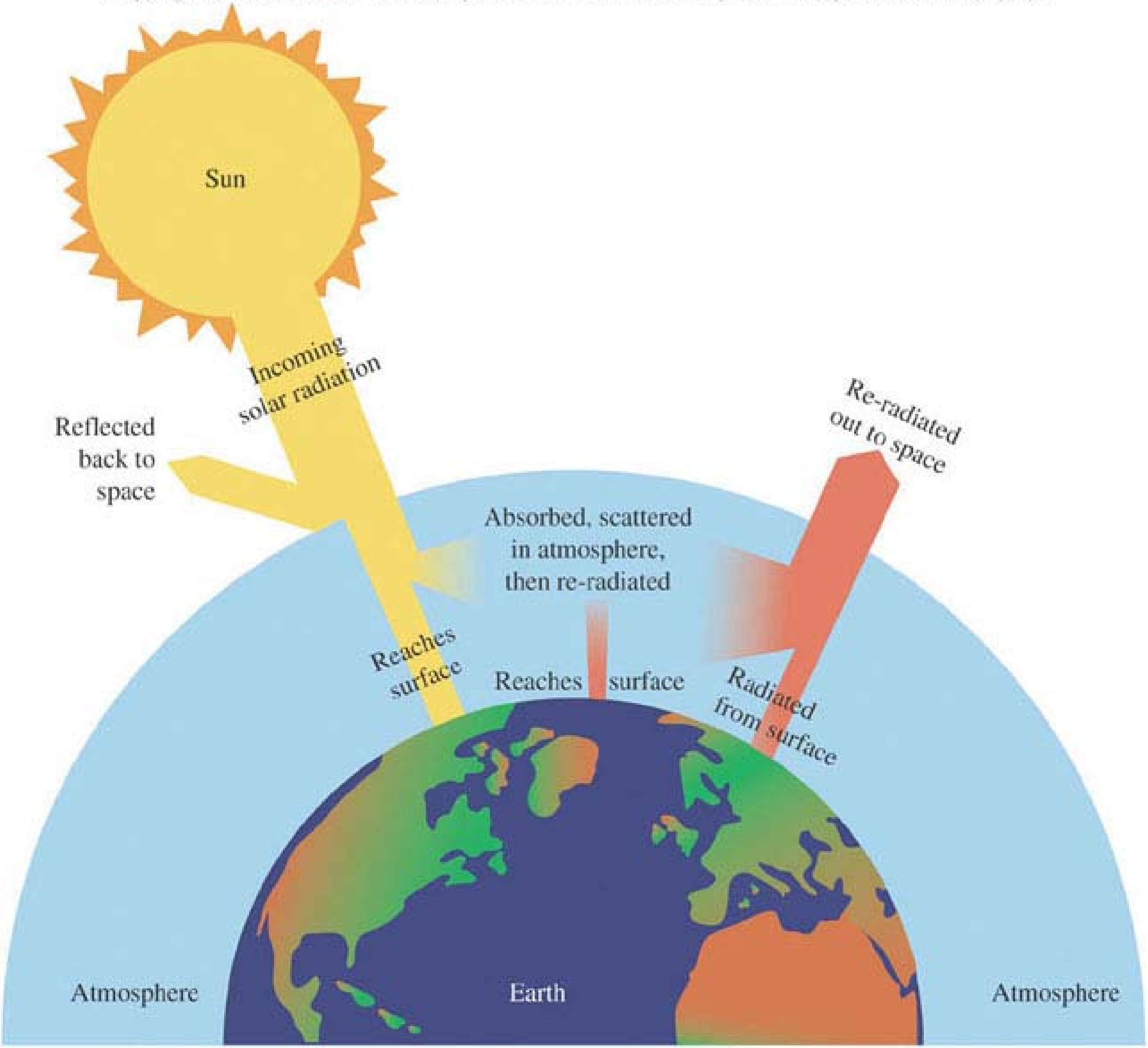
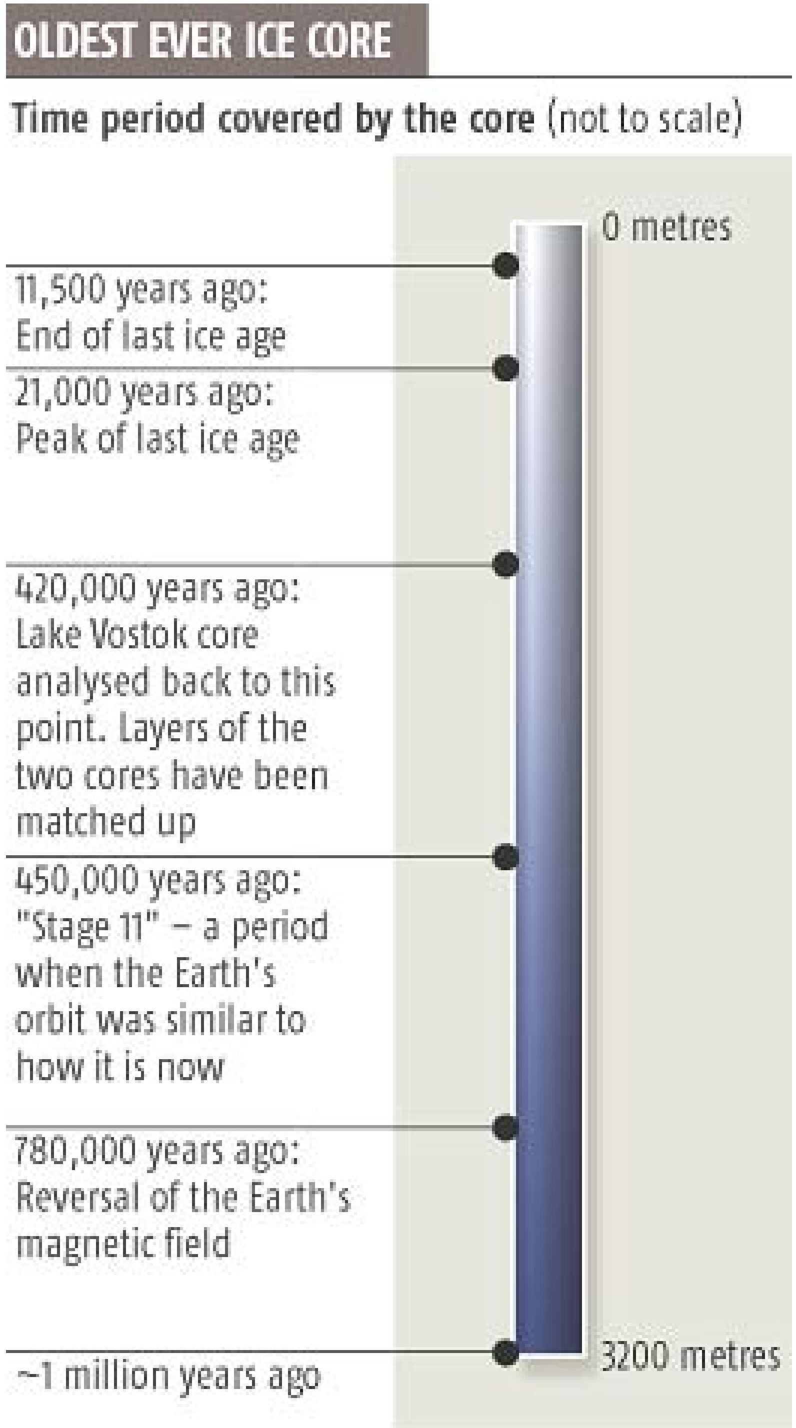


Sun
Incoming solar radiation
Reflected back to space
Re-radiated out to space
Absorbed, scattered in atmosphere, then re-radiated
Reaches surface
Reaches surface
Radiated from surface
Atmosphere
Earth
Atmosphere

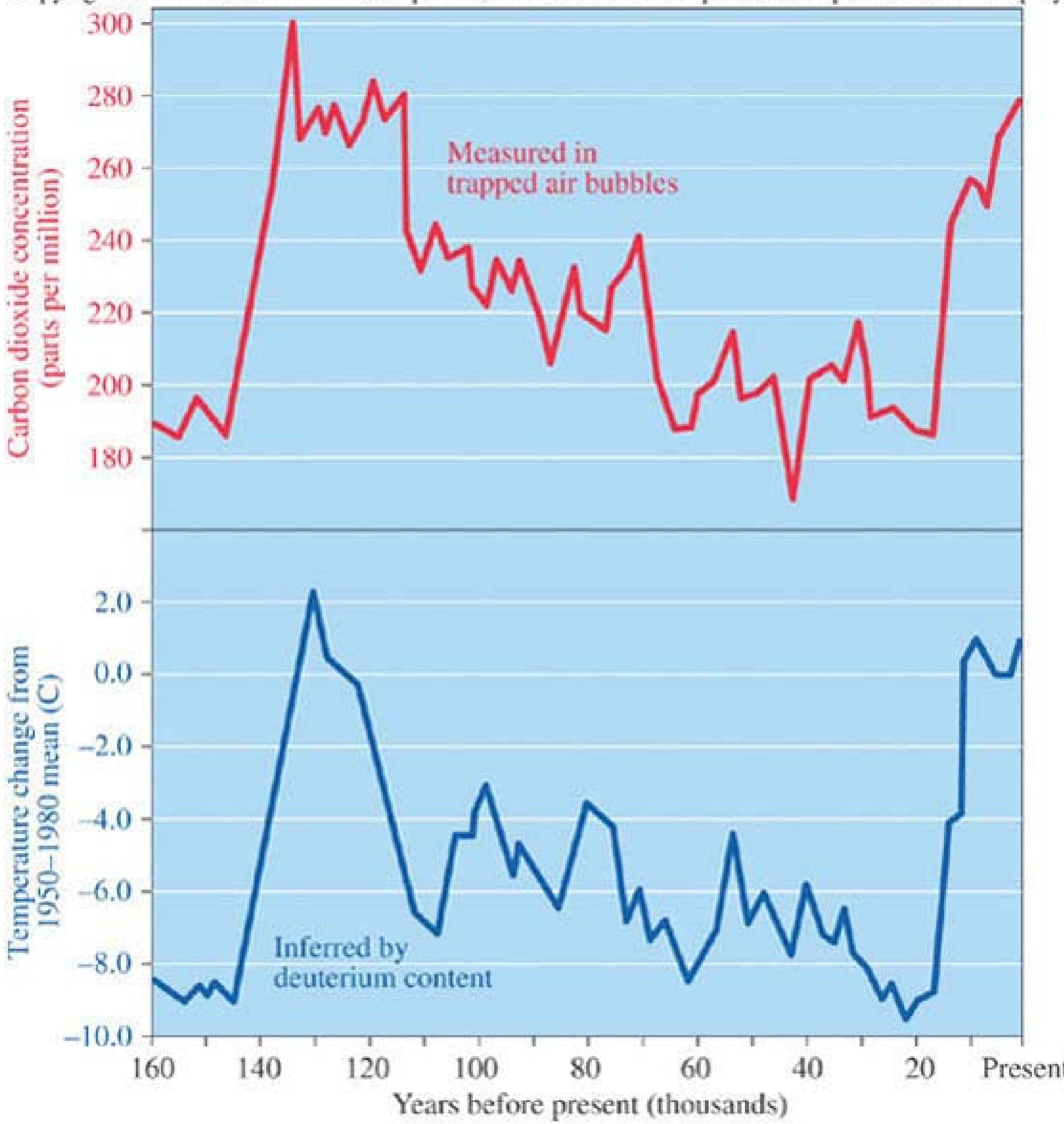



**Oldest ever ice core promises climate revelations**

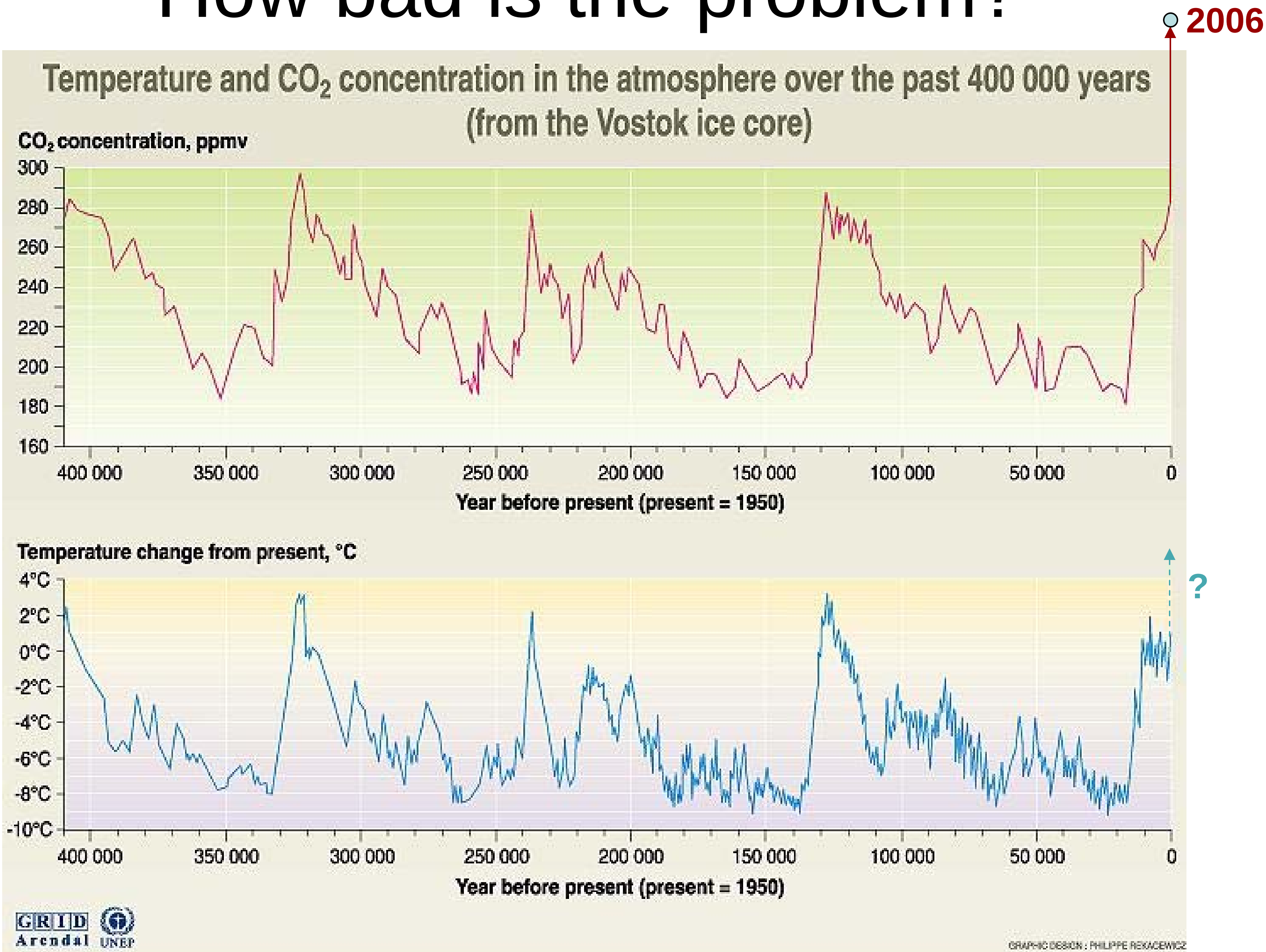
09:30 08 September 2003

Exclusive from New Scientist Print Edition

Magdeline Pokar, Milan

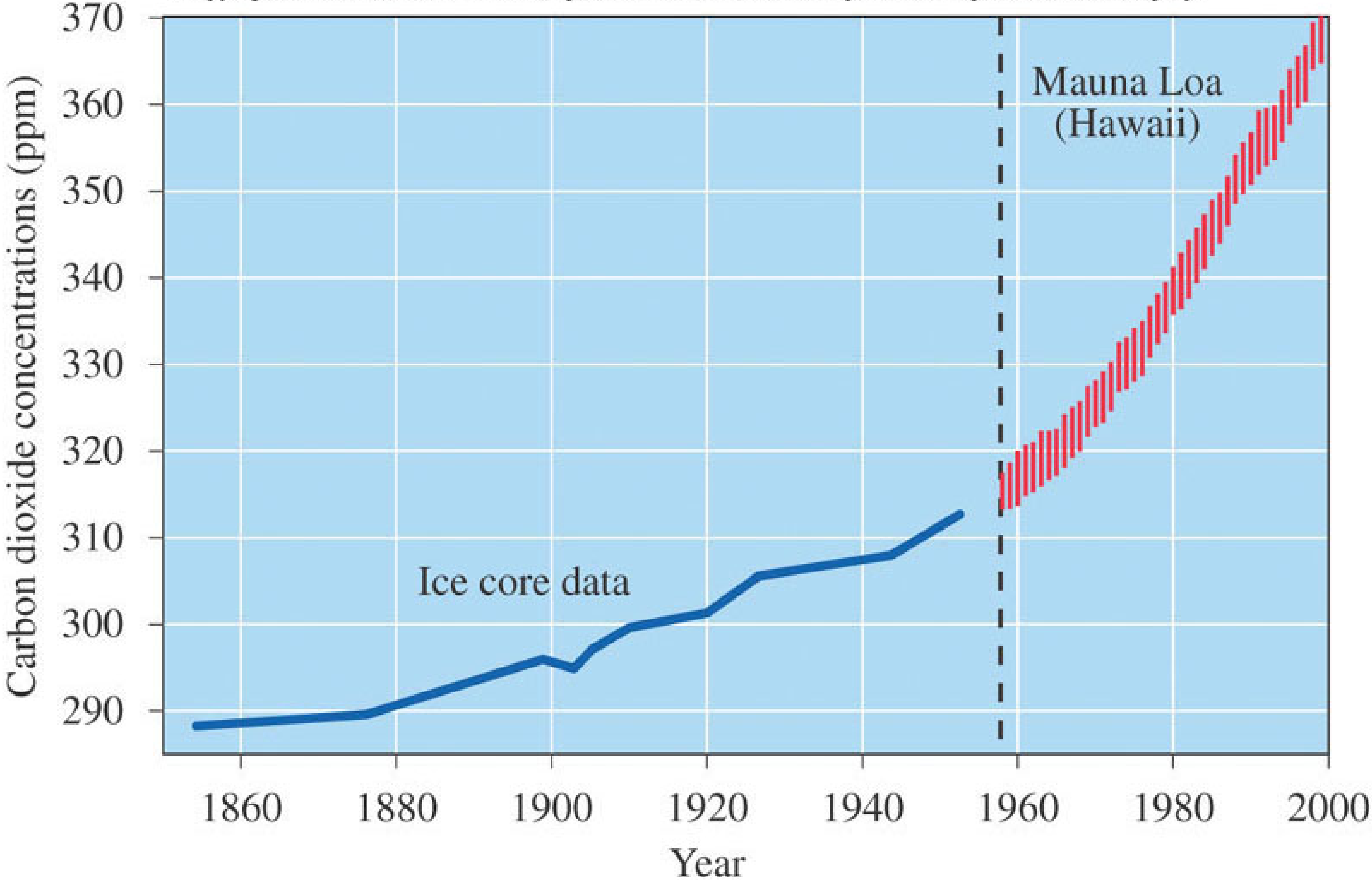

300
280
260
240
220
200
180
Carbon dioxide concentration (parts per million)
Measured in trapped air bubbles
2.0
0.0
−2.0
−4.0
−6.0
−8.0
−10.0
Temperature change from 1950–1980 mean (C)
Inferred by deuterium content
160
140
120
100
80
60
40
20
Present
Years before present (thousands)

# How bad is the problem?

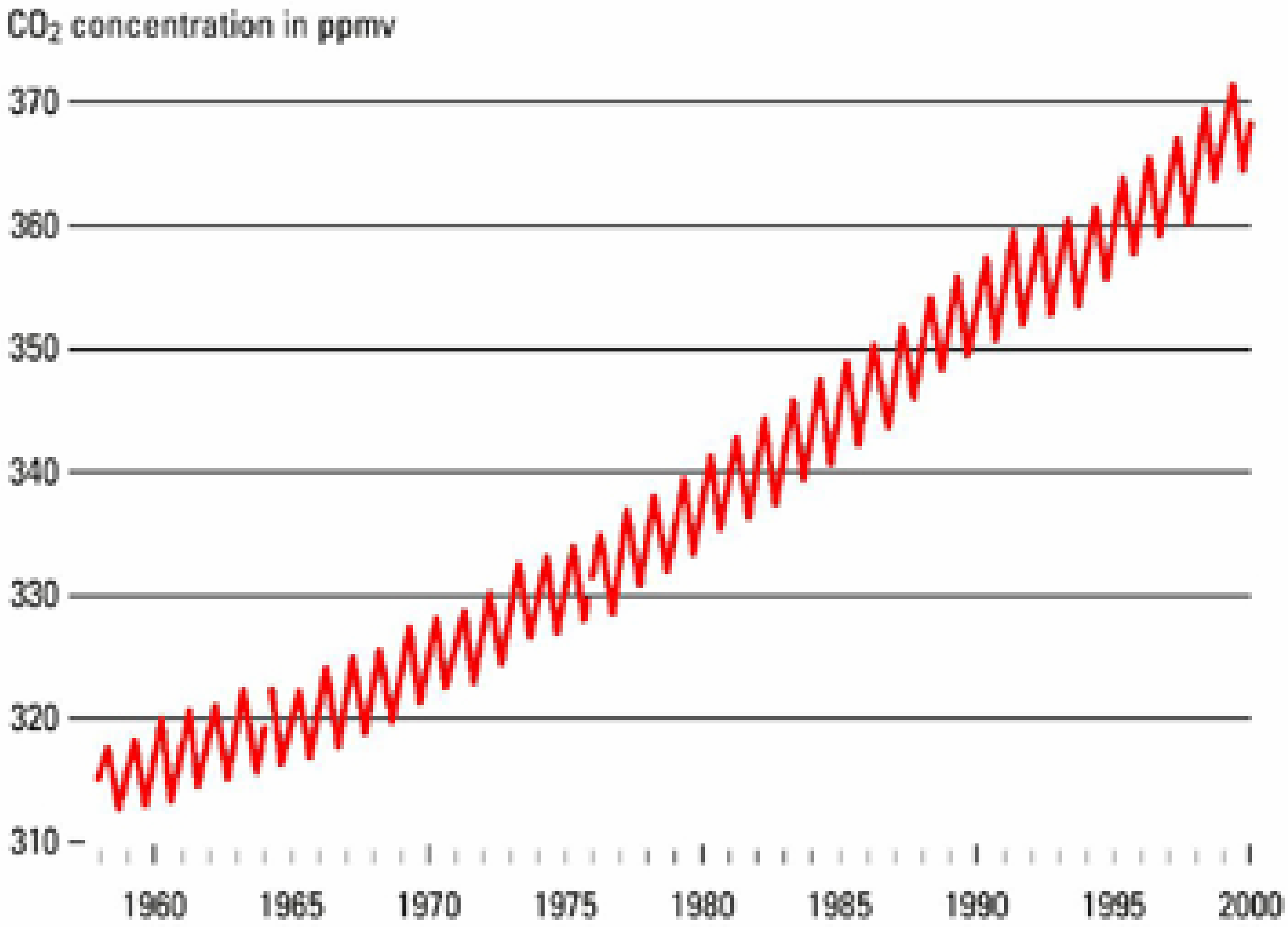


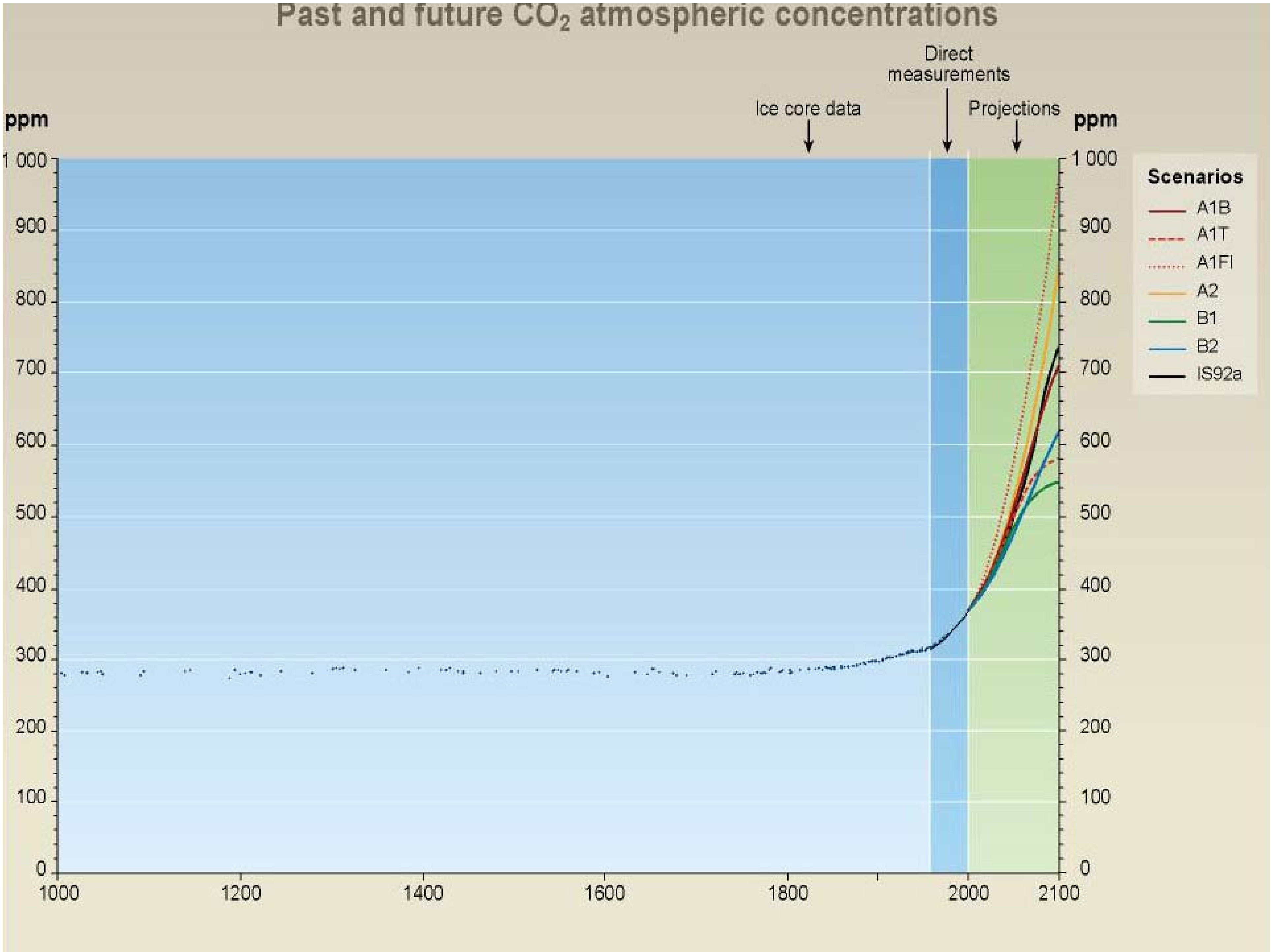

Source: J.R. Petit, J. Jouzel, et al. Climate and atmospheric history of the past 420 000 years from the Vostok ice core in Antarctica, Nature 399 (3JUne), pp 429-436, 1999.

For more info, see http://www.geology.iastate.edu/gccourse/overview/temp.html

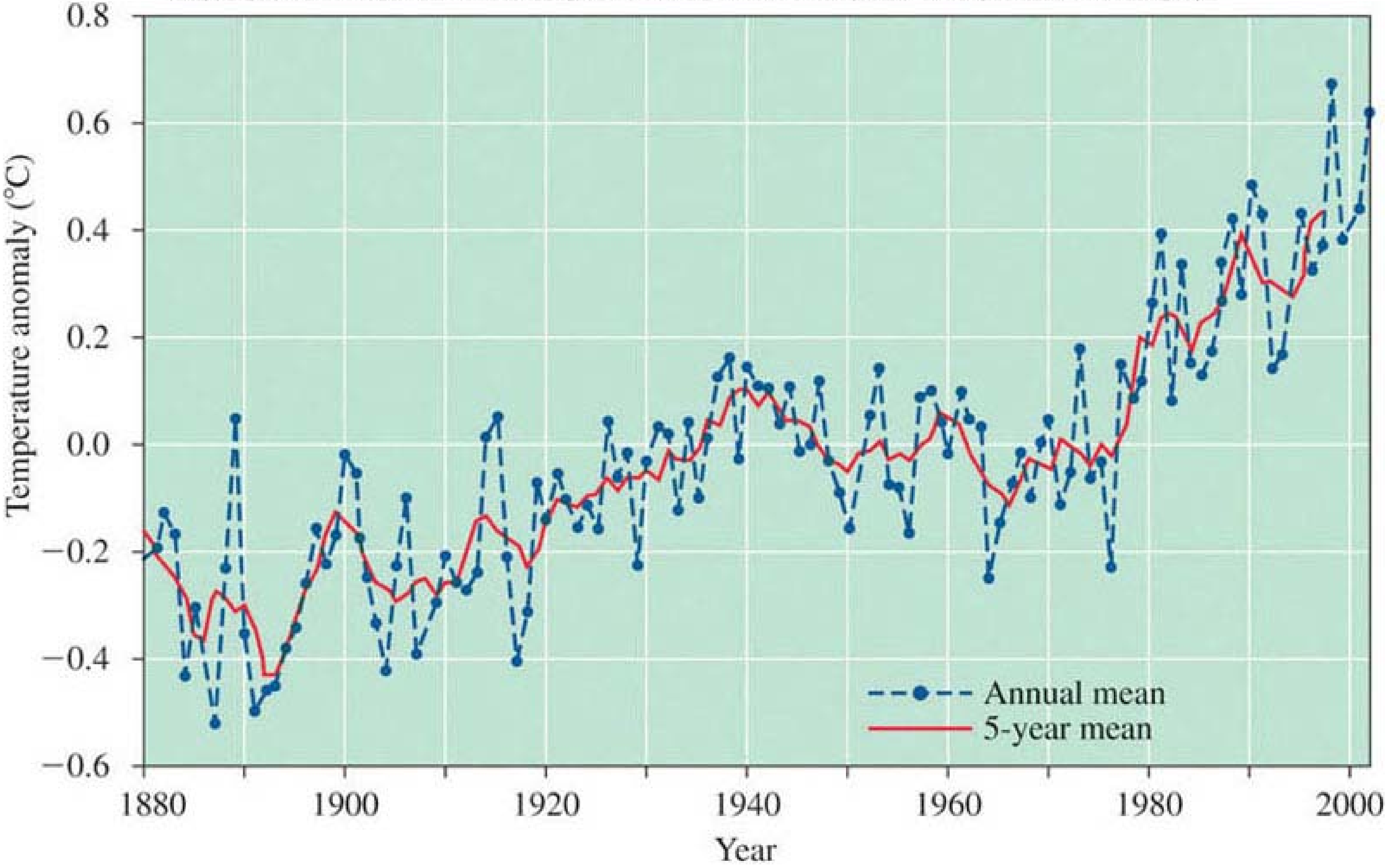

Carbon dioxide concentrations (ppm)
370
360
350
340
330
320
310
300
290
Mauna Loa
(Hawaii)
Ice core data
1860
1880
1900
1920
1940
1960
1980
2000
Year

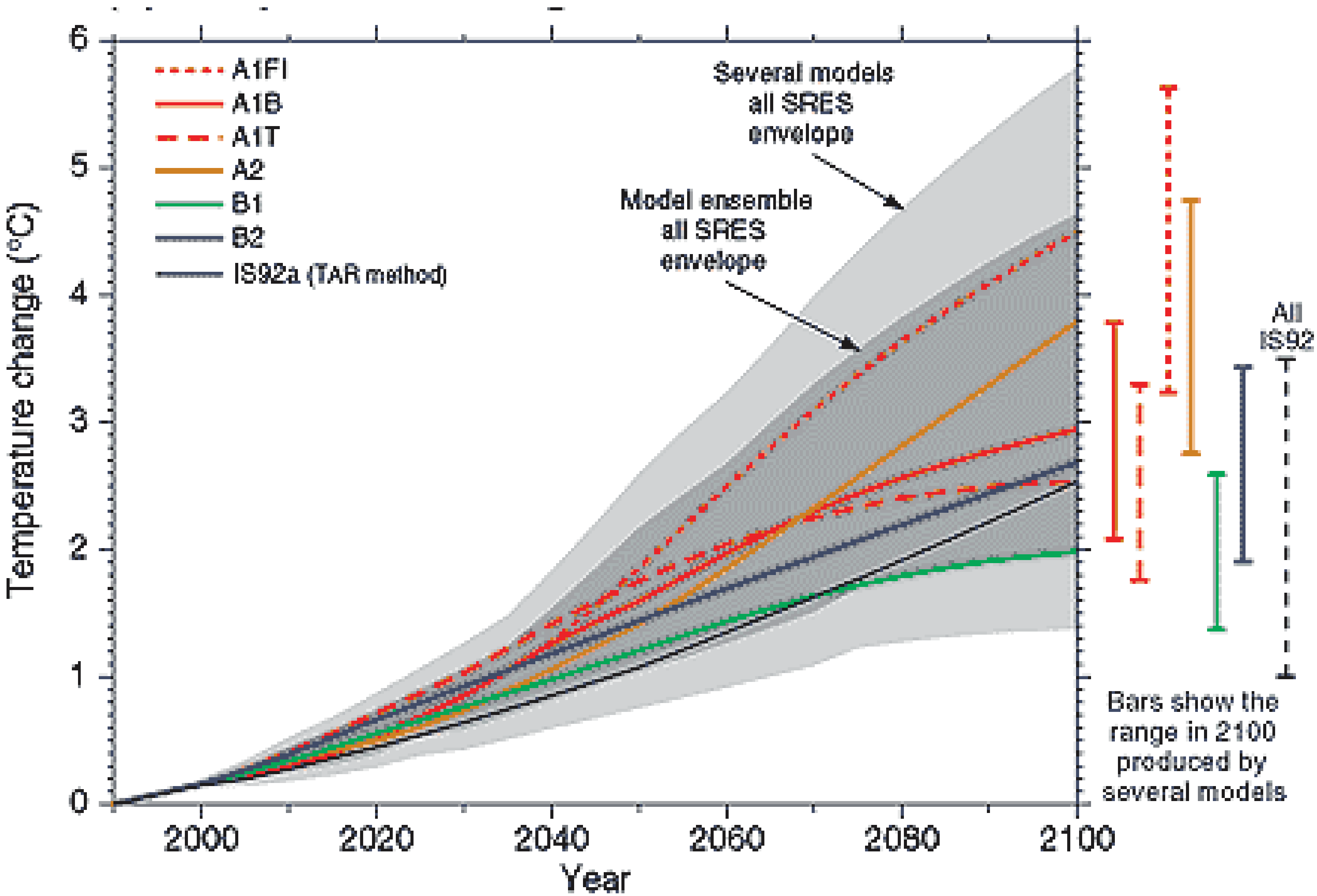
# Mauna Loa $CO_2$ increases



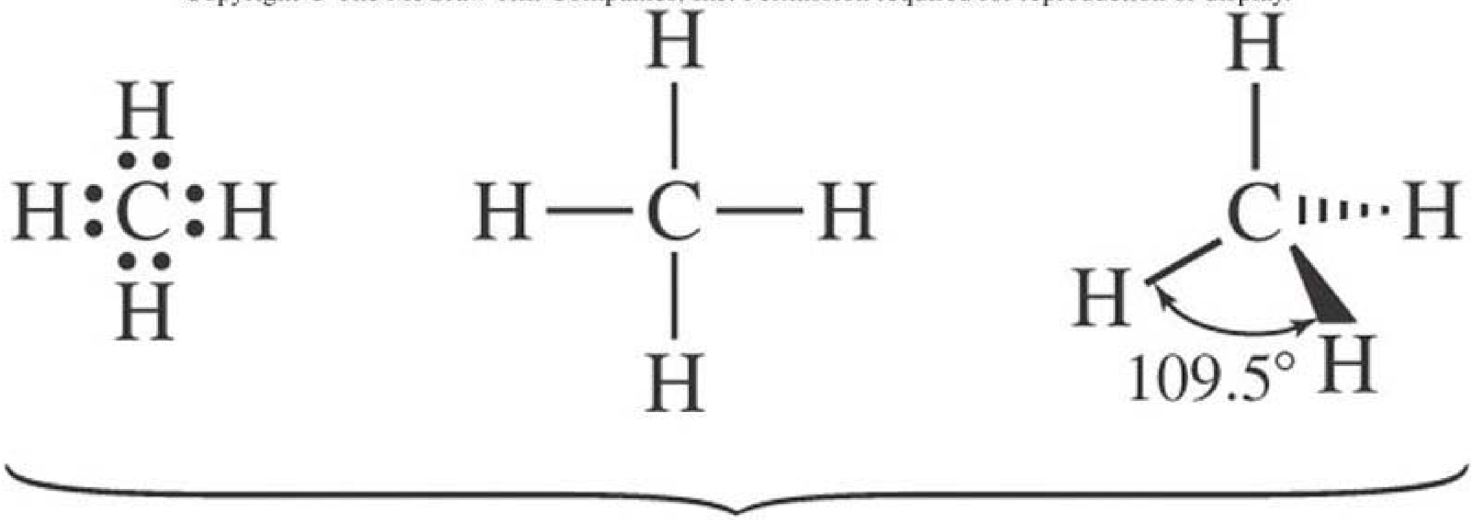


Past and future CO2 atmospheric concentrations
Direct measurements
Ice core data
Projections
ppm
ppm
1 000
900
800
700
600
500
400
300
200
100
0
1000
1200
1400
1600
1800
2000
2100
Scenarios
A1B
A1T
A1FI
A2
B1
B2
IS92a


0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
Temperature anomaly (°C)
1880
1900
1920
1940
1960
1980
2000
Year
Annual mean
5-year mean

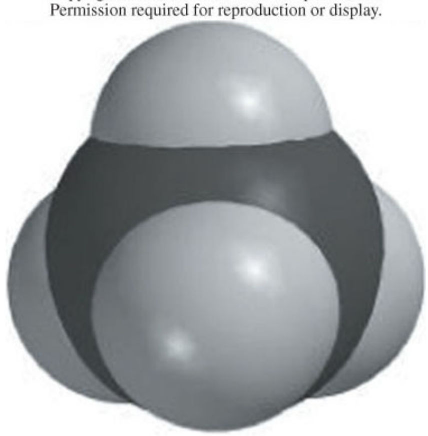


A1FI
A1B
A1T
A2
B1
B2
IS92a (TAR method)
Several models all SRES envelope
Model ensemble all SRES envelope
All IS92
Bars show the range in 2100 produced by several models
Temperature change (°C)
Year
0
1
2
3
4
5
6
2000
2020
2040
2060
2080
2100

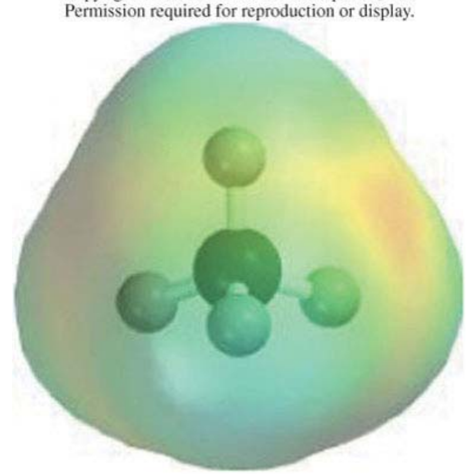



(a)





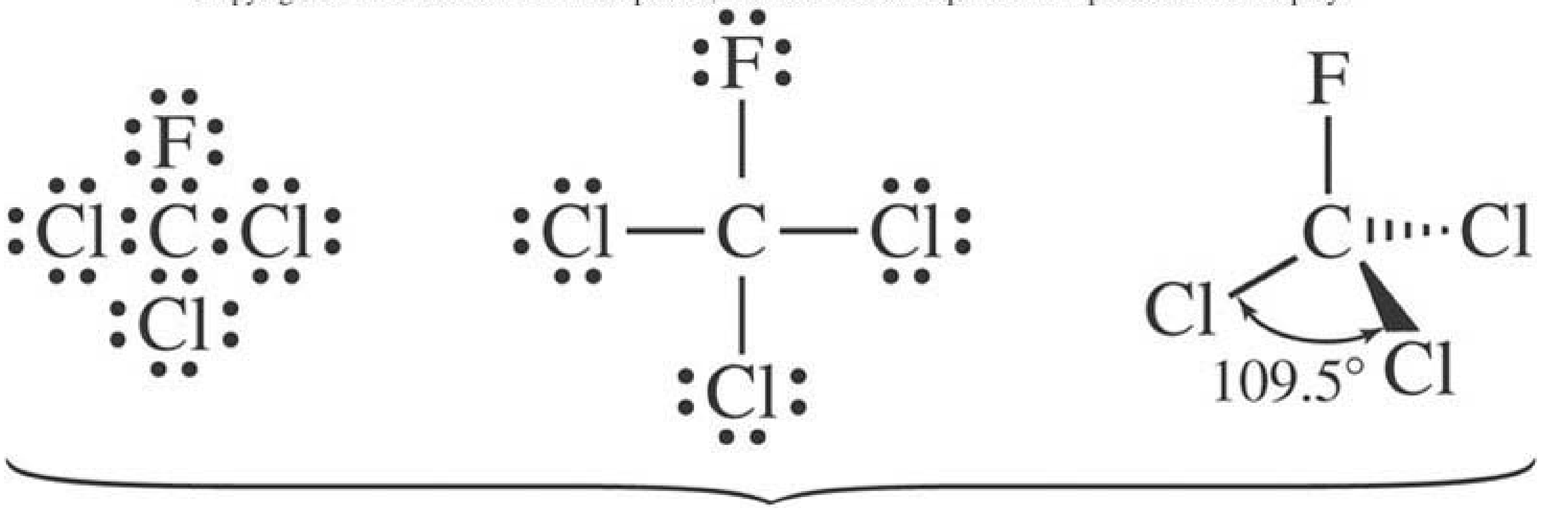




tetrahedron

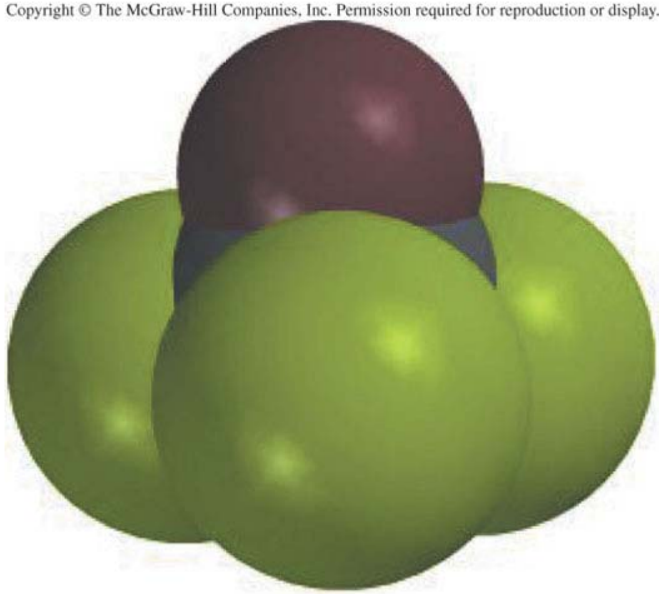
(b)

(c)



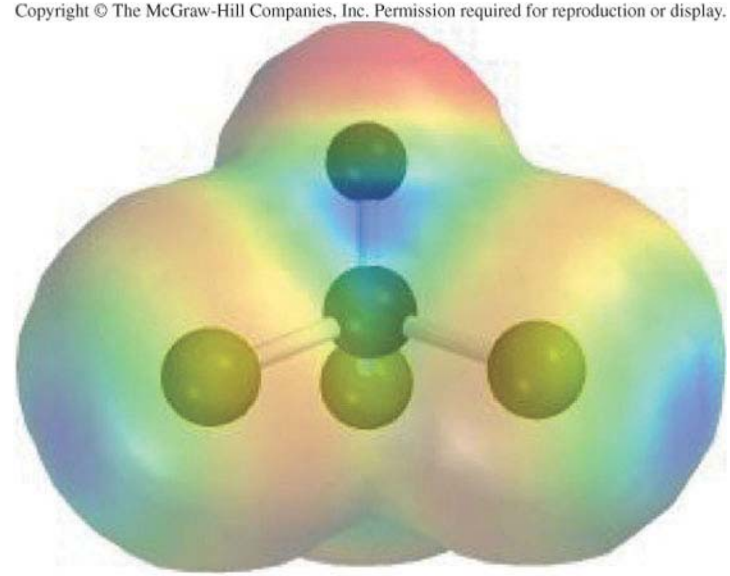

(a)





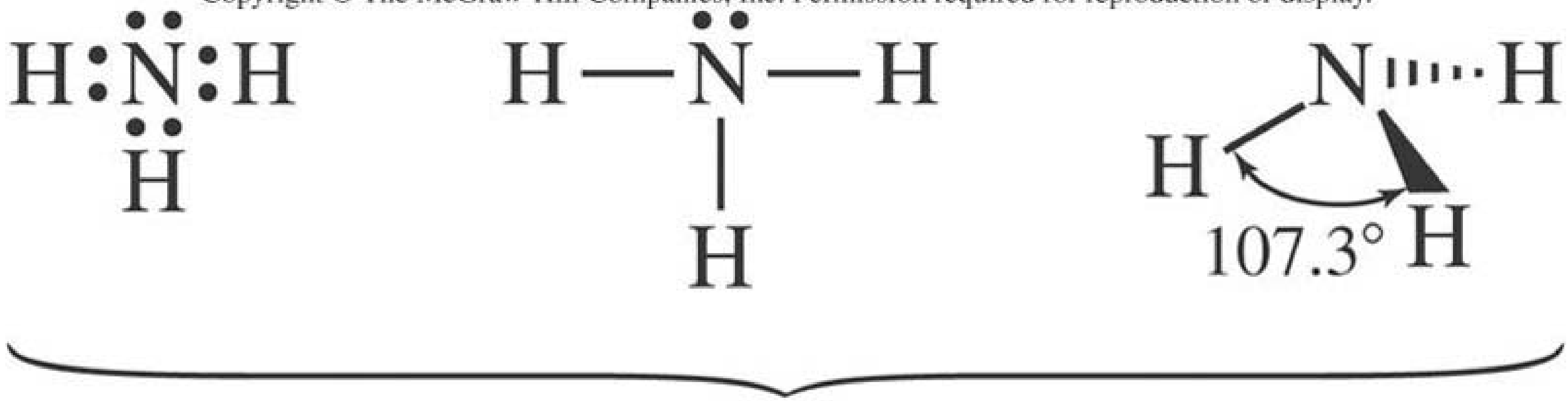
(b)





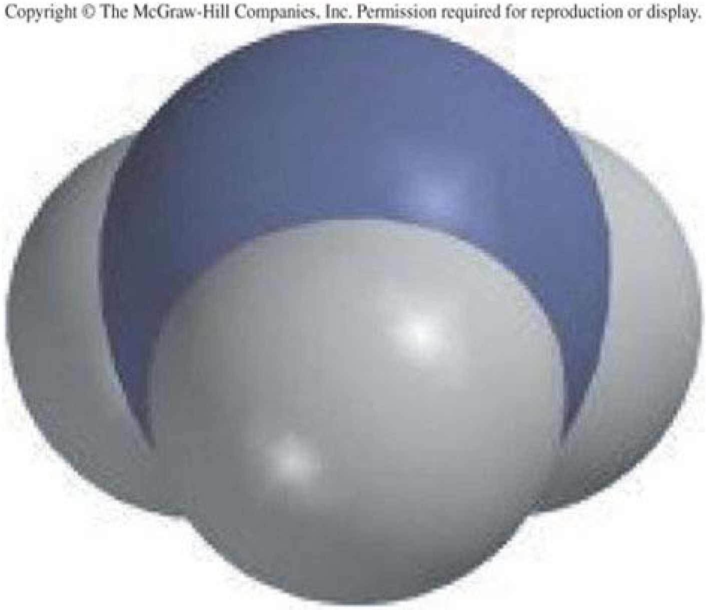
tetrahedron

(c)

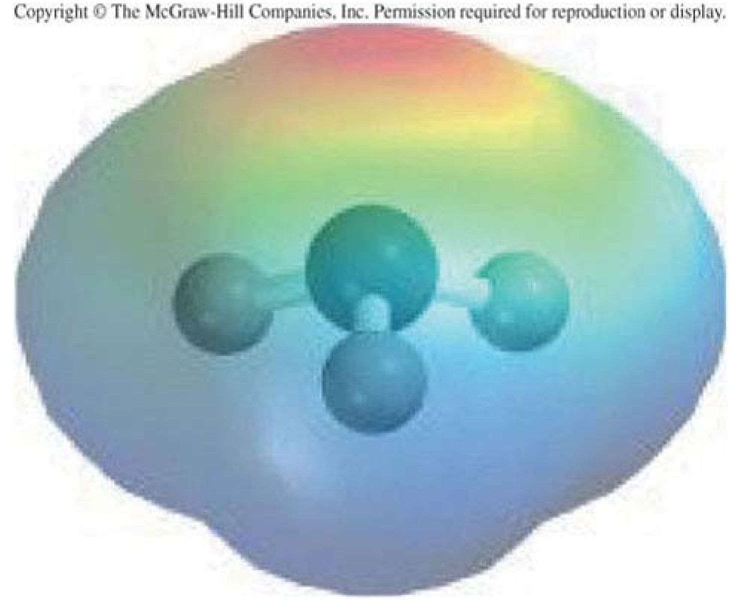



(a)





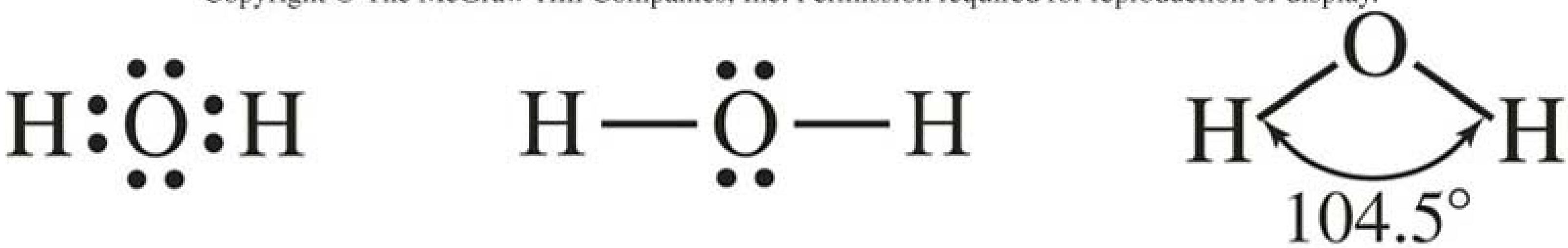




pyramid

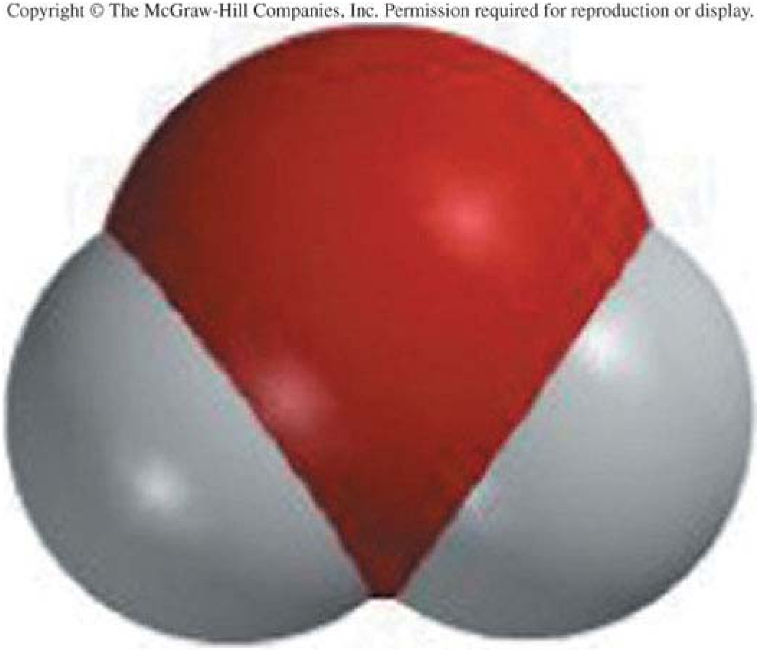
(b)

(c)




(a)





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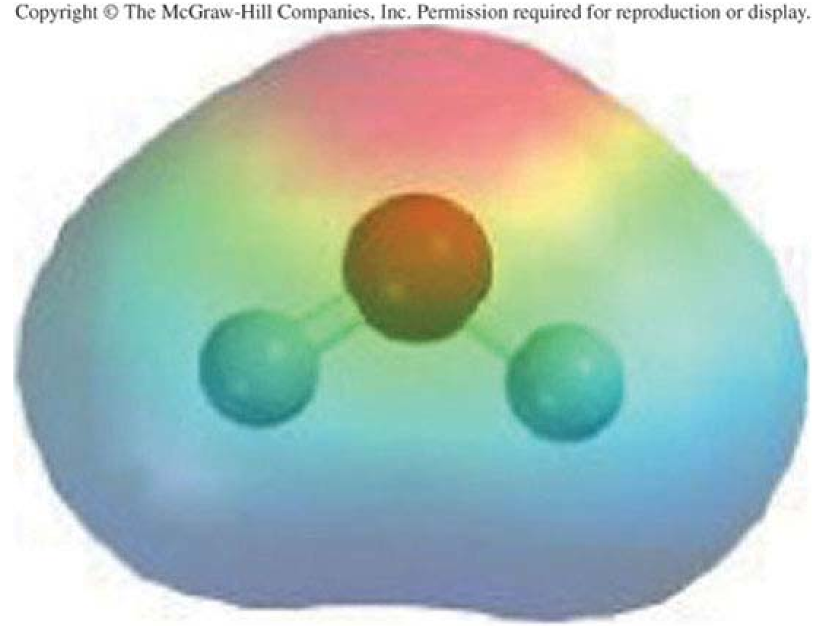
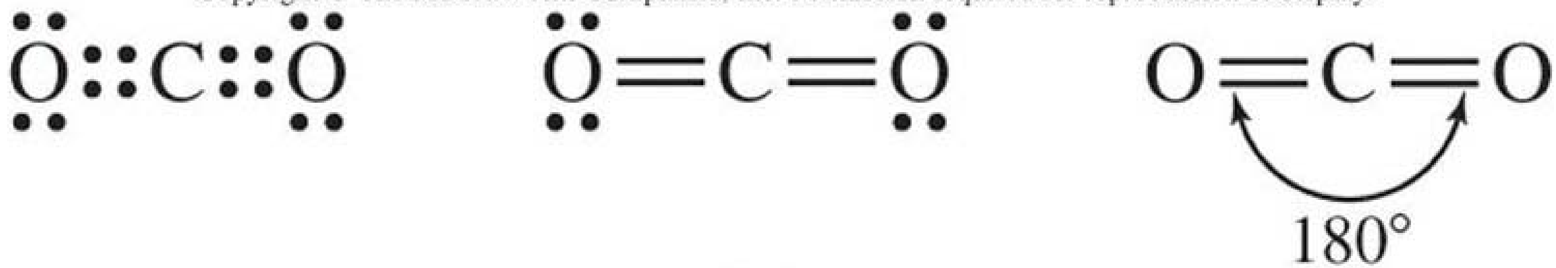


bent

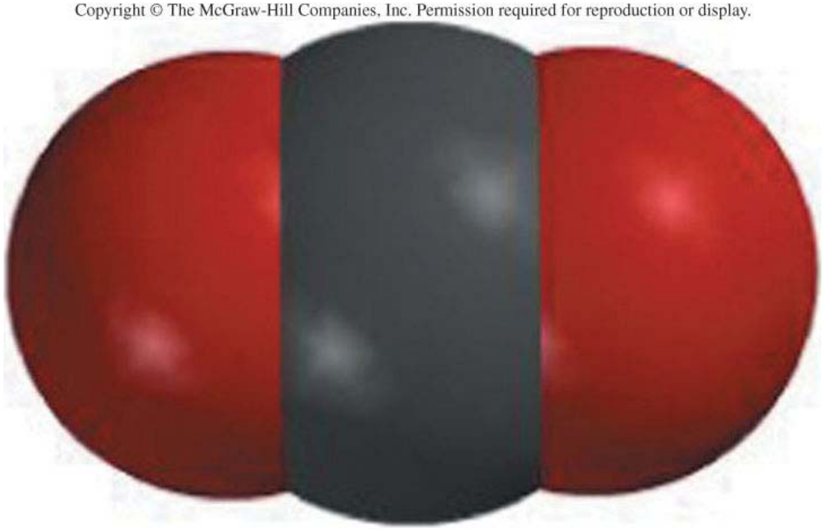
(b)

(c)



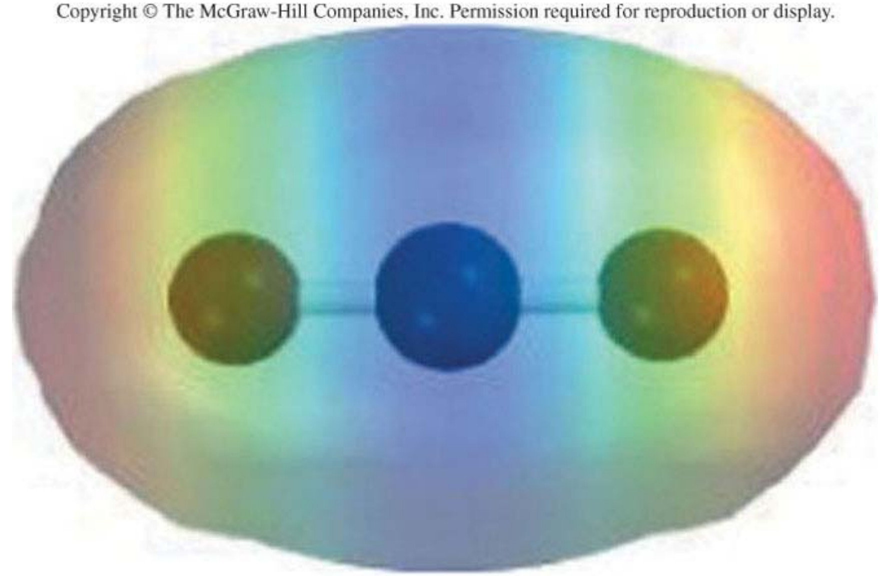

(a)



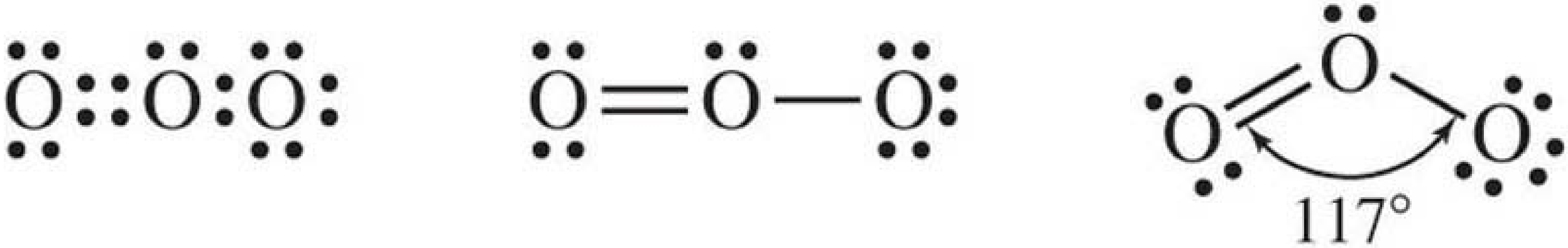


(b)





(c)

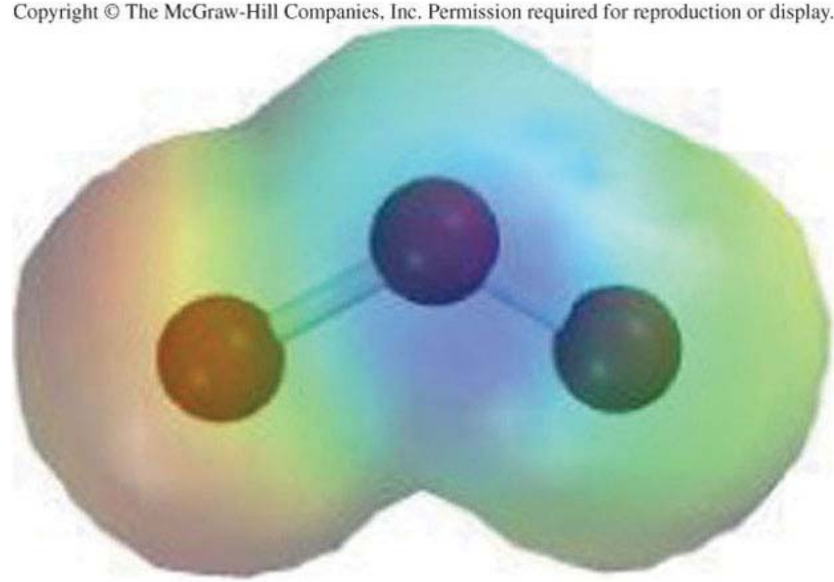



(a)



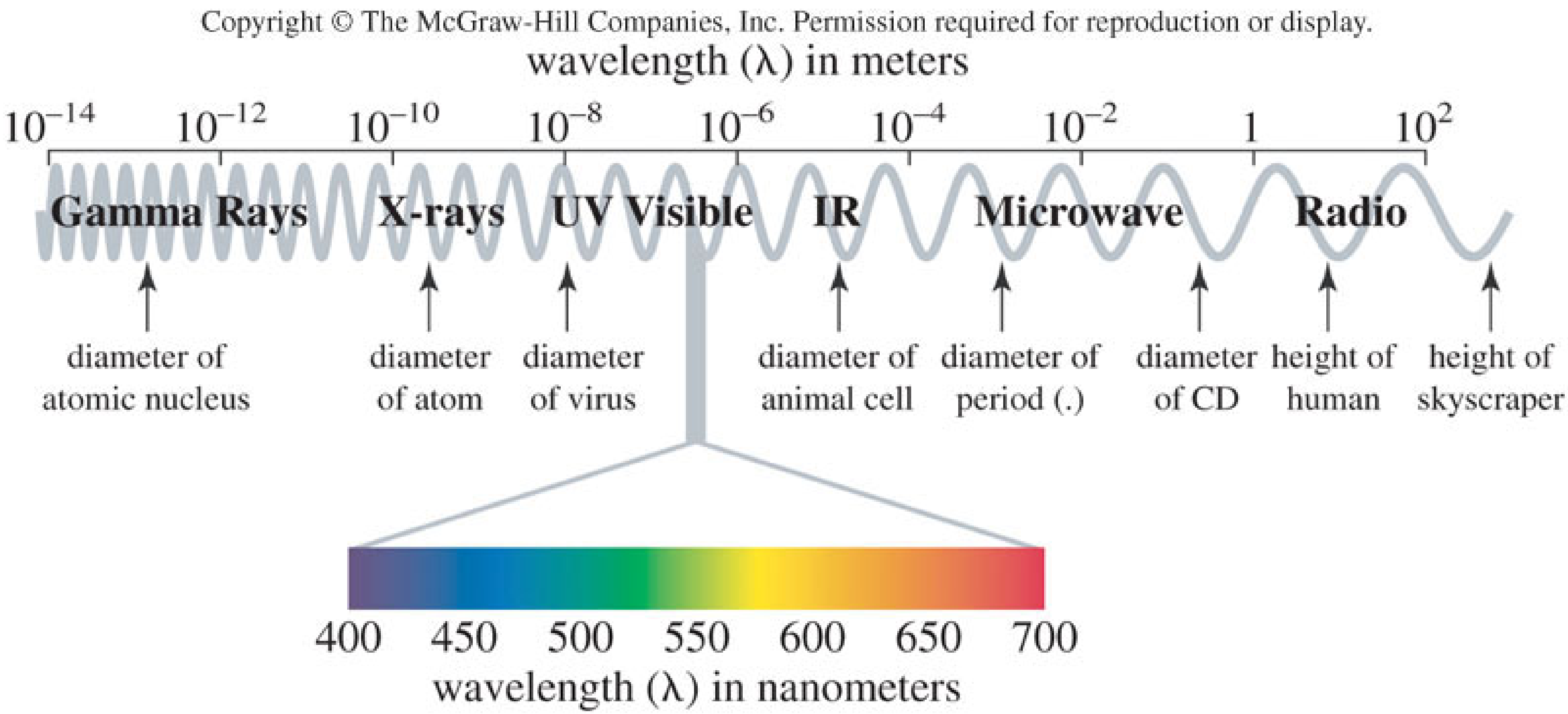
(b)

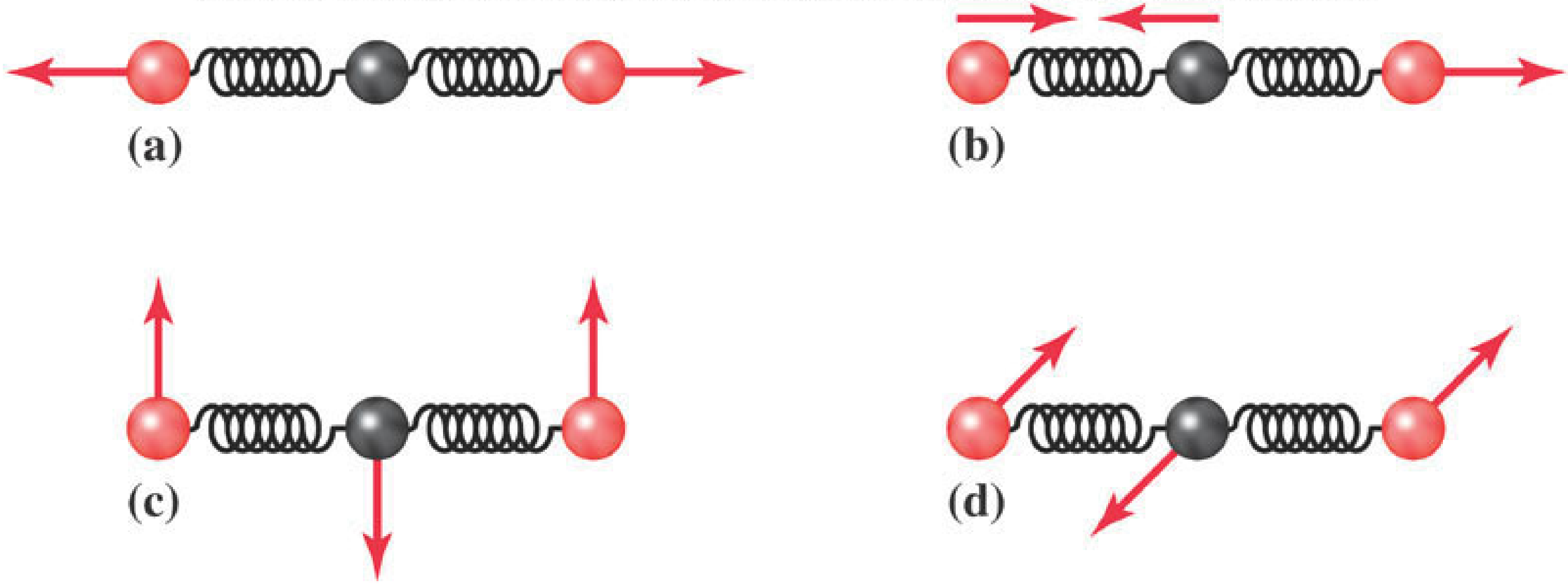


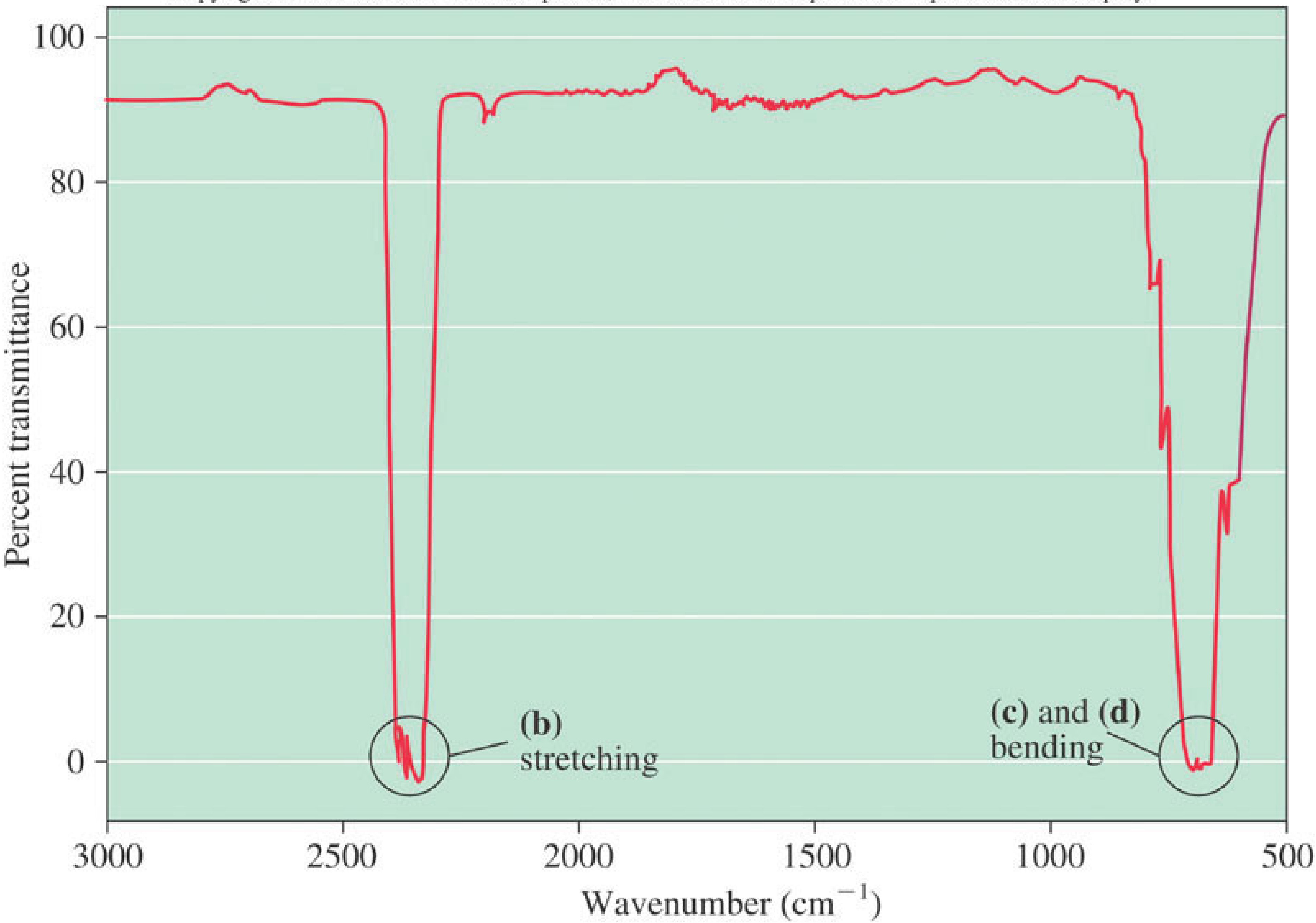


(c)

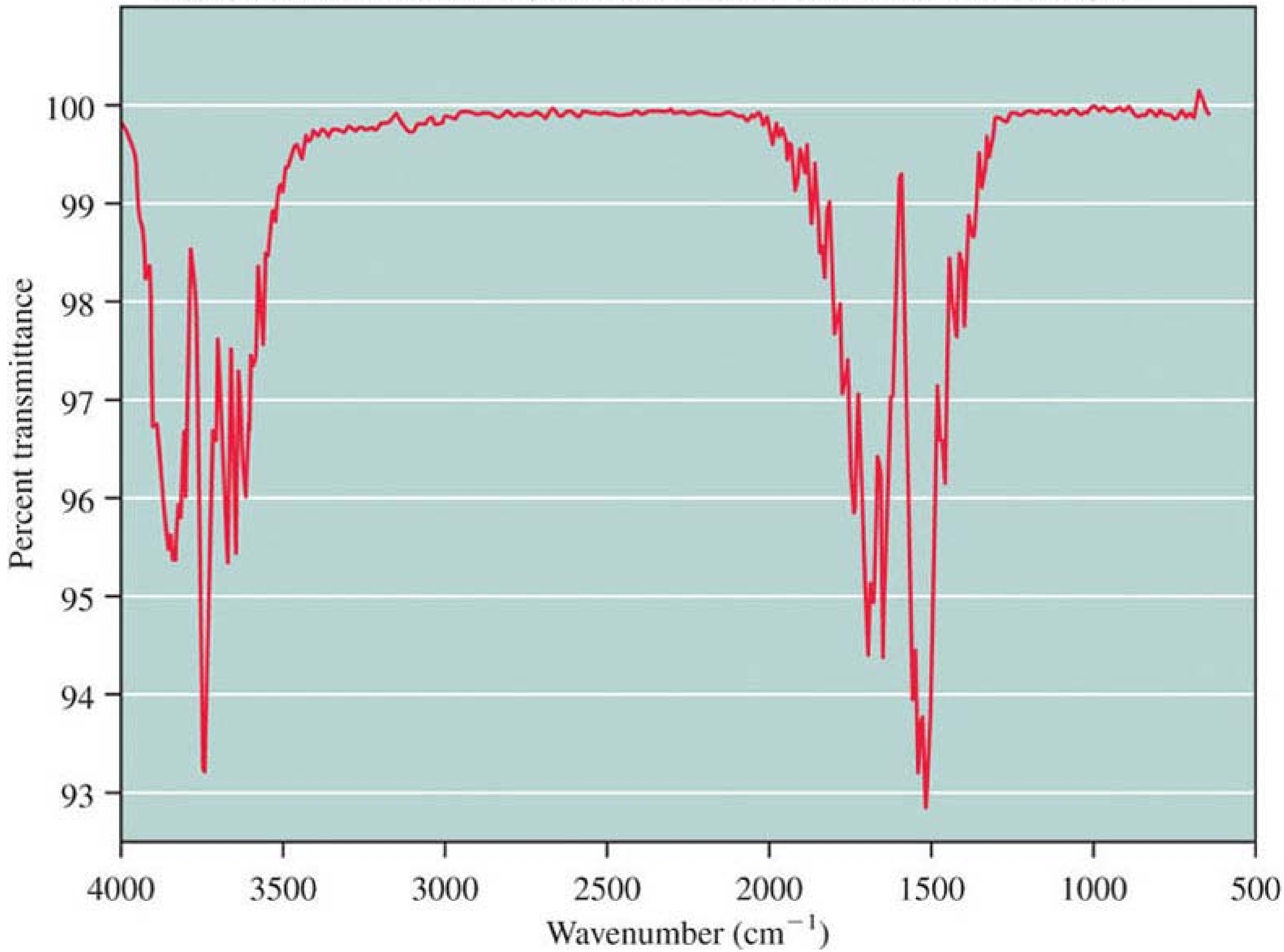
# Waves of Light




(a)
(b)
(c)
(d)



100
80
60
40
20
0
Percent transmittance
(b)
stretching
(c) and (d)
bending
3000
2500
2000
1500
1000
500
Wavenumber (cm$^{-1}$)


100
99
98
97
96
95
94
93
Percent transmittance
4000
3500
3000
2500
2000
1500
1000
500
Wavenumber (cm$^{-1}$)

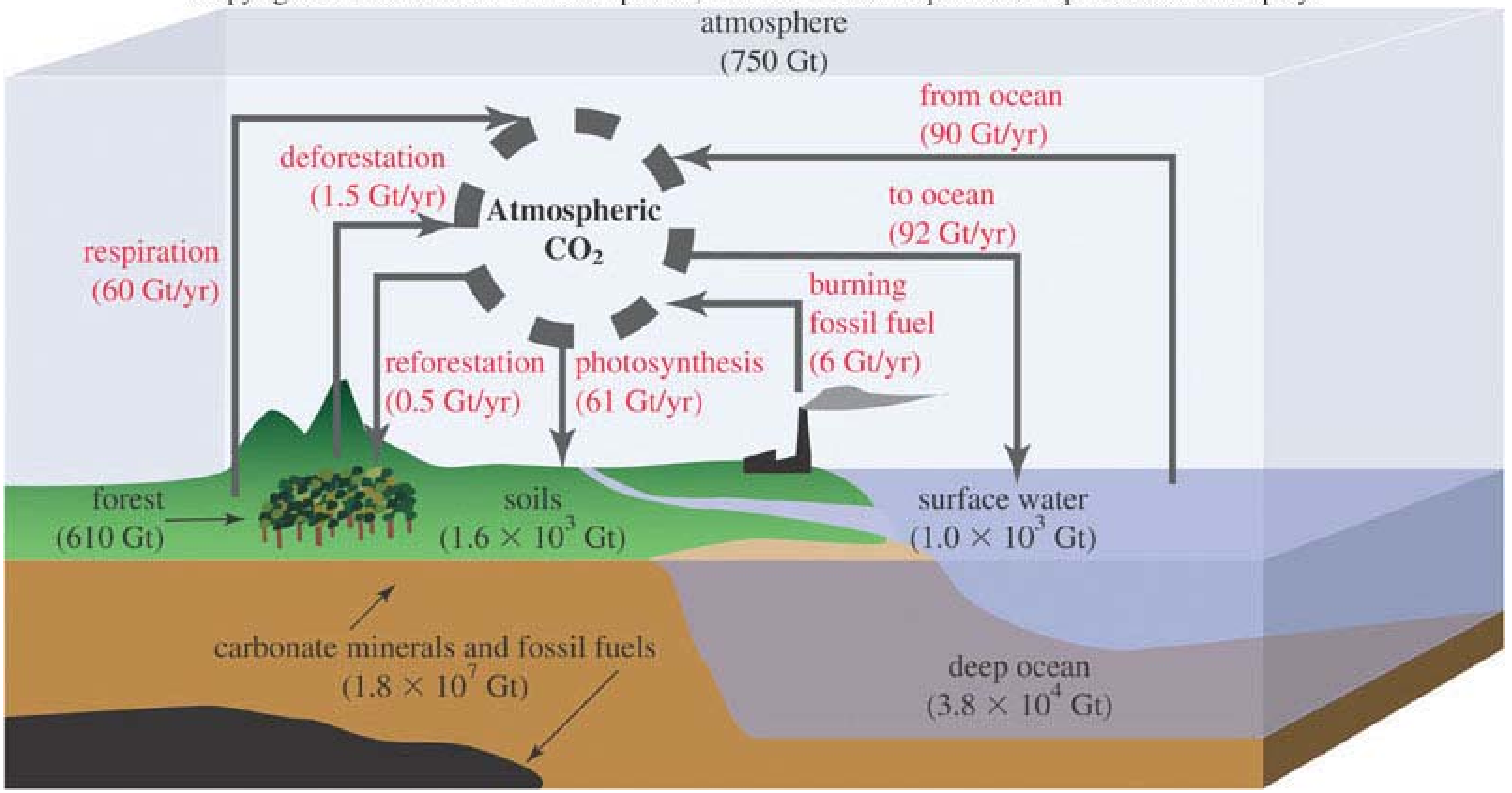

atmosphere
(750 Gt)
from ocean
(90 Gt/yr)
deforestation
(1.5 Gt/yr)
Atmospheric
$CO_2$
to ocean
(92 Gt/yr)
respiration
(60 Gt/yr)
burning
fossil fuel
(6 Gt/yr)
reforestation
(0.5 Gt/yr)
photosynthesis
(61 Gt/yr)
forest
(610 Gt)
soils
(1.6 × $10^3$ Gt)
surface water
(1.0 × $10^3$ Gt)
carbonate minerals and fossil fuels
(1.8 × $10^7$ Gt)
deep ocean
(3.8 × $10^4$ Gt)

**Table 3.1** The Earth's Carbon Reservoirs

| | Size (Gt Carbon) |
|---|---|
| **Reservoir** | |
| Atmosphere | 750 |
| Forests | 610 |
| Soils | 1,580 |
| Surface ocean | 1,020 |
| Deep ocean | 38,100 |
| Total carbon, excluding fossil fuels | 42,060 |
| **Fossil fuels** | |
| Coal | 4,000 |
| Oil | 500 |
| Natural gas | 500 |
| Total fossil fuel | 5,000 |
| **Total, all sources** | 47,060 |

Source: From James F. Kasting, "The Carbon Cycle, Climate, and the Long-Term Effects of Fossil Fuel Burning," *Consequences, The Nature & Implications of Environmental Change*, Vol. 4, No. 1, 1998. Reprinted with permission.

## Table 3.2 Human Perturbations to the Global Carbon Budget

| | Flux (Gt carbon/year) | |
|---|---|---|
| **$CO_2$ sources** | | |
| Fossil fuel combustion and cement production | 5.5 | 0.5 |
| Tropical deforestation | 1.6 | 1.0 |
| **Total anthropogenic emissions** | 7.1 | 1.1 |
| **$CO_2$ sinks** | | |
| Storage in the atmosphere | 3.3 | 0.2 |
| Uptake by the ocean | 2.0 | 0.8 |
| Northern Hemisphere forest regrowth | 0.5 | 0.5 |
| Other terrestrial sinks ($CO_2$ fertilization, nitrogen fertilization, climatic effects) | 1.3 | 1.5 |
| **Total sinks for $CO_2$** | 7.1 | 1.1 |

Source: From James F. Kasting, "The Carbon Cycle, Climate, and the Long-Term Effects of Fossil Fuel Burning," *Consequences, The Nature & Implications of Environmental Change,* Vol. 4, No. 1, 1998. Reprinted with permission.

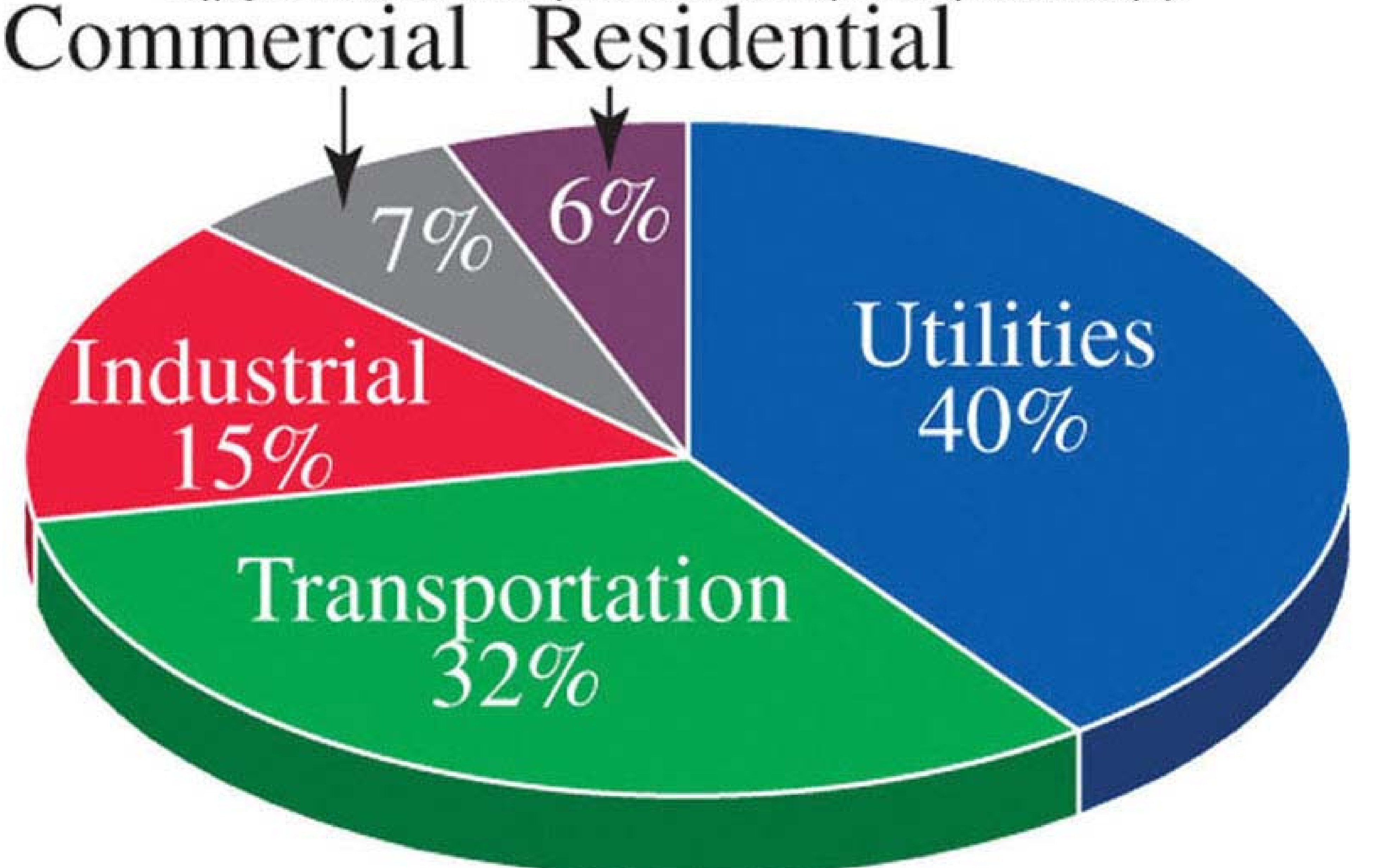

Commercial
Residential
7%
6%
Industrial
15%
Utilities
40%
Transportation
32%

**Table 3.4** Greenhouse Gases–Concentration Changes and Lifetimes

| | $CO_2$ | $CH_4$ | $N_2O$ |
|---|---|---|---|
| Preindustrial concentration | 280 ppm | 0.70 ppm | 0.28 ppm |
| 2000 concentration | 370 ppm | 1.8 ppm | 0.31 ppm |
| Rate of concentration change | 1.5 ppm/yr | 0.010 ppm/yr | 0.0008 ppm/yr |
| Atmospheric lifetime (yr) | 5–200* | 12 | 114 |

*A single value for the atmospheric lifetime of $CO_2$ is not possible. Different removal mechanisms take place at different rates, leading to variation in atmospheric lifetime.

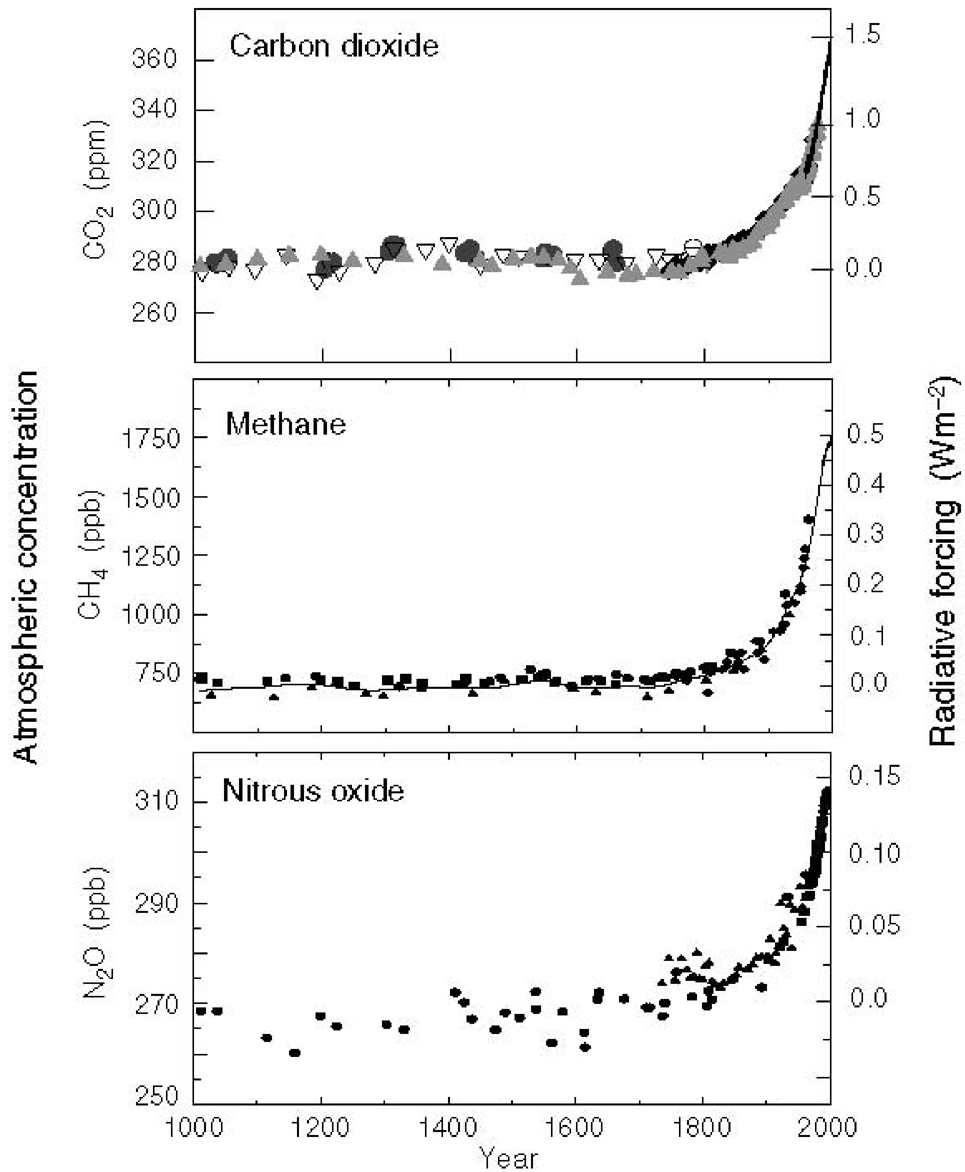
**Table 3.5** Global Warming Potential for Three Common Greenhouse Gases

| Substance | Global Warming Potential (GWP)* | Tropospheric Abundance (%) | Tropospheric Abundance (ppm) |
|---|---|---|---|
| $CO_2$ | 1 (assigned value) | $3.75 \times 10^{-2}$ | 375 |
| $CH_4$ | 23 | $1.8 \times 10^{-4}$ | 1.8 |
| $N_2O$ | 296 | $3.1 \times 10^{-5}$ | 0.31 |

*GWP values are given for the estimated relative direct and indirect effects over a 100-yr period.

## Indicators of the human influence on the atmosphere during the Industrial Era

### (a) Global atmospheric concentrations of three well mixed greenhouse gases



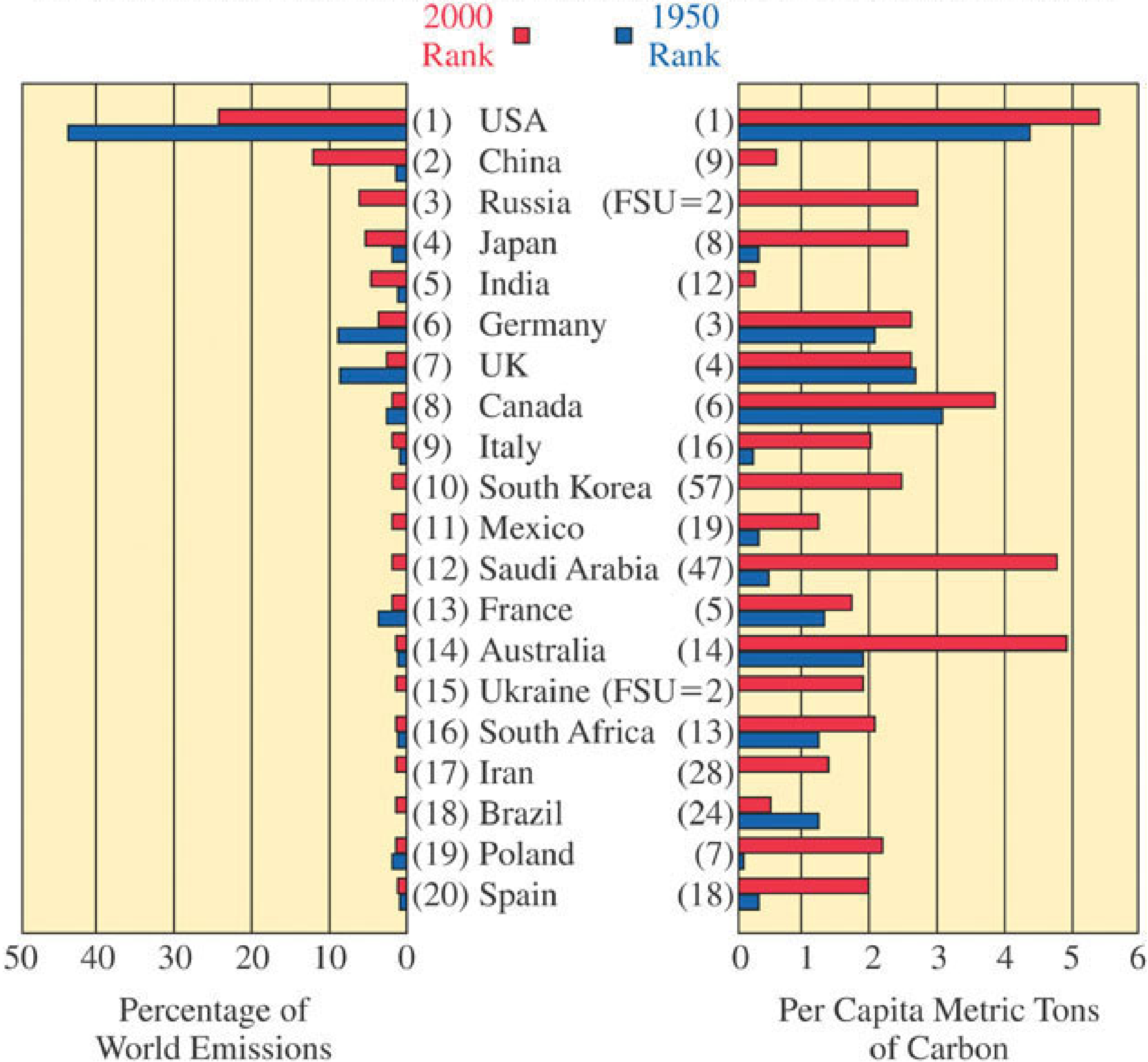
## Table 3.6 Judgmental Estimates of Confidence

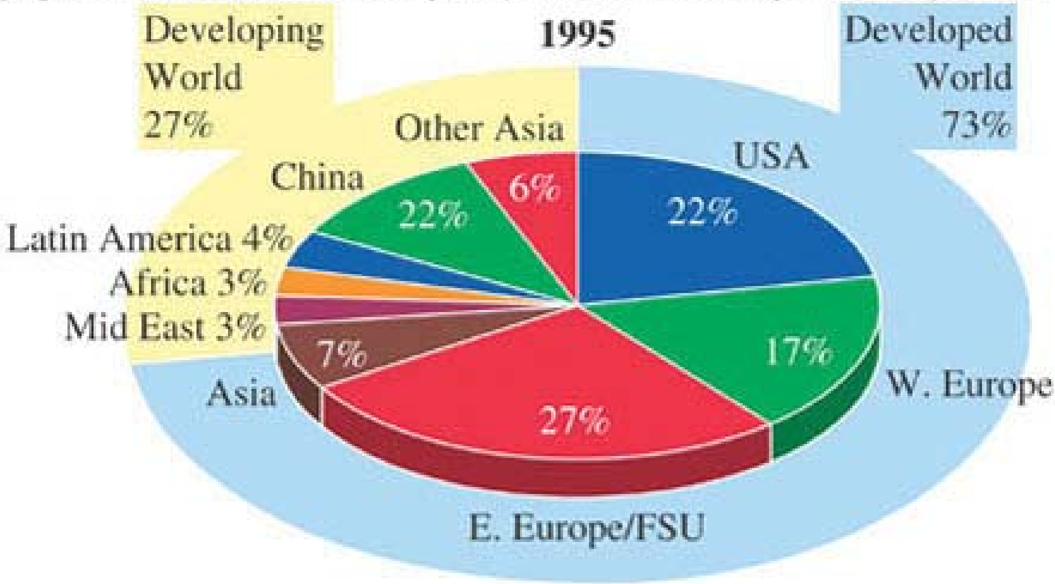
| Term Used | Probability That a Result is True |
|---|---|
| Virtually certain | 99% |
| Very likely | 90–99% |
| Likely | 66–90% |
| Medium likelihood | 33–66% |
| Unlikely | 10–33% |
| Very unlikely | 1–10% |

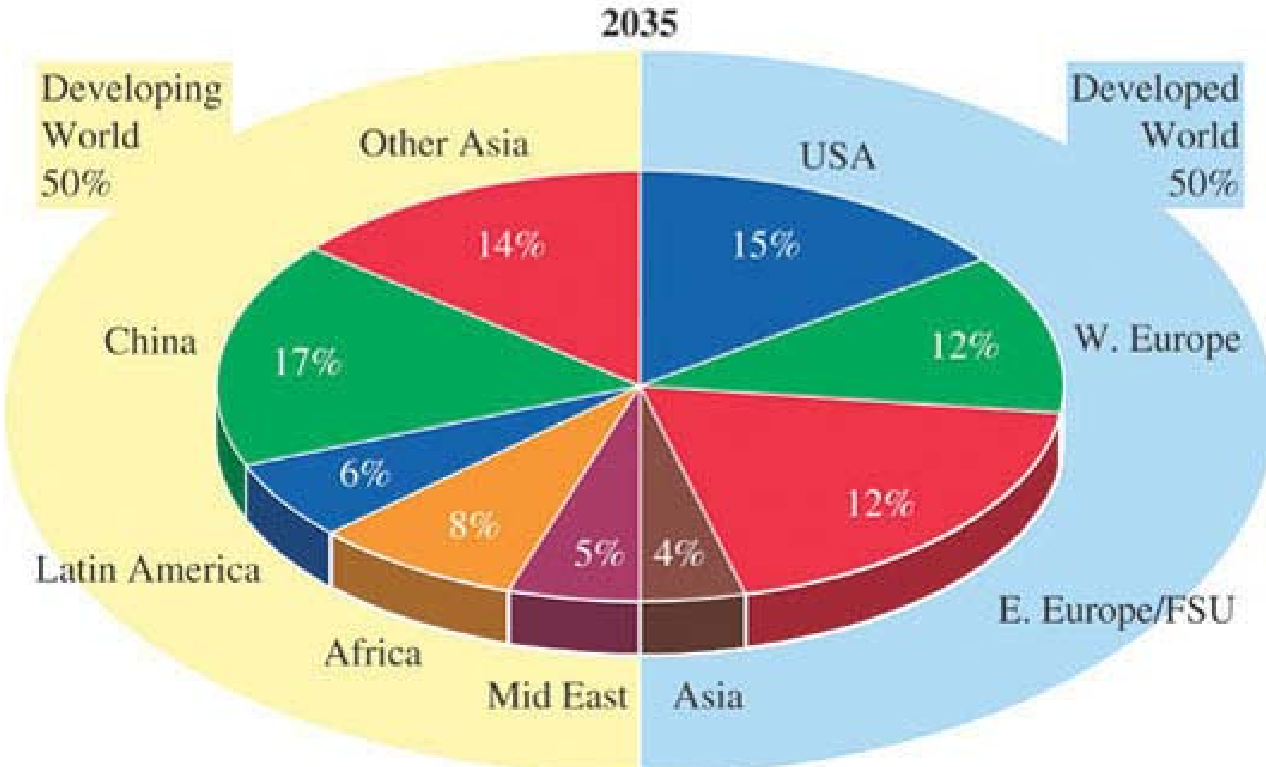
Source: *Summary for Policymakers, A Report of Working Group 1 of the Intergovernmental Panel on Climate Change*, Shanghai: IPCC, January 1, 2001.

**Table 3.7** IPCC Conclusions

| Very Likely | Likely | Very Unlikely |
|---|---|---|
| The 1990s were the warmest decade and 1998 the warmest year since 1861. | Temperatures in the Northern Hemisphere during the 20th century are *likely* to have been the highest of any century during the past 1000 years. | The observed warming over the past 100 years is due to climate variability alone, providing new and even stronger evidence that changes must be made to stem the influence of human activities. |
| Higher maximum temperatures are observed over nearly all land areas. | Arctic sea-ice thickness declined about 40% during late summer to early autumn in recent decades. | |
| Snow cover decreased about 10% since the 1960s (satellite data); in the 20th century there was a reduction of about two weeks in lake and river ice cover in the mid- and high-latitudes of the Northern Hemisphere (independent ground-based observations). | An increase in rainfall, similar to that in the Northern Hemisphere, has been observed in tropical land areas falling between 10 N and 10 S. | |
| Increased precipitation has been observed in most of the Northern Hemisphere continents. | Increased summer droughts are *likely* in a few areas. | |


2000 Rank
1950 Rank
(1) USA (1)
(2) China (9)
(3) Russia (FSU=2)
(4) Japan (8)
(5) India (12)
(6) Germany (3)
(7) UK (4)
(8) Canada (6)
(9) Italy (16)
(10) South Korea (57)
(11) Mexico (19)
(12) Saudi Arabia (47)
(13) France (5)
(14) Australia (14)
(15) Ukraine (FSU=2)
(16) South Africa (13)
(17) Iran (28)
(18) Brazil (24)
(19) Poland (7)
(20) Spain (18)
50 40 30 20 10 0
Percentage of World Emissions
0 1 2 3 4 5 6
Per Capita Metric Tons of Carbon


1995
Developing World 27%
Developed World 73%
Other Asia
6%
USA
22%
China
22%
Latin America 4%
Africa 3%
Mid East 3%
7%
Asia
27%
17%
W. Europe
E. Europe/FSU


2035
Developing World 50%
Developed World 50%
Other Asia
14%
USA
15%
China
17%
12%
W. Europe
6%
8%
5%
4%
12%
Latin America
Africa
Mid East
Asia
E. Europe/FSU

Is the depletion of the ozone layer a main cause of climate change?



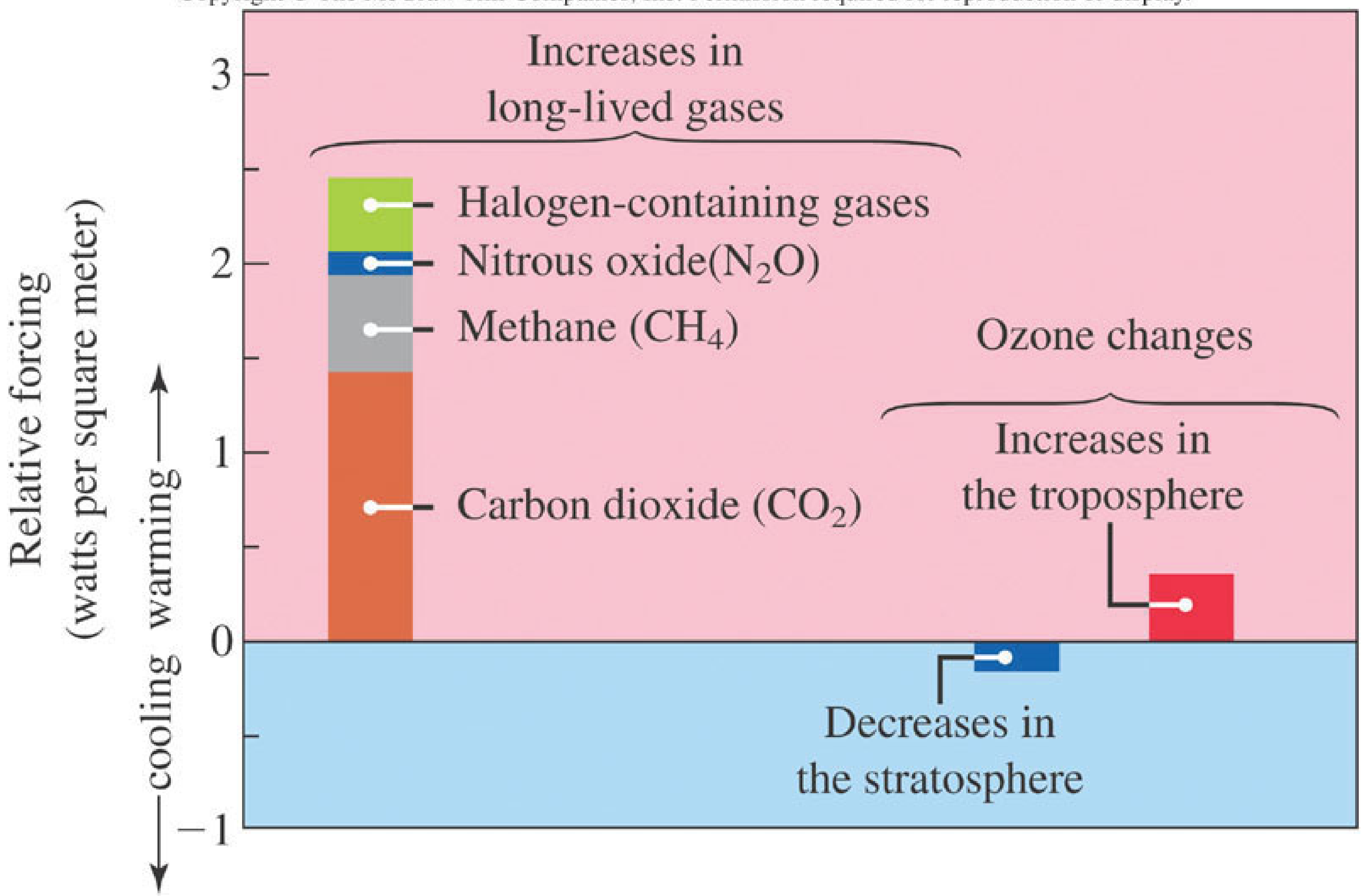
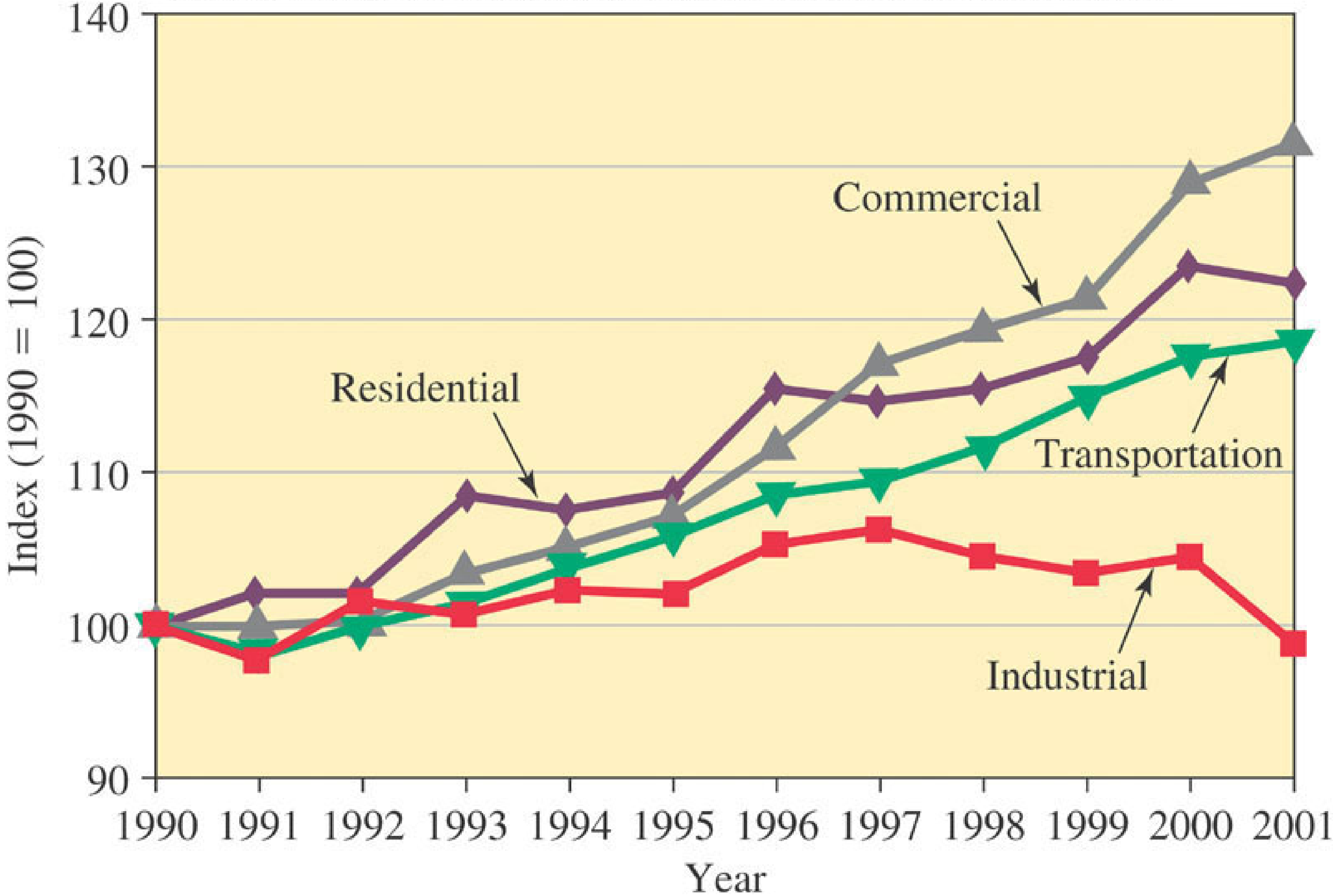
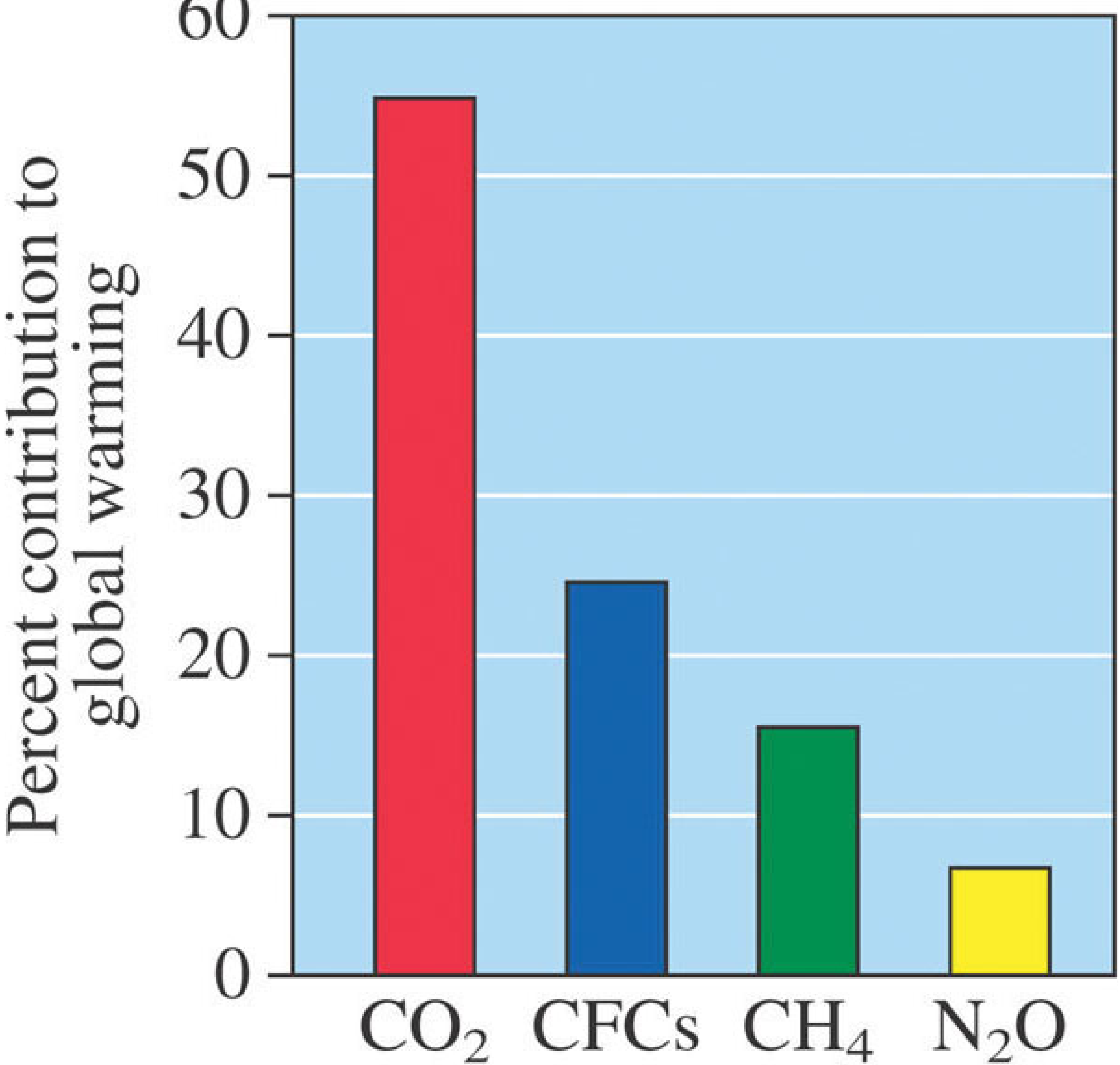
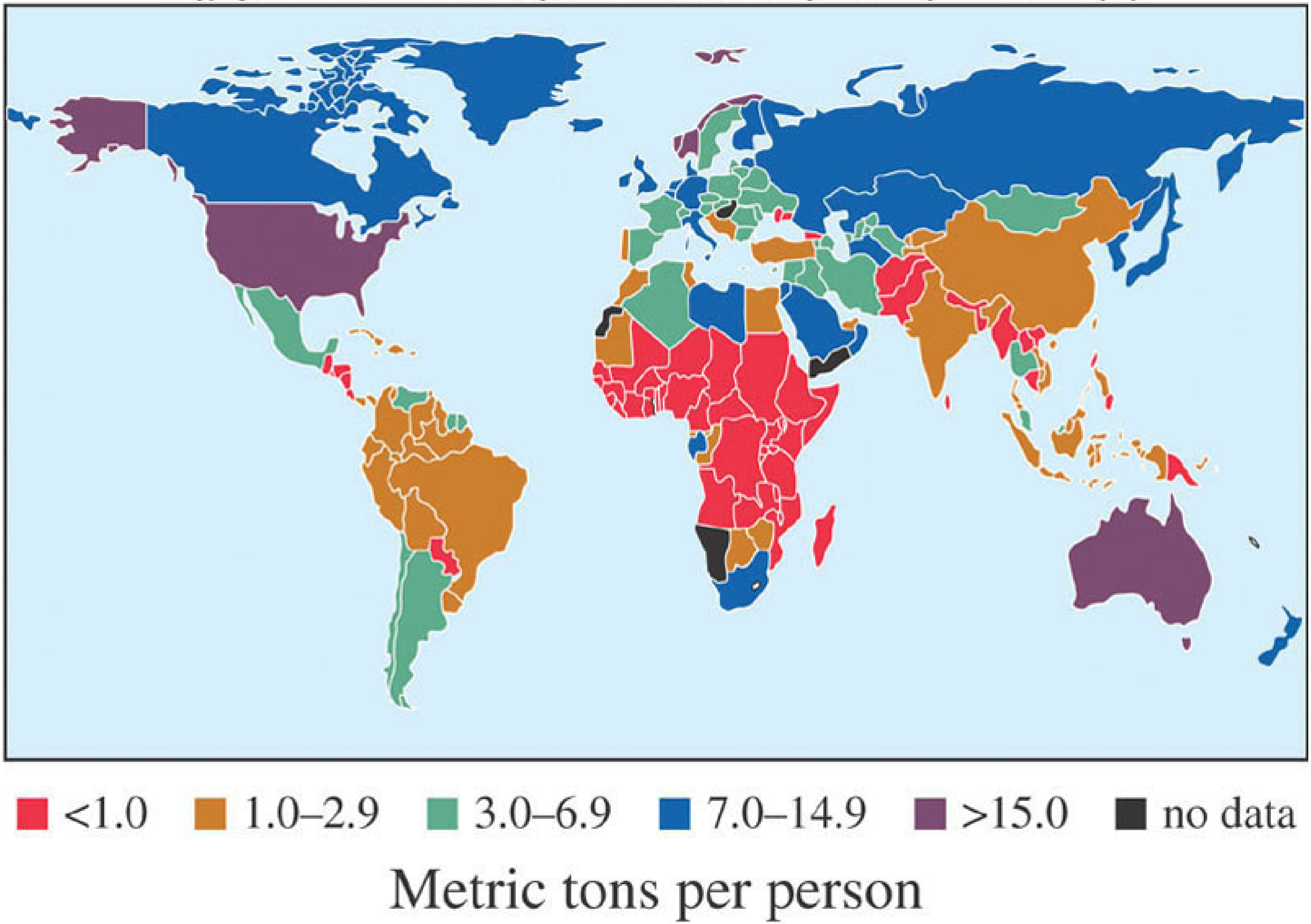


**Table 3.8** Global Warming and Ozone Depletion: Some Characteristics

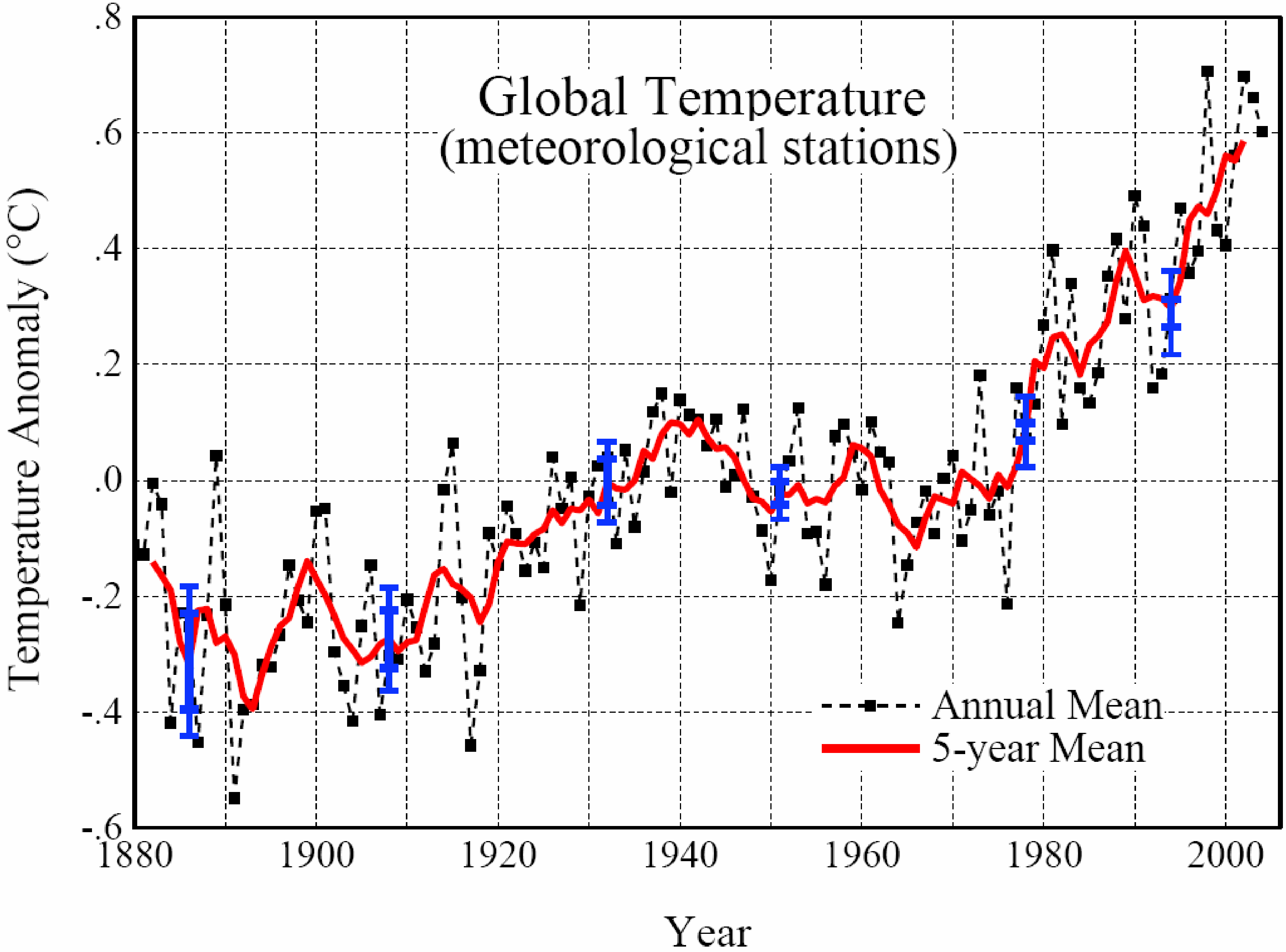
| | Global Warming | Stratospheric Ozone Depletion |
|---|---|---|
| Region of atmosphere involved | Stratosphere | Mostly troposphere |
| Major substances involved | $H_2O$, $CO_2$, $CH_4$, $N_2O$ | $O_3$, $O_2$, CFCs |
| Interaction with radiation | When molecules absorb IR radiation, they vibrate and return heat energy to Earth. | When molecules absorb UV radiation, they break apart into smaller molecules or atoms. |
| Nature of problem | Increasing concentrations of greenhouse gases are apparently increasing average global temperature. | Decreasing concentration of $O_3$ is increasing exposure to UV radiation. |
| Major sources | Release of $CO_2$ from burning fossil fuels, deforestation; $CH_4$ from agriculture. Natural sources of $H_2O$ | Release of long-lived CFCs from past uses as solvents, foaming agents, air conditioners. CFCs release Cl• that destroys $O_3$. |
| Credible consequences | Altered climate and agricultural productivity, increased sea level, effects on health | Increased incidence of skin cancer, damage to phytoplankton |
| Possible remedies | Decrease use of fossil fuels, slow deforestation; change agricultural practices | Eliminate use of CFCs, find suitable replacements |
| International response | Kyoto Protocol, 1997 and later amendments | Montreal Protocol, 1987 and later amendments |
| U.S. response | Signed Kyoto Protocol in 1998; not submitted to Senate for ratification, therefore not bound by its provisions; alternative proposals | Signed 1987; full participation in Protocol and its amendments |

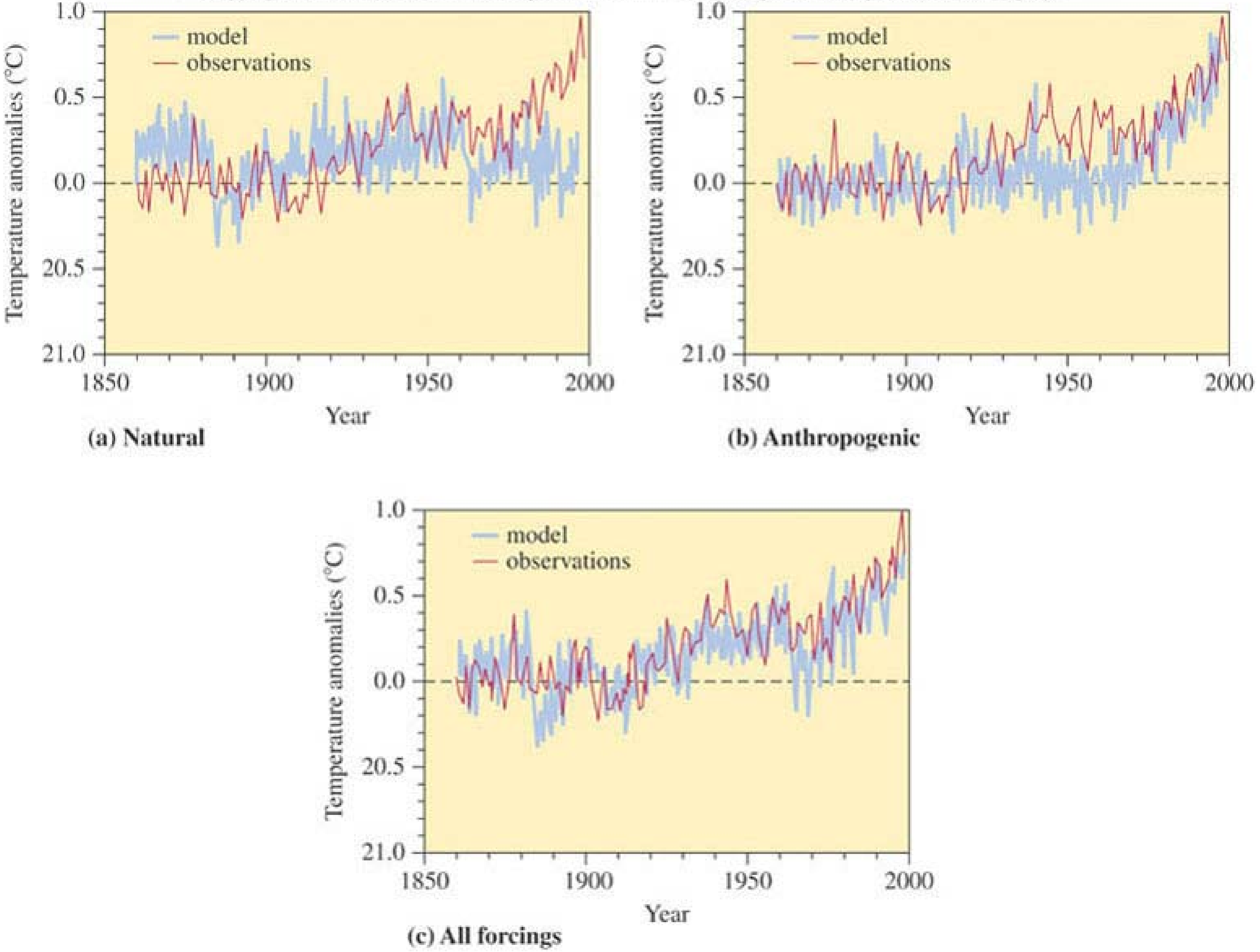

140
130
120
110
100
90
Index (1990 = 100)
Commercial
Residential
Transportation
Industrial
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
Year

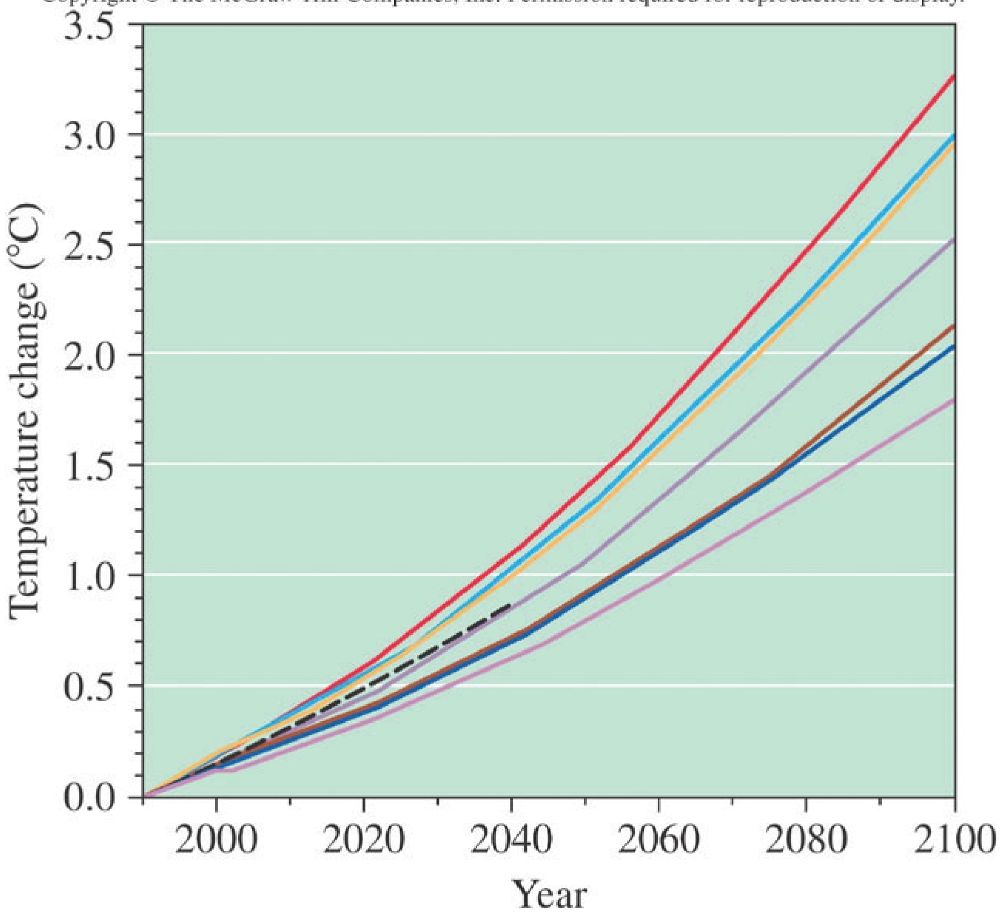

60
50
40
30
20
10
0
Percent contribution to global warming
$CO_2$
CFCs
$CH_4$
$N_2O$



<1.0
1.0–2.9
3.0–6.9
7.0–14.9
>15.0
no data
Metric tons per person


Global Temperature
(meteorological stations)
Temperature Anomaly (°C)
.8
.6
.4
.2
.0
-.2
-.4
-.6
1880
1900
1920
1940
1960
1980
2000
Year
Annual Mean
5-year Mean


model
observations
Temperature anomalies (°C)
1.0
0.5
0.0
20.5
21.0
1850
1900
1950
2000
Year
(a) Natural
(b) Anthropogenic
(c) All forcings




- Low end prediction
  - 2100 population of 6.4 billion
  - annual economic growth rate of 1.2 %
- Mid level prediction
  - 2100 population of 11.3 billion
  - annual economic growth rate of 2.3 %
- High end prediction
  - 2100 population of 11.3 billion
  - annual economic growth rate of 3.0 %

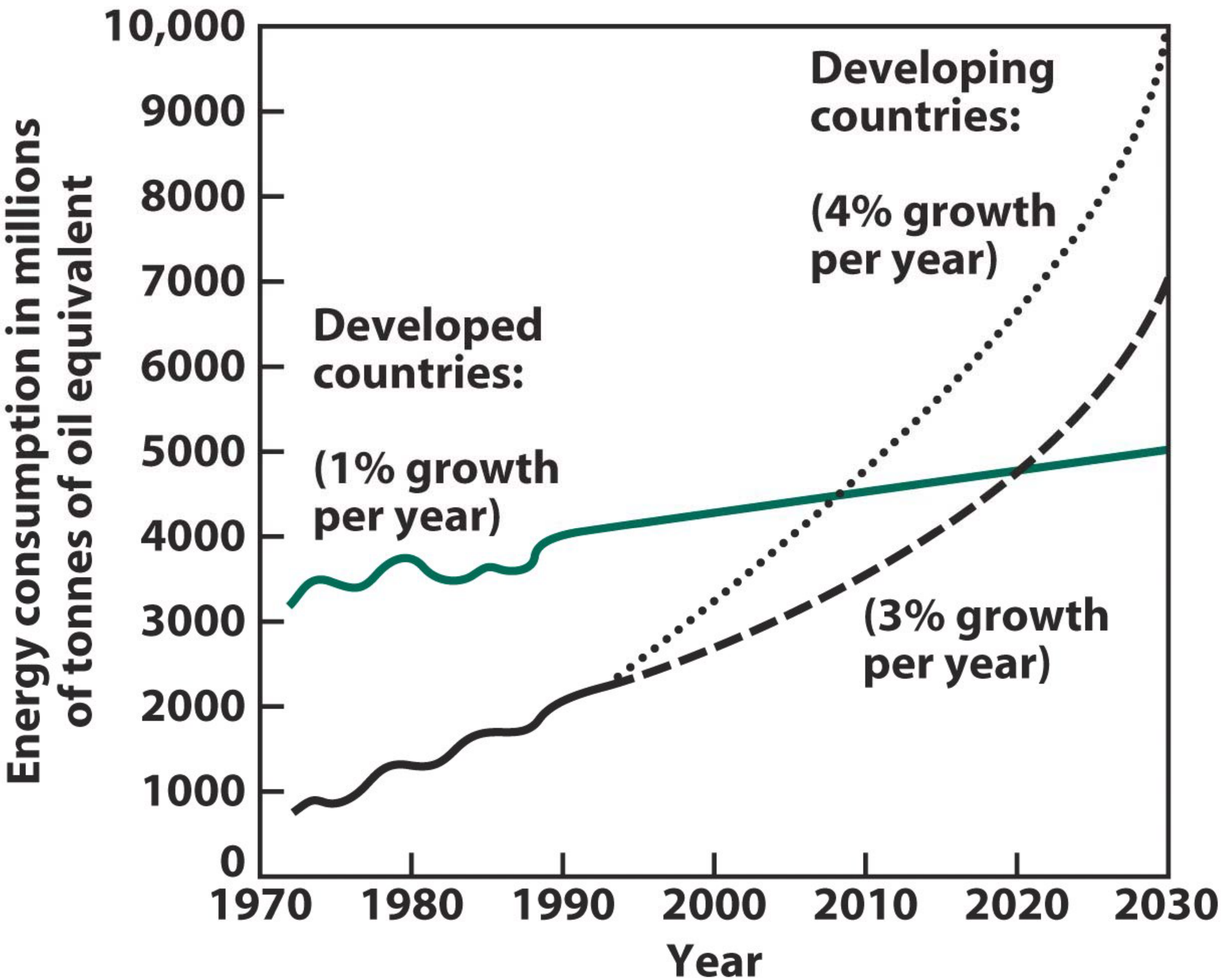



**Figure 5-3**
***Environmental Chemistry, Third Edition***

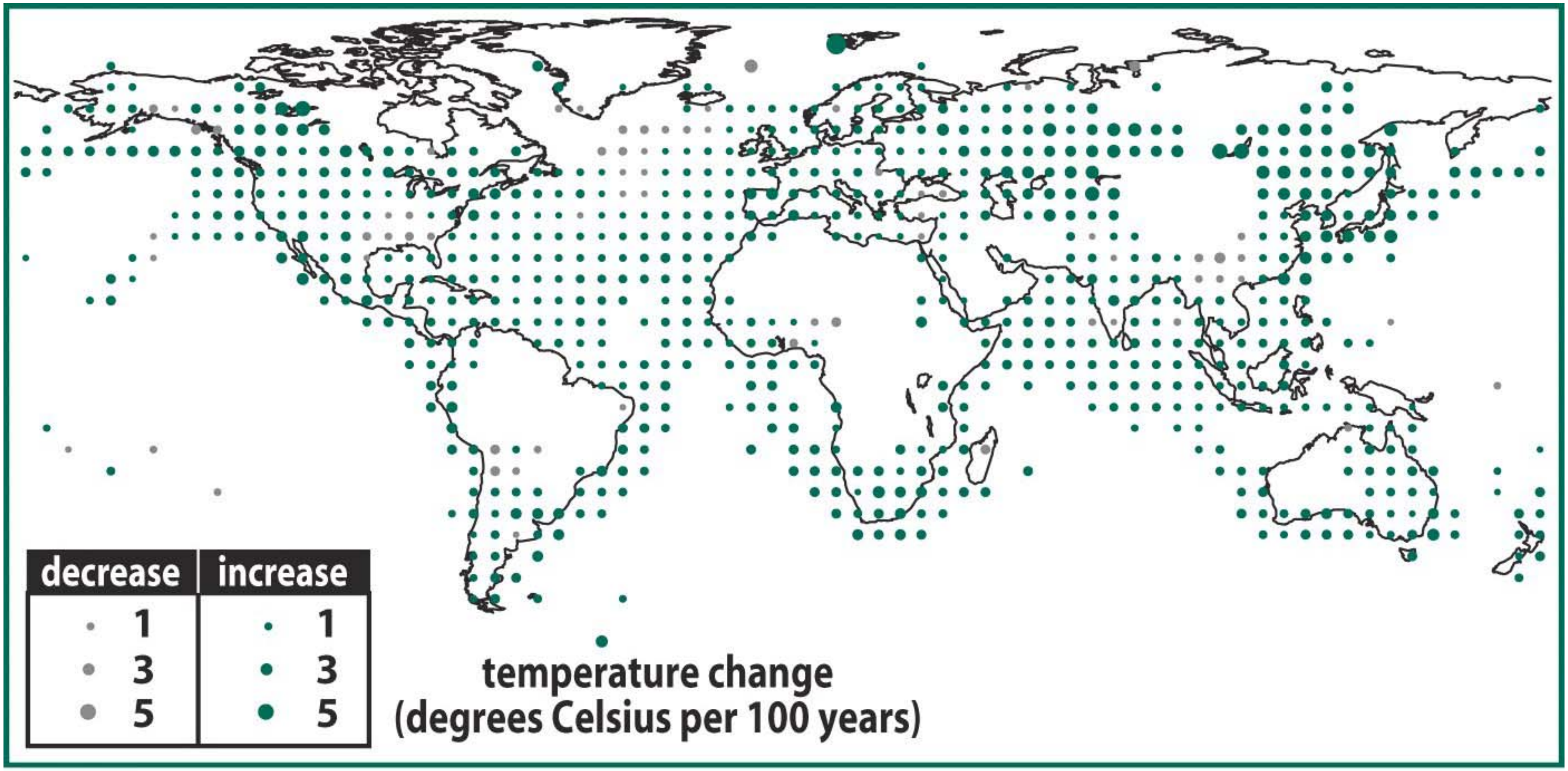



**Figure 4-23**
***Environmental Chemistry, Third Edition***


**Figure 4-24**
***Environmental Chemistry, Third Edition***