Energy on this world and elsewhere

Instructor: Gordon D. Cates
Office: Physics 106a, Phone: (434) 924-4792
email: cates@virginia.edu

Course web site available at www.phys.virginia.edu, click on classes and find Physics 1110.
or at http://people.virginia.edu/~gdc4k/phys111/fall11

October 18, 2011
Climate Change
Global Warming Skeptics

It is important to distinguish between those that doubt that the Earth is warming, and those that resist blaming it on anthropogenic effects (such as dumping $CO_2$ into the atmosphere).

Someone who was often quoted by global warming skeptics was Richard Muller, of the University of California at Berkely. While I don’t believe that he questioned whether any warming was occurring, he certainly questioned the view put forth by the Intergovernmental Panel on Climate Change.
The Hockey Stick Controversy

Considerable media coverage went into an examination of what was known as the “hockey-stick graph”. This plot, on which Michael Mann was one of the creators, has been criticized for being misleading. It synthesizes recent data from thermometers with “proxy data” from indirect measurements.

This plot, scanned from Richter’s book, shows a more recent compilation put together by the National Academy of the Sciences. It still shows a temperature rise, but perhaps not as precipitous.
Richard Muller’s testimony

From the Berkeley Earth Surface Temperature (BEST) Study

Figure: Land average temperatures from the three major programs, compared with an initial test of the Berkeley Earth dataset and analysis process. Approximately 2 percent of the available sites were chosen randomly from the complete set of 39,028 sites. The Berkeley data are marked as preliminary because they do not include treatments for the reduction of systematic bias.
Coverage of Richard Muller's testimony

From NY Times, March 31, 2011, by Lauren Morello

Muller's study, overseen by the nonprofit Novim Group, aims to create a new analysis of global surface temperature data that avoids what it deems to be problems with the existing analyses.

The effort is funded by the Lawrence Berkeley National Laboratory and several foundations, including a group set up by Microsoft Corp. founder Bill Gates and another funded by the Charles G. Koch Foundation, which has also supported efforts opposing mainstream climate change science.

Although the BEST group's final results remain to be seen, Muller said he was surprised to find that early results agree with existing temperature analyses.

"The Berkeley Earth agreement with the prior analysis surprised us, since our preliminary results don't yet address many of the known biases," he testified today. "When they do, it is possible that the corrections could bring our current agreement into disagreement."
How does the greenhouse effect work?
Blackbody or thermal radiation

The camera being used is only sensitive to the long wavelengths associated with thermal radiation.

Stefan-Boltzmann equation:
\[ P_{\text{radiated}} = \sigma \varepsilon A T^4 \]
Here \( \sigma = 5.67 \times 10^{-8} \, \text{W/(m}^2 \text{K}^4) \), \( \varepsilon \) is called the emissivity and is between 0 and 1, \( A \) is the area of the thing radiating, and \( T \) is its temperature.

Wien’s displacement law
\[ \lambda_{\text{max}} = \frac{b}{T} \]
Here lambda is the central wavelength of the radiation emitted, \( b = 2.9 \times 10^{-3} \, \text{m K} \), and \( T \) is the emitting object’s temperature.
Blackbody or thermal radiation

Stefan-Boltzmann equation:

\[ P_{\text{radiated}} = \sigma \varepsilon A T^4 \]

Here \( \sigma = 5.67 \times 10^{-8} \text{ W/(m}^2\text{ K}^4) \), \( \varepsilon \) is called the emissivity and is between 0 and 1, \( A \) is the area of the thing radiating, and \( T \) is its temperature.

Wien’s displacement law

\[ \lambda_{\text{max}} = \frac{b}{T} \]

Here lambda is the central wavelength of the radiation emitted, \( b = 2.9 \times 10^{-3} \text{ m K} \), and \( T \) is the emitting object’s temperature.

The camera being used is only sensitive to the long wavelengths associated with thermal radiation.
What is the temperature of a planet in the absence of the greenhouse effect?

- The Earth absorbs light from the sun, some quantity, $P_{\text{absorbed}}$.
- Thermal radiation is emitted by the Earth: $P_{\text{radiated}} = \sigma \varepsilon A T^4$.
- The two must EXACTLY balance one another for the Earth’s temperature to be in equilibrium: $P_{\text{absorbed}} = P_{\text{radiated}}$.
- For the Earth, I find $T = 250.7\ \text{K or} -8^\circ\ \text{F}$.
The greenhouse effect

- Visible light is absorbed by the earth.
- The earth re-radiates the energy in the form of infrared radiation.
- The infrared is largely absorbed by water vapor and CO$_2$ and reradiated, both into space, and back to the earth.
- I find that $T_{\text{new}} = 2^{1/4} T_{\text{no greenhouse}} = 298.1 \text{K or } 76.9^\circ \text{F}$ (correct answer is 60$^\circ$F)
Clicker question

Which planet’s temperature is most influenced by the largest greenhouse effect?

A. Venus
B. Earth
C. Mars
D. All three planets are about the same.
Is the greenhouse effect real?

Yes! - we wouldn't be here without it!

• Venus has a runaway greenhouse effect.
  - Venus receives roughly twice the sunlight of the earth.
  - In the absence of the greenhouse effect, its average temperature would be 90°F.
  - With the runaway greenhouse effect, its average temperature is 800°F.

• Mars has only a very small greenhouse effect.
  - In the absence of the greenhouse effect, its average temperature would be -65°F. In fact, there are huge variations ranging from roughly -225°F to as high as 70°F.

• Earth’s greenhouse effect is just right (for us).
  - In the absence of the greenhouse effect, Earth’s average temperature would be -4°F.
  - With the greenhouse effect, the Earth’s average temperature is roughly 60°F.
Report from the Intergovernmental Panel on Climate Change (IPCC)

CLIMATE CHANGE 2007 SYNTHESIS REPORT

 Won the 2007 Nobel Peace Prize

Also has caused considerable controversy.
Are anthropogenic greenhouse gases really changing the makeup of the atmosphere?

This is a different question than asking whether these greenhouse gases are causing the warming we are experiencing.
It is probably the case that warming on the Earth, with no other factors, causes \( CO_2 \) to levels to rise. Even if this is true, the recent rise in \( CO_2 \) is virtually impossible to explain other than anthropogenic causes.
Whatever you end up concluding about global warming, there is no question that we have increased the carbon dioxide levels in our atmosphere by something like 35% since the beginning of the industrial revolution.
Nation Academies report on climate change
Climate Modeling

NATURAL WARMING
(1) Sunlight brings energy into the climate system; most of it is absorbed by the oceans and land.
(2) Heat (infrared energy) radiates outward from the warmed surface of the Earth.
(3) Some of the infrared energy is absorbed by greenhouse gases in the atmosphere, which re-emit the energy in all directions.
(4) Some of the infrared energy further warms the Earth.
(5) Some of the infrared energy is emitted into space.

AMPLIFIED WARMING
(6) Higher concentrations of CO₂ and other "greenhouse" gases trap more infrared energy in the atmosphere than occurs naturally. The additional heat further warms the atmosphere and Earth's surface.
A small minority of climate scientists feel that the models in the IPCC studies don't take important factors into account. For example, Richard Lindzen from MIT has emphasized the importance of clouds, and worries that their "negative feedback" effect is underestimated.
Climate model results from the report of the Intergovernmental Panel on Climate Change (IPCC)

Table 5.1 Projected global average surface warming at the end of the twenty-first century

<table>
<thead>
<tr>
<th>Case</th>
<th>Global average temperature changes relative to 1980–1999</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Best estimate</td>
</tr>
<tr>
<td></td>
<td>°F</td>
</tr>
<tr>
<td>B1</td>
<td>3.2</td>
</tr>
<tr>
<td>A1T</td>
<td>4.3</td>
</tr>
<tr>
<td>B2</td>
<td>4.3</td>
</tr>
<tr>
<td>A1B</td>
<td>5.0</td>
</tr>
<tr>
<td>A2</td>
<td>6.1</td>
</tr>
<tr>
<td>A1FI</td>
<td>7.2</td>
</tr>
</tbody>
</table>