

The Science of Climatic Disruption

John P. Holdren

**Teresa & John Heinz Professor of Environmental Policy
and Professor of Earth and Planetary Sciences
Harvard University**



**Director,
The Woods Hole Research Center**



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The Wild Center

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The science of climate-change in summary

- “Global warming” is a misnomer because it implies gradual, uniform, mainly about temperature, & quite possibly benign.
- What’s happening is rapid, nonuniform, affecting everything about climate, & almost entirely harmful.

A more accurate term is “global climatic disruption”.

- This ongoing disruption is...

real without doubt

mainly caused by humans

already producing significant harm

growing more rapidly than expected.

What climate change means

Climate is the pattern of weather, meaning averages, extremes, timing, spatial distribution of...

- hot & cold
- cloudy & clear
- humid & dry
- drizzles & downpours
- snowfall, snowpack, & snowmelt
- zephyrs, blizzards, tornadoes, & typhoons

When climate changes, the patterns change.

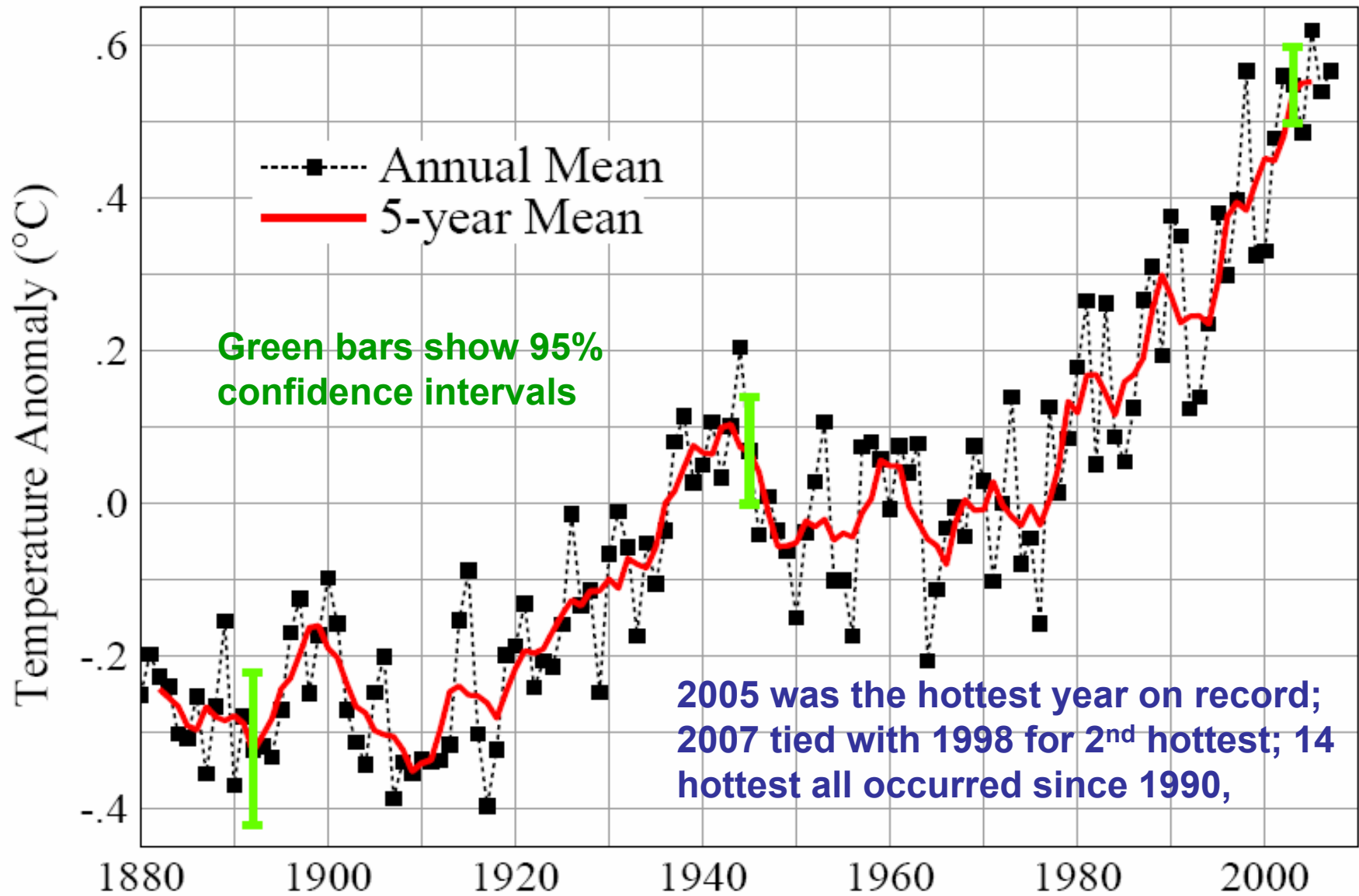
Global average temperature is just an index of the state of the global climate as expressed in these patterns. Small changes in the index → big changes in the patterns.

What climate change puts at risk

Climate governs (so climate change affects)

- availability of water
- productivity of farms, forests, & fisheries
- prevalence of oppressive heat & humidity
- formation & dispersion of air pollutants
- geography of disease
- damages from storms, floods, droughts, wildfires
- property losses from sea-level rise
- expenditures on engineered environments
- distribution & abundance of species

The Earth is getting hotter.



We know what's caused the heating

Human vs natural influences 1750-2005 (watts/m²)

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

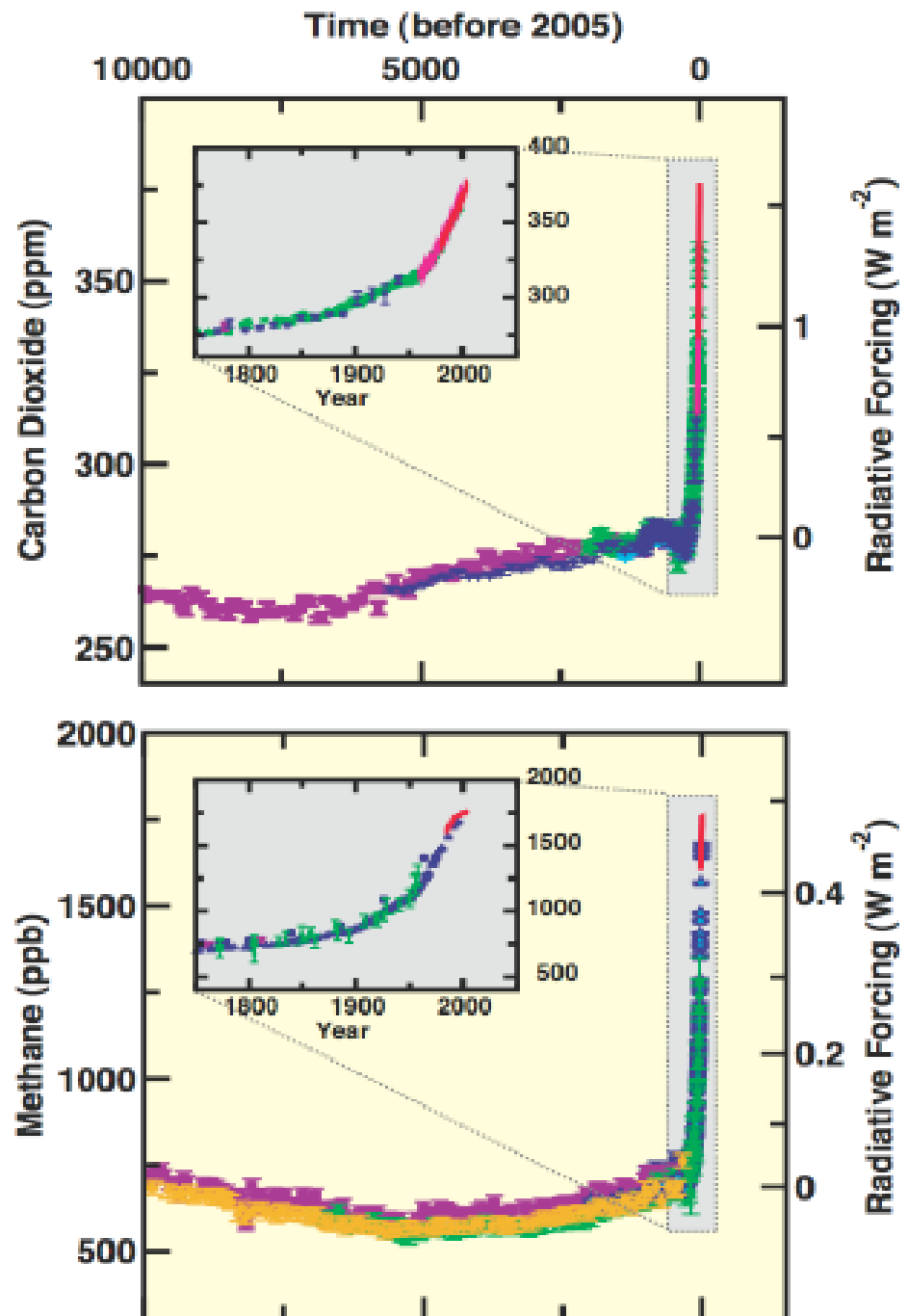
The warming influence of anthropogenic GHG and absorbing particles is ~30x the warming influence of the estimated change in input from the Sun.

The key greenhouse-gas increases were caused by human activities.

Compared to natural changes over the past 10,000 years, the spike in concentrations of CO₂ & CH₄ in the past 250 years is extraordinary.

We know humans are responsible for the CO₂ spike because fossil CO₂ lacks carbon-14, and the drop in atmospheric C-14 from the fossil-CO₂ additions is measurable.

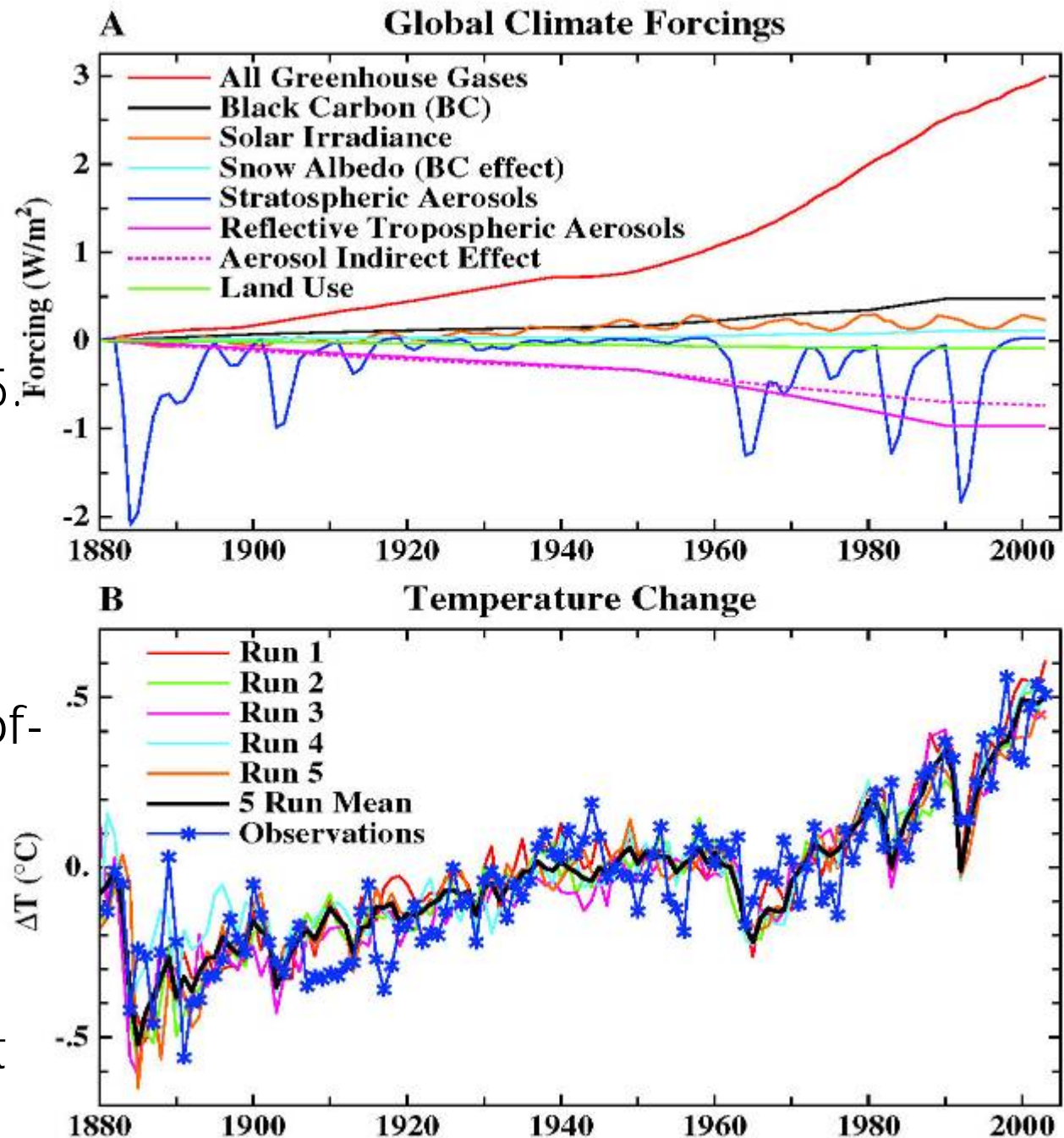
IPCC AR4, WG1 SPM, 2007



Human influence: the smoking gun

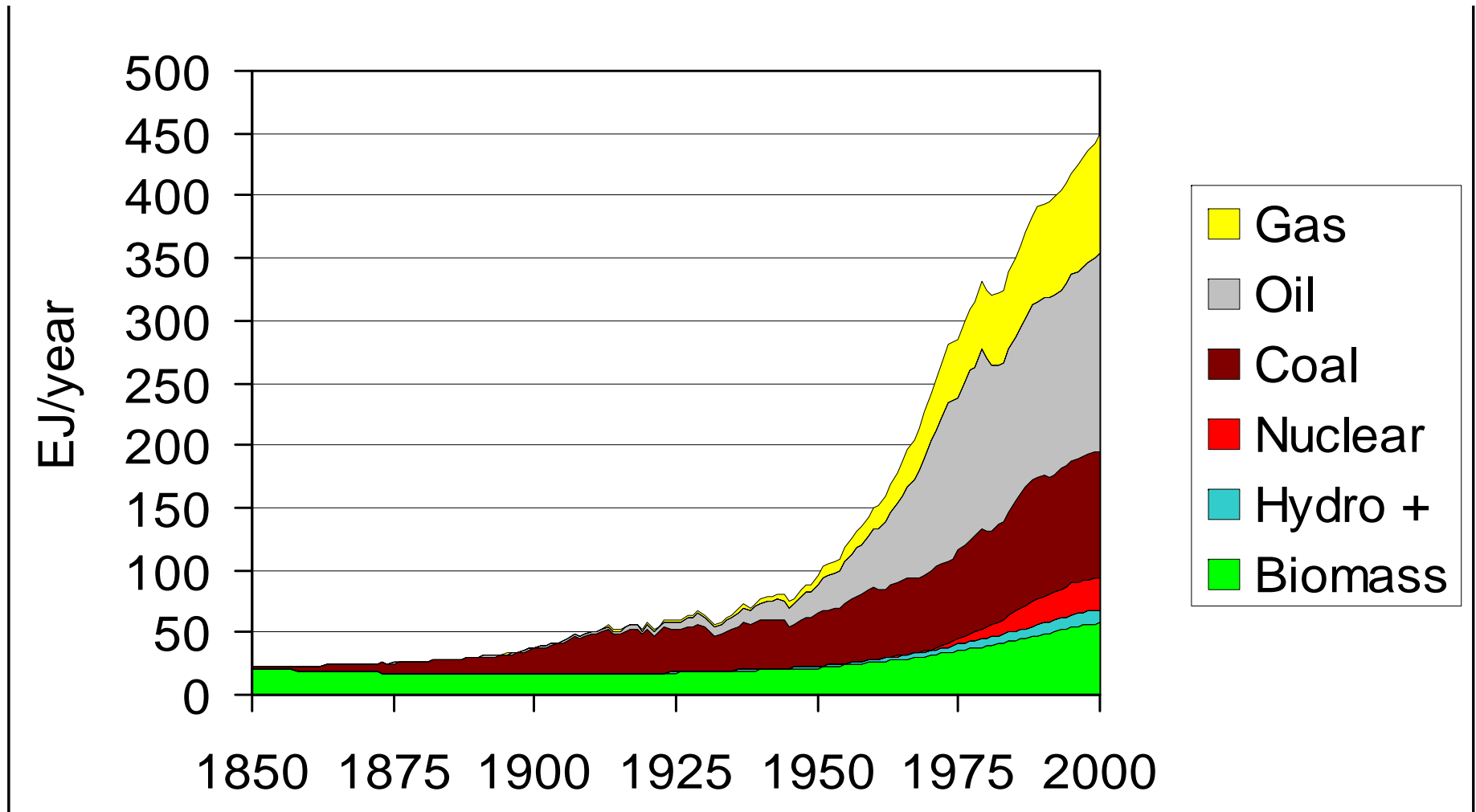
Top panel shows best estimates of human & natural forcings 1880-2005.

Bottom panel shows that state-of-the-art climate model, fed these forcings, predicts the same temperatures that were observed.



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

The biggest cause: 150+ years of world energy growth driven by fossil fuels



The 20-fold increase in world energy use in this period came mostly from coal (1850-1950) and oil & gas (1950-2000).

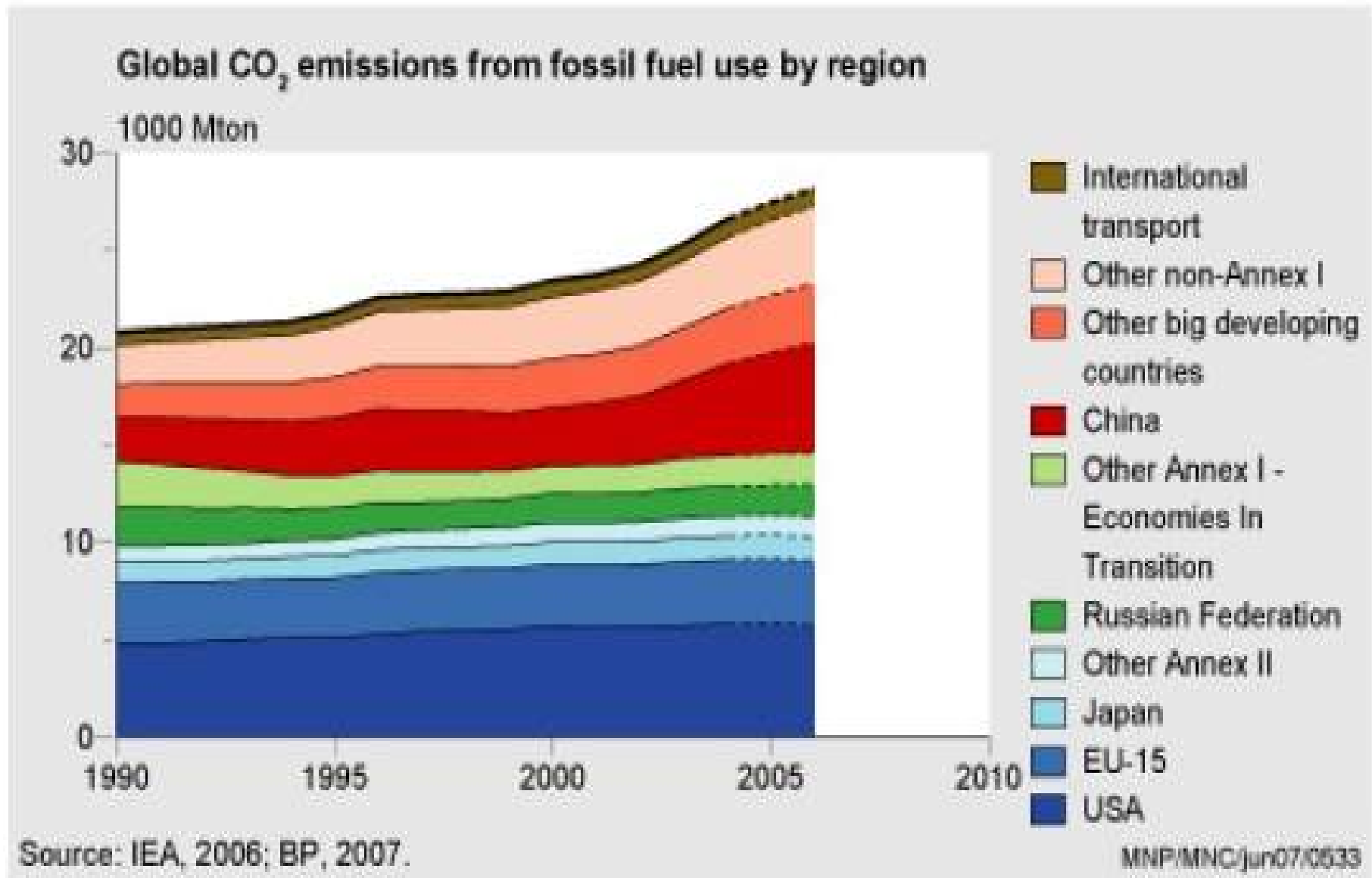
Fossil fuels continue to dominate world energy supply

2006

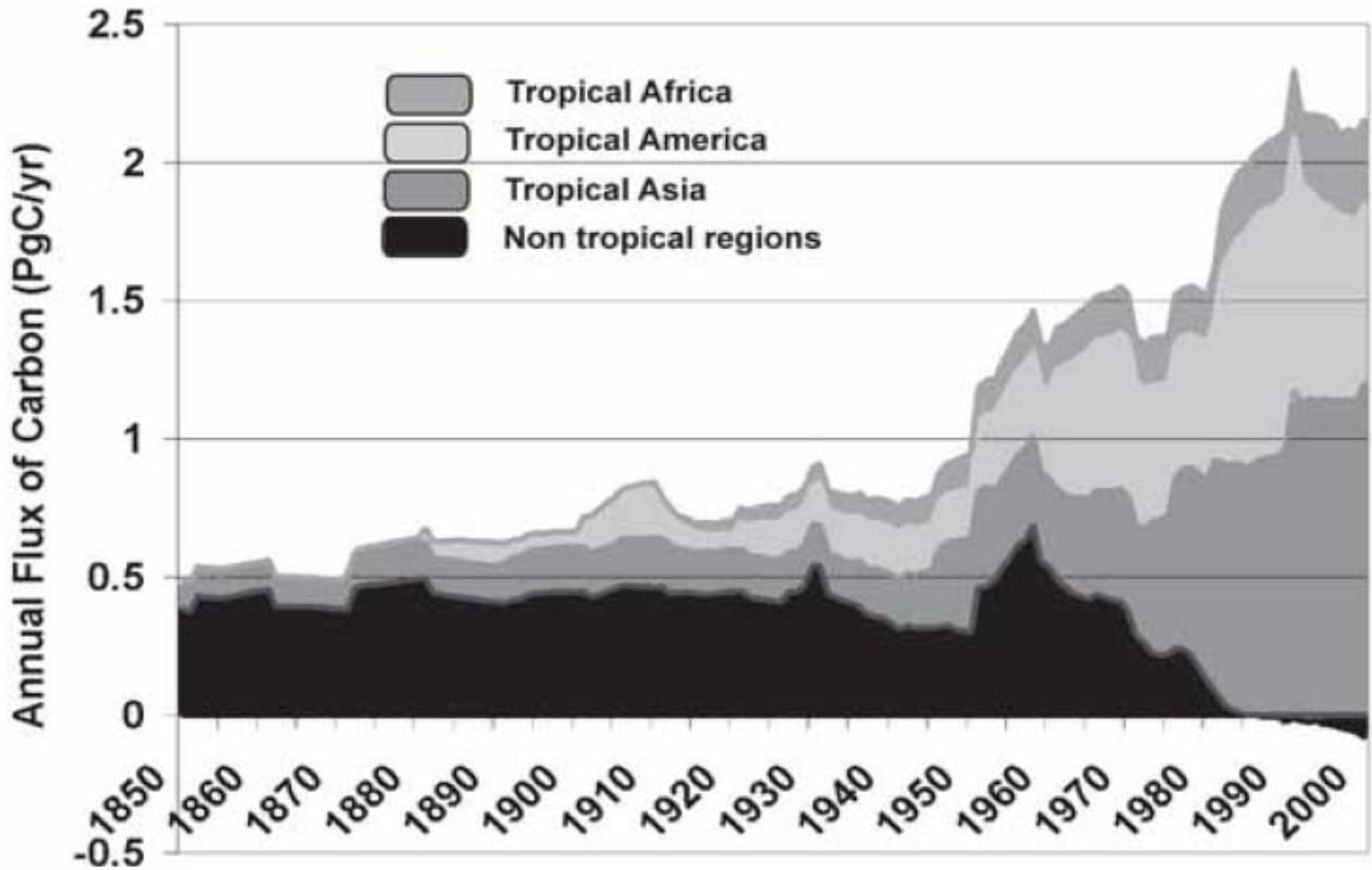
	population (millions)	ppp-GDP (trillion \$)	energy (EJ)	fossil E (percent)	fossil CO ₂ (MtC)
World	6555	67.0	525	82%	8060
USA	299	13.2	106	88%	1710
China	1311	10.4	86	84%	1640
India	1122	4.2	29	62%	380
Brazil	187	1.6	10	59%	100

But Brazil adds 200-400 MtC/yr from deforestation.

Fossil CO₂ emissions from developing countries are catching up



Deforestation is the 2nd biggest driver

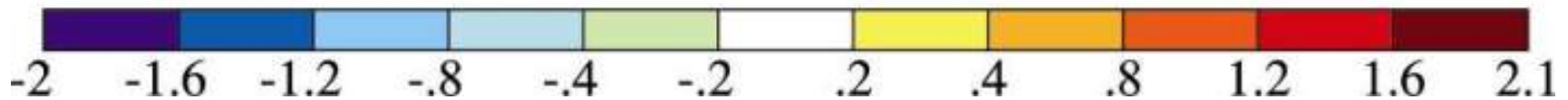
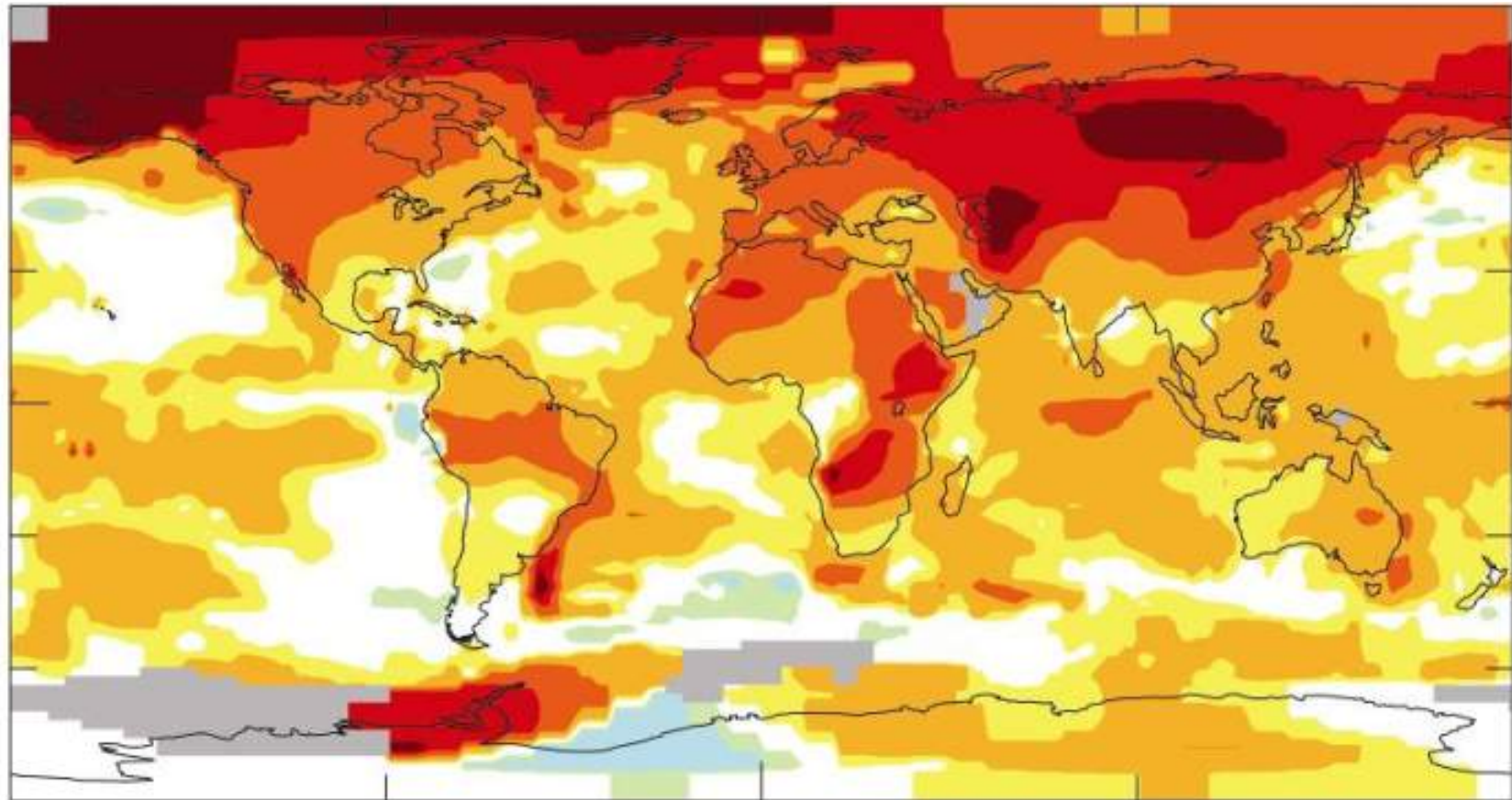


Houghton, in Moutinho & Schwartzman,

The heating is not uniform

(Biggest ΔT s are in far North & Antarctic peninsula)

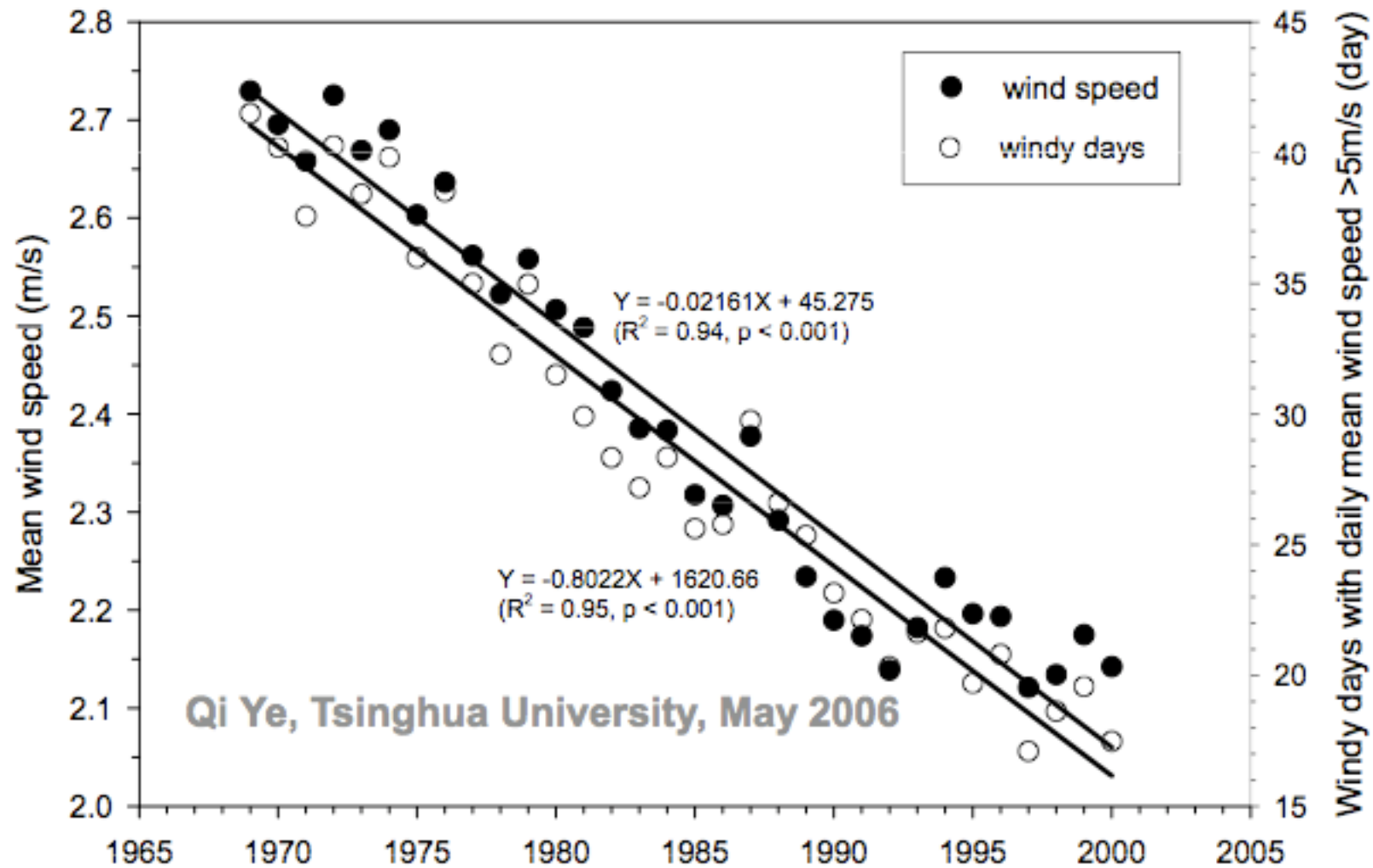
Surface T in 2001-2005 vs 1951-80, averaging 0.53°C increase



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

Uneven heating changes wind patterns

Weakening of the East Asia Monsoon is an example



The observations match model predictions, by Chinese researchers, for greenhouse-gas-driven disruption .

Glaciers are shrinking

Muir Glacier, Alaska

August 1941



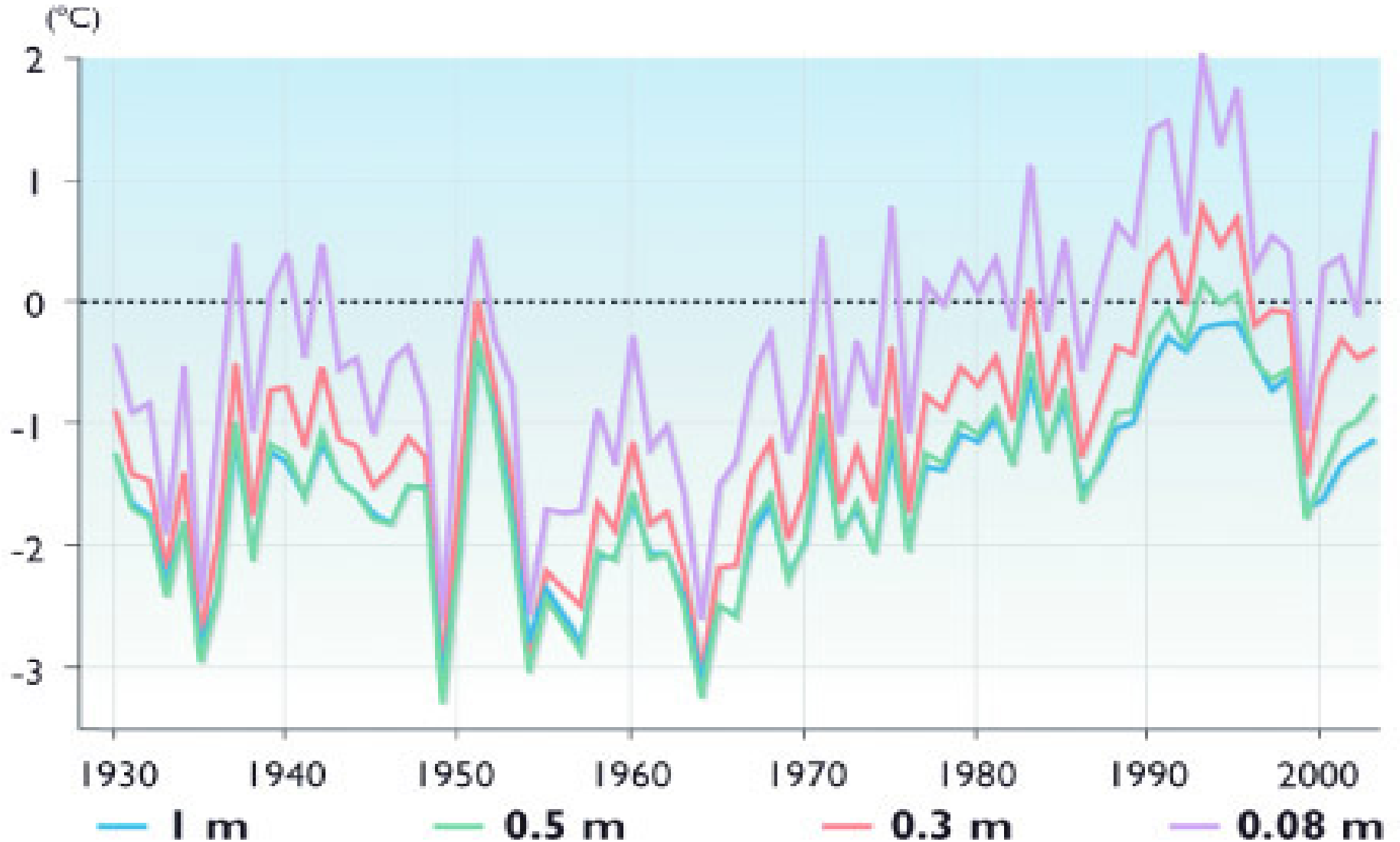
August 2004



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

Permafrost is thawing

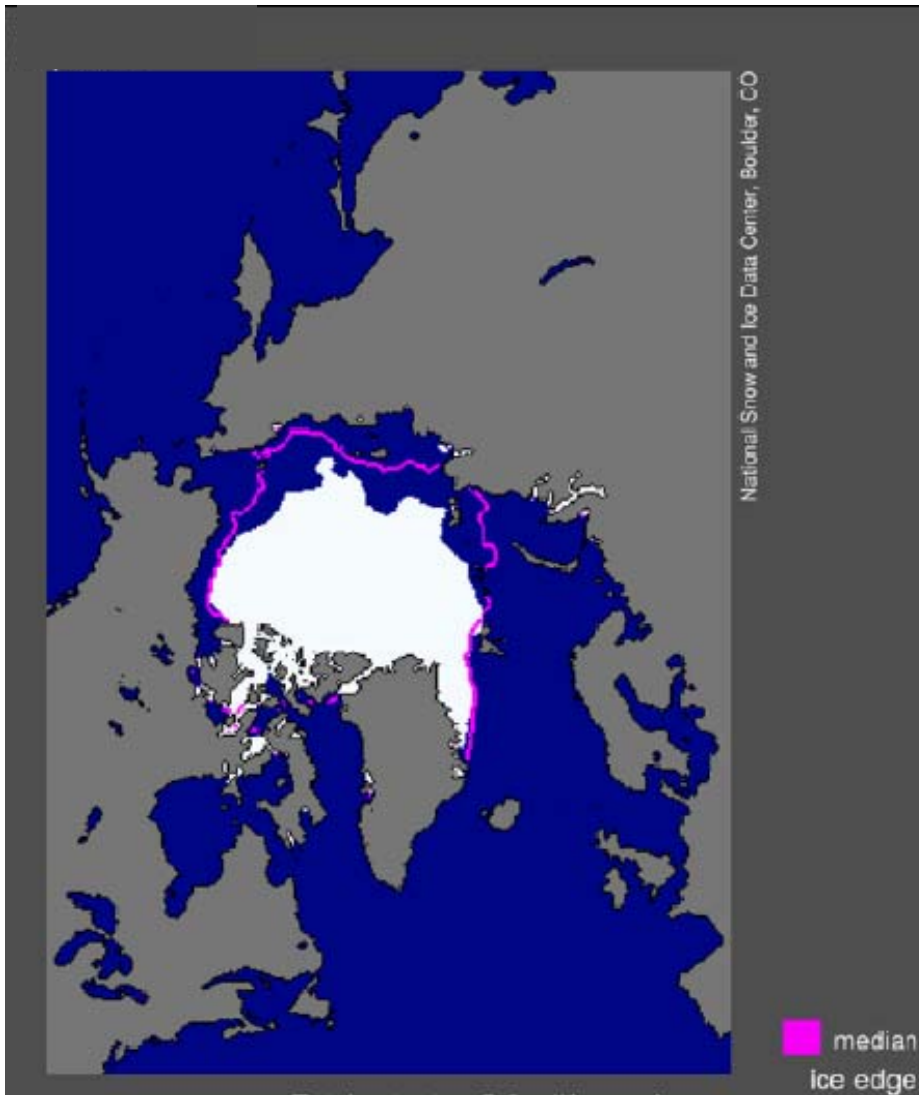
Average ground temperature near Fairbanks, Alaska, degrees C



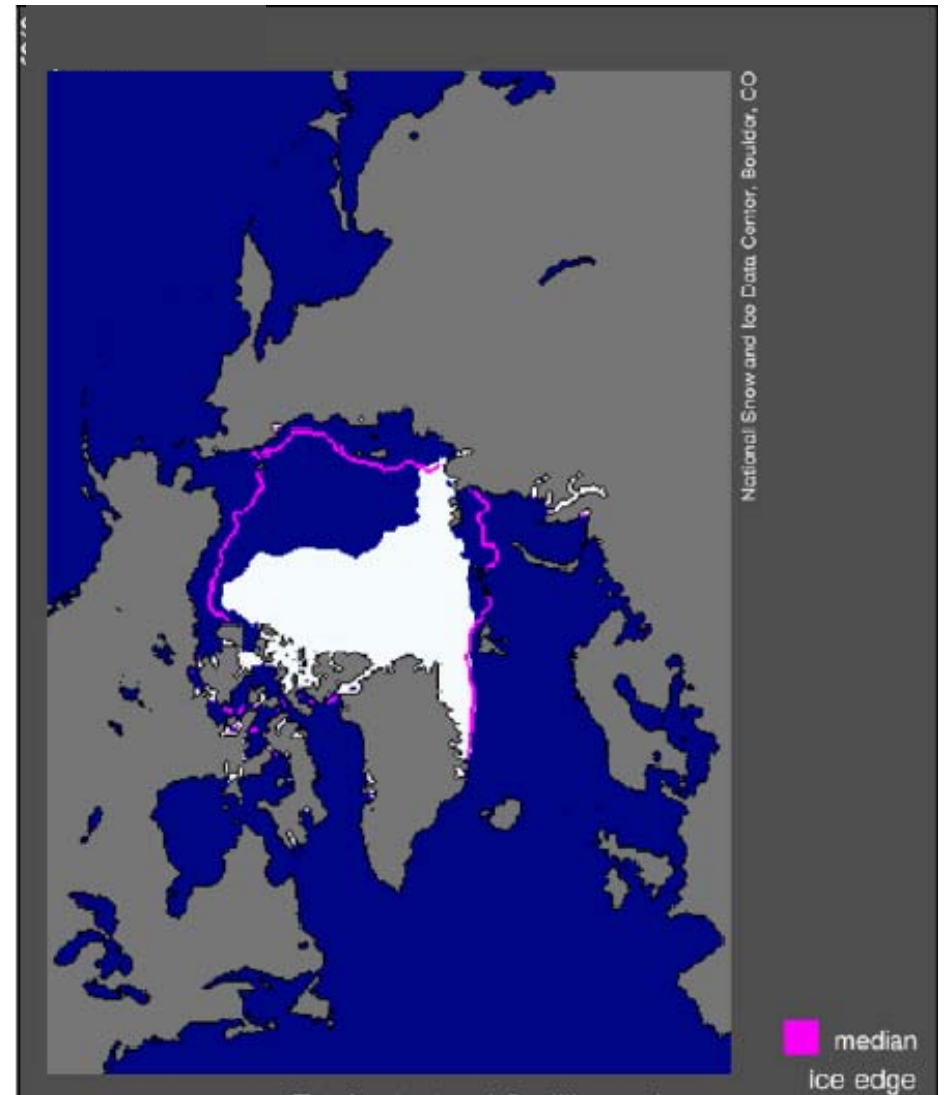
Permafrost thaws when $T \geq 0^\circ \text{C}$

ACIA 2004

Arctic summer sea ice is disappearing



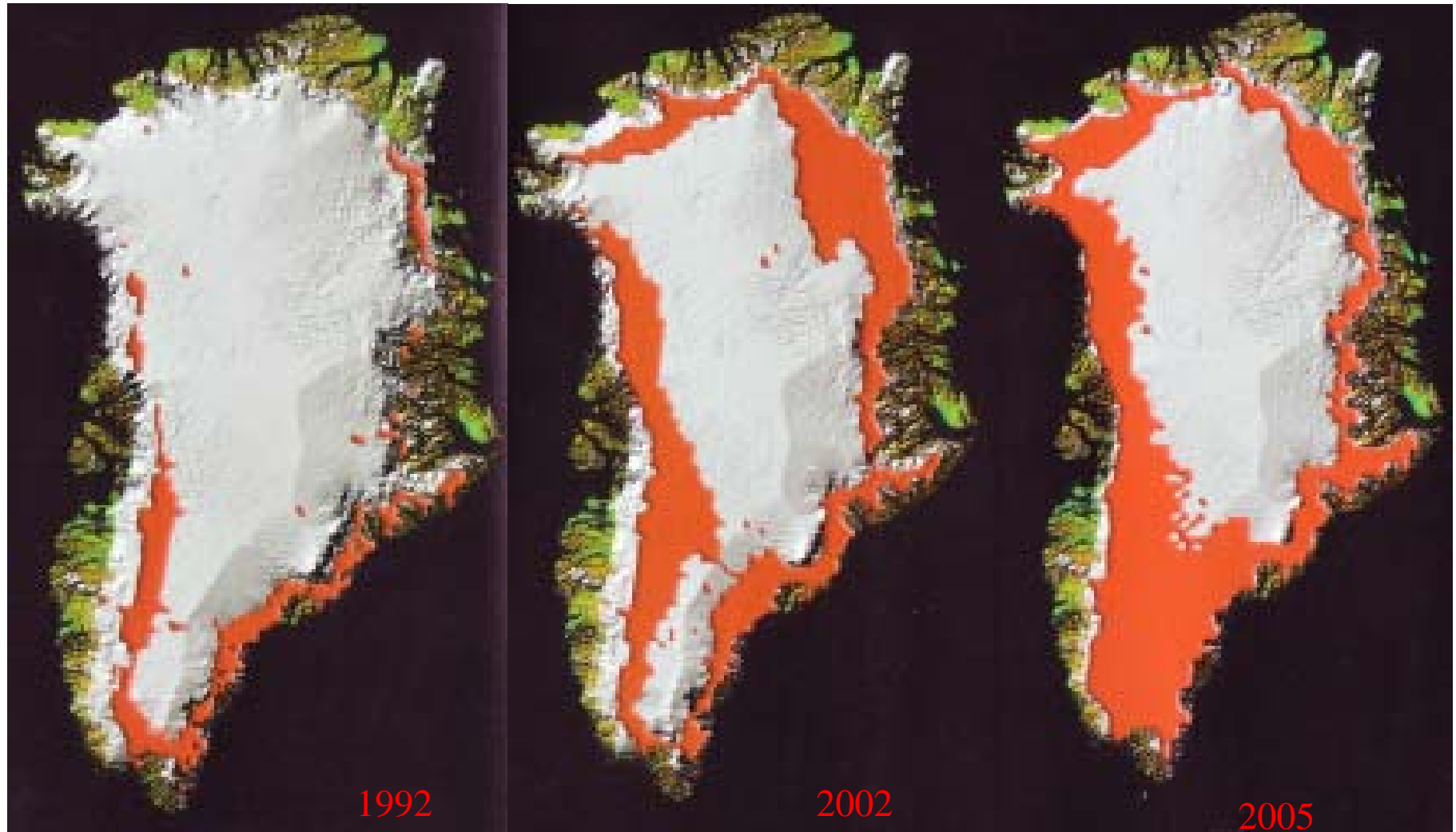
September 2005



September 2007

US National Snow & Ice Data Center, 2007

Surface melting on Greenland is expanding



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

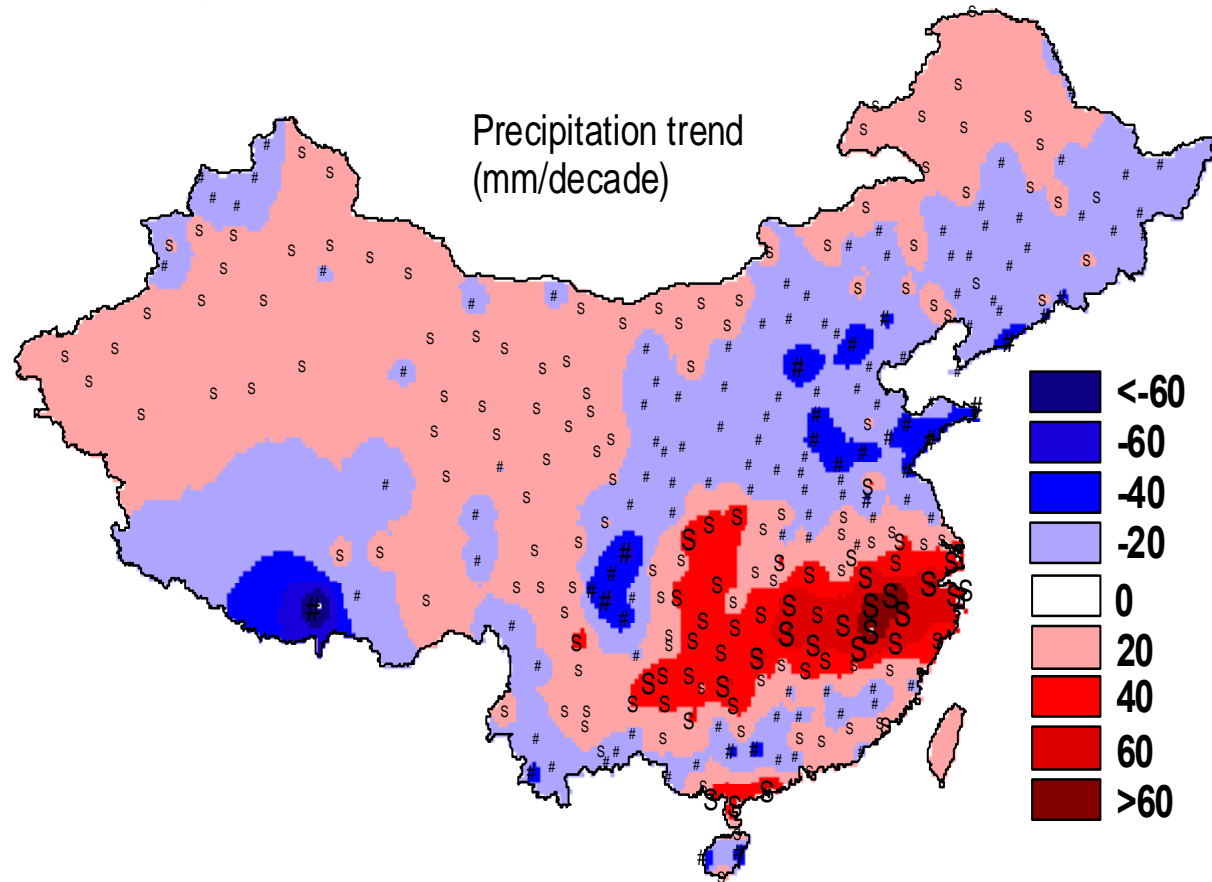
Ten years later, in 2002, the melting was much worse

And in 2005, it accelerated dramatically yet again

Source: ACIA, 2004 and CIRES, 2005

These changes are already causing harm

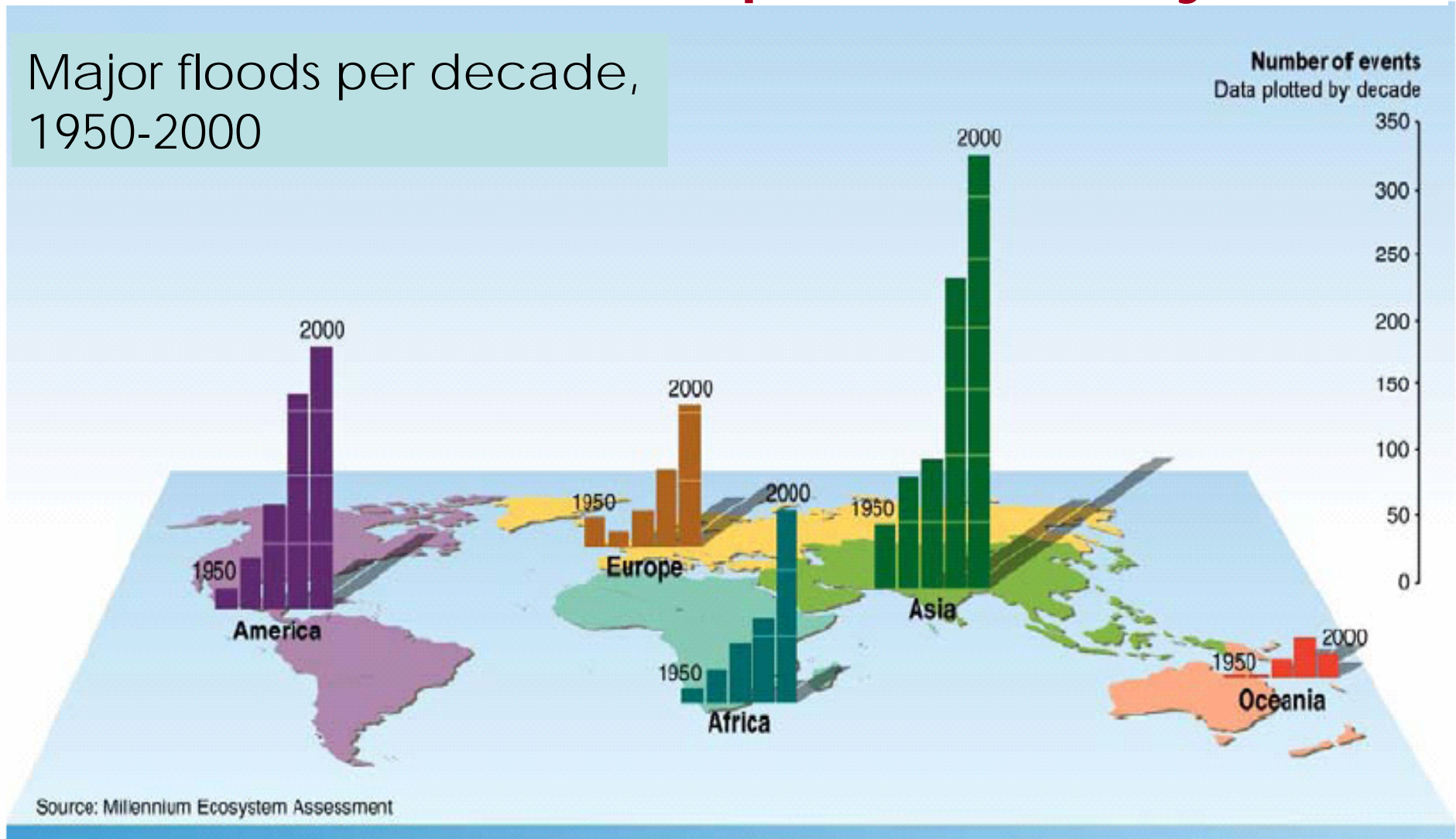
Weakening East-Asia monsoon has meant less moisture flow South to North, producing increased flooding in South, drought in North



Qi Ye, Tsinghua University, May 2006

Incidence of floods is up almost everywhere

Major floods per decade,
1950-2000

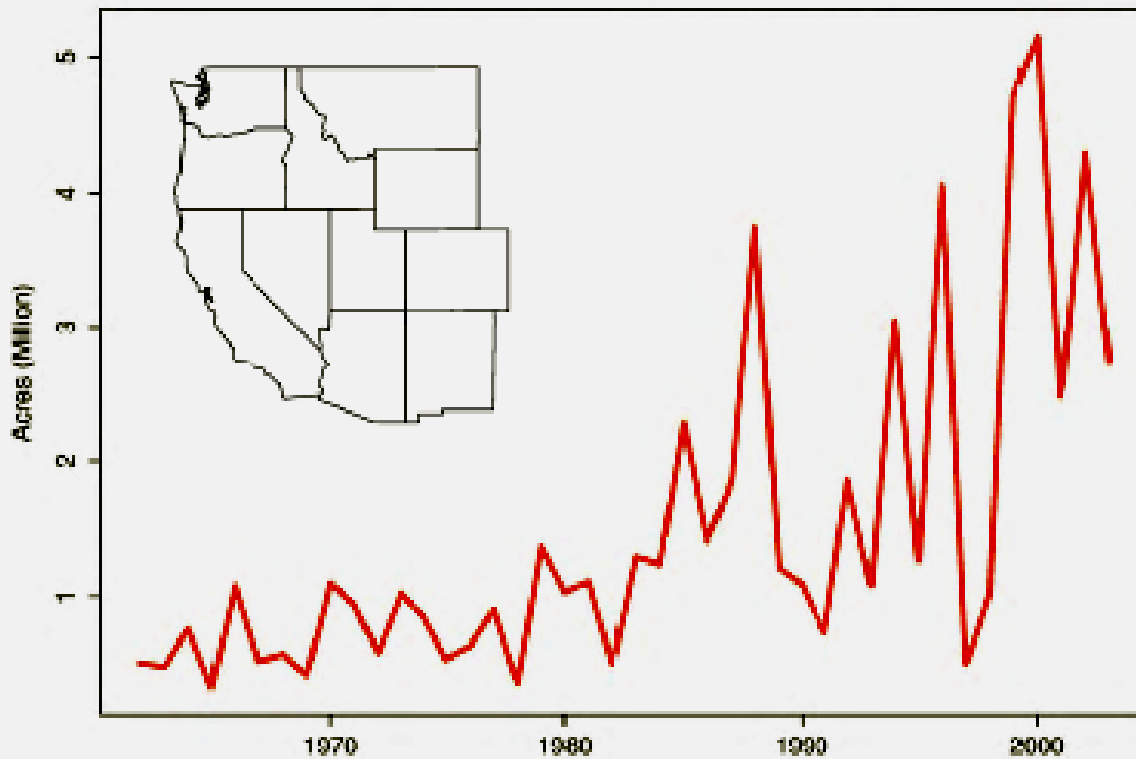


There's a consistent 50-year upward trend in every region except Oceania.

Harm is already occurring (continued)

Wildfires in the Western USA have increased 4-fold in the last 30 years.

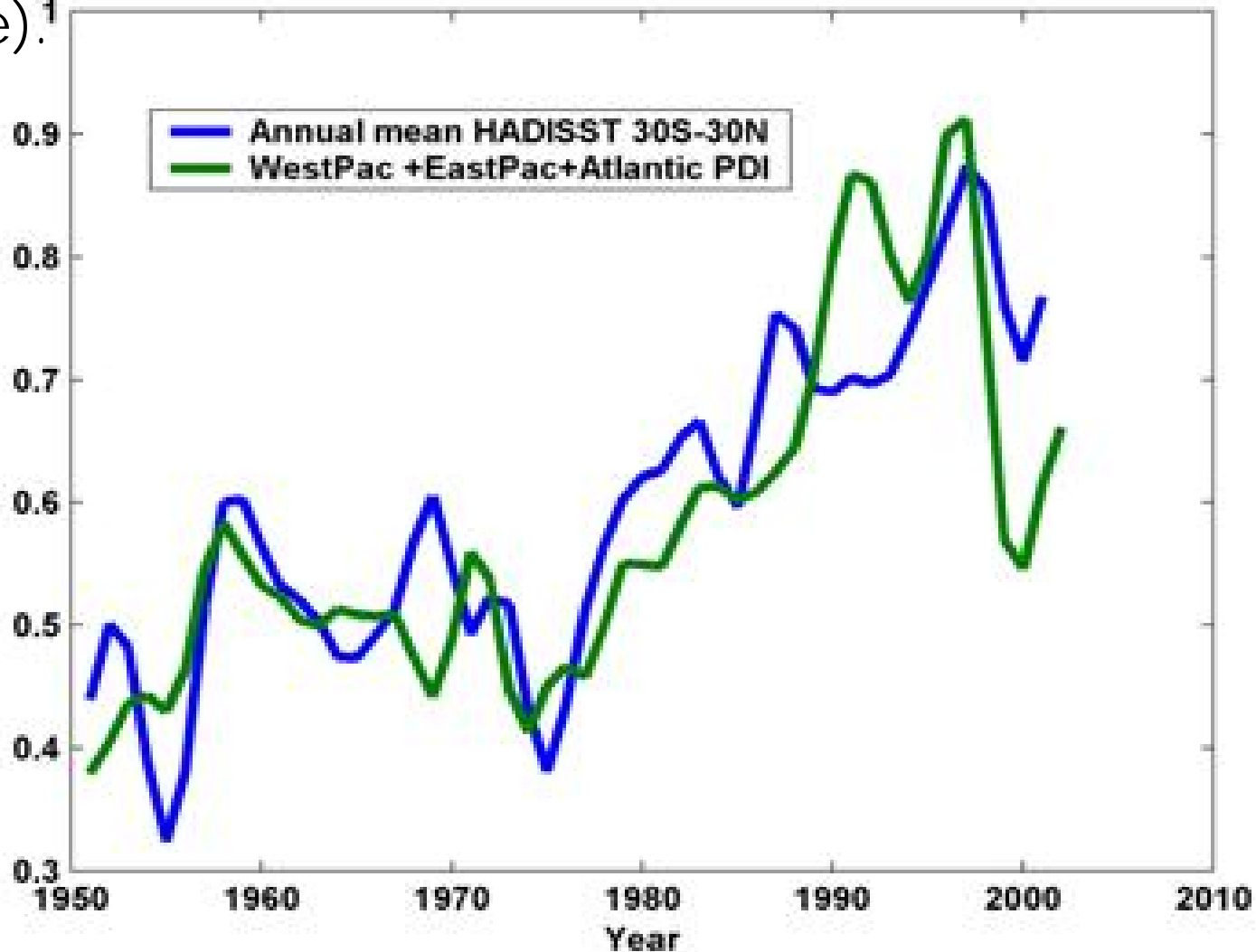
Western US area burned



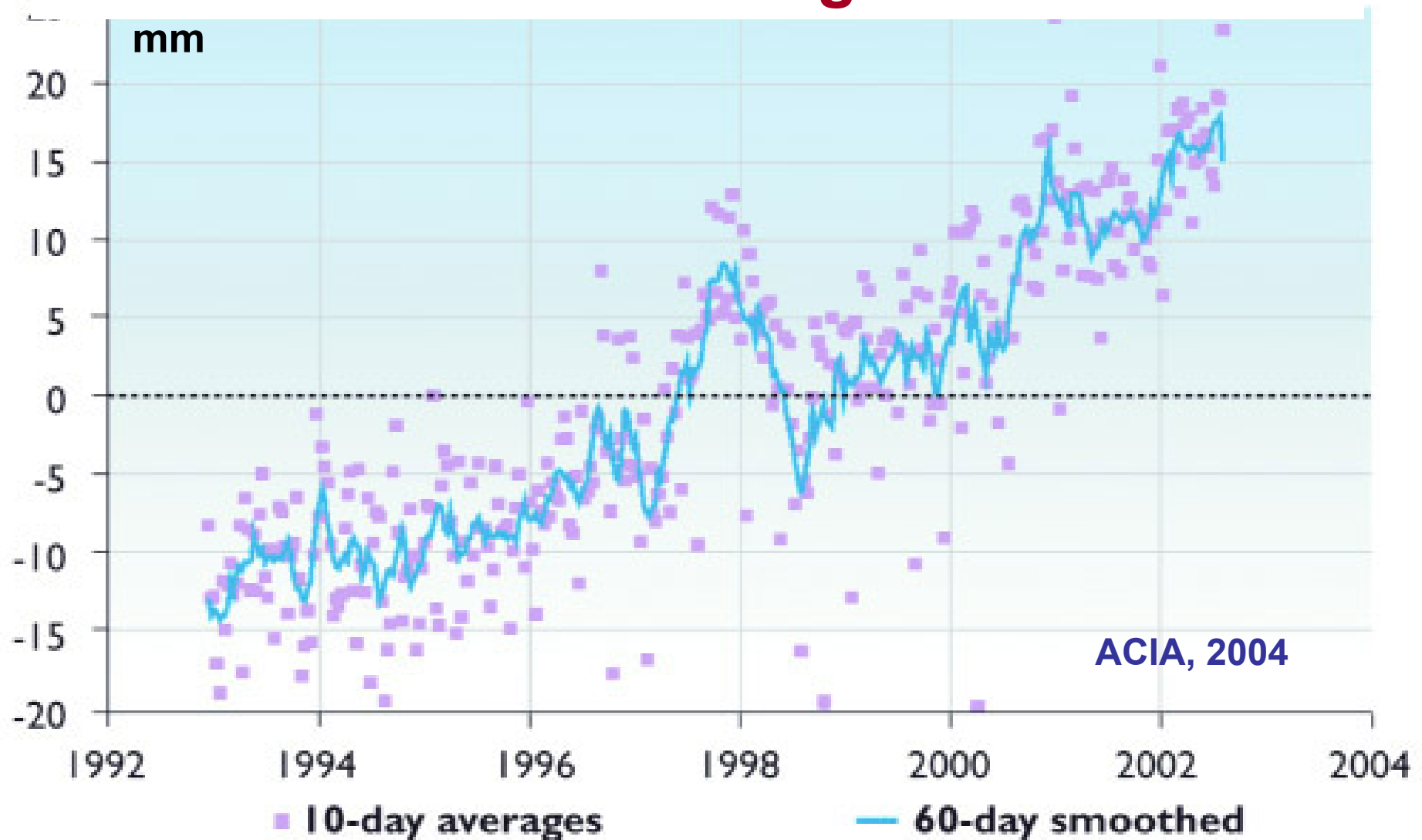
Source: Westerling et al. 2006

Harm is already occurring (continued)

Total power released by tropical cyclones (green) has increased along with sea surface temperatures (blue).¹

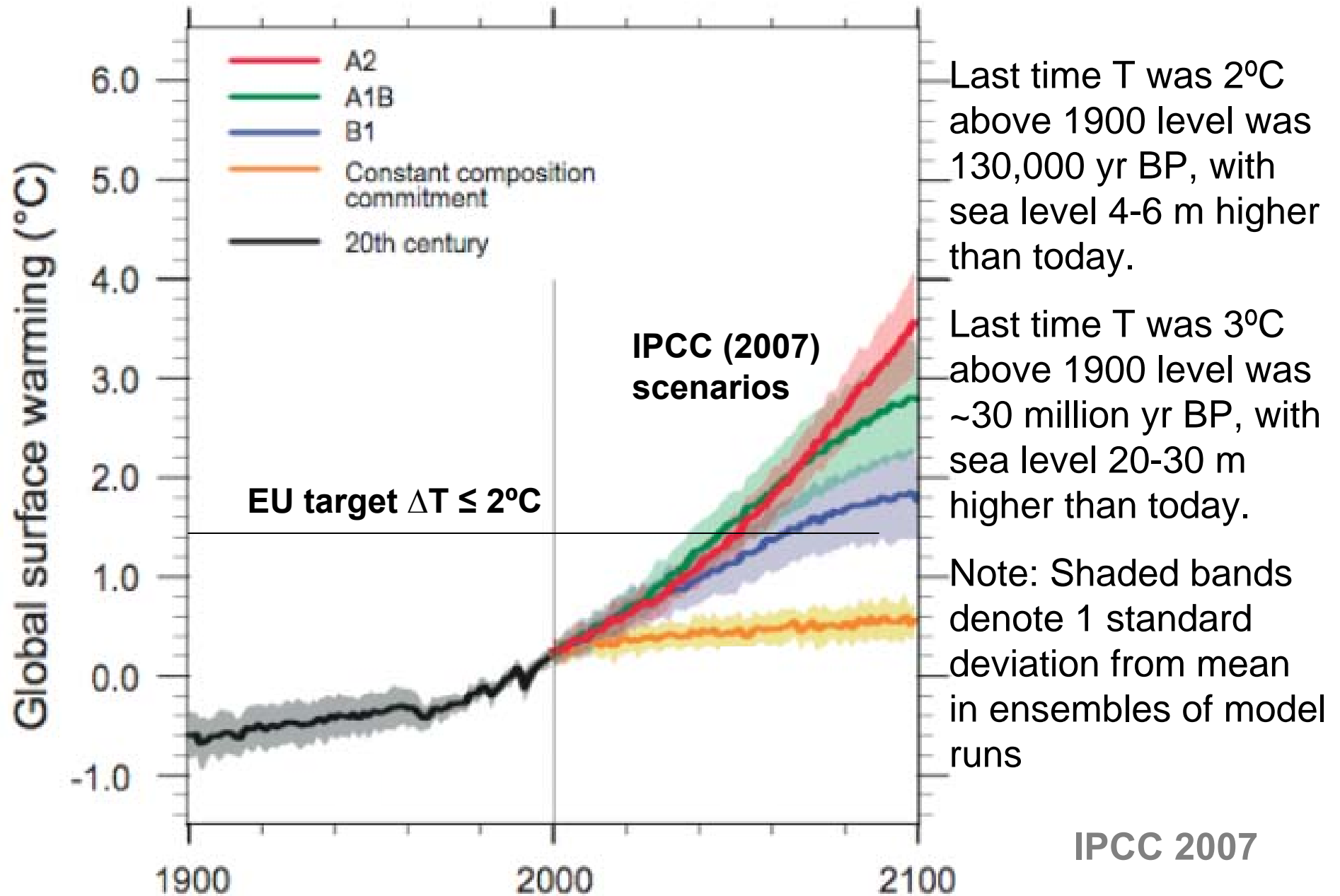


Melting land ice and thermal expansion of ocean water are raising sea level

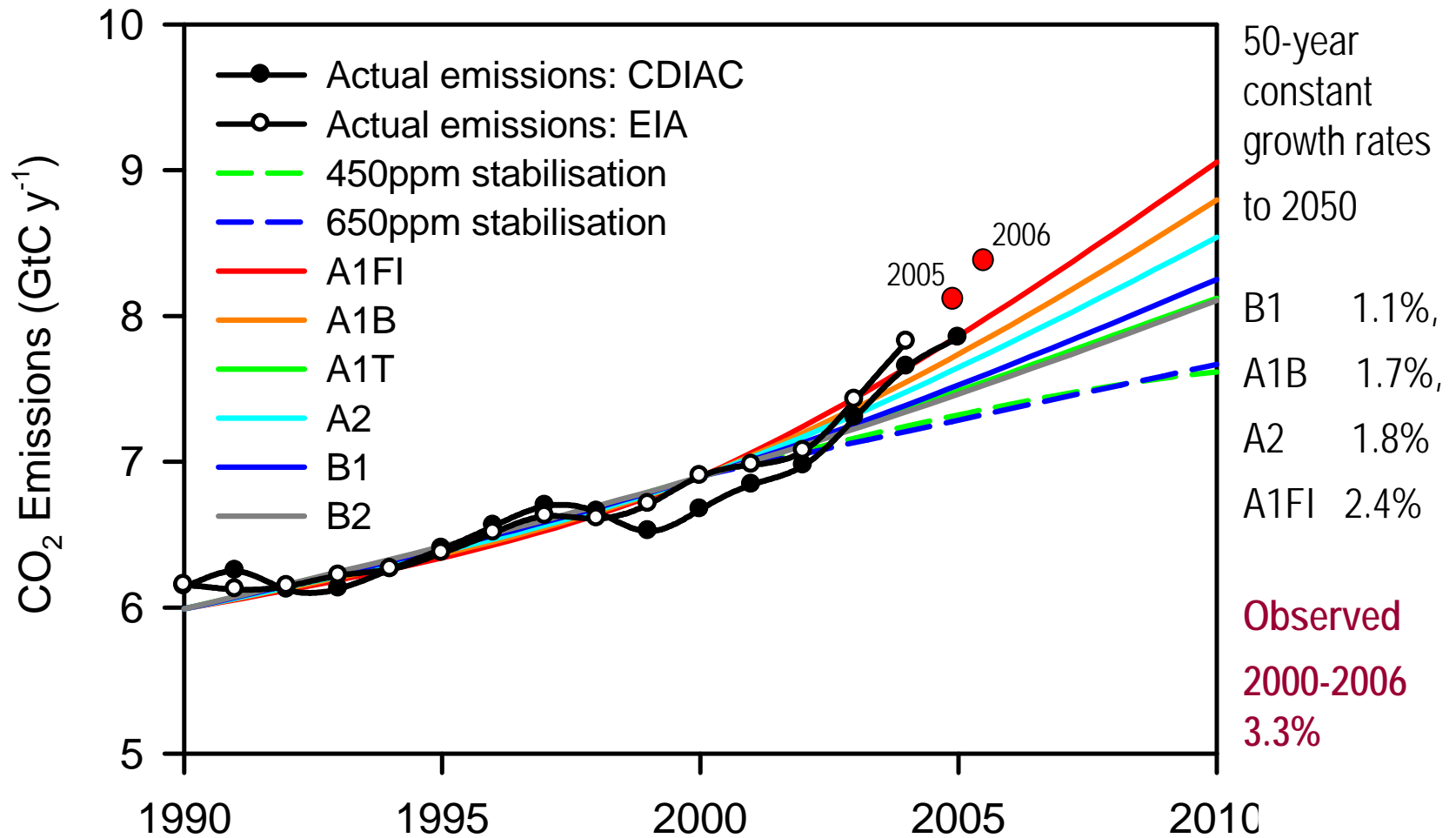


1993-2003 \approx 30 mm = 3.0 mm/yr; compare 1910-1990 = 1.5 ± 0.5 mm/yr.

Under BAU much bigger disruption is coming



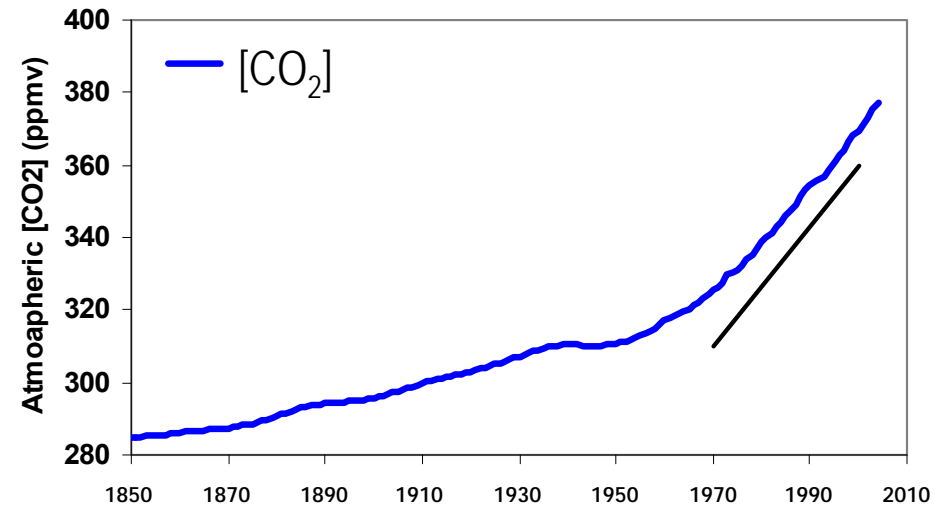
Past IPCC assessments have underestimated the rate of growth of emissions



Raupach et al. 2007, PNAS

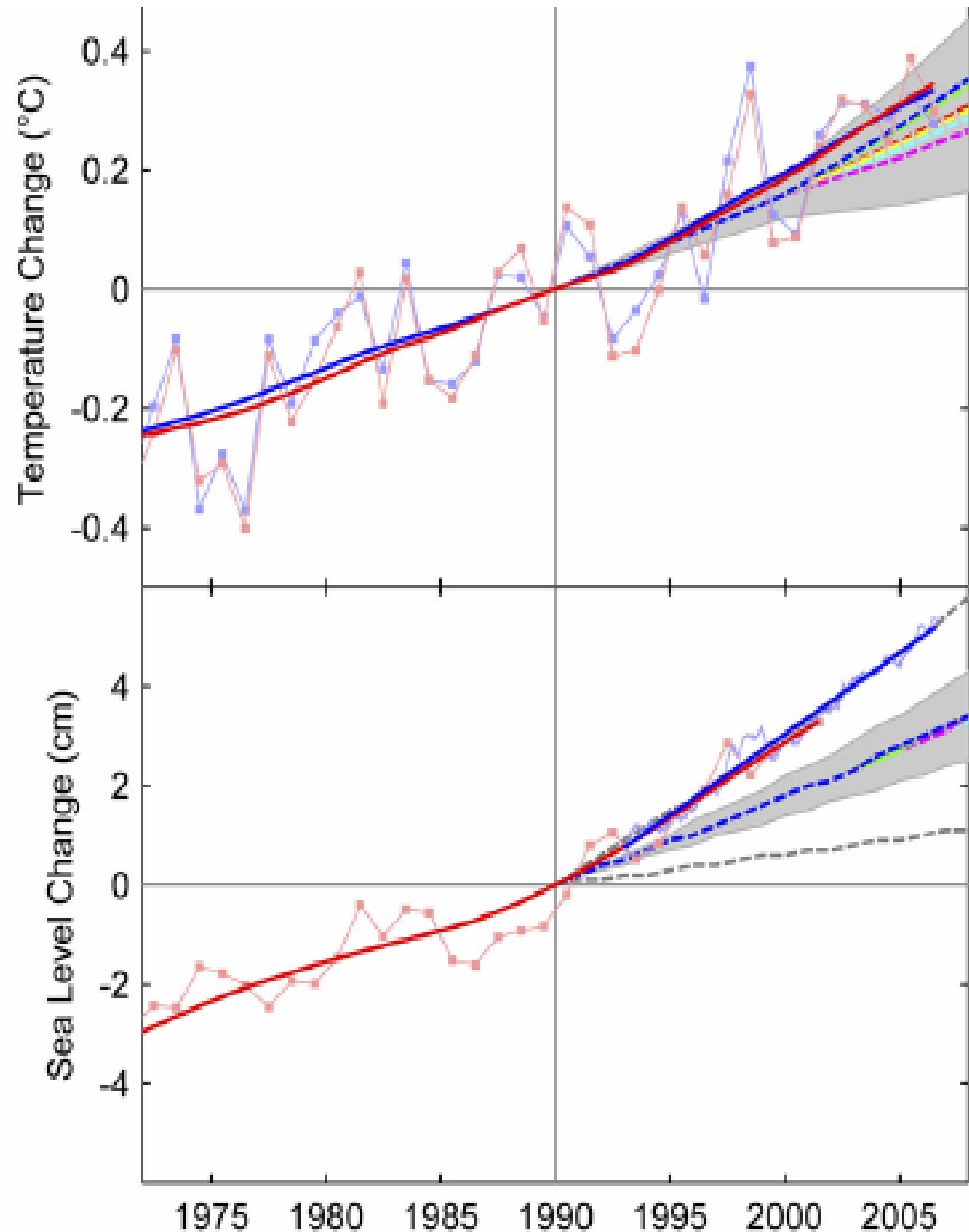
...and the rate of growth of the concentration of CO₂ is itself growing

Year 2007
Atmospheric CO₂
concentration:
384 ppm
38% above pre-industrial



1970 – 1979: 1.3 ppm y⁻¹
1980 – 1989: 1.6 ppm y⁻¹
1990 – 1999: 1.5 ppm y⁻¹
2000 - 2006: **1.9 ppm y⁻¹**

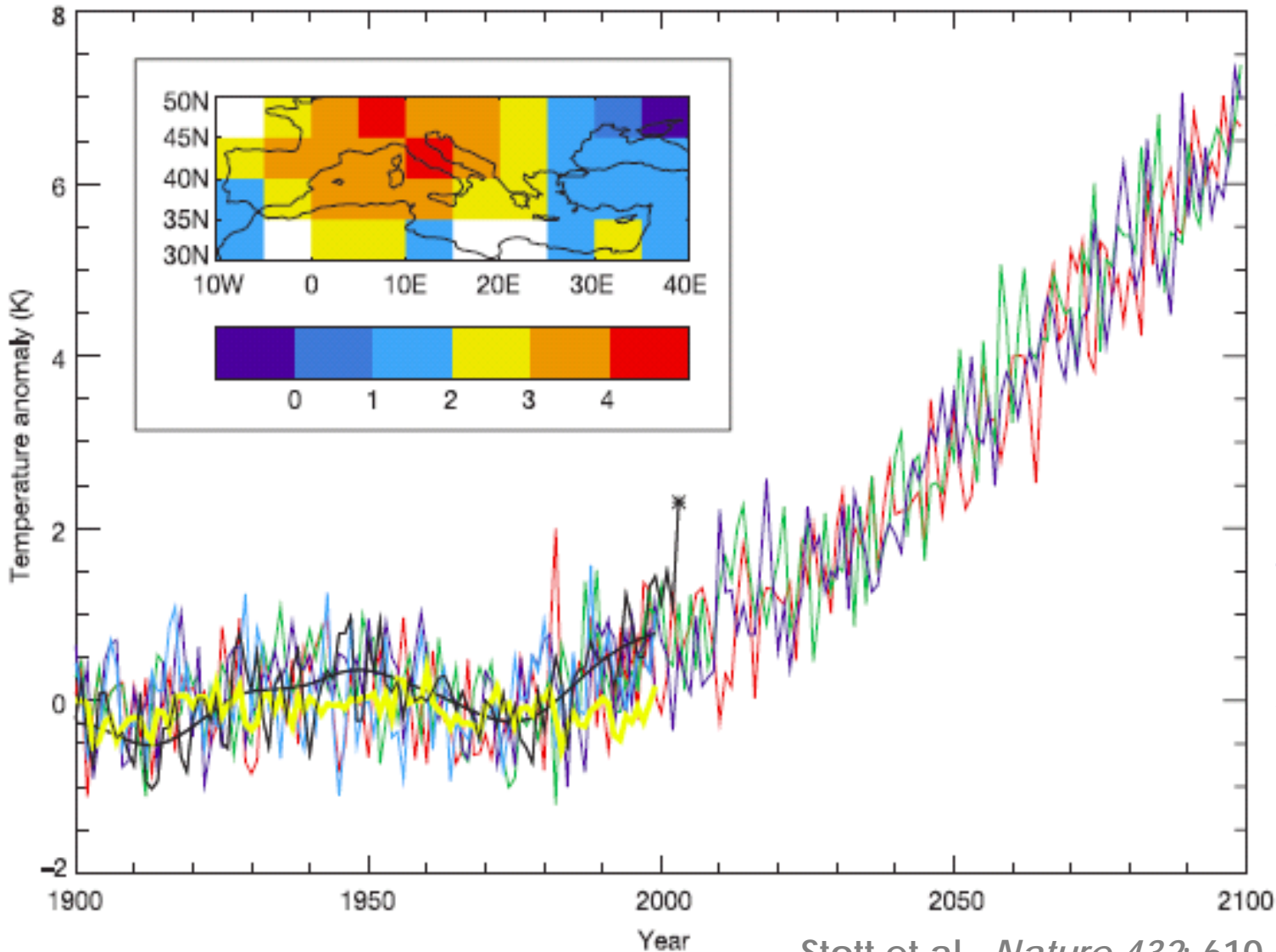
Impact variables –
temperature and
sea-level rise –
have been at the
high ends of the
IPCC 2001 scenario
range



Rahmstorff et al.
SCIENCE, Feb 2007

What more is in store: Heat waves

Extreme heat waves in Europe, already 2X more frequent because of global warming, will be “normal” in mid-range scenario by 2040

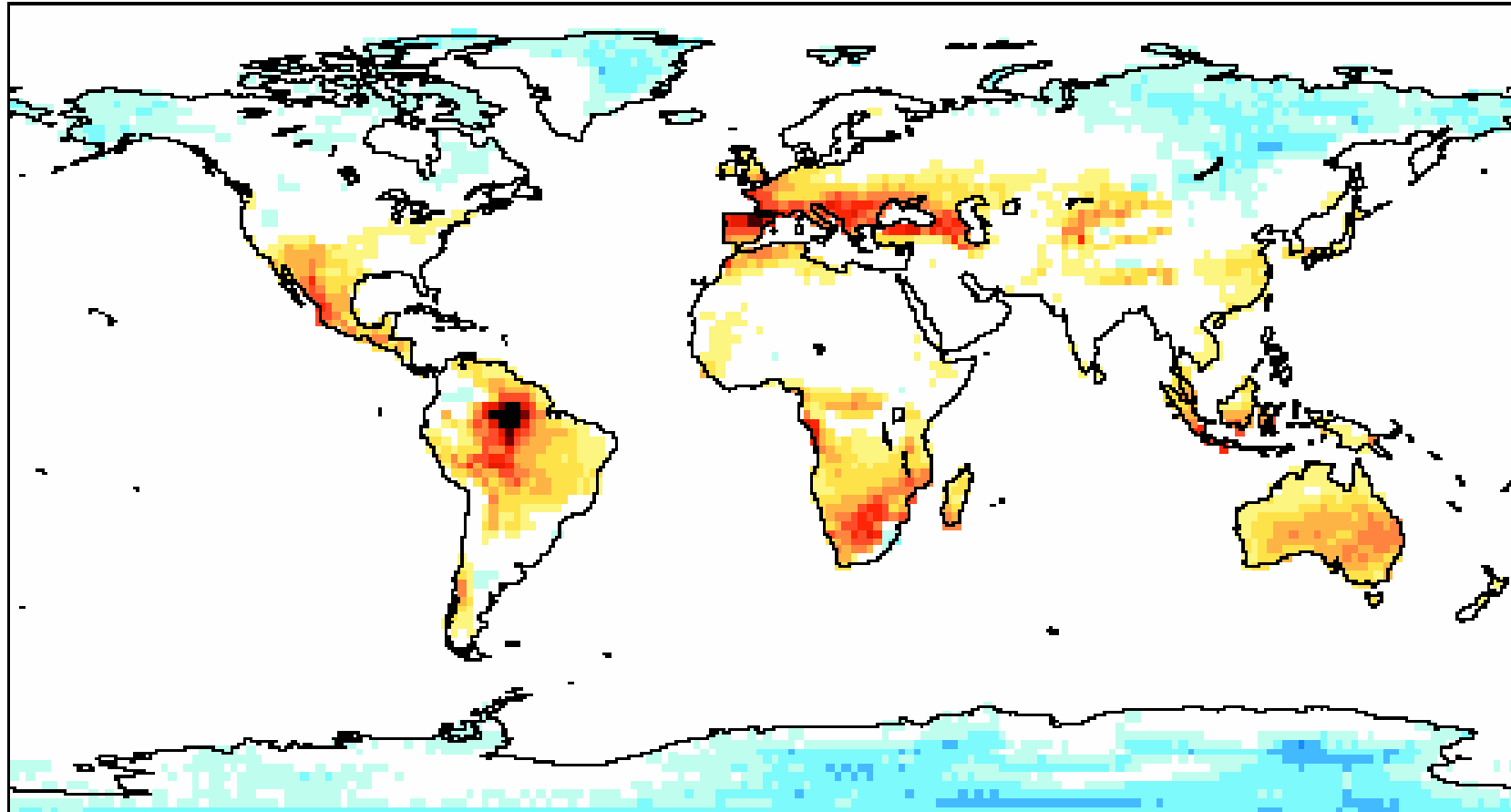


Black lines are observed temps, smoothed & unsmoothed; red, blue, & green lines are Hadley Centre simulations w natural & anthropogenic forcing; yellow is natural only.

Asterisk and inset show 2003 heat wave that killed 35,000.

What more is in store: 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.

What's in store for sea level?

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

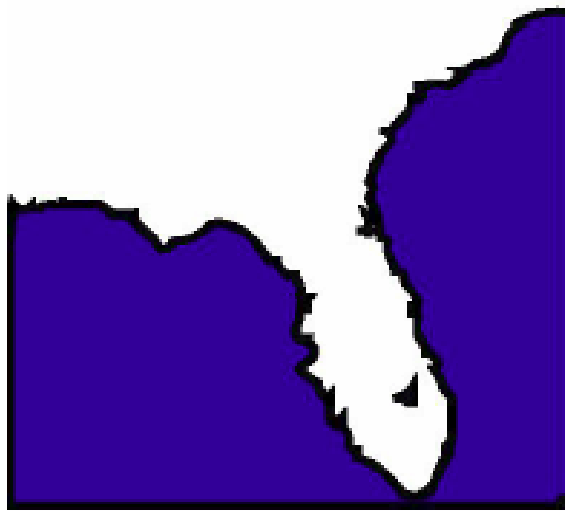
This would probably take 1000s of years, but rates of 2-5 m per century are possible.

GIS = Greenland Ice Sheet

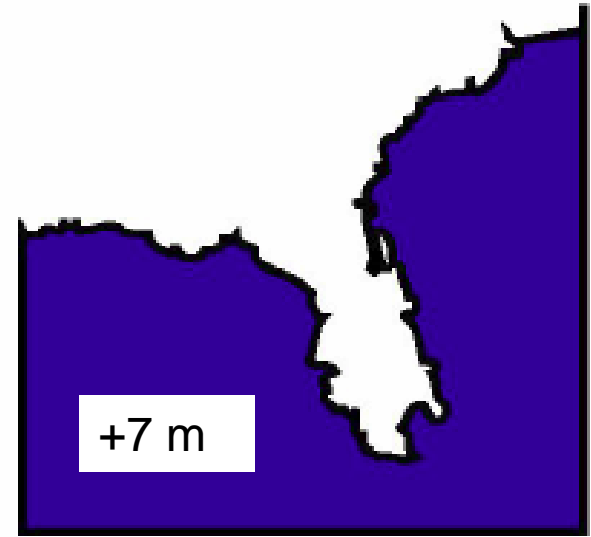
WAIS = West Antarctic Ice Sheet

EAIS = East Antarctic Ice Sheet

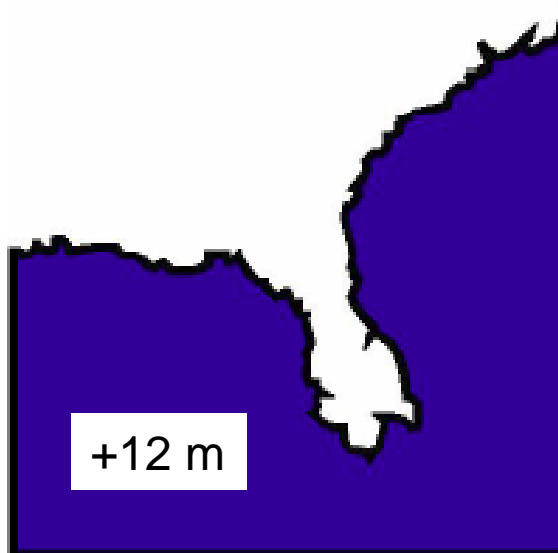
Modern Florida



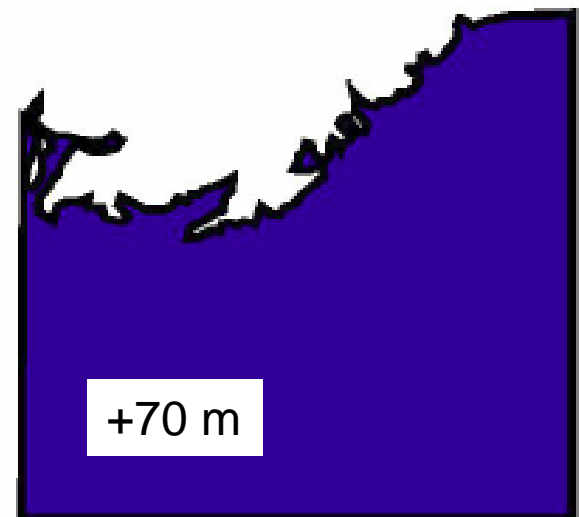
Florida w/o GIS

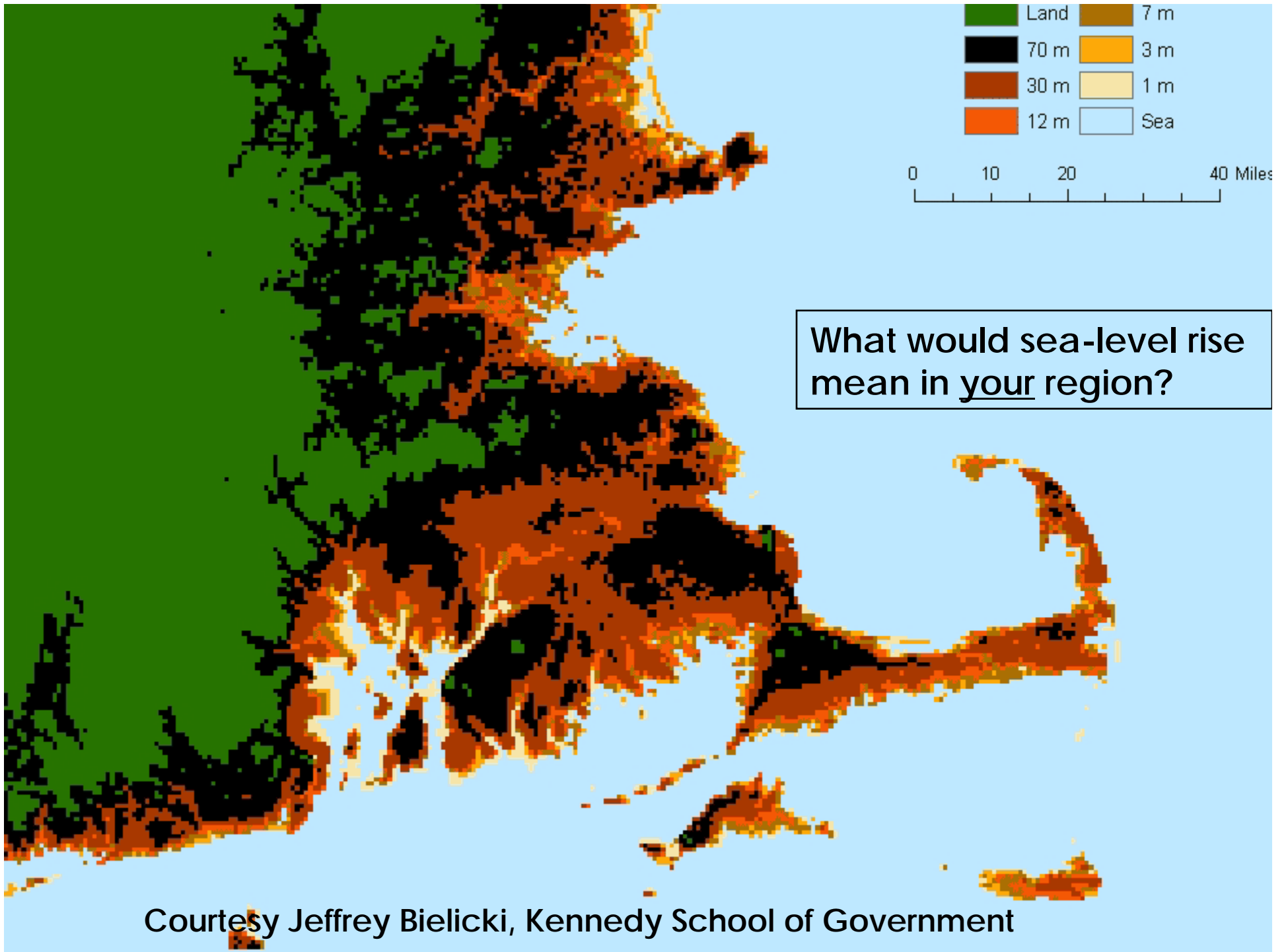


Florida w/o WAIS+GIS



Florida w/o WAIS+GIS+EAIS





REFERENCES

- UN Foundation / Sigma Xi 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* <http://www.ipcc.ch/>
- The National Academies, *Understanding and Responding to Climate Change*, 2008 Edition
<http://dels.nas.edu/basc/climate-change/>