An Update on Global Warming

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Chacaltaya Glacier, Bolivia, ~5240m
Senator James Inhofe (R-Oilahoma)

“The threat of catastrophic global warming is the greatest hoax ever perpetrated on the American people ... man-induced global warming is an article of religious faith...”
The Greenhouse effect

Solar radiation passes through the clear atmosphere
Incoming solar radiation: 343 Watt per m²

Some solar radiation is reflected by the atmosphere and Earth's surface
Outgoing solar radiation: 103 Watt per m²

Some of the infrared radiation passes through the atmosphere and is lost in space
Net outgoing infrared radiation: 240 Watt per m²

Some of the infrared radiation is absorbed and re-emitted by the greenhouse gas molecules. The direct effect is the warming of the Earth's surface and the troposphere.

Surface gains more heat and infrared radiation is emitted again

Solar energy is absorbed by the Earth's surface and warms it...
168 Watt per m²

... and is converted into heat causing the emission of longwave (infrared) radiation back to the atmosphere

Net incoming solar radiation: 240 Watt per m²

Sources: Okanagan University College, University of Oxford, EPA, IPCC.

Trend (°C per decade)
CHANGE IN FROST-FREE LENGTH
DAYS PER DECADE
1948-1999

Significance
> 90% *
> 95% **
> 99% ***
Not Significant

All U.S. = +2.0 ***
Natural forcings do not account for observed 20th century warming after 1970

Global Average Temperature

- Observations
- (Natural) volc+solar
- (Anthropogenic + Natural) volc+solar+ghg+so4

Anomalies from 1890-1919 (°C)

Source: Trenberth, NCAR 2005

Anthropogenic Increase: Records Over the Last Millennium

Source: Raynaud et al., 2003
“Northern Hemisphere temperatures during the past millennium: *inferences, uncertainties and limitations*”
M. Mann, R. Bradley & M. Hughes, 1999

“Mann[et al] effectively erased the well-known phenomena of the Medieval Warming Period--when, by the way, it was warmer than it is today--and the Little Ice Age…” J. Inhofe 2005
Blue=CO$_2$ (carbon dioxide)

Red=CH$_4$ (methane)

$Homo$ $erectus$ $\quad Homo$ $sapiens$

Dec 4$^{th}$ 2005: 380ppm

Source: Houghton et al., 2001
Homo sapiens
Homo erectus

180ppm
280ppm

Blue=CO₂ (carbon dioxide)
Red=CH₄ (methane)

Hundreds of thousands of years before today

Dec 4th 2005: 380ppm

~760ppm

Source: Houghton et al., 2001
CO₂ change over the last 650,000 years

Source: Siegenthaler et al., 2005
First Cities

1 hour = 6000 years;
1 minute = 100 years

Internal combustion engine
New World colonization
The Crusades
First Writing

Time...

Freezing level
1932:
Glacier National Park
Boulder ice cave

1988:
Glacier National Park
Boulder ice cave

Recession of the Grinnell Glacier

“Glacier National Park”

Source: D. Fagre, USGS, 2004
Total Area Of Ice On Kilimanjaro

1989 to 1912 maps are from Hastenrath and Greischar. The 2000 map was produced at Ohio State Univ.
1930

Photo: Mittelholzer, Kilimanjaro Flug
Glacier on Volcán Lanin, Argentina, 1896 and 2001
Chacaltaya Glacier
Bolivia: Water supply for La Paz

5M m³ m in 1940
<0.3M m³ m today
Widespread (global) glacier recession

169 glaciers:

Source: Oerlemans, 2005
Sea level is rising: from ocean expansion and melting glaciers

Since 1993, global sea level has risen 34 mm (1.33 inches)
- 2/3 from expansion as ocean temperatures rise,
- 1/3 from melting glaciers

Source: Trenberth, NCAR 2005
Permafrost occurrence at the Matterhorn

Source: Gruber & Biegger 2003
Climate change in mountains affects water supply

Even in non-glaciated mountains such as in Central California, warming will lead to more rain and less snow, and earlier melting,
Annual Number of Named Storms and Major Hurricanes

Atlantic, 1944-2005 (preliminary number for 2005)
North Atlantic SST anomalies: summer 2005

30°N-30°S: 3.8% increase in total water vapor since 1970

Tropical Atlantic SST Anomaly:
Order 2°F

Perhaps:
1.0°F: global warming
0.5°F: 2004-05 El Niño
0.5°F: from AMO

30°N-30°S: 3.8%
increase in total water vapor since 1970

Source: Trenberth, NCAR 2005
Source: Enfield et al., 2001
Yearly changes in ocean heat content (1955–59 to 1994–98) (units = $10^{22}$ J)

Source: Levitus et al., 2005
Pink = increasing

Contour interval is $2 \times 10^{18}$ J year$^{-1}$

Source: Levitus et al., 2005
Past and future CO₂ atmospheric concentrations
Variations of the Earth’s surface temperature: year 1000 to year 2100
Greenhouse gas forcing

Annual mean temperature change, 2071 to 2100, relative to 1990:
global average in 2085 = +3.1°C
Greenhouse gas forcing

Annual mean precipitation change: 2071 to 2100, relative to 1990
The Earth at night
Today there are ~6.3B people, & our impact on the planet is ubiquitous...
World population is currently increasing by 240,000 per day....
By 2060, UN projections indicate world population will be ~9B...
<table>
<thead>
<tr>
<th>Number of years to add each billion</th>
<th>Year</th>
</tr>
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<tbody>
<tr>
<td>First Billion</td>
<td>1800</td>
</tr>
<tr>
<td>Second</td>
<td>130</td>
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<tr>
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<td>30</td>
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<tr>
<td>Ninth</td>
<td>26</td>
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Sources: Population Reference Bureau; UN World Population Prospects (1998)
Conservation [less waste], reduced consumption + alternative energy sources
1834

WARMIEST EUROPE

1838

COLDEST EUROPE

Source: Mann et al., 2000
For accurate information about climate change & global warming, see:

http://www.realclimate.org