A Warm Planet in a Cold Universe

How the Earth stays warm and why it's getting warmer

Questions from Teacher Workshops (week 4)

Atmospheric Science
- What exactly do we mean by stability in the atmosphere and how does it relate to thunderstorms?
- What is a temperature inversion and how does that relate to what we are learning?
- How exactly are climate change and worsening storms related?
- Can people and other living things really change the temperature and pressure of the entire world?

Simple Climate Model
- Was it bit difficult to follow over zoom. Lots of moving tokens, but many folks lost the big picture.
- A video would be helpful to show the process and summarize the results.
- How do we make this relatable for younger elementary students?
- How does radiation absorption and emission relate to weather and climate?

Simulation
- Where exactly are temperatures calculated and recorded?

Space fridge
- The space refrigerator is super cool. How does it relate to weather and climate again?

Cloud in a bottle
- Is there a way to emulate the cloud in a bottle activity without needing to use matches? Why does this activity not work when you add too much water?
- Is there more to discuss this... I just talked about evaporation, condensation, precipitation, etc. Should I be adding information about needed particulate matter to my instruction (for third graders)? Also, does the fact that there is more pollution in our world then lead to more clouds?
- Why does the air temperature increase with altitude in the stratosphere?
- Why does adding food coloring do to the cloud?

Visible light & ultraviolet

<table>
<thead>
<tr>
<th>Description</th>
<th>Frequency (THZ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultraviolet</td>
<td>1,000</td>
</tr>
<tr>
<td>Visible light</td>
<td>550</td>
</tr>
<tr>
<td>Near infrared</td>
<td>350</td>
</tr>
<tr>
<td>Thermal infrared</td>
<td>30</td>
</tr>
</tbody>
</table>

| T = tera = 10^{12} |

Warm objects emit thermal radiation.

\[
\frac{Q}{\Delta t} = \varepsilon \sigma A T^4
\]

Emission & Absorption: Same physics

If you absorb, you emit.
Emission frequency is proportional to temperature. Higher temperatures mean higher frequencies.

<table>
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<th>Description</th>
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<th>Temperature (K)</th>
<th>Object</th>
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<tbody>
<tr>
<td>Ultraviolet</td>
<td>1,000</td>
<td>10,000</td>
<td>Arc welding</td>
</tr>
<tr>
<td>Visible light</td>
<td>550</td>
<td>5,300</td>
<td>Surface of the sun</td>
</tr>
<tr>
<td>Near infrared</td>
<td>350</td>
<td>3,400</td>
<td>Light bulb filament</td>
</tr>
<tr>
<td>Thermal infrared</td>
<td>30</td>
<td>290</td>
<td>Surface of the earth</td>
</tr>
</tbody>
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The earth warms by absorbing visible light.

The earth cools by emitting thermal radiation.

Over the course of a year, the average temperature of the Earth is approximately constant.

The Earth is shining as brightly as the sun.

What does this tell you about the magnitude of the energy absorbed and emitted by the earth?
It doesn't snow because it's cold. It's cold because it snowed. Explain using the principles we've discussed.

Snow is made of water, which strongly absorbs (and emits!) thermal radiation.

Visible light and thermal radiation are electromagnetic waves.

Electromagnetic waves interact with matter.

Does an electromagnetic wave interact with gas molecules?

Nitrogen/Oxygen: 
Nope.

Carbon Dioxide: 
Yes.

Water Vapor: 
Oh Yeah.

Greenhouse gases

Resonant frequencies of greenhouse gases mean they absorb (and emit!) thermal radiation, but not visible light.

Atmospheric Transmission

Relative Intensity

Solar radiation

Terrestrial radiation

Atmospheric transmission:

More than 50%

Less than 50%
Visible Light
Transmitted.

Thermal Radiation
Absorbed and emitted.

Wavelength: 12 microns

Wavelength: 7 microns

The sky is shining on you.

The surface of the earth receives more radiated thermal energy from the atmosphere than it does radiant energy from the sun.

The sun shines during the day. The sky shines 24/7.
The radiation from the sun is mostly at visible wavelengths. The atmosphere is mostly transparent to the incoming radiation.

Less than 50%

More than 50%

Outgoing radiation from the much cooler earth is mostly at infrared wavelengths. The atmosphere is mostly opaque to the outgoing radiation.

Solar radiation
Terrestrial radiation
Atmospheric transmission:

No atmosphere: -18°C (0°F)
With atmosphere: +15°C (59°F)

The Greenhouse Effect

Carbon dioxide is a key player. It absorbs and emits thermal radiation.

Carbon dioxide helps keep the earth warm.

Carbon dioxide is good. But you can have too much of a good thing.
Carbon dioxide in the atmosphere is increasing.

The increase in carbon dioxide is due to human activities.

Burning 1 gallon of gas (6 pounds) produces 20 pounds of carbon dioxide.

From the fuel

\[ 16 + 12 + 16 \]

From the air

120 gallons per year
2,400 pounds of CO₂

The radiative properties of the earth’s atmosphere are measurably different.

The earth is getting warmer.
Reducing Humanity’s Carbon Footprint

Individuals can make changes, but significant reductions in greenhouse gases will mean making some changes, worldwide, of how energy is created, how land is managed.

To put the planet on a path of stable emissions, we need to, over the next 30 years, implement 8 some changes, worldwide, of how energy is created, how land is managed.

Efficiency & Conservation

1. Increased efficiency of cars

**GOAL**

All cars in the world by must have a minimum fuel efficiency of 60 miles per gallon.

**COSTS**

This will require much more efficient engines and lighter weight vehicles.

2. Efficiency & Conservation

Reducing miles traveled by cars

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Reducing Your Carbon Footprint

Each year, every person in the United States adds about 36,000 pounds of carbon dioxide equivalents to the atmosphere. Suppose you want to shrink your carbon footprint by 10%, a reasonable goal. To accomplish this, you’ll need to make changes that remove 3,600 pounds of carbon dioxide equivalents from your carbon footprint annually.

So, what changes do you make? The following activities or products each contribute about 1 pound of carbon dioxide equivalents to the atmosphere. What can you do?

One pound of carbon dioxide corresponds to:

- 15 minutes of air conditioning
- 6 minutes of heating with a gas forced air furnace
- 2 minutes of a hot shower
- 8.0 miles on a light-rail train (per passenger)
- 2.7 miles on a bus (per passenger)
- 2.6 miles in a mid-size hybrid car (driving alone)
- 2.1 miles in a large hybrid car (driving alone)
- 1.8 miles in a small gas-powered car (driving alone)
- 1.1 miles on a domestic flight (per passenger)

Necessary materials:

- Glass, clearly with etching sites etched into the bottom.
- Beer or soda, ideally in a glass bottle. This item or reader to see why some of the phenomena will be hard to see.

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