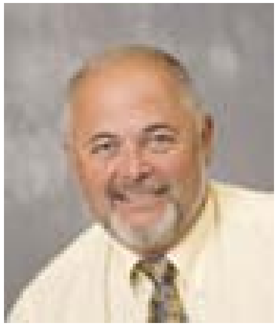
EAPS 10000 Y01
Online Course
Planet Earth
Prof. Lawrence Braile

Welcome to the EAPS 10000 Y01 online course ***Planet Earth*** *(also known as EAPS 100)!*



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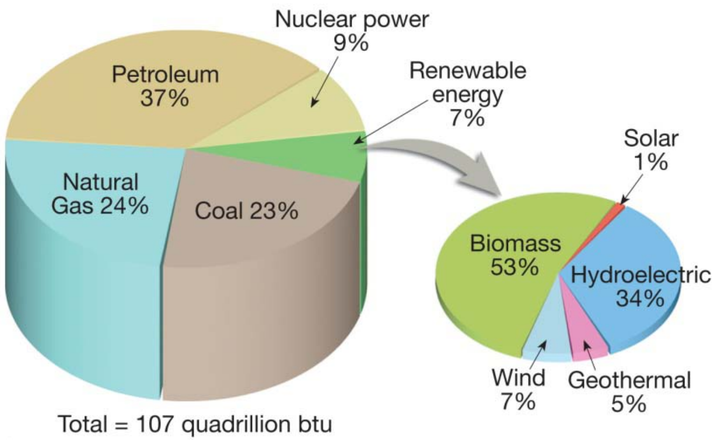
PURDUE UNIVERSITY

Earth Atmospheric Planetary Sciences

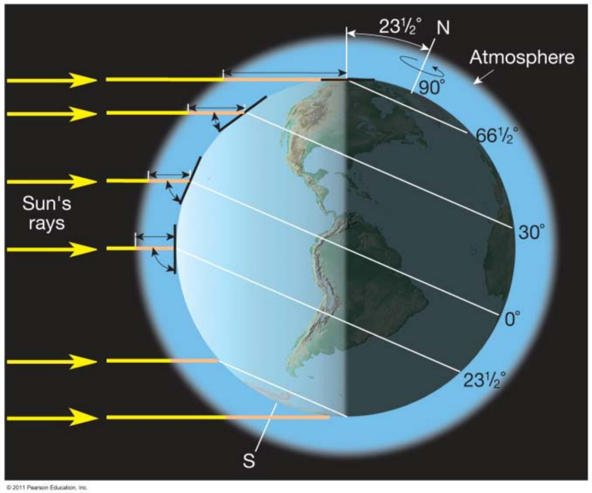
EAPS 10000 Y01 – Planet Earth (online course)
Week 6, Chapter 11 (pages 352-385, text)

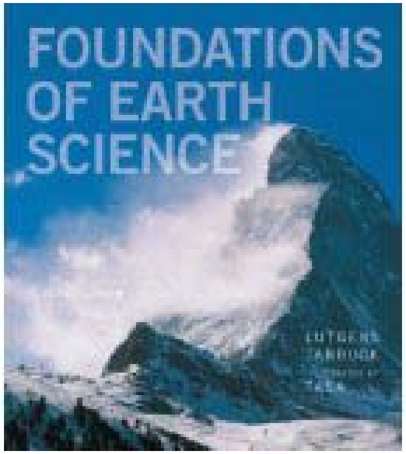
Week	Chapter	Assigned Pages	Major Concepts	Important Terms
6	**11 – Heating the Atmosphere**	352 – 385	Weather and climate, composition of the atmosphere, trace elements, structure of the atmosphere, solar heating, seasons, heat transfer (radiation, conduction, convection), human influence on the atmosphere (climate change)	Ozone, pressure, temperature, moisture content, Greenhouse effect, climate, troposphere, stratosphere

U.S. Energy consumption, 2008



Sun's rays, winter in N. hemisphere (thickness of atmos. Exaggerated)





EAPS 10000 Y01 – *Planet Earth* (online course)
Week 6, Chapter 11 (pages 352-385)

When you have finished reading Chapter 11 and viewing the weekly PowerPoint file for Chapter 11, take the weekly quiz (Quiz10; be sure to read the Syllabus for more information on quizzes). You can use your book, notes, etc. during the quiz.

The PPT files (converted to PDF files) are best viewed with the Full Screen view in browsers.

The following slides illustrate some of the important concepts and topics of Chapter 11:

The Earth's Atmosphere:

1. Composition:

$N_2 \approx 78\%$
$O_2 \approx 21\%$

a. Other elements and compounds (**minor constituents**) – (Ar, Ne, CH_4, Kr, H_2, etc.) $\leq 1\%$: and Water vapor $\approx 0 - 4\%$

b. Significant **trace elements** (although very small in volume in the Earth's atmosphere, these trace elements and water vapor have significant effects): $CO_2 \approx 390$ ppm*, CO ≈ 100 ppm, $O_3 \approx 0 - 10$ ppm, $SO_2 \approx 0 - 1$ ppm

*ppm = parts per million; one ppm equals 0.0001%

Composition of Dry Air

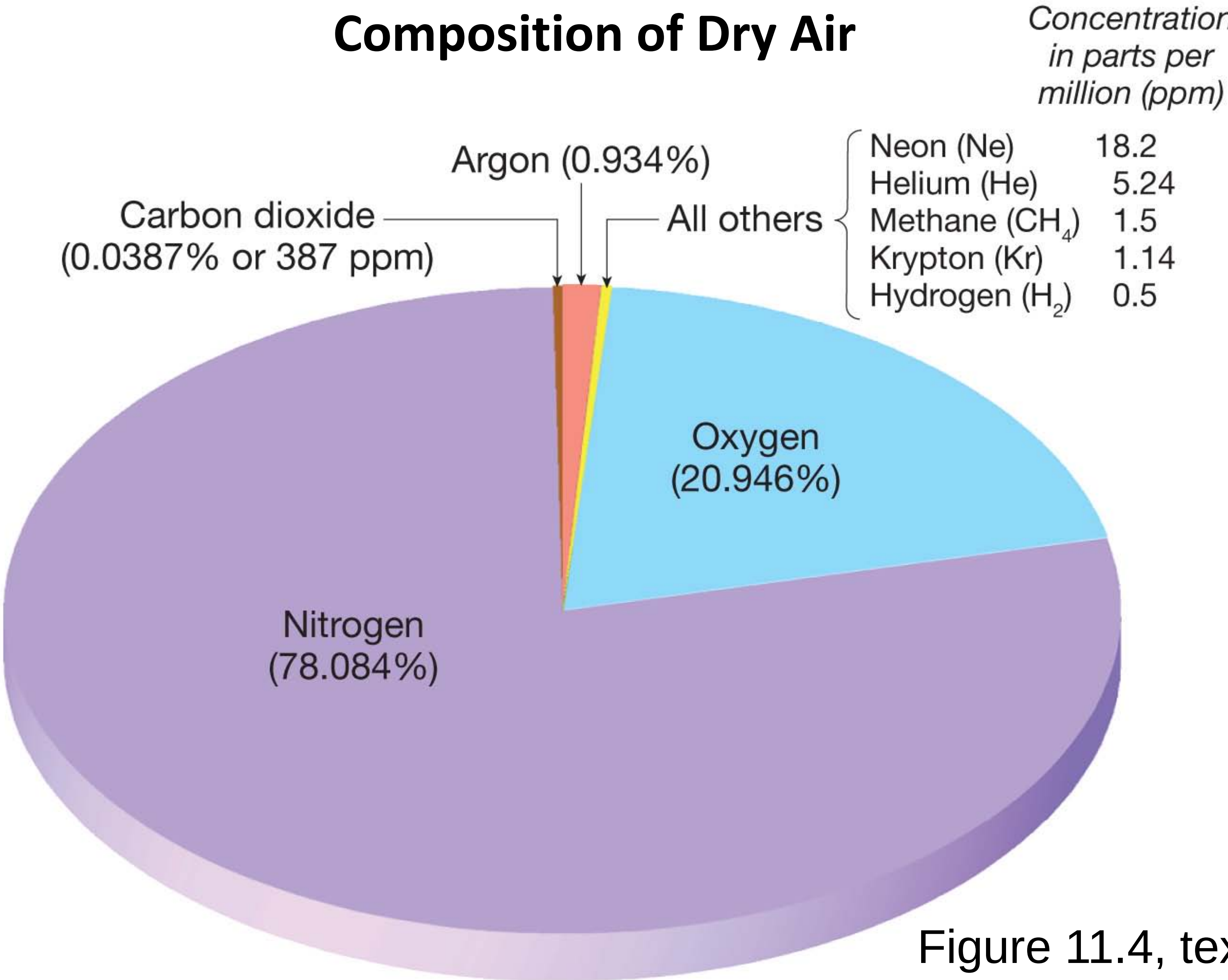


Figure 11.4, text

2. The atmosphere is layered by:

- Temperature (in lowest layer, temperature **decreases** with altitude)

- Pressure (pressure **decreases** with elevation – “less atmosphere above”)

- Moisture content (generally decreases with elevation; **why?**) – cold air (higher altitude) holds less moisture; source of most water is Earth’s surface (oceans, lakes rivers, land surface)

“The Earth's atmosphere is an extremely thin sheet of air extending from the surface of the Earth to the edge of space. The Earth is a sphere with a roughly 13,000 km diameter; the thickness of the atmosphere is about 100 km. In this picture, taken from a spacecraft orbiting at 300 km above the surface, we can see the atmosphere as the thin blue band between the surface and the blackness of space. If the Earth were the size of a basketball, the thickness of the atmosphere could be modeled by a thin sheet of plastic wrapped around the ball. At any given location, the air properties also vary with the distance from the surface of the Earth. The sun heats the surface of the Earth, and some of this heat goes into warming the air near the surface. The heated air rises and spreads up through the atmosphere. So the air temperature is highest near the surface and decreases as altitude increases. The pressure of the air can be related to the weight of the air over a given location. As we increase altitude through the atmosphere, there is some air below us and some air above us. But there is always less air above us than was present at a lower altitude. Therefore, air pressure decreases as we increase altitude.”

http://www.grc.nasa.gov/WWW/K-12/airplane/atmosphere.html

http://www.nasa.gov/mission_pages/station/multimedia/gallery/iss030e031275.html **The Moon and Earth's atmosphere**

“ISS030-E-031275 (8 Jan. 2012) --- One of a series of photos of the moon and Earth's atmosphere as seen from the International Space Station over a period of time that covered a number of orbits by the orbital outpost.”

“THE THIN BLUE LINE: Earth’s thin atmosphere is all that stands between life on Earth and the cold, dark void of space. Our planet's atmosphere has no clearly defined upper boundary but gradually thins out into space. The layers of the atmosphere have different characteristics, such as protective ozone in the stratosphere, and weather in the lowermost layer. The setting Sun is also featured in this image from ISS, 2008.”
http://fettss.arc.nasa.gov/collection/details/earth-atmosphere/

Space Shuttle Atlantis leaving the International Space Station on the last NASA Space Shuttle Mission (STS 135) July 21, 2011.

Earth’s Atmosphere – a thin layer

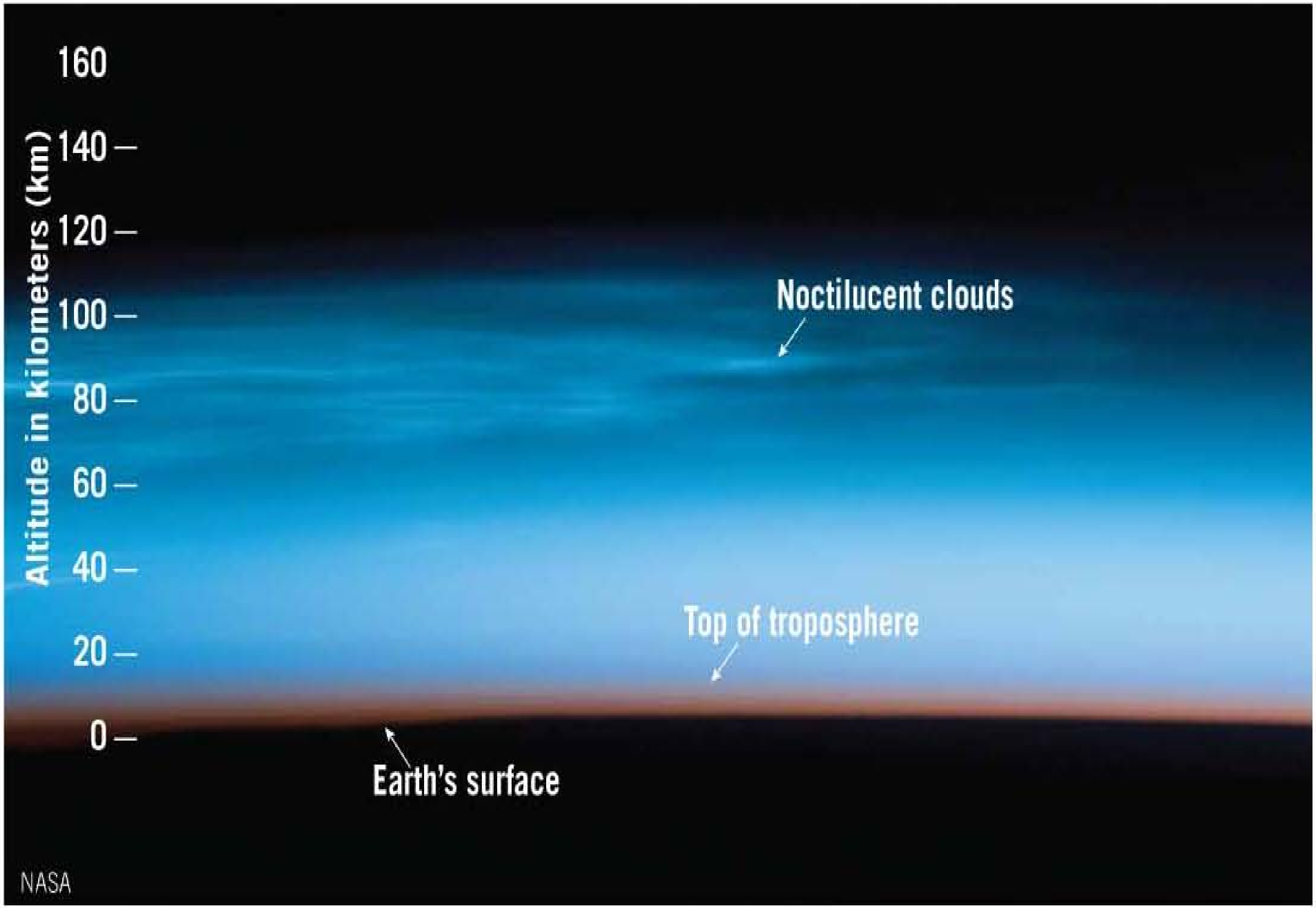


Image of the atmosphere taken from the space shuttle. The thin streaks, called noctilucent clouds, are 80 km (50 mi) high. It is in the dense troposphere that practically all weather phenomena occur.

Figure I.5, text

Air Pressure Variation with Altitude

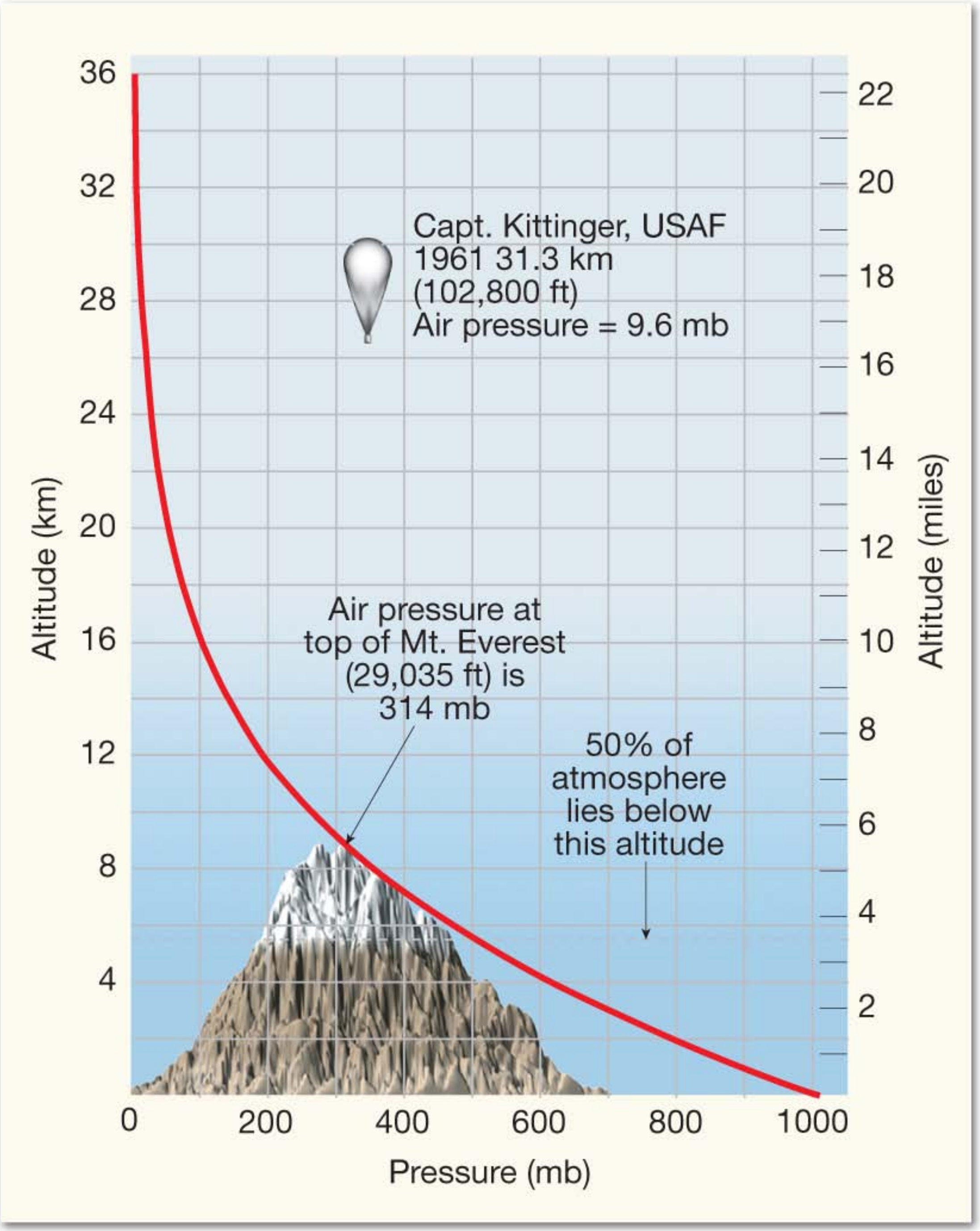


Figure 11.8, text

Air Pressure Decreases with Altitude – Because as altitude increases, there is less air above, and, the density of air decreases rapidly with altitude, the pressure versus altitude relationship is a curve

D = Density of air (in g/cm^3) – note that density of the atmosphere also decreases with altitude

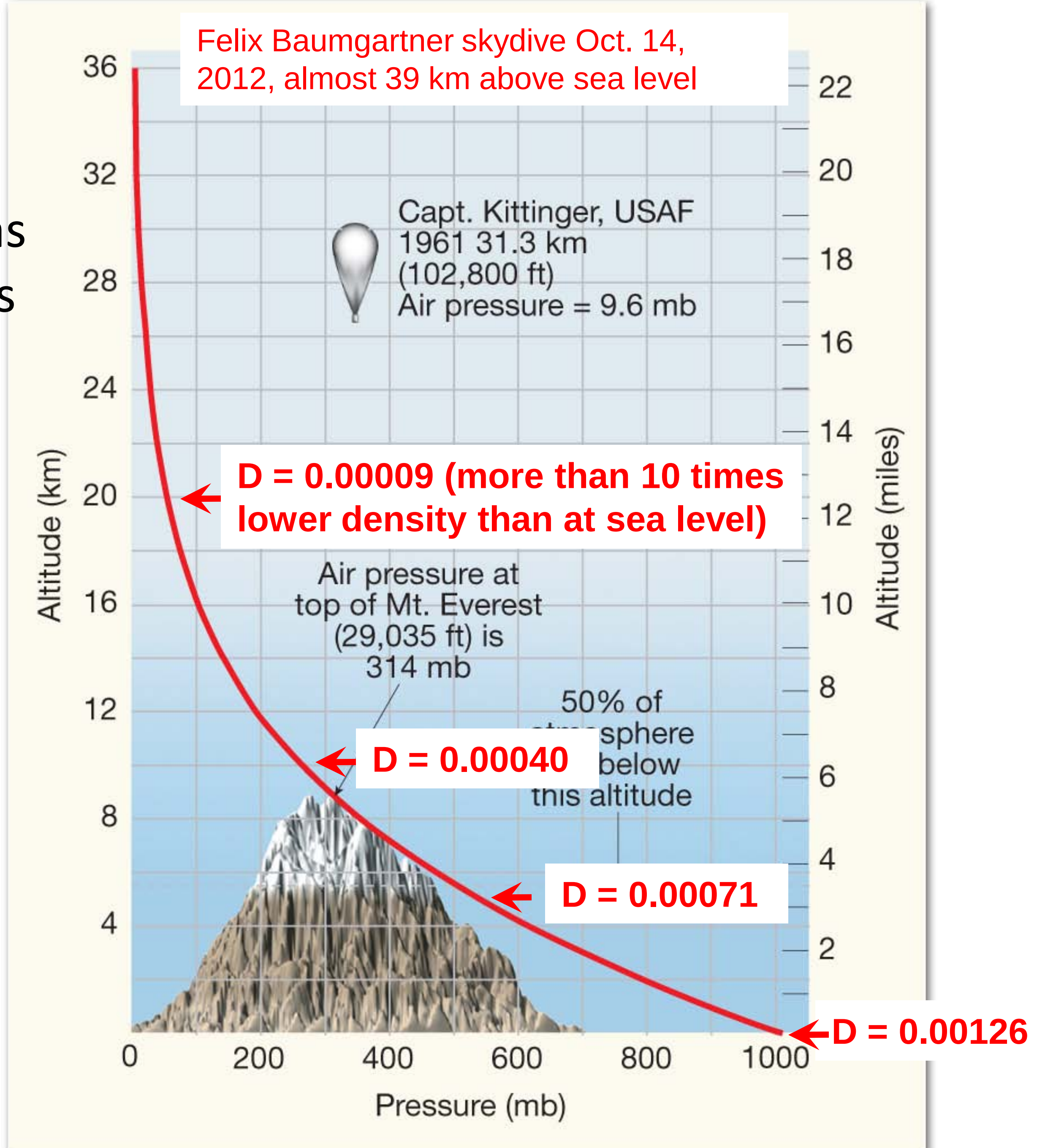


Figure 11.8, text

The difference between the number → of molecules per unit volume of air at the top and bottom of the atmosphere is much greater than illustrated in this diagram.

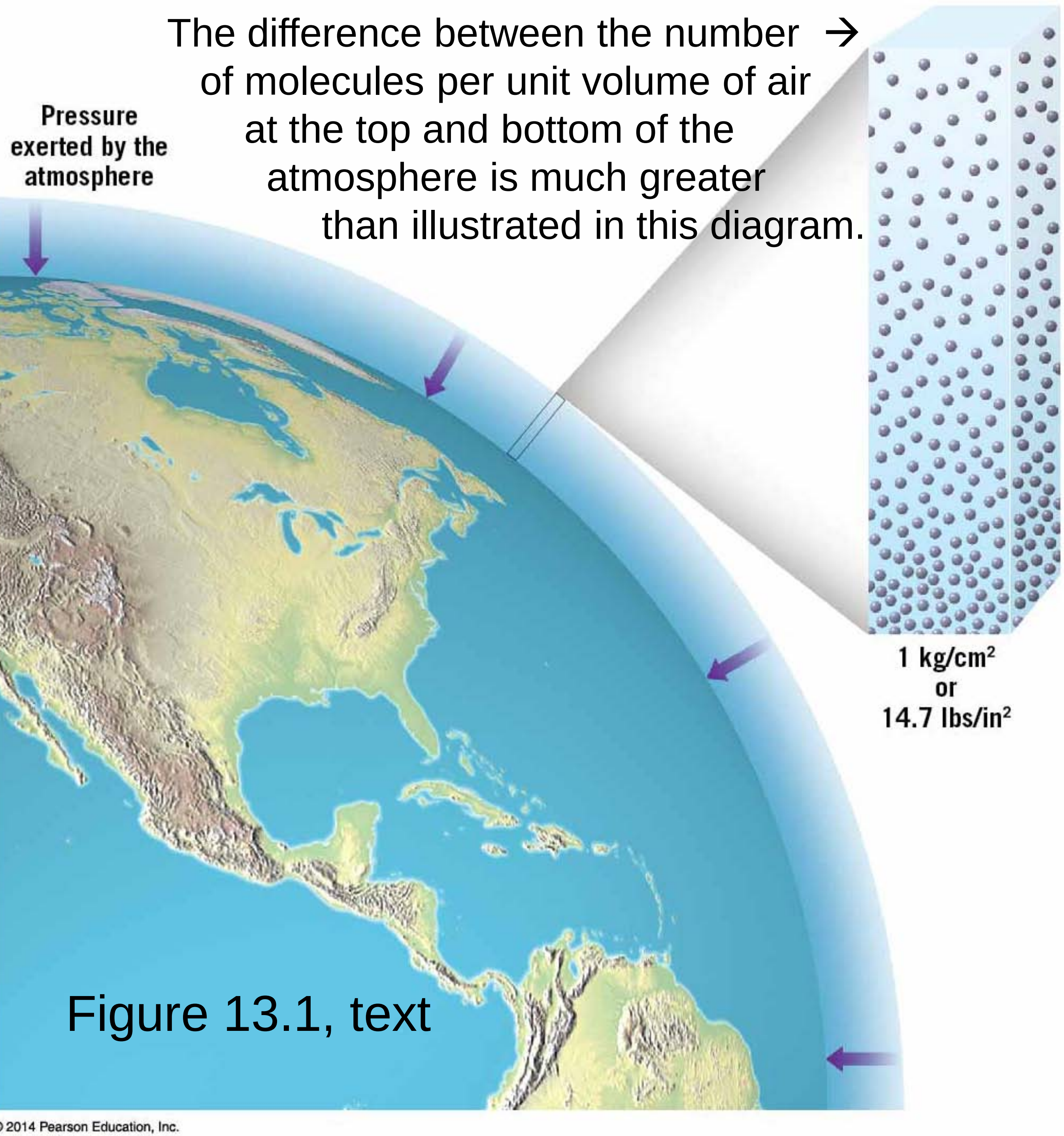
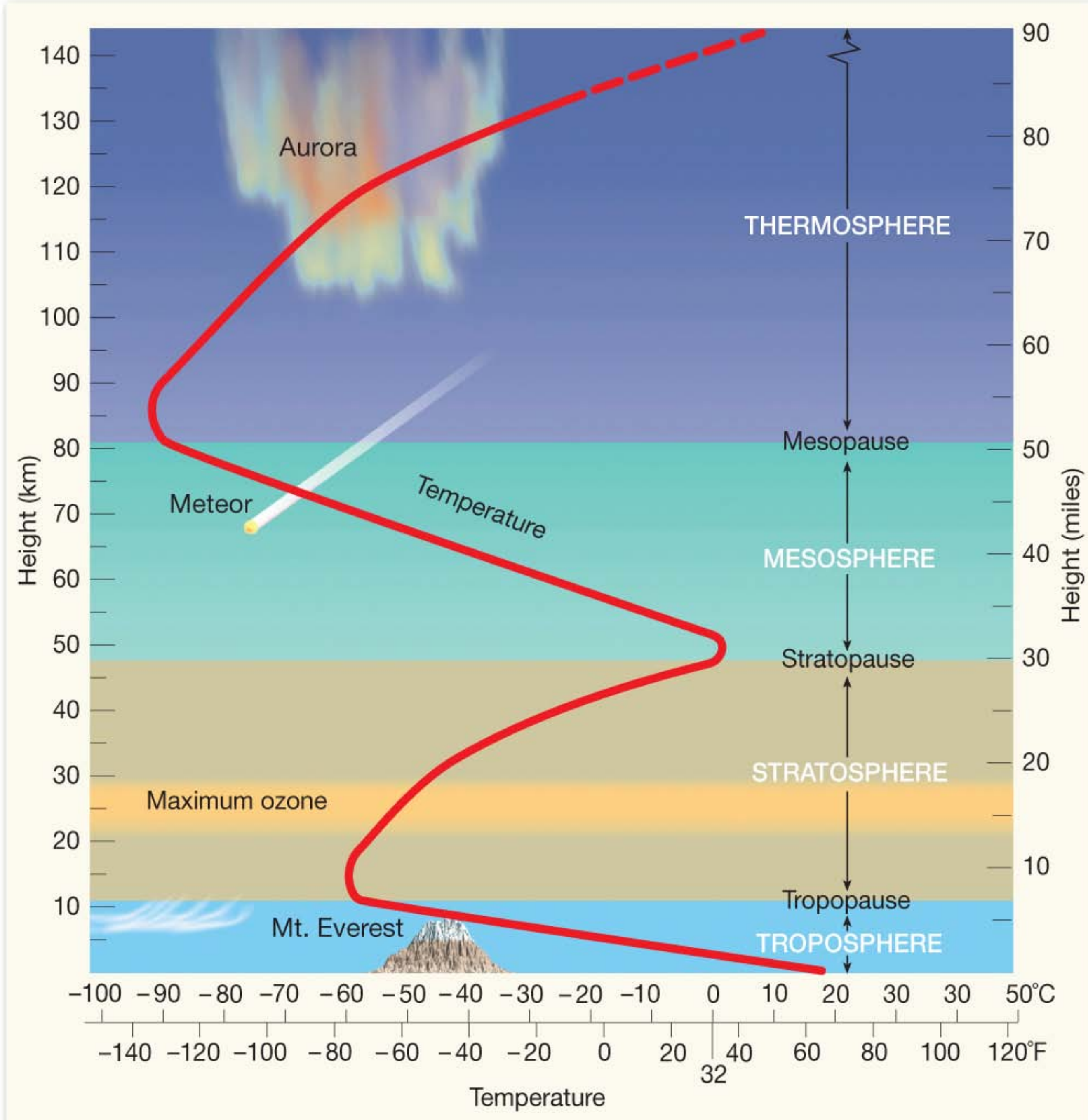


Figure 13.1, text

←
Because it is a gas, the layer of atmosphere is not homogeneous, as a layer of water would be. So, there are more molecules of air per cubic meter (because of the weight of the overlying atmosphere) at lower levels of the atmosphere. This causes the curved pressure vs. altitude relationship seen in the previous slide.

Temperature variation with altitude (we will focus on the lowermost layer, the troposphere, where most weather phenomena occurs)

Figure 11.10, text



Temperature variation with elevation (lowest layer of the atmosphere, the troposphere, where most weather phenomena occur – focus is on lowest layer)

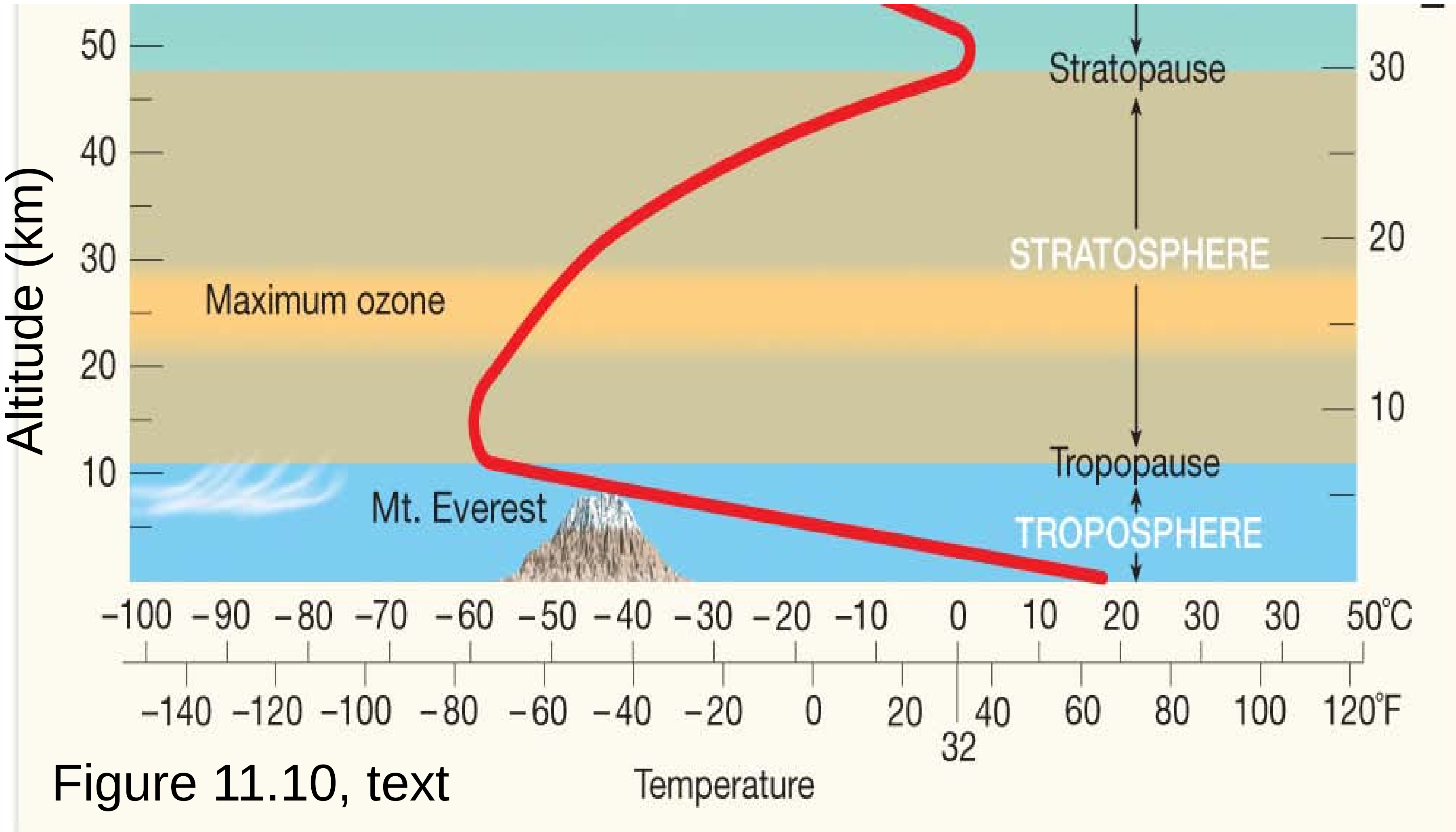


Figure 11.10, text

Temperature variation with elevation (lowest layer of the atmosphere, the troposphere, where most weather phenomena occur)

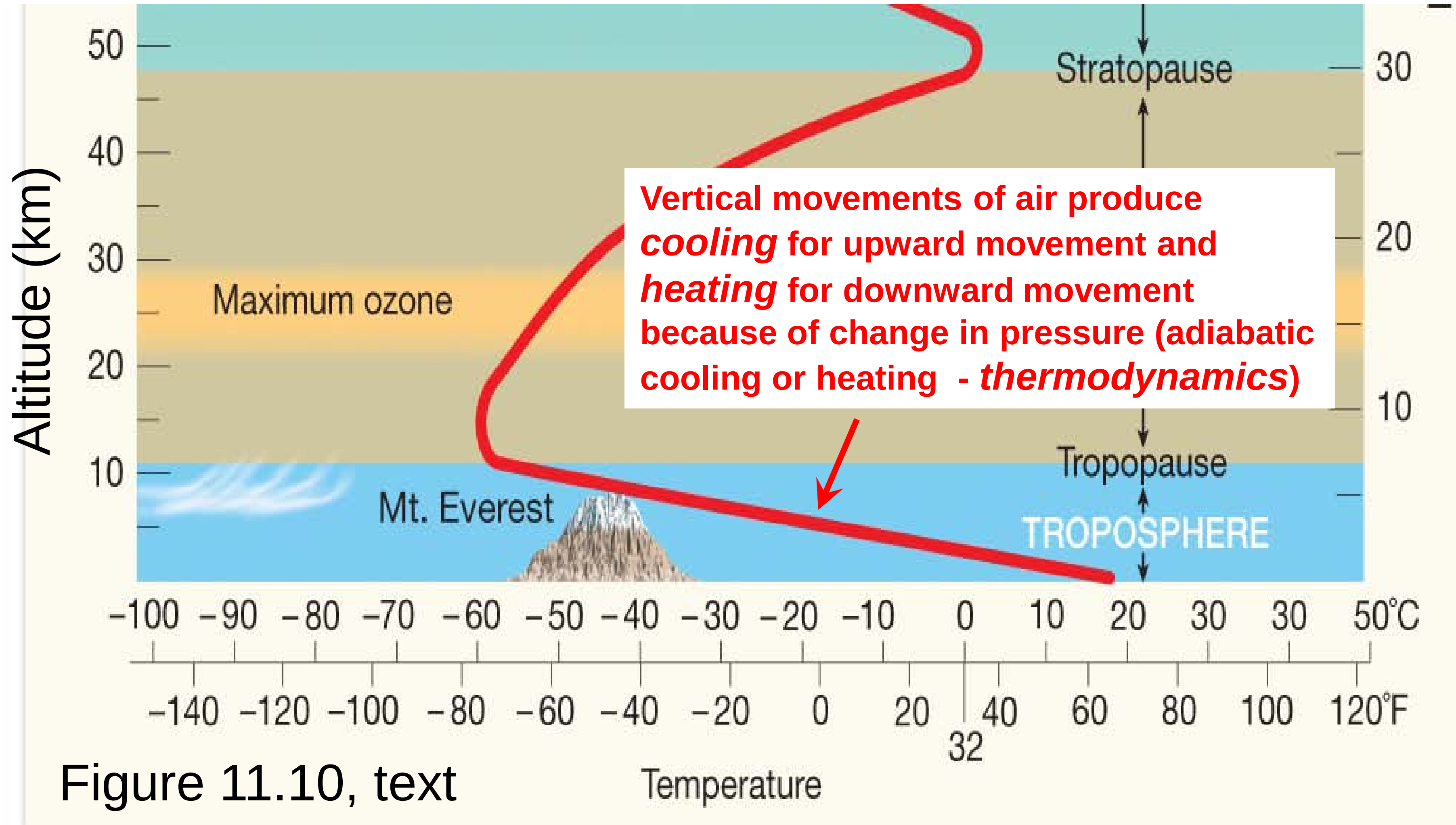
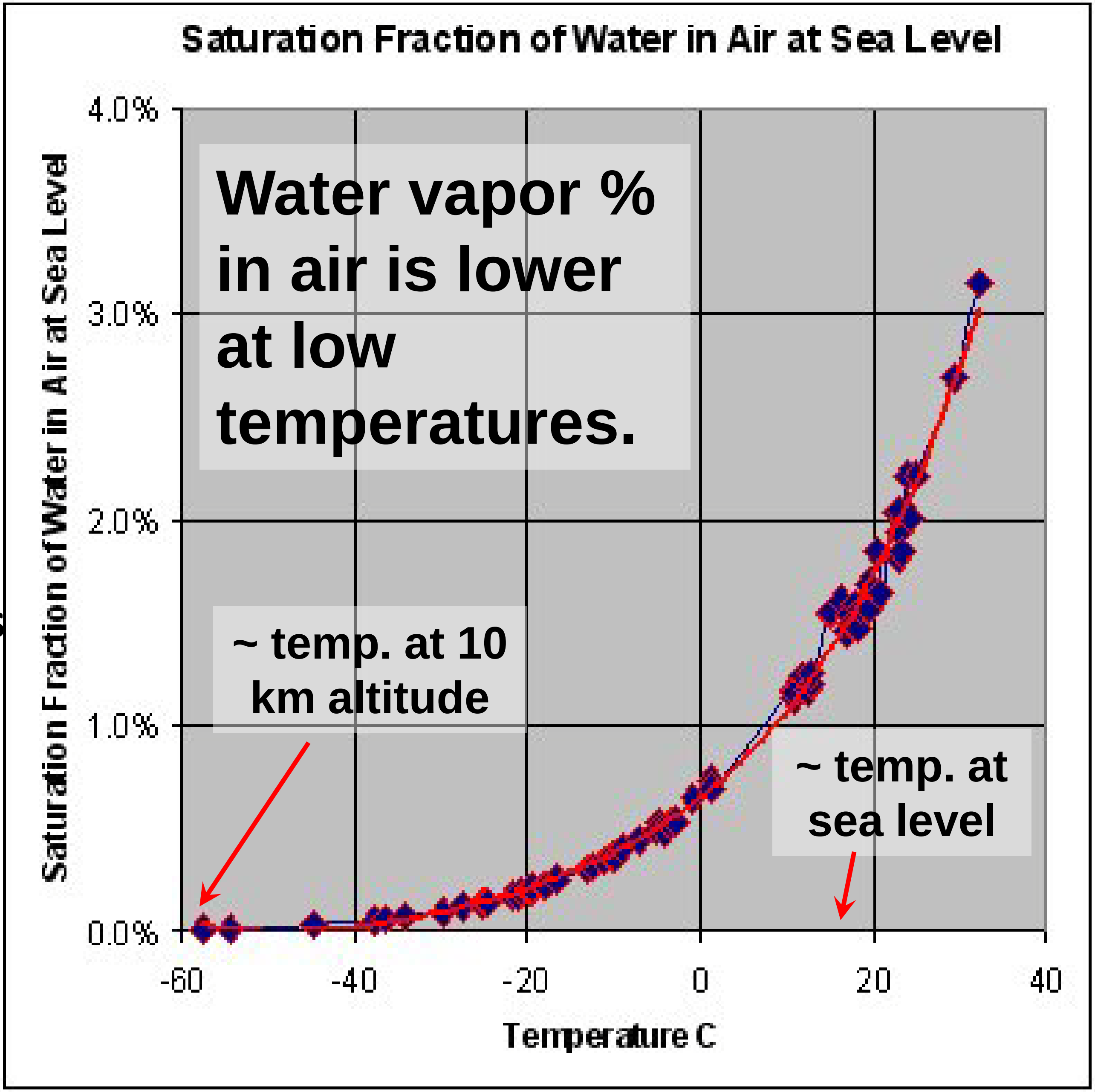


Figure 11.10, text

Because temperature decreases rapidly with altitude, water vapor % also decreases with altitude. (Atmospheric pressure also decreases with altitude and has an effect on water vapor %, but the temperature effect is more important.)



http://en.wikipedia.org/wiki/Water_vapor

3. Atmospheric circulation occurs on multiple scales of *distance* and *time*:

- Global pattern (large scale, changes over seasons as well as hundreds of years, and longer)

- Regional weather patterns (changes over days to weeks)

- Severe weather (local, and changes over hours to days)

(Details of atmospheric circulation are covered in Chapter 13)

Solar Radiation (primary energy source for atmospheric circulation and weather):

Electromagnetic radiation/energy

The Electromagnetic Spectrum

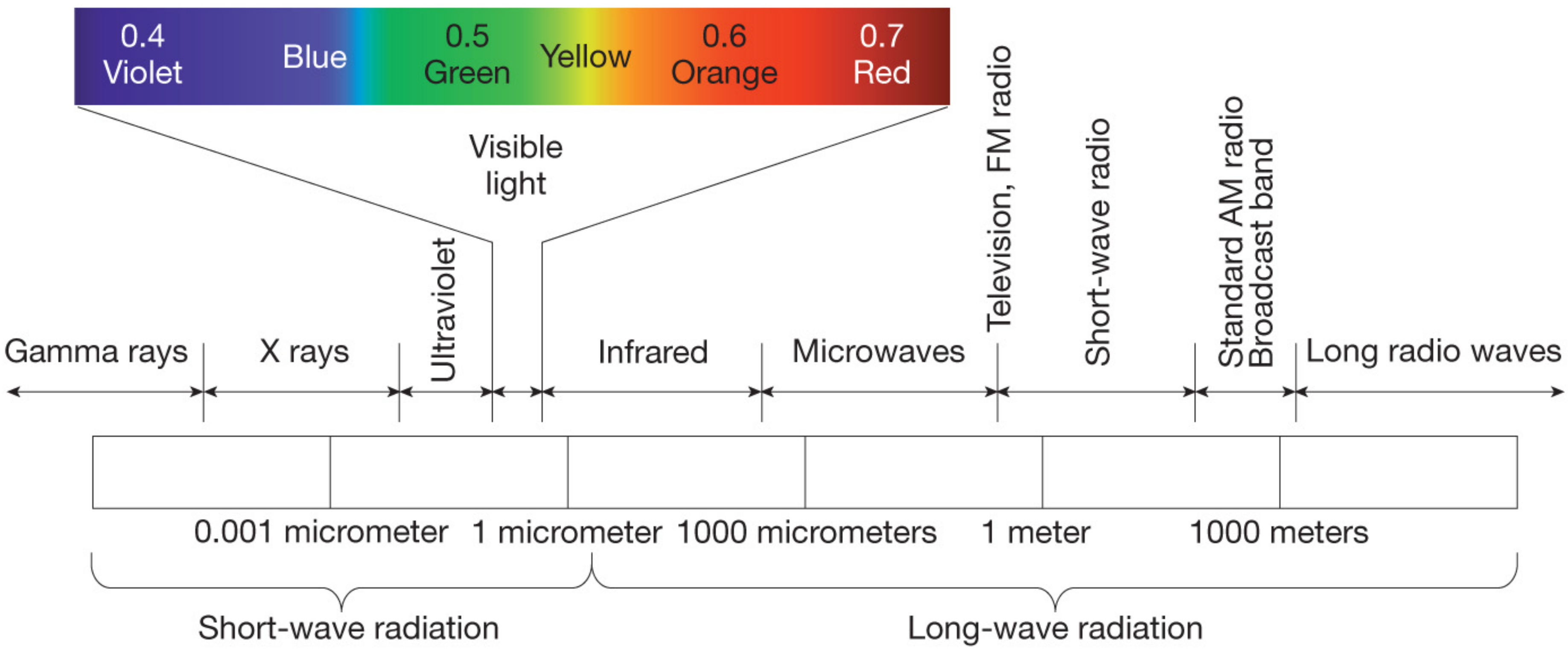
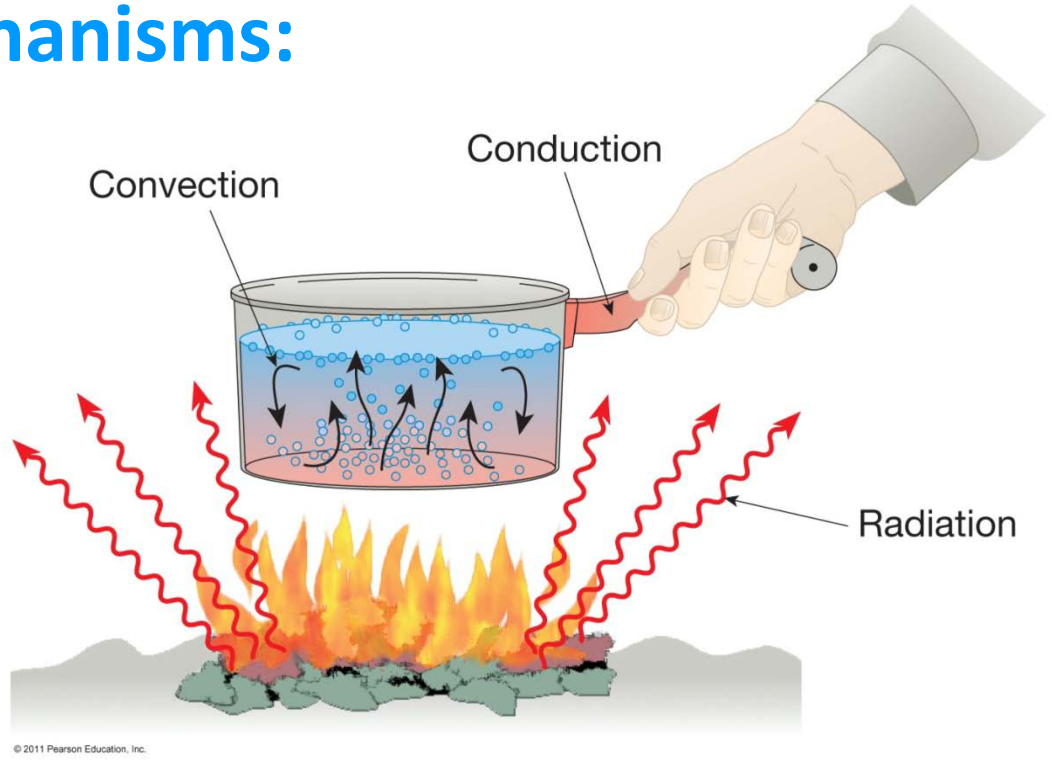


Figure 11.19, text

Solar Energy:

- 1 part in 10^9 strikes Earth
- in 1 minute, solar energy that strikes Earth is more than humans use in 1 year
- Solar emissions are mostly in visible, ultraviolet, and infrared parts of EM spectrum
- Energy is reflected, absorbed, transmitted through atmosphere
- Most energy eventually radiated back into space by Earth and atmosphere as infrared energy (so atmosphere is approximately in equilibrium)

Energy Transfer in the Atmosphere – Three Mechanisms:



-- Radiation

-- Conduction

-- Convection (mass transport – carries heat energy as mass moves; wind and other atmospheric circulation)

Figure 11.18, text

Temperature Changes:

- Heating near equator, cooling in polar regions (variations with seasons, weather systems, length of day)
- Adiabatic heating and cooling (a thermodynamic effect)

  - volume of air which moves to lower pressure (higher altitude) expands and cools;

  - volume of air which moves to higher pressure (lower altitude) compresses and warms

Temperature Changes:

- Warm air rises (less dense) and cools
- Similarly, cool air sinks (more dense) and warms

The Reason for Seasons:

Tilt of the Earth (results in less energy from the Sun per unit area hitting the Earth’s surface in winter and more in summer)

The tilt also causes significantly different length of day (hours with sunlight and therefore heating) during seasons

Time-lapse (about one hour) photograph from Earth (northern hemisphere) showing position of Polaris (“the North Star”) and other stars that *appear* to circle Polaris (actually due to Earth’s rotation)

Earth-Sun Relationships – The Reason for Seasons

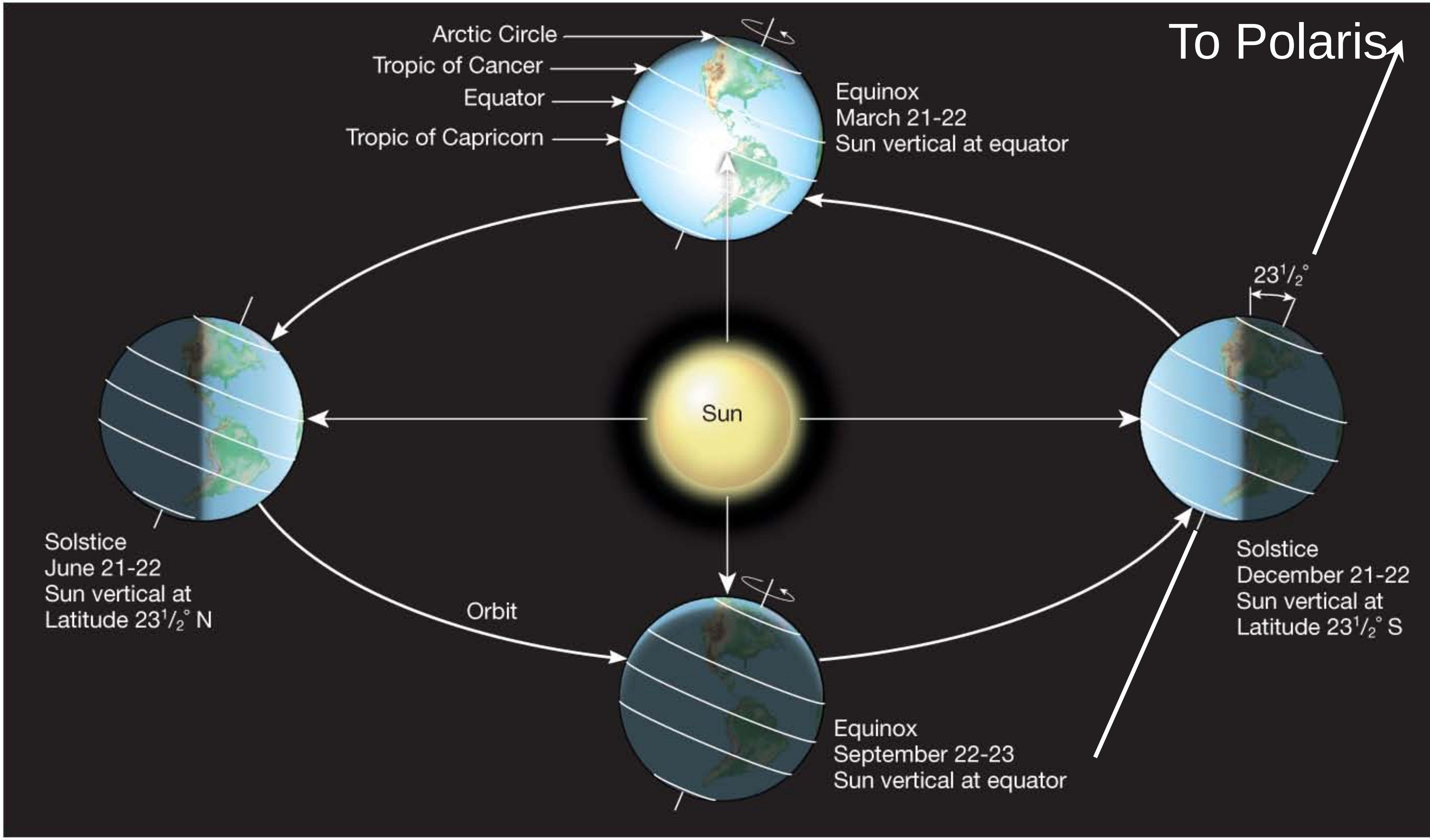


Figure 11.15, text

Area Covered by Different Sun Angles

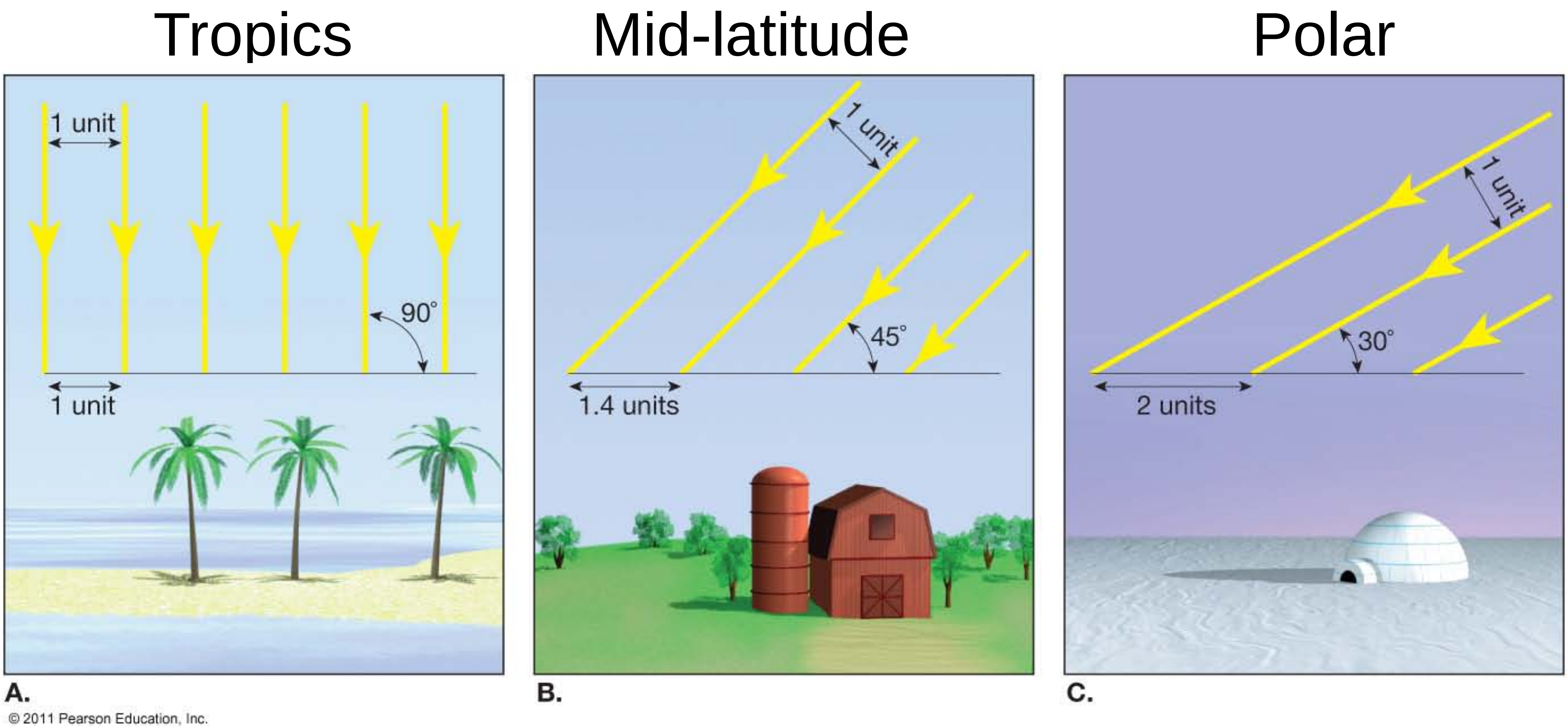


Figure 11.12. 11.13, text

Sun Angle vs. Depth Rays Must Travel through Atmosphere to Reach Earth's Surface

Figure depicts winter in the northern hemisphere. Note low angle of Sun in polar regions and distance that rays travel through the atmosphere (atmospheric thickness greatly exaggerated).

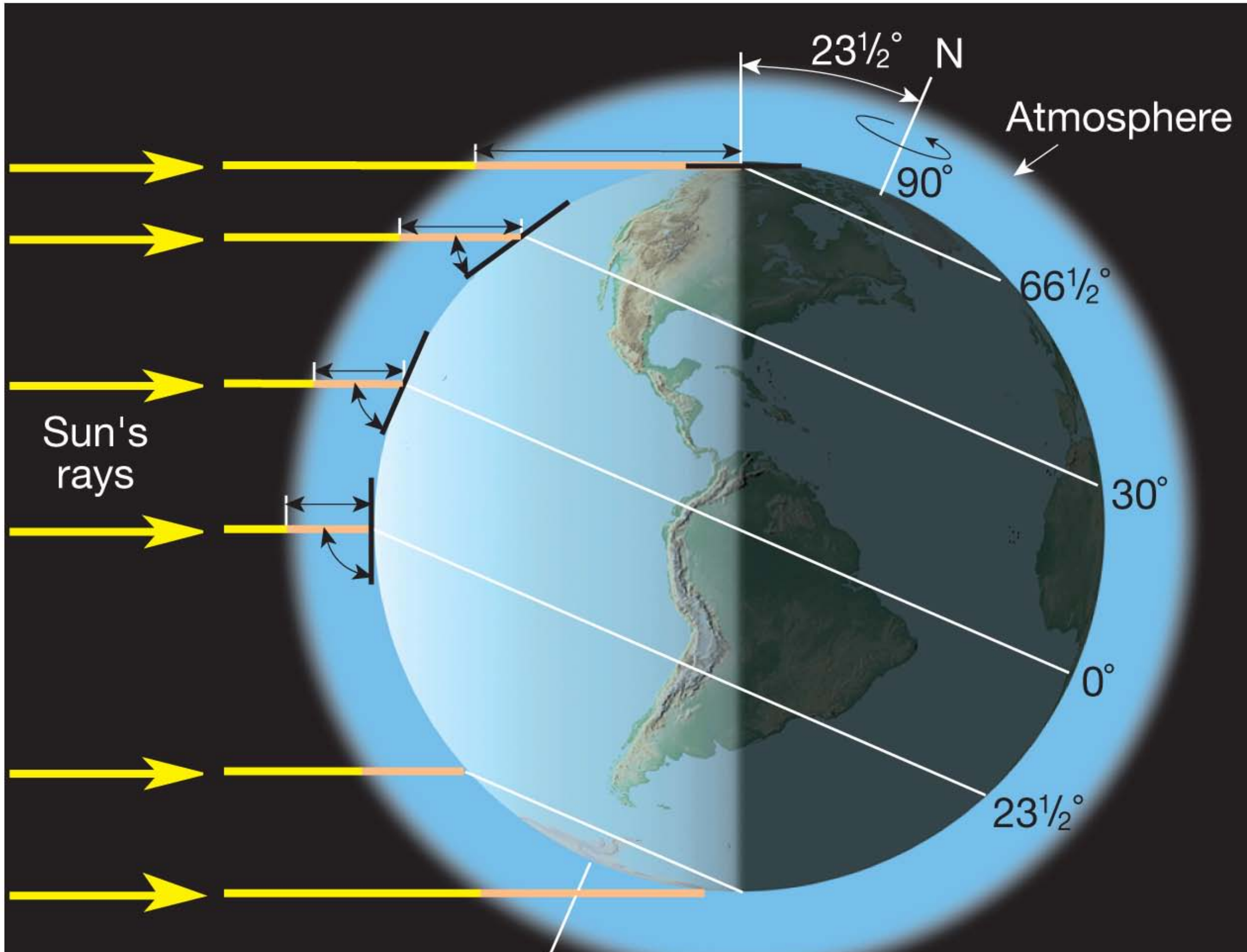


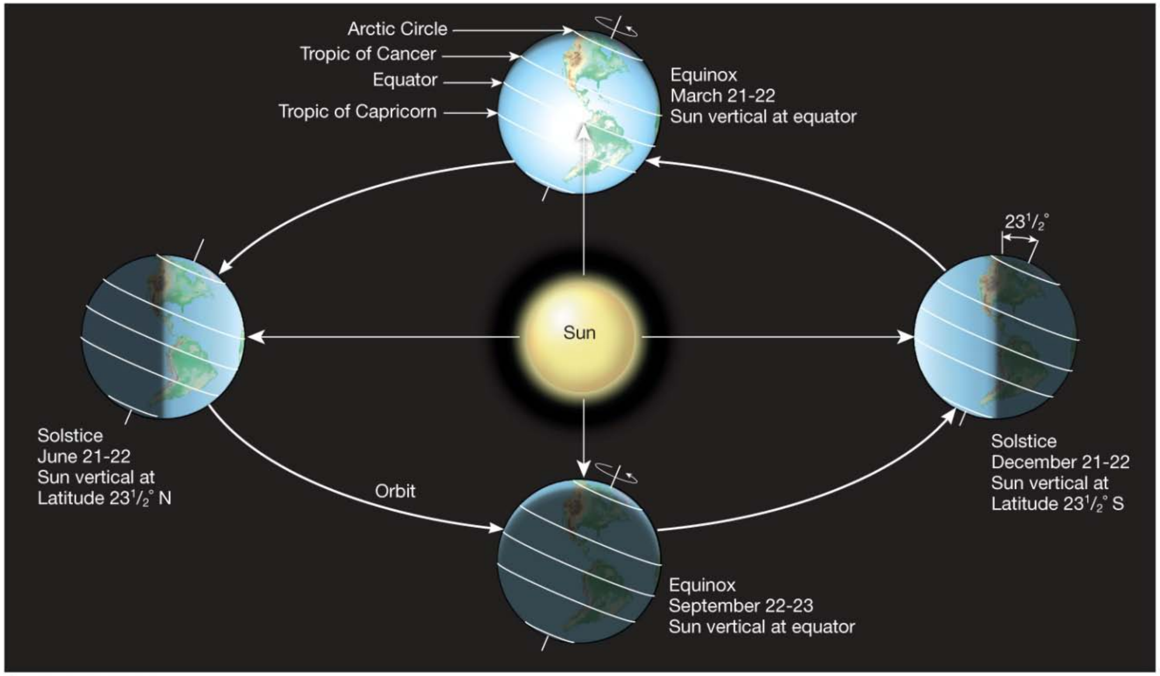
Figure 11.14, text

“Reasons for Seasons” – Earth and Sun orbit, tilt and Sun angle animations:

http://www.classzone.com/books/earth_science/terc/content/visualizations/es0408/es0408page01.cfm?chapter_no=04

http://www.mathsisfun.com/earth-orbit.html

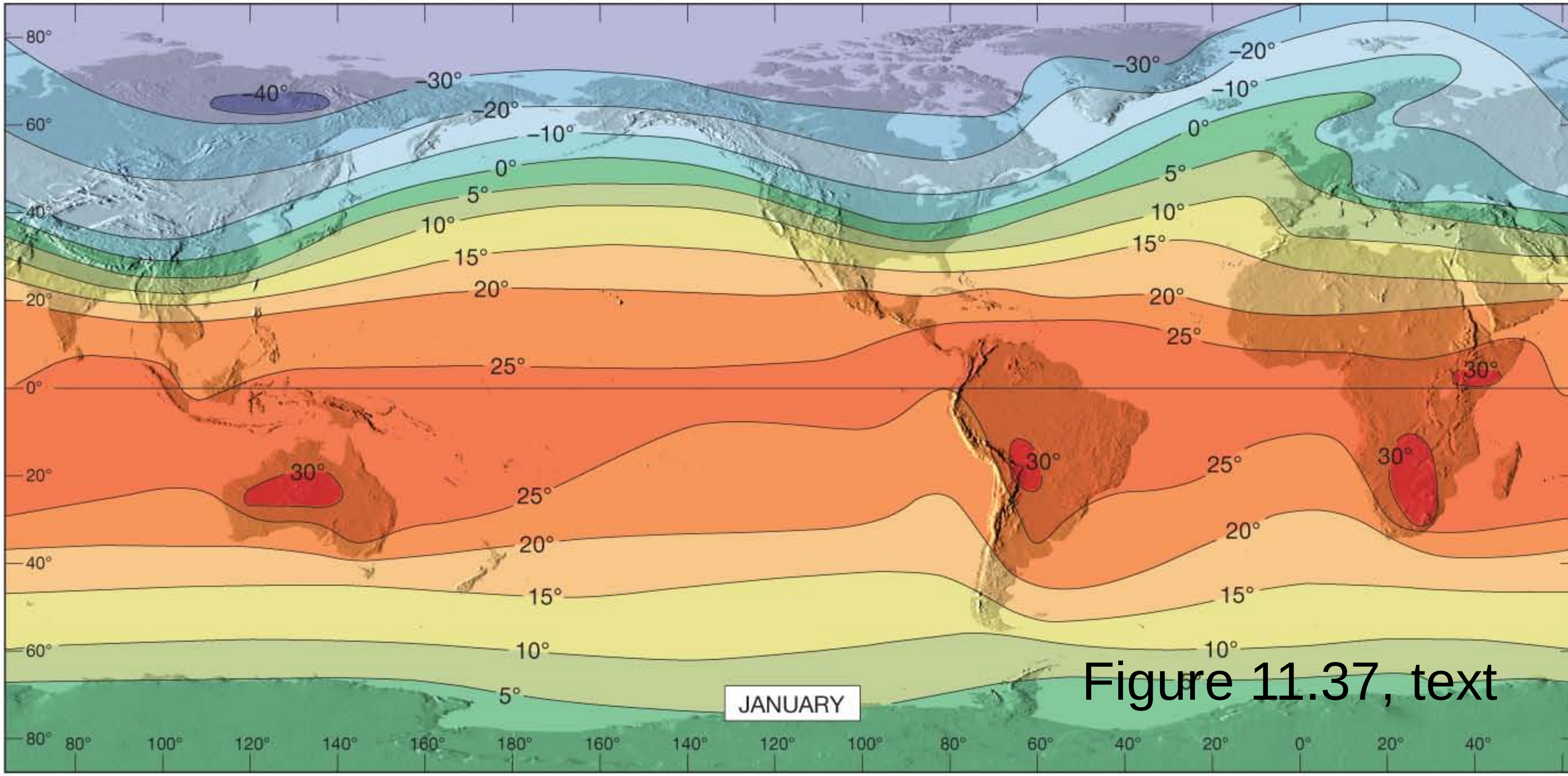
Reasons for Seasons - Summary



So, … ~23 degree tilt of the Earth causes:

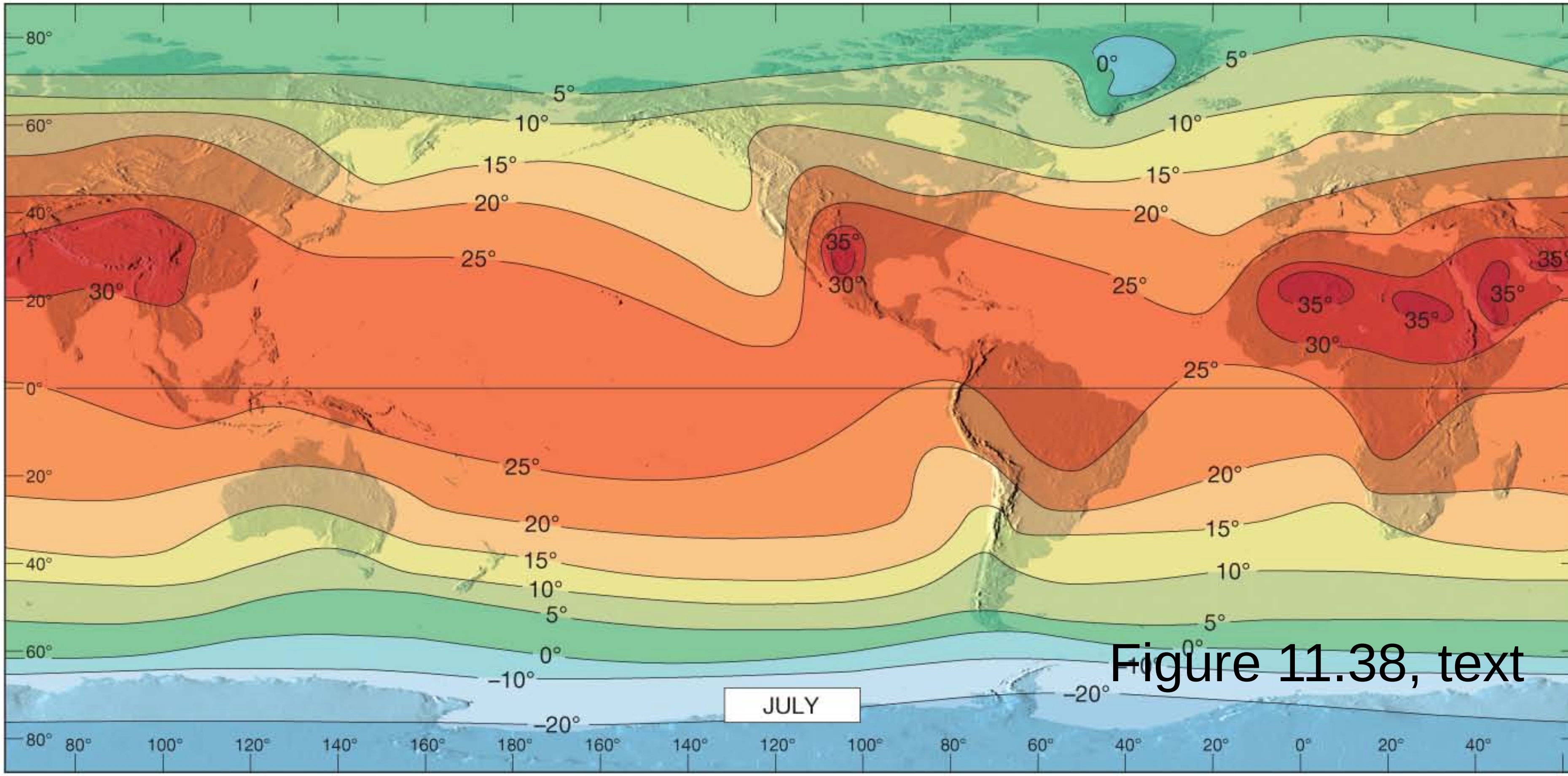
1. Variable heating dependent on latitude (more heating near equator than near poles), and dependent on season, because of angle of the Sun's rays hitting Earth.
2. Changes in length of day (versus night; winter versus summer).
3. More absorption and reflection of solar energy by the atmosphere in the polar regions because of the low angle of the Sun's rays.

Effects of Seasons and Latitude – World Distribution of Mean Temperature (Degrees C) - January



Note highest temperatures are south of the equator. Also note "moderation" of low temperatures in the N. Pacific and N. Atlantic areas due to exchange of heat from ocean.

Effects of Seasons and Latitude – World Distribution of Mean Temperature (Degrees C) - July



Note highest temperatures are north of the equator. Also note very cold temperatures in south polar region.

Climate (average or long term weather and atmospheric conditions – of Earth, region or specific location):

1. Classification (tropical, desert, alpine, etc.) - - Based on average temp. and precip.

2. Methods of climate study (climate change):
   - - Average weather statistics
   - - Paleo-records, infer temp.
     - ice cores (oxygen isotopes)
     - sediment cores (fossils, pollen)
   - - Numerical modeling of atmospheric circulation

3. Recent climate change

- - Last glaciation (max ≈ 18,000 years ago;

  ≈ 8°C cooler)

- - "Climatic Optimum" (≈ 6000 years ago;

  2 – 4°C warmer)

- - "Little Ice Age" (1500-1900;

  1 – 2°C cooler)

- - Since 1900 – Significant warming

4. Greenhouse Effect, greenhouse gasses, the importance of CO_2 in the atmosphere and human impact on climate

Causes of Climate Change:

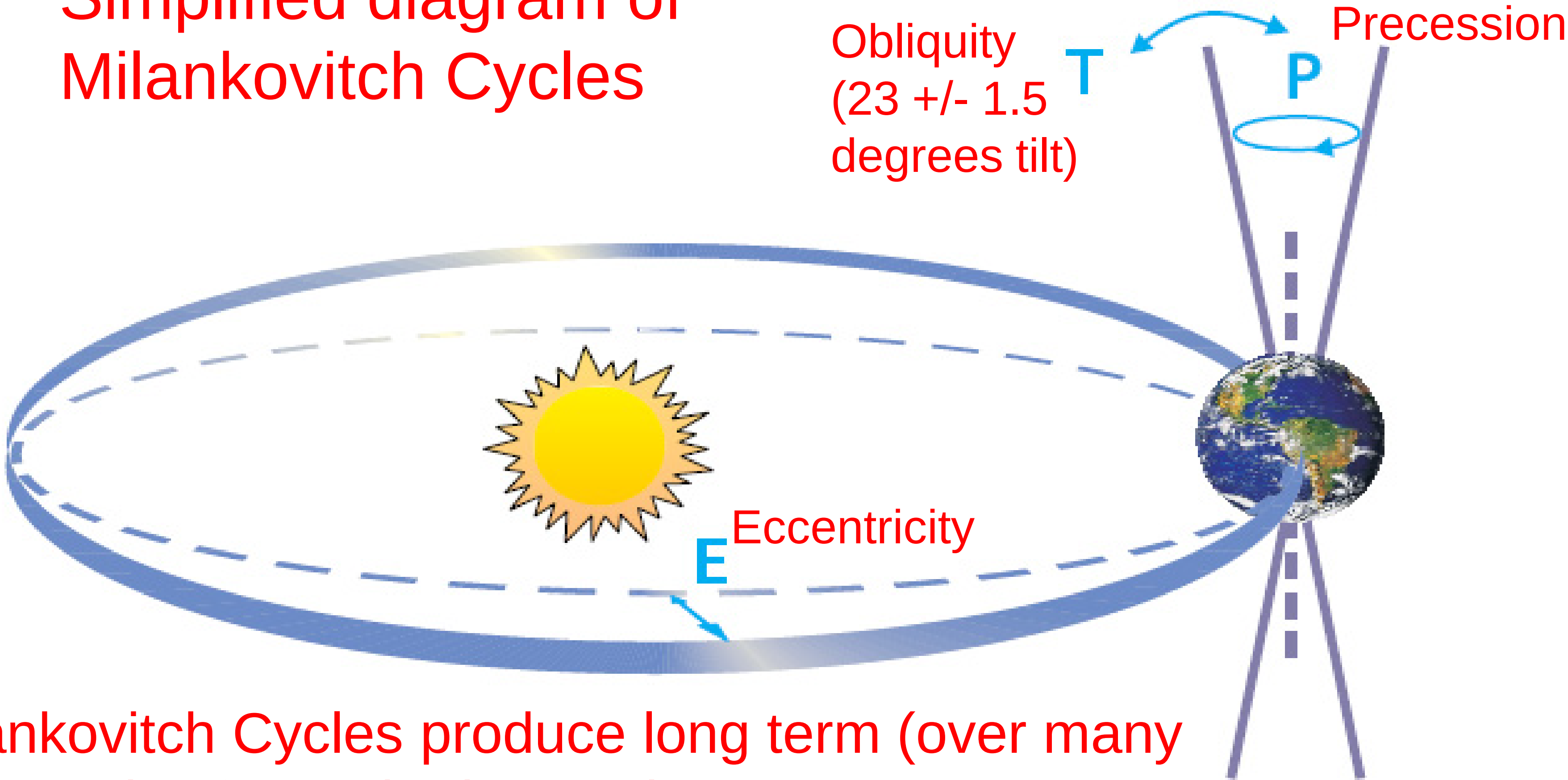
1. Astronomical effects (Milankovitch Cycles)- - Long-term changes in Earth's orbit produce small changes in solar heating at any location on Earth. (A natural phenomenon.)

2. Plate tectonics (continental drift - - **very** long-term changes) (A natural phenomenon.)

3. Changes in solar constant (the "solar constant" is not really a constant but a measure of energy output)? The total amount of solar energy (the solar constant) may change over long time periods or may vary periodically over shorter time periods. (A natural phenomenon.)

4. Periods of intense volcanism (ash and SO_2 in the atmosphere can reduce average temperature from the ash or increase the average temperature from the SO_2 – a greenhouse gas). (A natural phenomenon.)

Simplified diagram of Milankovitch Cycles

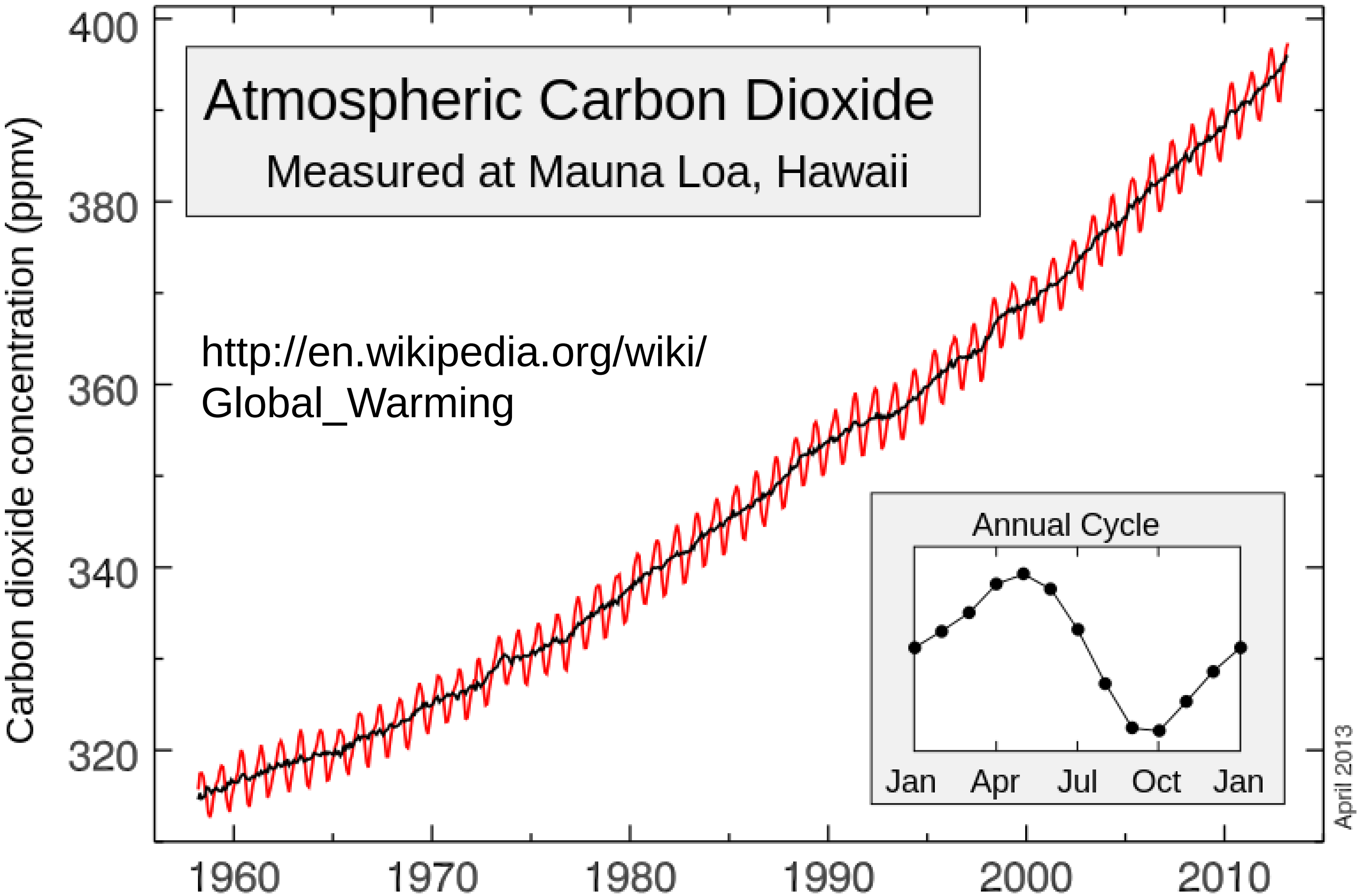


Milankovitch Cycles produce long term (over many thousands of years) climate change.

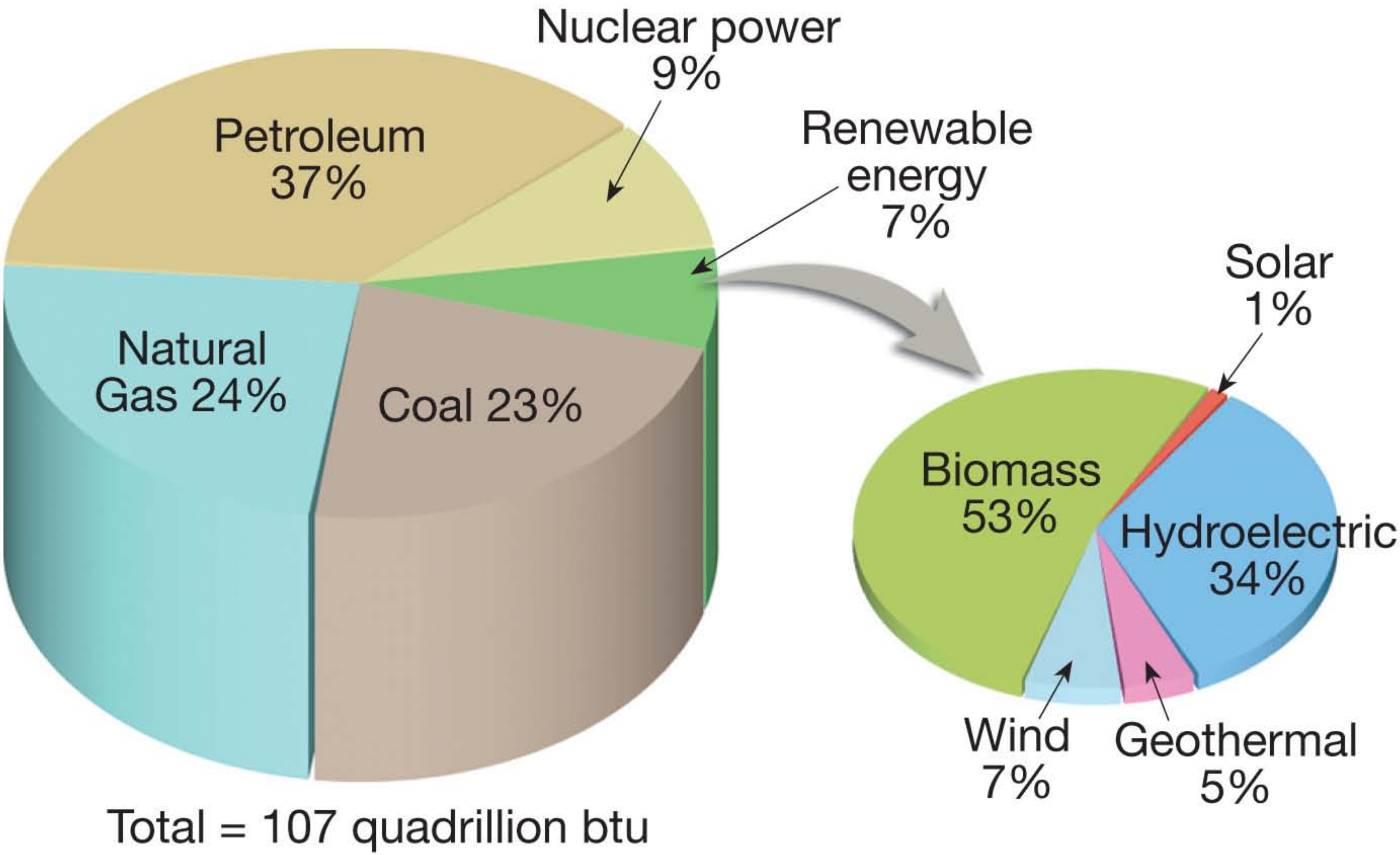
Milankovitch Cycles. *Schematic of the Earth's orbital changes (Milankovitch cycles) that drive the ice age cycles. 'T' denotes changes in the tilt (or obliquity) of the Earth's axis, 'E' denotes changes in the eccentricity of the orbit (due to variations in the minor axis of the ellipse), and 'P' denotes precession, that is, changes in the direction of the axis tilt at a given point of the orbit. Source: Rahmstorf and Schellnhuber (2006).*

http://www.global-greenhouse-warming.com/Milankovitch-cycles.html

5. CO_2 (and other greenhouse gases) increases and greenhouse effect. There has been a rapid increase in greenhouse gases in the past century due to burning of fossil fuels and other industrial processes. (Primarily a human-caused phenomenon.)

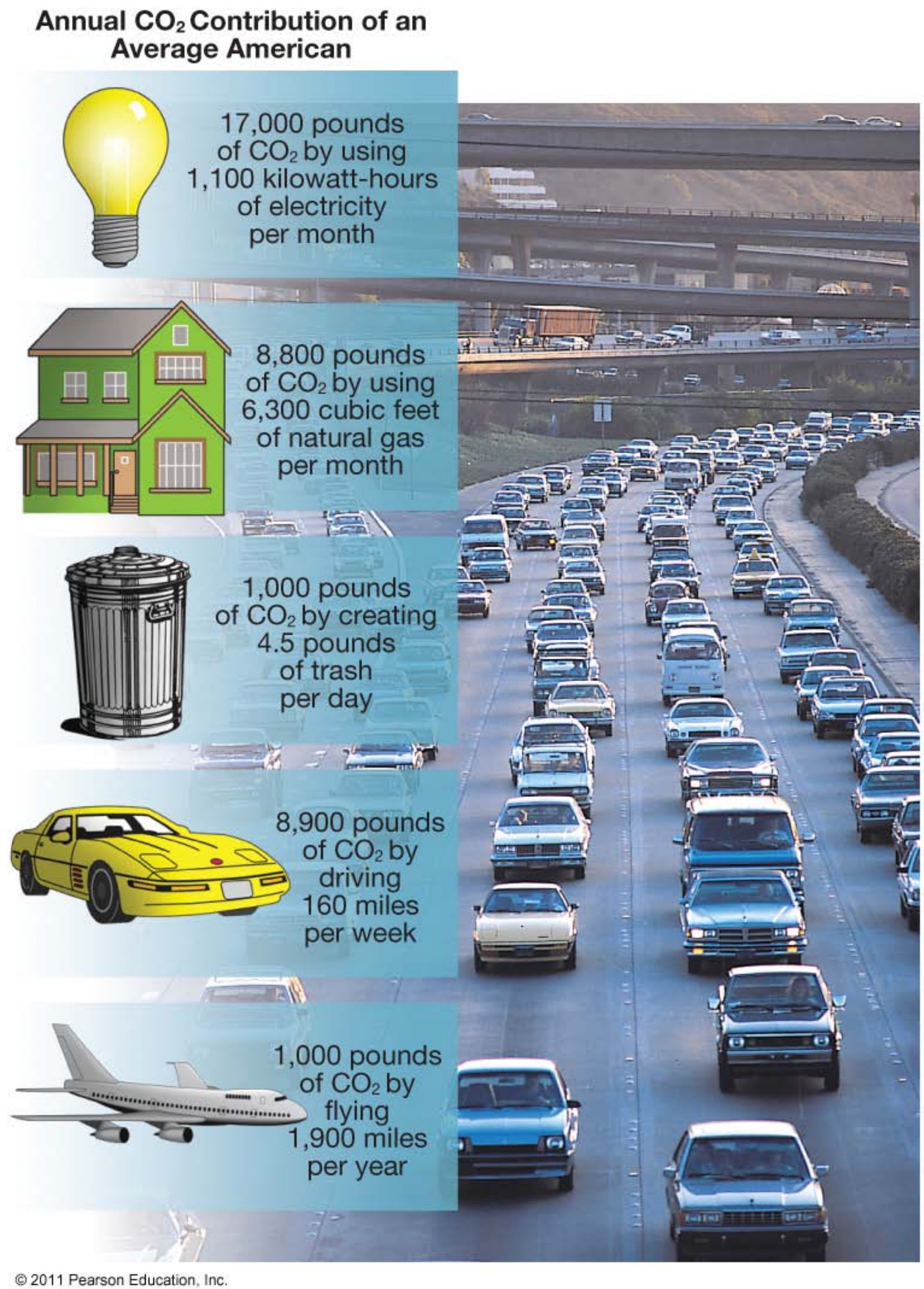


U.S. Energy Consumption – 2008, 84% Fossil Fuels (CO_2 Emissions)



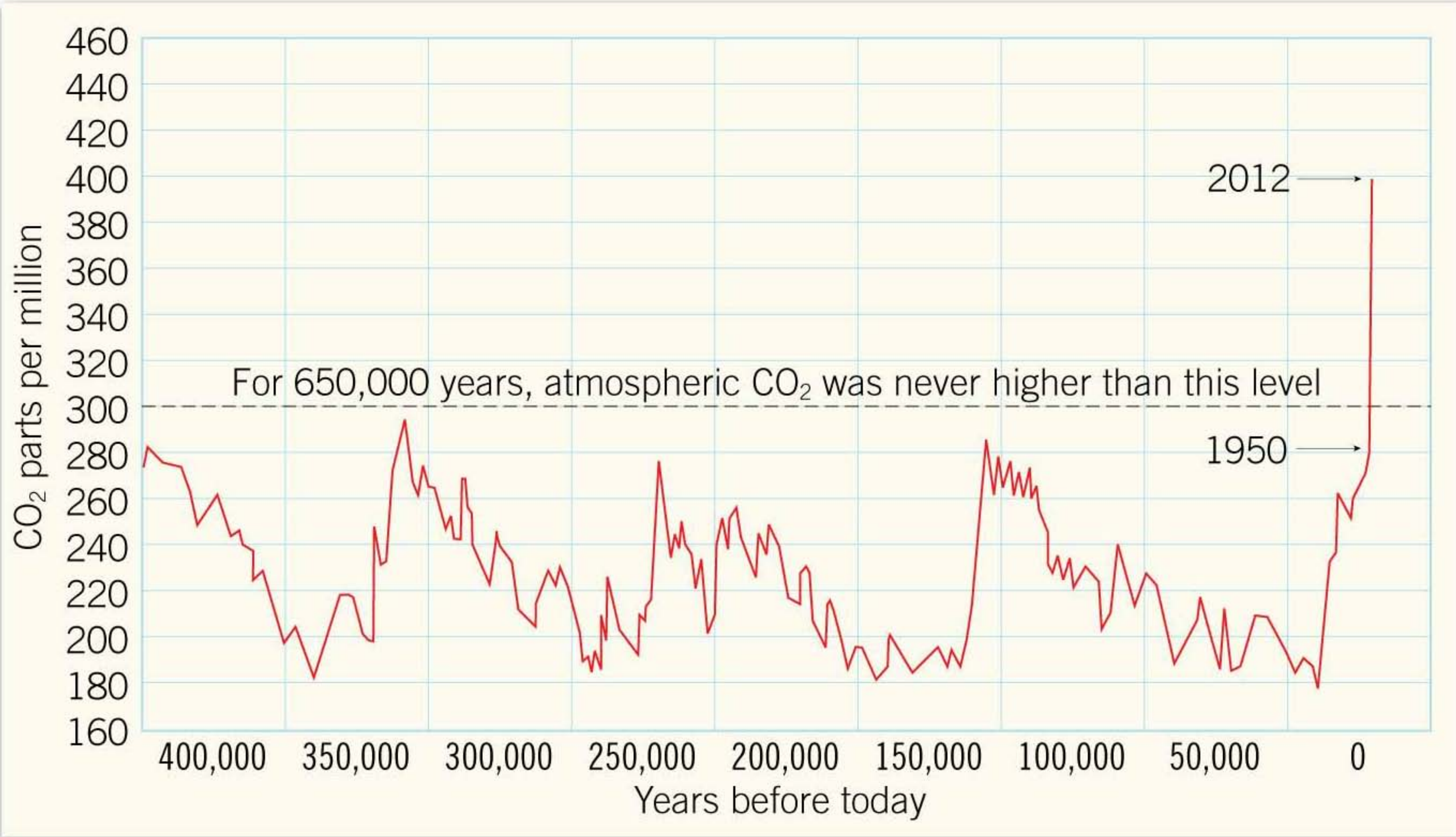
(World Energy Consumption ~95% Fossil Fuels), Figure 11.24, text

U.S. CO_2 Production – mostly from burning of Fossil Fuels (CO_2 Emissions), U.S. contributes about 15% of the world's greenhouse gas emissions! (It was 25% just a decade ago.)

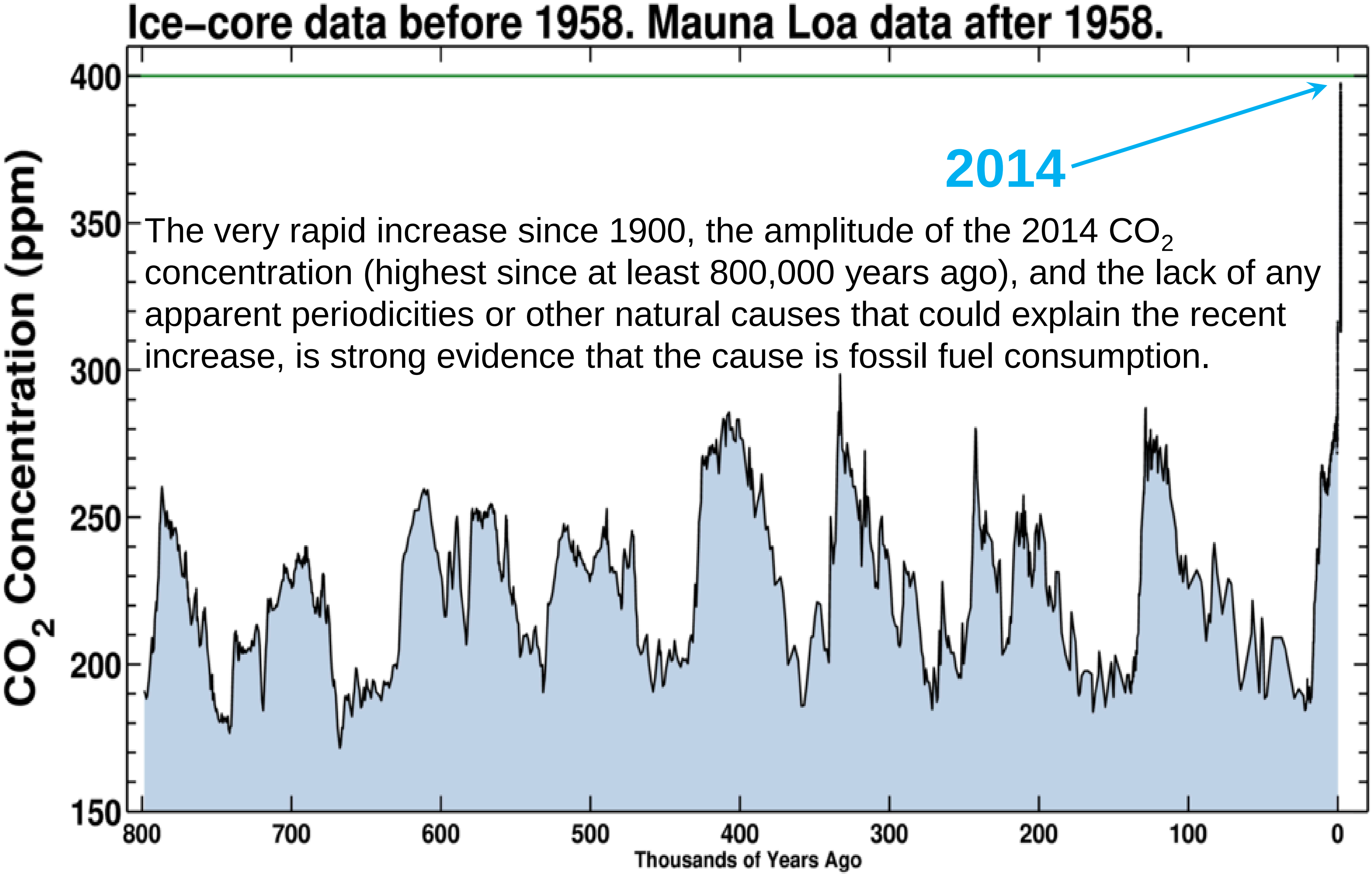


U.S. annual per capita CO_2 production (Figure 11.27, text)

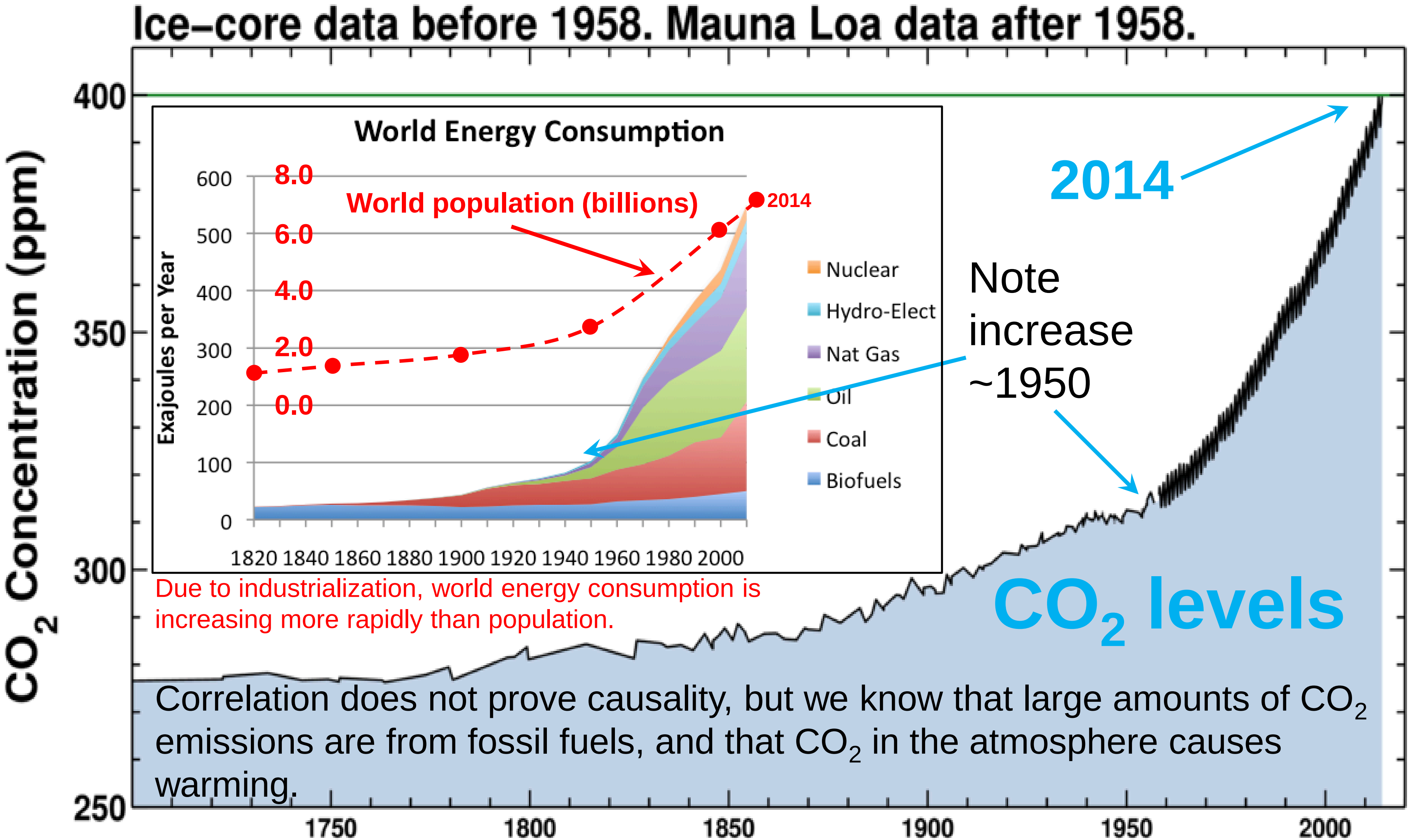
Global CO_2 (ppm) – past 450,00 Years



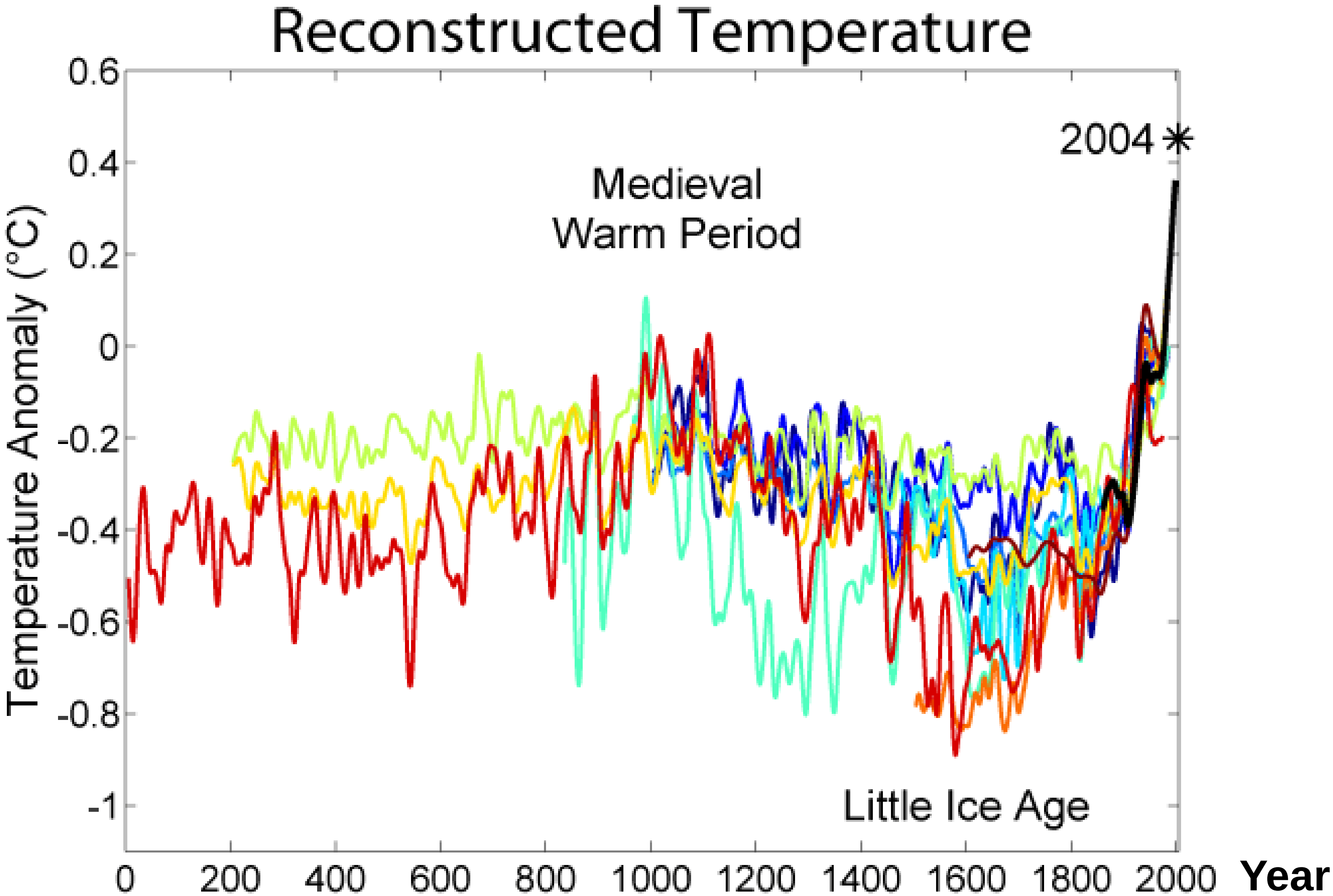
Data from Ice Cores, Mauna Loa Observations from 1958, Figure 11.26, text



Last 800,000 years of CO_2 levels in the atmosphere (Scripps, http://keelingcurve.ucsd.edu/)



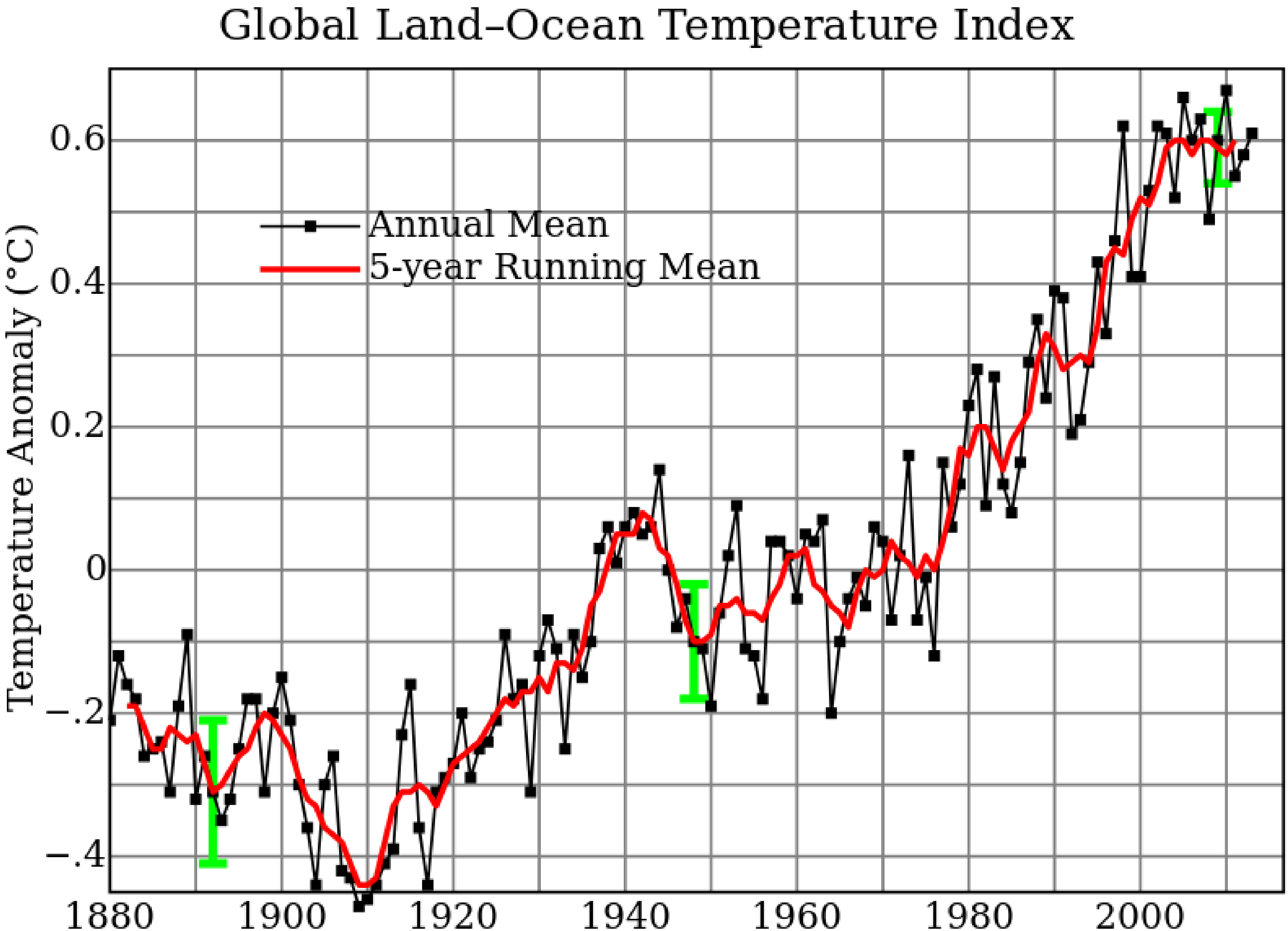
1700 to present - CO_2 levels in the atmosphere (Scripps, http://keelingcurve.ucsd.edu/) (World Energy: http://ourfiniteworld.com/2012/03/12/world-energy-consumption-since-1820-in-charts/)



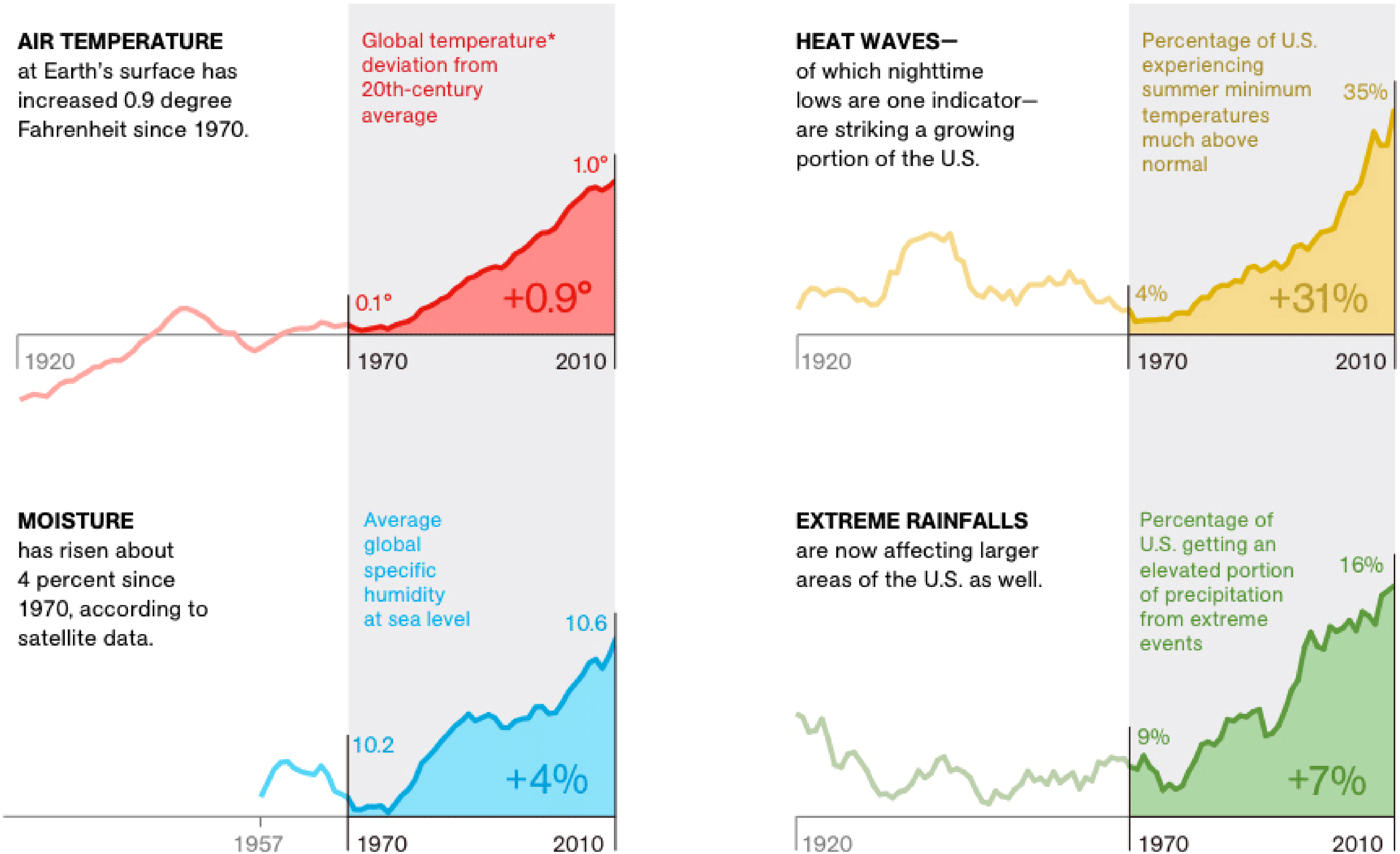
Two millennia of mean surface temperatures according to different reconstructions, each smoothed on a decadal scale. The unsmoothed, annual value for 2004 is also plotted for reference.

http://en.wikipedia.org/wiki/Global_warming

Recent Global Temperature Change



http://en.wikipedia.org/wiki/Global_warming



Data on recent climate change (National Geographic, September, 2012). There is some evidence that climate change results in an increase in the number of extreme events and the intensity of those events.