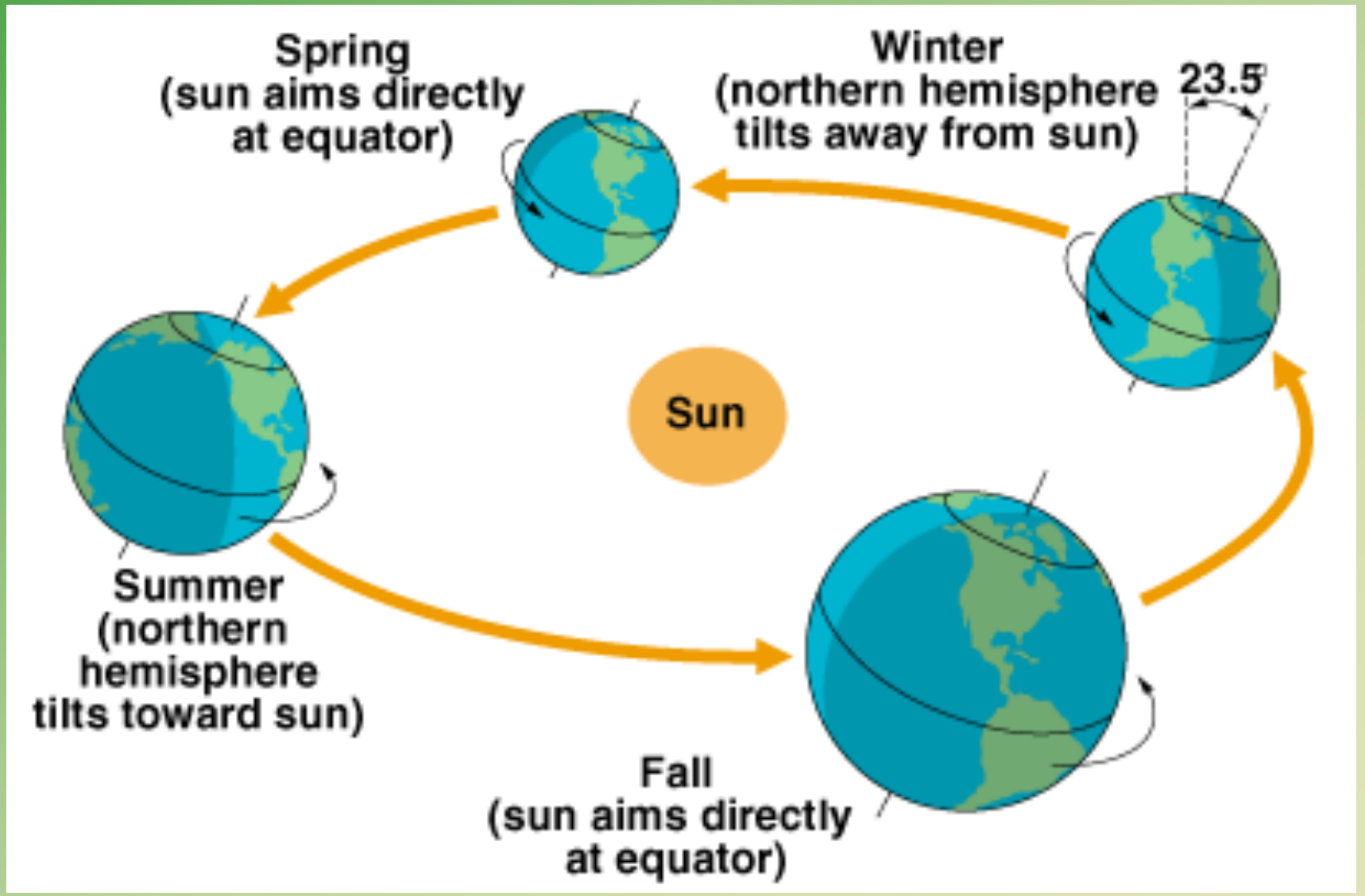
Climate

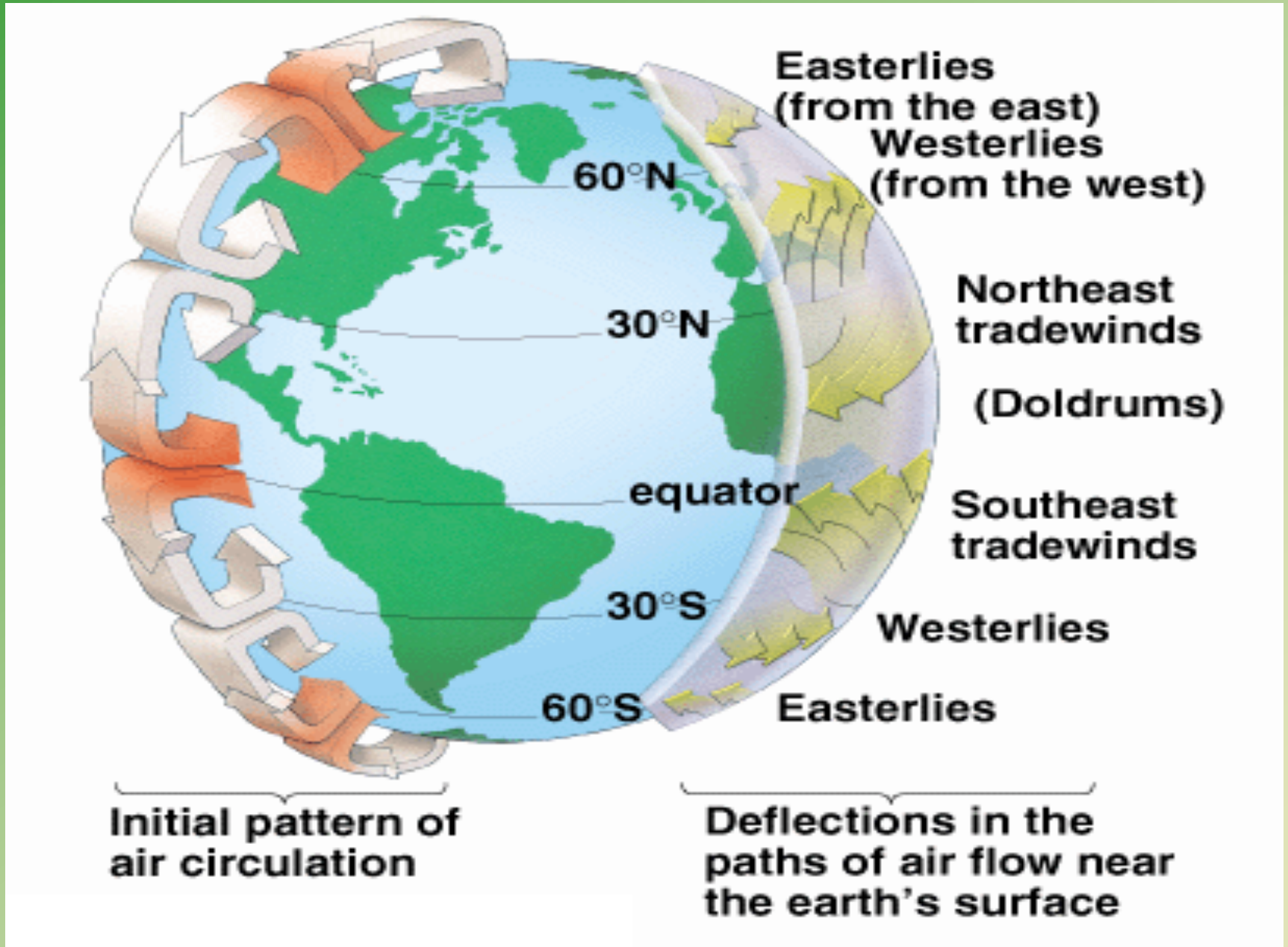
Global Warming

Ozone Loss

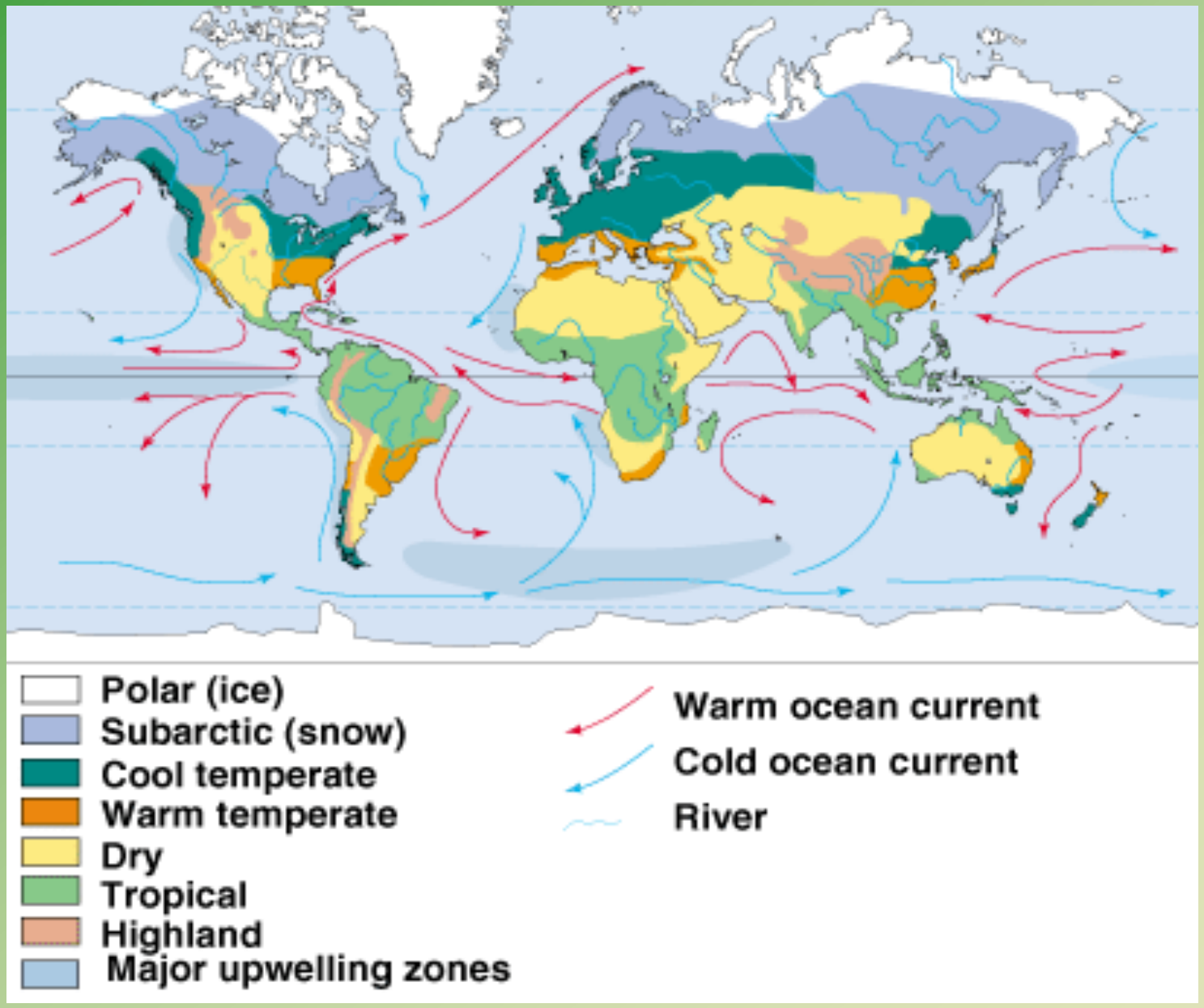
Geometry of Incoming Solar Radiation



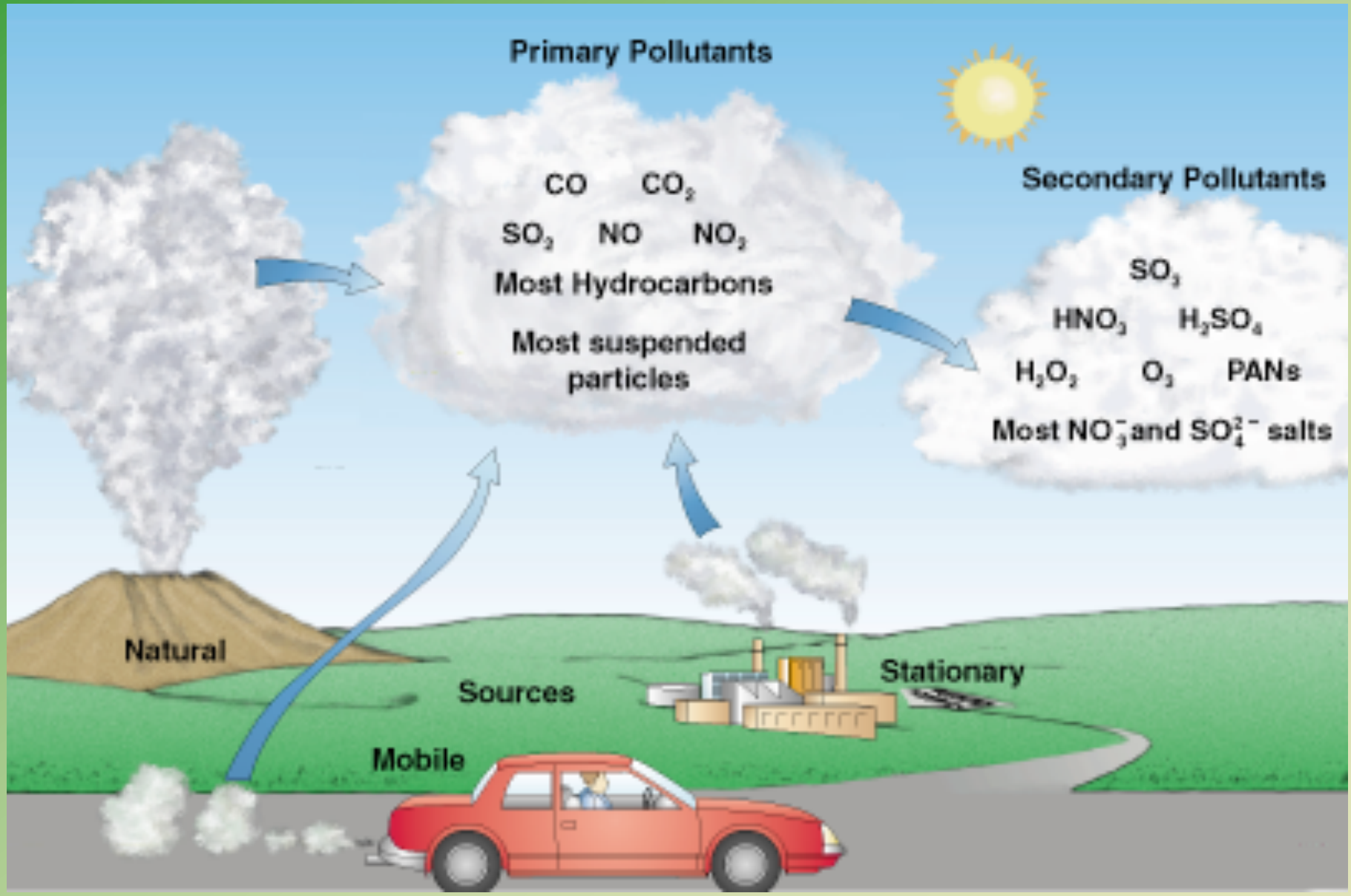
Air Circulation Patterns



Ocean Currents



Gases Released through Human Activities

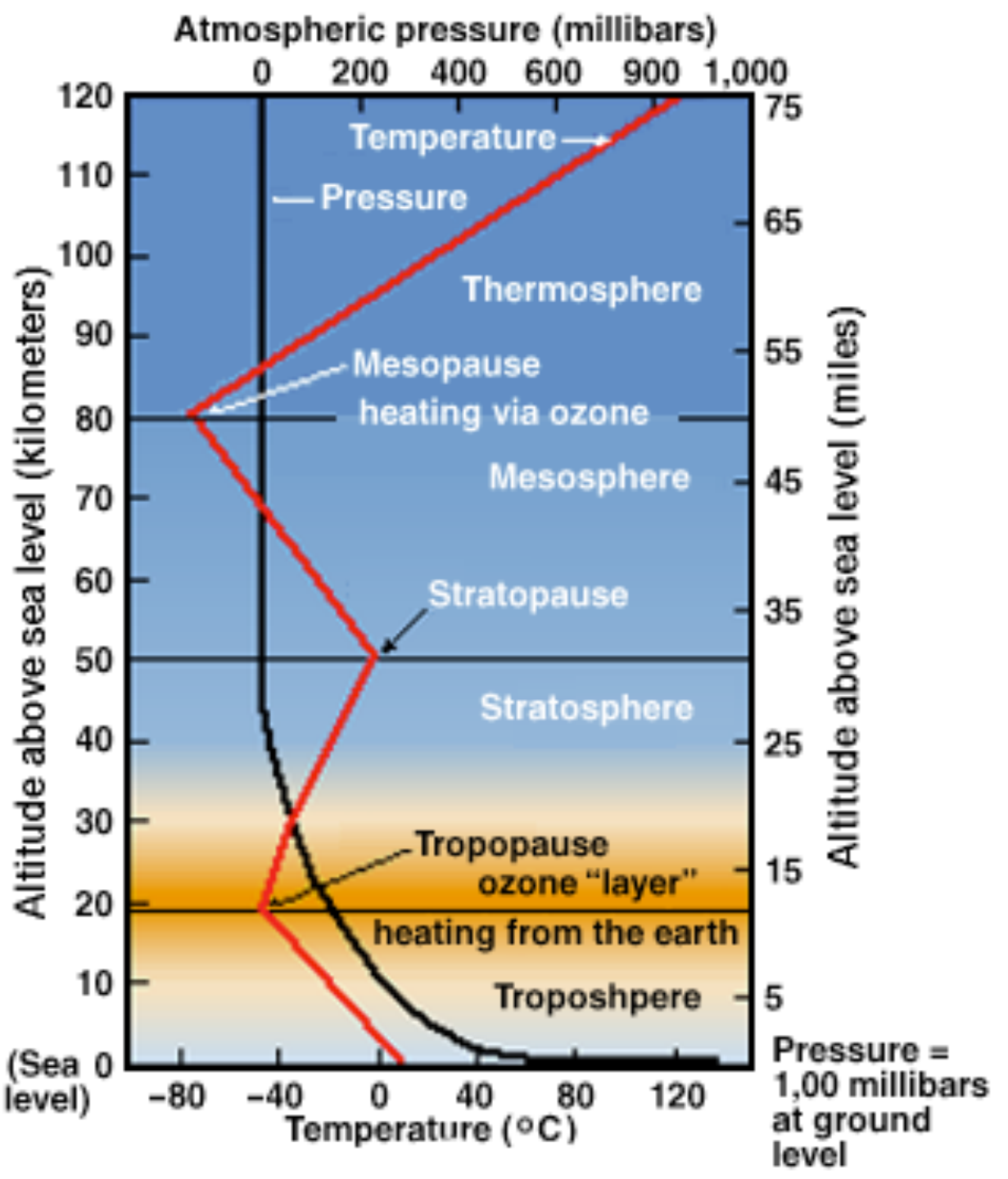


1. Natural Global Processes

- Greenhouse Effect
- Ozone Shield
- Questions
  - What?
  - Where?
  - Gases involved?
  - Human inputs?
  - What problems result?

Where?

- Greenhouse Effect: in troposphere
- Ozone Shield: in stratosphere



What is the Greenhouse Effect?

Greenhouse Effect: a natural process that traps heat near the Earth's surface.

- short wave radiation in
- long wave radiation out
- re-radiation downward by "greenhouse gases" in atmosphere

a. Rays of sunlight penetrate the lower atmosphere and warm the earth's surface.

b. The earth's surface absorbs much of the incoming solar radiation and degrades it to longer-wavelength infrared radiation (heat), which rises into the lower atmosphere. Some of this heat escapes into space and some is absorbed by molecules of greenhouse gases and emitted as infrared radiation, which warms the air.

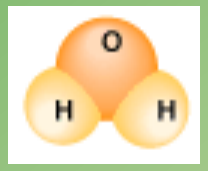
c. As concentrations of greenhouse gases rise, their molecules absorb and emit more infrared radiation, which adds more heat to the lower atmosphere.

Figure 6-8 The greenhouse effect. Without the atmospheric warming provided by this natural effect, the earth would be a cold and mostly lifeless planet. According to the widely accepted greenhouse theory, when concentrations of greenhouse gases in the atmosphere rise, the average temperature of the troposphere also rises. (Modified by permission from Cecie Starr, *Biology: Concepts and Principles*, 4th ed., Pacific Grove, Calif.: Brooks/Cole, 2000)

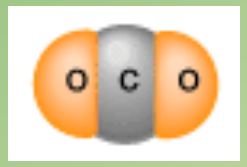
What Natural Gases?

- Greenhouse Effect:

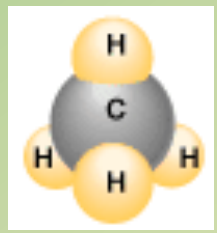
water H_2O



carbon dioxide CO_2



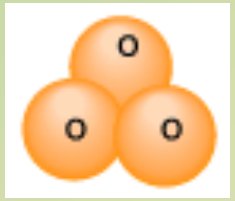
methane CH_4



- Ozone Shield:

oxygen O_2

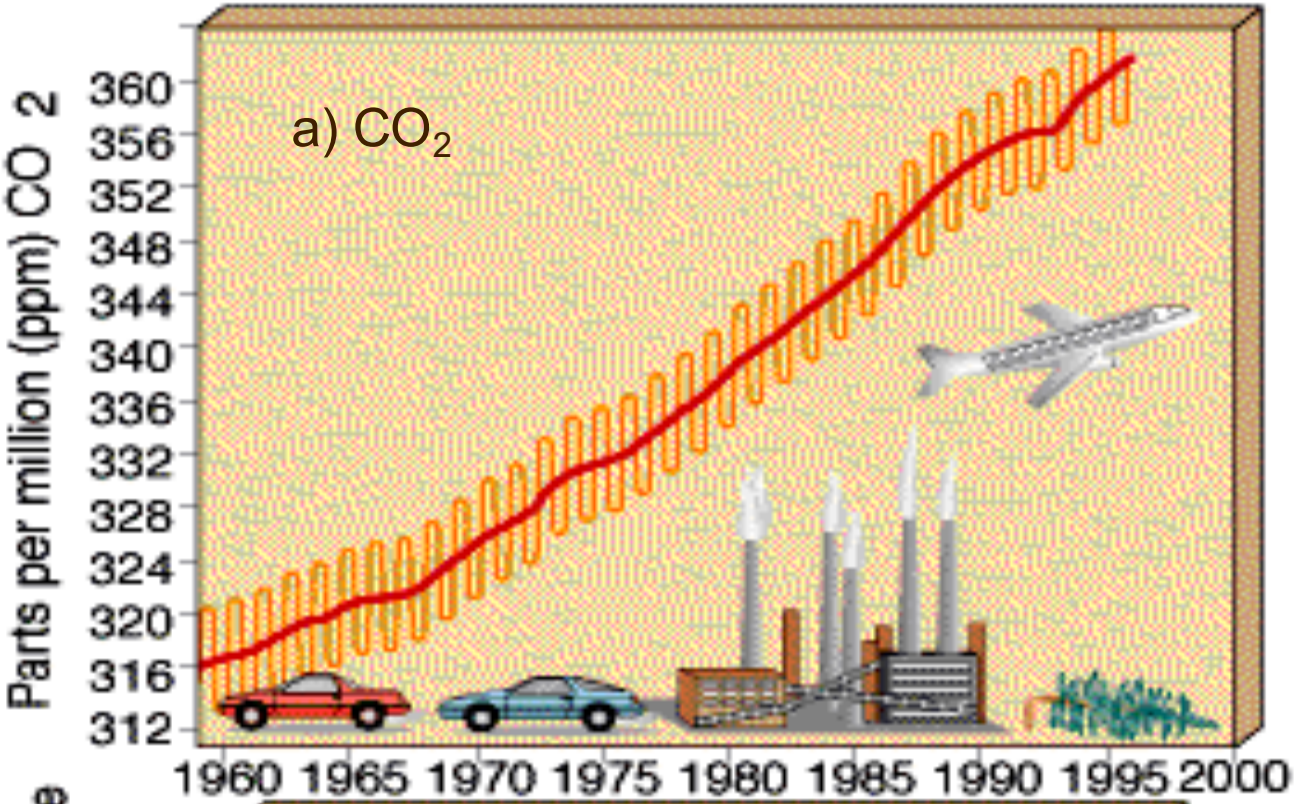
ozone O_3

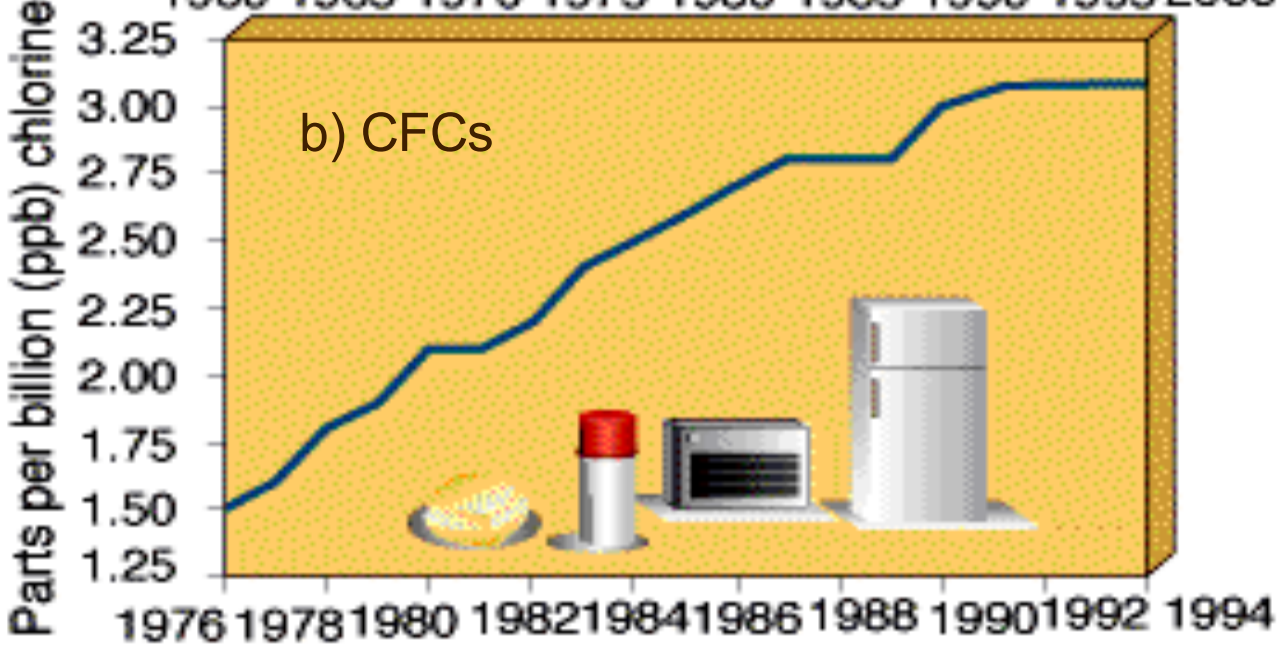


Human inputs?

Greenhouse Effect:

- carbon dioxide (CO_2)
  - 75% developed countries
  - 22% U.S.
- chlorofluorocarbons (CFCs)

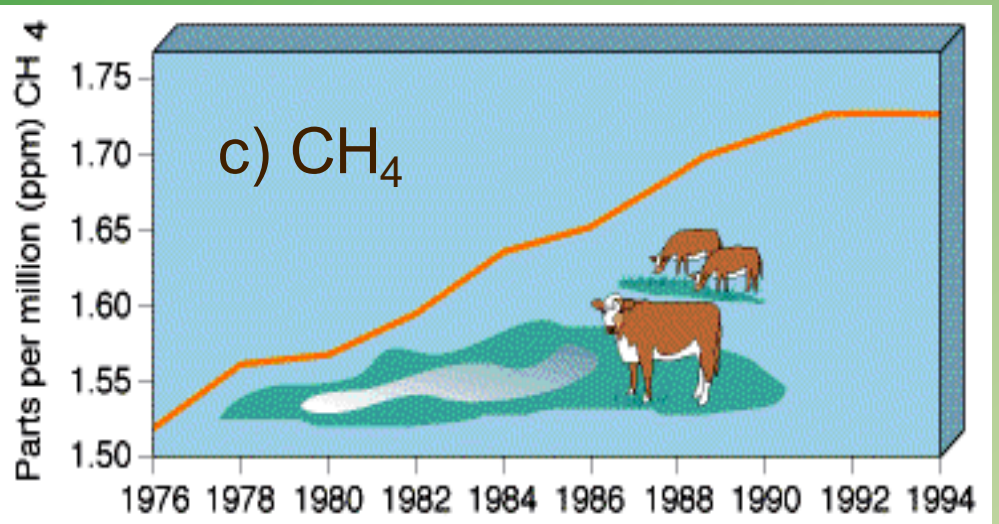


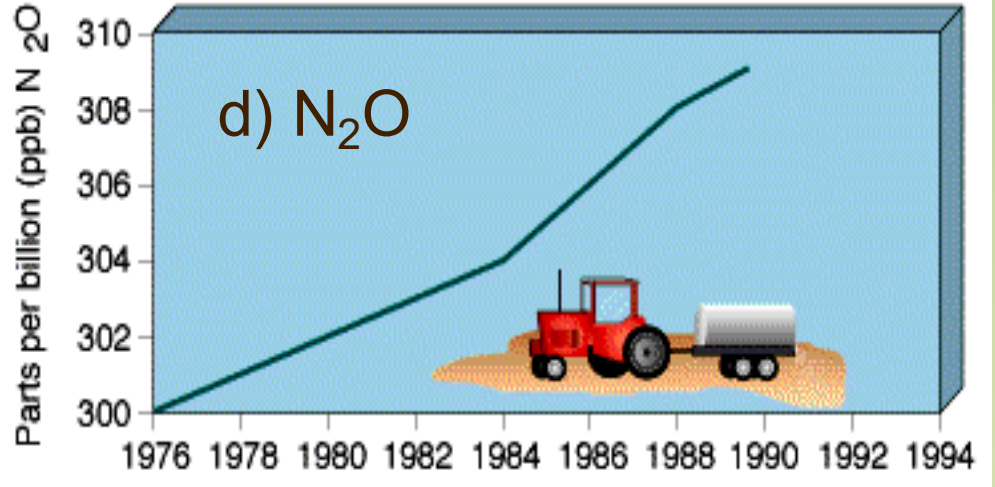


Human inputs?

Greenhouse Effect:

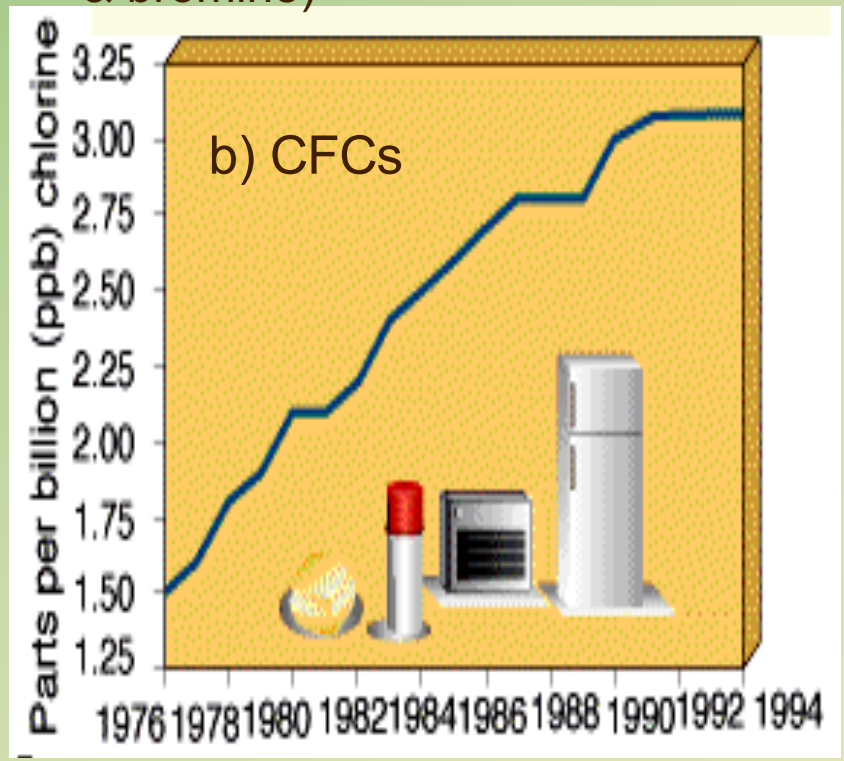
- methane (CH_4)
- nitrous oxide (N_2O)



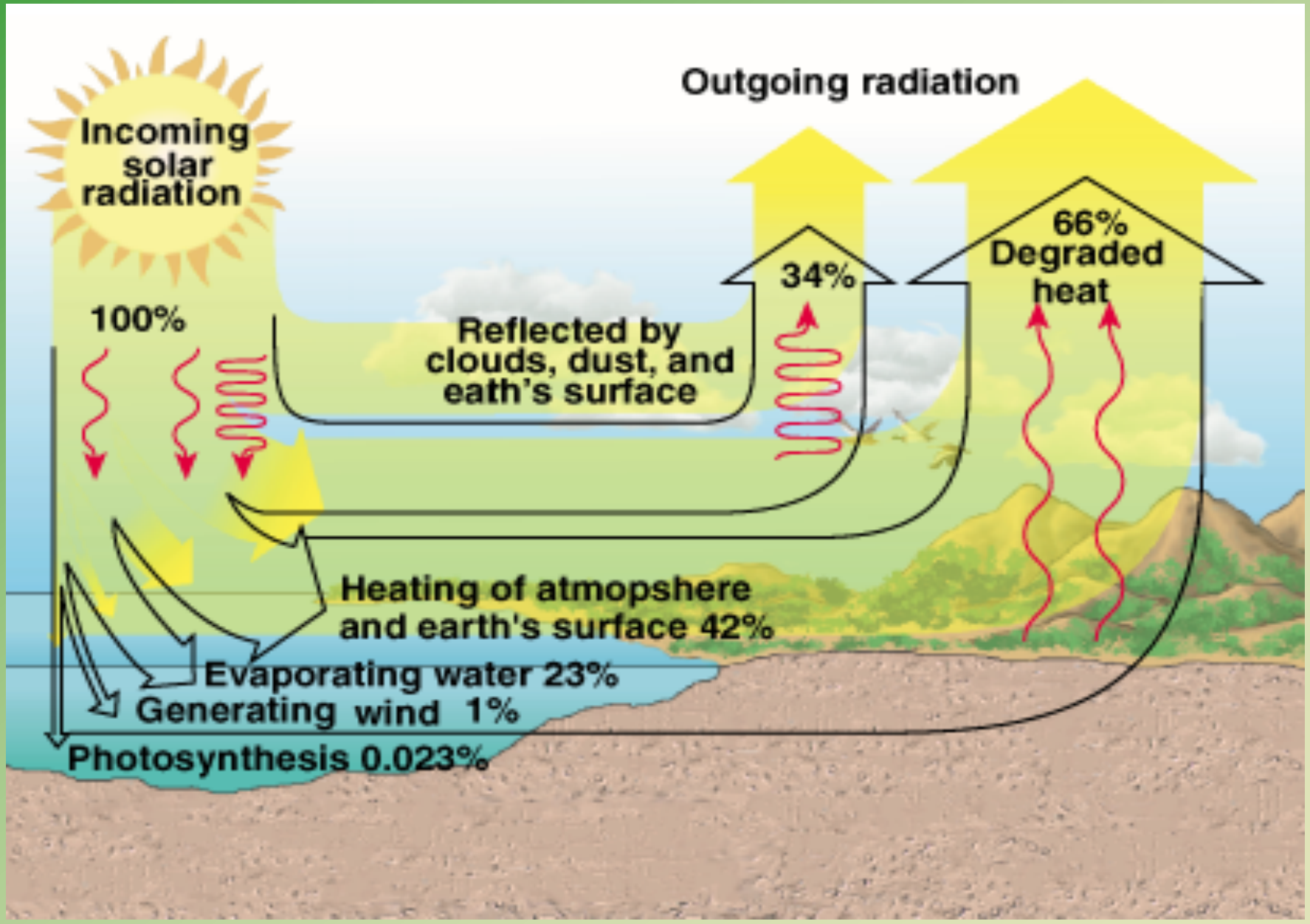


Ozone Shield:

- chlorofluorocarbons (CFCs)
- other stable halogen–containing gases (halogens = chlorine, fluorine, & bromine)



Greenhouse Effect



2. Global Warming

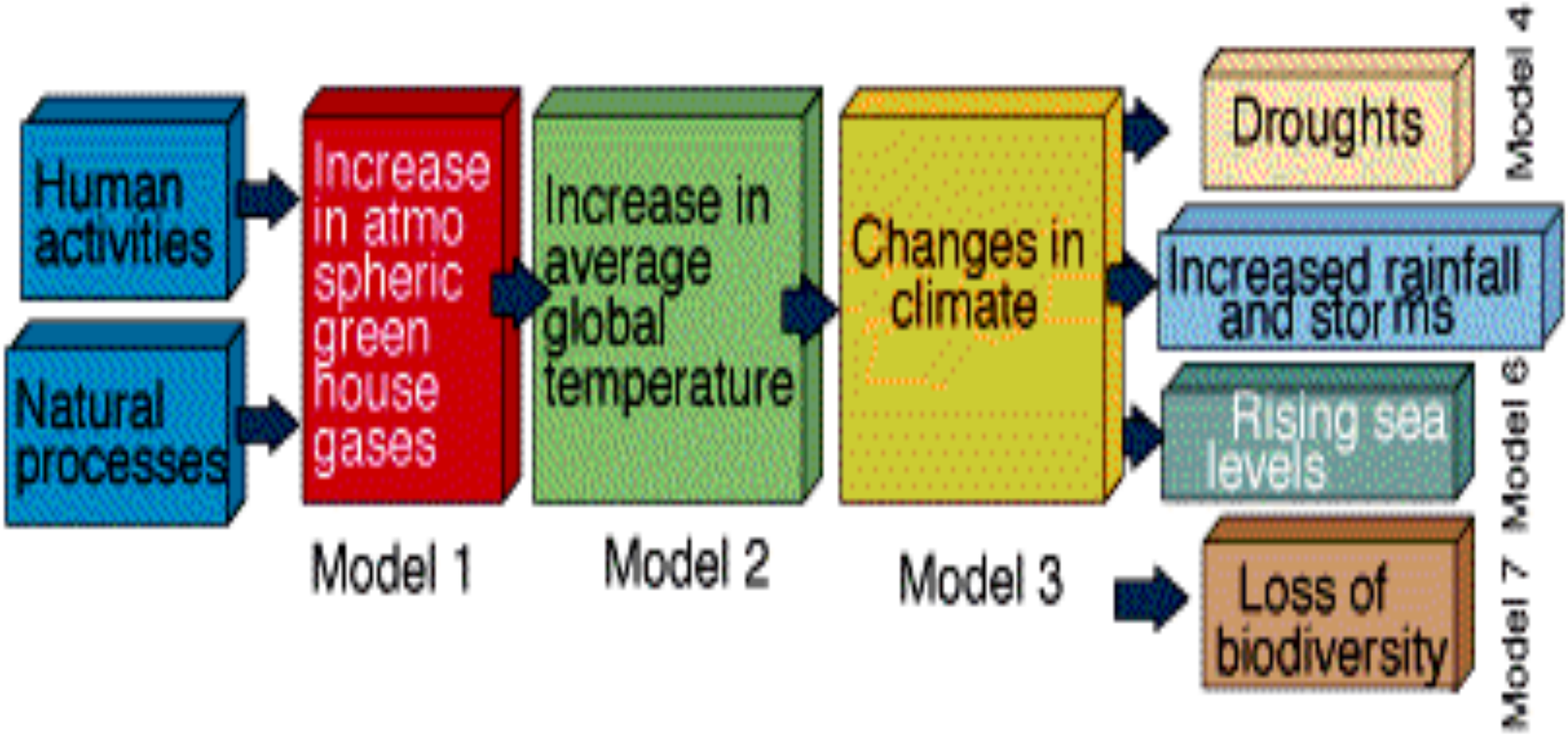
Questions:

- Is it proven?
- What are potential consequences?
- What can be done?

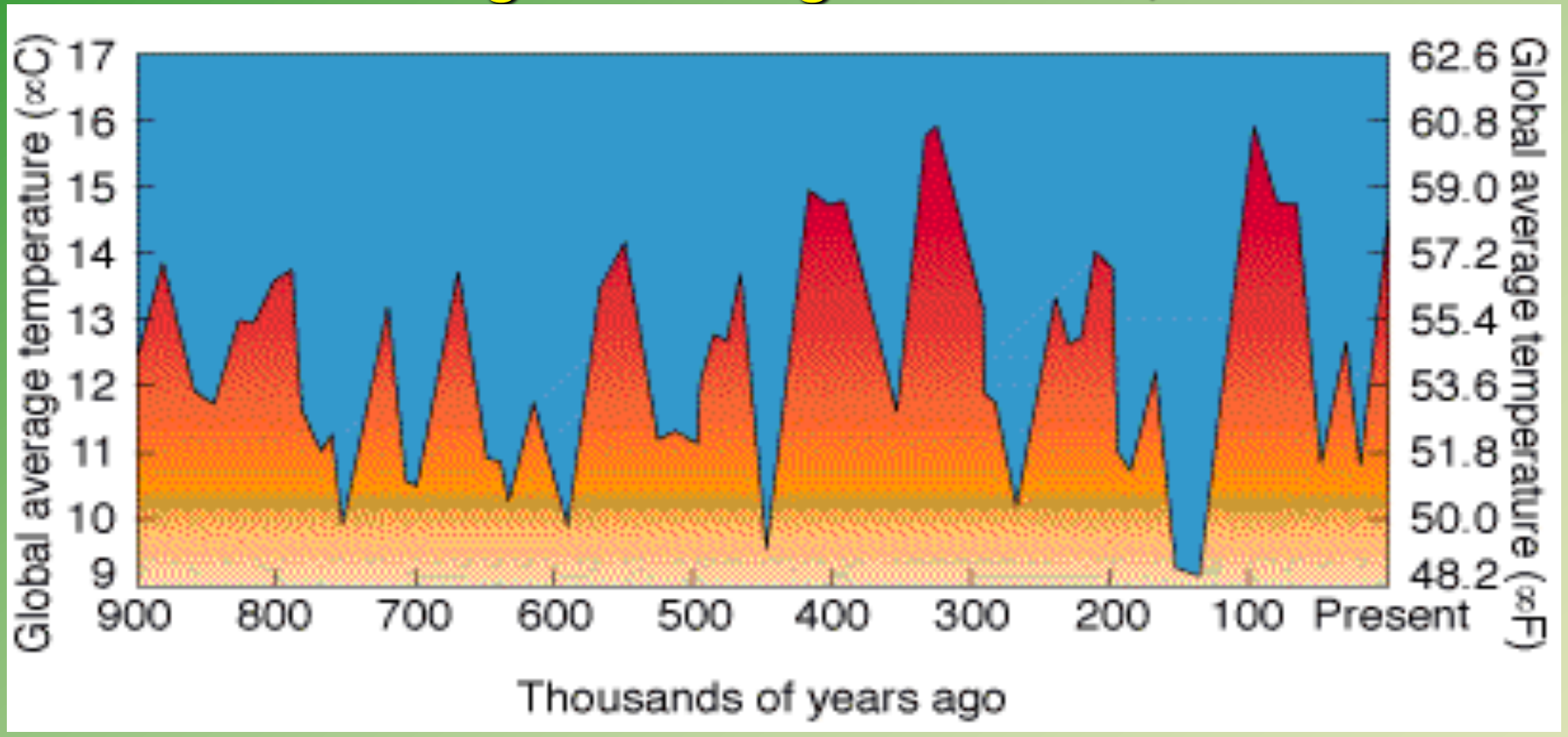
How Does This Relate to the Carbon Cycle?

- Sources of Increased Atmospheric CO_2
  - Burning Fossil Fuels
  - Deforestation
- Carbon Balance: increased atmospheric CO_2 less than expected based only on input
  - about 49% remains in atmosphere
  - about 29% uptake by oceans
  - carbon balance: about 22% unaccounted for

Consequences of Increased Greenhouse Gases



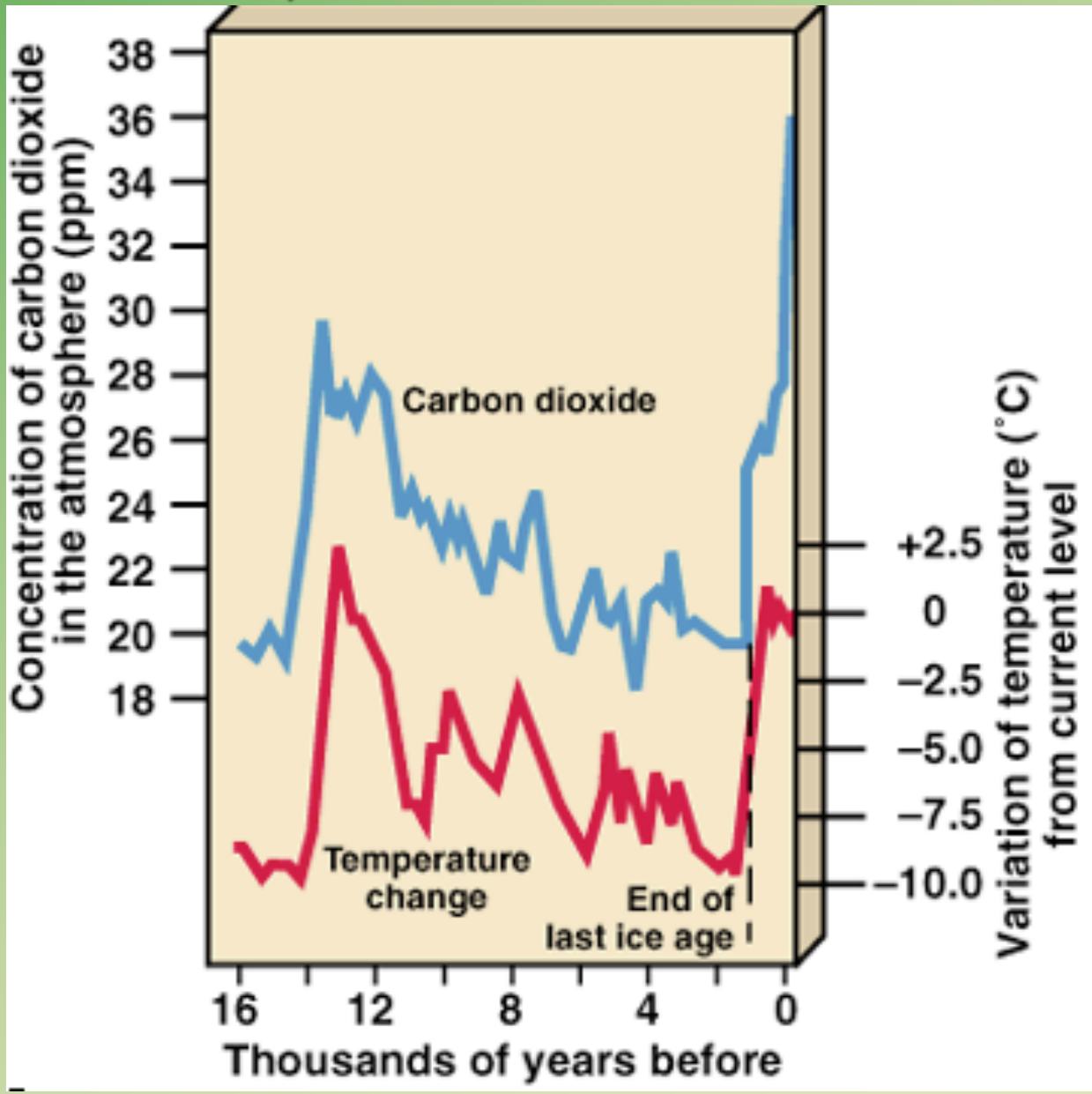
Climate Changes During Past 900,000 Years



- Past climate based on study of Antarctic glaciers
- Cycles of Ice Ages lasting about 100,000 years
- Interglacial Periods lasting 10,000 to 12,500 yrs

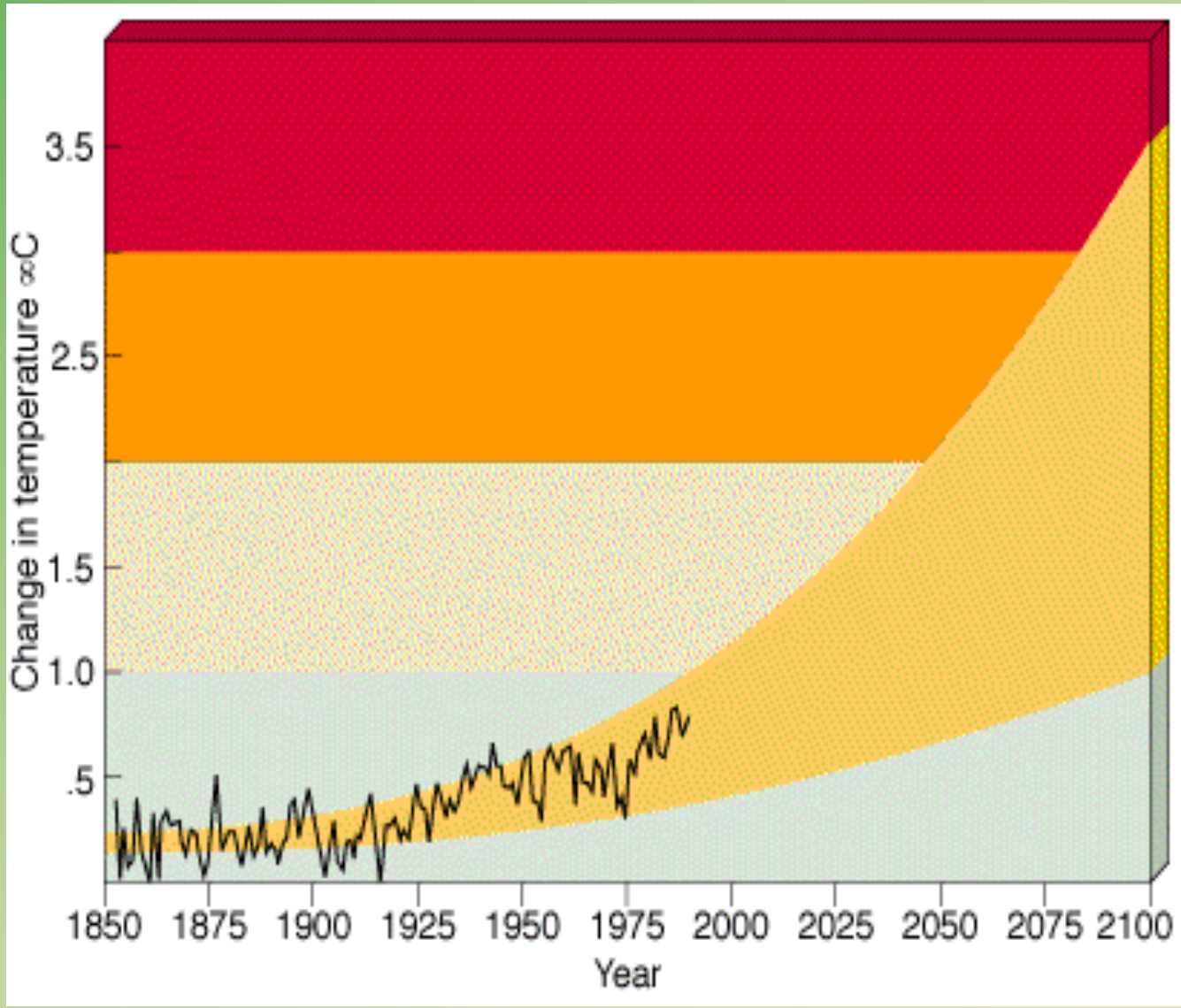
Climate During Past 160,000 Years

- End of last Ice Age about 10,000 yr BP
- Now in warm interglacial period
- Based on ice core data, analysis of trapped gas
- Correlation between CO_2 & mean temperature



What is the Scientific Consensus?

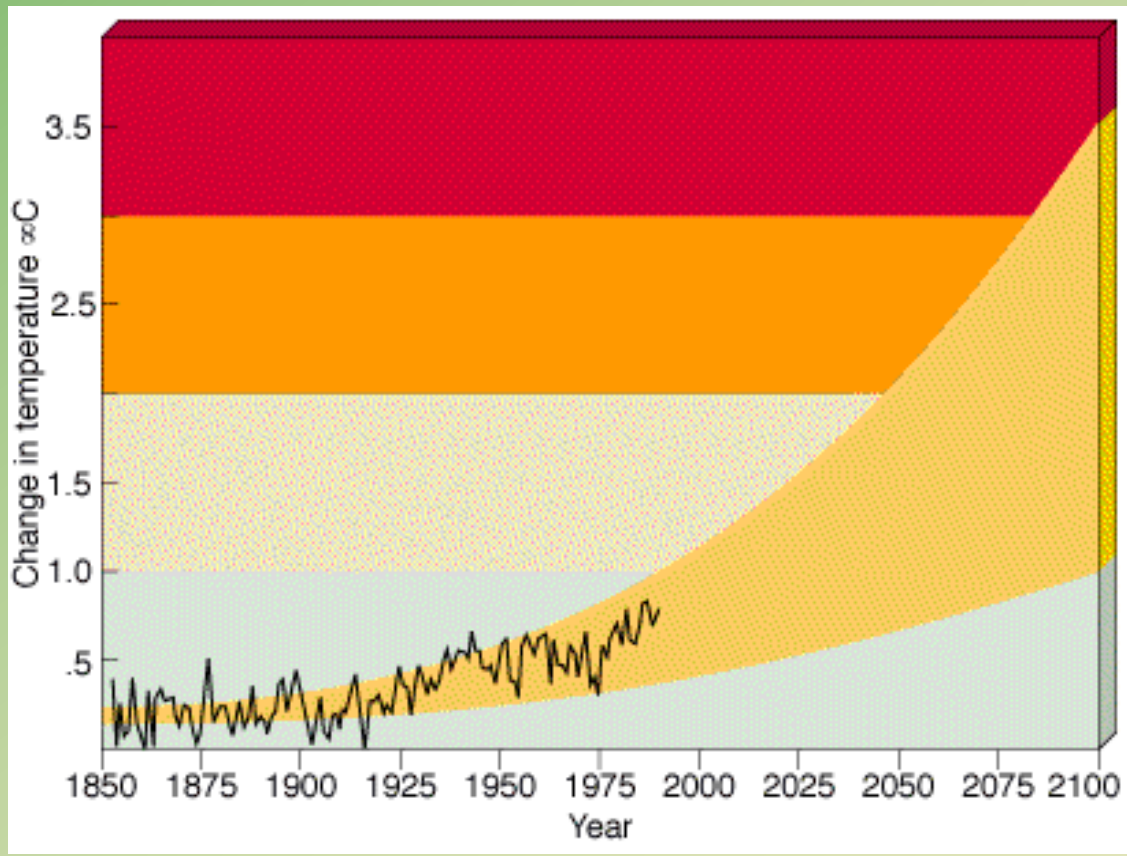
- Mean global temperature rose about 0.6º C (1º F) in past 100 years
- Increase is real, not explained by natural variation in solar radiation
- Warming greater at poles than equator, greater at night, mostly troposphere



Future Scenarios

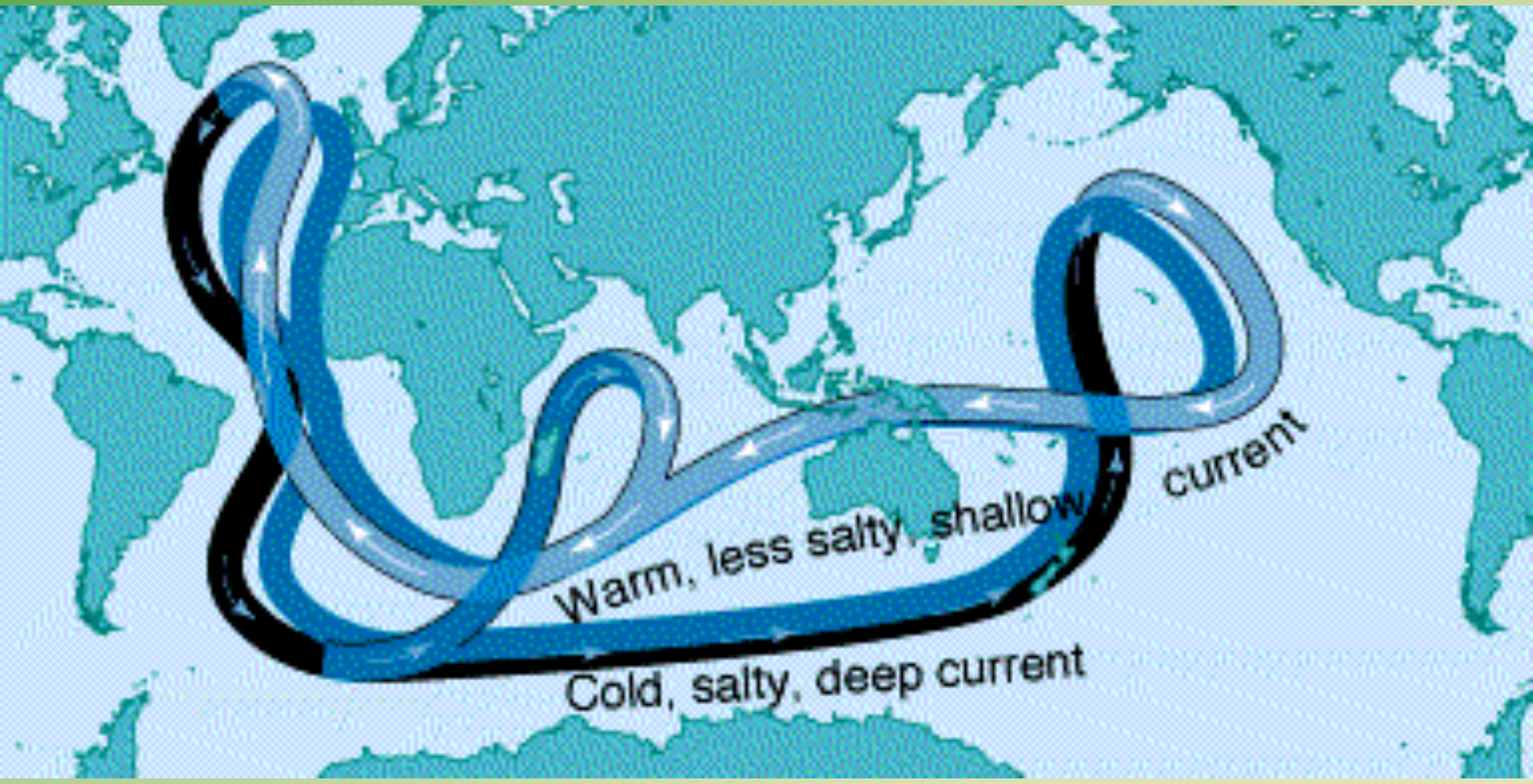
General Circulation Models (GMCs) used to predict future climate

- Projected warming of 1 to 3.5 º C between 1990 & 2100
- Likely scenario: doubling of CO_2 (from 280 ppm to 560 ppm) before 2100 leading to warming of 2º C



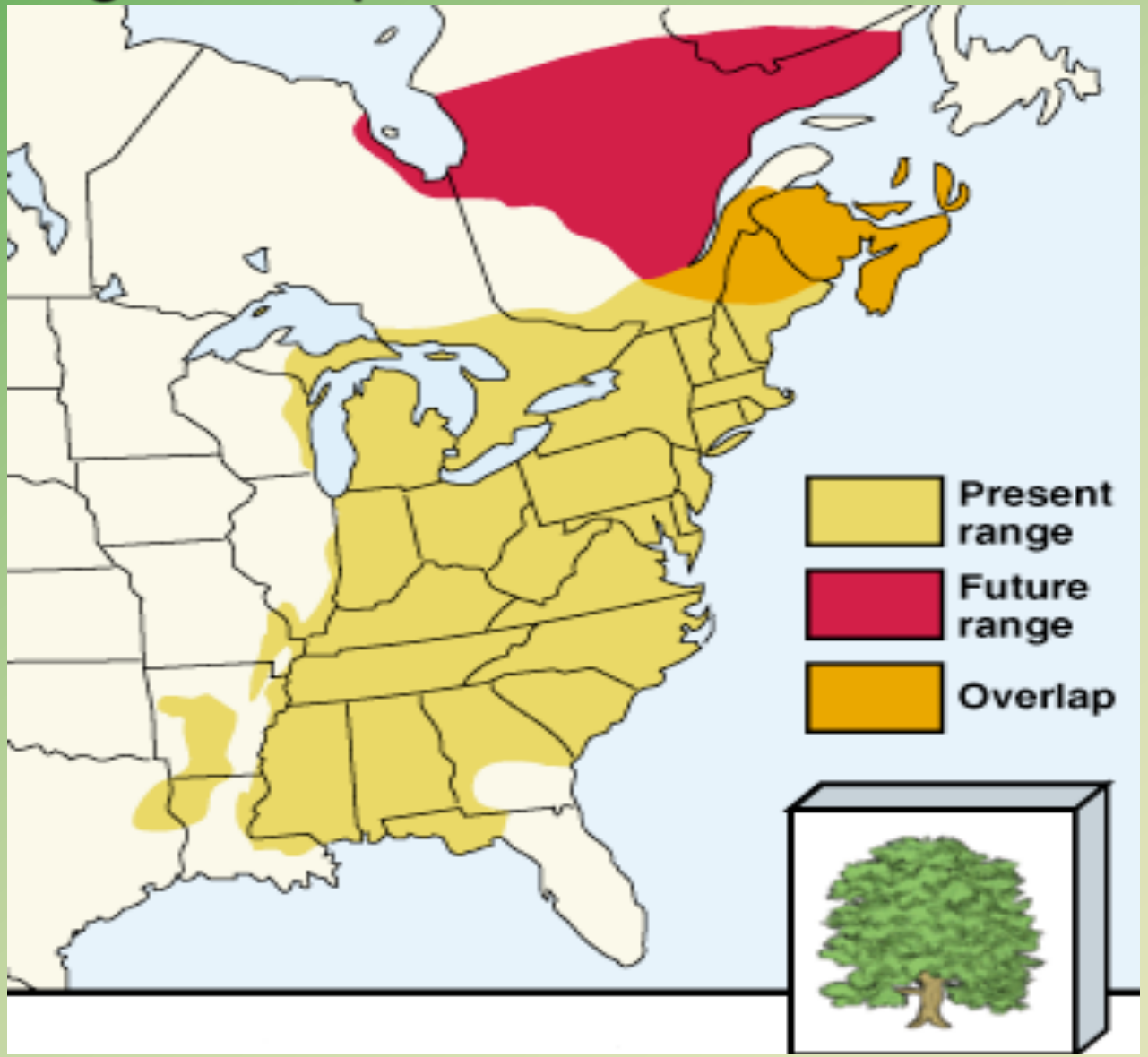
Role of Ocean

- Storage of CO_2 in deep water
- Warming could decrease ability of ocean to serve as “sink” for carbon



Ecological Implications

- Shift of habitat to higher latitudes
- Shift of habitat to higher elevations
- Potential large loss of biodiversity



Solutions to Global Warming

Prevention

Cut fossil fuel use (especially coal) in half

Improve energy efficiency

Shift to renewable energy resources

Reduce deforestation

Use sustainable agriculture

Slow population growth

Cleanup

Remove CO_2 from smokestack and vehicle emissions

Plant and tend trees

Solutions to Global Warming

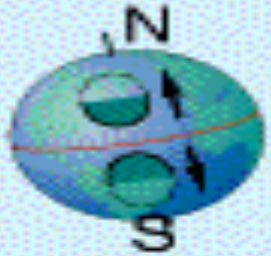
Waste less water

Develop crops that need less water

Move hazardous materials storage tanks away from coast

Prohibit new construction or remodeling on low-lying coastal areas

Stockpile 1–5 years supply of key foods



Expand existing wildlife reserves toward poles

Connect wildlife reserves with corridors

International Agreements

- Kyoto Agreement (1997)
  - 38 developed countries must cut greenhouse emissions to 5.2% below 1990 levels between 2008-2012
  - Developing countries exempted
  - Allow emissions trading, in which countries can sell its excess reductions to others
    - Countries can also plant trees to meet goal

Impact on U.S.: Economic Incentives/Regulatory Changes

- Reduce energy use by 18%
- Reduce electricity use by 30%
- Cut SO_2 emissions by 50%
- Cut NO_2 emissions by 25%
- Cut CO_2 emissions by 14% below 1990 levels
  - Twice amount specified in Kyoto Treaty

3. Ozone Depletion

- What causes it?
- What are the effects?
  - Humans
  - Other living organisms
- How can we stop it?

What is the Ozone Shield?

Ozone Shield: a natural process that filters ultraviolet (UV) radiation before it reaches the lower atmosphere.

- The layer of ozone gas (O_3) in the upper stratosphere that screens out harmful ultraviolet radiation from the sun.

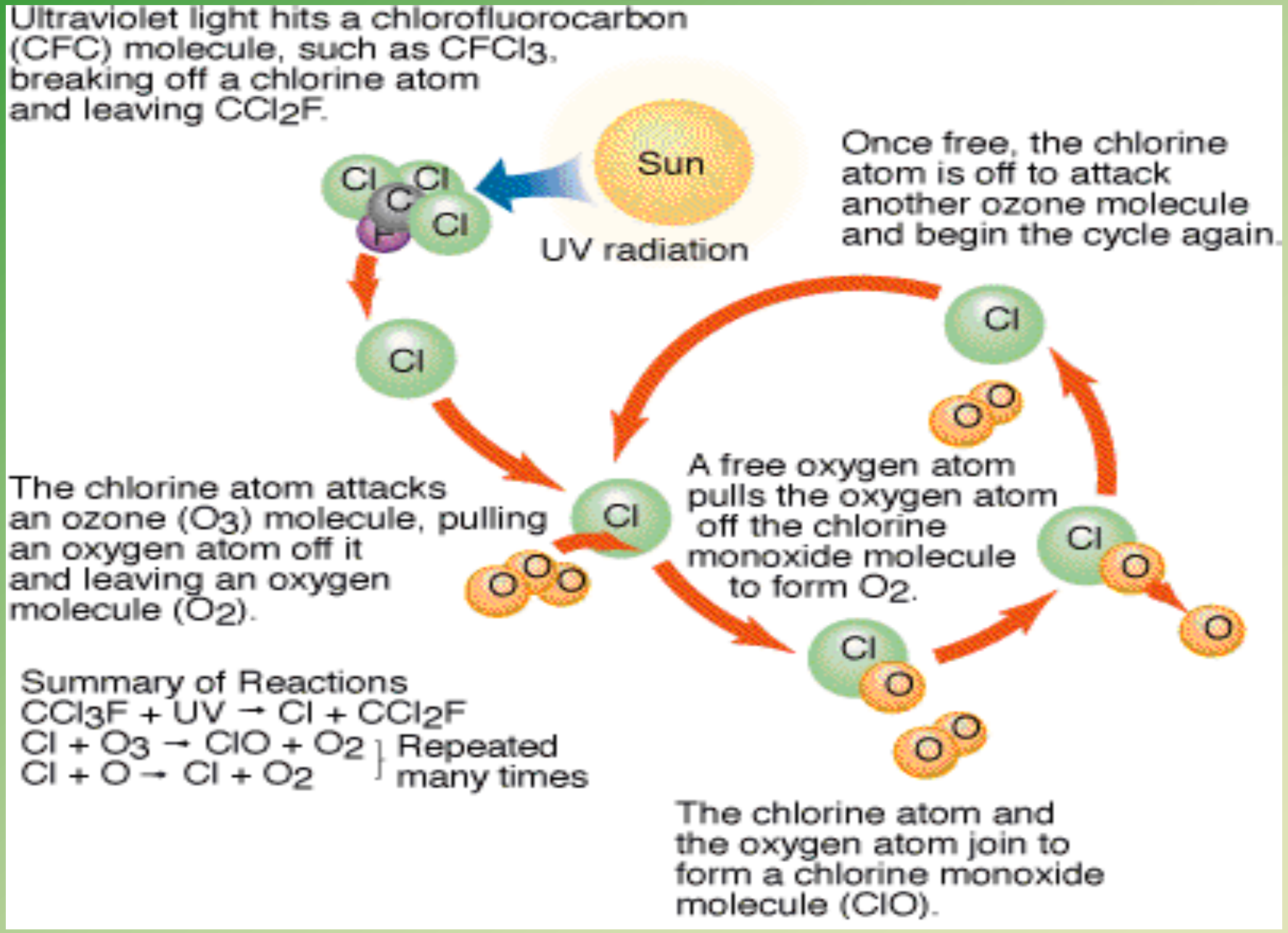
- If the full amount of ultraviolet radiation falling on the stratosphere reached Earth's surface; it is doubtful that any life could survive.

How Does Depletion Occur?

- CFCs emitted into atmosphere; they're stable, move from troposphere to stratosphere
- UV breaks off chlorine molecule (Cl) from CFC
- Cl acts as a catalyst to break down ozone (O_3)
  - catalyst – promotes a chemical reaction without itself being used up in the reaction
  - shifts equilibrium of oxygen / ozone reaction:

$$O_2 \longleftrightarrow O_3$$

Causes of Ozone Depletion



What causes Ozone Depletion?

- From Dream Chemicals to Nightmare Chemicals;
  - Thomas Midgley, Jr. A General Motors chemist, discovered the first chlorofluorocarbon (CFC) in 1930.
  - Family of highly useful CFCs – trichlorofluoromethane and dichlorodifluoromethane (AKA; freons)
  - Stable, odorless, nonflammable, nontoxic, and noncorrosive
  - Used in air conditioners, refrigerators, aerosol spray cans, cleaners for electronic parts, sterilants for hospital instruments, fumigants for granaries, bubbles in plastic foam used for packaging.

Consequences of Ozone Depletion

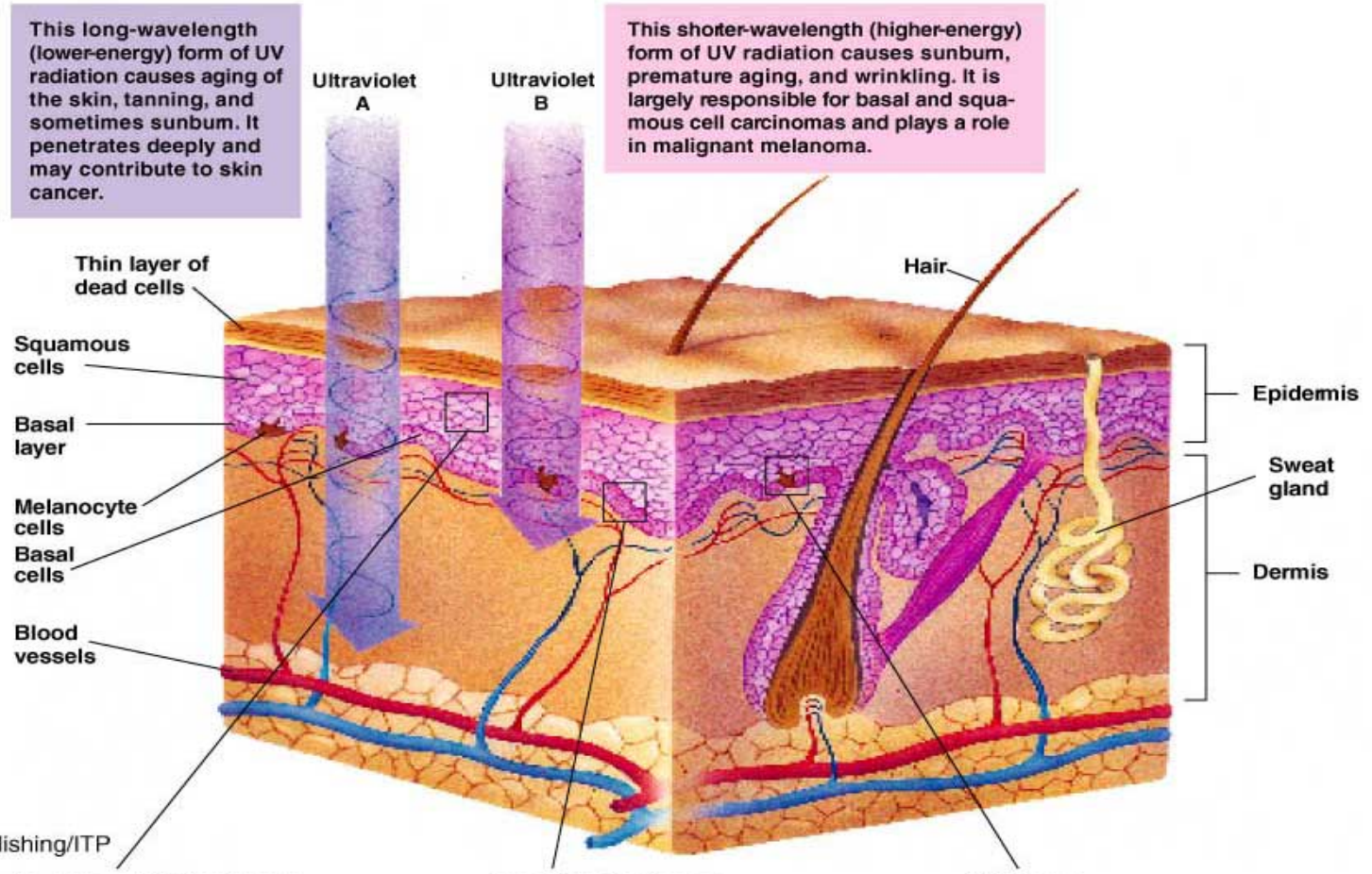
Humans:

- ✓ Increase in skin cancer & cataracts, especially in southern hemisphere
- ✓ More ozone near earth's surface, produced in photochemical smog – lung problems, suppressed immune response, cancer

What is the threat from Ozone Depletion?

- ✓ Radiation from the sun includes ultraviolet (UV) radiation; UVA and UVB
- ✓ UV radiation penetrates the atmosphere and is absorbed by biological tissues damaging protein and DNA molecules at the surfaces of all living things (sunburn).
- ✓ Most of the dangerous UVB radiation (over 99%) is absorbed by ozone in the stratosphere.

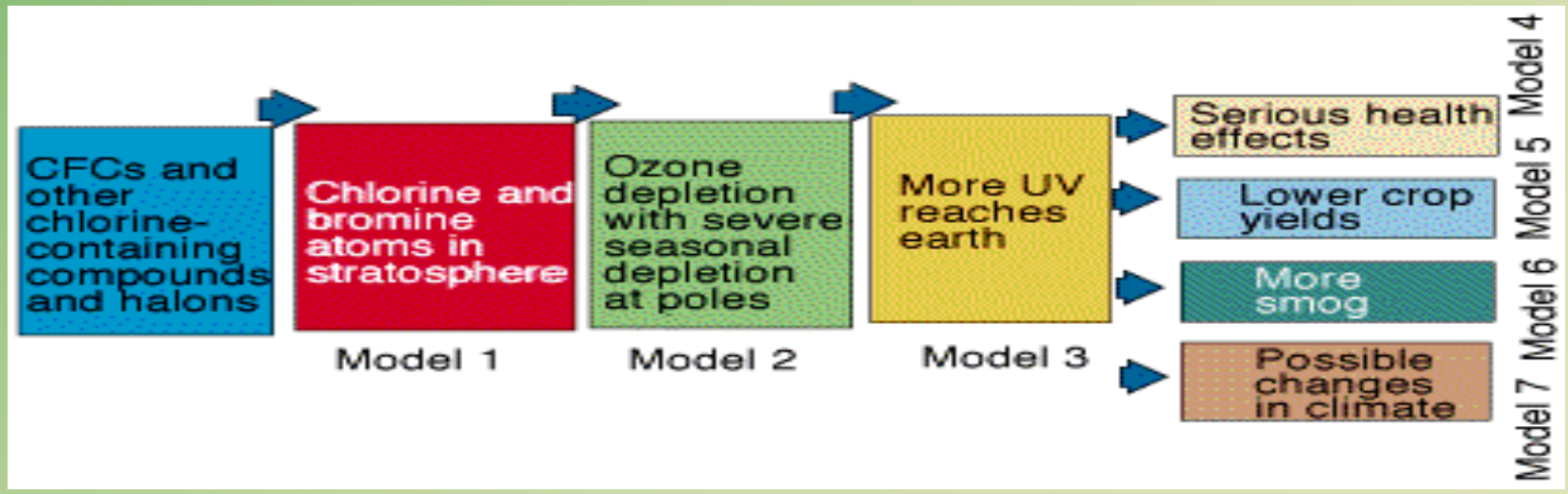
Skin Cancer


This long-wavelength (lower-energy) form of UV radiation causes aging of the skin, tanning, and sometimes sunburn. It penetrates deeply and may contribute to skin cancer.
Ultraviolet A
Ultraviolet B
This shorter-wavelength (higher-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.
Thin layer of dead cells
Hair
Squamous cells
Basal layer
Melanocyte cells
Basal cells
Blood vessels
Epidermis
Sweat gland
Dermis
© 2001 Brooks/Cole Publishing/ITP
Squamous Cell Carcinoma
Arising from cells in the upper layer of the epidermis, this cancer is also caused by exposure to sunlight or tanning lamps. It is usually curable if treated early. It grows faster than basal cell carcinoma and can metastasize.
Basal Cell Carcinoma
The most common skin malignancy is usually caused by excessive exposure to sunlight or tanning lamps. It develops slowly, rarely metastasizes, and is nearly 100% curable if diagnosed early and treated properly.
Melanoma
This deadliest of skin cancers involves melanocyte cells, which produce pigment. It can develop from a mole or on unblemished skin, grows quickly, and can spread to other parts of the body (metastasize).

Consequences of Ozone Depletion

Other organisms:

- ✓ Primary Producers:
  - Reduction in phytoplankton
  - Lower crop yields
  - Decline in forest productivity
- ✓ Animals:
  - Species disruption through increased exposure to UV-B radiation
  - Disruption of food chain

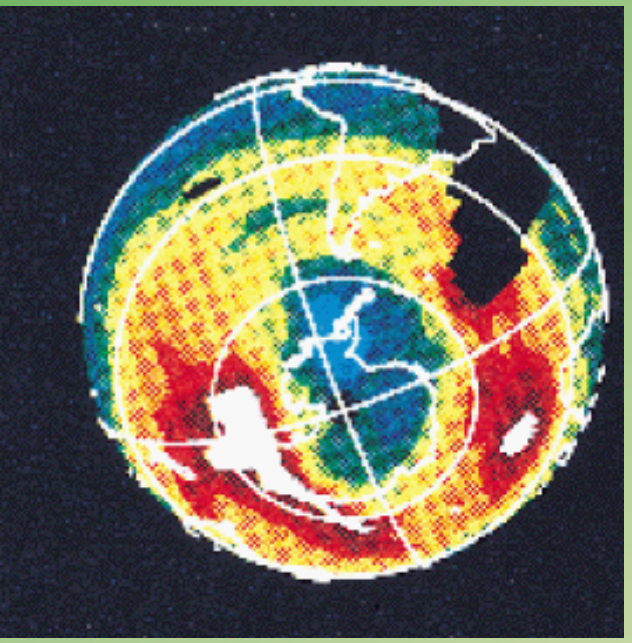


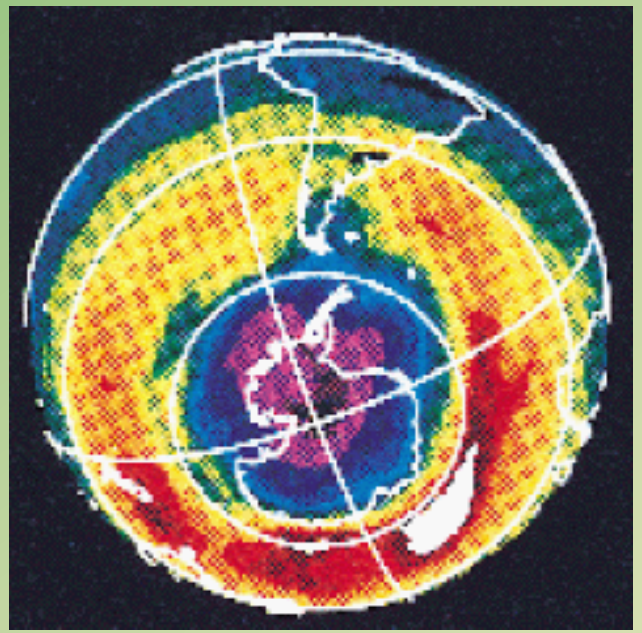
Ozone Depleting Chemicals

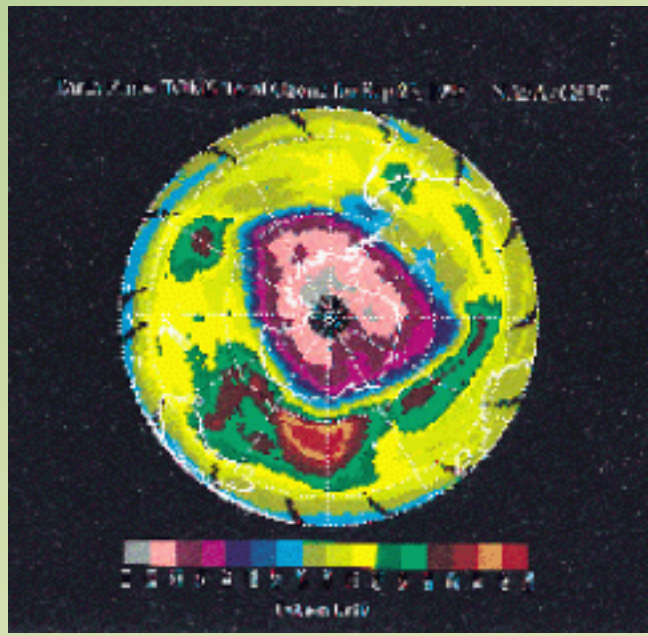
- Chlorofluorocarbons (CFCs)
- Halons: fire extinguishers
- Methyl bromide: fumigant
- Carbon tetrachloride: cheap, highly toxic solvent
- Methyl chloroform: cleaning solvent-clothes & metals
- Hydrogen chloride; U.S. space shuttles

Ozone Hole

- ✓ Seasonal thinning of the ozone layer has resulted at the poles, especially in the southern hemisphere
- ✓ Recent models suggest the hole may not get larger





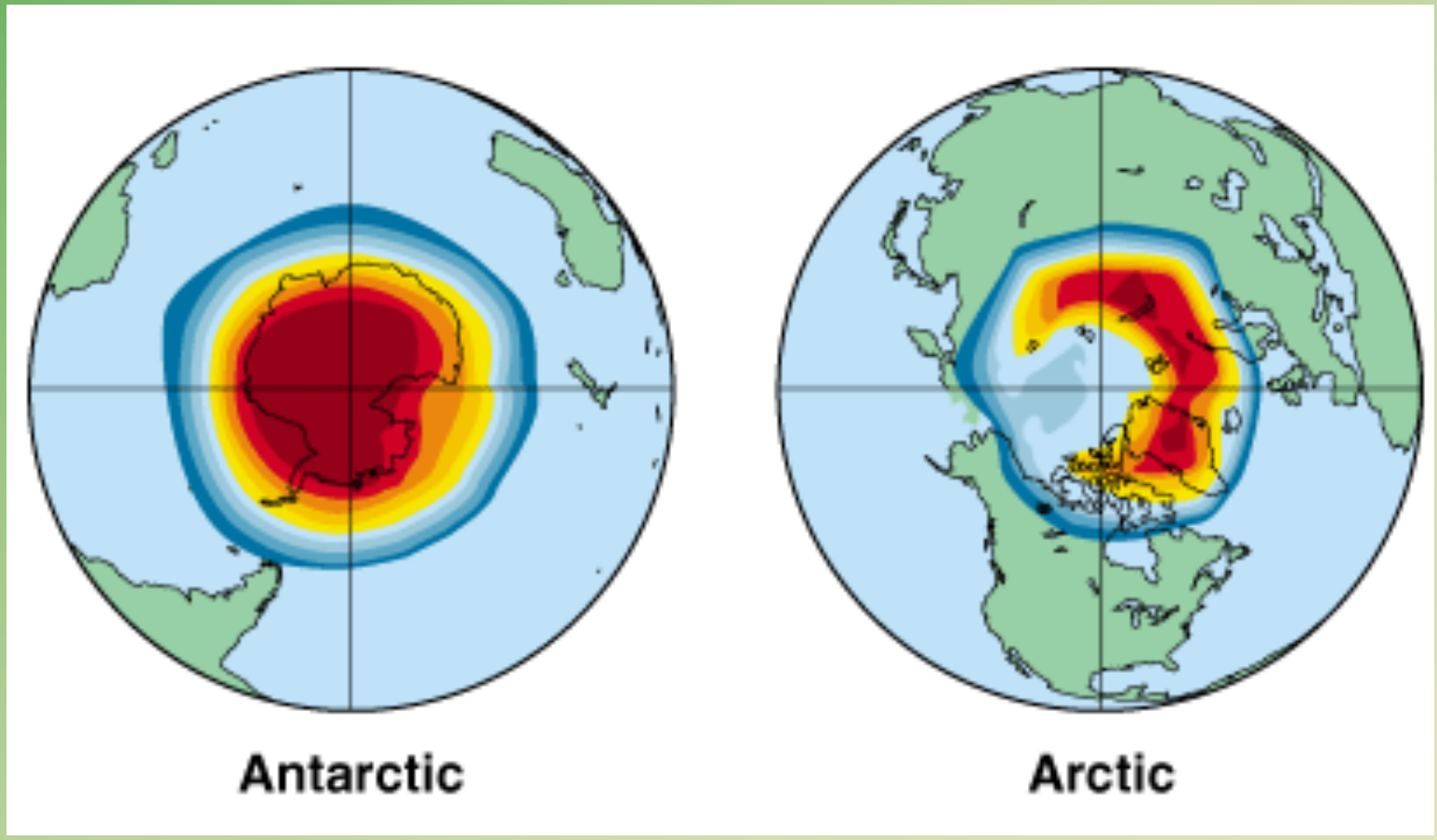


Why is there seasonal thinning of Ozone over the Poles?

- ✓ In 1984, researchers discovered 40-50% of the ozone in the upper stratosphere over Antarctica was being destroyed during the antarctic spring and early summer (Sept.-Dec.)
- ✓ In 2000, ozone thinning above Antarctica was the largest ever and covered an area three times the size of the continental U.S. (11 million square miles)
- ✓ Measurements indicate that CFCs are the primary culprits.

Ozone Loss

Projected total ozone loss, averaged over 2010-2019, during September for the Antarctic (left) and during March for the Arctic (right). Dark red represents ozone depletion of 54% or more; light blue, 18-30%; dark blue, 6-12%.



Solutions to Ozone Depletion

- Phase out use of ozone–depleting chemicals (halons, CFCs, methyl chloroform, methyl bromide)
- Phase in use of CFC substitutes [non–halogen aerosol propellants, hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), hydrocarbons (HCs), ammonia, water & steam, terpenes, helium]

International Agreements

✓ Montreal Protocol (1987)
  – Cut emission of CFCs by 35% by 2000

✓ London (1990) and Copenhagen (1992)
  – Accelerate phase-out of other key ozone-depleting chemicals

World Meteorological Organization

- Continued depletion for several decades
  - 11-20 year time lag between when CFCs are released into the atmosphere and when they actually reach the stratosphere.
  - Persistence for decades

- Return to 1980 levels by about 2050 and to 1950 levels by about 2100.
  - International agreements are followed
  - No major volcanic eruptions

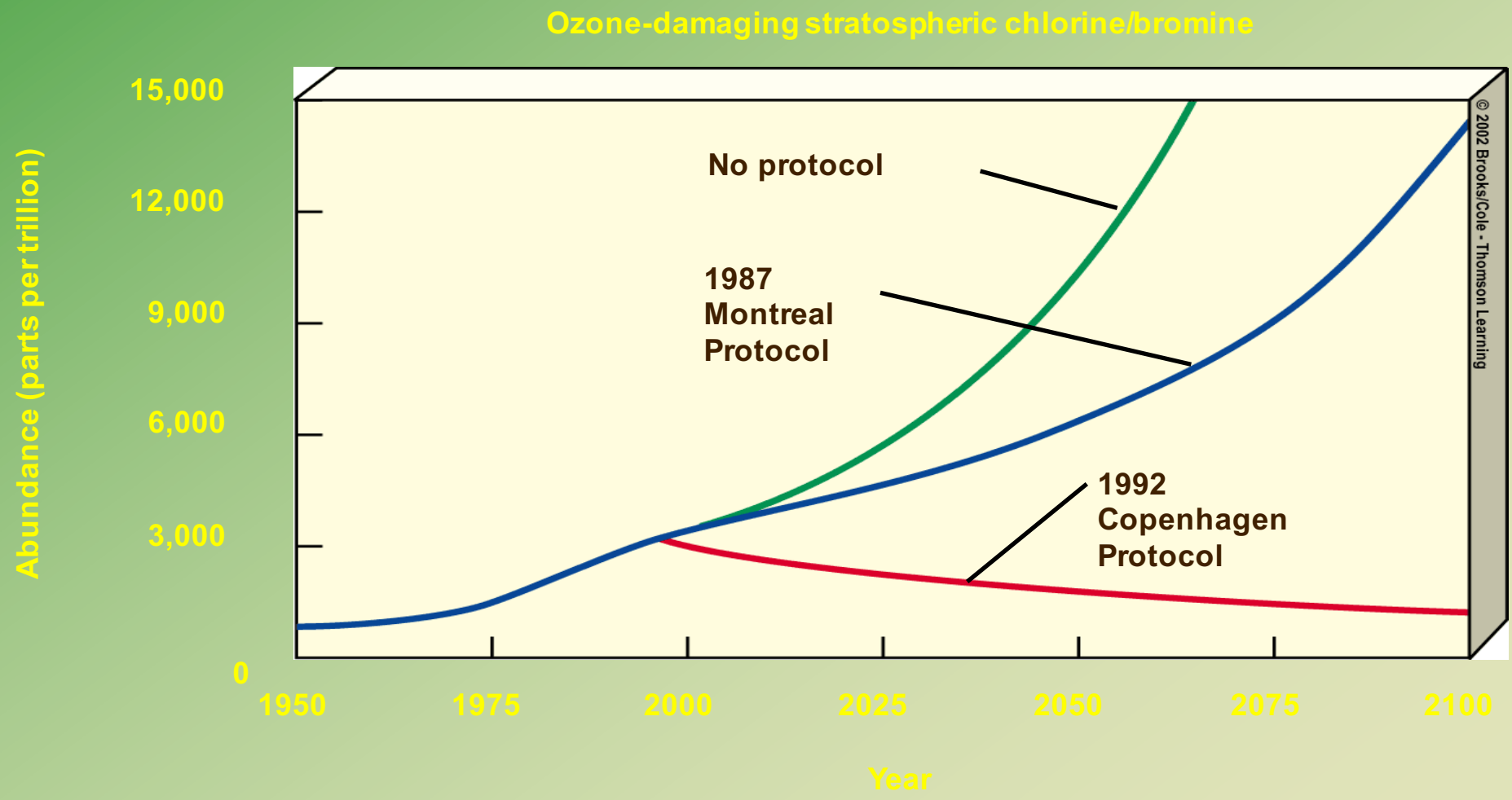
- Restoring the ozone layer may lead to an increase in global warming
  - Ozone depletion has been cooling the troposphere
  - Disguise as much as 30% of global warming caused by our greenhouse gas emissions.

How can we protect the Ozone layer?

- Technofixes
  - Huge radio-controlled blimps to form an electrical curtain.
  - Lasers blasting CFCs out of the atmosphere before they reach the stratosphere.
- Montreal Protocol
  - Phase-out CFC emissions
- Copenhagen Protocol
  - Phase-out CFC emissions and other ozone deleters

Solutions: Protecting the Ozone Layer

- **CFC substitutes**
- **Technofixes**
- **Montreal Protocol**



Reasons for Concern

- Increased incidence and severity of sunburn
- Increase in eye cataracts
- Increased incidence of skin cancer
- Immune system supression
- Increase in acid deposition
- Lower crop yields and decline in productivity

The Boiled Frog Syndrome

- Global warming occurs gradually over many decades until obvious and serious effects occur. By then it will be too late to take corrective action. During the early stages it is easy for people to deny that anything serious is happening.

- Psychologist Robert Ornstein calls this denial the Boiled Frog Syndrome: A frog in a pot of water does not become alarmed as it is slowly heated. The frog does not perceive the situation as dangerous because the water the process is very gradual, and the frog is alive from temperature increase to temperature increase. Eventually the frog dies because he has no evolutionary experience of the lethal effects.

What happens when the vortex breaks up?

Huge masses of ozone depleted air above Antarctica flow northward and linger for a few weeks over parts of Australia, New Zealand, South America, and South Africa.

- Raises biologically damaging UV-B levels in these areas by 3-10% and in some years as much as 20%.

Each sunless winter, steady winds blow in a circular pattern over the earth's poles – creating a polar vortex; huge swirling mass of very cold air that is isolated from the rest of the atmosphere until the sun returns a few months later.

Water droplets in clouds enter this circling frigid air, they form tiny ice crystals.

The surfaces of these ice crystals collects CFCs and releases Cl and ClO atoms which form molecules and accumulate in the polar vortex.

When sunlight returns, the light breaks up the stored Cl_2O_2 molecules, releasing large numbers of Cl atoms and initiating the catalyzed chlorine cycle – destroying ozone.

Shocking evidence discovered

- Rowland and Molina, two University of California chemists, in 1974 called for an immediate ban of CFCs (a $28 billion per year industry) in spray cans.
  - Large quantities of CFCs being released into troposphere
  - Remain in troposphere because they are insoluble in water
  - Over 11-20 years rise into stratosphere
  - In stratosphere, the CFC molecules facilitate the breakdown of the ozone shield.

4. Summary

	Greenhouse effect	Ozone shield
Where?	troposphere	stratosphere
Process?	traps heat near earth's surface	filters ultraviolet (UV) radiation
Gases?	H_20, CO_2, CH_4	O_2, O_3
Inputs?	CO_2, CH_4, CFCs, N_2O	CFCs, other halogen–containing gases
Problems?	global warming	ozone depletion