An Overview of Climate Change

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The Ecosystems Center
Woods Hole, MA

Climate Change and Cape Cod
04 December, 2007

OUTLINE

Background to climate change

- energy use and the global carbon cycle
- emissions, CO2 and temperature scenarios

Scientific Assessment of climate change and projections

- the Scientific Process & the IPCC Process
- has the earth warmed? how warm will it get?
- is the warming natural? why is that important?
- what will be the impacts? New England examples
- what can we do about it?

The Global Warming Debate

- elements of debate: positive and normative issues
- why is there still a debate?
- dealing with uncertainty

"The most original . . . history book I have read this year."
—Eric Hobsbawm

An Environmental History of the Twentieth-Century World | J. R. McNeill

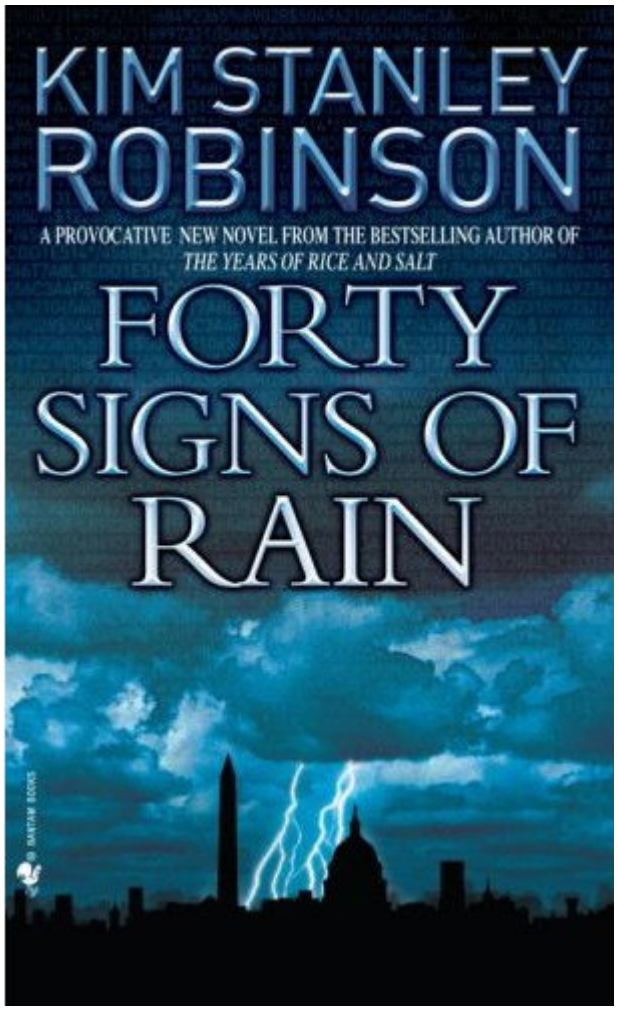
something new under the sun

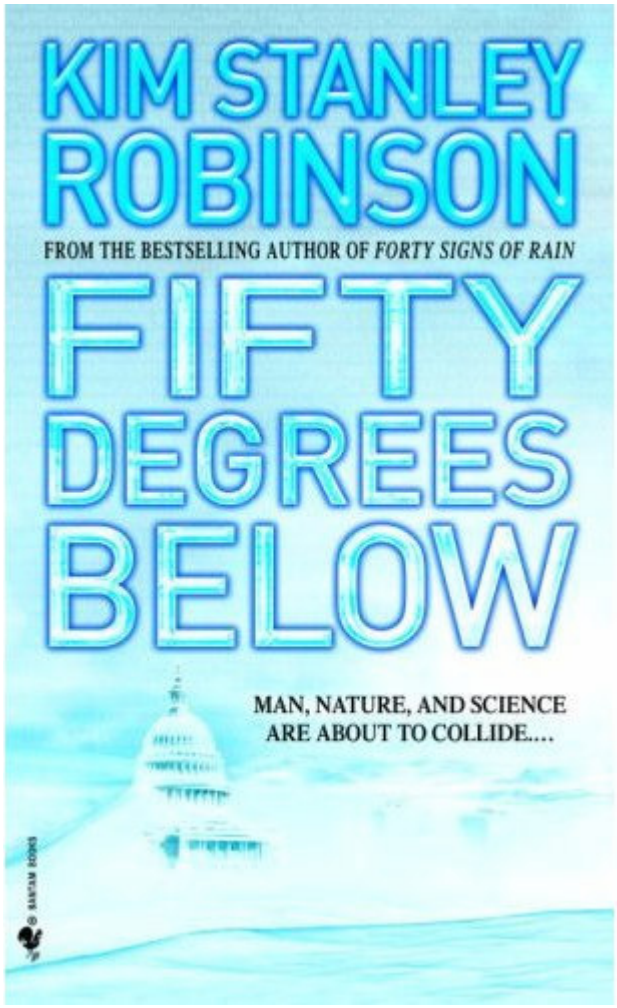
ANDREW E. DESSLER
EDWARD A. PARSON

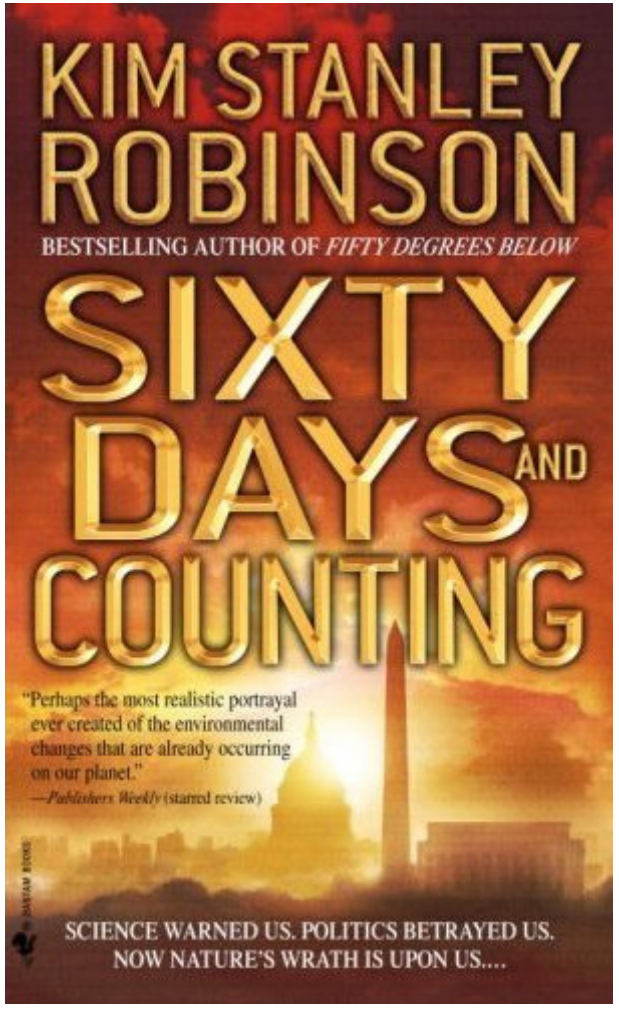
The Science and Politics of GLOBAL CLIMATE CHANGE

A Guide to the Debate

CAMBRIDGE







These are great books: scientifically informed, interesting and gripping reads about climate change and what to do about it (FICTION).

Robinson is an acclaimed science fiction author (Mars Trilogy and others)

20th century: a period of growing human dominance

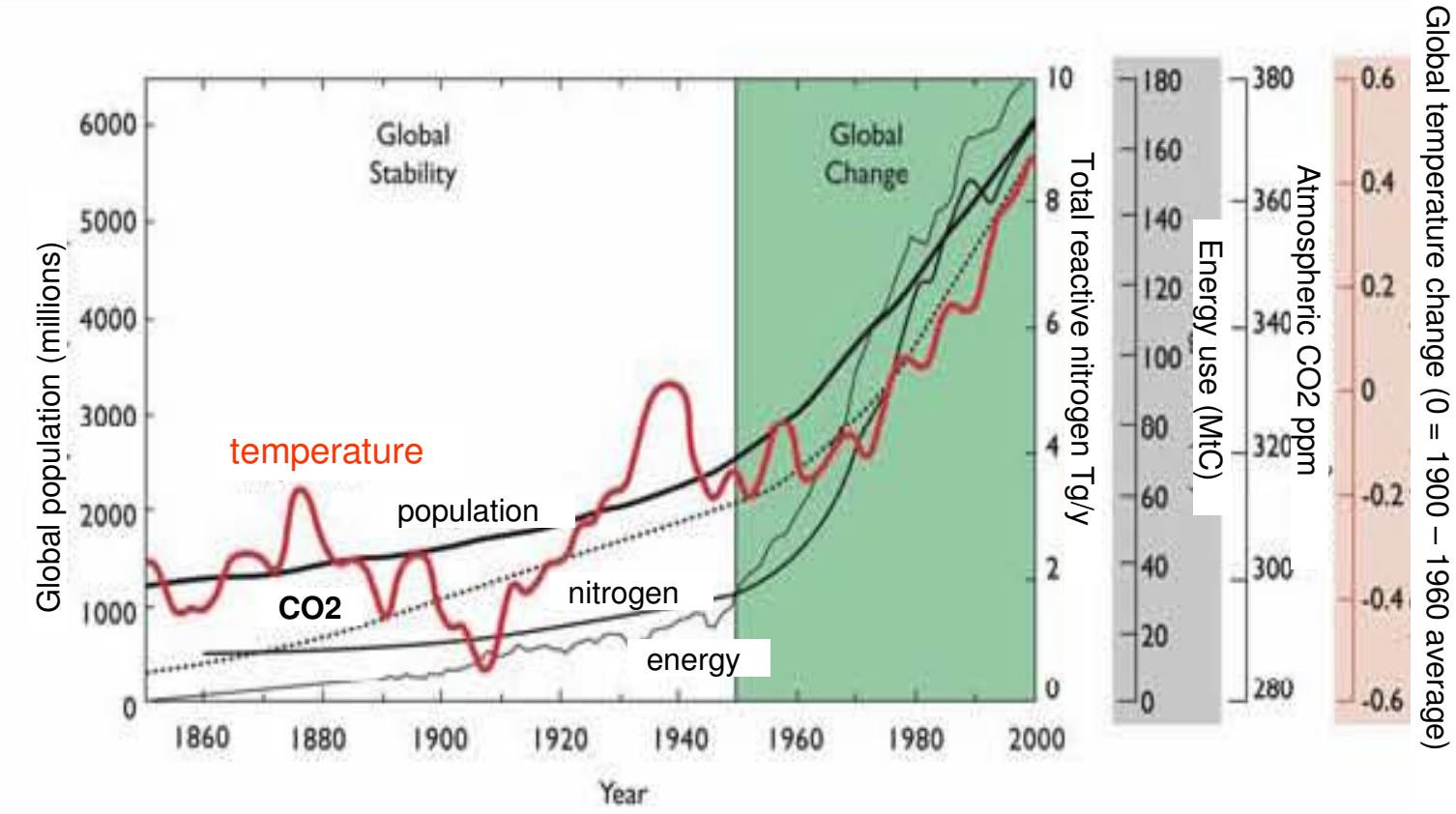
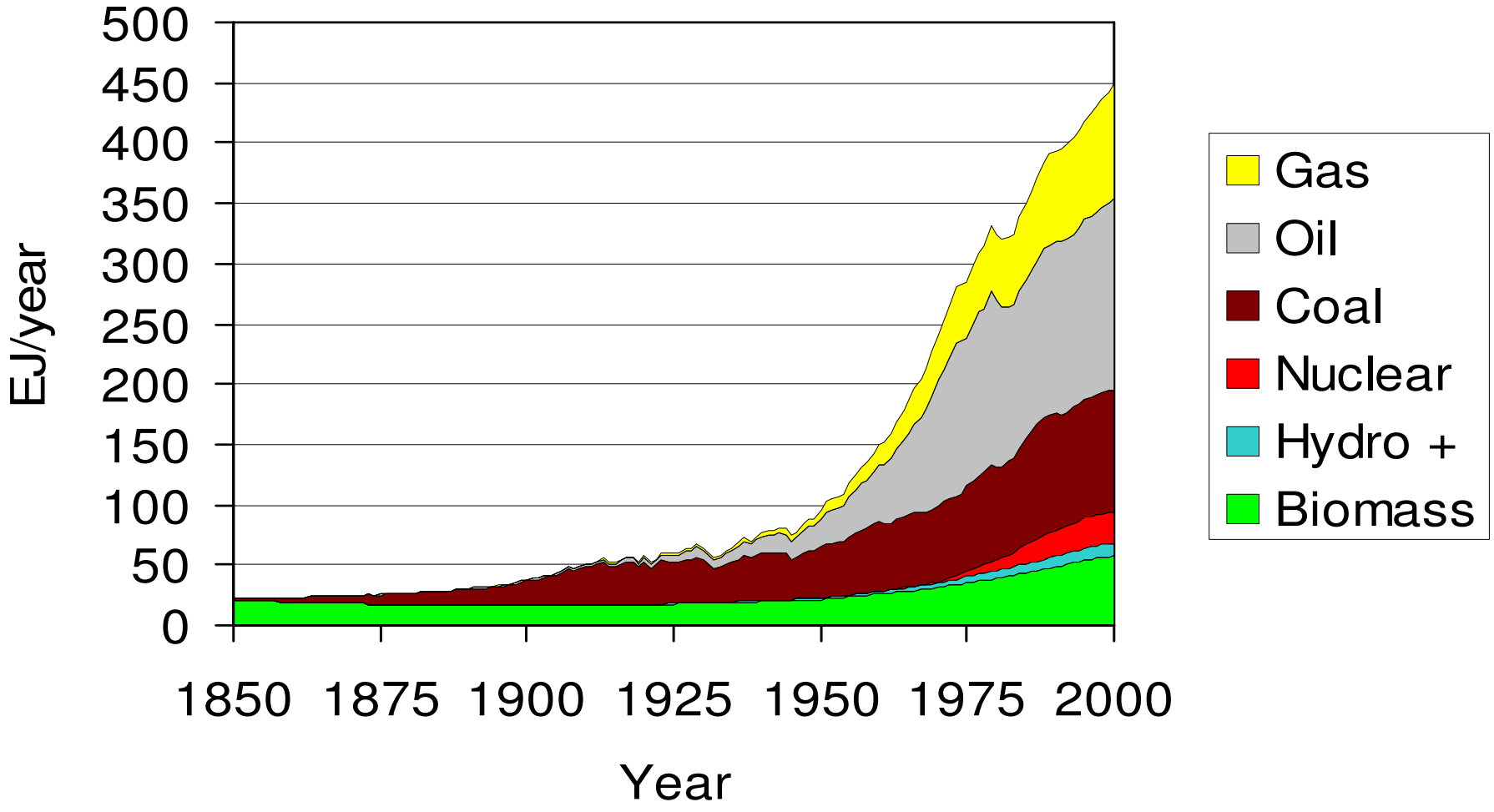


Figure 3.1. Rates of change in major social and ecological drivers: human population, atmospheric CO_2, reactive nitrogen, energy use, and temperature.

US LTER Network

World Energy 1850-2000

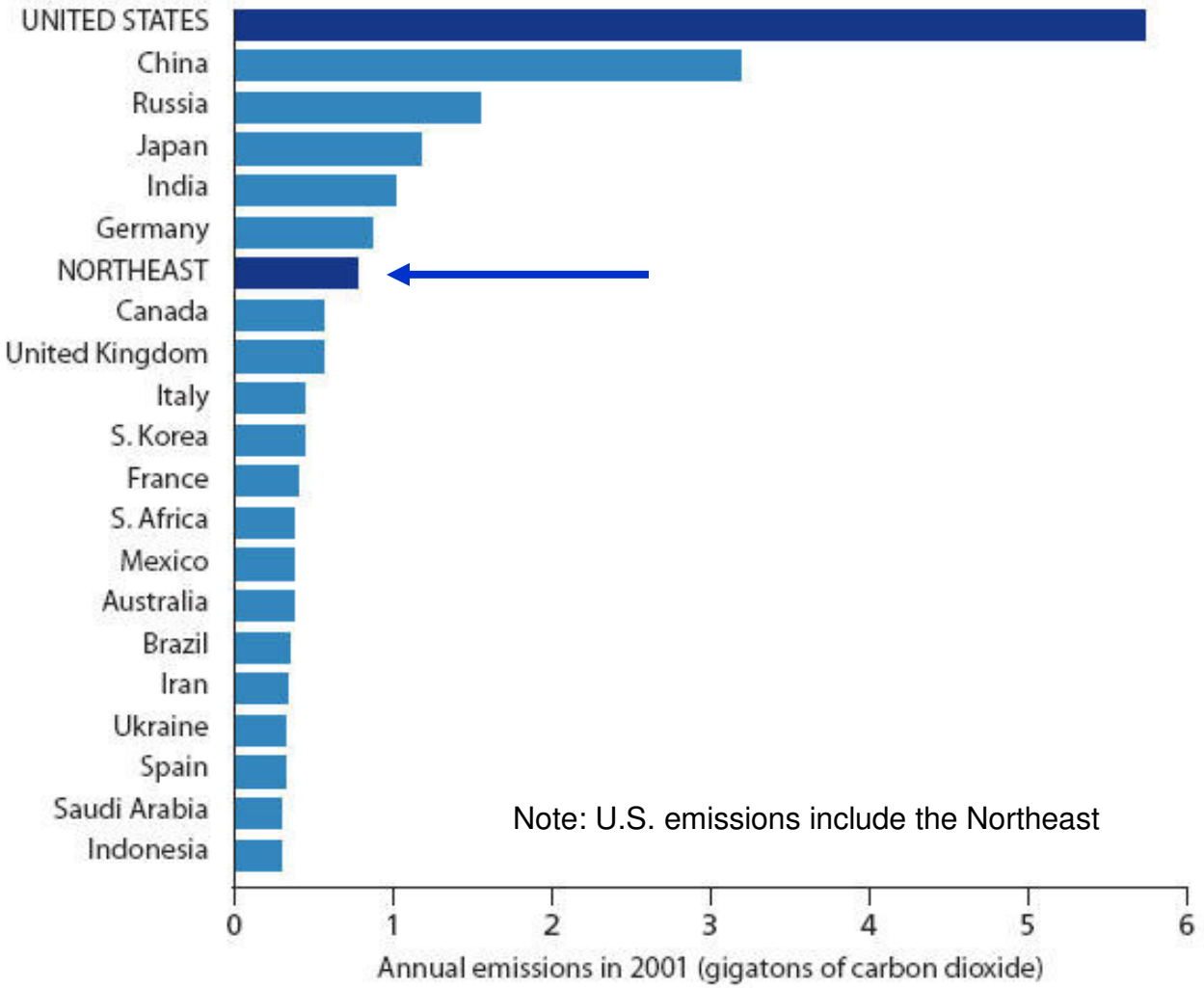


World Energy Use Projected to be between 1000 and 1500 EJ/yr by 2100

EJ = 10^{18} joules

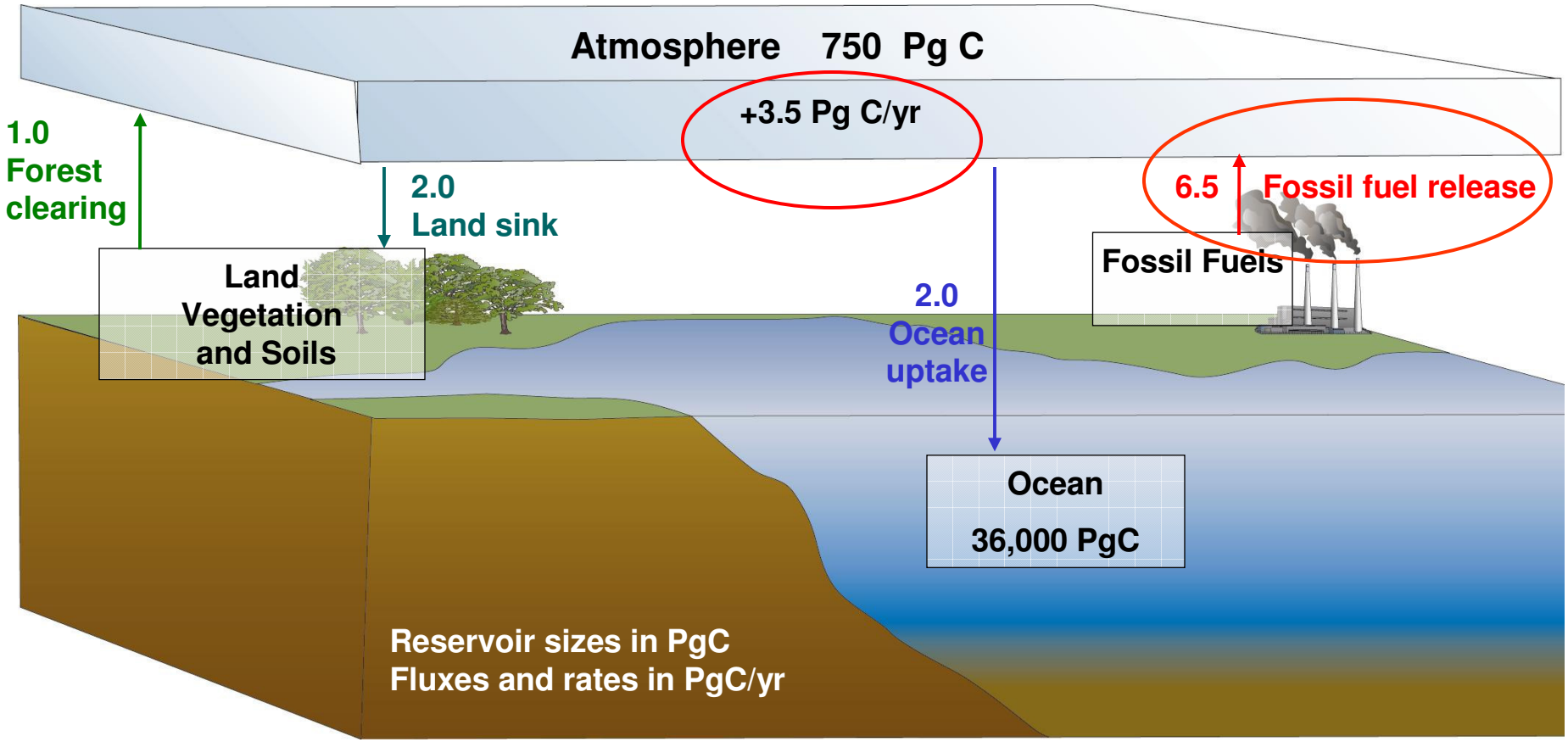
Energy-related CO2 emissions in the Northeast USA

compared with the major carbon-emitting nations of the world



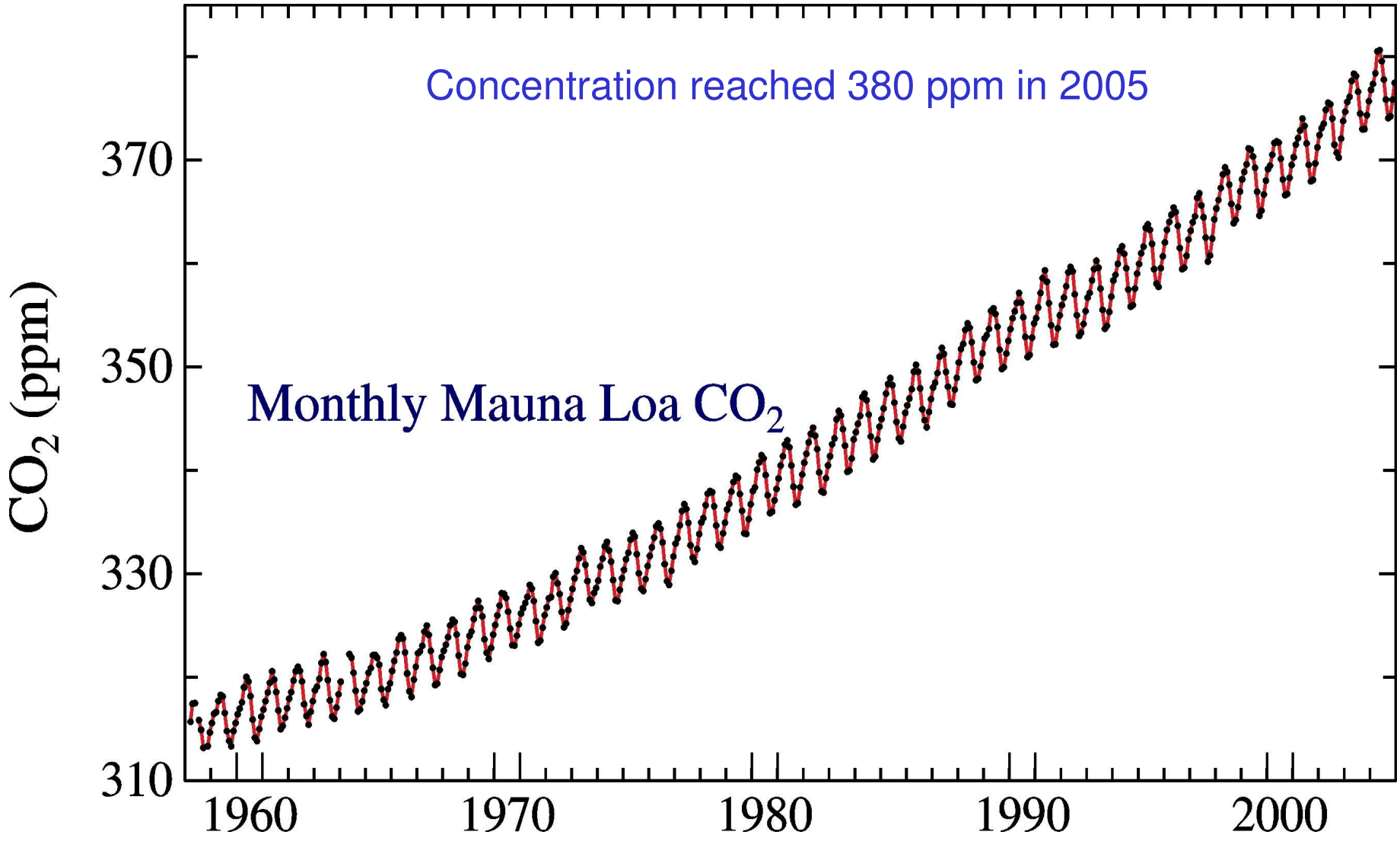
Source: Emissions data for 2001 from Energy Information Administration (EIA), *International energy annual* (2003), and EIA, *Emissions of greenhouse gases in the United States* (2004).

Carbon Fluxes Among Major Pools



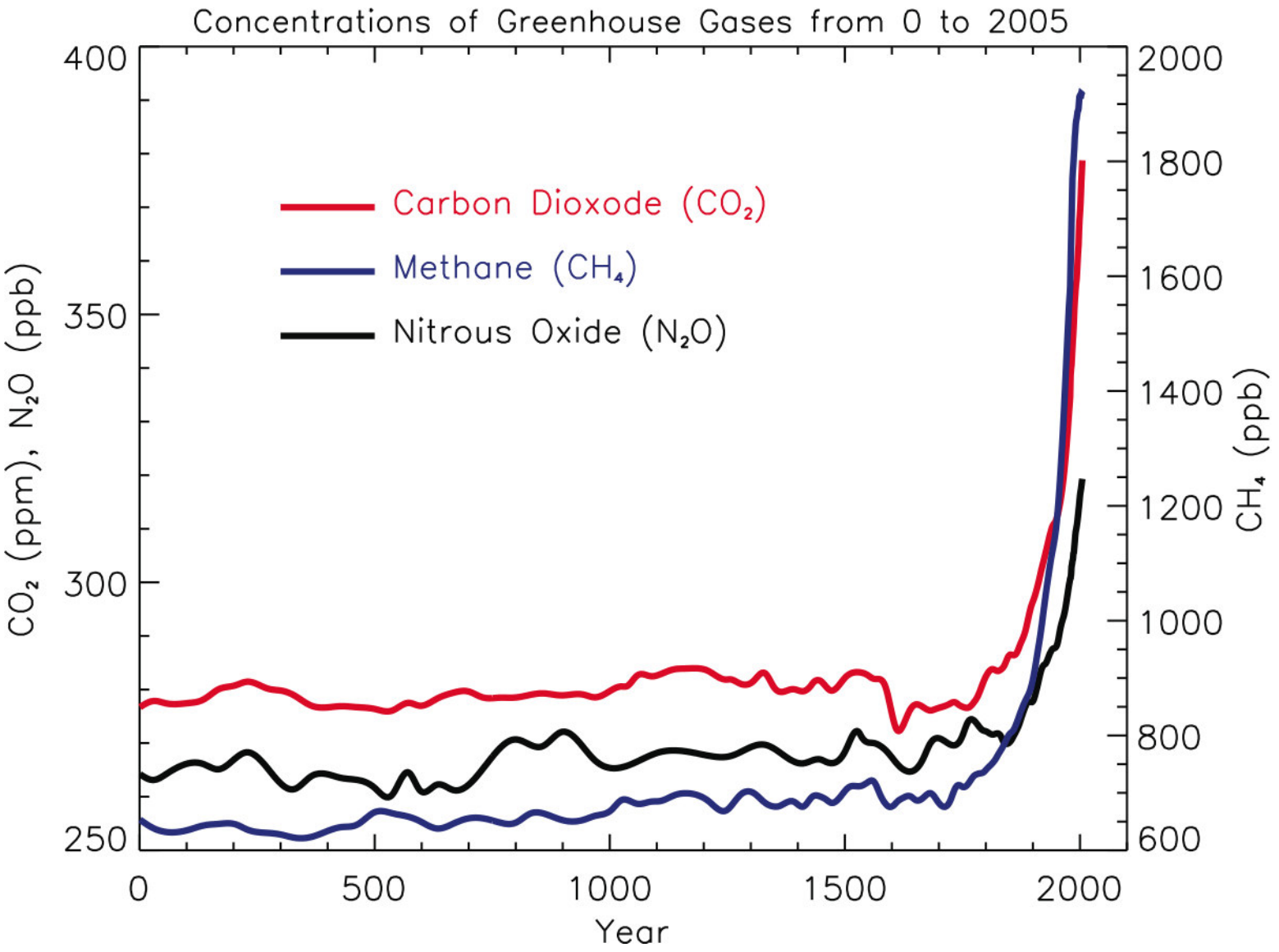
Early 21st Century

Direct measurements of CO_2 show continued rise



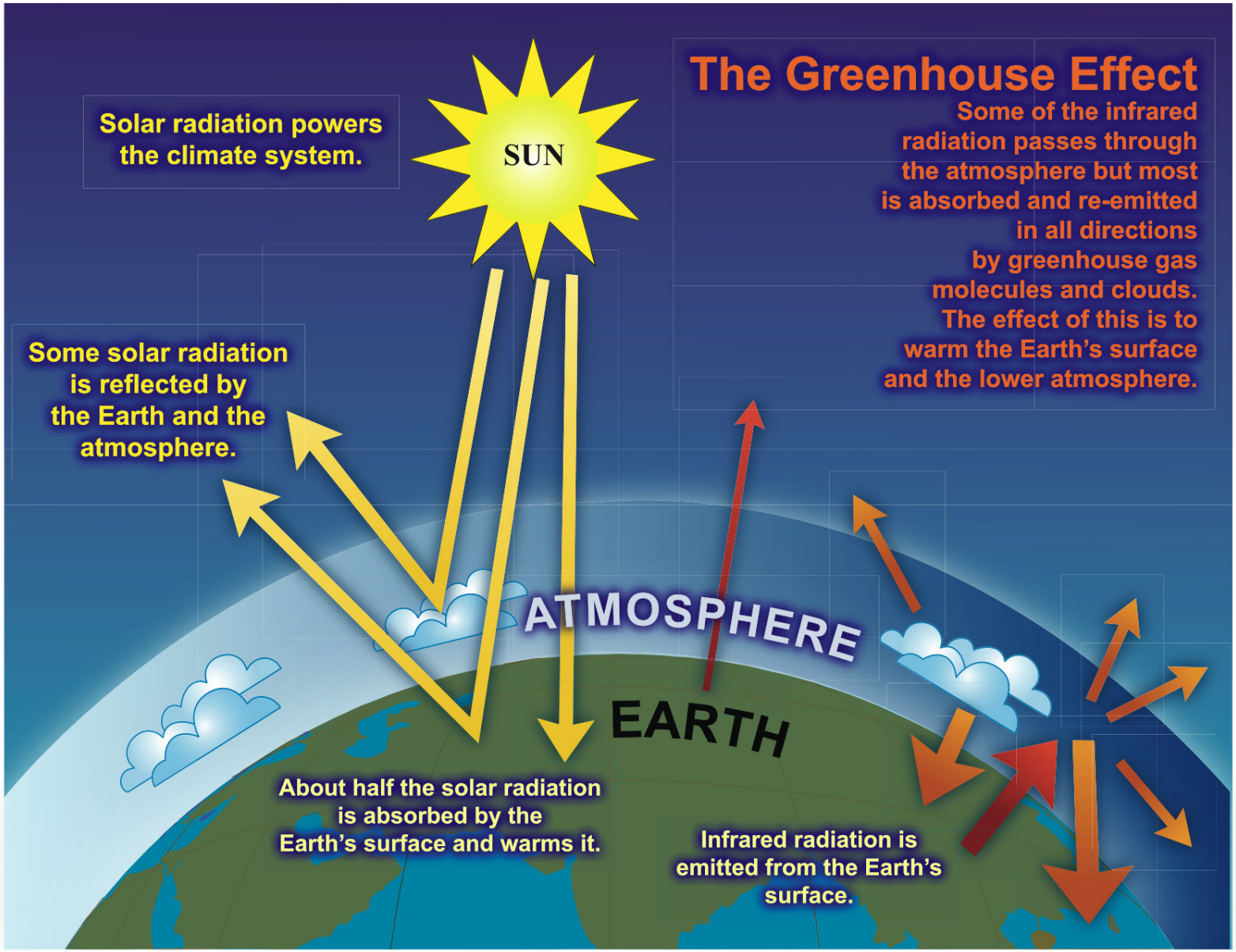
Atmospheric CO_2 measured at Mauna Loa, Hawaii.

Source: NOAA Climate Monitoring and Diagnostic Laboratory


Concentrations of Greenhouse Gases from 0 to 2005
Carbon Dioxode (CO_2)
Methane (CH_4)
Nitrous Oxide (N_2O)
CO_2 (ppm), N_2O (ppb)
CH_4 (ppb)
400
350
300
250
2000
1800
1600
1400
1200
1000
800
600
0
500
1000
1500
2000
Year

IPCC

Greenhouse effect: like wrapping yourself in a blanket to stay warm



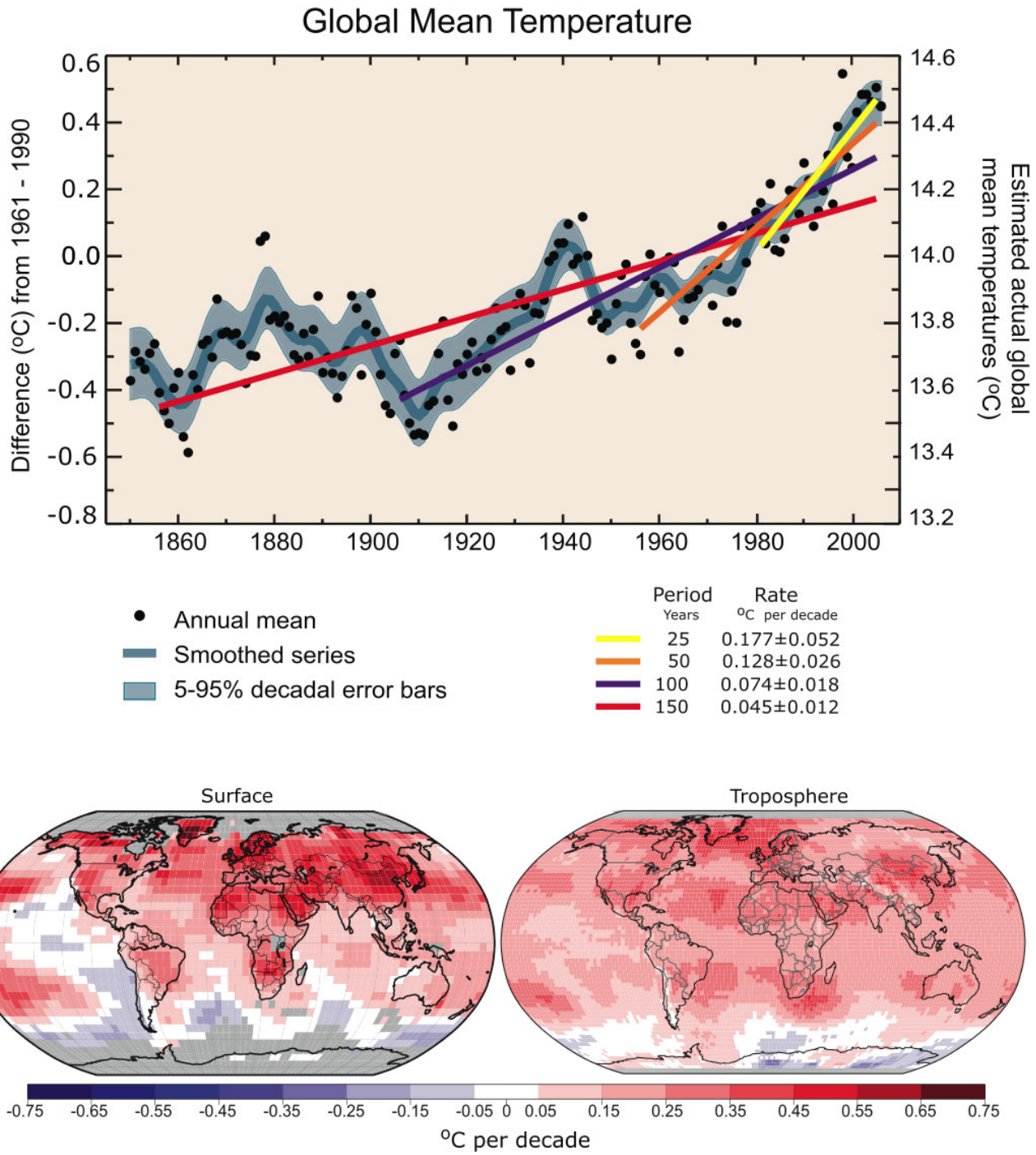
IPCC

Observed surface temperature record:

Warmer now than last 1000 years

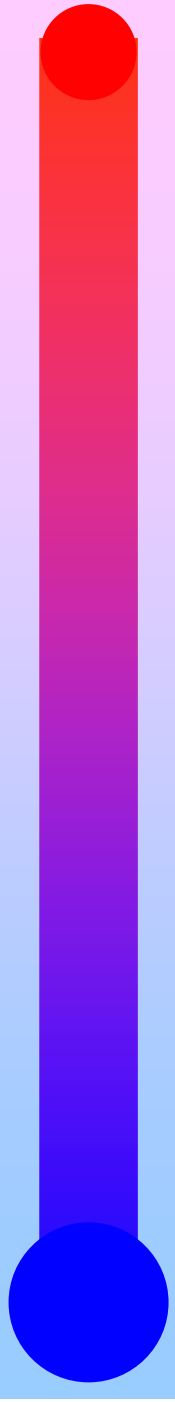
Warming trends are accelerating

Satellite troposphere and surface met records agree



IPCC

A global temperature scale:

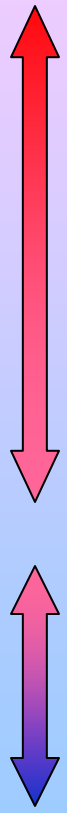


2100: 16-18 C

2005: 14 C

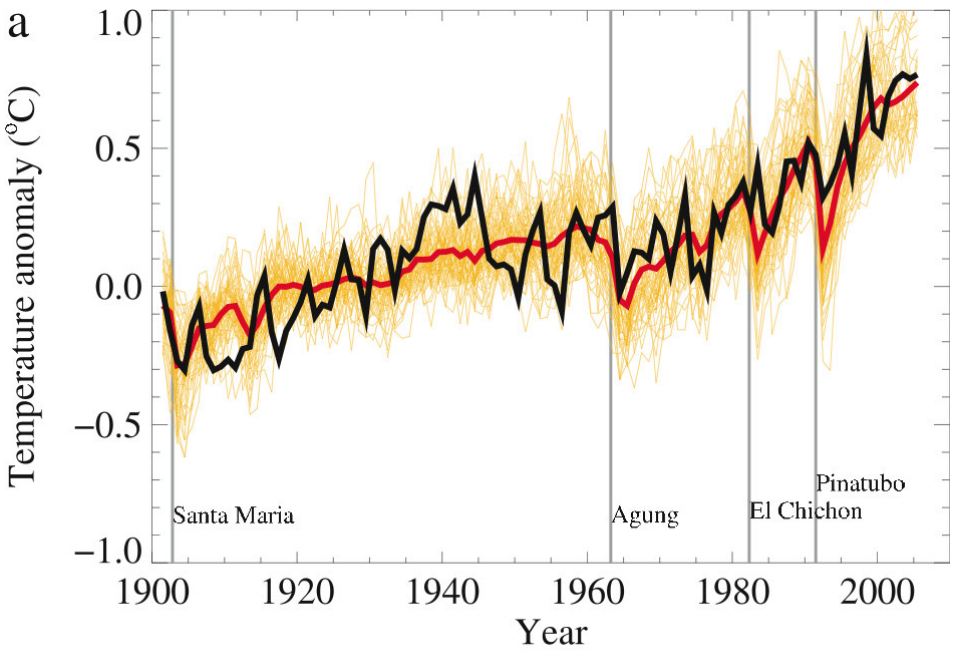
1000 – 1800: 12 C

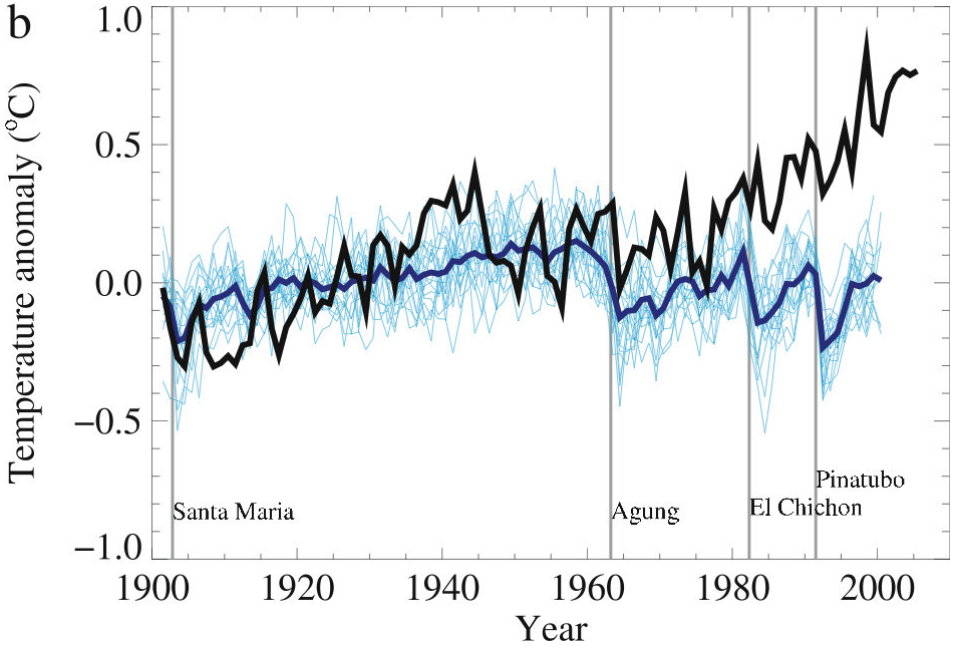
Last glacial 10,000 yrs BP: 6 C



“enhanced Greenhouse” difference = 2-6 C

“natural” glacial-interglacial difference = 6 C





Attribution: is the warming natural or caused by human activity?

IPCC concludes ""Most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations."

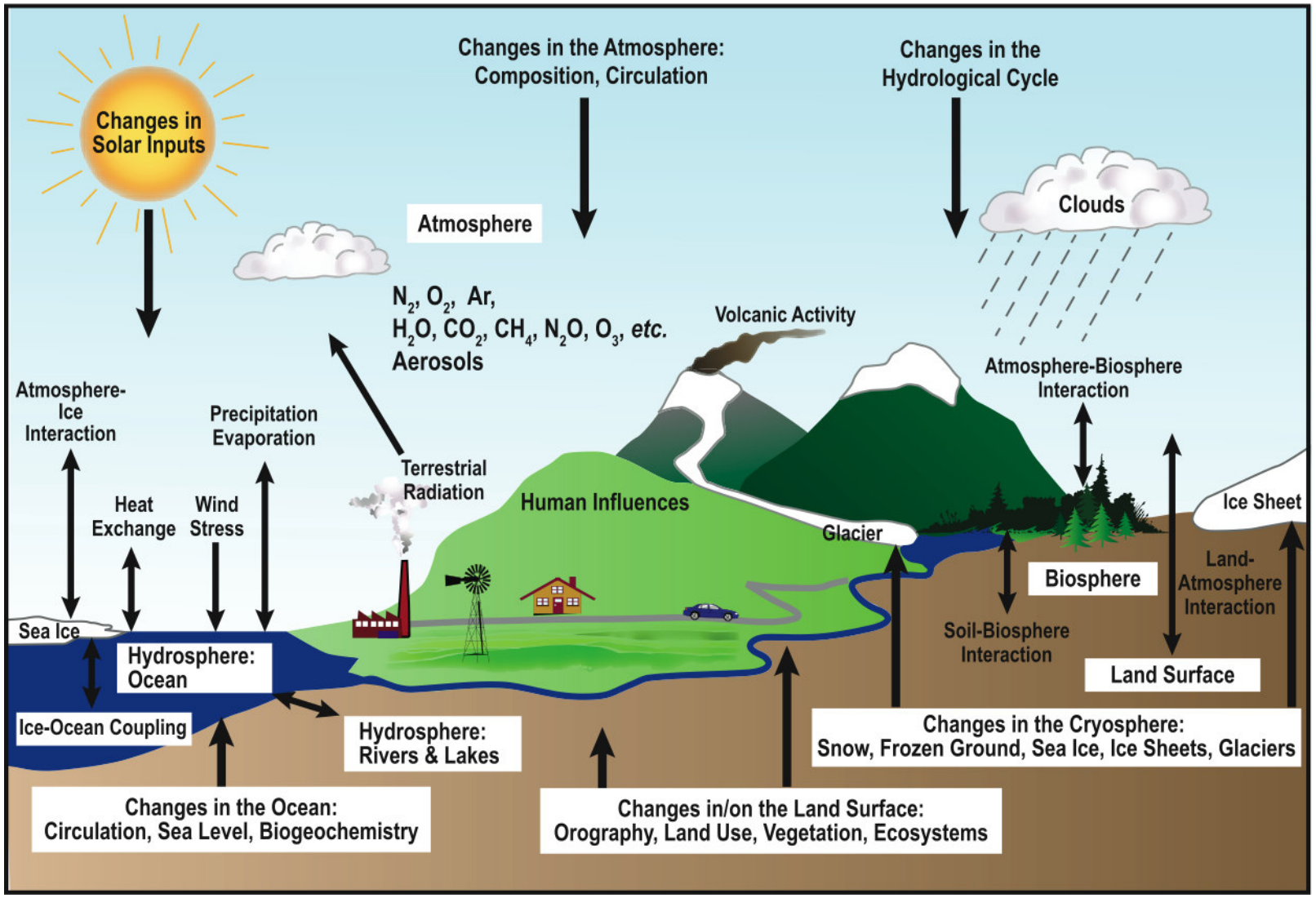
Top panel: observed temperatures and model simulation including anthropogenic forcings (greenhouse gases, aerosols)

Bottom panel: observed temperatures and model simulation including only natural forcings (volcanoes, solar input)

(0 anomaly = 1961-1990 average)

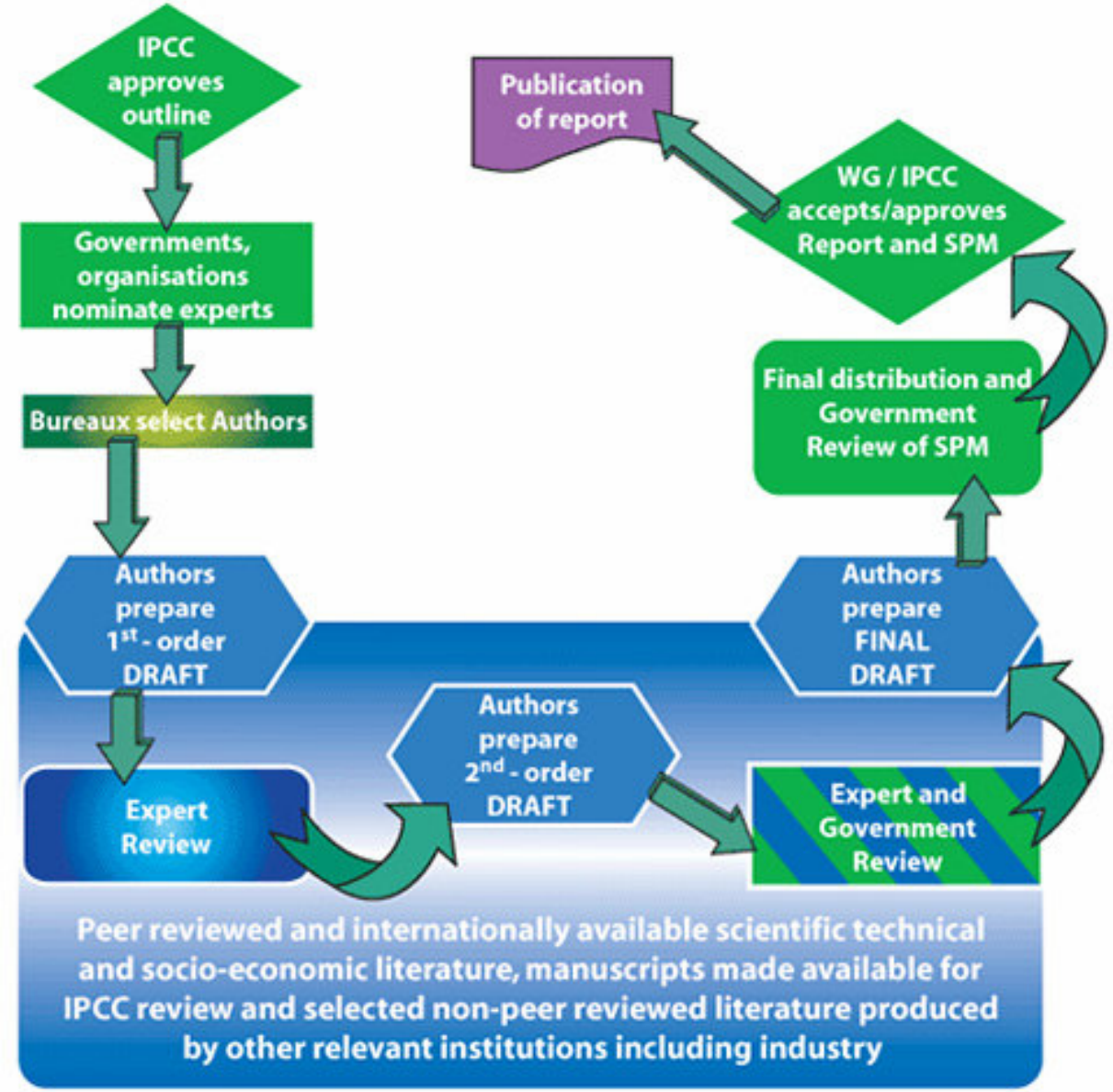
IPCC

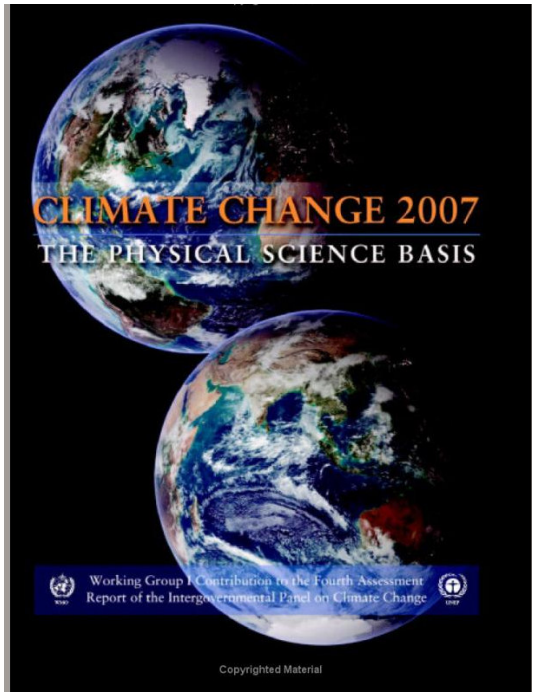
Processes included in current climate models:



IPCC

The IPCC Process: joint control by scientific community and world's governments produced the strongest scientific consensus in history





http://www.ipcc.ch/

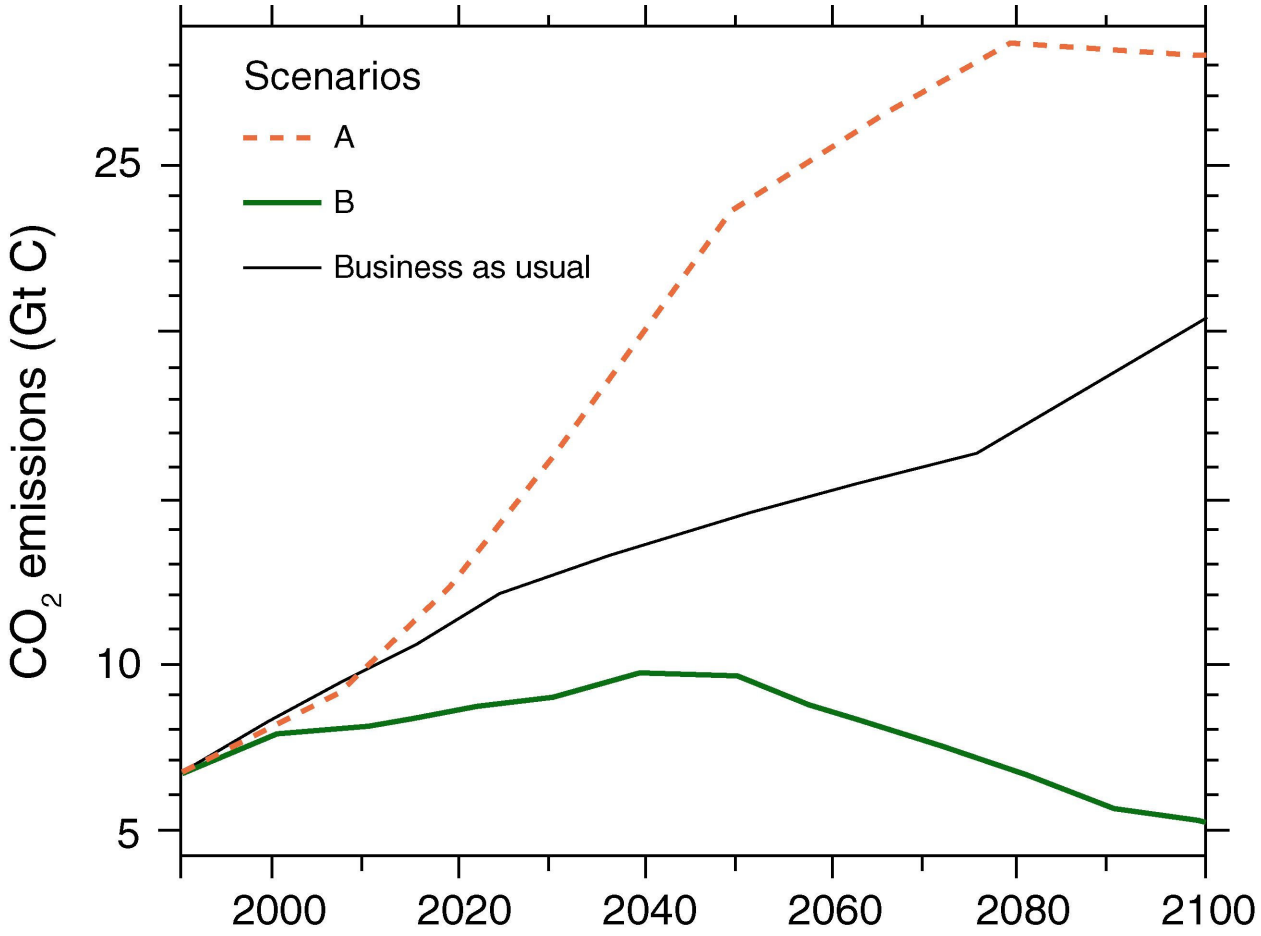
Emissions Scenarios

- **A** – rapid economic growth - fossil-fuel intensive, integrated global economy

- Business as usual (BAU) – moderate economic growth with gradual introduction of new technologies

- **B** – emphasis on solutions to economic, social and environmental problems - global solutions, rapid energy technology introductions including biofuels at large scales

IPCC Projected CO2 Emission Scenarios



Projection depends on:

Population

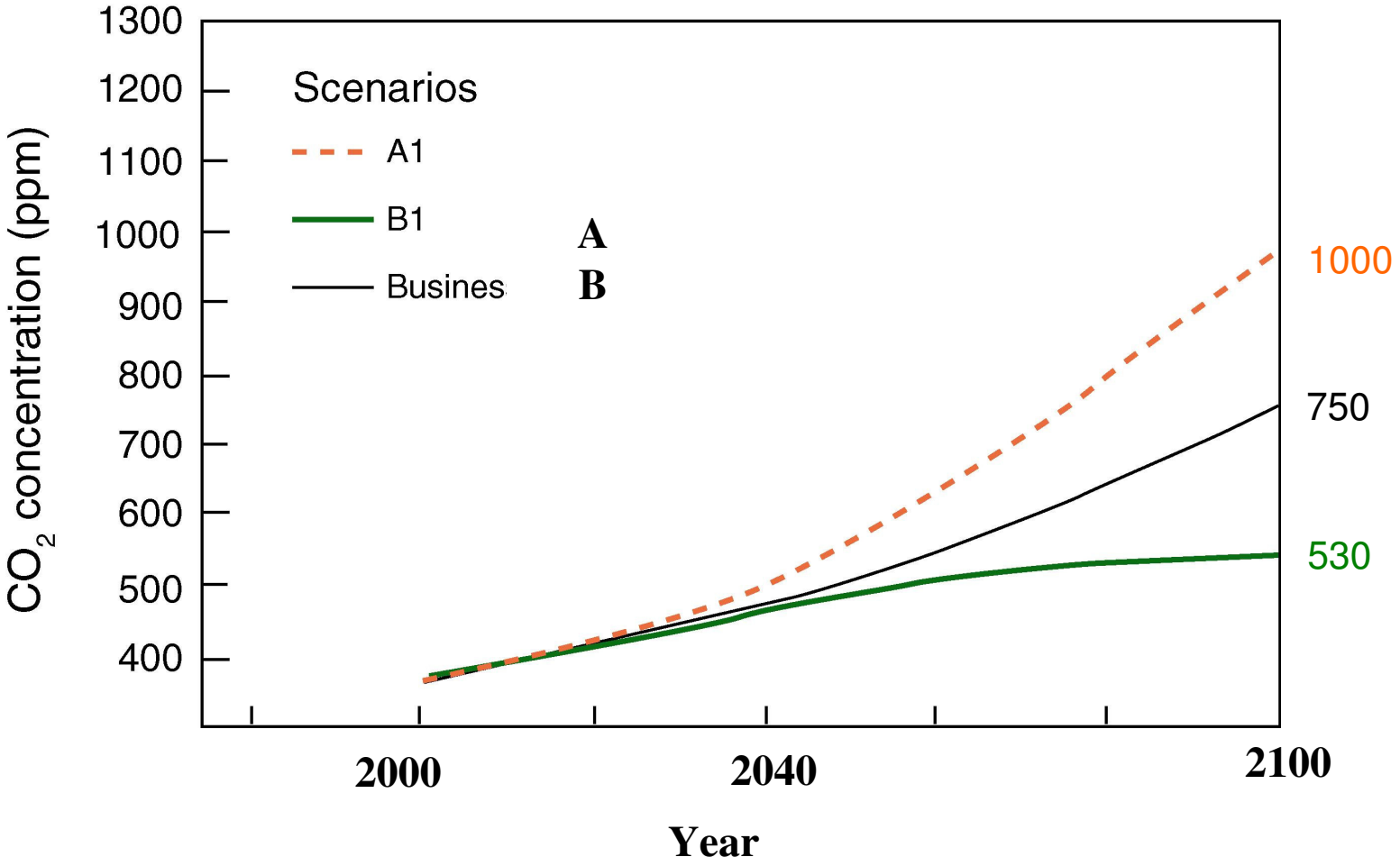
Economic growth

Technology Development

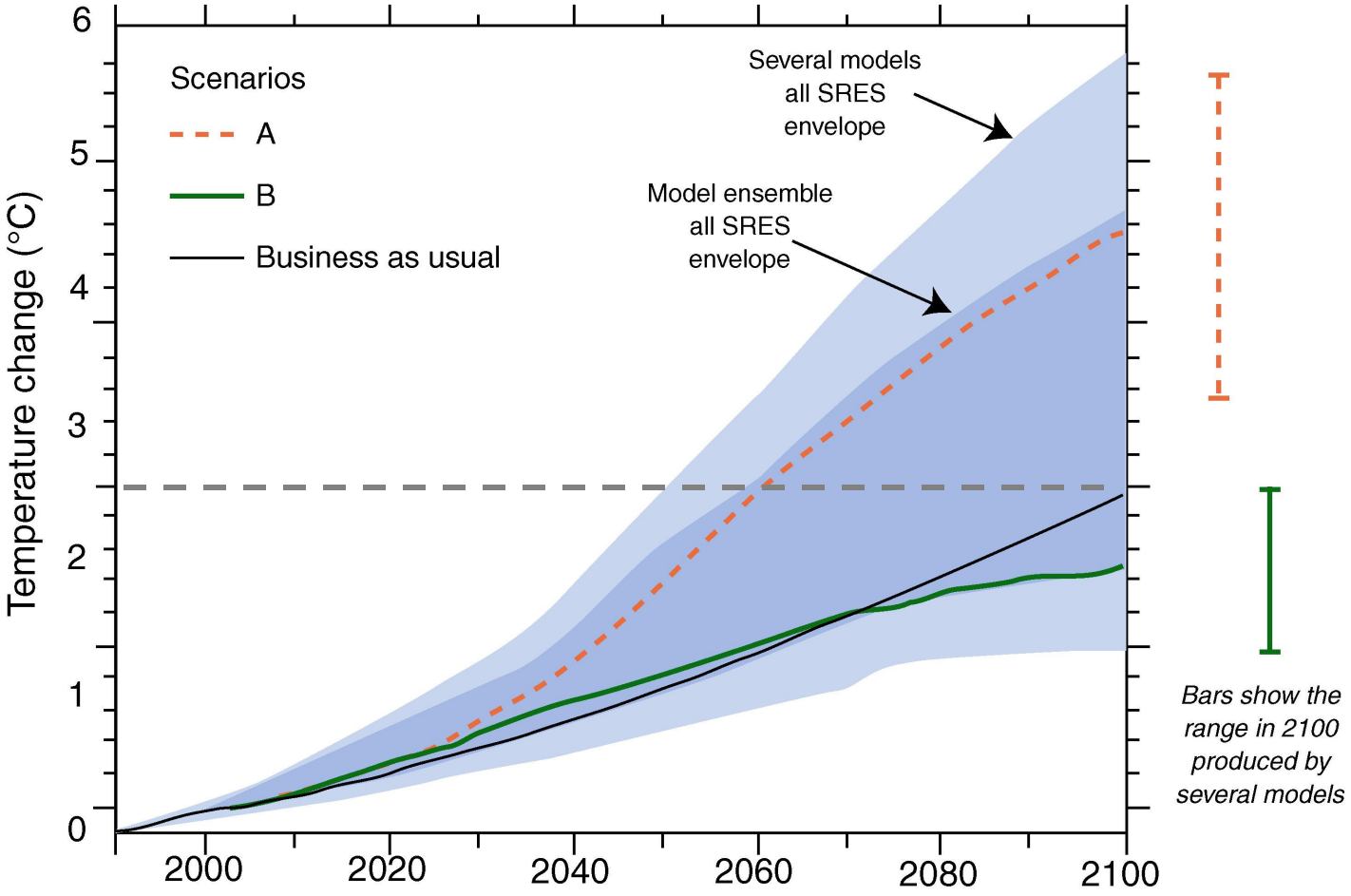
*** Human CHOICES***

Only the “green” scenario avoids “dangerous” warming

IPCC Projected Atmospheric CO2 Scenarios



IPCC Projected Global Temperature Scenarios



Business as usual and "Green" scenarios diverge sharply after 60 years

1-2°C uncertainty in estimates

The lowest and highest estimates are equally likely

+2°C: threshold for "dangerous" climate change

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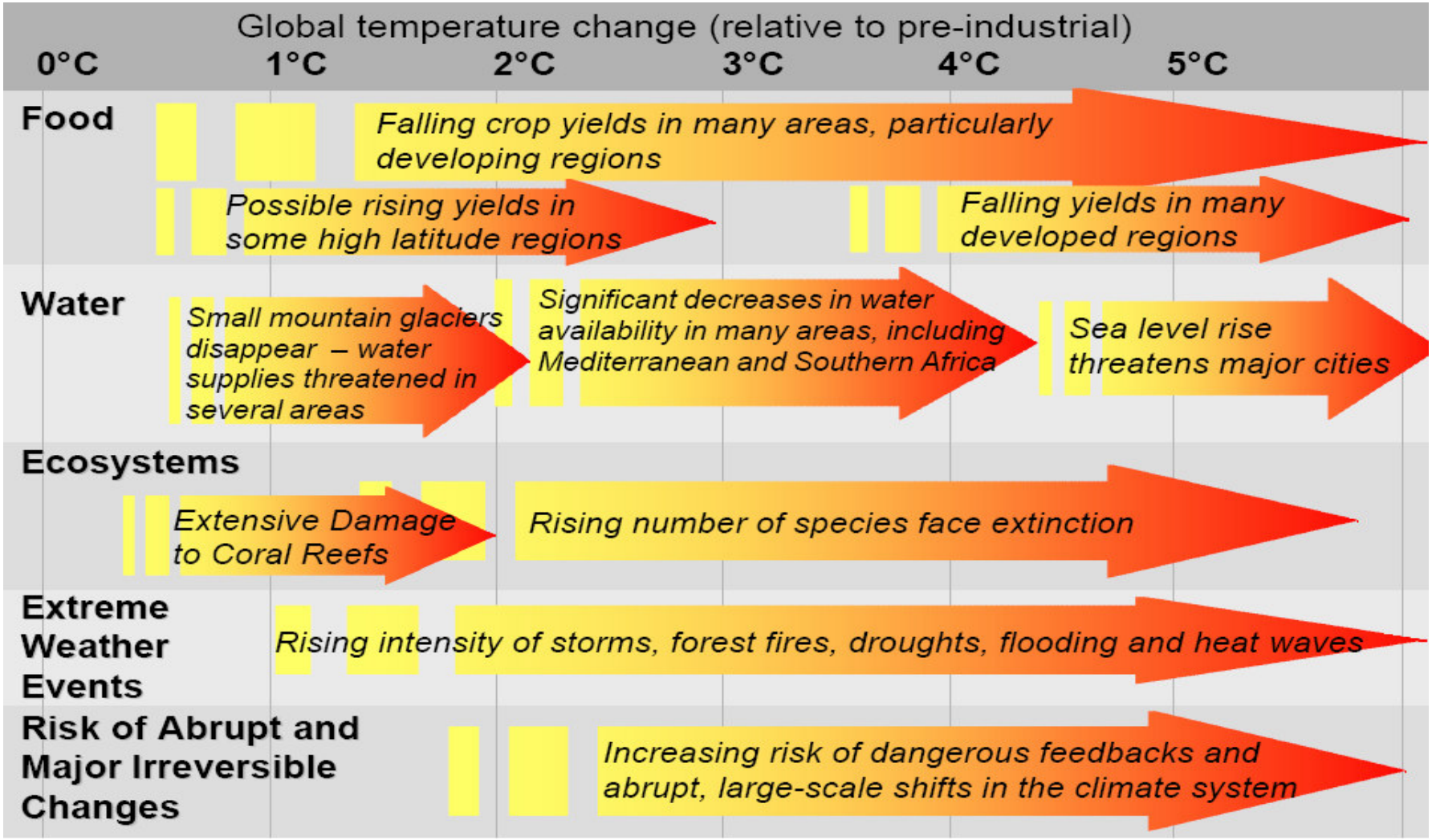
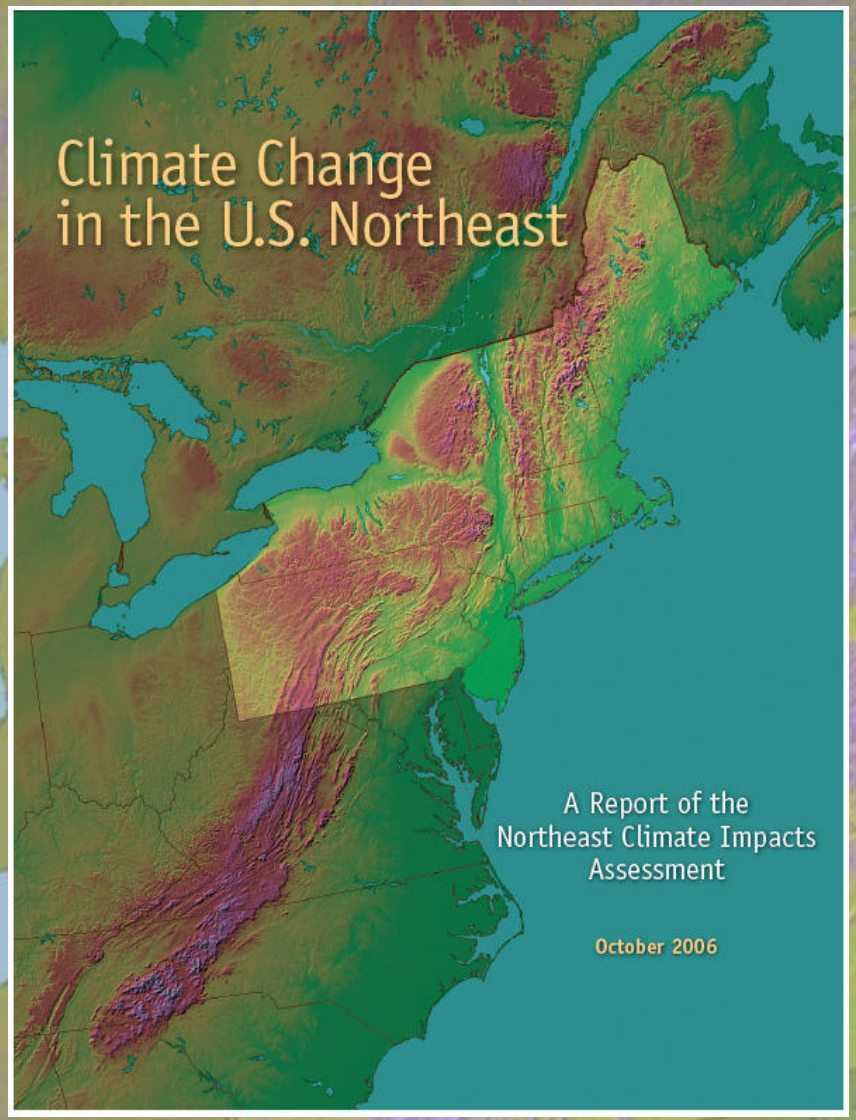
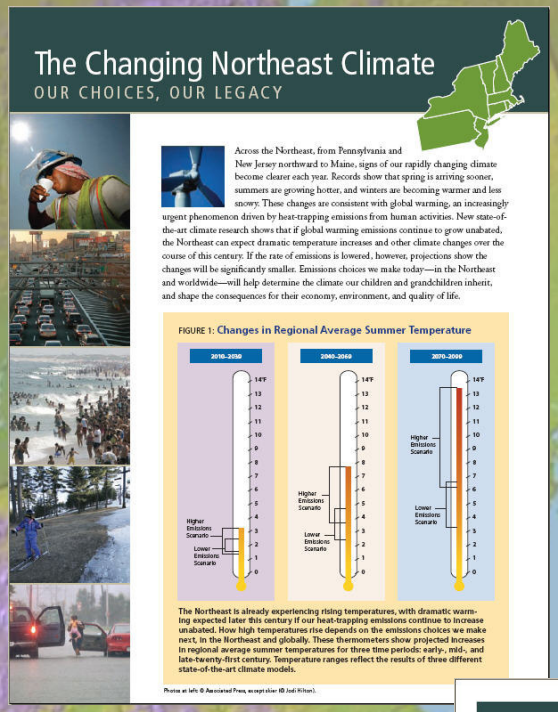
Note: see last 2 slides for details

Projected Impacts of Climate Change



IPCC, 2007





The Changing Northeast Climate

OUR CHOICES, OUR LEGACY

Across the Northeast, from Pennsylvania and New Jersey northward to Maine, signs of our rapidly changing climate become clearer each year. Records show that spring is arriving sooner, summers are growing hotter, and winters are becoming warmer and less snowy. These changes are consistent with global warming, an increasingly urgent phenomenon driven by heat-trapping emissions from human activities. New state-of-the-art climate research shows that if global warming emissions continue to grow unabated, the Northeast can expect dramatic temperature increases and other climate changes over the course of this century. If the rate of emissions is lowered, however, projections show the changes will be significantly smaller. Emissions choices we make today—in the Northeast and worldwide—will help determine the climate our children and grandchildren inherit, and shape the consequences for their economy, environment, and quality of life.

FIGURE 1: **Changes in Regional Average Summer Temperature**

The Northeast is already experiencing rising temperatures, with dramatic warming expected later this century if our heat-trapping emissions continue to increase unabated. How high temperatures rise depends on the emissions choices we make next, in the Northeast and globally. These thermometers show projected increases in regional average summer temperatures for three time periods: early-, mid-, and late-twenty-first century. Temperature ranges reflect the results of three different state-of-the-art climate models.

Photos at left: © Associated Press, except shirt: © Jodi Hilton).

Reducing Heat-Trapping Emissions

IN THE NORTHEAST

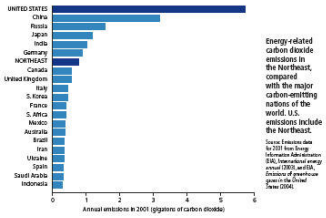
Global warming is under way and poised to have a substantial impact on the Northeast—a nine-state region extending from Maine to New Jersey. Some climate changes are now unavoidable, but the extent of these changes and the specific effects they have on our region depend largely on the emissions choices we make today—in the Northeast and worldwide.

While actions to reduce emissions in the Northeast alone will not stem global warming, the region is a global leader in technology, policy, finance, and innovation, and a major source of emissions of carbon dioxide, the most important heat-trapping gas. Thus, the Northeast is well positioned to be a technology and policy leader in reducing these emissions, and can drive the national and international progress essential to providing our children and grandchildren with a healthy future climate.

The Northeast, which accounted for 13.6 percent of the United States' energy-related carbon dioxide emissions in 2001, represents the world's seventh largest source of such emissions when compared with

entire nations (see the figure). The transportation sector is the Northeast's largest emissions source (35 percent), followed by the electric power sector (30 percent), buildings (22 percent), and industry (13 percent).

To the Northeast's credit, it has been one of this country's leading innovators in early efforts to reduce heat-trapping emissions. Examples of the region's leadership include:



Energy-related carbon dioxide emissions in the Northeast, compared with the major carbon-emitting nations of the world. U.S. emissions include the Northeast.

Source: Emissions data for 2001 from Energy Information Administration (EIA), International energy annual (2003), and EIA, Emissions of greenhouse gases in the United States (2004).

- The Regional Greenhouse Gas Initiative (RGGI), the first U.S. multi-state cap on carbon emissions, which will require the electric power sector to decrease its emissions 10 percent below current levels by 2019.
- Many state-level actions including policies to promote energy efficiency and renewable energy, clean cars, climate action plans, and efforts to reduce emissions from state government.
- Emissions reduction strategies being implemented by many municipalities, corporations, and universities.

In 2001, the New England Governors and the Eastern Canadian Premiers (NEG/ECP) adopted a long-term goal of reducing regional heat-trapping emissions 75 to 85 percent below then-current levels. If the Northeast and the industrialized world follow such a pathway, and developing nations follow a relatively low-emissions pathway as well, the world will be on track to avoid the more severe consequences of climate change.

Key Opportunities

A lower-emissions pathway could combine high economic growth with a shift toward less fossil fuel-intensive power production and the introduction of clean and resource-efficient buildings and technologies. Reductions in heat-trapping emissions of just three percent per year on average would enable the Northeast to meet the NEG/ECP goal by mid-century.

A rich array of options is available to the Northeast to help us pursue a low-emissions pathway and continue our leadership in policy and technology innovation. Examples in the key carbon-emitting sectors include:

- **Transportation**—Cost-effective technologies available today—such as better transmissions, improved tires and aerodynamics, and stronger but lighter frames—could reduce emissions by roughly one-third over the next decade and save consumers money at the pump. Gasoline-electric hybrids could eliminate

NECIA, 2007

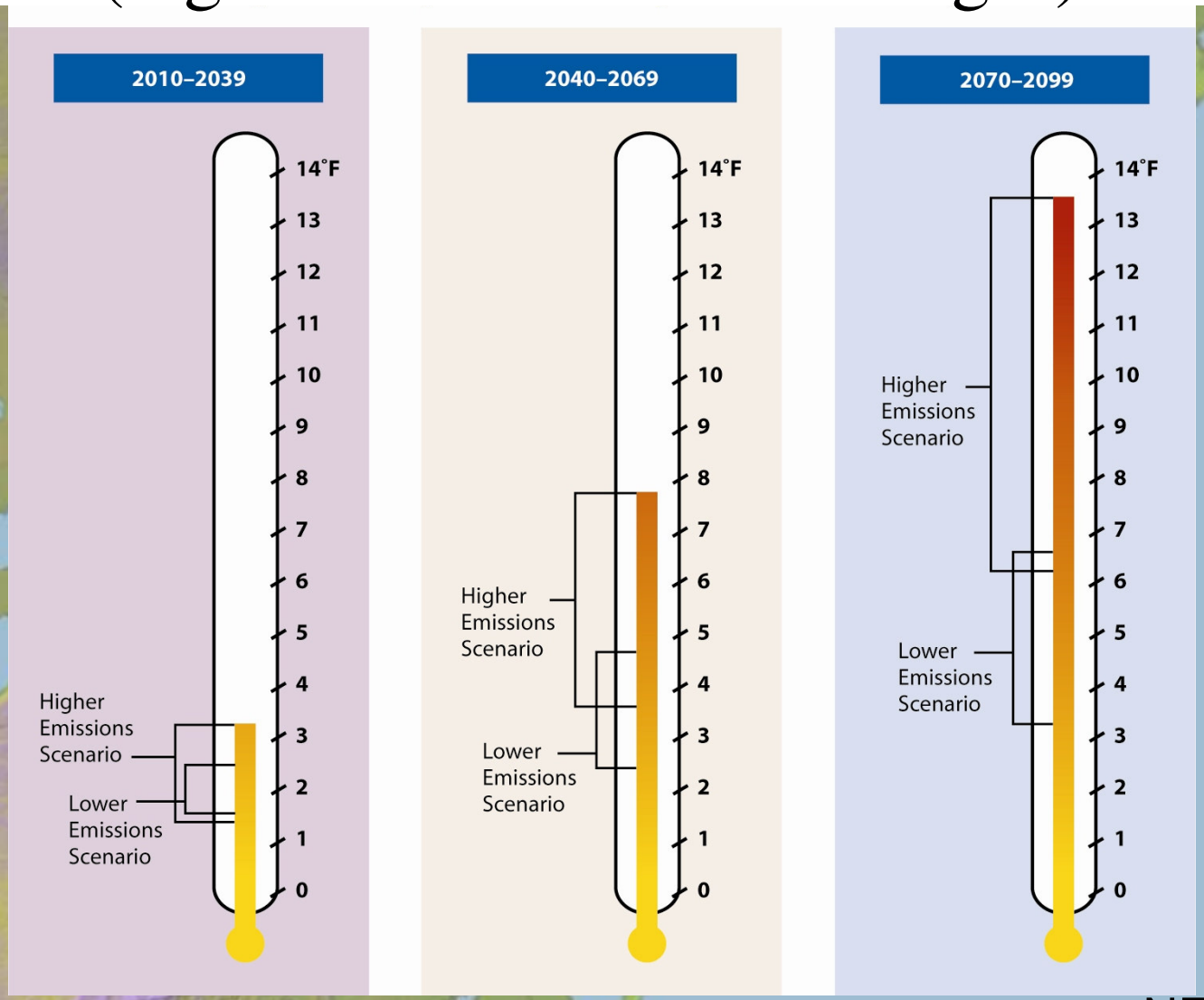
Climate across the Northeast is already changing

- Annual temperatures across the Northeast have warmed almost 2°F since 1970
- Winters have been warming fastest, at 1.3°F per decade since 1970
- Winter snowpack is decreasing
- Plants are flowering earlier in the spring
- Extreme heat in summer is becoming more frequent

NECIA, 2007

Rising Temperatures

(region-wide summer averages)



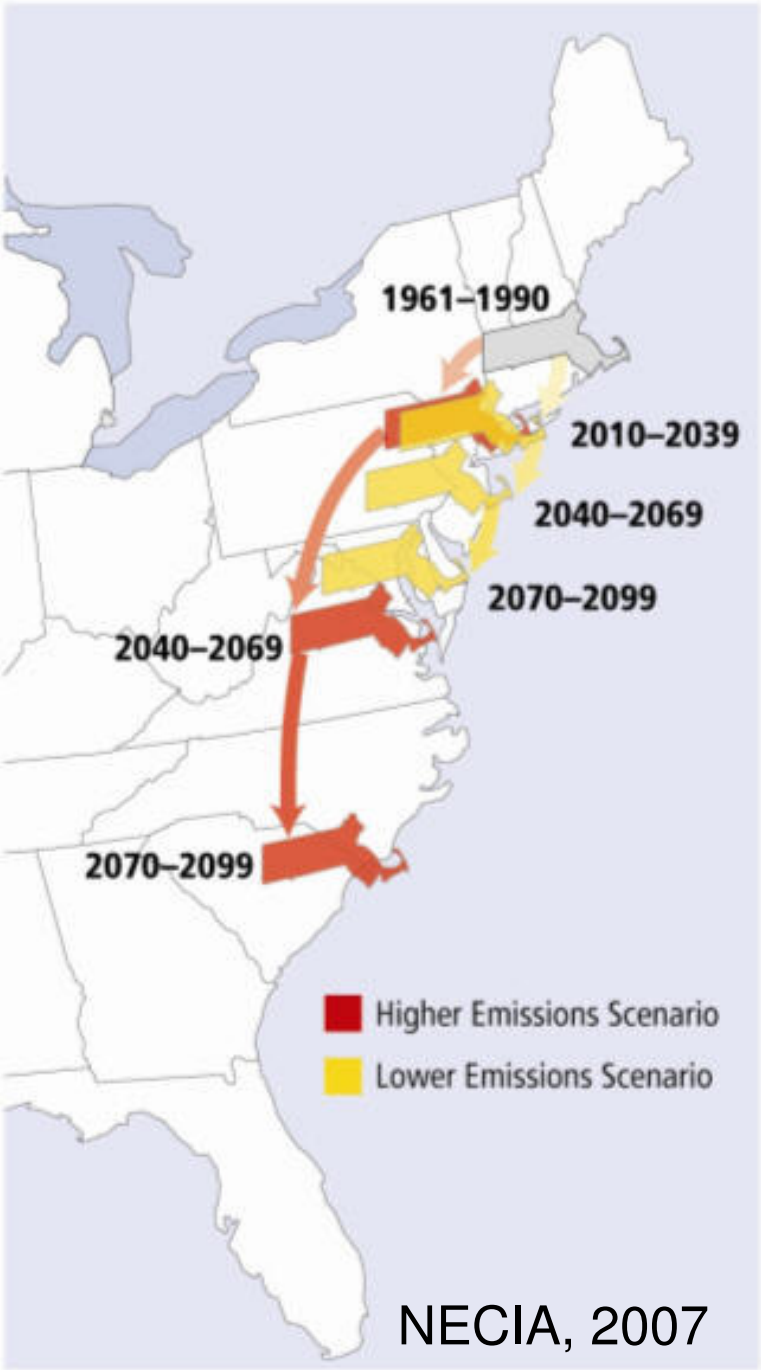
NECIA, 2007

Summer heat index

How hot will summers "feel" in

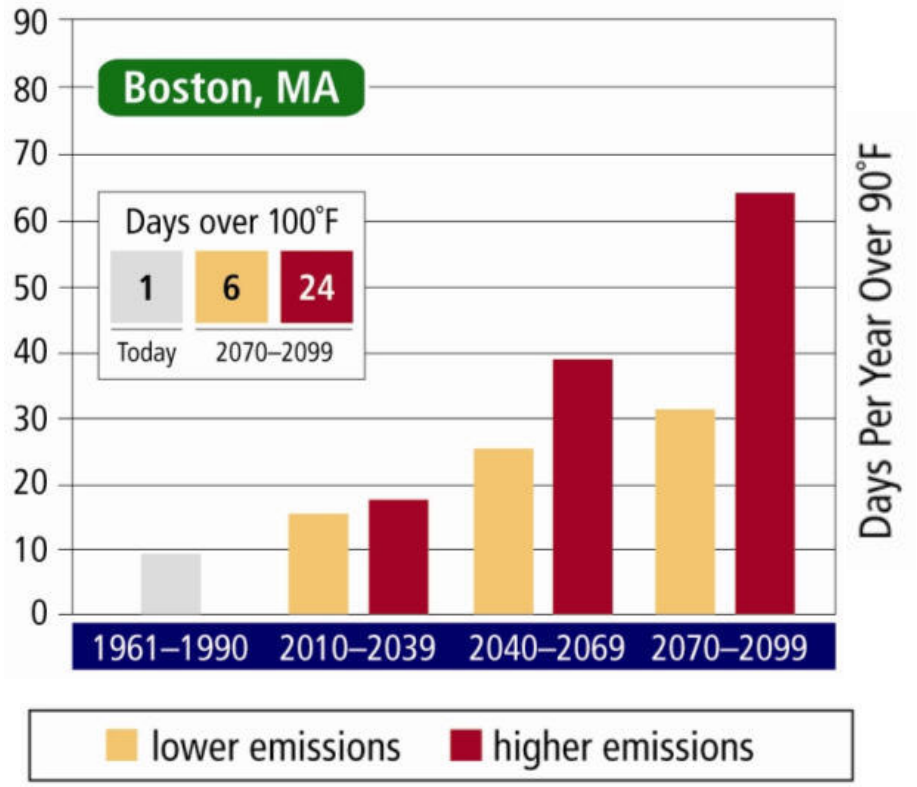
Massachusetts

credit: Jerry and Marcy Monkman



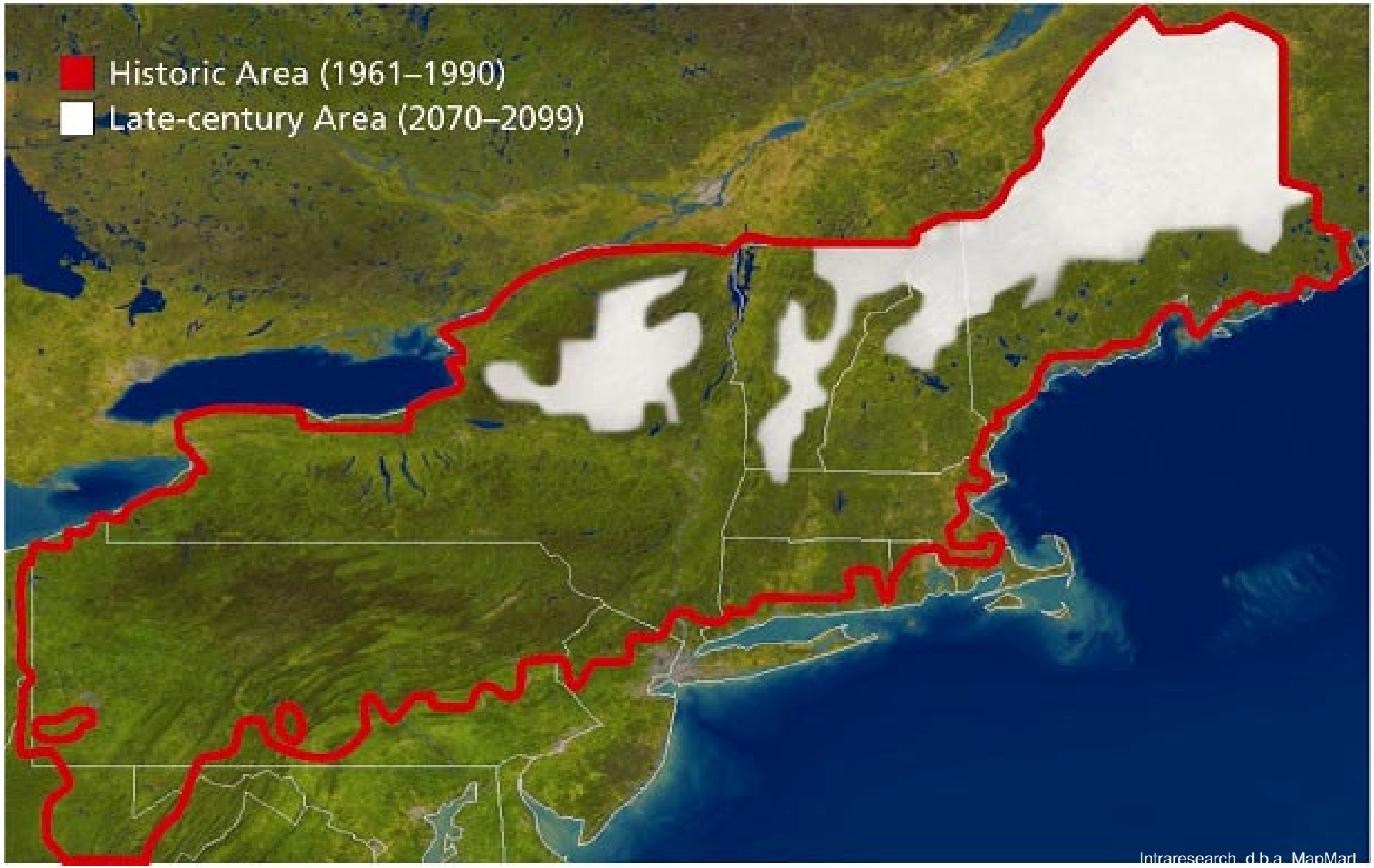
Heatwaves and Temperature Extremes: *Boston*

Photo credit: Associated Press



NECIA, 2007

The Changing Face of Winter



NECIA, 2007

Conclusions

- Climate is **already changing** across the Northeast
- Over the **next few decades**, similar changes expected under both emissions scenarios
- By **mid-century**, most changes are greater under the higher scenario
- By **late-century,** under the higher-emissions scenario**:**
  - Many changes are almost twice those seen under lower emissions, including:
  - winters warming by 8 -12°F and summers by 6 -14°F, with dramatic increases in extreme heat in cities.

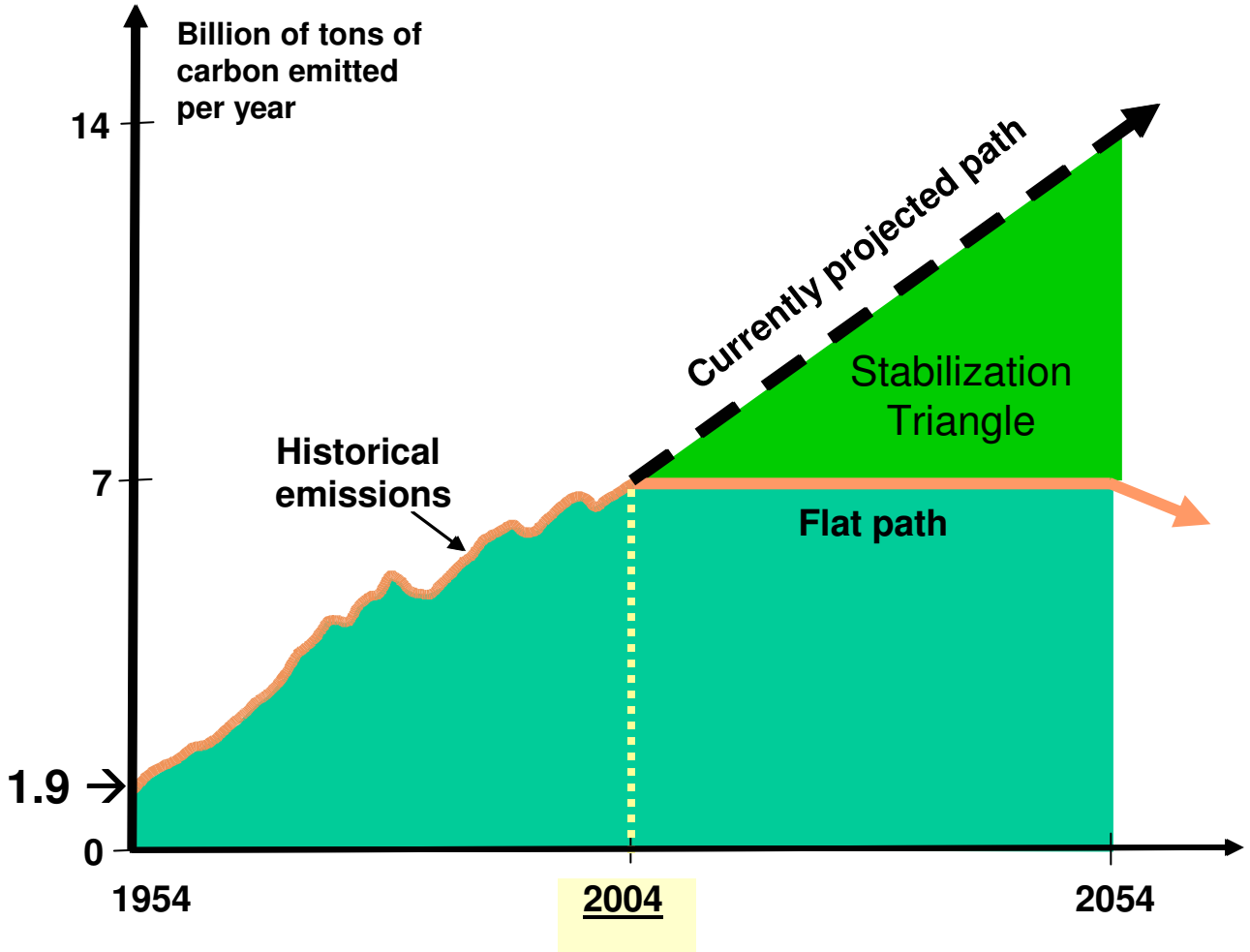
NECIA, 2007

Key considerations

- Some changes are now unavoidable, but the extent of change and the effect of these changes depend greatly on emissions choices we make today.
- Higher emissions scenario not a ceiling, lower scenario not a floor.
- Reductions on the order of 80% below 2000 levels by 2050 (3% per year) can keep emissions below the lower scenario described here.

The Stabilization Triangle

Pacala and Socolow, 2004



To get to 500 ppm starting now

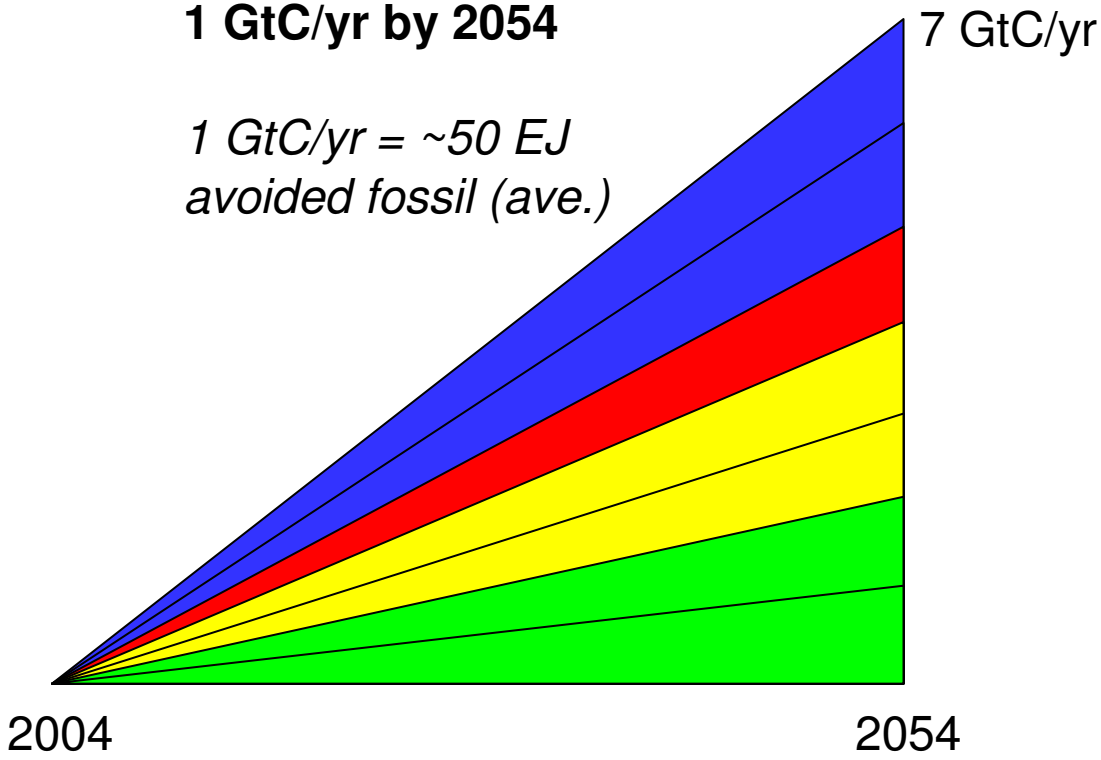
or

850 ppm waiting 50 yrs

Wedges (7) fill the Stabilization Triangle

1 wedge avoids
1 GtC/yr by 2054

1 GtC/yr = ~50 EJ
avoided fossil (ave.)



Possible Wedges

- •Efficient vehicles
- •Efficient buildings
- •Mass transit
- •Efficient coal power
- •Gas power for coal
- •C capture and storage
- •Nuclear power
- ✓Solar power for coal
- ✓Wind power for coal
- ✓Biomass fuel for fossil
- •Reforestation
- •Soil tillage

Even Pres. Bush says it's true!

The Climate Debate

There is no longer any true *scientific* debate about the reality of climate change or its anthropogenic causes

Points about the climate change debate:

The so-called "scientific debate" is being carried out in newspaper editorials, op-eds, letters, blogs etc – *not in the peer-reviewed scientific literature*

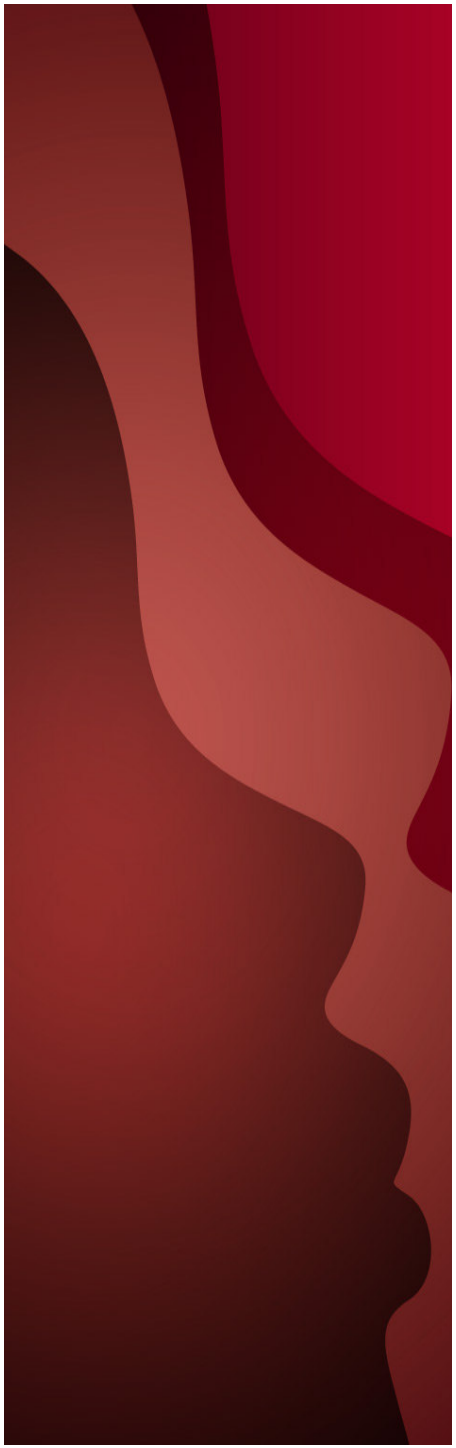
The media tends to give equal weight to both sides in the current bogus scientific debate, lending undeserved legitimacy to the skeptics

The bogus scientific debate is obscuring and preventing responsible debate about climate change: what we can and should be doing and at what cost?

It is expected and important to have a true debate on what we should do about it *!!*

Human Development Report 2007/2008

Fighting climate change: Human solidarity in a divided world



- **The world has less than a decade to avoid dangerous climate change that could bring unprecedented human development reversals**

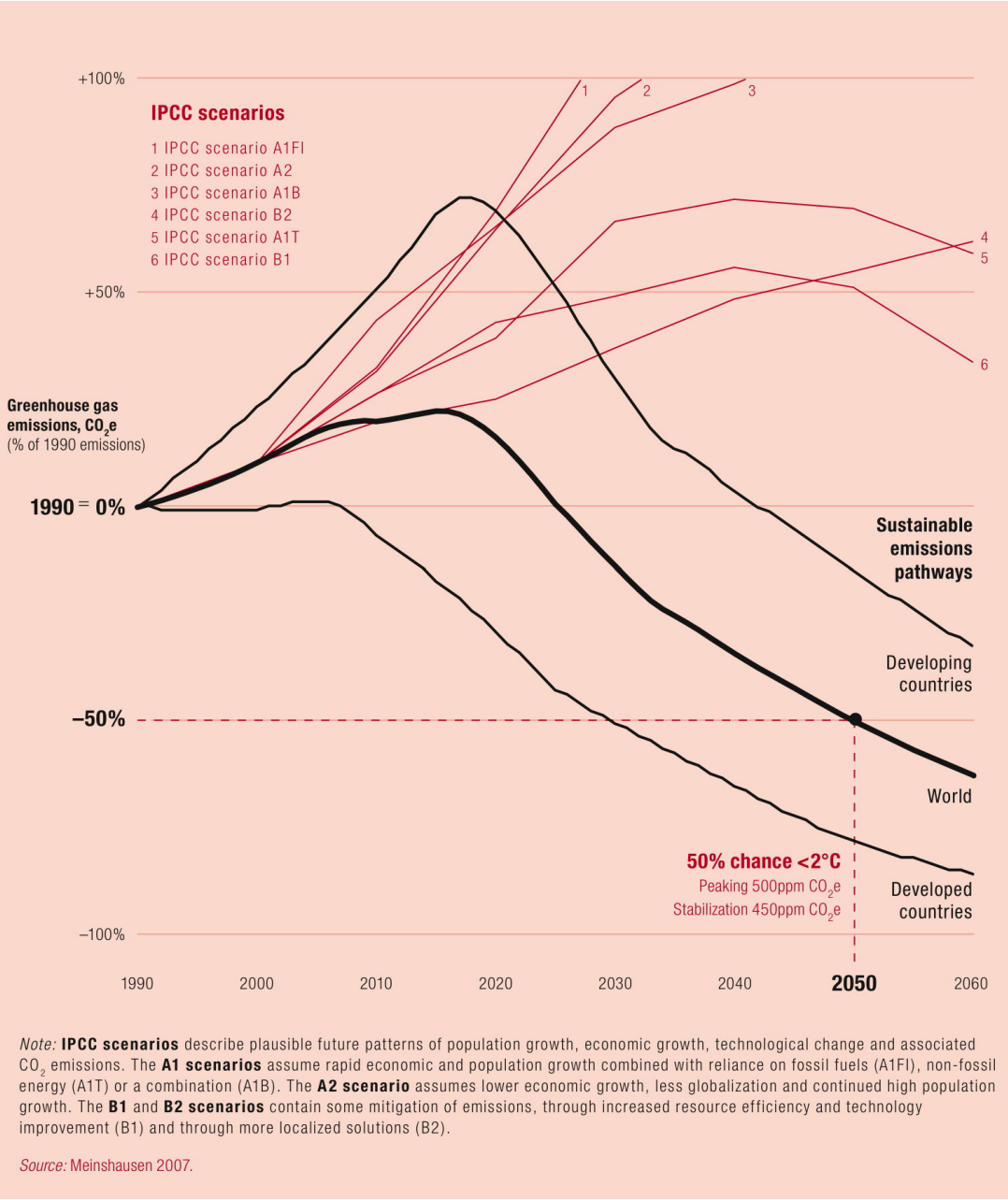
- **Climate change is a threat to humanity as a whole. But it is the poor, a constituency with no responsibility for the ecological debt we are running up, who face the most immediate and most severe human costs**

- **The Human Development Report 2007/2008 calls for a 'twin track' approach that combines stringent mitigation to limit 21st Century warming to less than 2 degree centigrade, with strengthened international cooperation on adaptation**

- **The forthcoming conference of the parties in Bali is a unique opportunity to put the interests of the world's poor and future generations at the heart of climate change negotiations**


Thanks for your interest

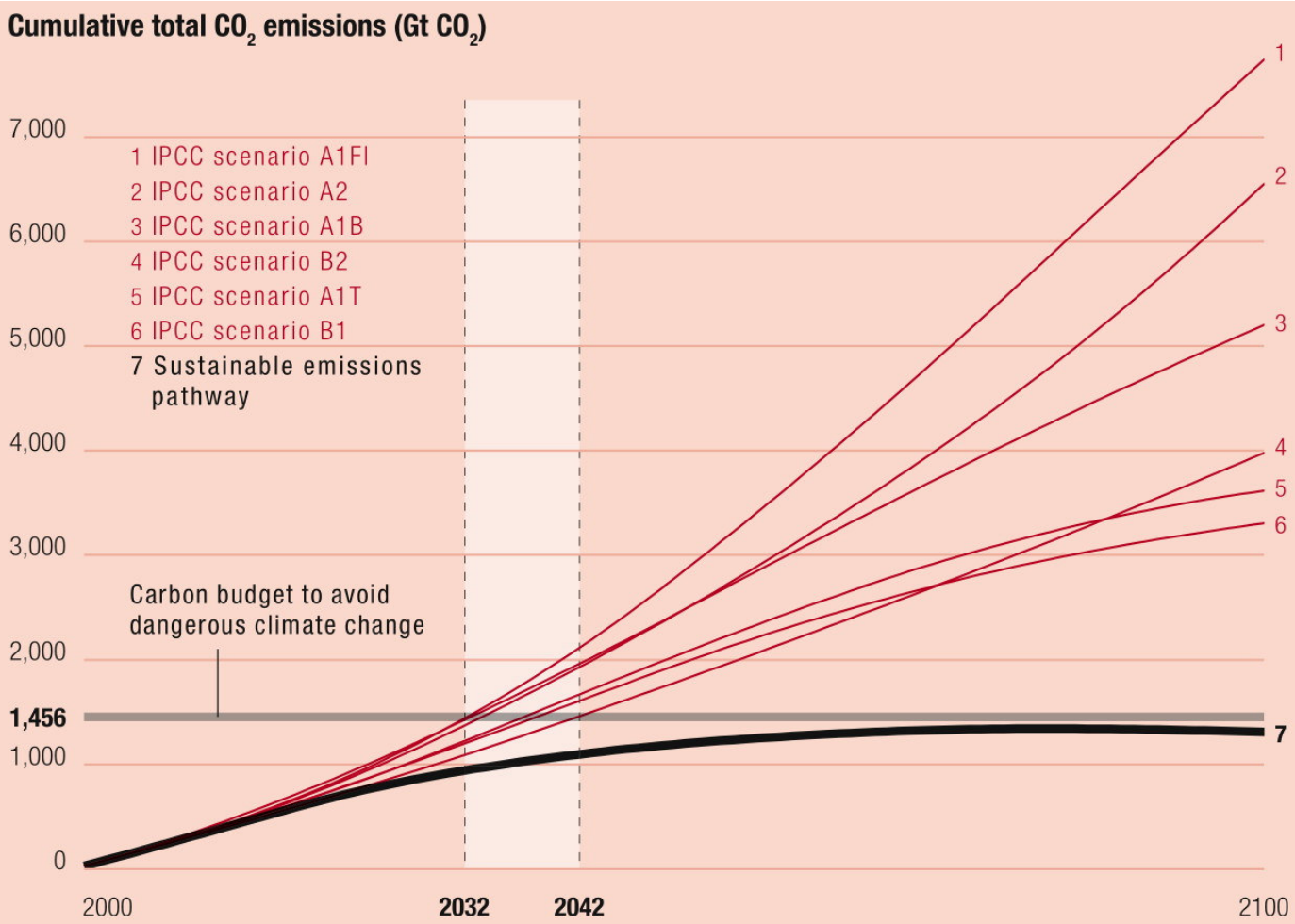
Scenarios for Total CO2 emissions reduction



Note: **IPCC scenarios** describe plausible future patterns of population growth, economic growth, technological change and associated CO_2 emissions. The **A1 scenarios** assume rapid economic and population growth combined with reliance on fossil fuels (A1FI), non-fossil energy (A1T) or a combination (A1B). The **A2 scenario** assumes lower economic growth, less globalization and continued high population growth. The **B1** and **B2 scenarios** contain some mitigation of emissions, through increased resource efficiency and technology improvement (B1) and through more localized solutions (B2).

Source: Meinshausen 2007.

Scenarios for Total cumulative CO2 emissions



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Some Presidential Candidates Views on Climate Change (New York Times)

Fred Thompson (R): ***Some people think that our planet is suffering from a fever. Now scientists are telling us that Mars is experiencing its own planetary warming: Martian warming. It seems scientists have noticed recently that quite a few planets in our solar system seem to be heating up a bit, including Pluto. NASA says that the Martian South Pole's ice cap has been shrinking for three summers in a row. Maybe Mars got its fever from earth. If so, I guess Jupiter's caught the same cold, because it's warming up too, like Pluto. This has led some people, not necessarily scientists, to wonder if Mars and Jupiter, non signatories to the Kyoto Treaty, are actually inhabited by alien SUV-driving industrialists who run their air-conditioning at 60 degrees and refuse to recycle. Silly, I know, but I wonder what all those planets, dwarf planets and moons in our solar system have in common. Hmmmm. Solar system. Hmmmm. Solar? I wonder. Nah, I guess we shouldn't even be talking about this. The science is absolutely decided. There's a consensus. Ask Galileo."***

Tom Tancredo (R): ***"I have no doubt that global warming exists. I just question the cause and what we can do to ameliorate it. But I wonder why the Sierra Club isn't going crazy about the environmental aspects of massive immigration into the U.S. The fact is, Americans consume more energy than anyone else, so if a person moves here from another country, they automatically become bigger polluters."***

Ron Paul (R): "I don't think everybody knows everything about global warming, because you have reputable scientists on both sides of that argument. ... [If the government were to play a role] then you have to deal with the volcanoes and you have to deal with the pollution of China. So, do you want to invade China to make sure they don't pollute? And what are you going to do about the volcanoes? They are all contributing factors to global warming. But that doesn't mean that you shouldn't do what we can to slow up the emissions and stop subsidizing big oil companies.