Update on Climate Science:
What Has Been Learned Lately?

JOHN P. HOLDREN

Director

The Woods Hole Research Center

Teresa & John Heinz Professor and Director
Program on Science, Technology, and Public Policy
John F. Kennedy School of Government
and Professor of Earth and Planetary Sciences

Harvard University

President

American Association for the Advancement of Science

February 2007

Topics

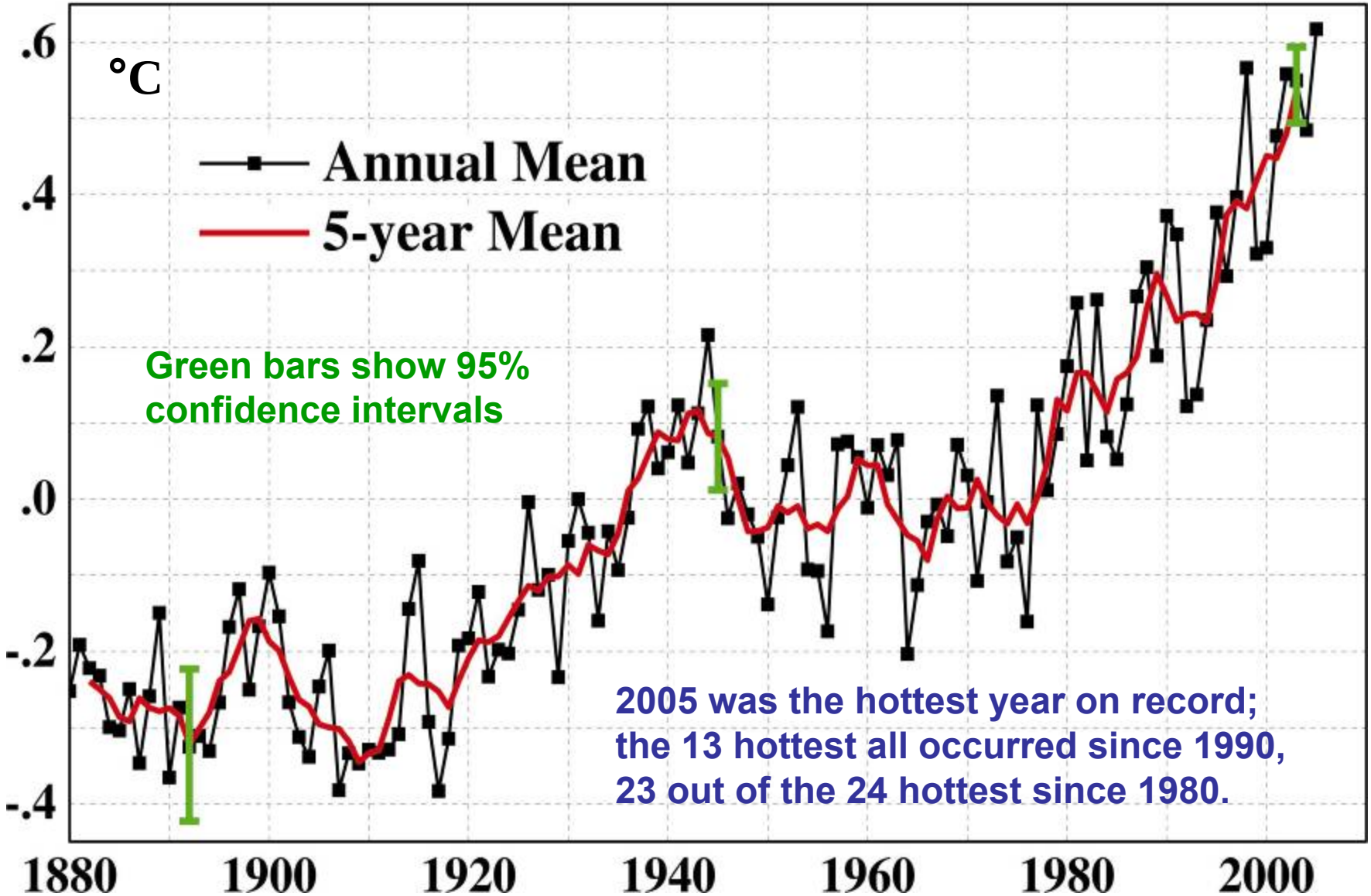
- Trends in Earth's mean surface temperature
- Other changes that track the T increases
- The "forcings" causing the changes
- The "sensitivity" of Earth's average temperature to the forcings
- Harm from climate change to date
- Projections of further damages
- The February 2007 report of IPCC WG1
- Society's options: mitigation, adaptation, suffering
- How much mitigation makes sense?

Trends in Earth's mean temperature

The mean annual surface temperature of the Earth, T_{avg} (averaged over the globe and over the year) is a sensitive indicator of the state of the climate. Small changes in T_{avg} reflect big changes in climatic state.

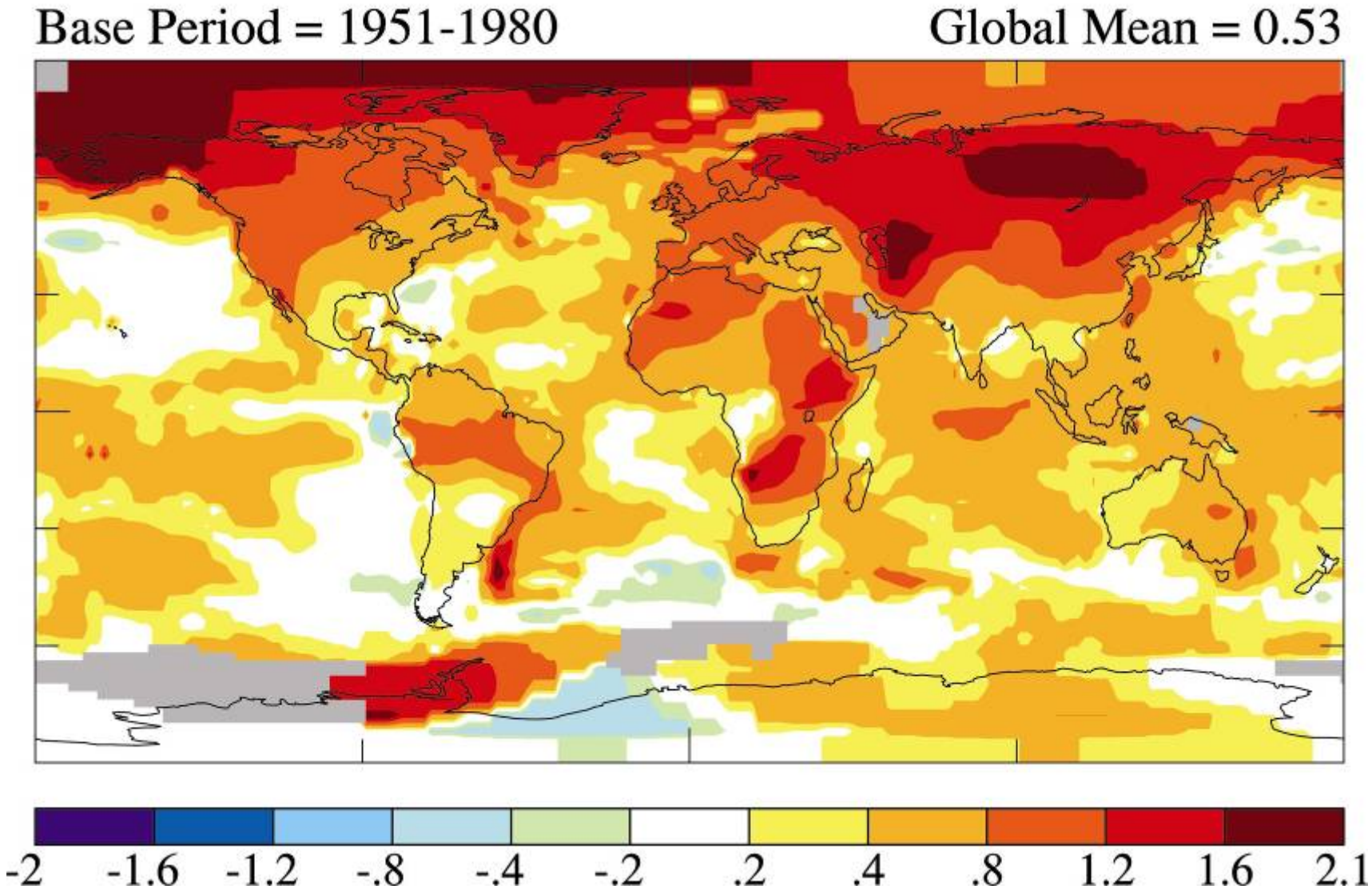
- The warming trend has been continuing, with 2005 the hottest year in the 125-year instrumental record; 2006 was the 6th warmest.
- The 13 warmest years in the record have all occurred since 1990, 23 out of the 24 warmest years since 1980.
- Discrepancies previously reported among satellite, balloon, and surface-thermometer measurements have been resolved; all 3 records are now in close agreement.
- A study by the National Academies has settled the "hockey stick" controversy, confirming that 1950-2000 was almost certainly the warmest half century in 1,000 years.

Global surface temperature since 1880



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

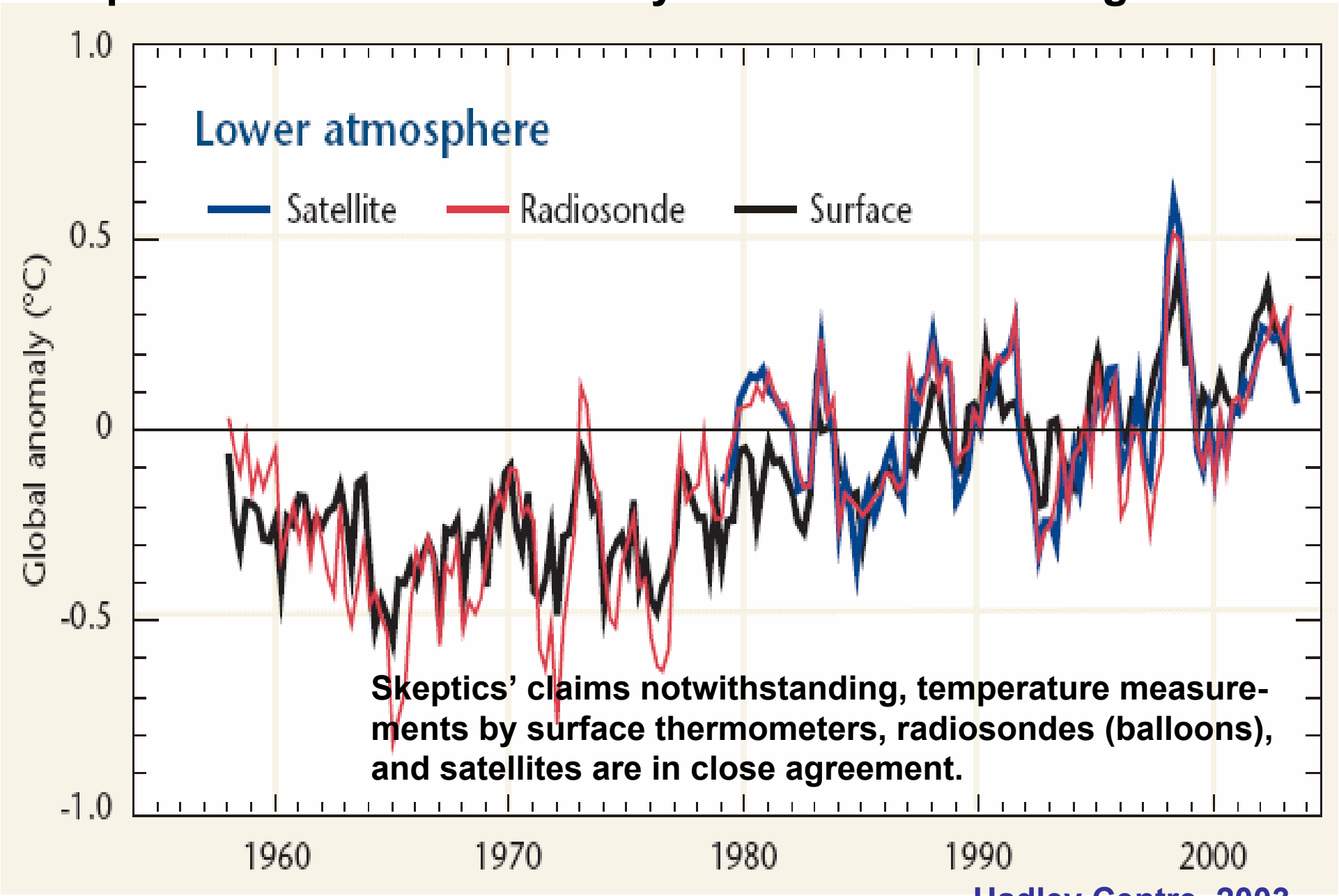
Average T in 2001-2005 versus 1951-80 base, °C



"Global warming" is a misnomer. T increases are nonuniform: higher mid-continent, highest in far North. Global average temperature is just an <u>index</u> of the state of the global climate.

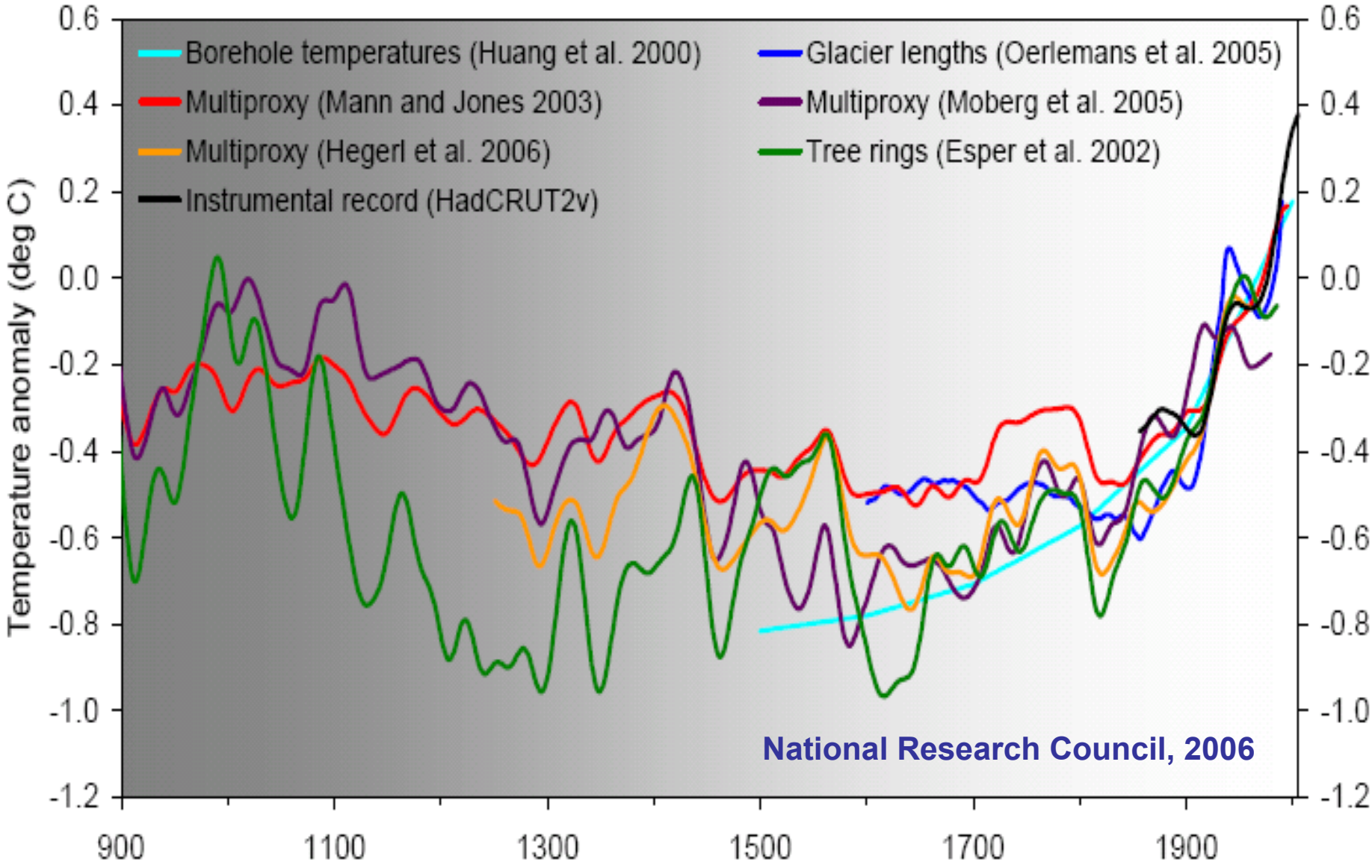
J. Hansen et al., *PNAS 103*: 14288-293 (2006)

Temperature measurements by different methods agree



Hadley Centre, 2003

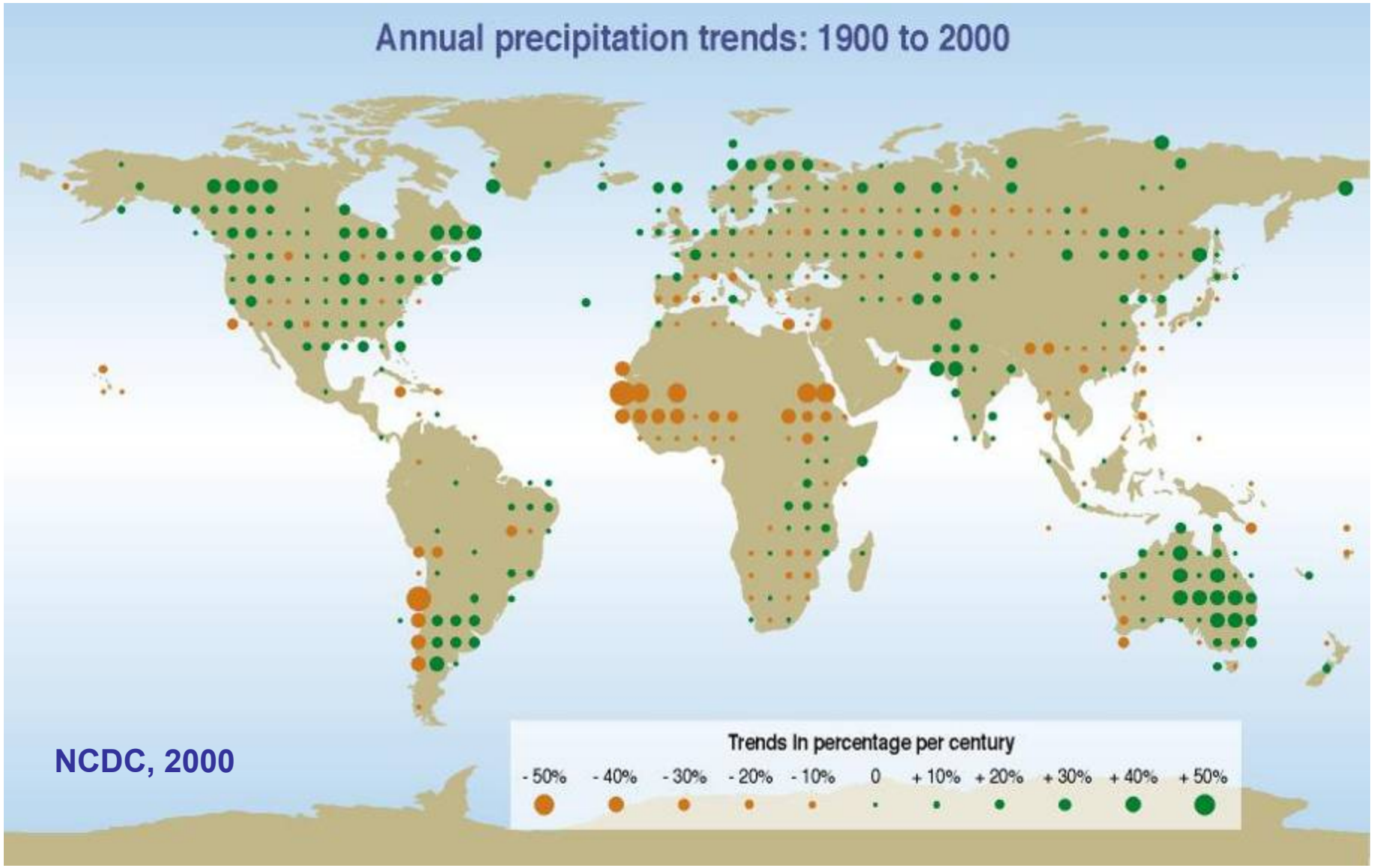
Temperature reconstructions for the past 1100 years



Nature was on a cooling trend from ~1000 to ~1800, when human heating took over.

Phenomena expected to accompany rising temperatures are being observed with increasing strength.

Evaporation & precipitation are increasing



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 likewise disappearing

Qori Kalis Glacier, Peru

a 1978

1978

b 2002

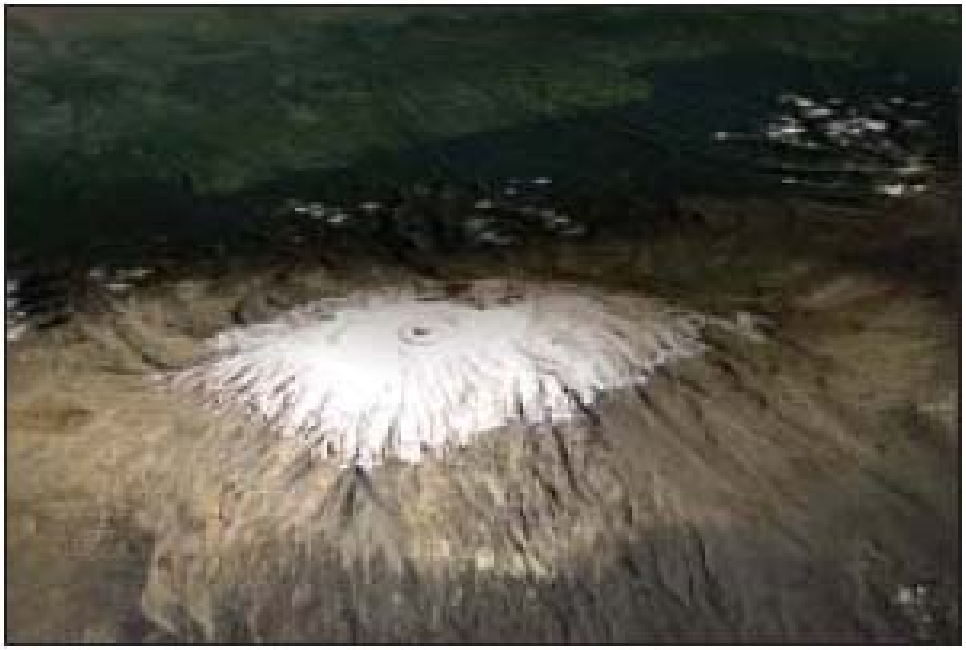
2002

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.

Some are nearly gone

Kilimanjaro, Africa's highest mountain, is almost exactly on the equator and largely immune from climatic changes that are not global, It's ice cover shrunk by 80% between 1912 and 2000.

These satellite images show the reduction just between 1993 and 2000.



Mt. Kilimanjaro, 1993 © NASA

Mt. Kilimanjaro, 2000 © NASA

NASA photograph

Sea ice is shrinking

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

The 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.

Greenland (at the right) is covered with a thick sheet of land ice. If this melts, sea level rises.

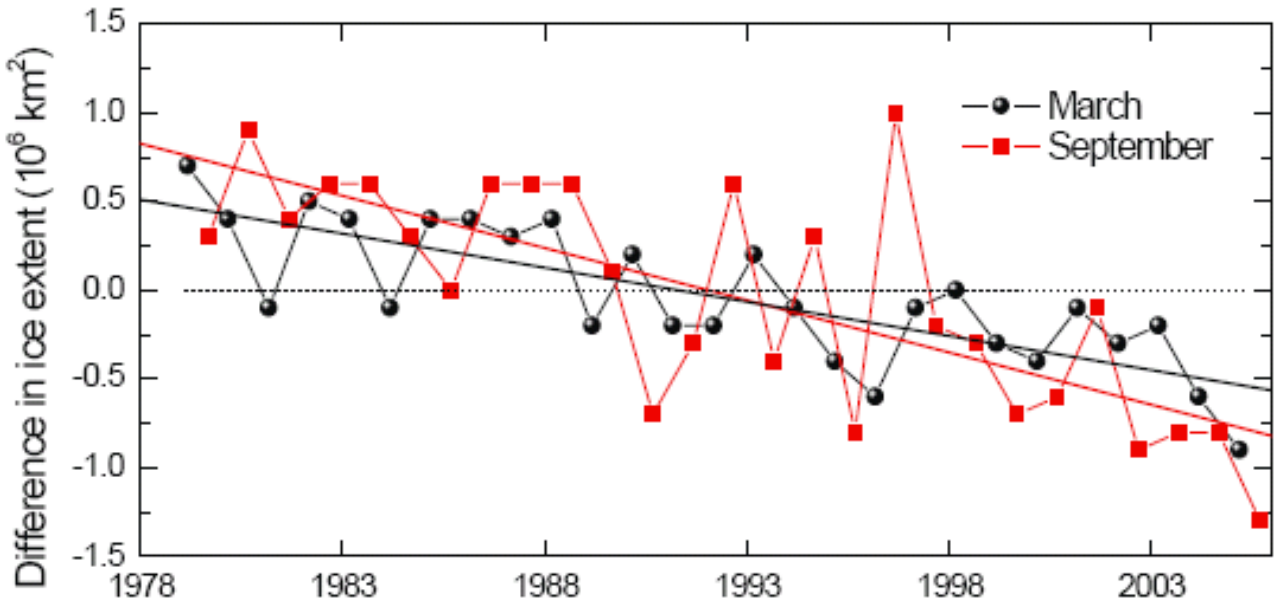


Figure 15: Time series of the difference in ice extent in March (maximum) and September (minimum) from the mean values for 1979–2005. Based on a least-squares linear regression, the rates of decrease in March and September were 2% per decade and 7% per decade, respectively. Recent data from March 2006 are also shown and represent a new record minimum for the period of observation.

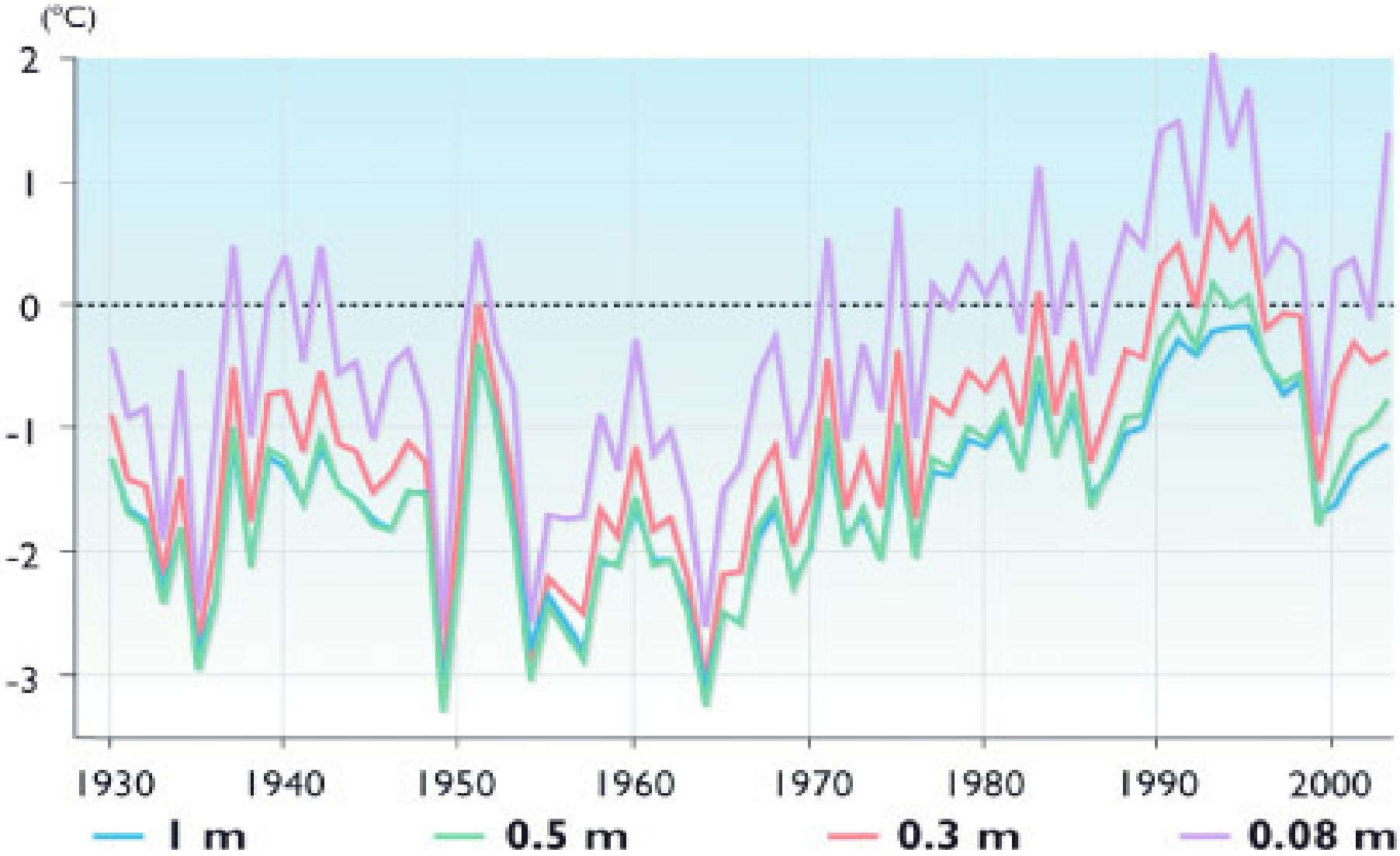
NOAA State of the Arctic Report, Nov 2006

“Sea ice extent continues to decrease. The sea ice extent in September 2005 was the minimum observed in summer during the satellite era (beginning in 1979), marking an unprecedented series of extreme ice extent minima beginning in 2002 (Fig. 3). The sea ice extent in March 2006 was also the minimum observed in winter during the satellite era.”

NOAA State of the Arctic Report, Nov 2006

Permafrost is melting

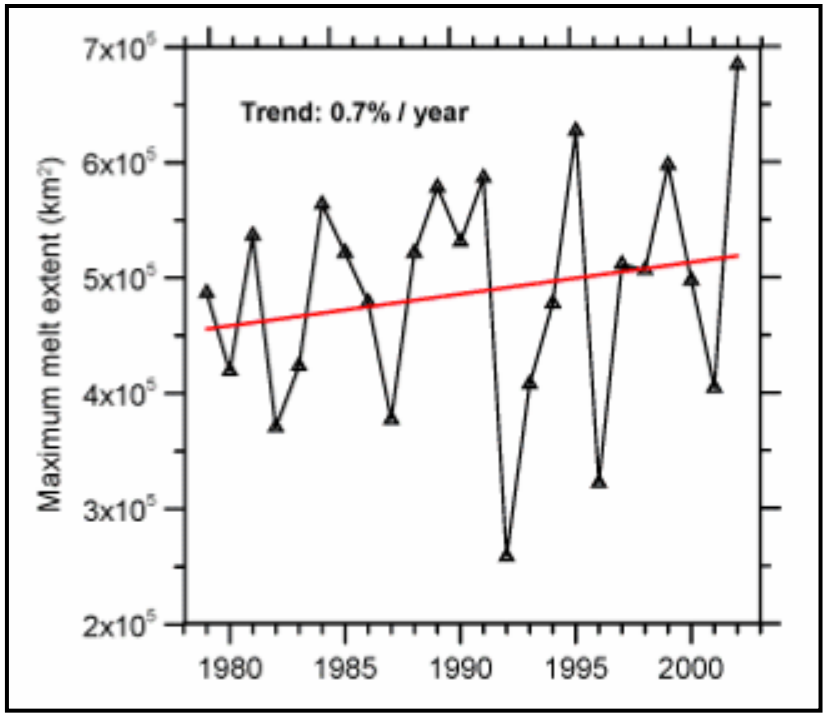
Average annual temperature near Fairbanks, Alaska, degrees C

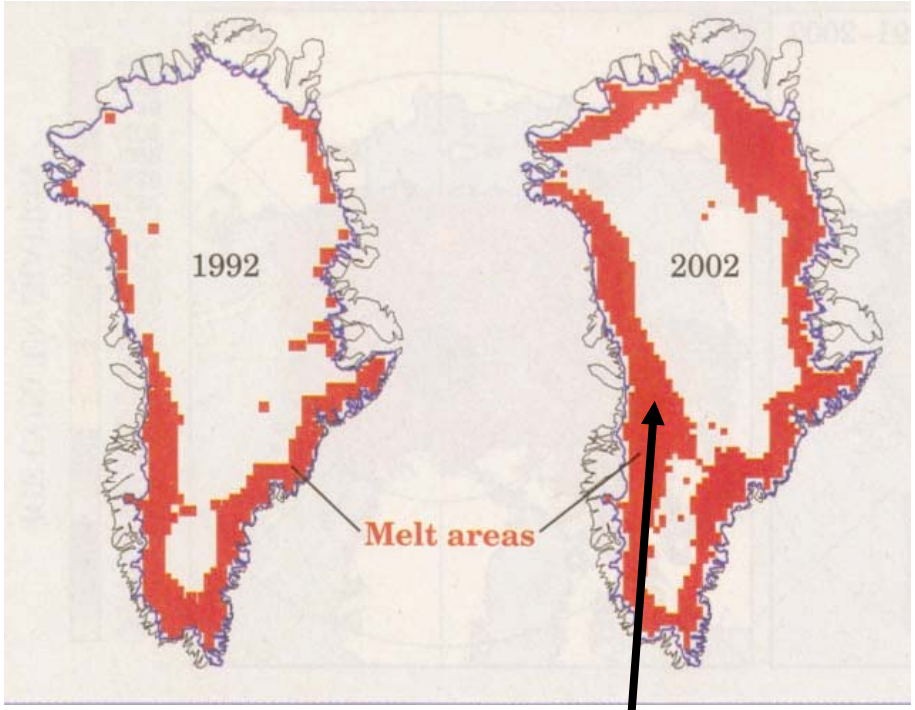


Permafrost melts when T ≥ 0°C

ACIA 2004

Greenland is melting





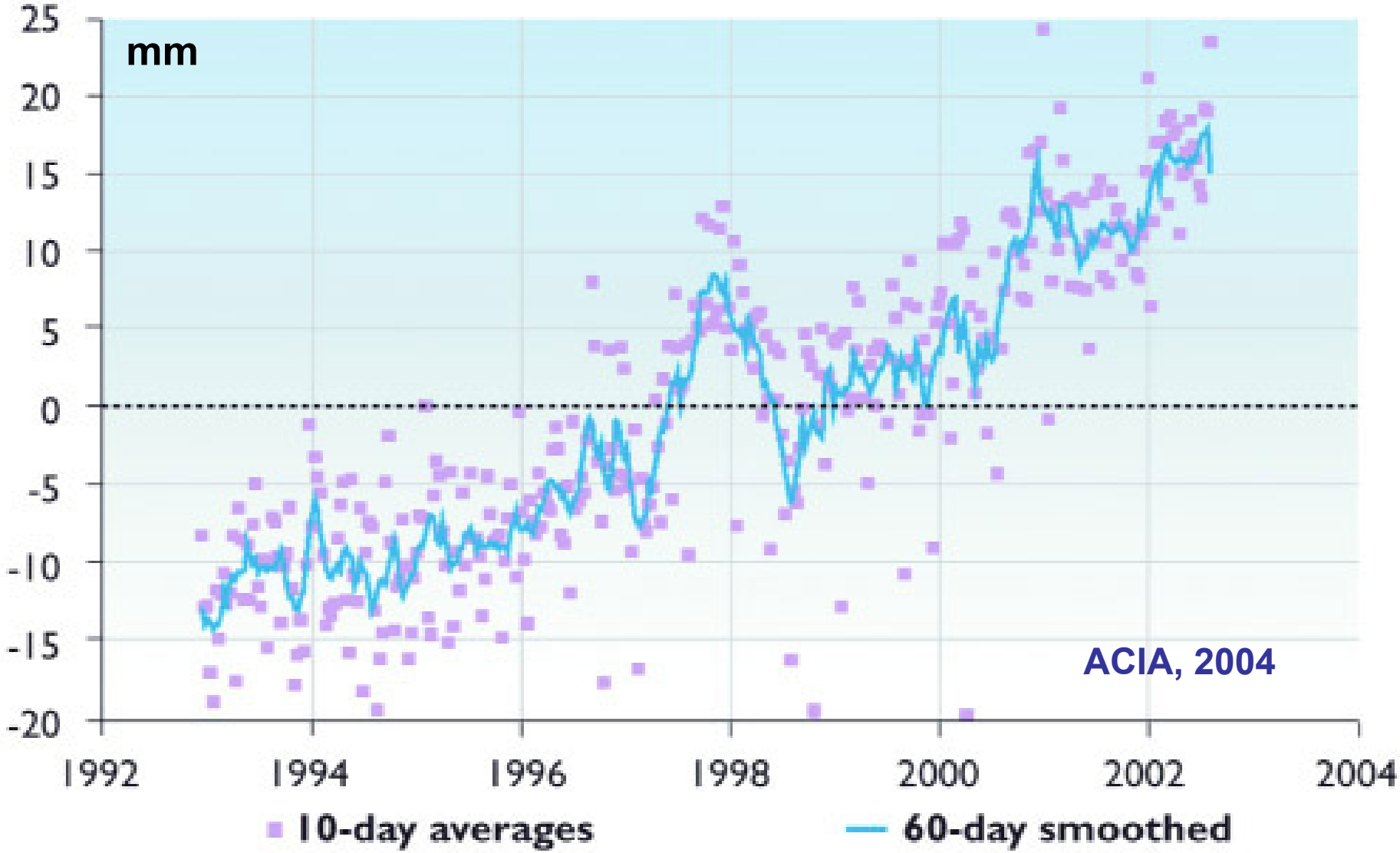
- 2002 set a record for the extent of summer surface melting.
- Melting is occurring up to elevation of 2000 m.

70 meters thinning in 5 years

The satellite-era record melt of 2002 was exceeded in 2005.

Source: Waleed Abdalati, Goddard Space Flight Center

Sea-level is rising



1993-2003 ≈ 35 mm = 3.5 mm/yr; compare 1910-1990 = 1.5±0.5 mm/yr.

Species are moving

articles

A globally coherent fingerprint of climate change impacts across natural systems

Camille Parmesan* & Gary Yohe†

** Integrative Biology, Patterson Laboratories 141, University of Texas, Austin, Texas 78712, USA*
† John E. Andrus Professor of Economics, Wesleyan University, 238 Public Affairs Center, Middletown, Connecticut 06459, USA

Causal attribution of recent biological trends to climate change is complicated because non-climatic influences dominate local, short-term biological changes. Any underlying signal from climate change is likely to be revealed by analyses that seek systematic trends across diverse species and geographic regions; however, debates within the Intergovernmental Panel on Climate Change (IPCC) reveal several definitions of a 'systematic trend'. Here, we explore these differences, apply diverse analyses to more than 1,700 species, and show that recent biological trends match climate change predictions. Global meta-analyses documented significant range shifts averaging 6.1 km per decade towards the poles (or metres per decade upward), and significant mean advancement of spring events by 2.3 days per decade. We define a diagnostic fingerprint of temporal and spatial 'sign-switching' responses uniquely predicted by twentieth century climate trends. Among appropriate long-term/large-scale/multi-species data sets, this diagnostic fingerprint was found for 279 species. This suite of analyses generates 'very high confidence' (as laid down by the IPCC) that climate change is already affecting living systems.

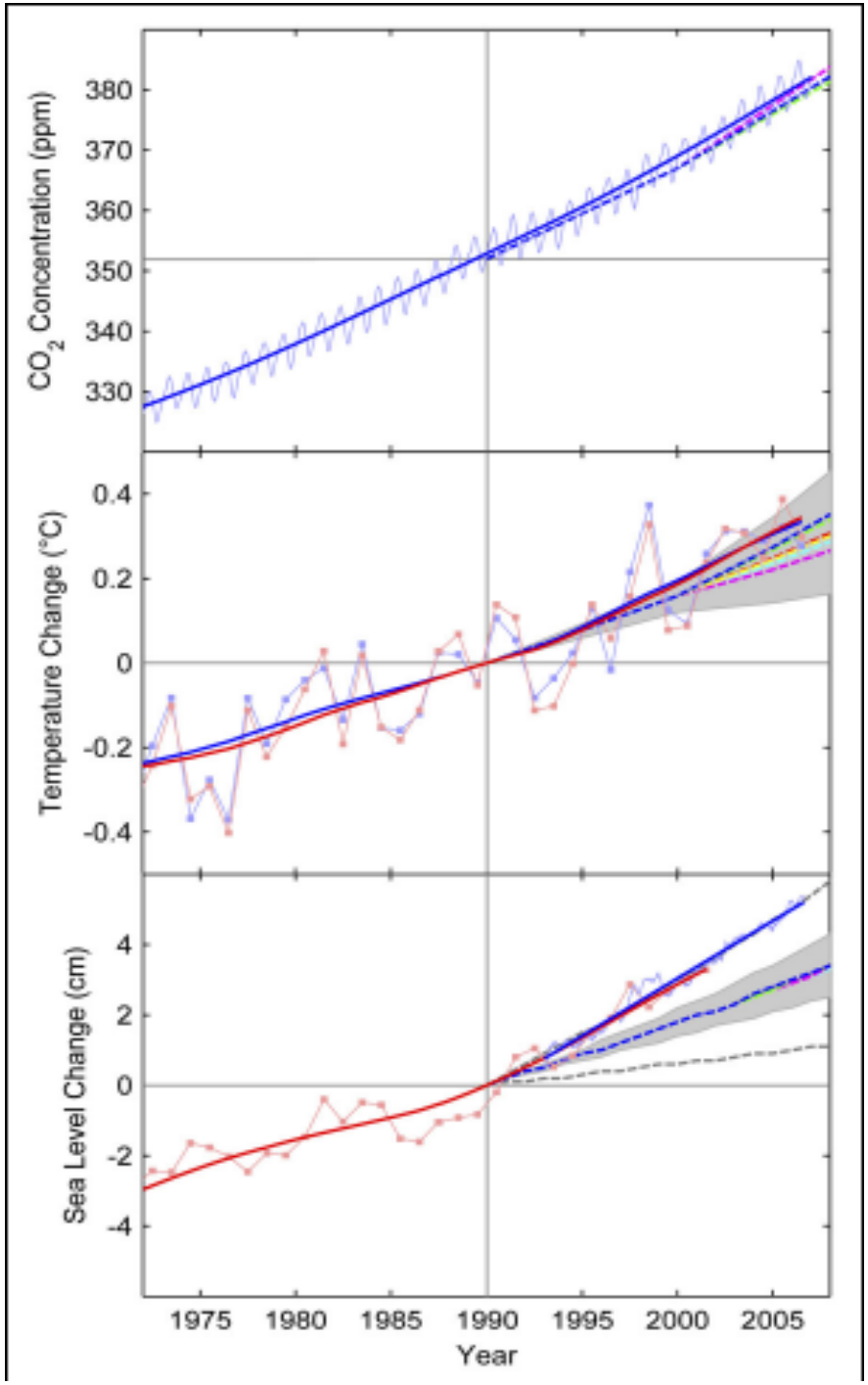
NATURE | VOL 421 | 2 JANUARY 2003

Key variables have been tracking or exceeding IPCC projections

IPCC projections published in the 2001 assessment were based on data to 1990.

Observations since 1990 have tracked the projections for CO2, have been near the high side of projected ranges for temperature, and have been at the extreme high side of the projections for sea-level rise.

Rahmstorf et al., *Science Express*, February 2007

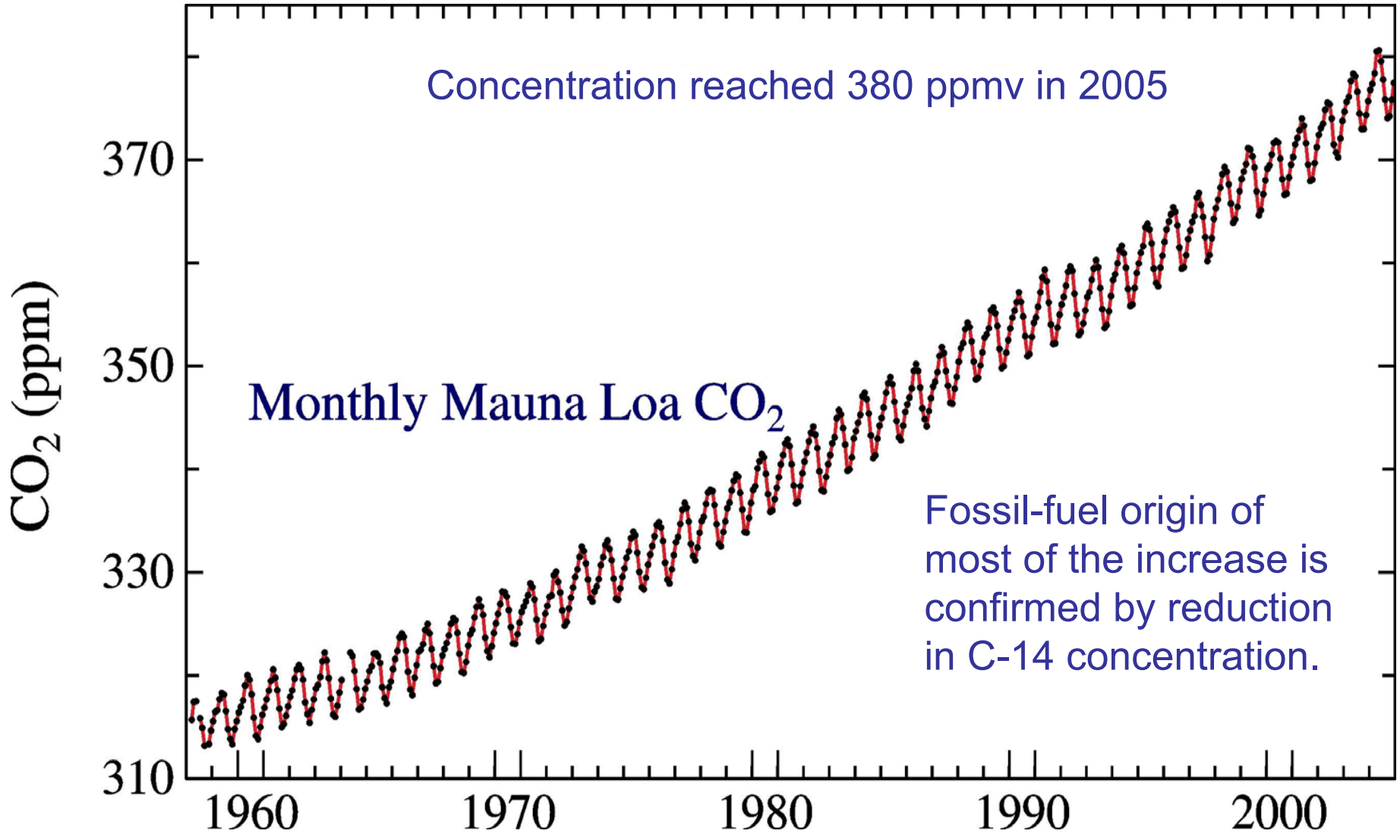


Understanding the forcings

"Forcings" are influences that "push" the climate toward overall warming (positive forcing) or cooling (negative forcing).

- Growth of the concentration of carbon dioxide – the most important forcing – has continued in step with emissions from fossil-fuel burning.
- Extending the ice-core record shows that CO_2 has not been as high as today in 650,000 years.
- Correlating diverse lines of evidence has narrowed the ranges of uncertainty on other important forcings, including the cooling effects of particulate matter and the (modest) warming effects of increased solar irradiance.

Direct measurements of CO_2 show continued rise



Atmospheric CO_2 measured at Mauna Loa, Hawaii.

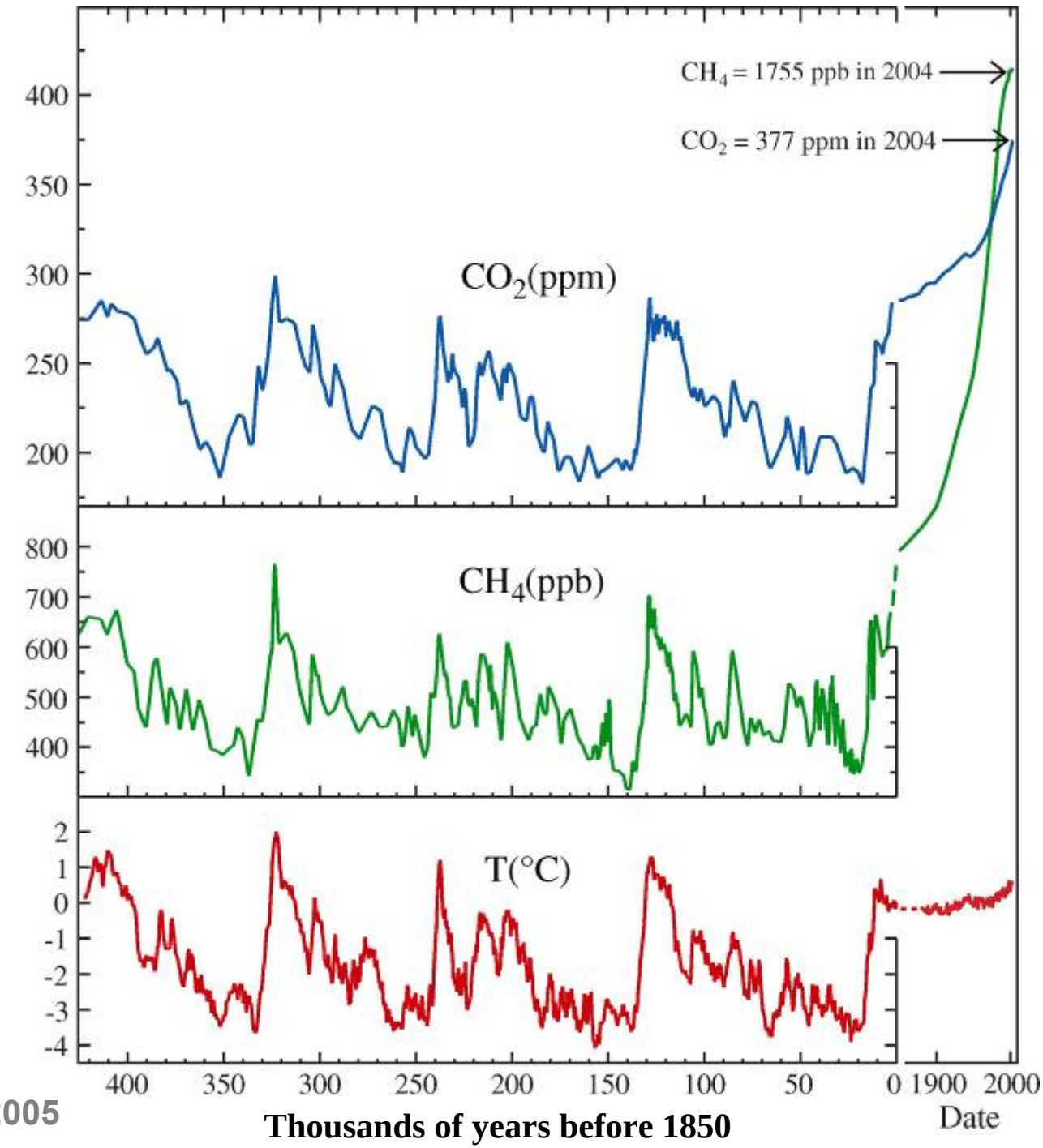
Source: NOAA Climate Monitoring and Diagnostic Laboratory

The last 450,000 years of natural change compared to the last century

Time scale expanded for last 150 years (right side of diagram)

Data are based on analysis of gas bubbles trapped in Antarctic & Greenland ice.

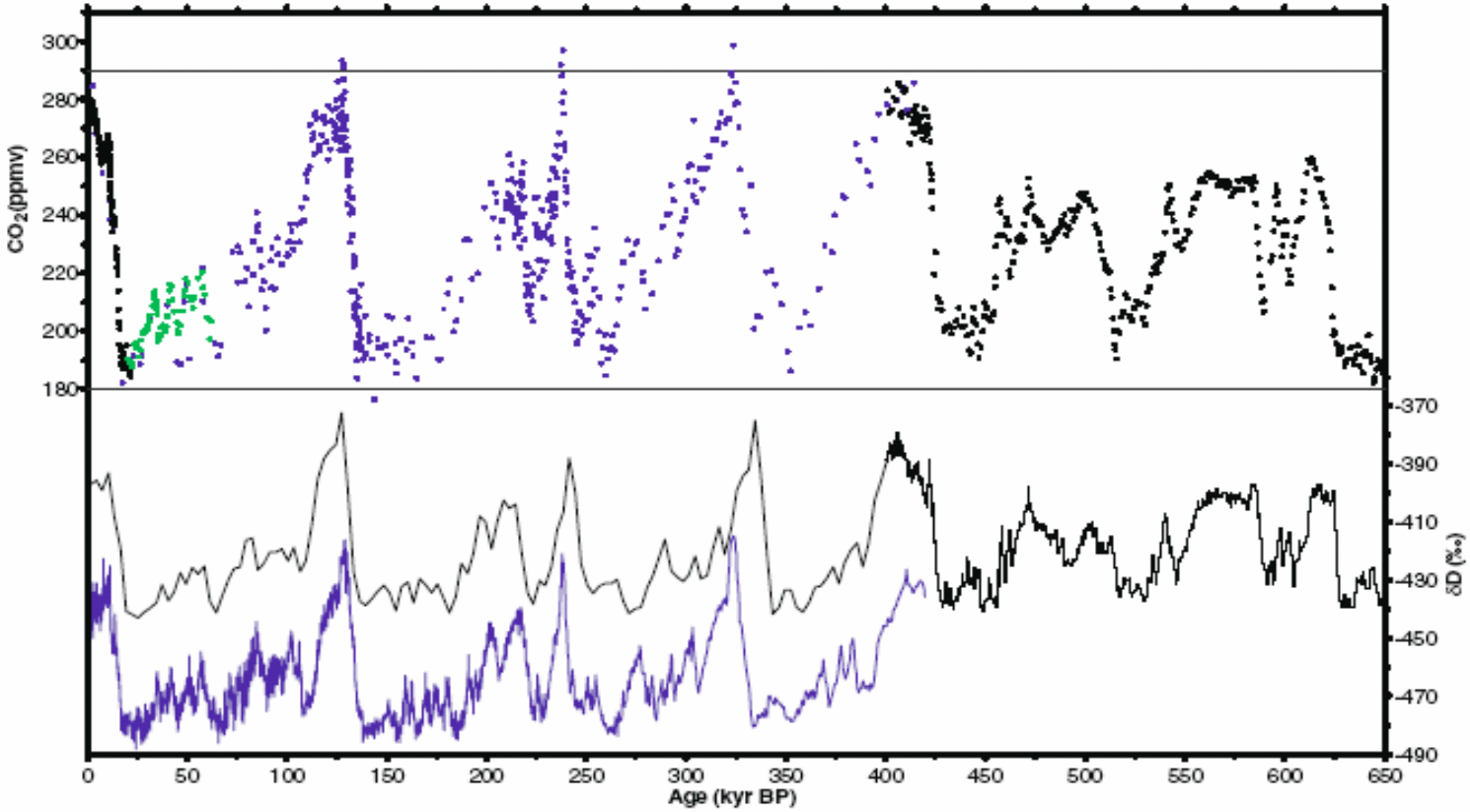
Last time Earth might have been as hot as today was interglacial peak ~6,000 years ago; last time it was definitely hotter was previous interglacial peak 130,000 years ago.



Hansen, Clim. Change 68, 2005

New ice core analyses extend direct measurement of atmospheric composition back to 650,000 years B.P.

Fig. 4. A composite CO_2 record over six and a half ice age cycles, back to 650,000 years B.P. The record results from the combination of CO_2 data from three Antarctic ice cores: Dome C (black), 0 to 22 kyr B.P. (*9*, *11*) and 390 to 650 kyr B.P. [this work including data from 31 depth intervals over termination V of (*1*)]; Vostok (blue), 0 to 420 kyr B.P. (*5*, *7*), and Taylor Dome (light green), 20 to 62 yr B.P. (*8*). Black line indicates δD from Dome C, 0 to 400 kyr B.P. (*1*) and 400 to 650 kyr B.P. (*18*). Blue line indicates δD from Vostok, 0 to 420 kyr B.P. (*7*).



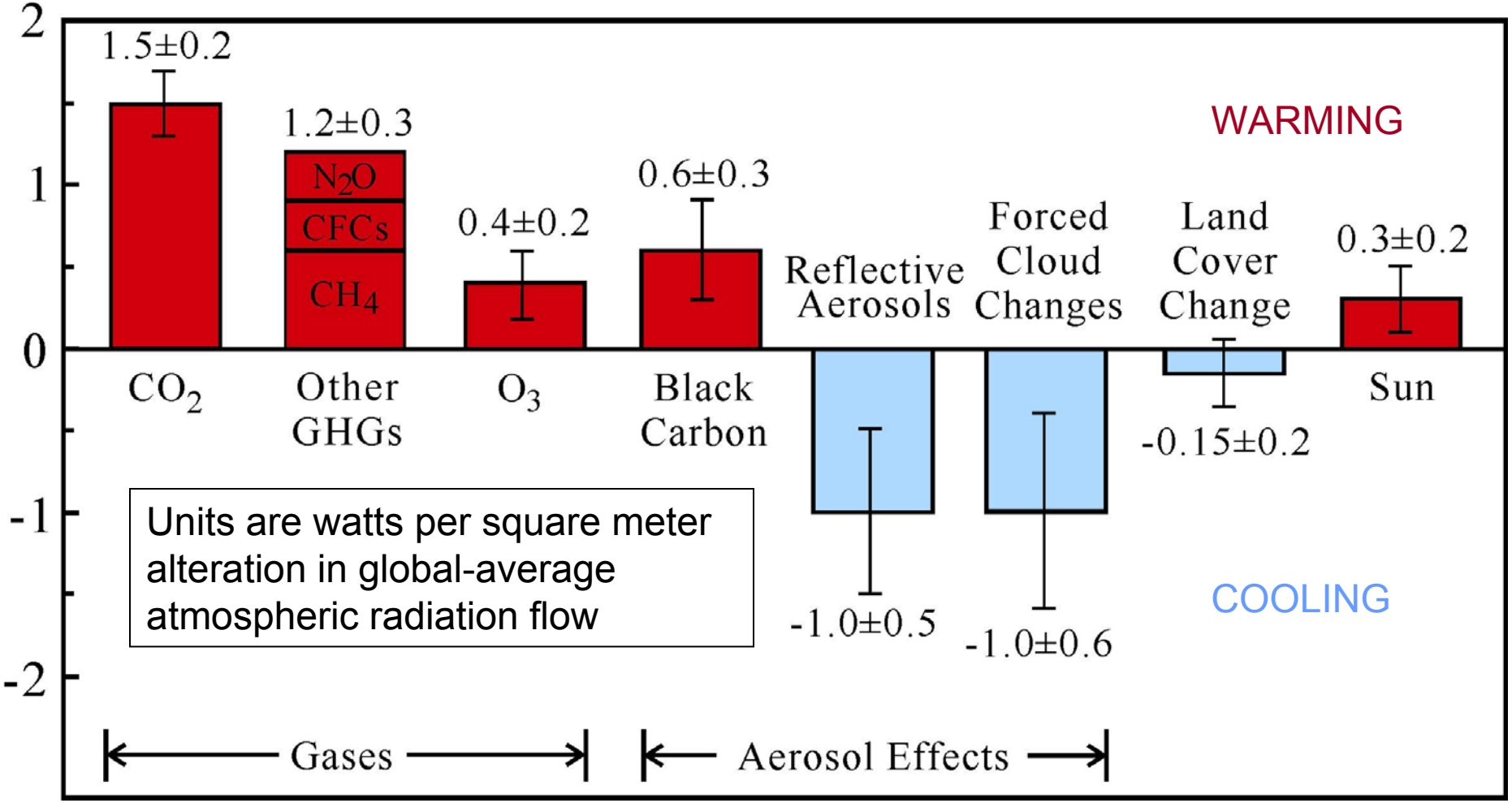
Offset in δD between Dome C and Vostok (bottom) is due to different distances from ocean, elevations, and different surface temperatures at the two sites.

It's now clear that atmospheric CO2 was not above 300 ppmv at any time in the last 650,000 years…until 1910.

Siegenthaler et al., SCIENCE 310: 1313-17 (25 Nov 2005)

Effective climate forcings 1750-2000

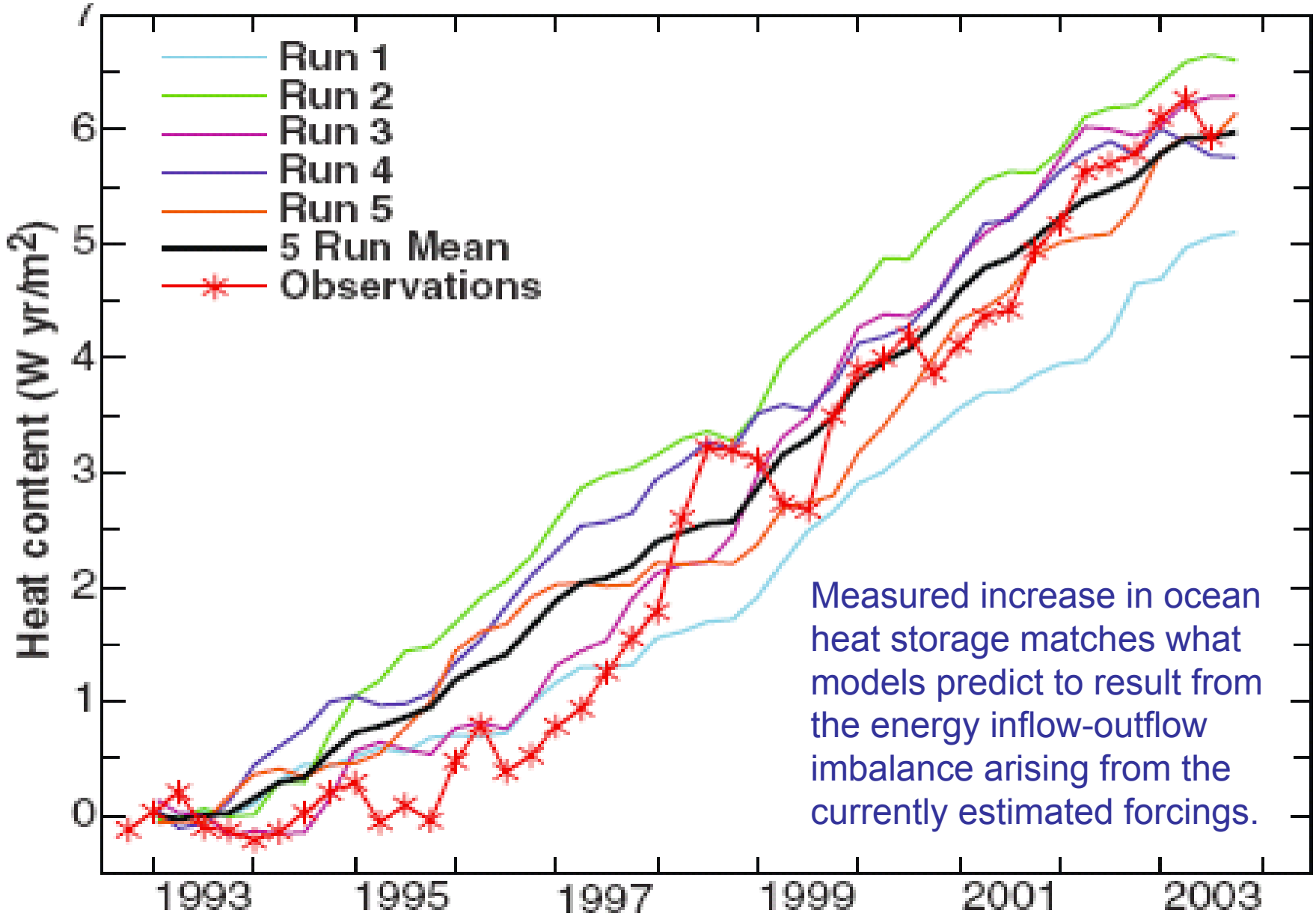
Correlating various lines of evidence has reduced uncertainties



Climate forcing agents in the industrial era. "Effective" forcing accounts for "efficacy" of the forcing mechanism.

Source: Hansen et al., JGR, **110**, D18104, 2005.

Ocean heat storage matches predictions for these forcings



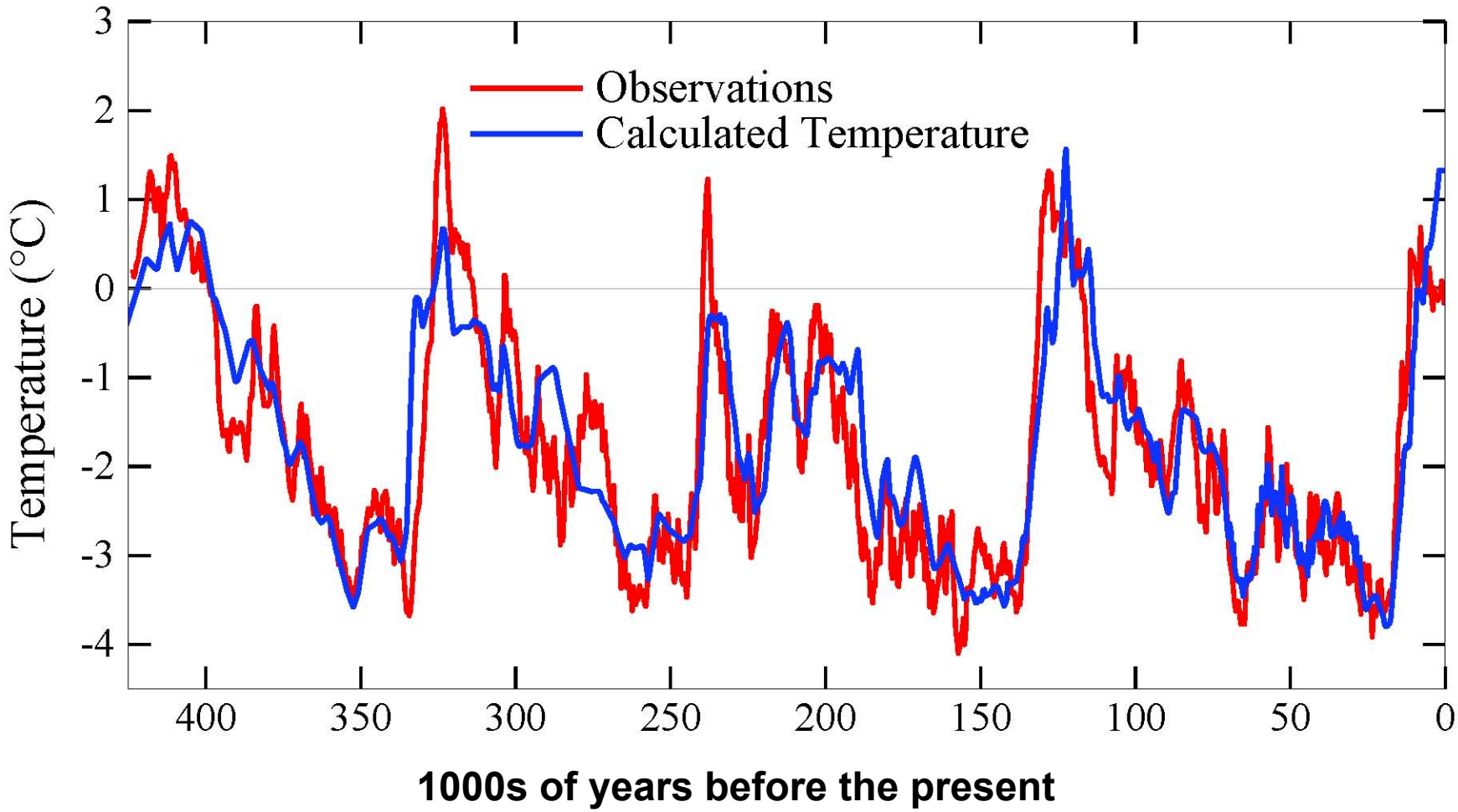
Measured increase in ocean heat storage matches what models predict to result from the energy inflow-outflow imbalance arising from the currently estimated forcings.

Hansen et al., SCIENCE 308:1425-31 (2005)

“Sensitivity” of Earth’s climate to forcings is defined as the change in average surface temperature produced by a forcing of 1 watt per square meter.

Sensitivity is also sometimes expressed as the change in average surface temperature that would be produced by a doubling of CO2 from its pre-industrial concentration of 278 ppmv, which corresponds to a forcing of 3.7 W/m^2.

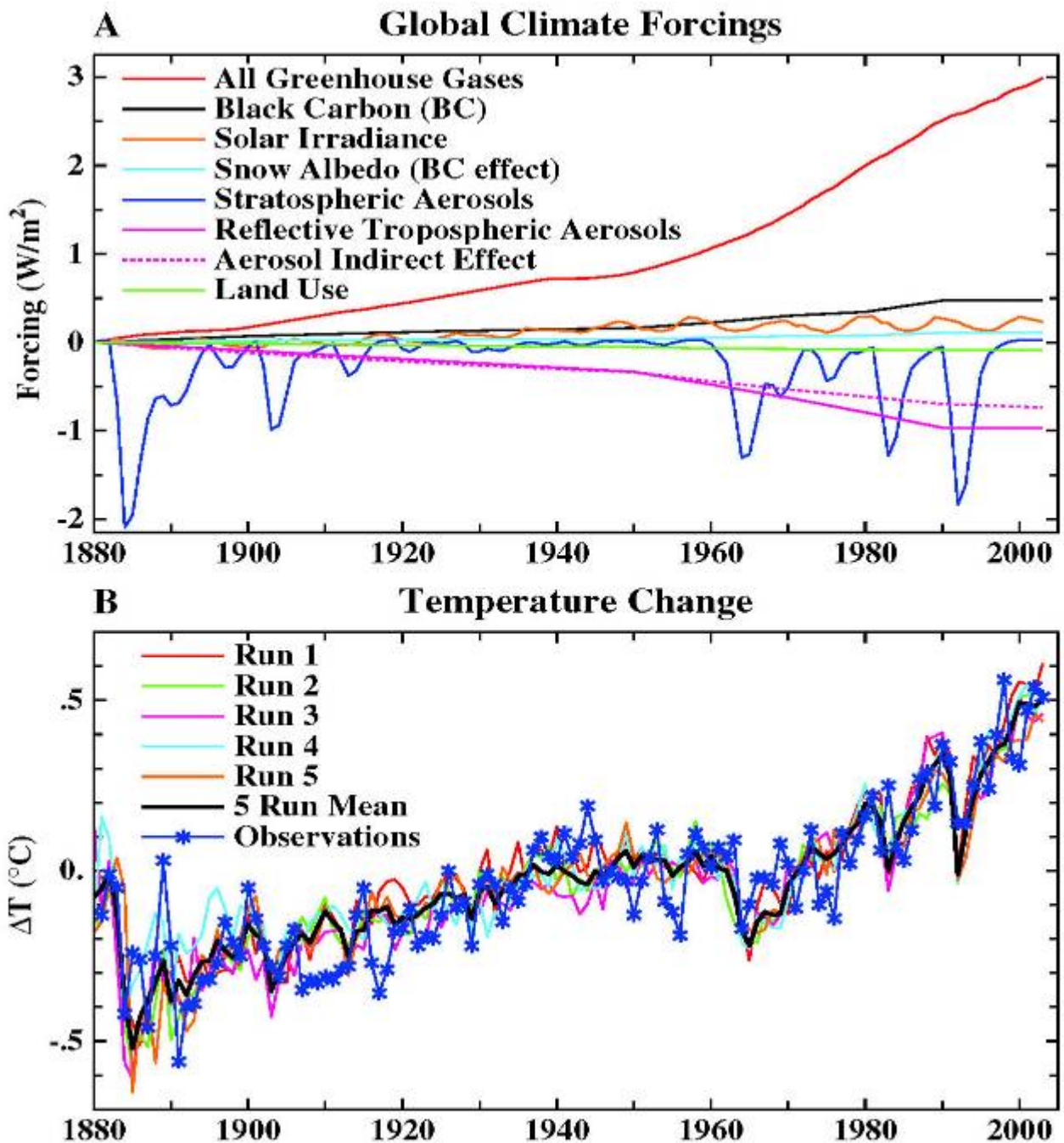
Ice-core record supports a sensitivity of ~0.75ºC per W/m²



Observations are Antarctic temperature anomaly (derived from ice-core δD) divided by 2 to give global-average T change. Calculated T is based on known forcings assuming sensitivity of 0.75°C per W/m². From J. Hansen 2005.

Current computer model with sensitivity ~0.75ºC per W/m², using best estimates of natural & human influences (A) as input, reproduces almost perfectly the last 125 years of observed temperatures (B).

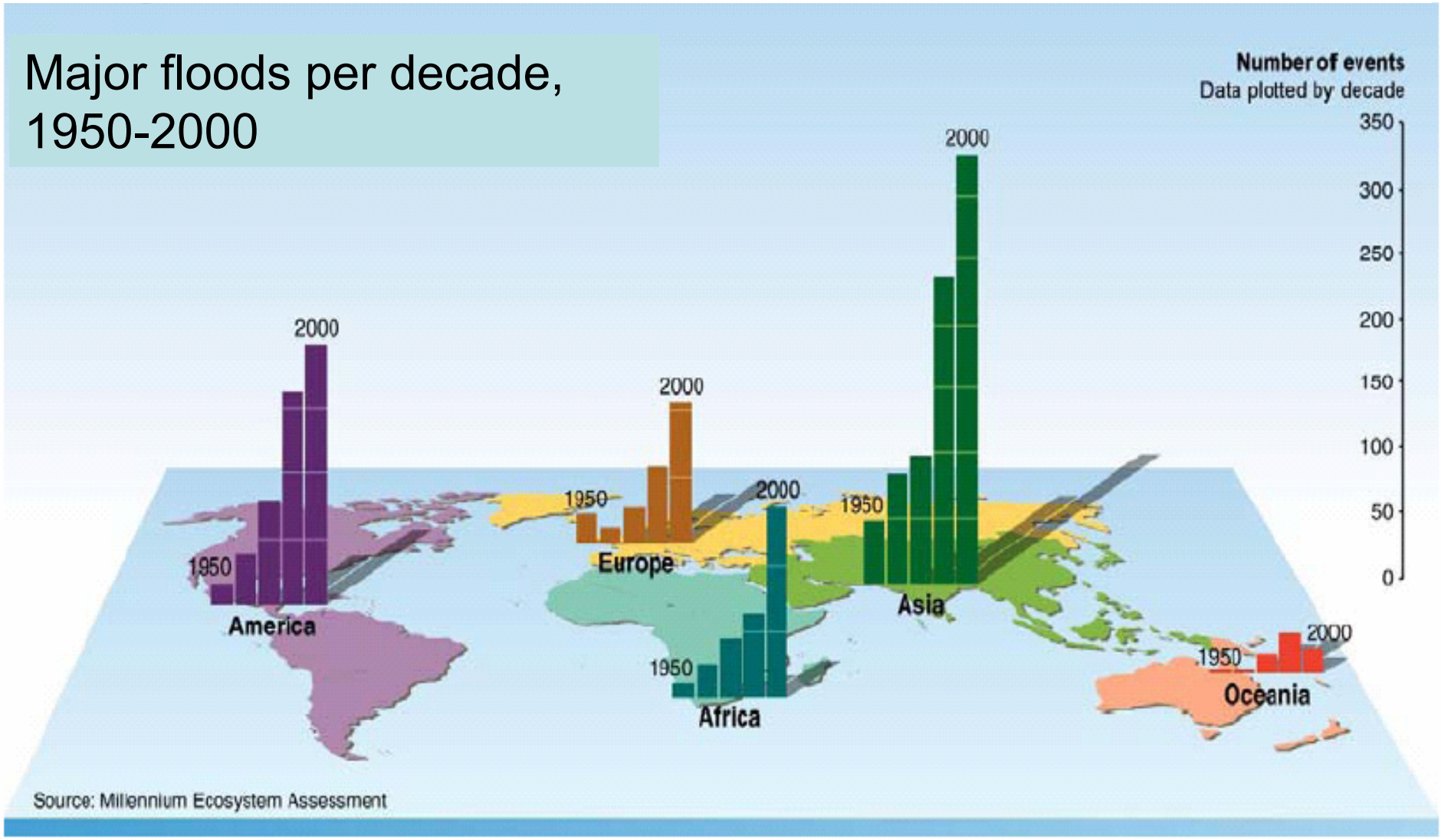
Other "fingerprints" of greenhouse-gas influence on climate also match the observations.



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

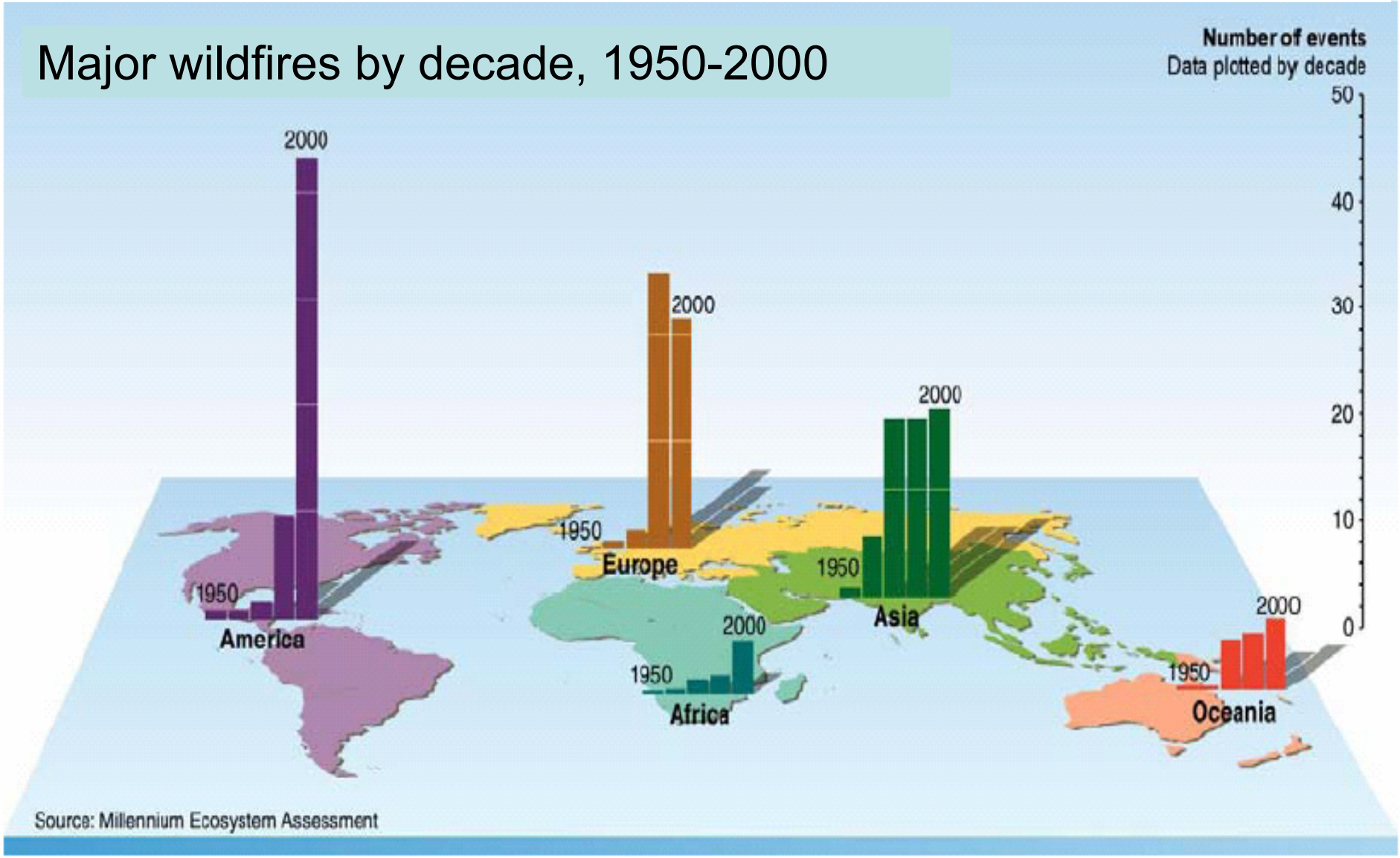
Many adverse impacts of the human-caused disruption of global climate are already evident

Harm from climate change is already occurring



There's a consistent 50-year upward trend in every region except Oceania, where the 1990s were a bit below the 1980s.

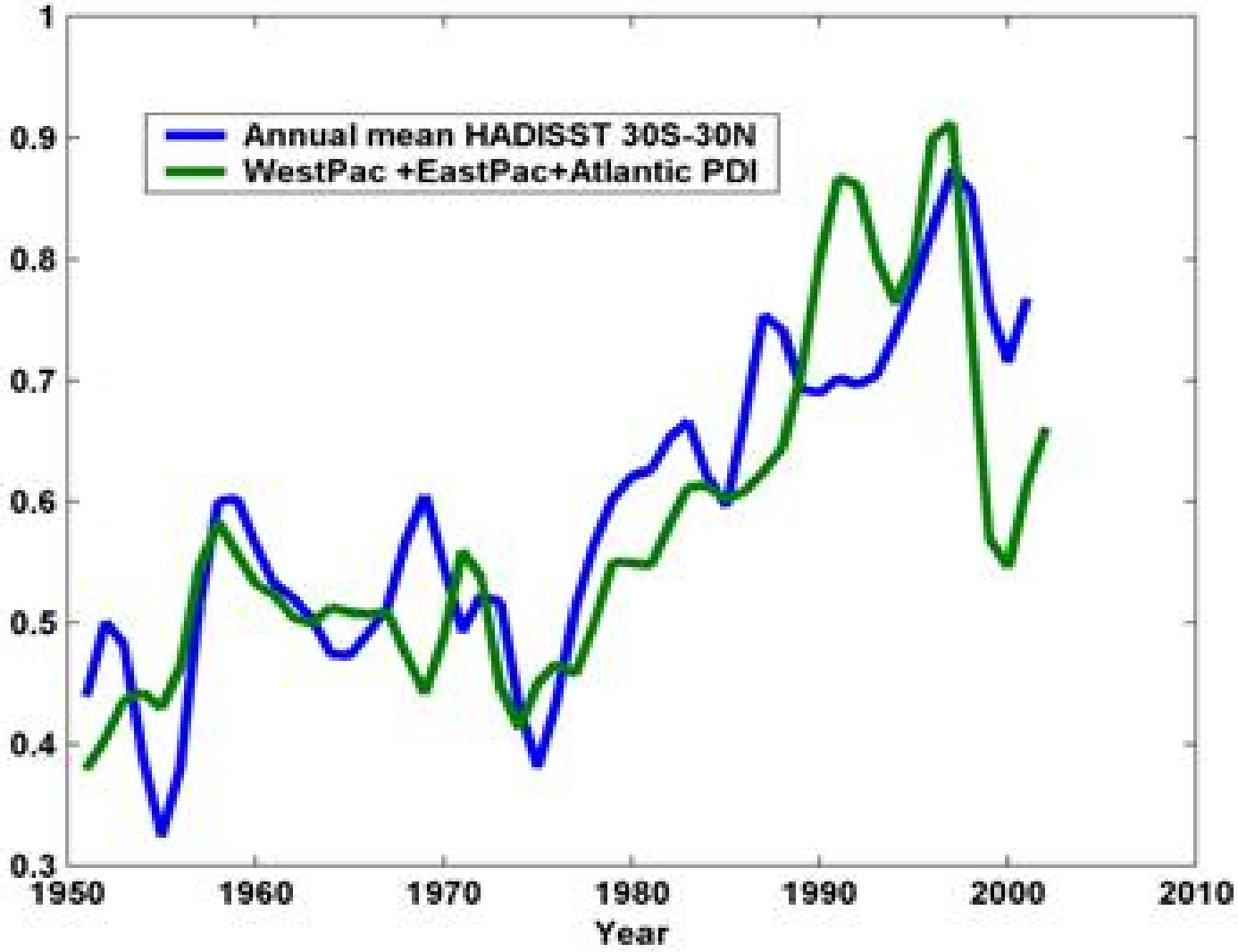
Harm is already occurring (continued)



The trend has been 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)

Bleaching of coral reefs has been increasing with sea surface temperature (SST) all over the world.

These results are from the Caribbean.

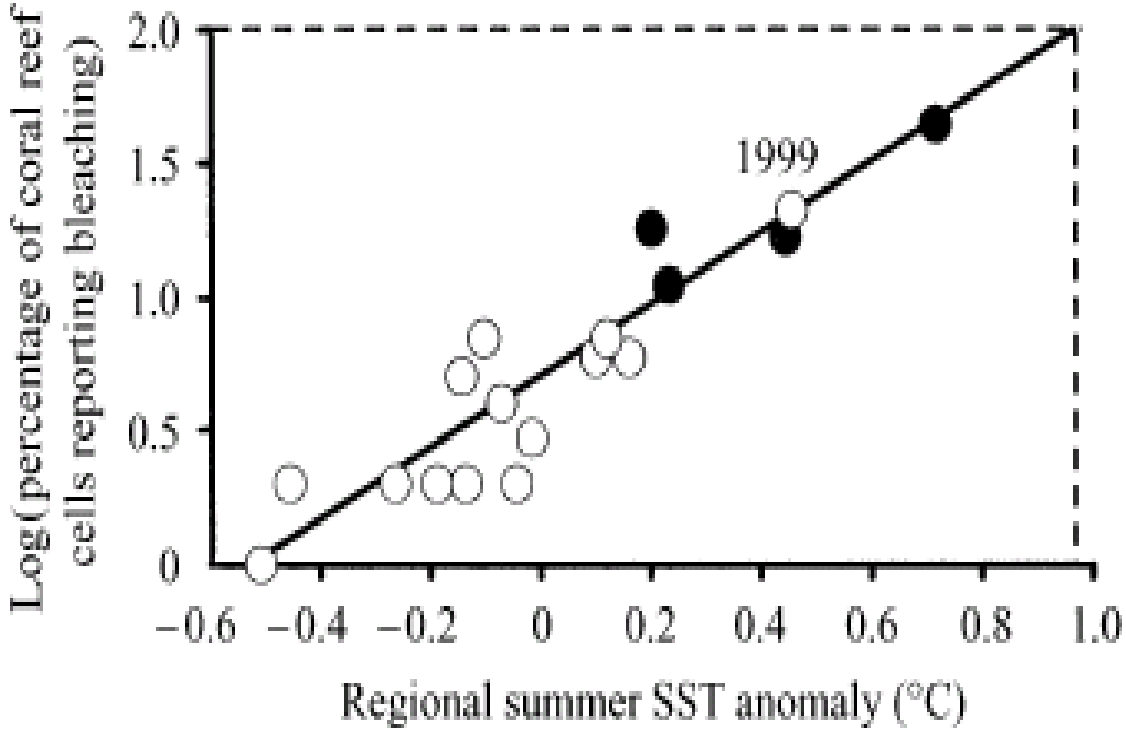
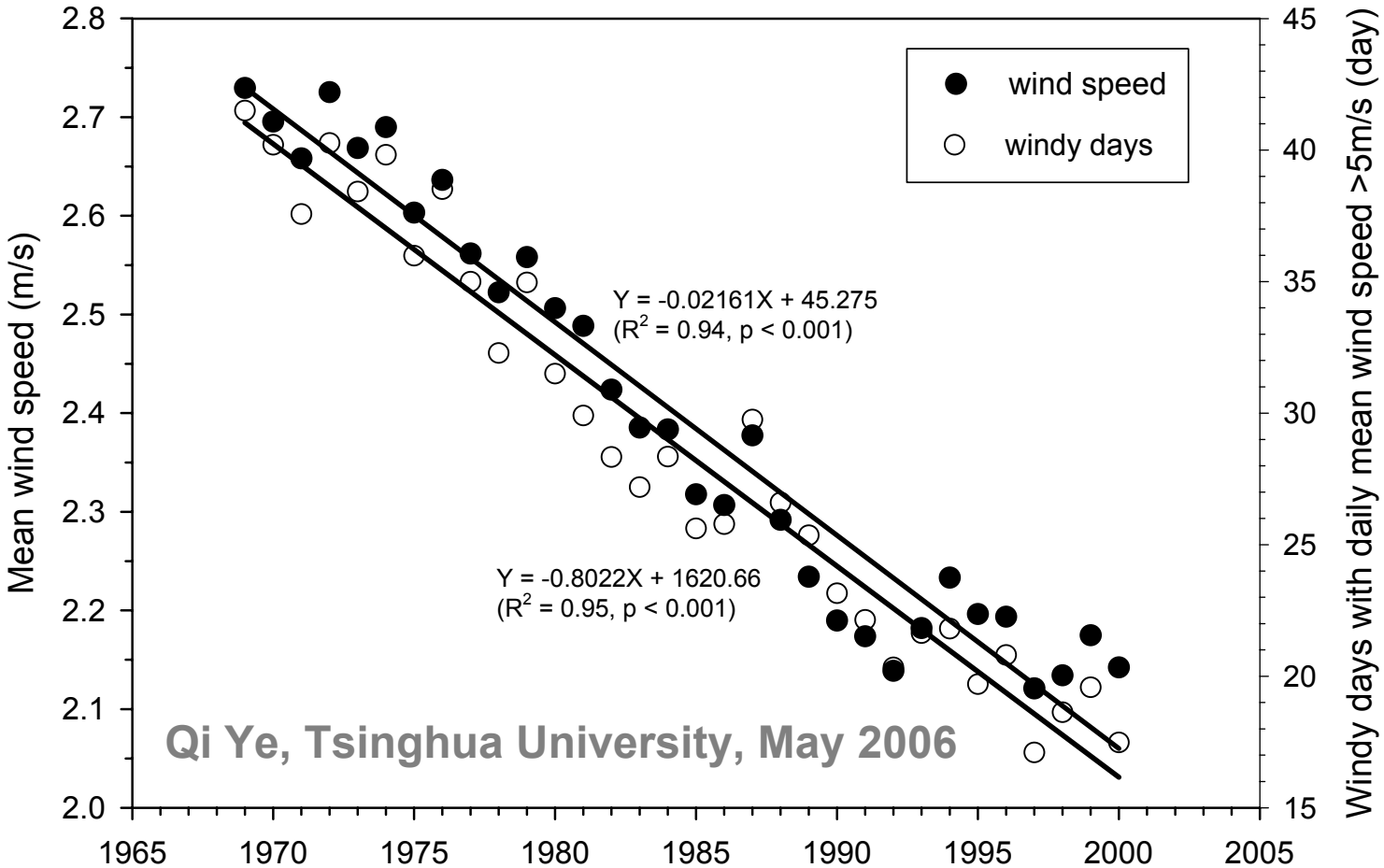


FIG. 2. The relationship between regional SST anomalies and the percentage of 1° cells from which at least one coral bleaching occurrence was recorded during August–October in the Caribbean between 1983 and 2000. Each data point represents one year. Solid circles represent years described in the literature as mass bleaching events, open circles represent other years. The solid line represents the regression line (log[cells] = 1.34[SST] + 0.71; $r^2 = 0.86$, $n = 18$, $P < 0.001$). The dashed line shows the SST at which maximum bleaching extent should occur based on extrapolation of the regression line.

McWilliams et al., ECOLOGY, 86, 2055, 2005

Harm is already occurring (continued)

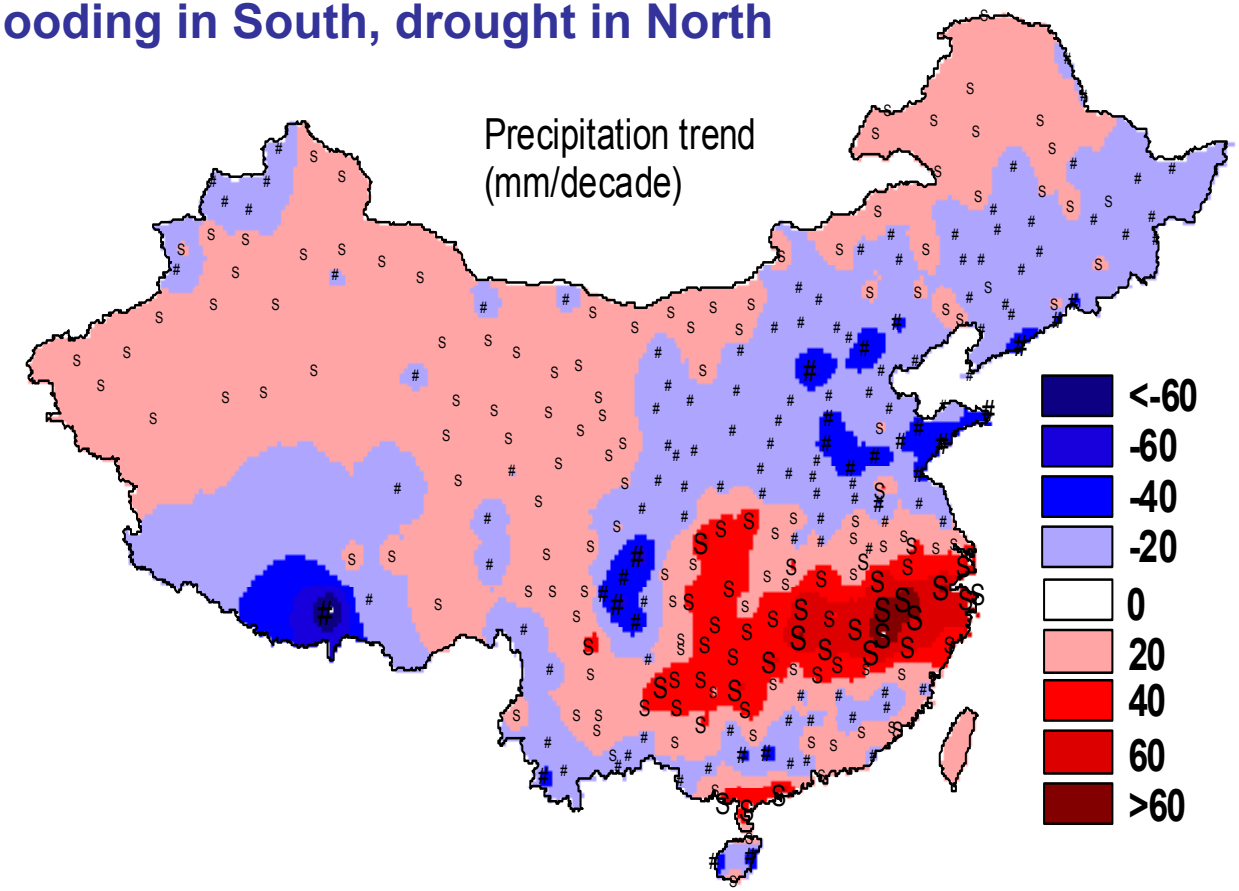
The East Asia monsoon has been weakening



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.

Weakening East Asia Monsoon (continued)

Weakening monsoon means less moisture flow South to North, producing increased flooding in South, drought in North



Qi Ye, Tsinghua University, May 2006

Glaciers feeding China's rivers are shrinking

Qinghai - Xizhan (Tibet) plateau

the roof-of-the-world, 2.5 million km^2

important role in climate of China

hot-spot of climate change

temperature rise by ~0.9°C since 1980s

Increase in thawing of permafrost

Decrease in glacier area by 7% per year

Xiangming Xiao, U of New Hampshire, May 2005

Harm is already occurring (concluded)

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

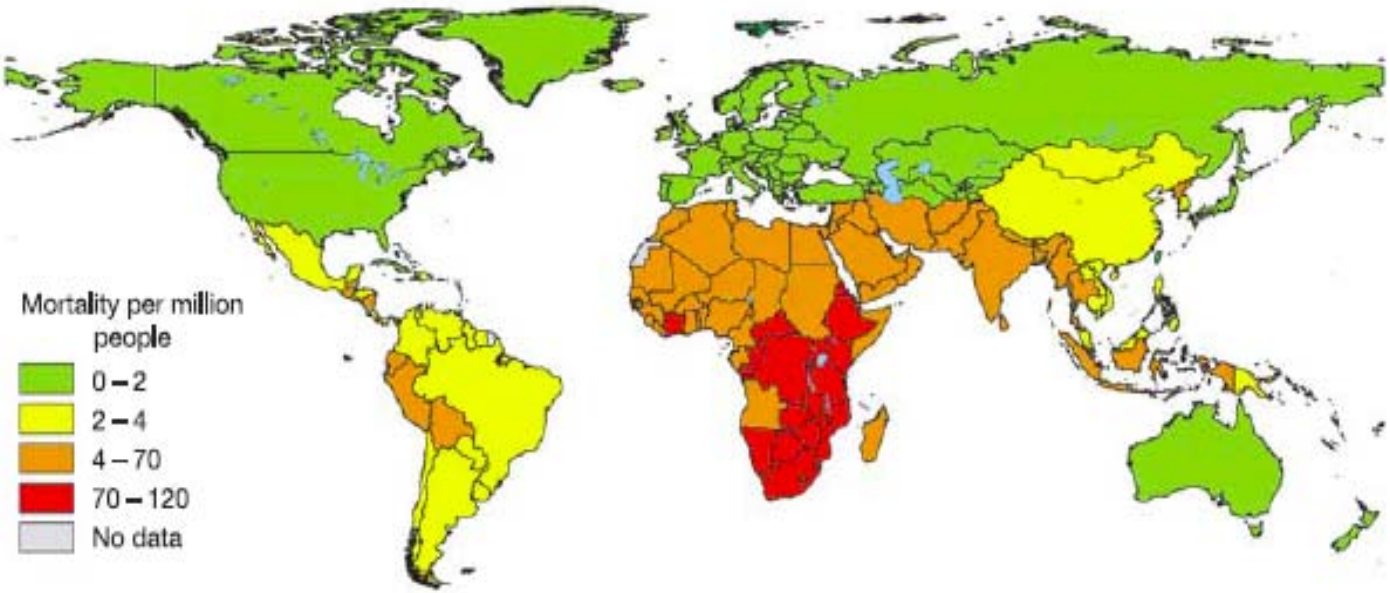
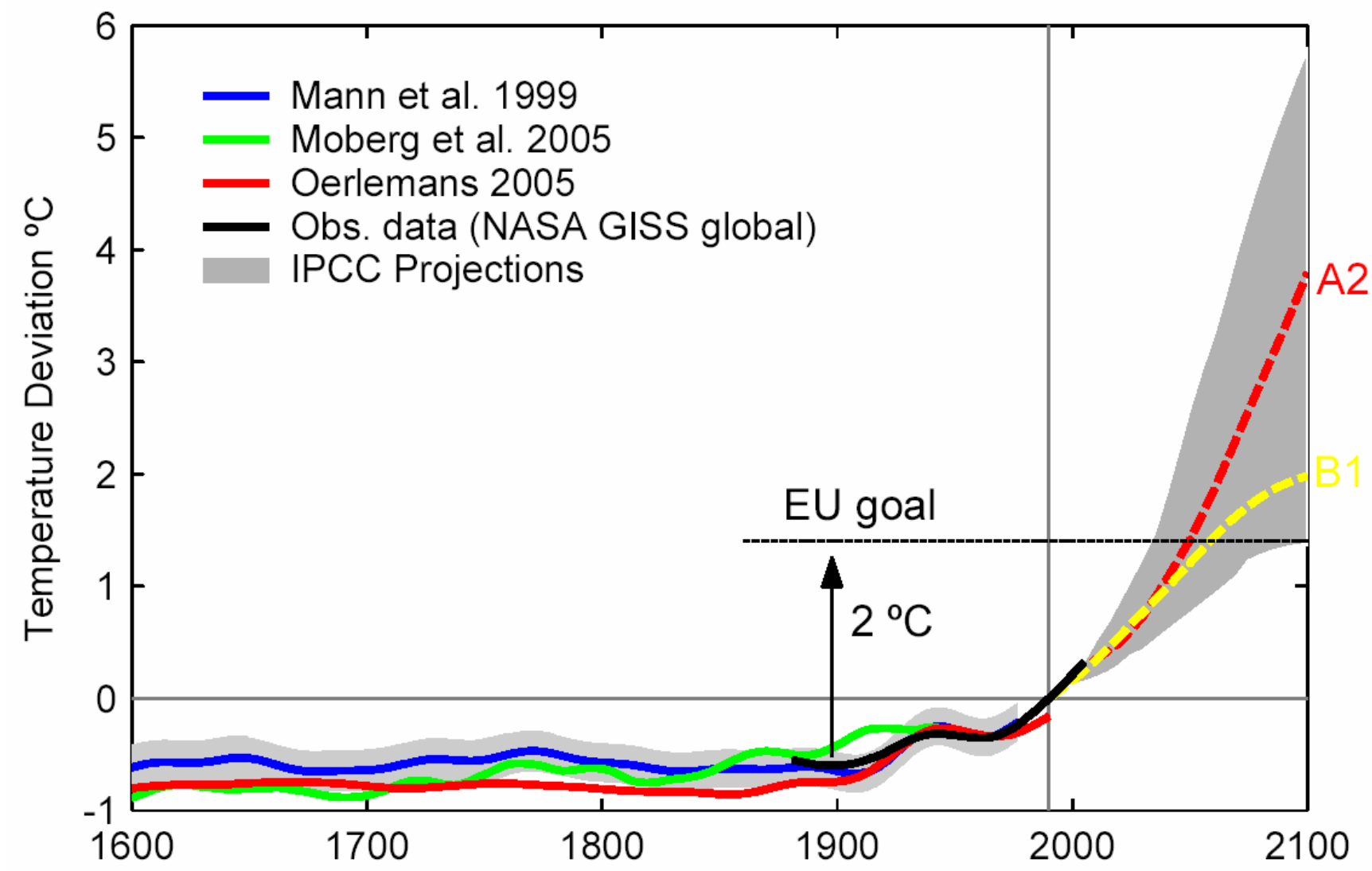


Figure 2 | WHO estimated mortality (per million people) attributable to climate change by the year 2000. The IPCC 'business as usual' greenhouse gas emissions scenario, 'IS92a' and the HadCM2 GCM of the UK Hadley Centre were used to estimate climate changes relative to 'baseline' 1961–1990 levels of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

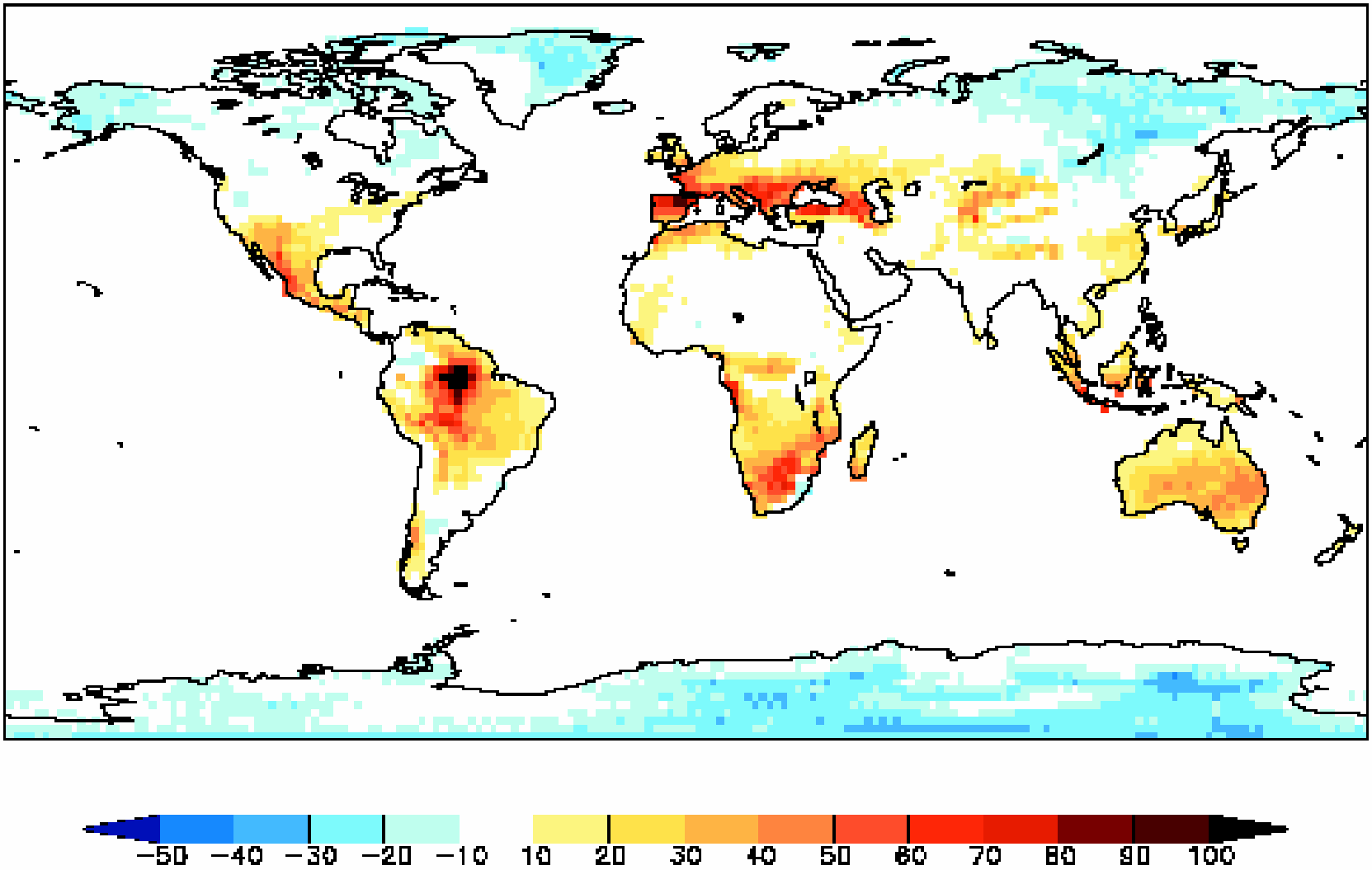
Damaging impacts are projected to grow greatly over the 21st century

The last 400 and next 100 years of global temperature



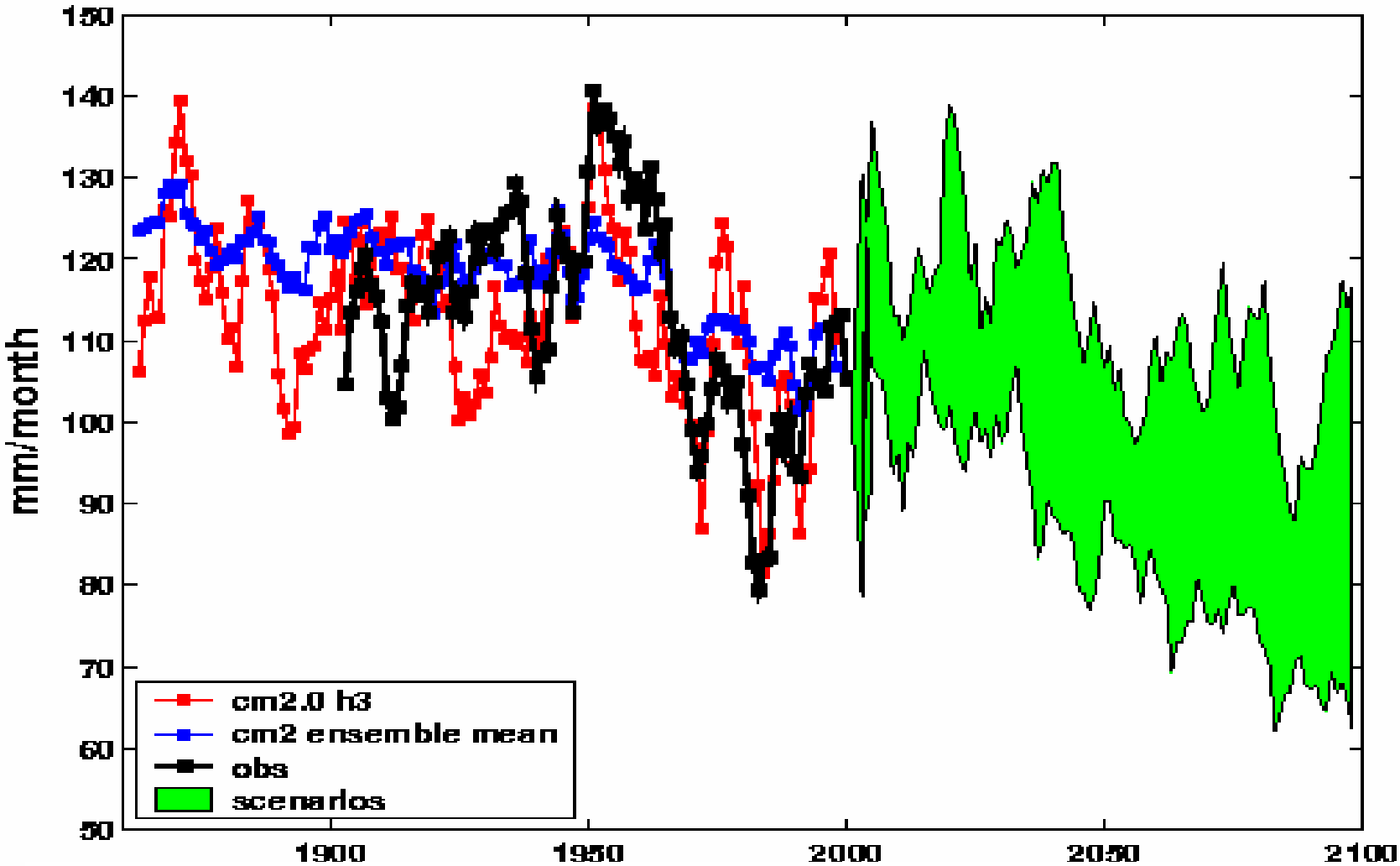
Mid-range scenarios are heading for T's last seen 30 million years ago.

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.

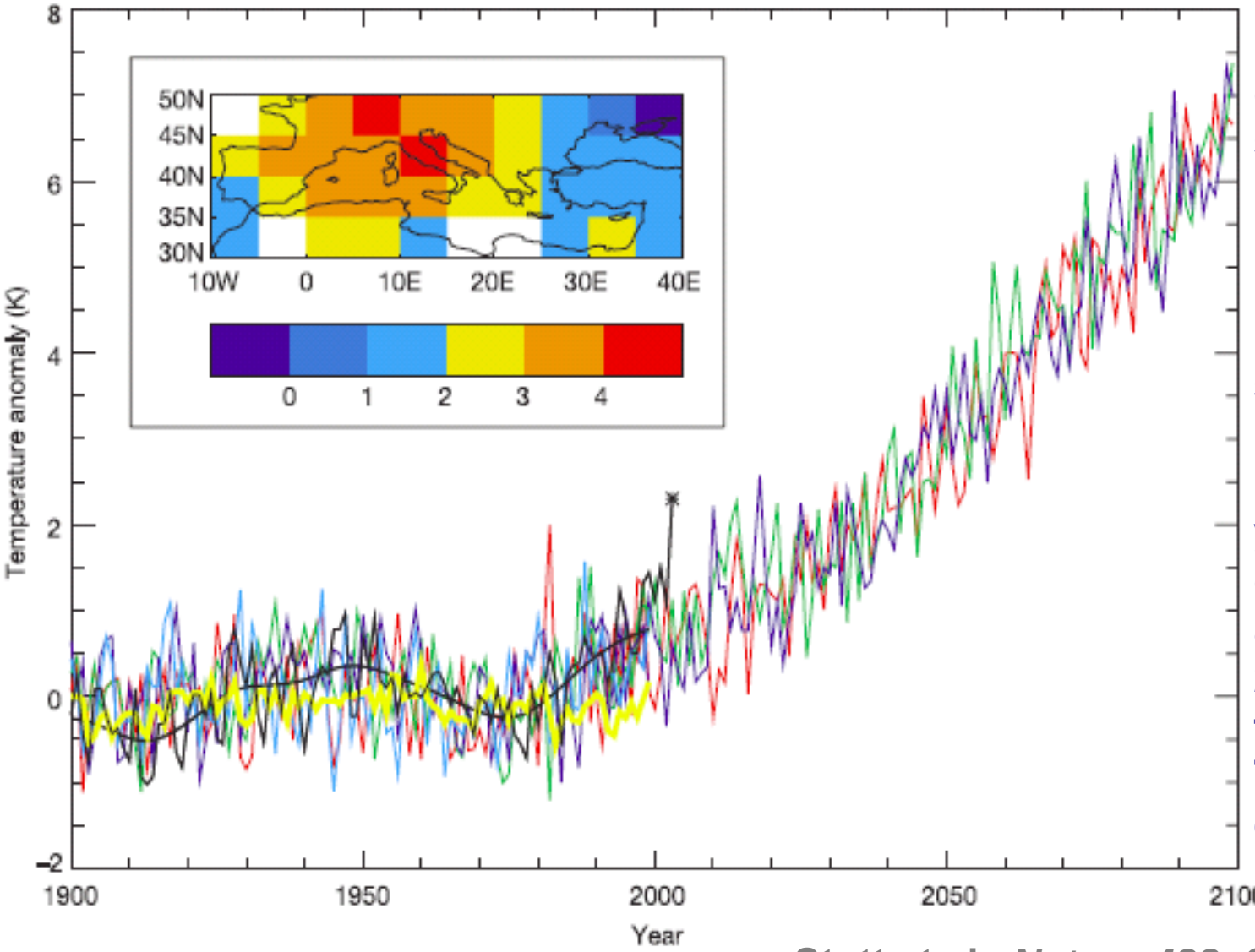
Drought in the Sahel gets worse in a warming world



Computer models that capture what <u>has</u> happened project a worsening.

Isaac Held, NOAA GFDL, 3-06

Extreme heat waves in Europe already 2X more frequent because of global warming, with much more to come



Black lines are observed T, smoothed & unsmoothed; red, blue, & green lines are Hadley Centre simulations w natural & anthro-pogenic forcing; yellow is natural only. Asterisk and inset show 2003 heat wave that killed 35,000. This is a 1 in 2 yr event by 2050.

Stott et al., *Nature 432*: 610-613 (2004)

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

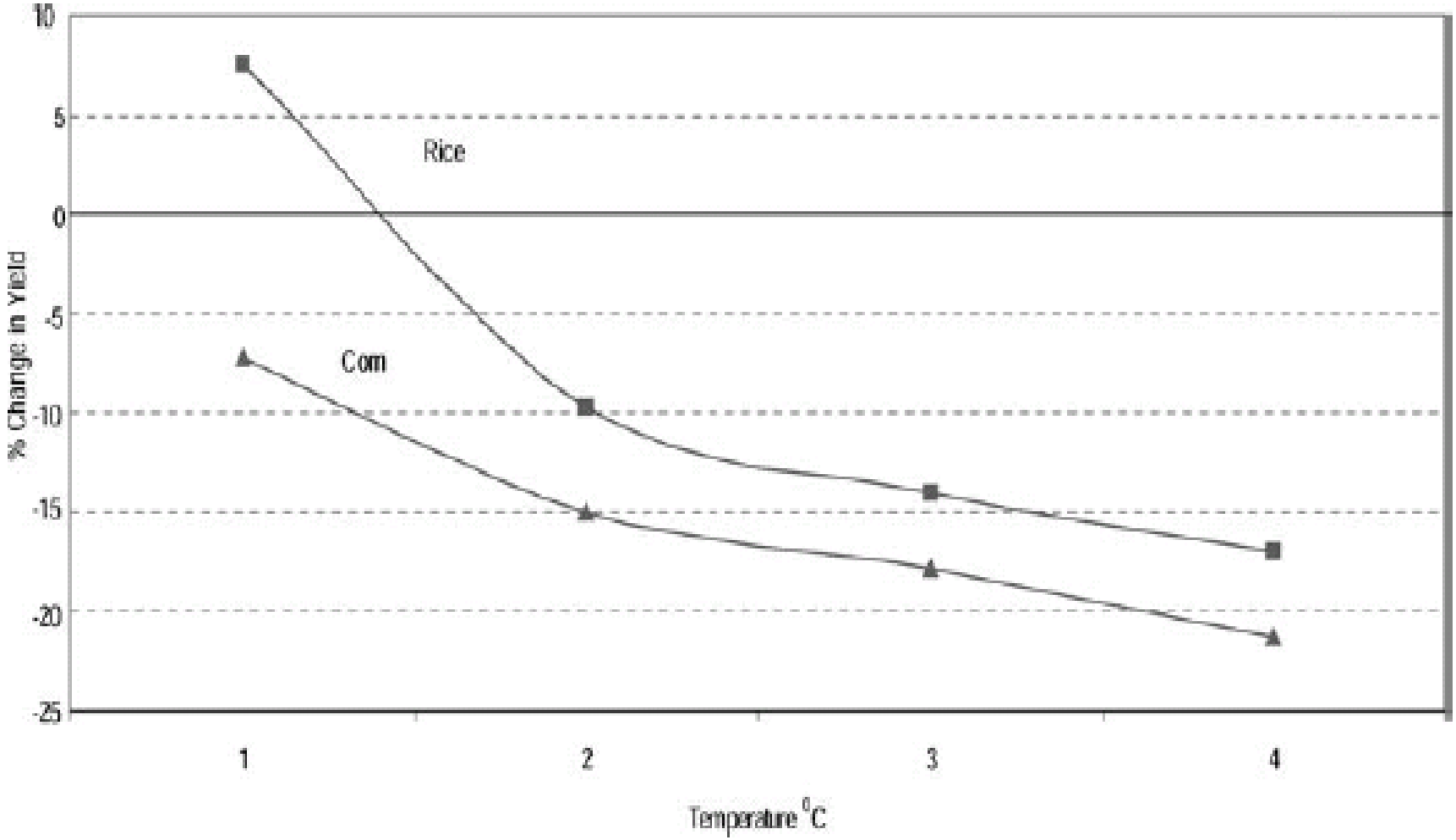


Figure 1. Corn and Rice yields versus temperature increase in the tropics averaged across 13 crop modeling studies. All studies assumed a positive change in precipitation. CO_2 direct effects were included in all studies.

Easterling and Apps, 2005

Temperate-zone crop yields start dropping at $\Delta T \geq 1\text{-}2°C$

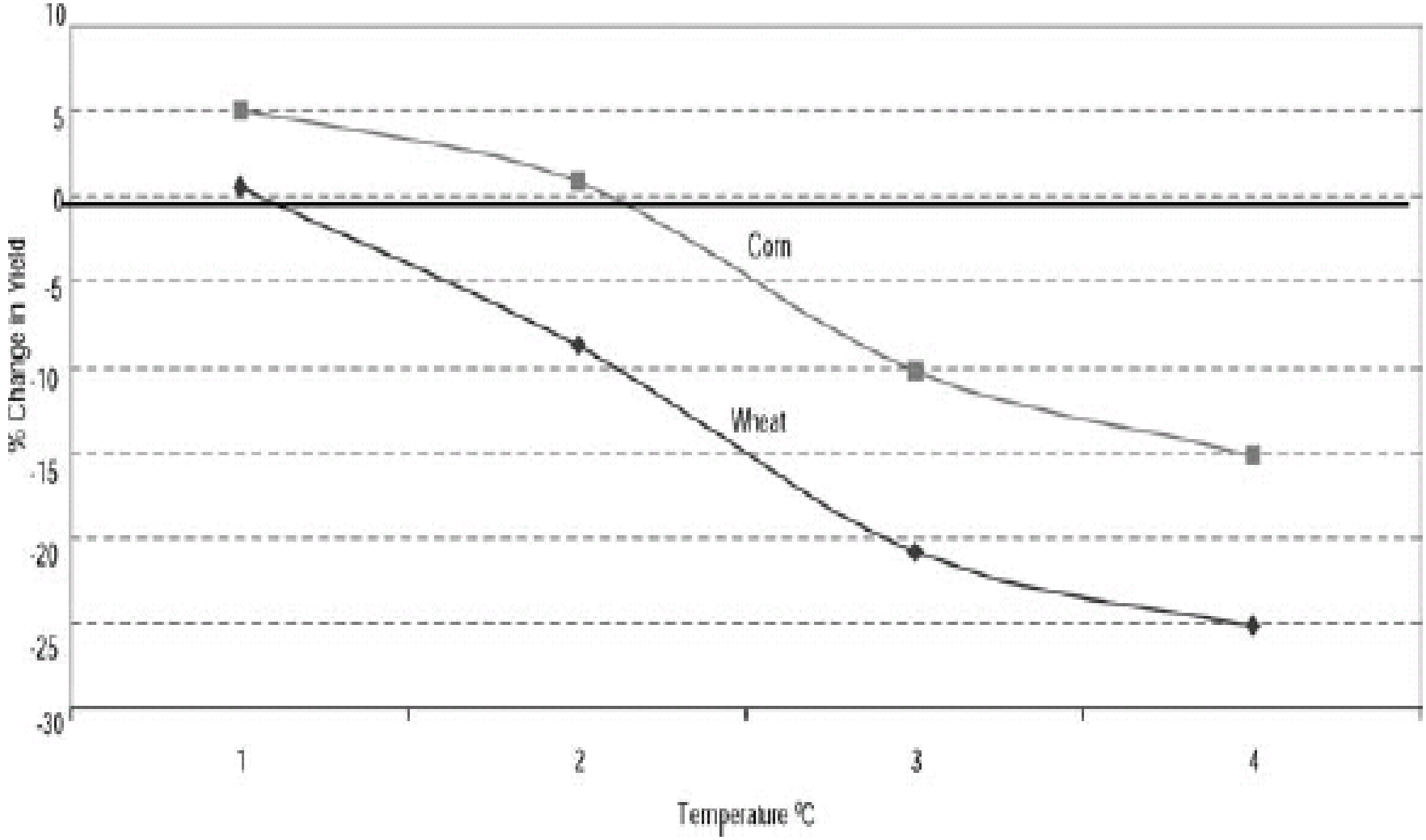
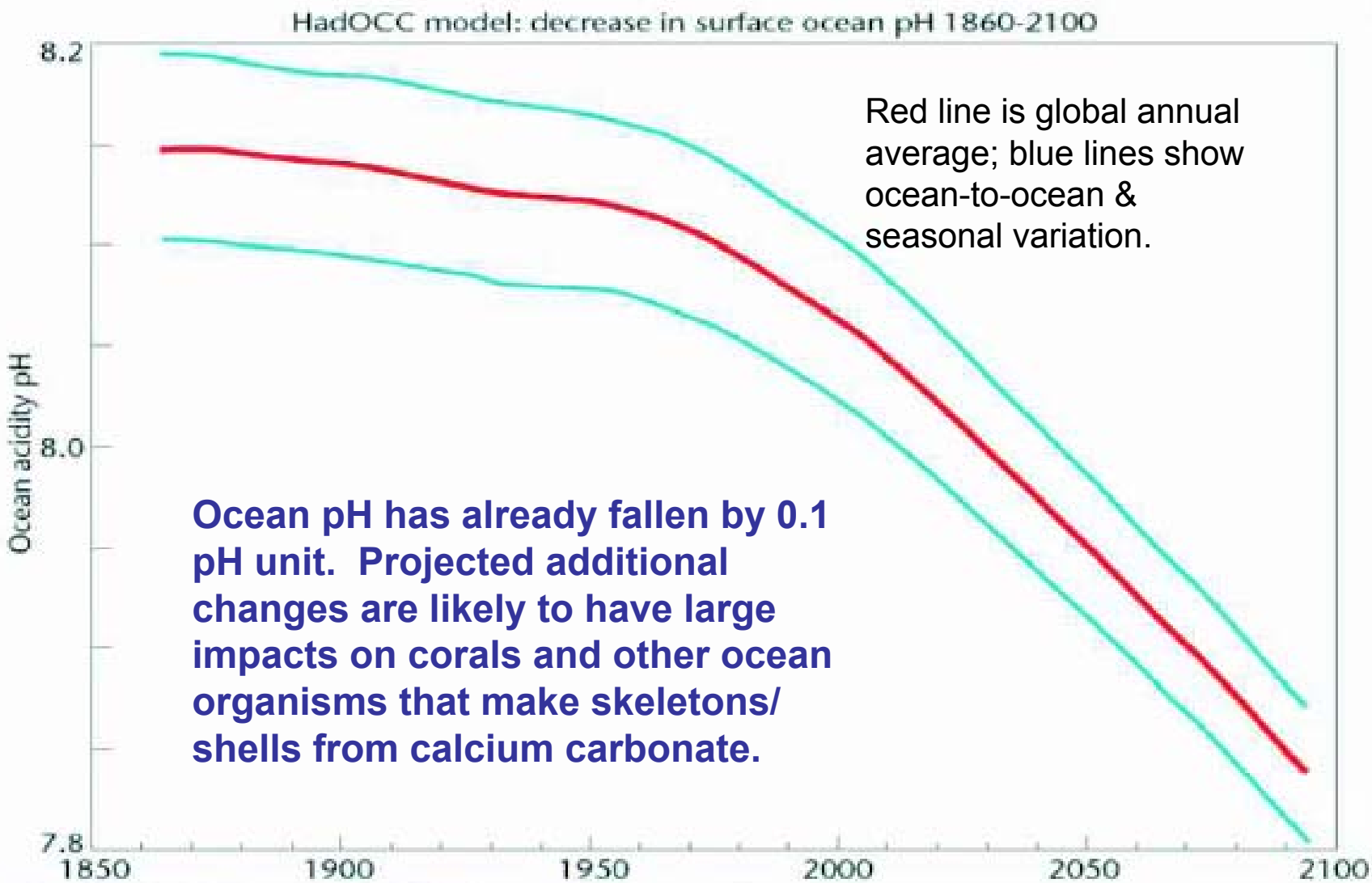


Figure 2. Corn and Wheat yields versus temperature increase in the temperate zone averaged across 30 crop modeling studies. All studies assumed a positive change in precipitation. CO_2 direct effects were included in all studies.

Easterling and Apps, 2005

Acidification of the ocean from CO_2 uptake: history and "business as usual" projection



Hadley Centre for Climate Prediction and Research

Greenland, Antarctica, & future sea level

- IPCC 2001 “central estimate” of ~0.5 meter further sea-level rise by 2100 could be a big underestimate because available models couldn’t (and still can’t) represent potential for rapid ice loss from Greenland & Antarctica.
- All the ice on Greenland ≈ 7 m increase in sea level; ice in West Antarctic Ice Sheet ≈ 5 m.
- Rates at which this ice could become sea water are highly uncertain, but 12 m in 350-500 years is possible (~3 m per century); some think 5 m per century is possible (Hansen 2005).
- East Antarctic Ice Sheet could add another 60 m, presumably only over many centuries…but recent surprises indicate science uncertain here.

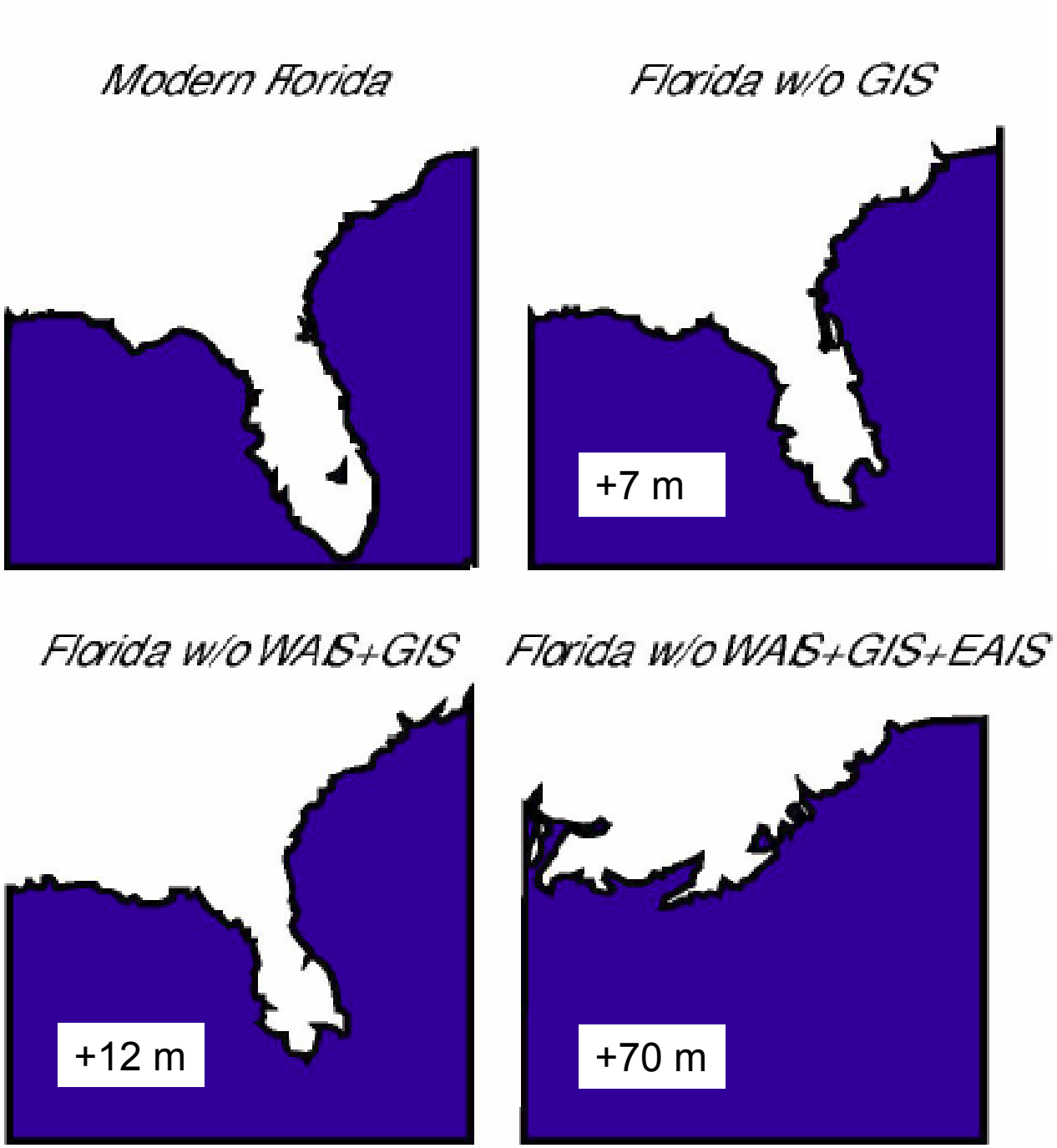
Melting the Greenland and Antarctic Ice Sheets would raise sea level up to 70 meters

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

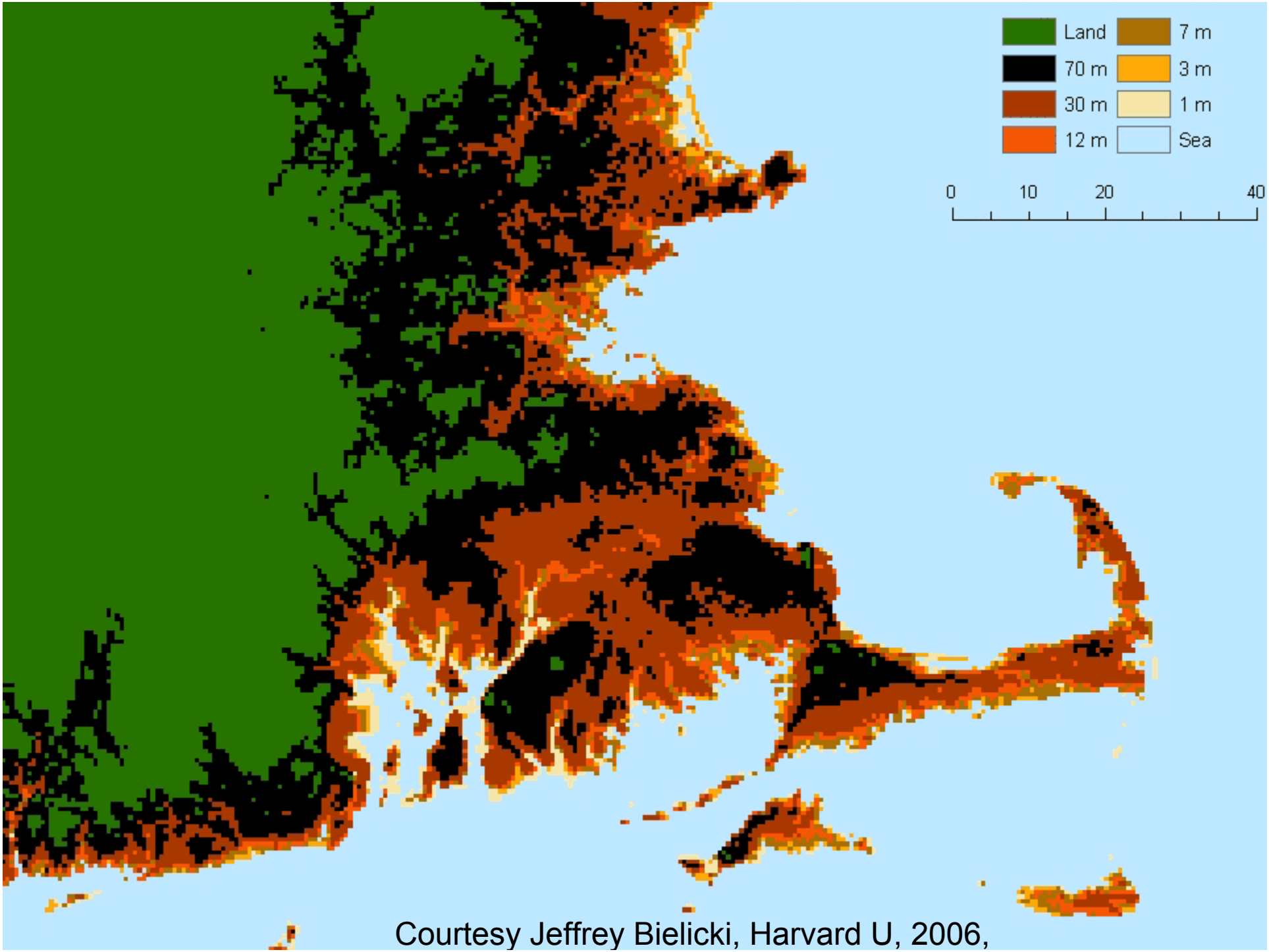
GIS = Greenland Ice Sheet

WAIS = West Antarctic Ice Sheet

EAIS = East Antarctic Ice Sheet



Dr. Richard Alley, 2005



Courtesy Jeffrey Bielicki, Harvard U, 2006,

Findings from the 4th Assessment of the Intergovernmental Panel on Climate Change

Summary for Policymakers

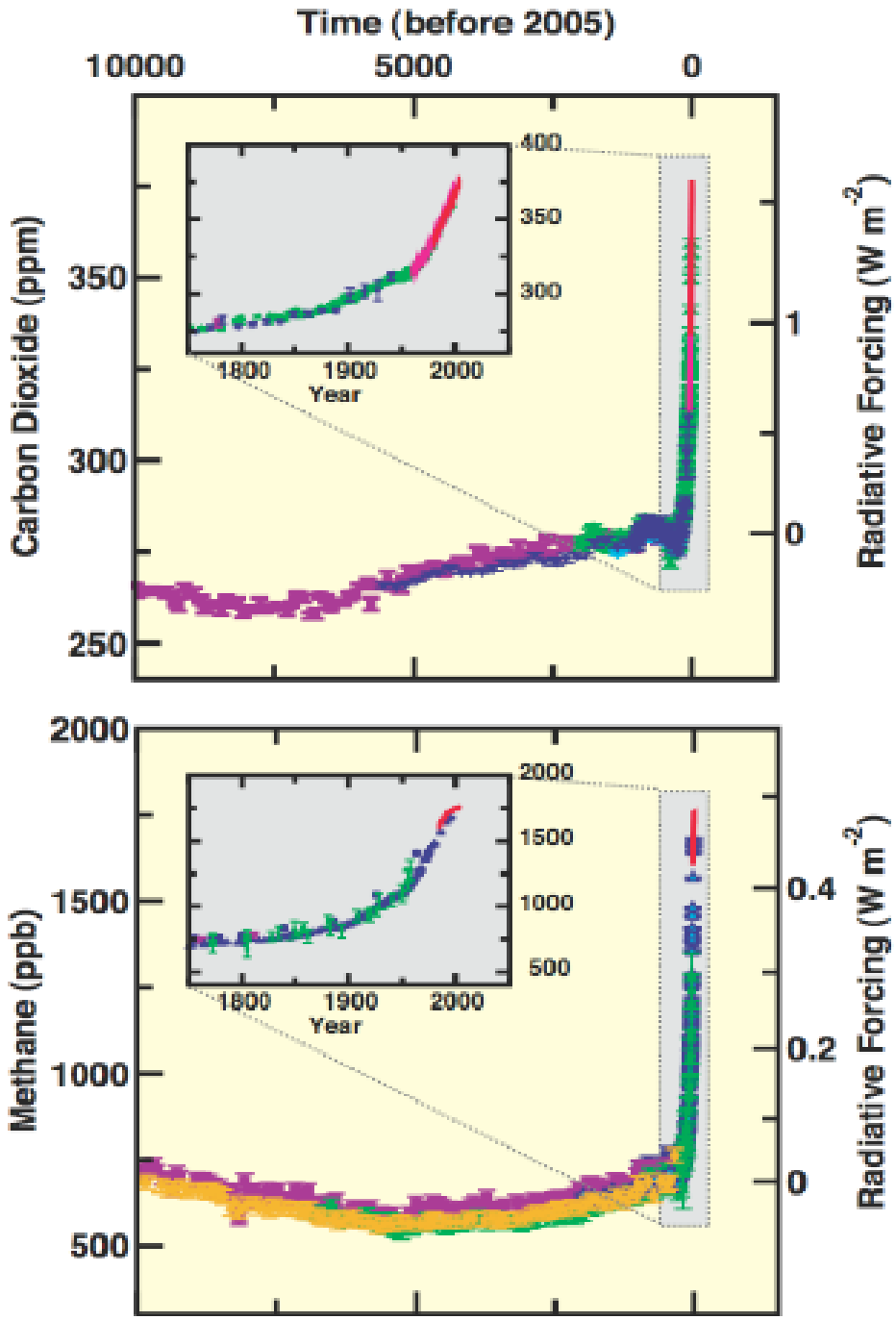
released 2 February 2007

IPCC findings on causes & consequences to date

- "Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years. The global increases in carbon dioxide concentration are due primarily to fossil fuel use and land-use change, while those of methane and nitrous oxide are primarily due to agriculture." (p 2)
- "The combined radiative forcing due to increases in carbon dioxide, methane, and nitrous oxide is +2.30 W/m2 (+2.07 to +2.53), and its rate of increase during the industrial era is <u>very likely</u> to have been unprecedented in more than 10,000 years." (p 3)

Atmospheric concentrations of CO_2 & CH_4 for the past 10,000 years

The drastic change imposed by human activities in the past 200 years, on top of the slow natural variation of the preceding 10,000 years, is striking.

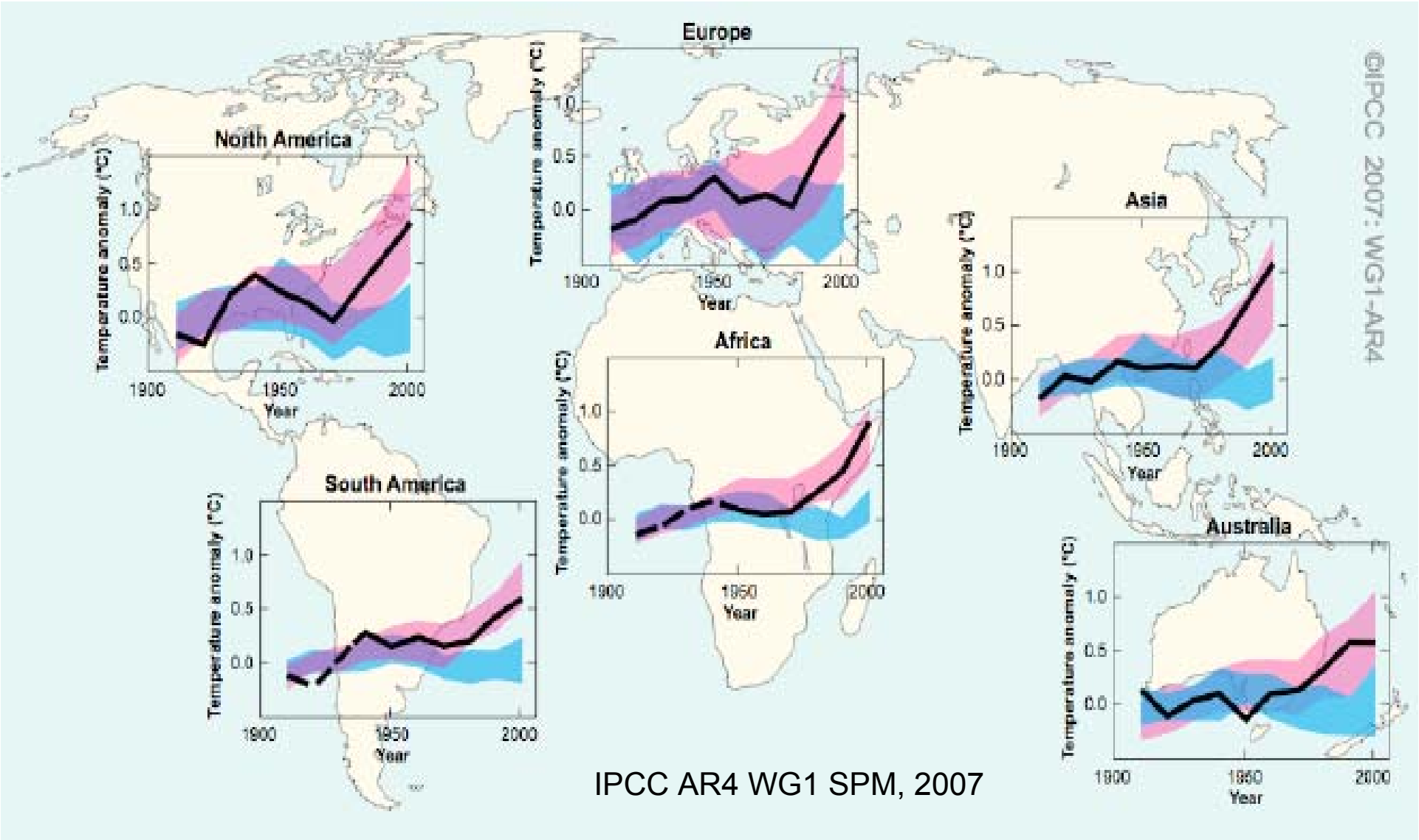


IPCC AR4, WG1 SPM, 2007

Causes & consequences to date (continued)

- "Changes in solar irradiance since 1750 are estimated to cause a radiative forcing of +0.12 W/m2 (+0.06 to +0.30), which is less than half the estimate given in the Third Assessment Report." (p 3)
- "At continental, regional, and ocean-basin scales, numerous long-term changes in climate have been observed. These include changes in Arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns, and aspects of extreme weather including droughts, heavy precipitation, heat waves, and the intensity of tropical cyclones." (p 4)
- "There is observational evidence for an increase of intense tropical cyclone activity in the North Atlantic since about 1970, correlated with increases of tropical sea surface temperatures." (p 6)

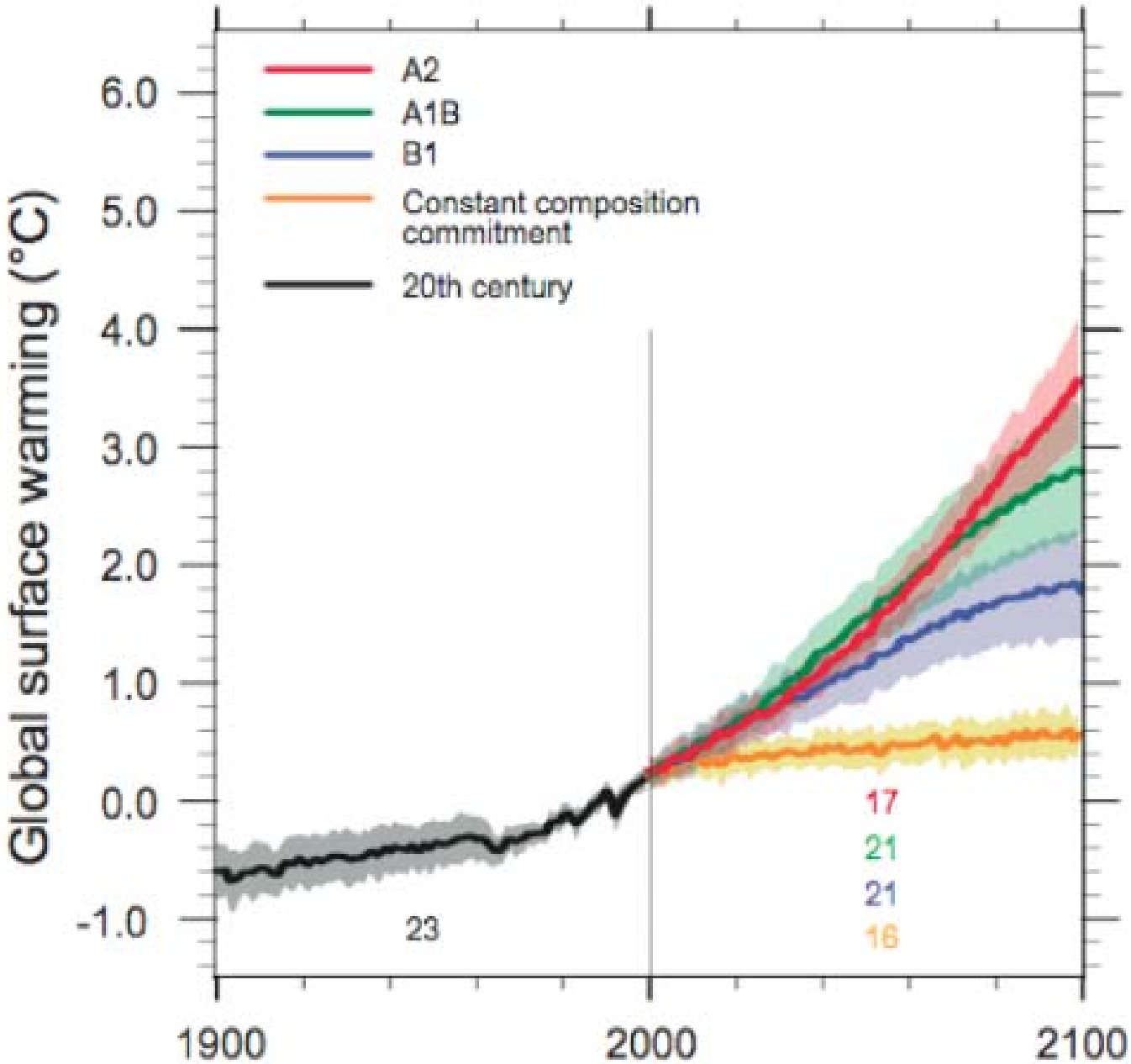
Computer models match observed ΔT on all continents



IPCC AR4 WG1 SPM, 2007

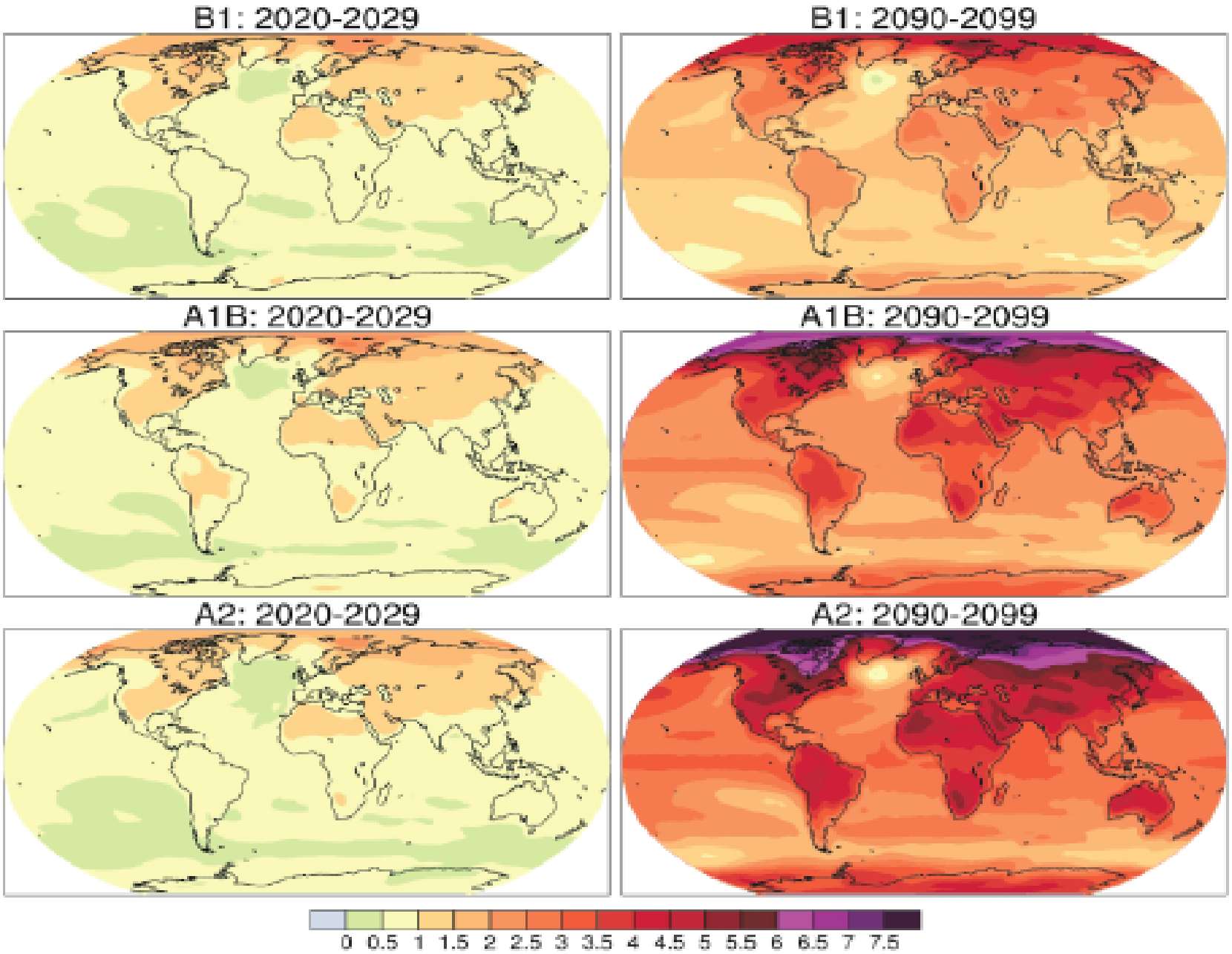
Black lines are decadally averaged observations. Blue bands are computer models with natural forcings only. Pink bands are computer models with human + natural forcings.

IPCC temperature projections for 3 scenarios



Colored numbers below curves denote number of coupled ocean-atmosphere climate models used for projections (and, at left, to simulate 20th century). Colored bands are 1 standard deviation from the mean in the model-ensemble T projections.

IPCC scenarios for 21st century ΔT (ºC) compared to 1980-99



Recent & future trends in warming-related phenomena

Phenomenon[a] and direction of trend	Likelihood that trend occurred in late 20th century (typically post 1960)	Likelihood of a human contribution to observed trend [b]	Likelihood of future trends based on projections for 21st century using SRES scenarios
Warmer and fewer cold days and nights over most land areas	*Very likely* [c]	*Likely* [e]	*Virtually certain* [e]
Warmer and more frequent hot days and nights over most land areas	*Very likely* [d]	*Likely (nights)* [e]	*Virtually certain* [e]
Warm spells / heat waves. Frequency increases over most land areas	*Likely*	*More likely than not* [f]	*Very likely*
Heavy precipitation events. Frequency (or proportion of total rainfall from heavy falls) increases over most areas	*Likely*	*More likely than not* [f]	*Very likely*
Area affected by droughts increases	*Likely* in many regions since 1970s	*More likely than not*	*Likely*
Intense tropical cyclone activity increases	*Likely* in some regions since 1970	*More likely than not* [f]	*Likely*
Increased incidence of extreme high sea level (excludes tsunamis) [g]	*Likely*	*More likely than not* [f, h]	*Likely* [i]

IPCC 4th Assessment, Figure SPM-1, Feb 2007

Quotes on expected future changes

- "It is very likely that hot extremes, heat waves, and heavy precipitation events will continue to become more frequent." (p 12)
- "Based on a range of models, it is likely that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical sea-surface temperatures." (p 12)
- "Projections based on SRES scenarios give reductions in average global surface ocean pH of between 0.14 and 0.35 units over the 21st century, adding to the present decrease of 0.1 units since pre-industrial times." (p 12)

Quotes on future changes (continued)

- "The corresponding future temperatures in Greenland are comparable to those inferred for the last interglacial period 125,000 years ago, when paleoclimatic information suggests reductions of polar land ice extent and 4 to 6 m of sea level rise." (p 13)
- "Both past and future anthropogenic carbon dioxide emissions will continue to contribute to warming and sea level rise for more than a millennium, due to the timescales required for removal of this gas from the atmosphere." (p 13)

End of summary of findings from IPCC WG1 Fourth Assessment

Faced with this challenge…

Society has three options:

- Mitigation, which means measures to reduce the pace & magnitude of the changes in global climate being caused by human activities.

  Examples of mitigation include reducing emissions of GHG, enhancing “sinks” for these gases, and “geo-engineering” to counteract the warming effects of GHG.

- Adaptation, which means measures to reduce the adverse impacts on human well-being resulting from the changes in climate that do occur.

  Examples of adaptation include changing agricultural practices, strengthening defenses against climate-related disease, and building more dams and dikes.

- Suffering the adverse impacts that are not avoided by either mitigation or adaptation.

Facing the challenge

Mitigation and adaptation are <u>both</u> essential.

- Human-caused climate change is already occurring.
- Adaptation efforts are already taking place and must be expanded.
- But adaptation becomes costlier and less effective as the magnitude of climate changes grows.
- The greater the amount of mitigation that can be achieved at affordable cost, the smaller the burdens placed on adaptation and the smaller the suffering.

How much mitigation is needed?

- The UN Framework Convention on Climate Change of 1992 is “the law of the land” in 188 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 mitigation is needed? (continued)

There's still no formal consensus, but it's becoming clear that the current level of anthropogenic interference is dangerous.

- The world is already experiencing rising incidence of floods, droughts, wildfires, heat waves, coral bleaching, summer melting of sea ice & permafrost, shrinkage of mountain glaciers, accelerating loss of Greenland and Antarctic ice, drying out of rainforests, and category 4 & 5 cyclones.
- T_{avg} would rise another 0.6°C even if GHG concentrations were stabilized today ("thermal lag" of oceans).

How much mitigation? (continued)

- Under continuation of "business as usual" (BAU) in growth of world GDP and use of fossil fuels, the increase in global average surface temperature above its pre-industrial value (ΔT_{avg}) is likely to reach almost 2°C by 2050, 3°C by 2100, and 4-5°C by 2150.
- The best current science indicates that…
  - ΔT_{avg} ~ 1.5°C <u>could</u> mean the end of coral reefs;
  - ΔT_{avg} ~ 2°C <u>could</u> mean catastrophic melting of Greenland & Antarctic ice, producing rates of sea-level rise that could reach 3-4 meters per century;
  - ΔT_{avg} ~ 2.5°C <u>is likely</u> to sharply reduce crop yields worldwide.

How much mitigation is needed? (continued)

- Until a few years ago, many analysts and groups were suggesting a target of about 3°C.

  A 3°C target corresponds to a sum of human influences (changes in all greenhouse gases and absorbing & reflecting particles) equivalent to a doubling of pre-industrial CO_2 (to ~550 ppmv).

  This was a compromise: perhaps the highest value that might be tolerable (taking into account potential for adaptation) <u>and</u> at the same time the lowest value that might be achievable (taking into account the known mitigation options and their costs).

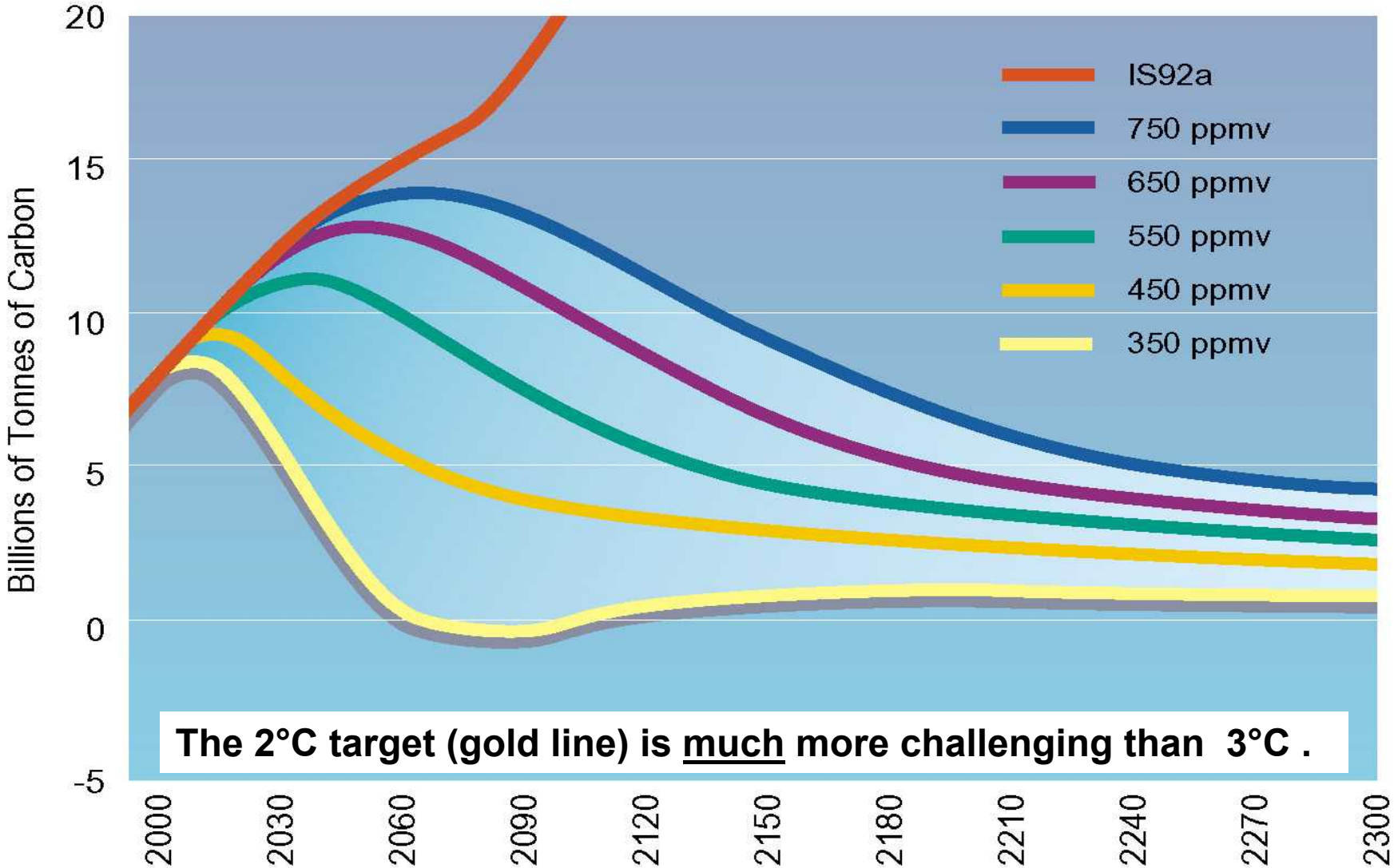
- Recent insights about impacts have led many analysts & groups, over the past few years, to argue for a tighter target, around 2°C.

  This would mean confining the sum of human influences to the equivalent of CO_2's reaching 400-450 ppmv.

  Many analysts doubt that so low a target can be achieved.

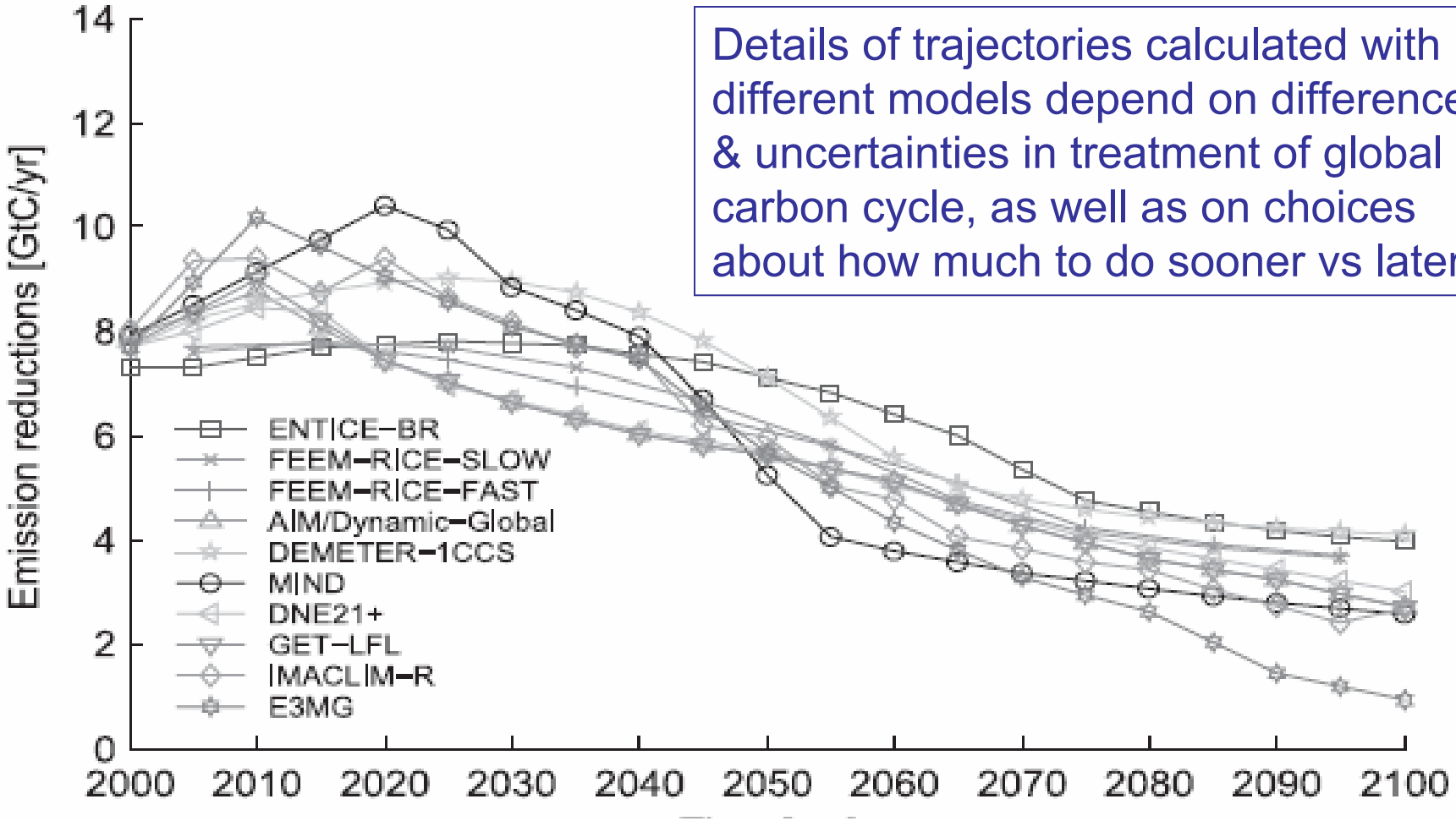
The CO_2 emissions challenge in summary

Emissions trajectories consistent with stabilizing atmospheric CO_2 at various levels (2005 = 380 ppmv)



A range of trajectories exists for each target

Emissions trajectories for stabilizing at 450 ppmv CO2



Details of trajectories calculated with different models depend on differences & uncertainties in treatment of global carbon cycle, as well as on choices about how much to do sooner vs later.

Grubb et al., The Energy Journal, 2006

How much mitigation? (continued)

AN OUNCE OF PREVENTION…

- The costs of delay in initiating reductions are likely to be substantial. They depend strongly on the choice of climate-change goals.
- The lower the stabilization target deemed prudent, the higher the costs of delay in starting to move toward it.
- Any further delay in starting puts the ability to stabilize below 450 ppmv in doubt, irrespective of cost.
- For higher targets, moderate early action will cost far less than waiting until only drastic action can meet the target.
- Early action can be considered to be an insurance policy against costly catastrophe.

Some key references

Intergovernmental Panel on Climate Change, *Climate Change 2001: Synthesis Report – Summary for Policymakers*, IPCC, 2001 http://www.ipcc.ch/pub/un/syreng/spm.pdf

U.S. Global Change Research Program, *Climate Change Impacts on the United States*, USGCRP, 2001 http://www.usgcrp.gov/usgcrp/Library/nationalassessment/

The Arctic Council, *Arctic Climate Impact Assessment*, Arctic Council, 2005. http://www.acia.uaf.edu

Millennium Ecosystem Assessment, *Ecosystems and Human Well-Being*, UN Environment Programme, 2005. http://www.millenniumassessment.org/en/index.aspx

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