

Climate Tipping Points*

The Threat to the Planet

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19 February 2008

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Bloomington, Illinois

***Any statements relating to policy are personal opinion**

Status of “Global Warming”

1. A Knowledge Gap

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

2. A Planetary Emergency

- Climate Inertia → Pipeline Effect
- Positive Feedbacks Predominate

3. Good News in Bad News: Opportunity

- Low-CO₂ Solution Technically

Perfect Storm, Perfect Disaster?

1. Great Inertia of Systems

- Climate: $>1/2$ Warming Still 'in Pipeline'
- Energy Infrastructure: Decades to Replace

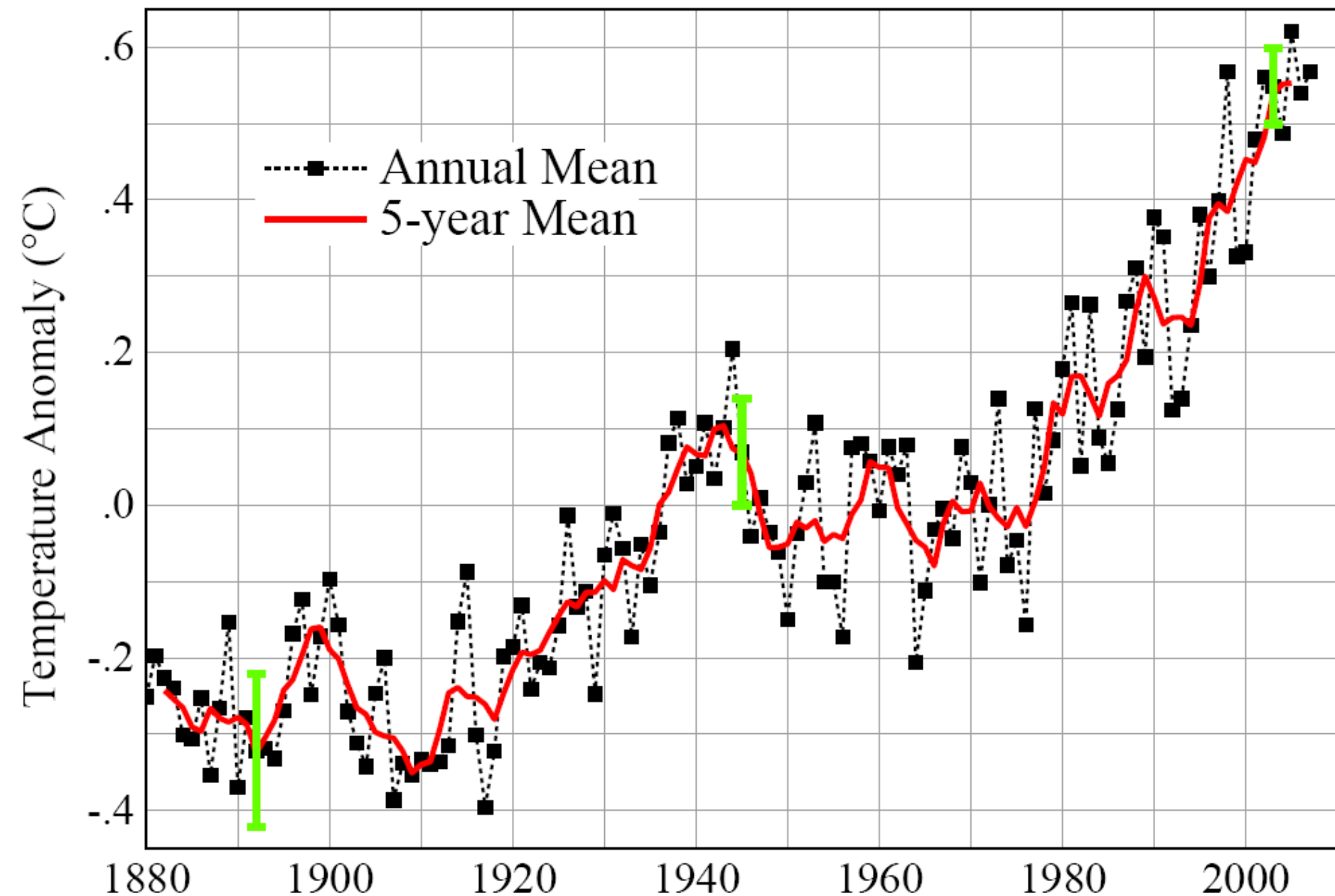
2. Non-Linear Problems

- Ice Sheet Disintegration
- Interdependencies of Species

3. Special Interests' Undue Sway

- Exert Media and Political Control
- Delay Actions a la Smoking & Health

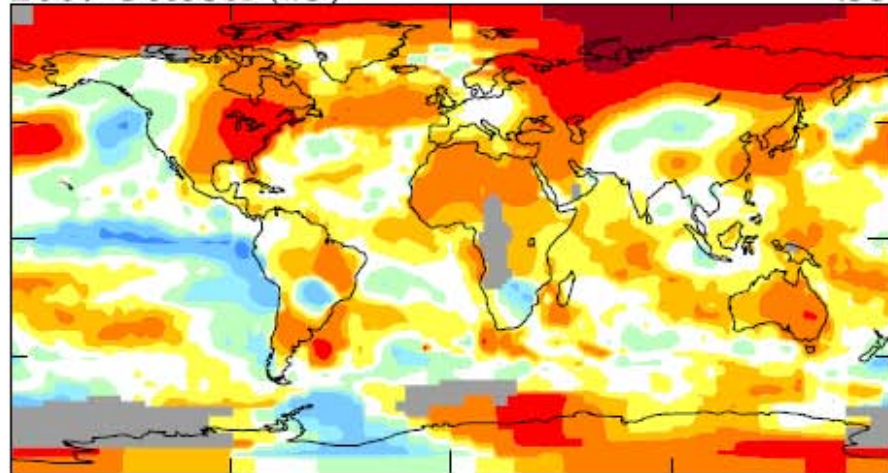
Global Temperature Land-Ocean Index



2007/08 Surface Temperature Anomalies ($^{\circ}\text{C}$) [Base Period 1951-80]

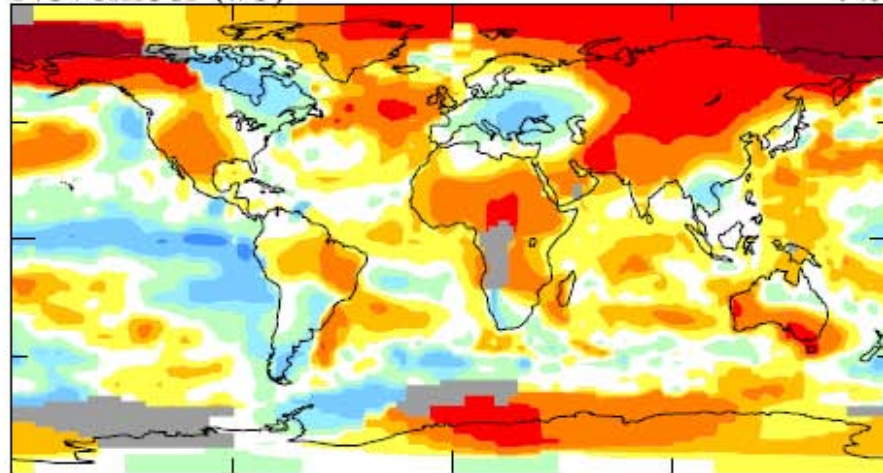
2007 October (#5)

.55



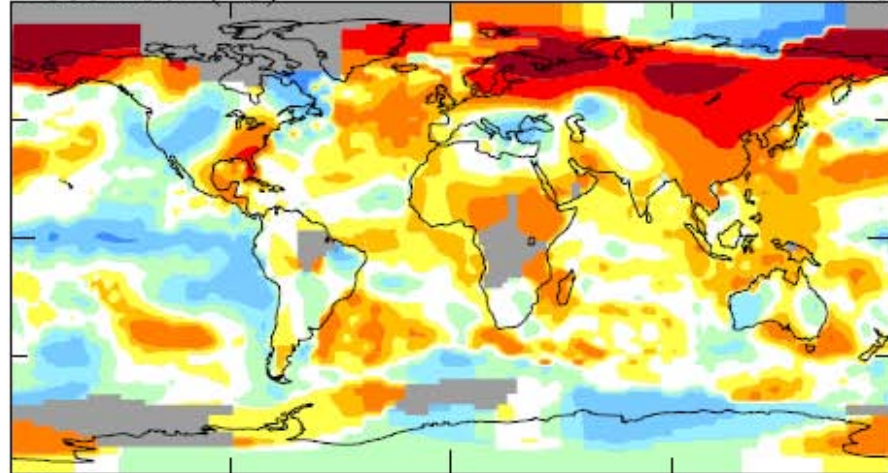
November (#8)

.49



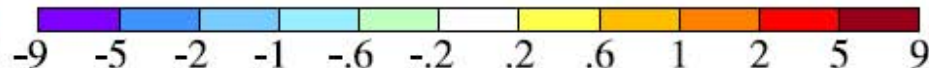
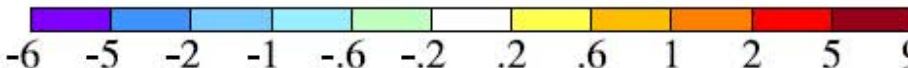
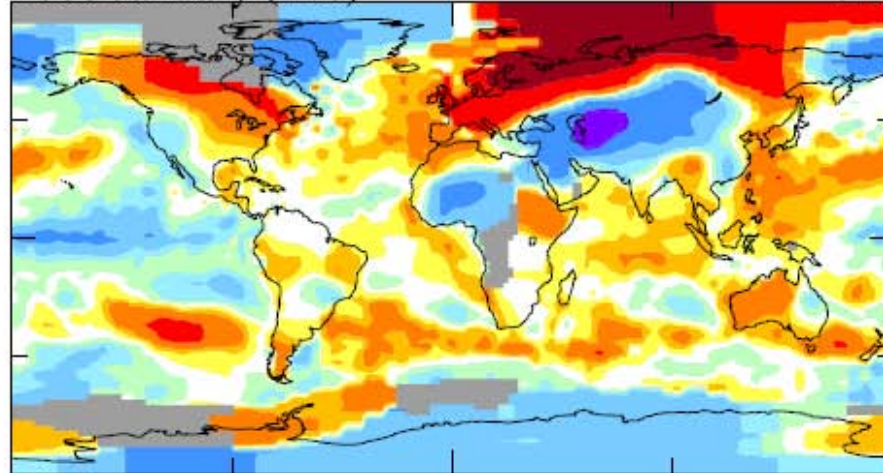
December (#8)

.40



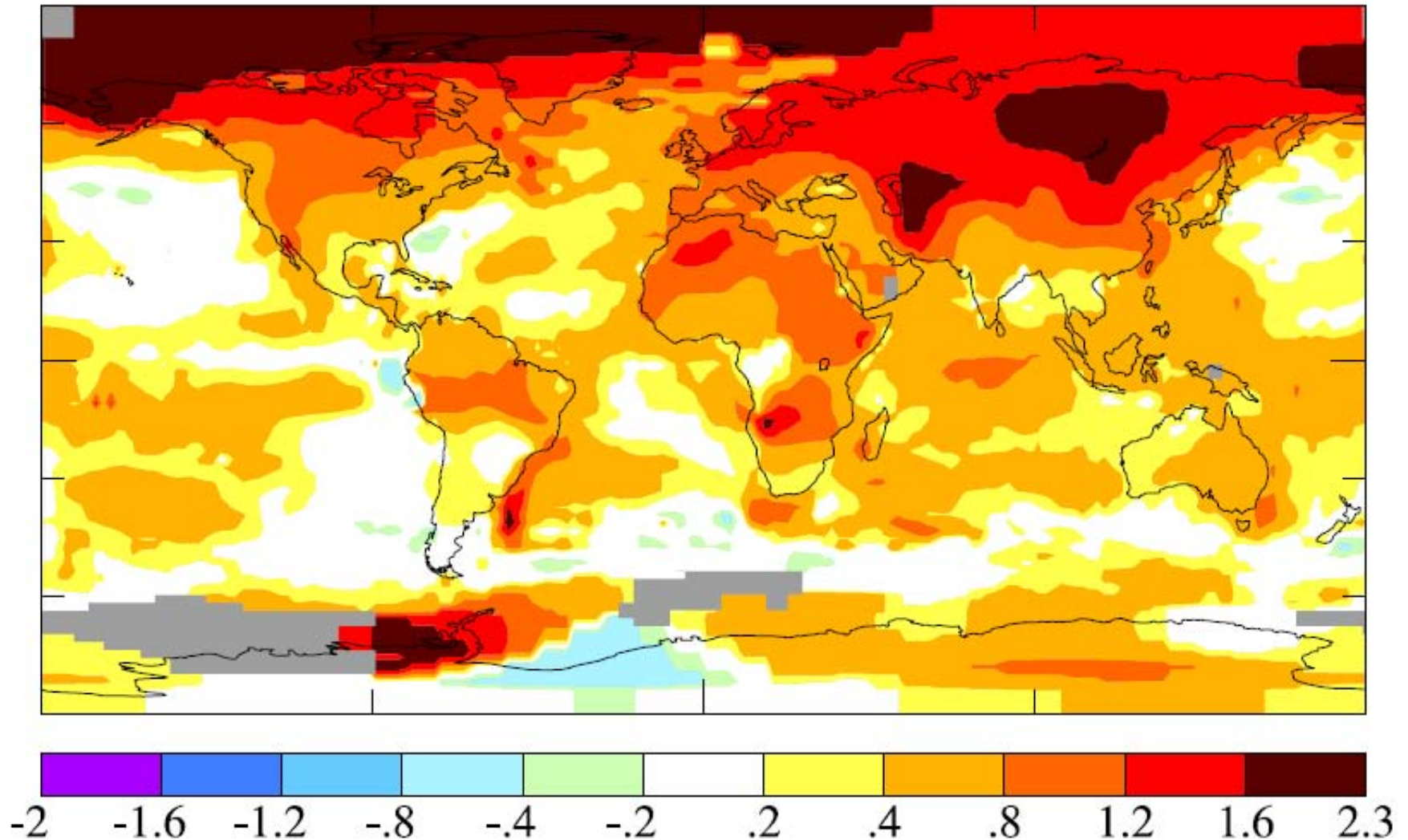
2008 January (#40)

.12



2001-2007 Mean Surface Temperature Anomaly ($^{\circ}\text{C}$)

Base Period = 1951-80, Global Mean = 0.54



Warming in the Pipeline? Tipping Points?

Isn't this just some sort of “theory”?

Do we really need to wrestle with global warming?

There have been huge climate changes in the past.

Isn't it arrogant to say that the present climate is the best?

Assessment Tools

1. Earth's Paleoclimate History

- Equilibrium vs Forcing
- Response Times (caveat re forcings)

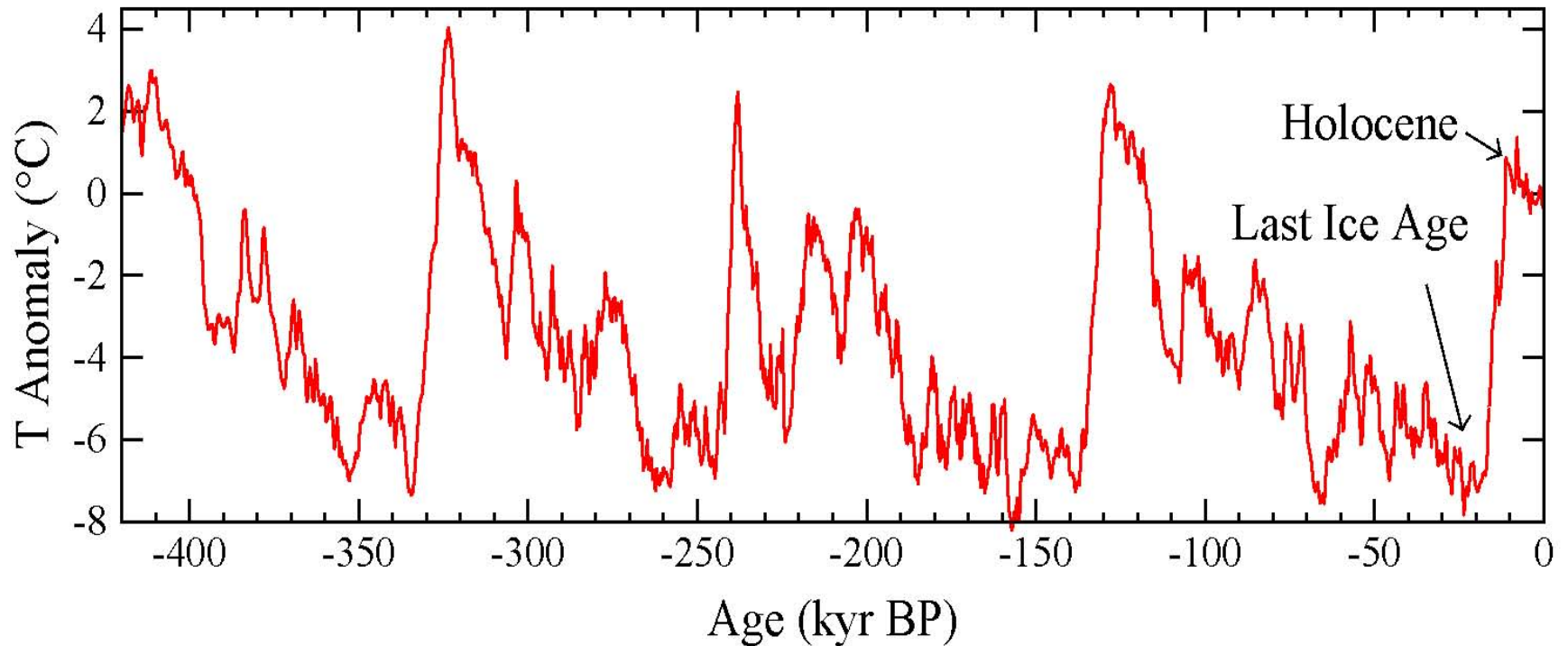
2. Ongoing Observations

- Satellite Data
- Field Data

3. Climate Models

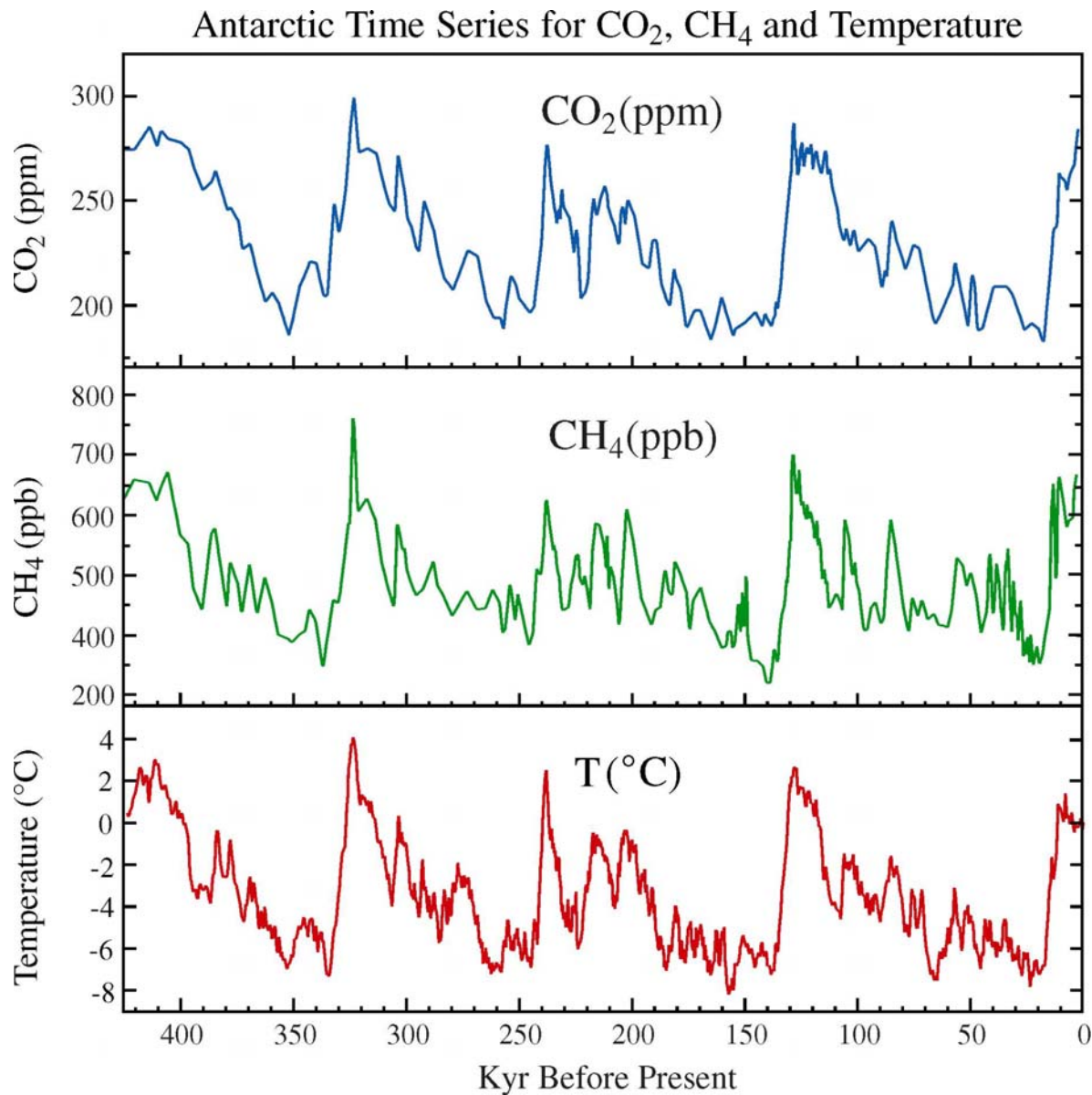
- Recognize Merits & Limitations
- Tend to be Lethargic

Antarctic (Vostok) Temperature



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

Recorded human history occurs within the Holocene warm period.



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)

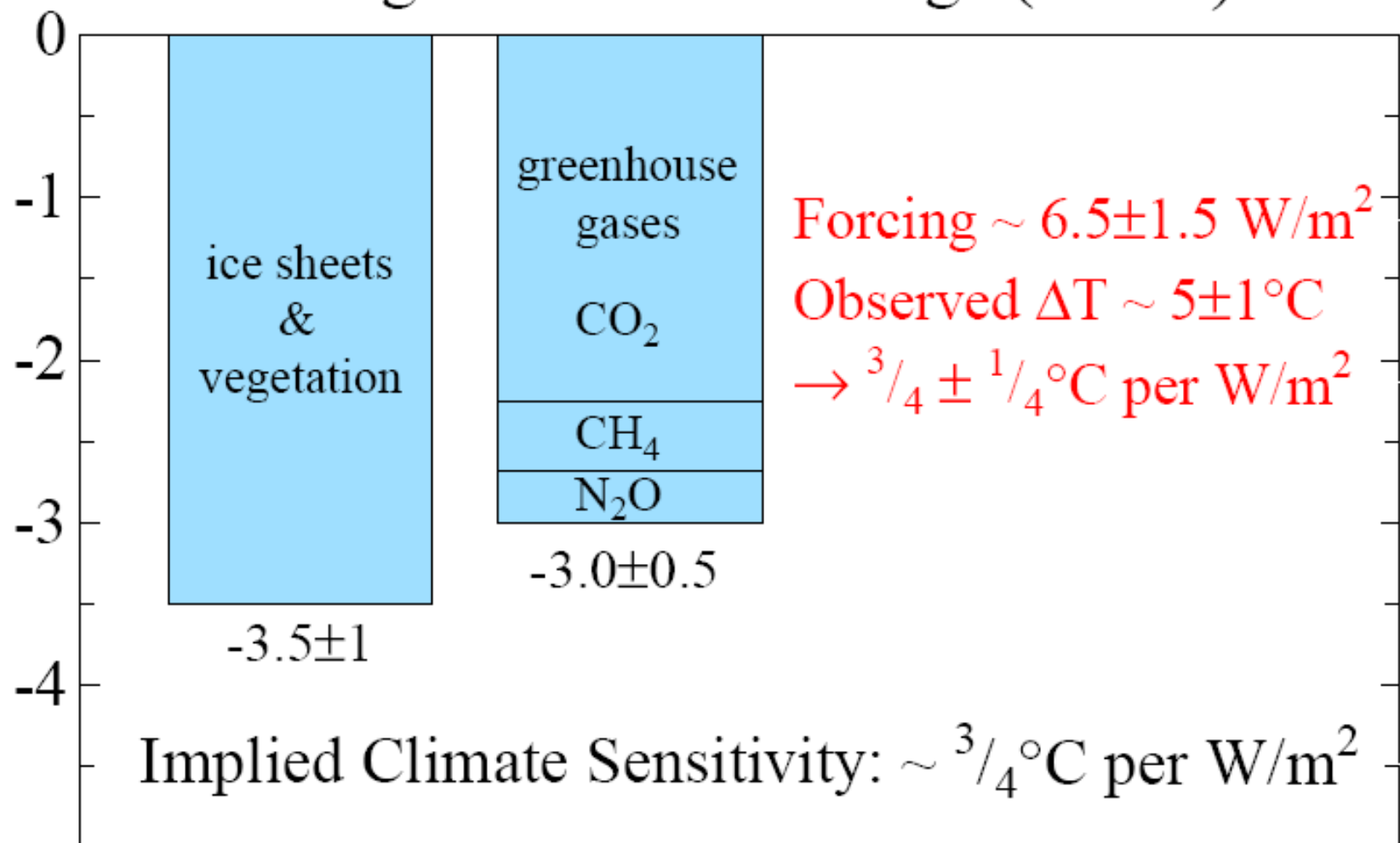
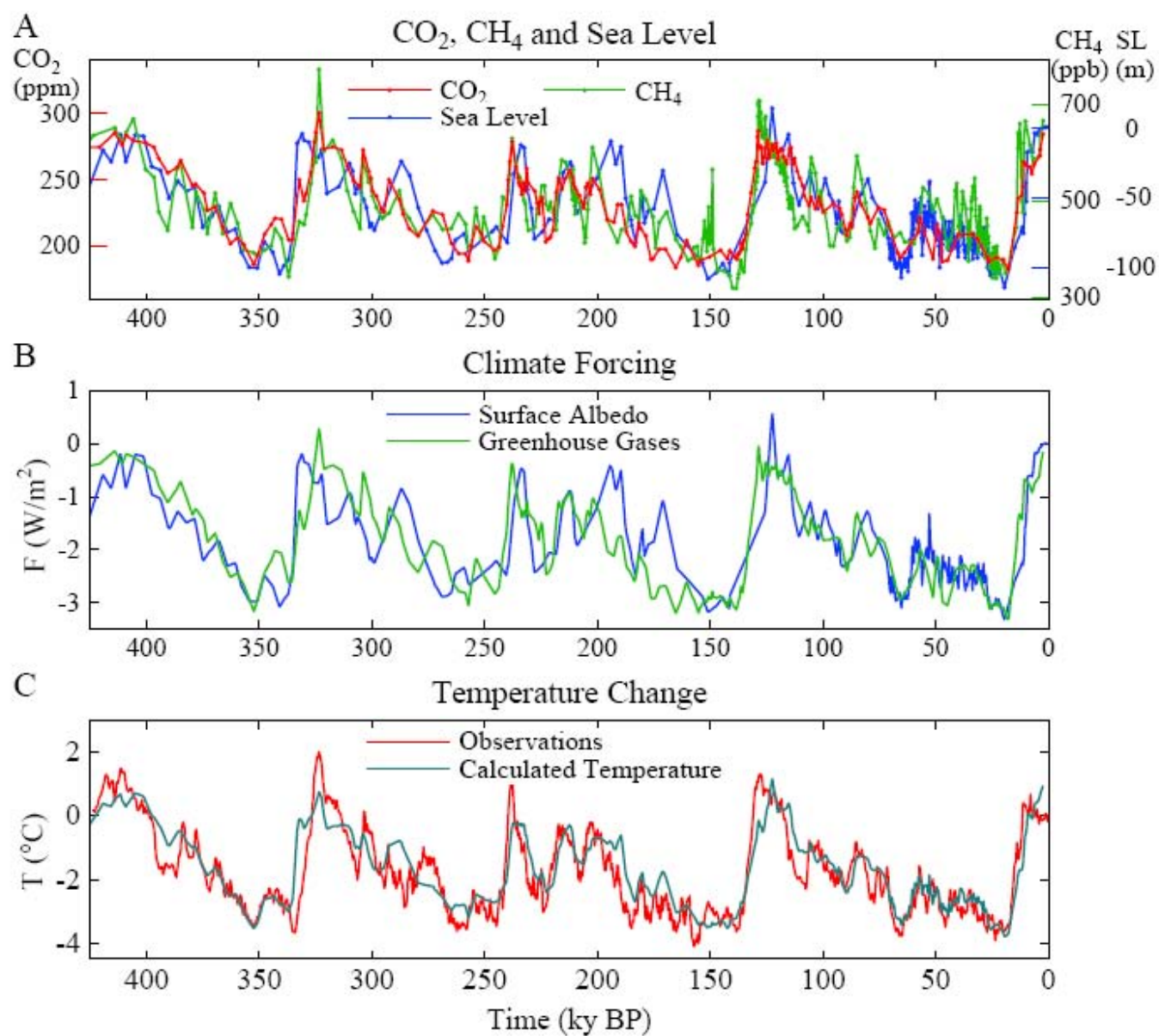
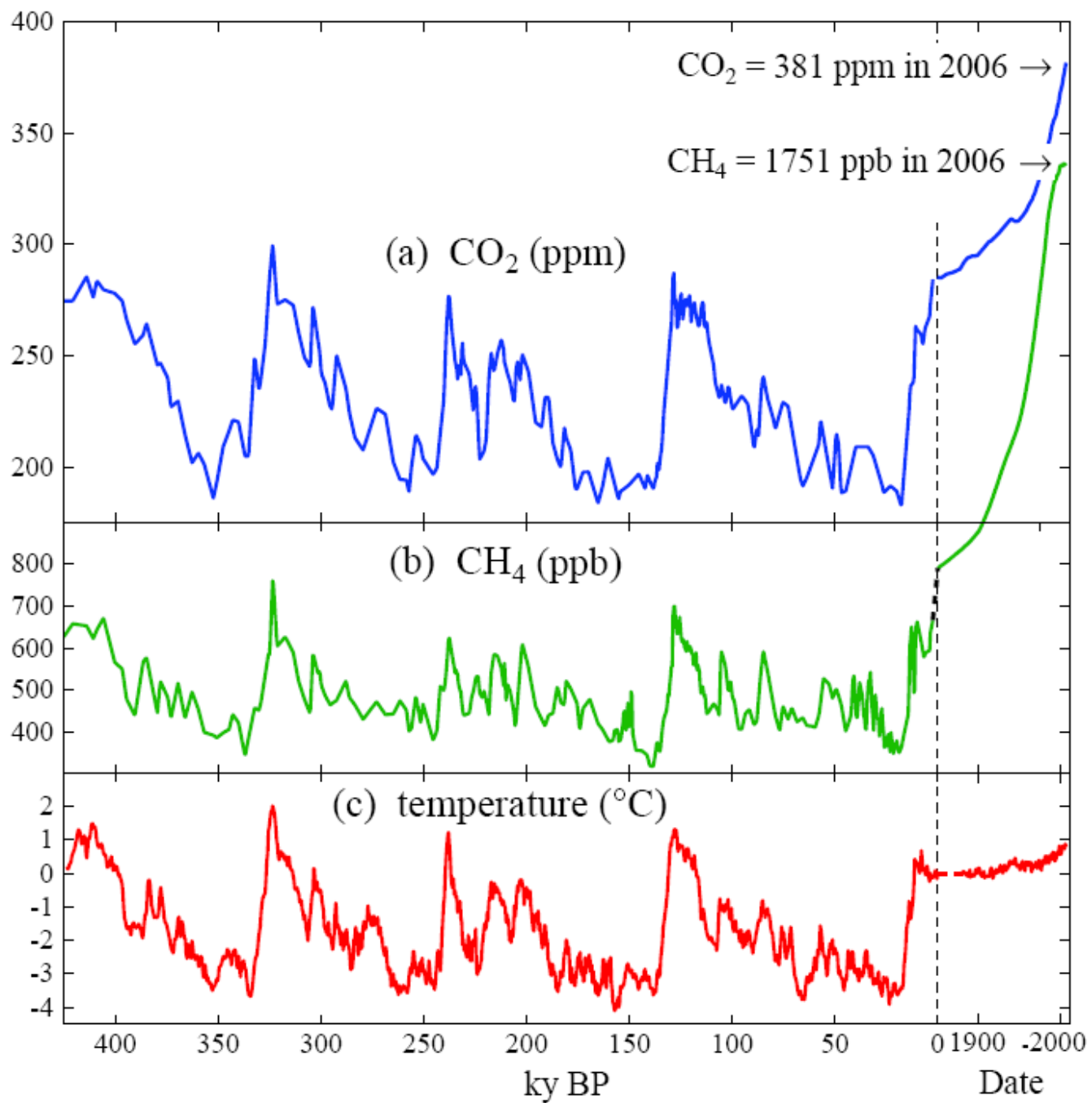


Fig. S2. Climate forcings during ice age 20 ky BP, relative to the present (pre-industrial) interglacial period.

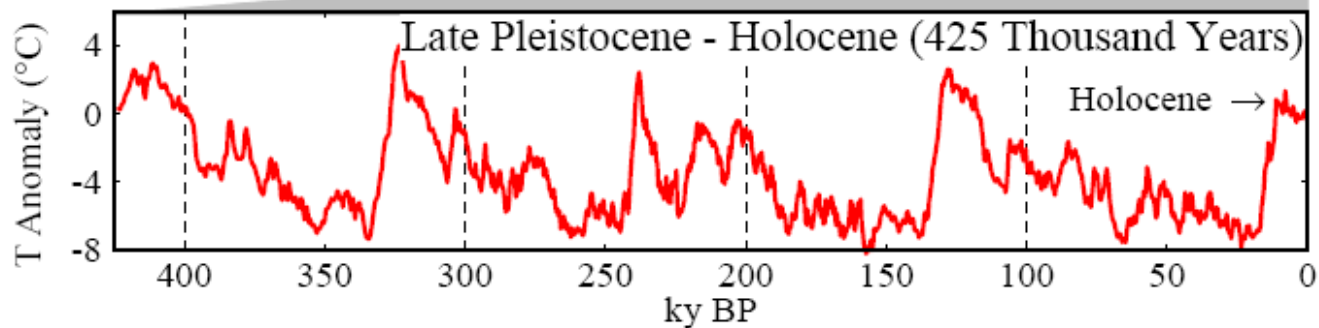
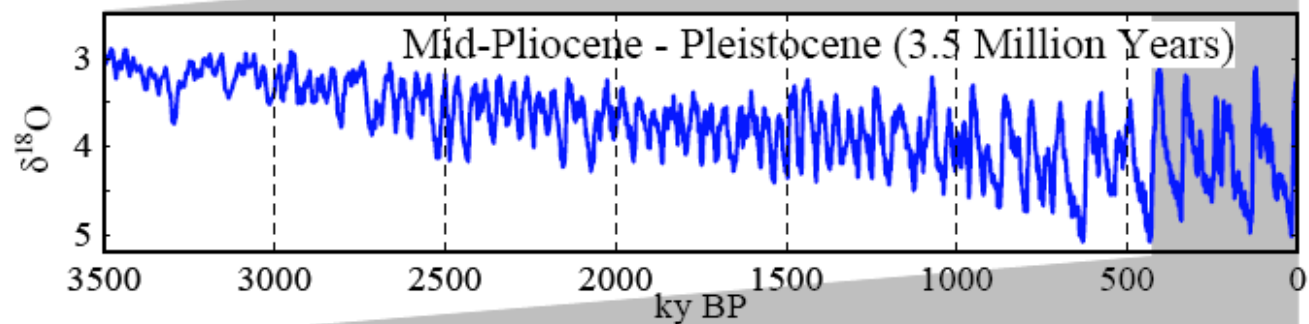
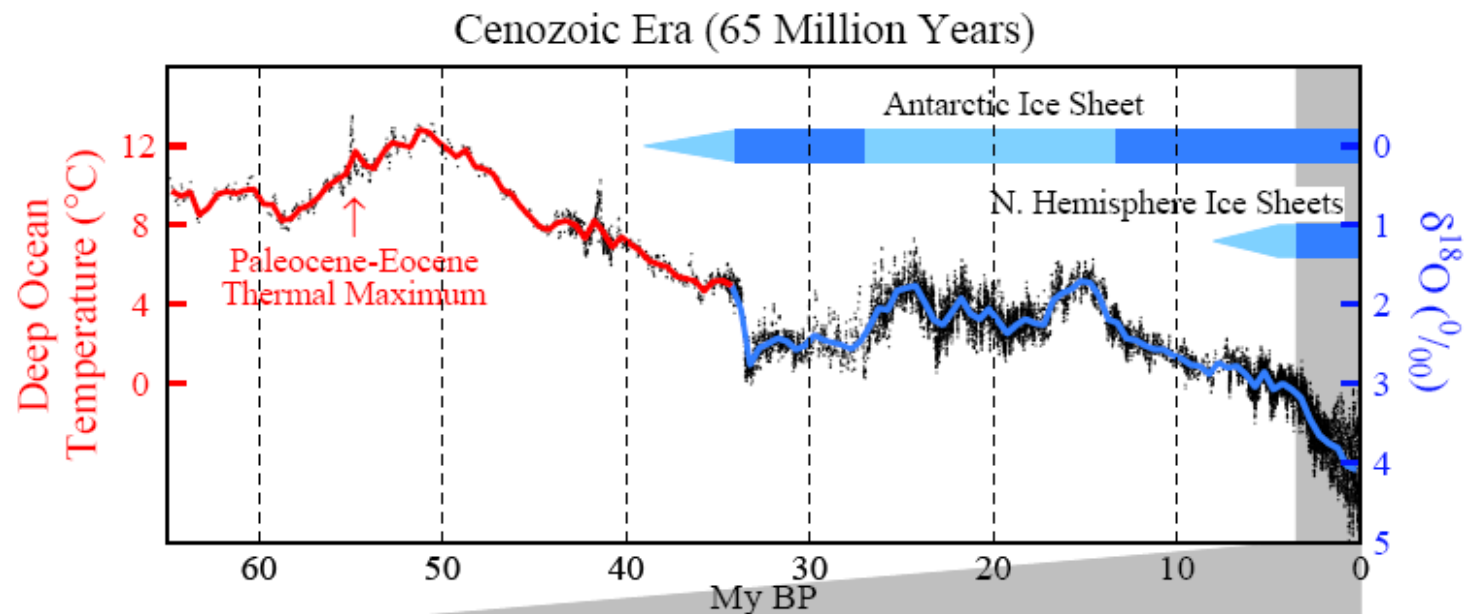


For past 425 ky, (A) GHGs and sea level, (B) Surface albedo and GHG forcings, (C) Observed and calculated temperatures

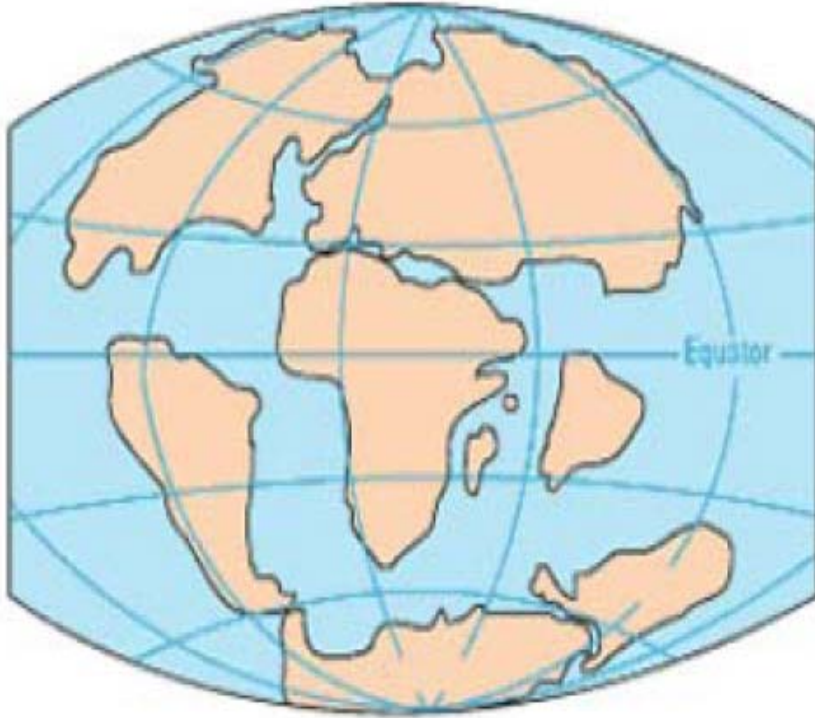


Implications of Pleistocene Climate Change

1. Chief instigator of climate change was earth orbital change, a very weak forcing.
2. Chief mechanisms of Pleistocene climate change are 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 caused glacial-interglacial climate change.
5. Humans now control the mechanisms for global climate change, for better or worse.



Cenozoic Era



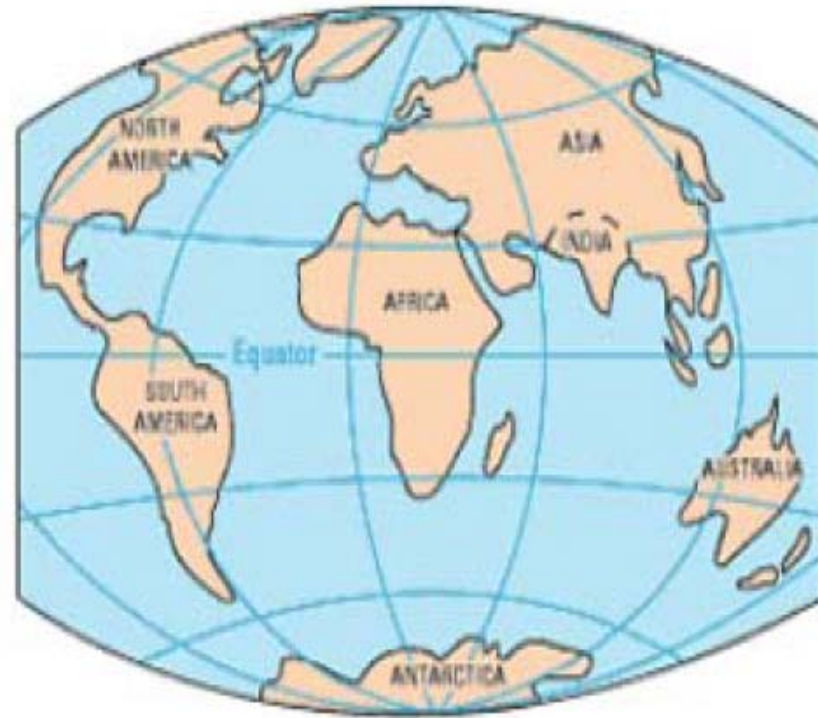
65 Million Years Ago

Global Climate Forcings

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

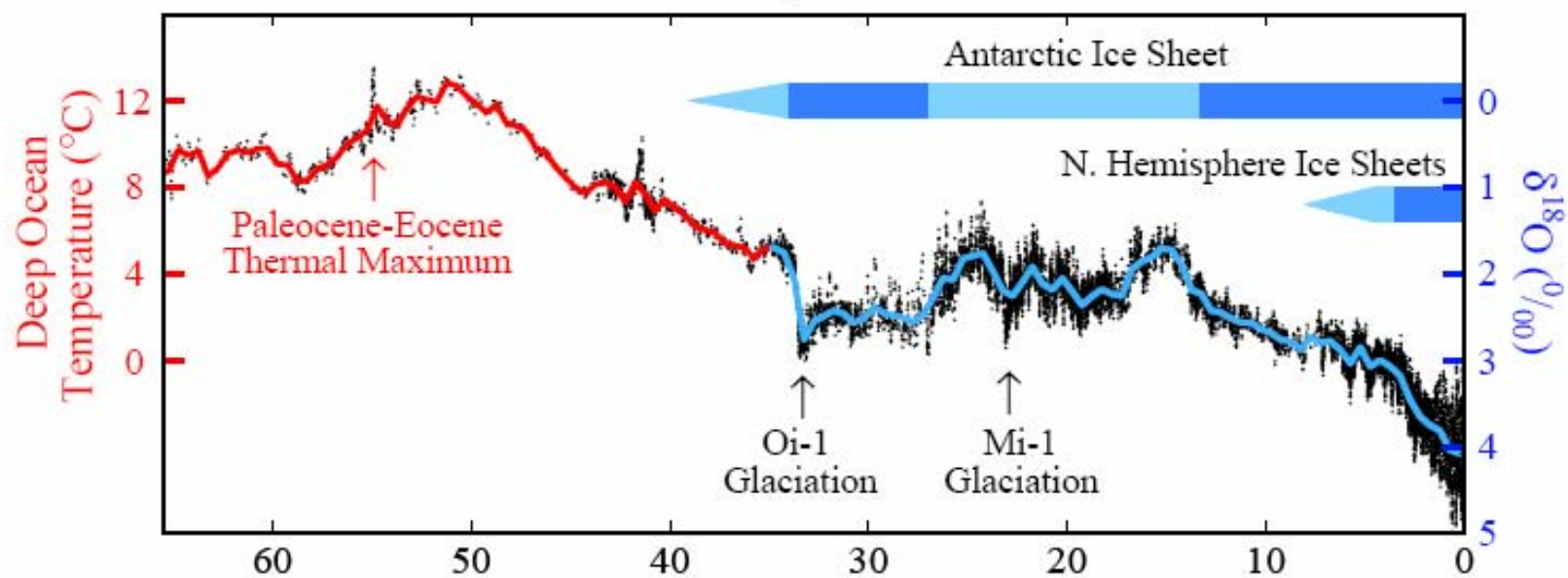
Surface (continent locations): $<1 \text{ W/m}^2$

Atmosphere (CO_2 changes): $> 10 \text{ W/m}^2$



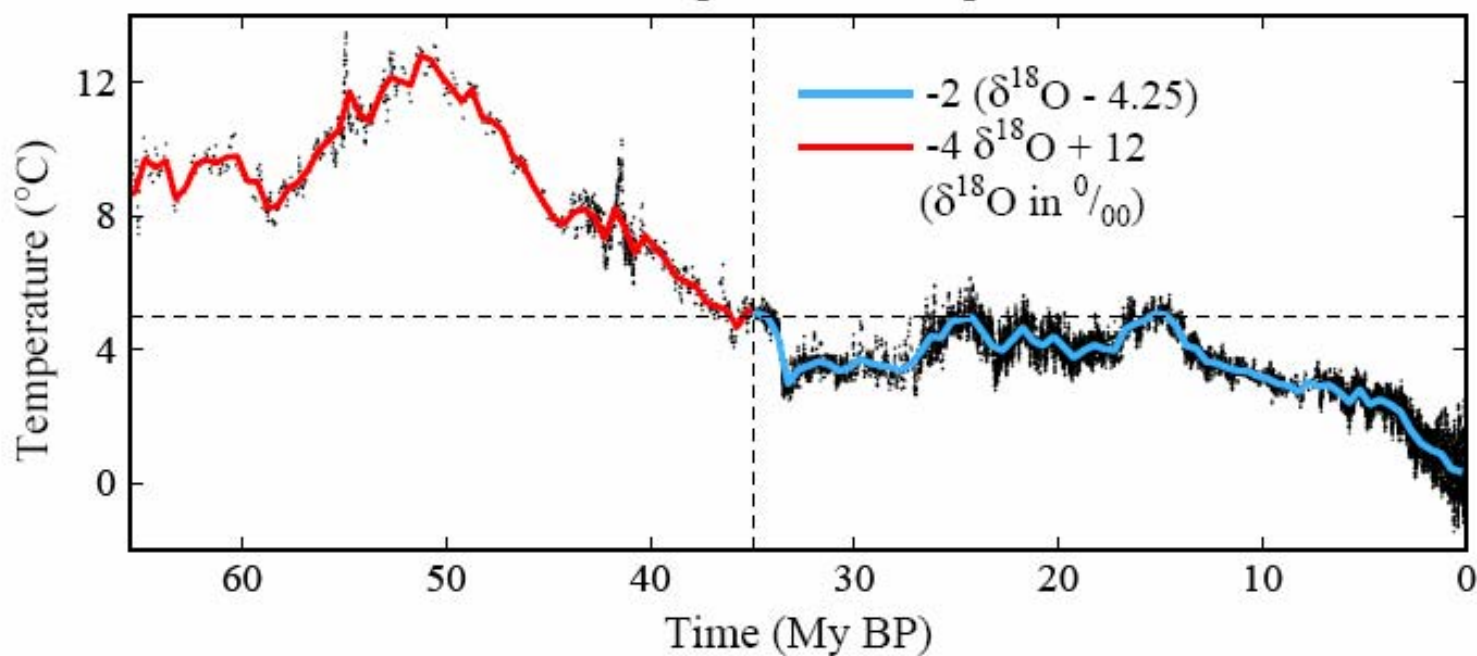
Present Day

A

Global Deep Ocean $\delta^{18}\text{O}$ 

B

Global Deep Ocean Temperature



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

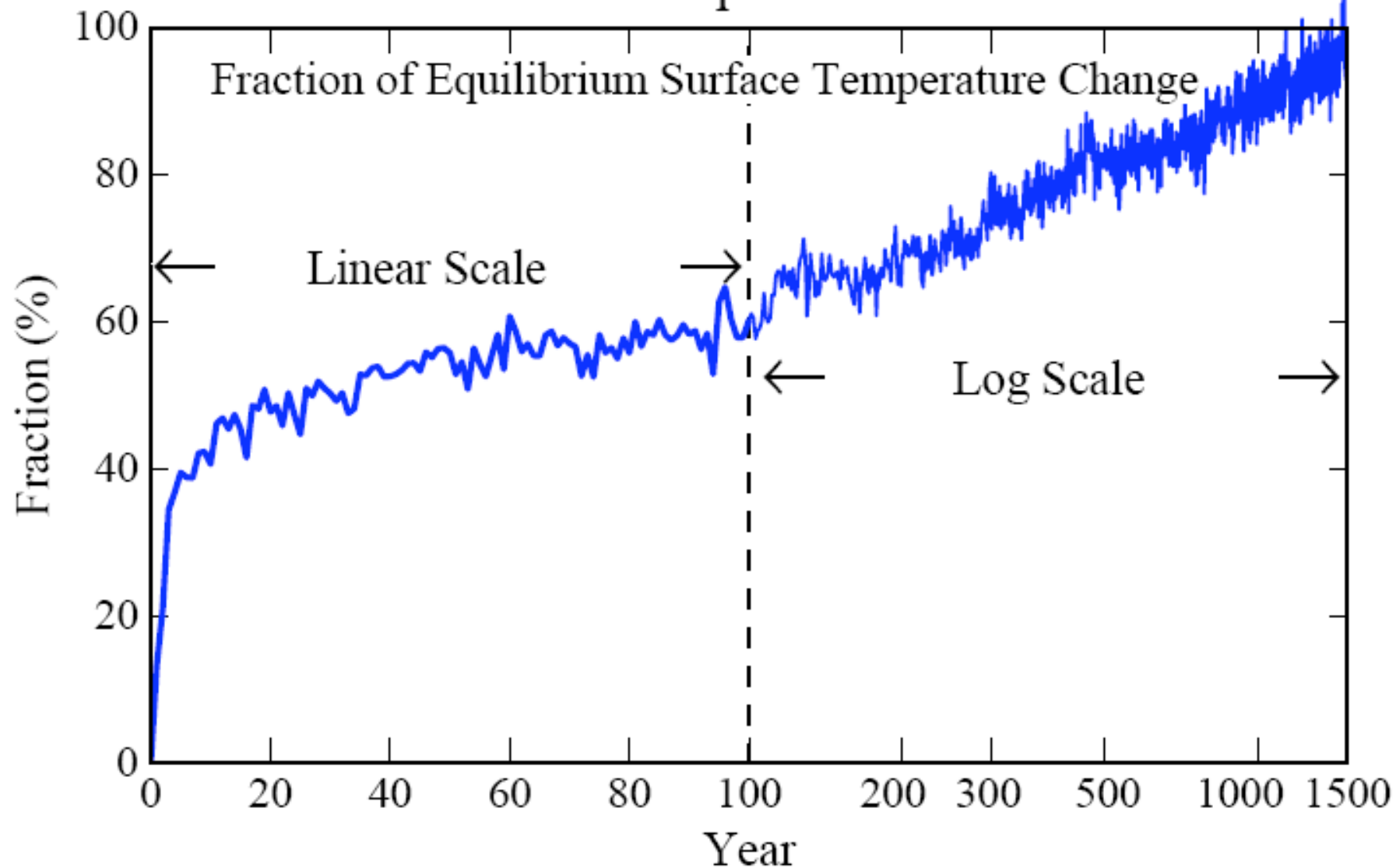
2. Climate Sensitivity High

- Antarctic ice forms if $\text{CO}_2 < \sim 450$ ppm
- Ice sheet formation reversible

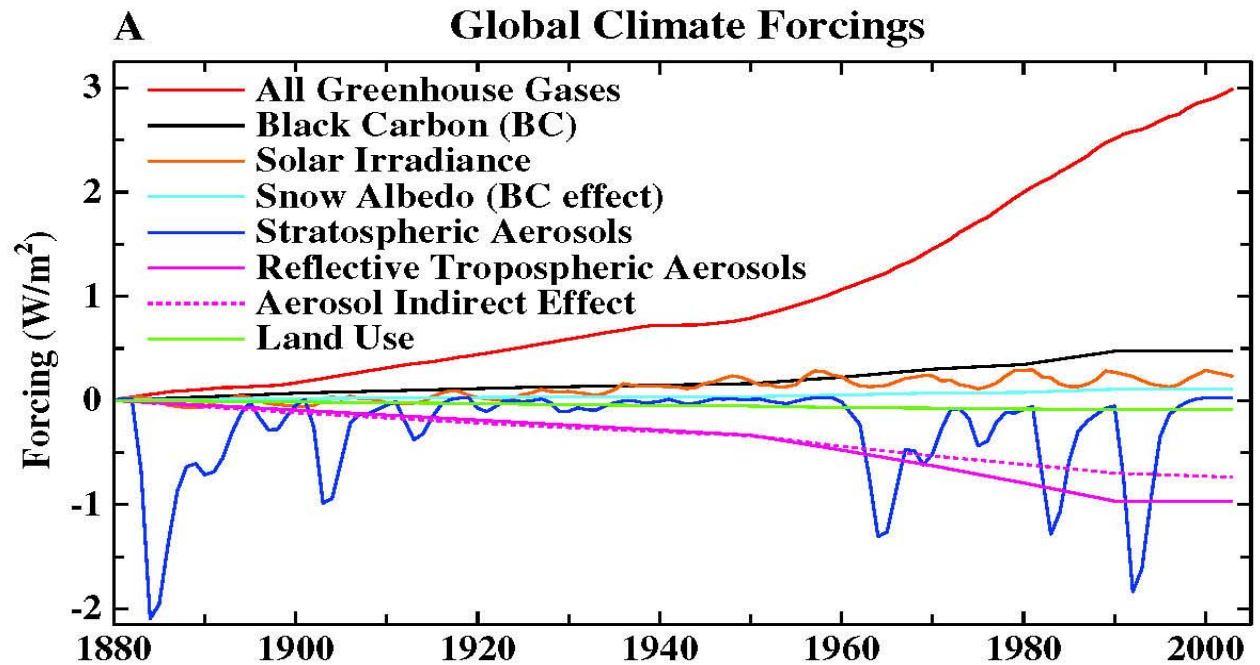
Humans Could Produce “A Different Planet”

Climate Response Function

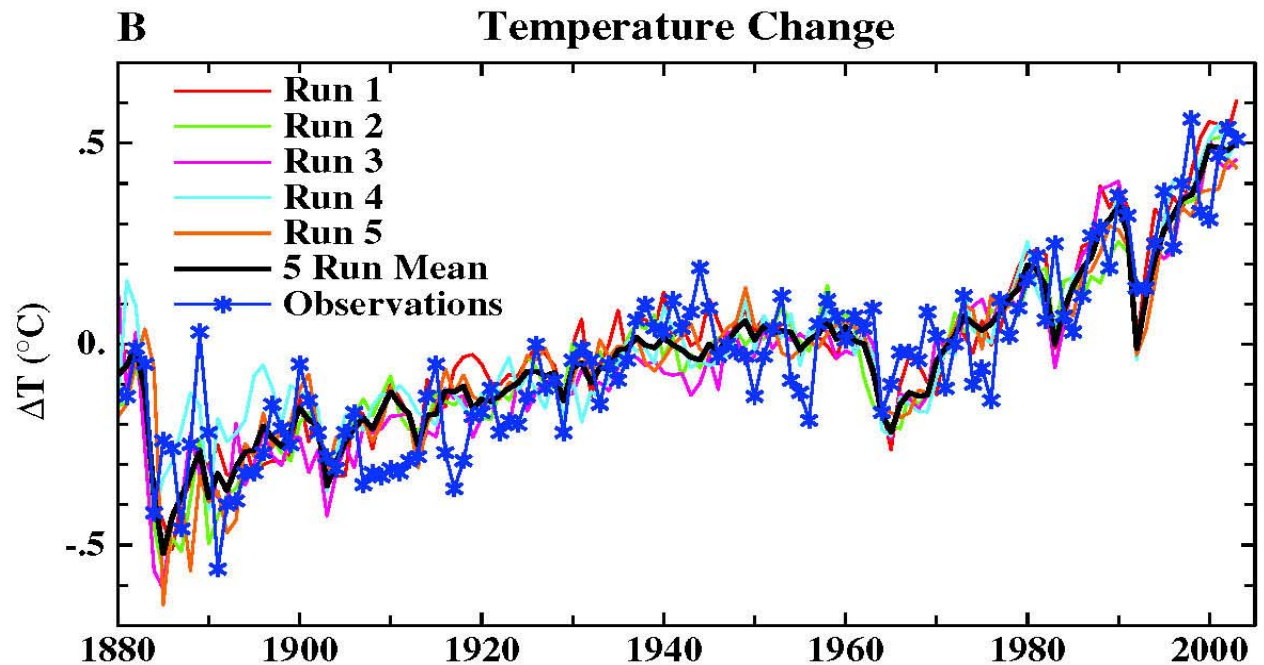
Fraction of Equilibrium Surface Temperature Change



(A) Forcings used to drive climate simulations.

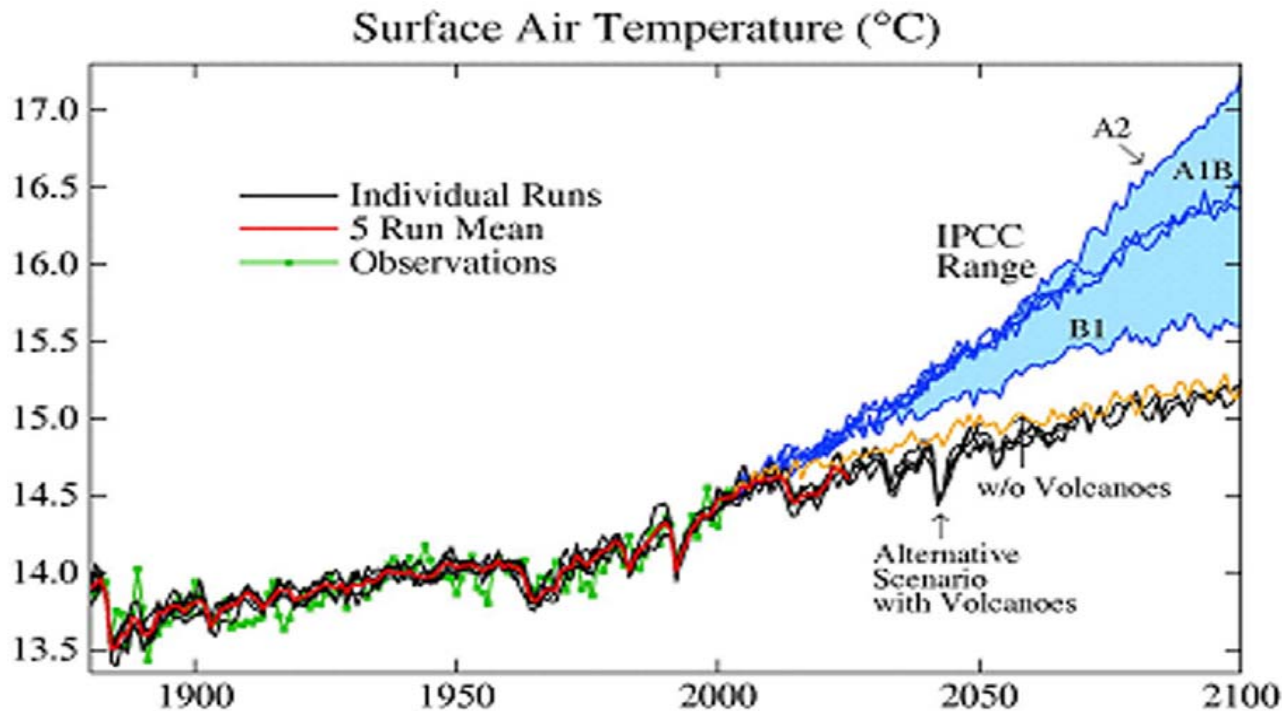


(B) Simulated and observed surface temperature change.



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

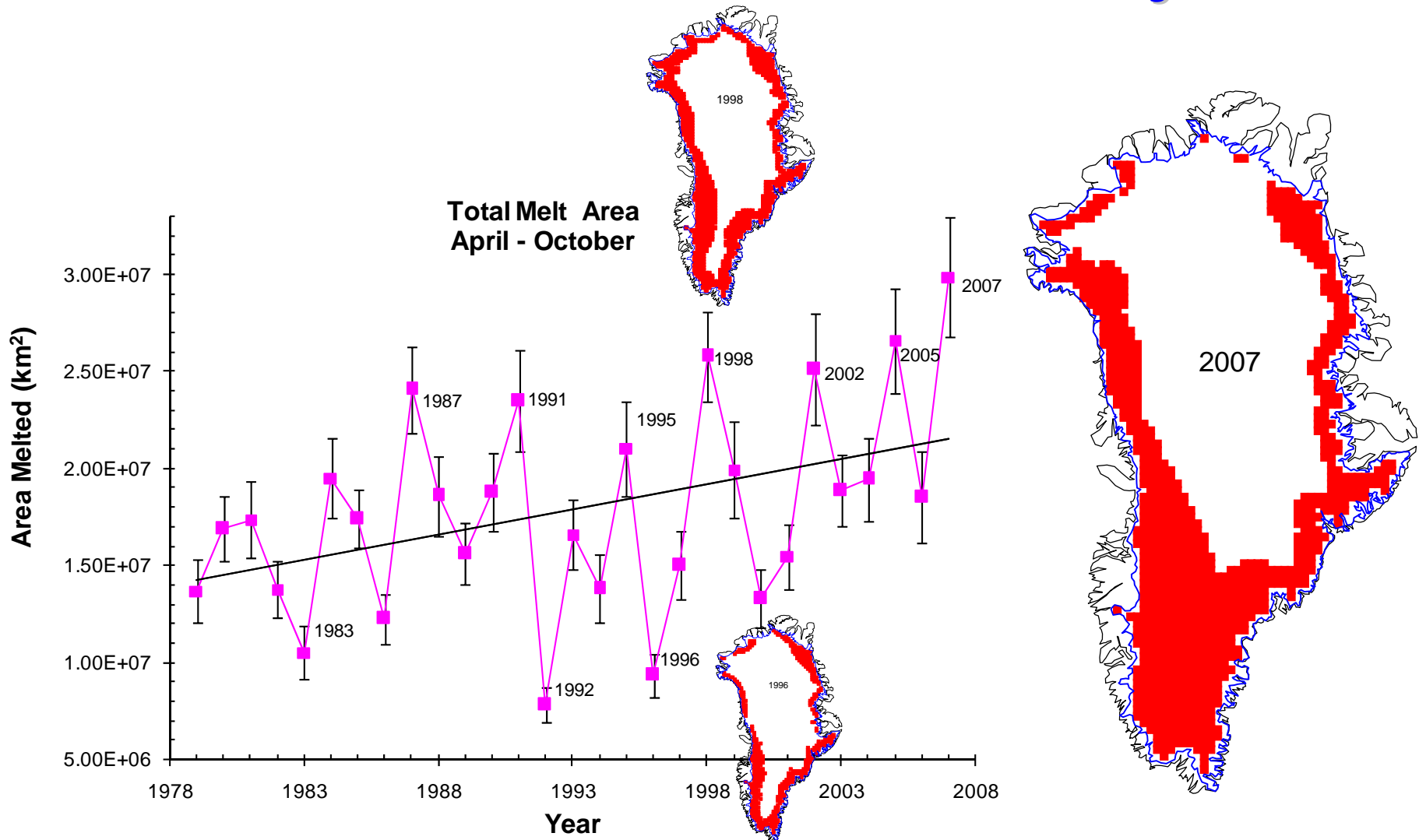
Extirpation of Animal & Plant Species

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

Regional Climate Disruptions

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

Greenland Total Melt Area - 2007 value exceeds last maximum by 10%



Konrad Steffen and Russell Huff, CIRES, University of Colorado at Boulder

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)*

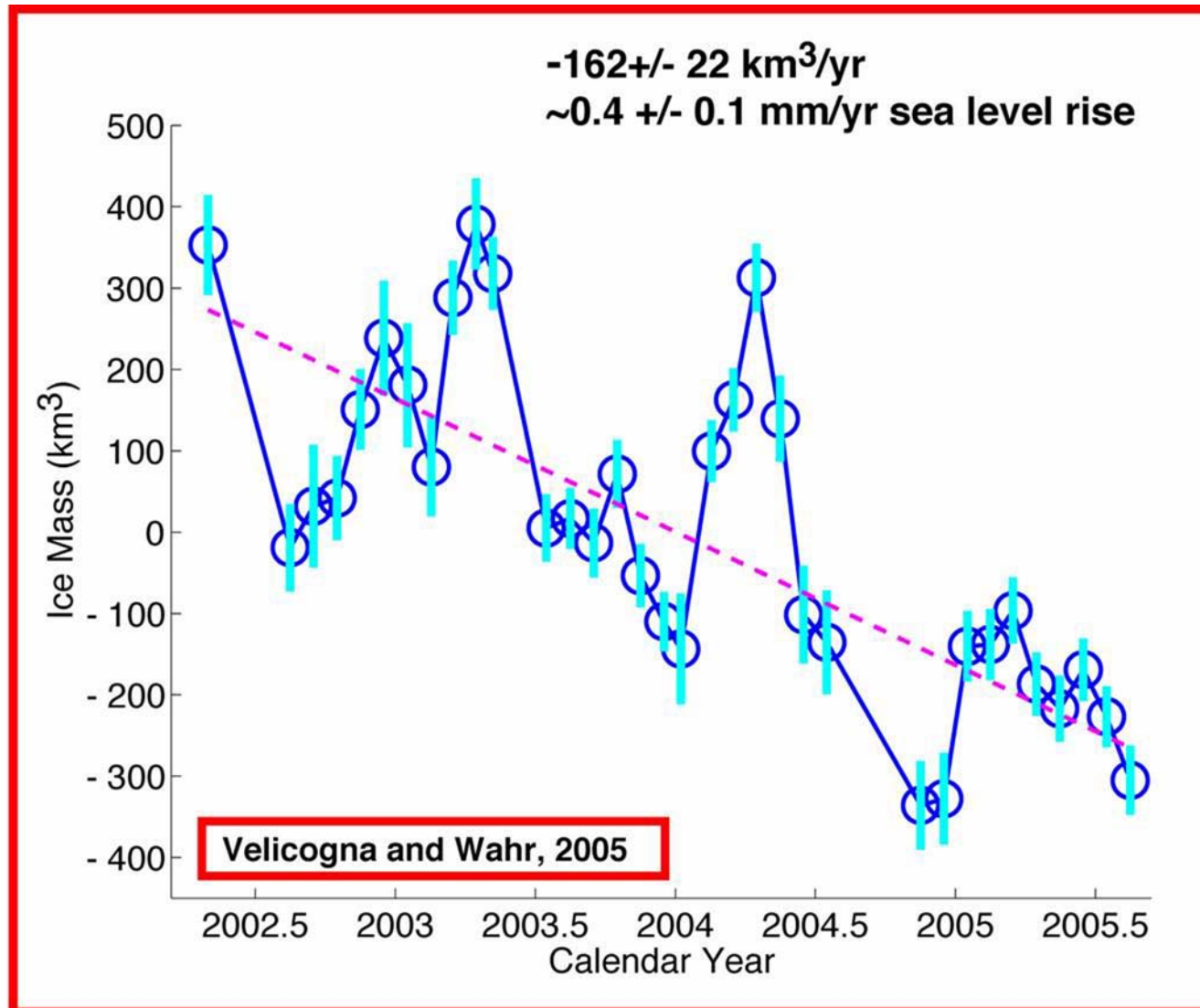
Jakobshavn Ice Stream in Greenland

Discharge from major Greenland ice streams is accelerating markedly.

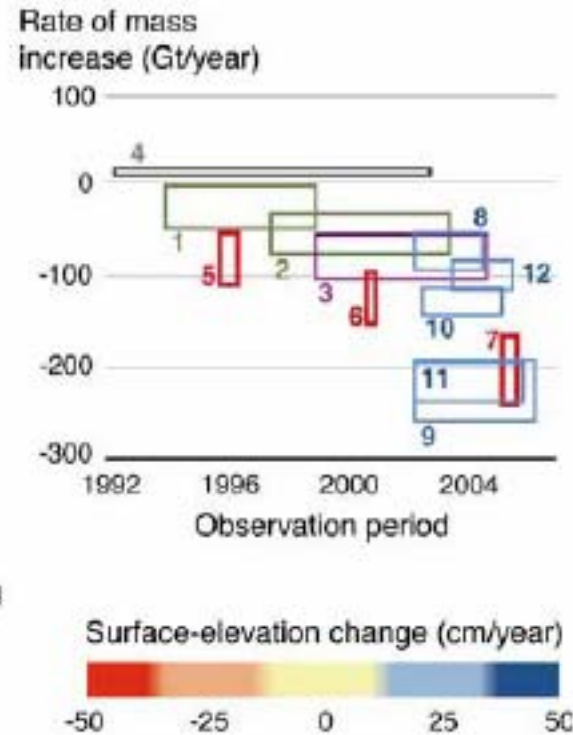
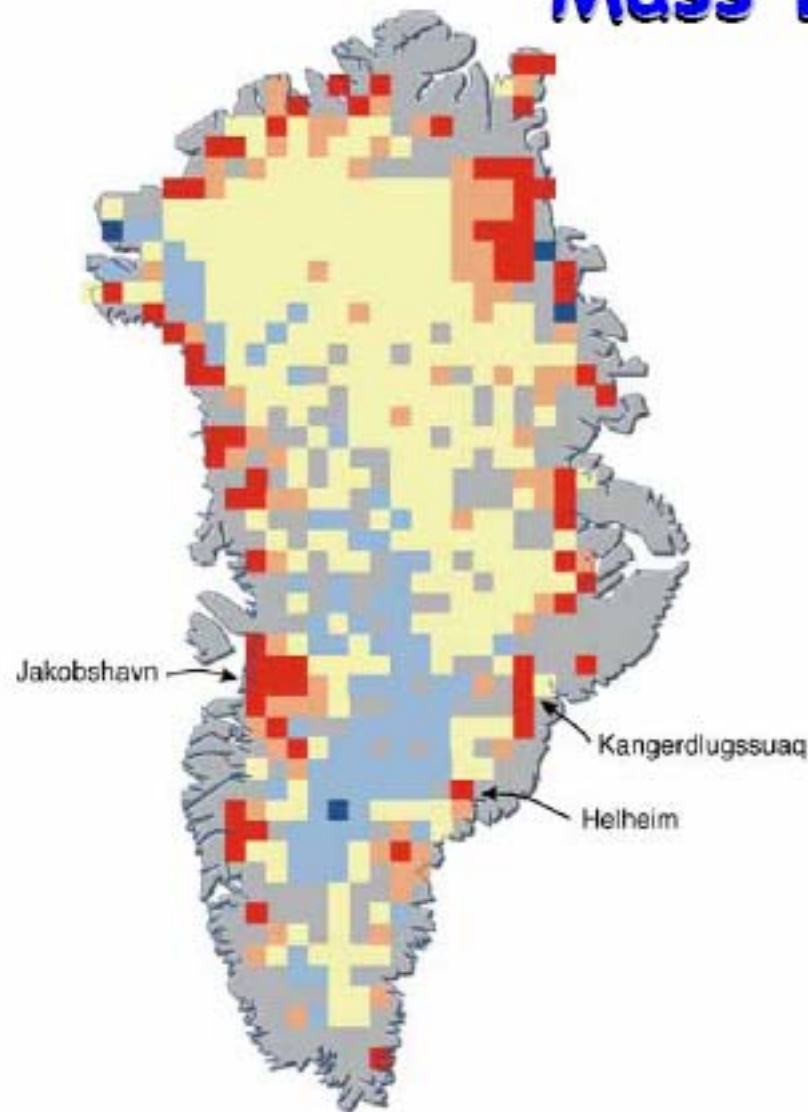


*Source: Prof. Konrad Steffen,
Univ. of Colorado*

Greenland Mass Loss – From Gravity Satellite



Mass Balance of Greenland



365 Gt/year = 1 mm SLR

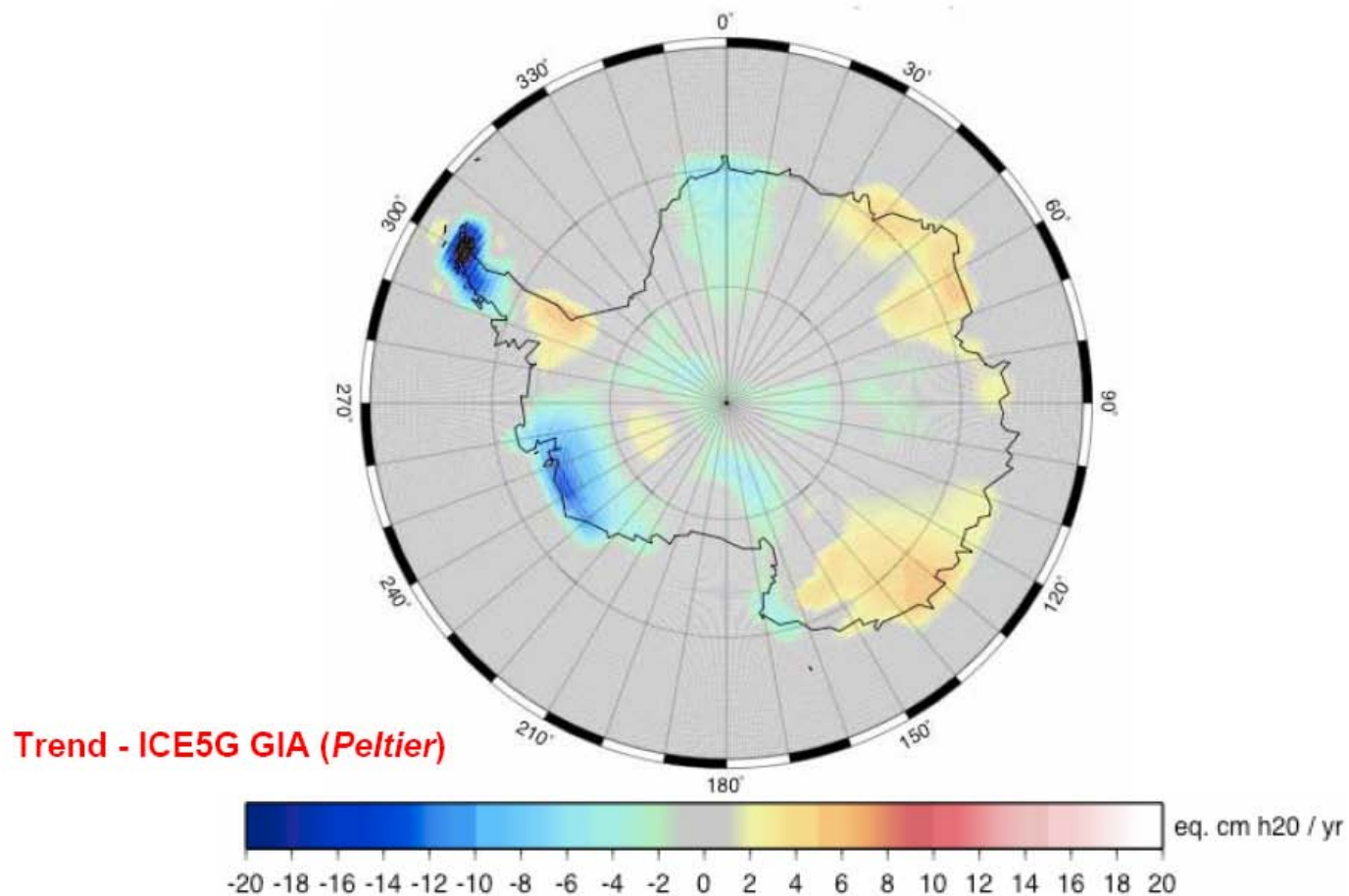
Greenland ice-sheet: rate of change from airborne laser-altimeter surveys (green), airborne/satellite laser-altimeter surveys (purple), mass-budget calculations (red), temporal changes in gravity (blue).

Sources (corresponding to numbers on rectangles): 1 and 2 Krabill and others 200016 and 2004[; 3 Thomas and others 200617; 4 Zwally and others 20055; 5 to 7 Rignot and Kanagaratnam 200618; 8 and 9 Velicogna and Wahr 2005[and 2006b; 11 Chen and others 2006[; 10 Ramillien and others 200632; 12 Luthke and others 2006[



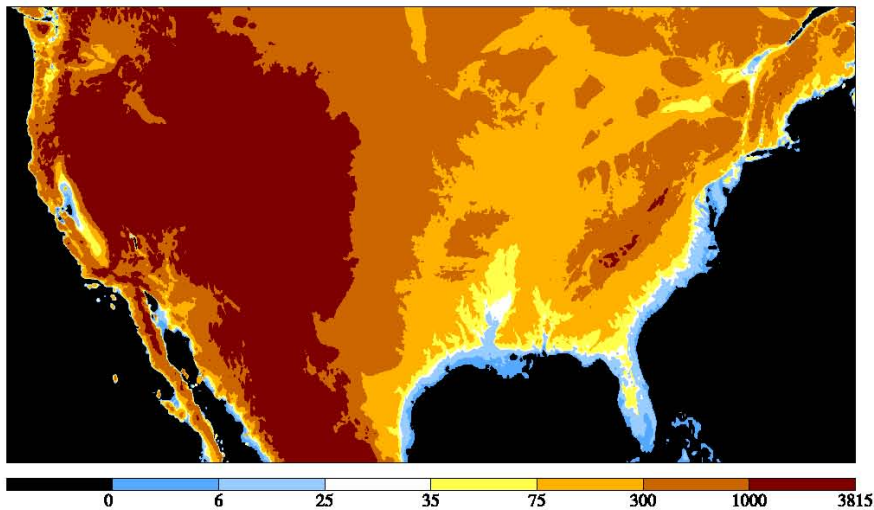
Antarctica Ice Sheet Hi-Res Mascon Solution

Spatial pattern of trend

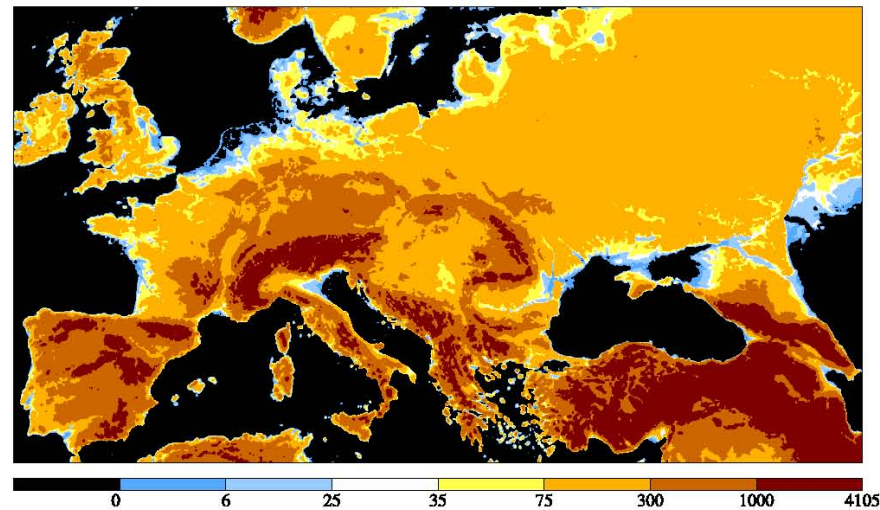


Areas Under Water: Four Regions

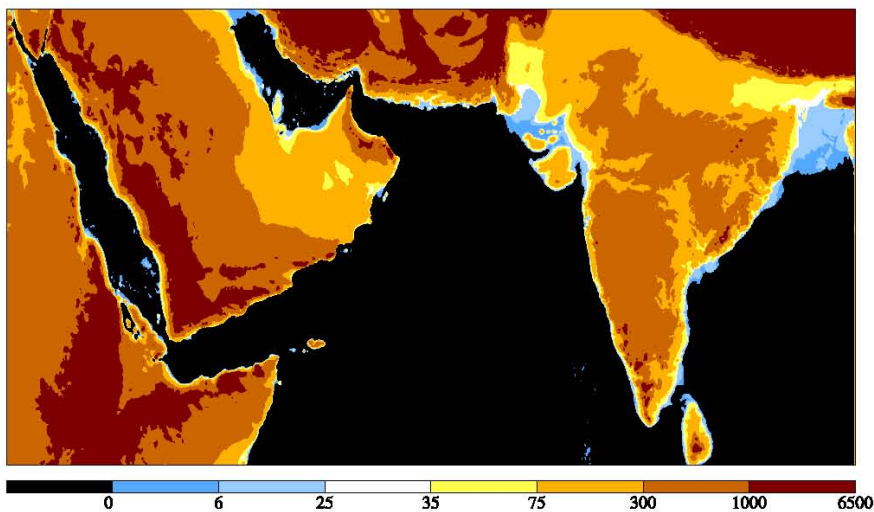
U.S. Area Under Water



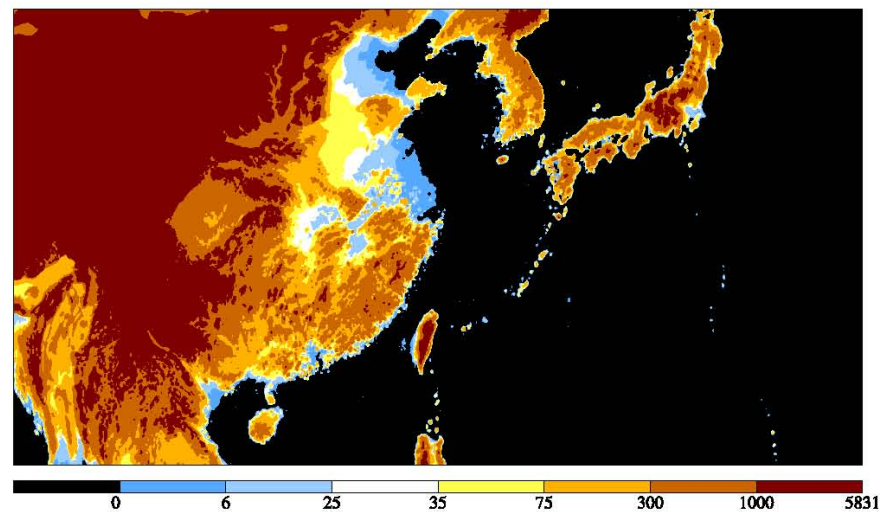
Europe Area Under Water



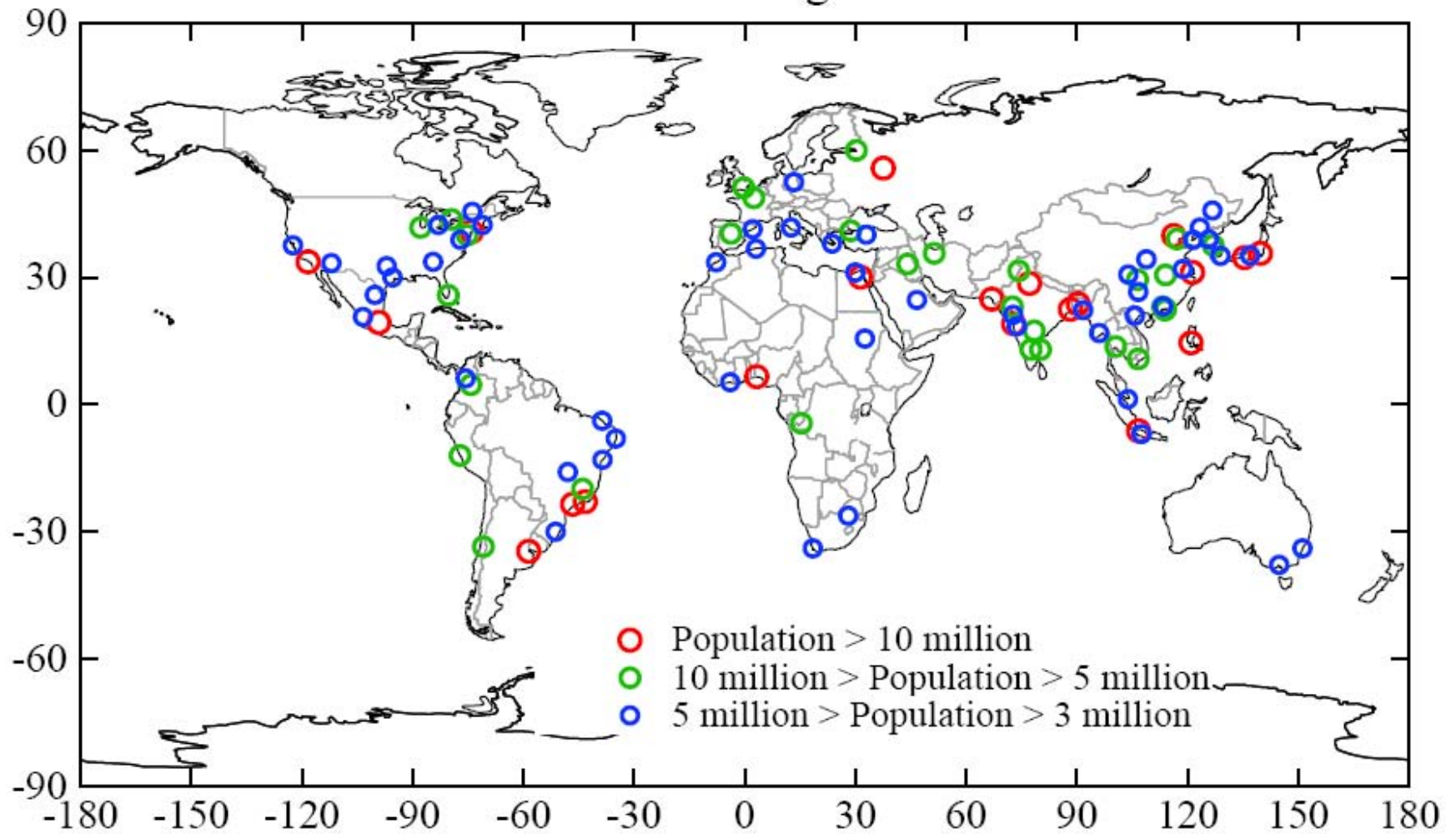
Central Asia: Area under Water



Far East: Area under Water



World's 100 Largest Cities



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/special/polar%5Fbears/

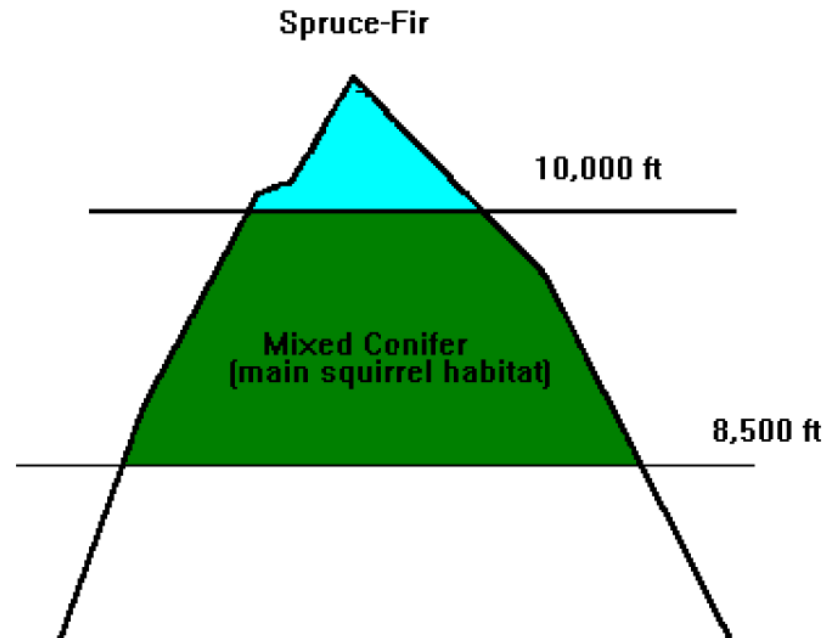
Images:
Sea Ice: Claire Parkinson
& Robert Taylor
Polar Bears: Unknown



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

Define a “Target CO₂”: Why?

1. Public Needs to Know

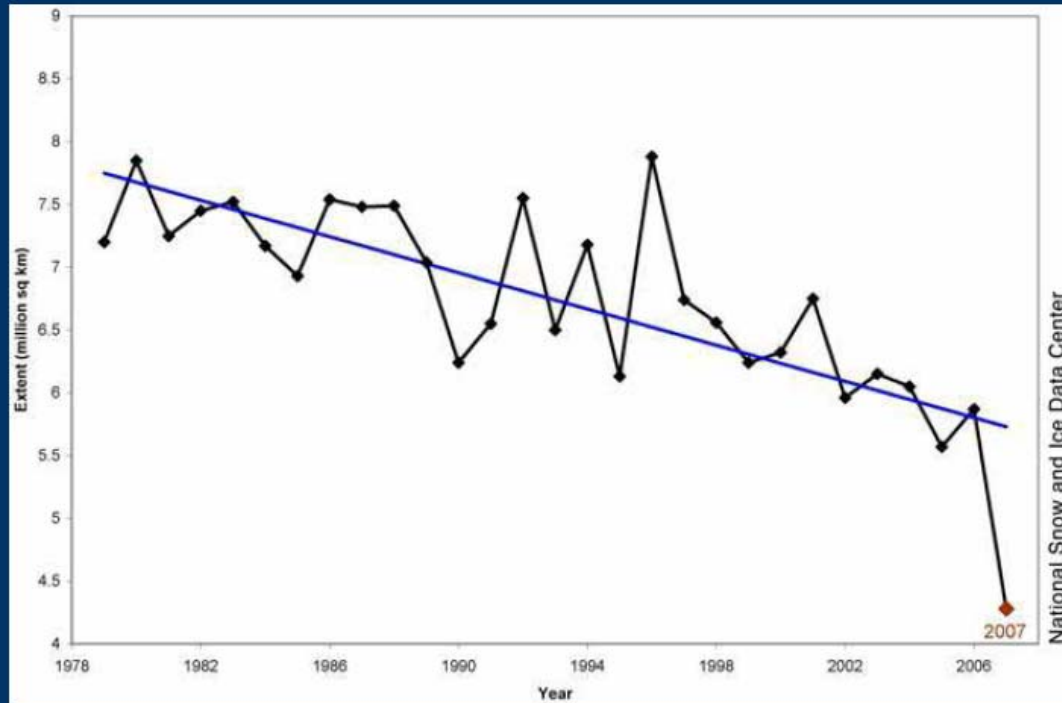
- For Energy Policies
- CO₂ Long-Lived (1/5 > 1000 years)

2. Flaws in ‘Dangerous Level’ Approach

- Standard of Proof too Great
- Levels Defined can be Absurd
 - ‘Burning Embers’ → +3°C Dangerous!!!
- If 450 ppm is Dangerous, is 449 ppm o.k.?

2007 Sea ice conditions in context

September Sea Ice Extent (1979–2007)



September 2007
4.28 million km²

Arctic Sea Ice Criterion*

1. Restore Planetary Energy Balance

→ CO₂: 385 ppm → 325-355 ppm

2. Restore Sea Ice: Aim for -0.5 W/m²

CO₂: 385 ppm → 300-325 ppm

Range based on uncertainty in present planetary energy imbalance (between 0.5 and 1 W/m²)

* Assuming near-balance among non-CO₂ forcings

Sea Level Criterion*

1. Prior Interglacial Periods

→ CO₂ ~ 300 ppm

2. Cenozoic Era

→ CO₂ ~ 300 ppm

3. Ice Sheet Observations

→ CO₂ < 385 ppm

* Assuming near-balance among non-CO₂ forcings



Pier on Lake Mead.

Assessment of Target CO₂

Phenomenon

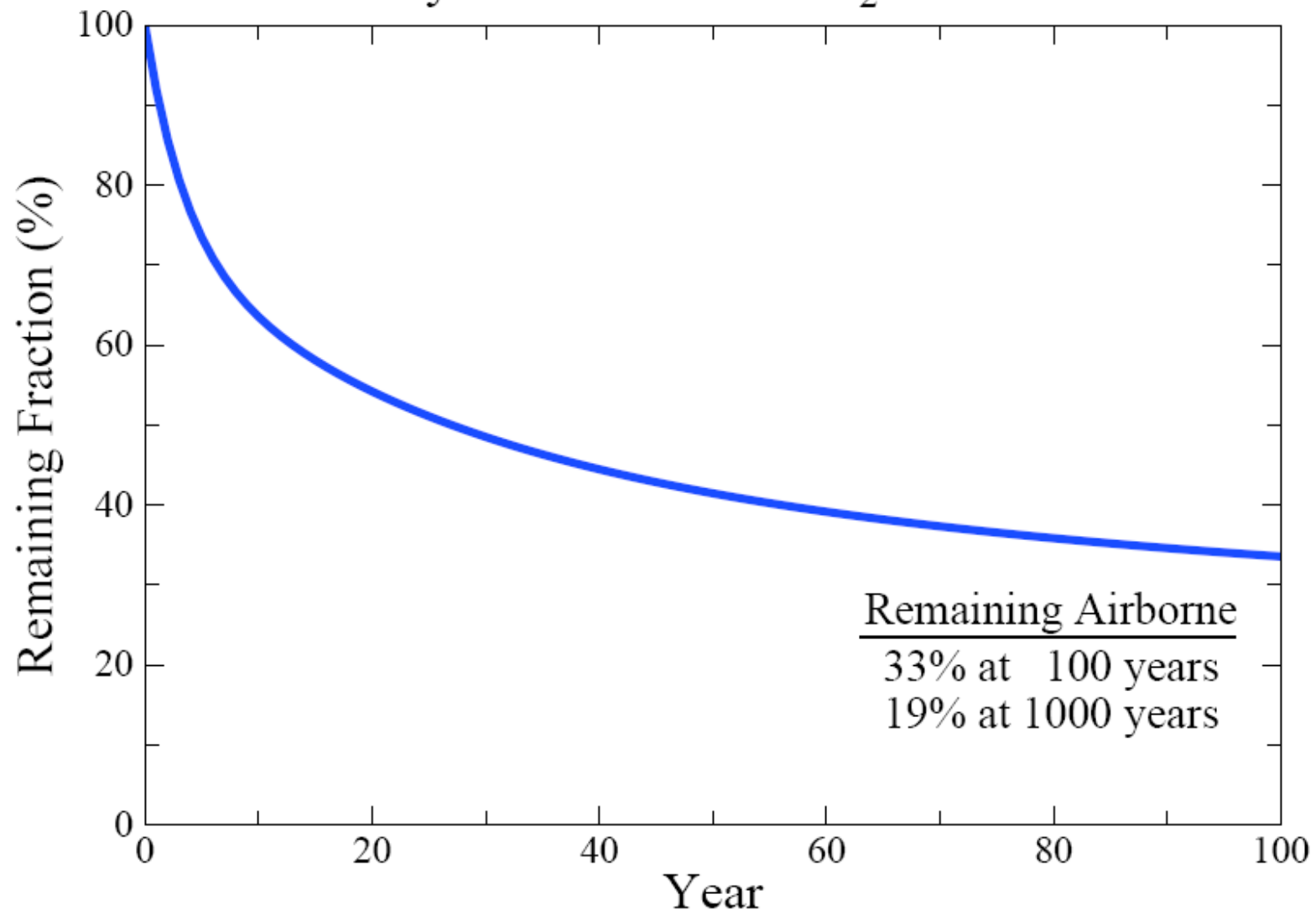
Target CO₂ (ppm)

- | | |
|------------------------------|---------|
| 1. Arctic Sea Ice | 300-325 |
| 2. Ice Sheets/Sea Level | 300-350 |
| 3. Shifting Climatic Zones | 300-350 |
| 4. Alpine Water Supplies | 300-350 |
| 5. Avoid Ocean Acidification | 300-350 |

→ Initial Target CO₂ = 350* ppm

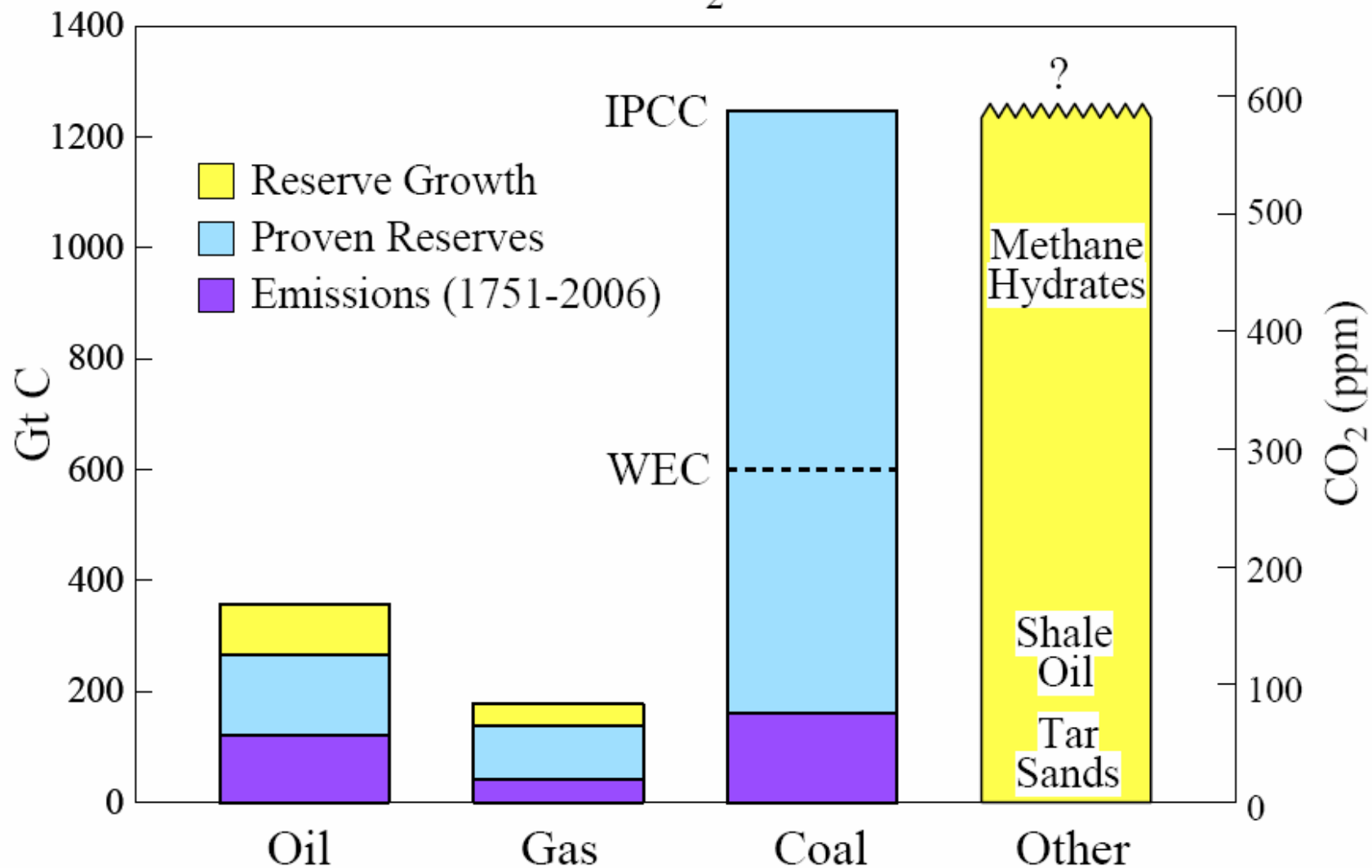
*assumes CH₄, O₃, Black Soot decrease

Decay of Fossil Fuel CO₂ Emission



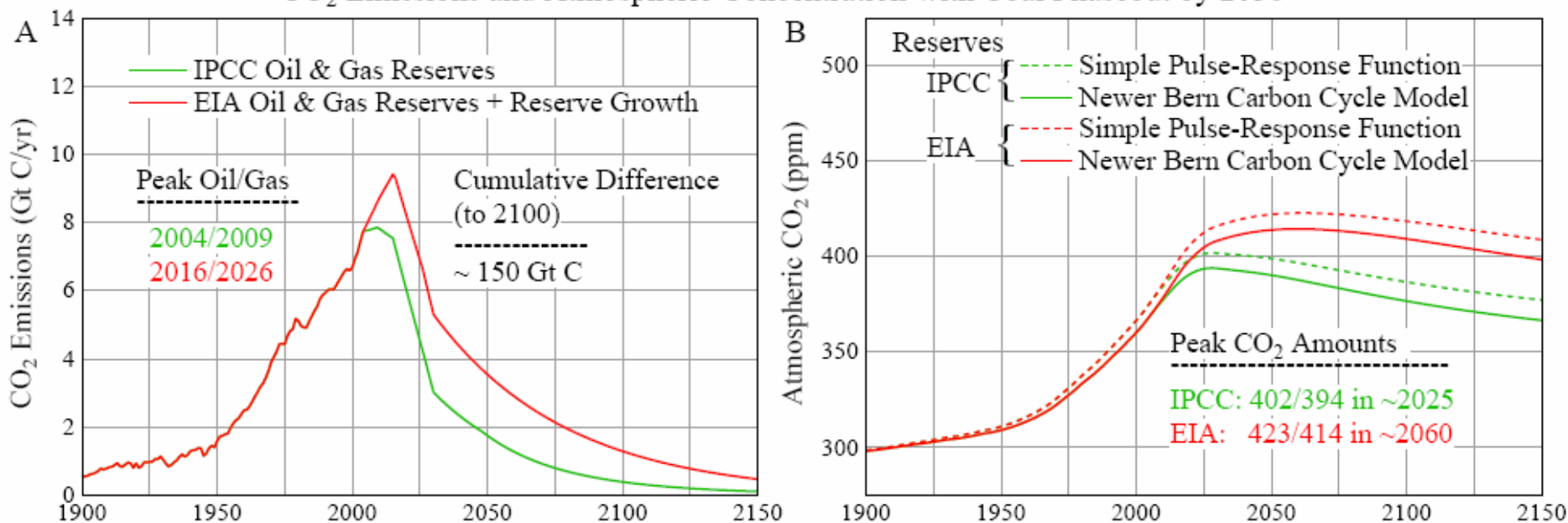
The fraction of CO₂ remaining in the air, after emission by fossil fuel burning, declines rapidly at first, but 1/3 remains in the air after a century and 1/5 after a millennium (*Atmos. Chem. Phys.* **7**, 2287-2312, 2007).

Fossil Fuel CO₂ Reservoirs

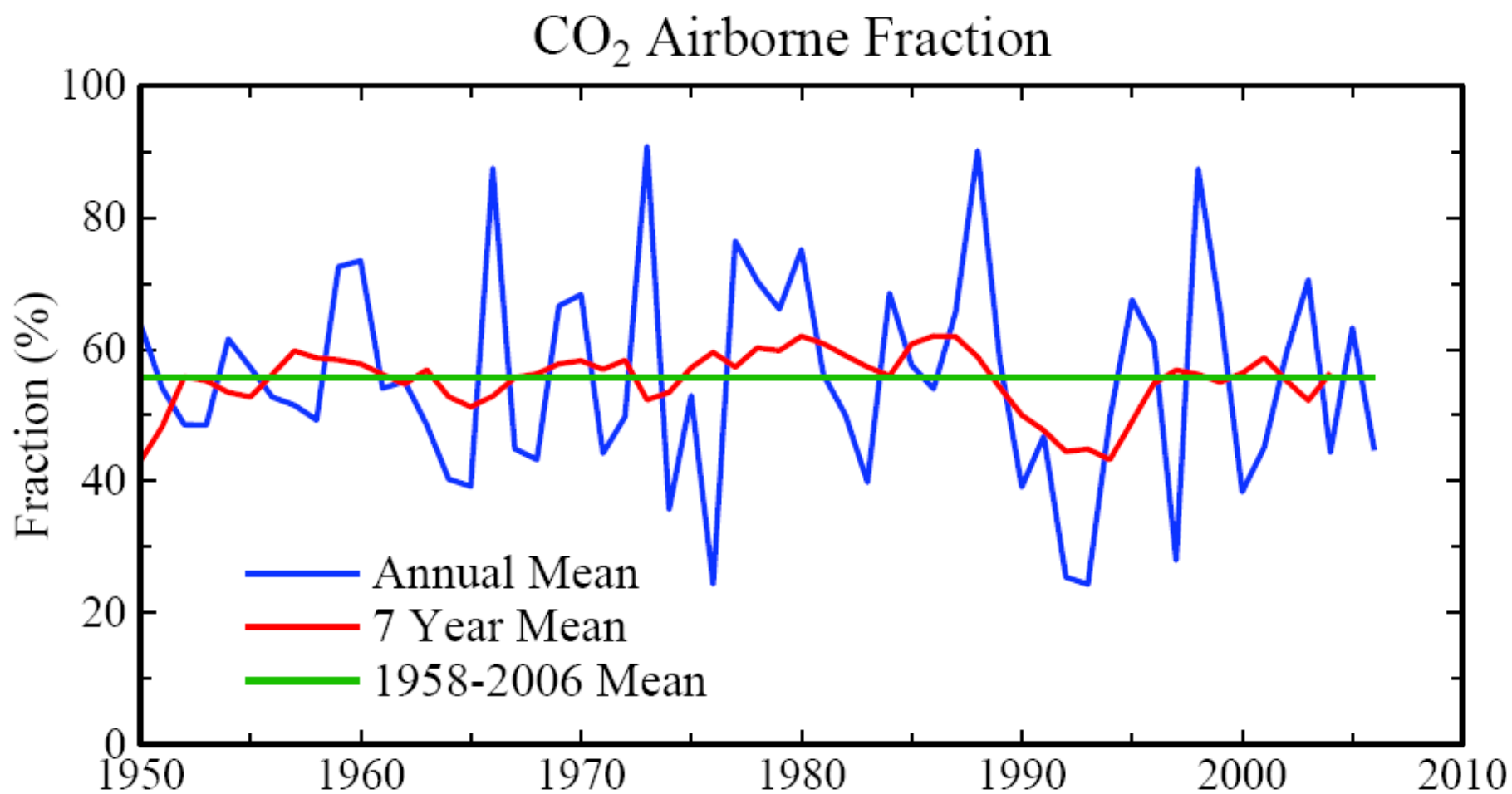


Estimated fossil fuel reserves; purple portions have already been used
(*Atmos. Chem. Phys.* **7**, 2287-2312, 2007)

CO₂ Emissions and Atmospheric Concentration with Coal Phaseout by 2030



(A) CO₂ emissions with coal phase-out by 2030 based on IPCC and EIA estimated fossil fuel reserves. (B) Resulting atmospheric CO₂.



Ratio: annual observed atmospheric CO₂ increase/annual fossil fuel CO₂ emissions

Carbon Dioxide and Our Future

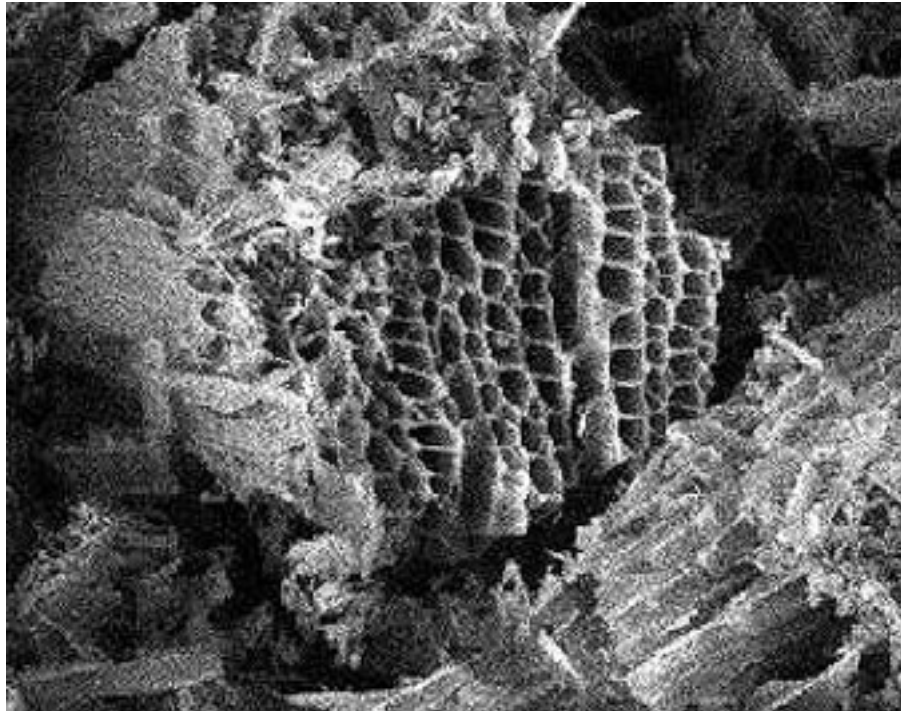
4 charts from a presentation of
Folke Günther

Holon Ecosystem Consultants

Lund

Sweden

Charcoal works as an adsorption
lattice for micro-organisms and
nutrient particles



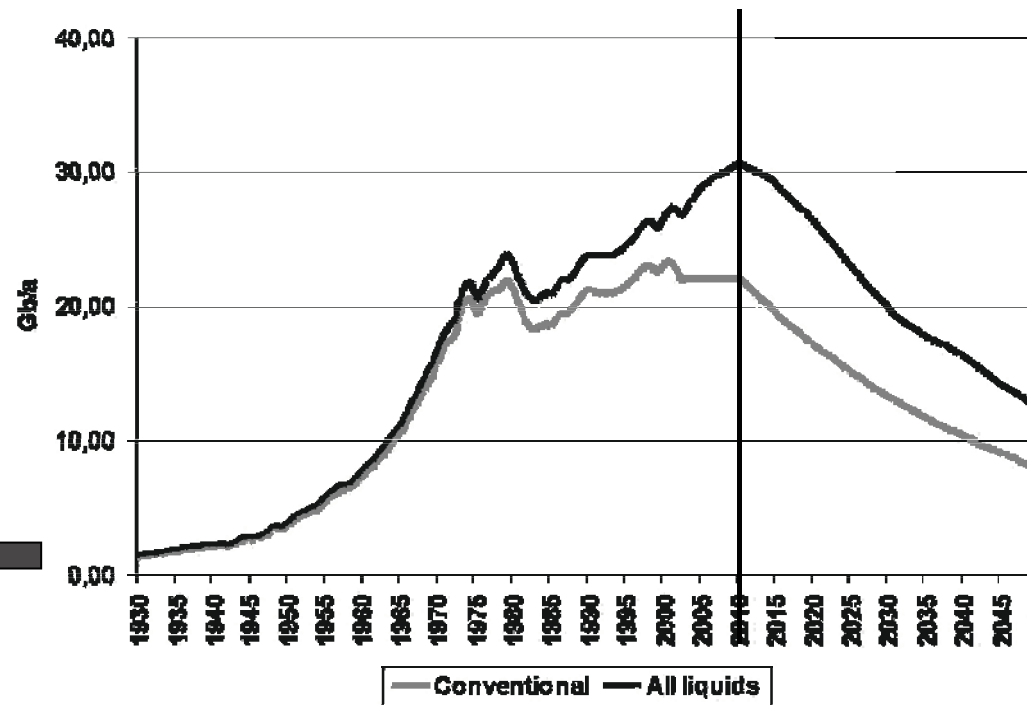
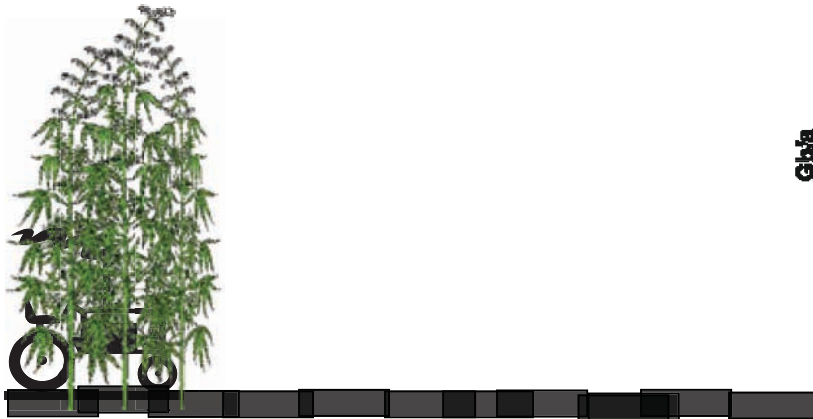
Rationale for Adding Biochar to Soil

- **Counteract the greenhouse effect**
- **Increase soil fertility**
- **Produce biofuels and industrial materials while making charcoal**

👉 You should be paid
the same amount as
the emission tax

👉 And you should be *the
only one* who has the right
to sell emission permits

A prosperous way down?



Initial Target CO₂: 350 ppm

Technically Feasible

(but not if business-as-usual continues)

Quick Coal Phase-Out Critical

(long lifetime of atmospheric CO₂)

(must halt construction of any new coal plants that do not capture & store CO₂)

Basic Conflict

Fossil Fuel Special Interests

VS

Young People & Nature (Animals)

Fossil Interests: God-given fact that all fossil fuels will be burned **(no free will)**

Young People: Hey! Not so fast!
Nice planet you are leaving us!

“Free Will” Alternative

1. Phase Out Coal CO₂ Emissions

- by 2025/2030 developed/developing countries

2. Rising Carbon Price

- discourages unconventional fossil fuels & extraction of every last drop of oil (Arctic, etc.)

3. Soil & Biosphere CO₂ Sequestration

- improved farming & forestry practices

4. Reduce non-CO₂ Forcings

- reduce CH₄, O₃, trace gases, black soot

What are the Chances?

Fossil Interests: have influence in capitols world-wide

Young People: need to organize, enlist others (parents, e.g.), impact elections

Animals: not much help (don't vote, don't talk)

The One Essential Action:

Halt Construction of Coal Plants that do not Capture and Store CO₂

Citizens Must Stand Up

Coal Industry is Very Powerful

Congress Unlikely to Act Decisively

The Big Tipping Point

Positive Feedbacks in Society

**Public/Businesses/Government
decide we are on the same side,
make rules that encourage energy
efficiency, renewable energies,
innovations.**



but animals can't do it

The Challenge

We can avoid destroying creation!

**We have to figure out how to live
without fossil fuels someday...**

Why not now?