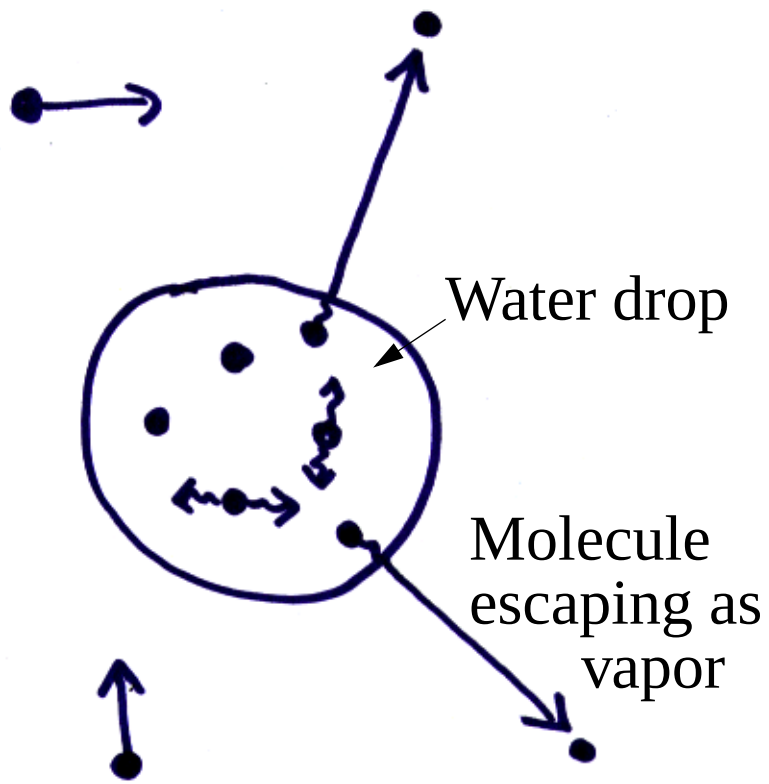
Lecture 3

Latent Heat

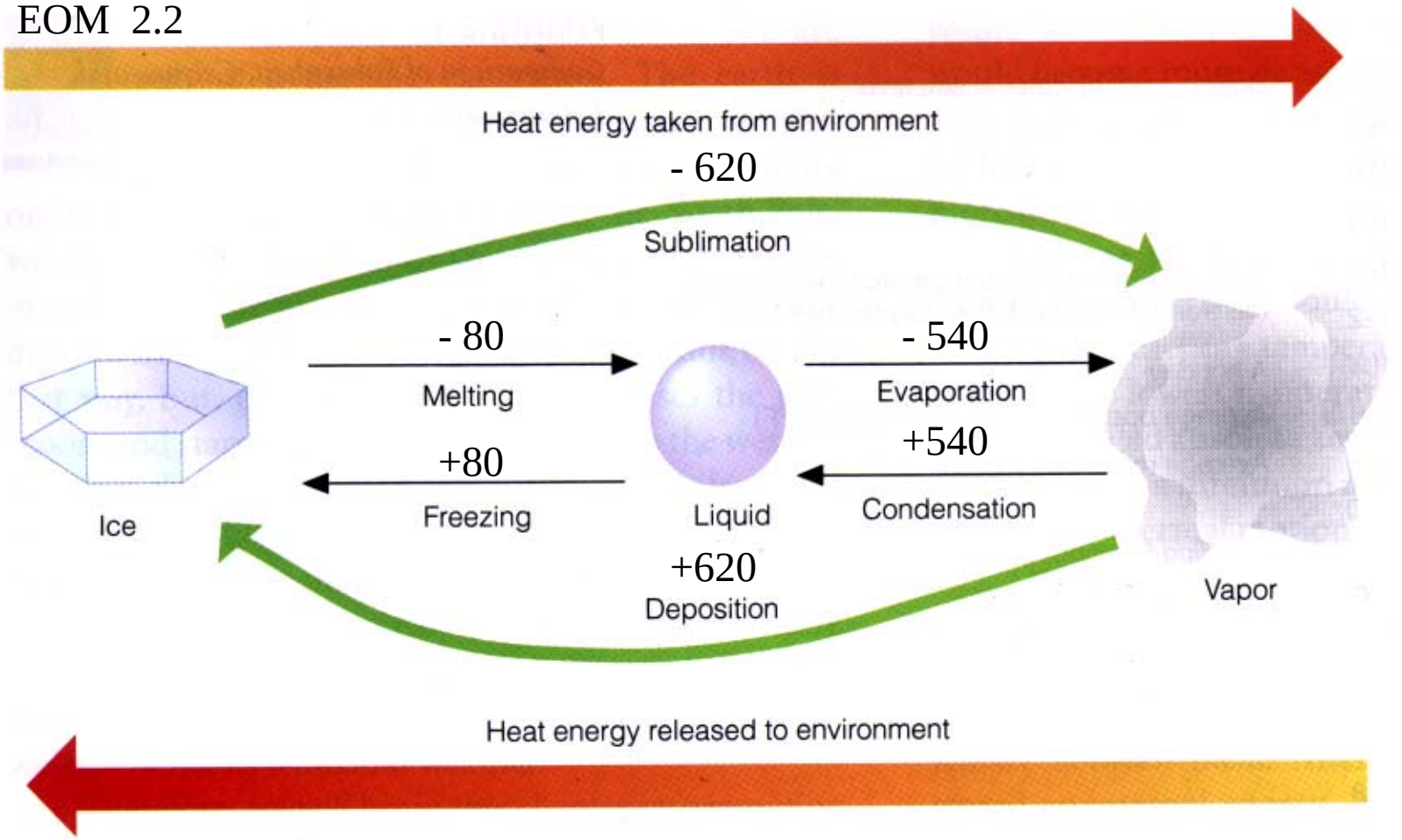
'Latent' heat is needed to convert from a more ordered to a less ordered phase (e. g. ice melting into liquid water, or liquid evaporating to vapor) and is released when the vapor condenses or liquid freezes.

- Why does evaporation cool liquid water?
- A water drop evaporates as the most rapidly jiggling molecules near its surface break free of their attraction to the other water molecules.
- The less jiggly molecules are left behind, so the temperature of the water drop decreases.



Latent Heat of Phase Changes of Water

EOM 2.2



- 1 calorie heats 1 g liquid water by 1 C. It takes 540 cal to evaporate the liquid, enough to bring the water from freezing to boiling five times over! This latent heat is released when the water vapor condenses again.

The Three Modes of Heat Transfer

Boiling water shows how heat travels

Conduction

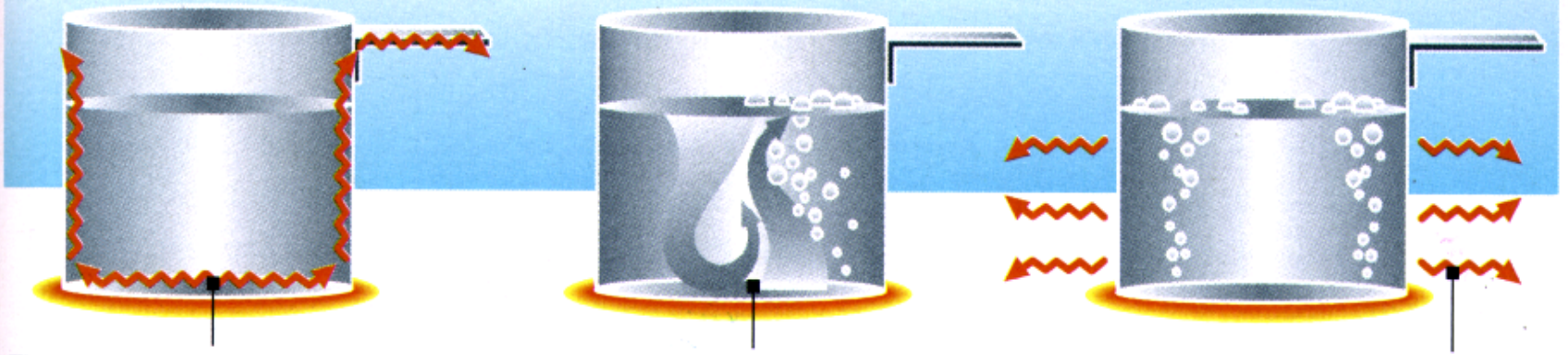
The transfer of heat by the collisions of molecules. Metal conducts heat very well. Air and other insulators are poor heat conductors.

Convection

The transfer of heat by actual movement of the heated material. Meteorologists usually use "convection" to refer to up and down motions of air. They use "advection" to describe the horizontal movement.

Radiation

The transfer of heat by wave motion. Heat, light and other kinds of waves radiate through the near vacuum of outer space from the sun to the Earth.



The stove's heat causes molecules in the pan's bottom to vibrate faster making it hotter. These vibrating molecules collide with their neighboring molecules, making them vibrate faster too. After a while, molecules in the pan's handle are vibrating so fast it's too hot to touch.

As water in the bottom of the pan heats up, some of it vaporizes making bubbles. The bubbles rise because they're lighter than the surrounding water. Water sinks from the top to replace the rising bubbles. This up and down movement eventually heats all the water.

Even though air conducts very little heat, you can feel the heat coming from the hot stove and the pan. It's radiating through the air.

(*The Weather Book*, p. 19)

Comments on Conduction

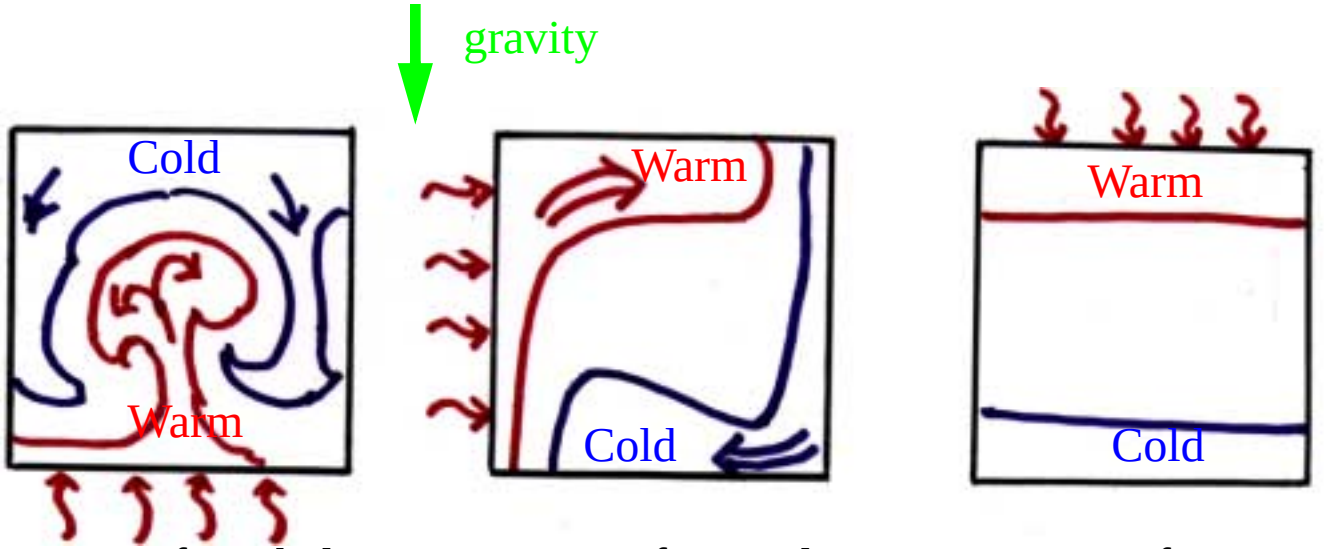
- Causes most heat transfer in solids
- *Conductivity*: Rate of heat transfer across a 1 cm thick slice of material if one side is maintained 1 C warmer than the other

Material	Heat Conductivity (cal s^{-1} cm^{-1} C^{-1})
Silver	1
Granite (rock)	0.006
Wet soil, ice	0.005
Still water, dense snow	0.0015
Dry soil	0.0006
Still air	0.00006

(from EOM Table 2.1)

Comments on Convection

- Convection (‘Hot air rises and cold air sinks’)only occurs in fluids (liquids, gases), and only because of Earth’s gravity.
- *Buoyant* (warmer, less dense) blobs of air are called *thermals*, much loved by birds and gliders.
- Convection does not occur if the most buoyant air is already on top.



Heating from below
⇒ convection

Heating from side
⇒ convection

Heating from top
⇒ no convection

Comments on Radiation

- *Every* object loses heat by radiation in the form of electromagnetic waves.
- Hotter objects radiate a lot more energy per unit of surface area and at shorter wavelengths.
- A cooling campfire:

  White hot $\rightarrow$ Red hot $\rightarrow$ Dull Red $\rightarrow$ Black

  (infrared)

- Ultimately, radiation from the sun provides the heat energy that creates air motions and weather (and permit life!)

Shortwave and Longwave Radiation

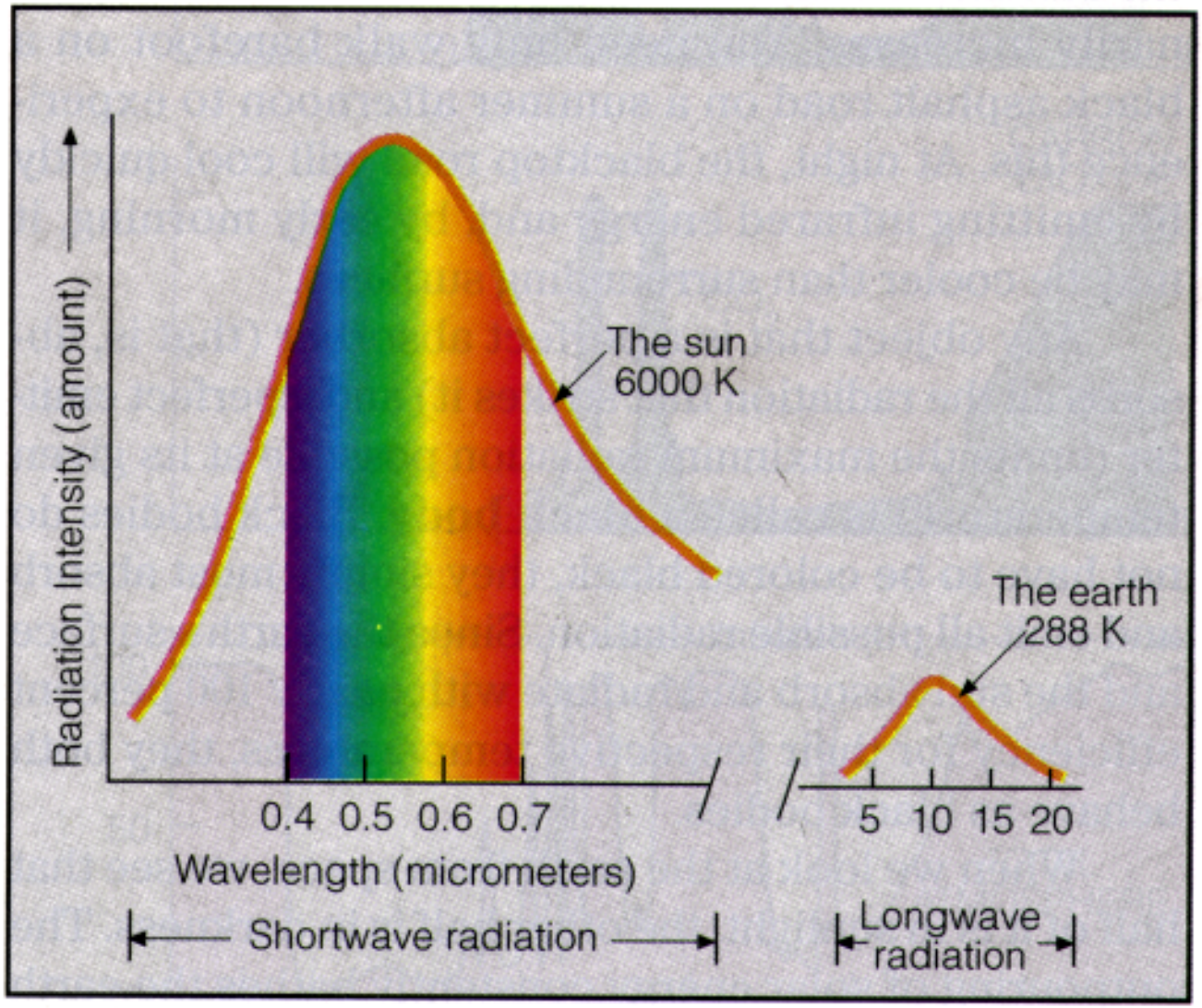
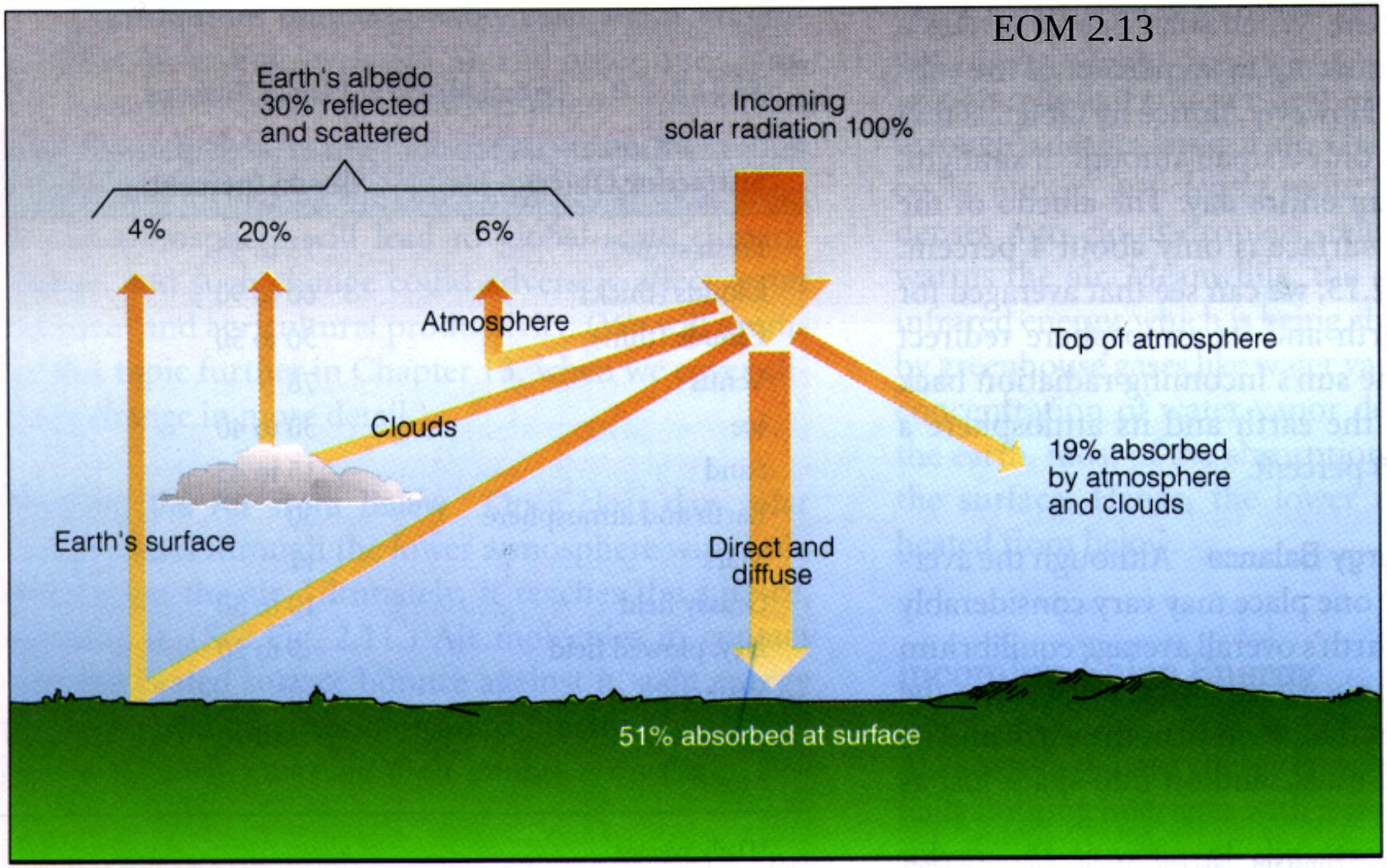


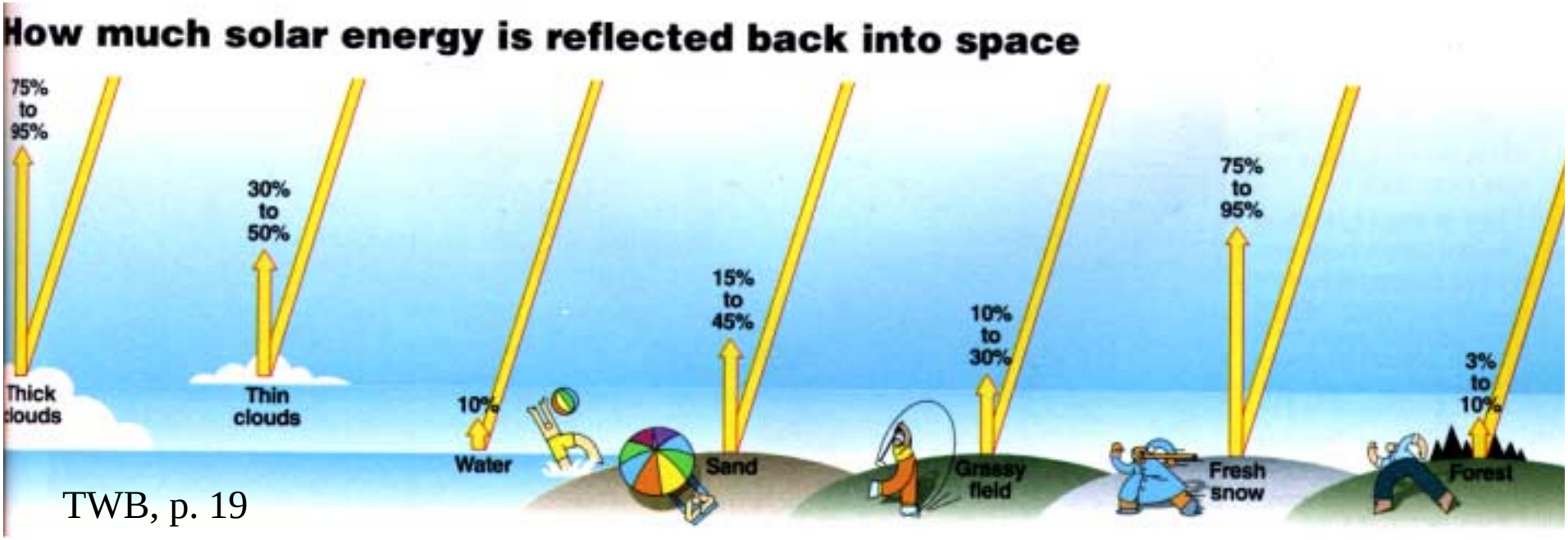
Figure 2.7
The hotter sun not only radiates more energy than the cooler earth, but it also radiates the majority of its energy at much shorter wavelengths.

The fate of incoming sunlight



- Of incoming sunlight, 50% is absorbed at surface, 20% is absorbed in the atmosphere, 30% is reflected (mainly by clouds).

Albedo



TWB, p. 19

- Albedo = Fraction of solar radiation hitting an object that is reflected.

  The remainder is absorbed (e. g. at water or land surface) or transmitted (e. g. through a cloud).

Radiative Energy Balance

- Globally, net incoming solar balances outgoing IR
- Air motions and ocean currents transfer energy poleward, keeping poles warmer, tropics cooler. To balance, the equator gains radiative energy and the poles lose it.

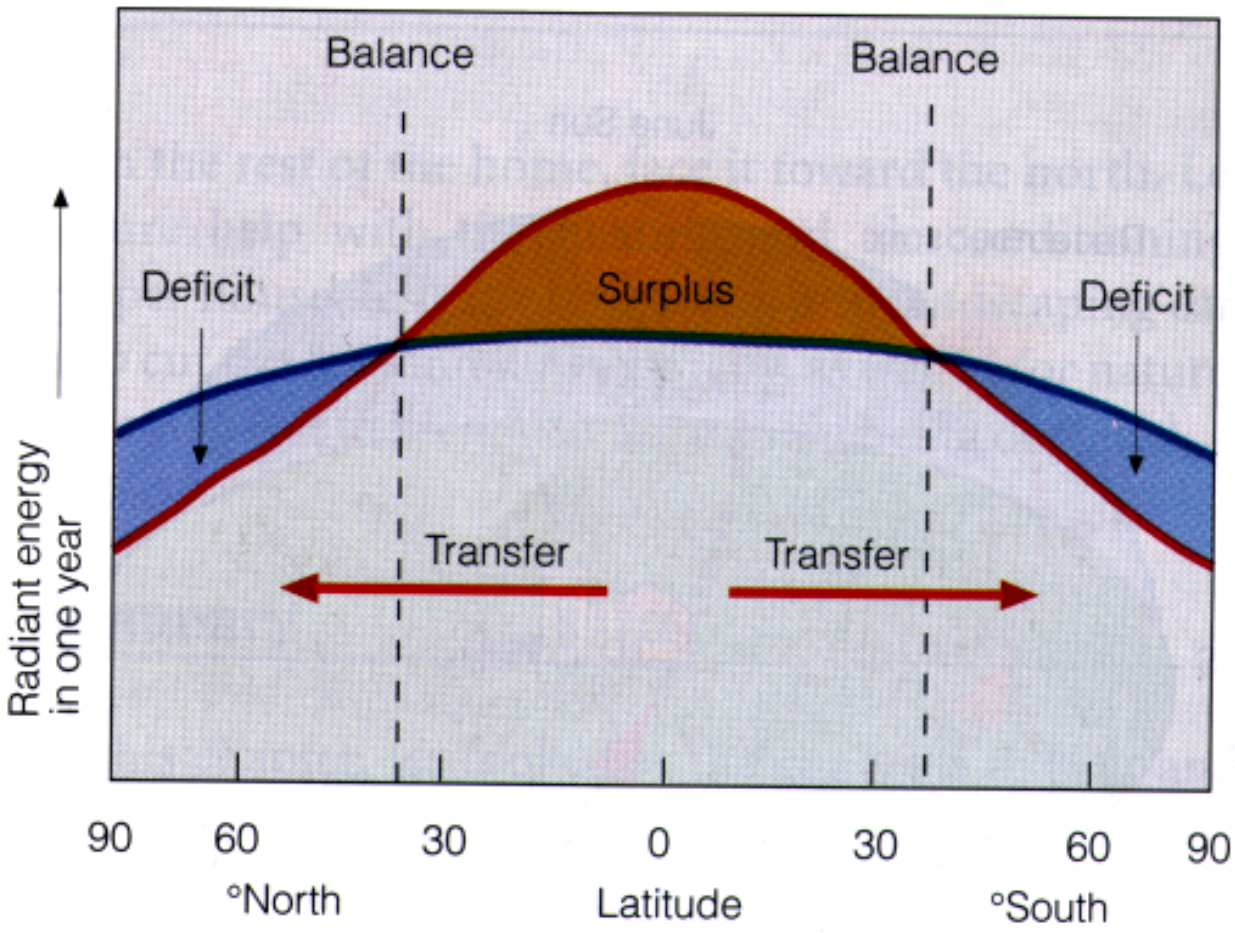


FIGURE 2.21 (EOM)
The average annual incoming solar energy (red line) absorbed by the earth and the atmosphere, along with the average annual outgoing energy (blue line) emitted by the earth and the atmosphere.

Why winds, storm, weather?