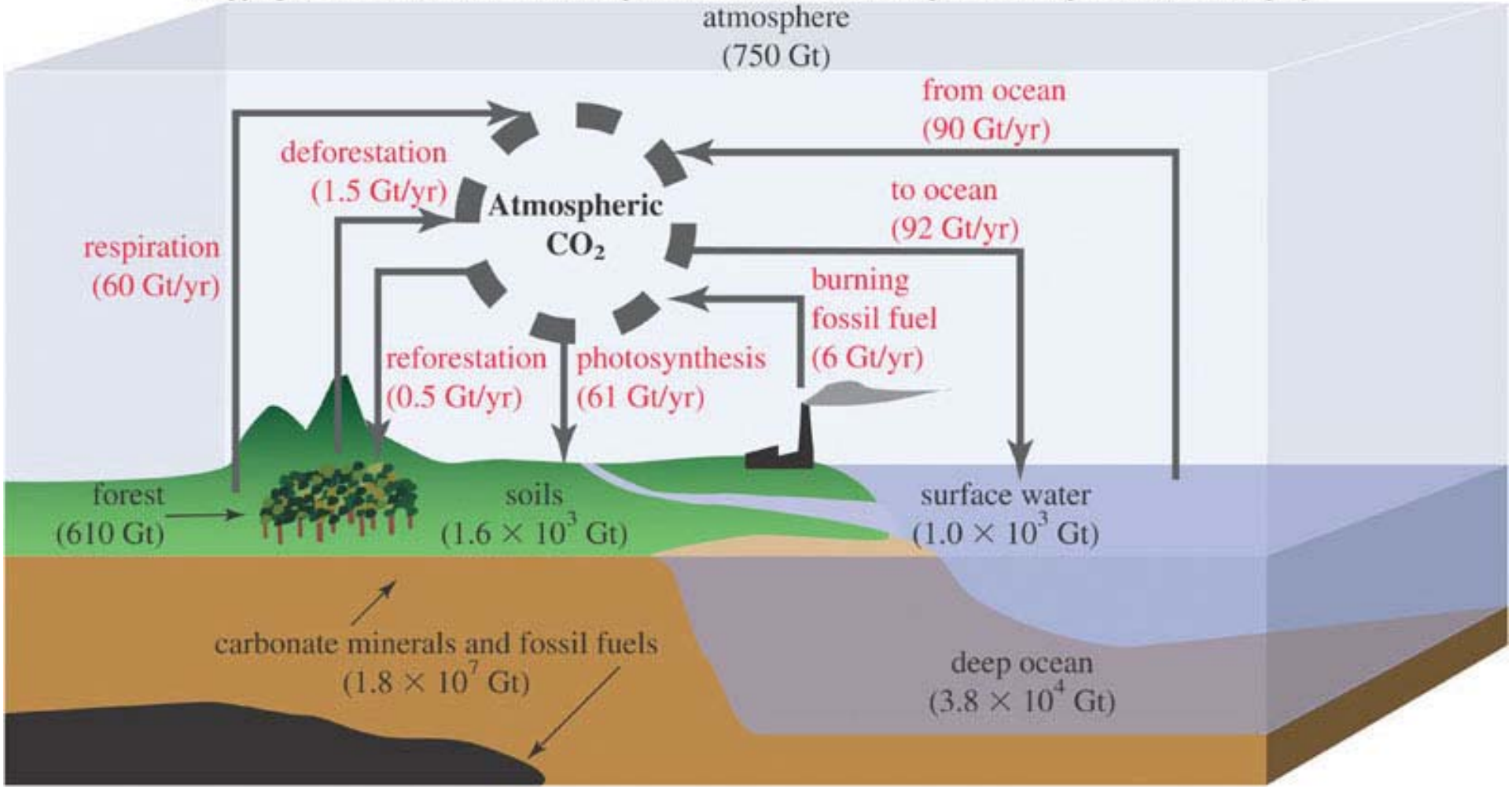
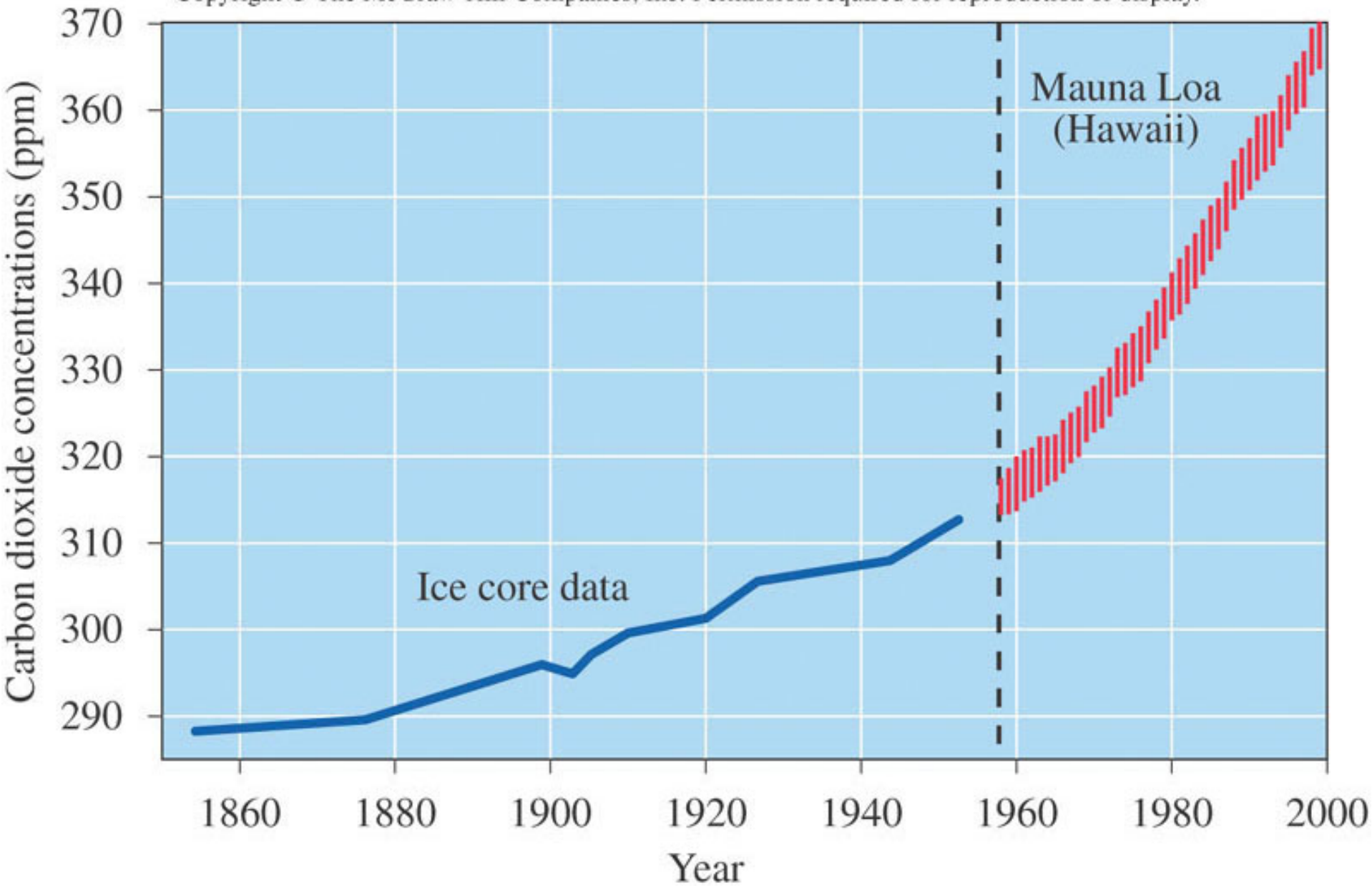
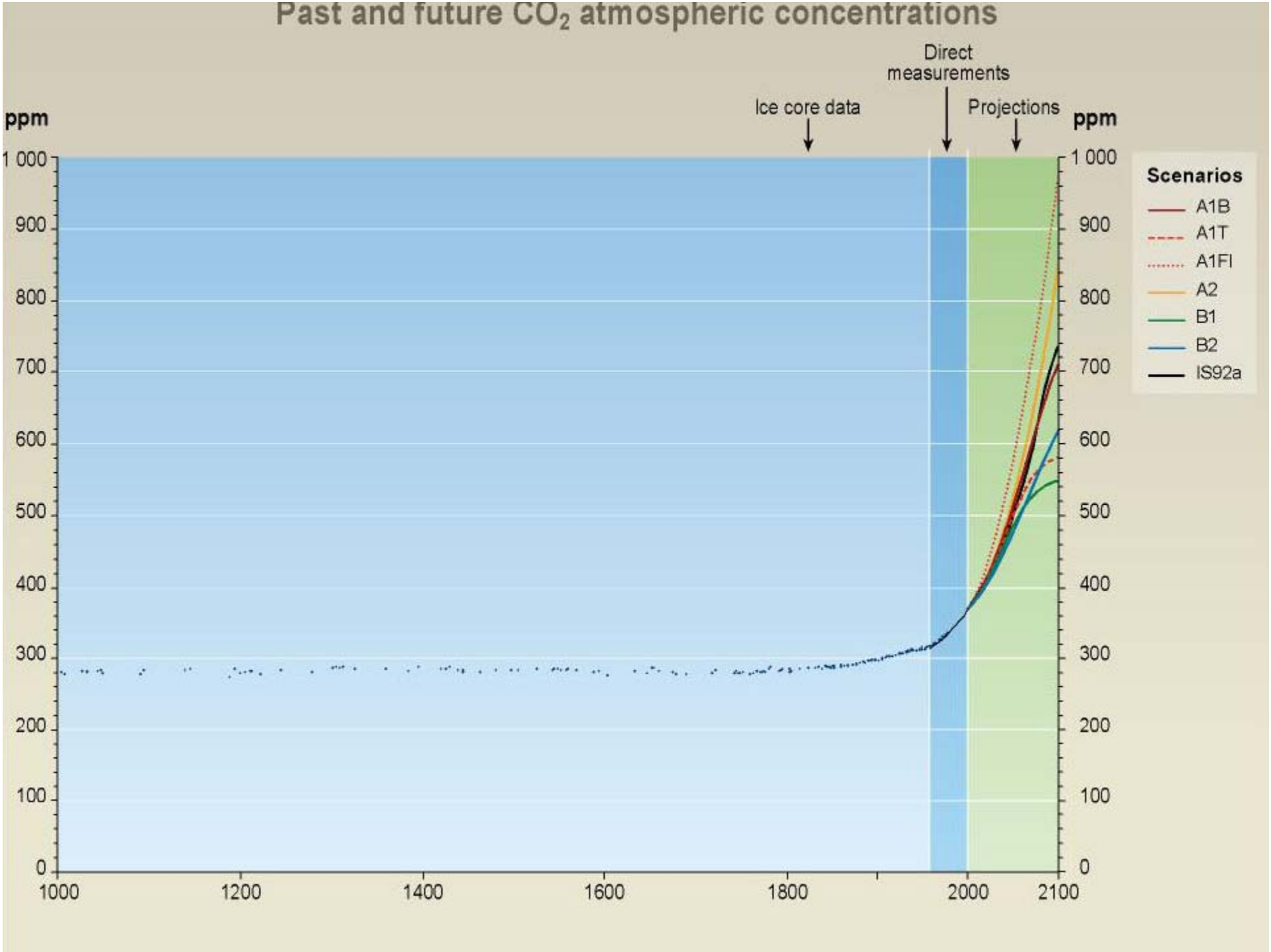


Table 3.2 Human Perturbations to the Global Carbon Budget

	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

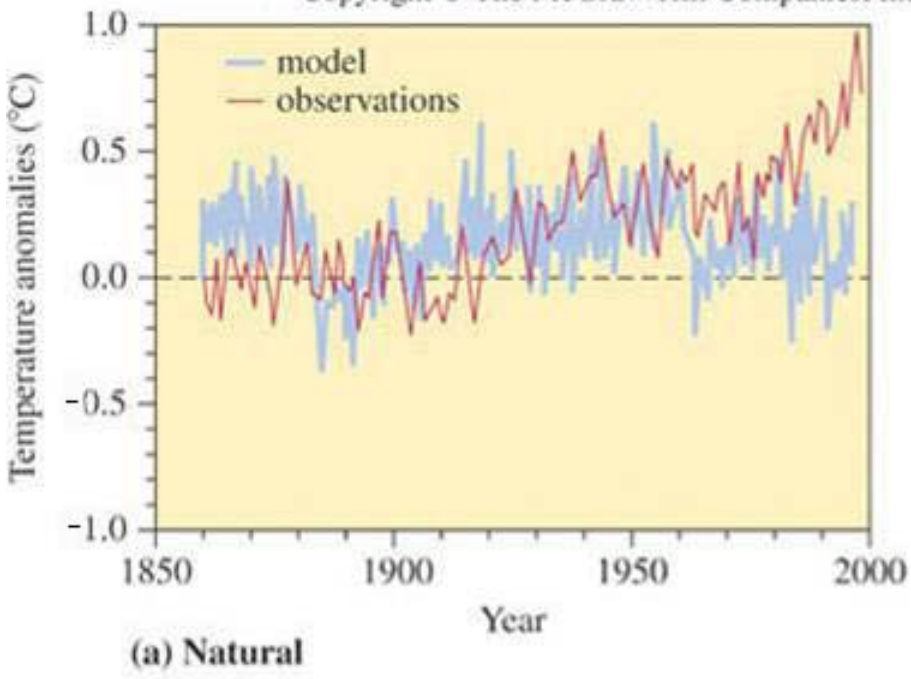
Source: From James F. Kasting, "The Carbon Cycle, Climate, and the Long-Term Effects of Fossil Fuel Burning," *Consequences, The Nature & Implications of Environmental Change,* Vol. 4, No. 1, 1998. Reprinted with permission.



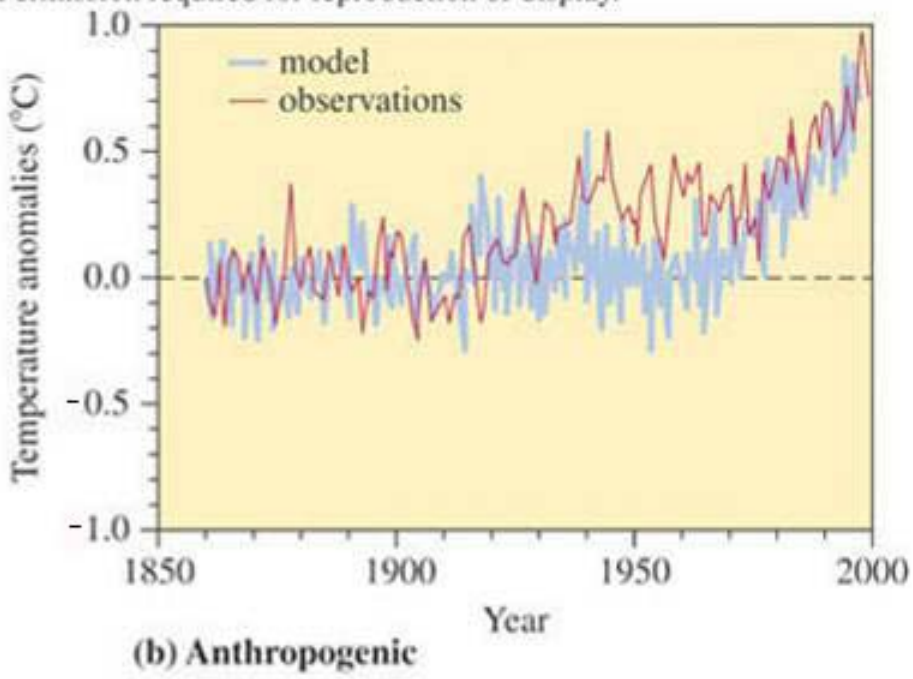

Past and future CO_2 atmospheric concentrations
Ice core data
Direct measurements
Projections
ppm
ppm
1 000
900
800
700
600
500
400
300
200
100
0
1000
1200
1400
1600
1800
2000
2100
Scenarios
A1B
A1T
A1FI
A2
B1
B2
IS92a

Gathering Evidence: Projecting into the Future

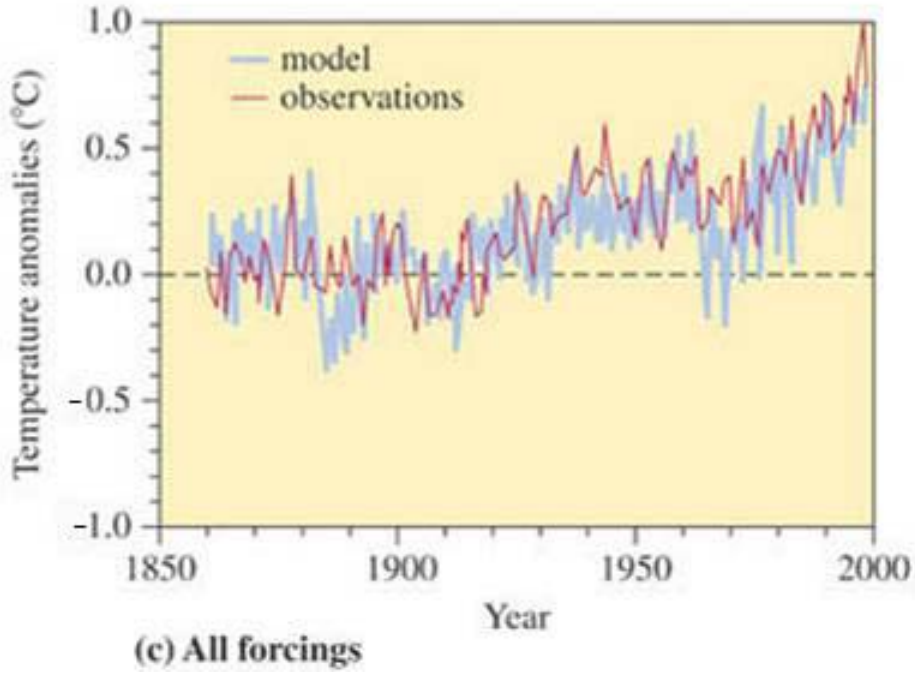
- Variables incompletely understood preventing prediction of results of extra CO_2 in atmosphere.
  - Intensity of Sun's radiation
  - Winds and air circulation patterns
  - Cloud cover
  - Volcanic activity
  - Dust and soot
  - Aerosols
  - Shifting sea ice and glaciers
  - Oceans
  - The extent and nature of living things, especially humans



(a) Natural

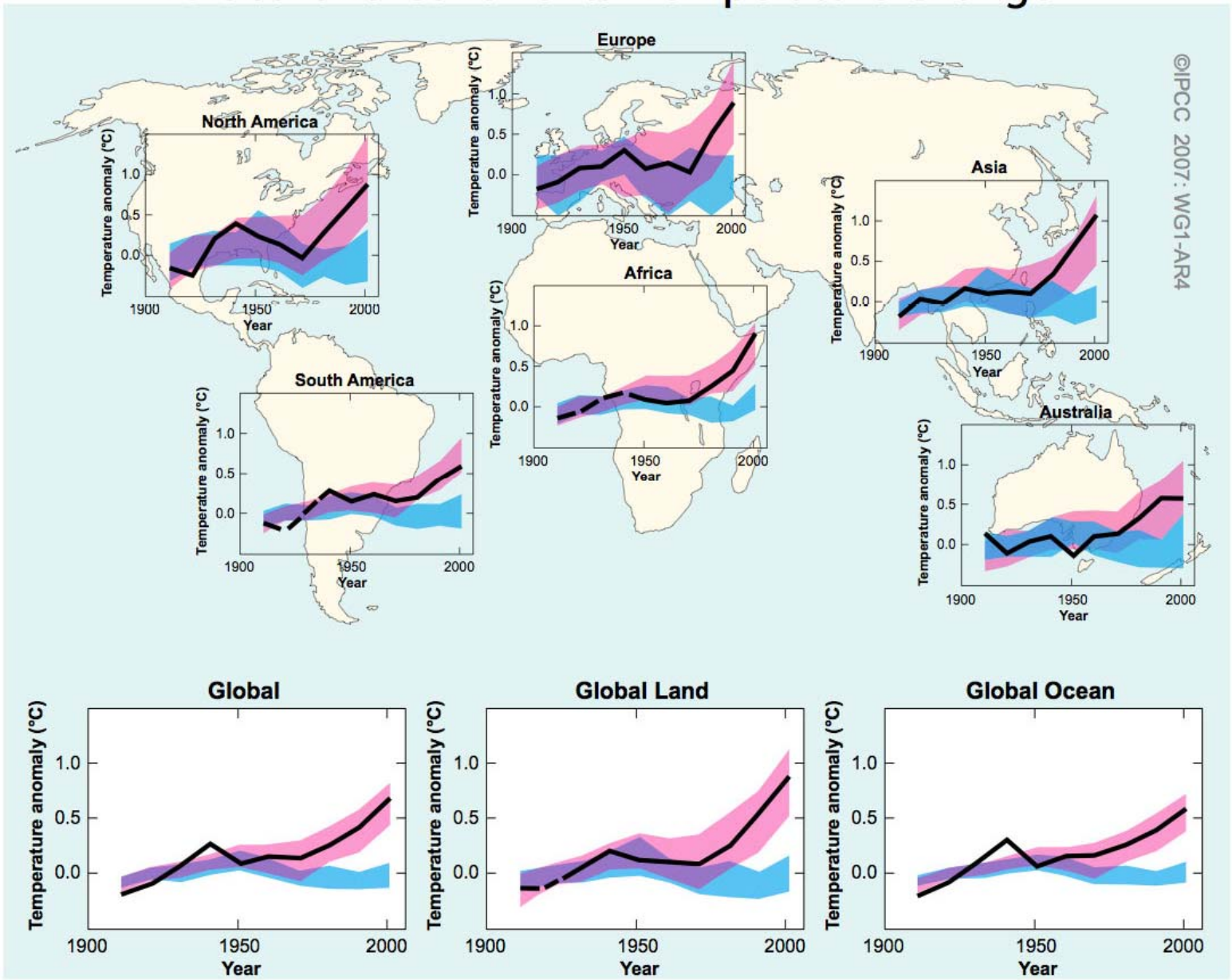


(b) Anthropogenic



(c) All forcings

The IPCC 2001: Inter-governmental panel on climate change



The IPCC Report of 2007

Rate of emission of greenhouse gases

- Current rates known
  - Current rates of growth known: 1.5% per year increase in emissions
- Future estimated, based on
  - Population
  - Economic Growth
    - Agricultural production
    - Industrialization
- It is predicted that the CO_2 concentration in the atmosphere will be double the 1860 level (2 x 280 ppm = 560 ppm) between 2030-2050.

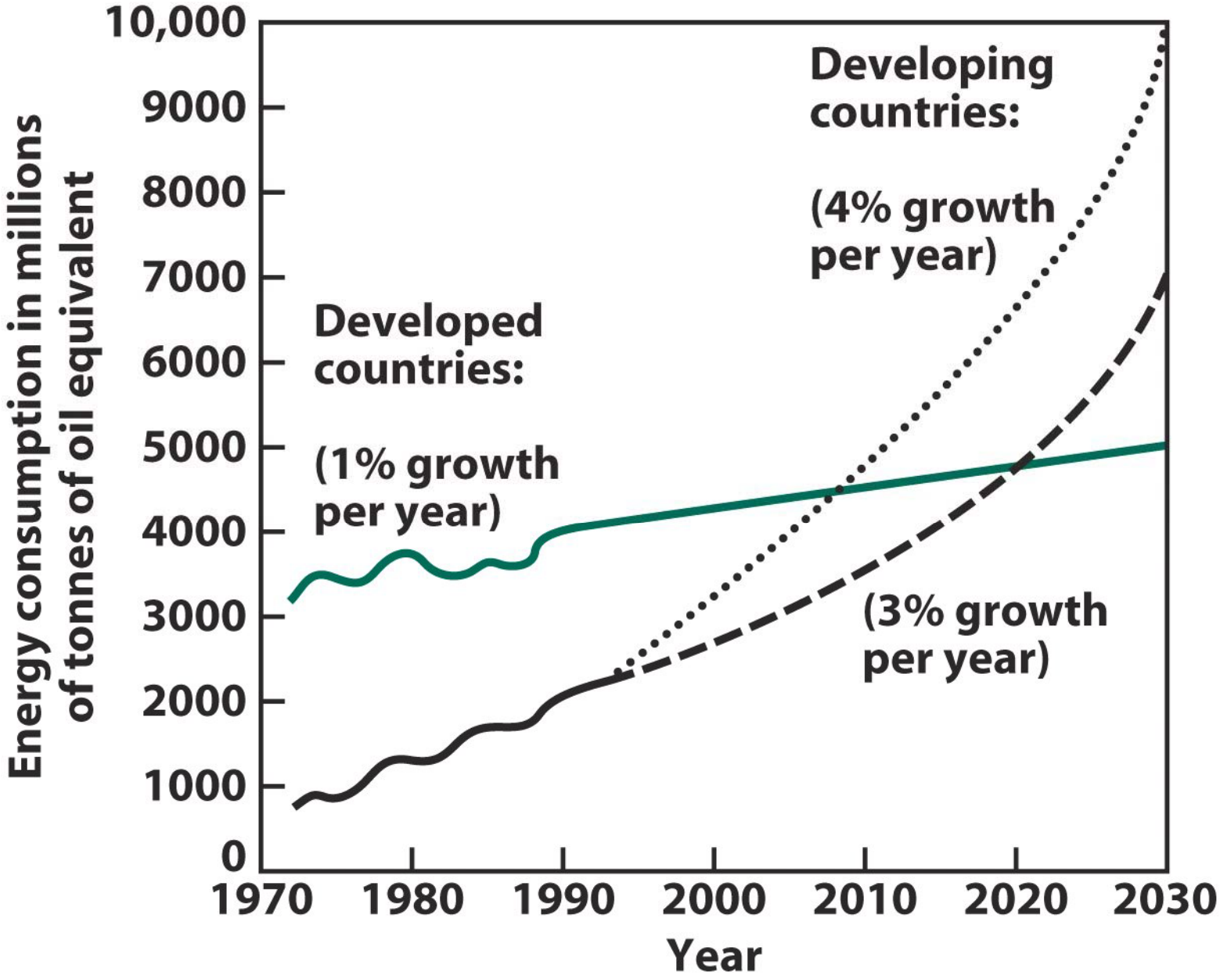
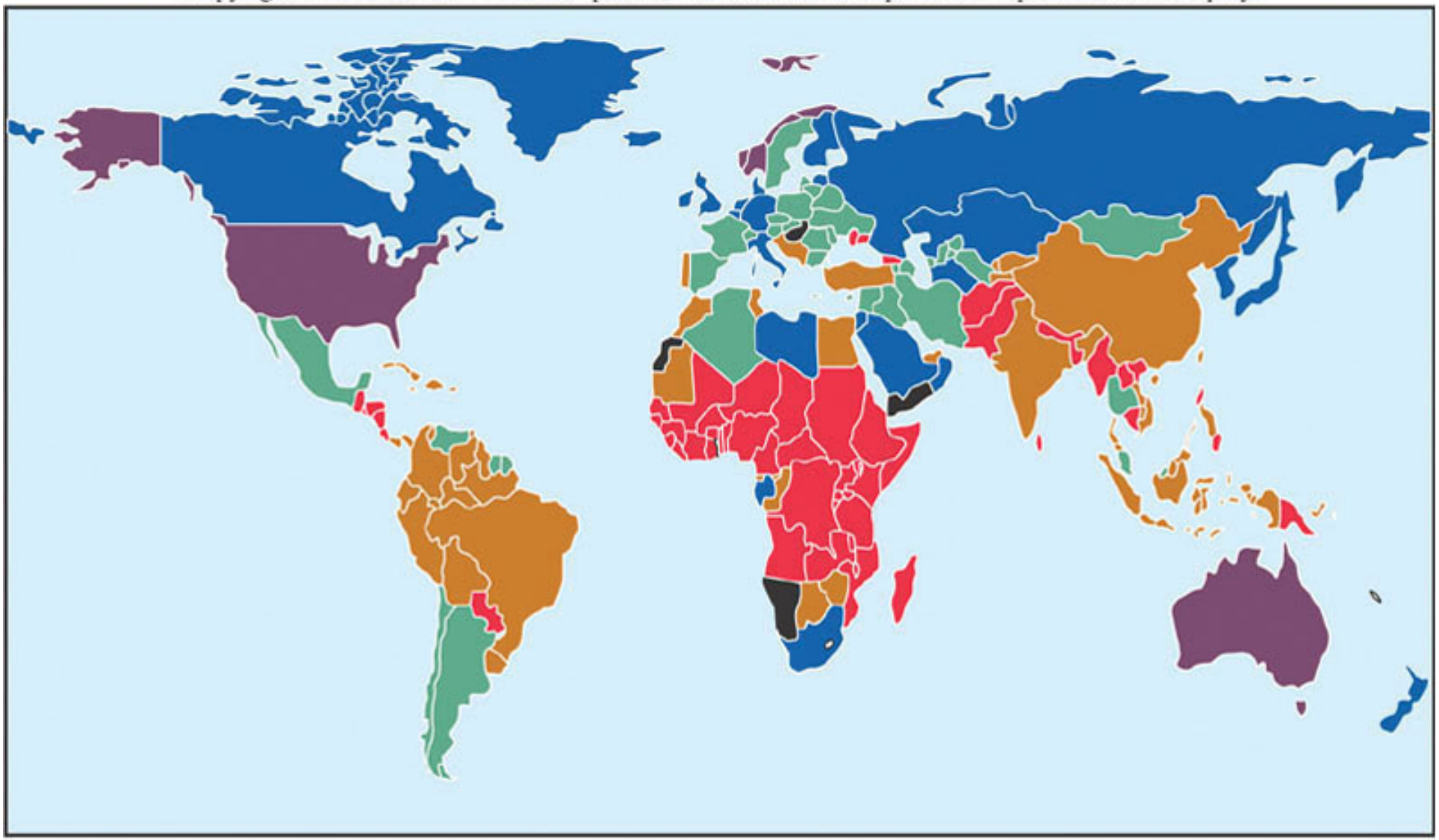
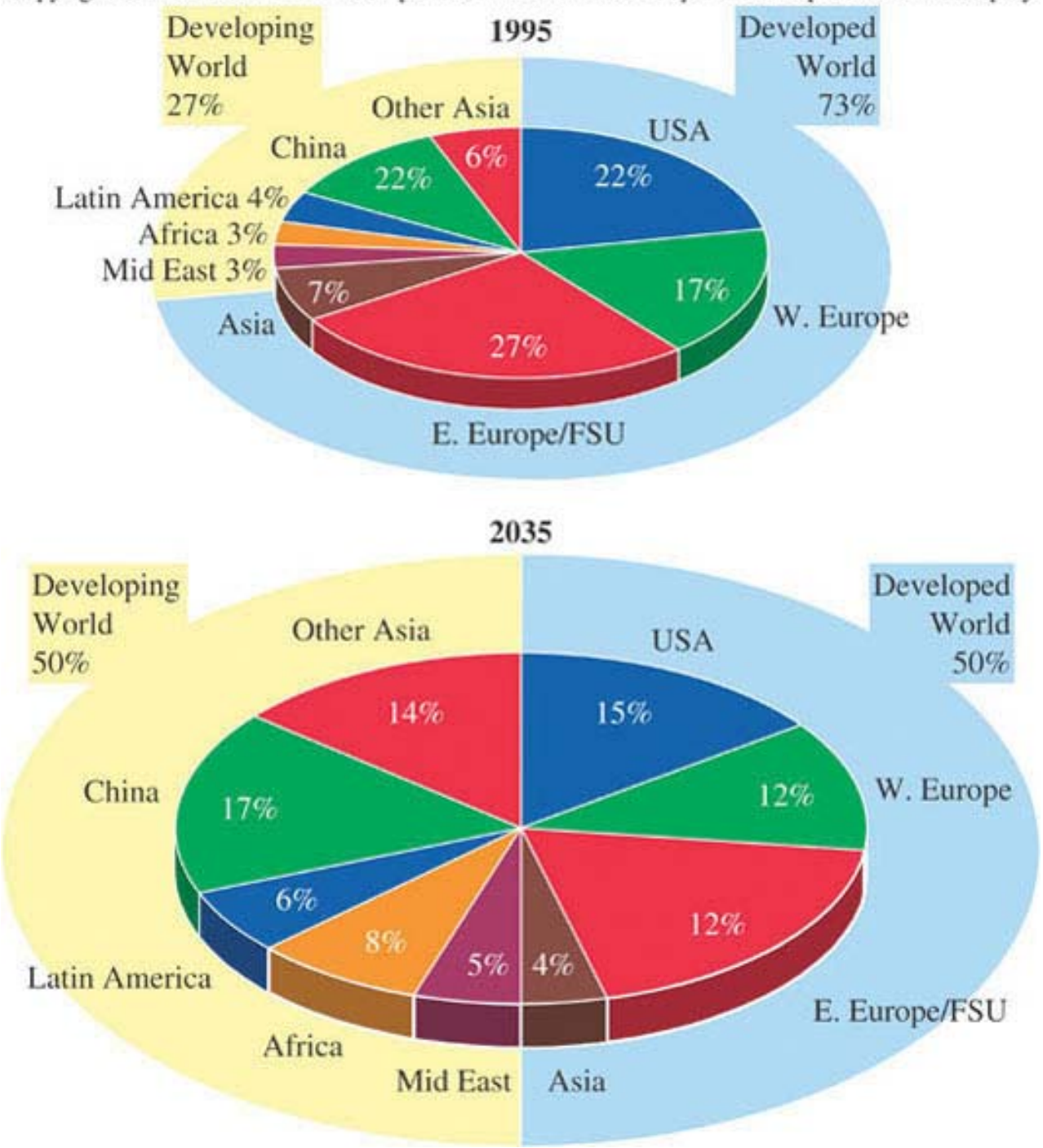


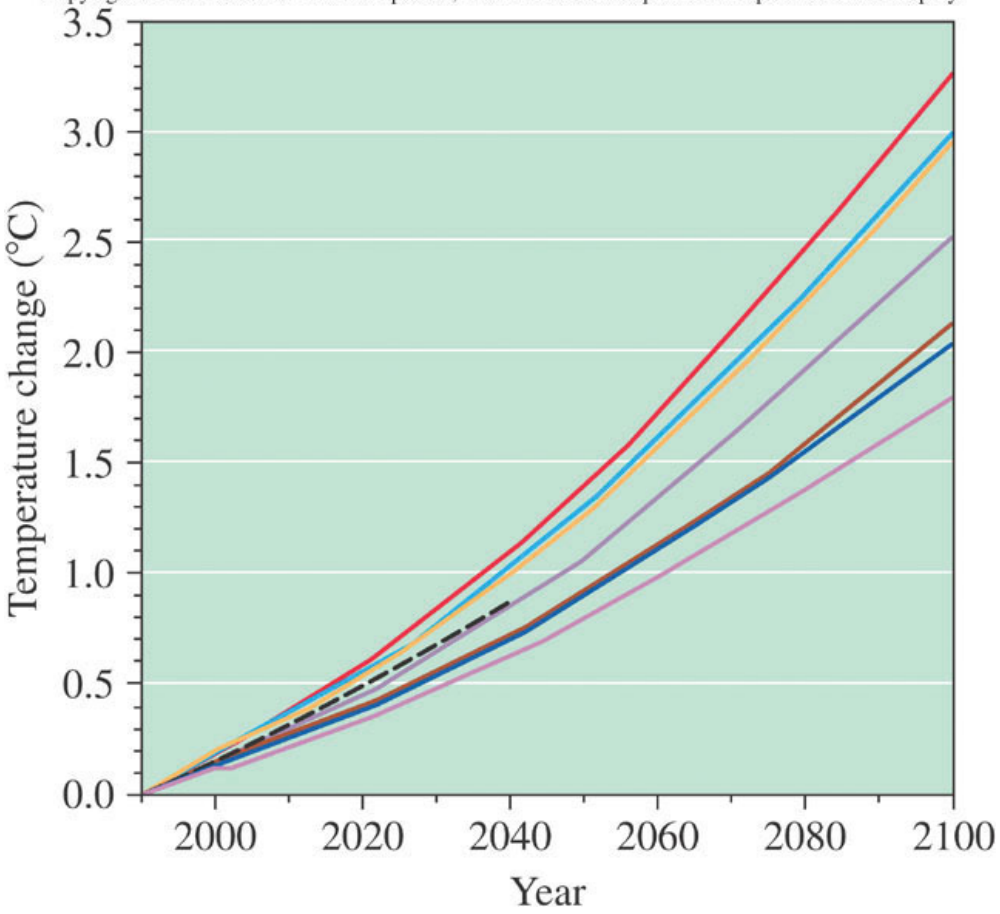
Figure 5-3
Environmental Chemistry, Third Edition



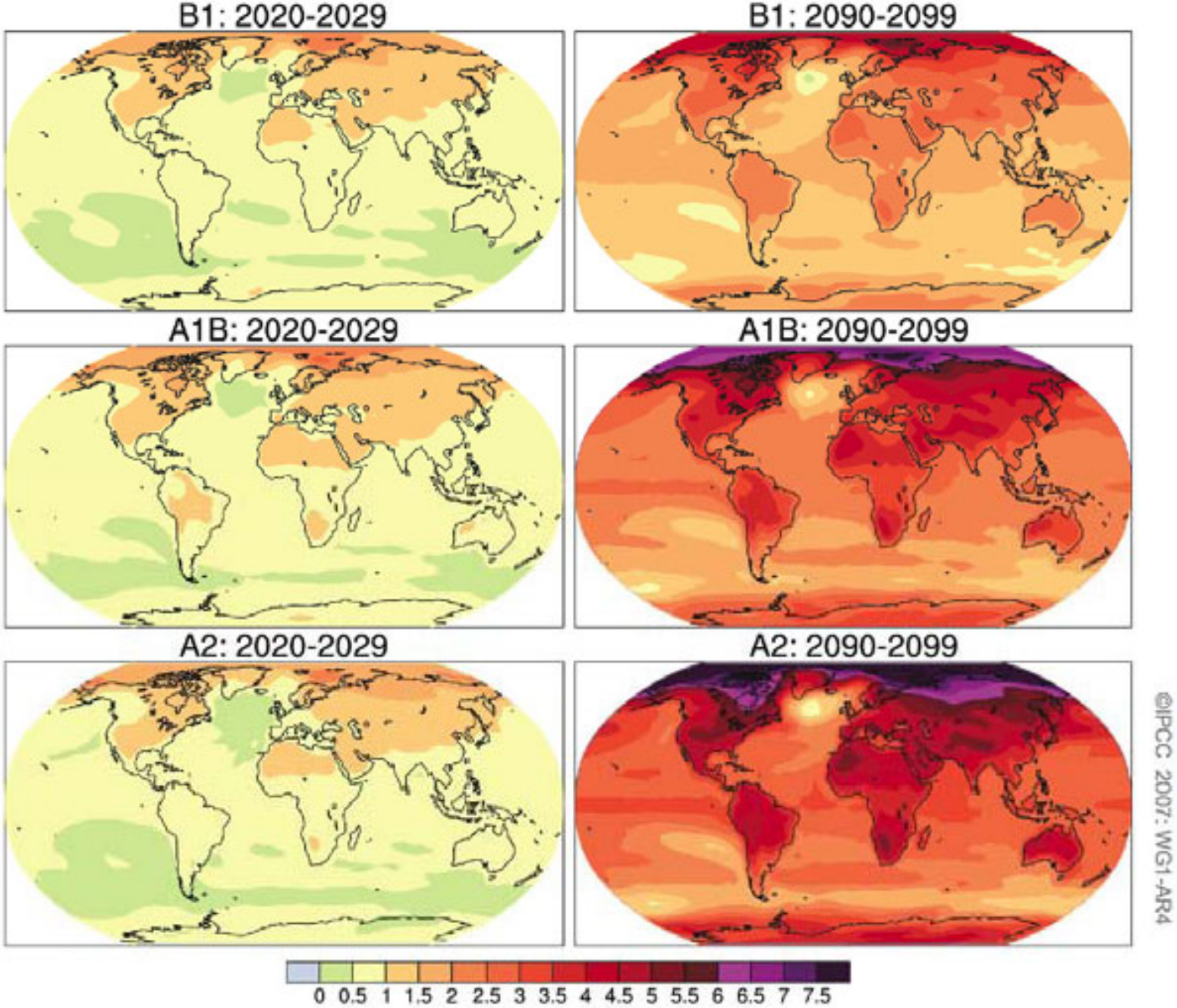
■ <1.0 ■ 1.0–2.9 ■ 3.0–6.9 ■ 7.0–14.9 ■ >15.0 ■ no data

Metric tons per person





- 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 %


B1: 2020-2029
B1: 2090-2099
A1B: 2020-2029
A1B: 2090-2099
A2: 2020-2029
A2: 2090-2099
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5
©IPCC 2007: WG1-AR4

)

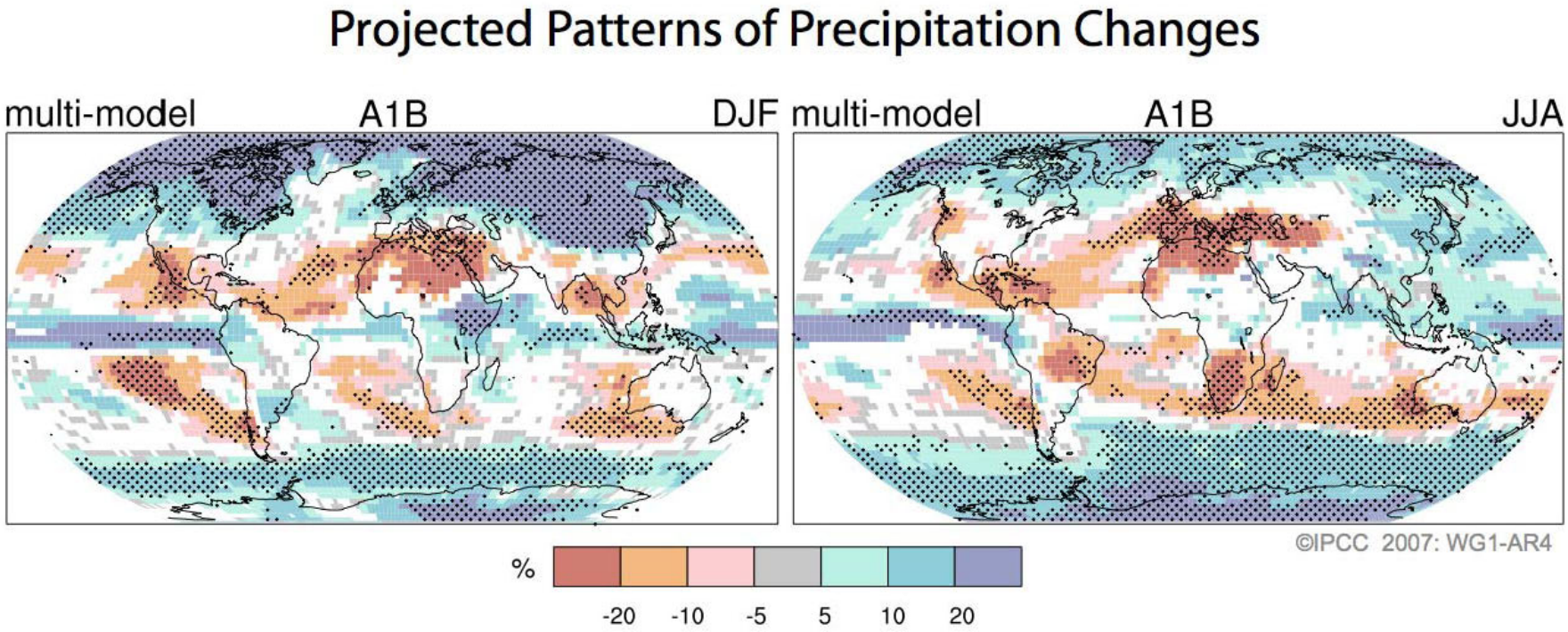


FIGURE SPM-7. Relative changes in precipitation (in percent) for the period 2090–2099, relative to 1980–1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change. {Figure 10.9}

Table 3.6 Judgmental Estimates of Confidence

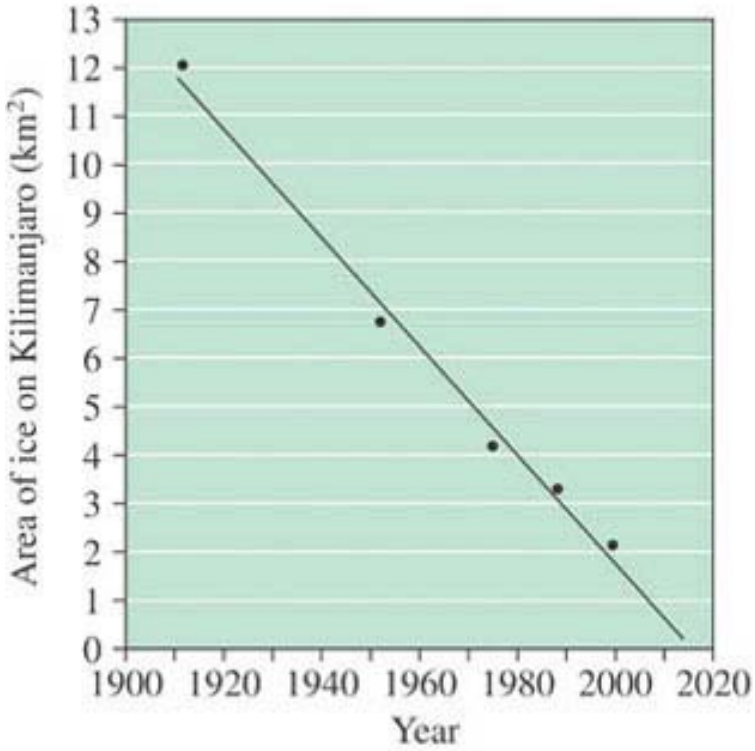
Term Used	Probability That a Result is True
Virtually certain	99%
Very likely	90–99%
Likely	66–90%
Medium likelihood	33–66%
Unlikely	10–33%
Very unlikely	1–10%

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.	

IPCC 2007: 11 of the last 12 years (1995-2006) rank among the 12 hottest years on record (since 1850).



Melting Ice

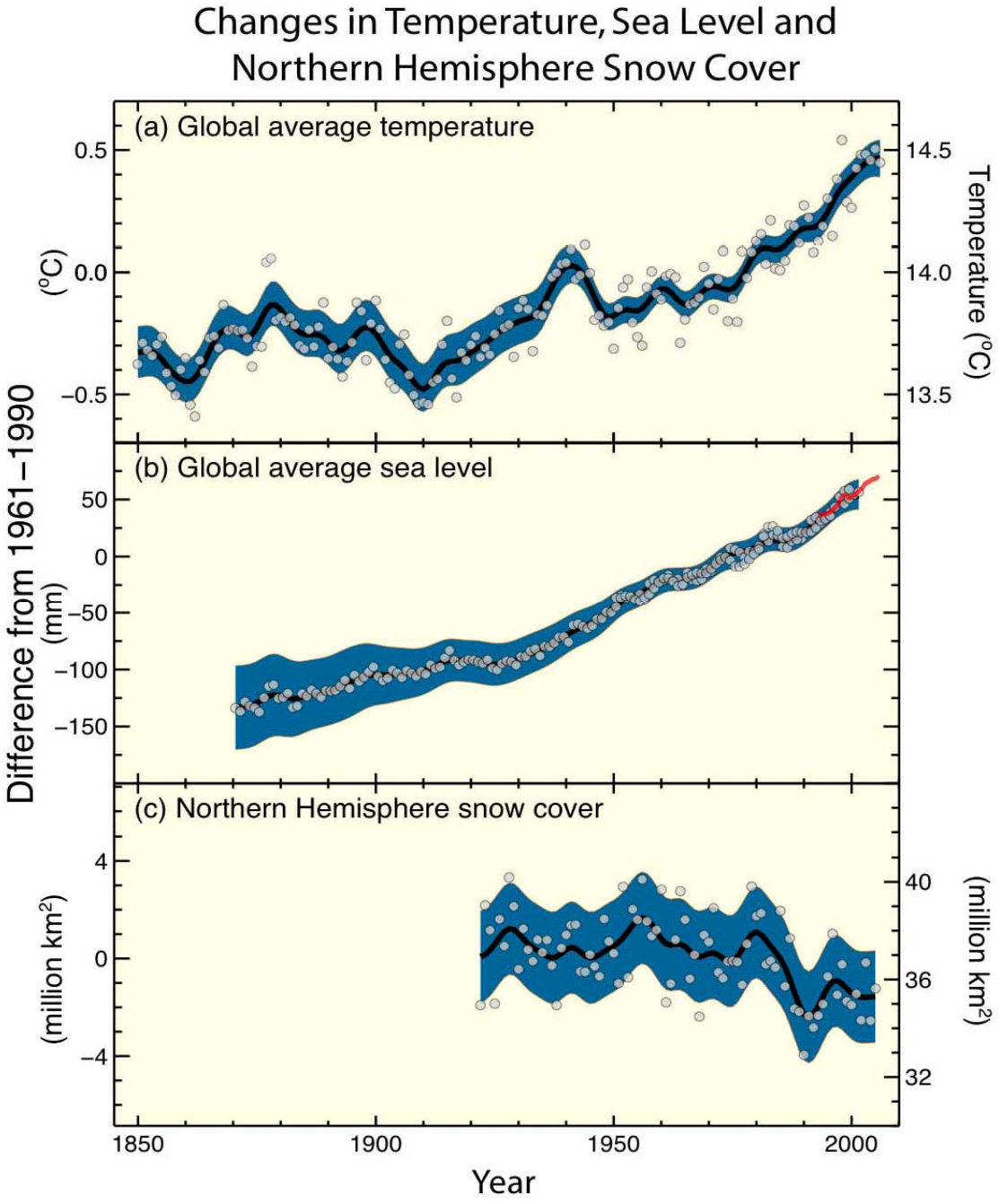
- Where does the water go?
  - Oceans
  - By 2100 sea levels predicted to rise by

    9 – 88 cm (3.5 – 34.6 in)

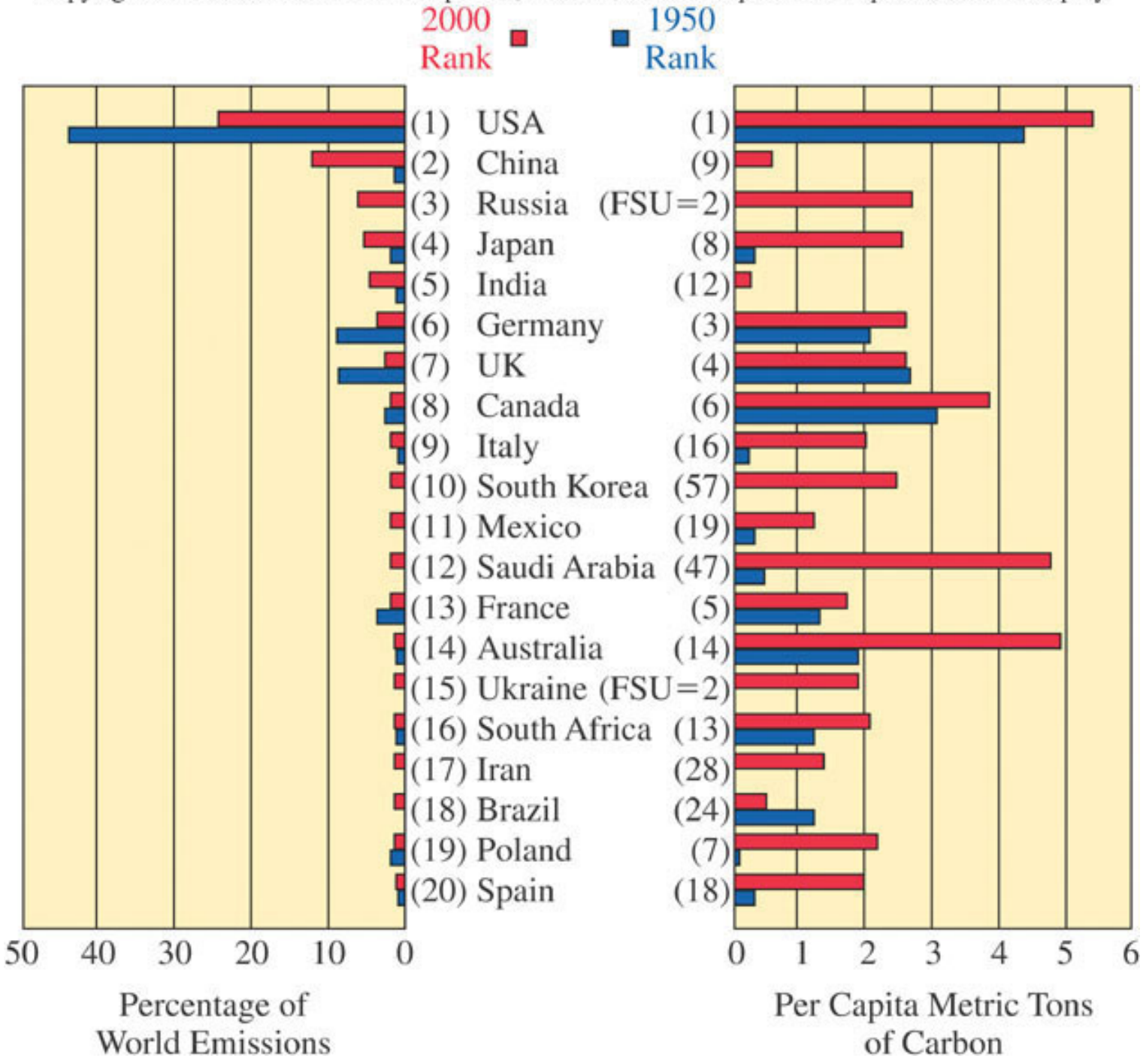
  This endangers all coastal cities - including Boston.

  But also some entire countries:

  The Netherlands, Indonesia, the Philippines, Bangladesh


Changes in Temperature, Sea Level and
Northern Hemisphere Snow Cover
(a) Global average temperature
(b) Global average sea level
(c) Northern Hemisphere snow cover
Difference from 1961–1990
(°C)
(mm)
(million km²)
Temperature (°C)
(million km²)
0.5
0.0
−0.5
14.5
14.0
13.5
50
0
−50
−100
−150
4
0
−4
40
36
32
1850
1900
1950
2000
Year

- 85 % of the worldwide energy needs are supplied by fossil fuels.
- What’s the solution?
- Reduce reliance on fossil fuels!
- Not that easy…



- The Montreal Protocol was enacted within 10 years of the discovery of the ozone hole, and had immediate and far-reaching impact on the problem
- What’s different about global warming?

- Common solution is to delay action until more is known.
- Still others feel that the level of uncertainty in current models is too high to gamble all that money and effort on what could possibly me a mistake.
- As of 2005, even the National Research Council cautioned
  - “Because there is considerable uncertainty in current understanding of how the climate system varies naturally and reacts to emissions of greenhouse gases and aerosols, current estimates of the magnitude of future warming should be regarded as tentative and subject to future adjustments (either upward or downward).”

- This wait and see attitude not good enough for others…
  - "Scientific uncertainties, which are substantial, of course, are not a reason to put off action. In fact, we have only on Earth to experiment on."
    - Chief scientist of the Environmental Defense Fund
  - "Doubt and uncertainty are the essential ingredients in science. The drive investigation and hypotheses, leading to predictions. Observations are the judge."
    - Head of NASA's Goddard Institute for Space Studies.

Alternative solutions: Sequestration

- Various ways of putting the CO_2 back into the earth
- Keeping it out of the troposphere
- Trapping it
  - Reforestation
  - Pumping CO_2 underground
  - CO_2 liquefied and pumped deep into the ocean
  - $100/ton currently

Kyoto Protocol

- 1997
- 10,000 participants from 161 countries
- Goals to stabilize and reduce GHG concentrations in stratosphere
- Annex I nations (developed or industrialized countries) targeted for emission reduction: by 2012, the U.S. was expected to reduce its GHG emissions by 7% relative to 1990; Europe by 8%; Canada and Japan by 6%
- Annex II nations (3rd World or developing countries) NOT targeted for emission reduction

Regulated Gases

- CO_2
- CH_4
- N_2O
- HFCs
- PFCs
- SF_6

Kyoto Protocol

- Designed to go in to effect when two conditions have been met:
  - The governments of 55 countries have ratified the requirements
  - When Annex I nations responsible for 55% of the 1990 CO_2 emissions have ratified
- As of February 2005, when Russia passed its laws, those requirements are met
- As of December 2006, 169 countries are on board, and 61.6% of 1990 CO_2 emissions are accounted for

U.S. Hasn’t Ratified Kyoto

- Bill Clinton didn’t sign
  - Annex II nations NOT targeted for emission reduction
  - The Senate voted 95-0 **opposing** any measure that did not bind developing nations
- George Bush hasn’t signed
  - China has an exemption but the U.S. does not
  - Economic concerns as well – enacting the requirements would have dramatic consequences for the U.S. economy

U.S. Hasn’t Ratified Kyoto

- Instead, GWB enacted the Global Climate Change Initiative, promising an 18% reduction by 2012. However, this Initiative is entirely voluntary
- It is left to local government offices to impose their own regulations and apply pressure to other local, state and federal governments
- One such policy: the Regional Greenhouse Gas Initiative (RGGI). Signed January 18, 2007, by eight Northeastern US states (including Massachusetts)