The Four Dimensions of Global Climate Change

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29 October 2012

1. Scientific
2. Economic
3. Political
4. Ethical

... Who am I?
Climate Forcings = factors that change energy balance of Earth

1. aerosols from volcanoes
Climate Forcings

1. aerosols from volcanoes
2. aerosols from other sources
Climate Forcings

1. aerosols from volcanoes
2. other aerosols
3. changes in solar radiation
Climate Forcings

1. aerosols from volcanoes
2. other aerosols
3. changes in solar radiation
4. greenhouse gases
Climate Forcings

1. aerosols from volcanoes
2. other aerosols
3. changes in solar radiation
4. greenhouse gases
5. changes in surface albedo
Climate Forcings = factors that change energy balance of Earth

1. aerosols from volcanoes episodic
2. other aerosols (pollution) \(-1.2 \text{ W/m}^2\) since 1750
3. changes in solar radiation +0.12
4. greenhouse gases +2.9
5. changes in surface albedo -0.1 (more later)

net human forcing +1.6 \text{ W/m}^2\) since 1750

\text{W/m}^2 = \text{Watts per square meter}
Jim Hansen of NASA
Jim Hansen’s grandkids

Sophie explains 2 Watts of forcing to brother Connor

Sophie Explains GH Warming: “It’s 2 W/m² Forcing.”

Connor only counts 1 Watt
How do greenhouse gases work?

- **transmit** incoming solar radiation to Earth’s surface
- **absorb** some of reradiation from Earth’s surface back to space

*The Greenhouse Effect (from U.S. EPA)*
What are greenhouse gases?

<table>
<thead>
<tr>
<th>Gas</th>
<th>Residence Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>water vapor</td>
<td>very short (days)</td>
</tr>
<tr>
<td>carbon dioxide*</td>
<td>very interesting</td>
</tr>
<tr>
<td>methane</td>
<td>12 years</td>
</tr>
<tr>
<td>nitrous oxide</td>
<td>114 years</td>
</tr>
<tr>
<td>ozone</td>
<td>weeks to months</td>
</tr>
</tbody>
</table>

*carbon dioxide = CO₂
Why is residence time of CO$_2$ “very interesting”?

\[
\text{Decay of Fossil Fuel CO$_2$ Emission}
\]

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).

→ Inertia in global climate change
The global carbon cycle
Where do greenhouse gases come from?

Animated Graph from Gapminder
How has atmospheric $\text{CO}_2$ changed in recent years?

Charles Keeling getting Medal of Science in 2001
Evidence for Long-Term Changes in CO$_2$ & Climate
Evidence from Ice Cores

What is the basis for the temperature reconstruction?

How do peaks of greenhouse gases compare to peaks of temperature? Why?
Summary of Atmospheric Carbon Dioxide

- **Pleistocene** 180 to 300 ppm
- **1750** 280 ppm
- **June 2012** 395 ppm

**rates of change**
- end of last Ice Age 40% increase in 5000+ years
- 1750 to 2012 40% increase in 262 years

ppm = parts per million
“September 2012 ties for the hottest on record worldwide”

• third September record since 2000

• 331 consecutive months of global average temperatures above 20th century average

• coolest September in U.K. since 1994

• warmest September ever in Australia
Evidence about recent temperature changes: weather vs. climate

2007/08 Surface Temperature Anomalies (°C) [Base Period 1951-80]

- 2007 October (#5) 0.55
- November (#8) 0.49
- December (#8) 0.40
- 2008 January (#40) 0.12

Maps showing temperature anomalies around the world for different months.
Evidence about recent temperature changes: weather vs. climate

2001-2007 Mean Surface Temperature Anomaly (°C)
Base Period = 1951-80, Global Mean = 0.54
Climate Forcings: Models and reality

Figure 4: Simulating the Earth's temperature variations, and comparing the results to measured changes, can provide insight into the underlying causes of the major changes.
It’s Not Just About Temperature
Does Antarctic ice refute global warming?

Newsmax: “Record Antarctica ice contradicts global warming trend”

RGJ: “If Arctic sea ice at the north pole is at a record low and Antarctic sea ice at the south pole is at a record high, doesn’t that mean they are balancing each other out?”
The backstory – What happens in the Arctic?
The backstory – What happens in the Arctic?
Belzebub II crossing the Arctic Ocean

Source: Boston Globe, 5 October 2012
2012 Arctic minimum

2012 Antarctic maximum
Arctic minima
1979-2012

Antarctic maxima
1979-2012

Source: National Snow & Ice Data Center
Facts in Context

• How should we interpret declining Arctic sea ice?

• In comparison to increasing Antarctic sea ice?
Facts in Context

• Comparisons are important
  – But they have to be appropriate
The Arctic and the Antarctic

• Similarities

• Differences

• Ted Scambos, NSIDC: “... in the north, a 4 degree difference can be the difference between skating and swimming. In Antarctica, it is the difference between one and two layers of long johns ...”
• Data from weather stations, satellites, air bubbles trapped in ice → Antarctic temperature increase of 1-4 °F in 50 years

• Why more sea ice?
  - air temperature, water vapor, snow
  - stronger winds
RGJ: “If Arctic sea ice at the north pole is at a record low and Antarctic sea ice at the south pole is at a record high, doesn’t that mean they are balancing each other out?”

-30,000 square miles/yr +5,000 square miles/yr
Summary of This Story

• Facts and Comparisons
  – but comparisons should be appropriate

• The world is complex
  – but much is known about chemistry and physics of weather and climate

• My ulterior motive!
Some good news and some bad news

• Does melting of Arctic sea ice contribute to increased sea level? (good news – sort of)

• Positive feedback (bad news)

↑ greenhouse gases → ↑ temperature

↓ darker surface → more melting
Some Worse News

NOAA Bombshell: Warming-driven Arctic Sea Loss is Boosting Chance of Extreme U.S. Weather

Joe Romm, Climate Progress, 11 October 2012
What causes extreme weather (droughts, heat waves, severe storms)?
An Even Worse Possibility

↑ greenhouse gases ➔ ↑ temperature

darker surface ➔ more melting
Does melting of Arctic sea ice contribute to increased sea level?

↑ greenhouse gases → ↑ temperature

darker surface → more melting

Maybe, if this positive feedback increases melting of Greenland ice sheet.
What should we do?

<table>
<thead>
<tr>
<th>Action?</th>
<th>Cost $</th>
</tr>
</thead>
<tbody>
<tr>
<td>YES</td>
<td>Saved Our Hides</td>
</tr>
<tr>
<td>NO</td>
<td>Global Catastrophes</td>
</tr>
</tbody>
</table>

- Environmental
- Social
- Political
- Public Health
- Economic

Greg Craven: What’s the Worst That Could Happen?
The Precautionary Principle

<table>
<thead>
<tr>
<th>GMSHs</th>
<th>A: Significant Action Now</th>
<th>B: Little to No Action Now</th>
</tr>
</thead>
<tbody>
<tr>
<td>False</td>
<td>Economic costs</td>
<td>Status quo</td>
</tr>
<tr>
<td>True</td>
<td>Economic costs But saved our bacon!</td>
<td>Hamster Chow!</td>
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*How to break the idea of the grid.*
## Probabilities Matter

### Table

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<th>GMSHs</th>
<th>TICKET A</th>
<th>TICKET B</th>
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| True  | Economic costs
      | But saved our bacon!     | Hamster Chow!          |

*How to fix the grid you just broke.*
Some Key Economic Questions – 1

• What economic mechanisms can be used?
  – regulations (e.g., emission controls for cars)
  – cap and trade (e.g., acid rain)
  – carbon tax
  – but climate change is a global problem!
    • international trade in permits, carbon tariffs on imports

Cap-and-Trade vs. Carbon Tax

• Some politics
  – a brief history of cap and trade
  – Naomi Oreskes: “Metaphors of warfare and the lessons of history: time to revisit a carbon tax?”

• Some ethics
  – James Hansen: cap-and-trade system doesn’t reward conscientious individuals
Some Key Economic Questions – 2

• How much would action on climate change depress economic growth?
  - CBO: cap-and-trade bill passed by U.S. House in 2009 → reduce GDP growth by less than 0.1% per year
  - A more aggressive worldwide policy might reduce gross world product by 1 to 3%
    → delay in doubling of per capita income in U.S. from 2060 to 2062
Some Key Economic Questions – 3

• Can a cost-benefit analysis work?

• Some reasons to be skeptical
  – not all costs and benefits can be expressed in $$$
  – relating present and future costs and benefits is guesswork
  – too much uncertainty
U. S. Politicians & Climate Change: 3 Positions

1. Denial

2. Believes climate change is happening, but doesn’t know whether we cause it and doesn’t want to act.

3. Believes we cause climate change and wants to act, but is unwilling to talk about it (NPR, 25-26 October).
U. S. Citizens & Climate Change

Growing Majority of Americans Believe Global Warming Is Happening
- Fewer Believe It Is Not -

Do you think global warming is happening?
Base: Americans 18+.

Source: Yale/George Mason
Jon Krosnick of Stanford: “candidates “may actually enhance turnout as well as attract voters over to their side by discussing climate change.”
“Science debate highlights Kansas board race” 
(AP, 27 October 2012)

• 5/10 seats on State Board of Education on ballot; 3 contested.

• Vote on new science standards likely next year.

• National Research Council has worked with states on new standards.
  – including more attention to human causes of global climate change.
Climate Change & Ethics

A PERFECT MORAL STORM
THE ETHICAL TRAGEDY OF CLIMATE CHANGE
STEPHEN M. GARDINER
The *Andrea Gail* ↔ Three Storms ↔ Climate Ethics

- the global storm
  - dispersion of causes and effects
  - fragmentation of agency
  - institutional inadequacy

- the intergenerational storm

- the theoretical storm
Gardiner: a result of the perfect moral storm

- Moral corruption
  - distraction
  - complacency
  - unreasonable doubt
  - selective attention
  - delusion
  - pandering
  - false witness
  - hypocrisy
Environmental Ethics Through Poetry