Climate Change
Absorption Spectra
What goes in doesn’t necessarily go out!

Greenhouse gas absorption spectra. Source The Resilient Earth.
N\textsubscript{2}O

Water Vapor

\text{CO}_2 \text{ and CH}_4

Oxygen
The Greenhouse Effect

Incoming solar short-wave radiation

Reflected back to space

Absorbed in the atmosphere by greenhouse gases

Absorbed by the Earth’s surface & atmosphere

Infra-red long-wave radiation from surface

Radiated out to space
What would the world be like without the Greenhouse Effect?

- The Earth’s black-body temperature is 5°C.
- With the Earth’s albedo (reflectivity) the temperature drops to -20°C.
- The natural Greenhouse Effect brings that temperature back to a comfortable 15°C.
Why is the Greenhouse Effect a bad thing?

Graph adapted from the Whitehouse Initiative on Global Climate Change.
CO$_2$ levels over the last 50 years
## Global Warming Potentials per kg of greenhouse gases relative to CO₂

<table>
<thead>
<tr>
<th>Greenhouse Gas</th>
<th>GWP</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>1</td>
</tr>
<tr>
<td>CH₄</td>
<td>21</td>
</tr>
<tr>
<td>H₂O</td>
<td>100</td>
</tr>
<tr>
<td>N₂O</td>
<td>290</td>
</tr>
<tr>
<td>CFCs</td>
<td>3000-8000</td>
</tr>
</tbody>
</table>
The water vapor problem

- Due to increases in temperature and, therefore, climatic changes, precipitation has increased 5% to 20% (depending on latitude) over the last century.

- However, in tropical areas precipitation has declined. (This is partly due to deforestation).
The amount of water vapor in the atmosphere increases with increasing temperature.

Water vapor is a more effective greenhouse gas than CO₂ — a hundred times more effective!

This creates a positive feedback loop that could increase global temperature much more than predicted.
Past climate and what it tells us about our future
Temperature variation over the last 160,000 years

Change in temperature from current level

End of last ice age

Thousands of years before present

°C
Variation in the amount of sunlight hitting Earth
Milankovich Cycles

**Precession**: a 23,000 year cycle that occurs because of the inherent “wobble” of the Earth’s axis. This produces a change in the point of maximum northern-hemisphere illumination (i.e., today, the summer solstice is on the long end of the Earth’s elliptical orbit; 12,000 years ago it was on the short end of the ellipse. When the northern hemisphere summer solstice occurs on the short end of the ellipse, it experiences greater summer illumination).

**Tilt**: a 41,000 year cycle where the Earth’s axis has a tilt that varies from ~25° to ~22°.

**Eccentricity**: a 100,000 year cycle where the Earth’s elliptical orbit varies from near circular (with an eccentricity close to 0) to distinctly elliptical (with an eccentricity close to 0.5).
Temperature- and density-driven circulation of deep ocean waters that contributes to the mild temperatures found in northern Europe. This volume is equal to roughly 100 Amazon rivers. As water enters the flow near Iceland, it loses heat to the atmosphere. This loss adds up to $5 \times 10^{21}$ calories/year (equal to ~30% of the annual solar input to the troposphere over the Atlantic, north of the Straits of Gibraltar).

The ocean plays a major role in the distribution of the planet’s heat through deep sea circulation. This simplified illustration shows this “conveyor belt” circulation which is driven by differences in heat and salinity. Records of past climate suggest that there is some chance that this circulation could be altered by the changes projected in many climate models, with impacts to climate throughout lands bordering the North Atlantic.
What happens when the conveyor belt is disrupted?
Has the Industrial Revolution prevented the next ice age or will the increase in freshwater to the Atlantic cause the next ice age?
Younger Dryas ~12,000 ybp
Abrupt cooling in the past

• Slowdowns or disruptions of the deep ocean circulation conveyor, caused by increased fresh water flux to the North Atlantic, cooled temperatures in Europe up to 5°C.
• This increased ice over the northern oceans and, therefore, the Earth’s albedo, creating a positive feedback mechanism.
• It took a restart of the conveyor to return to a warmer climate.
Hysteresis Loop

The graph illustrates the hysteresis loop in relation to temperature and freshwater flux. The red line represents the mode with deep-sea circulation, showing the relationship between temperature and freshwater flux. The blue line represents the mode without deep-sea circulation. The points marked with arrows indicate the shift in behavior at certain flux values, highlighting the hysteresis effect.
Abrupt warming in the past

Diagram showing variations in temperature and ventilation over time. The chart illustrates changes in air temperature, Greenland temperature, and North Atlantic temperature over calendar age (years before present).
Future consequences of global warming

- Sea-level rise
- Spread of tropical disease
- Flooding
- Massive starvation
- Glaciation?
Sea-level rise

- Due to the increases in temperature, the Polar Ice Sheets are shrinking in size, causing low level increases in sea level.

  20,000 yrs ago

- An EPA study has shown that global sea level has a 50% chance of rising 45cm by the year 2100.

  17 foot increase

  U.S. East Coast

  170 foot increase
Coastal Impacts

• A 2-foot rise in sea level could eliminate 17%-43% of U.S. wetlands; half of the loss would occur in Louisiana alone.
• The rate of coastal erosion is roughly 100 times the rate of sea level rise. (The coast erodes laterally much faster than the sea level rises.)
• Nearly 90% of the U.S. sandy coasts are eroding.
• Global warming could cause additional sea level rise through the steric effect (thermal expansion).
Spread of Tropical Diseases

• A sea-level rise could spread infectious disease by flooding sewage and sanitation systems in coastal cities.

• An expansion of tropical climates would bring malaria, encephalitis, yellow fever, dengue fever and other insect-borne diseases (such as the West Nile virus) to formerly temperate zones.
Flooding

• A warmer atmosphere holds more moisture.
• When the extra water condenses, it more frequently drops from the sky as heavier downpours.
• Atmospheric moisture has increased 10% over the last two decades.
• High intensity precipitation, leading to regional flooding, has steadily increased at the rate of 3% annually. (This is also a result of development in wetland regions.)
A new study in the journal *Nature* found that hurricanes and typhoons have become stronger and longer-lasting over the past 30 years. These upswings correlate with a rise in sea surface temperatures.
Enterprise Bridge spanning Lake Oroville in Butte County, CA

July 2011
Same reservoir April 2015
Fisheries Impacts

Most of the wetland regions (estuaries) are known as predominate nursing grounds. The changes in salinity and temperature in these wetlands will reduce or destroy many fisheries.
Agricultural Impacts

• Past evidence and computer models indicate that tolerance ranges of plant species will shift northward by 60-90 miles and vertically by 500 feet for each 1°C rise in the global temperature.

• Irrigation will become increasingly important as water becomes scarce in already arid regions.

• Crop-eating insects and disease will have better survival rates and more generations per season in food-growing areas with warmer climates.

• Rapidly fluctuating climate change (such as the record-breaking heatwaves followed by the record-breaking cold spells) will damage crops unable to cope with temperature extremes.
Massive Starvation

- Global population reached 7 billion in 2011.
- At current rates, population will reach 12 billion by 2100.
- Since 1978 food production has lagged behind population growth in 69 of the 102 lesser-developed countries for which data were available.
- The food crisis will only increase as stress on agriculture and fisheries continues.
What can I do?

• Turn off the lights!
• Turn off your computer when not in use.
• Drive a vehicle that gets better gas mileage. (If our gas mileage improved by even 5 mpg, we would save more fuel than all that is found in the Alaskan Wildlife Refuge).
• Support alternative energy sources.
• Recycle plastics and buy recycled plastic products.
• When possible, eat and buy products locally.
• Get involved in climate action awareness groups.
• Reduce your energy waste by managing your time!
Calculate your carbon footprint

Your Carbon Footprint:
- House: 2.36 metric tons of CO2e
- Flights: 0.34 metric tons of CO2e
- Car: 3.47 metric tons of CO2e
- Motorbike: 0.00 metric tons of CO2e
- Bus & Rail: 0.00 metric tons of CO2e
- Secondary: 3.54 metric tons of CO2e
Total = 9.71 metric tons of CO2e

To offset some or all of your carbon footprint, click the sections you would like to offset in the list above, and click the Offset Now button.

Total To Offset = 9.71 metric tons of CO2e  Offset Now

- Your footprint is 9.71 metric tons per year
- The average footprint for people in United States is 20.40 metric tons
- The average for the industrial nations is about 11 metric tons
- The average worldwide carbon footprint is about 4 metric tons
- The worldwide target to combat climate change is 2 metric tons

If you're using a public computer, or want to try again, you can [clear your carbon footprint data].
For ideas on how to reduce your carbon footprint, see the CO2 Reduction section of our website.
Why not sign up for our newsletter to keep informed of other ways you can reduce your carbon footprint?
References


http://www.cotf.edu/ete/modules/climate/GCremote3.html

http://www.animationlibrary.com/animation/25078/Pacman/