

# **Air Pollution:**

## **Air Pollutants & Human Health Effects**

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# Air Pollution



# Air Pollution Definitions

- Transfer of harmful and/or of Natural/Synthetic materials into the atmosphere as a direct/indirect consequences of human activity (OECD).
- The introduction of chemicals, particulate matter, or biological materials that cause harm or discomfort to humans or other living organisms, or damages the natural environment into the atmosphere
- The overwhelming scientific consensus is that the earth's atmosphere is warming rapidly, mostly because of human activities, and that this will lead to significant climate change during this century

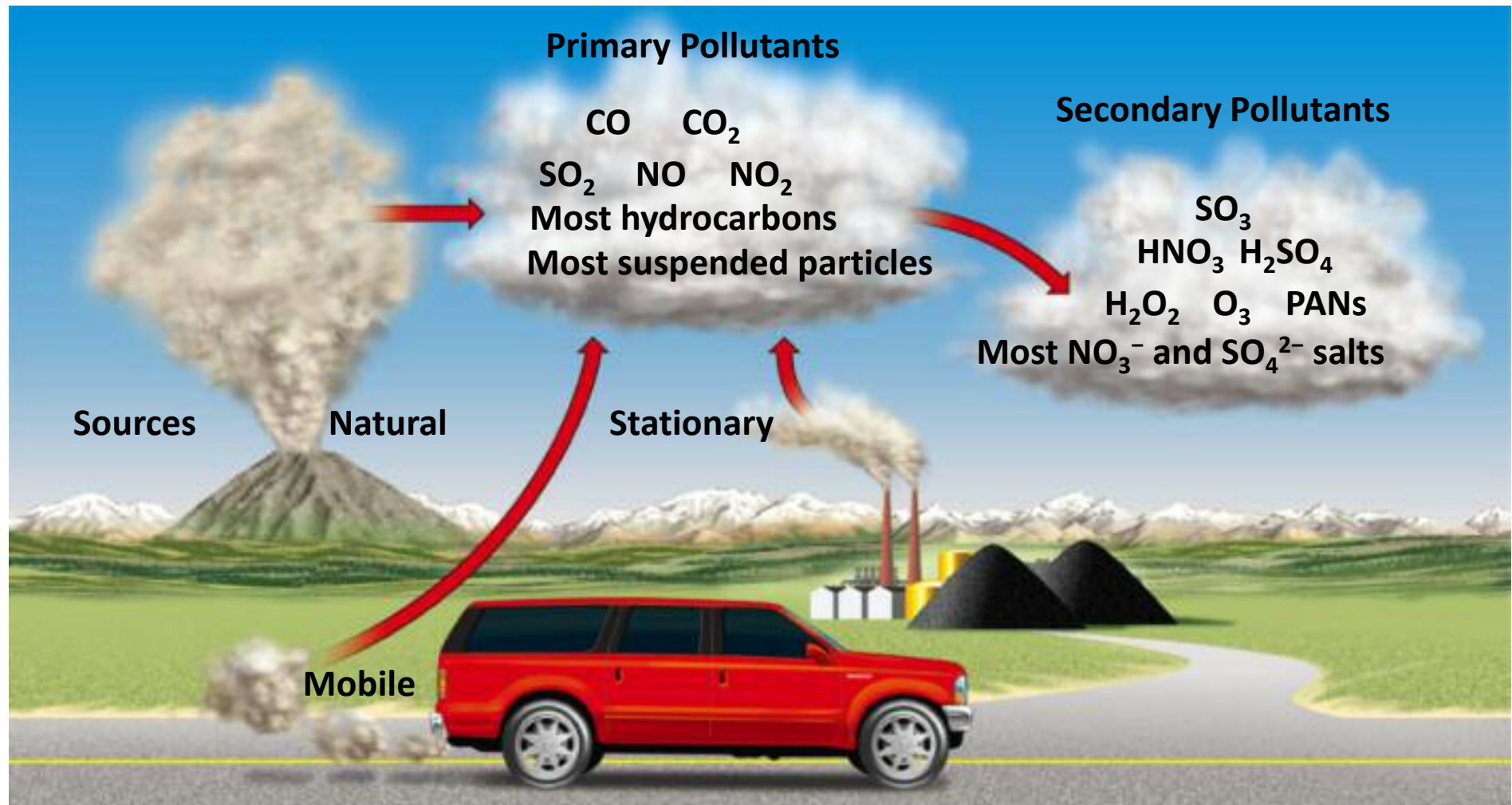
# Air Pollutants

- Pollutants mix in the air to form industrial smog, mostly the result of burning coal, and photochemical smog, caused by motor vehicle, industrial, and power plant emissions
- An air pollutant can be a gas or a particulate.
- Sources:
  - Natural sources
    - ✓ Dust blown by wind
    - ✓ Pollutants from wildfires and volcanoes
    - ✓ Volatile organics released by plants
  - Human sources: mostly in industrialized and/or urban areas
    - ✓ Stationary sources
    - ✓ Mobile sources

# Air Pollutants Classification

**Classified as:**

- 1. Primary pollutants:** foreign matter injected into the atmosphere by human activities.
- 2. Secondary pollutants:** resulting from chemical transformations, typically with primary pollutants and (often) sunlight.



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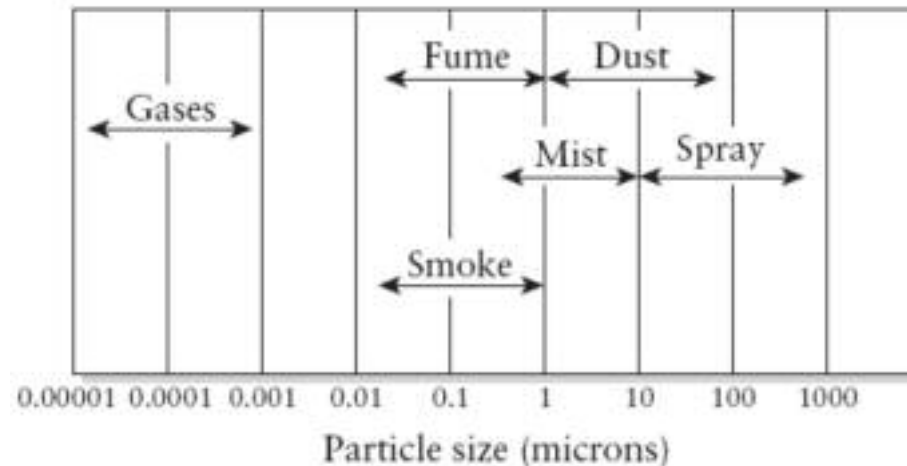
# Major Air Pollutants

## Suspended particulate matter (SPM):

- Consists of a variety of solid particles and liquid droplets small and light enough to remain suspended in the air.
- The most harmful forms of SPM are fine particles (PM-10, with an average diameter  $< 10$  micrometers) and ultrafine particles (PM-2.5).
- According to the EPA, SPM is responsible for about 60,000 premature deaths a year in the U.S.

# Major Air Pollutants

- Particulate matter or pollutants can be further classified as dusts, fumes, mists, smoke, or spray.



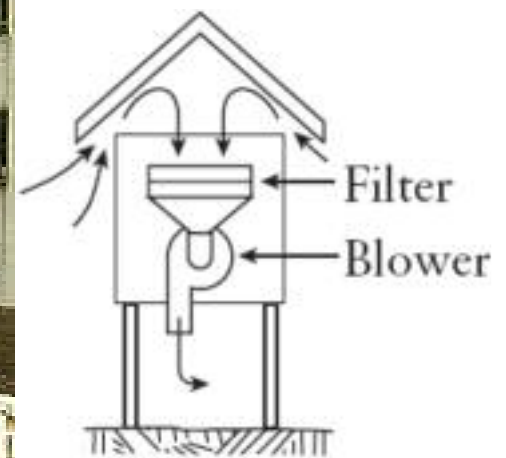
Terminology	Abbreviation	Diameter Range ( $\mu\text{m}$ )
Ultrafine	—	<0.1
Fine	PM <sub>2.5</sub>	<2.5
Coarse	PM <sub>10</sub>	2.5–10

# Particulate Matters

- Dust is defined as solid particles.
- A fume is also a solid particle, frequently a metallic oxide, formed by the condensation of vapors by sublimation, distillation, calcination, or chemical reaction processes. The particles in fumes are quite small, with diameters from 0.03 to 0.3  $\mu$ .
- A mist is an entrained liquid particle formed by the condensation of a vapor and perhaps by chemical reaction. Mists typically range from 0.5 to 3.0  $\mu$  in diameter.
- Smoke is made up of entrained solid particles formed as a result of incomplete combustion of carbonaceous materials. Smoke particles have diameters from 0.05 to approximately 1  $\mu$ .
- a spray is a liquid particle formed by the atomization of a parent liquid. Sprays settle under gravity

# Measurement of Particulates

- The measurement of PM<sub>10</sub> has been historically done by using the *high-volume sampler* (or hi-vol).
- The high-volume sampler operates much like a vacuum cleaner, forcing up to 86,000 ft<sup>3</sup> of air through a filter in 24 hr. The analysis is gravimetric; the filter is weighed before and after, and the difference is the particulates collected.



# Gaseous Pollutants

- Gaseous pollutants include substances that are gases at normal temperature and pressure as well as vapors of substances that are liquid or solid at normal temperature and pressure.

Name	Formula	Properties of Importance	Significance as Air Pollutant
Sulfur dioxide	SO <sub>2</sub>	Colorless gas, intense choking, odor, highly soluble in water — forming sulfurous acid, H <sub>2</sub> SO <sub>3</sub>	Damage to property, health, and vegetation
Sulfur trioxide	SO <sub>3</sub>	Soluble in water — forming sulfuric acid H <sub>2</sub> SO <sub>4</sub>	Highly corrosive
Hydrogen sulfide	H <sub>2</sub> S	Rotten egg odor at low concentrations, odorless at high concentrations	Highly poisonous
Nitrous oxide	N <sub>2</sub> O	Colorless gas, used as carrier gas in aerosol bottles	Relatively inert; not produced in combustion
Nitric oxide	NO	Colorless gas	Produced during high-temperature, high-pressure combustion; oxidizes to NO <sub>2</sub>
Nitrogen dioxide	NO <sub>2</sub>	Brown to orange gas	Major component in the formation of photochemical smog
Carbon monoxide	CO	Colorless and odorless	Product of incomplete combustion; poisonous
Carbon dioxide	CO <sub>2</sub>	Colorless and odorless	Formed during complete combustion; greenhouse gas
Ozone	O <sub>3</sub>	Highly reactive	Damage to vegetation and property; produced mainly during the formation of photochemical smog
Hydrocarbons	C <sub>x</sub> H <sub>y</sub> or HC	Many	Emitted from automobiles and industries; formed in the atmosphere
Methane	CH <sub>4</sub>	Combustible, odorless	Greenhouse gas
Chlorofluorocarbons	CFC	Nonreactive, excellent thermal properties	Deplete ozone in upper atmosphere

# Air Pollution Effects

- **Effects on Human Health**

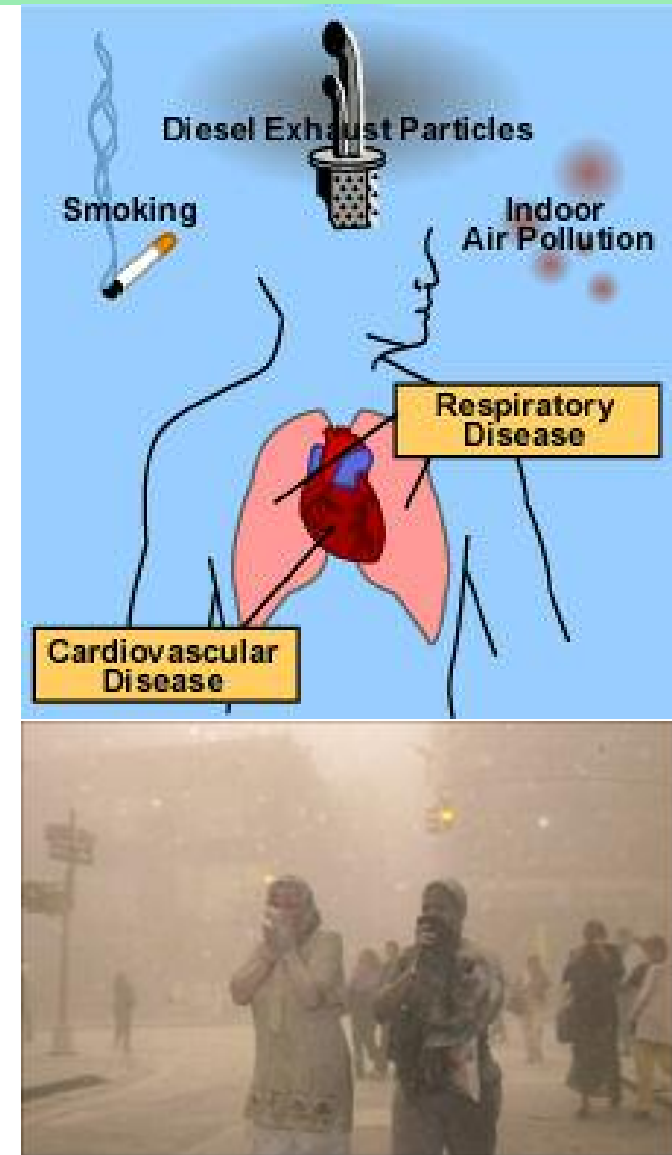
- Respiratory problems
- Allergies
- Risk for cancer

- **Effects on the environment**

- Acid rain (Regional)
- Ozone depletion (Stratospheric)
- Greenhouse Effect (Global warming)

# Human Health Effects

- Exposure to air pollution is associated with numerous effects on human health, including pulmonary, cardiac, vascular, and neurological impairments.
- The health effects vary greatly from person to person. High-risk groups such as the elderly, infants, pregnant women, and sufferers from chronic heart and lung diseases are more susceptible to air pollution.
- Children are at greater risk because they are generally more exposed to outdoor environment and their lungs are still developing stage.



**Table 1: Sources, Health and Welfare Effects for Criteria Pollutants.**

<b>Pollutant</b>	<b>Description</b>	<b>Sources</b>	<b>Health Effects</b>	<b>Welfare Effects</b>
Carbon Monoxide (CO)	Colorless, odorless gas	Motor vehicle exhaust, indoor sources include kerosene or wood burning stoves.	Headaches, reduced mental alertness, heart attack, cardiovascular diseases, impaired fetal development, death.	Contribute to the formation of smog.
Sulfur Dioxide (SO <sub>2</sub> )	Colorless gas that dissolves in water vapor to form acid, and interact with other gases and particles in the air.	Coal-fired power plants, petroleum refineries, manufacture of sulfuric acid and smelting of ores containing sulfur.	Eye irritation, wheezing, chest tightness, shortness of breath, lung damage.	Contribute to the formation of acid rain, visibility impairment, plant and water damage, aesthetic damage.
Nitrogen Dioxide (NO <sub>2</sub> )	Reddish brown, highly reactive gas.	Motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fuels.	Susceptibility to respiratory infections, irritation of the lung and respiratory symptoms (e.g., cough, chest pain, difficulty breathing).	Contribute to the formation of smog, acid rain, water quality deterioration, global warming, and visibility impairment.
Ozone (O <sub>3</sub> )	Gaseous pollutant when it is formed in the troposphere.	Vehicle exhaust and certain other fumes. Formed from other air pollutants in the presence of sunlight.	Eye and throat irritation, coughing, respiratory tract problems, asthma, lung damage.	Plant and ecosystem damage.
Lead (Pb)	Metallic element	Metal refineries, lead smelters, battery manufacturers, iron and steel producers.	Anemia, high blood pressure, brain and kidney damage, neurological disorders, cancer, lowered IQ.	Affects animals and plants, affects aquatic ecosystems.
Particulate Matter (PM)	Very small particles of soot, dust, or other matter, including tiny droplets of liquids.	Diesel engines, power plants, industries, windblown dust, wood stoves.	Eye irritation, asthma, bronchitis, lung damage, cancer, heavy metal poisoning, cardiovascular effects.	Visibility impairment, atmospheric deposition, aesthetic damage.

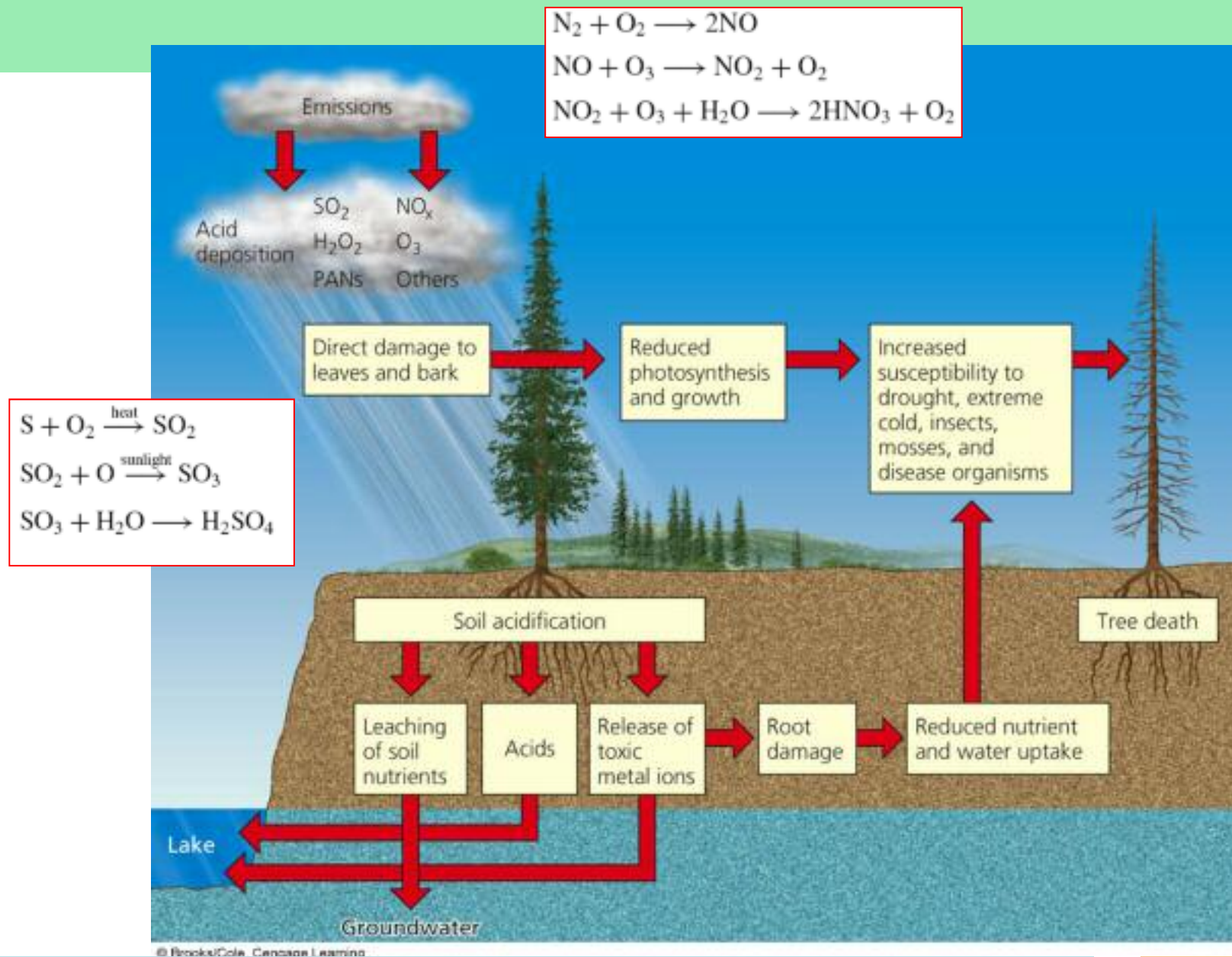
# Acid Rain

One way in which  $\text{SO}_2$  is removed from the atmosphere is the formation of acid rain

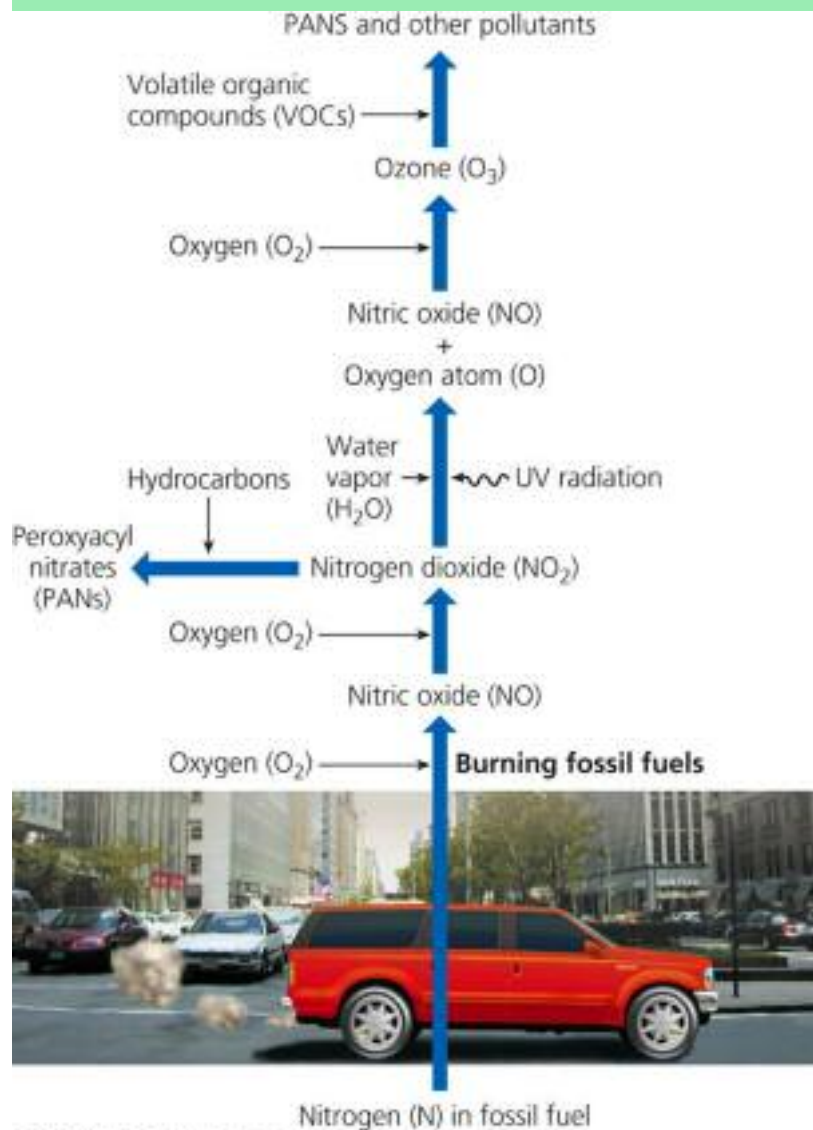
- contains high levels of sulfuric or nitric acids
- contaminate drinking water and vegetation
- damage aquatic life
- erode buildings
- Alters the chemical equilibrium of some soils



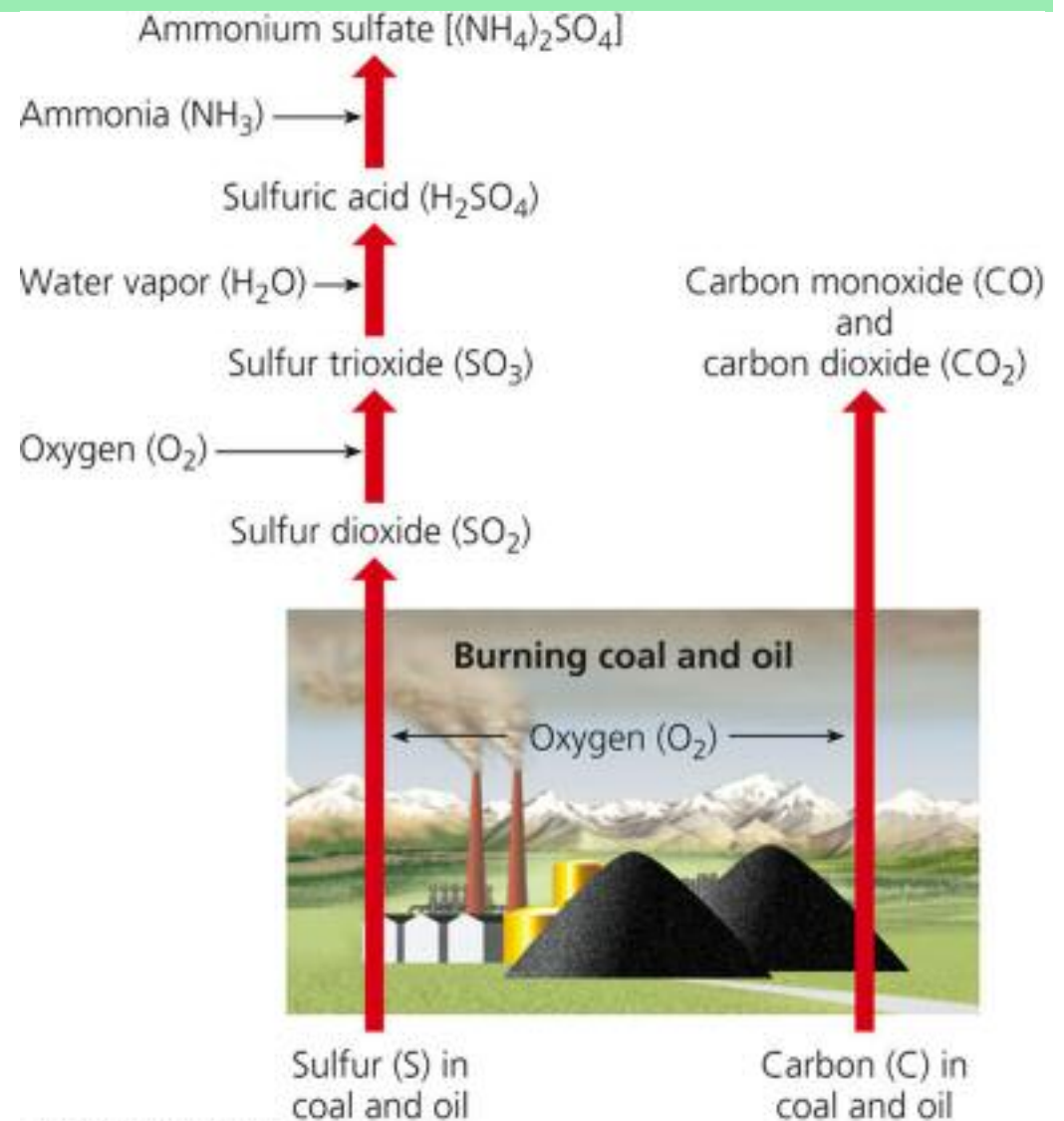
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# Photochemical Smog



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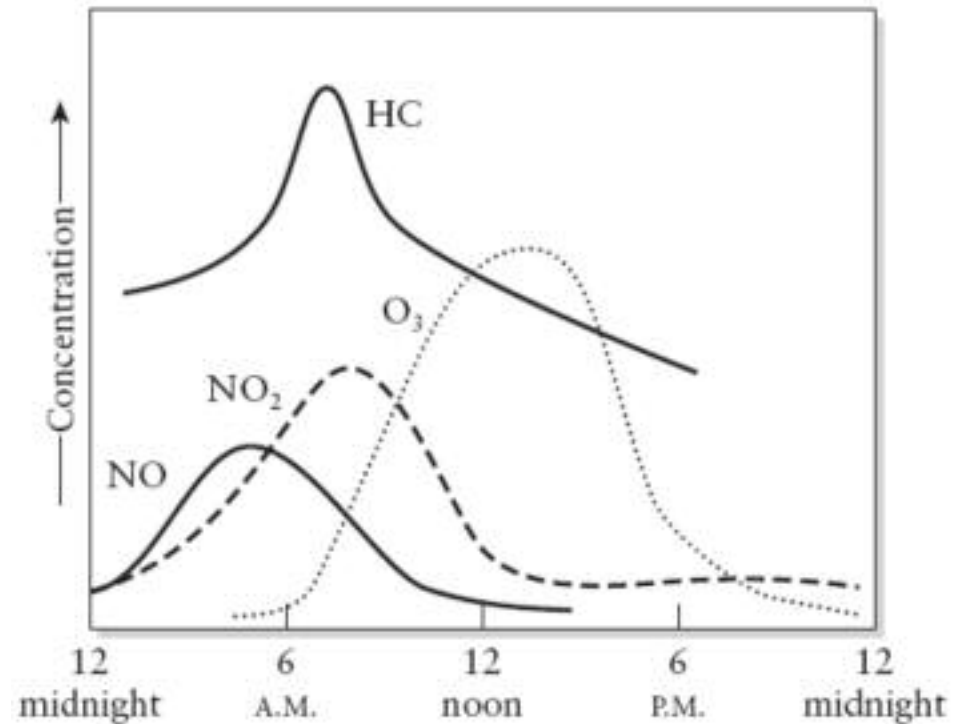
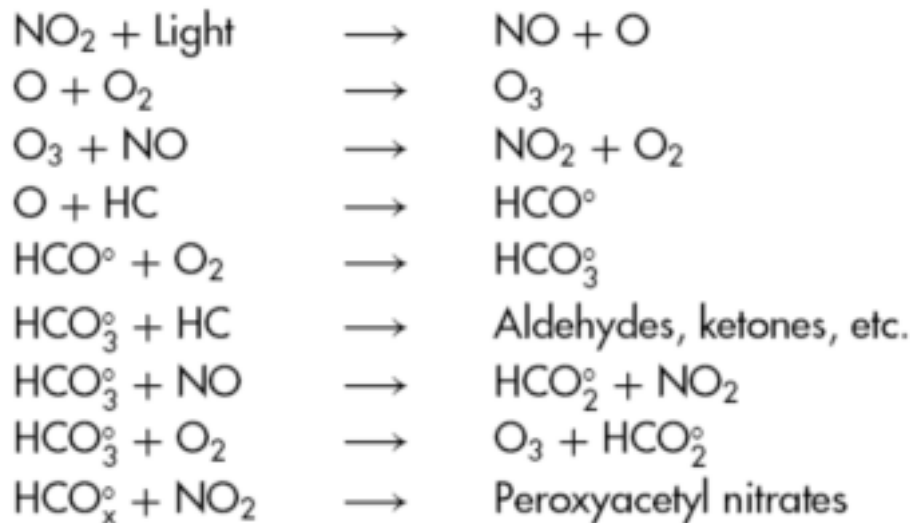


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# Simplified Reaction Scheme

Hydrocarbons + Nox + Sunlight  $\rightarrow$  photochemical smog (oxidants)

- primary oxidants produced: ozone ( $O_3$ ), formaldehyde, peroxyacetyl nitrate (PAN)



# Photochemical Smog in Santiago, Chile

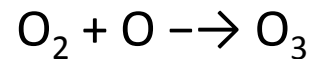
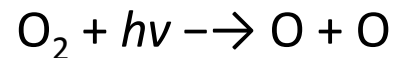


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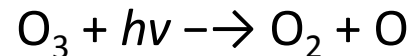
# Ozone Depletion

- Ozone ( $O_3$ ) is an eye irritant at usual urban levels, but urban  $O_3$  should not be confused with stratospheric  $O_3$ , 7 to 10 mile above the earth's surface.
- The latter acts as an ultraviolet radiation shield, and its alteration can increase the risk of skin cancer as well as change the ecology in unpredictable ways.

Ozone in the upper atmosphere is created when oxygen reacts with light energy ( $h\nu$ ):

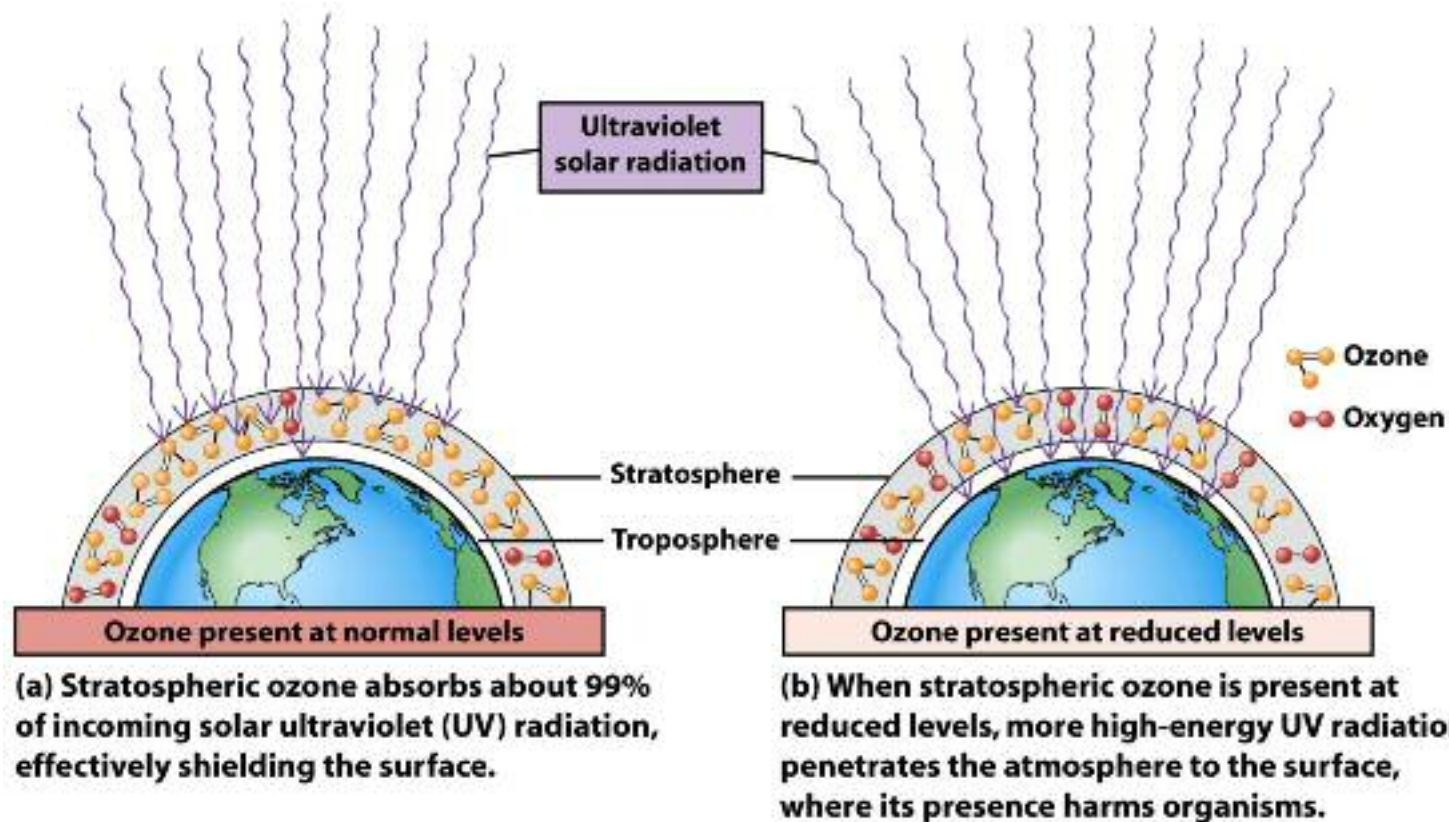


Light energy also destroys ozone:



This is the mechanism by which ozone prevents ultraviolet radiation from reaching earth's surface.

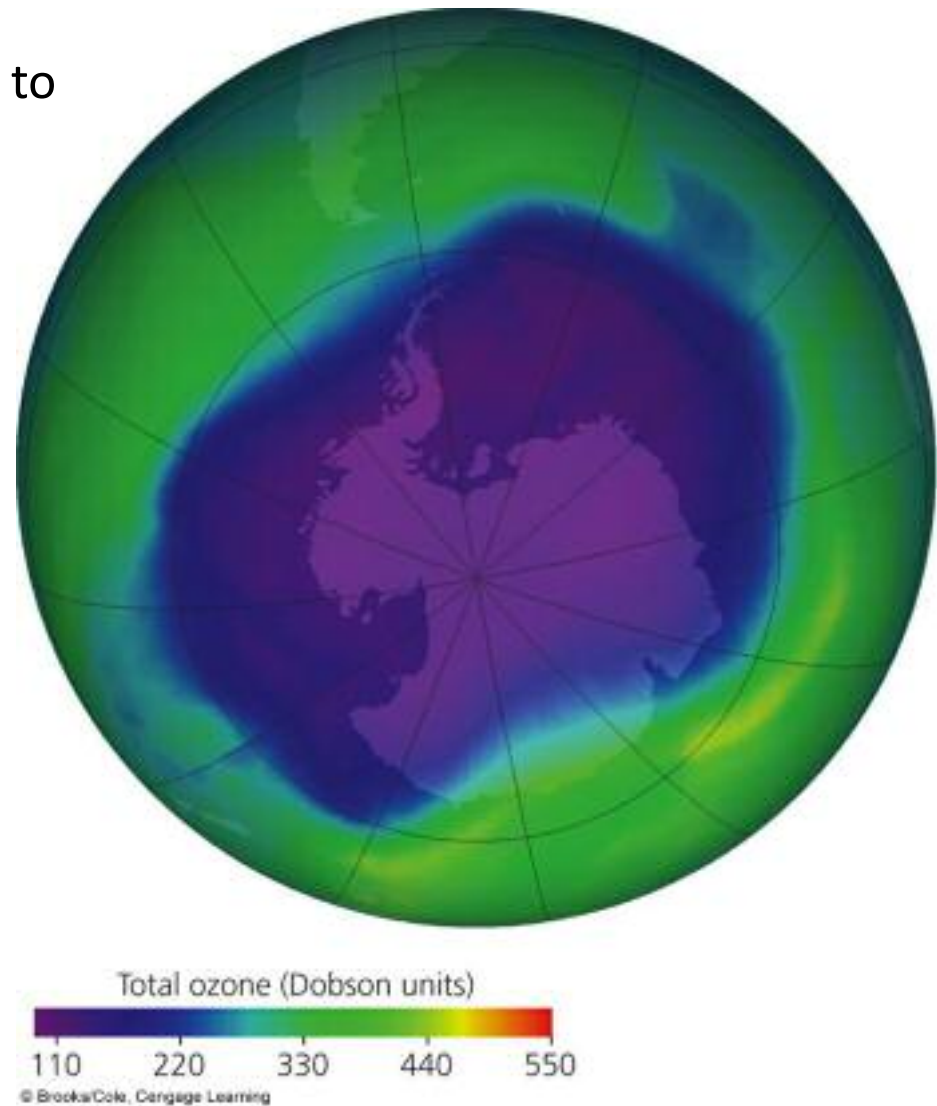
- ✓ Ozone Protects earth from UV radiation Part of the electromagnetic spectrum with wavelengths just shorter than visible light



**Dobson units (DU)** were developed to measure ozone concentration:

1 DU = 0.01 mm of O<sub>3</sub> at 1 atm and 0°C

At midlatitudes the ozone concentration is typically about 350 DU, at the equator it is 250 DU, and in the Antarctic region it is only 100 DU.

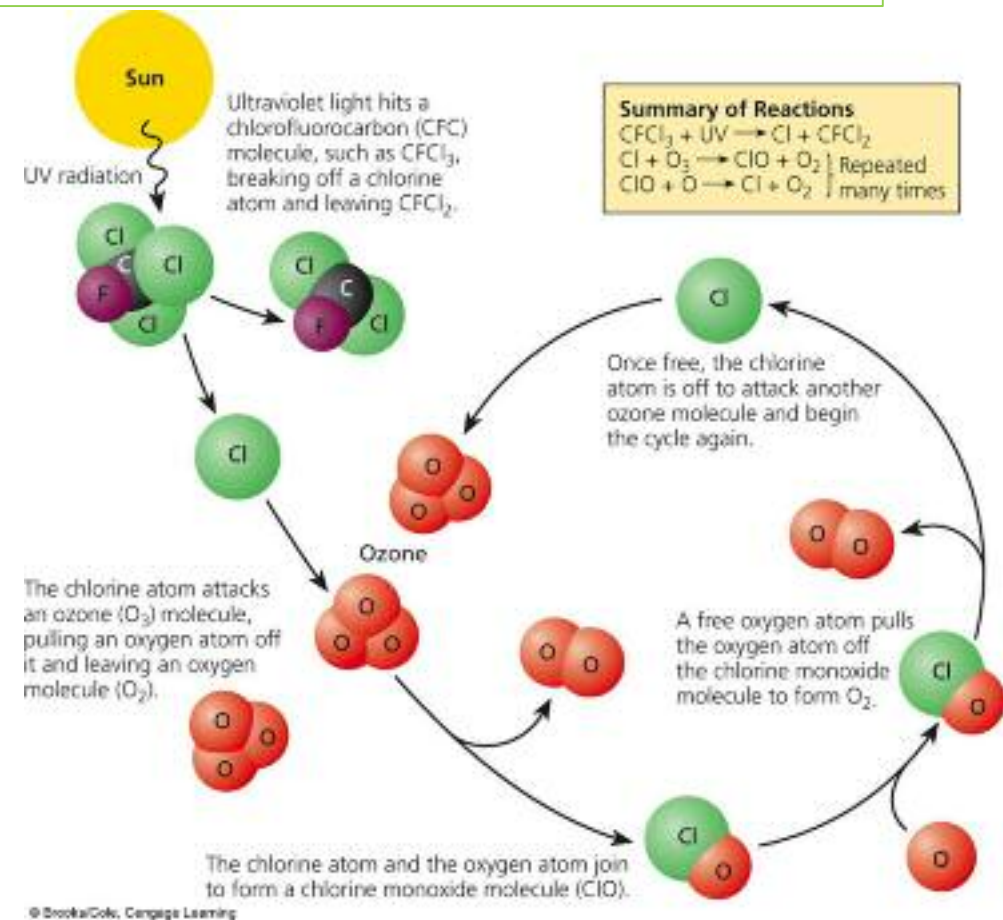


# How O<sub>3</sub> is Depleted in the Stratosphere?

- Widespread use of certain chemicals has reduced ozone levels in the stratosphere, which allows for more harmful ultraviolet radiation to reach the earth's surface

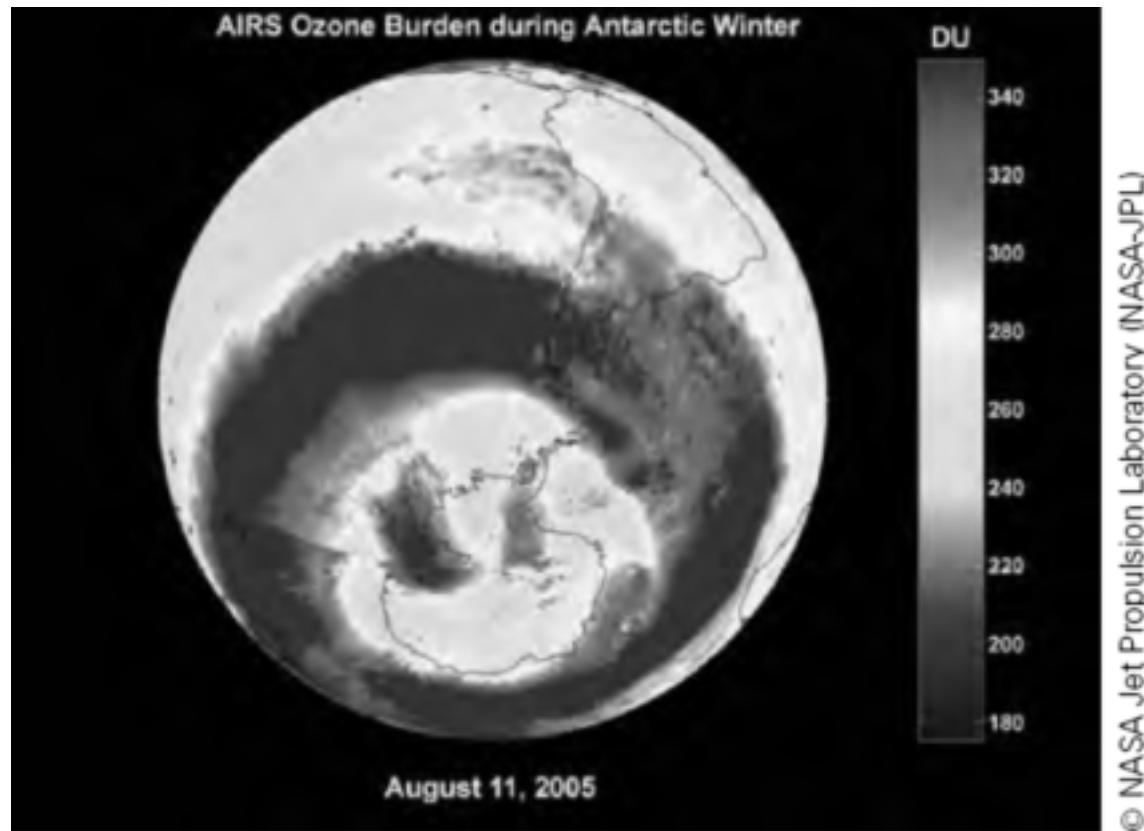
➤ The chlorofluorocarbons (CFCs). chemicals that found wide use in aerosols and refrigeration systems and are responsible for climate change as well as the depletion of the protective ozone layer in the stratosphere.

Two of the most important CFCs are trichlorofluoromethane, CFC13, and dichlorodifluoromethane, CFC12, both of which are inert and not water soluble and, therefore, do not wash out of the atmosphere.



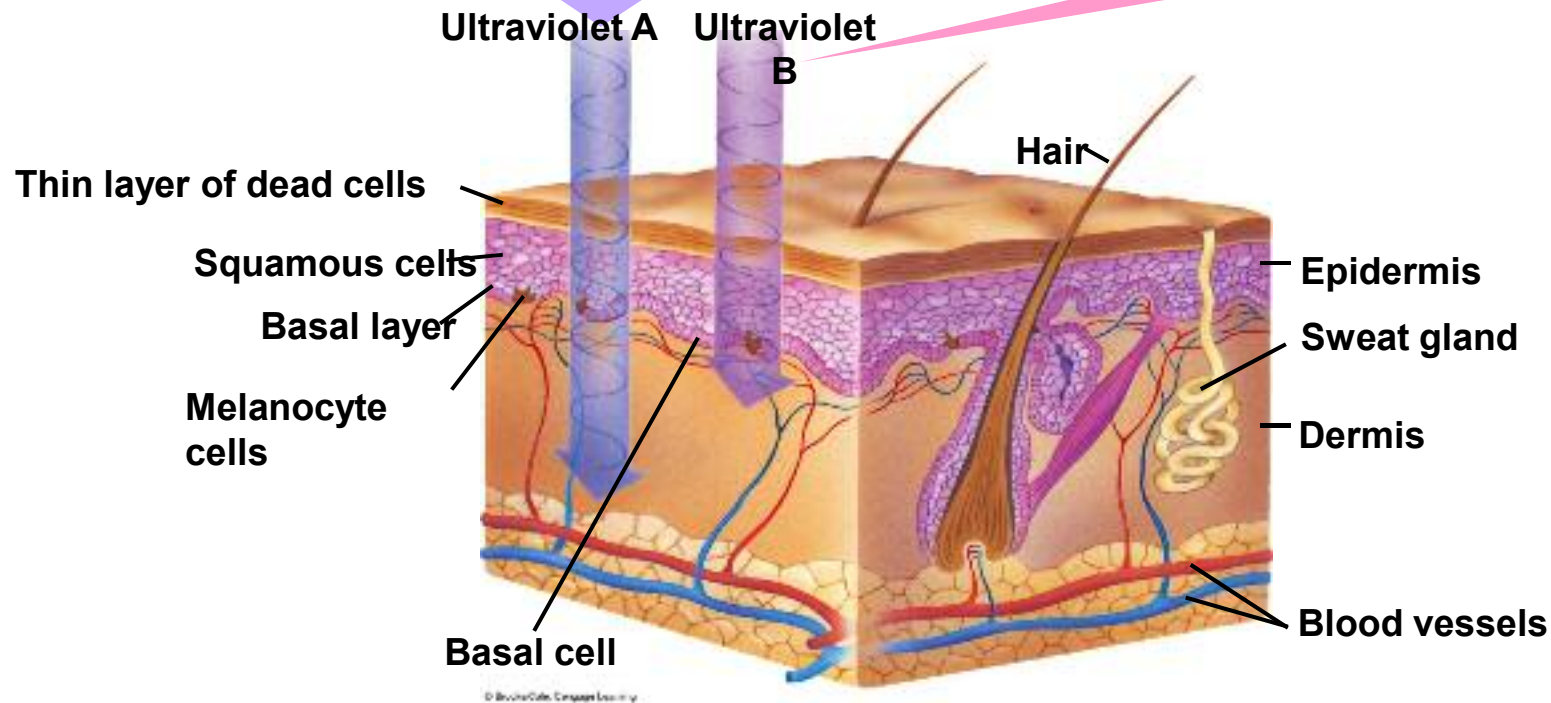
# The ozone hole & risks

There indeed was a huge monster hole right in the middle of the South Pole.



This long-wavelength (low-energy) form of UV radiation causes aging of the skin, tanning, and sometimes sunburn. It penetrates deeply and may contribute to skin cancer.

This shorter-wavelength (high-energy) form of UV radiation causes sunburn, premature aging, and wrinkling. It is largely responsible for basal and squamous cell carcinomas and plays a role in malignant melanoma.



**Squamous Cell Carcinoma**



**Basal Cell Carcinoma**



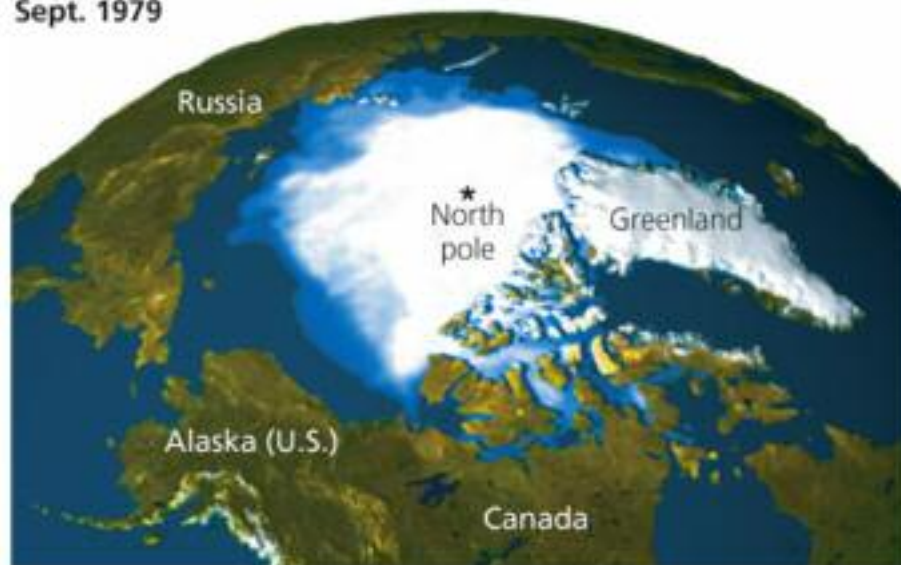
**Melanoma**



# Climate Change

- The overwhelming scientific consensus is that the earth's atmosphere is warming rapidly, mostly because of human activities, and that this will lead to significant climate change during this century.

Sept. 1979



Sept. 2007



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# Temperatures in the Past ?

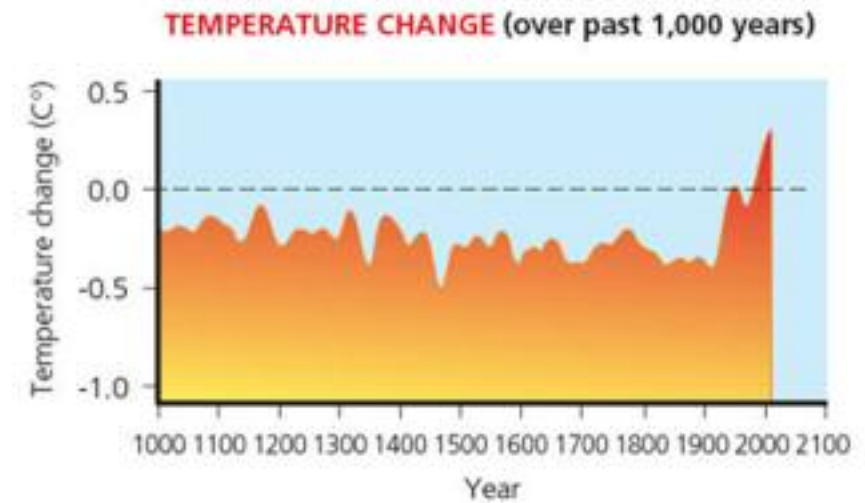
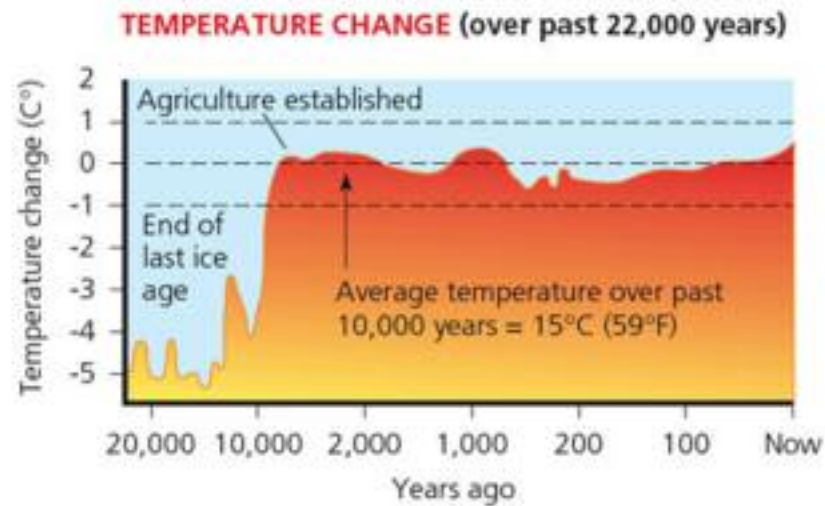
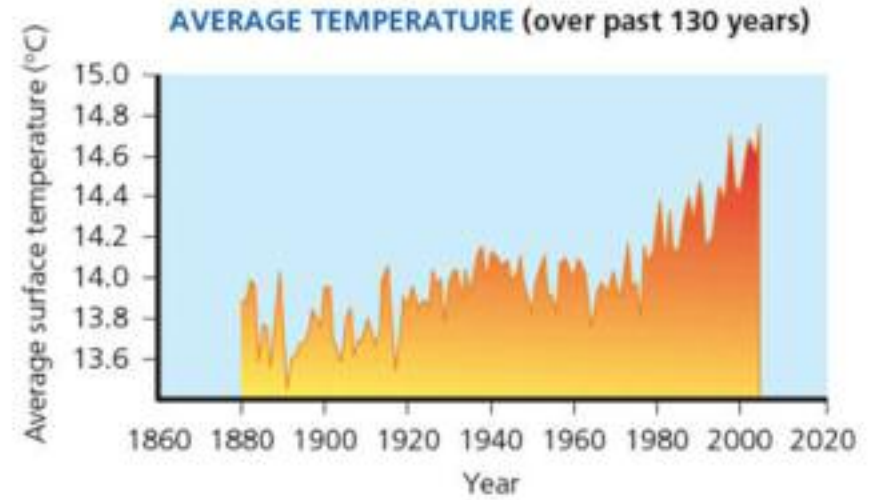
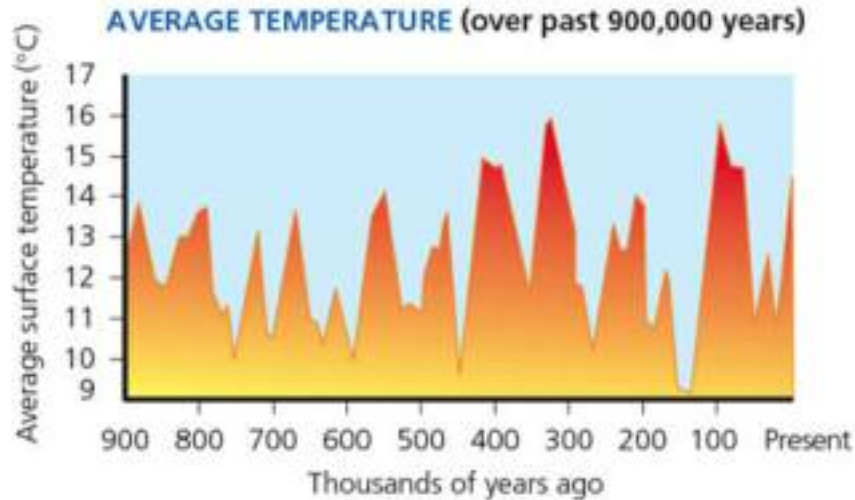


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Scientists analyze tiny air bubbles trapped in ice cores learn about past:

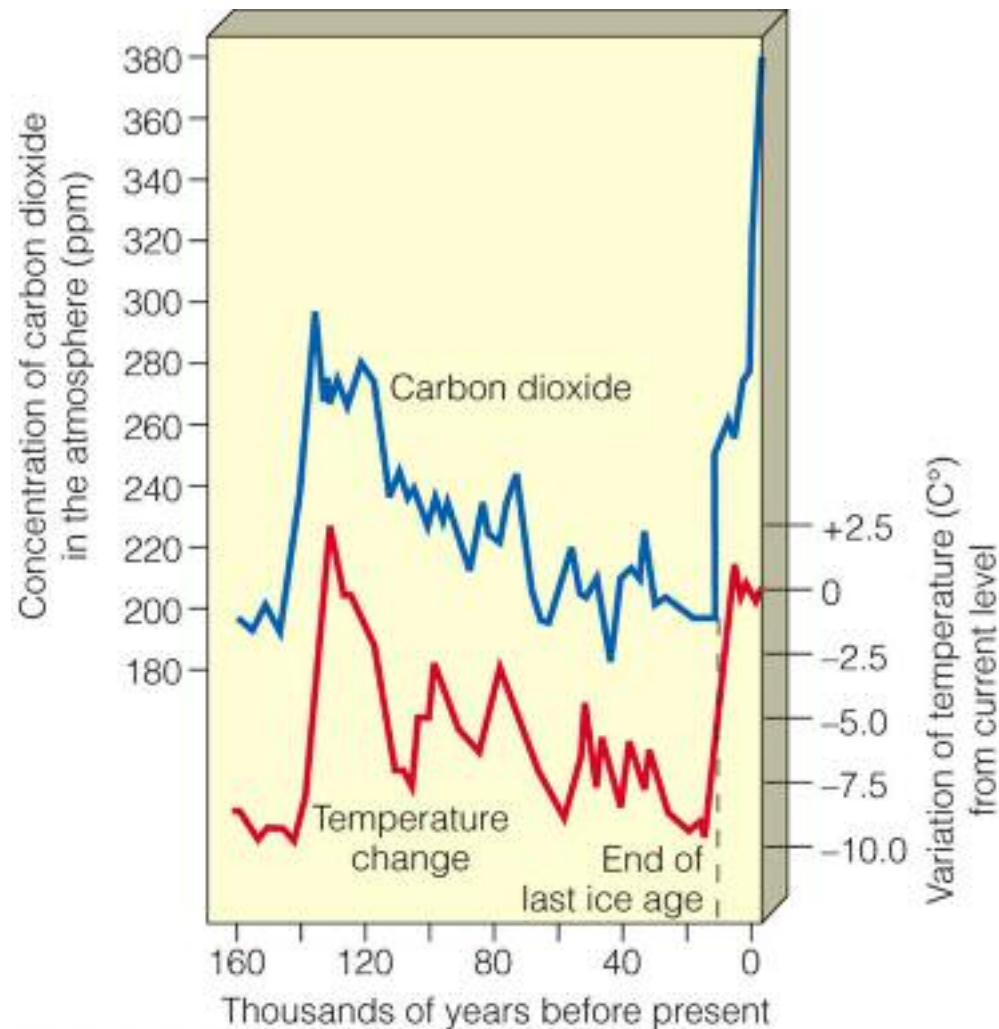
- troposphere composition.
- temperature trends.
- greenhouse gas concentrations.
- solar, snowfall, and forest fire activity.

# Estimated Changes

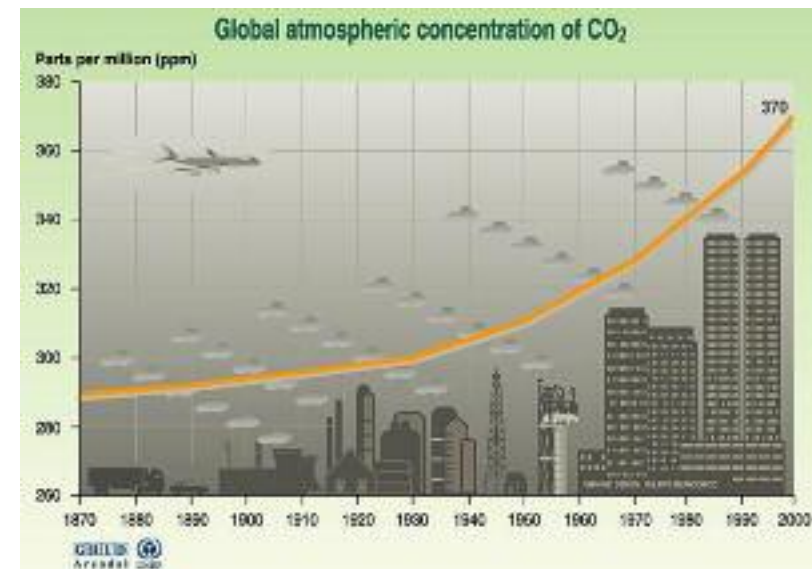


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# Carbon Dioxide at highest levels



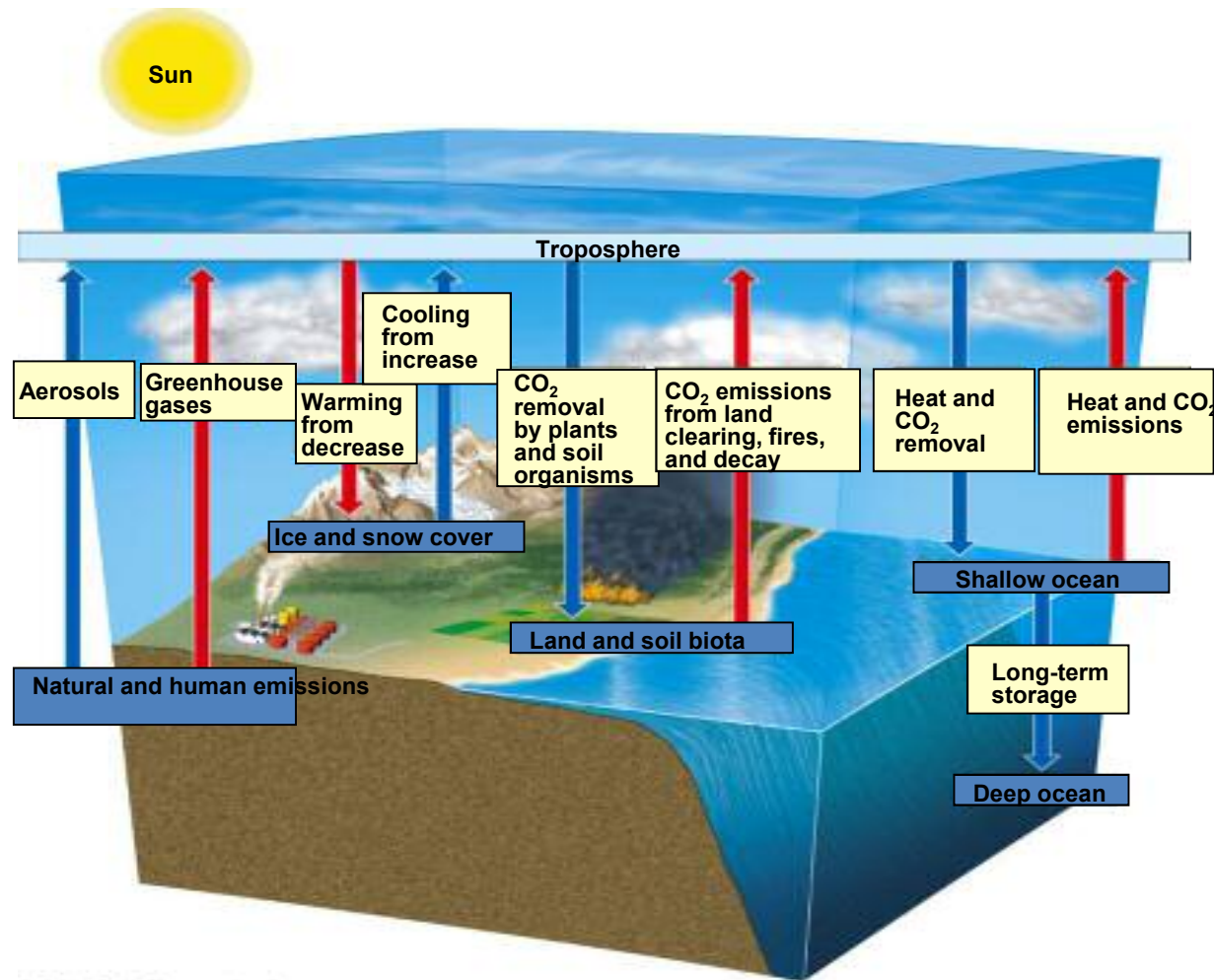
In 2005, an ice core showed that CO<sub>2</sub> levels in the troposphere are the highest they have been in 650,000 years.



# Climate Change Consequences

- 90–99% likely that lower atmosphere is warming
- 1906–2005: Ave. temp increased about 0.74°C
- 1970–2005: Annual greenhouse emissions up 70%
- Past 50 years: Arctic temp rising almost twice as fast as the rest of the earth
- Melting of glaciers and floating sea ice
- Prolonged droughts: increasing
- Last 100 years: sea levels rose 10–20 cm
- Warmer temperatures in Alaska, Russia, and the Arctic are melting permafrost releasing more CO<sub>2</sub> and CH<sub>4</sub> into the troposphere.

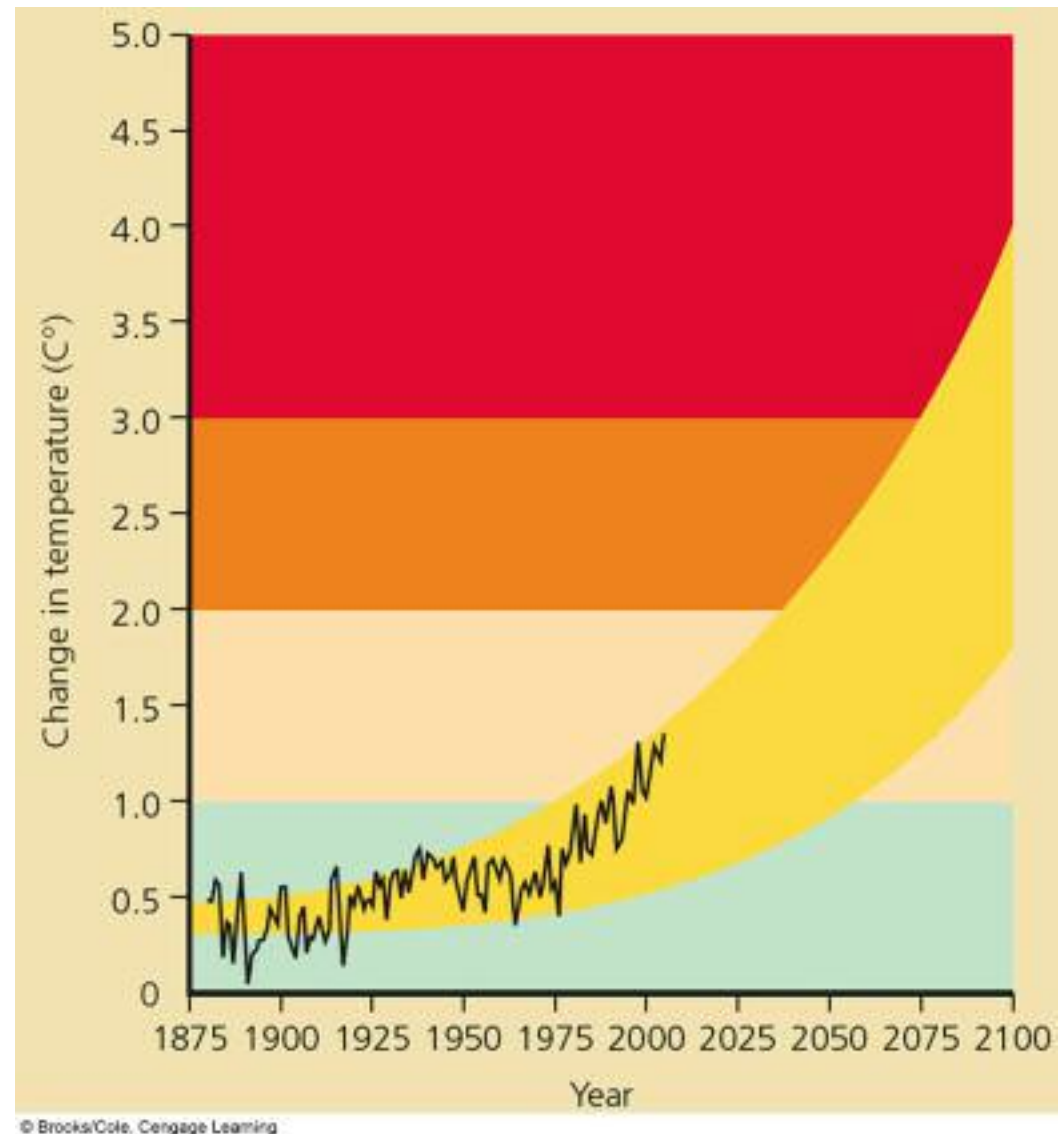
# Greenhouse Gases Effect



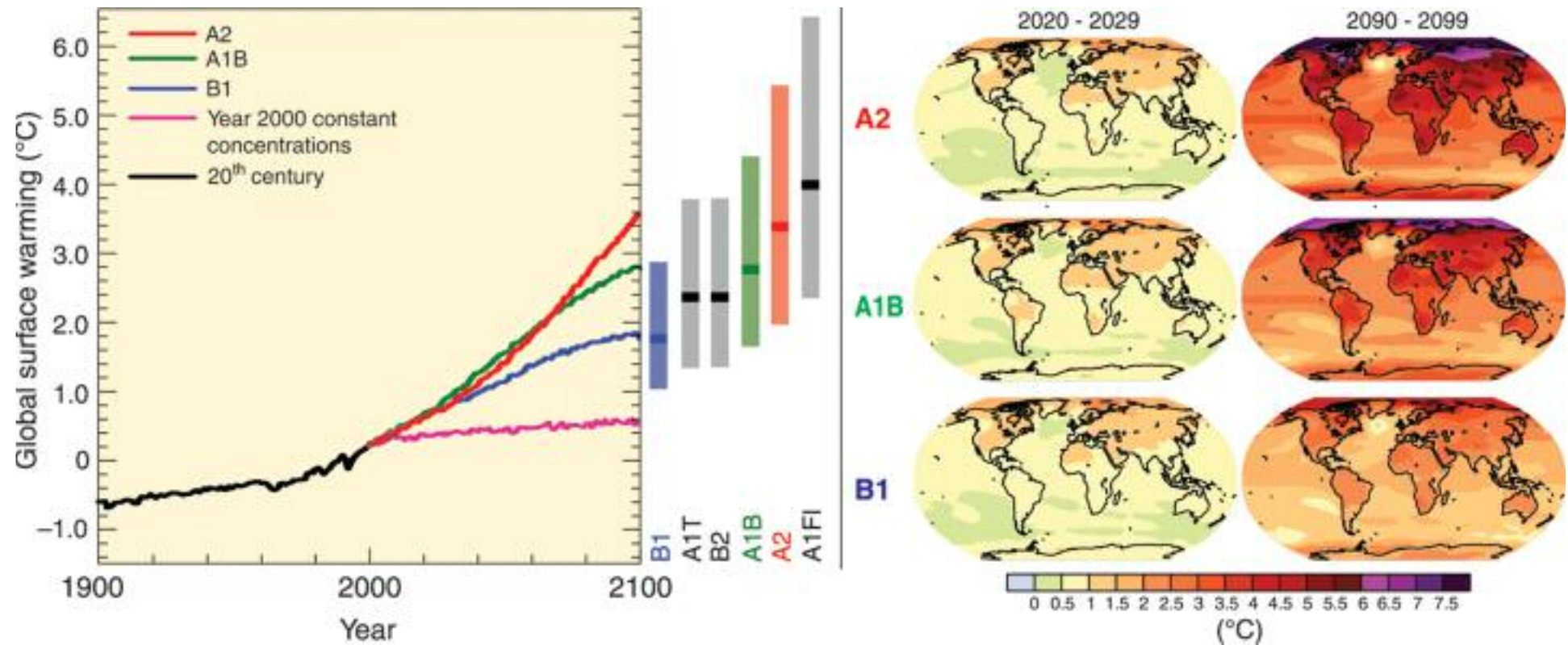
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# Measured Temperature and Projected Changes

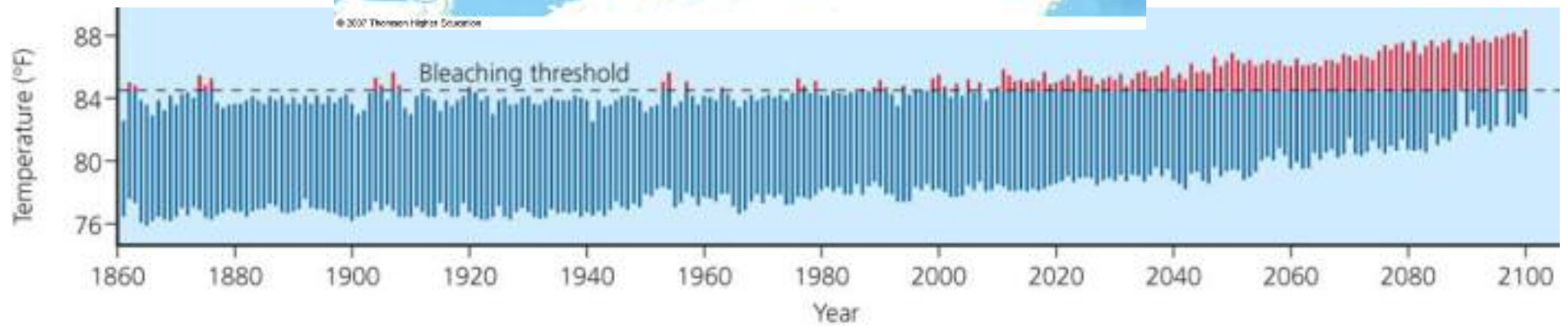
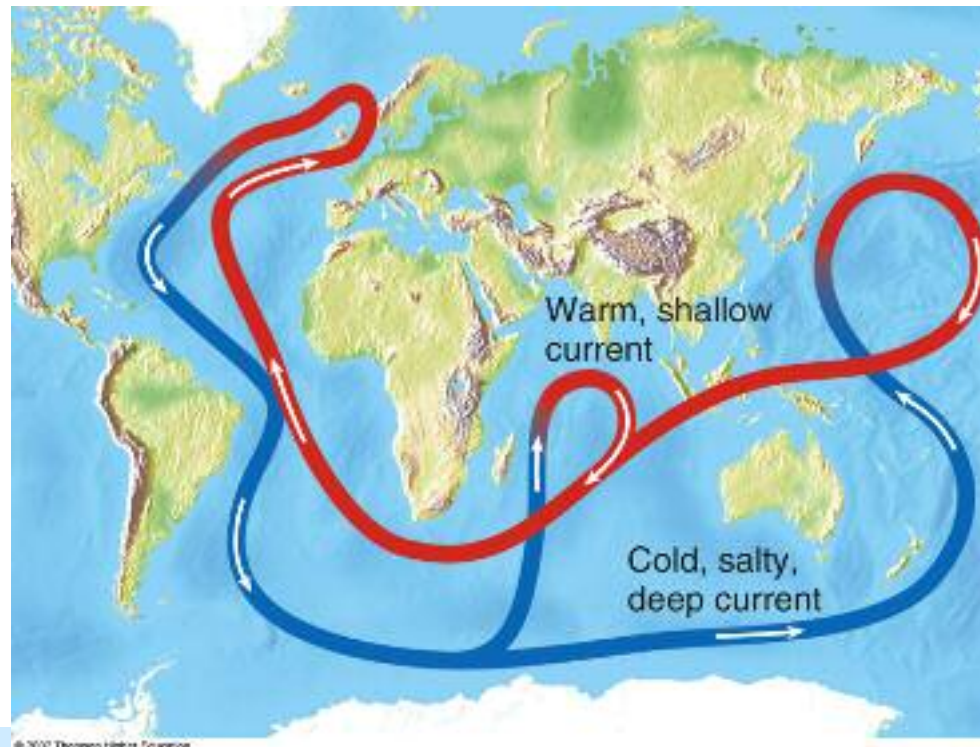
- The projected rapid change in the atmosphere's temperature during this century is very likely to increase drought and flooding, shift areas where food can be grown, raise sea levels, result in intense heat waves, and cause the premature extinction of many species.



# Temperature projections



# Changing Ocean Currents



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# Glacial Ice Melting & Decline in Arctic Tundra



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# CC Regional Impacts

<b>North America</b>	<ul style="list-style-type: none"><li>• Warming in western mountains is projected to cause decreased snowpack, more winter flooding and reduced summer flows, exacerbating competition for over-allocated water resources.</li><li>• In the early decades of the century, moderate climate change is projected to increase aggregate yields of rain-fed agriculture by 5 to 20%, but with important variability among regions. Major challenges are projected for crops that are near the warm end of their suitable range or which depend on highly utilised water resources.</li><li>• Cities that currently experience heat waves are expected to be further challenged by an increased number, intensity and duration of heat waves during the course of the century, with potential for adverse health impacts.</li><li>• Coastal communities and habitats will be increasingly stressed by climate change impacts interacting with development and pollution.</li></ul>
<b>Polar Regions</b>	<ul style="list-style-type: none"><li>• The main projected biophysical effects are reductions in thickness and extent of glaciers, ice sheets and sea ice, and changes in natural ecosystems with detrimental effects on many organisms including migratory birds, mammals and higher predators.</li><li>• For human communities in the Arctic, impacts, particularly those resulting from changing snow and ice conditions, are projected to be mixed.</li><li>• Detrimental impacts would include those on infrastructure and traditional indigenous ways of life.</li><li>• In both polar regions, specific ecosystems and habitats are projected to be vulnerable, as climatic barriers to species invasions are lowered.</li></ul>
<b>Small Islands</b>	<ul style="list-style-type: none"><li>• Sea level rise is expected to exacerbate inundation, storm surge, erosion and other coastal hazards, thus threatening vital infrastructure, settlements and facilities that support the livelihood of island communities.</li><li>• Deterioration in coastal conditions, for example through erosion of beaches and coral bleaching, is expected to affect local resources.</li><li>• By mid-century, climate change is expected to reduce water resources in many small islands, e.g. in the Caribbean and Pacific, to the point where they become insufficient to meet demand during low-rainfall periods.</li><li>• With higher temperatures, increased invasion by non-native species is expected to occur, particularly on mid- and high-latitude islands.</li></ul>

# CC Impacts

Very likely = 90% probable

**Table SPM.3.** Examples of possible impacts of climate change due to changes in extreme weather and climate events, based on projections to the mid- to late 21<sup>st</sup> century. These do not take into account any changes or developments in adaptive capacity. The likelihood estimates in column two relate to the phenomena listed in column one. {Table 3.2}

Phenomenon <sup>a</sup> and direction of trend	Likelihood of future trends based on projections for 21 <sup>st</sup> century using SRES scenarios	Examples of major projected impacts by sector			
		Agriculture, forestry and ecosystems	Water resources	Human health	Industry, settlement and society
Over most land areas, warmer and fewer cold days and nights, warmer and more frequent hot days and nights	<i>Virtually certain<sup>b</sup></i>	Increased yields in colder environments; decreased yields in warmer environments; increased insect outbreaks	Effects on water resources relying on snowmelt; effects on some water supplies	Reduced human mortality from decreased cold exposure	Reduced energy demand for heating; increased demand for cooling; declining air quality in cities; reduced disruption to transport due to snow, ice; effects on winter tourism
Warm spells/heat waves. Frequency increases over most land areas	<i>Very likely</i>	Reduced yields in warmer regions due to heat stress; increased danger of wildfire	Increased water demand; water quality problems, e.g. algal blooms	Increased risk of heat-related mortality, especially for the elderly, chronically sick, very young and socially isolated	Reduction in quality of life for people in warm areas without appropriate housing; impacts on the elderly, very young and poor
Heavy precipitation events. Frequency increases over most areas	<i>Very likely</i>	Damage to crops; soil erosion, inability to cultivate land due to waterlogging of soils	Adverse effects on quality of surface and groundwater; contamination of water supply; water scarcity may be relieved	Increased risk of deaths, injuries and infectious, respiratory and skin diseases	Disruption of settlements, commerce, transport and societies due to flooding; pressures on urban and rural infrastructures; loss of property