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
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)
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 Sea Ice Extent (1979–2007)

Extent (million sq km)

Mark Serreze, Juliennne Stroeve, Walt Meier, Ted Scambos, Marika Holland, Jim Maslanik, Stephanie Renfrow, Matt Savoie
Arctic Sea Ice Extent
Area of ocean with at least 15% sea ice

Extent (millions of square kilometers)

- 2008
- 2007
- 1979–2000 Average

Mar | Apr | May | Jun | Jul
---|---|---|---|---

Global Ocean Heat Content Change: Above 700 m, 3-Year Mean

- Observations (Domingues et al., Nature, 2008)
- GISS E-R Model (Hansen et al., Science, 2005)

Base Period: 1955-1970

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%
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
Mass Balance of Greenland

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 2000a and 2004[; 3 Thomas and others 2006a; 4 Zwally and others 2005; 5 to 7 Rignot and Kanagaratnam 2006a; 8 and 9 Veloogna and Wahr 2005[ and 2006b; 11 Chen and others 2006]; 10 Ramillien and others 2006; 12 Luthke and others 2006[}
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.
Rongbuk Glacier

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

Stresses on Coral Reefs

Coral Reef off Fiji (Photo: Kevin Roland)
**Assessment of Target CO₂**

<table>
<thead>
<tr>
<th>Phenomenon</th>
<th>Target CO₂ (ppm)</th>
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<tr>
<td>1. Arctic Sea Ice</td>
<td>300-325</td>
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<td>2. Ice Sheets/Sea Level</td>
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<td>3. Shifting Climatic Zones</td>
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<td>4. Alpine Water Supplies</td>
<td>300-350</td>
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<tr>
<td>5. Avoid Ocean Acidification</td>
<td>300-350</td>
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</tbody>
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→ **Initial Target CO₂ = 350* ppm**

*assumes CH₄, O₃, Black Soot decrease*
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).
(a) Fossil Fuel and Net Land Use Emissions

- Estimated Reserves
- Emissions to Date

(b) CO₂ Amount with Coal Phaseout by 2030

- 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 & lifestyle 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 CO₂: 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.

(b) Climate Forcings

- Ice Sheets
- Greenhouse Gases

(c) Paleoclimate Temperature Change

- Observations
- Calculated Temperature
Cenozoic Era

65 Million Years Ago

Global Climate Forcings
External (solar irradiance): +1 W/m²
Surface (continent locations): ~1 W/m²
Atmosphere (CO₂ changes): > 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$450 ppm
   - Ice sheet formation reversible

   **Humans Could Produce “A Different Planet”**
Fossil Fuel CO₂ Emissions
(a) 2007 Annual Emissions   (b) 1751-2007 Cumulative Emissions
Per Capita Fossil Fuel CO₂ Emissions

(a) 2007 Annual Emissions
(Tons Carbon/Year/Person)

(b) 1751-2007 Cumulative Emissions
(Tons Carbon/Person)