Climate Change By the Numbers

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Alabama State Climatologist

Consensus is not Science

Michael Crichton

Consensus is not Science

Michael Crichton

All Science is numbers

William Thompson (Lord Kelvin)

Some people will do anything to save the Earth ...

Some people will do anything to save the Earth ...

except take a science course.

Greenhouse "Affect", *Rolling Stone*

P.J. O'Rourke

The Basic Numbers

- Carbon Dioxide has increased 35%
- Global Surface temperature rose 0.7 °C in past 100 years
- Surface temperature response to 2xCO_2 increases (alone) is ~ 1 C
- The associated feedbacks are where the uncertainties are large (i.e. no confident numbers)

The Basic Numbers

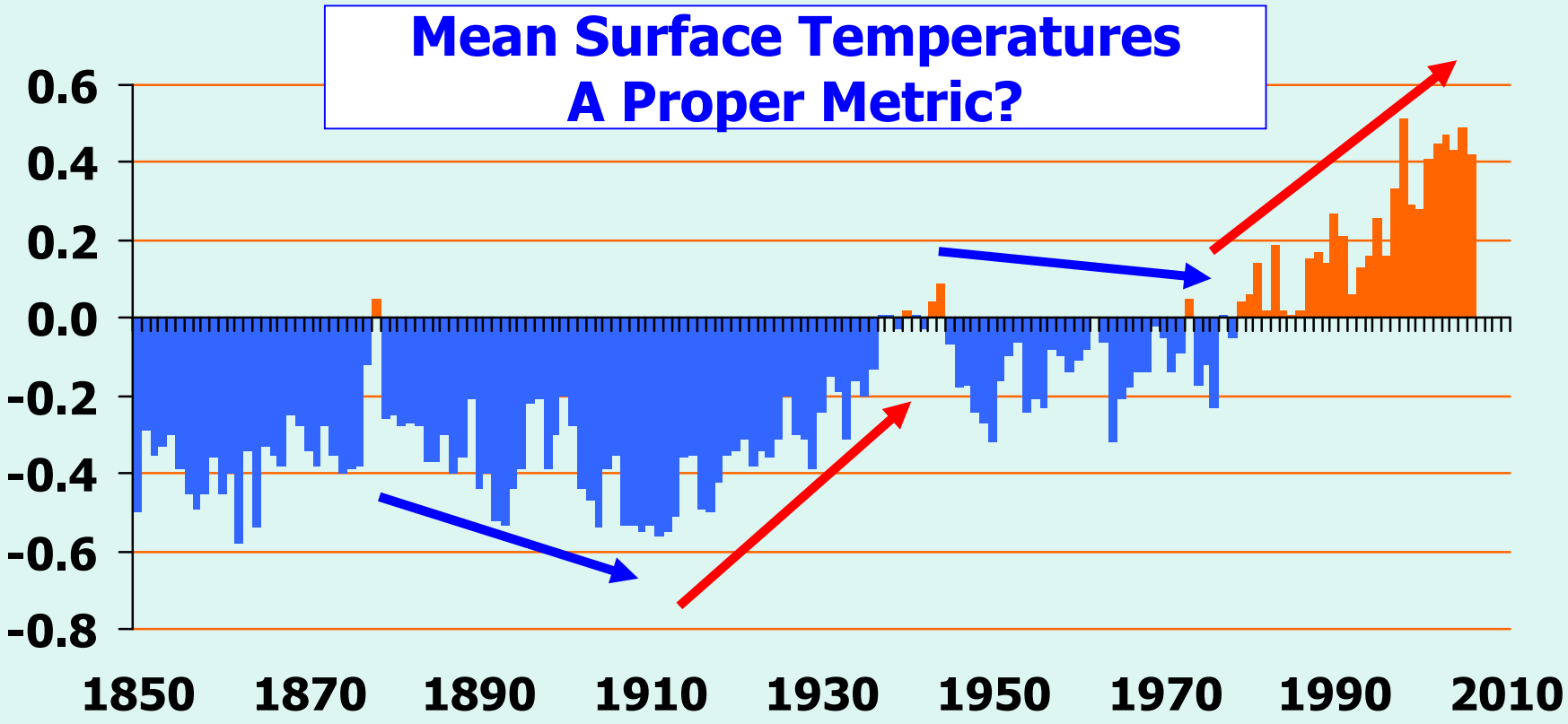
- **Humans produce about 7 to 8 gigatons of CO2 (carbon mass) per year mainly from energy production**
- **About 3.5 to 4 gigatons accumulate in the air each year**
- **There are about 740 gigatons of CO2 in the atmosphere**
- **CO2 in the atmosphere is increasing around 0.5% per year**

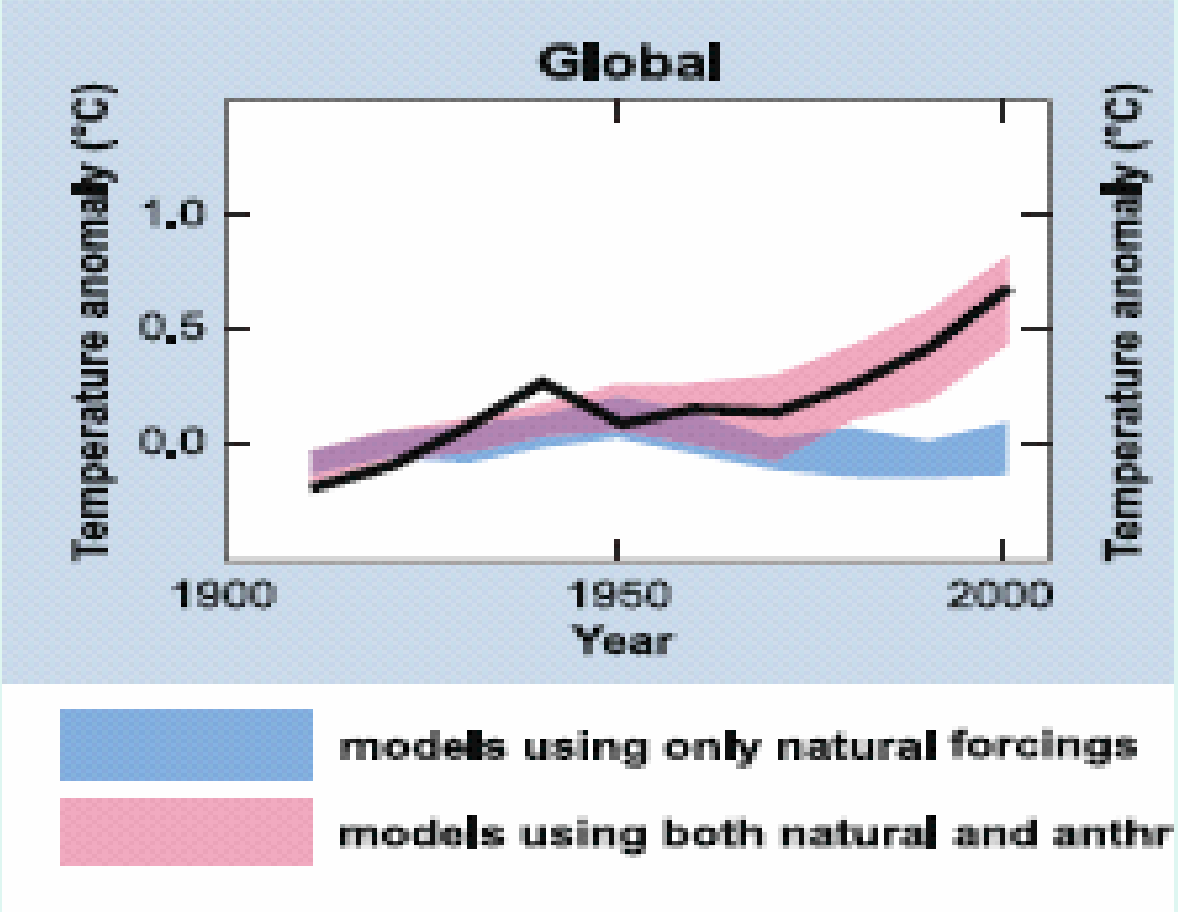
The Basics

- Climate is always "changing"
  - Global temperature is rising or falling
  - Sea level is rising or falling
  - Glaciers are retreating or advancing

"Global" Surface Temperature

HadCRUT3





IPCC SPM

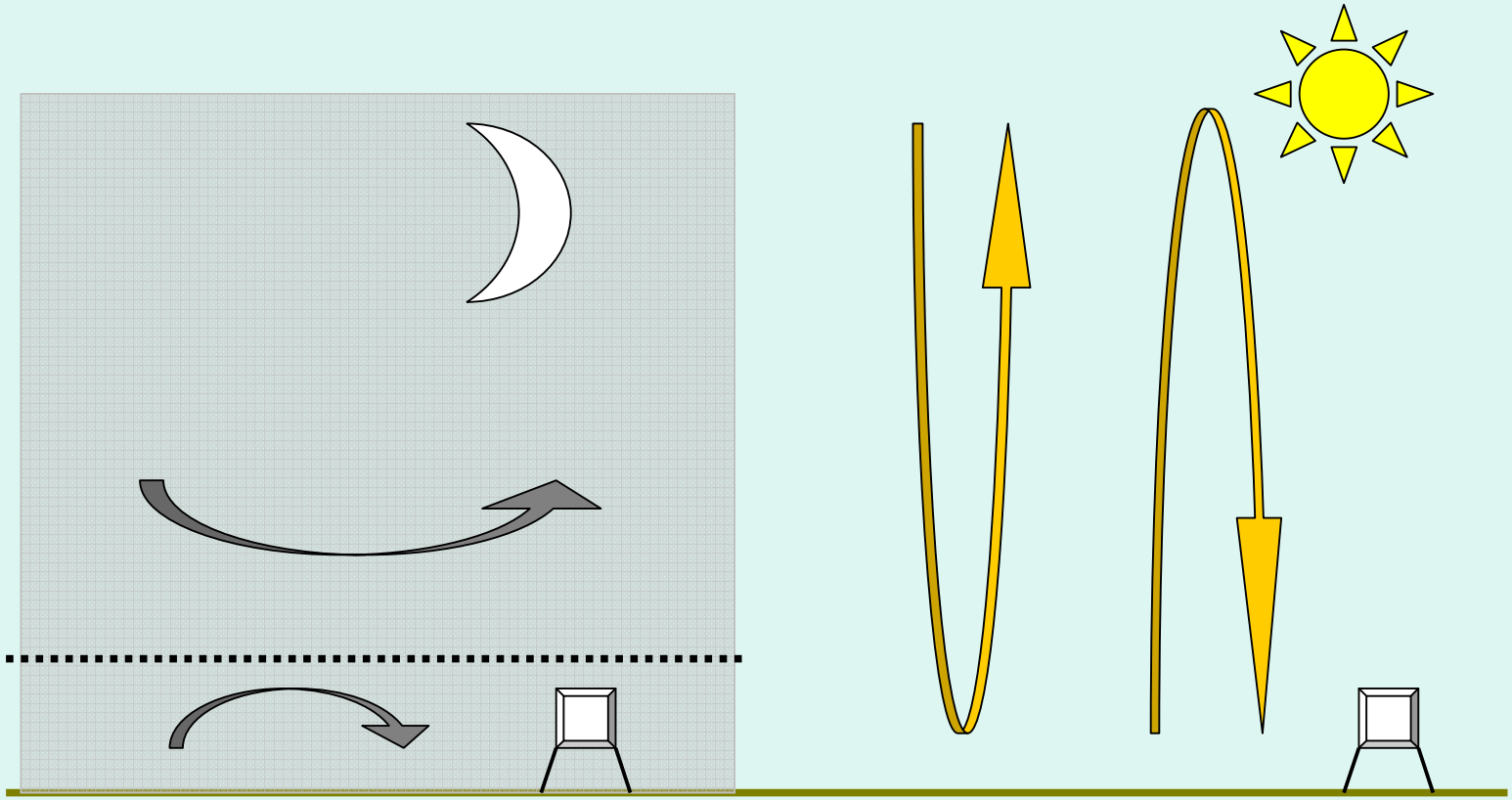
Modelers knew the answer ahead of time - not a true scientific experiment. The scientific method requires an independent comparison - i.e. upper air temperatures which modelers in general did not force agreement.

Is Mean Surface Temperature an Appropriate Index for the Greenhouse Effect?

TMean = (TMax + TMin)/2

TMean = (Daytime + Nighttime)/2

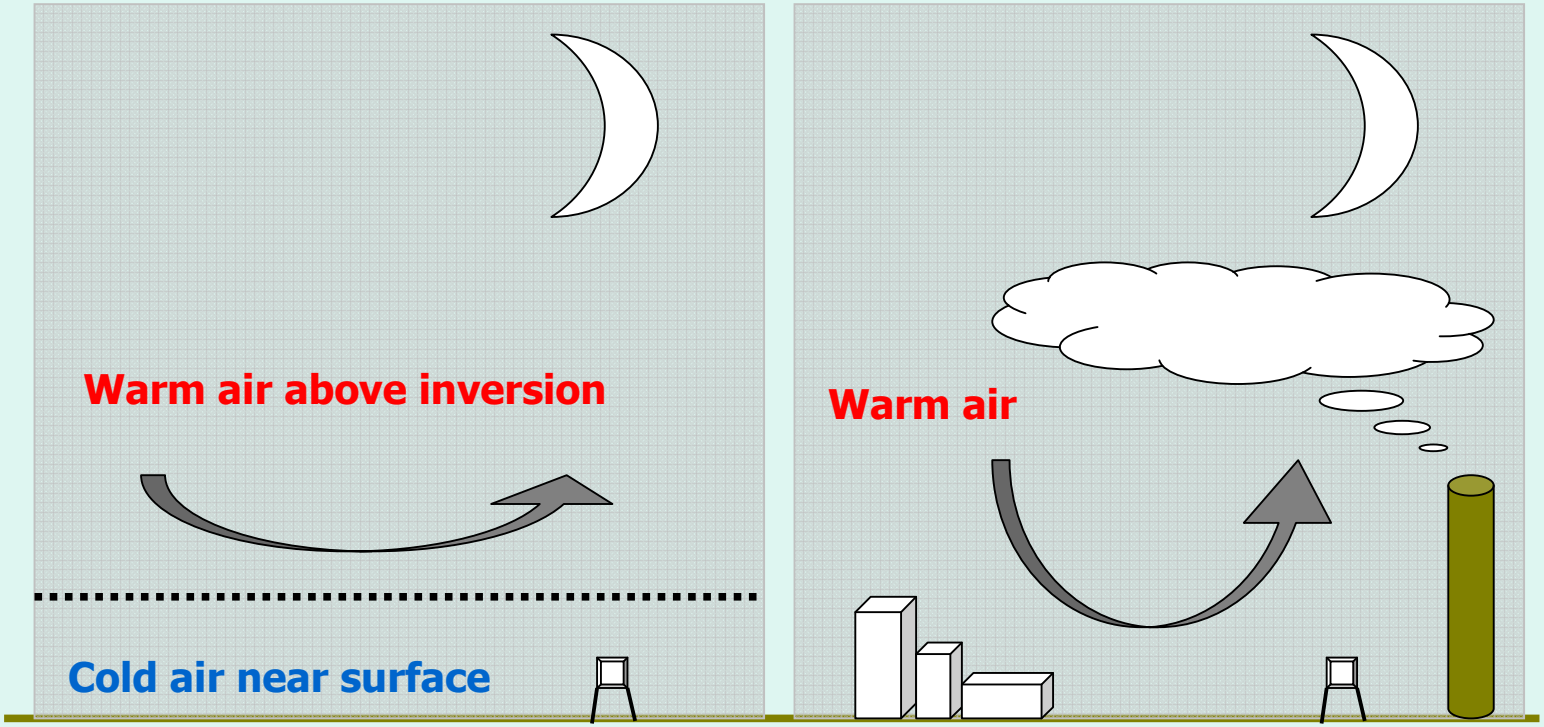
Day vs. Night Surface Temp



Nighttime - disconnected shallow layer/inversion. Temperature affected by land-use changes, buildings, farming, etc.

Daytime - deep layer mixing, connected with levels impacted by enhanced greenhouse effect

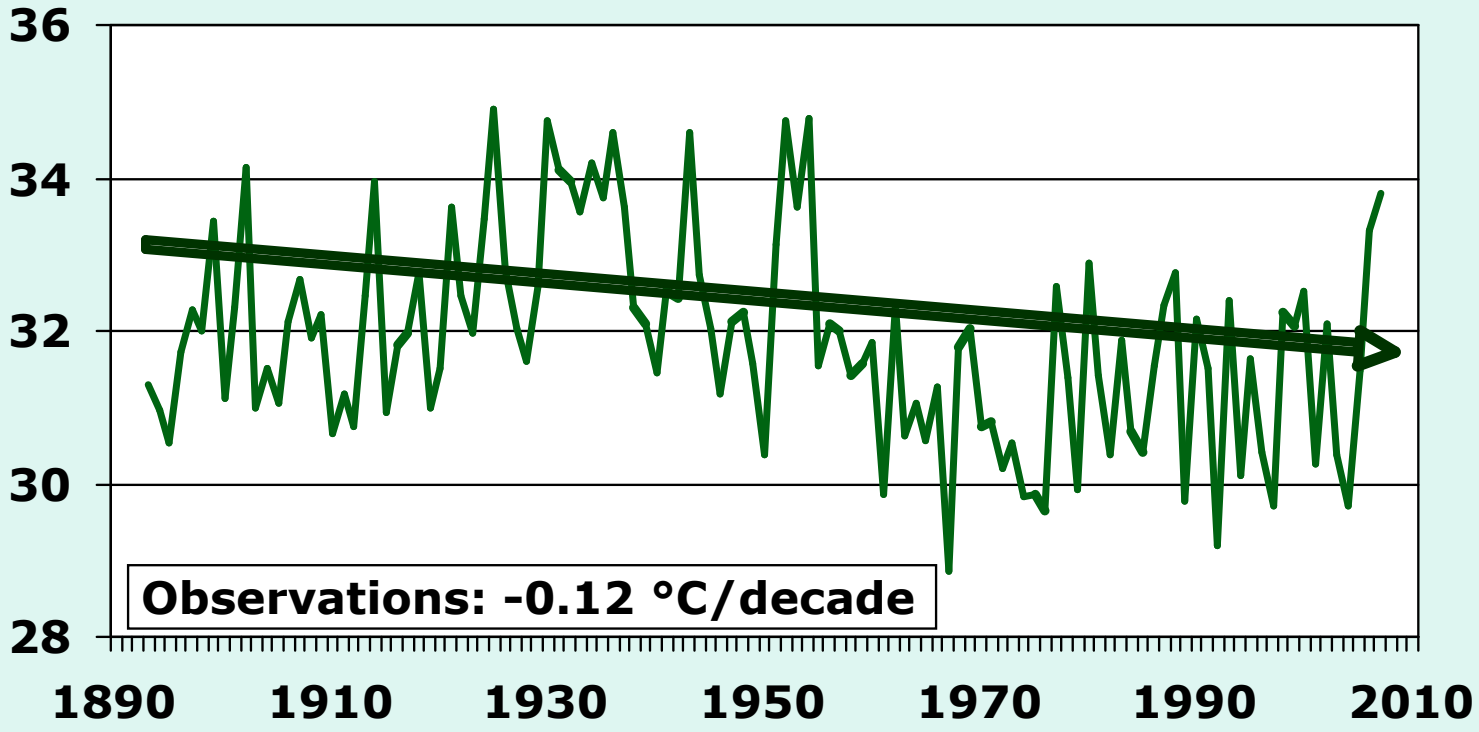
Night Surface Temp



Nighttime - disconnected shallow layer/inversion. But this situation can be sensitive to small changes such as roughness or heat sources.

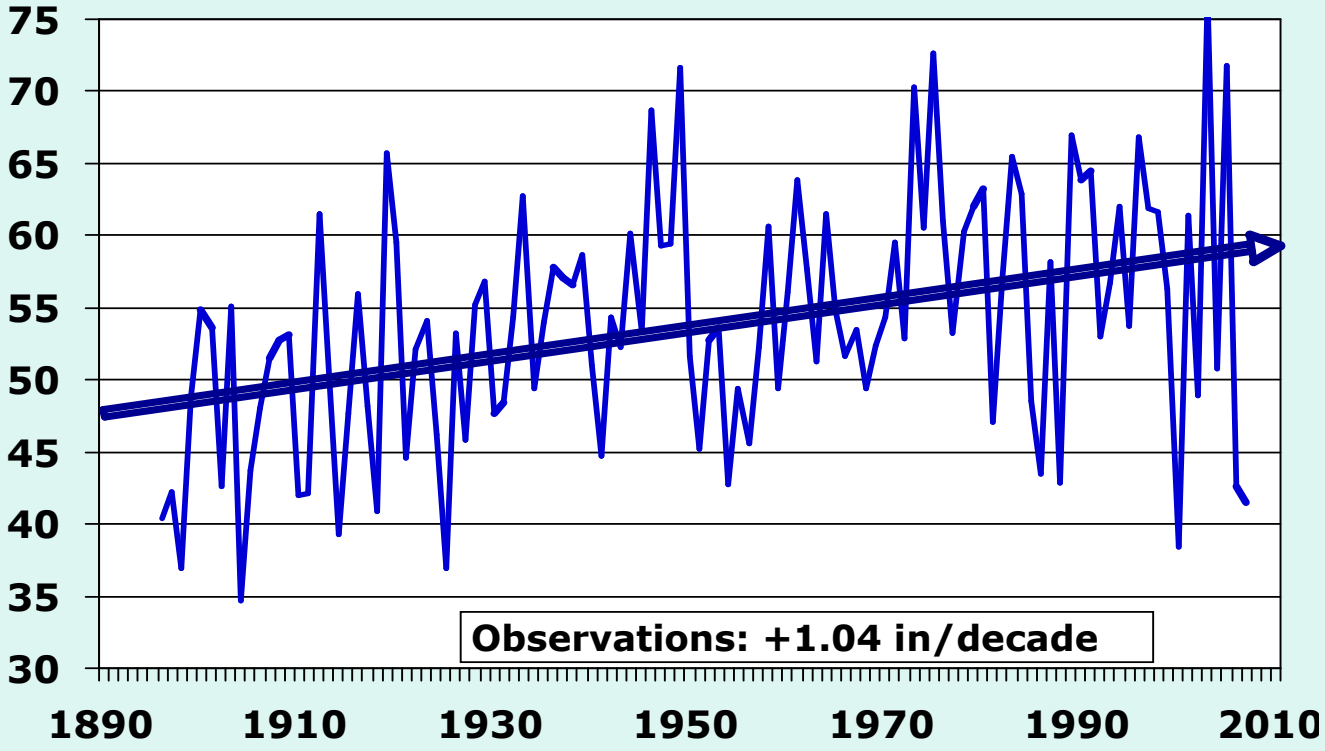
Buildings, heat releasing surfaces, aerosols, greenhouse gases, etc. can disrupt the delicate inversion, mixing warm air downward - affecting TMin.

No. Alabama Summer TMax Temperatures 1893-2007

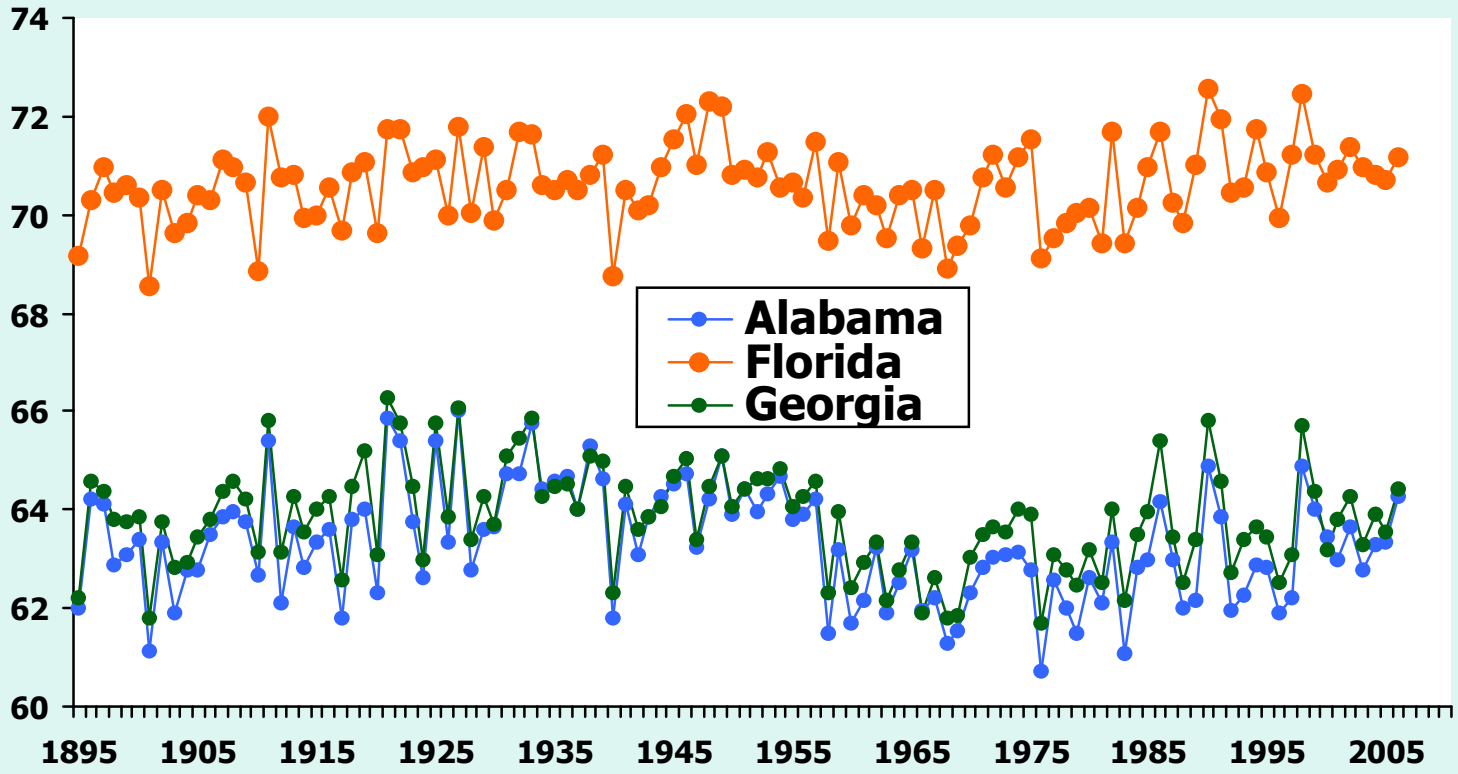


Christy 2002, updated to 2007

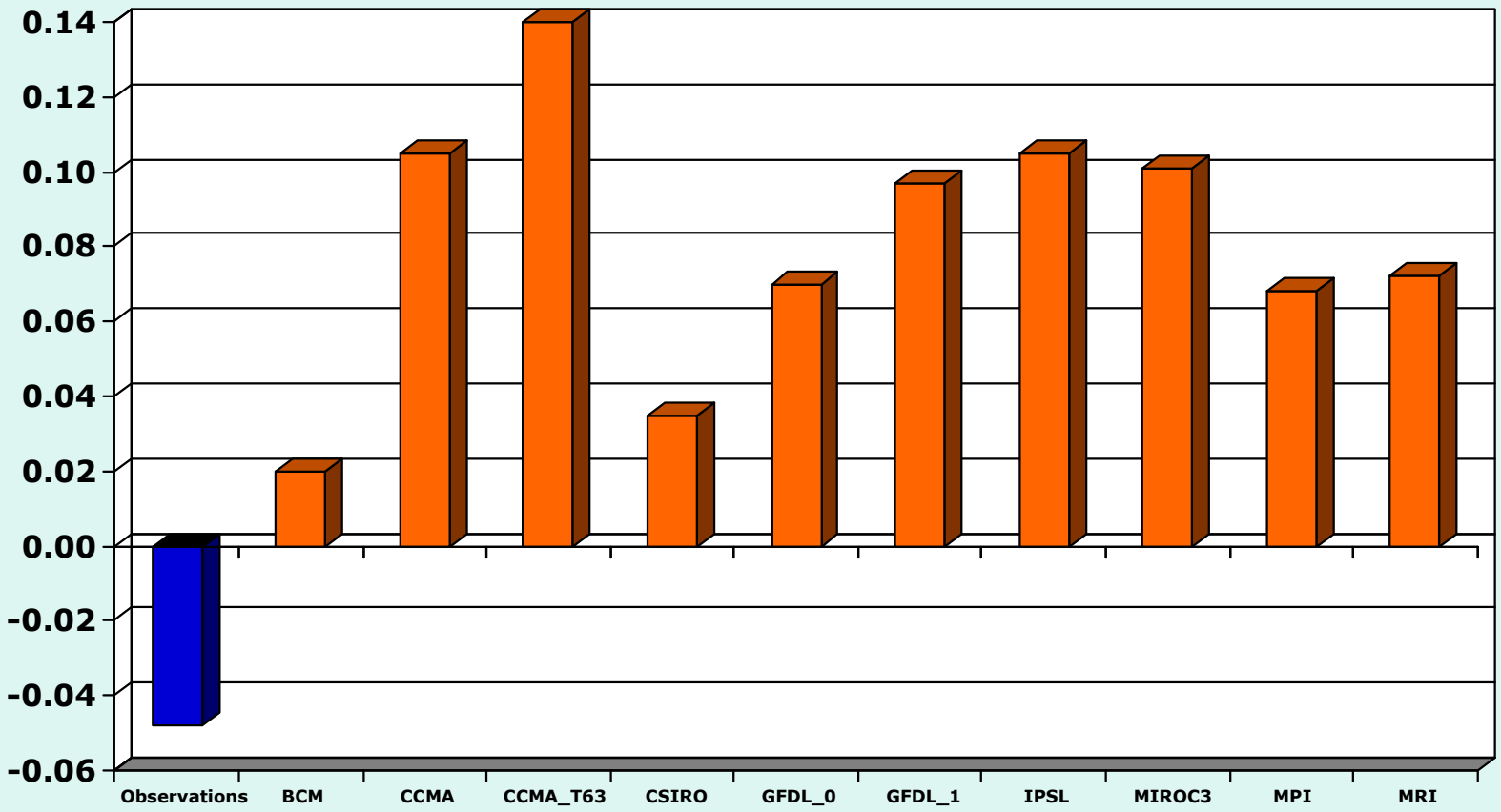
Alabama Annual Precipitation 1896-2007



Annual Mean Temperature



Mean Surface Temperature Southeast USA 1899-2003

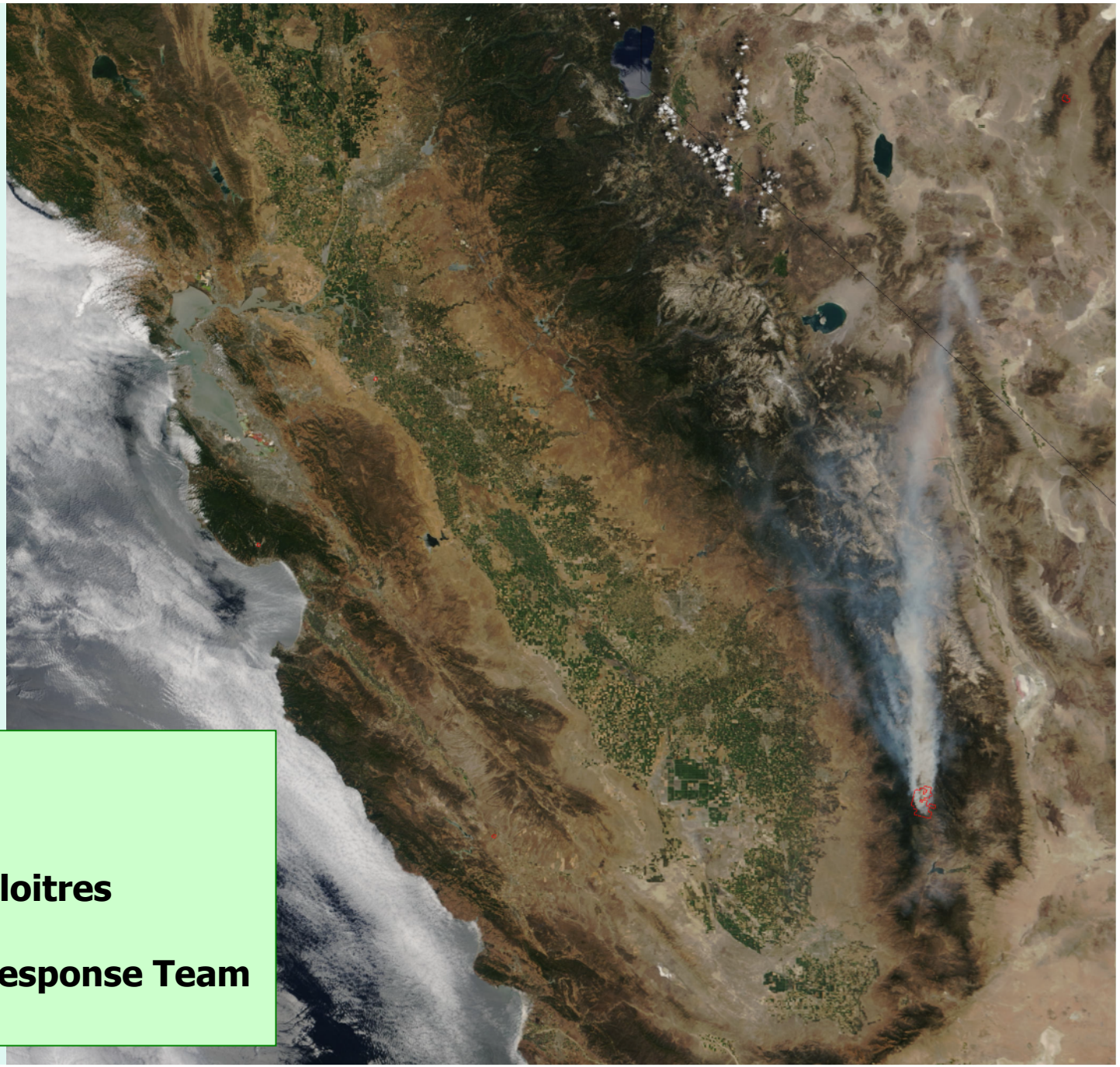


Observation **Models**

Darwin Glacier, 1908

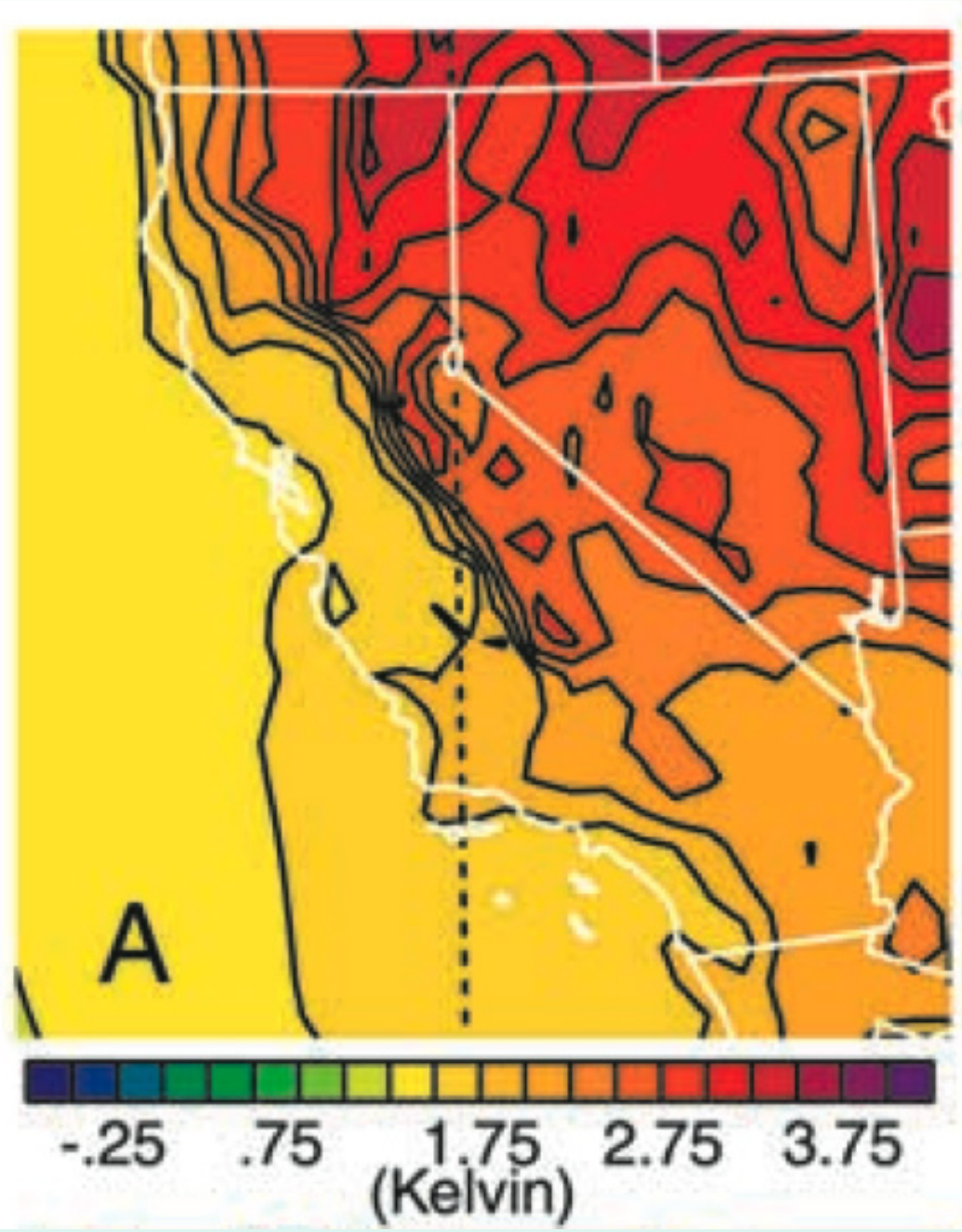
Darwin Glacier, 2003

Christy et al. 2006, *J. Climate*



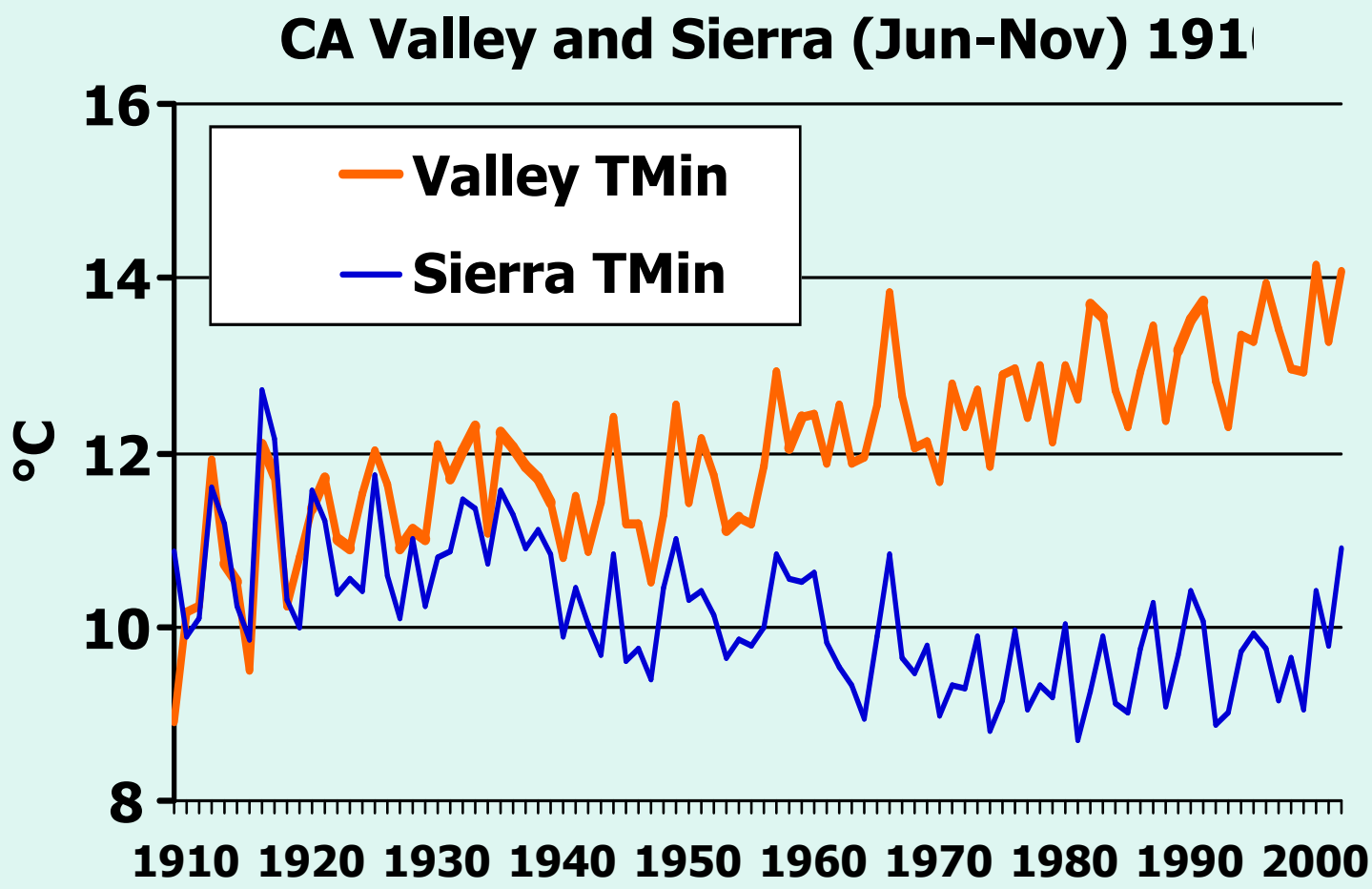
MODIS
21 Jul 2002

Jacques Descloitres
MODIS
Land Rapid Response Team
NASA GSFC



Sierras warm faster than Valley in model simulations

Snyder et al. 2002



Christy et al. 2006

Main Point:

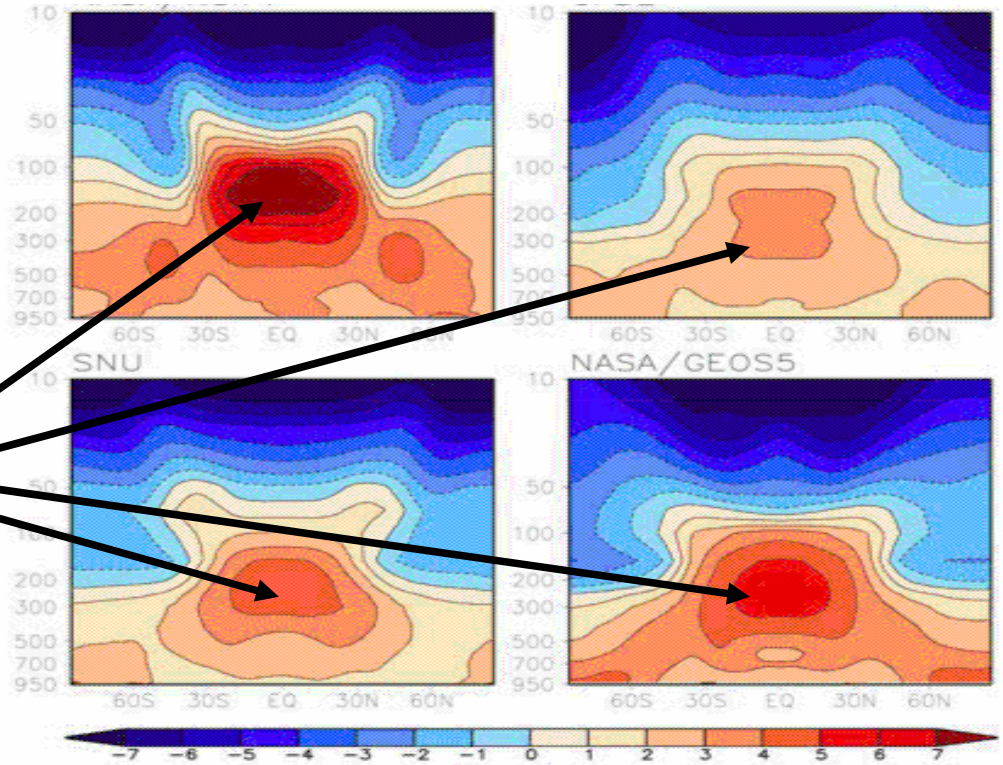
Average **surface temperatures (average of daytime and nighttime) are poor proxies for greenhouse detection because of nighttime contamination by human development - likely overstating actual atmospheric warming. Models do not replicate past regional temperature well in many places, including the Southeast.**

- **Christy 2002**
- **Christy et al. 2006**
- **Pielke, Sr. 2007**
- **Walters et al. 2007**

Upper Air Temperatures
A Better Proxy

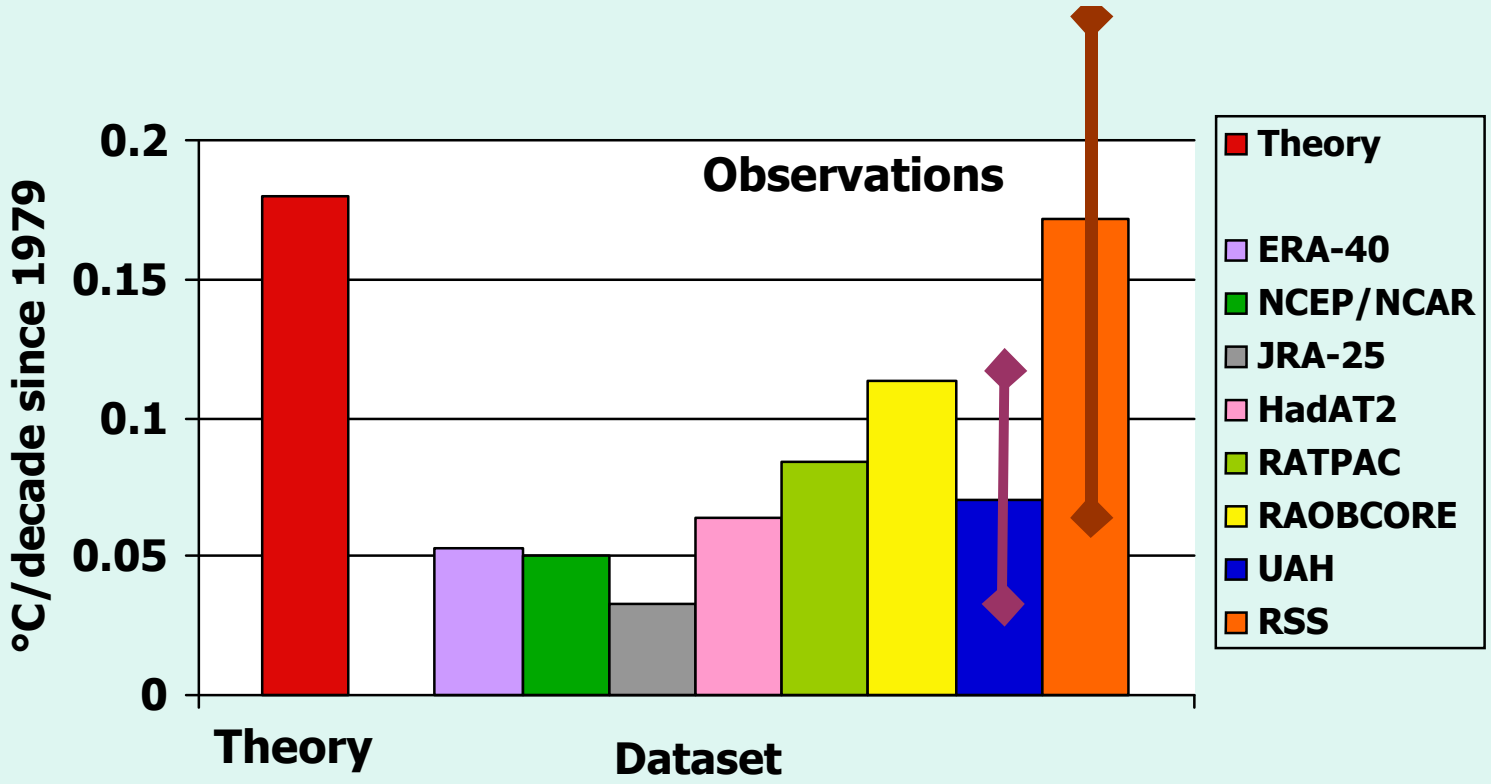
Vertical Temperature Change due to Greenhouse Forcing in Models

Model Simulations of Tropical Troposphere Warming: About 2X surface Lee et al. 2007



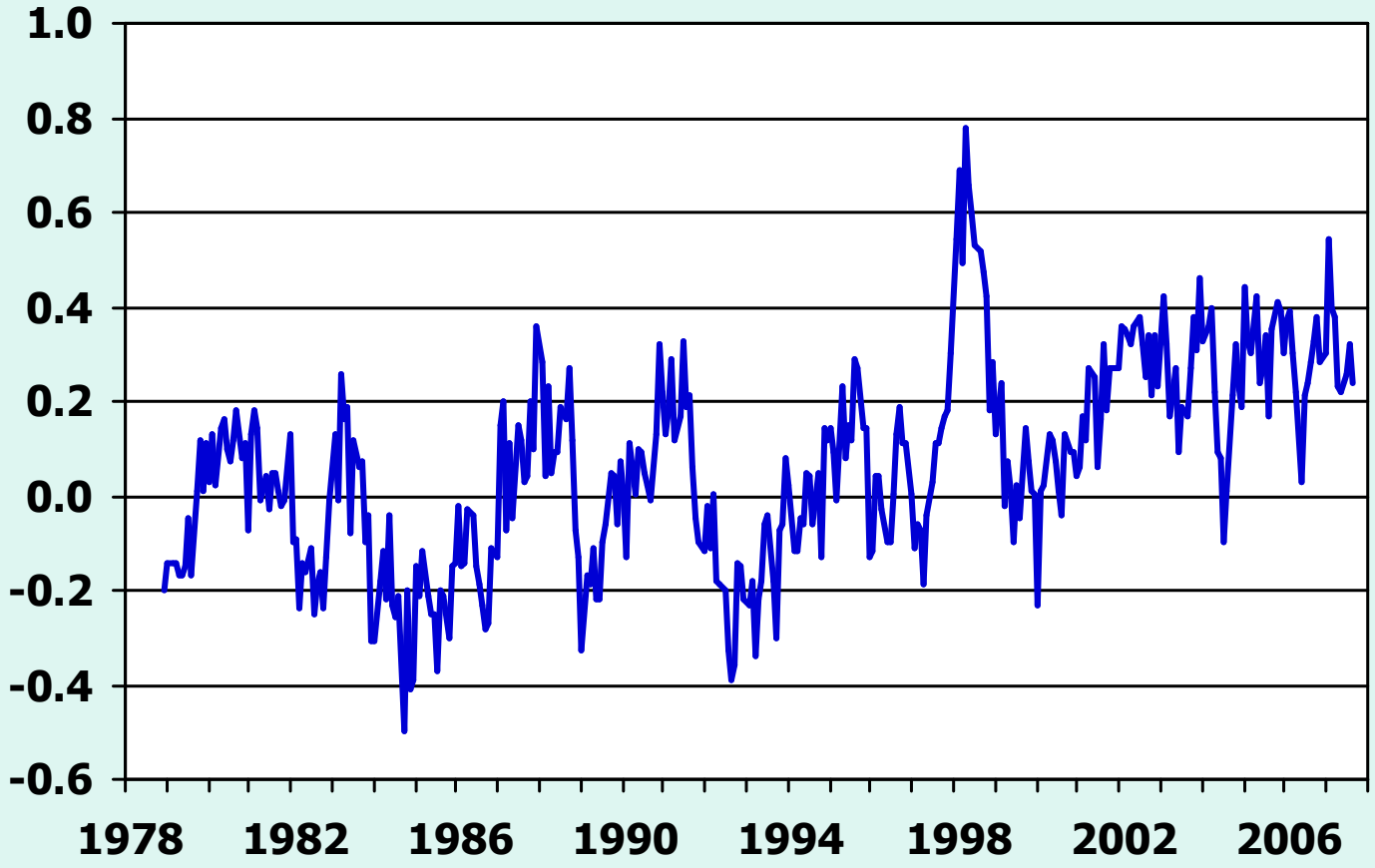
Zonal mean distributions of temperature change (2×CO2–Control). Units are Kelvin.

Upper Air Tropical Trends



Christy and Norris 2006,
Christy et al. 2007
Douglass et al. 2007

Global Bulk Atmospheric Temperatures
UAH Satellite Data



Warming rate 60% of model projections

Main Point:

Better proxies (daytime surface temperature and tropospheric temperatures) show only modest changes, and no change in the Southeast, neither of which are reproduced well in models.

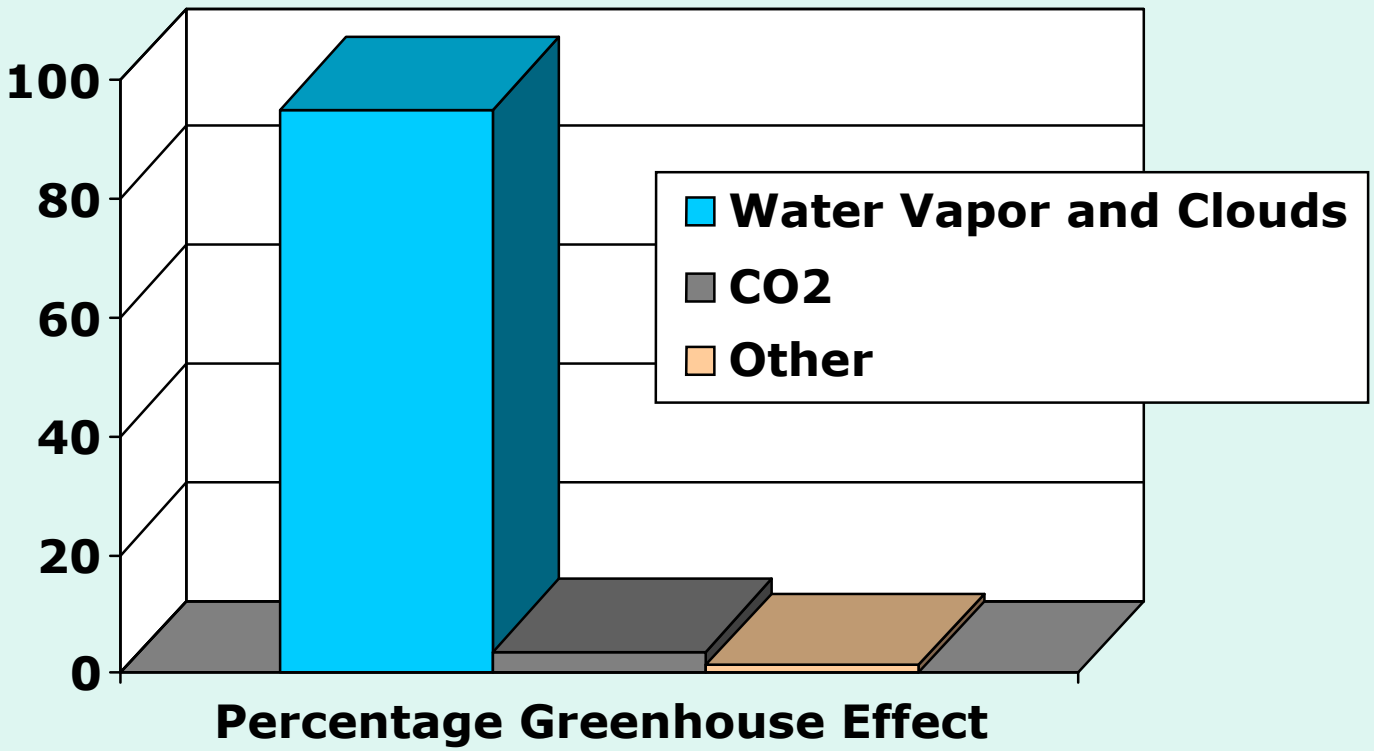
- Christy and Spencer 2005
- Christy and Norris 2006
- Christy et al. 2007

Greenhouse Effect

Total Greenhouse Effect

- **Water vapor and Clouds Dominate**
- **Total Greenhouse Effect is variable**
- **Climate models show strong water-vapor/cloud *positive* feedback with increased CO2**

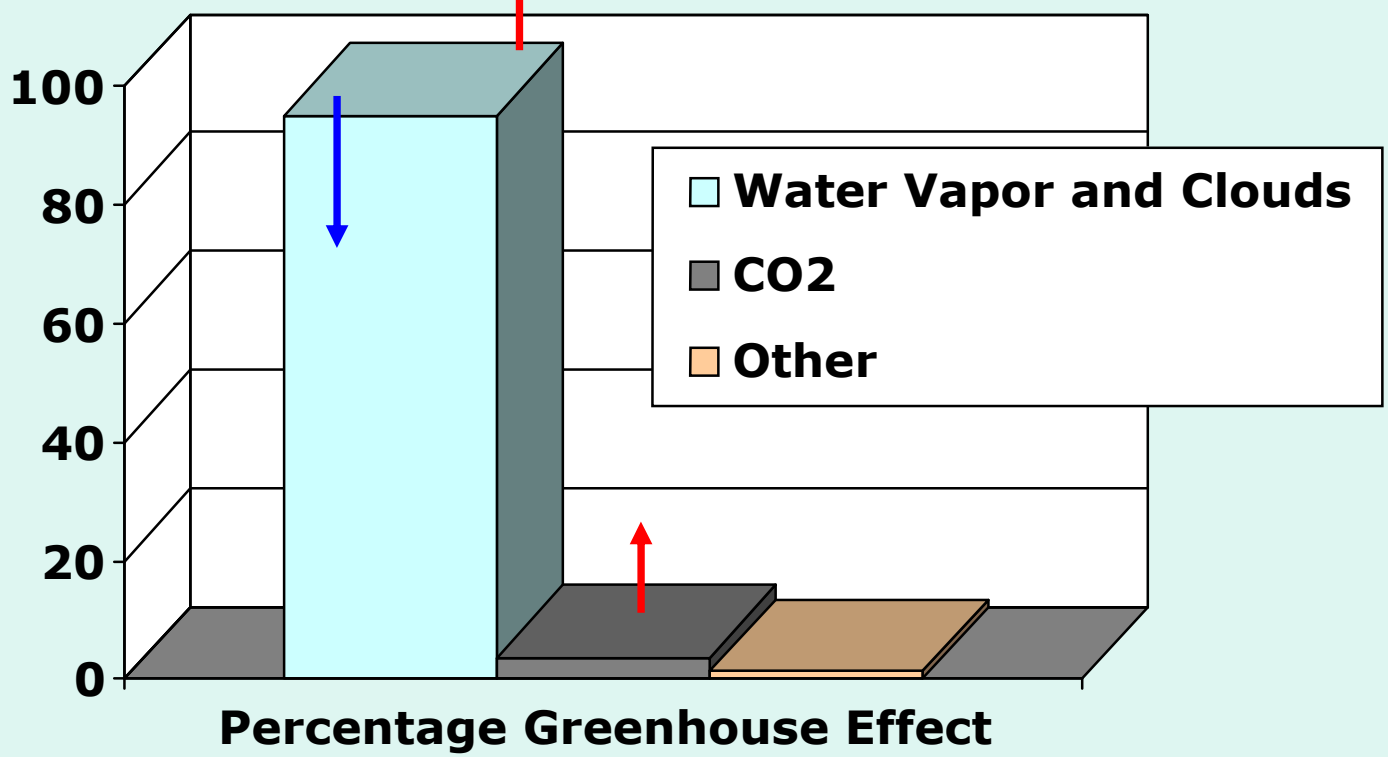
Greenhouse Effect



Greenhouse Response of Clouds and Water Vapor to Increasing CO2

Negative Feedback?
(mitigates CO2 impact)

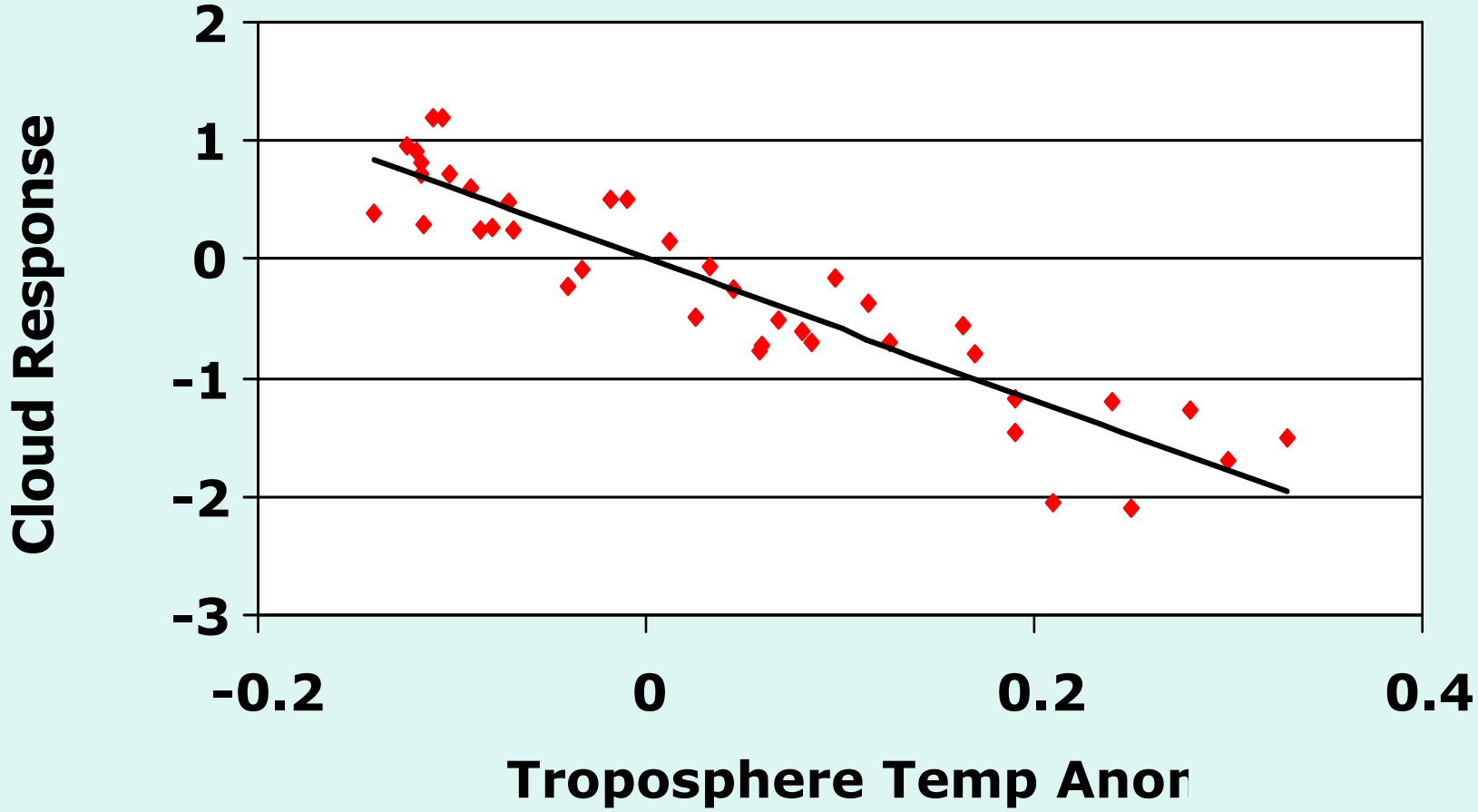
Positive Feedback?
(enhances CO2 impact - models)



Tropical Temp. and Cloud Forcing on month-to-month time scales

Negative feedback [Spencer et al. (2007)]

Cloud variations act to counter temperature rises (Heat trapping clouds decrease when air is warmed)



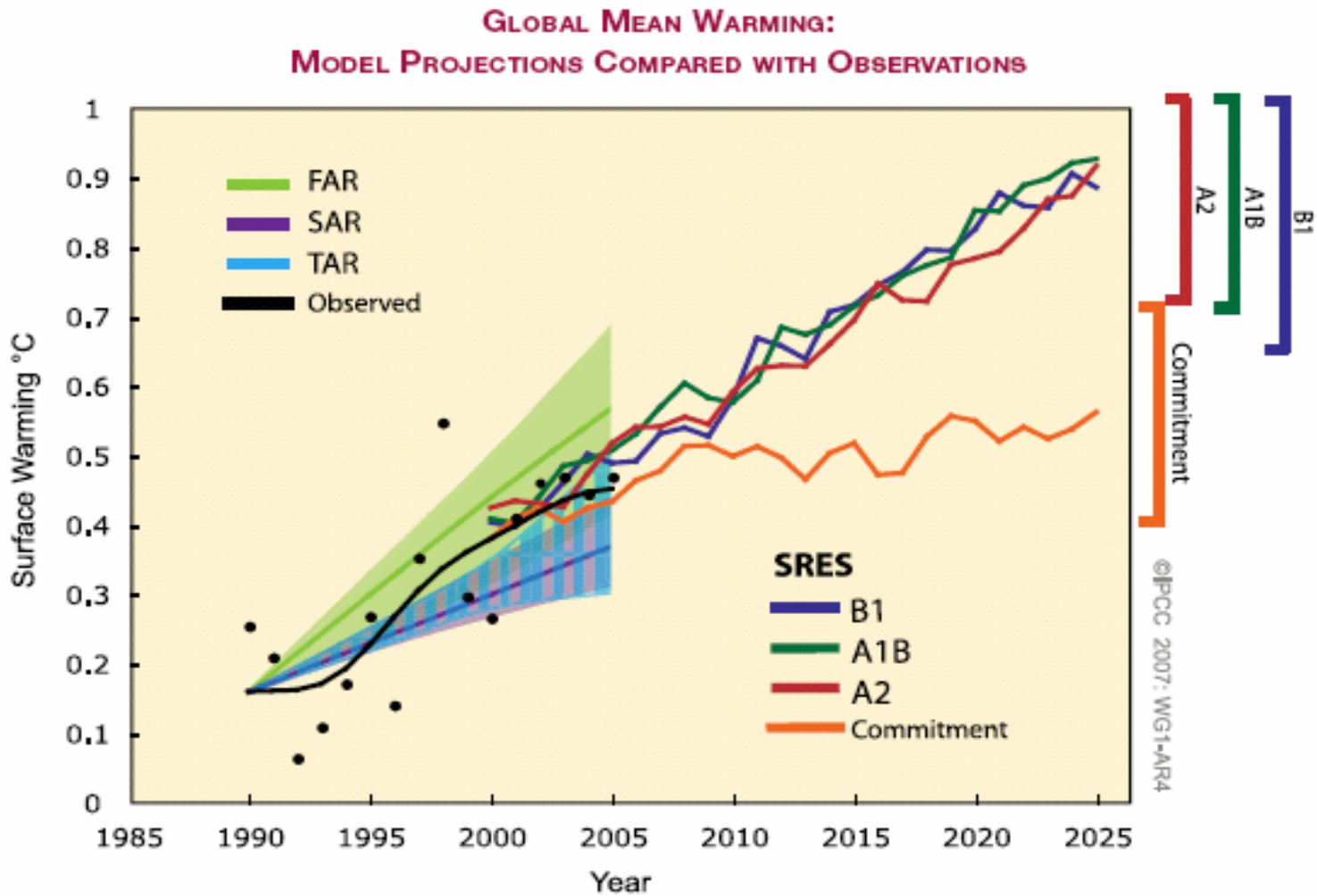
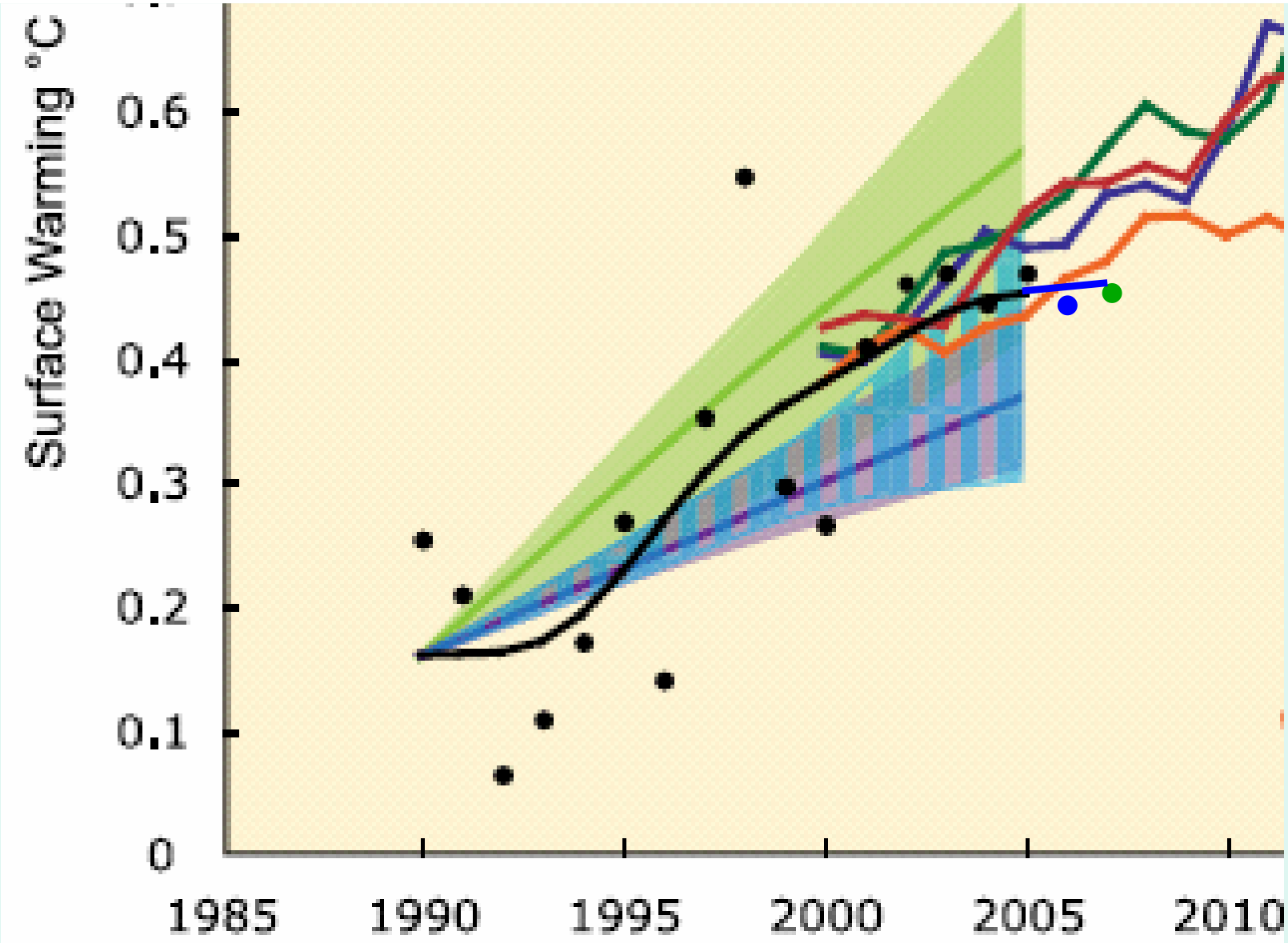


Figure TS.26. *Model projections of global mean warming compared to observed warming. Observed temperature anomalies, as in Figure TS.6, are shown as annual (black dots) and decadal average values (black line). Projected trends and their ranges from the IPCC First (FAR) and Second (SAR) Assessment Reports are shown as green and magenta solid lines and shaded areas, and the projected range from the TAR is shown by vertical blue bars. These projections were adjusted to start at the observed decadal average value in 1990. Multi-model mean projections from this report for the SRES B1, A1B and A2 scenarios, as in Figure TS.32, are shown for the period 2000 to 2025 as blue, green and red curves with uncertainty ranges indicated against the right-hand axis. The orange curve shows model projections of warming if greenhouse gas and aerosol concentrations were held constant from the year 2000 – that is, the committed warming. {Figures 1.1 and 10.4}*



2007: Jan-Aug only

Main Point:

The most important greenhouse components (clouds and water vapor) are poorly understood and poorly characterized in climate models

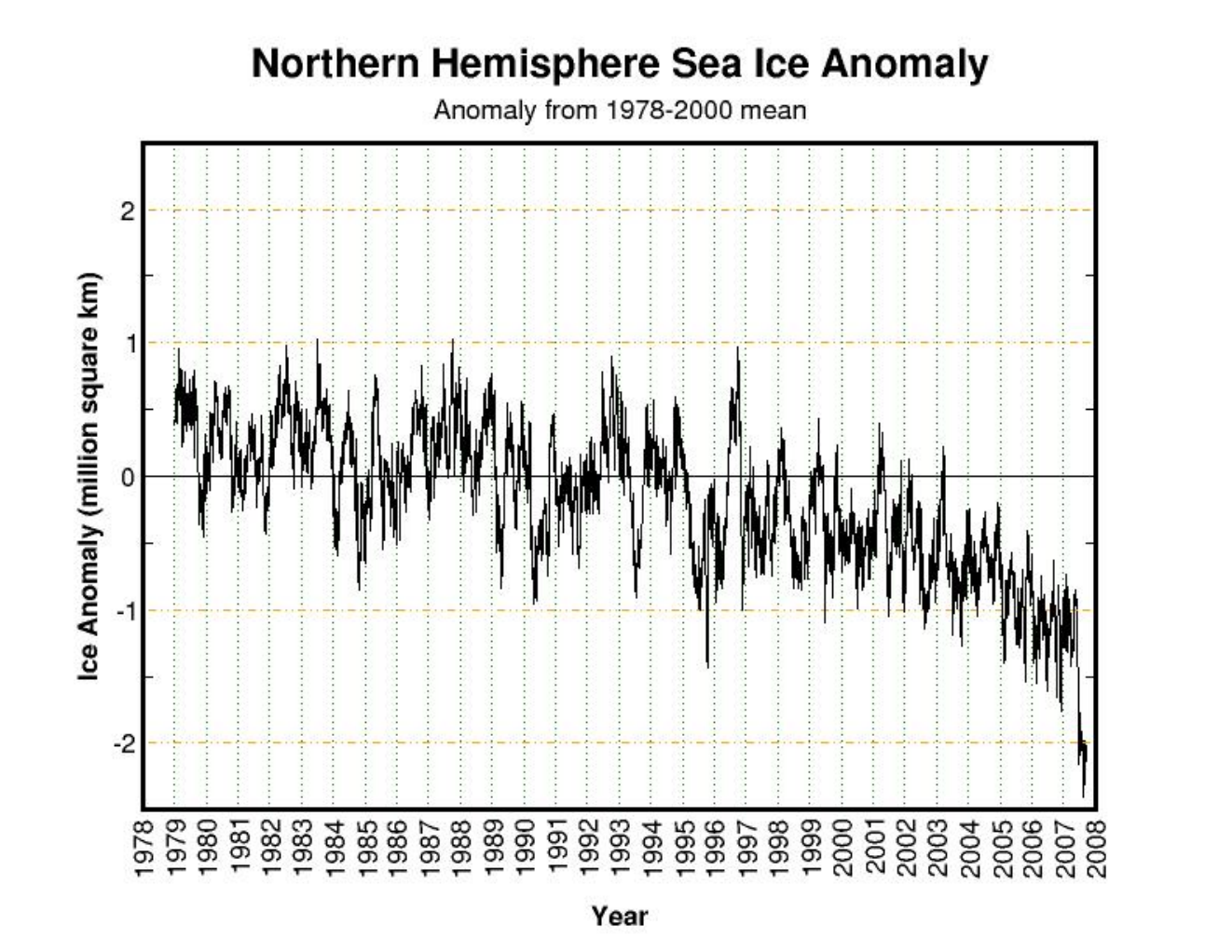
Spencer et al. 2007

"Models tend to overestimate positive feedback from water vapor ...[and] underestimate negative feedback from cloud[s]" Sun et al. 2007.

"The low equilibrium climate sensitivity ... [is] well below current best estimates ... in the IPCC (2007)" Schwartz 2007.

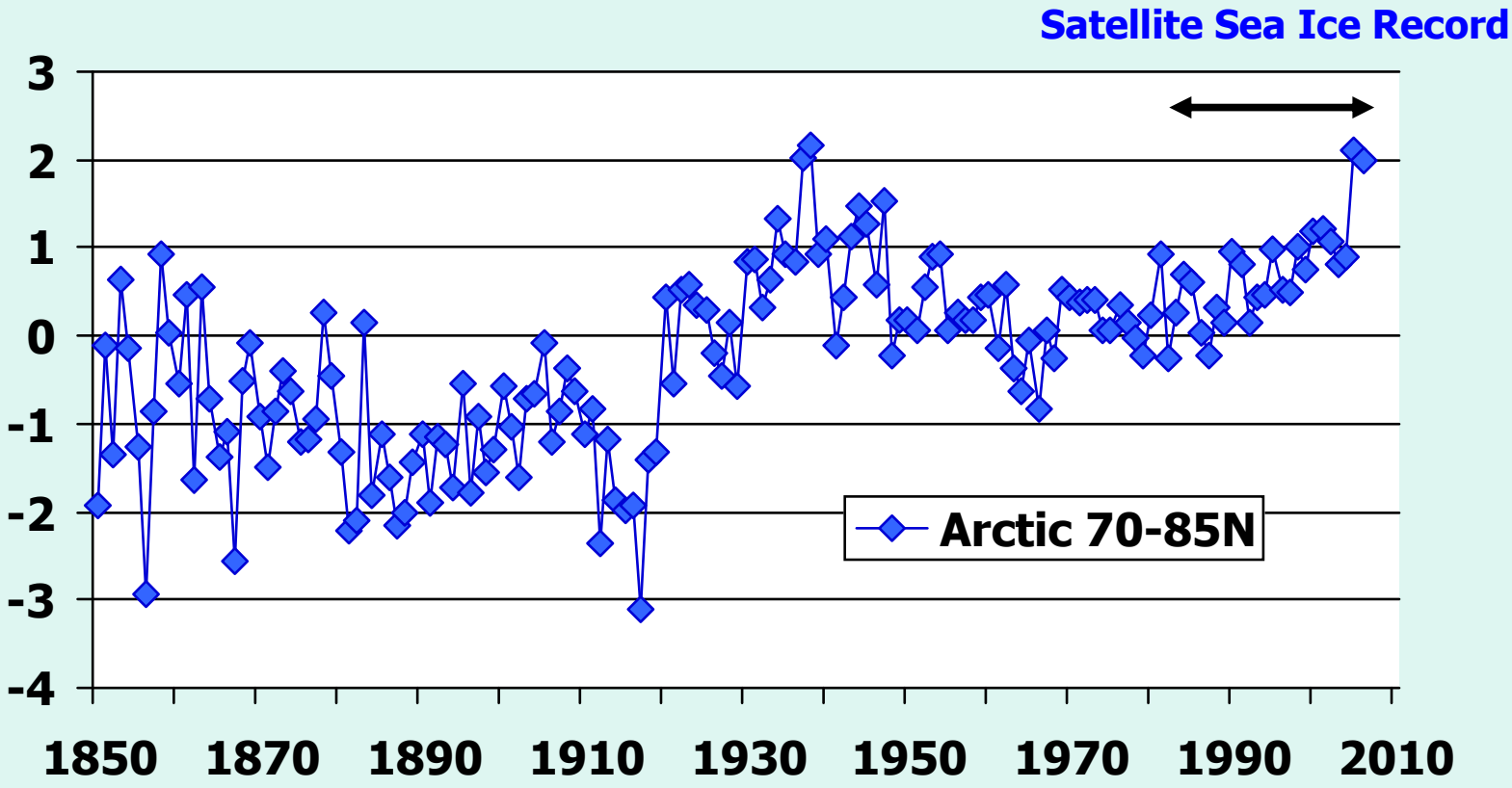
Cold Places?

Arctic Sea Ice

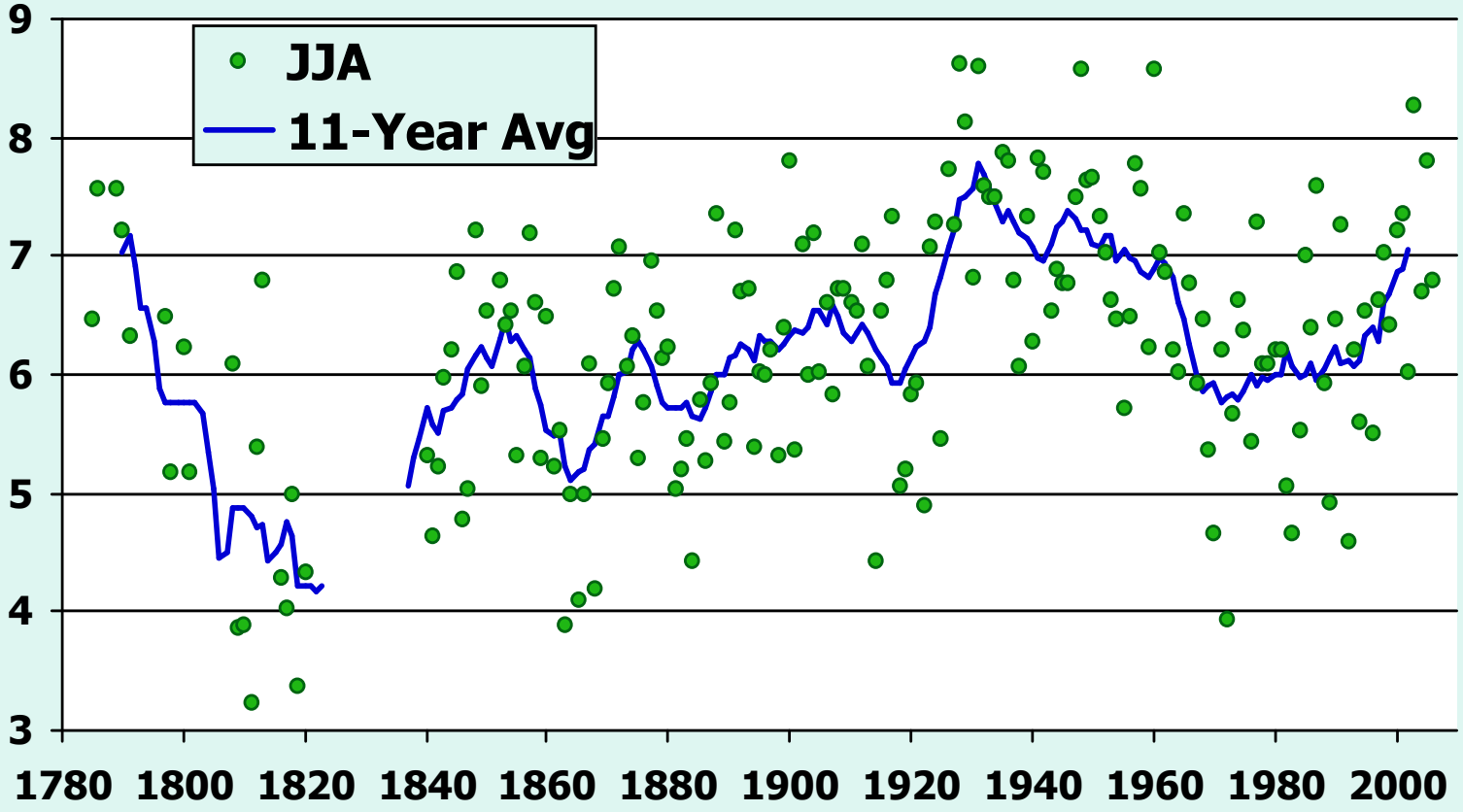


Chapman, U.Illinois

North Polar Regions
Temperature HadCRUT3

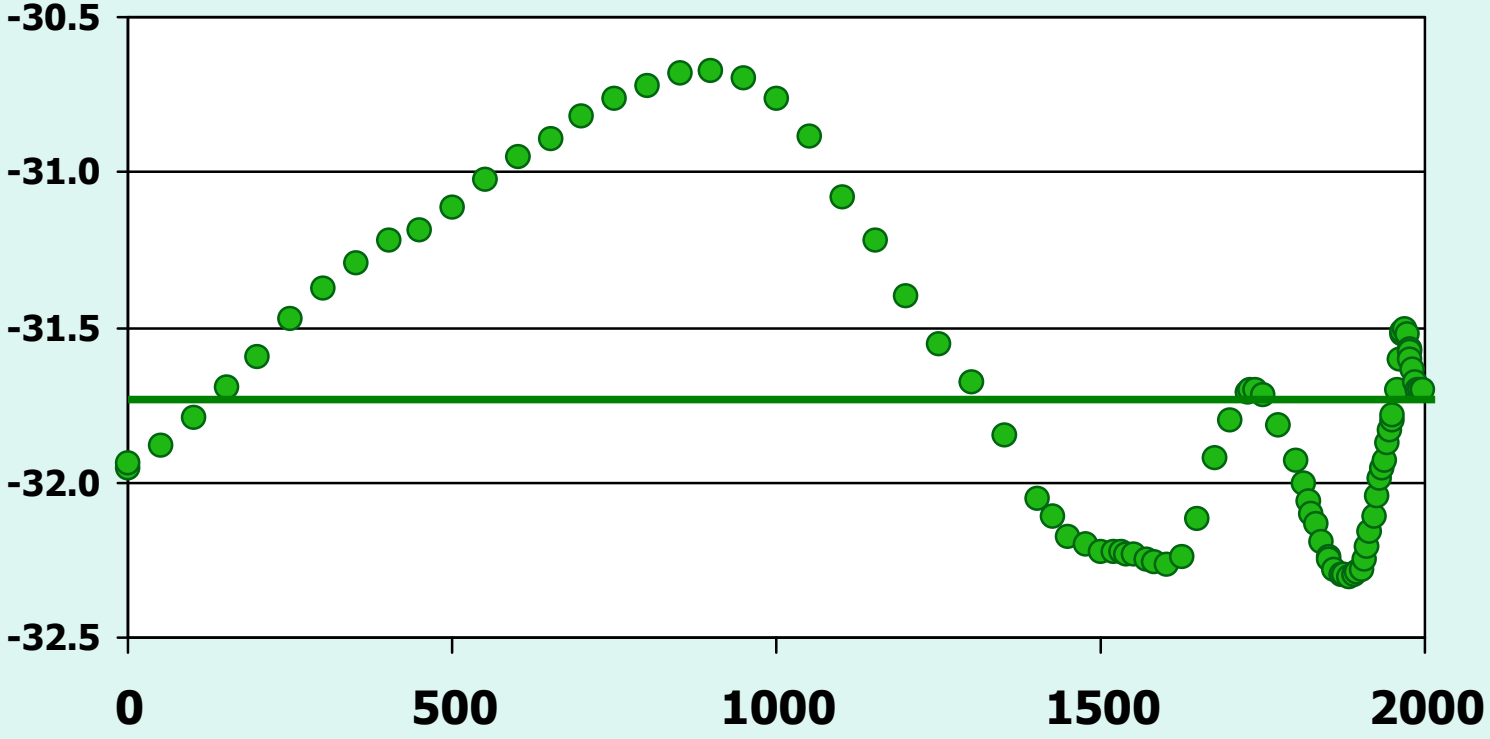


Greenland Summer Temperatures
Vinther et al. 2005



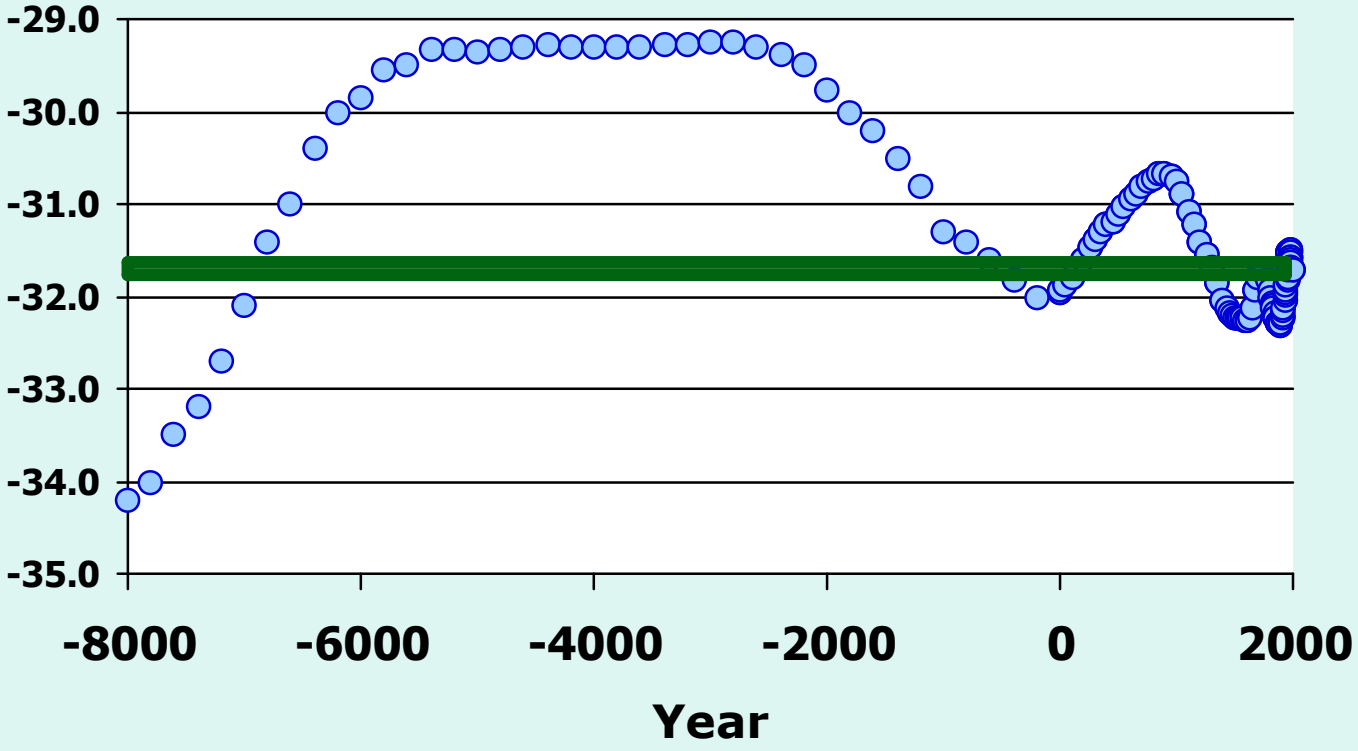
Greenland Borehole Temperature

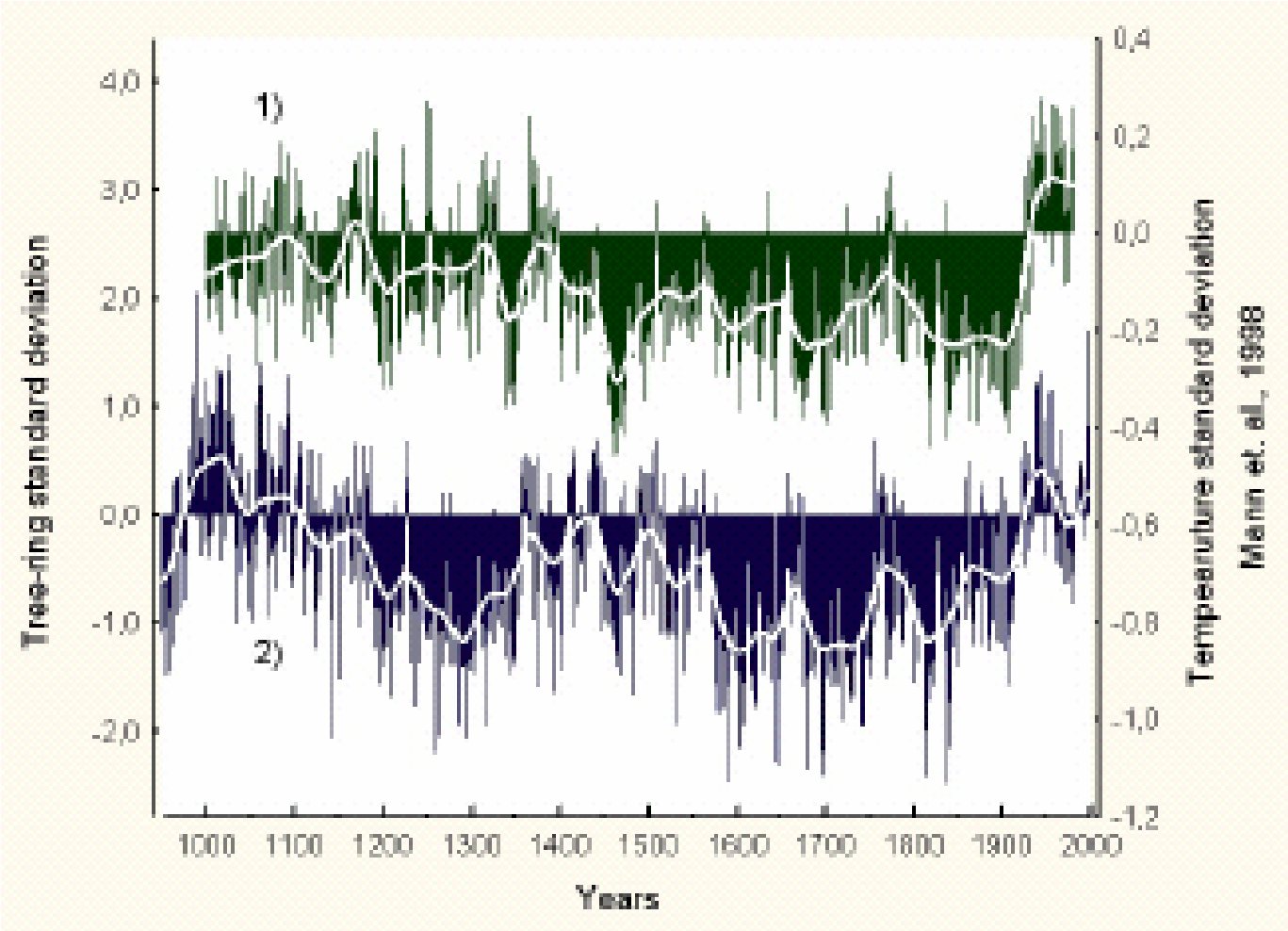
Dahl-Jensen et al. 1998



Greenland Borehole Temperature

Dahl-Jensen et al. 1998



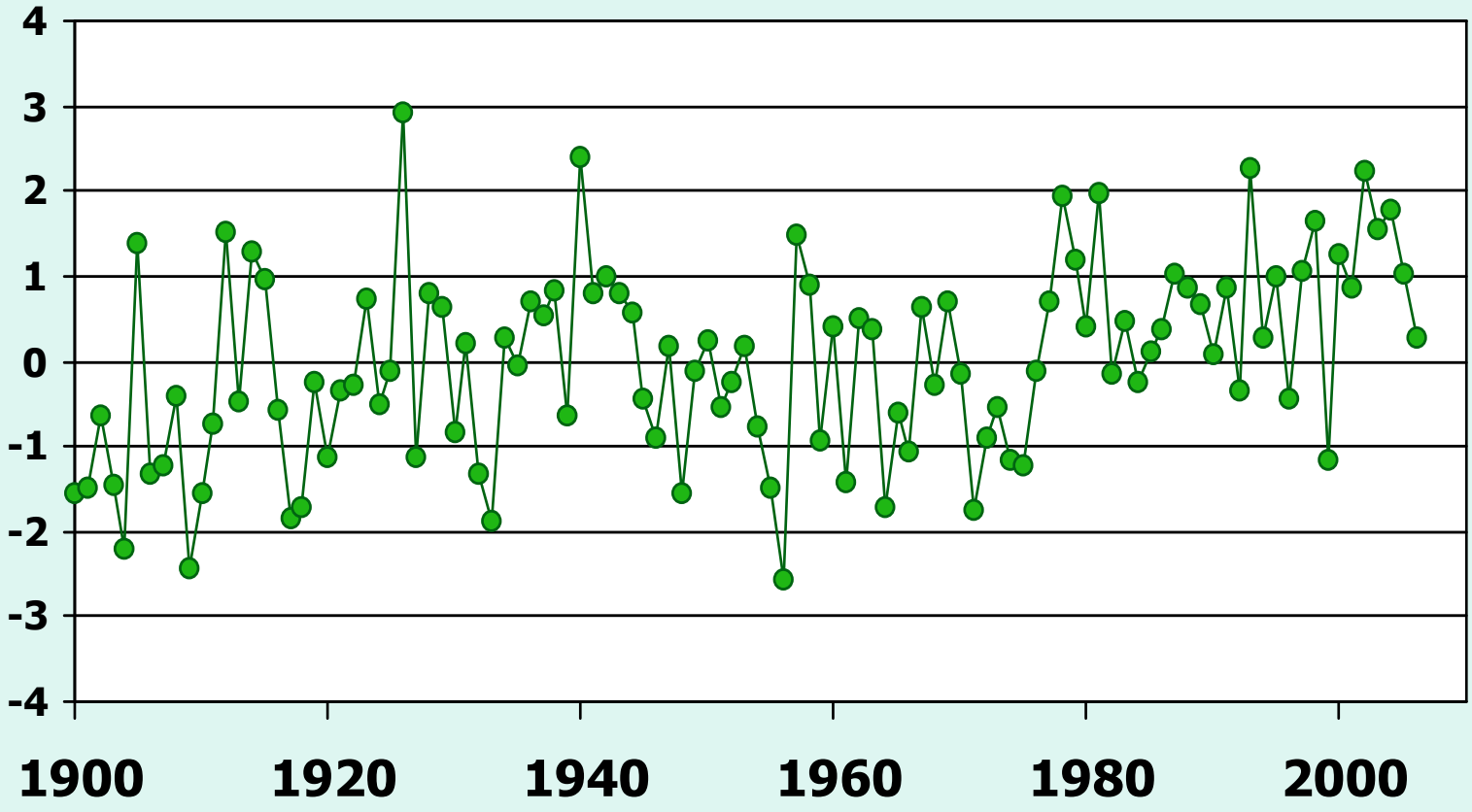


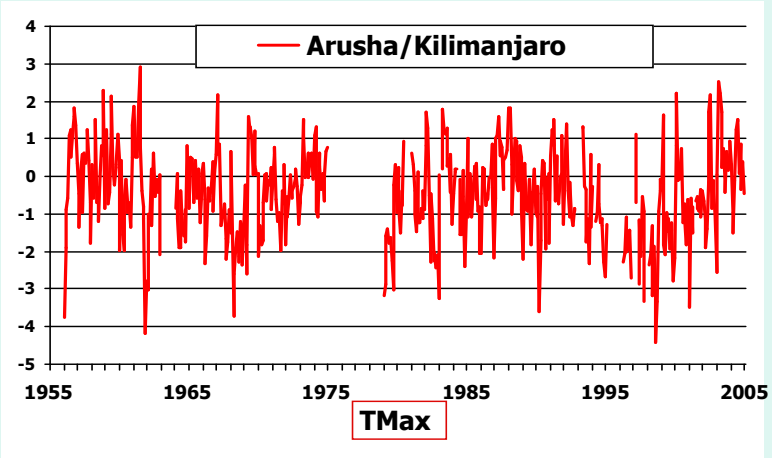
Sidorova et al. 2007

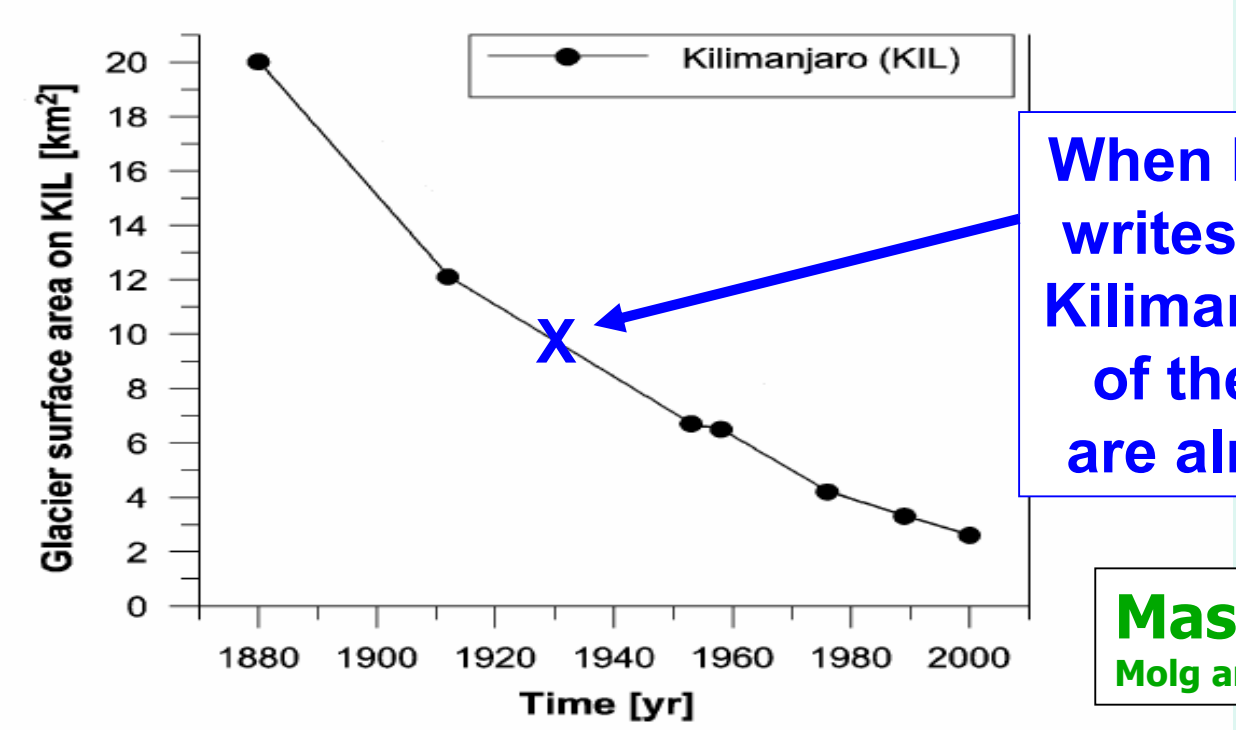
Alaska

Hadley CRU 3 (°C)

Shift in 1977, but high natural variability





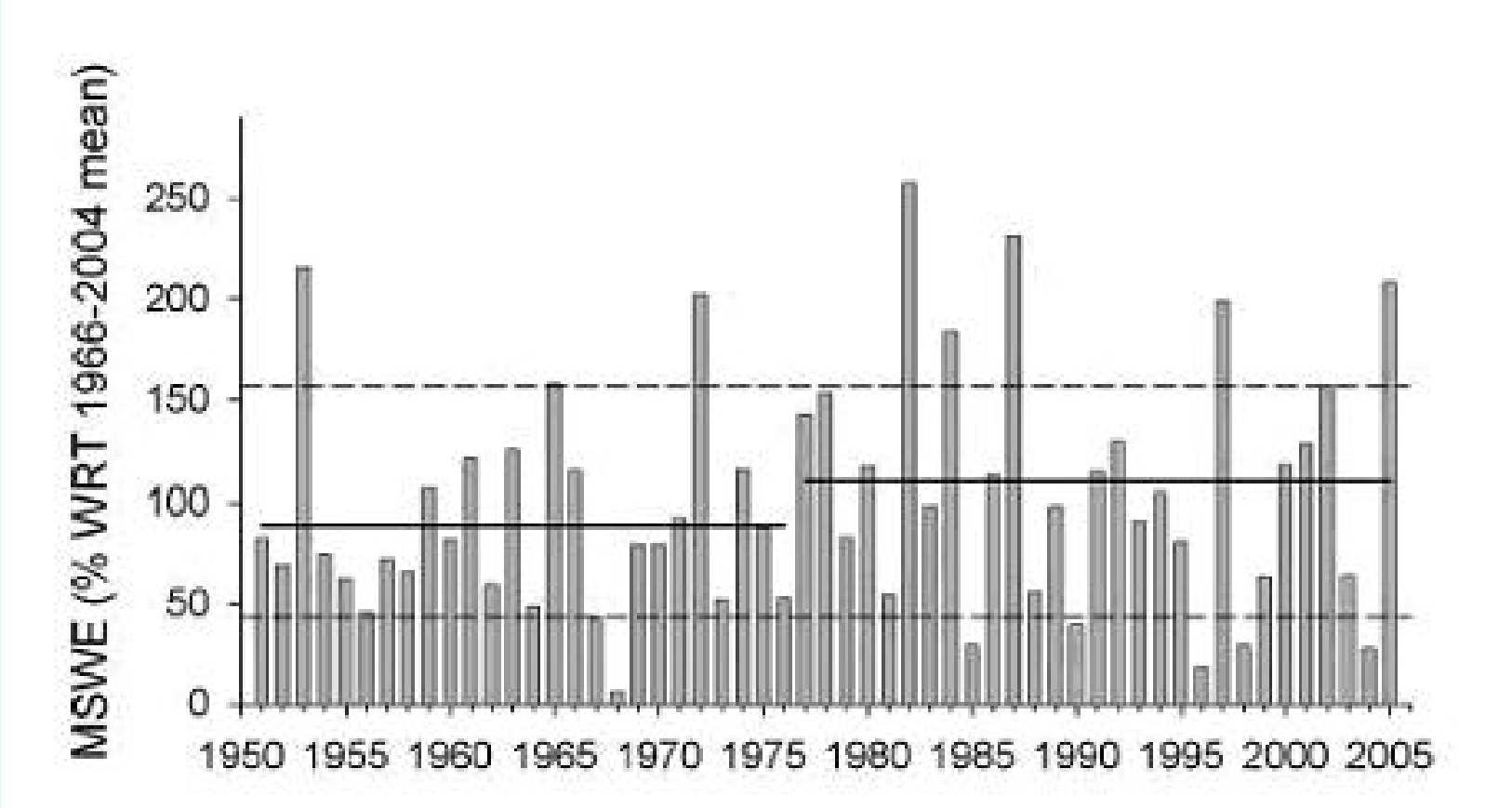


When Hemingway writes "Snows of Kilimanjaro"—half of the "snows" are already gone

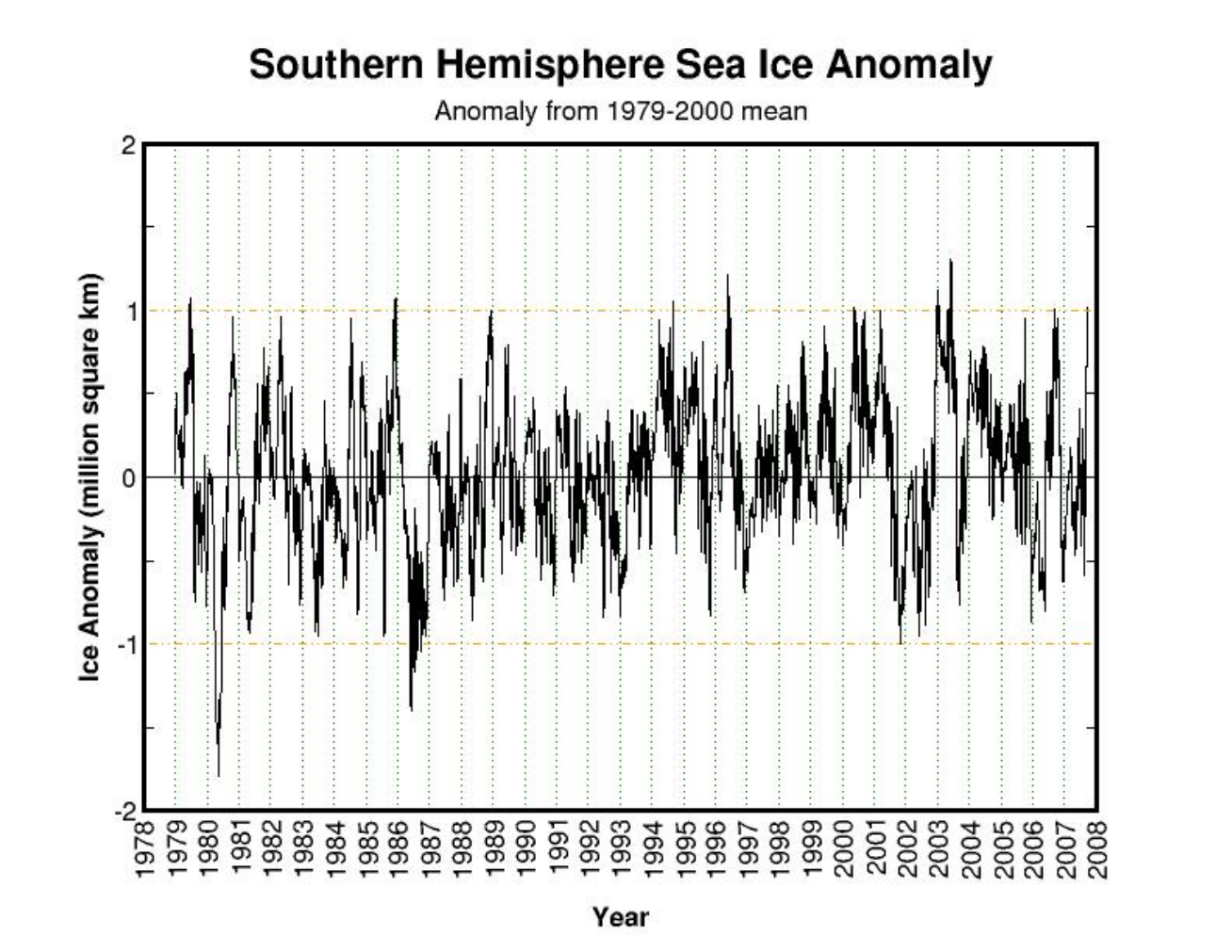
Mass Gain in 2006

Molg and Kaser 2007

Regional Snowpack, Central Andes, 1951-2005
Masiokas et al. 2006

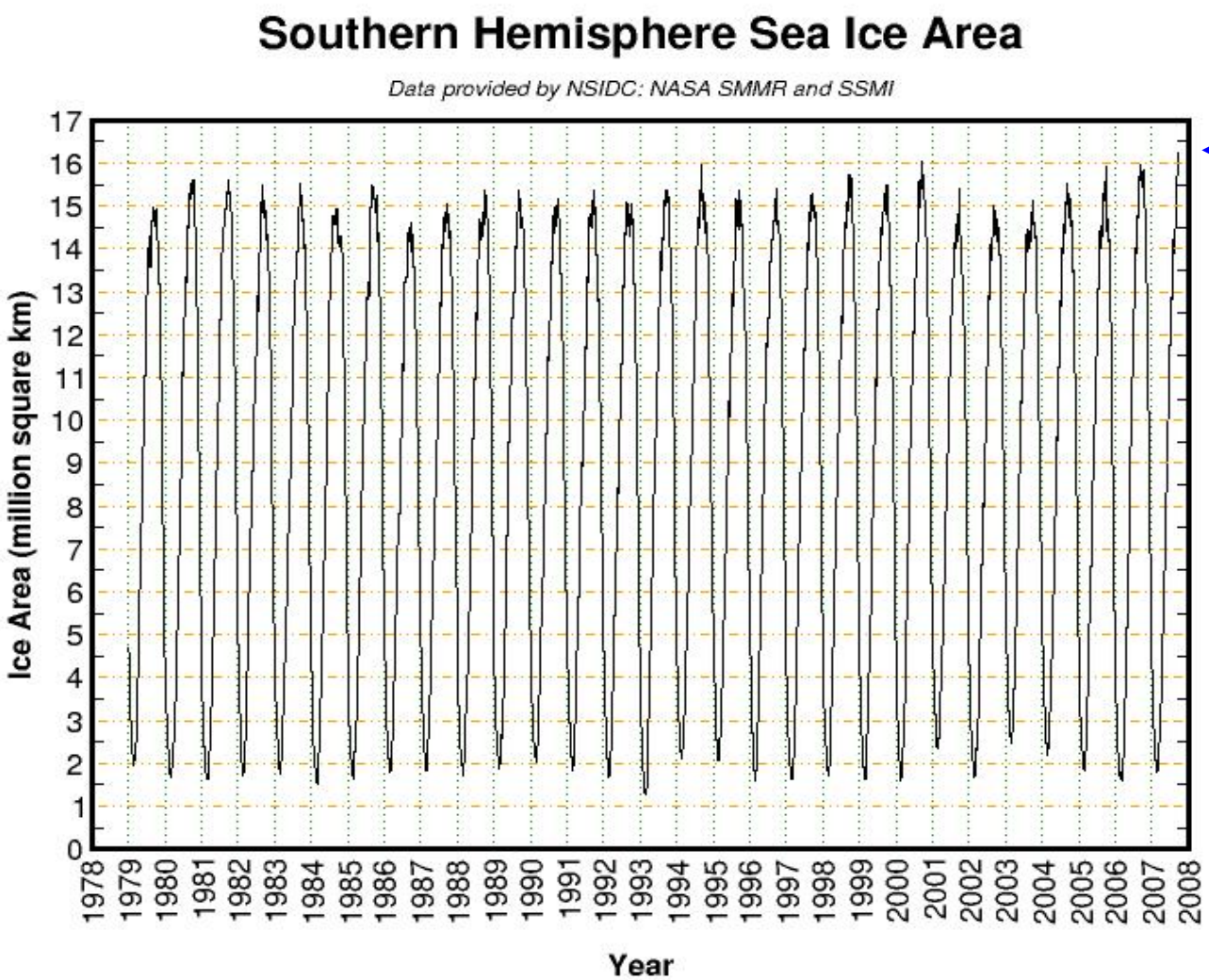


Antarctica Sea Ice



Chapman, U.Illinois

Antarctica Sea Ice



Chapman, U.Illinois

Rates of Observed Surface Elevation Change

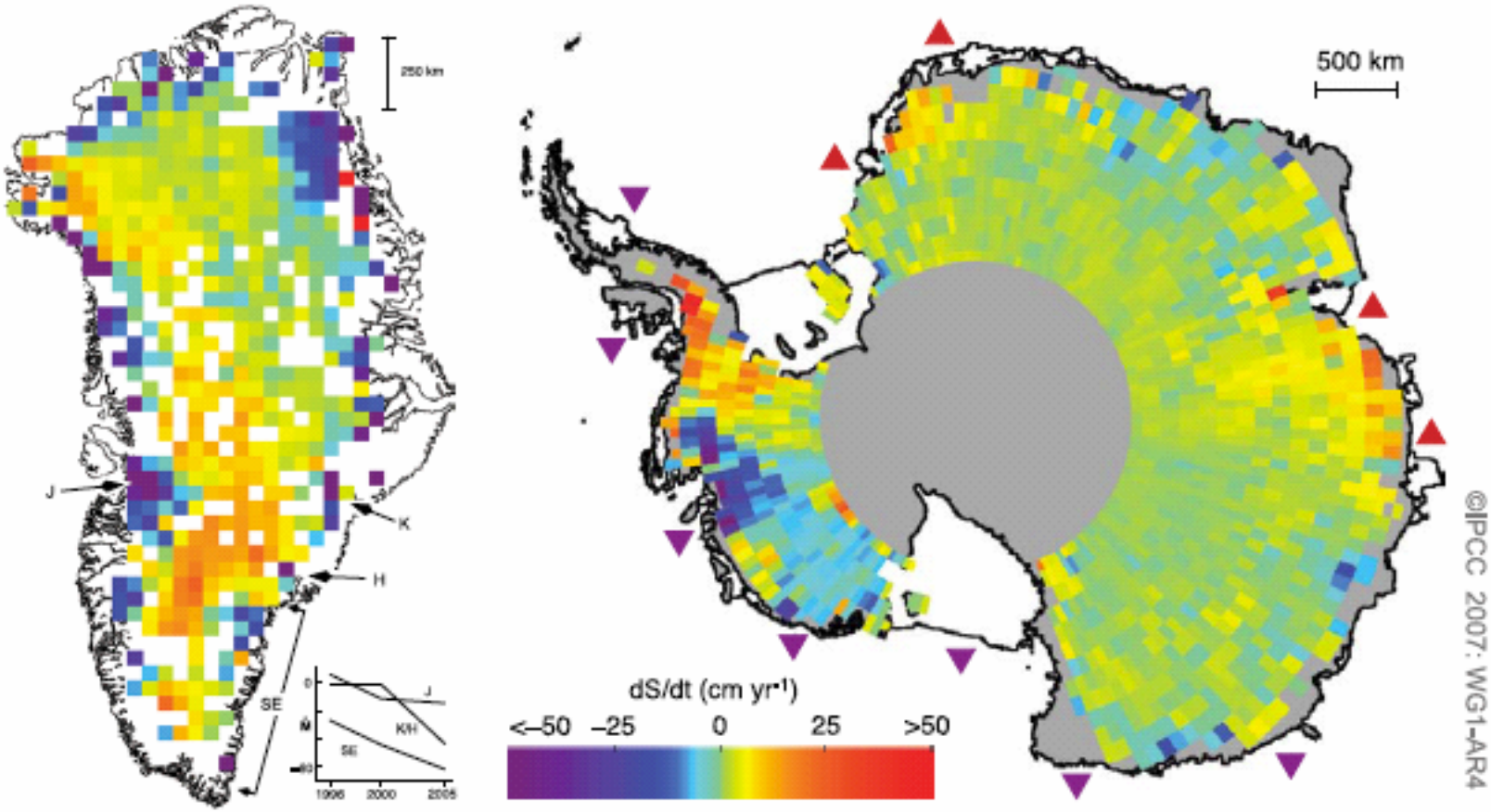
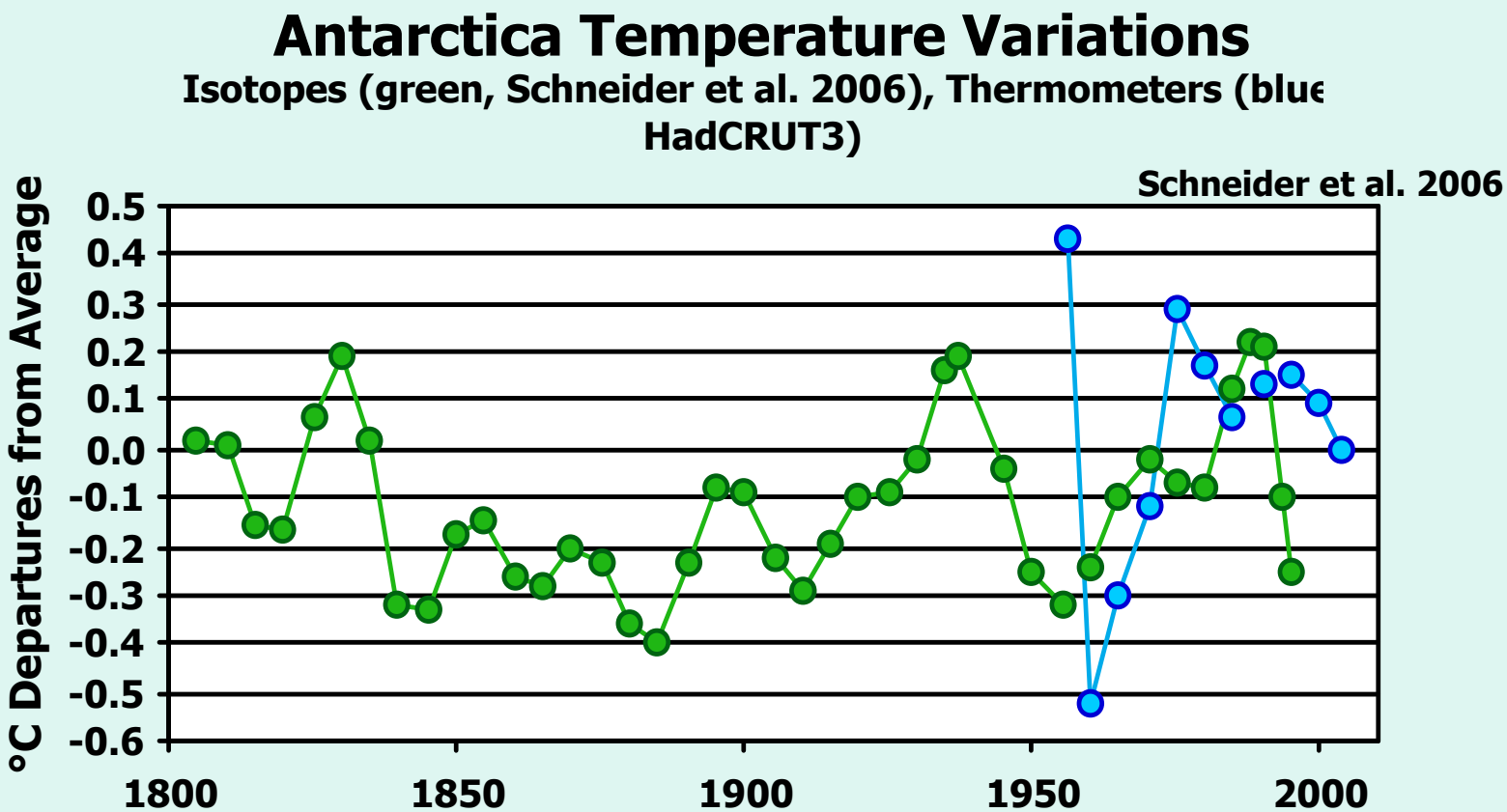


Figure TS.14. *Rates of observed recent surface elevation change for Greenland (left; 1989–2005) and Antarctica (right; 1992–2005). Red hues indicate a rising surface and blue hues a falling surface, which typically indicate an increase or loss in ice mass at a site, although changes over time in bedrock elevation and in near-surface density can be important. For Greenland, the rapidly thinning outlet glaciers Jakobshavn (J), Kangerdlugssuaq (K), Helheim (H) and areas along the southeast coast (SE) are shown, together with their estimated mass balance vs. time (with K and H combined, in Gt yr^{-1}, with negative values indicating loss of mass from the ice sheet to the ocean). For Antarctica, ice shelves estimated to be thickening or thinning by more than 30 cm yr^{-1} are shown by point-down purple triangles (thinning) and point-up red triangles (thickening) plotted just seaward of the relevant ice shelves. {Figures 4.17 and 4.19}*

Antarctica

Ice Cores

Thermometers



Sea Level Rise?

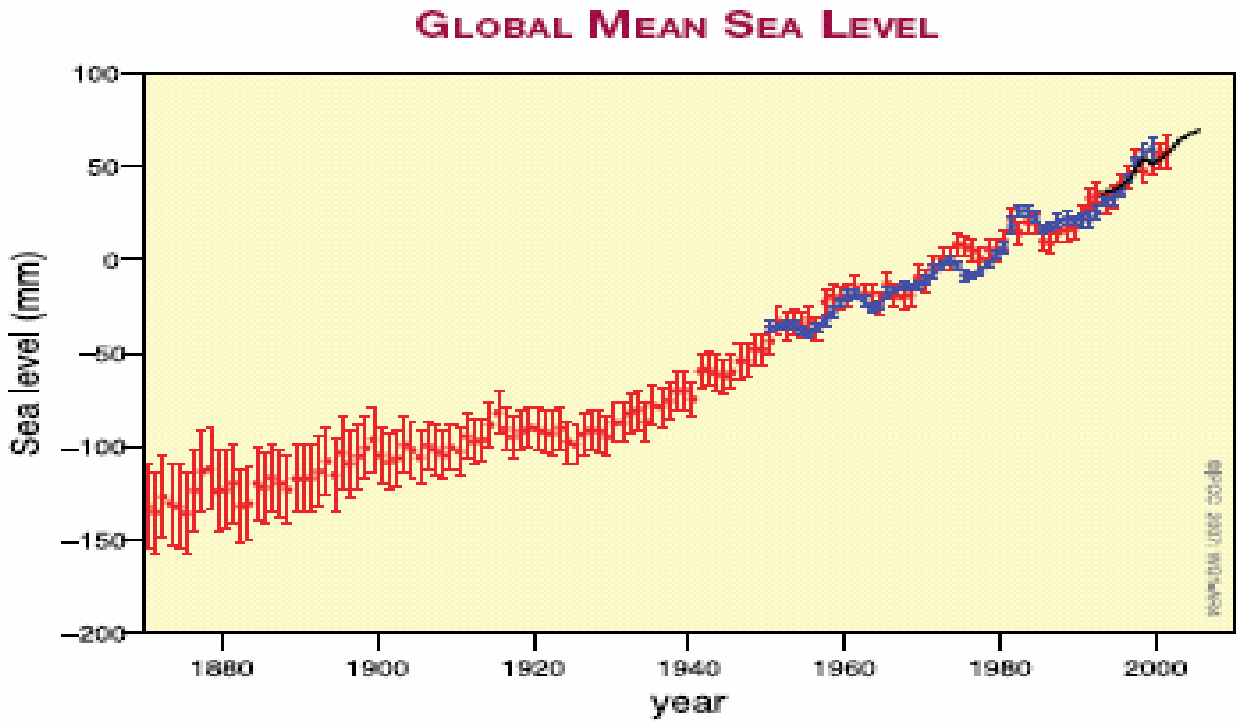
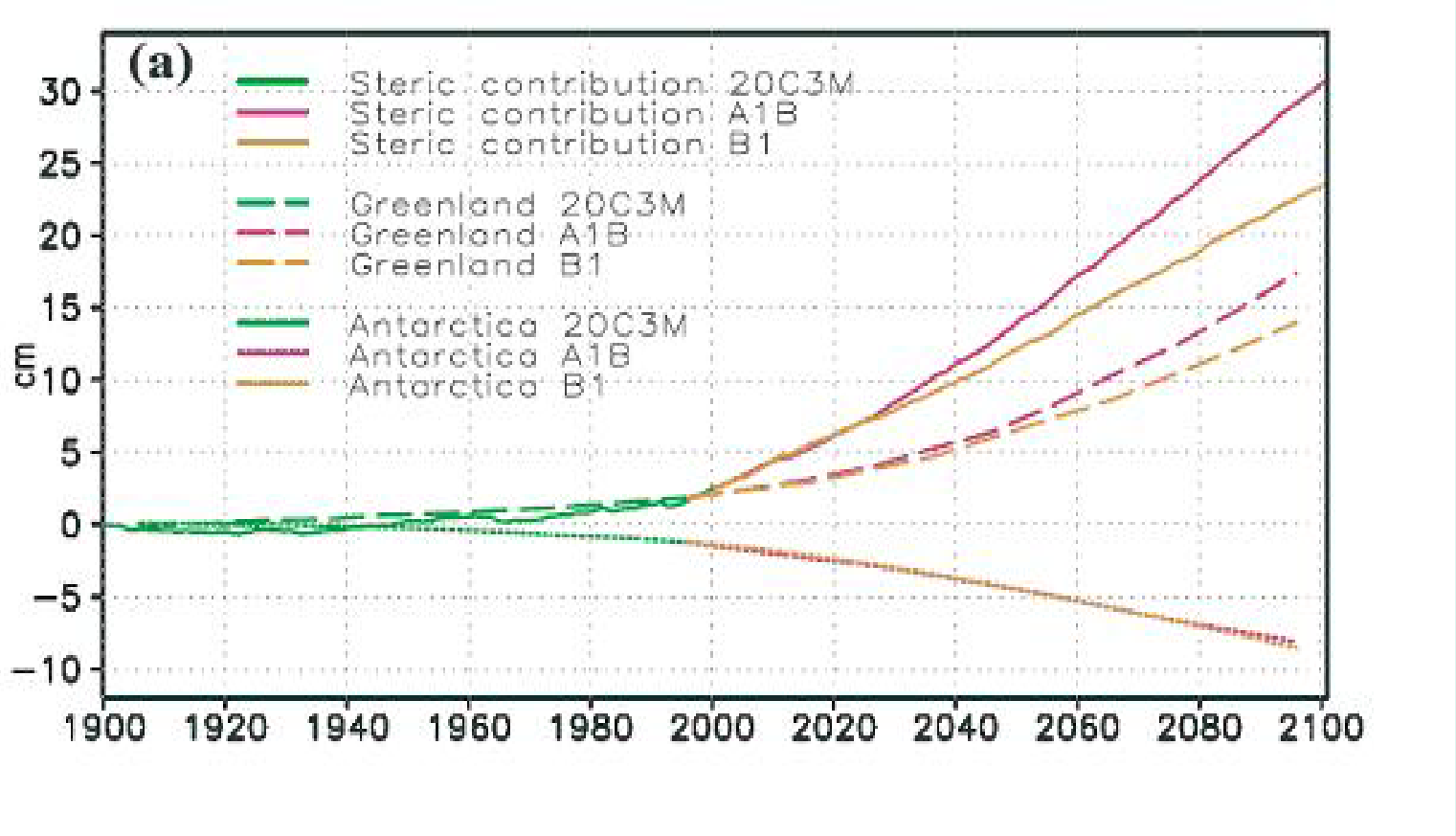


Figure TS.18. *Annual averages of the global mean sea level based on reconstructed sea level fields since 1870 (red), tide gauge measurements since 1950 (blue) and satellite altimetry since 1992 (black). Units are in mm relative to the average for 1961 to 1990. Error bars are 90% confidence intervals. {Figure 5.13}*

Rate of rise for last 50 Years:

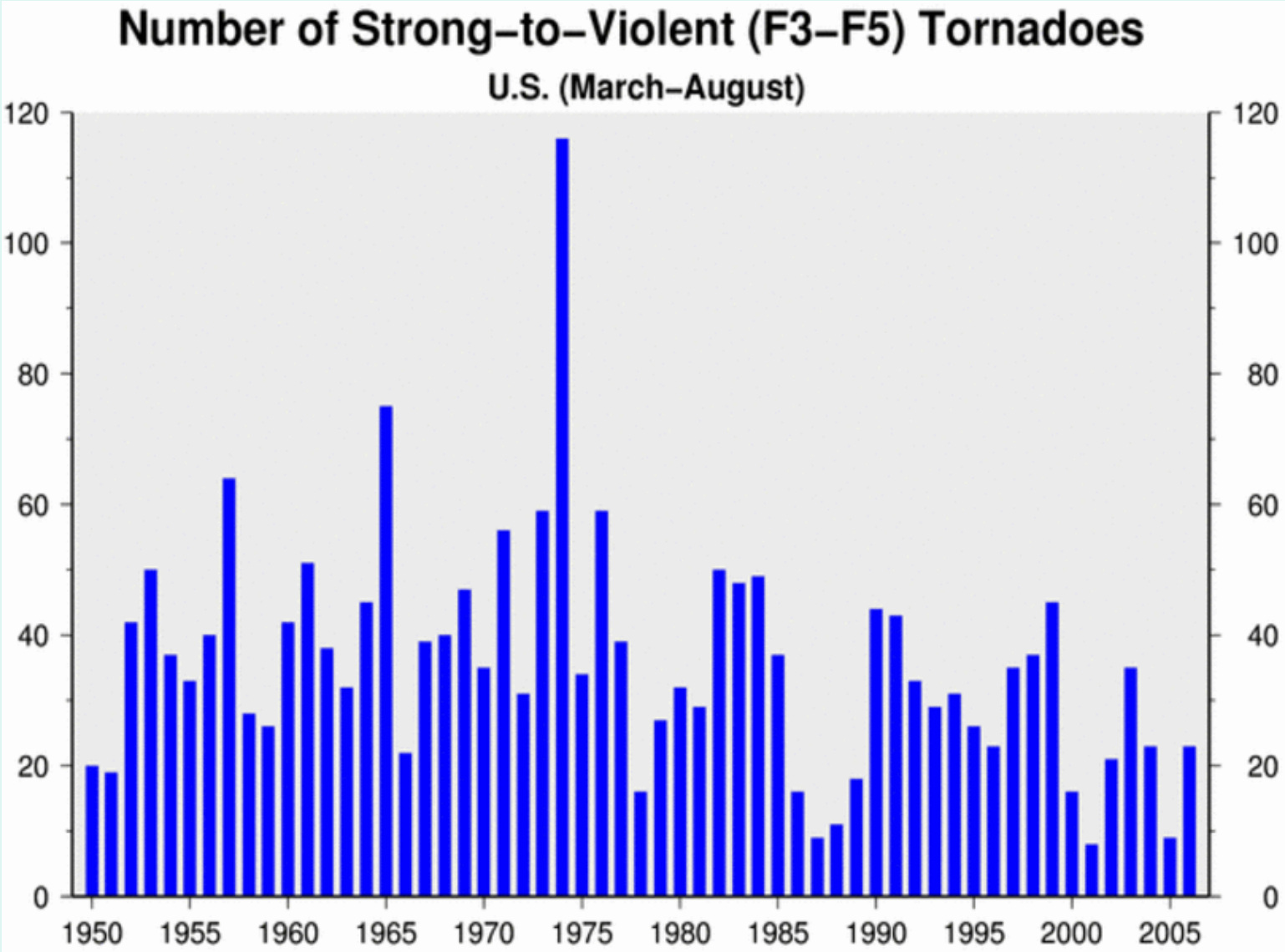
IPCC 2007	**9" / Century**
Jevrejeva et al. 2006	**9" / Century**
Woppelmann et al. 2007	**6" / Century**



+ Thermal Expansion
+ Greenland melting
- Antarctica accumulation

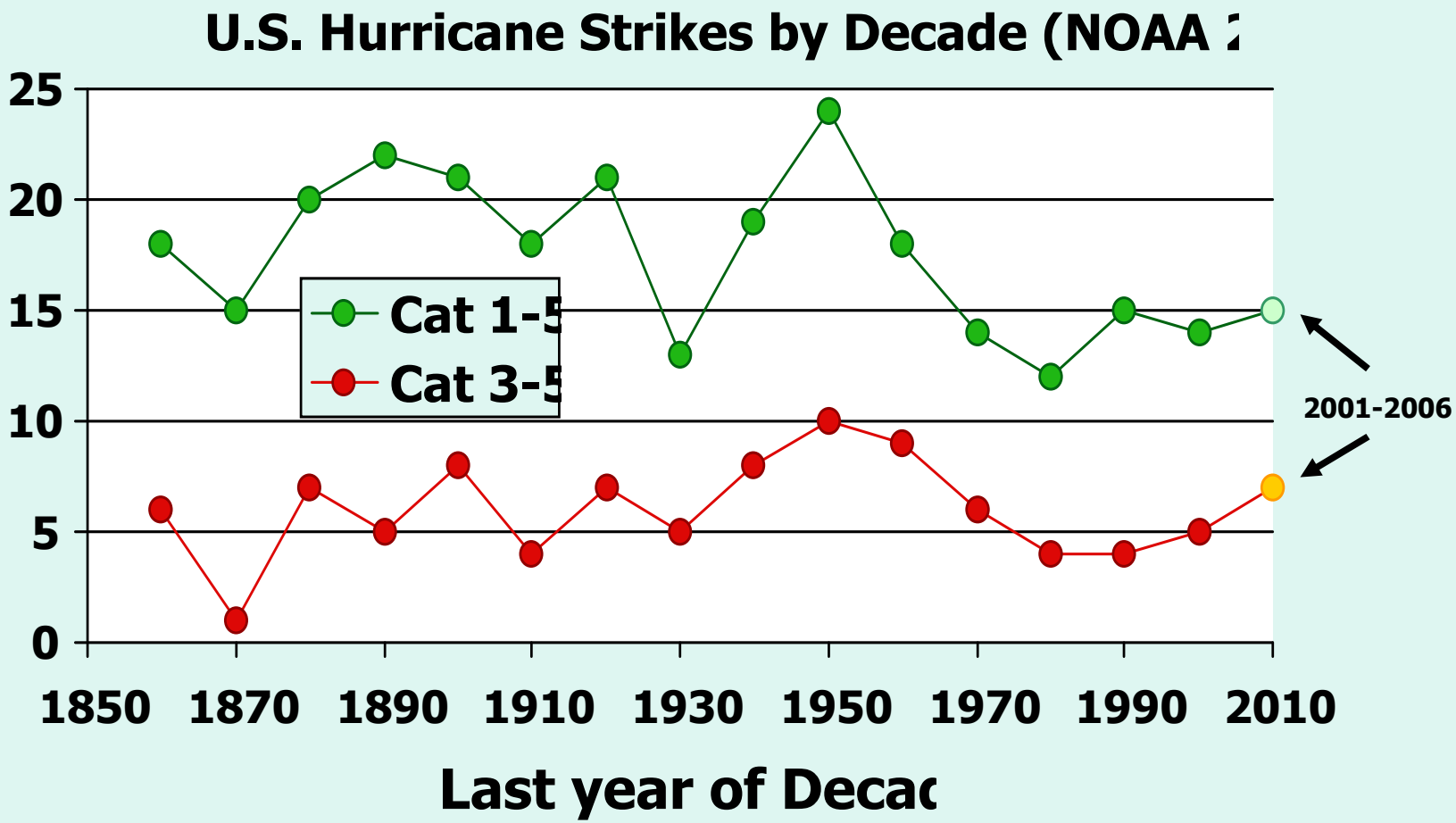
Suzuki et al. 2005

Extreme Weather?



Oklahoma - record long period (> 100 days) without a tornado 2003-04

US Hurricanes



Global Hurricane Activity

There has been no significant change in global net tropical cyclone activity (Klotzbach 2006)

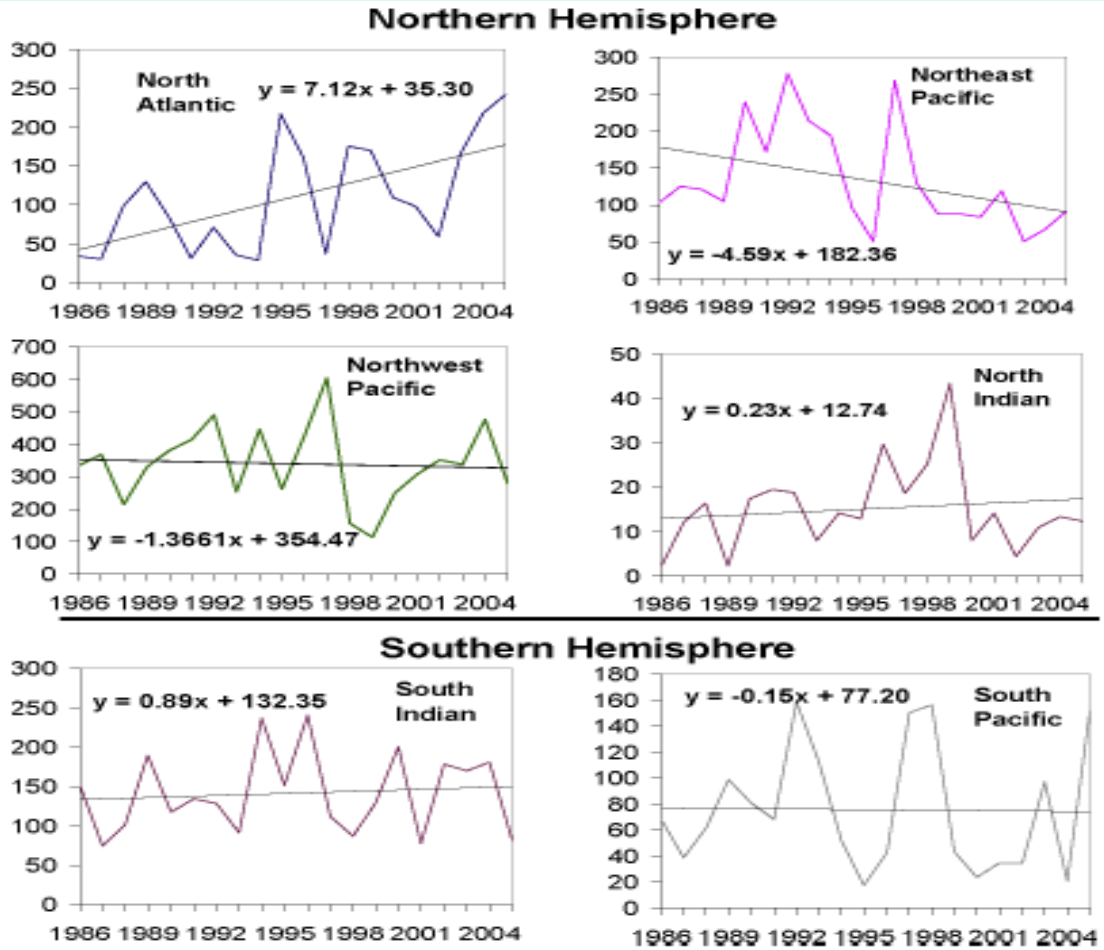
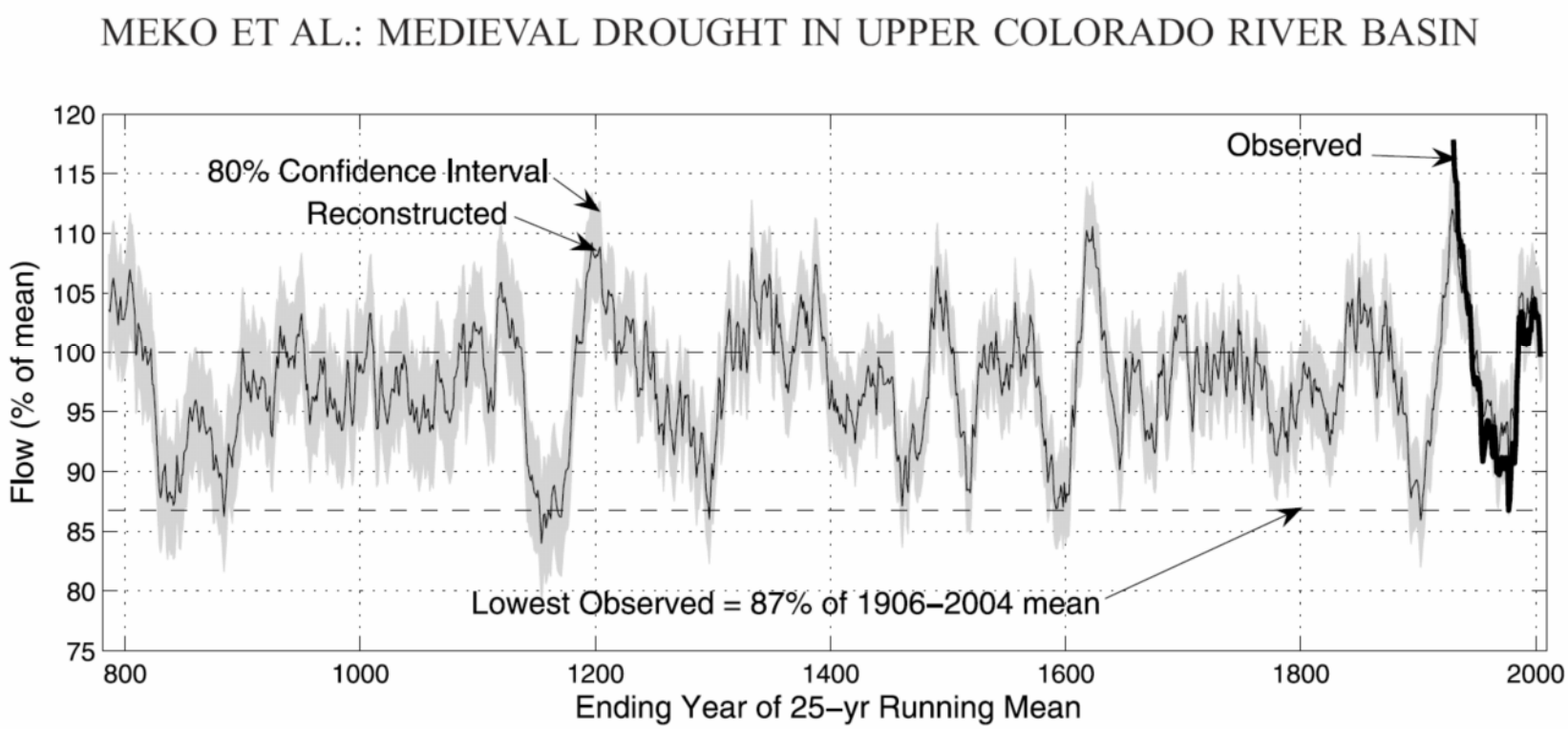


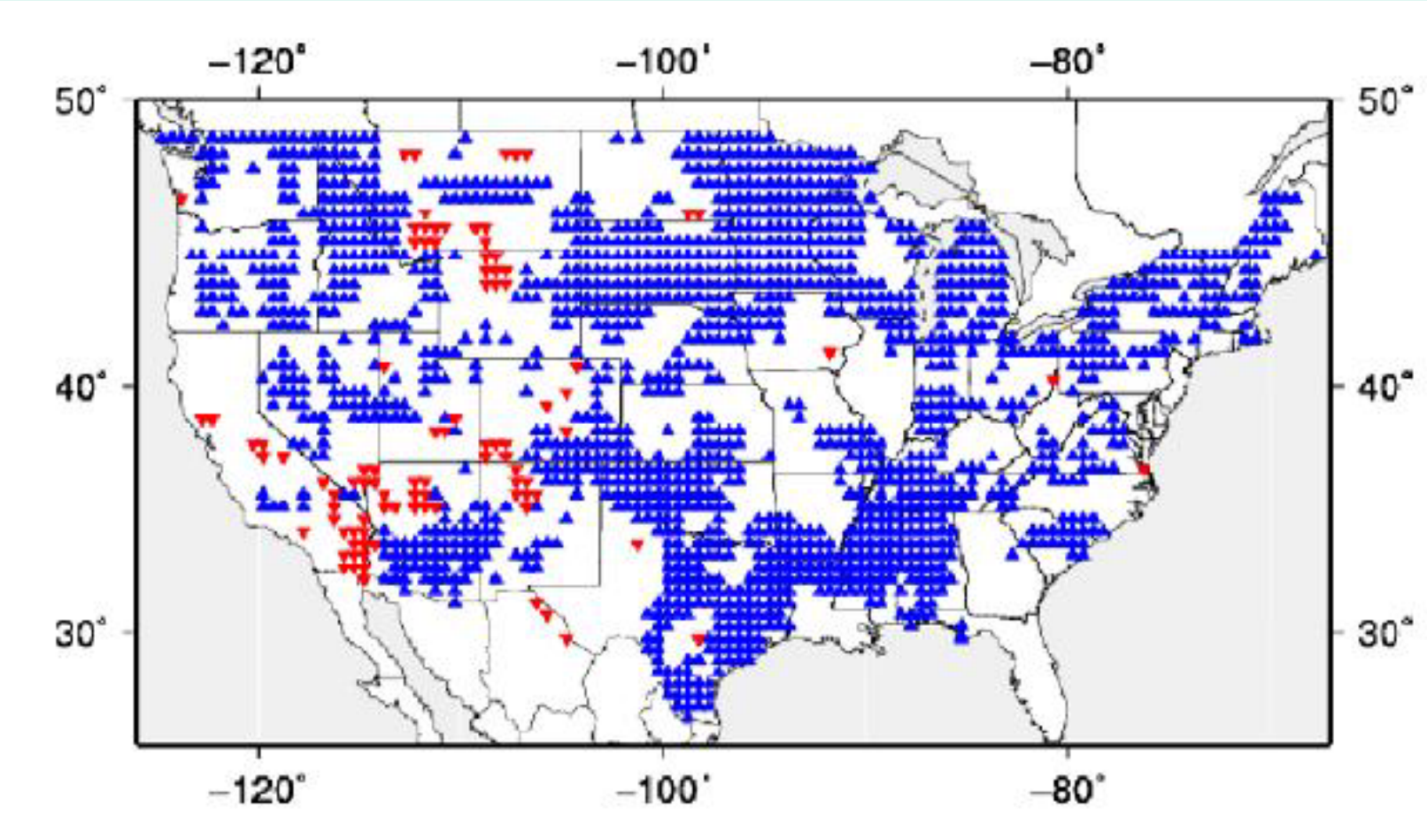
Figure 1. Accumulated Cyclone Energy (ACE) index values for individual TC basins from 1986–2005.



Bringing on prolonged drought, heat waves Greenhouse pollution: Utah warming faster than anywhere else on Earth!

By Patty Henetz
The Salt Lake Tribune
Gov. Huntsman commissioned the report on Aug. 25, 2006, with the specific instruction that it include a scientific report that was not subject to the same debate as the rest of the issues the council undertook.

Droughts?
US: Blue = Fewer and Shorter



Andreadis and Lettenmairer 2006

Evidence Thus Far

- Global surface temperature is rising, but in a way inconsistent with model projections of GHG forcing
- Overall decline in ice mass, with sea level rise of about 1” per decade
- Severe weather not becoming more frequent

Please don’t demonizing energy because:

Without energy, life is brutal and short

Energy Technology

1900: World supported

56 billion

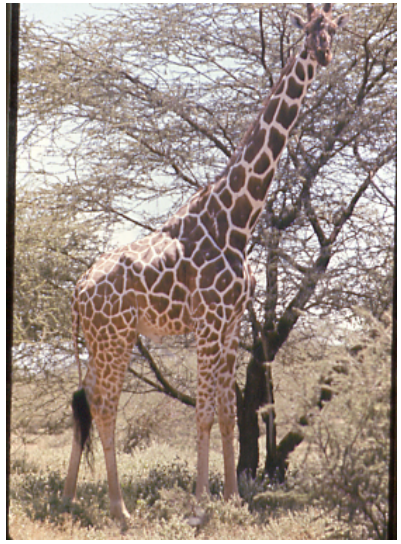
human-life years

2005: World supports

429 billion

human-life years

Kenya, East Africa



Energy System

Energy Source

Energy Transmission

Energy Use

The Dilemma of "doing something about global warming"

- Meet significant growth in energy demand
- Supply affordable energy
  - Benefits of energy are ubiquitous and innumerable. People want energy.
  - Health, security and longevity enhanced by affordable energy
- Reduce CO2 emissions substantially so as to have a detectable impact on emissions (massive reductions) and thus "manage the climate"

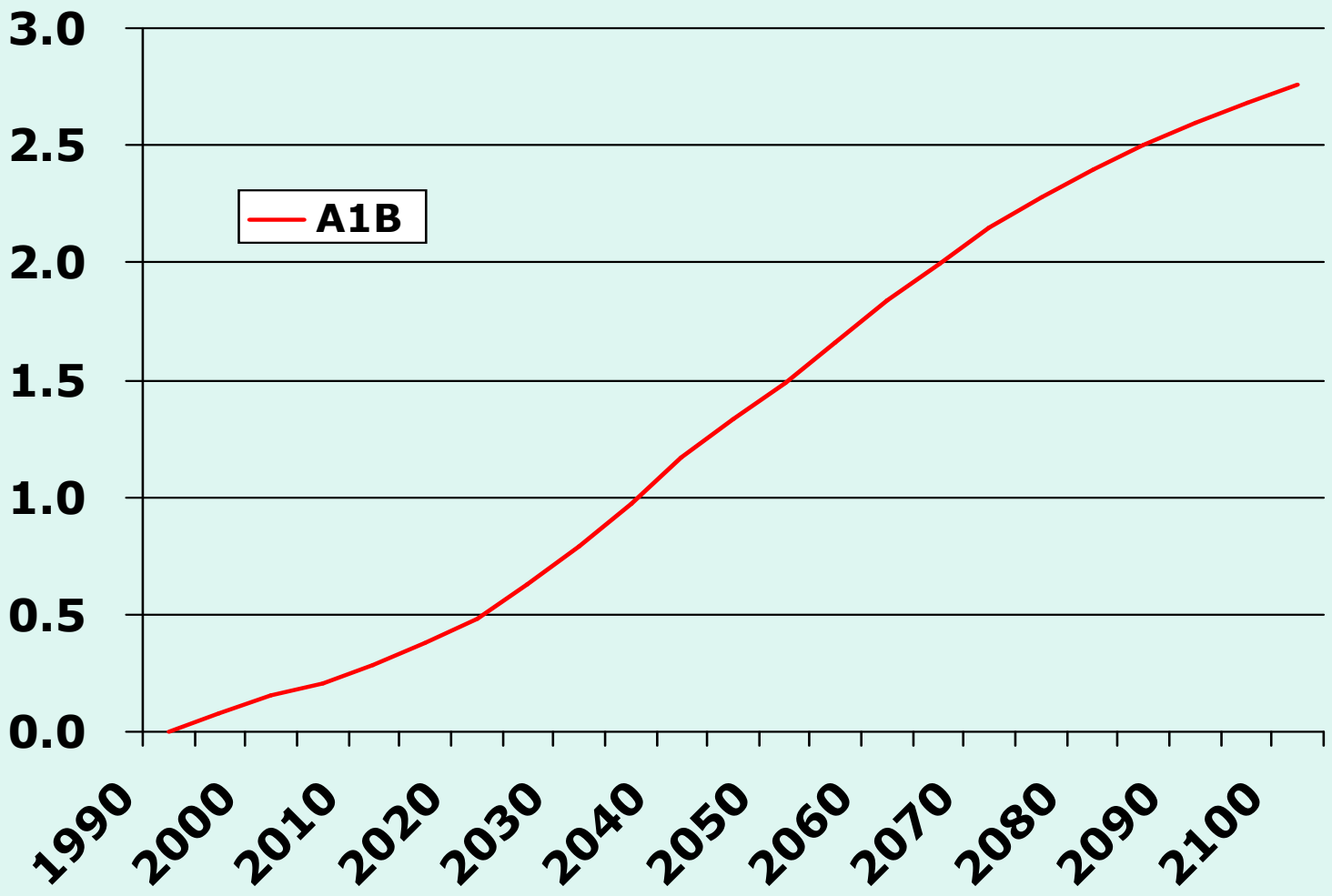
What did California do?

- **Force a limit on emissions of Light Duty Vehicles**
- **California AB 1493 seeks to reduce tail-pipe emissions of CO2 by 26% by 2016**
- **11 NE States adopted AB 1493**
- **Trial in Federal Court (Burlington VT) to address the engineering, legal and climate issues of AB 1493, April-May 2007**

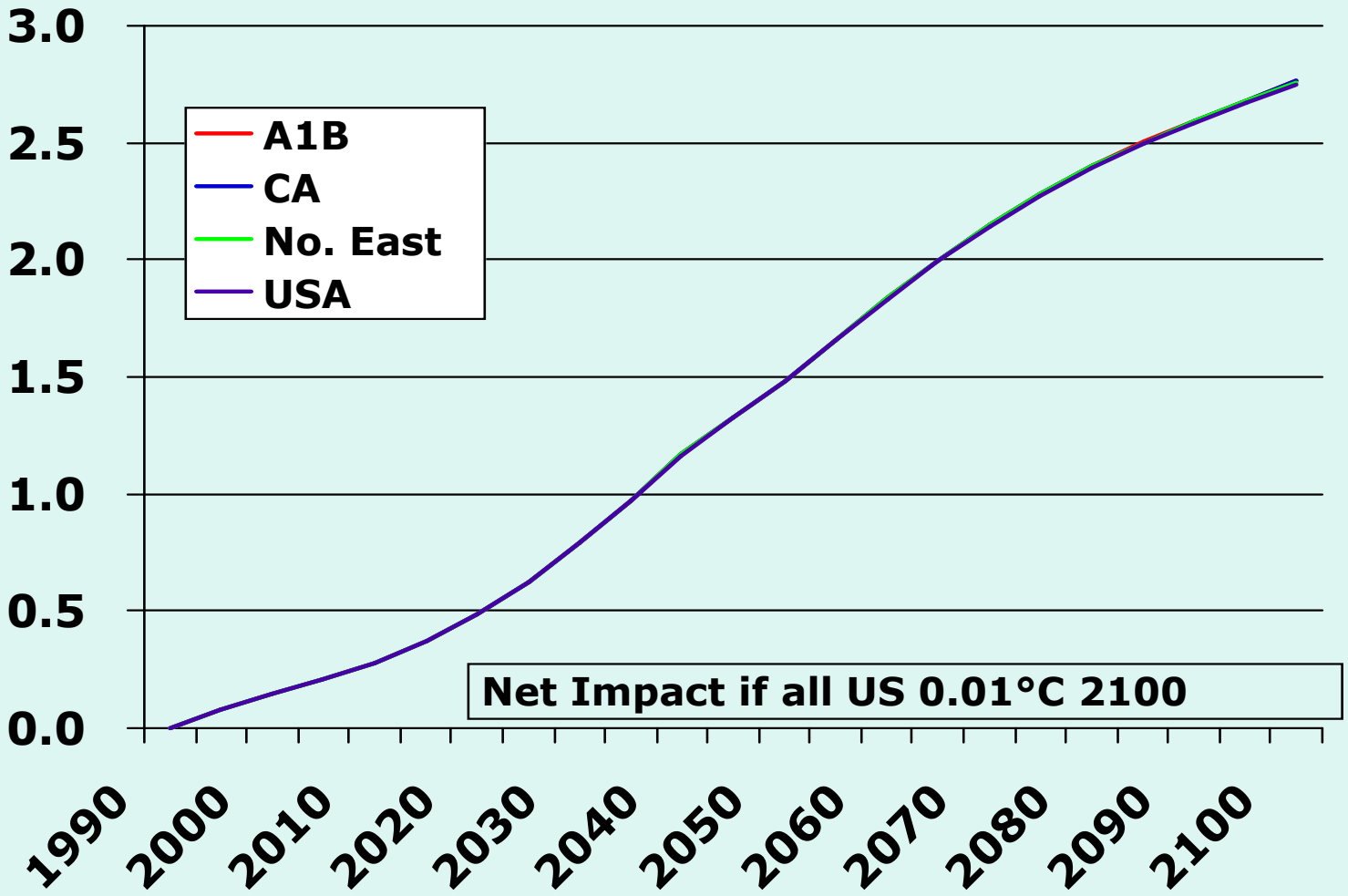
Question

- **What would be the impact on global surface temperatures of adopting and adhering to AB 1493?**
- **Start with IPCC AR4 "Best Guess" scenario (A1B "business as usual")**
- **Adjust CO2 emissions to reflect adoption and adherence by (a) California, (b) the Northeast and (c) all of U.S.**
- **Perform calculations so as to *overestimate* impact, not underestimate impact**

IPCC "Best Estimate"



California AB 1493
26% CO2 reduction LDV 2016



Answers

- **The answers indicated the impact would be so tiny as to be undetectable and immeasurable**
- **If applied to the *entire world*, the net impact by 2100 would be no more than 0.03 °C, again, an undetectable amount**
- **The impact on sea level rise would be 1 mm by 2100 if all U.S. adhered**

Judge William Sessions III Ruling 12 Sept 2007

AB 1493 is legal

Pg 46

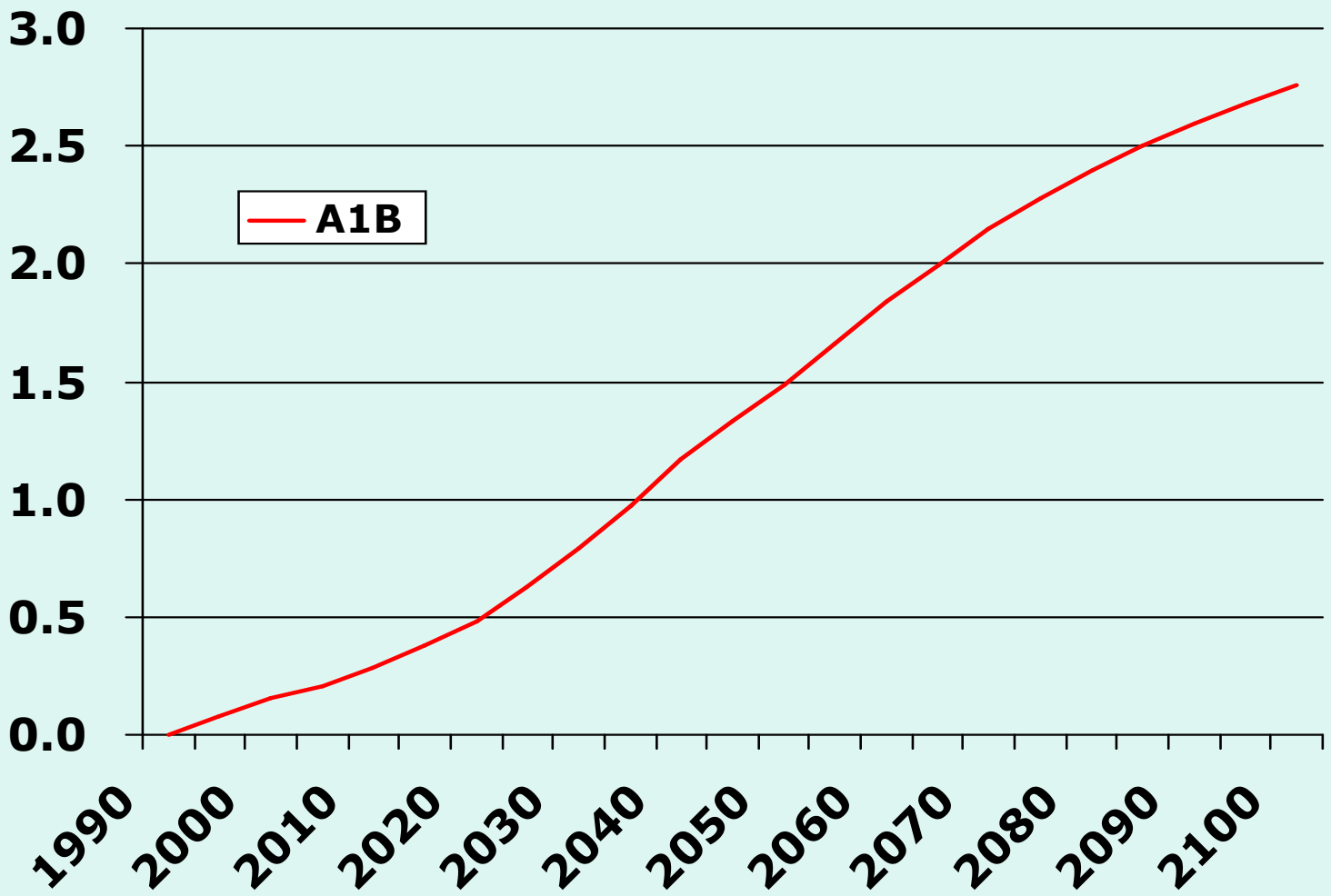
"Plaintiffs' expert Dr. Christy estimated that implementing the regulations across the entire United States would reduce global temperature by about 1/100th (.01) of a degree by 2100. Hansen did not contradict that testimony."

"This court mandates 43 mpg cars, 1,500 square-foot homes, size 32 pants, size 4 dresses, size . . . "

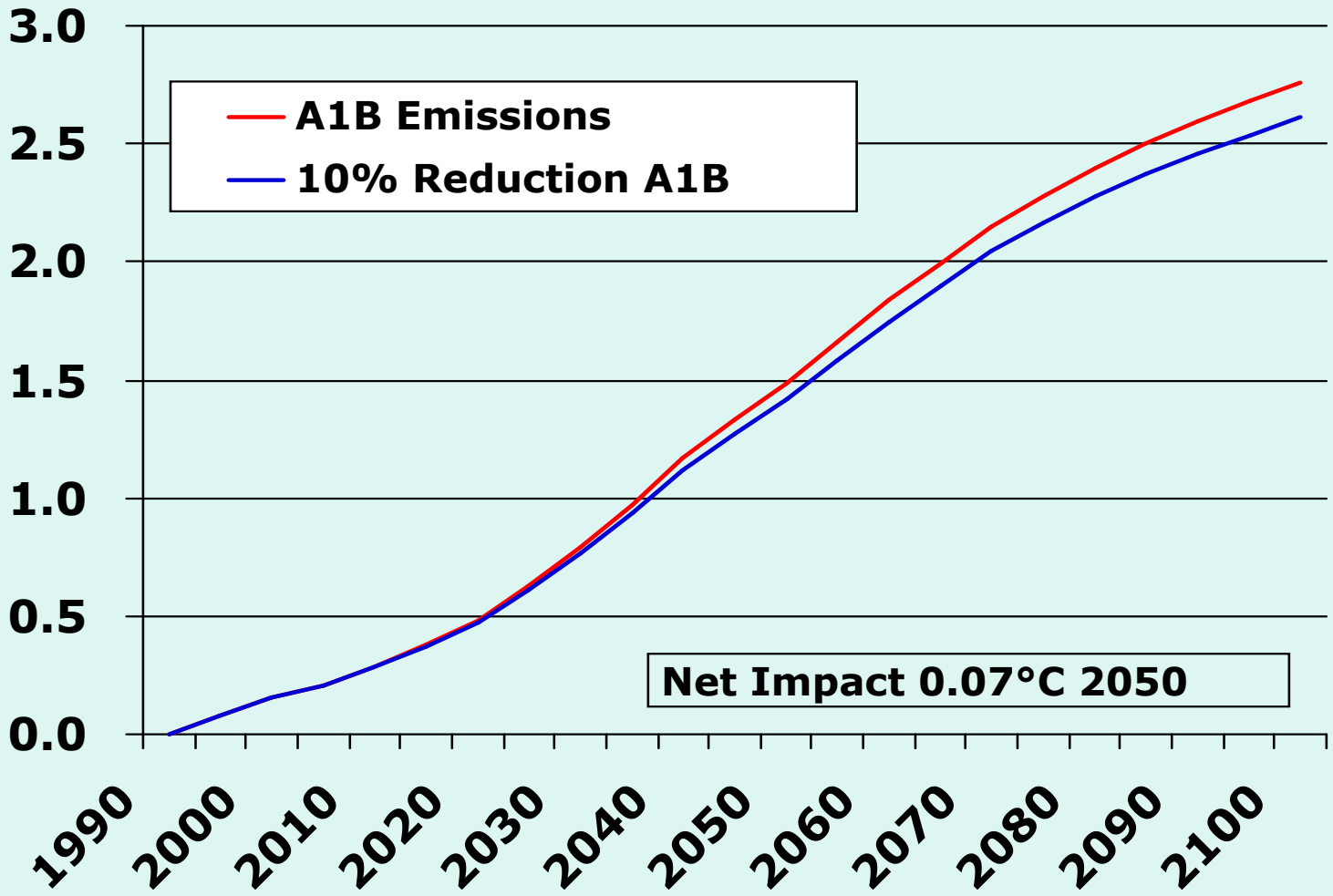
Questions

- **What *could* make a "dent" in forecasted global temperatures?**
- **What would be the impact of building 1000 nuclear power plants and putting them on-line by 2020?**
  - **(average 1.4 gigawatt output each)**

IPCC "Best Estimate"



Net Effect of 10% CO2 emission reduction to A1B Scenario (~1000 Nuclear Plants by 2020)



Answers about Nuclear Power

- **By 2050, a reduction of global surface temperature by at most 0.07 °C**
- **By 2100 a reduction of global surface temperature by at most 0.15 °C**

Main Points:

Without energy, life is brutal and short.

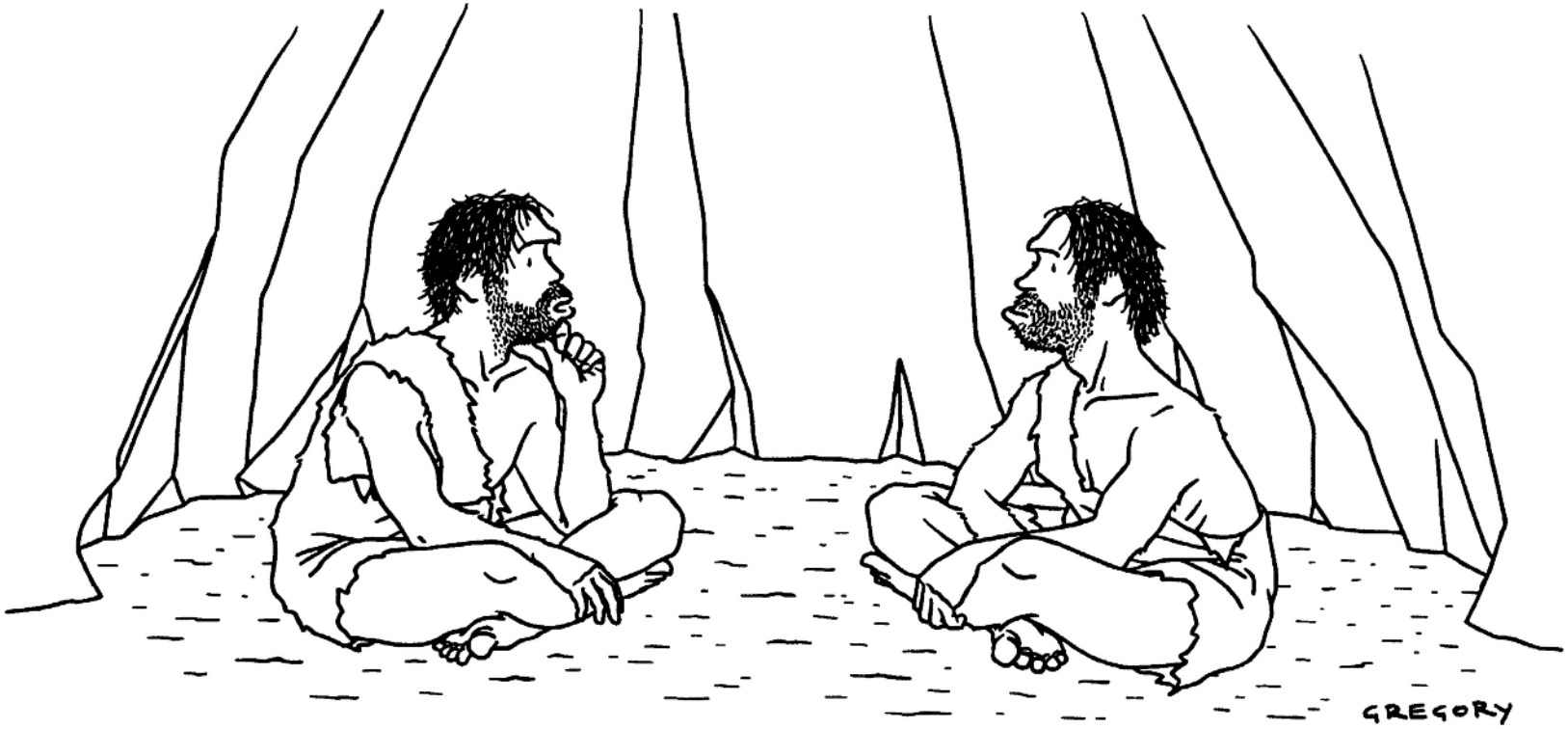
Proposed "do-something-about-global-warming" initiatives will not detectably alter whatever the climate is going to do.

A MORE RATIONAL APPROACH?

- In 50 years will we learn that the most cost-effective path was to adapt to changes we actually observed and measured, rather than try to outguess Mother Nature's course?
- In 50 years will we be surprised not by climate change but by the inventive minds of our scientists and engineers, unfettered by mandates, as they discover profitable and affordable ways to generate energy without carbon emissions?

20th Century Transportation was de-horsified

21st Century Energy will be de-carbonized



"Something's just not right—our air is clean, our water is pure, we all get plenty of exercise, everything we eat is organic and free-range, and yet nobody lives past thirty."