

Indoor air pollution

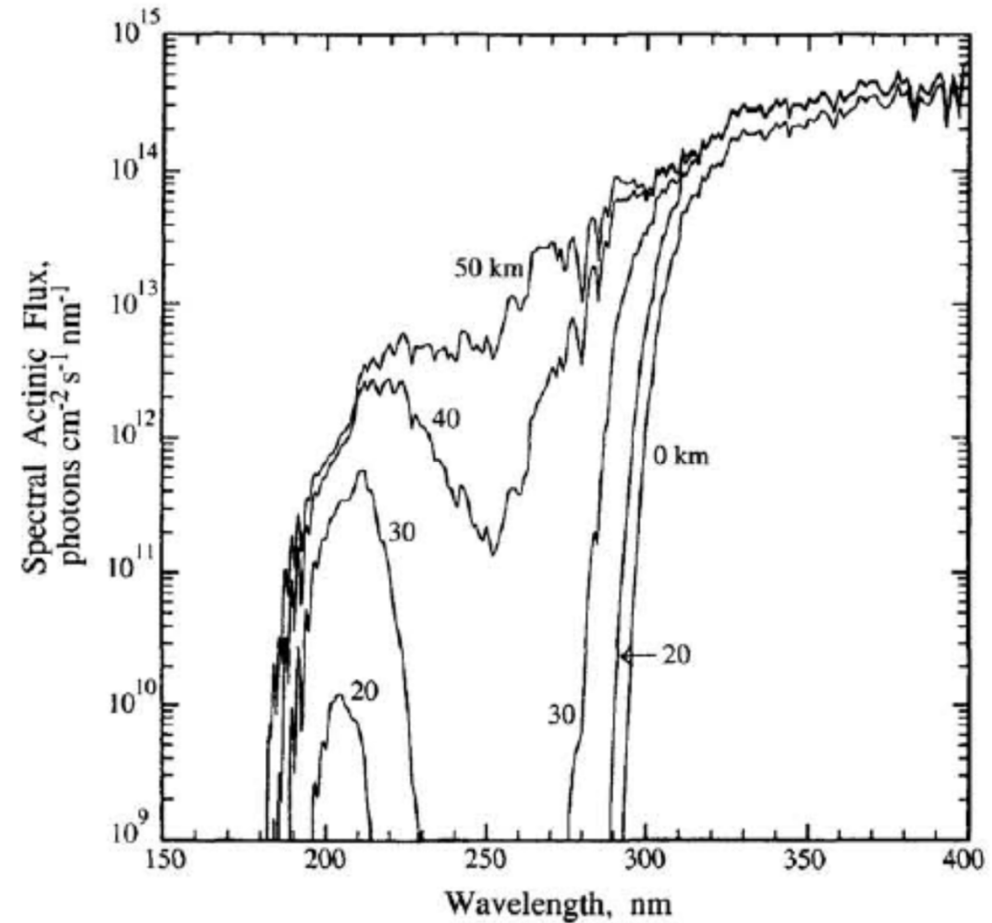
- Difficult to regulate!
- CO and NO_x from gas ranges, ovens, heaters, and cigarette smoke
- Cigarette smoke also contains toxic compounds including carcinogens
- Bioaerosols: bacteria, viruses, fungi, mites, and pollen
- Radon: emitted from the ground (high in basements)
- Volatile organic compounds
 - ex) formaldehyde: emitted from building materials (“sick building syndrome”)
- Heavy metals: emitted from paints

Acid rain

- SO_2 and NO_x in the air undergo series of reactions to form sulfuric acid (H_2SO_4) and nitric acid (HNO_3)
- pH in natural rain has a pH near 5.6 (why?)
- Rain pH in polluted areas can go below 5, sometimes even close to 2
- Adverse effects
 - Acidification of rivers, lakes, and soil: damage aquatic/terrestrial ecosystem including fish deaths
 - Nutrient leaching from soil (ex: Mg)
 - Mobilize aluminum from soil: enhanced uptake of Al by plants, increase Al concentration in waters (toxic effect)

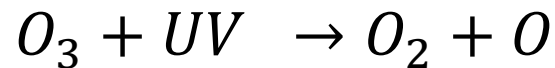
Ozone depletion

- Ozone protects life if it is in the stratosphere
- Ozone layer (20-40 km or up above the ground): absorbs UV light

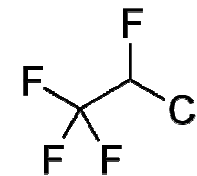
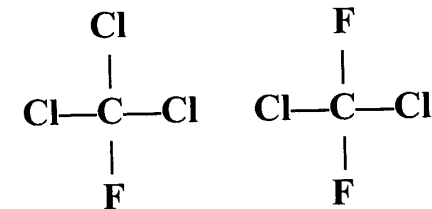


Ozone depletion

- Photoreactions of ozone to absorb UV light

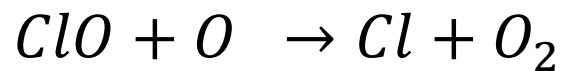
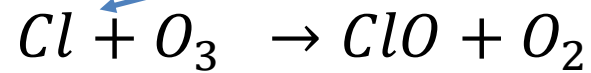
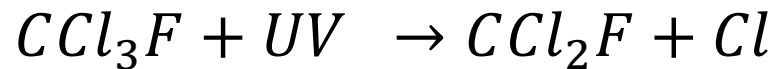


- CFCs (chlorofluorocarbons)
 - Good for refrigerants, propellants, and solvents
 - Stable in the troposphere → can reach the stratosphere without break-down
 - Causes ozone depletion



Ozone depletion

- Ozone destruction mechanism by CFCs



- Cl atom acts as a catalyst
- One CFC molecule can destroy uncountable number of ozone molecules

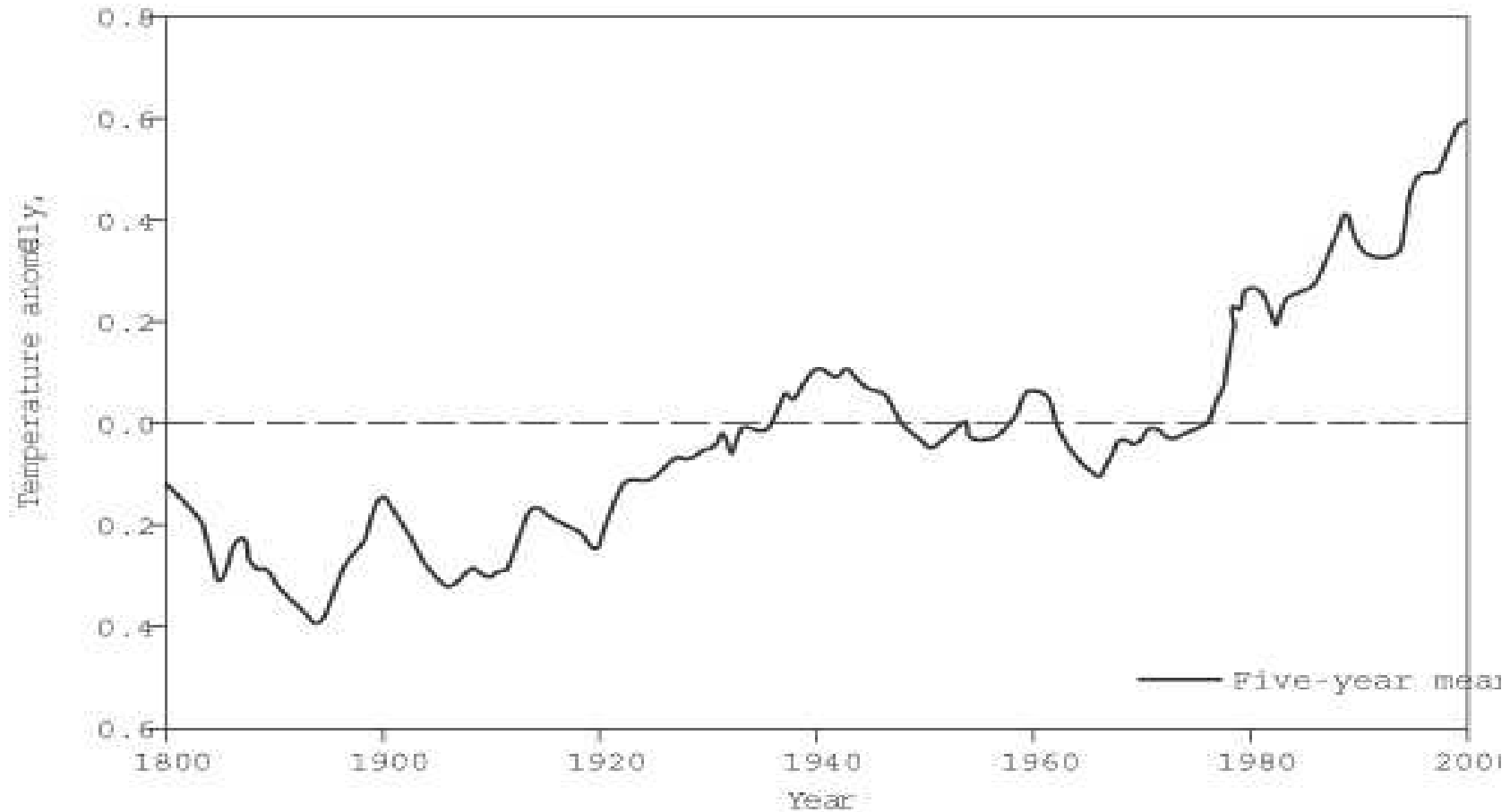
Ozone depletion

- Efforts to stop ozone depletion
 - **Montreal Protocol** on Substances That Deplete the Ozone Layer
 - An international treaty agreed on September 16, 1987
 - Became effective in January 1989
 - Eight revisions: 1990, 1991, 1992, 1993, 1995, 1997, 1999, and 2007
 - Goal: complete phase-out of CFCs

Ozone depletion

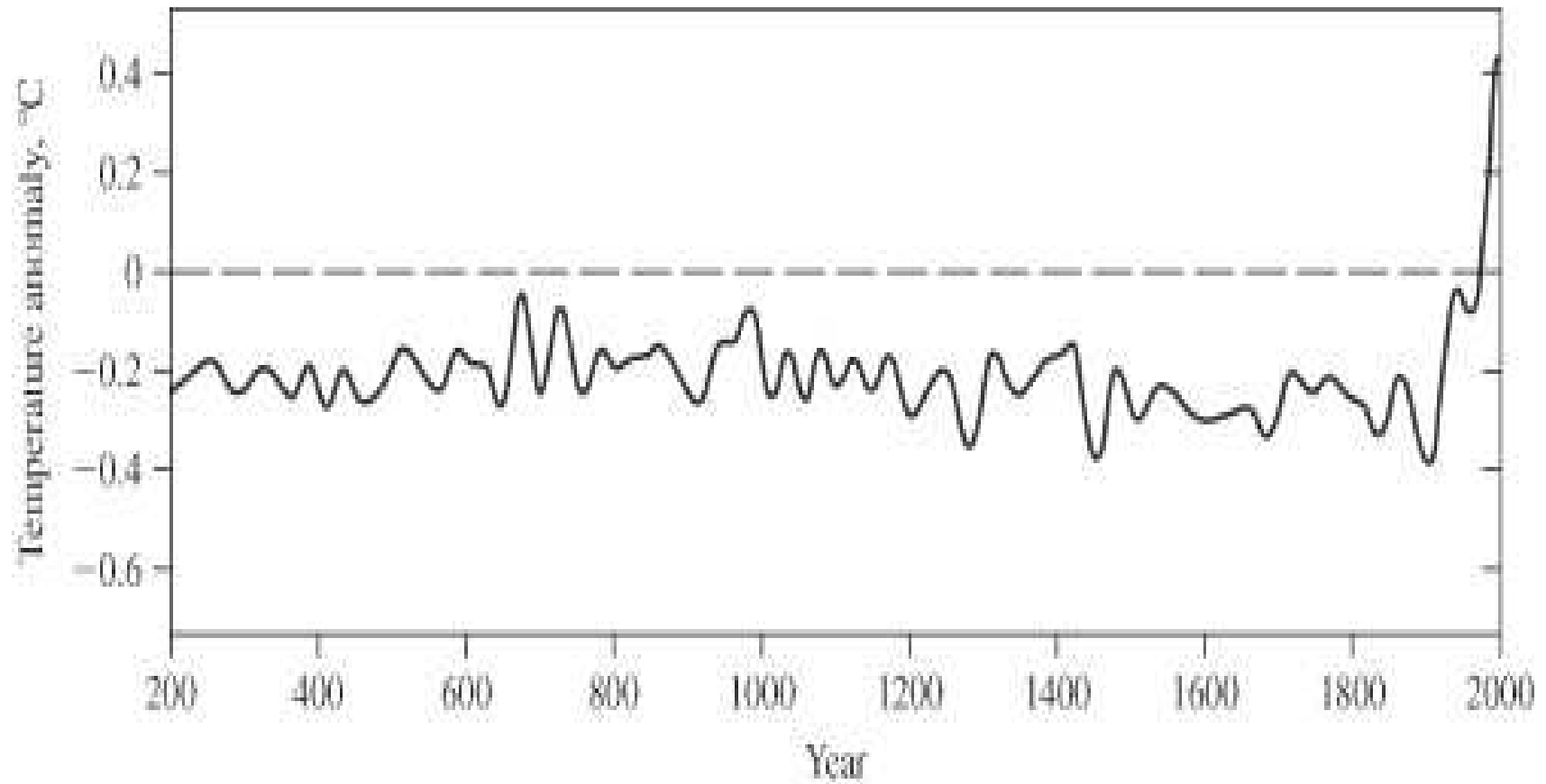
- Substitutes: HFCs and HCFCs
 - Hydrochlorofluorocarbons (HCFCs)
 - More reactive than CFCs in the troposphere
 - only small amount reaches the stratosphere
 - Still has some ozone depletion potential
 - used just as a transitional substitute of CFCs, amendments of Montreal Protocol also targets on the phase-out of HCFCs
 - Hydrofluorocarbons (HFCs)
 - No chlorine atoms → no ozone depletion potential
 - Problem: HFCs and HCFCs are greenhouse gases
 - HFCs are not considered as a permanent substitute of CFCs as well!

Global warming

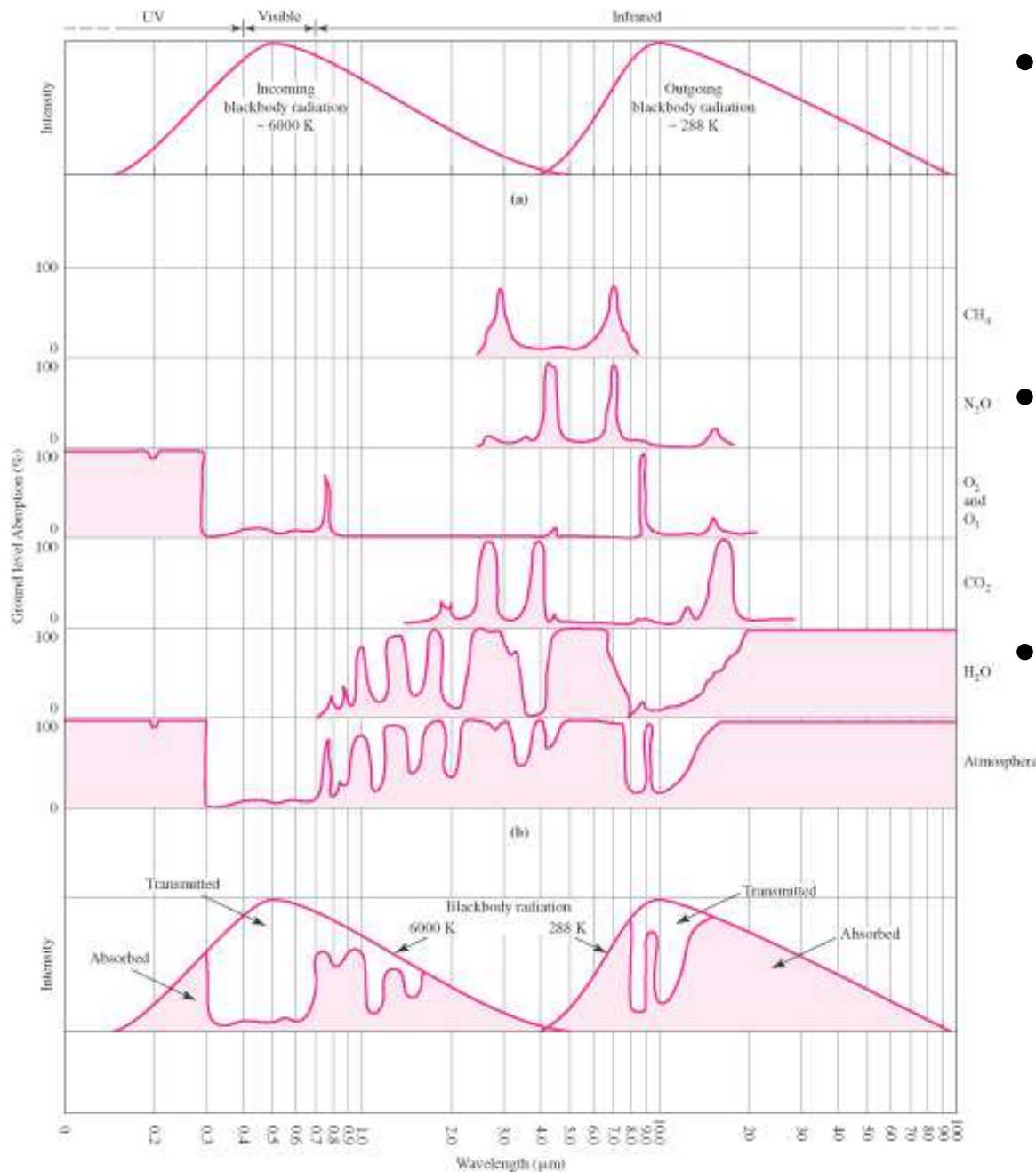


The temperature of the globe is really increasing!

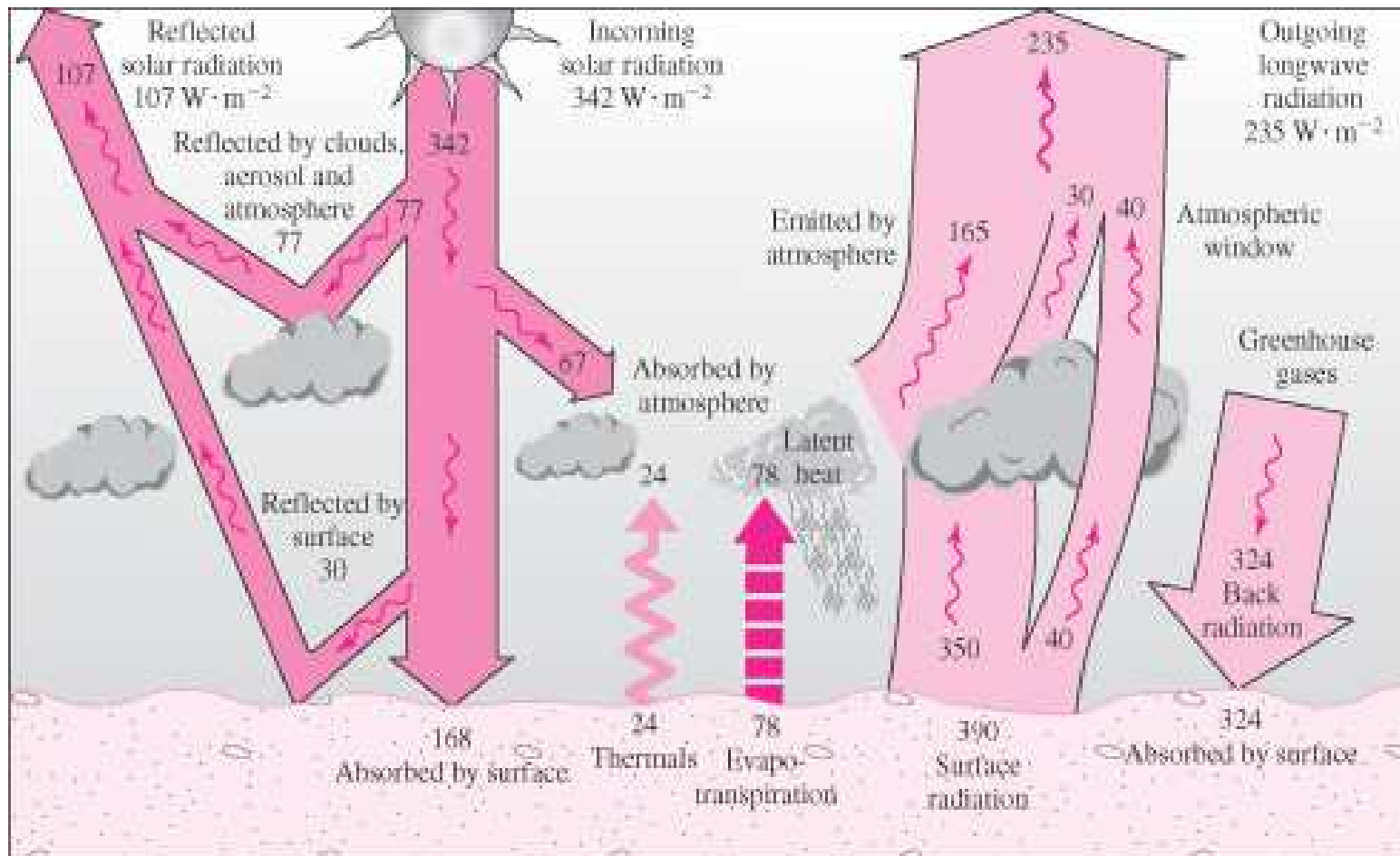
Global warming



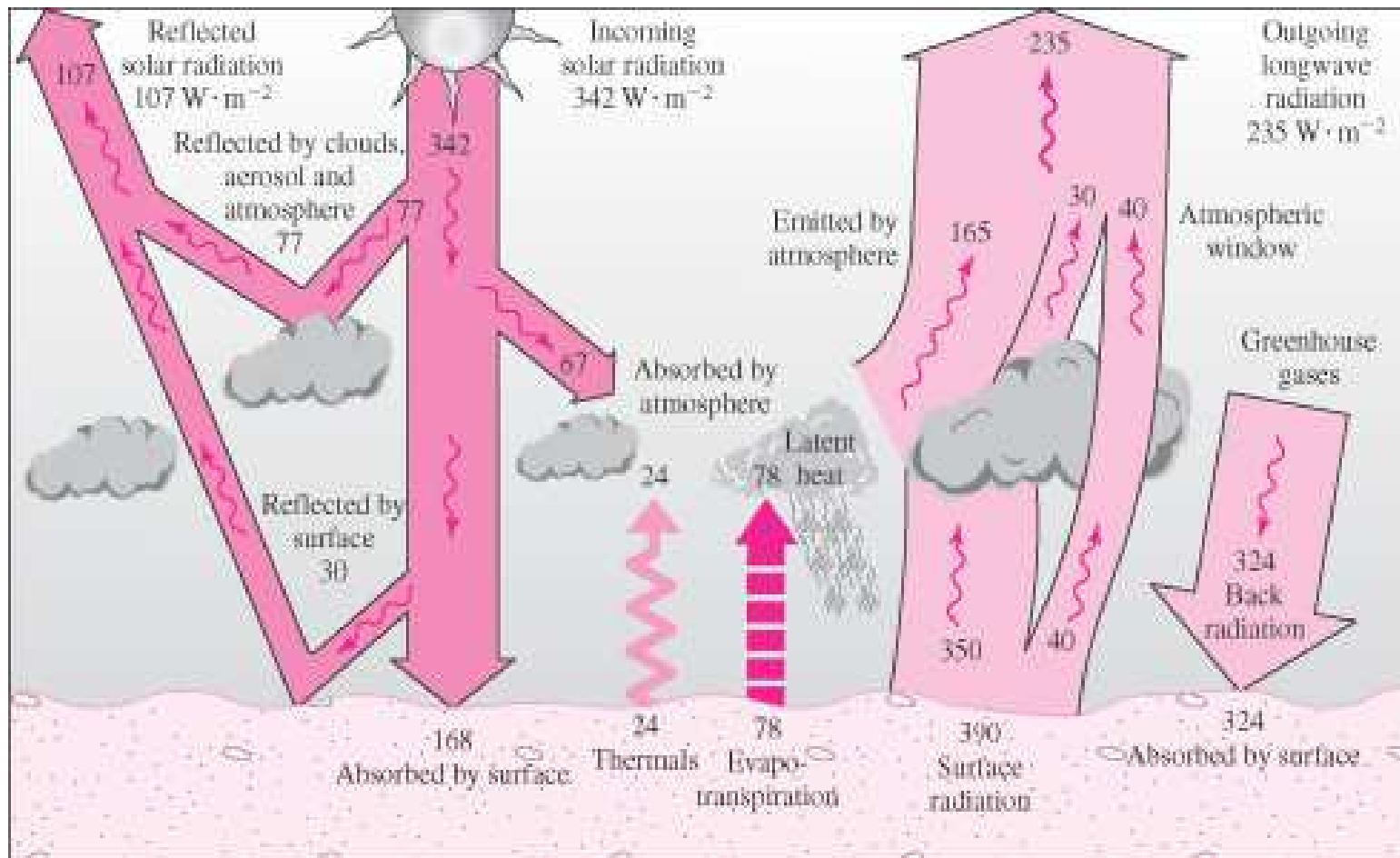
The “hockey stick” graph



- The earth receives short-wave radiation from the Sun
- The Earth's surface emits long-wave radiation
- Some molecules absorb the long-wave radiation → prevent energy to be released out of the Earth



- The greenhouse gases (GHGs) work like the glass on a greenhouse or a blanket
- Maintain the Earth's temperature good for life (without GHGs, the Earth's temperature will be around -17°C)



- 30% increase in the atmospheric CO_2 concentration since 1750
- The increased levels of greenhouse gases changes the radiation balance: greater back radiation \rightarrow higher surface temperature

Greenhouse gases (GHGs)

- CO₂ is major, but others can also be significant
- Overall greenhouse effect depends on concentration, global warming potential, and lifetime

Chemicals	Lifetime (year)	Global warming potential (kg CO ₂ /kg chemical)
Carbon dioxide (CO ₂)	30-200	1
Methane (CH ₄)	12	62
Nitrous oxide (N ₂ O)	114	275
CFC-12 (CF ₂ Cl ₂)	100	10200
HCFC-22 (CHF ₂ Cl)	12	4800
Tetrafluoromethane (CF ₄)	50000	3900
Sulfur hexafluoride (SF ₆)	3200	15100

Global warming

- Efforts to reduce GHG emissions: **Kyoto Protocol**
 - Adopted on December 11, 1997
 - Became effective in 2005
 - Targets to reduce GHG emissions in developed countries by an average of 5.2% compared to 1990 levels during the first commitment period (2008-2012)
 - U.S. did not ratify the protocol
 - Korea: classified as a “developing country”, no binding targets

Global warming

- Kyoto Protocol
 - Doha amendment (2012)
 - Reduce GHG emissions by 25-40% compared to 1990 levels during the second commitment period (2013-2020)
 - Major CO₂-producing countries (U.S., China, and India) are not included
 - U.S. (2nd), Japan, Russia, Canada did not participate
 - China (1st) and India (3rd) are classified as developing countries
 - Korea: still classified as a developing country, but “voluntarily” promised to reduce the GHG emissions

Global warming



- Paris agreement (Dec 2015)
 - For post-2020 reduction of GHG emissions (effect of Kyoto Protocol ends in 2020)
 - A bottom-up approach (cf. Kyoto Protocol: top-down)
 - Each country submit “Nationally Determined Contributions (NDC)” for GHG reduction
 - The NDC should be “ambitious”, “represent a progression over time”, and set “with the view to achieving the purpose of this Agreement”
 - Korea: set NDC as “37% reduction compared to 2030 BAU* value”

**BAU: Business As Usual*

Reading assignment

Textbook Ch 12 p. 587-615