ATM 10 Severe and Unusual Weather

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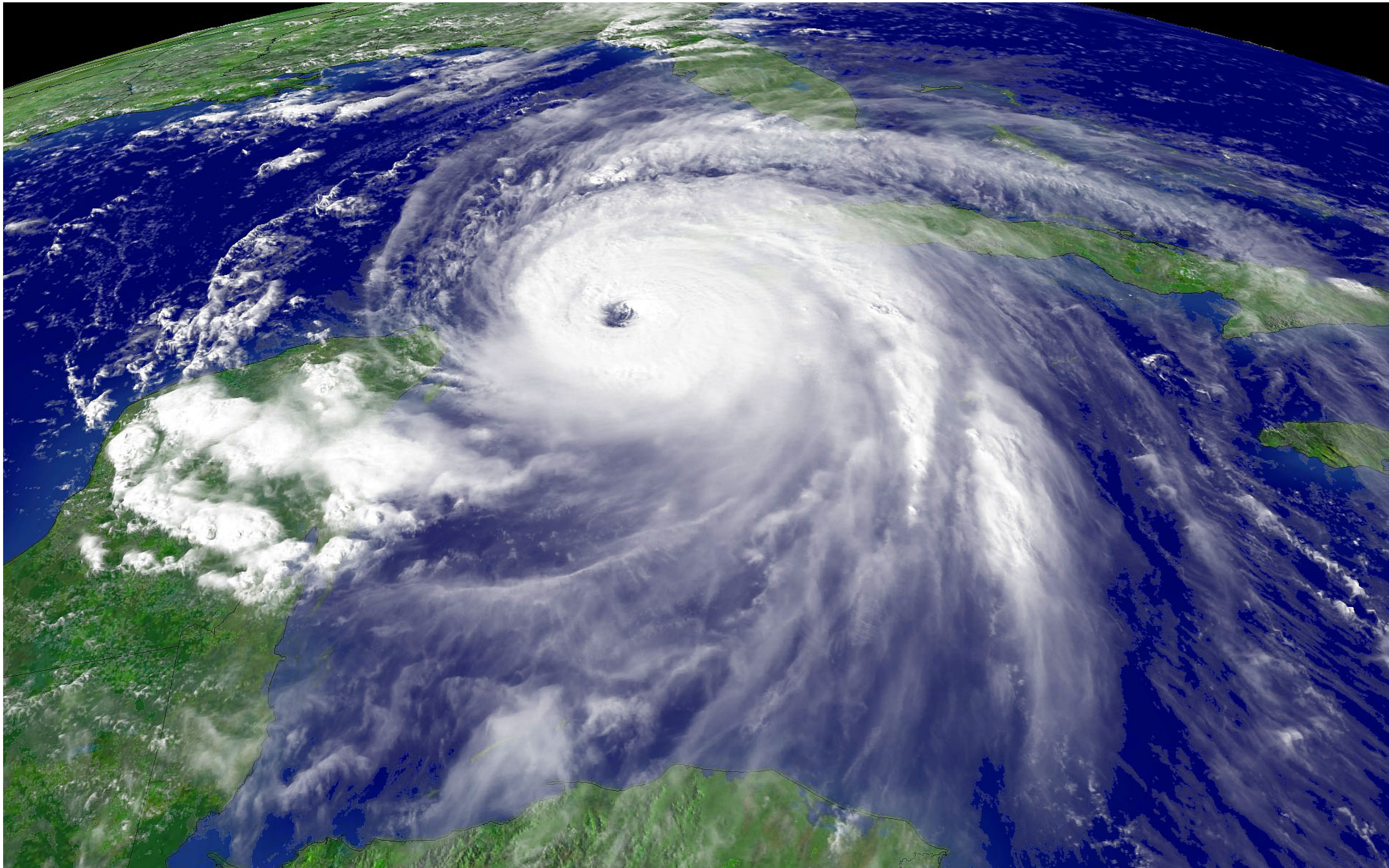
http://atm.ucdavis.edu/~grotjahn/course/atm10/index.html



Lecture topics:

- Units
- Pressure and density
- Temperature
- Ideal Gas Law
- Forms of energy and heat
- 3 ways to transfer heat energy
- Radiative energy properties

Units - Part 1

RECALL: Weather is comprised of measured *variables*. For examples:

a) air temperature
b) air pressure
etc.

The measured value is always expressed in terms of standard units

Standard units are needed to:

a) compare values
b) use the values in equations
etc.

Units - Part 2

Standard units are:

Quantity:	unit	abbreviation
Mass	kilogram	kg
Temperature	celsius	C
Temperature	Kelvin (use in eqns)	K
Temperature	fahrenheit	F
Length	meter	m
Time	second	s

Note: do not use “centigrade”

There are conversions between like quantity units

T in K = T in C + 273, T in C = (T in F- 32)*(5/9)

Ex: 275 K = 2 C + 273. 20 C = (68 F - 32)*(5/9)

Units - Part 3

Other standard units are:

Quantity:	form	abbreviation
Velocity	length / time	m / s
Acceleration	length / $time^2$	m / s^2
Force **	mass * acceleration	N
Density	mass / volume	kg / m^3
Pressure*	force / area	Pa
Energy#	force * length	J

*Pa stands for "Pascals". Pa = kg / (m * s^2)

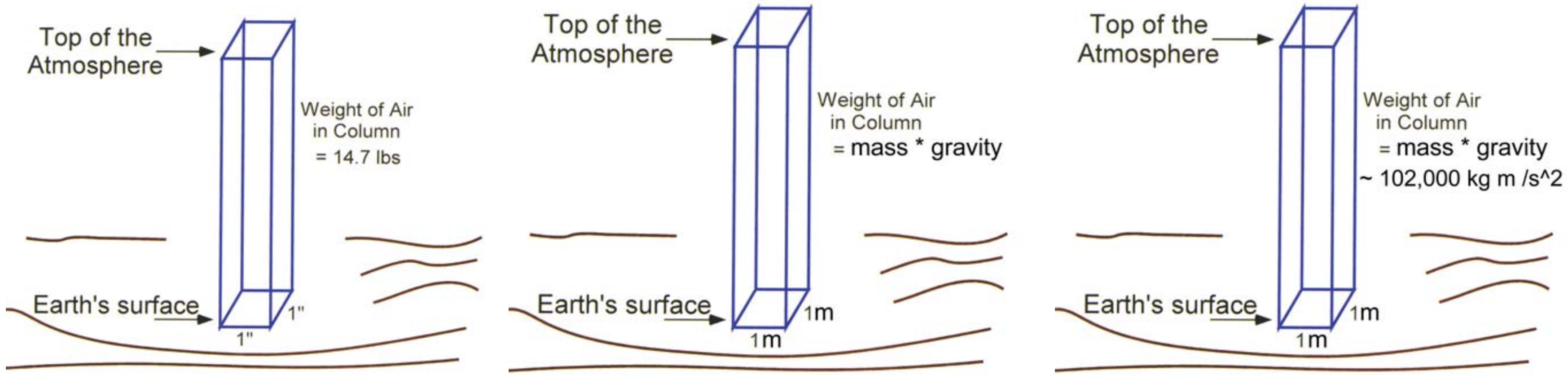
Note that 100 Pa = 1 mb.

**N stands for "Newtons". N = kg * m / s^2

J stands for "Joules". J = N * m = kg * m^2 / s^2

Chapter 1 – Weight, Mass and Pressure

- Mass is the amount of matter
- Weight is the mass times the gravitational acceleration (on earth that is: $g \sim 10 \text{ m} / s^2$)
- A mass times an acceleration = a "Force"
- So, weight is a force = Mass * g
- Pressure is a force/area
- $1000 \text{ mb} \sim 14.7 \text{ lbs} / in^2$

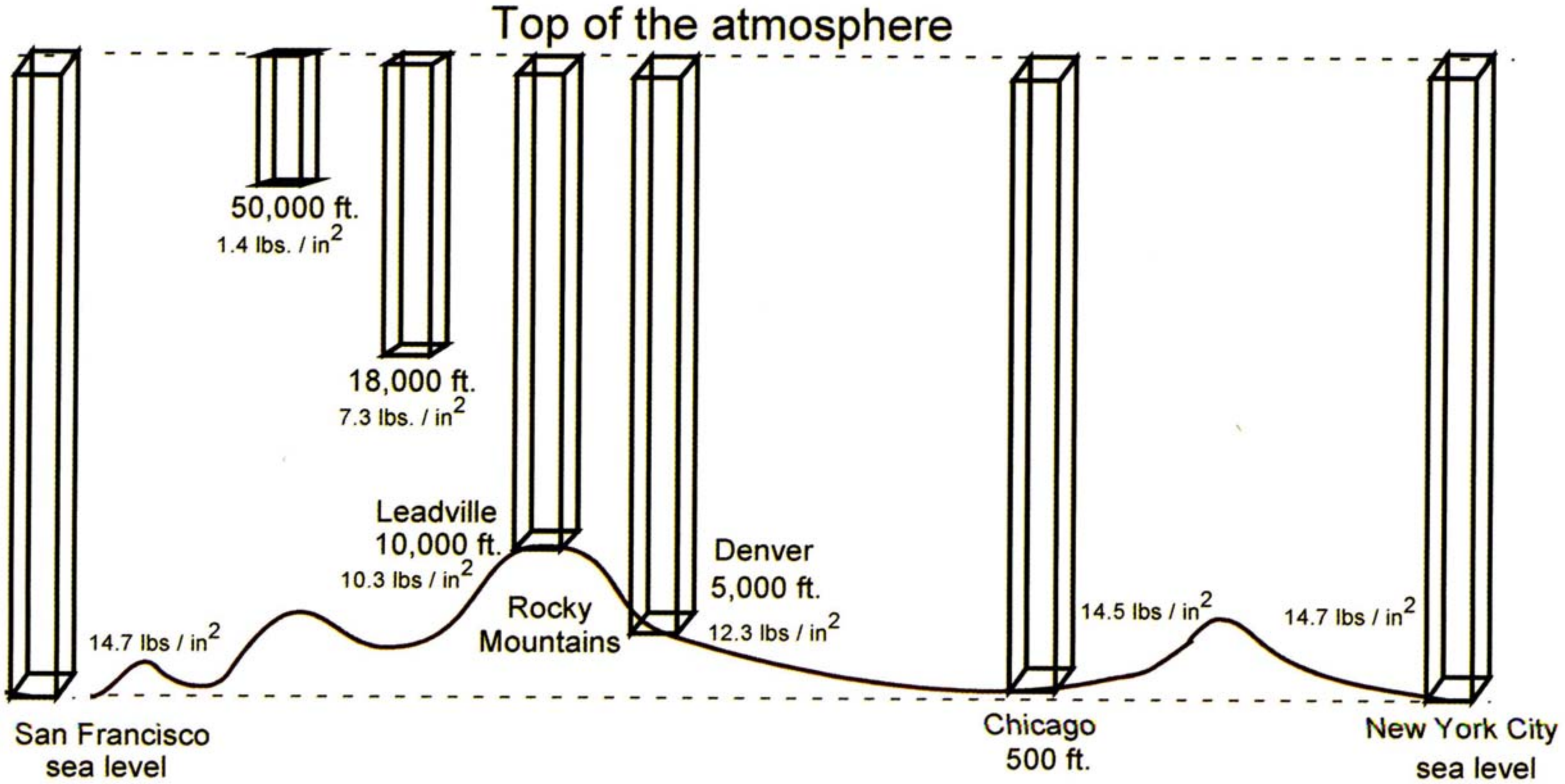


•The ~ symbol means "approximately"

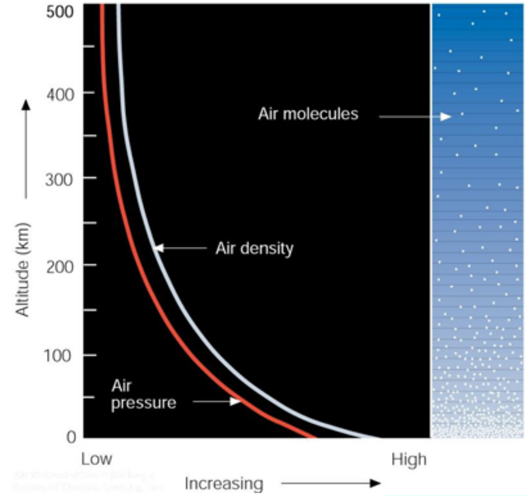
Chapter 1 – Vertical profile of Pressure

- At higher elevations less mass of air is above
- Less mass = less force = less pressure
- San Francisco Denver Leadville

14.7 lbs / in^2 12.3 = 84% of 14.7 10.3 = 70%



Chapter 1 – Pressure and Density



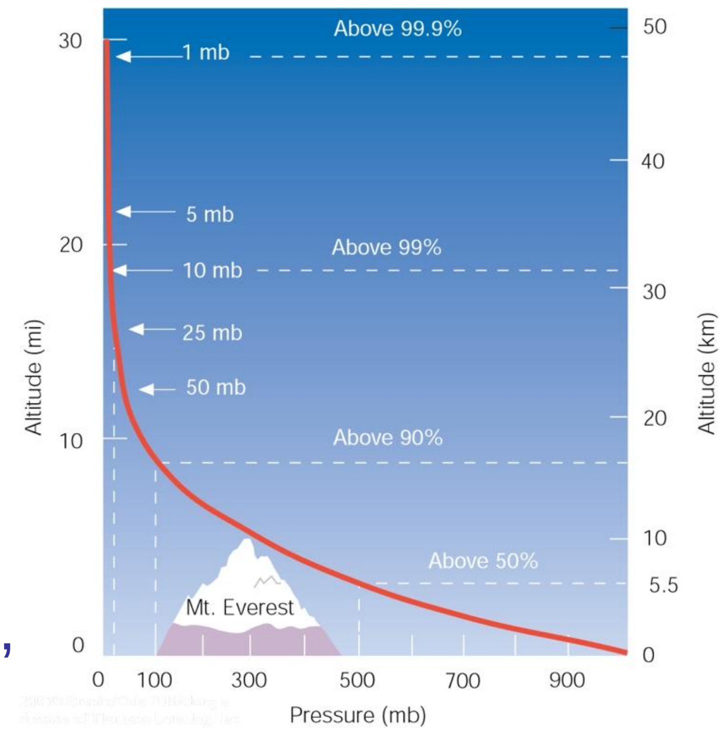
Recall: Figures 1.7 & 1.8

- Typical values:
- Density:

  $\rho = \rho_s \, \mathrm{Exp}(-z/10)$
  - At sea level:
  - $\rho_s \sim 1.2$ kg / m^3

- Pressure:

  $P = P_s \, \mathrm{Exp}(-z/10)$
  - At sea level: $P_s \sim 1000$ mb
  - At 5,000 feet: P ~ 850 mb
  - At 10,000 feet: P ~ 700 mb
  - At 18,000 feet: P ~ 500 mb



•The ~ symbol means “approximately”

Ideal Gas Law: pp. 220-221

- Three variables are related by a simple formula called the “Gas Law” in the text
- Temperature: T,
- Pressure: P and
- Density ρ.
- Equation: $P = \rho * R * T$
- R is a constant. $R = 287\ m^2 / (K * s^2)$
- Formula very useful.

Ideal Gas Law: Collapsing Jug

- The “Gas Law” explains how a jug may collapse when the air inside cools.
- T =Temperature, P =Pressure, R=constant
- Density ρ = mass / volume = M / Vol
- Equation: $P = \rho R T = \frac{M R T}{Vol}$
- T of air inside decreases
- Mass M of air inside does not change.
- P *outside*, pushing on jug does not change
- So, V decreases to match decrease of T

Energy – some basic concepts

- Energy comes in different forms
- Energy is conserved, but can be converted from one form to another
- Equations for some forms of energy:
  - Potential energy: $PE = M*g*z$

  g=acceleration of gravity, z=elevation, M=mass
  - Kinetic energy: $KE = ½ * M * v^2$

  v=velocity

- PE to KE conversion drives the winds

Energy & Temperature

When solar radiation collides with and is absorbed by atmospheric gas molecules, the air molecules move.

This produces:

a) **temperature**, defined as the moving molecules average **speed**

b) **kinetic energy**

Total energy increases with greater numbers of molecules because there is more mass.

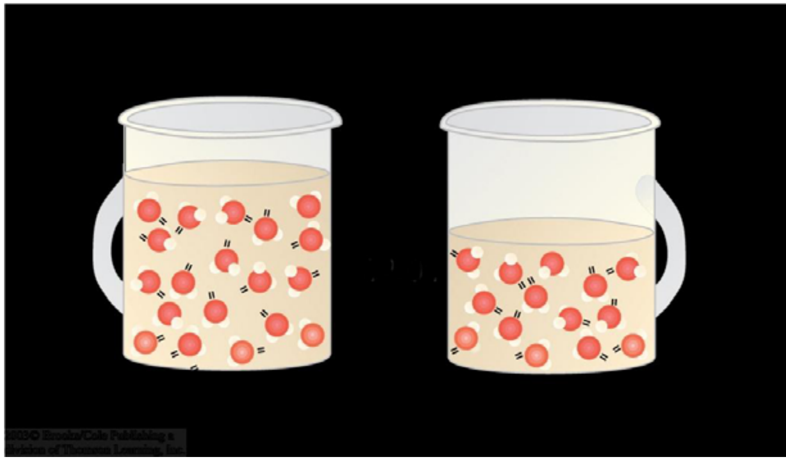


Figure 2.1

Recall:

$KE = \frac{1}{2} * M * v^2$

Temperature Scales

Thermometers detect the movement of molecules to register temperature.

Fahrenheit and Celsius scales are calibrated to freezing and boiling water, but the Celsius range is 1.8 times more compact.

Recall: °C = 5/9 (°F – 32)

Figure 2.2

Heat – some basic concepts, part 1

- Heat is energy in process of being transferred from one object to another

- Heat is transferred by 3 ways:
  - Conduction: molecules bump adjacent molecules who in turn bump their neighbors, etc.
  - Convection: physically moving the molecules
  - Radiation: send the energy via photons

Heat – some basic concepts part 2

- Heat capacity is amount of energy to raise temperature of object. Different objects need different amounts of heat to raise their temperature a given amount.

- Heat felt or measured is "sensible" heat

- Heat used to change the state of an object is "latent" heat.

  (Changes of state: gas-liquid-solid)

Changes of State – water

G. Moore photo

Figure 2.4

All 3 phases occur in the atmosphere:
Solid: ice particles, snow, hail, sleet
Liquid: rain, cloud droplets
Gas: water vapor

Latent heat released from the billions of vapor droplets during condensation.

Latent & Sensible Heat

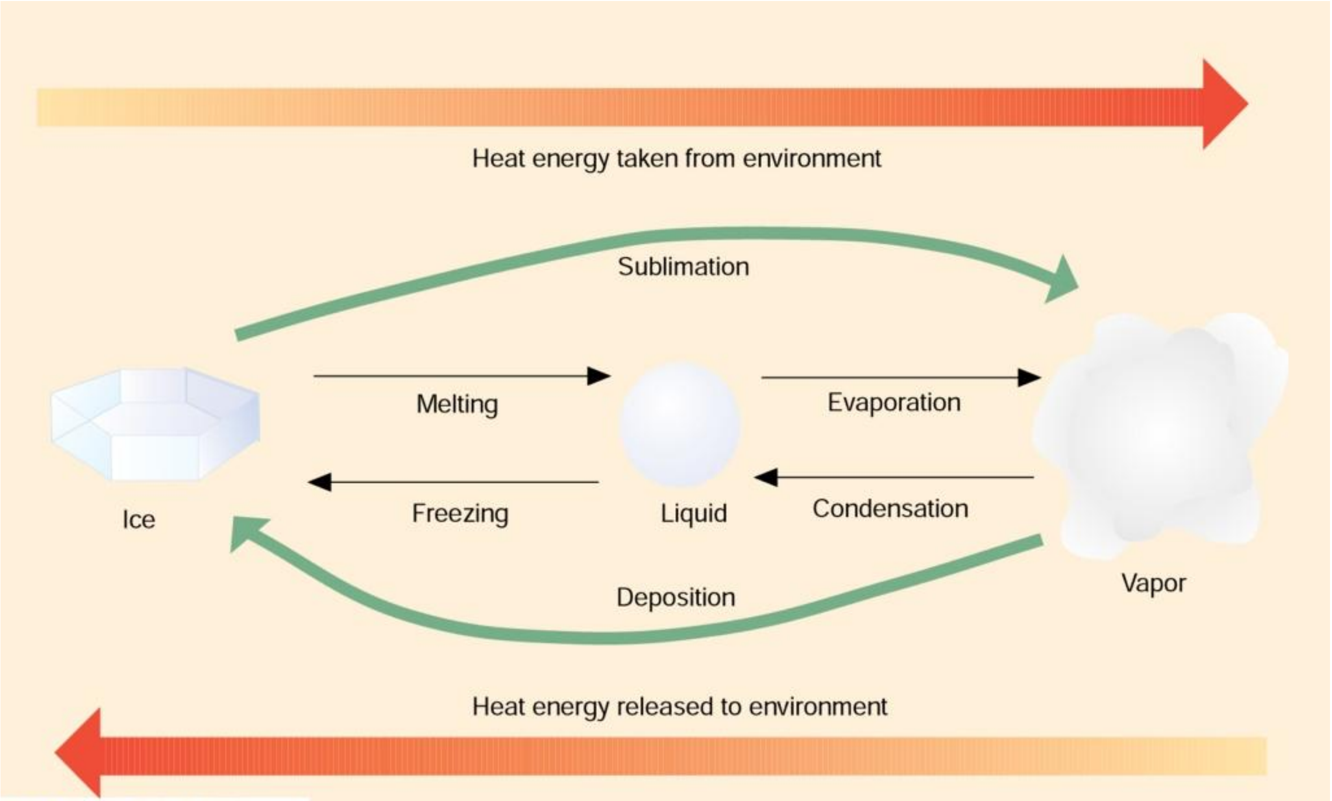


Figure 2.3

Heat energy, which is a measure of molecular motion, moves between water's vapor, liquid, and ice phases.

As water moves toward vapor it absorbs latent (e.g. not sensed) heat to keep the molecules in rapid motion.

Heat Transfer - Conduction

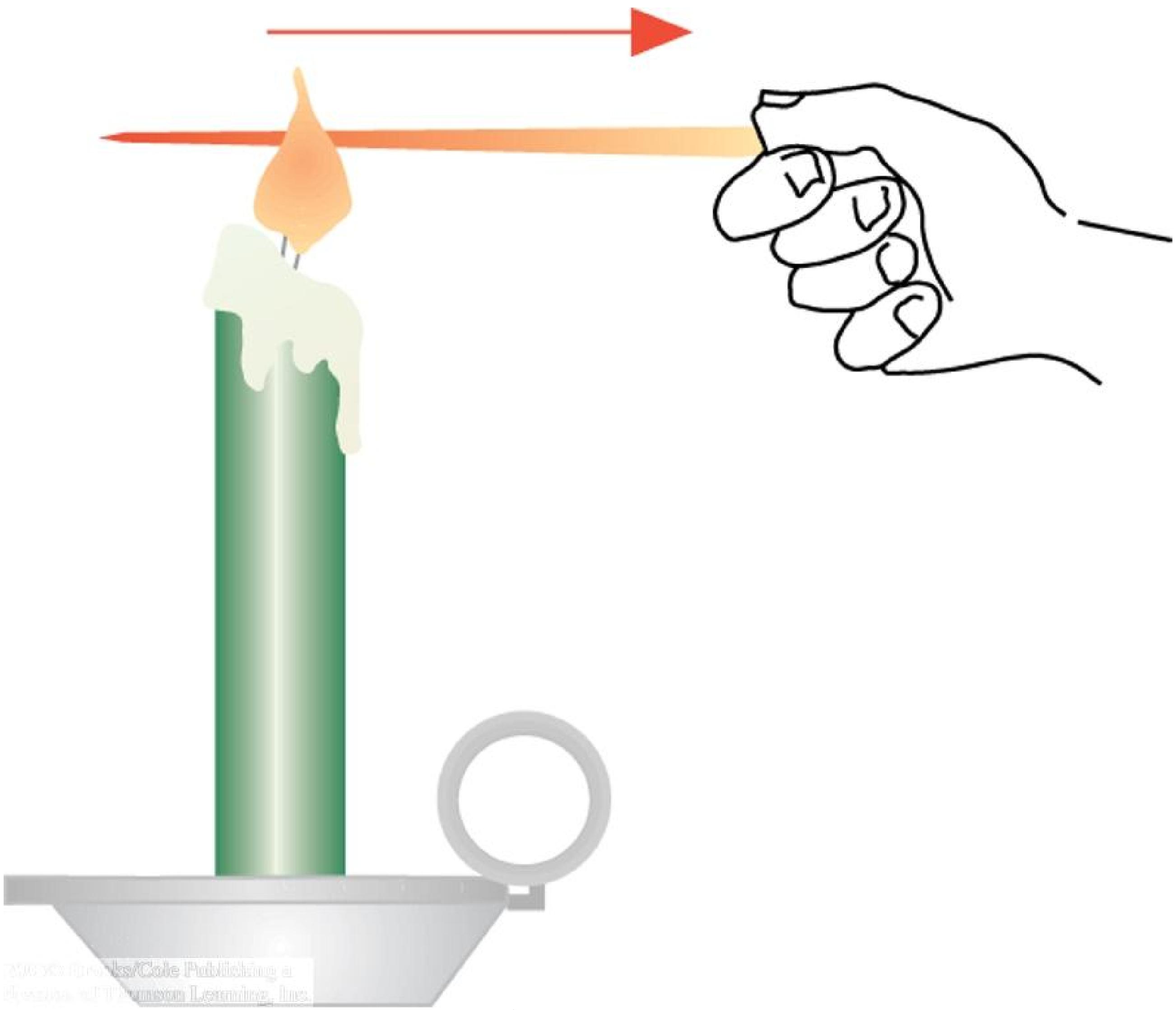


Figure 2.5

Conduction of heat energy occurs as warmer molecules transmit vibration, and hence heat, to adjacent cooler molecules.

Warm ground surfaces heat overlying air by conduction.

Heat Transfer -Convection

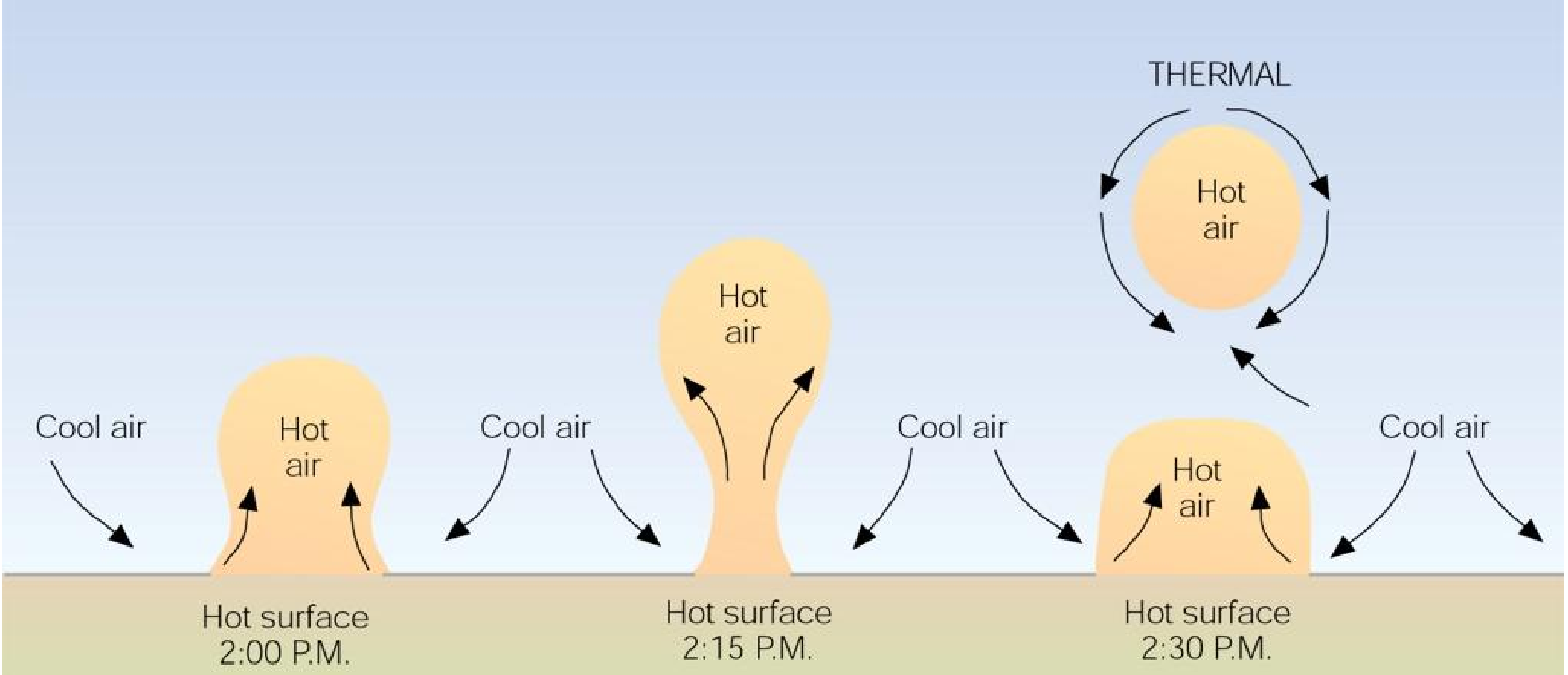


Figure 2.6

Convection is heat energy moving as a fluid from hotter to cooler areas.
Warm air at the ground surface rises as a thermal bubble, expends energy to expand, and hence cools.

Advection is heat energy transport in the horizontal by winds.

Heat Transfer - Changes of State (water)

G. Moore photo

Figure 2.4

All 3 phases occur in the atmosphere:
Solid: ice particles, snow, hail, sleet
Liquid: rain, cloud droplets
Gas: water vapor

Latent heat released from the billions of vapor droplets during condensation **and, releasing the latent heat warms the air, and encourages taller cloud growth.**

Heat transfer - Radiation

A candle illustrates all 3 types of radiation:
Conduction (fig. 2.5)
Convection (middle figure) blue arrows are air flow
Radiation (right figure) the light and infra red radiation emitted in all directions.

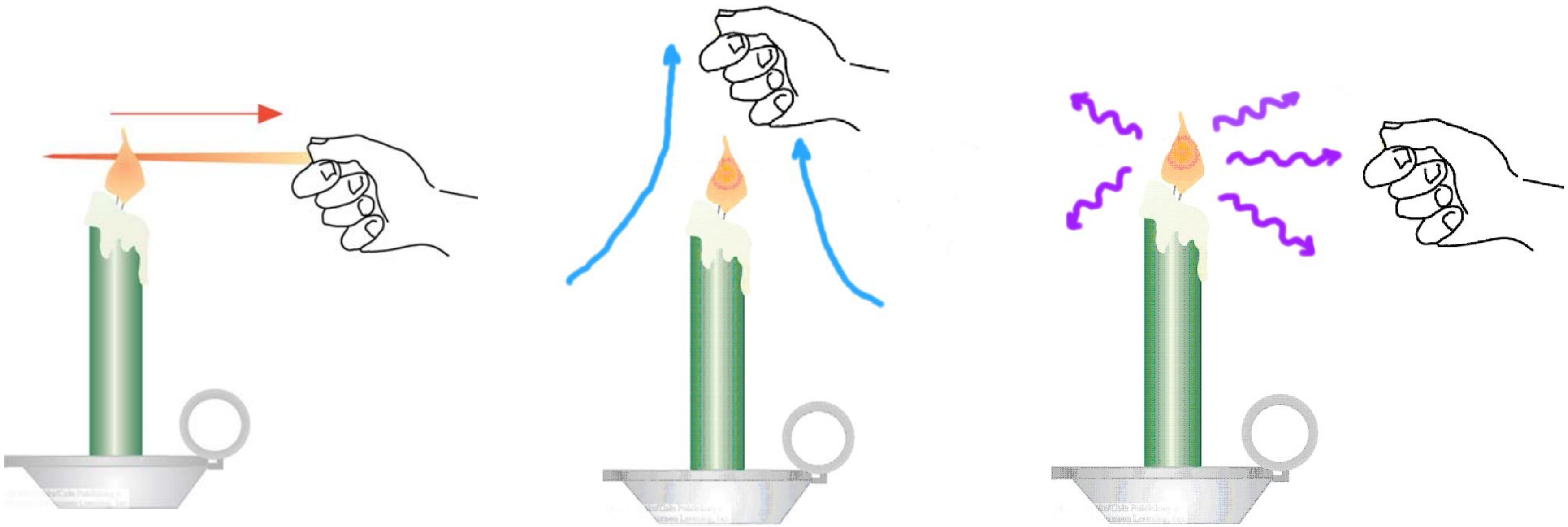


Figure 2.5

Radiation - Heat Transfer

Radiation travels as waves of photons that release energy when absorbed.

All objects above 0° K release radiation, and its heat energy value increases to the 4th power of its temperature:

$E = \sigma T^4$

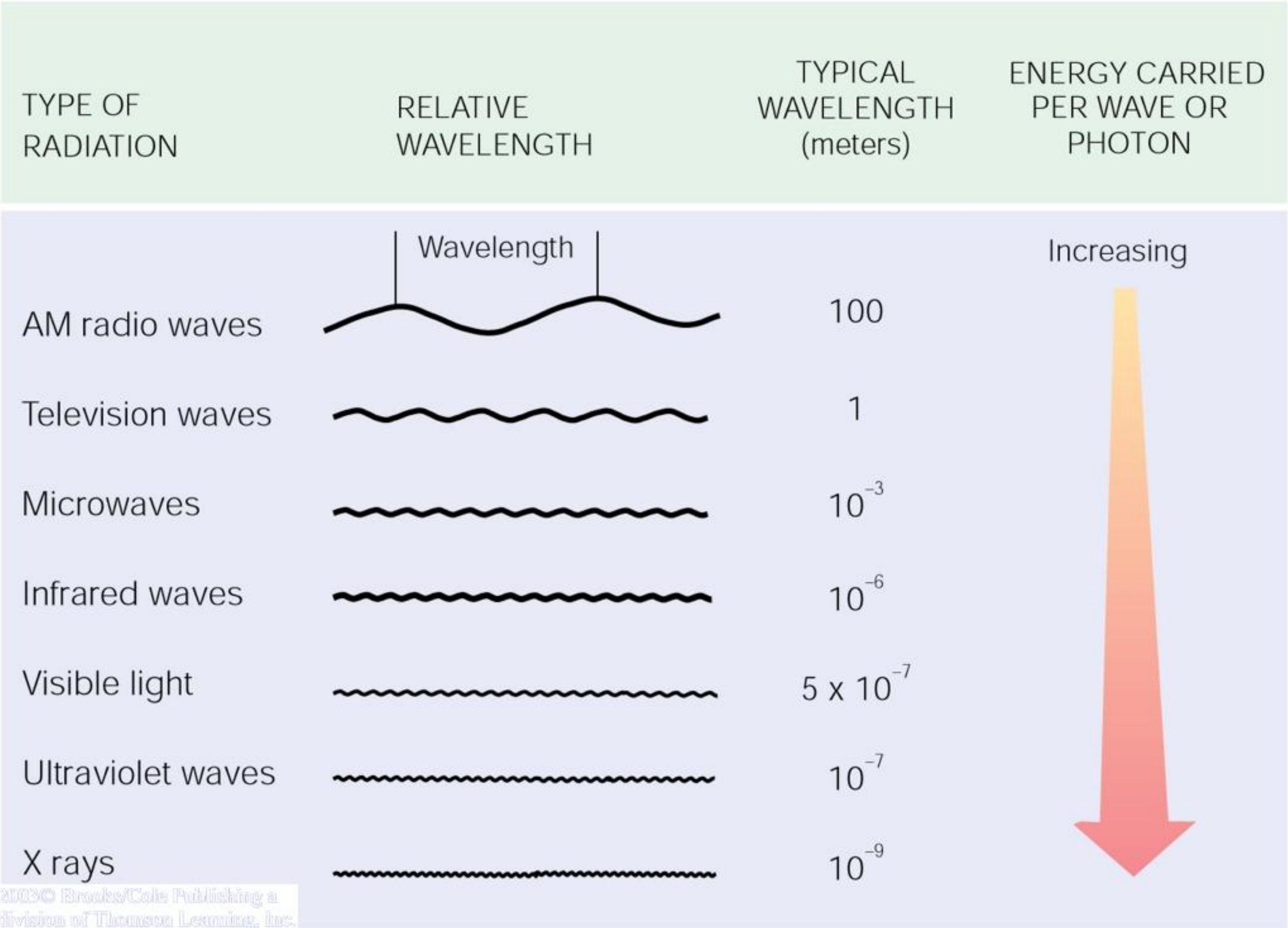


Figure 2.7

Longwave & Shortwave Radiation

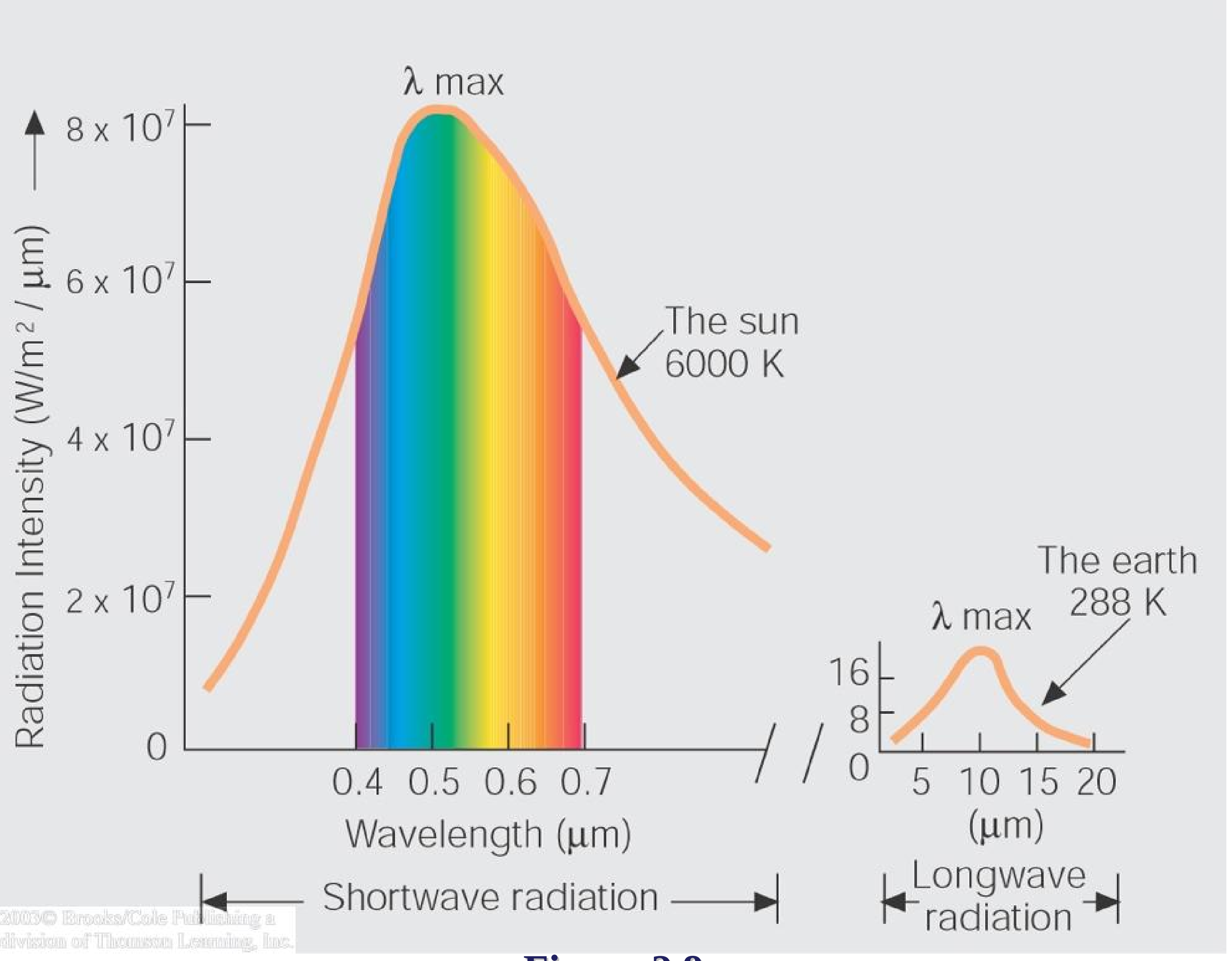


Figure 2.8

The hot sun radiates at shorter wavelengths that carry more energy, and the fraction absorbed by the cooler earth is then re-radiated at longer wavelengths, as predicted by Wein's law:

$$\lambda_{max} = 2897/T$$

Electromagnetic Spectrum

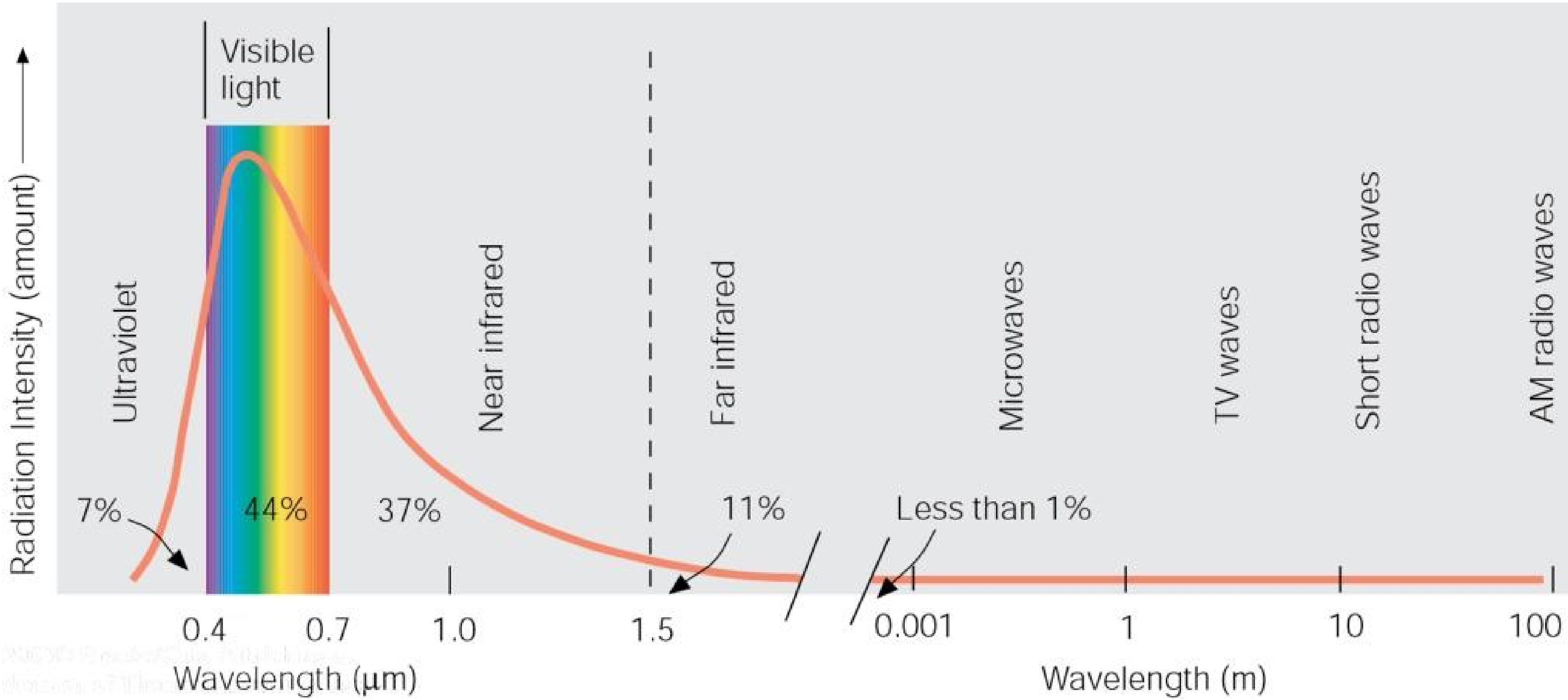


Figure 2.9

Solar radiation has peak intensities in the shorter wavelengths, dominant in the region we know as visible, but extends at low intensity into longwave regions.

Radiation in the atmosphere

Solar radiation passing through earth's atmosphere is absorbed by gases, aerosols, and dust.

The atmosphere also scatters and refracts radiation.

Knowing what these are helps us understand optical phenomena – subject of a future lecture.

Note: We are skipping most of the discussion of energy balance for the earth – that is covered in ATM 5

Figure 2.14

Review

- This lecture introduced these 6 equations:

- Formula for ρ: $\rho = \rho_s \text{ Exp}(-z/10)$
- Ideal gas law: $P = \rho R T$
- Potential energy: $PE = M*g*z$
- Kinetic energy: $KE = ½ * M * v^2$
- Total radiant energy formula: $E = \sigma T^4$
- Wein's law (radiant max): $\lambda_{max} = 2897/T$

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End of Lecture 2