

Chapter 13  
Atmosphere and Climate Change  
Section 1: Climate and Climate Change

**DAY ONE**



## Climate

- **Climate** is the average weather conditions in an area over a long period of time.
- Climate is determined by a variety of factors that include:
  - **latitude**
  - **atmospheric circulation patterns**
  - **oceanic circulation patterns**
  - **local geography of an area**
  - **solar activity**
  - **volcanic activity**
- The most important of these factors is distance from the equator.



## Latitude

- **Latitude** is the distance north or south from the equator and is expressed in degrees.
  - **0° latitude** = equator
  - **90° north** = North Pole, most northerly
  - **90° south** = South Pole, most southerly
- Latitude strongly affects climate because the **amount** of solar energy an area of the Earth receives **depends** on its latitude.



## Low Latitudes

- **More** solar energy falls on areas near the equator than on areas closer to the poles.
- The incoming solar energy is concentrated on a small surface at the equator.
- In regions near the equator, night and day are both about **12 hours** long throughout the year.
- In addition, temperatures are high year-round, and there are no summers or winters.



## High Latitudes

- In regions closer the poles, the sun is **lower** in the sky, reducing the amount of energy arriving at the surface.
- In the northern and southern latitudes, sunlight hits the Earth at an **oblique** angle and spreads over a larger surface area than it does at the equator.
- Yearly average temperatures near the poles are therefore lower than they are at the equator.

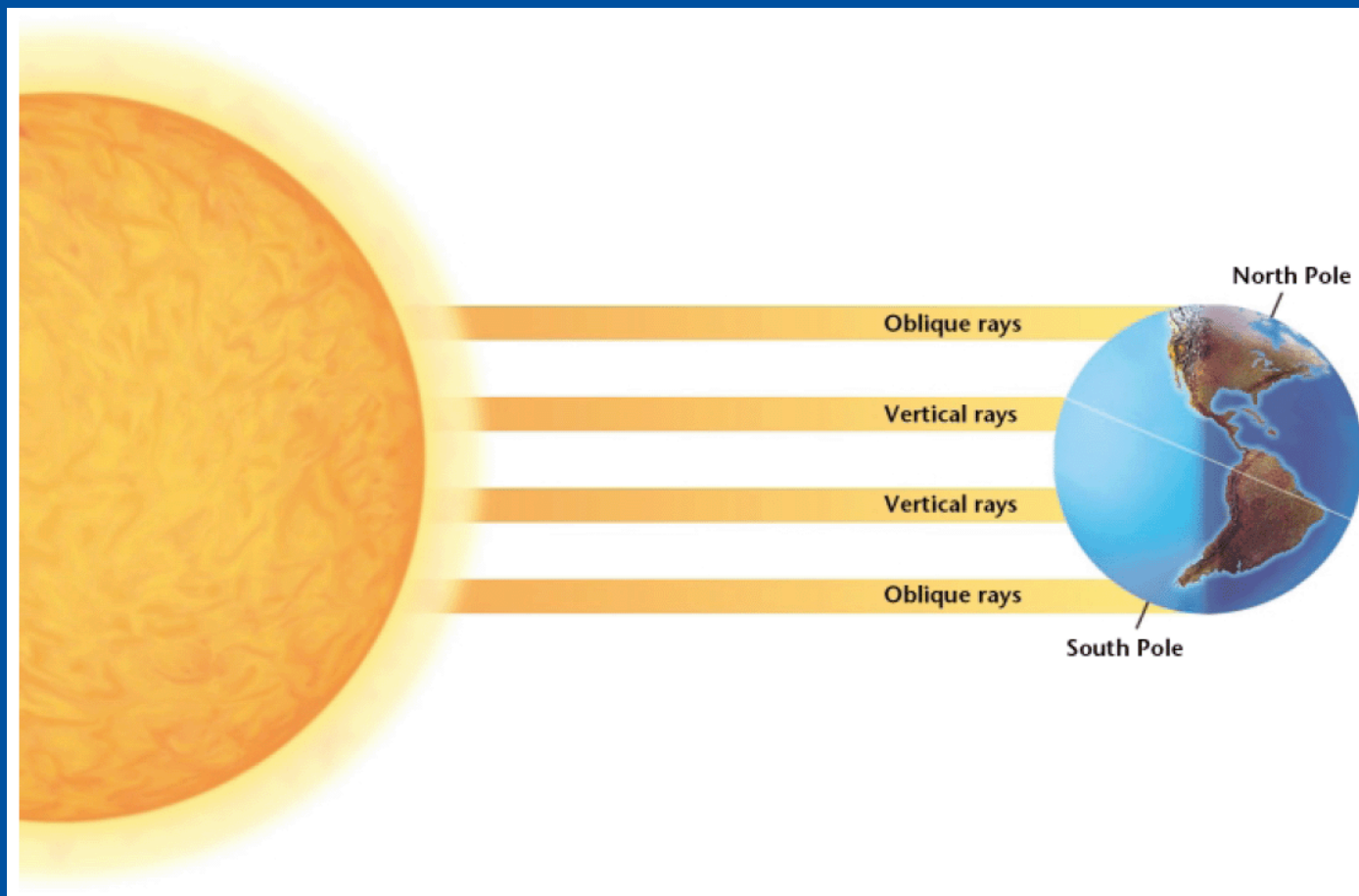


## High Latitudes

- The hours of daylight also vary.
  - At **45° north and south** latitude, there is as much as 16 hours of daylight each day during the summer and as little as 8 hours of sunlight each day in the winter.
- Near the poles, the sun sets for only a few hours each day during the summer and rises for only a few hours each day during the winter.
- Thus, the yearly temperature range near the poles is very large.



# Low and High Latitudes



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## Atmospheric Circulation

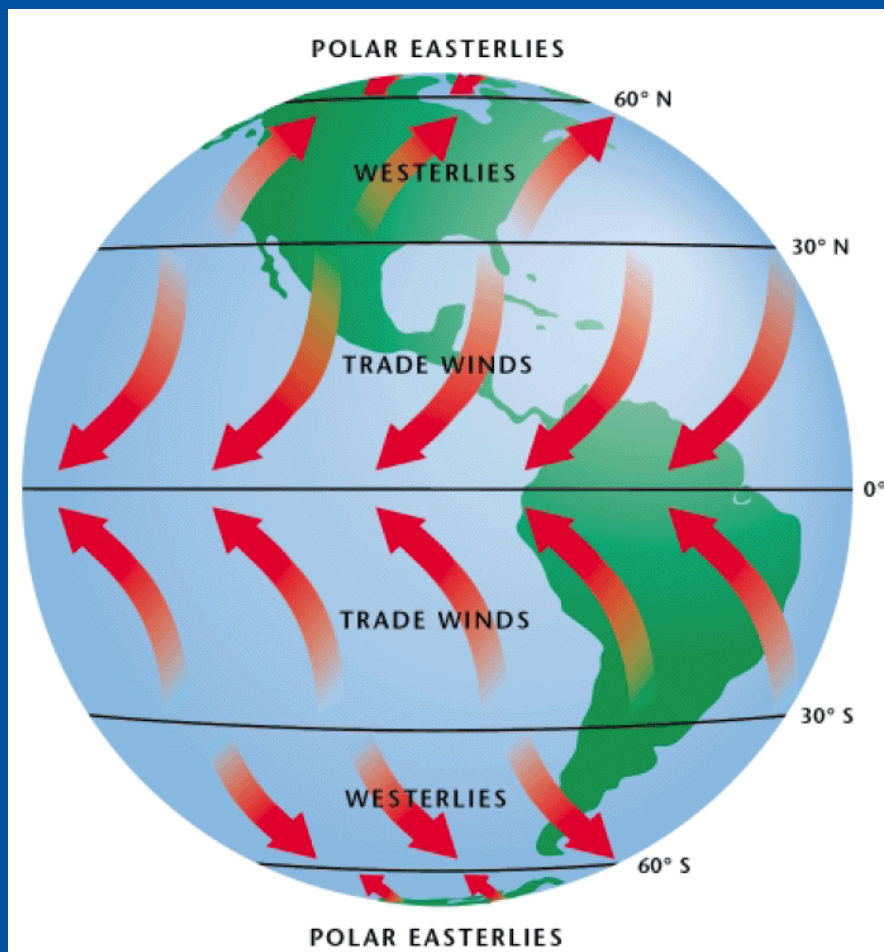
- Three important properties of air illustrate how air circulation affects climate.
  - Cold air **sinks** because it is denser than warm air. As the air sinks, it compresses and warms.
  - Warm air **rises**. It expands and cools as it rises.
  - Warm air can hold more water vapor than cold air can.
    - When warm air cools, the water vapor it contains may condense into liquid water to form rain, snow, or fog.



## Atmospheric Circulation

- Solar energy **heats** the ground, which warms the air above it.
  - This warm air rises, and cooler air moves in to replace it.
- Movement of air within the atmosphere is called **wind**.
- Because the Earth rotates, and because different latitudes receive different amounts of solar energy, a pattern of **global atmospheric circulation** results.
- This circulation pattern determines Earth's **precipitation** patterns.

# Atmospheric Circulation



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## Atmospheric Circulation

- For example, the intense solar energy striking the Earth's surface at the equator causes the surface as well as the air above the equator to become very warm.
- This warm air can hold large amounts of water vapor.
  - But as this warm air rises and cools, its ability to hold water is reduced.
- As a result, areas near the equator receive **large amounts** of rain.

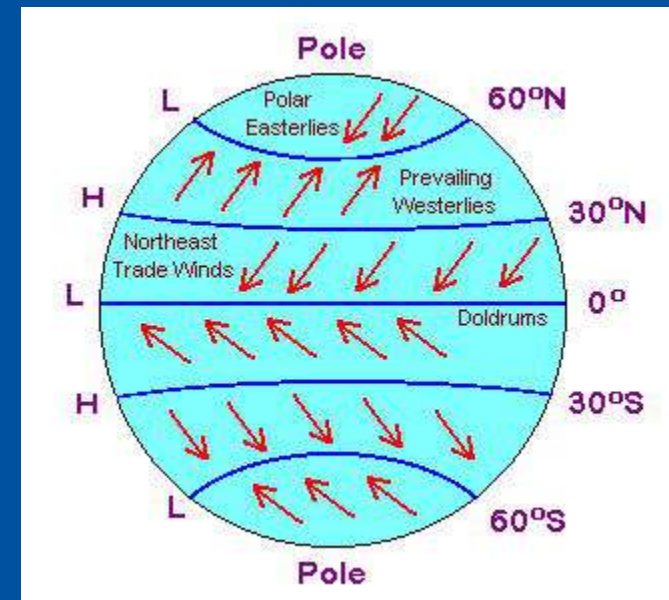


## Prevailing Winds

- Winds that blow predominantly in one direction throughout the year are called **prevailing winds**.
- Because of the rotation of the Earth, these winds do not blow directly northward or southward.
- Instead, they are deflected to the right in the Northern Hemisphere and to the left in the Southern Hemisphere.

## Prevailing Winds

- **Belts** of prevailing winds are produced in both hemispheres between  $30^\circ$  north and south latitude and the equator.
- These belts of winds are called the **trade winds**.
- The trade winds blow from the northeast in the Northern Hemisphere and from the southeast in the Southern Hemisphere.



## Prevailing Winds

- Prevailing winds known as the **westerlies** are produced between  $30^{\circ}$  and  $60^{\circ}$  north latitude and  $30^{\circ}$  and  $60^{\circ}$  south latitude.
- In the Northern Hemisphere, these westerlies are **southwest winds**, and in the Southern Hemisphere, these winds are **northwest winds**.
- The **polar easterlies** blow from the poles to  $60^{\circ}$  north and south latitude.

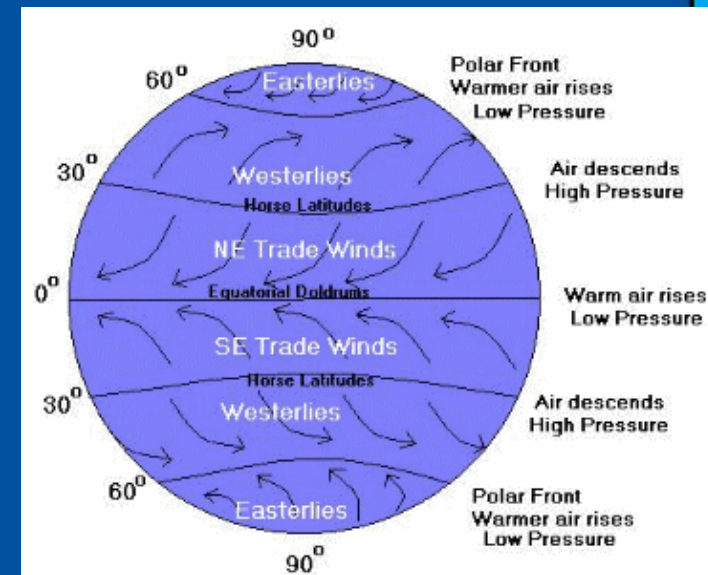


## Prevailing Winds

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## Oceanic Circulation

- **Ocean currents** have a great effect on climate because water holds large amounts of heat.
- The movement of surface ocean currents is caused mostly by **winds and the rotation** of the Earth.
- These **surface currents** redistribute warm and cool masses of water around the world and in doing so, they affect the climate in many parts of the world.



## El Niño–Southern Oscillation

- **El Niño** is the warm phase of the El Niño–Southern Oscillation.
- It is the **periodic occurrence** in the eastern Pacific Ocean in which the surface-water temperature becomes unusually warm.
- During El Niño, winds in the western Pacific Ocean, which are usually weak, strengthen and push warm water eastward.
- Rainfall follows this warm water eastward and produces **increased** rainfall in the southern half on the U.S., but drought in Australia.



## El Nino Patterns Video

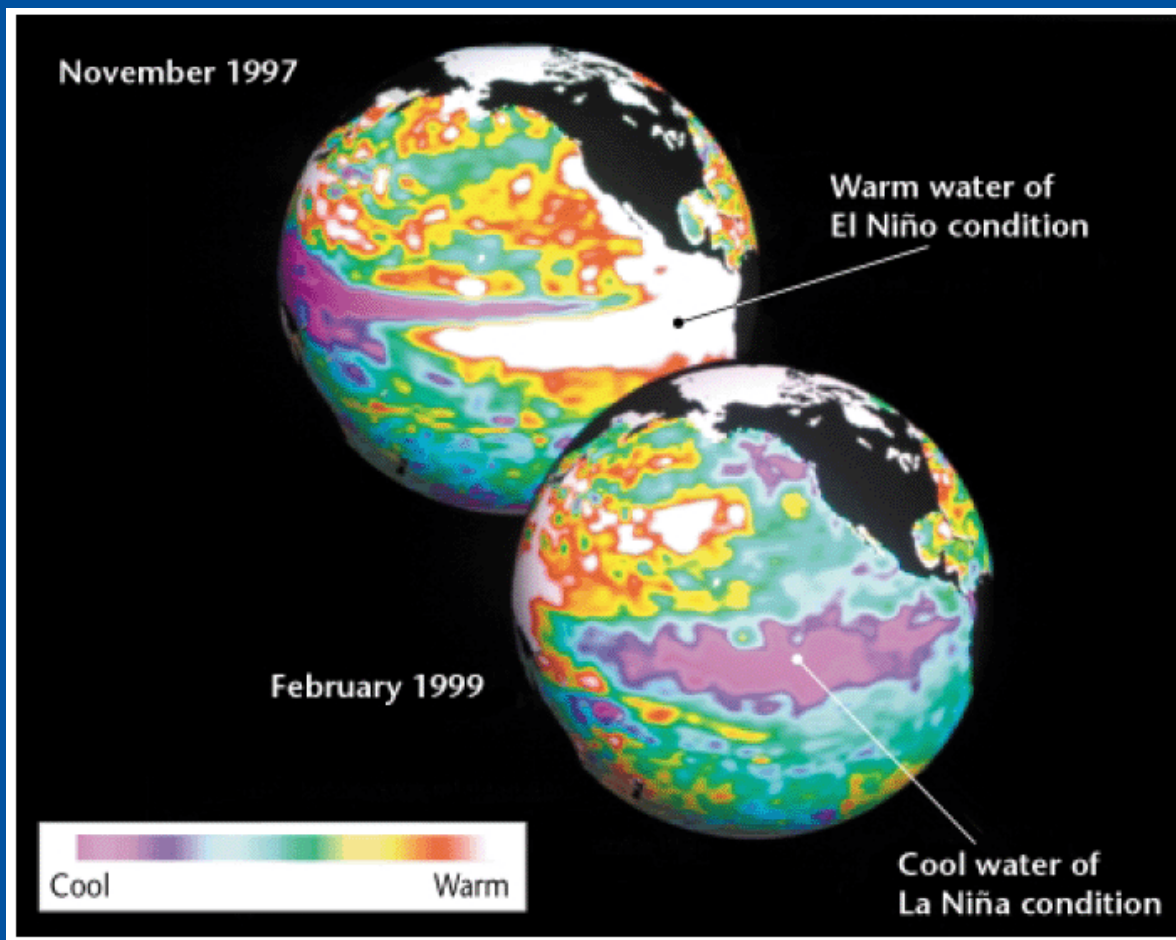
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## El Niño–Southern Oscillation

- **La Niña** is the cool phase of the El Niño–Southern oscillation.
- It is the **periodic occurrence** in the eastern Pacific Ocean in which the surface water temperature becomes unusually cool.
- El Niño and La Niña are opposite phases of the El Niño–Southern Oscillation (ENSO) cycle.

# El Niño–Southern Oscillation



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## Global Circulation Patterns

- Air descending at the 30° north and 30° south latitude either moves toward the equator or flows toward the poles.
- Air moving toward the equator warms while it is near the Earth's surface.
- At about 60° north and 60° south latitudes, this air collides with cold air traveling from the poles.
- The warm air rises, and most of this uplifted air is forced toward the poles.
- Cold, dry air descends at the poles, which are essentially very cold deserts.

## Global Circulation Patterns

- Cool air normally sinks, but cool air over the equator cannot descend because hot air is rising up below it.
  - This cool air is forced away from the equators toward the North and South Poles where it **accumulates** at about  $30^{\circ}$  north latitude and  $30^{\circ}$  south latitude.
- Some of the air sinks back to the Earth's surface and becomes **warmer** as it descends.
- This warm, dry air then moves across the surface and causes water to evaporate from the land below, creating dry conditions.

## Pacific Decadal Oscillation

- The **Pacific Decadal Oscillation** (PDO) is a long-term, 20 to 30 year change in the location of warm and cold water masses in the Pacific Ocean.
- PDO **influences** the climate in the northern Pacific Ocean and North America.
- It affects **ocean surface temperatures, air temperatures, and precipitation patterns.**



## Topography

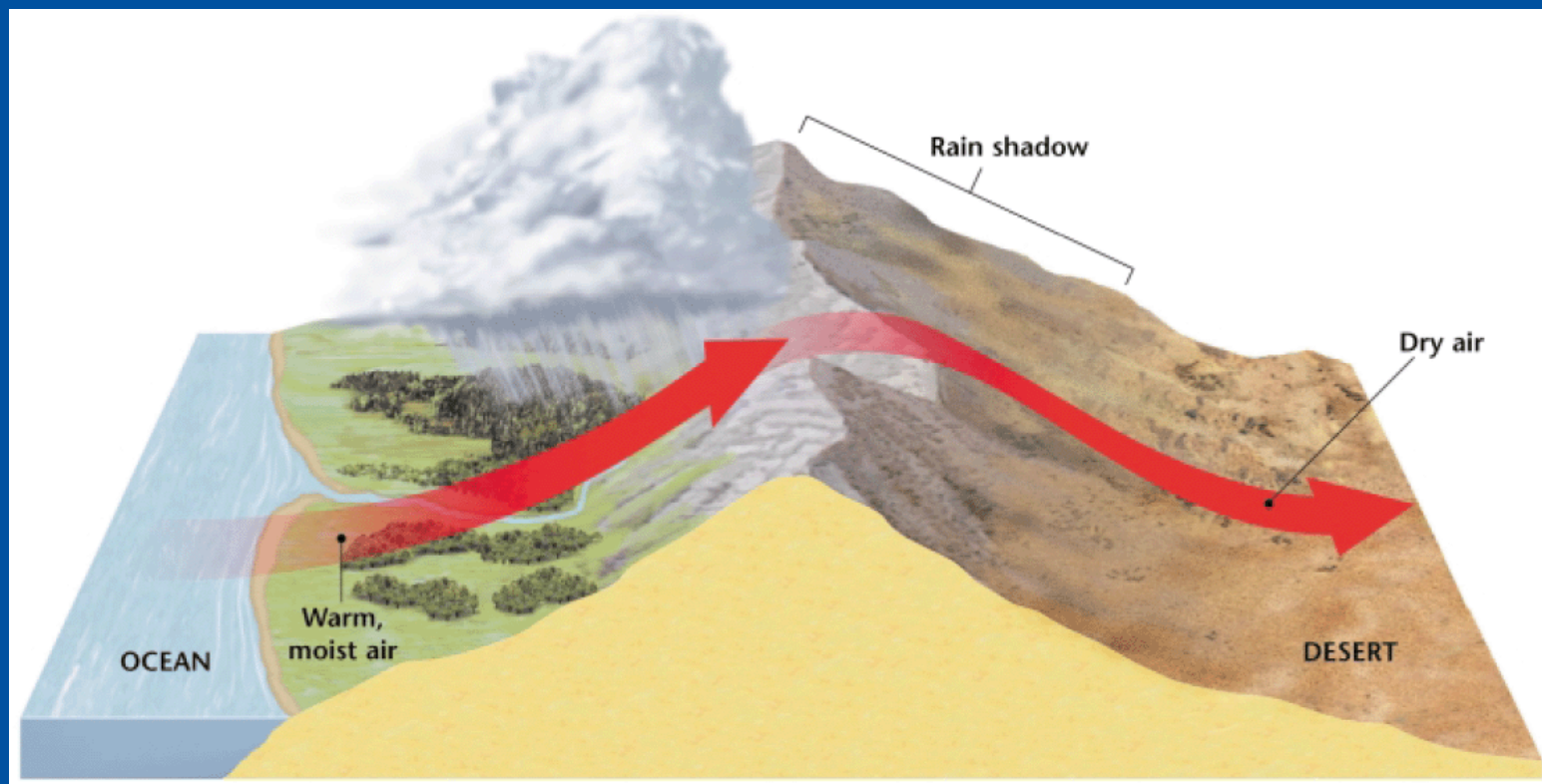
- Height above sea level (**elevation**) has an important effect on climate. Temperatures fall by about 6°C (about 11°F) for every 1,000 m increase in elevation.
- Mountain ranges also influence the **distribution** of precipitation.
  - For example, warm air from the ocean blows east, hits the mountains, and rises.
- As the air rises, it cools, causing it to rain on the western side of the mountain. When the air reaches the eastern side of the mountain it is dry.
  - This effect is known as a **rain shadow**.

## Rain Shadow

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# Topography





## Other Influences on Earth's Climate

- Both the **sun and volcanic eruptions** influence Earth's climate.
- At a solar maximum, the sun emits an increased amount of ultraviolet (UV) radiation.
- UV radiation produces more **ozone**, which warms the stratosphere.
- The increased solar radiation can also warm the lower atmosphere and surface of the Earth a little.

## Other Influences on Earth's Climate

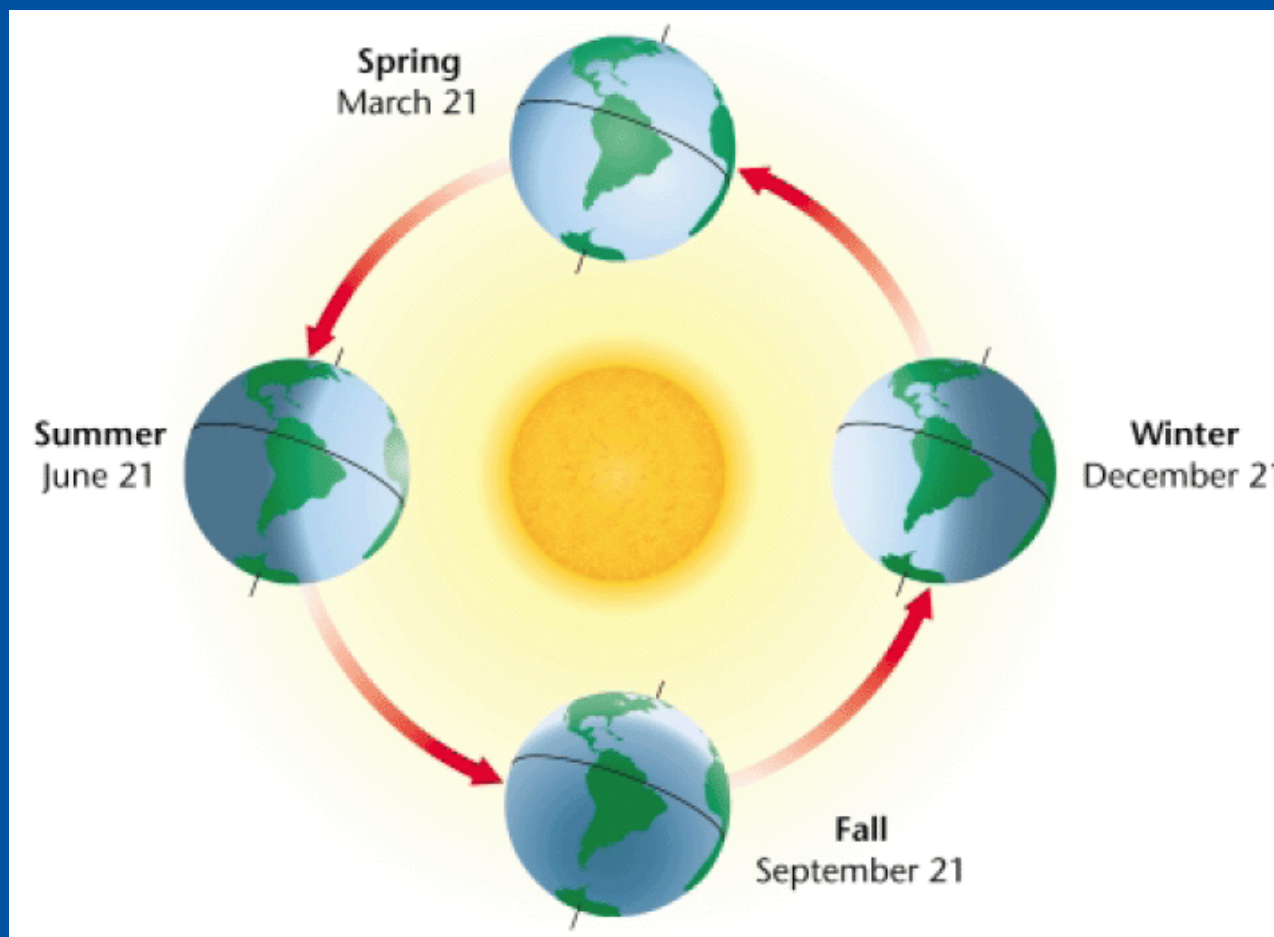
- In large-scale volcanic eruptions, **sulfur dioxide** gas can reach the upper atmosphere.
- The sulfur dioxide, which can remain in the atmosphere for up to 3 years, reacts with smaller amounts of water vapor and dust in the stratosphere.
- This reaction forms a **bright layer of haze** that reflects enough sunlight to cause the global temperature to decrease.

## Seasonal Changes in Climate

- The seasons result from the **tilt of the Earth's axis**, which is about **23.5°** relative to the plane of its orbit.
- Because of this tilt the angle at which the sun's rays strike the Earth changes as the Earth moves around the sun.



# Seasonal Changes in Climate



## Seasonal Changes in Climate

- During summer in the Northern Hemisphere, the Northern Hemisphere tilts toward the sun and receives **direct sunlight**.
- The number of hours of daylight is **greatest** in the summer.
  - Therefore, the amount of time available for the sun to heat the Earth becomes greater.
- During summer in the Northern Hemisphere, the Southern Hemisphere tilts away from the sun and receives **less direct sunlight**.
  - But, during the summer in the Southern Hemisphere, the situation is reversed.

## Earth's Seasons

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## The Ozone Shield

- The **ozone layer** is the layer of the atmosphere at an altitude of 15 to 40 km in which ozone absorbs ultraviolet solar radiation.
  - **Ozone** is a molecule made of three oxygen atoms.
- **UV light** is harmful to organisms because it can damage the genetic material in living cells.
- By shielding the Earth's surface from most of the sun's UV light, the ozone in the **stratosphere** acts like a sunscreen for the Earth's inhabitants.

## Chemicals That Cause Ozone Depletion

- **Chlorofluorocarbons (CFCs)** are hydrocarbons in which some or all of the hydrogen atoms are replaced by chlorine and fluorine.
- Used in:
  - **coolants** for refrigerators and air conditioners
  - **cleaning solvents.**
  - **propellant in spray cans** of everyday products
    - deodorants, insecticides, and paint.
- Their use is now restricted because they destroy ozone molecules in the stratosphere.



## When CFC's meet the ozone layer?

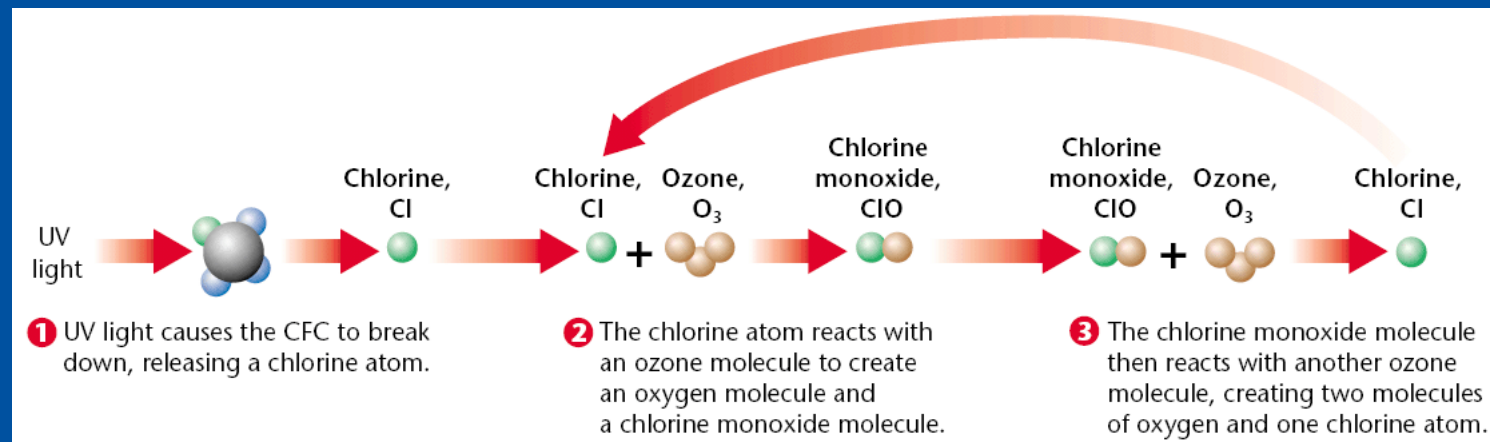
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## Chemicals That Cause Ozone Depletion

- At the Earth's surface, CFCs are chemically **stable**.
- They do not combine with other chemicals or break down into other substances.
- But, CFC molecules **break apart** high in the stratosphere, where UV radiation is absorbed.
- Once CFC molecules break apart, parts of the CFC molecules destroy the protective ozone.

## Chemicals That Cause Ozone Depletion

- Each CFC molecule contains from one to four chlorine atoms, and scientists have estimated that a single chlorine atom in the CFC structure can destroy 100,000 ozone molecules.





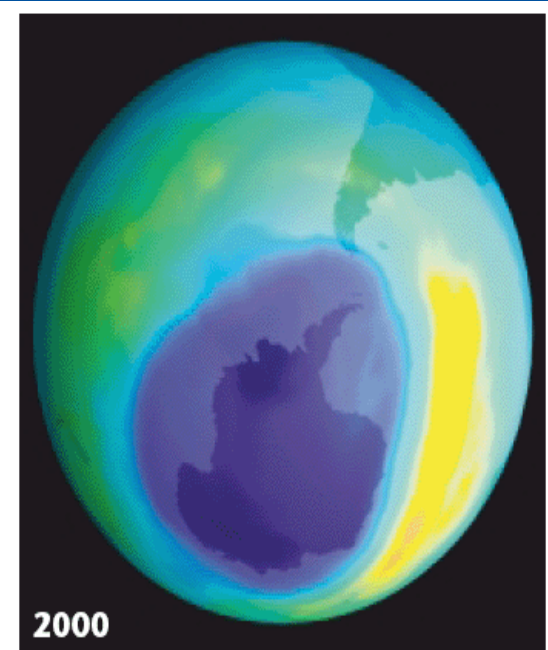
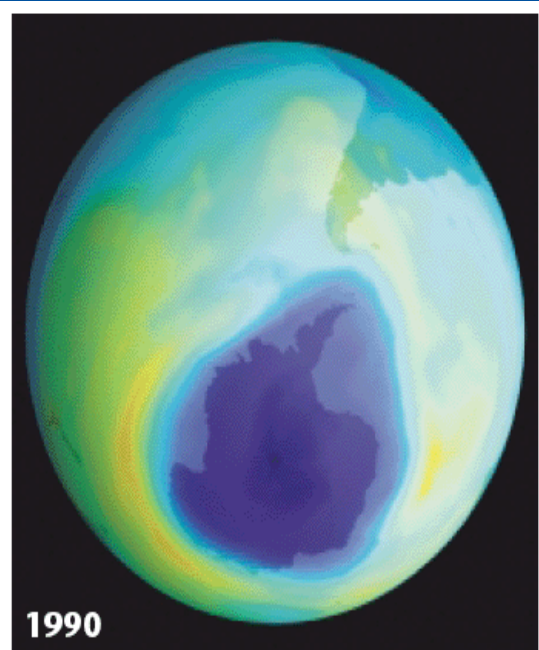
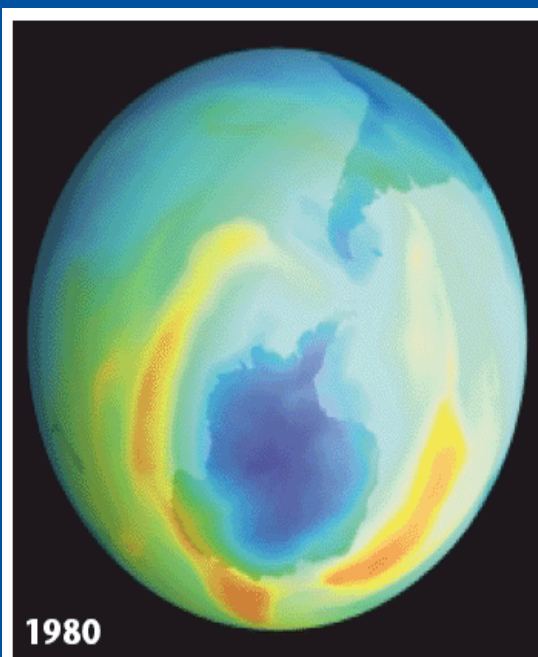
## The Ozone Hole

- In 1985, studies by scientists working in Antarctica revealed that the ozone layer above the South Pole had thinned by 50 to 98 percent.
- The **ozone hole** is a thinning of stratospheric ozone that occurs over the poles during the spring.
- This was the first news of the hole, and was published in an article in the scientific journal *Nature*.

## The Ozone Hole

- After the results were published, NASA scientists reviewed data that had been sent to Earth by the *Nimbus 7* weather satellite.
  - Able to see the first signs of ozone thinning in the data from **1979**.
- Although the concentration of ozone fluctuated during the year, the data showed a **growing hole**.
- Ozone levels over the Arctic have decreased as well. In March 1997, ozone levels over part of Canada were 45 percent below normal.

# The Ozone Hole



2005 Ozone Layer Hole

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## Ozone Hole Video

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## How Does the Ozone Hole Form?

- During the dark polar winter, strong circulating winds over Antarctica, called the **polar vortex**, isolate cold air from surrounding warmer air.
  - Air within the vortex is extremely cold.
- **Polar stratospheric clouds** are clouds that form at altitudes of about 21,000 m during the Arctic and Antarctic winter or early spring, when air temperatures drop below  $-80^{\circ}\text{C}$ .

## How Does the Ozone Hole Form?

- On the surfaces of polar stratospheric clouds, the products of CFCs are converted to molecular **chlorine**.
- When sunlight returns to the South Pole in the spring, molecular chlorine is split into two chlorine atoms by **UV radiation**.
  - The chlorine atoms rapidly **destroy** ozone.
- The destruction of ozone causes a thin spot, or **ozone hole**, which lasts for several months.



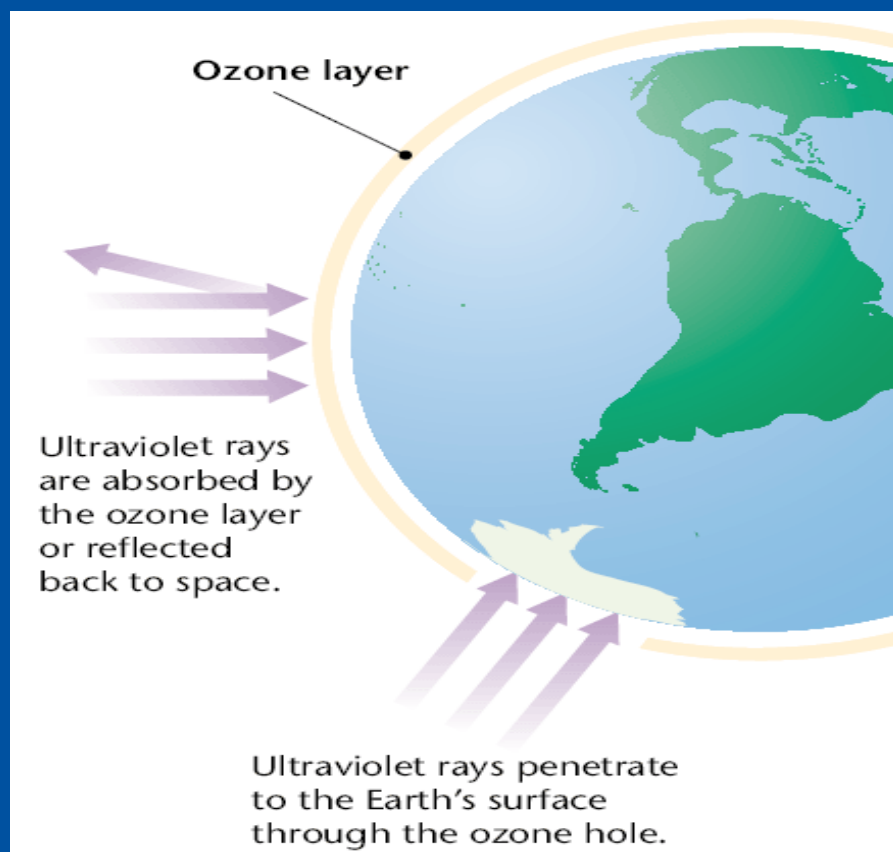
## How Does the Ozone Hole Form?

- You may be thinking, “If ozone is also being produced as air pollution, why does this ozone not repair the ozone hole in the stratosphere?”
- The answer is that ozone is very chemically reactive.
- Ozone produced by pollution **breaks down or combines** with other substances in the troposphere long before it can reach the stratosphere to replace ozone that is being destroyed.

## Effects of Ozone Thinning on Humans

- As the amount of ozone in the stratosphere **decreases**, **more UV light** is able to pass through the atmosphere and reach Earth's surface.
- UV light is dangerous to living things because it **damages DNA**, the genetic material that contains the information that determines inherited characteristics.
- Exposure to UV light makes the body more susceptible to skin cancer, and may cause other damaging effects to the human body.

## Effects of Ozone Thinning on Humans





## Effects of Ozone Thinning on Animals and Plants

- High levels of UV light can kill single-celled organisms called **phytoplankton** that live near the surface of the ocean.
- The loss of phytoplankton could disrupt ocean food chains and reduce fish harvests.
- In addition, a reduction in the number of phytoplankton would cause an **increase** in the amount of carbon dioxide in the atmosphere.

## Effects of Ozone Thinning on Animals and Plants

- Scientists believe that increased UV light could be especially damaging for amphibians, such as toads, because they lay eggs that lack shells in the shallow water of ponds and streams.
- UV light at natural levels kills many eggs of some species by damaging unprotected DNA.
- Higher UV levels might kill more eggs and put amphibian populations at risk.

## Effects of Ozone Thinning on Animals and Plants

- In fact, ecologists often use the health of amphibian populations as an **indicator** of environmental change due to the environmental sensitivity of these creatures.
- UV light can damage plants by interfering with photosynthesis. This damage can lower crop yields.



# Effects of Ozone Thinning of Animals and Plants

Damaging Effects of UV Light	
Humans	<ul style="list-style-type: none"><li>• increased incidence of skin cancer</li><li>• premature aging of the skin</li><li>• increased incidence of cataracts</li><li>• weakened immune response</li></ul>
Amphibians	<ul style="list-style-type: none"><li>• death of eggs</li><li>• genetic mutations among survivors</li><li>• reduction of populations</li></ul>
Marine Life	<ul style="list-style-type: none"><li>• death of phytoplankton in surface water</li><li>• disruption of food chain</li><li>• reduction in the number of photosynthesizers</li></ul>
Land Plants	<ul style="list-style-type: none"><li>• interference with photosynthesis</li><li>• reduced crop yields</li></ul>

## Protecting the Ozone Layer

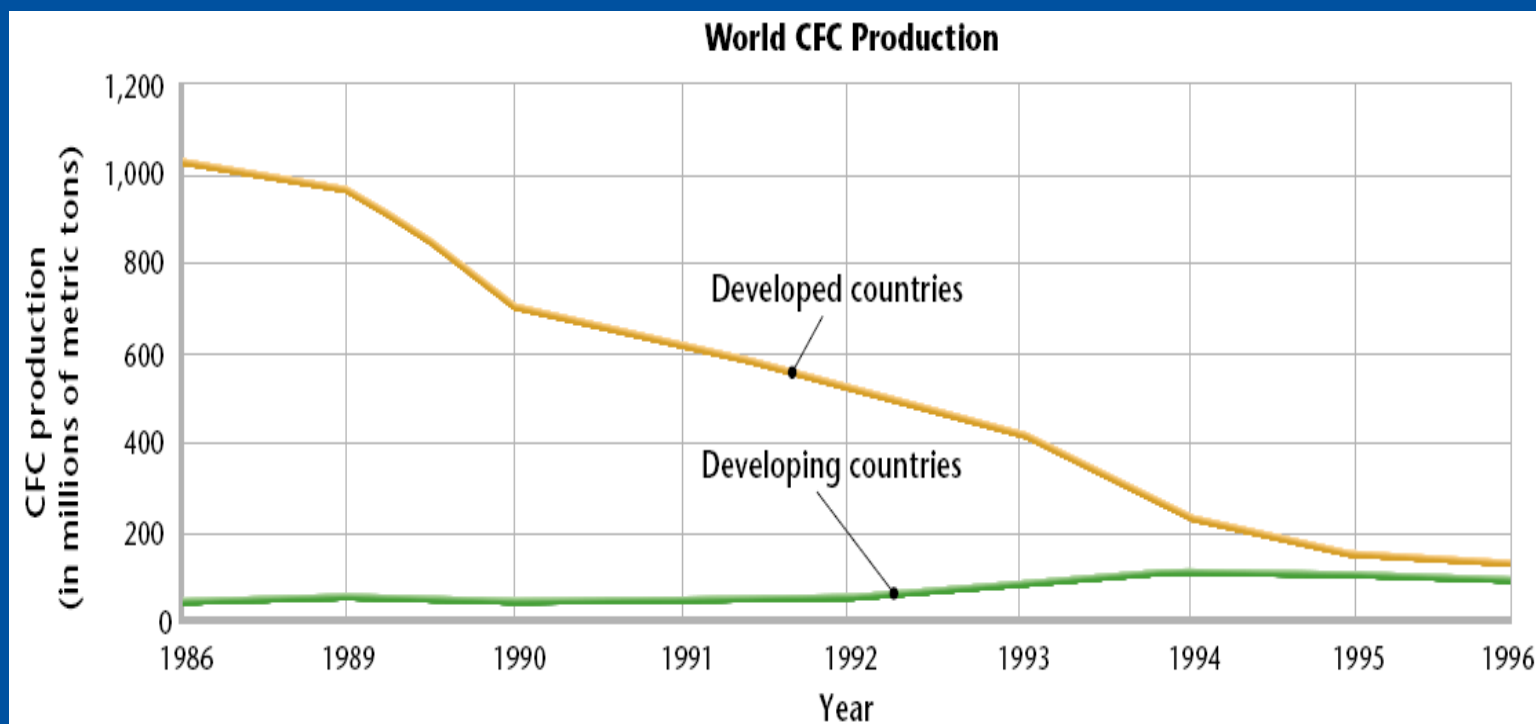
- In 1987, a group of nations made an agreement, called the **Montreal Protocol**, to sharply limit their production of CFCs.
- At a second conference in Copenhagen, Denmark in 1992, developed countries agreed to **eliminate** most CFCs by 1995.
- The United States pledged to ban all substances that pose a significant danger to the ozone layer by the year 2000.

## Protecting the Ozone

- After developed countries banned most uses of CFCs, chemical companies developed **CFC replacements**.
- Aerosol cans no longer use **CFCs** as propellants, and air conditioners are becoming CFC free.
- Because many countries were involved and decided to control CFCs, many people consider ozone protection an international environmental success story.



# Protecting the Ozone Layer



## Protecting the Ozone Layer

- However, the battle to protect the ozone layer is not over.
- CFC molecules remain active in the stratosphere for **60 to 120 years**.
- CFCs released 30 years ago are still destroying ozone today, so it will be many years before the ozone layer completely recovers.

## Ticket out the Door

1. What is the ozone layer?
2. What is ozone made up of?
3. What are CFC's?
4. What is the ozone hole?
5. What is a polar vortex?



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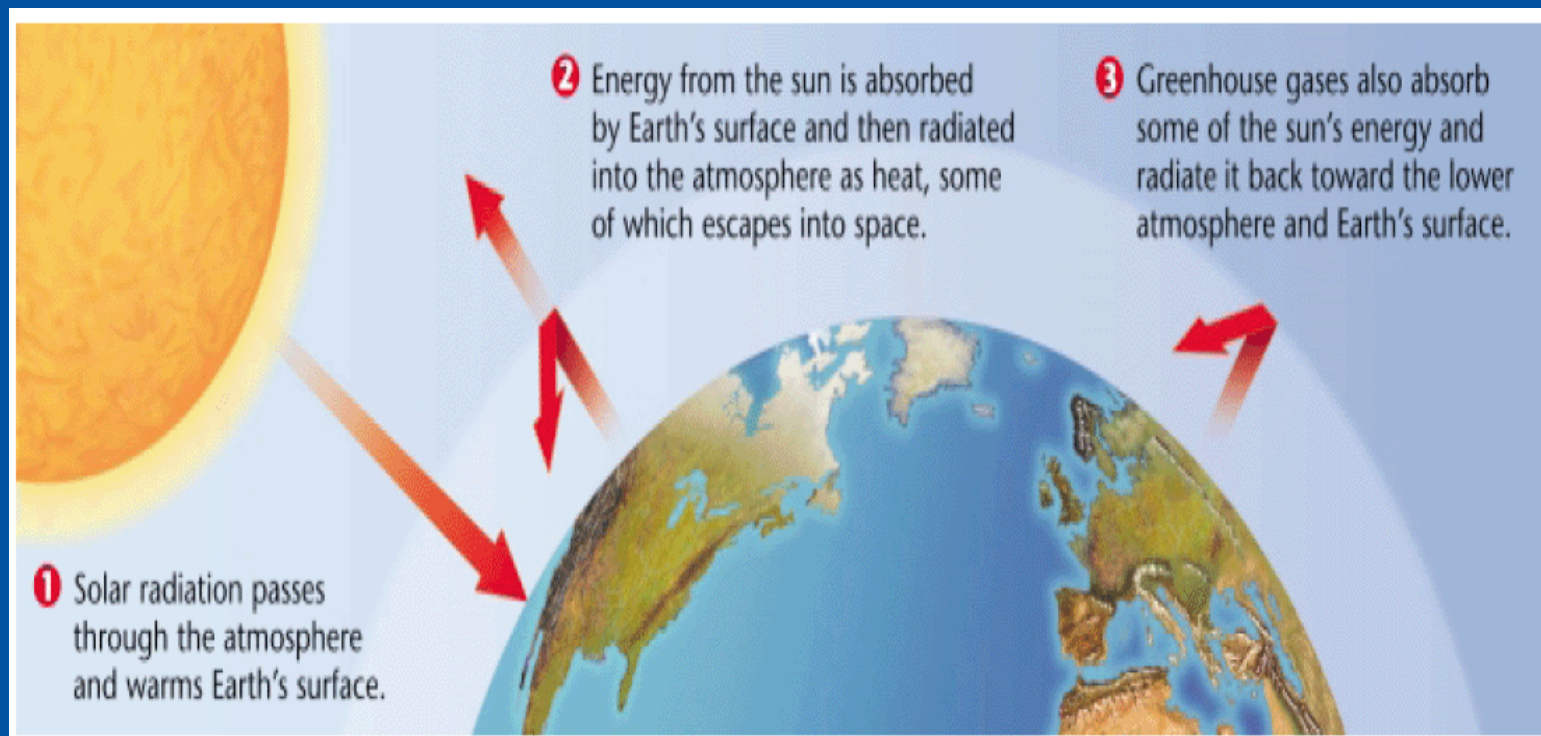
**DAY ONE**



## The Greenhouse Effect

- The Earth is similar to a **greenhouse**. The Earth's atmosphere acts like the glass in a greenhouse.
- Sunlight streams through the atmosphere and heats the Earth. As this heat radiates up from Earth's surface, some of it escapes into space.
- The rest of the heat is absorbed by gases in the **troposphere** and warms the air.
- This process of heat absorption is called the **greenhouse effect**.

## The Greenhouse Effect





## The Greenhouse Effect

- Not every gas in our atmosphere absorbs heat in this way.
- A **greenhouse gas** is a gas composed of molecules that absorb and radiate infrared radiation from the sun.
- The major greenhouse gases are **water vapor, carbon dioxide, CFCs, methane, and nitrous oxide**.
  - Water vapor and carbon dioxide account for most of the absorption of that occurs in the atmosphere.

## Greenhouse Effect

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## Measuring Carbon Dioxide in the Atmosphere

- In 1985, a geochemist named **Charles Keeling** installed an instrument at the top of a tall tower on the volcano **Mauna Loa** in Hawaii.
  - He wanted to precisely measure the amount of carbon dioxide in the air, far away from forests and cities.
- In a forest, carbon dioxide levels rise and fall with the daily rhythms of **photosynthesis**.
- Near cities, carbon dioxide from traffic and industrial pollution raises the local concentration of gas.



## Measuring Carbon Dioxide in the Atmosphere

- The winds that blow steadily over Mauna Loa have come thousands of miles across the Pacific Ocean, far from most forests and human activities, swirling and mixing as they traveled.
- Keeling reasoned that at Mauna Loa, the **average** carbon dioxide levels for the entire Earth could be measured.

## Measuring Carbon Dioxide in the Atmosphere

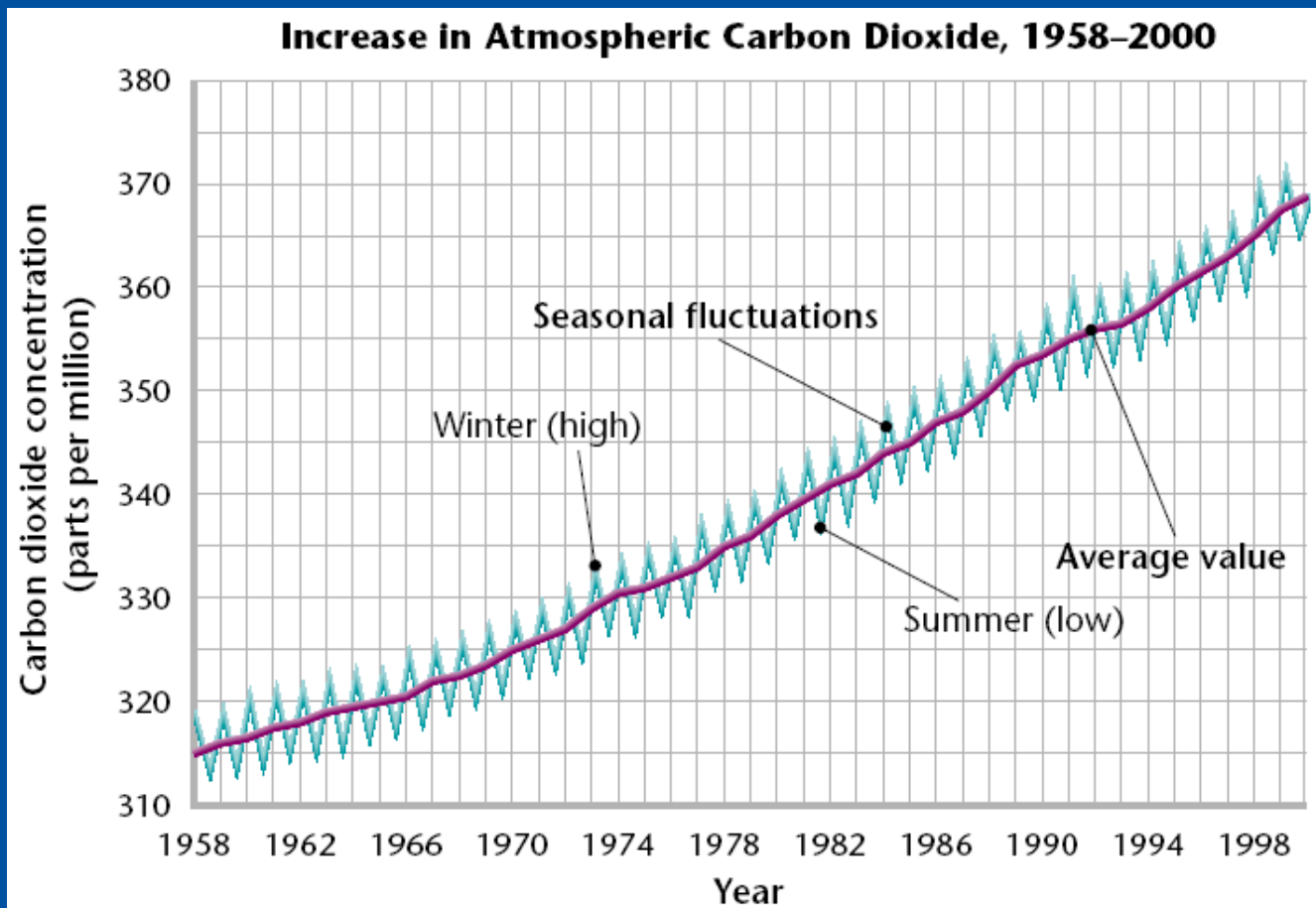
- Keeling's first measurement, in March of 1958, was **0.0314 percent**, and the levels rose slightly the next month.
- By summer the levels were falling, but in the winter, they rose again.
- During the summer, growing plants use more carbon dioxide for photosynthesis than they release in respiration, causing the levels to **drop**.
- In the winter, dying grasses and fallen leaves decay and **release** the carbon that was stored in them, causing levels to rise.

## Rising Carbon Dioxide Levels

- After a few years of measurement, it was obvious that the levels were undergoing **changes** other than seasonal fluctuations.
- Each year, the high carbon dioxide levels of winter were higher, and each year, the summer levels did not fall as low.
- In 42 years, carbon dioxide has gone from 314 to 386 parts per million, an increase of 54 parts per million.
  - This increase may be due to the **burning of fossil fuels**.



# Rising Carbon Dioxide Levels



## Greenhouse Gases and the Earth's Temperature

- Many scientists think that because greenhouse gases trap heat near the Earth's surface, more greenhouse gases in the atmosphere will result in an **increase** in global temperature.
- A comparison of carbon dioxide in the atmosphere and average global temperatures for the past 400,000 years support that view.

## Greenhouse Gases and the Earth's Temperature

- Today, we are releasing more carbon dioxide than any other greenhouse gas into the atmosphere.
- Millions of tons of carbon dioxide are released into the atmosphere each year from **power plants that burn coal or oil, and cars that burn gasoline.**
- Millions of trees are burned in tropical rainforest to clear the land for farming.
- We also release other greenhouse gases, such as CFCs, methane, and nitrous oxide, in significant amounts.



# Greenhouse Gases

## Major Greenhouse Gases and Their Sources

**Carbon dioxide, CO<sub>2</sub>:** burning fossil fuels and deforestation

**Chlorofluorocarbons (CFCs):** refrigerants, aerosols, foams, propellants, and solvents

**Methane, CH<sub>4</sub>:** animal waste, biomass burning, fossil fuels, landfills, livestock, rice paddies, sewage, and wetlands

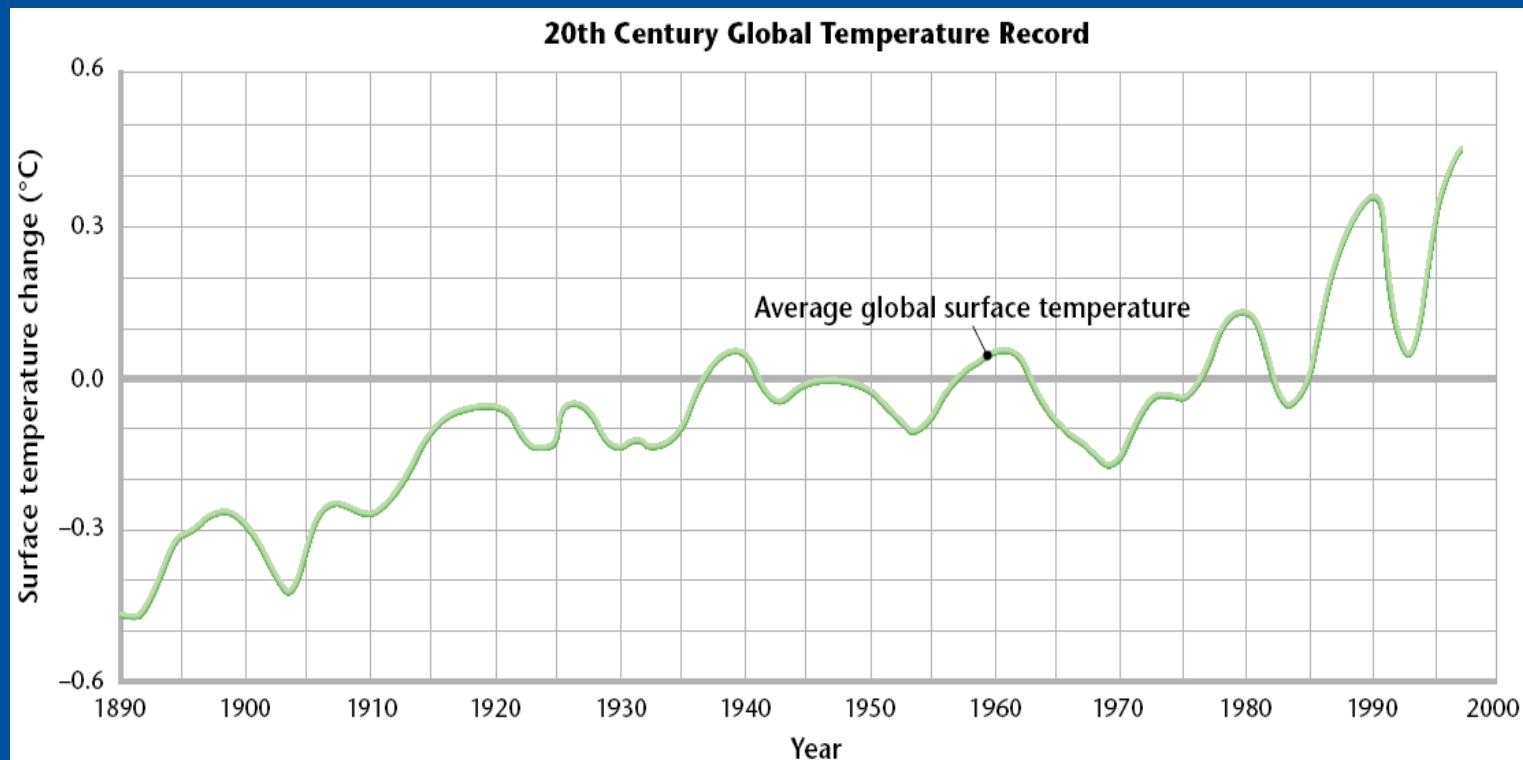
**Nitrous Oxide, N<sub>2</sub>O:** biomass burning, deforestation, burning of fossil fuels, and microbial activity on fertilizers in the soil

**Water vapor, H<sub>2</sub>O:** evaporation, plant respiration

## How Certain is Global Warming?

- **Global warming** is a gradual increase in the average global temperature that is due to a higher concentration of gases such as carbon dioxide in the atmosphere.
- Earth's average global temperature increased during the 20th century and many scientists predict that this warming trend will continue throughout the 21st century.

# How Certain is Global Warming



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## How Certain is Global Warming?

- However, not all scientists agree that the observed global warming is due to greenhouse gases.
- Some scientists believe that the warming is part of **natural climatic variability**.
- They point out that widespread fluctuations in temperature have occurred throughout geological time.

## The Consequences of a Warmer Earth

- The impacts of global warming could include a number of potentially serious environmental problems.
- These problems range from the disruption of **global weather patterns** and a **global rise in sea level** to adverse impacts on human health, agriculture, and animal and plant populations.
- Other impacts on the environment that could not be predicted by computer models might also arise.

## Melting Ice and Rising Sea Levels

- If the global temperature increased, the amount of ice and snow at the poles would **decrease**, causing sea levels around the world to rise.
- Coastal wetlands, and other low-lying areas could be **flooded**. People who live near coastlines could lose their homes and sources of income.
- The salinity of bays and estuaries might **increase**, adversely affecting marine fisheries. Also, freshwater aquifers could become too salty to be used as sources of fresh water.



## Global Weather Patterns

- If the Earth warms up significantly, the surface of the oceans will **absorb** more heat, which may make hurricanes and typhoons more common.
- Some scientists are concerned that global warming will also cause a change in ocean current patterns, shutting off the Gulf Stream.
- Such a change could significantly affect the world's weather. Severe flooding could occur in some regions at the same time droughts devastate other regions.

## Human Health Problems

- Greater numbers of heat related deaths could occur. Very young and very old people would have the greatest risk of **heat exhaustion**.
- Concentrations of ground level ozone could **increase** as air temperatures rise, causing respiratory illnesses, especially in urban areas, to increase.
- Warmer temperatures might enable **mosquitoes**, which carry diseases such as malaria and encephalitis, to greatly increase in number.

## Agriculture

- Agriculture would be most severely impacted by global warming if extreme weather events, such as drought, became **more frequent**.
- Higher temperatures could result in **decreased crop yields**.
- As a result, the demand for irrigation could increase, which would further deplete aquifers that have already been overused.



## Effects on Plants

- Climate change could alter the range of plant species and could change the composition of plant communities.
- A warmer climate could cause trees to **colonize northward** into cooler areas.
- Forests could shrink in areas in the southern part of their range and lose diversity.

## Effects on Animals

- Global warming could cause a **shift** in the geographical range of some animals. For example, Northern birds may not migrate as far south during the winter.
- Warming of surface waters of the ocean might cause a reduction of zooplankton, tiny shrimp-like animals, that many marine animals depend on for food.
- Warming tropical waters may kill algae that nourish corals, thus destroying coral reefs.

## Recent Findings

- The International Panel on Climate Change (IPCC) issued its Third Assessment Report (TAR) in 2001 that described what was currently known about the global climate system and provided future estimates about the state of the global climate system.
- The IPCC reported that the average global surface temperature increased by **0.6°C** during the 20th century, snow and ice cover has dropped, and the global sea level has risen.



## Recent Findings

- The IPCC also reported that concentrations of atmospheric gases have continued to **increase** as a result of human activities.
- It has also predicted that human influences will continue to change the composition of the Earth's atmosphere and continue to warm the Earth throughout the 21st century.

## Reducing the Risk

- The **Kyoto Protocol** is an international treaty according to which developed countries that signed the treaty agree to reduce their emissions of carbon dioxide and other gases that may contribute to global warming by the year 2012.
- In March of 2001, the United States decided **not** to ratify the Kyoto Protocol. However, most other developed nations are going ahead with the treaty.

## Reducing the Risk

- The need to slow global warming has been recognized by the global community. Some nations and organizations have engaged in reforestation projects to reduce carbon dioxide.
- However, the attempt to slow global warming is made difficult by the economic, political, and social factors faced by different countries.



# Reducing the Risk

