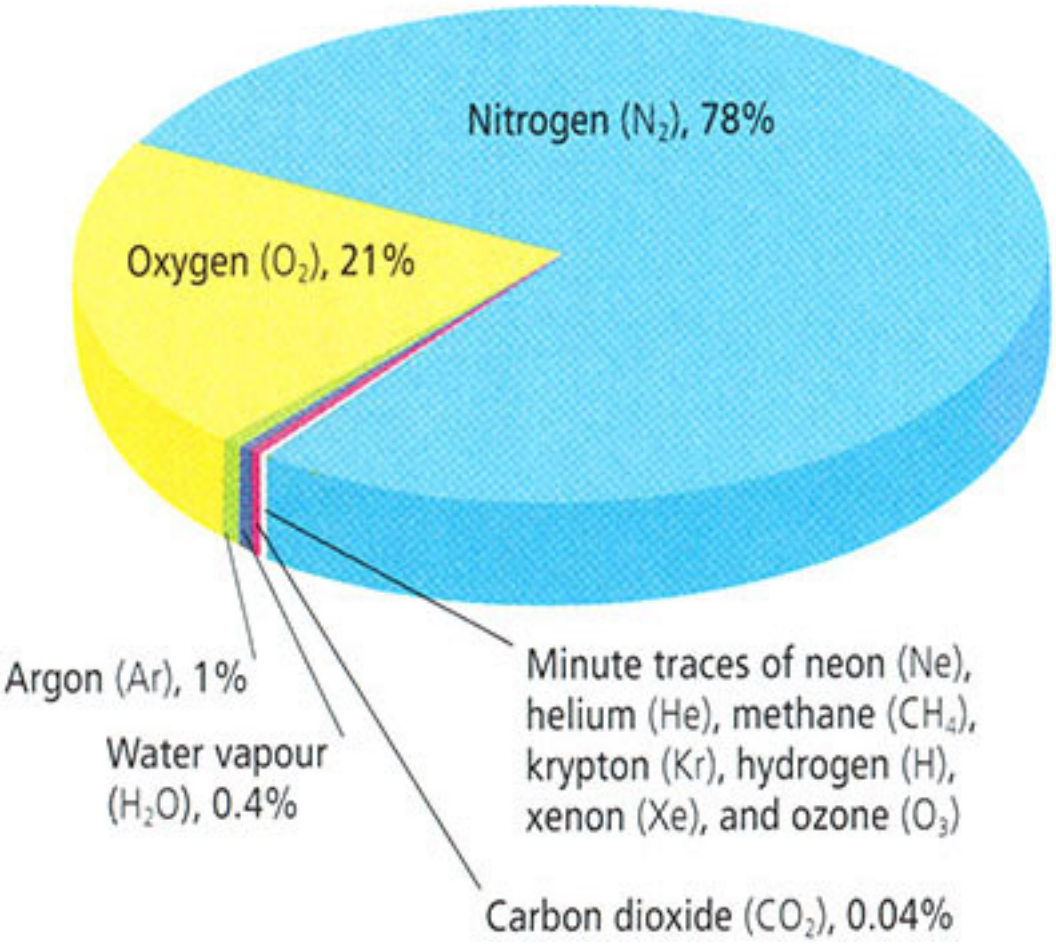
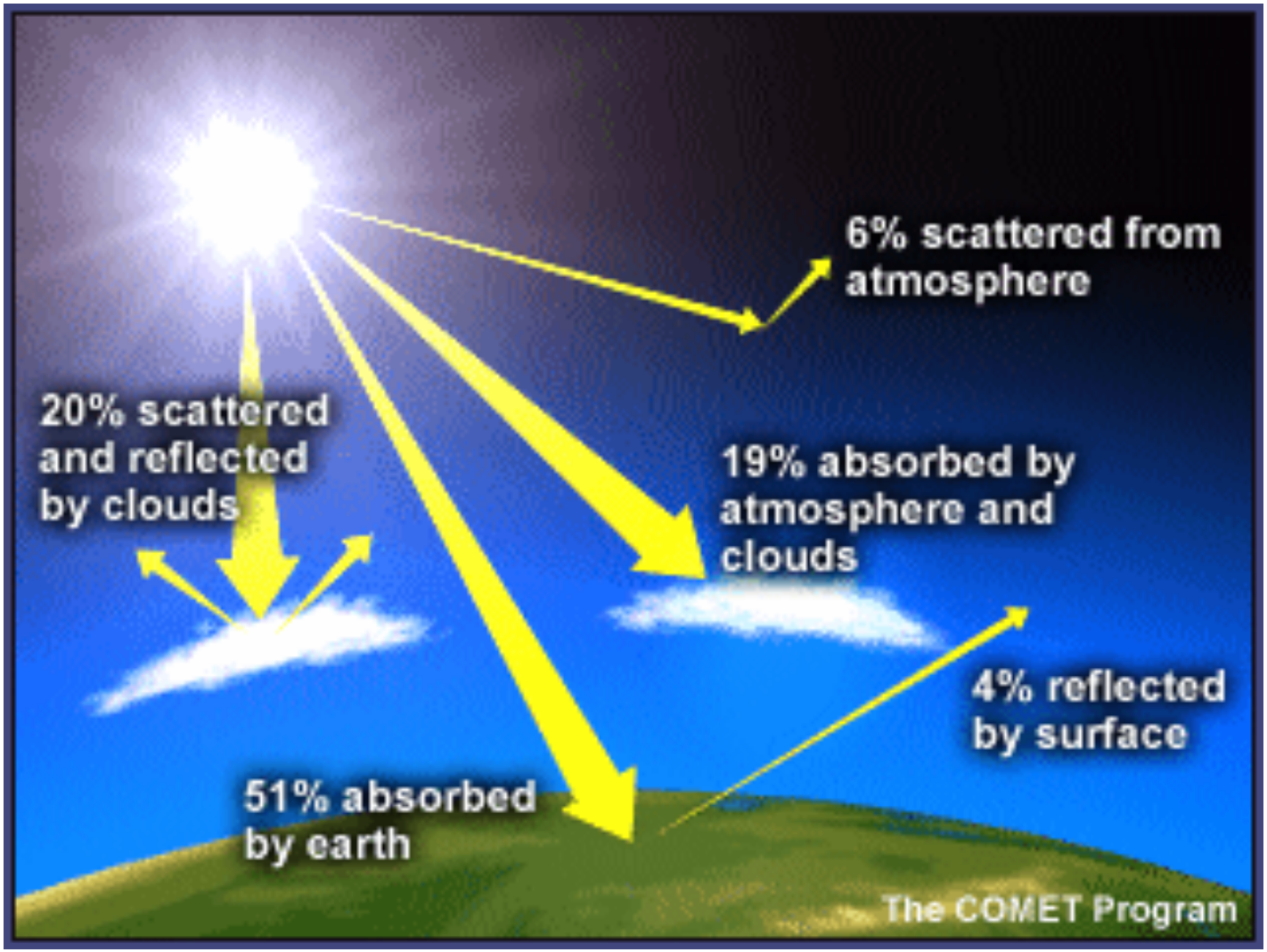
Unit 4 SG 1 - The Origin of the Earth's Climate

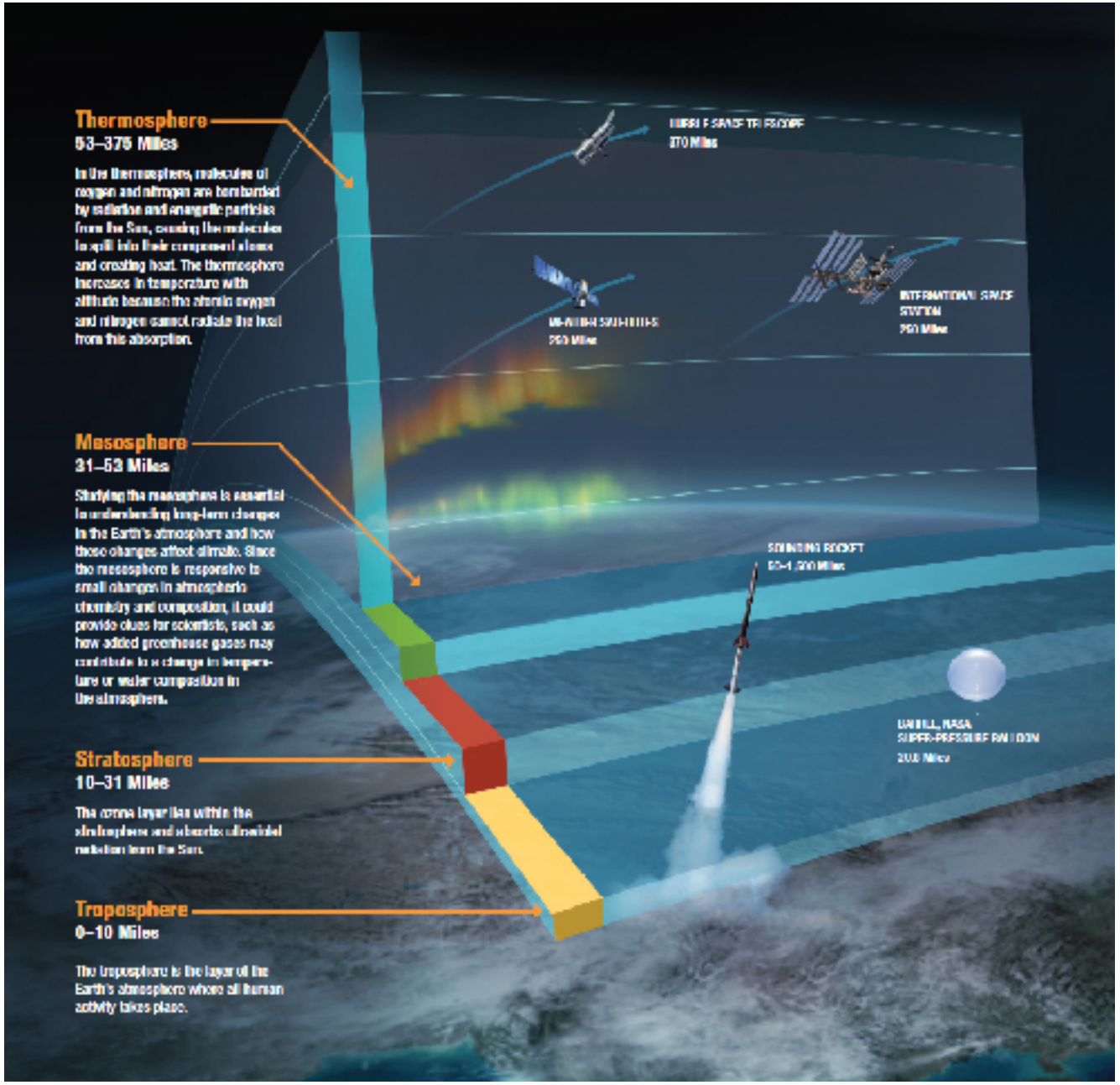
I. The Atmosphere

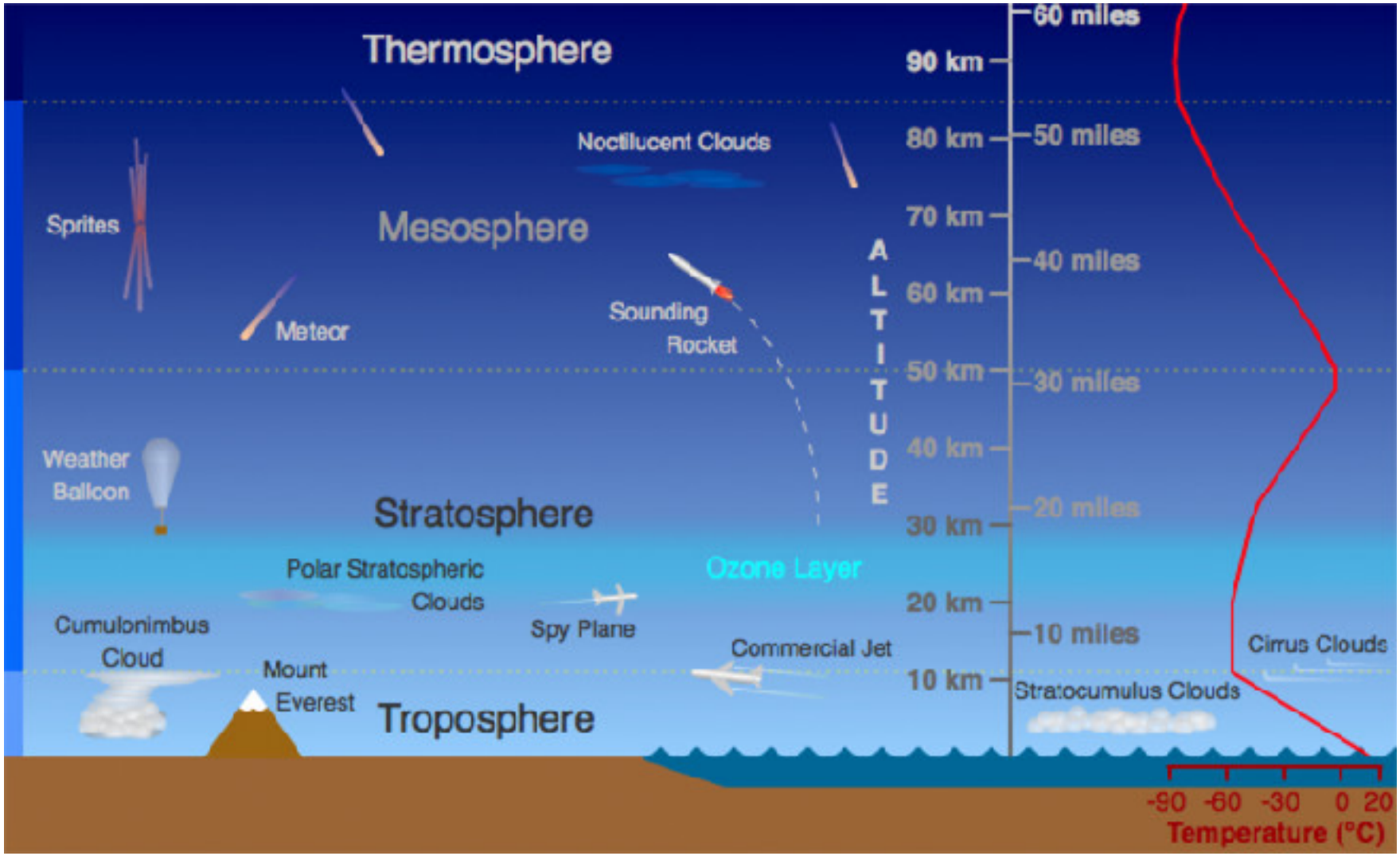
- **A. The atmosphere today is comprised of 2 main gases: Nitrogen (N) at 78% and Oxygen (O) at 21%.**
  - **1. The remaining 1% is mainly Argon (Ar) at 0.934%.**
  - **2. 0.66% is made up of the following gases in order from most to least: water vapor, carbon dioxide (CO_2) at 0.039%, neon, helium, methane, krypton, & hydrogen.**
    - **a. Water vapor, CO2 and methane are called greenhouse gases. What does this mean?**
  - **3. There are also small amounts of ozone, but this is an important gas in our atmosphere.**

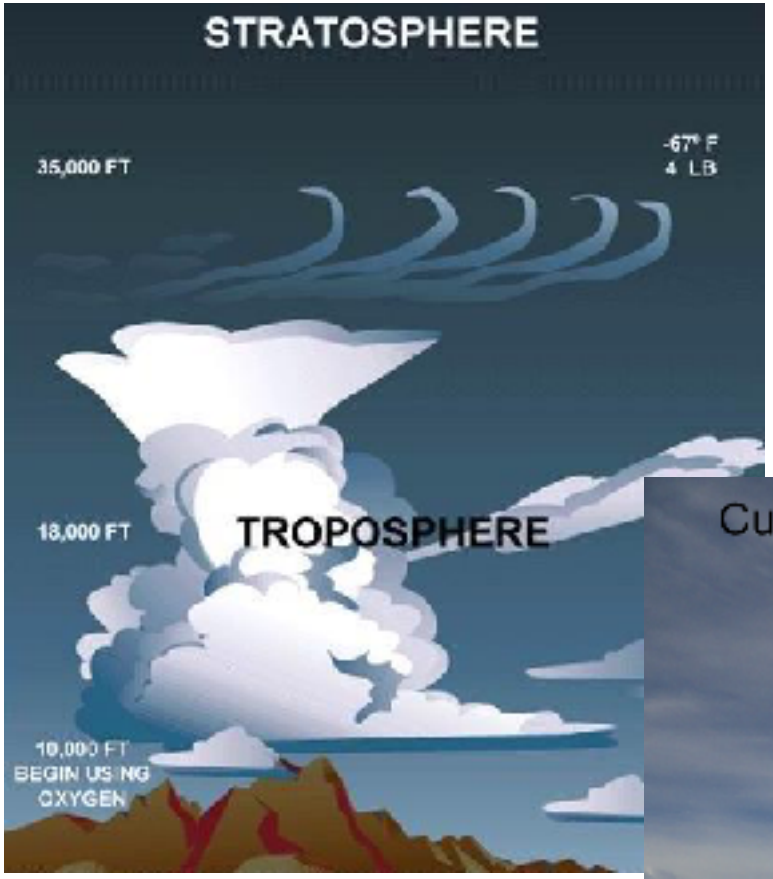

Nitrogen (N_2), 78%
Oxygen (O_2), 21%
Argon (Ar), 1%
Water vapour (H_2O), 0.4%
Minute traces of neon (Ne), helium (He), methane (CH_4), krypton (Kr), hydrogen (H), xenon (Xe), and ozone (O_3)
Carbon dioxide (CO_2), 0.04%

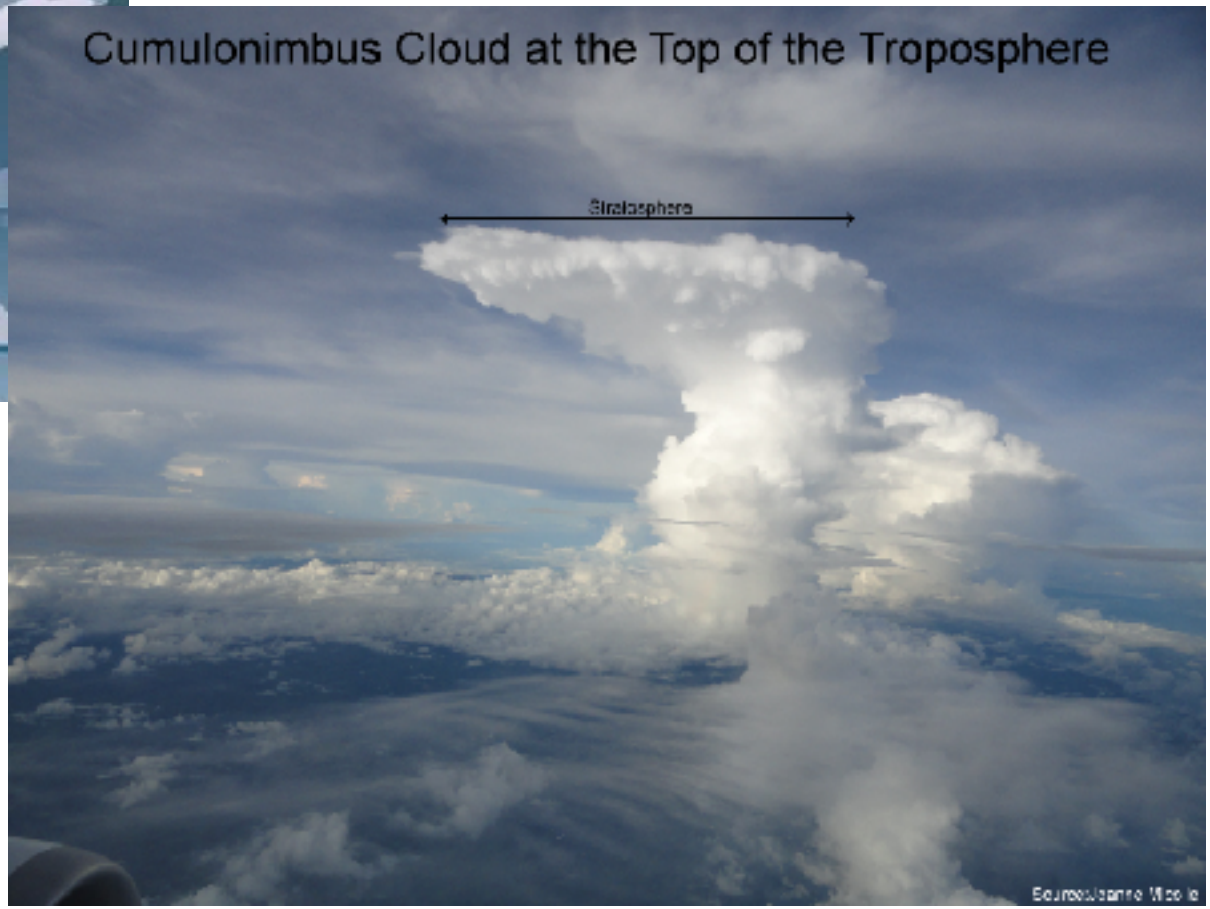

6% scattered from atmosphere
20% scattered and reflected by clouds
19% absorbed by atmosphere and clouds
4% reflected by surface
51% absorbed by earth
The COMET Program

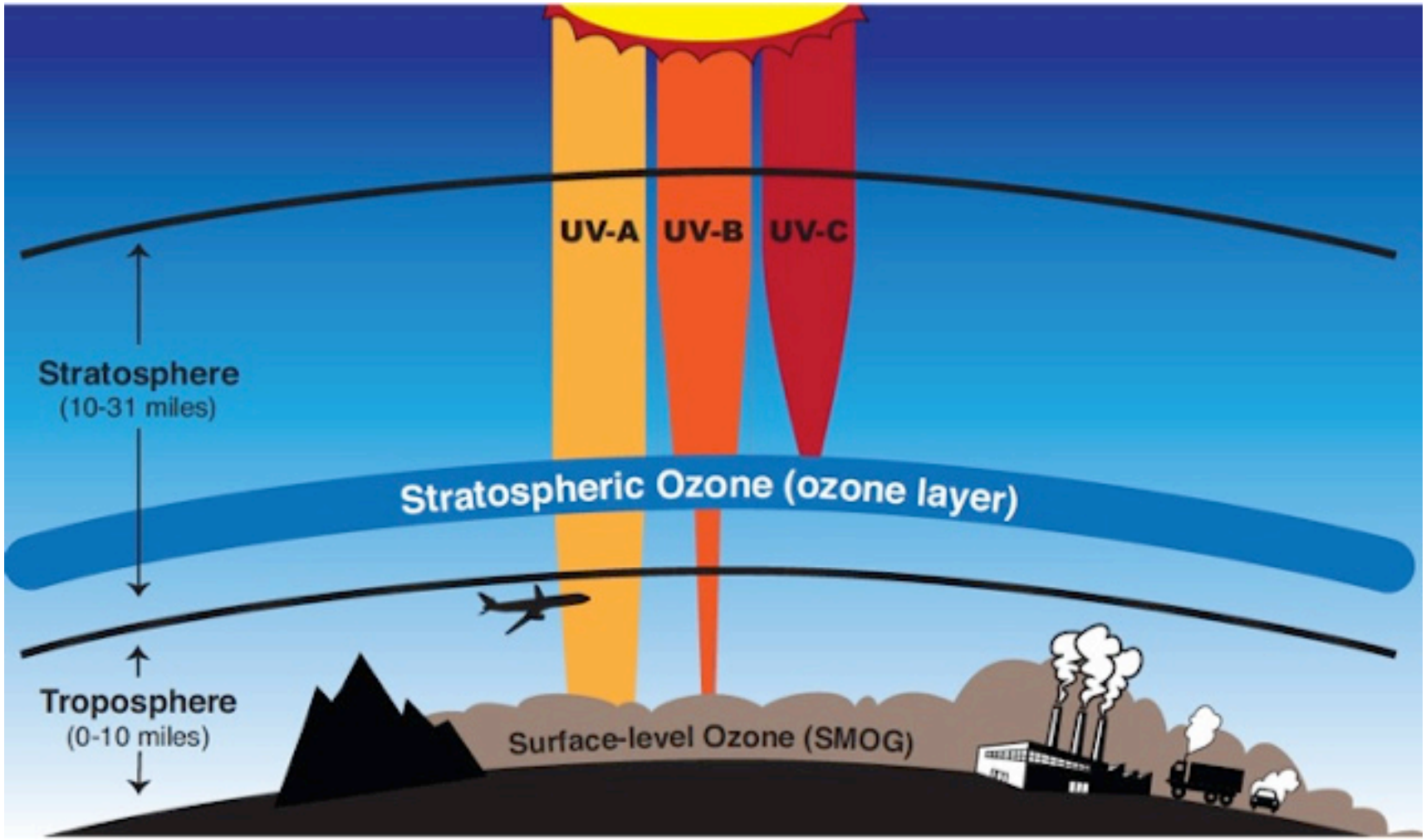
- **B. The atmosphere has several layers. Climate and weather occur in the lowest layer called the troposphere.**
  - **1. The troposphere extends up to about 11 miles above the Earth's surface at the equator, and 5 miles at the poles.**
    - **a. As you increase in altitude in the troposphere, the temperature decreases.**


Thermosphere
53–375 Miles
In the thermosphere, molecules of oxygen and nitrogen are bombarded by radiation and energetic particles from the Sun, causing the molecules to split into their component atoms and creating heat. The thermosphere increases in temperature with altitude because the atomic oxygen and nitrogen cannot radiate the heat from this absorption.
Mesosphere
31–53 Miles
Studying the mesosphere is essential to understanding long-term changes in the Earth's atmosphere and how those changes affect climate. Since the mesosphere is responsive to small changes in atmospheric chemistry and composition, it could provide clues for scientists, such as how added greenhouse gases may contribute to a change in temperature or water composition in the atmosphere.
Stratosphere
10–31 Miles
The ozone layer lies within the stratosphere and absorbs ultraviolet radiation from the Sun.
Troposphere
0–10 Miles
The troposphere is the layer of the Earth's atmosphere where all human activity takes place.
INTERNATIONAL SPACE STATION
250 Miles
SOUNDING ROCKET
UNIBALL, NASA SUPER-PRESSURE BALLOON

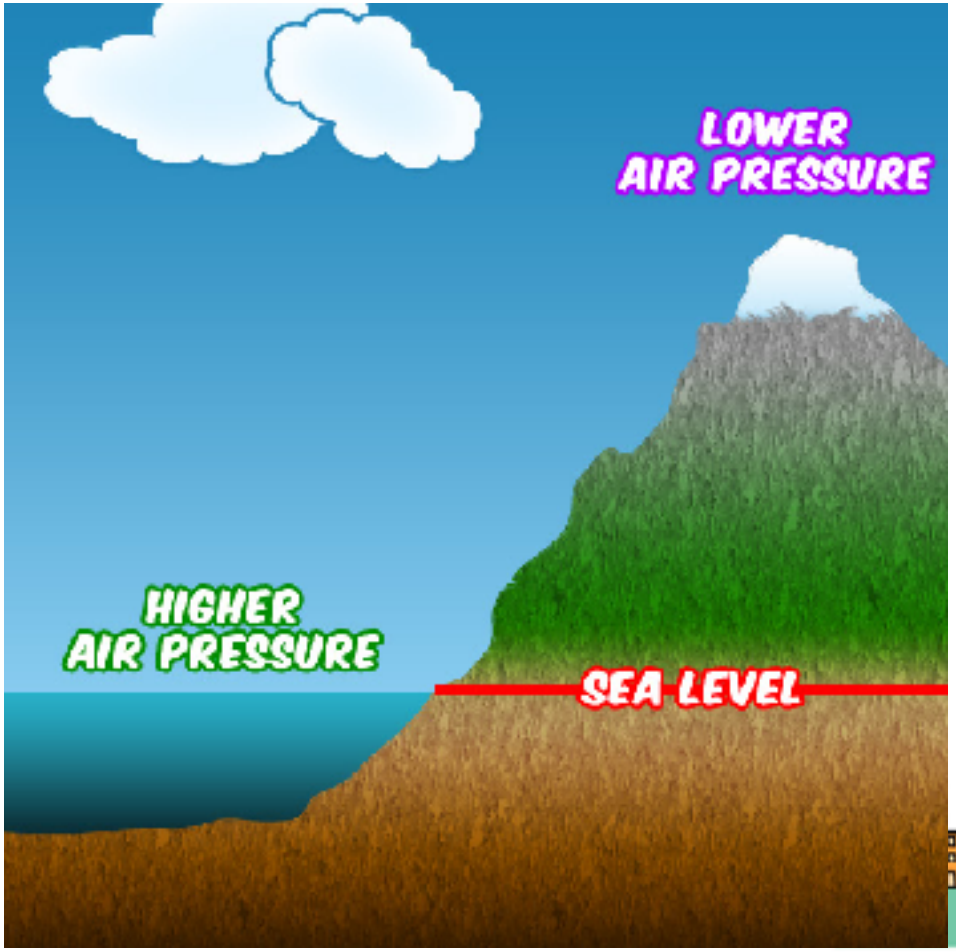

Thermosphere
Noctilucent Clouds
Sprites
Mesosphere
Meteor
Sounding Rocket
Weather Balloon
Stratosphere
Polar Stratospheric Clouds
Ozone Layer
Spy Plane
Cumulonimbus Cloud
Mount Everest
Commercial Jet
Troposphere
Cirrus Clouds
Stratocumulus Clouds
ALTITUDE
90 km
80 km
70 km
60 km
50 km
40 km
30 km
20 km
10 km
60 miles
50 miles
40 miles
30 miles
20 miles
10 miles
-90 -60 -30 0 20
Temperature (°C)

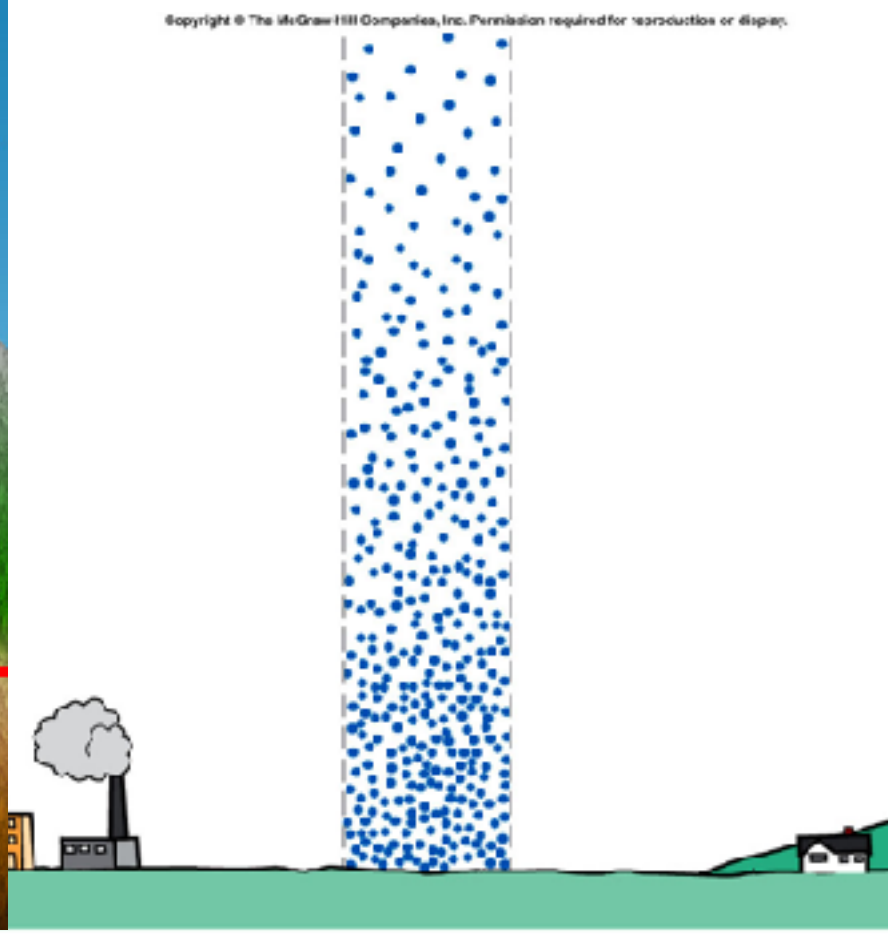

STRATOSPHERE
35,000 FT
-67° F
4 LB
18,000 FT
TROPOSPHERE
10,000 FT
BEGIN USING
OXYGEN


Cumulonimbus Cloud at the Top of the Troposphere
Stratosphere


UV-A
UV-B
UV-C
Stratosphere
(10-31 miles)
Stratospheric Ozone (ozone layer)
Troposphere
(0-10 miles)
Surface-level Ozone (SMOG)

- **C. The atmosphere exerts pressure on the surface of the earth.**
  - **1. The highest air pressures are at sea level (100%) and the lowest is on Mt. Everest (30%).**
  - **2. Because of the uneven heating of the Earth by the Sun's rays, the atmosphere circulates and this also causes differences in air pressure.**


LOWER
AIR PRESSURE
HIGHER
AIR PRESSURE
SEA LEVEL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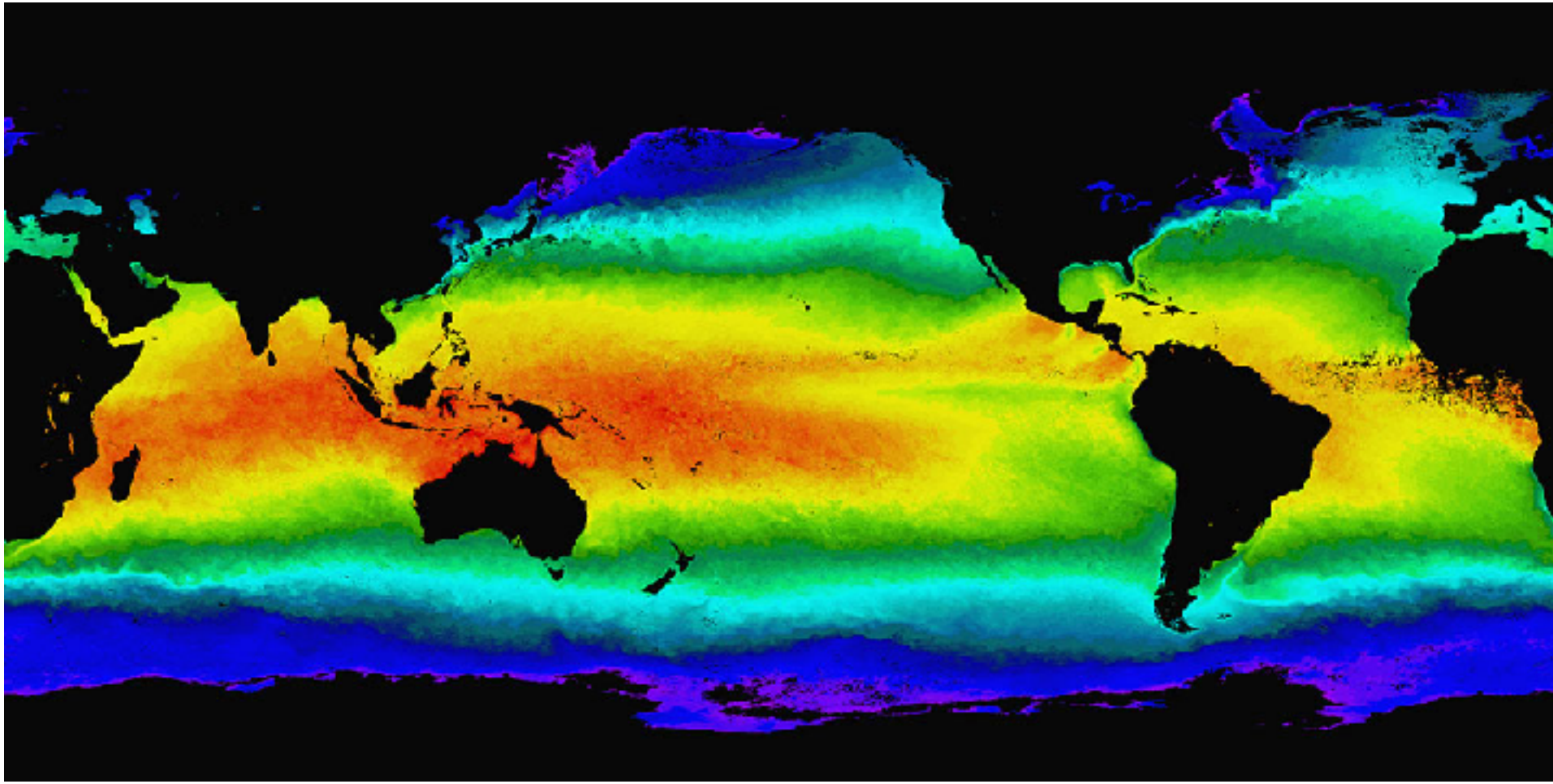
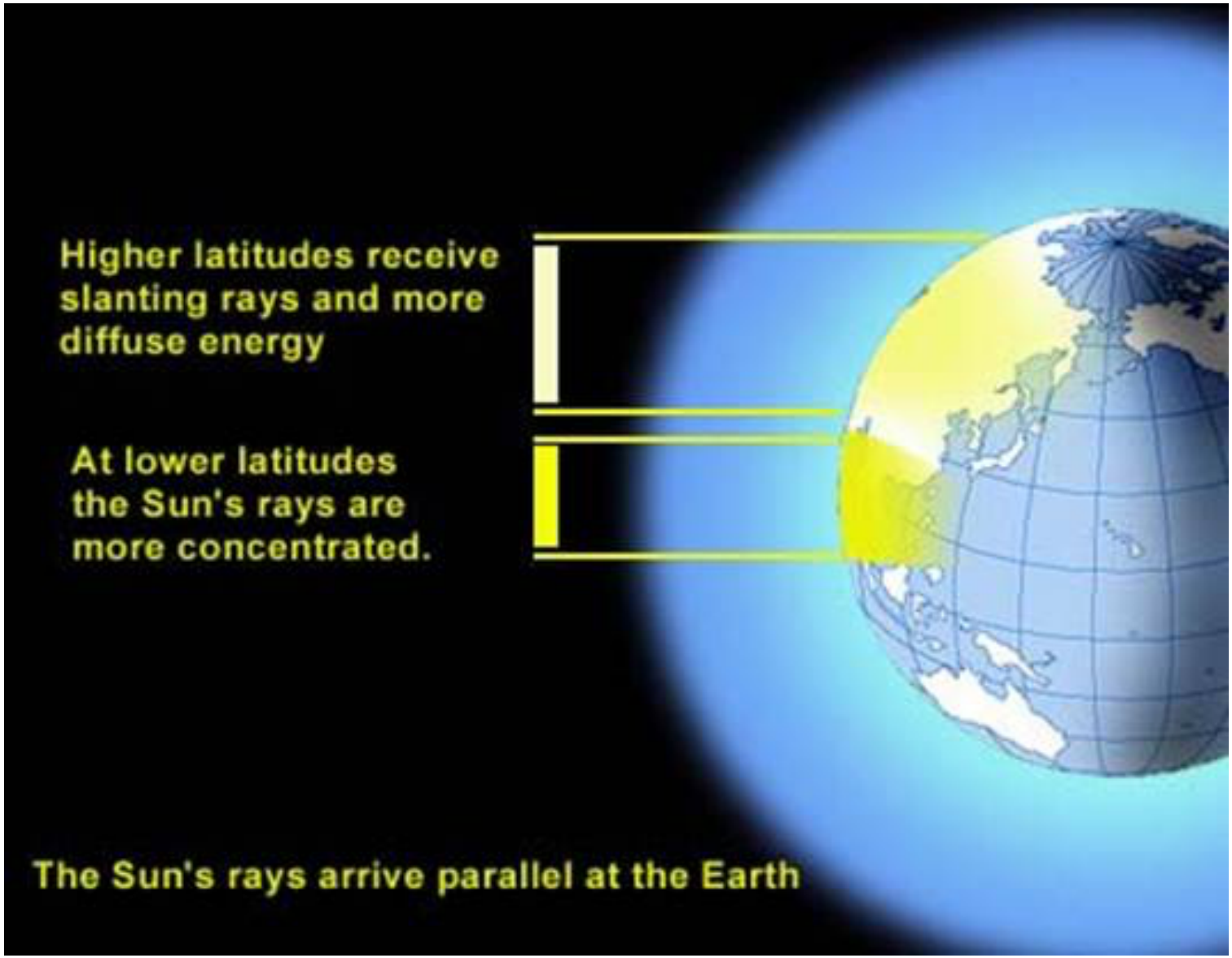
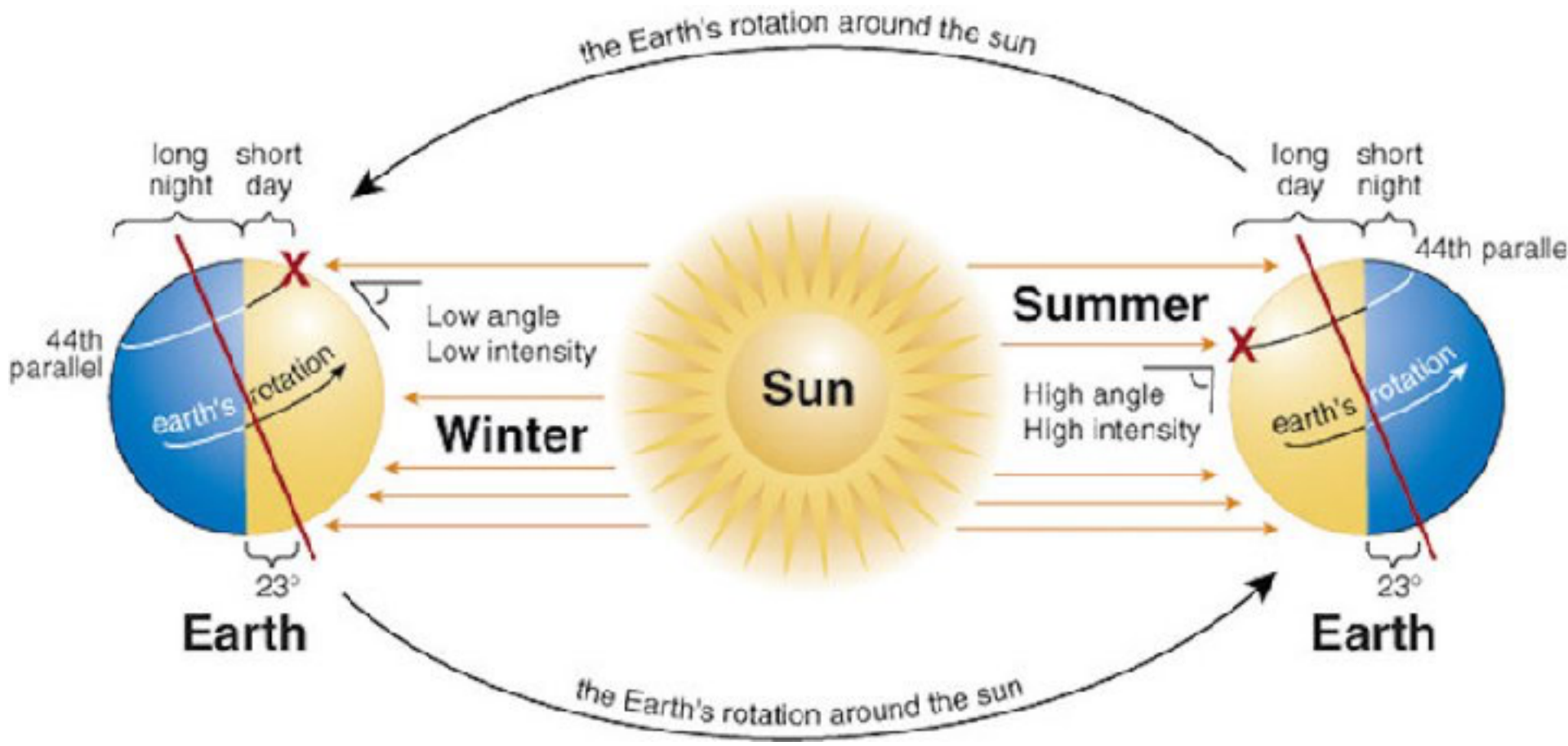


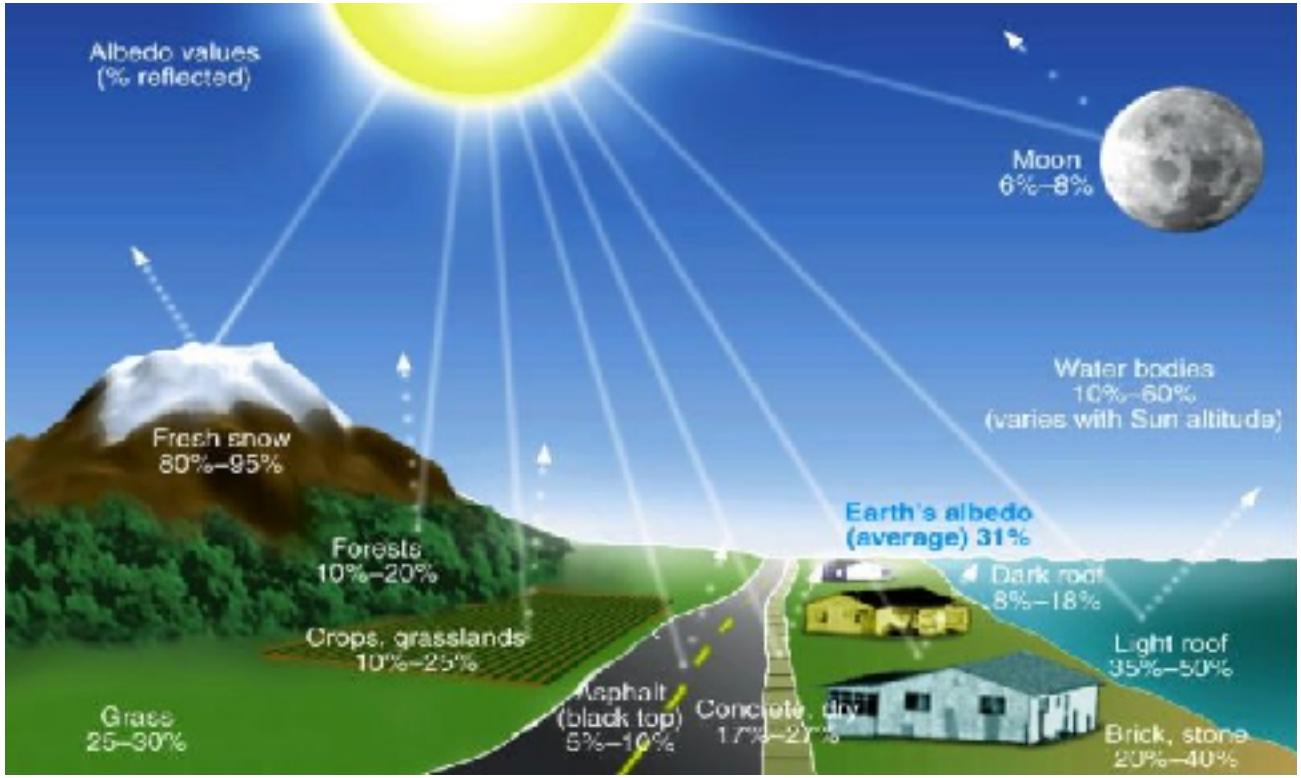
II. Insolation & Temperature

- **A. Insolation AKA solar radiation comes from the Sun and because the earth's surface is curved, this radiation does not hit the earth evenly at all latitudes.**
  - **1. The tilt of the Earth also causes some areas to receive more and less radiation at different times of the year.**

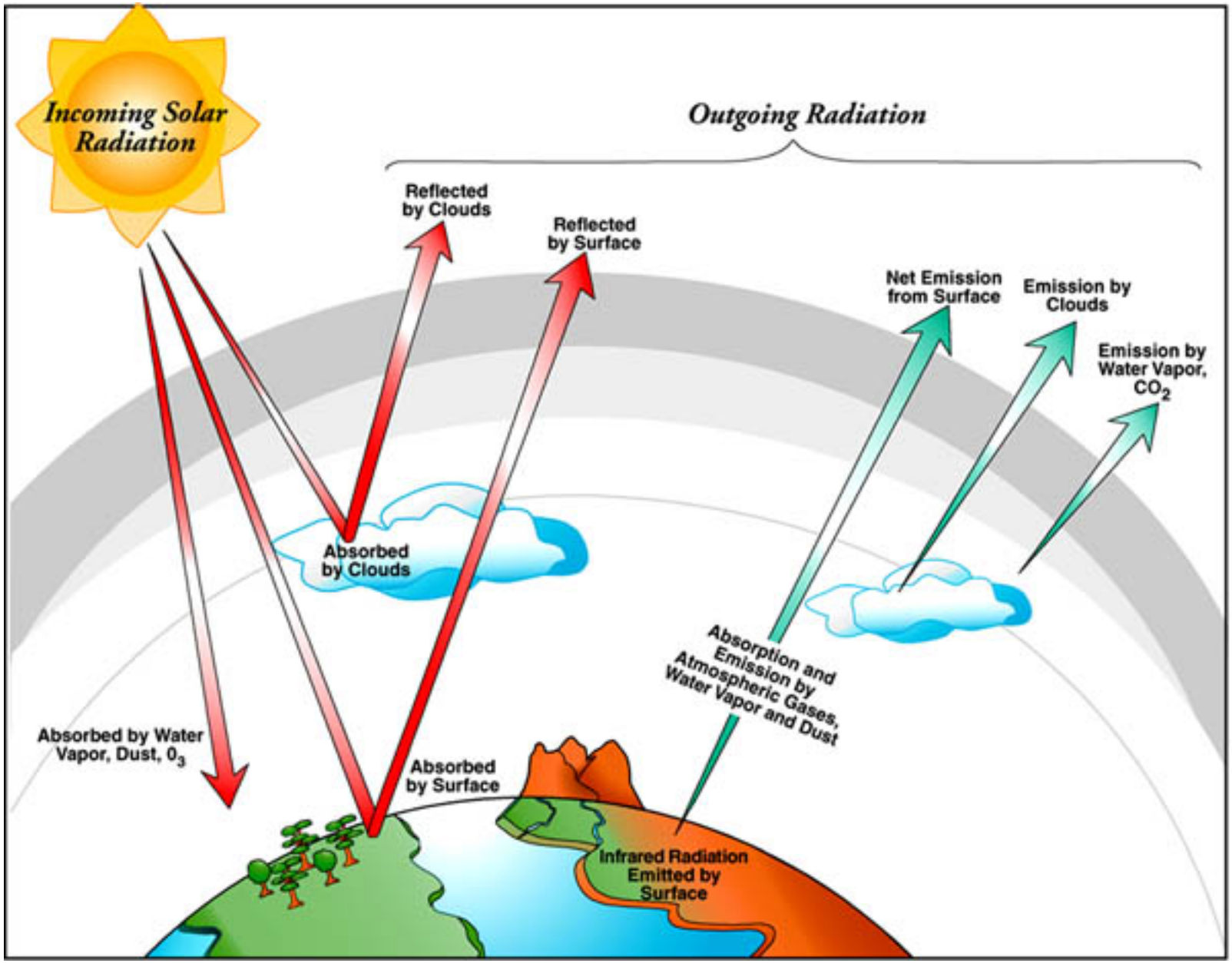

Higher latitudes receive slanting rays and more diffuse energy
At lower latitudes the Sun's rays are more concentrated.
The Sun's rays arrive parallel at the Earth

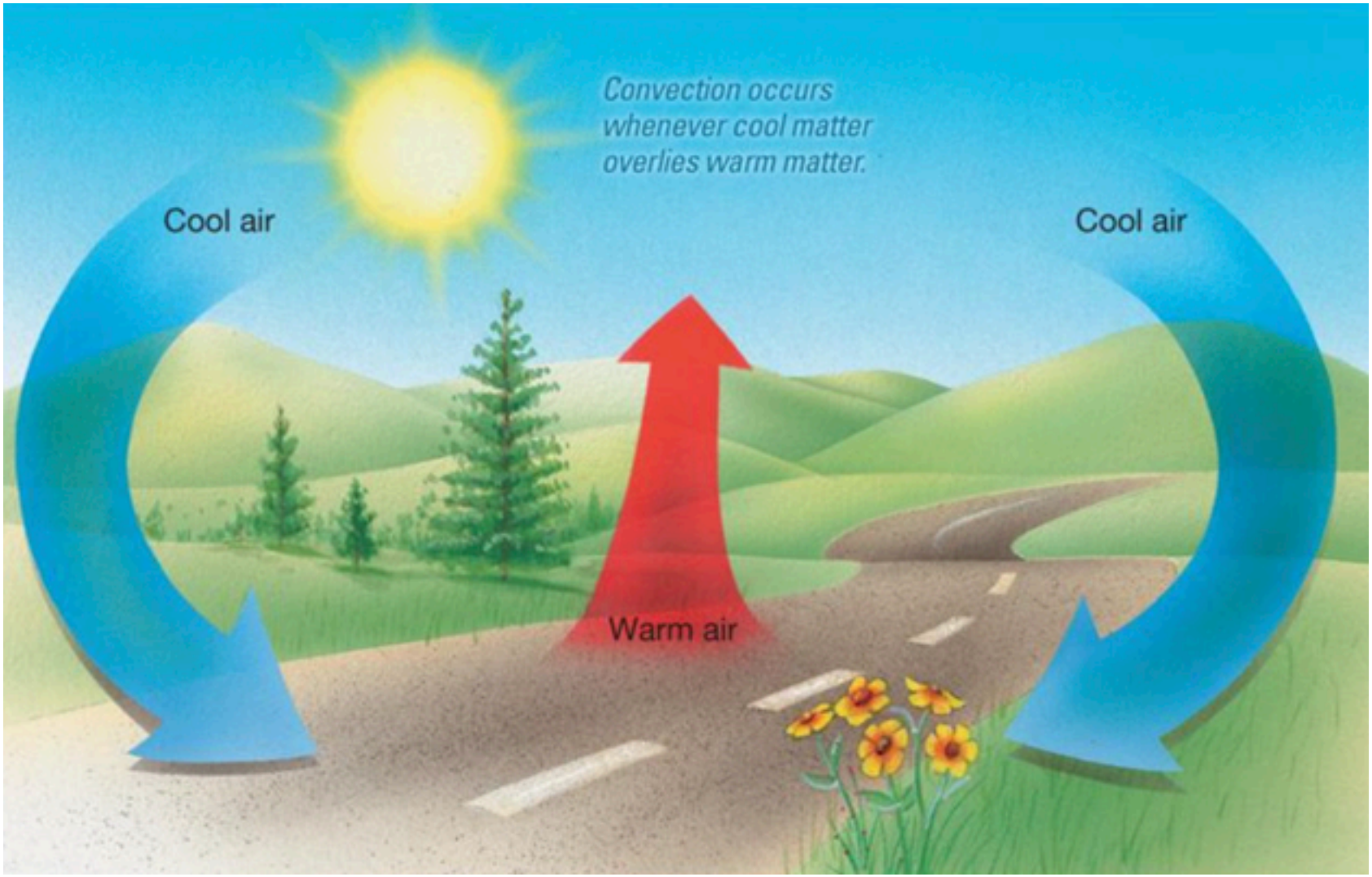

the Earth's rotation around the sun
long night
short day
long day
short night
44th parallel
44th paralle
Low angle
Low intensity
Winter
Sun
Summer
High angle
High intensity
earth's rotation
earth's rotation
23°
23°
Earth
Earth
the Earth's rotation around the sun

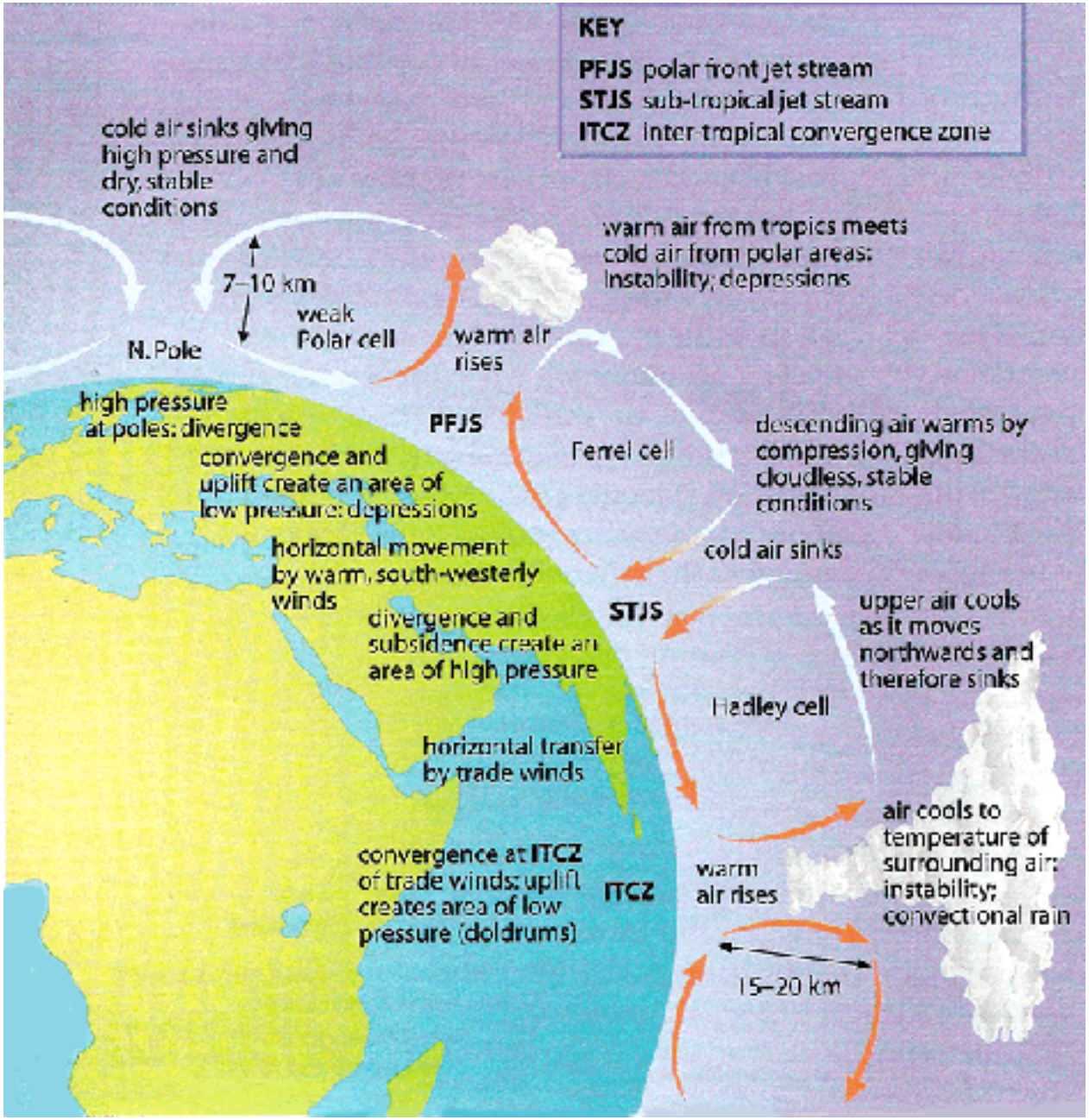
- B. The radiation from the Sun that most impacts climate is infrared (IR) radiation.
  - 1. Like the visible light from the Sun, IR can be reflected.
    - a. The amount of reflected light can be measured and is called the Earth's albedo.



- **2. Unlike visible light, IR can be absorbed & reradiated back into the atmosphere as heat energy.**
  - **a. This is how the atmosphere receives its heat, not directly from the Sun, but by way of convection.**
    - **(1) Convection is a way in which heat is transferred vertically throughout the atmosphere.**

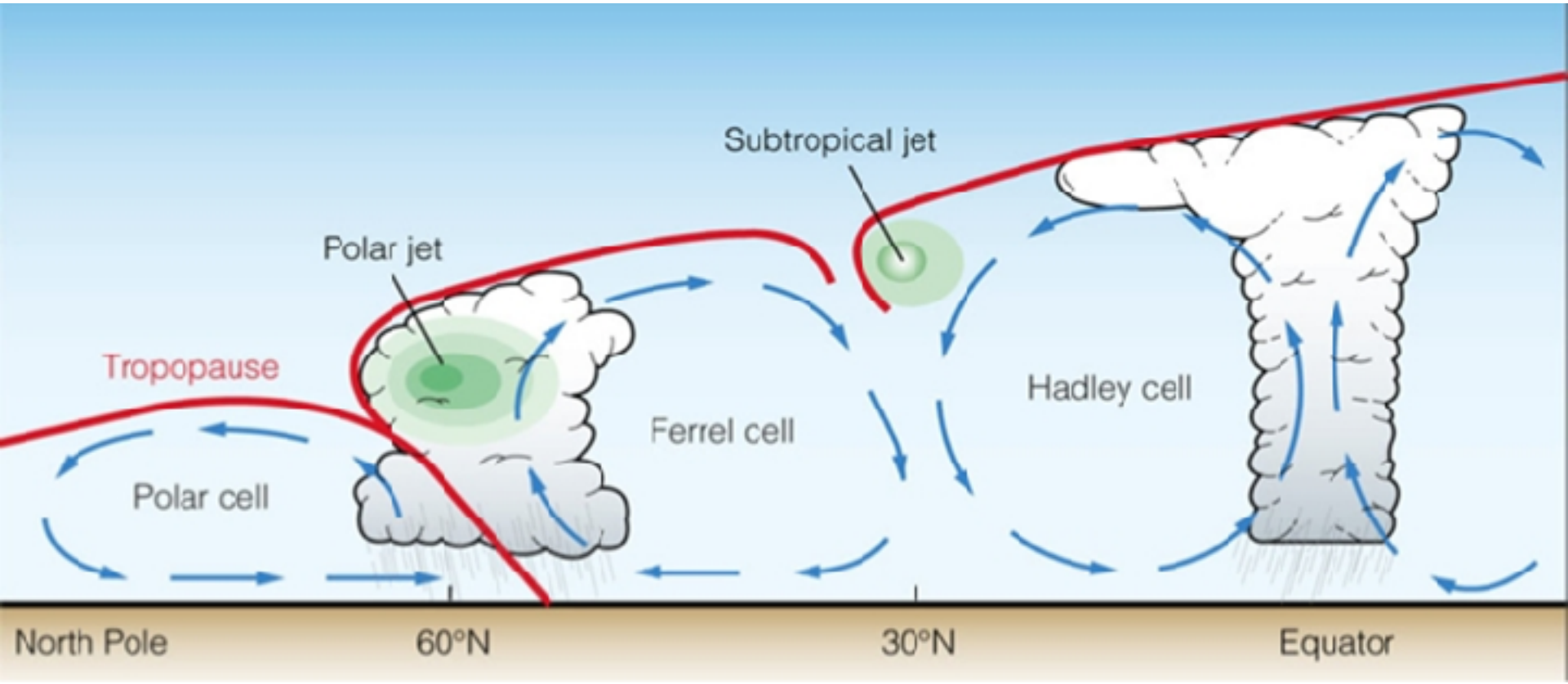

Incoming Solar Radiation
Outgoing Radiation
Reflected by Clouds
Reflected by Surface
Net Emission from Surface
Emission by Clouds
Emission by Water Vapor, CO_2
Absorbed by Clouds
Absorption and Emission by Atmospheric Gases, Water Vapor and Dust
Absorbed by Water Vapor, Dust, 0_3
Absorbed by Surface
Infrared Radiation Emitted by Surface


Convection occurs whenever cool matter overlies warm matter.
Cool air
Cool air
Warm air

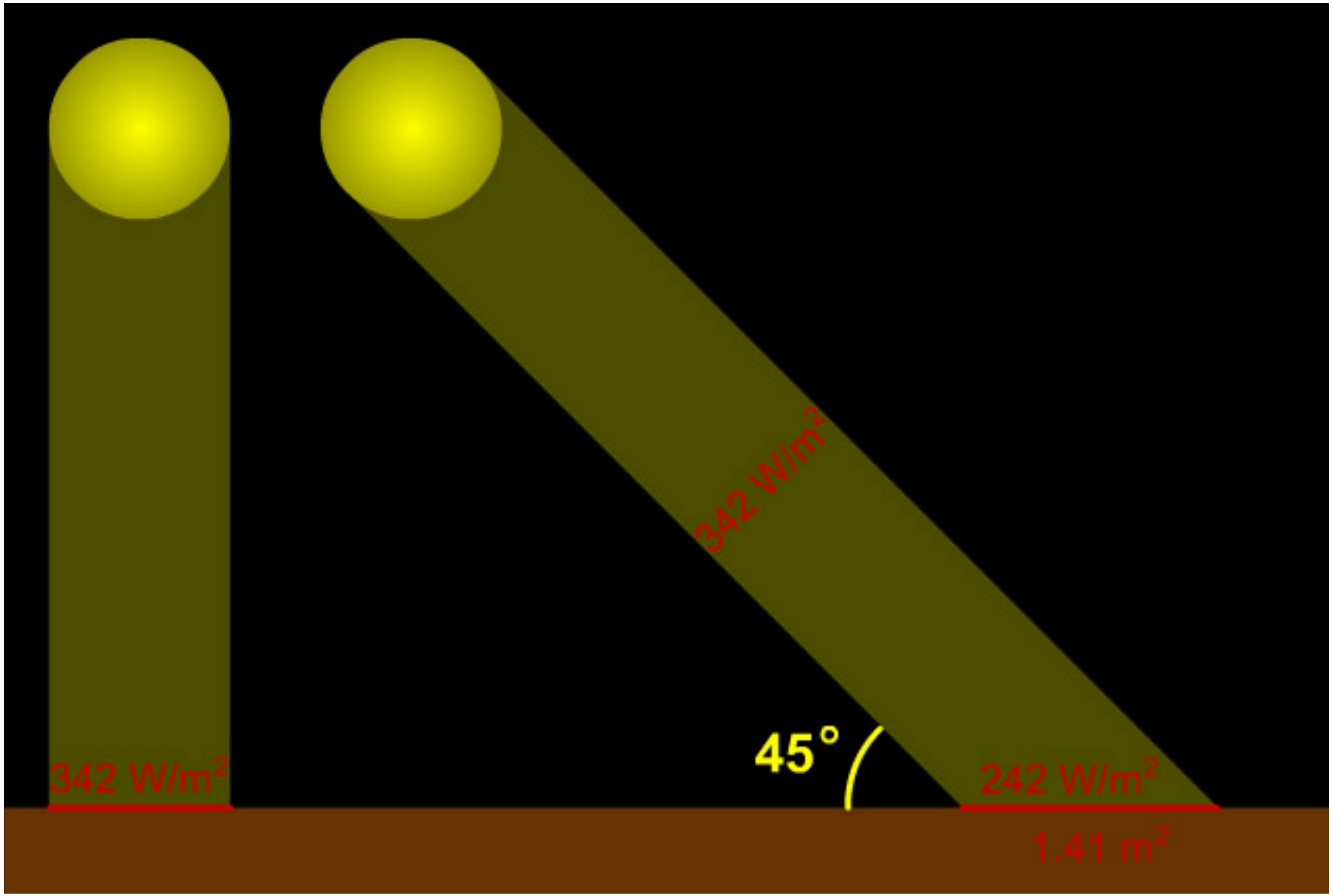

KEY
PFJS polar front jet stream
STJS sub-tropical jet stream
ITCZ inter-tropical convergence zone
cold air sinks giving high pressure and dry, stable conditions
7–10 km
weak Polar cell
N. Pole
warm air rises
warm air from tropics meets cold air from polar areas: instability; depressions
high pressure at poles: divergence
PFJS
convergence and uplift create an area of low pressure: depressions
Ferrel cell
descending air warms by compression, giving cloudless, stable conditions
horizontal movement by warm, south-westerly winds
cold air sinks
STJS
divergence and subsidence create an area of high pressure
upper air cools as it moves northwards and therefore sinks
Hadley cell
horizontal transfer by trade winds
air cools to temperature of surrounding air: instability; convectional rain
convergence at ITCZ of trade winds: uplift creates area of low pressure (doldrums)
ITCZ
warm air rises
15–20 km

b. The rising and subsiding air causes atmospheric circulation and is the main way in which heat is transferred from the equator towards higher latitudes.

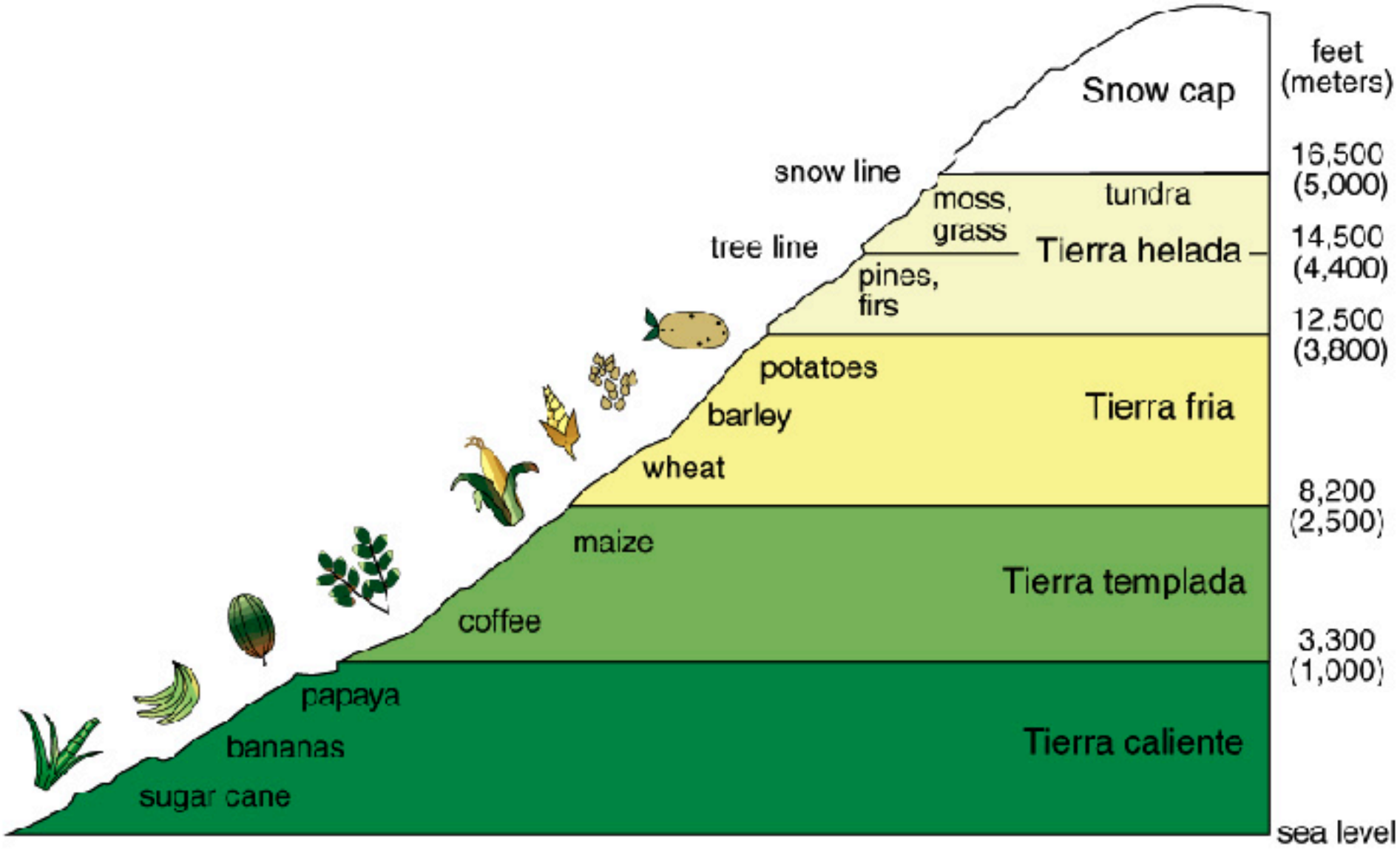
- **(1) 80% of the heat transfer on Earth is caused by atmospheric circulation.**

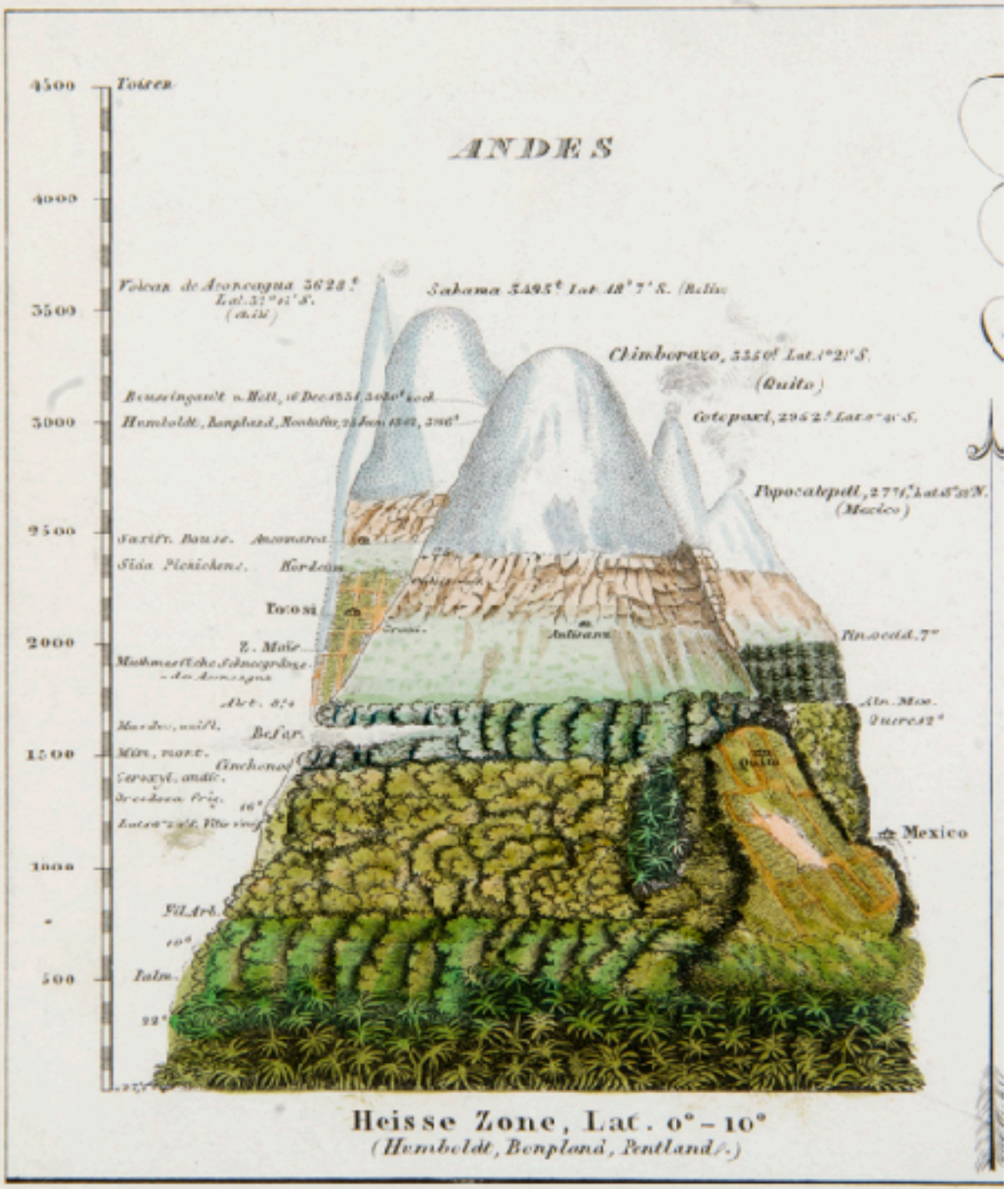

Subtropical jet
Polar jet
Tropopause
Hadley cell
Ferrel cell
Polar cell
North Pole
60°N
30°N
Equator

- **C. The main reason average temperatures on Earth are different in many places is due to latitude.**
  - **1. The angle of the Sun in the sky determines how much insolation an area will receive.**
    - **a. Low latitudes receive much more daily insolation than polar latitudes and thus tend to be warmer.**


342 W/m²
342 W/m²
45°
242 W/m²
1.41 m²

- **b. However, altitude makes a difference. Even at the equator you can have mountains with snow caps all year. This affects vegetation at each elevation and is called vertical zonation.**


feet
(meters)
Snow cap
16,500
(5,000)
snow line
moss,
grass
tundra
tree line
Tierra helada
14,500
(4,400)
pines,
firs
12,500
(3,800)
potatoes
barley
wheat
Tierra fria
8,200
(2,500)
maize
Tierra templada
coffee
3,300
(1,000)
papaya
bananas
sugar cane
Tierra caliente
sea level



Heisse Zone, Lat. 0° – 10°

(Humboldt, Bonpland, Pentland &c.)

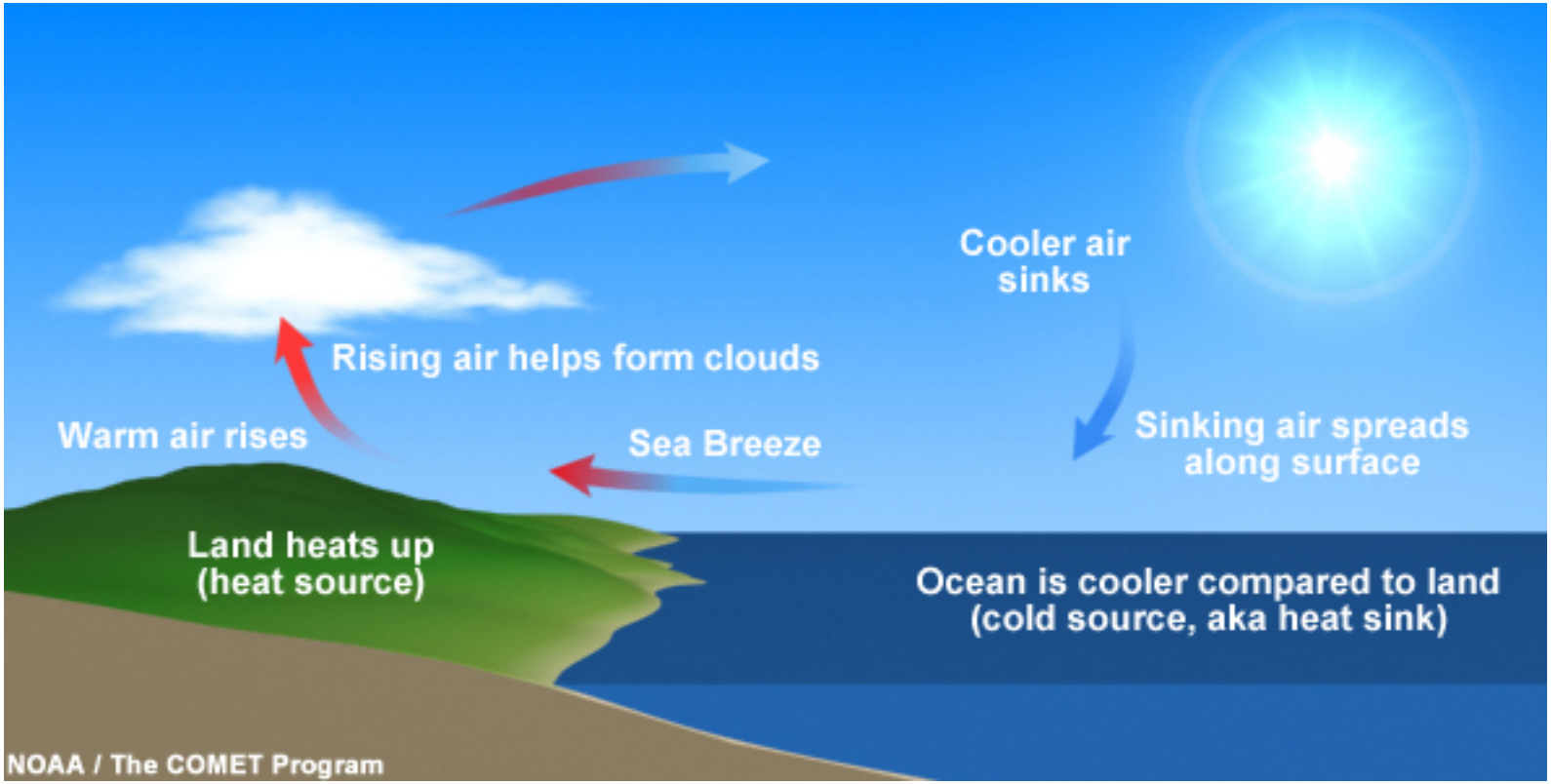
- **2. Day length also contributes to these temperature differences. The tilt of the Earth causes day lengths increase or decrease as you move away from the equator.**

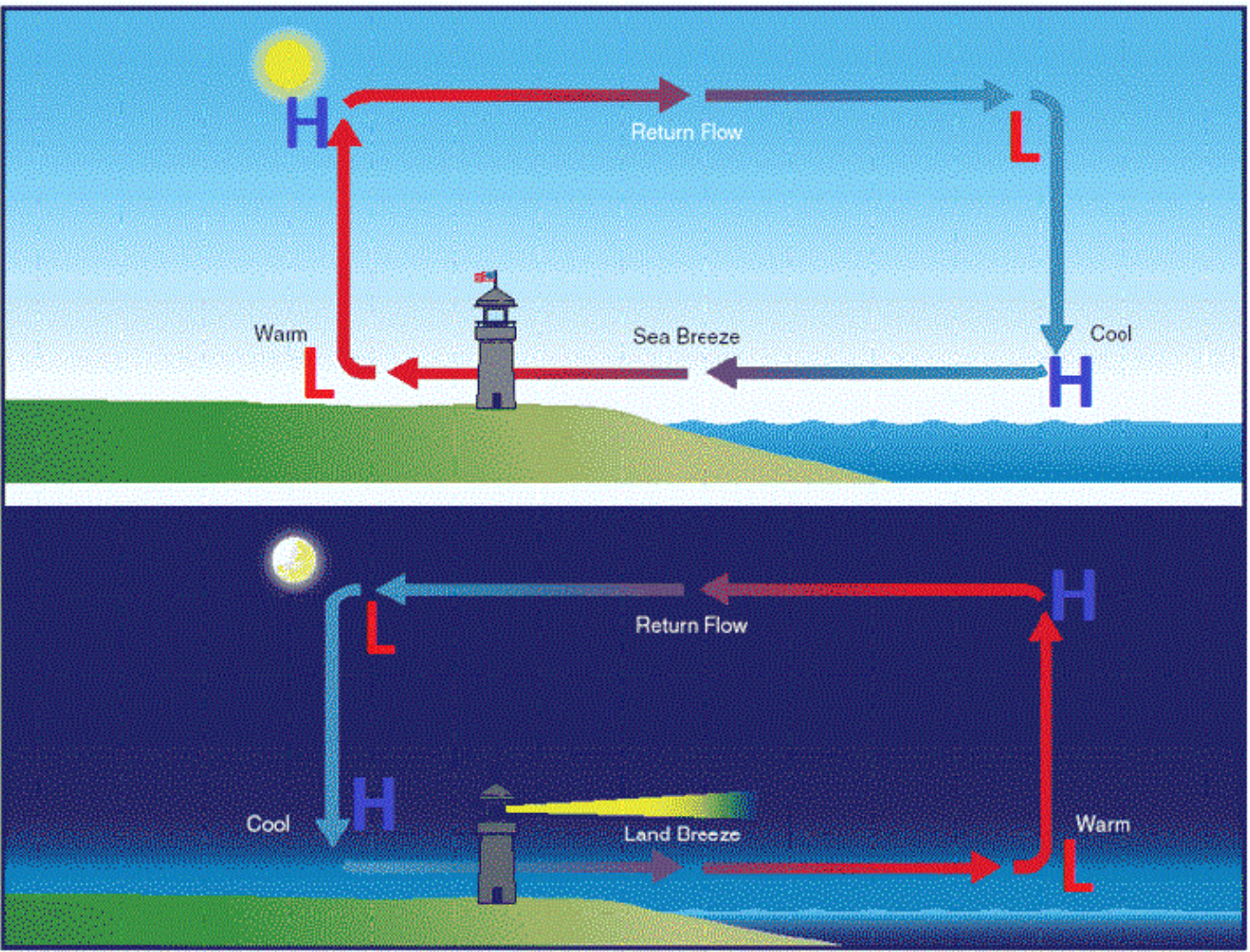
- **D. Another contributor to variable earth temperatures is due to the differences in which land and water reflect & absorb solar radiation.**
  - **1. Water takes an enormous amount of energy to heat. Water needs 5 times as much energy to heat than does land.**

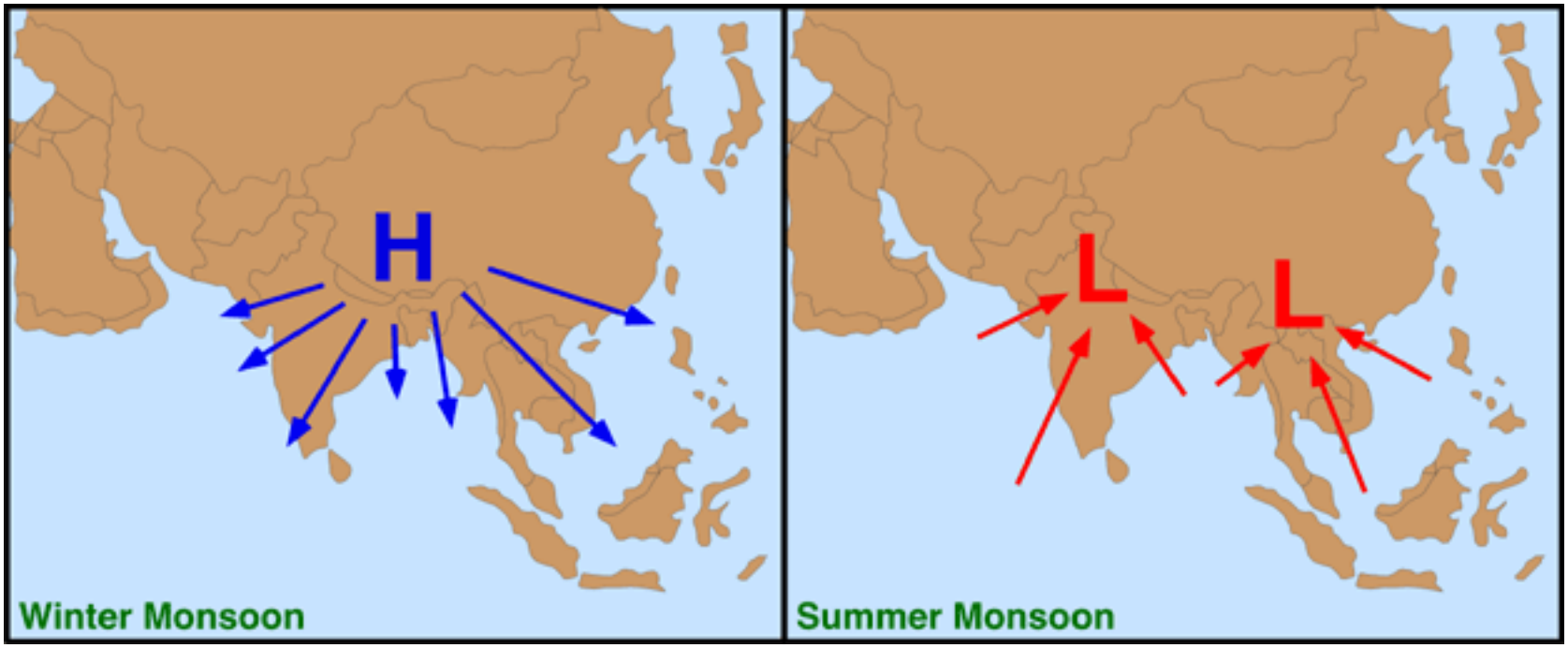
Water has to absorb 4.184 J of heat energy to raise the T of 1 g of water by 1°C.

For comparison sake, copper has to absorb only 0.385 J kg/ 1°C

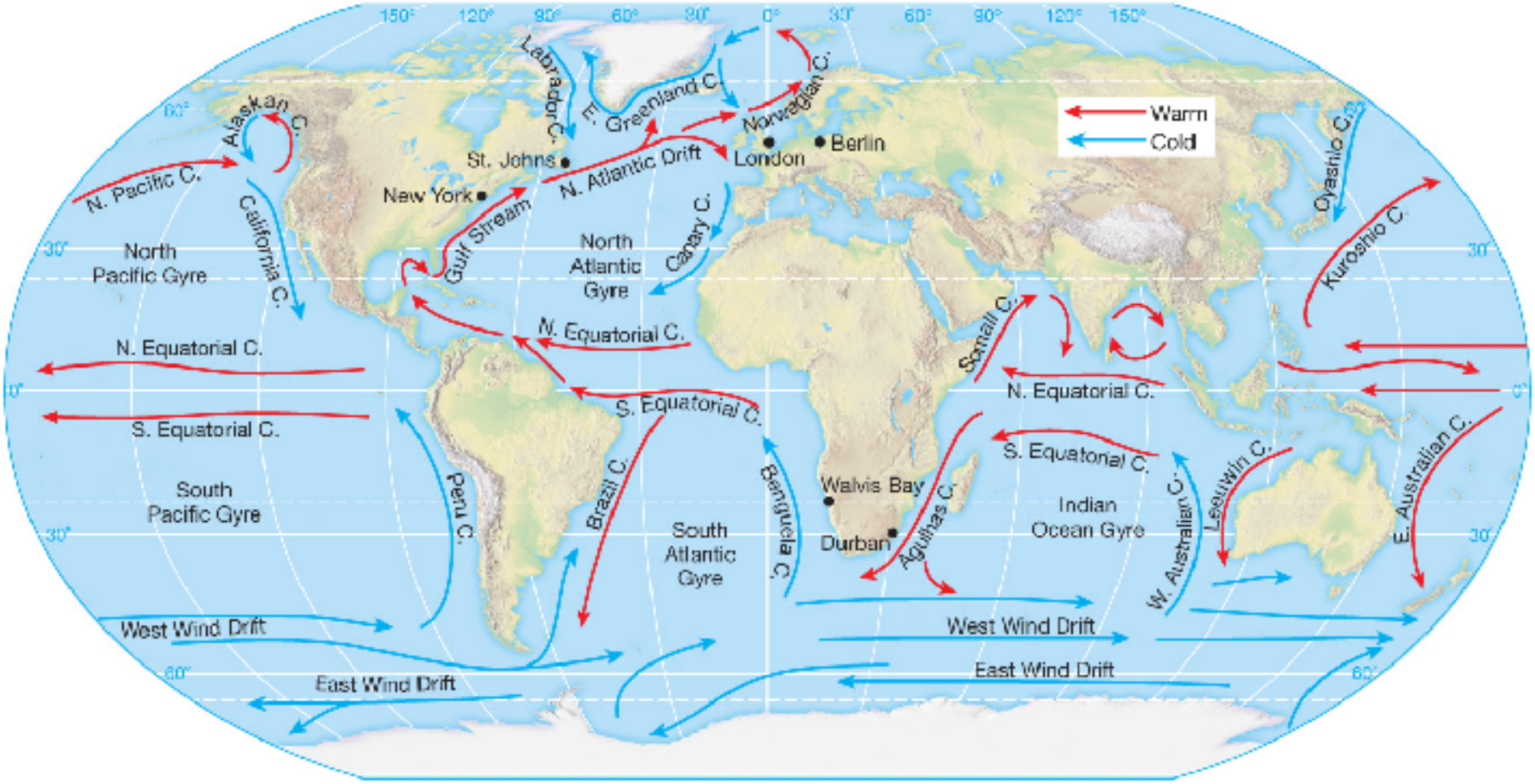
- **a. This means that water both heats up very slowly, but also cools down very slowly. Land heats up and cools down much quicker.**
- **b. Because the Southern Hemisphere is mainly water compared to the Northern Hemisphere, summers and winters are milder for this reason.**


Cooler air
sinks
Rising air helps form clouds
Warm air rises
Sea Breeze
Sinking air spreads
along surface
Land heats up
(heat source)
Ocean is cooler compared to land
(cold source, aka heat sink)
NOAA / The COMET Program

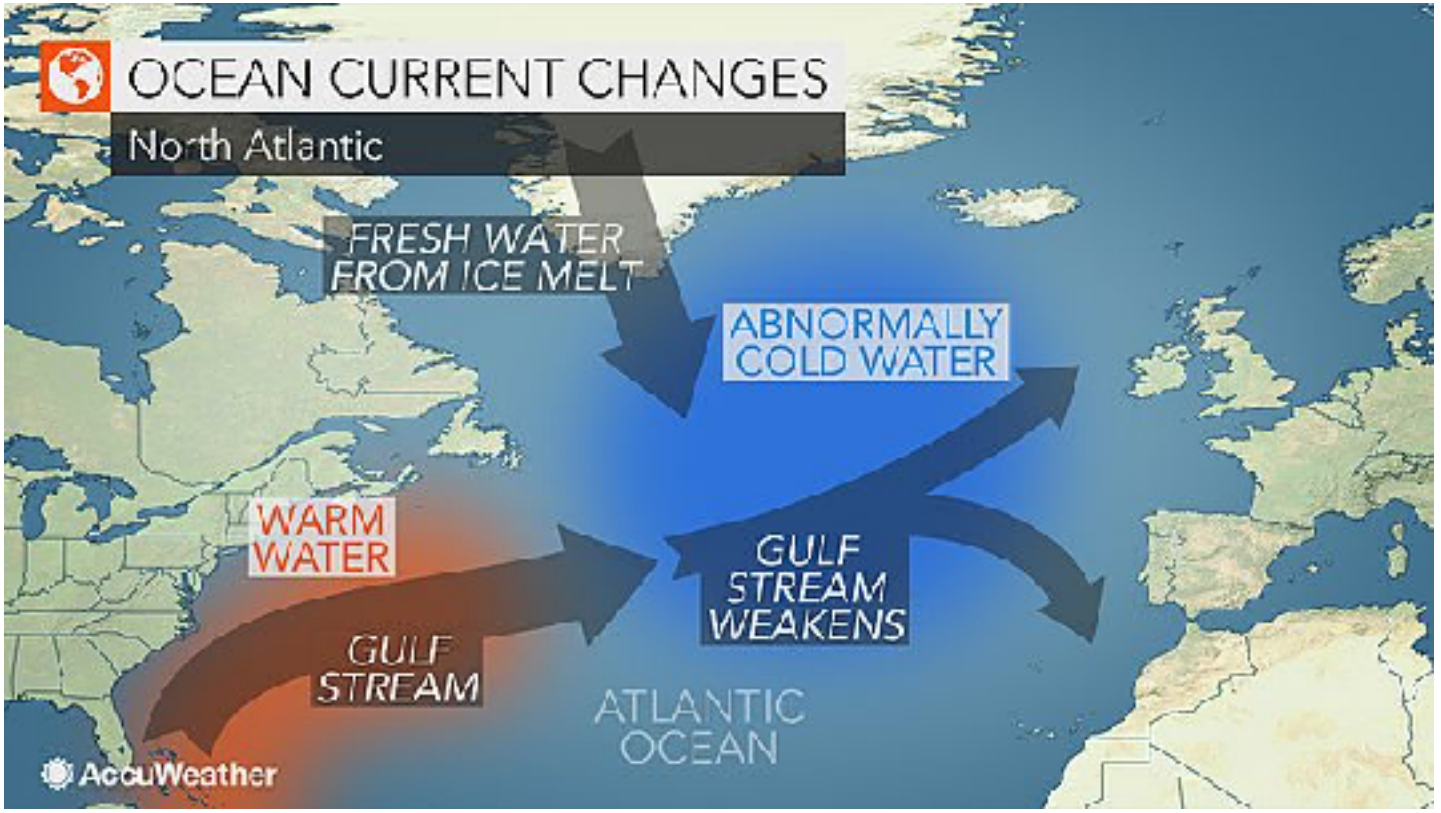

H
Return Flow
L
Warm
L
Sea Breeze
Cool
H
L
Return Flow
H
Cool
H
Land Breeze
Warm
L


H
Winter Monsoon
L
L
Summer Monsoon

- **E. Surface ocean currents, circulated mainly by winds, can also affect local temperature variations.**
- **1. Warm water currents that originate near the equator move poleward, thus transferring heat to higher latitudes.**
- **2. Cold water currents that originate near the poles move equatorward, thus transferring cooler water to lower latitudes.**
- **3. This is called oceanic circulation and comprises 20% of the heat transfer on Earth.**



- **4. The Gulf Stream is a warm-poleward moving current that affects the climate in Georgia and along the east of coast of the U.S.**

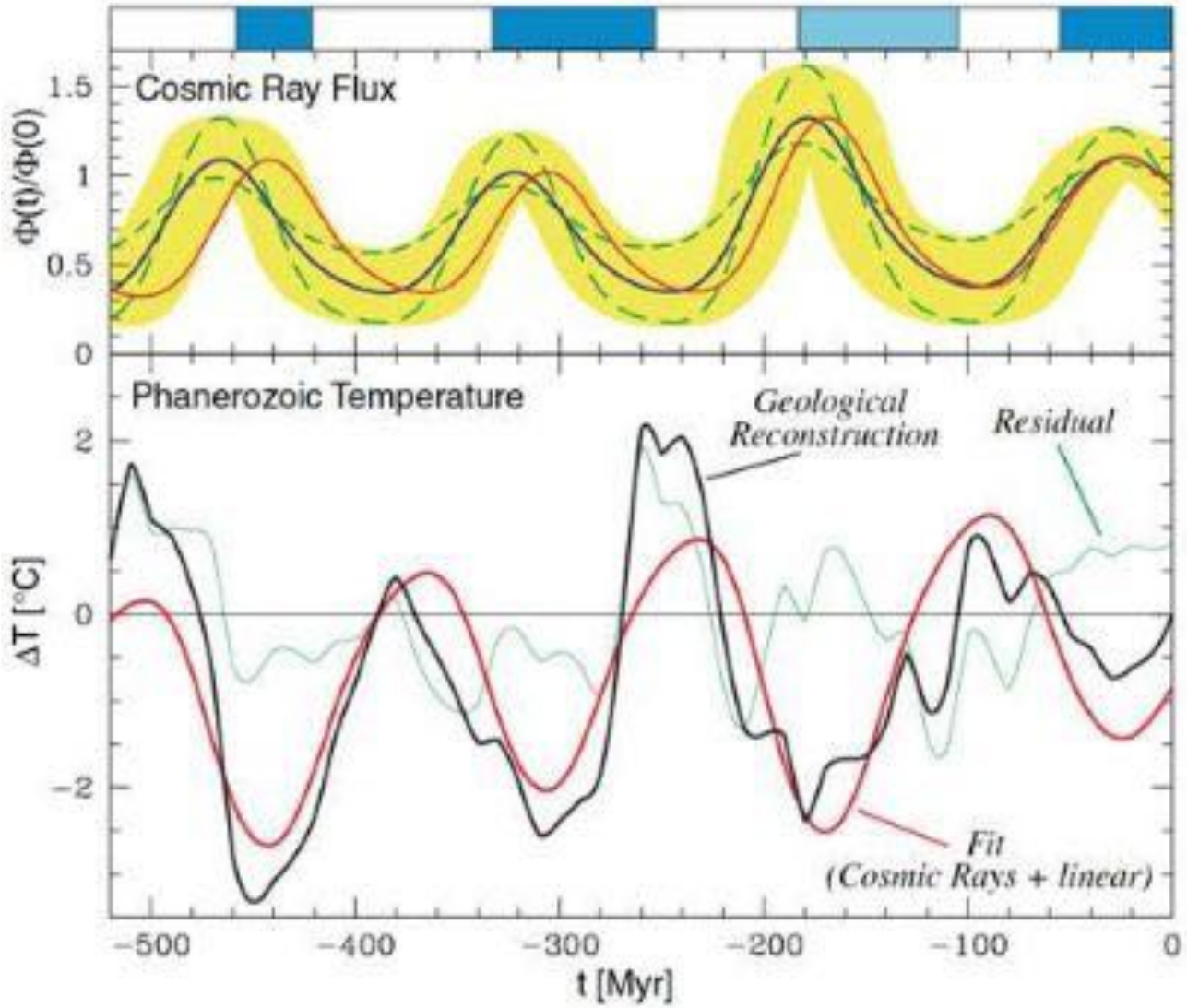


IV. Climate

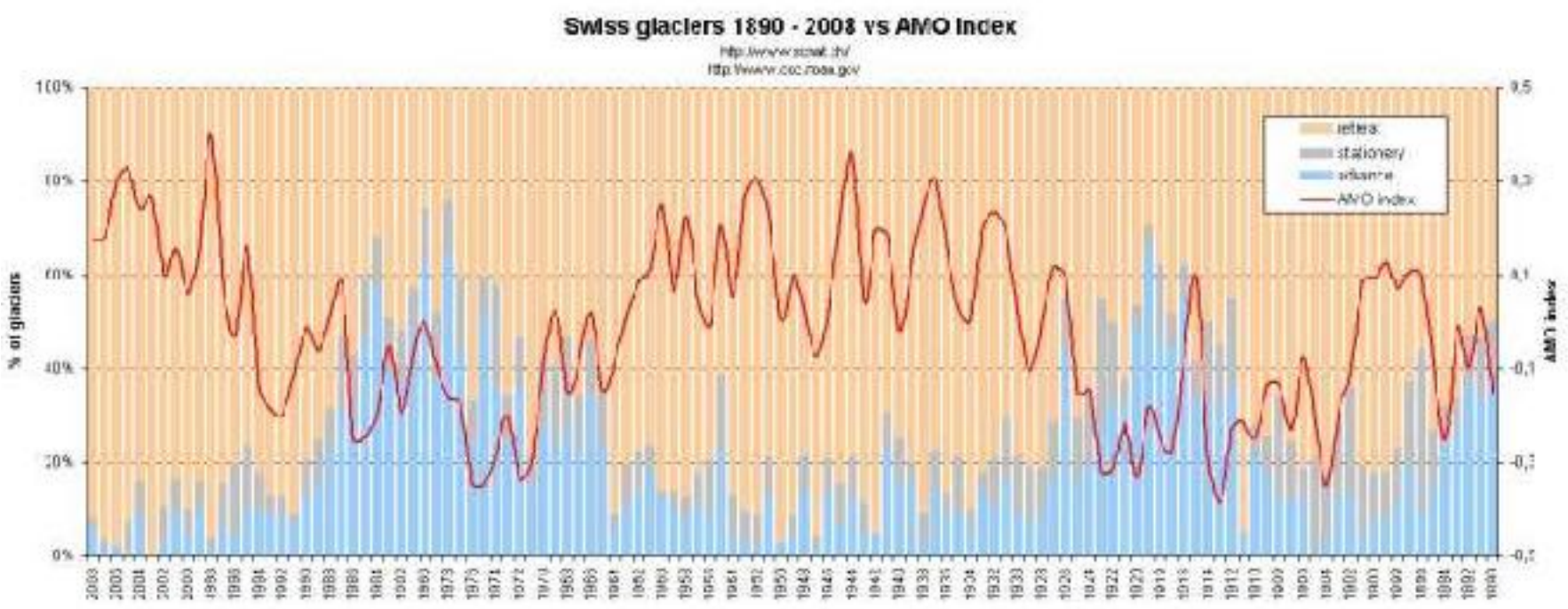
- **A. Latitude, altitude, land/water temperature contrasts, atmospheric & oceanic heat transfer all contribute to the average annual temperatures and precipitation to regions on Earth.**
  B. These averages constitute long-term rather patterns we call climate.
- **C. The composition of the Earth's atmosphere has changed over time, so the climate of the earth has not always been the same.**
- **D. There are many factors that contribute to the Earth's overall climate and how it changes over time.**
  - **1. The Earth's overall climate has been cooling for the last 70 million years.**

What Causes Earth's Temperature to Change???

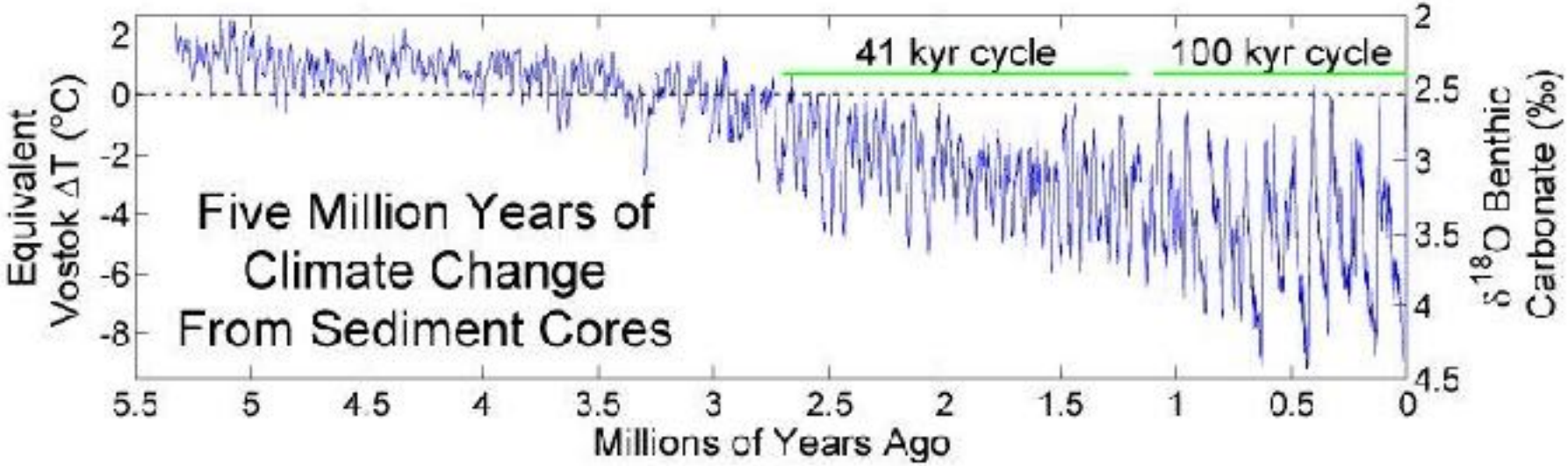
Cosmic Rays


Cosmic Ray Flux
Φ(t)/Φ(0)
1.5
1
0.5
0
Phanerozoic Temperature
Geological Reconstruction
Residual
Fit
(Cosmic Rays + linear)
ΔT [°C]
2
0
−2
−500
−400
−300
−200
−100
0
t [Myr]

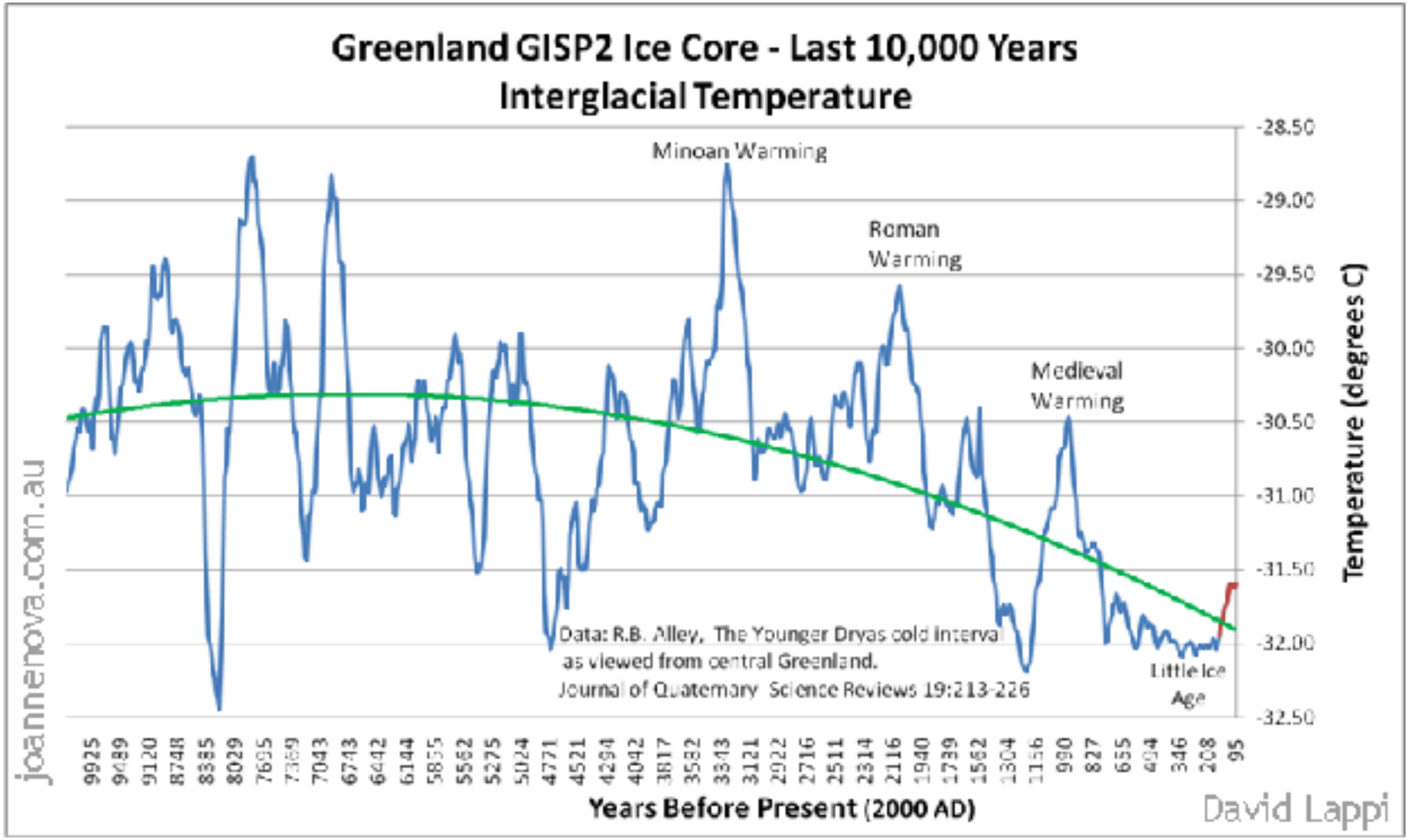
Sun Cycle and Glaciers



5 Million Years of Climate Change Based on Sediment Cores



10,000 Years of Climate Change - Greenland Ice Cores



12,000 Years of Climate Change – Vostok Antarctica Cores