

# ENVIRONMENT

*THE SCIENCE BEHIND THE STORIES*

Jay Withgott • Scott Brennan

## Ch 18

### Global Climate Change

Part 2: Environmental Issues  
and the Search for Solutions

PowerPoint® Slides prepared by  
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**Third Edition**

# Our dynamic climate

- Climate influences everything around us
- The 2007 Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) made it clear that:
  - Climate is changing, we are the cause, and this change is already exerting impacts that will become increasingly severe
- Al Gore's movie *An Inconvenient Truth* has been seen by millions
- Climate change is the fastest-moving area of environmental science today

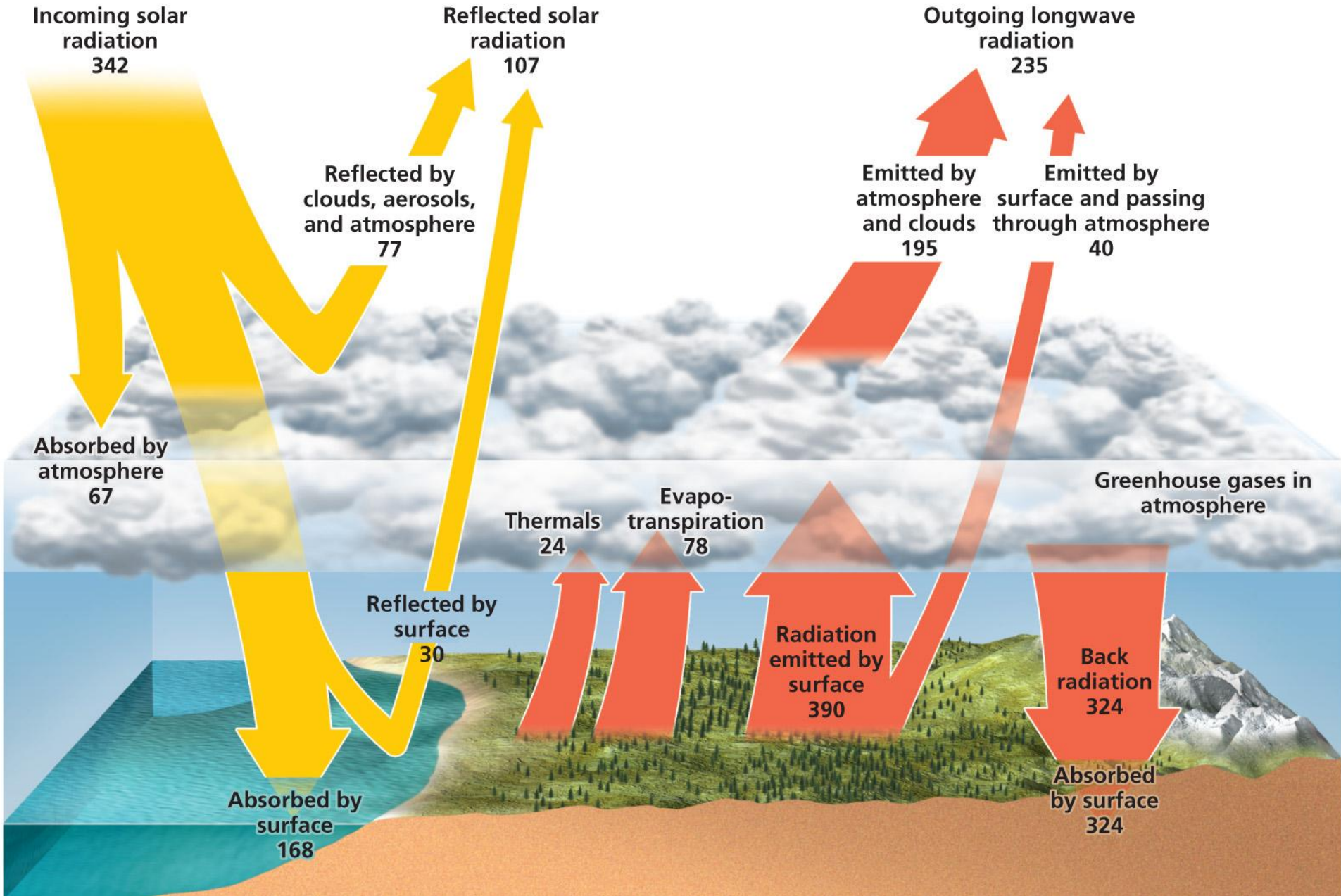
# What is climate change?

- **Climate** = an area's long-term atmospheric conditions
  - Temperature, moisture content, wind, precipitation, etc.
- **Global climate change** = describes trends and variations in Earth's climate
  - Temperature, precipitation, storm frequency
- **Global warming** = an increase in Earth's average temperature
  - Earth's climate has varied naturally through time
  - The rapid climatic changes taking place now are due to human activity: fossil fuels, combustion, and deforestation
  - It is only one aspect of global climate change

# The Sun and atmosphere keep the Earth warm

- Three factors exert more influence on climate than all others
- The Sun = without it, the Earth would be dark and frozen
  - Also supplies most of our planet's energy
- The atmosphere = without it, the Earth's temperature would be much colder
  - Earth's atmosphere, clouds, land, ice, and water absorb 70% of incoming solar radiation
- The oceans = shape climate by storing and transporting heat and moisture

# The fate of solar radiation



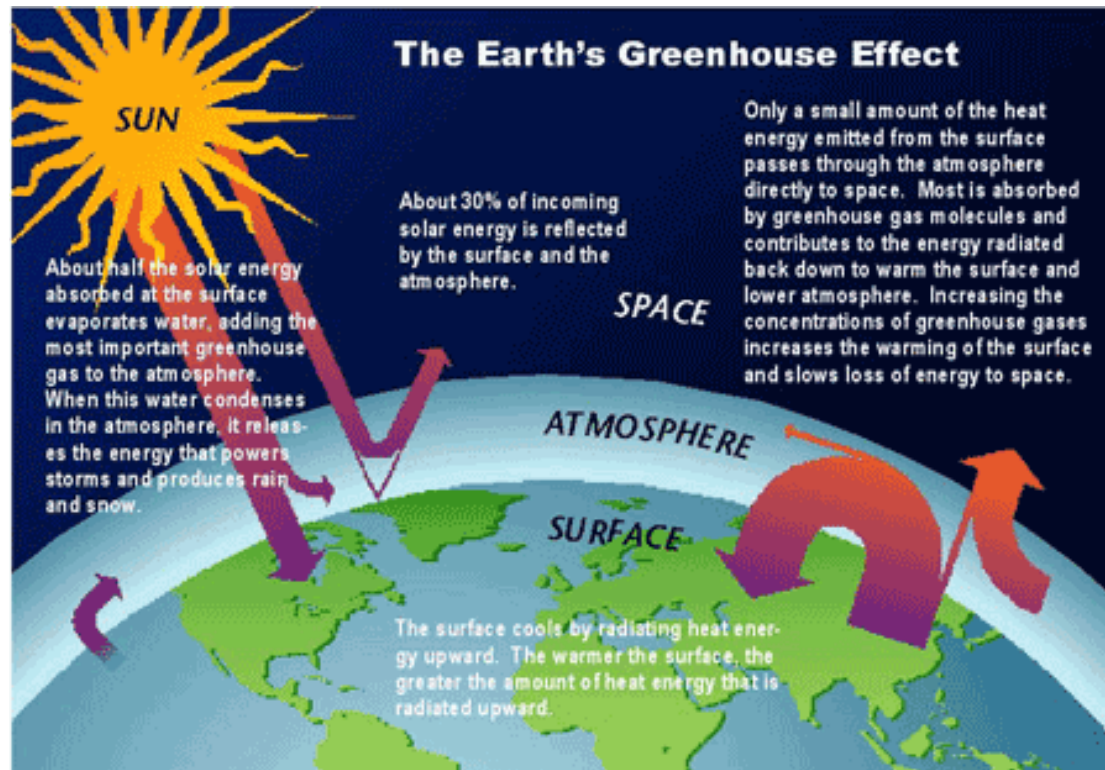


# Greenhouse gases warm the lower atmosphere

- As Earth's surface absorbs solar radiation, the surface increases in temperature and emits infrared radiation
- **Greenhouse gases** = atmospheric gases that absorb infrared radiation
  - Water vapor, ozone, carbon dioxide, nitrous oxide, methane, chlorofluorocarbons (CFCs)
  - Greenhouse gases differ in their ability to warm the troposphere and surface

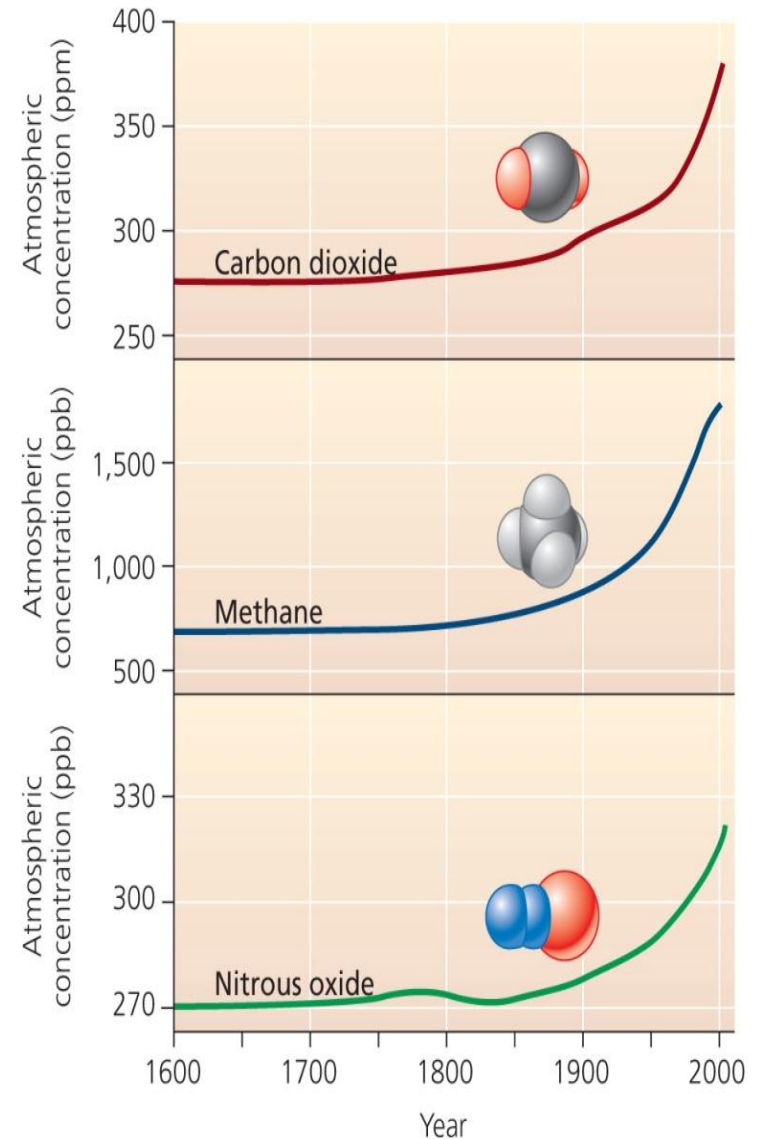
# The greenhouse effect

- After absorbing radiation, greenhouse gases re-emit infrared energy
  - Some energy is lost to space
  - **Greenhouse effect** = some energy travels back downward, warming the atmosphere and planet's surface



# Carbon dioxide is of primary concern

- Not the most potent greenhouse gas, but it is extremely abundant
  - *The major contributor to global warming*
- Human activities have boosted atmospheric concentrations from 280 parts per million (ppm) to 383 ppm
  - To their highest levels in more than 650,000 years



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# What caused levels of CO<sub>2</sub> to increase?

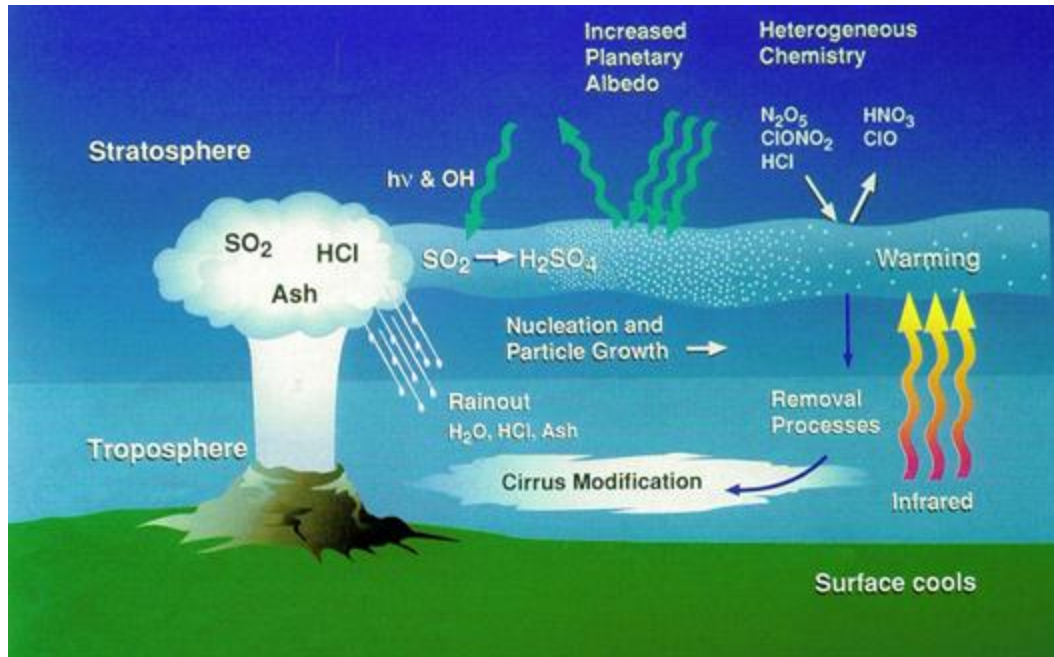
- Burned fossil fuels in our homes, factories, and automobiles
  - Transferred large amounts of carbon dioxide from lithospheric reservoirs into the atmosphere
  - The main reason atmospheric carbon dioxide concentrations have increased so dramatically
- Deforestation has contributed to rising atmospheric CO<sub>2</sub> concentration
  - Forests serve as sinks for recently active carbon
  - Their removal reduces the biosphere's ability to absorb carbon dioxide from the atmosphere

# Other greenhouse gases add to warming

- Methane = fossil fuel deposits, livestock, landfills, and crops such as rice
- Nitrous oxide = feedlots, chemical manufacturing plants, auto emissions, and synthetic nitrogen fertilizers
- Ozone = risen due to photochemical smog
- Halocarbon gases (CFCs) = are declining due to the Montreal Protocol
- Water vapor = the most abundant greenhouse gas and contributes most to the greenhouse effect
  - Could increase cloudiness, which might slow global warming by reflecting more solar radiation back into space

# Aerosols may exert a cooling effect

- **Aerosols:** Soot, or black carbon aerosols, cause warming by absorbing solar energy
  - But, most tropospheric aerosols cool the atmosphere by reflecting the Sun's rays
- Sulfate aerosols produced by fossil fuel combustion may slow global warming, at least in the short term

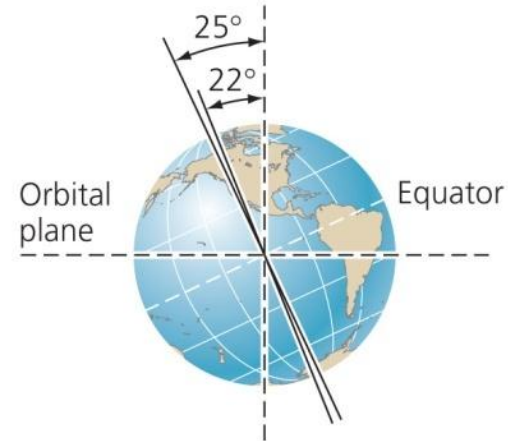


# Milankovitch cycles influence climate

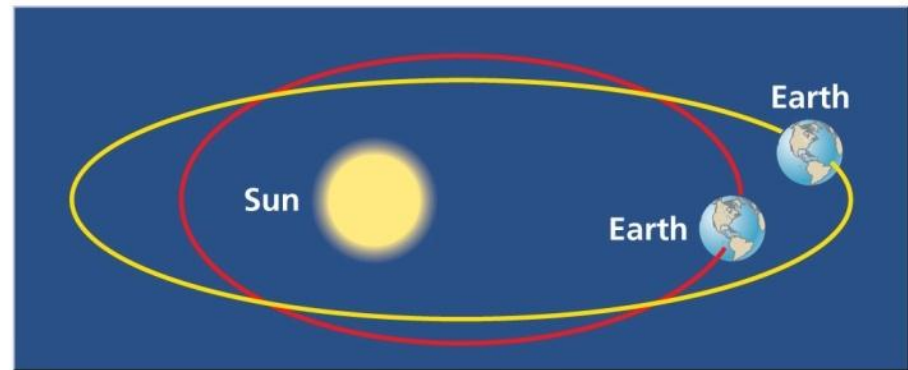
- **Milankovitch cycles** = periodic changes in Earth's rotation and orbit around the Sun
  - Alter the way solar radiation is distributed over Earth's surface
  - By modifying patterns of atmospheric heating, these cycles trigger long-term climate variation such as periodic glaciation



(a) Axial wobble



(b) Variation of tilt

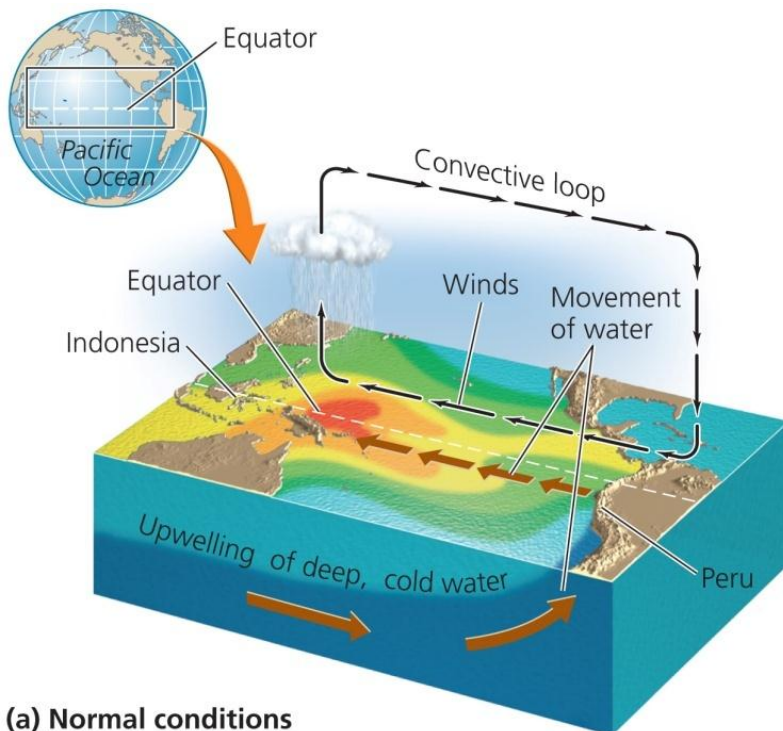


(c) Variation of orbit

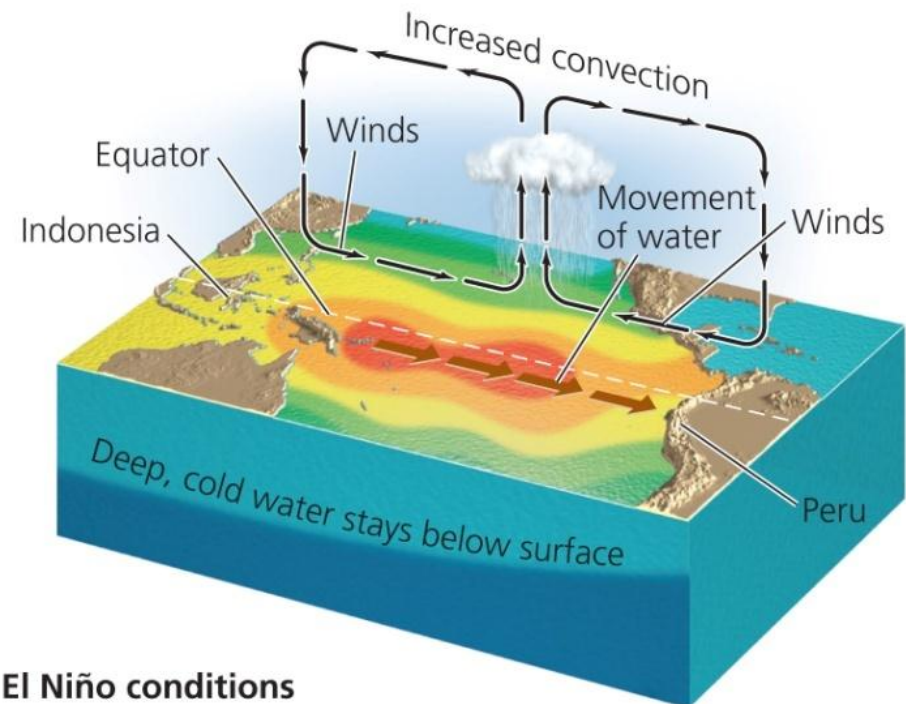
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# Ocean circulation and ENSO influence climate

- **Ocean circulation** = ocean water exchanges tremendous amounts of heat with the atmosphere, and ocean currents move energy from place to place
- **El Niño-southern oscillation (ENSO)** = a systematic shift in atmospheric pressure, sea surface temperature, and ocean circulation in the tropical Pacific



(a) Normal conditions



(b) El Niño conditions

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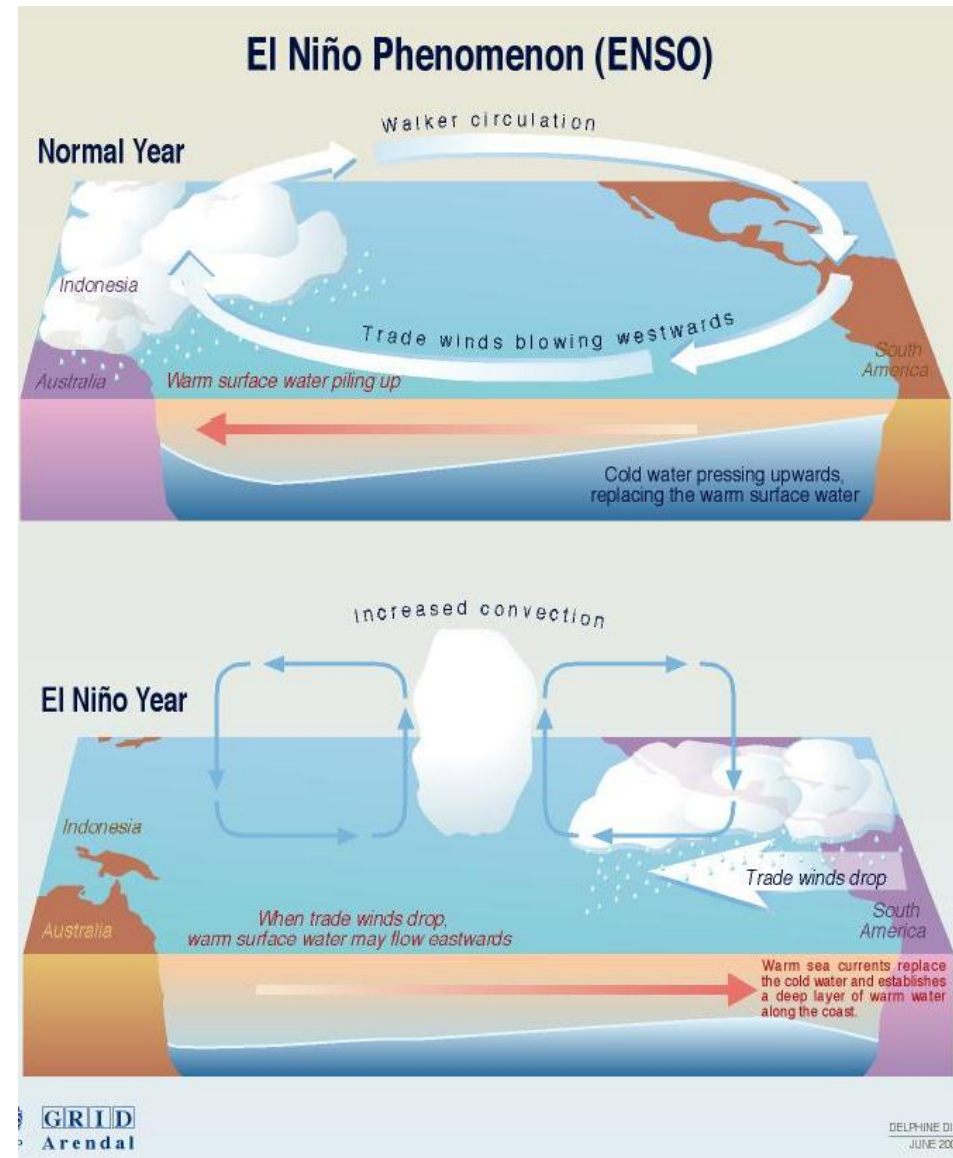


# El Niño

- Normally, winds blow from east to west along the equator, from high to low pressure
- Westward-moving surface waters allow nutrient-rich upwelling along the coast of Peru
- ENSO occurs when air pressure increases in the western Pacific and decreases in the eastern Pacific, causing the equatorial winds to weaken
- Water flows eastward, suppressing upwellings, shutting down delivery of nutrients that support aquatic life
- Alter weather patterns- creating rainstorms and flood where generally dry and drought and fire in moist areas.

# La Niña events

- The opposite of El Niño events
  - Cold surface waters extend far westward in the equatorial Pacific and weather patterns are affected in opposite ways
- ENSO cycles are periodic, occurring every 2-8 years
  - Globally warming air and sea temperatures may be increasing their frequency and strength



Source: Climate Prediction Center-NCEP; NOAA.

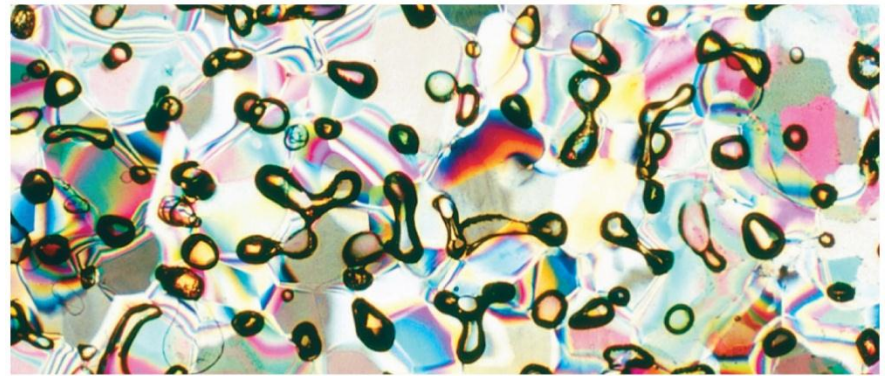
# Proxy indicators tell us about the past

- **Proxy indicators** = types of indirect evidence that serve as substitutes for direct measurements
  - Shed light on past climate
  - Ice caps, ice sheets, and glaciers hold clues to Earth's climate
  - Trapped bubbles in ice cores show atmospheric composition, greenhouse gas concentration, temperature trends, snowfall, solar activity, and frequency of fires



(a) Ice core

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(b) Micrograph of ice core

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# More proxy indicators

- Cores in sediment beds preserve pollen grains and other plant remnants
- Tree rings indicate age, wetness of the season, droughts, and seasonal growth
- Researchers also gather data on past ocean conditions from coral reefs
- Scientists need to combine multiple records to get a global perspective



# Current and future trends and impacts

Evidence that climate conditions have changed since industrialization has increased

- **Intergovernmental Panel on Climate Change (IPCC)**
  - An international panel of scientists and government officials established in 1988
  - Has presented a series of reports on the synthesis of scientific information concerning climate change

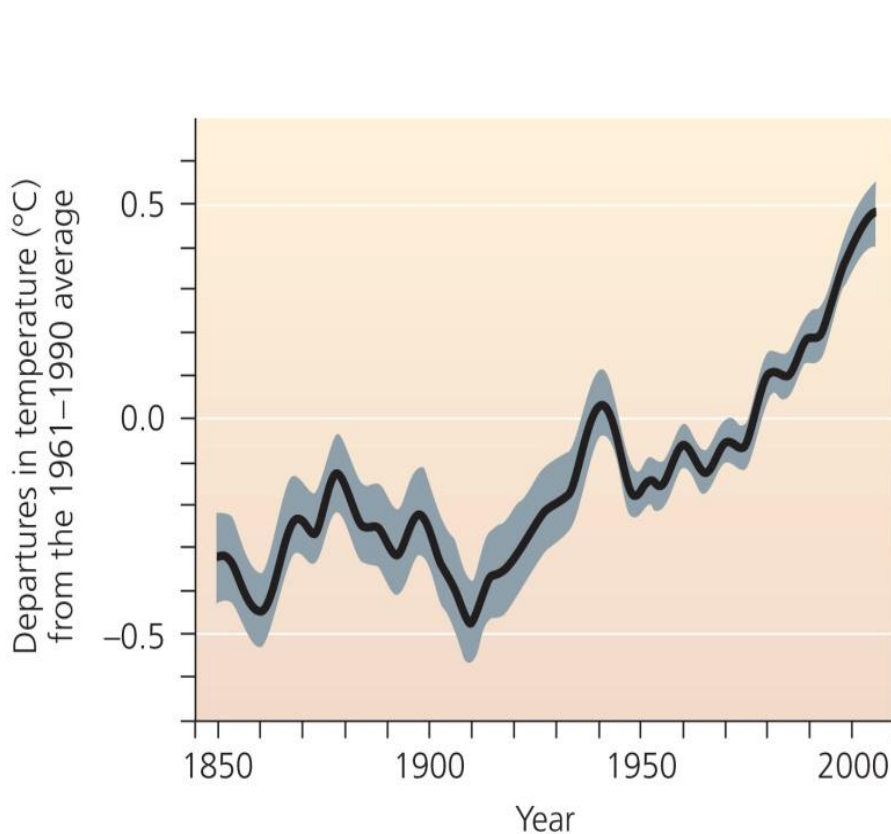


# The fourth assessment report

- *Fourth Assessment Report (2007)*
  - Consensus of scientific climate research from around the world
  - Summarizes thousands of studies
  - It documents observed trends in surface temperature, precipitation patterns, snow and ice cover, sea levels, storm intensity, etc.
  - Predicts future changes, addressing impacts of current and future climate change on wildlife, ecosystems, and human societies
  - Discusses possible strategies to pursue in response to climate change

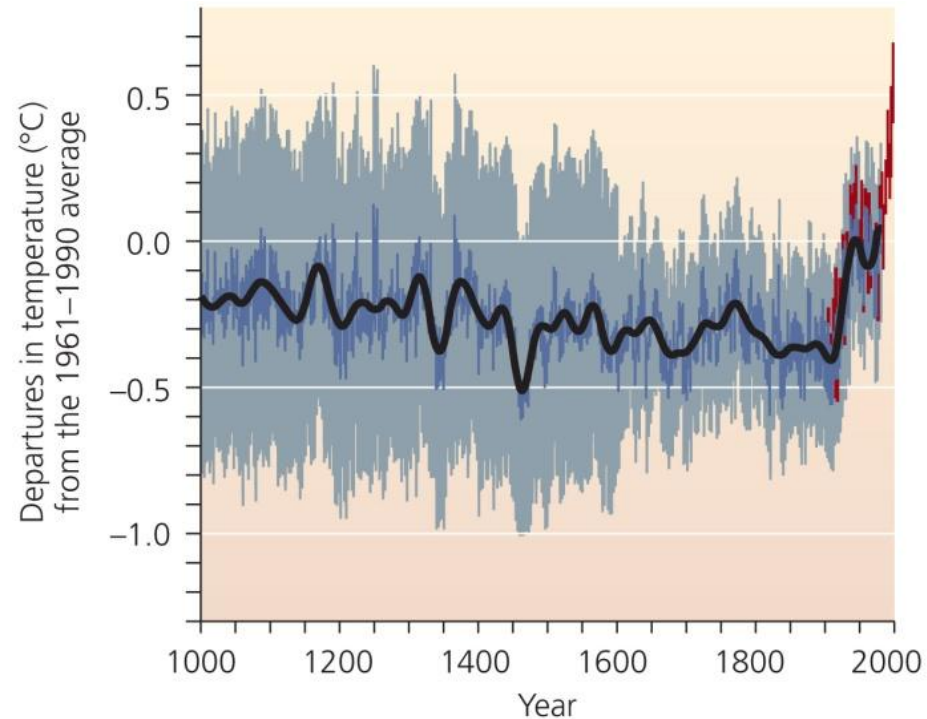
# Temperature increases will continue

- The IPCC report concludes that average surface temperatures on earth have been rising since 1906, with most of the increase occurring in the last few decades



**(a) Global temperature measured since 1850**

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**(b) Northern Hemisphere temperature over the past 1,000 years**

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# Temperature changes are greatest in the Arctic



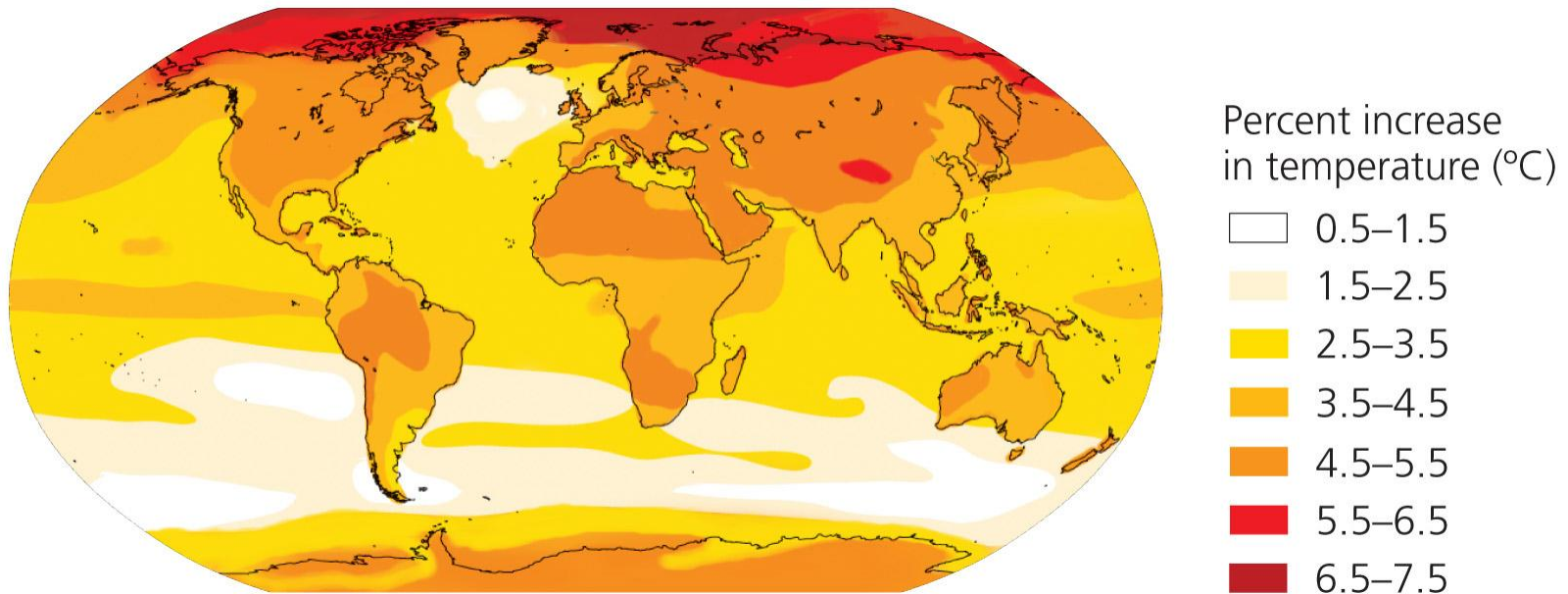
- Ice caps are melting
- Polar bears are starving
- Storms are increasing
- Sea ice is thinning



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# Temperatures will rise 0.2 degree Celsius per decade

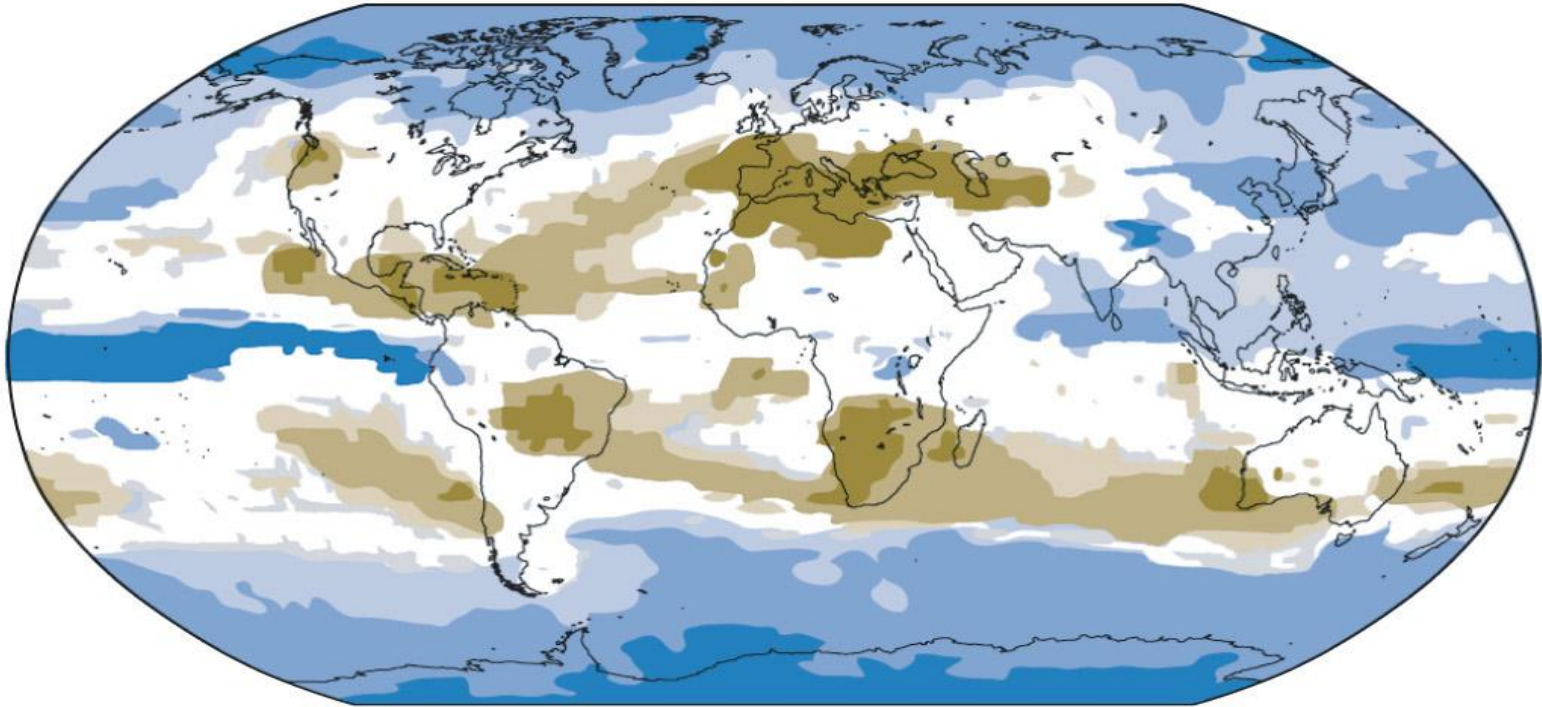
- More frequent heat waves
- Temperature change will vary by region
- Stronger storms










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# Projected changes in precipitation



Percent change  
in precipitation

-  >20% decrease
-  10–20% decrease
-  5–10% decrease
-  5% decrease to 5% increase
-  5–10% increase
-  10–20% increase
-  >20% increase

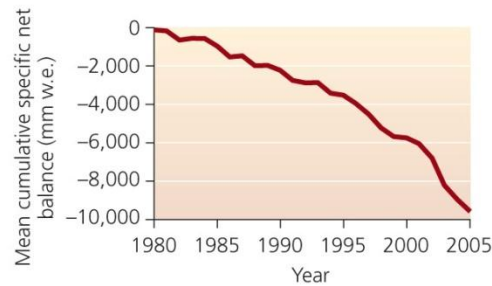


# Melting snow and ice

- Mountaintop glaciers are disappearing
  - In Glacier National Park, only 27 of 150 glaciers remain
  - Risks of sudden floods as ice dams burst
  - Reducing summertime water supplies
- Melting of the Greenland ice sheet is accelerating
- *As ice melts, darker, less-reflective surfaces are exposed and absorb more sunlight, causing more melting*



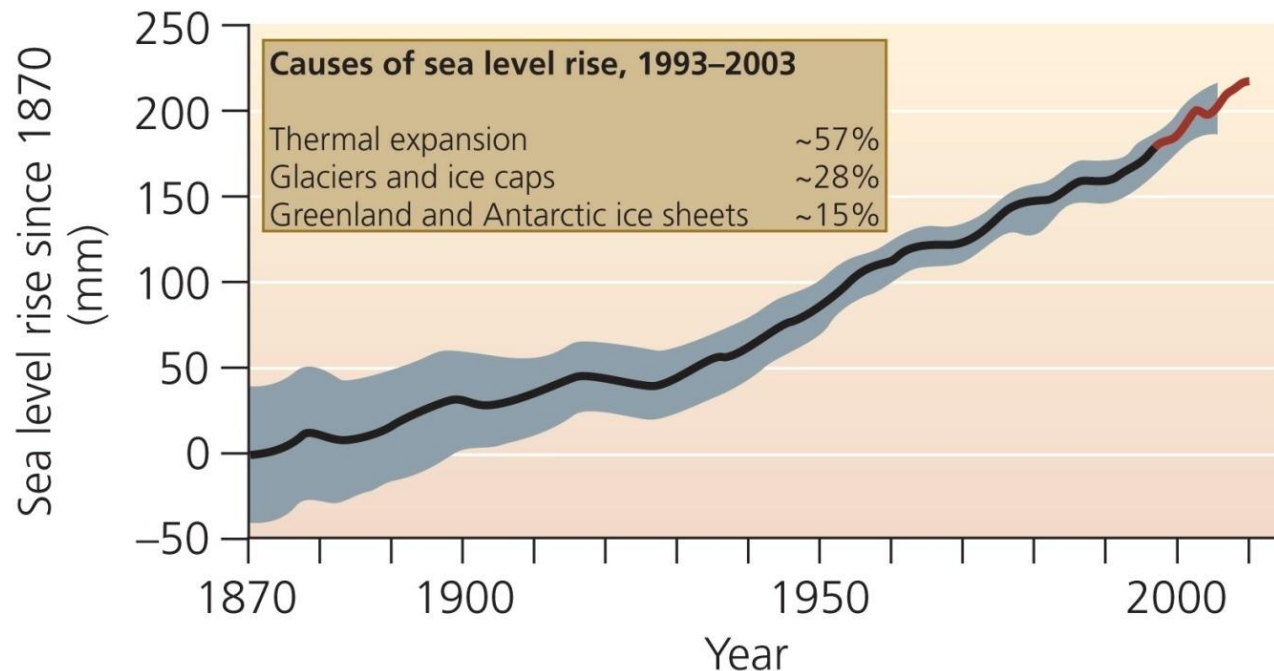
(a) Grinnell Glacier in 1938



(b) Grinnell Glacier in 2005

# Rising sea levels

- As glaciers and ice melt, increased water will flow into the oceans
- *As oceans warm, they expand*
- Leads to beach erosion, coastal floods, and intrusion of salt water into aquifers



# Coastal areas will flood



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- **Storm surge** = temporary and localized rise in sea level brought on by the high tides and winds associated with storms
- Cities will be flooded
- Millions of people will be displaced from coastal areas
- IPCC predicts mean sea level to be 18-59 cm (7-23 in) higher than today's at the end of the 21st century

# Climate change affects organisms and ecosystems

- Organisms are adapted to their environments, so they are affected when those environments change
- Global warming modifies temperature-dependent phenomena
  - Timing of migration, breeding
- Spatial shifts in the range of organisms
  - Animals and plants will move towards the poles or upward in elevation
  - 20-30% of all species will be threatened with extinction
- Plants act as carbon sinks; fewer plants means more CO<sub>2</sub> in the atmosphere

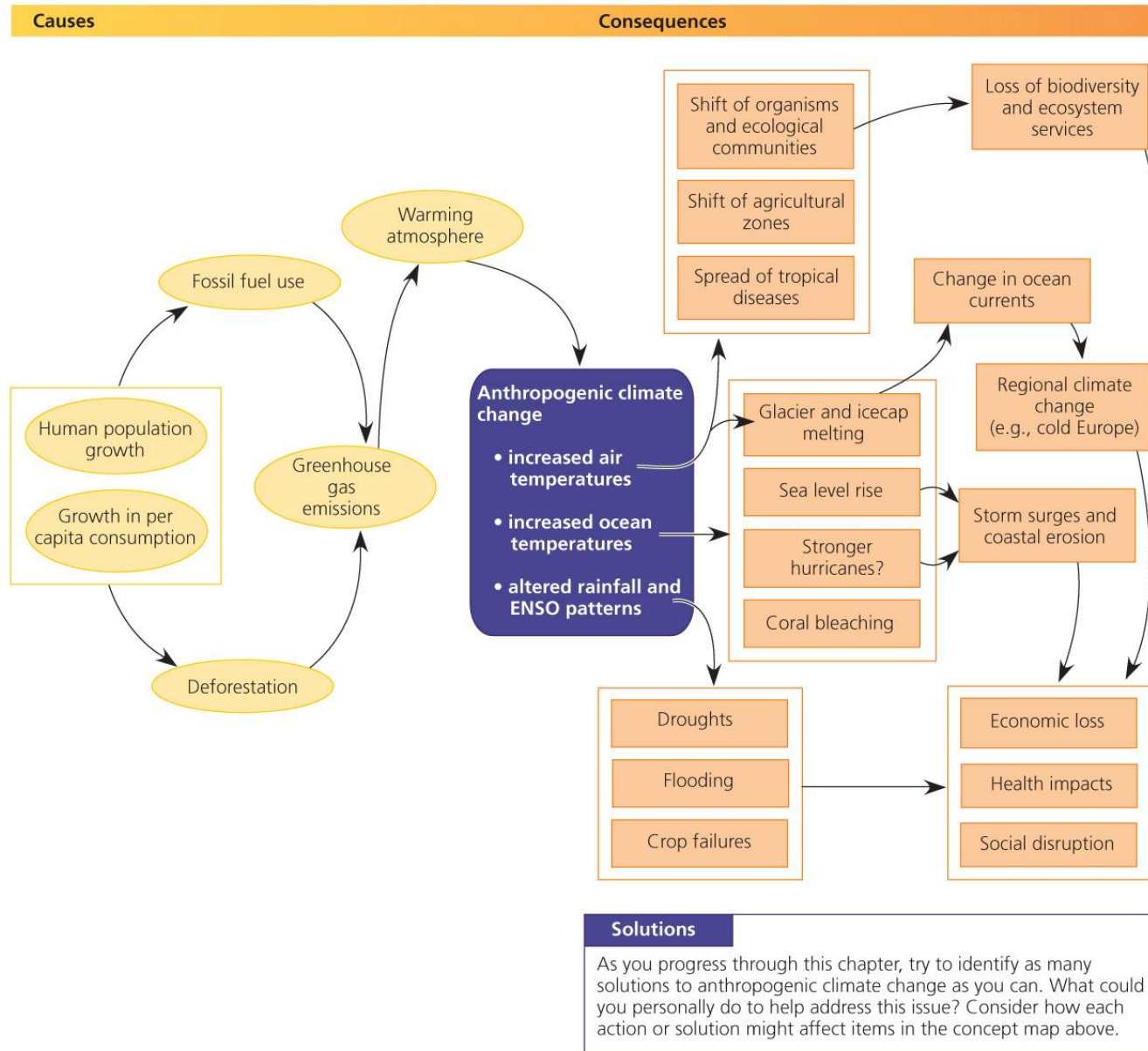


# Climate change exerts societal impacts

- Human society is beginning to feel the impacts of climate change
- Agriculture: growing seasons shortened, crops more susceptible to droughts and failure; crop production will decrease, worsening hunger
- Forestry: increased insect and disease outbreaks, increased chance of forest fires (especially in rainforests)
- Health: heat waves and stress can cause death, respiratory ailments, expansion of tropical diseases, increased chance of drowning if storms become intense, hunger-related ailments

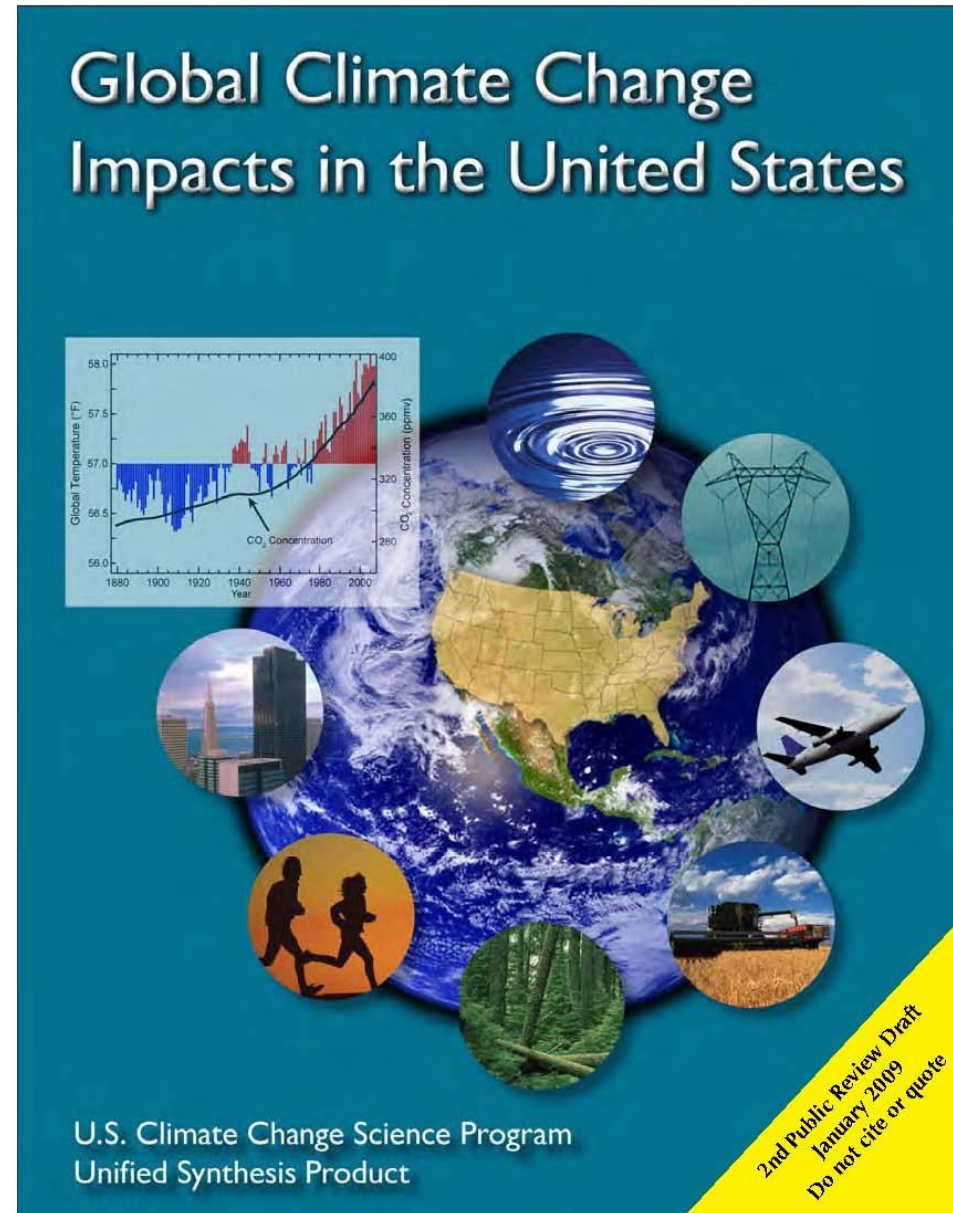


# Causes and consequences of climate change



# U.S. Global Change Research Program (2000)

- Predicted:
  - *Temperature increases*
  - Worse droughts and flooding
  - *Decreased crop yields and water shortages*
  - Health problems and mortality
  - Altered forest ecosystems
  - *Lost coastal areas*



# Shall we pursue mitigation or adaptation?

- **Mitigation** = pursue actions that reduce greenhouse gas emissions, in order to lessen severity of future climate change
  - Renewable energy sources, farm practices to protect soil integrity, preventing deforestation
- **Adaptation** = accept climate change is happening and pursue strategies to minimize its impacts on us
  - Criticized as sidestepping
- Both are necessary

# Electricity generation



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*A coal-fired,  
electricity-  
generating power  
plant*

- **Largest source of U.S. CO<sub>2</sub> emissions**
- Two ways to reduce fossil fuel use: conservation and efficiency
  - Arise from technology and individual choices
  - Replacing worn-down appliances with newer models, lifestyle choices
  - Use fewer greenhouse-gas-producing products

# Transportation

- 2nd largest U.S. greenhouse gas
- The typical automobile is highly inefficient
- Ways to help:
  - Technology: make vehicles more fuel-efficient, hybrid cars
  - Drive less and use public transportation
  - Public transportation is the most effective way to conserve energy, reduce pollution
  - Live nearer your workplace, so you can bike or walk



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# The Kyoto Protocol seeks to limit emissions

- The Kyoto Protocol mandates that, *between 2008-2012, signatory nations must reduce emissions of six greenhouse gases to levels below those of 1990*
  - This treaty took effect in 2005, after Russia became the 127th nation to ratify it
- The United States will not ratify the Kyoto Protocol because it requires industrialized nations to reduce emissions, but it does not require the same of rapidly industrializing nations such as China and India
- Businesses in industrialized nations feel they have more to lose economically from restrictions