Climate Change

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Main Points for Today
• Physics of Global Change
• Evidence of Change
• Consequences of Change
• Impact of Changing our Habits

280 ppm preindustrial

Mauna Loa, Hawaii

Source: Dave Keeling and Tim Whorf (Scripps Institution of Oceanography)
Review of Global Climate

Incoming Solar Radiation
- Not blocked by atmosphere

Outgoing Terrestrial Radiation
- Some blocked by atmosphere
- $\text{H}_2\text{O, CO}_2$

Earth’s Surface
- Incoming different wavelength than outgoing
The Greenhouse effect

**ATMOSPHERE**

- 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

**GREENHOUSE GASES**

- Solar radiation passes through the clear atmosphere.
- 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.
- Surface gains more heat and infrared radiation is emitted again.

**Sources:**
Trends in Greenhouse Gas Amounts in Atmosphere

Measurements
Black - in situ observations
Dots - from ice cores

CFCs - in situ since 1977, before that estimated from industrial production and lifetimes

Leveling off 😊
Industrial Nations Produce the most Carbon Dioxide
Due to changes in land use, rainforests cut down, leading to urbanization, roads, and grassland which can hold less carbon.

<table>
<thead>
<tr>
<th>Greenhouse gases</th>
<th>Chemical formula</th>
<th>Pre-industrial concentration</th>
<th>Concentration in 1994</th>
<th>Atmospheric lifetime (years)**</th>
<th>Anthropogenic sources</th>
<th>Global warming potential (GWP)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon-dioxide</td>
<td>CO₂</td>
<td>278 000 ppbv</td>
<td>358 000 ppbv</td>
<td>Variable</td>
<td>Fossil fuel combustion Land use conversion Cement production</td>
<td>1</td>
</tr>
<tr>
<td>Methane</td>
<td>CH₄</td>
<td>700 ppbv</td>
<td>1721 ppbv</td>
<td>12.2 +/- 3</td>
<td>Fossil fuels Rice paddies Waste dumps Livestock</td>
<td>21**</td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td>N₂O</td>
<td>275 ppbv</td>
<td>311 ppbv</td>
<td>120</td>
<td>Fertilizer industrial processes combustion</td>
<td>310</td>
</tr>
<tr>
<td>CFC-12</td>
<td>CCl₂F₂</td>
<td>0</td>
<td>0.503 ppbv</td>
<td>102</td>
<td>Liquid coolants. Foams</td>
<td>6200-7100 ****</td>
</tr>
<tr>
<td>HCFC-22</td>
<td>CHClF₂</td>
<td>0</td>
<td>0.105 ppbv</td>
<td>12.1</td>
<td>Liquid coolants</td>
<td>1300-1400 ****</td>
</tr>
<tr>
<td>Perfluoromethane</td>
<td>CF₄</td>
<td>0</td>
<td>0.070 ppbv</td>
<td>50 000</td>
<td>Production of aluminium</td>
<td>6 500</td>
</tr>
<tr>
<td>Sulphur hexa-fluoride</td>
<td>SF₆</td>
<td>0</td>
<td>0.032 ppbv</td>
<td>3 200</td>
<td>Dielectric fluid</td>
<td>23 900</td>
</tr>
</tbody>
</table>

Note: pptv = 1 part per trillion by volume; ppbv = 1 part per billion by volume, ppm v = 1 part per million by volume

* GWP for 100 year time horizon. ** Includes indirect effects of tropospheric ozone production and stratospheric water vapour production. *** On page 15 of the IPCC SAR. No single lifetime for CO₂ can be defined because of the different rates of uptake by different sink processes. **** Net global warming potential (i.e., including the indirect effect due to ozone depletion).

Source: IPCC radiative forcing report, Climate change 1995. The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 1996.
Indirect - change in cloud properties due to aerosols (cloud nucleation)
Aerosols Cool the Atmosphere
Observed Trends in Surface Air Temperature

- The mean global surface temperature has increased by about 0.3 to 0.6°C since the late 19th century and by about 0.2 to 0.3°C over the last 40 years.
- The recent warming has been greatest between 40°N and 70°N.
• Info is derived mainly from tide-gauge data
• Over last 100 years, the global sea level has risen by ~10 - 25 cm
• 2-7 cm due to thermal expansion and 2-5 due to glacier melt
• Precipitation has increased over land at high latitudes of the Northern Hemisphere, especially during the cold season.
• Precip decreased in steps after the 1960s in subtropics & tropics
• Precip over land increased 1900-1960, but decreased since ~1980
• No good record of precip over the ocean
Trends Arctic Ice Thickness & Fairbanks Permafrost Temperature

Graphs and charts illustrating the thinning of the Arctic sea-ice and changes in permafrost temperatures at various depths in Fairbanks (Alaska). The graphs show a clear trend of increased temperatures and ice thickness reduction, leading to the release of methane and damage to roads and buildings.

Release Methane
Damage Roads and Buildings
Changes in River Ice Breakup in Finland and in Nenana

Fig. 1. Townspeople of Nenana, Alaska, raise the tripod on the frozen Tanana River, 4 March 2001. [Photo by J. Coghil (9)]

Fig. 2. (A) Ice breakup trends on the Tanana River. Breakup occurs between calendar dates 20 April and 20 May. Light line: linear regression (slope = 0.07, t = 2.53, P = 0.01, R² = 0.07). Heavy line: third-order polynomial regression (ice break = -1E-04 year^3 + 0.59 year^2 + 1144 year + 744660, F = 4.18, P = 0.006, adjusted R² = 0.10). (B) Temperature data for Nenana and Fairbanks, Alaska. ● and ■, TMAX; ○ and □, TMIN.
Economic Costs that have increased from weather events

- Caution ==> Increase in cost partially due to more people
- Fewer frosts in several widespread areas
- Increase in the proportion of rainfall from extreme events over Lower 48
Potential climate changes impact

Temperature

Sea level rise

Precipitation

Impacts on...

Health
- Weather-related mortality
- Infectious diseases
- Air-quality respiratory illnesses

Agriculture
- Crop yields
- Irrigation demands

Forest
- Forest composition
- Geographic range of forest
- Forest health and productivity

Water resources
- Water supply
- Water quality
- Competition for water

Coastal areas
- Erosion of beaches
- Inundation of coastal lands
- Additional costs to protect coastal communities

Species and natural areas
- Loss of habitat and species
- Cryosphere: diminishing glaciers

Source: United States environmental protection agency (EPA)
1000 year temperature reconstruction

- dendroclimatic, coral, and ice-core proxy records as calibrated by instrumental measurements
Paleoclimate Record shows increase in CO₂ and Temperature

- Rapid changes in climate have occurred in the past 400,000 years

Ocean and Climate Change

Schematic picture of deep slow ocean circulation

- Increase air temperature, warm ocean
- Stop this slow circulation (Halocline Catastrophe) + Feedback
Range of Projections Based on Varying Sensitivities
increase in global mean sea level of between 13 and 94 cm.
• Storm surges have impacted 100km inland, sea level country
• Already a very poor country, 1.5m increase devastating
Other evidence that supports climate has warmed

• Tropical glaciers are melting fast
  E. Africa, New Guinea, Andes
  Kilimanjaro may be ice free by 2015
  73% decrease from 1913-1989

• Arctic sea ice has retreated, particularly in summer

**Polar Climate Change Largest and Ice Albedo Feedback**

Ice-albedo feedback
(more ice, more reflected Solar, cooler temperatures, more ice-----positive feedback loop)
High latitude thawing of permafrost-->methane!
Impact on Humans

- Disease transmissions - Malaria

- Change in Variability - more extremes
  - more hurricanes
  - more El Niños
  - increased flooding of rivers in the US

- Permafrost thaws

- Sea level rises - ocean warms and expands
<table>
<thead>
<tr>
<th>Disease</th>
<th>Vector</th>
<th>Population at risk (million)</th>
<th>Number of people currently infected or new cases per year</th>
<th>Present distribution</th>
<th>Likelihood of altered distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malaria</td>
<td>Mosquito</td>
<td>2,400²</td>
<td>300-500 million</td>
<td>Tropics and Subtropics</td>
<td>Highly likely</td>
</tr>
<tr>
<td>Schistosomiasis</td>
<td>Water snail</td>
<td>600</td>
<td>200 million</td>
<td>Tropics and Subtropics</td>
<td>Very likely</td>
</tr>
<tr>
<td>Lymphatic Filariasis</td>
<td>Mosquito</td>
<td>1,094³</td>
<td>117 million</td>
<td>Tropics and Subtropics</td>
<td>Likely</td>
</tr>
<tr>
<td>African Trypanosomiasis (Sleeping sickness)</td>
<td>Tsetse fly</td>
<td>55⁴</td>
<td>250 000 to 300 000 cases per year</td>
<td>Tropical Africa</td>
<td>Unknown</td>
</tr>
<tr>
<td>Dracunculiasis (Guinea worm)</td>
<td>Crustacean (Copepod)</td>
<td>100⁵</td>
<td>100 000 per year</td>
<td>South Asia, Arabian Peninsula, Central-West Africa</td>
<td>Unknown</td>
</tr>
<tr>
<td>Leishmaniasis</td>
<td>Phlebotomine sand fly</td>
<td>350</td>
<td>12 million infected, 500 000 new cases per year⁶</td>
<td>Asia, Southern Europe, Africa, Americas</td>
<td>Likely</td>
</tr>
<tr>
<td>Onchocerciasis (River blindness)</td>
<td>Black fly</td>
<td>123</td>
<td>17.5 million</td>
<td>Africa, Latin America</td>
<td>Likely</td>
</tr>
<tr>
<td>American Trypanosomiasis (Chagas Disease)</td>
<td>Triatomine bug</td>
<td>100⁷</td>
<td>18 million</td>
<td>Central and South America</td>
<td>Likely</td>
</tr>
<tr>
<td>Dengue</td>
<td>Mosquito</td>
<td>1,800</td>
<td>10-30 million per year</td>
<td>All Tropical countries</td>
<td>Unknown</td>
</tr>
<tr>
<td>Yellow Fever</td>
<td>Mosquito</td>
<td>450</td>
<td>more than 5 000 cases per year</td>
<td>Tropical South America, Africa</td>
<td>Unknown</td>
</tr>
</tbody>
</table>

- Vector Borne Diseases increase with warmer climate
- VBD cause significant numbers of deaths in tropics
- Malaria and other fun stuff to think about

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1. Top three entries are population-prorated projections, based on 1989 estimates.
Change in cereal production under three different GCM equilibrium scenarios in percent from base estimated in 2060

Notes: Level 1 adaptation included changes in crop variety but not the crop, the planting date of less than 1 month, and the amount of water applied for areas already irrigated. Level 2 adaptation additionally included changes in the type of crop grown, changes in fertilizer use, changes in the planting of more than 1 month, and extension of irrigation to previously unirrigated areas.

Source: Climate change 1995, Impacts, adaptations and mitigation of climate change: scientific-technical analyses, contribution of working group 2 to the second assessment report of the Intergovernmental Panel on Climate Change, UNEP and WMO. Cambridge: Cambridge University, 1996.
2001 OZONE HOLE ABOUT THE SAME SIZE AS PAST 3 YEARS

October 16, 2001 - News Story

26 million square kilometers - size of North America, area and depth
Chlorine compounds leveling off due to decreased production
Summary

• Atmospheric greenhouse gases are increasing
• Atmospheric temperature increasing

• Past Climate evidence
  • Greenhouse gas increase goes with Temperature increase

• Impact on Humans
  • Due to climate change
  • Due to change in extremes

• Natural Variability
  • long time scales in ocean
  • solar variability
Global warming  Web pages
• IPCC  http://www.ipcc.ch/
• ACIA, Arctic Climate Impact Assessment  http://www.acia.uaf.edu/
• Climate Ark, Climate Change & Renewal Energy Portal  http://www.climateark.org/
• UNEP site, many graphics from there  http://www.grida.no/climate/vital/17.htm

Anti-global warming  of points of view
• http://www.junkscience.com/ anti-environment web page
• Pat Michaels  
  http://www.evsc.virginia.edu/faculty/people/michaels.shtml
• Fred Singer  
  http://www.sepp.org/bios/singer/biosfs.html