ATM S 111: Global Warming
Solar Radiation

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Day 2: June 22 2010

Yesterday We Asked…

- What factors influence climate at a given place?
  - Sunshine (and latitude)
  - Topography/mountains
  - Proximity to oceans and large lakes
  - Ocean currents
  - Presence of trees/vegetation
  - Etc.
- But what are the main factors that control the global climate?
  - We'll study this next

Outline of This Lecture

Today:

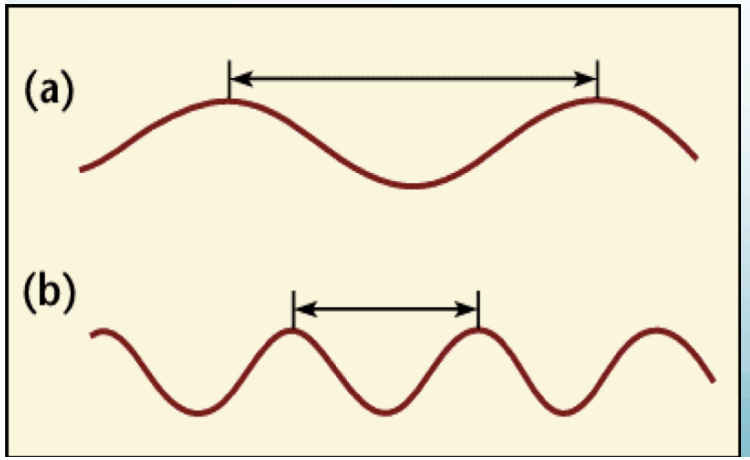
- How exactly **the Sun** heats the Earth
  - How strong?
  - Important concept of **"albedo"**: reflectivity

Tomorrow & Thursday:

- How the **greenhouse effect** works
  - How the Earth cools
  - And how greenhouse gases lead to *less cooling*
- What are the main greenhouse gases?
  - And which are changed by human activity?

How Does Energy Arrive From the Sun?

- Energy from the Sun is **"electromagnetic radiation"** or just **"radiation"** for short
  - Goes through space at the speed of light
  - Radiation is absorbed or reflected once it gets to Earth
- Radiation with **shorter wavelengths** are **more energetic**
  - And radiation is classified in terms of its wavelength

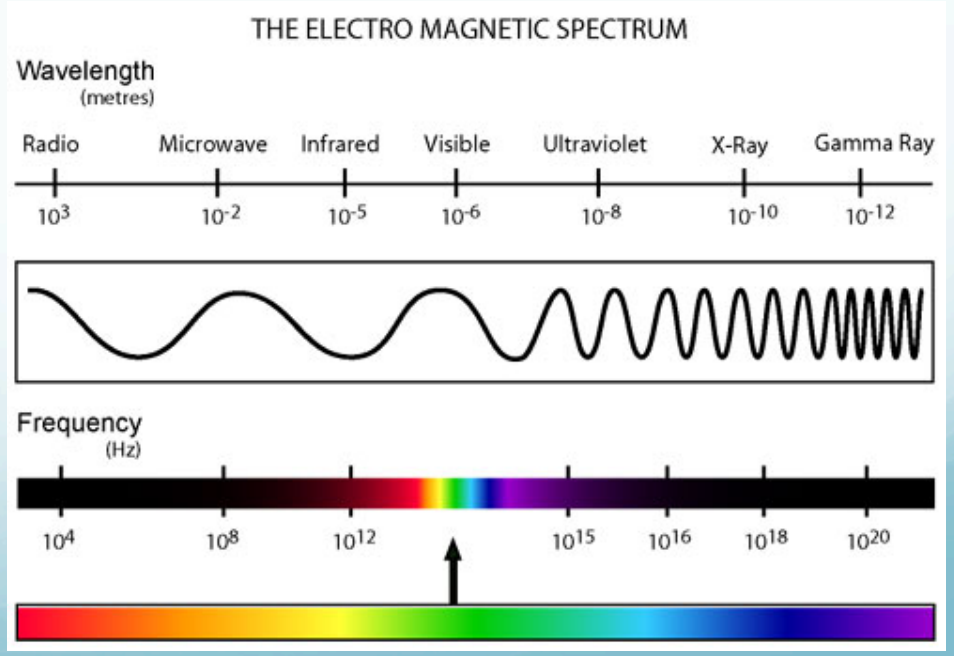


← This has long wavelength and low energy

← This has short wavelength and high energy

Types of Radiation

- Types of electromagnetic radiation, from most powerful to least powerful (or shortest wavelength to longest wavelength)
  - Gamma rays
  - X-rays
  - Ultraviolet (UV) radiation
  - Visible light
  - Infrared radiation
  - Microwaves
  - Radio waves



Sun's Radiation

- The Sun emits at all wavelengths, but primarily:
  - **Visible light** (of course)
  - Also "**near infrared**" radiation (infrared with very short wavelength)
  - A small (but dangerous) amount of ultraviolet radiation
    - This is what makes us sunburn
- These three bands together we call **"shortwave radiation"**

How Strong is the Sun?

- By the time it gets to the top of Earth's atmosphere, the Sun shines at a strength of **1366 Watts per square meter**

- **Watt** (abbreviated as **W**): unit of *power* or *energy per unit time*

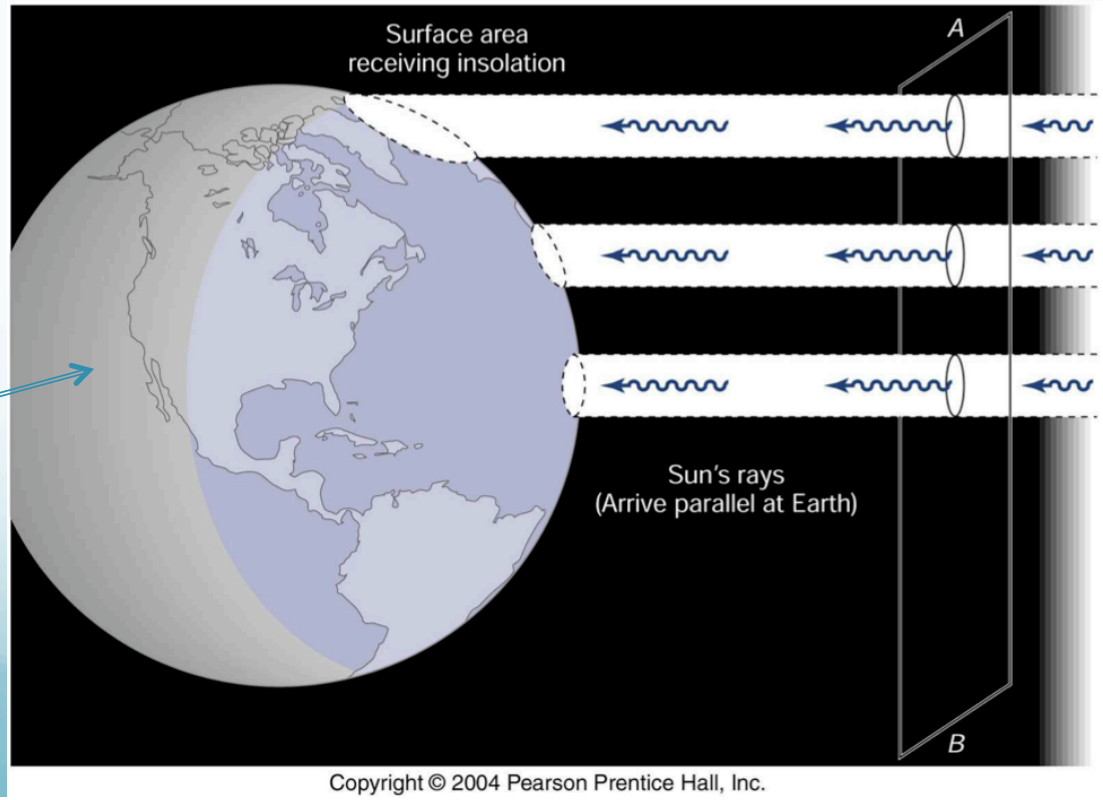
- 1366 W/m^2 is roughly what's experienced in the **tropics** when the sun is **directly overhead**

Average Solar Radiation

- The average incoming solar radiation is not 1366 W/m^2 though
  - It's only 342 W/m^2 (exactly ¼ of this). Why?

Half the planet is dark at all times...

Here it's nighttime



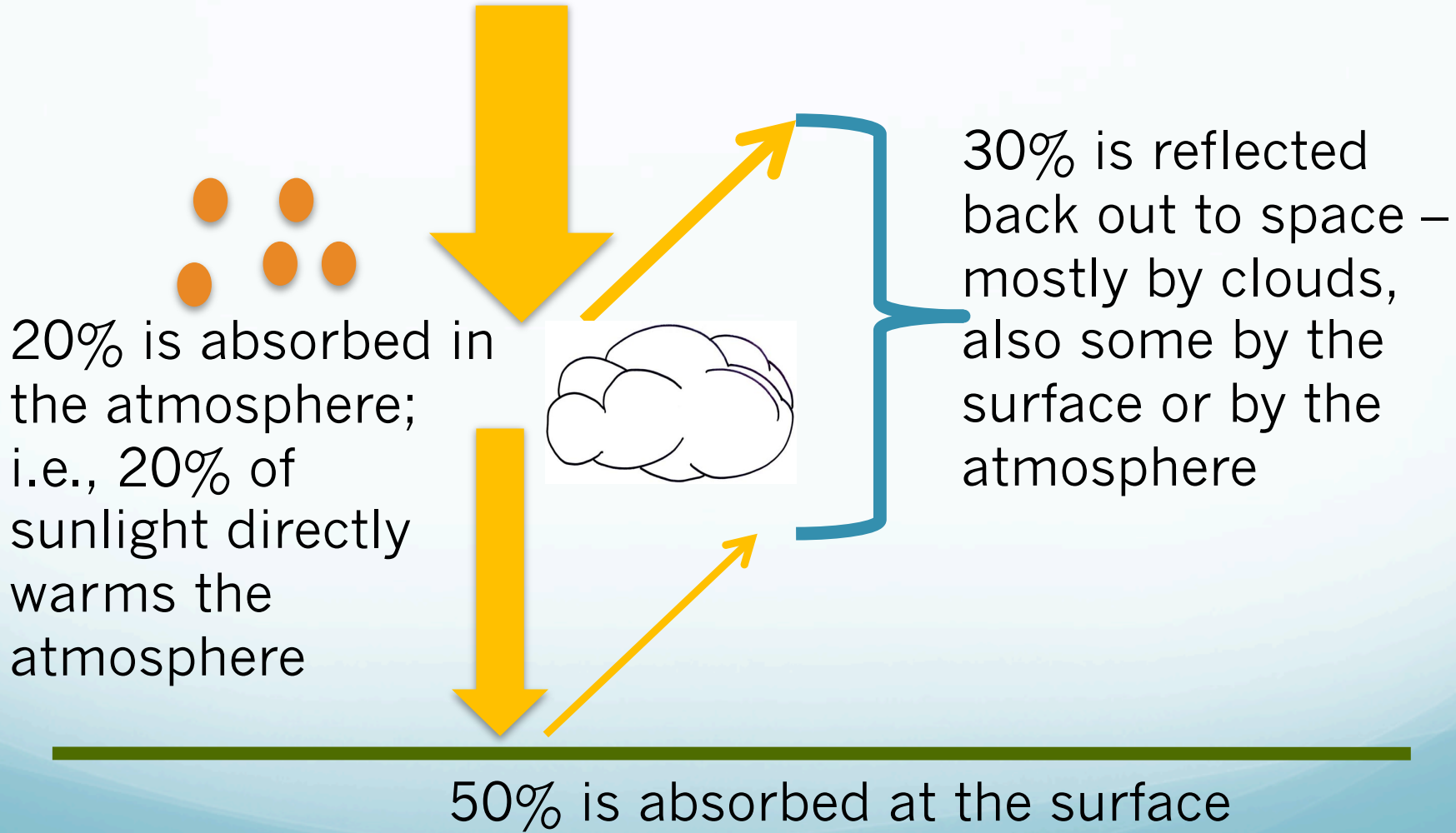
High latitudes get **less direct radiation**, which spreads out more

Reason for seasons: Winter is tilted away from the Sun, gets less direct light, and thus is colder

Radiation and Matter

- When light or radiation of any wavelength is intercepted by matter (solid, liquid or gas), the following can happen:
  - A) **Scattering or Reflection**: The light changes direction because of electromagnetic forces from the protons & electrons. (For this class, you can think of the light as bouncing off the substance.)
  - B) **Absorption**: The light gives its energy to the substance that absorbed it, often increasing its temperature.
  - C) **Transmission**: The light passes directly through the substance with no change in energy or direction.

Solar Radiation on Earth



Key Concept for Climate: **Albedo**

- Albedo: fraction of incident light that's reflected away
  - Albedo ranges from 0 to 1:
    - 0 = no reflection
    - 1 = all reflection
  - Things that are **white** tend to **reflect** more (high albedo)
  - **Darker** things **absorb** more radiation (low albedo)

(Actually the cause-effect is the other way around – things that reflect more look white to us because more light is hitting our eyes! Things that absorb more look dark because our eyes are receiving less light.)

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Pop Quiz! (Not really.) Rank these from highest to lowest albedo: fresh snow, fresh asphalt, grassland.

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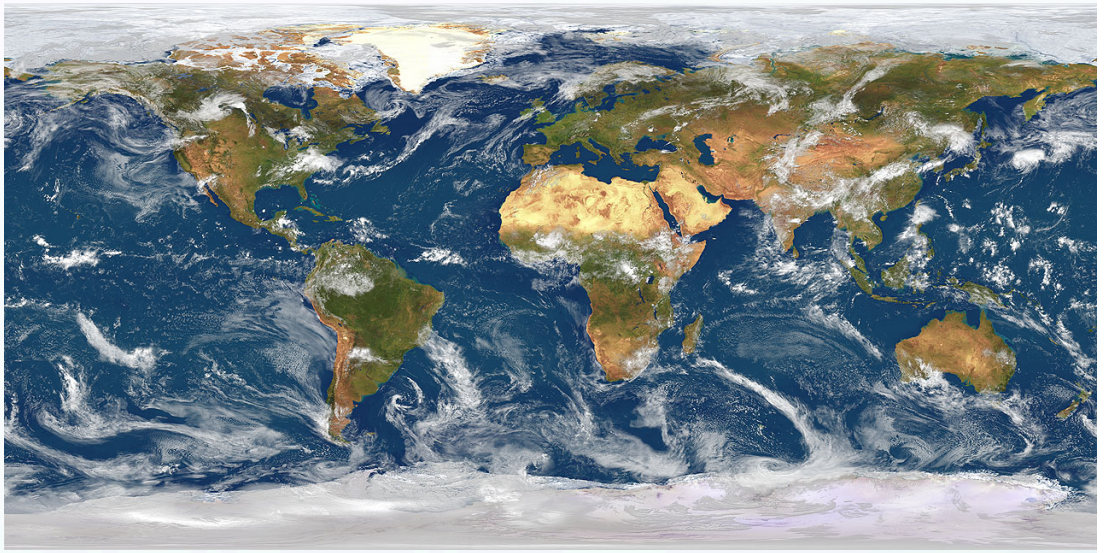
Pop Quiz! (Not really.) Rank these from highest to lowest albedo: fresh snow, fresh asphalt, grassland.
Answer: Snow, grassland, fresh asphalt.
So, what effect might building a city have on how much sunlight is absorbed in an area? This is the "urban heat island" effect.

Albedo Values for Earth

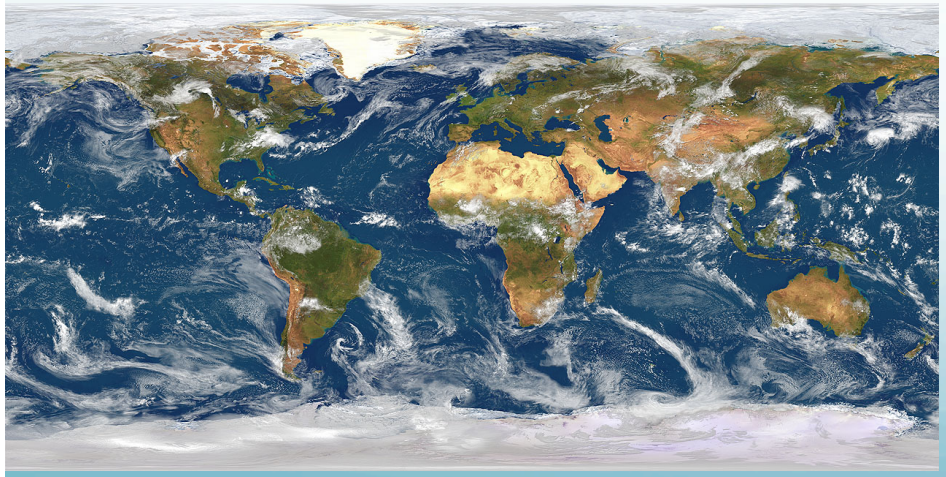
- Clouds, ice, and snow have high albedo
  - **Cloud** albedo varies from **0.2** to **0.7**
  - Thicker clouds have higher albedo (reflect more)
  - **Snow** has albedo ranging from **0.4** to **0.9** (depending on how old the snow is) and ice is approximately 0.4

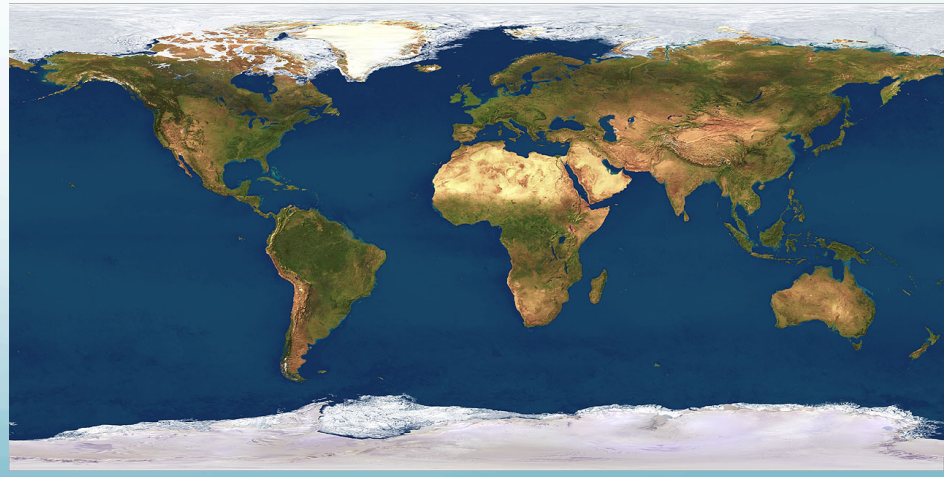


- Ocean is very dark (< 0.1), as are forests (0.15)
- Desert has albedo of 0.3

Relative Contributions to Earth Albedo

- Remember we said 30% of incoming solar radiation is reflected away?
  - 20% is from clouds
  - 5% is by the surface
  - 5% is by the atmosphere (things like dust from deserts and air pollution are key players here)





Total Solar Input

- Total **absorbed solar radiation** is 70% of the incoming solar radiation
  - Because 30% is reflected away
  - 70% of 341 W/m^2 = **240 W/m^2**

Summary So Far

- The Sun heats the Earth
  - Some is reflected back, a bit is absorbed in the atmosphere
  - But other than that, the atmosphere is pretty much transparent when it comes to solar radiation (half is absorbed right at the surface)
  - Clouds and snow/ice are primary contributors to the albedo of Earth
- Tomorrow & Thursday: how energy escapes from Earth and the greenhouse effect