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

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*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

Temperature Anomaly (°C)

- 4
- 2
  0
  2
  4
  6

1880 1900 1920 1940 1960 1980 2000

- Annual Mean
- 5-year Mean
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 (°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?
Earth’s history provides most important information on global warming.

Recorded human history occurs within the Holocene warm period.
Temperature, CO$_2$ and Sea Level

Sea level variations ~400 feet; unusually stable for past 7000 years.
Atmospheric CO$_2$ 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
Global climate forcings: external, within atmosphere, surface.
External: solar irradiance +1 W/m²
Surface: < ~1 W/m²
CO₂ changes: order of 10 W/m²

Present Day
Summary: Cenozoic Era

1. Dominant Forcing: Natural $\Delta CO_2$
   - Rate $\sim 100$ ppm/My (0.0001 ppm/year)
   - Human-made rate today: $\sim 2$ ppm/year
   **Humans Overwhelm Slow Geologic Changes**

2. Climate Sensitivity High
   - Antarctic ice forms if $CO_2 < \sim 500$ ppm
   - Ice sheet formation reversible
   **Human Could Produce “A Different Planet”**
Cenozoic Era (65 Million Years)

Deep Ocean Temperature (°C)

Paleocene-Eocene Thermal Maximum

Antarctic Ice Sheet

N. Hemisphere Ice Sheets

δ¹⁸O (%)

My BP

Mid-Pliocene - Pleistocene (3.5 Million Years)

δ¹⁸O

ky BP

Late Pleistocene - Holocene (425 Thousand Years)

T. Anomaly (°C)

ky BP

Holocene →
Winter Solstice

Axis

Plane of

SUN

the Ecliptic

Summertime Solstice

Axis
CO₂, CH₄ and temperature records from Antarctic ice core data

Ice Age Forcings Imply Global Climate Sensitivity \(~ 3/4{}^\circ\text{C per W/m}^2\).

### Ice Age Climate Forcings (W/m\(^2\))

- **Ice sheets & vegetation**: -3.5 ± 1
- **greenhouse gases**:
  - CO\(_2\): -2.6 ± 0.5
  - CH\(_4\)
  - N\(_2\)O
- **aerosols**: -0.5 ± 1

Forcing \(~ 6.6 ± 1.5 \text{ W/m}^2\)

Observed \(\Delta T \sim 5 ± 1{}^\circ\text{C}\)

\[\rightarrow \frac{3}{4} ± \frac{1}{4} {}^\circ\text{C per W/m}^2\]

$\text{CO}_2, \text{CH}_4$ and estimated global temperature (Antarctic $\Delta T/2$ in ice core era) $0 = 1880-1899$ mean.

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.

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

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

-162 +/- 22 km$^3$/yr
~0.4 +/- 0.1 mm/yr sea level rise

Velicogna and Wahr, 2005
Areas Under Water: Four Regions
Paleo and Modern Temperatures in Critical Global Regions

(a) Western Equatorial Pacific SST
(b) Indian Ocean SST
Lake Wobegone

Lake level 200.0 m. Area flooded 2.54e+12 m^2. Volume 3.69e+14 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 m^2. Volume 3.62e+14 m^3. 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/special/polar%5Fbears/](http://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
Carbon Cycle Constraints

(a) Decay of Pulse CO$_2$ Emission

Fit to Bern Carbon Cycle Model:
$CO_2(t) = 18 + 14 \exp(-t/420) + 18 \exp(-t/70) + 24 \exp(-t/21) + 26 \exp(-t/3.4)$

Remaining Airborne:
- 22% at 500 years
- 19% at 1000 years

(b) Fossil Fuel Reservoirs

- Reserve Growth
- Proven Reserves
- Emissions (1750-2004)

Shale Oil
Tar Sands
Methane Hydrates

IPCC
EIA

Gt C
CO$_2$ (ppm)
Fossil Fuel Reservoirs and 1750–2004 Emissions

Reserve growth
Proven reserves*
Emissions (CDIAC)

*Oil & gas from EIA
**Unconventional oil & gas; uncertain, could be large

Oil
Gas
Coal
Other

Oil
Gas
Coal
Other

CO₂ (ppmv)

Gt C
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-\(\text{CO}_2\) Power Plants

Cellulostic Biofuels Electrical Power Generation
Fail-Safe \(\text{CO}_2\) 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

2004 Per Capita Fossil Fuel CO₂ Emission Rate (tons Carbon/year/person)

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

1. Scientists: Clear warning

2. Media: Transmitted the message well

3. Special Interests: Initial oposition, 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 CO$_2$.

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