Global Warming 20 Years Later:
Tipping Points Near

Jim Hansen

23 June 2008

National Press Club, and
House Select Committee on
Energy Independence & Global Warming

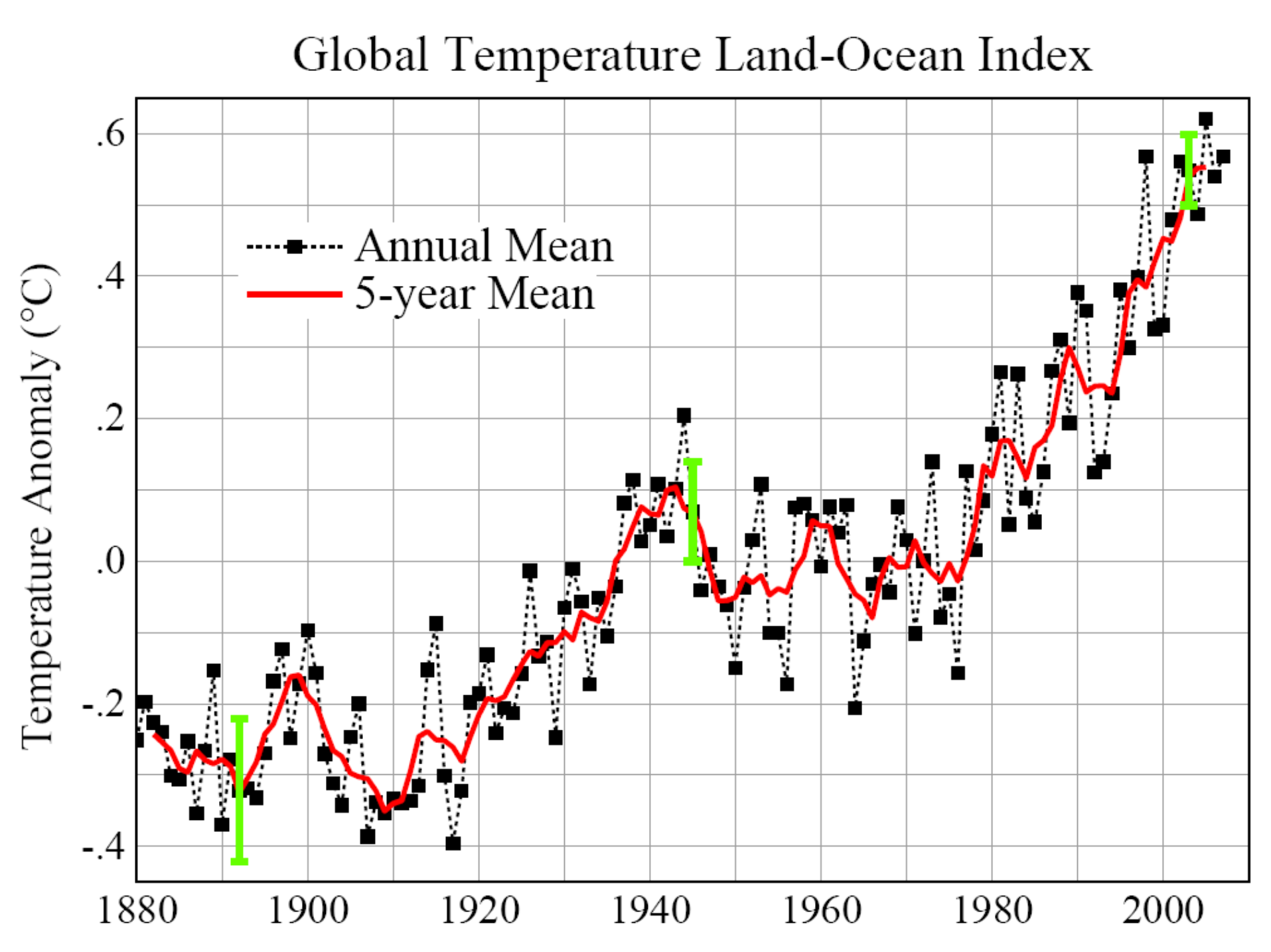
Washington, DC

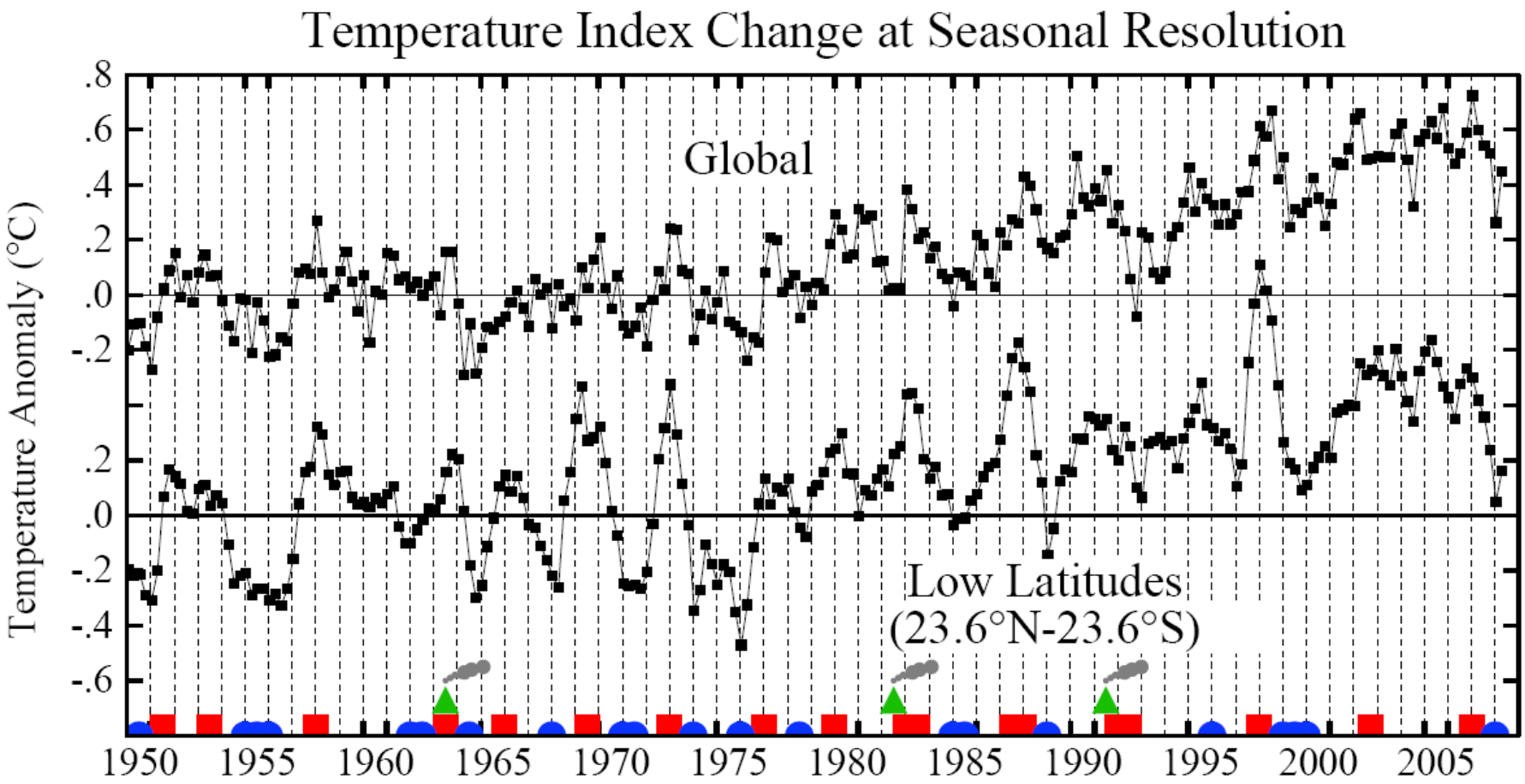
1988 Testimony: Conclusions

1. Earth is warmer in 1988 than at any time in the history of instrumental measurements

2. Global warming is now large enough that we can ascribe with a high degree of confidence a cause and effect relationship to the greenhouse effect

3. Greenhouse effect is already large enough to effect the probability of extreme events such as summer heat waves


Global Temperature Land-Ocean Index
Annual Mean
5-year Mean
Temperature Anomaly (°C)
.6
.4
.2
.0
-.2
-.4
1880
1900
1920
1940
1960
1980
2000


Temperature Index Change at Seasonal Resolution
Temperature Anomaly (°C)
.8
.6
.4
.2
.0
-.2
.2
.0
-.2
-.4
-.6
Global
Low Latitudes
(23.6°N-23.6°S)
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005

Basis of Testimony

1988

1. Basic Physics, Planetary & Paleo Studies
2. Observed On-Going Climate Change
3. Climate Models

2008

1. Paleoclimate: History of Earth's Climate
2. Global Observations of Climate Processes
3. Climate Models

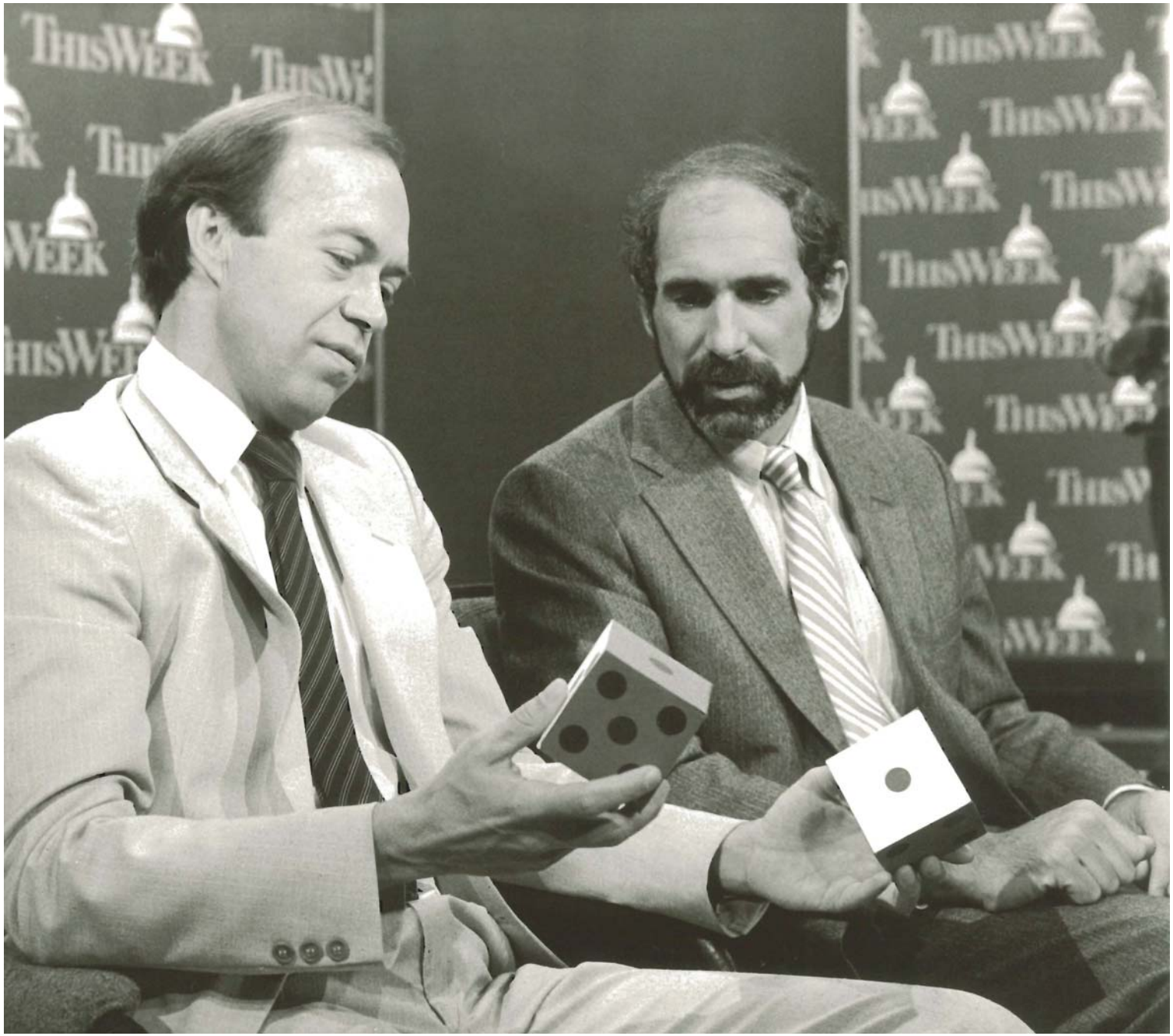
Major Flaws in 1988 Testimony

Did Not Emphasize Warming vs Chaos

- Weather Variations >> Climate Trend
- Small Change of Mean Has Big Effects

Did Not Emphasize That Global Warming Enhances Both Extremes of Water Cycle

- More Intense Droughts, Heat Waves, Fires
- Heavier Rainfall, Greater Floods, Stronger Storms Driven by Latent Heat (Thunder Storms, Tornados, Tropical Storms)


ThisWeek

Global Warming Status

1. **Knowledge Gap Between**
   - **What is Understood (science)**
   - **What is Known (public)**

2. **Planetary Emergency**
   - **Climate Inertia → Warming in Pipeline**
   - **Tipping Points → Could Lose Control**

3. **Good News & Bad News**
   - **Safe Level of CO_2 < 350 ppm**
   - **Multiple Benefits of Solution**

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

Extermination of Animal & Plant Species

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

Ice Sheet Disintegration: Global Sea Level

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

Regional Climate Disruptions

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

Target CO_2:

< 350 ppm

To preserve creation, the planet on which civilization developed

Tipping Point Definitions

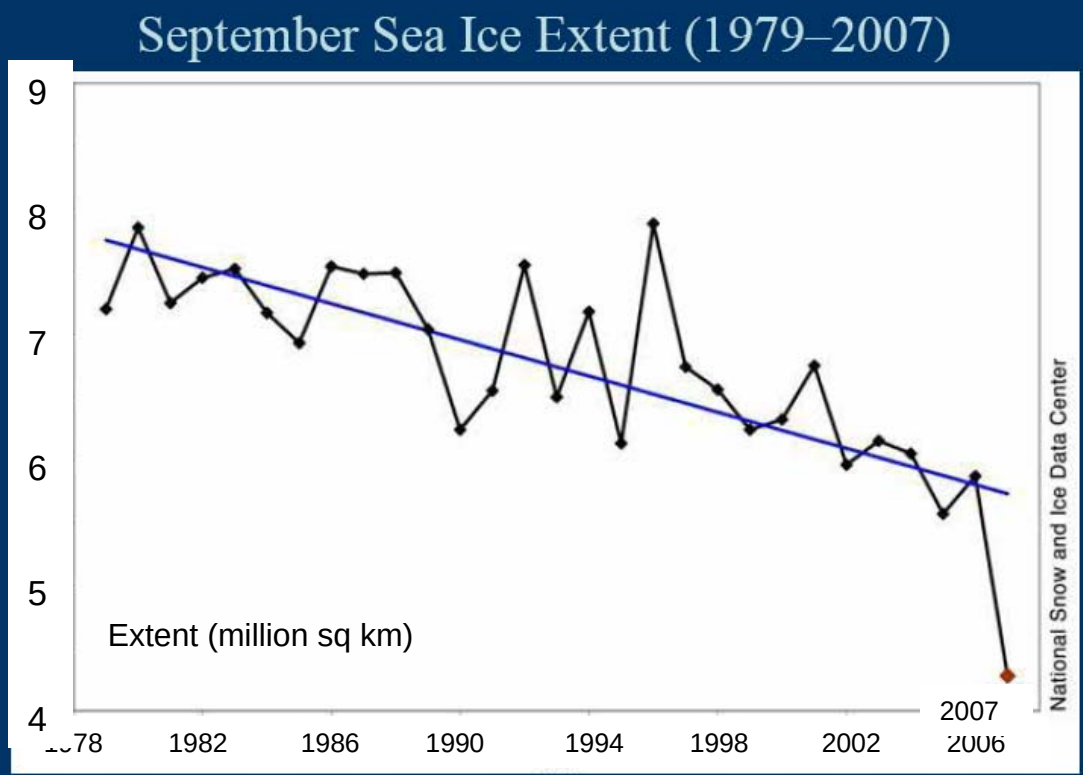
1. Tipping Level

- Climate forcing (greenhouse gas amount) reaches a point such that no additional forcing is required for large climate change and impacts

2. Point of No Return

- Climate system reaches a point with unstoppable irreversible climate impacts (irreversible on a practical time scale)
  Example: disintegration of large ice sheet

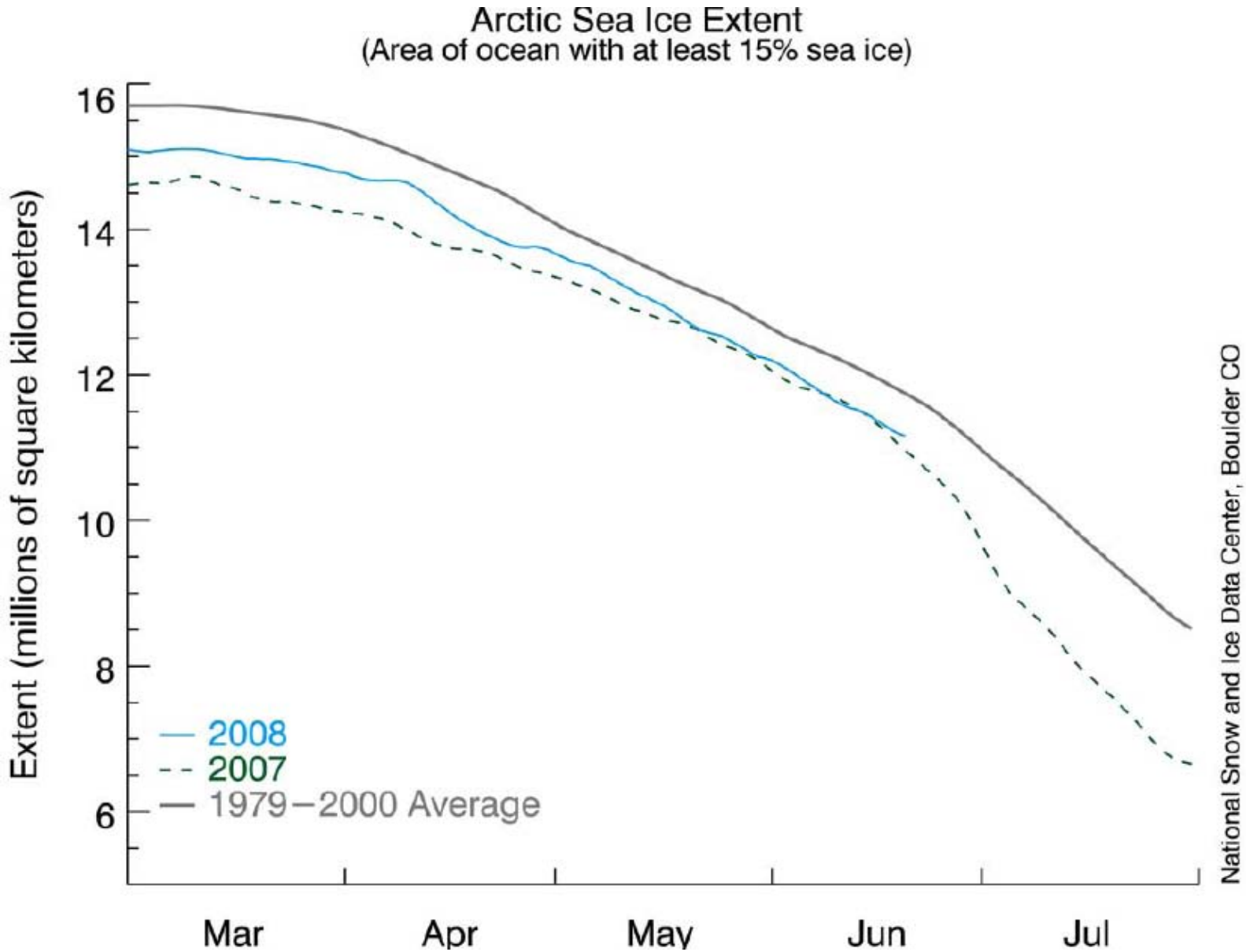
2007 Sea ice conditions in context

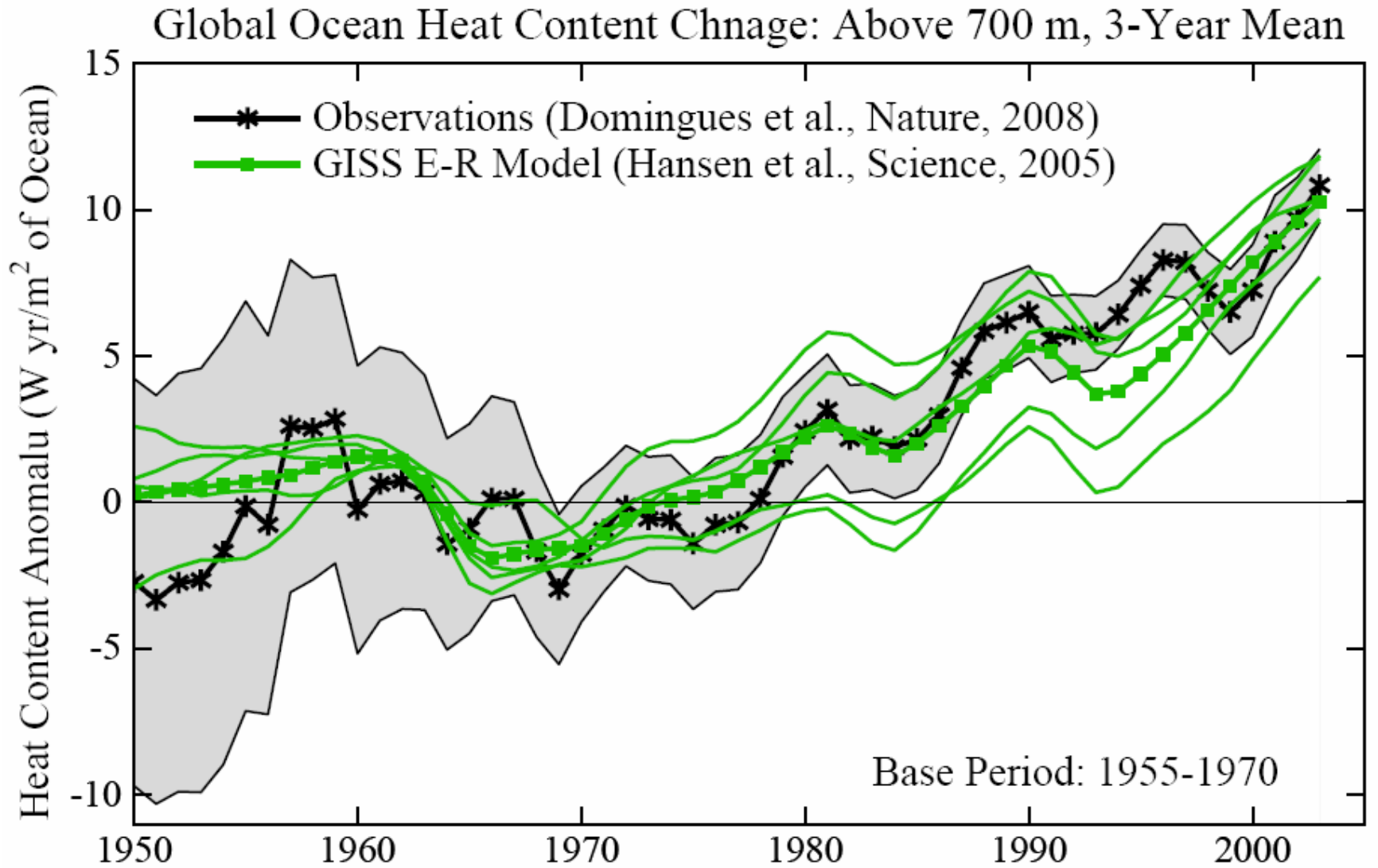


September 2007
4.28 million km^2

Mark Serreze, Julienne Stroeve, Walt Meier, Ted Scambos, Marika Holland, Jim Maslanik, Stephanie Renfrow, Matt Savoie

NSIDC


Arctic Sea Ice Extent
(Area of ocean with at least 15% sea ice)
Extent (millions of square kilometers)
16
14
12
10
8
6
2008
2007
1979–2000 Average
Mar
Apr
May
Jun
Jul
National Snow and Ice Data Center, Boulder CO



Observations: Domingues, C.M. et al., Nature 453, 1090-1093, 2008.
Model: Hansen, J. et al., Science 308, 1431-1435, 2005.

Arctic Sea Ice Criterion*

1. Restore Planetary Energy Balance

→ CO_2: 385 ppm → 325-355 ppm

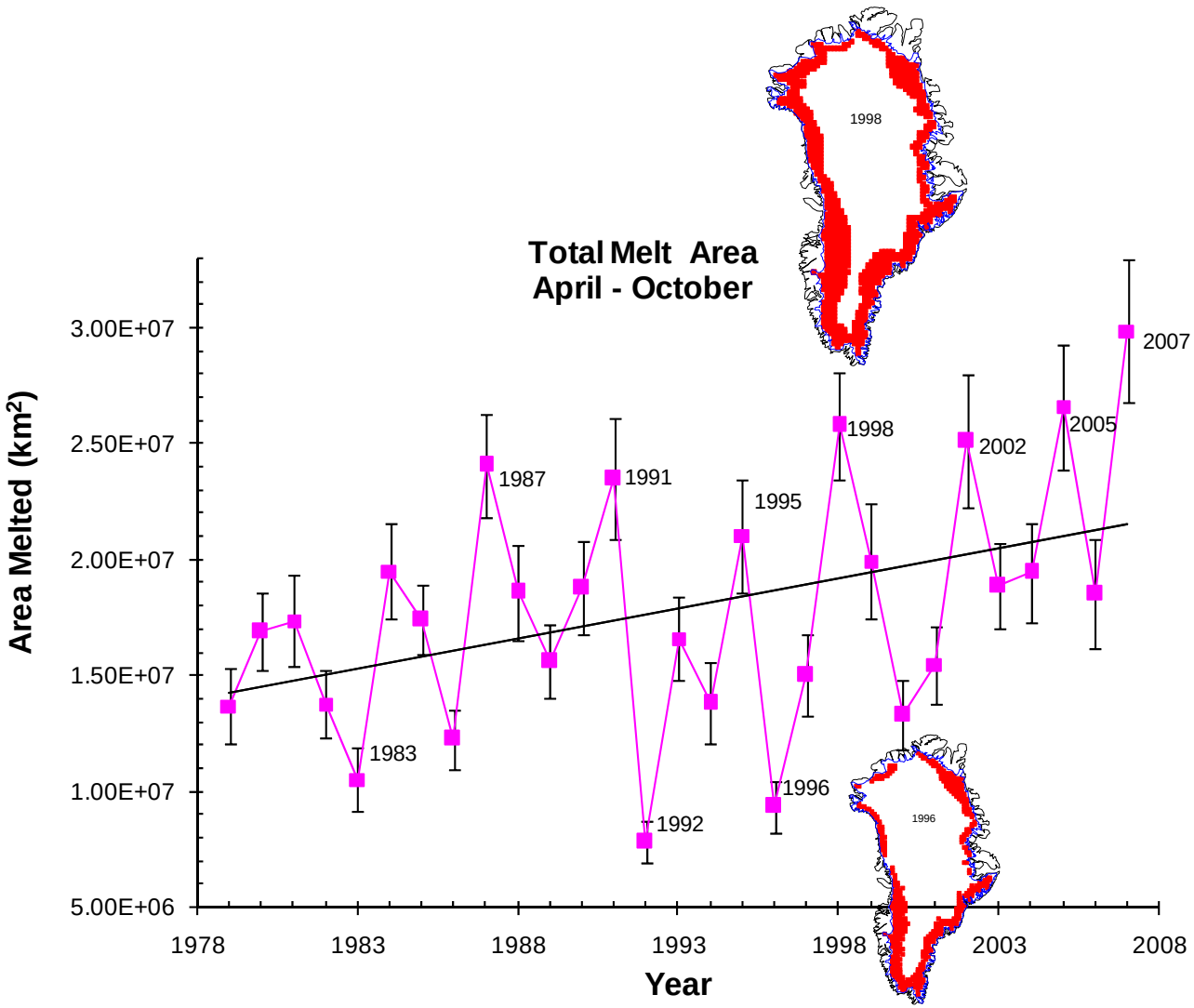
2. Restore Sea Ice: Aim for -0.5 W/m^2

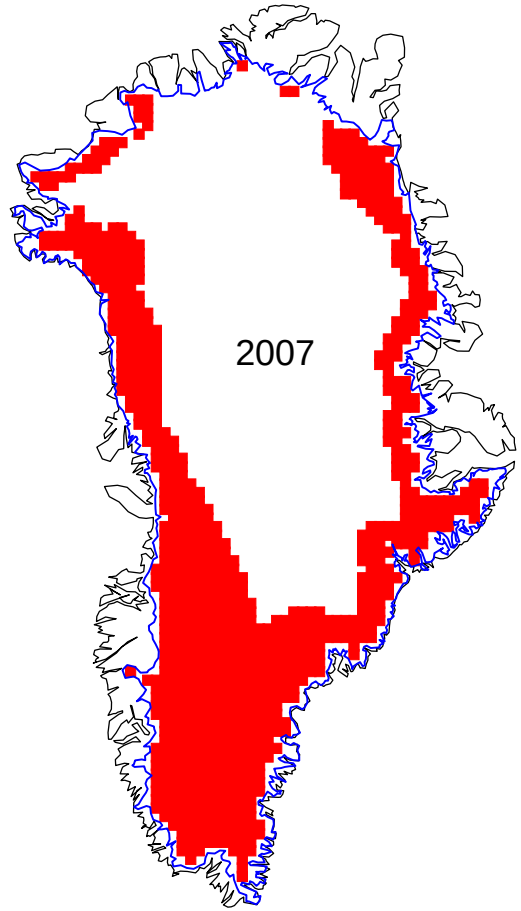
CO_2: 385 ppm → 300-325 ppm

Range based on uncertainty in present planetary energy imbalance (between 0.5 and 1 W/m^2)

***Assuming near-balance among non-CO_2 forcings**

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.

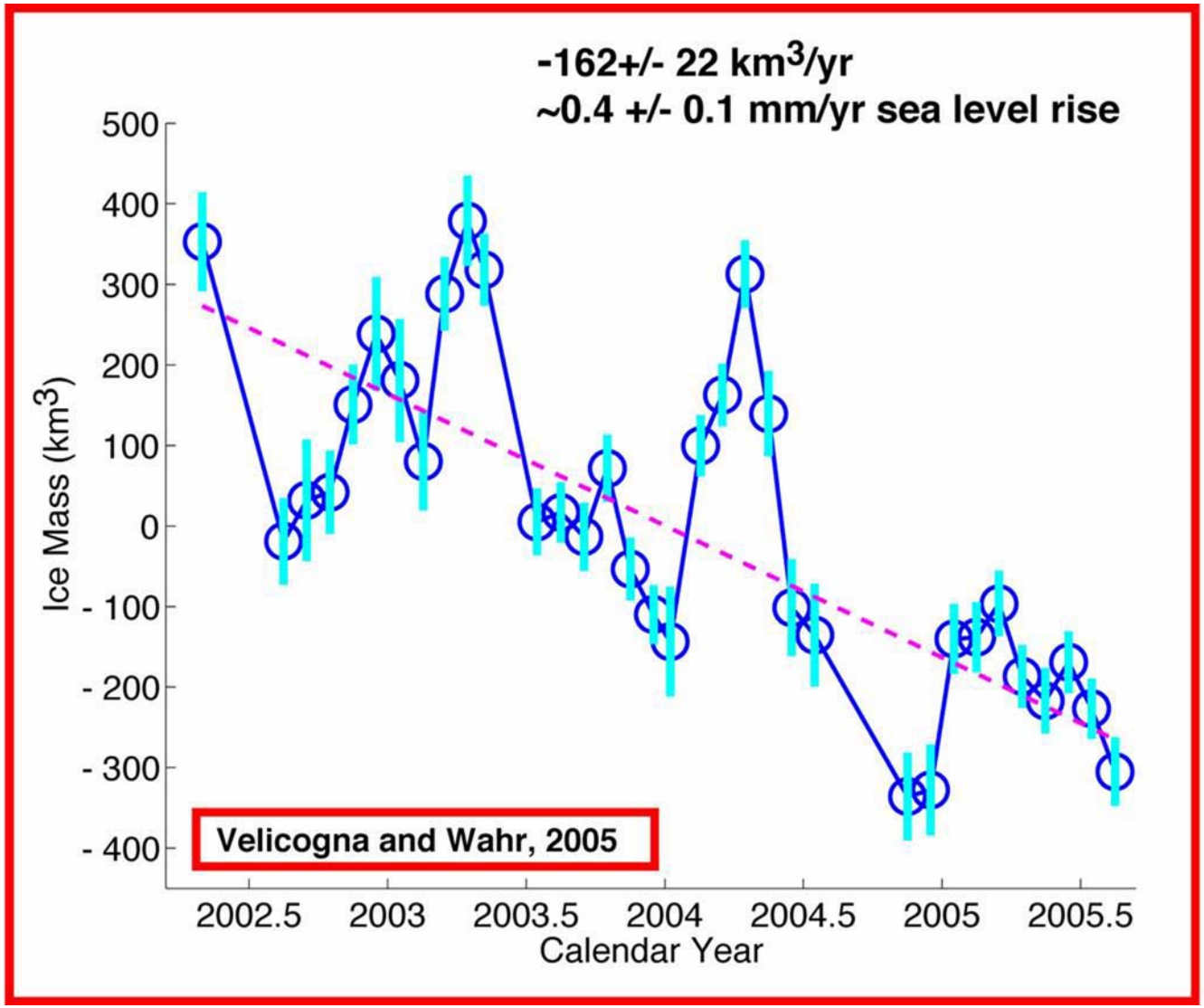
Source: Roger Braithwaite, University of Manchester (UK)

Jakobshavn Ice Stream in Greenland

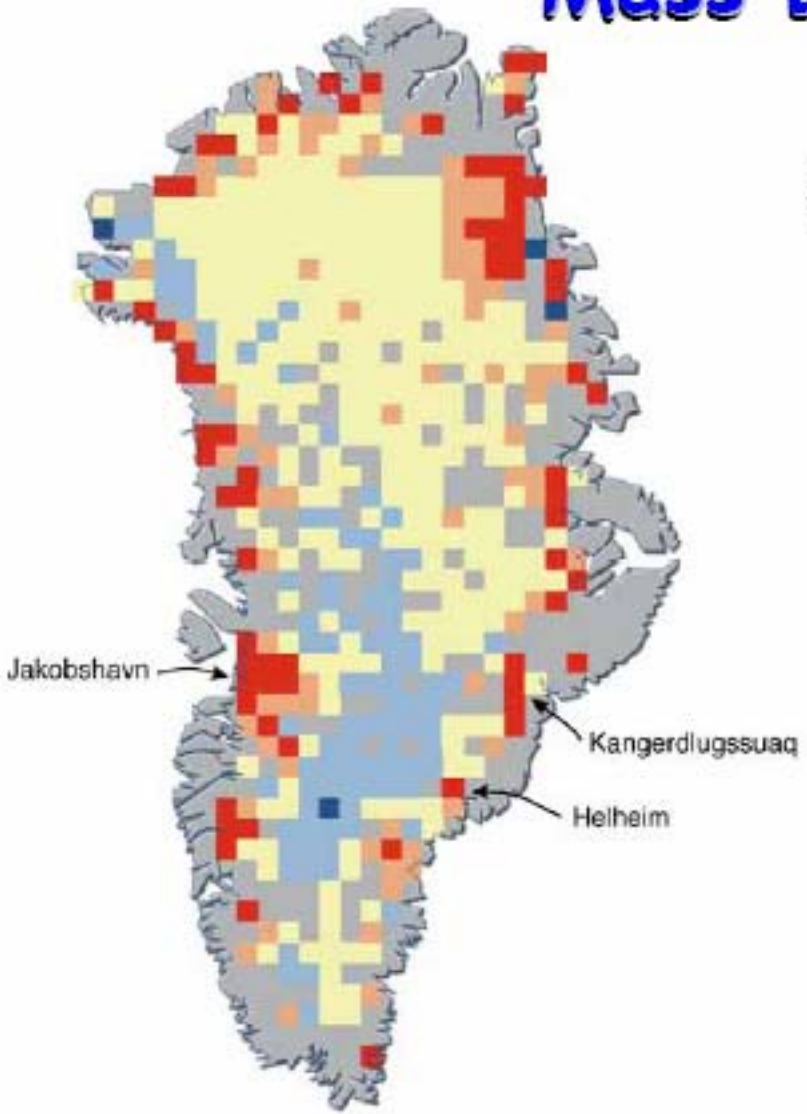
Discharge from major Greenland ice streams is accelerating markedly.

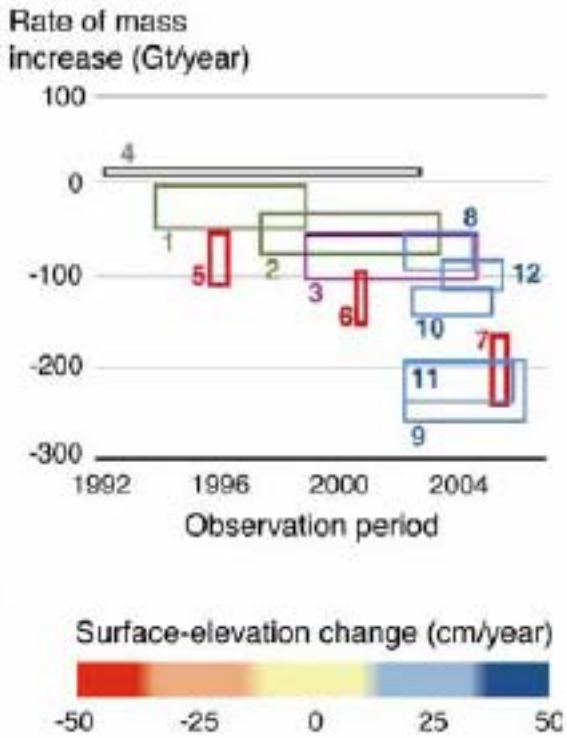
Source: Prof. Konrad Steffen, Univ. of Colorado

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[

Sea Level Criterion*

1. **Prior Interglacial Periods**

   → CO_2 <~ 300 ppm

2. **Cenozoic Era**

   → CO_2 <~ 300 ppm

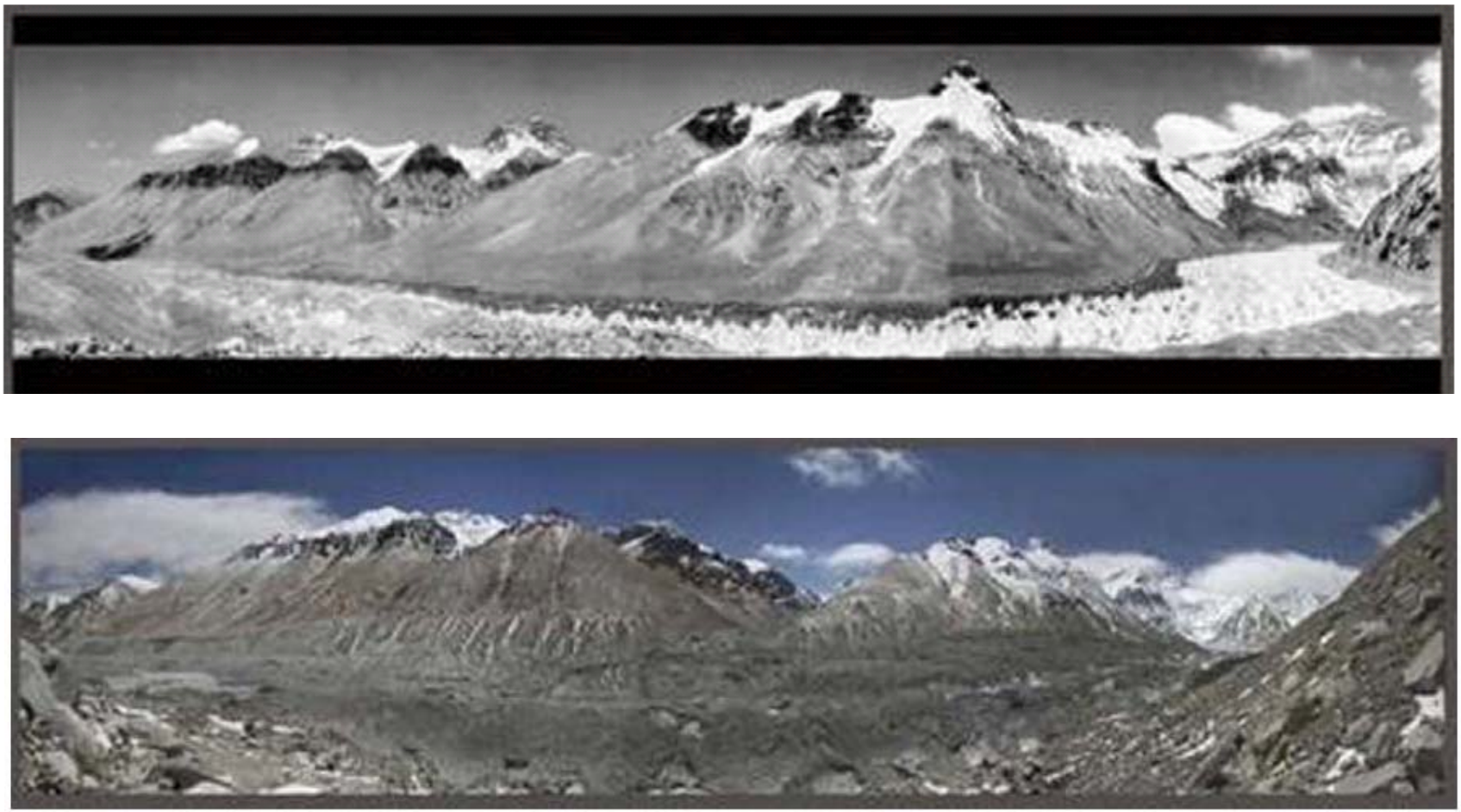
3. **Ice Sheet Observations**

   → CO_2 < 385 ppm

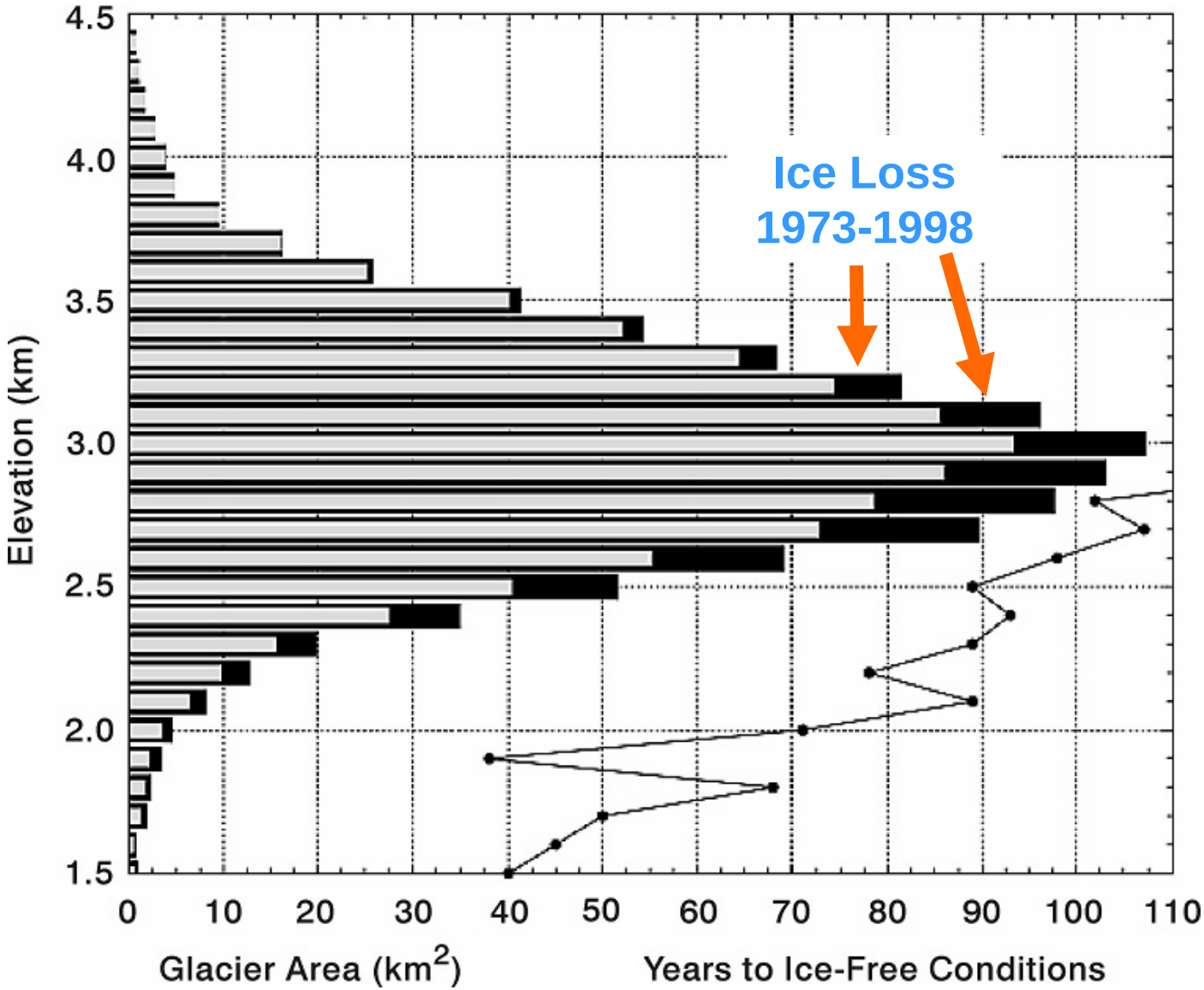
*Assuming near-balance among non-CO_2 forcings

Pier on Lake Mead.

Rongbuk Glacier



Rongbuk glacier in 1968 (top) and 2007. The largest glacier on Mount Everest's northern slopes feeds Rongbuk River.



Black bar: ice loss in 1973-1998. Curve:years until ice gone, at that loss rate.

Paul, F. et al., Geophys. Res. Lett. 31, L21402, 2004.

Stresses on Coral Reefs

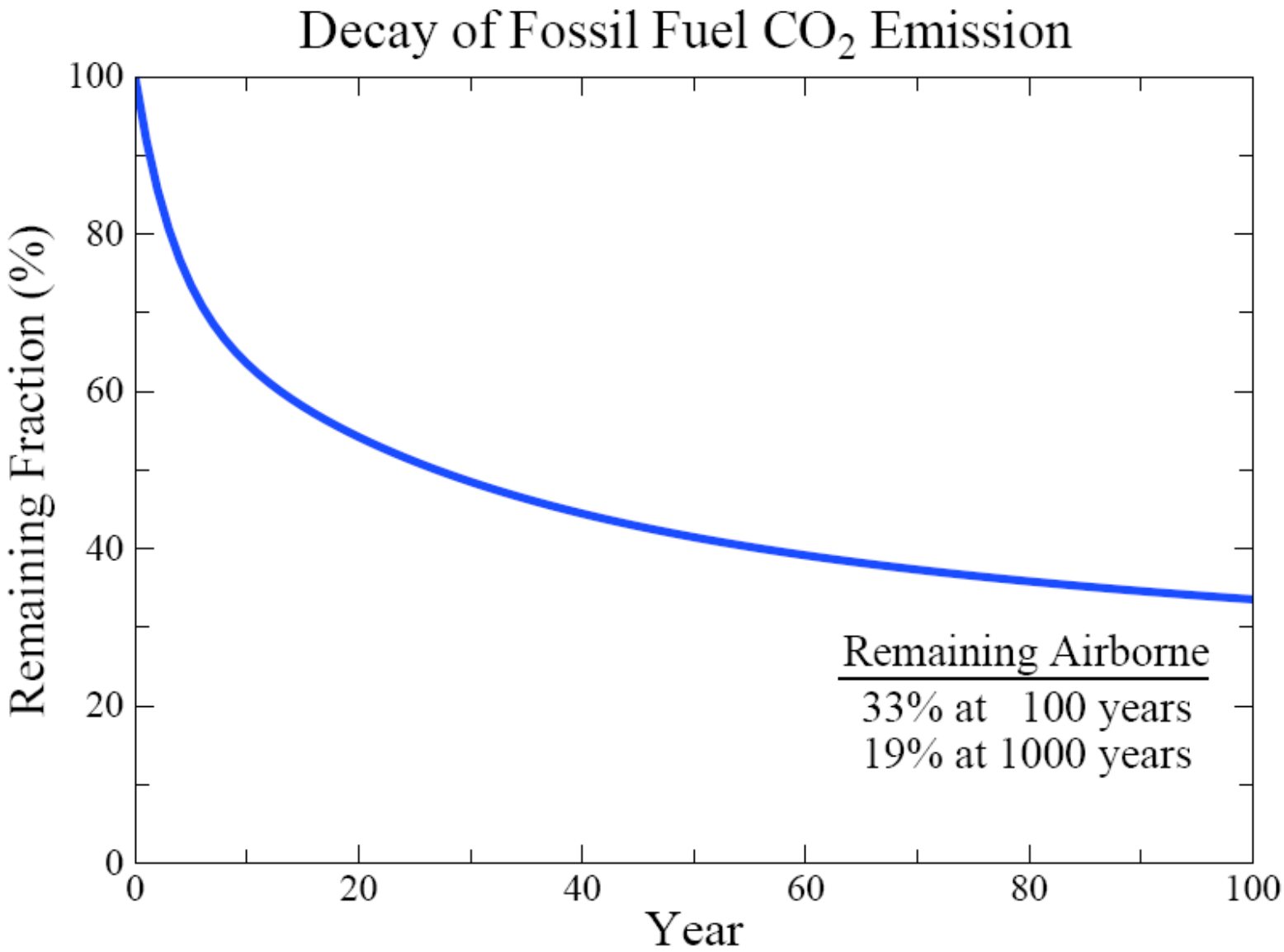
Coral Reef off Fiji (Photo: Kevin Roland)

Assessment of Target CO_2

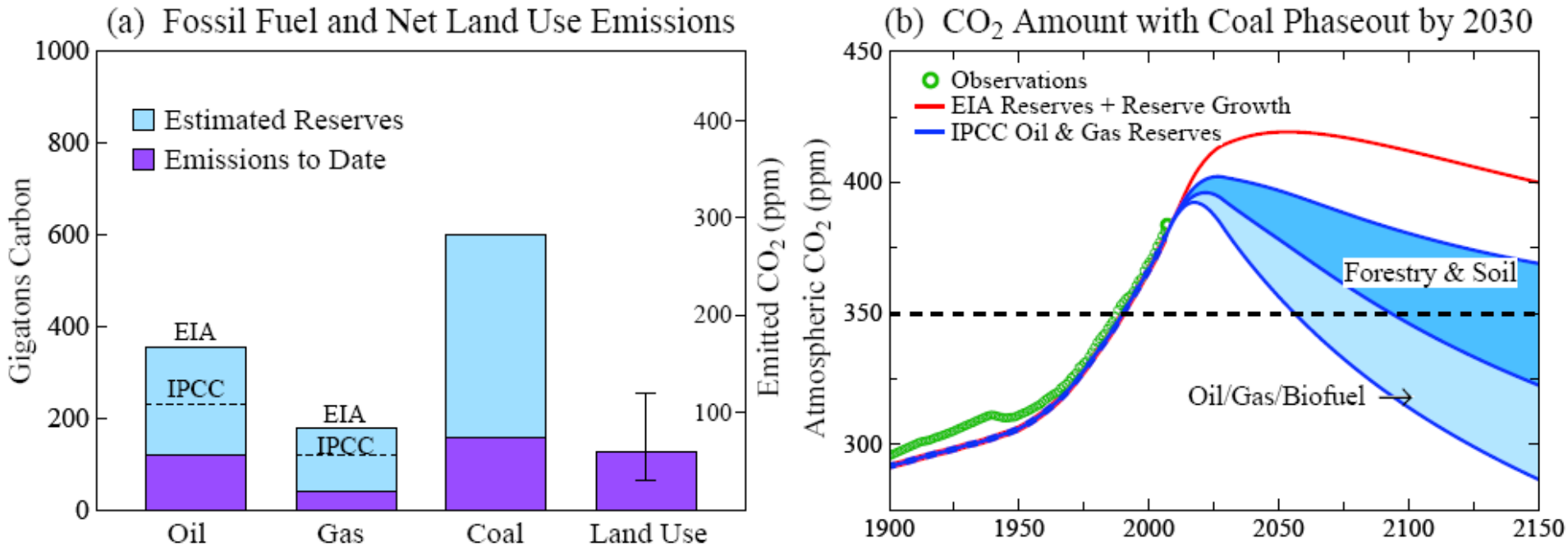
Phenomenon	Target CO_2 (ppm)
1. Arctic Sea Ice	300-325
2. Ice Sheets/Sea Level	300-350
3. Shifting Climatic Zones	300-350
4. Alpine Water Supplies	300-350
5. Avoid Ocean Acidification	300-350

→ **Initial Target CO_2 = 350* ppm**

***assumes CH_4, O_3, Black Soot decrease**



The fraction of CO_2 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).


(a) Fossil Fuel and Net Land Use Emissions
Gigatons Carbon
Emitted CO_2 (ppm)
Estimated Reserves
Emissions to Date
EIA
IPCC
EIA
IPCC
Oil
Gas
Coal
Land Use
(b) CO_2 Amount with Coal Phaseout by 2030
Atmospheric CO_2 (ppm)
Observations
EIA Reserves + Reserve Growth
IPCC Oil & Gas Reserves
Forestry & Soil
Oil/Gas/Biofuel

Initial Target CO_2: 350 ppm

Technically Feasible

(but not if business-as-usual continues)

Quick Coal Phase-Out Critical

(long lifetime of atmospheric CO_2)
(must halt construction of any new coal plants that do not capture & store CO_2)

“Free Will” Alternative

1. **Phase Out Coal CO_2 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 CO_2 Sequestration**
   - improved farming & forestry practices
4. **Reduce non-CO_2 Forcings**
   - reduce CH_4, O_3, trace gases, black soot

Carbon Tax & 100% Dividend

1. **Tax Large & Growing (but get it in place!)**
   - tap efficiency potential & life style choices
2. **Entire Tax Returned**
   - equal monthly deposits in bank accounts
3. **Limited Government Role**
   - keep hands off money!
   - eliminate fossil subsidies
   - let marketplace choose winners
   - change profit motivation of utilities
   - watch U.S. modernize & emissions fall!

Key Elements in Transformation

Low-Loss Electric Grid

- Clean Energy by 2020 (West) & 2030
- Allows Renewable Energy Ascendancy

Carbon Tax and 100% Dividend

- Tax at First Sale of Coal/Oil/Gas
- Tax Can Rise & Spur Transformations
- “100% or Fight! No Alligator-Shoes!”

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!

What are the Odds?

Fossil Interests: have influence in capitals 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 Challenge

We can avoid destroying creation!

(+cleaner planet, + good jobs!)

We have to figure out how to live without fossil fuels someday…

Why not now?

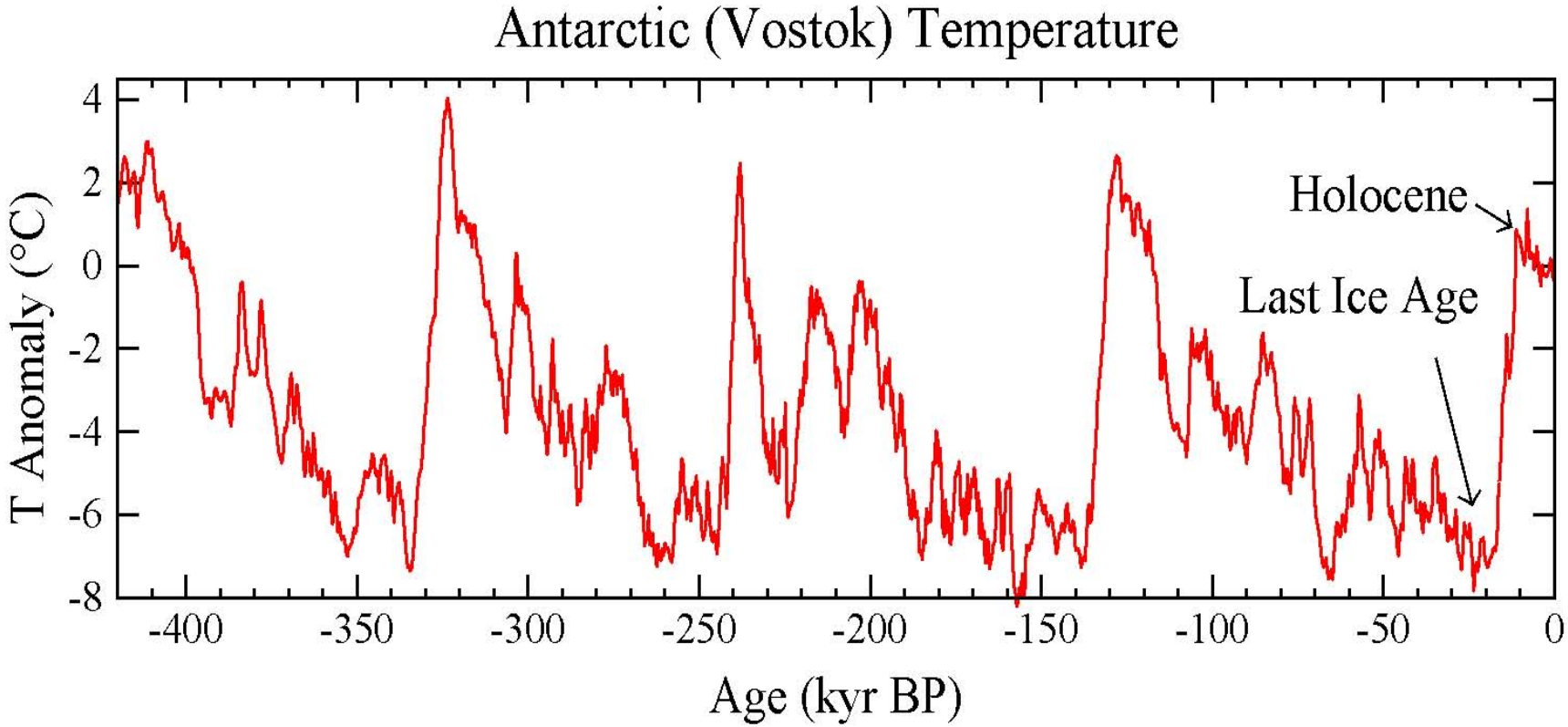
Web Site

www.columbia.edu/~jeh1

includes

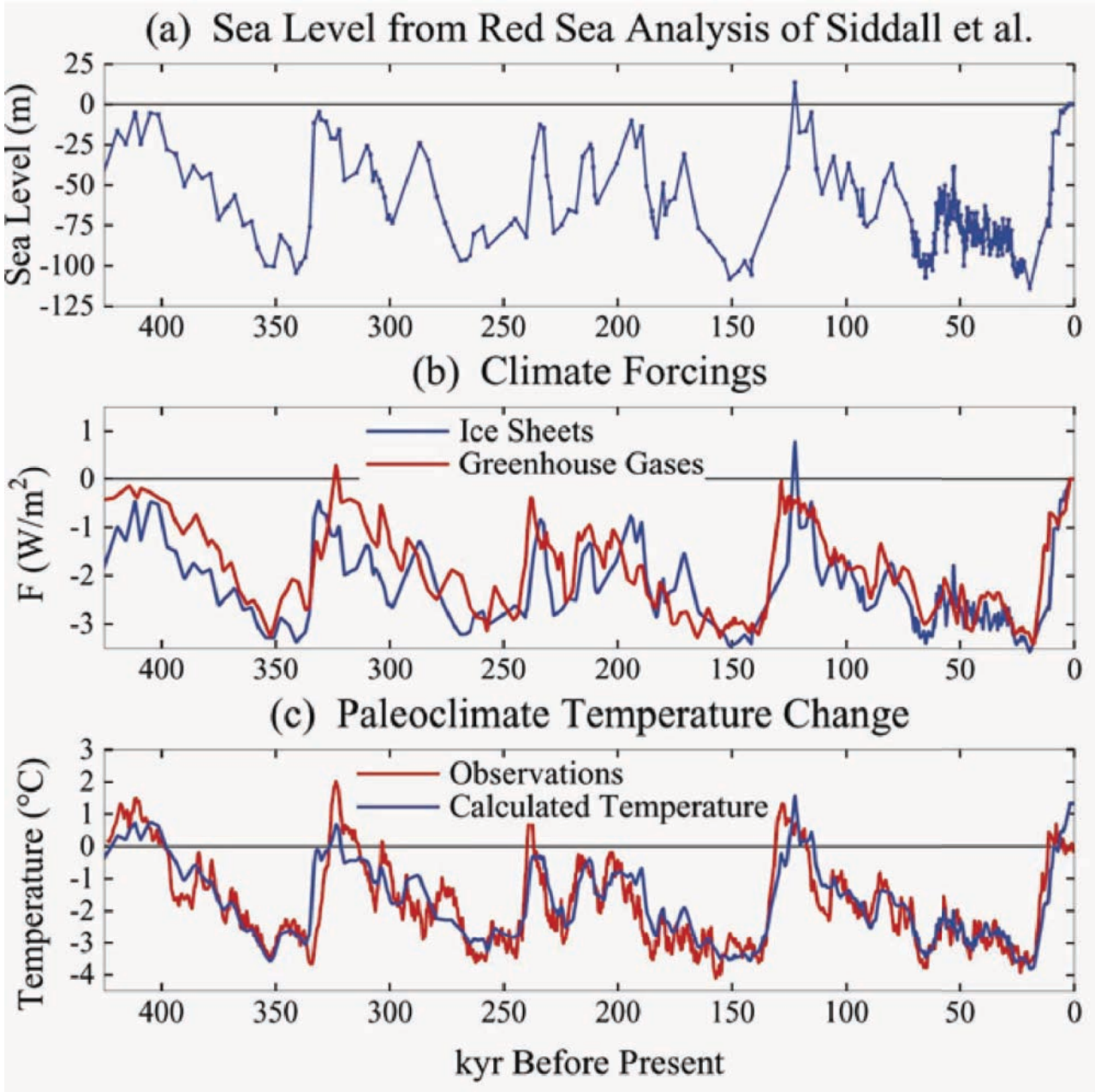
Global Warming Twenty Years Later: Tipping Points Near (today's statement)

Target Atmospheric CO_2: Where Should Humanity Aim?

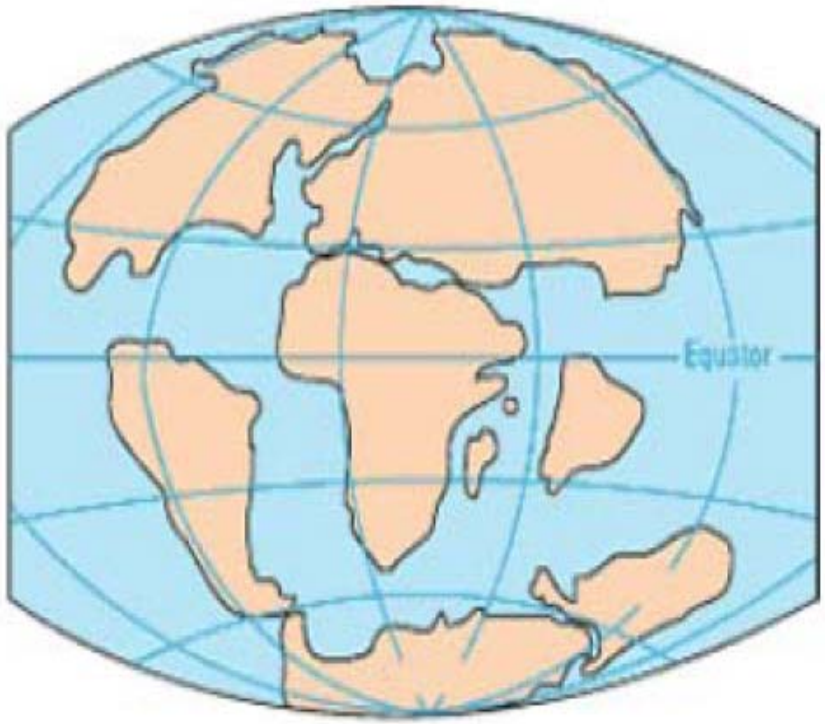


Earth's history provides most important information on global warming.

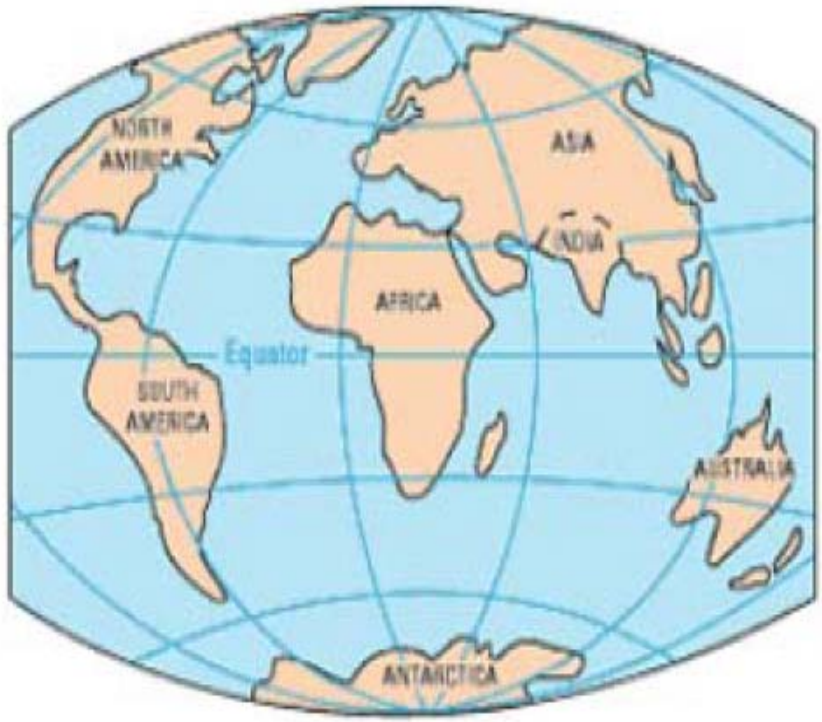
Recorded human history occurs within the Holocene warm period.


(a) Sea Level from Red Sea Analysis of Siddall et al.
Sea Level (m)
25
0
-25
-50
-75
-100
-125
400
350
300
250
200
150
100
50
0
(b) Climate Forcings
F (W/m^2)
Ice Sheets
Greenhouse Gases
1
0
-1
-2
-3
(c) Paleoclimate Temperature Change
Temperature (°C)
Observations
Calculated Temperature
3
2
1
0
-1
-2
-3
-4
kyr Before Present

Cenozoic Era



65 Million Years Ago



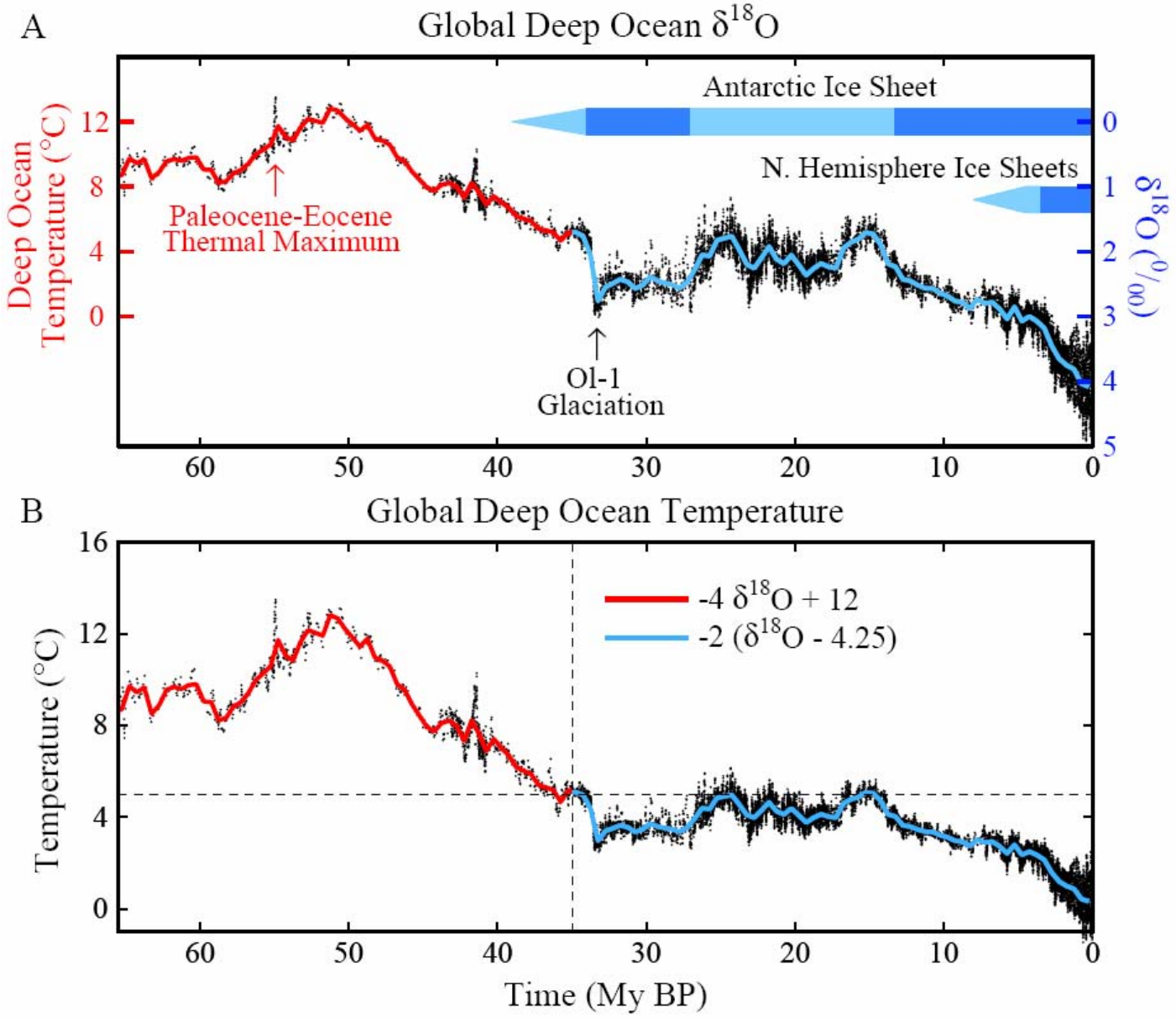
Present Day

Global Climate Forcings

External (solar irradiance): +1 W/m^2

Surface (continent locations): ~1 W/m^2

Atmosphere (CO_2 changes): > 10 W/m^2


A
Global Deep Ocean $\delta^{18}O$
Antarctic Ice Sheet
N. Hemisphere Ice Sheets
Deep Ocean Temperature (°C)
12
8
4
0
Paleocene-Eocene Thermal Maximum
Ol-1 Glaciation
$\delta^{18}O$ (‰)
0
1
2
3
4
5
60
50
40
30
20
10
0
B
Global Deep Ocean Temperature
-4 $\delta^{18}O$ + 12
-2 ($\delta^{18}O$ - 4.25)
Temperature (°C)
16
12
8
4
0
60
50
40
30
20
10
0
Time (My BP)

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

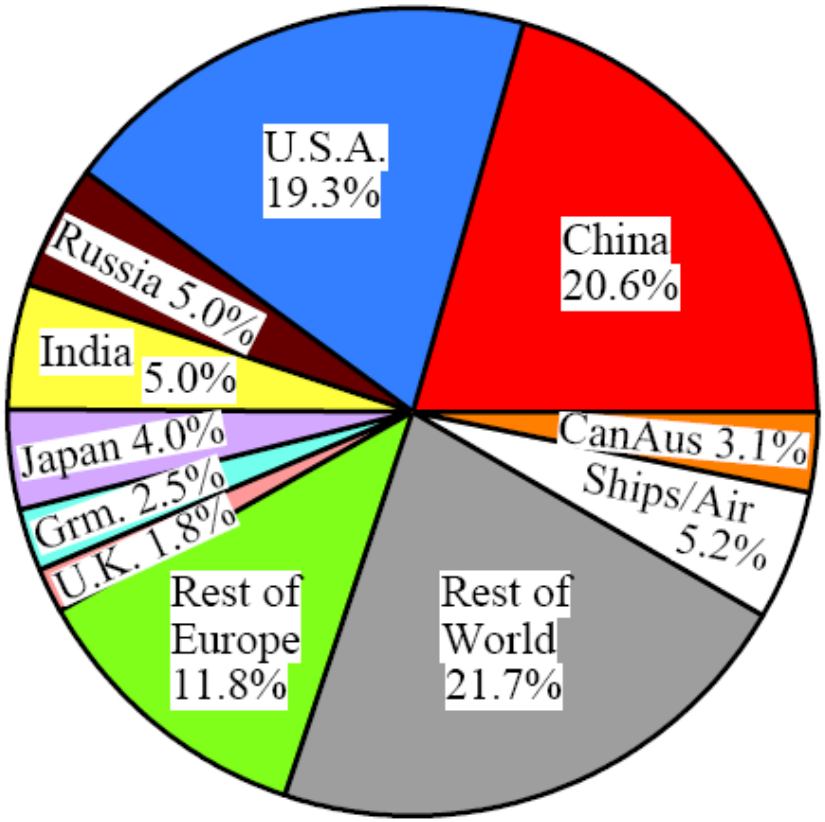
2. Climate Sensitivity High

- Antarctic ice forms if CO_2 < ~450 ppm
- Ice sheet formation reversible

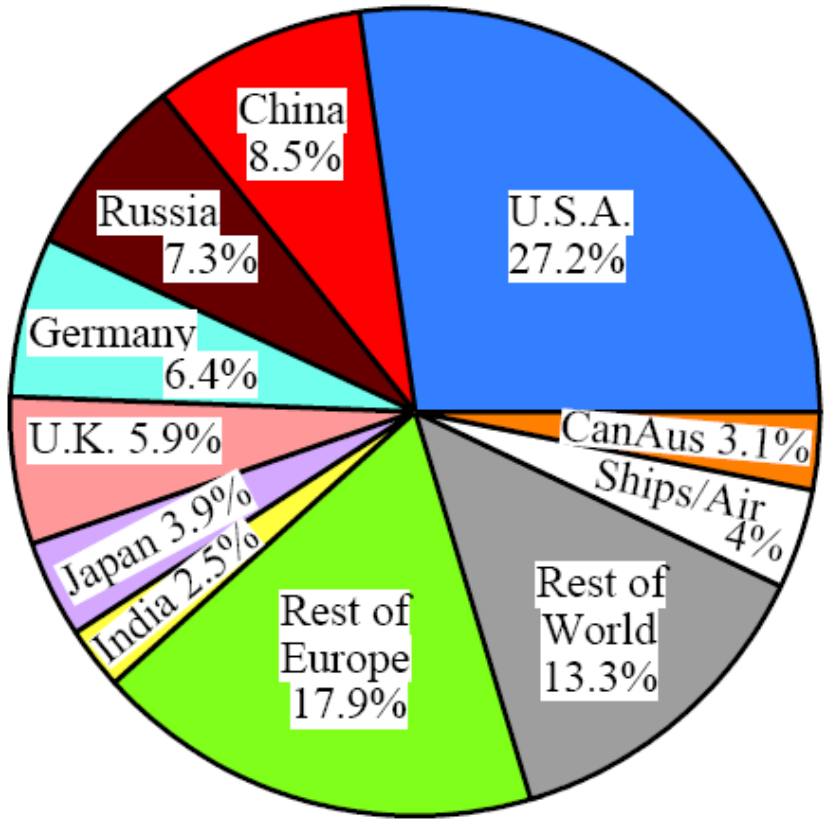
Humans Could Produce "A Different Planet"

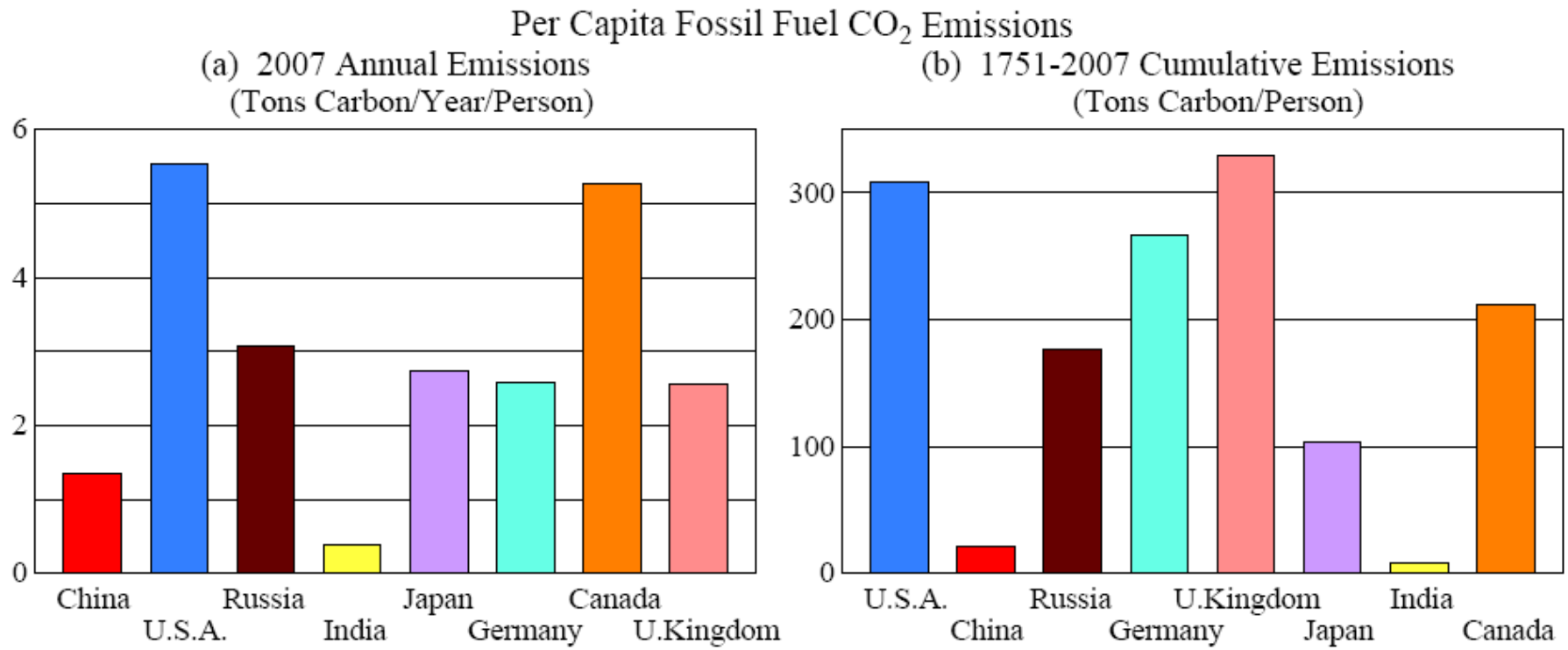
Fossil Fuel CO_2 Emissions

(a) 2007 Annual Emissions



(b) 1751-2007 Cumulative Emissions




Per Capita Fossil Fuel CO_2 Emissions
(a) 2007 Annual Emissions
(Tons Carbon/Year/Person)
6
4
2
0
China
U.S.A.
Russia
India
Japan
Germany
Canada
U.Kingdom
(b) 1751-2007 Cumulative Emissions
(Tons Carbon/Person)
300
200
100
0
U.S.A.
China
Russia
Germany
U.Kingdom
Japan
India
Canada