Global Warming is unequivocal

- The recent IPCC report has clearly stated that "Warming of the climate system is unequivocal" and it is "very likely" caused by human activities.

- Moreover, most of the observed changes are now simulated by climate models over the past 50 years adding confidence to future projections.

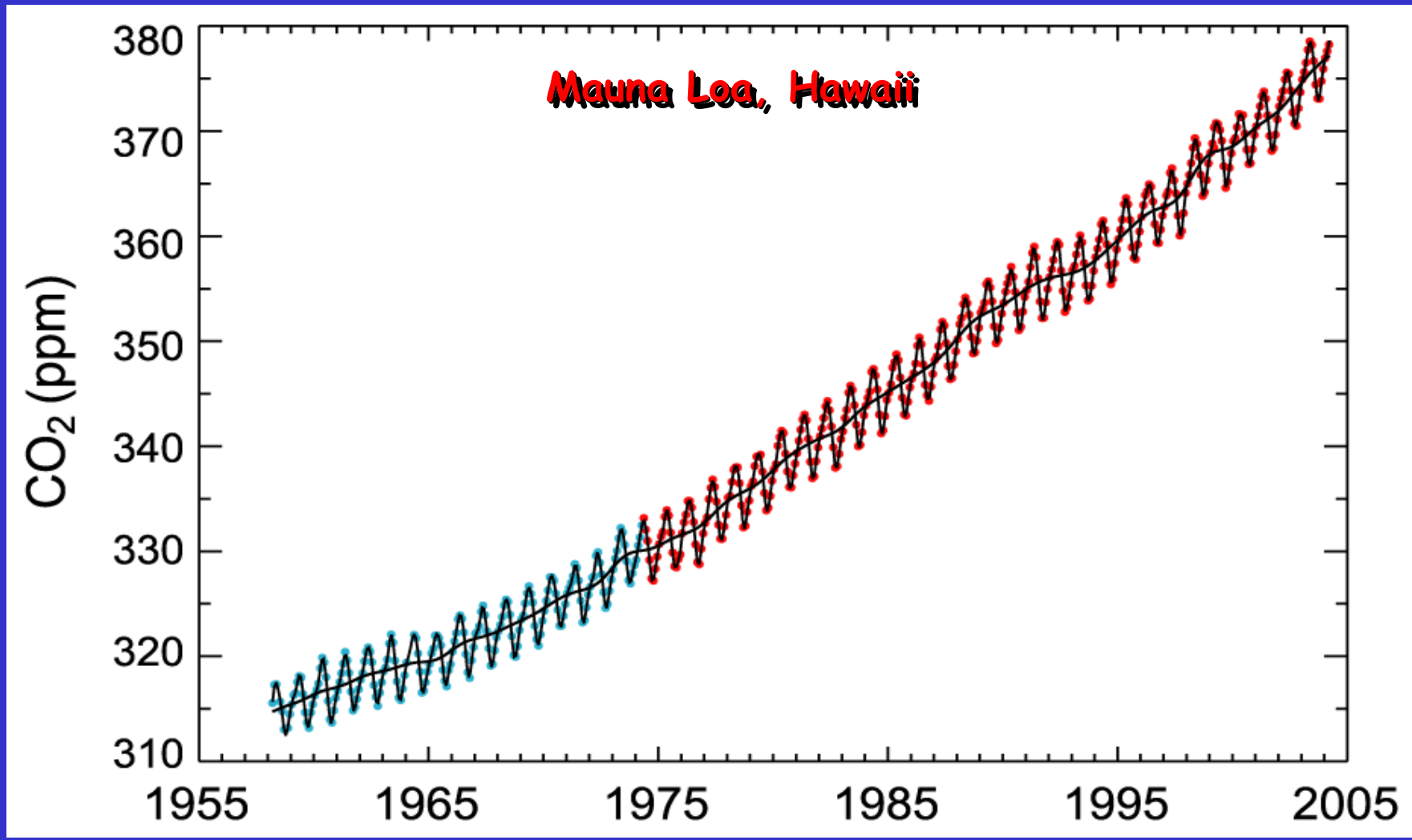
Key issue for transportation: What is your carbon footprint?

Climate

The atmosphere is a "global commons." Air over one place is typically half way round the world a week later, as shown by manned balloon flights.

The atmosphere is a dumping ground for all nations for pollution of all sorts. Some lasts a long time and is shared with all. **One consequence is global warming!**

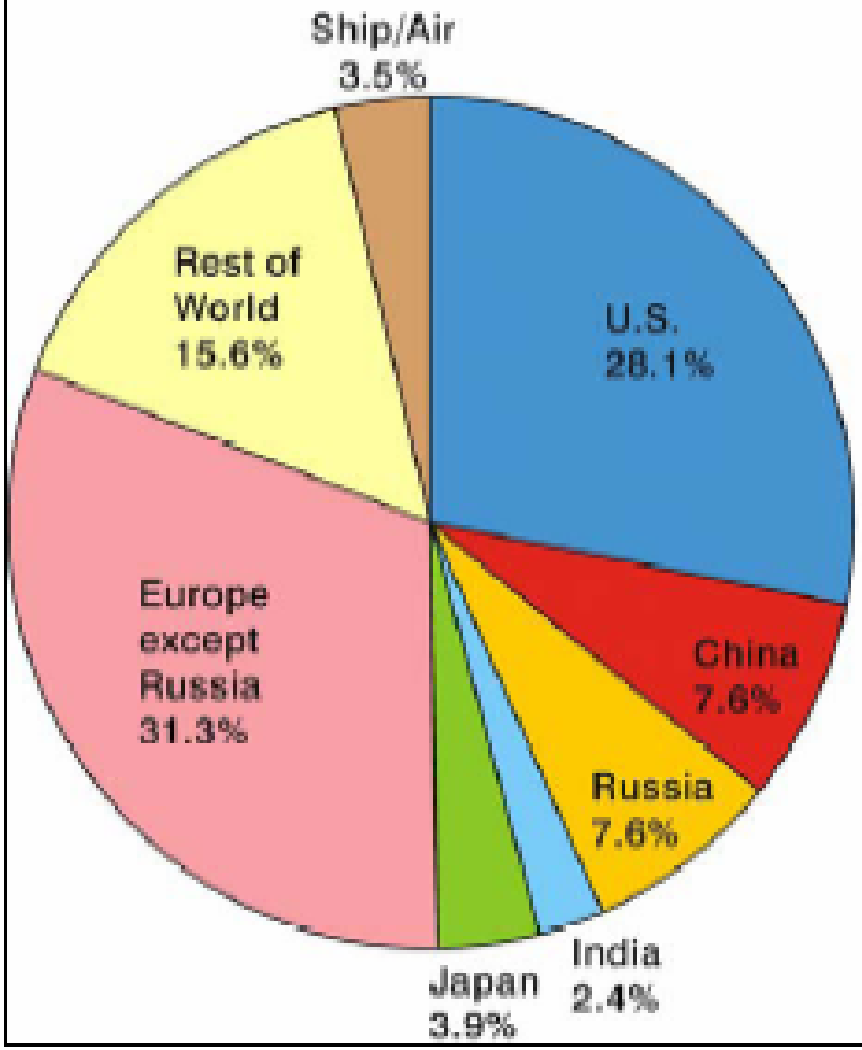
Changing atmospheric composition: CO_2

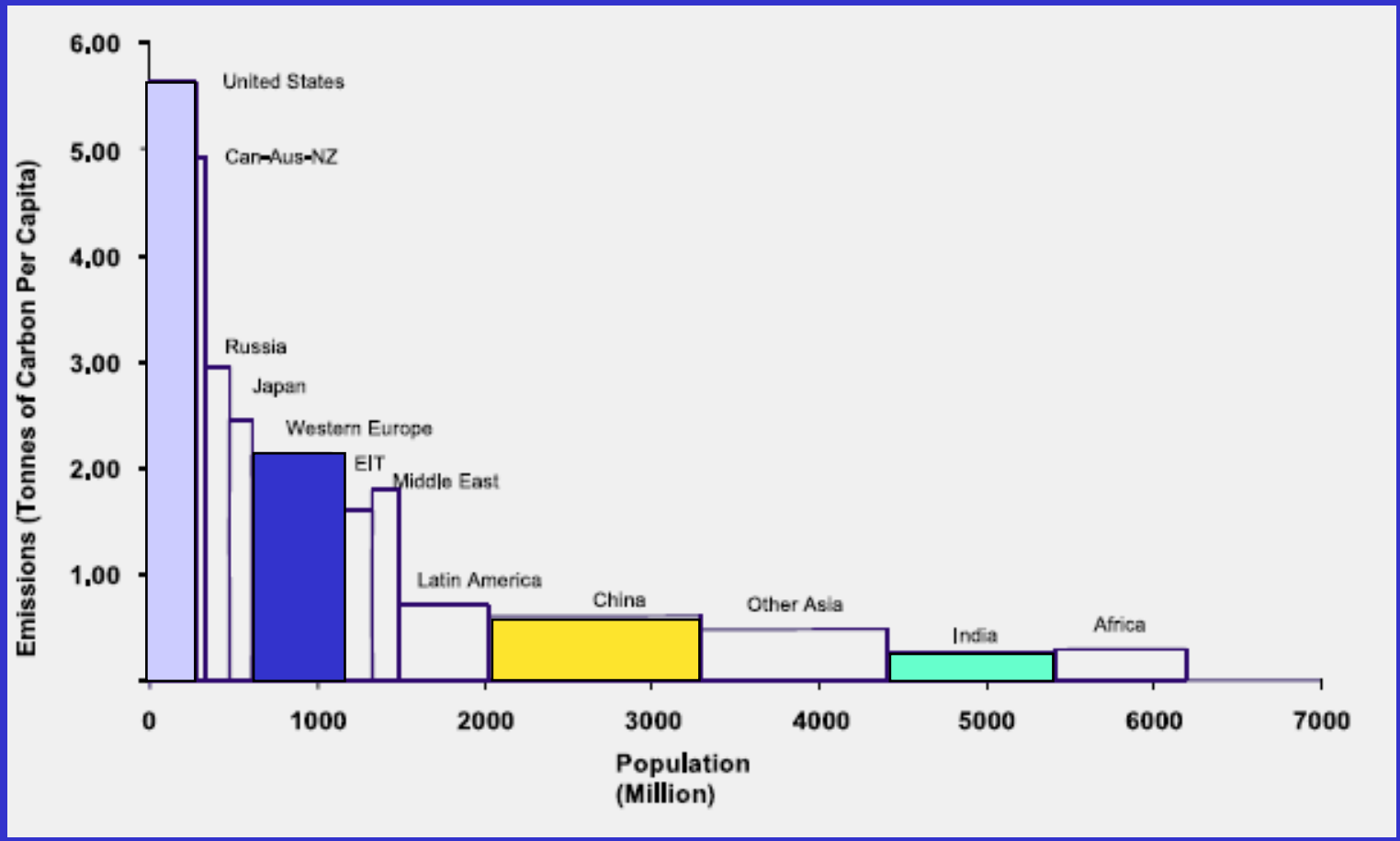


Data from Climate Monitoring and Diagnostics Lab., NOAA. Data prior to 1973 from C. Keeling, Scripps Inst. Oceanogr.

Fossil Fuel CO_2 Emissions

Accumulated Fossil Fuel CO_2 (1850-2004)

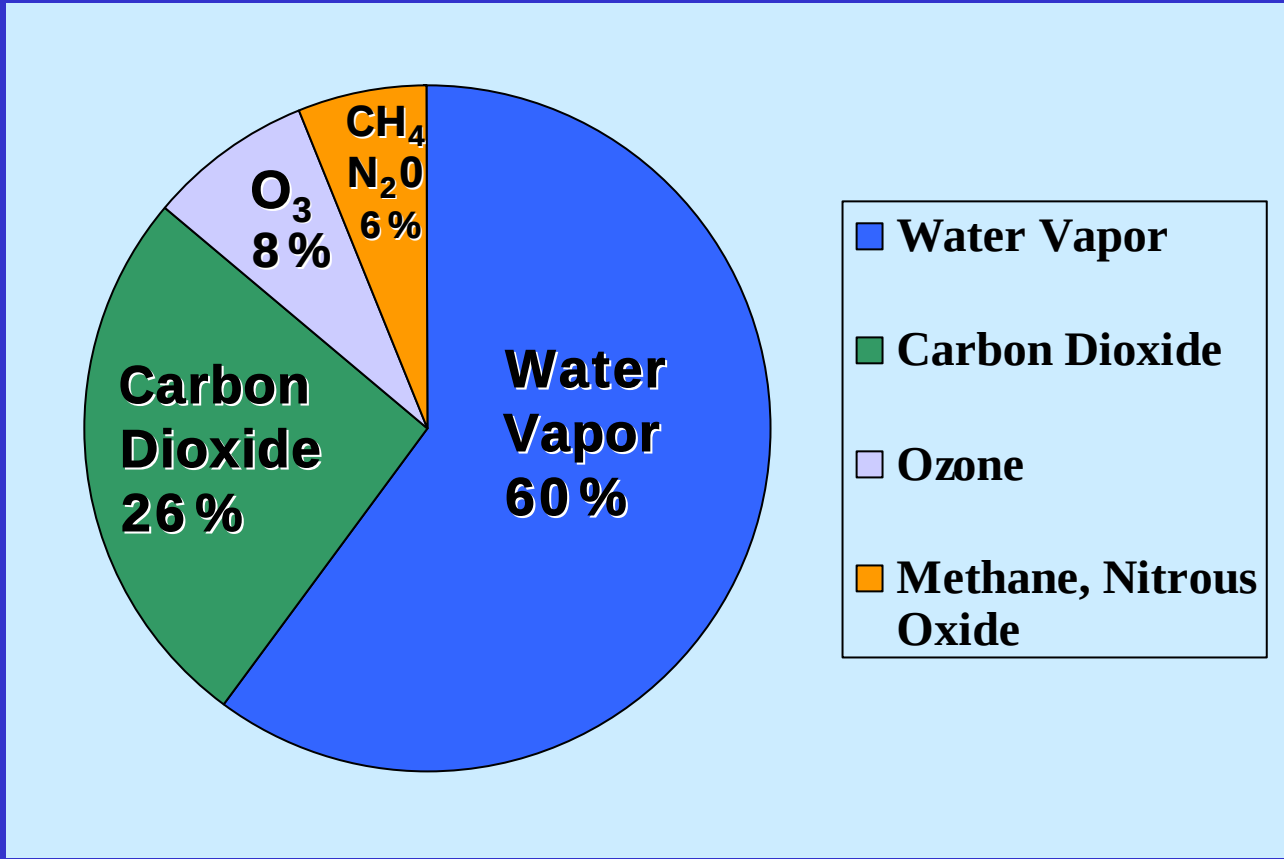




CO2 emissions in different regions in 2000 in terms of emissions per capita (height of each block); population (width of each block); and total emissions (product of population and emissions per capita = area of block).

Source: M. Grubb, http://www.eia.doe.gov/iea/

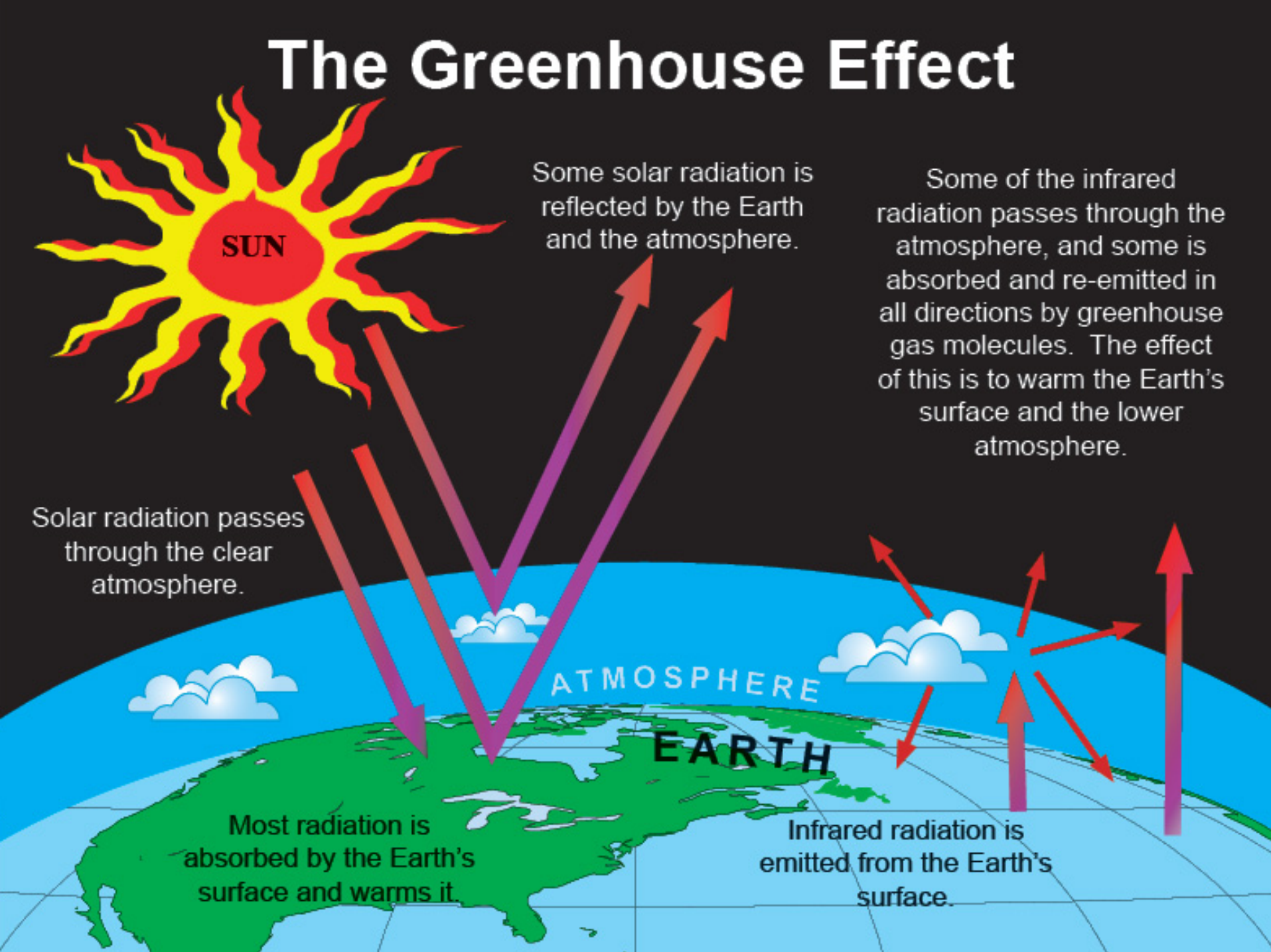
The Natural Greenhouse Effect: clear sky



Clouds also have a greenhouse effect

Kiehl and Trenberth 1997

The Greenhouse Effect



Global Warming is unequivocal

Since 1970, rise in:

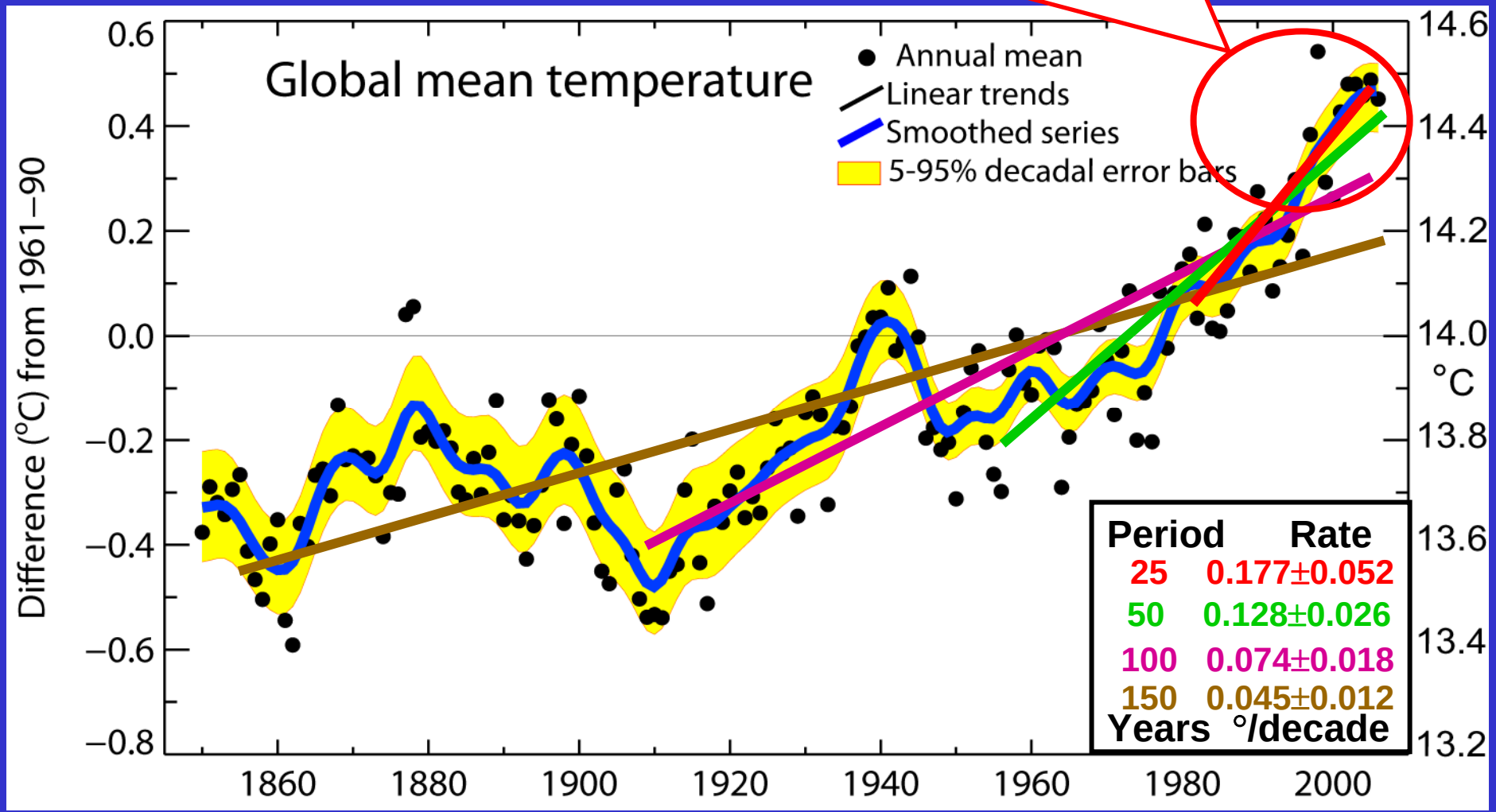
- Global surface temperatures
- Tropospheric temperatures
- Global SSTs, ocean Ts
- Global sea level
- Water vapor
- Rainfall intensity
- Precipitation extratropics
- Hurricane intensity
- Drought
- Extreme high temperatures
- Heat waves

Decrease in:

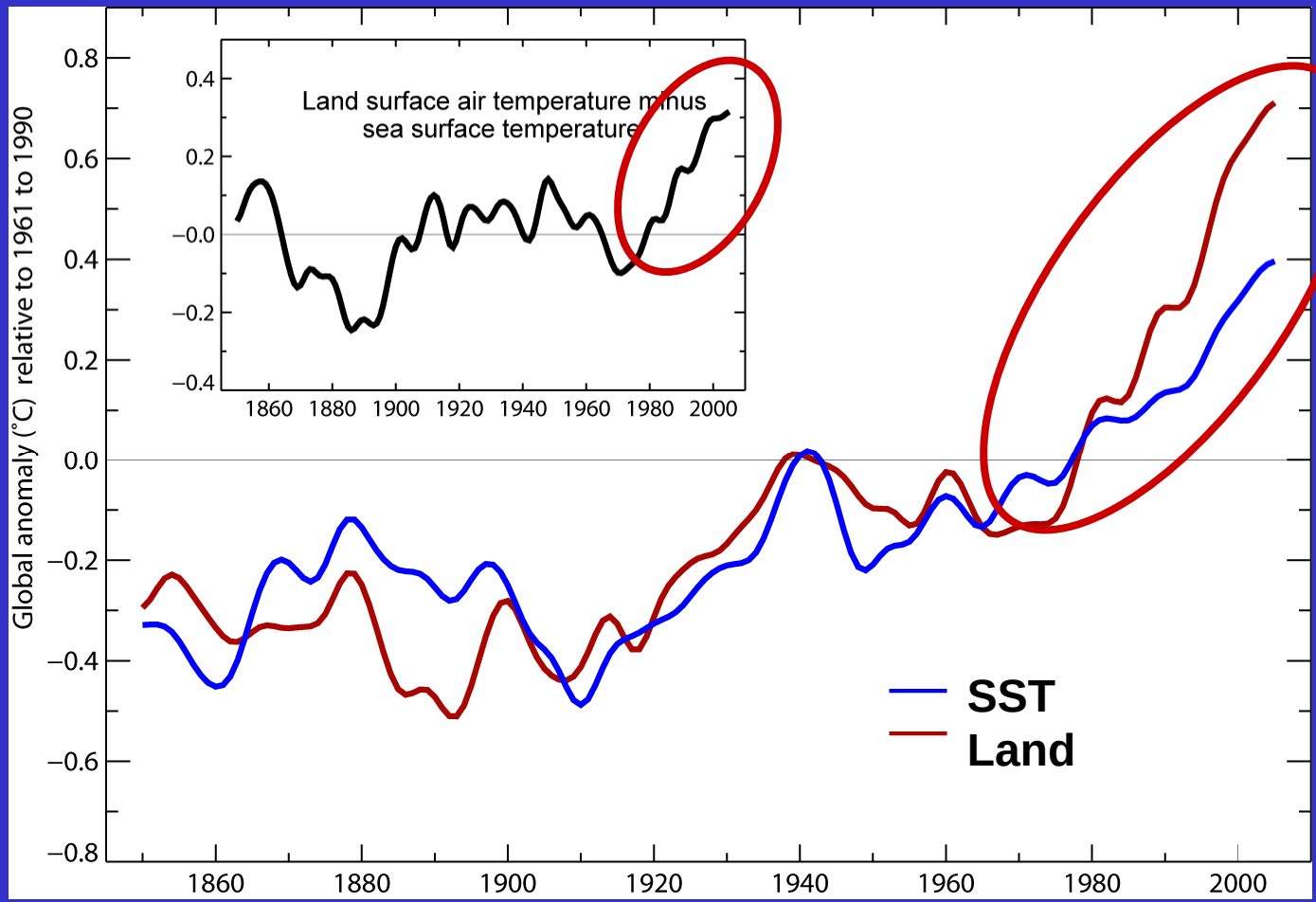
- NH Snow extent
- Arctic sea ice
- Glaciers
- Cold temperatures

Global mean temperature time

Warmest 12 years:
1998, 2005, 2003, 2002, 2004, 2006,
2001, 1997, 1995, 1999, 1990, 2000



Land surface temperatures are rising faster than SSTs



Annual anomalies of global average SST and land surface air temperature

Controlling Heat

Human body: sweats

Homes: Evaporative coolers (swamp coolers)

Planet Earth: Evaporation (if moisture available)

e.g., When sun comes out after showers,

the first thing that happens is that the puddles dry up: before temperature increases.

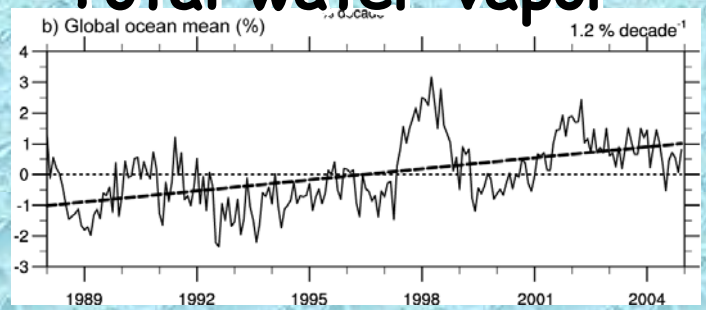
Air holds more water vapor at higher temperatures

A basic physical law tells us that the water holding capacity of the atmosphere goes up at about 7% per degree Celsius increase in temperature.

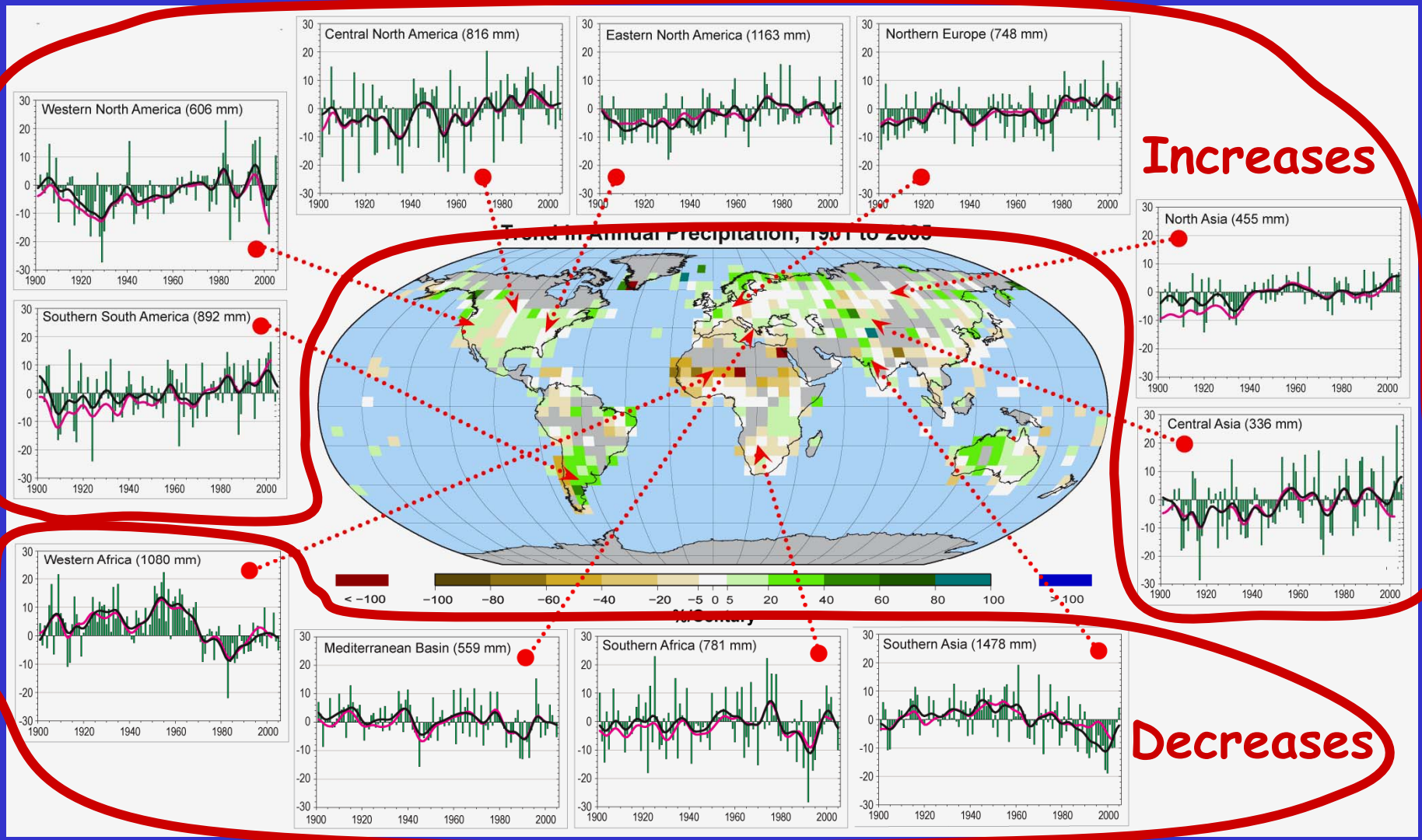
Observations show that this is happening at the surface and in lower atmosphere: 0.6°C since 1970 over global oceans and 4% more water vapor.

This means more moisture available for storms and an enhanced greenhouse effect.

Total water vapor

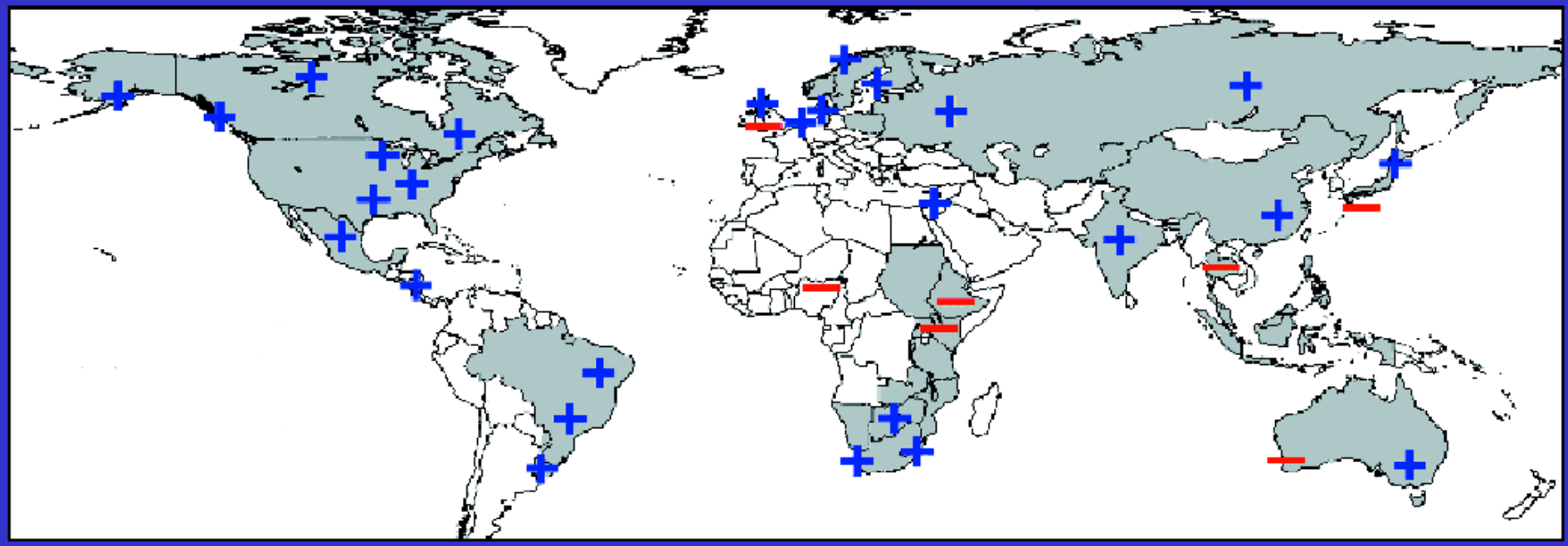


Land precipitation is changing significantly over broad areas



Smoothed annual anomalies for precipitation (%) over land from 1900 to 2005; other regions are dominated by variability.

Proportion of heavy rainfalls: increasing in most land areas



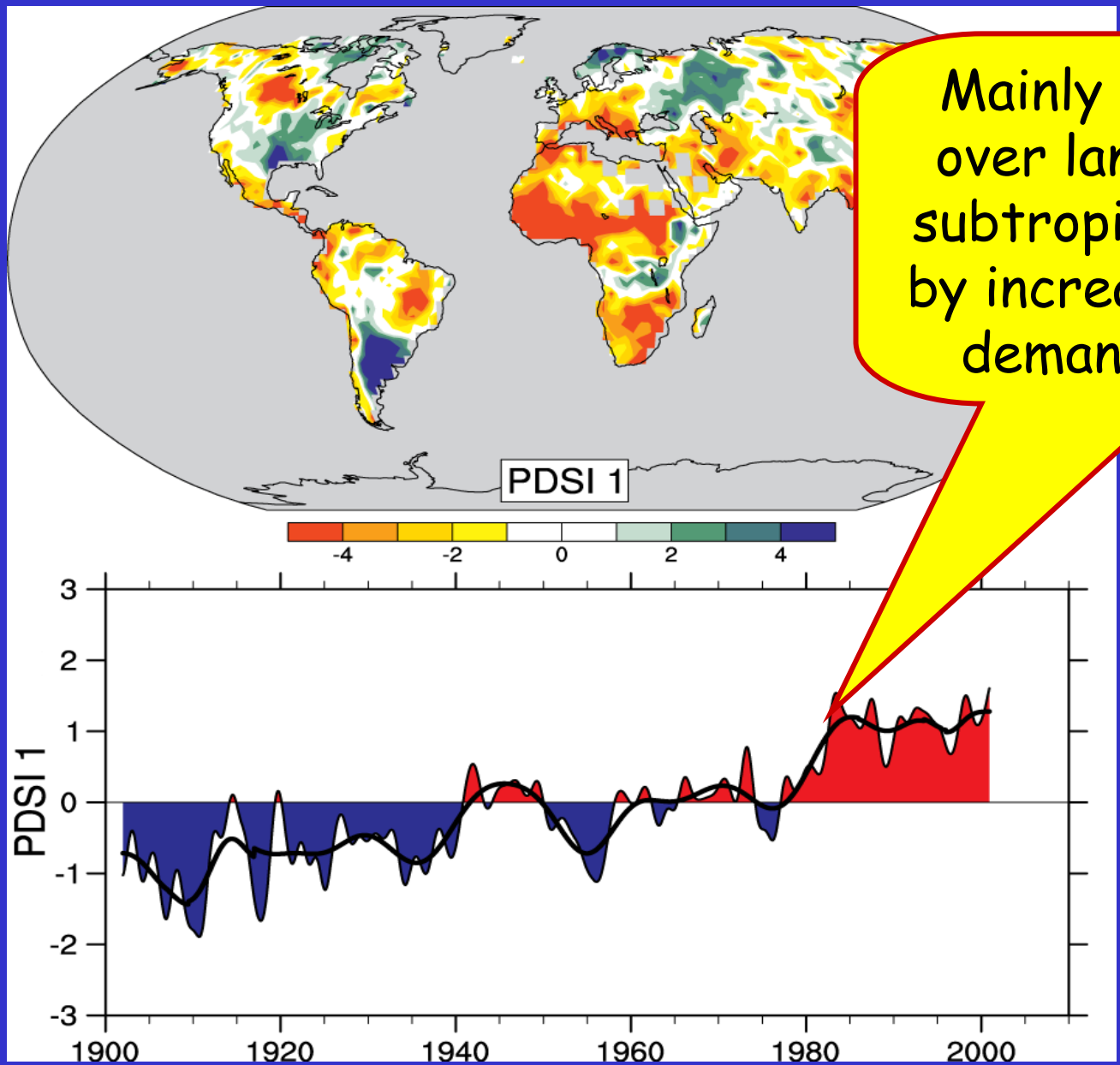
Regions of disproportionate changes in heavy (95^{th}) and very heavy (99^{th}) precipitation

Declining Snow Pack in many mountain and continental areas contributes to drought

- more **precipitation** falls as **rain** rather than **snow**, especially in the fall and spring.
- **snow melt** occurs faster and sooner in the spring
- **snow pack** is therefore less
- **soil moisture** is less as summer arrives

- the risk of **drought** increases substantially in summer
- Along with wild fire

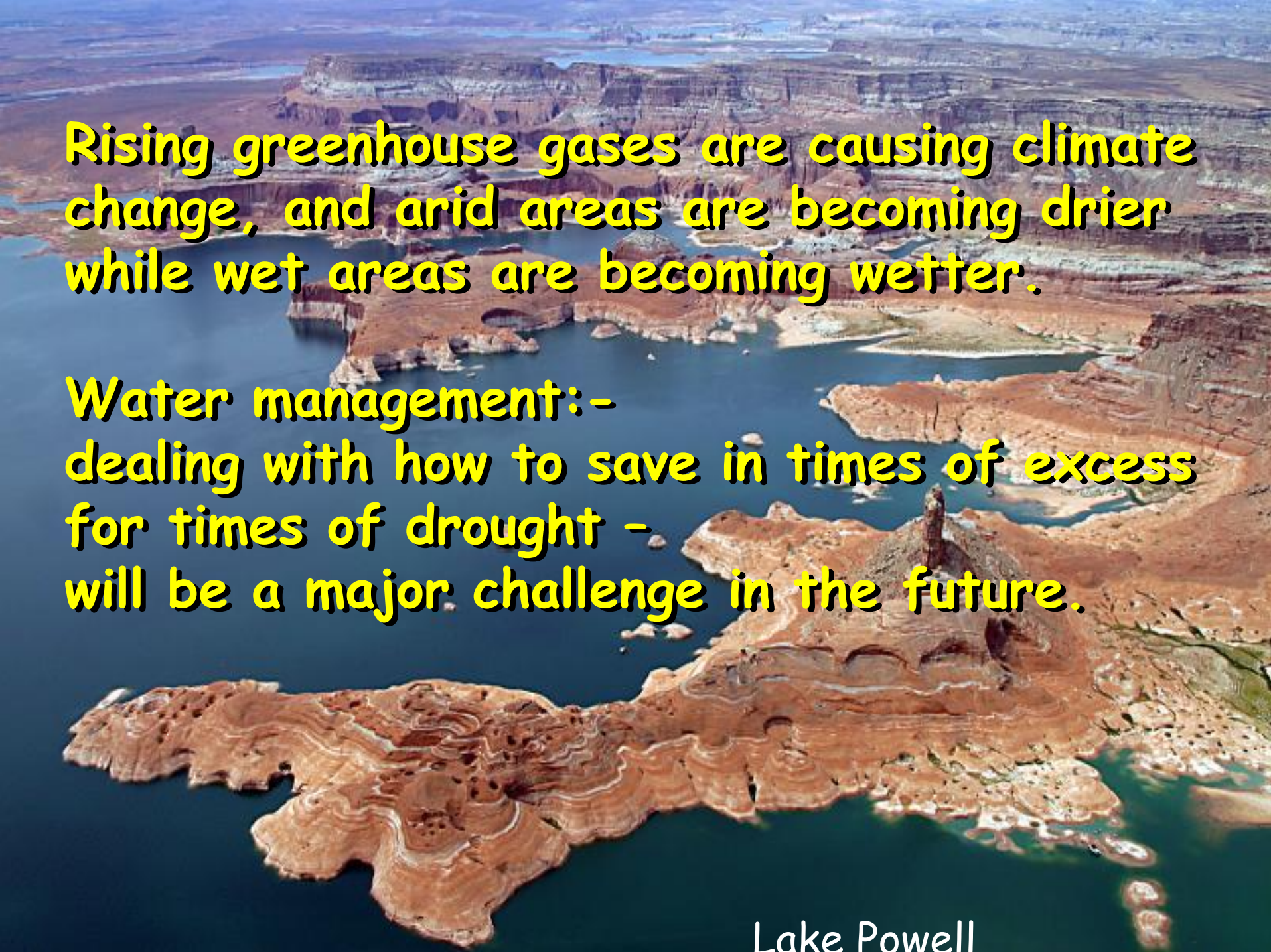
Drought is increasing most places



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

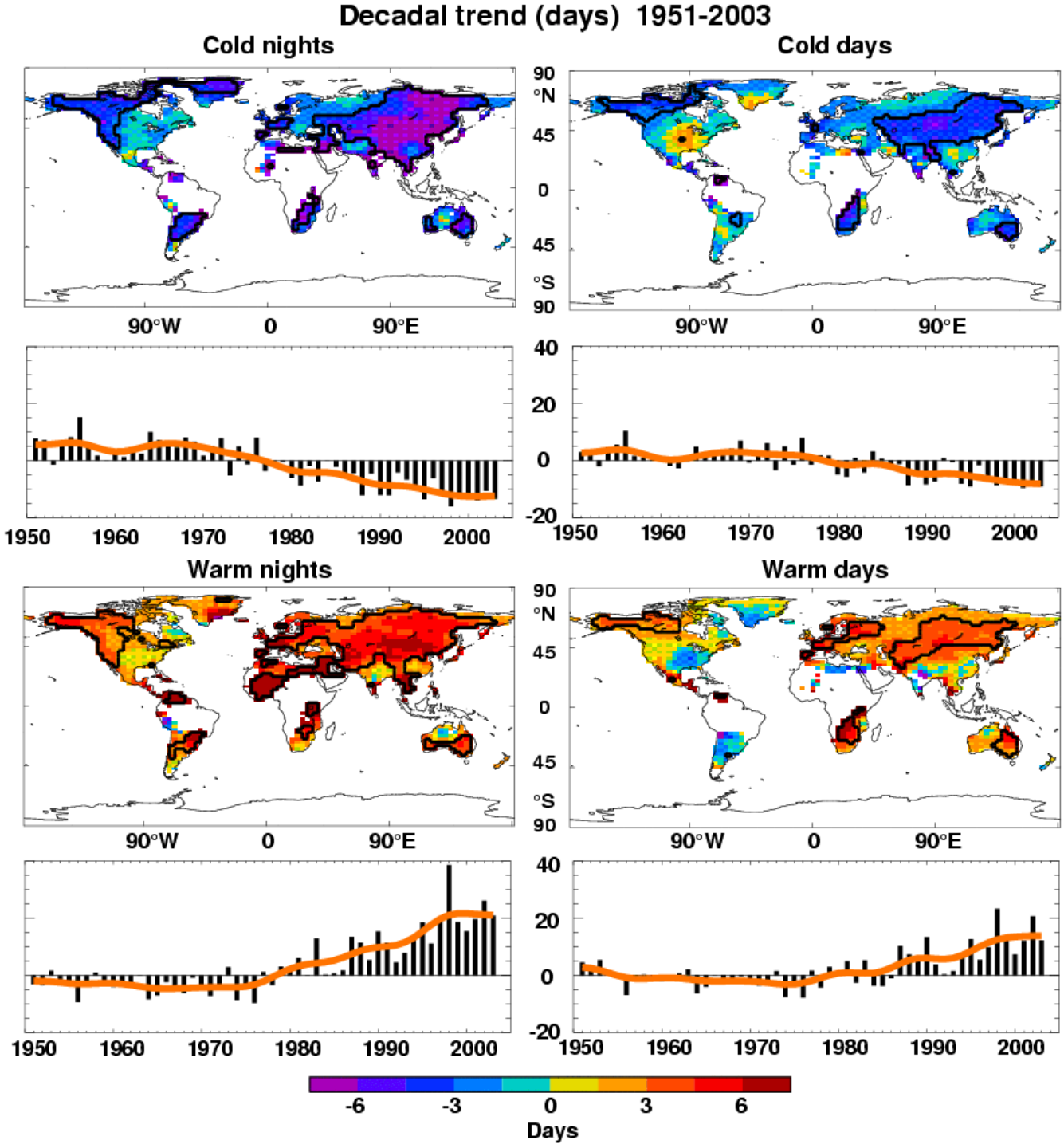
Severity Index (PDSI) for 1900 to 2002.

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


Rising greenhouse gases are causing climate change, and arid areas are becoming drier while wet areas are becoming wetter.
Water management:-
dealing with how to save in times of excess for times of drought -
will be a major challenge in the future.
Lake Powell

Heat waves and wild fires

Impacts on human health and mortality, economic impacts, ecosystem and wildlife impacts



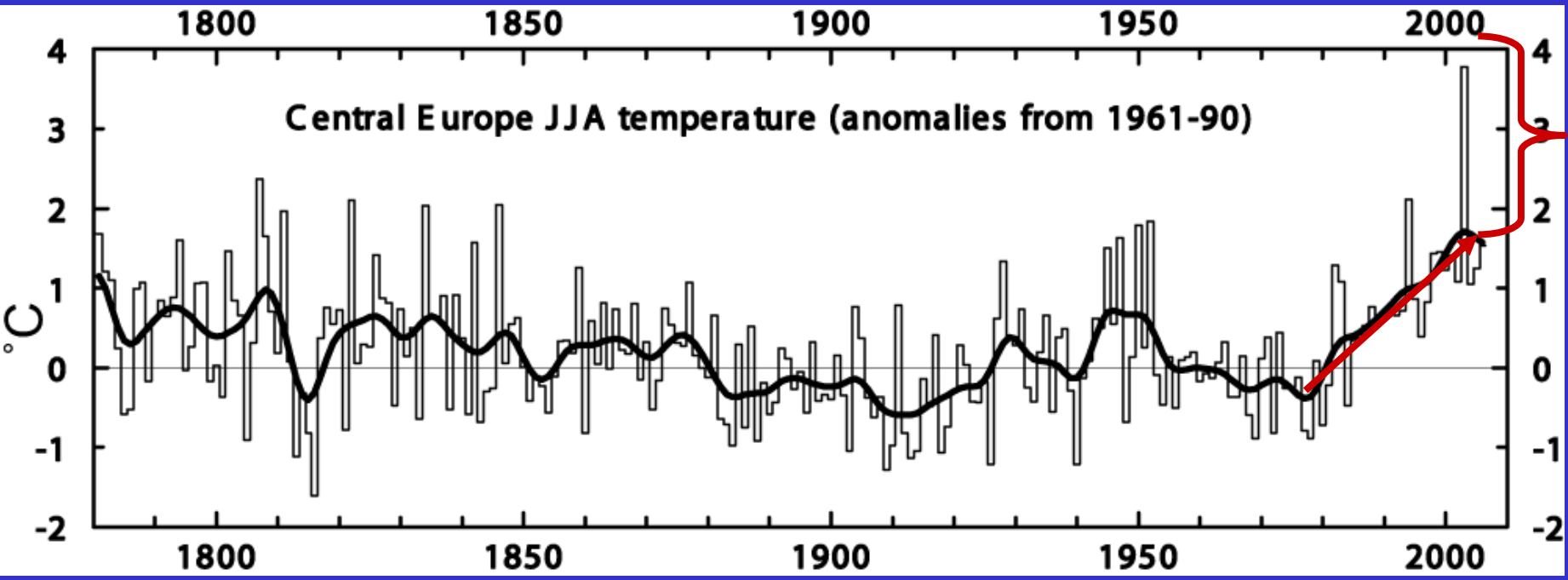
Extremes of temperature are changing!

Observed trends (days) per decade for 1951 to 2003:

5th or 95th percentiles

From Alexander et al. (2006)

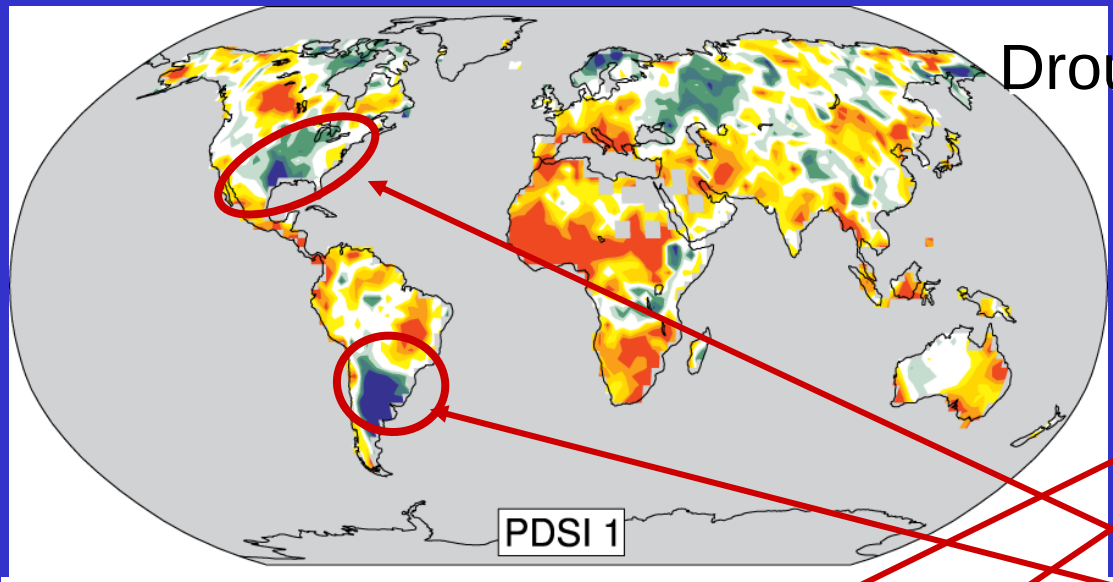
Heat waves are increasing: an example



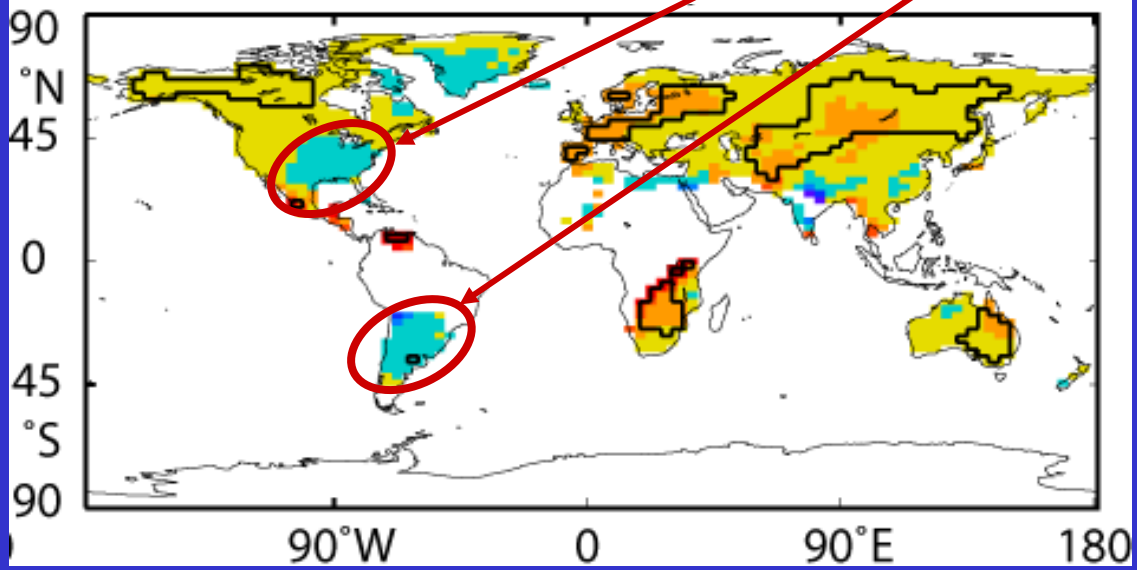
Extreme Heat Wave
Summer 2003
Europe
30,000 deaths

Trend plus variability?

Increases in rainfall and cloud counter warming

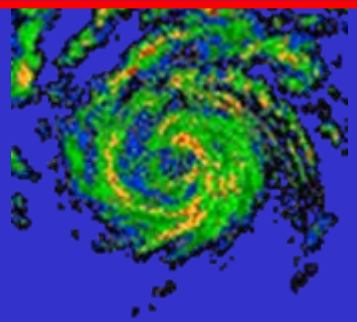


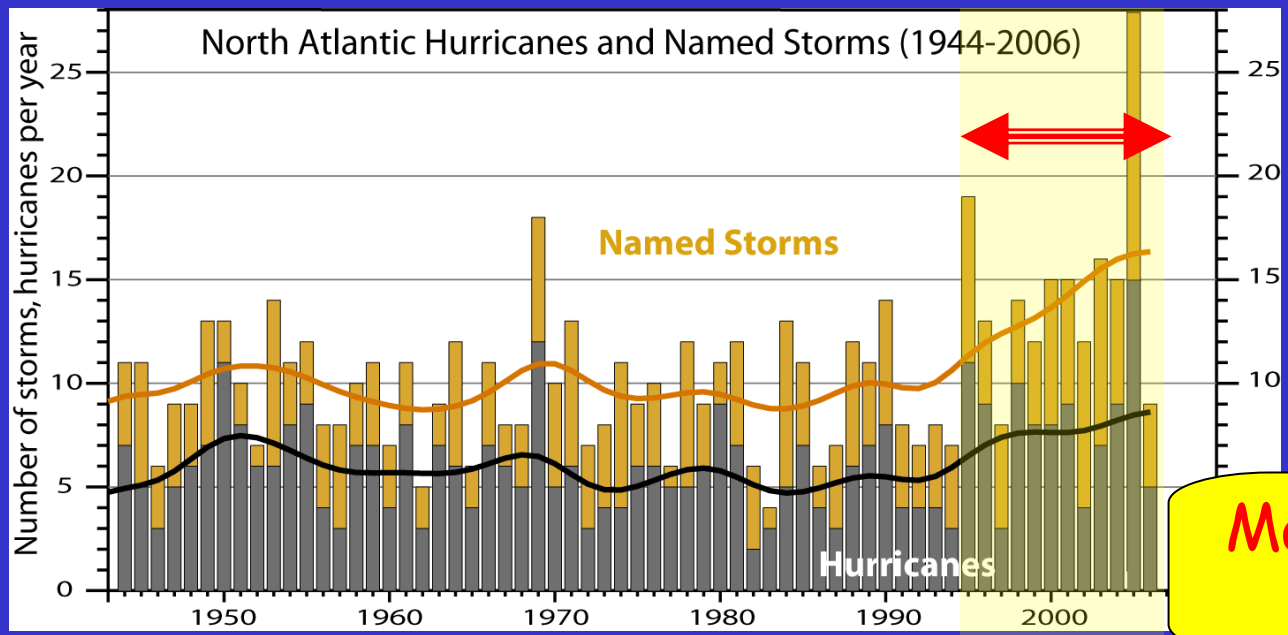
Trend in Warm Days 1951-2003



Absence of warming by day coincides with wetter and cloudier conditions

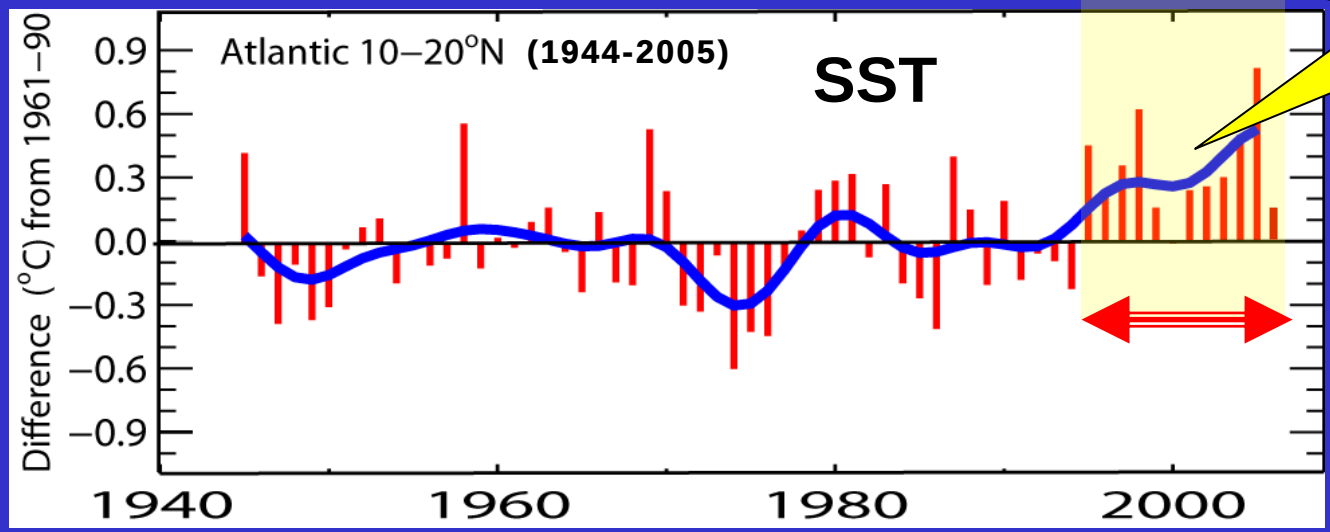
North Atlantic hurricanes have increased with SSTs





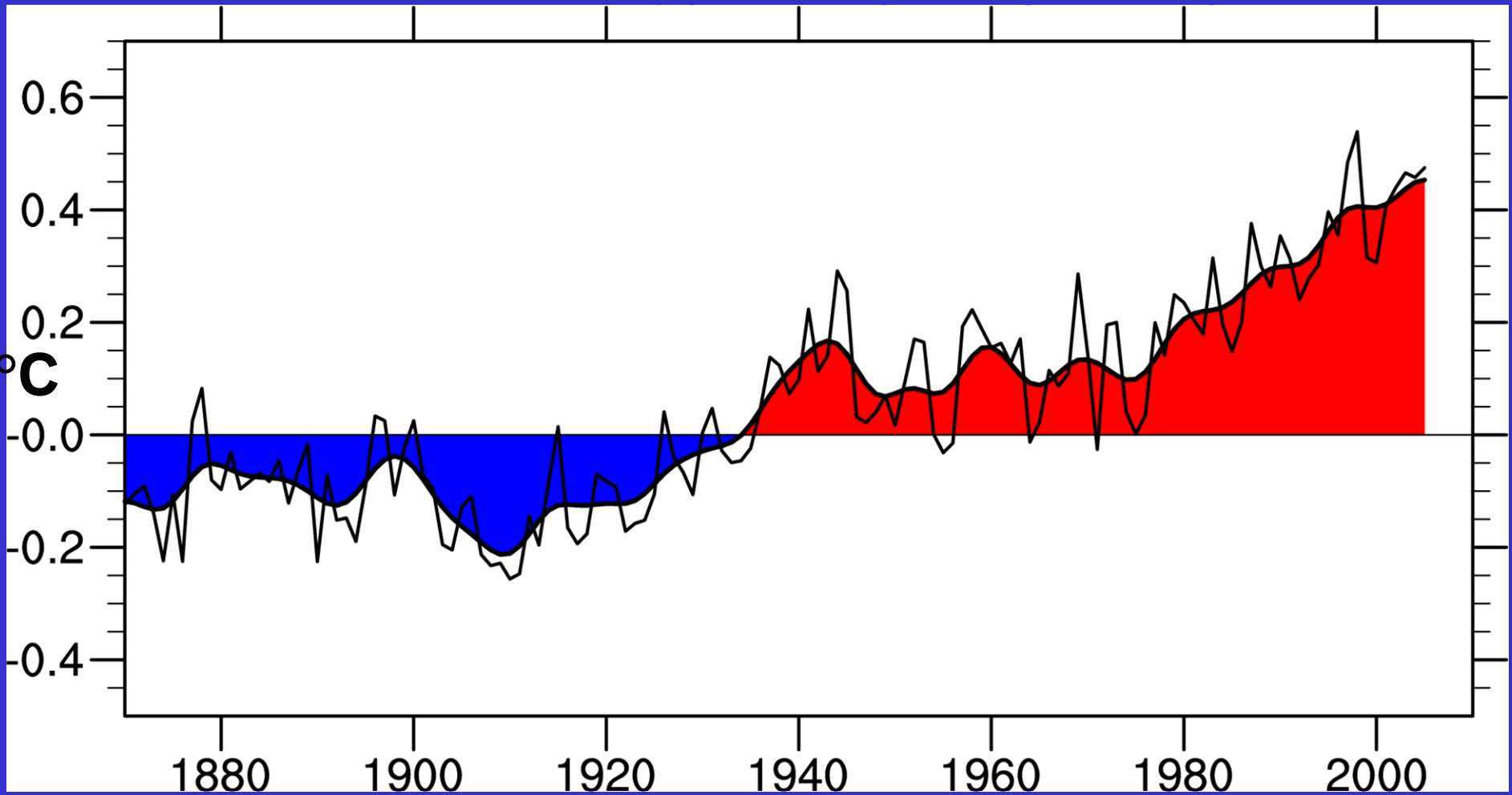
N. Atlantic hurricane record best

Marked increase after 1994

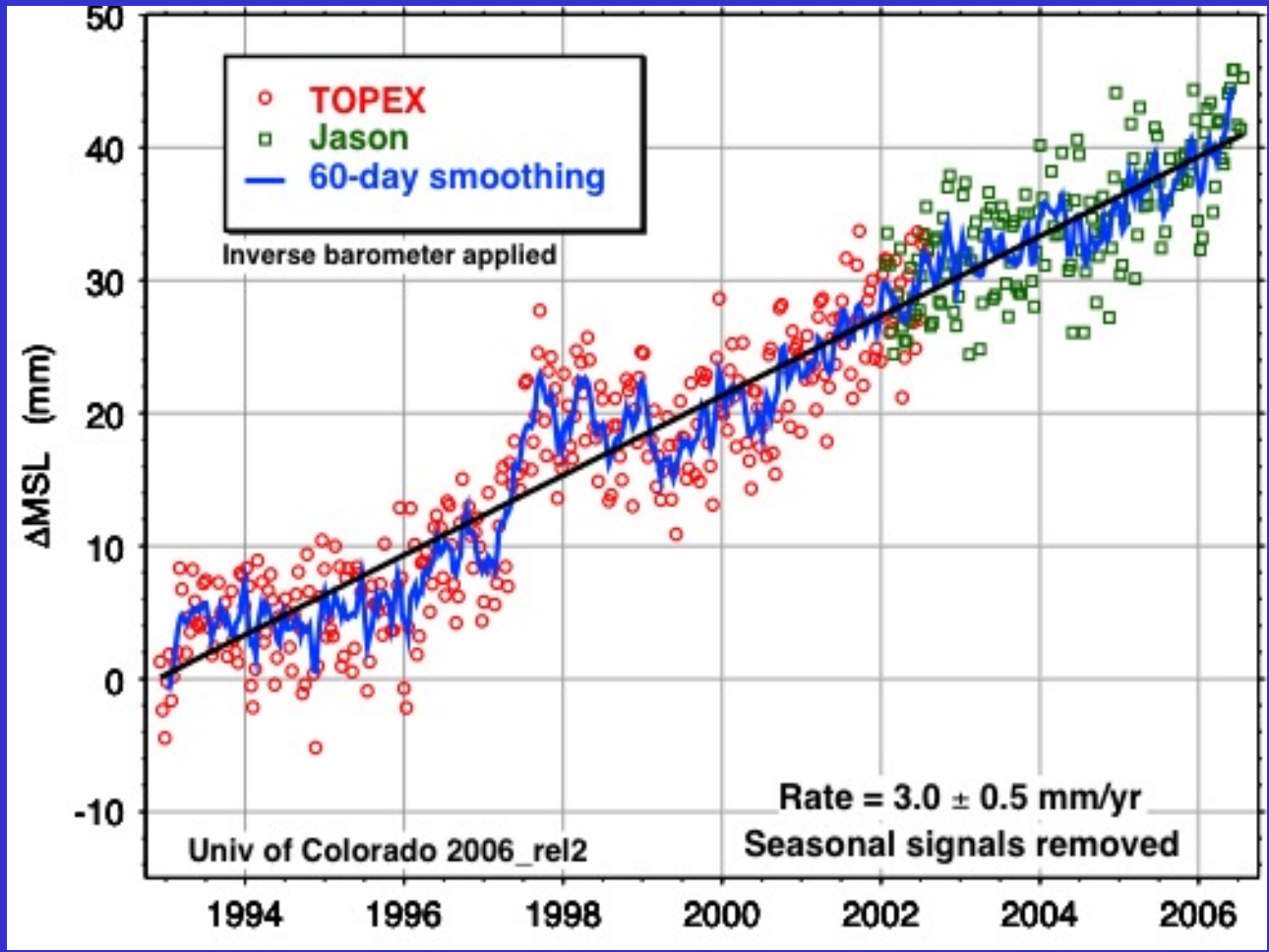


Global number and percentage of intense hurricanes is increasing

Global SSTs are increasing: base period 1901-70



Sea level is rising:
from ocean expansion and melting glaciers



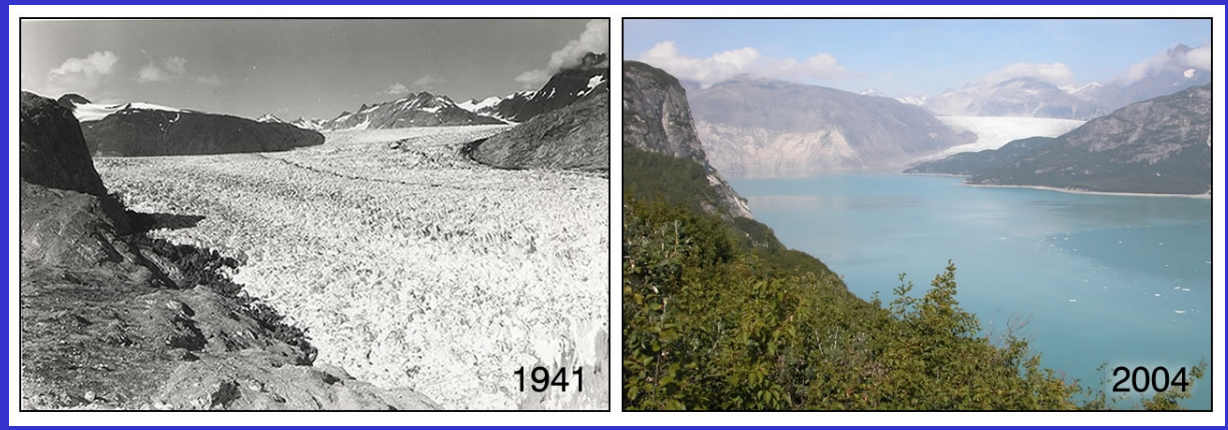
Since 1993 Global sea level has risen 41 mm (1.6 inches)

- 60% from expansion as ocean temperatures rise,
- 40% from melting glaciers

Steve Nerem

Evidence for reality of climate change

Glaciers melting

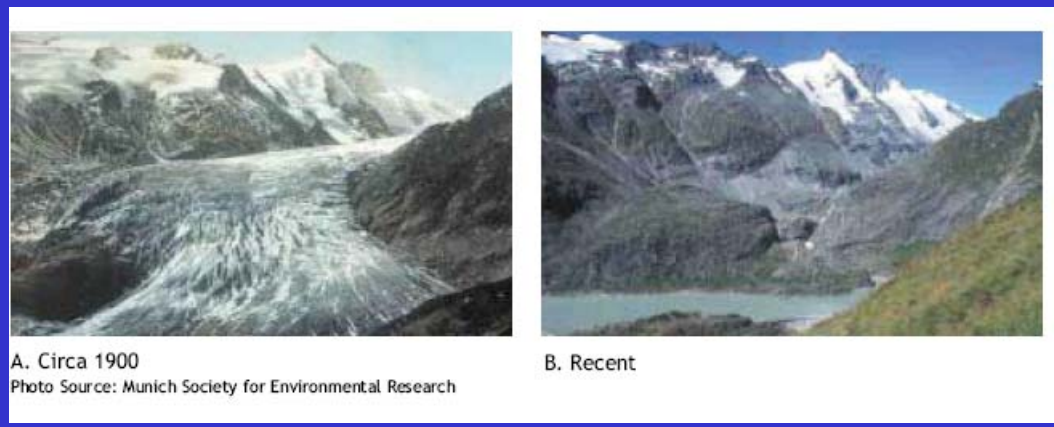


Muir Glacier, Alaska

1909

Toboggan Glacier Alaska

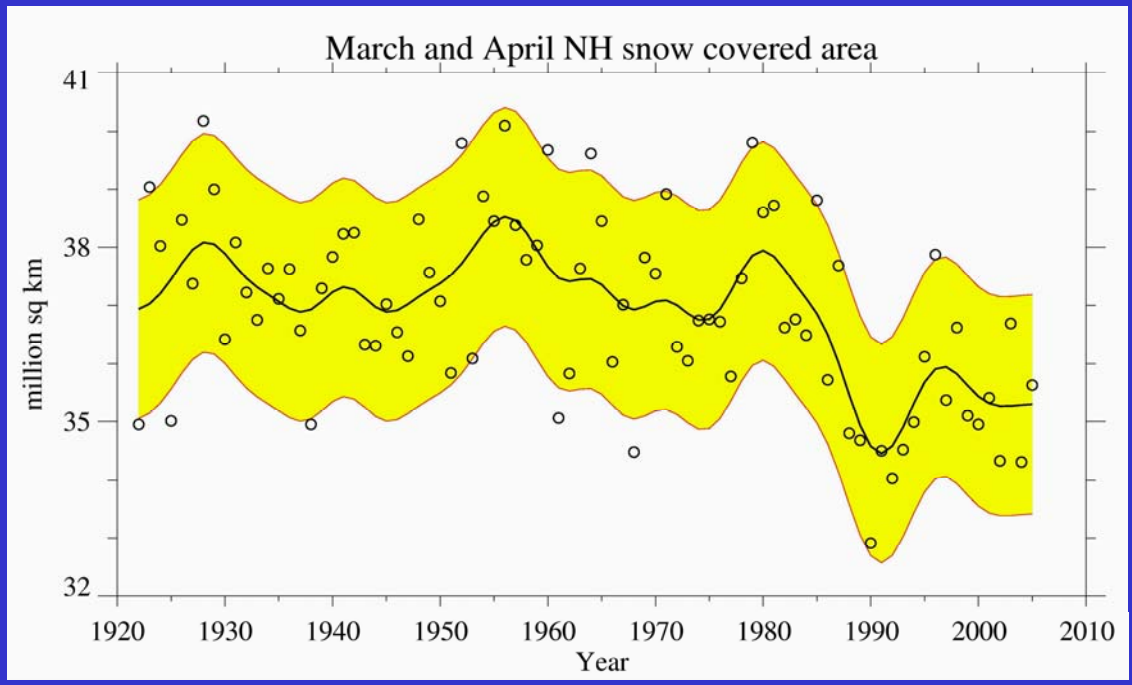
2000



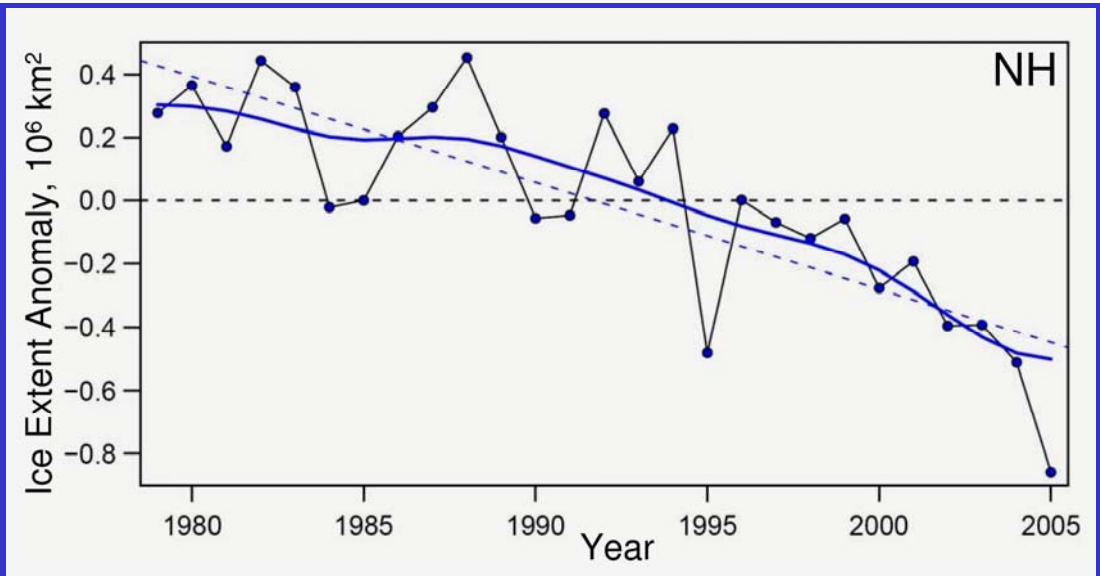
1900 2003

Alpine glacier, Austria

Snow cover and Arctic sea ice are decreasing

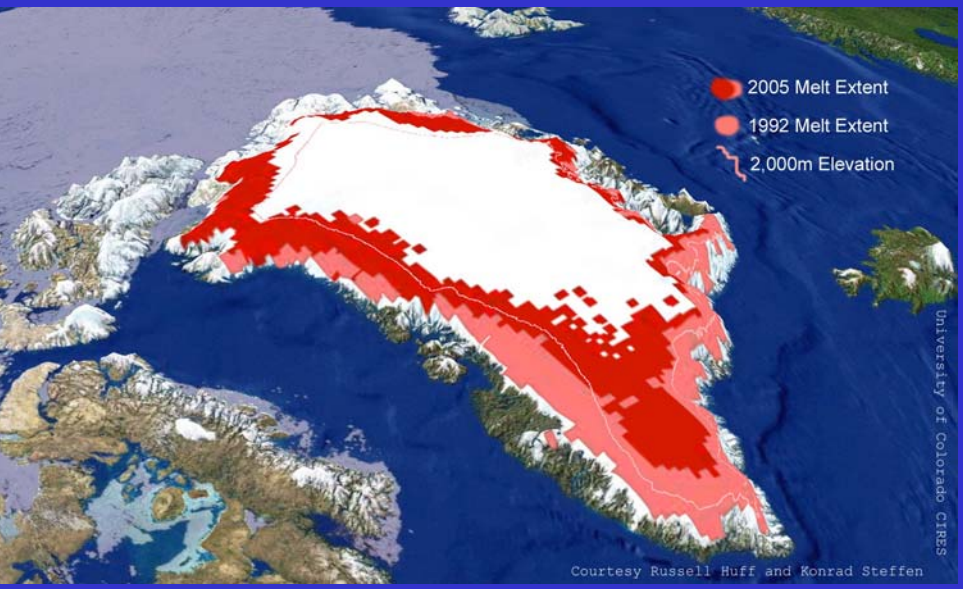


Spring snow cover shows 5% stepwise drop during 1980s



Arctic sea ice area decreased by 2.7% per decade (Summer: -7.4%/decade)

Surface melt on Greenland

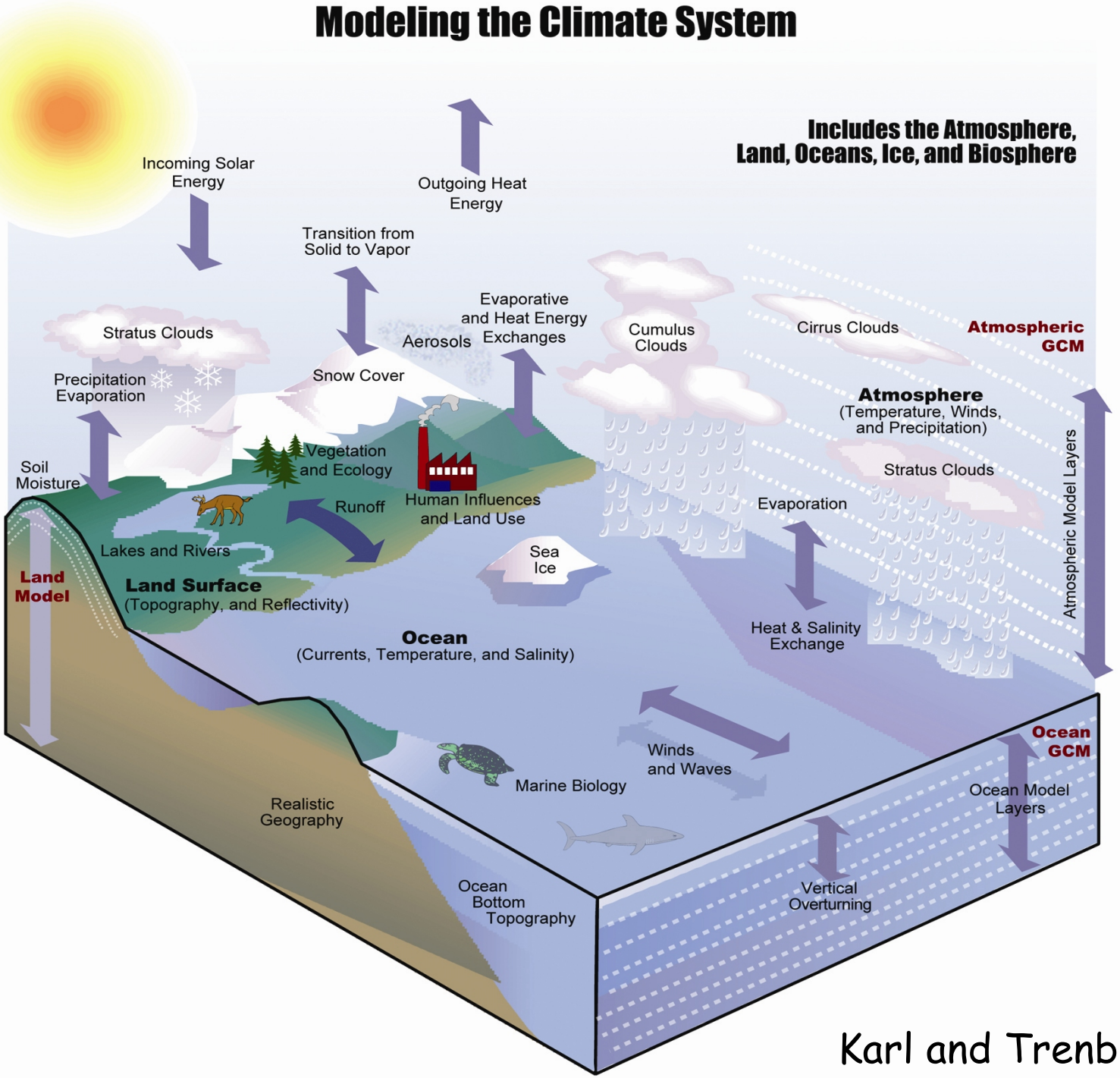


Increasing melt zones.

Melt descending into a moulin: a vertical shaft carrying water to the base of the ice sheet.

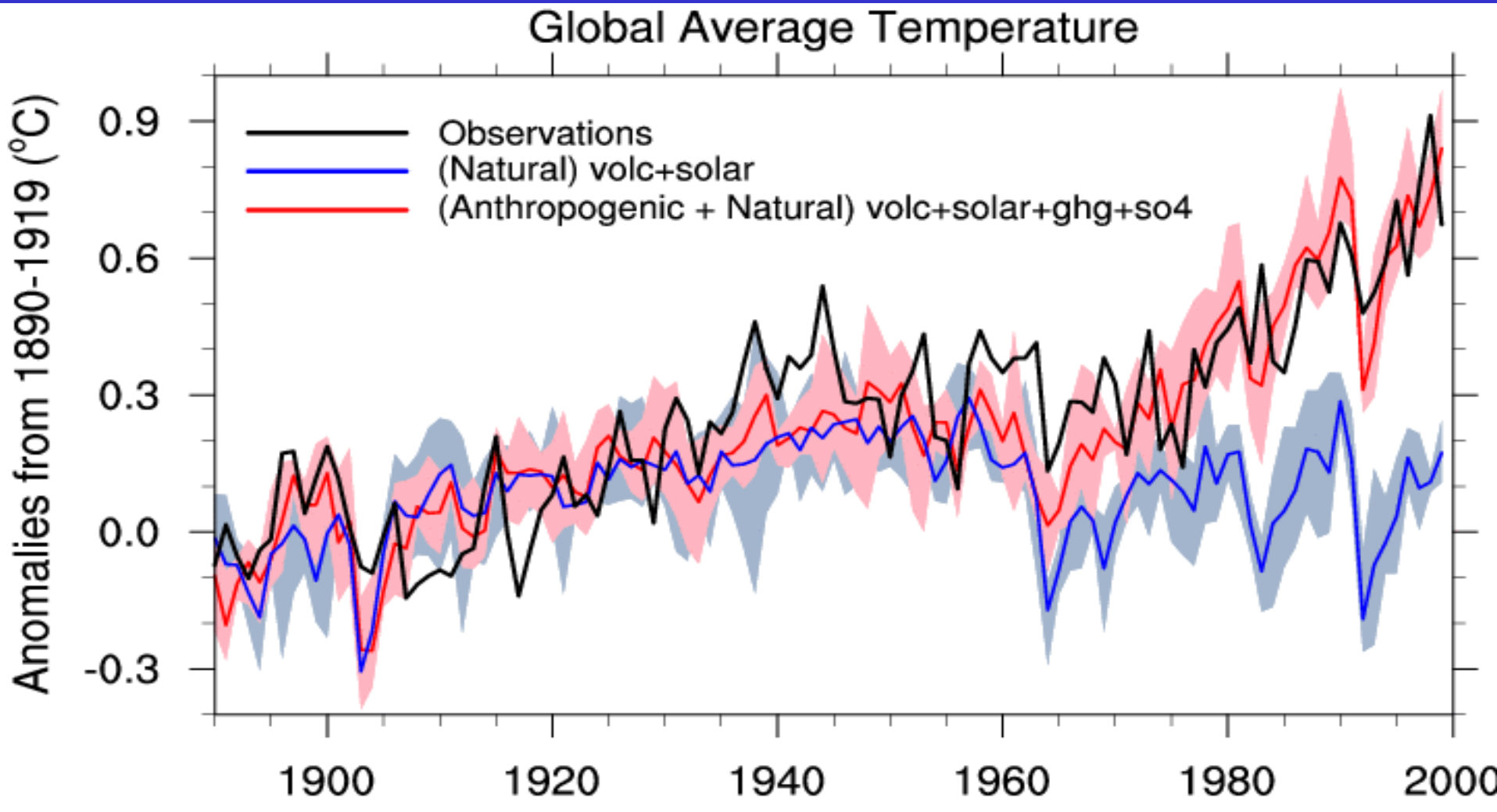
NSIDC (above)
Braithwaite: Univ. Manchester

Modeling the Climate System

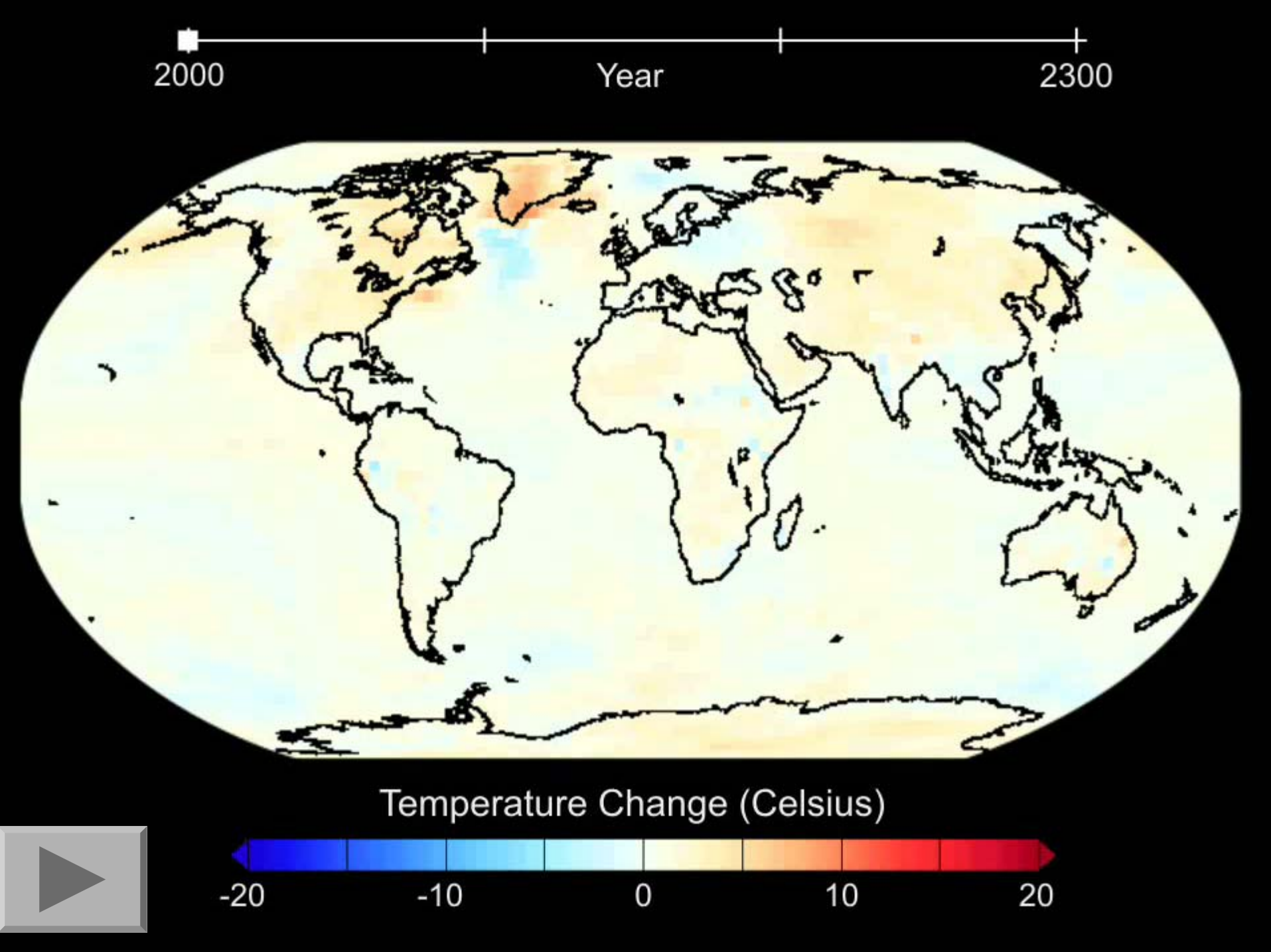


Karl and Trenberth 2003

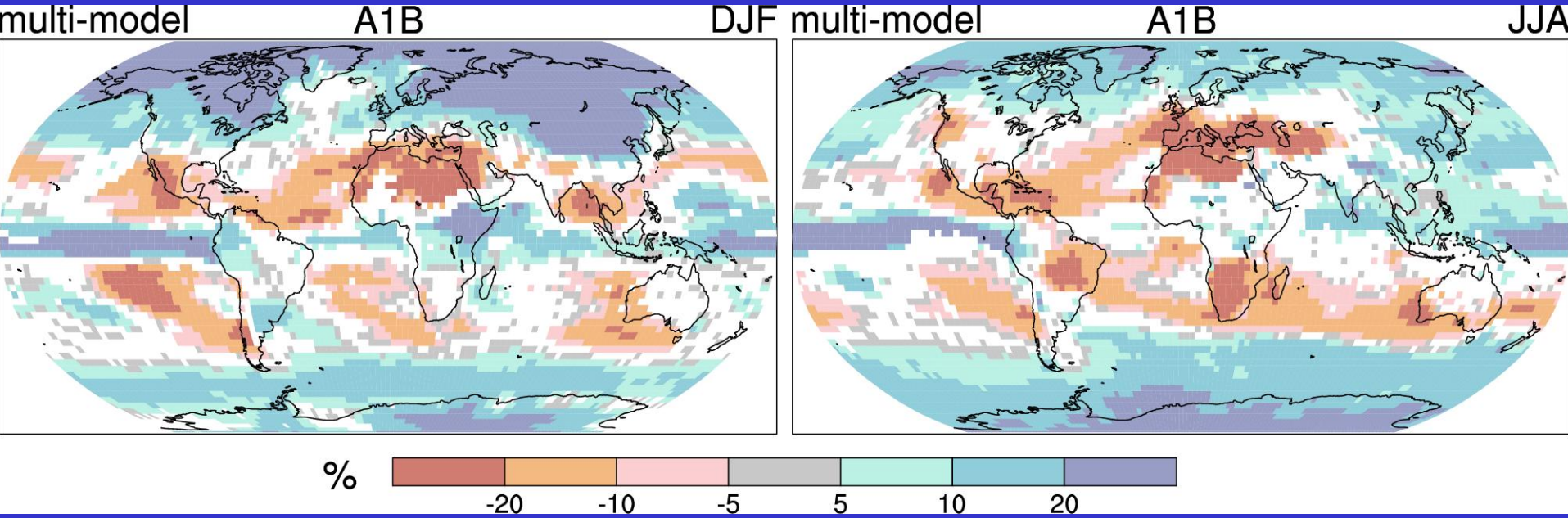
Natural forcings do not account for observed 20th century warming after 1970



Meehl et al, 2004: J. Climate.


2000
Year
2300
Temperature Change (Celsius)
-20
-10
0
10
20

Projected Patterns of Precipitation Change 2090-2100



Precipitation increases very likely in high latitudes

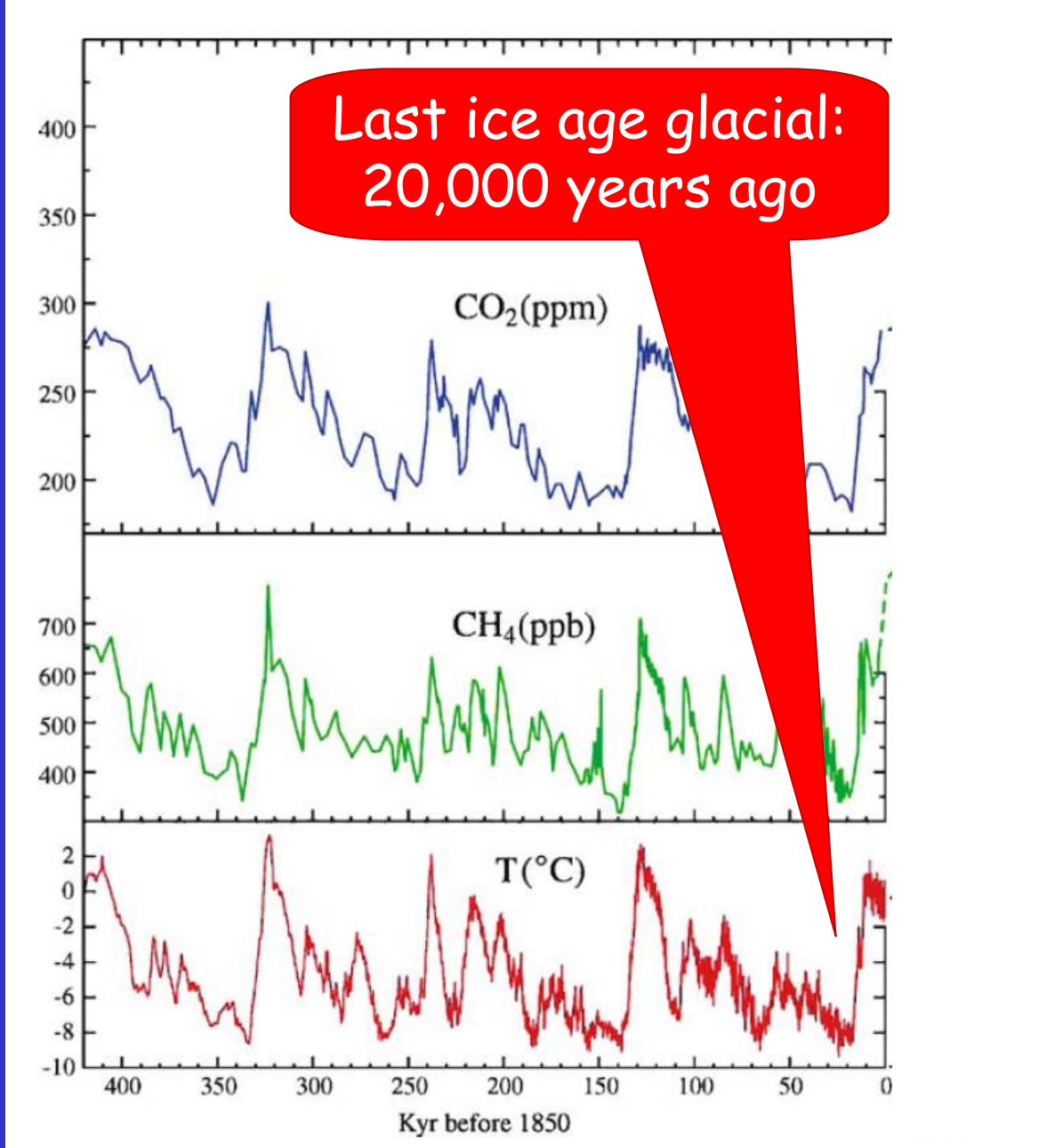
Decreases likely in most subtropical land regions

This continues the observed patterns in recent trends

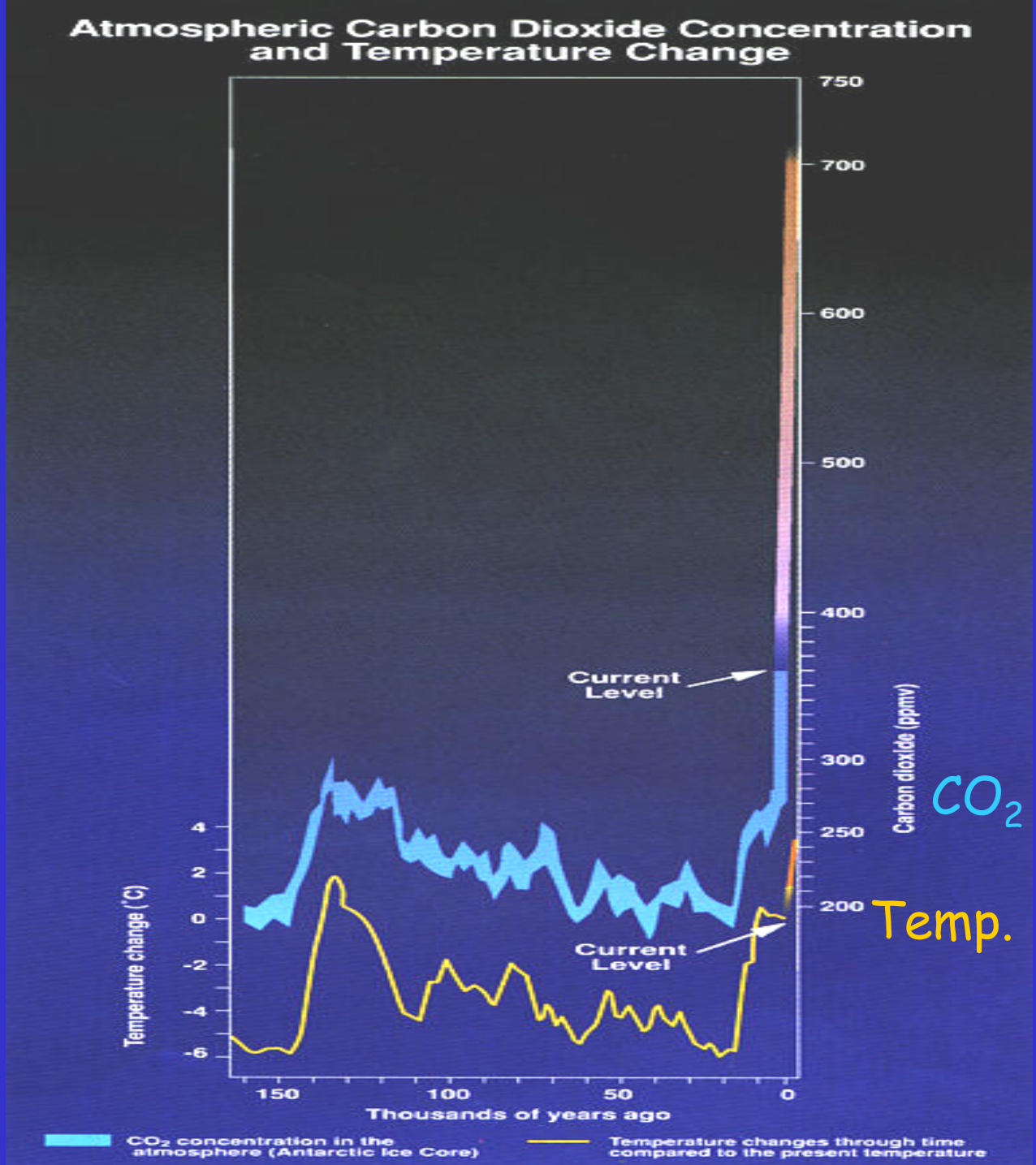
Summary for Policymakers (IPCC AR4)

Context:

400,000 years of Antarctic ice core records of Temperatures, Carbon dioxide and Methane.



Source: Hansen, Climatic Change 2005, based on Petit, Nature 1999


Atmospheric Carbon Dioxide Concentration and Temperature Change
750
700
600
500
400
300
250
200
Carbon dioxide (ppmv)
Current Level
Current Level
4
2
0
-2
-4
-6
Temperature change (°C)
150
100
50
0
Thousands of years ago
CO2 concentration in the atmosphere (Antarctic Ice Core)
Temperature changes through time compared to the present temperature
CO2
Temp.

The UN Framework Convention on Climate Change

- Ratified by 189 countries
- Ratified by the US
- Article 2 is statement of the objective
- Convention entered into force 21 March 1994

Kyoto Protocol

- A legal instrument under **UNFCCC**
- Requires net reduction in developed country averaged annual GHG emissions of 5% (US 7%) over the period 2008-12 compared to 1990 levels
- "Basket" of GHGs (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6)
- Provisions for "flexible" market mechanisms: international trading system, credits, etc.
- 164 countries have ratified
- Protocol was ratified; took effect Feb 16, 2005.
- US withdrew in 2001. In 2004 US emissions were 16% (20%) over 1990 levels for GHG (CO_2).

What about a carbon tax?

Anyone can burn stuff and put Carbon Dioxide into the atmosphere as a waste product. If there was a value to Carbon Dioxide then this would presumably be reduced.

A carbon tax, carbon emission limits, or pollution fines are designed to create a **cost** for burning carbon products, like coal and oil.

Given a target (such as in the Kyoto Protocol) only so much can be burned and credits to allow burning can be traded (carbon emissions trading).

Such a solution can be equitable if implemented across the board. But it can favor those who pollute if a country does not subscribe.

Recent trends: March 2007

Coal fired power stations have been brought on line at a rate of 2 per week over the past 5 years. China leads with **one every 3 days** or so last years (560 new plants from 2002 to 2006 and 113 GigaWatts of coal fired power).

(200 MW each)

In the next 4 years, China is expected to bring online over 55 GW of coal fired power, but the US is right behind with 38 GW, and India with 36 GW, and the rest of the world 47 GW.

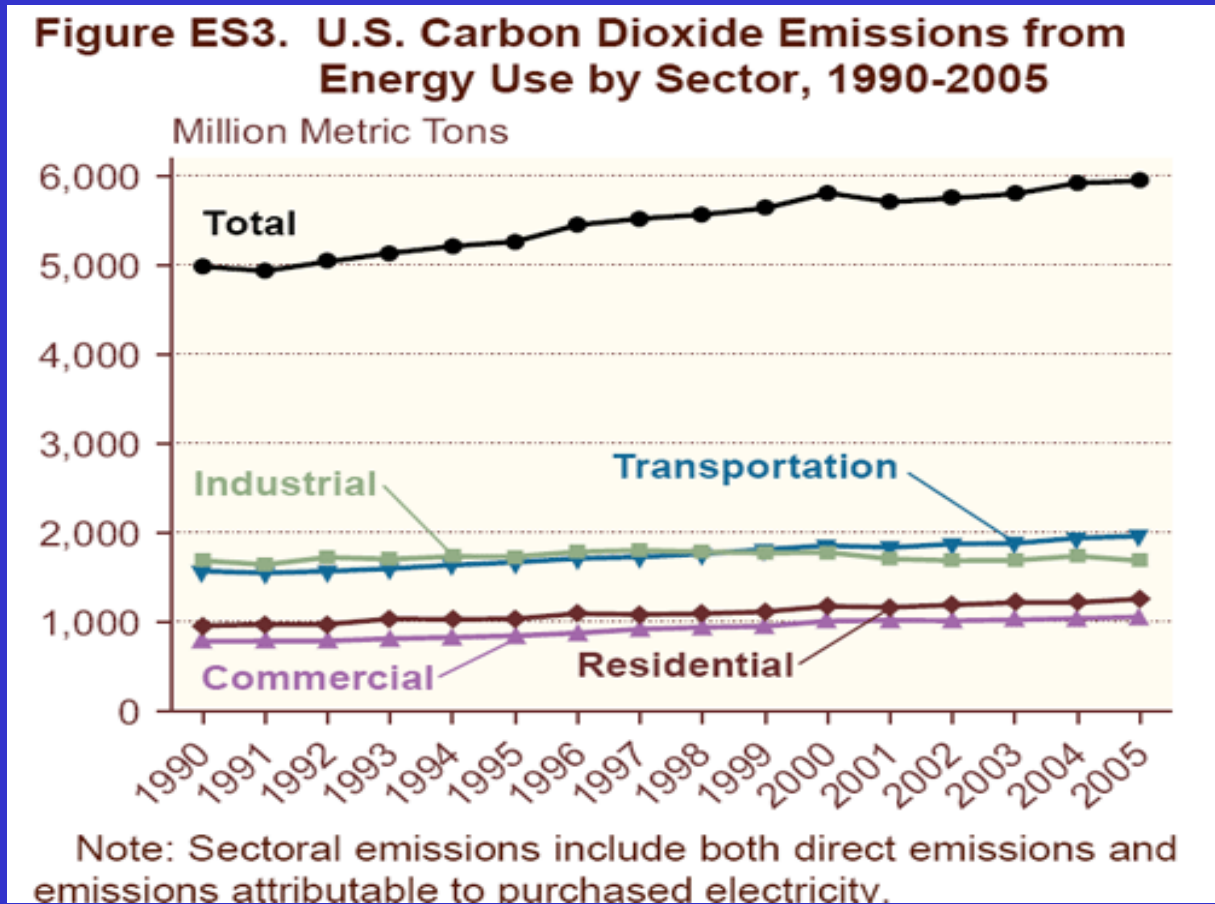
(Total 176 GW)

Far from decreasing carbon dioxide emissions, the trend is much worse than what is assumed as "business as usual".

Christian Science Monitor: March 22, 2007

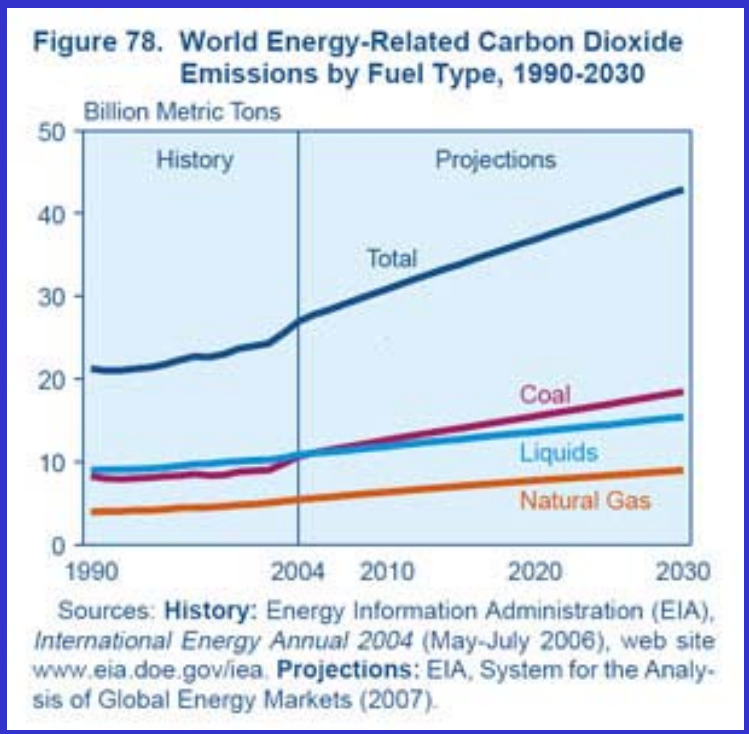
Recent trends: May 2007

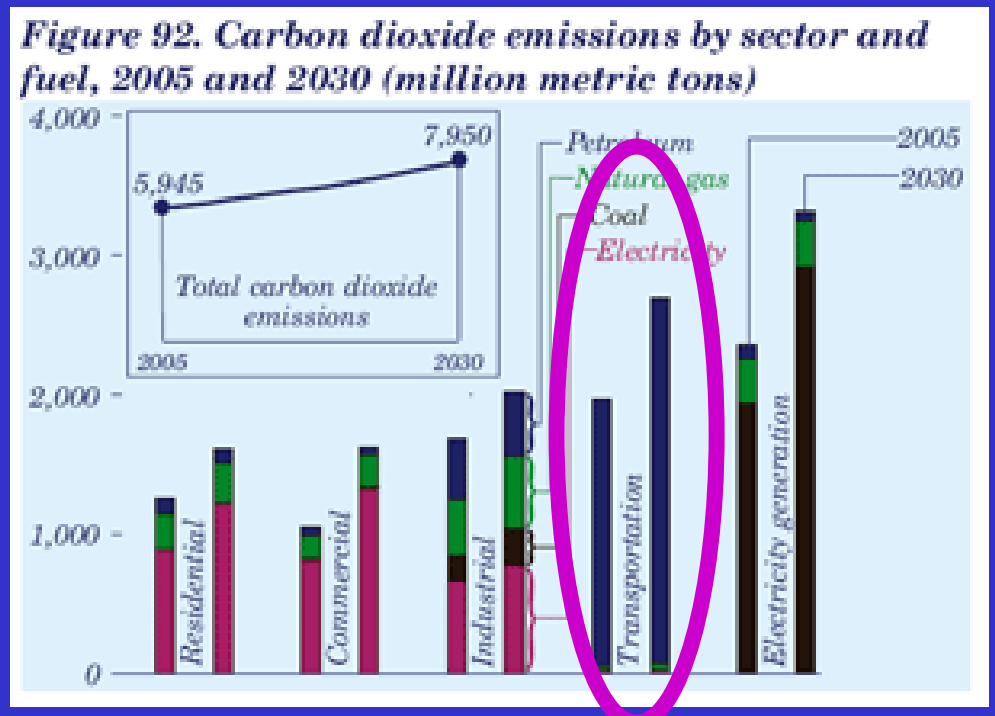
In the U.S. transportation makes up about 33% of carbon dioxide emissions (source EIA)



Recent trends: May 2007

In 2030 global emissions will likely be up by 59% relative to 2004 according to the U.S. Energy Information Administration in its annual International Energy Outlook in May 2007.

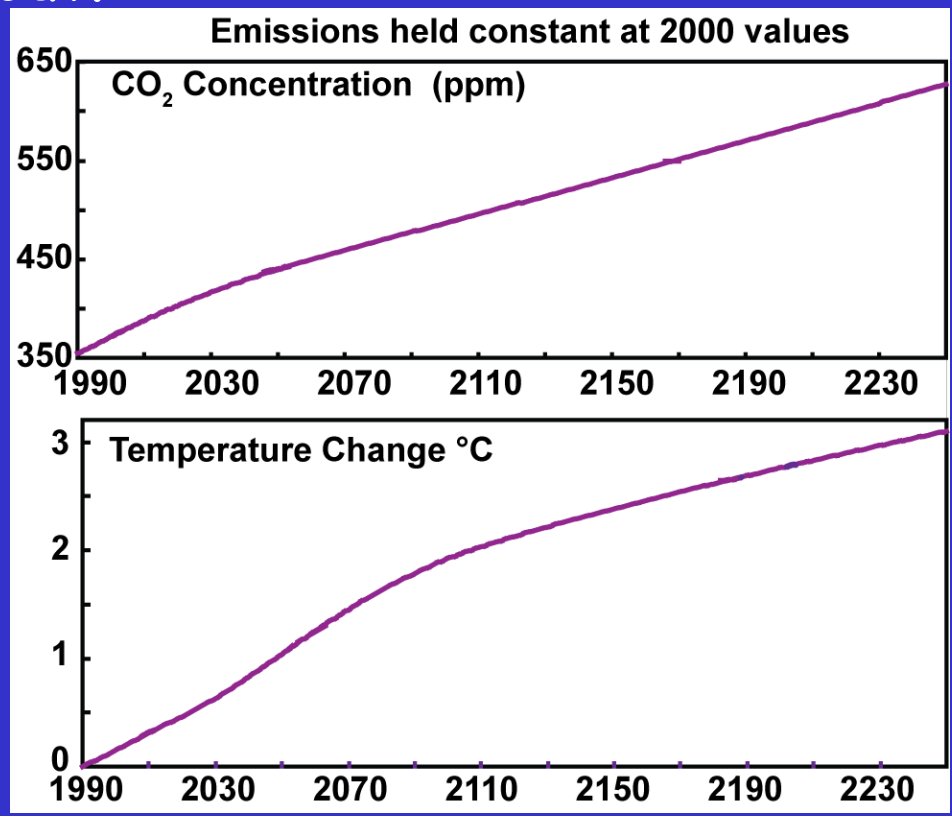




Global Warming

The **Kyoto Protocol** basically calls for a **freeze** on emissions to 1990 levels for developed countries. Similarly, the Montreal Protocol for ozone depletion initially called for a freeze on CFC emissions and only later was this changed to a phase out.

A freeze on emissions means that concentrations of carbon dioxide continue to increase. Climate continues to change, temperatures rise and sea level continues to rise.



Global Warming

We can slow global warming down!

Disruption arises more
from rapid change than from the climate per se.

Mitigation effects mainly payoff beyond 2050.

So we **must** adapt to climate change:
we will adapt, whether unplanned (disruptive untold damage and loss of life), autonomously, or planned.

3 Key questions:

1. How would you or your activity respond to a carbon tax?
2. How can you reduce your carbon footprint?
3. How can you be part of the solution, not part of the problem?


Bäfittere