Global Change Biology

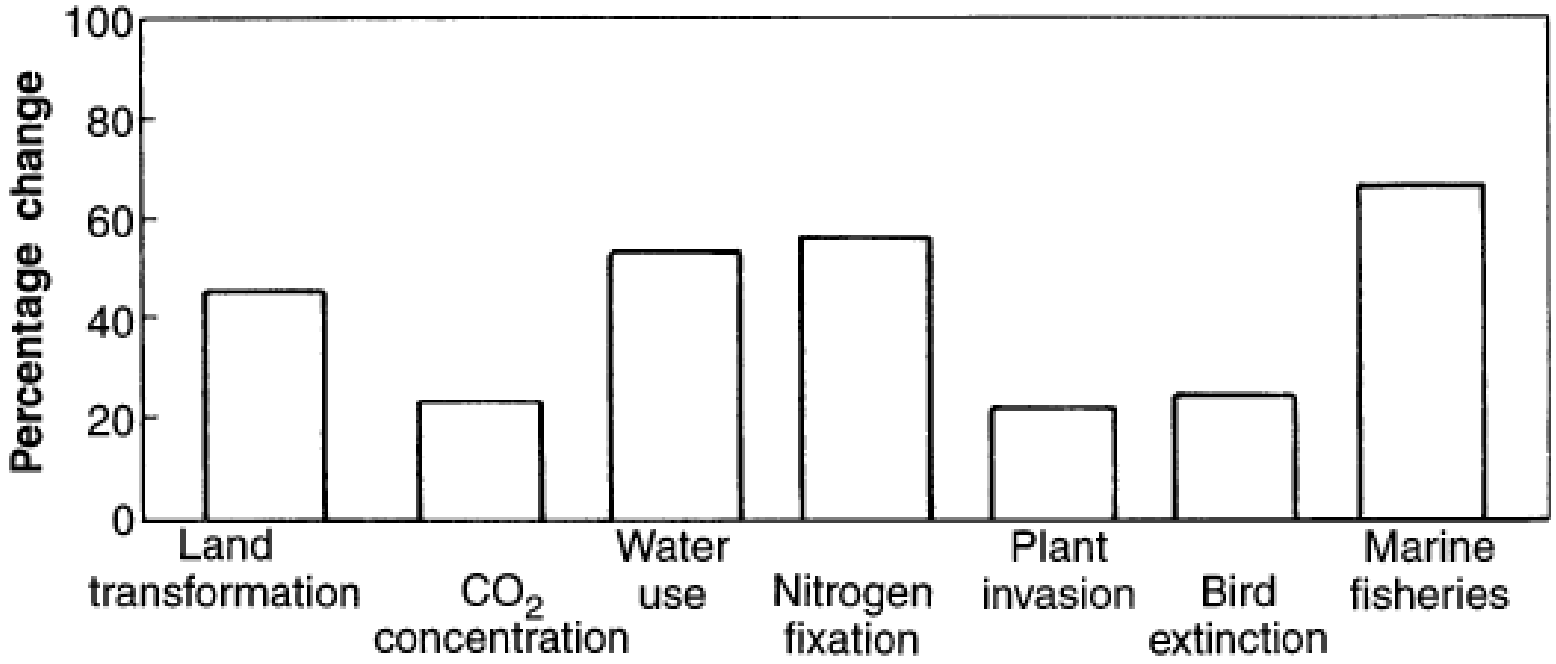
- Objectives
  - Introduce some of the more important issues in global change biology
    - Predominate role of humans
    - Importance for management of natural resources

Global Change Biology

- Humans dominate the Earth
  - This has led to substantial changes in the structure and function of terrestrial, marine, and freshwater ecosystems
  - The “Anthropocene” Epoch

Global Change Biology

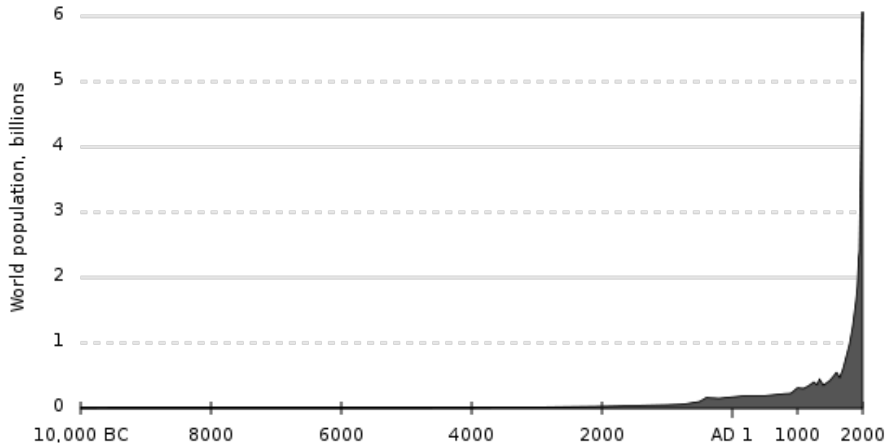
- The “Anthropocene” Era

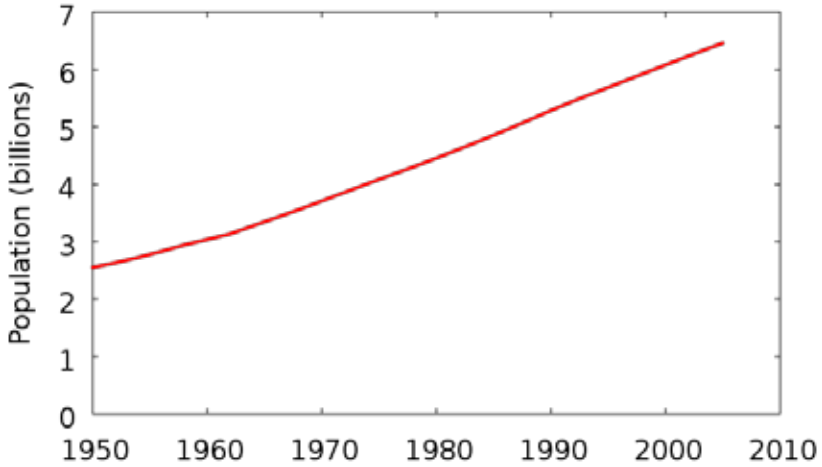


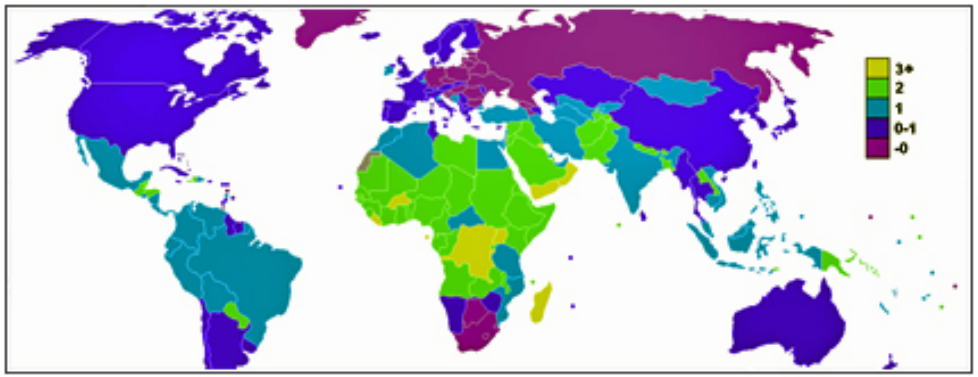
Vitousek et al. 1997

Global Change Biology

- Human Population Growth



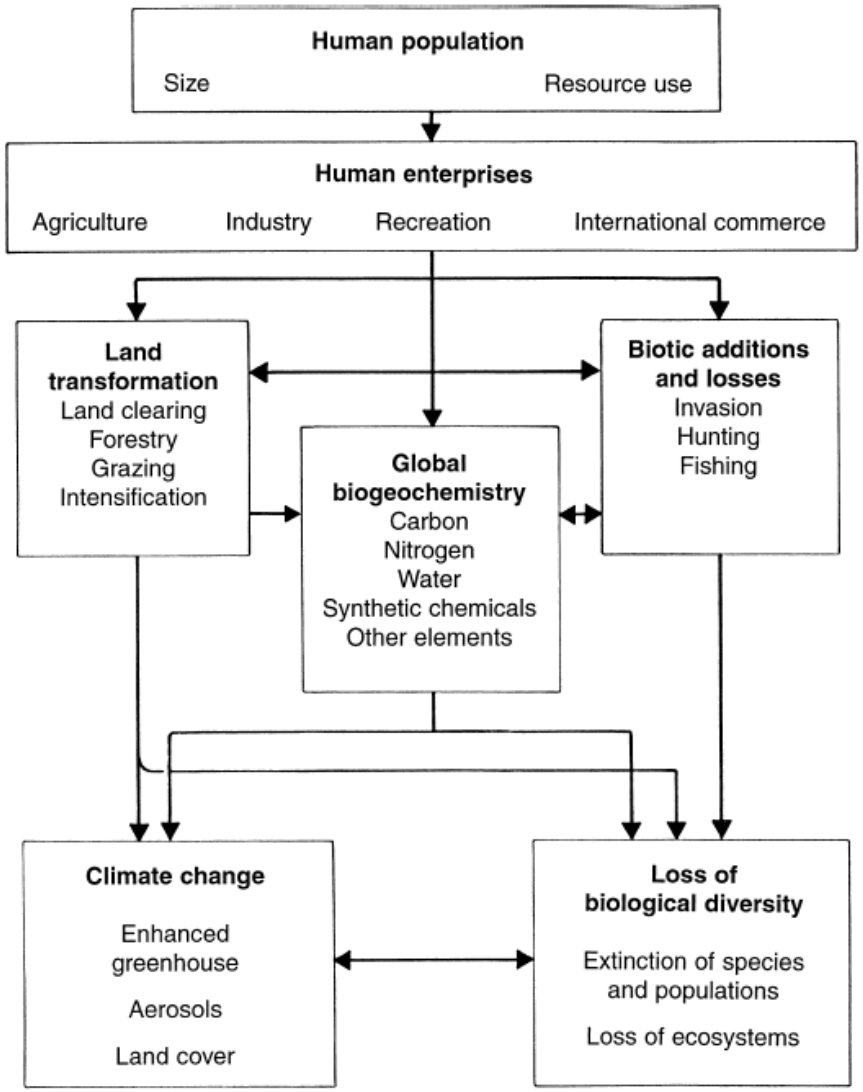




Population growth rate

Global Change Biology

- Direct and indirect influence of humans on the Earth system



Vitousek et al. 1997

Global Change Biology

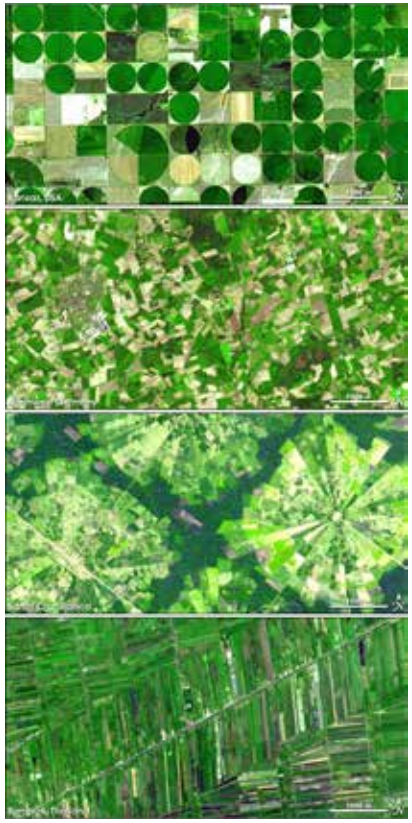
- Land transformations (39-50% of Earth's surface)
  - Row crop agriculture and urbanization (10-15%)

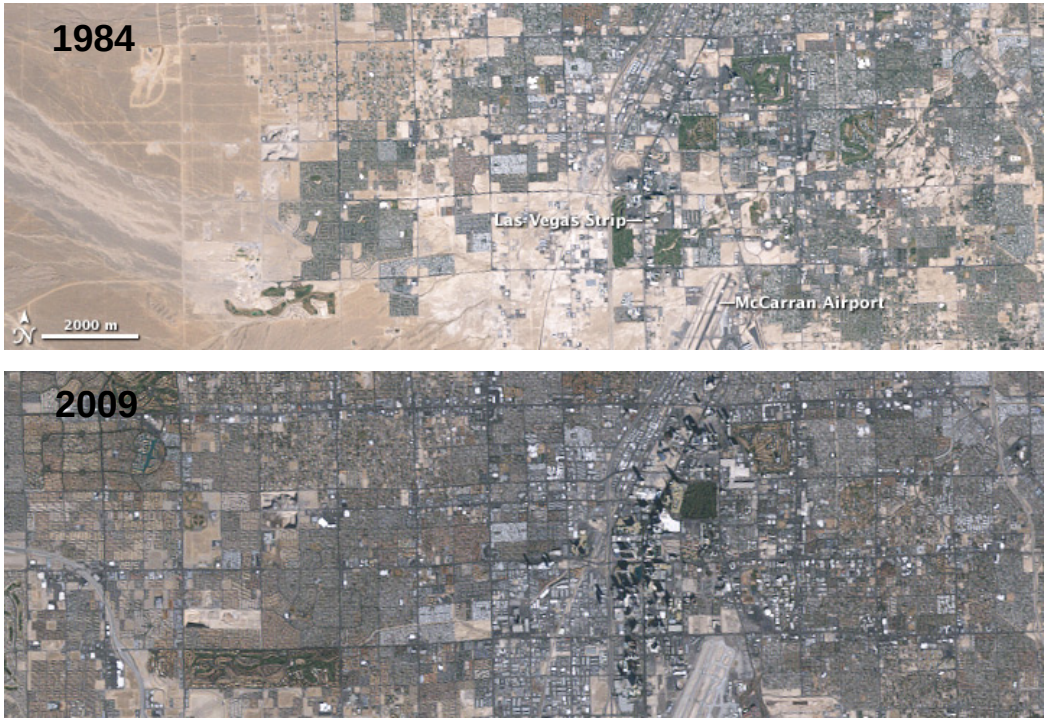
Kansas, USA

Germany

Bolivia

Thailand





Global Change Biology

- Land transformations (39-50% of Earth's surface)
  - Urbanization
    - Suburbs of Dallas, TX

1990

2010

Global Change Biology

- Land transformations (39-50% of Earth's surface)
  - Mining
    - Boone County, WV

1984

1996

2010

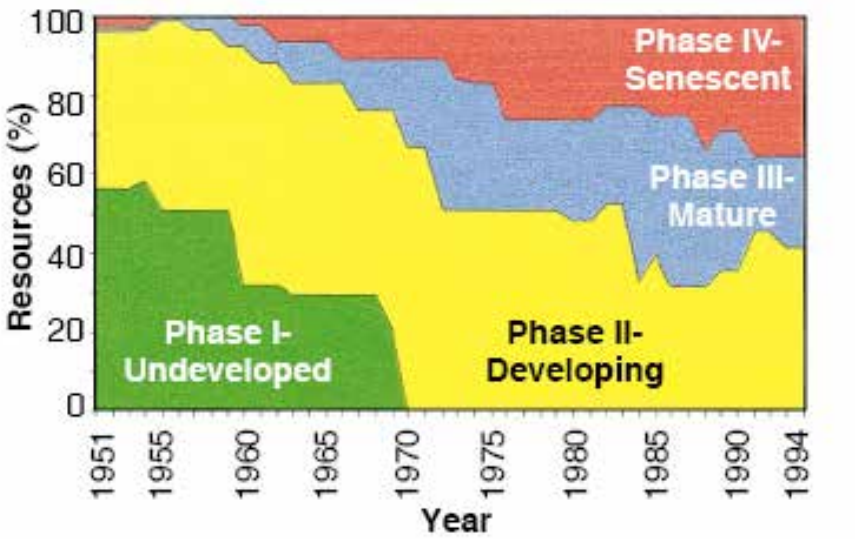
Global Change Biology

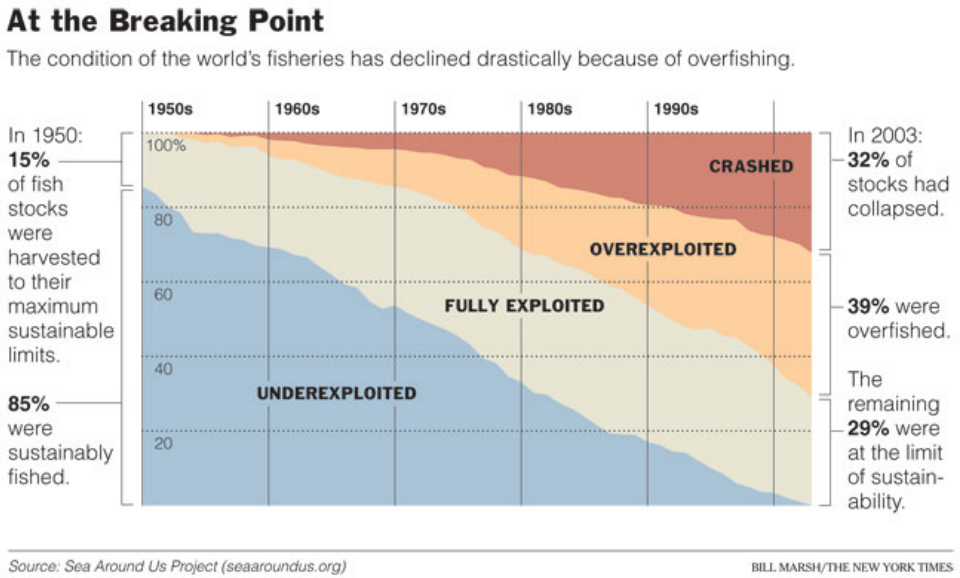
- Land transformations (39-50% of Earth's surface)
  - Conversion to pastureland (6-8%)
  - Grazing by domestic animals (???%)
  - Extraction of wood (???%)



Global Change Biology

- Alteration of marine ecosystems

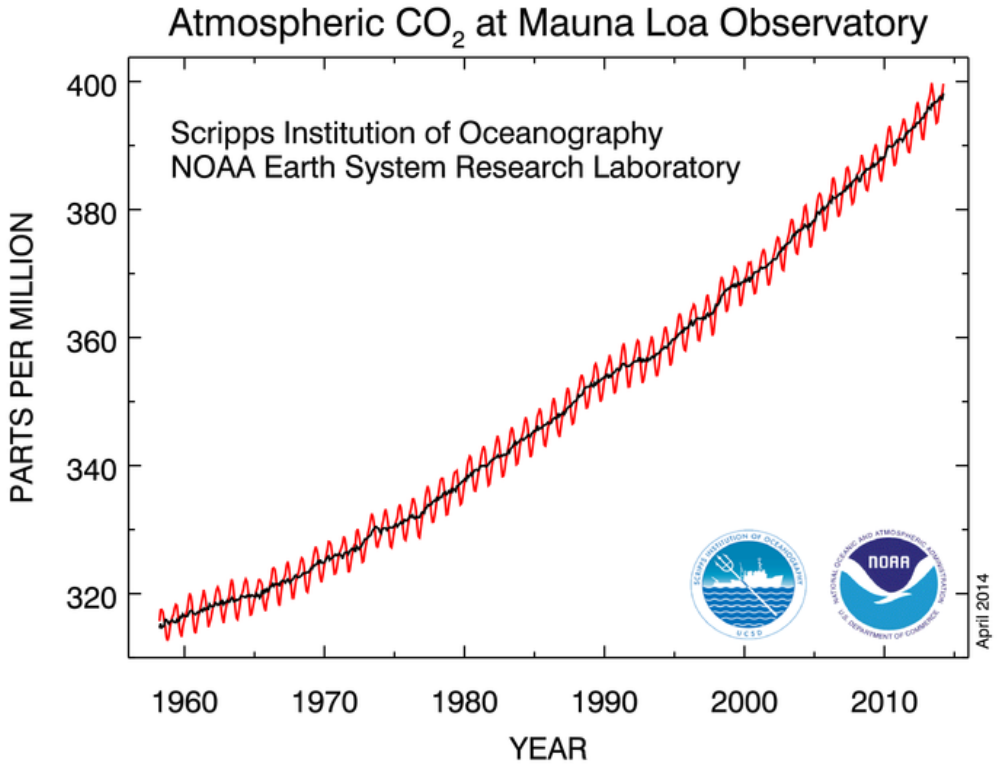




Vitousek et al. 1997

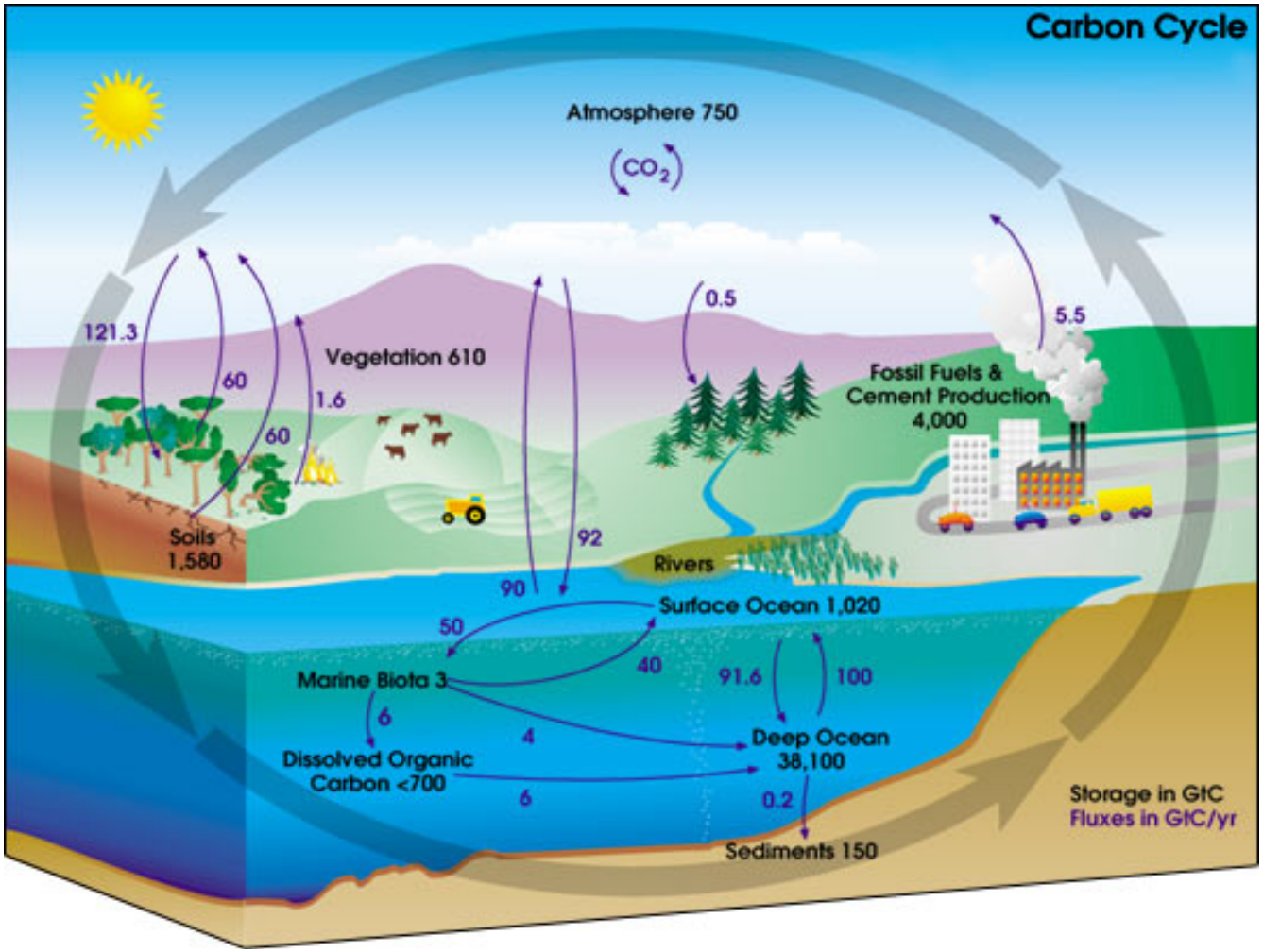
Global Change Biology

- Alteration of biogeochemical cycles - Carbon
  - Increased atmospheric CO_2 concentrations by ~45% since the industrial revolution



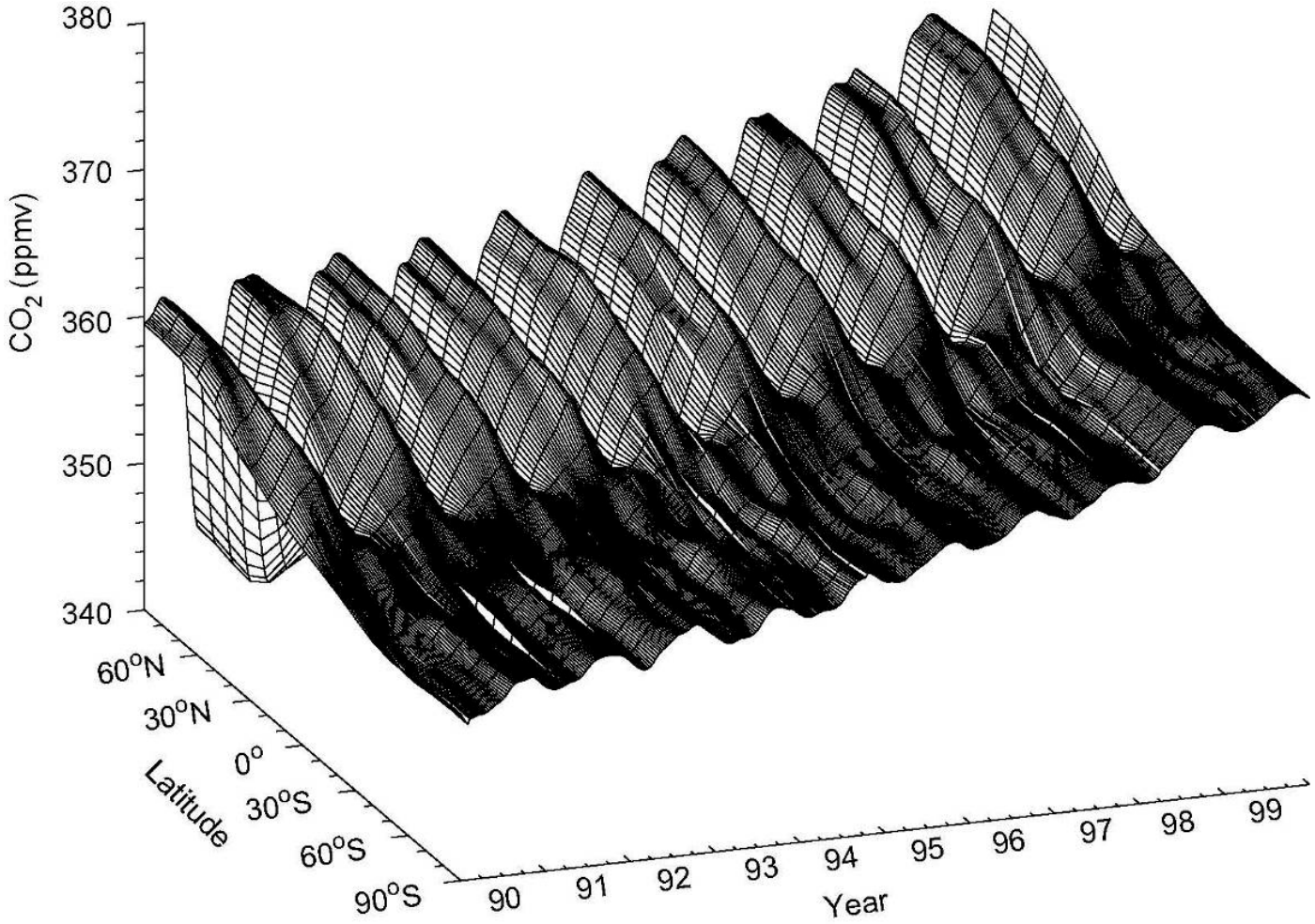
Global Change Biology

- Alteration of biogeochemical cycles - Carbon



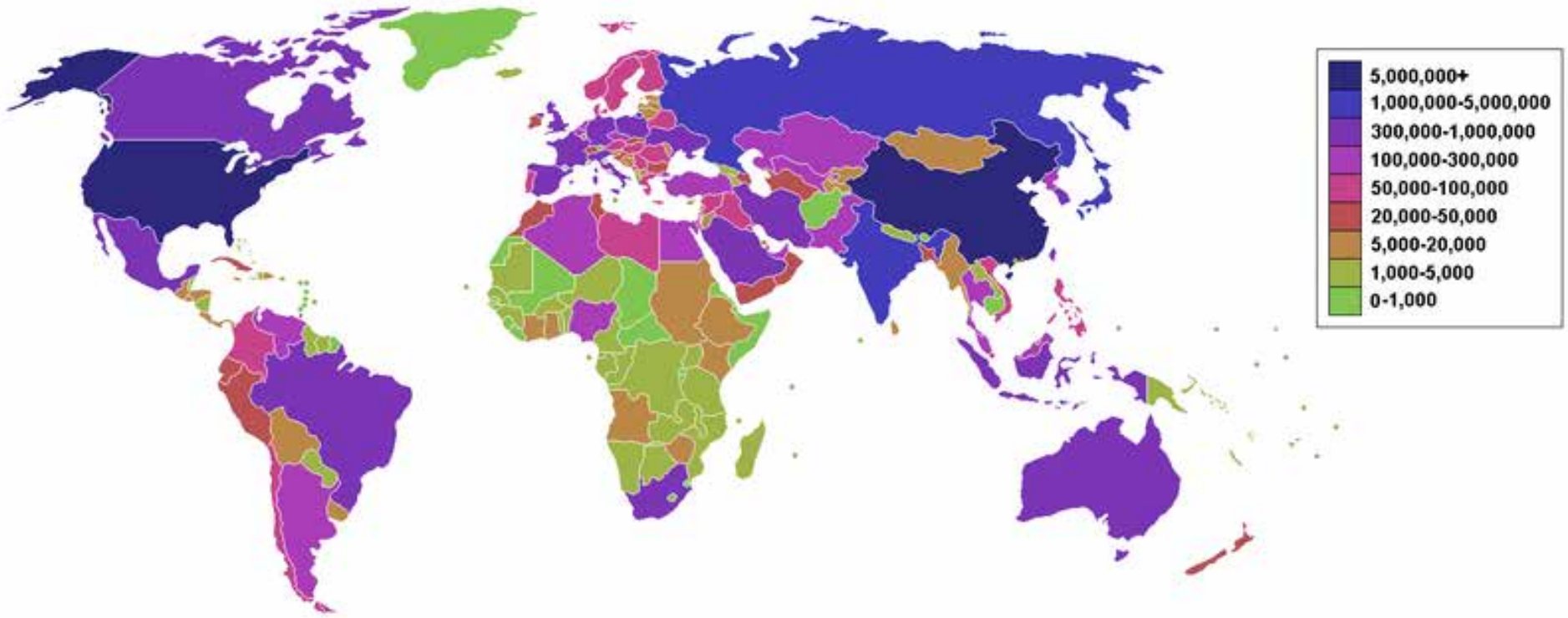
Global Change Biology

- Terrestrial C metabolism: The “breathing” of Earth



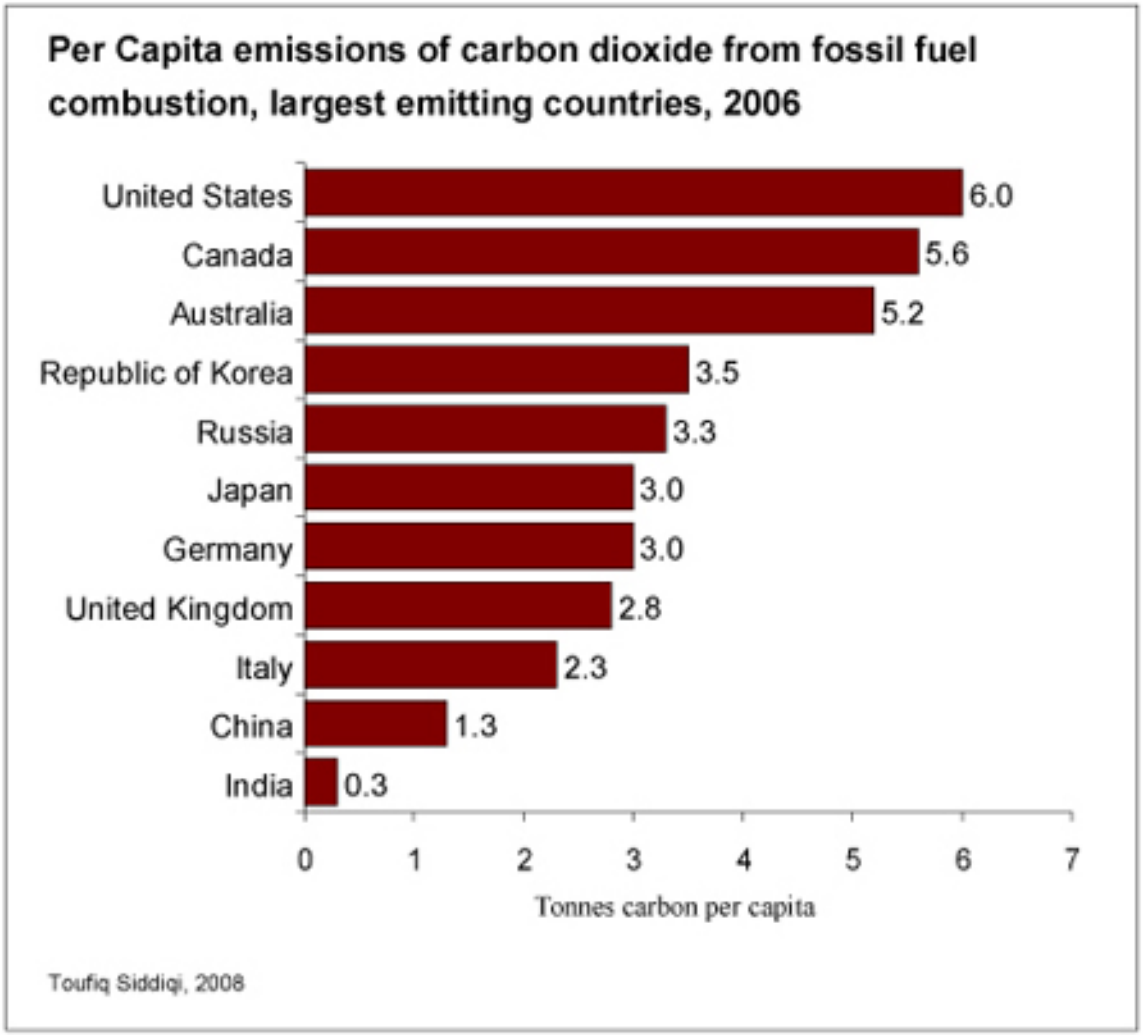
Global Change Biology

- World-wide CO_2 emissions



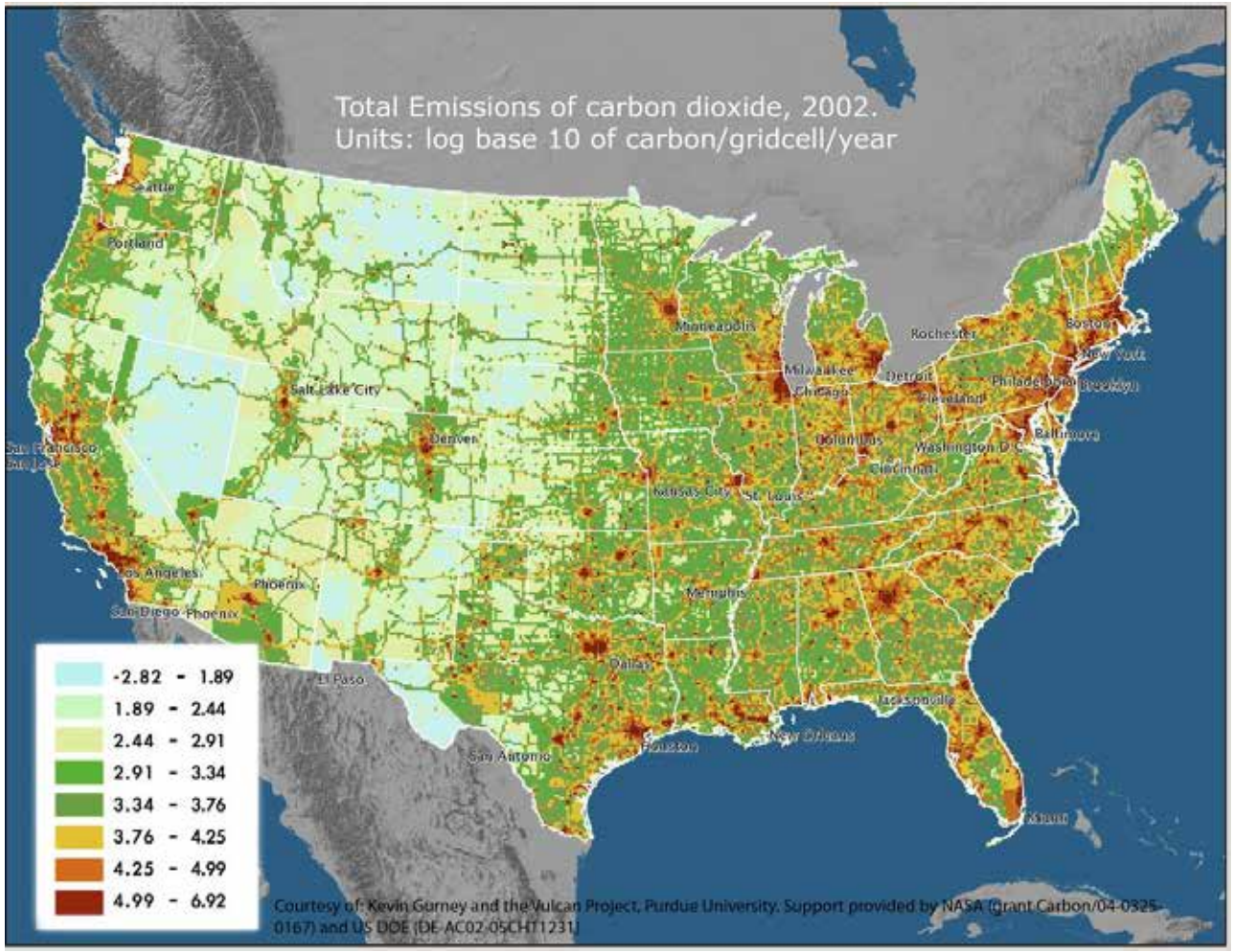
Global Change Biology

- World-wide CO_2 emissions



Global Change Biology

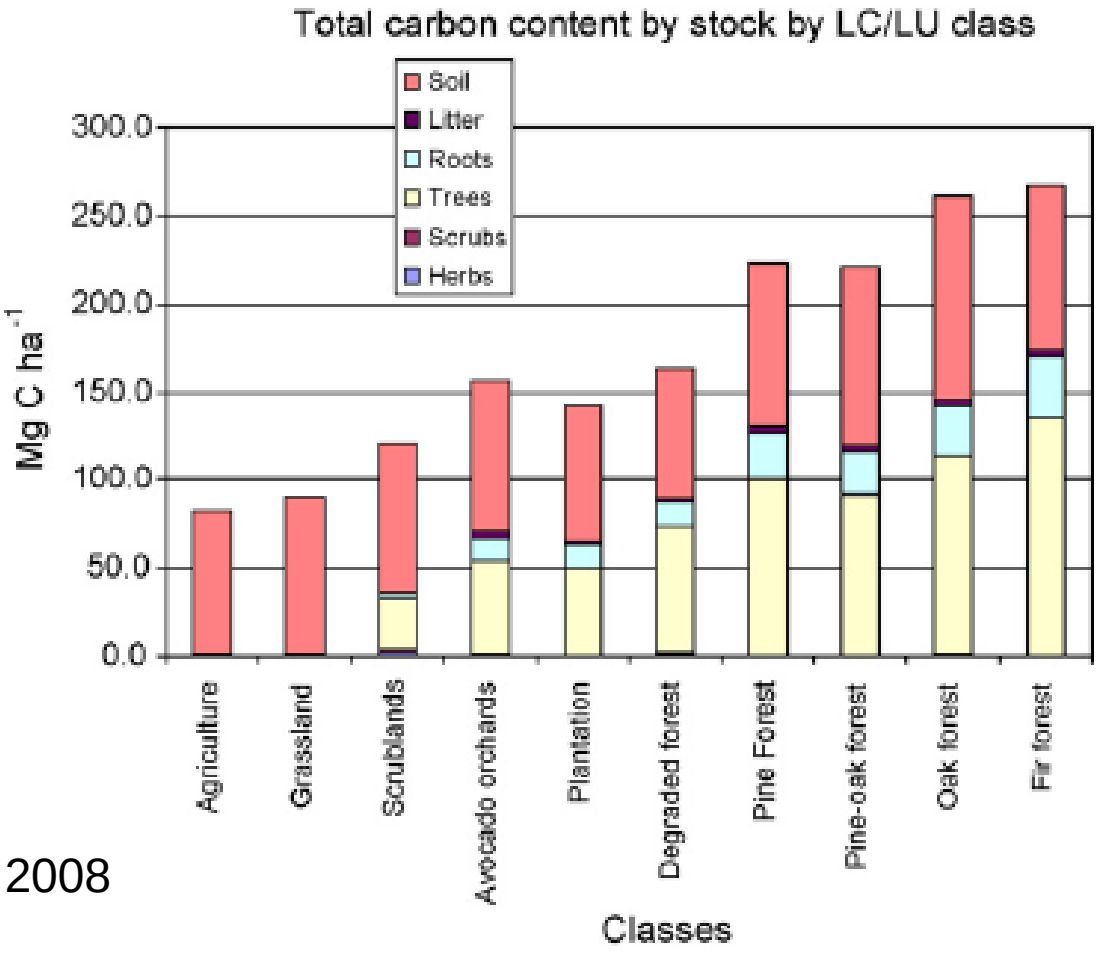
- Human CO2 “footprint” in the U.S.



The Vulcan Project

Global Change Biology

- Effect of land use change on ecosystem C stock

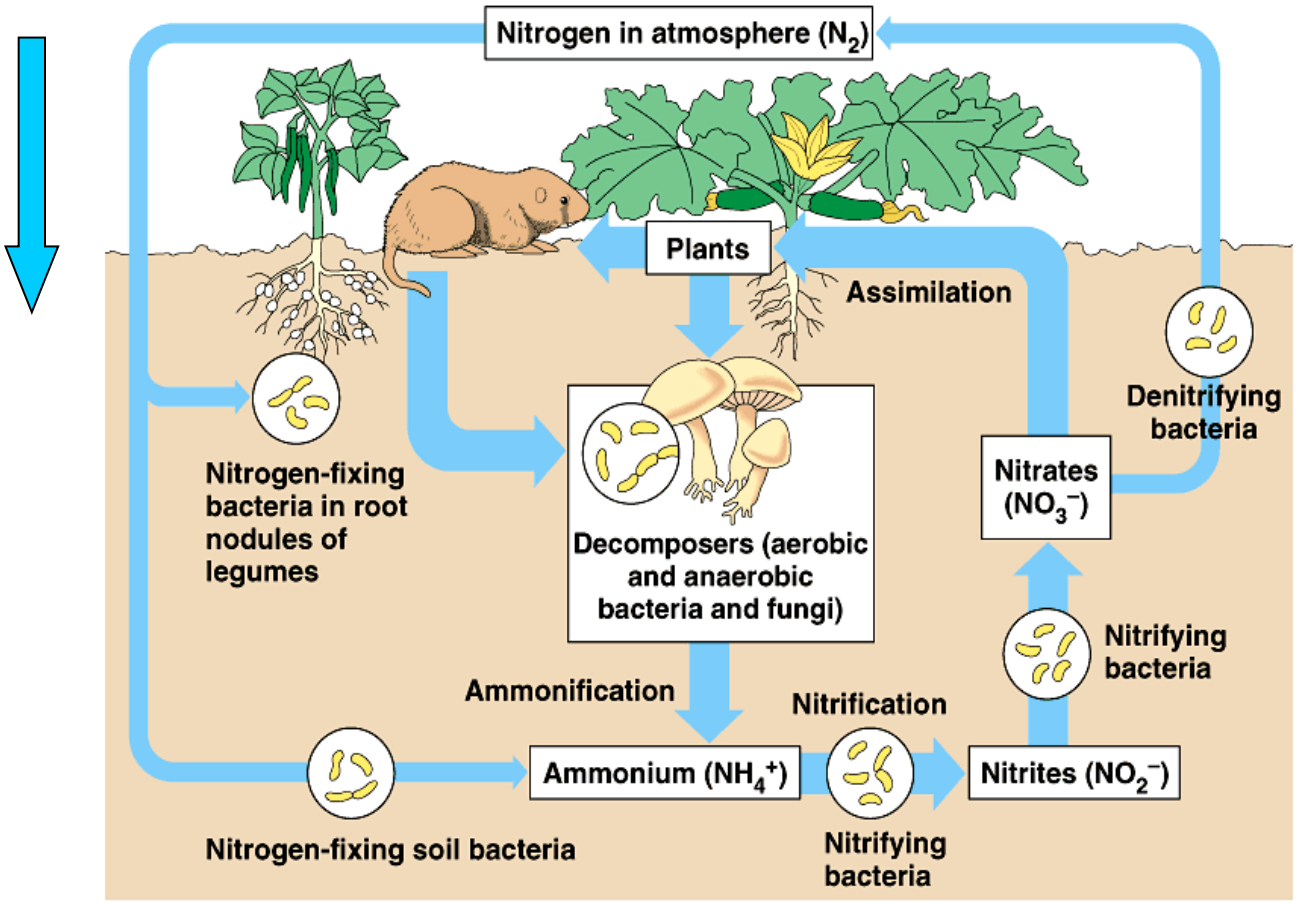


Ordóñez et al. 2008

Global Change Biology

- Alteration of biogeochemical cycles - Nitrogen

N Deposition



Global Change Biology

- Alteration of biogeochemical cycles - Nitrogen

N fixation

← Natural →

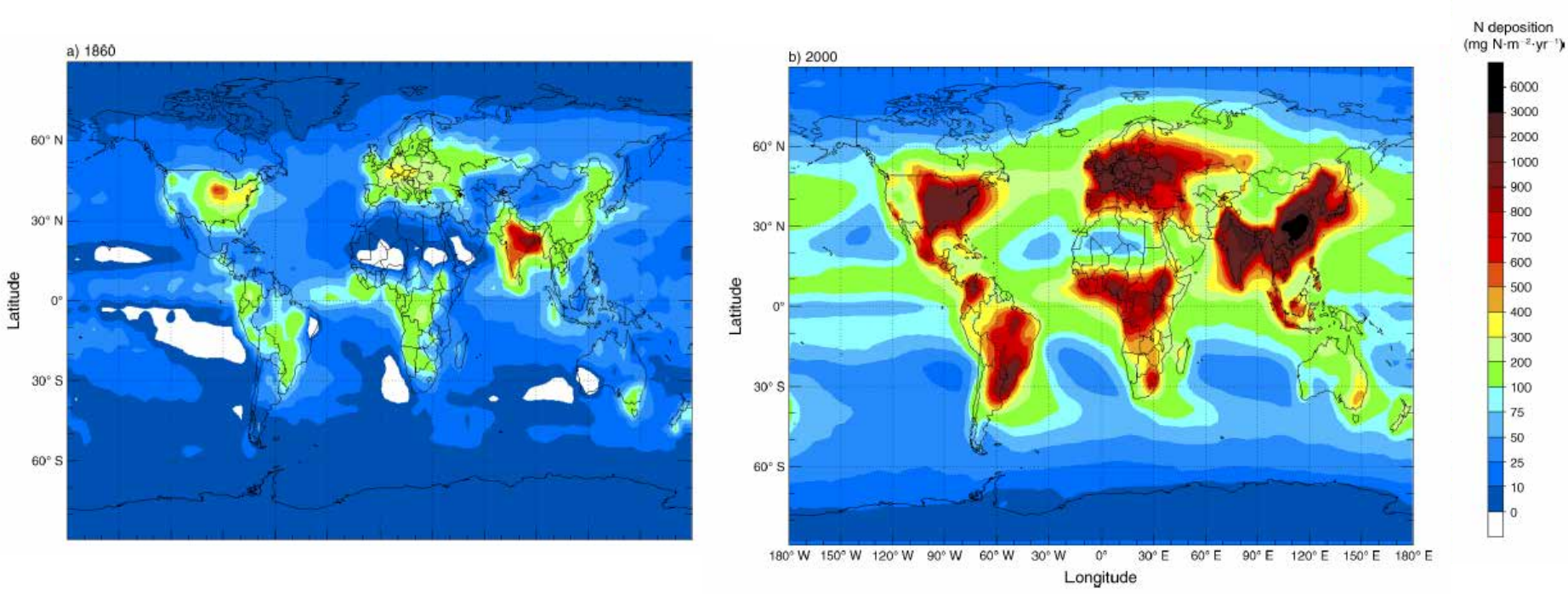
N deposition

vs.

← Anthropogenic →

Global Change Biology

- Alteration of biogeochemical cycles - Nitrogen



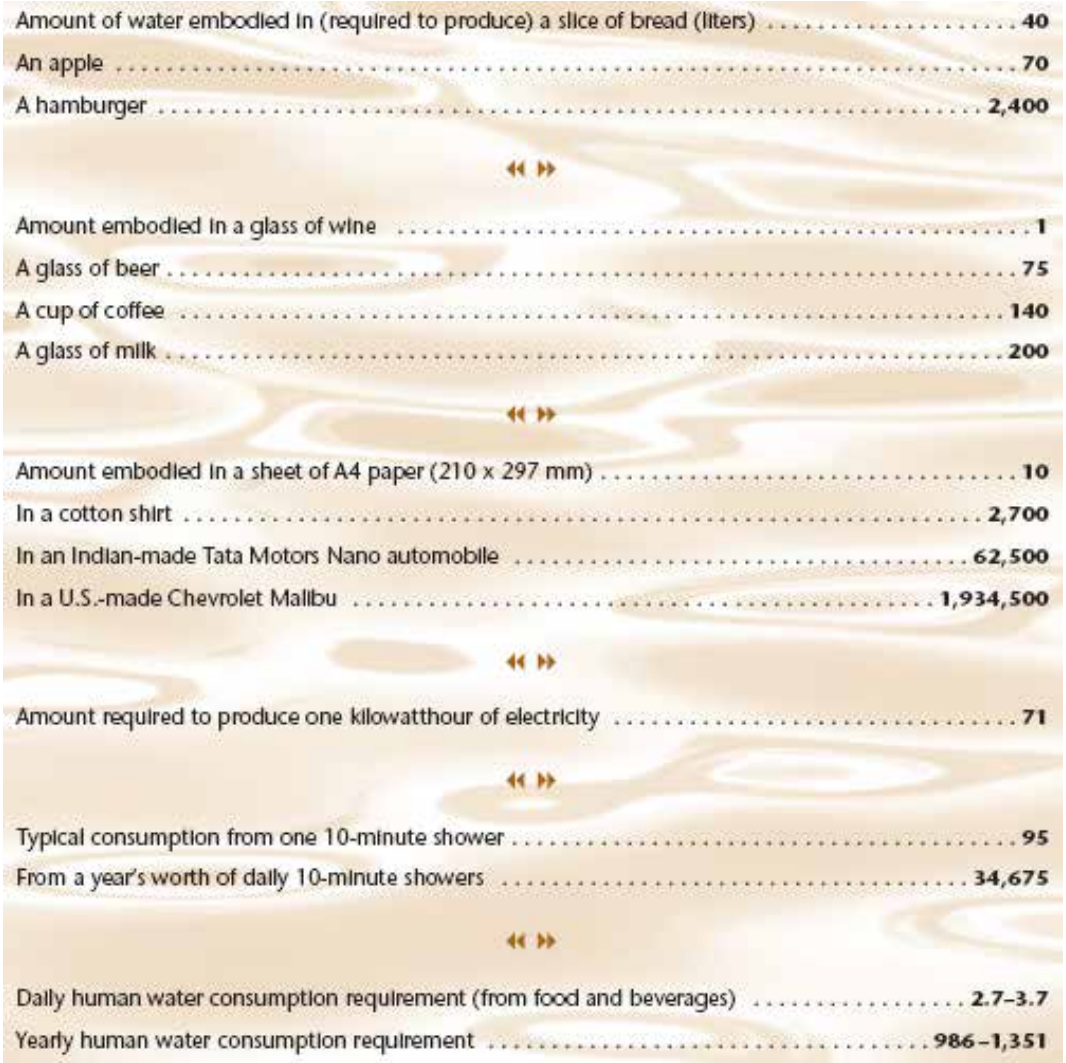
Bobbink et al. (2010)

Global Change Biology

- Alteration of biogeochemical cycles - Water

Global Change Biology

- Alteration of biogeochemical cycles - Water



Amount of water embodied in (required to produce) a slice of bread (liters)	40
An apple	70
A hamburger	2,400
Amount embodied in a glass of wine	1
A glass of beer	75
A cup of coffee	140
A glass of milk	200
Amount embodied in a sheet of A4 paper (210 x 297 mm)	10
In a cotton shirt	2,700
In an Indian-made Tata Motors Nano automobile	62,500
In a U.S.-made Chevrolet Malibu	1,934,500
Amount required to produce one kilowatthour of electricity	71
Typical consumption from one 10-minute shower	95
From a year's worth of daily 10-minute showers	34,675
Daily human water consumption requirement (from food and beverages)	2.7–3.7
Yearly human water consumption requirement	986–1,351

World Watch (April 2008)

Global Change Biology

- Alteration of biodiversity - Extinctions

from left to right

www.oahunaturetours.com

Kauai O'O Extinct, Kauai Akialoa Extinct, O'u Extinct,
Kauai Nukupu'u Extinct, Puaiohi less then 200 remain, Kamao Extinct

Global Change Biology

- Alteration of biodiversity – Additions (invasions)

Hawaii

Psidium cattleianum

Pennisetum setaceum

***Puccinia* rust**

Global Change Biology

- A human dominated planet (Vitousek et al. 1997)
  - "*The global consequences of human activity are not something to face in the future…they are with us now*."
  - "*The rates, scales, kinds, and combinations of changes occurring now are fundamentally different from those at any other time in history*…"
  - "*In a very real sense, the world is in our hands – and how we handle it will determine its composition and dynamics, and our fate*."

Global Change Biology

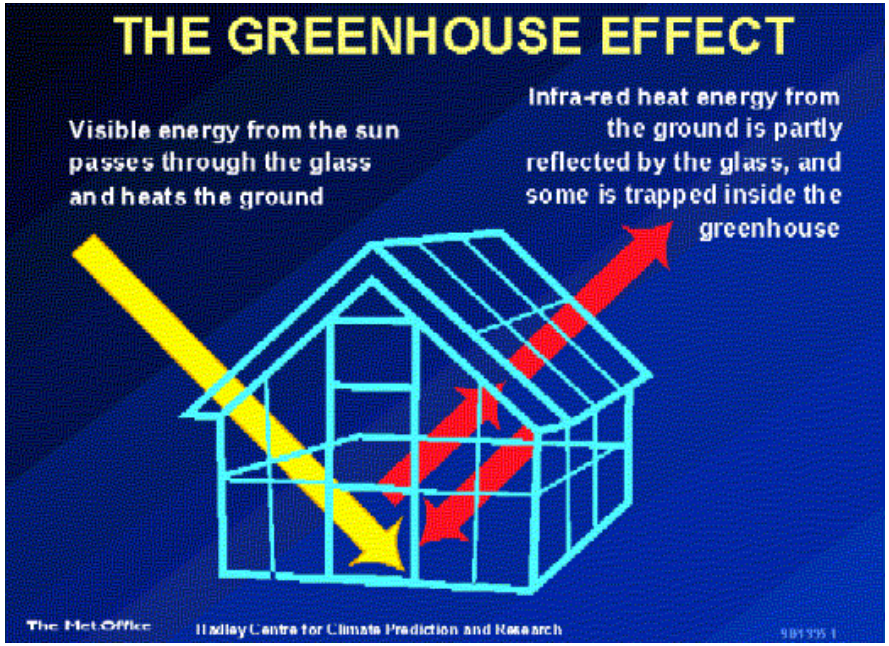
- A human dominated planet – What can we do?
  1. **Reduce** the rate of alterations to the Earth system
     - Slow human population growth & consumption
     - Use resources as efficiently as possible (sustainability)
  2. **Gain a better understanding** of the Earth system and how it is impacted by global change
     - Rigorous scientific study
     - Include human dimensions (social, economic and cultural)
  3. **Be responsible** for managing Earth now & for future generations
     - Active management of populations, species, and ecosystems for goods and services

Global Climate Change

- Is the global climate changing and, if so, is it the result of human activities?
  - Only need to believe 2 things
    - 1) Atmospheric constituents (i.e., greenhouse gases) trap outgoing longwave radiation, thereby warming the atmosphere
    - 2) Human activities are increasing the concentrations of greenhouse gases in the atmosphere
  - There is no argument about # 1 or 2
  - The questions we should be asking are:
    - How much will the climate change?
    - What will the impacts of that change be for the goods and services that ecosystems provide humankind?

Global Climate Change

- Greenhouse Effect



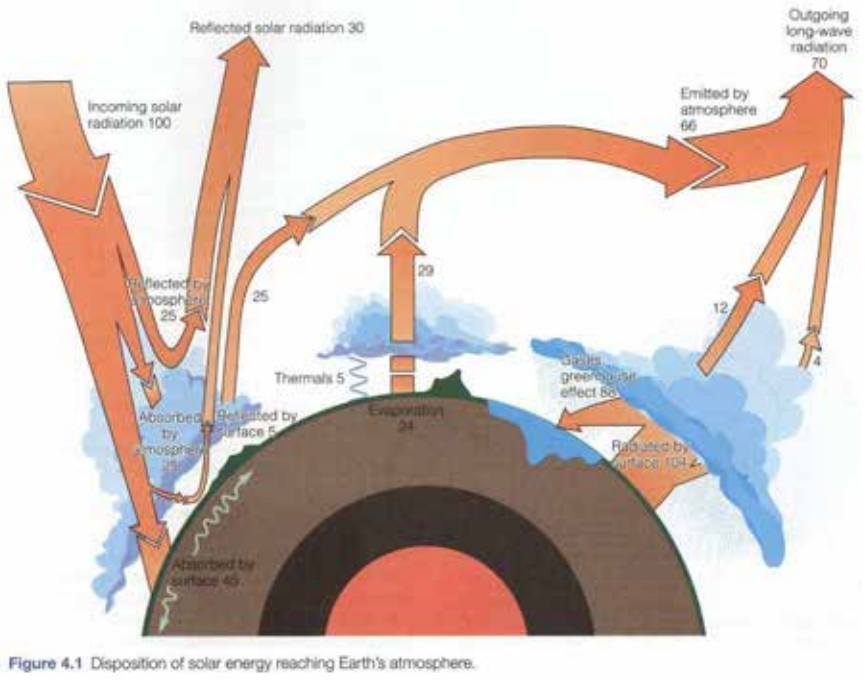
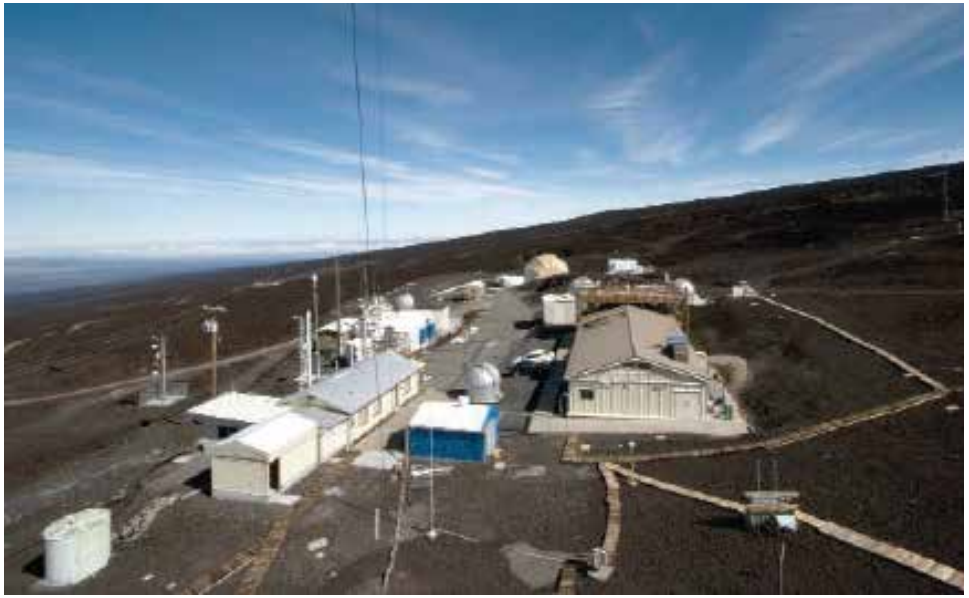
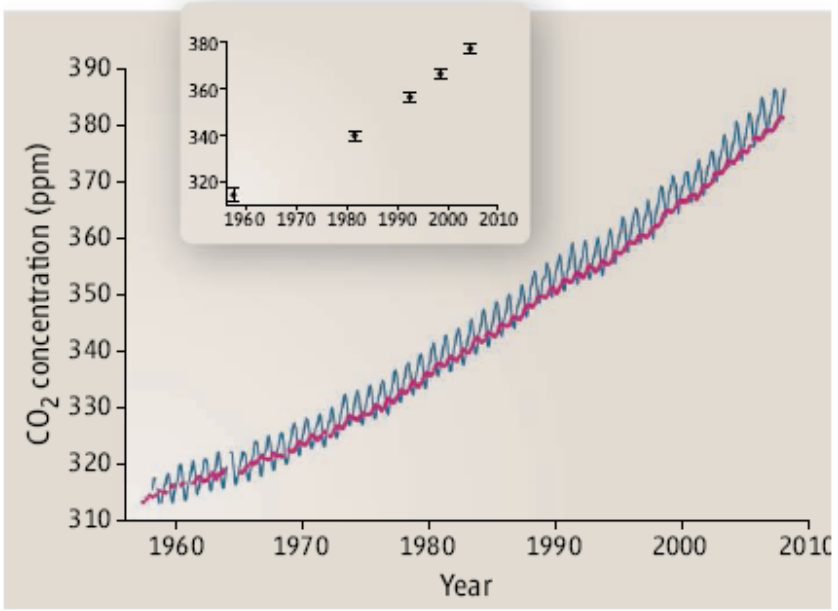


Figure 4.1 Disposition of solar energy reaching Earth's atmosphere.

Global Climate Change

- Mauna Loa Observatory



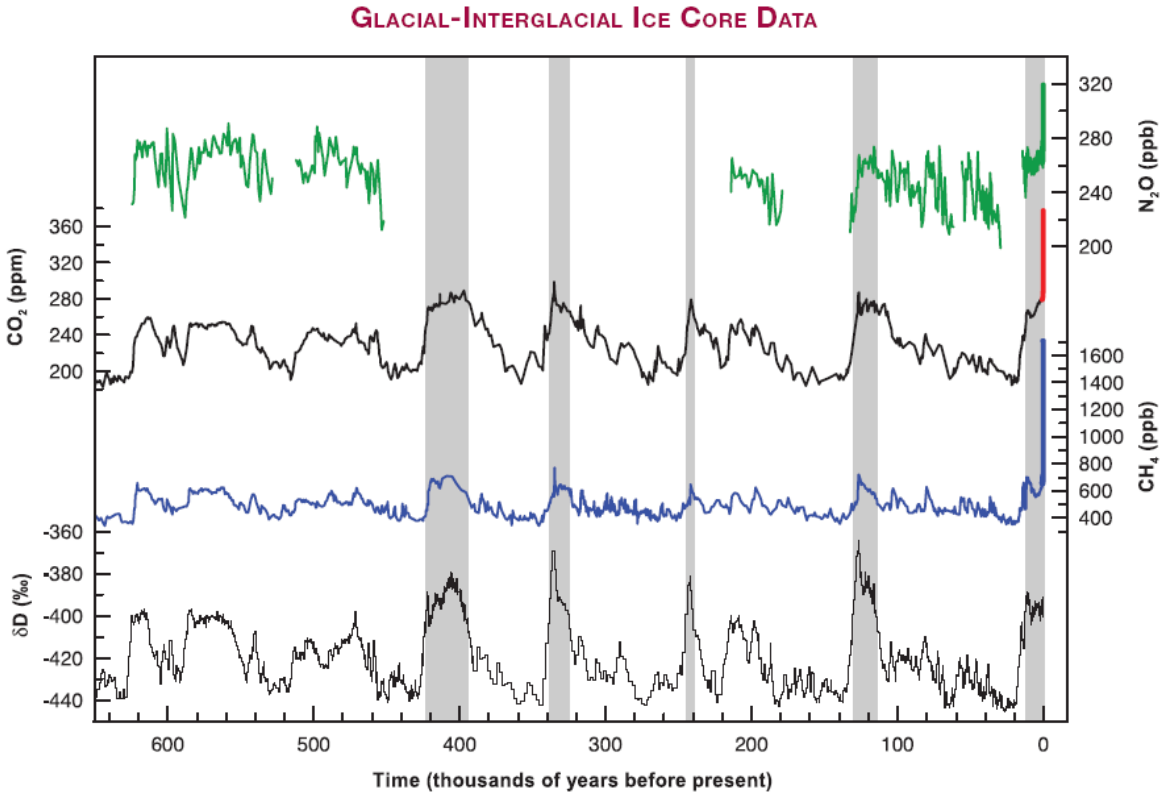


Keeling 2008

Global Climate Change

- How do we know that climate is changing now, and that it is a result of human activities?

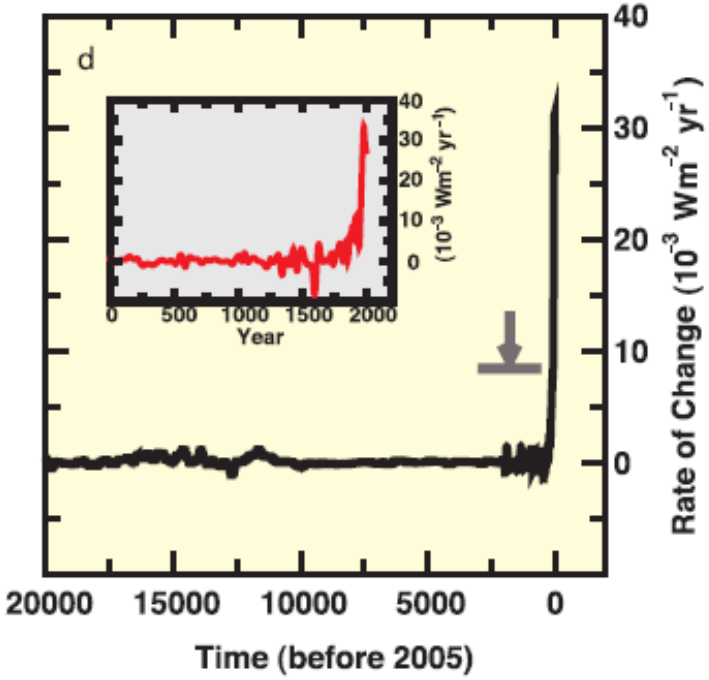
- Ice cores
  - Strong correlation between greenhouse gas conc. and temp.
  - Higher conc. of CO_2, CH_4, and N_2O than anytime in the past 650,000 years
  - Biosphere has taken up ~50% of CO_2 emissions

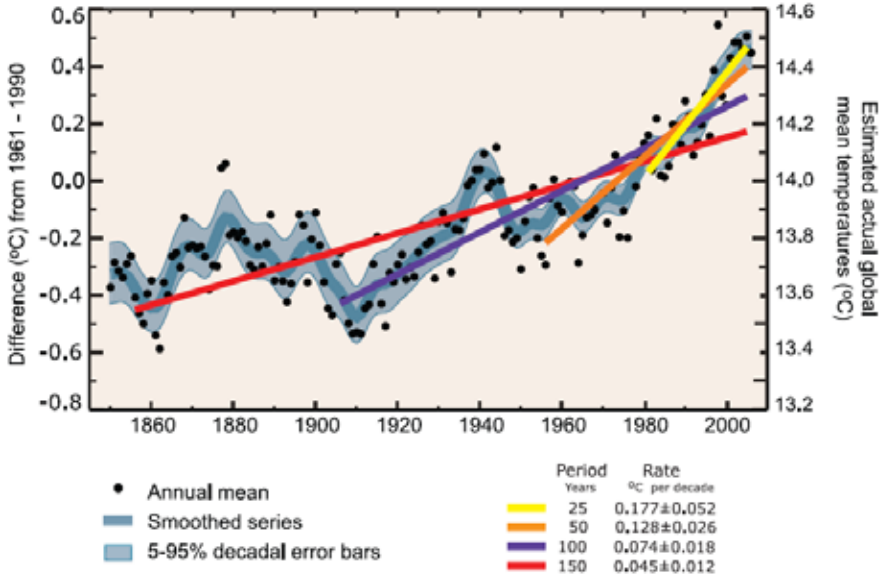


IPCC 2007

Global Climate Change

- Climate has always been variable in the past, so why should we care if it is changing now?
  - Rate of change far exceeds anytime in the past
    - Prior to 1750, CO_2 increased by 20 ppm over 8,000 years
    - Since 1750, CO_2 has increased by >100 ppm





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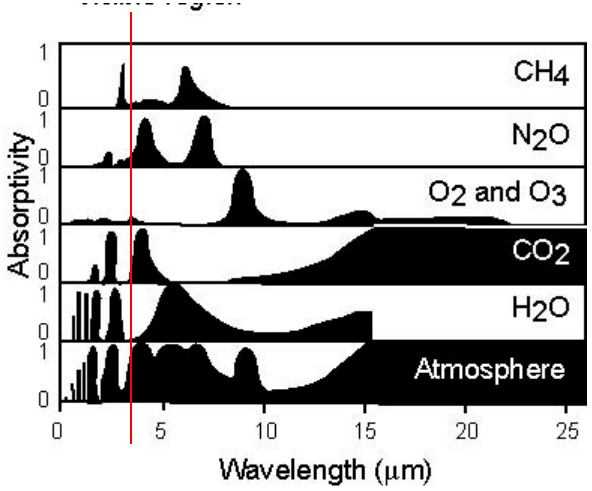
Global Climate Change

- Major greenhouse gases occur naturally, but have increased in past 250 yrs from human activities
  - CO_2
    - fossil fuels burning (2/3); land use/land cover change (1/3)
  - CH_4
    - Ruminant domestication (37%); reservoirs (>20%); landfills & waste treatment (20%); biomass burning (12%); ag.; fossil fuels
  - N_2O
    - animal waste products (~65%); industry and fossil fuels (~20%); fertilizers & agriculture
  - Other greenhouse gases are entirely due to human activities
    - CFCs, HCFCs, etc. from industrial activities

Global Climate Change

- Concentration vs. Warming potential



Industrial Designation or Common Name (years)	Chemical Formula	Lifetime (years)	Radiative Efficiency (W m^{-2} ppb^{-1})	Global Warming Potential for Given Time Horizon			
				SAR‡ (100-yr)	20-yr	100-yr	500-yr
Carbon dioxide	CO_2	See below[a]	[b]1.4x10^{-5}	1	1	1	1
Methane[c]	CH_4	12[c]	3.7x10^{-4}	21	72	25	7.6
Nitrous oxide	N_2O	114	3.03x10^{-3}	310	289	298	153
Substances controlled by the Montreal Protocol							
CFC-11	CCl_3F	45	0.25	3,800	6,730	4,750	1,620
CFC-12	CCl_2F_2	100	0.32	8,100	11,000	10,900	5,200
CFC-13	$CClF_3$	640	0.25		10,800	14,400	16,400
CFC-113	CCl_2FCClF_2	85	0.3	4,800	6,540	6,130	2,700
CFC-114	$CClF_2CClF_2$	300	0.31		8,040	10,000	8,730
CFC-115	$CClF_2CF_3$	1,700	0.18		5,310	7,370	9,990
Halon-1301	$CBrF_3$	65	0.32	5,400	8,480	7,140	2,760
Halon-1211	$CBrClF_2$	16	0.3		4,750	1,890	575
Halon-2402	$CBrF_2CBrF_2$	20	0.33		3,680	1,640	503
Carbon tetrachloride	CCl_4	26	0.13	1,400	2,700	1,400	435
Methyl bromide	CH_3Br	0.7	0.01		17	5	1
Methyl chloroform	CH_3CCl_3	5	0.06		506	146	45
HCFC-22	$CHClF_2$	12	0.2	1,500	5,160	1,810	549
HCFC-123	$CHCl_2CF_3$	1.3	0.14	90	273	77	24
HCFC-124	$CHClFCF_3$	5.8	0.22	470	2,070	609	185
HCFC-141b	CH_3CCl_2F	9.3	0.14		2,250	725	220
HCFC-142b	CH_3CClF_2	17.9	0.2	1,800	5,490	2,310	705
HCFC-225ca	$CHCl_2CF_2CF_3$	1.9	0.2		429	122	37
HCFC-225cb	$CHClFCF_2CClF_2$	5.8	0.32		2,030	595	181

IPCC 2007

Global Climate Change

Table TS.6. *Projected global average surface warming and sea level rise at the end of the 21st century. {10.5, 10.6, Table 10.7}*

Case	Temperature Change (°C at 2090-2099 relative to 1980-1999) [a]		Sea Level Rise (m at 2090-2099 relative to 1980-1999)
	Best estimate	*Likely* range	Model-based range excluding future rapid dynamical changes in ice flow
Constant Year 2000 concentrations [b]	0.6	0.3 – 0.9	NA
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	4.0	2.4 – 6.4	0.26 – 0.59

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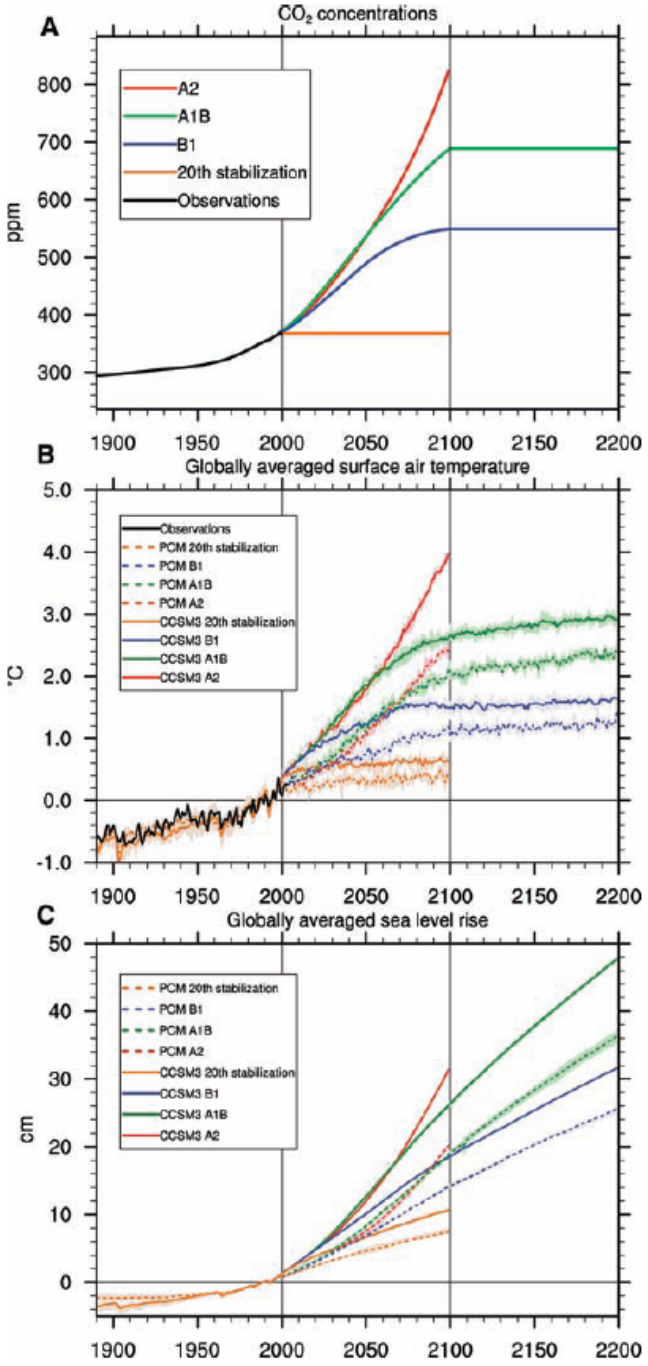
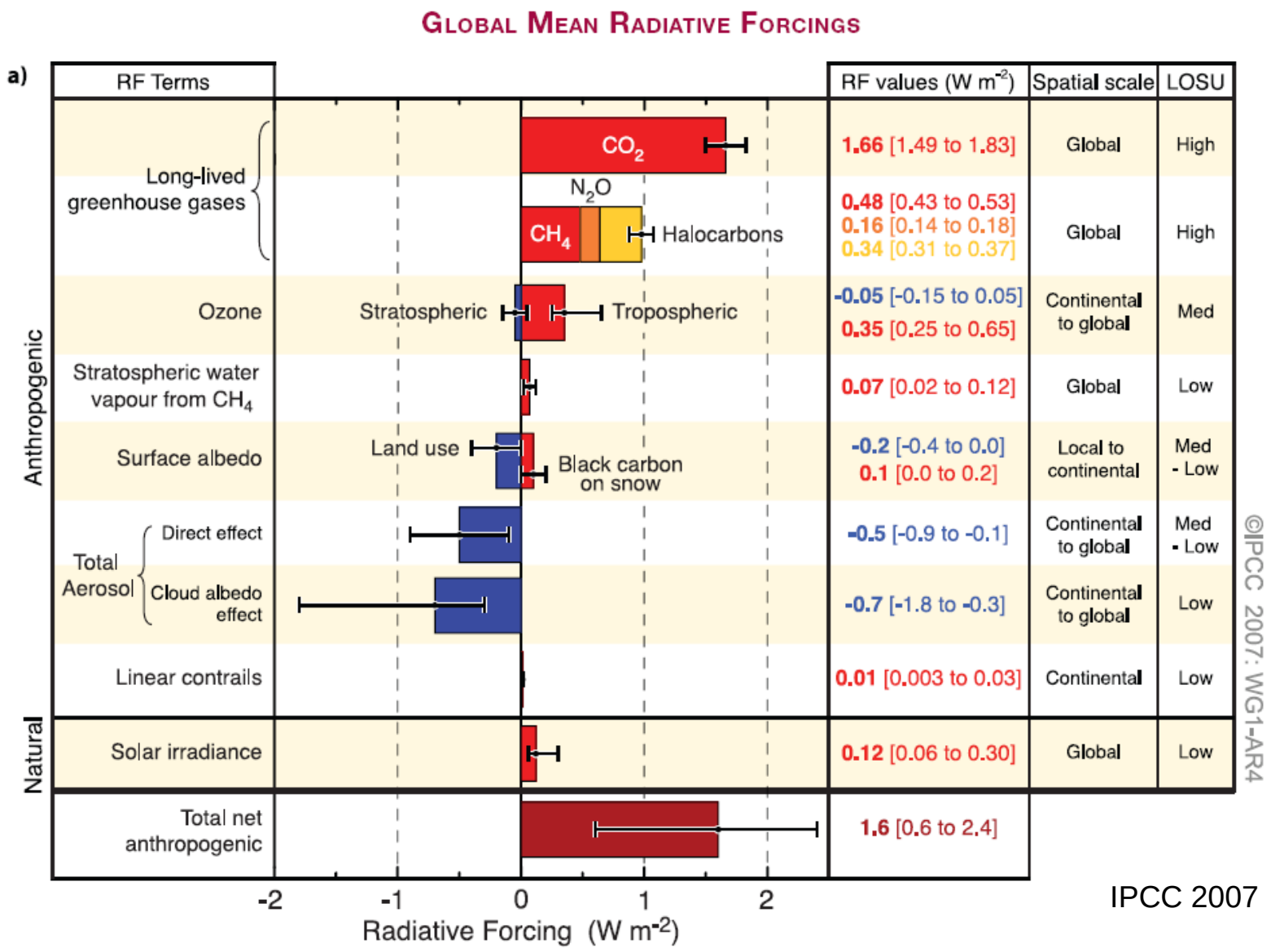
Global Climate Change

- Projected changes in CO_2, temperature, and sea level
  - low (B1), medium (A1B), and high (A2) increases in CO_2



Meehl et al. 2005

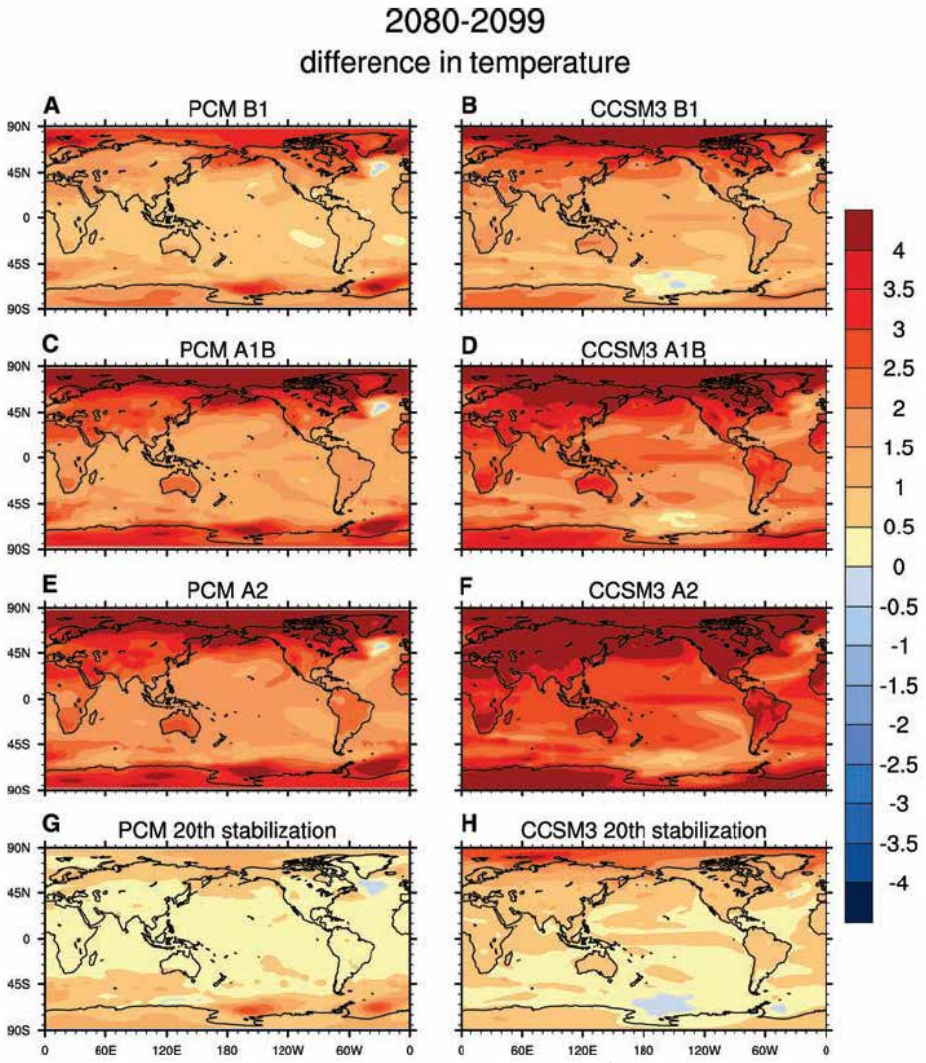
Global Climate Change



IPCC 2007

Global Climate Change

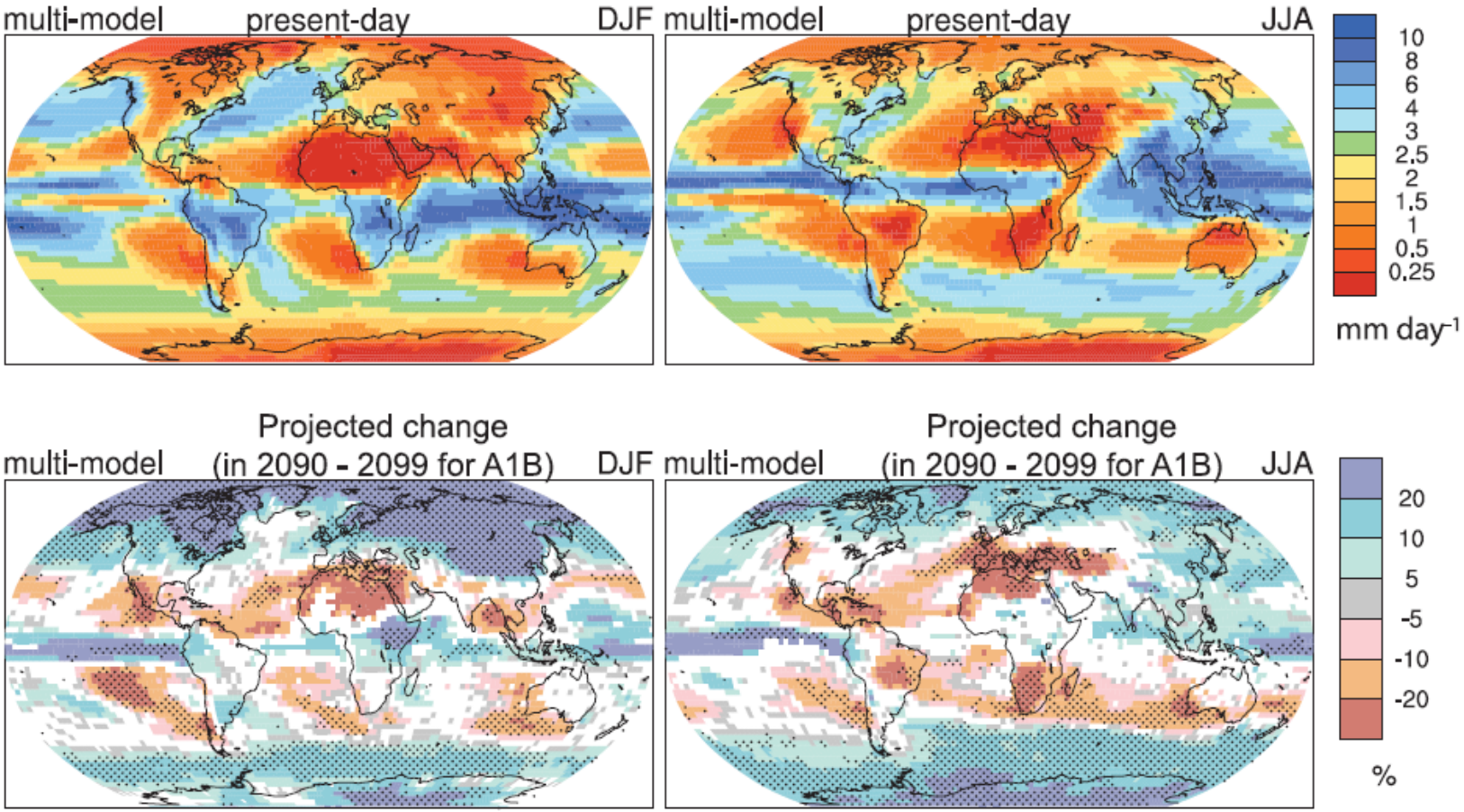
- Projected temperature change
  - Uneven distribution of temperature increase across the globe
- What's the big deal about a 2-5°C increase?
  - Difference between glacial & interglacial is ~5-8°C



Meehl et al. 2005

Global Climate Change

- Projected change in precipitation (mm day^{-1})



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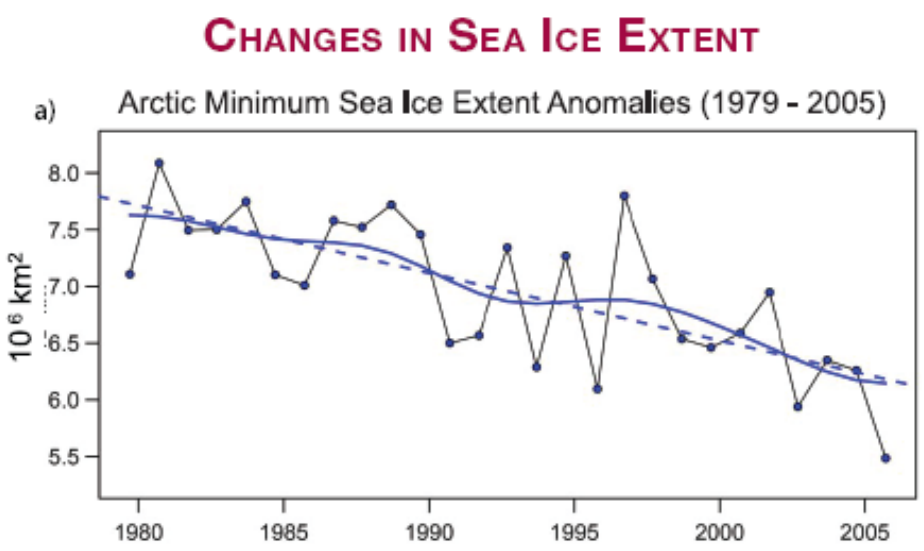
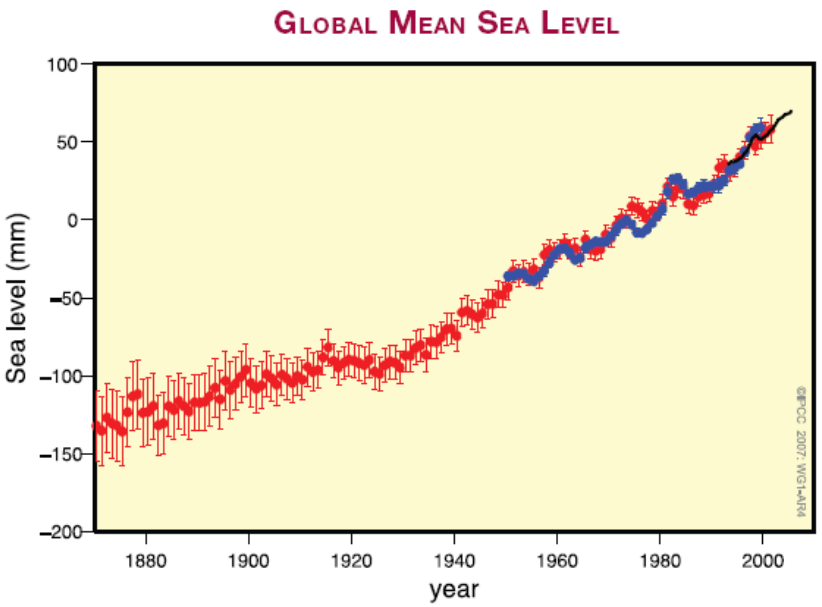
Global Climate Change

- Sea ice extent and sea level rise





IPCC 2007

Global Climate Change

- What can be done, or are we already doomed?
  - Cut back on consumption
    - US is ~5% of world's population and uses ~25% of resources
    - China? India?
  - Stop burning fossil fuels (CO_2 & CH_4)
    - Develop alternative energy sources (solar, wind, wave, bioenergy)
  - Reduce land use & land cover change (CO_2 & CH_4)
    - Rehabilitation of degraded lands; stop deforestation for agriculture
  - Reduce unnecessary biomass burning (CH_4, NO_x)
  - Reduce/eliminate fertilizer use and air pollution (N_2O, NO_x)
  - Reduce/eliminate use of CFCs & HCFCs
  - ***Become land stewards instead of land manipulators***