Special Topics of Climate Change: Glaciers and Hazards

Dr. Brandon J. Weihs, PhD

View from inside Matanuska Glacier, AK

Matanuska Glacier, Alaska

Matanuska Glacier

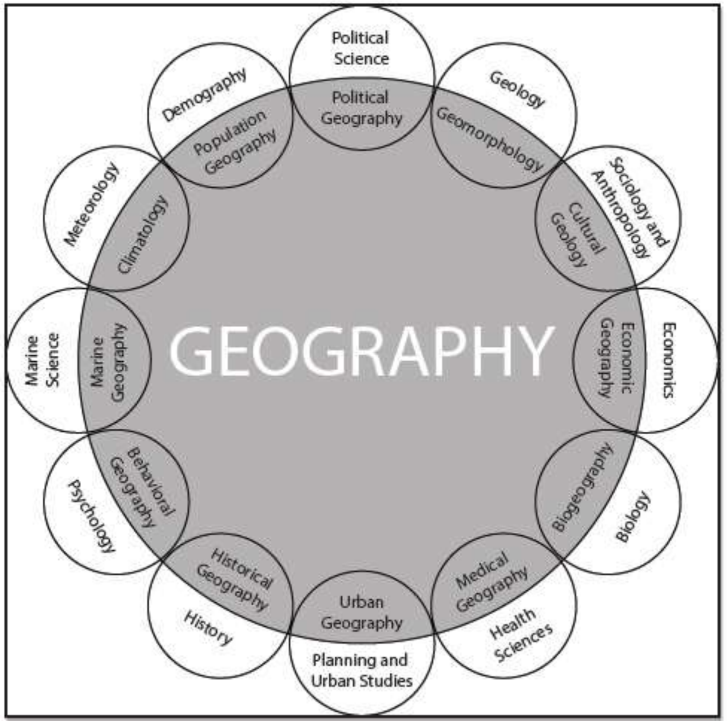
- As you can see, glaciers are not flat blocks of ice.
  - The have rock, and debris, and water around (peri-glacial), in (en-glacial), on (supra-glacial), and under them (sub-glacial).
  - Glaciers are dynamic, and constantly changing because they are flowing, some are much like a river of ice.
  - The light filtering effect of water (ice) causes that classic glacier-blue color. It’s the same reason the sky or a lake is blue: light is being filtered by water.
    - Conversely, sunsets are often red, orange, and/or yellow because of atmospheric dust (basically a red/brown filter)

Dr. Brandon J. Weihs?

- PhD in Geography and Geospatial Science
  - M.A. in Geography
  - B.S. in Geography

- I’m a Geomorphologist

- Geomorphology
  - Study of landforms and their genesis and changes
    - “Geo” = Earth
    - “morph” = change
    - “ology” = study of
  - Earth surface processes
    - Wind (aeolian geomorphology)
    - Water (fluvial geomorphology)
    - Ice (glacial geomorphology)
    - Animals (zoogeomorphology)
    - Plants (phytogeomorphology)
    - Etcetera…………



From alg.manifoldapp.org

- I also study plant genetics (*Medicago sativa* L. ~ alfalfa) at the USDA
  - Using and AI and Computer Vision

- FAA licensed sUAS (drone) pilot

Other Research Topics of Mine

- Plant genetics and phenology using Artificial Intelligence and hyperspectral imagery
  - Alfalfa
- Loess – the soil we have here
- Mountain Geomorphology
- Mass Movements (landslides)
- Glaciers and their valleys
- Streams and rivers
- Disturbances (mass movements, dams, fires, etc.)
- Dendrochronology – tree ring dating
- Animals
- Plants
- Water resources
- Water/soil pollution
- Medical Geography
  - Mapping disease
- Cartography
- Remote Sensing
- Geographical Information Systems/Science (GIS, GISc)
- Climate & Climate Changes
- Geoarchaeology
- Small unoccupied aerial systems (sUAS)

I teach Environmental Geology at UNO

Yellowstone River Upper Falls

What is Environmental Geology?

Earth’s impact on humans AND Human’s impact on Earth

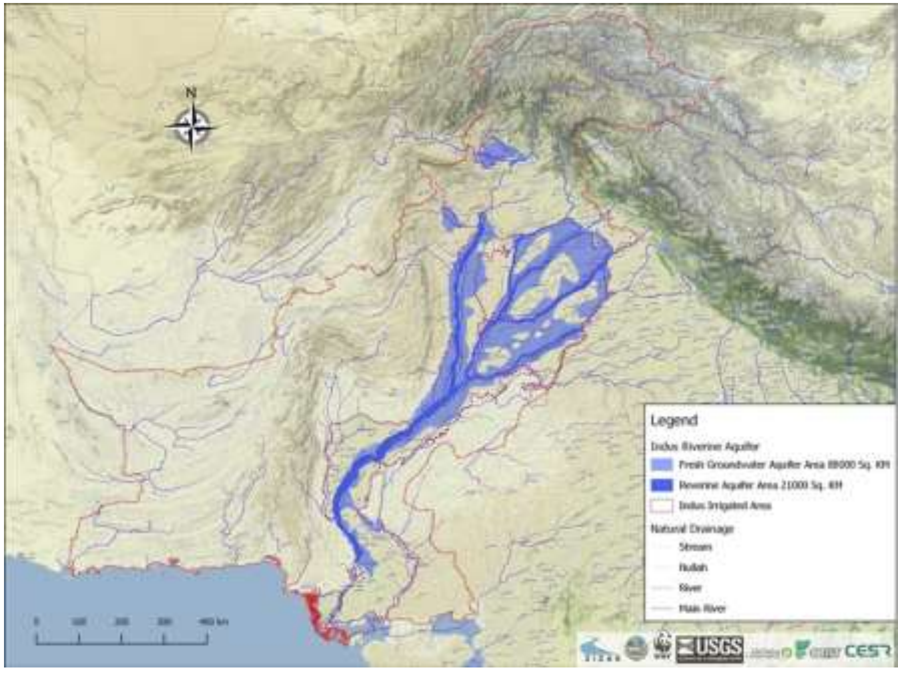
Teton Range, WY

Pakistan’s Water Resources…

- Most of Pakistan’s fresh water comes from glaciers.
  - Delivered from the Himalayan Range to major rivers, such as the Swat, Hunza, Jheum, Chenab, Sutlej, and Indus Rivers.
  - If glaciers completely melt, Pakistan’s water situation will become dire…
    - Glaciers take 100s (alpine) to 100,000s (Antarctic) of years to accumulate…

- Groundwater / Aquifers
  - Becoming more and more polluted in urban areas…

- Rainwater
  - Becoming less predictable deliveries as climate changes.



Hydrosphere Reservoirs

- <1% of water on Earth is liquid freshwater, mostly groundwater. Surface freshwater available for human use amounts to only ~ **3/10,000 of Earth's total water**.
- The hydrosphere contains a tremendous amount of water—about 1360 million km^3 (326 million mi^3)—would cover the entire U.S. to depth of 145 km (90 mi) or equivalent to 171 million gallons of water per person on Earth. A problem is that 97.2% is ocean water, which is too salty to drink or grow crops with. Just 2.8% is freshwater (including ice).

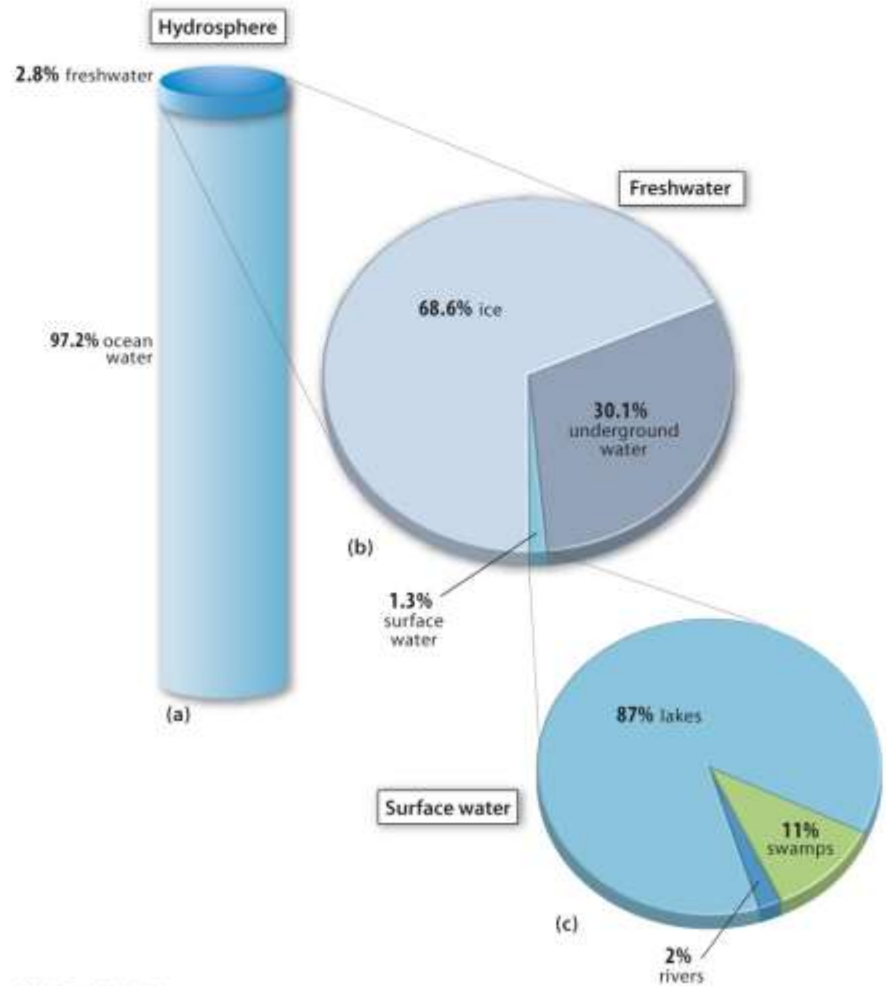
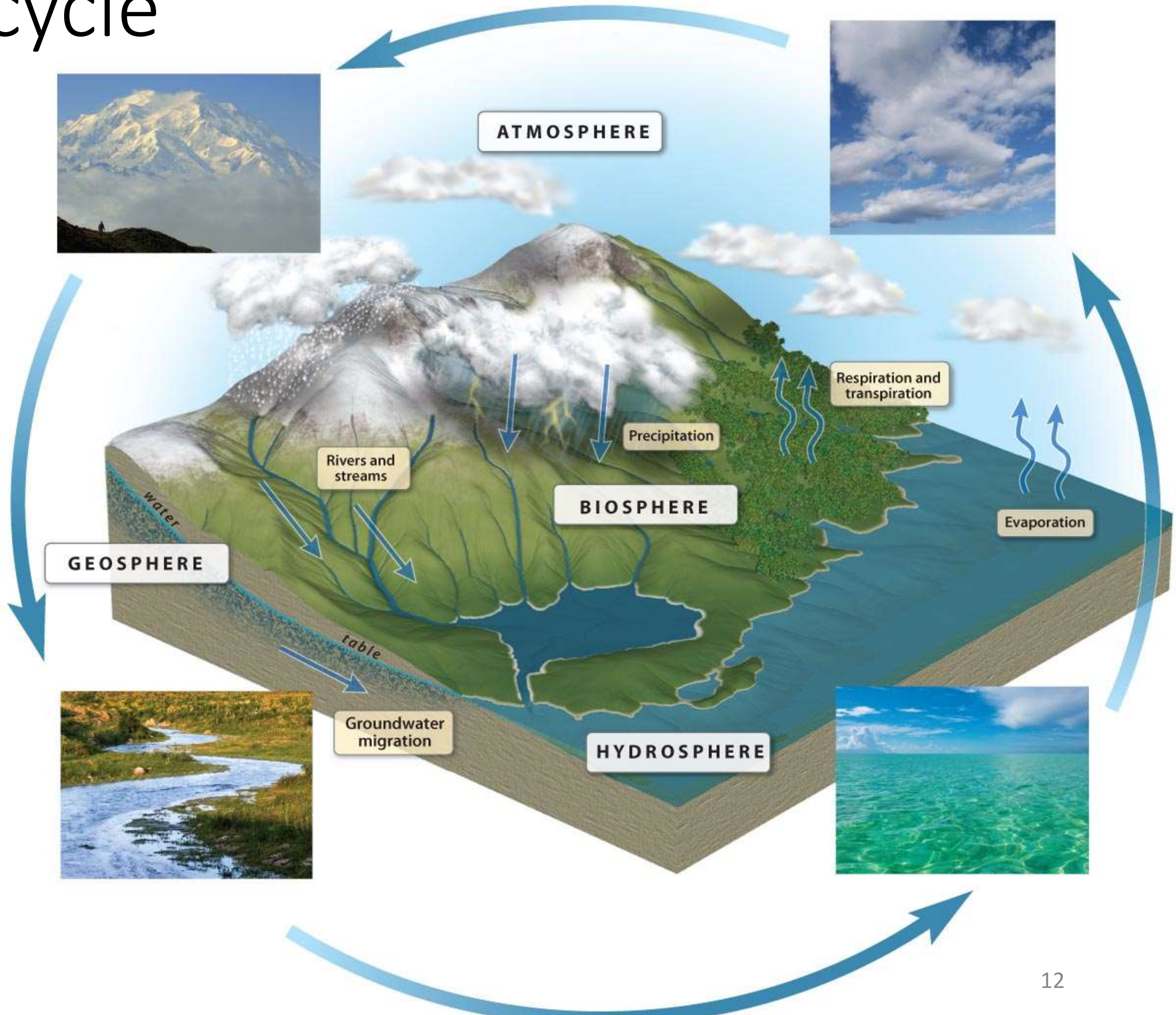


Figure 10-3 Major Hydrosphere Reservoirs

Indus River Valley – Northern Pakistan

Water cycle



ATMOSPHERE
Respiration and transpiration
Precipitation
Rivers and streams
BIOSPHERE
Evaporation
water table
GEOSPHERE
Groundwater migration
HYDROSPHERE

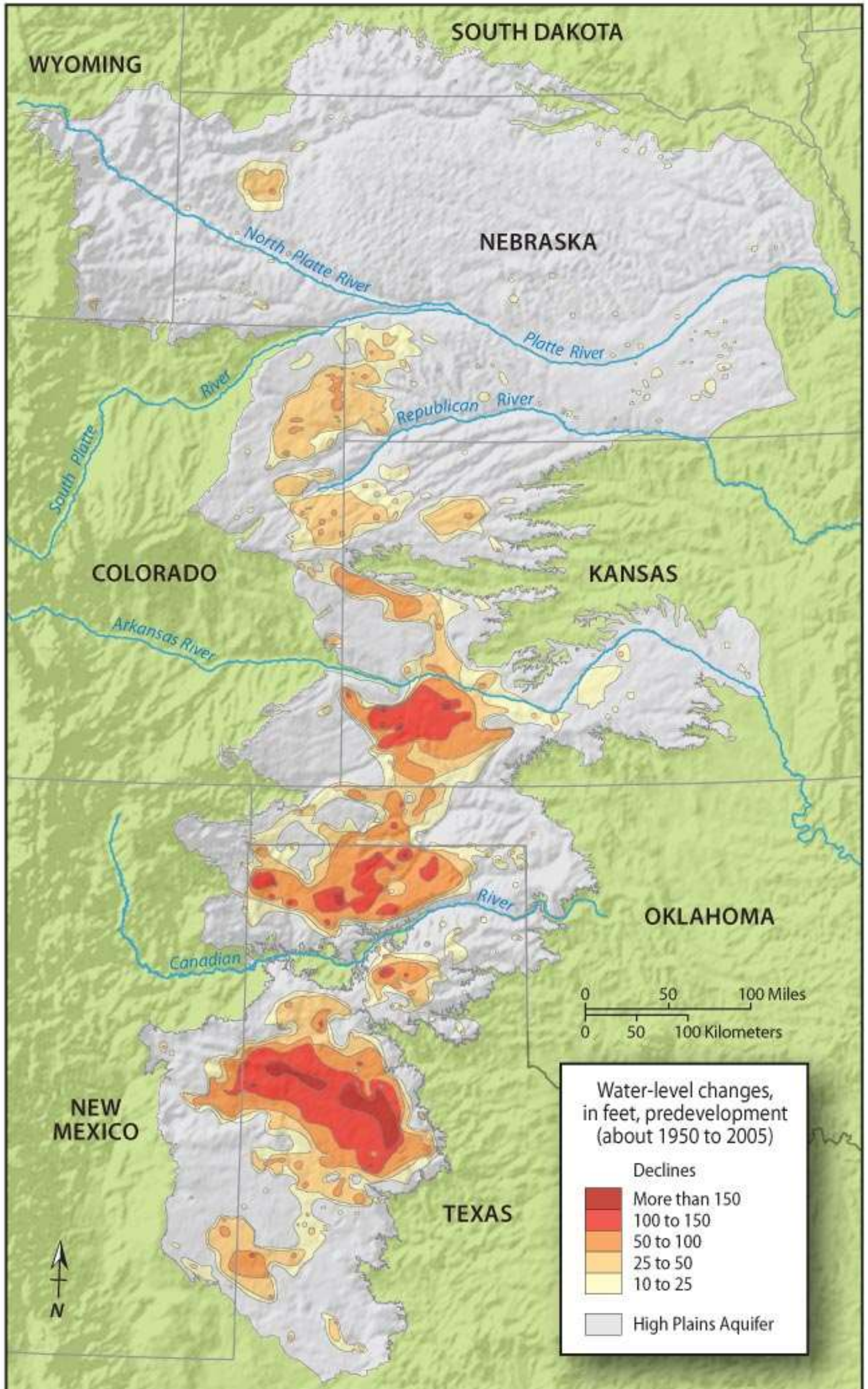
The Water Cycle Reservoirs

- One of the shortest paths possible is evaporation from the ocean, then precipitation back into the ocean.

- One of the oldest possible paths is precipitation as snow onto a glacier.
  - Antarctic ice has been dated at ~800,000 years old.

- Ground water can stay underground indefinitely as well (billions of years). It can take 1000's of years for surface water to reach aquifers. Once in the aquifer, it remains relatively unaltered, except by humans.

- Surface water is one of the smaller reservoirs and has the shortest residency time for water due to evaporation.



Great Plains Aquifer—the Ogallala

Figure 10-9 The High Plains Aquifer

- Groundwater withdrawal from this unconfined aquifer has lowered the water table over 46 m (150 ft) in places (red areas on map).
- One of the largest aquifers on Earth.
- Unconfined

Why is groundwater being pumped so heavily here in the Southern High Plains? Because they are growing water-intensive crops like cotton there.
Question: If we are going to use water to grow crops in an arid place like this, shouldn't we at least be making food?

Causes of Climate Changes:

- Solar insulation
  - Changes in Earth’s orbit
    - Tilt
    - Eccentricity
    - Precession
  - Combined effects produce Milankovitch Cycles
- Greenhouse effect
  - Trapped heat via the conversion of UV radiation into LW radiation (heat)

Composition of the Atmosphere

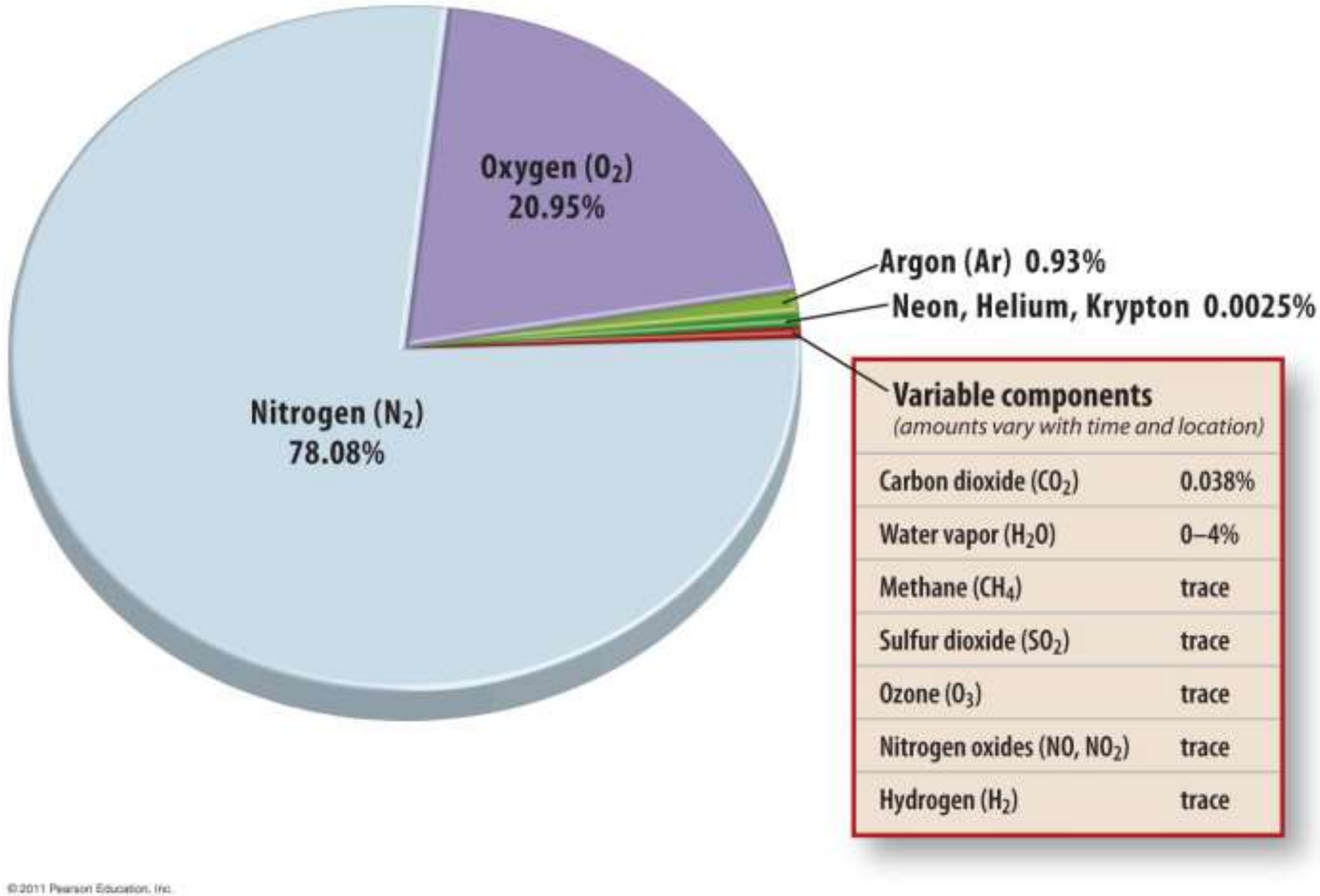


FIGURE 14-2 Composition of the Atmosphere, Including Variable Components (by Volume) [Interactive Periodic Table]

Composition of Atmosphere (cont.)

- Three elements (N, O, Ar)—make up over 99.9% of the atmosphere

- Pure **nitrogen** (N_2) is used in its very cold, liquid state
  - Instantly freezes biological specimens
  - Nonreactive; used to purge vessels of reactive gases like oxygen
  - Prevents food spoilage, and refrigerate perishables during shipping
  - Prevents corrosion of metal surfaces

- Pure **oxygen** (O_2)—is used in iron and steel smelting
  - Cutting and welding torches to achieve higher temperatures
  - Oxidizing agent in processes that produce a variety of chemicals
  - Increases the efficiency of waste incinerators
  - Medical applications

Composition of Atmosphere (cont.)

- **Argon** (Ar)—is a colorless, odorless, nontoxic, and nonreactive gas
  - Creates inert environments for growing crystals—in semiconductors
  - Protects materials against corrosion
  - Fills the air space in double-pane insulating windows
  - The gas in incandescent and fluorescent lightbulbs.

- **Water vapor**, **methane**, **carbon dioxide**—greenhouse gases
  - Keep Earth's climate from being unbearably cold

The Atmosphere Screens Earth from Harmful Solar Radiation

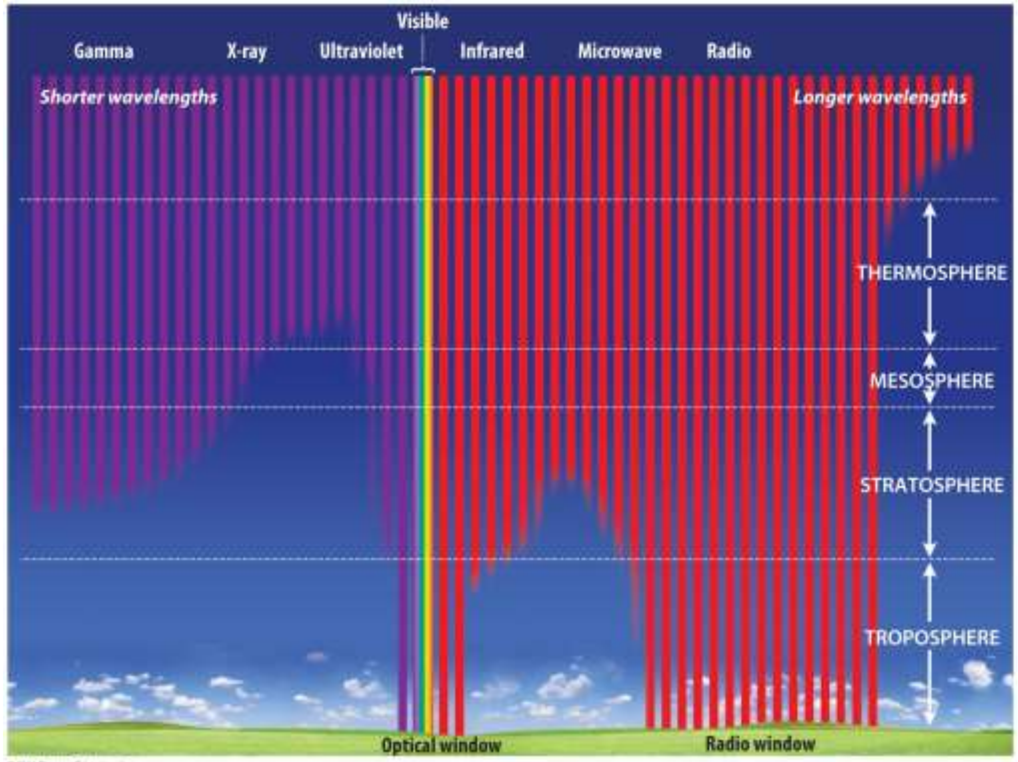


FIGURE 14-4 The Atmosphere Screens Earth from Harmful Solar Radiation
Shorter wavelength gamma and X-ray radiation and large amounts of infrared radiation are completely absorbed by the atmosphere. The ozone layer absorbs the most harmful ultraviolet wavelengths. Only radio waves, visible light, and some ultraviolet radiation reach Earth's surface relatively unimpeded. It should be clear why humans see in the "visible" spectrum…our eyes evolved to detect the optical window wavelengths!

The Greenhouse Effect

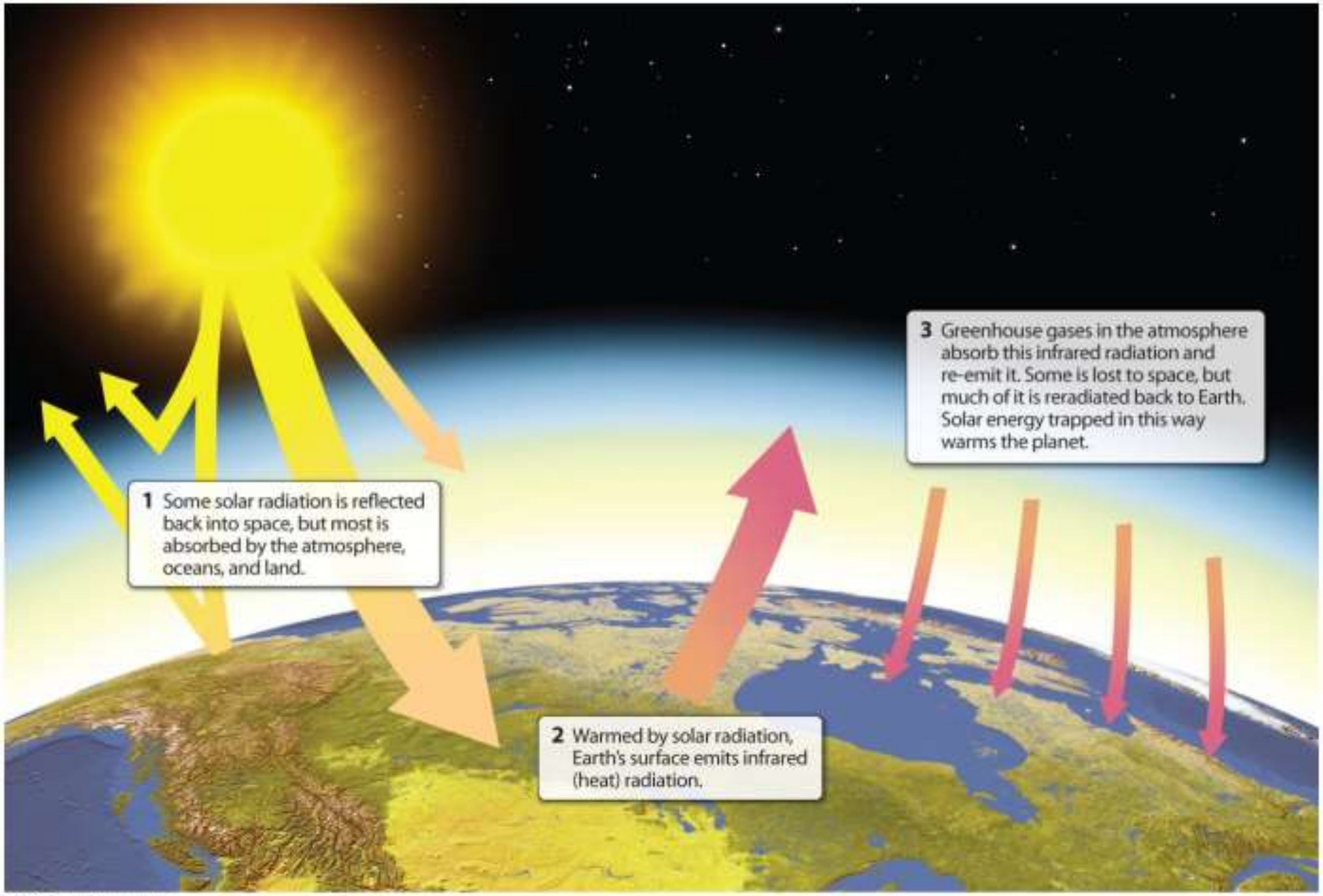


FIGURE 14-18 The Greenhouse Effect
Solar radiation reflected or reradiated by Earth's surface is absorbed by greenhouse gases and warms the atmosphere. The warmed atmosphere reemits radiation back to Earth, causing surface warming.

Atmosphere and Climate Change

- Earth's climate is strongly influenced (*forced*) by:
  1) **atmosphere composition**; 2) **solar radiation Earth receives**
- **Composition—greenhouse gases**
  - Let shorter-wavelength incoming sunlight through to Earth's surface
  - Warm the ground, the ocean, and lower regions of the atmosphere
  - Reradiate some of their heat energy back at longer wavelengths
  - Infrared wavelengths are absorbed by greenhouse gases
  - Trapping energy in the atmosphere
  - Part of this trapped energy is, in turn, reradiated back to Earth

Atmosphere and Climate Change (cont.)

- This trapping of heat in the atmosphere is often likened to the effect of glass in a greenhouse—hence the term **greenhouse effect.**

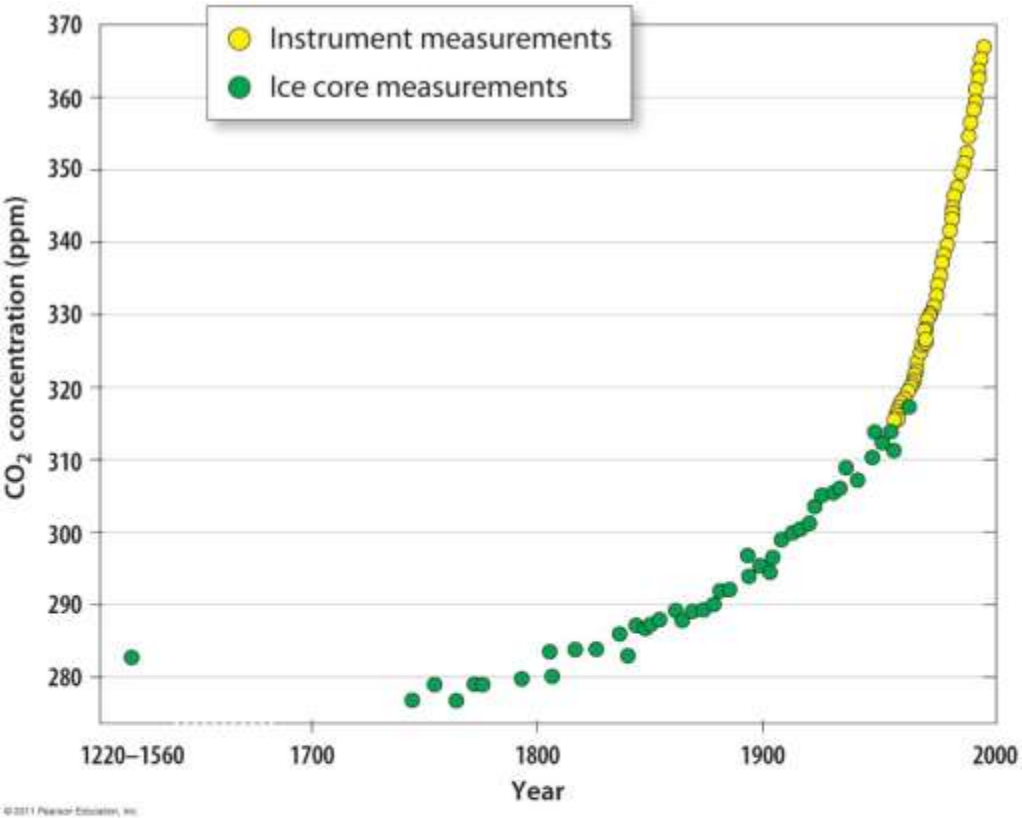
- This greenhouse effect keeps Earth's surface habitable
  - We need it…in the right amounts…

- CO_2—low warming potential—very abundant, hence important
  - Human activities make lots of CO_2 …

- Methane—56x warming potential of CO_2—not abundant
  - Human activities make lots of methane…

- Nitrous oxide—280 warming potential of CO_2—not abundant
  - Human activities make lots of NOx…

- Water vapor is a very potent greenhouse gas too—temperature-dependent
  - Humans can add water vapor to atmosphere and effect incoming radiation (contrails cause cooling…noticeable warming during ground stops post 9-11-2001 for example)



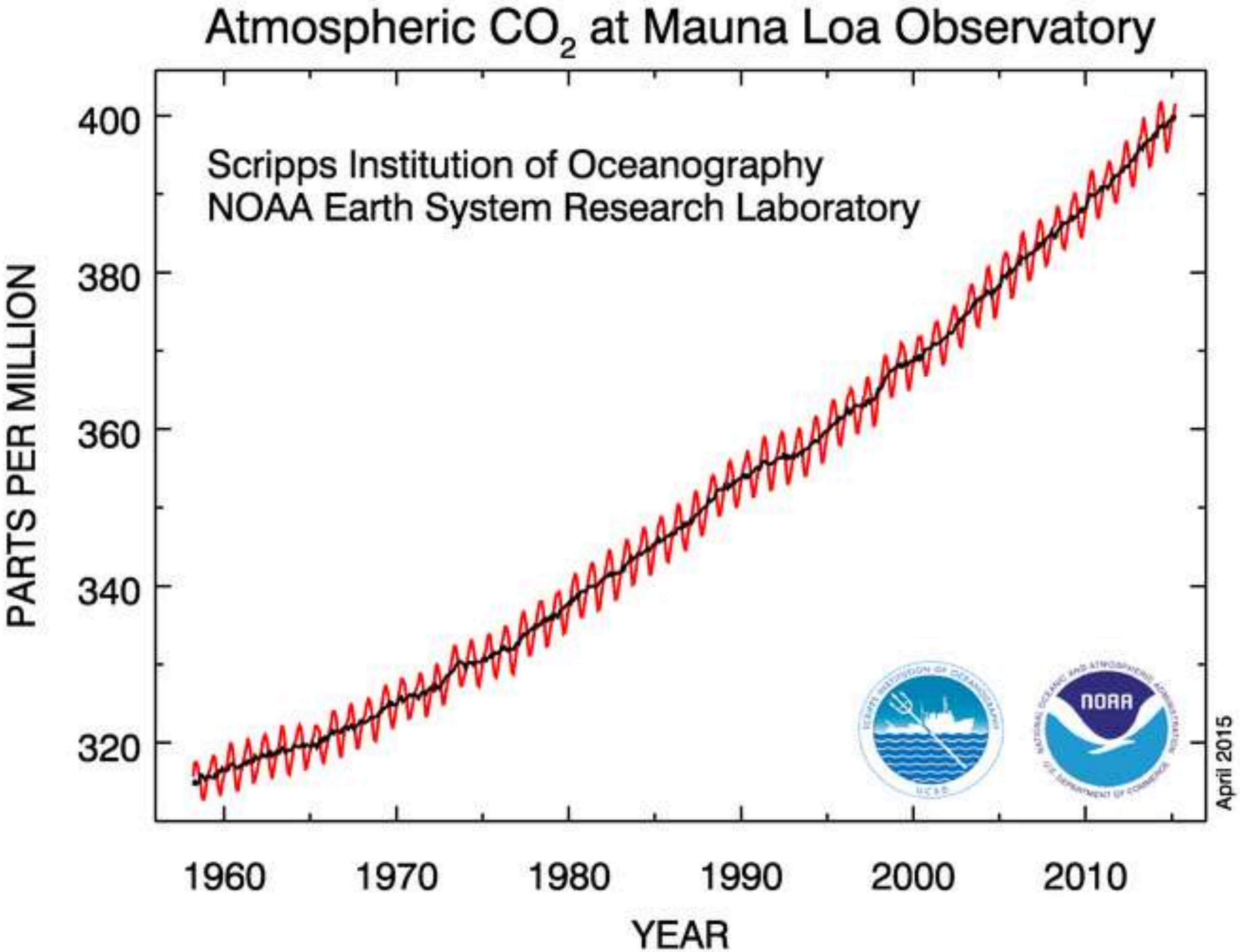
We Are in a "NO ANALOG CO_2 WORLD"

Meaning we have never seen levels this high, and cannot use past data to interpolate/predict the consequences with certainty…

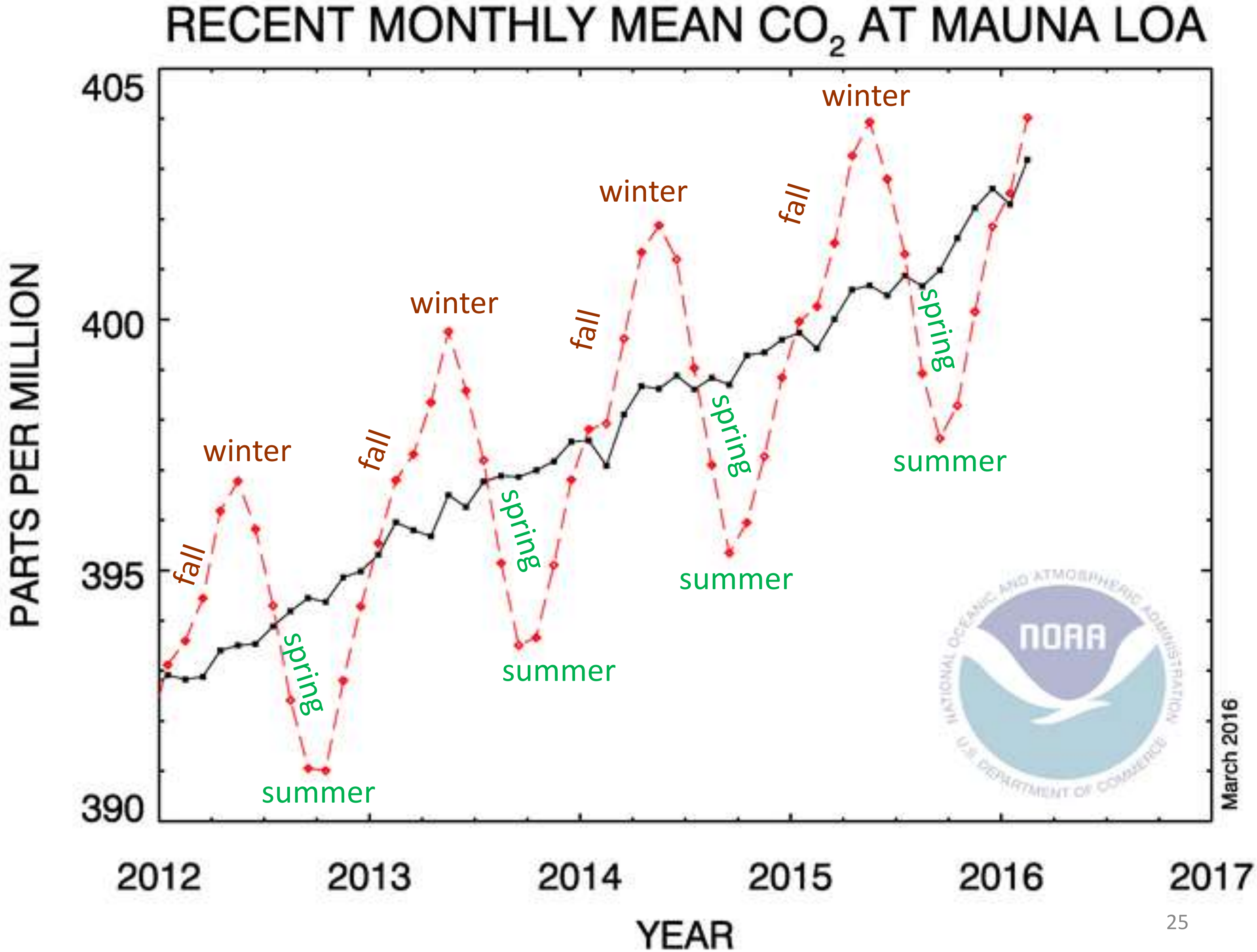
FIGURE 14-35 Atmospheric CO_2 Concentrations Increased Very Rapidly during the Last 200 Years

The change from about 280 ppm in 1800 to **421** ppm today (March 2023) reflects the impact of the Industrial Revolution and the increased use of fossil fuels. [NOAA tracks CO_2]

Why does this annual CO2 curve have a high and a low? Hint: the highs happen in the winter. Plants! They are decaying in northern hemisphere fall and winter (adding CO2) and growing in spring and summer (removing CO2)



https://youtu.be/gH6fQh9eAQE


RECENT MONTHLY MEAN CO_2 AT MAUNA LOA
PARTS PER MILLION
405
400
395
390
YEAR
2012
2013
2014
2015
2016
2017
winter
fall
spring
summer
NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE
March 2016

How Axis Tilt Affects the Intensity of Solar Radiation

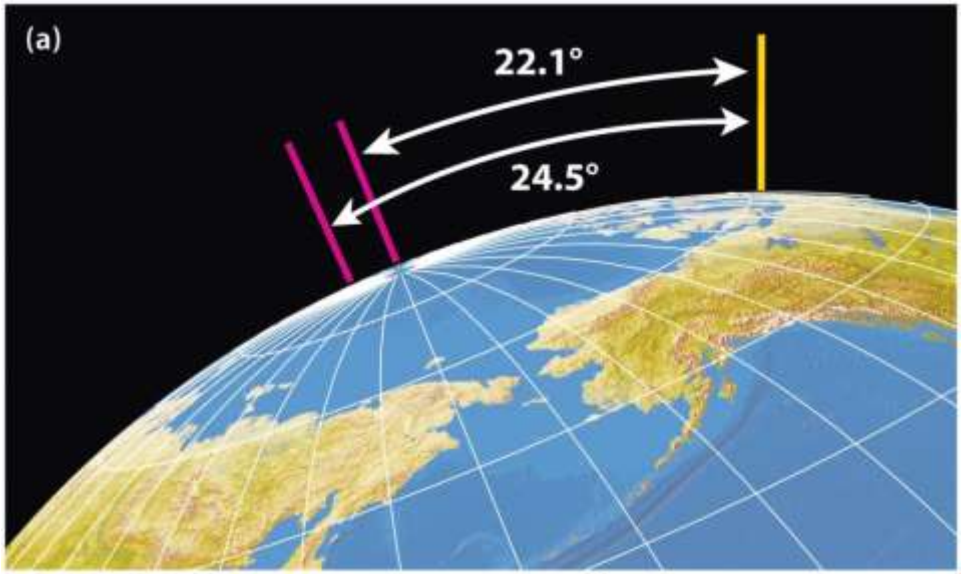
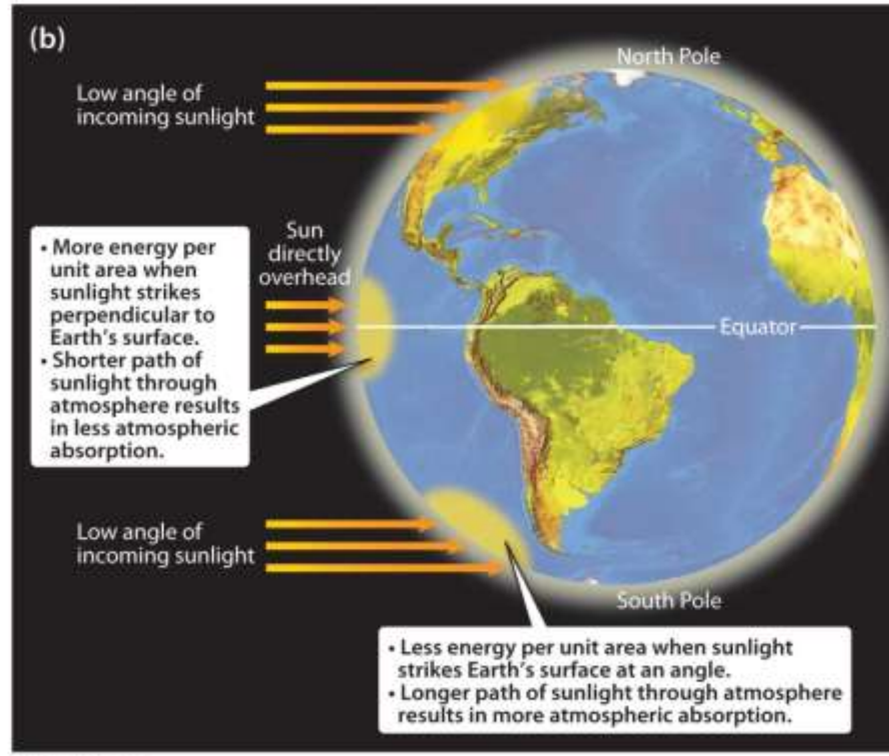


FIGURE 14-19 It is because the axis is tilted that we have seasons.

(a) The tilt of Earth's axis of rotation changes from 22.1 to 24.5 degrees and back in a 41,000-year cycle.

At higher latitudes, even the shift of a few degrees can cause a significant change in the intensity of solar radiation.



(b) Solar radiation reaching Earth's surface is strongest when the Sun is directly overhead and becomes weaker when Sun's rays strike at a more oblique angle.

How Axis Tilt Affects the Intensity of Solar Radiation (cont.)

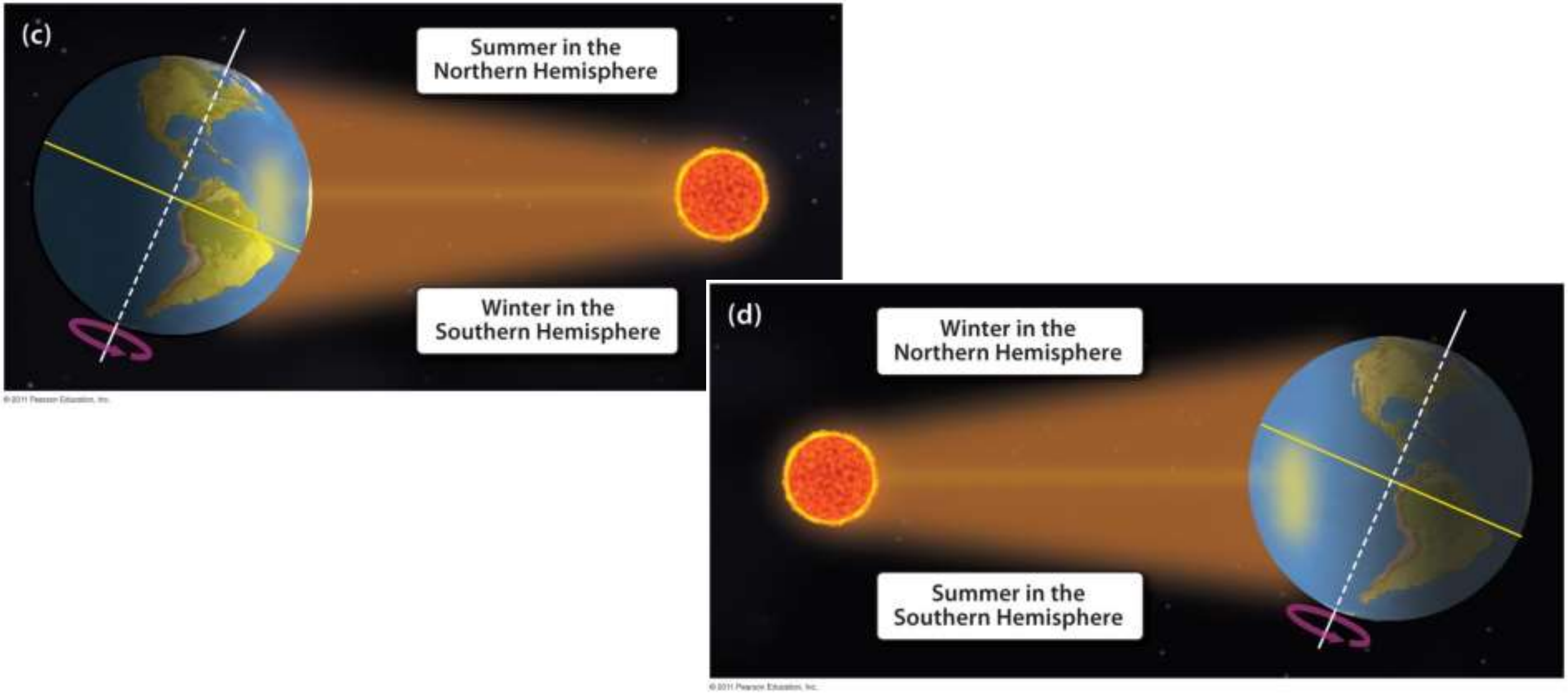
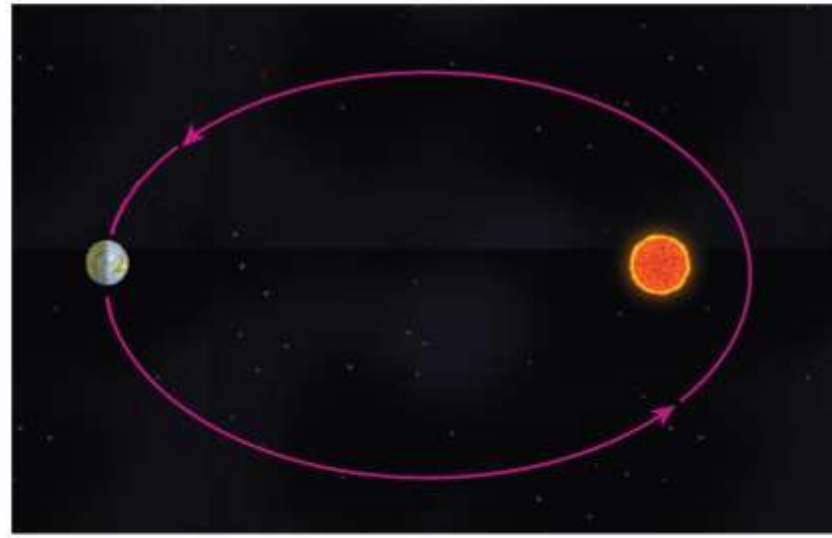


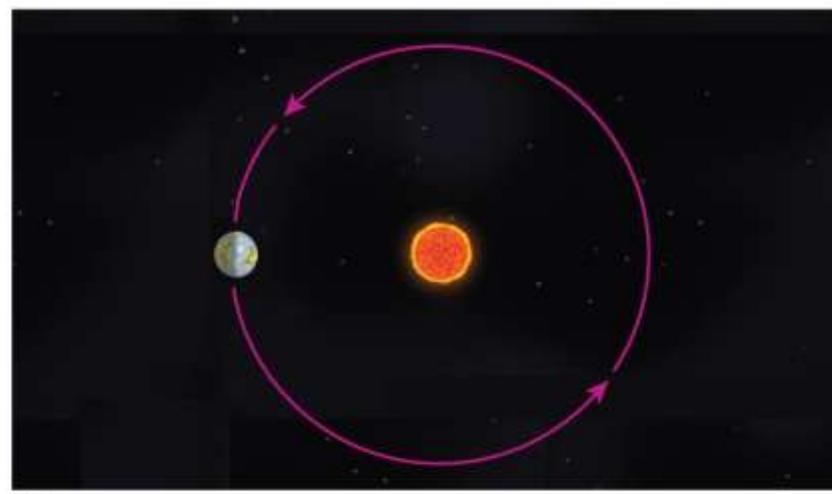
FIGURE 14-19 How Axis Tilt Affects the Intensity of Solar Radiation
In **(c)**, the Northern Hemisphere is tilted toward the Sun and experiences summer while the Southern Hemisphere experiences winter. Six months later, when Earth is on the opposite side of its orbit **(d)**, the Northern Hemisphere is tilted away from the Sun and experiences winter while the Southern Hemisphere experiences summer.

Influence of Orbital Eccentricity

FIGURE 14-20
How Orbital Eccentricity Changes the Amount of Solar Radiation Earth Receives
Earth's orbit around the Sun changes from more elliptical **(a)** to less elliptical **(b)** and back about every 100,000 years. (The extent of the elongation in part (a) has been exaggerated.) When the orbit is more elliptical, the Earth moves both closer to and farther from the Sun during a year than it does when the orbit is less elliptical.



(a)



(b)

Precession

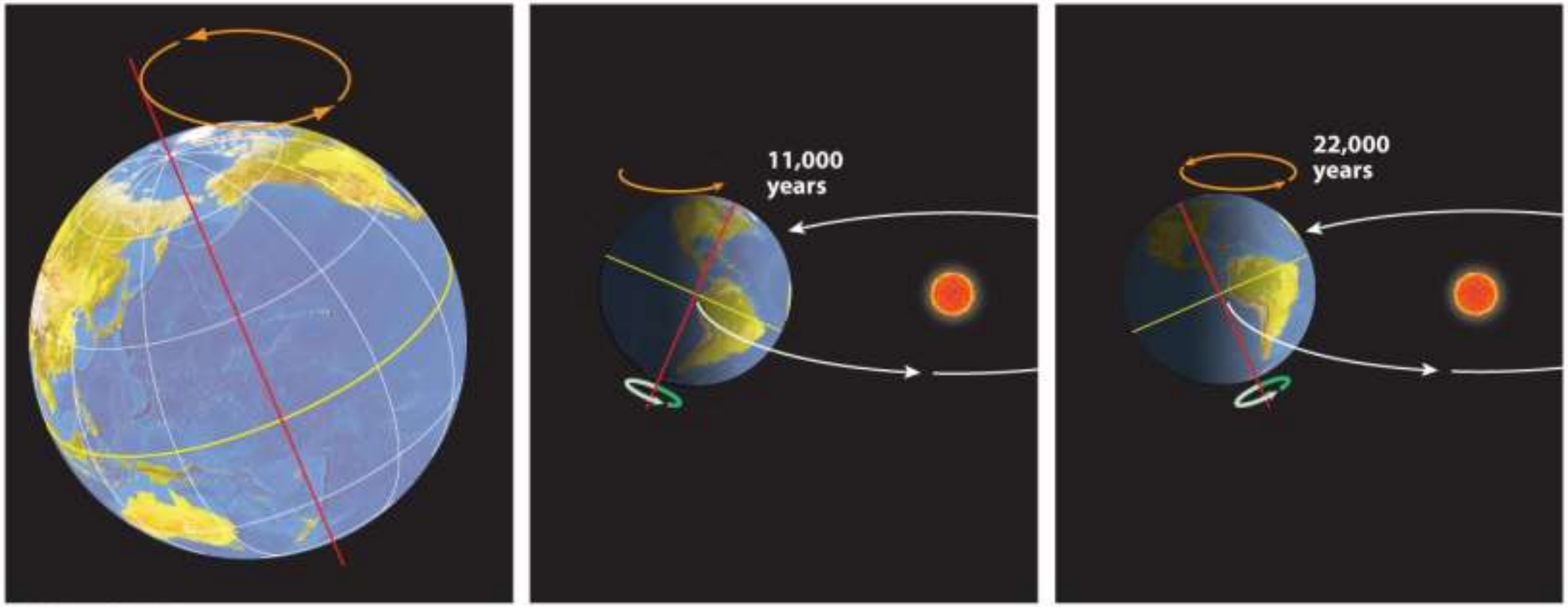
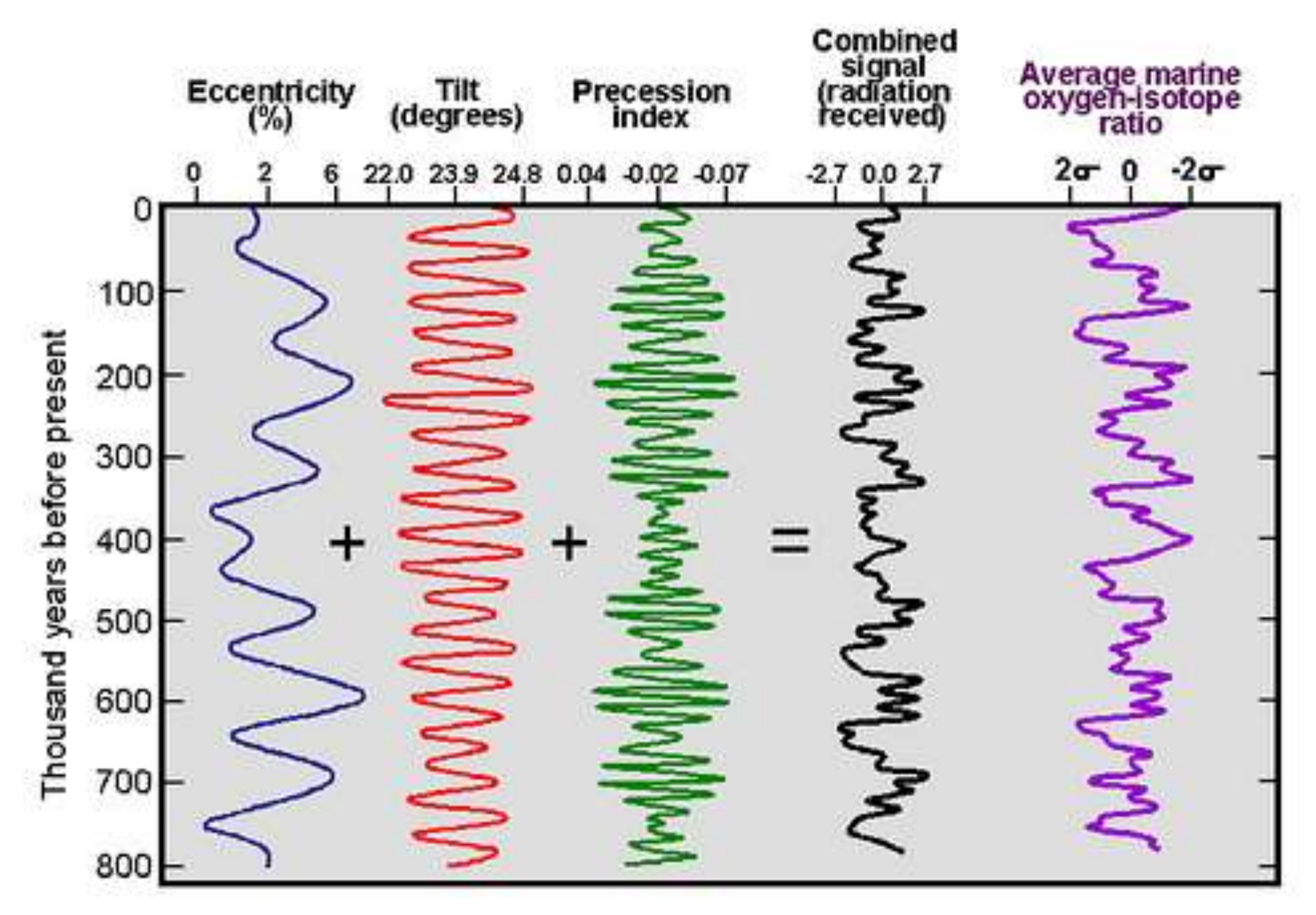


FIGURE 14-21 Precession
Earth wobbles as it orbits the Sun, much as a top wobbles as it spins. This wobble gradually rotates the poles in a circle. Precession changes the direction of Earth's tilt about its axis, but not the amount of tilt. Rotation of the poles shifts them slightly toward or away from the Sun. A complete precession cycle takes 22,000 years.

Milankovitch Cycles—cyclic changes in axis tilt, orbital eccentricity, and precession cycles lead to cycles of colder climate (glacial maximums) and warmer climate (*interglacial periods*)

Milankovitch Cycles Graphed (a simplified version)



Paleoclimatology—Studying Past Climates (cont.)

- **Oxygen isotopes**
- Almost all oxygen has an atomic mass of 16 (^{16}O, or O-16 atoms)
- Two other stable oxygen isotopes are: O-17 and O-18.
- O-18 is five times more abundant than O-17—easier to use
- O-18 is slightly heavier than O-16
  - Water containing O-18 does not evaporate as easily as water with O-16
  - The escaping water vapor is slightly enriched in O-16
  - Seawater left behind is slightly enriched in O-18
- During cold periods
  - O-16-enriched water vapor is added to ice sheets
  - Ratio of O-18 to O-16 in seawater increases
  - Marine organism incorporate this O-18 : O-16 into shells and skeletons
    - Locking in ratio for time they grew
- **Expanding** ice sheets—**higher** O-18 to O-16 ratios
- **Contracting** ice sheets—**decreasing** O-18 to O-16 ratios

Oxygen-16 in Glacial Ice

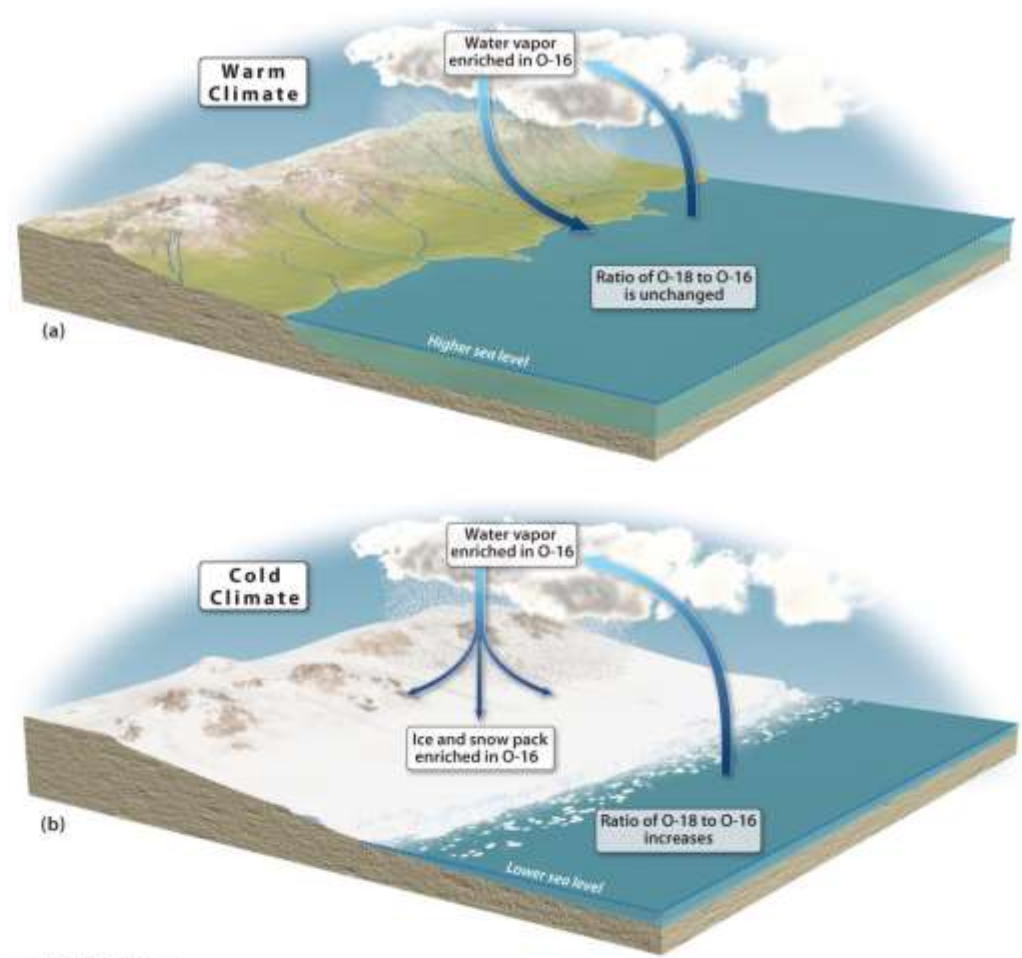
FIGURE 14-25

How Oxygen-16 Becomes More Concentrated in Glacial Ice

(a) Because O-16 is lighter than O-18, water vapor evaporated from the oceans is slightly enriched in O-16.

Because most of this water eventually finds its way back to the oceans in rain and runoff, however, the ratio of the two isotopes in seawater is largely unaffected.

(b) During times of glaciation, water vapor enriched in O-16 becomes trapped in ice accumulations and doesn't return to the oceans. As a result, the relative concentration of
O-18 in seawater increases.



Rayleigh Distillation

Sea Level during the Last Glaciation

Sea level during Interglacial periods = higher

Sea level during Glacial periods = lower

Figure 9-15
Large ice sheets covered Canada and parts of the northern United States during the last glacial maximum 20,000 years ago. Shorelines were about 110 to 125 meters lower than today, and much of the Gulf of Mexico and Atlantic continental shelves were exposed plains with rivers and forests.

[Laurentide Ice Sheet]

[Glacial erosion process] https://apps.npr.org/arctic-ice-melting-climate-change/