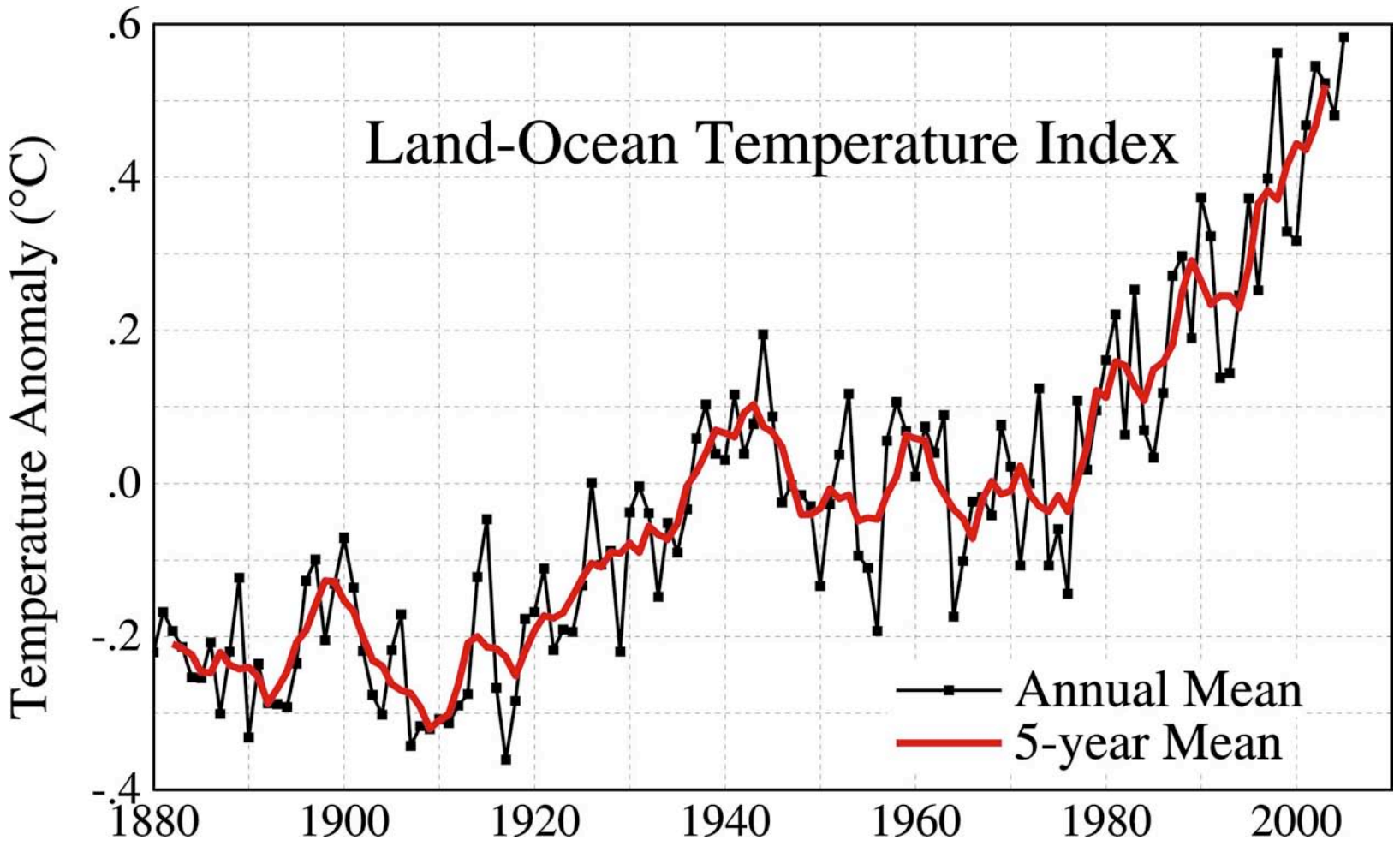
Global Warming:

Is There Still Time to Avoid Disastrous Human -Made Climate Change?

i.e.

Have We Passed a ‘ Tipping Point ’?

Discussion on 23 April 2006 by Jim Hansen
National Academy of Sciences, Washington, DC

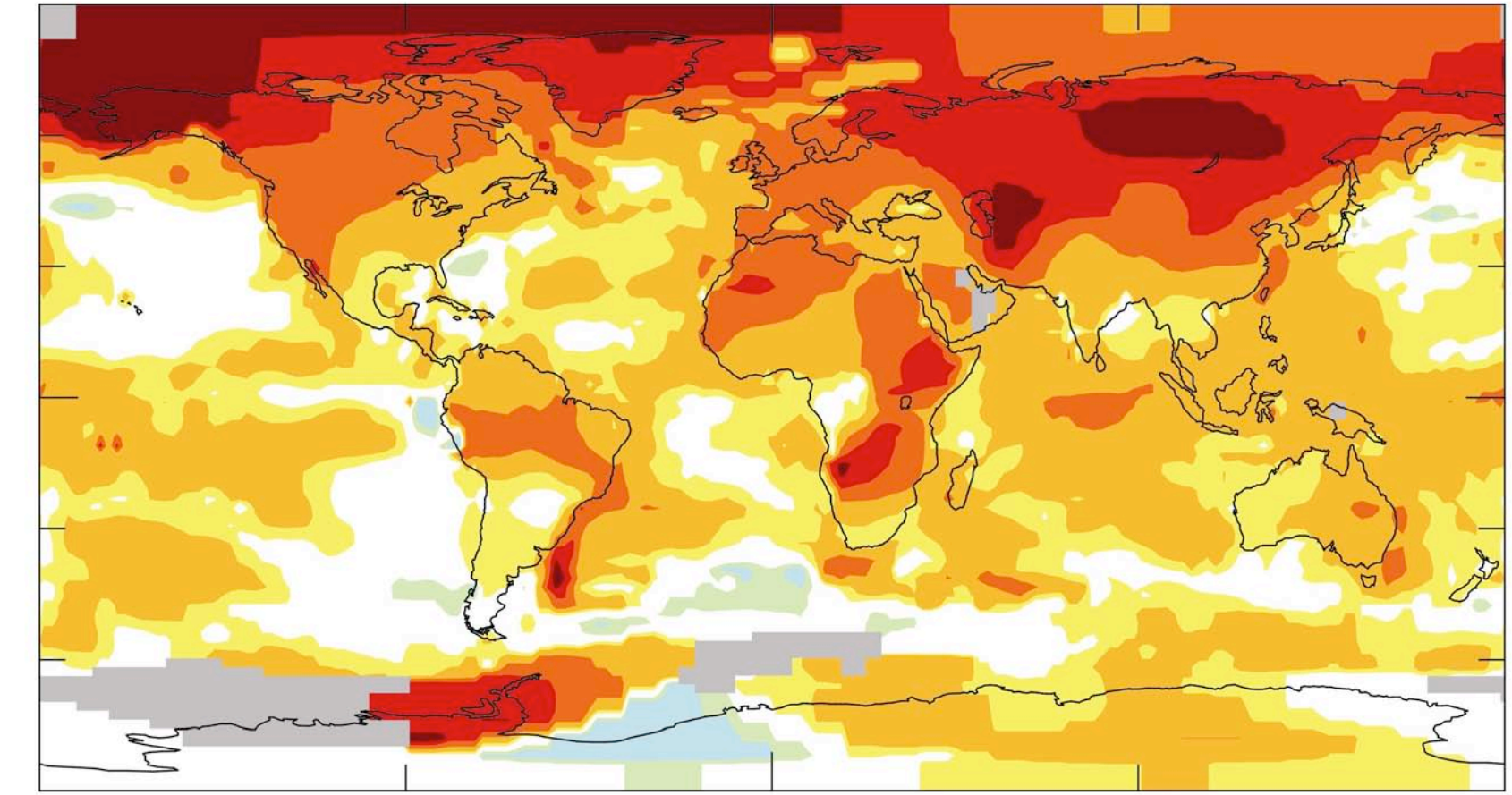


Global mean surface temperature change based on surface air measurements over land and SSTs over ocean

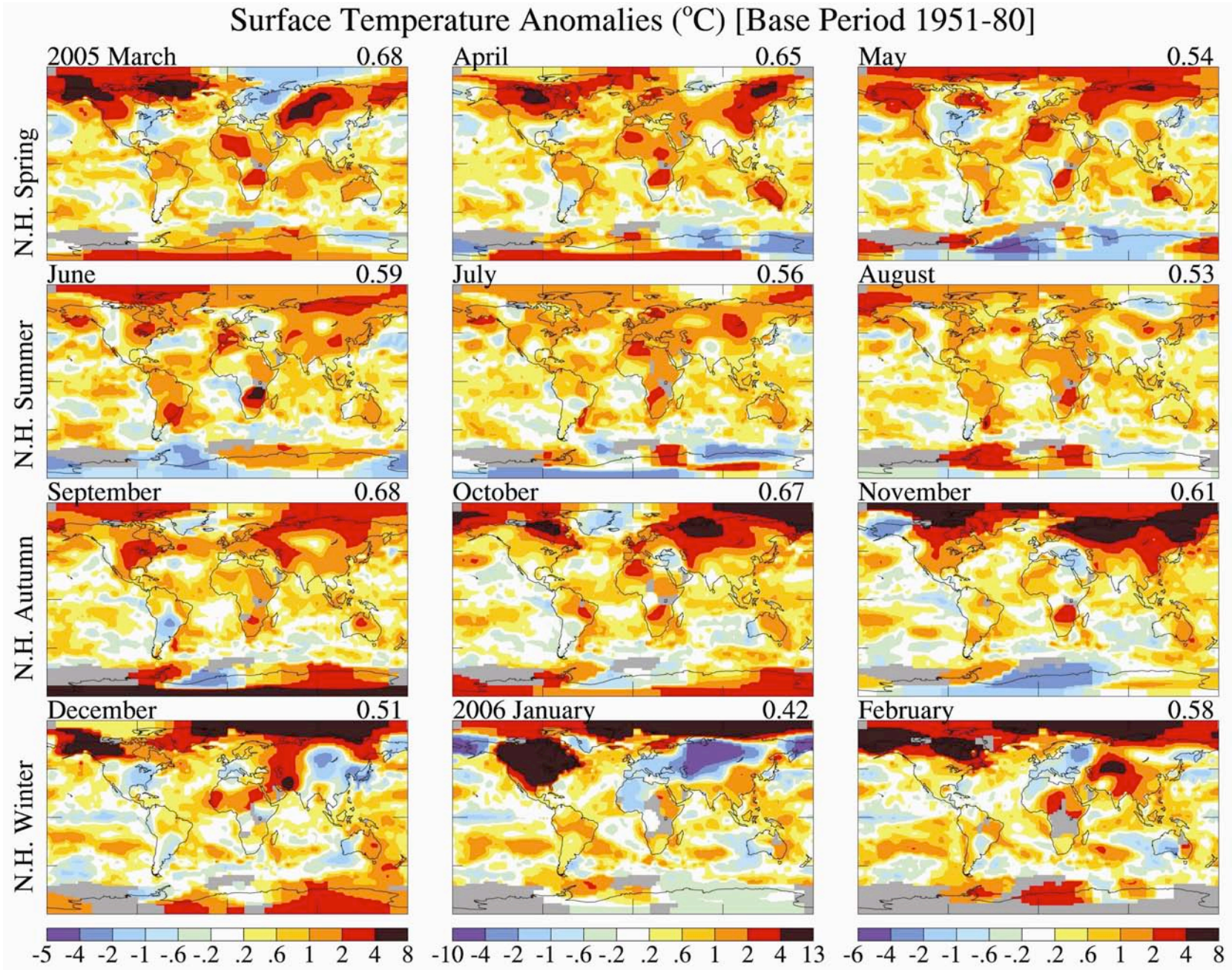
Source: Update of Hansen et al., *JGR,* **106**, 23947, 2001; Reynolds and Smith, *J. Climate,* **7**, 1994; Rayner et al., *JGR,* **108**, 2003.

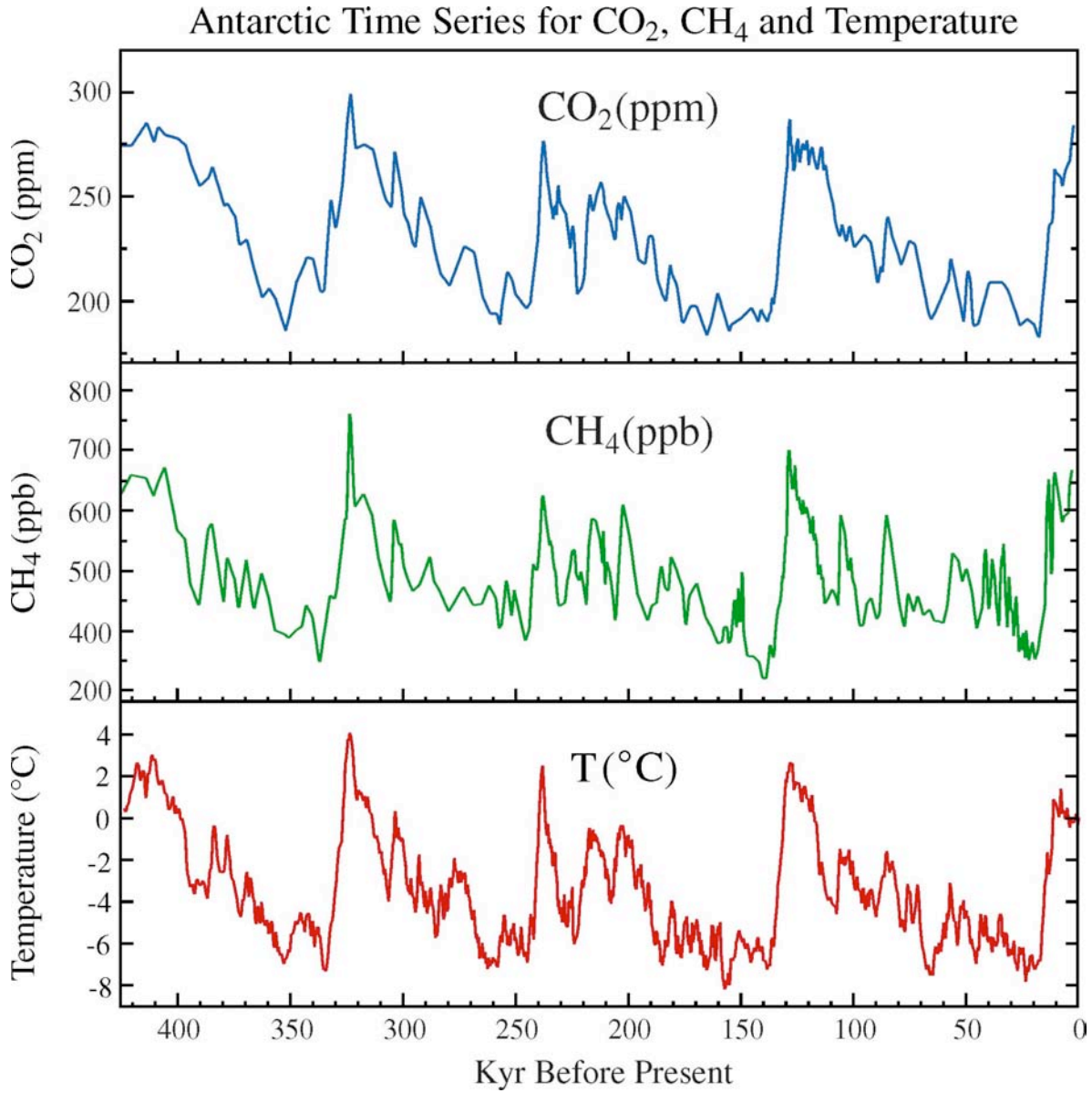
2001-2005 Mean Surface Temperature Anomaly (°C)

Base Period = 1951-1980 Global Mean = 0.53



-2 -1.6 -1.2 -.8 -.4 -.2 .2 .4 .8 1.2 1.6 2.1

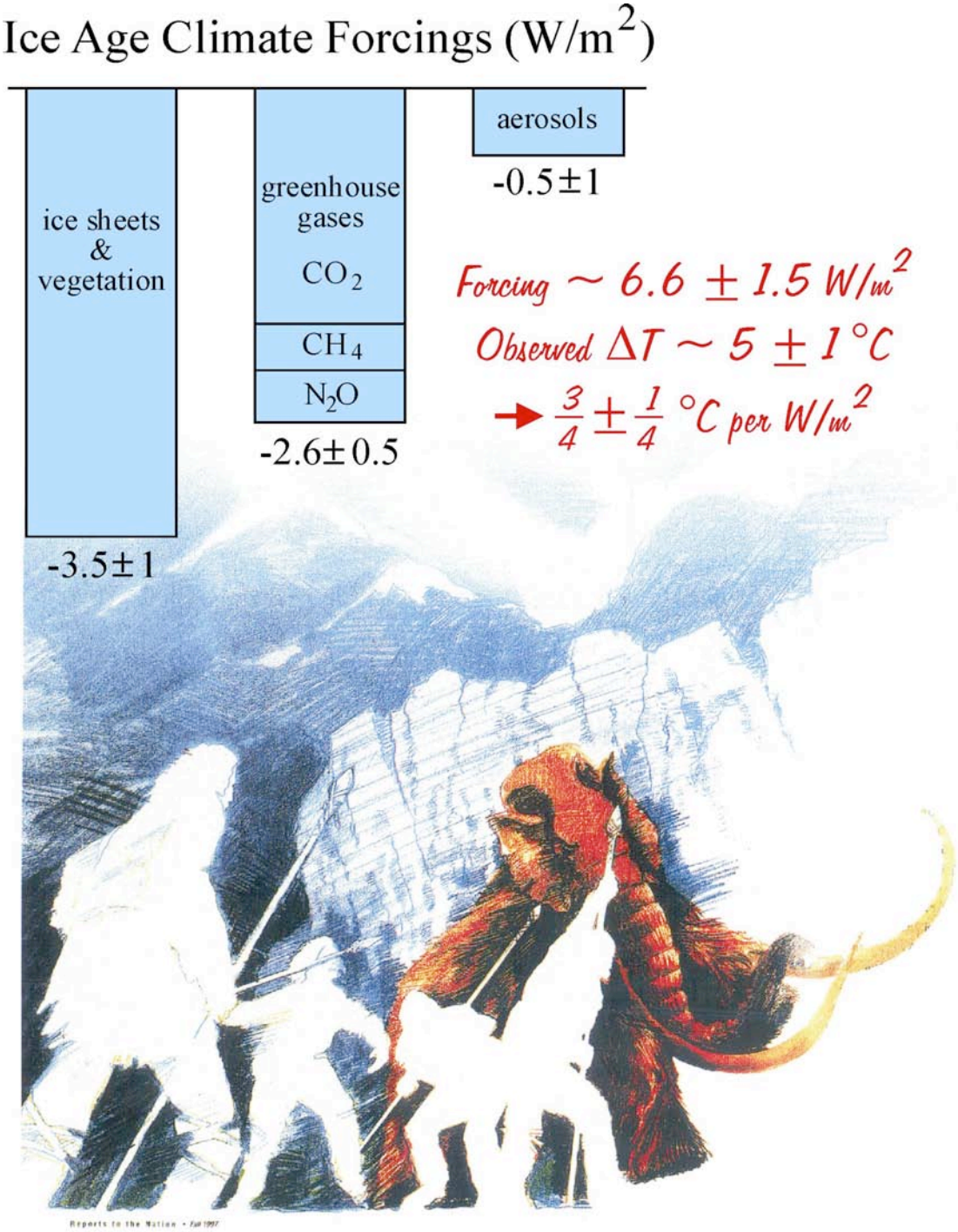

Surface Temperature Anomalies (°C) [Base Period 1951-80]
N.H. Spring
N.H. Summer
N.H. Autumn
N.H. Winter
2005 March 0.68
April 0.65
May 0.54
June 0.59
July 0.56
August 0.53
September 0.68
October 0.67
November 0.61
December 0.51
2006 January 0.42
February 0.58
-5 -4 -2 -1 -.6 -.2 .2 .6 1 2 4 8
-10 -4 -2 -1 -.6 -.2 .2 .6 1 2 4 13
-6 -4 -2 -1 -.6 -.2 .2 .6 1 2 4 8



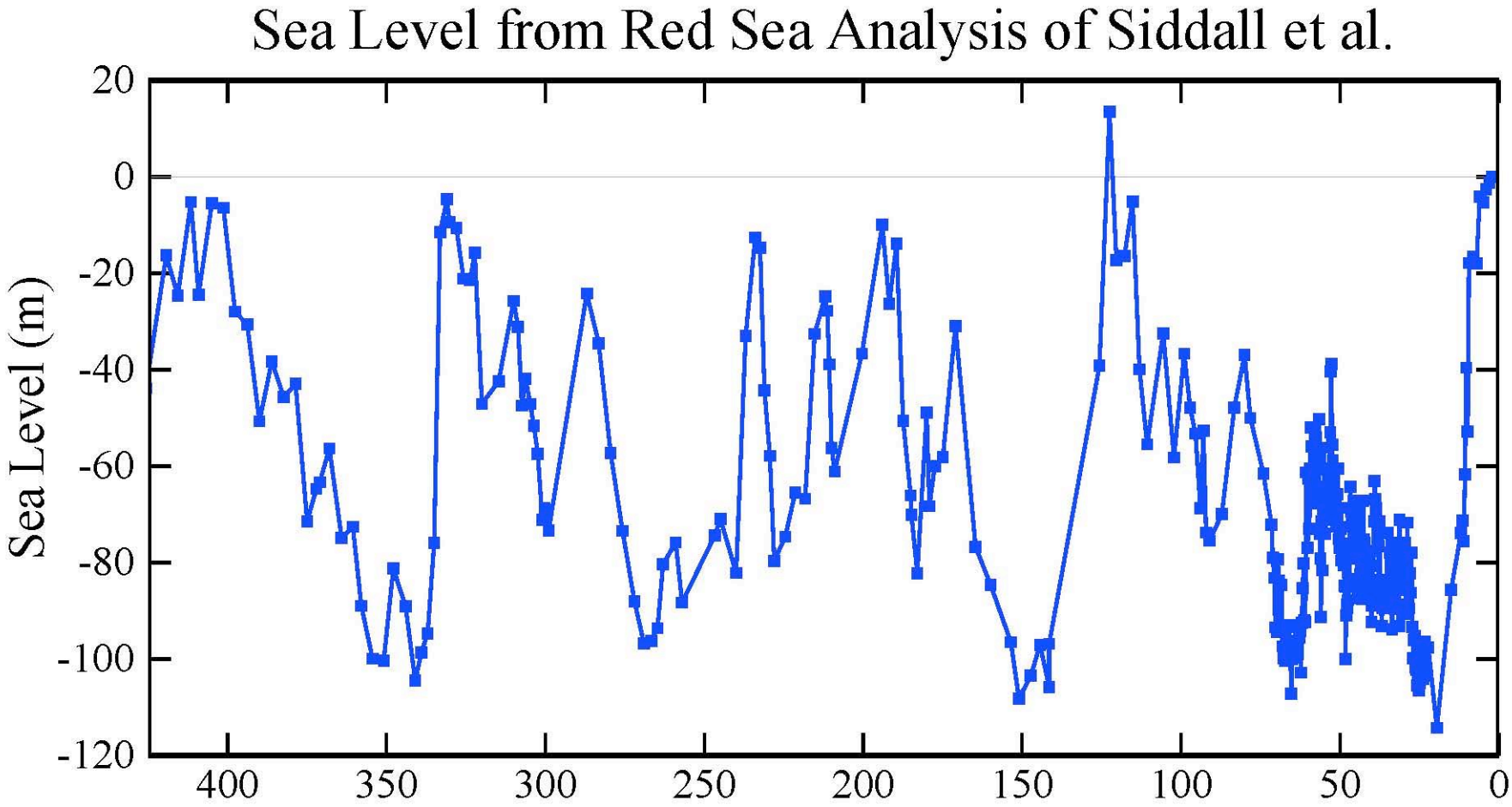
CO_2, CH_4 and temperature records from Antarctic ice core data

Source: Vimeux, F., K.M. Cuffey, and Jouzel, J., 2002, "New insights into Southern Hemisphere temperature changes from Vostok ice cores using deuterium excess correction", *Earth and Planetary Science Letters*, **203**, 829-843.

Ice Age Forcings Imply Global Climate Sensitivity ~ ¾°C per W/m^2.

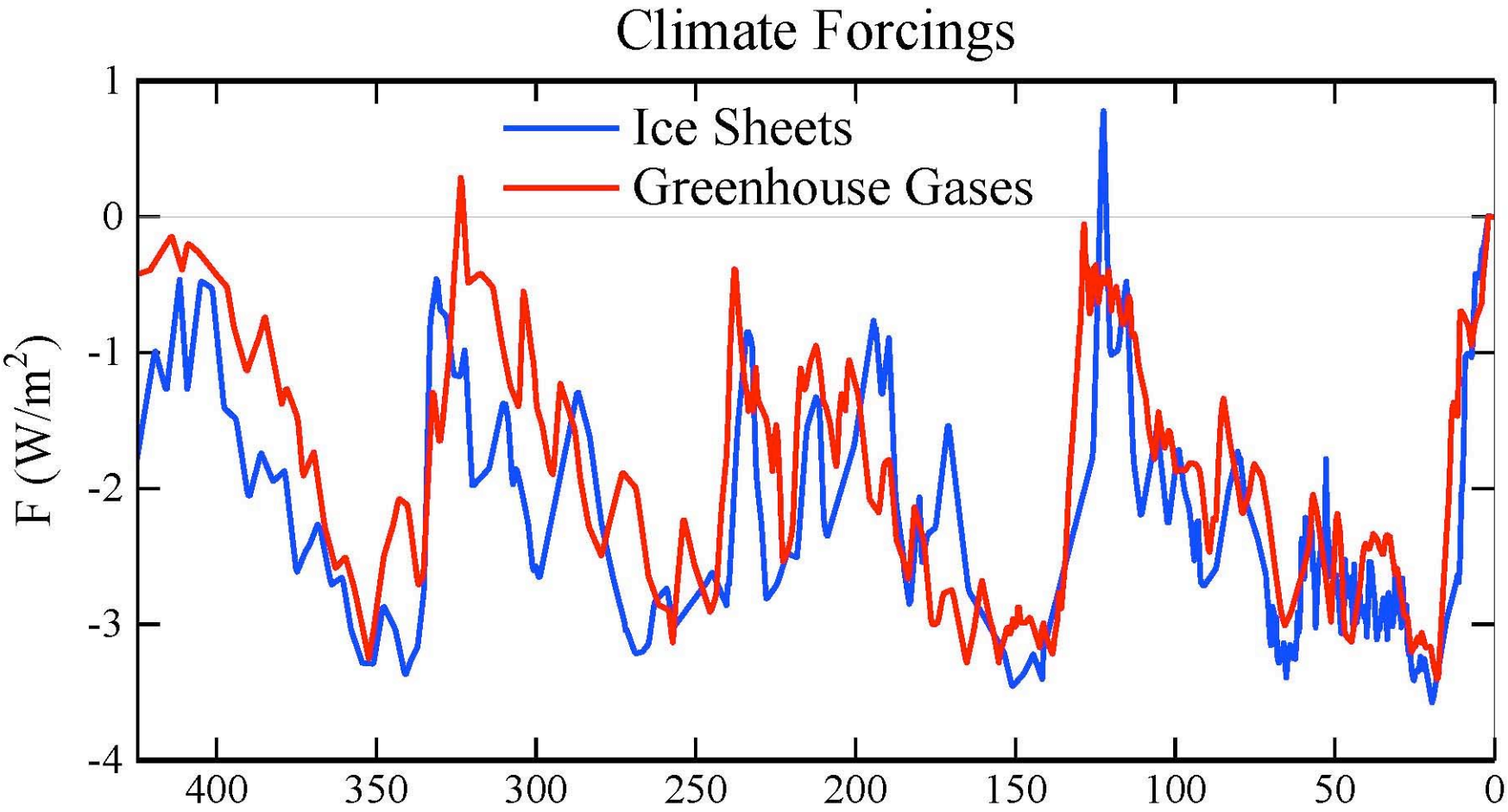


Source: Hansen et al., *Natl. Geogr. Res. & Explor.,* **9**, 141, 1993.



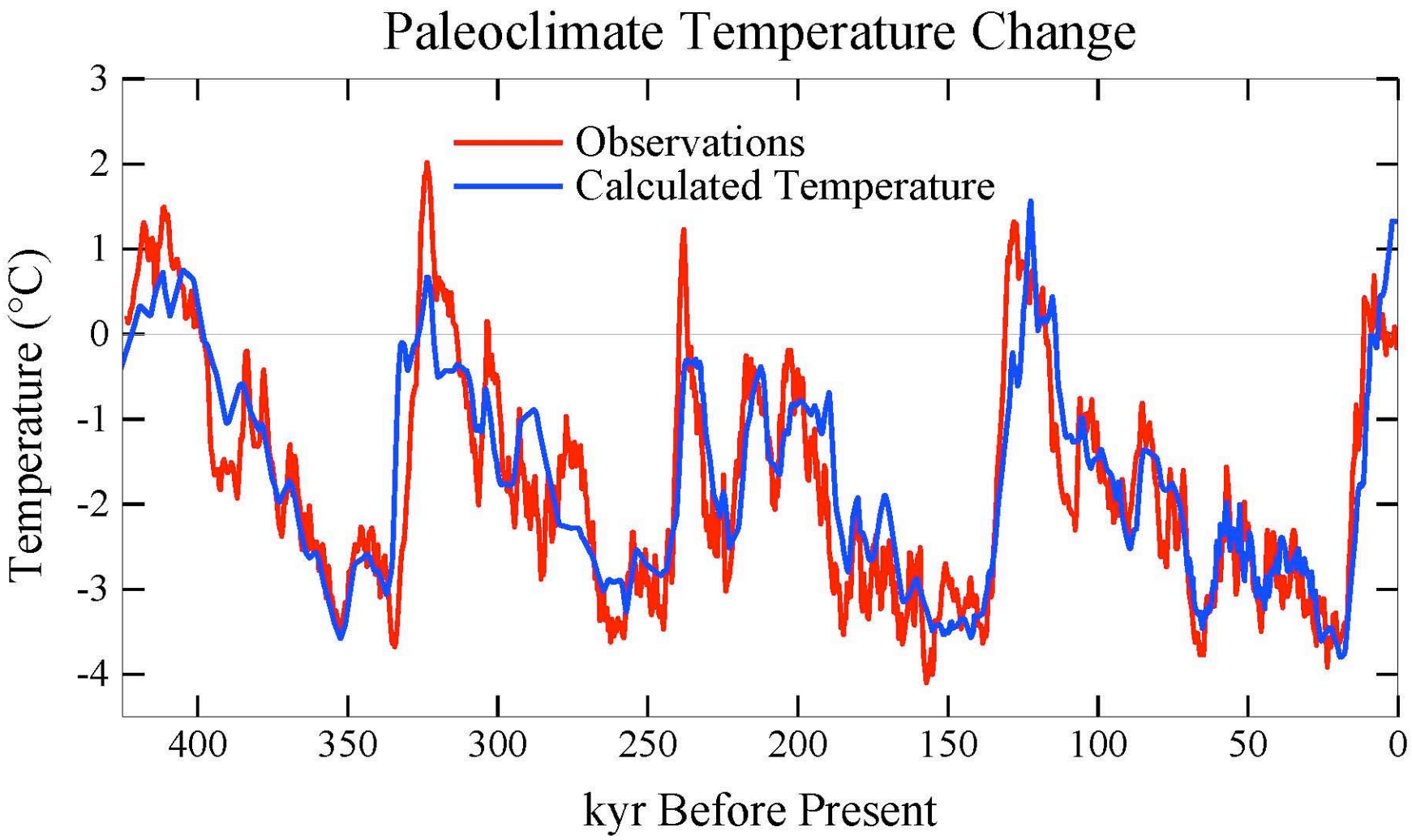
Global sea level extracted, via a hydraulic model, from an oxygen isotope record for the Red Sea over the past 470 kyr (concatenates Siddall's MD921017, Byrd, & Glacial Recovery data sets; AMS radiocarbon dating).

Source: Siddall et al., *Nature*, **423**, 853-858, 2003.



Ice sheet forcing ≅ (sea level)$^{2/3}$

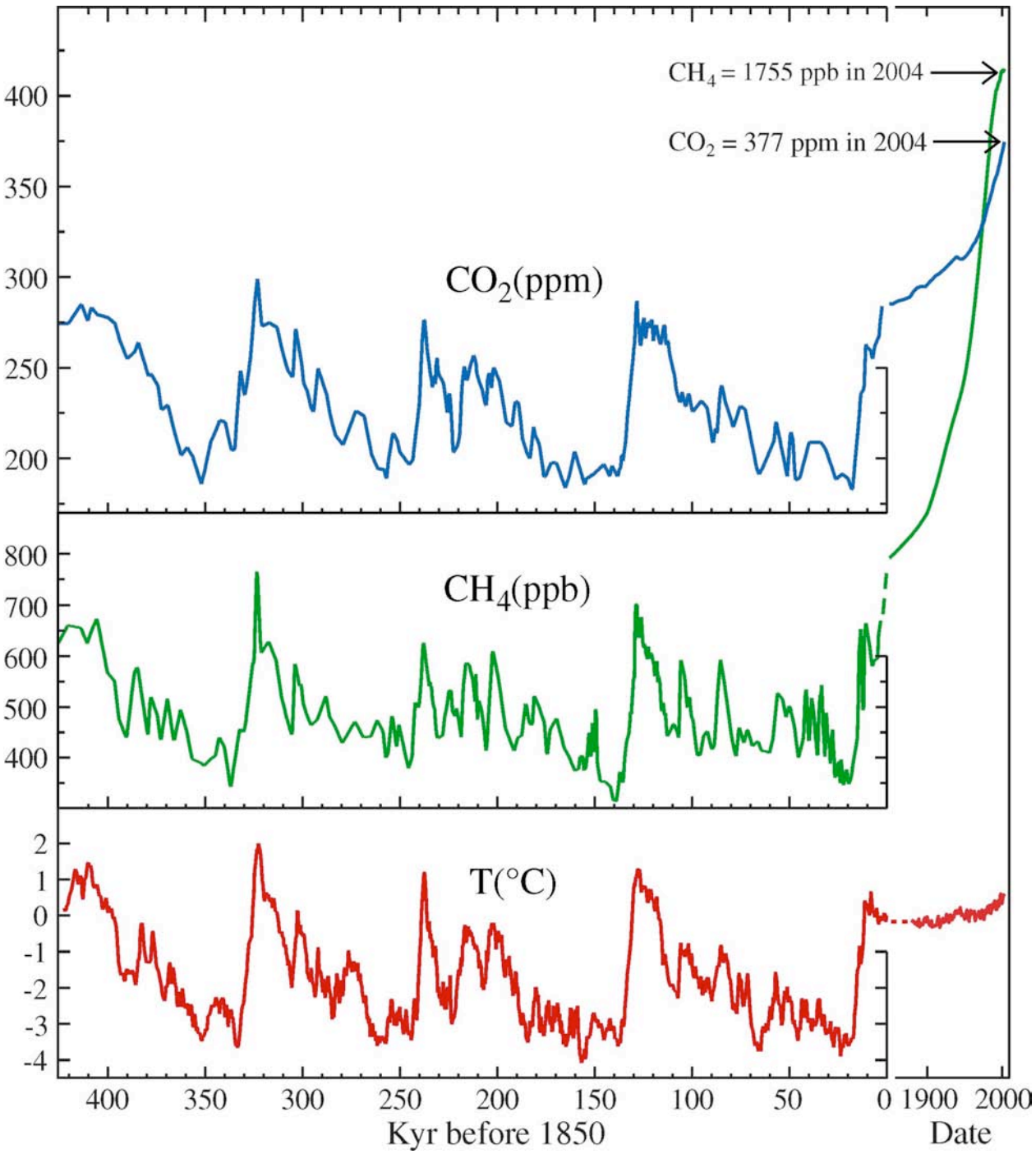
GHGs = CO_2 + CH_4 + N_2O (0.15 forcing of CO_2 + CH_4)



Observations = Vostok ΔT/2.

Calculated temperature = Forcing x 0.75°C /W/m^2

CO_2,CH_4 and estimated global temperature (Antarctic $\Delta T/2$ in ice core era) 0 = 1880-1899 mean.



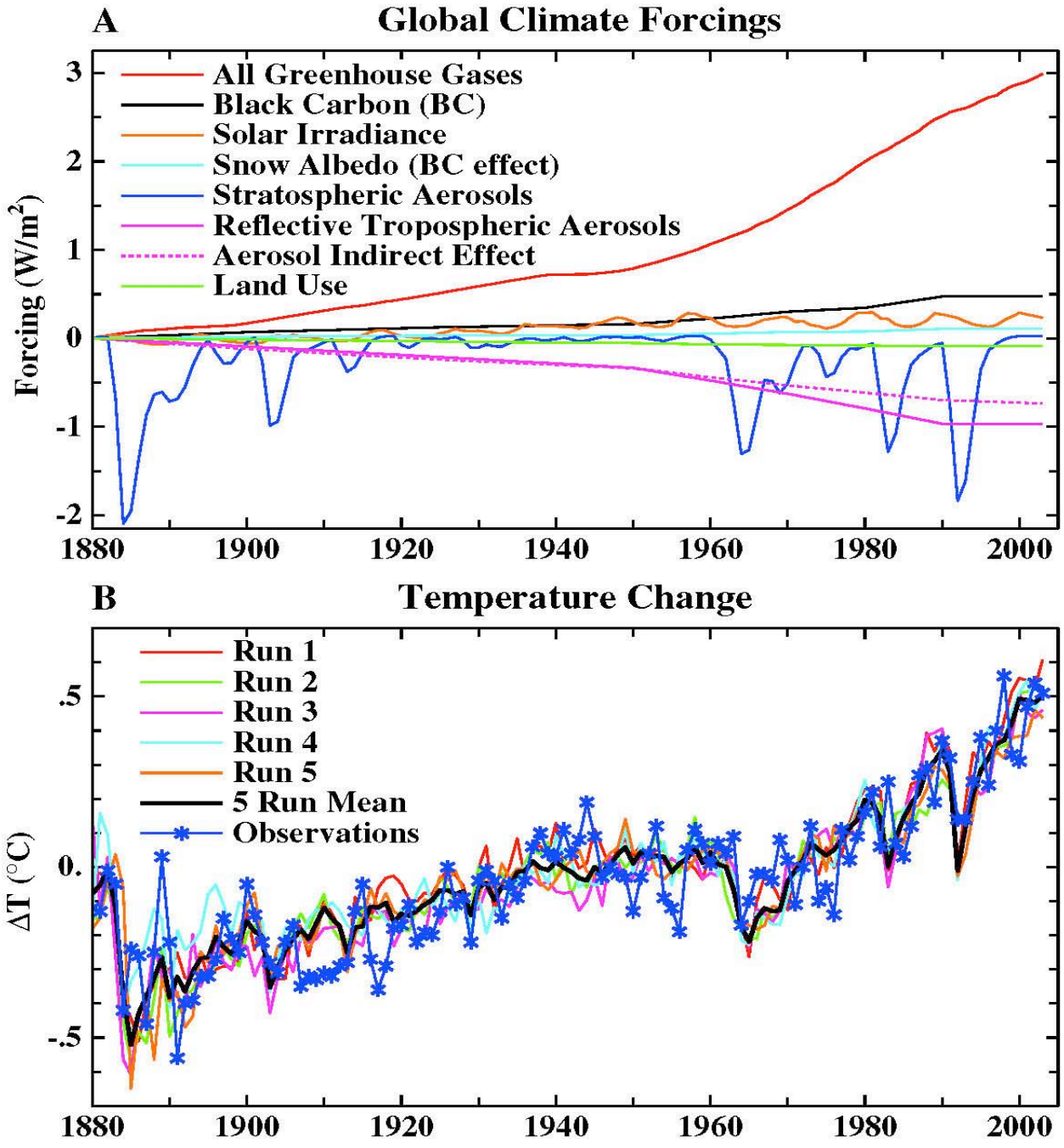
Source: Hansen, *Clim. Change*, **68**, 269, 2005.

Implications of Paleo Forcings and Response

1. "Feedbacks" (GHGs and ice area) cause almost all paleo temperature change.
2. Climate on these time scales is very sensitive to even small forcings.
3. Instigators of climate change must include: orbital vari ations, other small forcings, noise.
4. Another "ice age" cannot occur unless humans become extinct. Even then, it would require thousands of years. Humans now control global climate, for better or worse.

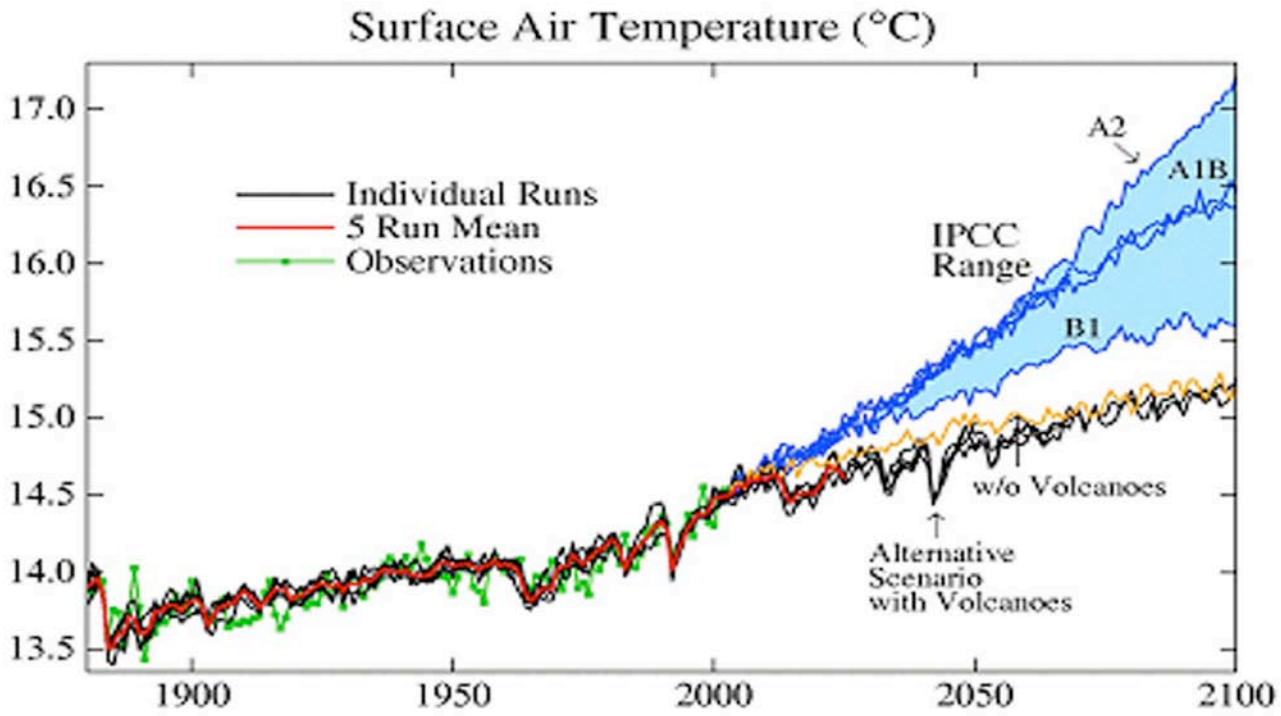
(A) Forcings used to drive climate simulations.

(B) Simulated and observed surface temperature change.



Source: Earth's energy imbalance: Confirmation and implications. *Science* **308**, 1431, 2005.

21st Century Global Warming



Climate Simulations for IPCC 2007 Report

- **Climate Model Sensitivity ~ 2.7ºC for 2xCO_2**
  (consistent with paleoclimate data & other models)
- **Simulations Consistent with 1880-2003 Observations**
  (key test = ocean heat storage)
- **Simulated Global Warming < 1ºC in Alternative Scenario**

Conclusion: Warming < 1ºC if additional forcing ~ 1.5 W/m²

Source: Hansen et al., *to be submitted to J. Geophys. Res.*

United Nations
Framework Convention on Climate Change

Aim is to stabilize greenhouse gas emissions…

"…at a level that would prevent dangerous anthropogenic interference with the climate system."

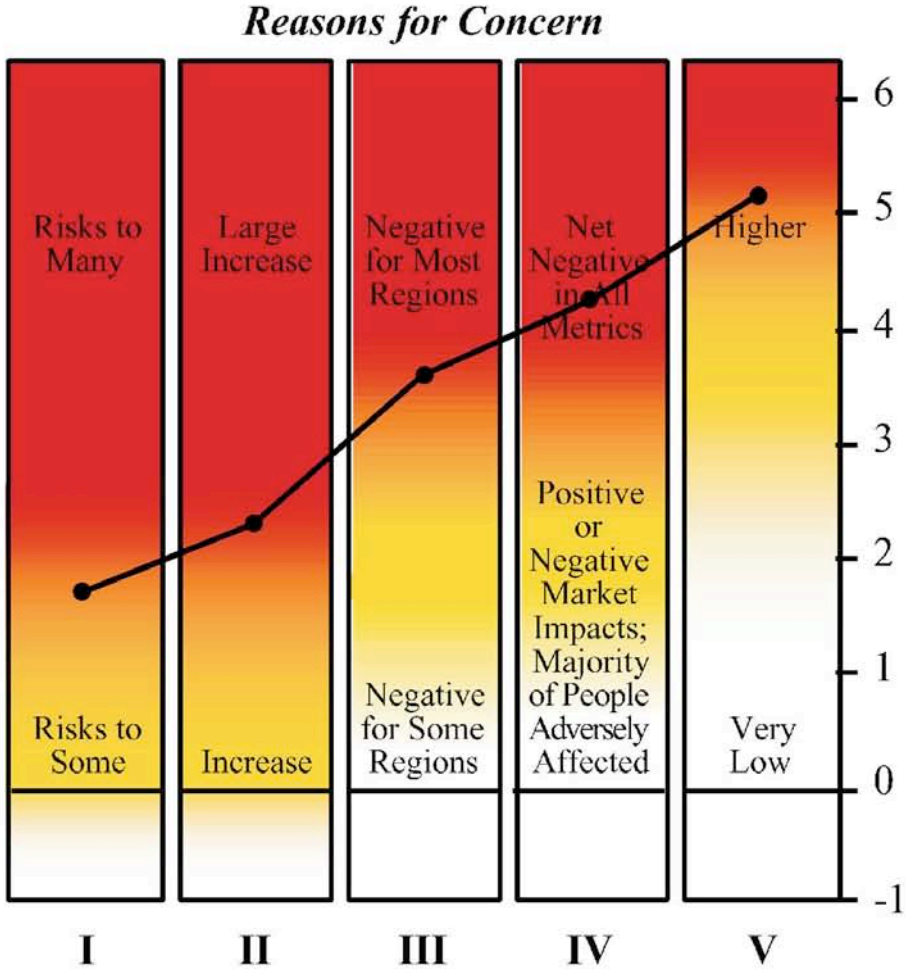
IPCC Burning Embers

White: neutral or small positive or negative impacts

Yellow: negative impacts for some systems or low risks

Red: negative impacts or risks that are more widespread and/or greater in magnitude

I	Risks to Unique and Threatened Systems
II	Risks from Extreme Climate Events
III	Distribution of Impacts
IV	Aggregate Impacts
V	Risks from Future Large-Scale Discontinuities



Reasons for concern about projected climate change impacts

Source: IPCC *Climate Change 2001;* S. Schneider & M. Mastrandrea, *PNAS,* **102**, 15728, 2005.

Metrics for "Dangerous" Change

Global Sea Level

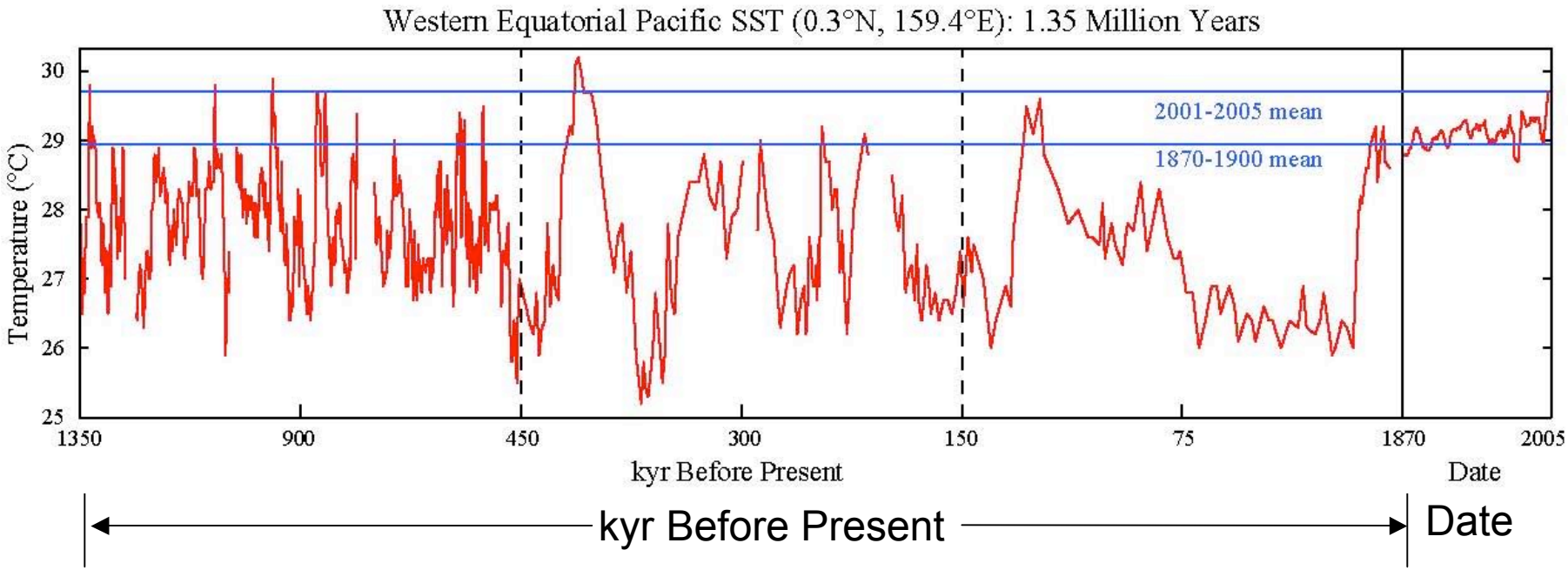
1. Long-Term Change: Paleoclimate Data
2. Ice Sheet Response Time

Loss of Animal + Plant Species

1. Extinction of Polar and Alpine Species
2. Unsustainable Migration Rates

Regional Climate Change

1. General Statement
2. Arctic, Tropical Storms, Droughts/Floods



SST in Pacific Warm Pool (ODP site 806B, 0°N, 160°E) in past millennium. Time scale expanded in recent periods. Data after 1880 is 5-year mean.

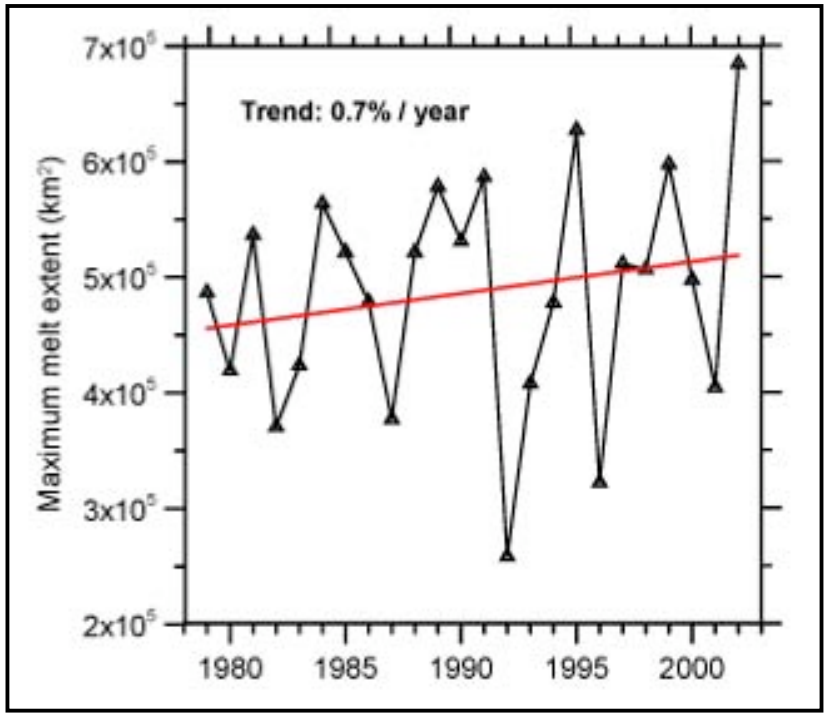
Source: Medina-Elizalde and Lea, ScienceExpress, 13 October 2005;data for 1880-1981 based on Rayner et al., *JGR*, **108**, 2003, after 1981 on Reynolds and Smith, *J. Climate*, **7**, 1994.

Surface Melt on Greenland

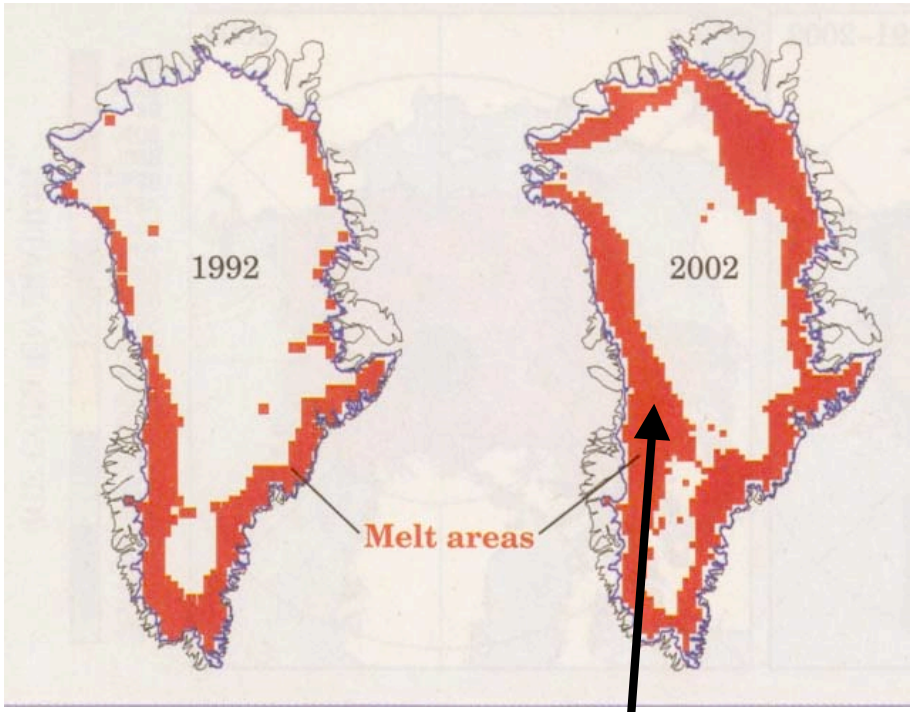
Melt descending into a moulin, a vertical shaft carrying water to ice sheet base.

Source: Roger Braithwaite, University of Manchester (UK)

Increasing Melt Area on Greenland



- 2002 all-time record melt area
- Melting up to elevation of 2000 m
- 16% increase from 1979 to 2002

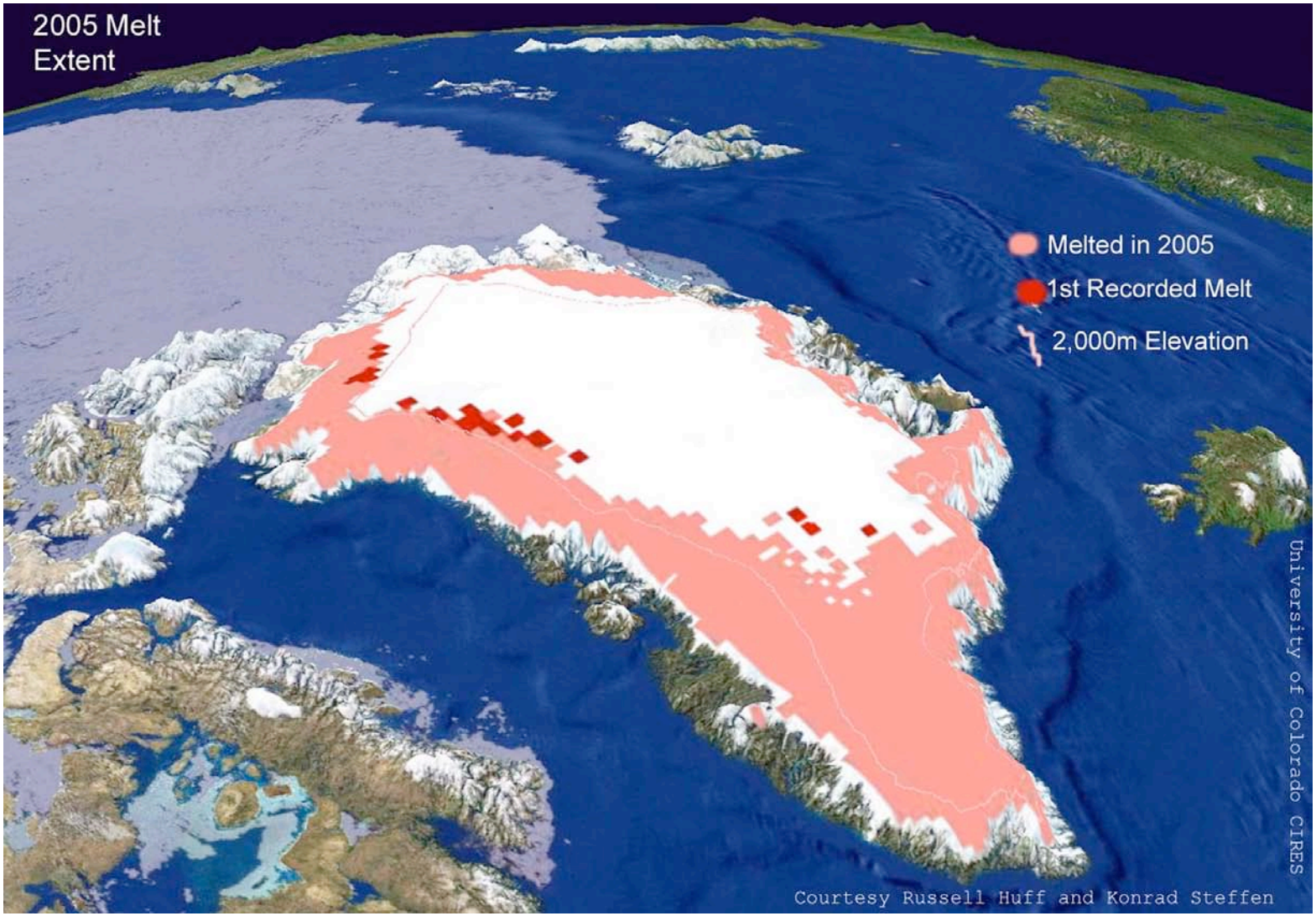


70 meters thinning in 5 years

Satellite-era record melt of 2002 was exceeded in 2005.

Source: Waleed Abdalati, Goddard Space Flight Center

2005 Melt Area on Greenland



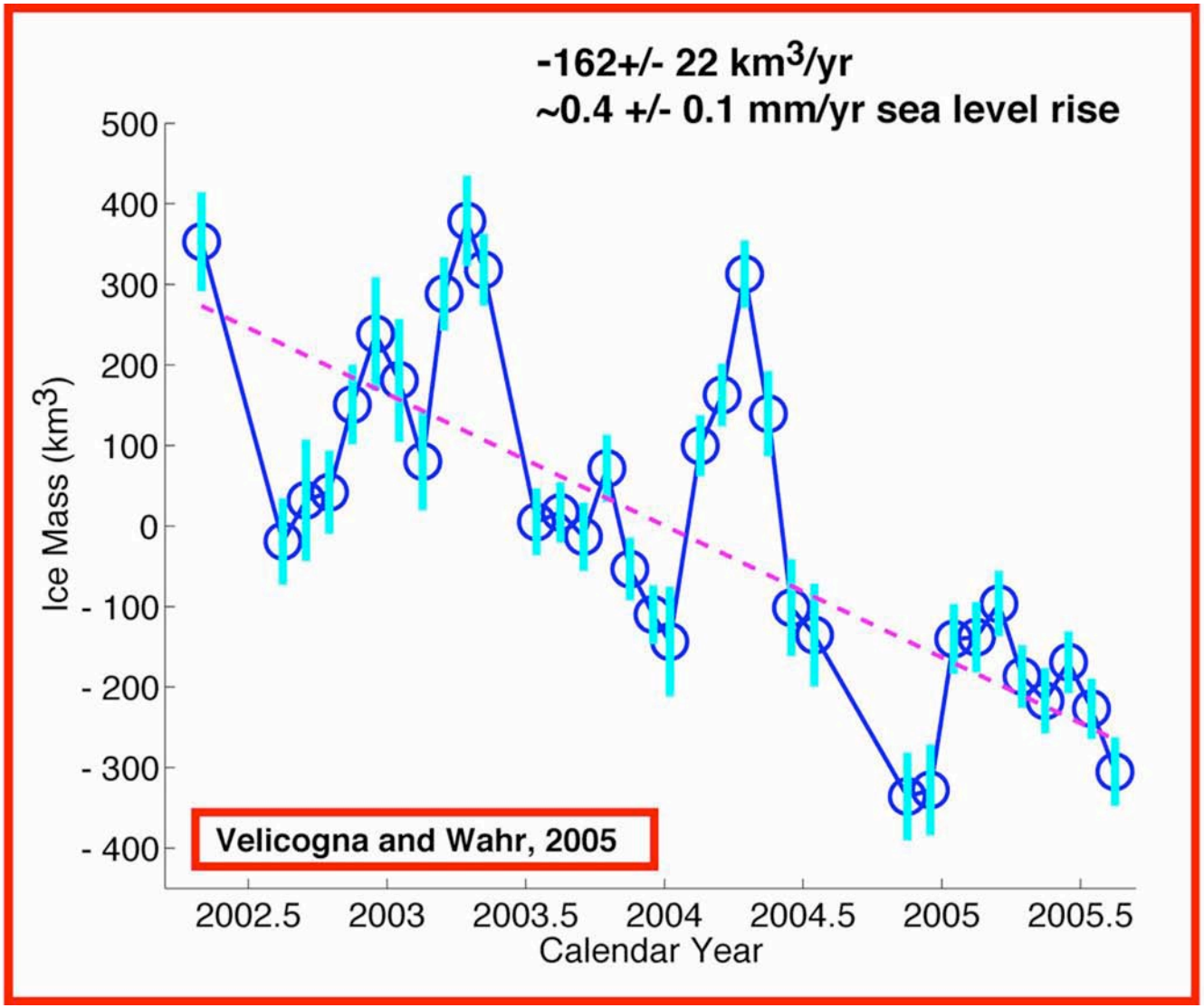
Source: University of Colorado CIRES (courtesy Russell Huff and Konrad Steffen)

Jakobshavn Ice Stream in Greenland

Discharge from major Greenland ice streams is accelerating markedly.

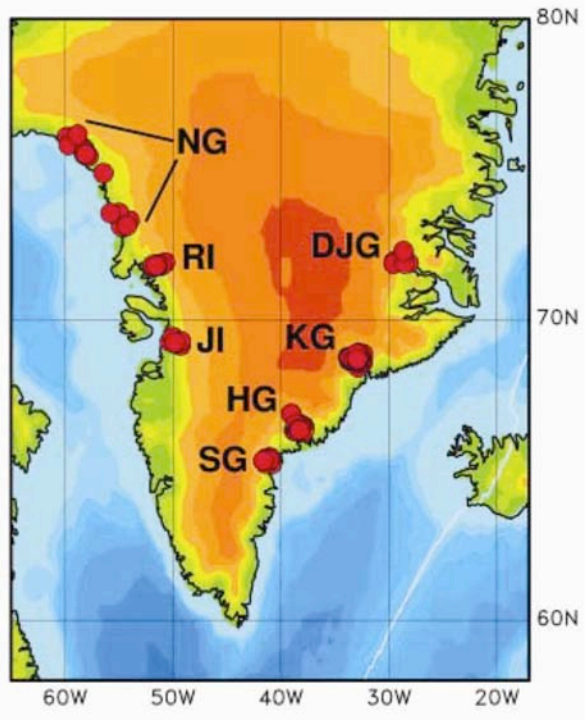
Source: Prof. Konrad Steffen, Univ. of Colorado

Greenland Mass Loss – From Gravity Satellite

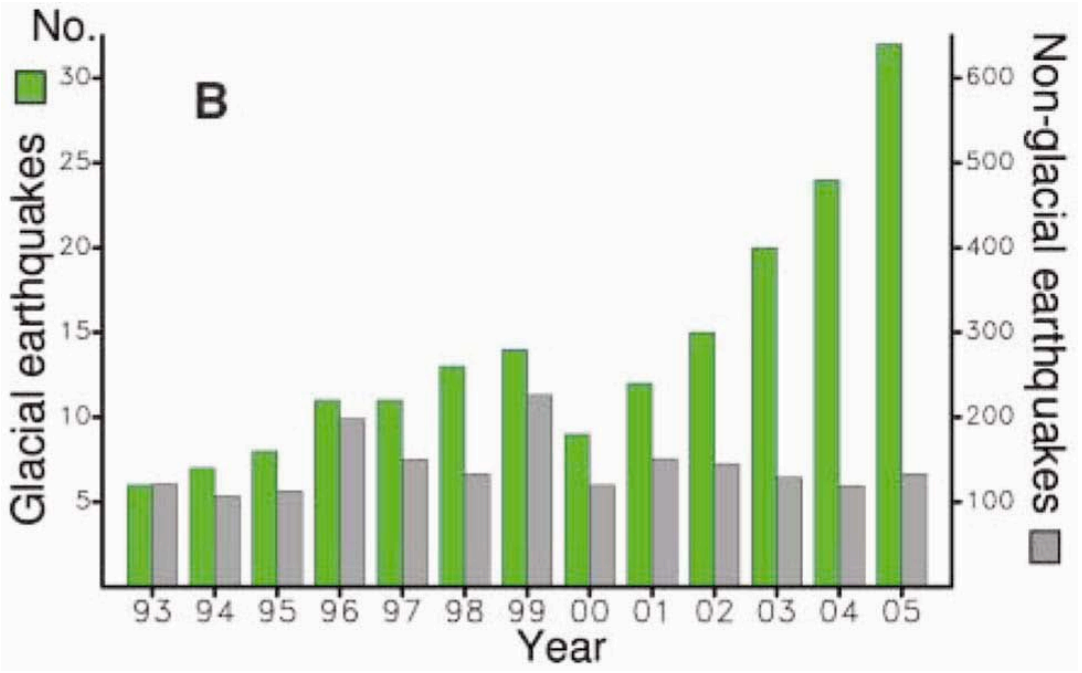


Glacial Earthquakes on Greenland

Earthquake Locations



Annual Number of Quakes*



* 2005 bars capture only first 10 months of 2005

Location and frequency of glacial earthquakes on Greenland. Seismic magnitudes are in range 4.6 to 5.1.

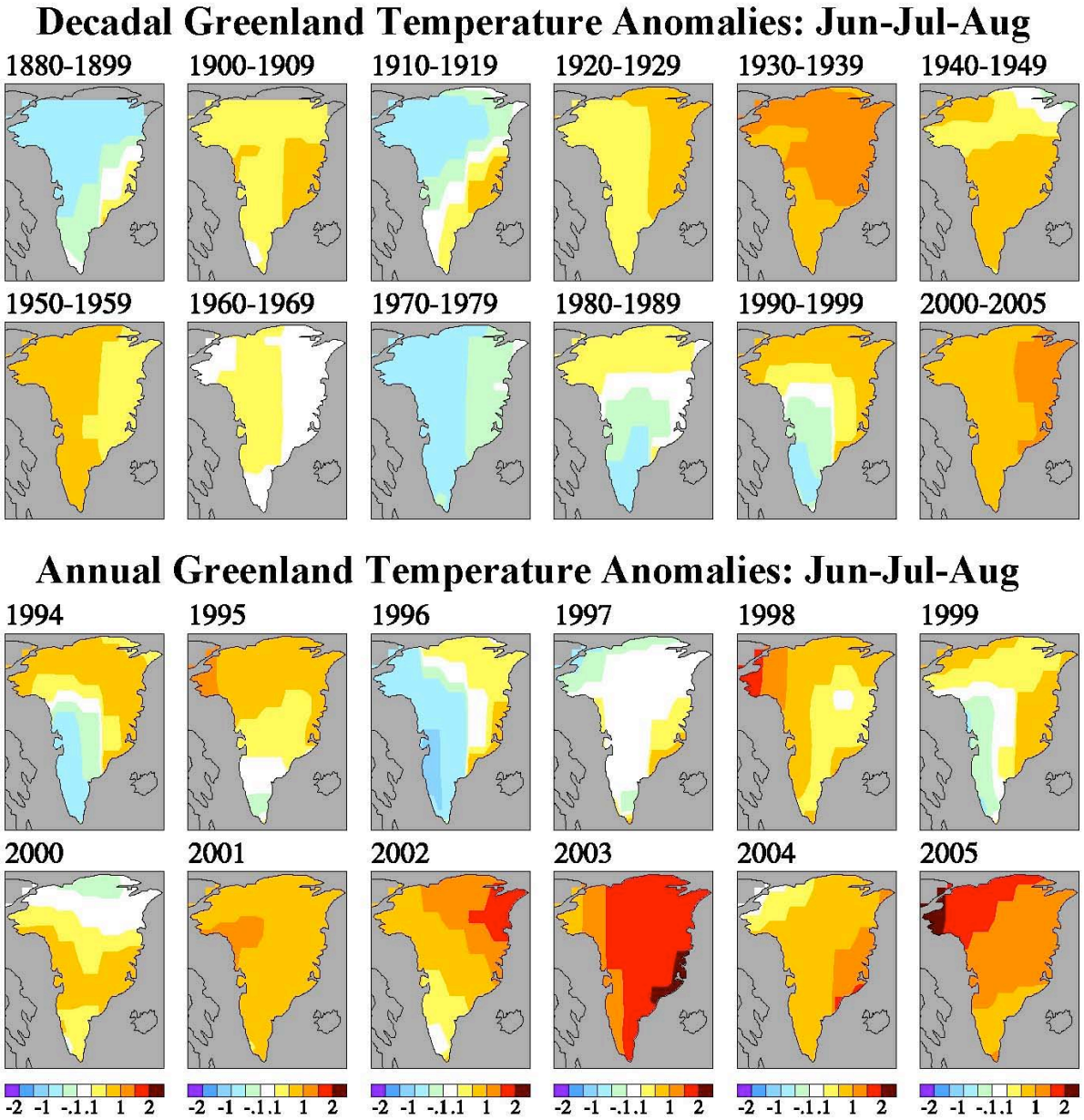
Source: Ekstrom, Nettles and Tsai, *Science*, **311**, 1756, 2006.

Summer temperature anomalies over Greenland based on global surface temperature analyses of Hansen et al. (2001).

Top: Decadal means (two decades first graph, six years final graph).

Bottom: Most recent 12 summers.

Source: Hansen *et al.*, *JGR*, **106**, 23947, 2001.



Paleoclimate Sea Level Data

1. **Rate of Sea Level Rise**

   - Data reveal numerous cases of rise of several m/century (e.g., MWP 1A)

2. **"Sub-orbital" Sea Level Changes**

   - Data show rapid changes ~ 10 m within interglacial & glacial periods

Ice Sheet Models Do Not Produce These

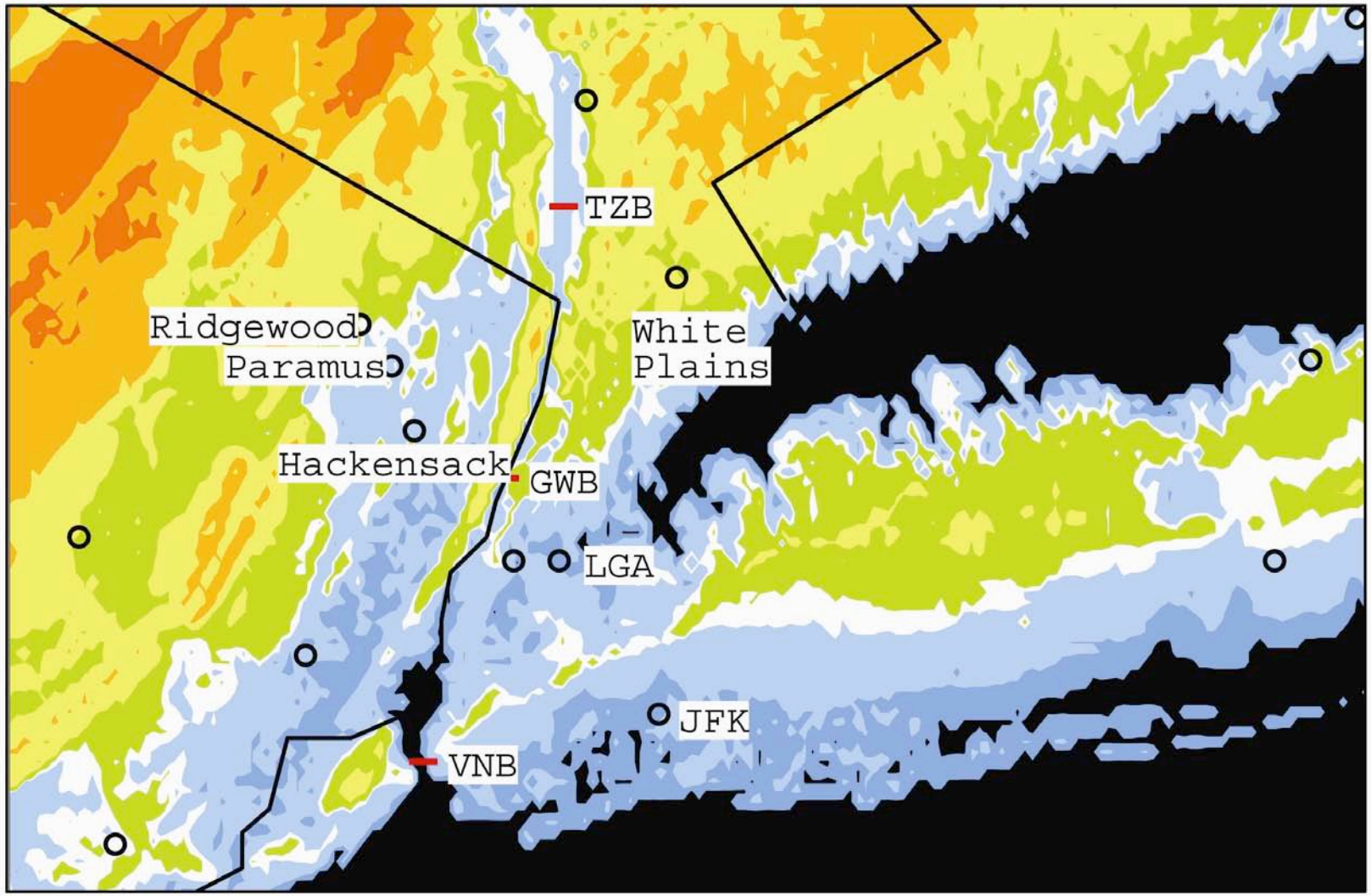
Summary: Ice Sheets

1. Human Forcing Dwarfs Paleo Forcing

2. Sea Level Rise Starts Slowly as Interior Ice Sheet Growth Temporarily Offsets Ice Loss at the Margins

3. Equilibrium Sea Level Response for ~3C Warming (25±10 m = 80 feet) Implies Potential for a System Out of Our Control

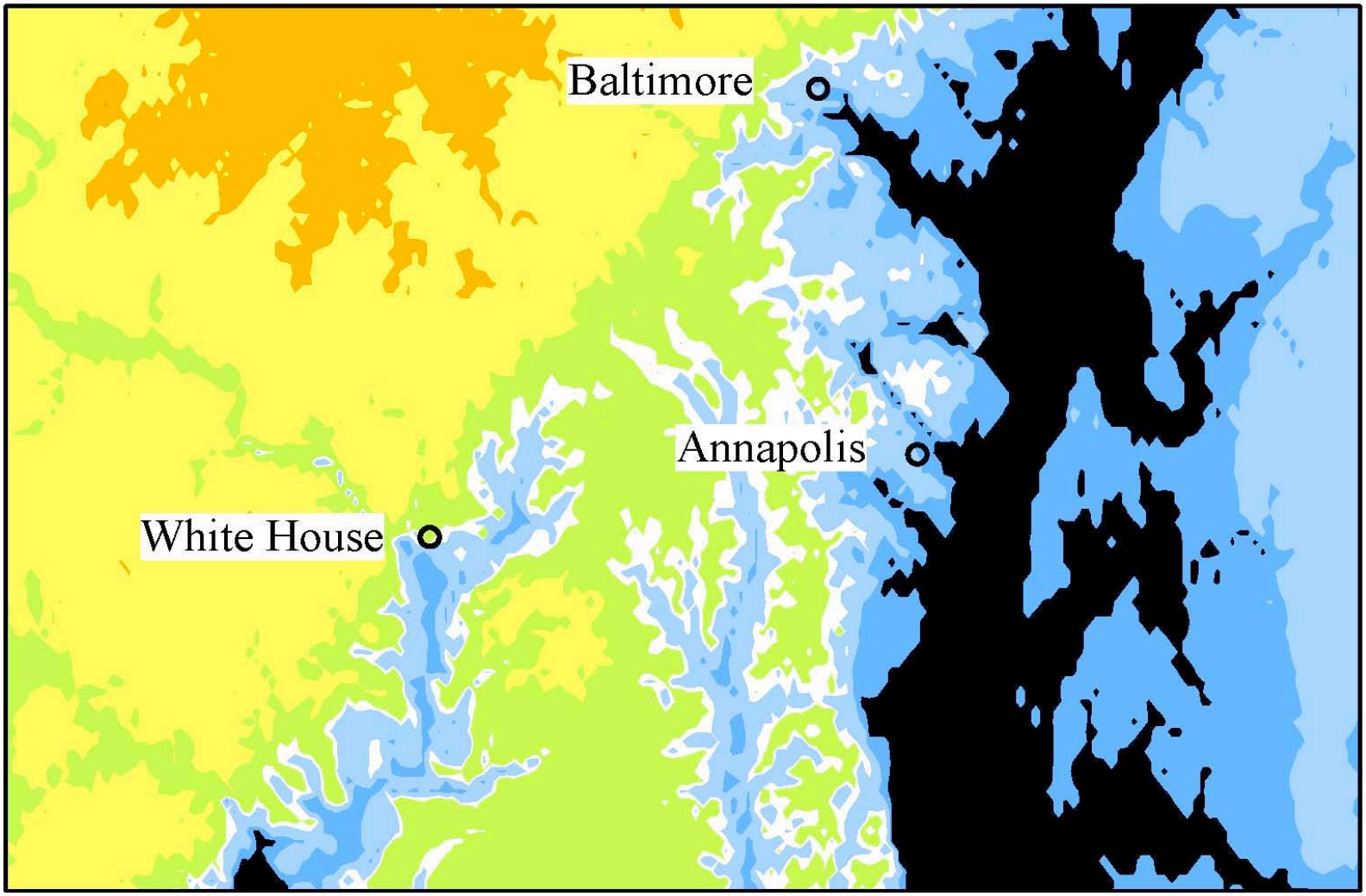
Area under Water (New York Region)



Due to Sea Level Rise (m)

0 6 25 35 75 150 300 500

Area under Water (Washington Region)

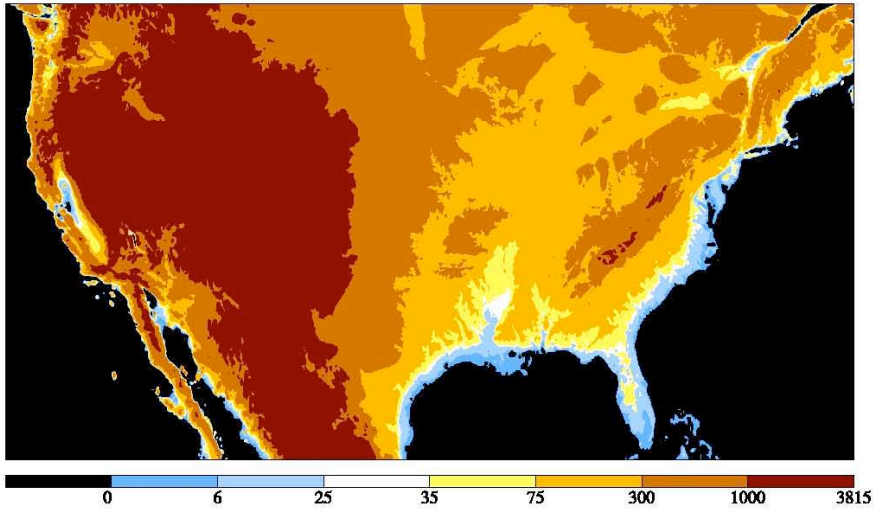


Due to Sea Level Rise (m)

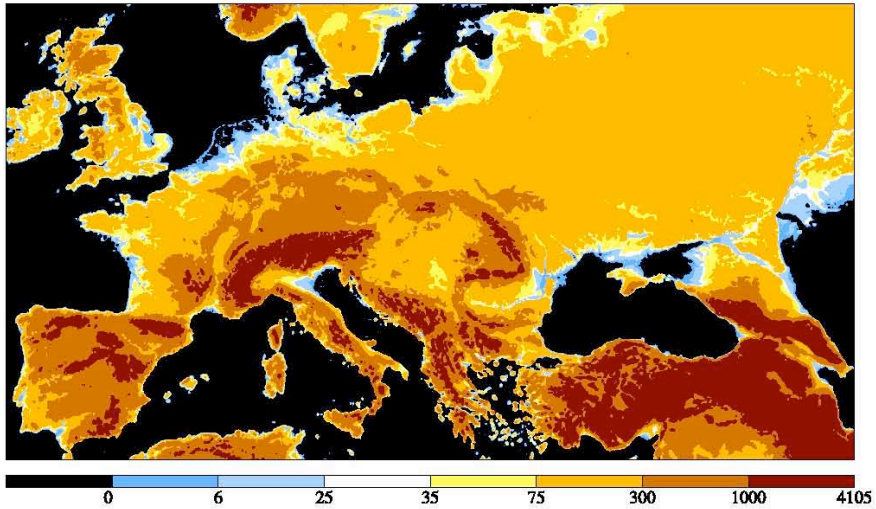
0 6 25 35 75 150 300 500

Areas Under Water: Four Regions

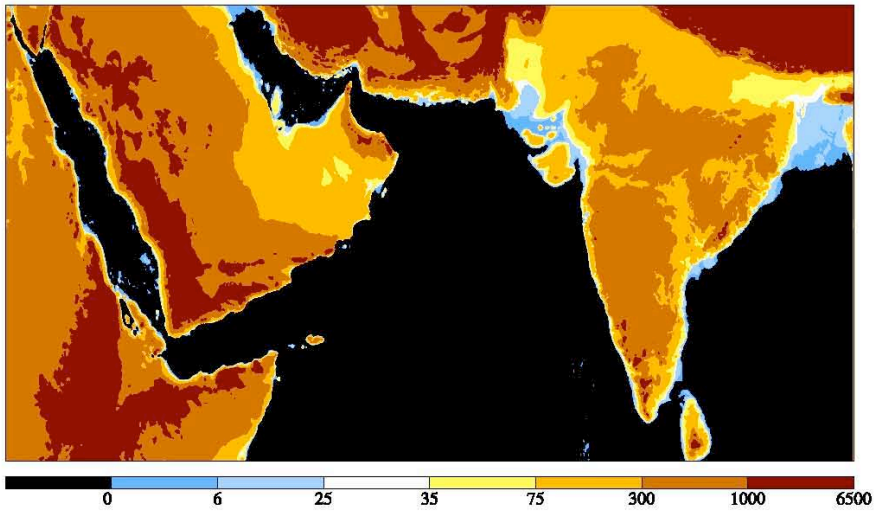
U.S. Area Under Water



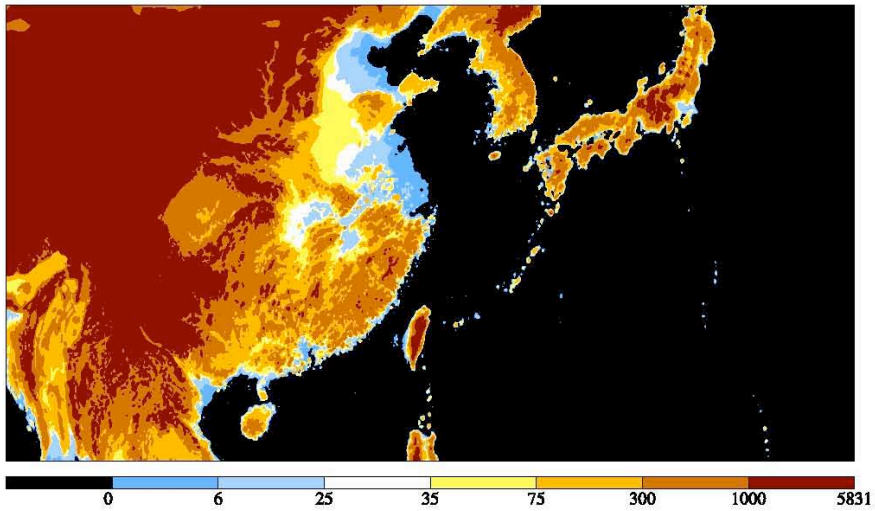
Europe Area Under Water



Central Asia: Area under Water



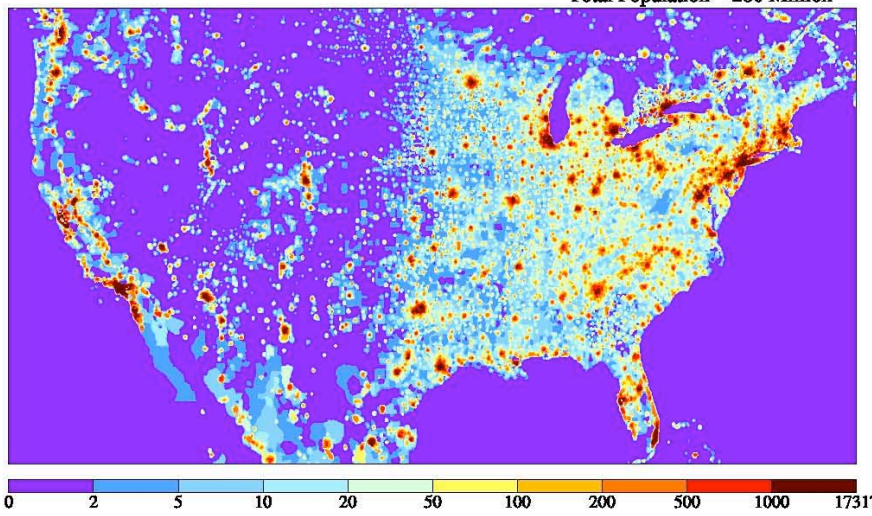
Far East: Area under Water



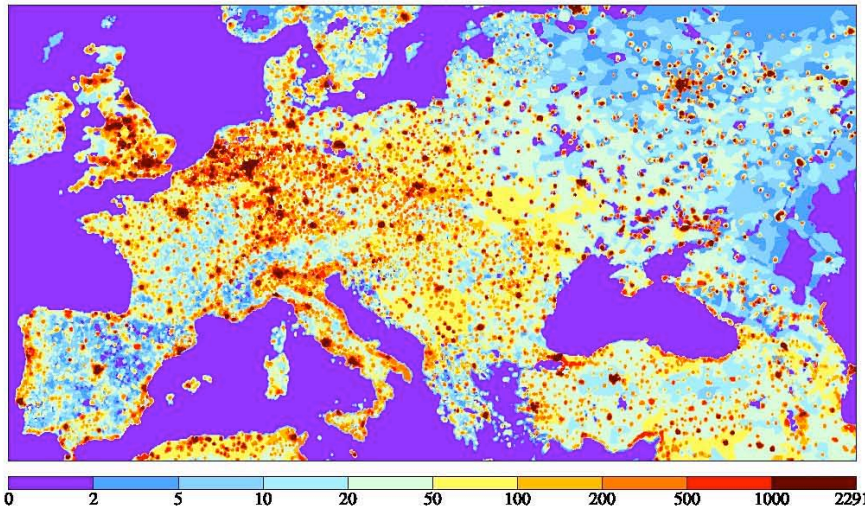
Population Density: Four Regions

U.S. Population Density in 2000 (Persons/km^2)

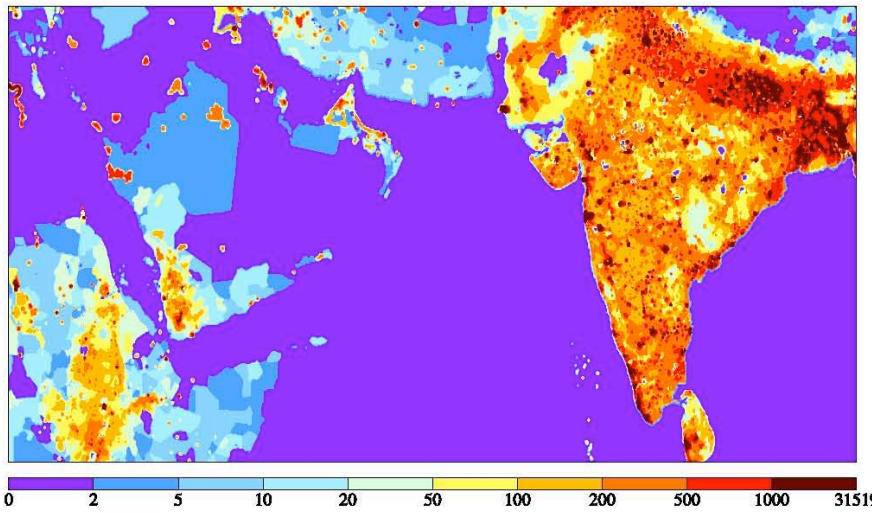
Total Population = 280 Million



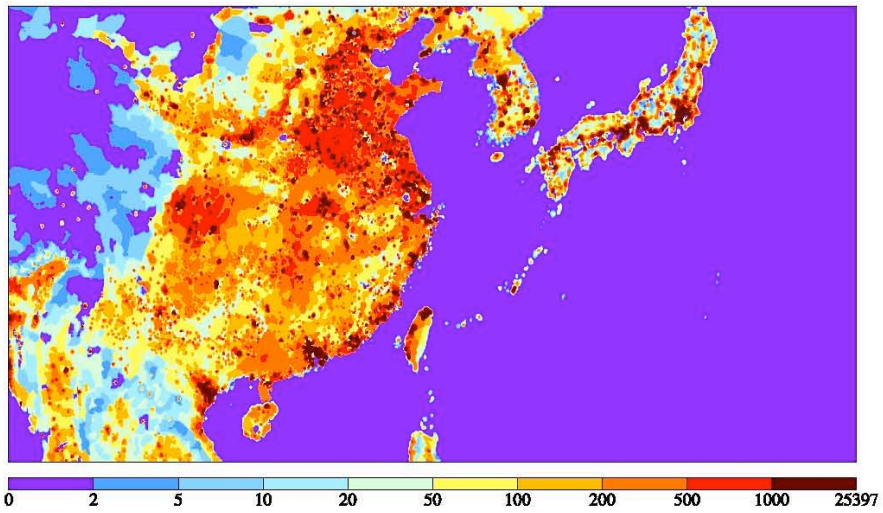
Europe: Population Density in 2000 (Persons/km^2)



Central Asia Population Density in 2000 (Persons/km^2)



Far East Population Density in 2000 (Persons/km^2)



Population (millions) in 2000

Region (total population)	Population Under Water (for given sea level rise)			
	6m	*25 m*	*35m*	*75m*
United States (283)				
East Coast	9	41	51	70
West Coast	2	6	9	19
China + Taiwan (1275+23)	93	224	298	484
India + Sri Lanka (1009+19)	46	146	183	340
Bangladesh (137)	24	109	117	130
Indonesia + Malaysia (212+22)	23	72	85	117
Japan (127)	12	39	50	73
Western Europe (454)	26	66	88	161

Extermination of Species

(a.k.a. decrease of biological diversity)

1. Distributions of plants and animals reflect climate
2. Extinctions are occurring due to variety of stresses
3. Added stress of climate change forces migrations
4. Some paths blocked by natural and human barriers
5. Observed rates (~6 km & 6 m/decade) < isotherms
6. Non-linear because of species interdependencies

_ large difference between BAU/alternative scenario

Armadillos in Arkansas

19 March 2006 E -Mail

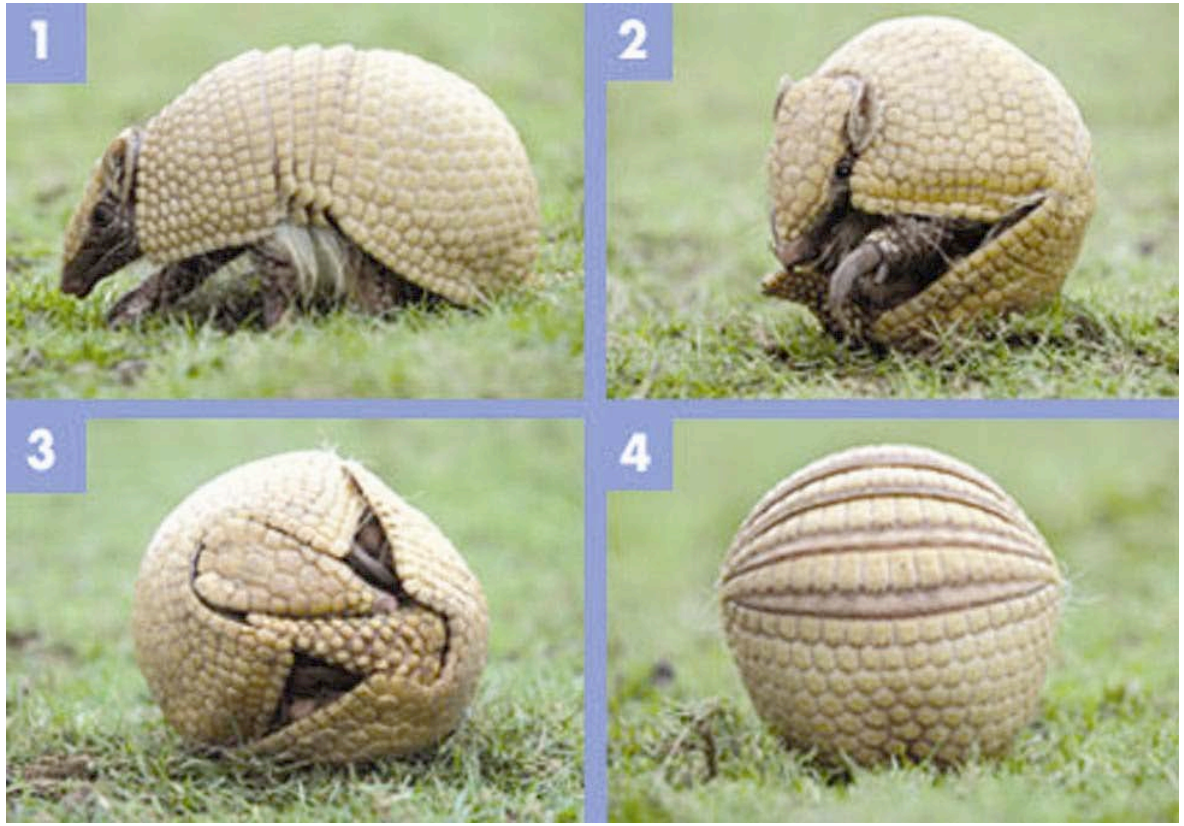
Dear Sir:

I wish to tell you how much I enjoyed your 60 Minutes Report…

If you have the time, I would like to tell you of an observation I have had over the last 10 years. I live in the Northeastern part of Arkansas, and except for a few years have been in this area for 53 years of my life.

The observation is the armadillo. I had not seen one of these animals my entire life, until the last 10 years. I drive the same 40 mile trip on the same road every d ay and have slowly watched these critters advance further north every year for the last 10 years and they are not stopping. Every year they will move 10 to 20 miles. Call it what you may, but I know these critters are not too happy with cold weather.

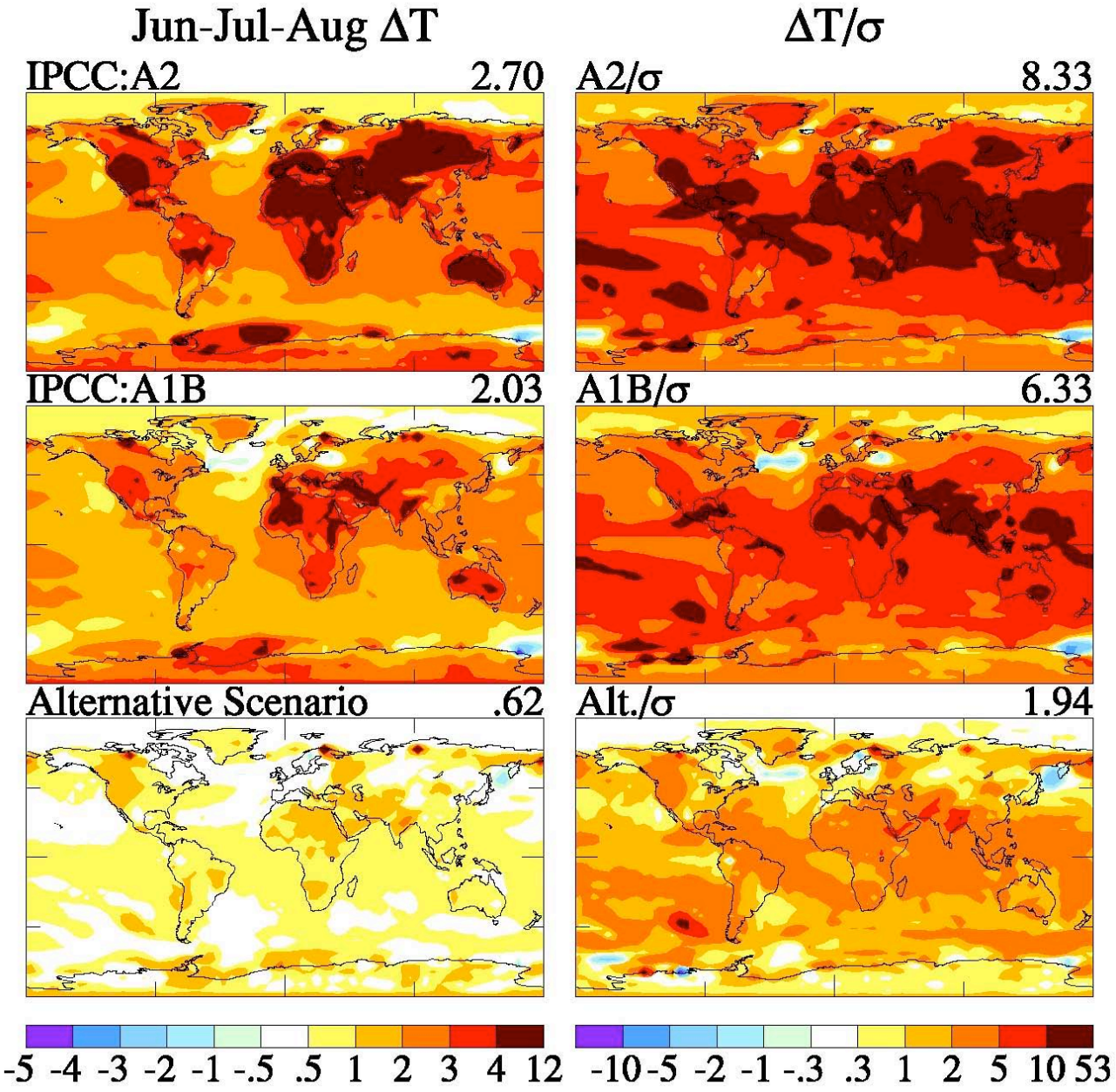
Armadillos: One of the Surviving Species?



Photos © Mark Payne-Gill, naturepl.com
source:http://seabed.nationalgeographic.com/splat_ngx_pathfinder/templates/output/articles/gallery.tmpl?DB_NUM_PARAMS=2&DB_PARAM_0=0503&DB_PARAM_1=2

Simulated 2000-2100 Temperature Change

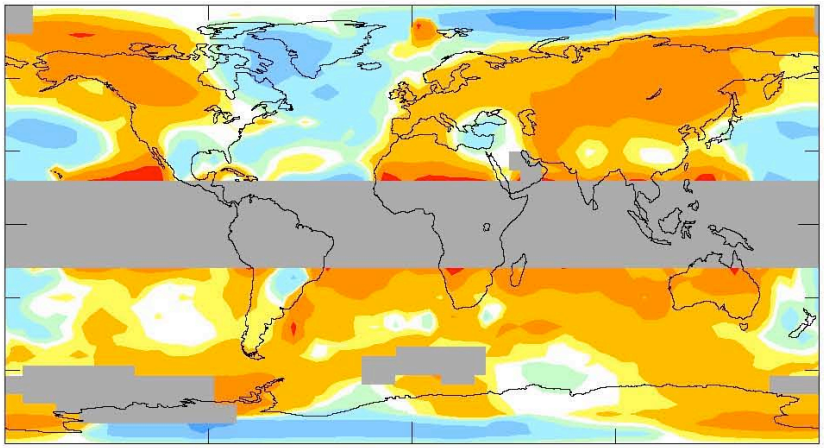
σ is interannual standard deviation of observed seasonal mean temperature for period 1900-2000.



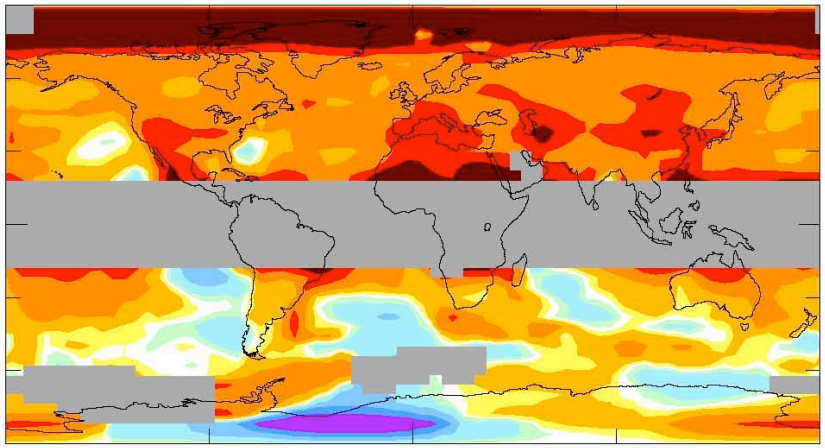
Source: Hansen et al., *J. Geophys. Res.*, submitted.

Poleward Migration Rate of Isotherms (km/decade)

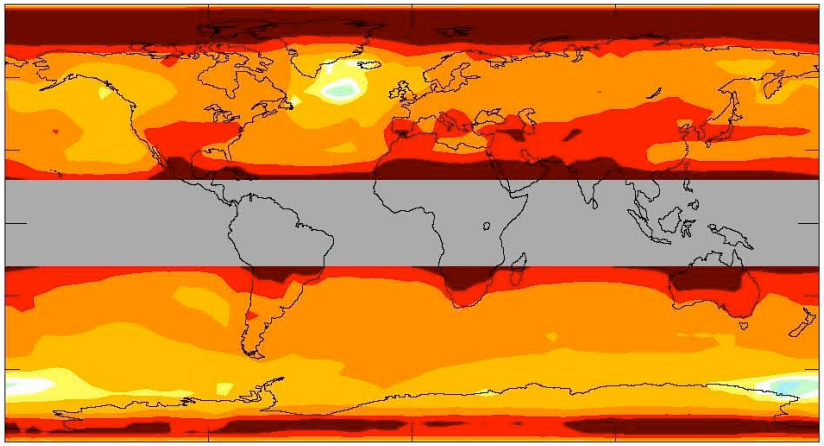
Observations: 1950-1995 12



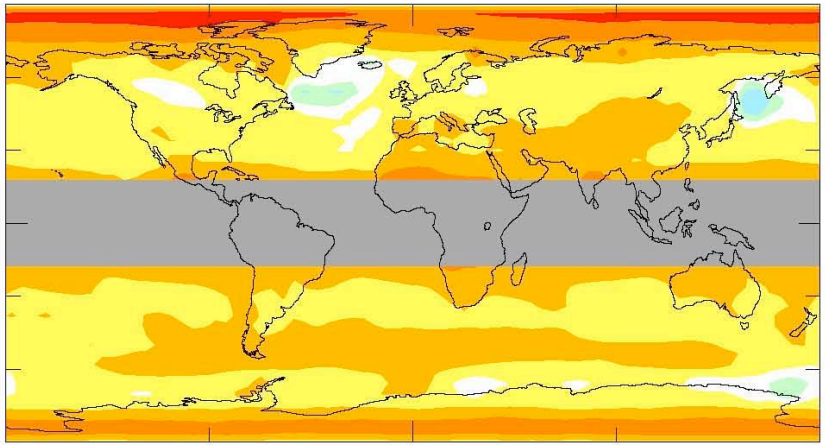
Observations: 1975-2005 38

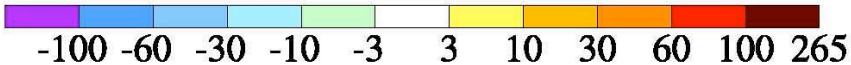


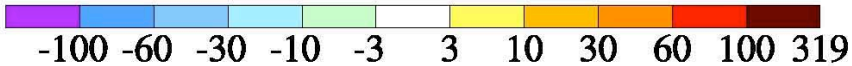
Model: IPCC Scenario A2 59



Model: Alternative Scenario 11

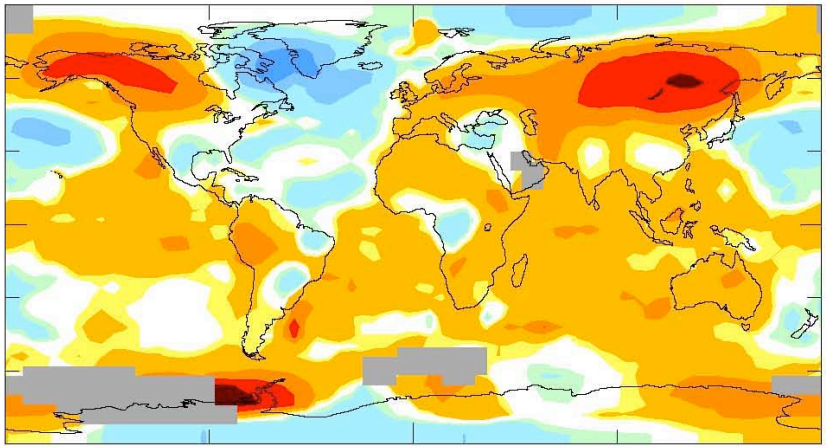




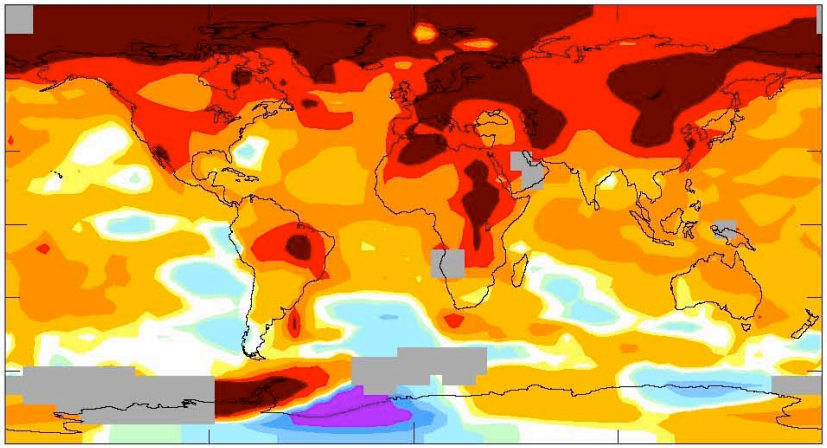


Vertical Migration Rate of Isotherms (m/decade)

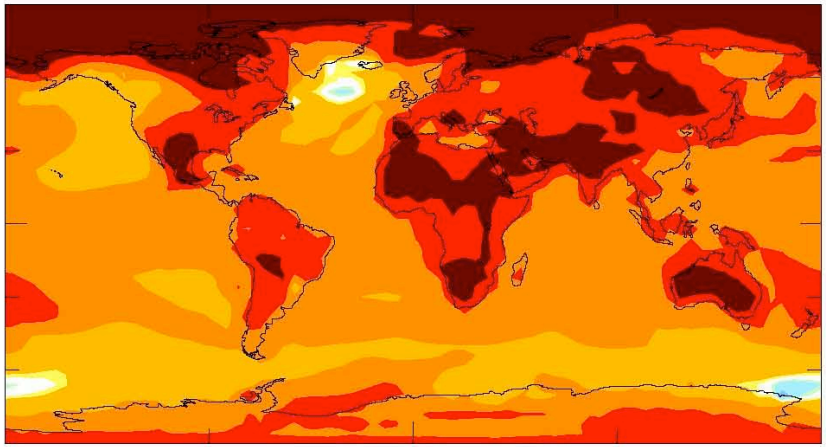
Observations: 1950-1995 12



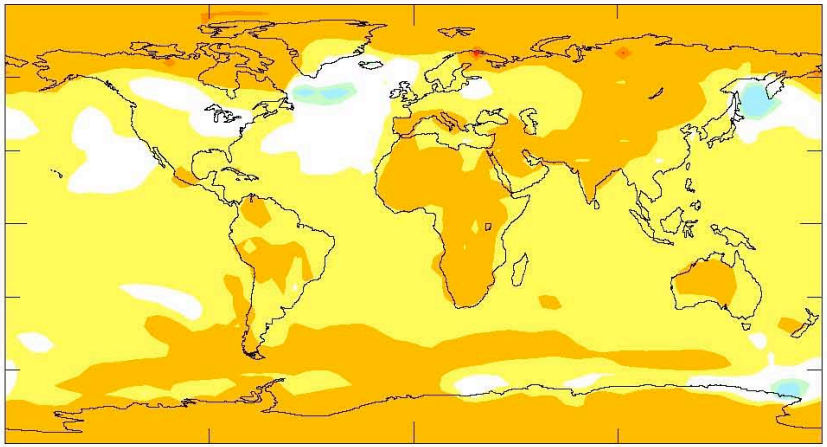
Observations: 1975-2005 31

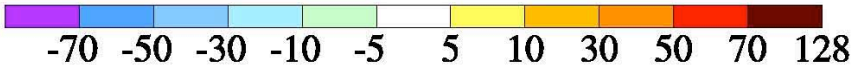


Model: IPCC Scenario A2 46



Model: Alternative Scenario 9

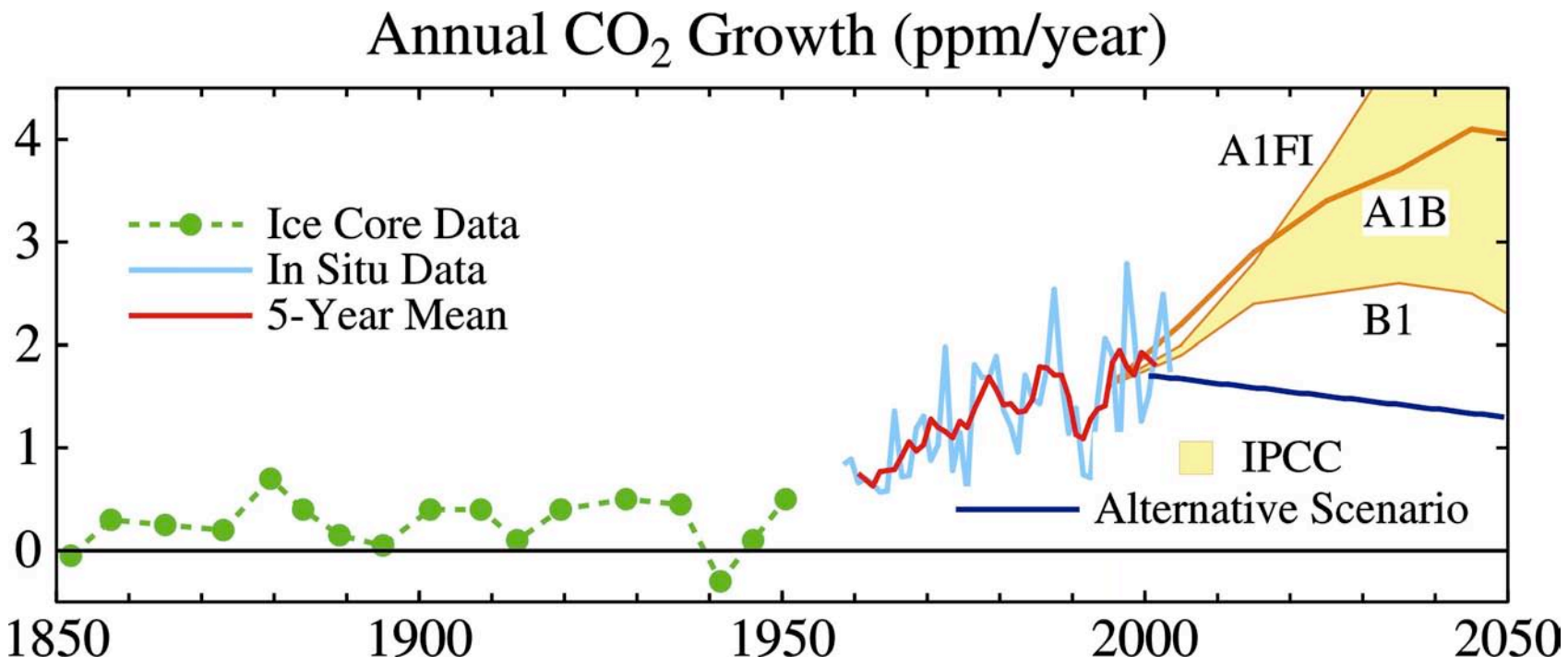




Arctic Climate Impact Assessment (ACIA)

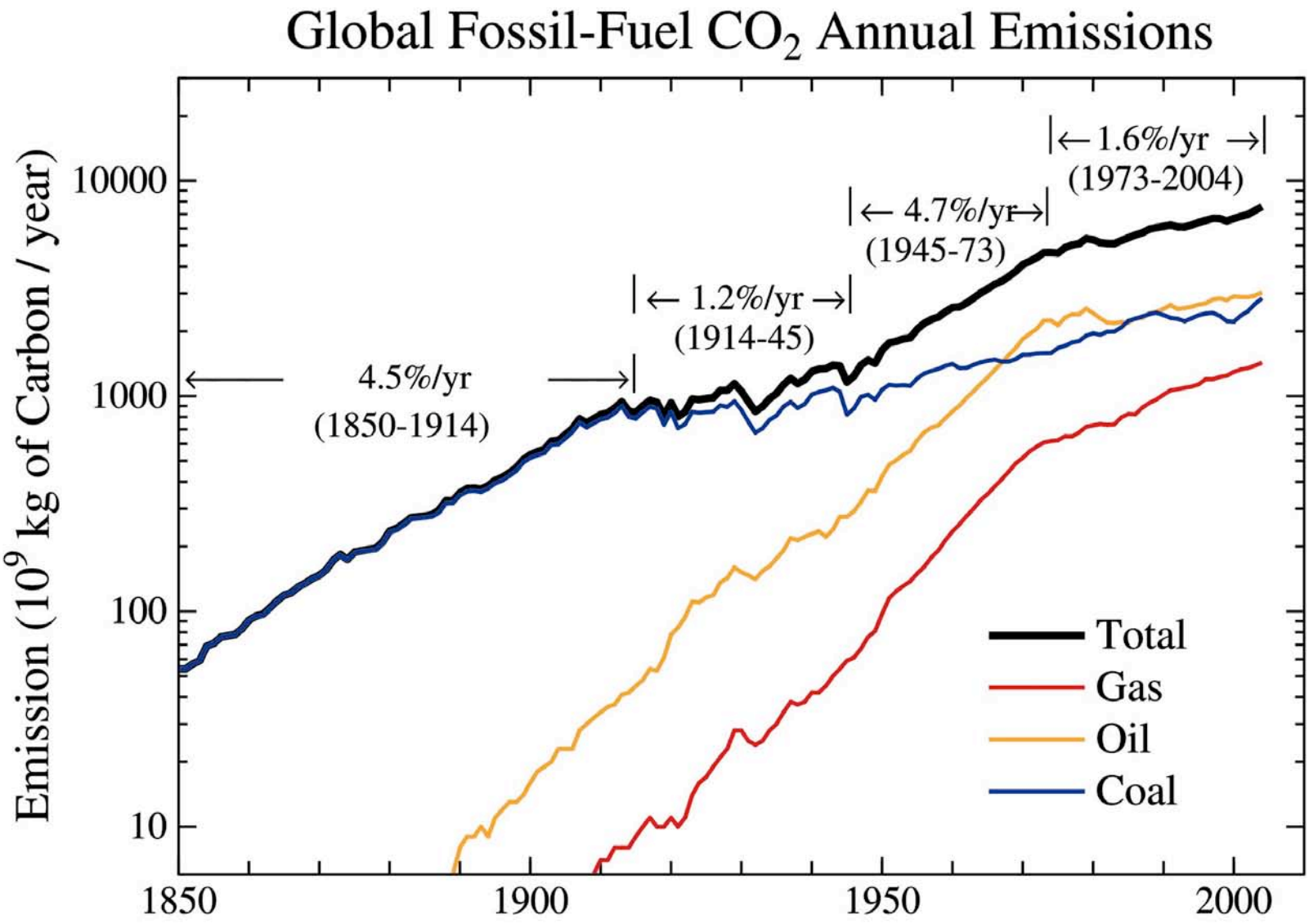
- 140-page synthesis report released in November 2004.
- Main science report imminent (chapters available electronically at www.acia.uaf.edu).
- Concerns over wide-ranging changes in the Arctic.
  - Rising temperatures
  - Rising river flows
  - Declining snow cover
  - Increasing precipitation
  - Thawing permafrost
  - Diminishing late and river ice
  - Melting glaciers
  - Melting Greenland Ice Sheet
  - Retreating summer sea ice
  - Rising sea level
  - Ocean salinity changes
- Species at risk include polar bears, seals, walruses, Arctic fox, snowy owl, and many species of mosses and lichens

Sources: Claire Parkinson and Robert Taylor



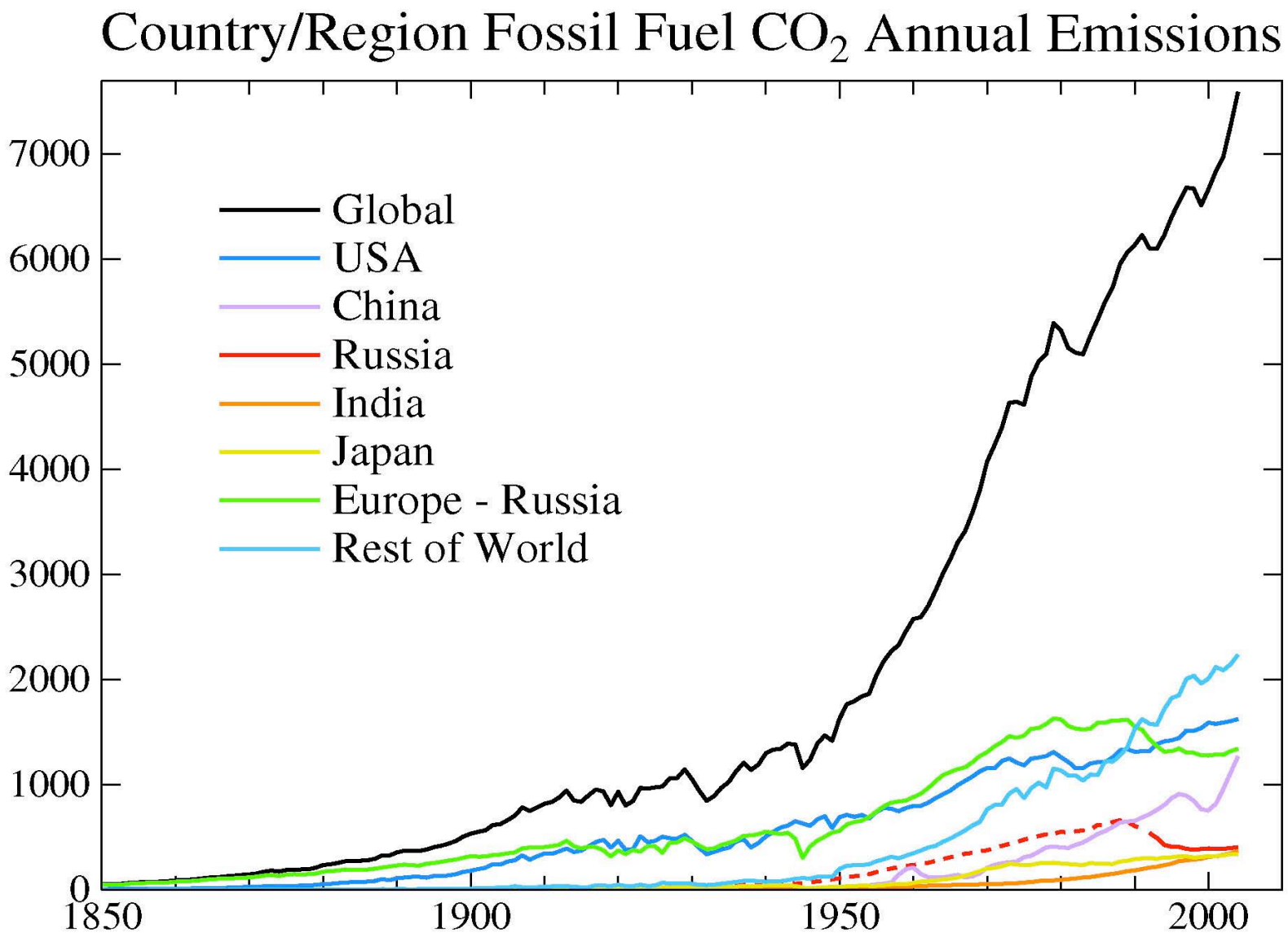
Growth rate of atmospheric CO_2 (ppm/year).

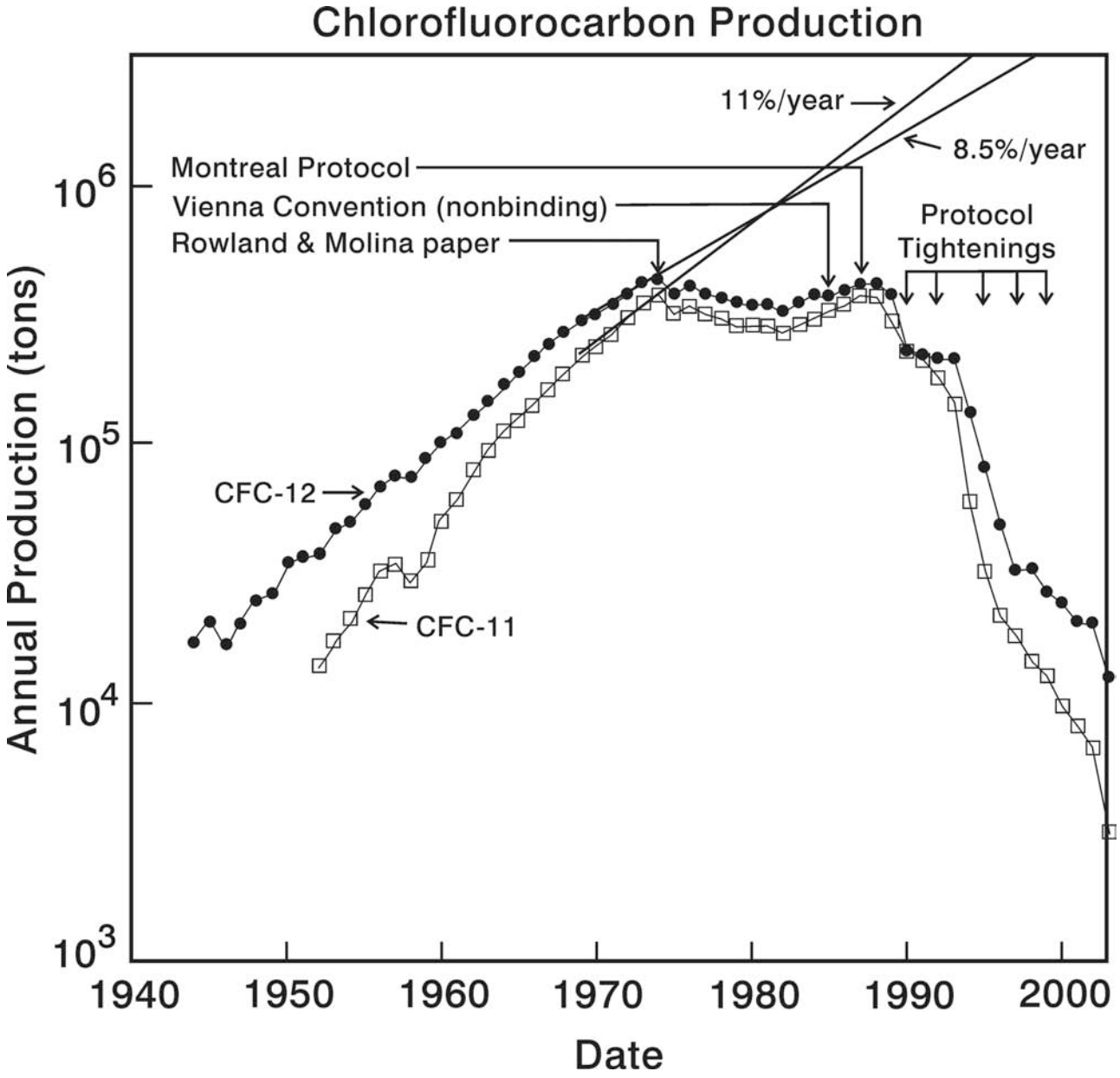
*Source: Hansen and Sato, PNAS, **101**, 16109, 2004.*



Fossil fuel CO_2 emissions based on data of Marland and Boden (DOE, Oak Ridge) and British Petroleum.

Source: Hansen and Sato, *PNAS,* **98**, 14778, 2001.


Country/Region Fossil Fuel CO_2 Annual Emissions
7000
6000
5000
4000
3000
2000
1000
0
1850
1900
1950
2000
Global
USA
China
Russia
India
Japan
Europe - Russia
Rest of World


Chlorofluorocarbon Production
11%/year
8.5%/year
Montreal Protocol
Vienna Convention (nonbinding)
Rowland & Molina paper
Protocol
Tightenings
CFC-12
CFC-11
Annual Production (tons)
10^6
10^5
10^4
10^3
1940
1950
1960
1970
1980
1990
2000
Date

Ozone Success Story

1. **Scientists** : Clear warning

2. **Media**: Transmitted the message well

3. **Special Interests** : Initial skepticism, but forsook disinformation, pursued advanced technologies

4. **Public**: quick response; spray cans replaced; no additional CFC infrastructure built

5. **Government**: U.S./Europe leadership; allow delay & technical assistance for developing countries

Global Warming Story

_1. **Scientists** : Fail to make clear distinction between climate change & BAU = A Different Planet

_2. **Media**: False “balance”, and leap to hopelessness

_3. **Special Interests** : Disinformation campaigns, emphasis on short-term profits

_4. **Public**: understandably confused , disinterested

_5. **Government**: Seems affected by special interests; fails to lead – no Winston Churchill today

As it appears that the world may pass a tipping point soon, beyond which it will be impossible to avert massive future impacts on humans and other life on the planet:

Who Bears (Legal/Moral) Responsibility?

1. Scientists?
2. Media?
3. Special Interests?
4. U.S. Politicians?

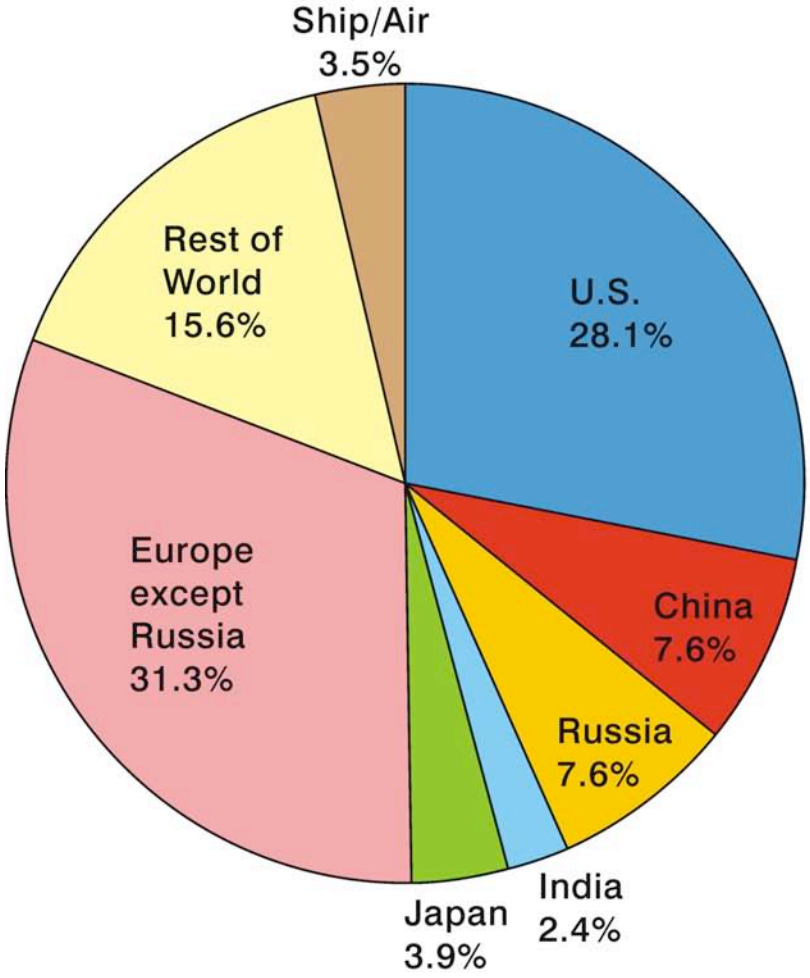
5a. Today's U.S. Public?

5b. U.S. Children/Grandchildren?

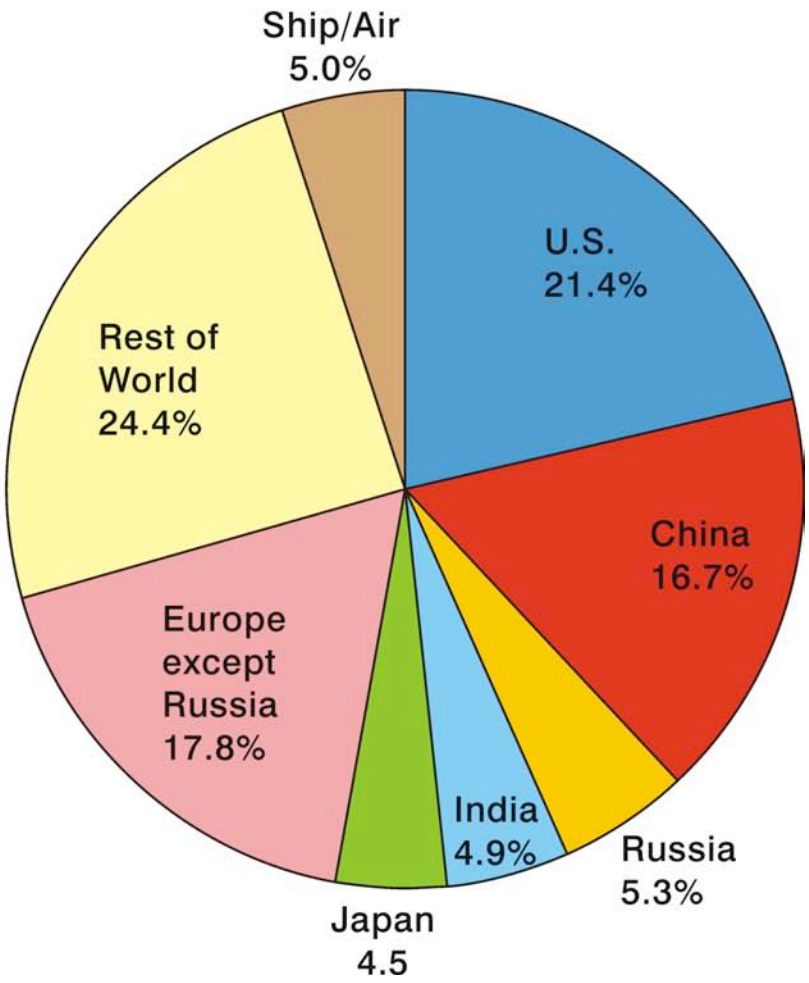
Who Will Pay?

Fossil Fuel CO_2 Emissions

Accumulated Fossil Fuel CO_2 (1850-2004)

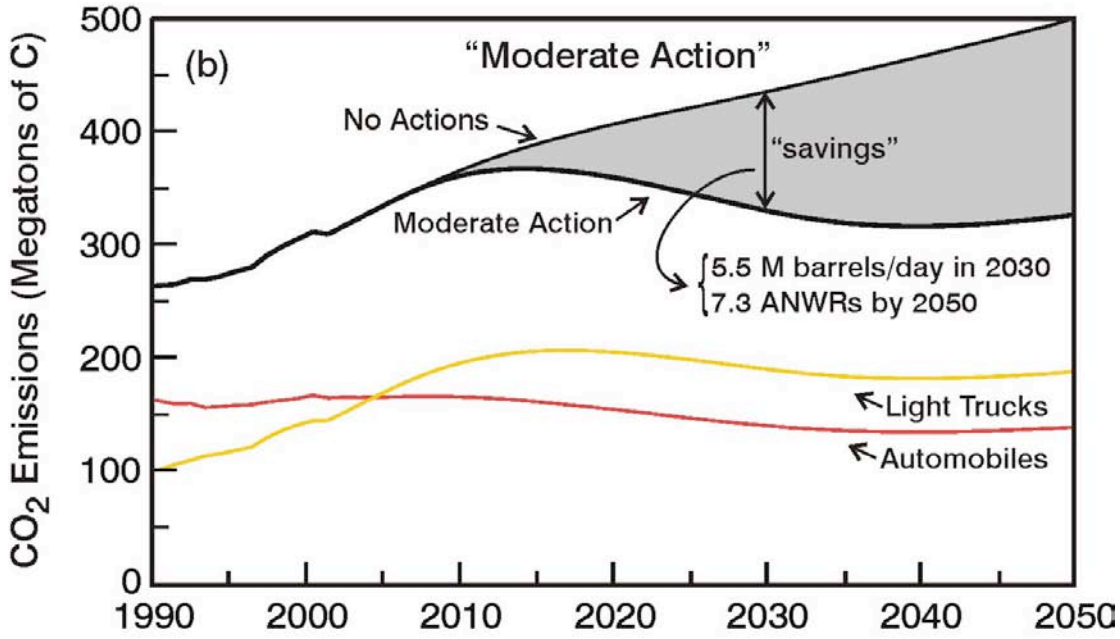


2004 Portions of CO_2 Emissions

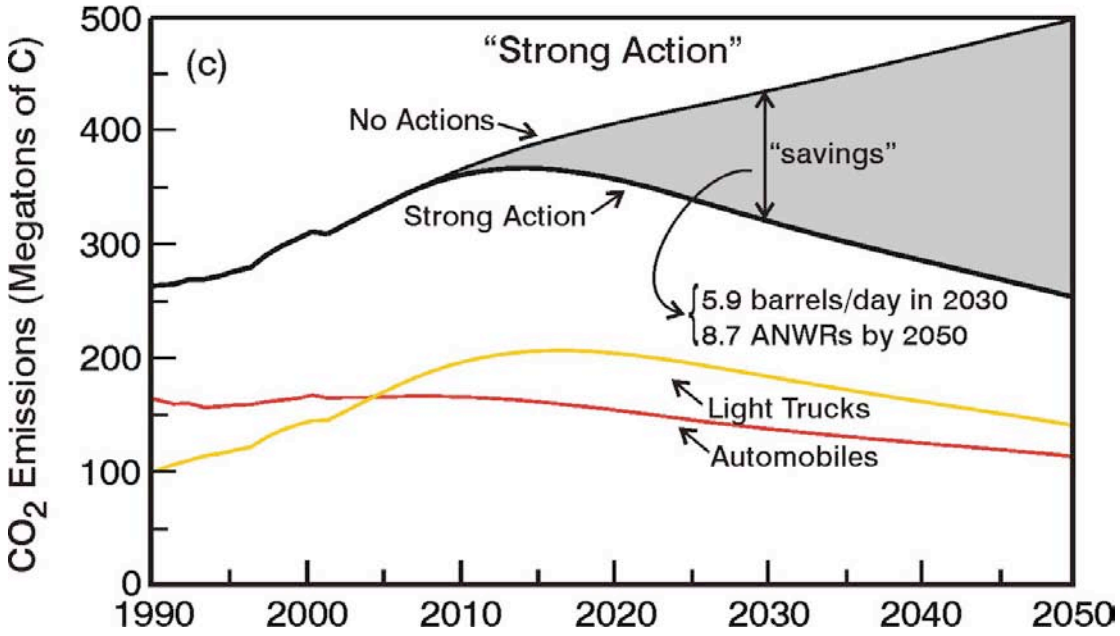


U.S. Auto & Light Truck CO_2 Emissions

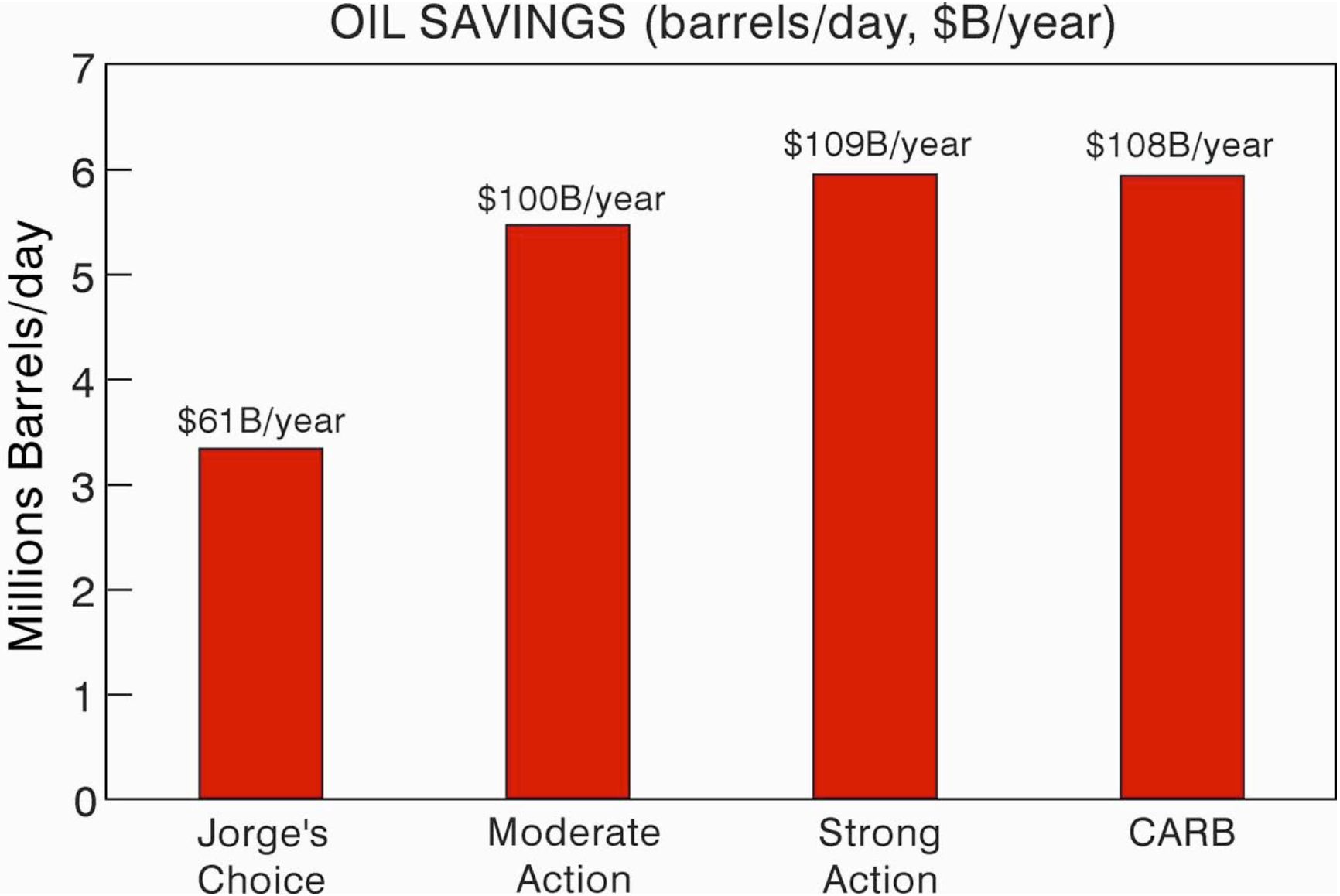
"Moderate Action" is NRC "Path 1.5" by 2015 and "Path 2.5" by 2030.



"Strong Action" adds hydrogen-powered vehicles in 2030 (30% of 2050 fleet).
Hydrogen produced from non-CO_2 sources only.



Source: On the Road to Climate Stability, Hansen, J., D. Cain and R. Schmunk., *to be submitted*.



United States annual savings (at $50/barrel, today's dollars) in 2030 for alternative automotive efficiency improvements.

Source: On the Road to Climate Stability, Hansen, J., D. Cain and R. Schmunk., to be submitted.

Workshop at East-West Center, Honolulu

April 4-6, 2005; Local Host: Intn'l. Center for Climate & Society, Univ. Hawaii

"Air Pollution as Climate Forcing: A Second Workshop"

- **Multiple Benefits by Controlling CH_4 and CO**
  (benefits climate, human health, agriculture)
- **Multiple Benefits from Near-Term Efficiency Emphasis**
  (climate & health benefits, avoid undesirable infrastructure)
- **Targeted Soot Reduction to Minimize Warming from Planned Reductions of Reflective Aerosols**
  (improved diesel controls, biofuels, small scale coal use)
- **Targeted Improvements in Household Solid Fuel Use**
  (reduces CH_4, CO, BC; benefits climate, human health, agriculture)

Conclusion: Technical Cooperation Offers Large Mutual Benefits to Developed & Developing Nations.

References:
- **Air Pollution as Climate Forcing: 2002 Workshop; 2005 Workshop** http://www.giss.nasa.gov/meetings/pollution02/ and 2005/

Summary: Is There Still Time?

Yes, But:

- Alternative Scenario is Feasible, But It Is Not Being Pursued
- Action needed now; a decade of BAU eliminates Alter. Scen.
- Best Hope: Public Must Become Informed and Get Angry