Heating the Atmosphere

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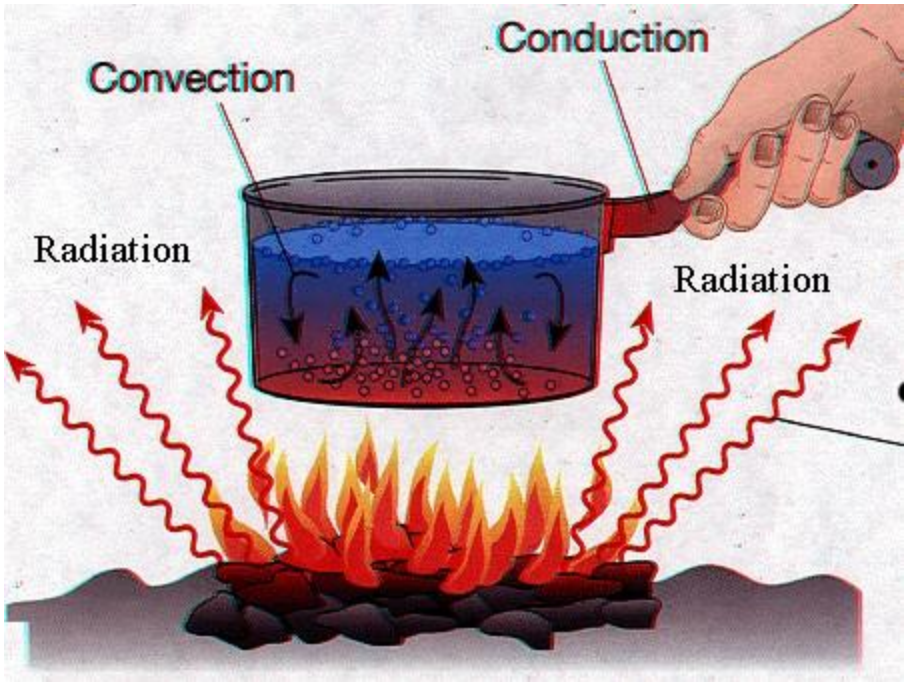
“Heat” vs. “Temperature”

- “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

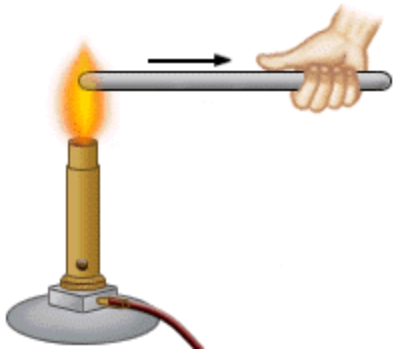
- CONDUCTION
- CONVECTION
- RADIATION



http://blogs.saschina.org/morena01pd2016/files/2009/10/ccr.jpg

Conduction

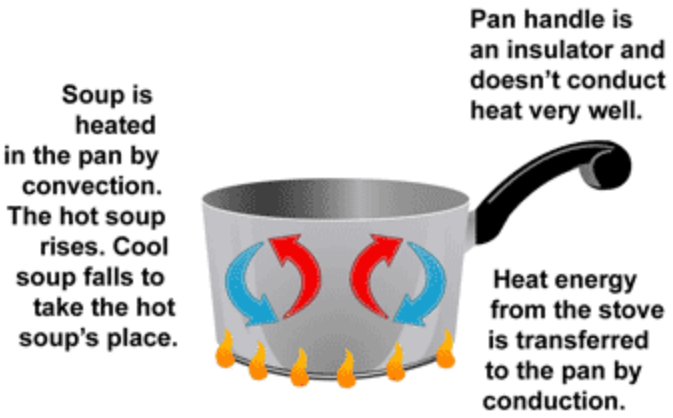
- Conduction is the transfer of energy through matter, from hotter toward colder
- Energy is transferred by collisions from the warmer substance toward the cooler one



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

Convection

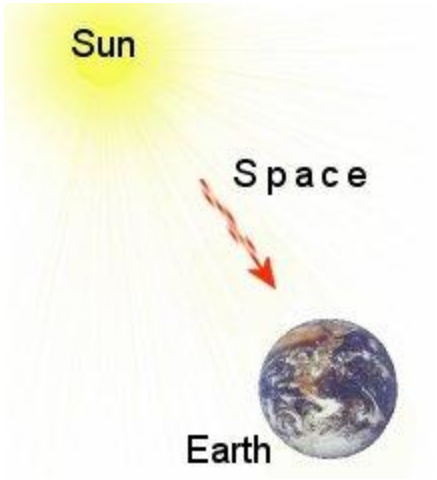
- Convection is the transfer of heat by circulation within a fluid—liquid or gas
- “Warm air rises and cool air sinks”



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

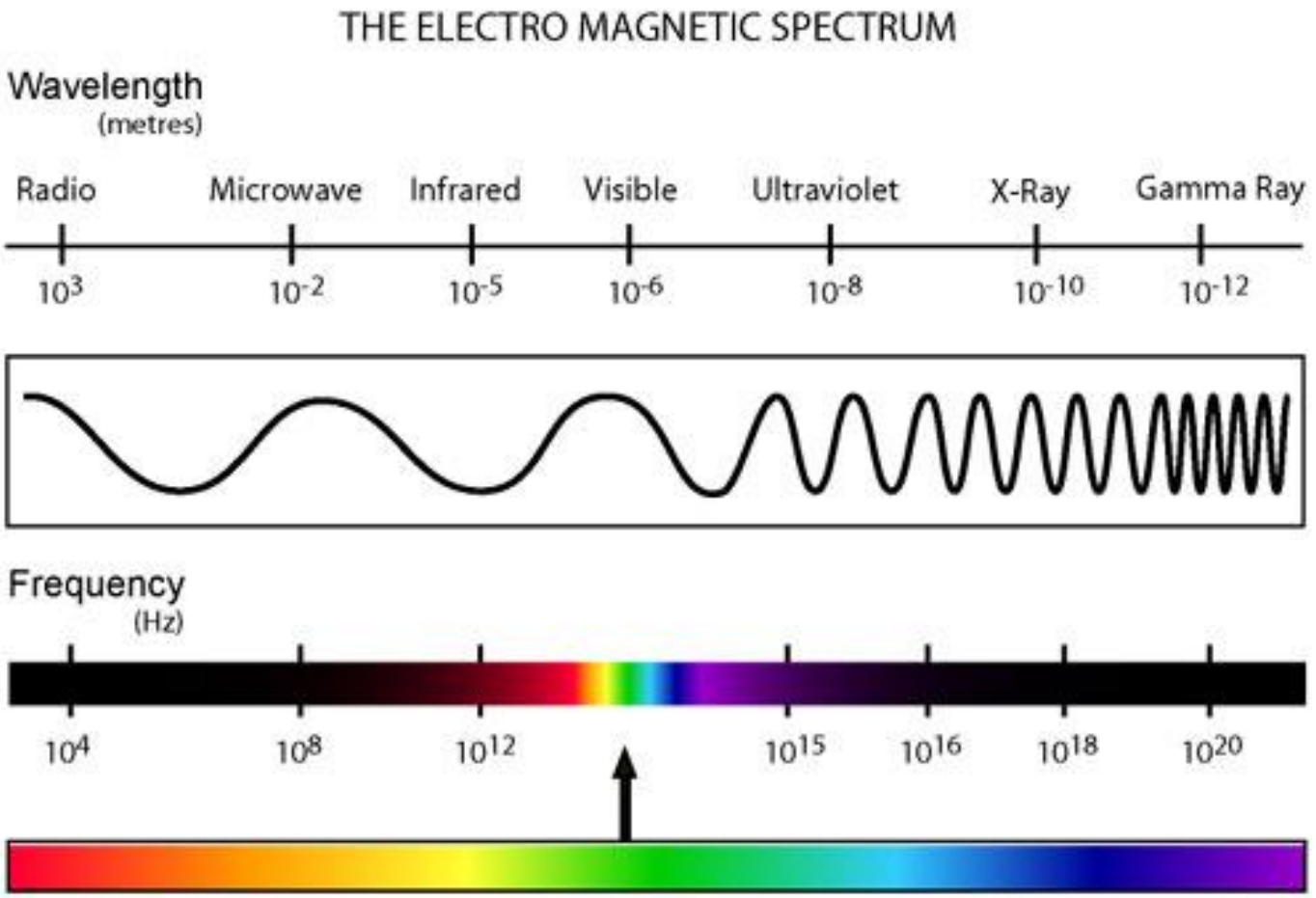
Radiation

- 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.

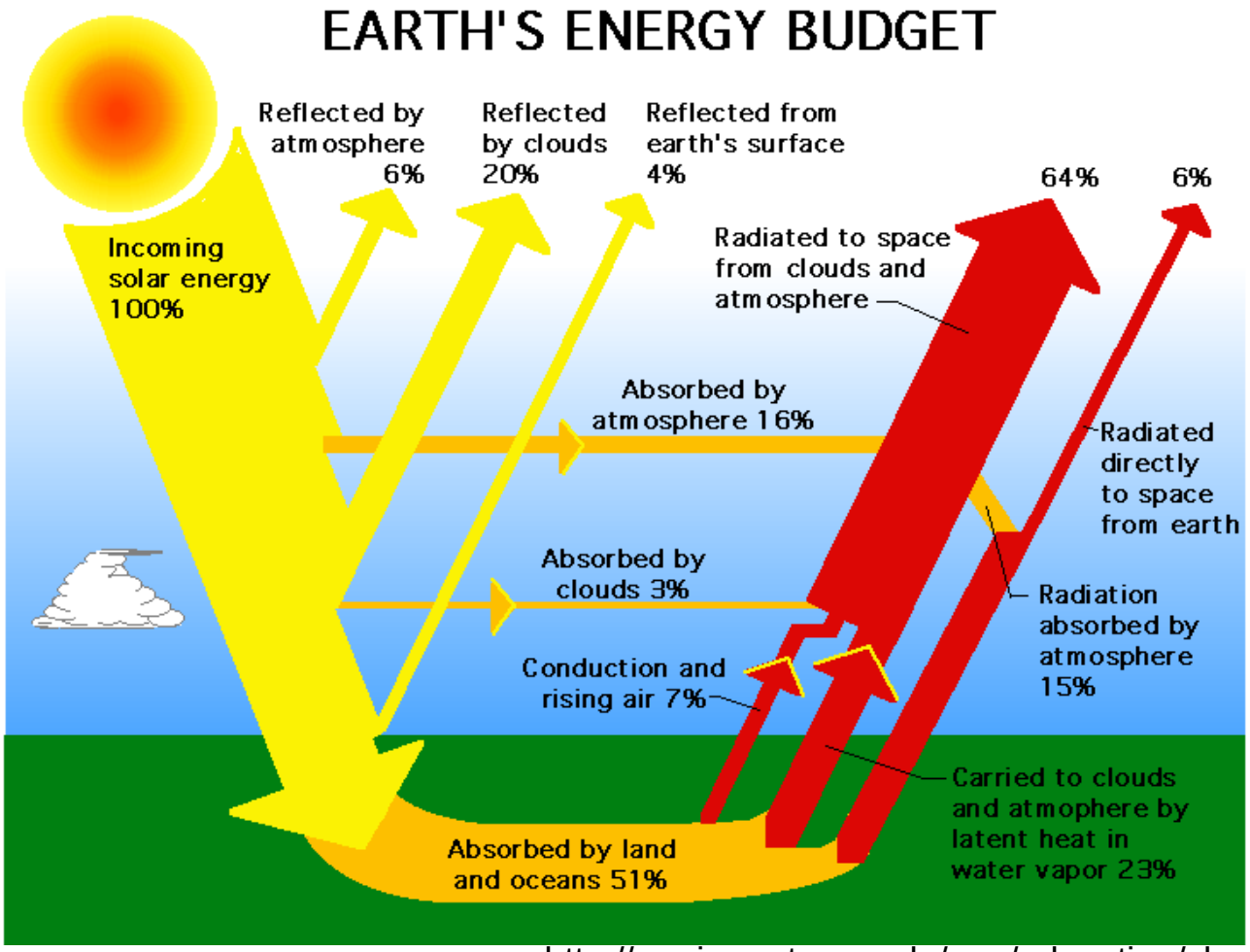
Energy and the Atmosphere

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:



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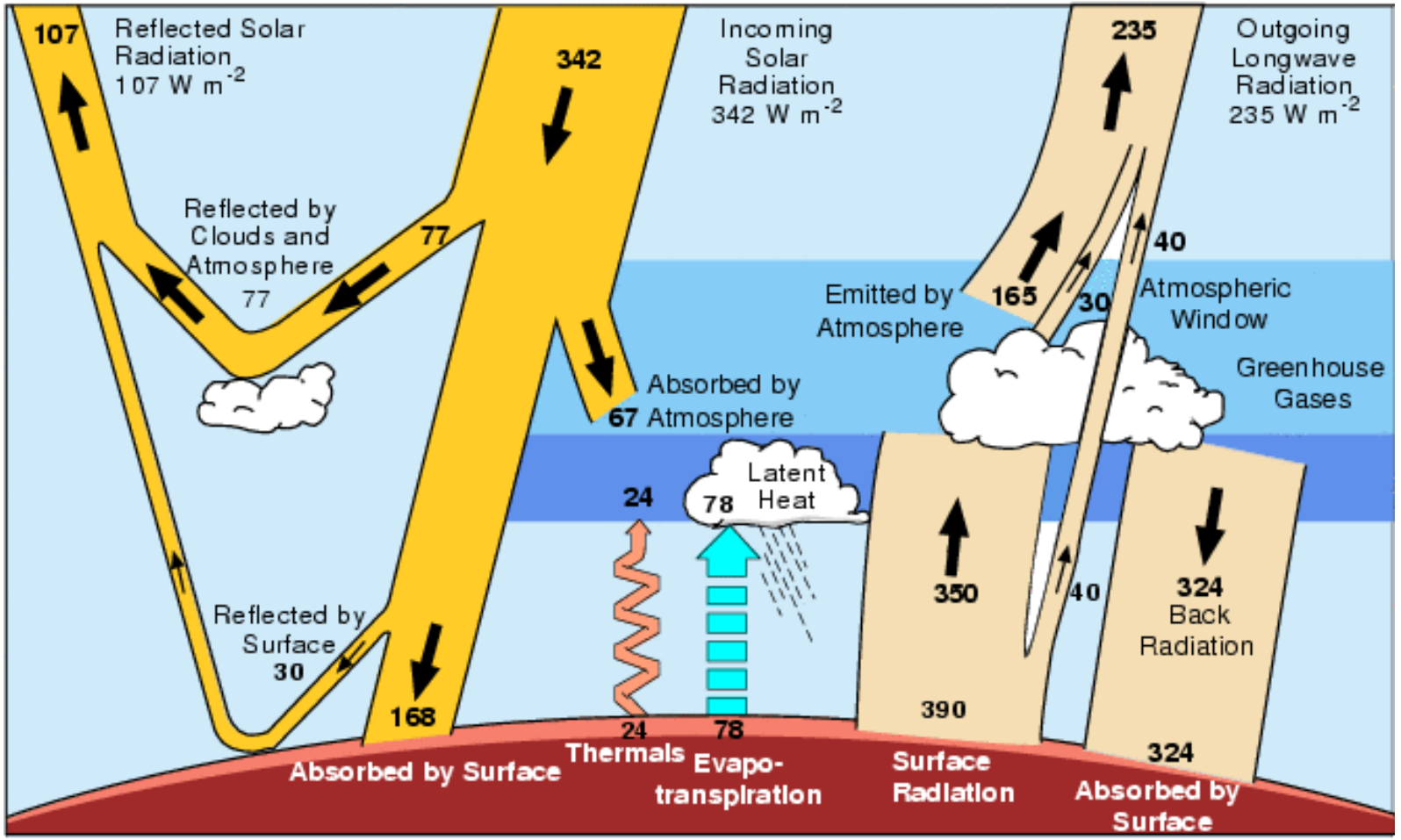
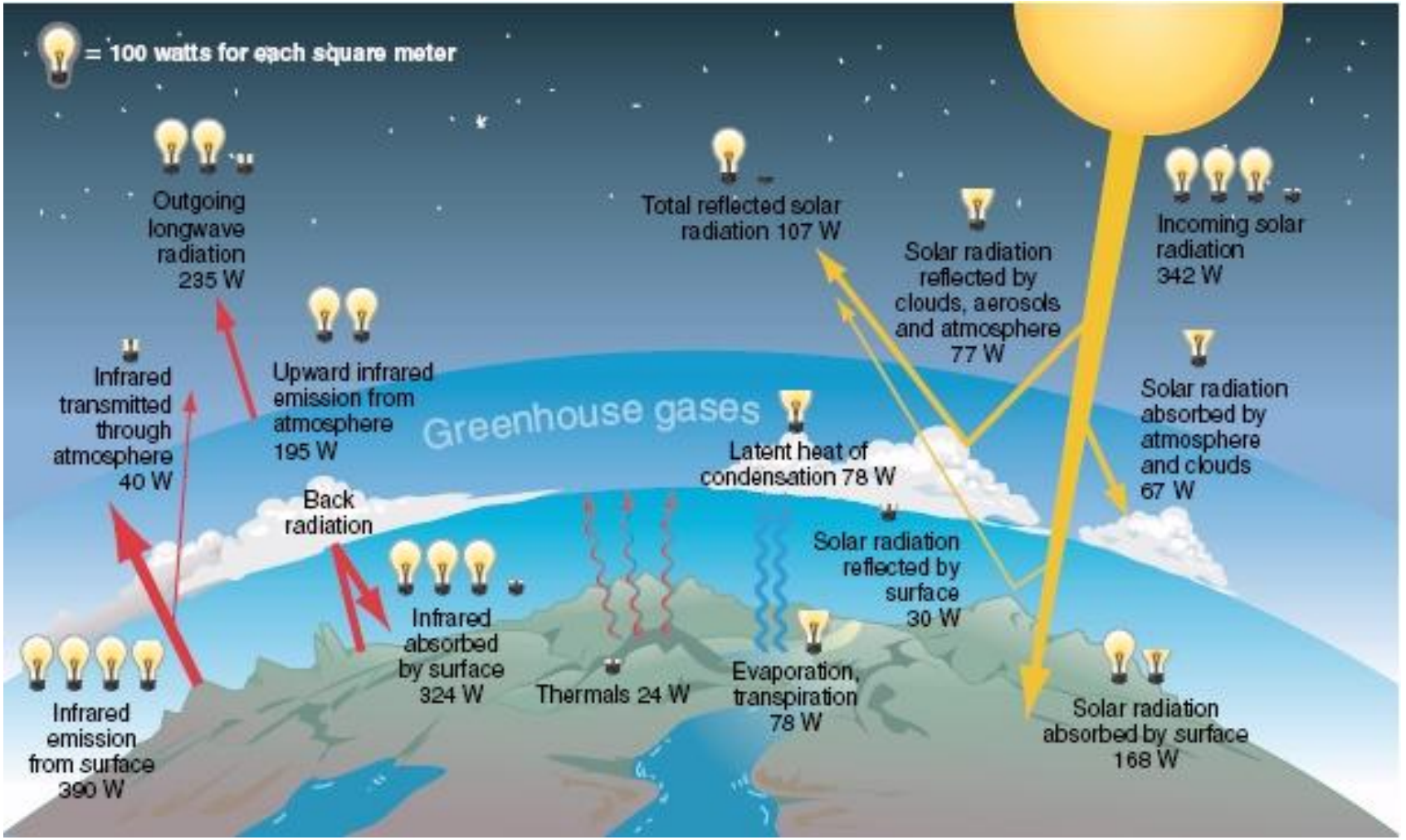
Global Heat Flows

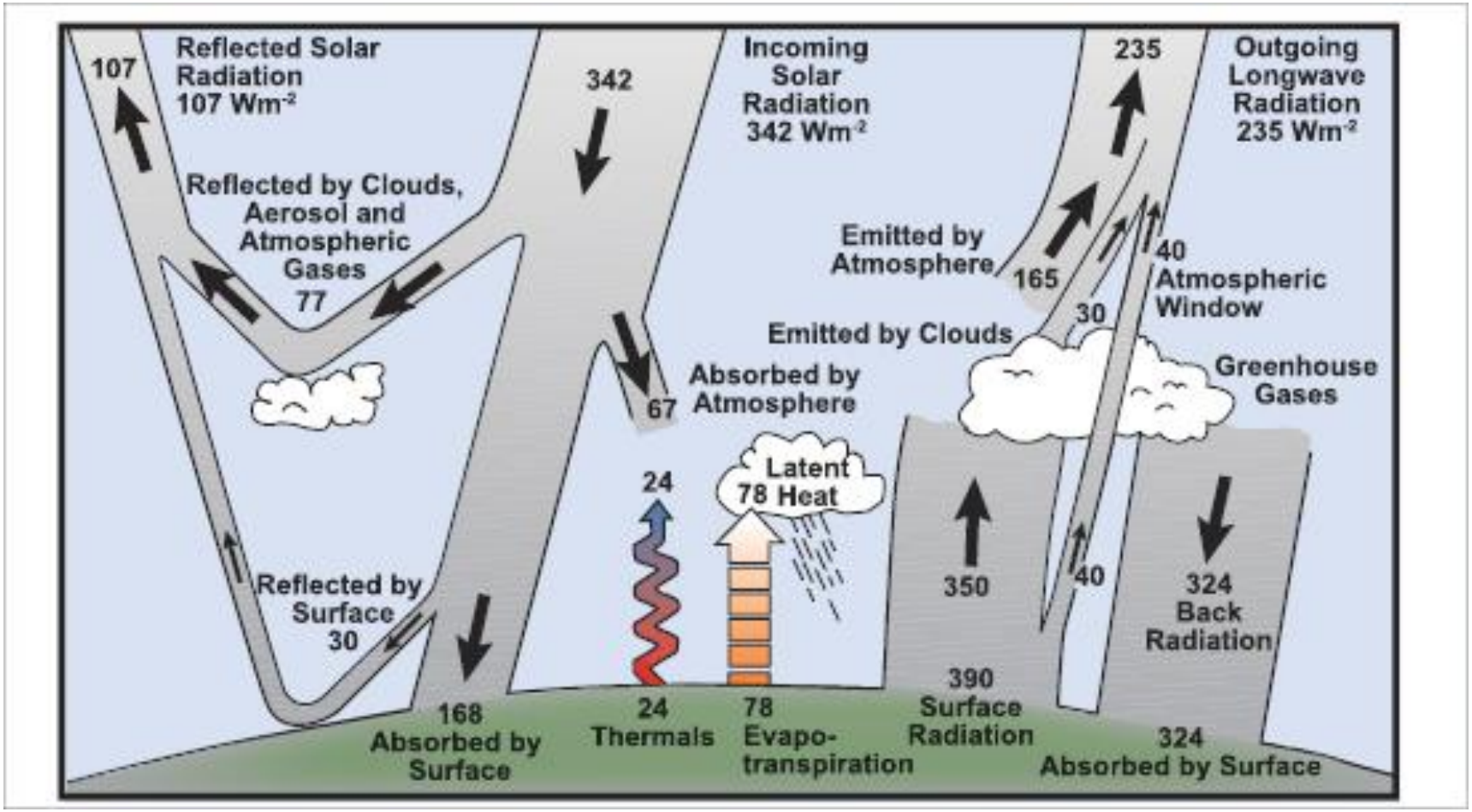


Kiehl and Trenberth 1997

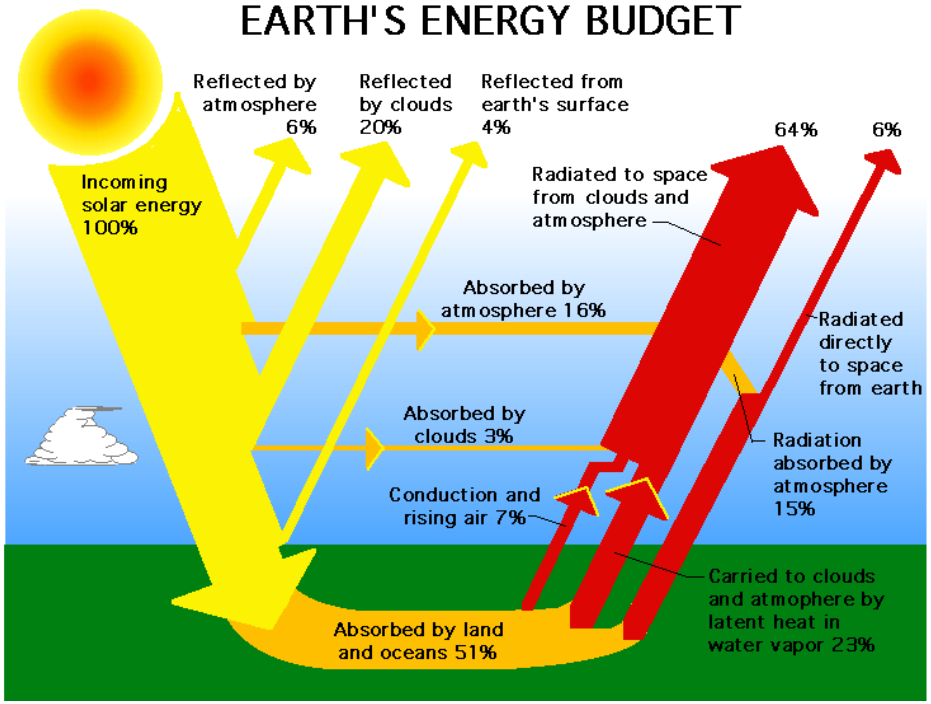
http://atoc.colorado.edu/~dcn/ATOC3600/images/earth_rad_budget_kiehl_trenberth_1997_big%5B1%5D.gif



http://cimss.ssec.wisc.edu/sage/meteorology/lesson1/images/EnergyBudget.jpg



http://www.ipcc.ch/publications_and_data/ar4/wg1/en/faq-1-1.html



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

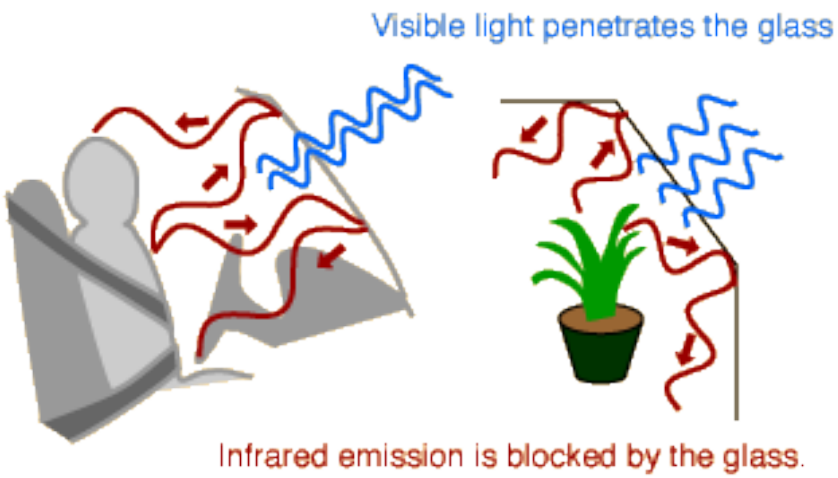
What's Absorbed is then Re-Radiated

- 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^{o} C/0^{o} F
- But gases in Earth's atmosphere—especially $H_2O_{(g)}$, CO_2, and CH_4—absorbs heat energy that makes our planet inhabitable
- These are called the "greenhouse gases"

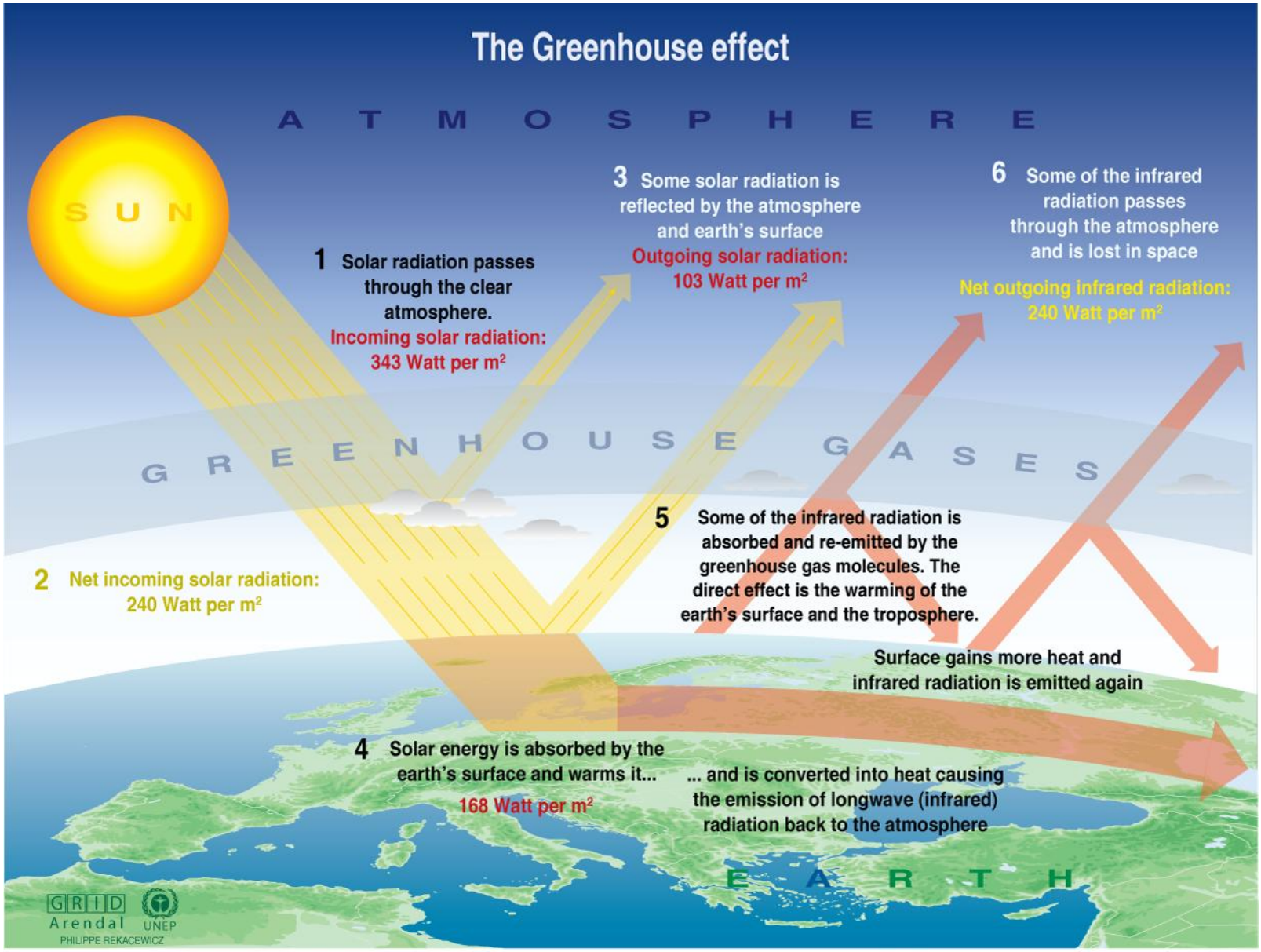
It’s like why your car gets hot in the summer



- 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— $H_2O_{(g)}$, CO_2, and CH_4— absorb much of this energy to warm up our planet's surface to an average of about 20^o
- Without this greenhouse warming, Life on Earth would not be possible
- The next slide shows this in more detail.



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, 1996.

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