CHAPTER 6

OUR EARTH'S CLIMATE AND SEASONS

6. 1. INTRODUCTION

6. 1. 1. Climate and Weather Defined

Climate, like weather, is an endless topic of conversation, guesswork, and scientific study. Many people confuse climate with weather because they are similarly defined and closely related topics. Actually, they are two separate things.

Weather is the daily and hourly combination of temperature, precipitation, humidity, cloudiness, air pressure, and wind. Climate is also made up of these elements. What is the difference then?

Climate is the combination of these elements over a long period of time rather than just daily or hourly conditions. In short, climate is the average weather in a particular place over a period of years.

6. 1. 2. Climatic Factors

The elements of climate are caused by climatic control factors. Some of these factors are latitude, altitude, land and water surface areas, mountain barriers, air masses, prevailing winds, ocean currents, local topographic relief, and storm and air pressure centers.

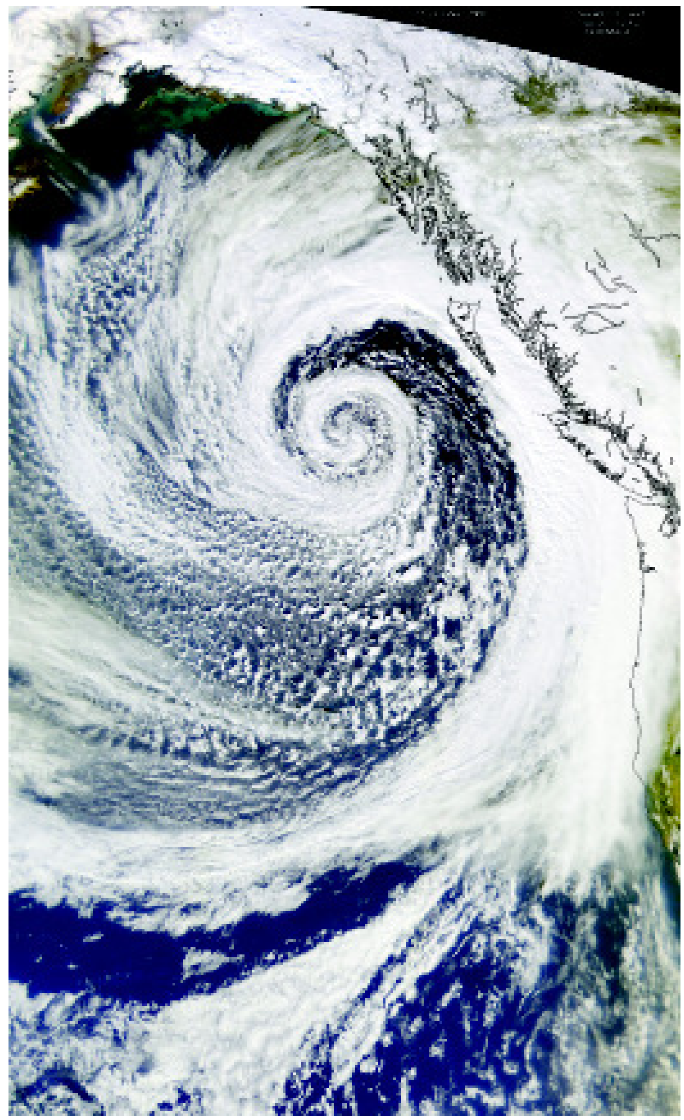
Climate also includes the different extremes of weather. These extremes include typhoons, tornadoes, or blizzards, which may strike a particular place from time to time.

6. 1. 3. Climatic Regions

After careful study, **climatologists** have divided the world into certain specific climatic regions. These, however, should not be seen as rigid classifications. It is very hard to say where one climate ends and another begins. In this section we will learn about the major climatic areas of the world and the effects of climate on people.

6. 1. 4. The Global Atmosphere

The global atmosphere that covers our earth has been compared to the skin of an apple. This thin layer contains life-sustaining oxygen (20.95%) required by humans and other creature's respiration.



Climate, like weather, is an endless topic of conversation, guesswork, and scientific study.

It also has the carbon dioxide (0.03%) so essential for plant growth, and nitrogen (78.09%). Atmospheric nitrogen can be chemically converted or 'fixed' into the soil and then used as a nutrient by plants. See chapter 11 for more on nutrient cycles.

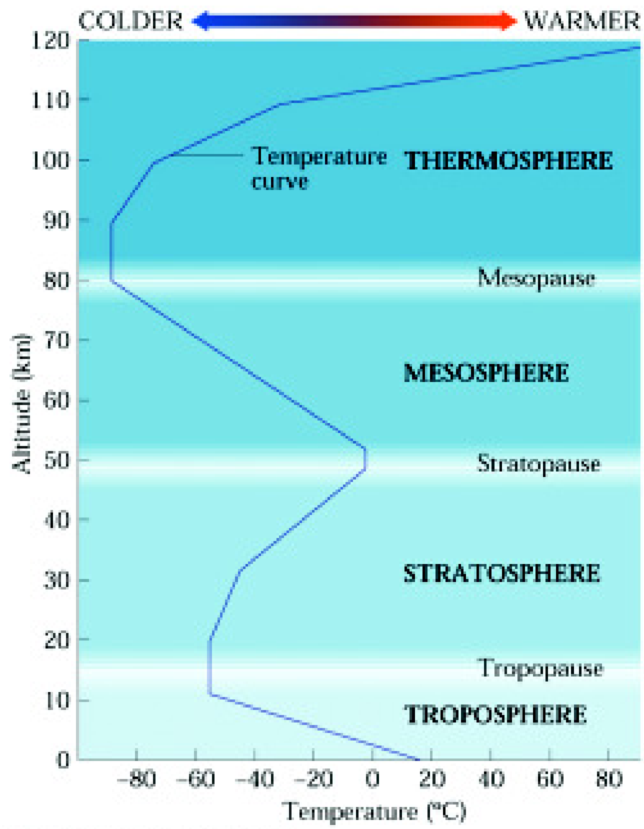
Additionally, the remaining atmosphere (0.3%) holds the trace gases argon, neon, helium, methane, krypton, hydrogen, xenon, and ozone. Varying amounts of water vapor and airborne particles are also present. How these trace gases and particles may be utilized by living organisms is unknown.

The force of gravity holds about half the weight of the whole atmosphere—a fairly uniform mixture of these gases—in the lowest 18,000 feet; 98% of the material in the atmosphere is below 100,000 feet.

The atmosphere is often referred to in oceanic terms because of its flowing nature. It has currents just like the fluid sea. We will use terms like "our ocean of air" several times in these next two chapters.

Although the atmosphere is considered to have a thickness of 40-50 miles, we are primarily concerned with the **troposphere**. This is the part of the earth's atmosphere that extends from the earth's surface to a height of about 26,000 feet above the poles, about 36,000 feet in mid-latitudes, and about 52,000 feet over the equator. The air in the troposphere decreases in temperature as one goes higher in altitude. This continues until the **tropopause** is reached.

Above the troposphere is the **stratosphere**. Interestingly, here the air generally increases in temperature with altitude, until it reaches its upper limit of 260,000 feet. This is true except for the high latitudes in winter.



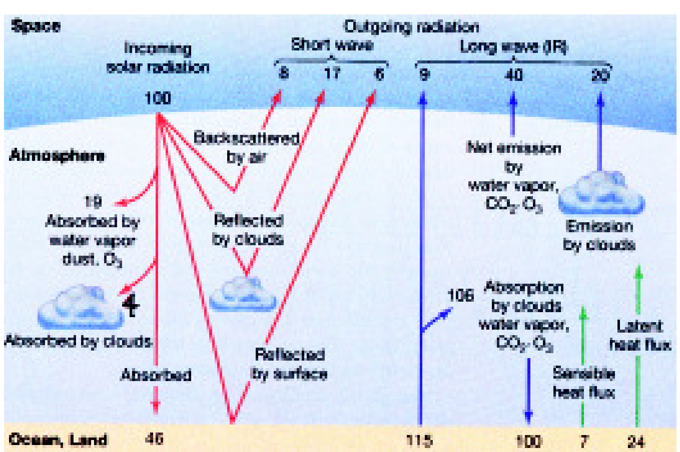
Heights of the four main layers of our atmosphere and the decreasing and increasing temperature related to height.

6. 1. 5. Water Vapor

The most variable, as well as the most remarkable, of the atmospheric trace gases is water vapor. Water exists in the atmosphere in gas, liquid, and solid form. Water adds or extracts (draws out), heat to and from the air whenever it changes from one phase to another.

Water vapor and airborne particles are essential for the stability of the global ecosystem. Their variations and interactions, combined with the global circulation of the atmosphere, produce the world's weather.

The weather that water vapor and particles produce includes clouds and precipitation. They are responsible for the blue-green-white appearance of the earth as seen from space.



Measurements of incoming and outgoing short and long wave solar radiation.

6. 1. 6. How We Perceive the Atmosphere

The natural atmosphere has many features that everyone knows and enjoys. Such features include the blue of the sky, the clarity of the air, and the brilliance of the stars at night. The color of the rainbow, the smell of the sea, the fresh air following a thunderstorm, and the red of the sunset are also atmospheric features.

The atmosphere has another face. The atmosphere produces the terrible destructiveness of a tornado, a hailstorm, or a typhoon.

The roar of a wildfire sweeping up a mountain slope is another terrifying example of a disturbed atmosphere.

Fortunately for the survival of all earth's organisms, the atmosphere has many self-healing properties. Clouds are its air-cleaning agents. Our ocean of air's global circulation system is remarkable. It constantly cleans the air of foreign matter. It is only when contamination in the air overloads the system that living organisms are faced with serious trouble.

6. 1. 7. Airborne Particles

The largest airborne particles may be in the air for only minutes or hours. The intermediate sizes are likely to be suspended for hours or days. The truly fine particles may *reside* in the atmosphere, staying aloft for weeks, months, and even years.

There is a wonderful balance in the particle concentration in the atmosphere. It is rarely modified by natural forces. Changes in concentration of airborne particles are most noticeable during catastrophic events.

The volcanic eruption of **Krakatoa** in 1883 threw huge amounts of particles into the atmosphere. The long droughts of the 1930s and the large forest fires in Canada of the late 1940s and again in the 1990s also increased the particle concentration. Two more recent examples were the tremendous 1991 eruption of Mt. Pinatubo in the Philippines and the massive 1997 forest fires throughout Indonesia, and the 2003 eruption of Anatahan.

The volcanic eruption of Krakatoa threw particles into the stratosphere that caused vivid sunsets for several years. The great dust bowl clouds from the western states obscured the sun over the eastern United States. The smoke from the widespread fires in Canada during the late forties produced a blue moon in the Northeast. This smoke extended across the Arctic into Europe.

The atmosphere is a tremendously complex system. It is difficult to describe in complete and accurate detail, but great progress is being made in that direction.

The CNMI's air is usually free of particulates.

6. 1. 8. Air's Composition: Sources of Natural Airborne Particles

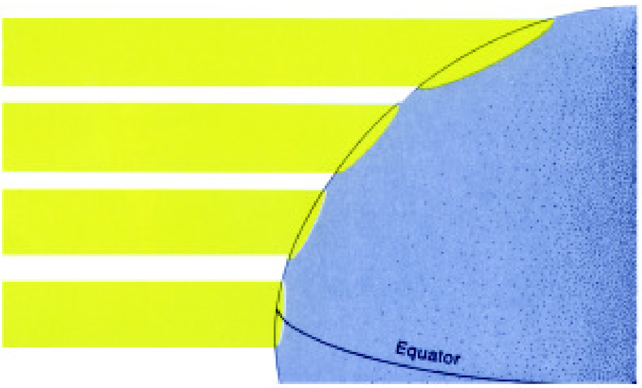
The substance called **air** is a mixture made up of different gases. Some of these gases are plentiful, but others are very rare. They are all continually blended by atmospheric motions.

As mentioned, by volume, air is about 78% nitrogen, 21% oxygen, and nearly 1% argon. There are fairly constant trace percentages of helium, ozone, neon, and krypton (other gases, including carbon dioxide, appear as variable trace gases). The gases that make up our ocean of clean, pure air are a mixture that has evolved over a time span of millions of years.

The air found at the bottom of this atmospheric ocean is anything but clean. It is polluted by a variety of foreign substances from both natural and manmade sources.

Loess
One of the chief natural processes for introducing pollutants into the air is the rubbing—the friction—of the wind over the earth's surface. When this occurs over land, rocks are slowly eroded until pieces of the land become dust-sized.

The dust from this polishing effect is fine enough to be carried high by the wind. It becomes more or less evenly distributed throughout the atmosphere. We give the name **loess** to such wind-derived dust particles.



The sun's radiation is weaker at the poles than at the equator because each unit of sunlight spreads over a larger area.

Salt Molecules
Frictional rubbing of wind over a water surface is what causes waves. As the wind grows stronger, the height of the wave increases. When the wind speed exceeds about 25 miles per hour, filaments of liquid are torn from the tops of the whitecaps.

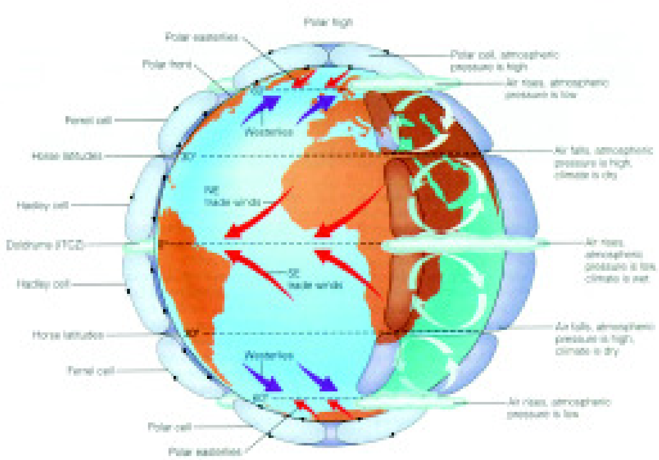
They disintegrate into spray droplets, most of which are so heavy that they fall back into the water. Smaller ones, however, fall slowly and evaporate, leaving airborne salt particles whose mass is a trillionth of a kilogram. These tiny residues of salt become centers for future cloud droplets.

Volcanic Ash
A volcanic eruption is an important natural mechanism that operates infrequently, but sometimes has a massive effect. It adds immense quantities of dust into the high troposphere and the stratosphere.

6. 2. RISING AND FALLING AIR

6. 2. 1. Introduction
The earth is a spinning globe. The earth's atmosphere is gravitationally attached to the globe and it is also spinning. Since it is not rigidly attached, it sometimes spins faster than the globe and sometimes lags behind.

The earth's absorption of solar energy, by latitude, is unequal over its surface. This continuously upsets the state of the air's heat equilibrium. The earth's atmosphere constantly moves to restore the balance.



The atmosphere is permeated with convection cells of all dimensions.

6. 2. 2. Convection
Air rises for a number of reasons. The first and most obvious one is that there are many physical barriers that moving air (wind) cannot go through. A moving air mass, therefore, must rise and go over them. There are hills, mountain ranges, and hummocks of all sizes and shapes that the moving air must travel over.

Air also rises and falls due to **convection**. As air warms, it expands. A locally warmed, and thus less dense, volume of a gas or fluid will experience a positive (upward-directed) buoyant force, moving upward and cooling.

Because this air rises, a compensatory sinking flow will appear around the rising column. The volume of atmosphere in a single up and then down movement is referred to as a **convection cell**.

The atmosphere is permeated with convection cells of all dimensions. These cells range from those that are microscopically small to those that are global in scope.

Convection cells are of great importance, since convection is the process that transports heat energy from one place to another. In nature, excess heat energy must be moved from low-latitude equatorial places where the sun's rays hit more directly, to the high-latitude arctic regions where the sun's rays hit at steep angles.

The earth's atmosphere and oceans are the means by which this heat energy movement is accomplished. Both the gases and the fluids have an important function in this respect.

The 18th century English scientist George Hadley was one of the first persons to understand the global dimension of convection. The labeled convection cell shown in Diagram 6.1 is the Hadley Cell. It represents the most basic convection circulation pattern near the equator. Convection cells are always present, but are sometimes hidden by the complexities of day to day global circulation.

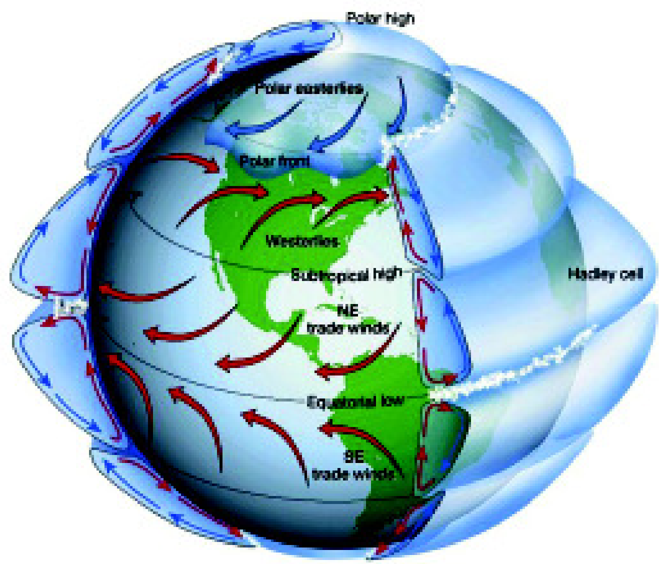


Diagram 6.1: Convection cells are always present, but are sometimes hidden by the complexities of day to day global circulation.

6. 2. 3. Humidity, Cooling and Water Vapor Condensation

Air Pressure

As mentioned, the atmosphere is a gas that is held to the surface of the earth by gravity. The pressure exerted by the atmosphere is greatest at the surface of the earth. It decreases with elevation.

Pressure decreases much faster in the lower levels of the atmosphere. About 50% of the atmosphere by weight is contained in a seemingly paper-thin, spherical shell that is only about 3.1 to 3.7 miles (4.99 to 5.95 Kilometers) thick.

Water Vapor and Air Pressure Changes

As stated earlier, air contains water vapor. How much water vapor it contains varies from day to day and from place to place at any given time. Recall that water vapor is the most variable component of air. There is usually more water vapor in the air in the atmospheric regions closest to the surface of the earth.

Since water vapor enters the air by evaporation from such sources as large bodies of water, as well as by transpiration from masses of vegetation, the ocean particularly has a lot of water vapor above it.

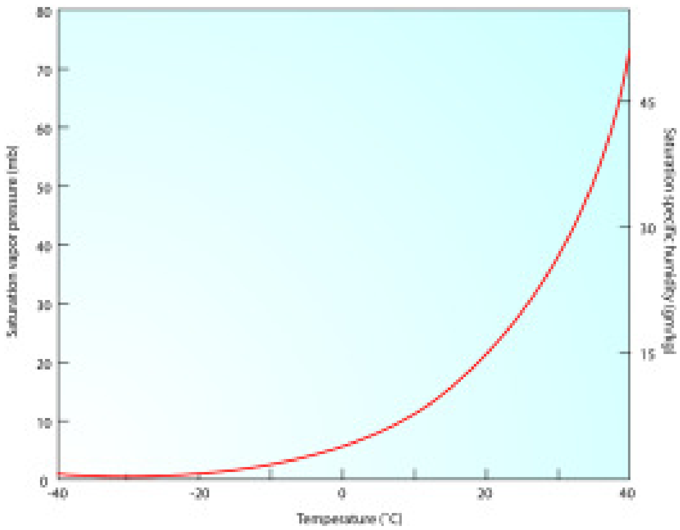
If warm regions, such as the Sahara, are cut off from sources of water they can be very dry.

There is usually more water vapor in warm regions than in cold regions since warm air can hold more water vapor than cold air. However, if warm regions are cut off from sources of water—the Sahara Desert is an example—they can be very dry. This can occur if there are intervening mountains, long distances between land and sea, or even by constant offshore-moving winds.

The atmosphere is restless, always in motion: horizontally or vertically or both. As air rises, pressure on it decreases and in response it cools and expands. Conversely, sinking air is compressed and it warms.

Relative Humidity

The term *relative humidity* is the ratio of the actual water vapor pressure to the maximum possible water vapor pressure. It is expressed as a percentage. For example when the relative humidity is 80%, the air contains 80% of the moisture it can hold at that temperature.



Wet air is lighter, not heavier, than dry air. This is due to latent heat.

Condensation Nuclei and the Dew Point
Humid air forms clouds by means of **condensation**. Condensation occurs when water vapor molecules attach onto small particles in the atmosphere. These particles are called **cloud condensation nuclei**. A single particle is a nucleus.

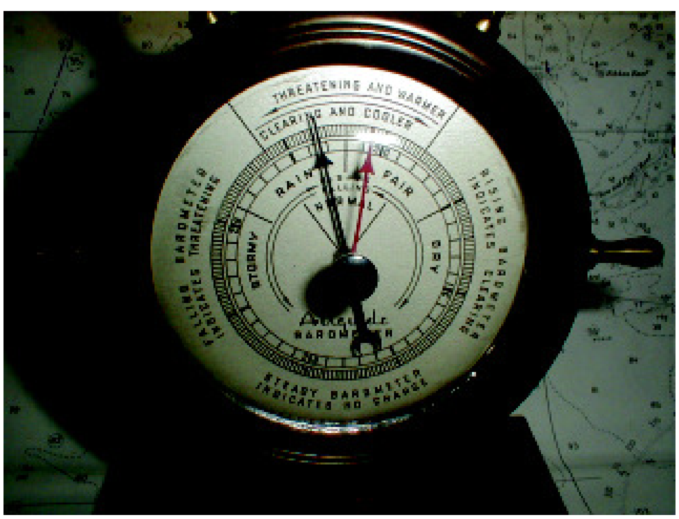
Dust particles and airborne salt molecules form the majority of these tiny air particles onto which water condenses. These nuclei start to attract water at relative humidities of slightly less than or slightly greater than 100%. This narrow humidity range is called the **dew point**. This means that these nuclei tend to form chemical bonds with water that enables the water molecules to stick to the nucleus.

Latent Heat and Air Buoyancy
Condensation is a complex process. When water molecules in the gaseous state cluster about and stick to a nucleus, they lose their respective kinetic energies to the air; they release what is called **latent heat**.

With water, this is a large amount of energy—nearly 600 kilocalories for each kilogram of condensed water. A **calorie** is the amount of heat energy needed to raise the temperature of 1 gram of water, 1 degree Celsius. A **kilocalorie** is 1,000 calories and a **kilogram** is 1,000 grams. This release of latent heat is of great importance because it adds buoyancy to the air.

6. 3. ABOUT AIR PRESSURE

One of the principal things to learn about climate and weather is that these are largely caused by air in motion. Air moves because, in different places, it has different weights.



A standard analog barometer is one example of an air weighing machine.

Yes, air has weight. If air were poured out from a big pitcher in space, it would flow because of its own weight, exactly like water. Changes in a mass of air's weight causes it to flow towards or away from other air masses, and new weather then evolves. These observable changes are caused mainly by heat differences.

However, no matter how many times we say that "air has weight," the statement remains hard to grasp. For instance, it is difficult to realize that a broken electric light bulb weighs more than an unbroken one, which, with its partial vacuum, actually contains less air. It is also hard to grasp that wet air is lighter, not heavier, than dry air. This is due to the latent heat just mentioned.

One of the reasons that we find it hard to visualize air as having weight is because atmospheric weight is referred to as pressure. This is so because the weight of a gas *presses* out in all directions. The pressure of air at any given altitude is the weight of all the air above that presses down on it.

Another reason is that air is a gas and so it is invisible, and it's hard to think of something invisible as having weight.

6. 3. 1. The Barometer—An Air-Weighing Machine

We cannot see the high- and low-pressure areas, but we can weigh all the air above, and be on the watch for changes of weight. We can do this by means of a **barometer**, which is our air-weighing machine.

The column of mercury in a barometer acts as a balance-weight against a similar column of all the air above it. Naturally, the more air density there is above, the more height and weight of mercury is needed to balance that greater air weight.

So there you have it: the barometer is no more than a plain scale that weighs the mountains and valleys of air that pass overhead!

When the barometer is high, it reveals that a mountain of good-weather density is pressing its weight down on us. All of the surrounding atmosphere is flowing downhill, towards an outlying, rainy, low-pressure area somewhere else.

The actual reading on a barometer is often not as important as the way in which the reading changes. This is because we often refer to changes in barometric measurements when forecasting future weather ("the barometer is falling").

6. 4. AIR CIRCULATION & WINDS

6. 4. 1. Introduction

Winds are always an important feature of the atmosphere. Their presence or absence, force, and frequency often decide the climate of any particular place.

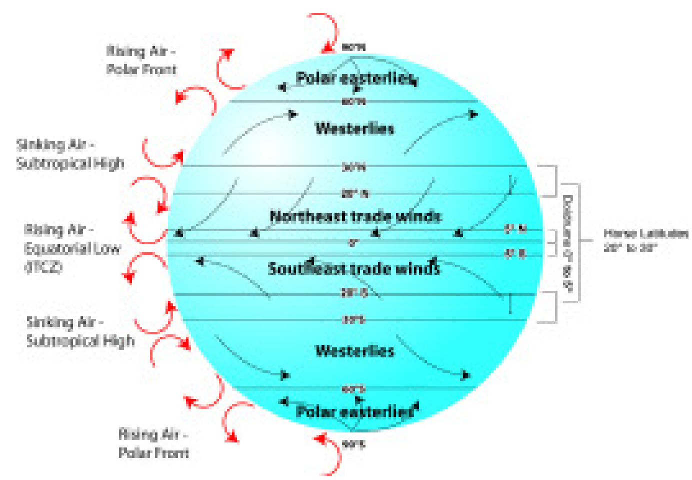


Diagram 6.2: Atmospheric circulation

The One Equatorial Low

In equatorial regions, the sun's rays hit the earth most directly, so there is a big uprising of heated air from the earth's surface. The upward moving warm air spreads outwards north and south at a high level in the atmosphere. At the ground level, cooler air flows in from either side of the equator causing our normally-felt trade winds to take the place of the rising air. The area where the air rises is called the **equatorial low**.

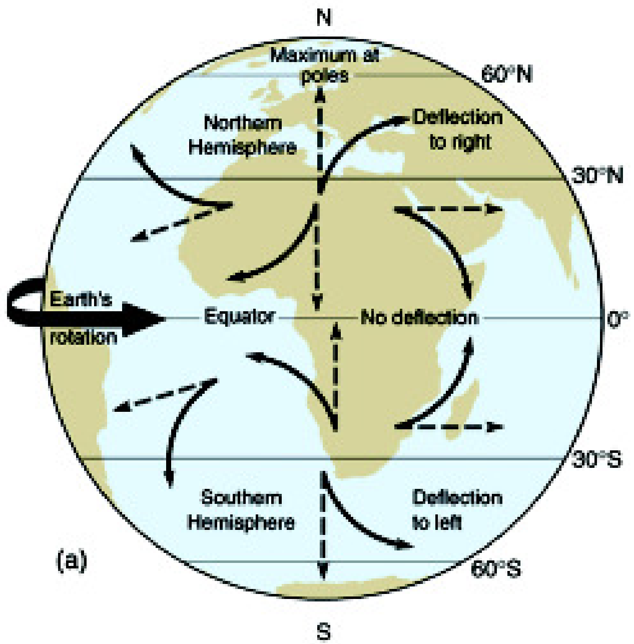
The Two Subtropical Highs

The risen air, once up in the high atmosphere, moves in the opposite direction to the air at ground level. It travels northward and southward to above the place where the wind at ground level began. There it sinks once more to the earth's surface.

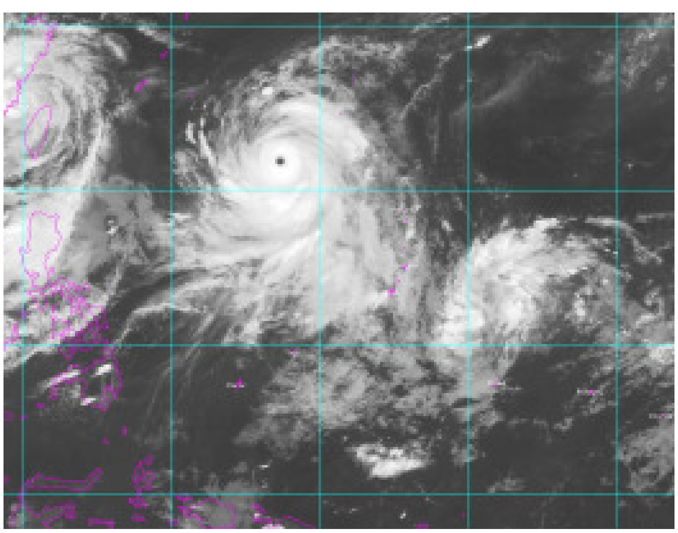
In this way a circulation system is set up. It turns out that the descending air comes down at about latitude 30 degrees on either side of the equator. This descending air gets mixed with other descending air that has traveled from the north. After both air currents descend to the earth's surface, some of it goes north and some goes south. The two places (north and south) where the air falls are called the two **subtropical highs**.

The Two Subpolar Lows

At about latitude 60 degrees, another loop of circulation occurs, and air is found rising again. This time the rising is not due directly to heat, but to the meeting of the warm air from the south with the cold air from the north. The two areas where this air rises are called the two **subpolar lows**.



The Coriolis Force causes deflections in the prevailing winds, thus curving them.



The strongest tropical-storm-generated wind is called a typhoon here in the western Pacific.

The Two Polar Highs
Around the North and South Poles, cold air sinks and flows away from each pole at the surface. This occurs at the two **polar highs**. At the same time, higher in the atmosphere, the direction of the wind is toward the north, so this forms a third circulating system.

Diagram 6.2 (previous page) shows what happens. The height of these air currents is greatly exaggerated in the diagram. They occur in the region of the atmosphere which contains the clouds, and which is, in reality, a mere film around the surface of the earth.

6. 4. 2. The Coriolis Force

In studying the weather, we are mainly concerned with the surface winds. We now have to consider a complication which arises because the earth is not fixed, but rotates on its axis.

The speed of rotation at the equator is over 1,000 miles per hour, but nearer the poles it is much less. We do not directly feel this motion because everything around us is carried along with us.

The earth however, does not have a perfect grip on the air, and the winds flowing north and south slither sideways as the earth rotates. Winds that start from a higher latitude have a lower initial speed. Winds that start from a lower latitude have a higher initial speed. Remember that the equator is at 0 degrees latitude and the poles are at 90 degrees. The rotating earth and their differing initial speeds cause these winds to curve. The force which causes these deflections is known as the **Coriolis Force**.

Since they start from lower latitudes and move to higher ones, the winds blowing towards the equator from both the subtropical highs and from the subpolar highs get left behind, and effectively flow from the east rather than from directly north.

Winds blowing from the subpolar and subtropical highs toward the poles begin at higher latitude, thus they have a faster initial speed and effectively move from the west, rather than directly from the south.

6. 4. 3. The General Wind Names

Diagram 6. 2. on the previous page indicates the names of the general wind patterns. These wind names come from the time when sailing ships relied on these winds for power. Finding steady winds meant that good trade could develop. Poor, nonconstant winds often resulted in the deaths of frequently transported livestock, such as horses.

The **doldrums** and the **horse latitudes** winds occur respectively at the equatorial low and the two subtropical highs. Here air is rising or falling, and is generally not moving very rapidly side to side. Sailing ships were often becalmed in these latitudes.

The *northeast* (ours) and the *southeast* (southern hemisphere's) **tradewinds** occur where surface air is moving from the falling-air, subtropical highs to the equatorial low. The *prevailing westerlies*, occur where air moves away to the north from the subtropical highs. The polar-easterlies returns air which falls at the Poles in a south or north easterly direction.

6. 4. 4. Typhoons

The strongest tropical-storm-generated wind is called a *typhoon* here in the western Pacific. It is called a *hurricane* in Hawaii and the Mainland US, a *cyclone* in the Indian Ocean, and a *willy-willy* off the coast of northwestern Australia.

These storms may be hundreds of miles across. The winds blow round in spiral fashion toward a center, becoming ever more furious until they reach tremendous speeds.

At the very center, which is called the "eye" of the storm, the winds cease, or are much abated. Around the eye, the lashing fury of the wind raises mountainous seas. The typhoon requires large and continuous supplies of water vapor, such as are only found over warm waters.

When it moves over a land area, its strength weakens and the winds die out. Typhoons will be discussed in greater detail in our next chapter (CNMI weather). We mention these briefly here as they are also part of our climate.

Warm, humid air coming inland from the ocean during summer brings the monsoon to Eastern Asia.

6. 4. 5. Coastal Breezes and Monsoons

One of the gentlest winds is the coastal sea breeze. It occurs due to the fact that the land gains and loses heat more quickly than the water does.

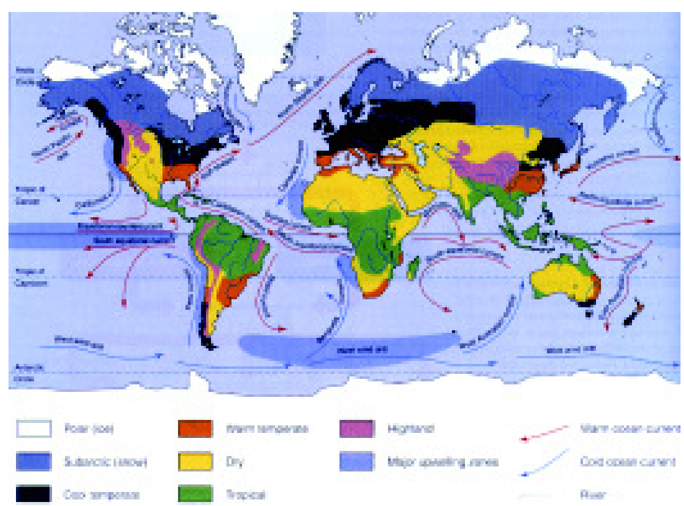
By day, the warm air over the land rises and is replaced by cooler air from the sea. By night, the air over the sea is warmer than the land air and the process is reversed.

In eastern Asia, the same effect on a grand scale causes **monsoons**. In winter, cold air flows off the continent toward the sea. In summer, when the land surface becomes much more heated, the general direction of the winds is reversed, and humid air from the ocean brings the monsoon, or months of rain.

6. 5. CLIMATES OF THE WORLD

6. 5. 1. Introduction

Climate may differ widely in places within a short distance of each other. However, certain types of climate appear in the same general location all around the world. In this section we will learn about the major climates of the world.



Certain types of climate appear in the same general location all around the world.

Latitude is the most obvious of all the factors we use to classify climatic conditions. The air is always cold above the earth's poles. It is always hot above equatorial lands, except near the summits of a few high mountains.

Poleward from the equator, climates generally pass from *wet heat* through *dry heat* to *wet cold* and, finally, to *dry cold*. These are the four primary climates, but among them there are many variations and peculiarities.

6. 5. 2. The Equatorial Belt (wet heat)

Around the Equator, the climate is perpetually hot, humid, and rainy, with little difference between the hottest and coolest months, or between night and day. Included in this area are Central America, Brazil, the Congo, and the East Indies.

Temperatures seldom rise above 100 and seldom drop below 60 degrees at low to moderate altitudes. The high humidity makes the region something like a Turkish bath: very hot and steamy.

Vegetation grows in chaotic profusion here. Parasitic plants abound in the lush, crowded conditions. Metals corrode, and leather, paper, and cloth rapidly mold. The water-soaked air rises in steamy torrents, and thunderstorms dump floods of rain almost daily. Thunderstorms are frequent and sometimes severe, but other climatic catastrophes, such as hurricanes and tornadoes, are almost unknown.

At around 30 degrees of latitude, between the equatorial belt and the temperate zones, lie the hot, but dry subtropical regions.

6. 5. 3. A String of Deserts (dry heat)

At around 30 degrees of latitude, between the equatorial belt and the temperate zones, lie the hot but dry subtropical regions. The air that rose in the equatorial belts descends here after having been relieved of its moisture.

The air is initially hot, and its descent serves to heat it dynamically, by compression and friction, so that it bakes the earth. The result is a string of deserts around the world. The Sahara, the Libyan, the Arabian, and the Great Australian deserts have the highest temperatures and some of the driest conditions on the face of the globe.

The air reaches 130 degrees in the shade, while the ground, which soaks up the direct rays of the Sun, is baked to as much as 170 degrees. Somewhat surprisingly, desert nights are cool. Differences of 60 degrees between day and night are not unusual in the desert.

Because of the humidity of the air in the night, the variation feels greater still. Rainfall is slight or even nonexistent in these regions. In the deserts of Peru, there are places where, for centuries, rain has not fallen at all.

Sandstorms and dust storms are frequent in the larger deserts, notably the Sahara. Low-level desert air seems to be filled perpetually with a fine haze of dust particles, except after a rare desert rainstorm.

On hot afternoons, rising thermal currents of air create whirling pillars of sand, and when the wind is strong the ground itself seems to be in motion; walking is difficult at such times.

The desert is not just a waste area of heat, sand, and wind. Each infrequent rain causes plant life to spring up, grow to maturity, and produce seeds in the space of a very few days. The new seeds will be ready to lie dormant, for years if necessary, waiting for the next rainfall.

The temperate zones are two climatic belts encircling the earth between roughly 30 and 60 degrees latitude north and south.

Around wells and where irrigation brings water, the desert becomes a veritable garden. In parts of Egypt, Iraq, and our western United States, irrigation and abundant sunshine combine to produce crops throughout the year.

6. 5. 4. Temperate Climates (wet cold)

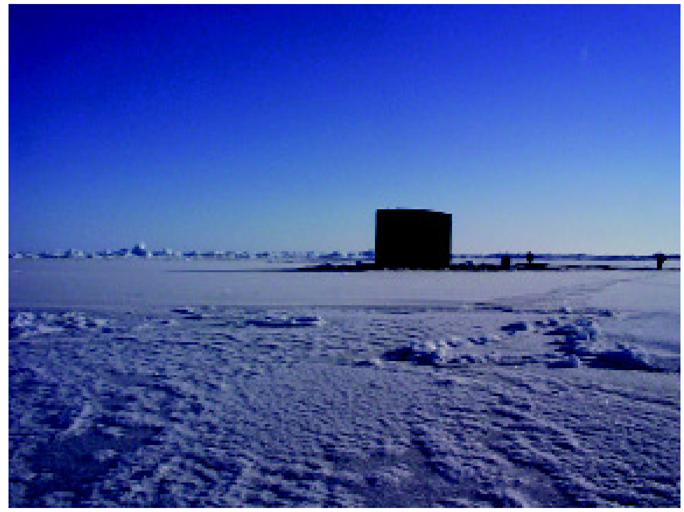
Much of the world's population lives in so called *temperate* climates, two climatic belts encircling the earth between roughly 30 and 60 degrees latitude north and south. These are the most changeable climates.

In summer, the temperate zones are either dry and hot, or wet and hot. Thunderstorms dominate the sky. Occasionally, even during summer, a polar mass of air intrudes upon the area. As autumn approaches, polar air becomes more restless. At first mildly, but then with increasing authority, it exerts its influence.

One day the weather is fair, maybe even mild, while on the next day ice or snow blankets the land. Changes in temperature, from day to night and from winter to summer, are very significant in the temperate zones.

Both daily and seasonal temperature changes may vary widely from the long-term average. One winter may be as much as 8 to 10 degrees warmer or colder than the preceding one.

In addition to great variations of temperature, every possible weather hazard is common in these zones. Warm and cold fronts, tornadoes, thunderstorms, hurricanes, sandstorms, dust storms, and snowstorms are all common occurrences. The real meaning of the term temperate zone is “middle latitude”. Its chief atmospheric feature is change.



Poleward from the temperate zones are the polar regions. These cold, dry areas are largely undeveloped.

6. 5. 5. The Polar Regions (dry cold)

Poleward from the temperate zones are the polar regions. They encompass Siberia, northern Canada, Greenland in the north, and Antarctica in the south. These are largely undeveloped areas.

The sun remains above the horizon in summer, then hides below it in winter. This is as important a feature of the arctic scene as the wintertime cold. Though low in the sky even in midsummer, the sun sends down a great quantity of energy by working around the clock.

North Pole
An occasional thunderstorm forms over the north polar region, even at the North Pole, in the summer. Wintertime gales and blizzards can turn the region into a wilderness of ice and snow, while temperatures drop to between 70 and 90 degrees below zero Fahrenheit. Strong winds are infrequent.

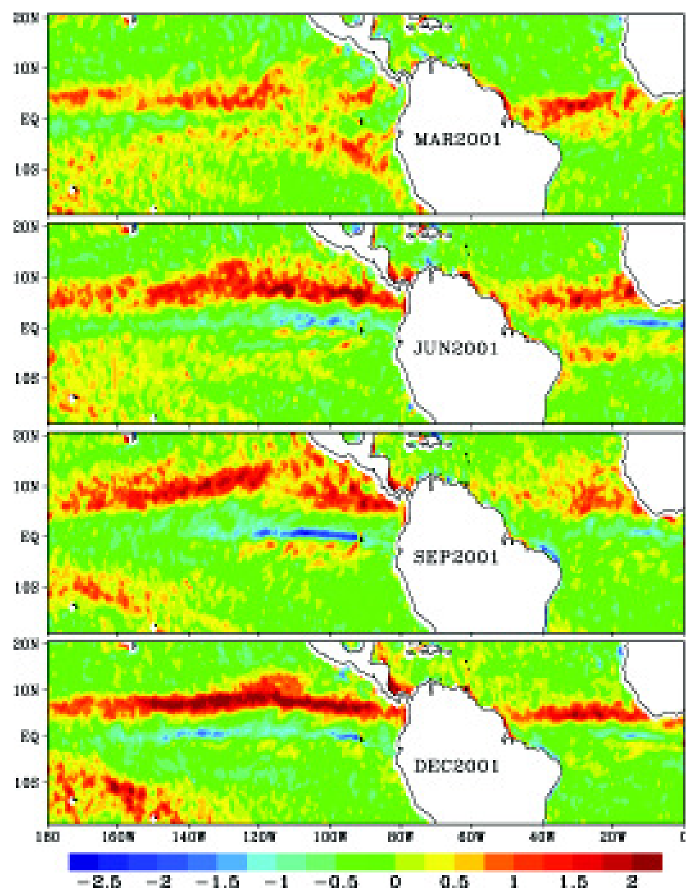
South Pole
In the south polar region, Antarctica is an elevated land mass, so it is much colder and far stormier than the Arctic. Summer temperatures of zero are normal and winter temperatures drop to below minus 100 degrees Fahrenheit.

A team of Russian explorers reported the record low. It was minus 114 degrees. Blizzards develop with surprising suddenness, even in midsummer.

6. 5. 6. Mixed Climates

Though the subject of climates has been introduced in terms of four distinct types, pure climates around the earth are rare. A major cause of climate mixture is the annual pacing back and forth of the sun across the noonday sky.

Hanging above the Tropic of Cancer in June, the sun shifts position to look directly down upon the Tropic of Capricorn in December. With this shifting, climates sway back and forth, too.



Climates sway back and forth, with maximum temperatures in the Northern Hemisphere occuring in mid-July.

One interesting feature of the change is that maximum temperatures lag a month or so behind the sun's position. That is, maximum average temperatures in the Northern Hemisphere occur in mid-July instead of mid-June.

In monsoon areas such as India (pictured), summer's approach brings equatorial thunderstorms and rain in superabundance.

The causes of this phenomenon are complex. They involve time for the earth's surface to warm and for the air itself to adjust its flow pattern about the globe.

6. 5. 7. Monsoon Climates

Areas caught between two climatic zones like our own Mariana Islands will receive a dose of both types of climates as the sun advances and retreats. Regions between wet and dry tropical climates have the half-and-half climate, called **tropical monsoon**, described earlier. Tropical monsoon areas include Burma and India in Asia, the Sudan in Africa, Northern Australia, and the CNMI.

Here summer's approach brings equatorial thunderstorms and rain in superabundance. With the coming of winter, the rains disappear and dry tropical conditions prevail. During the dry season, trees may shed their leaves just as their cousins do in the colder winters of the temperate zones.

6. 5. 8. Mediterranean Climates

The opposite of the tropical monsoon is the so-called **Mediterranean climate**. It is wet and mild in winter and dry and warm in summer.

It was named Mediterranean climate because the northern shores of the Mediterranean Sea are an excellent example of this type of climate. However, in addition to Italy, Spain, Greece, the Balkans, Turkey, and Palestine, Mediterranean climates are found in southwest Africa, central Chile, and southern California.

Mediterranean climates are wet and mild in winter and dry and warm in summer.

6. 5. 9. Coastal Climates

The differing nature of land and sea also shapes the climatic behavior of coastal areas. The sea warms and cools slowly because it presents a fairly smooth watery plain having a tremendous heat-holding capacity. Its temperature changes are never extreme, day to day or week to week.

The vast currents move slowly, smoothly, and constantly within the sea. They carry tropical waters into the Arctic, and carry Arctic waters into equatorial zones. Traces of arctic cold are still within them. Land, on the other hand, may be mountainous, covered with dense vegetation, barren, flat, or rocky, and hence subject to rapid weather changes which each wind brings.

Depending on the latitude, both western and eastern continental coastal climates can be greatly influenced by the sea. On the other hand, coastal areas may not be affected much by the sea, whatsoever. Much depends on which way the prevailing wind blows, towards land (onshore winds) or away from land (offshore winds).

Where prevailing winds blow from the sea landward, there are lesser extremes of temperature. This is because of the constant temperature effect caused by the prevailing ocean winds. Where prevailing winds blow out to sea, climates are much like their continental interiors. Their days are warm and their nights are cool. Summers are hot while winters are cold.

Since prevailing wind directions are generally determined by latitude, at any one particular latitude, continental coastlines along western or eastern edges will have opposite coastal climates. One coast (for example western) will have prevailing winds blowing onshore. The other coast (for example eastern), at the same latitude, will have prevailing winds blowing offshore. One coast would have much temperature fluctuations while the other would not.

6. 5. 10. Mountain Climates

Mountains and high plateaus have climates very different from the lower terrain of the same geographic location. There is an increase of precipitation with elevation. There is also a clear distinction between the windward and leeward sides of a mountain range. A decrease in the air's density and temperature is the final characteristic of mountain climates.

Strong sunlight from the thinner air and the bracing quality of the cool, brisk winds, give many mountain districts very enjoyable climates.

Precipitation is usually high on the windward side of mountain ranges. Even in normally dry country, vegetation crowns the tops of mountains unless they are so high that they are permanently covered with snow.

When a mountain range fronts the sea, its precipitation is especially heavy, often two hundred inches a year. Mountain slopes in Hawaii are annually soaked with as much as four hundred inches.

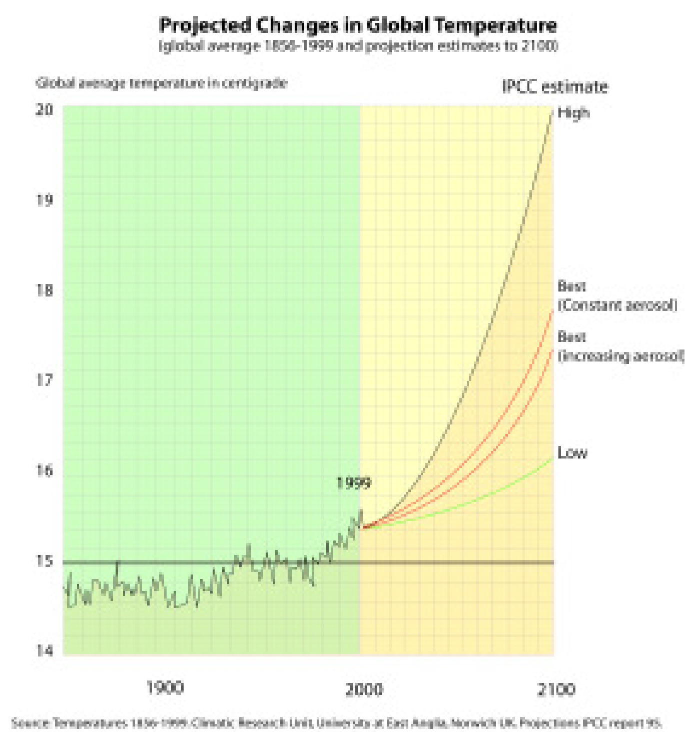
Leeward mountain slopes are much drier, and may even be deserts. The Gobi Desert in Asia, in the *rain shadow* of the high Himalayan Mountains, is a striking example. The Atacama Desert in South America, in the rain shadow of the Andes Mountains, is another.

Strong sunlight from the thinner air and the bracing quality of the cool, brisk winds, give many mountain districts very enjoyable climates.

6. 6. THE EARTH's CHANGING CLIMATE

6. 6. 1. Introduction

Due to the time limitation of our human experience, it is natural for us to assume that climates do not change. Nothing could be less true. For at least ninety percent of the earth's geologic history, the average temperature has been considerably higher than it is now. There have been low extremes of temperature, too.



Global warming since 1856

Between epochs of roughly 250 million years, in which almost the entire earth had tropical climates, there have been cold periods. These were periods of ice and severe glaciation, each lasting a few million years. In addition, there have been numerous smaller fluctuations of climate. Recall as well that continents have moved due to plate tectonics.

Remains of tropical vegetation have been found near both of the earth's poles. Both regions have coal deposits which, as far as we know, could only have come from extensive tropical forests. Additionally, the Sahara was not always dry.

Glaciers were invading northern Europe about ten thousand years ago. At that time, a plateau about nine hundred miles southeast of Algiers supported a vigorous population. Judging by thousands of colorful drawings in the area's caves, it must have been a fertile, well-watered land back then. Today this area is a dry, almost uninhabited desert. Glaciers advanced on Northern Asia and North America as well.

Deposits in peat beds, such as this one in Ireland, show that the climate of the entire hemisphere began to grow warmer around 8000 B.C.

6. 6. 2. Stories in Peat Moss

Debris trapped in English peat beds during the same period reveals that region was largely open tundra with scattered patches of silver birch trees. After 8000 B.C., the English climate, and that of the entire hemisphere, began to grow warmer. Remains of warmth-demanding plants, such as oak and elm trees, are found in deposits of this period in England.

As the glacial ice farther north melted, the level of the oceans rose. This fact is clearly demonstrated by salt water flowing over more and more of the peat beds. By 5000 B.C., England became separated from the rest of the continent of Europe. Since that time, its present day climate has occurred.

6. 6. 3. Global Cooling and Warming

In modern times, a pattern of climatic change persists. Detailed records go back only about a hundred years. Such a short period of time does not show what some people might consider a very impressive change, but small changes may have very significant consequences.

Global Cooling

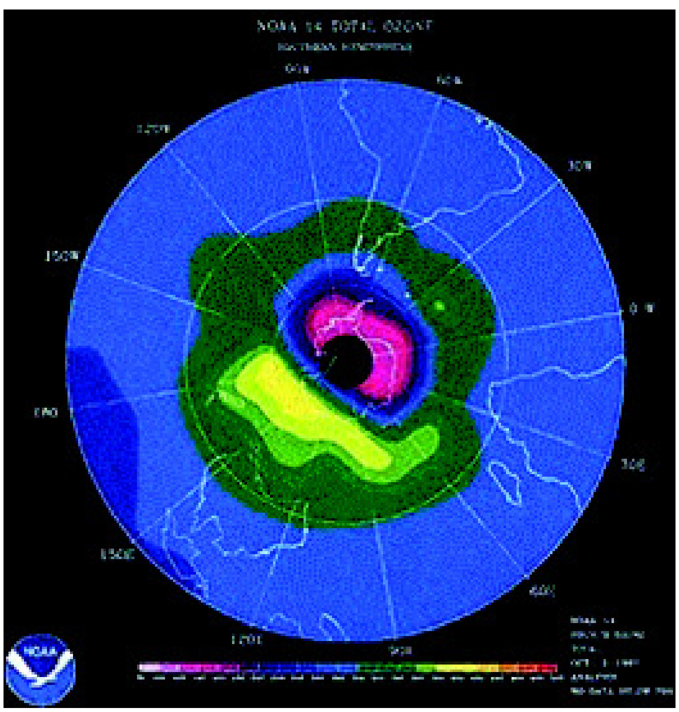
A 1-degree shift in the average annual temperature is equal to a change of about a hundred miles in latitude. An 8- to 10-degree drop in the world's temperature would be enough for a gradual accumulation of ice and snow in temperate regions each year just as occurs today only in the polar regions. Much of North America, Europe, and Asia would eventually disappear under sheets of ice. This is what happened during an ice age about twenty thousand years ago.

Global Warming

The earth is currently going through a warming trend. Even small amounts of warming can be significant and the potential effects are being hotly debated among scientists today.

A 5-degree rise, if maintained for a few thousand years, would surely melt some of the six million square miles of ice and snow now collected at the poles. This would raise the levels of the oceans throughout the world.

Such an increase would very likely bring tropical conditions to most of the earth. Islanders would immediately feel the effects of rising sea level and concern is particularly focused on Micronesia's low-lying atolls. These would be covered by water if the sea level rose significantly.



The ozone layer has been found to have a significant depletion zone, called the ozone hole, over the Antarctic region.

6. 6. 4. The Ozone Layer and Its Recent, Documented Changes

Ozone is produced in the stratosphere by the intense ultraviolet radiation from the Sun. The absorption of the Sun's radiation by ozone warms the stratosphere. It makes it stable, too. This absorption by the ozone also protects living things on earth from destructive ultraviolet rays.

The total amount of ozone in the atmosphere is small. If it were compressed to a liquid layer over the globe at sea level, it would be less than 5 millimeters thick. In the troposphere, the average concentration of this protective layer is about 20 parts of ozone per billion parts of air.

In recent years, the earth's ozone layer has been carefully measured. It was found to have a significant depletion zone. This zone has been called the **ozone hole**. It is over the Antarctic region.

Scientists have found that certain aerosol chemicals cause a depletion effect on stratospheric ozone. This lessens the protection of the ozone layer. An international agreement was made and laws around the world were changed to ban the use of **chlorinated fluorocarbons**, or **CFC's** and other known ozone-depleting chemicals. Read more about this in our Chapter 38.

6. 7. THE EARTH's TILT AND THE REASONS FOR SEASONS

So far, we have portrayed our planet's climate patterns by depicting an upright earth with the North Pole at the top. This however, is not the case. Our planet is *tilted* with its axis constantly pointing at an angle respective to the sun. This causes a skewing effect on our seemingly perfectly-parallel, climate-by-latitude lines.

As the earth makes its 365.242190 day solar orbit, during one half of this orbit one of our two hemispheres is slightly closer to the sun. The other is slightly further away.

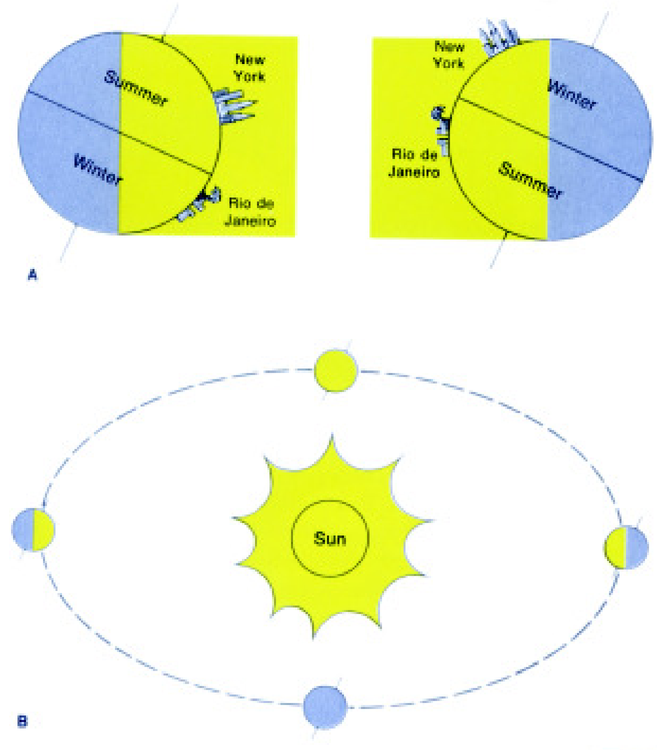
At the two midway points (called the **equinoxes**), a switching occurs. Afterwards, until the next equinox switch, the opposite hemisphere is closer to the sun. Exactly at each equinox, the two hemispheres are equally distant from the sun. The vernal equinox (spring) is March 20/21 and the autumnal equinox is September 22.

The resulting effect is our **seasons**. We experience these seasons as fall, winter, spring, and summer, dependent upon which time of the year it is, and dependent upon which hemisphere we are standing on at the time. The Northern Hemisphere's winter is the Southern Hemisphere's summer, and vice-versa.

As we have learned, critically important is the location on our planet for the most direct solar rays and their resulting equatorial low effect. This is not fixed at the Equator's 0 degree location. Instead it rotates northwards and then southwards, as our planet makes its solar orbit.

Each of our planet's climatic and wind regimes, depicted by latitudes above, is similarly affected. Depending on the time of year, a particular earth location, such as an island, may be in the dry heat of the subtropical high and later have the wet warm equatorial low get close to or even actually shift over it.

Likewise, the length of a day's sunlight and darkness changes with the seasons. During summers, in each respective hemisphere, the day's length is greatest and the night's is shortest. Longer and longer nights ensue as winter arrives. The pattern reverses six months later.



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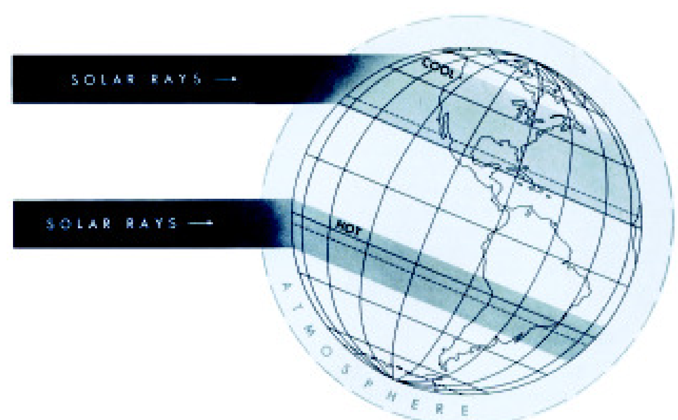
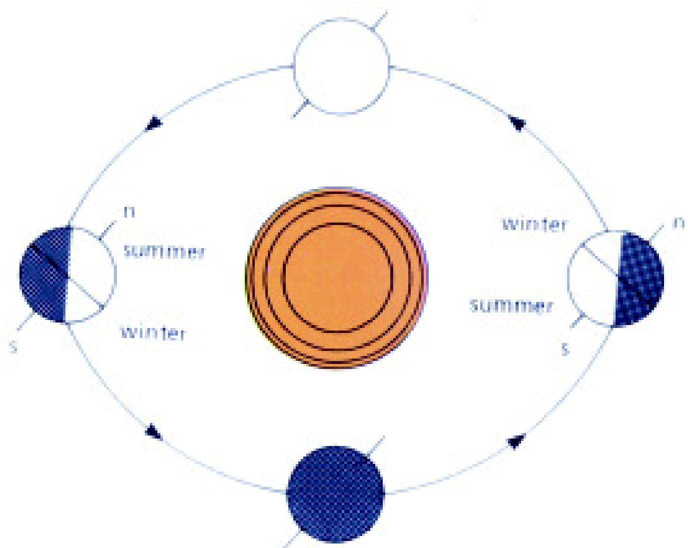


Relative amount of sunlight striking the earth's surface due to tilt.



The solar year

The longest and shortest day for each opposite hemisphere occurs when the closest solar contact point is at its furthest north (June 20 to 22) and its furthest south (December 21 or 22). These are the **summer solstice** and the **winter solstice**, again depending on which side of the equator you reside. The term solstice comes from two words, *sol* meaning sun, and *sistere* meaning to stand.

There are two points of each year when the day length is exactly the same in each hemisphere. Yes, you figured it out. These are the two equinoxes. In fact the word equinox means “equal nights”.

The places where the northward and southward closest point movements of the sun’s rays end are called the **Tropic of Cancer** (23 degrees, 26 minutes north) and the **Tropic of Capricorn** (23 degrees, 26 minutes south). Want to learn what the word “tropics” means? It comes from the Greek word *tropikos*, meaning “of a turn (of the sun at the solstices)”.

In our tropics, extreme rainy and dry seasons result from this annual solar migration. In temperate areas, extremes of warm and cold temperatures result. At the poles, hours of daylight and hours of darkness fluctuate tremendously with the seasons.

All of this is dependent upon the time of the year and which earth pole is oriented towards, and which away from the sun. Our sun, the main source of our heat, light, and other forms of energy, greatly affects our planet’s various locations in different ways and at different times of each year.