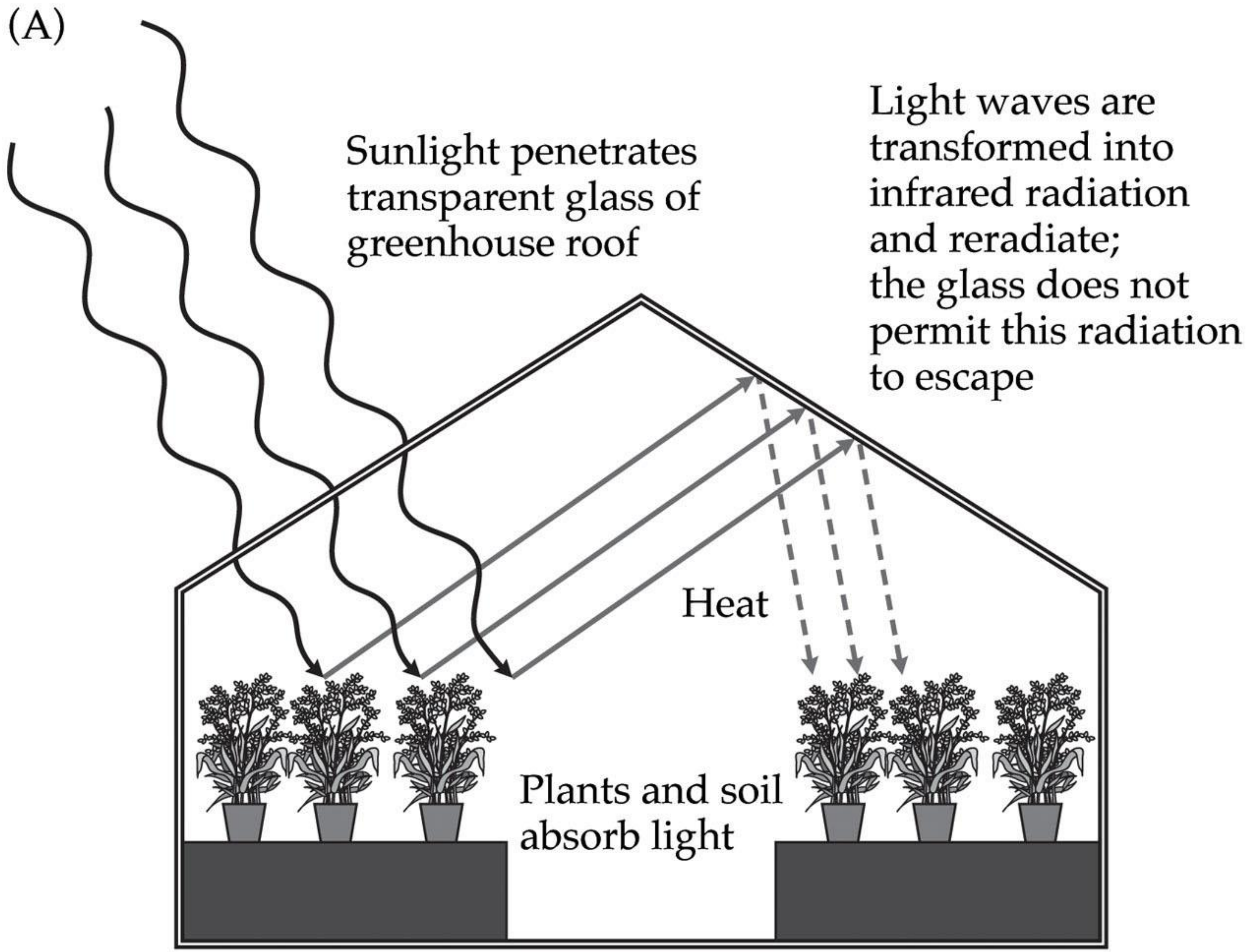
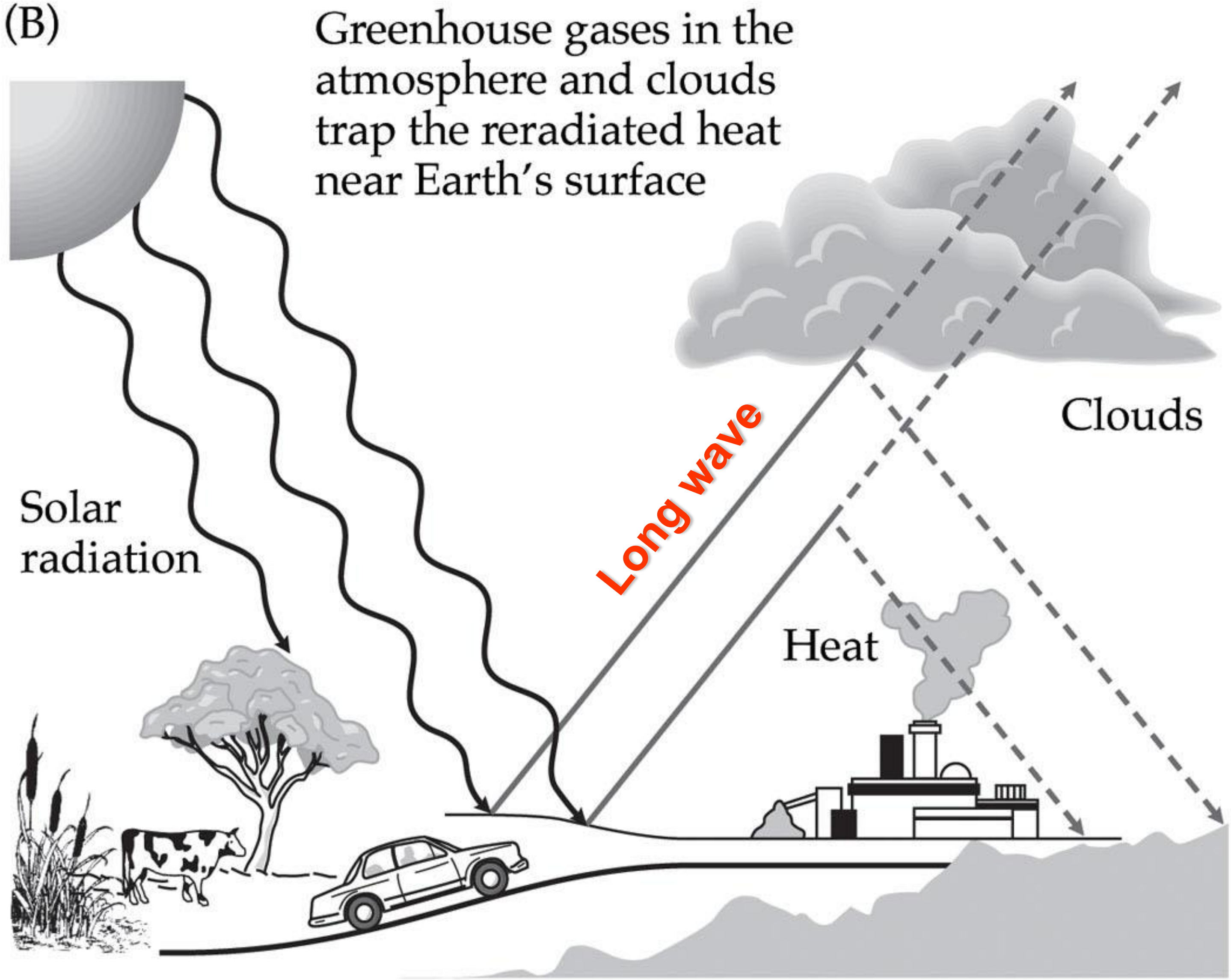
Biological Impacts of Climate Change

1. Nature of Climate Change
2. Current and Future Climate Change
3. Predicted Biological Impacts
4. Observed Biological Impacts
5. Conservation Implications

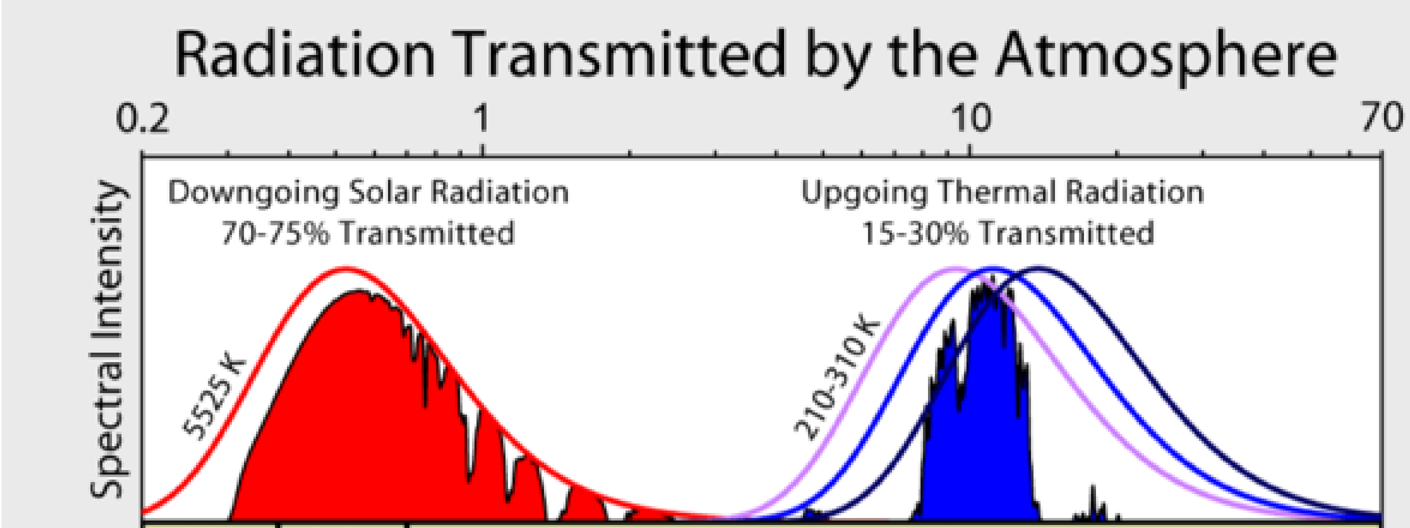
1. Nature of Climate Change

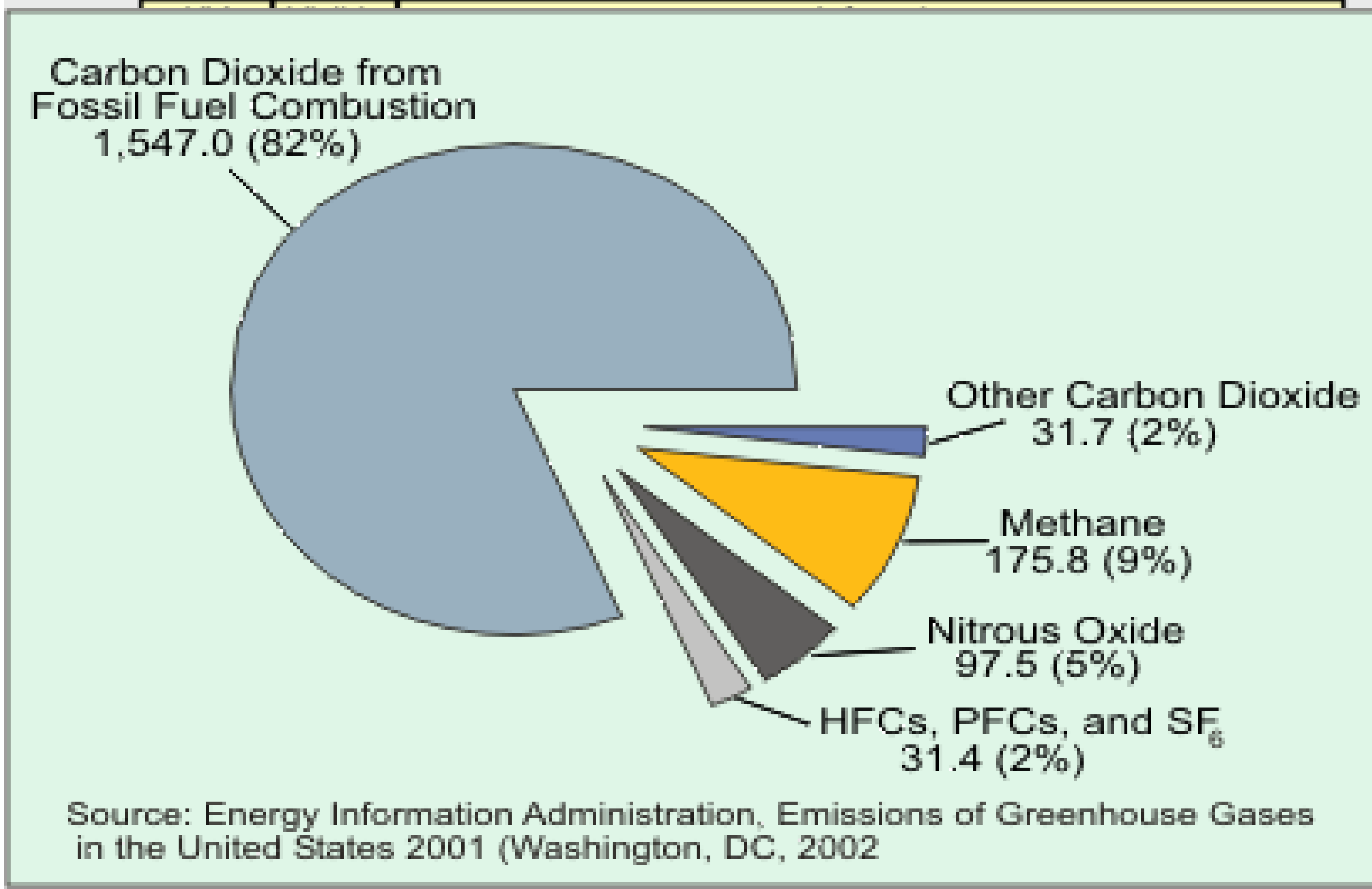


PRINCIPLES OF CONSERVATION BIOLOGY, Third Edition, **Figure 10.1 (Part 1)** © 2005 Sinauer Associates, Inc.



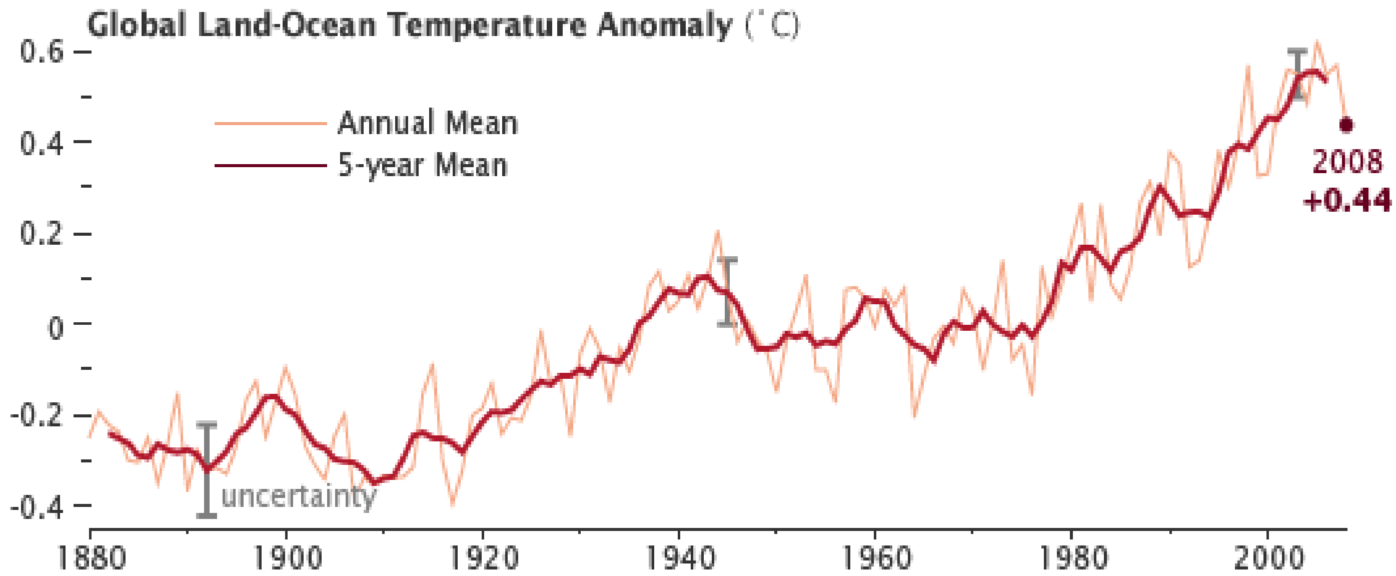
Light waves are transformed into infrared radiation reflected back to Earth by clouds and reradiated


Radiation Transmitted by the Atmosphere
0.2
1
10
70
Spectral Intensity
Downgoing Solar Radiation
70-75% Transmitted
Upgoing Thermal Radiation
15-30% Transmitted
5525 K
210-310 K

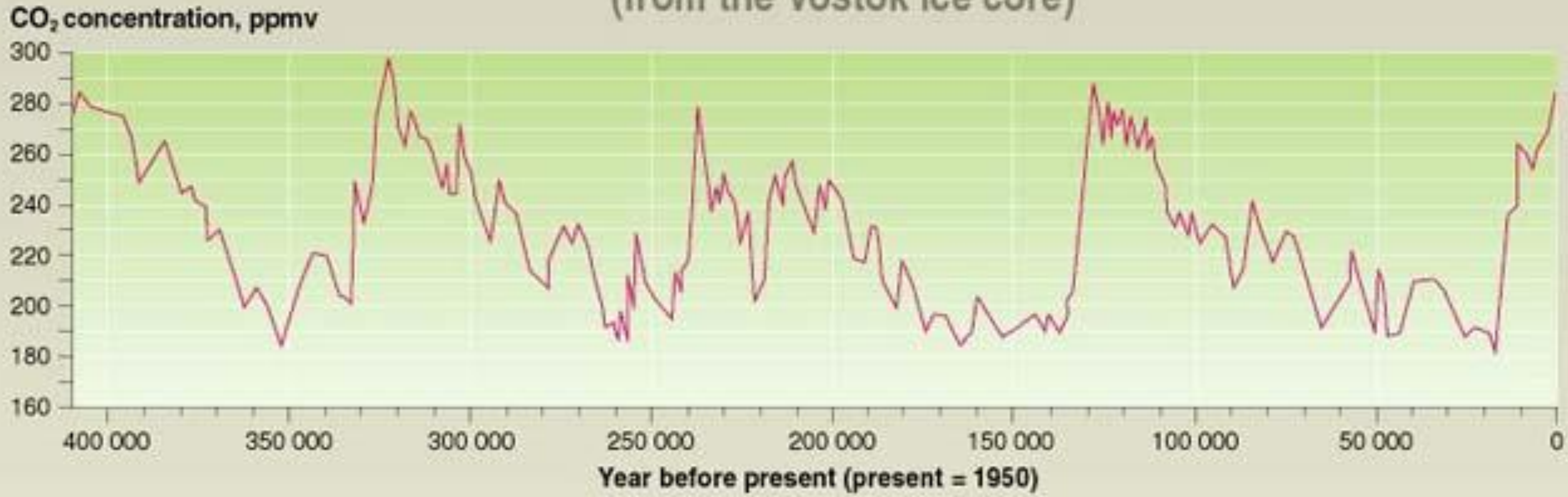

Carbon Dioxide from Fossil Fuel Combustion
1,547.0 (82%)
Other Carbon Dioxide
31.7 (2%)
Methane
175.8 (9%)
Nitrous Oxide
97.5 (5%)
HFCs, PFCs, and SF6
31.4 (2%)
Source: Energy Information Administration, Emissions of Greenhouse Gases in the United States 2001 (Washington, DC, 2002

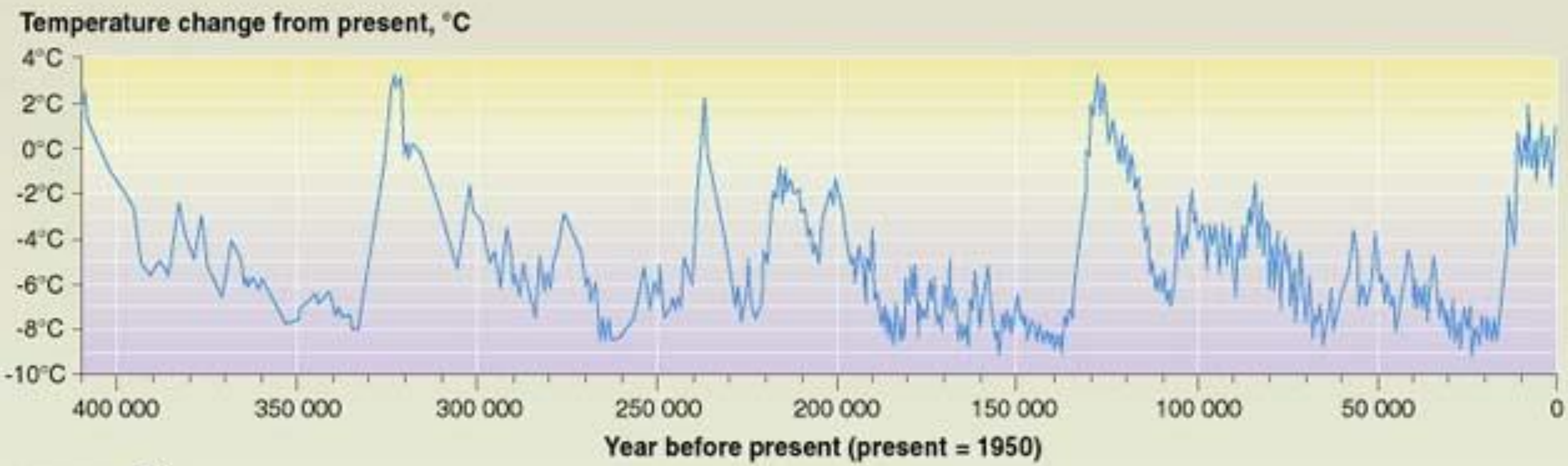
Some greenhouse gases such as carbon dioxide occur naturally and are emitted to the atmosphere through natural processes and human activities. Other greenhouse gases (e.g., fluorinated gases) are created and emitted solely through human activities. The principal greenhouse gases that enter the atmosphere because of human activities are:

- **Carbon Dioxide (CO_2)**: CO_2 enters the atmosphere through the burning of fossil fuels (oil, natural gas, and coal), solid waste, trees and wood products, and also as a result of other chemical reactions (e.g., manufacture of cement). CO_2 is also removed from the atmosphere (or "sequestered") when it is absorbed by plants as part of the biological carbon cycle.
- **Methane (CH_4)**: Methane is emitted during the production and transport of coal, natural gas, and oil. CH_4 emissions also result from livestock and other agricultural practices and by the decay of organic waste in municipal solid waste landfills.
- **Nitrous Oxide (N_2O)**: Nitrous oxide is emitted during agricultural and industrial activities, as well as during combustion of fossil fuels and solid waste.
- **Fluorinated Gases**: Hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride are synthetic, powerful greenhouse gases that are emitted from a variety of industrial processes. Fluorinated gases are sometimes used as substitutes for ozone-depleting substances (i.e., CFCs, HCFCs, and halons). These gases are typically emitted in smaller quantities, but because they are potent greenhouse gases, they are sometimes referred to as High Global Warming Potential gases ("High GWP gases").


Global Land-Ocean Temperature Anomaly (°C)
0.6
0.4
0.2
0
-0.2
-0.4
Annual Mean
5-year Mean
uncertainty
2008
+0.44
1880
1900
1920
1940
1960
1980
2000

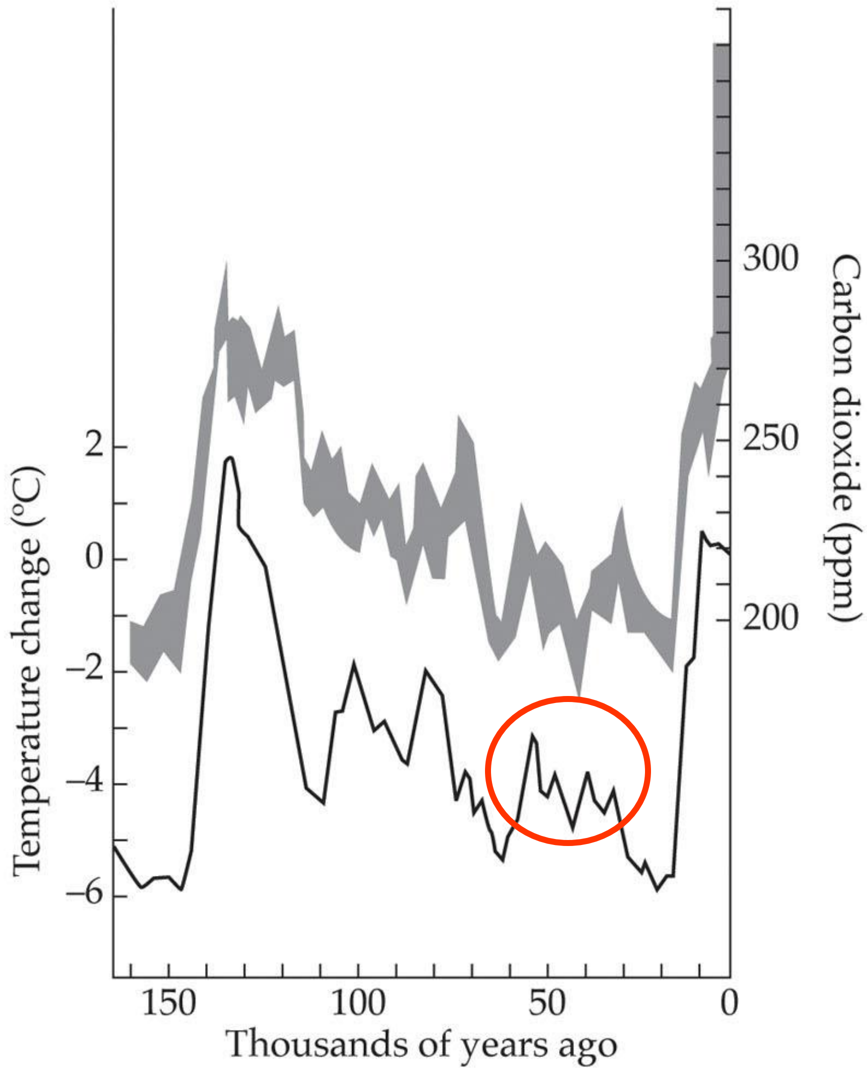
Temperature and CO_2 concentration in the atmosphere over the past 400 000 years (from the Vostok ice core)





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.

The relationship between temperature and carbon dioxide over the past 160,000 years



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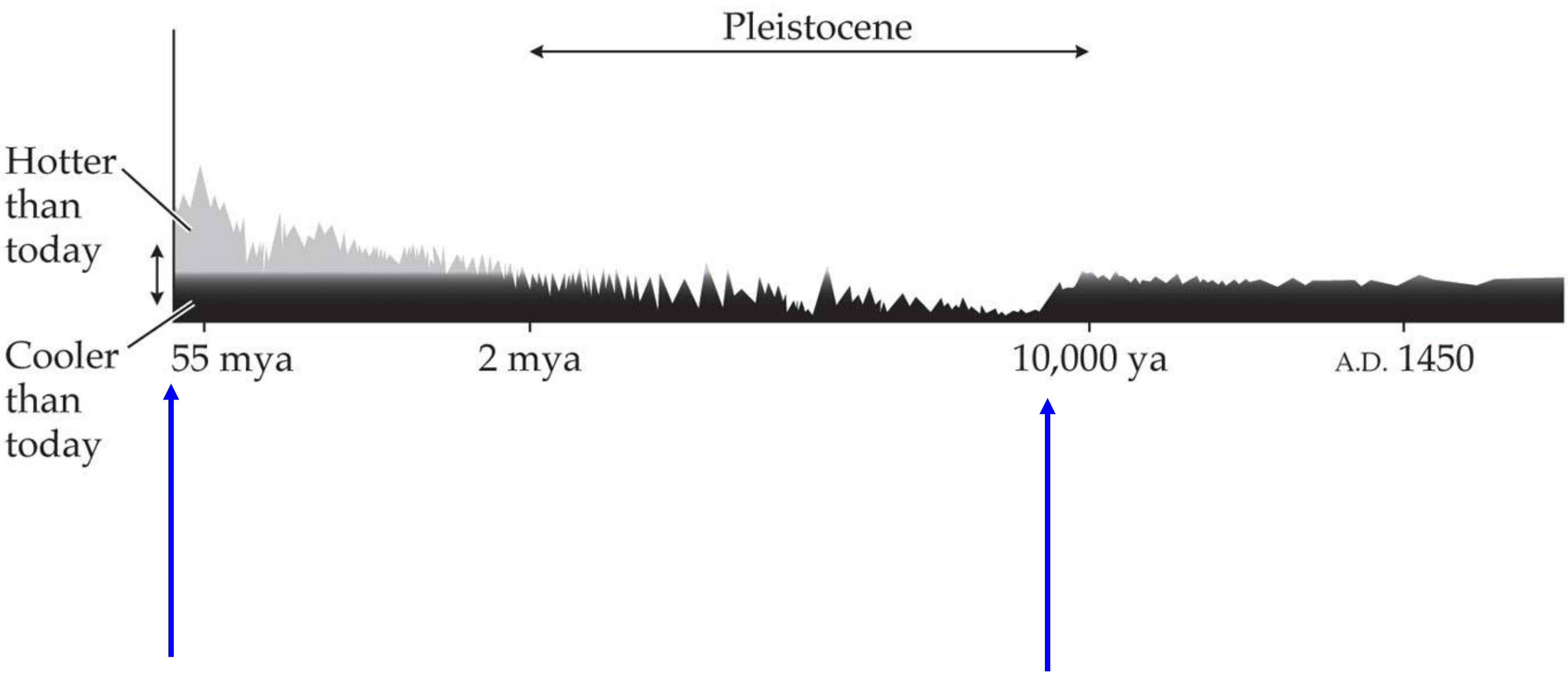
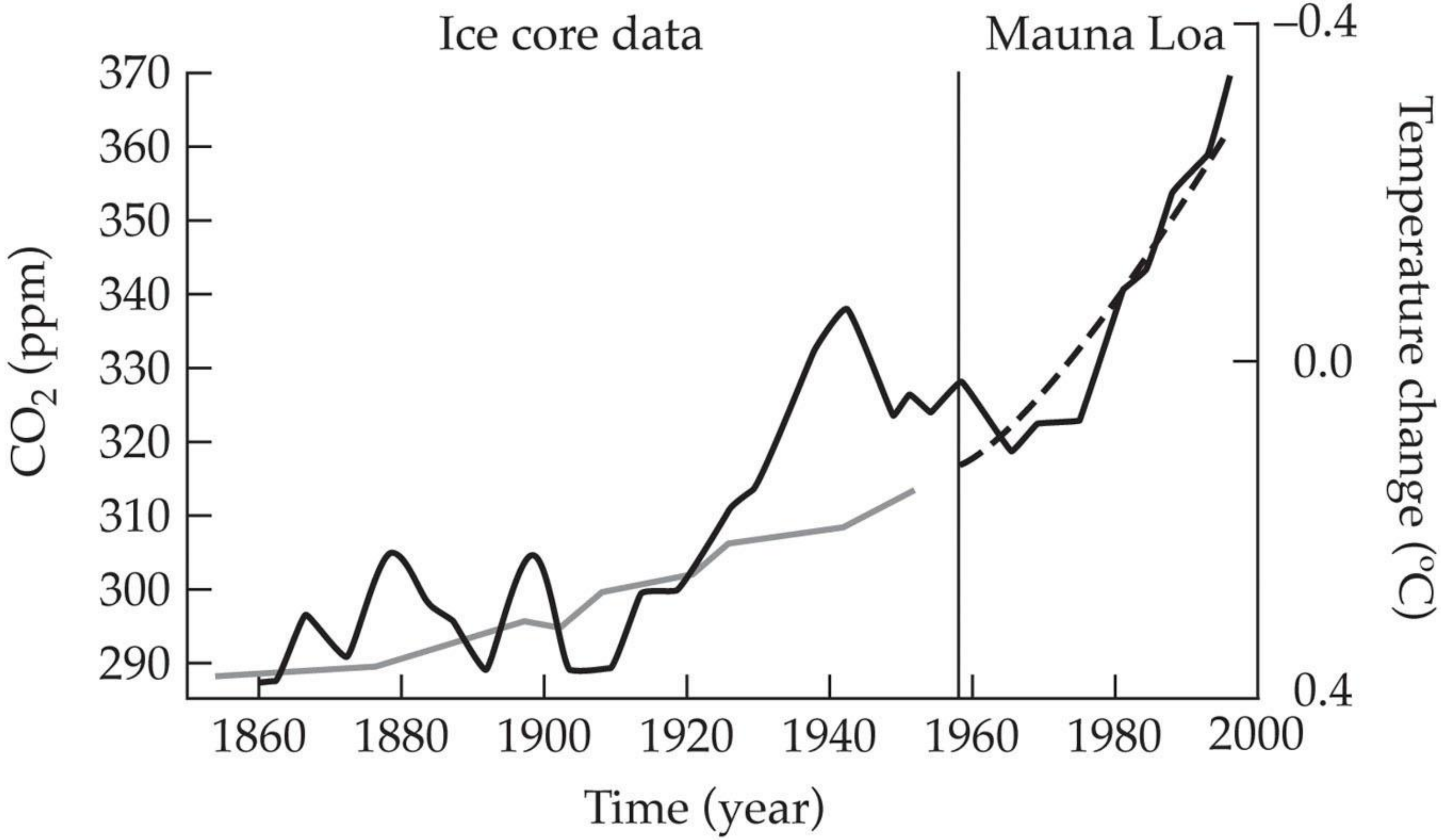
Average global temperature over the last 65 million years



Dinosaur Extinction

Most recent glacier

Relationship between twentieth century levels of atmospheric carbon dioxide and global temperature



PRINCIPLES OF CONSERVATION BIOLOGY, Third Edition, Figure 10.4

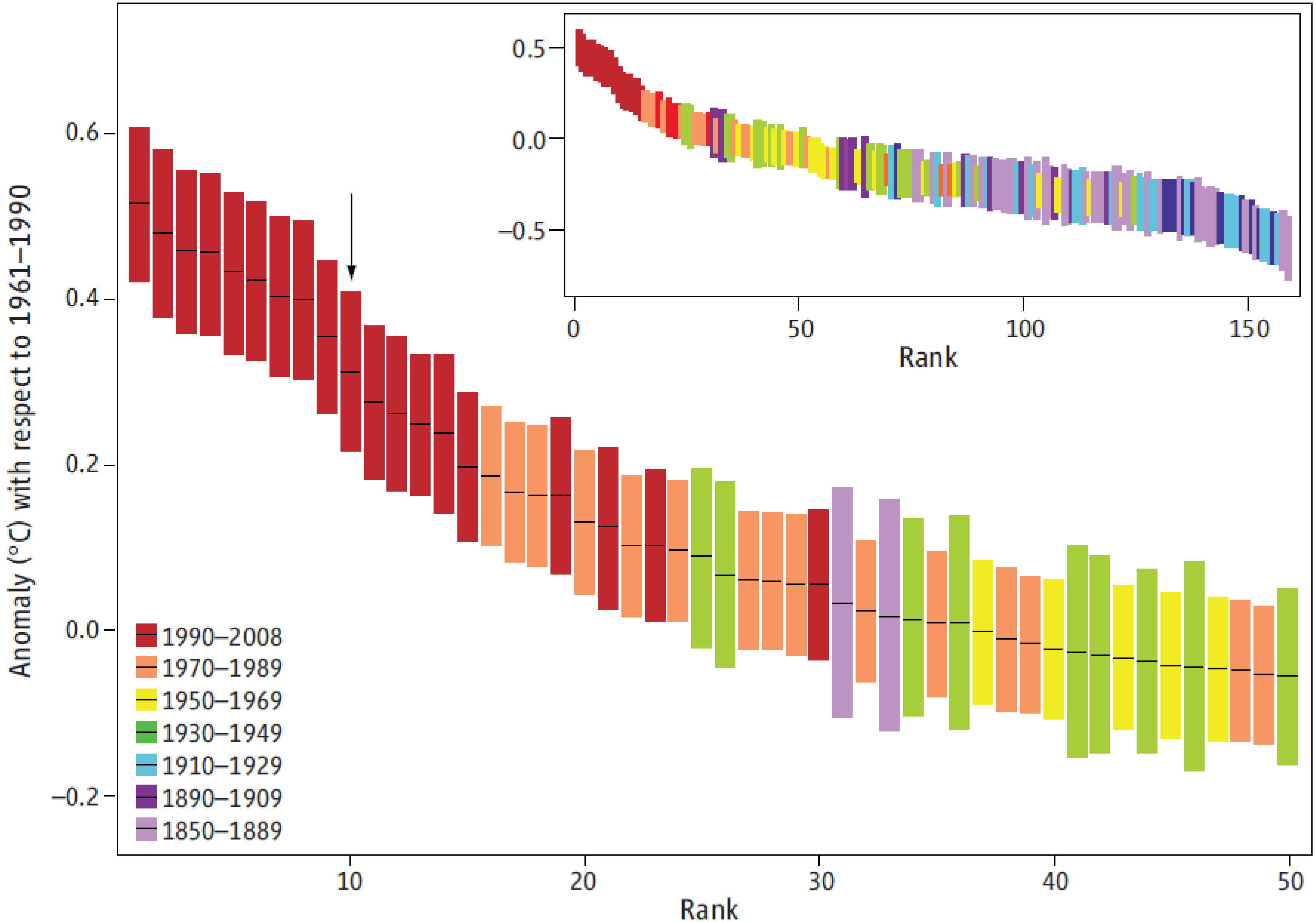
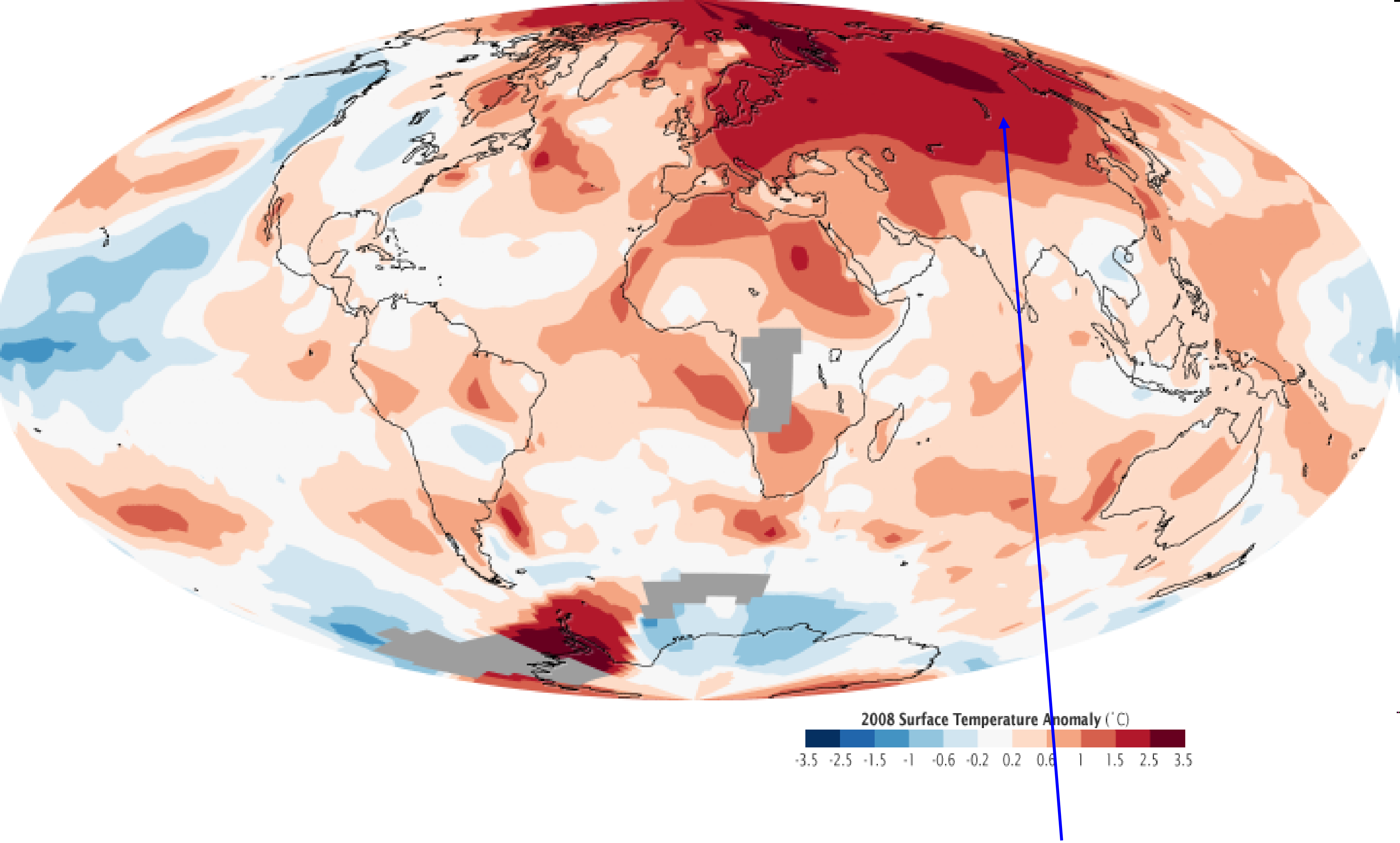


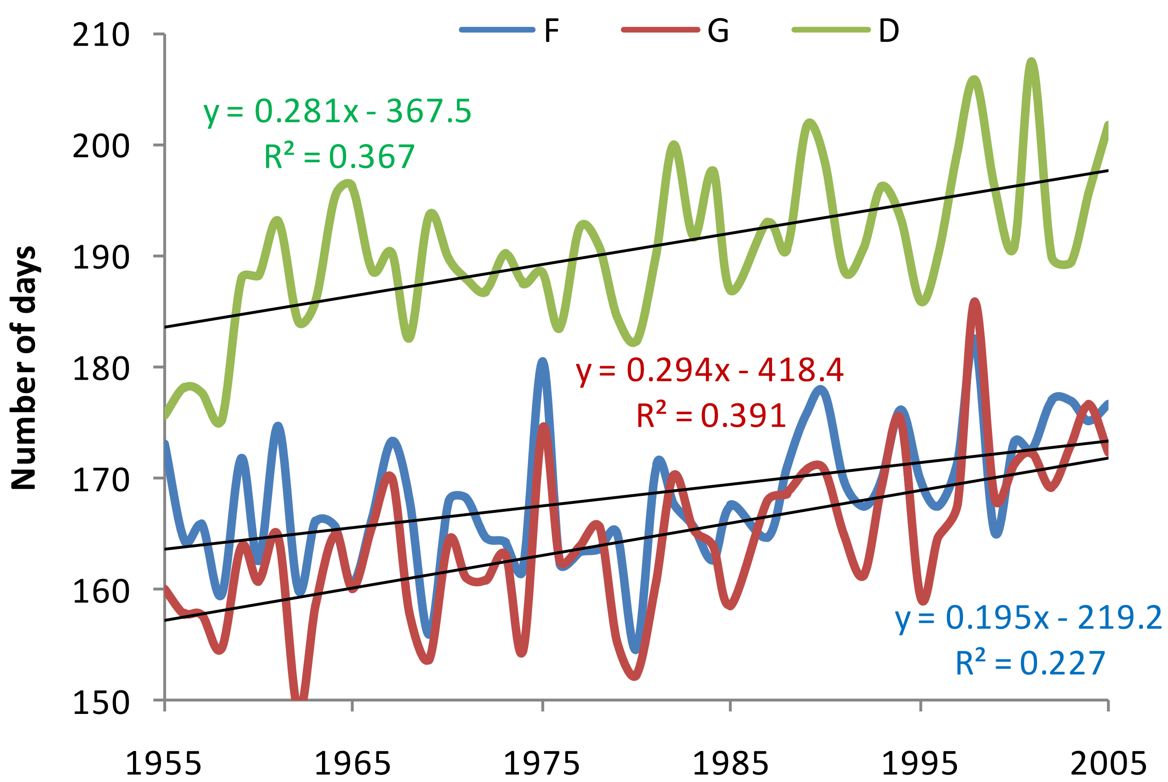
Fig. 6. Global surface temperature. Global ranked surface temperatures for the warmest 50 years. The inset shows global ranked surface temperatures from 1850. The size of the bars indicates the 95% confidence limits associated with each year. The source data are blended land-surface air temperature and sea surface temperature from the HadCRUT3 series. Values are simple area-weighted averages for the whole year (*28*).



Why focus research on Mongolia Plateau ?

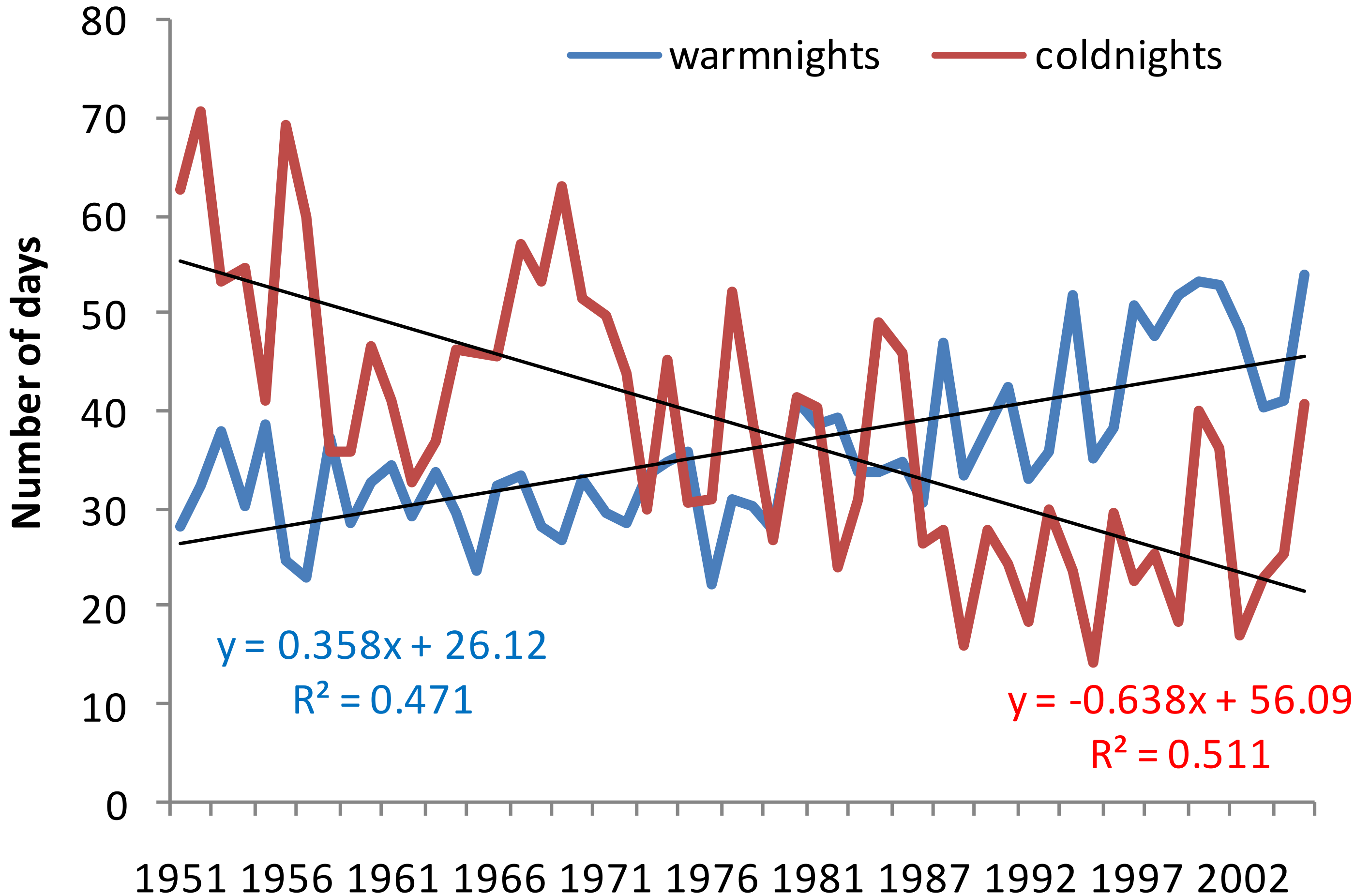
http://earthobservatory.nasa.gov/IOTD/view.php?id=36699

Comparison of trend in growing season length (GSL) among three biomes



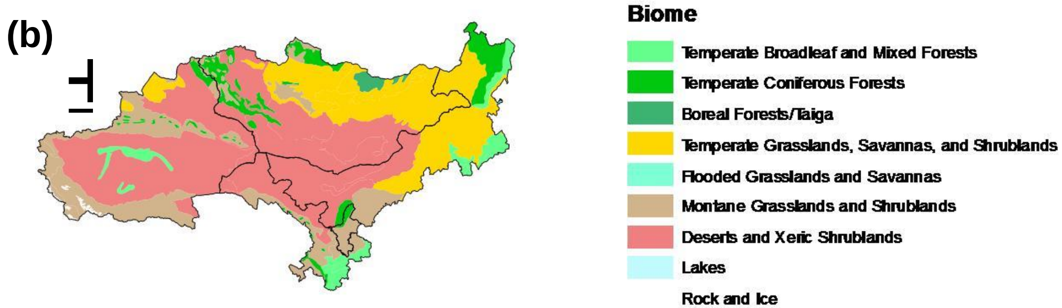
Lu et al. 2009. ERL

Regional trend of warm nights and cold nights

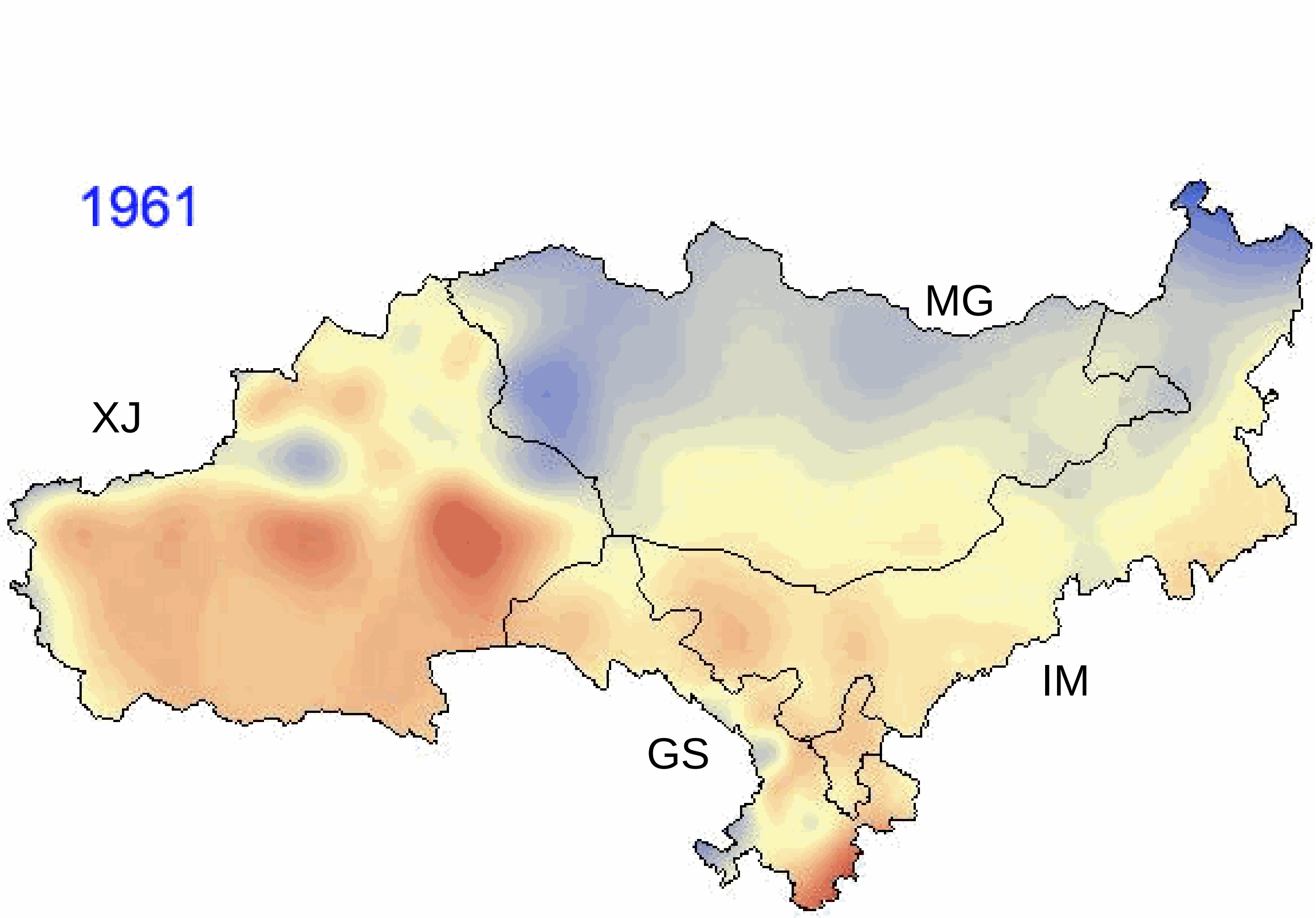


Lu et al. 2009. ERL

Dryland East Asia Region (DEAR)



Changes in annual temperature in DEA between 1961-2009



Changes in annual precipitation in DEA between 1961-2009

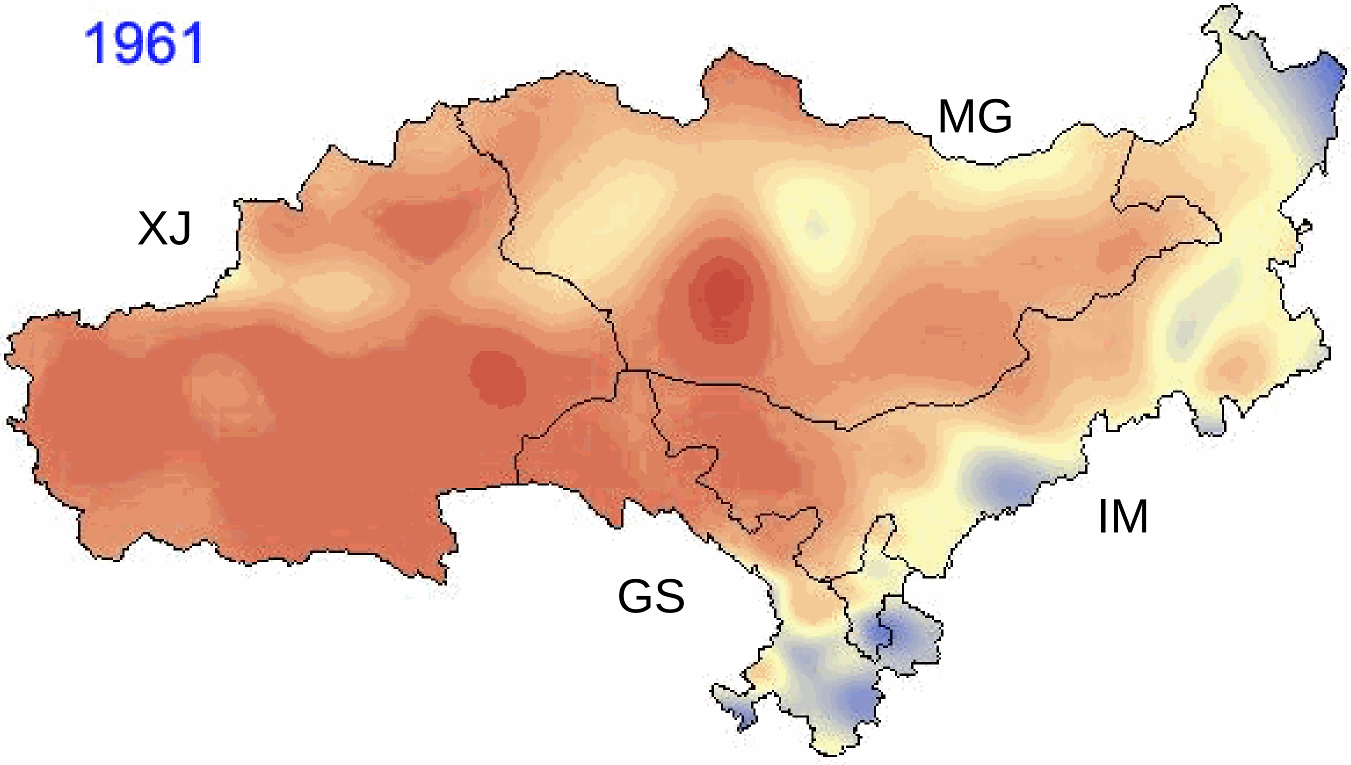
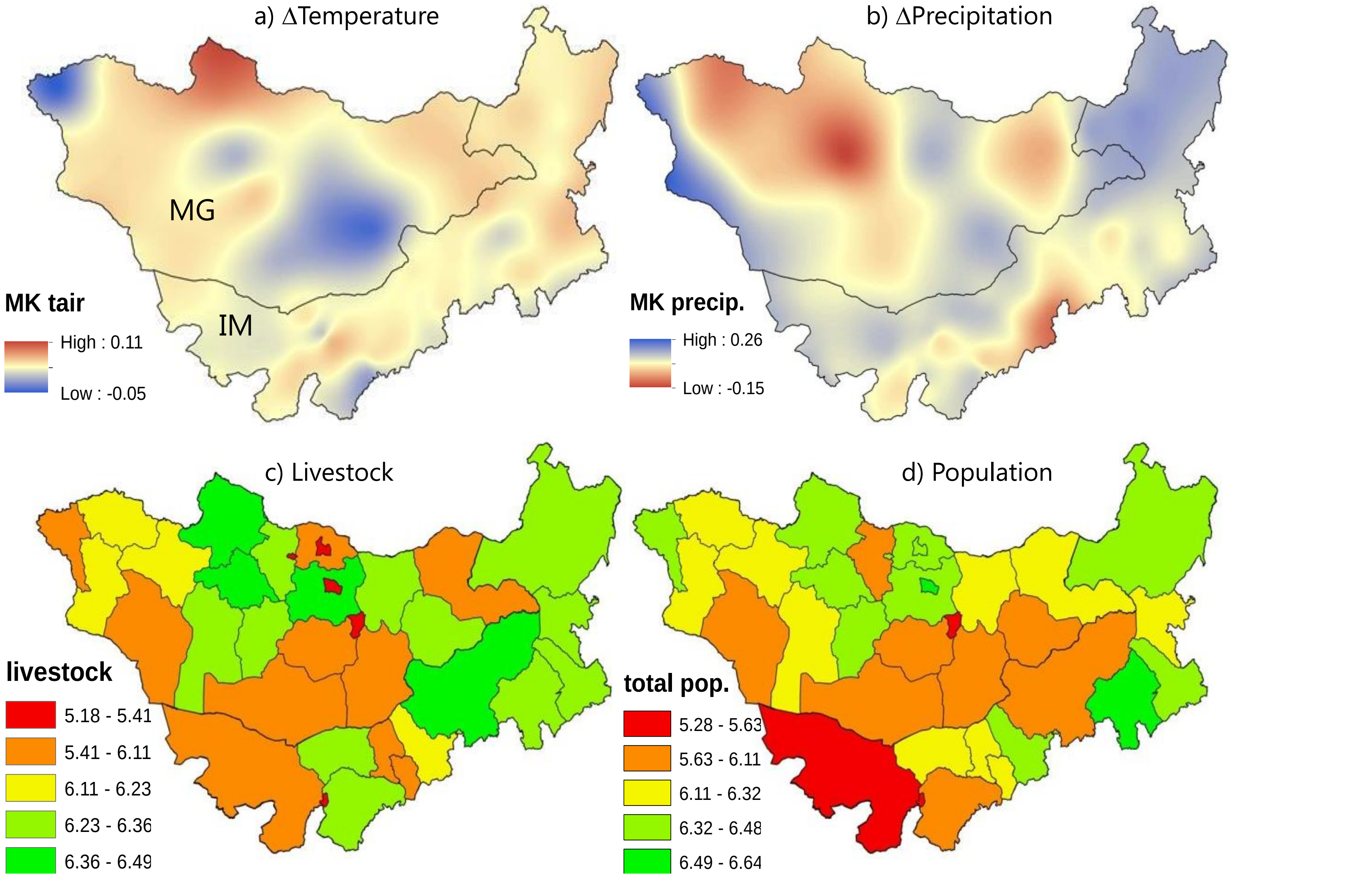


Fig. x. The contrasting distributions of four demonstrative variables on the Plateau showing the mismatches in space and time: a) rate of temperature increase (1955-2010), b) rate of precipitation change (1955-2010), c) log-transformed livestock of MG in 2009 and IM in 2003 (relative values to each country), and d) log-transformed population density of IM in 2000 and MG in 2010. Nonlinear trends were interpolated using the Mann-Kendall method.

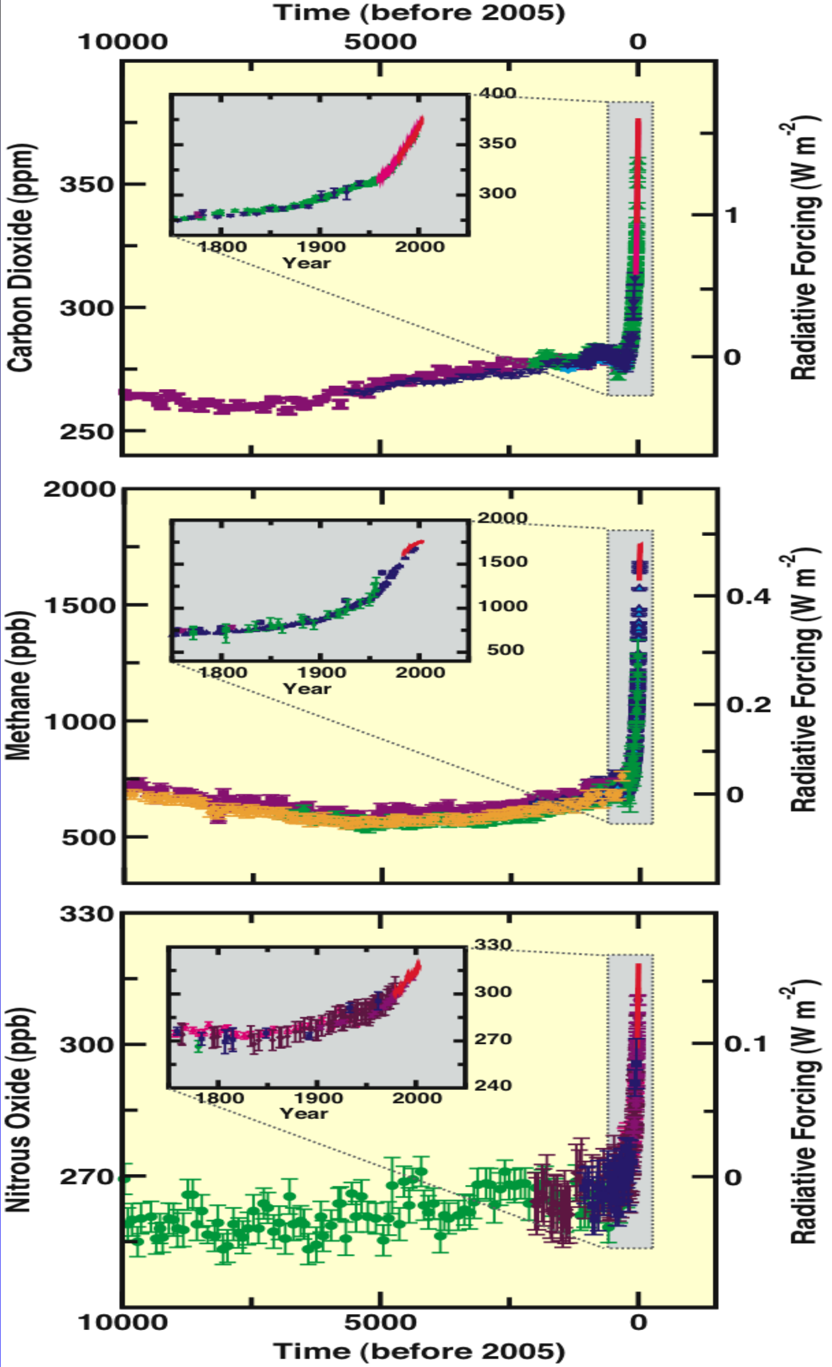


Human and Natural Drivers of Climate Change

CO_2, CH_4 and N_2O Concentrations

- far exceed pre-industrial values
- increased markedly since 1750 due to human activities

Relatively little variation before the industrial era



IPCC 2007

2. Current and Future Climate Change

Direct Observations of Recent Climate Change

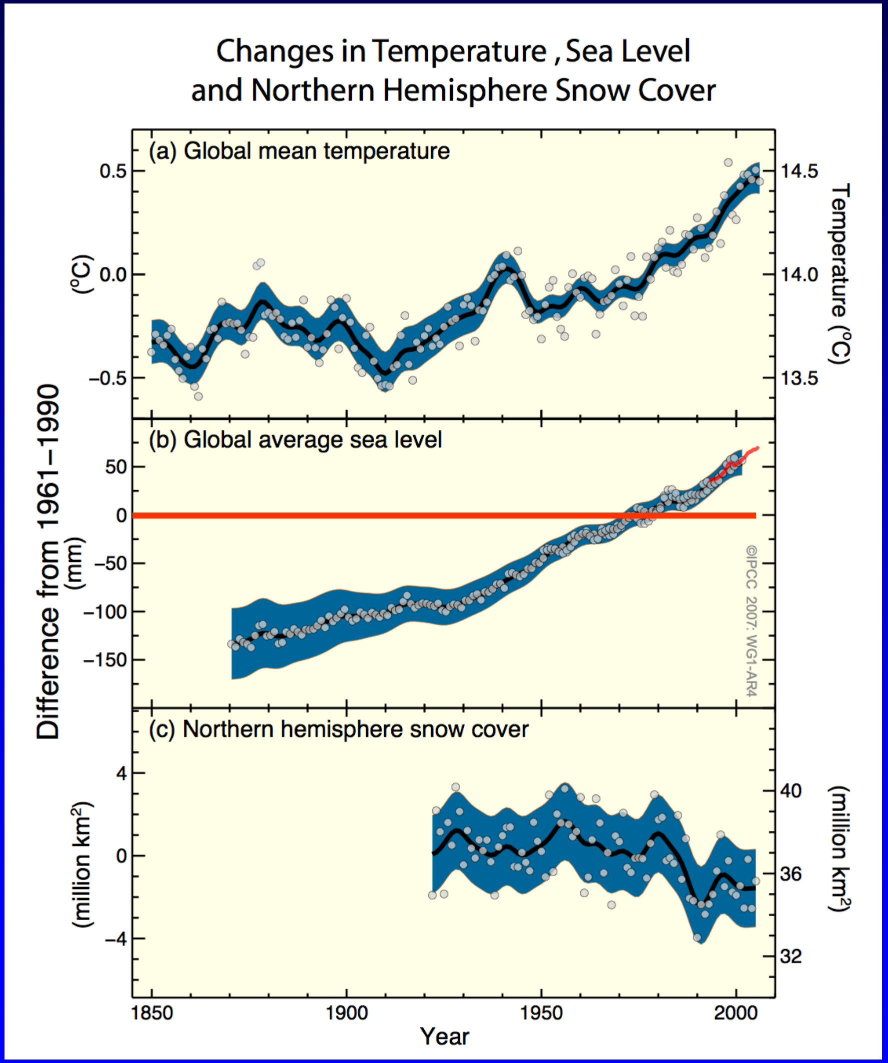
Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level.

Direct Observations of Recent Climate Change

Global mean temperature

Global average sea level

Northern hemisphere Snow cover



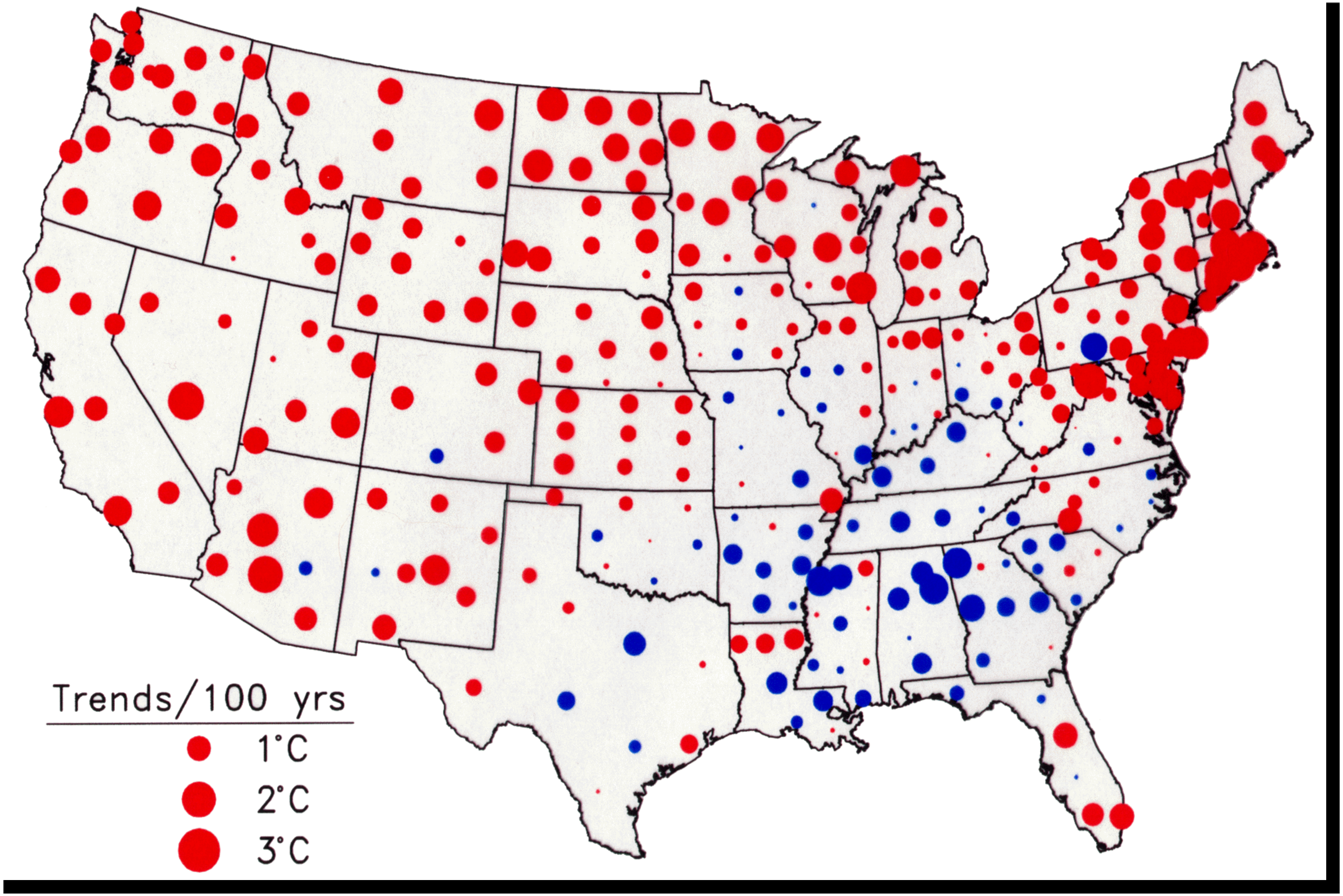
Direct Observations of Recent Climate Change

- Global average air temperature Updated 100-year linear trend of 0.74 [0.56 to 0.92] ^{o}C for 1906-2005

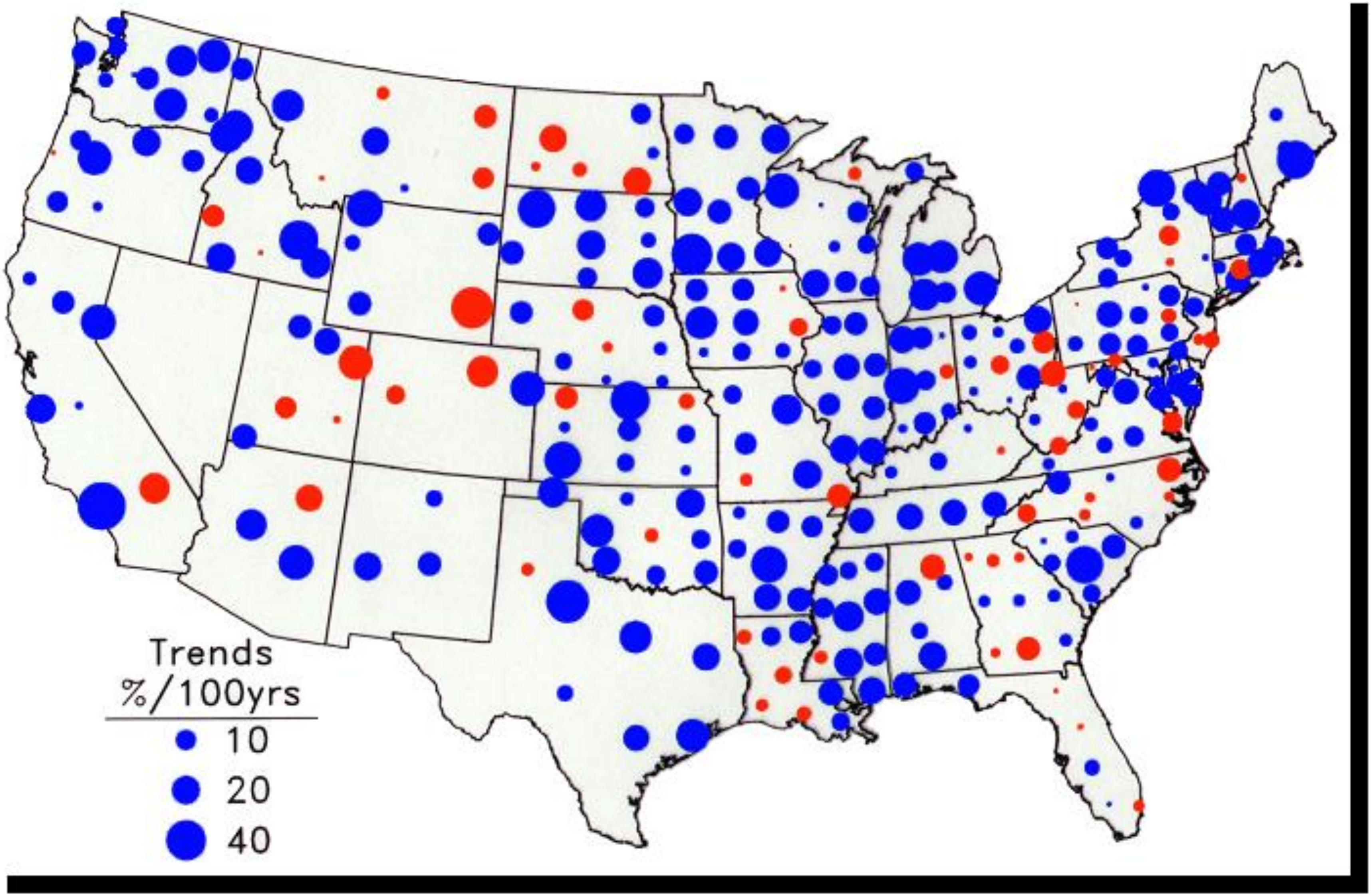
- Larger than corresponding trend of 0.6 [0.4 to 0.8] ^{o}C for 1901-2000 given in TAR

- Average ocean temperature increased to depths of at least 3000 m – ocean has absorbed 80% of heat added

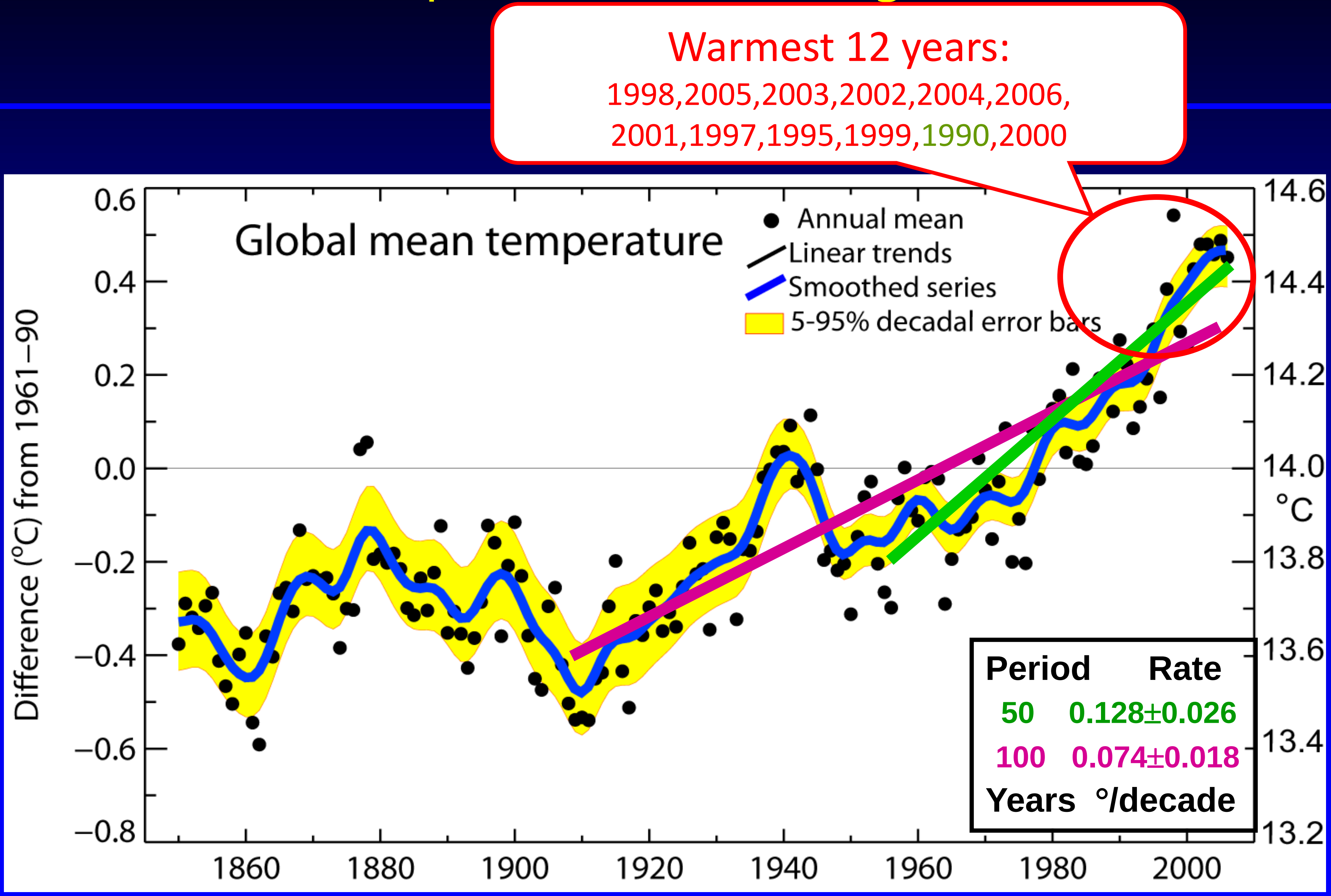
Temperature trends in the lower United States from 1901 to 1998



Precipitation trends from 1901 to 1998



Global mean temperatures are rising faster with time



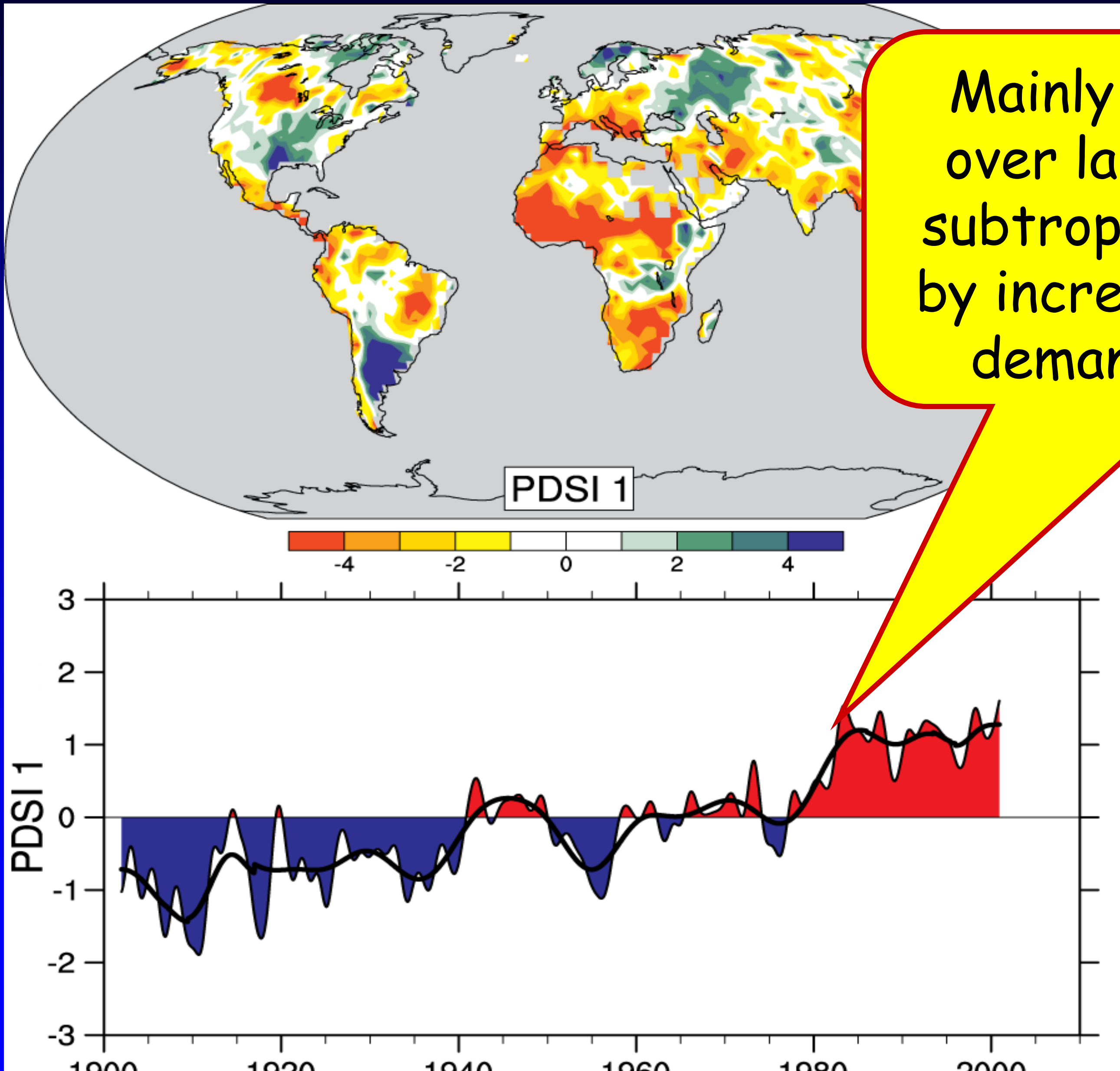
Changes in Precipitation, Increased Drought

- Significantly increased precipitation in eastern parts of North and South America, northern Europe and northern and central Asia.
- The frequency of heavy precipitation events has increased over most land areas - consistent with warming and increases of atmospheric water vapour
- Drying in the Sahel, the Mediterranean, southern Africa and parts of southern Asia.
- More intense and longer droughts observed since the 1970s, particularly in the tropics and subtropics.

Other changes in Extreme Events

- Widespread changes in extreme temperatures observed
- Cold days, cold nights and frost less frequent
- Hot days, hot nights, and heat waves more frequent
- Observational evidence for an increase of intense tropical cyclone activity in the North Atlantic since about 1970, correlated with increases of tropical sea surface temperatures

Drought is increasing most places

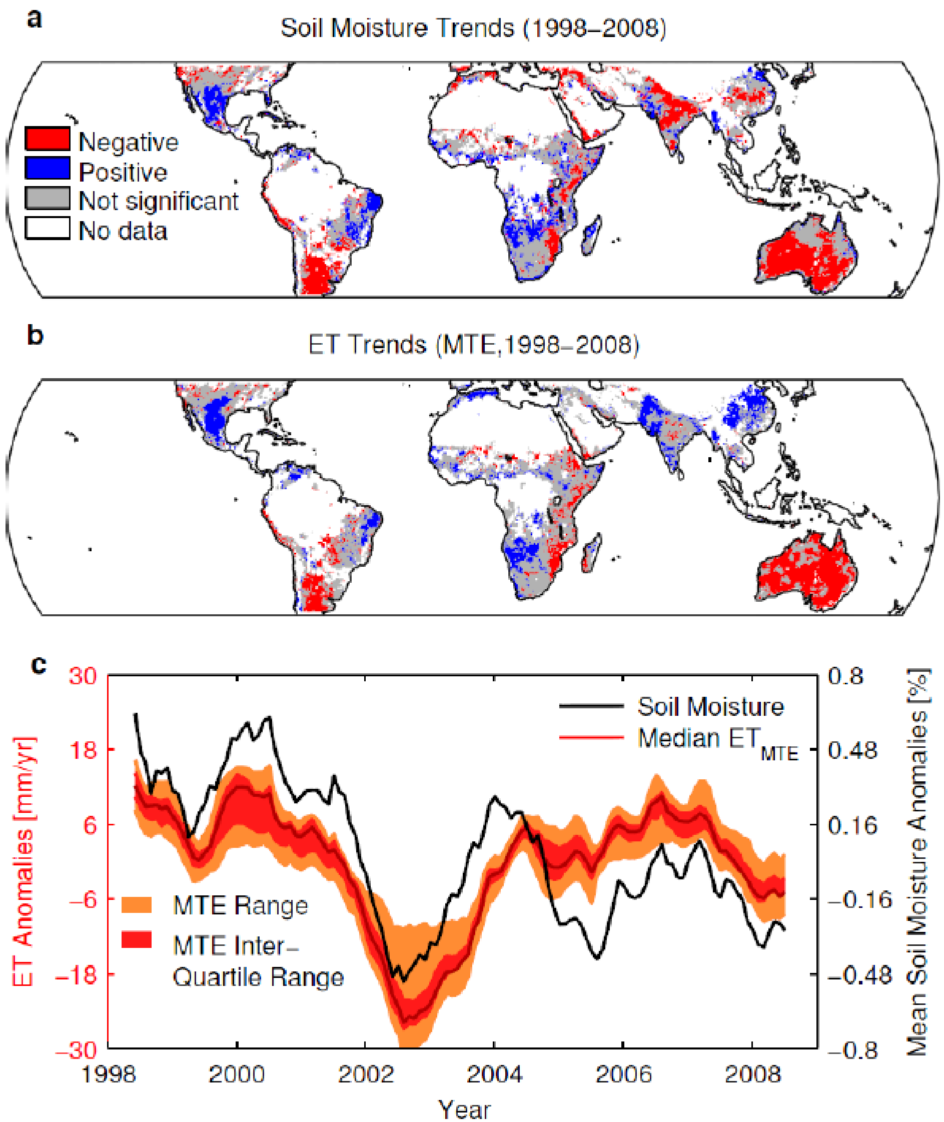


Mainly decrease in rain over land in tropics and subtropics, but enhanced by increased atmospheric demand with warming

Severity Index (PDSI) for 1900 to 2002.

The time series (below) accounts for most of the trend in PDSI.

Global annual evapotranspiration (ET) increased on average by 7.1 mm/yr per decade from 1982 to 1997. After that, coincident with the last major El Nin˜o event in 1998, the global ET increase had ceased until 2008. This change was driven primarily by moisture limitation in the Southern Hemisphere, particularly Africa and Australia.



Jung et al. (2010). Nature.

Projections of Future Changes in Climate

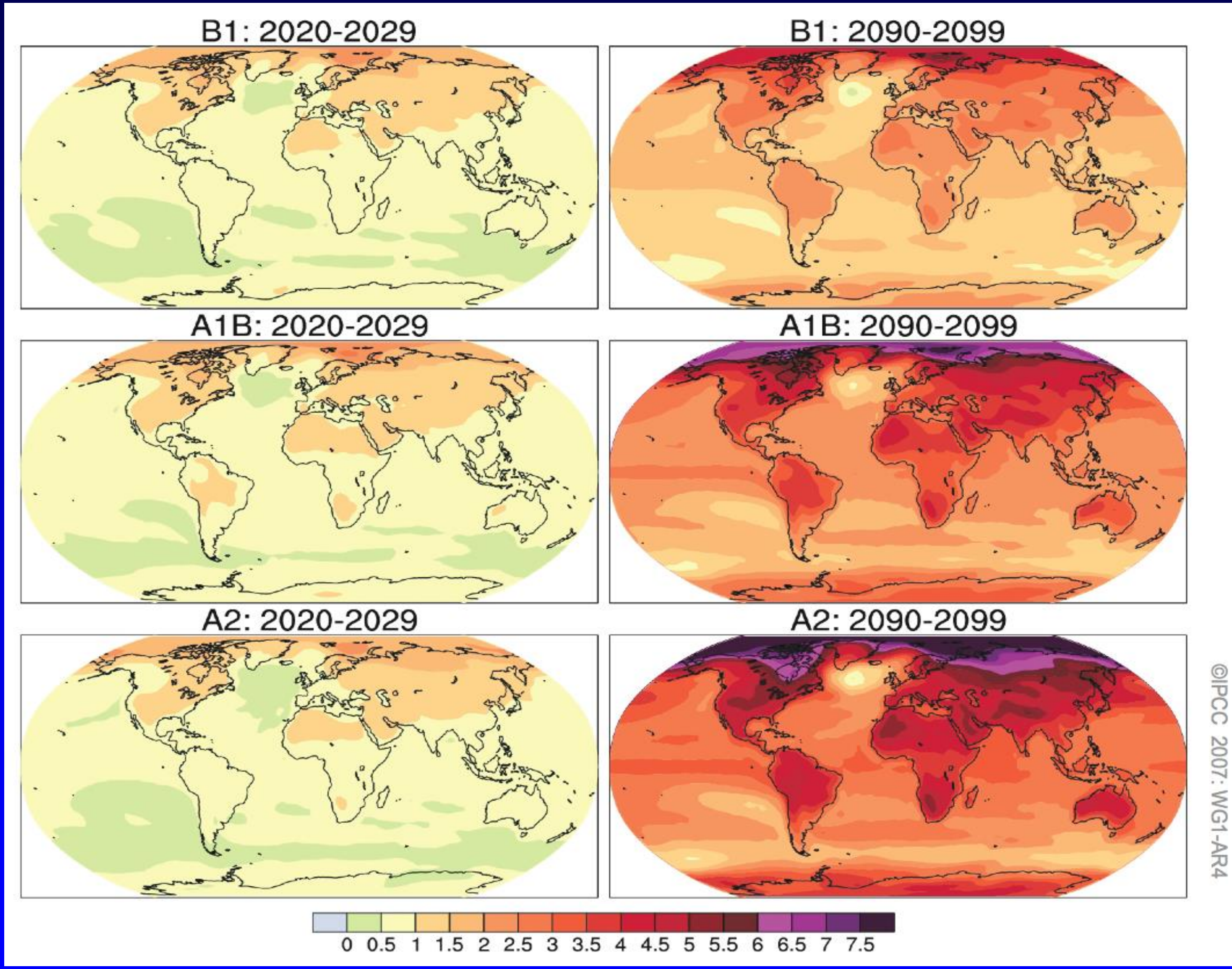
- For the **next two decades** a warming of about **0.2°C per decade** is projected for a range of SRES emission scenarios.
- **Even if the concentrations** of all greenhouse gases and aerosols had been **kept constant** at year 2000 levels, a further warming of about **0.1°C per decade** would be expected.
- Earlier IPCC projections of 0.15 to 0.3 ^{o}C per decade can now be compared with **observed values of 0.2 ^{o}C**

Projections of Future Changes in Climate

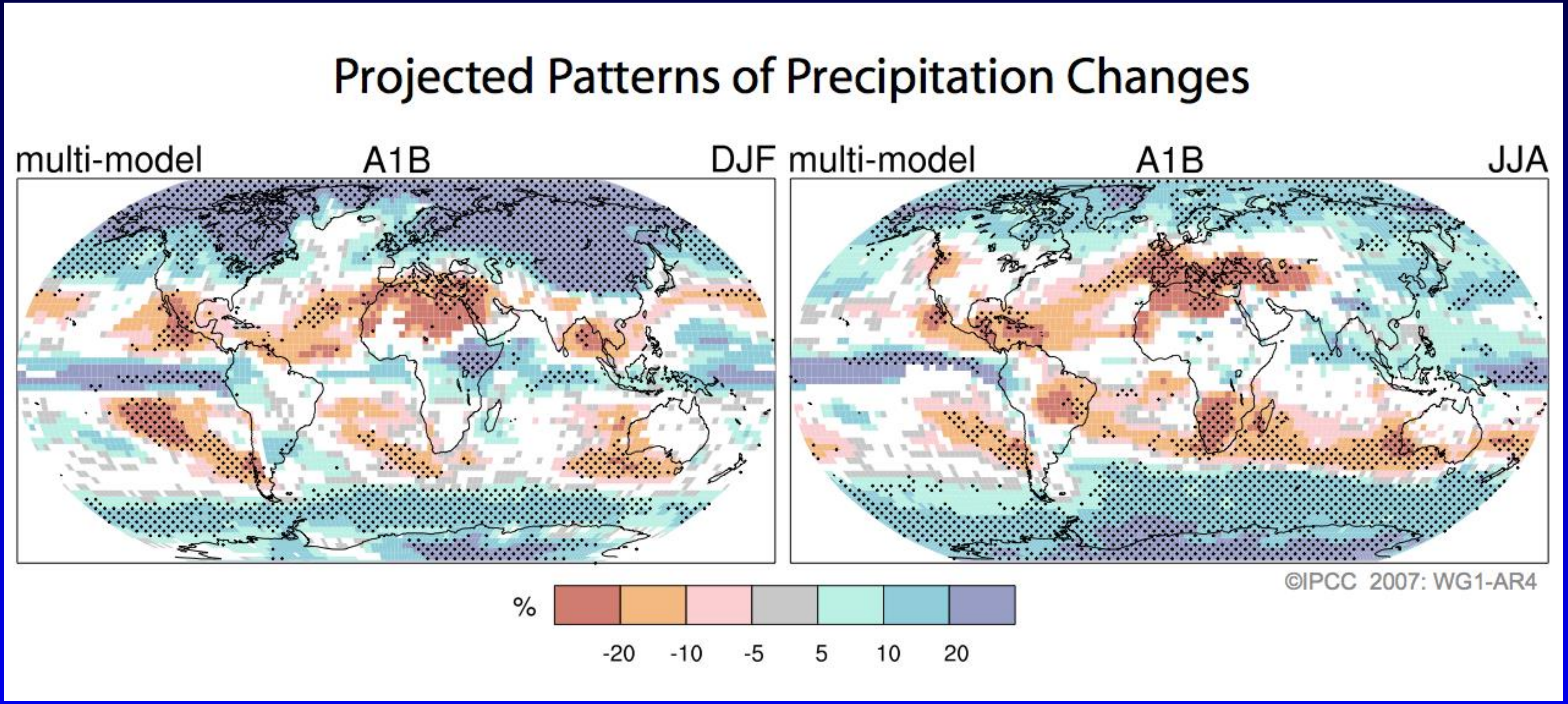
Projected warming in 21st century expected to be

greatest over land and at most high northern latitudes

and least over the Southern Ocean and parts of the North Atlantic Ocean



Projections of Future Changes in Climate



Precipitation increases *very likely* in high latitudes

Decreases *likely* in most subtropical land regions

Projections of Future Changes in Climate

There is now higher confidence in projected patterns of warming and other regional-scale features, including changes in wind patterns, precipitation, and some aspects of extremes and of ice.

PROJECTIONS OF FUTURE CHANGES IN CLIMATE

- Snow cover is projected to contract
- Widespread increases in thaw depth most permafrost regions
- Sea ice is projected to shrink in both the Arctic and Antarctic
- In some projections, Arctic late-summer sea ice disappears <u>almost entirely by the latter part of the 21st century</u>

PROJECTIONS OF FUTURE CHANGES IN CLIMATE

- *Very likely* that hot extremes, heat waves, and heavy precipitation events will continue to become more frequent
- *Likely* that future tropical cyclones will become more intense, with larger peak wind speeds and more heavy precipitation
  - **less confidence in decrease of total number**
- Extra-tropical storm tracks projected to move poleward with consequent changes in wind, precipitation, and temperature patterns

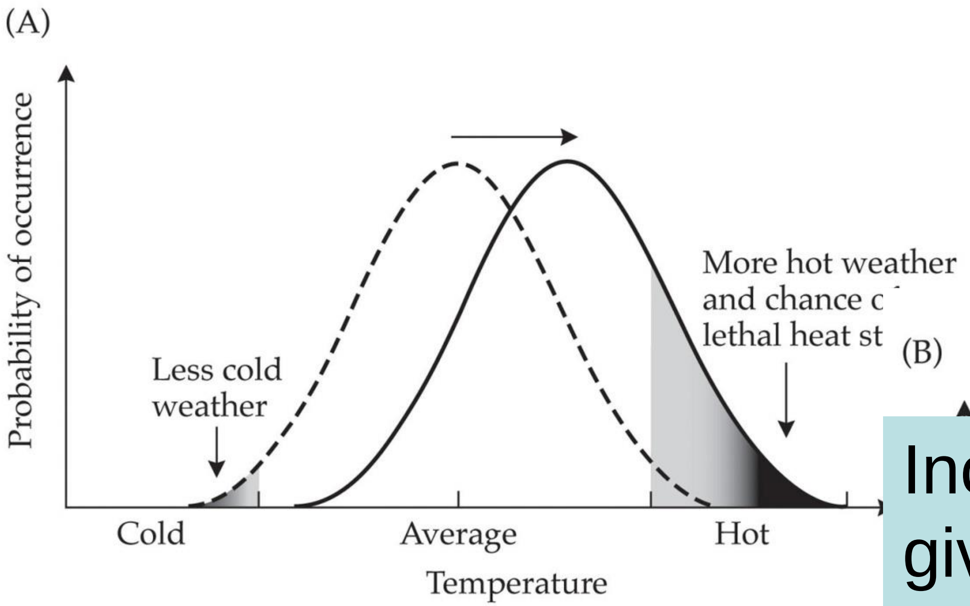
PROJECTIONS OF FUTURE CHANGES IN CLIMATE

- Based on current model simulations, it is *very likely* that the meridional overturning circulation (MOC) of the Atlantic Ocean will slow down during the 21st century.
  - longer term changes not assessed with confidence
- Temperatures in the Atlantic region are projected to increase despite such changes due to the much larger warming associated with projected increases of greenhouse gases.

PROJECTIONS OF FUTURE CHANGES IN CLIMATE

- Anthropogenic warming and sea level rise would continue for centuries due to the timescales associated with climate processes and feedbacks, even if greenhouse gas concentrations were to be stabilized.
- Temperatures in excess of 1.9 to 4.6°C warmer than pre-industrial sustained for millennia…eventual melt of the Greenland ice sheet. Would raise sea level by 7 m. Comparable to 125,000 years ago.

3. Predicted Biological Impacts



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Sudden Shift!

Map Turtles (*Graptemys spp*)

Incubation at 25 degrees C. gives a high percentage of male turtles, while eggs kept at 30 to 35 degrees C. yield females, at least in *G. pseudogeographica*, *G. geographica*, and *G. ouachitensis*.

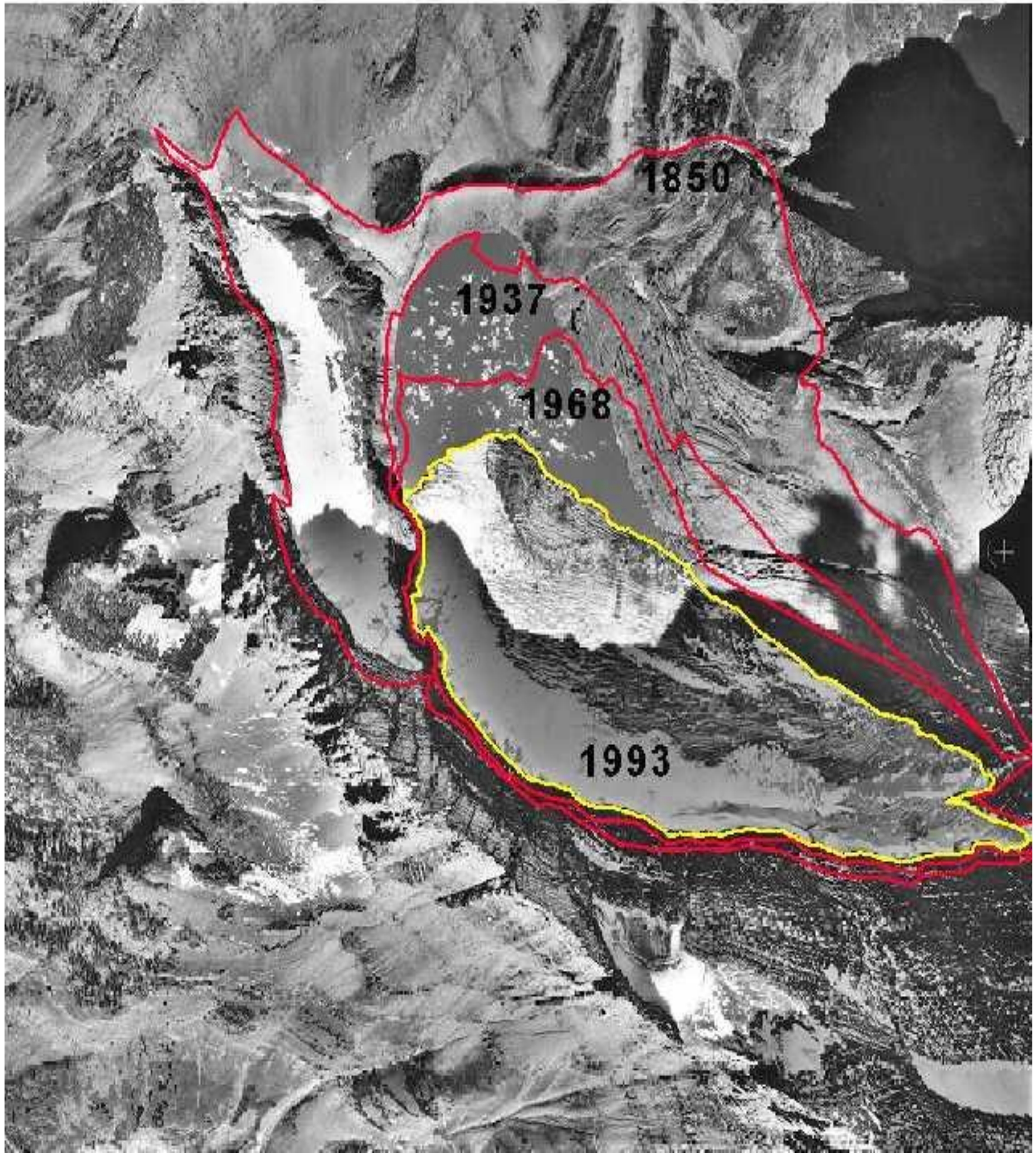
PRINCIPLES OF CONSERVATION BIOLOGY, Third Edition, Figure 10.10 (Part 2) © 2005 Sinauer Associates, Inc.

28 ºC and 35 ºC as threshold temperature for incubation.

4. Observed Biological Impacts

Arctic sea ice gets thinner

Grinnell Glacier 1850-1993
Aerial View



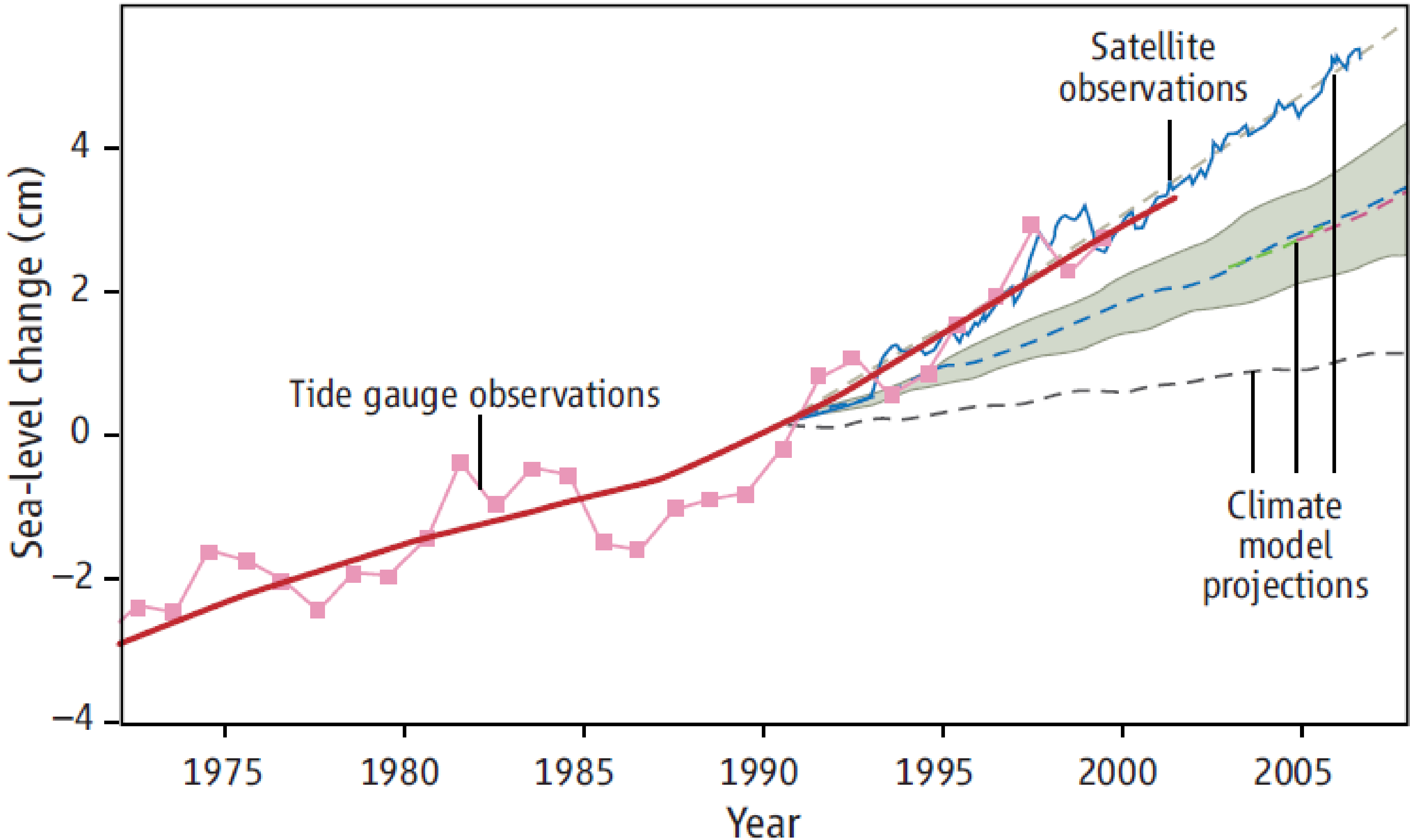
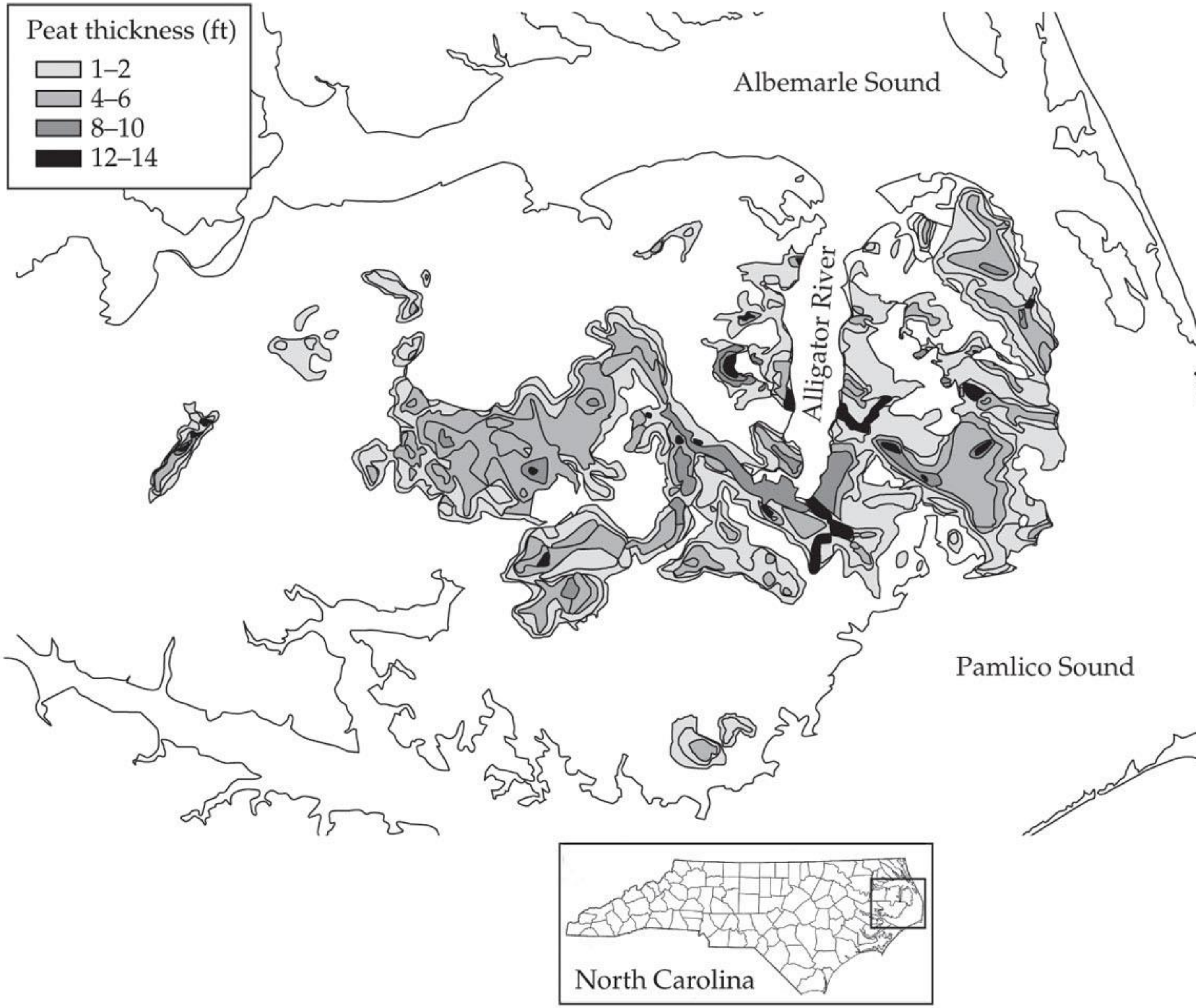
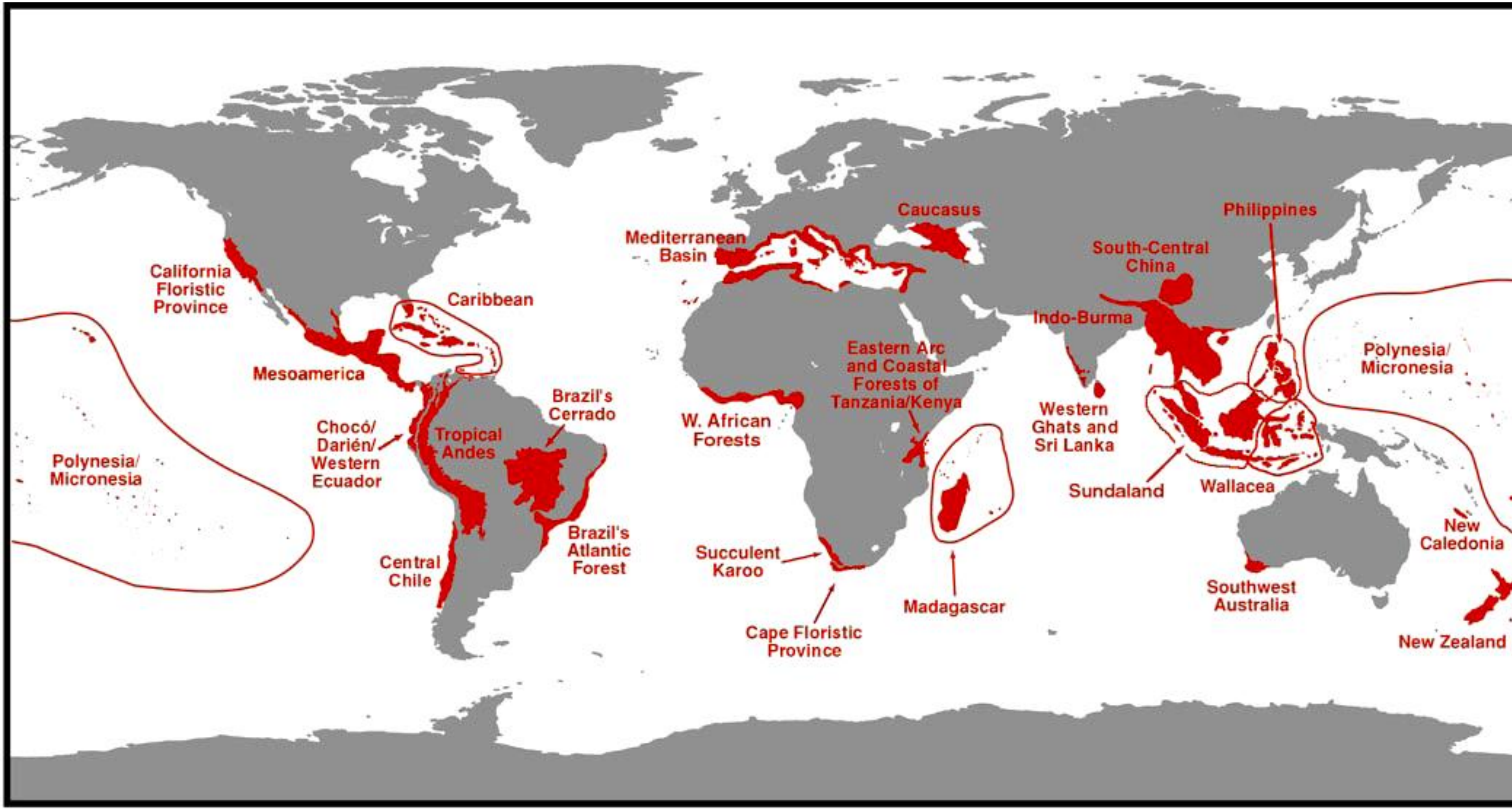


Fig. 8. Sea-level rise. Sea-level data are based primarily on tide gauges (annual, red) and satellite altimeter measurements (3-month data spacing, blue; up to mid-2006) and their trends.



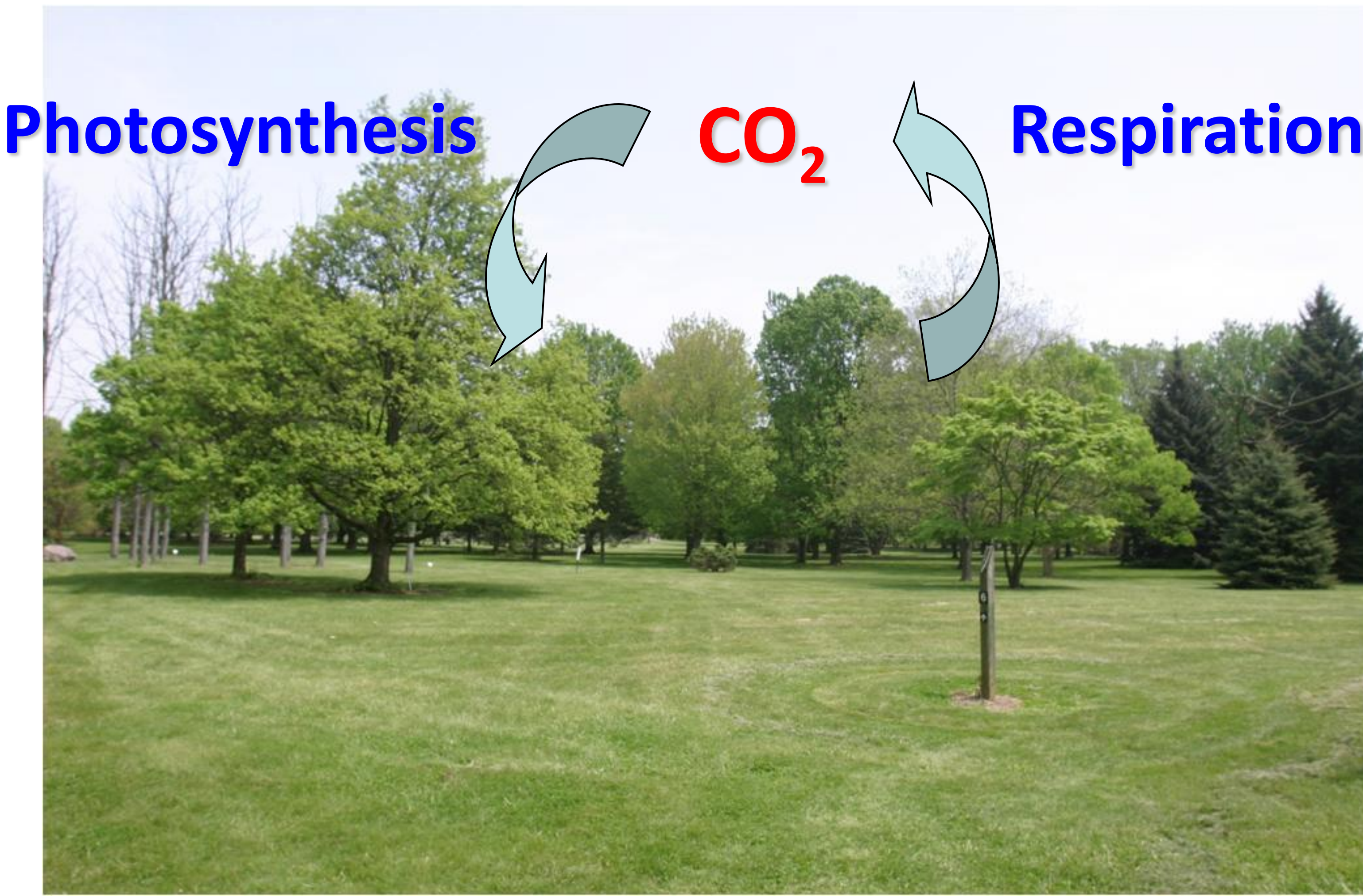
PRINCIPLES OF CONSERVATION BIOLOGY, Third Edition, **Case Study 10.3, Figure B**

The 25 hotspots, most in coastal areas that will be hit first by the rising seas.



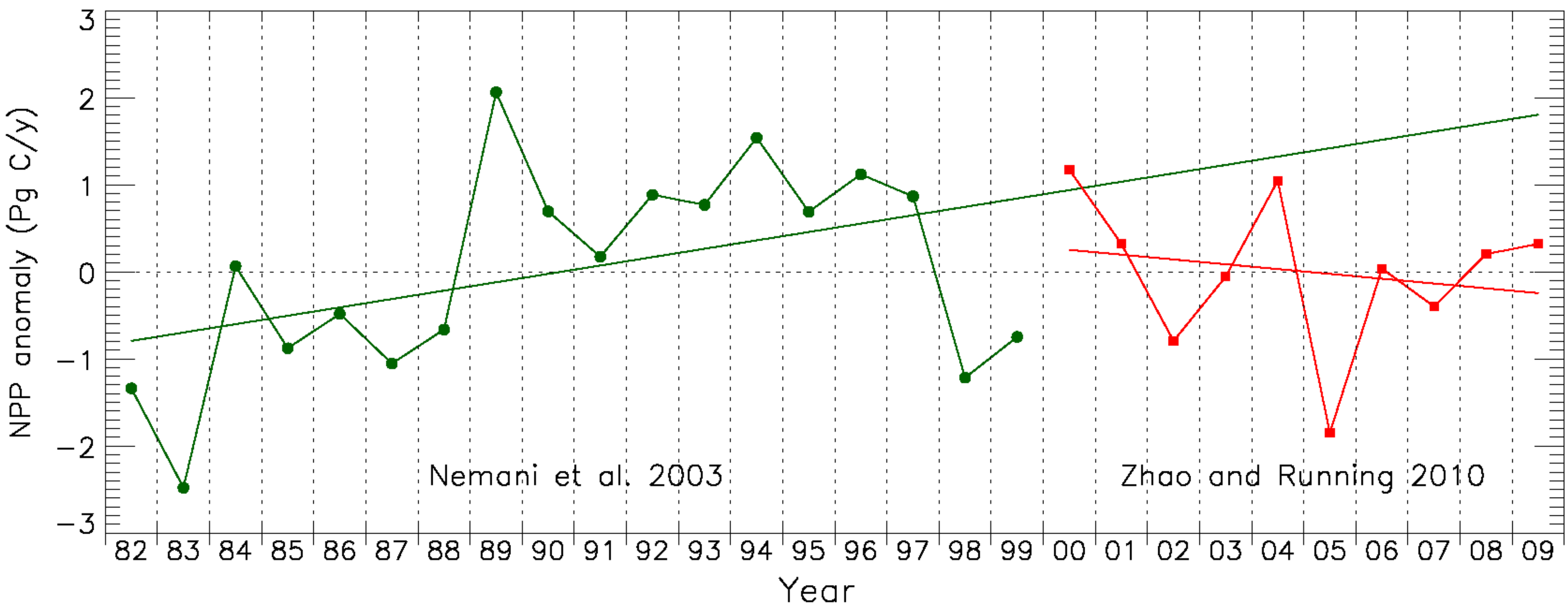
Myers *et al*. 2000

Keeping Carbon in Terrestrial Ecosystems to Battle Global Warming



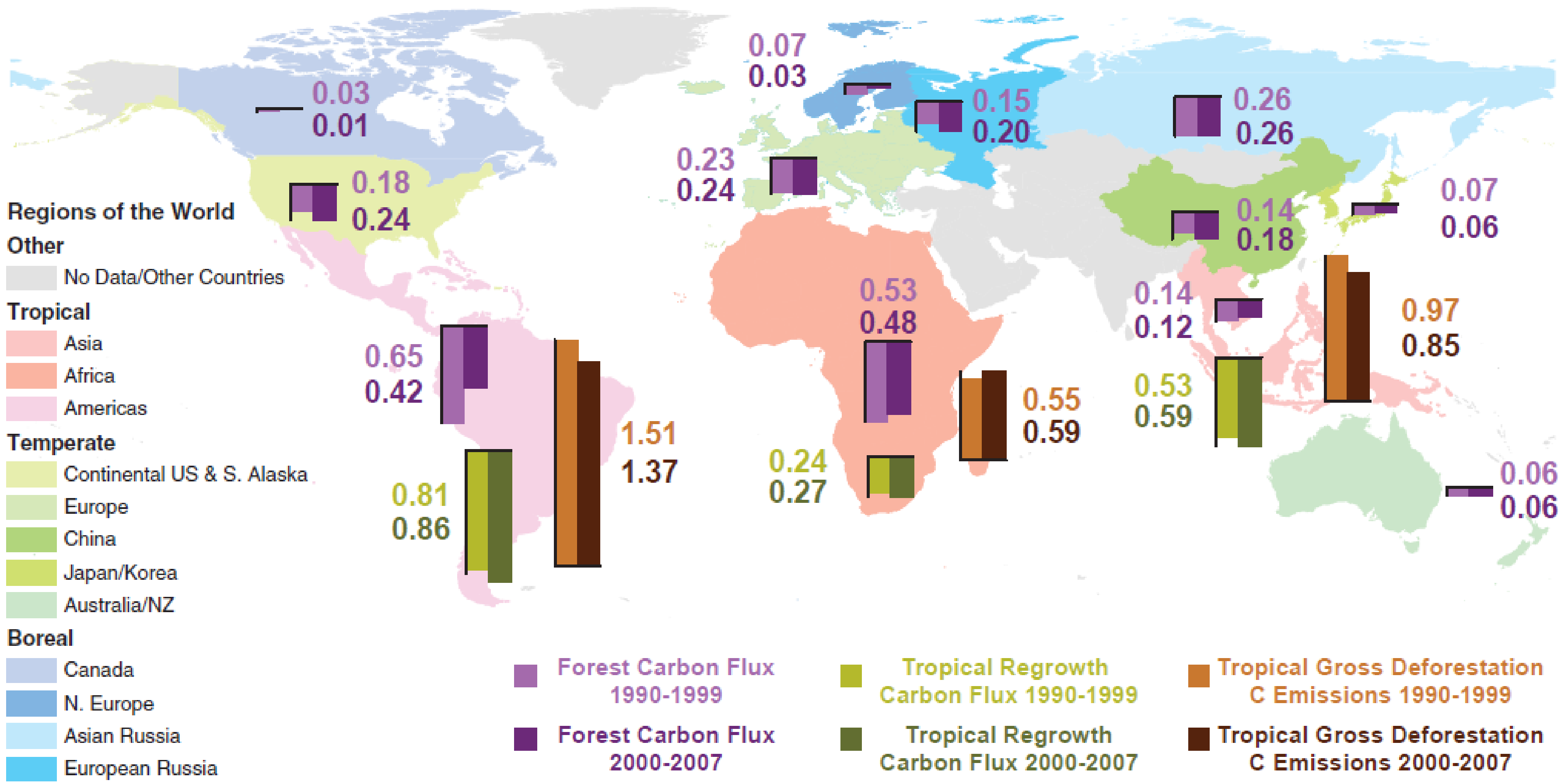
Global Perspective

Global NPP decreased from 2000 to 2009, with NPP over North Hemisphere continued increasing (winner) and over South Hemisphere decreased; Recent drying trend caused the reduction in NPP in SH.



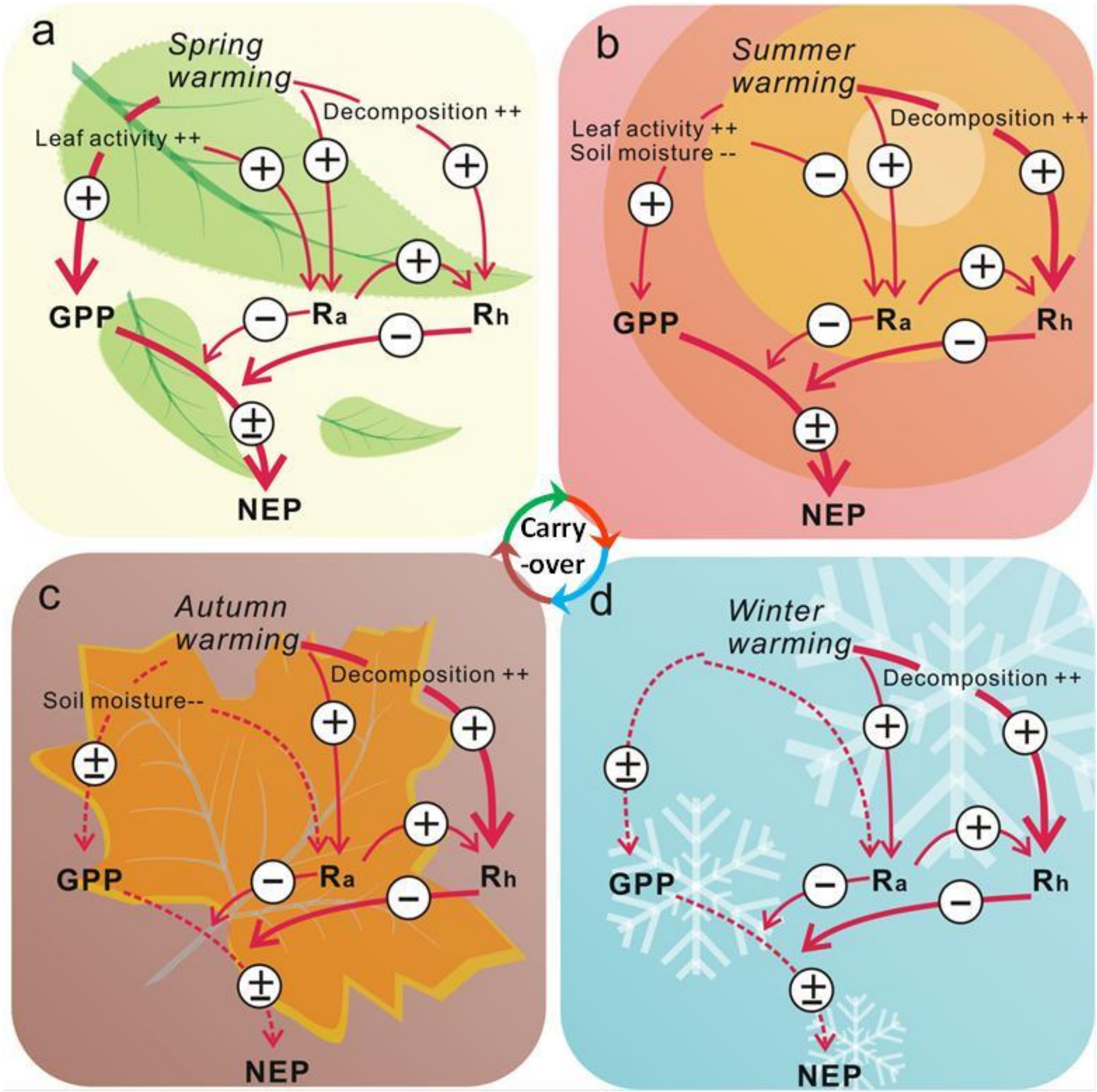
Zhao & Running (2010). Science

Carbon Sinks and Sources (Pg C yr^{-1}) in the World's Forests



Pan *et al*. (2011) *Science*

Ecosystem NPP, R_a & R_h respiration, and NEP in response directly to global warming in (a) spring, (b) summer, (c) autumn, and (d) winter.



Xia et al. (Nature-Geoscience), 2014

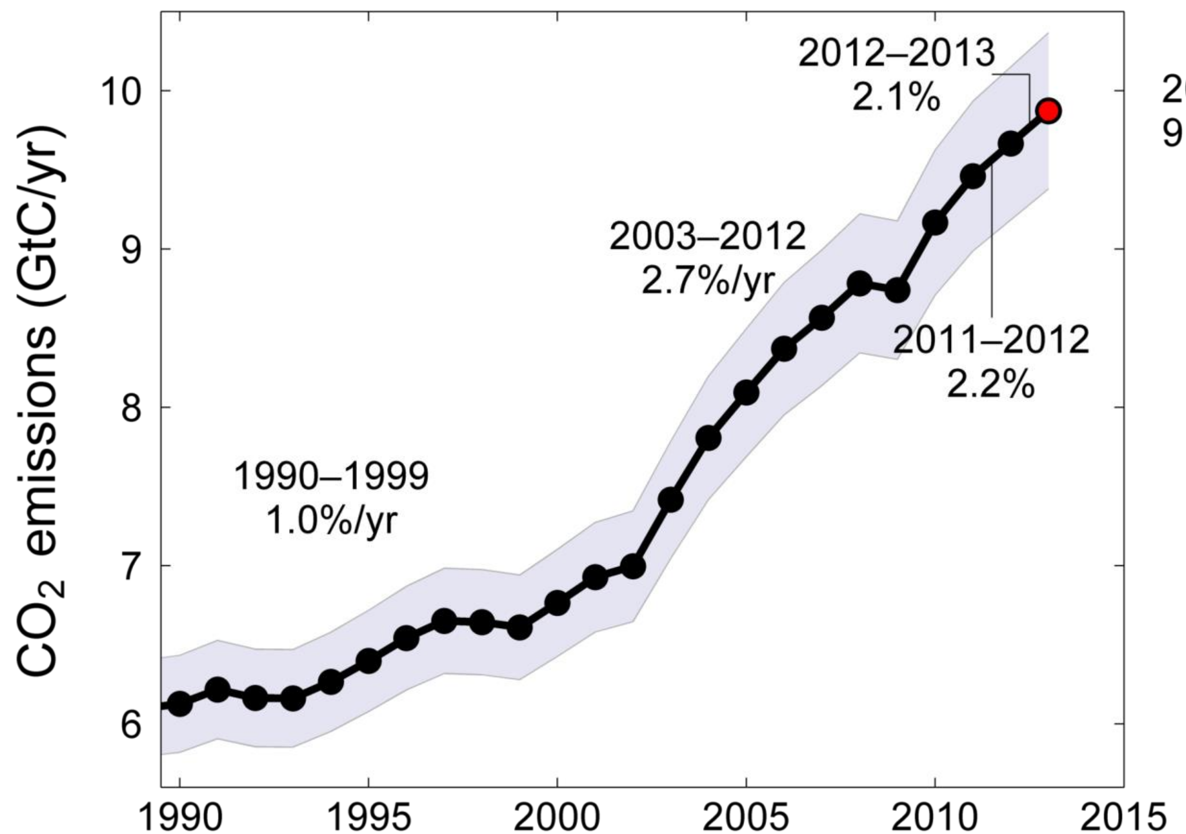
Fossil Fuel and Cement Emissions


Copyright: Global Carbon Project I Glynn Gorick

Fossil Fuel and Cement Emissions

Global fossil fuel and cement emissions: 9.7 ± 0.5 GtC in 2012, 58% over 1990

● Projection for 2013 : 9.9 ± 0.5 GtC, 61% over 1990



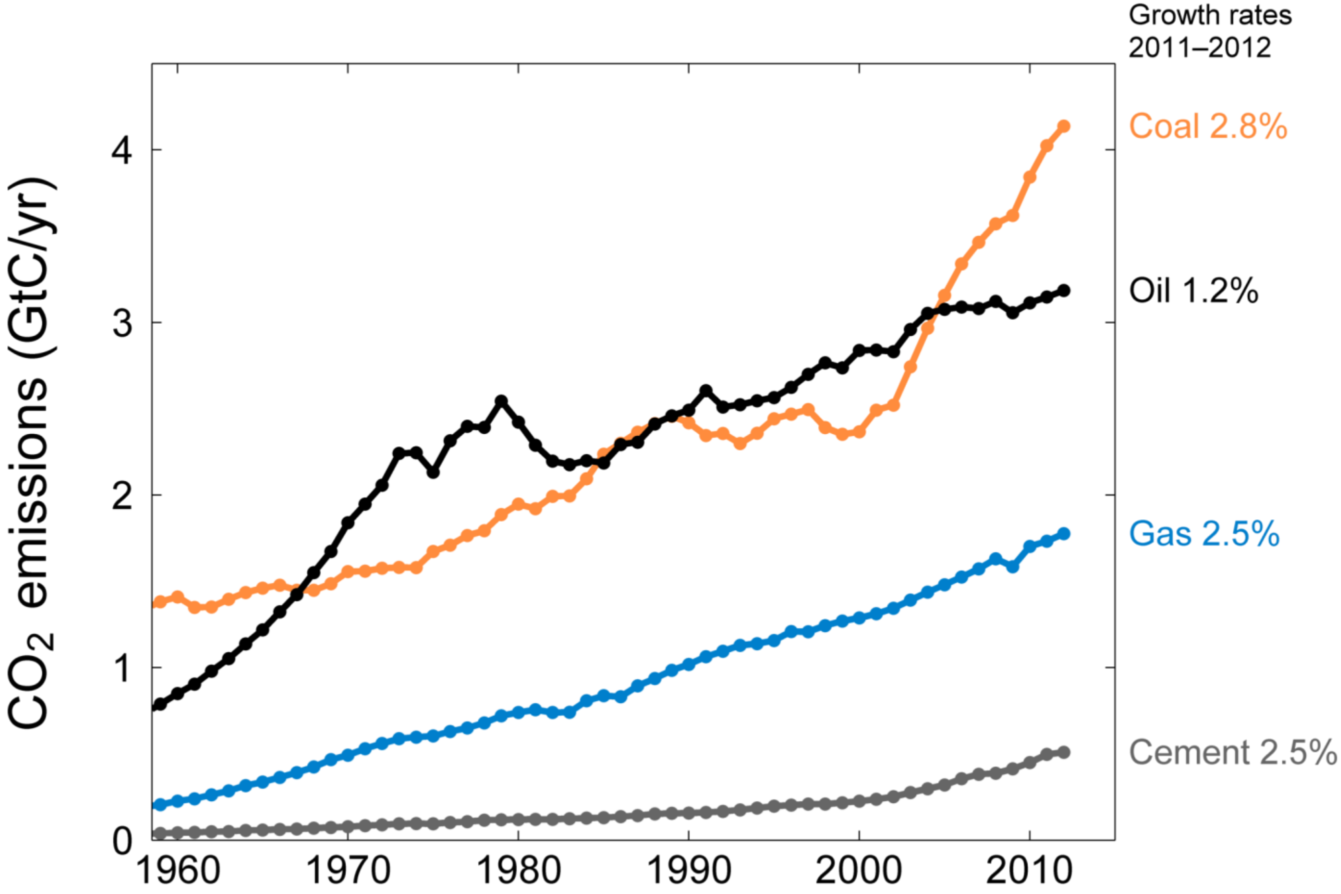
Uncertainty is ±5% for one standard deviation (IPCC "likely" range)

With leap year adjustment: 2012 growth rate is 1.9% and 2013 is 2.4%

Source: Le Quéré et al 2013; CDIAC Data; Global Carbon Project 2013

Emissions from Coal, Oil, Gas, Cement

Share of global emissions in 2012:
coal (43%), oil (33%), gas (18%), cement (5%), flaring (1%, not shown)

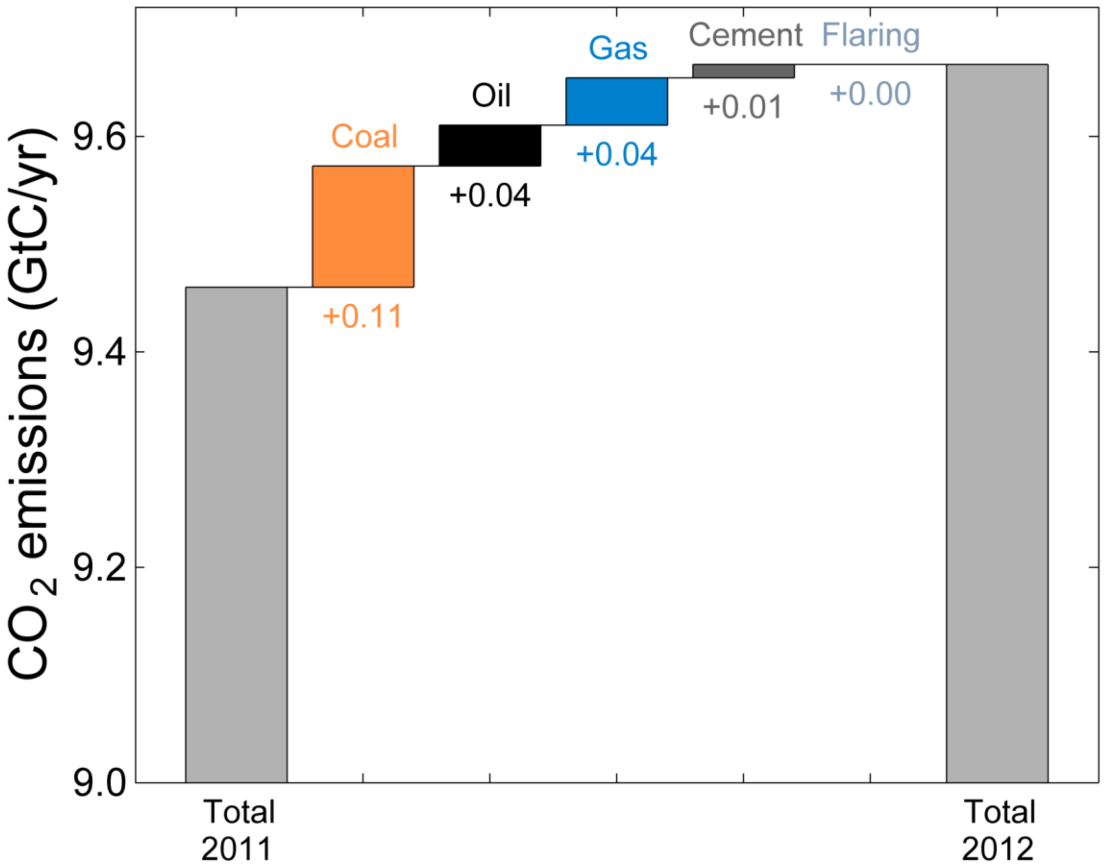


With leap year adjustment in 2012 growth rates are: coal 2.5%, oil 0.9%, gas 2.2%, cement 2.2%.

Source: CDIAC Data; Le Quéré et al 2013; Global Carbon Project 2013

Fossil Fuel and Cement Emissions Growth 2012

Coal accounted for 54% of the growth in global emissions in 2012, oil (18%), gas (21%), and cement (6%).



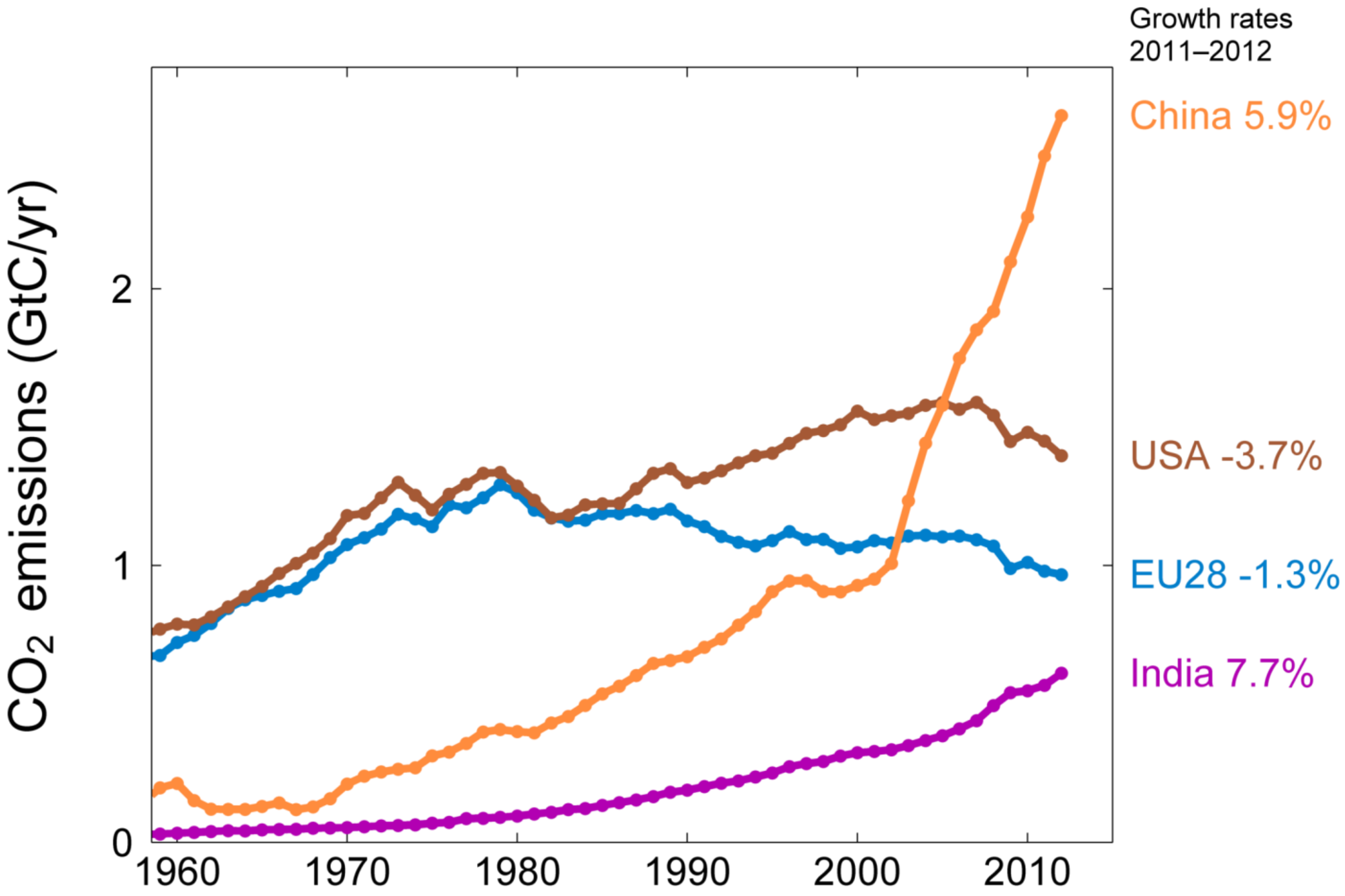
Many countries increased dependence on coal in 2012:

Emissions from coal grew 4.2% in Germany, 5.6% in Japan, 3.0% in the EU28, 10.2% in India.

Source: CDIAC Data; Le Quéré et al 2013; Global Carbon Project 2013

Top Fossil Fuel Emitters (Absolute)

Top four emitters in 2012 covered 58% of global emissions
China (27%), United States (14%), EU28 (10%), India (6%)



With leap year adjustment in 2012 growth rates are: China 5.6%, USA -4.0%, EU -1.6%, India 7.4%.

Source: CDIAC Data; Le Quéré et al 2013; Global Carbon Project 2013

Fossil Fuel and Cement Emissions Growth 2012

China accounted for 71% of the global emissions growth in 2012, India 21%, Japan 11%.
The USA contributed to a decrease in emissions.

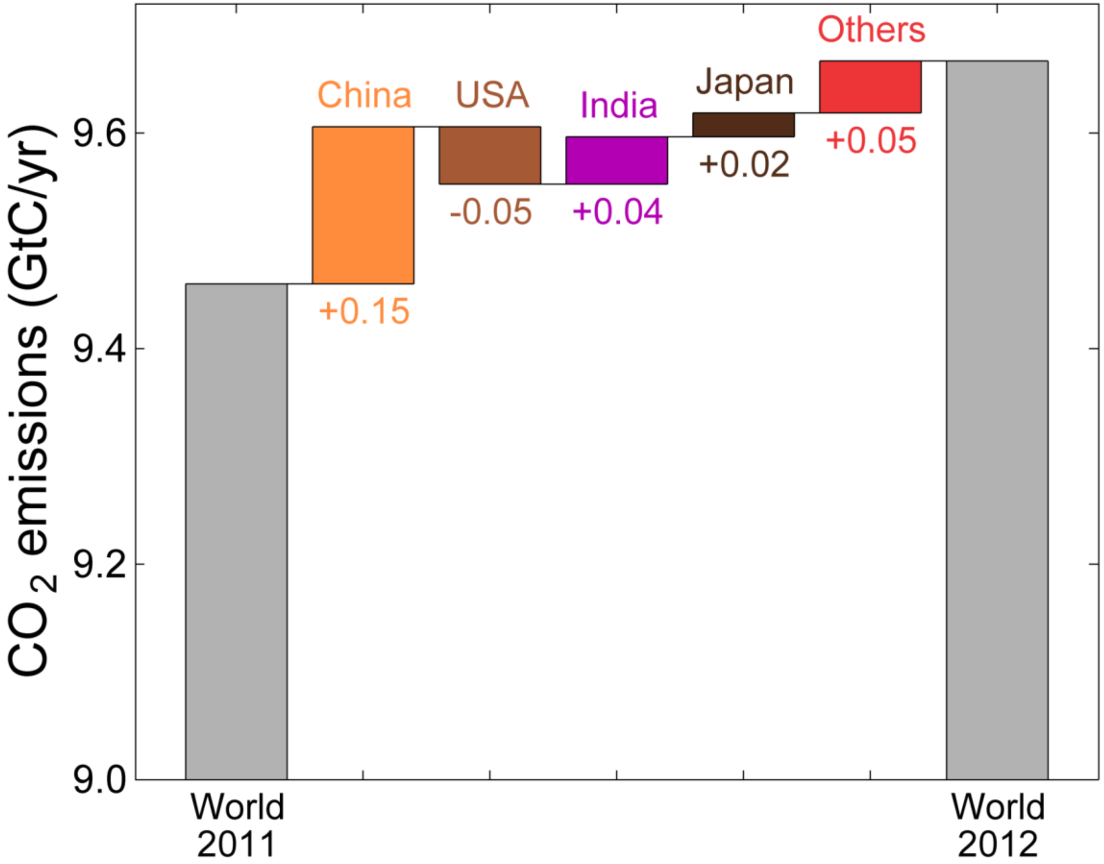
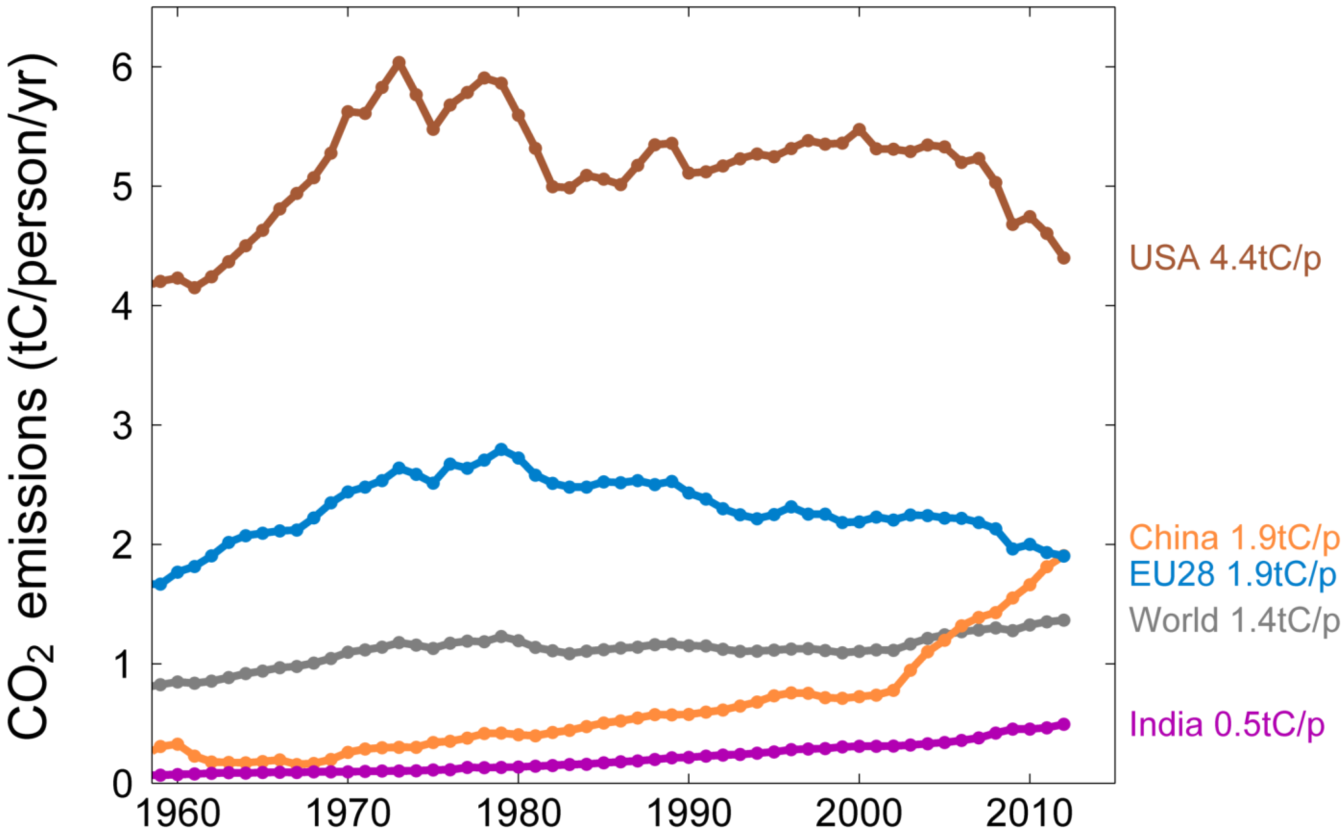


Figure shows the top four countries contributing to emissions changes in 2012

Source: CDIAC Data; Le Quéré et al 2013; Global Carbon Project 2013

Top Fossil Fuel Emitters (Per Capita)

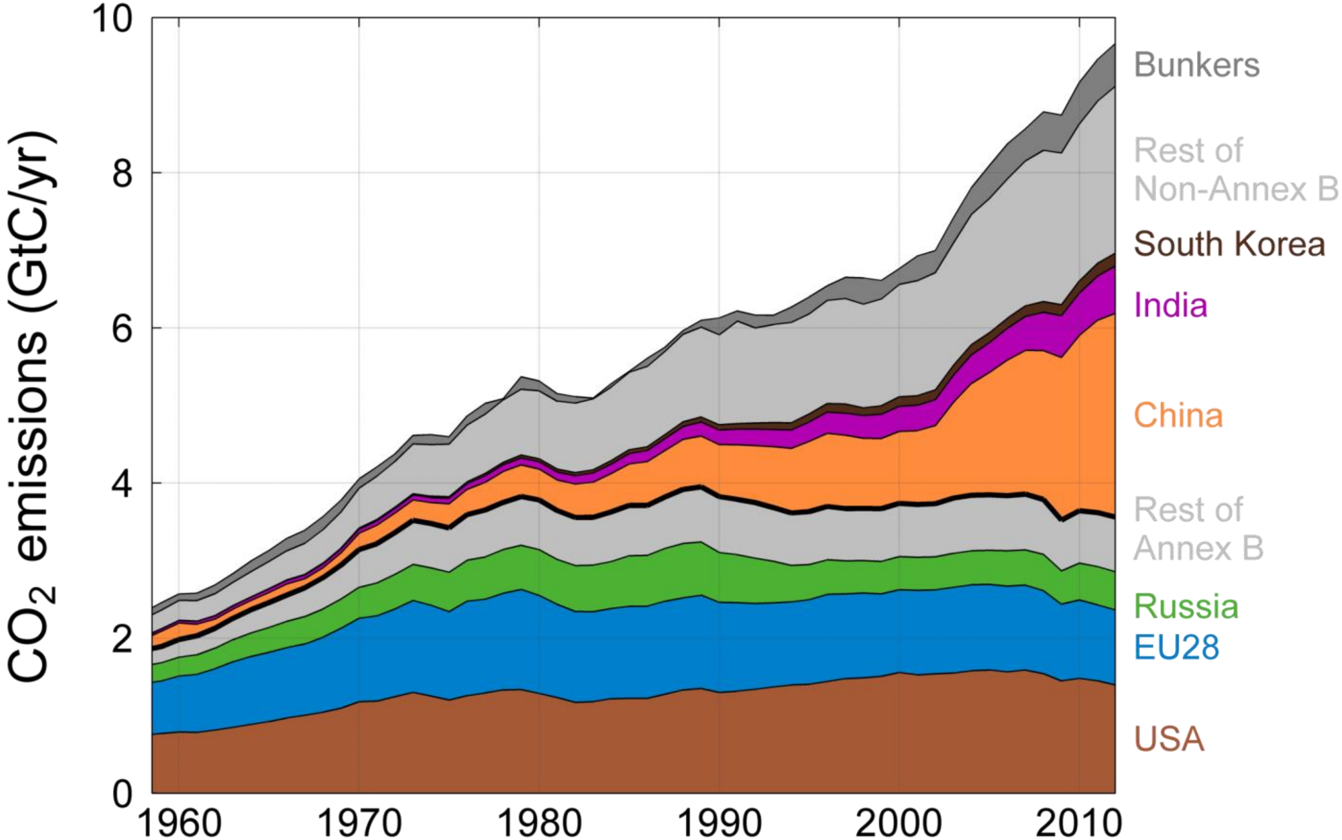
Average per capita emissions in 2012
China is growing rapidly and the US is declining fast



Source: CDIAC Data; Le Quéré et al 2013; Global Carbon Project 2013

Breakdown of Global Emissions by Country

Emissions from Annex B countries have slightly declined
Emissions from non-Annex B countries have increased rapidly in recent years

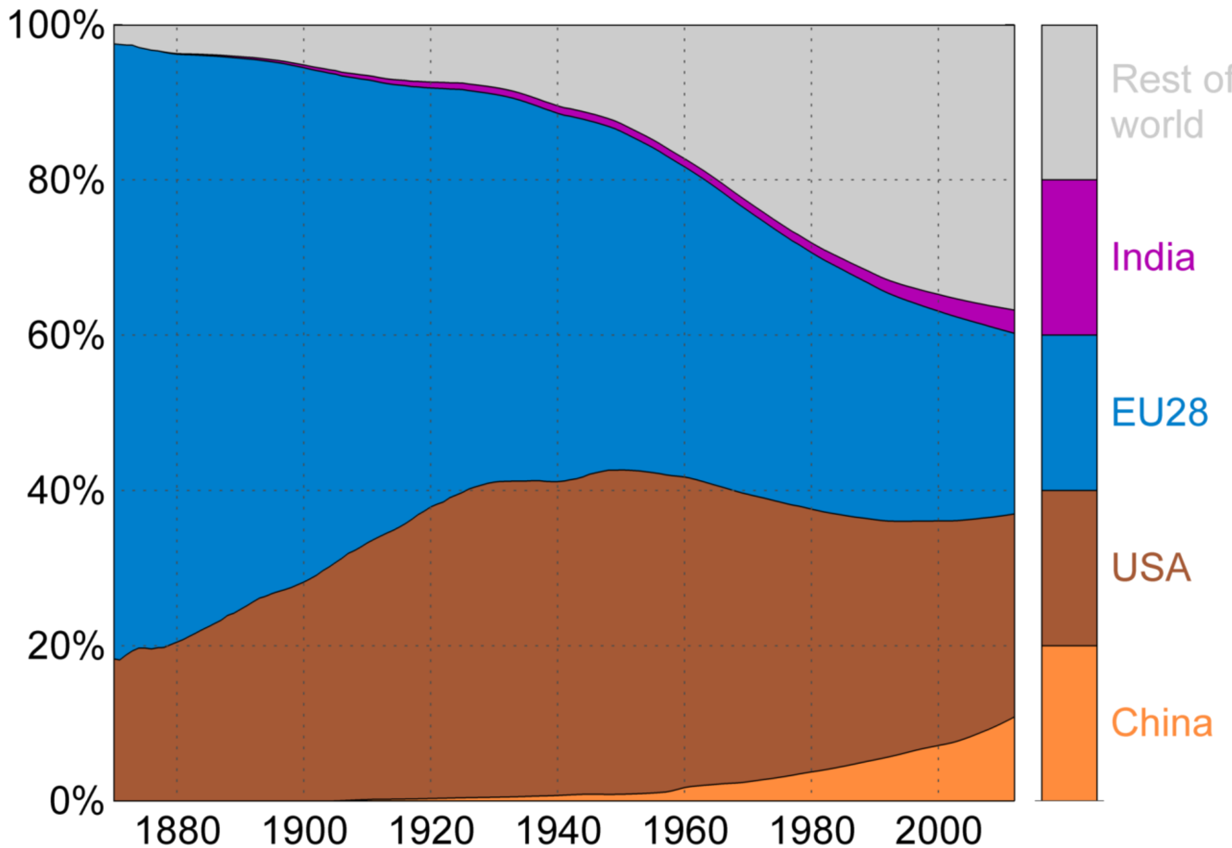


Annex B countries have emission commitments in the Kyoto Protocol

Source: CDIAC Data; Le Quéré et al 2013; Global Carbon Project 2013

Historical Cumulative Emissions by Country

Cumulative emissions from fossil-fuel and cement were distributed (1870–2012):
USA (26%), EU28 (23%), China (11%), and India (4%) covering 64% of the total share



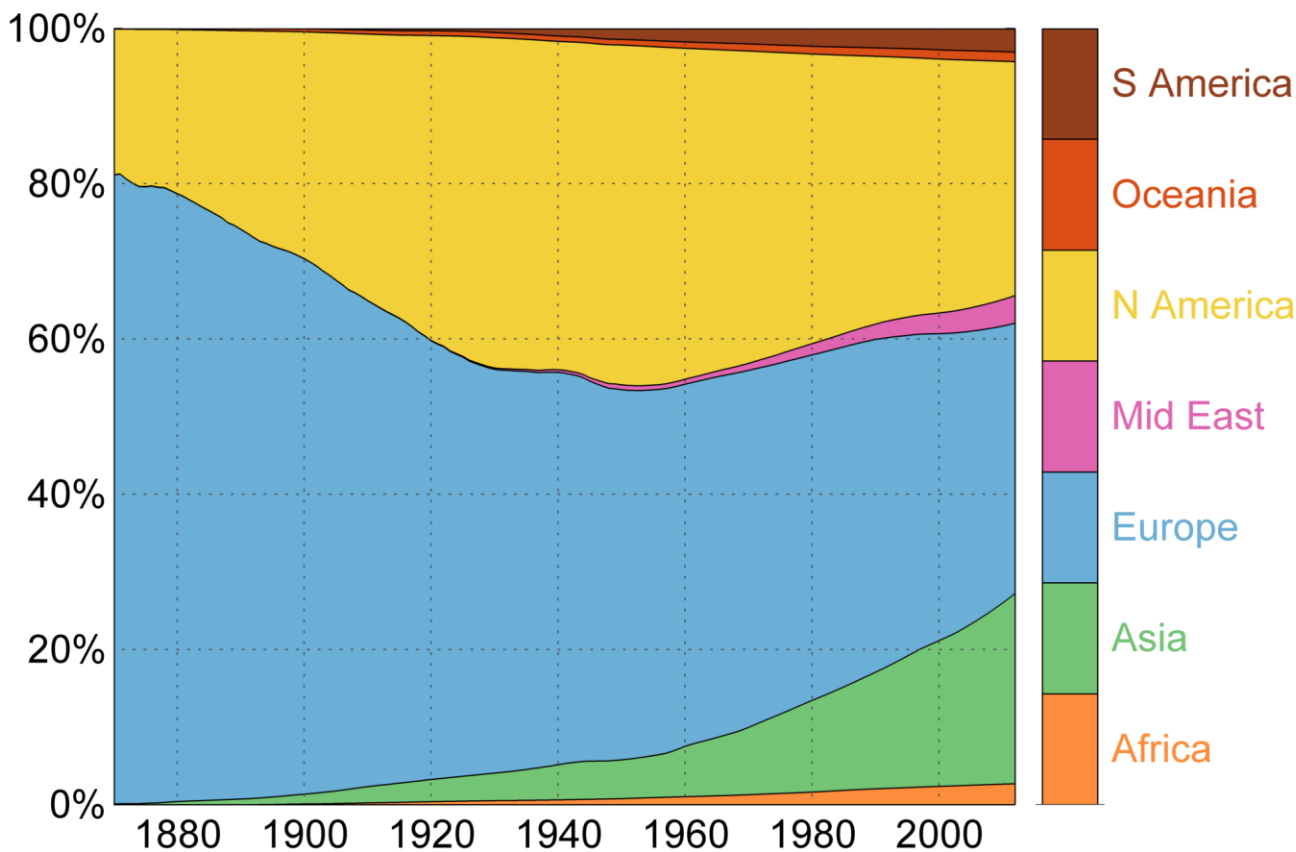
Cumulative emissions (1990–2012) were distributed USA (20%), EU28 (15%), China (18%), India (5%)

Source: CDIAC Data; Le Quéré et al 2013; Global Carbon Project 2013

Historical Cumulative Emissions by Region

Cumulative emissions from fossil-fuel and cement (1870–2012)

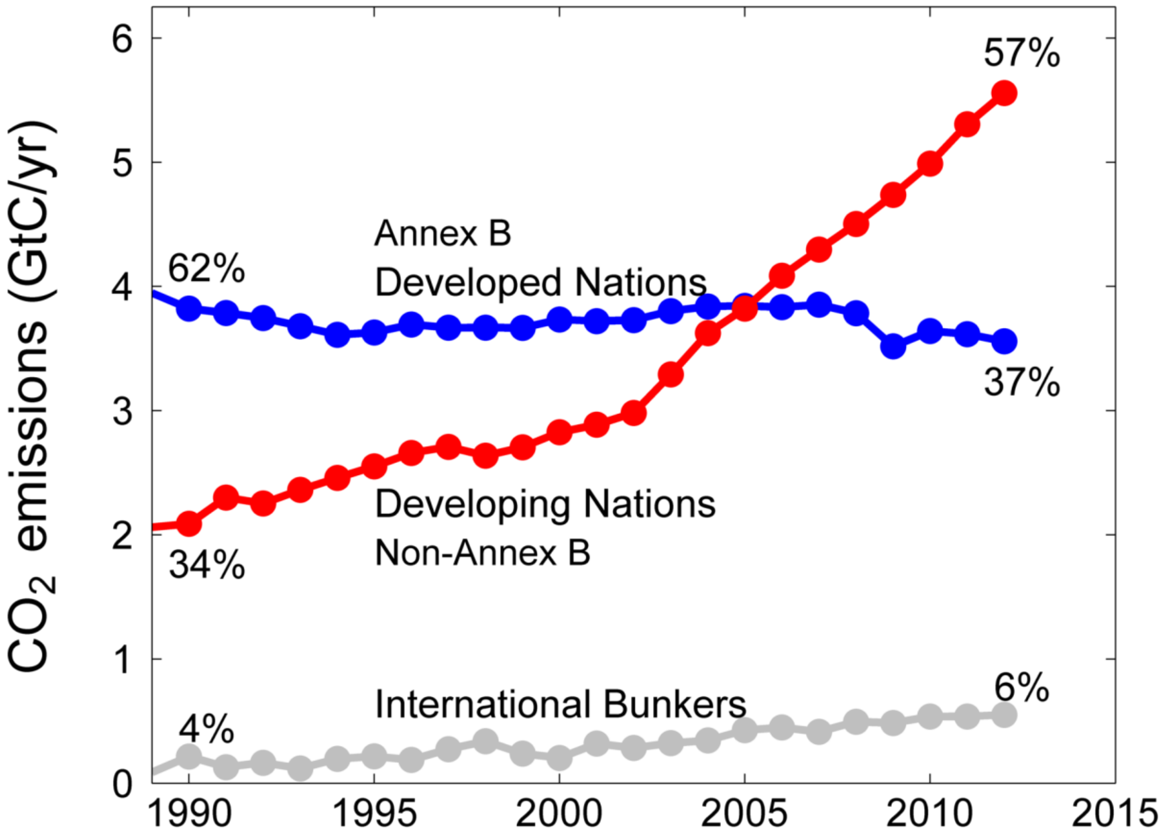
North America and Europe responsible for most cumulative emissions, but Asia growing fast



Source: CDIAC Data; Le Quéré et al 2013; Global Carbon Project 2013

Territorial Emissions as per the Kyoto Protocol

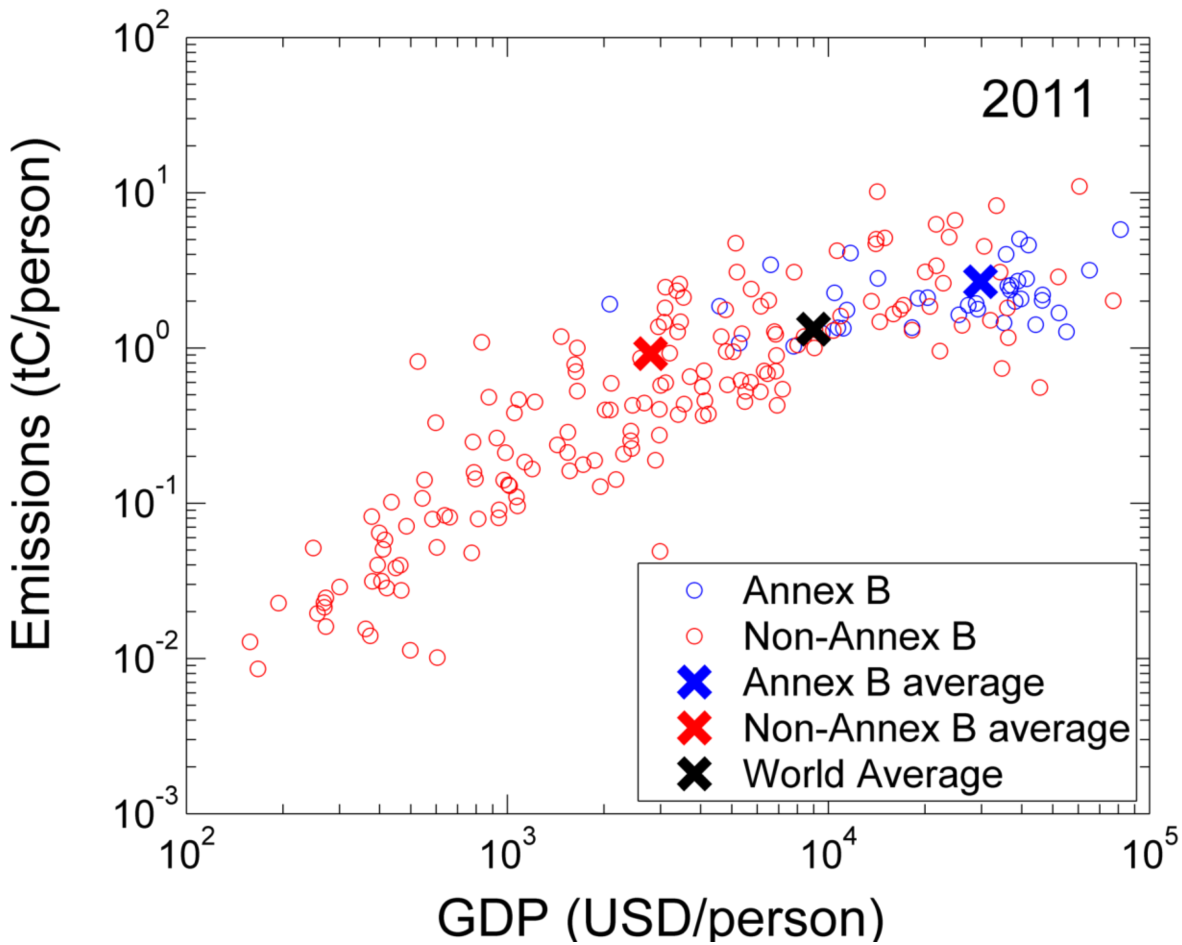
The Kyoto Protocol was negotiated in the context of emissions in 1990
The global distribution of emissions is now starkly different



Source: CDIAC Data; Le Quéré et al 2013; Global Carbon Project 2013

Annex B versus non-Annex B Countries

Annex B countries have emission reduction commitments in the Kyoto Protocol
Annex B countries do not necessarily have highest economic activity per capita

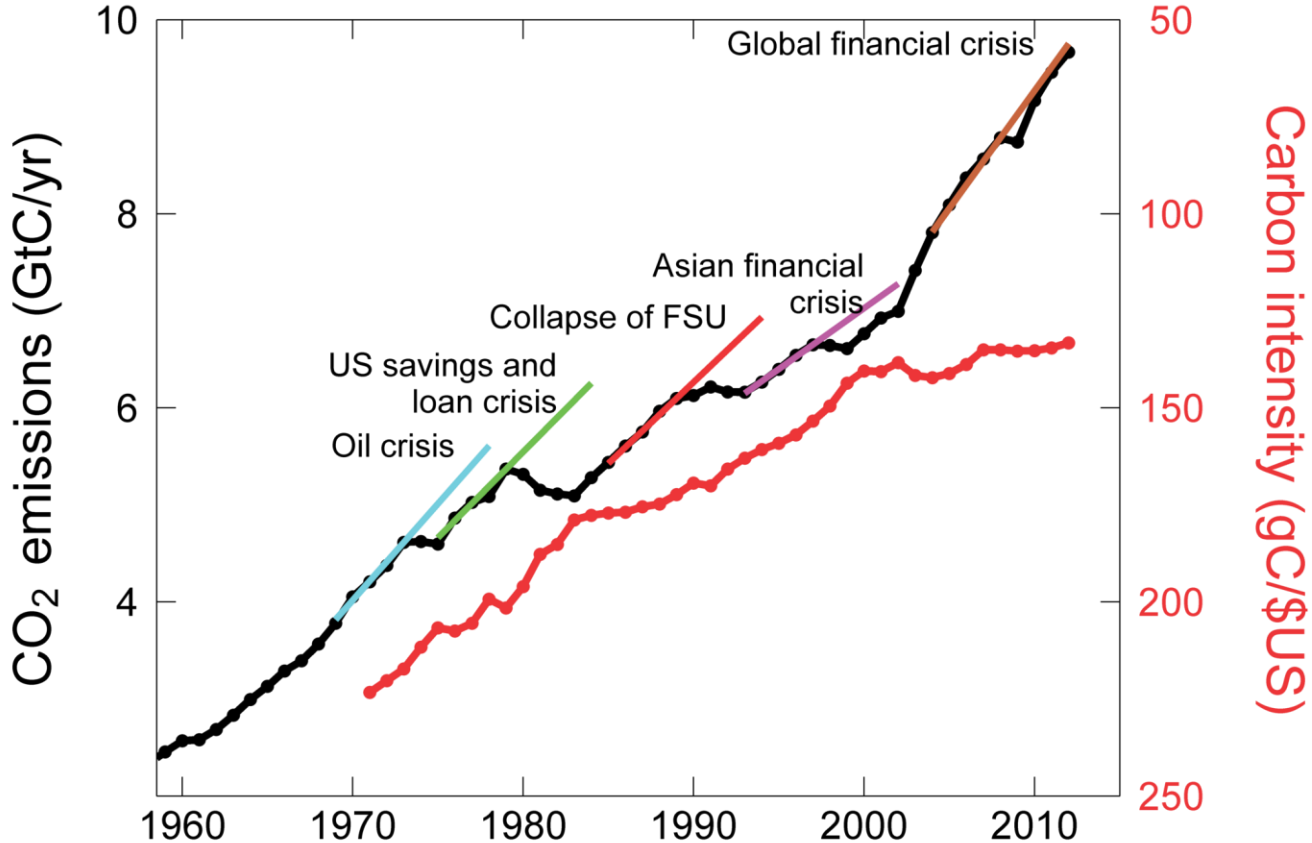


GDP is measured in Market Exchange Rates

Source: CDIAC Data; Unstats; Global Carbon Project 2013

Carbon Intensity of Economic Activity

The global financial crisis of 2008–2009 had no lasting effect on emissions
Carbon intensity has had minimal improvement with increased economic activity since 2005



Source: CDIAC Data; Le Quéré et al 2013; Global Carbon Project 2013

Key Statistics

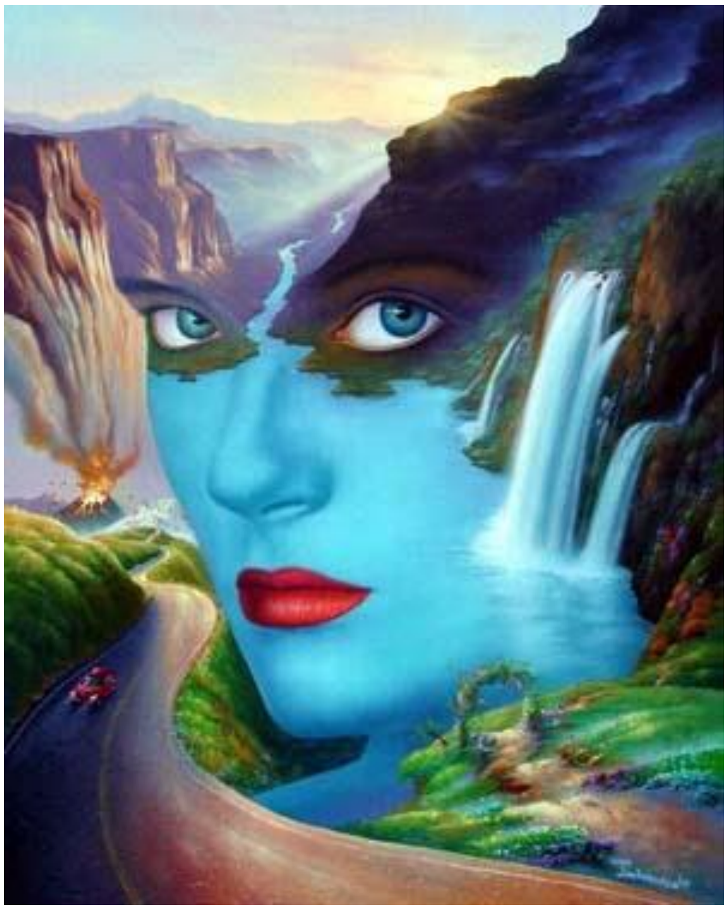
Emissions 2012

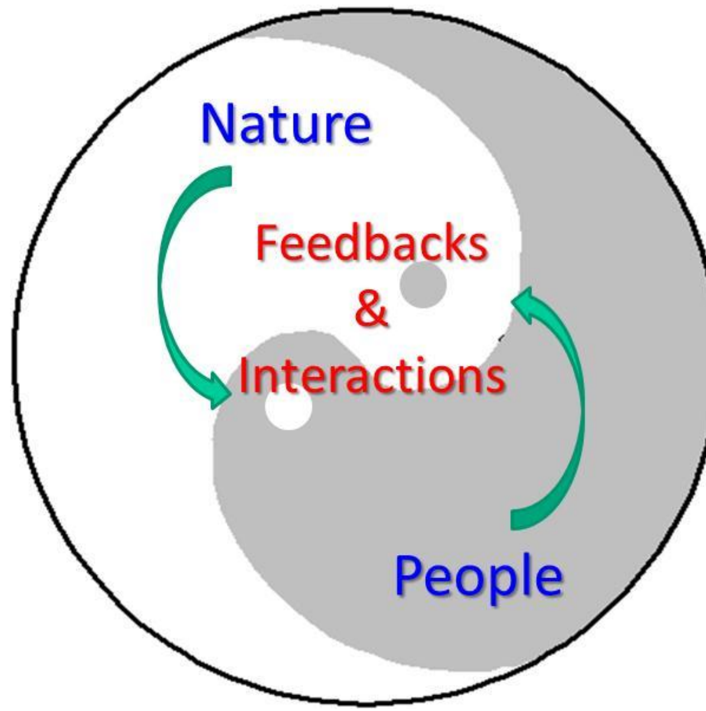
Region/Country	Per capita	Total		Growth 2012	
	tC per person	Gt C	%	Gt C	% per year
Global (with bunkers)	1.4	9.7	-	0.21	2.2
Developed Countries (Annex B)					
Annex B	3.0	3.60	37	-0.058	-1.6
USA	4.6	1.40	14	-0.053	-3.7
Russian Federation	3.4	0.50	5.0	-0.001	-0.2
Japan	2.5	3.40	3.5	0.022	6.9
Germany	2.4	0.20	2.1	0.004	1.8
Canada	4.0	0.14	1.4	-0.001	-0.6
Developing Countries (non-Annex B)					
Non-Annex B	0.9	5.6	57	0.251	4.7
China	1.8	2.6	27	0.146	5.9
India	0.5	0.61	6.3	0.044	7.7
South Korea	3.4	0.17	1.7	0.002	1.1
Iran	2.1	0.16	1.7	0.005	3.1
Saudi Arabia	4.6	0.14	1.4	0.008	5.9
International Bunkers					
Aviation and Shipping	-	0.55	6	0.014	2.5

Source: CDIAC Data; Le Quéré et al 2013; Global Carbon Project 2013

One Thing in Common among These Examples

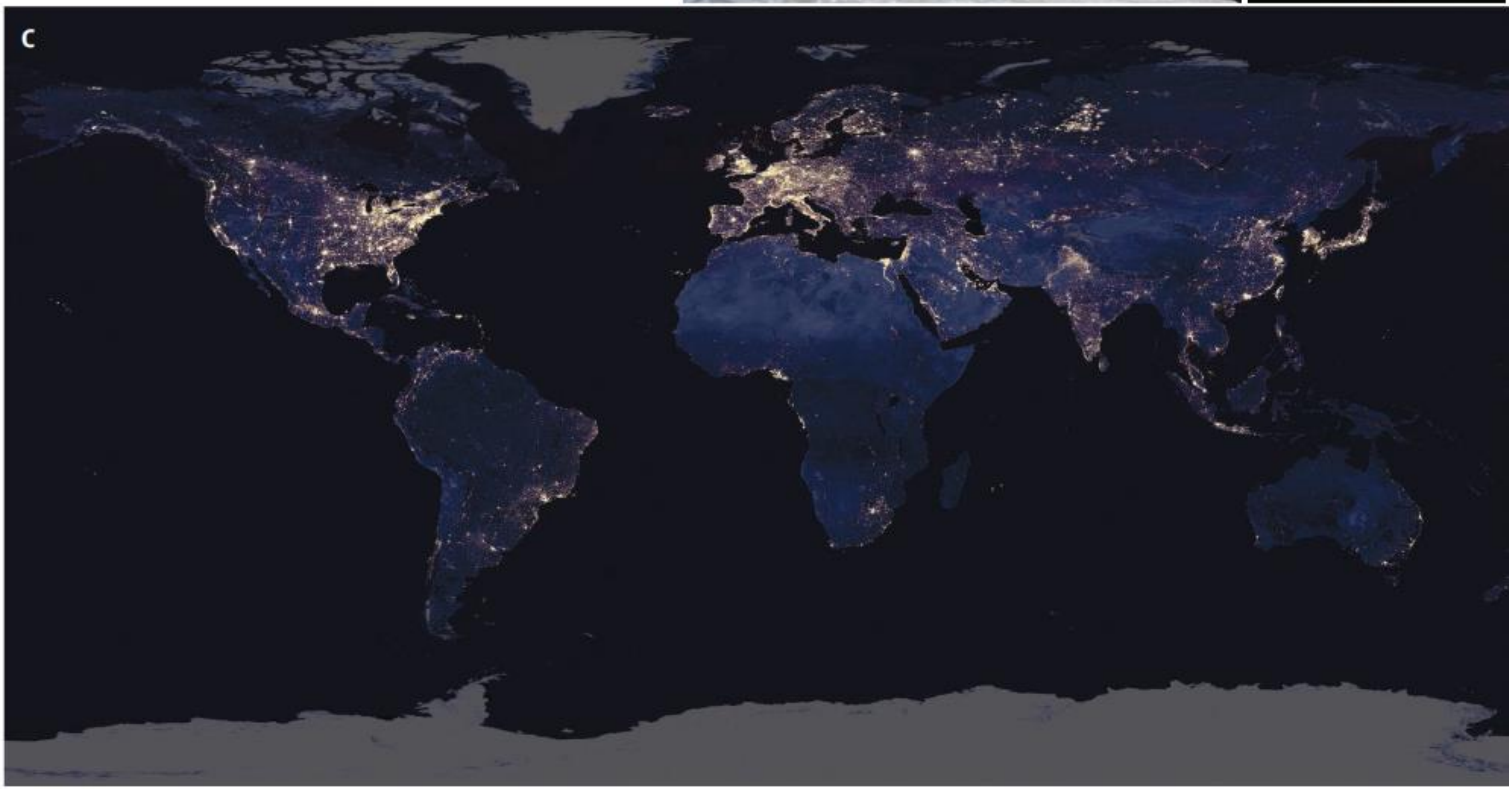
People ~ Nature





Coupled Human & Natural System (CHN)

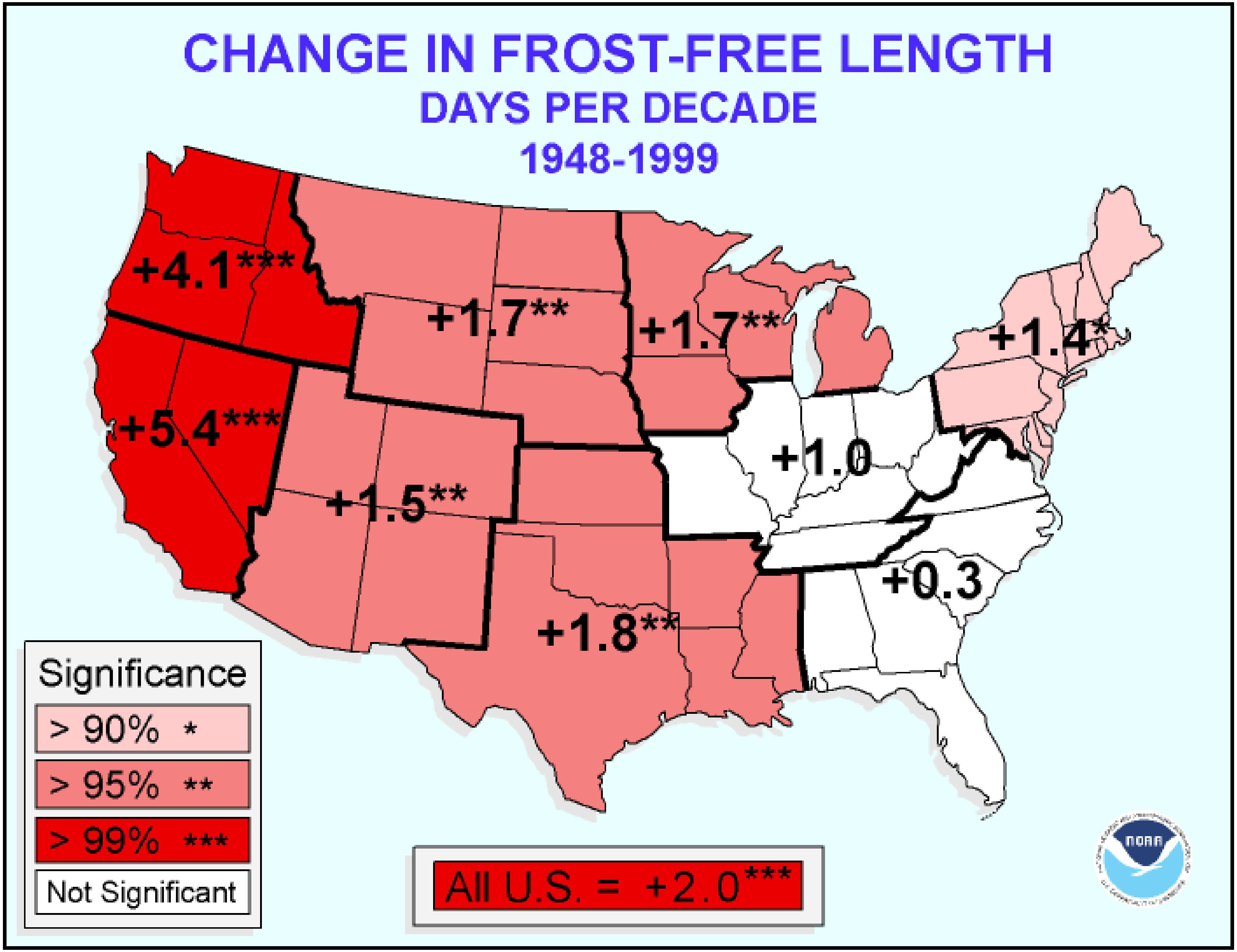
Fig. 2. (**A**) Earthrise (24 December 1968). Image of the rising Earth taken from the Apollo 8 spacecraft. (**B**) Earth taken on 7 December 1972 by the crew of the Apollo 17 spacecraft at a distance of about 29,000 km. This is the first time that the Apollo trajectory made it possible to photograph the south polar ice cap. (**C**) Earth's cities at night. This image of Earth's city lights at night shows the spatial distribution or arrangement of settlements. White areas of light show organized areas where population is typically large.



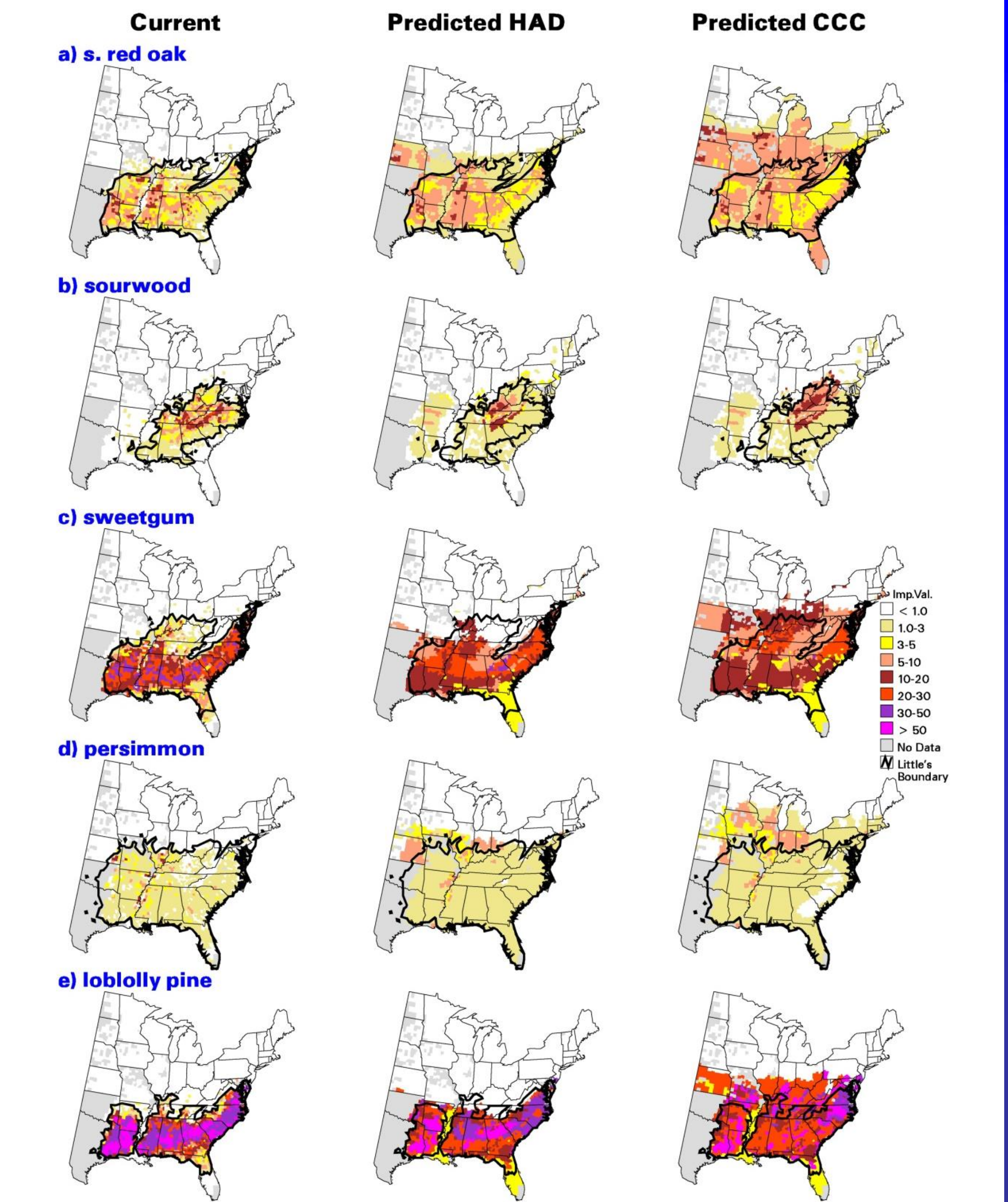
LEES Lab

http://research.eeescience.utoledo.edu/lees/index.html

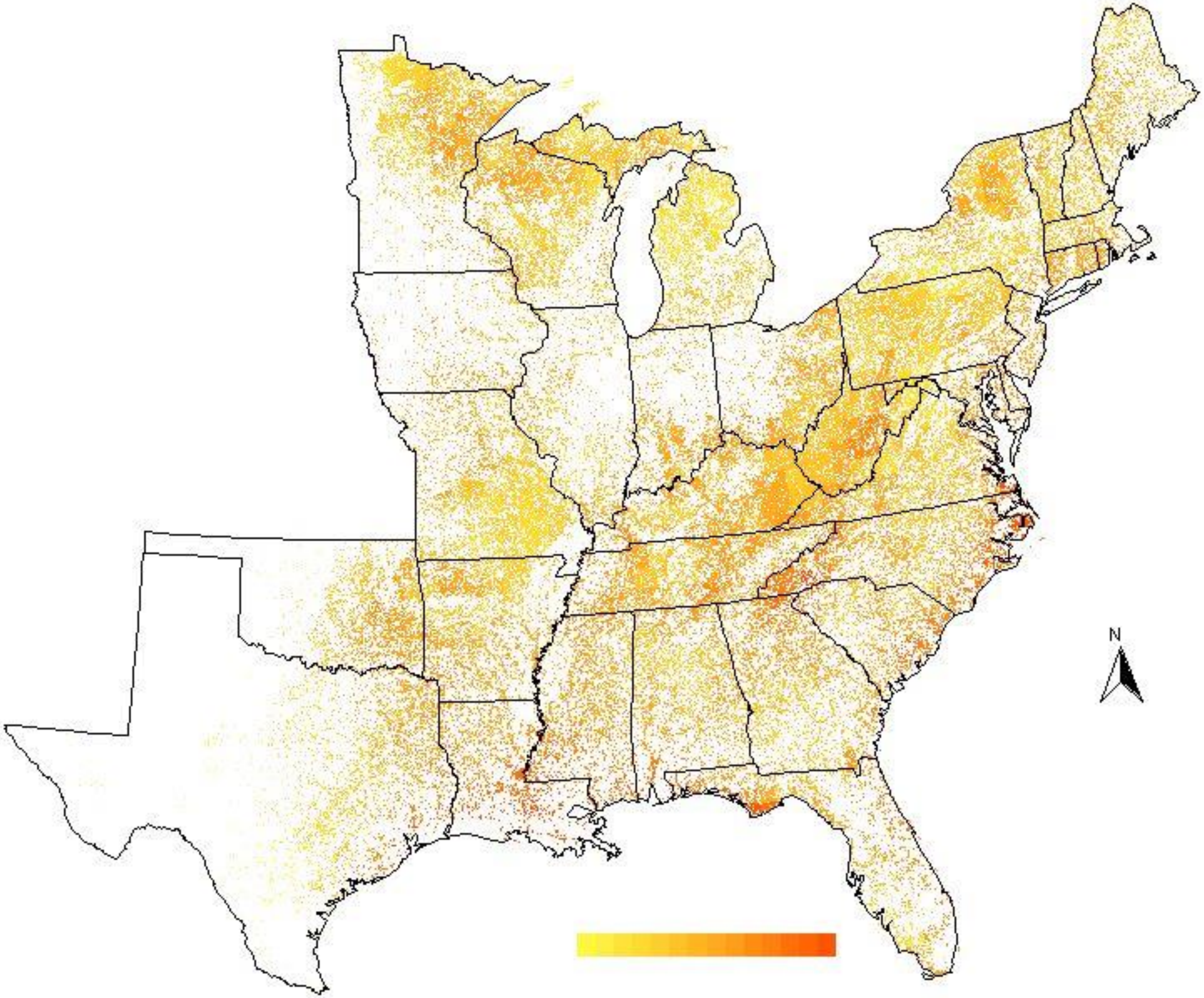
Questions?



CHANGE IN FROST-FREE LENGTH
DAYS PER DECADE
1948-1999
+4.1***
+5.4***
+1.7**
+1.7**
+1.4*
+1.5**
+1.0
+0.3
+1.8**
Significance
> 90% *
> 95% **
> 99% ***
Not Significant
All U.S. = +2.0***

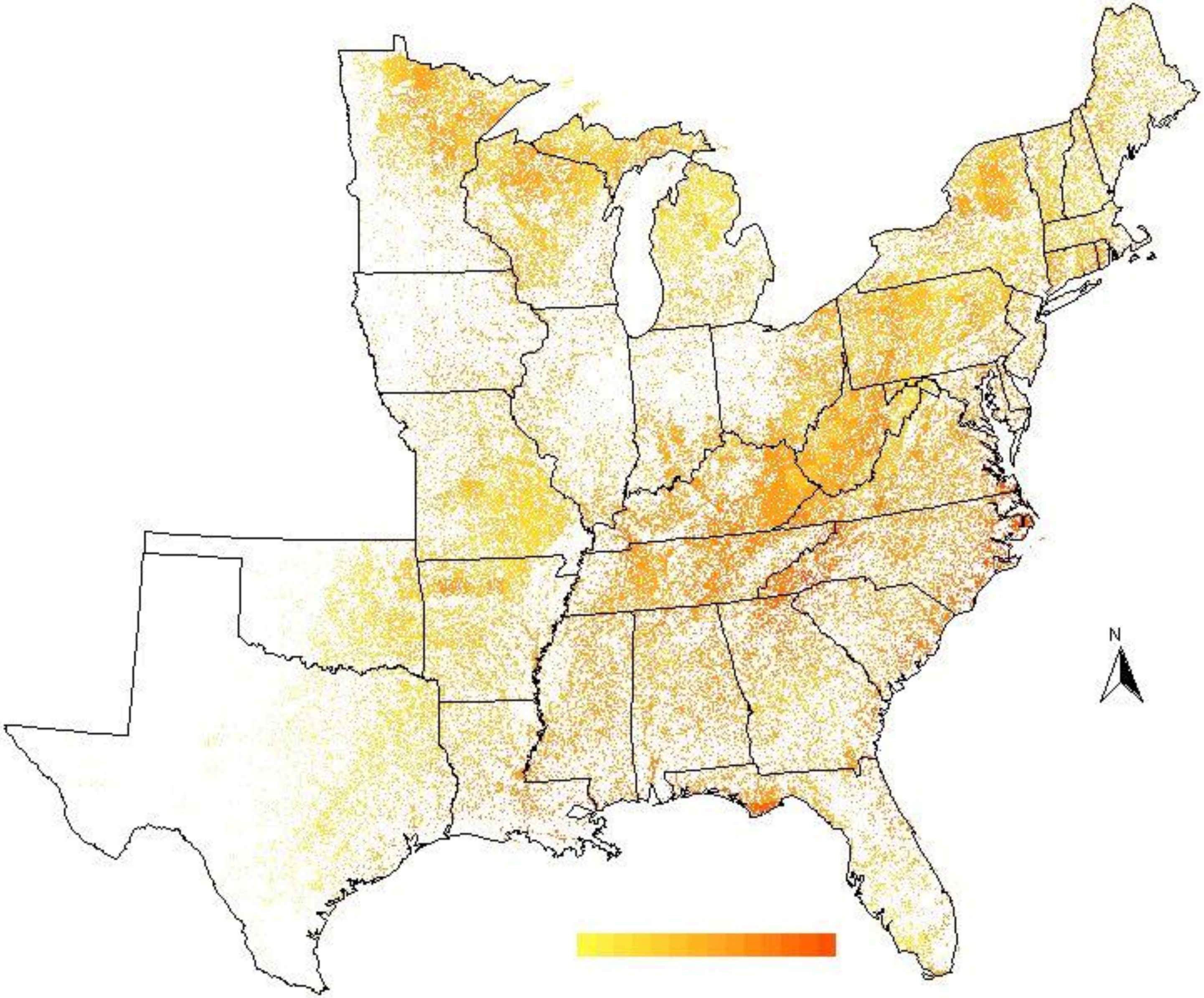

Current
Predicted HAD
Predicted CCC
a) s. red oak
b) sourwood
c) sweetgum
d) persimmon
e) loblolly pine
Imp.Val.
< 1.0
1.0-3
3-5
5-10
10-20
20-30
30-50
> 50
No Data
Little's Boundary

1990 Deciduous Forest Net Primary Production



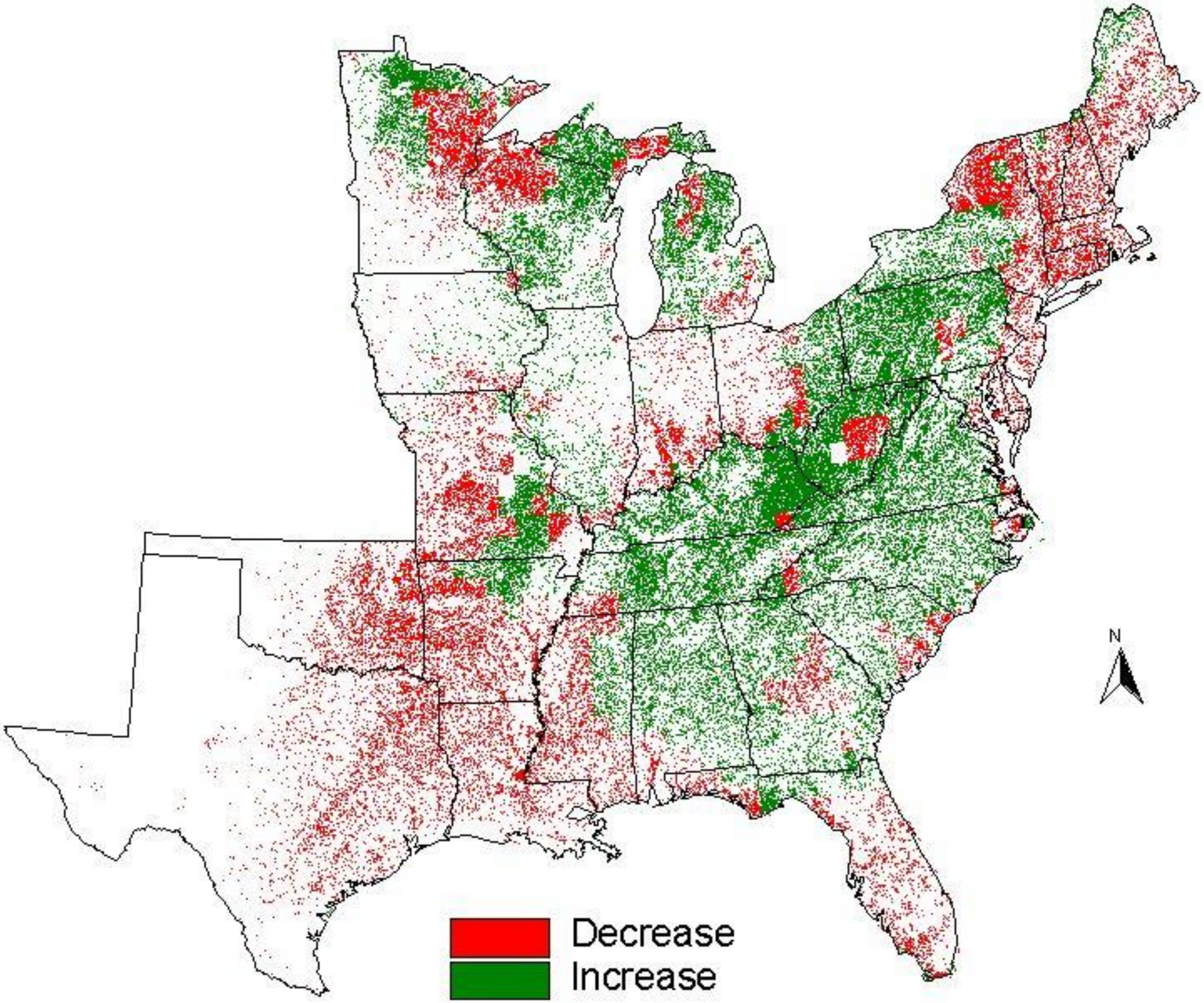
Source: Southern Global Change Program

2050 Deciduous Forest Net Primary Production



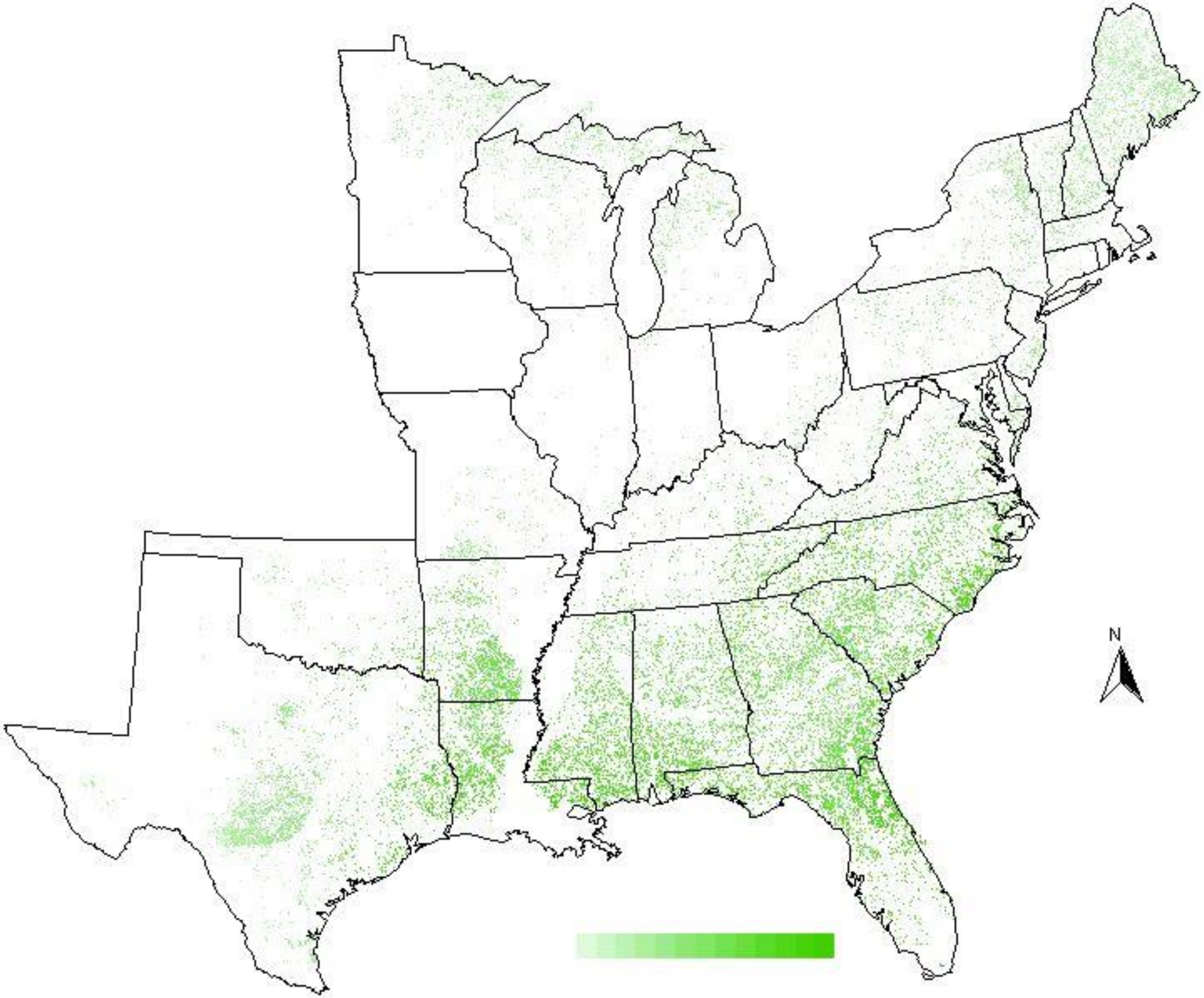
urce: Southern Global Change Program

Change in Deciduous Forest Net Primary Production from 1990 to 2050



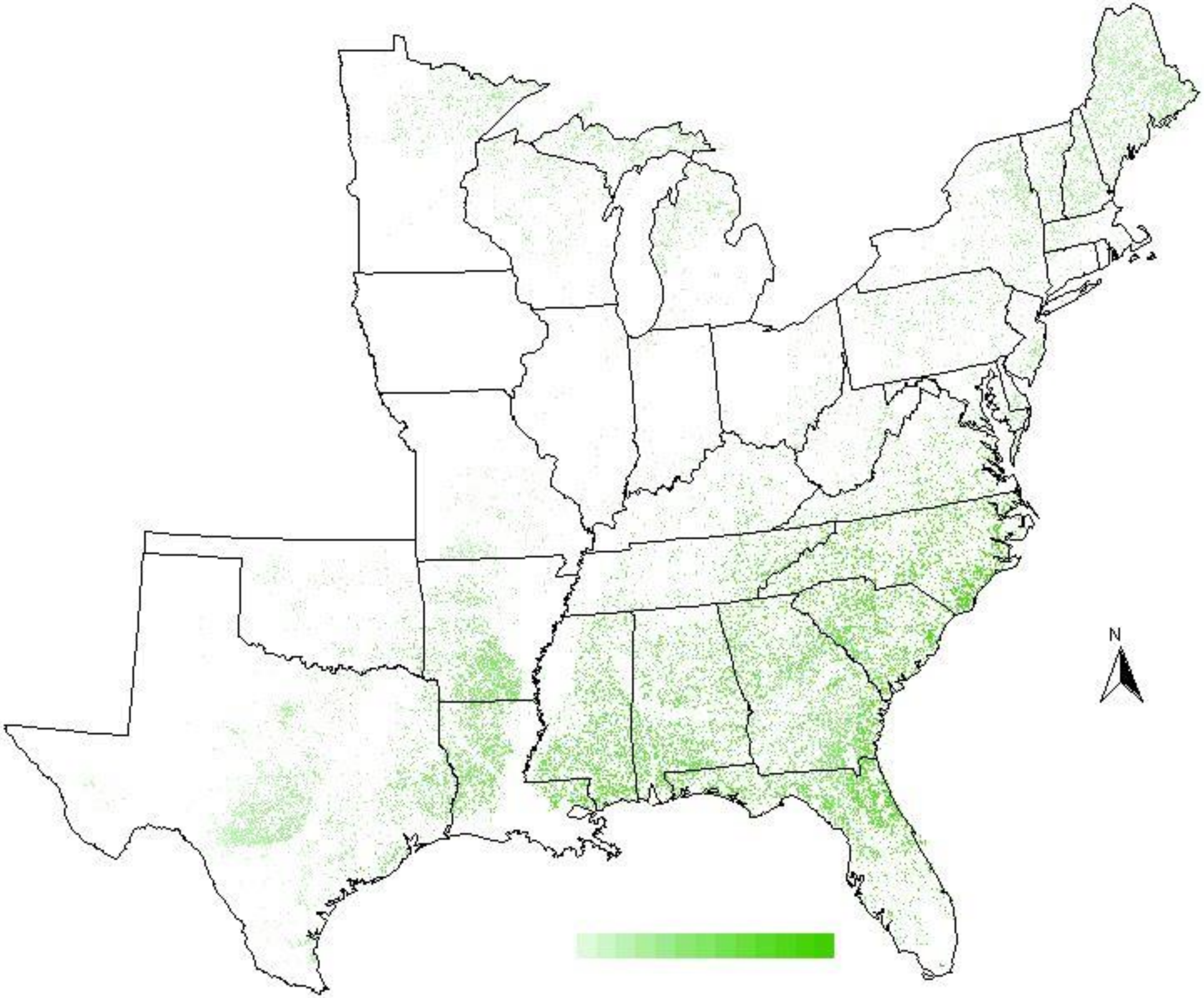
urce. Southern Global Change Program

1990 Evergreen Forest Net Primary Production



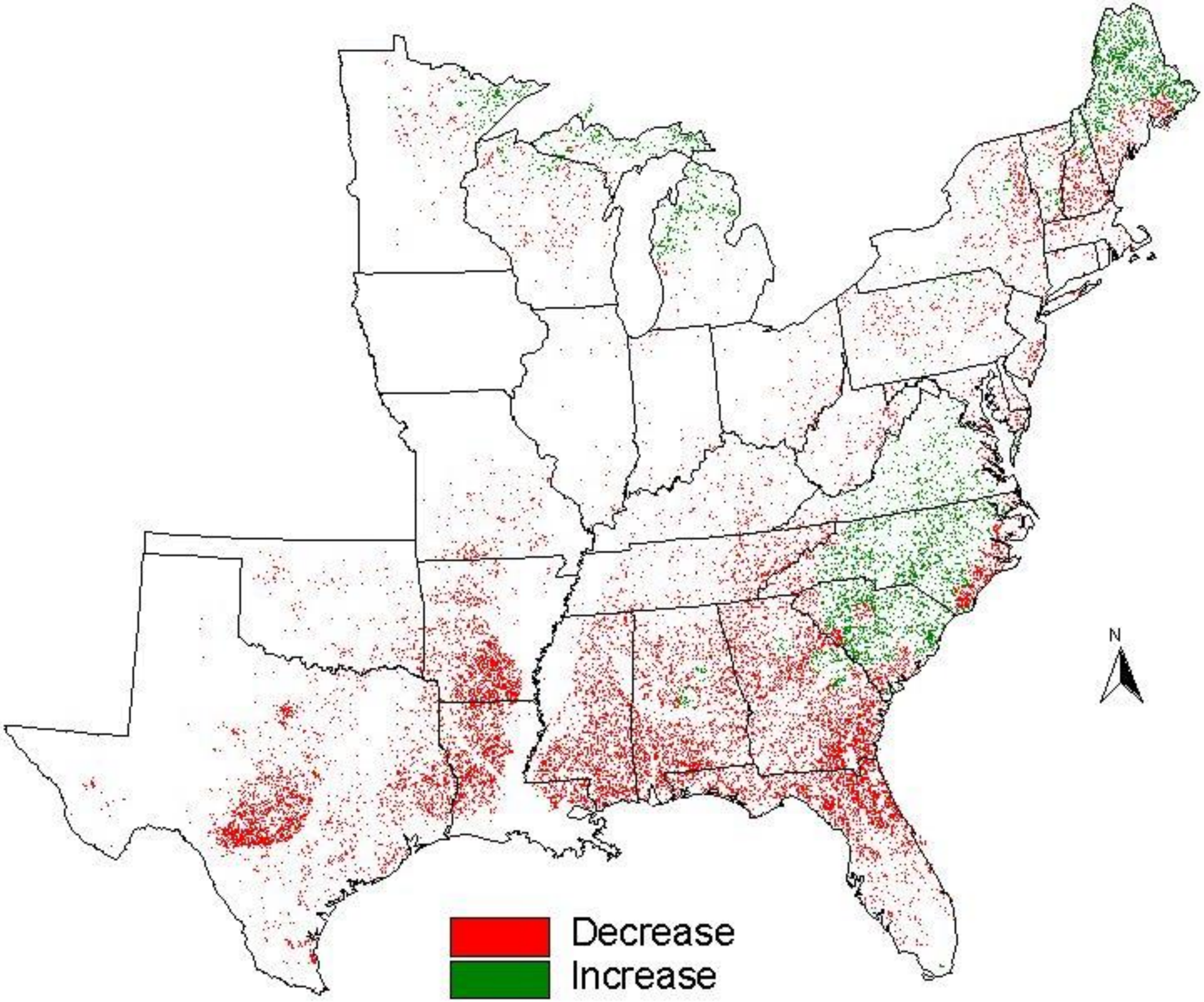
Source: Southern Global Change Program

2050 Evergreen Forest Net Primary Production



Source: Southern Global Change Program

Change in Evergreen Forest Net Primary Production from 1990 to 2050



urce. Southern Global Change Program

5. Conservation Implications

- **Species extinction**: toad and frog in Costa Rica; more on threatened/endangered species?
- **Species movements** cannot match the pace of warming
- **Policy**: carbon credit and management, sustainable management, biofuels, renewable energy, etc.
- **The Bottom Line**: Adaptation and emission reduction

Projected US Primary Energy Consumption

Seeking renewable energy!

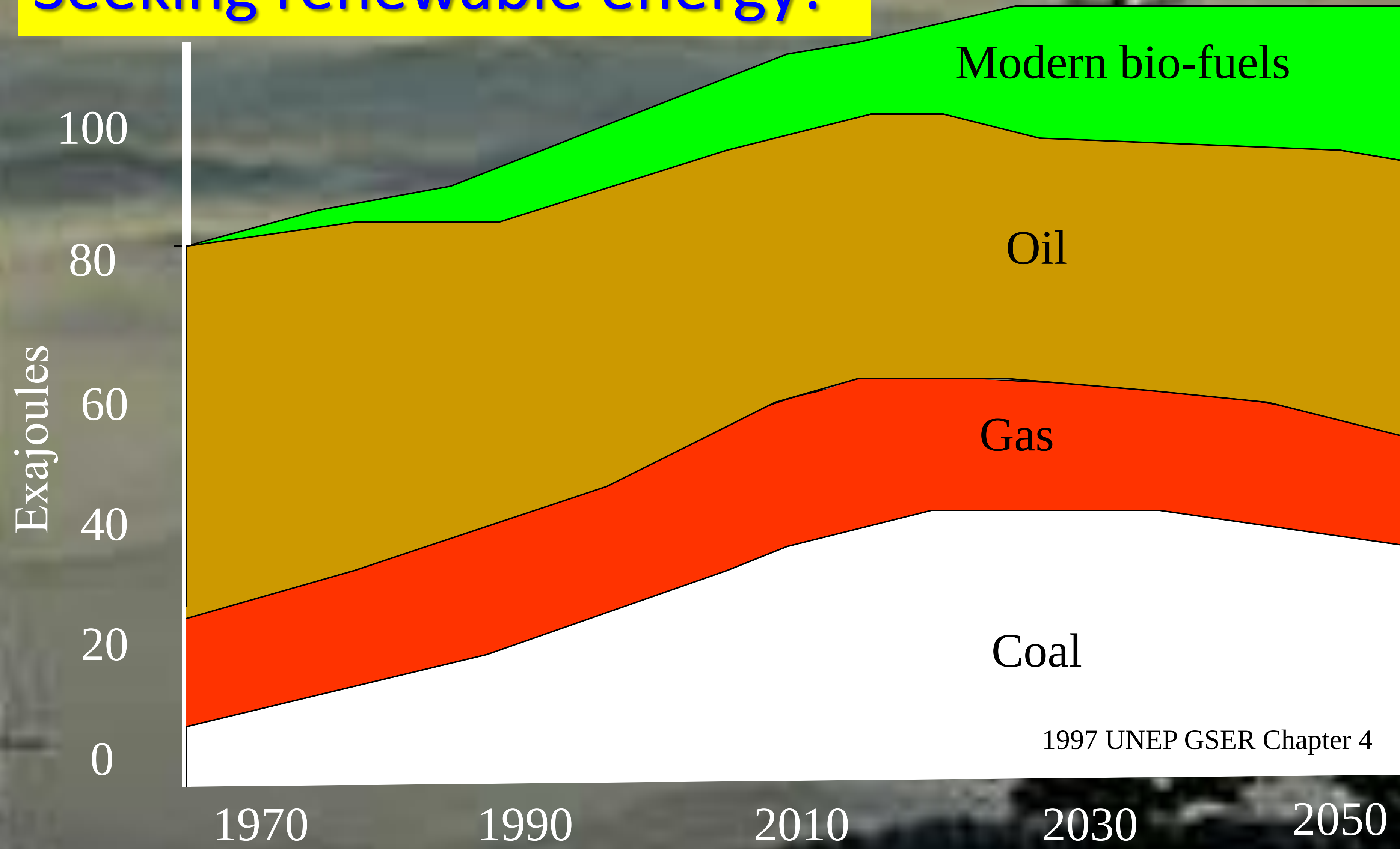
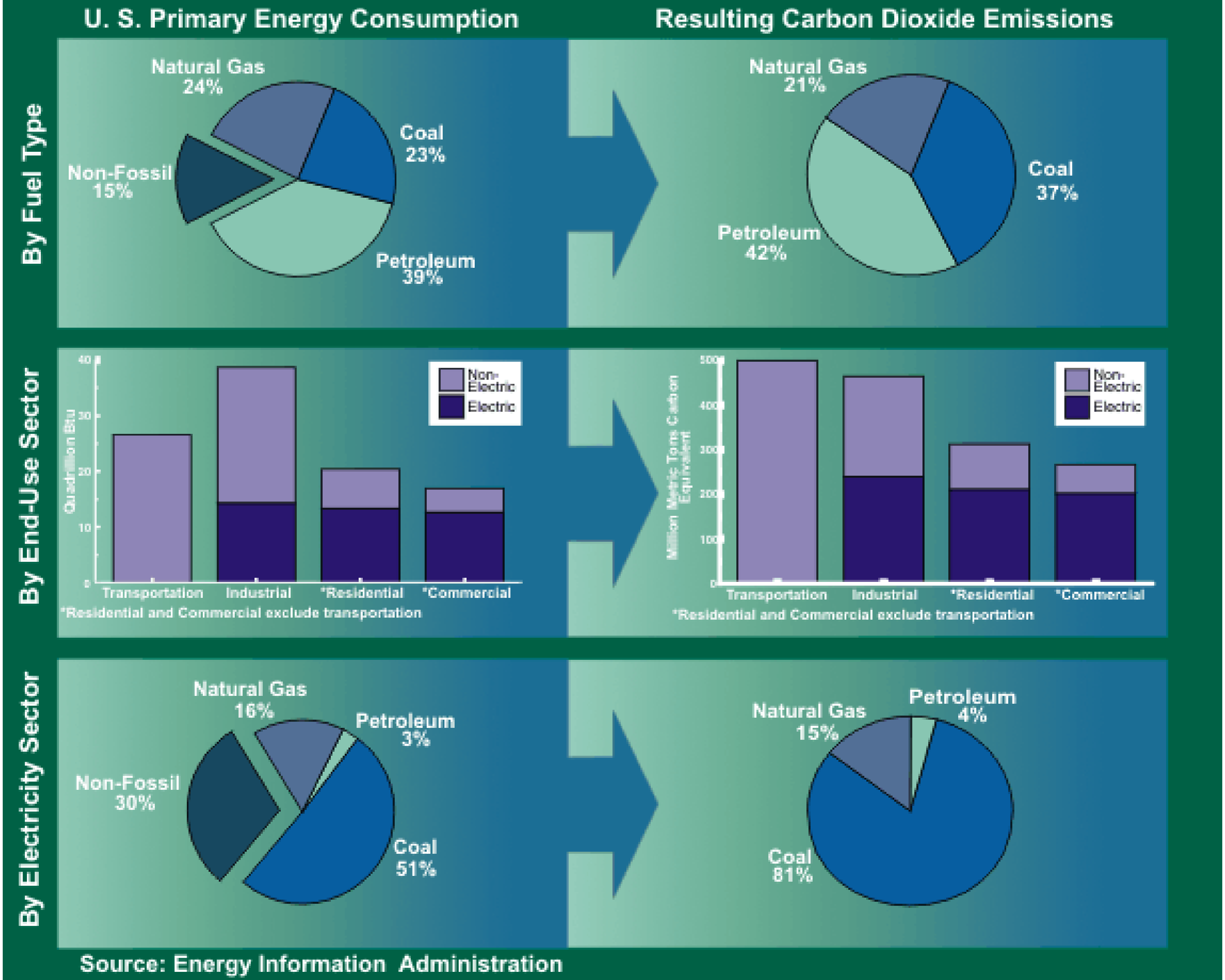


TABLE 10.2 *A Chronology of Major Climate Change Policy Events* (Part 1)

Date	Meeting or event	Results and conclusions
1896	First attribution of the connection between atmospheric carbon and climate	Svante Arrhenius made the connection between CO_2 and atmospheric temperature and speculated that burning fossil fuels such as coal could increase the concentration of carbon in the atmosphere in the future and lead to an increase in global temperatures. His research was widely disregarded by other scientists at the time.
1979	First World Climate Conference	Human-induced climate change is identified as a potential threat.
1980	Montreal Protocol	World leaders meet to sign an agreement designed to gradually phase out the production and use of chemicals that destroy atmospheric ozone.
1988	Formation of IPCC	The United Nations Environment Program (UNEP) and the World Meteorological Organization (WMO) create the Intergovernmental Panel on Climate Change (IPCC) to coordinate research and analysis of climate change.
1990	First IPCC Report	The IPCC states global climate is clearly changing, and these changes are probably a result of human activity.

Al Gore and IPCC received the Nobel Price in 2007.


U. S. Primary Energy Consumption
Resulting Carbon Dioxide Emissions
By Fuel Type
Natural Gas 24%
Coal 23%
Non-Fossil 15%
Petroleum 39%
Natural Gas 21%
Coal 37%
Petroleum 42%
By End-Use Sector
Quadrillion Btu
40
30
20
10
0
Non-Electric
Electric
Transportation
Industrial
*Residential
*Commercial
*Residential and Commercial exclude transportation
Million Metric Tons Carbon Equivalent
Non-Electric
Electric
Transportation
Industrial
*Residential
*Commercial
*Residential and Commercial exclude transportation
By Electricity Sector
Natural Gas 16%
Petroleum 3%
Non-Fossil 30%
Coal 51%
Natural Gas 15%
Petroleum 4%
Coal 81%
Source: Energy Information Administration