Heating the Atmosphere

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“Heat” vs. “Temperature”

• “Heat” refers to energy transferred from one object to another
• “Temperature” measures the average kinetic energy in a substance.
• When heat energy is transferred to a substance, its atoms or molecules move faster and the temperature rises
• When a substance loses energy, its atoms or molecules slow down and the temperature falls
3 ways to transfer energy

• CONDUCTION
• CONVECTION
• RADIATION

Conduction

- Conduction is the transfer of energy through matter, from hotter toward colder.
- Energy is transferred by collisions from the warmer substance toward the cooler one.

http://www.educationalelectronicsusa.com/p/images/heat_a.gif
Convection

• Convection is the transfer of heat by circulation within a fluid—liquid or gas
• “Warm air rises and cool air sinks”

http://www.energyquest.ca.gov/story/images/chap01_conduction.gif
Radiation

• Radiation is the transfer of energy outward in all directions from its source
• Radiation does not need to move through a substance—it can even travel through the vacuum (emptiness) of space

http://www.mikecurtis.org.uk/images/radiation.jpg
Different Kinds of Energy make up the Electromagnetic (EM) Spectrum

http://www.colourtherapyhealing.com/colour/images/electromagnetic-spectrum.jpg
Understanding the EM Spectrum

- **Wavelength**—energy behaves like a wave, and different types of energies have different distances between their crests/wavelengths
- Your eyes can detect waves in the visible range
- Your skin can detect waves in the infrared (heat) range
- We have created receivers that detect all wavelengths of energy (radios, TV, cell phones)
- **Frequency** is another way to describe waves (radio stations are identified by their frequency number)
4 Rules of Radiation

• All objects, at any temperature, **emit** radiant energy.
• Hotter objects radiate more energy per unit area than colder objects do.
• The hottest radiating bodies produce the shortest wavelengths of maximum radiation. [Sun/6000 C radiates visible light; Earth/25 C radiates heat energy]
• Objects that are good radiators/emitters are good absorbers.
Energy and the Atmosphere

Before we study what happens to energy in the atmosphere, we need to learn some key terms

- Emit = radiate, give off – from the source
- Absorb = receive, take in – the sink
- Reflect = bounce off an object (like a mirror)
- Scatter = spread out energy in all directions
- Transparent = all energy passes through
- Opaque = no energy passes through
Earth’s Energy Budget

There are many ways to represent what happens when solar energy reaches Earth. Here are some:

EARTH’S ENERGY BUDGET

- Incoming solar energy: 100%
- Reflected by atmosphere: 6%
- Reflected by clouds: 20%
- Reflected from earth’s surface: 4%
- Radiated to space from clouds and atmosphere: 64%
- Radiated directly to space from earth: 6%
- Absorbed by atmosphere: 16%
- Absorbed by clouds: 3%
- Conduction and rising air: 7%
- Radiation absorbed by atmosphere: 15%
- Carried to clouds and atmosphere by latent heat in water vapor: 23%
- Absorbed by land and oceans: 51%
http://cimss.ssec.wisc.edu/sage/meteorology/lesson1/images/EnergyBudget.jpg
Going back to the first, we see that, of the 100% of incoming solar radiation (insolation):

-- about 30% is reflected back to space (albedo)
-- about 19% is absorbed by clouds and the atmosphere
-- about 51% is absorbed by land and oceans
What’s Absorbed is then Re-Radiated

• That 51% of the insolation provides all the energy involved in photosynthesis and respiration, which keeps living things alive
• But eventually all of the 51% that is absorbed is re-radiated back to the atmosphere and, eventually, into space
• There are short-term imbalances when Earth warms up or cools down, but over long time periods, the Earth Energy Budget is balanced
The Greenhouse Effect

• Based only on Earth’s distance from the Sun, temperatures on the surface would be about -18° C/0° F

• But gases in Earth’s atmosphere—especially $\text{H}_2\text{O}(g)$, $\text{CO}_2$, and $\text{CH}_4$—absorbs heat energy that makes our planet inhabitable

• These are called the “greenhouse gases”
It’s like why your car gets hot in the summer

- In a plant greenhouse or your car, visible light passes through the transparent glass.
- Visible rays are absorbed and re-radiated as heat (infrared) waves.
- Glass is opaque to the IR radiation.
What happens in the atmosphere?

• In a similar, but not identical, way, air is transparent to visible light
• When IR energy is re-radiated from the surface, certain gases—H$_2$O$_{(g)}$, CO$_2$, and CH$_4$—absorb much of this energy to warm up our planet’s surface to an average of about 20°
• Without this greenhouse warming, Life on Earth would not be possible
• The next slide shows this in more detail.
The Greenhouse effect

1. Solar radiation passes through the clear atmosphere.
   - Incoming solar radiation: 343 Watt per m²

2. Net incoming solar radiation: 240 Watt per m²

3. Some solar radiation is reflected by the atmosphere and earth’s surface.
   - Outgoing solar radiation: 103 Watt per m²

4. 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

5. Some of the infrared radiation is absorbed and re-emitted by the greenhouse gas molecules. The direct effect is the warming of the earth’s surface and the troposphere.

6. Some of the infrared radiation passes through the atmosphere and is lost in space.
   - Net outgoing infrared radiation: 240 Watt per m²

Sources:
- Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; 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 university press, 1995.

http://maps.grida.no/go/graphic/greenhouse-effect