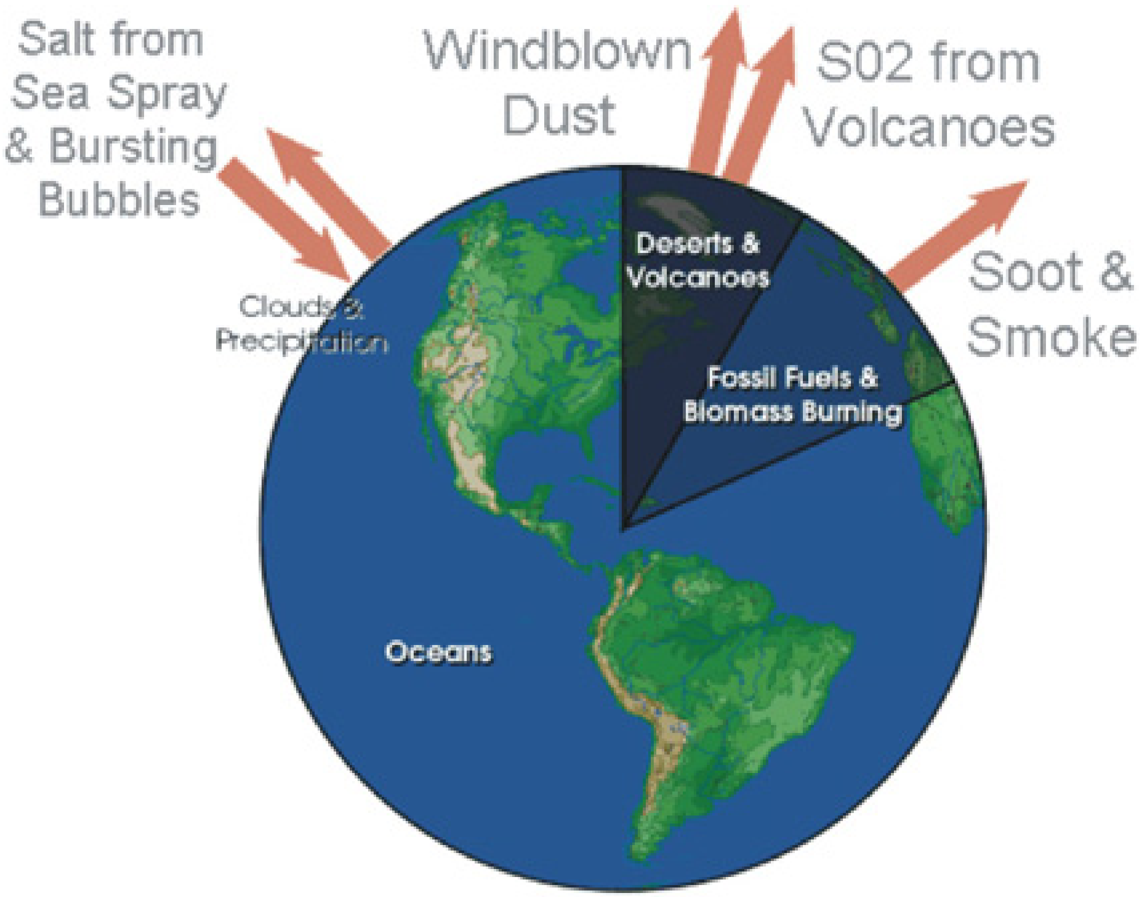
# Atmosphere

Richard Wilson

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# What is the ATMOSPHERE?

The atmosphere is the air that we breathe. It is also the wind that blows through our hair and the clouds that float in the sky. All the weather that takes place is part of the atmosphere. The atmosphere surrounds us at every moment, keeping us alive and warm. It is the part of the Earth system that we are most familiar with; so familiar that we often take it for granted. Without the atmosphere, we would perish within minutes.

There are a few important properties that have to do with the atmosphere. The first is temperature. That is simply how hot or cold the air is. During the day, the atmosphere is warmed by the sun, so the temperature goes up. At night, after the sun goes down, the atmosphere cools and the temperature drops.

Another property is called pressure. Pressure is how thick or dense the air is. The atmosphere is several kilometers thick. That means there is a lot of air above us, and it's all pushing down on top of us. On the surface, pressure is usually pretty constant from one place to another. But, often there are small differences, and these differences are what lead to all the weather we experience.

When two neighboring regions are at different pressures, they are out of balance with each other. The atmosphere produces winds and storms which try to restore the balance.

The atmosphere is the most dense near the surface because of gravity. As one goes higher, the air gets thinner and thinner. At an altitude of about ten kilometers, the atmosphere is only half as thick as at the surface. That's why air tanks are needed to climb Mt. Everest (nine kilometers high) and commercial airliners must be pressurized (flying at a height of about ten kilometers).

The last important property of the atmosphere is humidity. Humidity is a measure of how much water is in the atmosphere. When water evaporates from lakes and oceans, it turns into a gas and becomes part of the atmosphere. It is this water that sometimes condenses into clouds and becomes rain.

## Why do we care about the ATMOSPHERE?

The atmosphere is shared by every person on this Earth. When one person (or group or nation) affects the atmosphere, it affects all of us. Without the atmosphere, we would find it very hard to survive. Humans can last weeks without food, days without water, but only minutes without air. We also consume it at a higher rate: humans breathe the equivalent of 13 kg of air each day, compared with eating 2.4 kg of food and drinking 1 kg of liquid. Our daily lives are also influenced by the atmosphere. How warm it is or whether it's raining determine what kind of clothing we wear and what kind of activities we participate in. Local climates affect what kind of houses we build.

Our daily lives are also influenced by the atmosphere. How warm it is or whether it's raining determine what kind of clothing we wear and what kind of activities we participate in. Local climates affect what kind of houses we build.

We are also protected by the atmosphere. It acts as a huge blanket, keeping the Earth warmer than it would be without the atmosphere. This is known as the greenhouse effect. (Without the atmosphere, the average temperature on Earth would be below freezing!) The atmosphere also protects living things on Earth from the sun's harmful ultraviolet radiation. A thin layer of gas called ozone high up in the atmosphere filters out these dangerous rays.

The atmosphere also helps to sustain life of Earth. It provides oxygen for humans and animals to breathe, and carbon dioxide for plants. Through the hydrological (precipitation) cycle, plants and animals receive the water they need to survive.

The atmosphere can also affect us in negative ways. Most of the natural catastrophes that occur are due to phenomena in the atmosphere. Things like hurricanes, lightning and thunderstorms, hail, flooding, and tornadoes. Severe consequences can also occur when humans pollute the atmosphere, such as creating smog or destroying ozone. These kinds of things can cause illnesses and even cancer.

## How do we study the ATMOSPHERE?

There are many ways in scientists can study the atmosphere. These range from looking at a simple thermometer to launching a spacecraft into orbit.

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**Weather Stations**

To study the atmosphere, we need to sample it at many places. This is because the atmosphere can change quite a bit over only a few kilometers. Temperature, pressure, and air moisture can all vary a great deal in a short distance. Because of this, most cities and towns have their own weather stations. Scientists can then look at information gathered across the country and around the world.

CHECKING WEATHER STATION
U.S. Fish and Wildlife Service/J&K Hollingsworth

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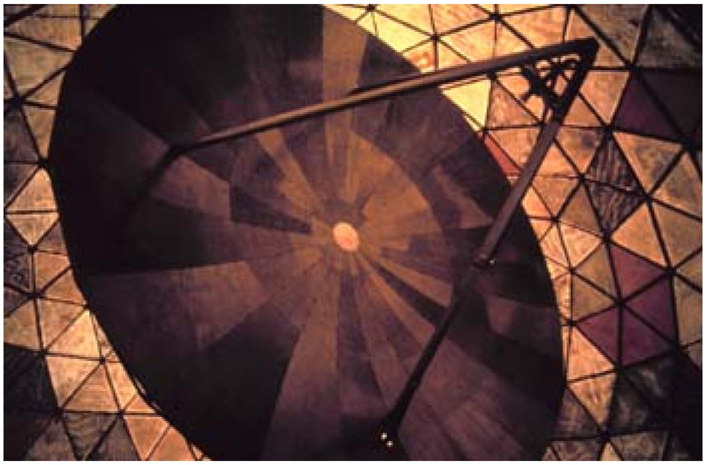
**Weather Radar**

But a weather station provides information for one isolated point in an area. Scientists who want to get a continuous view of the weather need to use other devices. One such device is radar. Just like airports use radar to track airplanes, scientists can use radar to track weather.



These pictures are of a radar station. The radar dish itself is housed inside a dome, which protects it. The dome is made out of a material that the radar can see through, so it doesn't interfere with the radar signal. The radar dish rotates in a circle, looking at the weather in all directions.

**Weather Balloons**

Just taking measurements at the surface, however, is not enough. The atmosphere is many tens of km high, and all of it needs to be sampled for scientists to understand it better. Common methods include using weather balloons and sounding rockets. These devices can reach a very high altitude, taking measurements all the way up. This information can then be automatically radioed to a weather station or retrieved when the balloon or rocket falls back to the ground. Weather balloons are launched twice a day from a network of sites across the country. This provides a continuous set of information at regular times and locations.

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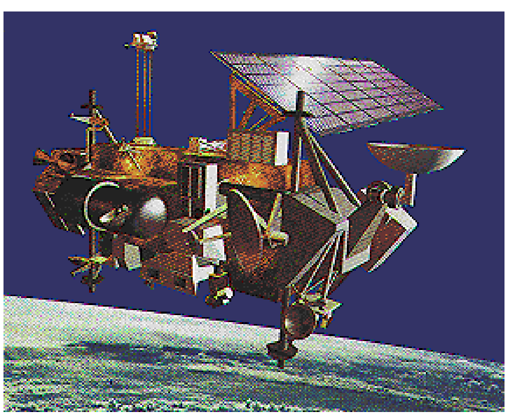
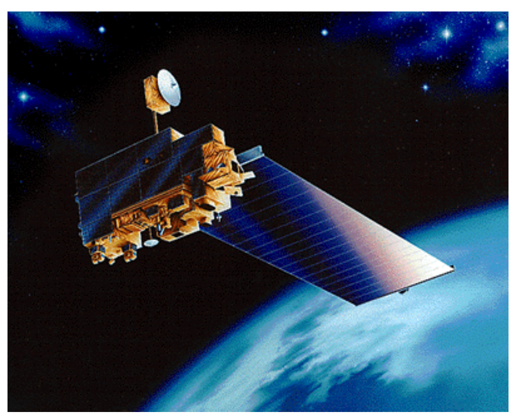
**Satellites**

Even balloons and rockets have their shortcomings. While they gather lots of information, the information itself is relatively sparse. It would take many thousands of weather balloons to provide a complete data set, and launching these would be very expensive and time-consuming. Scientists want to know what's going on everywhere in the atmosphere immediately. The way that they can get close to this is by using satellites. Once a satellite is in orbit around the Earth, cameras and sensors on board can see what's occurring in all parts of the atmosphere. One satellite can replace thousands of weather stations.





## Who are the people interested in the ATMOSPHERE?

Somehow, nearly everyone is interested in the atmosphere.

How often do people ask, "What's the weather going to be like tomorrow?" Or "What's it like outside?" Weather plays an important role in our daily lives. What we do, what we wear, and where we go can all be influenced by the weather.

Of course, there are many kinds of scientists who are very interested in the atmosphere. Meteorologists observe the daily, short-term changes in the weather and try to predict what the weather will be like for the next few days. Meteorologists look at how weather has changed in the past and use current measurements and computer models to predict what will happen.

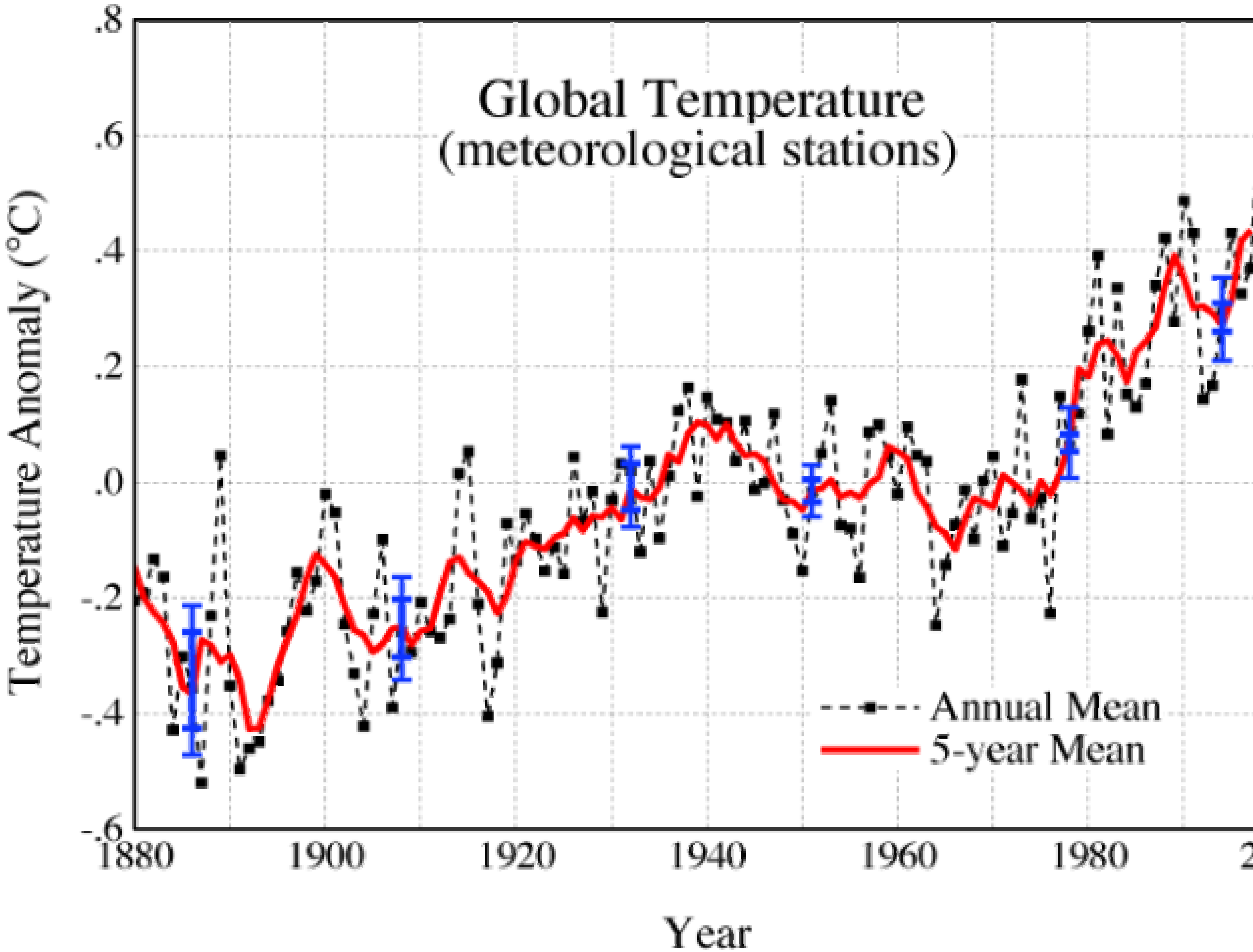
Climatologists are similar to meteorologists, except they study atmospheric changes over many years and decades. Climatologists try to predict whether the Earth will heat up or cool down in the years to come, and how these changes occur.

There are also atmospheric scientists who will study almost anything that goes on in the atmosphere, from different chemical reactions to how raindrops form. They study how different parts of the atmosphere are heated and what makes lightning and thunder.

Many people across the country and around the world dedicate their lives to learning about the atmosphere. Their work allows television weathermen to predict the week's weather or warns people about the damage pollution can do.

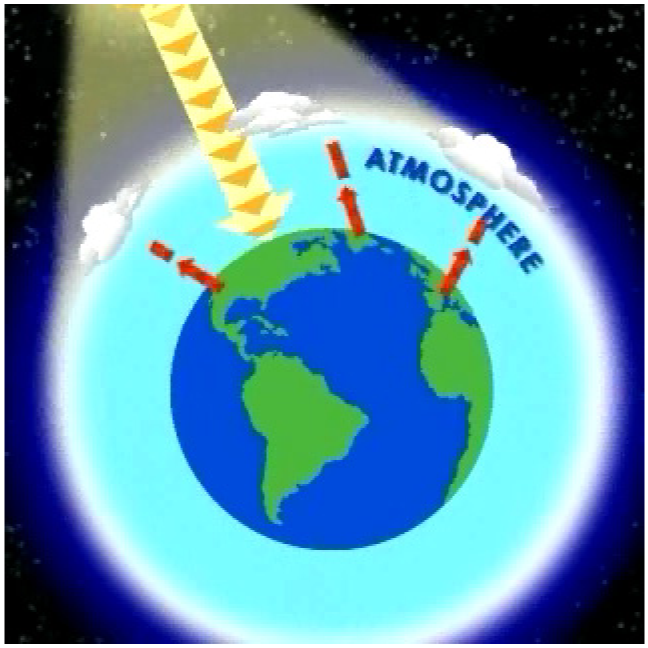

Many people's jobs also depend on the weather. Those who work in transportation, such as airline pilots and ship captains must keep the weather in mind when they plan their trips. And farmers are very concerned about the weather because it is so important in the growing of crops.

**1998 was the hottest year on record**



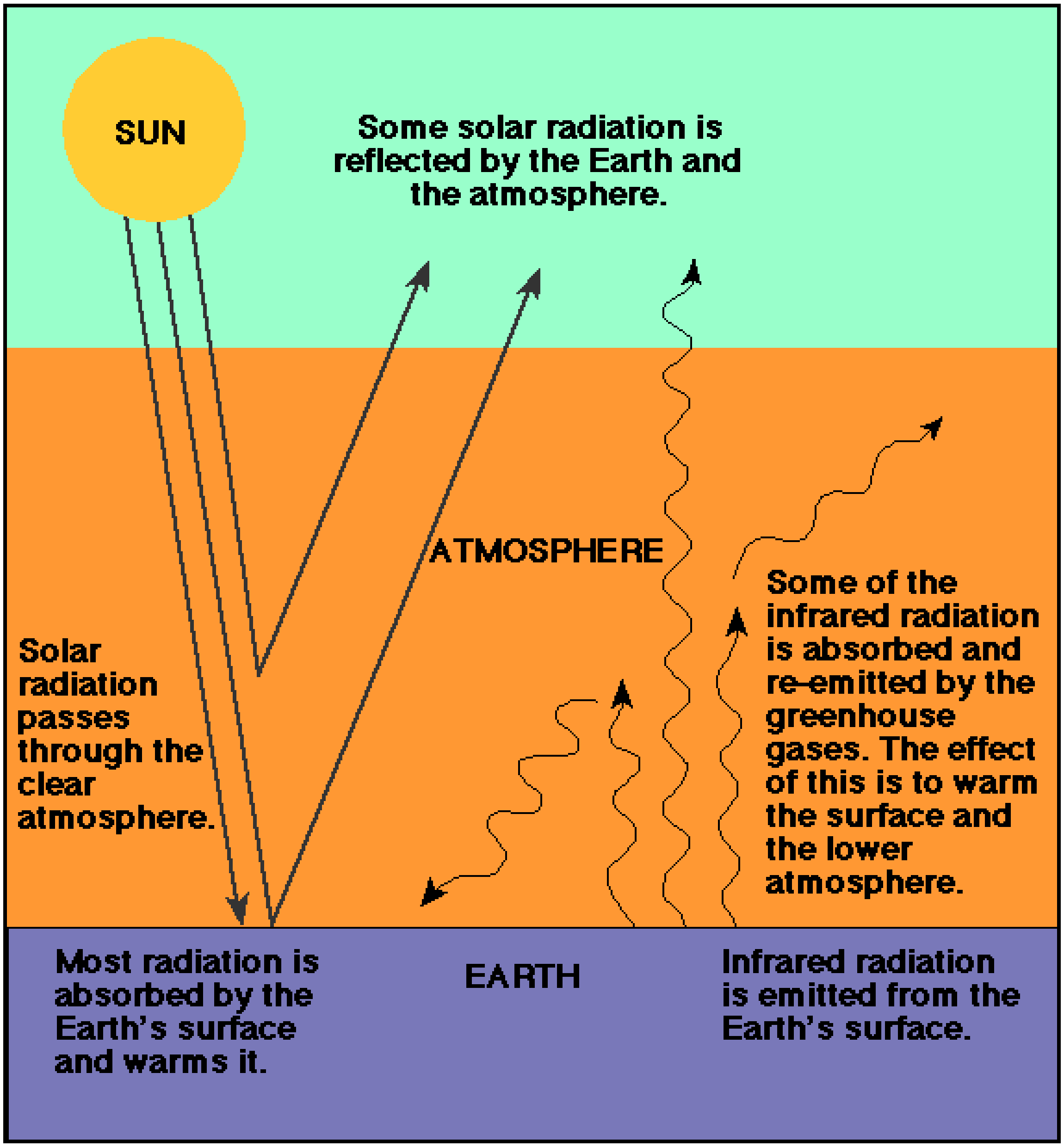

The year 1998 had the highest average global temperature ever recorded, as calculated by scientists at the National Aeronautics and Space Administration and the National Oceanographic and Atmospheric Administration (NOAA). The average temperature for 1999 and 2000 is similar to, but only slightly lower than, the record year of 1998. The temperature is determined by averaging thousands of readings from land and ocean weather stations all over the world.

**Gases absorb IR radiation**




The atmosphere of the Earth behaves like a blanket, retaining a portion the heat generated by solar energy. This "greenhouse effect" keeps the average temperature of the Earth about 30 degrees (C) (86 degrees F) warmer than it would be without an atmosphere. This movie describes how clouds and certain atmospheric gasses (such as water vapor and carbon dioxide) provide this warming effect.

## Greenhouse gases




The atmosphere of the Earth acts in a very similar way to a greenhouse. Sunlight penetrates the transparent air and causes the ground to warm. The atmosphere then acts as a blanket, keeping the warmth of the Earth from escaping back into space. This effect is due to certain gases in the atmosphere which are very good at absorbing and re-radiating the heat energy before it is lost to space. These gases, called "greenhouse gases", include carbon dioxide, water vapor, and methane. Without the greenhouse effect, the entire planet would be much colder, by about 63 degrees Fahrenheit (35 degrees Celsius), than it presently is.

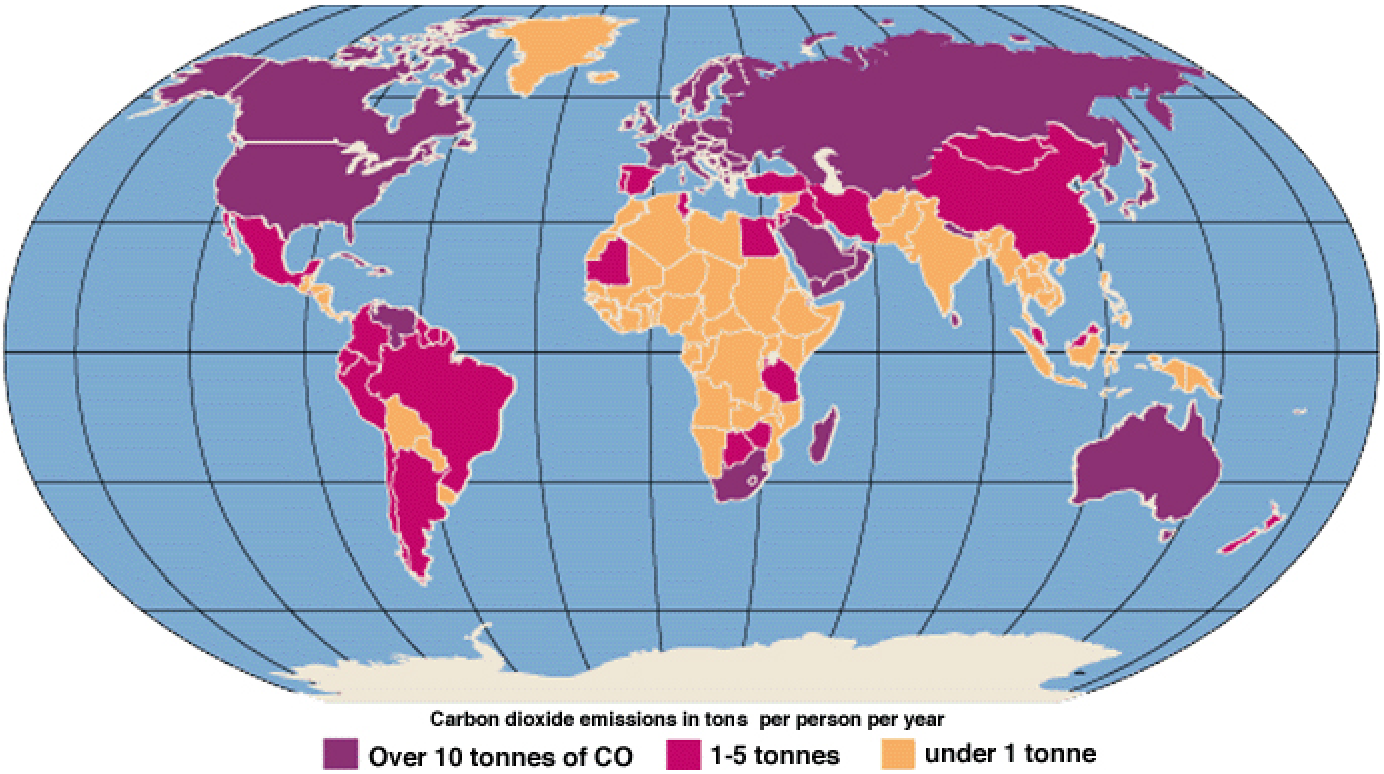
## Examples of climate change


Climate on Earth is never constant. For billions of years, natural forces affected the planet's climate. Now humans are affecting climate with the burning of fossil fuels. What was Earth's climate like in ancient times?

## CO2 is steadily rising

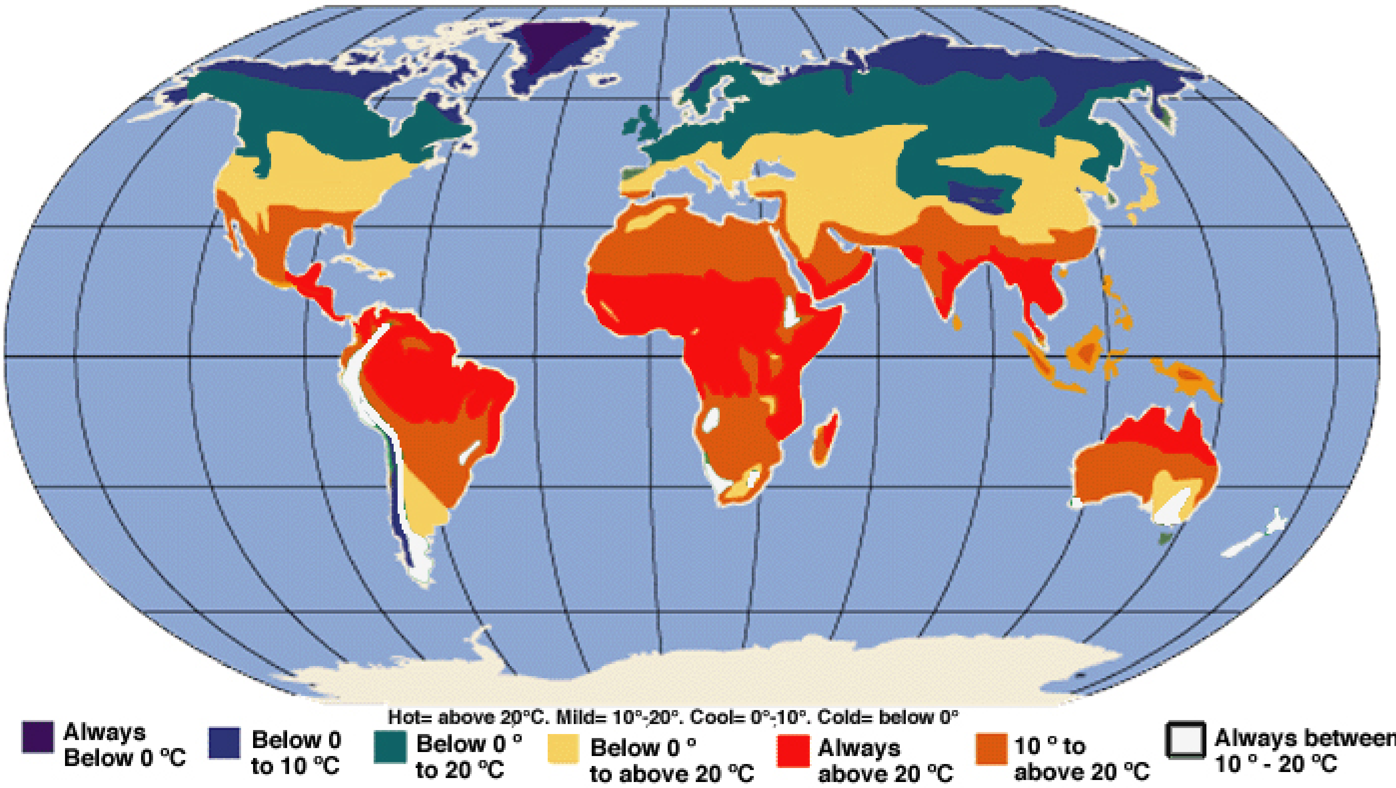
The amount of carbon dioxide in the atmosphere has been monitored for over forty years. These measurements show that the carbon dioxide levels have increased every year. Carbon dioxide is known to be a greenhouse gas, which means that increased levels of carbon dioxide in the atmosphere could lead to global warming. This could have serious environmental consequences for the entire world. Scientists also think that humans may be responsible for the increases, from such things as cars, industry, and the burning of the rainforests. If this is the case, we may be doing irreversible harm to the environment. The annual fluctuations in the graph above are due to the seasons. During the fall and winter, vegetation stops growing and decays, leading to higher amounts of carbon dioxide in the air. Vegetation then begins to grow during the spring and summer, absorbing some of the atmospheric carbon dioxide.

## Maps of CO2 emission



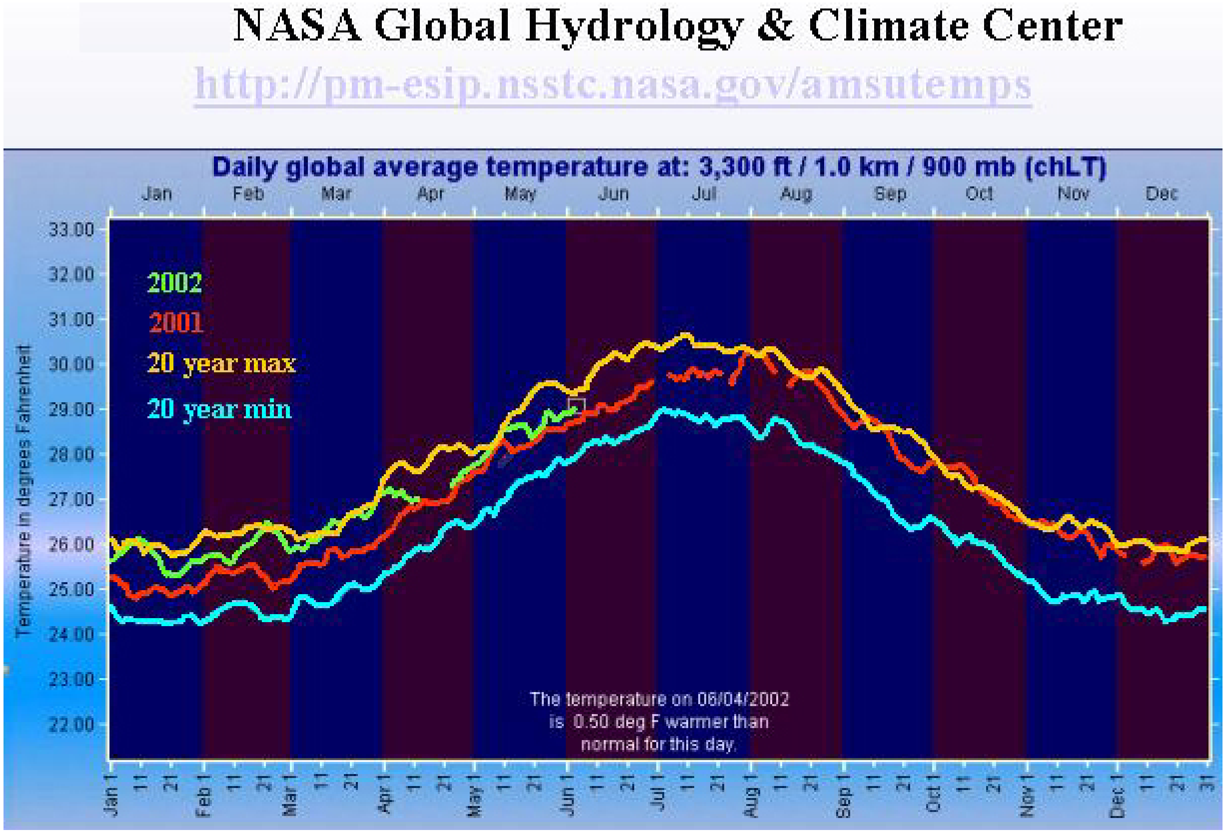

Above is a map showing the amount of carbon dioxide emissions, per person, for each of the world's nations. The map lists the emissions in tons of carbon dioxide released per person each year. Carbon dioxide is a greenhouse gas and can affect the climate of the Earth. The nations that release the most carbon dioxide are the industrialized nations, such as the United States, Canada, Russia, Japan, Australia, and the nations of Europe. Carbon dioxide is released when fossil fuels such as coal, gas and oil or traditional fuels such as wood are burned. Thus, the amount of carbon dioxide released per person is related to the amount of energy used per person. For example, for each ton of methane burned, 2.75 tons of carbon dioxide are released. The countries of Africa and Central and Southeast Asia do not release nearly as much carbon dioxide per person.

## Typical temperatures



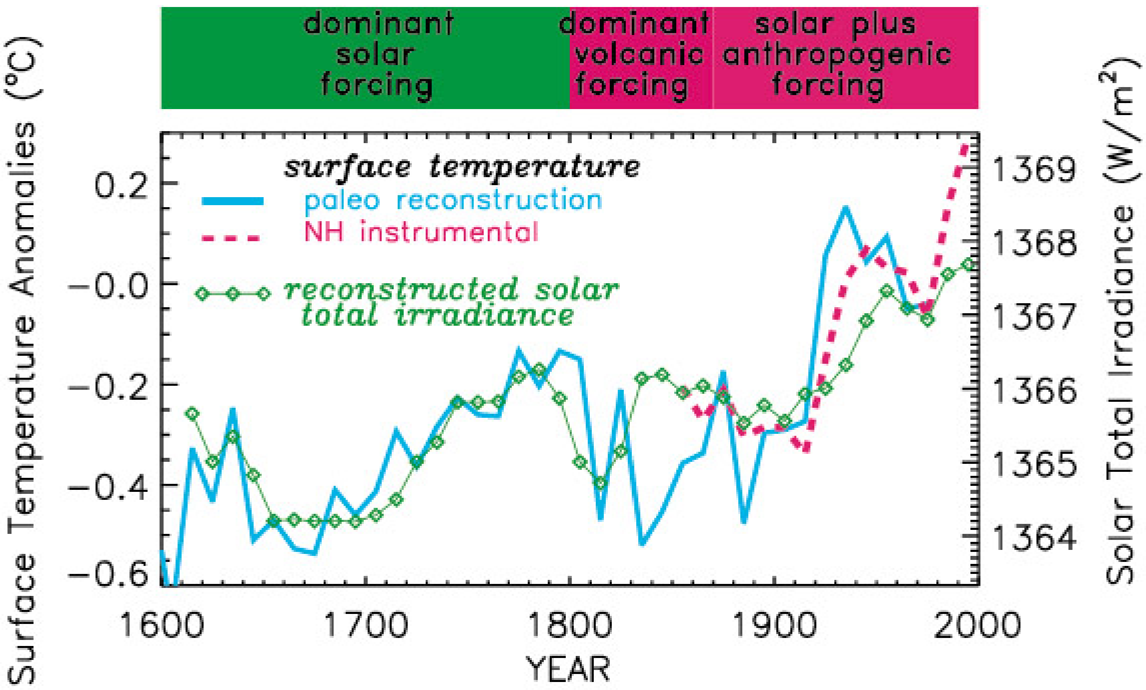

Above is a map showing the typical temperatures for various regions on Earth, in degrees Celsius. Zero degrees is freezing; 23 degrees is "room temperature". The red regions, which never fall below 20 ¡C, are hot and the purple regions, which never get above freezing, are very cold.

**Global average temperatures**




NASA's Global Hydrology and Climate Center at Marshall Space Flight Center now provides a way to interactively show the current global mean temperature and compare this year to previous years. You can plot the temperatures at altitudes from 1 km to 36 km. Go to the site in the "more info" section to create a plot for today.

## Only about a third




This graph shows the change of Earth's global temperature over the past 400 years. The recent measurements are shown as red, and the estimated temperatures from the past are shown in blue. On the same plot is the green curve, the estimated solar energy input to the surface (reconstructed from several kinds of data). Measured over centuries, the largest changes are due to variations in the solar input ("solar forcing"). However, in the 1800's three dips in temperature are seen which are not associated with the Sun. These are caused by dust from volcanoes shielding out sunlight, resulting in a cooler Earth ("volcanic forcing"). In the last hundred years we observe a rise in temperature and a rise in solar energy. However, the rise in temperature is considerably larger than what would be predicted from the change in solar energy alone. Roughly 1/3 of the recent temperature increase is from the Sun; the rest is presumably from man-made sources such as increased carbon dioxide and methane ("anthropogenic forcing").

## Natural and enhanced greenhouse

Most scientists agree: Earth is warming up. What has caused the slow rise in global temperatures? This movie looks at Swedish chemist Svante Arrhenius who first proposed the 'Greenhouse Effect' theory in the 1890's. Arrhenius observed that the rise of global warming appeared to be happening in tandem with increased burning of fossil fuels like coal and oil.

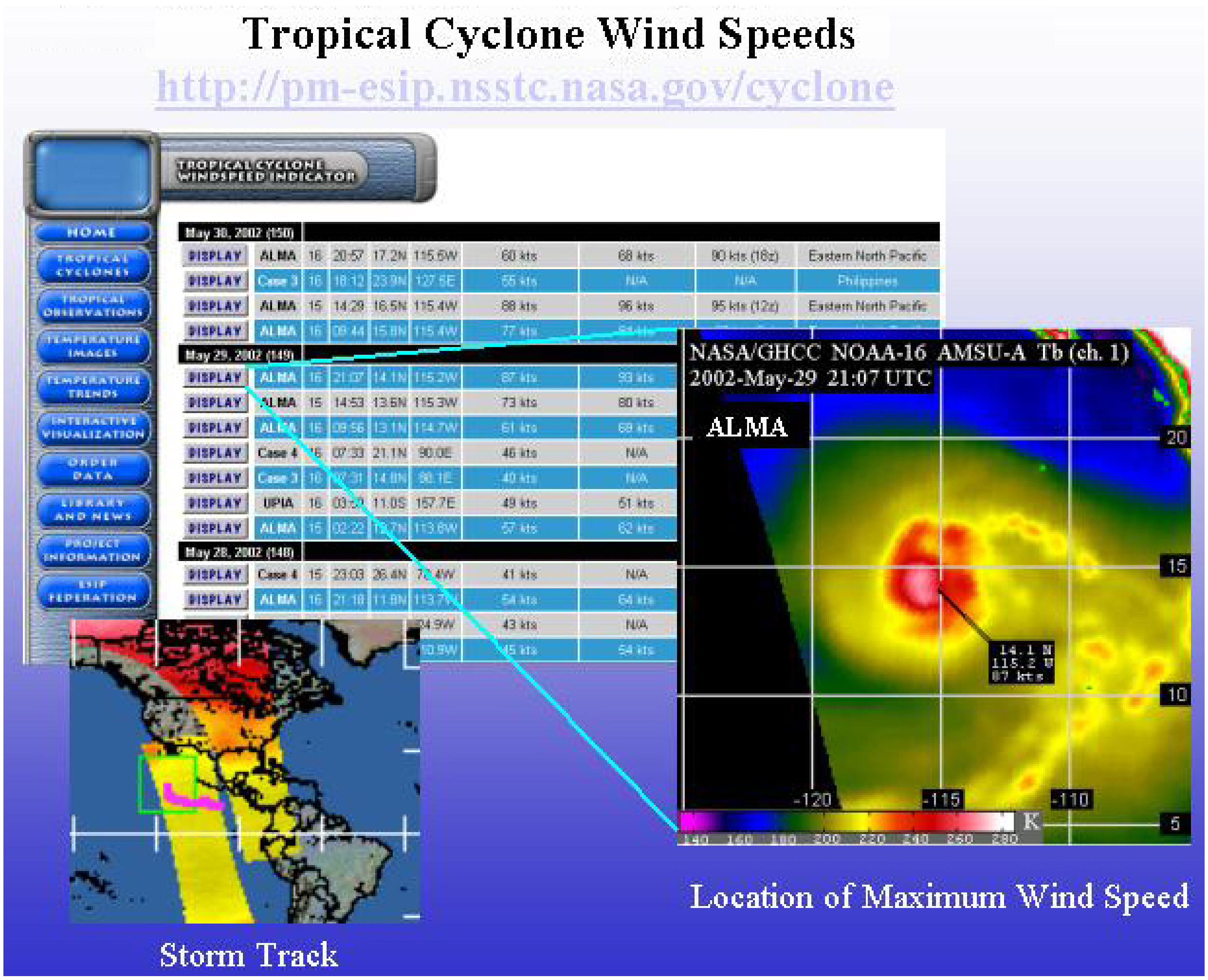
## Tree rings tell the tale


Climate on Earth is never constant. For billions of years, natural forces affected the planet's climate. Now humans are affecting climate with the burning of fossil fuels. What was Earth's climate like in ancient times? One way we can learn more about past clismate is by studying tree rings. We look at scientists coring the trunks of ancient pine trees in Siberia. By studying the pattern of annual growth rings in trees, they can better understand how ancient climate affected a single region or the world.

## Hurricanes, tornadoes, and tropical storms

Violent weather affects humans across the globe. Hurricanes, tornadoes, and tropical storms can cause billions of dollars of damage and many deaths. Remote sensing can help predict these massive events and save lives.

### Creating plots at the GHCC




The Global Hydrology and Climate Center at NASA Marshall Space Flight Center provides the maximum sustained wind speeds for current cyclone activity. Shown is one example, with the wind speed maps and storm tracks plotted.

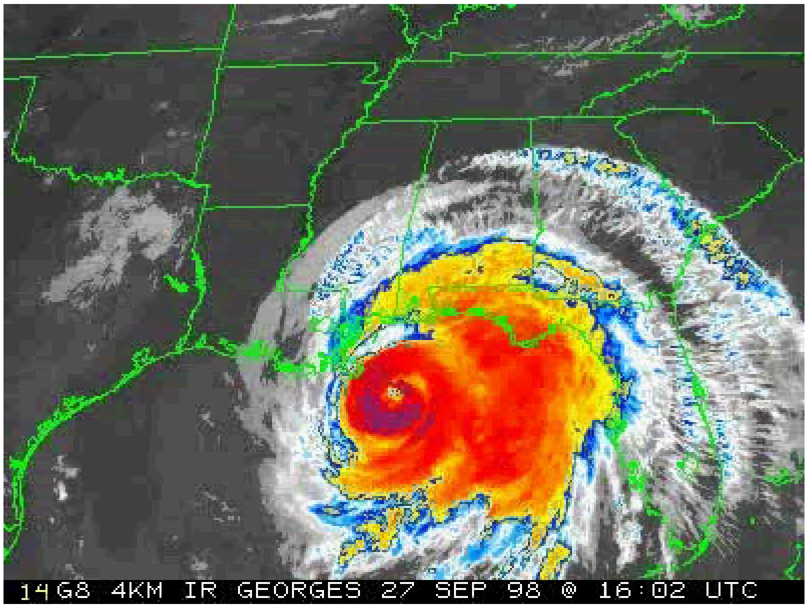
### Tropical storm Allison

The tropical storm Allison, taken by the MODIS instrument on the TERRA satellite, June 11, 2001. Dumping over 24 inches of rain in a 24-hour period after a week of rainfall, Allison caused the death of 24 humans and 30,000 laboratory animals, and damage to 3,500 homes.. The estimated destruction is nearly 5 billion dollars, making it the most costly storm in U.S. history.

**A space shuttle photo of Hurricane Bonnie**

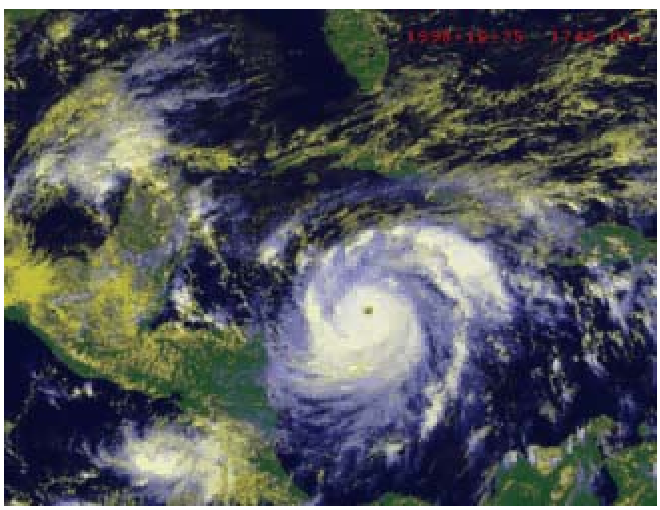
This photograph of Hurricane Bonnie (September 20, 1992) was taken by astronauts orbiting the Earth in the space shuttle (STS-47). The winds in a hurricane can be anywhere from 75 to more than two hundred miles per hour. Hurricanes can be several hundreds of miles across, and up to 50,000 feet high. At the center of the hurricane is the "eye", a relatively calm and clear area that's 20-30 miles wide.

### A satellite movie of Hurricane Georges



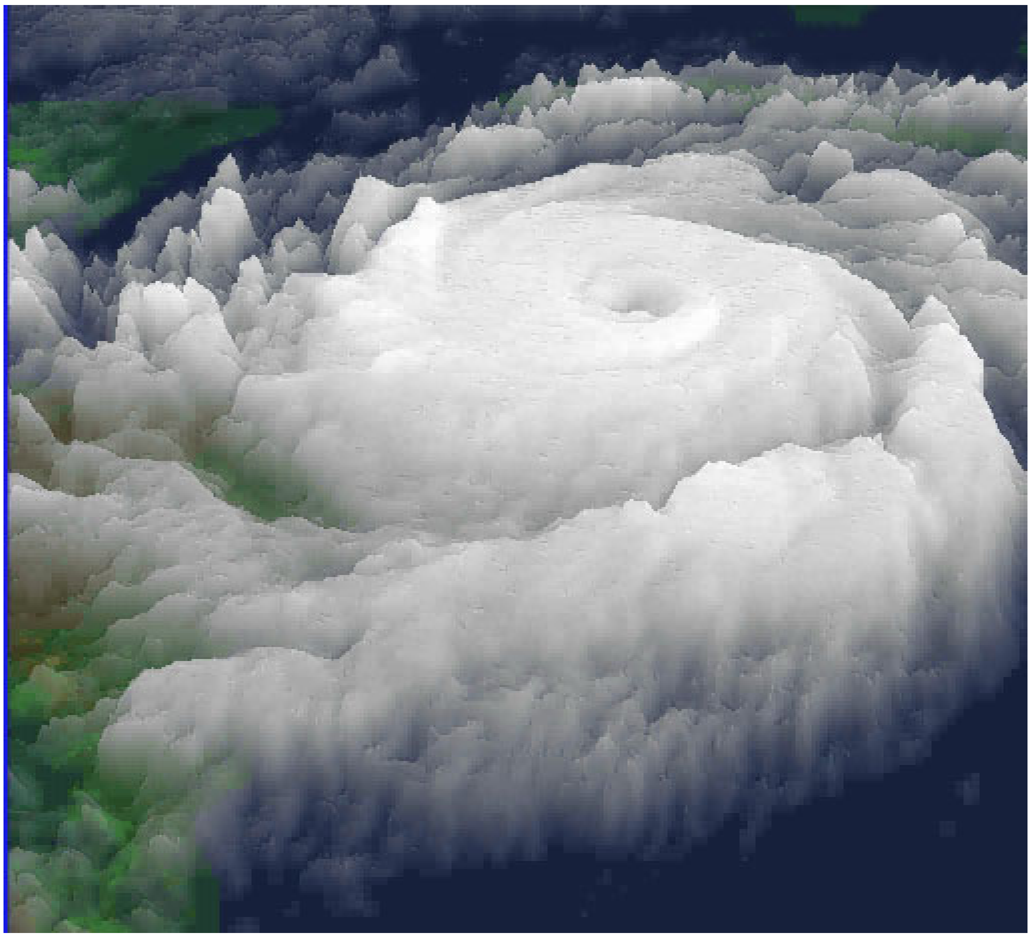

This is a movie of Hurricane Georges (September, 1998) in the Gulf of Mexico. The colors are enhancements using infrared data from satellites. These colors show how intense the storm is. Notice how the storm starts to weaken as it makes landfall. This is normally the case with most hurricanes

### A satellite movie of Hurricane Mitch



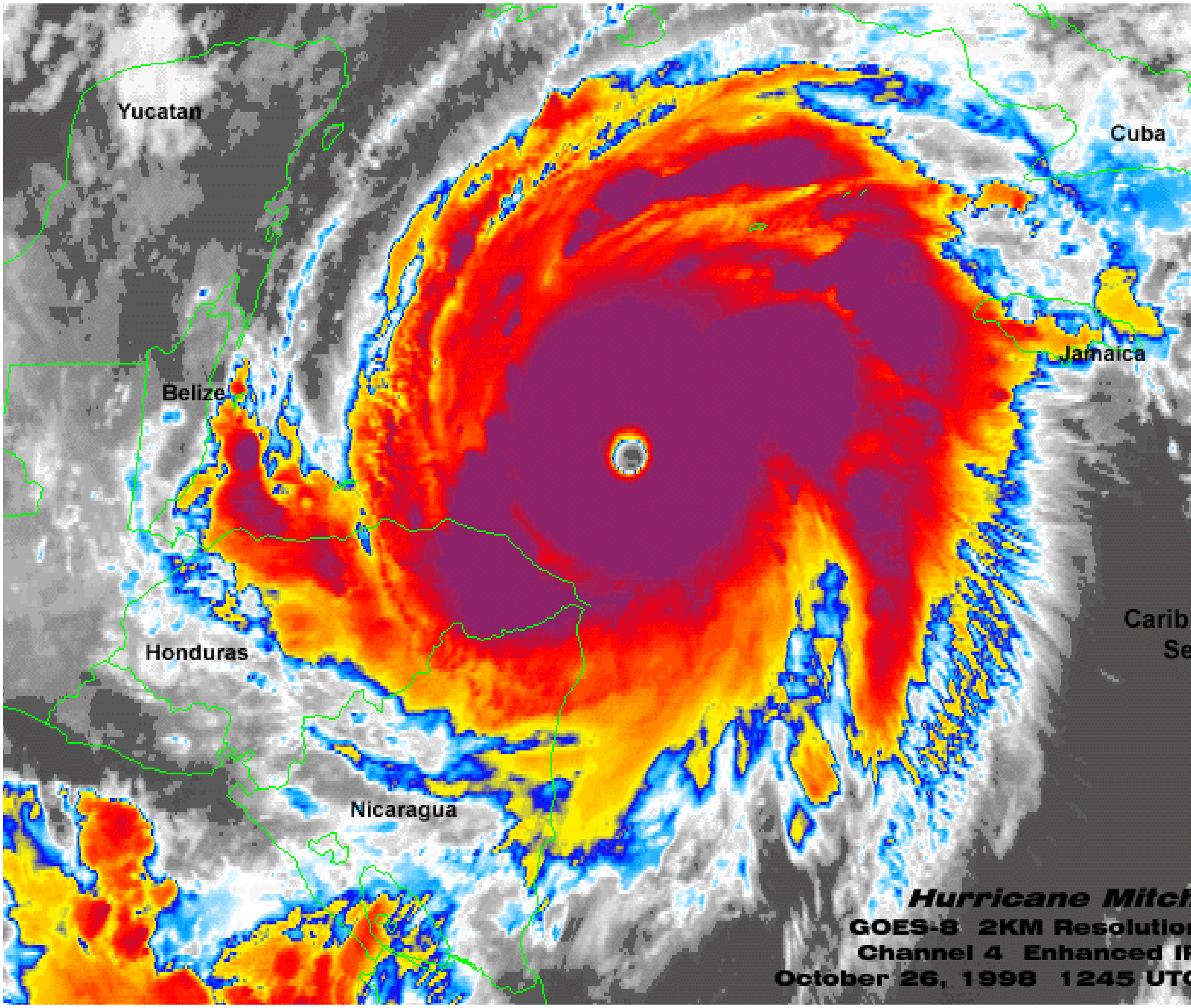
A movie of Hurricane Mitch (October 19-27, 1998) is pictured here. A hurricane is an immense circulating storm, an intense case of a class of weather systems called tropical cyclones. At the center of a cyclone is a region of extremely low atmospheric pressure. Because this region is at a lower pressure than its surroundings, winds blow from the high pressure areas inward toward the central low. The coriolis force (which is due to the rotation of the Earth) causes these winds to be deflected to the side. So instead of the winds blowing straight toward the center of the hurricane, they begin to blow around it. This causes the hurricane to circulate. Hurricanes always rotate counter-clockwise in the northern hemisphere and clockwise in the southern hemisphere. Mitch traveled westward in this week.

## A 3D movie of hurricane Mitch



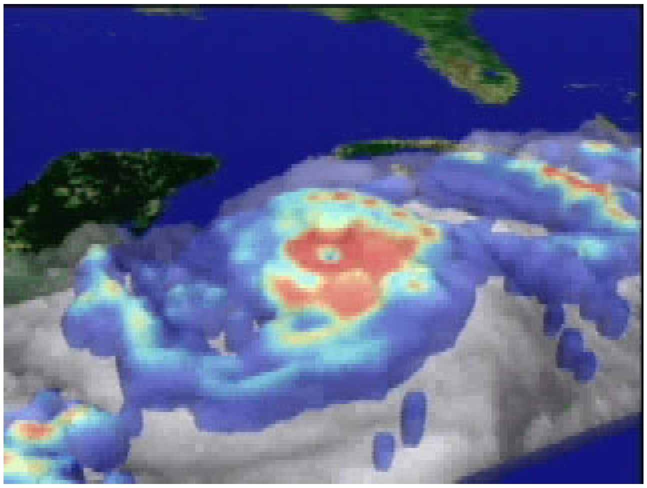
This is a model of hurricane Mitch that was created with three-dimensional data from weather satellites. A model such as this allows meteorologists to view the hurricane up close and from many different angles.

## An infrared photo of hurricane Mitch



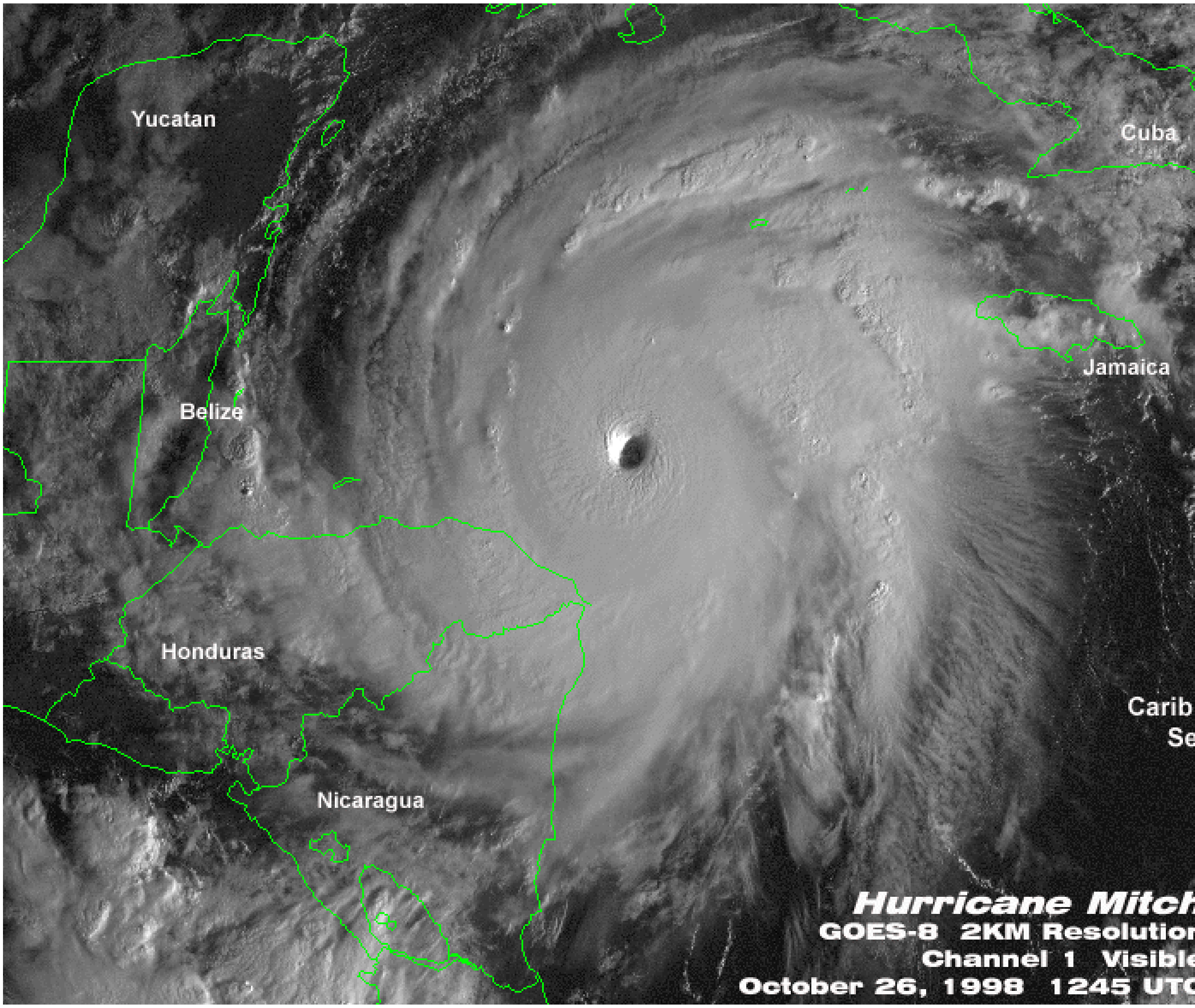

This photo of hurricane Mitch is enhanced using infrared data from a weather satellite. The colors represent intensity. Notice that the hurricane is most intense near the center, where the "eye" is located. Compare this picture to the visible version of the photo.

## A "fly-by" of hurricane Mitch



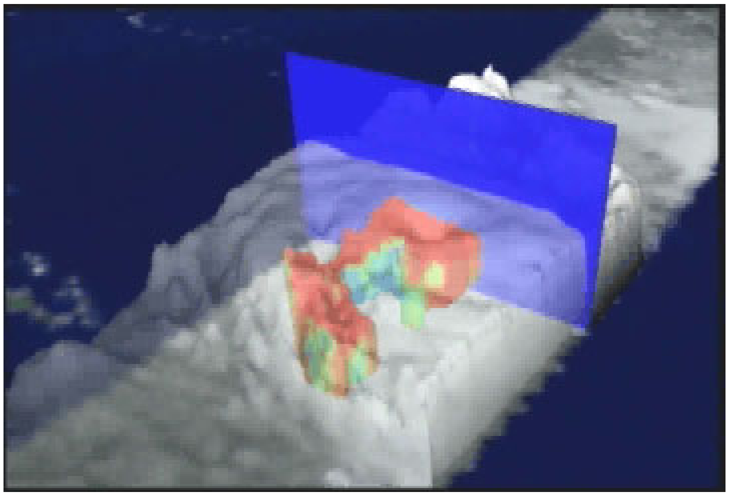
This is a simulated "fly-by" of hurricane Mitch. It was constructed using data taken from a NASA satellite called TRMM (the Tropical Rainfall Measuring Mission). Being able to model the structure of the hurricane like this helps meteorologists better understand hurricanes and their behavior.

**A visible photo of hurricane Mitch**



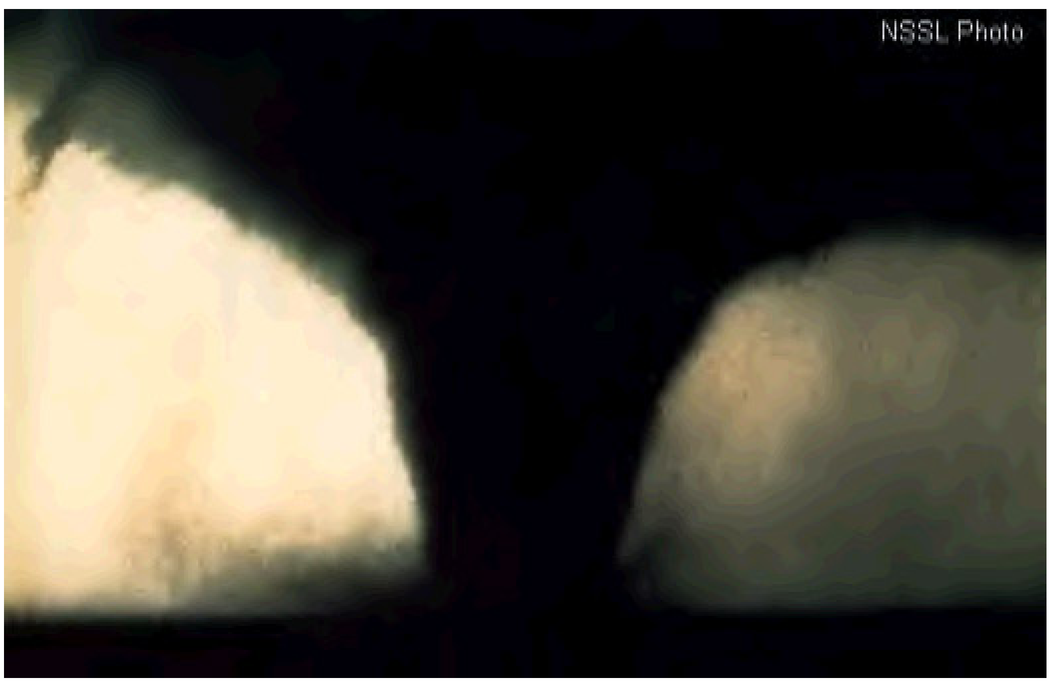

This photo of hurricane Mitch was taken from a weather satellite. Compare this picture to the infrared version of the photo. Notice how much more difficult it is to determine the intensity of the storm using this image, compared to using the infrared view.

## A "fly-thru" of Cyclone Susan



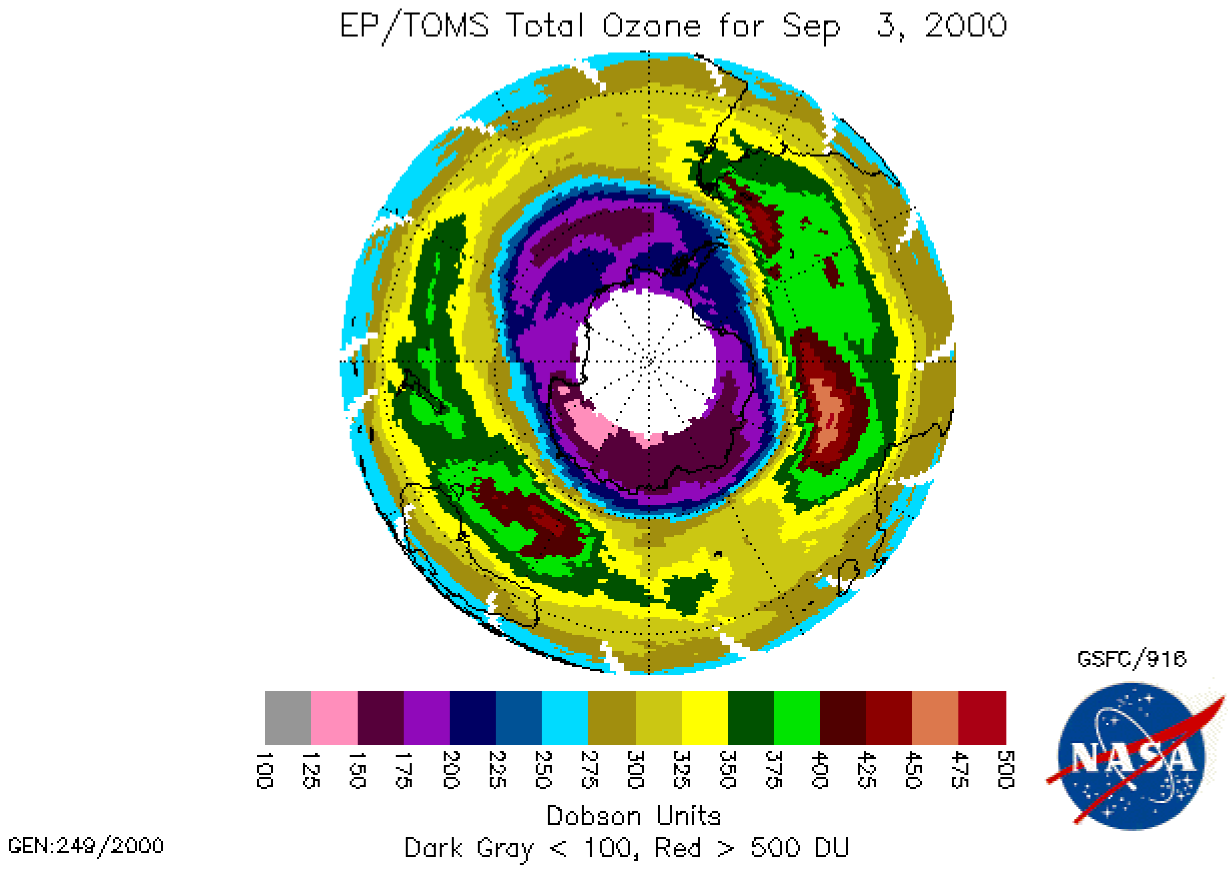
This is a simulated "fly-thru" of Cyclone Susan (January 5, 1998), traveling inside the hurricane and between the spiral arms. It was constructed using data taken from a NASA satellite called the Tropical Rainfall Measuring Mission (TRMM).

## Introduction to tornadoes



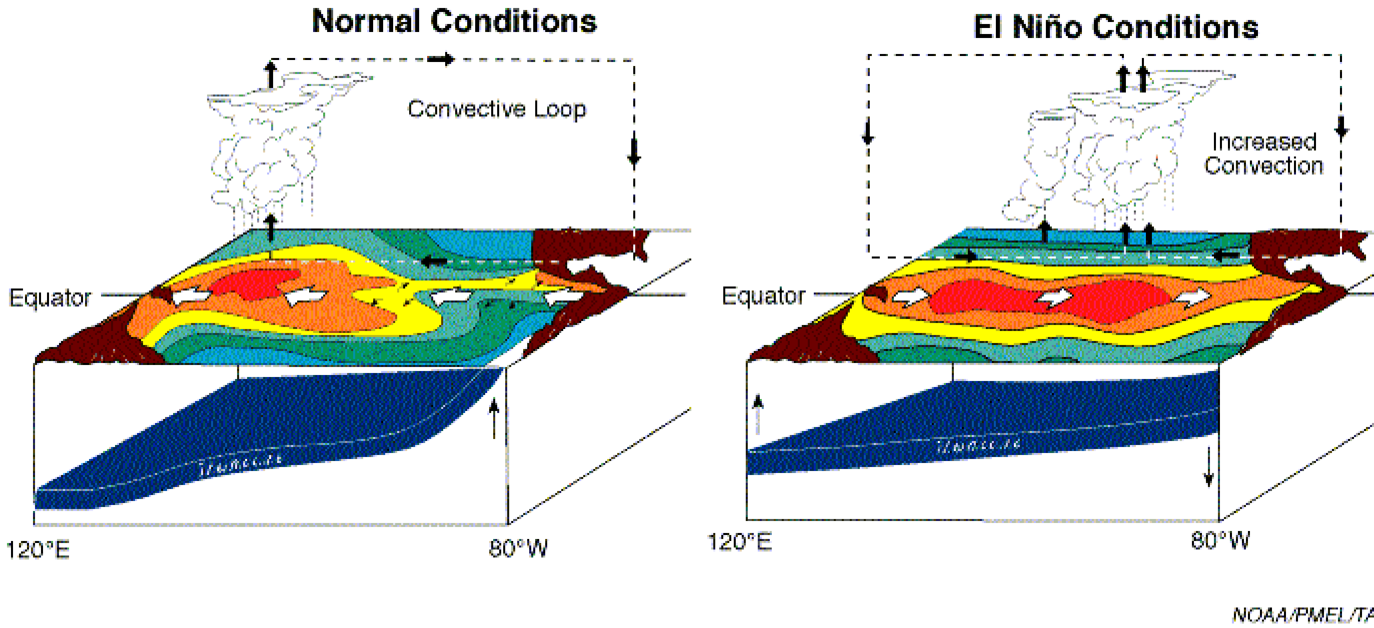

Although tornadoes occur in many parts of the world, these destructive forces of nature are found most frequently in the United States east of the Rocky Mountains during the spring and summer months. In an average year, 800 tornadoes are reported nationwide, resulting in 80 deaths and over 1,500 injuries. A tornado is defined as a violently rotating column of air extending from a thunderstorm to the grousnd. The most violent tornadoes are capable of tremendous destruction with wind speeds of 250 mph or more. Damage paths can be in excess of one mile wide and 50 miles long. Once a tornado in Broken Bow, Oklahoma, carried a motel sign 30 miles and dropped it in Arkansas! This is an image of the Seymour, TX tornado of April 10, 1979.

## The ozone hole on September 3, 2000 was the largest ever



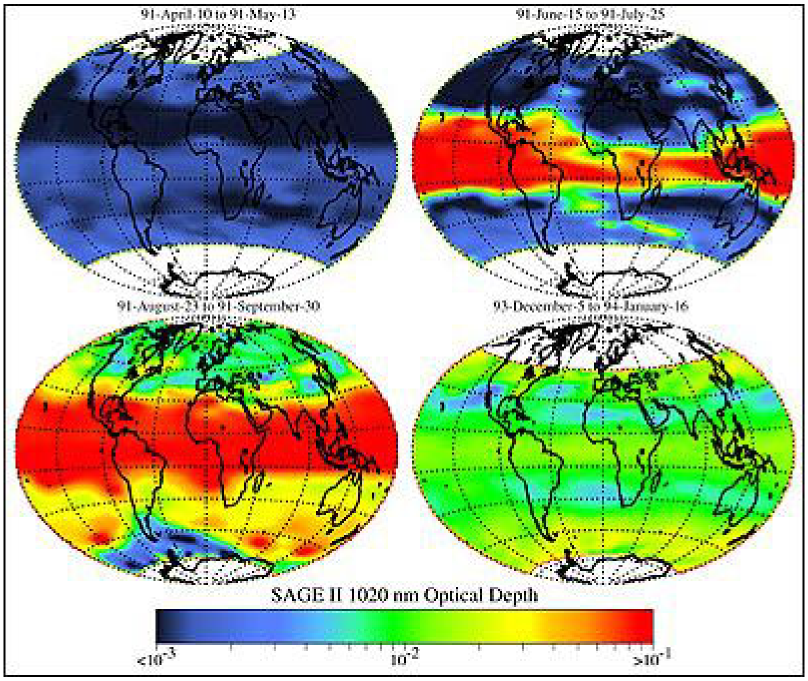

On September 3, 2000, NASA's TOMS-EP satellite observed that the Antarctic ozone hole was three times larger than the entire landmass of the United States. On that date, the ozone hole measured about 28.3 million square kilometers (about 11 million square miles). This exceeded the previous record of 27.2 million square km set on September 19, 1998. Ozone usually occurs between 9.5 and 29 km up in the atmosphere. While production of ozone-destroying gases has been reduced in recent years, their concentrations are reaching peak levels now at these high layers of the atmosphere. These ozone-destroying gases stay in the atmosphere a long time. As a result, we will be observing the ozone hole for many years to come.

## Changes in atmospheric winds during an El Niño



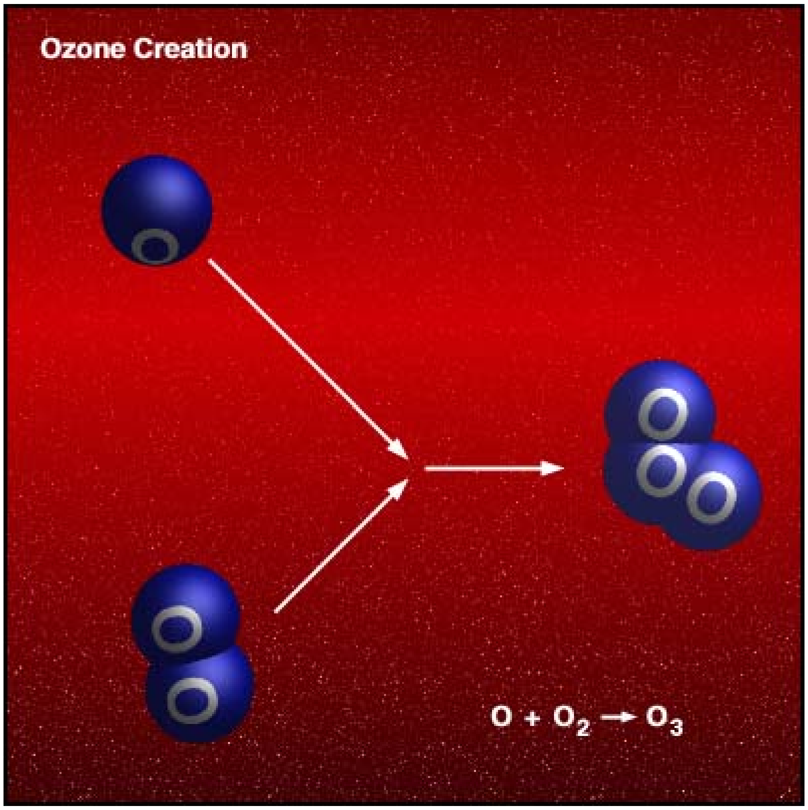

Under normal conditions there is an east-west circulation of air in the tropical Pacific which rises in the western tropical Pacific near Australia, moves at high altitude eastward, sinks in the eastern tropical Pacific near South America, and then moves westward near the surface. This pattern produces relatively high sea surface pressure and very little rain in the east (Tahiti, near the right center of the plot) and relatively low sea surface pressure and much precipitation in the west (Darwin, Australia, the bottomleft edge of the plot). Under El Niño conditions the strength of the westward winds near the surface decreases and the circulation of the convection cell breaks down. The east now has lower sea surface pressure and more rain and the west has higher sea surface pressure and drought conditions. These changes in circulation have an impact on the sea surface. For more information, go to the El Niño pages in the "Hydrosphere" section.

## Mt. Pinatubo released large amounts of aerosols



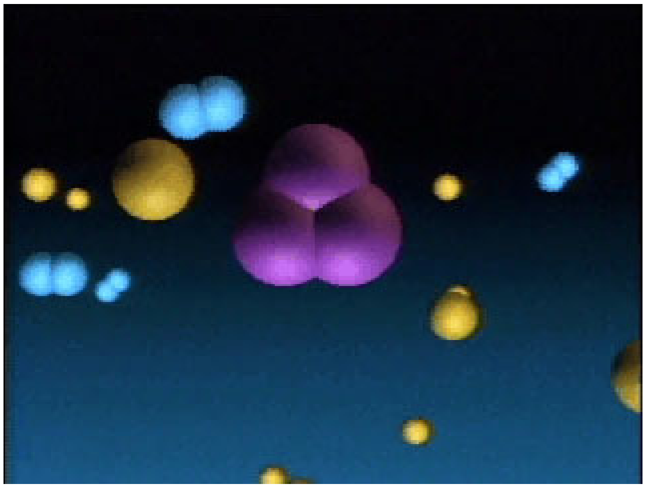

The images above show the effect that the 1991 eruption of Mt. Pinatubo had on the atmosphere. The picture in the upper left shows the atmosphere before the eruption, with low levels of aerosols present. (The thicker the optical depth is, the more aerosols are in the air.) The image in the upper right shows the atmosphere after the eruption, with large amounts of the volcanic aerosols having spread around the world. Because the dominant winds are east-west, the aerosols by this time have not had a chance to travel to higher latitudes. The lower two images, taken in the months following the eruption, show the aerosols moving to higher latitudes and eventually being spread evenly throughout the entire atmosphere. These images were taken by a satellite instrument called the Stratospheric Aerosol and Gas Experiment (SAGE) II.

## How ozone protects us



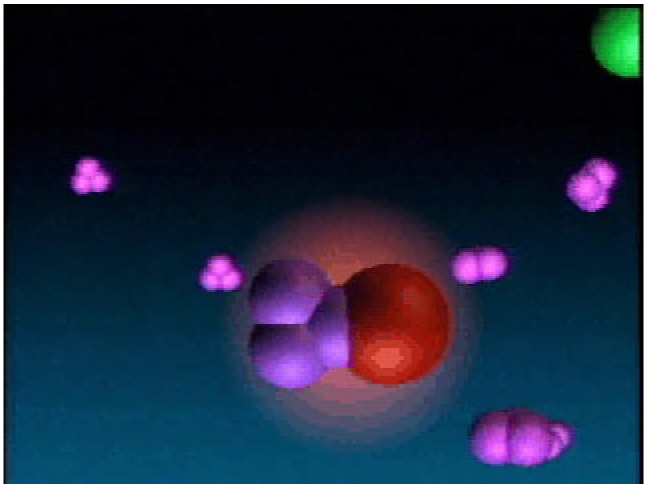

Ozone is a gas in the atmosphere that protects everything living on the Earth from harmful ultraviolet (UV) rays from the Sun. Without the layer of ozone in the atmosphere, it would be very difficult for anything to survive on the surface. (Think of a very bad sunburn, only much worse!) Plants cannot live and grow in heavy ultraviolet radiation, nor can the plankton that serve as food for most of the ocean life. The ozone layer acts as a shield to absorb the UV rays, and keep them from doing damage at the Earth's surface.

### A movie of how ozone is made from oxygen



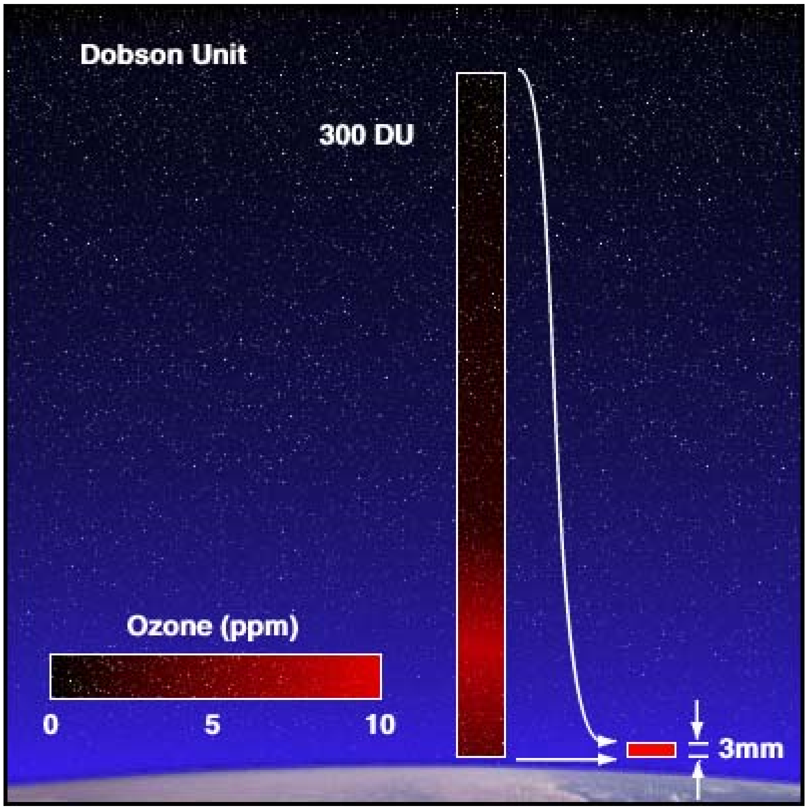
Ozone is made up of ordinary oxygen, just like what we breathe. The only difference is that ozone is made up of three oxygen atoms, while the stuff we breathe (molecular oxygen) is made up of only two atoms. Solar rays high in the atmosphere convert O2 to O3. In the upper atmosphere, rays from the Sun break a normal oxygen molecule into two separate oxygen atoms. Another oxygen molecule then picks up one of these atoms to form an ozone molecule.

## Humans may be destroying the ozone layer



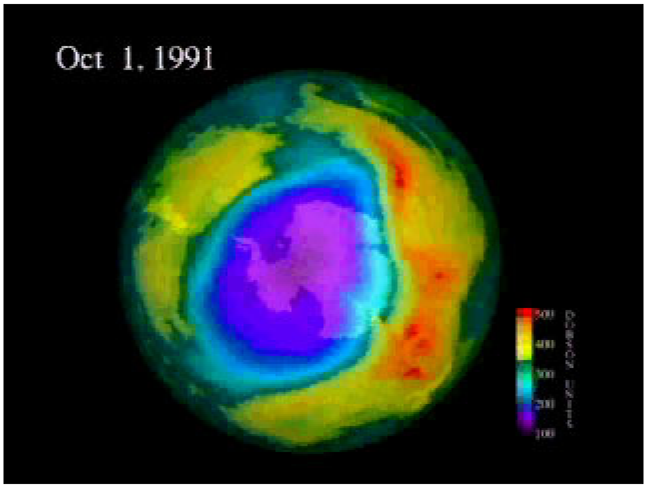
Scientists think ozone is being destroyed, and they think people are responsible. For many years humans have been polluting the atmosphere with man-made chemicals. It turns out that some of these chemicals are very good at destroying ozone. The worst of these chemicals are called CFC's, and were used in the past in things like spray cans and cooling devices.

## The abundance and measurement of ozone levels



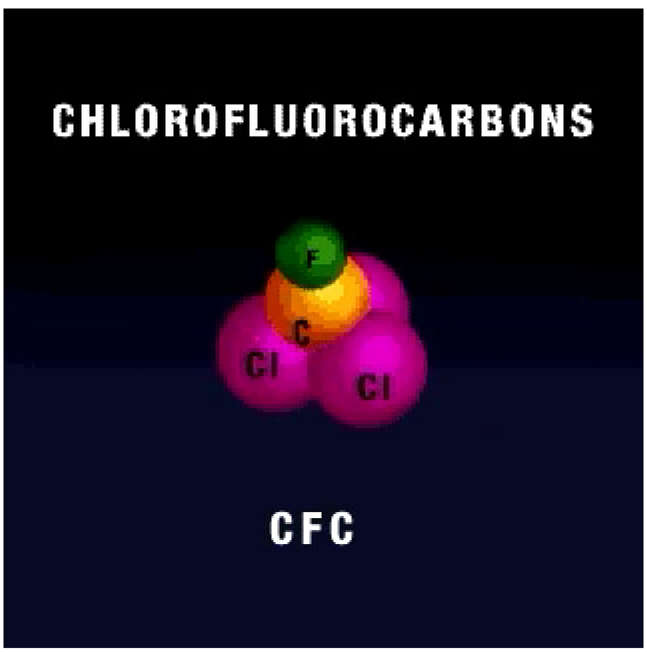

Ozone is what is known as a trace gas, meaning there is very little of it in the atmosphere. In fact, out of every million molecules of gas in the atmosphere, less than ten are ozone. Ozone is measured in what are called Dobson units. A Dobson unit of gas is equal to a layer of gas, at the surface of the Earth, with a thickness of one hundredth of a millimeter. The ozone in the atmosphere is about 300 Dobsons. That means if you brought all of the ozone in the atmosphere down to a layer of pure ozone at the surface, it would be about three millimeters thick. It doesn't seem like much, but it's enough to protect you from the Sun's UV rays. Much of the ozone is located about twenty kilometers above the ground, in a part of the atmosphere called the stratosphere. This is why it's called the "ozone layer".

### A movie of ozone layer hole




The ozone hole is a region of the ozone layer where a significant amount of ozone has been destroyed. In this false-color movie, regions with reduced ozone are shown in purple or blue. Regions with enhanced ozone are shown in red. The ozone hole is generally located over the South Pole where not very many people or animals live - however, planckton in the polar oceans can be harmed, which are the food stuff for many ocean dwellers. A similar but smaller ozone hole occurs in the Northern hemisphere.

## Man-made chemicals destroy the ozone

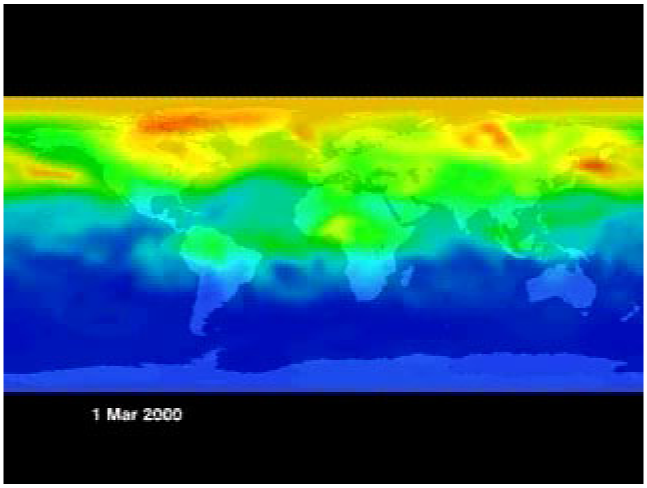



The role of CFCs (industrial gasses) on the creation of the ozone hole in the Antarctic is now well known. The consequences of reduced Ozone include an increase in the amount of ultraviolet radiation at the surface of the Earth. This movie describes the causes of ozone depletion and some of the consequences of this reduction.

## TOMS monitors the ozone levels

The Total Ozone Mapping Spectrometer (TOMS) instrument onboard Earth-orbiting satellitses can provide measurements of atmospheric ozone. These measurements allow scientists to track the varying amounts of ozone in places like the Antarctic. This movie explains satellite imaging of the ozone hole and displays their life cycle over Antarctica.

## A movie showing global CO levels

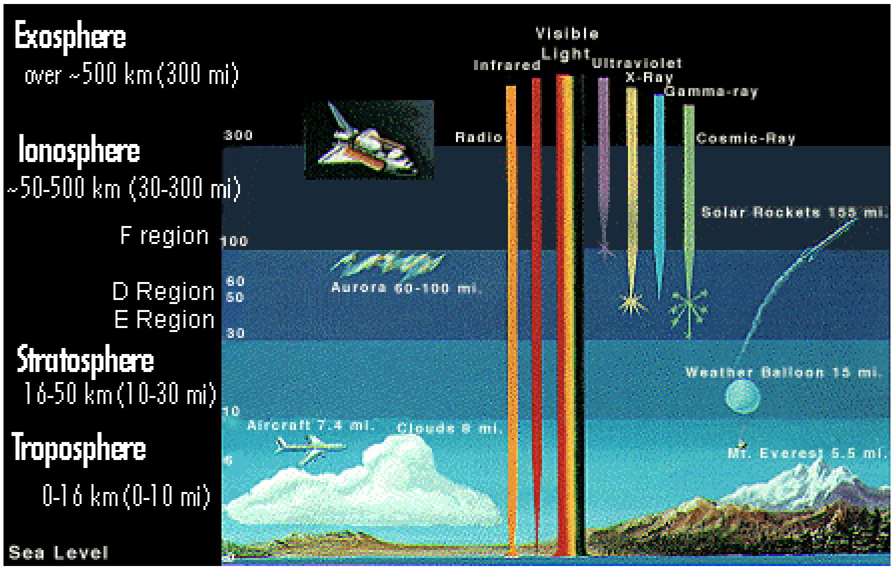



The movie above shows the global levels of Carbon Monoxide (CO) in the atmosphere over the year 2000. The blue and green colors represent fairly low levels of CO (blue areas are approximately 50 parts per billion), while high pollution levels are shown by red and brown colors (dark brown regions have CO levels of 390 ppb). The main source of CO pollution in the atmosphere are due to grassland and forest fires, agricultural burning, and industry. Notice that many of the CO plumes are picked up by the prevailing winds and can travel quite far. Clouds of CO produced in Asia can travel all the way across the Pacific Ocean and even over North America. The data used to create this movie was aquired by the Measurements of Pollution In The Troposphere (MOPITT) instrument on NASA's Terra satellite.

## The atmosphere as a membrane

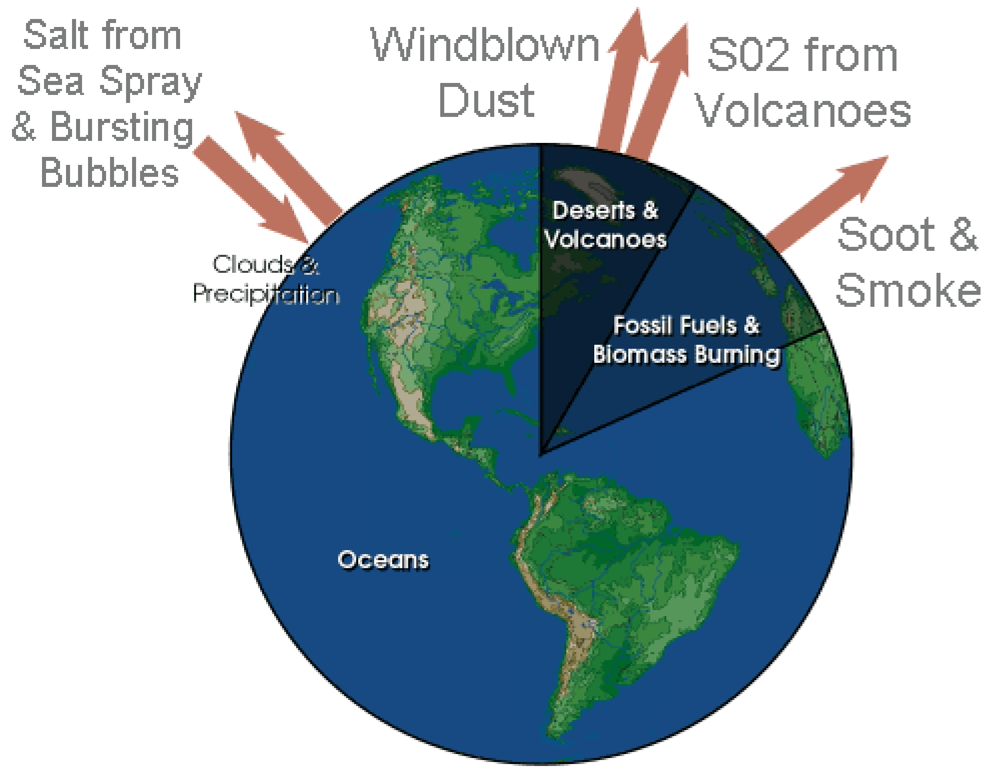
The Earth has been compared to a single cell, and the atmosphere is the cell's membrane. The atmosphere serves to protect the delicate functions of life from the harsh radiation of the Sun. It filters out the harmful ultraviolet rays, while allowing visible light to shine through and nourish the Earth's vegetation. Most people look to the sky and are amazed by the wide open space that seems to go on forever. In reality, however, the atmosphere is very small compared to the rest of the planet. The Earth itself is nearly 13,000 km in diameter, but the atmosphere rises only a few tens of kilometers above the surface. If you were to compare the Earth to an ordinary apple, the atmosphere would be only as thick as the apple's skin.

## The atmosphere has several different layers



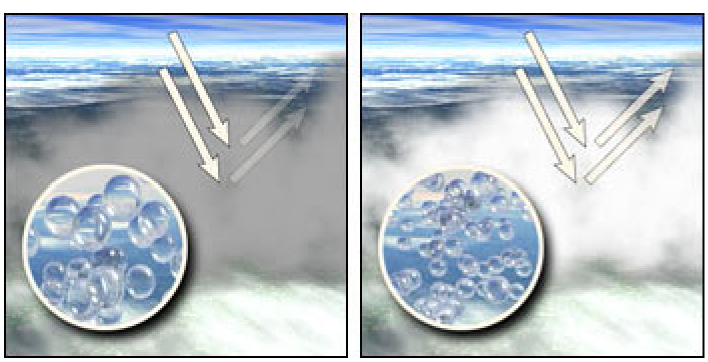

The Earth's atmosphere has several distinct layers, some of which are shown in the image above. The layer nearest the Earth's surface is called the troposphere. The troposphere is usually approximately 16 km (ten miles) thick and is the layer that contains most of the weather. Above the troposphere is the stratosphere, which stretches from ten miles to 30 miles high. The stratosphere contains the ozone layer, which protects the Earth's surface from dangerous ultraviolet radiation from the Sun. The ionosphere is found above the stratosphere. This layer contains many free electrons and ions, which reflect radio waves. This reflection allows radio waves to travel much farther than they would without the ionosphere. The highest layer of the atmosphere is the exosphere. Here the air is extremely thin and some of the air molecules are lost to space.

## The many sources of aerosols




Aerosols are tiny particles, either solid or liquid, which are suspended in the atmosphere. Aerosols are typically about one micrometer (one-thousandth of a millimeter) in diameter and are found throughout the atmosphere. Aerosols play an important role in the formation of clouds, as they act as seeds for the growth of individual cloud droplets. They can also act to reflect sunlight out of the atmosphere, causing the surface of the Earth to be cooler than if aerosols did not exist. Common sources of aerosols are smoke from burning forests, salt particles from ocean spray, and dust blown up from the deserts of the world. The eruption of a volcano can also send a large amount of aerosols into the atmosphere in a very short period of time.

## Aerosols can alter cloud properties



Aerosols are very important in the formation of clouds. Often aerosols act as Cloud Condensation Nuclei (CCN's), around which cloud droplets are formed. Without aerosols in the air, there would be far fewer clouds. Aerosols can also affect the properties of existing clouds. Recent studies have found that in the presence of high amounts of aerosols, clouds will have more droplets than normal, with droplets tending to be smaller than usual. Because the droplets are smaller and more numerous, the clouds last longer and are reflect sunlight better than before. This effect could have significant implications on the climate. As the clouds reflect more sunlight, less of the sun's energy reaches the surface of the earth, which then cools. This means that by putting more aerosols in the atmosphere, humans have the potential to alter the world's climate and cause global cooling.

## Lightning introduction

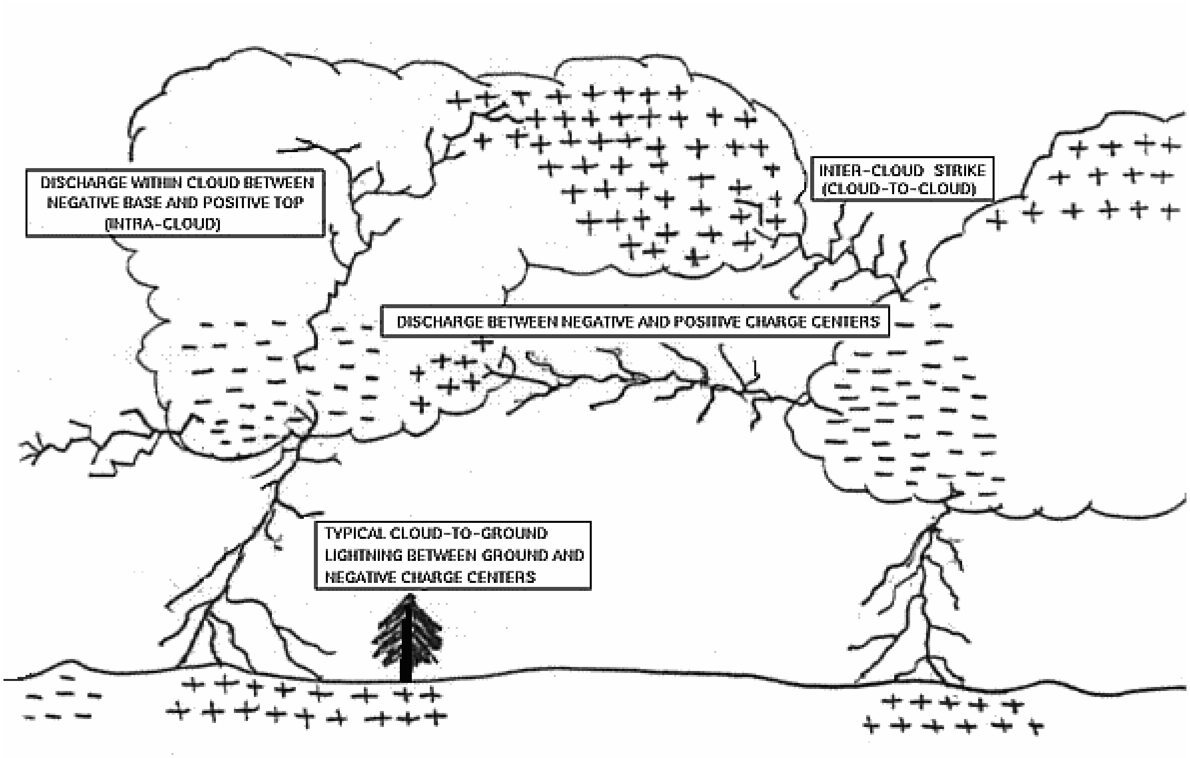
Lightning is one of the most impressive displays of power in all of nature. It has been a source of mystery and wonder throughout history and can occur just about anywhere on Earth. It is also one of the most deadly forces in nature (second only to flooding in terms of total fatalities).

## General information about lightning

The lightning you see is the air heating up as the electricity passes through it.

The air heats to 20,000 degrees Celsius, or three times as hot as the surface of the Sun! This sudden heating of the air also produces a shock wave, which you hear as thunder. Because thunder travels at the speed of sound, it usually takes some time to reach you after the lightning has occurred. If you count the number of seconds between the lighting and the thunder and divide by five, that's how many miles away from you the lightning was.

## How thunderclouds produce lightning

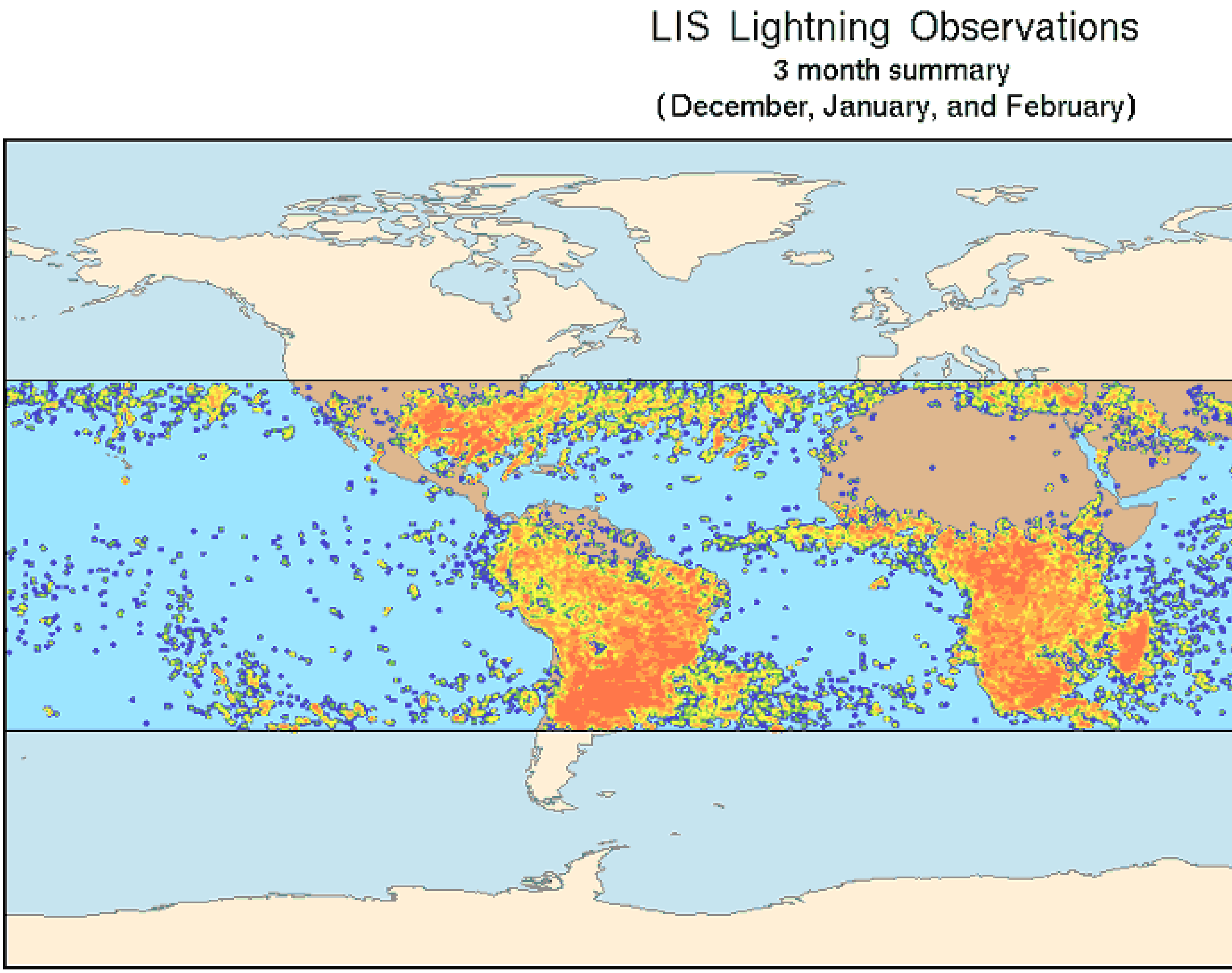



As you probably know, lightning is really not much more than a very large and powerful spark. It is caused by a discharge of electrical energy that has built up inside a thundercloud. During a thunderstorm, processes involving things such as vertical winds and different-sized water droplets cause electrical charges to build up in various parts of the cloud. When these charges become powerful enough, they discharge, causing a stroke of lightning.

## Lightning that's hidden

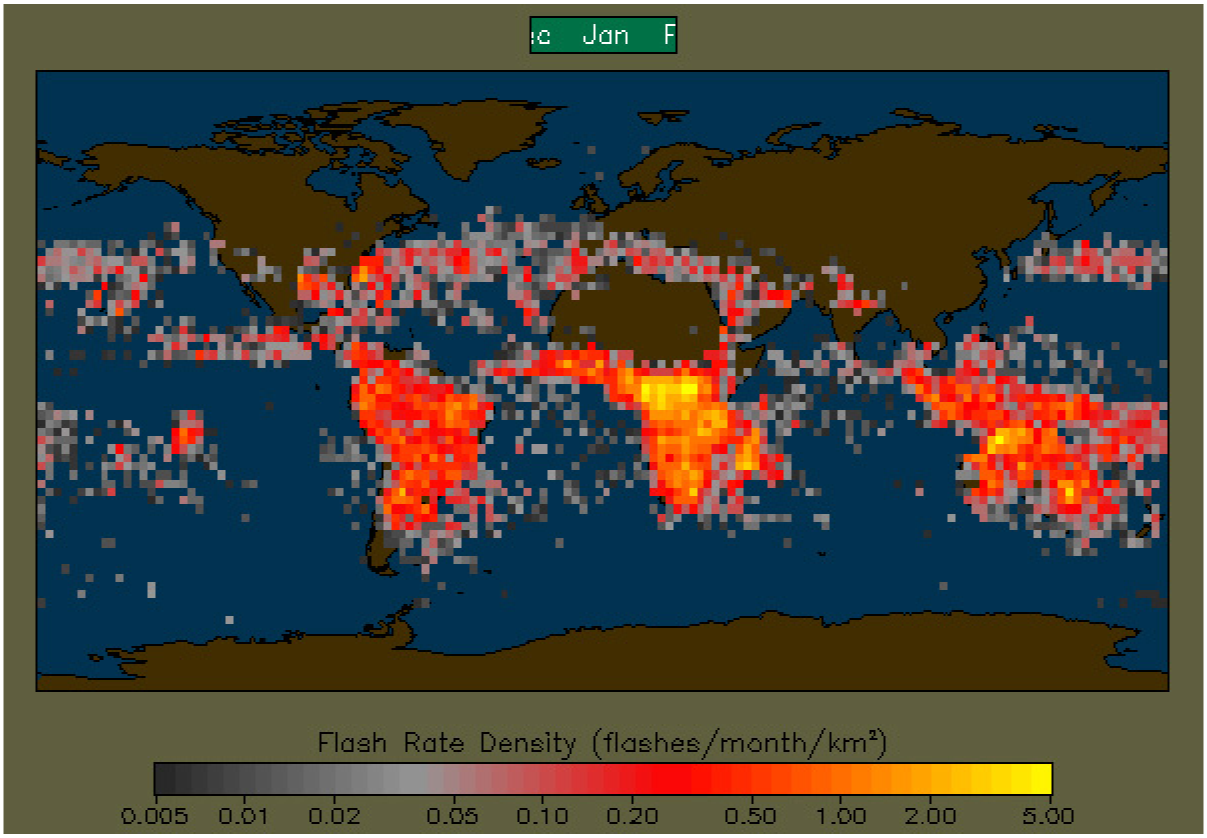
Lightning doesn't always strike the ground. A stroke of lightning can travel from one part of the cloud to another part of the same cloud ("intra-cloud lightning"), from one cloud to another cloud ("inter-cloud lightning"), or from a cloud to the ground ("cloud-to-ground lightning"). There have even been reports of lightning travelling up from the top of a cloud and disappearing into thin air.

## Lightning occurs more over land than over water



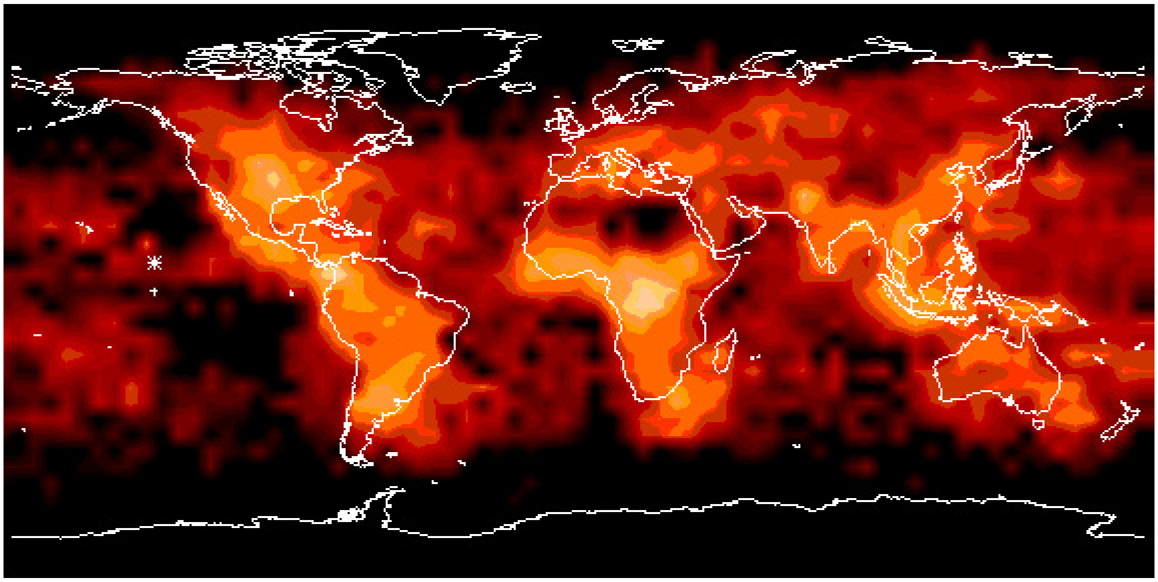

Satellites are now in orbit which can see lightning all over the globe. One of the interesting results of this is that scientists have discovered that lightning occurs much more often over land than over water.

**Over land and during the summer**



This movie shows the location of lightning flashes worldwide over the course of a year. The lightning in the Northern hemisphere is most common in June, July and August, and in the Southern hemisphere in December, January and February. The summer heat provides the energy for lightning. The annual cycle of observed lightning is measured by the space-based Optical Transient Detector (OTD). Notice the annual migration of lightning from the southern to northern hemispheres, with peaks during the hemispheric summer months. Lightning primarily occurs over land due to the strong differential heating and the resultant thunderstorms. Globally, the peak mean annual flash density is over Kamembe, Rawanda with about 82 flashes per square kilometer per year. Over North America, the peak flash density is in the Tampa-Orlando area with 35 flashes per square kilometer per year.

### Most lightning is in the afternoon



This movie shows the location of lightning flashes worldwide over the course of a day, separated by the local time at the place of observation. Most lightning occurs between 1 pm and 6 pm local time. The data come from NASA'a space-based Optical Transient Detector instrument. Each frame of this 24-hour movie represents global lightning observed during that hour. The movie starts at local midnight; a "clock" appears in the tropical mid-Pacific to the southeast of Hawaii, and indicates the loscal time everywhere on the map. (The center of the clock is a small +, and the hour indicator is an *.) Note the maximum lightning rates occurs at about 1500-1600 local time (3-4 pm).