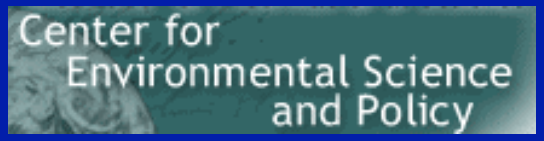
Global Environmental Change: Biophysical Processes of Urbanization

Karen C. Seto

Center for Environmental Science and Policy
&
Dept. of Geological and Environmental Sciences
Stanford University



Outline

- Global environmental change defined
- Examples of GECs
- Impact of urbanization on biophysical processes
  - Direct and indirect effects of urbanization
  - Urban growth and land-use change
  - Urban lifestyles and consumption patterns

What is Global Environmental Change?

- Earth is a dynamic system
- Global environmental change: part of Earth system functioning
  - e.g.: glacial/interglacial cycles of past 2 million years
- Current interest: human-caused global change ≥ natural change

Components of GEC

- Global changes: defined as those that alter well-mixed fluid envelopes of the Earth system (atmosphere & oceans)
- Consequences are global
- May occur in discrete sites but widespread enough to constitute global change

Examples of GECs

- Change in composition of atmosphere
- Climate change
- Decreased stratospheric ozone concentrations
- Increased ultraviolet input
- Land use change
- Loss of biological diversity
- Biological invasions
- Changes in atmospheric chemistry

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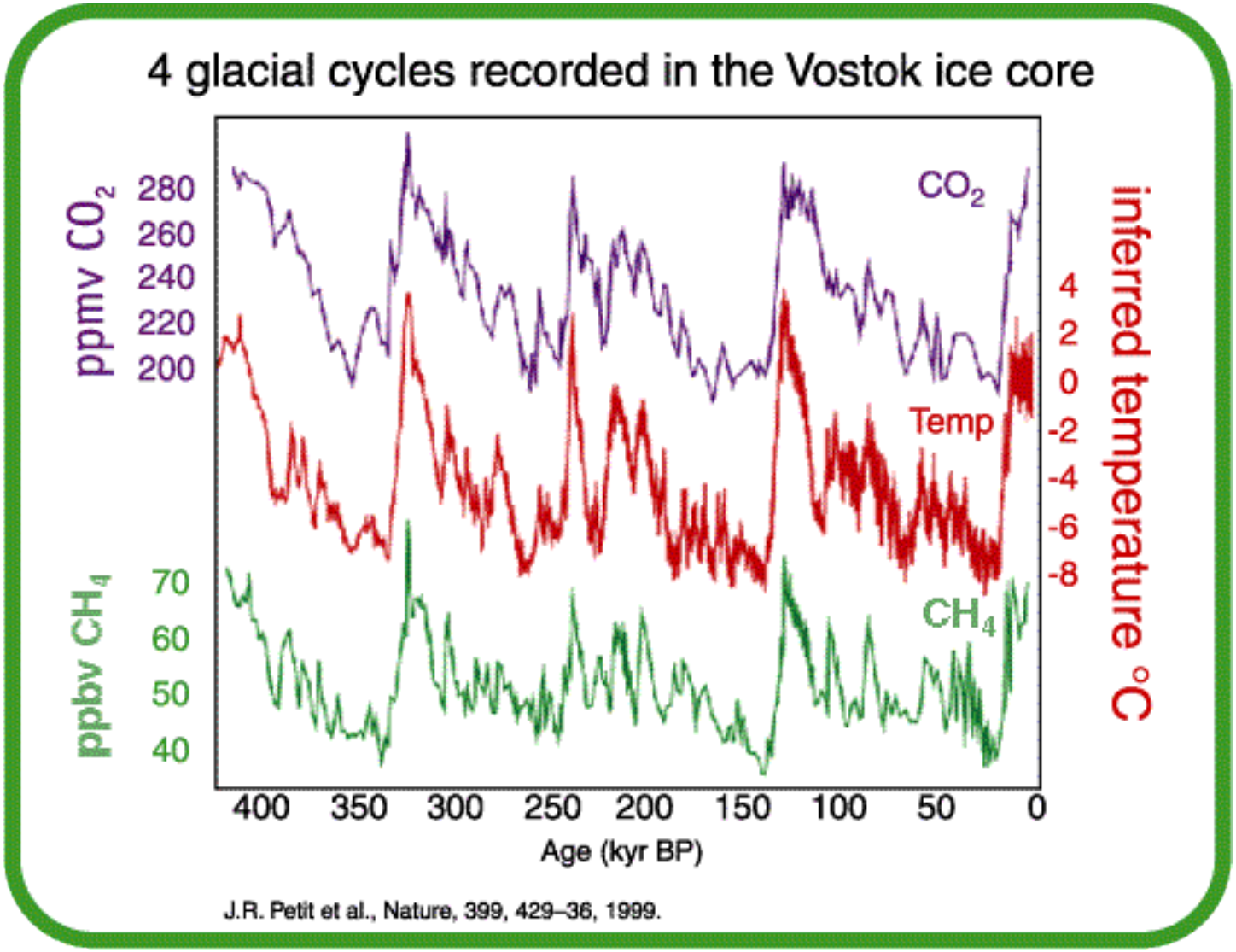
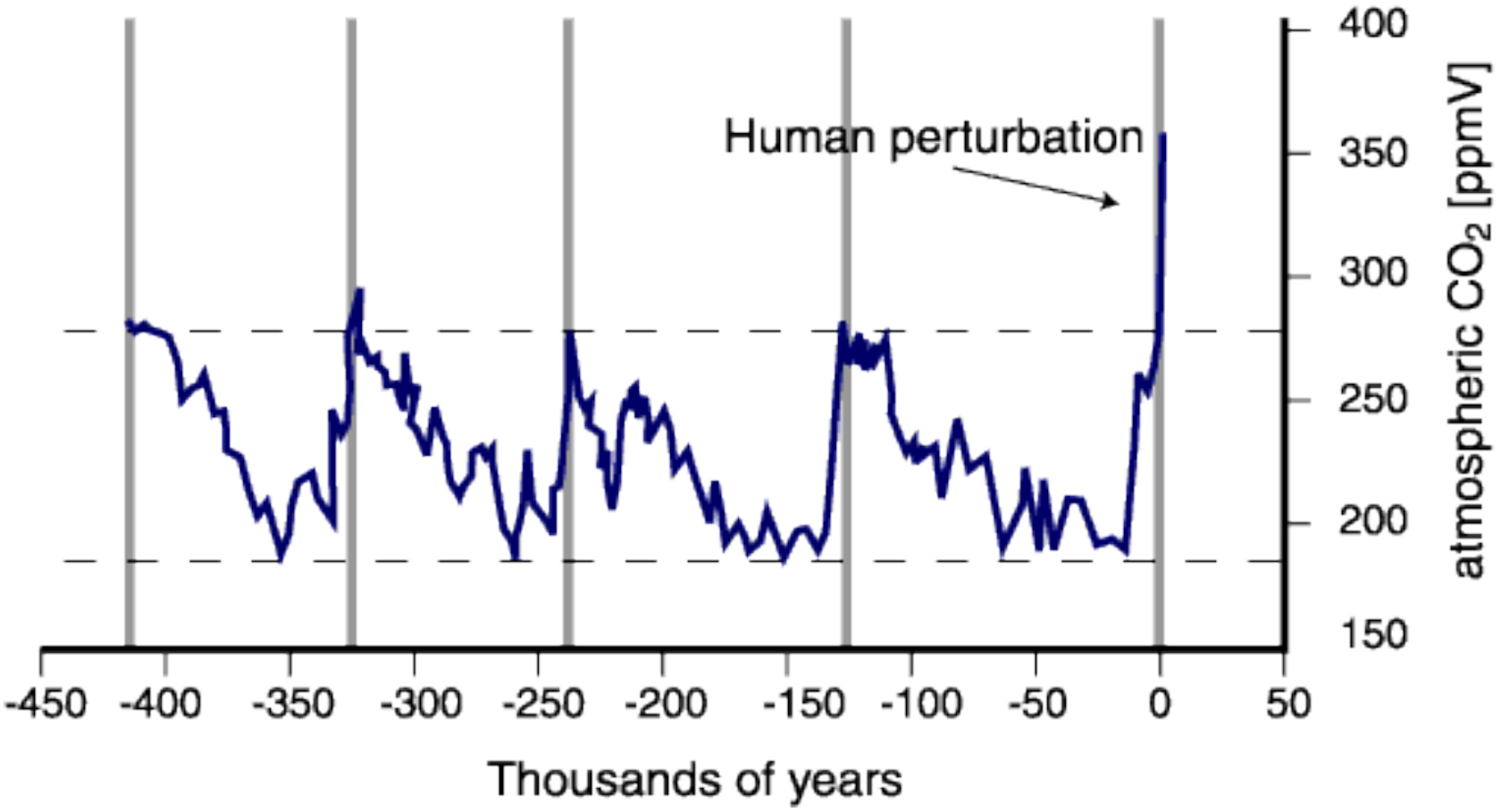
Change in the Composition of the Atmosphere

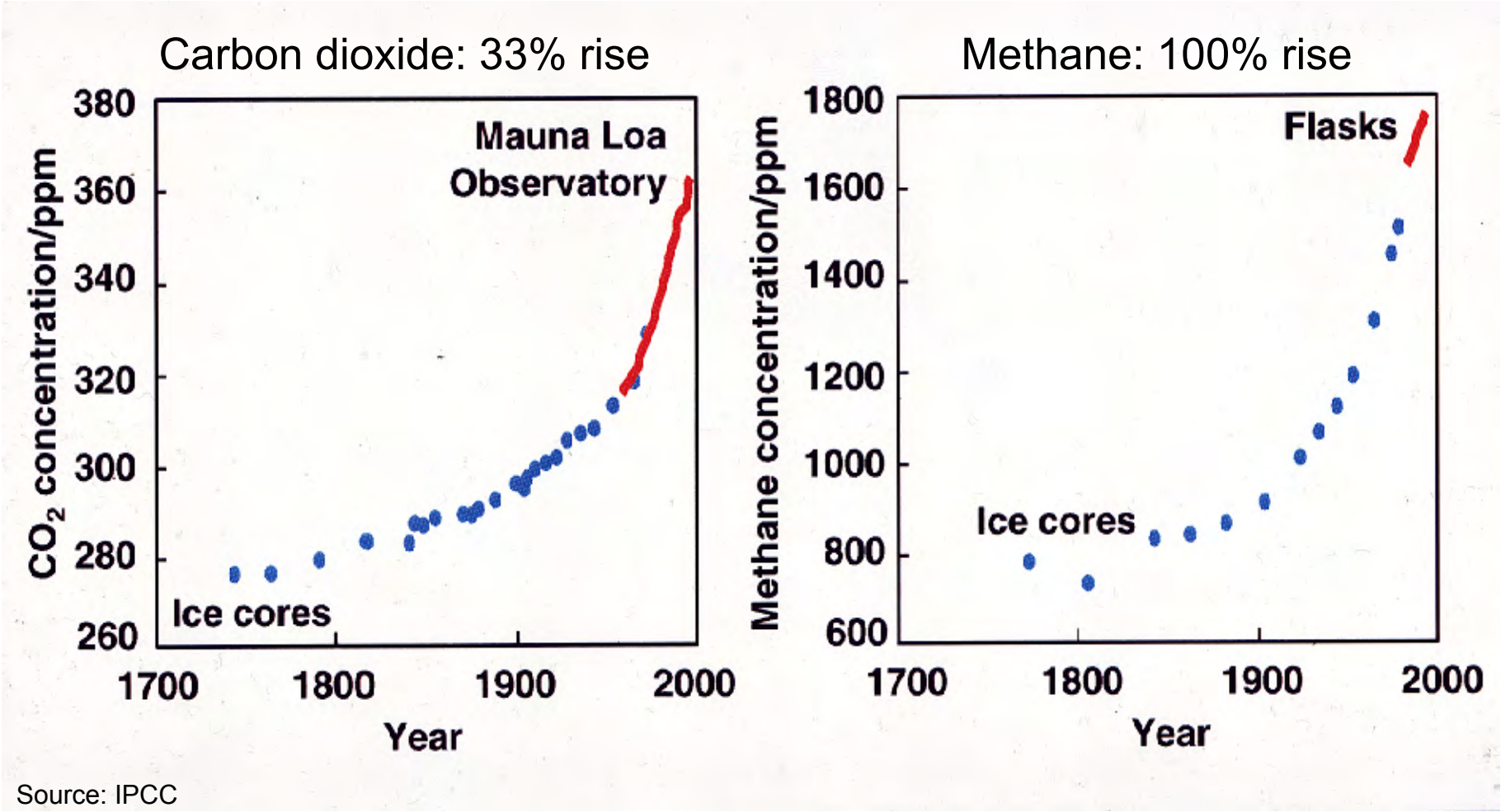
- Increases in global concentrations of carbon dioxide well documented
- Current increases in carbon dioxide caused by
  - 1) fossil fuel combustion
  - 2) changes in land use


4 glacial cycles recorded in the Vostok ice core
ppmv CO_2
280
260
240
220
200
CO_2
Temp
CH_4
ppbv CH_4
70
60
50
40
inferred temperature °C
4
2
0
-2
-4
-6
-8
400
350
300
250
200
150
100
50
0
Age (kyr BP)
J.R. Petit et al., Nature, 399, 429–36, 1999.



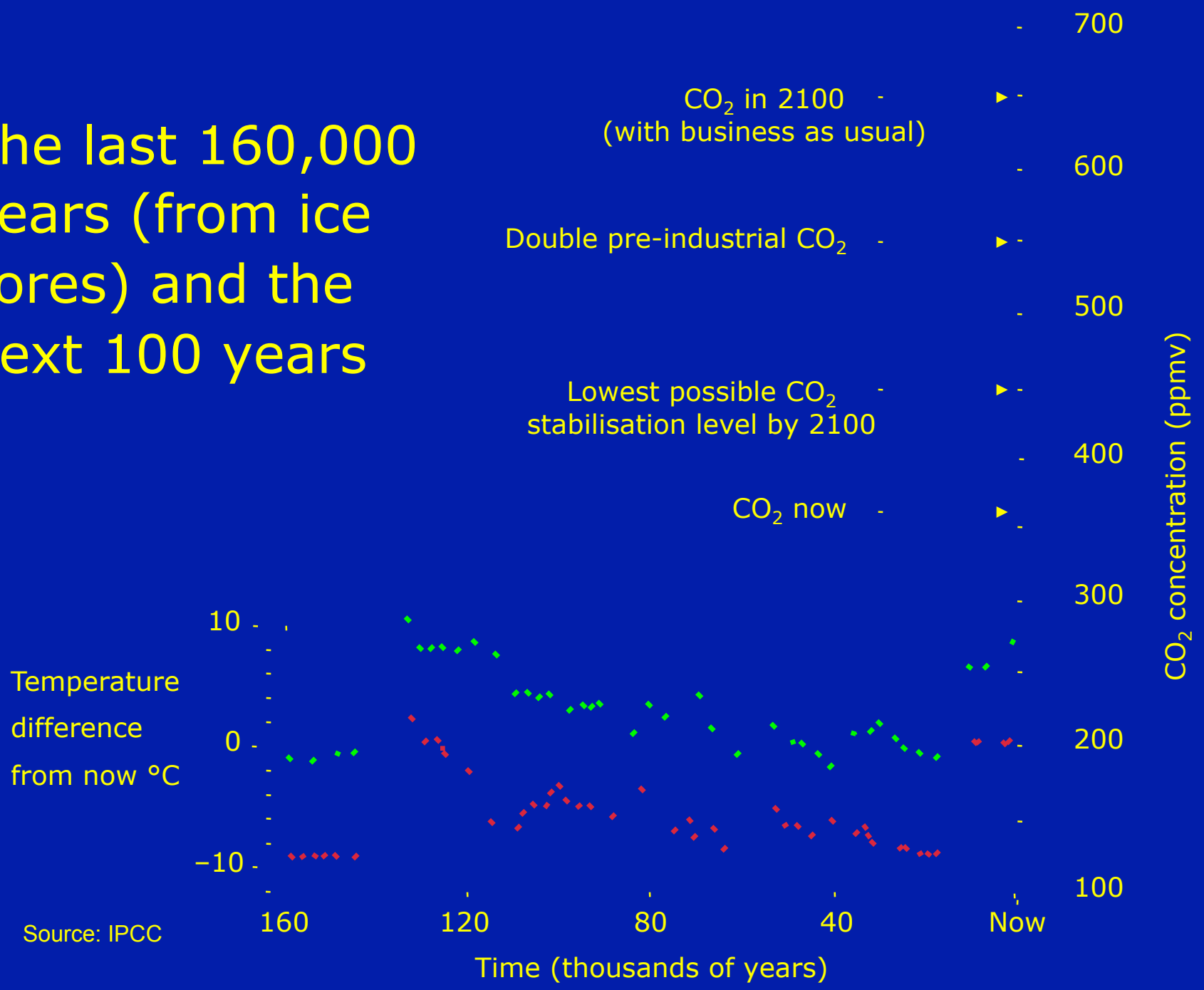
Sources: Petit et al. (1999) Nature 399, 429-436 and National Oceanic and Atmospheric Administration (NOAA), USA

Concentrations of CO_2 and CH_4 have risen significantly since pre-industrial times



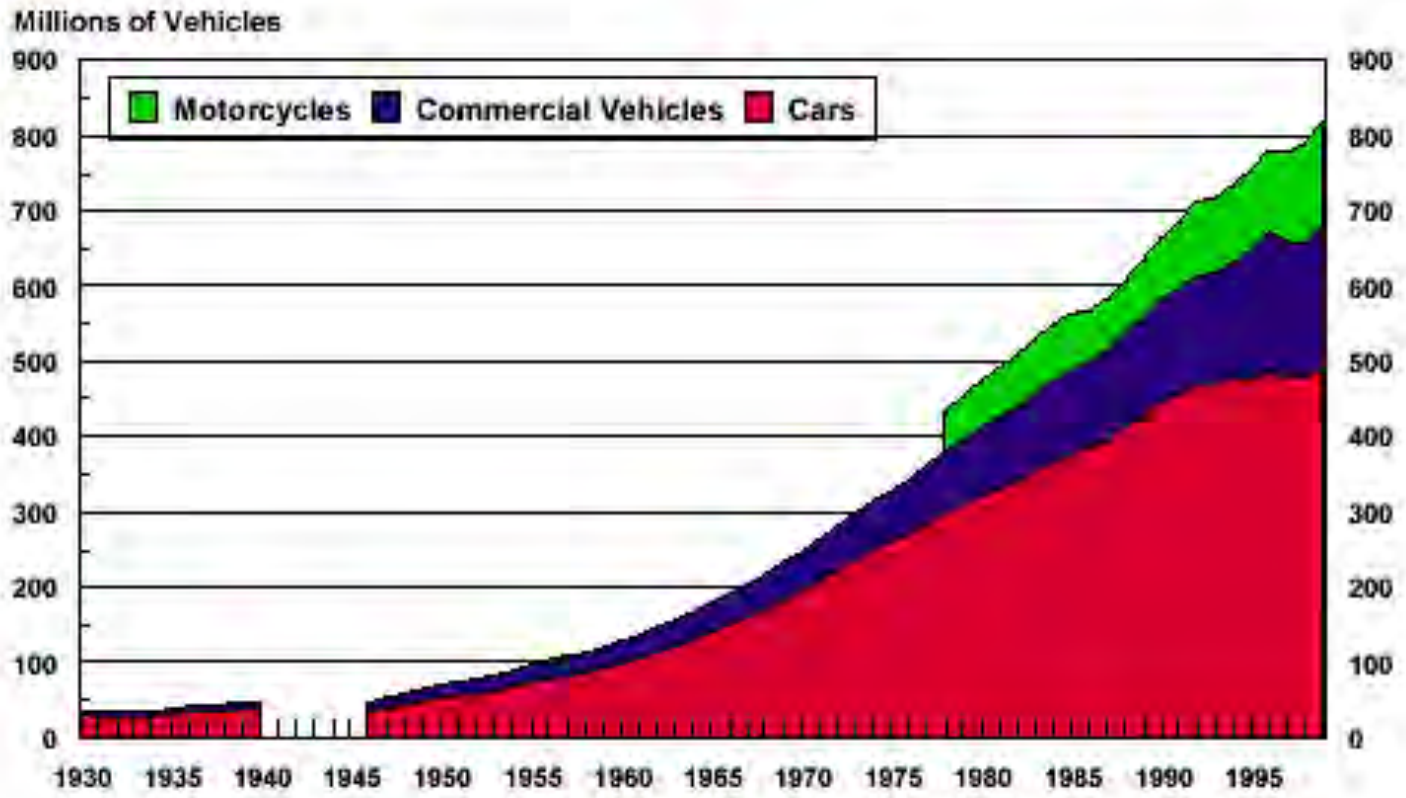
Source: IPCC

The last 160,000 years (from ice cores) and the next 100 years



Source: IPCC

Global Trend In Motor Vehicles

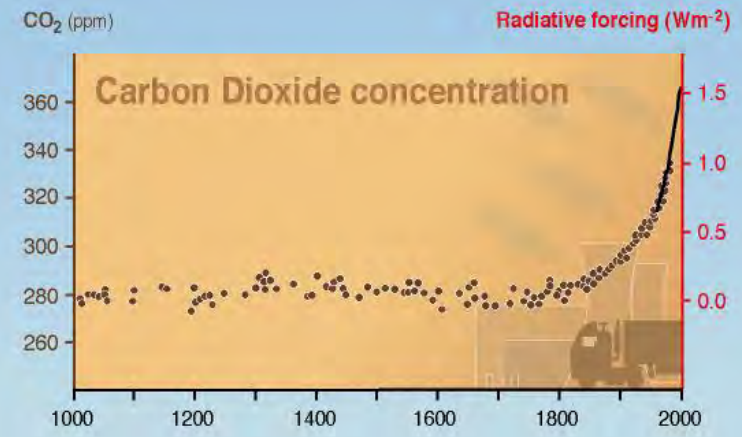


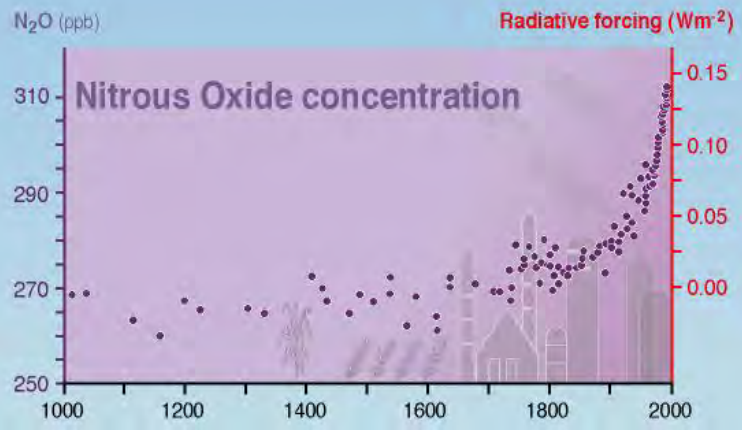
Source: Walsh 2003

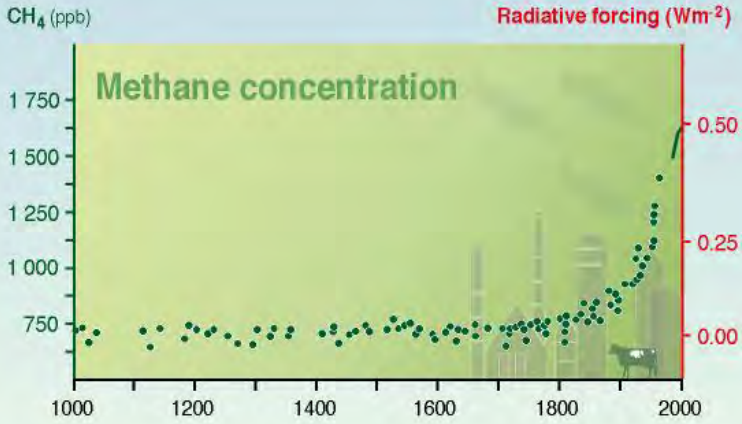
Not only an increase in CO_2…

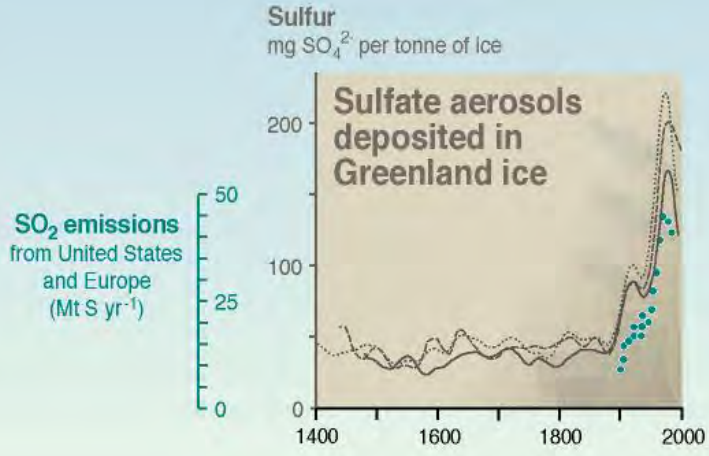
- But also other greenhouse gases
  - Transparent to incoming solar radiation
  - Absorbs outgoing infrared radiation (IR)
- Chlorofluorocarbons (CFCs) increasing
- Concentrations of methane have more than doubled since 1750
- Nitrous oxide increasing more slowly

Indicators of the human influence on the atmosphere during the Industrial era



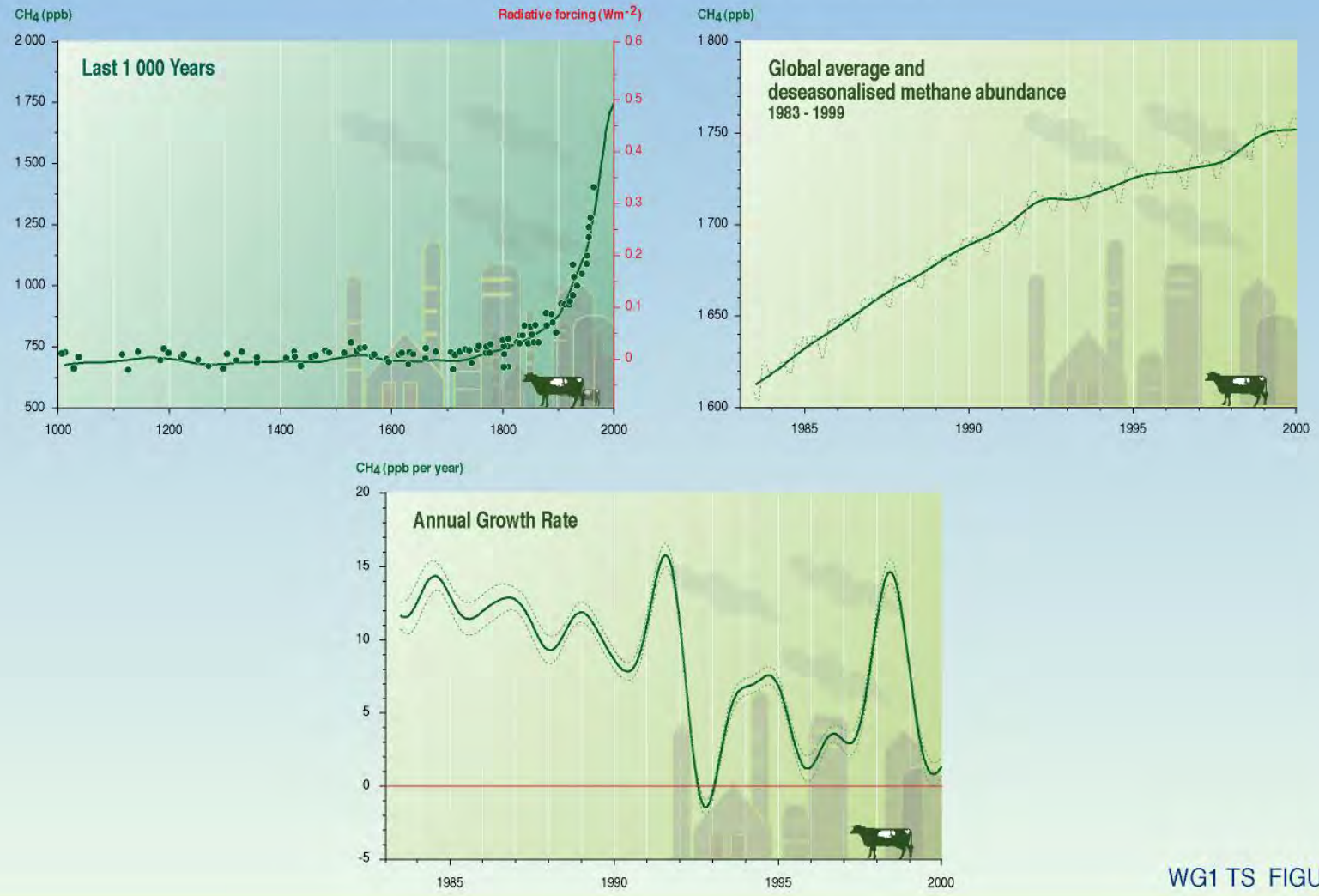






Source: IPCC

Change in methane abundance



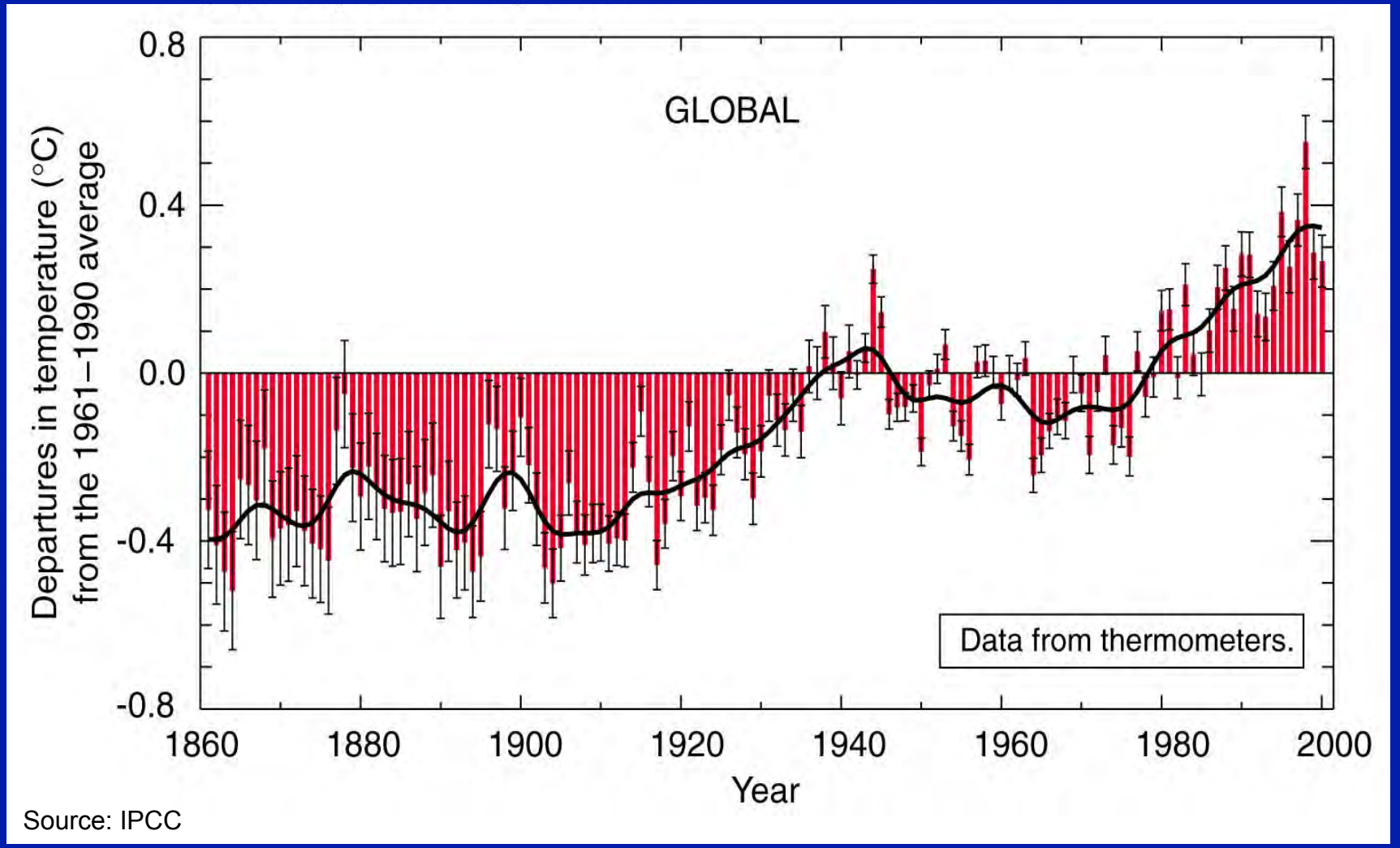
WG1 TS FIGURE 11

Source: IPCC

Examples of GECs

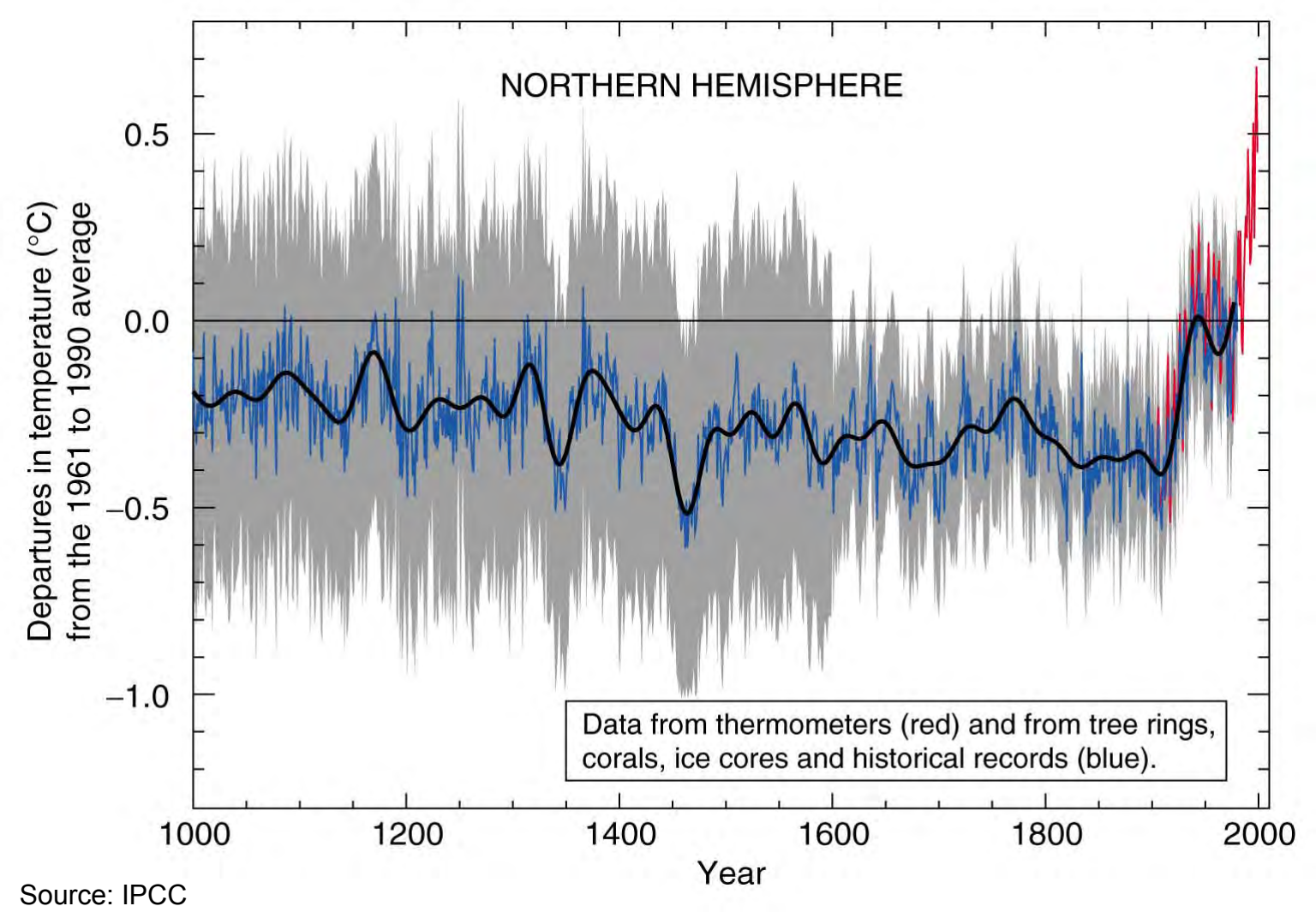
- Change in composition of atmosphere
- Climate change
- Decreased stratospheric ozone concentrations
- Increased ultraviolet input
- Land use change
- Loss of biological diversity
- Biological invasions
- Changes in atmospheric chemistry

Variations in Earth's surface temperature over the past 140 years



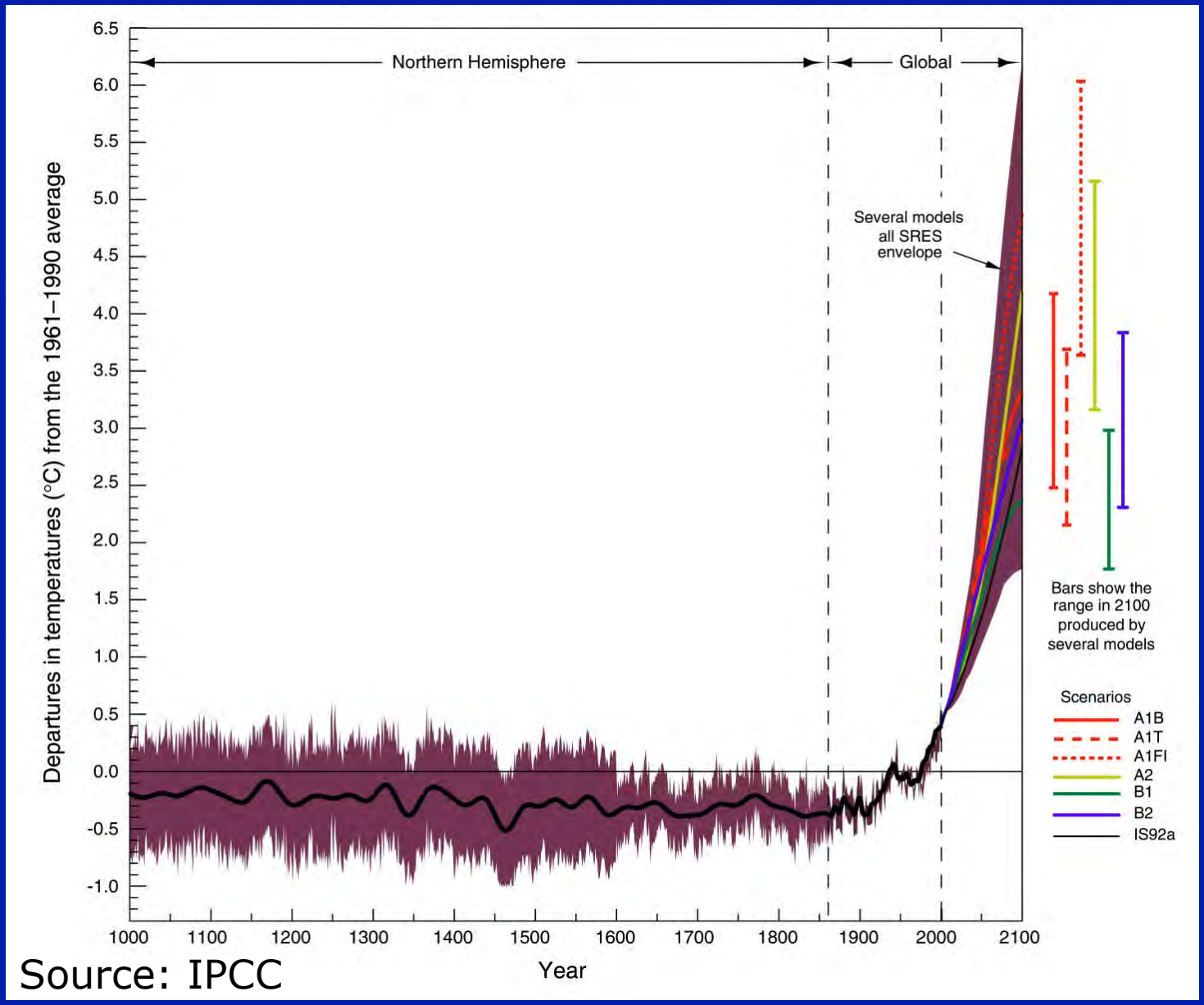
Source: IPCC

Variations in Earth's surface temperature over the past 1,000 years



Source: IPCC

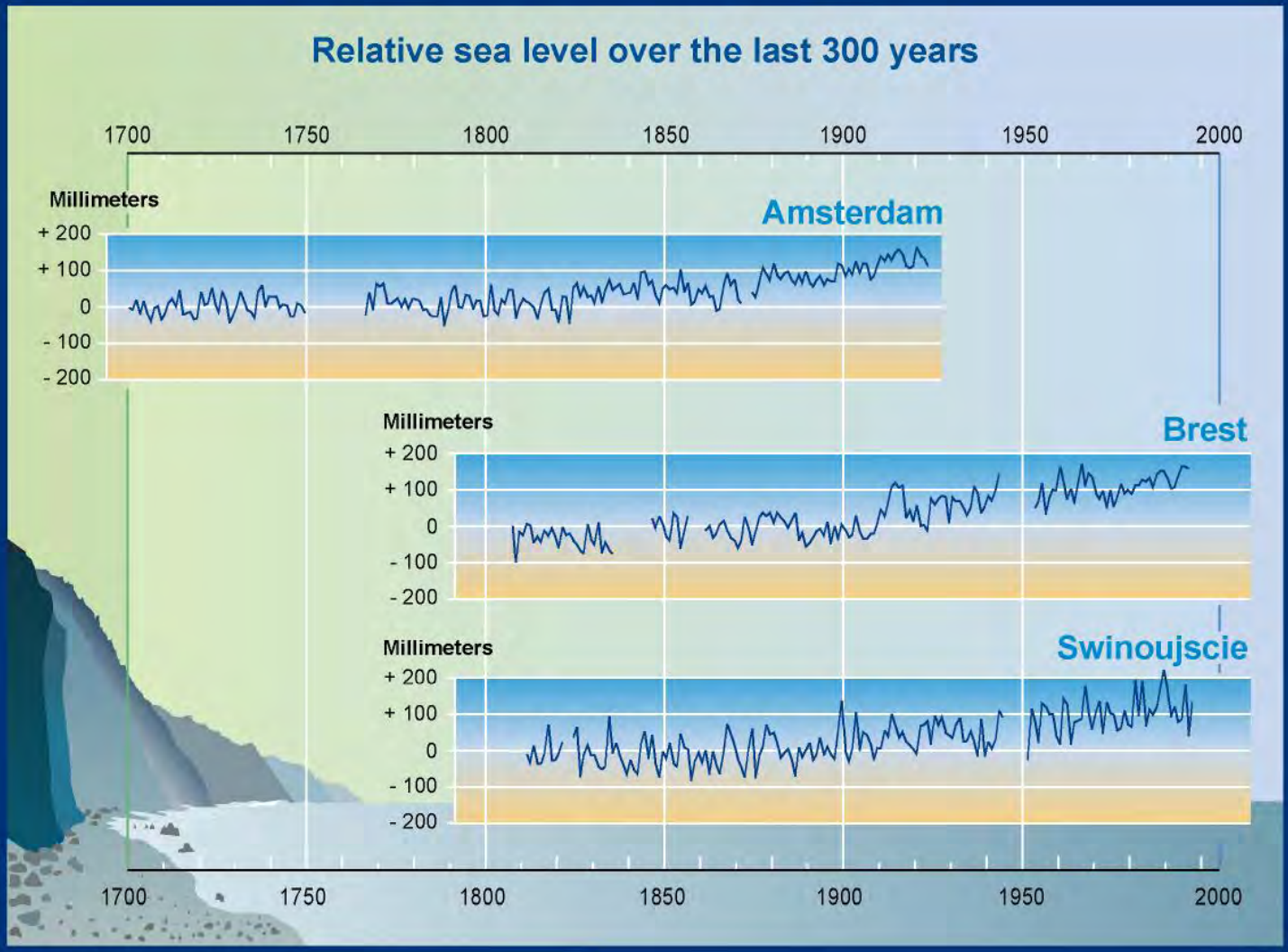
Variations in Earth's surface temperature, 1000-2100



Source: IPCC

Main climate changes

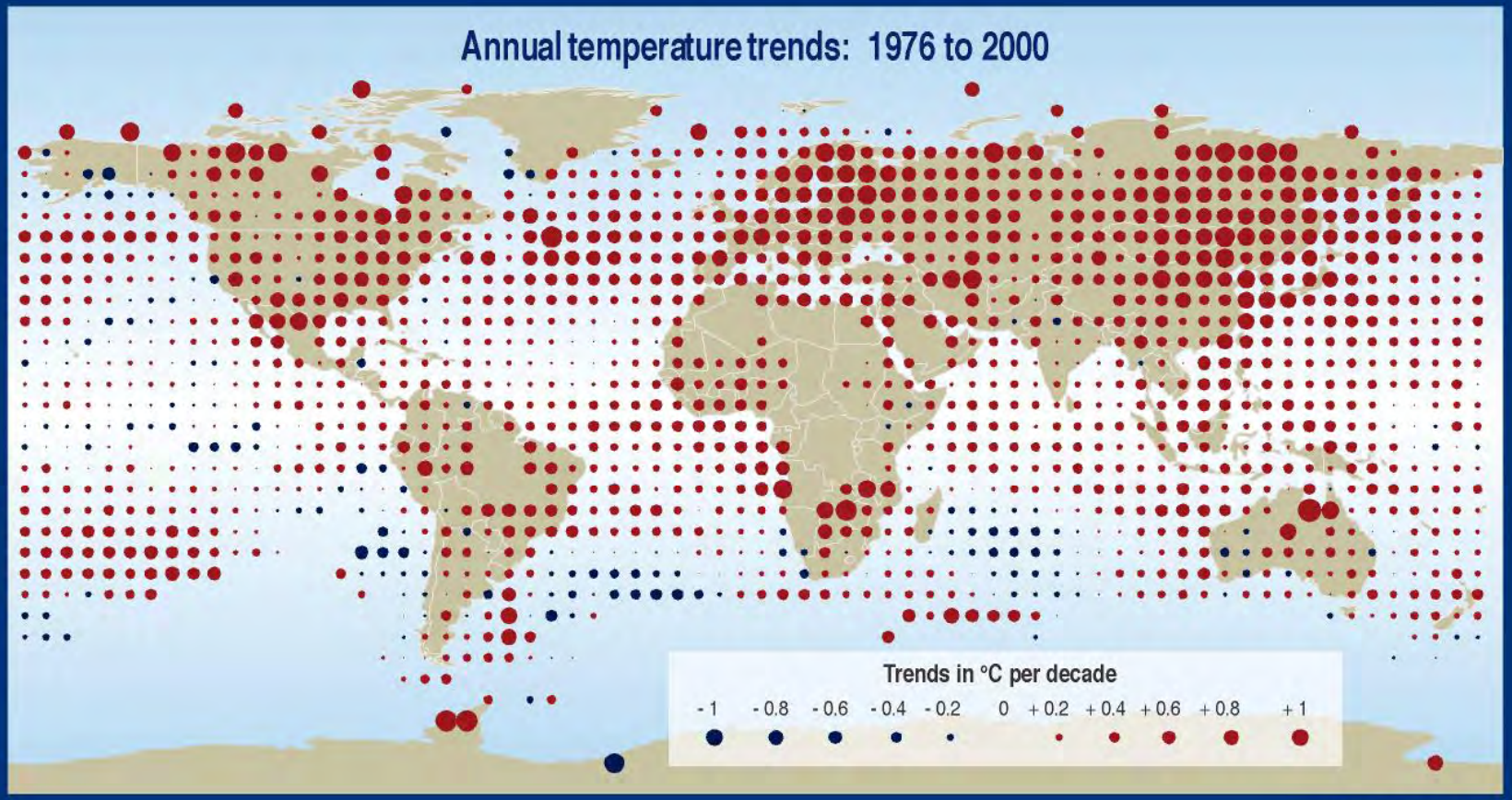
- Sea level rise
- Higher temperatures – land and sea
- Hydrological cycle more intense
- Changes at regional level



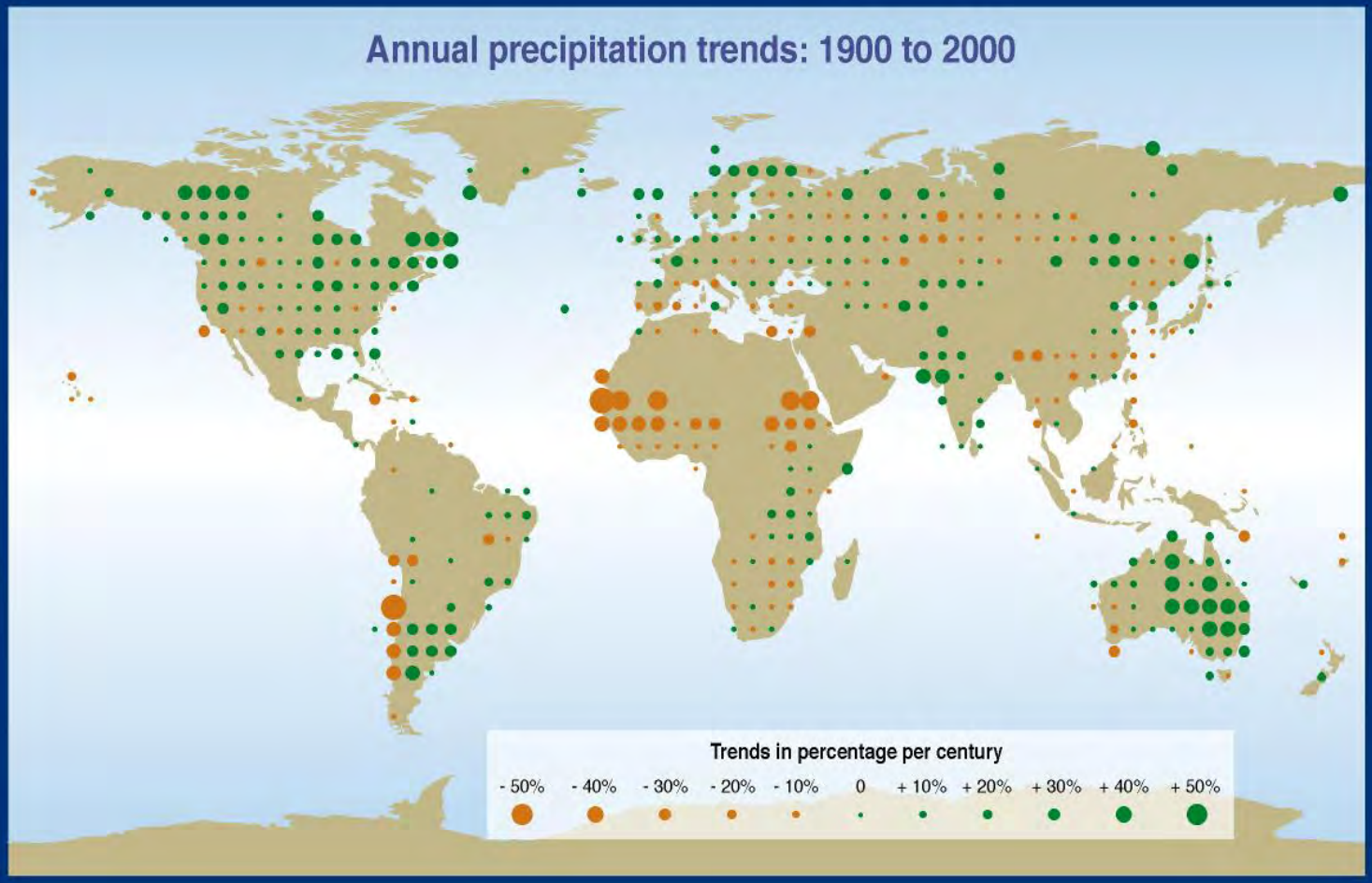
SYR - FIGURE 2-5

Sea-level transgression scenarios for Bangladesh

Adapted from Milliman *et al.* (1989).

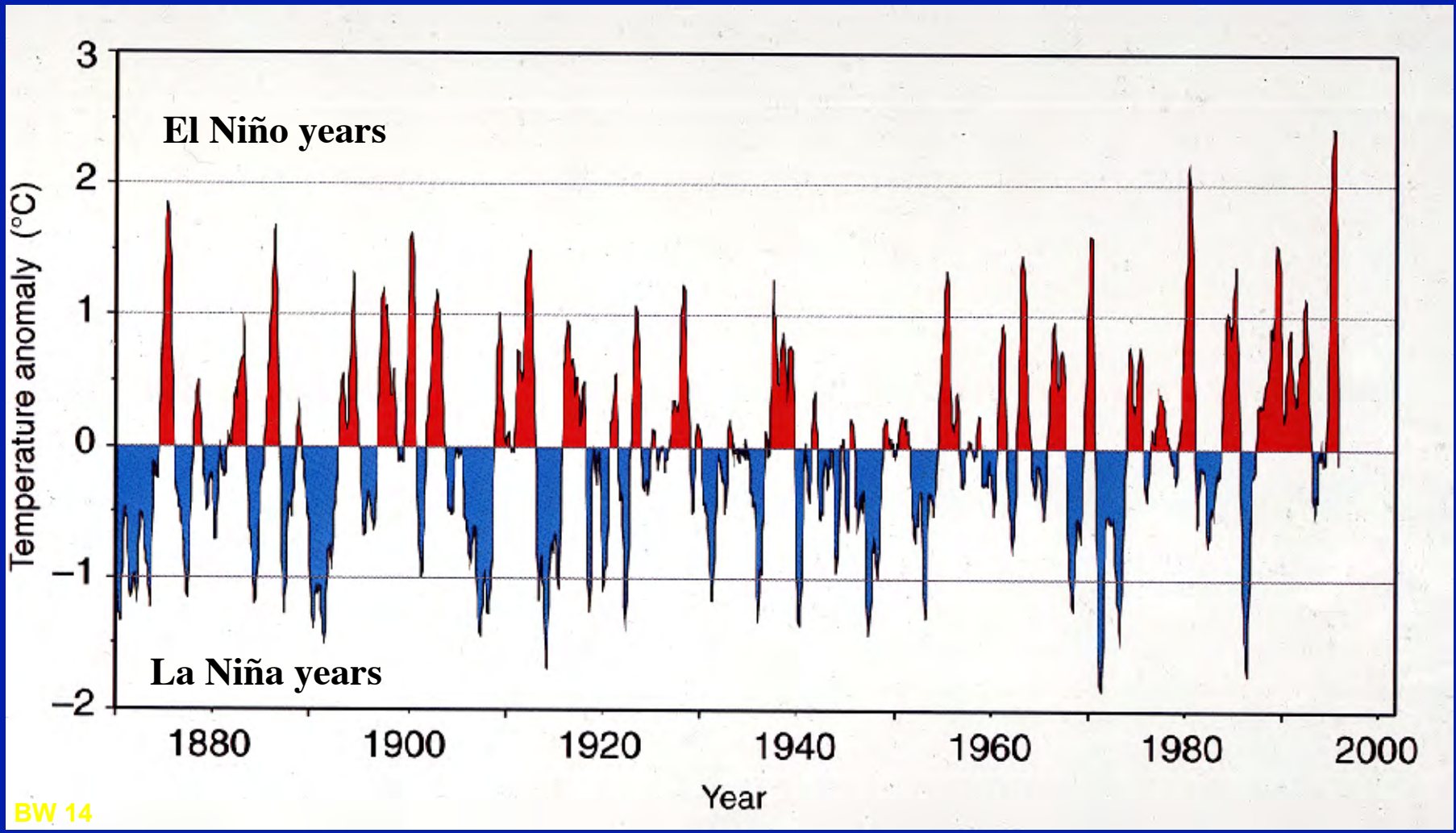


SYR - FIGURE 2-6b



SYR - FIGURE 2-6a

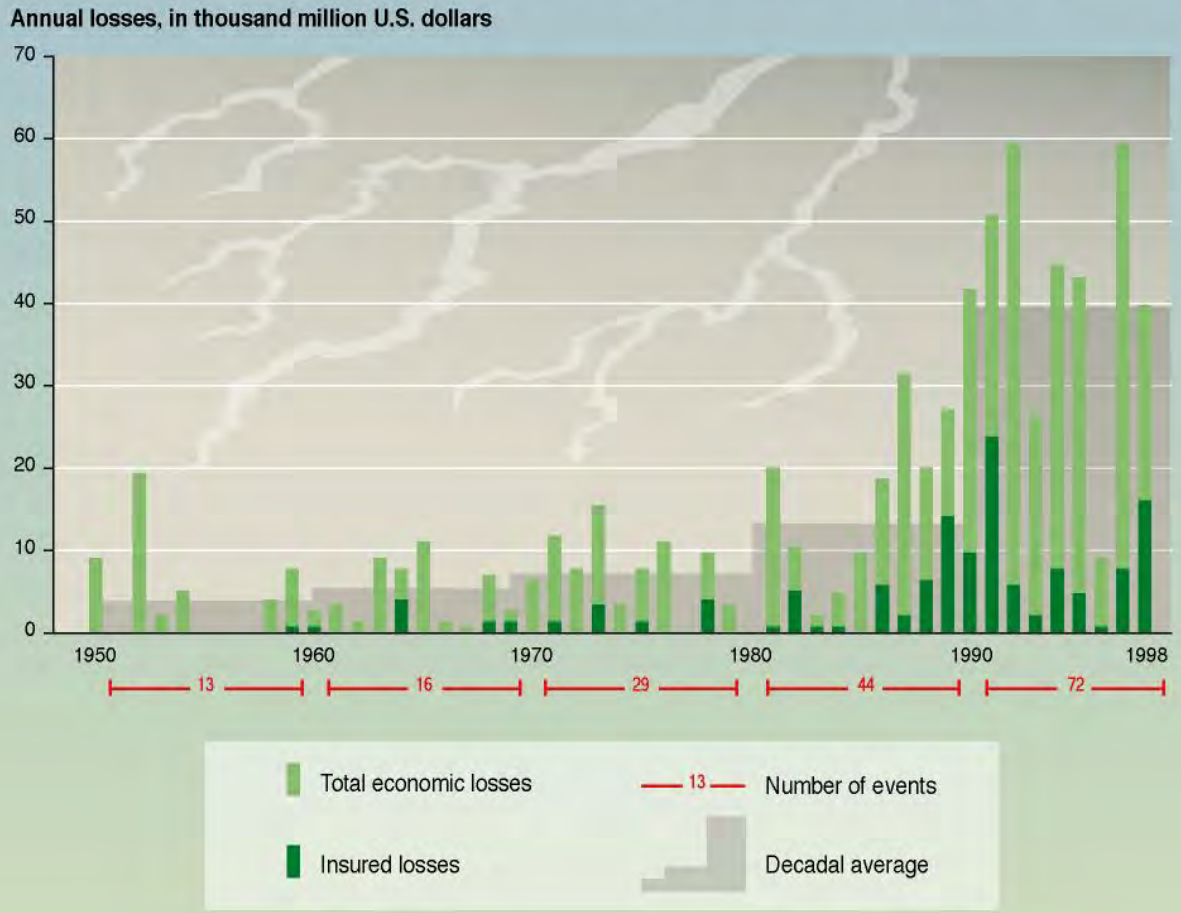
The 1997/98 El Niño Strongest on Record*



*As shown by changes in sea-surface temperature (relative to the 1961-1990 average) for the eastern tropical Pacific off Peru

Source: IPCC

Global costs of extreme weather events (inflation-adjusted)



SYR - FIGURE 2-7

Examples of GECs

- Change in composition of atmosphere
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Motivations for Land-Use Research

Agricultural expansion
- Δ natural ecosystems
- ↑ CH_4 , N_2O

Urbanization
- Δ biologically productive land
- Δ lifestyle, diet, energy use
- ↑ CH_4 , N_2O , O_3 , CO_2
- 2% Earth's surface
- 2001: 50% population
- 2030: 65% population

Impacts of LCLUC

- At a global scale: biodiversity, biogeochemical cycles & climate
- Sustainability, ecosystem goods & services
- Critical regions, vulnerable places & people

IHDP-IGBP LUCC Project

- Patterns of LUCC
- Causes of LUCC
- Future rates and patterns of change
- International and interdisciplinary network of researchers

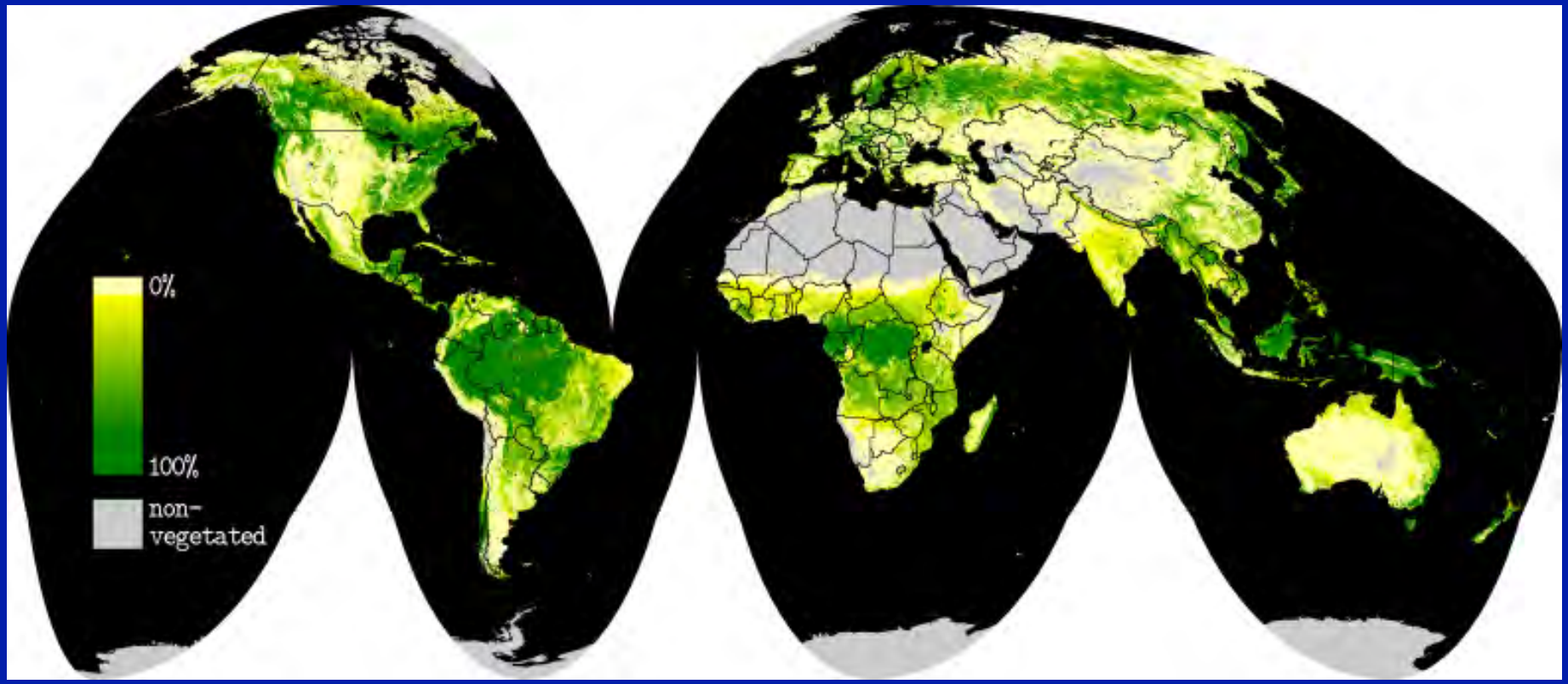
US NASA LCLUC Program

- Where are land cover and land use changing, what is the extent and over what time scale?
- What are the causes and consequences of LCLUC?
- What are the potential impacts of LCLUC?
- What are the impacts of climate variability and on LCLUC and what are the potential feedbacks?

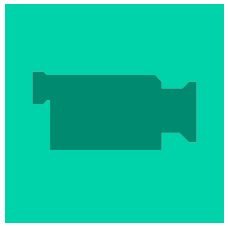
Trends in Land Use Change & LUC Research

- Global
- Forests
- Cropland
- Regional Case Studies
- Urban

Global land cover: remote sensing data

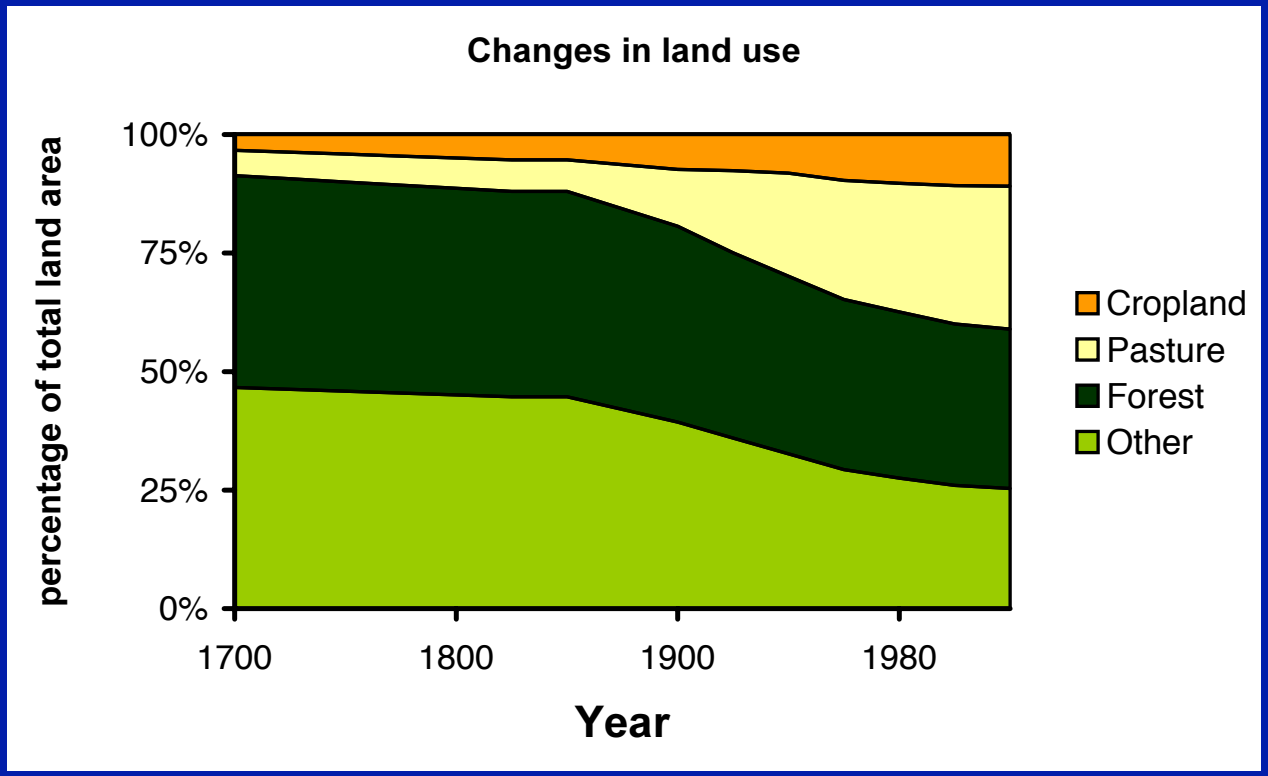


De Fries et al.

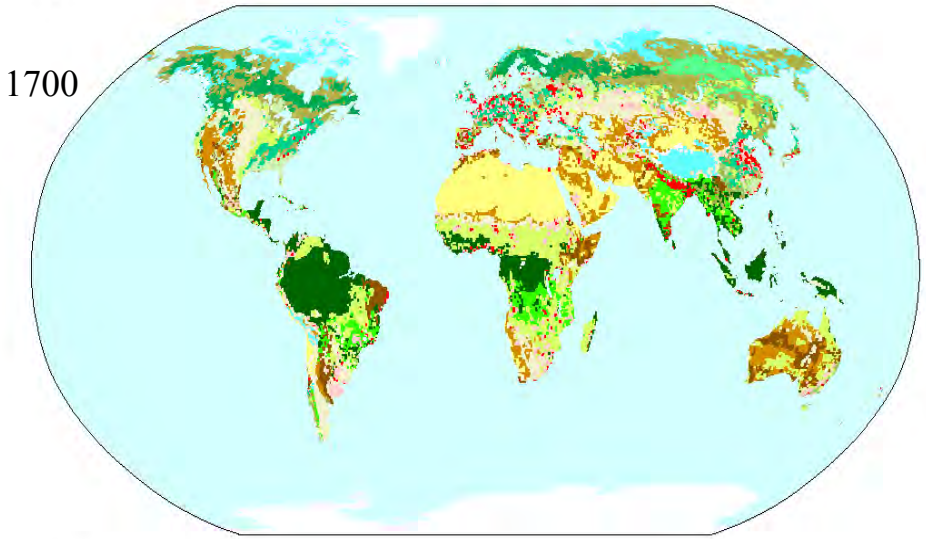


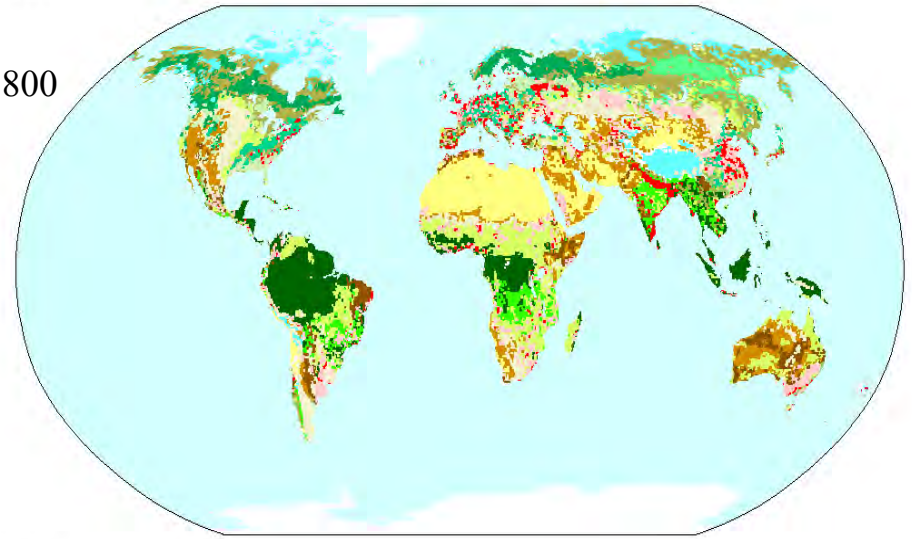
Global: Patterns of surface temperature and vegetation

Estimated changes in land use,1700-1995

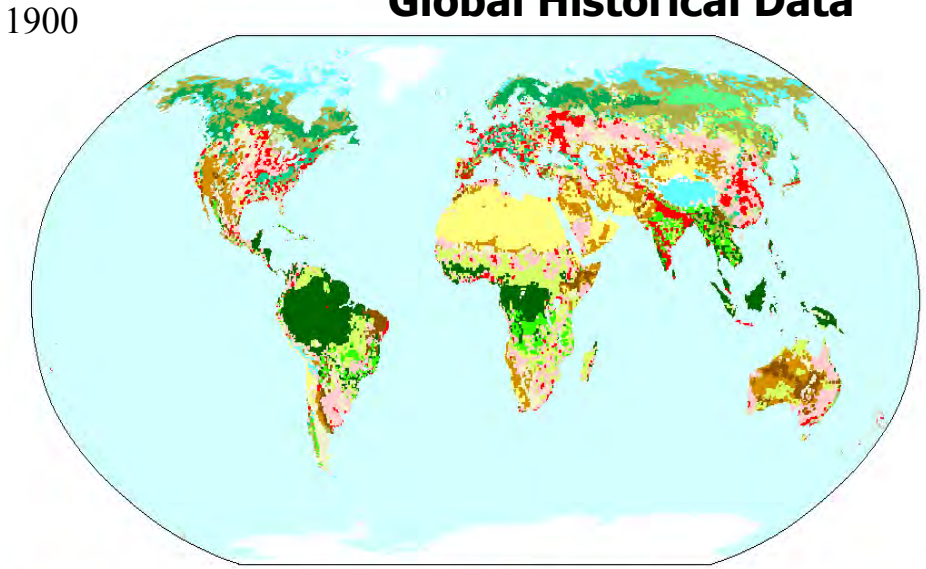


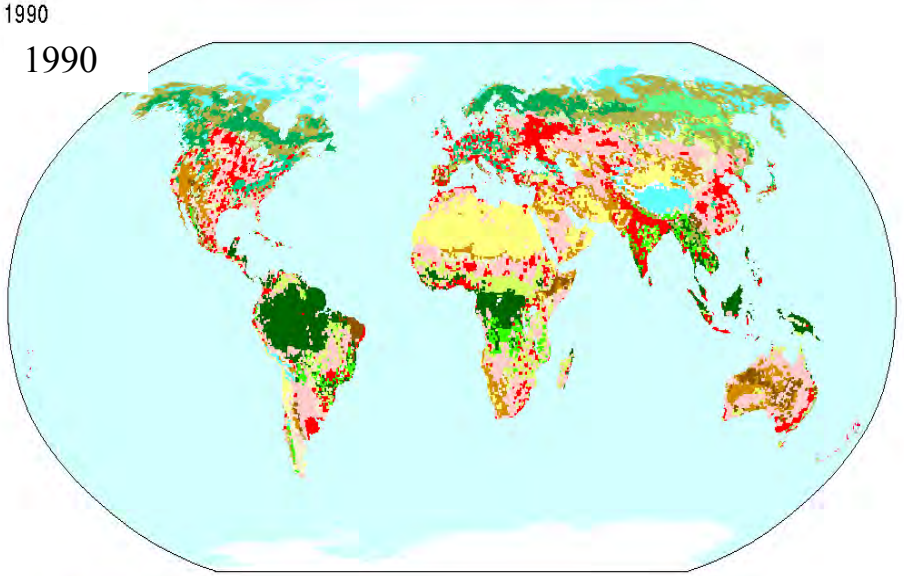
Goldewijk K and Battjes J.J., 1997





Global Historical Data



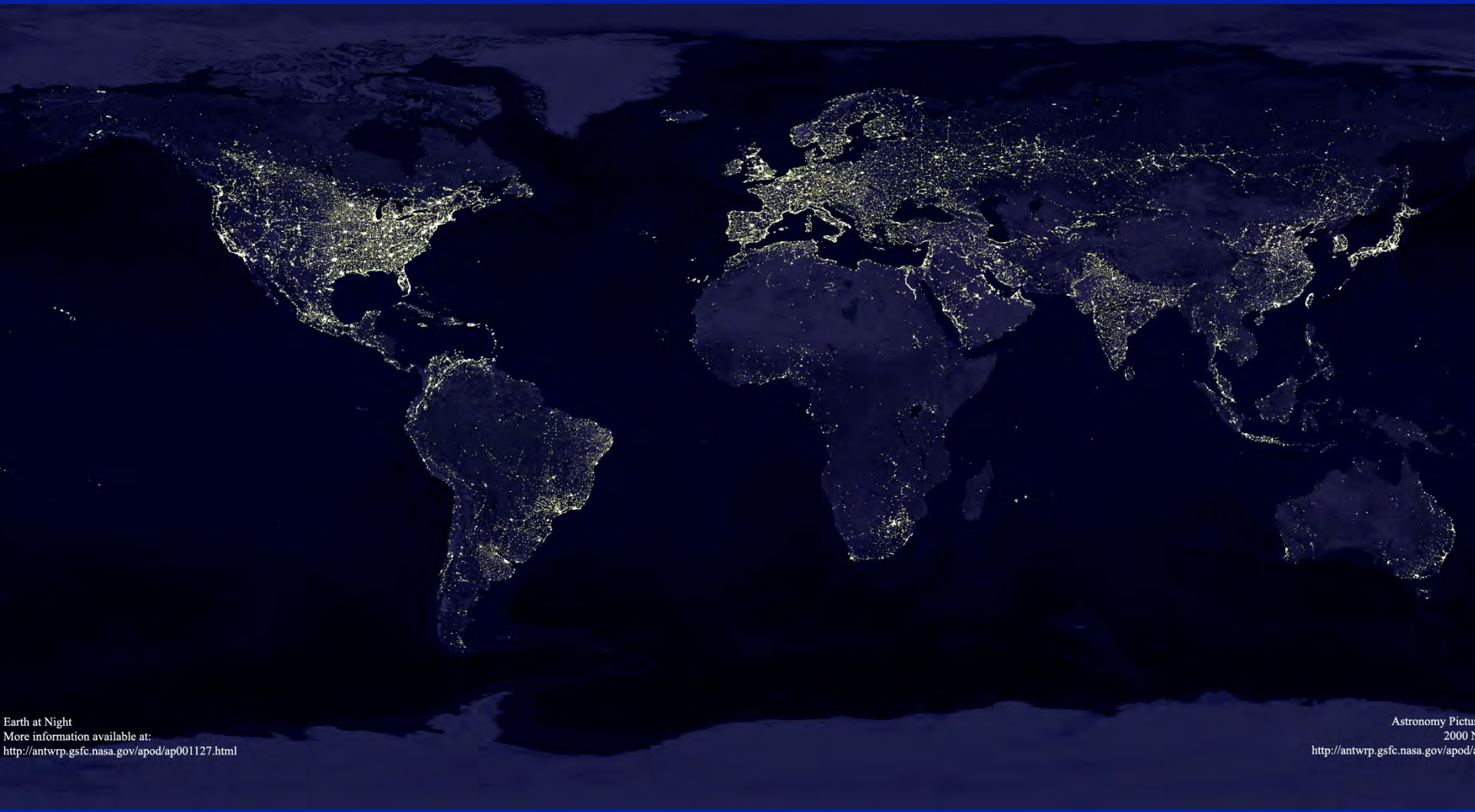


Intensive Cropland
Marginal Cropland/Used for Grazing
Trop. Evergr. Forest/Woodland
Trop. Decid. Forest/Woodland
Temp. Broadl. Evergr. Forest/Woodland
Temp. Ndleaf Evergr. Forest/Woodland
Temp. Decid. Forest/Woodland
Boreal Evergr. Forest/Woodland
Boreal Decid. Forest/Woodland
Evergr./Decid. Mixed Forest/Woodland
Savanna
Grassland/Steppe
Dense Shrubland
Open Shrubland
Tundra
Hot Desert
Polar desert/Rock/Ice

Klein Goldewijk: HYDE (2001)

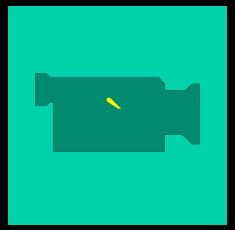
Urban LUC

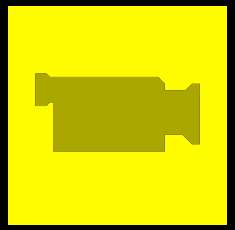
- New interest and emphasis
- Many unanswered questions: global rate of urban growth?
- Regional case studies
- Focus on areas of rapid expansion



Night-time data from the Defense Meteorological Satellite Program (DMSP)
Operational Linescan System (OLS)

Elvidge et al., 1997



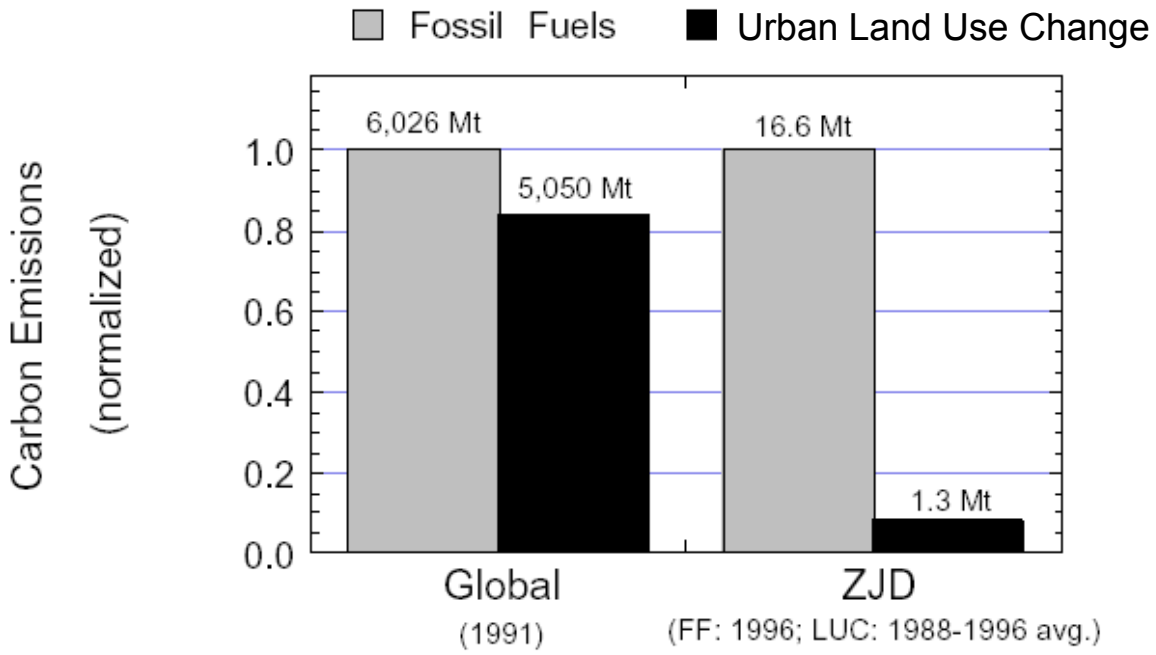


Challenges in Urban LUC Research

- Land-cover modifications vs. change
- Spatial patterns of change
- Driving forces of land-use change
- Spatial scale of change

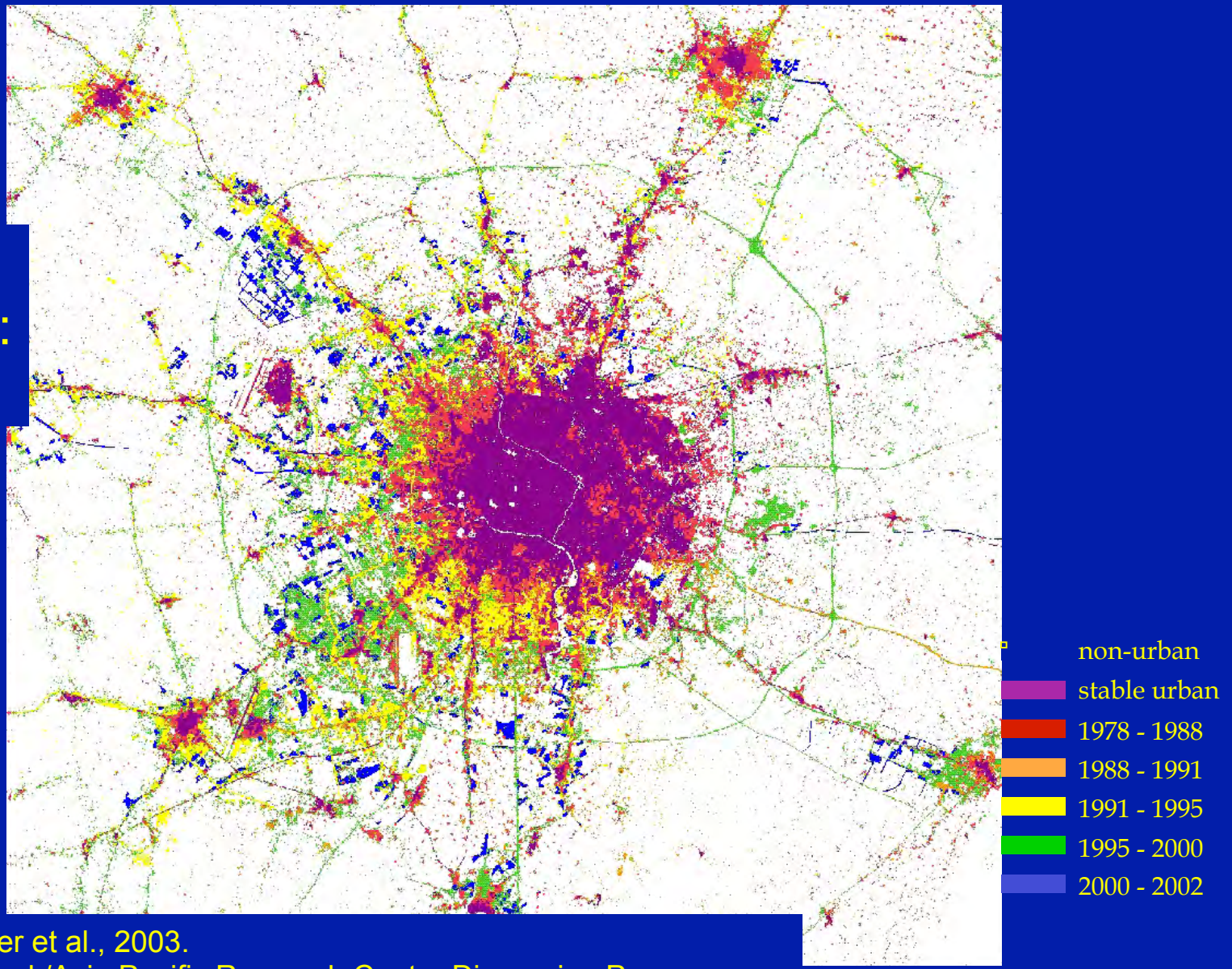
- We know very little at the global scale!

Carbon Emissions Associated with Urban Growth



Dye et al., 2004. *Asian Journal of Geoinformatics*

Chengdu, 1973-2002: 300% ↑



Schneider et al., 2003.
World Bank/Asia Pacific Research Center Discussion Paper.

Sprawl?
Measures of Urban Land-Use Efficiency

		change land/change pop (m^2/person)				change land/change gdp (m^2/yuan)	
		1978-1988	1988-1991	1991-1995	1995-2000	1990-1995	1995-2000
Chengdu's districts	**Jinniu**			0.19	0.09	2.38	1.08
	Chenghua			0.06	0.09	0.52	0.99
	Qingyang			0.23	-0.67	1.47	1.22
	Jinjiang			**0.38**	-0.19	0.92	0.89
	Wuhou			0.22	**6.54**	**2.73**	**4.25**
Chengdu	**total**	0.03	0.04	0.18	0.36	1.63	1.48

Schneider et al., 2003.

Concluding Comments

- Direct and indirect effects of urbanization
- Urban growth and land-use change
- Urban lifestyles and consumption patterns
- Need to think beyond urban population

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