Climate 2050:
Technology & Policy Solutions – An Introduction

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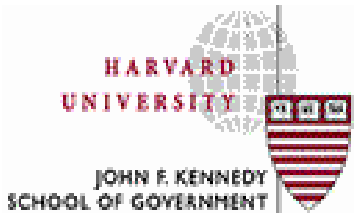


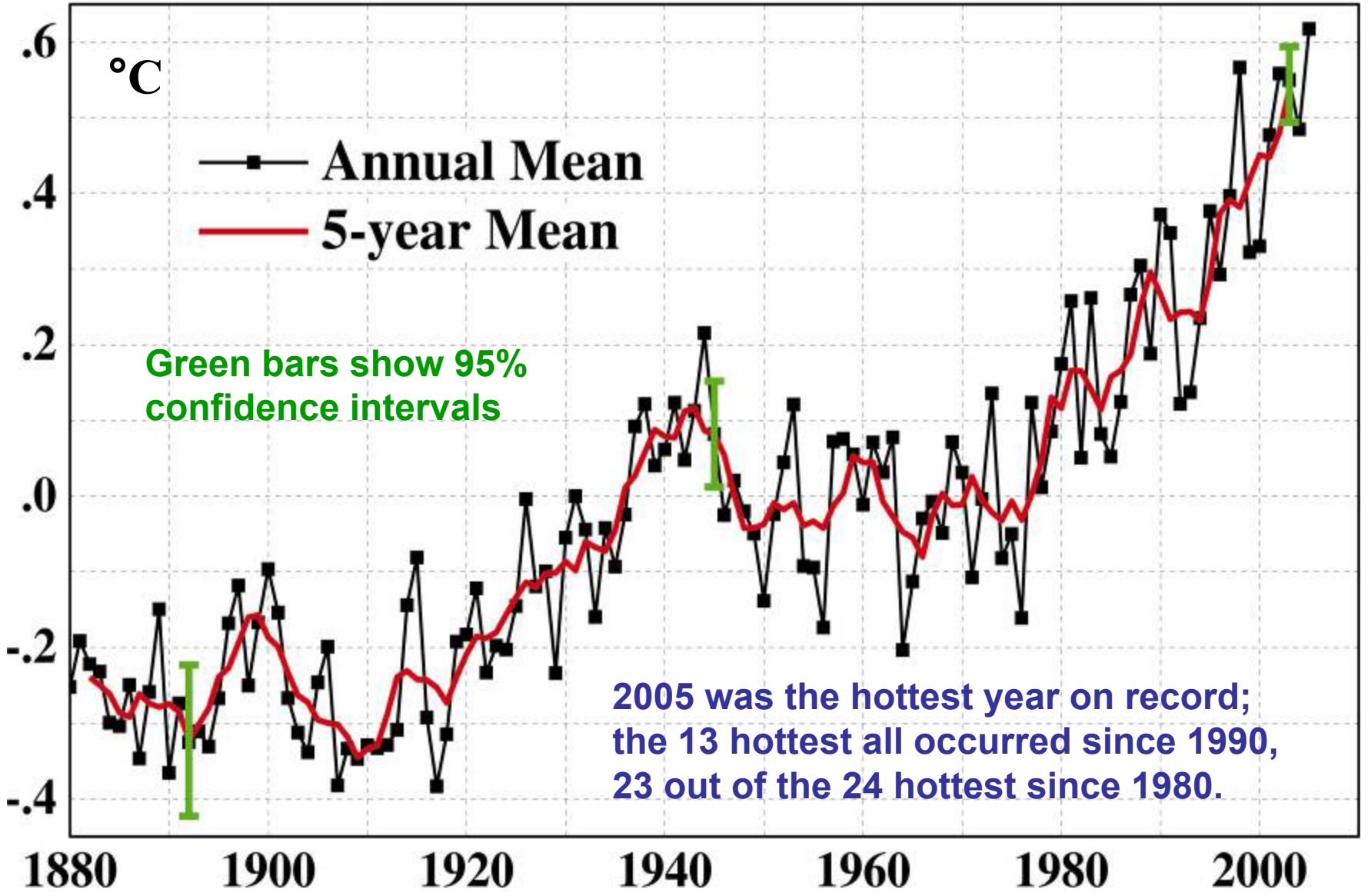
Climate 2050 Conference

Montreal, 25-26 October 2007

The scientific backdrop

- "Global warming" is a misnomer because it implies gradual, uniform, & quite possibly benign.
  - But what's happening is rapid, nonuniform, harmful.
  - A more accurate term is "global climatic disruption".
- The disruption is…
  - real without doubt;
  - mainly human-caused;
  - already producing significant harm; and
  - growing more rapidly than expected.

The Earth is getting hotter.



J. Hansen et al., *PNAS 103*: 14288-293 (26 Sept 2006)

We know why:

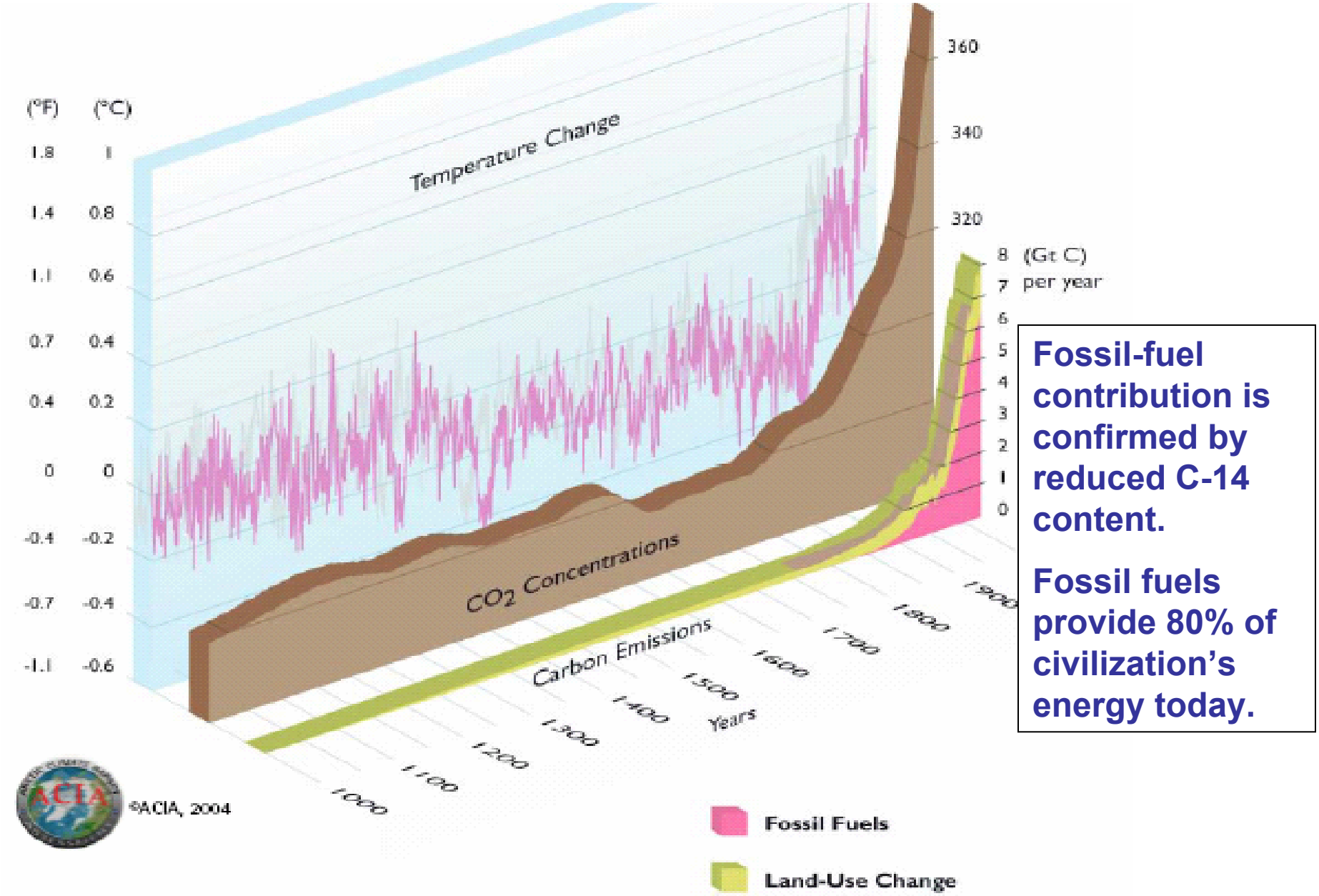
Human vs natural influences 1750-2005 (watts/m^2)

Human emissions leading to increases in…	
atmospheric carbon dioxide	+ 1.7
methane, nitrous oxide, CFCs	+ 1.0
net ozone (troposphere↑, stratosphere↓)	+ 0.3
absorptive particles (soot)	+ 0.3
reflective particles (sulfates, etc.)	- 0.7
indirect (cloud forming) effect of particles	- 0.7
Human land-use change increasing reflectivity	- 0.2
Natural changes in sunlight reaching Earth	+ 0.1

The warming influence of anthropogenic GHG and absorbing particles is ~30x the warming influence of the estimated change in input from the Sun.

IPCC AR4, WG1 SPM, 2007

The main cause of the CO_2 build-up in the last 250 years has been emissions from fossil fuels & deforestation



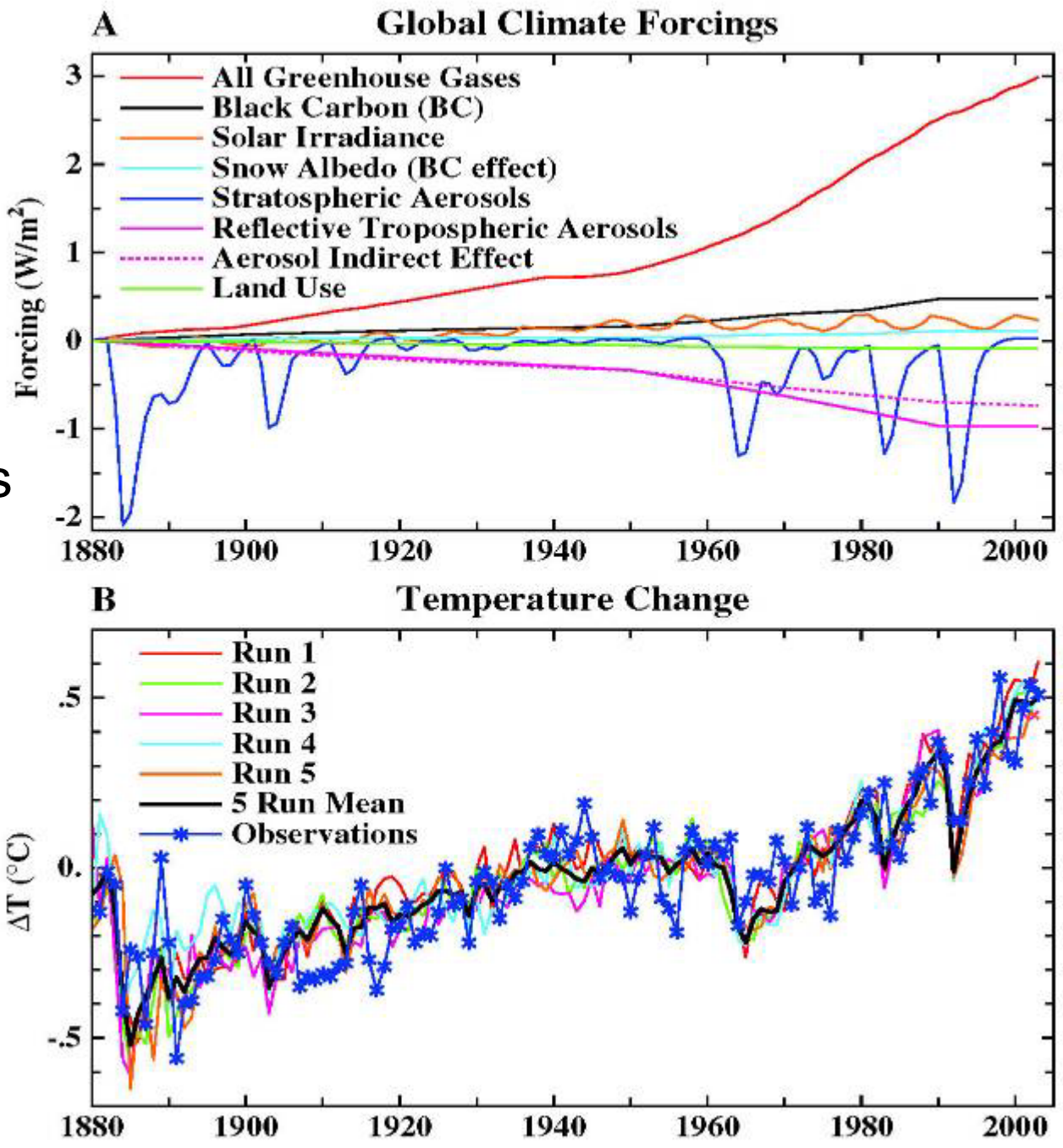
Fossil-fuel contribution is confirmed by reduced C-14 content.

Fossil fuels provide 80% of civilization's energy today.

Human influence: the smoking gun

Top panel shows best estimates of human & natural forcings 1880-2005.

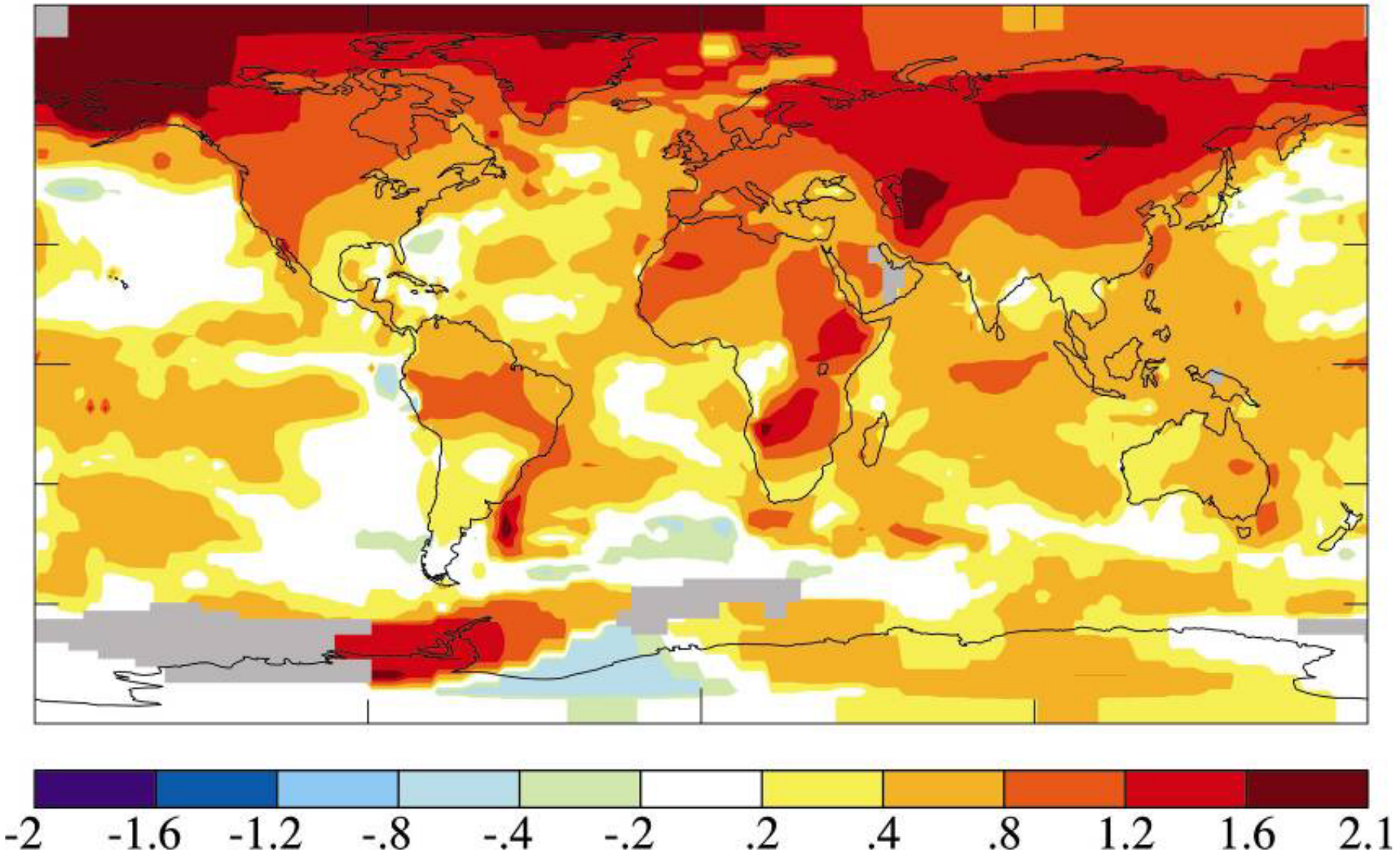
Bottom panel shows that state-of-the-art climate model, fed these forcings, reproduces almost perfectly the last 125 years of observed temperatures.



Source: Hansen et al., *Science 308*, 1431, 2005.

The heating is not uniform geographically…

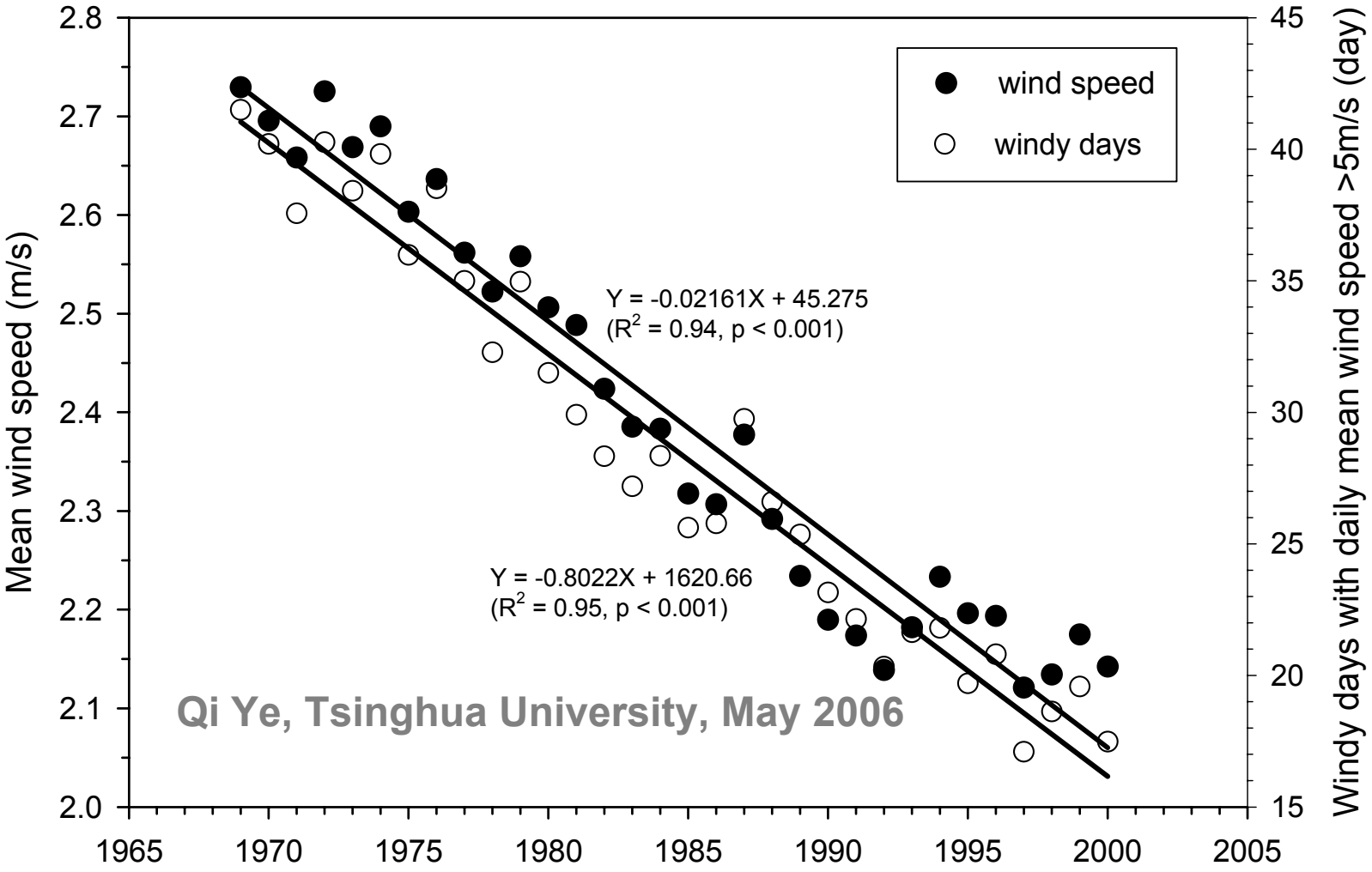
Average T for 2001-2005 compared to 1951-80, degrees C



J. Hansen et al., *PNAS 103*: 14288-293 (2006)

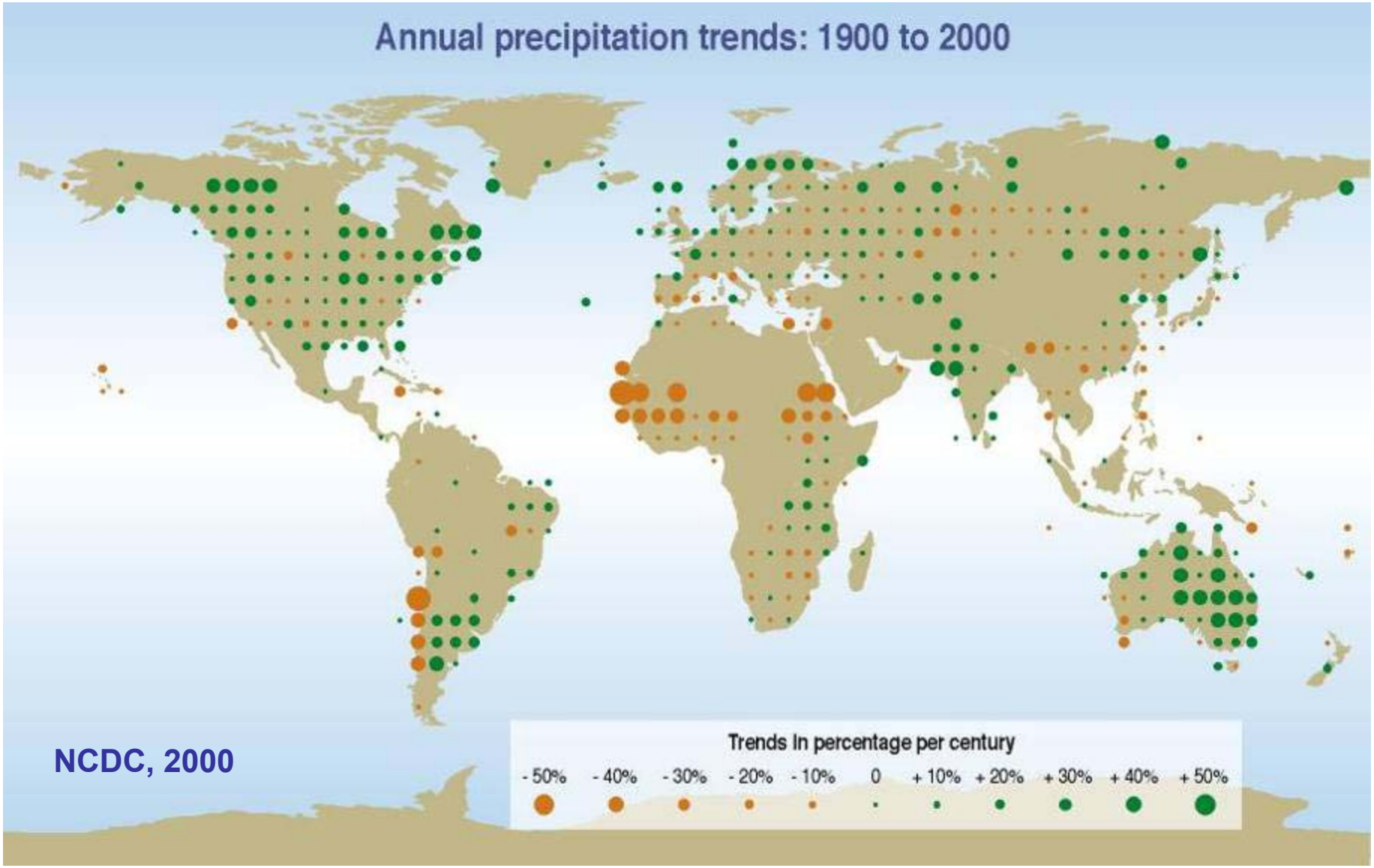
Circulation patterns are changing

Weakening of the East Asia Monsoon is an example



Chinese studies conclude that this phenomenon is indeed a result of greenhouse-gas-driven global climatic change.

Evaporation & precipitation are increasing



Effect is not uniform; most places getting wetter, some getting drier.

Glaciers are retreating

Muir Glacier, Alaska, 1941-2004

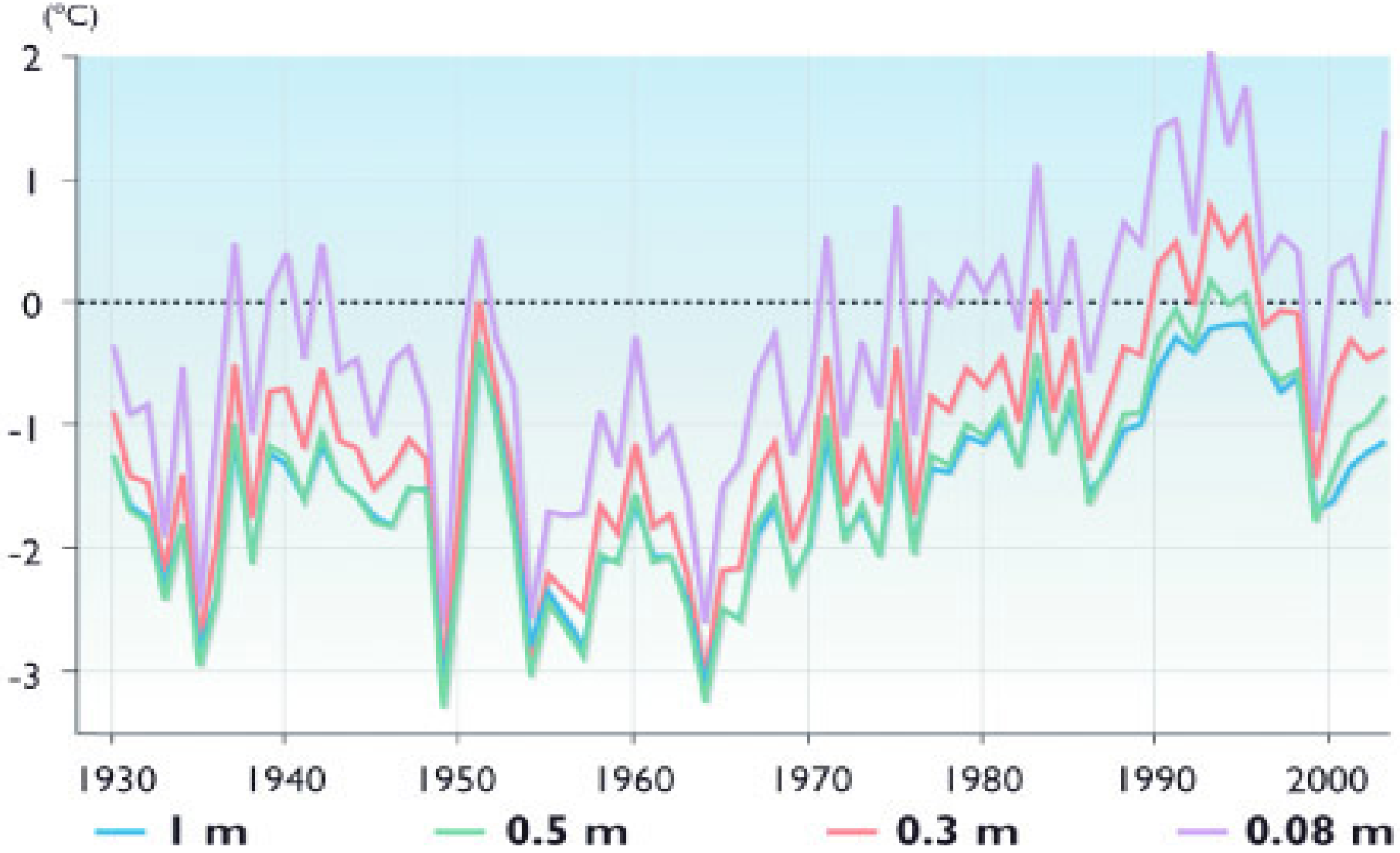
August 1941

August 2004

NSIDC/WDC for Glaciology, Boulder, compiler. 2002, updated 2006. *Online glacier photograph database.* Boulder, CO: National Snow and Ice Data Center.

Permafrost is thawing

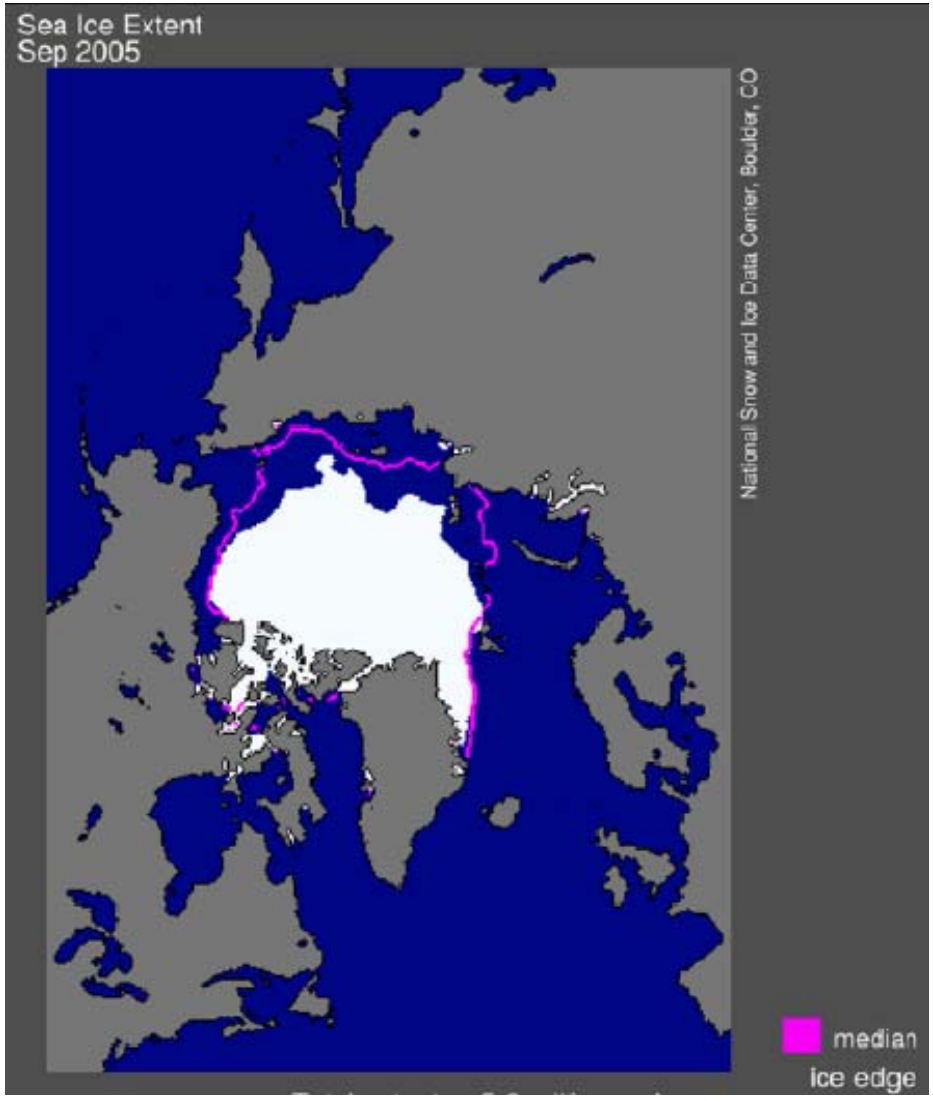
Average ground temperature near Fairbanks, Alaska, degrees C

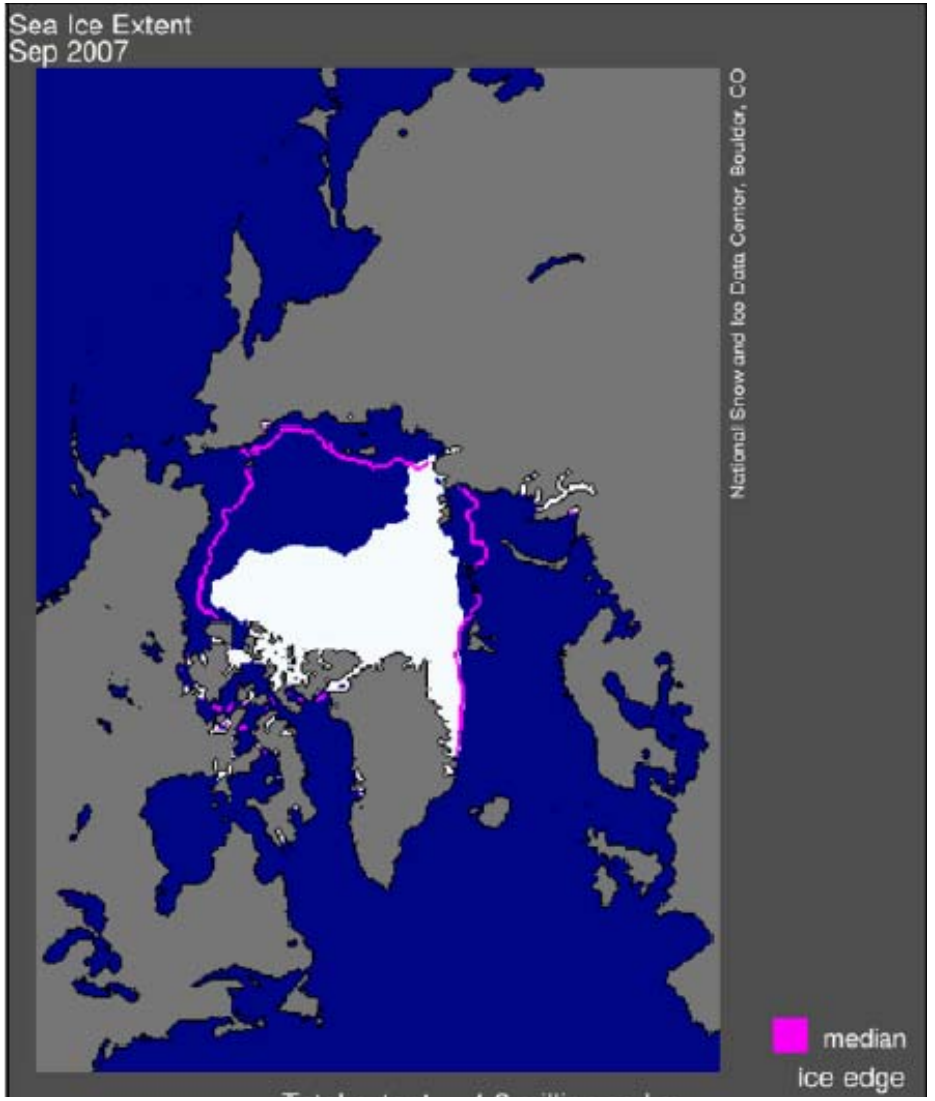


Permafrost thaws when T ≥ 0°C

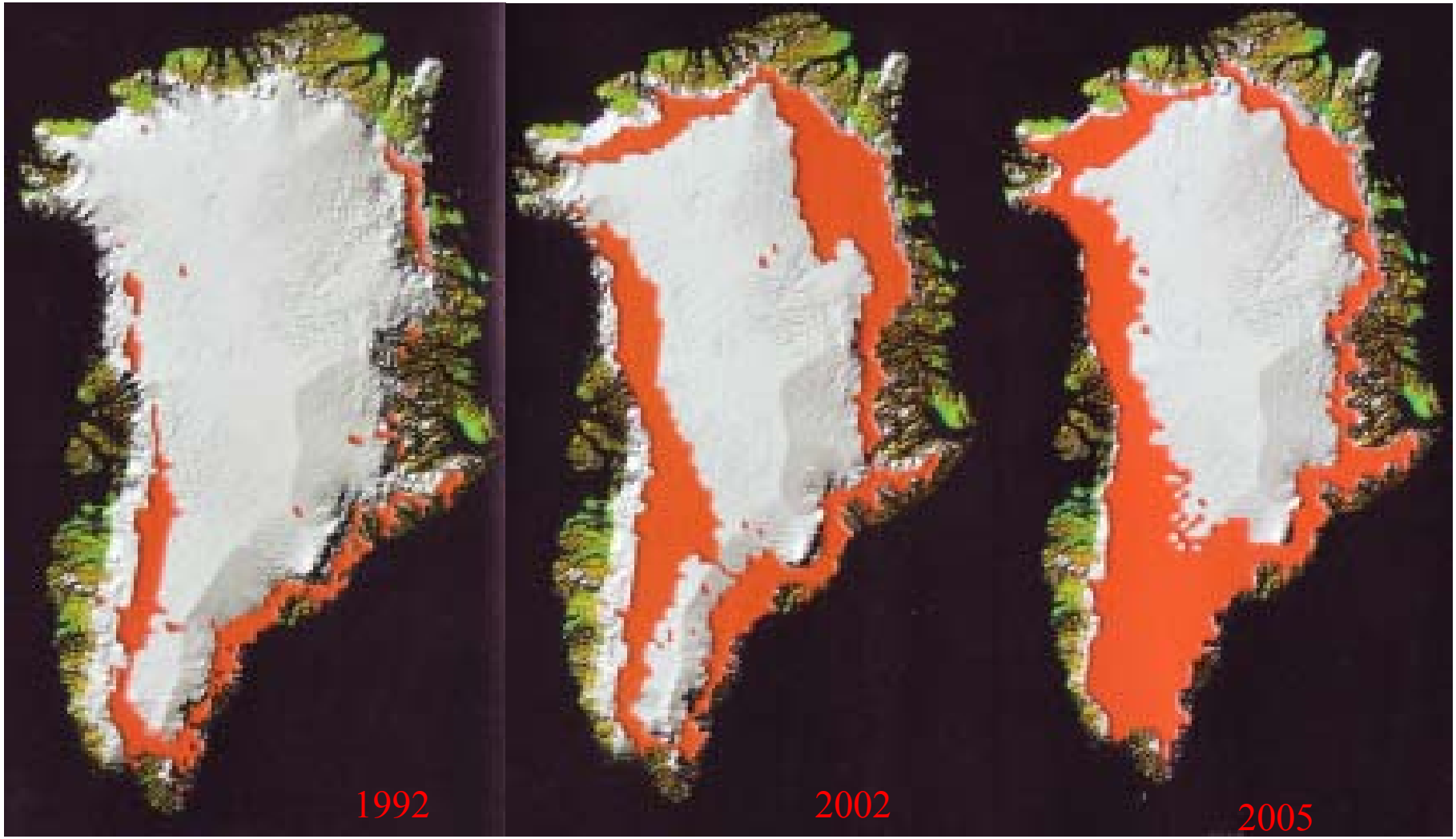
ACIA 2004

Summer sea ice is disappearing





Surface melting on Greenland is expanding



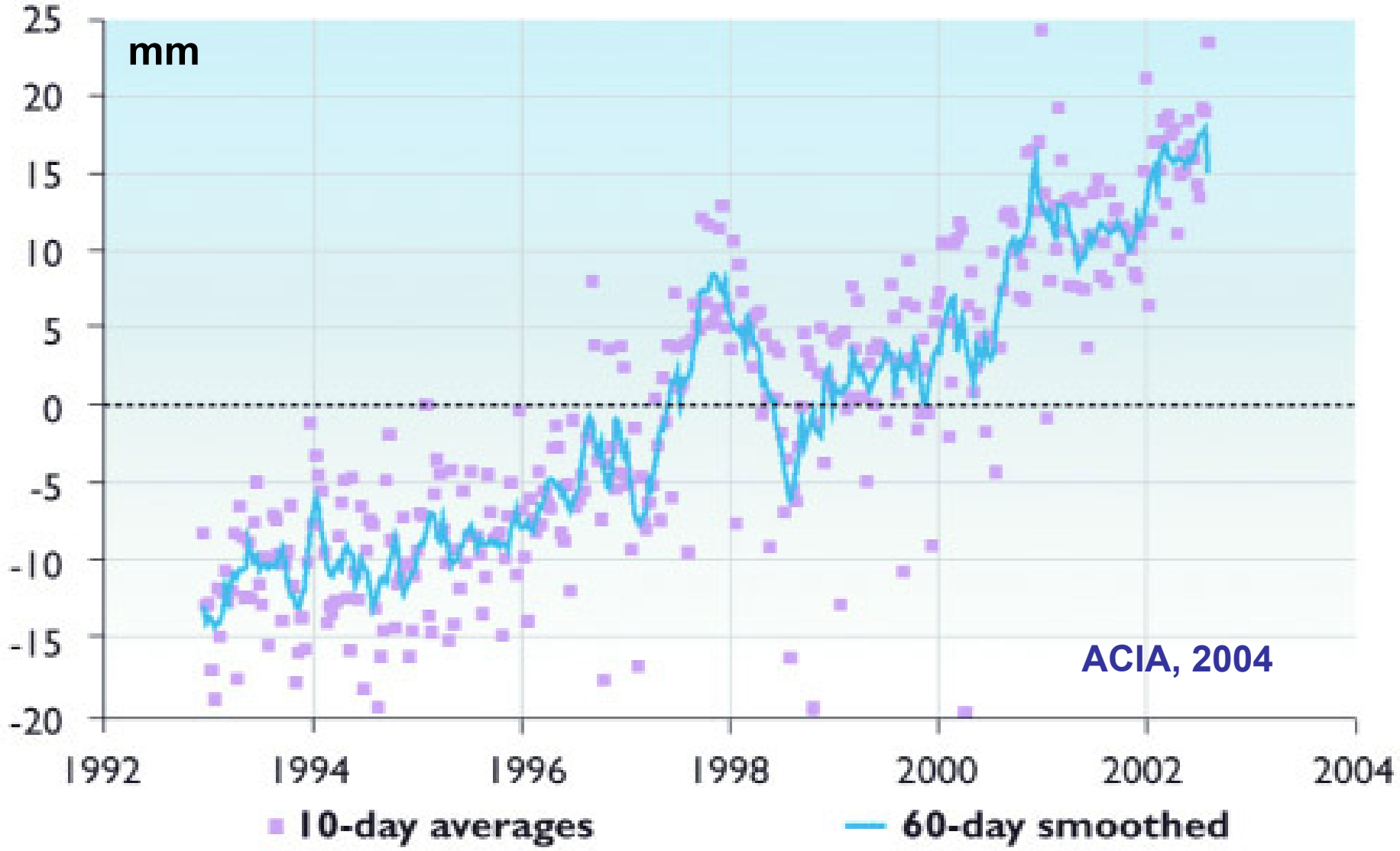
In 1992 scientists measured this amount of melting in Greenland as indicated by red areas on the map

Ten years later, in 2002, the melting was much worse

And in 2005, it accelerated dramatically yet again

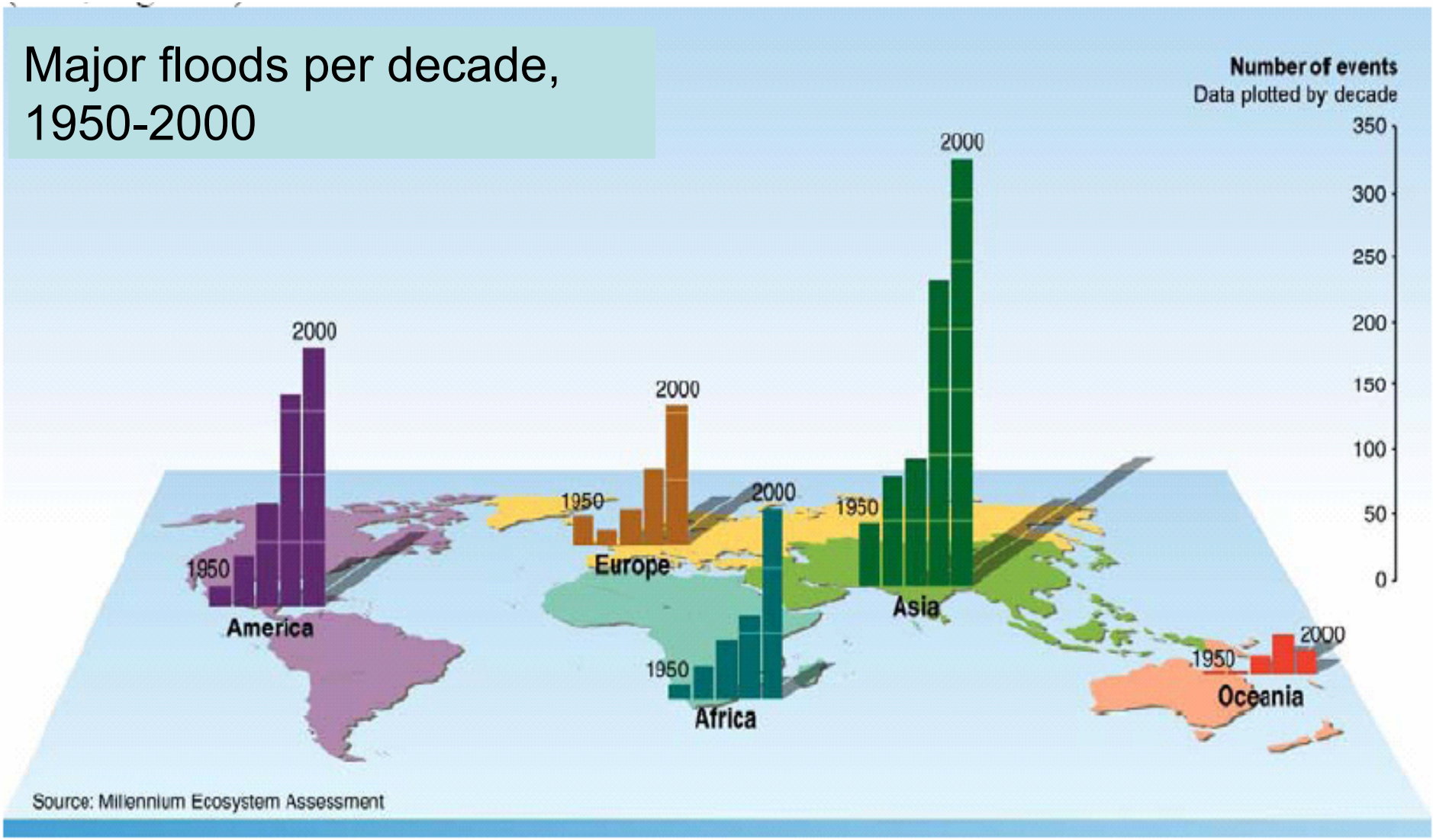
Source: ACIA, 2004 and CIRES, 2005

Sea-level rise is accelerating



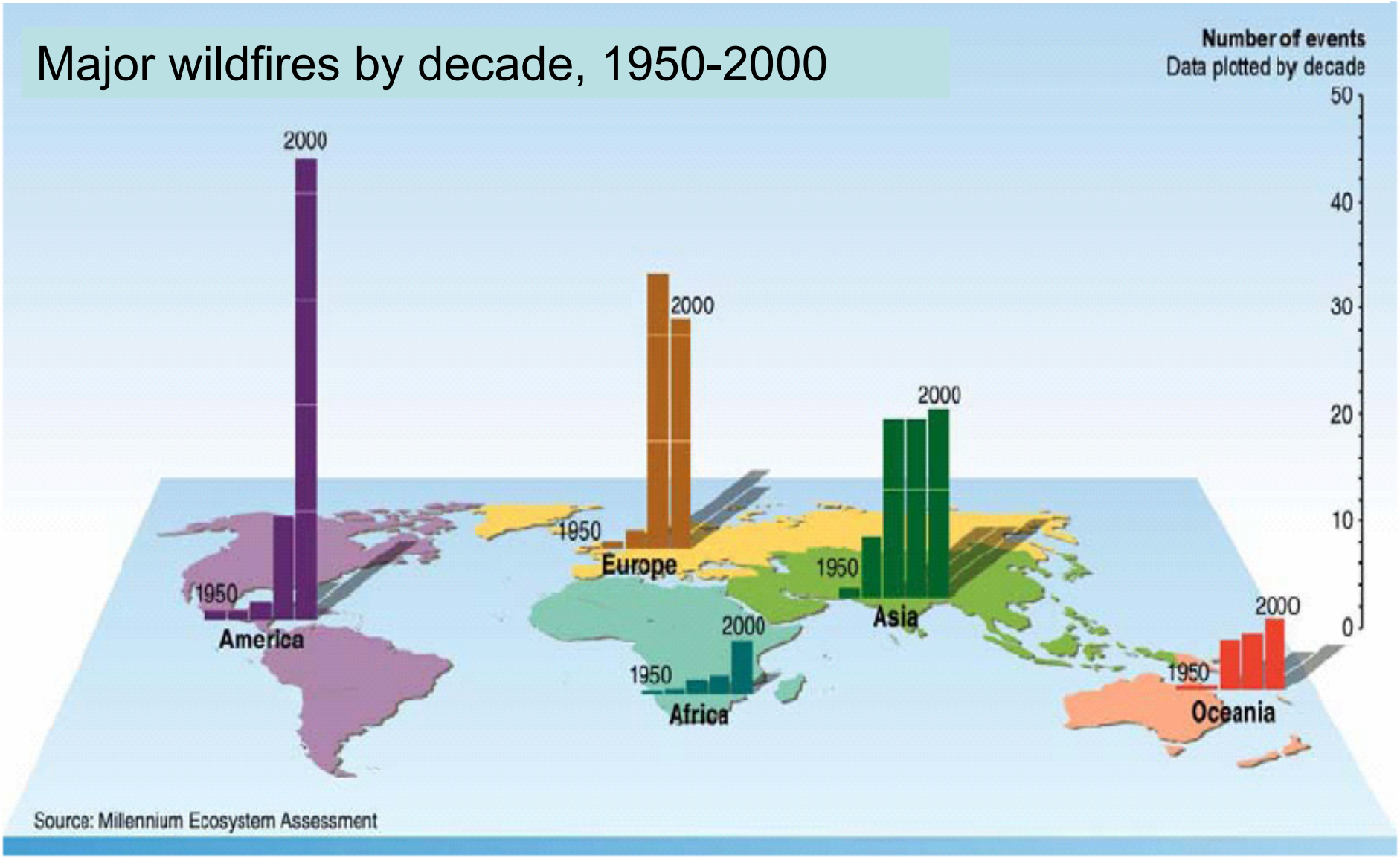
1993-2003 ≈ 30 mm = 3.0 mm/yr; compare 1910-1990 = 1.5±0.5 mm/yr.

These changes are already causing harm



The most dramatic rising trend is in Asia.

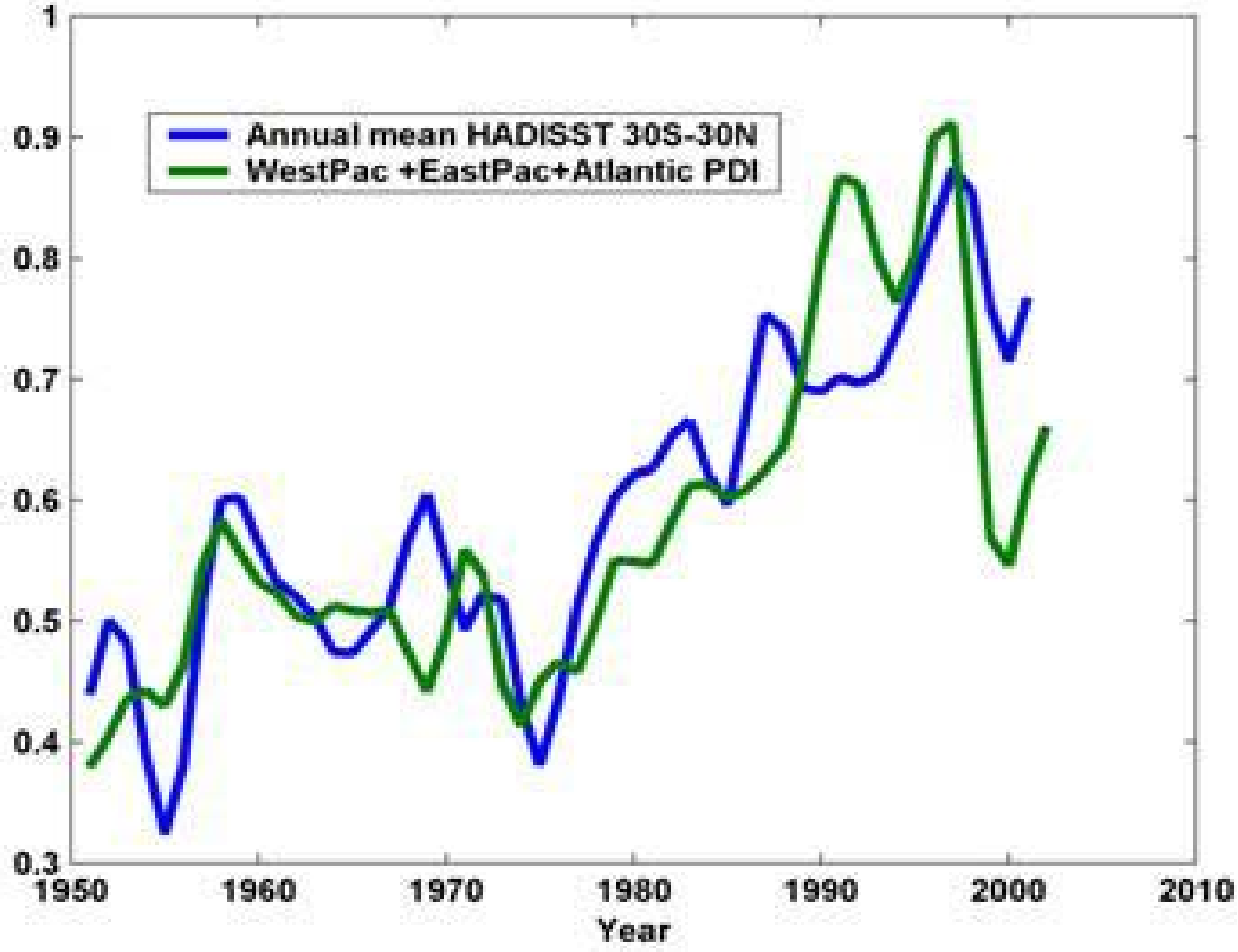
Harm is already occurring (continued



The trend has been sharply upward everywhere.

Harm is already occurring (continued)

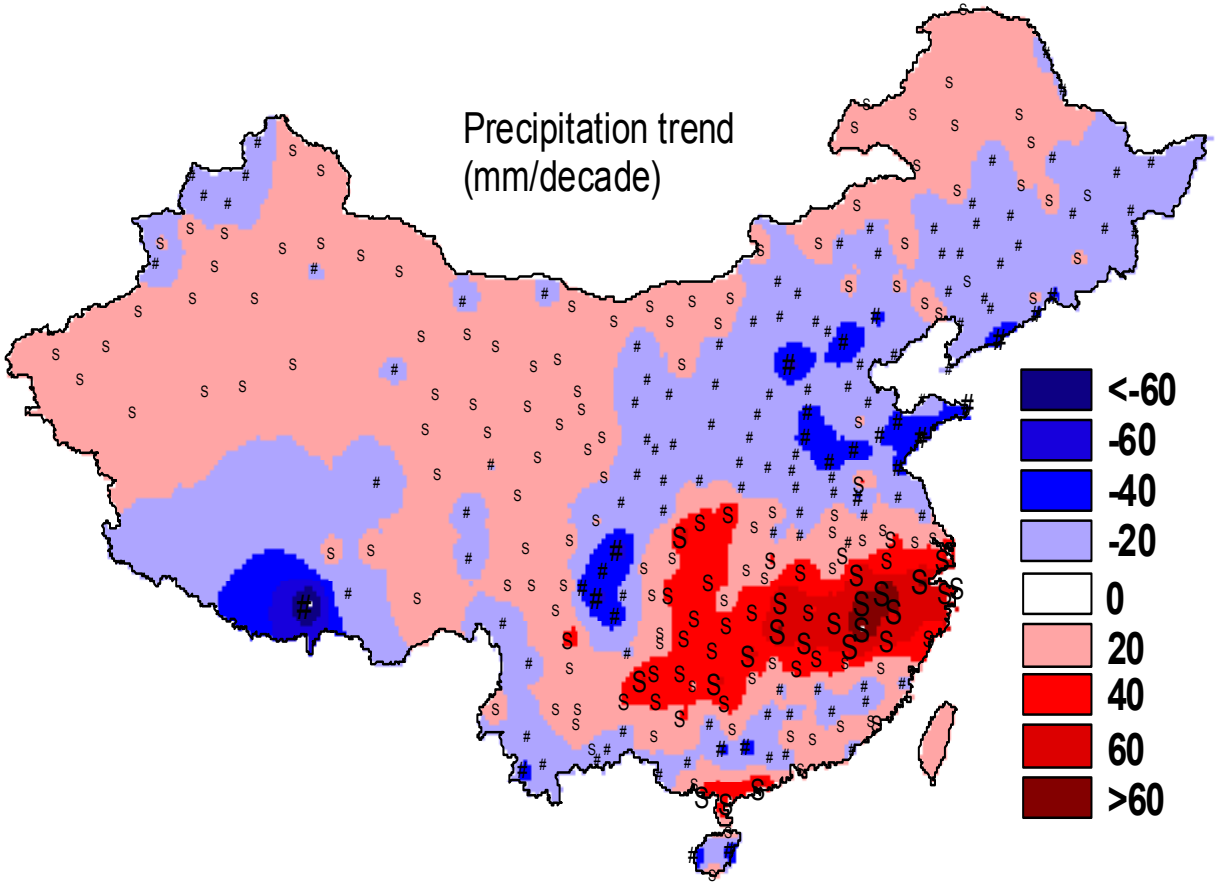
Total power released by tropical cyclones (green) has increased along with sea surface temperatures (blue).



Kerry Emanuel, MIT, 2006

Harm is already occurring (continued)

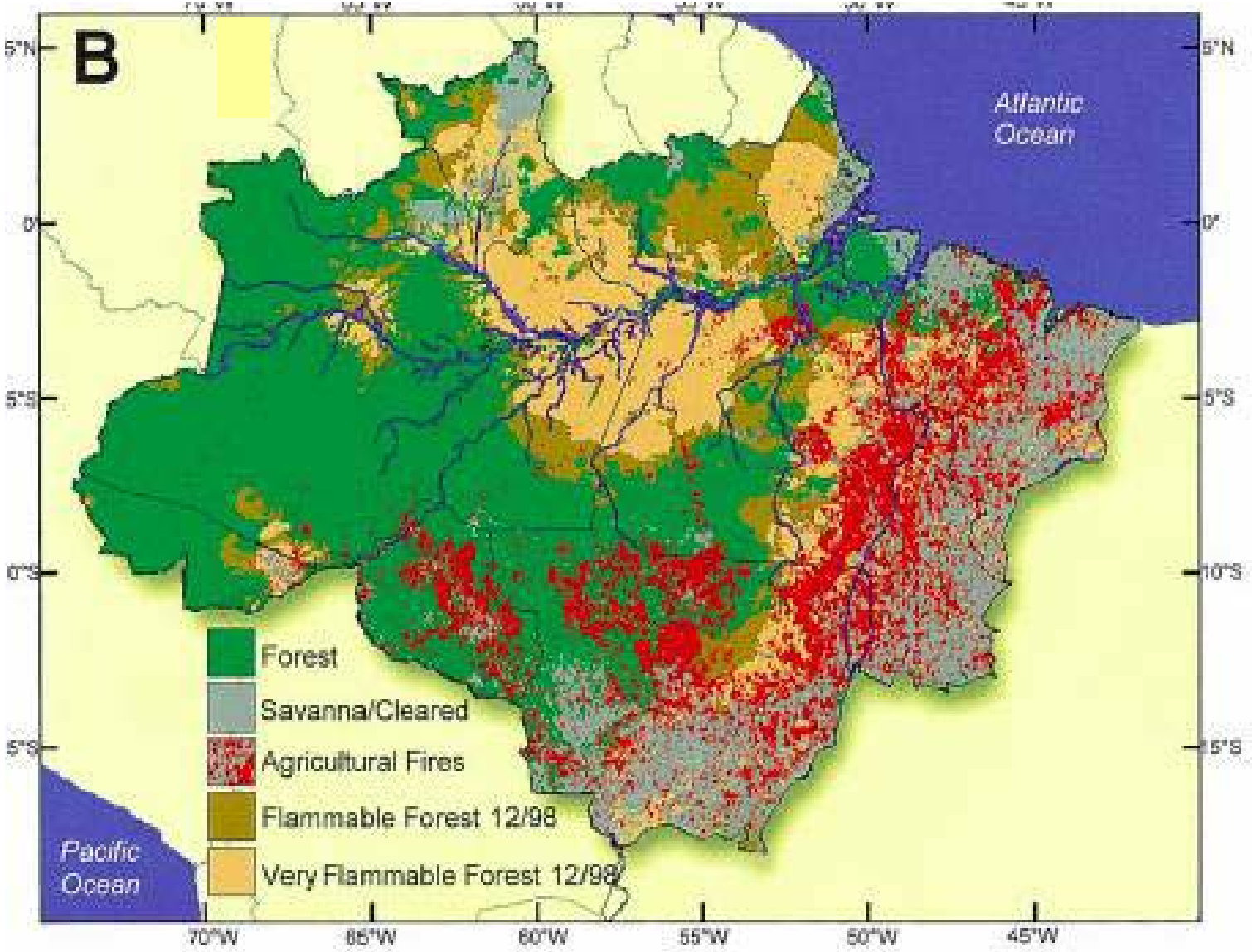
Weakening East-Asia monsoon has meant less moisture flow South to North, producing increased flooding in South, drought in North



Qi Ye, Tsinghua University, May 2006

Harm is already occurring (continued)

The Amazon is drying & burning



This results from the reinforcing effects of altered atmospheric circulation patterns linked to global climate change and the drying influence of deforestation itself.

Nepstad et al., Forest Ecology & Management 154, 2001

Harm is already occurring (concluded)

WHO estimates climate change already causing ≥150,000 premature deaths/yr in 2000

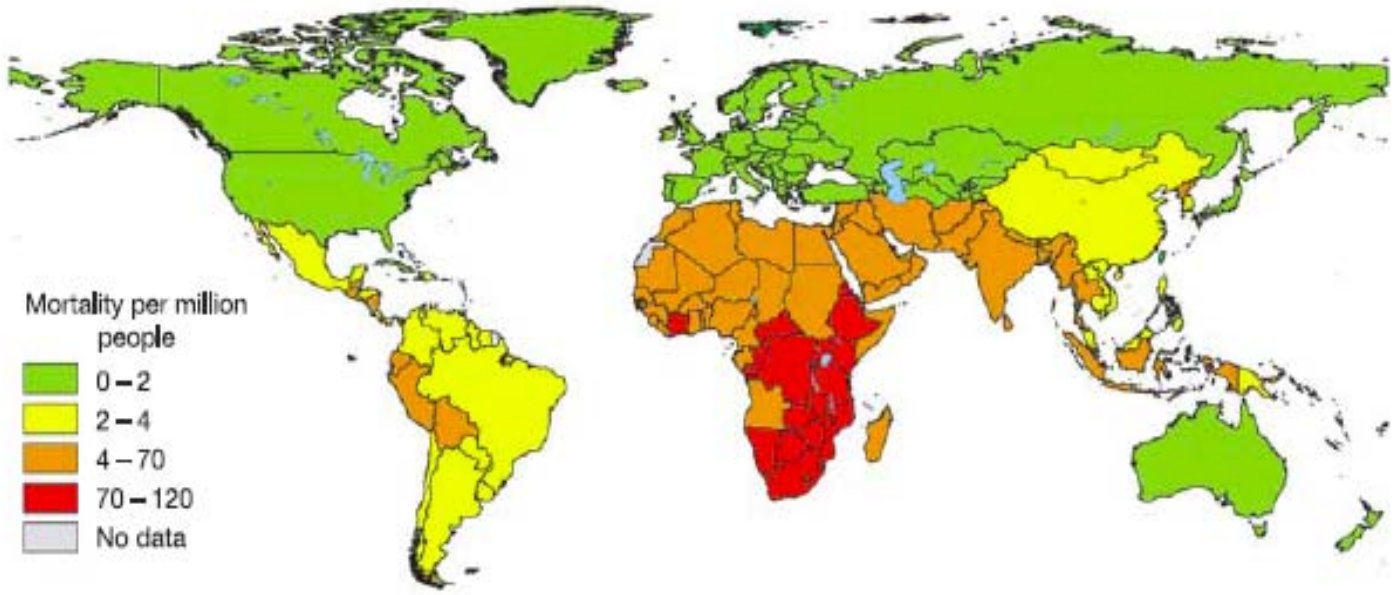
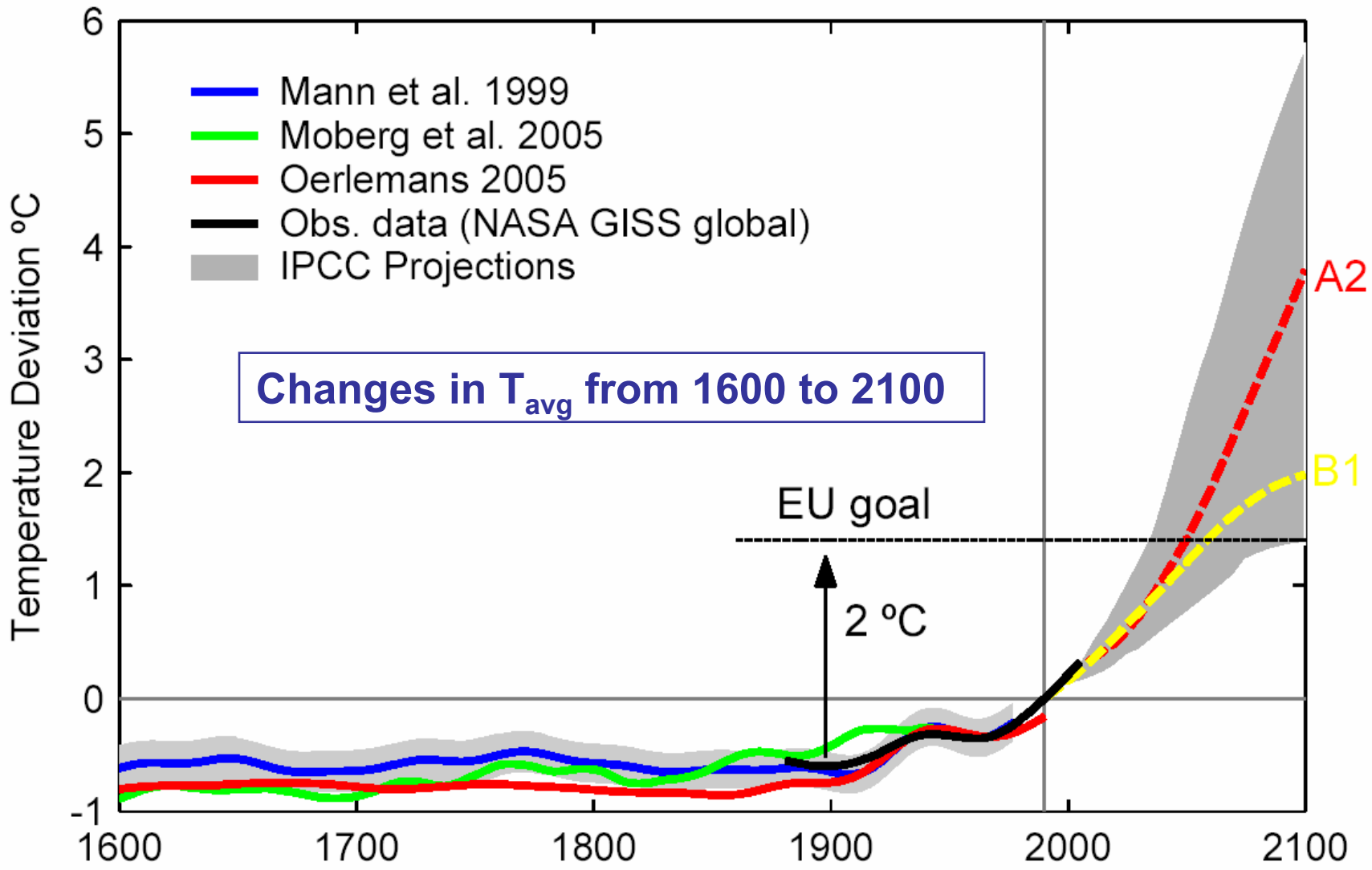


Figure 2 | WHO estimated mortality (per million people) attributable to climate change by the year 2000. The IPCC 'business as usual' greenhouse gas emissions scenario, 'IS92a' and the HadCM2 GCM of the UK Hadley Centre were used to estimate climate changes relative to 'baseline' 1961–1990 levels of greenhouse gases and associated climate conditions. Existing quantitative studies of climate–health relationships were used to estimate relative changes in a range of climate-sensitive health outcomes including: cardiovascular diseases, diarrhoea, malaria, inland and coastal flooding, and malnutrition, for the years 2000 to 2030. This is only a partial list of potential health outcomes, and there are significant uncertainties in all of the underlying models. These estimates should therefore be considered as a conservative, approximate, estimate of the health burden of climate change. Even so, the total mortality due to anthropogenic climate change by 2000 is estimated to be at least 150,000 people per year. Details on the methodology are contained in ref. 57.

Bigger disruption is coming under BAU



Last time T was 2ºC above 1900 level was 130,000 years ago, and sea level was 4-6 m higher. Last time it was 3ºC above 1900 level was ~25 million years ago, and sea level was 20-30 m higher.

Bringing more harm…

Crop yields in tropics start dropping at local $\Delta T \geq 1\text{-}1.5°C$

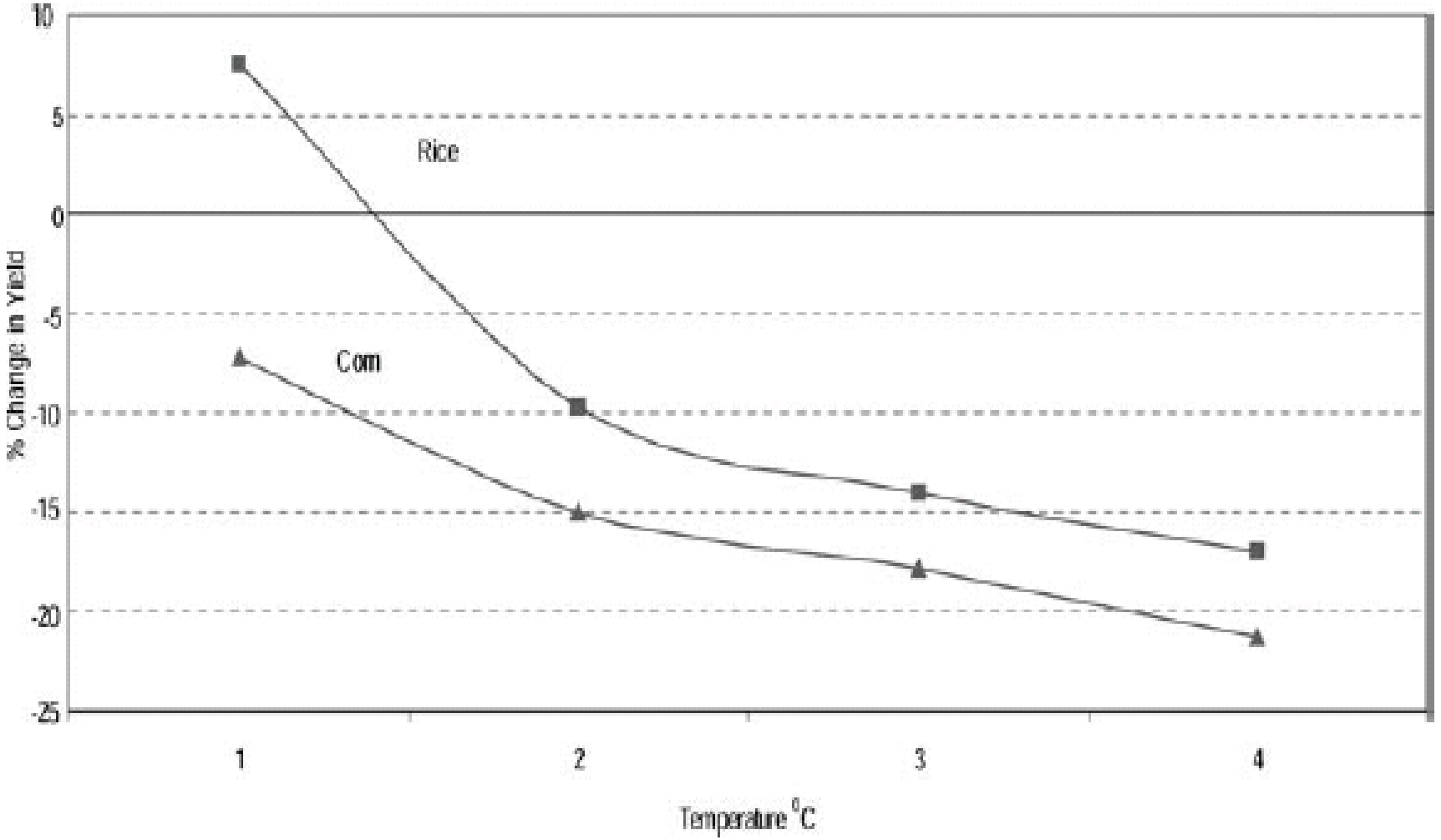
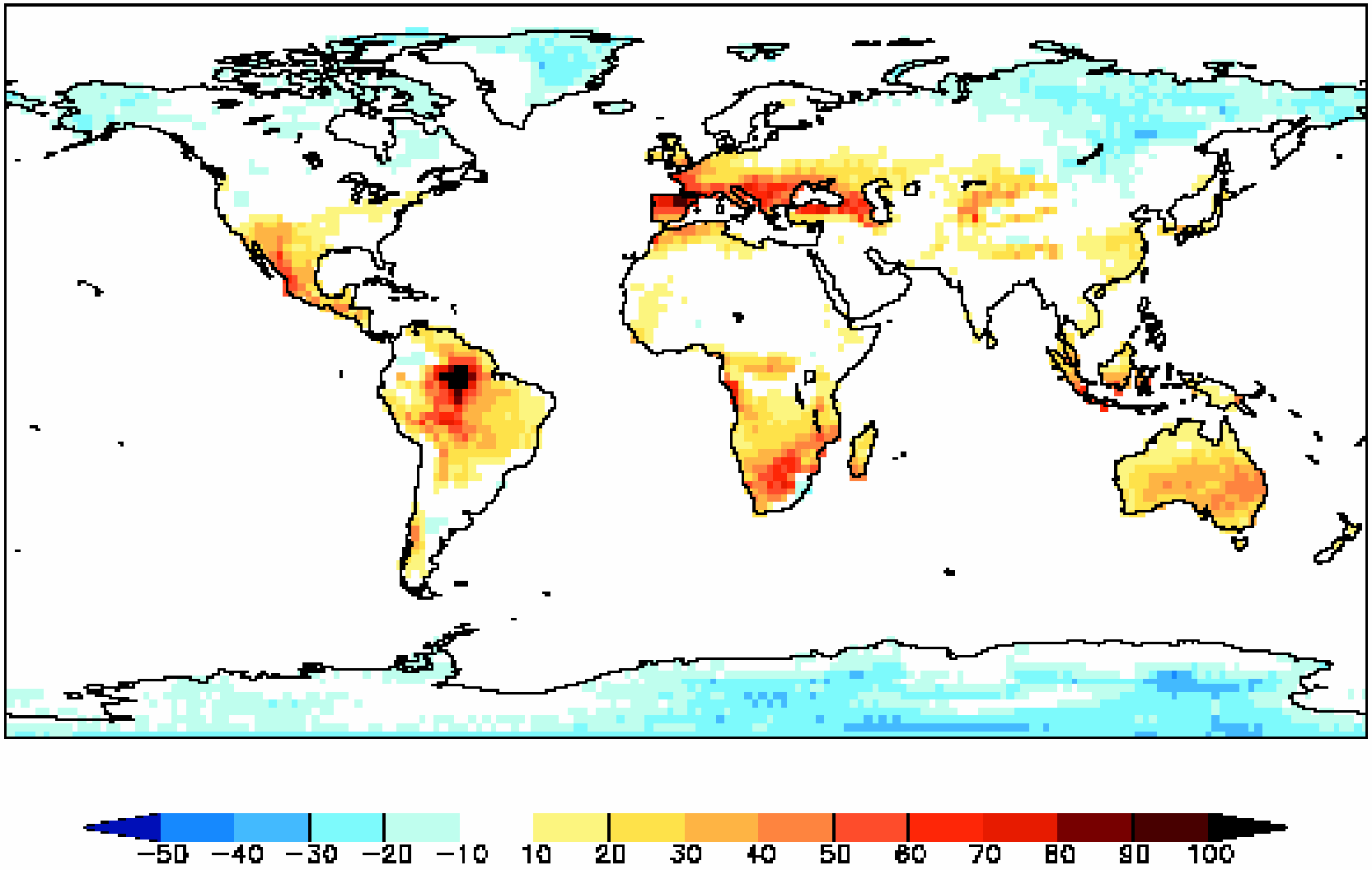


Figure 1. Corn and Rice yields versus temperature increase in the tropics averaged across 13 crop modeling studies. All studies assumed a positive change in precipitation. CO_2 direct effects were included in all studies.

Easterling and Apps, 2005

More harm (continued)…

Drought projections for IPCC's A1B scenario



Percentage change in average duration of longest dry period, 30-year average for 2071-2100 compared to that for 1961-1990.

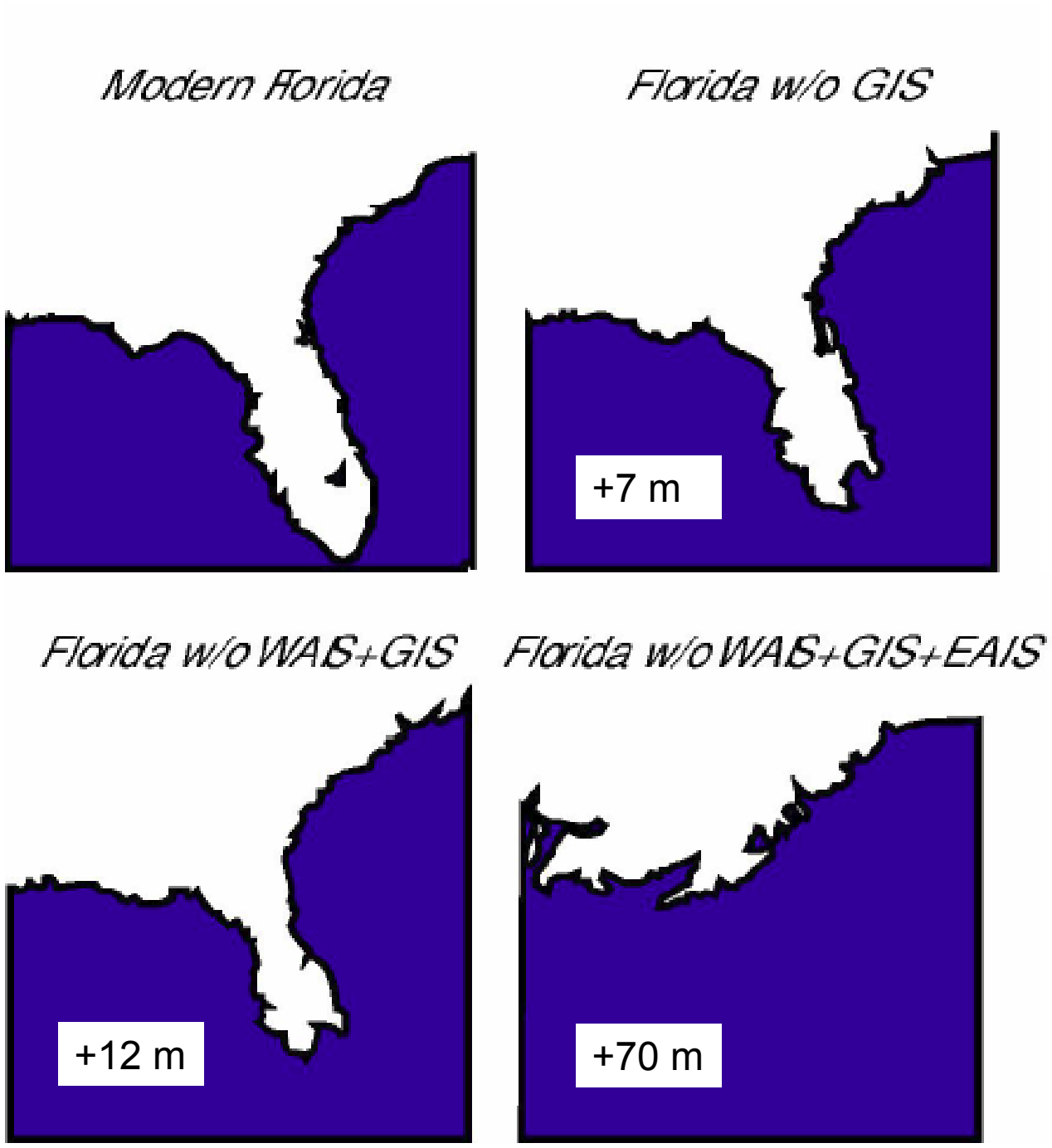
More harm… melting Greenland and Antarctic Ice Sheets would raise sea level up to 70 meters

This would probably take 1000s of years, but rates of 5 m per century can't be ruled out.

GIS = Greenland Ice Sheet

WAIS = West Antarctic Ice Sheet

EAIS = East Antarctic Ice Sheet



Dr. Richard Alley, 2005

Confronting this global disruption…

…there are only three options:

- Mitigation, meaning measures to reduce the pace & magnitude of the changes in global climate being caused by human activities.
- Adaptation, meaning measures to reduce the adverse impacts on human well-being resulting from the changes in climate that do occur.
- Suffering the adverse impacts that are not avoided by either mitigation or adaptation.

Concerning the three options…

- We're already doing some of each.
- What remains to be determined is what the future mix will be.
- Minimizing the amount of suffering in that mix can only be achieved by doing a lot of mitigation and a lot of adaptation.

The dual challenge of climate change is to
- avoid the unmanageable (mitigation)
- manage the unavoidable (adaptation)

Adaptation options include…

- Changing cropping patterns
- Developing heat-, drought-, and salt-resistant crop varieties
- Strengthening public-health & environmental-engineering defenses against tropical diseases
- Building new water projects for flood control & drought management
- Building dikes and storm-surge barriers against sea-level rise
- Avoiding further development on flood plains & near sea level

Mitigation options include…

(CERTAINLY)

- Reduce deforestation; increase reforestation & afforestation
- Modify agricultural practices to reduce emissions of greenhouse gases & build up soil carbon
- Reduce emissions of greenhouse gases & soot from the energy sector

(CONCEIVABLY)

- “Scrub” greenhouse gases from the atmosphere technologically
- “Geo-engineering” to create cooling effects offsetting greenhouse heating

How much mitigation is needed, how soon?

- The UN Framework Convention on Climate Change of 1992 is “the law of the land” in 191 countries (including the United States).
- It calls for

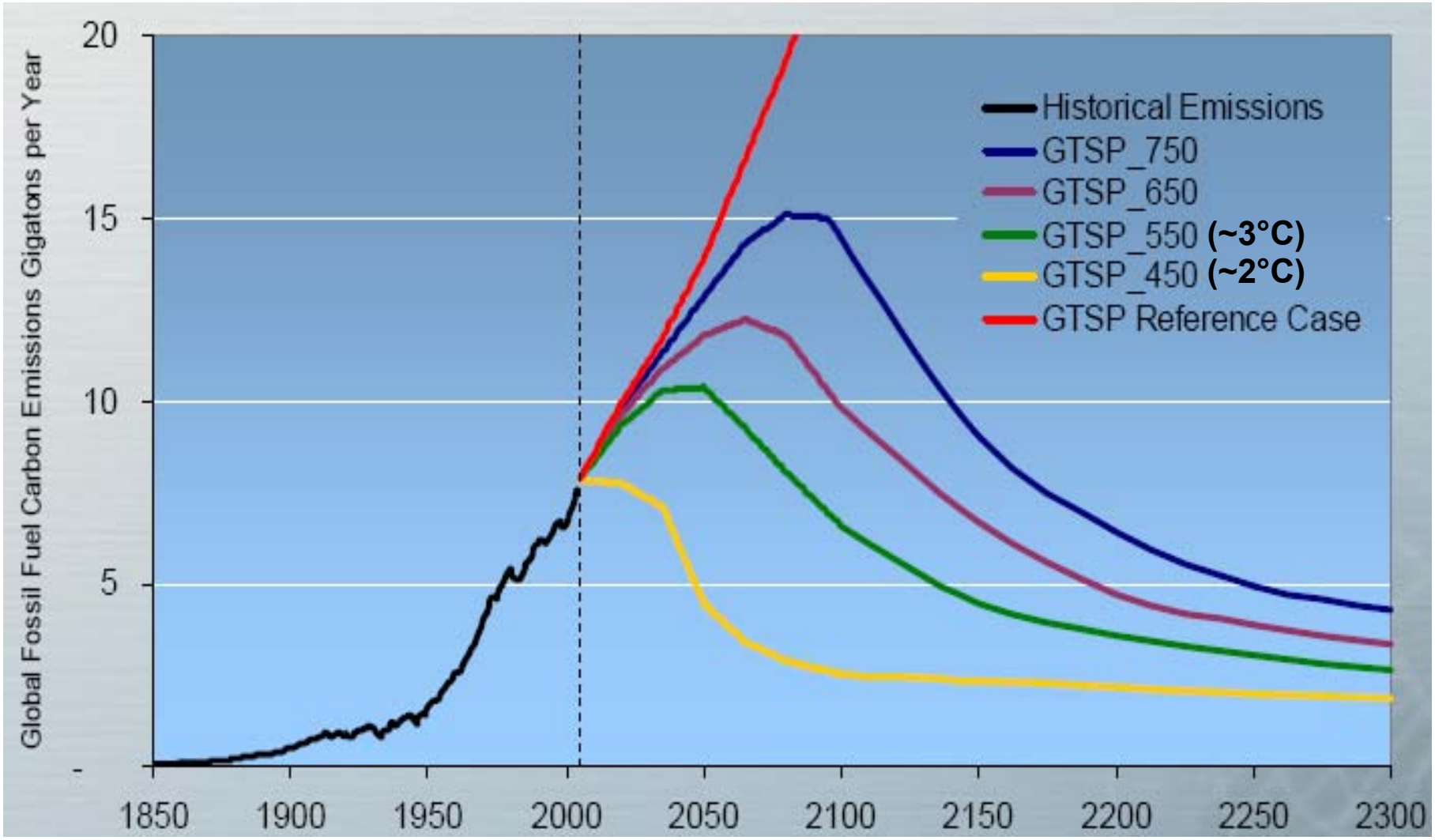
  “*stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system”.*

- But there was no formal consensus in 1992 as to what constitutes “dangerous anthropogenic interference” or what level of GHG concentrations will produce it.

How much, how soon? (continued)

- There's still no "official" consensus, but it's becoming clear that the current level of interference is dangerous:
- T_{avg} would rise 0.6°C more (to 1.4ºC above pre-industrial) even if GHG concentrations were stabilized today.
- Chance of a tipping point into catastrophic change grows rapidly for T_{avg} more than 2ºC above pre-industrial (IPCC 2007, UNSEG 2007).
- For a better than even chance of not exceeding ΔT_{avg}=2ºC, CO2 emissions must peak no later than 2015-2025 & fall steadily thereafter.

Fossil CO_2 emissions paths: BAU versus stabilizing CO_2 concentration to limit ΔT_{avg}

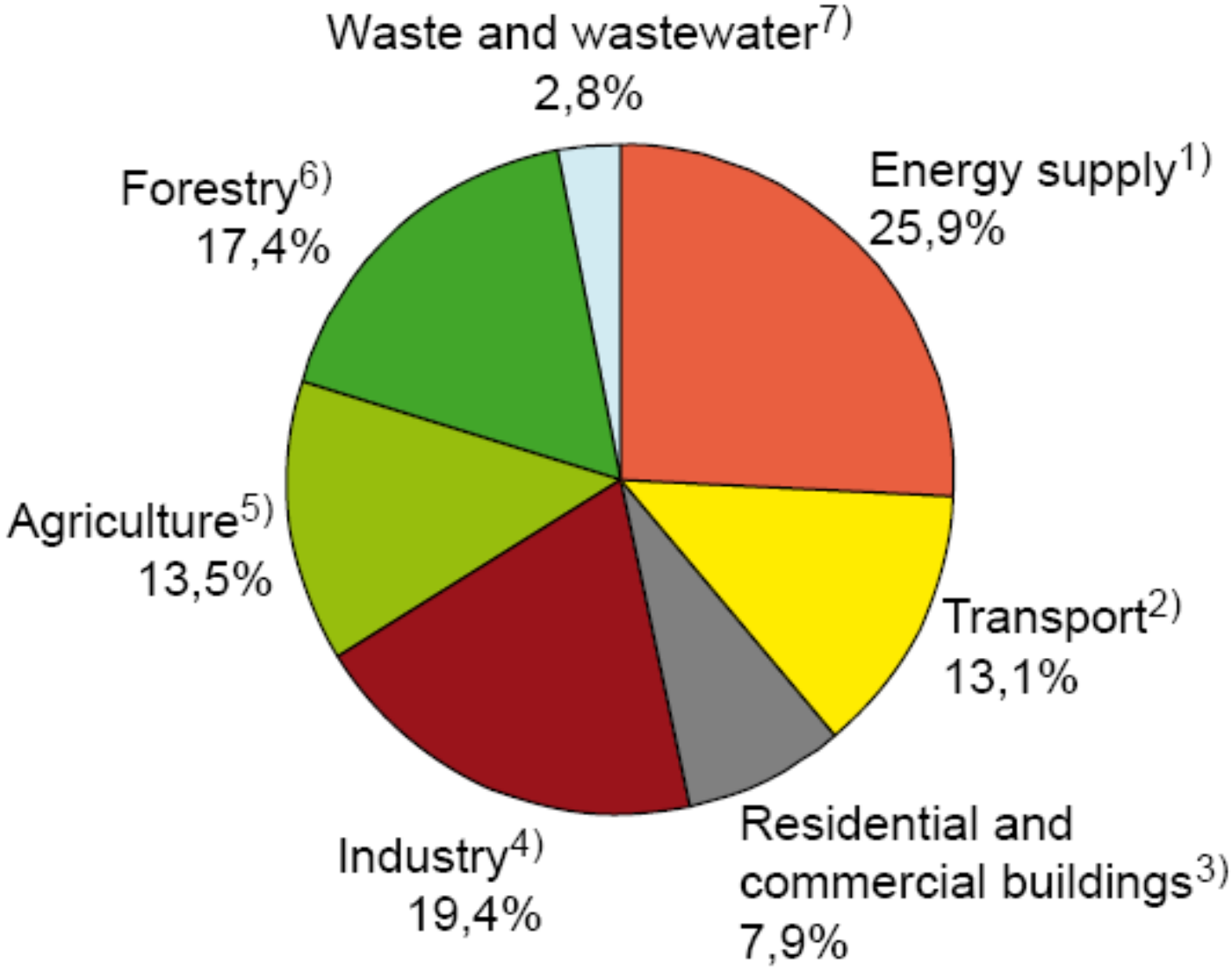


Global Energy Technology Strategy, Battelle, 2007

Some mitigation realities

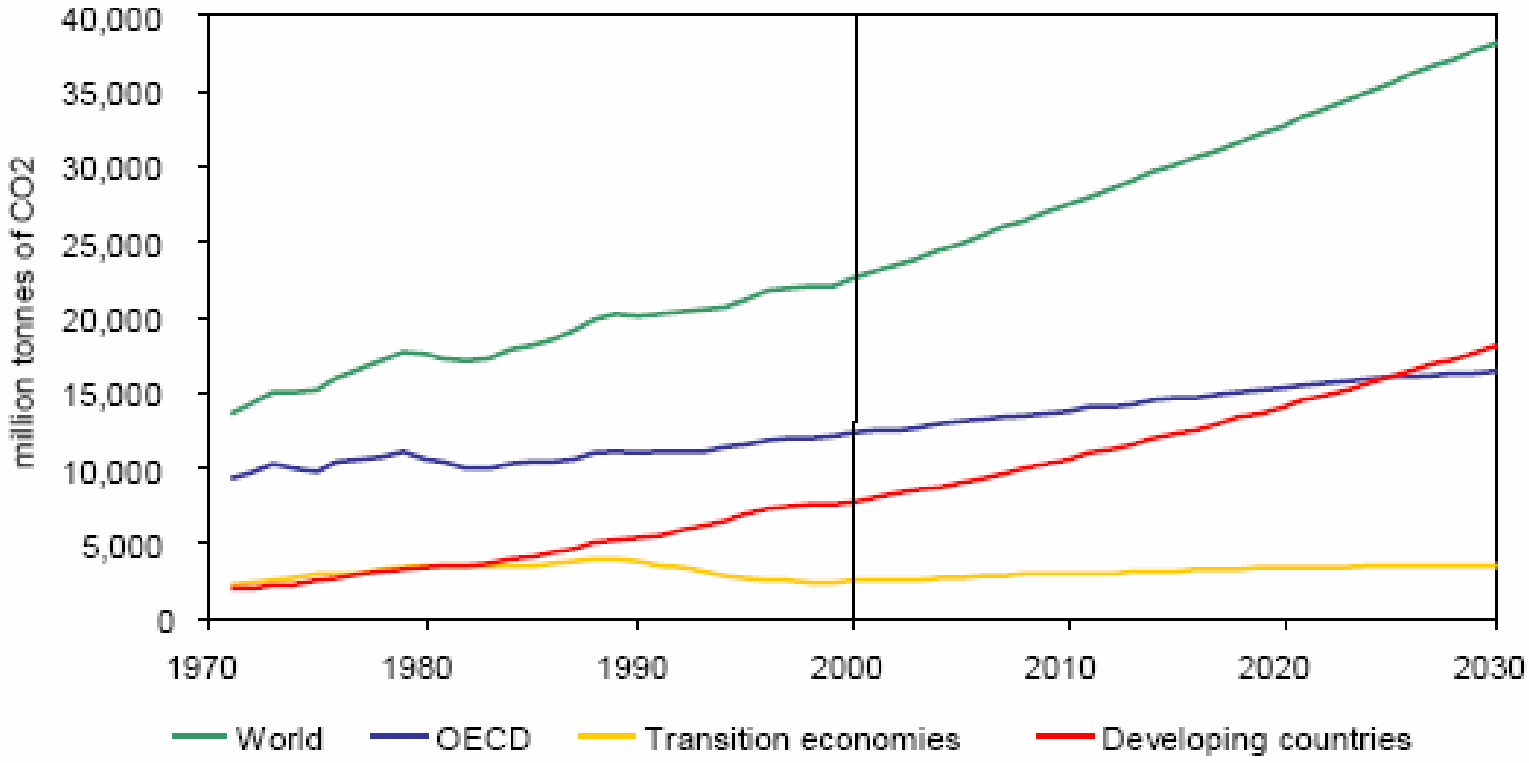
- Burning coal, oil, & natural gas supplies 80% of the world's energy, accounts for ~3/4 of human CO_2.
- Deforestation & burning in the tropics account for most of the other 1/4.
- 2/3 of fossil CO_2 emissions now come from industrialized countries, but developing countries to dominate after 2020.
- Global energy system can't be changed quickly: ~$15T is invested in it, & normal turnover time is ~40 yrs.
- Deforestation isn't easy to change either: forces driving it are deeply embedded in the economics of food, fuel, timber, trade, & development.

Sources of GHG emissions, 2004



IPCC WGIII, 2007

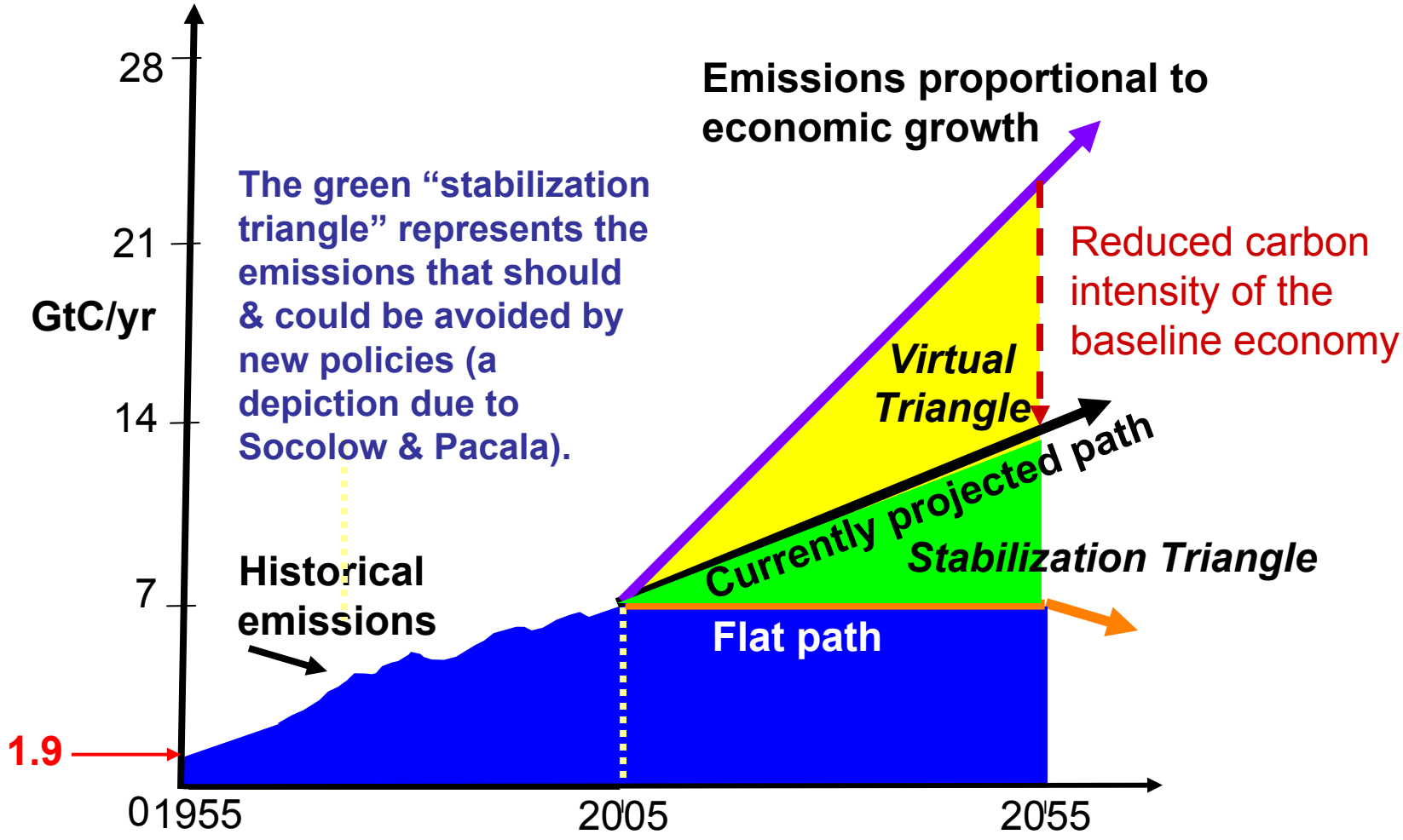
Energy-related CO_2 emissions



World emissions increase by 1.8% per year to 38 billion tonnes in 2030 – 70% above 2000 levels

Source: *IEA World Energy Outlook*, 2002

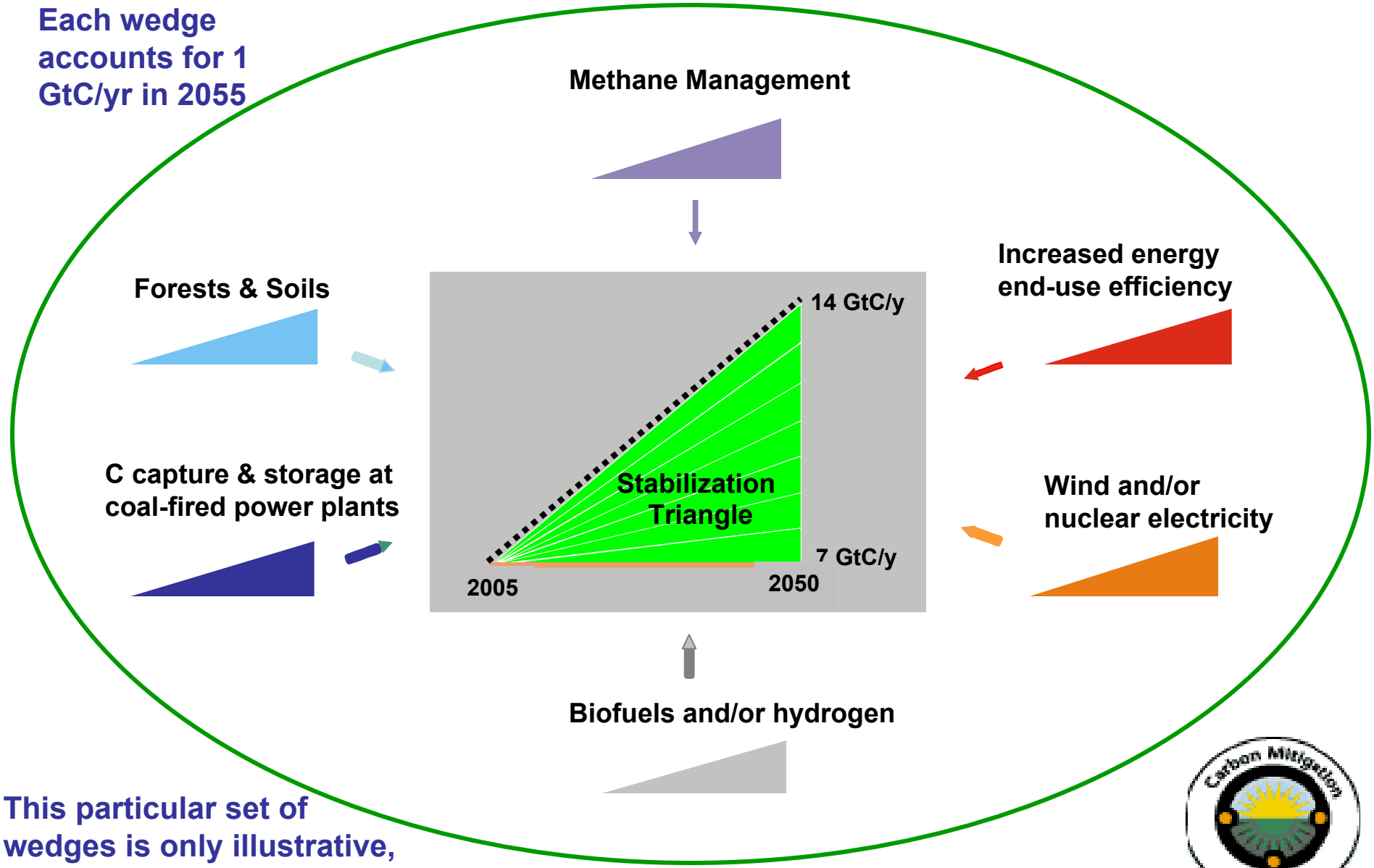
Stabilizing at 450-500 ppmv would be possible if emissions were flat for ~50 years, then declined.



The virtual triangle results more from structural shifts in the economy (toward services) and less from the carbon-saving activity required to fill the stabilization triangle.

The triangle can be filled by a portfolio of 7 wedges

Each wedge accounts for 1 GtC/yr in 2055



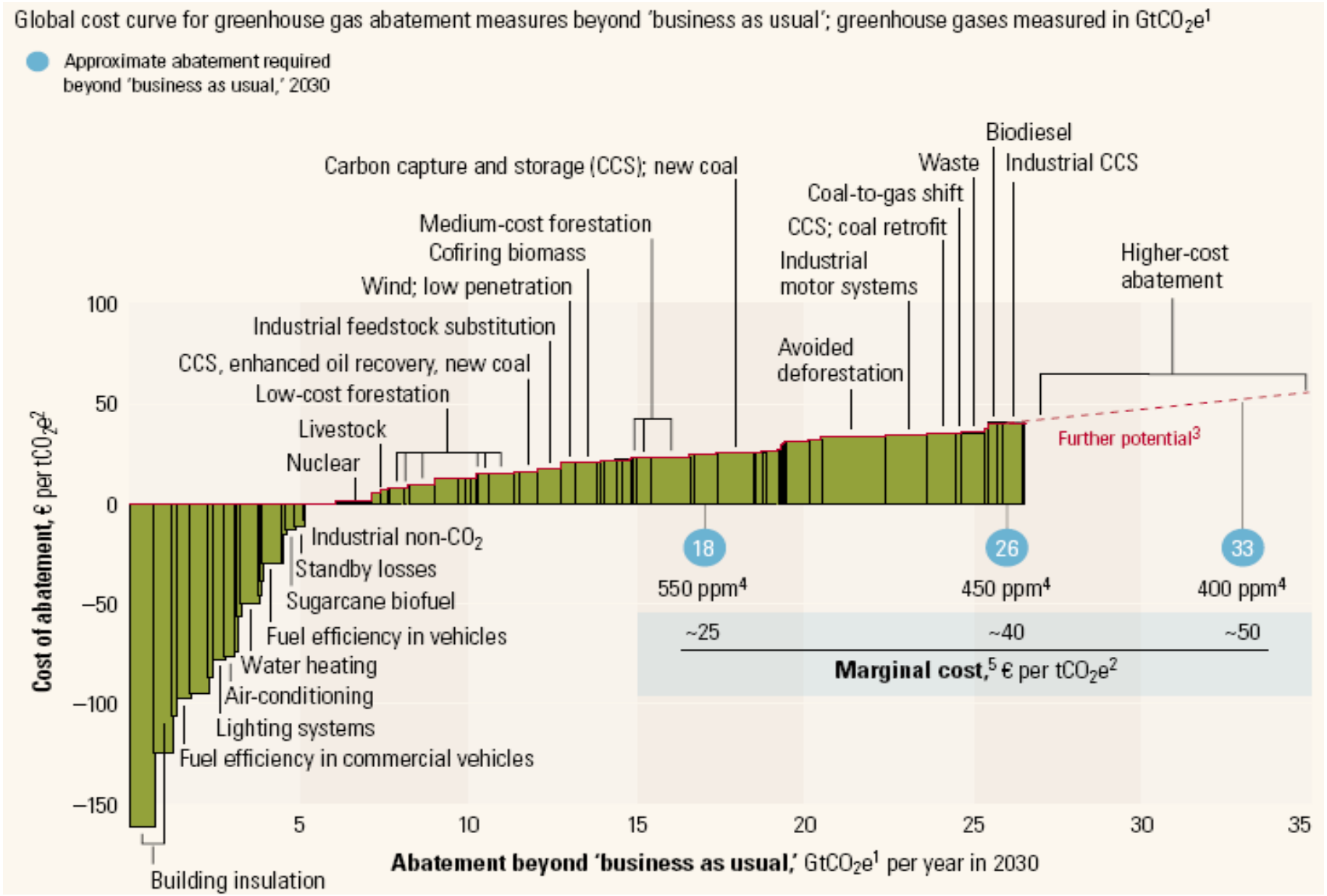
This particular set of wedges is only illustrative, not prescriptive.

Carbon Mitigation Initiative

More mitigation realities

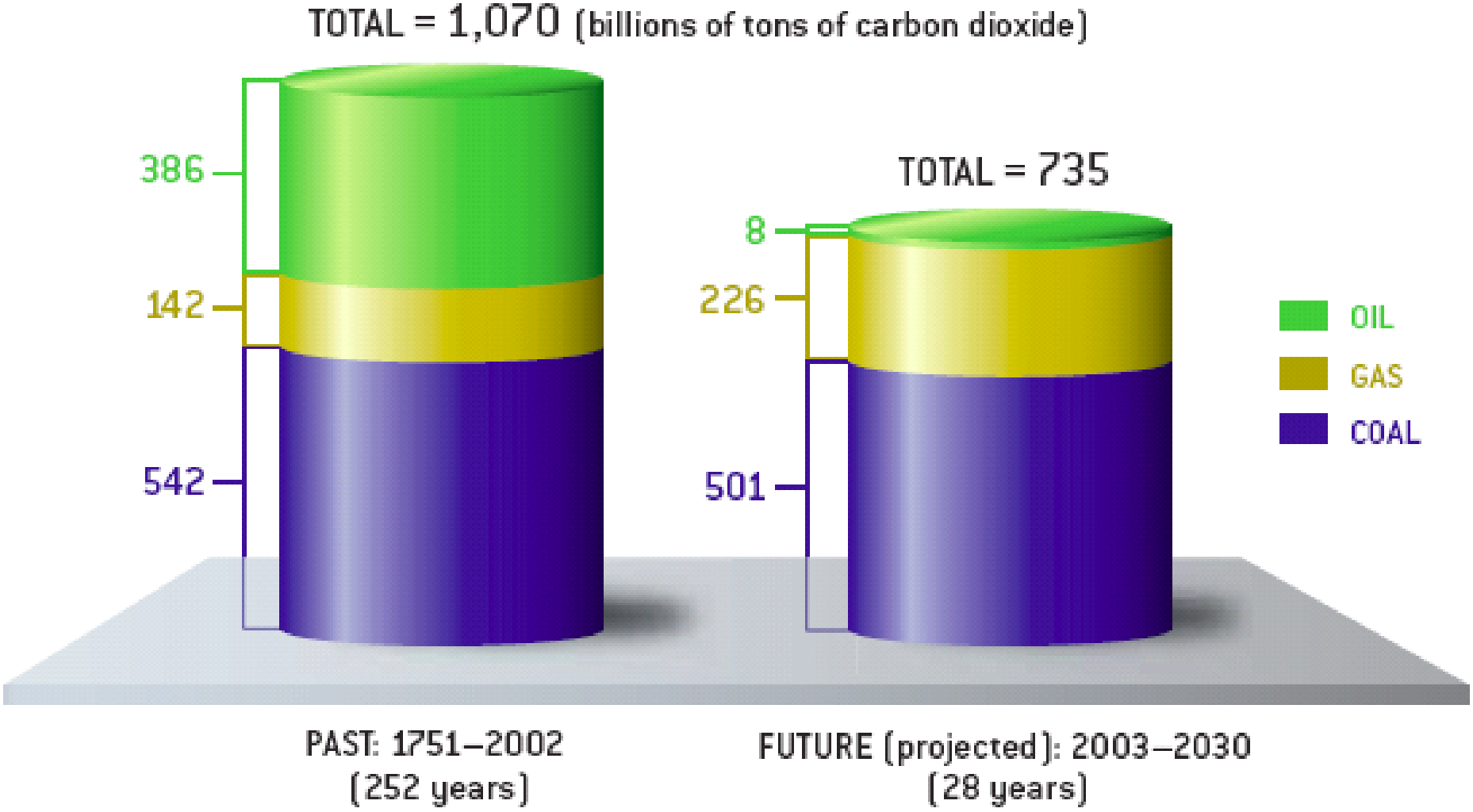
- The cheapest, fastest, cleanest, surest source of emissions reductions is to increase the efficiency of energy use in buildings, industry, and transport.
- Many such approaches are "win-win": their co-benefits in saved energy, increased energy security, reduced conventional pollution, etc., are more than worth their costs.
- Some supply-side mitigation options (wind, some biofuels) are also "win-win", as are many adaptation options.
- The "win-win" approaches will not be enough. Adequate mitigation will require putting a price on emissions of GHG (via emissions tax or tradable emissions permits).
- Cost might reach 1-2% of world GDP.

Supply curve for GHG abatement in 2030



McKinsey, 2006

Capturing CO_2 from power plants will be costly, but concentrations can't be stabilized soon enough unless we do it.



LIFETIME FOSSIL-FUEL EMISSIONS from power plants projected to be built during the next quarter of a century will be comparable to all the emissions during the past 250 years.

Courtesy David Hawkins, Rob Socolow, & Scientific American

Some policy realities

- In applying the costlier solutions, the industrialized nations must lead – going first, paying more of the up-front costs, offering assistance to developing countries.

  This is a matter of historical responsibility, capacity, equity, and international law (the UNFCCC).

- Developing countries will need to be compensated for reducing/avoiding deforestation.
- Without a formal & binding global agreement on the allocation of emissions in the post-Kyoto period, the needed global reductions will not be achieved.
- The best basis for such an agreement in the short term is probably reductions in emission intensity (GHG/GDP); in the longer run, the only politically acceptable basis will be equal per-capita emissions rights.

The most important next steps

- Accelerate “win-win” mitigation and adaptation measures
- Put a price on GHG emissions so marketplace can work to find cheapest reductions
- Pursue a new global framework for mitigation and adaptation in the post-Kyoto period
- Sharply increase investments in energy-technology research, development, demonstration
- Expand international cooperation on deploying advanced energy technologies

Some references

John P. Holdren, "The energy innovation imperative", *Innovations: Technology/ Globalization/Governance*, Vol. 1, No. 2, Spring 2006
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