

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:

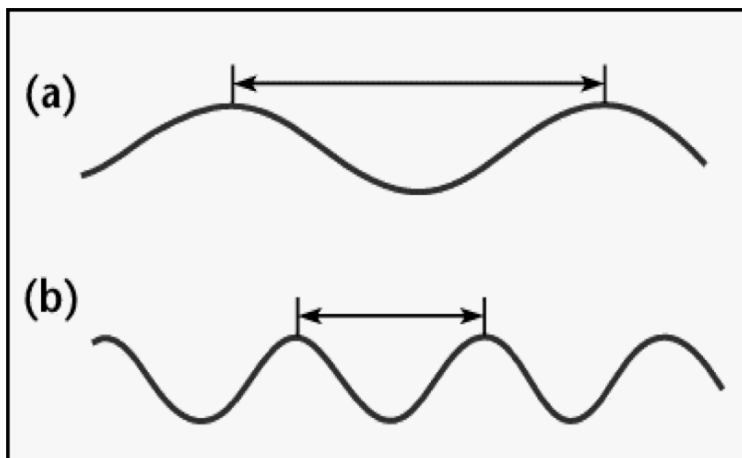
- How exactly **the Sun** heats the Earth
 - How strong?
 - Important concept of “**albedo**”: reflectivity

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’s surface
- Radiation with **shorter wavelengths** is **more energetic**
 - And radiation is classified in terms of its wavelength

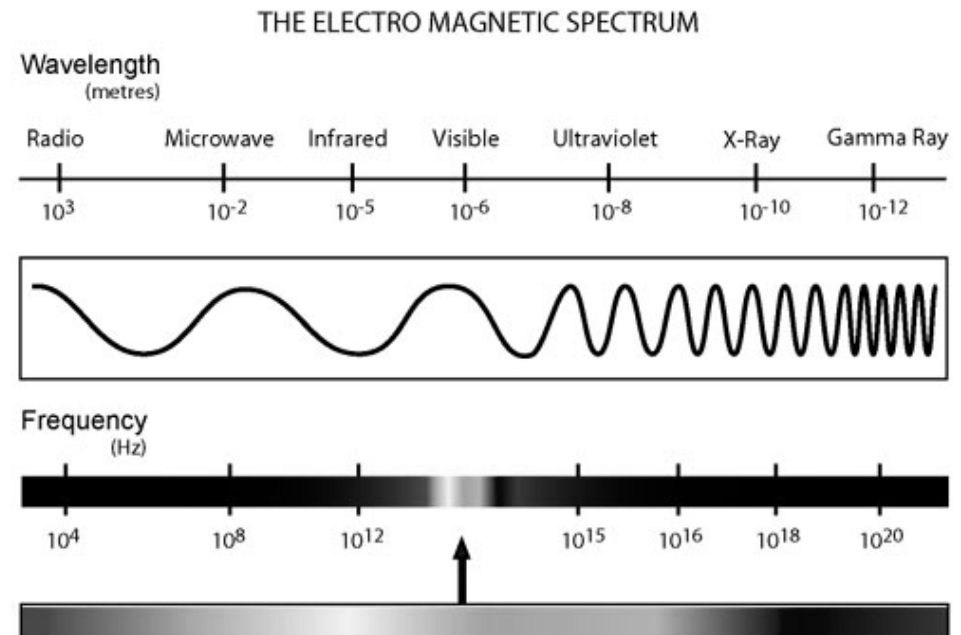


← This has long wavelength and low energy

← 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
 - Most UV, especially the most dangerous, is absorbed by ozone high in the atmosphere
- These three bands together we call “**shortwave radiation**”

How Strong is the Sun?

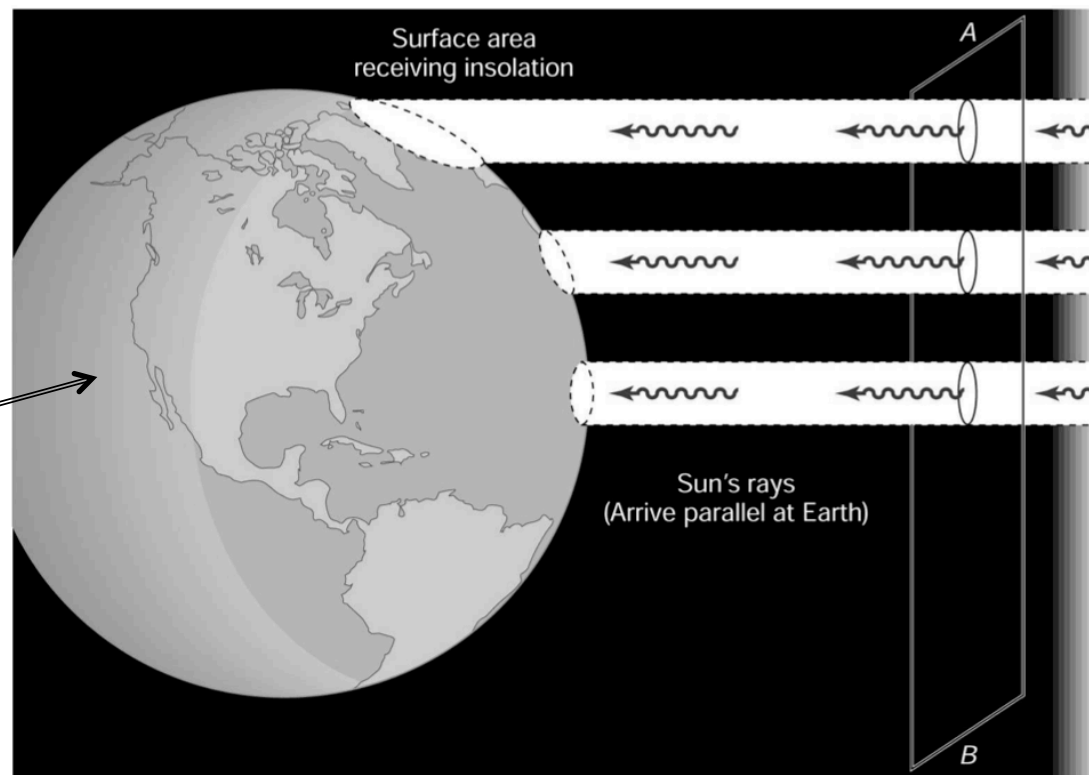
- By the time it gets to the top of Earth's atmosphere, the Sun shines at a strength of **1366 Watts per square meter**
- **Watt** (abbreviated as **W**): unit of *power* or *energy per unit time*
- 1366 W/m² is roughly what's experienced in the **tropics** when the sun is **directly overhead**

Average Solar Radiation

- The average incoming solar radiation is not 1366 W/m² though
 - It's only 342 W/m² (exactly 1/4 of this). Why?

Half the planet is dark at all times...

Here it's nighttime

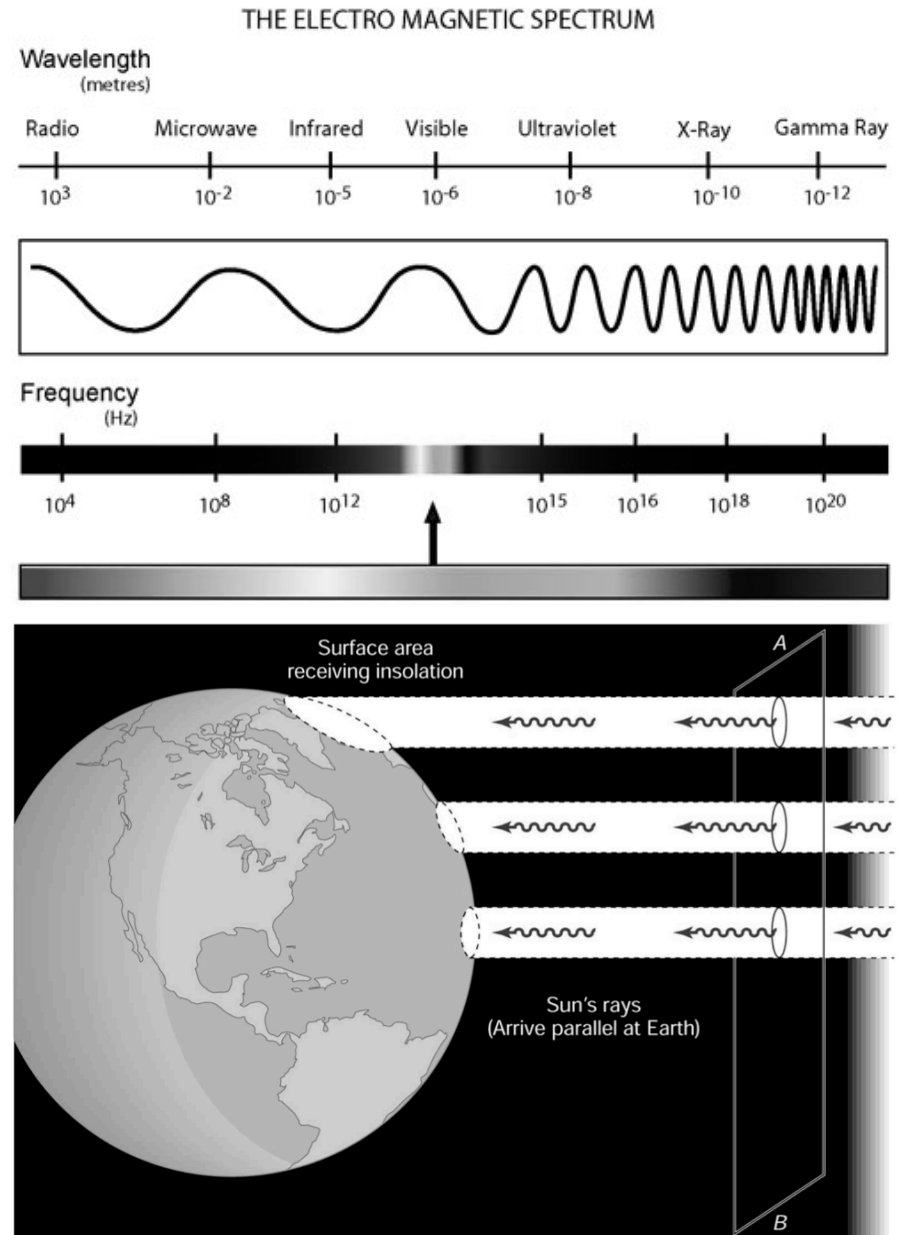


High latitudes get **less direct radiation**, which spreads out more

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

Last time

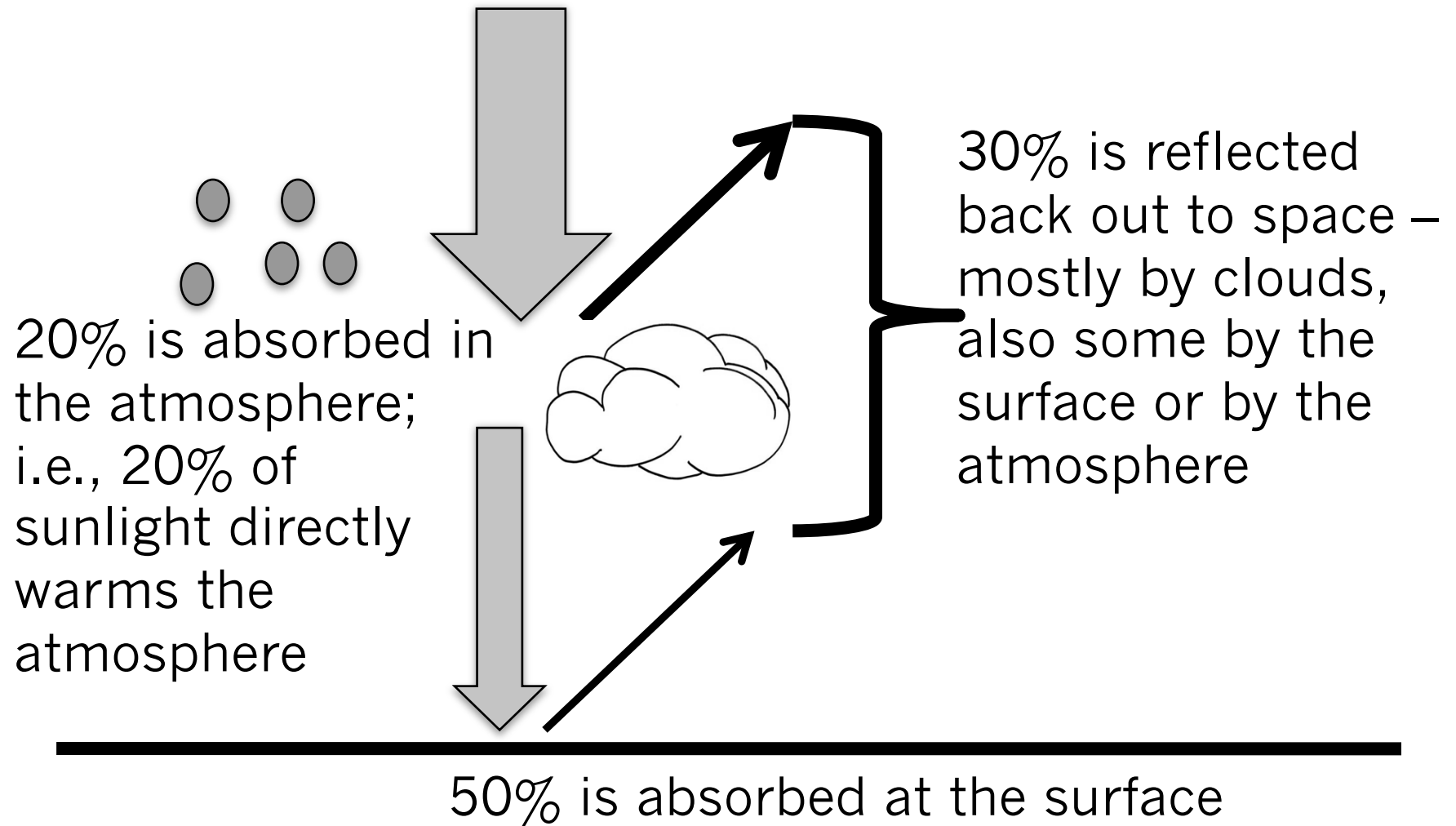
- Earth gets most of its energy from the sun.
- Solar radiation is mostly in visible, near infrared, and near UV wavelengths (shortwave)
- Earth's curvature reduces the intensity of sunlight closer to the North & South Poles
- Earth's tilt affects how intense the sunlight is as Earth revolves around the sun, causing seasons.



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 in the matter. (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 from them.)

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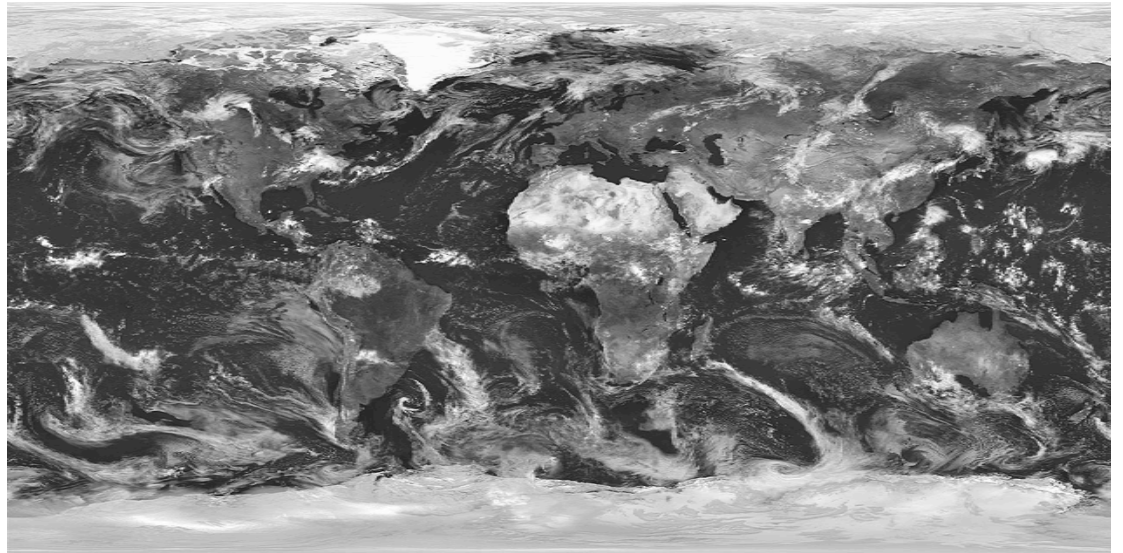
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Answer: Snow, grassland, fresh asphalt.

So, what effect might building a city have on how much sunlight is absorbed in an area? This is the “urban heat island” effect.

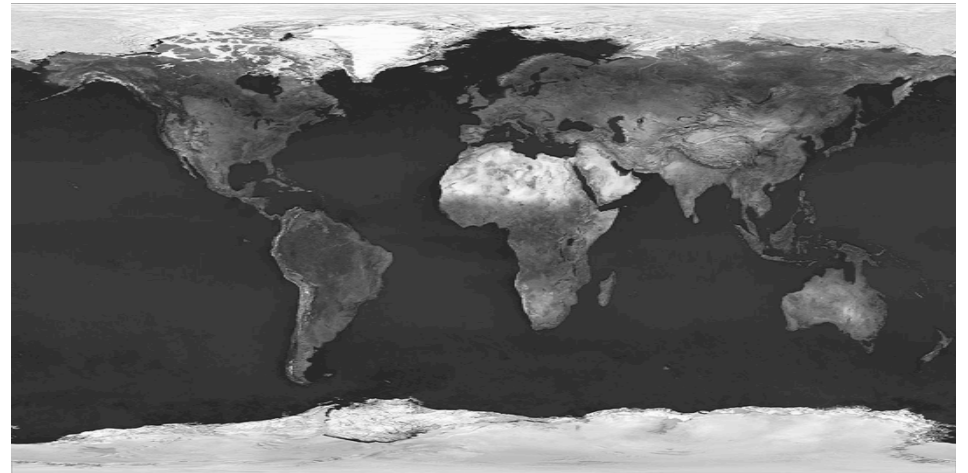
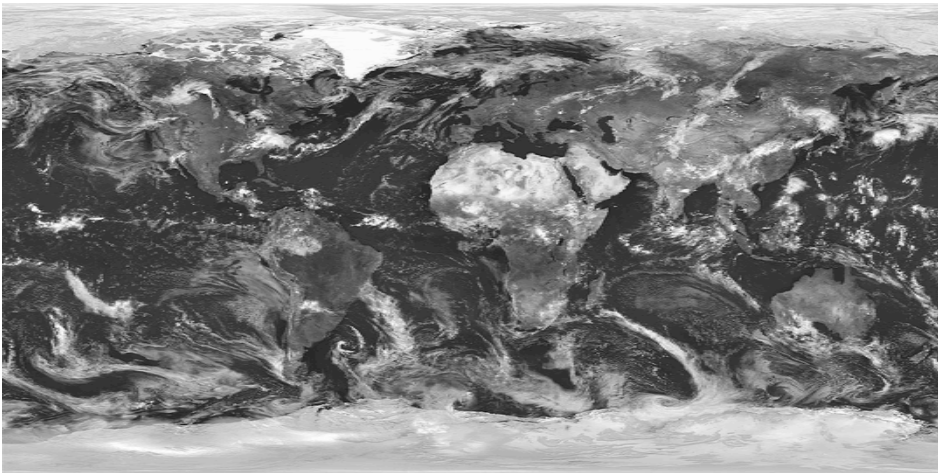
Albedo Values for Earth

- 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 $341 \text{ W/m}^2 = \mathbf{240 \text{ W/m}^2}$

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