Recent Findings from Climate Science and their Implications for Policy

John P. Holdren

Teresa & John Heinz Professor of Environmental Policy
and Professor of Environmental Science and Policy

HARVARD UNIVERSITY

Director

THE WOODS HOLE RESEARCH CENTER

Informal Thematic Debate of the General Assembly
"Climatic Change as a Global Challenge"
United Nations, New York • 31 July 2007

My comments will cover:

Round 1: Summary of the science

Round 2: Implications of the science for adaptation & mitigation

Round 1:

Summary of the Science

Main science messages: 1

- Significant disruption of global climate by human activities is an observed fact

  "Global warming" is a misleading term. It implies something uniform, gradual, and benign. What is happening is nonuniform, rapid, and damaging.

- The most important cause is carbon dioxide accumulating in the atmosphere from burning fossil fuels and cutting down tropical forests.

Main science messages: 2

- Global climatic disruption is <u>already causing serious harm</u> to human well-being in many places around the world.

  This includes increased floods, droughts, heat waves, wildfires, and severe tropical storms, plus, probably, more tropical disease.

- Continued "business as usual" in fossil-fuel burning & deforestation will lead to <u>much greater disruption and harm</u>…soon:

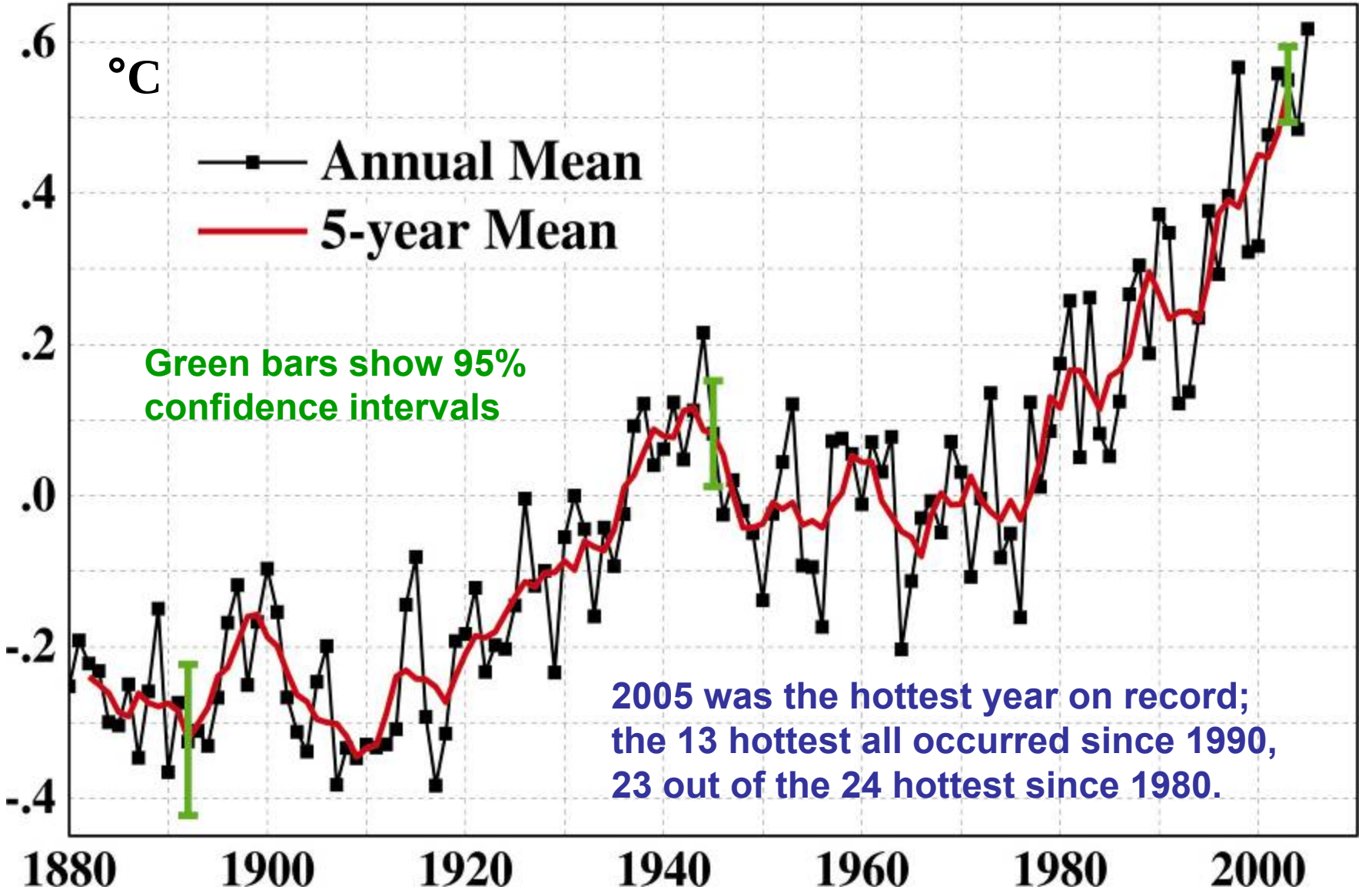
  more of the above plus falling crop production, loss of coral reefs, disruption of ocean fisheries, accelerating sea-level rise.

These conclusions are supported by…

- **Intergovernmental Panel on Climate Change** (http://www.ipcc.ch)
- **UN Foundation / Sigma Xi Scientific Expert Group on Climate Change and Sustainable Development** (http://www.unfoundation.org/SEG/)
- **The leadership of the academies of science of Brazil, Canada, China, France, Germany, Italy, India, Japan, Russia, UK, USA** (http://nationalacademies.org/onpi/06072005.pdf)
- **Board of Directors of the American Association for the Advancement of Science** http://www.aaas.org/news/press_room/climate_change/mtg_200702/aaas_climate_statement.pdf

Supplementary materials for round 1

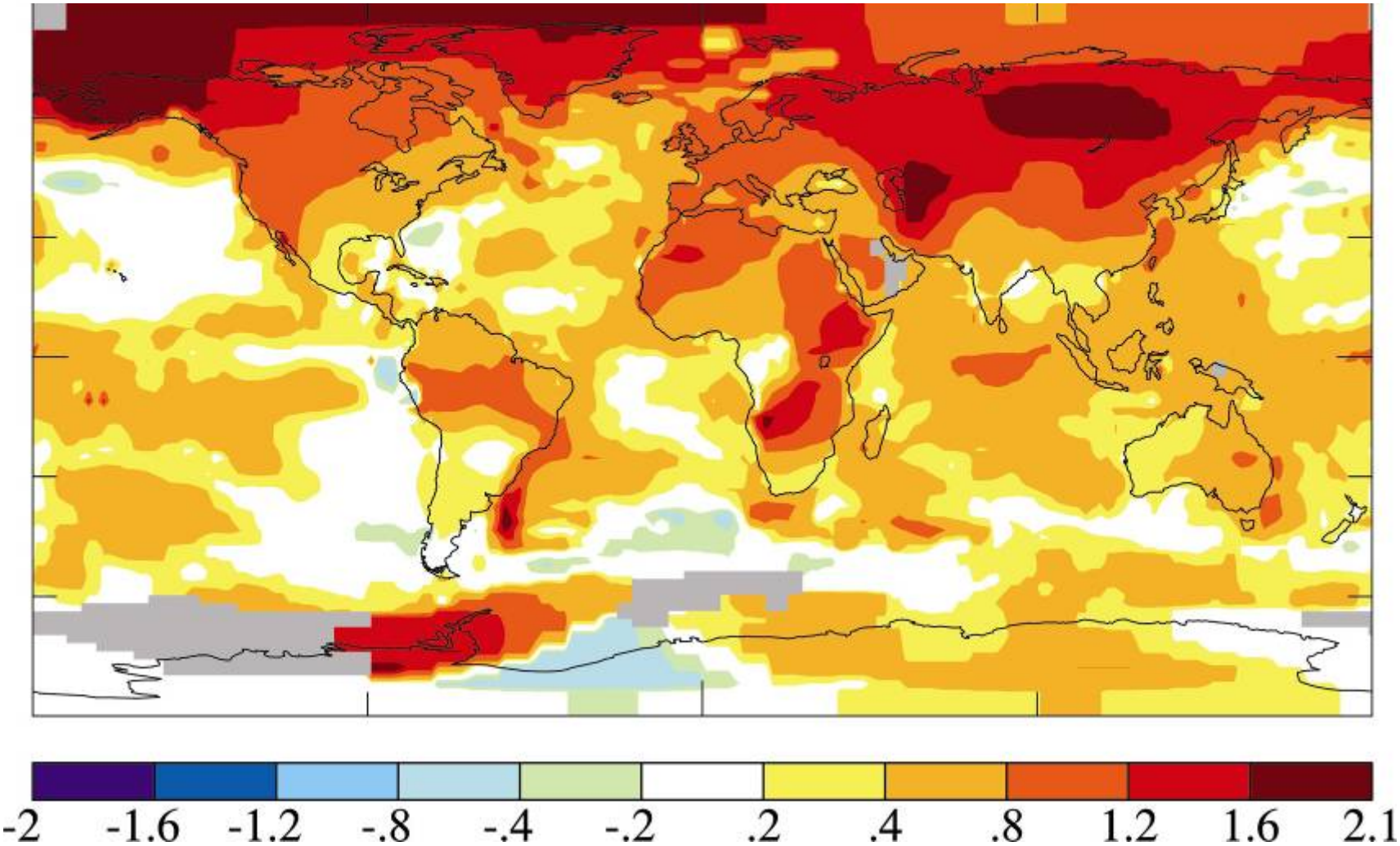
The Earth continues to get hotter



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

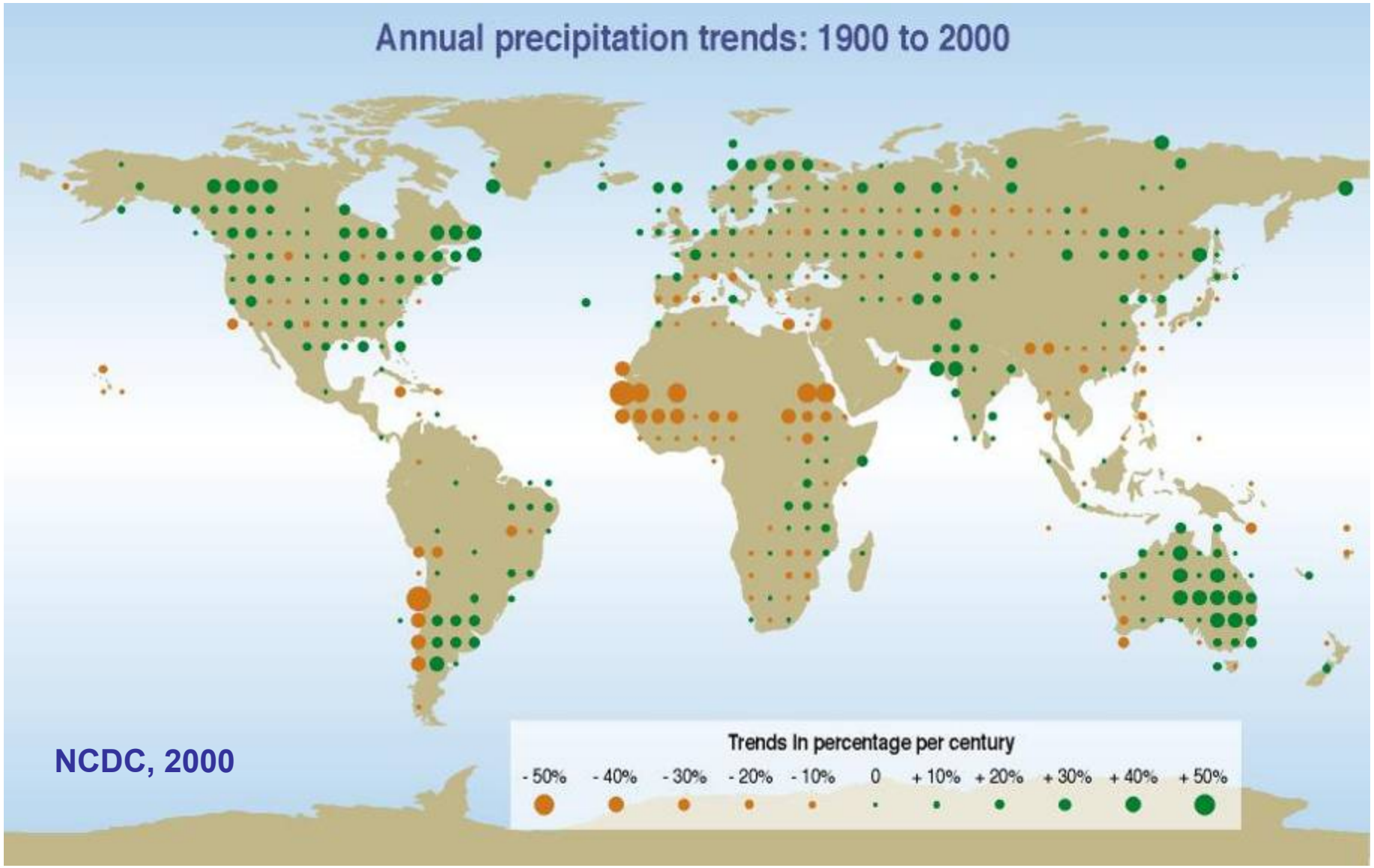
But the heating is not uniform geographically

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



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

And T is not the only factor that's changing



NCDC, 2000

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

Coastal 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.

Mountain glaciers are shrinking

Qori Kalis Glacier, Peru

a 1978

1978

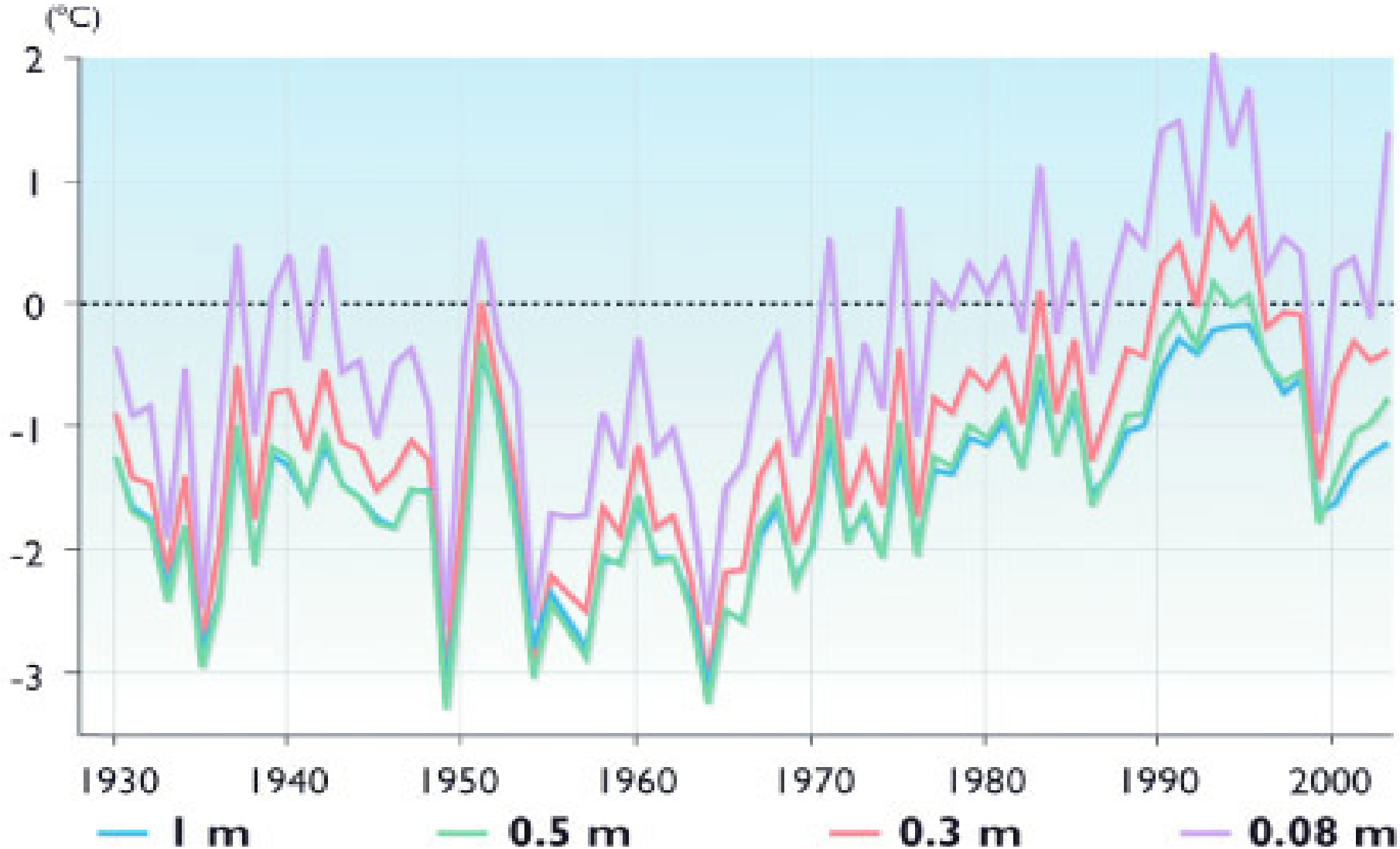
b 2002

2002

Figure 3 | Changes in the Qori Kalis Glacier, Quelccaya Ice Cap, Peru, between 1978 (a) and 2002 (b). Glacier retreat during this time was 1,100 m (L. Thompson, personal communication). Photographs courtesy of L. Thompson.

Permafrost is thawing

Average ground temperature near Fairbanks, Alaska, degrees C



Permafrost thaws when T ≥ 0°C

ACIA 2004

NASA

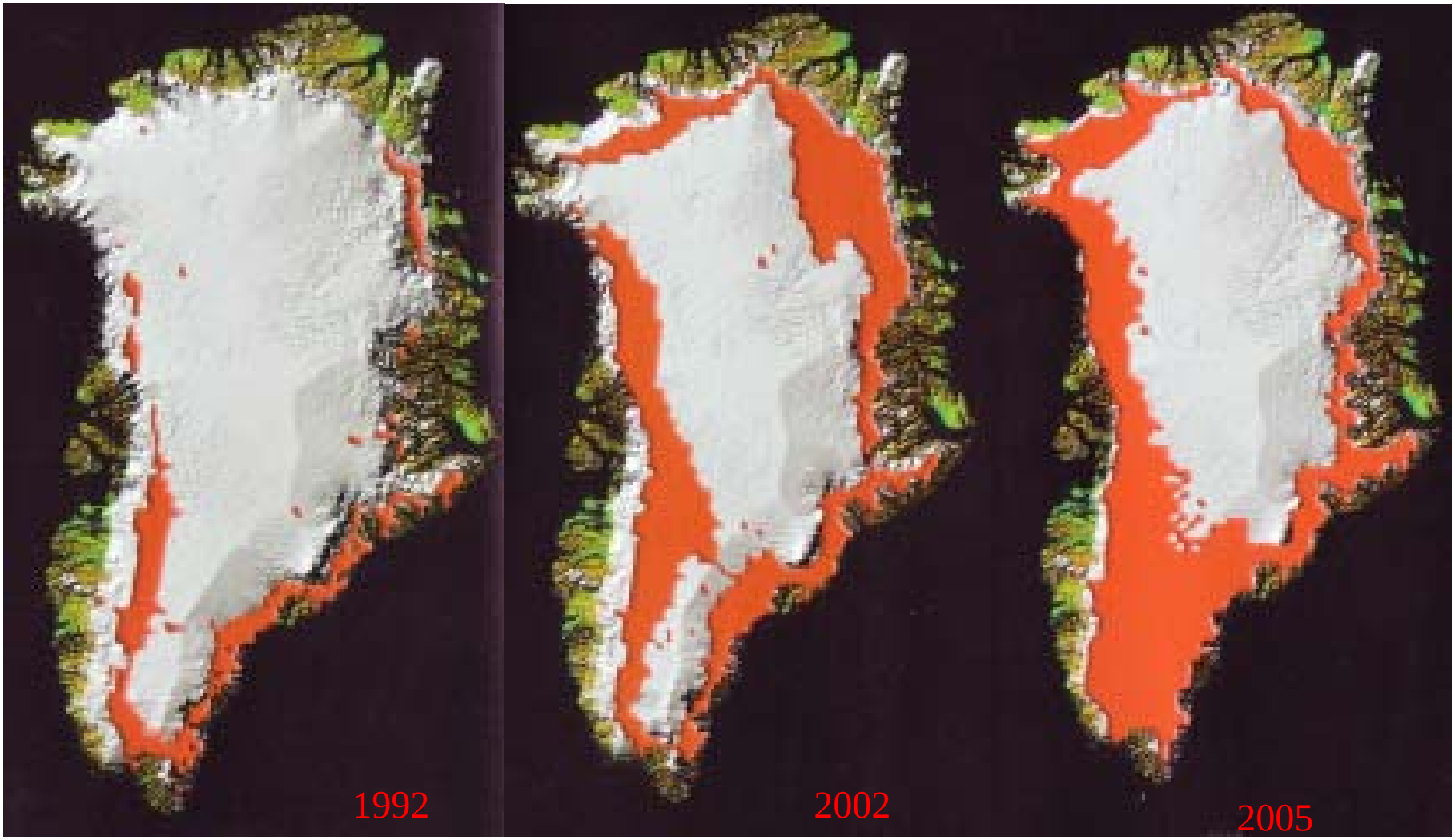
Sea ice is receding

Extent of Arctic summer ice in 1979 (top satellite image) and in 2003 (lower satellite image).

North Polar ice cap is sea ice -- it's floating and so does not change sea level when it melts.

But the reduced reflectivity when the ice is replaced by water amplifies the warming effect of greenhouse gases.

Surface melting on Greenland is expanding



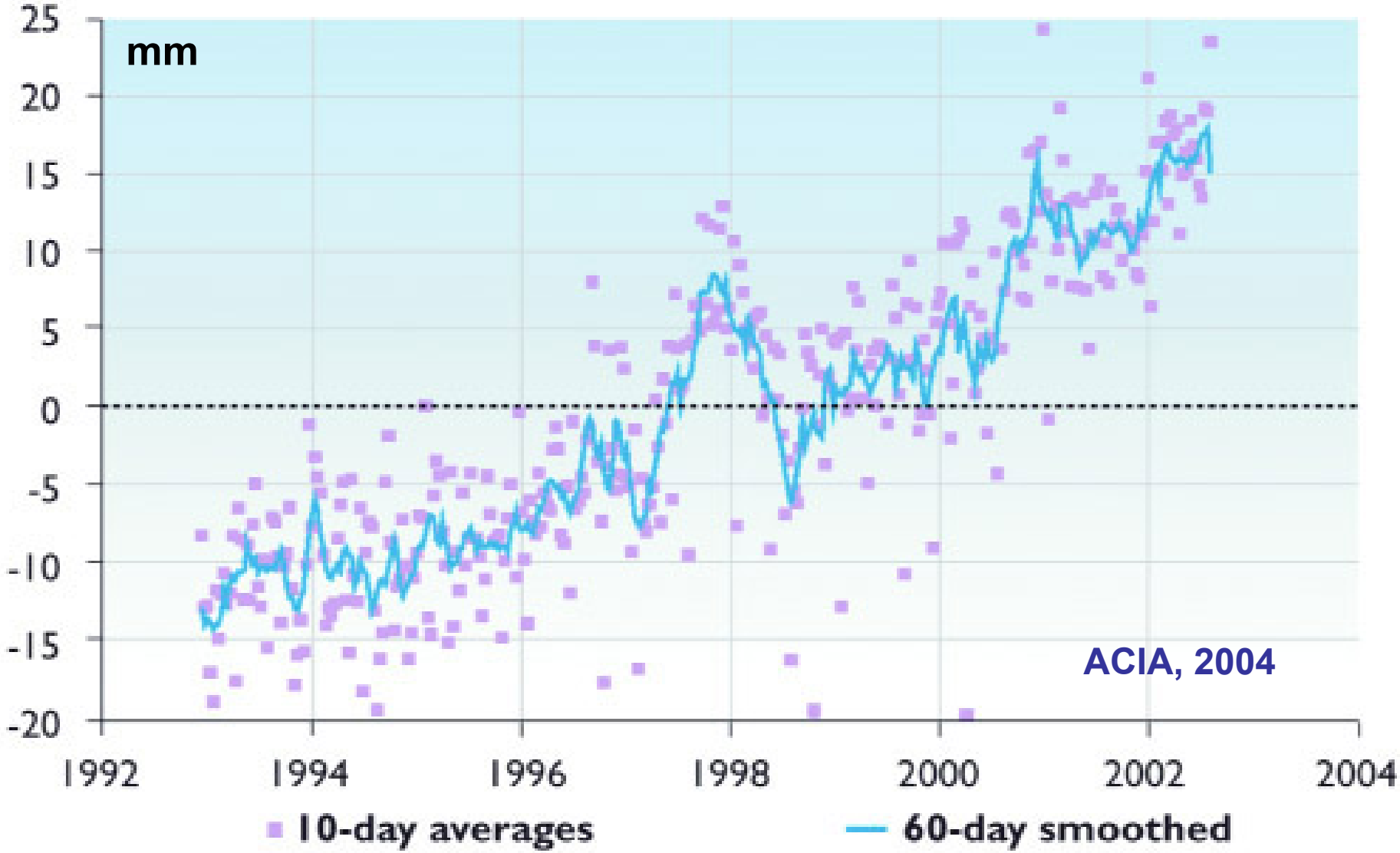
In 1992 scientists measured this amount of melting in Greenland as indicated by red areas on the map

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

And in 2005, it accelerated dramatically yet again

Source: ACIA, 2004 and CIRES, 2005

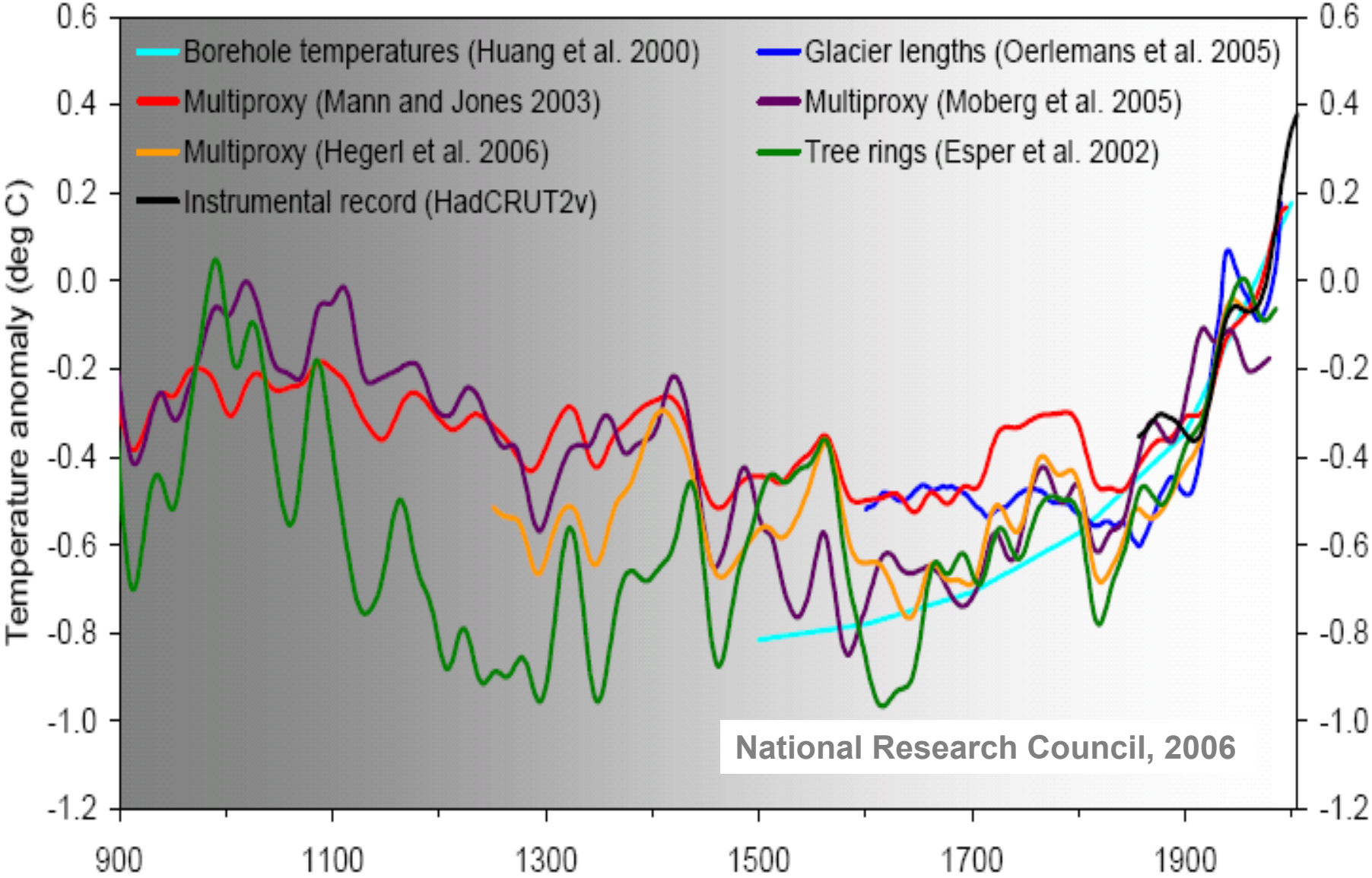
Sea-level rise is accelerating



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

What's happening reverses a long cooling trend

"Proxy" temperature reconstructions + 125-yr thermometer record



Direction & rate of temperature change switched suddenly in 1800s

Humans are the dominant cause:

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

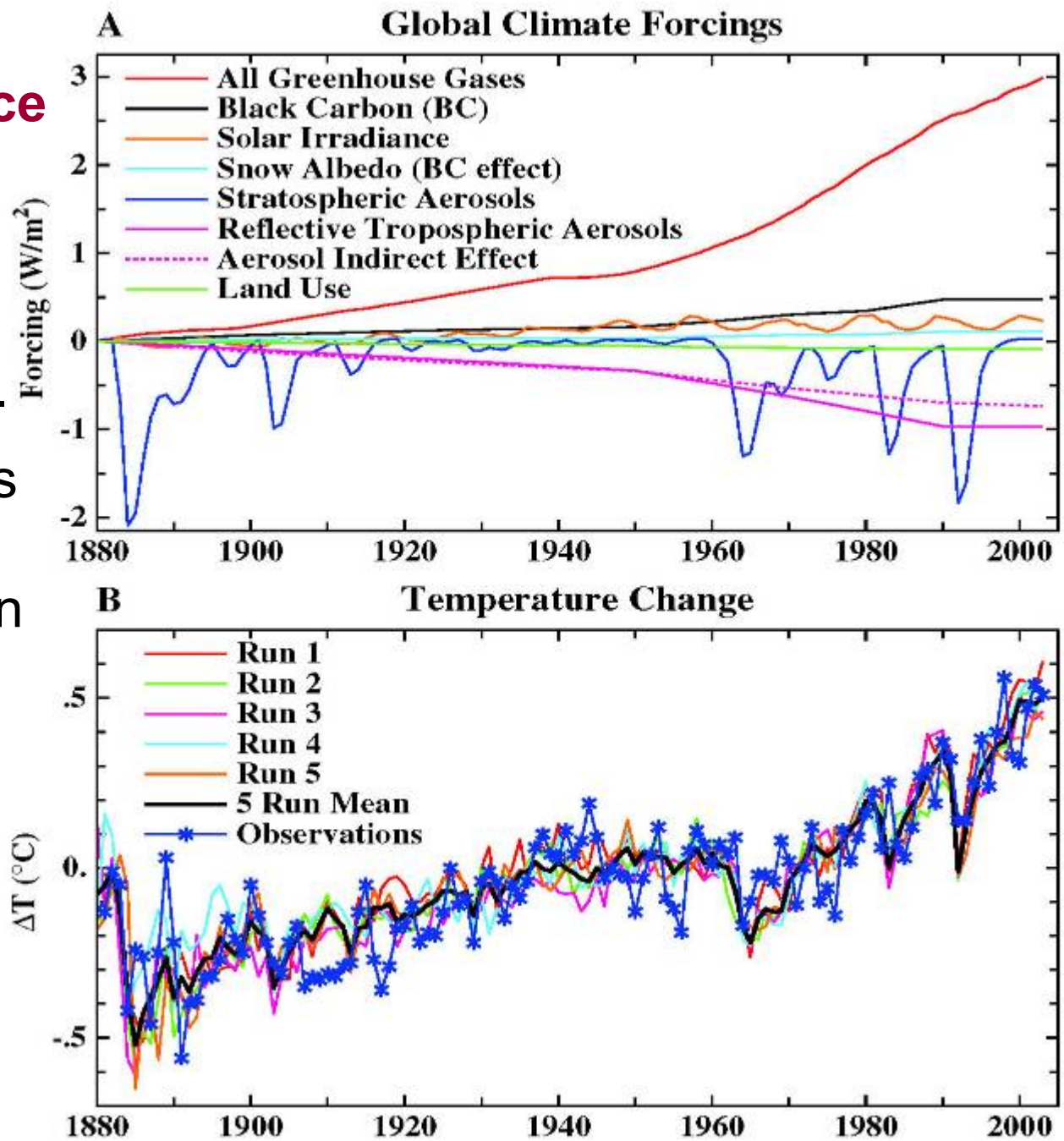
The warming influence of anthropogenic GHG and absorbing particles is ~30x the warming influence of the estimated change in input from the Sun.

IPCC AR4, WG1 SPM, 2007

The smoking gun for human influence

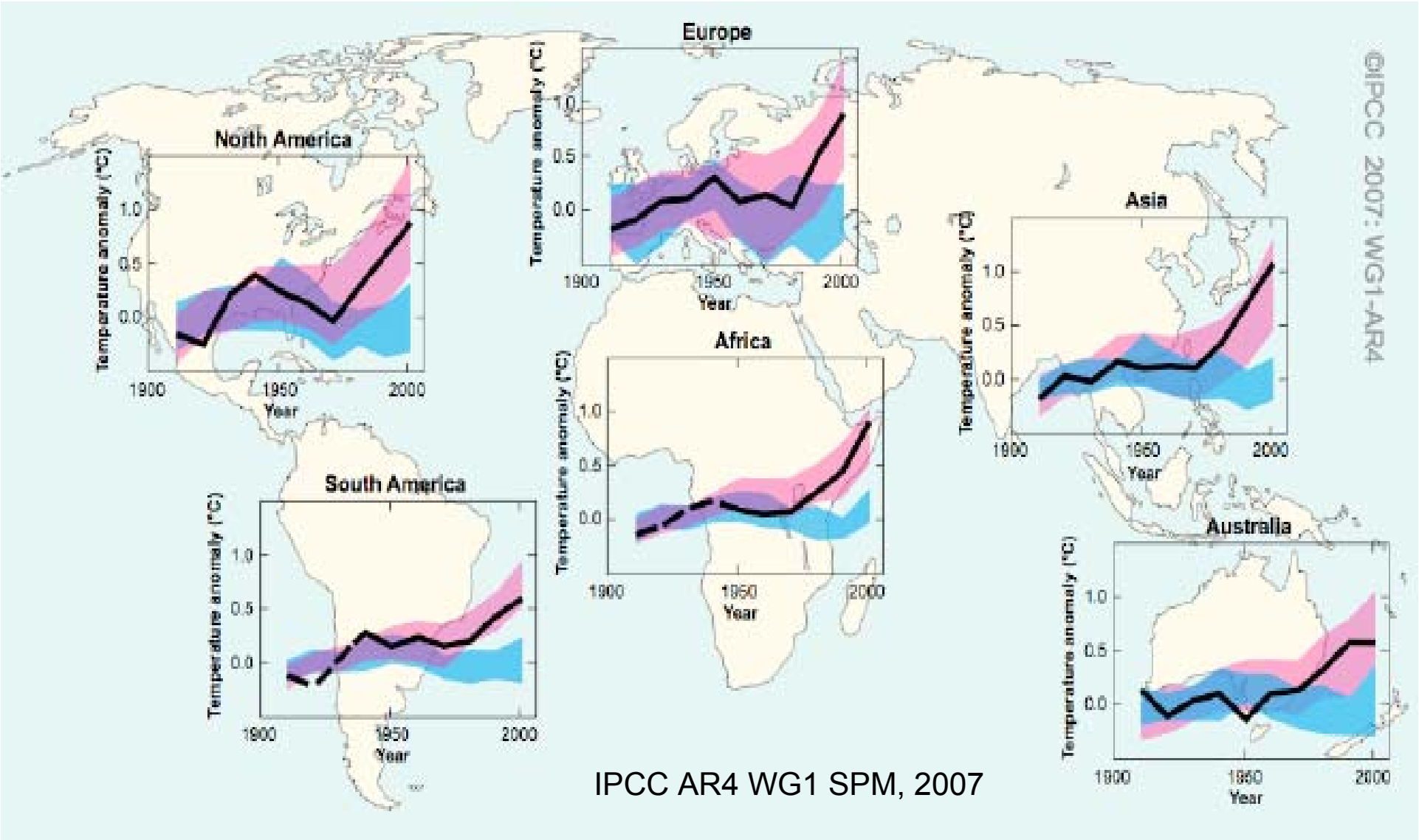
Top panel shows best estimates of human & natural forcings 1880-2005.

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



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

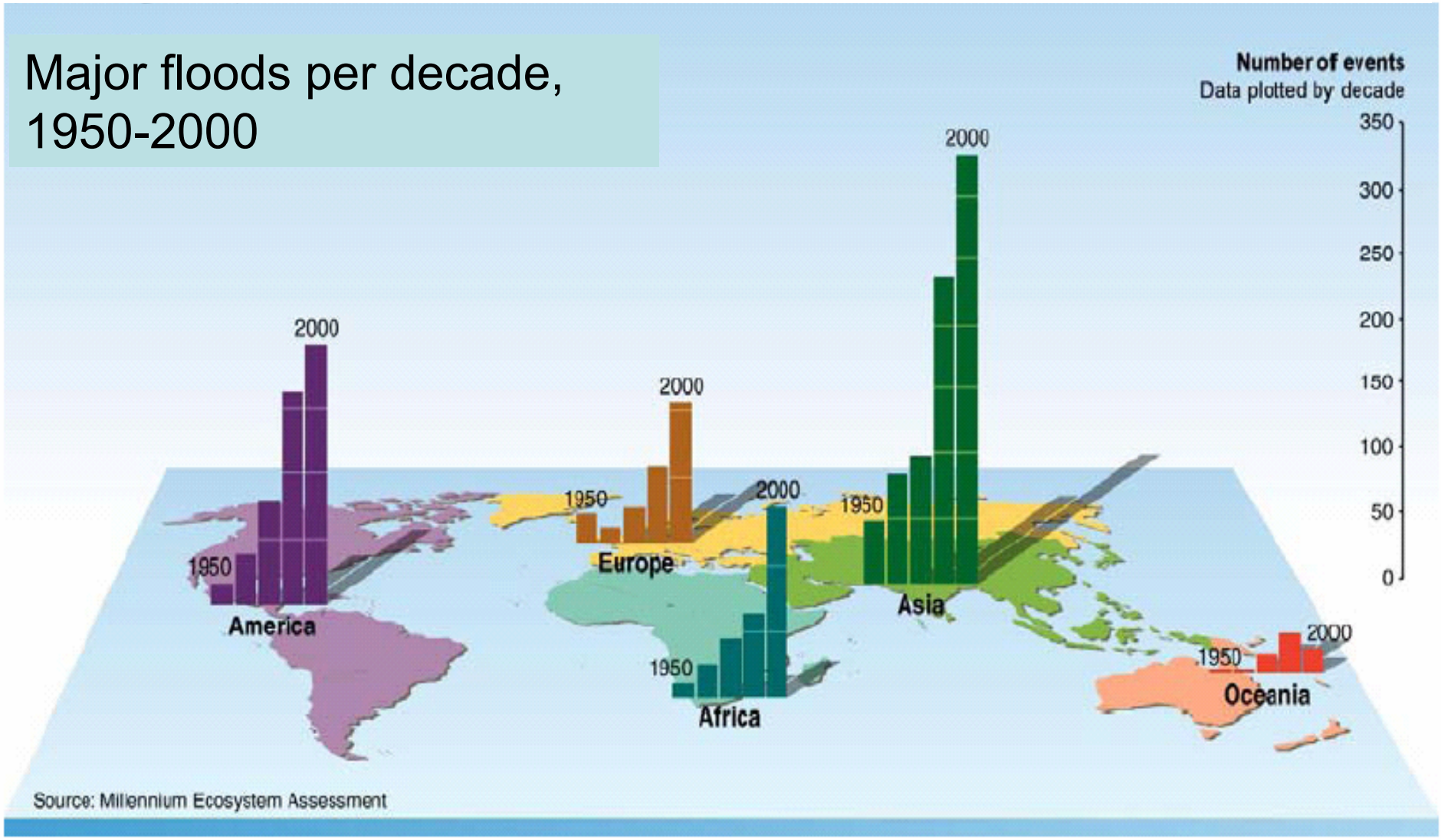
Computer models match observed ΔT on all continents



IPCC AR4 WG1 SPM, 2007

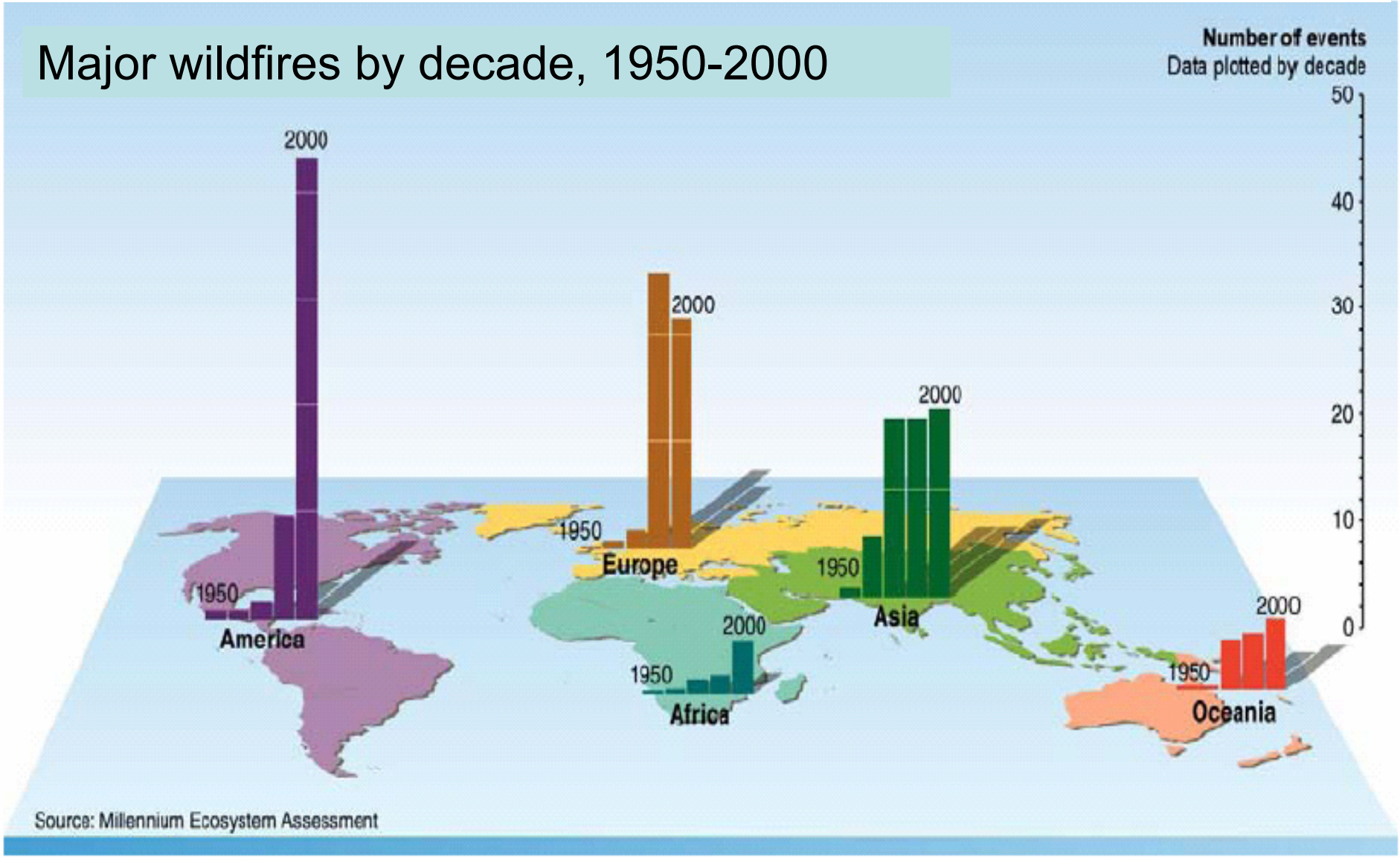
Black lines are decadally averaged observations. Blue bands are computer models with natural forcings only. Pink bands are computer models with human + natural forcings.

Changes in climate are already causing harm



There's a consistent 50-year upward trend in every region except Oceania.

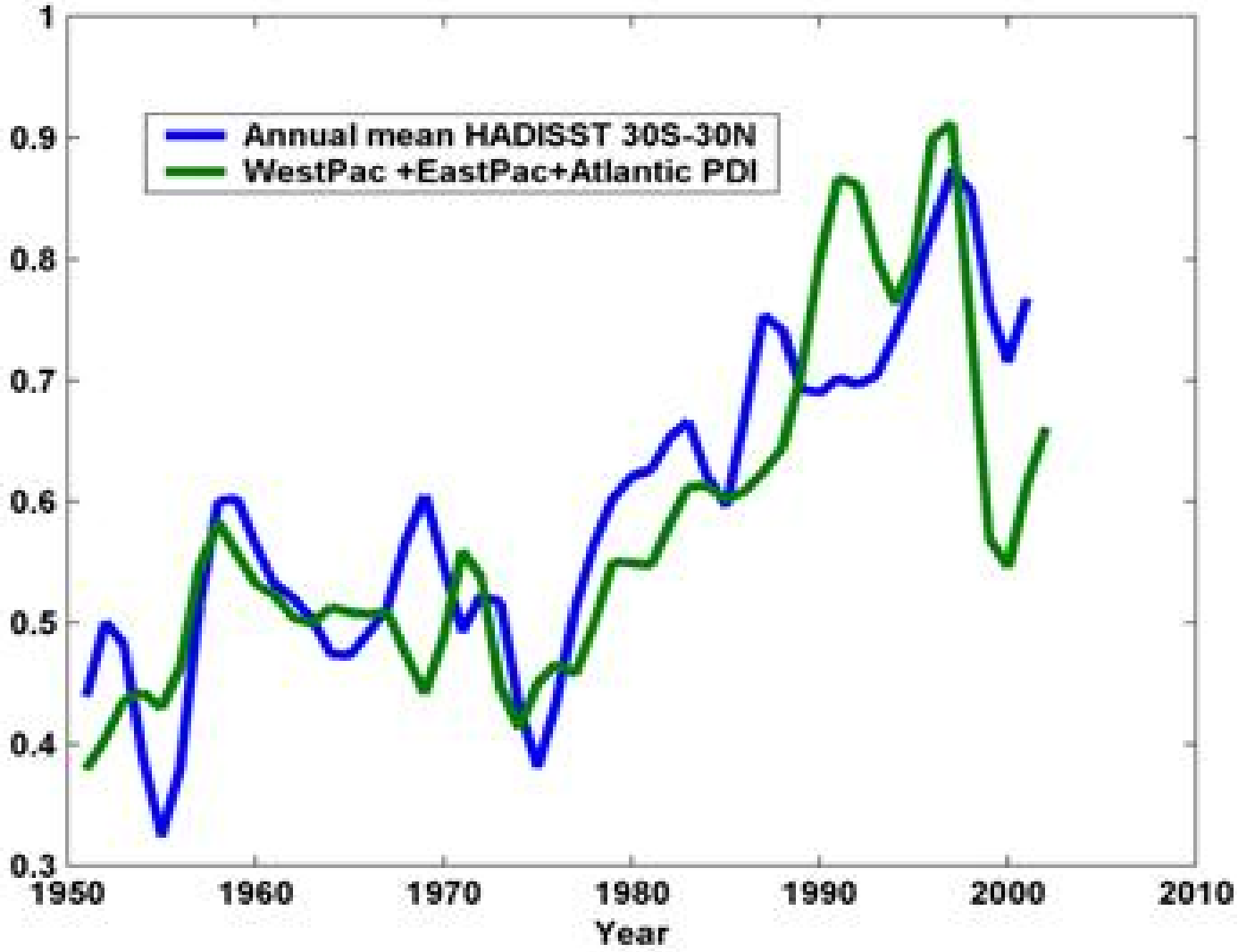
Harm is already occurring (continued)



The trend has been sharply upward everywhere.

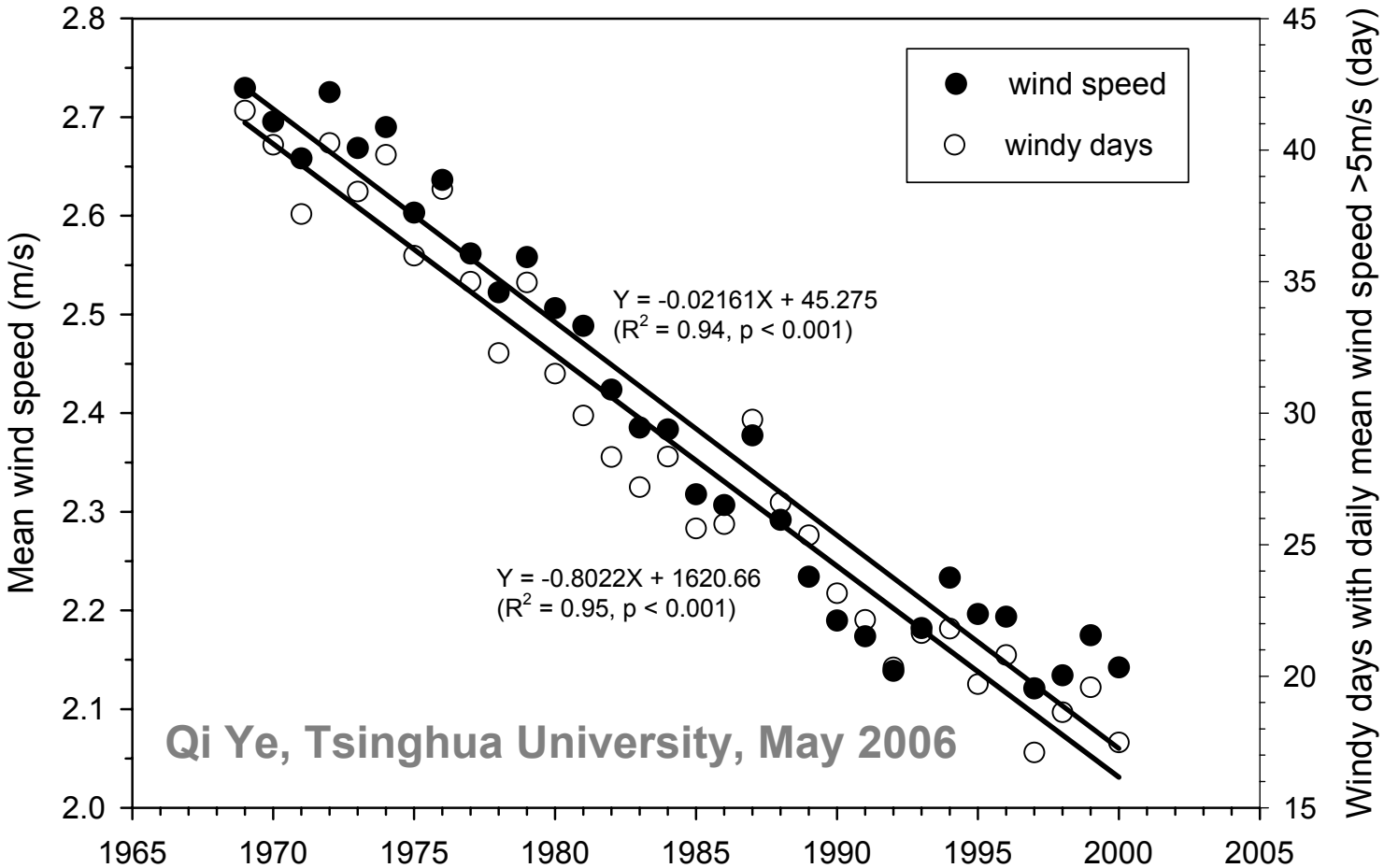
Harm is already occurring (continued)

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



Kerry Emanuel, MIT, 2006

Harm is already occurring (continued):
The East Asia monsoon is weakening



The change is as predicted by Chinese climate modelers. It has produced increased flooding in the South of China and increased drought in the North.

Harm is already occurring (concluded)

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

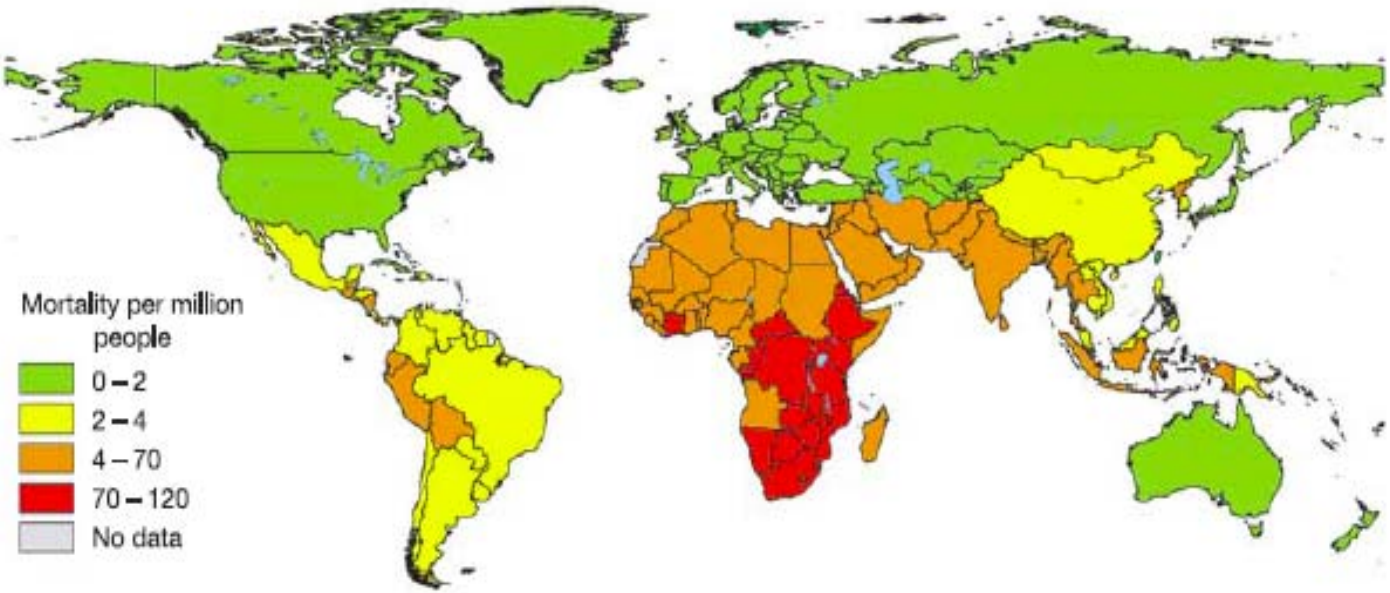
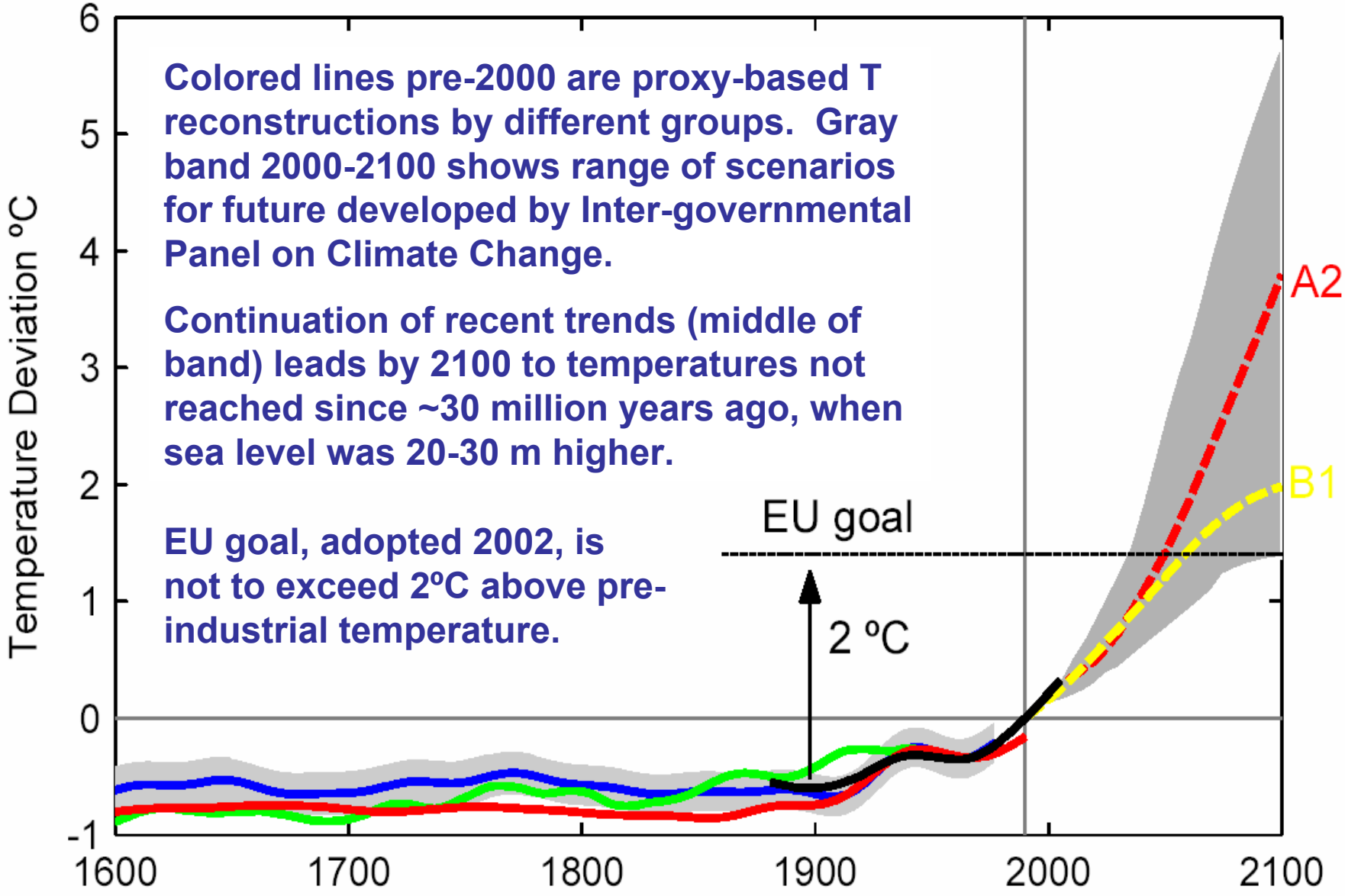


Figure 2 | WHO estimated mortality (per million people) attributable to climate change by the year 2000. The IPCC 'business as usual' greenhouse gas emissions scenario, 'IS92a' and the HadCM2 GCM of the UK Hadley Centre were used to estimate climate changes relative to 'baseline' 1961–1990 levels of 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.

Where we're headed:

The next 100 years compared to the last 400



Where we're headed: agriculture in the tropics

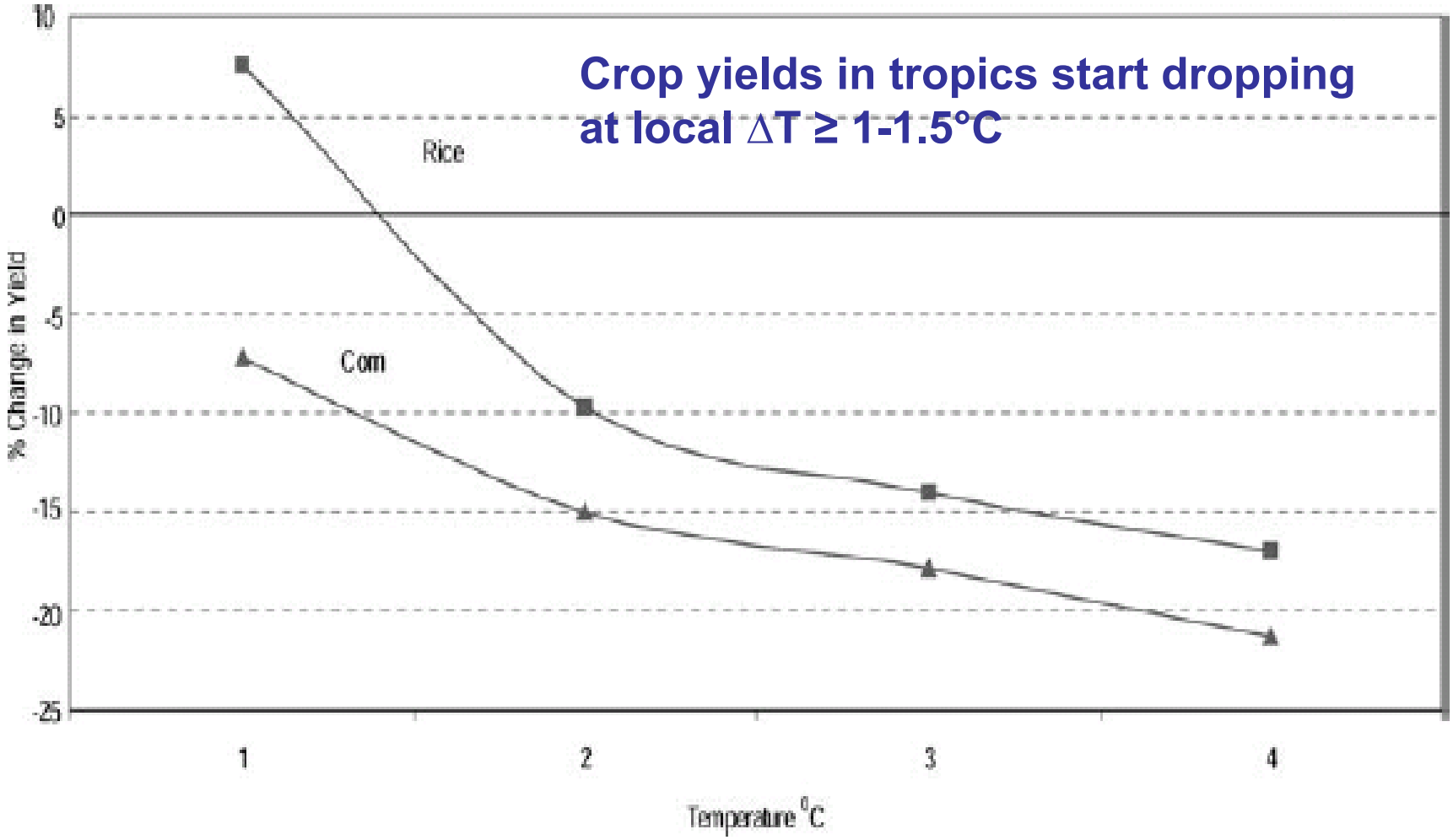


Figure 1. Corn and Rice yields versus temperature increase in the tropics averaged across 13 crop modeling studies. All studies assumed a positive change in precipitation. CO_2 direct effects were included in all studies.

Easterling and Apps, 2005

Where we're headed: temperate-zone agriculture

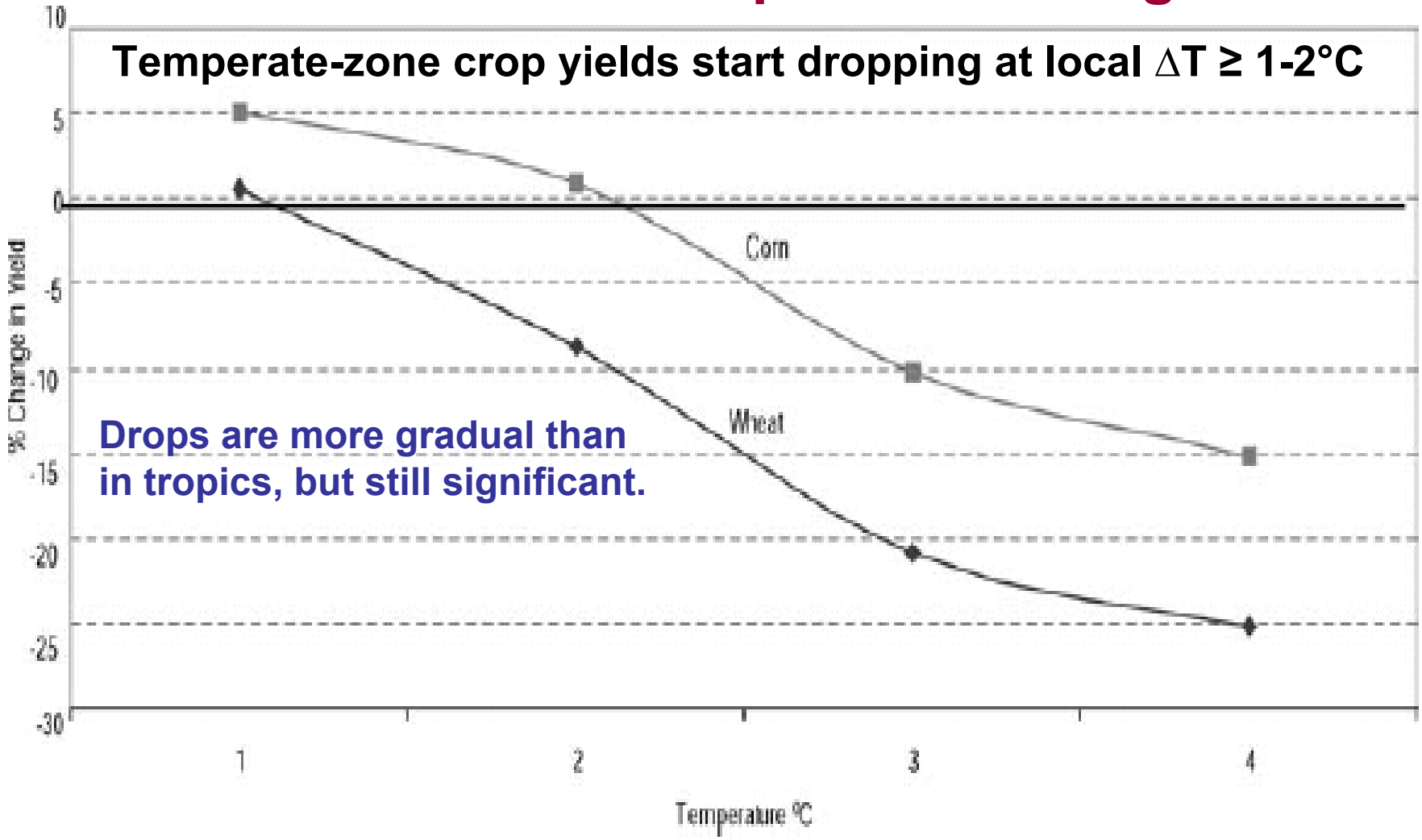
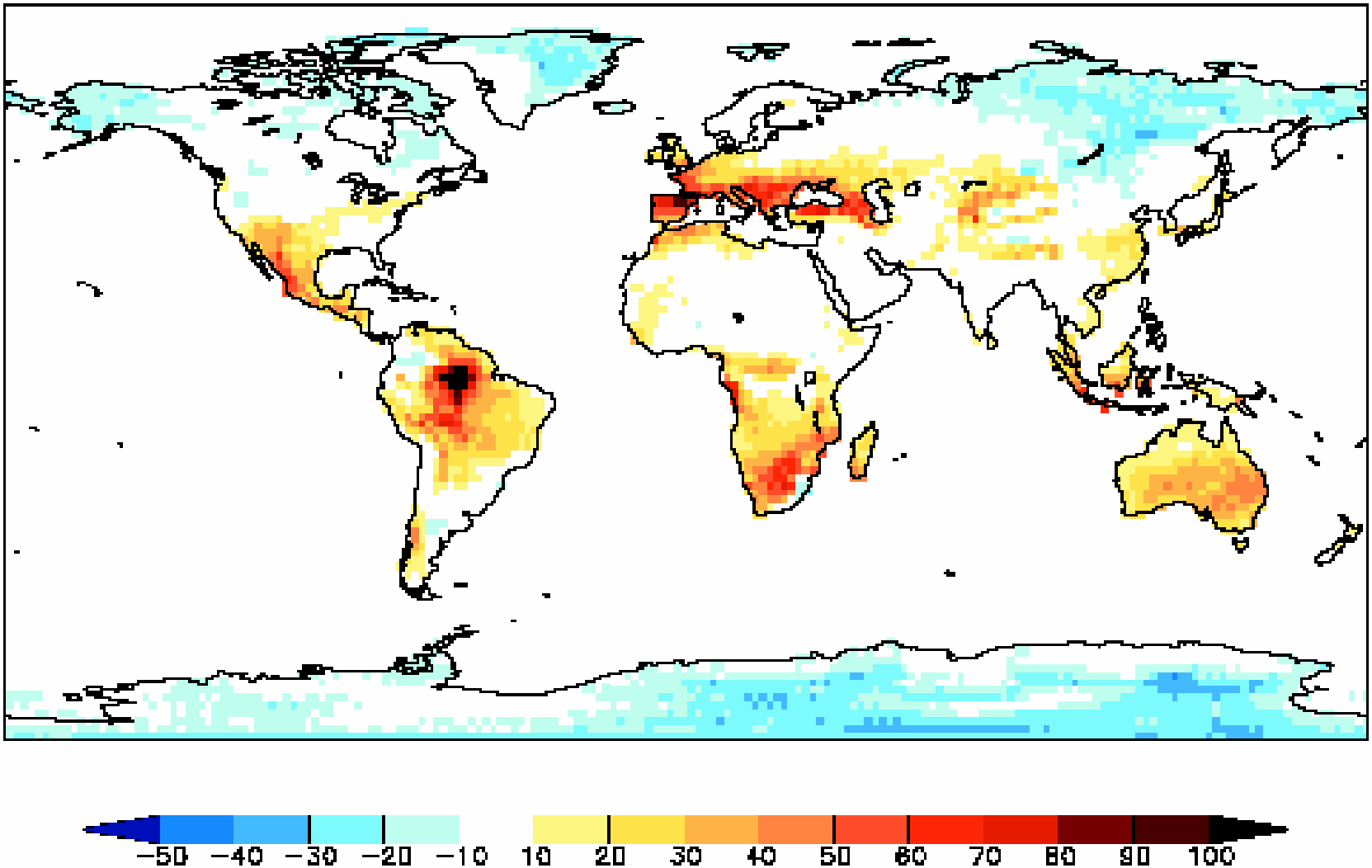


Figure 2. Corn and Wheat yields versus temperature increase in the temperate zone averaged across 30 crop modeling studies. All studies assumed a positive change in precipitation. CO_2 direct effects were included in all studies.

Easterling and Apps, 2005

Where we're headed: droughts

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.

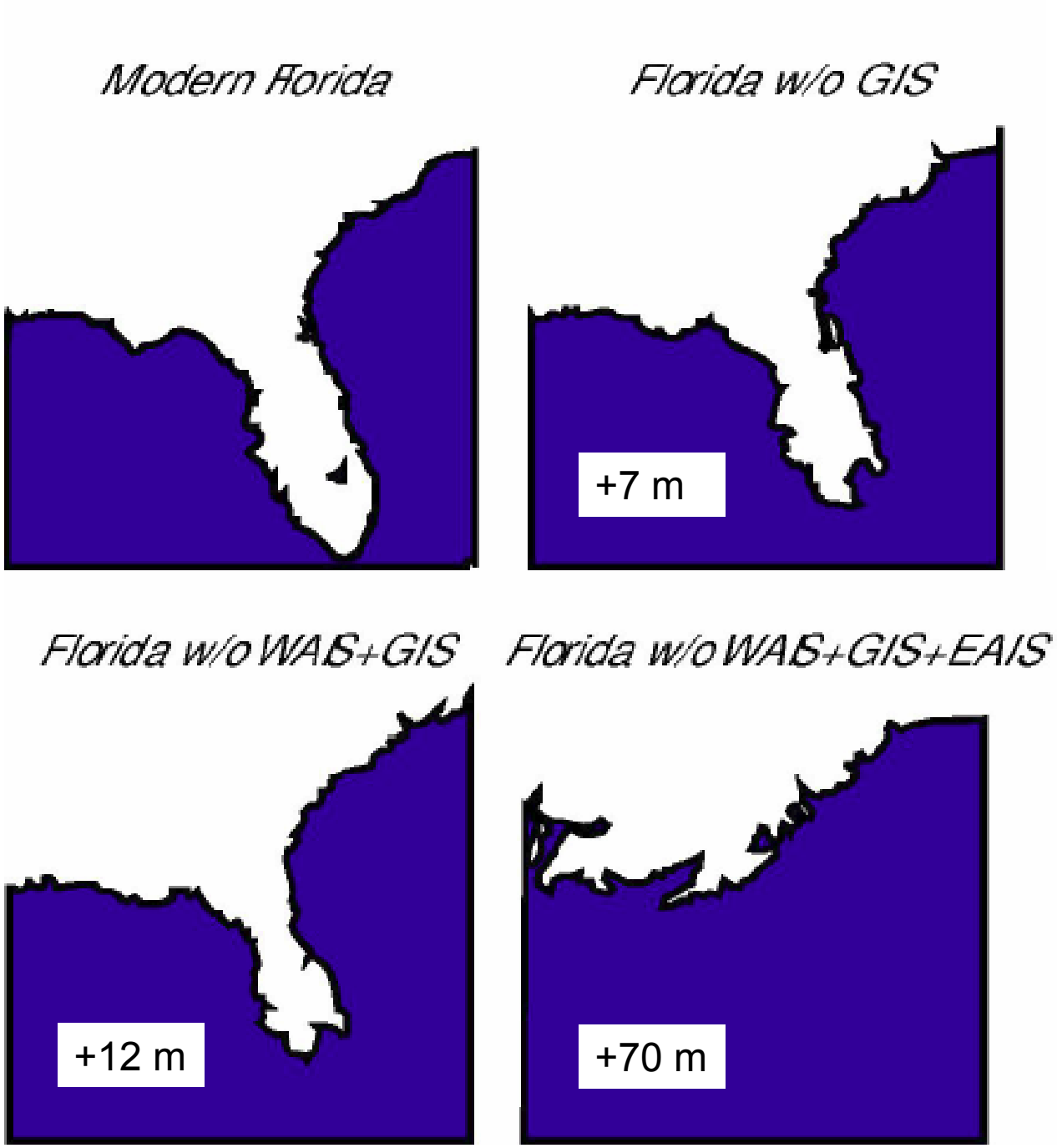
Melting the Greenland and Antarctic Ice Sheets would raise sea level up to 70 meters

This would probably take 1000s of years, but rates of 5 m per century are possible.

GIS = Greenland Ice Sheet

WAIS = West Antarctic Ice Sheet

EAIS = East Antarctic Ice Sheet



Dr. Richard Alley, 2005

Round 2:

Implications of the science for adaptation & mitigation

The choices

Society has three options:

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

Adaptation & mitigation are <u>both</u> essential

- Human-caused climate change is already occurring and is already causing damage.
- Mitigation is crucial, but it cannot stop climate change quickly or completely.
- Adaptation efforts are already taking place and must be expanded, but adaptation becomes costlier and less effective as the magnitude of climate changes grows.
- To minimize the suffering, we need mitigation “to avoid the unmanageable” <u>and</u> adaptation “to manage the unavoidable”.

How much action is needed, how soon?

- The UN Framework Convention on Climate Change of 1992 is "the law of the land" in 188 countries (yes, including the United States!)
- The Convention calls for

  "*stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent <u>dangerous anthropogenic interference</u> 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 clear that current level of interference is "dangerous". Question now is how to avoid "catastrophic".
- T_{avg} would rise ~0.5°C more (to ~1.5ºC above pre-industrial) even if GHG concentrations could be stabilized instantly. (They can't.)
- Chance of a tipping point into catastrophic change grows rapidly for T_{avg} more than 2ºC above pre-industrial.
- For a >50% chance of not exceeding ΔT_{avg}=2ºC, global CO_2 emissions must peak no later than ~2015 and must fall steadily thereafter.

The size of the challenge: 1

- Over 80% of world energy comes from fossil fuels, produced & burned in costly infrastructure with long turnover time.
- Resulting CO_2 emissions are immense (~28 billion tonnes in 2005) and correspondingly difficult to capture & store.
- Tropical deforestation accounts for another 4-12 billion tonnes/year) and is deeply embedded in current development trajectories.

The size of the challenge: 2

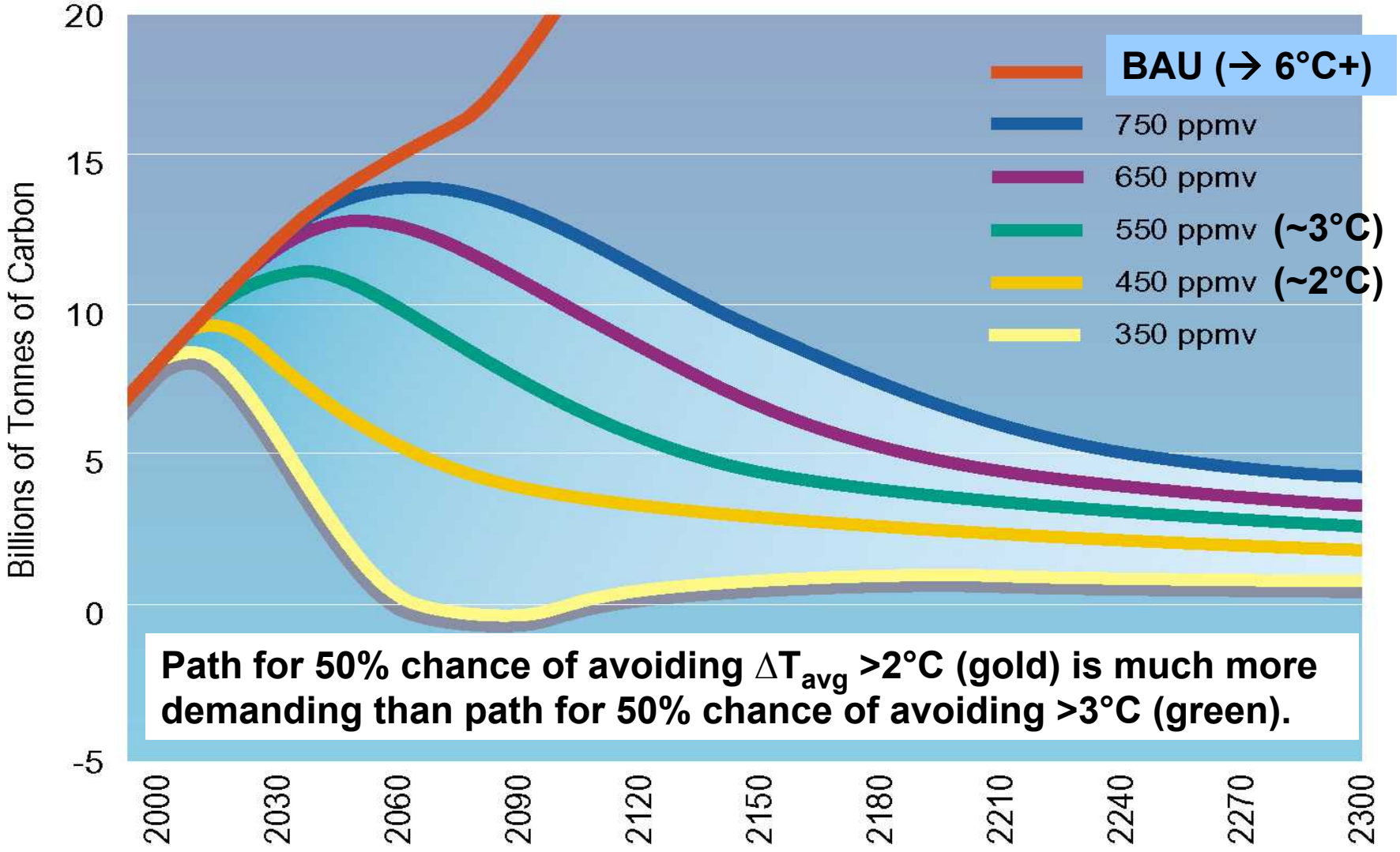
- Allowing for historic responsibility for the problem & current capacity to address it implies that emissions cuts must come even sooner & grow even faster in the North than in the South.
- But South emissions must be declining too by 2020-2025.

Conclusions

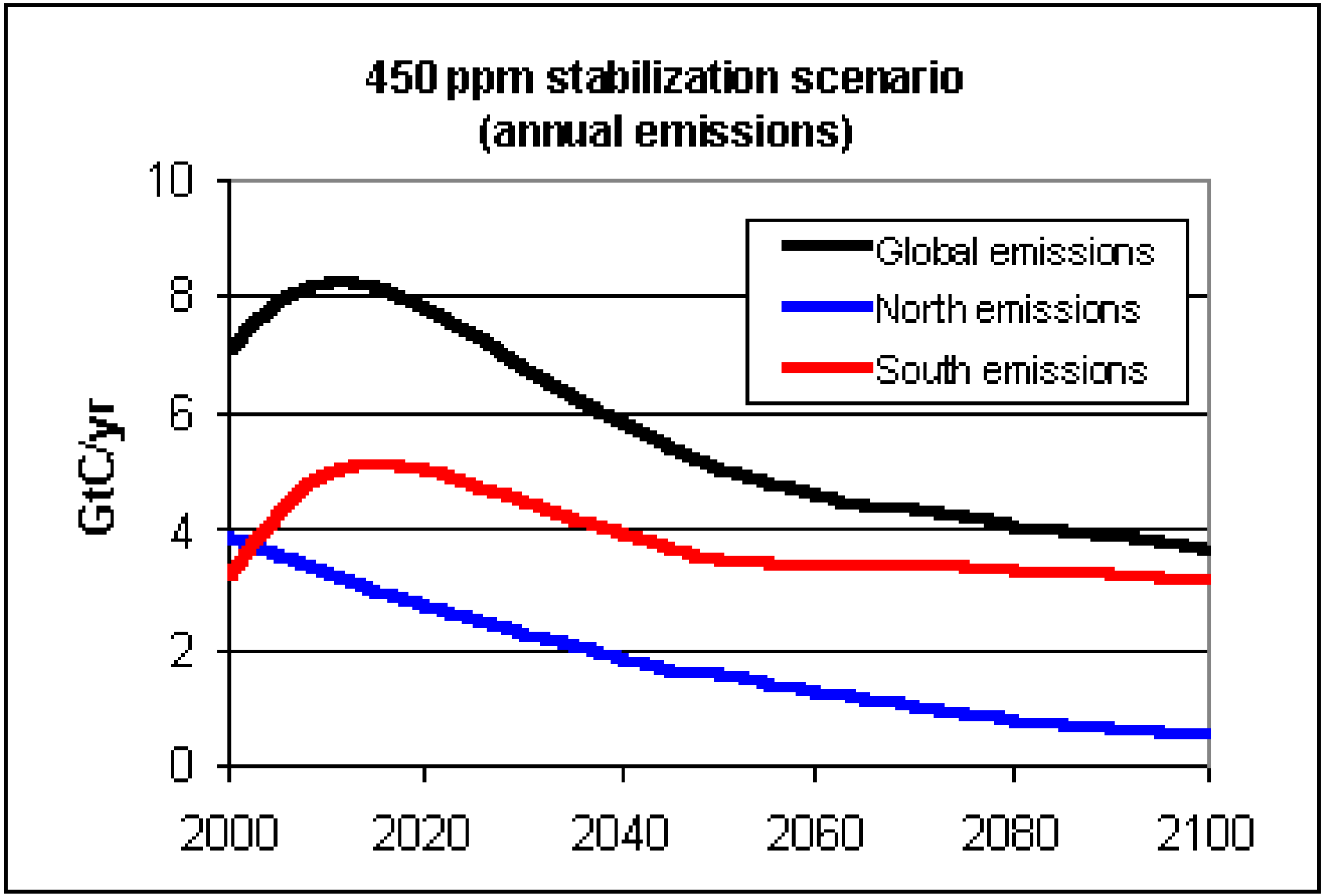
- Far more serious mitigation efforts than seen so far must be started at once in industrial nations & soon in developing ones.
- Even assuming great success in mitigation efforts, an immediate and large increase in adaptation efforts is required in North and South alike.
- Increased international cooperation in both domains, including an expanded role for the United Nations, will be crucial.

Supplementary materials for round 2

Business as usual (BAU) emissions vs. paths for stabilizing CO_2 concentration to limit $\Delta T_{average}$



Straw-man disaggregation of 450 ppmv CO_2 stabilization trajectory (corresponding to ΔTavg = 2.0°C for mid-range sensitivity)



Stephen Bernow and Sivan Kartha at http://www.ecoequity.org/ceo/ceo_7_4.htm

Recommendations for the United Nations by the UN Foundation / Sigma Xi Scientific Expert Group on Climate Change & Sustainable Development (SEG)

SEG mitigation recommendations for the UN

- Promote through the UNFCCC a post-2012 global climate-change regime incorporating
  - concentration targets & emissions trajectories compatible with not exceeding 2-2.5ºC above pre-industrial T
  - performance metrics suitable for developing as well as industrialized countries
  - early imposition of prices on CO_2 emissions everywhere
  - mechanisms for CO_2-revenue transfer from high-income, high-emitting countries & consumers to low-income, low-emitting ones
- Draw on capacities and clout of UN agencies to
  - Promote a 3-4X increase in global public/private investments in energy technology research, development, demonstration, and accelerated deployment, emphasizing partnerships.
  - Advance public & policy-maker education on climate-change impacts & solutions related to the agencies' missions.

SEG adaptation recommendations for the UN

- Inventory & evaluate the incorporation of adaptation concerns & programs in existing UN organizations
  - identifying needs/opportunities for improvements & additions
  - establishing increased communication & data-sharing
- Conduct vulnerability analyses & monitoring, including
  - focused efforts to identify regions & sectors of high vulnerability
  - assistance to vulnerable regions in monitoring & capacity-building
- Integrate adaptation into ongoing development efforts by
  - using 2006-2007 CSD focus on climate and 2008 International Year of Planet Earth to integrate adaptation into Agenda 21 action plans and national sustainable-development strategies
  - convening experts engaged in existing development information-sharing initiatives to create a global adaptation information clearinghouse

Adaptation recommendations (concluded)

- Refocus UN diplomatic, scientific, and technological capabilities to encompass additional adaptation work, such as
  - strengthening the proposed five-year program on adaptation in the UNFCCC, including the efforts on altered cropping patterns, water conservation, germ-plasm preservation, & weather-disaster response
  - accelerating the development of drought-, salt-, and flood-tolerant crop varieties
  - promoting expedited development of improved forecasting models and early-warning systems
- Develop an operational plan for environmental refugees

Some key references

Intergovernmental Panel on Climate Change, *Climate Change 2007: The Physical Science Basis. Summary for Policy Makers.* 2007. http://www.ipcc.ch/SPM2feb07.pdf

Scientific Expert Group on Climate Change & Sustainable Development, *Confronting Climate Change: Avoiding the Unmanageable and Managing the Unavoidable*, United Nations Foundation, February 2007 http://www.unfoundation.org/SEG/

Intergovernmental Panel on Climate Change, Climate Change 2007: Climate Change Impacts, Adaptation, and Vulnerability, Summary for Policy Makers. April 2007. http://www.ipcc.ch/

Intergovernmental Panel on Climate Change, *Climate Change 2007: Mitigation. Summary for Policy Makers.* May 2007. http://www.ipcc.ch/