where there is more abundant sea ice. This is now being observed. Ice has a high albedo (reflectivity), and thus reduction of ice will reduce the albedo of the Earth and less solar radiation will be reflected back into space, thus enhancing the warming effect.

- Thawing of frozen ground - Currently much of the ground at high latitudes remains frozen all year. Increased temperatures will cause much of this ground to thaw. Organic compounds in the frozen ground will be subject to decay, releasing more methane into the atmosphere and enhancing the greenhouse effect. Ecosystems and human structures currently built on frozen ground will have to adjust.

- Rise of sea level - Warming the oceans results in expansion of water and thus increases the volume of water in the oceans. Along with melting of mountain glaciers and reduction in sea ice, this will cause sea level to rise and flood coastal zones.

- Changes in the hydrologic cycle - With new patterns of precipitation changes in stream flow and groundwater level will be expected.

- Decomposition of organic matter in soil - With increasing temperatures of the atmosphere the rate of decay of organic material in soils will be greatly accelerated. This will result in release of CO_2 and methane into the atmosphere and enhance the greenhouse effect.

- Breakdown of gas hydrates - This is basically solid water with gas molecules like methane locked into the crystal structure. They occur in oceanic sediments and beneath frozen ground at the high latitudes. Warming of the oceans or warming of the soil at high lattitudes could cause melting of the gas hydrates which would release methane into the atmosphere. Since methane is a greenhouse gas, this would cause further global warming.

Climate Change

Because human history is so short compared to the time scales on which global climate change occurs, we do not completely understand the causes. However, we can suggest a few reasons why climates fluctuate.

- Long term variations in climate (tens of millions of years) on a single continent are likely caused by drifting continents. If a continent drifts toward the equator, the climate will become warmer. If the continent drifts toward the poles, glaciations can occur on that continent.

- Short-term variations in climate are likely controlled by the amount of solar radiation reaching the Earth. Among these are astronomical factors and atmospheric factors.

    - Astronomical Factors -

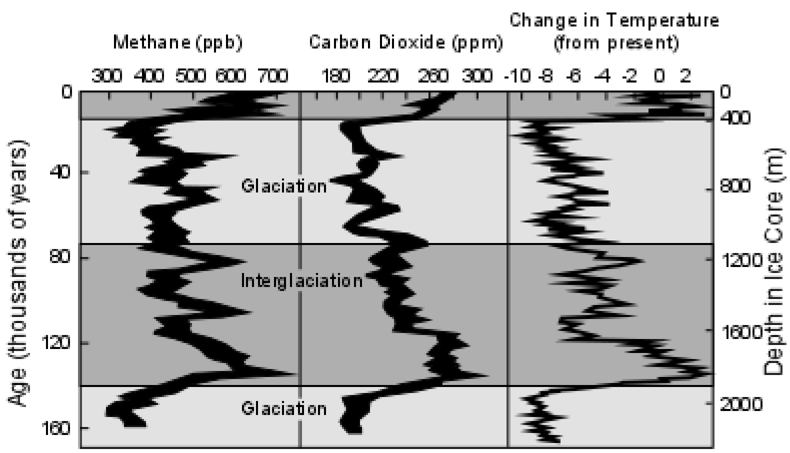
- Variation in the eccentricity of the Earth's orbit around the sun has periods of about 400,0000 years and 100,000 years.

- Variation in the tilt of the Earth's axis has a period of about 41,000 years.

- Variation in the way the Earth wobbles on its axis, called precession, has a period of about 23,000 years.

- The combined effects of these astronomical variations results in periodicities similar to those observed for glacial - interglacial cycles.

- Atmospheric Factors- the composition of the Earth's atmosphere can be gleaned from air bubbles trapped in ice in the polar ice sheets. Studying drill core samples of such glacial ice and their contained air bubbles reveals the following:
  - During past glaciations, the amount of CO_2 and methane, both greenhouse gasses that tend to cause global warming, were lower than during interglacial episodes.



After Skinner & Porter (1993)

  - During past glaciations, the amount of dust in the atmosphere was higher than during interglacial periods, thus more heat was likely reflected from the Earth's atmosphere back into space.

  - The problem in unraveling what this means comes from not being able to understand if low greenhouse gas concentration and high dust content in the atmosphere caused the ice ages or if these conditions were caused by the ice ages.

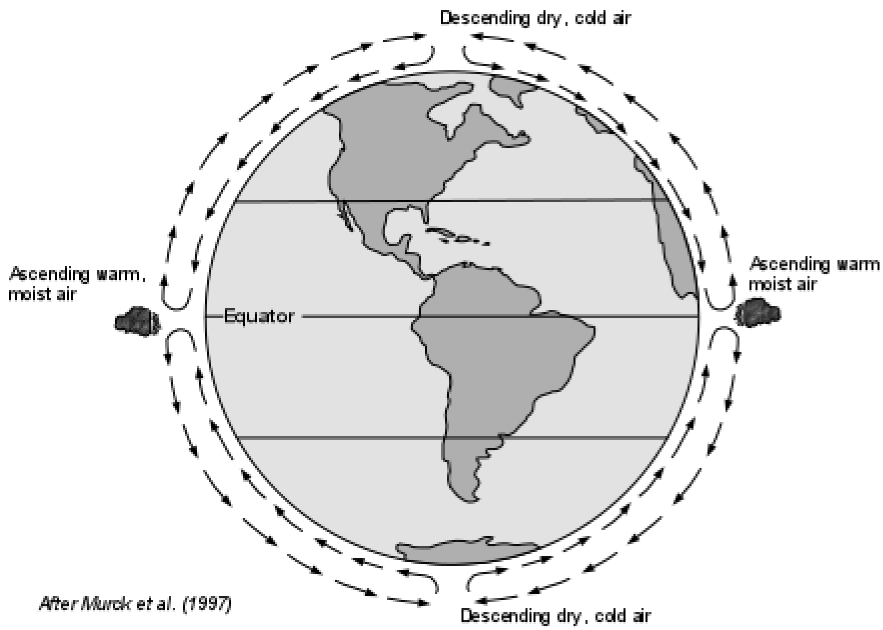
- Changes in Oceanic Circulation - small changes in ocean circulation can amplify small changes in temperature variation produced by astronomical factors.

- Other factors
  - The energy output from the sun may fluctuate.

  - Large explosive volcanic eruptions can add significant quantities of dust to the atmosphere reflecting solar radiation and resulting in global cooling.

Circulation in the Atmosphere

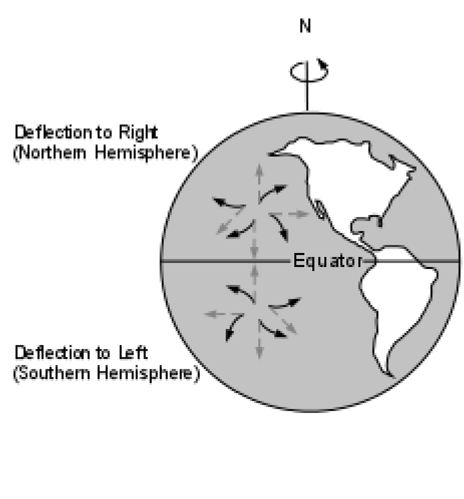
The troposphere undergoes circulation because of convection. Recall that convection is a mode of heat transfer. Convection in the atmosphere is mainly the result of the fact that more of the Sun's heat energy is received by parts of the Earth near the Equator than at the poles. Thus air at the equator is heated reducing its the density. Lower density causes the air to rise. At the top of the troposphere this air spreads toward the poles.



If the Earth were not rotating, this would result in a convection cell, with warm moist air rising at the equator, spreading toward the poles along the top of the troposphere, cooling as it moves poleward, then descending at the poles, as shown in the diagram above. Once back at the surface of the Earth, the dry cold air would circulate back toward the equator to become warmed once again.

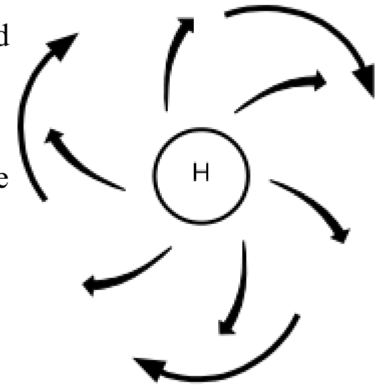
Areas where warm air rises and cools are centers of low atmospheric pressure. In areas where cold air descends back to the surface, pressure is higher and these are centers of high atmospheric pressure.

- **The Coriolis Effect -** Again, the diagram above would only apply to a non-rotating Earth. Since the Earth is in fact rotating, atmospheric circulation patterns are much more complex. The reason for this is the ***Coriolis Effect***. The Coriolis Effect causes any body that moves on a rotating planet to turn to the right (clockwise) in the northern hemisphere and to the left (counterclockwise) in the southern hemisphere. The effect is negligible at the equator and increases both north and south toward the poles. The Coriolis Effect occurs because the Earth rotates out from under all moving bodies like water, air, and even airplanes. Note that the Coriolis effect depends on the initial direction of motion and not on the compass direction. If you look along the initial direction of motion the mass will be deflected toward the right in the northern hemisphere and toward the left in the southern hemisphere.



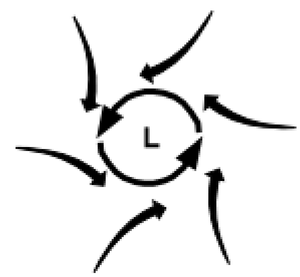
Wind Systems

- **High Pressure Centers -** In zones where air descends back to the surface, the air is more dense than its surroundings and this creates a center of high atmospheric pressure. Since winds blow from areas of high pressure to areas of low pressure, winds spiral outward away from the high pressure. But, because of the Coriolis Effect, such winds, again will be deflected toward the right in the northern hemisphere and create a general clockwise rotation around the high pressure center. In the southern hemisphere the effect is just the opposite, and winds circulate in a counterclockwise rotation about the high pressure center. Such winds circulating around a high pressure center are called ***anticyclonic winds***.

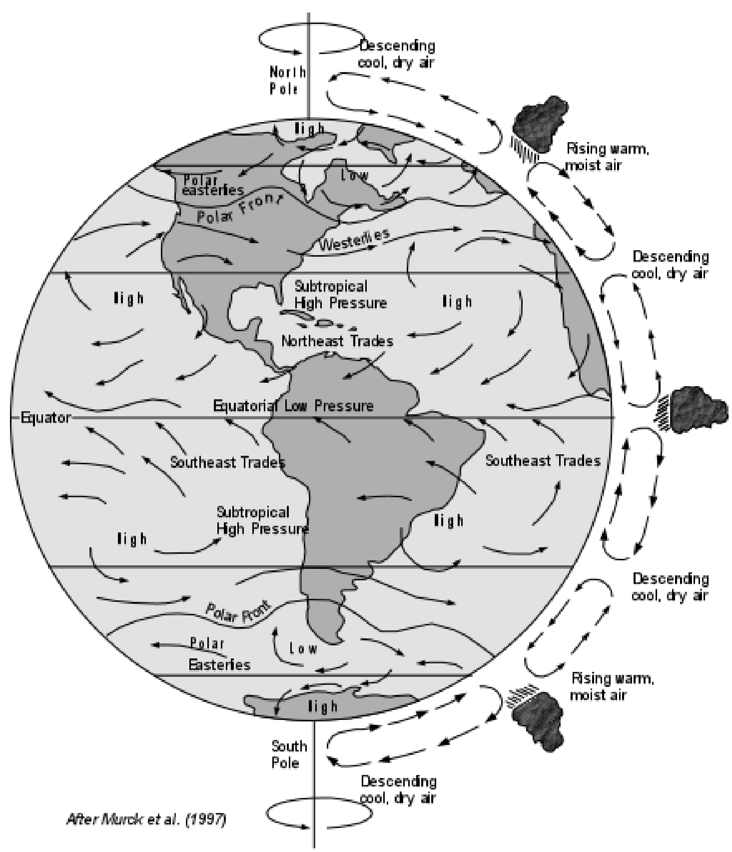


- **Low Pressure Centers** - In zones where air ascends, the air is less dense than its surroundings and this creates a center of low atmospheric pressure, or low pressure center. Winds blow from areas of high pressure to areas of low pressure, and so the surface winds would tend to blow toward a low pressure center.

  But, because of the Coriolis Effect, these winds are deflected. In the northern hemisphere they are deflected to toward the right, and fail to arrive at the low pressure center, but instead circulate around it in a counter clockwise fashion as shown here. In the southern hemisphere the circulation around a low pressure center would be clockwise. Such winds are called ***cyclonic winds***.



- Because of the Coriolis Effect, the pattern of atmospheric circulation is broken into belts as shown here. The rising moist air at the equator creates a series of low pressure zones along the equator.



- Water vapor in the moist air rising at the equator condenses as it rises and cools causing clouds to form and rain to fall. After this air has lost its moisture, it spreads to the north and south, continuing to cool, where it then descends at the mid-latitudes (about 30^{o} North and South).

- Descending air creates zones of high pressure, known as subtropical high pressure areas. Because of the rotating Earth, these descending zones of high pressure veer in a clockwise direction in the northern hemisphere, creating winds that circulate clockwise about the high pressure areas, and giving rise to winds, called the ***trade winds***, that blow from the northeast back towards the equator. In the southern hemisphere the air circulating around a high pressure center is veered toward the left, causing circulation in a counterclockwise direction, and giving rise to the southeast trade winds blowing toward the equator.

- Air circulating north and south of the subtropical high pressure zones generally blows in a westerly direction in both hemispheres, giving rise to the prevailing westerly winds.

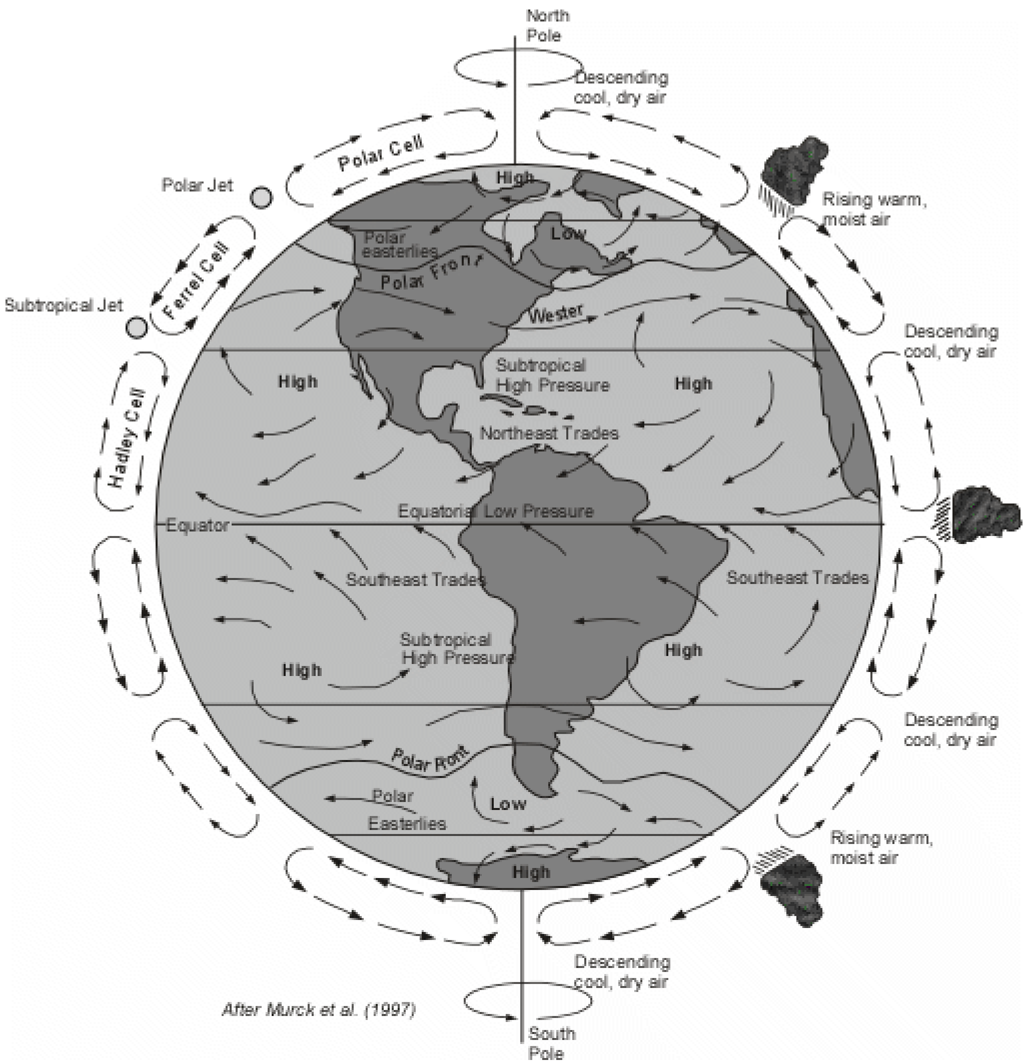
    - These westerly moving air masses again become heated and start to rise creating belts of subpolar lows. Meeting of the air mass circulating down from the poles and up from the subtropical highs creates a polar front which gives rise to storms where the two air masses meet. In general, the surface along which a cold air mass meets a warm air mass is called a ***front***.

    - The position of the polar fronts continually shifts slightly north and south, bringing different weather patterns across the land. In the northern hemisphere, the polar fronts shift southward to bring winter storms to much of the U.S. In the summer months, the polar fronts shift northward, and warmer subtropical air circulates farther north.

The convection cells circulating upward from the equator and then back to surface at the mid-latitudes are called Hadley cells. Circulation upward at high latitudes with descending air at the poles are called Polar cells. In between are cells referred to as Ferrel cells.

At high altitudes in the atmosphere narrow bands of high velocity winds flowing from west to east are called the jet streams. The polar jet occurs above the rising air between the Polar cells and the Ferrel cells. The subtropical jet occurs above the descending air between the Ferrel cells and the Hadley cells.

These jet streams meander above the Earth's surface in narrow belts. In the northern hemisphere, where the jet streams meanders to the south it brings low pressure centers (and associated storms) further to the south. Where it meanders to the north, the high pressure centers move to the north.



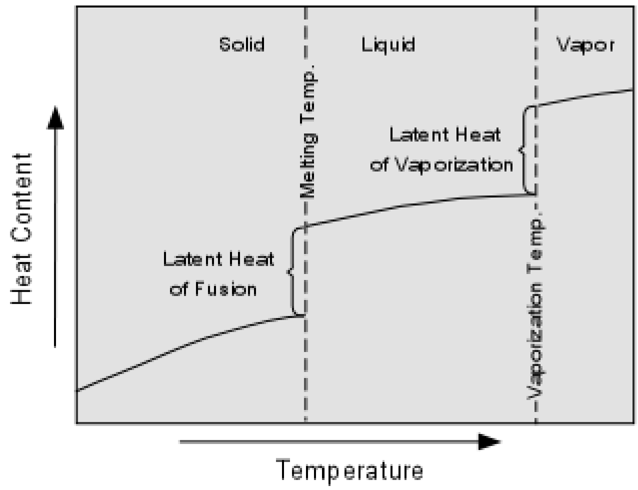
- **Effect of Air Circulation on Climate**

  Atmospheric circulation is further complicated by the distribution of land and water masses on the surface of the Earth and the topography of the land. If the Earth had no oceans and a flat land surface, the major climatic zones would all run in belts parallel to the equator. But, since the oceans are the source of moisture and the elevation of the land surface helps control where moist air will rise, climatic zones depend not only on latitude, but also on the distribution and elevation of land masses. In general, however, most of the world's desert areas occur along the mid-latitudes where dry air descends along the mid-latitude high pressure zones.

Water and Heat

Water has one of the highest heat capacities of all known substances. This means that it takes a lot of heat to raise the temperature of water by just one degree. Water thus absorbs a tremendous amount of heat from solar radiation, and furthermore, because solar radiation can penetrate water easily, large amounts of solar energy are stored in the world's oceans.

Further energy is absorbed by water vapor as the latent heat of vaporization, which is the heat required to evaporate water or change it from a liquid to a vapor. This latent heat of vaporization is given up to the atmosphere when water condenses to form liquid water as rain. If the rain changes to a solid in the form of snow or ice, it also releases a quantity of heat known as the latent heat of fusion.



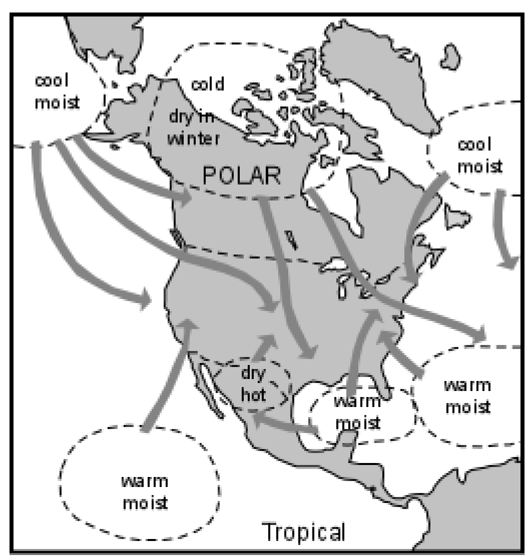
Thus, both liquid water and water vapor are important in absorbing heat from solar radiation and transporting and redistributing this heat around the planet.

As we will see throughout the next part of the course, this heat provides the energy to drive the convection system in the atmosphere and thus drives the water cycle and is responsible for such hazards as floods, thunderstorms, tornadoes, and tropical cyclones.

Air Masses

Due to general atmospheric circulation patterns, air masses containing differing amounts of heat and moisture move into and across North America.

Polar air masses, containing little moisture and low temperatures move downward from the poles. Air masses that form over water are generally moist, and those that form over the tropical oceans are both moist and warm. Because of the Coriolis effect due to the Earth's rotation, air masses generally move across North America from west to east. But, because of the differences in moisture and heat, the collision of these air masses can cause instability in the atmosphere.

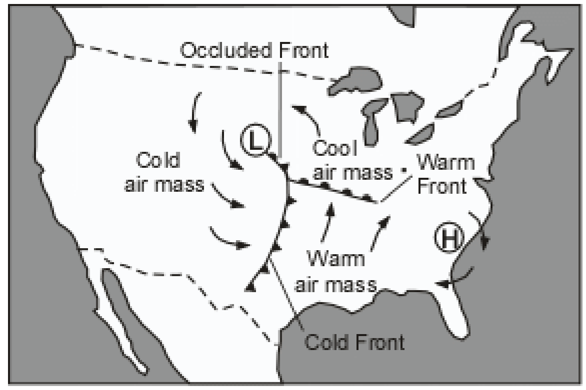


After Eagleman, 1983

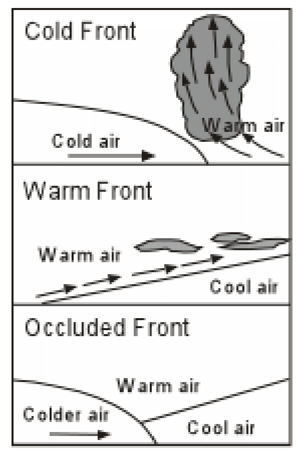
Fronts and Mid-latitude Cyclones

Different air masses with different temperatures and moisture content, in general, do not mix when they run into each other, but instead are separated from each other along boundaries called ***fronts.***

When cold air moving down from the poles encounters warm moist air moving up from the Gulf of Mexico, Pacific Ocean, or Atlantic Ocean, a cold front develops and the warm moist air rises above the cold front. This rising moist air cools as it rises causing the condensation of water vapor to form rain or snow. Note that the cold air masses tend to circulate around a low pressure center in a counterclockwise fashion in the northern hemisphere. Such circulation around a low pressure center is called a ***mid-latitude cyclone***.



When warm air moving northward meets the cooler air to the north, a warm front forms. As the warm air rises along a gently inclined warm front, clouds tend to form, and can also cause rain, but rain is less likely because the warm front is not as steep as a cold front. If the rapidly moving cold front overtakes the warm front, an occluded front forms, trapping warm air above a layer of cold and cool air. Mid-latitude cyclones and their associated fronts are responsible for such severe weather conditions as thunderstorms, snow storms and associated hail, lightening, and occasional tornadoes.



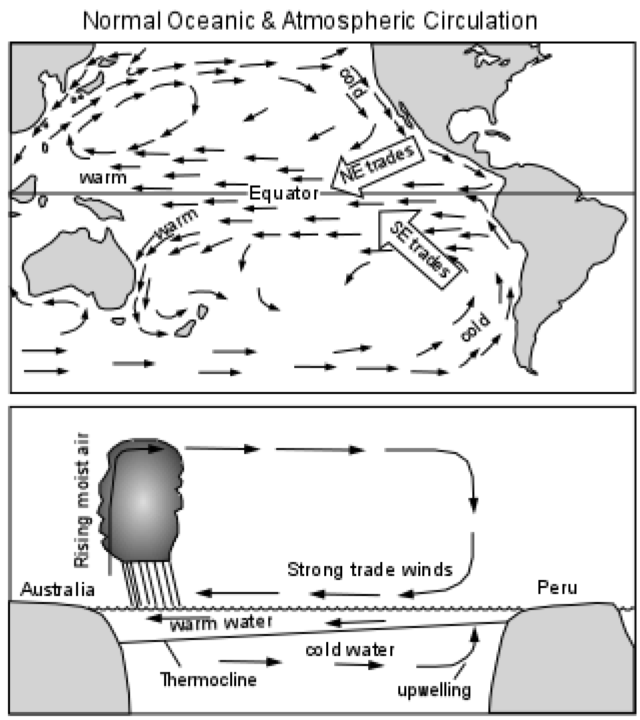
El Niño

One of the dramatic manifestations of the interaction between the oceans and the atmosphere and its effects on both climate and weather is the Southern Oscillation, one of the consequences of which is El Niño. The Southern Oscillation is a back and forth variation in atmospheric pressure between a high pressure system normally located off the west coast of South America and a low pressure system normally located in the western Pacific near Indonesia and Australia. In the U.S. El Niño conditions result in heavy rains, flooding, landslides, and tornadoes in greater than normal amounts because El Niño conditions drive abnormal amounts of moist warm air across North America. El Niño causes flooding in Peru, as well as drought and fires in Indonesia and Australia.

The phenomena is manifested by the arrival of warm water off the coast of Peru around Christmas time, and thus is called El Niño (Spanish for the boy child) because it arrives at this time. An El Niño event occurs every 2 to 7 years with various degrees of strength. Some El Niño events are more intense than others, and the condition lasts from 18 to 24 months. The following table lists the years of El Niño events.

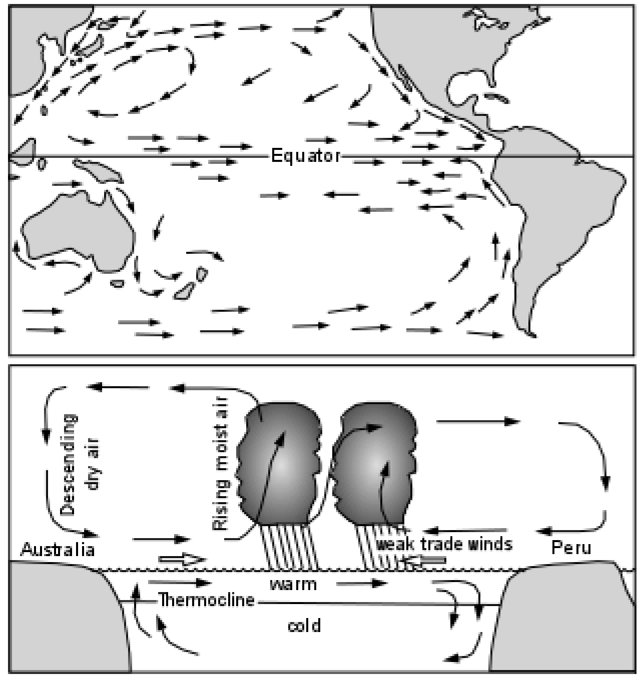
El Niño Years			
1902-1903	1905-1906	1911-1912	1914-1915
1918-1919	1923-1924	1925-1926	1930-1931
1932-1933	1939-1940	1941-1942	1951-1952
1953-1954	1957-1958	1965-1966	1969-1970
1972-1973	1976-1977	1982-1983	1986-1987
1991-1992	1994-1995	1997-1998	2002-2003
2006-2007	2009-2010	2015-2016	

"Normal" Conditions - Under "normal" conditions the easterly trade winds, driven by the pressure difference between the eastern Pacific high and the western Pacific low and blowing toward the equator, push warm water toward the equator and across the Pacific Ocean toward Australia and Indonesia. This causes a pool of warm water to form near the equator in the western Pacific. It also causes the ***thermocline*** (the boundary between warm waters in the upper layers of the ocean and the cold deep waters below) to move closer to the surface off the coast of South America, bringing nutrient-rich waters to surface by upwelling.



Such nutrient-rich waters help sustain large fish populations. The upwelling cold water cools the atmosphere above, and prevents rain clouds from forming off the coast of Peru.The warm water pushed to the west by the trade winds, heats as it flows along the equator, so that on arrival in the western Pacific heat is added to the overlying atmosphere causing it to rise, form clouds, and produce extensive rainfall.The moisture depleted upper atmosphere then circulates back to east where it descends off the coast of South America contributing to the dry conditions. During periods of exceptionally strong trade winds the upwelling of cold water off the South America cools the water even further creating a condition called La Niña (girl child).

El Niño Oceanic & Atmospheric Circulation



El Niño Conditions - During El Niño periods there is a weakening of the easterly trade winds and the warm waters of the western Pacific are pushed toward the east. This causes the thermocline in the eastern Pacific to sink, preventing the upwelling of cold waters from below, depleting the waters in nutrients, and thus leading to starvation of fish populations. As the warm water shifts eastward so does the development of atmospheric disturbances that lead to upwelling of the atmosphere to form thunderstorms.

Rising bodies of moist air thus occur closer to the coast of the Americas, leading to increased storminess, not only in South America, but in North America as well. These low pressure systems that develop in the eastern Pacific can move over the continent and cause severe weather as noted above. In addition, they create upper level winds that tend to shear the tops off of developing tropical storms and hurricanes in the Atlantic Ocean and Gulf of Mexico, leading to a decrease in the number of intense tropical cyclones that develop in these regions.

La Niña conditions have about the opposite effect of El Niño conditions. i.e. better fishing harvests off the west coast of South America, drier conditions in North and South America, more hurricanes in the Atlantic, and wetter conditions in Australia and Indonesia.

Over the past 50 years, the oscillation of warm water back and forth across the tropical Pacific Ocean has created El Niño conditions 31% of the time, La Niña conditions 23% of the time, and "normal" conditions 46% of the time.

Prediction of El Niño

As can be seen from the data presented above, the southern oscillation which creates the El Niño condition has operated throughout the last century. Archeological evidence from South America indicates that the oscillation has been operating for thousands of years. Still, it has only been in recent years that atmospheric and ocean scientists have become aware of the phenomenon, and then only because particularly strong El Niños occurred in the years 1982-83 and 1997-98 causing considerable damage from natural disasters in North America.

The frequency of El Niño events and the intensity of the events is not statistically predictable. In other words we do not as yet know when the next El Niño will occur. This is due to the relatively short amount of historical data currently available. Still, the 1997-98 event and its intensity were predictable several months beforehand because measurements of sea surface temperature from satellites and instrument buoys in the Pacific Ocean were able to identify the movement warm surface waters from west to east across the Pacific Ocean.

Thus, future El Niño events will likely be predictable several months before they actually develop. This could have important economic consequences. For example, knowing that an El Niño event is coming could result in farmers in normally dry parts of South America preparing the soil for a good crop months in advance because of the expected wetter weather in the months ahead. Fishermen could begin preparing for a poor fishing harvest off the coast of South America. In terms of Natural disasters, Peru was much better prepared for the 1997-98 El Niño and constructed storm drains and stockpiled emergency supplies, probably saving thousands of lives.

It is important to remember that because the southern oscillation shifts back and forth, some areas receive beneficial aspects of the phenomenon while other areas receive adverse aspects. For example, even though the 1997-98 El Niño produced many natural disasters in North and South America, the northern part of the U.S. was somewhat warmer during the winter months resulting in the estimated savings of $5 billion in heating costs.

Examples of questions on this material that could be asked on an exam

1. What is the difference between weather and climate?
2. What are greenhouse gases, how does their concentration in the atmosphere affect climate, and what are the major greenhouse gases?
3. What is the evidence for global warming and how is this explicable if one considers the carbon cycle?
4. Besides warming of the atmosphere, what are some of the other possible effects of global warming?
5. Why does water in the oceans store solar energy, and how does this solar energy stored in the oceans get into the atmosphere?
6. What is convection and why does it occur?
7. What happens at high pressure centers and low pressure centers in the atmosphere?
8. Explain through words and pictures what happens along a cold front, warm front and occluded front.
9. What are the effects El Niño and La Niña in terms of their potential to contribute to natural disasters?

References

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