Global warming: Is it real? Does it matter for a chemical engineer?

Dr David Karoly
School of Meteorology
Email: dkaroly@ou.edu

Recent global warming quotes

- Senator James Inhofe (R, Oklahoma), Chair, Senate Env. and Public Works Comm., in a speech to the US Senate on Jan 4, 2005 "I called the threat of catastrophic global warming the 'greatest hoax ever perpetrated on the American people' "
- British Prime Minister Tony Blair in a speech on 14 Sept 2004 "I want to concentrate on what I believe to be the world's greatest environmental challenge: climate change"

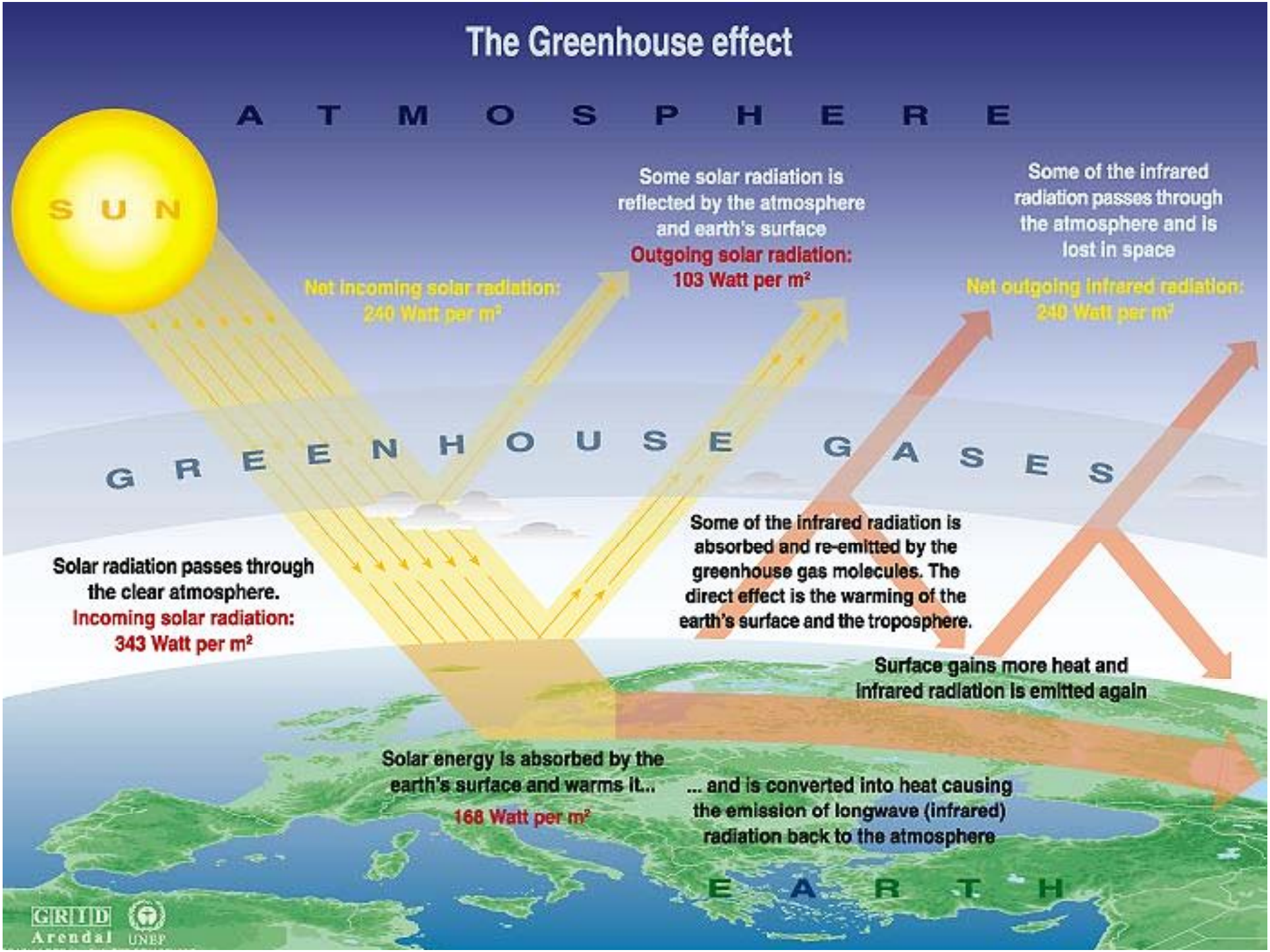
'Oh great, now we can't talk about religion, politics, OR the weather.'

Global warming references

- IPCC web site http://www.ipcc.ch/
- US EPA global warming site http://www.epa.gov/globalwarming/
- US National Assessment of climate change http://www.usgcrp.gov/usgcrp/nacc/default.htm
- Skeptical view on global warming http://www.globalwarming.org/
- A site maintained by some climate scientists http://www.realclimate.org/

Introduction

- What is the greenhouse effect?
- Natural climate variations
- The latest assessment of global warming and its causes
- International policy and agreements
- Options for reducing and stabilizing greenhouse concentrations


The Greenhouse effect
A T M O S P H E R E
S U N
Some solar radiation is reflected by the atmosphere and earth's surface
Outgoing solar radiation: 103 Watt per m²
Some of the infrared radiation passes through the atmosphere and is lost in space
Net incoming solar radiation: 240 Watt per m²
Net outgoing infrared radiation: 240 Watt per m²
G R E E N H O U S E G A S E S
Some of the infrared radiation is absorbed and re-emitted by the greenhouse gas molecules. The direct effect is the warming of the earth's surface and the troposphere.
Solar radiation passes through the clear atmosphere.
Incoming solar radiation: 343 Watt per m²
Surface gains more heat and infrared radiation is emitted again
Solar energy is absorbed by the earth's surface and warms it...
168 Watt per m²
... and is converted into heat causing the emission of longwave (infrared) radiation back to the atmosphere
E A R T H
GRID Arendal
UNEP

The greenhouse effect

Most gaseous molecules in the atmosphere with more than two atoms are very strong absorbers of infrared radiation and are called greenhouse gases.

If there were no greenhouse gases in the atmosphere, the average surface temperature of the Earth would be about 30°C colder than at present. The greenhouse effect makes the Earth habitable.

Water vapor is the most important greenhouse gas in the atmosphere but its concentration is not changing directly due to human activity. Carbon dioxide and methane concentrations are increasing, causing an enhanced greenhouse effect.

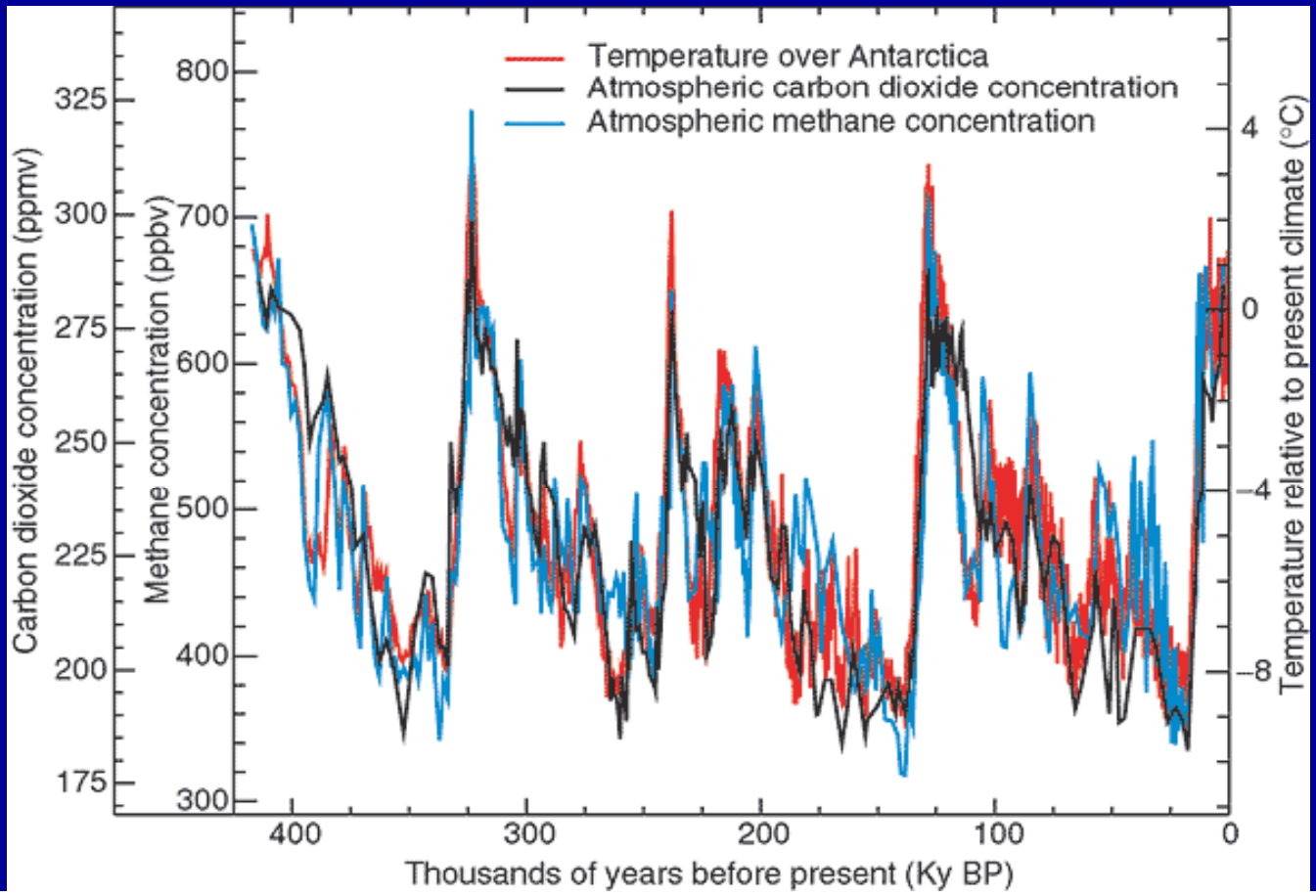
Natural climate variability

Climate can vary over a wide range of timescales due to internal processes; coupling between the atmosphere and its weather variability with oceans, land surface, and snow and ice. The ocean response time is very long because of the large heat capacity of the ocean and the very slow currents. This is called internal climate variability.

External climate forcing is due to processes external to the climate system, such as volcanic eruptions, changes in solar forcing, or changes in greenhouse gas concentrations etc.

Natural climate variations: Ice ages

On longer timescales, there have been pronounced periods of much colder temperature at regular intervals over the last million years. These ice ages are relatively stable climate states with similar total solar irradiance at the top of the atmosphere, but a much higher albedo. Global temperature decreases during past ice ages are ~ 7 – 10°C.

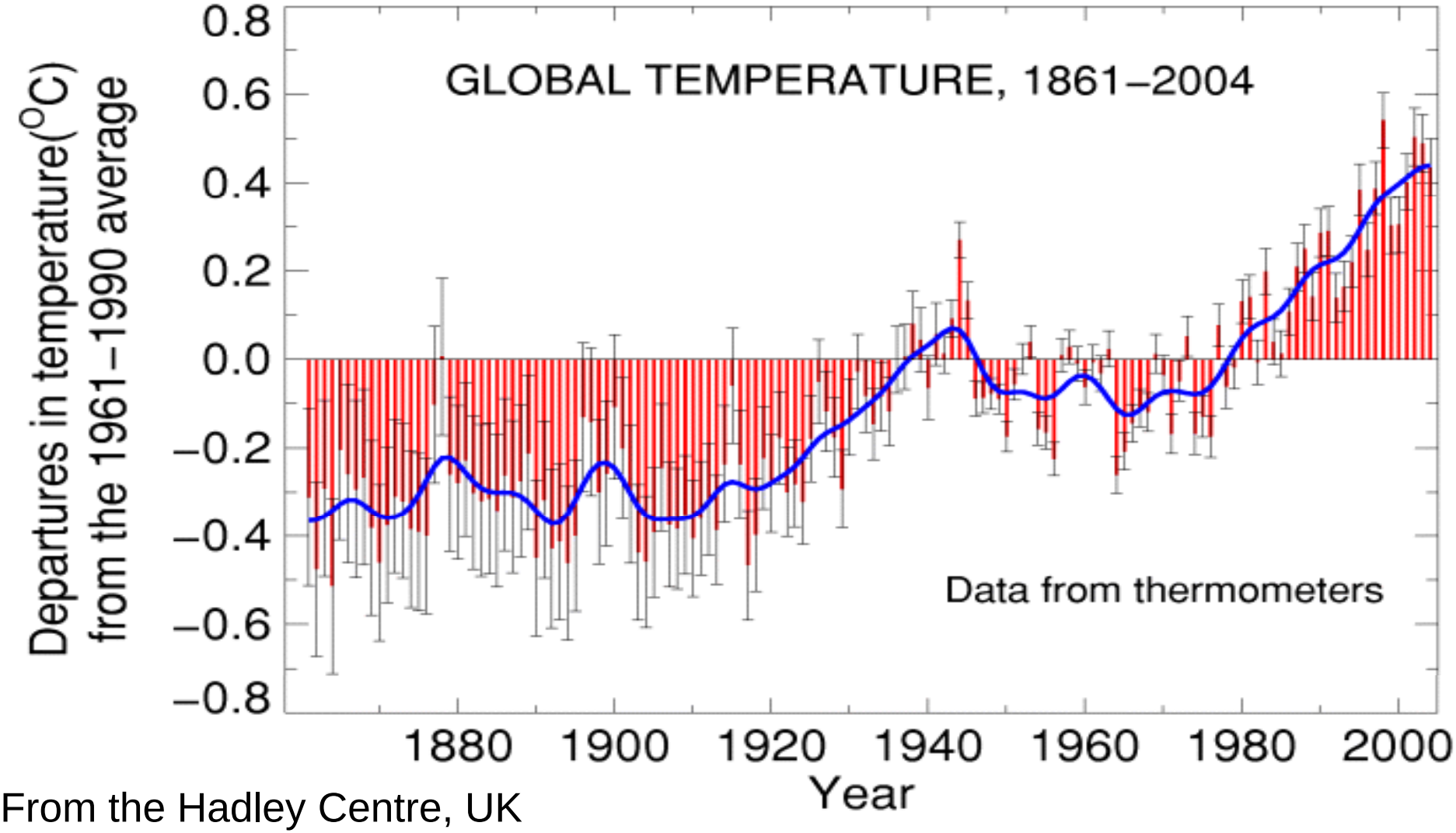


Intergovernmental Panel on Climate Change (IPCC)

- Joint body of UN Environment Program and World Meteorological Organization
- Every 5 years, carries out an assessment of climate change science, impacts, and approaches for mitigation and adaptation to climate change
- Includes representatives from all countries
- Reports are approved and accepted by consensus
- Latest assessment in 2001 was reviewed by the US National Academy of Sciences, which confirmed the assessment was correct.

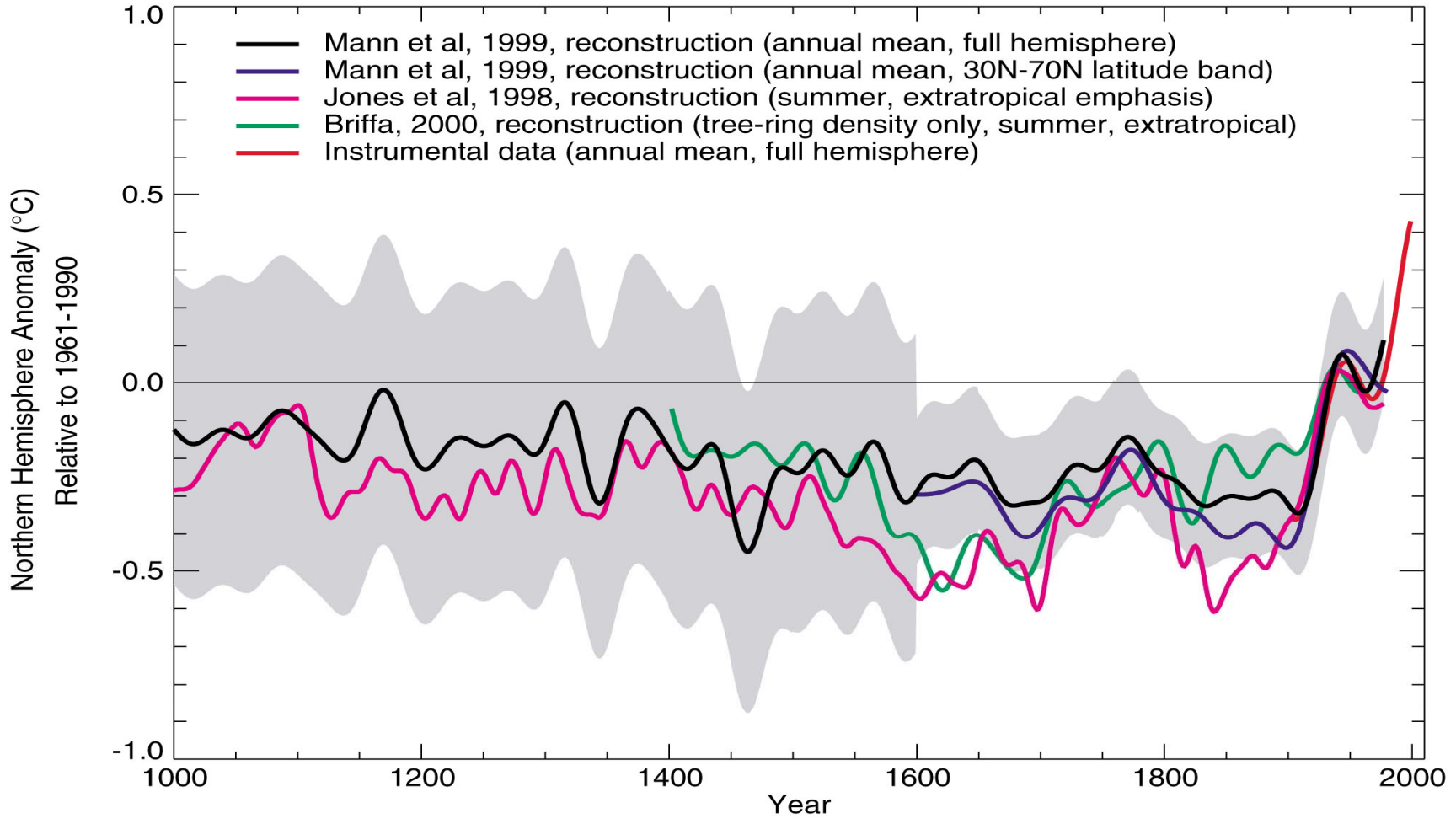
“The global-average surface temperature has increased over the 20th century by 0.6±0.2ºC”

The 5 hottest years globally were 1998, 2002, 2003, 2004 and 2005.



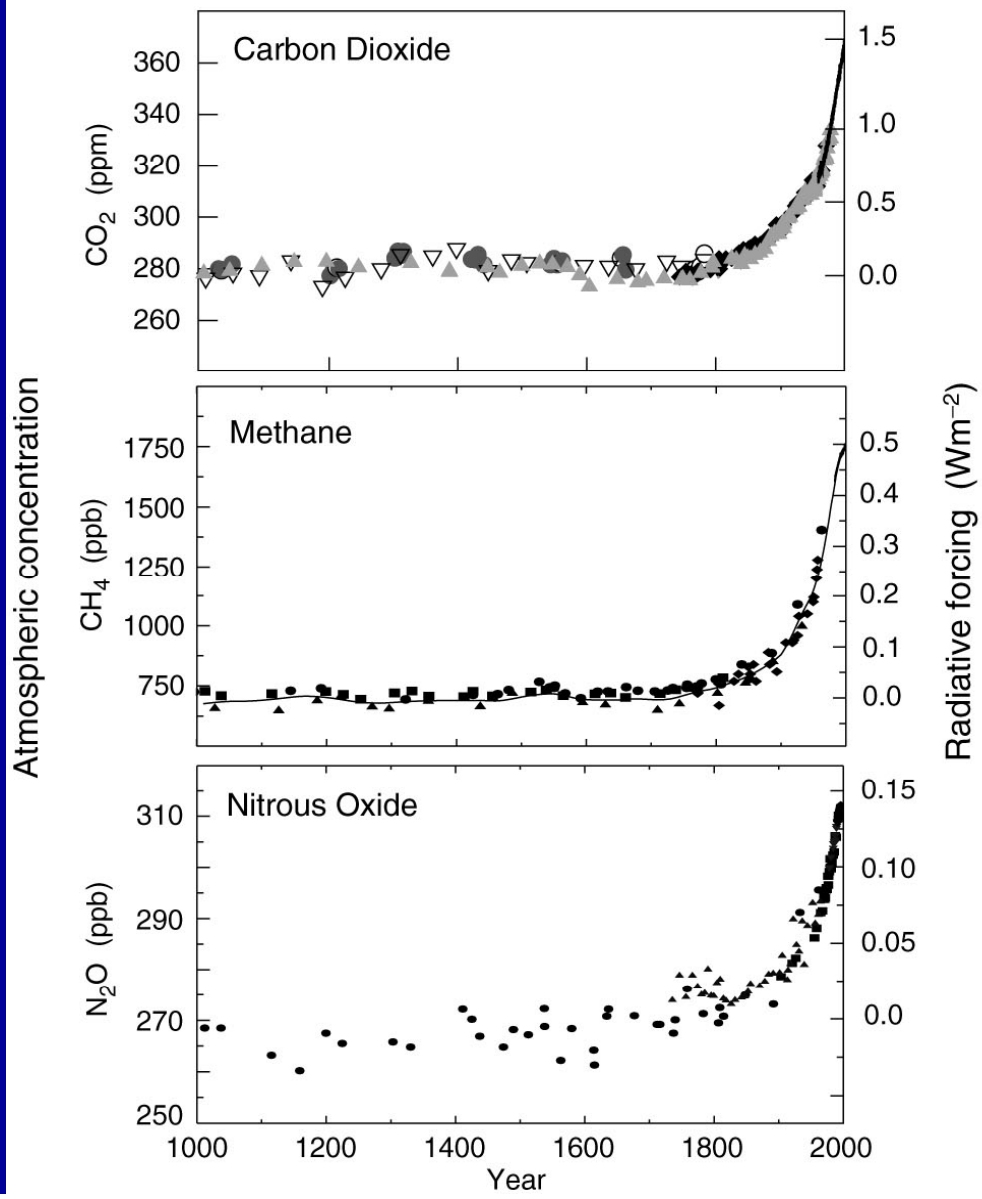
From the Hadley Centre, UK

“Reconstructions of climate data for the last 1000 years ... indicate this warming was unusual and is unlikely to be entirely natural in origin”



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

(a) Global atmospheric concentrations of three well mixed greenhouse gases



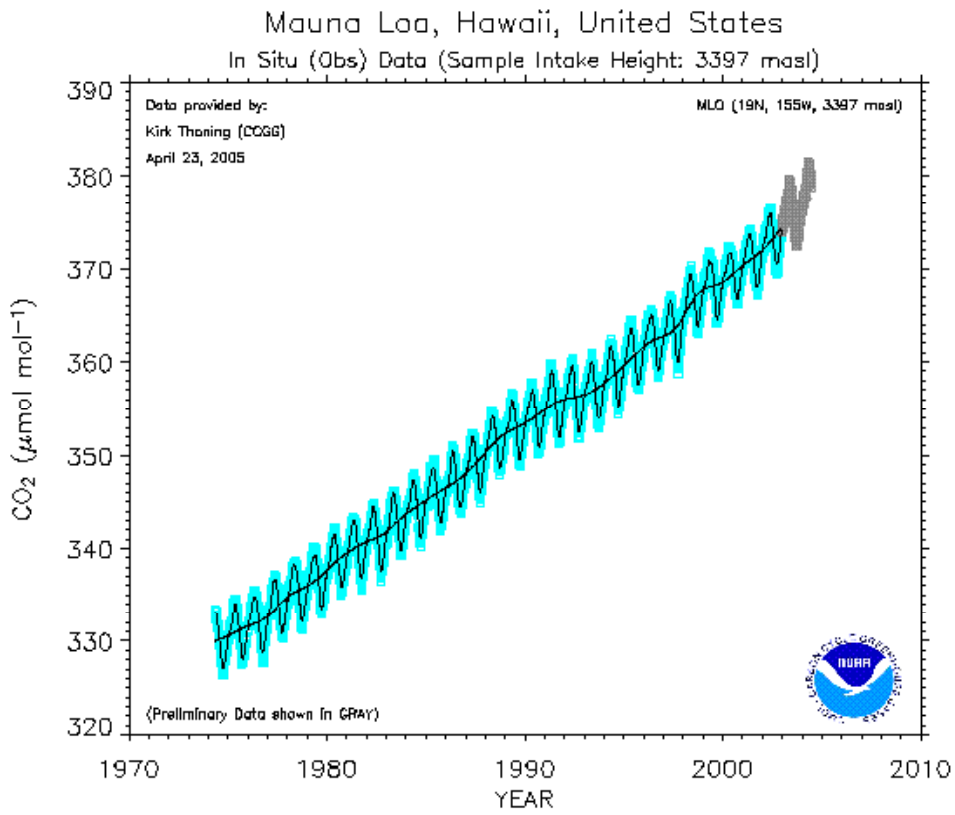
"Concentrations of atmospheric greenhouse gases ... have continued to increase as a result of human activities"

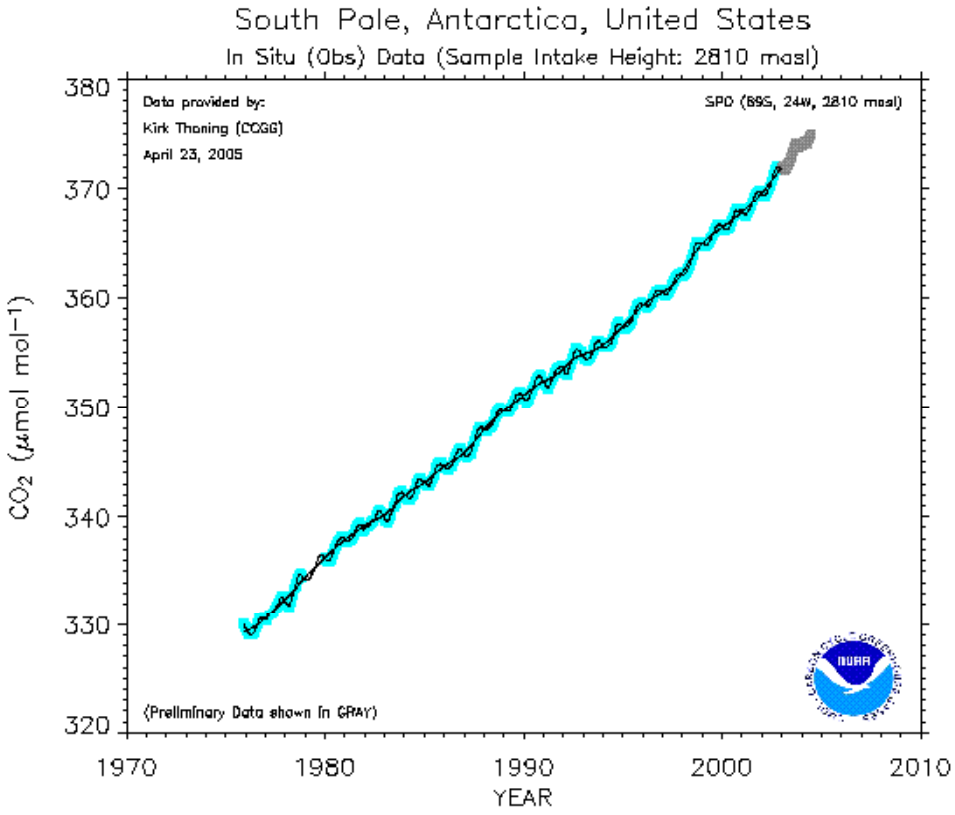
THE UNIVERSITY OF OKLAHOMA SCHOOL OF METEOROLOGY

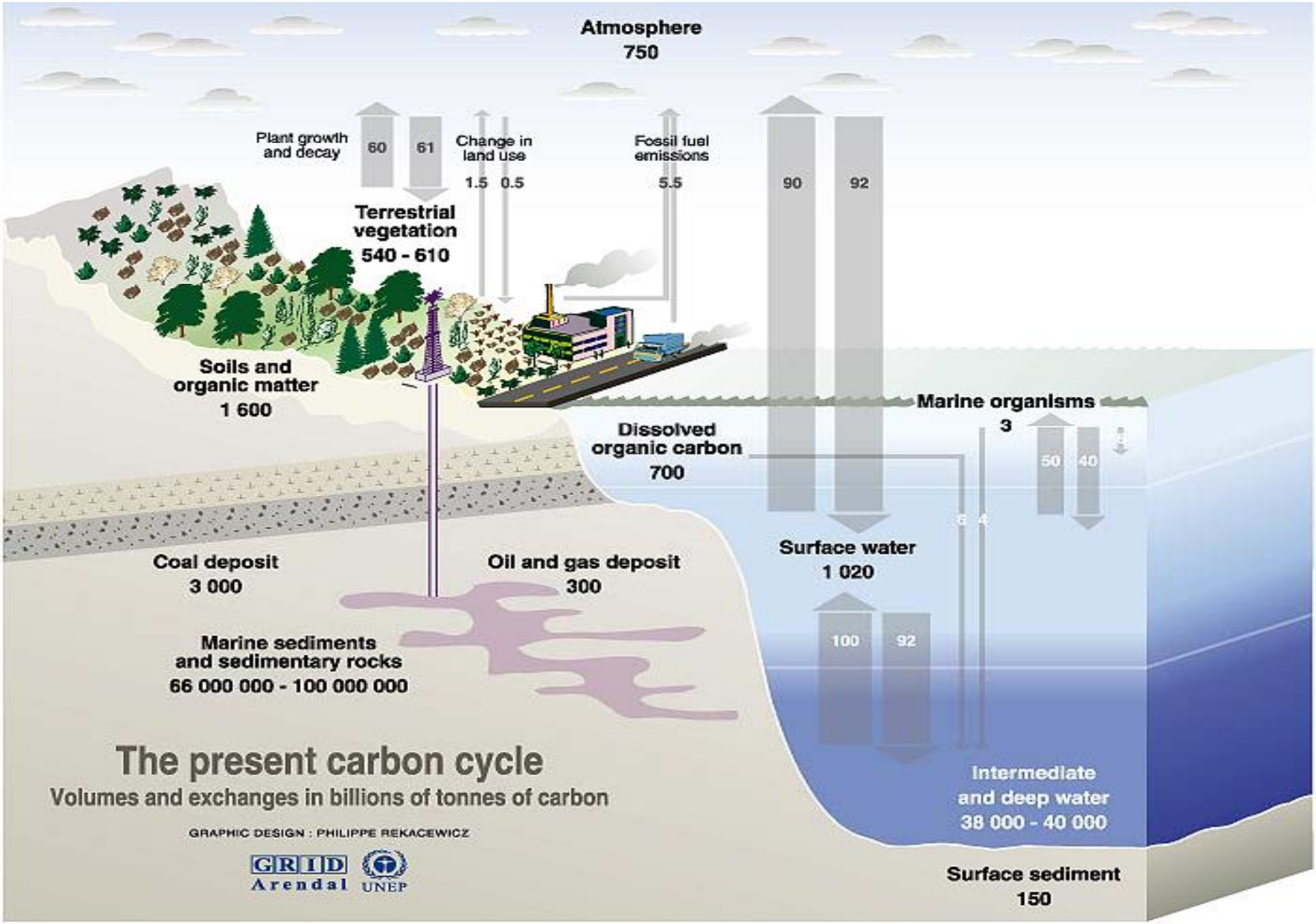
Recent instrumental observations show:

- increasing concentrations in both hemispheres
- a pronounced seasonal cycle in the NH, with max concentrations in winter
- Slightly lower concentrations in the SH but similar increases

These show many aspects of the natural carbon cycle and the human perturbations imposed on it.

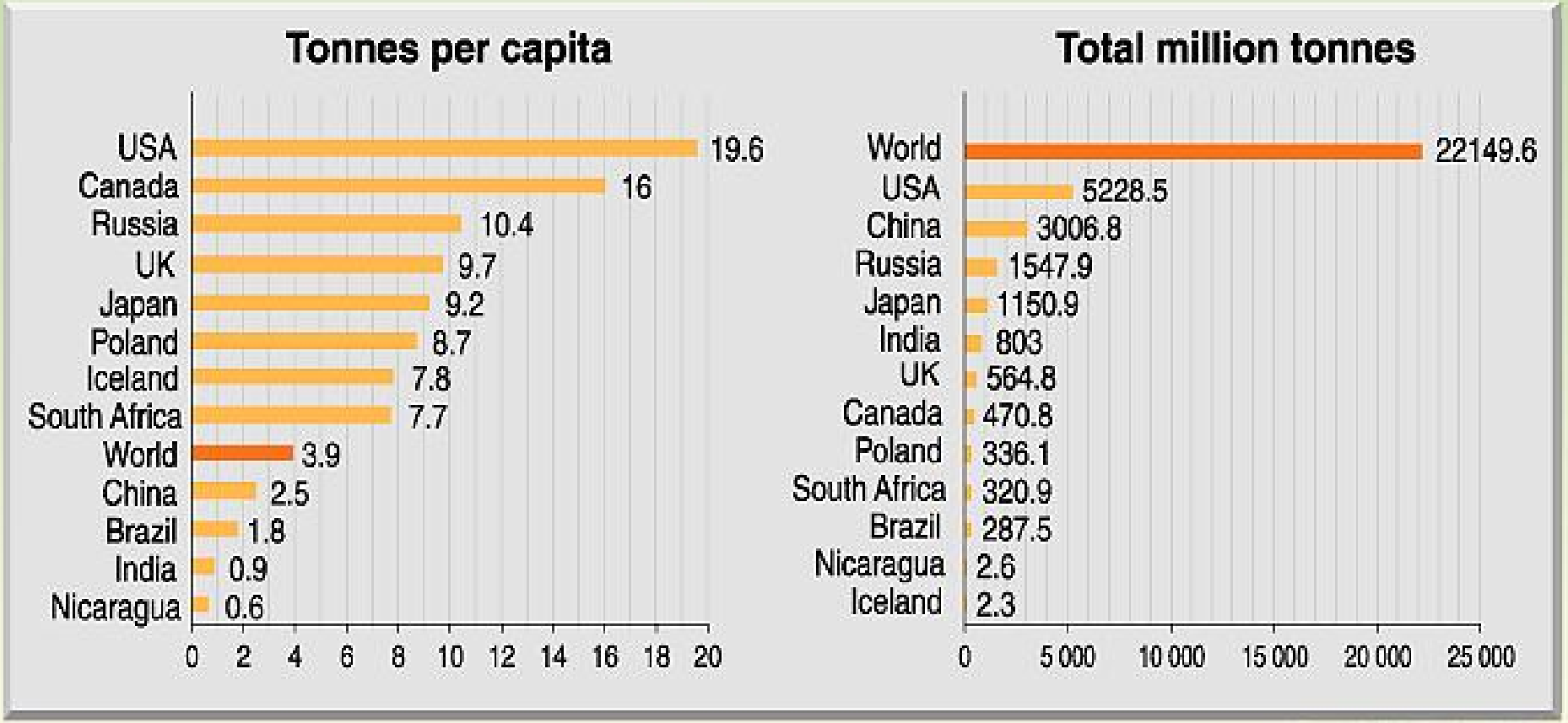






Sources: Center for climatic research, Institute for environmental studies, university of Wisconsin at Madison; Okanagan university college in Canada, Department of geography; World Watch, November-December 1998; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 1996.

Emissions of CO_2 - selected countries (1995)



GRAPHIC DESIGN : PHILIPPE REKACEWICZ

GRID Arendal UNEP

Source : International Energy Agency, 1998.

Emissions in tonnes of CO_2, not tonnes of carbon

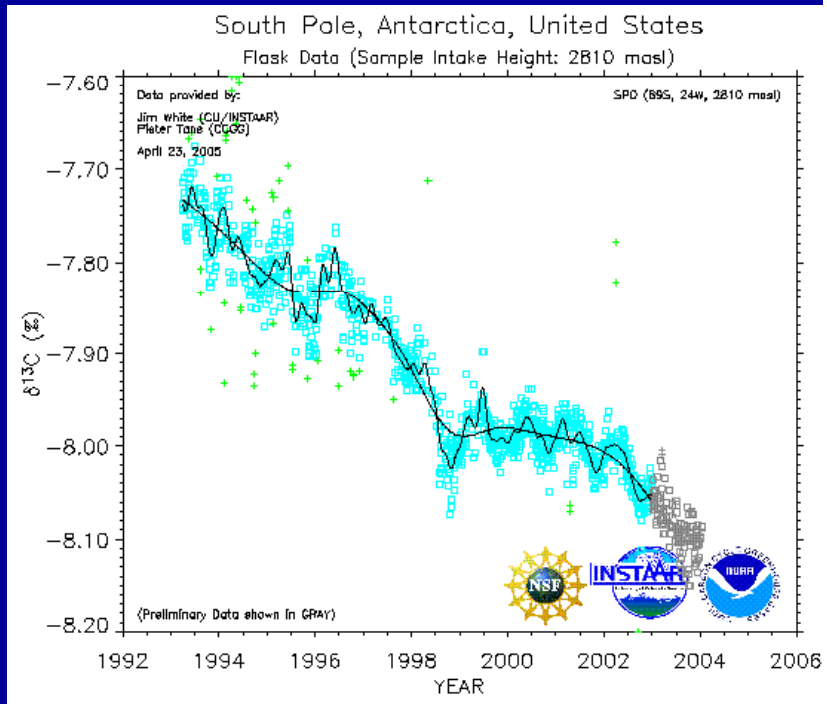
THE UNIVERSITY OF OKLAHOMA SCHOOL OF METEOROLOGY

Sinks for the human perturbation

- Uptake into the land biosphere: associated with regrowth of NH forests in middle and high latitudes and CO_2 fertilization of plant photosynthesis
- Uptake into the ocean: CO_2 dissolves into water in the upper layers of the ocean, then is slowly mixed into the deeper ocean. In addition, ocean biological activity fixes CO_2 from the water, and plant and animal debris sinks into the deeper ocean waters

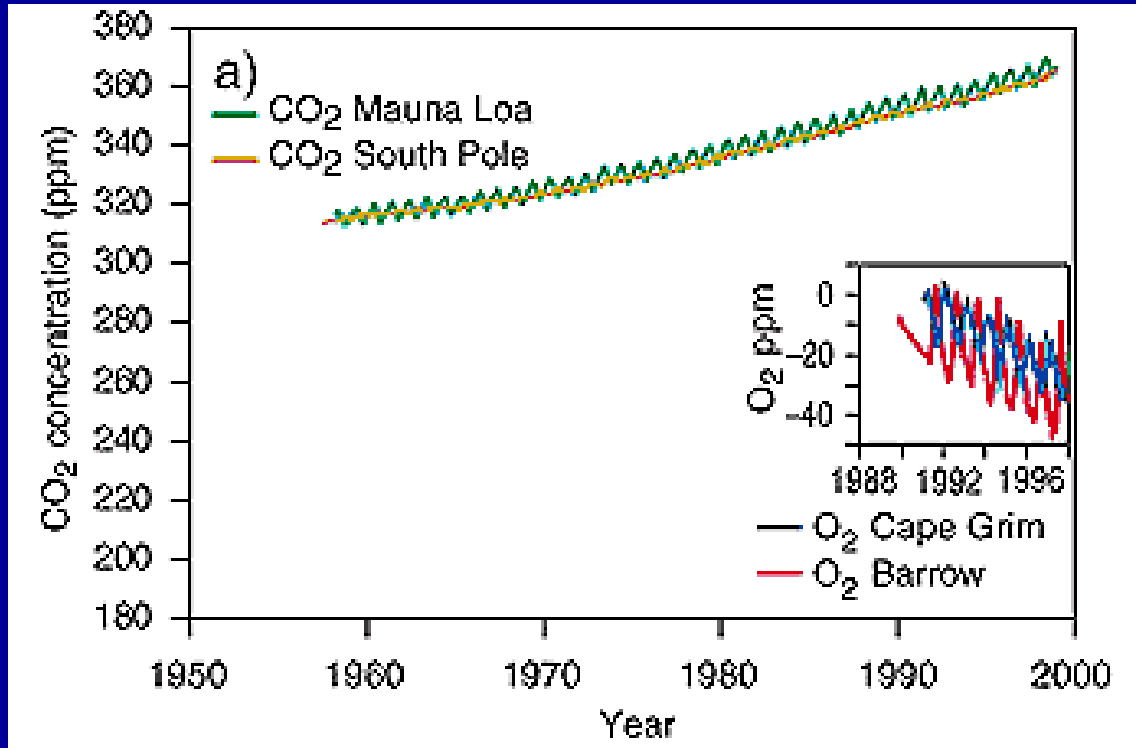
How do we know that the increase in CO_2 is due to fossil fuel burning?

- Carbon isotopes: Carbon is found in three isotopes with different atomic weights, ^{12}C, ^{13}C, and ^{14}C which decays radioactively. Photosynthesis takes up less ^{13}C than ^{12}C, so fossil fuel contains less ^{13}C than normal air. Adding CO_2 from burning fossil fuels or decaying vegetation will decrease the proportion of ^{13}C
- Since fossil fuels are very old vegetation, all the ^{14}C would have decayed. CO_2 from fossil fuels would reduce the proportion of ^{14}C compared with land clearing.



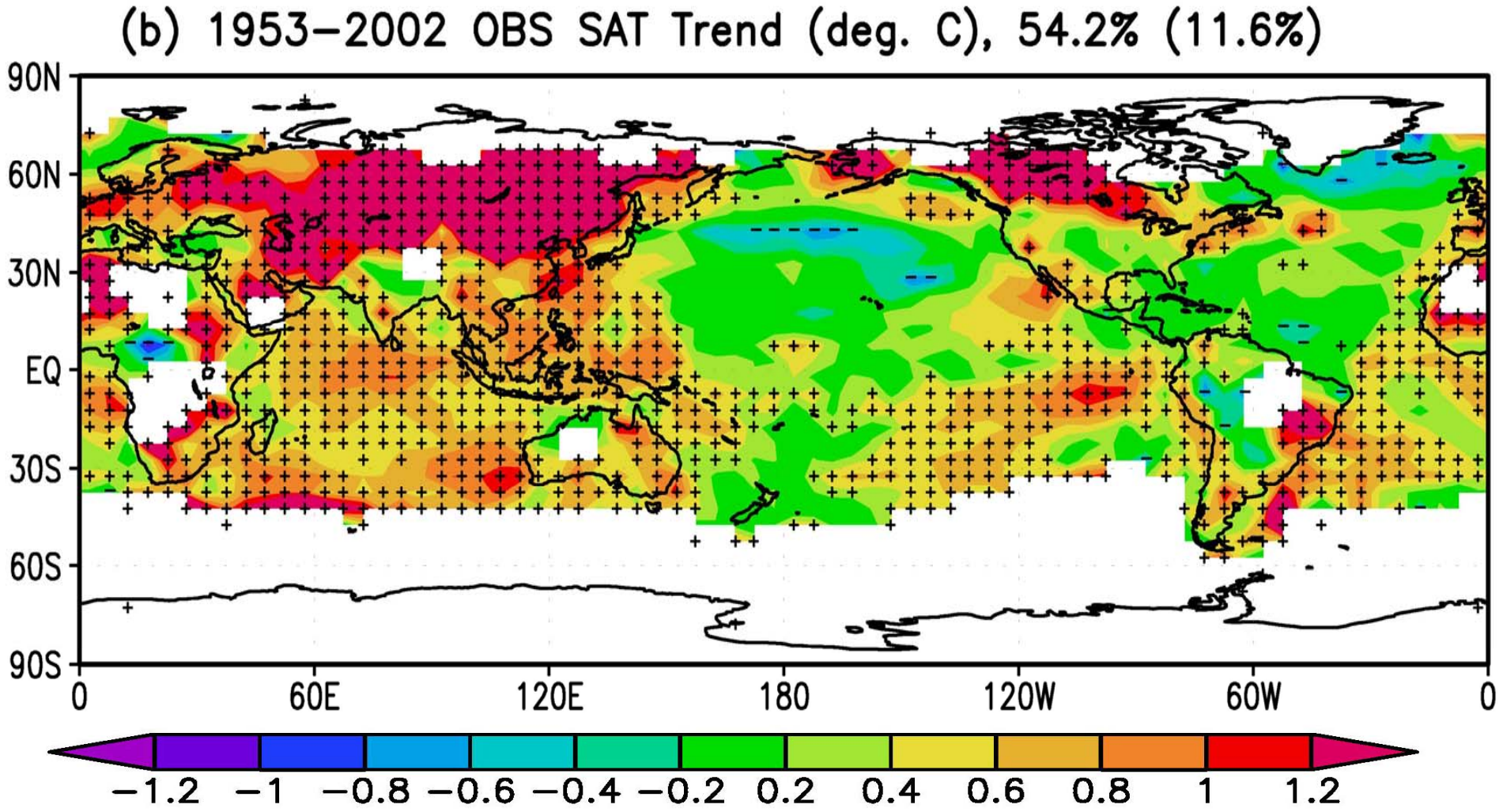
Couldn't the increased CO_2 be due to volcanic emissions, like the early Earth?

- When fossil fuels are burned or vegetation decays, oxygen is combined with carbon to make CO_2
- If CO_2 increases in the atmosphere were due to volcanic emissions, there would be no decreases in oxygen concentrations
- Recent increases in CO_2 concentrations have been matched by observed decreases in oxygen concentrations.

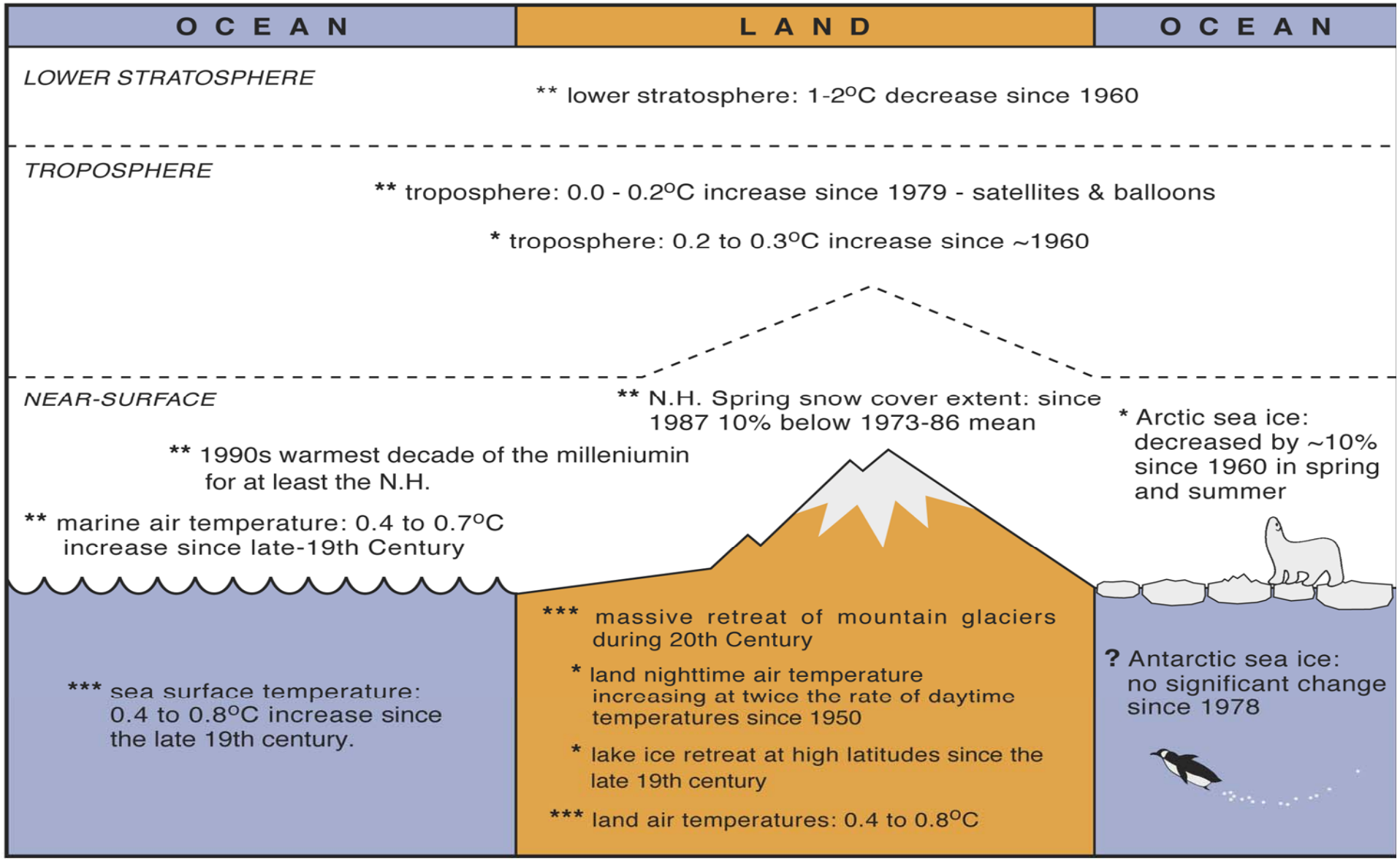


Observed warming

Observed trend over last 50 years based on surface temperature observations over land and sea.
'+' marks locations with significant trends



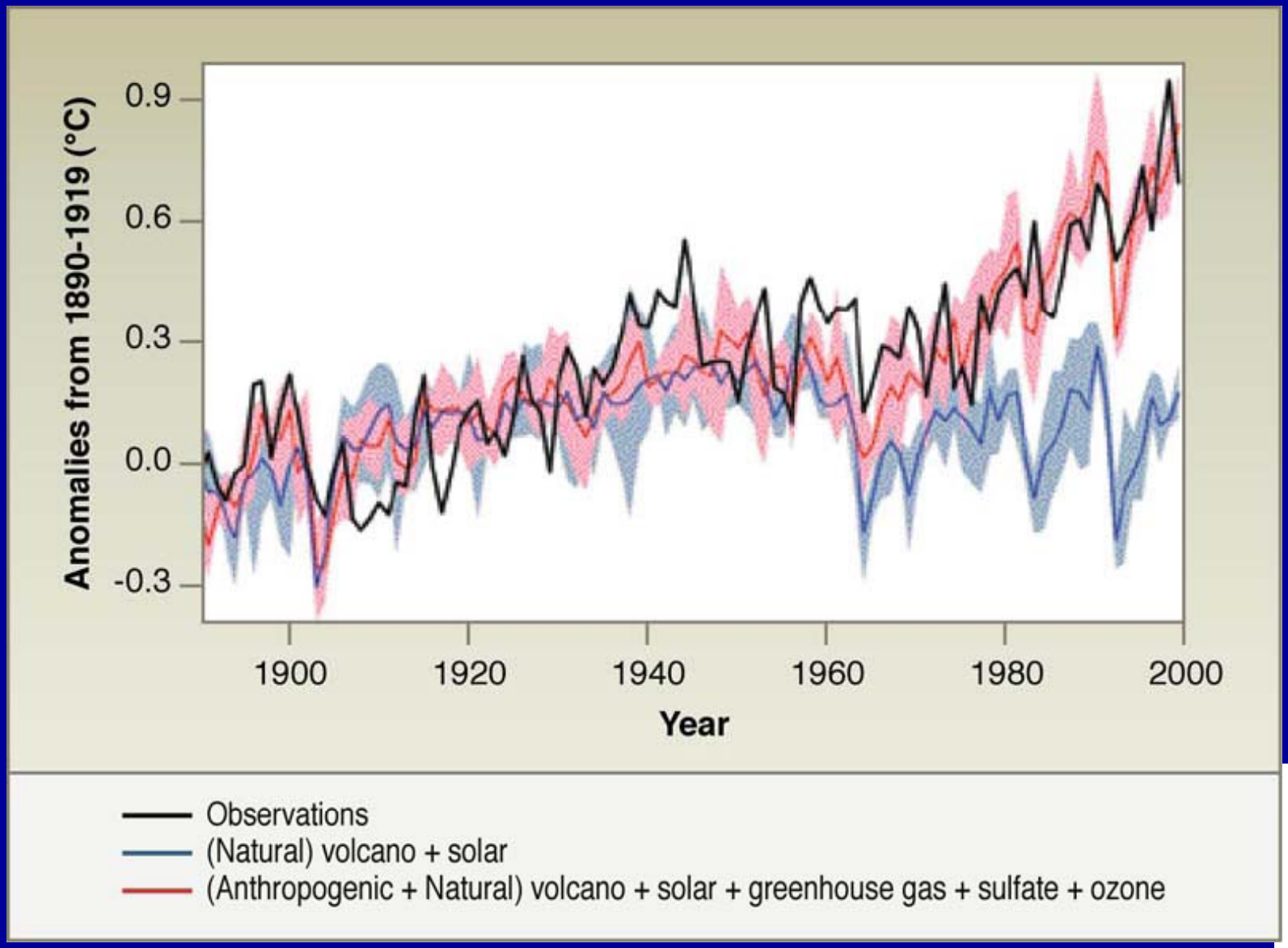
Temperature Indicators



Asterisk indicates Confidence Level :
(i.e. assessment)

*** **Virtually certain (probability > 99%)**
** **Very likely (probability > 90% but ≤ 99%)**
* **Likely (probability > 66% but < 90%**
? **Possible (probability > 33% but ≤ 66%)**

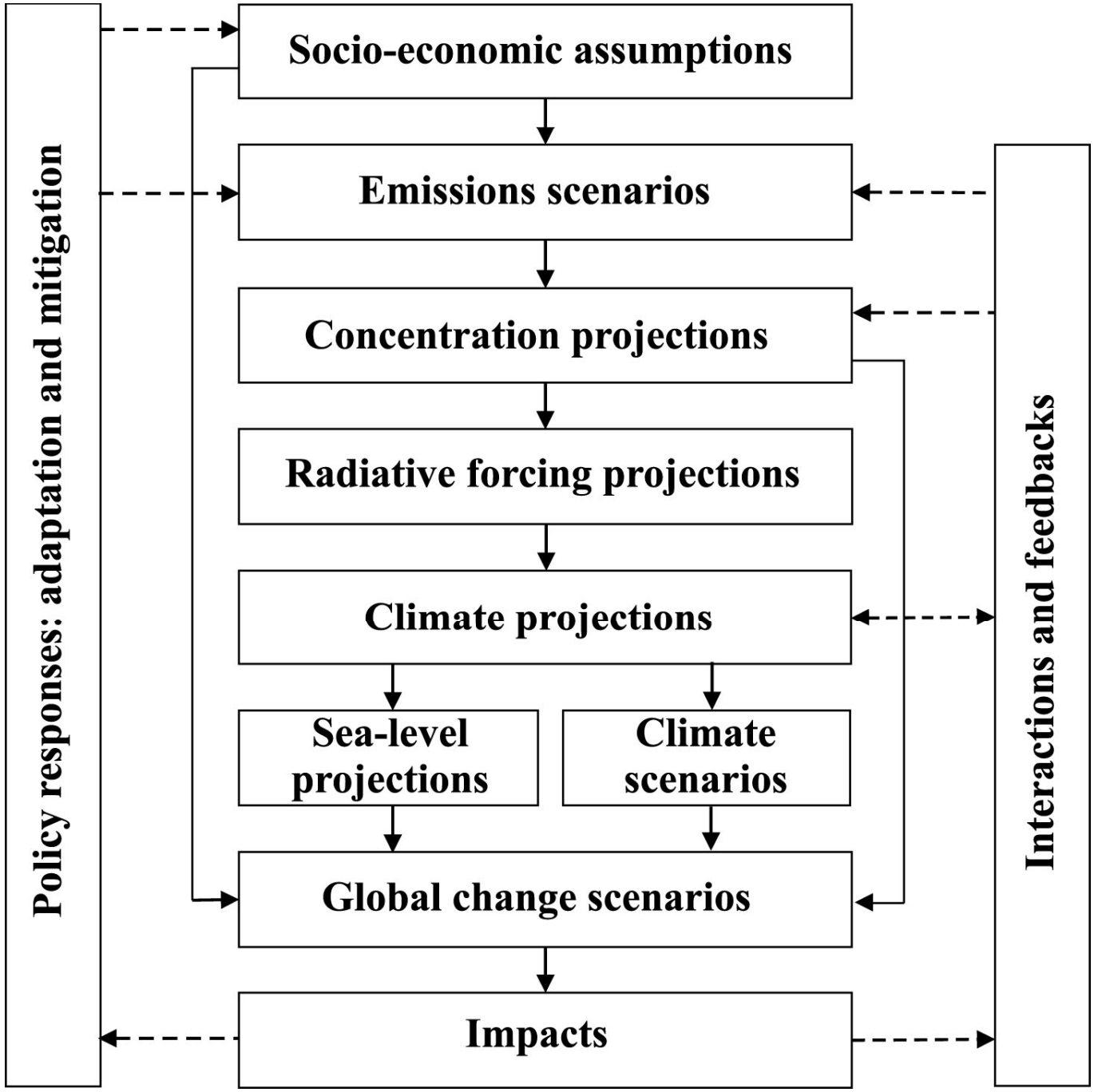
"Most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations"

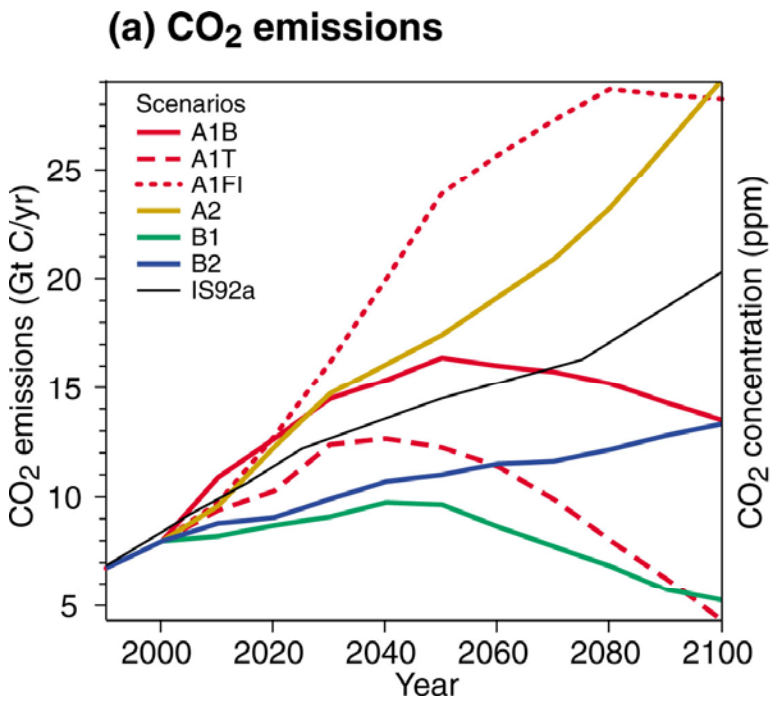


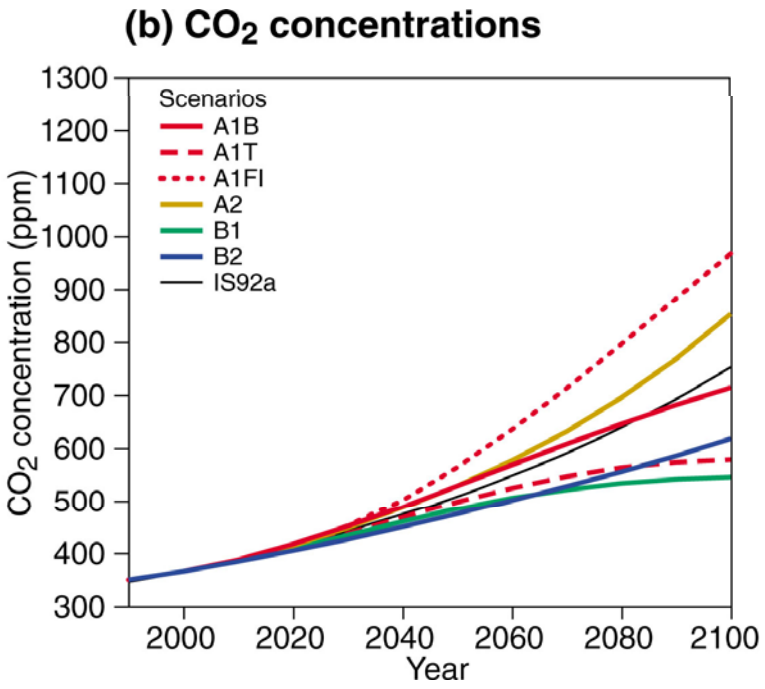
Runs with NCAR climate model

THE UNIVERSITY OF OKLAHOMA SCHOOL OF METEOROLOGY

“In the light of new evidence and taking into account the remaining uncertainties, most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations”


Socio-economic assumptions
Emissions scenarios
Concentration projections
Radiative forcing projections
Climate projections
Sea-level projections
Climate scenarios
Global change scenarios
Impacts
Policy responses: adaptation and mitigation
Interactions and feedbacks





"Human influences will continue to change atmospheric composition throughout the 21st century"

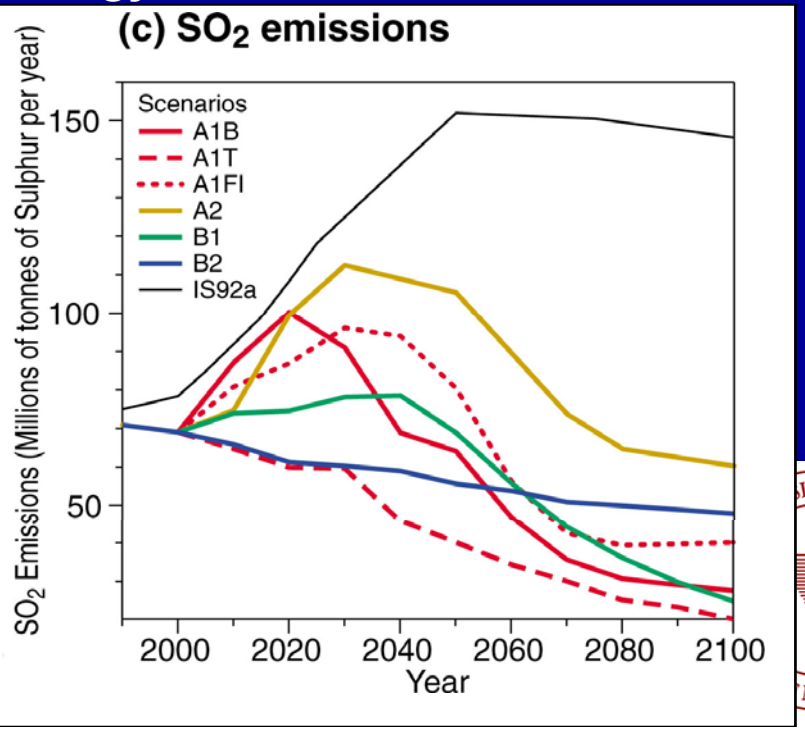
Emission Scenarios of the IPCC

A1: rapid growth, rapid technology introduction

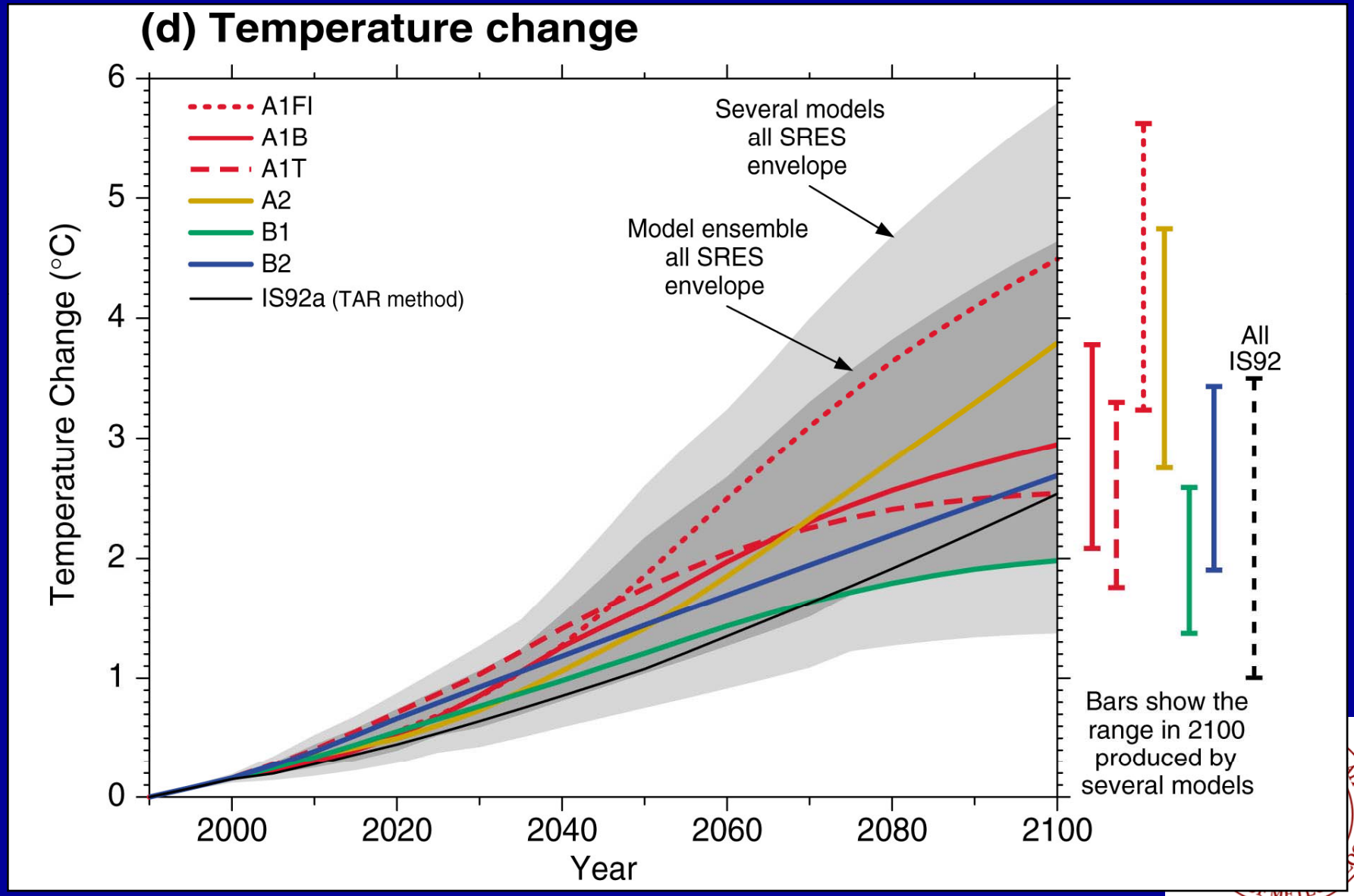
A2:self-reliance and local identity

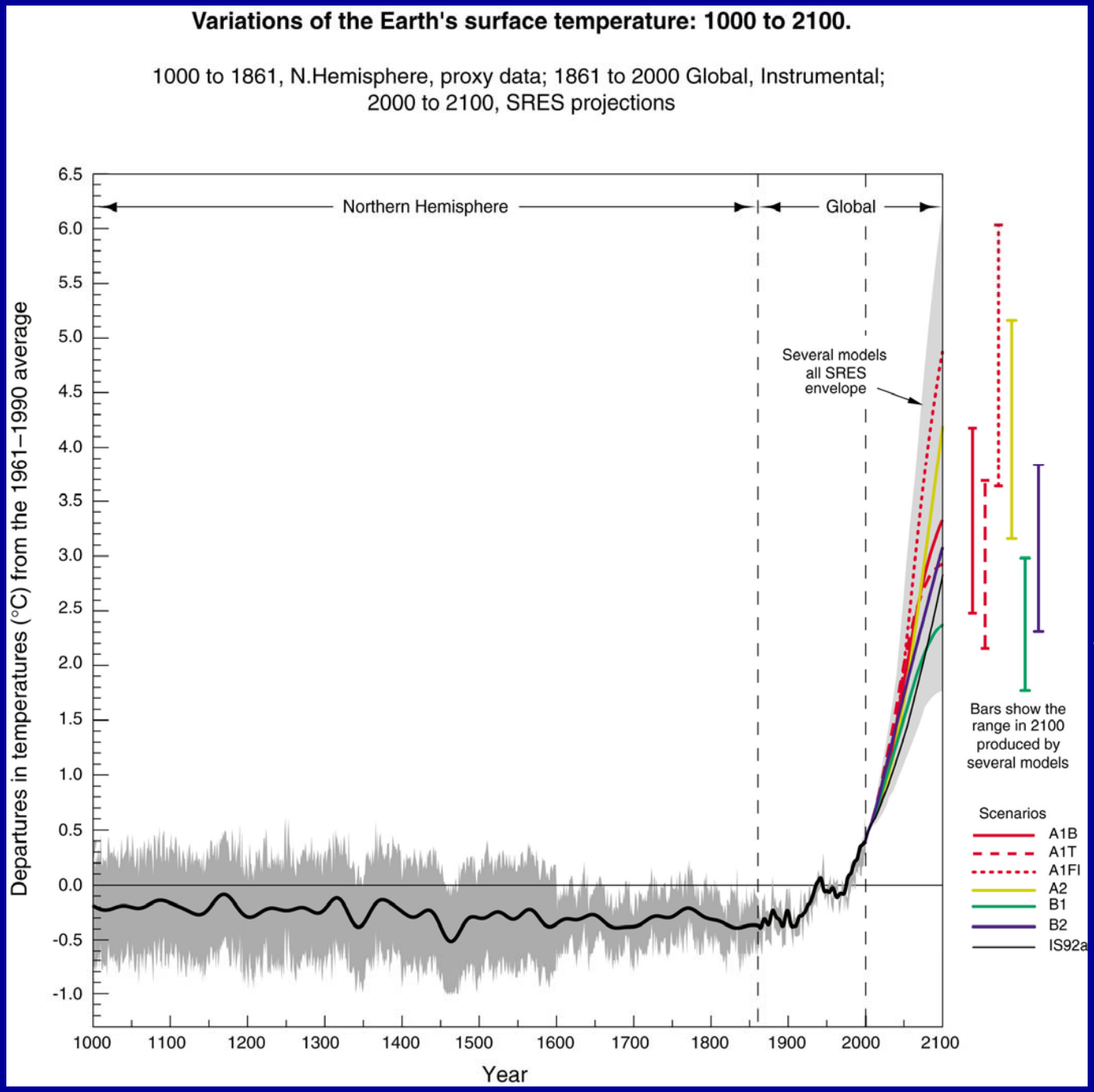
B1: clean and resource efficient technology

B2: local, environmental, social equity diverse technology



“Global average temperature and sea level are projected to rise under all IPCC SRES scenarios.”





"The projected rate of warming is much larger than the observed changes during the 20th century and is very likely to be without precedent during at least the last 10,000 years"

THE UNIVERSITY OF OKLAHOMA SCHOOL OF METEOROLOGY

Future Impacts

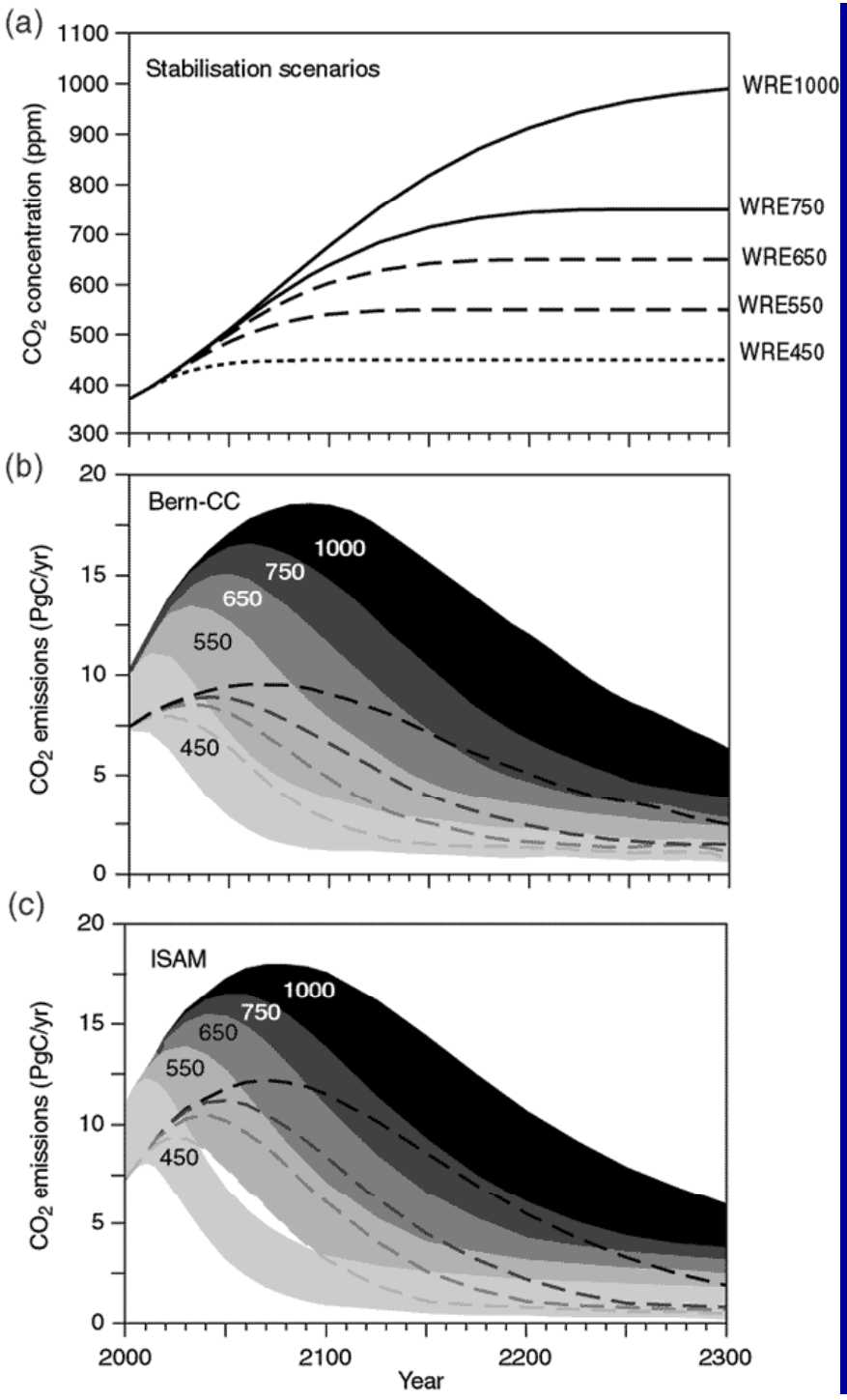
- Global warming and sea level increases
- Increasing night time minimum temperatures - fewer frosts
- Increasing daytime maximum temperatures
- Greater plant growth in high CO_2 atmosphere and longer growing season in middle and high latitudes
- Increasing rainfall intensity - more flooding
- Reducing snow cover
- More evaporation - less soil moisture - more droughts
- Coral bleaching

UN Framework Convention on Climate Change (UNFCCC)

- Established following the United Nations conference on Environment and Development in Rio de Janeiro in 1992
- Objective is “stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system”
- “Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner”
- Signed by 160 countries, including the USA, and came into force in March 1994

Kyoto Protocol

- Conference of Parties to the UNFCCC in Dec 1997
- Annex 1 (developed) countries agreed to targets for reductions of greenhouse gas emissions in 2008-2012 below 1990 levels
- Reductions: EU 8%, USA 7%, Canada, Japan 6%
- Russia 0%
- Australia allowed increase of 8%
- Non-Annex 1 (developing countries) have no targets
- Protocol came into force on Feb 16, 2005 following ratification by Russia



Stabilization scenarios

Projected CO_2 emissions permitting stabilization of atmospheric CO_2 concentrations at different final values.

All of the stabilization profiles studied require emissions to eventually drop well below current levels. Stabilisation at 450, 650 or 1,000 ppm would require global anthropogenic emissions to drop below 1990 levels within a few decades, about a century, or about two centuries, respectively, and continue to steadily decrease thereafter.

THE UNIVERSITY OF OKLAHOMA SCHOOL OF METEOROLOGY

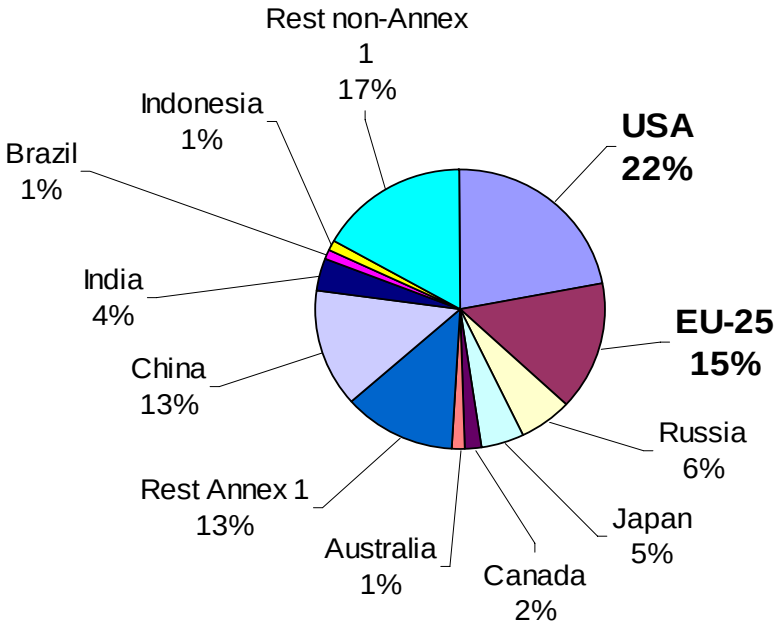
Stabilization of climate

- Substantial reductions of greenhouse gas emissions are required below 1990 levels to stabilise atmospheric concentrations
- Due to the very long adjustment time scales of the climate system, global warming will continue for many years after greenhouse gas concentrations are stabilized
- Global mean temperatures will stabilize centuries after stabilization of ghg concentrations, but sea level rise will continue for many more centuries

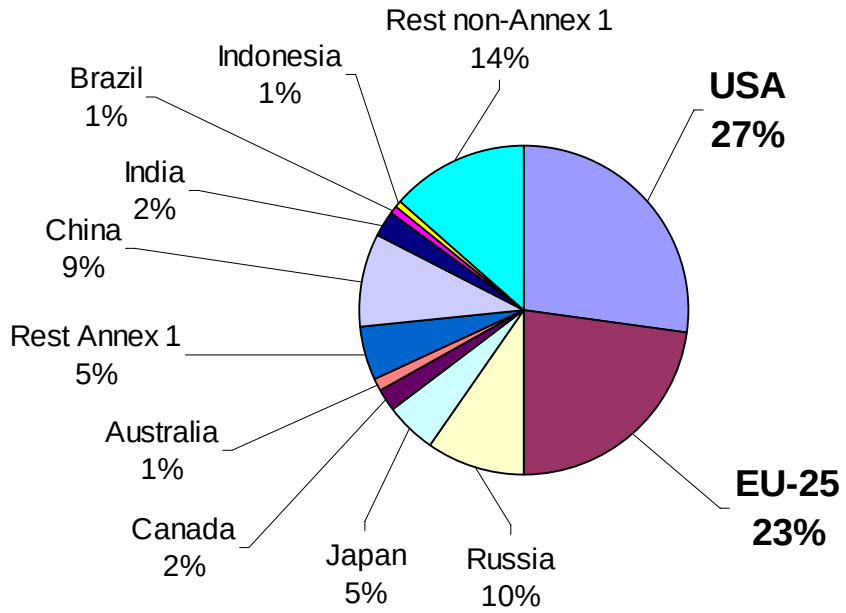
Who has caused the problem?

UNFCCC includes principle that: **"Parties should protect the climate system...on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities. Accordingly, the developed country Parties should take the lead in combating climate change"** (UNFCCC, Art.3.1).

2000 CO_2 shares by UN member State



Cumulative CO_2 1950-2000 Shares by UN member State

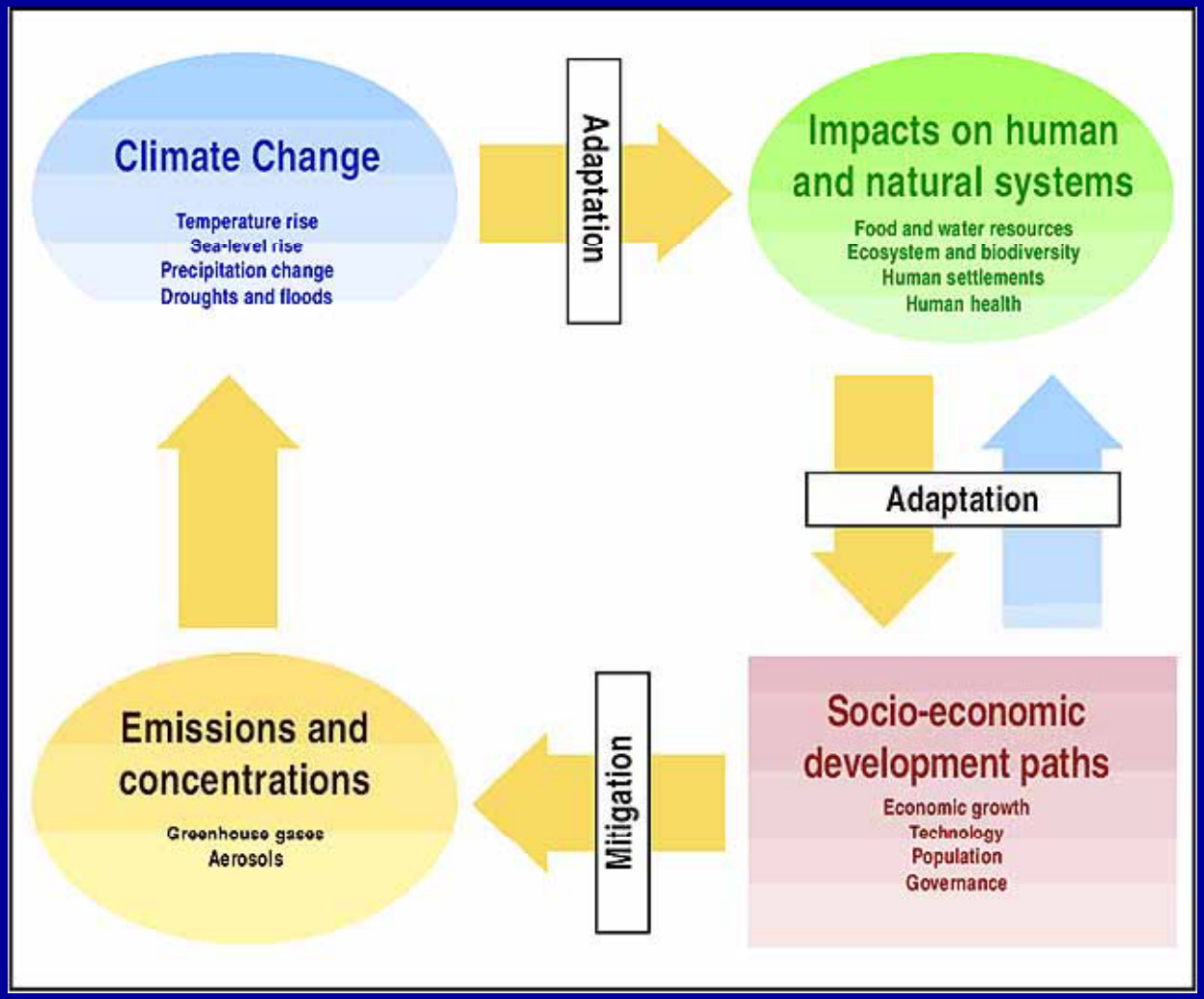


Costs and benefits

- The costs of reducing greenhouse gas emissions have to be balanced against the future costs of the impacts of climate change
- Economic analysis
  - Reduces future costs compared with current costs
  - Quantifies the value of life in terms of contribution to GDP
  - Finds it difficult to quantify costs associated with environmental quality
- Most of the winners will be in colder climates while losers will be more in tropical and subtropical climates
- Developing countries have the least capacity to adapt and will be the most adversely affected by climate change

Adaptation or mitigation?

Since climate change will increase, some adaptation, as well as mitigation, will be needed in all countries.

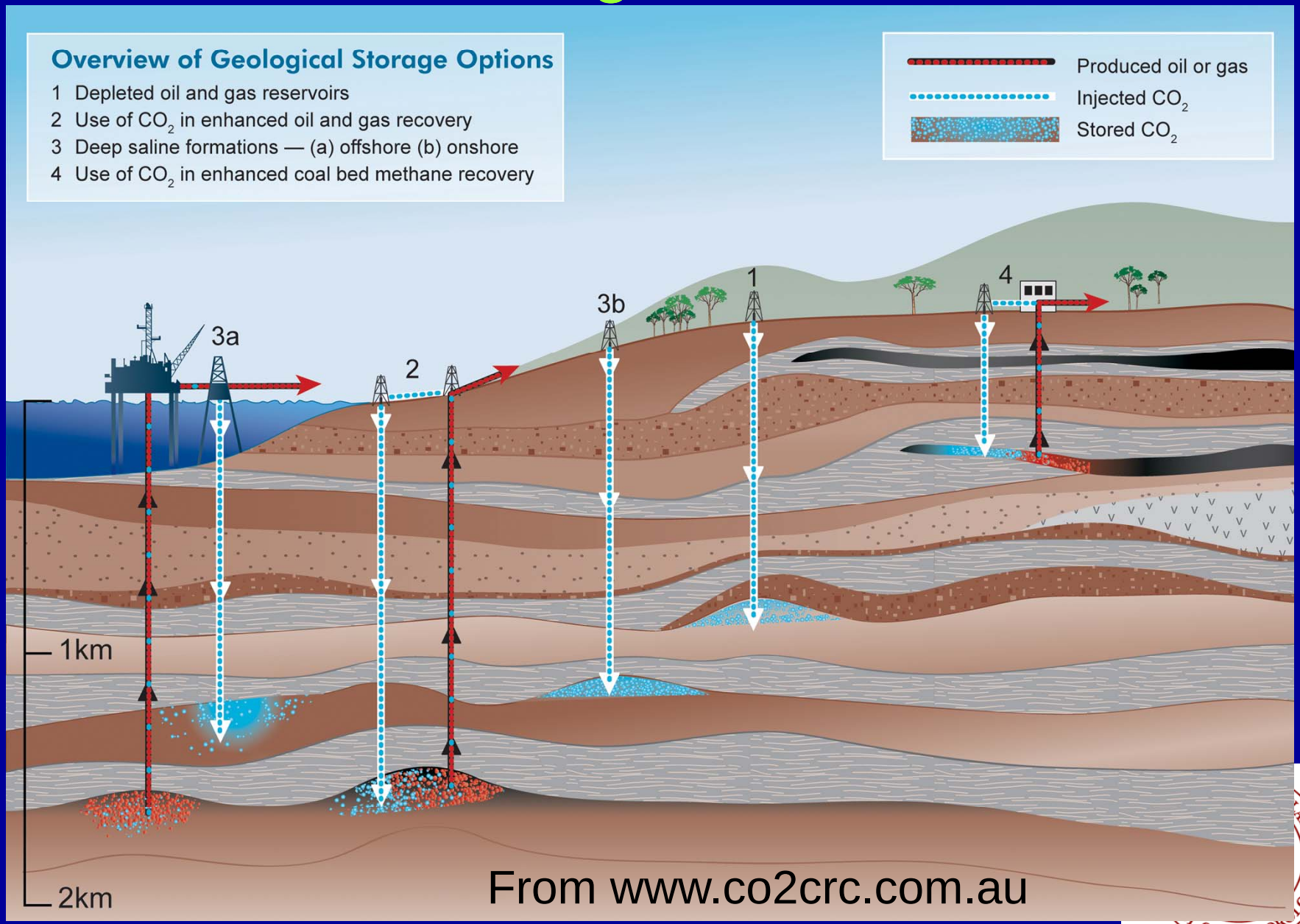


THE UNIVERSITY OF OKLAHOMA SCHOOL OF METEOROLOGY

Reducing emissions

- Atmospheric concentrations of greenhouse gases can be reduced either by reducing emissions or by removing the gases from the atmosphere
- Reducing methane emissions (preventing natural gas leaks or fugitive emissions from waste dumps) is effective due to the high GWP of methane
- CO_2 emissions can be reduced through improvements in energy efficiency, in carbon efficiency, or in alternative, zero carbon technologies
- CO_2 concentrations can be reduced through carbon sequestration through enhanced photosynthesis or chemical capture and storage
- IPCC assesment of CO_2 capture & storage
  http://www.ipcc.ch/activity/ccsspm.pdf

Reducing emissions



Summary

- Climate has changed over the past century
- Climate is expected to continue to change in the future
- Substantial reductions in greenhouse gas emissions are required to achieve stabilisation of atmospheric concentrations
- With increasing energy use in developing countries, developed countries will need to reduce their per-capita emissions substantially to stabilise greenhouse gas concentrations
- There are complex ethical, economic, and environmental issues involved

What can you do?

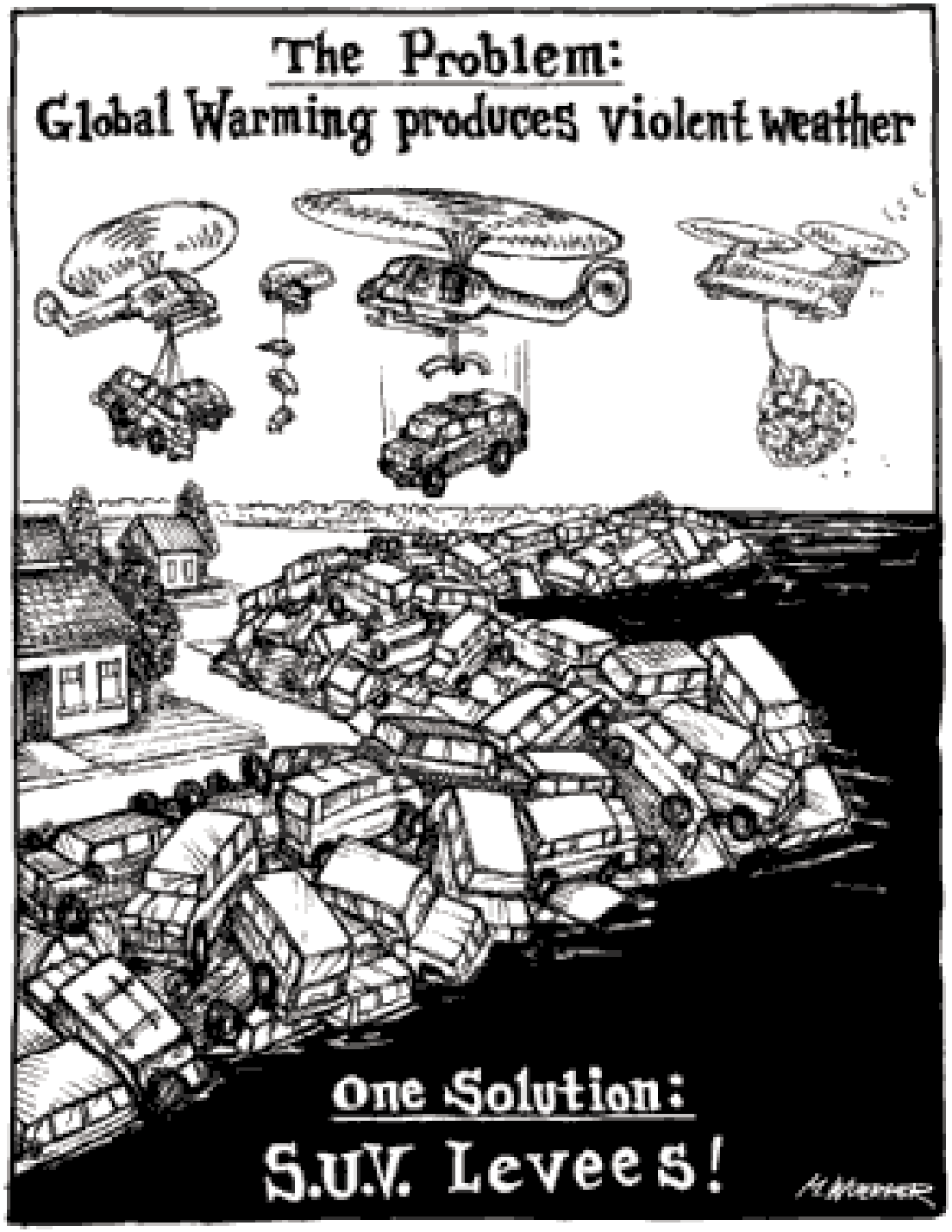
- **Use energy efficient appliances**
- **Use a more fuel efficient car**
- **Choose wind power for your electricity**

"We know the science. We see the threat posed by changes in our climate. The time for action is now."

Gov. of California on July 5, 2005

OG&E Wind Power

THE UNIVERSITY OF OKLAHOMA SCHOOL OF METEOROLOGY

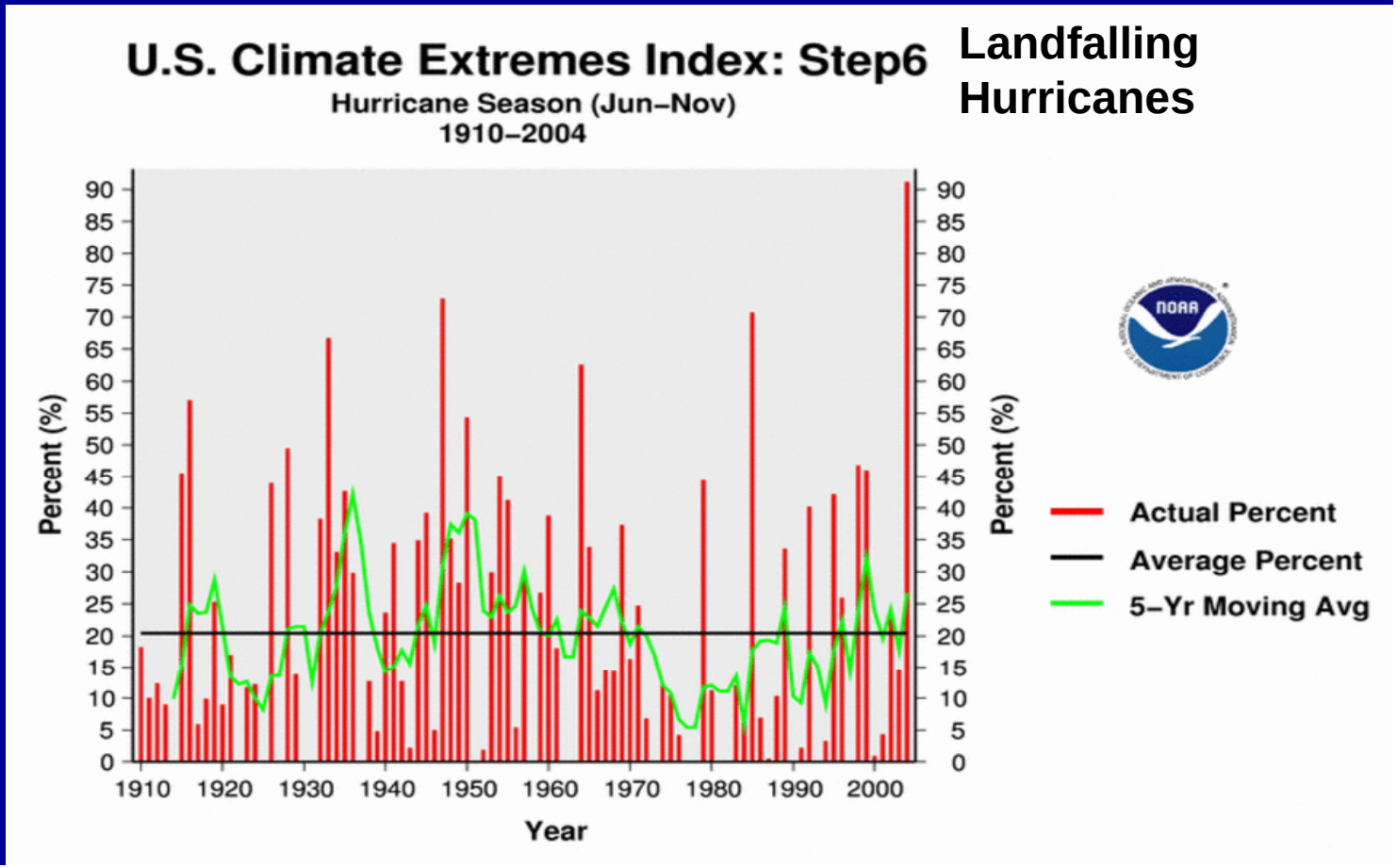


THE UNIVERSITY OF OKLAHOMA SCHOOL OF METEOROLOGY

Hurricanes and tropical SSTs

- Recent papers have reported increasing intensity of hurricanes over the last 30-50 years
- There is large low frequency variability of hurricane intensity and SST in the Atlantic

An index of the strength of US landfalling hurricanes, based on sum of squares of the wind speed at land fall



Tropical SSTs

Show a warming trend over the 20th century in observations and model simulations with anthropogenic forcing.

The warming over the last 30 or 50 years is not outside the range of natural variability in the Atlantic. However, the warming over the century cannot be explained by natural variability in any of the 3 regions.