



Lec 12

Air Pollution and Climate Change

Fires in California

- Burning results in severe air pollution
- Smoke is full of small particles that can lodge in lungs and cause illness/disease



Thomas fire leaves a thick layer of smoke in Ventura County, Southern California

Atmosphere as a Resource

- Atmospheric Composition
 - ▣ Nitrogen 78%
 - ▣ Oxygen 21%
 - ▣ Argon 0.93%
 - ▣ Carbon dioxide 0.04%

- Ecosystem services
 - ▣ Blocks UV radiation
 - ▣ Moderates the climate
 - ▣ Redistributes water in the hydrologic cycle



SPL/Science Source

Air Pollution - Terminology

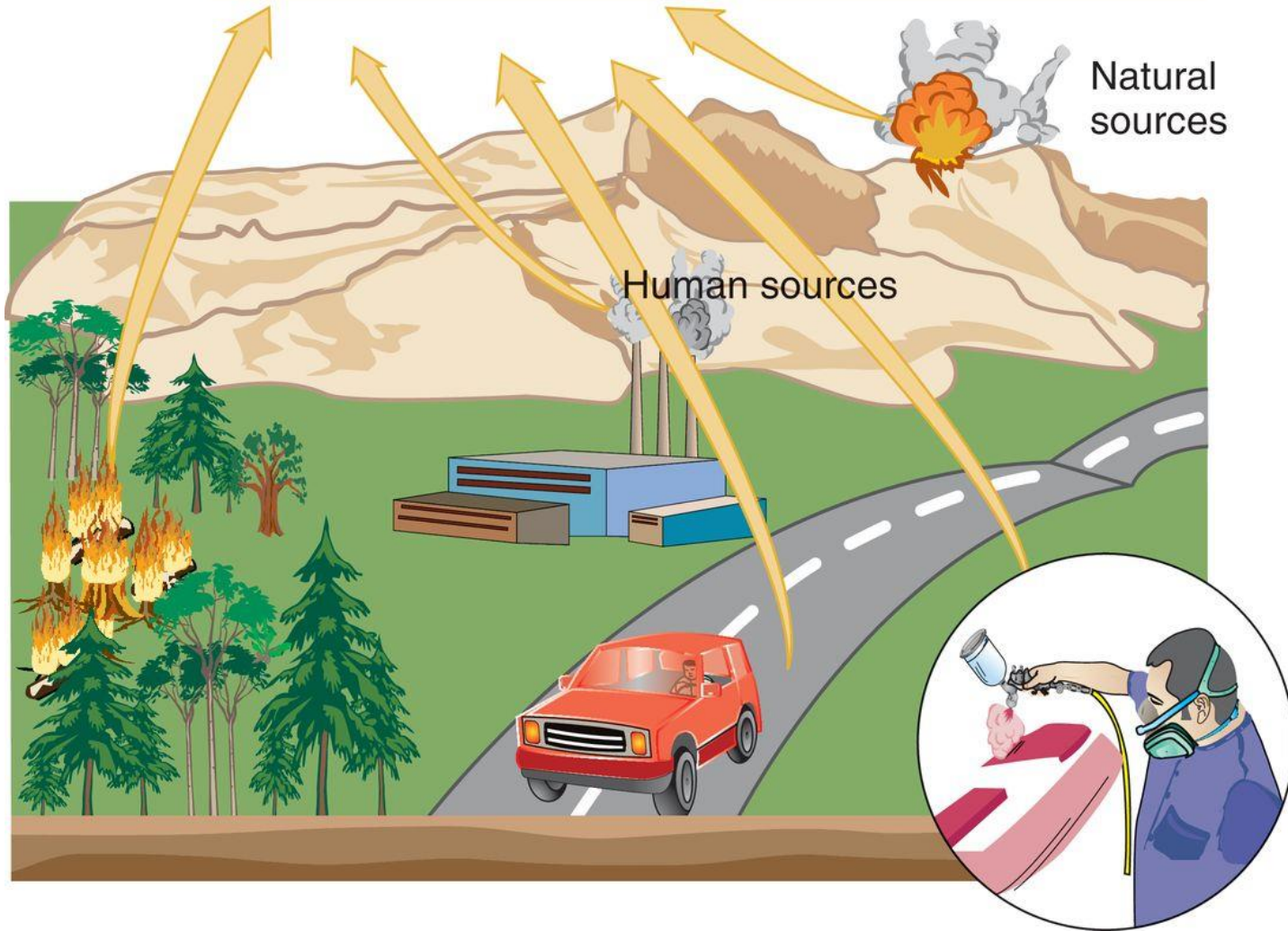
- Air Pollution
 - Chemicals added to the atmosphere by natural events or human activities in high enough concentrations to be harmful
- Two categories
 - Primary Air Pollutant
 - Harmful substance emitted directly into the atmosphere
 - Secondary Air Pollutant
 - Harmful substance formed in the atmosphere when a primary air pollutant reacts with substances normally found in the atmosphere or with other air pollutants

Primary air pollutants

CO
SO₂ NO CO₂
NO₂
Most hydrocarbons
Most particulates

Secondary air pollutants

HNO₂ SO₃
HNO₃ H₂SO₄
H₂O₂ O₃ salts
Most NO₃⁻ and SO₄²⁻

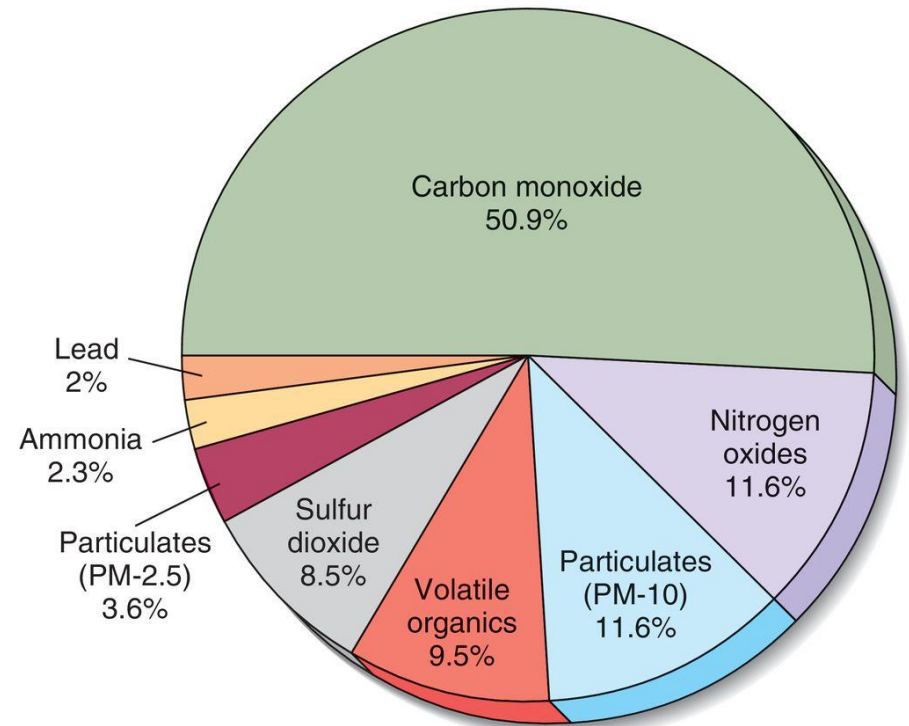


Major Classes of Air Pollutants

Based on their chemistry

Major Classes of Air Pollutants

- Particulate Material
- Nitrogen Oxides
- Sulfur Oxides
- Carbon Oxides
- Hydrocarbons
- Ozone



Particulate Material (PM)

- Thousands of different solid or liquid particles suspended in air
 - **Includes: soil particles, soot, lead, asbestos, sea salt, and sulfuric acid droplets**
- Dangerous
 - May contain materials with toxic/carcinogenic effects
 - Small particles can become lodged in lungs

Nitrogen and Sulfur Oxides

- Nitrogen Oxides (NO , NO_2 , N_2O)
 - Gases produced by the chemical interactions between atmospheric nitrogen and oxygen at high temperature
 - Greenhouse gases that cause difficulty breathing
- Sulfur Oxides (SO_2 , SO_3)
 - Gases produced by the chemical interactions between sulfur and oxygen
 - Causes acid precipitation

Carbon Oxides and Hydrocarbons

- Carbon Oxides

- Gases carbon monoxide (CO) and carbon dioxide (CO₂)
- Greenhouse gases

- Hydrocarbons

- Diverse group of organic compounds that contain only hydrogen and carbon (ex: CH₄ - methane)
- Some are related to photochemical smog and greenhouse gases

Ozone

- Tropospheric Ozone (O_3)
 - Man-made pollutant in the lower atmosphere
 - Secondary air pollutant
 - Component of photochemical smog
- Stratospheric Ozone
 - Essential component that screens out UV radiation in the upper atmosphere
 - Man-made pollutants (ex: CFCs) can destroy it

Ozone Damage to Grape Leaves

TED SPIEGEL/National Geographic Creative



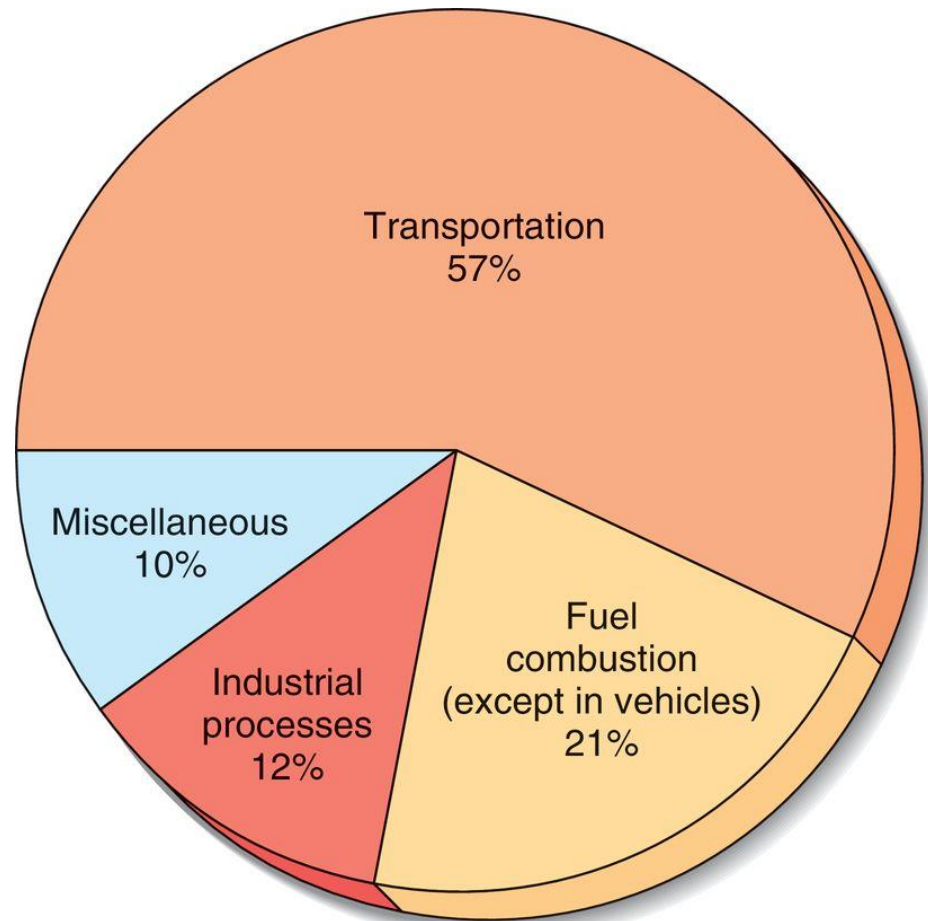
TED SPIEGEL/National Geographic Creative



Outdoor Air Pollution

Sources of outdoor pollution

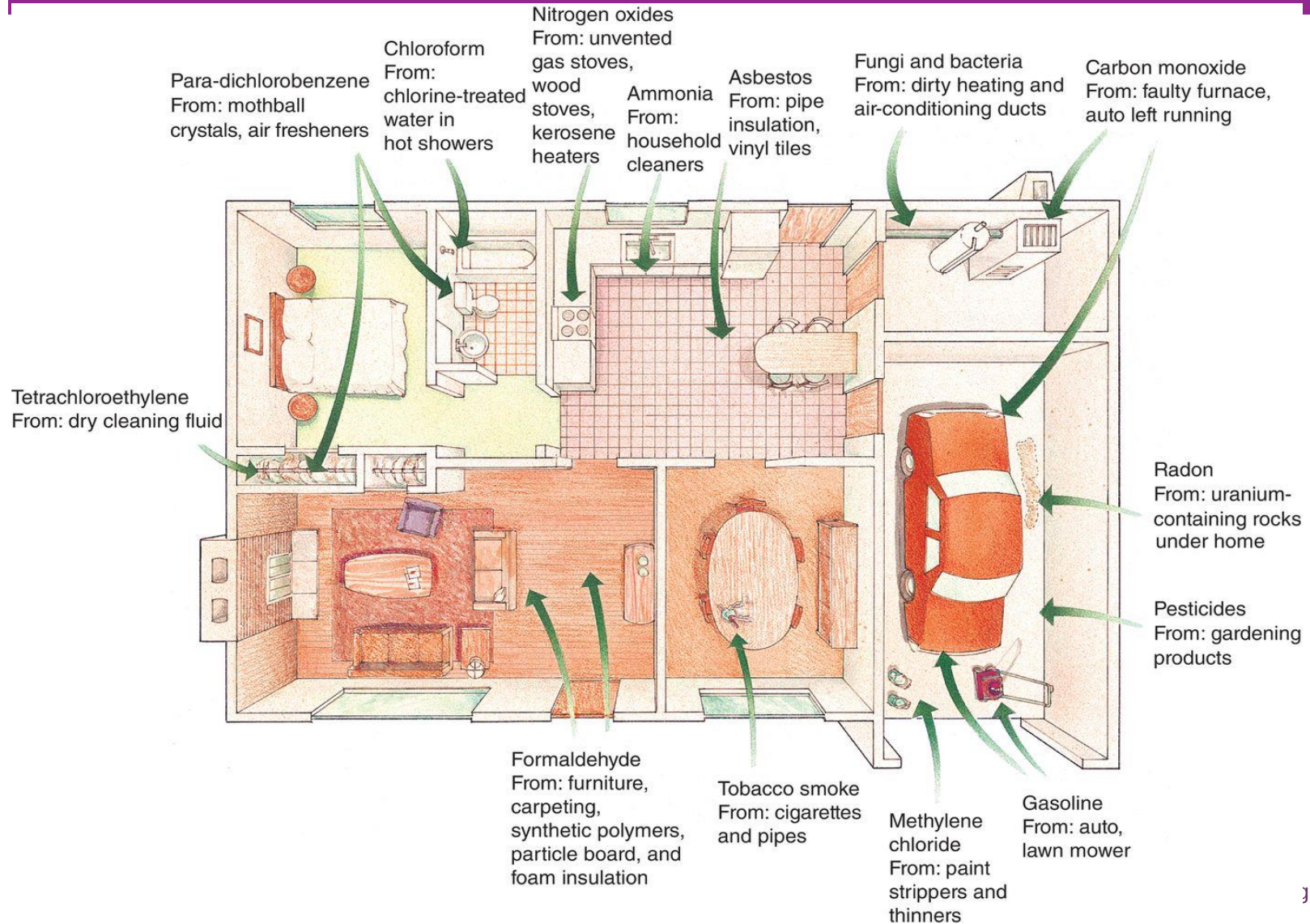
- Two main sources
 - ▣ Transportation
 - ▣ Industry
- Intentional forest fires is also high



Indoor Air Pollution

- Pollutants can be 5–100x greater than outdoors
- Radon, cigarette smoke, carbon monoxide, nitrogen dioxide, formaldehyde pesticides, lead, cleaning solvents, ozone, and asbestos

Indoor Air Pollution



Urban Air Pollution: Los Angeles

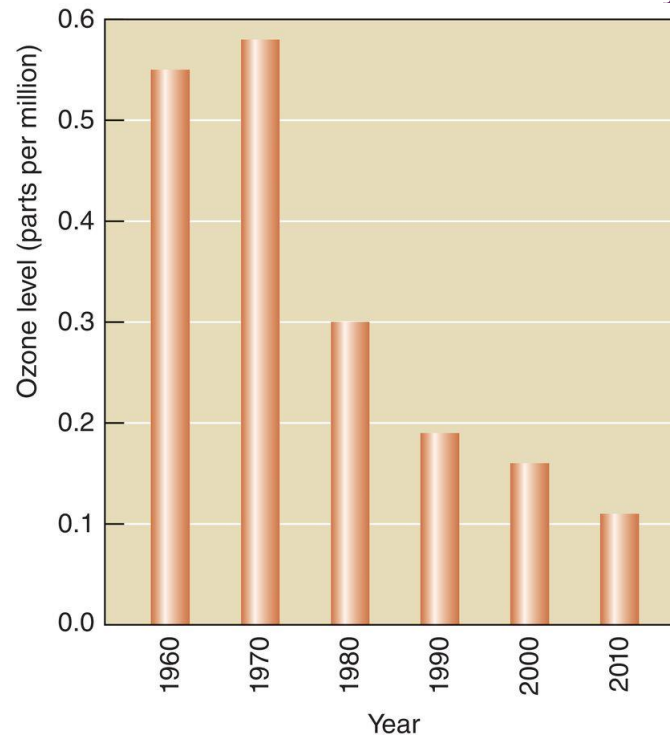
- Industrial Smog – sulfur oxides and PM
- Photochemical Smog (ex: Los Angeles)
 - Brownish-orange haze formed by chemical reactions involving sunlight, nitrogen oxide, and hydrocarbons
- Volatile organic compounds (VOCs) Ex: compounds released from paints, cleaning products, dry cleaners, bakeries
 - Temperature inversions: increases with altitude (usually reverse)

Jodi Cobb/National Geographic Creative



Efforts to Reduce Ozone in S. California

- CA consolidated efforts to improve air quality (1977)
- Improvements due to a few major regulations



Air Pollution Around the World

- Air quality is deteriorating rapidly in developing countries
 - Developing countries have older cars
- Shenyang, China
 - Residents only see sunlight a few weeks each year
- 5 worst cities in world
 - Beijing, China and New Delhi, India are tied for first; Santiago, Chile; Mexico City, Mexico; Ulaanbaatar, Mongolia

Case-In-Point Air Pollution in Beijing, New Delhi, and Mexico City



© SHENG LI/Reuters / Corbis



Adam Jones/Science Source

- Liaoning Province, China (right)
- New Delhi, India (left)

You tube break

https://www.youtube.com/watch?v=Yx7Ar21_Q1I

Effects of Air Pollution

1. Health Effects
2. Ozone depletion
3. Acid Deposition
4. Climate Change

Effects of Air Pollution

1. In Human Health

- Low level exposure
 - Irritates eyes
 - Causes inflammation of respiratory tract
- Can develop into chronic respiratory diseases
 - Emphysema
 - Chronic bronchitis



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Health Effects of Pollutants

Table 19.2 Health Effects of Several Major Air Pollutants

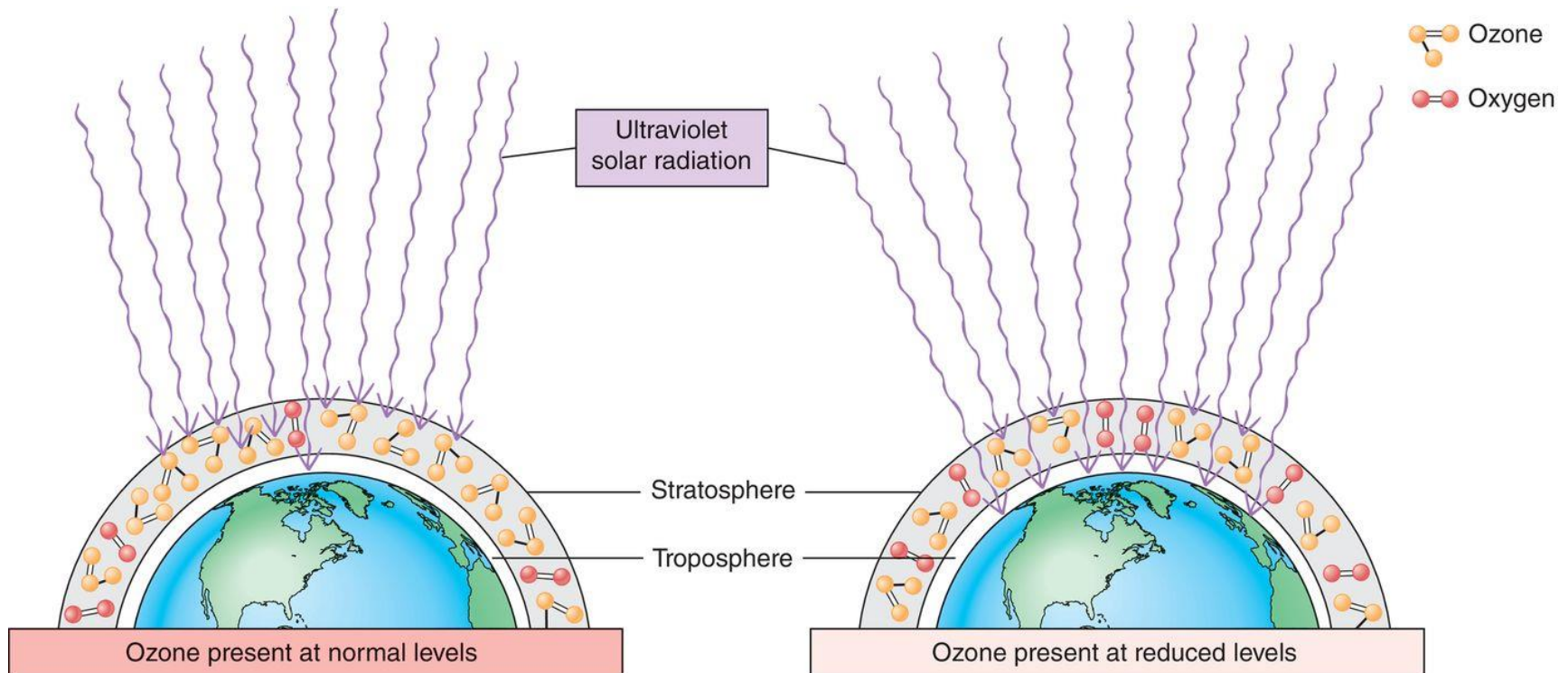
<i>Pollutant</i>	<i>Source</i>	<i>Effects</i>
Particulate matter	Industries, electric power plants, motor vehicles, construction, agriculture	Aggravates respiratory illnesses; long-term exposure may cause increased incidence of chronic conditions such as bronchitis; linked to heart disease; suppresses immune system; some particles, such as heavy metals and organic chemicals, may cause cancer or other tissue damage
Nitrogen oxides	Motor vehicles, industries, heavily fertilized farmland	Irritate respiratory tract; aggravate respiratory conditions such as asthma and chronic bronchitis
Sulfur oxides	Electric power plants and other industries	Irritate respiratory tract; same effects as particulates
Carbon monoxide	Motor vehicles, industries, fireplaces	Reduces blood's ability to transport oxygen; headache and fatigue at lower levels; mental impairment or death at high levels
Ozone	Formed in atmosphere (secondary air pollutant)	Irritates eyes; irritates respiratory tract; produces chest discomfort; aggravates respiratory conditions such as asthma and chronic bronchitis

- Greater health threat to children than adults
 - Air pollution can restrict lung development
 - Children breathe more often than adults
 - Children who live in high ozone areas are more likely to develop asthma

Effects of Air Pollution

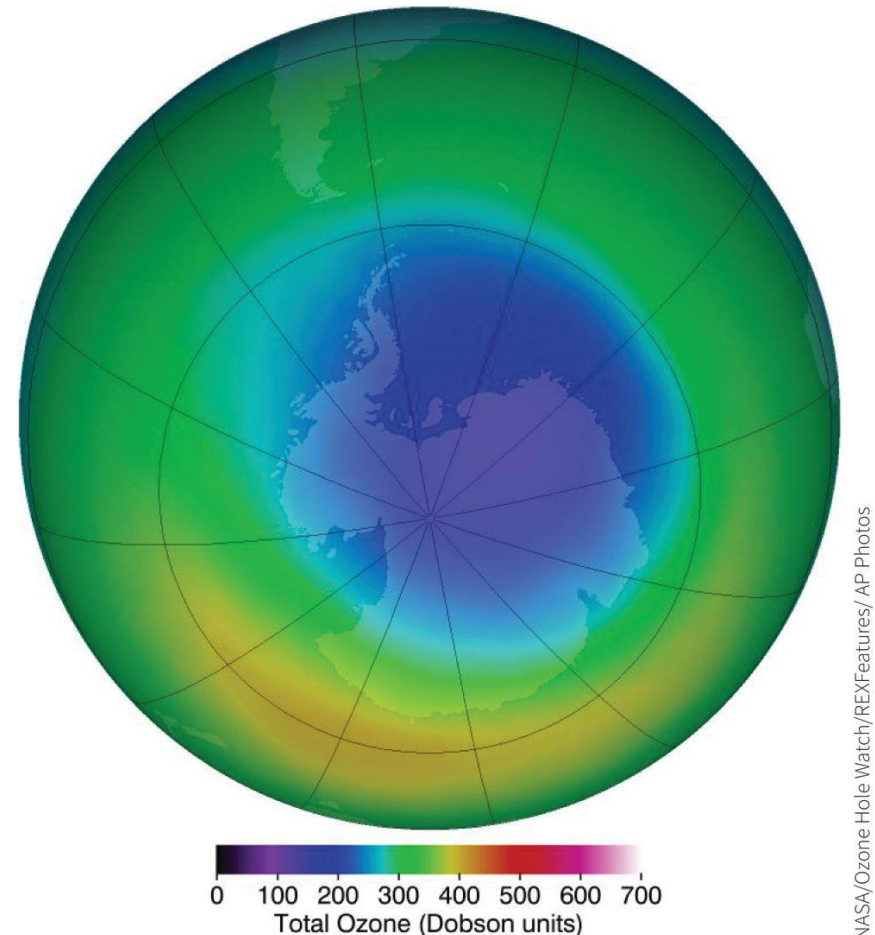
2. Ozone Depletion in Stratosphere

- Ozone Protects earth from UV radiation



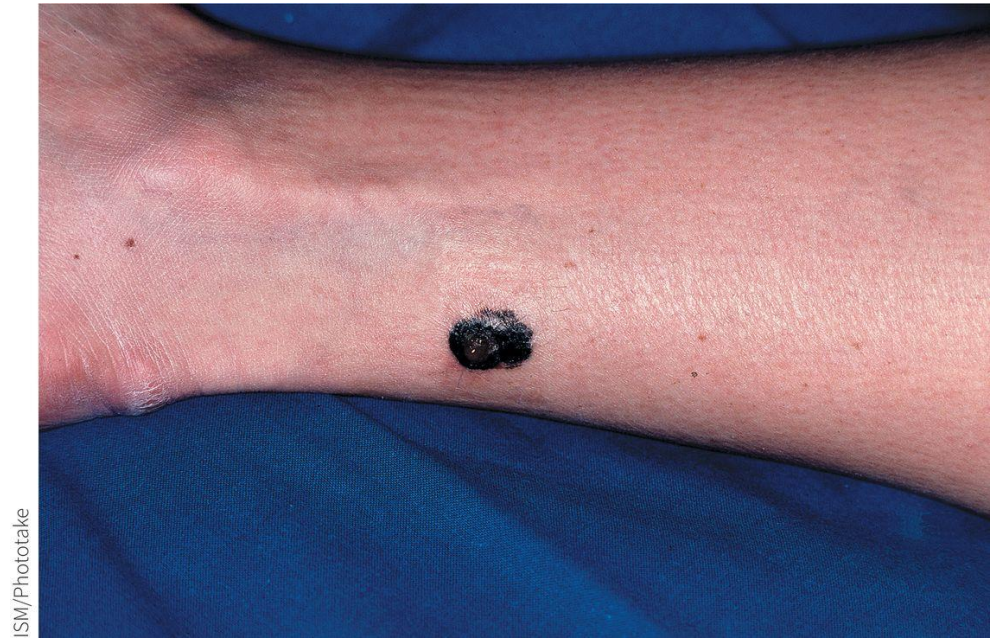
Ozone Depletion in Stratosphere

- Ozone thinning/hole
 - Over Antarctica, occurs naturally annually between Sept and Nov
 - Greater than could be explained in 1985
 - Caused by human-produced bromine and chlorine containing chemicals (Ex: CFCs)



Effects of Ozone Depletion

- Higher levels of UV-radiation hitting the earth
 - Eye cataracts
 - Skin cancer (right)
 - Weakened immunity
- May disrupt ecosystems
- May damage crops and forests



ISM/Phototake

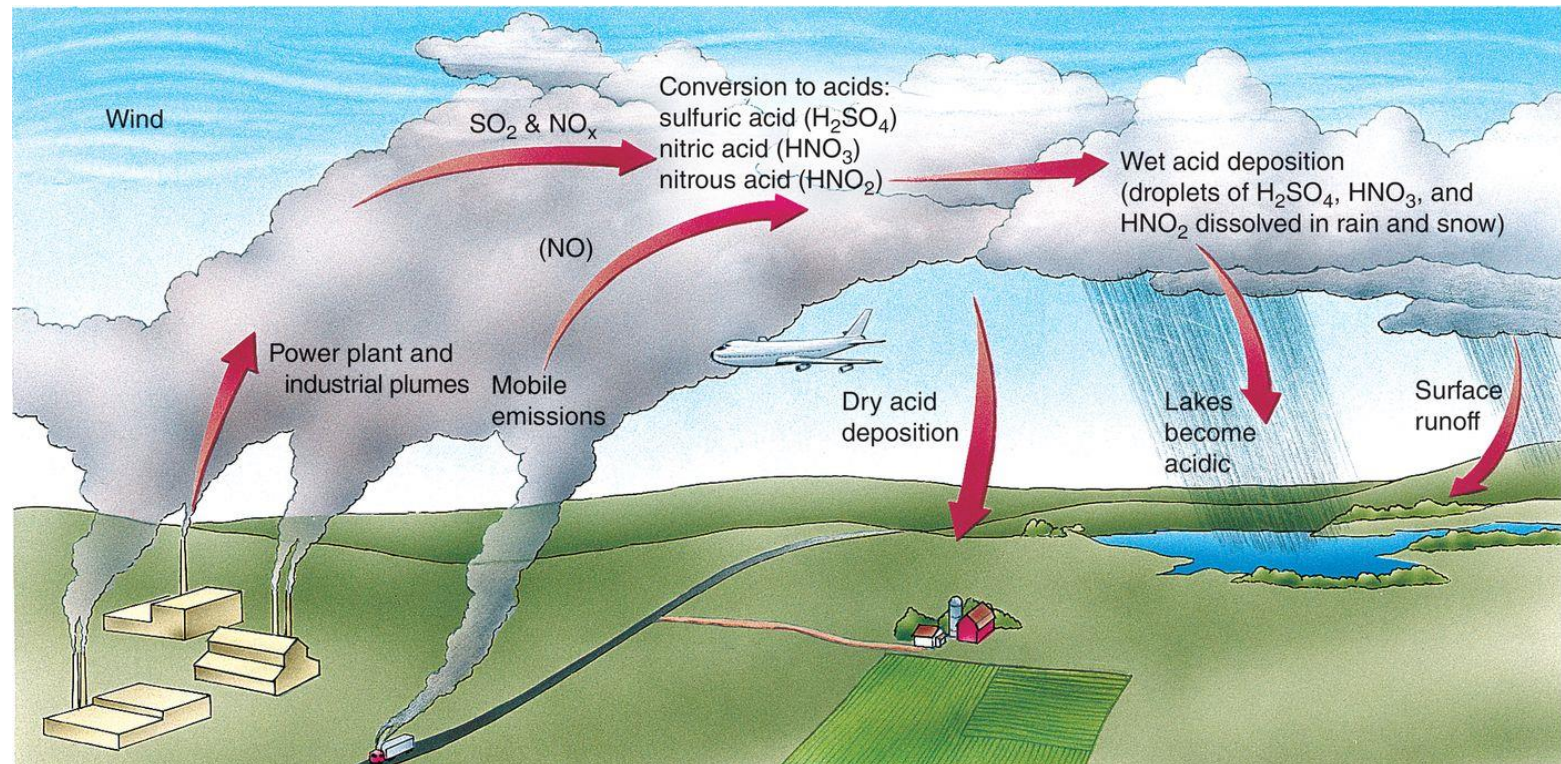
Recovery of Ozone Layer

- Montreal Protocol (1987)
 - Reduction of CFCs
 - Started using HCFCs (greenhouse gas)
- Phase out of all ozone destroying chemicals is underway globally
- Satellite pictures in 2000 indicated that ozone layer was recovering
- Full recovery will not occur until 2050

Effects of Air Pollution

3. Acid Deposition

- Sulfur dioxide and nitrogen dioxide emissions react with water vapor in the atmosphere and form acids that return to the surface as either dry or wet deposition



Effects of Acid Deposition

- Declining Aquatic Animal Populations
- Thin-shelled eggs prevent bird reproduction
 - Calcium is unavailable in acidic soil
- Forest decline
 - (right) Black Forest in Germany



Hans Reinhard/Bruce Coleman, Inc./Photoshot

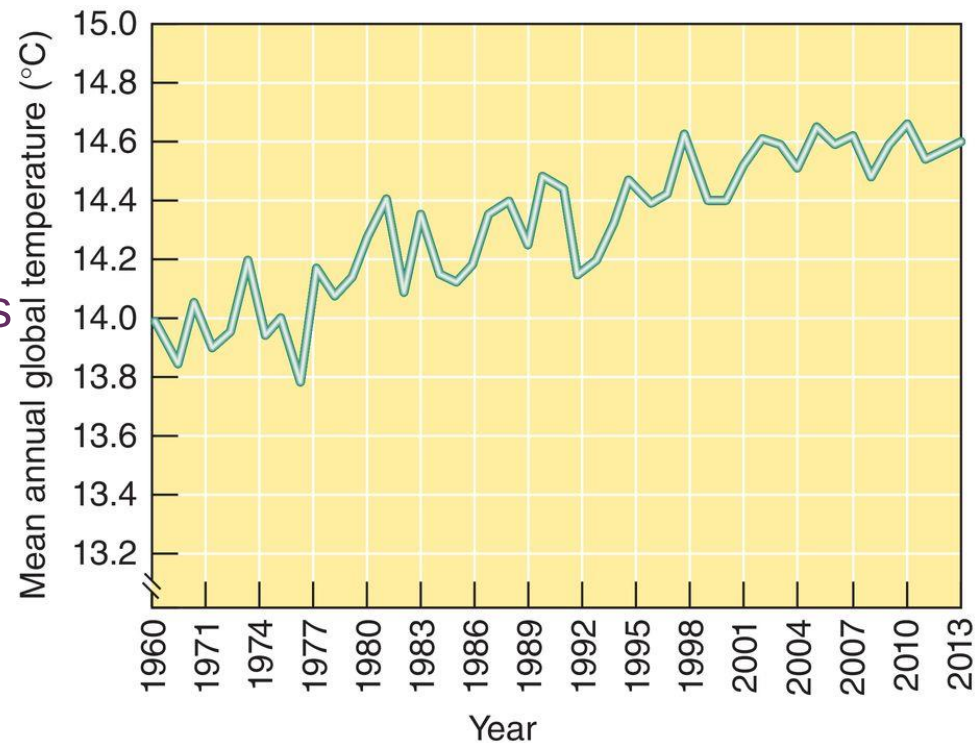
Management of Acid Deposition

- It's very hard
 1. Because acid deposition does not recognize borders
 - Pollution in one place, problem in another
 - Strong legislation and international disputes for air pollution devices at sourcing countries
 - Reduce emissions of SO₂ and NOs (including cars), clean coal technologies
 2. Recovery of acidic soils is very hard

Effects of Air Pollution

4. Global climate change

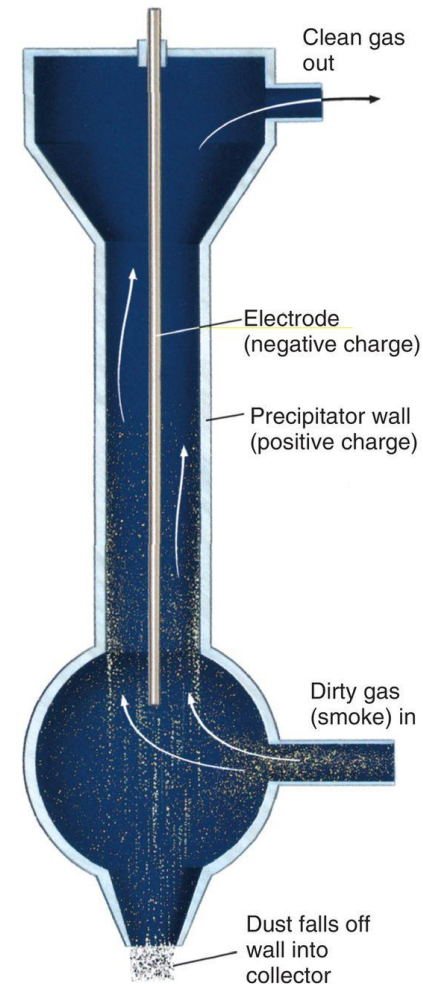
- Evidence for Climate Change
 - 20 consecutive warmest years
 - Phenological spring in N. hemisphere now begins 6 days earlier (date the buds of specific plants open)
 - Sea level rise:
 - <2cm/decade for most of 20th century, now ~3cm/decade



20 warmest years (since ~1880) have occurred since 1990

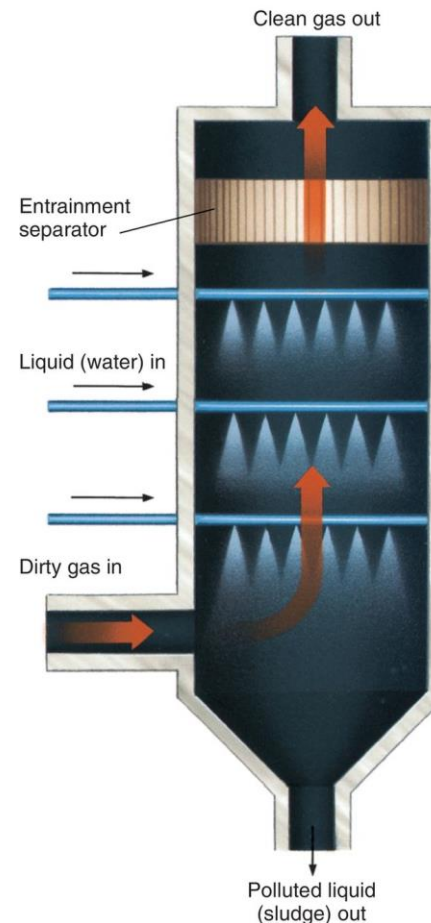
Controlling Air Pollution

- Smokestacks with electrostatic precipitator (right)
 - Electrode imparts negative charge on the air pollutants
 - Negatively charged pollutants are then attracted to positively charged walls- fall into collector



Controlling Air Pollution

- Smokestacks with scrubbers (right)
- Particulate material can also be controlled by proper excavating techniques
- Cars – catalytic converters



Scrubbers



**Emissions not controlled-
heavily polluted (China)**

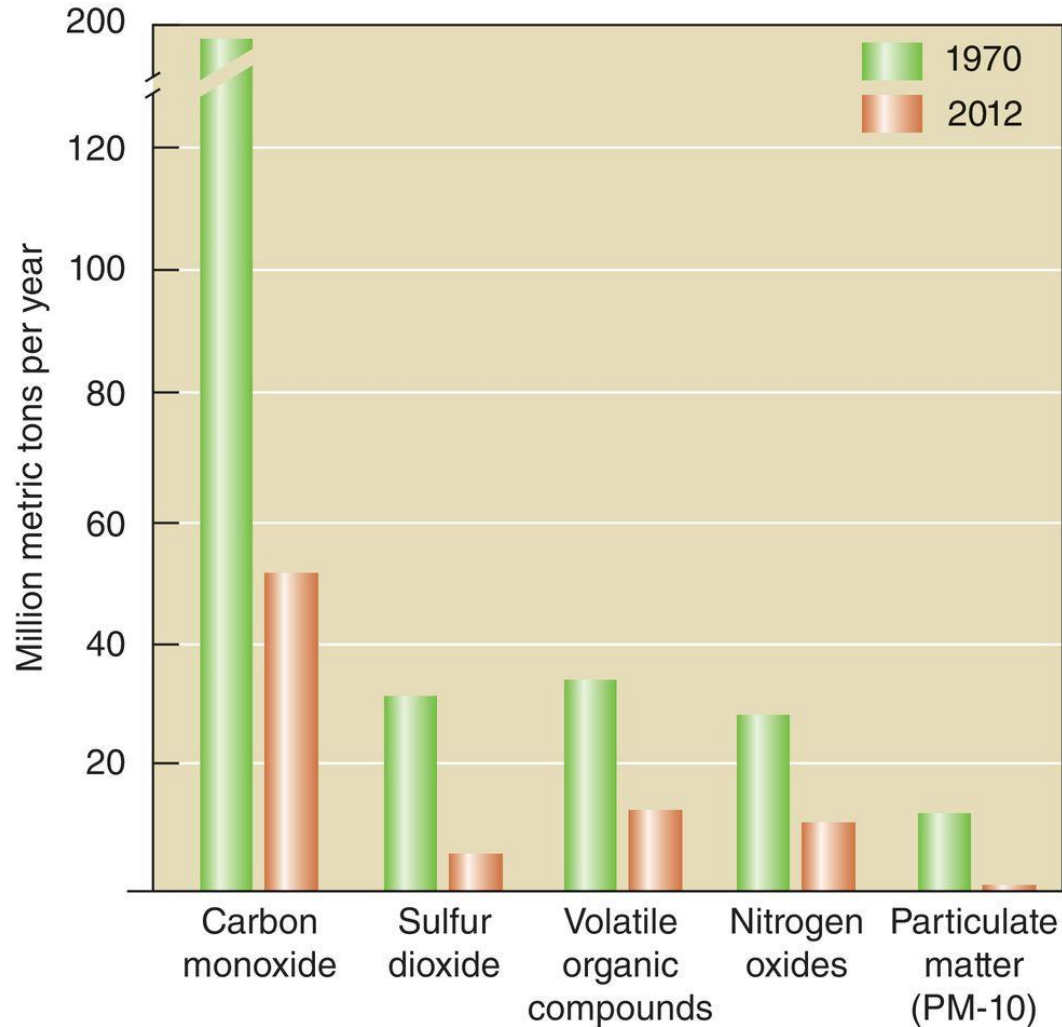


**Emissions controlled with
scrubbers-only steam
expelled (North Carolina)**

The Clean Air Act

- 1955 and significant updates in 1990
- Authorizes EPA to set limits on amount of specific air pollutants permitted
- Focuses on 6 pollutants:
 - lead, particulate matter, sulfur dioxide, carbon monoxide, nitrogen oxides, and ozone
- Act has led to decreases in air pollutants
 - Most dramatic is lead - decreased by 98% since 1970 (due to switch to unleaded gasoline)

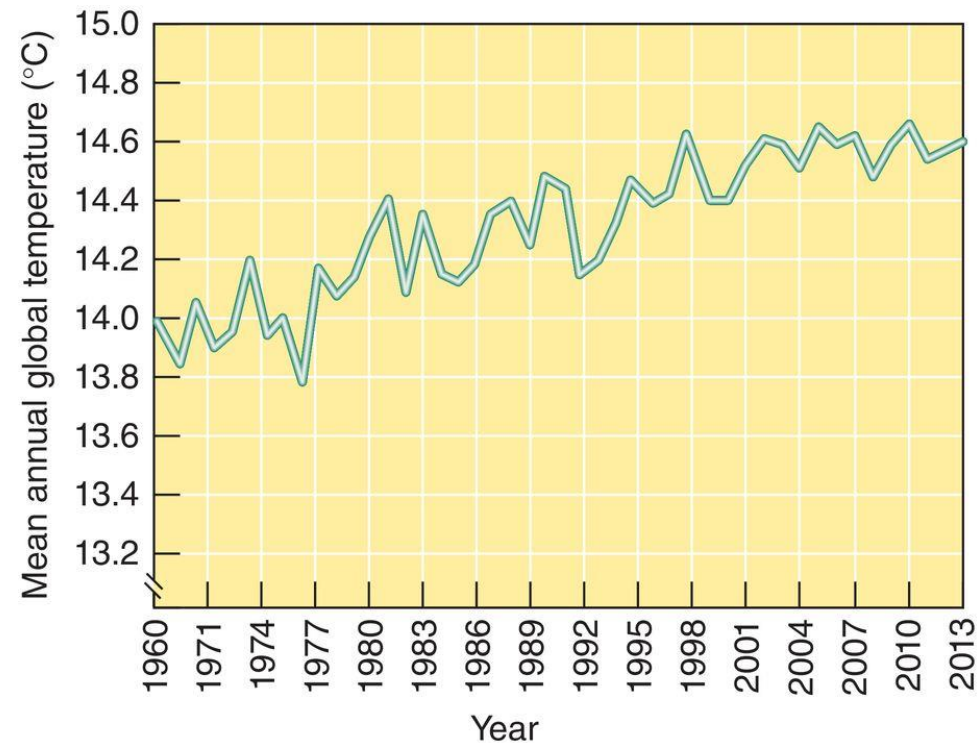
The Clean Air Act



Effects of Air Pollution

4. Global climate change

- Warming can't be explained with by natural causes
 - Human produced greenhouse gases are most plausible explanation



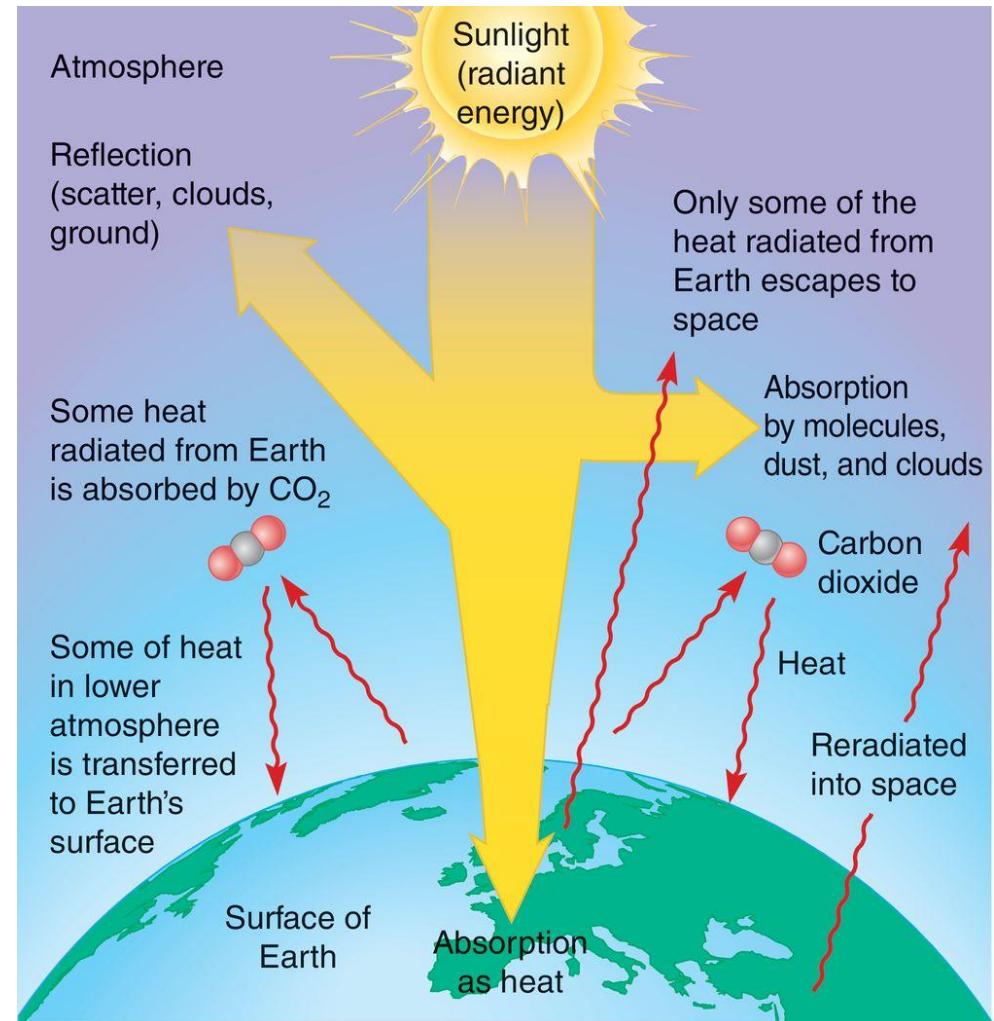
20 warmest years (since ~1880) have occurred since 1990

Climate Change Terminology

- Greenhouse Gas
 - Gas that absorbs infrared radiation (Ex. CO₂, Methane, (CH₄), Nitrous oxide (N₂O), chlorofluorocarbons)
- Greenhouse Effect
 - Natural trapping of heat in the atmosphere; greenhouse gases absorb energy and keep it from leaving

Greenhouse Effect

- Enhanced greenhouse effect
 - Build up of greenhouse gases (CO_2 and others) due to human activities



Greenhouse Gases

- Greenhouse gas concentrations are increasing

Table 20.1 Increases in Selected Atmospheric Greenhouse Gases, Preindustrial Times to the Present

<i>Gas</i>	<i>Estimated Preindustrial Concentration*</i>	<i>2014 Concentration</i>
Carbon dioxide	288 ppm**	401 ppm
Methane	848 ppb***	1874 ppb
Nitrous oxide	285 ppb	324 ppb
Chlorofluorocarbon-12	0 ppt****	531 ppt
Chlorofluorocarbon-11	0 ppt	238 ppt

*The preindustrial value is for the 17th and 18th centuries. There have been significant variations, as, for example, over the course of the ice ages.

**ppm = parts per million.

***ppb = parts per billion.

****ppt = parts per trillion.

Source: Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory (historical estimates), NOAA Annual Greenhouse Gas Index (2014 data).

Effects of Global Climate Change

□ Wildfire in California??



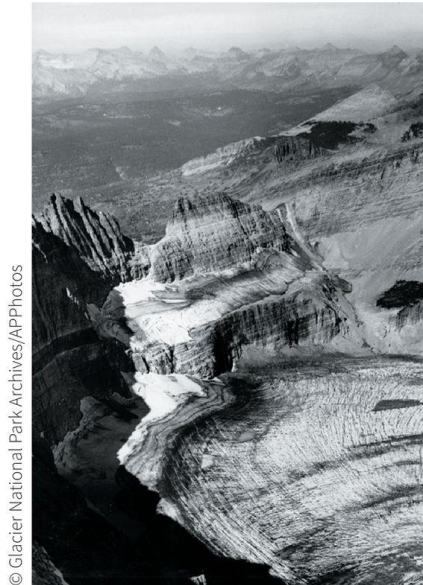
Climate change affects timing of snowmelt, earlier in the spring

Effects of Global Climate Change

Melting Ice and Rising Sea Levels

- IPCC projects sea-level rise of 18-59cm by 2100
- Sea level rise caused in 2 ways
 - Thermal Expansion (> 50% in the 20th century)
 - Melting of land ice
- Melting has positive feedback
 - Increased melting decreases ice, which decreases water albedo leading to further warming

Grinnell Glacier, Glacier National Park



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1938



© Glacier National Park Archives/APPhotos

1981



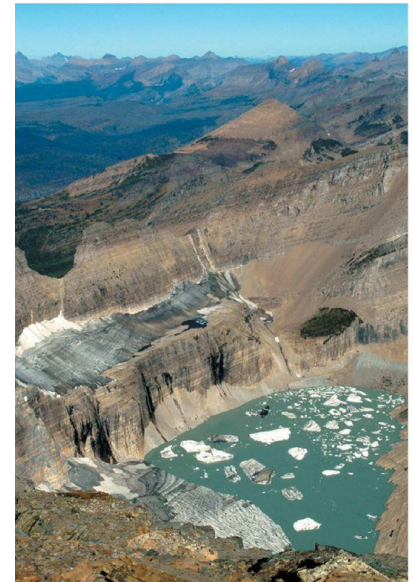
1998



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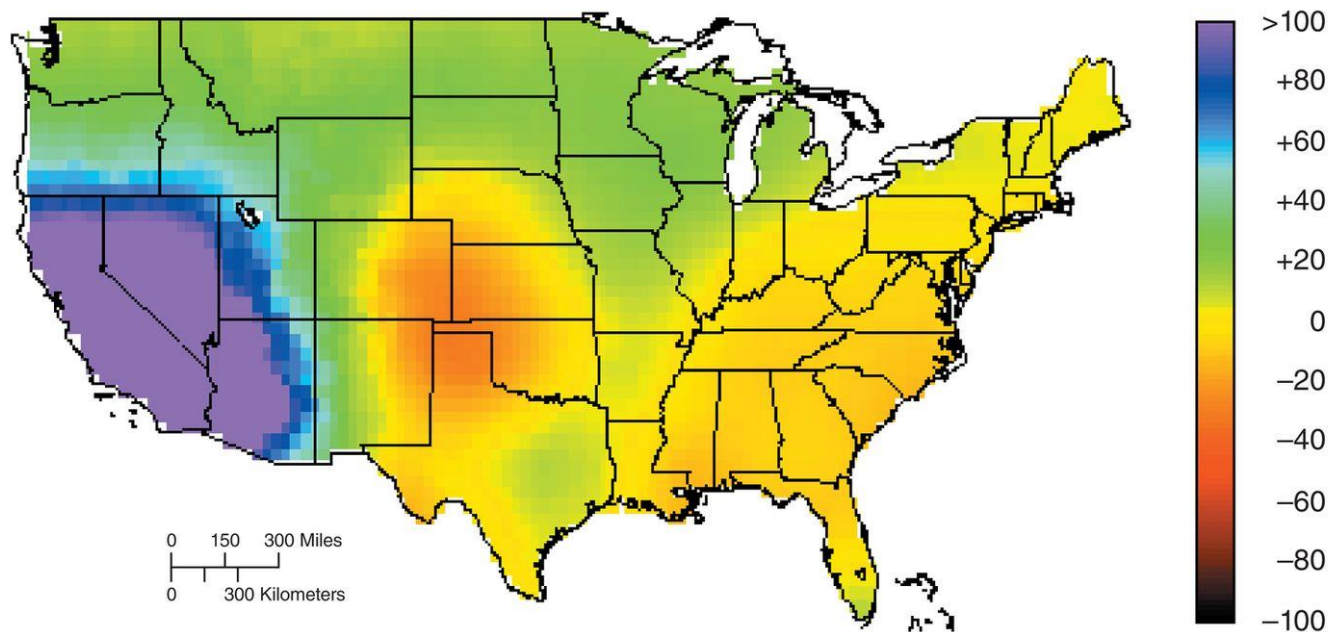
2005



© Glacier National Park Archives/APPhotos

Effects of Global Climate Change- Changing Precipitation Patterns

- Some areas will get more water, some areas will have greater droughts



Effects of Global Climate Change- Effects on Organisms

- Zooplankton in parts of California Current have decreased by 80% since 1951
 - Affecting entire food chain
- Migrating birds are returning to summer homes earlier
- Ecosystems at greatest risk of species loss (short term):
 - coral reefs, mountain ecosystems, coastal wetlands, tundra, and polar areas
- Species have shifted their geographic range

"Mother Goose and Grimm" used with the permission of Grimm, Inc. and the Cartoonist Group. All rights reserved.



Effects on Human Health

Table 20.2 Some Known and Expected Effects of Climate Change on Human Diseases

Type of Disease	Known Effects	Predicted Effects
Vector-borne* disease (e.g., Lyme disease, malaria)	Warming-related expansion or shift of geographic range of disease vector. Precipitation-related expansion or shift of geographic range. Travel-related risk of disease. Changes in temperature, precipitation could lead to major ecosystem shifts, impacting disease burden and incidence.	Increased transmission of some diseases transmitted from animals to humans. Establishment of novel imported infectious diseases. Regional variability in changes; some areas will be impacted more than others.
Water- and food-borne disease (e.g., <i>E. coli</i> , <i>Salmonella</i>)	Temperature-related increase in survival of disease organisms. Precipitation-related shifts in geographic range of disease organisms. Increased temperature expected to shift northernmost tolerance of many diseases.	Increased intensity and frequency of water- and food-borne diseases, particularly in the northernmost parts of the United States and Canada.
Respiratory disease (e.g., influenza, <i>Streptococcus bacillus</i>)	Shorter/warmer winter could reduce disease incidence and burden. Migration of nonimmune populations to areas with endemic disease increases incidence. Air pollution changes could cause/exacerbate disease.	Reduced number of respiratory diseases with cold weather.** Increased respiratory diseases associated with dense populations.** Increased respiratory diseases associated with diminished air quality.**
Fungal diseases (e.g., <i>Blastomyces dermatitis</i> , <i>Cryptococcus gatti</i>)	Soil ecology changes could shift range of fungus populations. Warm, dry summers followed by warm, wet winters could increase fungus counts. Changes in temperature, precipitation, and humidity could expand geographic range of some fungi	Growing conditions that favor infectious fungal spores. Regional variability in changes of numbers and types of fungi.

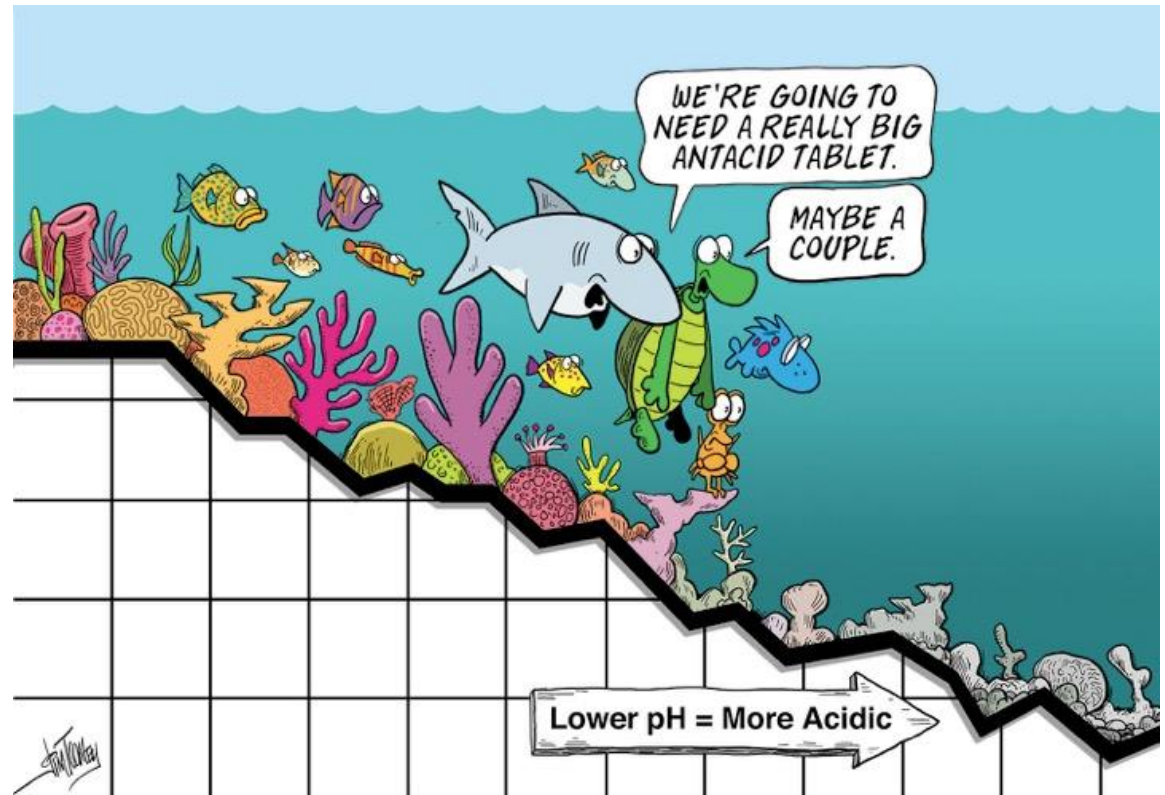
*Vectors are the animals that carry a disease organism or a stage of a disease organism. Mosquitoes are a common vector, but many diseases require a mammalian vector (e.g., fox, deer, rat).

**It is not clear which of these effects will dominate.

Source: Greer, Ny, and Fisman, "Climate Change and Infectious Diseases in North America: The road ahead, *Canadian Medical Association Journal* (2008).

Effects on Ocean

- Ocean acidification
- Increase of pH due to the increase of CO_2 in the seawater
- Since IR the ocean pH has decreased 0.1 only but means 30% increase in acidity
- Problematic for shell forming marine life



Dealing with Global Climate Change

- Two ways to manage climate change
 - Mitigation: Limiting greenhouse gas emissions to moderate global climate change
 - Adaptation: Learning to live with environmental changes and societal consequences brought about by global climate change

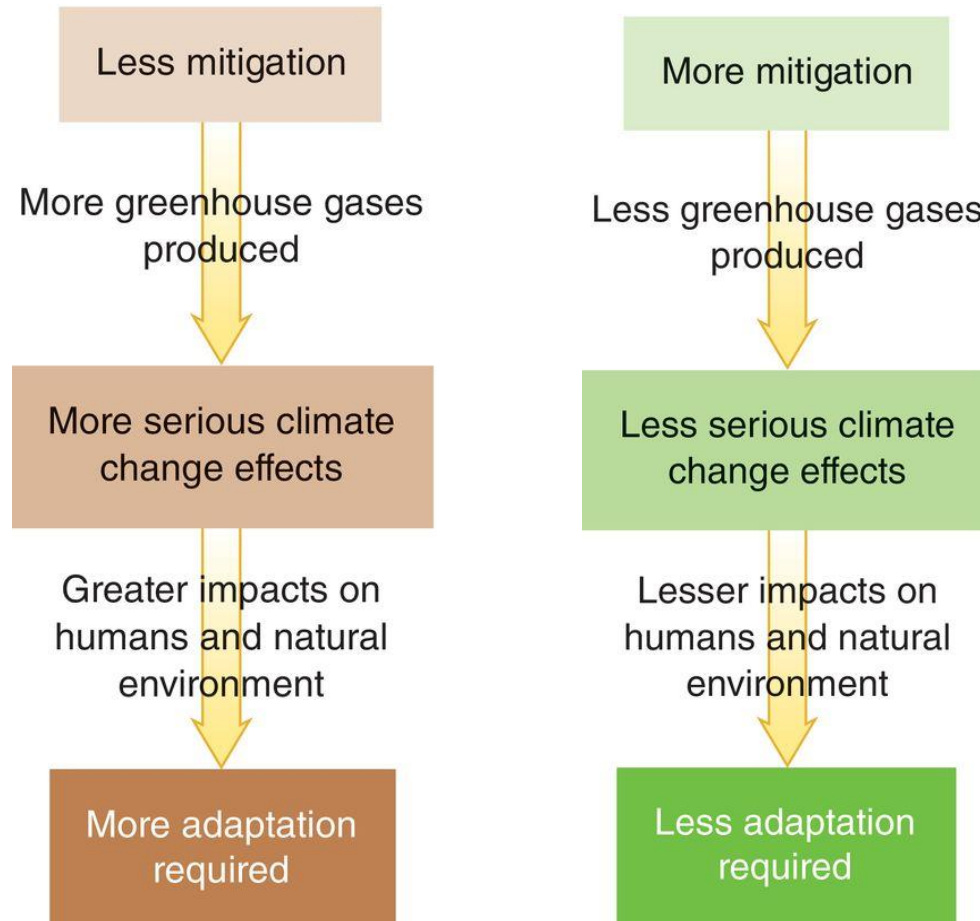
Dealing with Global Climate Change - Mitigation

- Locate/invent alternative fuels to fossil fuels
- Increase efficiency of cars and trucks
- Carbon Capture and Storage
- Plant and maintain trees to naturally sequester carbon
- Geoengineering
 - Global scale projects to mitigate effects
 - Example: seeding ocean with iron to stimulate phytoplankton growth and CO₂ storage in deep ocean

Dealing with Global Climate Change - Adaptation

- Rising sea levels and coastal populations
 - Move inland
 - Construct dikes and levees
- Adapt to shifting agricultural zones
- NYC sewer line
- Climate change refugees
 - People having to leave homes because of climate change effects
 - Example: rising sea levels, storm surges

Relationship Between Mitigation and Adaptation



International Efforts to Reduce Greenhouse Gas Emission

- Kyoto Protocol
 - Legally binding
 - Provides operational rules on reducing greenhouse gases
 - By 2014, 192 countries had ratified it
 - US has not sign it - it will be difficult to implement without US backing
 - EPA is taking it upon itself to define laws associated with CO₂ reduction in U.S.
 - Obama administration meetings with other nations