Risks from Global Climate Change:
What Do We Know?
What Should We Do?

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Introduction: the problem in a nutshell

- The problem of disruption of global climate by human-produced greenhouse gases (GHG) in the atmosphere will likely come to be understood over the next decade or so, by publics and policy makers alike, as the most dangerous and intractable of all the environmental problems caused by human activity.
- It is the most <u>dangerous</u> because climate is the "envelope" within which all other environmental conditions and processes operate. Distortions of this envelope of the magnitude that are in prospect are likely to so badly disrupt these conditions and processes as to impact adversely every dimension of human well-being that is tied to environment – which is most of them.

The problem in a nutshell (continued)

- The problem is highly <u>intractable</u> because the dominant cause of the disruption – emission of carbon dioxide from fossil-fuel combustion – arises from the process that currently supplies nearly 80 percent of civilization's energy, and because the technologies involved cannot be quickly or inexpensively changed or replaced in ways that would eliminate the problem.
- Most current policies and practices of governments, firms, consumers, and investors are either actively contributing to driving up the risks we face from human-induced climate change or, if aimed at abating those risks, are falling far short of what would be needed to reduce the risks significantly.

The problem in a nutshell (concluded)

- Embedded in the challenge of climate change are both…
  - immense dangers for firms and investors who make bad choices (or no choices) about how to respond to the risks posed by climate change and are then held accountable in the marketplace, the boardroom, or the courts; and
  - immense possibilities for firms and investors to turn challenge into opportunity, acting prudently and creatively to help society educe the risks it faces from climate change…and making money doing so.

Elements of the closer look that follows

- What climate is and why it matters
- The evidence that climate is changing
- The evidence that humans are responsible
- Climate-change consequences of continued "business as usual" (BAU)
- Impacts of BAU climate change on human well-being
- What can be done to reduce the risks to society from climate change

(What investors can do to reduce their risks from climate change – and to exploit the opportunities that the climate-change challenge will present – will be the focus of the rest of the day.)

Why does climate matter?

Climate consists of averages and extremes of

- hot & cold
- wet & dry
- snowpack & snowmelt
- winds & storm tracks
- ocean currents & upwellings

and not just how much & where, but also when.

Why does climate matter? (continued)

Climate governs

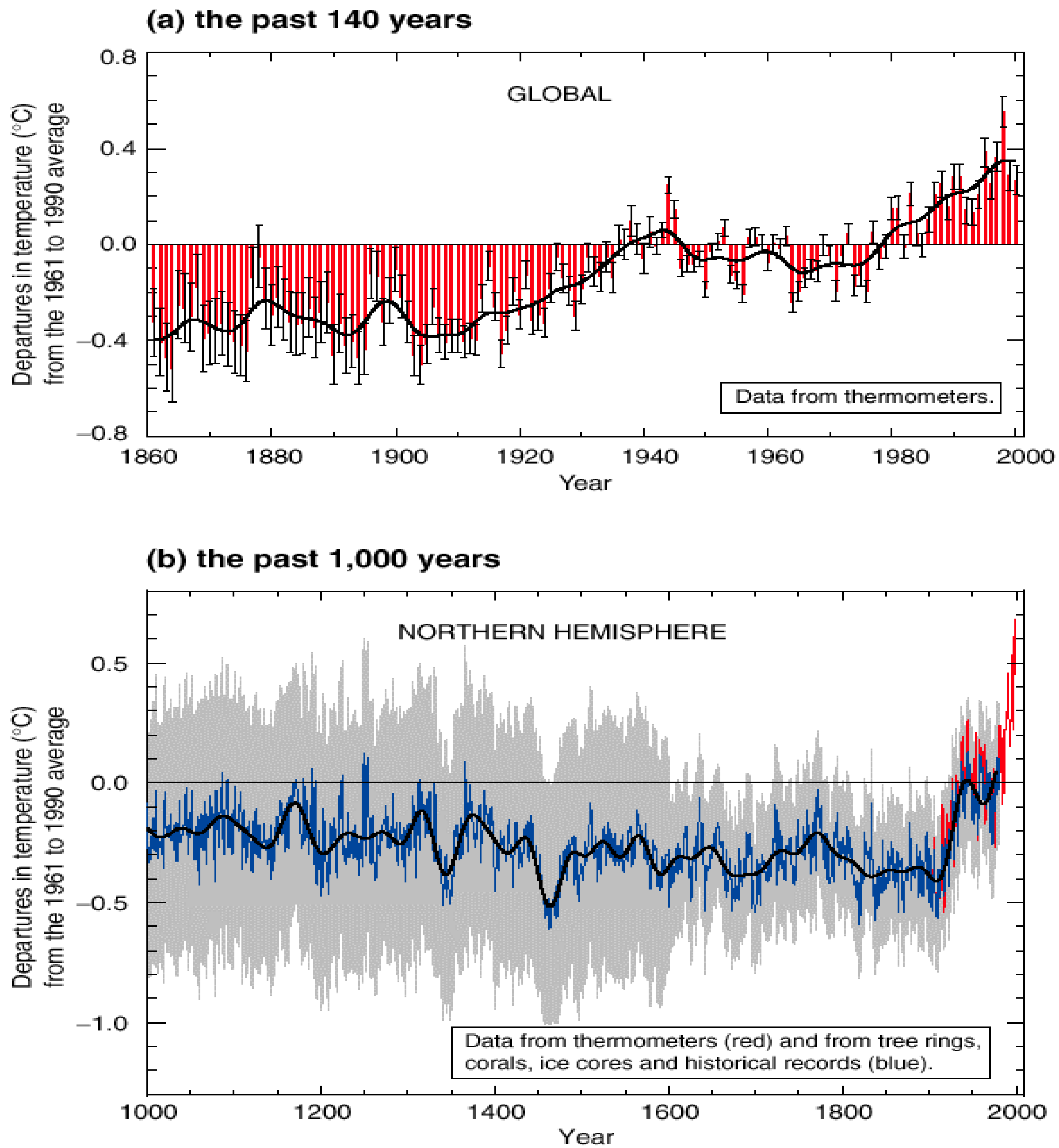
- Productivity of farms, forests, & fisheries
- Geography of disease
- Livability of cities in summer
- Damages from storms, floods, wildfires
- Property losses from sea-level rise
- Expenditures on engineered environments
- Distribution & abundance of species

Evidence for recent unusual climate change

The average temperature of the earth is rising:

- up 0.7±0.2°C in last 140 years (instrumental records);
- 19 of the 20 warmest years since 1860 have all occurred since 1980, the 11 warmest all since 1990;
- 1998 was the warmest year in the instrumental record and probably the warmest in 1,000 years (tree rings, ice cores); 2002 was the second warmest;
- the last 50 years appear to have been the warmest half century in 6,000 years (ice cores);
- compilation of worldwide ocean-temperature measurements shows significant ocean warming between the mid-1950s and the mid-1990s.

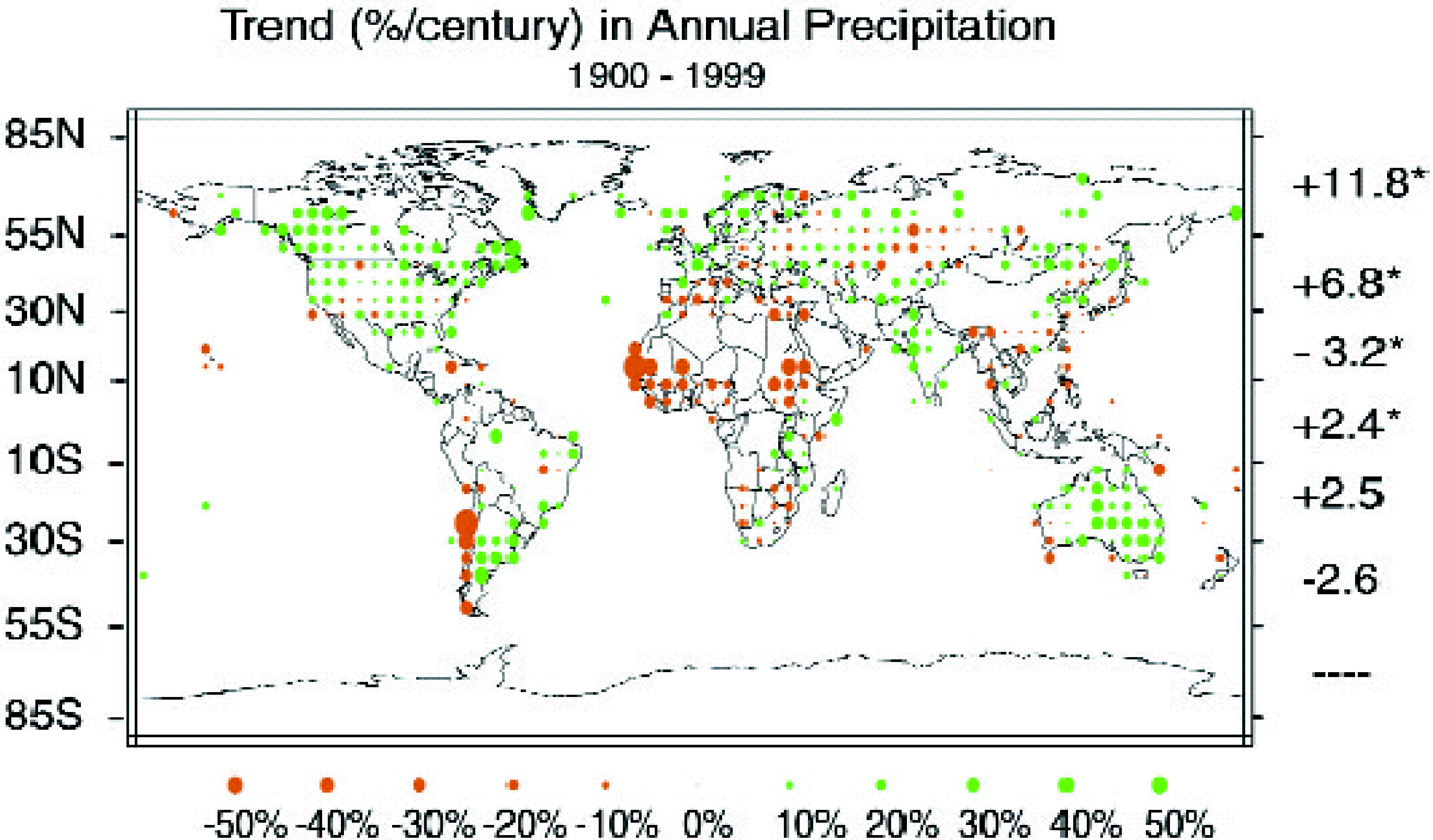
Variations of the Earth's surface temperature for:



Evidence that climate is changing (cont)

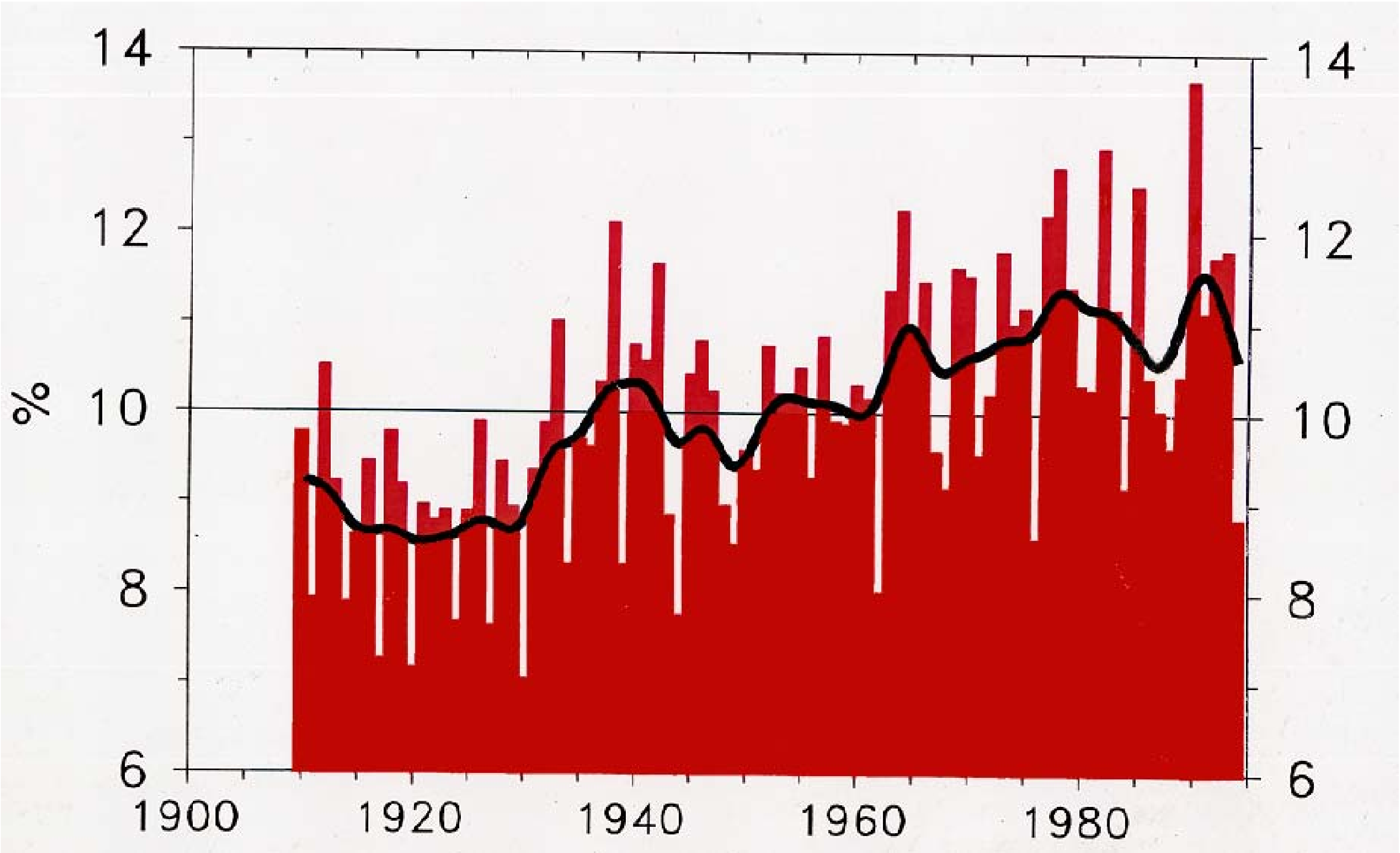
Observations over recent decades also show…

- Evaporation & rainfall are increasing;
- More of the rainfall is occurring in downpours;
- Permafrost is melting;
- Corals are bleaching;
- Glaciers are retreating;
- Sea ice is shrinking;
- Sea level is rising;
- Wildfires are increasing;
- Storm & flood damages are soaring.

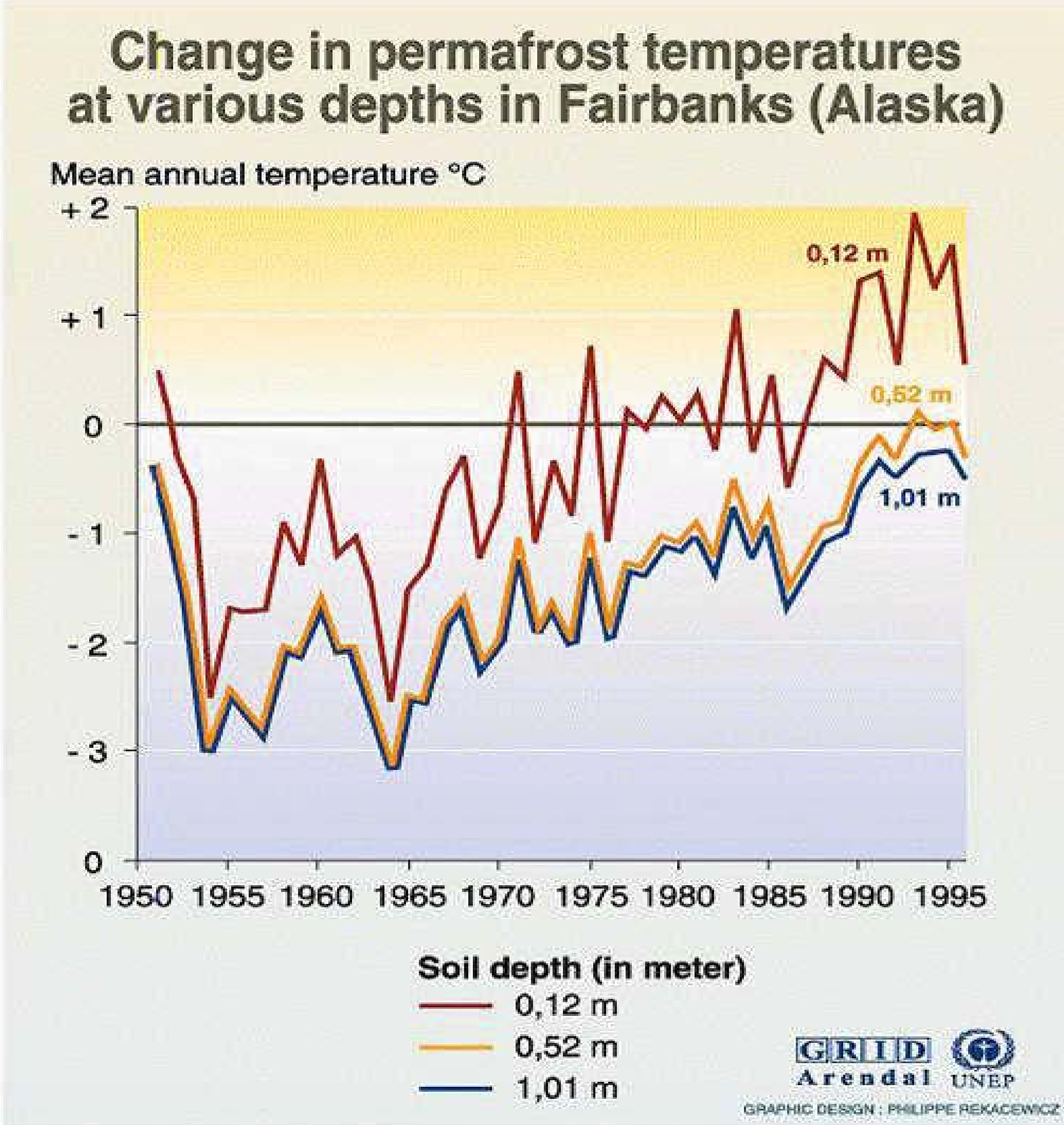


Effects of climate change are not uniform. Precipitation in the 20th century increased overall, as expected with a global warming, but decreased in some regions.

Percent of the Continental U.S. with Much Above Normal Proportion of Total Annual Precipitation From 1-day Extreme Events (more than 2 inches)



Source: Karl, et.al. 1996.

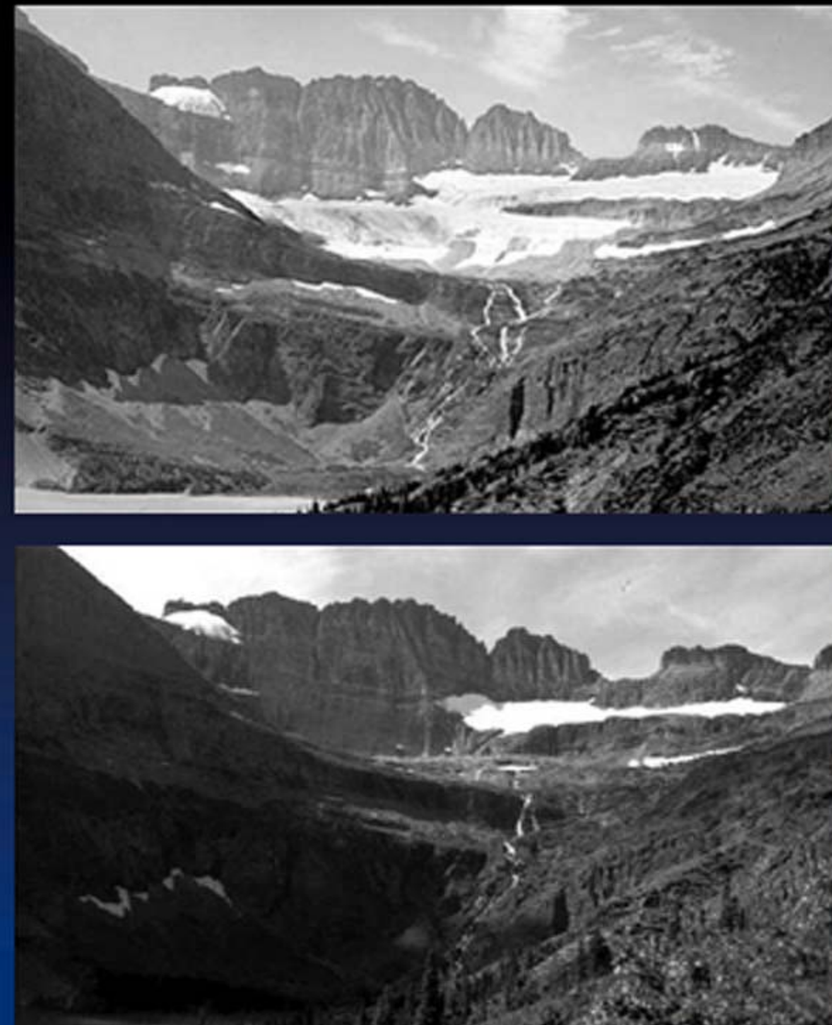


Source: Romanovsky, in Impacts of global climate change in the Arctic regions, IASC, Tromsø, April 1999.

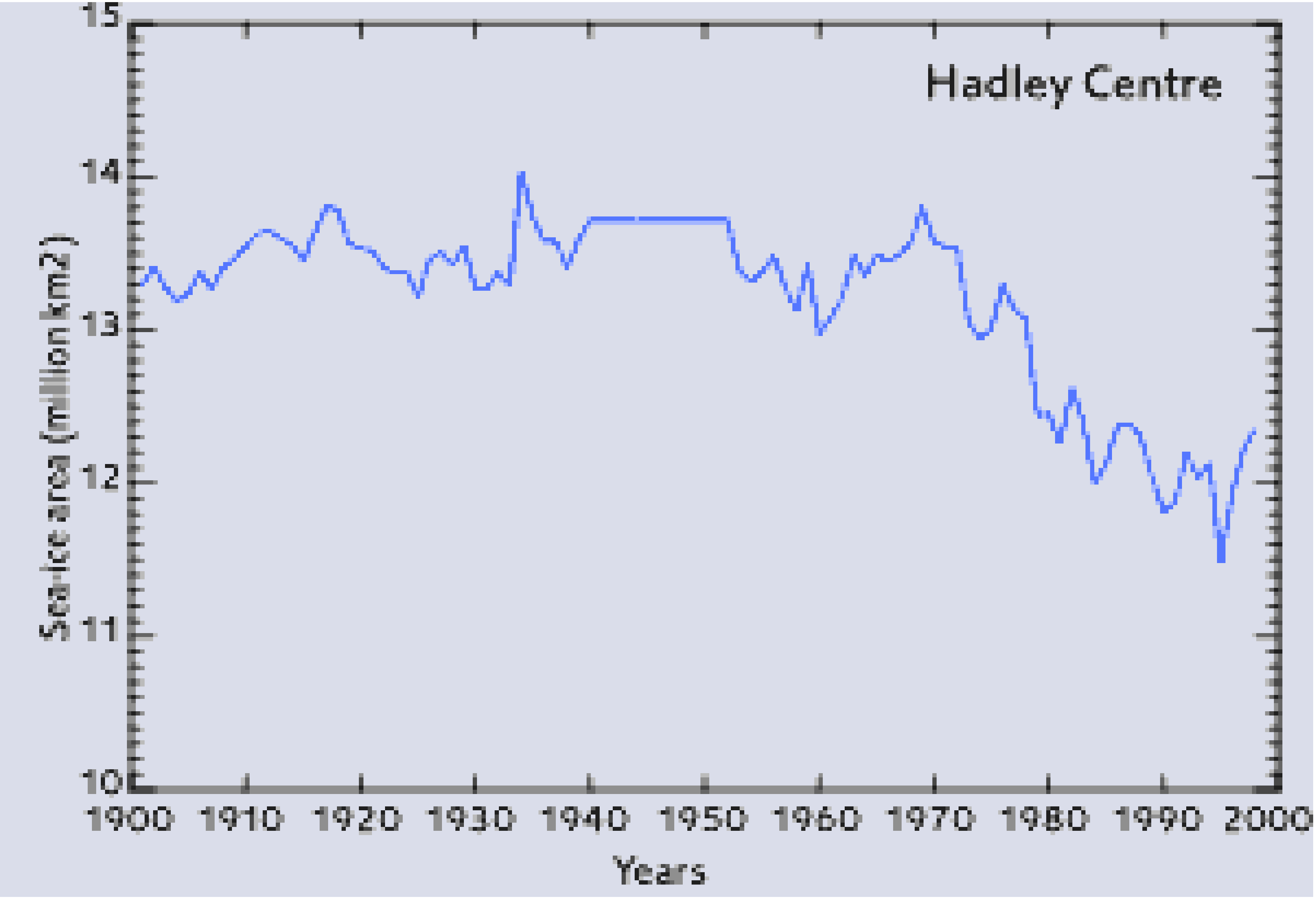
When permafrost T rises above the freezing point and the perma-frost melts, power lines, pipelines, and buildings built over the permafrost can topple, sag, and crack.

Bleached coral head: Bleaching occurs when high water temperature kills the living organisms in the coral, leaving behind only the calcium carbonate skeleton.

Grinell Glacier and Grinnell Lake, Glacier National Park, 1910-1997



Soon Americans will have to settle for a Non-Glacier National Park.



Sea-ice extent has dropped by ~1.5 million km2 since 1970.

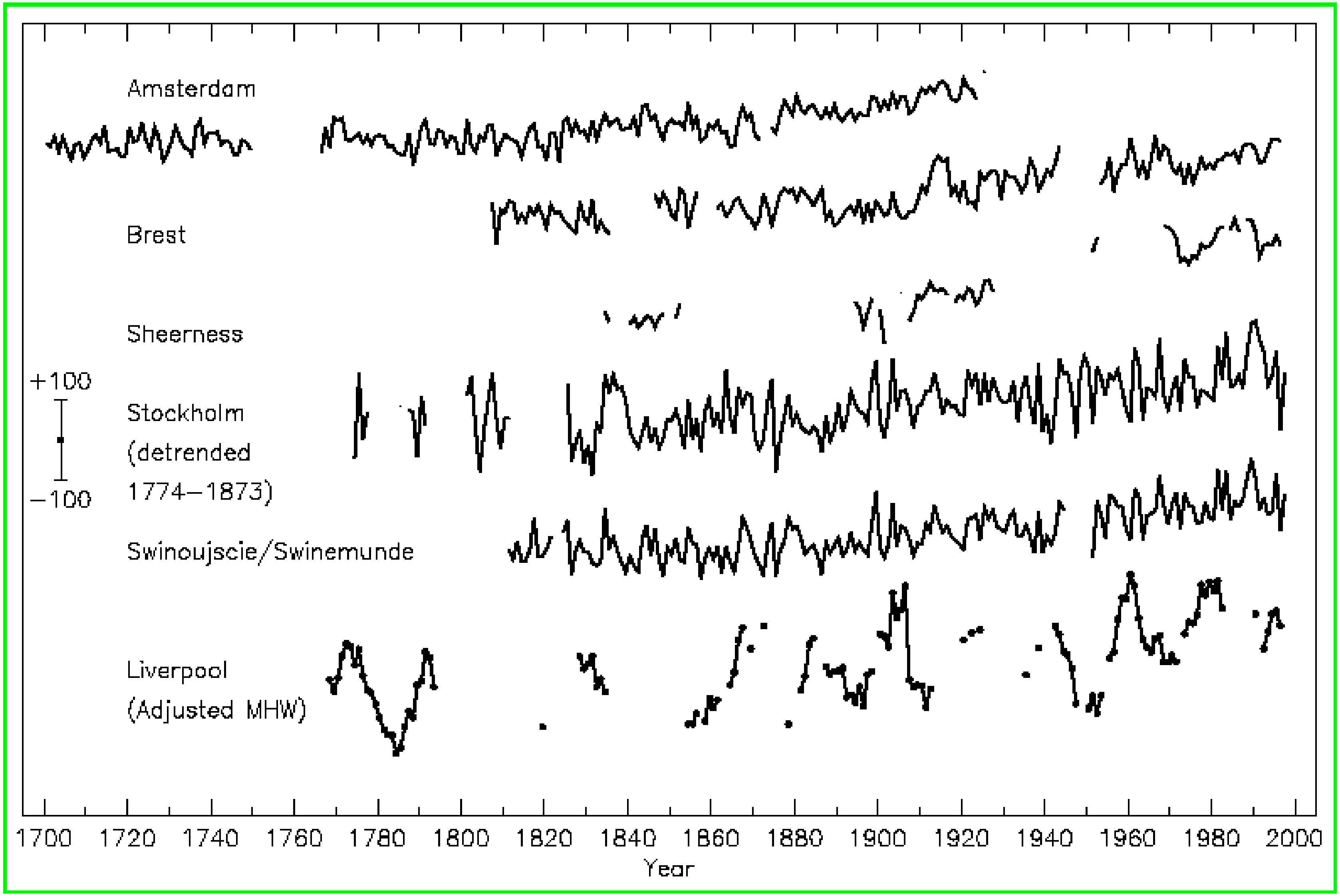
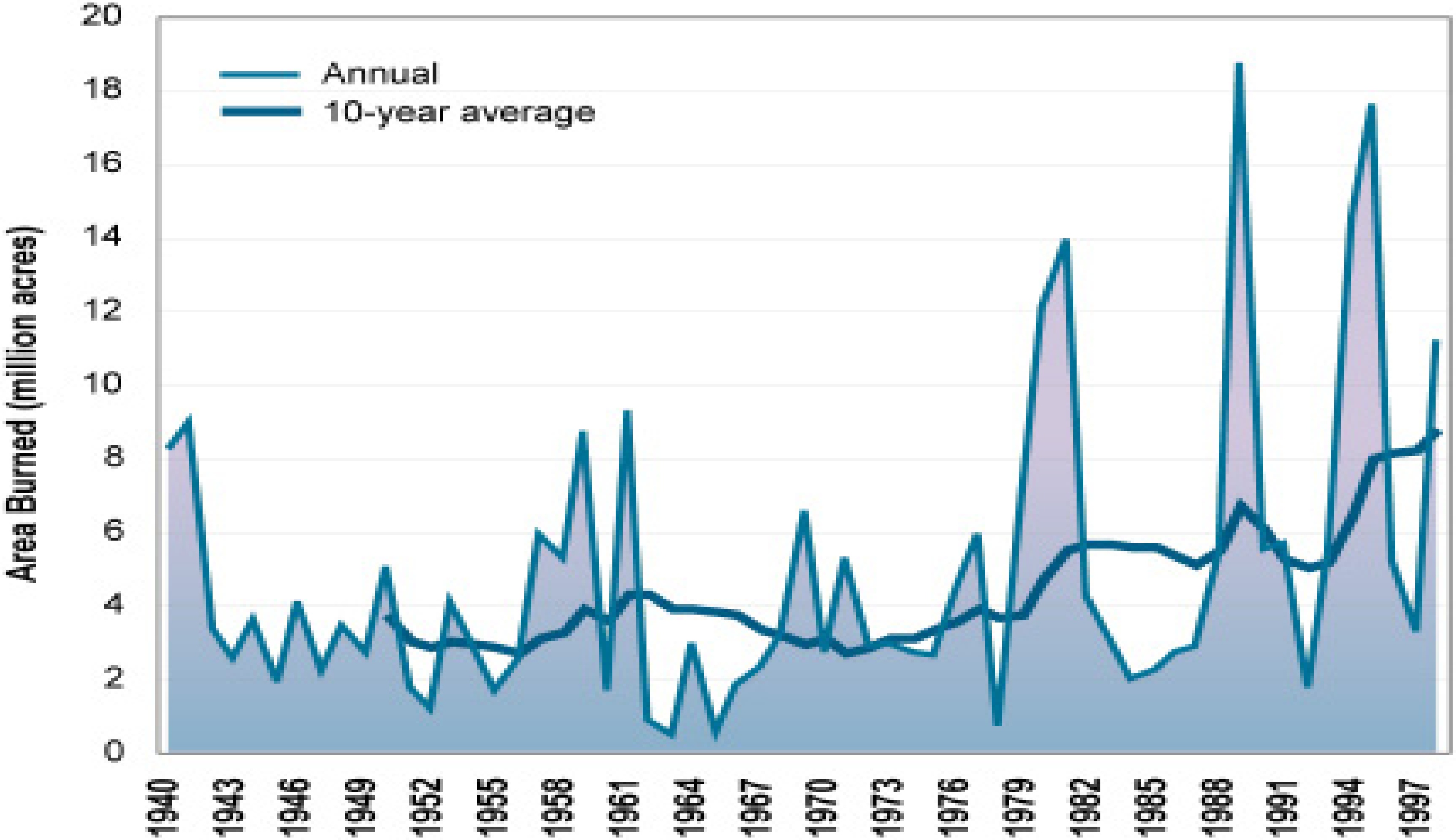


Figure 6: Time-series of relative sea level for the past 300 years from Northern Europe: Amsterdam, Netherlands; Brest, France; Sheerness, UK; Stockholm, Sweden (detrended over the period 1774 to 1873 to remove to first order the contribution of post-glacial rebound); Swinoujscie, Poland (formerly Swinemunde, Germany); and Liverpool, UK. Data for the latter are of "Adjusted Mean High Water" rather than Mean Sea Level and include a nodal (18.6 year) term. The scale bar indicates ±100 mm. [Based on Figure 11.7]

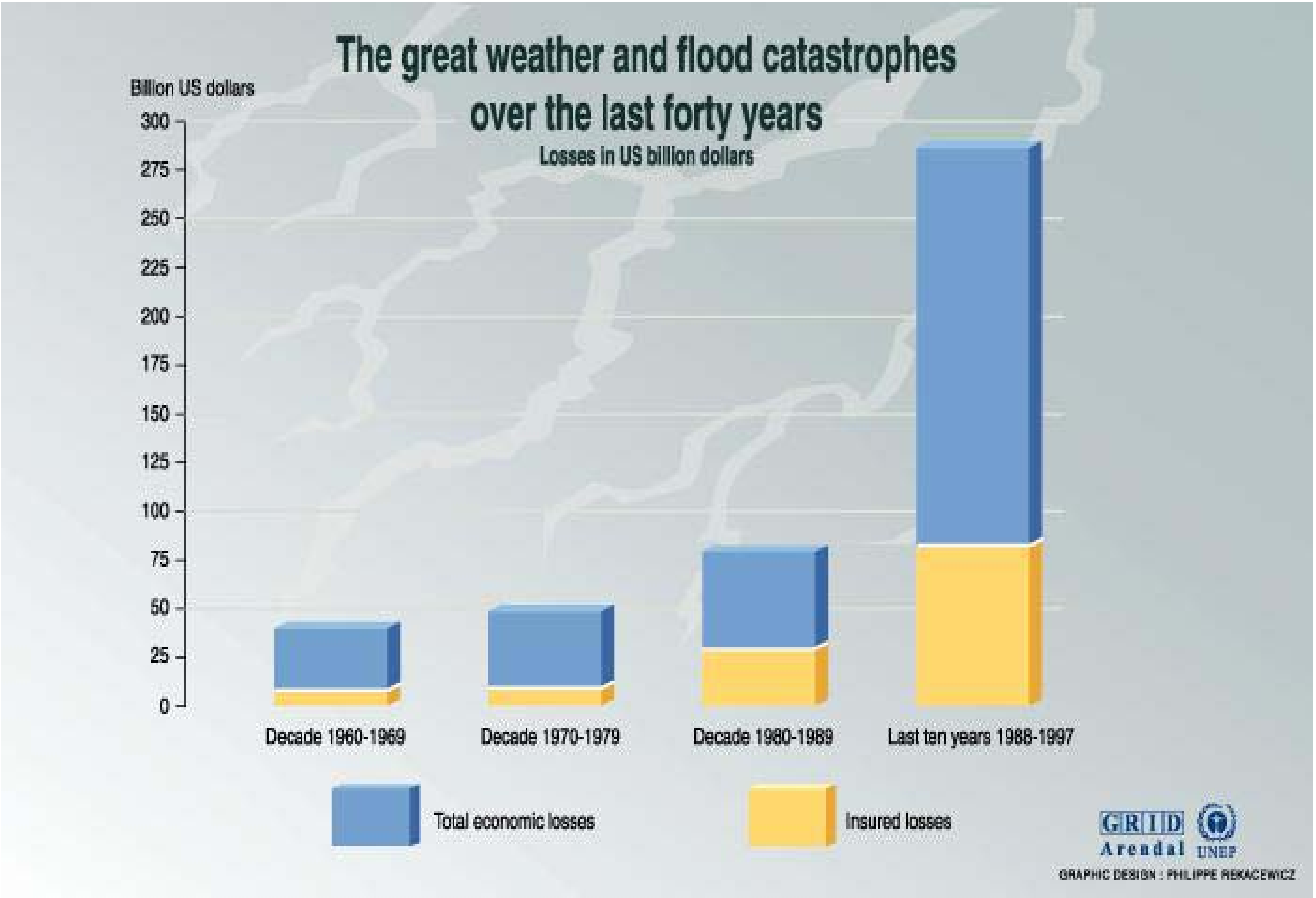
The gradual rise of sea level is evident in these data. (IPCC)

Annual Area of Northern Boreal Forest Burned in North America



The Alaskan boreal forest is a small part of an enormous forest that extends continuously across the northern part of North America. The average area of this forest burned annually has more than doubled since 1970.

Satellite photo of smoke from S California wildfires, October 2003



Source: Munich Re Group, 1999.

So, global climate is changing…

- in the direction of average warming,
- accompanied by many phenomena consistent with this,
- and at pace that is unusual in the recent historical record.

But we know climate has sometimes changed quite abruptly in the past from <u>natural</u> causes.

Is it really humans who are responsible for what is happening now? Or is it nature? What is the evidence?

The main natural and human phenomena affecting climate are known.

- NATURAL INFLUENCES ON GLOBAL CLIMATE
  - variations in the energy output of the Sun
  - variations in the Earth's orbit and tilt
  - continental drift
  - changes in atmospheric composition from volcanoes, biological activity, weathering of rocks
- HUMAN INFLUENCES ON GLOBAL CLIMATE
  - emission of "greenhouse gases" (GHG) as a result of deforestation, agricultural practices, fossil-fuel burning
  - emission of particulate matter from agricultural burning, cultivation, fossil-fuel burning,
  - alteration of Earth's surface reflectivity by deforestation, desertification
  - cloud formation by aircraft contrails

The strengths of these natural and human influences can be measured or estimated, and then compared.

- The measure used in the climate-science community for quantifying and comparing natural & human influences is the change they cause in the flow of radiant energy in the atmosphere. This measure is called radiative forcing or just forcing.

  Its units are watts per square meter (W/m^2), averaged over the globe and over the year, defined as positive when the effect is in the direction of warming Earth's surface.

- The best estimates of the forcings from all the influences on global climate in the 250 years since the beginning of the Industrial Revolution indicate that the biggest effect has been from the rising concentrations of greenhouse gases in this period.

Best estimates of global-climate forcings 1750-2000, watts per square meter

Increase in…

atmospheric CO_2	+ 1.5
other well-mixed GHG* (CH_4, N_2O, halons)	+ 1.0
net ozone (troposphere↑, stratosphere↓)	+ 0.2
absorptive particles (soot)	+ 0.2
reflective particles (sulfates, etc.)	- 0.7
indirect (cloud forming) effect of particles	- 0.8
Land transformations increasing reflectivity	- 0.2
Change in solar input	+ 0.3

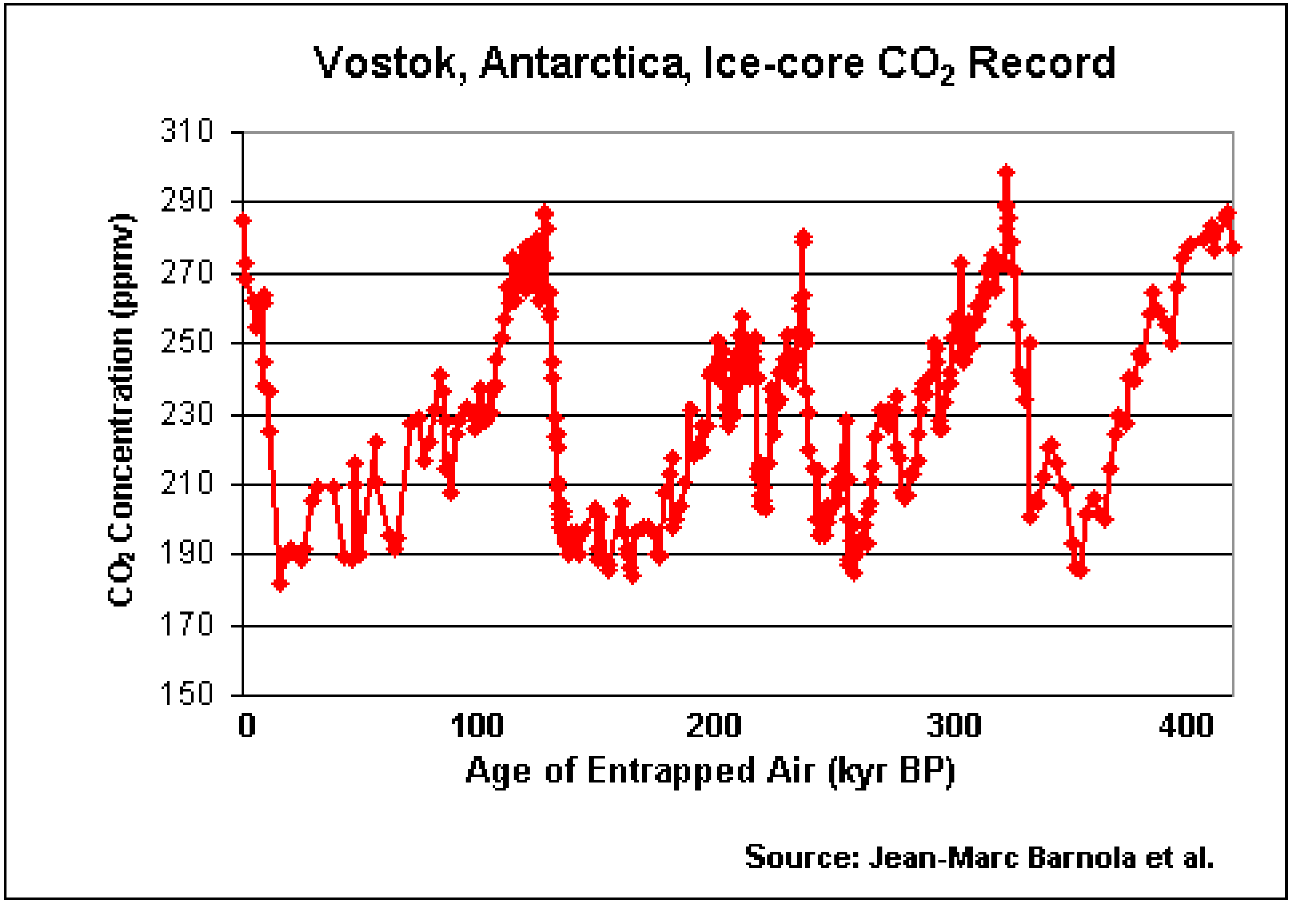
The warming influence of anthropogenic GHG and absorbing particles is ~10x the warming influence of the estimated change in input from the Sun. CO_2 alone is ~5x the sun's effect.

* GHG = greenhouse gases

There is no scientific doubt that most of the indicated GHG increases are human-caused.

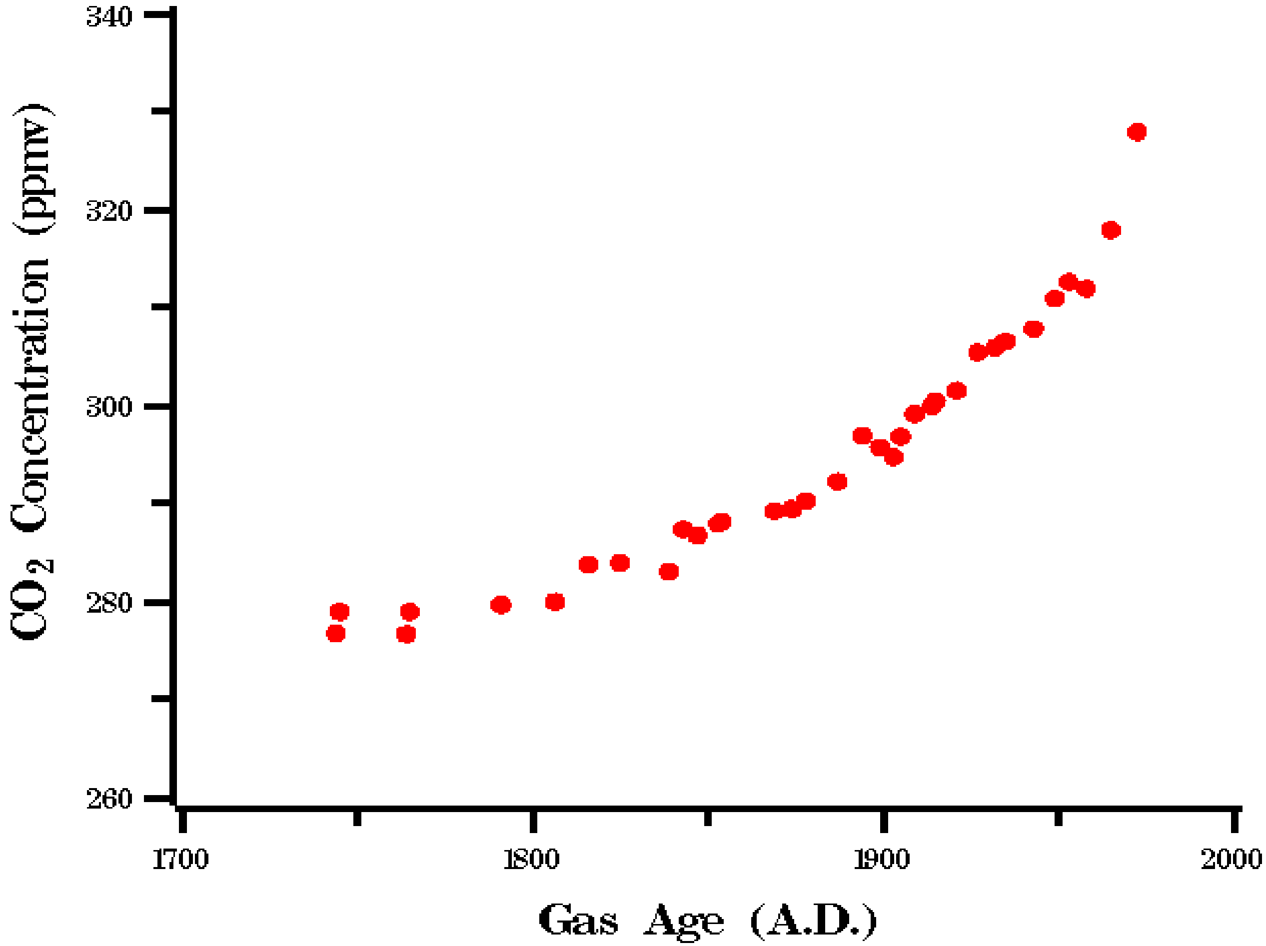
- The increases in atmospheric CO_2 and other globally mixed GHG have been accurately measured in real time for decades
- Their atmospheric concentrations going back for centuries and millennia have been determined by analysis of air trapped in bubbles in Antarctic & Greenland ice.
- The main human sources of CO_2 – deforestation and fossil-fuel burning – are quite well quantified. The observed CO_2 build-up in the atmosphere matches these human inputs, after subtraction of estimated rates of uptake in the oceans and northern forests.
- The ice-core data show that atmospheric CO_2 has not been above 300 ppmv in the last 400,000 years (it's over 370 ppmv today) and that natural fluctuations in atmospheric CO_2 over the past 10,000 years have been only $\pm$10 ppmv (compared to the 90 ppmv increase since the start of the Industrial Revolution).
- Carbon-14 analysis of tree rings back to 1800 confirms the fossil-fuel contribution to the atmospheric CO_2 burden in the last 200 years.

Ice Cores Preserve the History of Atmospheric CO_2

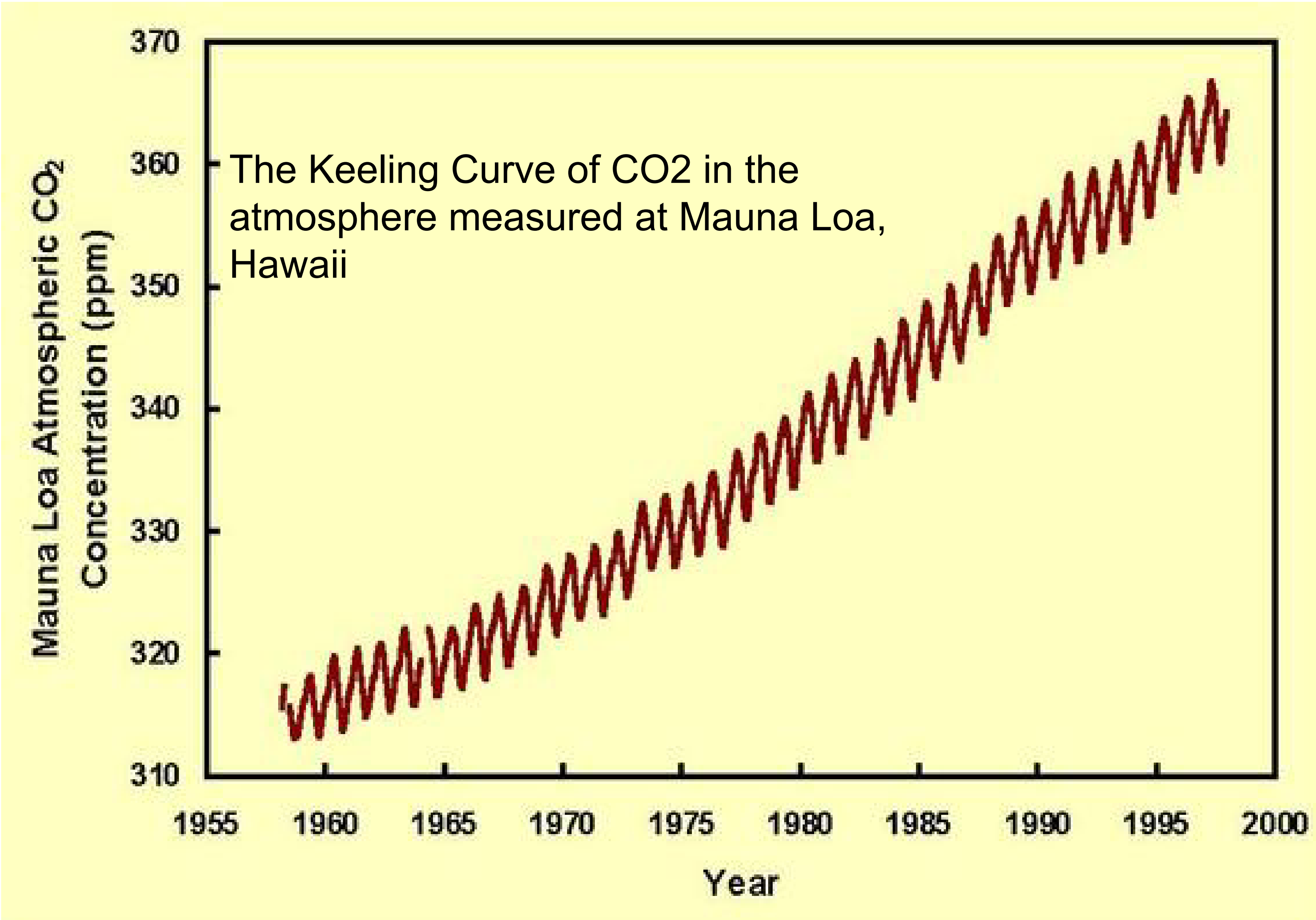


The concentration of carbon dioxide in the atmosphere has never been above 300 ppm for at least the last 430,000 years (and probably not for the last 30 million years!)

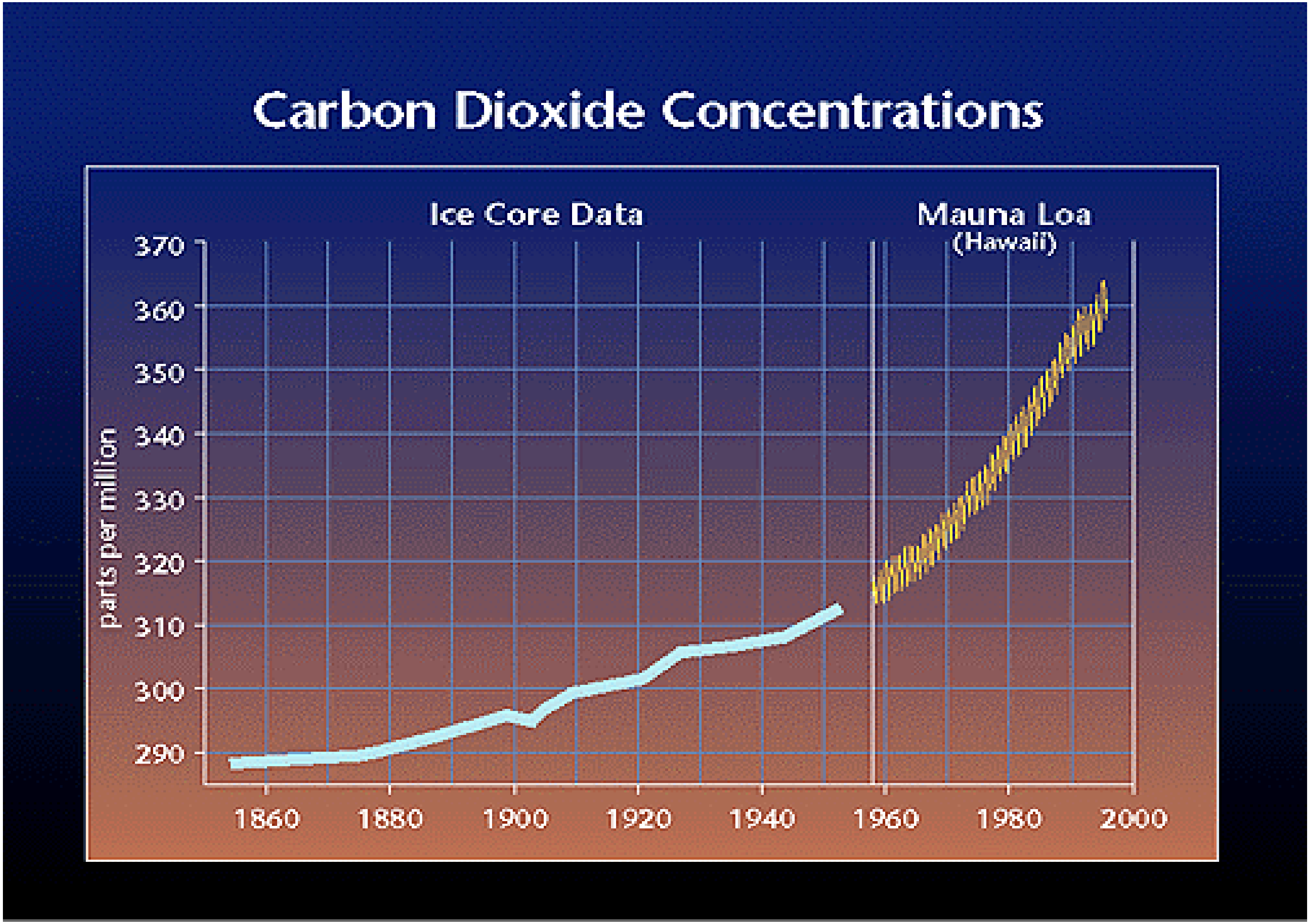
CO2 in an ice core from Siple Dome, Antarctica



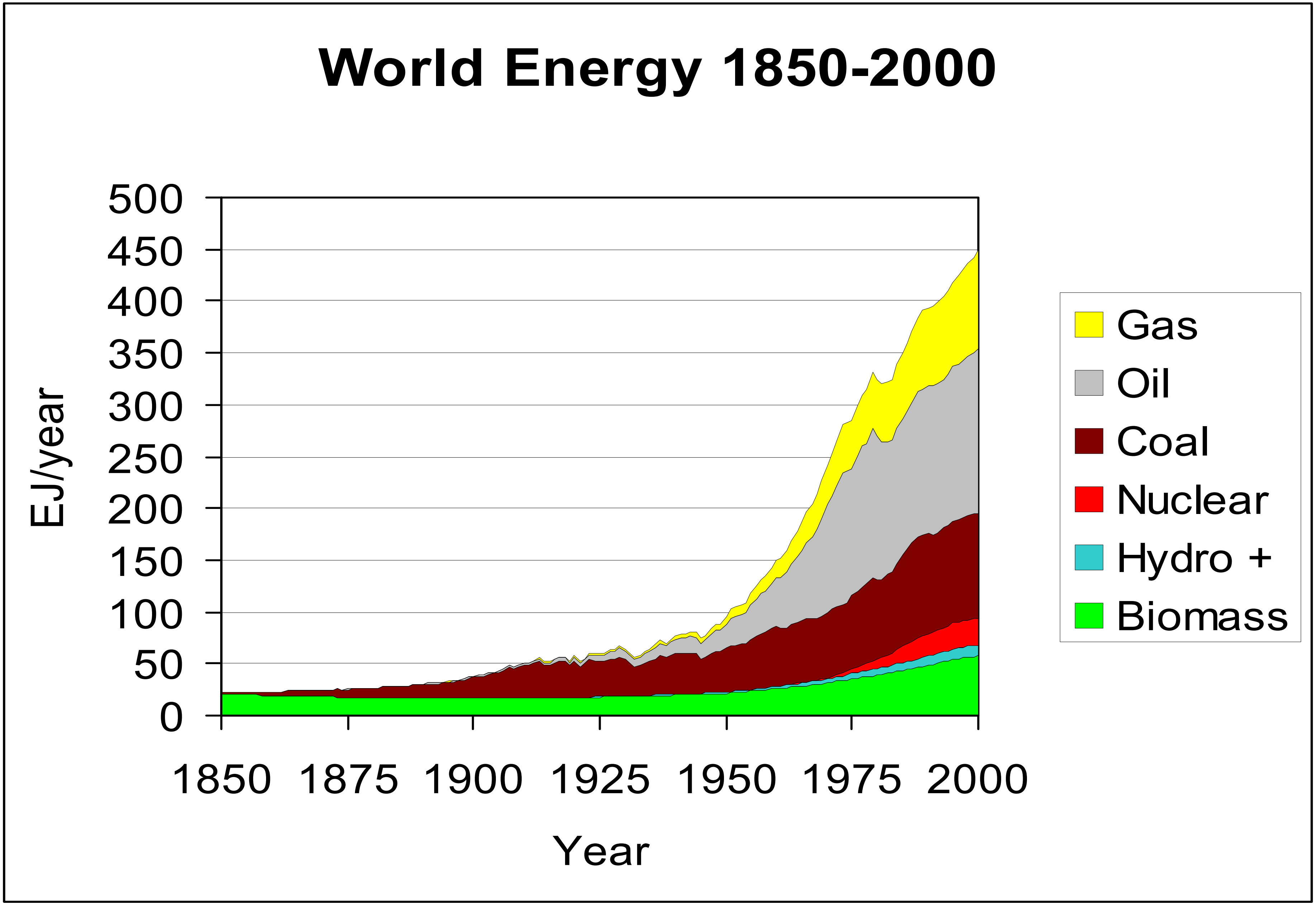
The exponential increase in atmospheric CO2 during the industrial era is clearly recorded in the air bubbles trapped in Antarctic ice.



Direct measurements of CO2 at a remote location began in 1958.



Combining the ice-core data and the direct measurements from Mauna Loa yields a curve strikingly similar to the curve that describes…

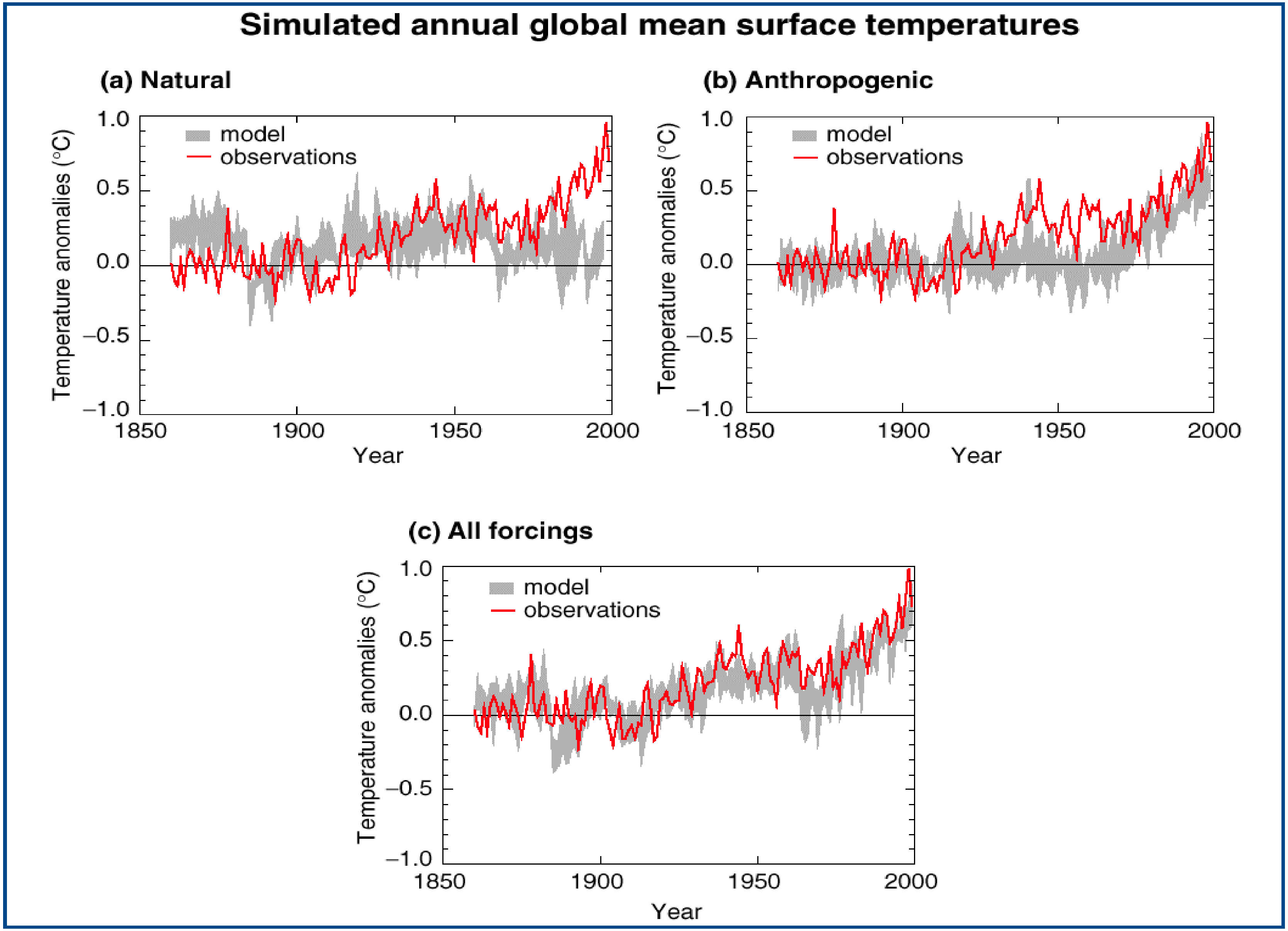


...the increase in worldwide fossil-fuel combustion in the past 150 years.

The “fingerprint” of GHG on global climate

Observations

- increased air temperatures over land & oceans
- warming of near-surface ocean waters
- decreased day-night temperature differences
- reduced stratospheric temperatures
- geographic and temporal patterns of changes matching what models predict for the observed changes in globally mixed greenhouse gases in concert with observed changes in volcanic and anthropogenic particulates and best estimates of solar variability



Computer models of climate match the observations only when natural and human “forcings” are included in the models. The human forcings are responsible for most of the rapid warming 1970-2000.

The smoking gun

- Essentially all of the observed climate-change phenomena are consistent with the predictions of climate science for GHG-induced warming.
- No alternative "culprit" identified so far – no potential cause of climate change other than greenhouse gases – yields this "fingerprint" match.
- A credible skeptic would need to explain both what the alternative cause of the observed changes is and how it could be that GHGs are NOT having the effects that all current scientific understanding says they should have. (No skeptic has done either thing.)

Climatic Consequences of Continuation of Business as Usual

THE "BUSINESS AS USUAL" SCENARIO TO 2100

- World population increases from 6.1 billion in 2000 to 9.8 billion in 2050, stabilizing by 2100 at about 11 billion.
- Economic growth averages 2.8% per year from 2000 to 2020 and 2.5% per year over the whole century, in real terms. World economic product (in 2000 US$, corrected for purchasing power parity), grows from ~$45 trillion in 2000 to ~$180 trillion in 2050 and ~$500 trillion in 2100.
- Energy intensity of economic activity falls at the long-term historical rate of 1%/yr. Energy use increases about 2.5 fold by 2050 and quadruples by 2100.
- Carbon intensity of energy supply falls at 0.2%/yr. Carbon emissions from fossil-fuel burning go from a bit over 6 billion tonnes/yr in 2000 to some 20 billion tonnes/yr in 2100.

An aside: Why are scenarios of future climate change so often described only in terms of CO_2 emissions and concentrations, even though other gases and particles also have significant effects?

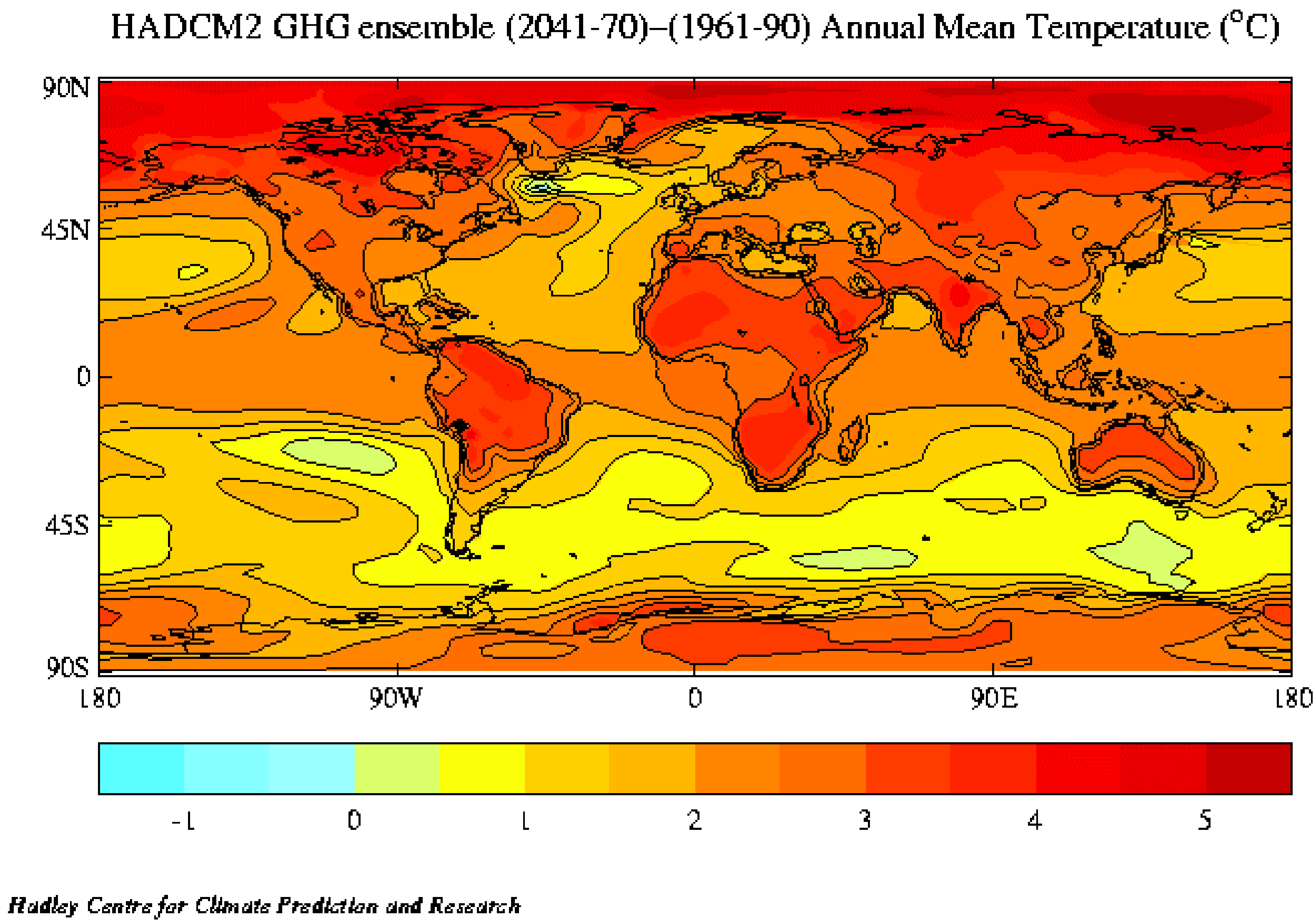
1. The warming effects of increases over the past 250 years in non-CO_2 GHG & absorbing particles have been approximately balanced by the cooling effects of increases in reflecting particles. Thus the net effect of all the human additions to the atmosphere over the past 250 years is (by coincidence) about equal to the CO_2 effect alone.
2. This is likely to remain approximately true in the future: reductions in emissions that add to reflective-particle concentrations are likely to be matched by reductions in emissions of black soot and non-CO_2 GHG, so that these positive & negative forcings will continue to more or less balance each other in the 21st century.
3. To study scenarios in which this might not be the case, one can express the greenhouse-warming effects of non-CO_2 GHG in terms of “tonnes of CO_2 equivalent” (for emissions) and “parts per million of CO_2 equivalent” (for concentrations).

Consequences of continued “business as usual”

The scientific-consensus **“best estimates”** are that:

- Continuing "business as usual" GHG emissions will lead to increases of 0.2-0.4°C per decade in global-average surface temperature, or 2-4°C warmer than now by 2100.* Mid-continent warming will be 2-3x greater.
  - The earth will then be warmer than at any time in the last 160,000 years. Sea level will be 20-100 cm higher than today (best estimate 50 cm).
  - This global-average warming will entail major changes in climatic patterns: storm tracks, distribution of precipitation & soil moisture, extremes of hot & cold.
- Because of the pace and magnitude of the changes in climatic patterns and because society’s interactions with the environment are attuned to the current climate, impacts on human well-being will be far more negative than positive.

* The full range of IPCC scenarios (from lower emissions than my BAU to higher) gives 1.4-5.8°C increase by 2100.

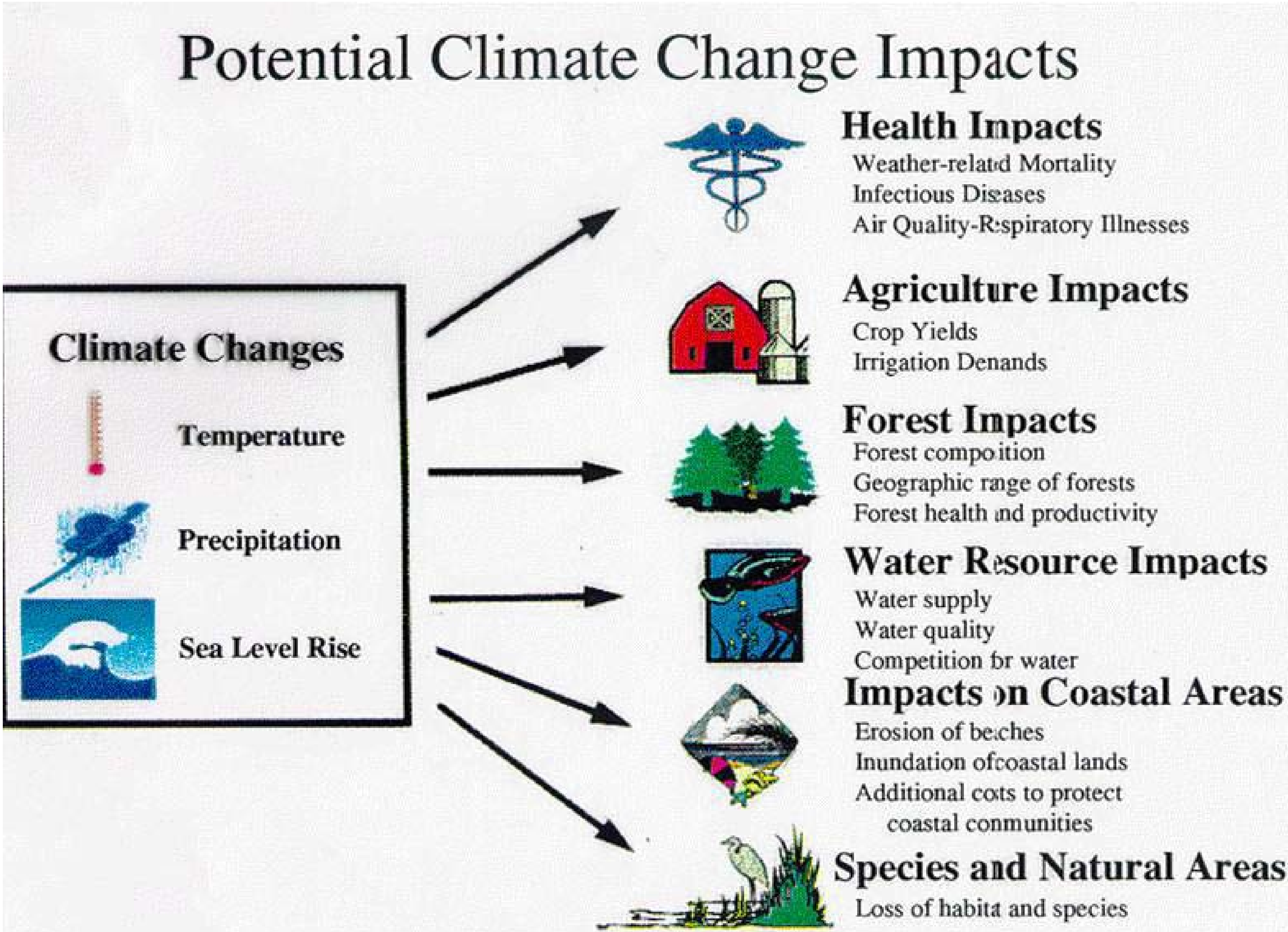


This computer simulation of mid-21st-century warming under BAU shows how continental warming far exceeds the global average.

Confidence in observed changes (latter half of the 20th century)	Changes in Phenomenon	Confidence in projected changes (during the 21st century)
Likely[7]	**Higher maximum temperatures and more hot days over nearly all land areas**	Very likely[7]
Very likely[7]	**Higher minimum temperatures, fewer cold days and frost days over nearly all land areas**	Very likely[7]
Very likely[7]	**Reduced diurnal temperature range over most land areas**	Very likely[7]
Likely[7], over many areas	**Increase of heat index[12] over land areas**	Very likely[7], over most areas
Likely[7], over many Northern Hemisphere mid- to high latitude land areas	**More intense precipitation events[b]**	Very likely[7], over many areas
Likely[7], in a few areas	**Increased summer continental drying and associated risk of drought**	Likely[7], over most mid-latitude continental interiors. (Lack of consistent projections in other areas)
Not observed in the few analyses available	**Increase in tropical cyclone peak wind intensities[c]**	Likely[7], over some areas
Insufficient data for assessment	**Increase in tropical cyclone mean and peak precipitation intensities[c]**	Likely[7], over some areas

Source: IPCC, 2001

Impacts of BAU Climate Changes on Human Well-Being


Potential Climate Change Impacts
Climate Changes
Temperature
Precipitation
Sea Level Rise
Health Impacts
Weather-related Mortality
Infectious Diseases
Air Quality-Respiratory Illnesses
Agriculture Impacts
Crop Yields
Irrigation Denands
Forest Impacts
Forest compoition
Geographic range of forests
Forest health and productivity
Water Resource Impacts
Water supply
Water quality
Competition for water
Impacts on Coastal Areas
Erosion of beaches
Inundation ofcoastal lands
Additional costs to protect
coastal communities
Species and Natural Areas
Loss of habitt and species

IPCC 2001 WG III report on impacts..

“Projected adverse impacts based on models and other studies include

- A general reduction in potential crop yields in most tropical and sub-tropical regions for most projected increases in temperature;
- A general reduction, with some variation, in potential crop yields in most regions in mid-latitudes for increases in average-annual temperature of more than a few degrees C;
- Decreased water availability for populations in many water-scarce regions, particularly in the sub-tropics;
- An increase in the number of people exposed to vector-borne diseases (e.g. malaria) and water-borne diseases (e.g. cholera) and an increase in heat-stress mortality;
- A widespread increase in the risk of flooding for many human settlements (tens of millions of inhabitants in settlements studied) from both increased heavy precipitation events and sea-level rise;
- Increased energy demand for space cooling due to higher summer temperatures.”

IPCC WG3: The benefit side of impacts

"Projected beneficial impacts based on models and other studies include:

- Increased potential crop yields in some regions at mid-latitudes for increases in temperature of less than a few degrees C;
- A potential increase in global timber supply from appropriately managed forests;
- Increased water availability for populations in some water-scarce regions, e.g., in parts of South East Asia;
- Reduced winter mortality in mid- and high-latitudes;
- Reduced energy demand for space heating due to higher winter temperatures."

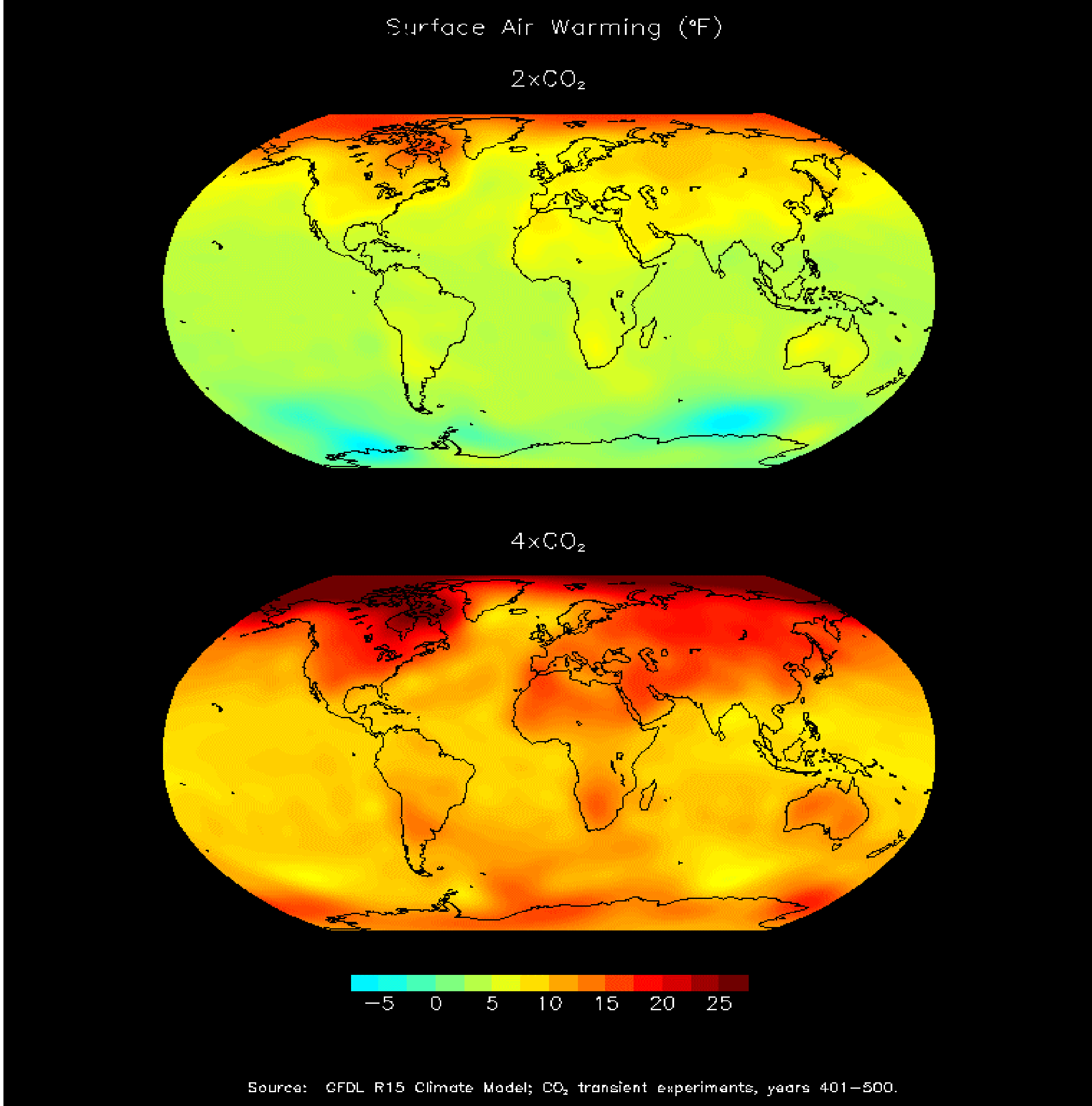
But…

- Most studies to date of adverse & beneficial impacts of climate change have focused on just a doubling of pre-industrial CO_2 (for comparability among models).
- Alas, under BAU, we'll careen past a doubling around mid-century, heading for a tripling by 2100 and a quadrupling soon after.
- At these higher levels of forcing and resulting climate disruption, early positive impacts are reversed and negative ones become overwhelming.

Computer simulations performed by the Princeton Geophysical Fluid Dynamics Lab to compare the warming expected under a doubling of CO_2 from the pre-industrial level with the warming expected from a quadrupling.

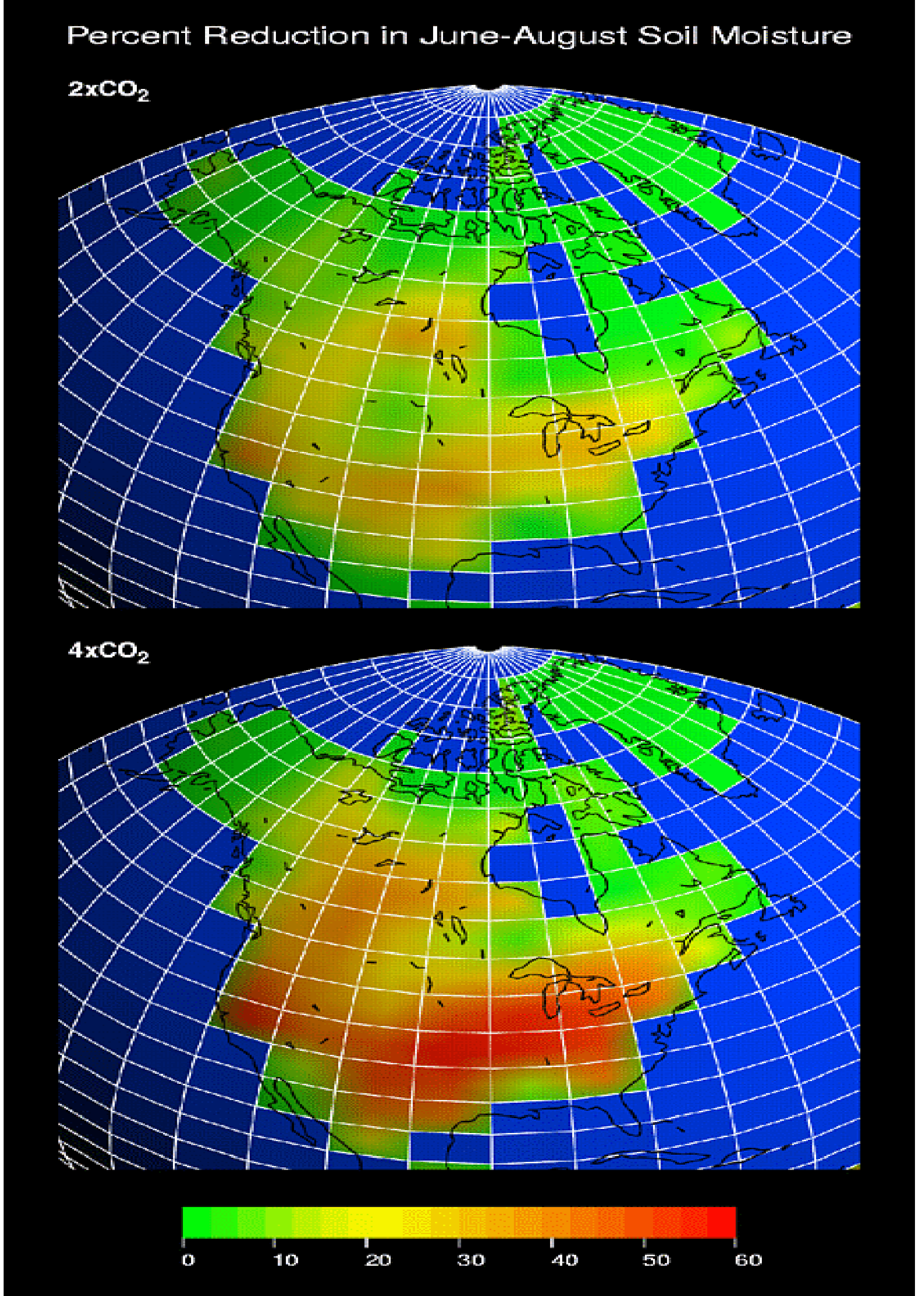
Note that N hemisphere mid-continent average warming in the $4xCO_2$ world is 15-25°F!

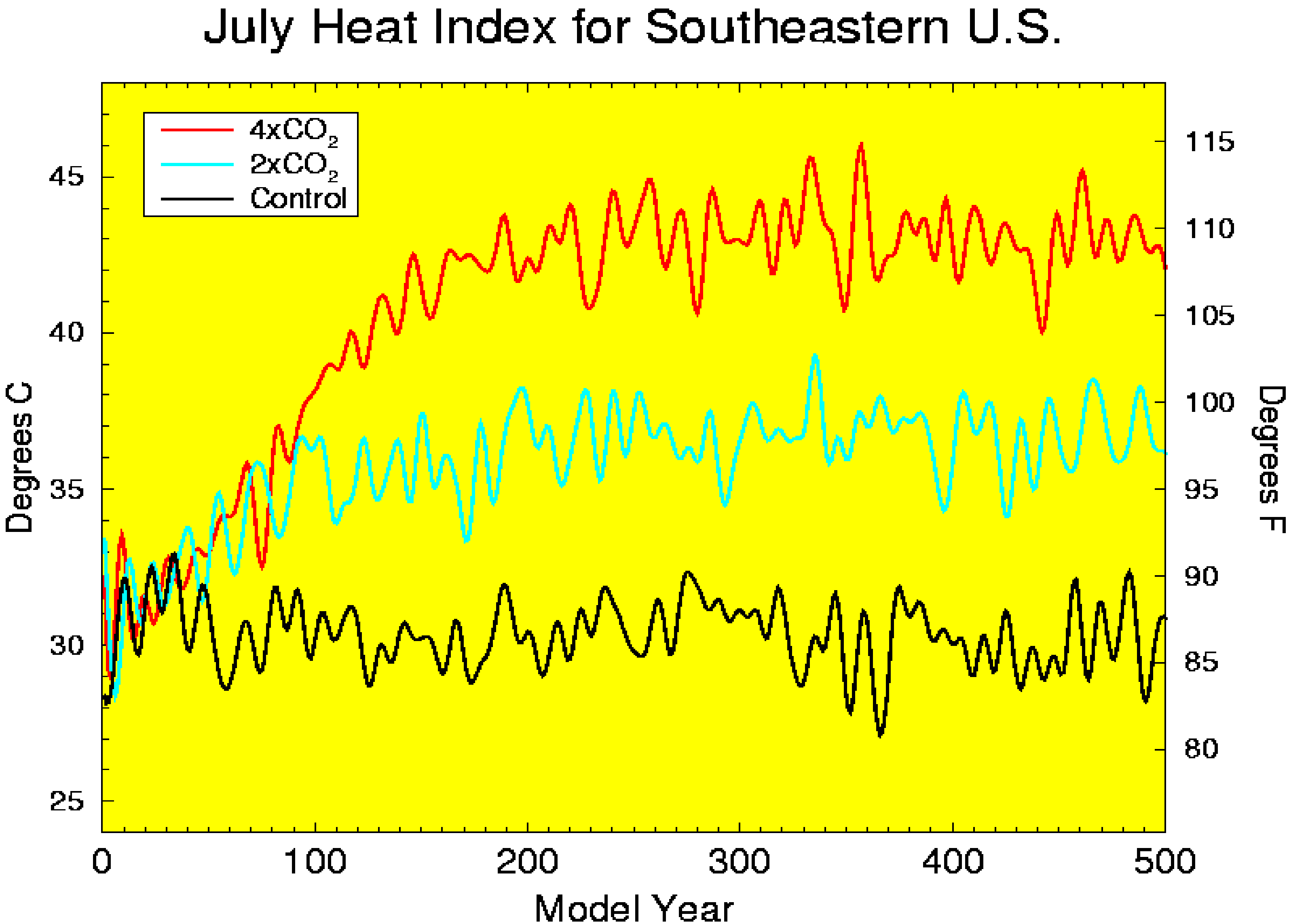
This is a roasted world.



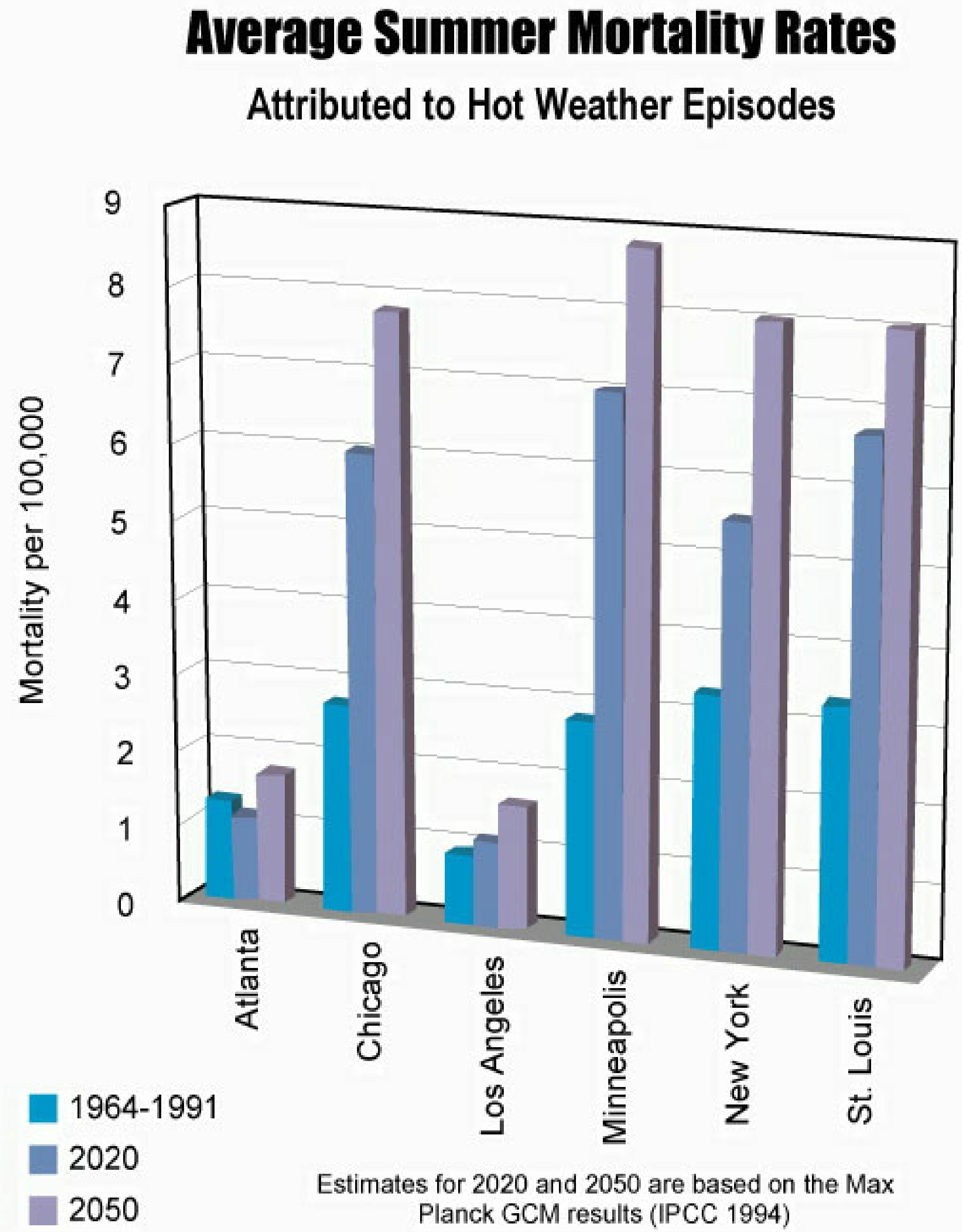
Summer soil moisture in N America under doubled & quadrupled CO_2 (from the Princeton GFDL model)

Mid-continent soil-moisture reductions reach 50-60% in the $4xCO_2$ world – a catastrophe for agriculture.





“Heat index” combines temperature and humidity to measure discomfort. Washington DC July heat index was 87°F in 1970, reaches about 98°F in a $2xCO_2$ world and 110°F in a $4xCO_2$ world. Under BAU, we’re headed for 4x.


Average Summer Mortality Rates
Attributed to Hot Weather Episodes
Mortality per 100,000
0
1
2
3
4
5
6
7
8
9
Atlanta
Chicago
Los Angeles
Minneapolis
New York
St. Louis
1964-1991
2020
2050
Estimates for 2020 and 2050 are based on the Max Planck GCM results (IPCC 1994)

Disease	Vector	Population at risk (million)[1]	Number of people currently infected or new cases per year	Present distribution	Likelihood of altered distribution
Malaria	Mosquito	2,400[2]	300-500 million	Tropics and Subtropics	Highly likely
Schistosomiasis	Water snail	600	200 million	Tropics and Subtropics	Very likely
Lymphatic Filariasis	Mosquito	1 094[3]	117 million	Tropics and Subtropics	Likely
African Trypanosomiasis (Sleeping sickness)	Tsetse fly	55[4]	250 000 to 300 000 cases per year	Tropical Africa	Likely
Dracunculiasis (Guinea worm)	Crustacean (Copepod)	100[5]	100 000 per year	South Asia, Arabian Peninsula, Central-West Africa	Unknown
Leishmaniasis	Phlebotomine sand fly	350	12 million infected, 500 000 new cases per year[6]	Asia, Southern Europe Africa, Americas	Likely
Onchocerciasis (River blindness)	Black fly	123	17.5 million	Africa, Latin America	Very likely
American Trypanosomiasis (Chagas disease)	Triatomine bug	100[7]	18 million	Central and South America	Likely
Dengue	Mosquito	1,800	10-30 million per year	All Tropical countries	Very likely
Yellow Fever	Mosquito	450	more than 5 000 cases per year	Tropical South America Africa	Likely

Highly likely | Very likely | Likely | Unknown

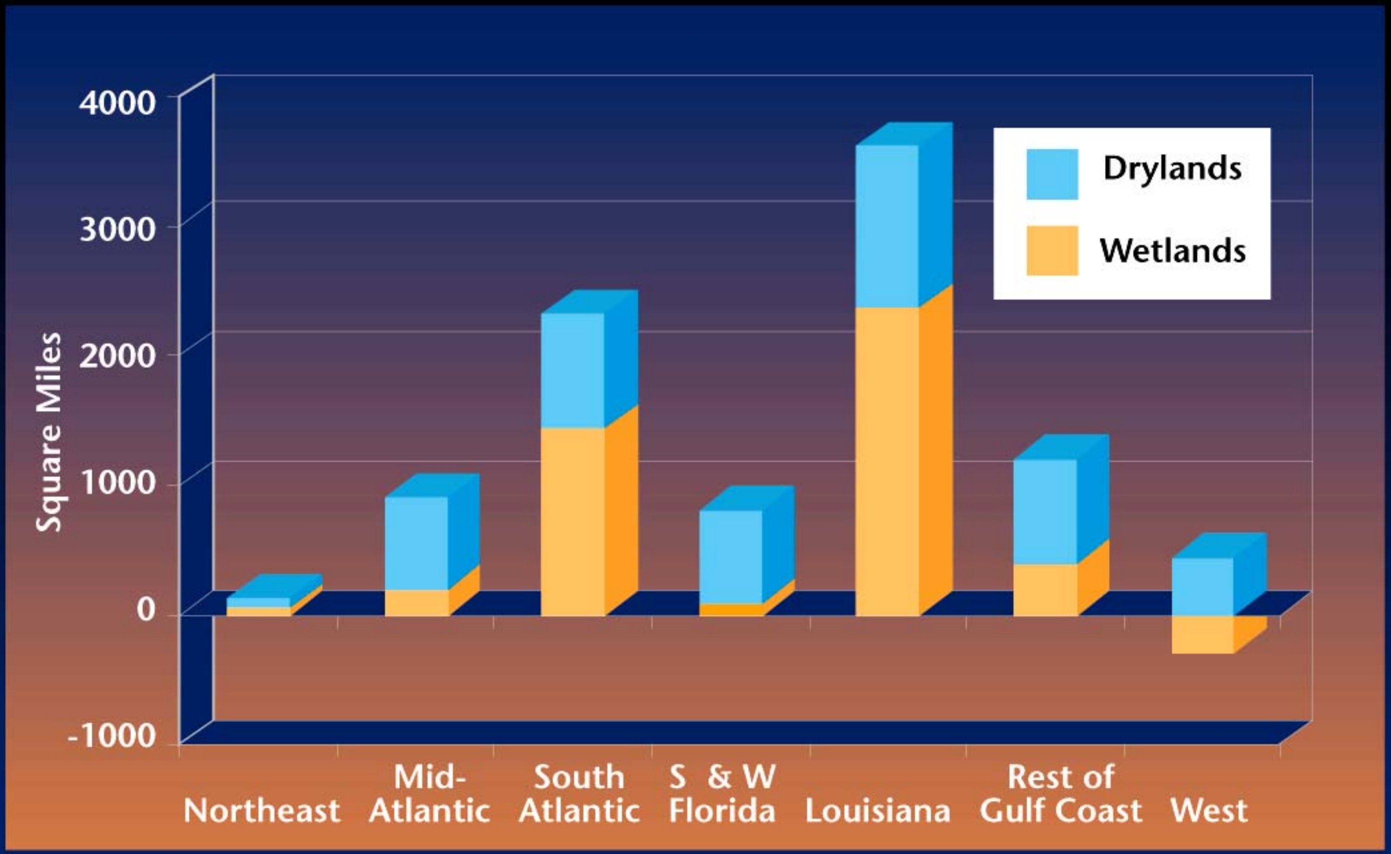
1. Top three entries are population-prorated projections, based on 1989 estimates.
2. WHO, 1994.
3. Michael and Bundy, 1995.
4. WHO, 1994.
5. Ranque, personal communication.
6. Annual incidence of visceral leishmaniasis; annual incidence of cutaneous leishmaniasis is 1-1.5 million cases/yr (PAHO, 1994).
7. WHO, 1995.

GRID Arendal UNEP

GRAPHIC DESIGN : PHILIPPE REKACEWICZ

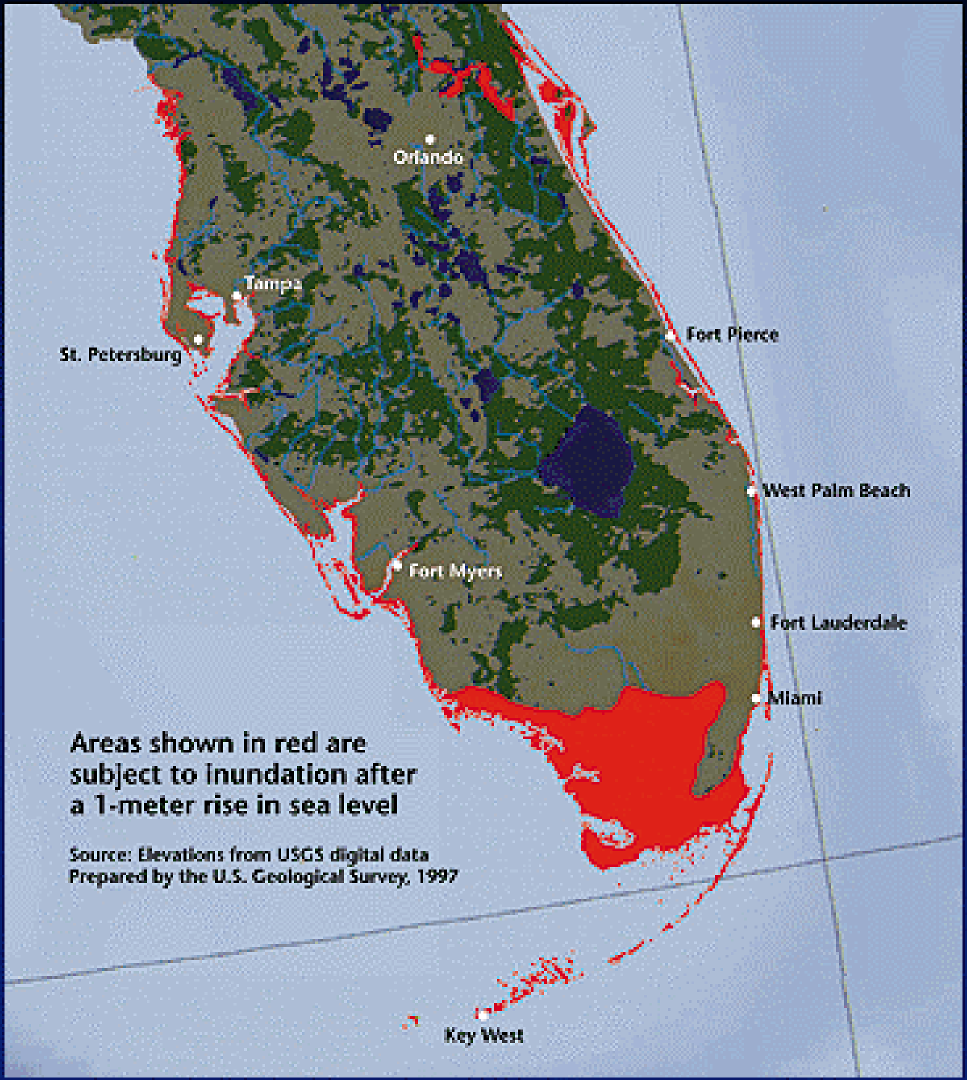
Source: Climate change 1995, Impacts, adaptations and mitigation of climate change: scientific-technical analyses, contribution of working group 2 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 1996.

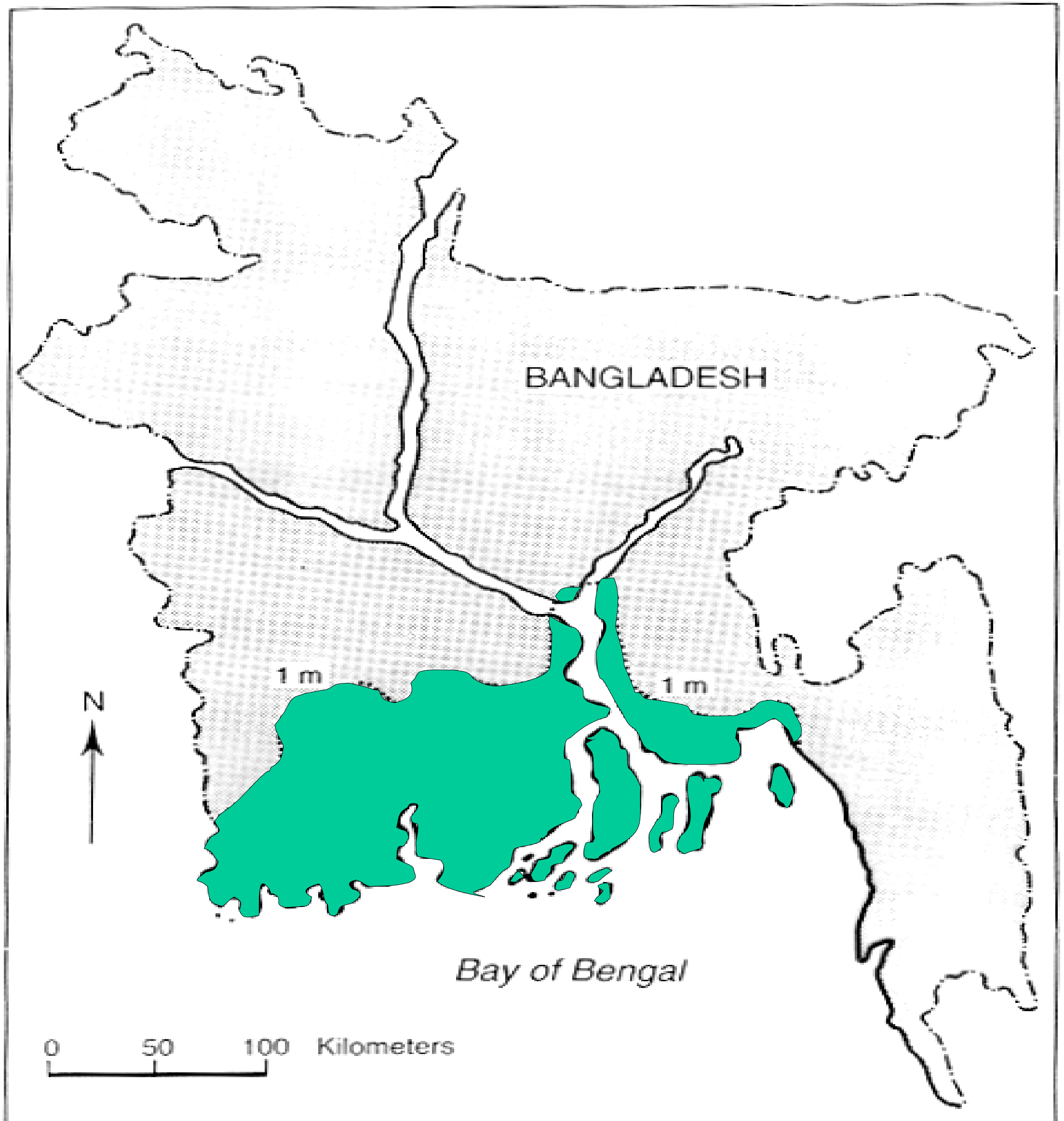
U.S. Coastal Lands at Risk from a 20-inch Sea Level Rise in 2100



Source: U.S. EPA (1989).

South Florida Shoreline Change after a 1-Meter Rise in Sea Level





Land at risk in Bangladesh due to a 1m rise in sea level (after Huq *et al.* 1995).

Possibilities for unpleasant “surprises”

- Large increases in the frequency of highly destructive storms
- Drastic shifts in ocean current systems that control regional climates (e.g., Gulf stream / Western Europe)
- Multi-meter sea-level rise, over a period of centuries, from disintegration of West-Antarctic ice sheet
- Runaway greenhouse effect from decomposition of methane clathrates, drastically increasing the severity of all expected impacts as well as the probability of big surprises.

These outcomes are all possible but none can be assigned a probability with confidence at the current state of knowledge. Our ignorance is not a reason for complacency!

Options:

What actions could reduce the magnitude of climate change & its impacts?

WHAT ARE THE OPTIONS FOR CORRECTIVE ACTION?

POSSIBLE APPROACHES

1. **REDUCE** EMISSIONS OF GREENHOUSE GASES
2. **REMOVE** GHGs FROM THE ATMOSPHERE (by growing more trees, or phytoplankton, or by technological means)
3. **COUNTERACT** THEIR CLIMATIC EFFECTS (by "geotechnical engineering")
4. **ADAPT** TO GHG-INDUCED CLIMATE CHANGE (dams, dikes, changed patterns of agriculture…)
5. **COMPENSATE** THE VICTIMS

Nos. 2-5 cannot avoid the need for No.1. Adaptation becomes costlier & less effective as degree of climate disruption grows. Emissions reductions are essential.

Determinants of CO2 emissions

$C = P \times GDP / P \times E / GDP \times C / E$

where

C = carbon content of emitted CO2, kilograms

P = population, persons

GDP / P = economic activity per person, \$/pers

E / GDP = energy intensity of economic activity, GJ/\$

C / E = carbon intensity of energy supply, kg/GJ

For example, in the year 2000, we had

6.1×10^{9} pers x \$7400/pers x 0.061 GJ/\$ x 14 kgC/GJ

= 6.4×10^{12} kgC = 6.4 billion tonnes C

What is the leverage in the different determinants of emissions?

POPULATION

Lower is better for lots of reasons: 8 billion people in 2100 is preferable by far to 12 billion. Reduced growth can be achieved by measures that are attractive in their own right (e.g., increased education, opportunity, health care for women).

GDP PER PERSON

This is not a lever that anybody wants to pull on purpose, because higher is generally accepted to be better. But we are not getting rich as fast as we think if GDP growth comes at the expense of the environmental underpinnings of well-being. Internalizing environmental costs (including those of climate change) may slow GDP growth somewhat.

Leverage (continued)

ENERGY INTENSITY OF GDP

Getting more GDP out of less energy – i.e. increasing energy efficiency – is a trend that has been underway for a long time. It could be accelerated. This opportunity offers the largest, cheapest, fastest leverage on carbon emissions.

CARBON INTENSITY OF ENERGY SUPPY

This has been falling, but more slowly than energy intensity of GDP. Reducing it entails changing the mix of fossil & non-fossil energy sources and/or the characteristics of fossil-fuel technologies. This will need to be done, because the combined leverage in the other factors will not do all that is required.

Options for reducing E-intensity, C-intensity

TECHNICAL POSSIBILITIES

- increased efficiency of energy end-use in buildings, transportation, & industry
- transition to a lower-energy-intensity mix of economic activities
- increased efficiency of conversion of fossil fuels to end-use energy forms
- switching from coal & oil to natural gas
- capturing & sequestering carbon when fossil fuels are transformed or used
- increased deployment of renewable & nuclear energy options

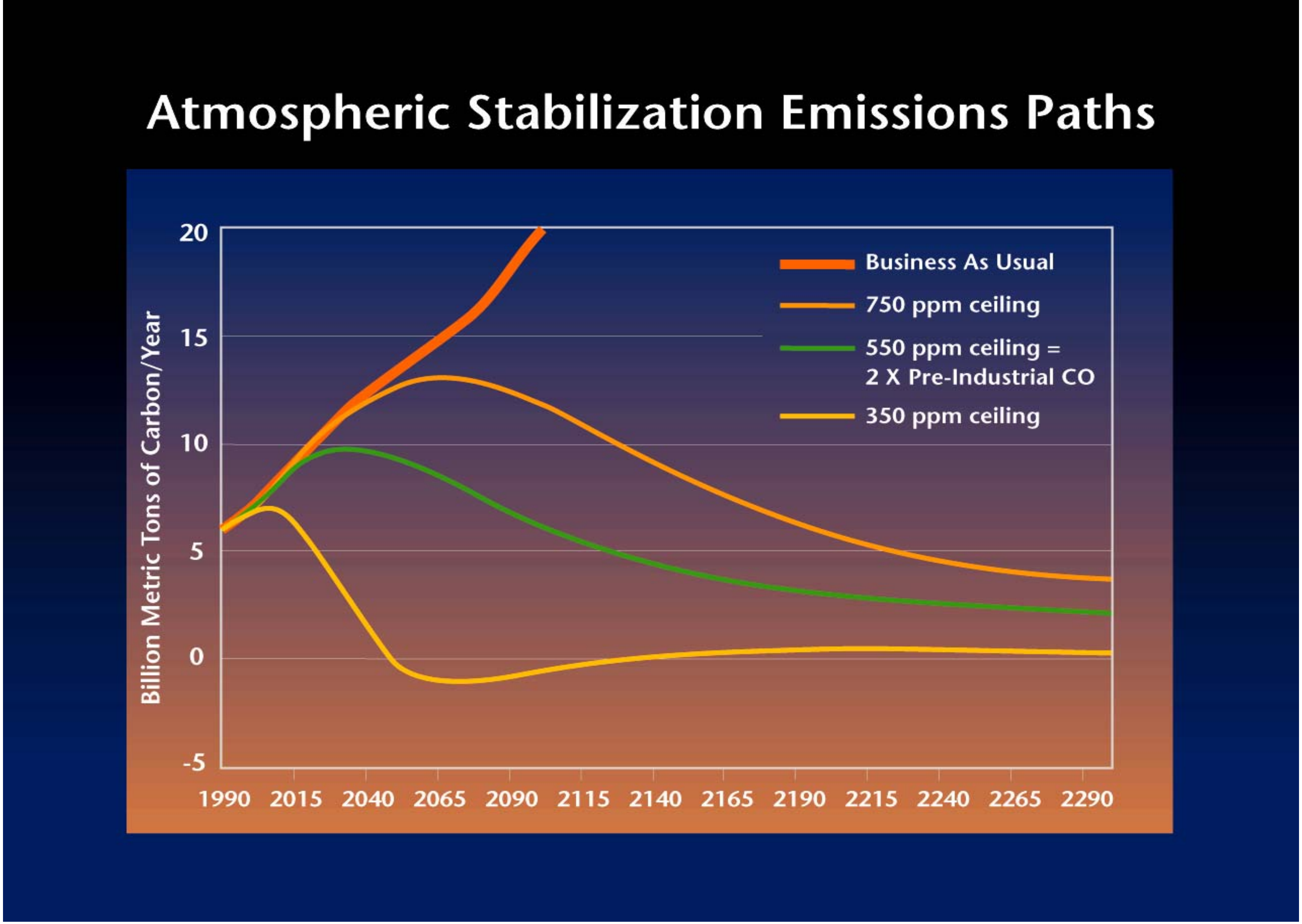
POLICY MEASURES

- increased incentives & diminished barriers for low-carbon choices from existing energy-technology mix
- research, development, & demonstration to improve characteristics of low-carbon options

Scenarios

How much deflection from BAU is required?

How much reduction in climate-change drivers will be need to achieve this?



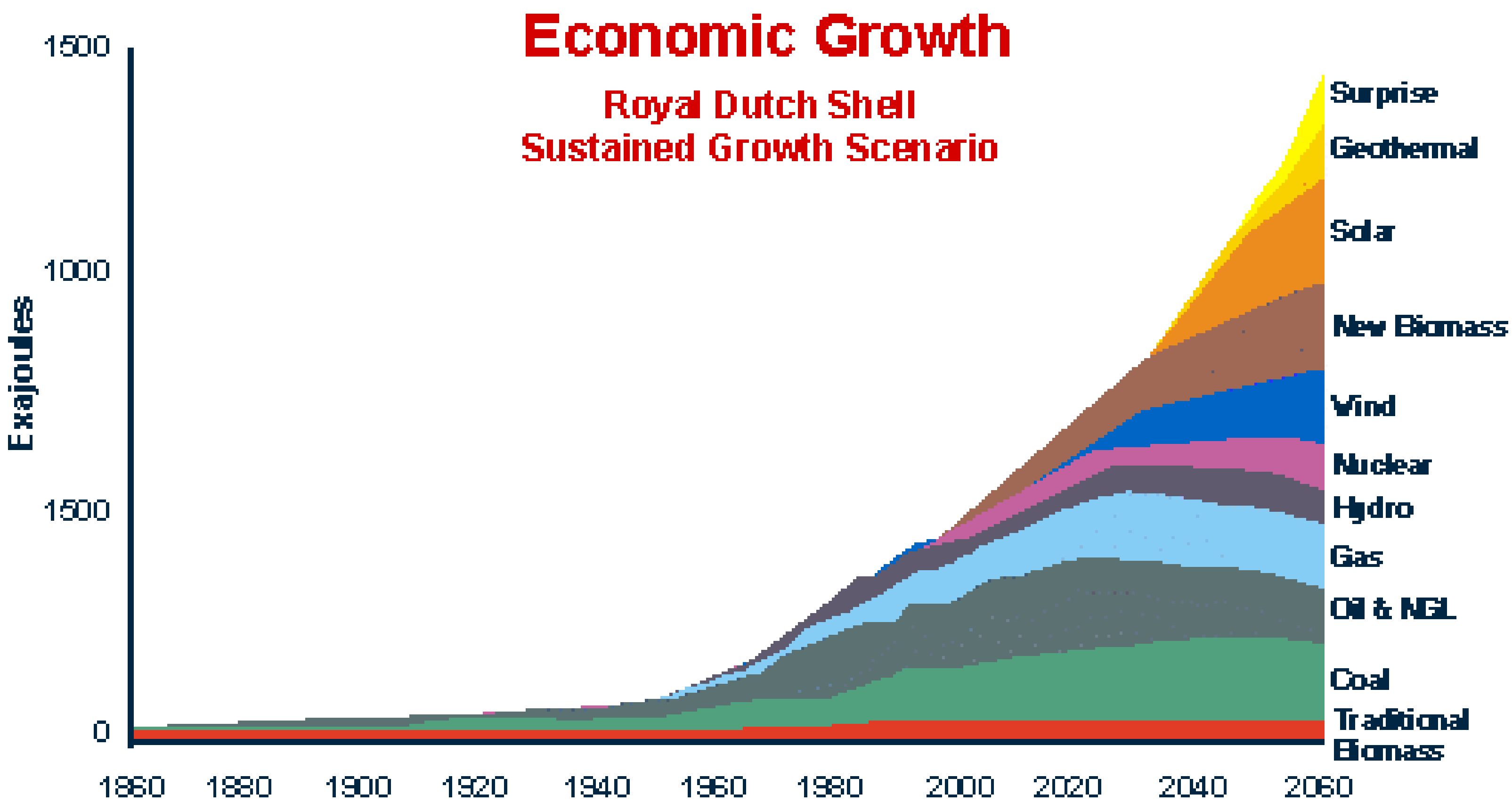
Stabilizing at 2xCO_2 (green curve) is by no means "safe", but achieving this much will be very difficult and more might not be possible.

Increase in C-free energy needed to stabilize atmospheric CO_2 below 550 ppm_v

To avoid a doubling of preindustrial CO_2, conventional fossil primary energy must not exceed 500 EJ in 2050 and 350 EJ in 2100. Starting from 350 EJ of conventional fossil fuel in 2000 and BAU rates of change in world GDP and energy intensity, it follows that EJ/yr of C-free energy needed in 2050 and 2100, compared to 100 EJ/yr actual in 2000, are…

	2000	2050	2100
	-------	------	------
C-free energy under BAU	100	600	1500
...if E/GDP falls 1.5%/yr	100	350	800
...if E/GCP falls 2.0%/yr	100	180	350

Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy



Source: Shell

Here’s a Shell Oil scenario for the role non-fossil energy could play in a high-economic-growth energy future. 2nd point on y-axis should be 500 EJ.

What should be done?

- In the USA, impose an escalating carbon tax or, alternatively, a declining emissions cap implemented through tradable permits, to promote (i) low- and no-carbon choices from the current energy-technology menu and (ii) increased private-sector innovation to improve the menu over time.
- Increase US government investments in low- and no-carbon energy-technology innovation (supply-side & demand side) and in international cooperation on energy-technology innovation by 5-10x.
- Sharply increase US efforts (and US support for international efforts) on adaptation to climate-change.
- In the United Nations, devise an adequate, affordable, and equitable global framework for reducing climate-change risks (because we are all in this together).

An "afterword" about controversy & uncertainty

WHAT ABOUT THE CLIMATE-CHANGE "SKEPTICS"?

- Among those with the training and knowledge to penetrate the relevant scientific literatures, the debate about whether global climate is now being changed by human-produced greenhouse-gases is essentially over. Few of the climate-change "skeptics" who appear in the op-ed pages of *The Washington Times* and *The Wall Street Journal* have any scientific credibility at all.
- The most distinguished scientist from the camp of the more-or-less skeptical – meteorology professor Richard Lindzen of MIT – signed without dissent the 2001 National Academy of Sciences report (requested by President Bush), which affirmed the soundness of the Third Assessment of the Intergovernmental Panel on Climate Change (IPCC) and which declared in its opening sentence that "Greenhouse gases are accumulating in Earth's atmosphere as a result of human activities, causing surface air temperatures and subsurface ocean temperatures to rise."

Afterword on controversy & uncertainty (continued)

UNCERTAINTIES REMAIN

Significant uncertainties remain about the climate-change issue, and debates about them persist. But the argument is no longer about whether climate is changing or whether human GHG emissions are responsible, but about…

- the precise magnitude of the climatic changes to be expected by 2030, 2050, or 2100 if civilization does not change course;
- the details of the character, geographic distribution, and timing of the damages to human well-being to be expected, and the probability that much bigger than “expected” damages will result from pushing the climate over a threshold or “tipping point”;
- the feasibility, costs, and leverage of various potential remedies; and
- the appropriate character and timing of national and international policies to reduce the risks from anthropogenic disruption of global climate.

Afterword on controversy & uncertainty (continued)

UNCERTAINTIES ARE TWO-SIDED

- Yes, it could be that the climate changes occurring under a continuation of business as usual would be less disruptive, and the adverse impacts on human well-being less severe, than the "best estimate" portrayals presented here (which are based on the work of the Intergovernmental Panel on Climate Change [IPCC] & other mainstream scientific groups).
- But it could equally well turn out that the climate changes under business as usual are <u>more</u> disruptive, and the impacts on human well-being <u>more</u> severe, than the current "best estimates" suggest.
- The assertion of the "skeptics" that the IPCC consensus scientific view has been biased by political pressures toward overstating the problem is nonsense. The principal political pressures on the IPCC have been in the other direction.

Afterword on controversy & uncertainty (continued)

BURDEN OF PROOF

- The "skeptics" routinely brandish some single contrary piece of evidence or analysis, often a newly reported one that has not yet been subjected to the scrutiny of the scientific community, and declare that this new result invalidates the mainstream view.
- That's not how science works. Contrary results appear regularly in all scientific fields. When a strong preponderance of evidence points the other way (as in the case of climate-change science), isolated apparent contradictions are given due scrutiny but not, initially, very much weight, because it's <u>far more likely</u> that the "contradiction" will turn out to be explainable as a mistake, or otherwise consistent with the preponderance of evidence, than that the preponderance of evidence will turn out to have been wrong.

Afterword on controversy & uncertainty (concluded)

PRUDENCE

- All science is contingent. It is always possible that persuasive new evidence and analysis will come to light that will change the mainstream view.
- But the greater the consistency and coherence of the existing body of evidence and analysis, the lower the likelihood that the principal conclusions derived from it will be overturned. The consistency and coherence of the evidence and analysis supporting the mainstream view of climate-change risks presented here are substantial.
- Supposedly prudent decision-makers, on whose decisions the preservation and expansion of their own and the public's well-being depends, are irresponsibly gambling against large odds if they bet that the mainstream position is wrong.
- Even a 50% chance that the mainstream is right would justify far more risk-reduction effort than is underway today.

For additional detail, please see…

Intergovernmental Panel on Climate Change, *Climate Change 2001: Synthesis Report – Summary for Policymakers*, IPCC, 2001

http://www.ipcc.ch/pub/un/syreng/spm.pdf

National Academy of Sciences, *Climate Change Science: An Analysis of Some Key Questions*, National Academy Press, 2001

http://books.nap.edu/html/climatechange/climatechange.pdf

John P. Holdren, "The Energy-Climate Challenge", *Environment,* vol. 43, no. 5, June 2001

http://www.aspeninstitute.org/aspeninstitute/files/Img/pdf/holdren.pdf

U.S. Global Change Research Program, *Climate Change Impacts on the United States*, USGCRP, 2001

http://www.usgcrp.gov/usgcrp/Library/nationalassessment/foundation.htm

John P. Holdren, "US Climate Policy Post-Kyoto", *Aspen Institute Congressional Program*, Vol. 18, No. 3, 2003

bcsia.ksg.harvard.edu/BCSIA_content/documents/ClimatePostKyoto.pdf