

The Threat to the Planet*
Dark & Bright Sides of Global Warming

Jim Hansen

3 October 2007

presented at conference:

Heating Up the Energy Debate

Gustavus Adolphus College

St. Peter, Minnesota

*Any statements relating to policy are personal opinion

Status of the Matter

1. A Knowledge Gap

- What is Understood (scientists)
- What is Known (public/policymakers)

2. The Climate Crisis

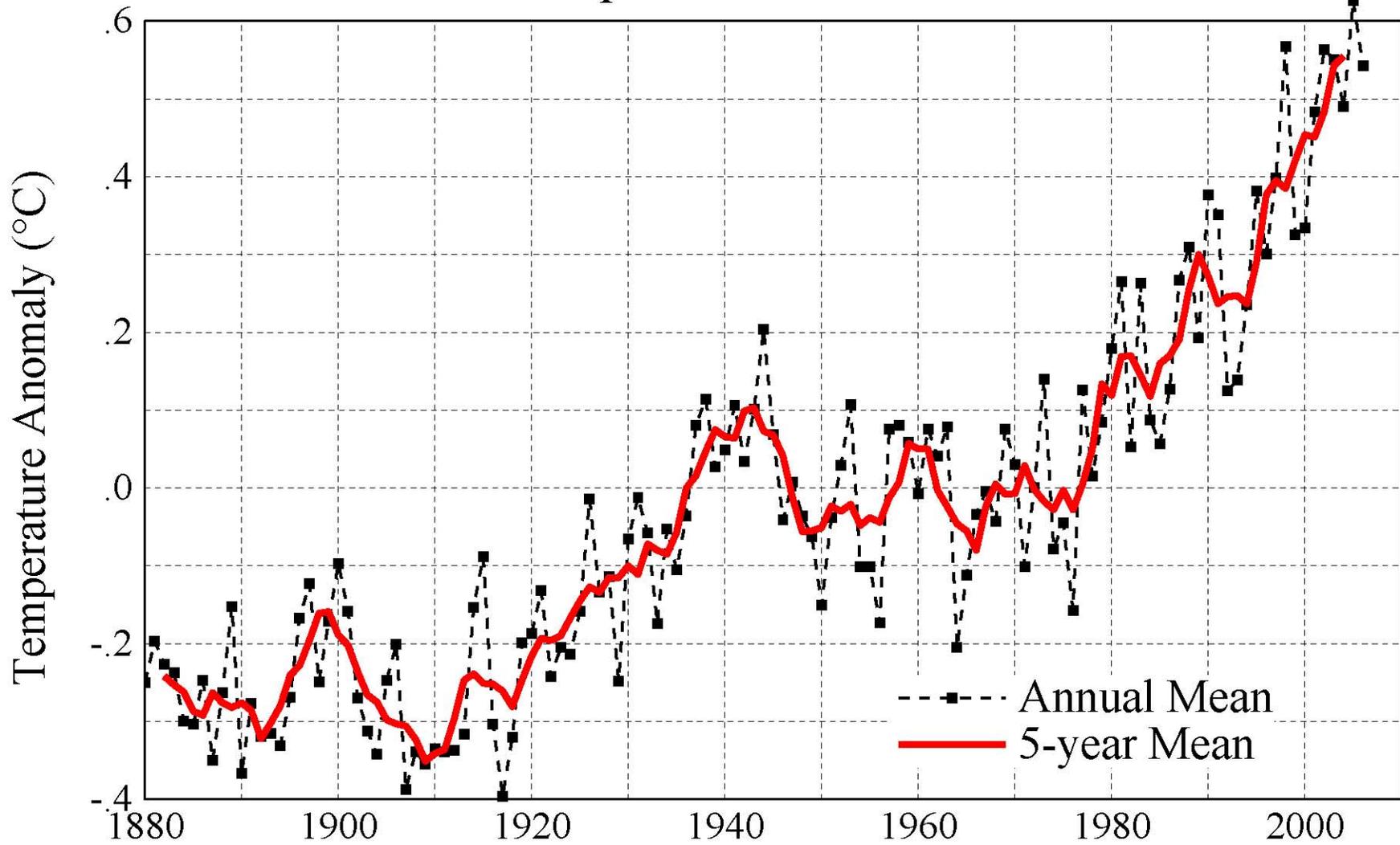
- Climate Inertia → Pipeline Effect
- Positive Feedbacks Predominate

Danger: Tipping Points → Different Planet

3. Good News in Bad News: Opportunity

- CO₂ below 450 ppm technically feasible
- Low CO₂ Limit → less Ocean Acidification
- Fewer Pollutants → + Health, Agriculture
- Special Interests → Need Public's Help!

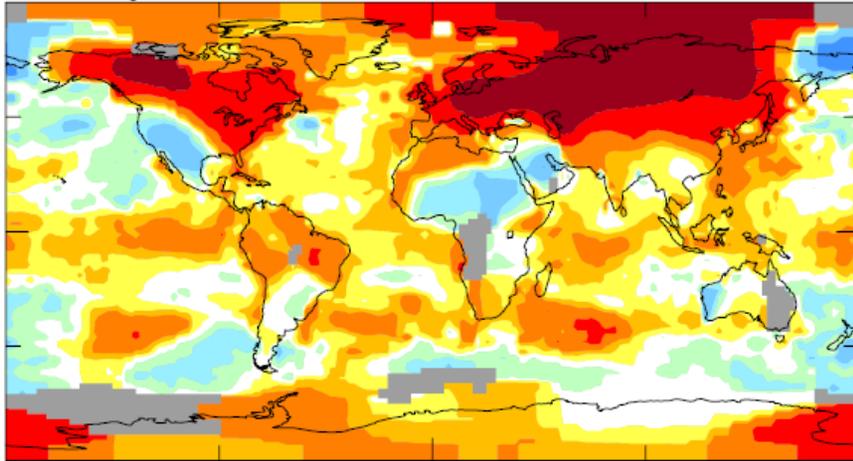
Global Temperature: Land-Ocean Index



2007 Surface Temperature Anomalies (°C) [Base Period 1951-80]

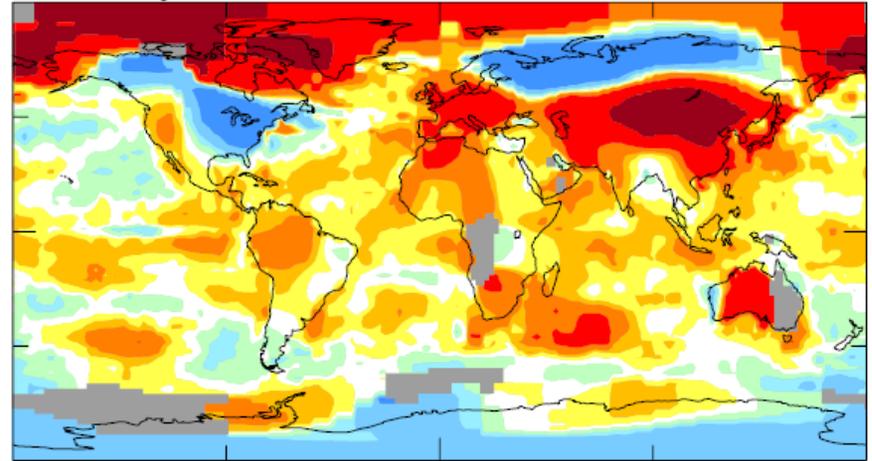
January (#1)

.88



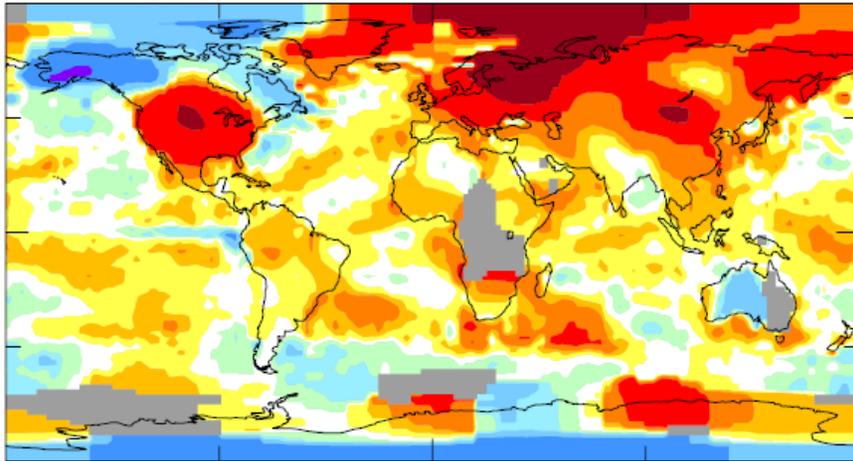
February (#5)

.64



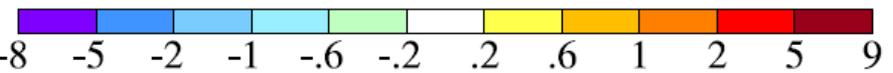
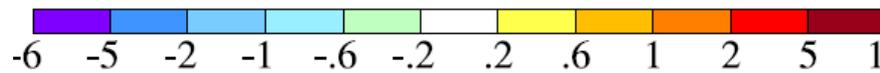
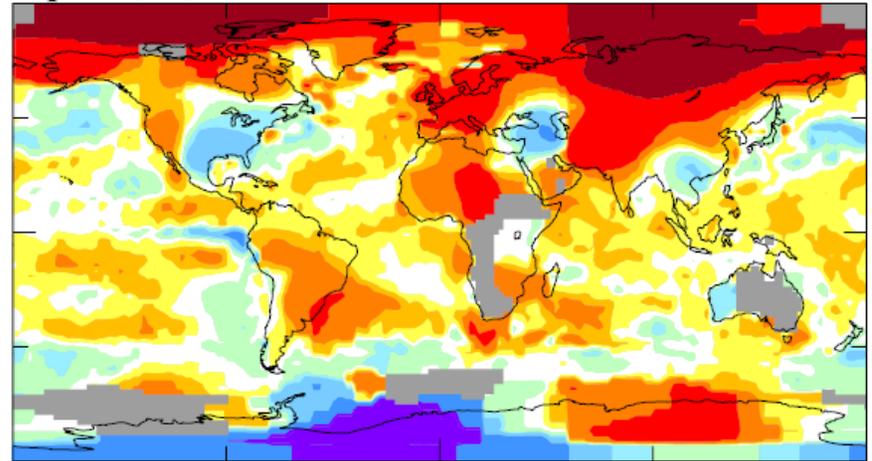
March (#4)

.61

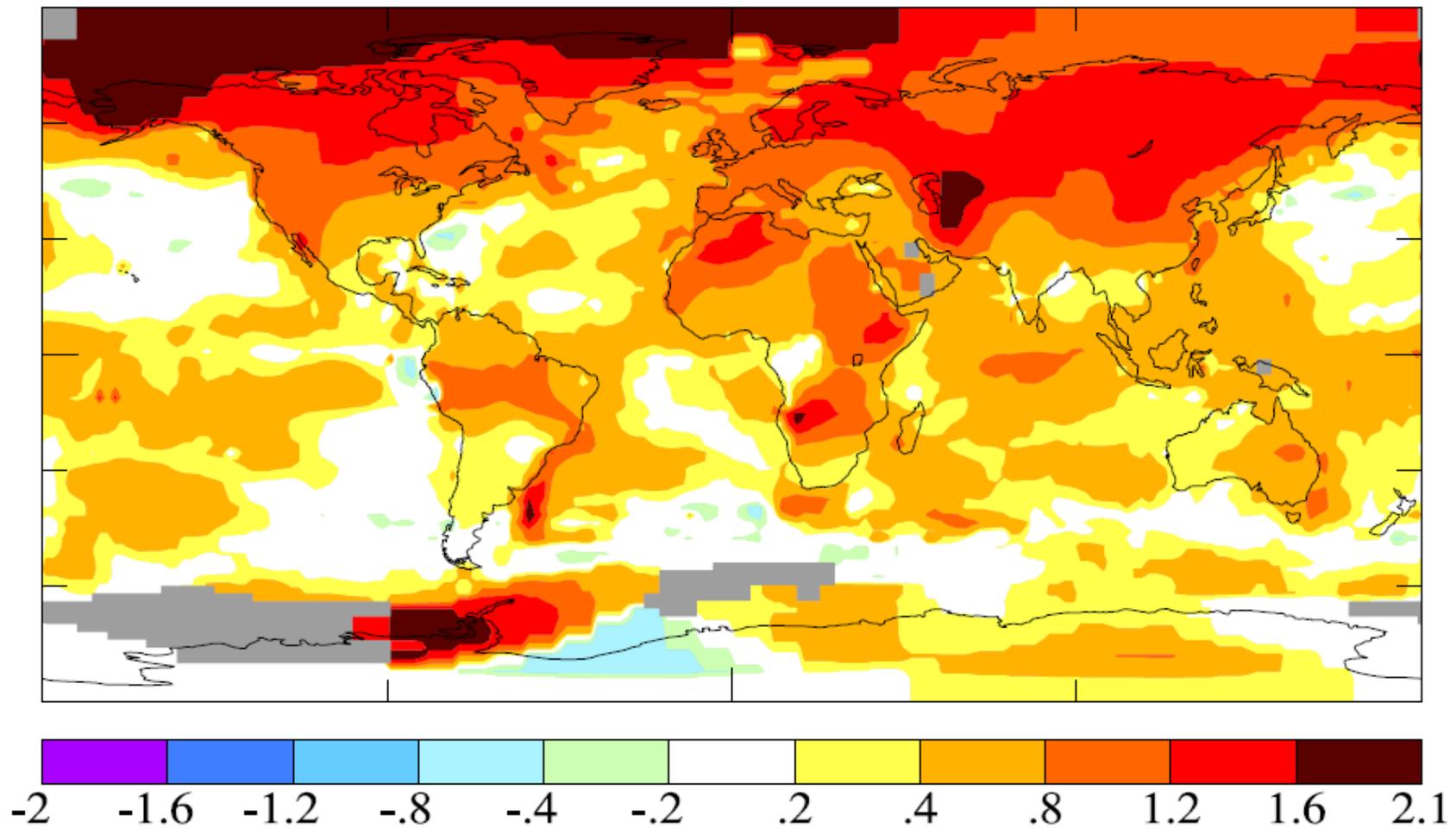


April (#2)

.63



2001-2006 Mean Surface Temperature Anomaly ($^{\circ}\text{C}$)
Base Period = 1951-1980 Global Mean = 0.54



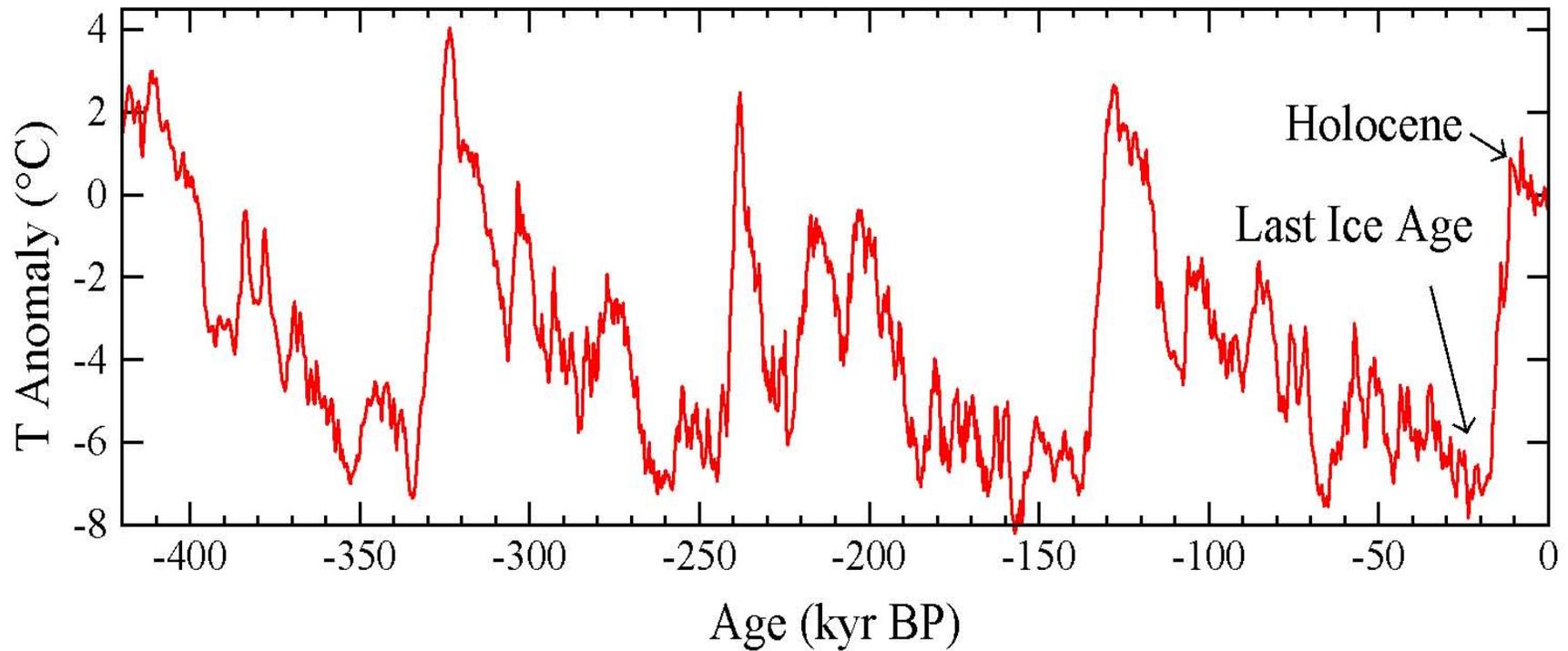
Warming in the Pipeline? Tipping Points?

Isn't this just some sort of "theory"?

Really need to wrestle with warming?

There were huge climate changes in past,
who are we to say present climate is
the best?

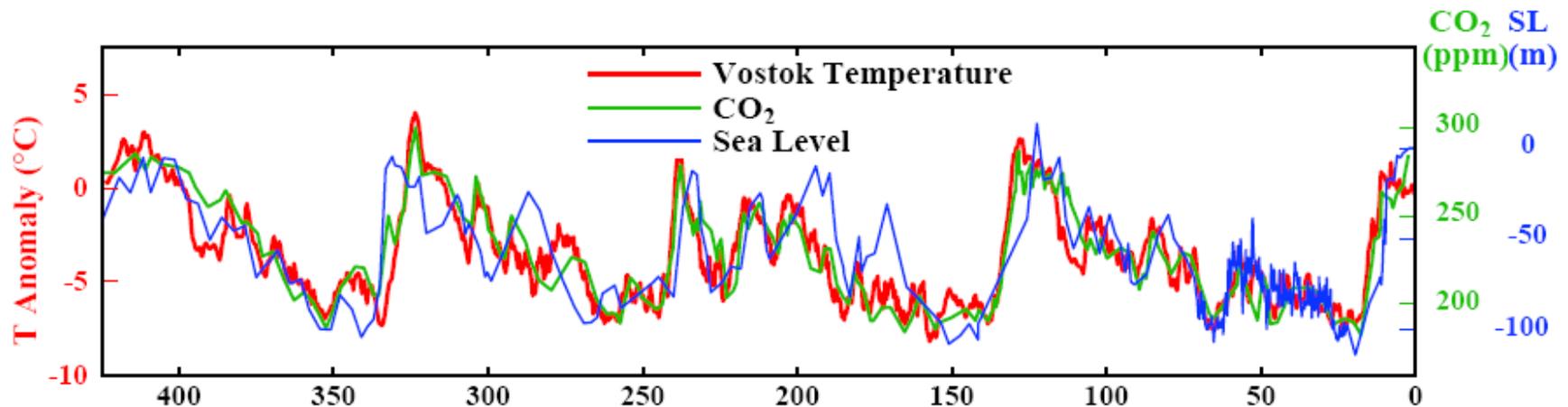
Antarctic (Vostok) Temperature



Earth's history provides most important information on global warming.

Recorded human history occurs within the Holocene warm period.

Temperature, CO₂ and Sea Level



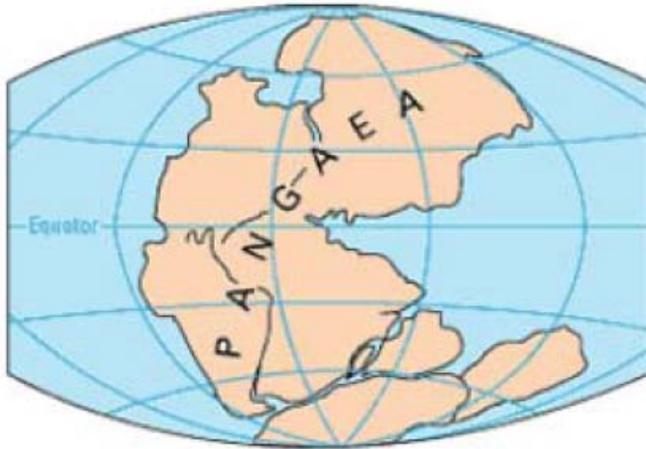
Sea level variations ~400 feet; unusually stable for past 7000 years.

Atmospheric CO₂ variation due to exchange among surface reservoirs.

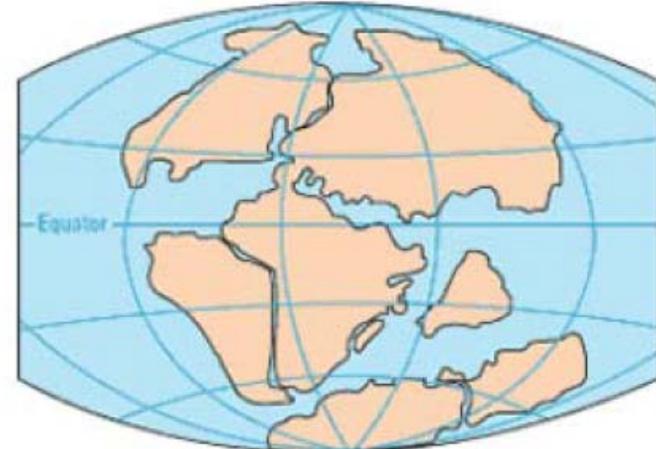
Drive for these large climate change is perturbations of Earth's orbit.

Fig. .3a. "Climate change and trace gases", Hansen et al. Phil. Trans. Roy. Soc. A, 365, 1925, 2007

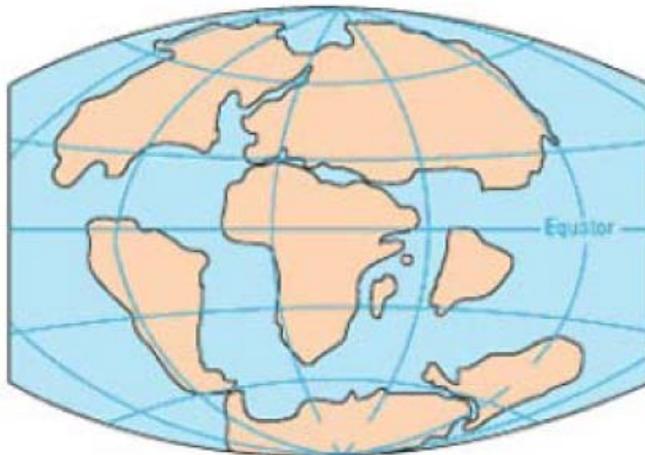
Continental Drift



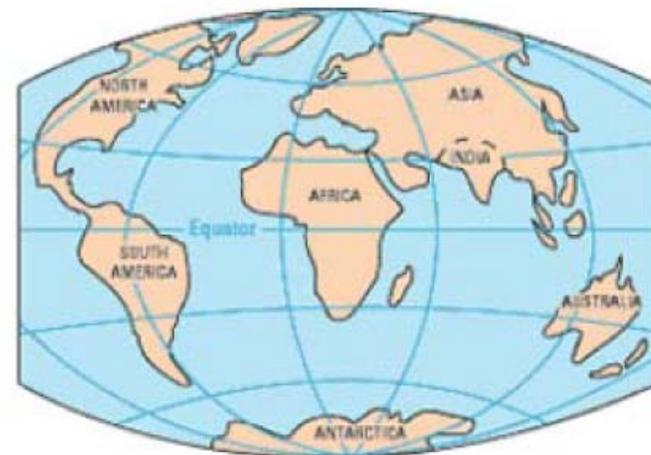
End of Permian (250 My BP)



End of Jurassic (145 My BP)



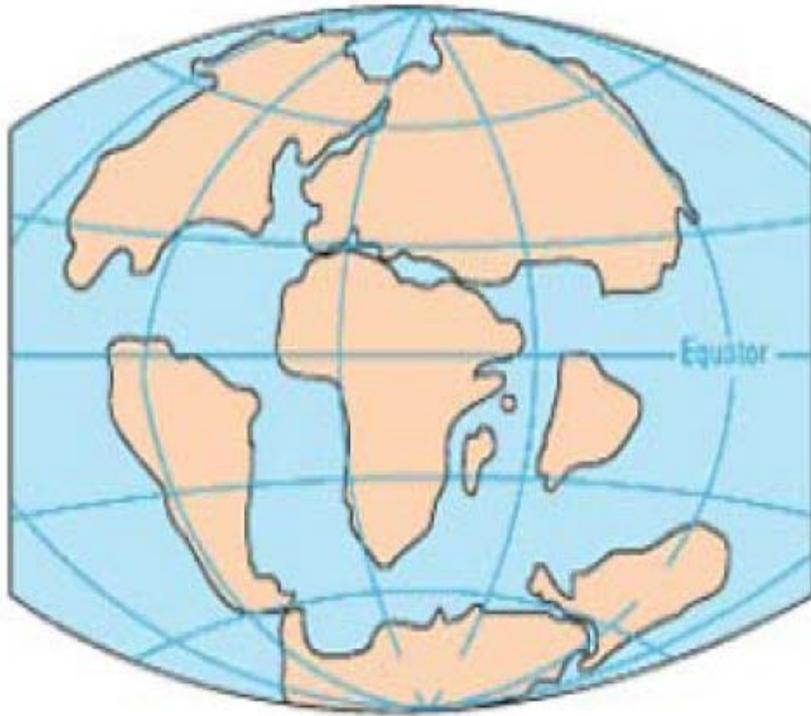
End of Cretaceous (65 My BP)



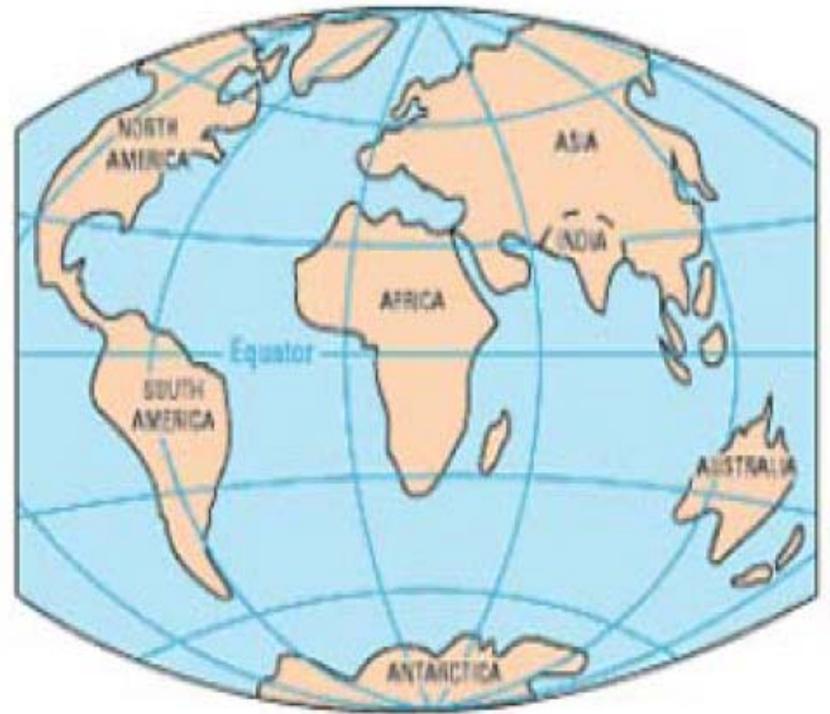
Present Day

Fig. 1 "Global Warming: East-West Connections"(adapted from Keller&Pinter, 1996)

Cenozoic Era



65 Million Years Ago



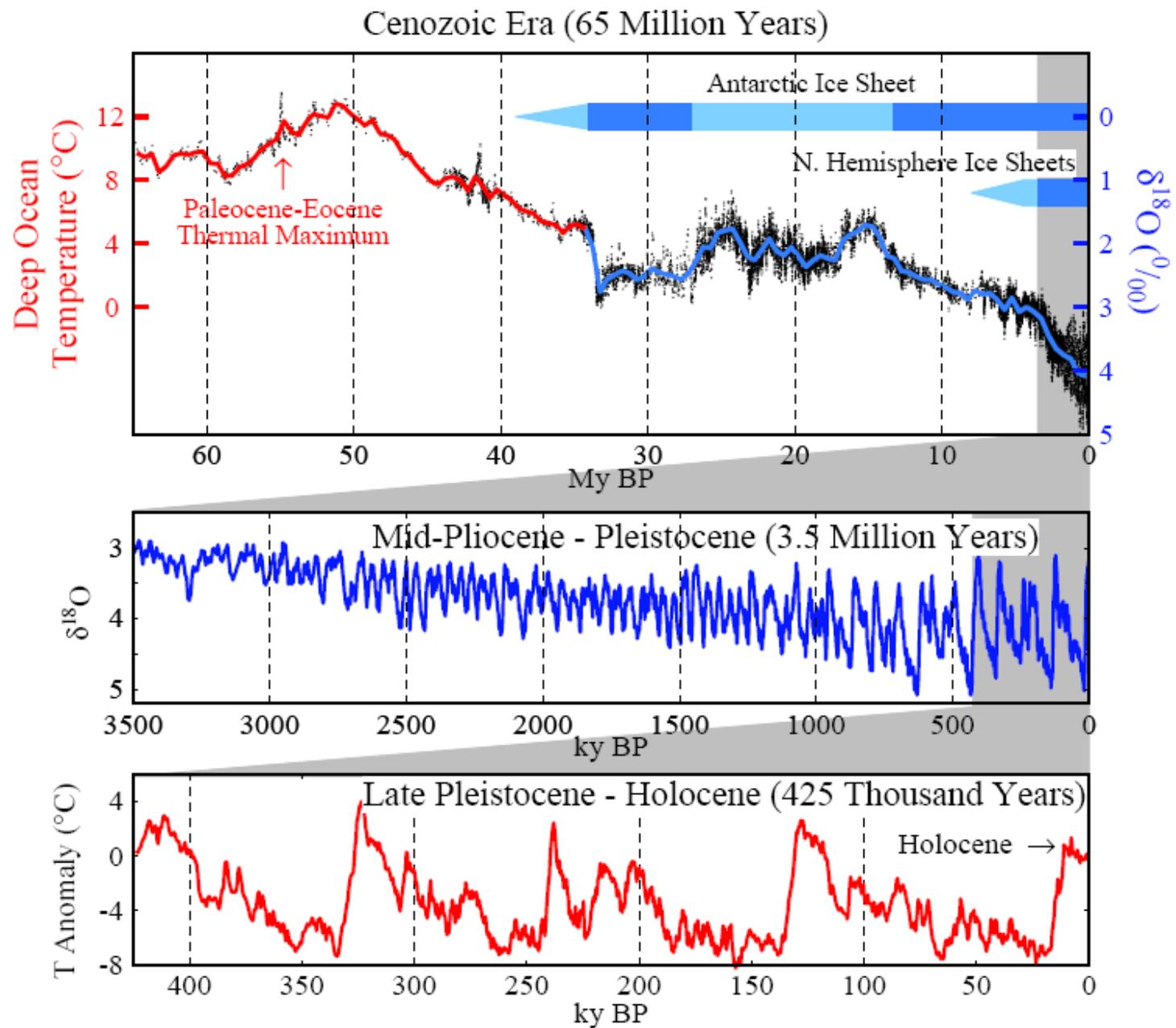
Present Day

Global climate forcings: external, within atmosphere, surface.

External: solar irradiance $+1 \text{ W/m}^2$

Surface: $< \sim 1 \text{ W/m}^2$

CO₂ changes: order of 10 W/m^2



Summary: Cenozoic Era

1. Dominant Forcing: Natural ΔCO_2

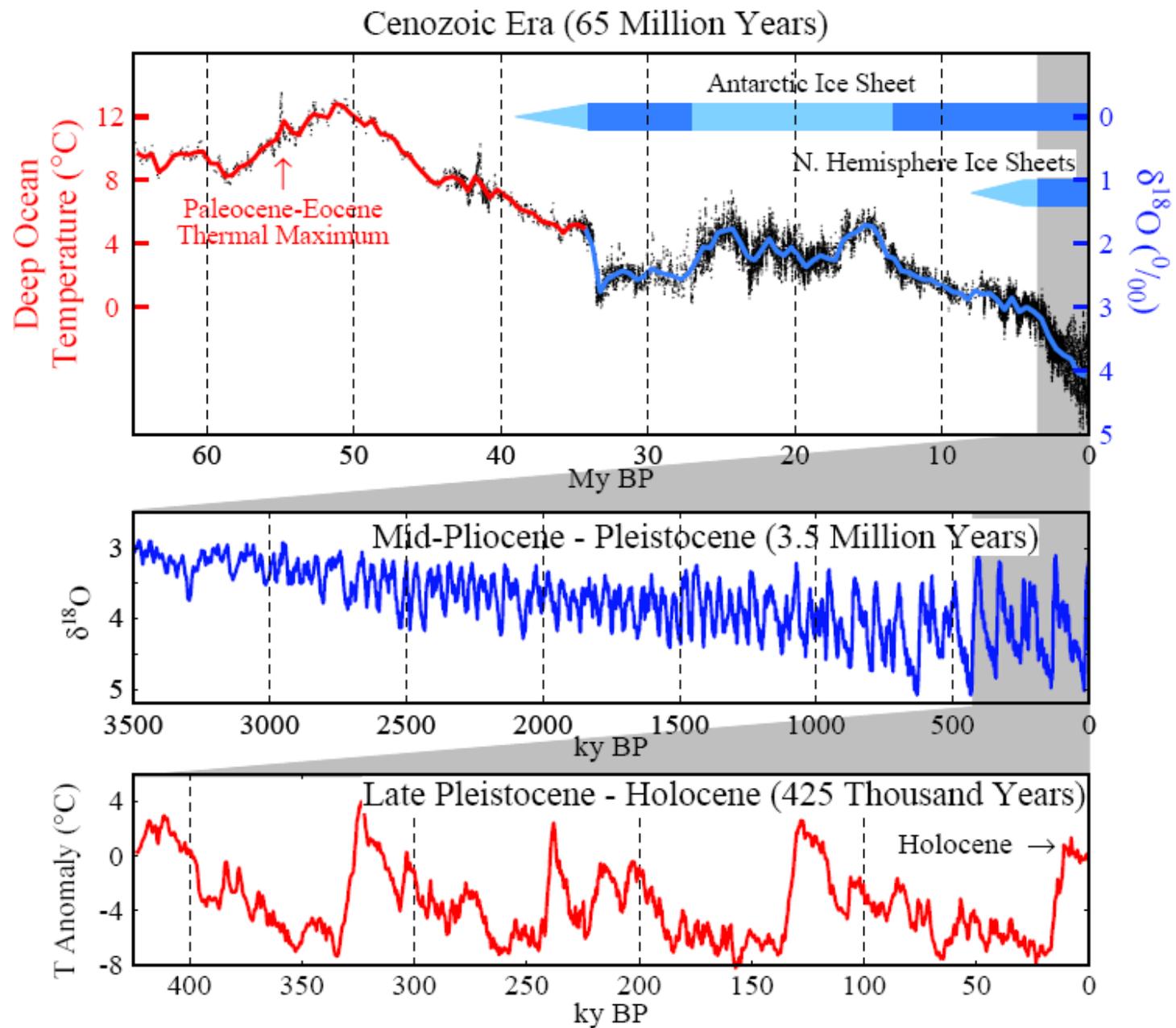
- Rate ~ 100 ppm/My (0.0001 ppm/year)
- Human-made rate today: ~ 2 ppm/year

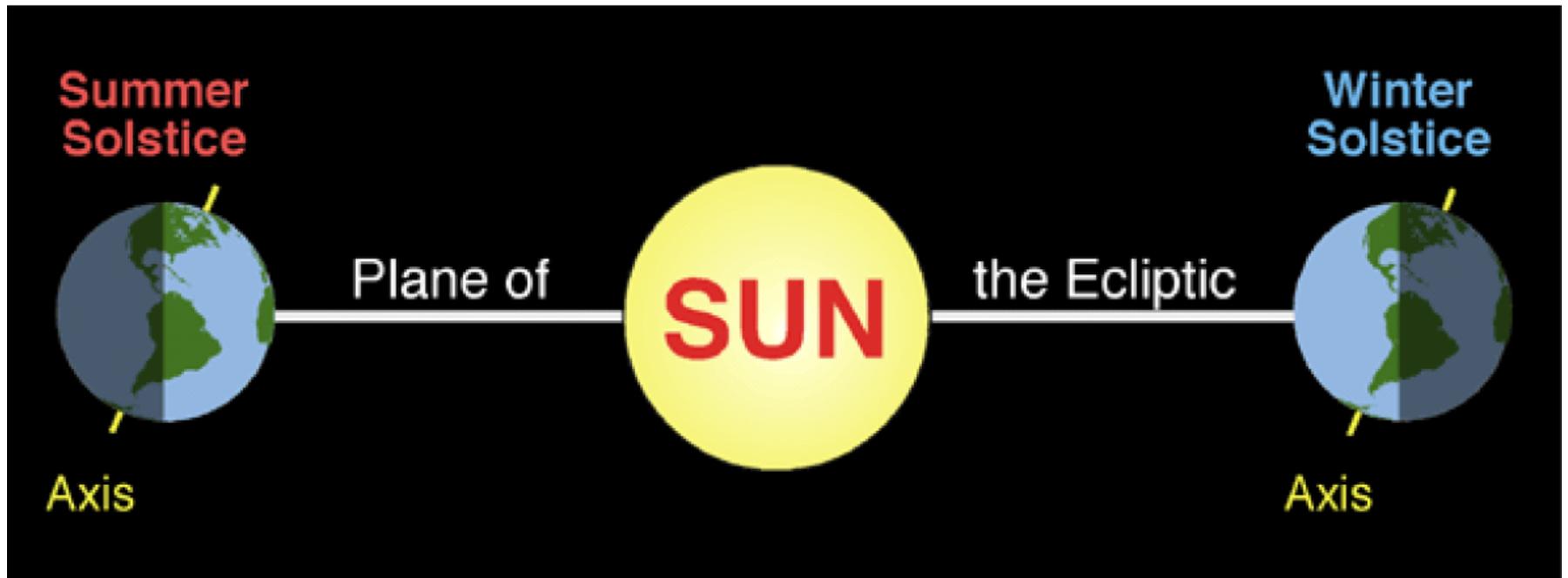
Humans Overwhelm Slow Geologic Changes

2. Climate Sensitivity High

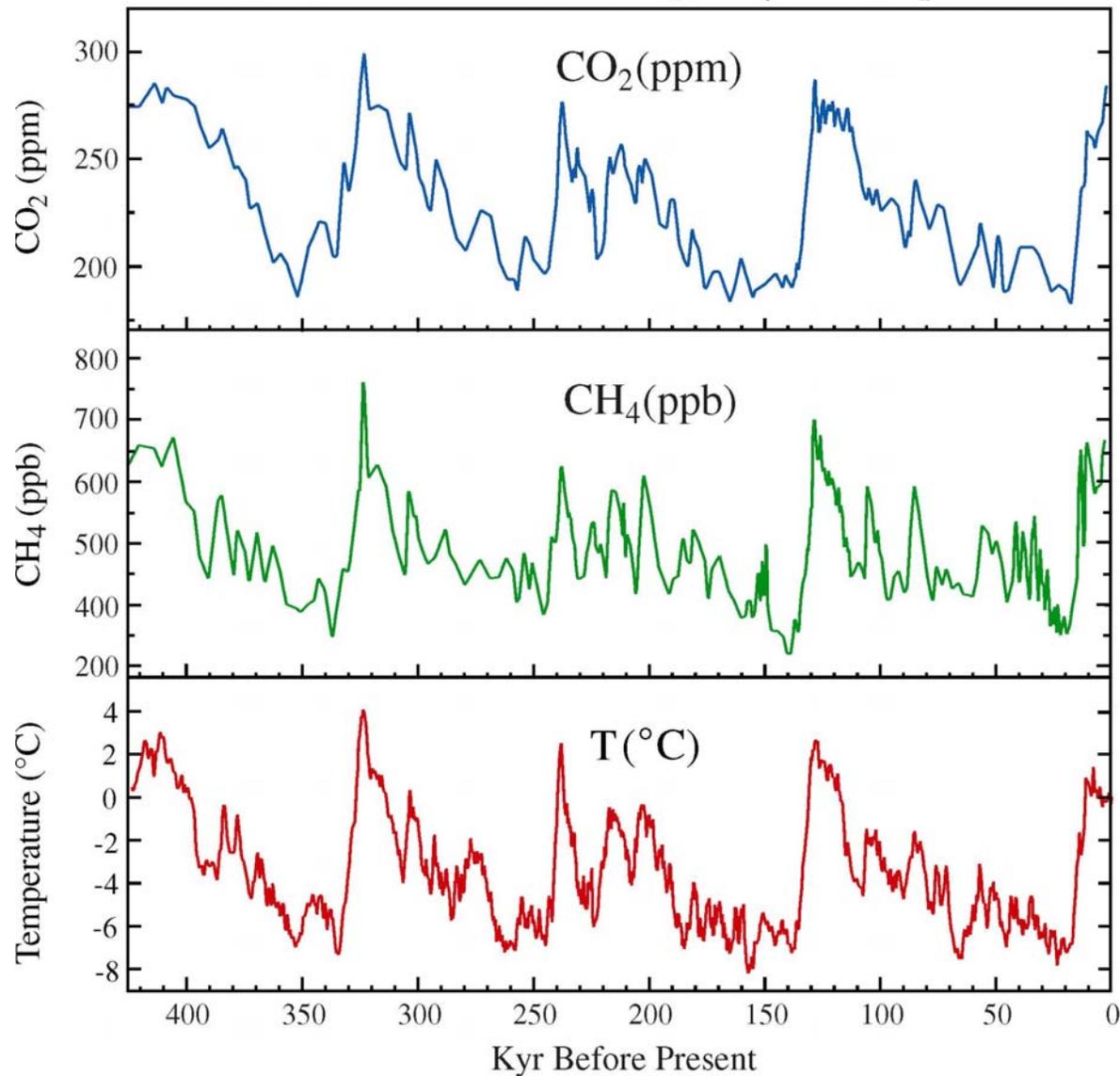
- Antarctic ice forms if $\text{CO}_2 < \sim 500$ ppm
- Ice sheet formation reversible

Human Could Produce “A Different Planet”





Antarctic Time Series for CO₂, CH₄ and Temperature

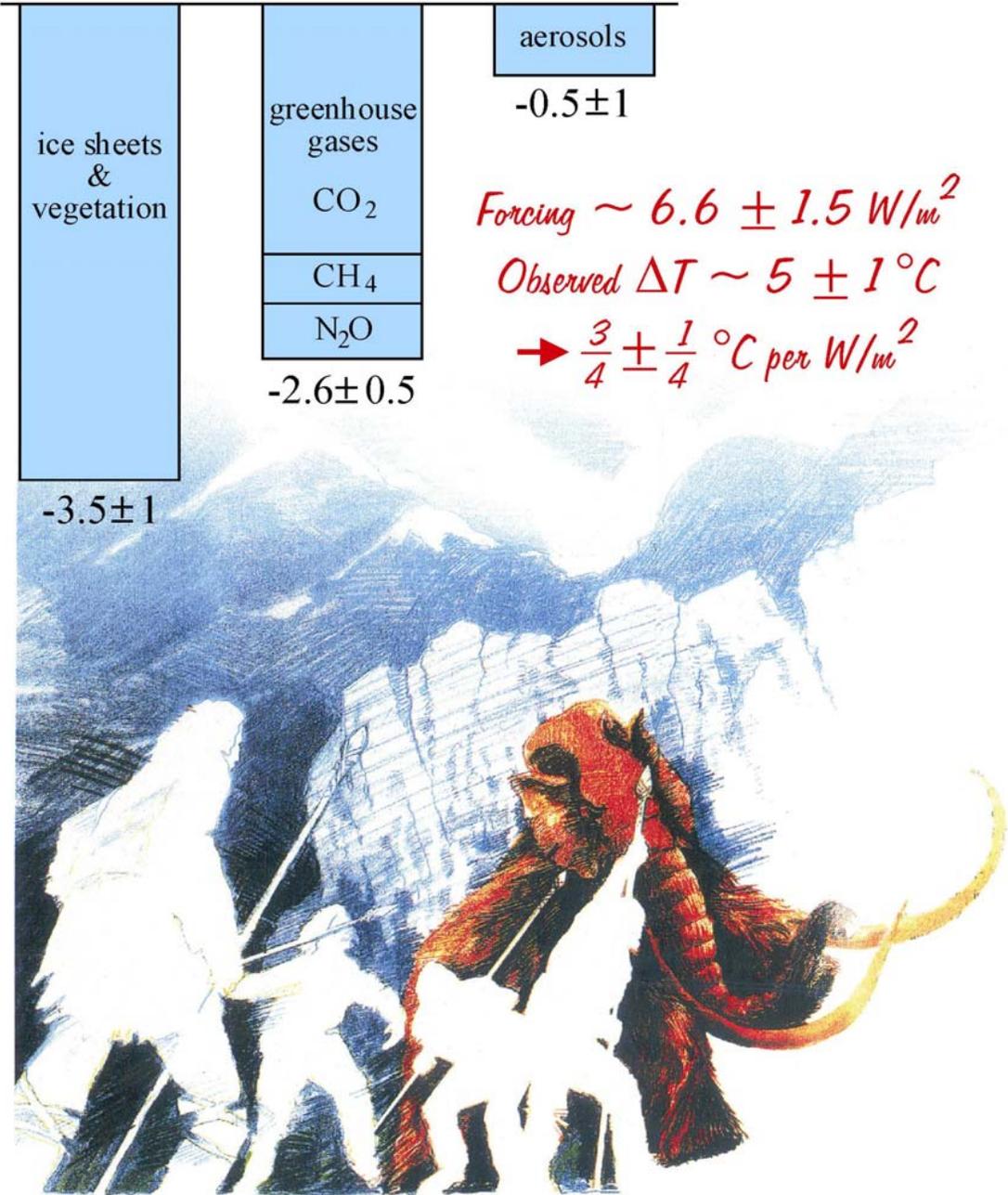


CO₂, CH₄ and temperature records from Antarctic ice core data

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.

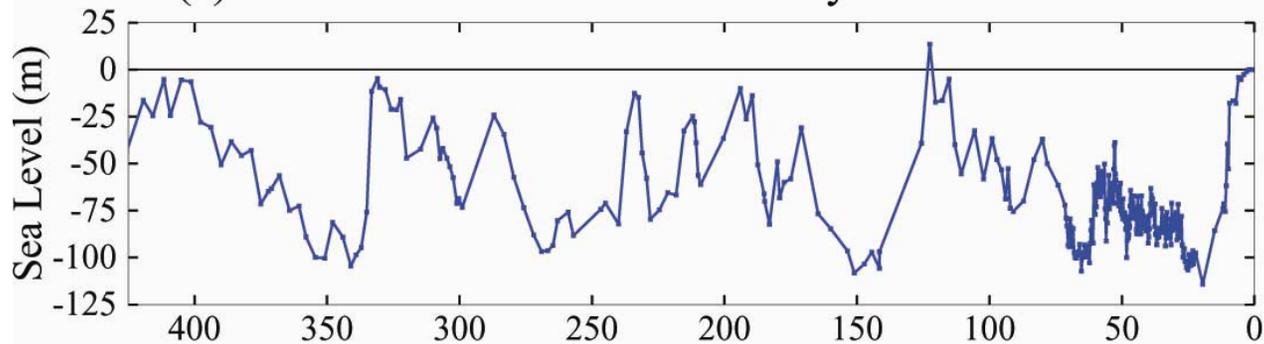
Ice Age Climate Forcings (W/m^2)

Ice Age Forcings
 Imply Global
 Climate Sensitivity
 $\sim \frac{3}{4}^\circ\text{C}$ per W/m^2 .

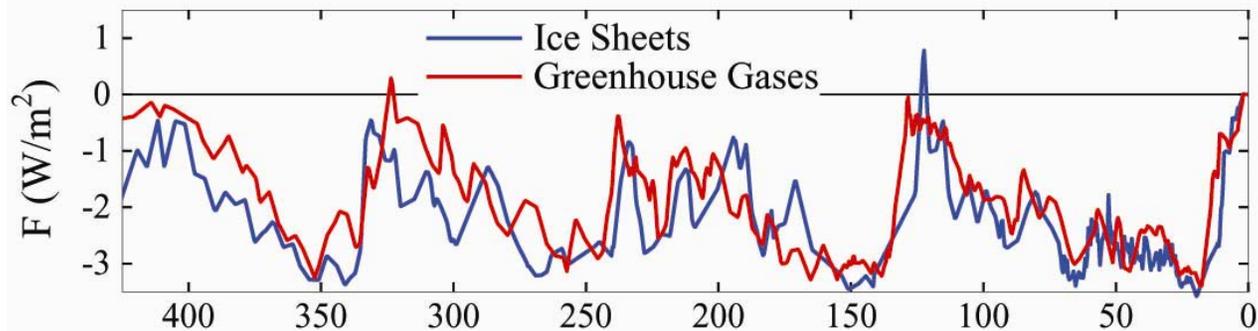


Source: Hansen et al., *Natl. Geogr. Res. & Explor.*, **9**, 141, 1993.

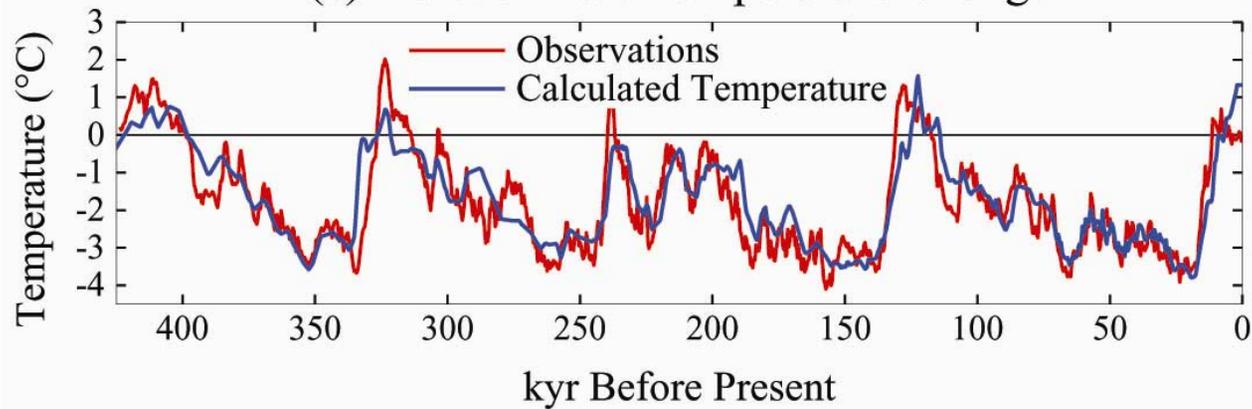
(a) Sea Level from Red Sea Analysis of Siddall et al.



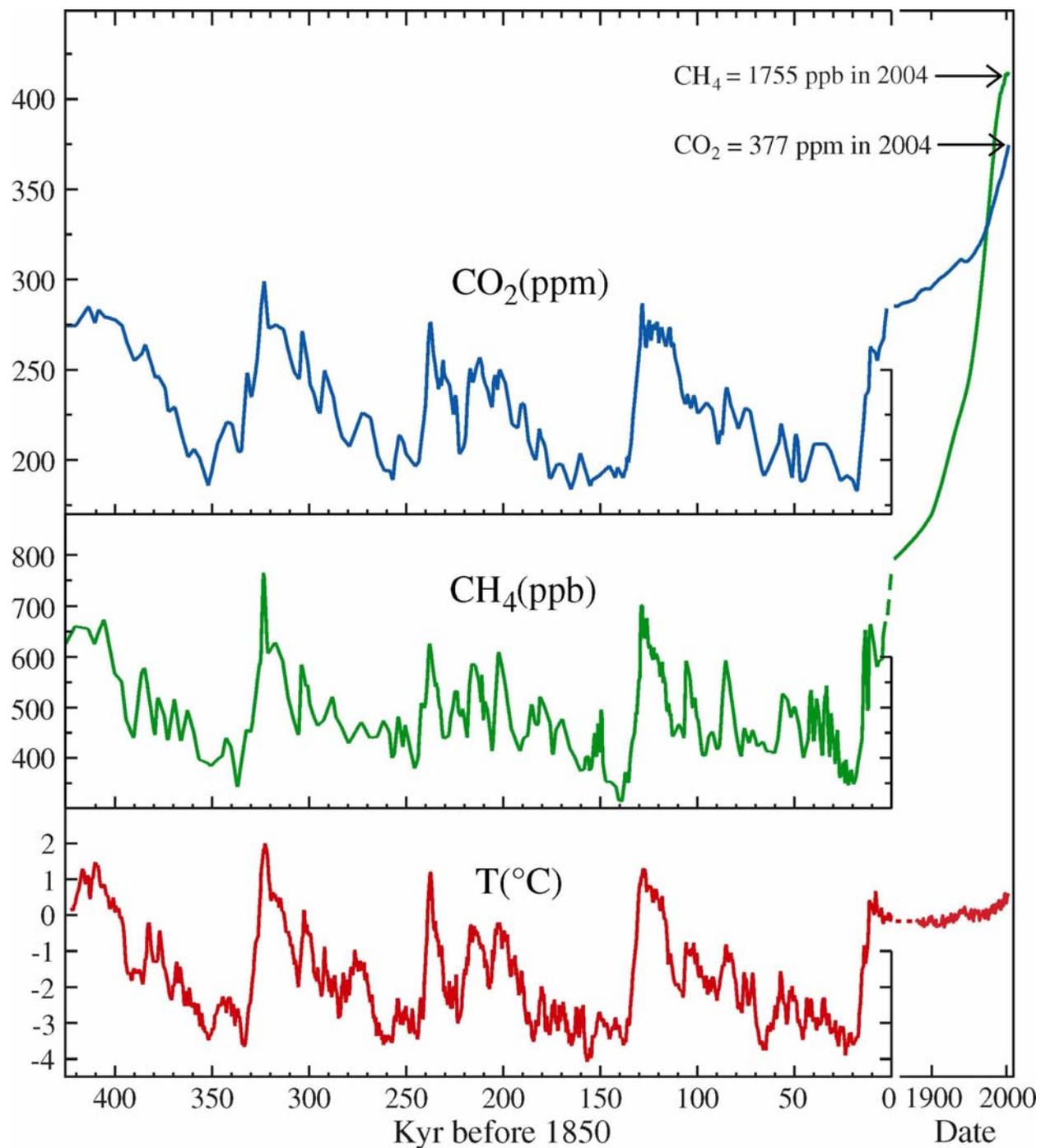
(b) Climate Forcings



(c) Paleoclimate Temperature Change



CO₂, CH₄ and estimated
global temperature
(Antarctic $\Delta T/2$
in ice core era)
0 = 1880-1899 mean.

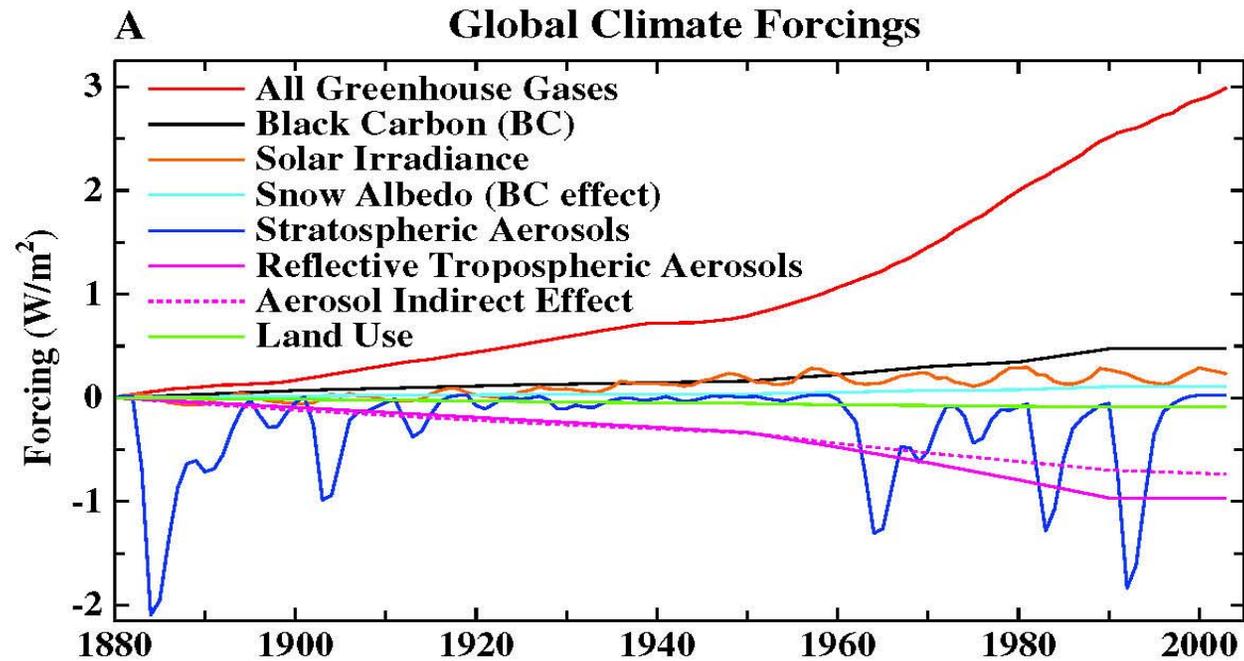


Source: Hansen, *Clim. Change*, **68**, 269, 2005.

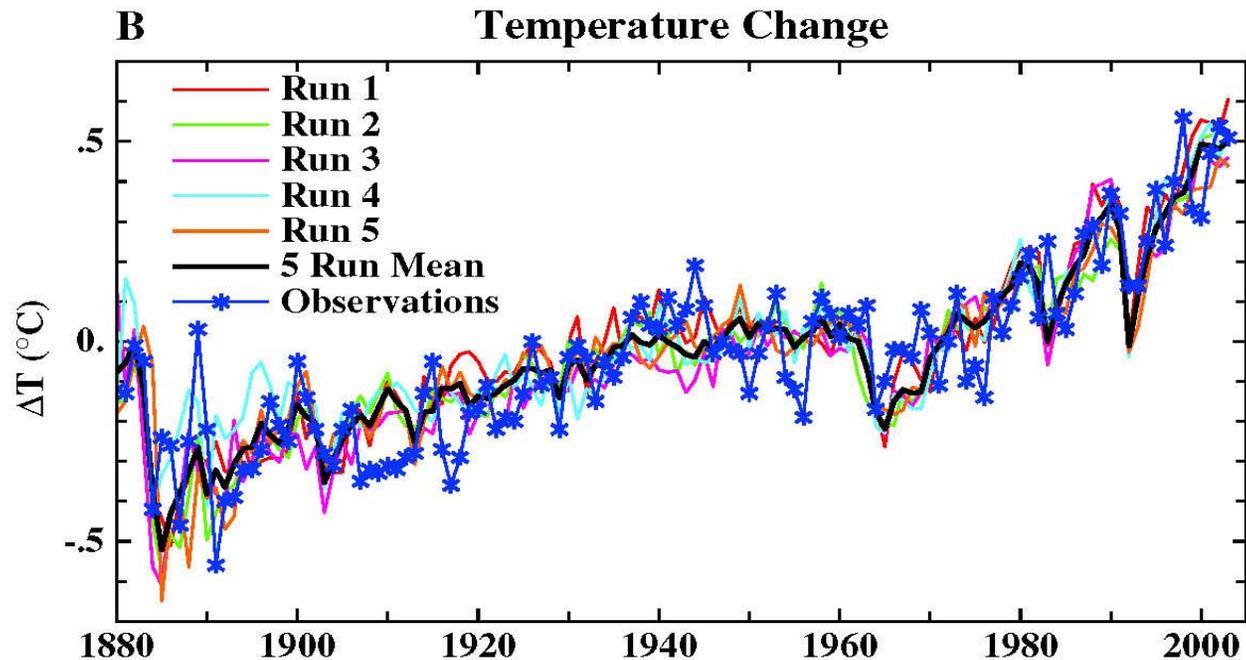
Implications of Paleo Forcings and Response

1. Chief instigator of climate change was earth orbital change, a very weak forcing.
2. Chief mechanisms for paleoclimate change GHGs & ice sheet area, as feedbacks.
3. Climate on long time scales is very sensitive to even small forcings.
4. Human-made forcings dwarf natural forcings that drove glacial-interglacial climate change.
5. Humans now control the mechanisms for global climate change, for better or worse.

(A) Forcings used to drive climate simulations.

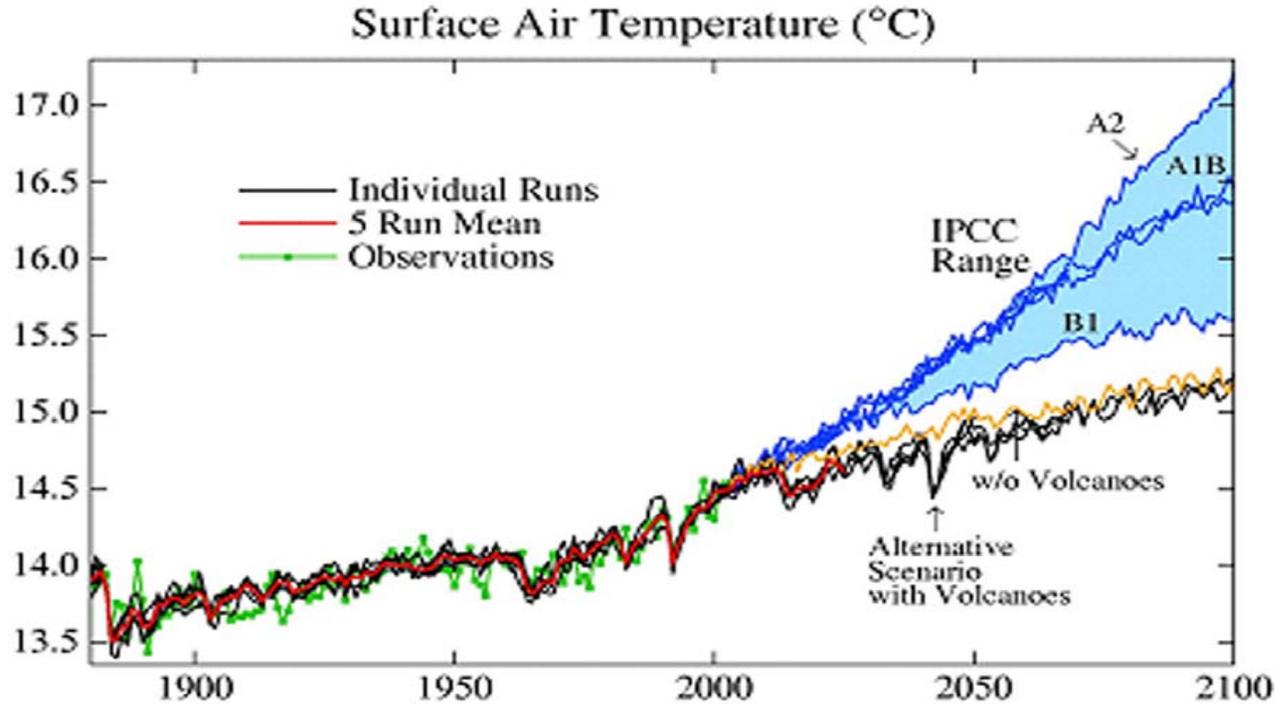


(B) Simulated and observed surface temperature change.



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 2.7-2.9°C for 2xCO₂**
(consistent with paleoclimate data & other models)
- ▶ **Simulations Consistent with 1880-2003 Observations**
(key test = ocean heat storage)
- ▶ **Simulated Global Warming < 1°C in Alternative Scenario**

Conclusion: Warming < 1°C 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.”

Metrics for “Dangerous” Change

Ice Sheet Disintegration: Global Sea Level

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

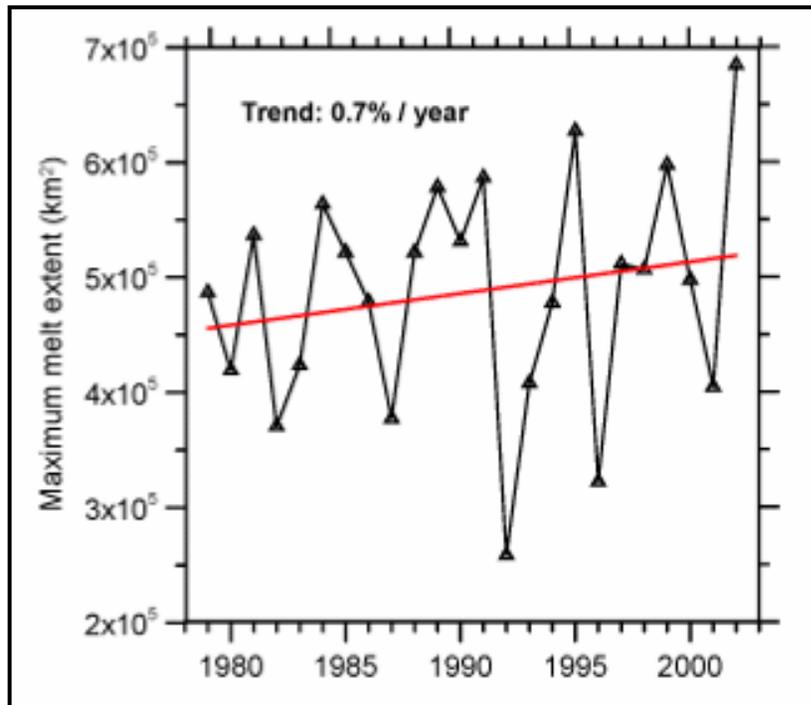
Extermination of Animal & Plant Species

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

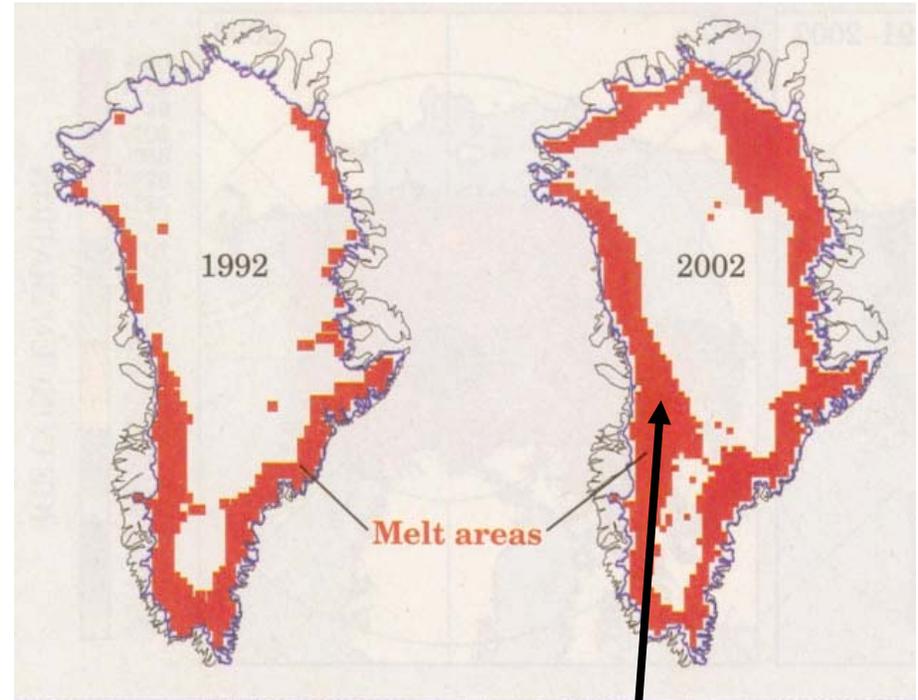
Regional Climate Disruptions

- 1. Increase of Extreme Events**
- 2. Shifting Zones/Freshwater Shortages**

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

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)*

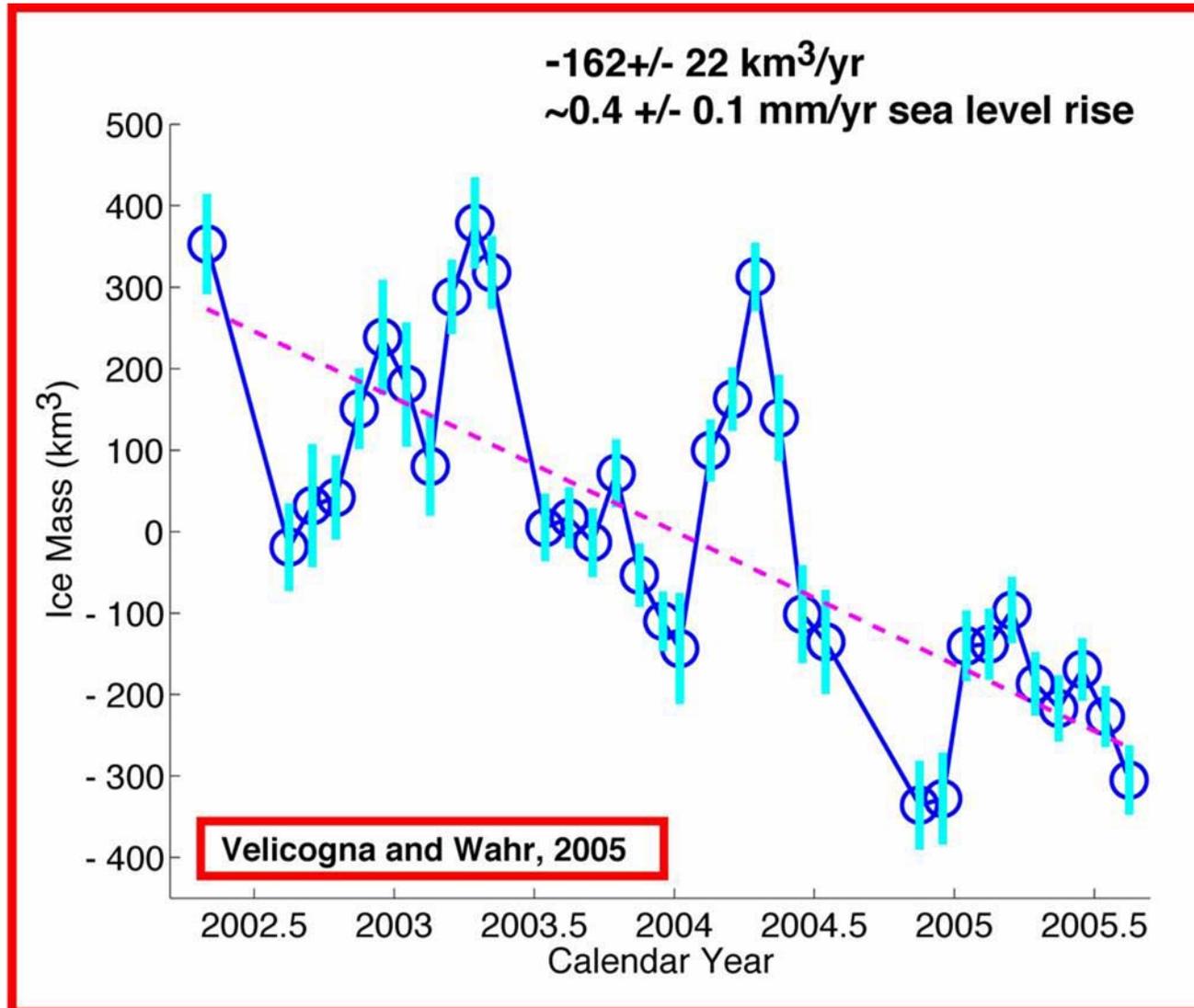
Jakobshavn Ice Stream in Greenland

Discharge from major Greenland ice streams is accelerating markedly.



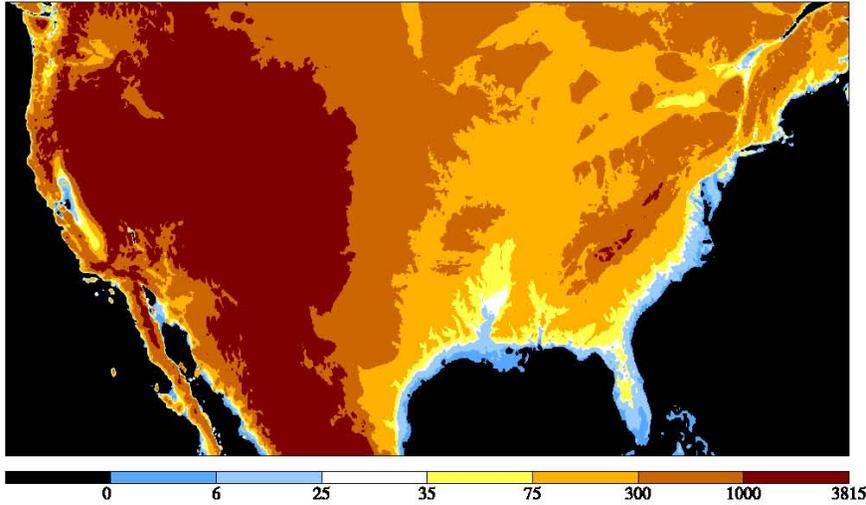
*Source: Prof. Konrad Steffen,
Univ. of Colorado*

Greenland Mass Loss – From Gravity Satellite

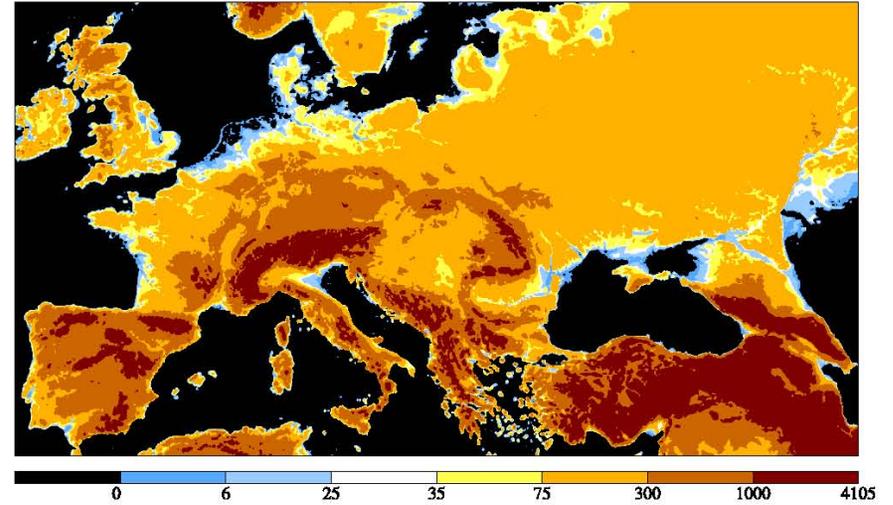


Areas Under Water: Four Regions

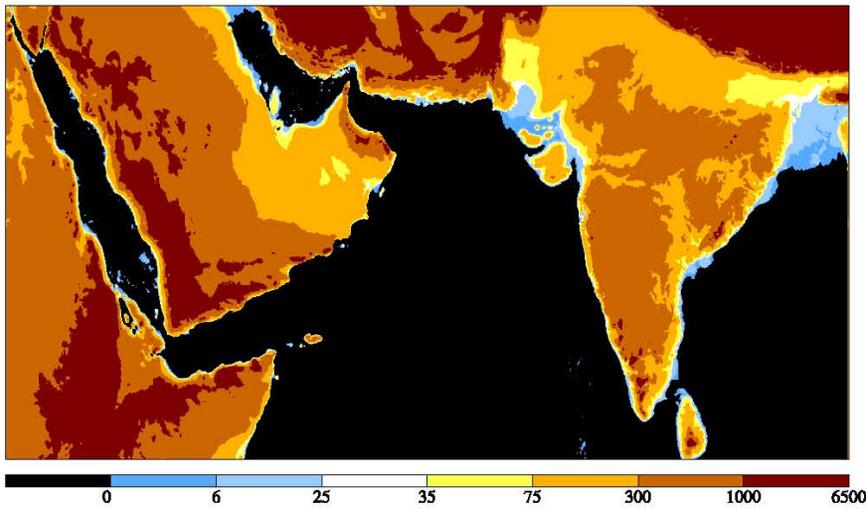
U.S. Area Under Water



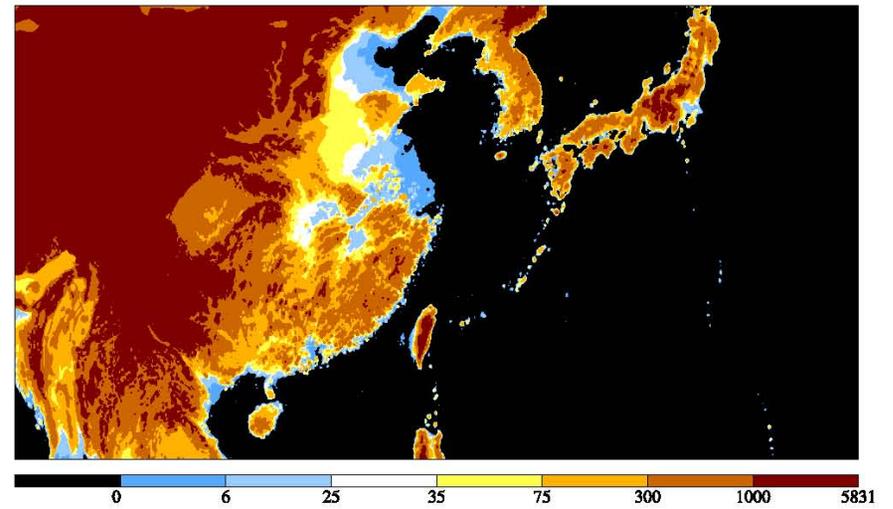
Europe Area Under Water



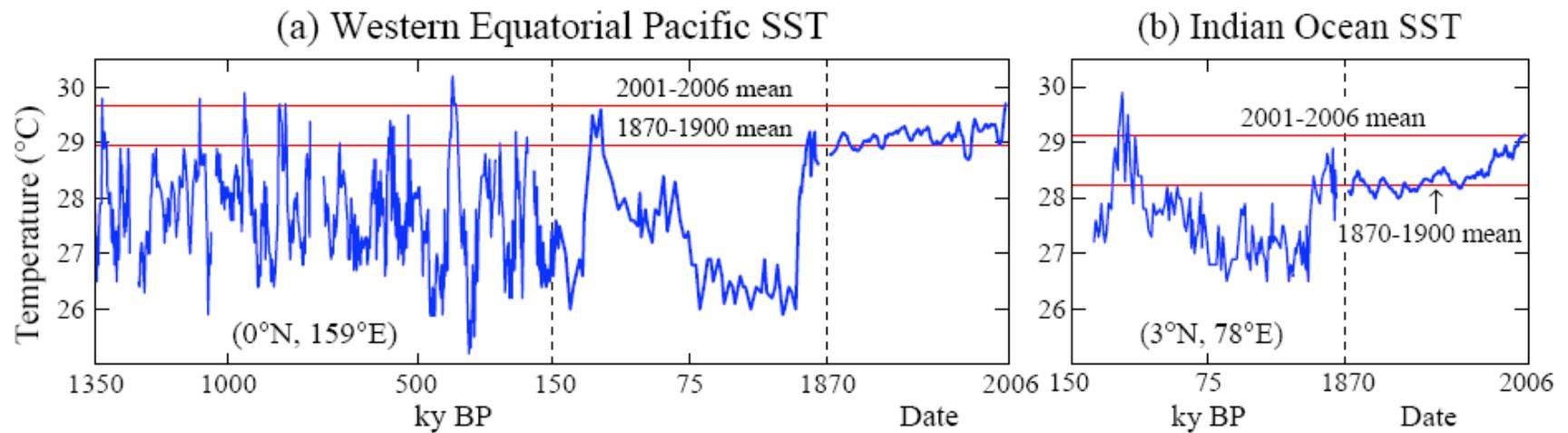
Central Asia: Area under Water



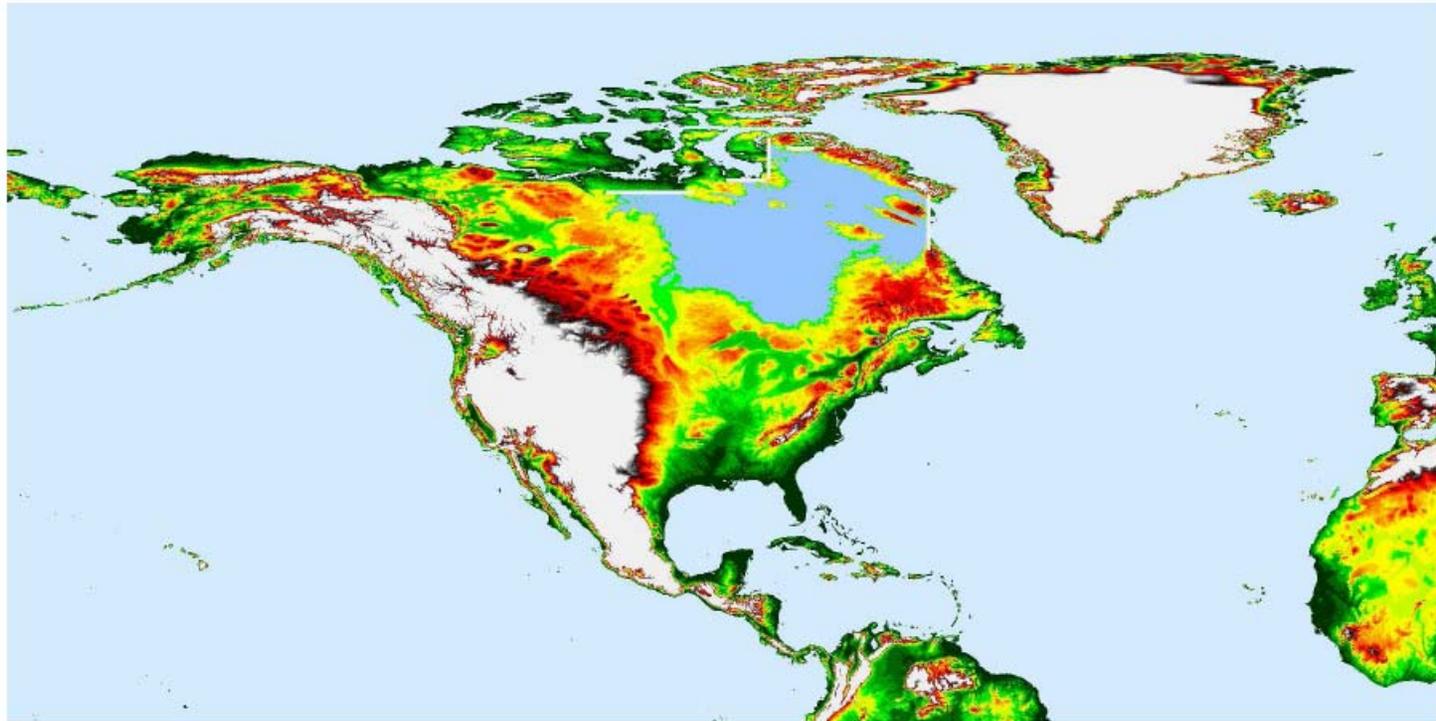
Far East: Area under Water



Paleo and Modern Temperatures in Critical Global Regions



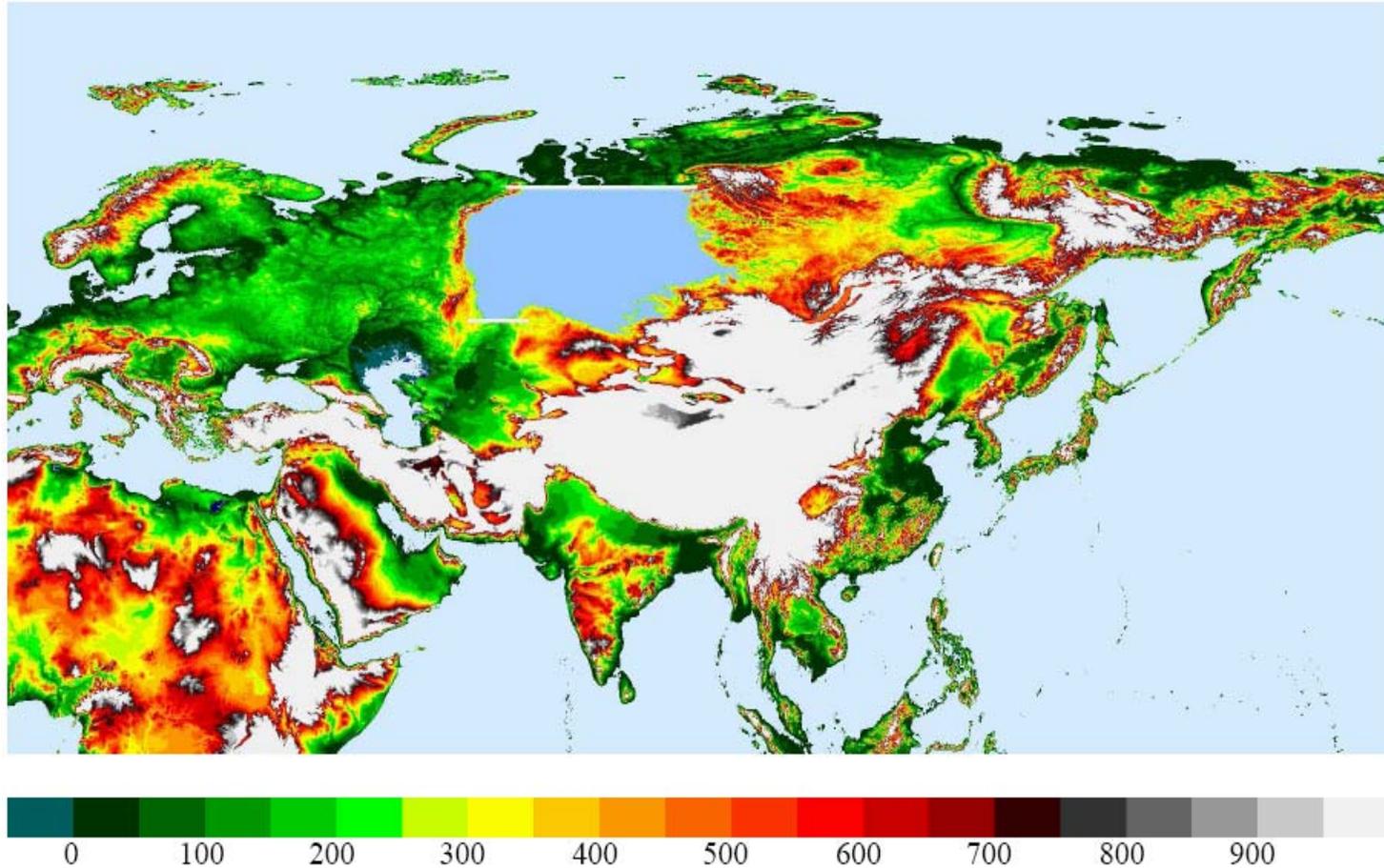
Lake Wobegone



Lake level 200.0 m. Area flooded $2.54 \times 10^{12} \text{ m}^2$. Volume $3.69 \times 10^{14} \text{ m}^3$. Sea level equiv. 1.023 m

Lake from indicated 200-meter high dams holds 1 meter sea level

Lake Wobegone II



Lake level 242.0 m. Area flooded $2.72e+12$ m². Volume $3.62e+14$ m³. Sea level equiv. 1.002 m

Lake from indicated 242-meter high dams holds 1 meter sea level

Arctic Change:

Future loss of Arctic sea ice could result in a loss of 2/3 of the world's polar bears within 50 years.

*Source: U.S. Geological Survey
www.usgs.gov/newsroom/pecial/polar%5Fbears/*

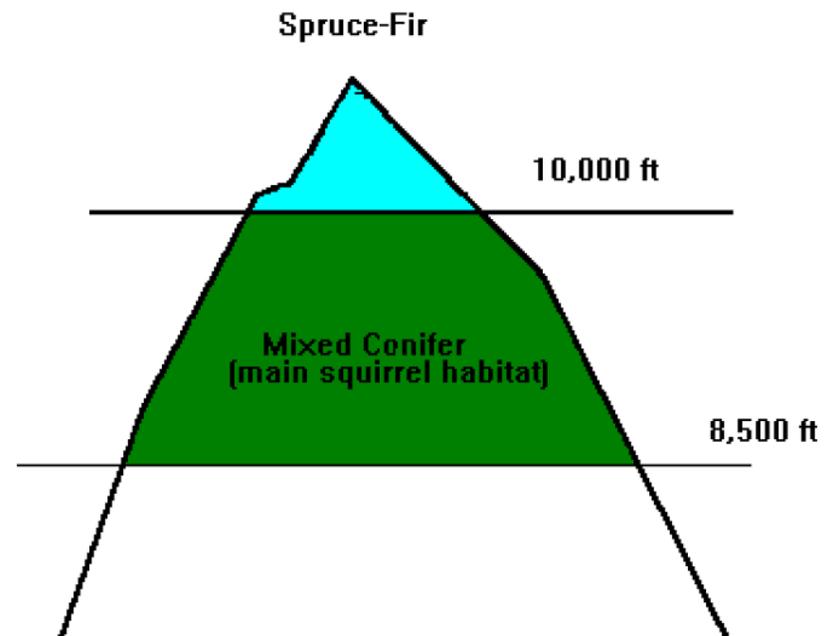
*Images:
Sea Ice: Claire Parkinson & Robert Taylor
Polar Bears: Unknown*



Mt. Graham Red Squirrel



Mount Graham Red Squirrel (Credit: Claire Zugmeyer)



Survival of Species

1. “Business-as-Usual” Scenario

- Global Warming ~ 3°C
- Likely Extinctions ~25-50 percent

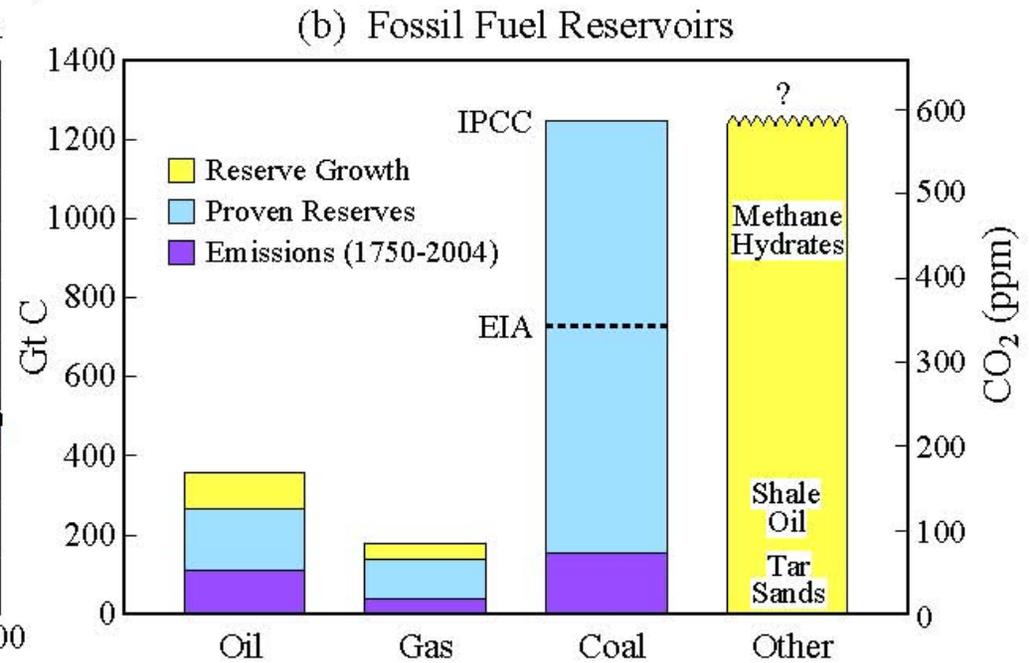
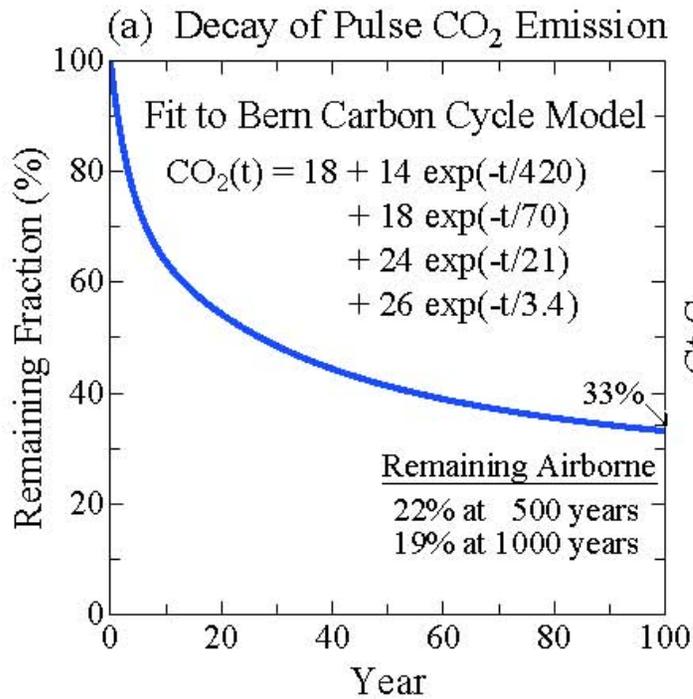
2. “Alternative” Scenario

- Global Warming <1°C
- Likely Extinctions <10 percent

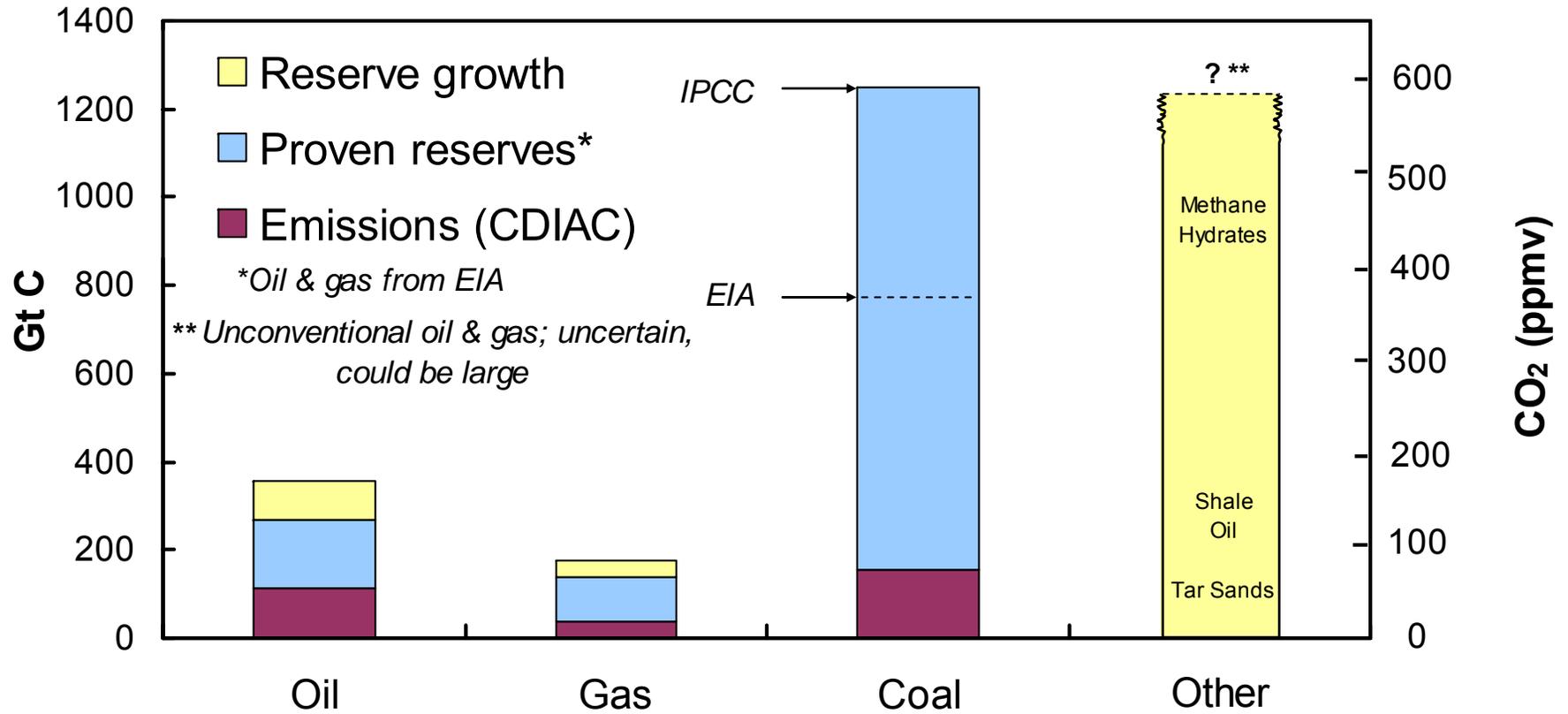
How Many Species to Survive Bottleneck?

Climate Feedbacks → Scenario Dichotomy

Carbon Cycle Constraints



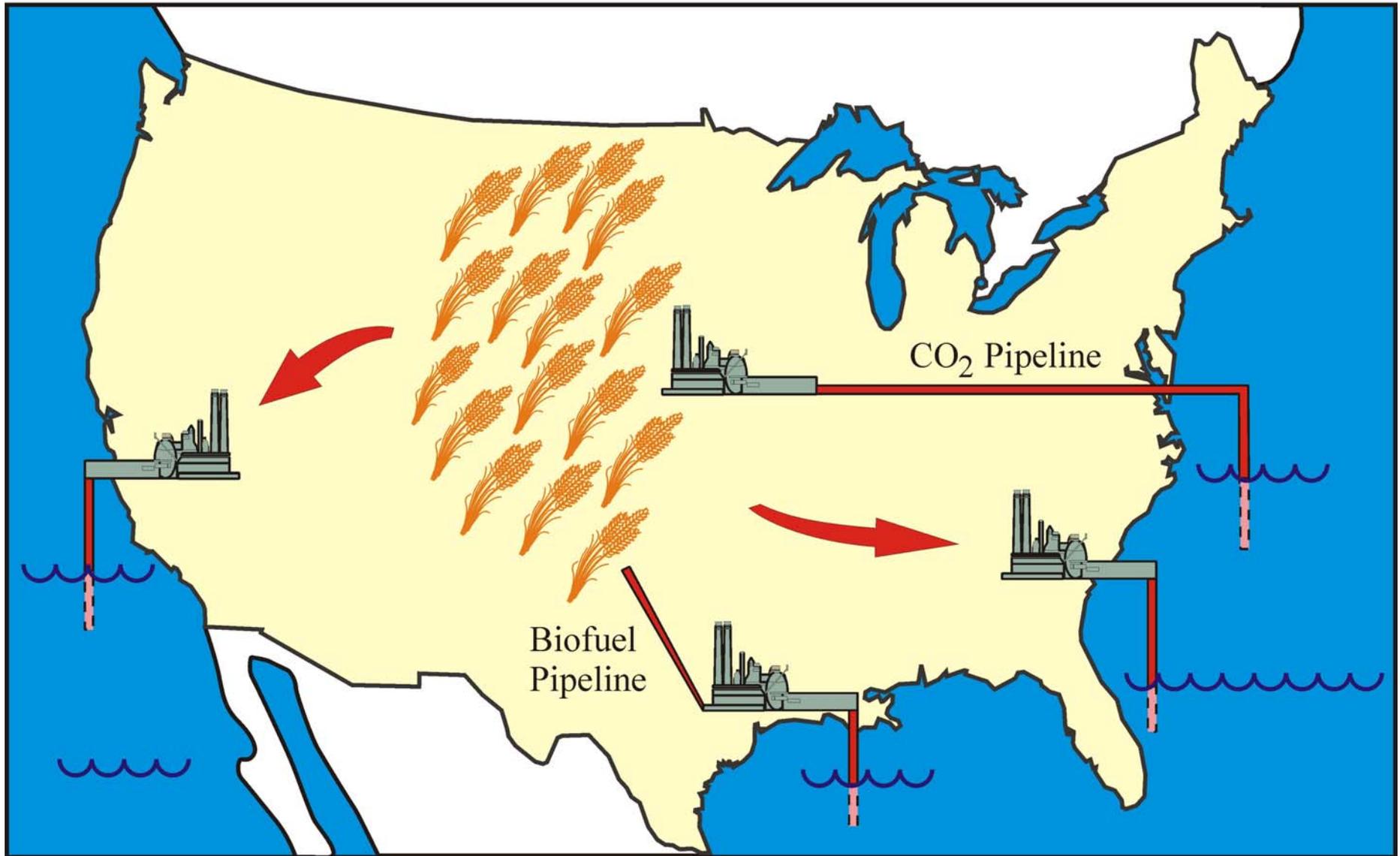
Fossil Fuel Reservoirs and 1750–2004 Emissions



Outline of Solution

- 1. Coal only in Powerplants w Sequestration**
Old Technology 'Bulldozed' in Decades
 - 2. Stretch Conventional Oil & Gas**
Via Incentives (Cap or Tax) & Standards
No Unconventional F.F. (Tar Shale, etc.)
-
- 3. Reduce non-CO₂ Climate Forcings**
Methane, Black Soot, Nitrous Oxide
 - 4. Draw Down Atmospheric CO₂**
Agricultural & Forestry Practices
Biofuel-Powered Power-Plants

Biofuel Negative-CO₂ Power Plants



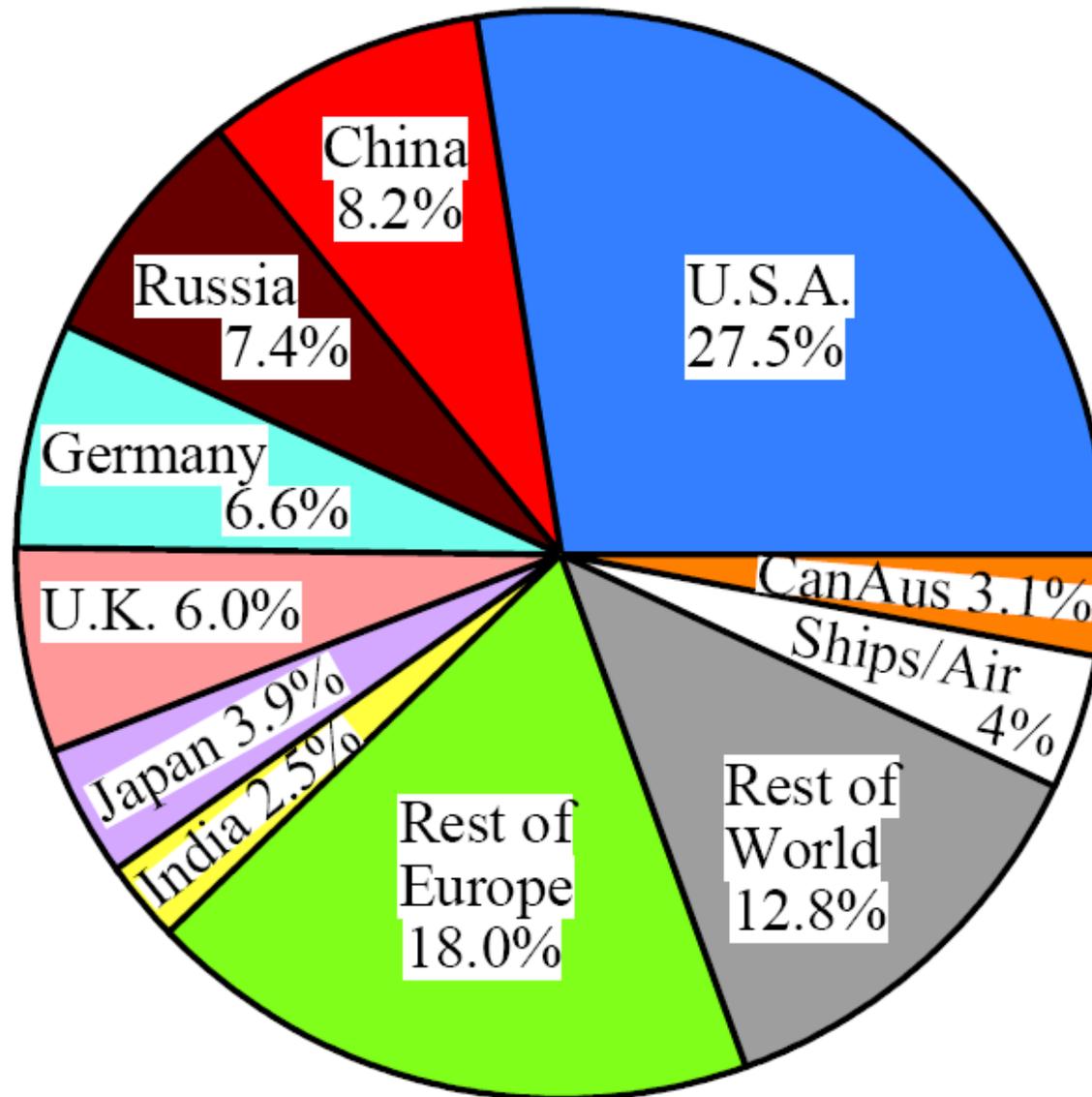
Cellulosic Biofuels Electrical Power Generation
Fail-Safe CO₂ Sequestration in Deep-Sea Sediments

Summary: Is There Still Time?

Yes, But:

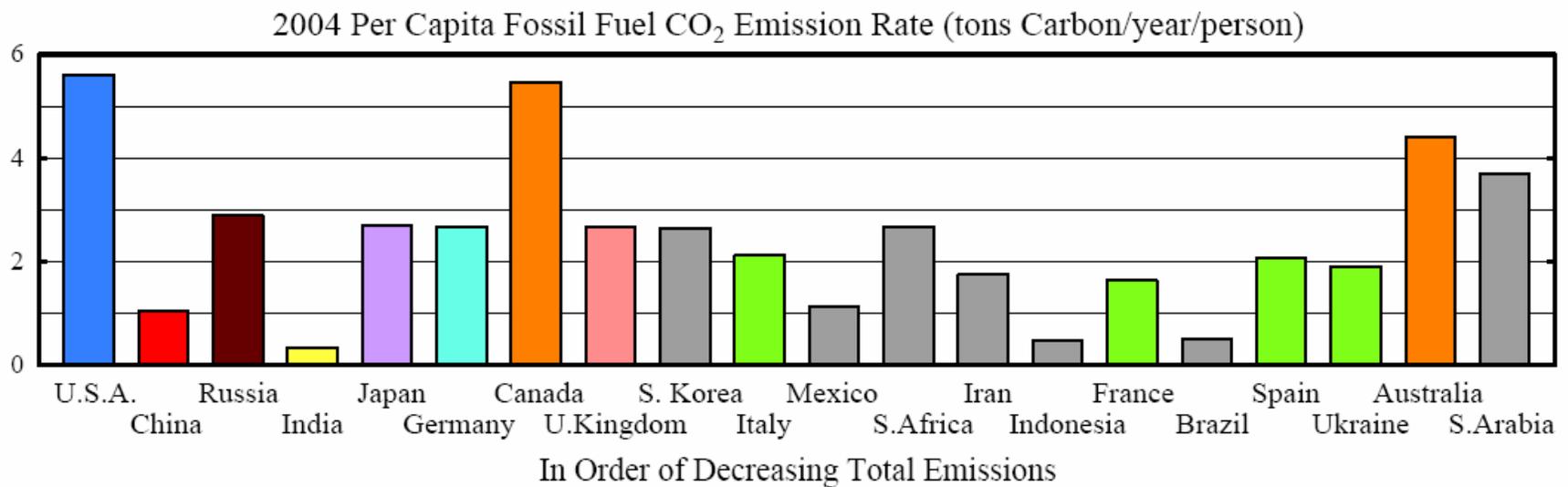
- **Alternative Scenario is Feasible, yielding a healthy, clean planet.**
 - **But It Is Not Being Pursued**
- **Action needed now.**
 - A decade of Business-as-Usual eliminates Alternative Scenario**

1751-2006 Cumulative Fossil Fuel CO₂ Emissions



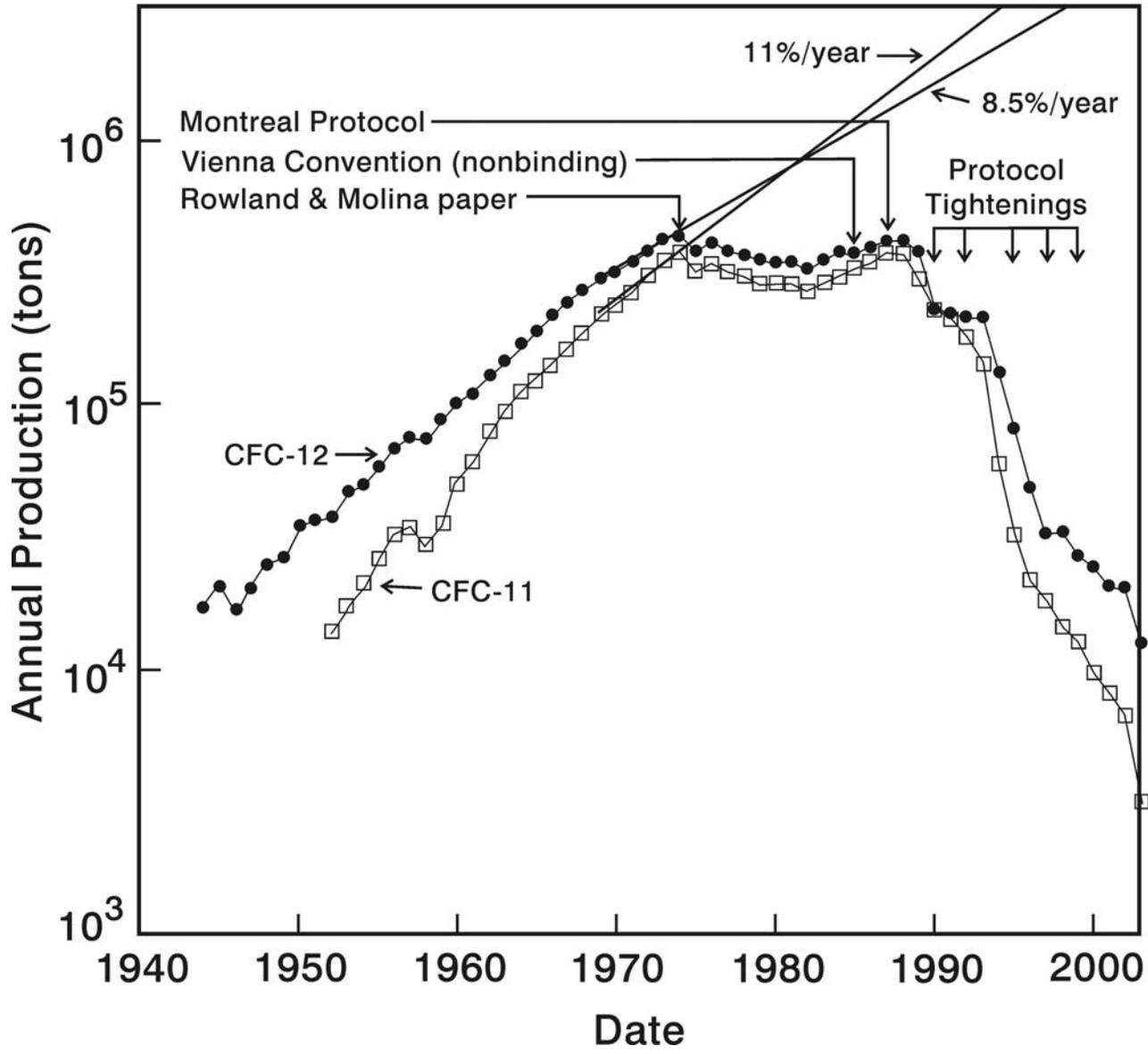
Update of Figure 10(e) of “Dangerous human-made interference with climate”

Per Capita Carbon Emissions



Update of Figure 10(g) of “Dangerous human-made interference with climate”

Chlorofluorocarbon Production



Ozone Success Story

- ↑ **1. Scientists:** Clear warning
- ↑ **2. Media:** Transmitted the message well
- 3. Special Interests:** Initial opposition, 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. **Government**: Seems affected by special interests; fails to lead – no Winston Churchill today
- ↓ 5. **Public**: understandably confused, uninterested

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?

Urgent Action Needed:

Moratorium on New Coal Powerplants

Plant Lifetime ~ 50-75 Years

Sequestration Technology ~10 Years Away

Efficiency, Renewables in Interim

Need to Remove Barriers to Efficiency

Citizens Must Stand Up

Coal Industry is Very Powerful

Congress Unlikely to Act Decisively

Declaration of Stewardship for the Earth and all Creation

1. **Moratorium on Dirty Coal**

I will support a moratorium on coal-fired power plants that do not capture and sequester CO₂.

2. **Price on Carbon Emissions**

I will support a fair, gradually rising, price on carbon emissions, reflecting costs to the environment. Mechanisms to adjust price should be apolitical and economically sound.

3. **Energy and Carbon Efficiency Incentives**

I will support legislation to reward utilities and others based on energy or carbon efficiencies rather than the amount of energy sold.

Summary

- 1. Climate Situation Clear, but not Communicated**
 - Tipping Points near, Potential to lose control
 - Must draw down CO₂ & reduce other forcings
- 2. Struggle Against Ignorance**
 - Some progress recently
 - Misconceptions are shocking
 - Inappropriately political
- 3. Struggle Against Greed**
 - Special Interests guarding short-term profits
 - Must draw attention to generational inequity
 - Watch deeds, not words