“Global Warming”
Anthropogenic Climate Change

Composition of Earth’s Atmosphere

<table>
<thead>
<tr>
<th>Gas Name</th>
<th>Chemical Formula</th>
<th>Percent Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>$N_2$</td>
<td>78.08%</td>
</tr>
<tr>
<td>Oxygen</td>
<td>$O_2$</td>
<td>20.95%</td>
</tr>
<tr>
<td>Water</td>
<td>$H_2O$</td>
<td>0 to 4%</td>
</tr>
<tr>
<td>Argon</td>
<td>Ar</td>
<td>0.93%</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>$CO_2$</td>
<td>0.0360%</td>
</tr>
<tr>
<td>Neon</td>
<td>Ne</td>
<td>0.0018%</td>
</tr>
<tr>
<td>Helium</td>
<td>He</td>
<td>0.0005%</td>
</tr>
<tr>
<td>Methane</td>
<td>$CH_4$</td>
<td>0.00017%</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>$H_2$</td>
<td>0.00005%</td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td>$N_2O$</td>
<td>0.00003%</td>
</tr>
<tr>
<td>Ozone</td>
<td>$O_3$</td>
<td>0.000004%</td>
</tr>
</tbody>
</table>

Significant greenhouse gases
Minor greenhouse gases

Increase in atmospheric CO$_2$
from 1958 to 2004

Why does the curve abruptly rise and fall each year?
Countries ranked by total carbon dioxide emissions from burning fossil fuels - 2006

World Carbon Dioxide Emissions from the Consumption and Flaring of Fossil Fuels, 2006
(Million Metric Tons of Carbon Dioxide)

Source: Energy Emission Administration
Countries ranked by **per capita** carbon dioxide emissions from burning fossil fuels - 2006

China has 4X the population of the U.S. but produces the same amount of CO₂ as the U.S.

Countries ranked by **total** greenhouse gas emissions from deforestation and fossil fuels - 2000

Greenhouse gas emissions by country in 2000 (including land-use change)
Vostok Station, Antarctica

Ice Core

400 Thousand Years of Atmospheric Carbon Dioxide Concentration and Temperature Change


Graphic: Michael Emel, The Woods Hole Research Center
If current trends in fossil fuel consumption continue, by 2100, the concentration of CO$_2$ in the Earth’s atmosphere will likely double relative to its maximum in the last 400,000 years.

We are performing an unprecedented experiment on our planet’s atmosphere and climate!
What factors “force” climate?

- Greenhouse gas emissions
- Natural (e.g. volcanic eruptions)
- Anthropogenic (e.g. fossil fuel emissions)
- Albedo (% of surface covered by snow and ice.
- Solar output
- Orbital cycles (Milankovitch Cycles)


Computer model of global temperature change for the past 150 years - Natural Forcing Only


Computer model of global temperature change for the past 150 years - Anthropogenic Forcing Only

**Comparison of observed temperature anomalies and modeled anomalies predicted under varying “forcing” scenarios. Source: IPCC, Third Assessment Report, Climate Change 2001.**

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**Other Evidence for Anthropogenic Forcing of Climate**

- Satellite measurements show that the troposphere is heating up but the stratosphere is cooling, indicating more interception of heat radiated from the surface of the Earth.
- Melting of alpine glaciers, permafrost, arctic pack ice, ice shelves in Antarctica and Greenland, as well as flow rates of glaciers in Antarctica and Greenland, may be unprecedented for the Holocene (last 10,000 years).
- Area of winter snow cover is decreasing in the northern hemisphere.
- Animals, plants, and diseases are shifting their historical ranges. Timing of migrations and flowering is changing.

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**Climate change is already underway. We have already measured changes in:**

- Temperature
- Sea level
- Snow melt
- Drought intensity
- Storm Intensity
- Heat waves
- Mid-latitude winds

This is not a prediction.

These changes are happening now.

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**IPCC WGI Fourth Assessment Report, 2007**
Why “Global Warming” is good science

- The mechanism is reasonable - the greenhouse effect is quantifiable and based on well understood physics.
- Anthropogenic additions of greenhouse gases to the atmosphere are measurable and profound - and increasing every year.
- Climate should be warming given the changes we are making to the atmosphere. Burden of proof should rest with the skeptics!
- Evidence of warming - historical and geological records show that climate is warming. Satellite observations confirm warming. Predicted effects of warming are being observed - ocean temps are rising, ice is melting.
- NO evidence that climate has been stable for the last 50 years or that observed climate change is "natural".

Why is climate change bad?

We are heavily invested in the climate status quo.

- We grow food where it rains (or where we have an abundance of fresh water).
- We have extensive population and infrastructure located near present sea level (app. 30% of global population).
- We have infrastructure appropriate to traditional climate.
- Our economies are based on traditional biological resources.
- Our insurance industry assesses risk based on past trends.
- Adapting to change is costly, both in money and lives.
- The more rapid and extreme the change, the higher the cost.
- Why is preventing climate change NOT a conservative issue? It is all about preserving our way of life as it is.
Urban areas face increased numbers of extreme heat days

- Increase in heat-related fatalities
- Increase in air pollution and related respiratory problems such as asthma
- Disproportionately impacts the poor and elderly

Projected Changes in Precipitation in a Warmer World

- American Southwest - drier
- American Northeast - wetter
- Northern Africa - drier
- Europe - more seasonally wetter and drier (monsoonal)
- Canada / Siberia - wetter
- Amazon - drier
Alpine glaciers and continental ice sheets are melting at increasing rates

References


Collapse of the Larsen B ice shelf, 31 Jan – 7 Mar 2002:

- Antarctic Peninsula on left, melt ponds on ice shelf on right
- first melt phase: 800 square km
- second melt phase: 2600 square km (~half of Rhode Island)
- paleoceanographic research suggests this area has never been ice-free in the last 10,000 years (Domack et al., 2005, Nature)

MODIS images from NASA’s Terra satellite, National Snow and Ice Data Center, University of Colorado, Boulder.

Minimum Extent of Summer Sea Ice
1979
Projected changes in the extent of winter snow cover, Northeast U.S.

Minimum Extent of Summer Sea Ice
2003

Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions
Union of Concerned Scientists, July 2007

Sea level rise due to global warming
Sea level rise over the last century
Sea level rise scenarios for 2100

Coastal Flooding Will Increase in Extent and Frequency as Sea Level Continues to Rise

- Current 100 year flood event in NYC will occur on average once every 10 years by the end of the 21st Century.
- Large sections of Lower Manhattan and Queens could flood during relatively moderate hurricanes and nor’easters.
Coastal Flooding Will Increase in Extent and Frequency as Sea Level Continues to Rise

- Barrier Islands such as Fire Island, Long Beach, and the Jersey Shore could face major flooding on a semi-annual basis by 2100.

The Insurance Industry is Retreating from the Coast

Due to heavy losses associated with recent hurricanes such as Katrina, insurers are reluctant to issue policies to coastal homeowners:

- 2006 - Allstate drops coverage for 1000s of homes along the Middle Atlantic and Northeast coast.
- State Farm no longer insures properties within 1 mile of the ocean (formerly, the cutoff was 1000 ft).
- 2006 - Hingham Mutual Group cancels 9000 homeowner policies on Cape Cod.

Commercial Fisheries are Threatened By Climate Change

- Warming ocean waters will cause commercially important species to go regionally extinct (for example, cod - see diagram to right).
- Marine species fail to breed or become vulnerable to disease in warmer waters.
- 1999 - massive die-off of lobster in Long Island Sound due to outbreak of disease correlates with unusually elevated water temperature that summer.
- Lobster have not recovered to anywhere near their previous levels and most experts agree that the lobster fishery is unlikely to ever recover.
Fire Ants - currently restricted to southern states, but moving north!

Spruce Bark Beetles

- Kenai Peninsula, Alaska: Spruce bark beetles have destroyed nearly 4 million acres of mature forest on the peninsula.
- Warmer weather allows the beetles to mature and breed faster, completing a two-year life cycle in just one year.
- In cooler times on the peninsula, the forests and the beetles lived in balance, but today, the trees are unable to withstand the explosion in the beetle population.
Climate Change is Causing Extinctions

- 74 species of frog in Costa Rica have gone extinct in the last two decades.
- Numbers of species extinctions correlate with temperature for the previous year. Hot years see elevated extinctions in the following year.
- Warmer weather favors growth of a fungus that attacks the skin of these tropical frogs.
- Extinctions do not correlate with El Nino changes in sea surface temperature (drives fluctuations in rainfall).

Widespread amphibian extinctions from epidemic disease driven by global warming
J. Alan Pounds et al.
Nature 439, 161-167(12 January 2006)
In the face of climate change, what are our options?

- Adaptation: adjust to changes as they happen.
- Prevention: try to slow and / or mitigate climate change to reduce the need for adaptation.
- Reduce the production of greenhouse gases – particularly CO₂

The Big Question:
Which is more costly – prevention now or adaptation later?

How do we reduce CO₂ emissions?

Producer - Energy

More efficient distribution
- Non-Carbon energy sources (solar, wind, tidal, geothermal, nuclear)
- Carbon sequestration
  Invest in new technology
Payoff?
Carbon taxes and emissions caps create economic incentives

Consumer
- Reduce consumption
- Reduce waste
  Invest in new technology
Payoff - lower energy costs
I THINK IS CALIFORNIA A GLOBAL WARMING ULTRA LIGHT!

HOW TO DOE NICE COOL AIR CON TRICKS AND GET CARRGAGE MEATIVEH!