Global Warming

Global warming: Causes and effects

Earth's temperature has risen about 1 degree Fahrenheit in the last century. The past 50 years of warming has been attributed to human activity.

Burning fuels such as coal, natural gas and oil produces greenhouse gases in excessive amounts. The United States was responsible for 20 percent of the global greenhouse gases emitted in 1997.

Greenhouse gases are emissions that rise into the atmosphere and trap the sun's energy, keeping heat from escaping. Most of the world's emissions are attributed to the United States' large-scale use of fuels in vehicles and factories.

Some predictions for local changes include increasingly hot summers and intense thunderstorms. Damaging storms, droughts and related weather phenomena cause an increase in economic and health problems. Warmer weather provides breeding grounds for insects such as malaria-carrying mosquitoes.

During the past 100 years, global sea levels have risen 4 to 8 inches.

Sea Ice Extent

10/06/2012

National Snow and Ice Data Center, Boulder, CO

median

1979–2000

Source: Environmental Protection Agency
Science belief

• Why is there “debate” about these scientific topics?
  – Climate change
  – Vaccines
  – Evolution

• But no debate about other scientific topics?
  – Germ theory
  – Relativity (general, special)
  – Aerodynamics (airplanes, helicopters)
  – Chemistry
  – DNA
  – Nuclear physics (bombs, stars, nuclear power*)
  – Quantum theory, atomic physics (iphones)
  – Radiation (microwaves, light)
  – Thermodynamics (ovens)

*nuclear power “debate” about safety, not about science.
“Do you believe in global warming?”
Perceived Cause of Global Warming

And from what you have heard or read, do you believe increases in the Earth’s temperature over the last century are due more to -- [the effects of pollution from human activities (or) natural changes in the environment that are not due to human activities]?

![Graph showing perceived cause of global warming over years from 2001 to 2014. The x-axis represents the years: '01 to '14. The y-axis represents the percentage of people who believe increases in Earth’s temperature are due more to human activities (green line) or natural causes (yellow line). The graph shows a trend where the belief in human activities being the cause decreases and belief in natural causes increases over time. The percentage for human activities ranges from 61% in '01 to 50% in '10, while the percentage for natural causes ranges from 33% in '01 to 46% in '09. The year 2014 shows equal percentage for both, 57%.]

GALLUP
Trend in % Believing Global Warming Is Caused by the Effects of Pollution From Human Activities

By self-described understanding of global warming

- Very well
- Fairly well
- Not well

GALLUP®
Percentage Believing Global Warming Is Caused by Human Activities

Trend by education

GALLUP®
Believe Rise in Earth's Temperature in Last Century Due Mainly to Human Activities

Trend by party ID

Democrats
Independents
Republicans

GALLUP
How Well Do You Understand Global Warming?

Next, thinking about the issue of global warming, how well do you feel you understand this issue? Would you say -- very well, fairly well, not very well, or not at all?

GALLUP®
Questions

• What questions can we ask about climate change?

• Is the Earth Warming?
• If yes, what is causing it?
• If humans are causing it,
  – what can we do about it?
  – what should we do about it?
Group exercise

In groups of 3 or 4, nominate a scribe. Discuss and answer the following questions:

1. What is the best evidence you’ve seen or heard in support of the idea that Earth is warming?

2. What is the best evidence you’ve seen or heard in support of the idea that the warming of the Earth is a byproduct of mankind?

3. What is the best evidence you’ve seen or heard that Earth is not warming?

4. What is the best evidence you’ve seen or heard that Earth is warming from natural effects, not due to man’s influence?
• Main Entry:
  – con·sen·sus
• Pronunciation:
  – \kən-'sen(t)-səs\n• Function:
  – noun
• Usage:
  – often attributive
• Etymology:
  – Latin, from consentire
• Date:
  – 1843
• 1 a: general agreement : unanimity <the consensus of their opinion, based on reports...from the border — John Hersey> b: the judgment arrived at by most of those concerned <the consensus was to go ahead> 2: group solidarity in sentiment and belief
2007 Nobel Peace Prize

"for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change"

Intergovernmental Panel on Climate Change (IPCC)

Albert A. Gore (US)
Intergovernmental Panel on Climate Change (IPCC)

The IPCC is a scientific body. It reviews and assesses the most recent scientific, technical and socio-economic information produced worldwide relevant to the understanding of climate change. It does not conduct any research nor does it monitor climate related data or parameters.

Thousands of scientists from all over the world contribute to the work of the IPCC on a voluntary basis. Review is an essential part of the IPCC process, to ensure an objective and complete assessment of current information. IPCC aims to reflect a range of views and expertise. The Secretariat coordinates all the IPCC work and liaises with Governments.

The IPCC is an intergovernmental body. It is open to all member Countries of the United Nations (UN) and WMO. Governments can participate in the review process and plenary Sessions, where main decisions about the IPCC work programme are taken and reports are accepted, adopted and approved. The IPCC Bureau Members including the Chair are also elected during the plenary Sessions.

Because of its scientific and intergovernmental nature, the IPCC embodies a unique opportunity to provide rigorous and balanced scientific information to decision makers. By endorsing the IPCC reports, governments acknowledge the authority of their scientific content. The work of the organization is therefore policy-relevant and yet policy-neutral, never policy-prescriptive.
IPCC 2007

- Working Group I concluded that warming since the mid-20th century was **unequivocal** and was caused primarily by human activities (>90% probability), and that past emissions of heat-trapping gases make some continued warming unavoidable.

- Working Group II concluded that the consequences of recent warming were already apparent around the world, and that the severity of future impacts depends largely on the amount of heat-trapping gases emitted by current and future human activities.
IPCC 2013

• Working Group I again concluded that warming since the mid-20th century was unequivocal. Now they say, “It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century.”
Questions

• What questions can we ask about climate change?

• Is the Earth Warming?
• If yes, what is causing it?
• If humans are causing it,
  – what can we do about it?
  – what should we do about it?
IPCC 2007

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Observed globally averaged combined land and ocean surface temperature anomaly 1850–2012

(a)

Annual average

Decadal average

Year: 1850, 1900, 1950, 2000

Anomaly (°C) relative to 1961–1990

IPCC 2013
Observed change in average surface temperature 1901–2012

Trend (°C over period)

IPCC 2013
(a) Northern Hemisphere spring snow cover

Year

(b) Arctic summer sea ice extent

Year

(c) Change in global average upper ocean heat content

Year

(d) Global average sea level change

Year

IPCC 2013
(a) Global average surface temperature

(b) Global average sea level

(c) Northern Hemisphere snow cover

IPCC 2007
(a) Global average surface temperature change

(b) Northern Hemisphere September sea ice extent
IPCC is not alone in its conclusions. In recent years, all major scientific bodies in the United States whose members' expertise bears directly on the matter have issued similar statements. For example, the National Academy of Sciences report, *Climate Change Science: An Analysis of Some Key Questions*, begins: "Greenhouse gases are accumulating in Earth's atmosphere as a result of human activities, causing surface air temperatures and subsurface ocean temperatures to rise" [p. 1 in (5)]. The report explicitly asks whether the IPCC assessment is a fair summary of professional scientific thinking, and answers yes: "The IPCC's conclusion that most of the observed warming of the last 50 years is likely to have been due to the increase in greenhouse gas concentrations accurately reflects the current thinking of the scientific community on this issue" [p. 3 in (5)].

Others agree. The American Meteorological Society (6), the American Geophysical Union (7), and the American Association for the Advancement of Science (AAAS) all have issued statements in recent years concluding that the evidence for human modification of climate is compelling (8).

Naomi Orestes, Science Magazine, 3-Dec-2004
Decadal Land-Surface Average Temperature

10-year moving average of surface temperature over land
Gray band indicates 95% uncertainty interval

Temperature Anomaly (°C)

1750  1800  1850  1900  1950  2000

NASA GISS
NOAA / NCDC
Hadley / CRU
Berkeley Earth
• Linear trends (solid lines) in the three global annual mean temperature anomaly time series over the decade 1998-2007.
CO₂ is rising ... But global temperature isn't rising!

NOTE: CO₂ measurements taken at Mauna Loa Observatory in Hawaii (in black, rising) plotted against Global surface temperature since 1995 (in red, steady and falling) taken from Hadley Centre and Climatic Research Unit of the University of East Anglia. These two sets of statistics are used by the IPCC in its reports.
Questions

• What questions can we ask about climate change?

• Is the Earth Warming?
  – IPCC says yes, unequivocal

• If yes, what is causing it?

• If humans are causing it,
  – what can we do about it?
  – what should we do about it?
Radiation

- Things radiate energy
  - Hotter -> more radiation
  - Most radiation in the infrared
The Greenhouse effect

Visible energy from the sun passes through the glass and heats the ground. Infra-red heat energy from the ground is partly reflected by the glass, and some is trapped inside the greenhouse.
Some energy is radiated back into space by the Earth in the form of infrared waves.

Some of this outgoing infrared radiation is trapped by the Earth's atmosphere and warms it.

Most of this radiation is absorbed by the Earth and warms it.
Is the Earth Warming

- Heat IN from the sun (radiation)

- Heat OUT by radiation
Venus

- **Venus**
  - Diameter 94% size of Earth
  - 70 million miles from Sun (Earth 93 million mi)
  - Radiation from the Sun is almost 2x Earth

- **If no greenhouse effect**
  - Venus temperature about 90° F

- **Temperature on Venus is about 800° F**
  - Runaway greenhouse effect
  - Atmosphere 90x denser than Earth
  - Mostly CO₂
Earth

- Temperature would be about 26° F without greenhouse effect.

- Observed temperature about 57° F
  Thanks to greenhouse effect.
Global cooling?

- Newsweek magazine, April 28, 1975

“To scientists, these seemingly disparate incidents represent the advance signs of fundamental changes in the world’s weather. The central fact is... the earths’ climate appears to be cooling down.”
Questions

• What questions can we ask about climate change?

• Is the Earth Warming?
  – IPCC says yes, unequivocal

• If yes, what is causing it?
  – Greenhouse effect is real
  – Other causes?

• If humans are causing it,
  – what can we do about it?
  – what should we do about it?
Temperatures versus CO$_2$

- CO$_2$ concentrations “track” temperatures
  - correlated
- Cause? Effect?
- Hypothesis is that warmer temperatures release CO$_2$ from oceans.
  - CO$_2$ concentrations lag behind temperature changes.

- Could “natural” global warming be happening on top of manmade CO$_2$ increase?
  - IPCC says 10% chance…
- Could this be a feedback effect?
## Energy Costs

- **Fuel**  
  - market cost  
  - cost per kWh  
  - cost if converted to electricity  
  
<table>
<thead>
<tr>
<th>Fuel</th>
<th>market cost</th>
<th>cost per kWh (1000 Cal)</th>
<th>cost if converted to electricity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>$40/ton</td>
<td>0.4¢</td>
<td>1.2¢</td>
</tr>
<tr>
<td>natural gas</td>
<td>$10/mil/f3</td>
<td>3¢</td>
<td>9¢</td>
</tr>
<tr>
<td>Gasoline</td>
<td>$3/gallon</td>
<td>9¢</td>
<td>27¢</td>
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<tr>
<td>Electricity</td>
<td>$0.10/kWh</td>
<td>10¢</td>
<td>10¢</td>
</tr>
<tr>
<td>car battery</td>
<td>$50/battery</td>
<td>21¢</td>
<td>21¢</td>
</tr>
<tr>
<td>Comp bat</td>
<td>$100/battery</td>
<td>$4.00</td>
<td>$4.00</td>
</tr>
<tr>
<td>AAA bat</td>
<td>$1.50/battery</td>
<td>$1000.00</td>
<td>$1000.00</td>
</tr>
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</table>
Who has the energy?

- Billion barrels of oil equivalent

<table>
<thead>
<tr>
<th>Country</th>
<th>oil</th>
<th>coal</th>
<th>natural gas</th>
<th>total</th>
</tr>
</thead>
<tbody>
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<td>21</td>
<td>1194</td>
<td>32</td>
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</tr>
<tr>
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<td>Canada</td>
<td>179</td>
<td>32</td>
<td>9</td>
<td>220</td>
</tr>
</tbody>
</table>

- US and Russia have largest reserves of shale.