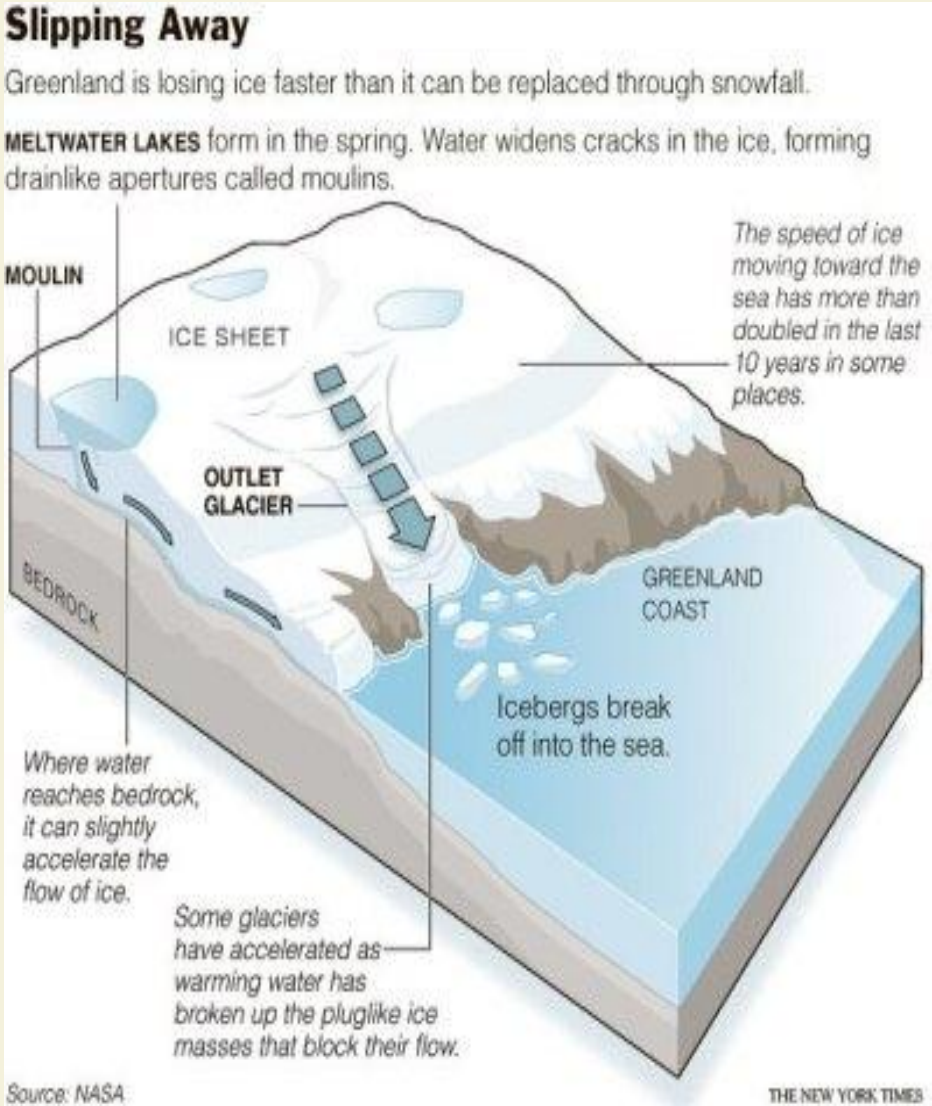
Chapter 19: Climate Control and Ozone Depletion

Civilization has evolved during a period of remarkable climate stability, but this era is drawing to a close. We are entering a new era, a period of rapid and often-unpredictable climate change.

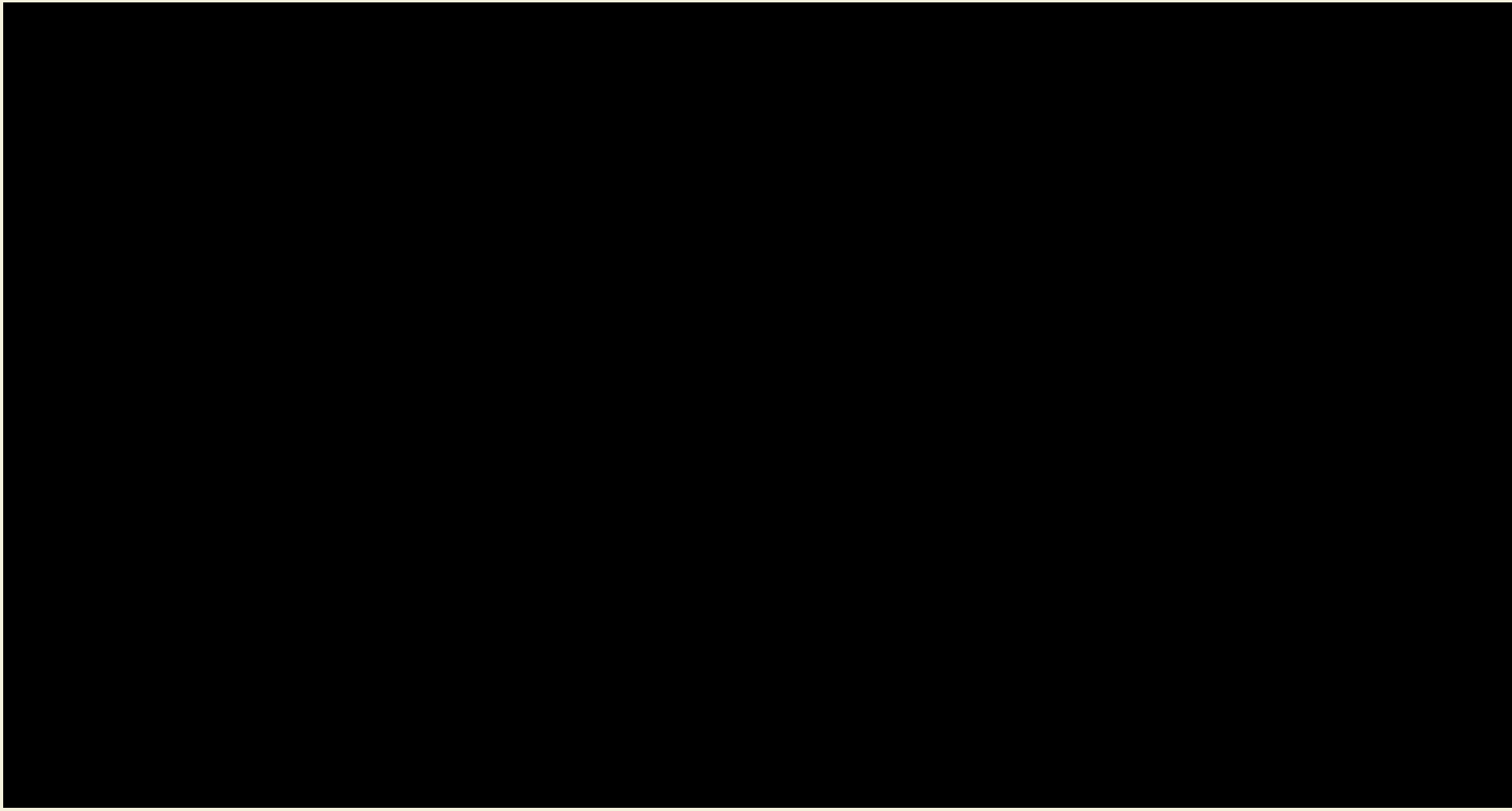
- Lester R. Brown

Science Focus: Melting Ice in Greenland

- Largest island: 80% composed of glaciers
- 10% of the world's fresh water
- Glacial melting and movement accelerating
- Effect on sea level if melting continues
  - 1 meter rise by 2100

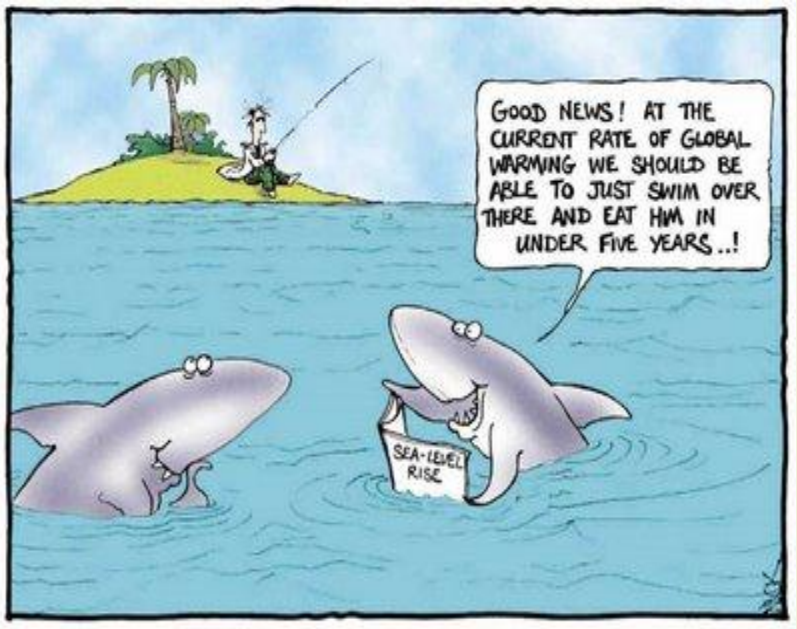


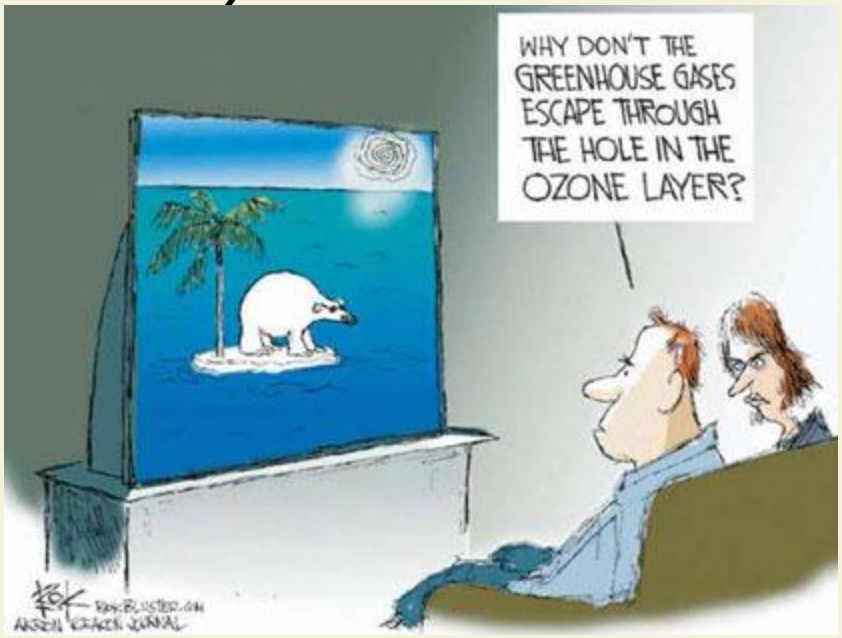
VIDEO: Global Warming



19-1 How Might the Earth's Temperature and Climate Change in the Future?

Concept 19-1 *Considerable scientific evidence indicates that the earth's atmosphere is warming, because of a combination of natural effects and human activities, and that this warming is likely to lead to significant climate disruption during this century.*





Weather and Climate Are Not the Same

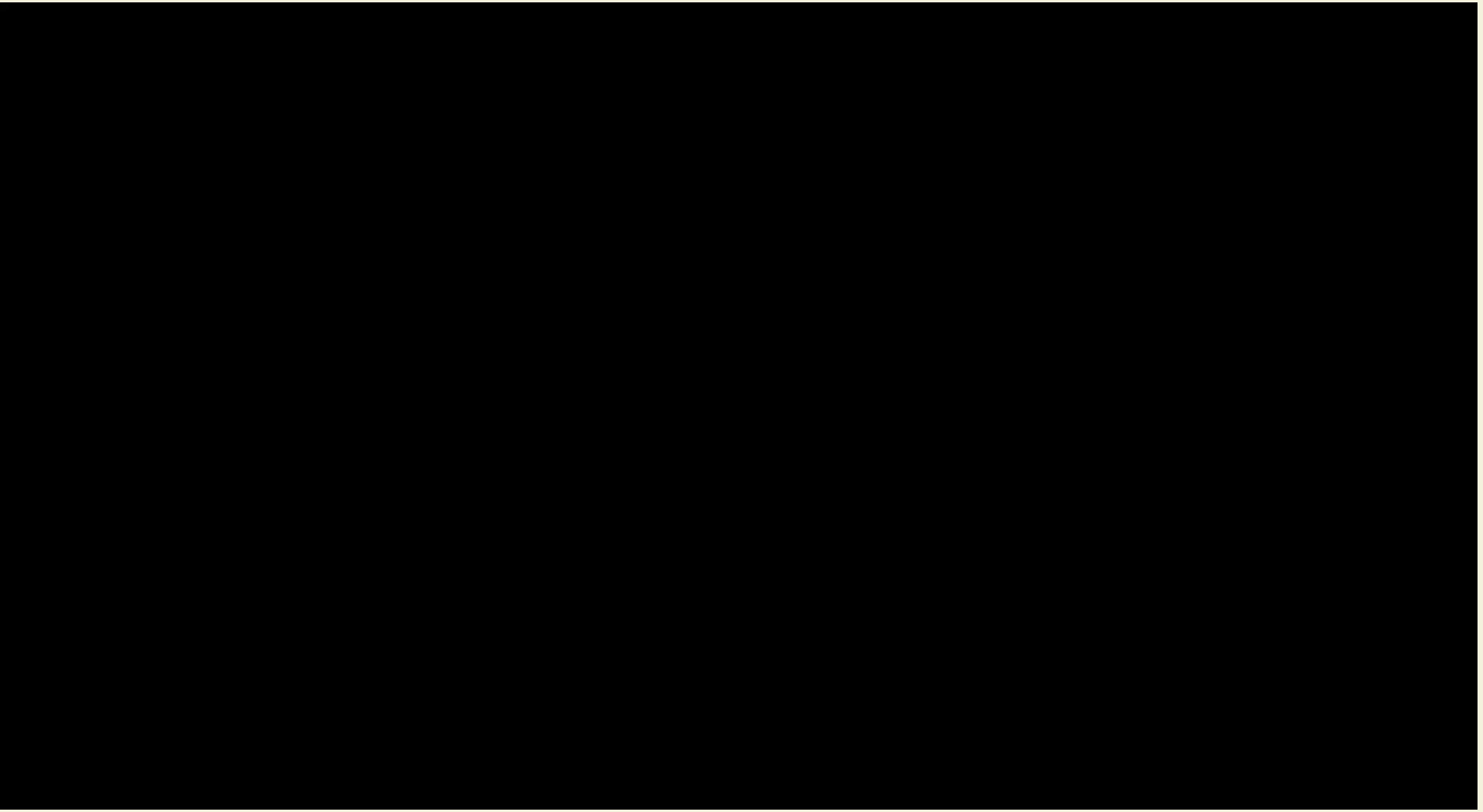
Weather is short-term changes

- Temperature
- Air pressure
- Precipitation
- Wind

Climate is average conditions in a particular area over a long period of time

- Temperature
- Precipitation
- Fluctuations are normal

VIDEO: What is Climate?



Climate Change is Not New

Over the past 4.7 billion years the climate has been altered by

- Volcanic emissions
- Changes in solar input
- Movement of the continents
- Impacts by meteors
- Changing global air and ocean circulation

Over the past 900,000 years

- Glacial and interglacial periods

Estimated Changes in the Average Global Temperature of the Atmosphere

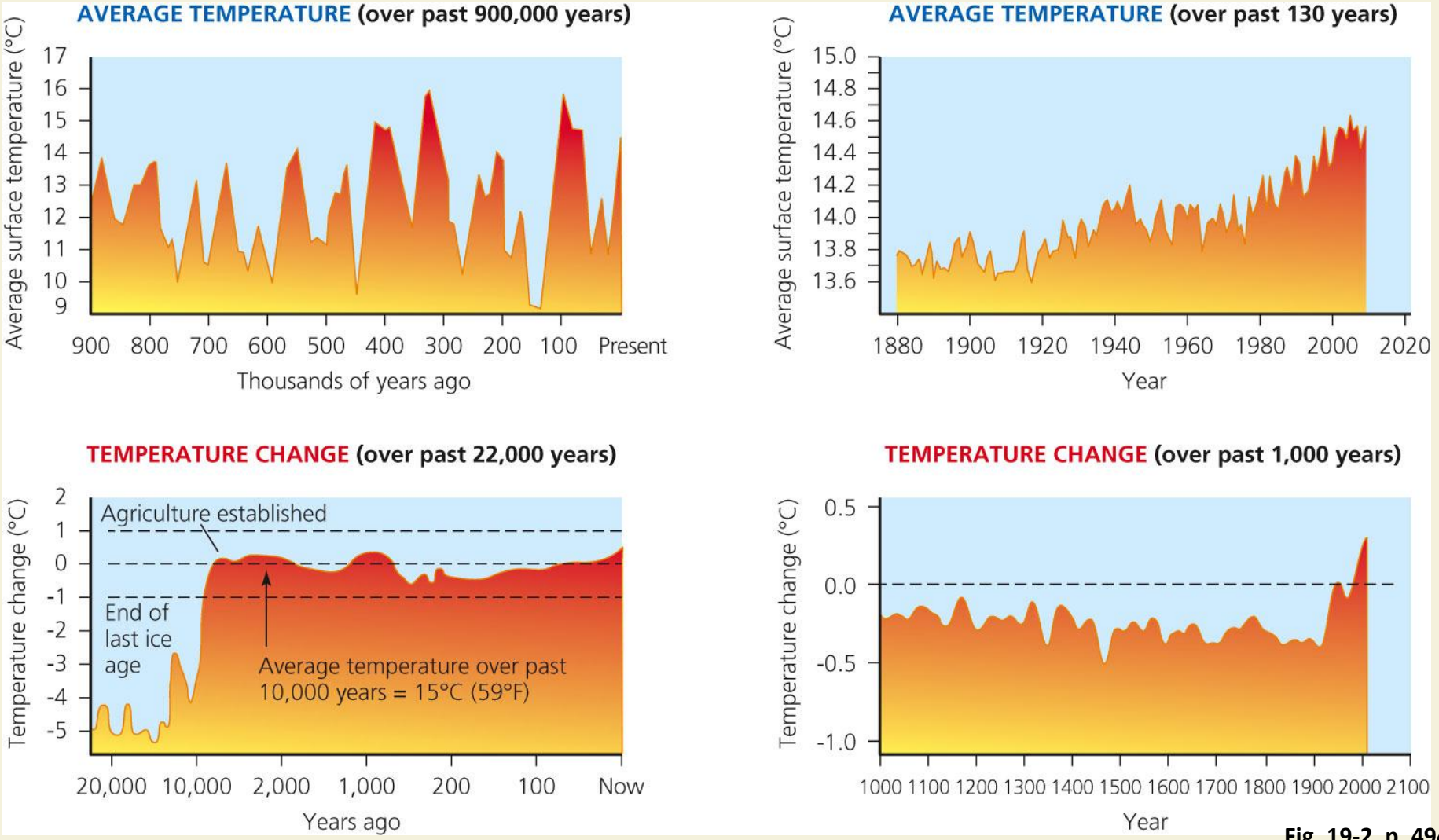
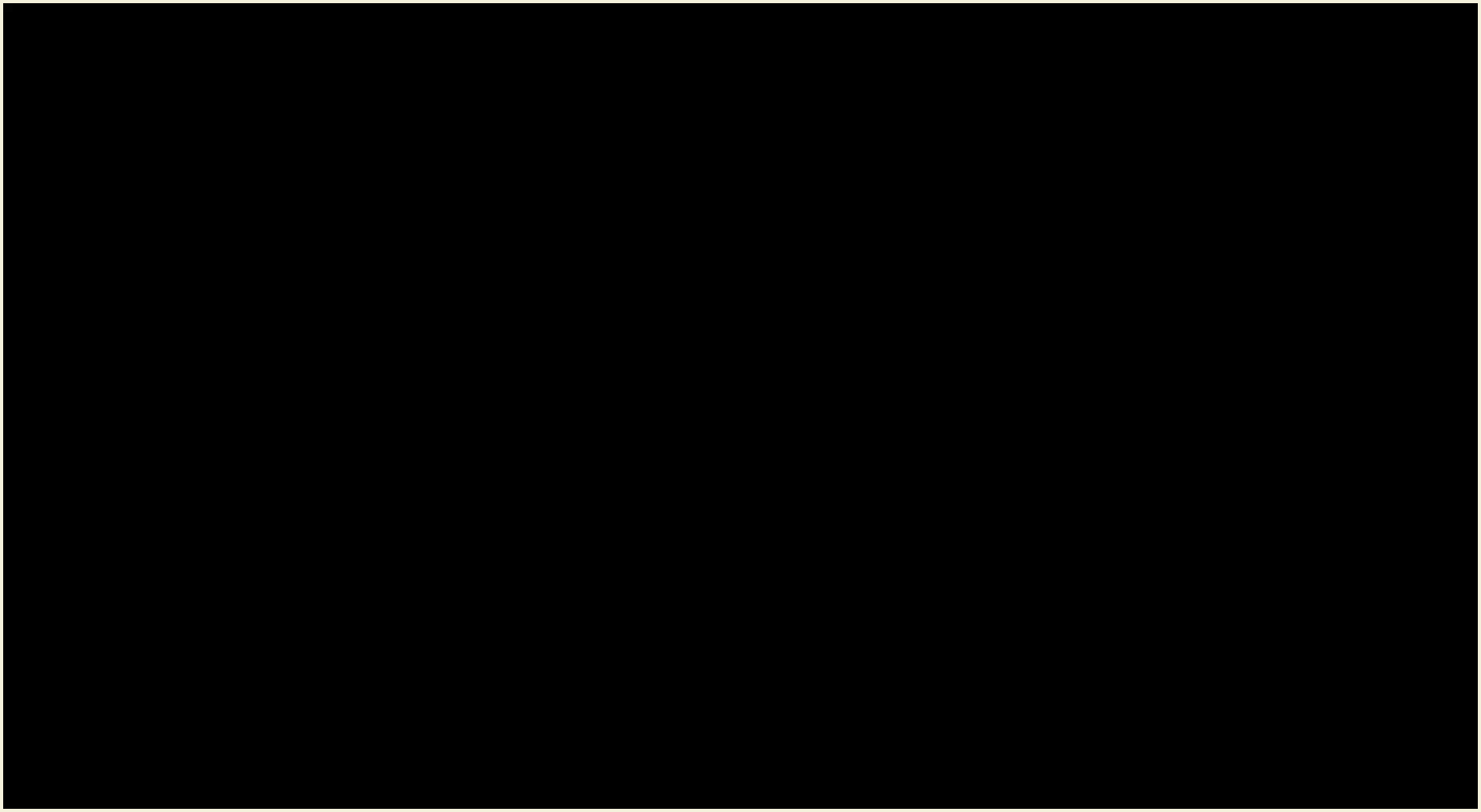


Fig. 19-2, p. 494

VIDEO: Is Earth Warming?



Science: Ice Cores Are Extracted by Drilling Deep Holes in Ancient Glaciers

Fig. 19-3, p. 495

Our Climate, Lives, and Economies Depend on the Natural Greenhouse Effect

Greenhouse gases absorb heat radiated by the earth

- The gases then emit infrared radiation that warms the atmosphere

Without the natural greenhouse effect

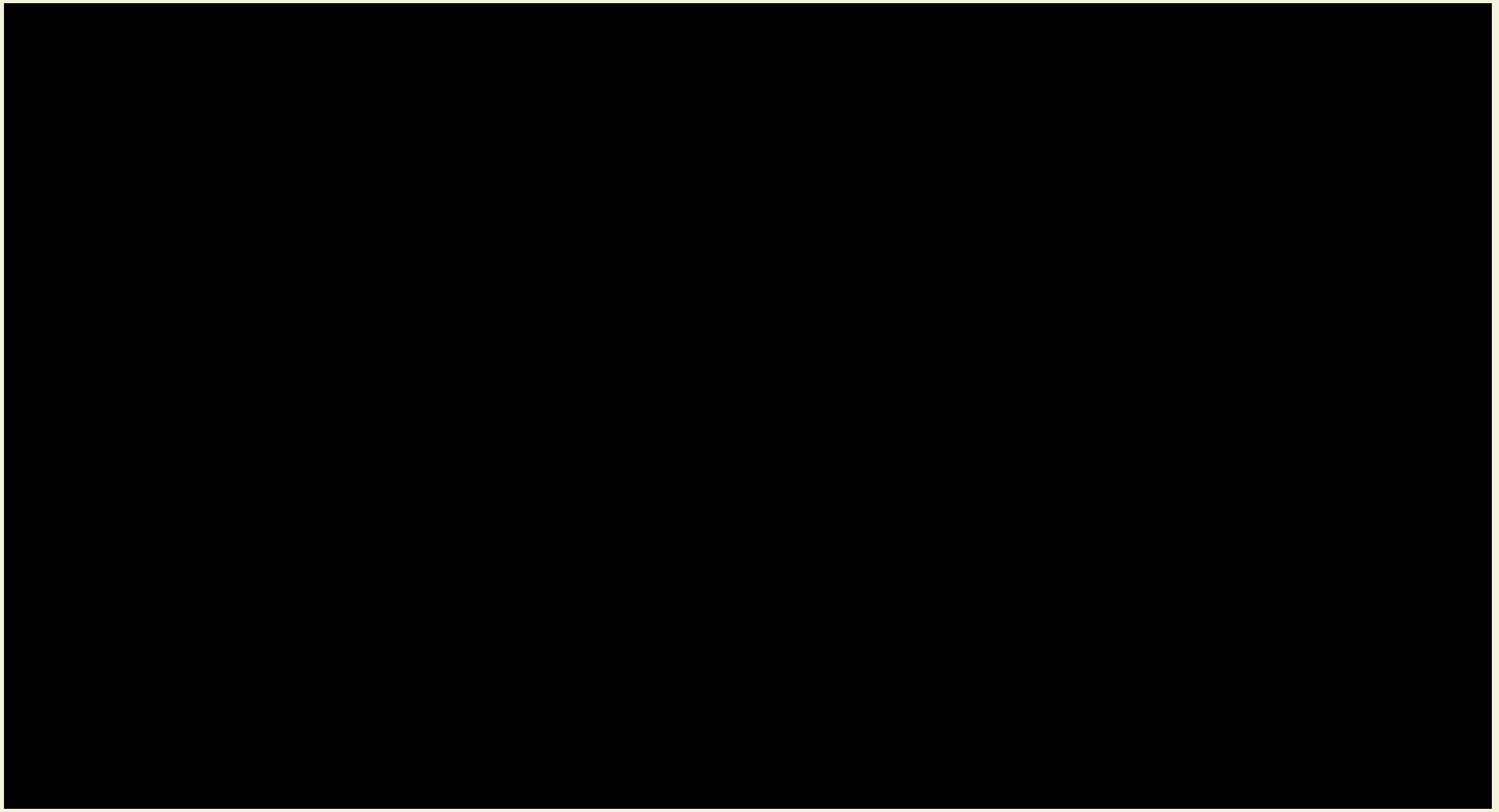
- Cold, uninhabitable earth

Human Activities Emit Large Quantities of Greenhouses Gases

- Since the Industrial Revolution
  - CO_2, CH_4, and N_2O emissions higher
  - Main sources: agriculture, deforestation, and burning of fossil fuels

- Correlation of rising CO_2 and CH_4 with rising global temperatures

VIDEO: Greenhouse Gases



Atmospheric Levels of CO_2 and CH_4, Global Temperatures, and Sea Levels

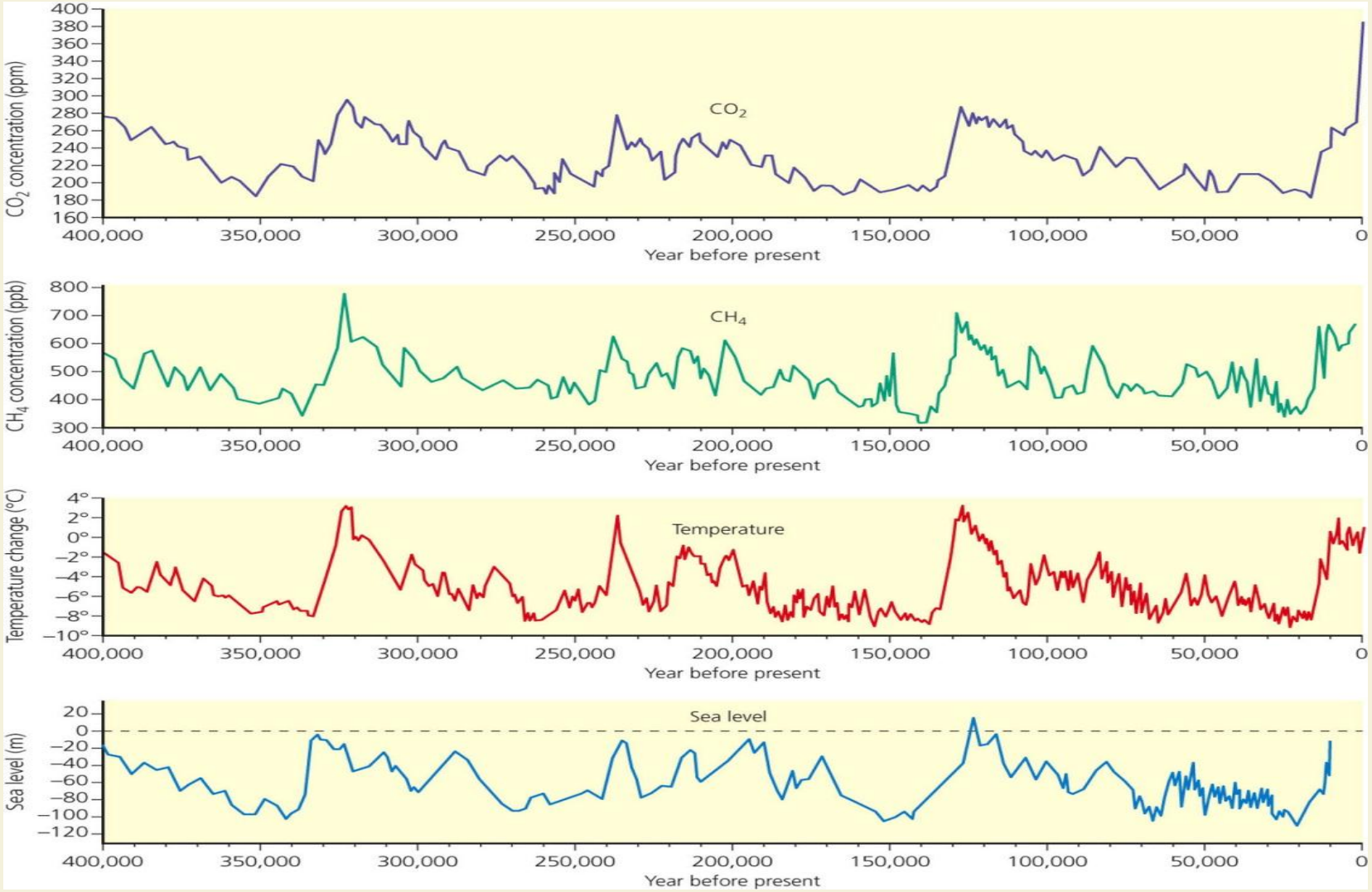


Fig. 19-4, p. 496

Correlation of CO_2 and Temperature

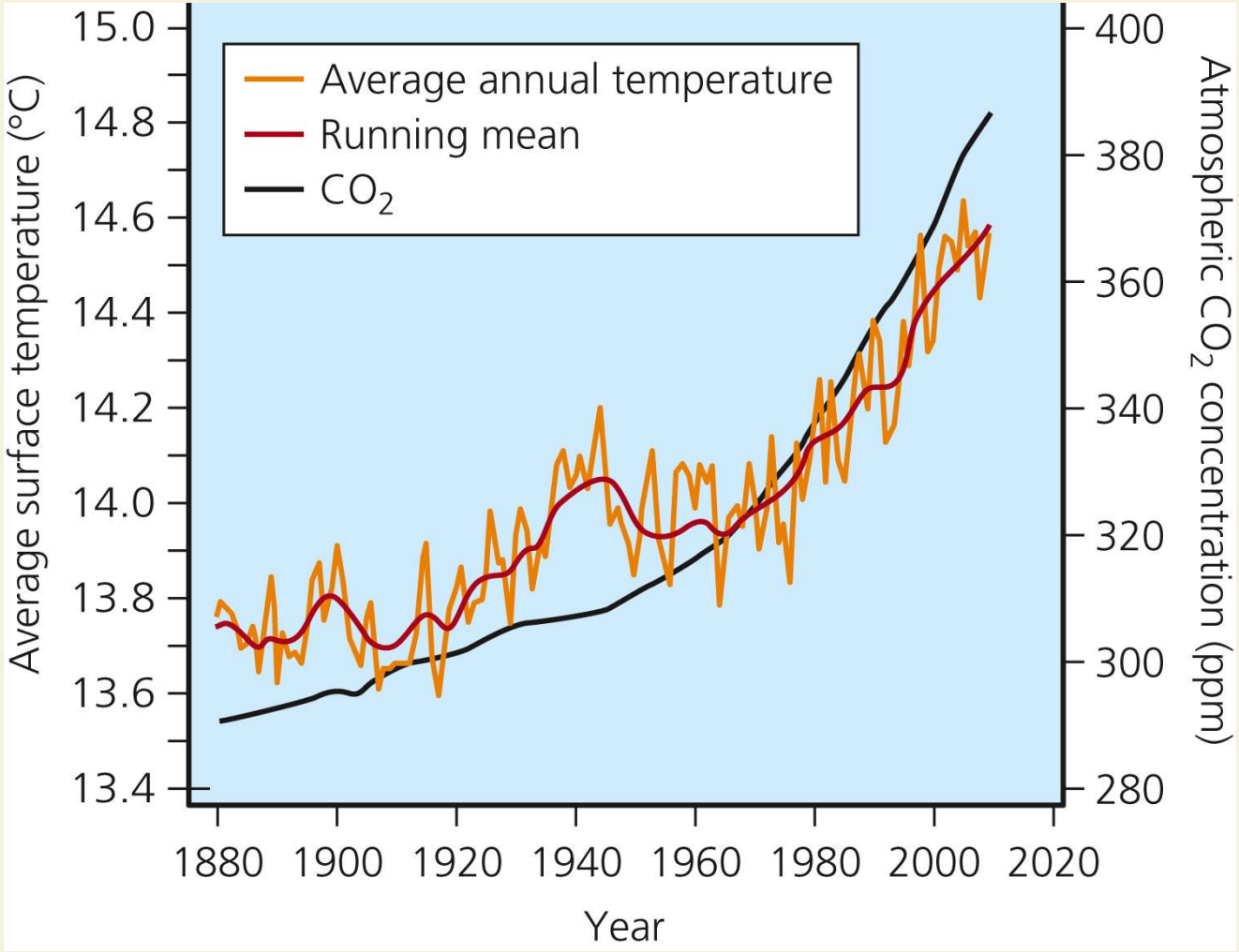


Fig. 19-5, p. 497

CO_2 Concentrations, 1960-2009

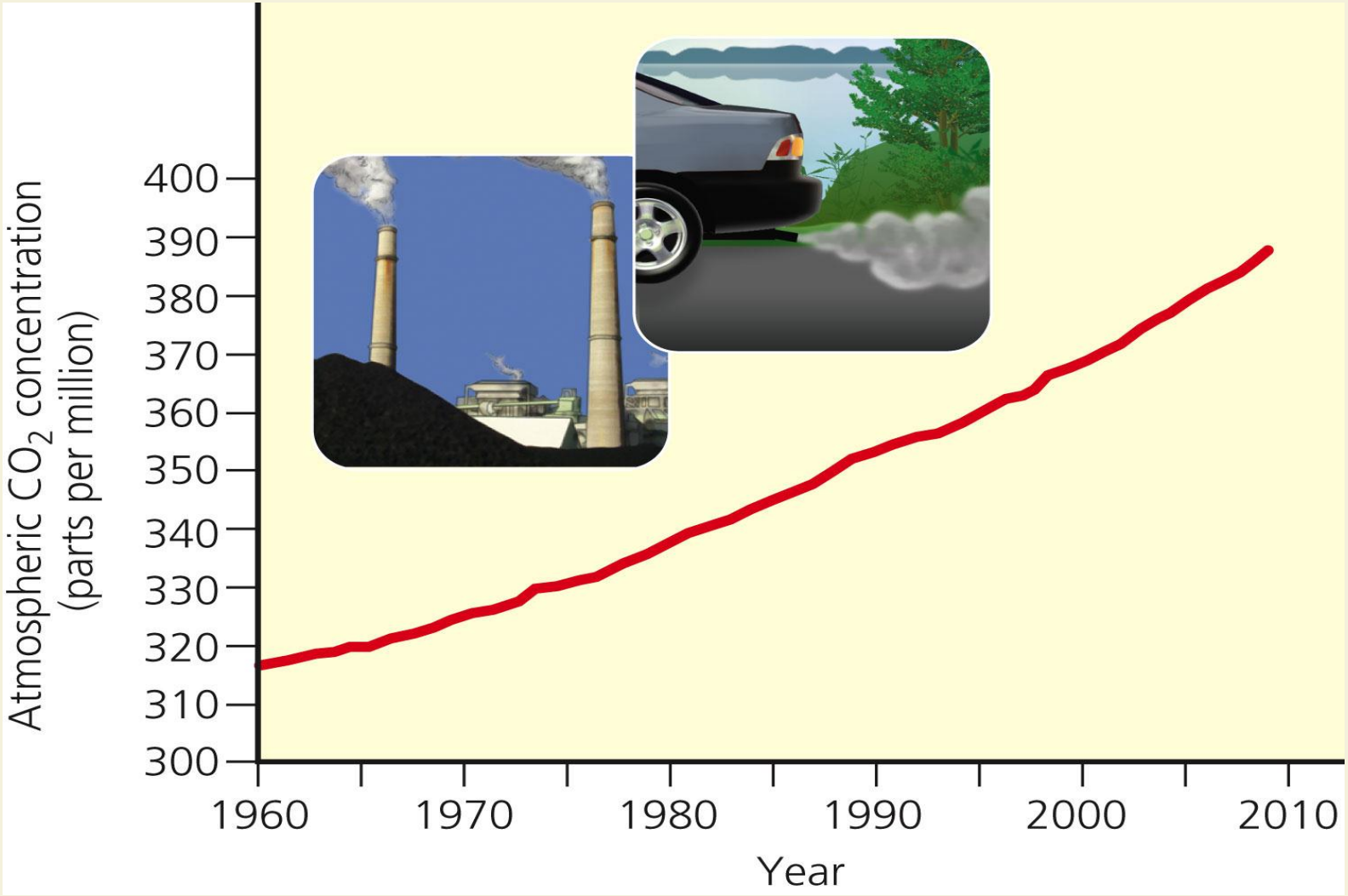


Figure 14, Supplement 9

VIDEO: Increased Emissions

Human Activities Play a Key Role in Recent Atmospheric Warming

Intergovernmental Panel on Climate Change (IPCC), with 2010 updates

- 90–99% likely that lower atmosphere is warming
  - Especially since 1960
  - Mostly from human-caused increases in greenhouse gases
  - Earth's climate is now changing from increased greenhouse gases
- Increased greenhouse gas concentrations will likely trigger significant climate disruption this century
- Ecological, economic, and social disruptions

Human Activities Play a Key Role in Recent Atmospheric Warming (2)

Intergovernmental Panel on Climate Change (IPCC), with 2010 updates, cont.

- 1906–2005: Ave. temp increased about 0.74˚C
- 1970–2009: Annual greenhouse emissions from human activities up 70%
- 2000-2009 warmest decade since 1881
- Past 50 years: Arctic temp rising almost twice as fast as the rest of the earth
- Melting of glaciers and increased floating sea ice
- Last 100 years: sea levels rose 19 cm

Melting of Alaska's Muir Glacier between 1948 and 2004

Fig. 19-6, p. 499

The Big Melt: Some of the Floating Sea Ice in the Arctic Sea

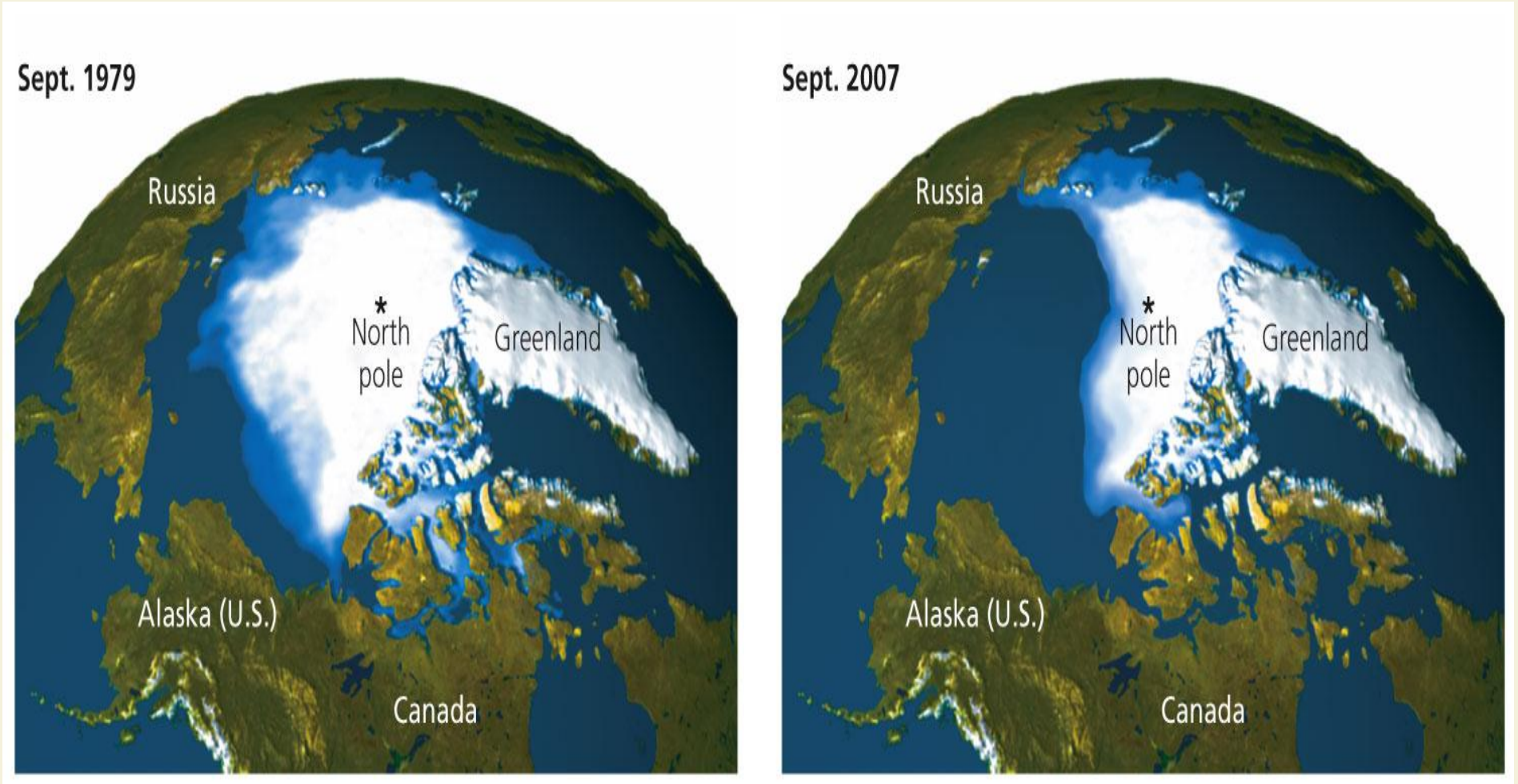
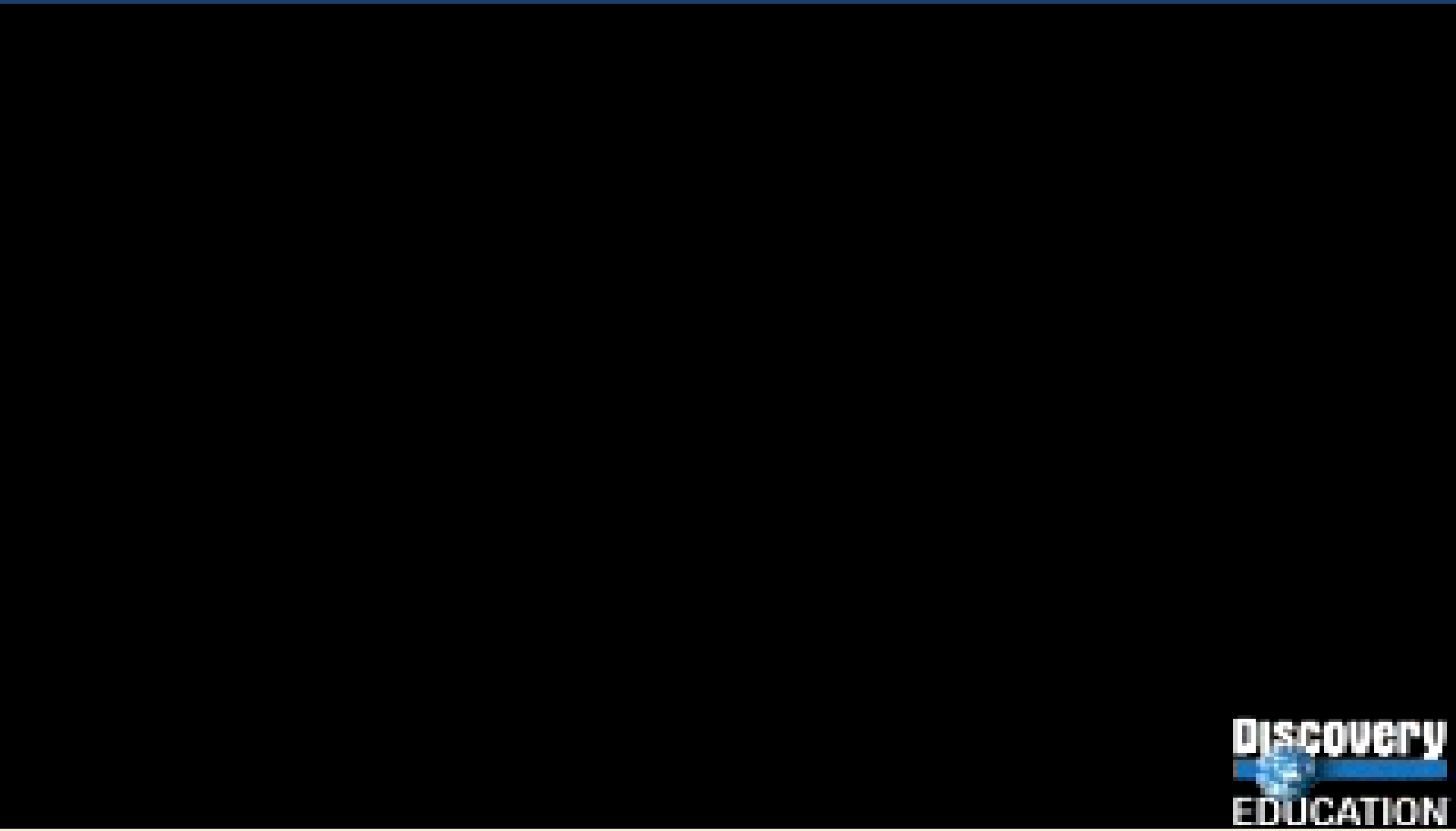


Fig. 19-7, p. 499

VIDEO: Melting Glaciers



2°C (3.6°F) Warming with 450 ppm CO_2 (now unavoidable effects)

- Forest fires worsen
- Prolonged droughts intensify
- Deserts spread
- Major heat waves more common
- Fewer winter deaths in higher latitudes
- Conflicts over water supplies increase
- Modest increases in crop production in temperate regions
- Crop yields fall by 5–10% in tropical Africa
- Coral reefs affected by bleaching
- Many glaciers melt faster and threaten water supplies for up to 100 million people
- Sea levels rise enough to flood low-lying coastal areas such as Bangladesh
- More people exposed to malaria
- High risk of extinction for Arctic species such as the polar bear

3°C (5.4°F) Warming with 550 ppm CO_2 (potentially avoidable effects)

- Forest fires get much worse
- Prolonged droughts get much worse
- Deserts spread more
- Major heat waves and deaths from heat increase
- Irrigation and hydropower decline
- 1.4 billion people suffer water shortages
- Water wars, environmental refugees, and terrorism increase
- Malaria and several other tropical diseases spread faster and further
- Crop pests multiply and spread
- Crop yields fall sharply in many areas, especially Africa
- Coral reefs severely threatened
- Amazon rainforest may begin collapsing
- Up to half of Arctic tundra melts
- Sea levels continue to rise
- 20–30% of plant and animal species face premature extinction

4°C (7.2°F) Warming with 650 ppm CO_2 (potentially avoidable effects)

- Forest fires and drought increase sharply
- Water shortages affect almost all people
- Crop yields fall sharply in all regions and cease in some regions
- Tropical diseases spread even faster and further
- Water wars, environmental refugees, terrorism, and economic collapse increase sharply
- Methane emissions from melting permafrost accelerate
- Ecosystems such as coral reefs, tropical forests, alpine and Arctic tundra, polar seas, coastal wetlands, and high-elevation mountaintops begin collapsing
- Glaciers and ice sheets melt faster
- Sea levels rise faster and flood many low-lying cities and agricultural areas
- At least half of plant and animal species face premature extinction

Fig. 19-7, p. 507

Science Focus: Using Models to Project Future Changes in Atmospheric Temperatures

- Mathematical models used for projections
- Global warming: rapid rate
- Human factors are the major cause of temperature rise over the last 30 years
- Always uncertainty with any scientific model

Simplified Model of Some Major Processes That Interact to Determine Climate

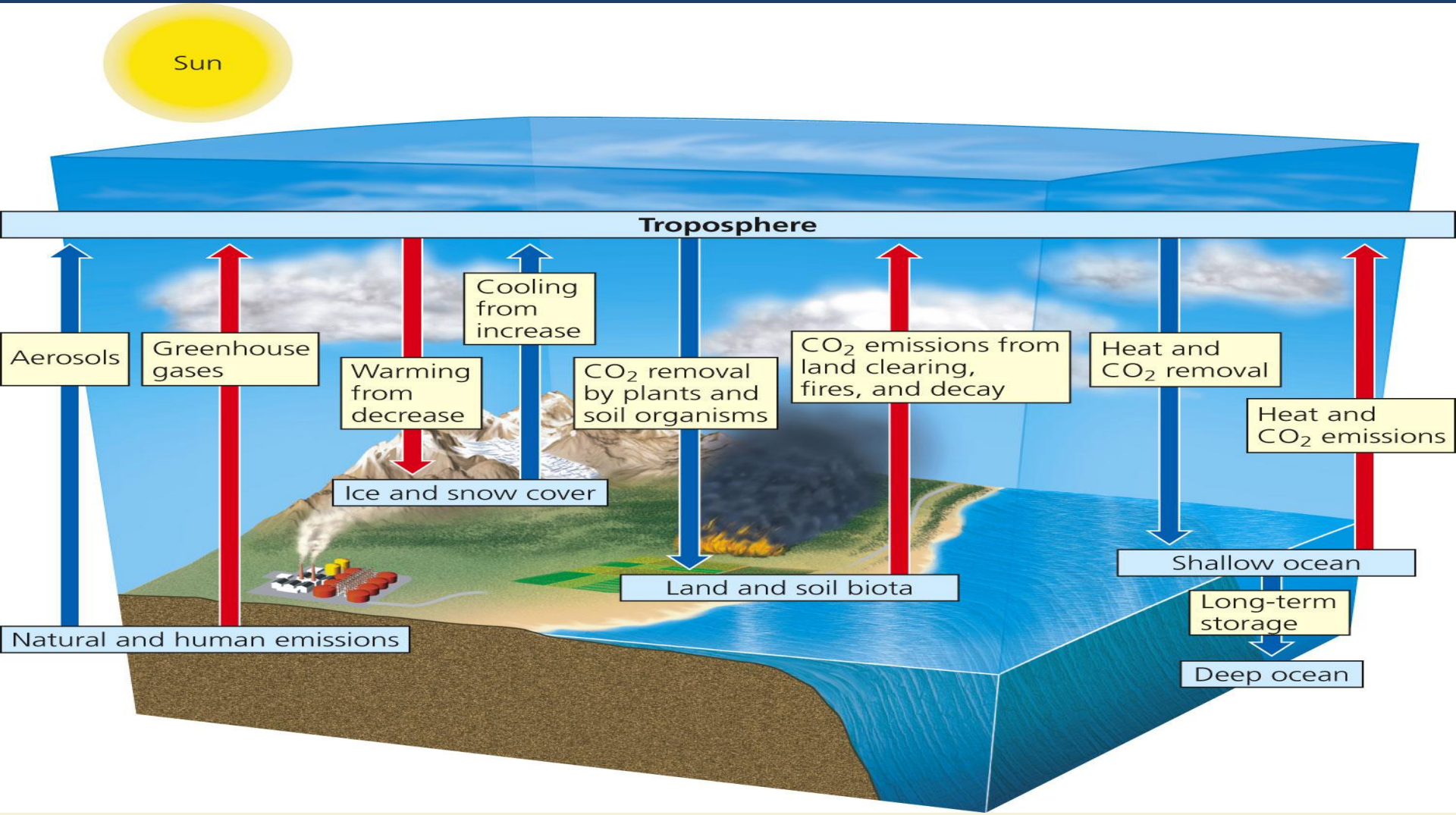


Fig. 19-A, p. 500

Comparison of Measured Temperature from 1860–2008 and Projected Changes

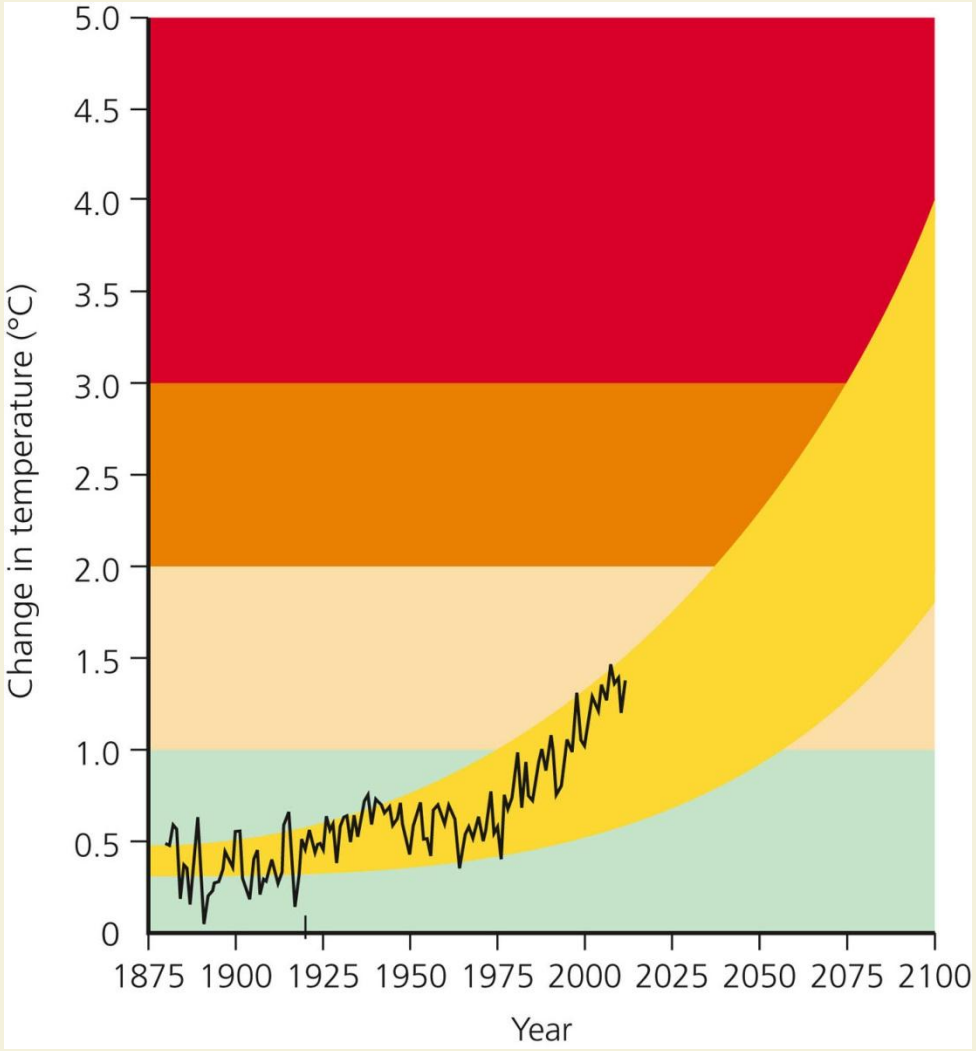
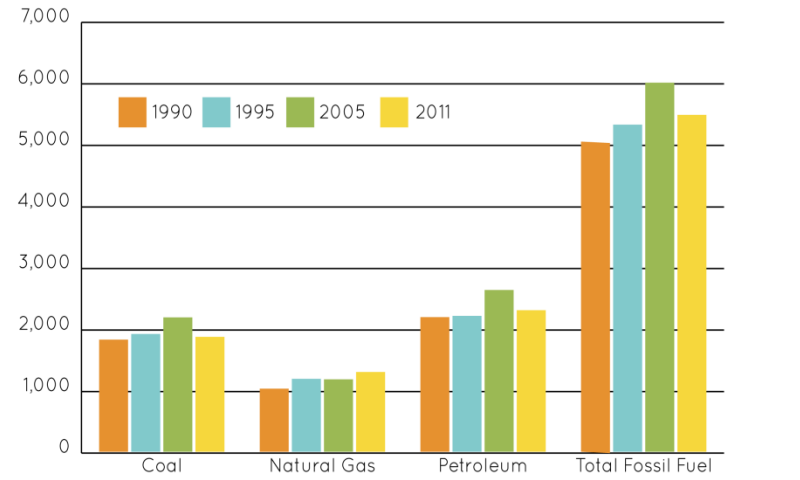


Fig. 19-B, p. 501

CO_2 Emissions Play an Important Role

- From burning fossil fuels and forests
- Abetted by deforestation; forests remove CO_2 from the atmosphere
- 2010: 389 ppm
- 2050: 560 ppm
- 2100: 1,390 ppm
- 450 ppm as tipping point



CO_2 Emissions Play an Important Role (2)

Largest emitters, 2009

1. China
2. United States
3. European Union (27 countries)
4. Indonesia
5. Russia
6. Japan
7. India

iStockphoto/Dino Ablakovic

THE CARBON MAP

Cumulative CO2 emissions, 1900-2005

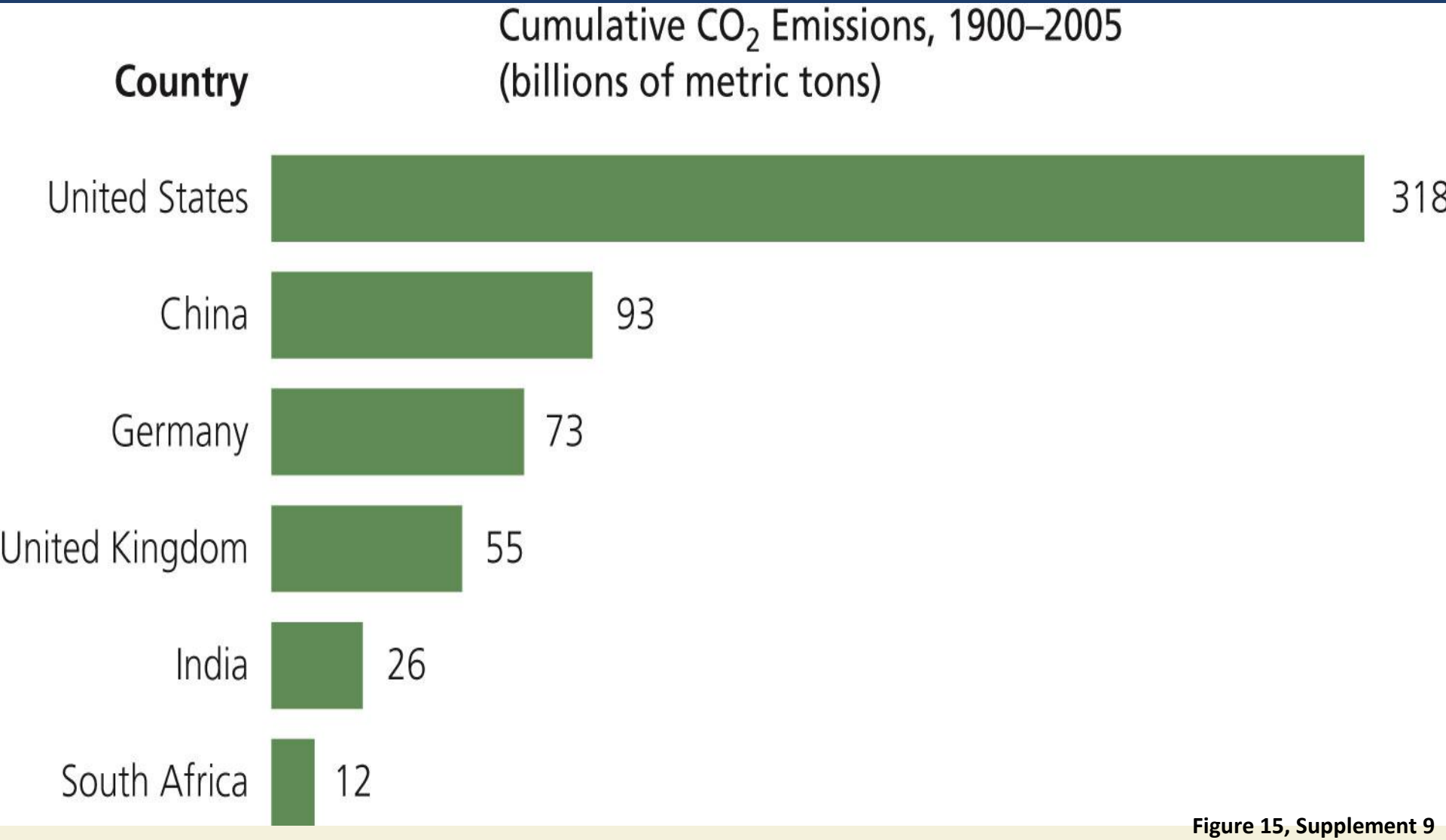
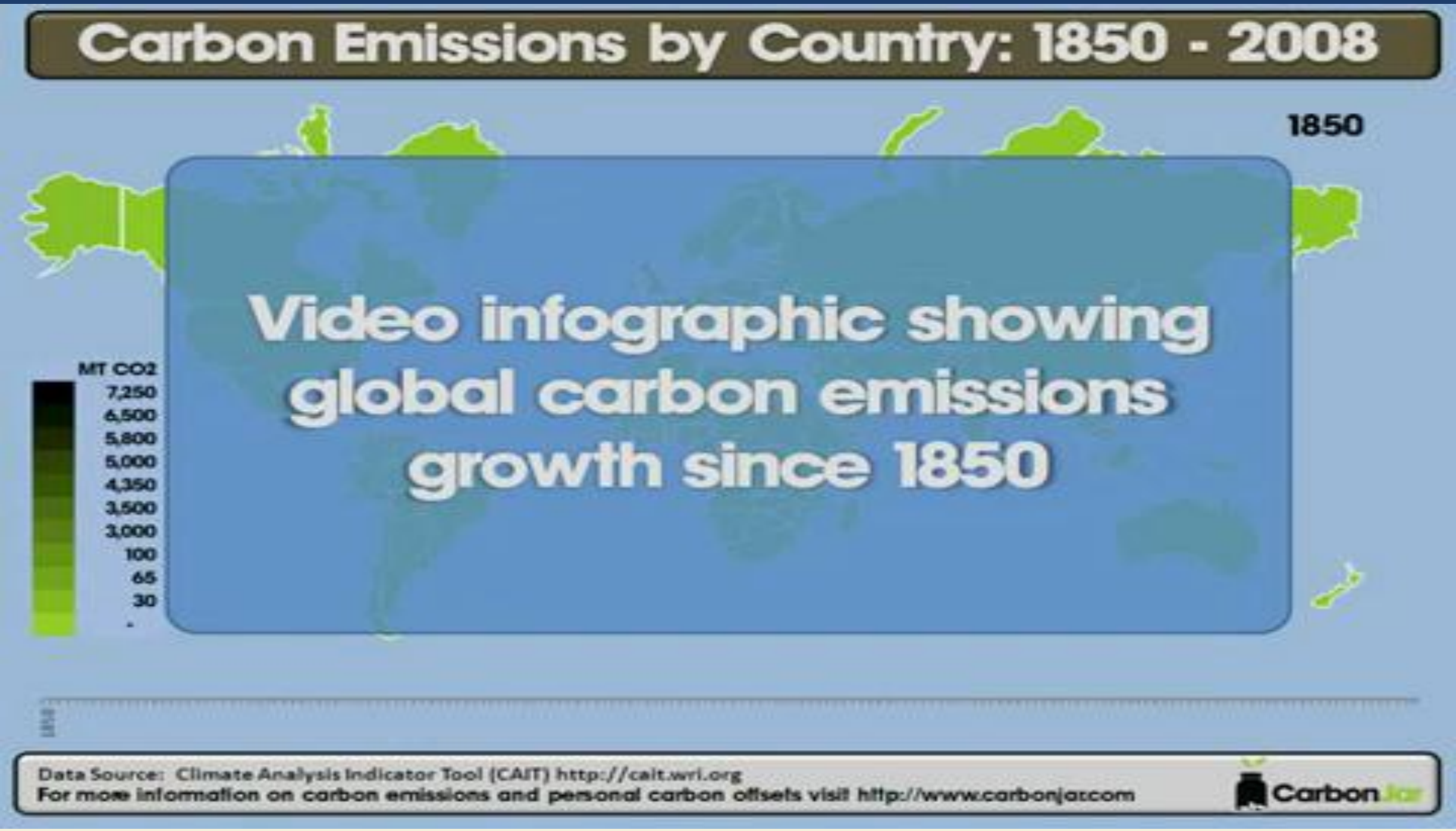


Figure 15, Supplement 9

VIDEO: Carbon Emissions by Country

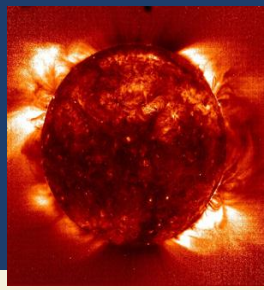


Waste Heat Also Plays a Role in Climate Disruption

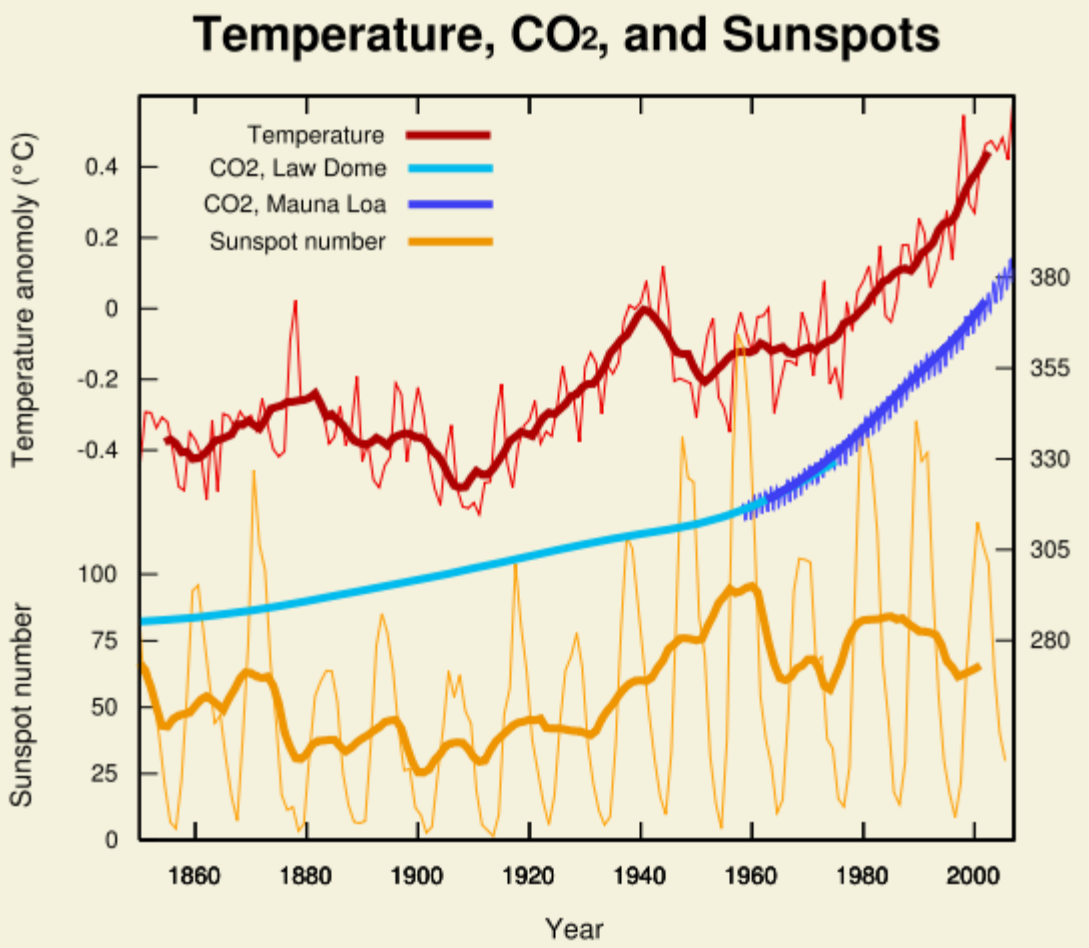
- Burning any fuel creates heat

- Many sources of heat
  - Power plants
  - Internal combustion engines
  - lights

What Role Does the Sun Play?



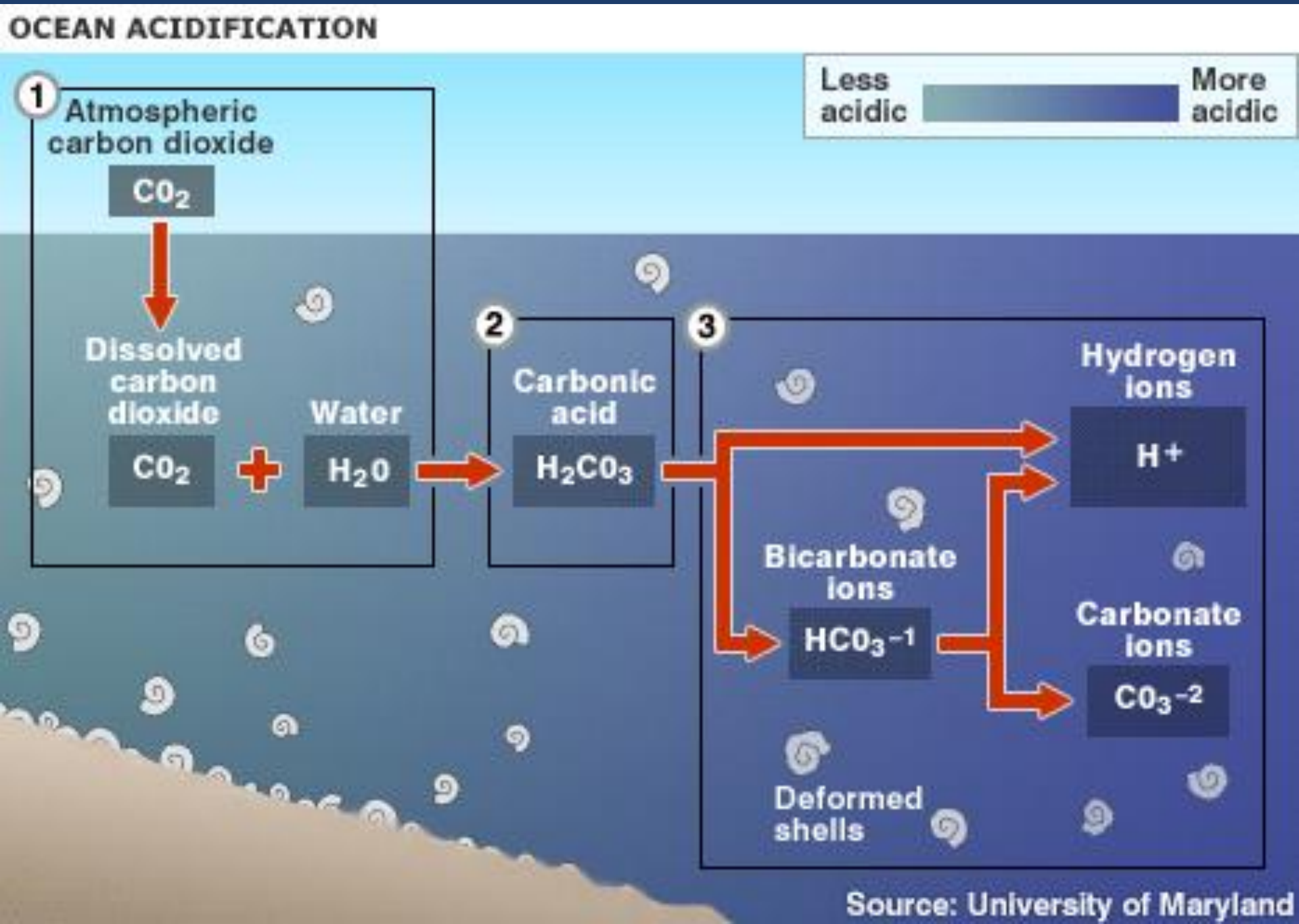
- Researchers think atmospheric warming not due to an increase in energy output from the sun
- Since 1975
  - Troposphere has warmed
  - Stratosphere has cooled
- This is not what a hotter sun would do



What Role Do the Oceans Play in Projected Climate Disruption?

- Solubility of CO_2 in ocean water

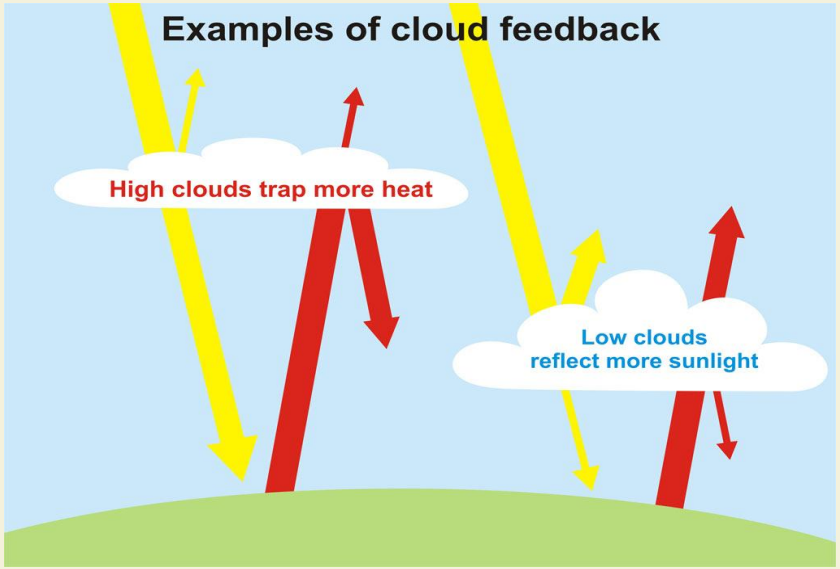
- Warmer oceans
  - Last century: 0.32-0.67C° increase
  - Absorb less CO_2 and hasten atmospheric warming
  - CO_2 levels increasing acidity
  - Affect phytoplankton and other organisms


OCEAN ACIDIFICATION
Less acidic
More acidic
1
Atmospheric carbon dioxide
CO_2
Dissolved carbon dioxide
CO_2
Water
H_2O
2
Carbonic acid
H_2CO_3
3
Hydrogen ions
H^+
Bicarbonate ions
HCO_3^{-1}
Carbonate ions
CO_3^{-2}
Deformed shells
Source: University of Maryland

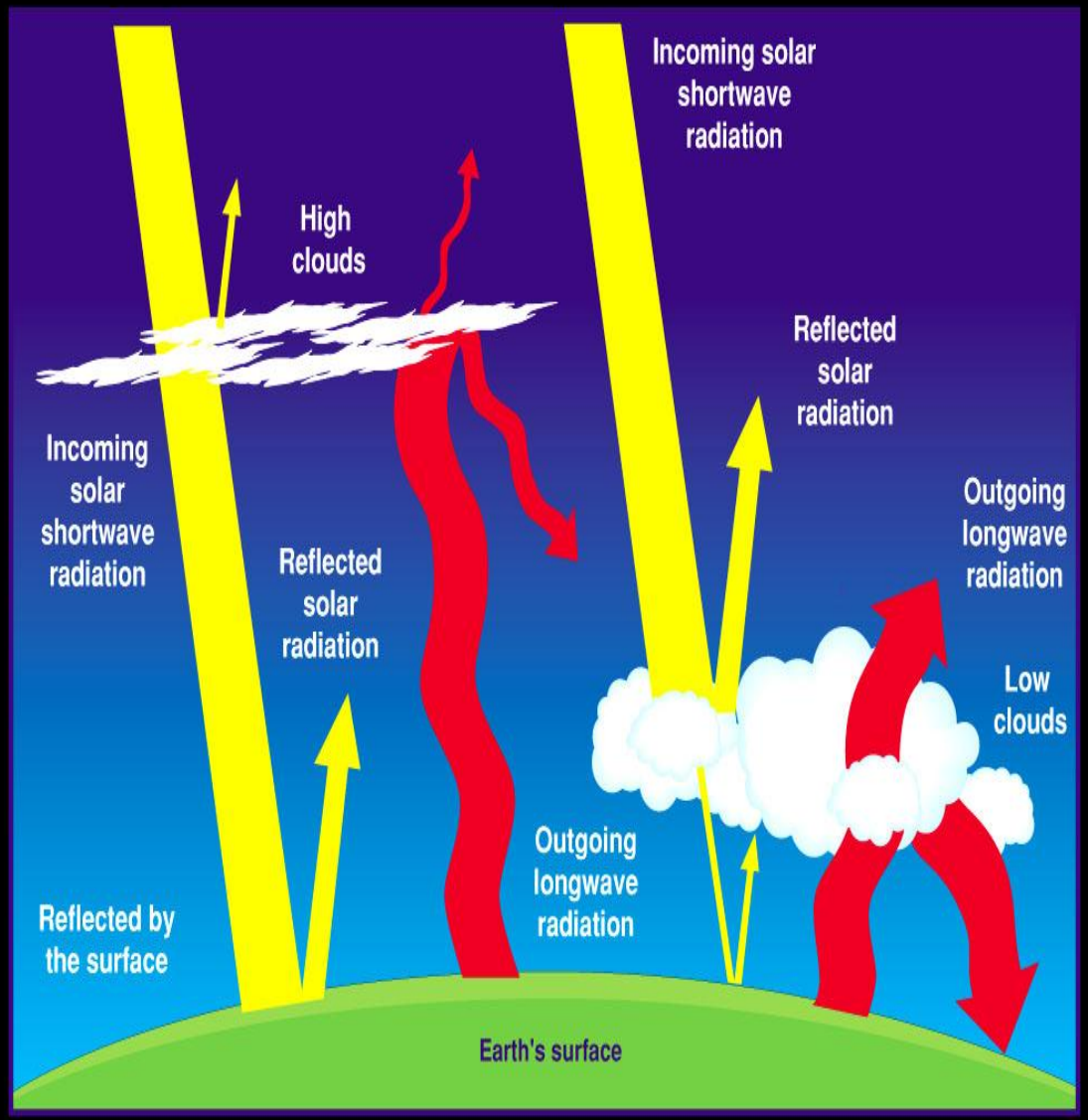
There Is Uncertainty about the Effects of Cloud Cover on Global Warming

Warmer temperatures create more clouds

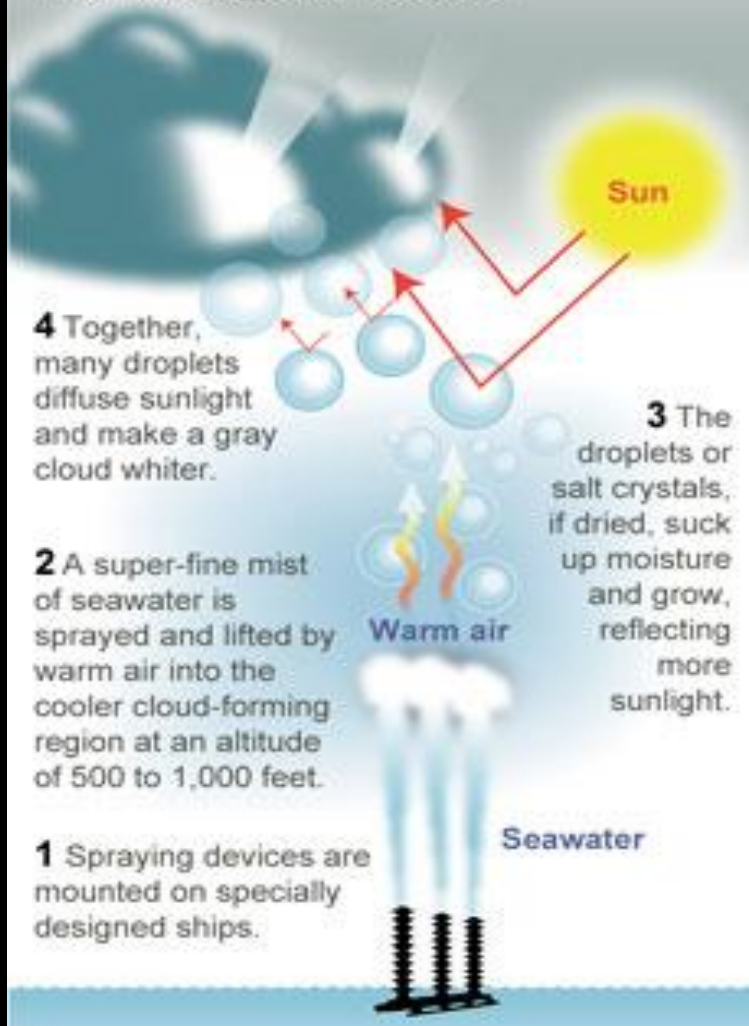
- Thick, low altitude cumulus clouds: decrease surface temperature
- Thin, cirrus clouds at high altitudes: increase surface temperature



Cloud Effects On Earth's Radiation



Scientists are researching ways to counter global warming by using the natural way clouds form to make clouds whiter and reflect more of the sun's energy back into space.



Source: Armand Neukermans. Reported by Oren Dorell, USA TODAY

By Julie Snider, USA TODAY

Cumulus Clouds and Cirrus Clouds

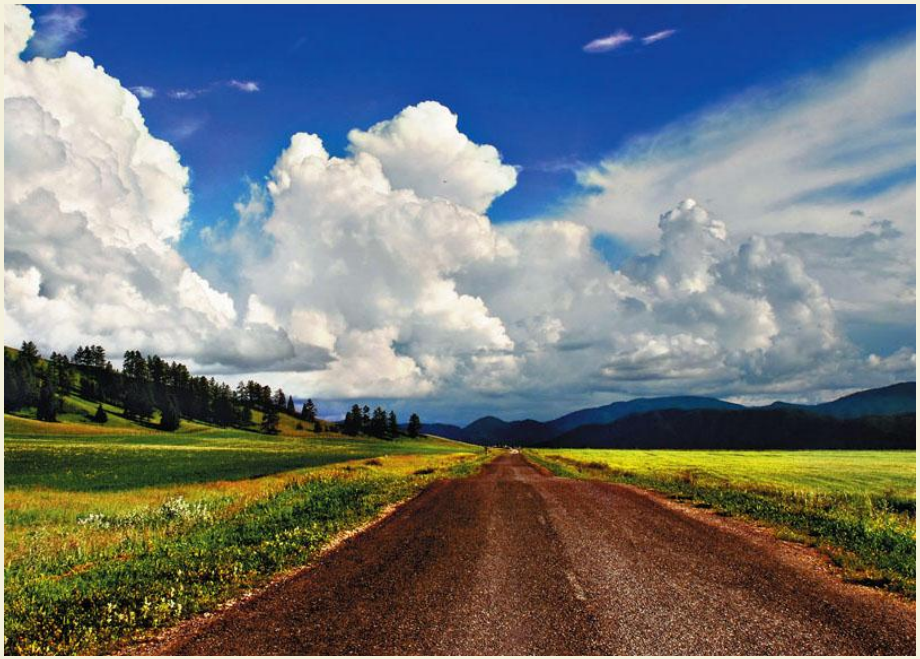
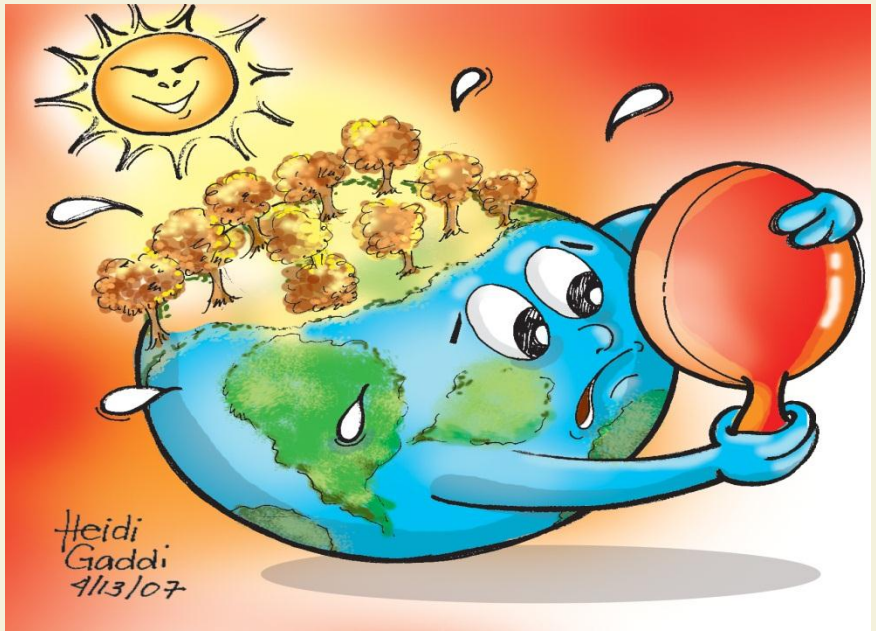


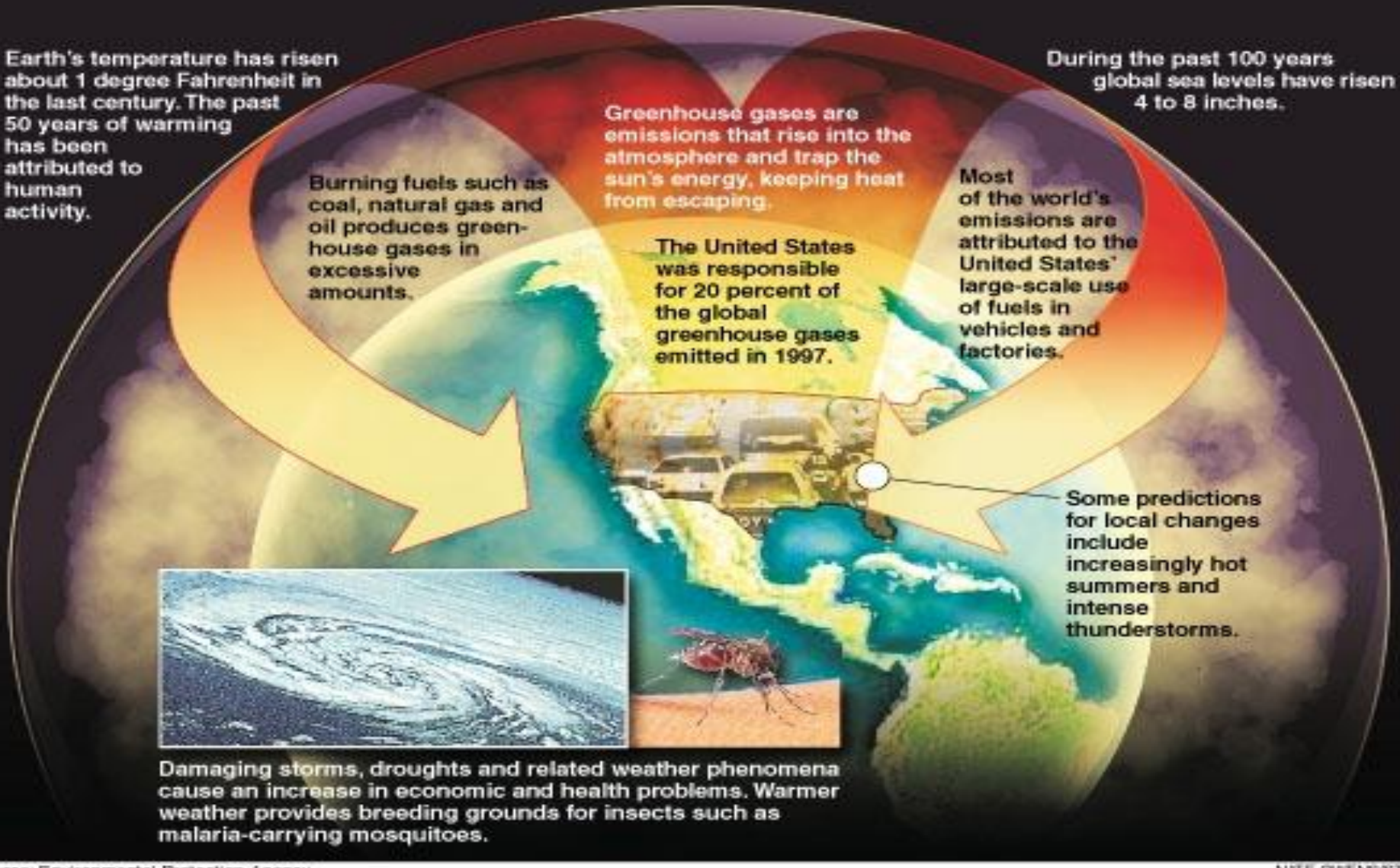
Fig. 19-8, p. 503

19-2 What Are Some Possible Effects of a Warmer Atmosphere?

Concept 19-2 *The projected rapid change in the atmosphere's temperature could have severe and long-lasting consequences, including increased drought and flooding, rising sea levels, and shifts in the locations of croplands and wildlife habitats.*



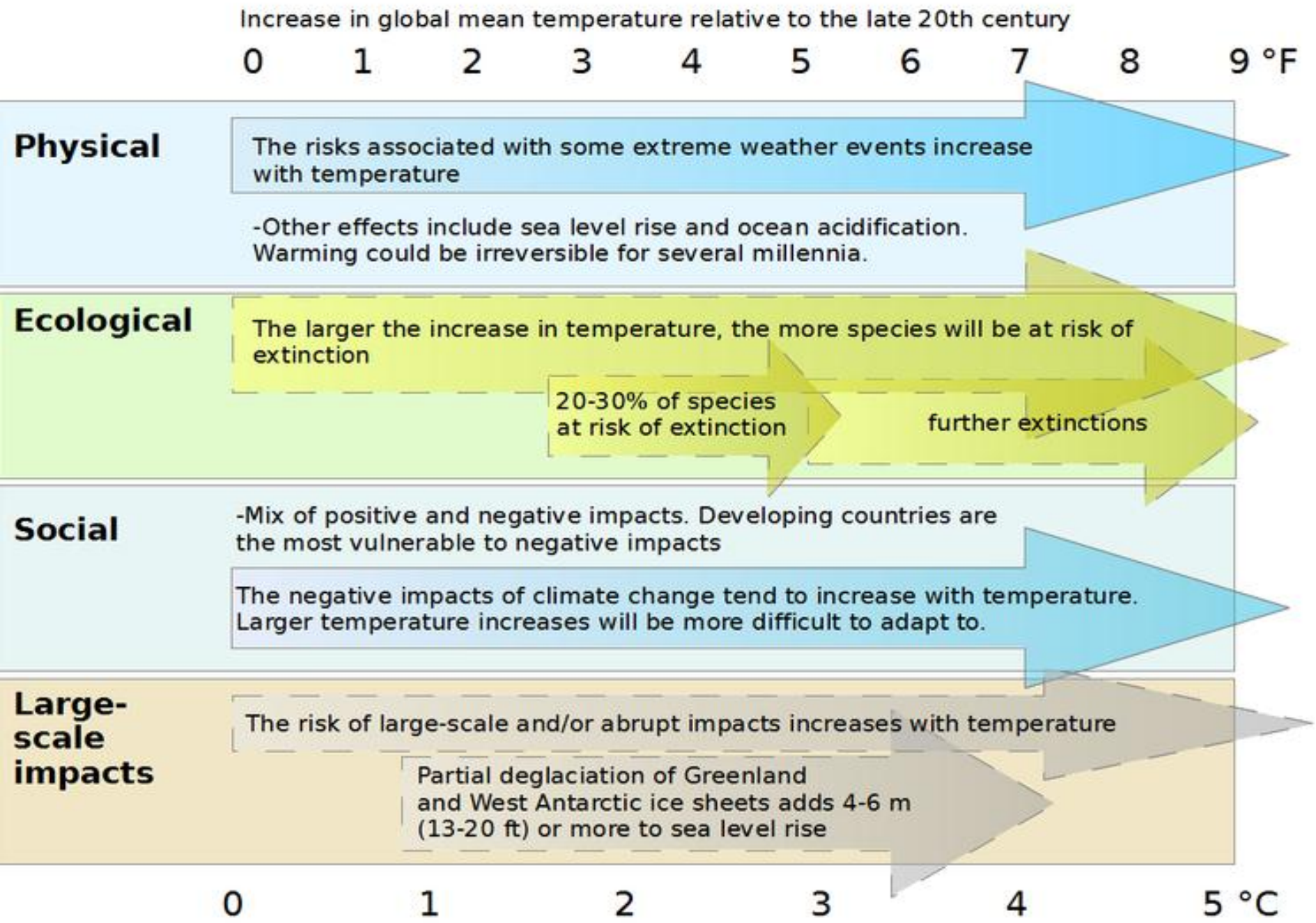
Global warming: Causes and effects



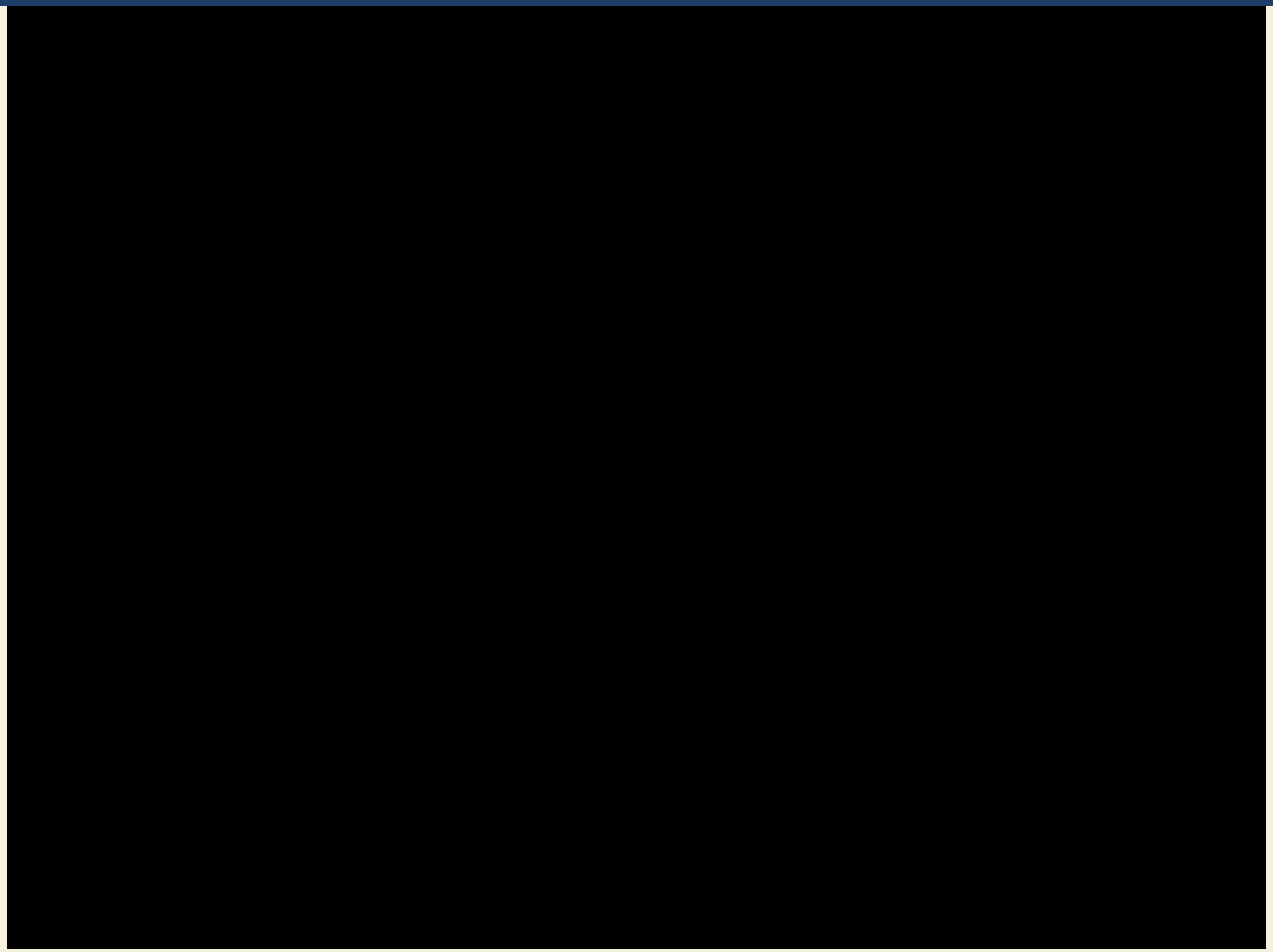
Source: Environmental Protection Agency

NATE OWENS/STAFF

Summary of global warming impacts



VIDEO: Are Cows Causing Global Warming

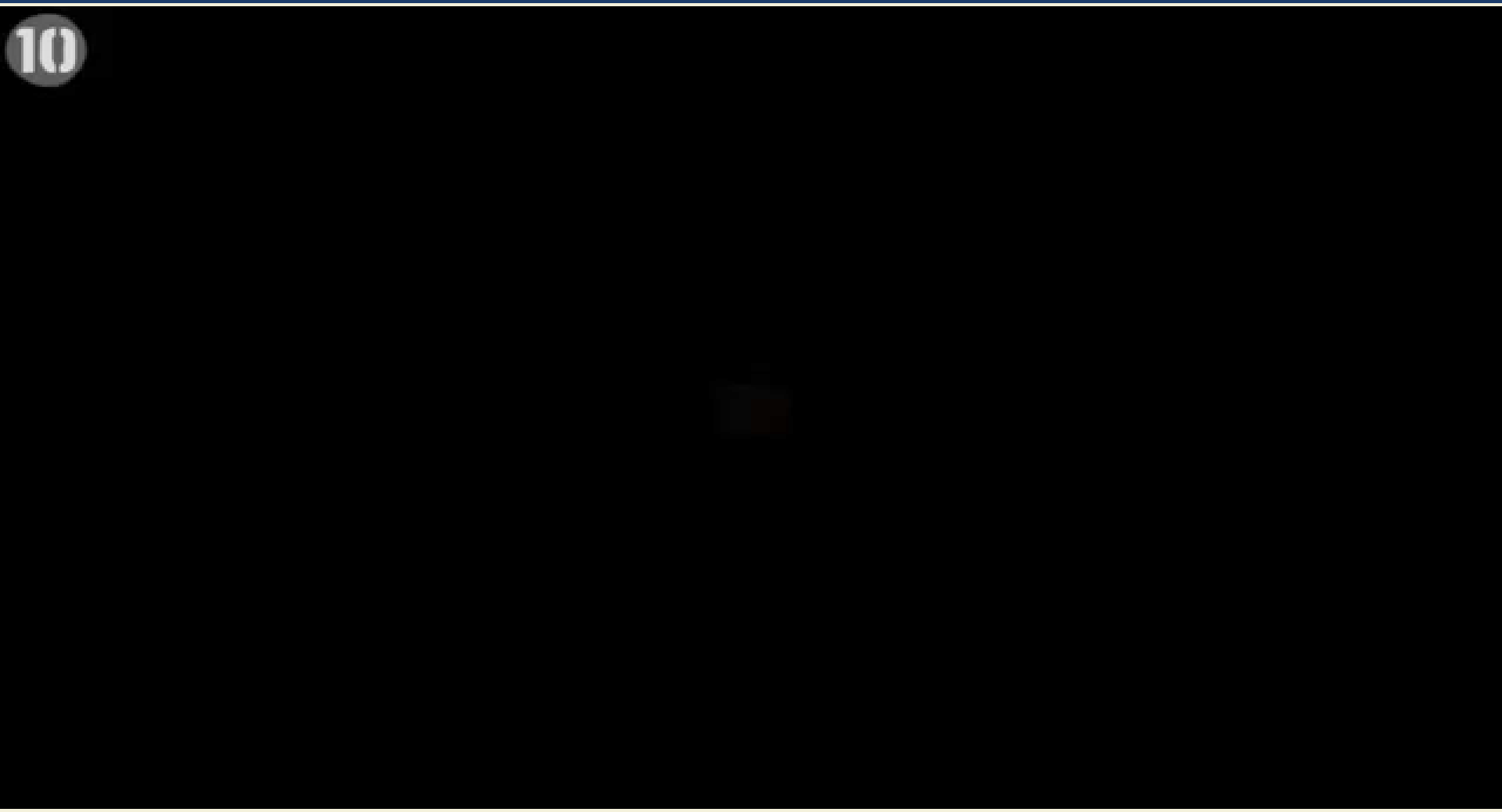


Enhanced Atmospheric Warming Could Have Serious Consequences

Worst-case scenarios

- Ecosystems collapsing
- Low-lying cities flooded
- Wildfires in forests
- Prolonged droughts
- More destructive storms
- Glaciers shrinking; rivers drying up
- Extinction of up to half the world's species
- Spread of tropical infectious diseases

VIDEO: Effects of Global Warming



Severe Drought Is Likely to Increase

- Accelerate global warming, lead to more drought
- Increased wildfires
- Declining streamflows, dry lakes, lower water tables
- Dry climate ecosystems will increase
- Other effects of prolonged lack of water

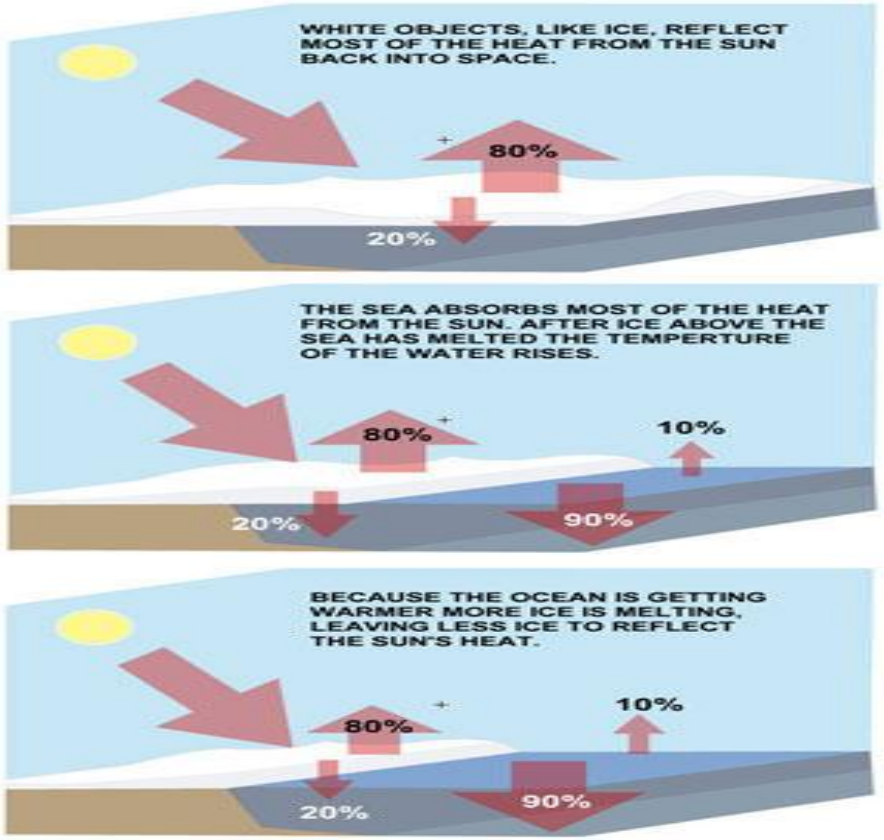
More Ice and Snow Are Likely to Melt

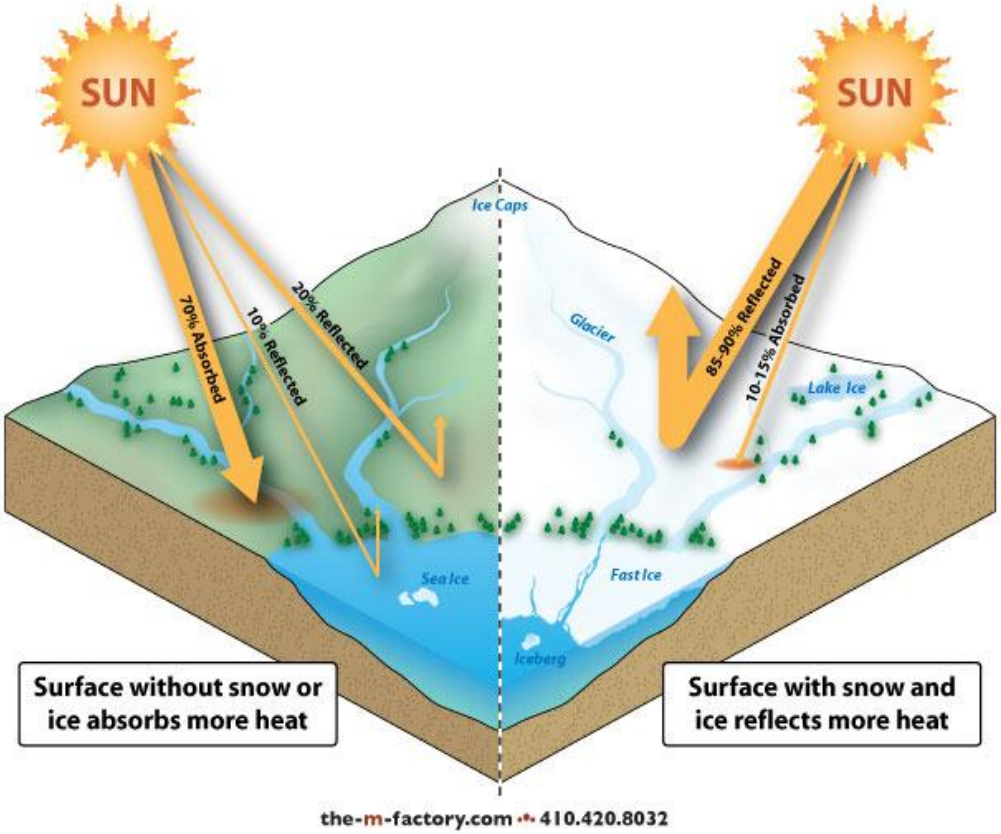
- Why will global warming be worse in the polar regions?

- Mountain glaciers affected by
  - Average snowfall
  - Average warm temperatures
  - 99% of Alaska's glaciers are shrinking

- When mountain glaciers disappear, there will be far less water in many major rivers

ALBEDO EFFECT





Website: [Earth's Albedo and Global Warming]

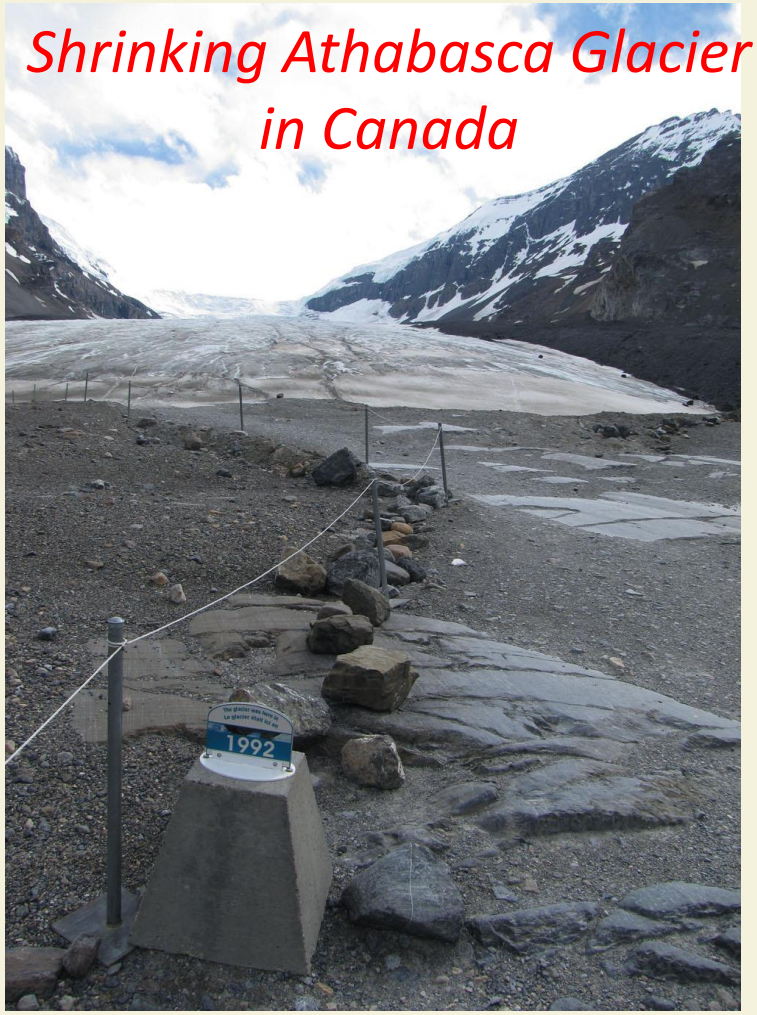
More Ice and Snow Are Likely to Melt

Glaciers disappearing from

- Himalayas in Asia
- Alps in Europe
- Andes in South America

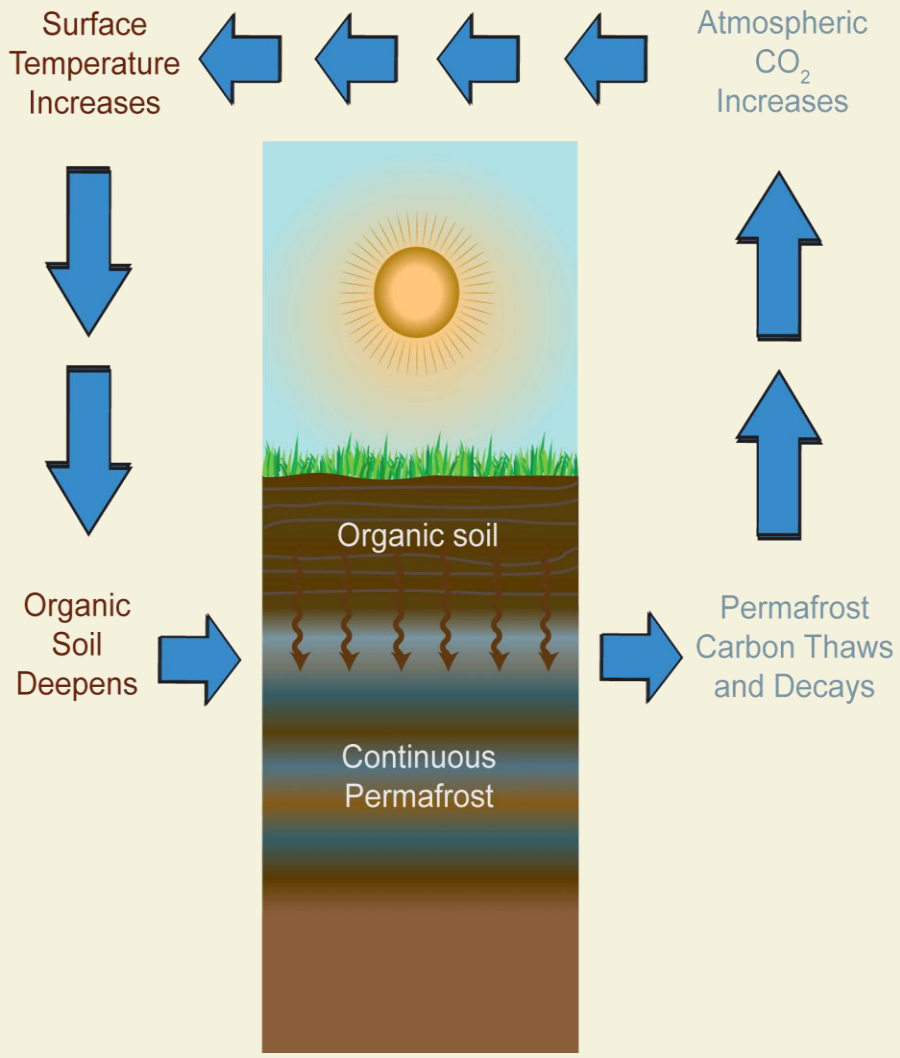
Greenland

- Warmer temperatures



Shrinking Athabasca Glacier in Canada

Permafrost Is Likely to Melt: Another Dangerous Scenario



If permafrost in Arctic region melts

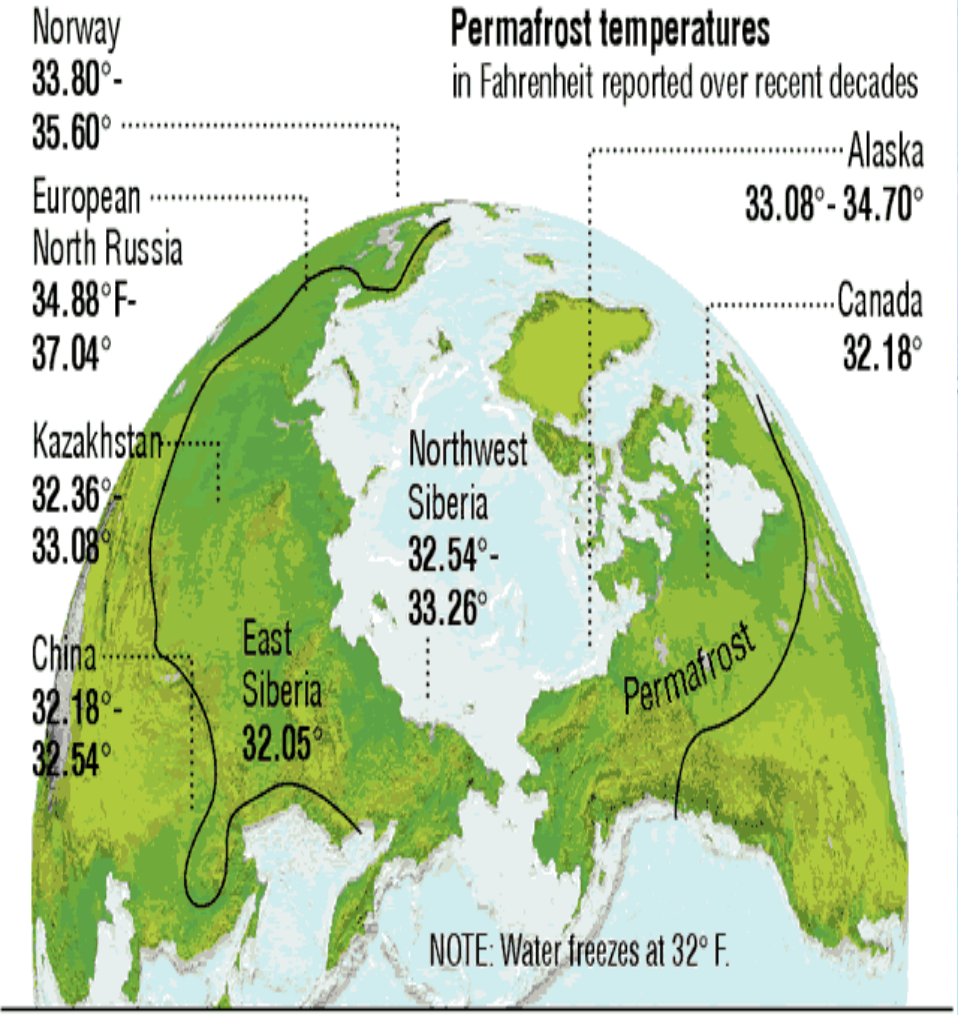
- Methane, a greenhouse gas, will be released into the atmosphere

- Arctic permafrost contains 50-60x the amount of carbon dioxide emitted annually from burning fossil fuels

- Methane in permafrost on Arctic Sea floor

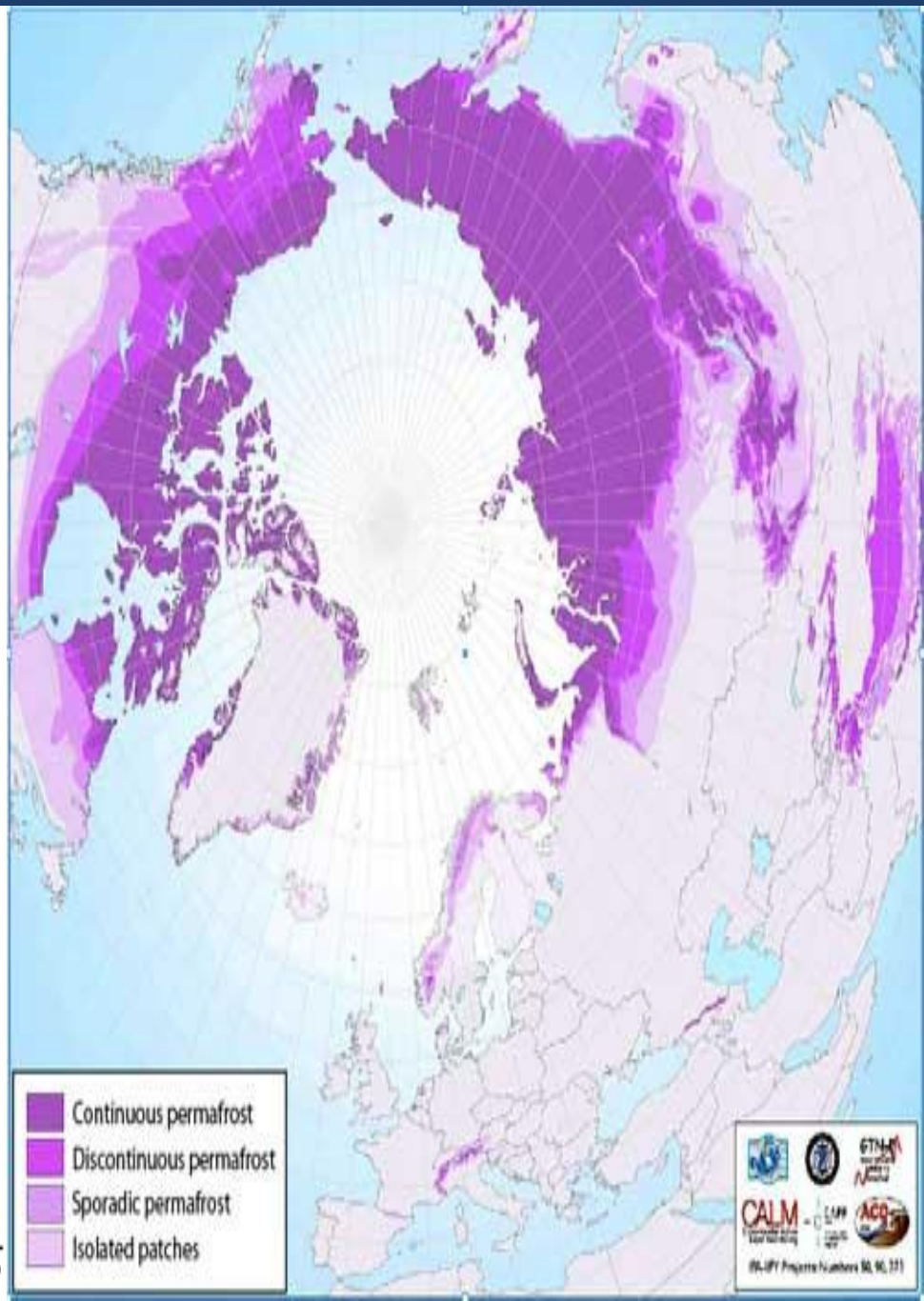
Arctic thaw releases greenhouse gases

As the Earth warms, greenhouse gases, once captive in the long-frozen soil, are bubbling into the atmosphere in much larger amounts than previously anticipated.



SOURCES: Nature; National Oceanic & Atmospheric Administration

AP

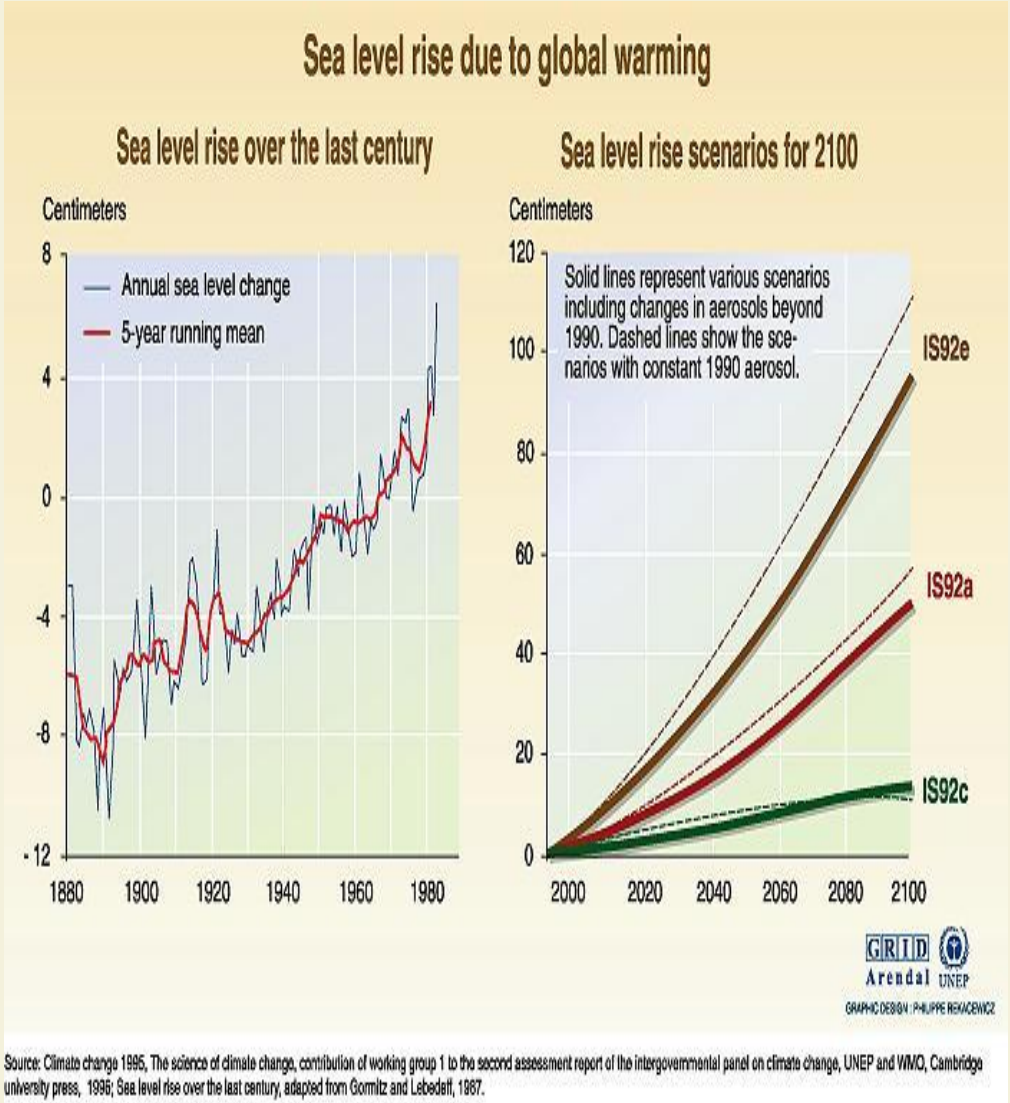


Projected Decreases in Arctic Tundra in Russia, 2004-2100

Fig. 19-10, p. 507

Sea Levels Are Rising

- 0.8-2 meters by 2100
- Expansion of warm water
- Melting of land-based ice
- What about Greenland?



Effects of Sea Levels Rising

Projected irreversible effect

- Degradation and loss of 1/3 of coastal estuaries, wetlands, and coral reefs
- Disruption of coastal fisheries
- Flooding of
  - Low-lying barrier islands and coastal areas
  - Agricultural lowlands and deltas
- Contamination of freshwater aquifers
- Submergence of low-lying islands in the Pacific and Indian Oceans and the Caribbean
- Flooding of coastal cities

Areas of Florida to Flood If Average Sea Level Rises by One Meter

Fig. 19-11, p. 507

Low-Lying Island Nation: Maldives in the Indian Ocean

Fig. 19-12, p. 508

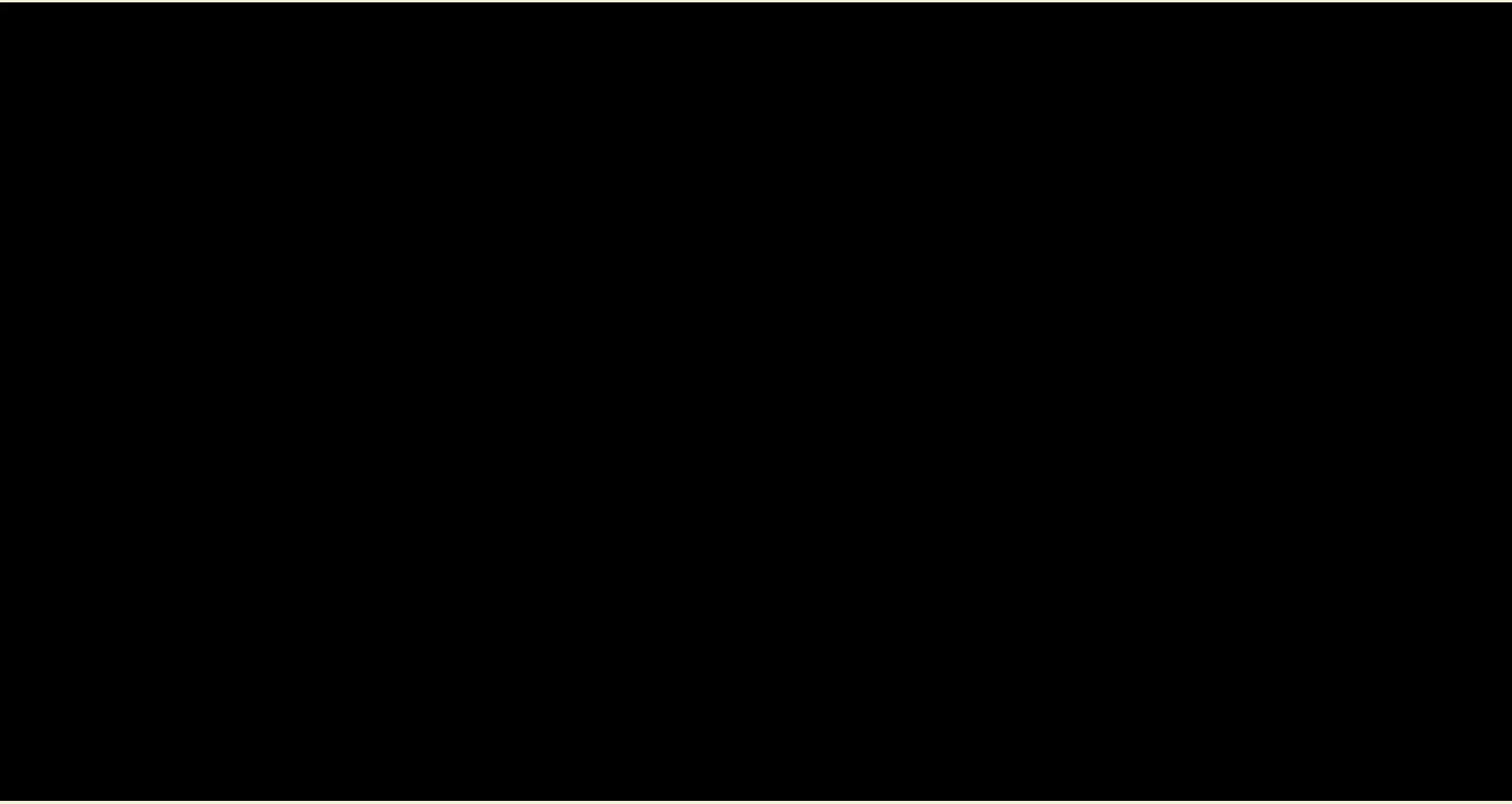
Health Effects of Sea Level Rising

Exposure/hazard	Health outcome
(Catastrophic) flooding	Deaths (drowning, other causes), injuries, infectious disease (respiratory, intestinal, skin), mental health disorders, impacts from interruption of health services and population displacement.
Impairment of food quality and/or food supplies (loss of crop land, decreased fisheries productivity). Climate change effects on HABs.	Food safety: marine bacteria proliferation, shellfish poisoning, ciguatera. Malnutrition and micro-nutrient deficiencies.
Reduced water quality and/or access to potable water supplies due to salinisation, flooding or drought.	Diarrhoeal diseases (giardia, cholera), and hepatitis, enteric fevers. Water-washed infections.
Change in transmission intensity or distribution of vector-borne disease. Changes in vector abundance.	Changes in malaria, and other mosquito-borne infections (some *Anopheles* vectors breed in brackish water).
Effects on livelihoods, population movement, and potential "environmental refugees".	Health effects are less well described. Large-scale rapid population movement would have severe health implications.

Extreme Weather Is Likely to Increase in Some Areas

- Heat waves and droughts in some areas
  - Could kill large numbers of people
- Prolonged rains and flooding in other areas
- Will storms get worse?
  - More studies needed

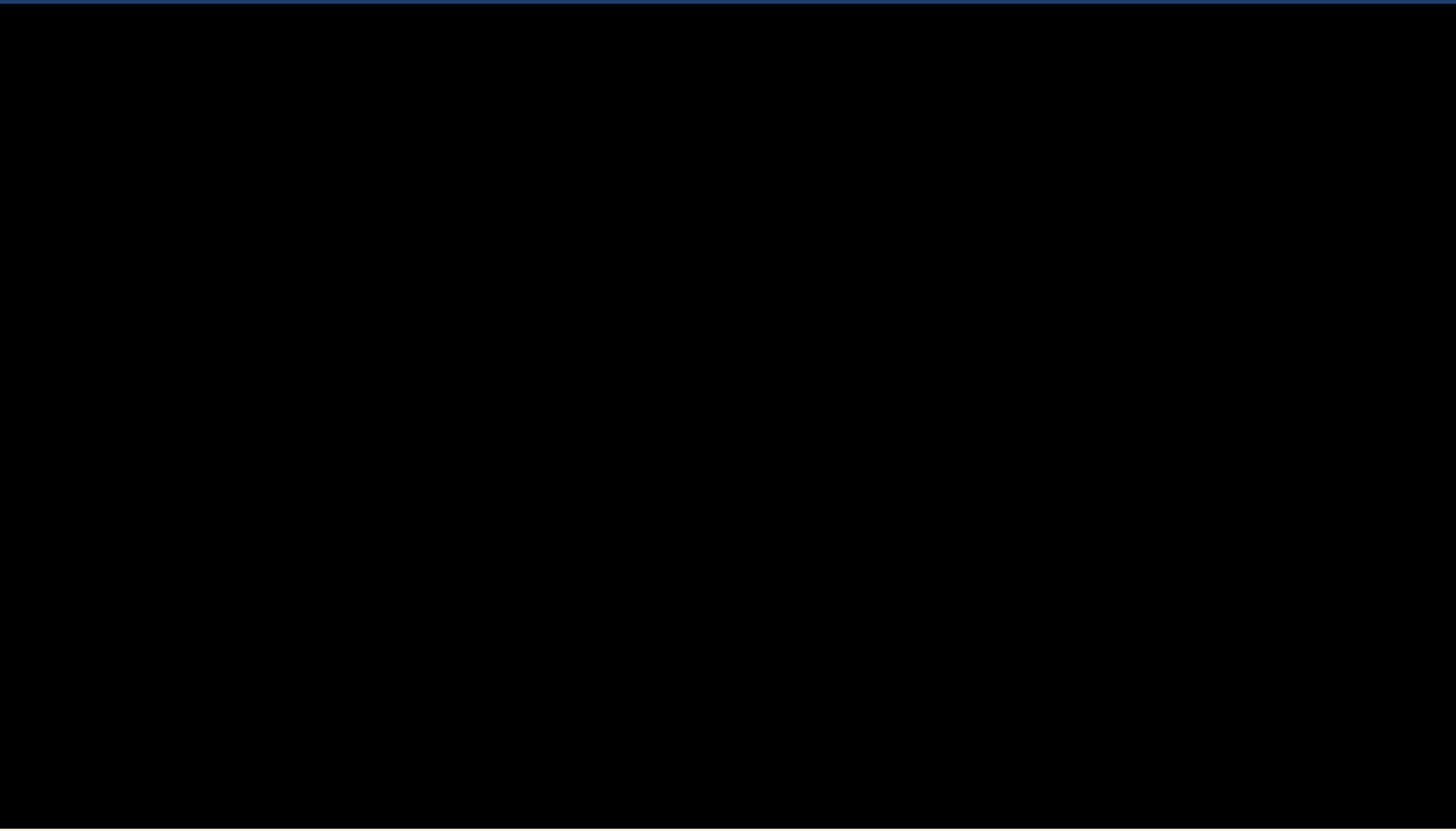
VIDEO: Extreme Weather & Global Warming



Climate Disruption Is a Threat to Biodiversity (1)

- Most susceptible ecosystems
  - Coral reefs
  - Polar seas
  - Coastal wetlands
  - High-elevation mountaintops
  - Alpine and arctic tundra

VIDEO: Impacts on Biodiversity



Climate Disruption Is a Threat to Biodiversity (2)

What about

- Migratory animals
- Forests

Which organisms could increase with global warming?
Significance?

- Insects
- Fungi
- Microbes

A VARIETY OF RESPONSES

Shifting Habitats

The American pika, a small rodent that lives in California mountains, cannot tolerate temperatures much higher than 80 degrees. As temperatures have risen, some pika populations have moved more than 1,300 feet further up the slopes to find a cooler home.

Predators Decline as Prey Declines

On Isle Royale, Mich., higher temperatures mean that one species of tick is growing more numerous and becoming more troublesome for the island's moose. As the population of moose has declined, so has the population of wolves, which prey on the moose for food.

Shifting Migration Patterns

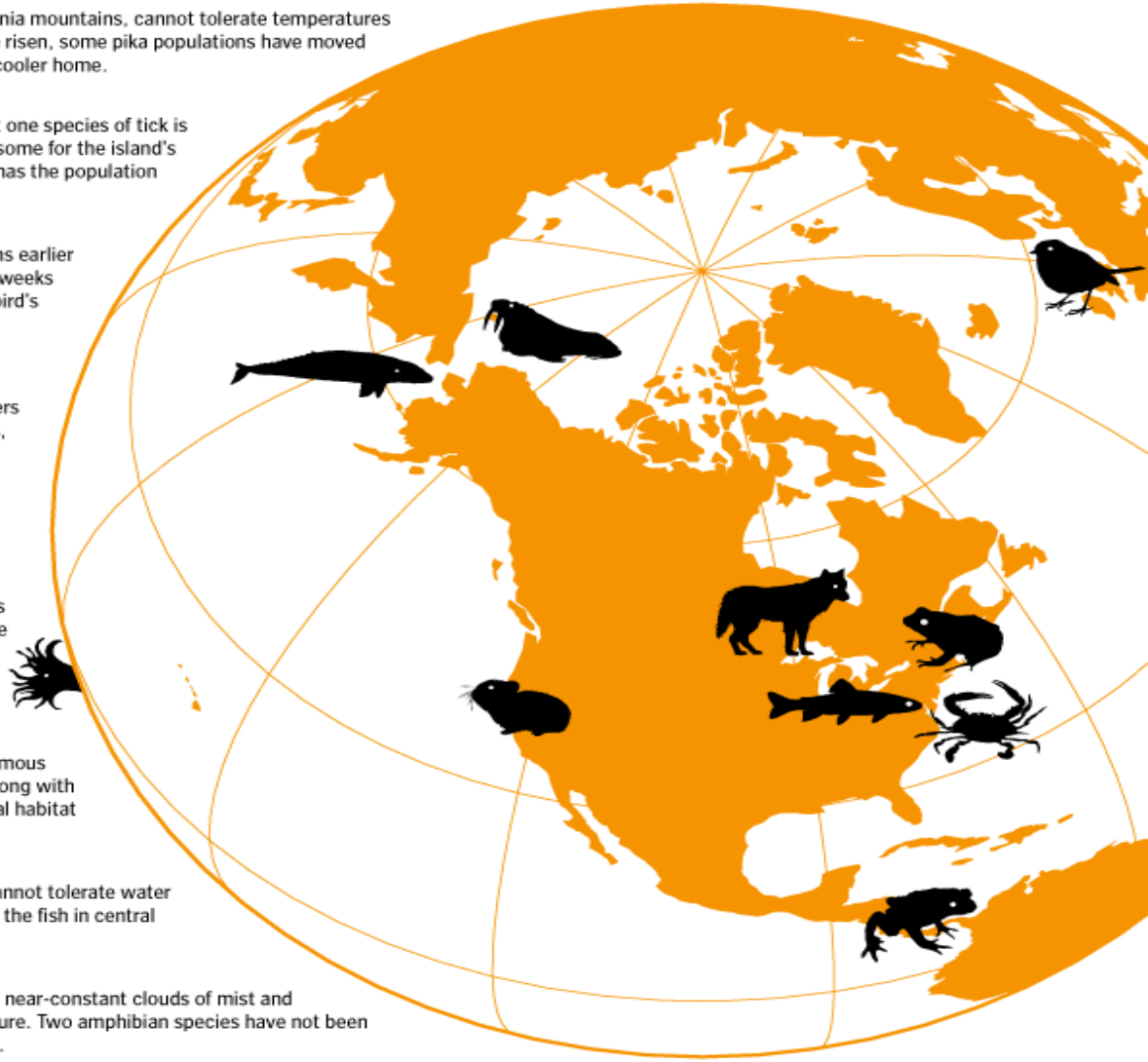
Many birds have begun making their annual migrations earlier — some British species have shifted by two to three weeks over the past 30 years. That can be a problem if the bird's main food source doesn't also shift its timing so it is available when the bird needs to eat.

Entire Ecosystem Changes

In the northern Bering Sea, near Alaska, warmer waters are causing an entire ecosystem shift. Native animals, such as walruses and gray whales, are finding less of the prey animals they rely on. At the same time, fish are moving in from less frigid areas.

Adaptation

Research on wood frogs in New England seems to show that they may be able to evolve and adapt to rising temperatures. That is good news, but scientists say that many animals will not be able to evolve in the same way.



CHANGES LOCAL AND BEYOND

Blackwater National Wildlife Refuge, Md.

Rising water levels threaten to turn most of this enormous swamp — which shelters baby fish and blue crabs along with migrating birds — into open water by 2030. A crucial habitat on the Eastern Shore could vanish.

Catoctin Mountain, Frederick County

The brook trout that live in mountain streams here cannot tolerate water much hotter than 68 degrees. As temperatures rise, the fish in central Maryland could be gone in a century.

Monteverde Cloud Forest, Costa Rica

Animals living in this forest depend on moisture from near-constant clouds of mist and fog. Climate change seems to be reducing this moisture. Two amphibian species have not been seen since the 1980s and are now presumed extinct.

South Pacific Ocean

Warming waters have become too hot for coral reefs in some places, leading to so-called "bleachings" in which large amounts of coral die. During 1998, warm temperatures killed off about 16 percent of all the world's coral.

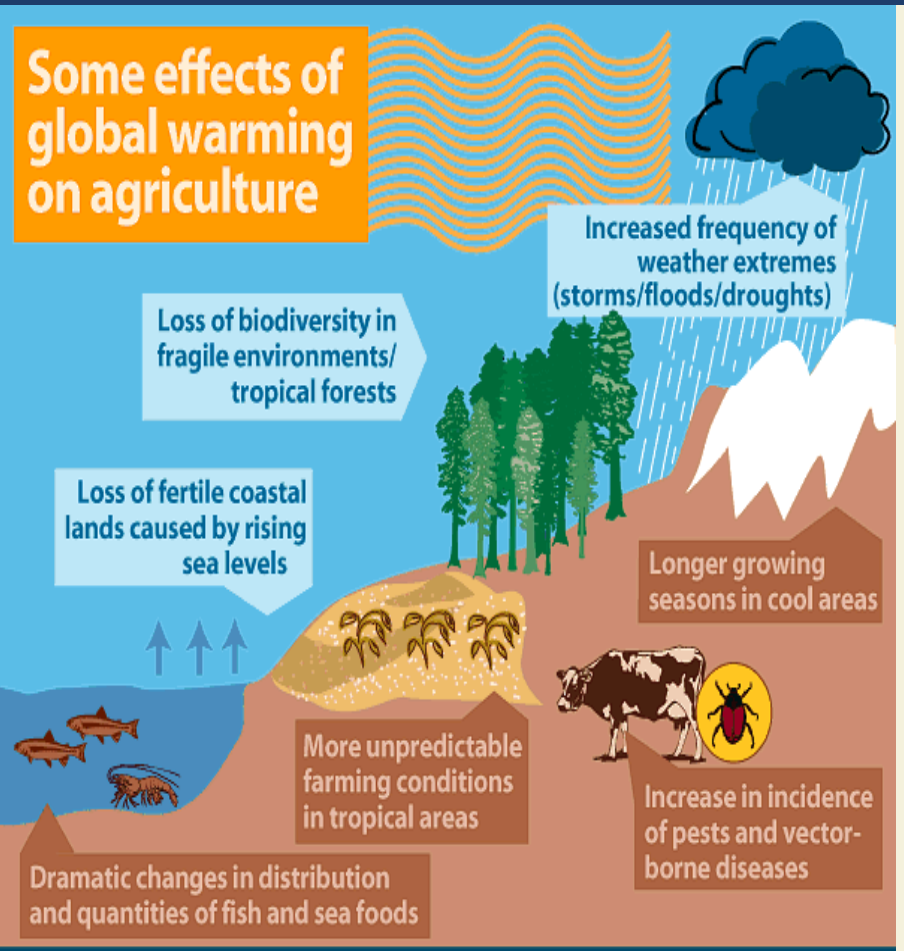
Beaufort and Chukchi seas, off Alaska

Walrus mothers in this area typically leave their young on the sea ice while they dive down to find food on the bottom. But now, sea ice is melting more rapidly than before, which can leave walrus calves floating helplessly in open water.

Exploding Populations of Mountain Pine Beetles in British Columbia, Canada

Fig. 19-13, p. 509

Agriculture Could Face an Overall Decline



- Regions of farming may shift
  - Decrease in tropical and subtropical areas
  - Increase in northern latitudes
    - Less productivity; soil not as fertile
- Hundreds of millions of people could face starvation and malnutrition

A Warmer World Is Likely to Threaten the Health of Many People

- Deaths from heat waves will increase
- Deaths from cold weather will decrease
- Higher temperatures can cause
  - Increased flooding
  - Increase in some forms of air pollution, more O_3
  - More insects, microbes, toxic molds, and fungi

Detection of Dengue Fever in Mosquitoes, as of 2005

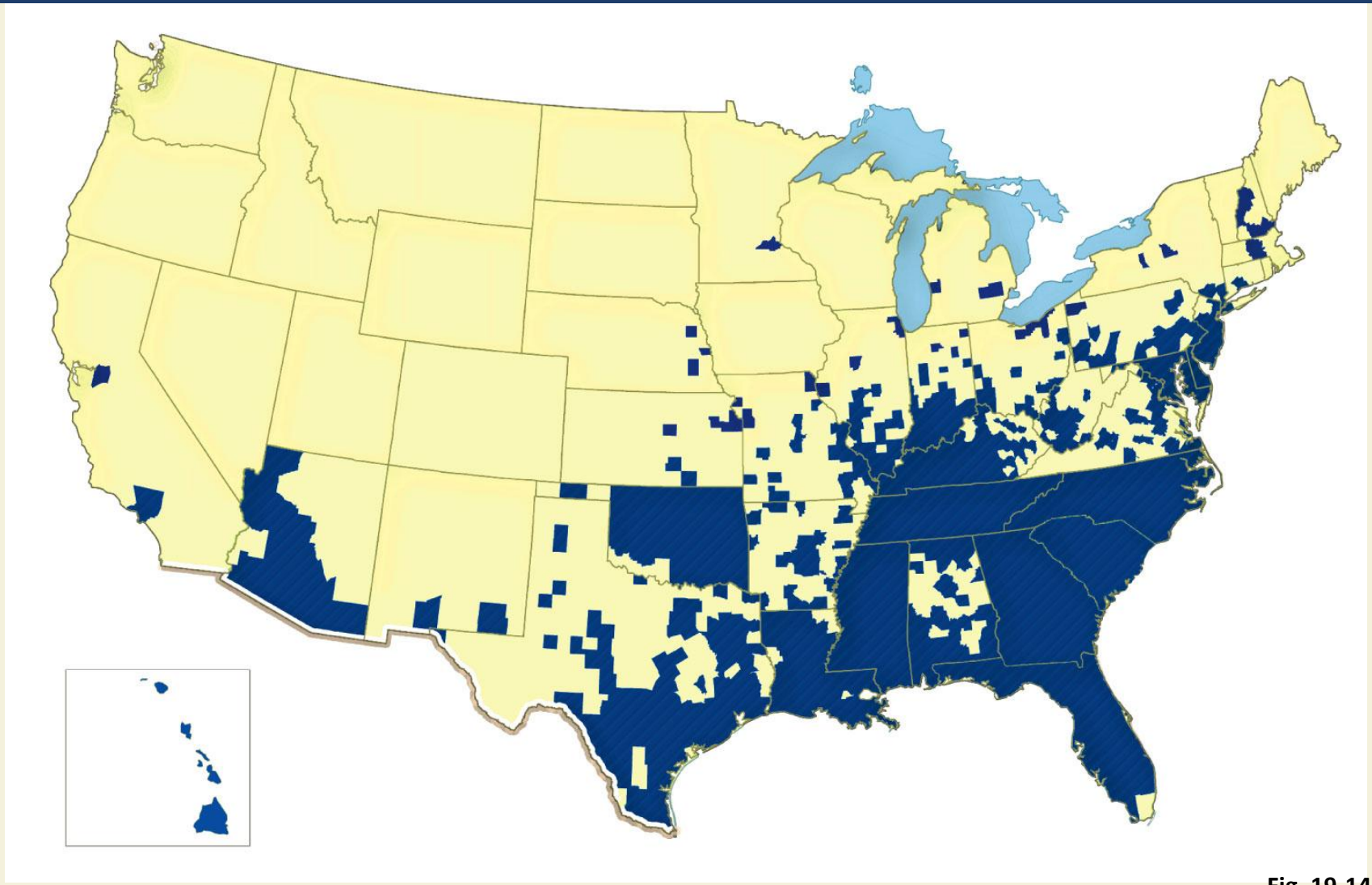


Fig. 19-14, p. 510

19-3 What Can We Do to Slow Projected Climate Disruption?

- ***Concept 19-3*** *To slow the projected rate of atmospheric warming and climate change, we can increase energy efficiency, sharply reduce greenhouse gas emissions, rely more on renewable energy resources, and slow population growth.*

Dealing with Climate Disruption Is Difficult

- Global problem with long-lasting effects
- Long-term political problem
- Harmful and beneficial impacts of climate change unevenly spread
- Many proposed actions disrupt economies and lifestyles
- Humans don’t deal well with long-term threats

Possible Climate-Change Tipping Points

- Atmospheric carbon level of 450 ppm
- Melting of all Arctic summer sea ice
- Collapse and melting of the Greenland ice sheet
- Severe ocean acidification, collapse of phytoplankton populations, and a sharp drop in the ability of the oceans to absorb CO_2
- Massive release of methane from thawing Arctic permafrost
- Collapse and melting of most of the western Antarctic ice sheet
- Severe shrinkage or collapse of Amazon rainforest

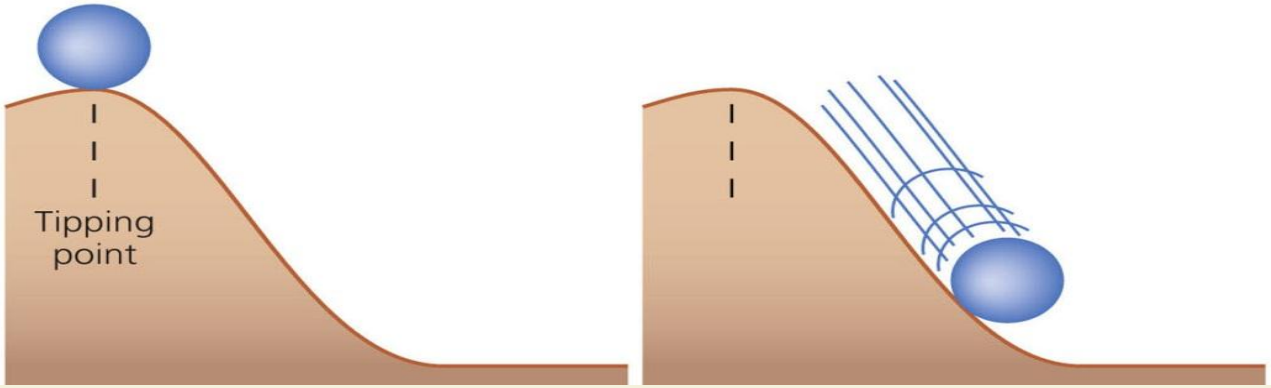


Fig. 19-15, p. 511

Science Focus: Science, Politics, and Climate

- 2006-2010: increase from 30% to 48% of Americans who think global warming is exaggerated

- Fossil fuel industries

- Play on public's lack of knowledge of
  - How science works
  - Difference between weather and climate

What Are Our Options?

- Three approaches
  1. Drastically reduce the amount of greenhouse gas emissions
  2. Devise strategies to reduce the harmful effects of global warming
  3. Suffer consequences of inaction

Solutions: Slowing Climate Disruption

Solutions

Slowing Climate Disruption

Prevention

Cut fossil fuel use (especially coal)

Shift from coal to natural gas

Improve energy efficiency

Shift to renewable energy resources

Transfer energy efficiency and renewable energy technologies to developing countries

Reduce deforestation

Use more sustainable agriculture and forestry

Put a price on greenhouse gas emissions

Reduce poverty

Slow population growth

Cleanup

Remove CO_2 from smokestack and vehicle emissions

Store (sequester) CO_2 by planting trees

Sequester CO_2 in soil by using no-till cultivation and taking cropland out of production

Sequester CO_2 deep underground (with no leaks allowed)

Sequester CO_2 in the deep ocean (with no leaks allowed)

Repair leaky natural gas pipelines and facilities

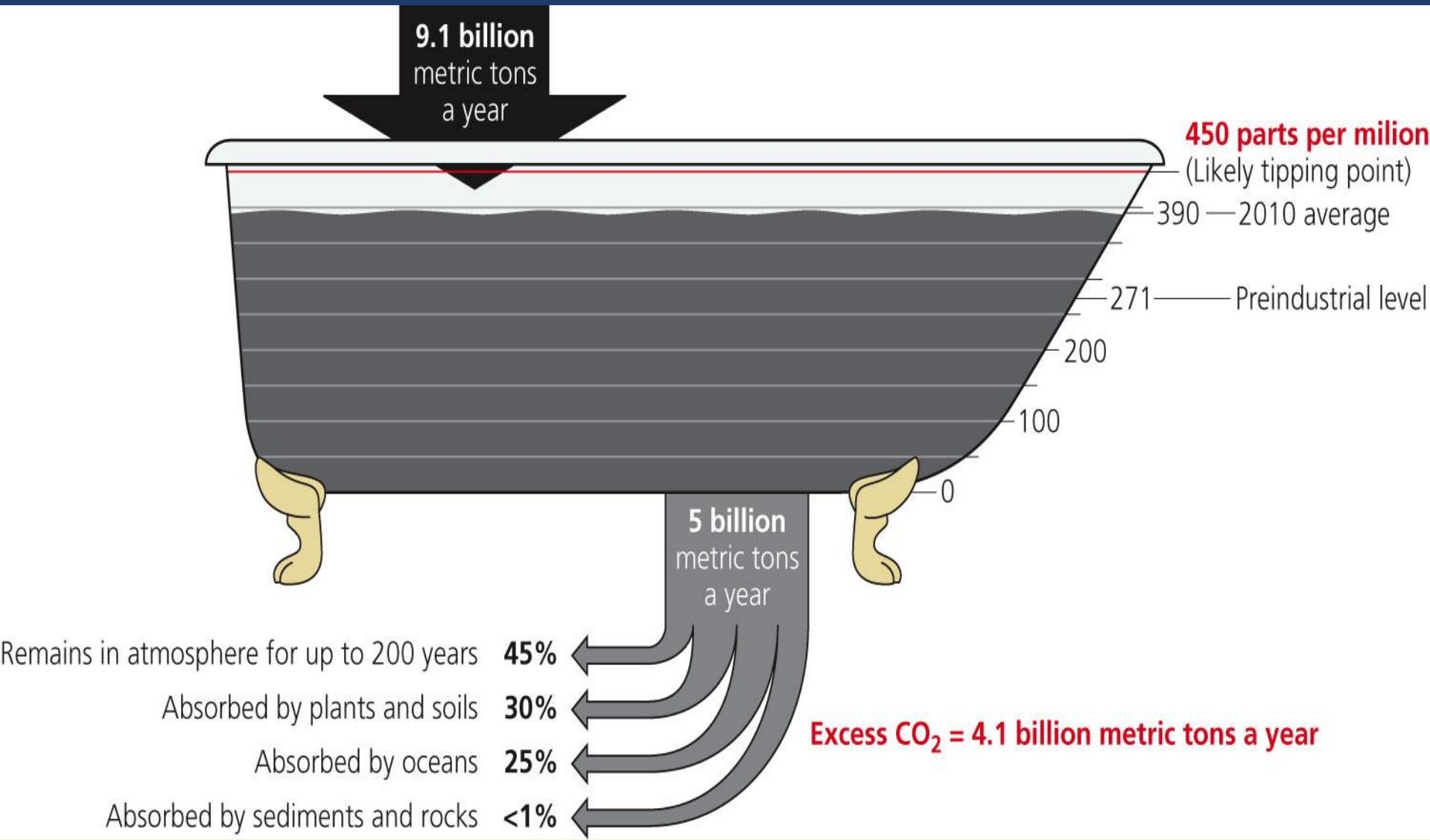
Use animal feeds that reduce CH_4 emissions from cows (belching)

Fig. 19-16, p. 513

Individuals Matter: John Sterman's Bathtub Model

- Atmosphere as a bathtub
- Inputs of CO_2
- Ways CO_2 is removed from atmosphere

Bathtub Model of CO_2 in Atmosphere



Prevent and Reduce Greenhouse Gas Emissions

- Improve energy efficiency to reduce fossil fuel use
- Increased use of low-carbon renewable energy resources
- Stop cutting down tropical forests
- Shift to more sustainable and climate-friendly agriculture

Collect Greenhouse Gas Emissions and Stash Them Somewhere

- Solutions
  1. Massive global tree planting; how many?
  2. Restore wetlands that have been drained for farming
  3. Plant fast-growing perennials on degraded land
  4. Preserve and restore natural forests
  5. Promote biochar
  6. Seed oceans with iron to stimulate growth of phytoplankton
  7. **Carbon capture and storage** – from coal-burning plants

Science Focus: Is Capturing and Storing CO_2 the Answer?

- **Carbon capture and storage (CCS)**

- Several problems with this approach
  - Large inputs of energy to work
    - Increasing CO_2 emissions
  - Promotes the continued use of coal (world's dirtiest fuel)
  - Effect of government subsidies and tax breaks
  - Stored CO_2 would have to remain sealed forever: no leaking

Capturing and Storing CO_2

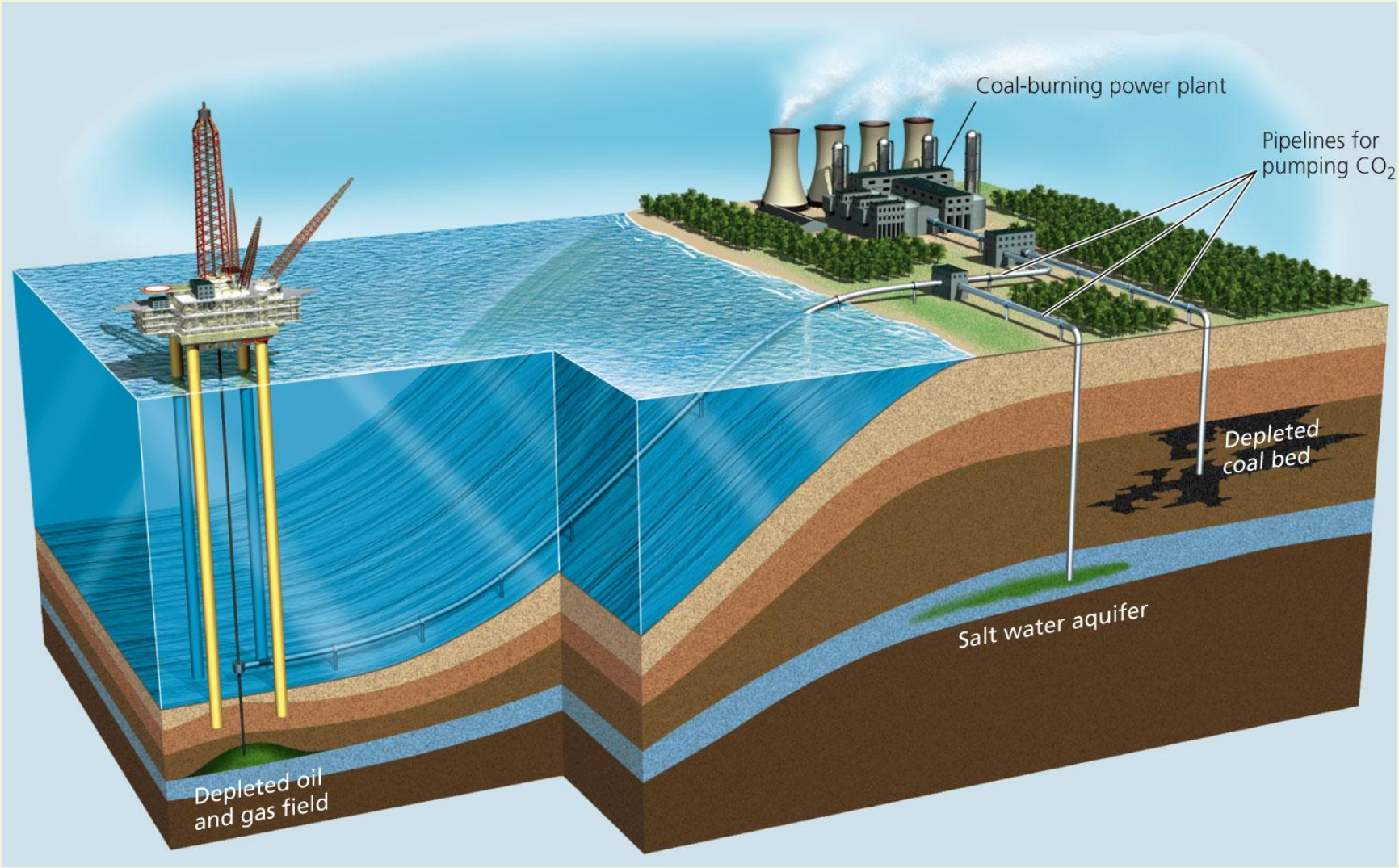


Fig. 19-E, p. 515

Some Propose Geo-Engineering Schemes to Help Slow Climate Change (1)

- Last resort, if other methods and policies fail
- Injection of sulfate particles into the stratosphere
  - Would it have a cooling effect?
  - Would it accelerate O_3 depletion?
- Giant mirrors in orbit around earth
- Large pipes to bring nutrients from bottom of ocean to top to promote algae growth

Some Propose Geo-Engineering Schemes to Help Slow Climate Change? (2)

- Doesn't address the continued build-up of CO_2 in the atmosphere
- All depend on costly and complex plans
- If any of these fixes fail, what about a rebound effect?

Governments Can Help Reduce the Threat of Climate Disruption

1. Strictly regulate CO_2 and CH_4 as pollutants
2. Carbon tax on fossil fuels
3. Cap-and-trade approach
4. Increase subsidies to encourage use of energy-efficient technology
5. Technology transfer

Trade-Offs: Carbon and Energy Taxes

Trade-Offs

Carbon and Energy Taxes

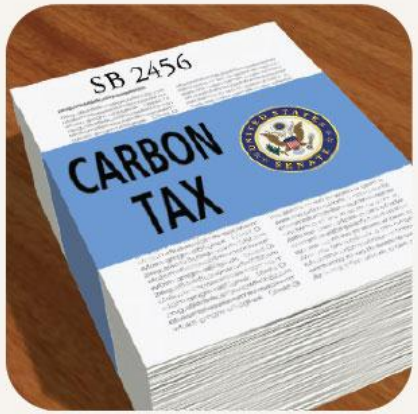
Advantages

Simple to administer

Clear price on carbon

Covers all emitters

Predictable revenues



Disadvantages

Tax laws can get complex

Vulnerable to loopholes

Doesn't guarantee lower emissions

Politically unpopular

Fig. 19-17, p. 516

Trade-Offs: Cap and Trade Policies

Trade-Offs

Cap and Trade Policies

Advantages

Clear legal limit on emissions

Rewards cuts in emissions

Record of success

Low expense for consumers

Disadvantages

Revenues not predictable

Vulnerable to cheating

Rich polluters can keep polluting

Puts variable price on carbon

Fig. 19-18, p. 516

VIDEO: How Does the Emission Trading Scheme Work?

Science Focus: What Is a Pollutant?

- Pollutant:
  - A chemical or any other agent that proves harmful to the health, survival, or activities of humans or other organisms
  - Carbon dioxide now classified as a pollutant
  - Concentration of carbon dioxide as the key factor

Governments Can Enter into International Climate Negotiations

- The Kyoto Protocol
  - 1997: Treaty to slow climate change
  - Reduce emissions of CO_2, CH_4, and N_2O by 2012 to 5.2% of 1990 levels
  - Not signed by the U.S.

- 2009 Copenhagen
  - Nonbinding agreement

Some Governments Are Leading the Way

- Costa Rica: goal to be carbon neutral by 2030
- China and India must change energy habits
- U.S. cities and states taking initiatives to reduce carbon emissions
  - California
  - Portland

Some Companies and Schools Are Reducing Their Carbon Footprints (1)

- Major global companies reducing greenhouse gas emissions
  - Alcoa
  - DuPont
  - IBM
  - Toyota
  - GE
  - Wal-Mart
    - Fluorescent light bulbs
    - Auxiliary power units on truck fleets

Some Companies and Schools Are Reducing Their Carbon Footprints (2)

- Colleges and universities reducing greenhouse gas emissions
  - Oberlin College, Ohio, U.S.
  - 25 Colleges in Pennsylvania, U.S.
  - Yale University, CT, U.S.

- What is your carbon footprint?

- What can you do?

What Can You Do? Reducing CO_2 Emissions

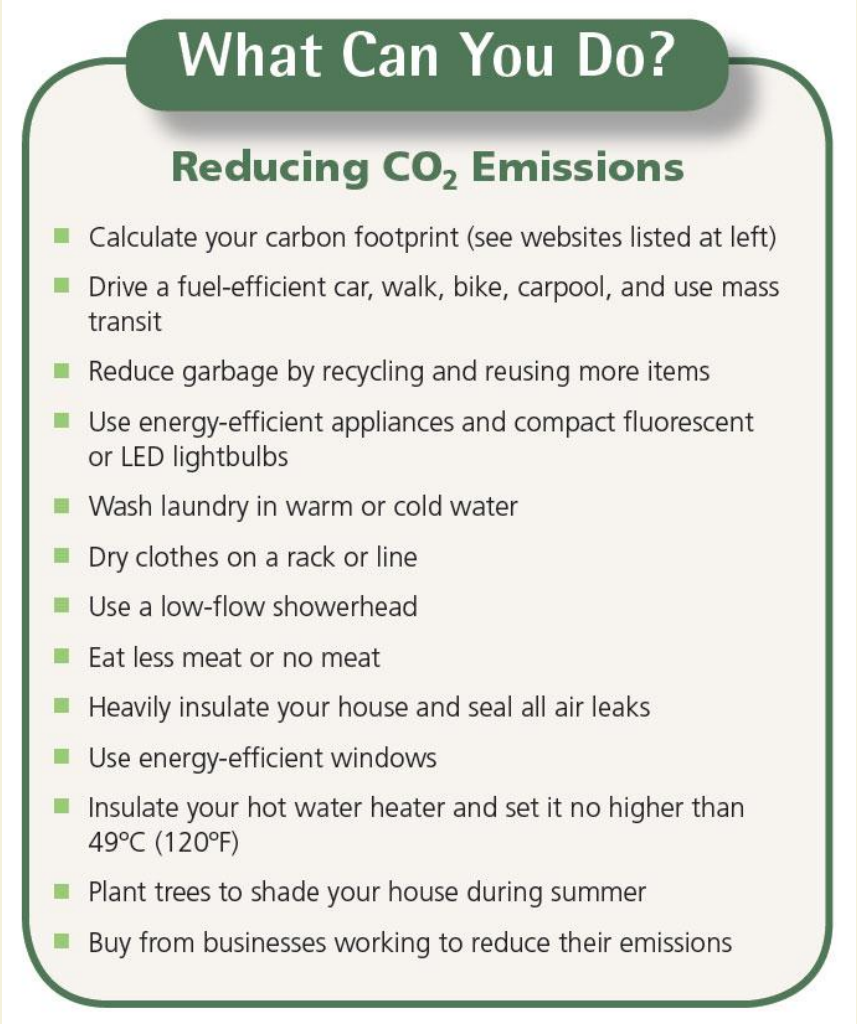
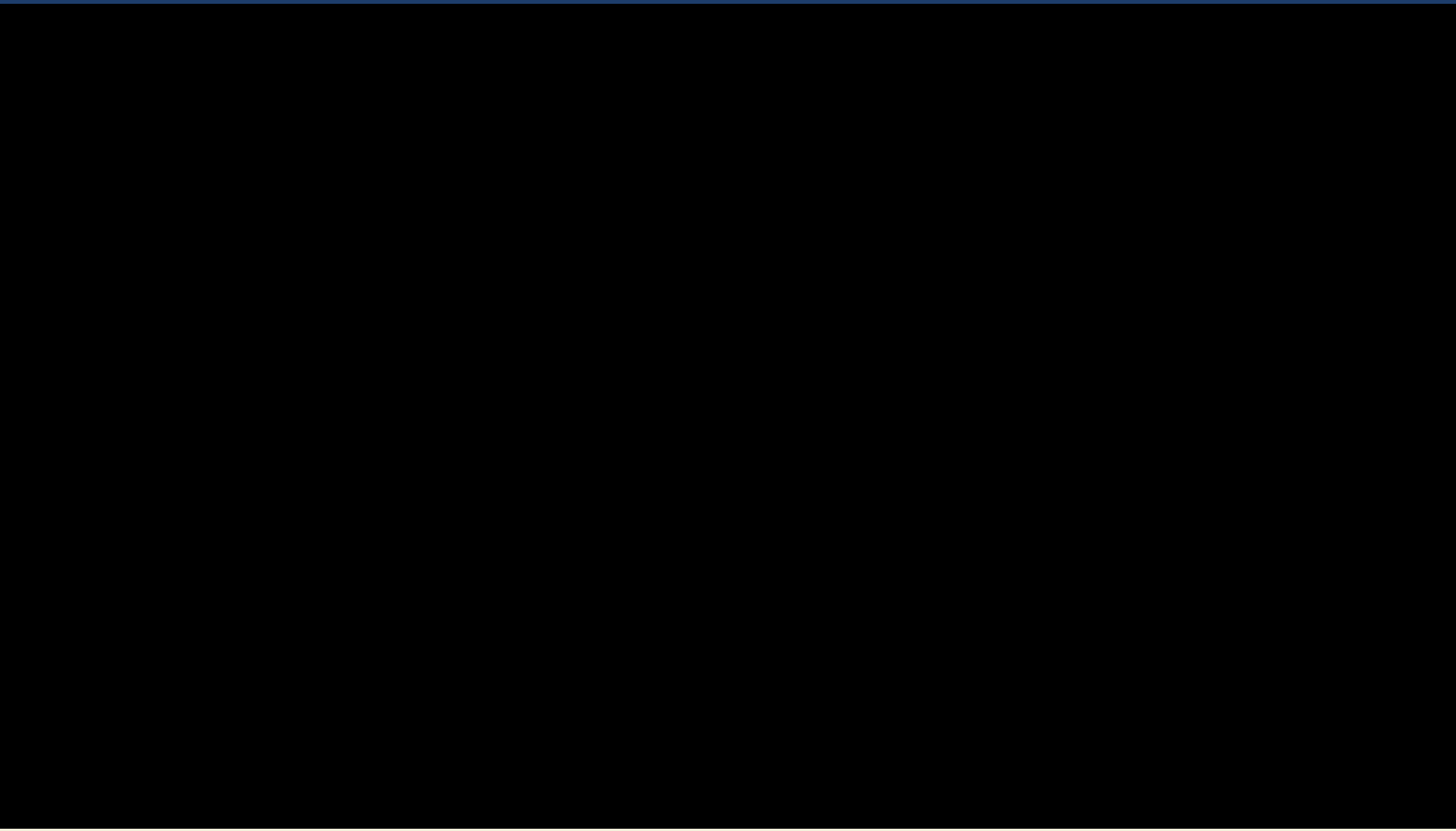


Fig. 19-19, p. 519

VIDEO: Reduce Your Carbon Footprint



We Can Prepare for Climate Disruption (1)

- Reduce greenhouse gas emissions as much as possible
- Move people from low-lying coastal areas
- Take measures against storm surges at coast
- Cooling centers for heat waves

We Can Prepare for Climate Disruption (2)

- Prepare for more intense wildfires
- Water conservation, and desalination plants

Ways to Prepare for the Possible Long-Term Harmful Effects of Climate Disruption

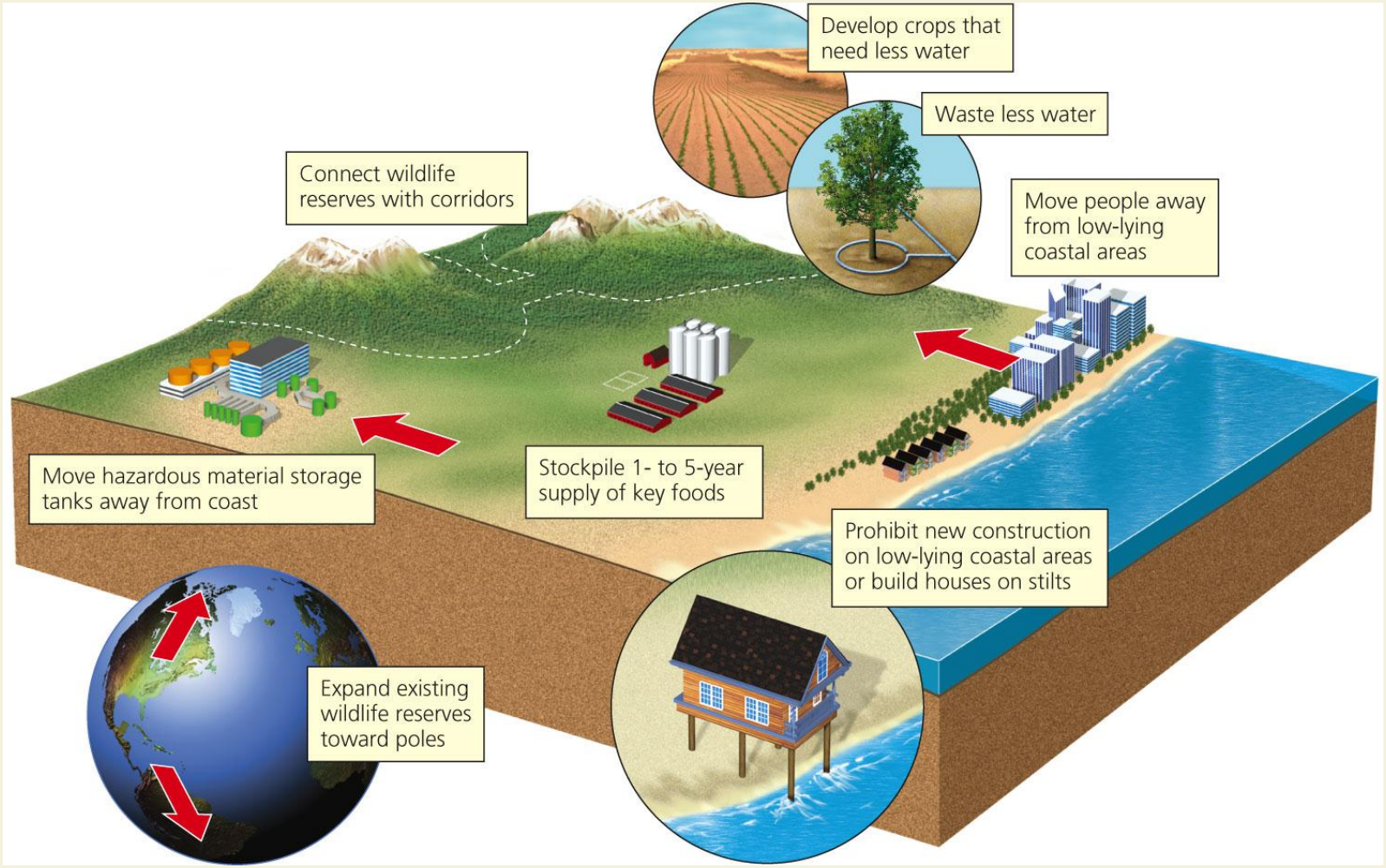


Fig. 19-20, p. 520

A No-Regrets Strategy

- What if climate models are wrong and there is no serious threat of climate disruption?

- No-regrets strategy
  - Environmental benefits
  - Health benefits
  - Economic benefits
  - Reduce pollution and energy use
  - Decrease deforestation
  - Promote biodiversity

19-4 How Have We Depleted O_3 in the Stratosphere and What Can We Do?

Concept 19-4A *Our widespread use of certain chemicals has reduced ozone levels in the stratosphere, which has allowed more harmful ultraviolet radiation to reach the earth's surface.*

Concept 19-4B *To reverse ozone depletion, we must stop producing ozone-depleting chemicals and adhere to the international treaties that ban such chemicals.*

The Discovery

- **In 1985, using satellites, balloons, and surface stations, a team of researchers had discovered a balding patch of ozone in the upper stratosphere, the size of the United States, over Antarctica.**

Team who discovered the hole 1985.
From left: Joe Farman, Brian Gardiner, and Jonathan Shanklin

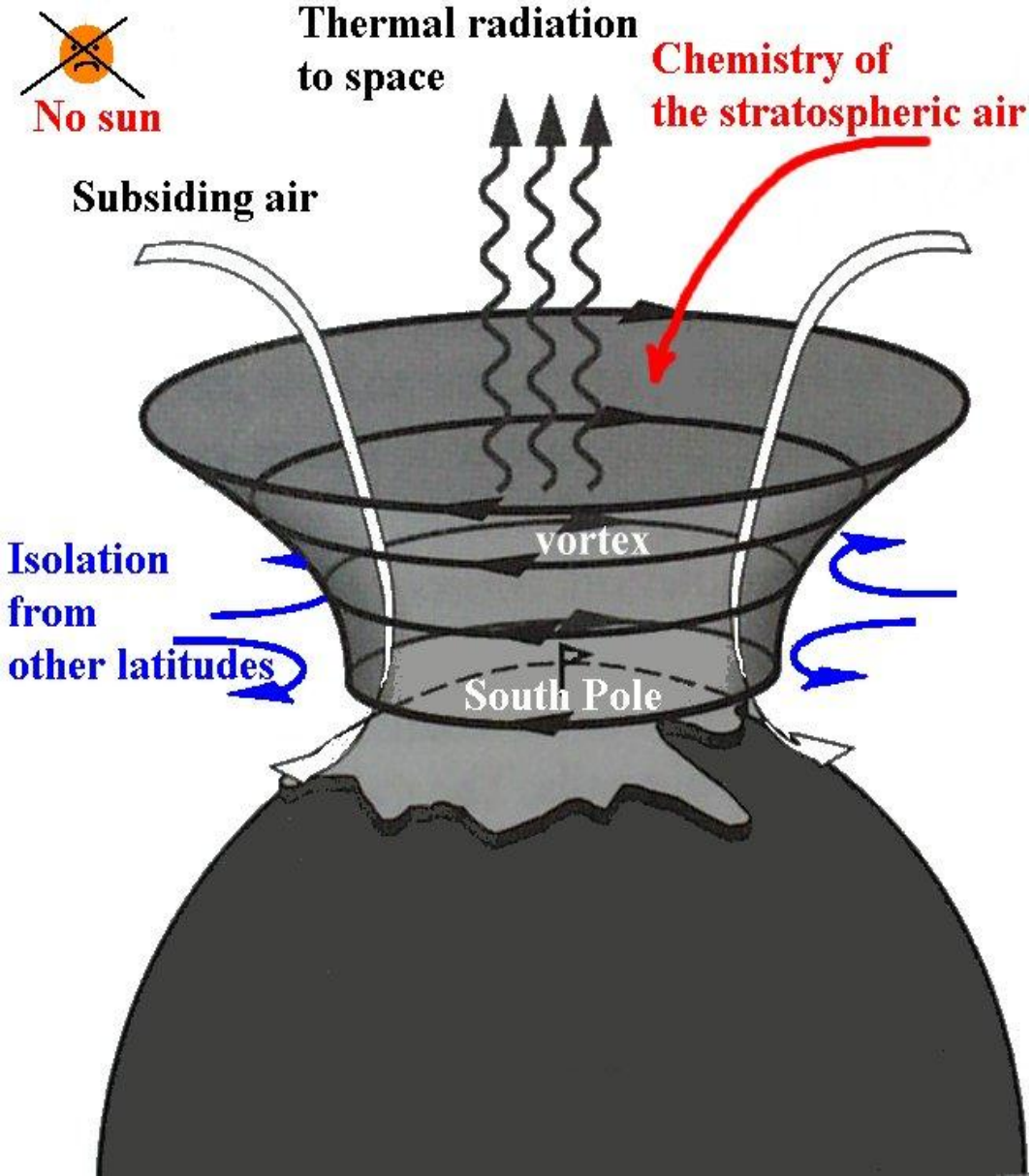
British Atlantic Survey Research station, Holly Bay, Antarctic coast

Total Ozone Mapping Spectrometer (TOMS)

- Used by NASA to measure ozone concentrations
- TOMS – a satellite-borne instrument
- TOMS launched in 1996 – makes 35 measurements every 8 seconds
- Levels of ozone are measured in Dobson units (DU), where 100 DU is equivalent to a 1 millimeter thick layer of pure ozone

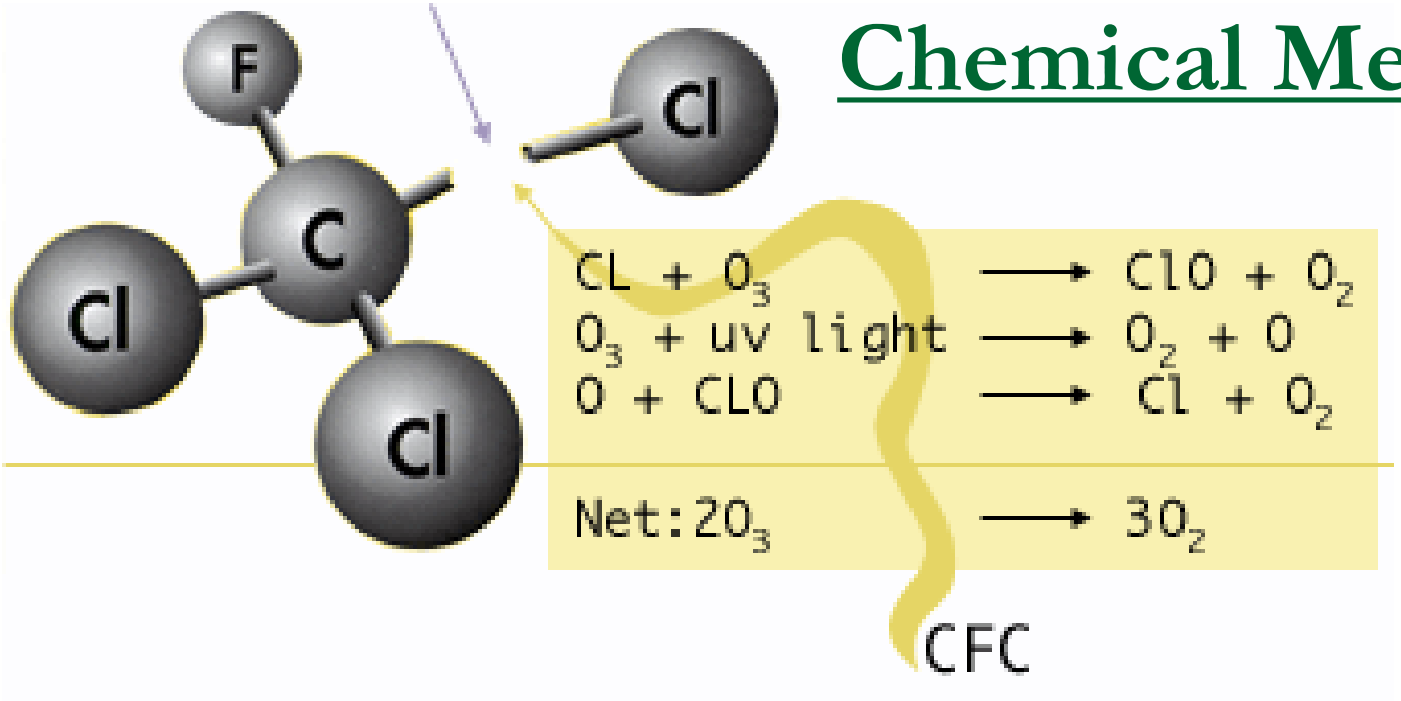
Artist's view of the QuikTOMS spacecraft (image credit: NASA)

Hole Formation Based on Two different mechanisms:

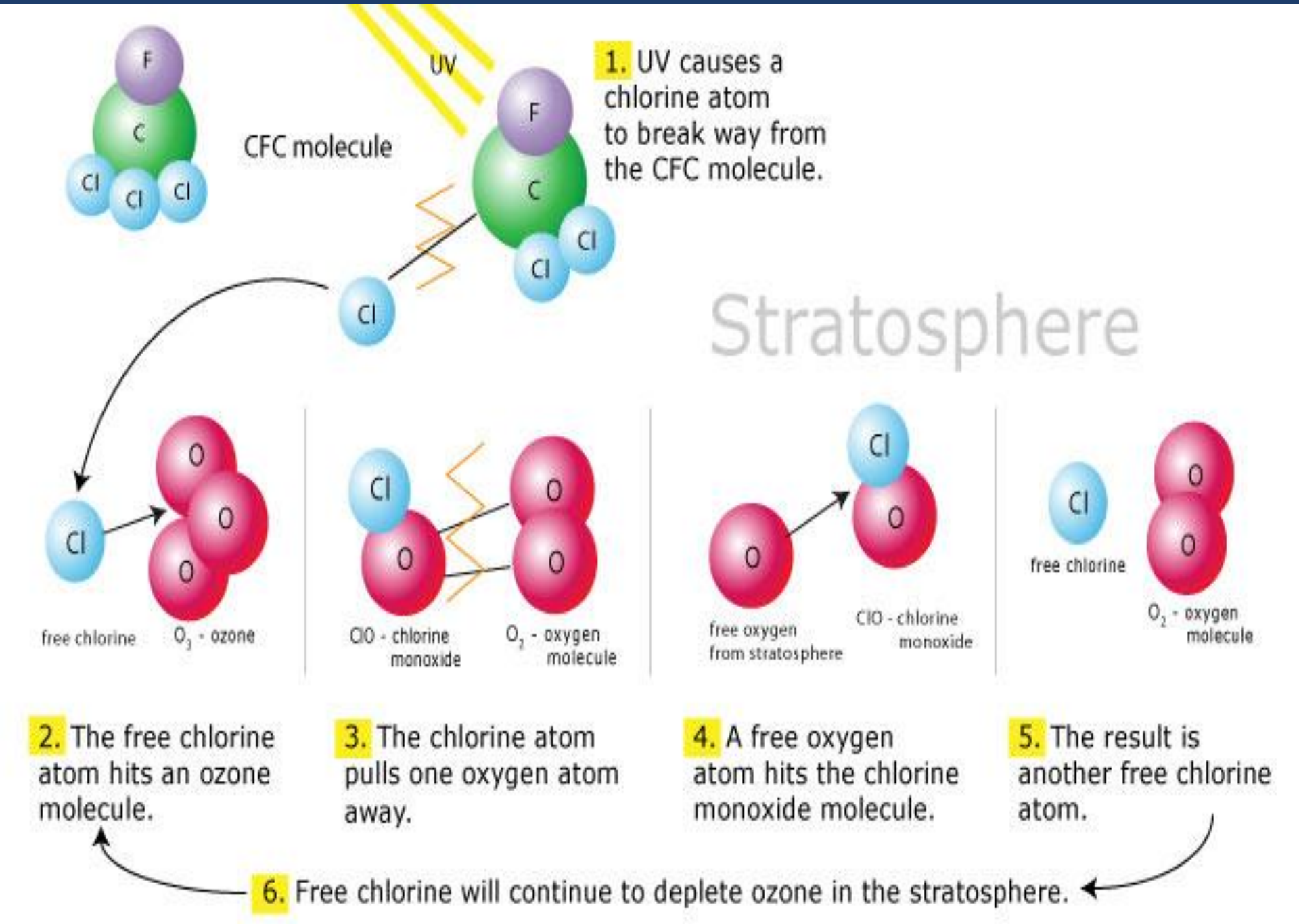


- Meteorological mechanism
  - Movement of air from one place to another in the upper stratosphere
  - Cold temperature in the upper atmosphere causes nitric acid to freeze into crystals forming wispy pink clouds
  - Forms a vortex of tightly twisted winds thus forming a hole in the upper atmosphere

Chemical Mechanism



- Different chemicals are responsible for the destruction of the ozone layer
- Topping the list :
  - chlorofluorocarbons (CFC's)
  - man-made, non-toxic and inert in the troposphere
  - In the stratosphere are photolysed, releasing reactive chlorine atoms that catalytically destroy ozone


F
C
Cl
Cl
Cl
CFC molecule
UV
F
C
Cl
Cl
Cl
1. UV causes a chlorine atom to break way from the CFC molecule.
Stratosphere
Cl
O
O
O
free chlorine
O_3 - ozone
2. The free chlorine atom hits an ozone molecule.
Cl
O
O
O
ClO - chlorine monoxide
O_2 - oxygen molecule
3. The chlorine atom pulls one oxygen atom away.
O
Cl
O
free oxygen from stratosphere
ClO - chlorine monoxide
4. A free oxygen atom hits the chlorine monoxide molecule.
Cl
free chlorine
O
O
O_2 - oxygen molecule
5. The result is another free chlorine atom.
6. Free chlorine will continue to deplete ozone in the stratosphere.

Our Use of Certain Chemicals Threatens the Ozone Layer

Ozone thinning

- Seasonal depletion in the stratosphere
  - Antarctica and Arctic
  - Affects Australia, New Zealand, South America, South Africa

1984: Rowland and Molina

- CFCs were depleting O_3

Why is loss of ozone over Antarctica seasonal during winter?

- its sunless
- steady winds blow in circular pattern over earth's poles
- creates polar vortex
- swirling mass of very cold air that is isolated from rest of atmosphere
  - until sun returns a few months later
- water droplets in clouds enter polar vortex
- form tiny ice crystals which collect CFCs on their surfaces
  - serve as catalysts for speeding up chemical reactions that release Cl & ClO
  - Cl and ClO react with each other to form Cl_2O_2
  - in dark of winter Cl_2O_2 molecules can't react with ozone so they accumulate in polar vortex

Why is loss of ozone over Antarctica seasonal during spring?

- when sunlight returns (October)
- Cl_2O_2 molecules are broken apart by UV light
- releasing large numbers of Cl atoms
  - which begin reacting with ozone
- sunlight
- gradually melts ice crystals
- breaks up vortex of trapped polar air
- allows trapped air to begin mixing with rest of atmosphere
- within weeks
- 40-50% of ozone above Antarctica is destroyed
- when vortex breaks up
- huge masses of ozone depleted air above Antarctica flows northward
  - lingers for few weeks over Australia, New Zealand, South America, South Africa
  - resulting in increases of 3-20% levels of biologically damaging UV-B radiation

Natural Capital Degradation: Massive Ozone Thinning over Antarctica in 2009

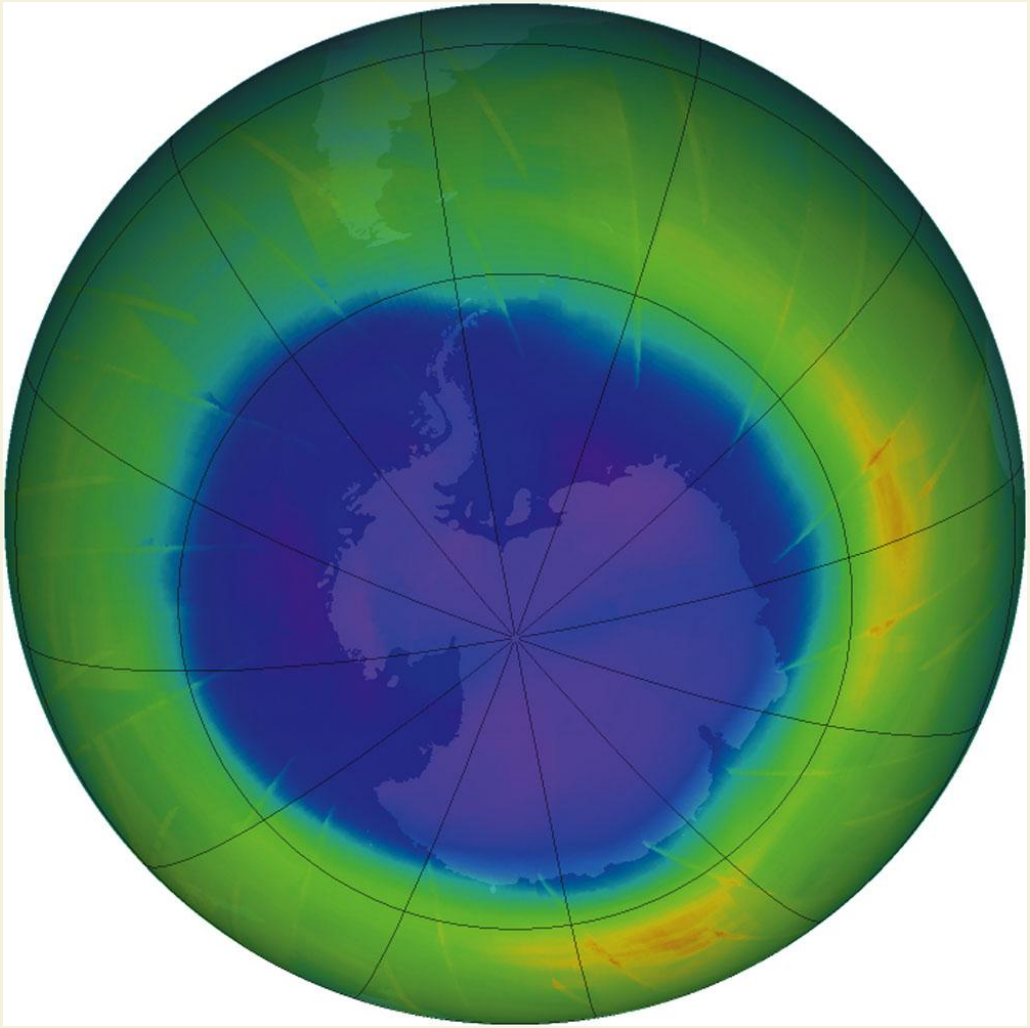
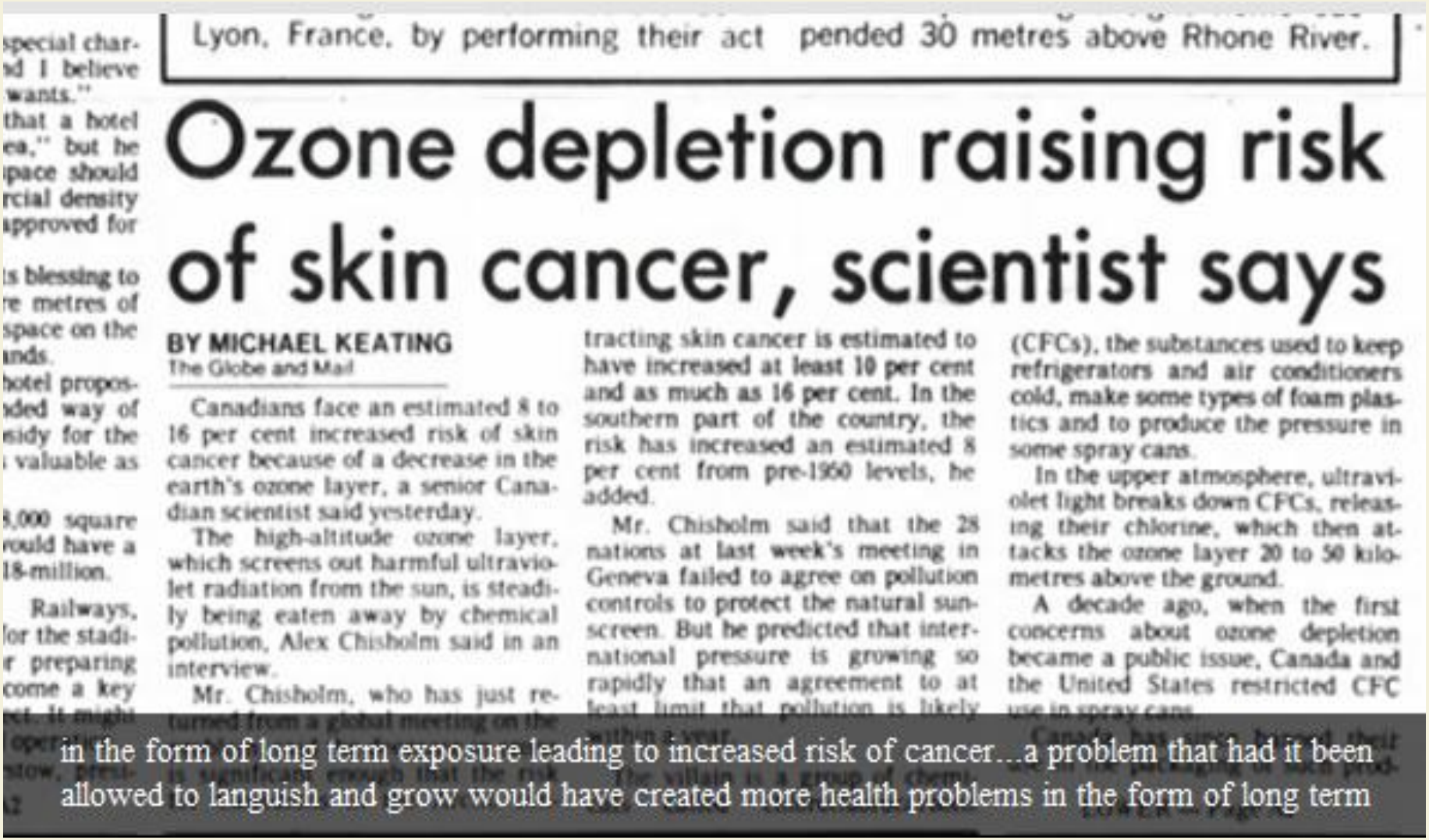


Fig. 19-21, p. 521

VIDEO: From Discovery, To Solution, To Evolution: Observing Earth's Ozone Layer



Lyon, France, by performing their act pended 30 metres above Rhone River.

Ozone depletion raising risk of skin cancer, scientist says

BY MICHAEL KEATING
The Globe and Mail

Canadians face an estimated 8 to 16 per cent increased risk of skin cancer because of a decrease in the earth's ozone layer, a senior Canadian scientist said yesterday.

The high-altitude ozone layer, which screens out harmful ultraviolet radiation from the sun, is steadily being eaten away by chemical pollution, Alex Chisholm said in an interview.

Mr. Chisholm, who has just returned from a global meeting on the

tracting skin cancer is estimated to have increased at least 10 per cent and as much as 16 per cent. In the southern part of the country, the risk has increased an estimated 8 per cent from pre-1960 levels, he added.

Mr. Chisholm said that the 28 nations at last week's meeting in Geneva failed to agree on pollution controls to protect the natural sunscreen. But he predicted that international pressure is growing so rapidly that an agreement to at least limit that pollution is likely

(CFCs), the substances used to keep refrigerators and air conditioners cold, make some types of foam plastics and to produce the pressure in some spray cans.

In the upper atmosphere, ultraviolet light breaks down CFCs, releasing their chlorine, which then attacks the ozone layer 20 to 50 kilometres above the ground.

A decade ago, when the first concerns about ozone depletion became a public issue, Canada and the United States restricted CFC use in spray cans.

in the form of long term exposure leading to increased risk of cancer...a problem that had it been allowed to languish and grow would have created more health problems in the form of long term

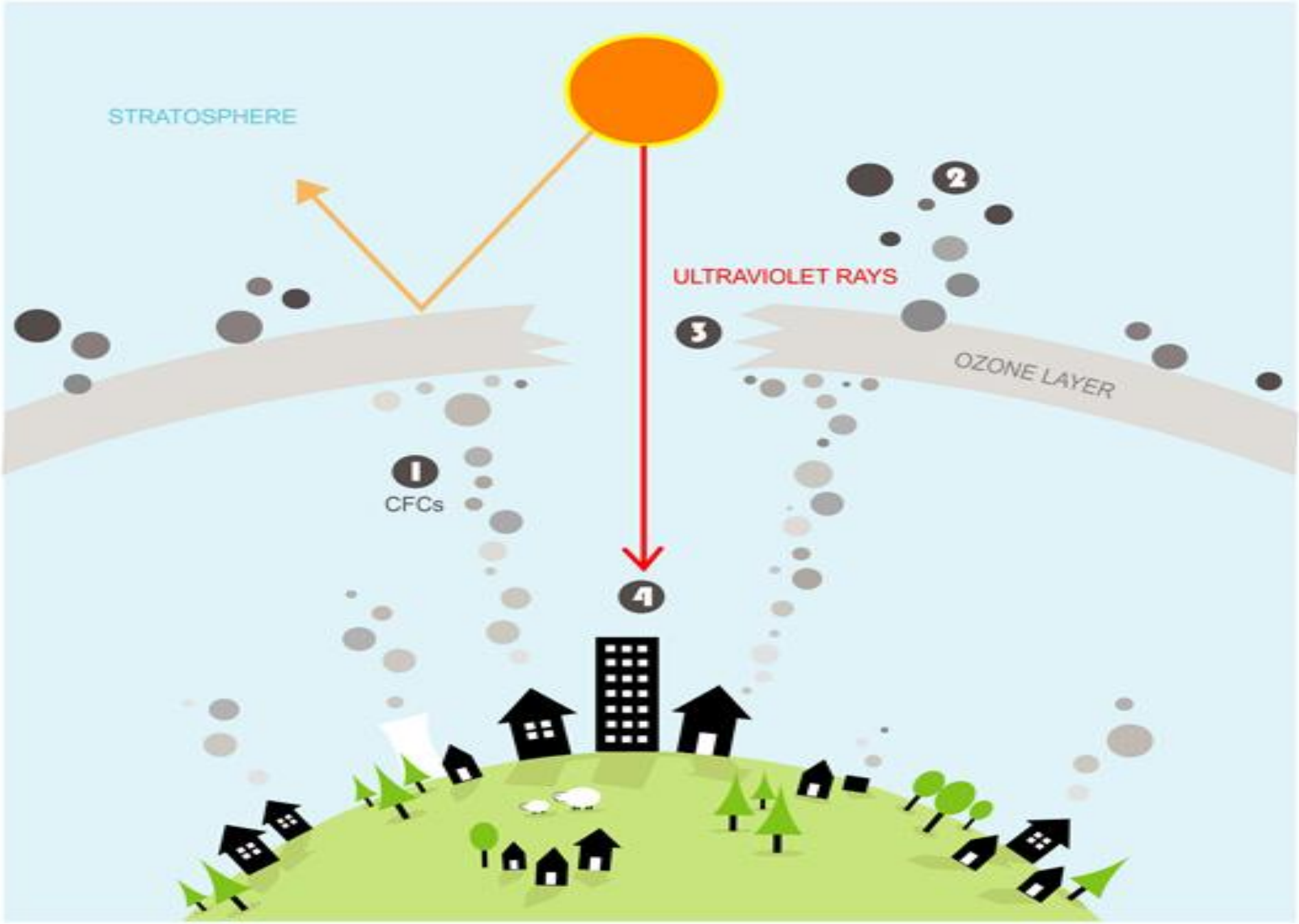
Individuals Matter: Rowland and Moline—A Scientific Story of Courage and Persistence

- Research
  - CFCs are persistent in the atmosphere
  - Rise into the stratosphere over 11-20 years
  - Break down under high-energy UV radiation
    - Halogens produced accelerate the breakdown of O_3 to O_2
  - Each CFC molecule can last 65-385 years

- 1988: Dupont stopped producing CFCs

- 1995: Nobel Prize in chemistry

ozone depletion



VIDEO: Ozone Layer

Why Should We Worry about Ozone Depletion?

- Damaging UV-A and UV-B radiation
  - Increase eye cataracts and skin cancer
- Impair or destroy phytoplankton
  - Significance?

Natural Capital Degradation: Effects of Ozone Depletion

Natural Capital Degradation

Effects of Ozone Depletion

Human Health

- Worse sunburns
- More eye cataracts and skin cancers
- Immune system suppression

Food and Forests

- Reduced yields for some crops
- Reduced seafood supplies from reduced phytoplankton
- Decreased forest productivity for UV-sensitive tree species

Climate Change

- While in troposphere, CFCs act as greenhouse gases

Wildlife

- Increased eye cataracts in some species
- Decreased populations of aquatic species sensitive to UV radiation
- Reduced populations of surface phytoplankton
- Disrupted aquatic food webs from reduced phytoplankton

Air Pollution and Materials

- Increased acid deposition
- Increased photochemical smog
- Degradation of outdoor paints and plastics

Fig. 19-22, p. 522

Effects of UV radiation on biological organisms

- **DNA damage** …….. Maximum effect on small and single cell organisms
- **Impaired growth and photosynthesis** ...poor crop yields
- **Phytoplankton**: ……...Reduced uptake of CO2
  ……..mortality
  ……..Impaired reproductive capacity
- **Nitrogen-fixing soil bacteria**…… Reduced, damaged
- **Human health effects**:

  Suppressed immune system……..Enhanced susceptibility to infection
  ……..Increase risk of Cancer
  Dermatology (skin)……...Sunburn
  ……....Loss of skin elasticity (Premature aging)
  …… Photosensitivity
  Neoplasia (cancer)……...Melanocytic (malignant melanoma)
  ……....Squamous cell skin – cancer
  ……Basal skin – cancer
  Still questionable if causes lip cancer or cancer of the salivary glands
  Oculur (Eye)…….....Cataract
  ……...Pterygium

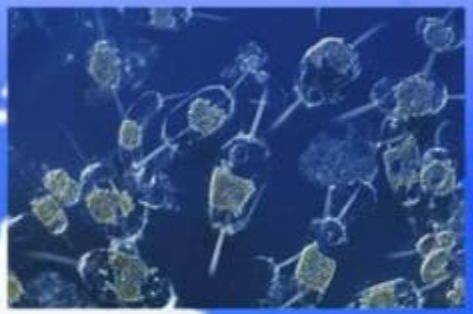
(last, 1993)

UVB causes a clouding of the eye's lens

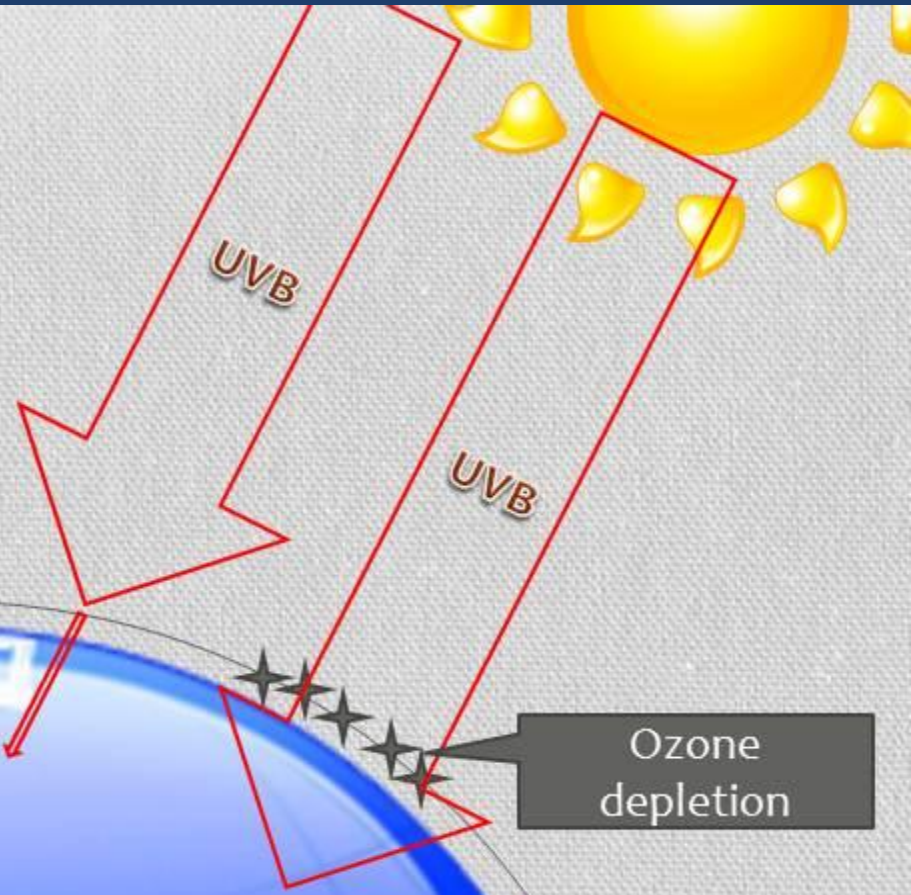
UVB causes skin cancer

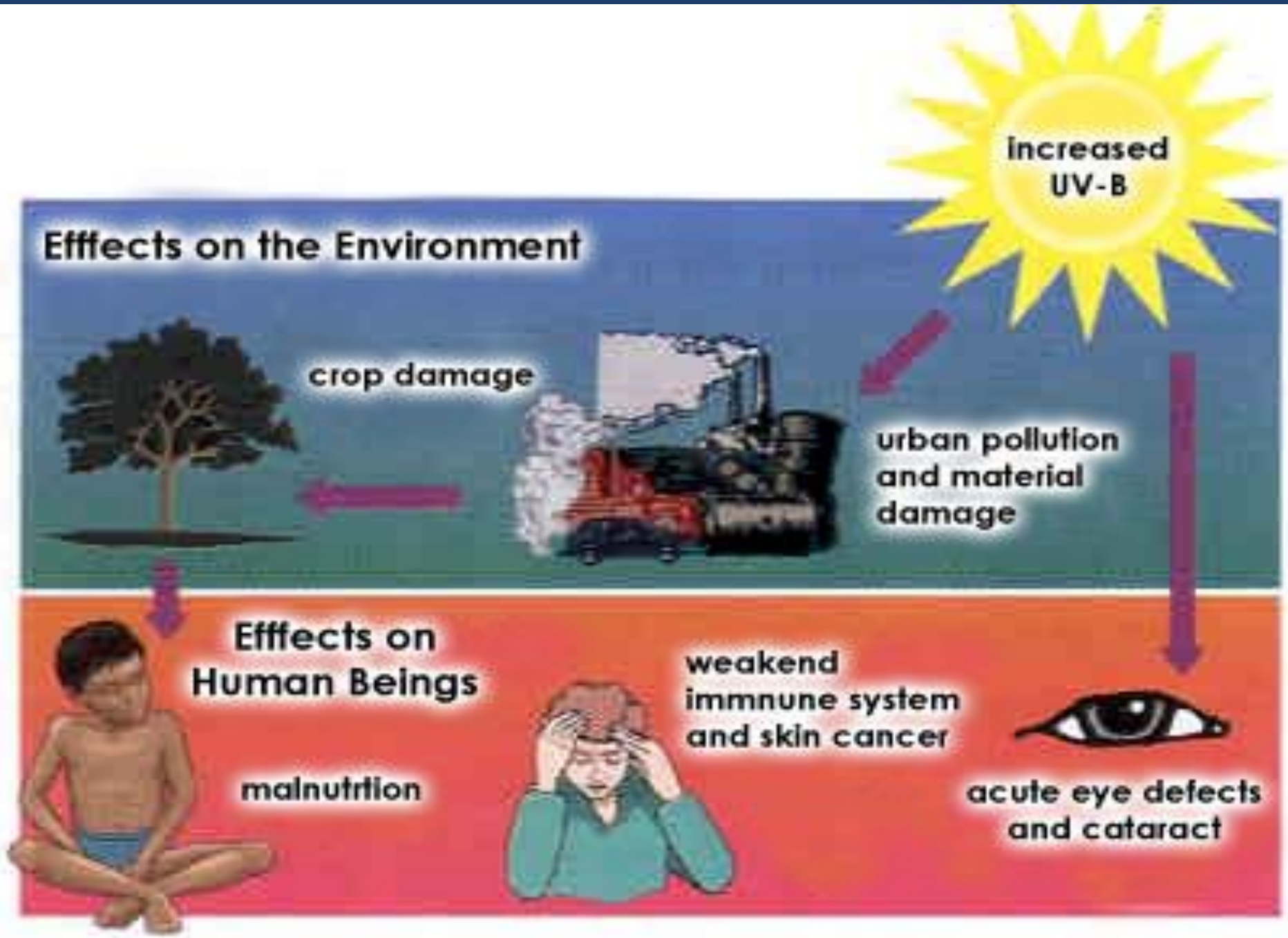
UVB alters terrestrial and aquatic biogeochemical cycle.

UVB deteriorates plant development



The exposure to UVB reduces phytoplankton, the foundation of marine food web




increased
UV-B
Efffects on the Environment
crop damage
urban pollution
and material
damage
Efffects on
Human Beings
malnutrtion
weakend
immnune system
and skin cancer
acute eye defects
and cataract

What Can You Do? Reducing Exposure to UV Radiation

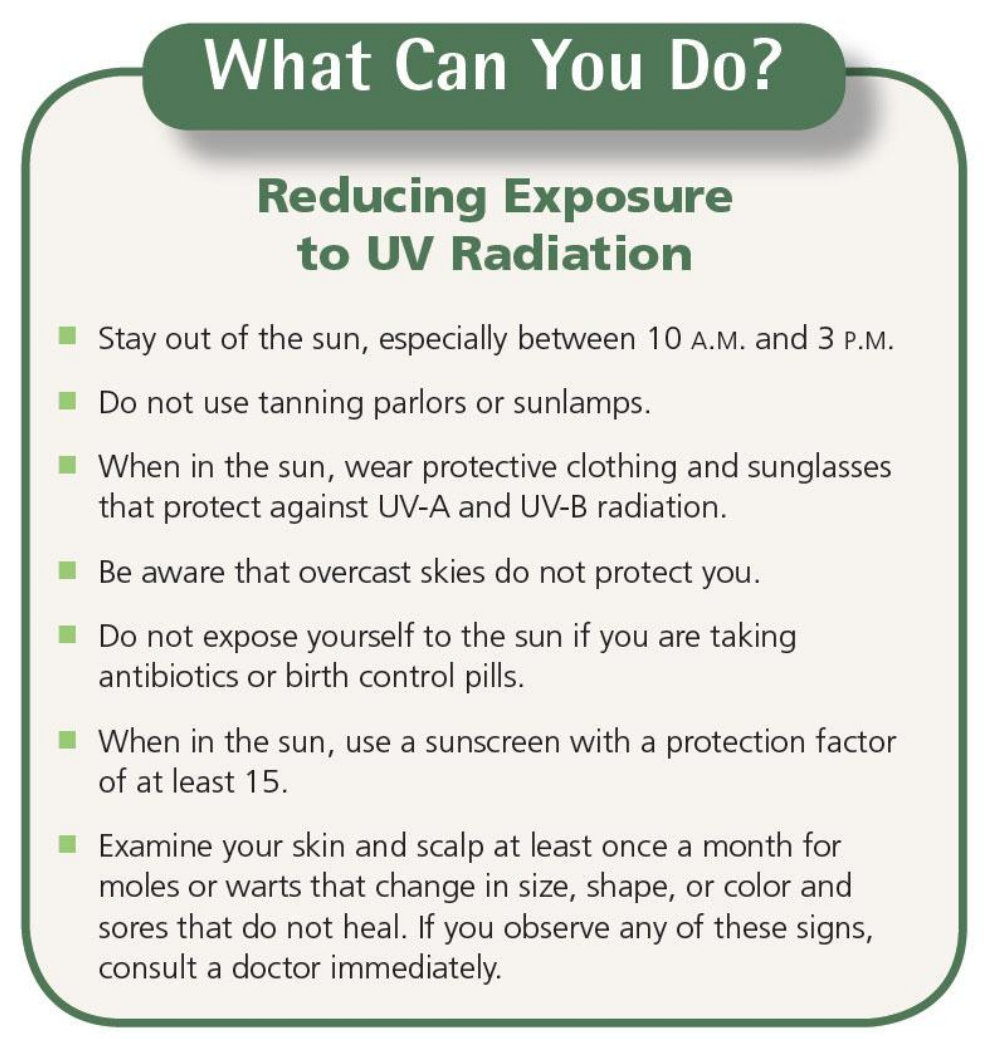


Fig. 19-23, p. 523

We Can Reverse Stratospheric Ozone Depletion (1)

- Stop producing all ozone-depleting chemicals
- 60–100 years of recovery of the O_3 layer
- 1987: Montreal Protocol
- 1992: Copenhagen Protocol
- Ozone protocols: prevention is the key

What Is Being Done to Counter the Effects of Ozone Depletion?

- **<u>Montreal Protocol</u> (adopted in 1987)** – panel of experts was formed to investigate substances responsible for hole formation
  - Established policies that prevent future use of certain types of chemicals
  - Stipulated that the production and consumption of compounds contributing towards depletion of ozone in the stratosphere were to be phased out by the year 2000 (2005 for methylchloroform)

The Environmental Protection Agency (EPA)

- Responsible for enforcing the Montreal Protocol within the U.S.
  - The EPA has several programs in place;
    - Regulating and enforcing on-road car and truck air-conditioning systems
    - Regulating most air-conditioning and refrigeration appliances
    - Technician certification
    - Service equipment

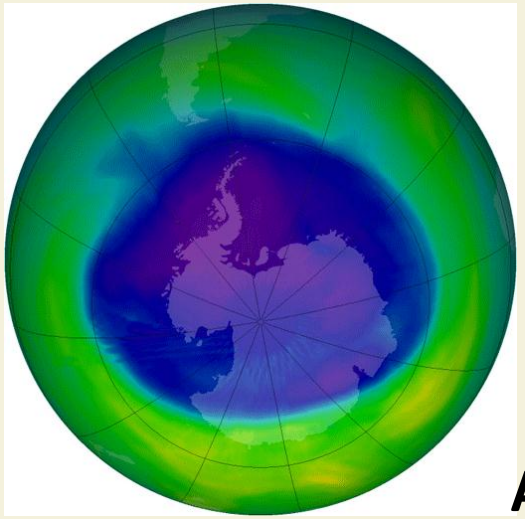
Signs of Recovery???

There have been some signs of recovery

- 1997 satellite showed a decline of several known ozone-depleting gases
- Satellite images show some slowing down of ozone loss

However….

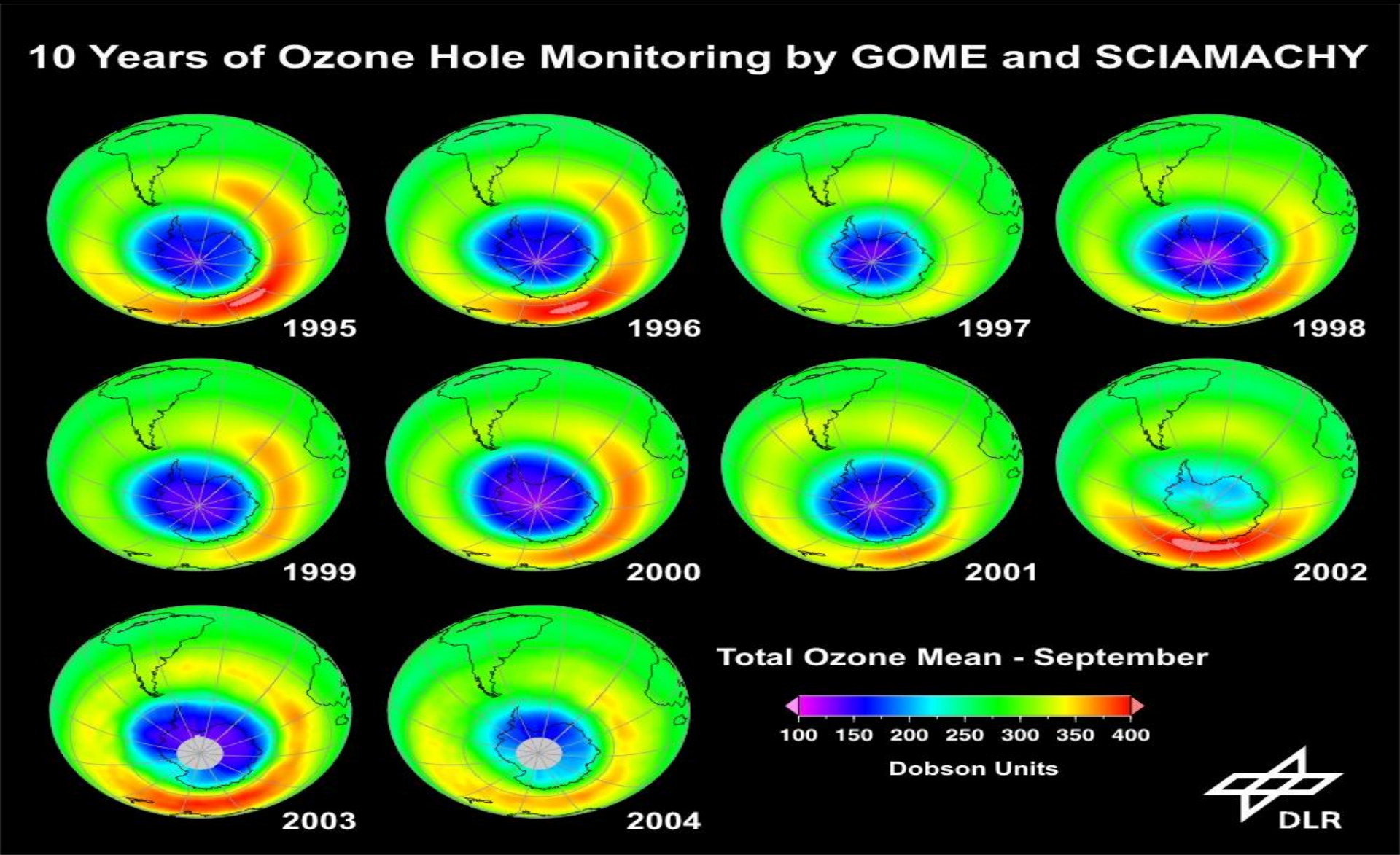
Recovery is slow



Antarctica - Dec. 2005

www.coolantarctica.com/. ../ozone_hole.htm

Images of Antarctica Taken Indicate A Slow Recovery



We Can Reverse Stratospheric Ozone Depletion (2)

- Substitutes for CFCs are available
- More are being developed
- HCFC-22
  - Substitute chemical
  - May still be causing ozone depletion
  - 2009: U.S. asks UN for mandatory reductions in HFC emissions through Montreal Protocol

Three Big Ideas

1. Considerable scientific evidence indicates that the earth's atmosphere is warming, mostly because of human activities, and that this is likely to lead to significant climate disruption during this century that could have severe and long-lasting harmful consequences.

Three Big Ideas

2. Reducing the projected harmful effects of rapid climate disruption during this century requires emergency action to increase energy efficiency, sharply reduce greenhouse gas emissions, rely more on renewable energy resources, and slow population growth.

3. We need to continue phasing out the use of chemicals that have reduced ozone levels in the stratosphere and allowed more harmful ultraviolet radiation to reach earth's surface.