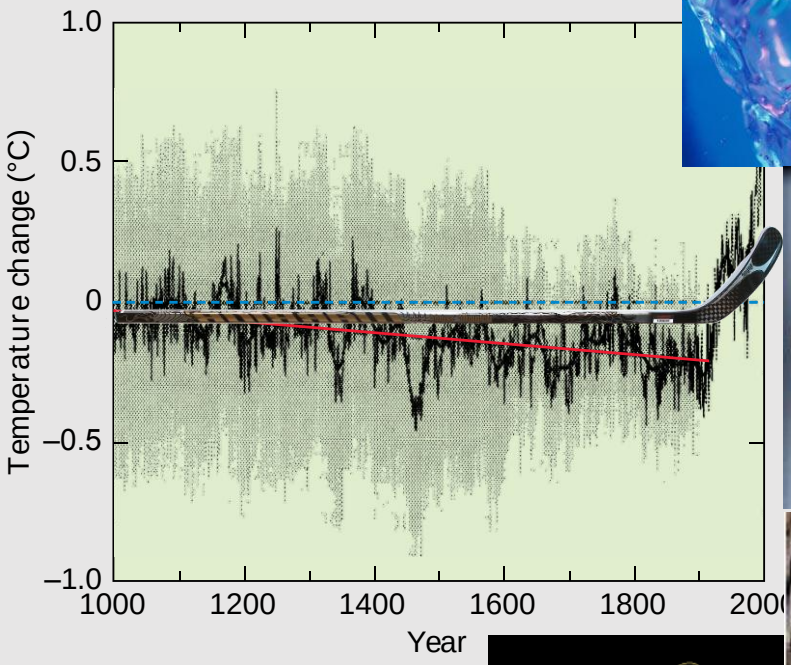
Last Time…

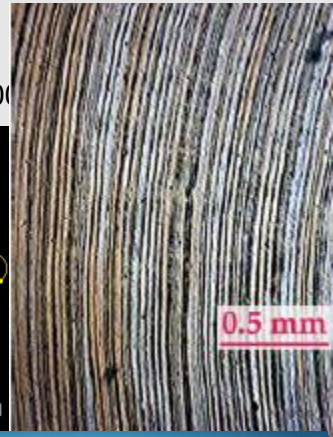
Are rising temperatures part of normal fluctuations?

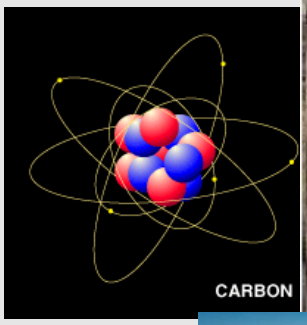
How did climate vary before the Industrial Revolution?

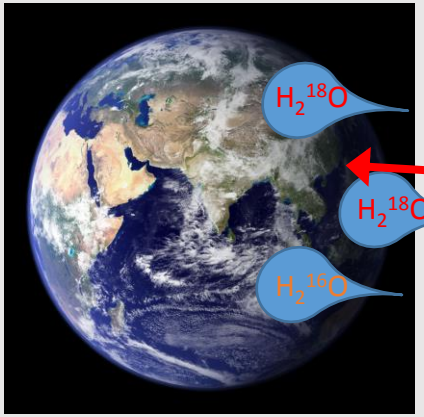
Key Concepts

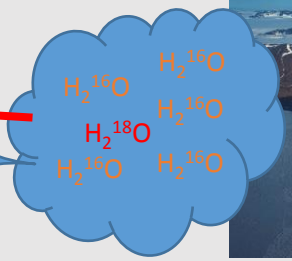
- Hockey Stick Graph
- Proxy Measures
  - –Ice Cores
  - –Tree Rings
  - –Glacial Extent
  - –Corral Reefs
- Isotopes
- The Rainout Effect











1 ring = 1 year

Tree Rings

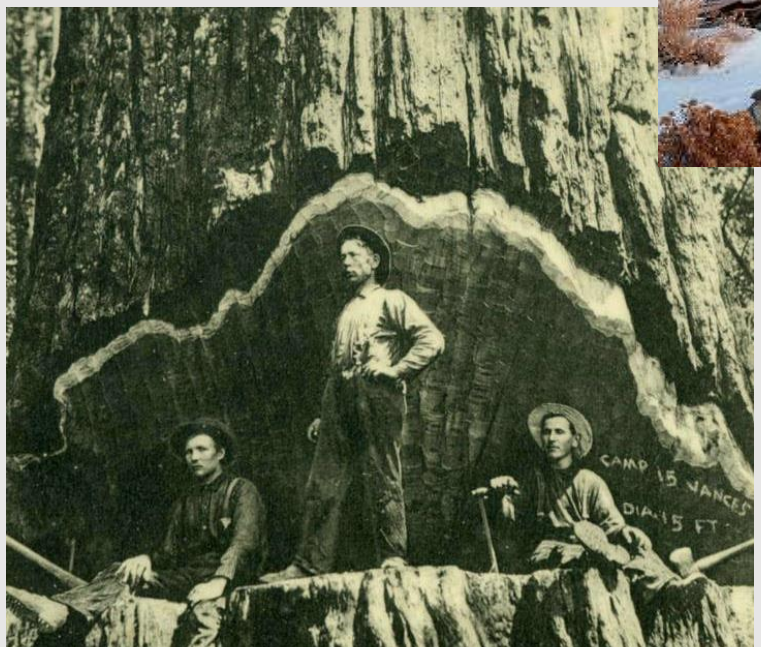
Errors in measurement

- Reflect local conditions
- Stressful conditions during growing season prevents formation of a growth ring
- Temporary growth stop, then continued growth in one season leads to a false ring.

Trees can live for thousands of years

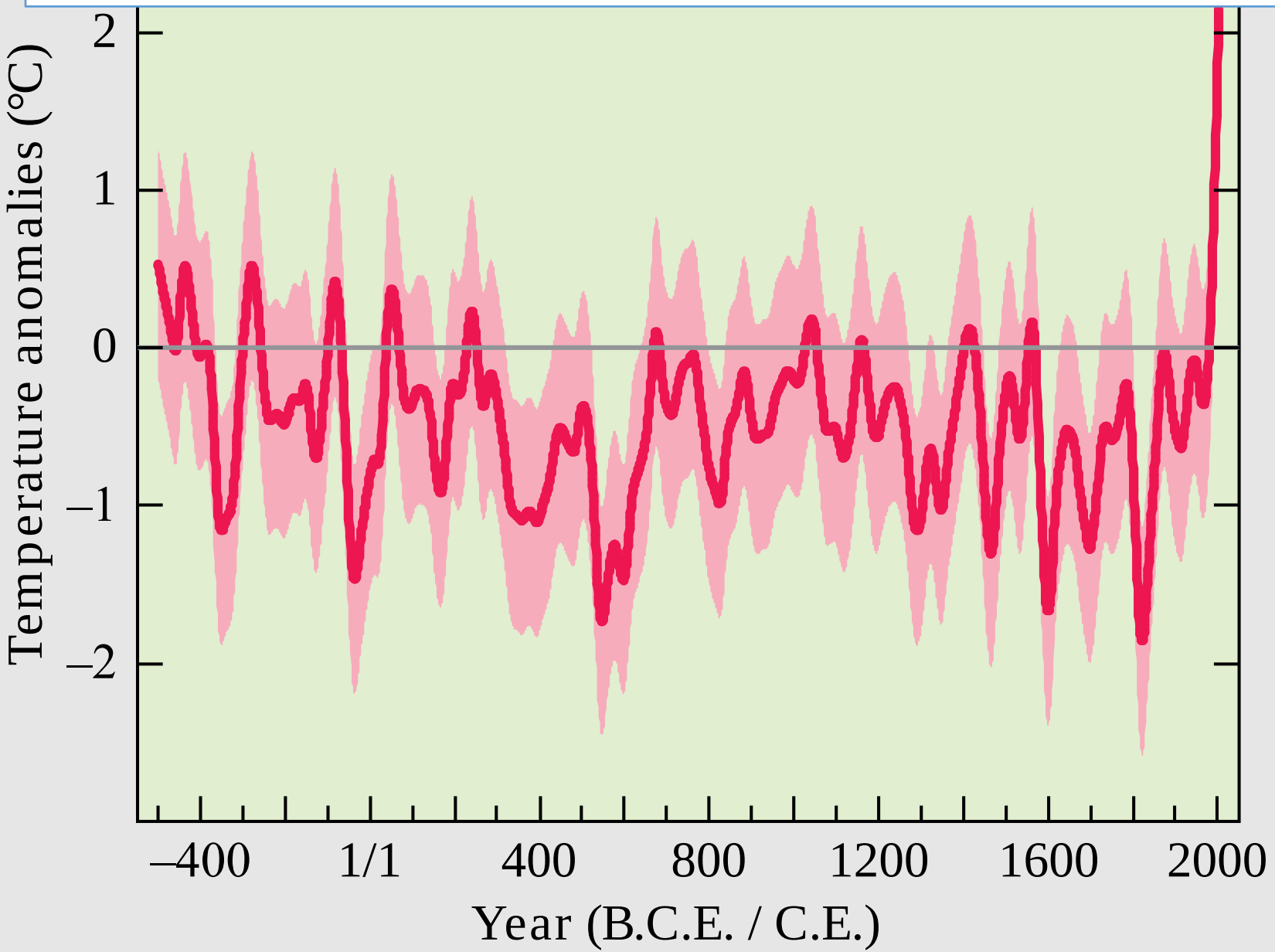
Wood from ancient structures can be used to look further back

- One chronology in Germany extends more than 10,000 years.



Oldest living thing on Earth:
Bristle cone pine 4,844 rings

Summer temperature changes in Europe over the past 2,500 years

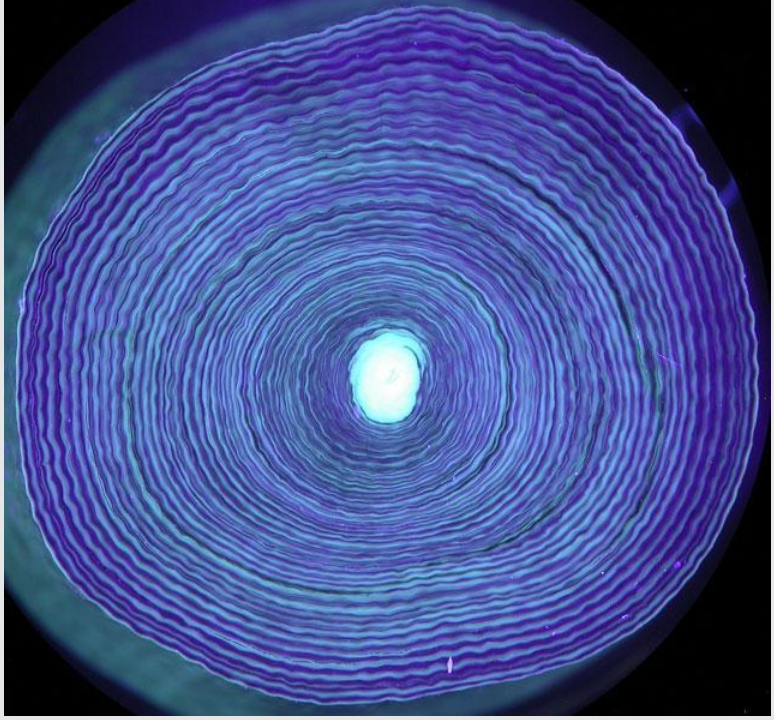


Coral Rings

Similar to tree rings

Corals form exoskeletons of calcium carbonate.

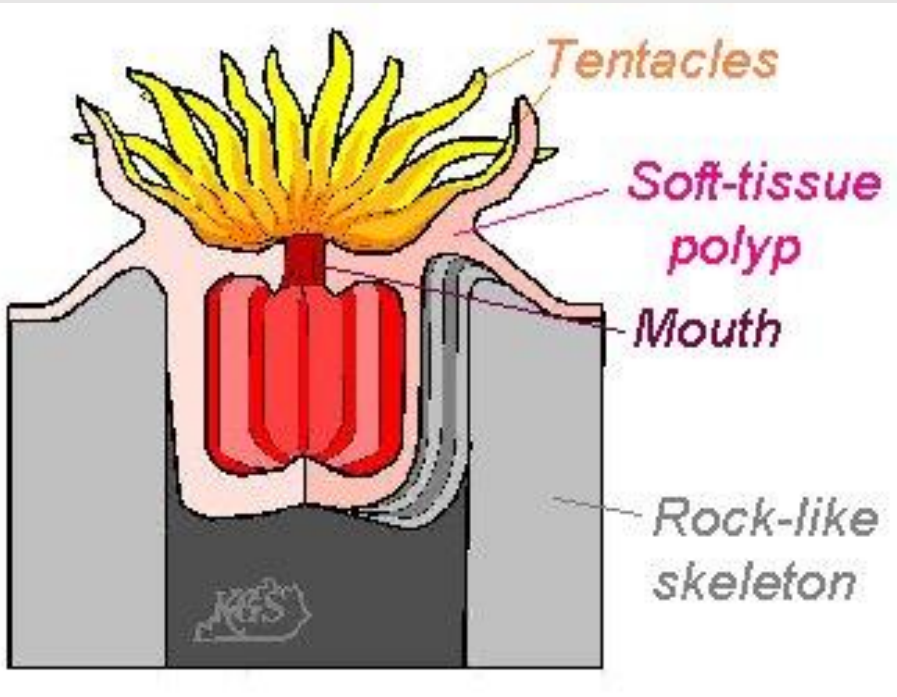
- More growth during good conditions
- Dense growth during poor conditions (storms)
- Creates annual bands



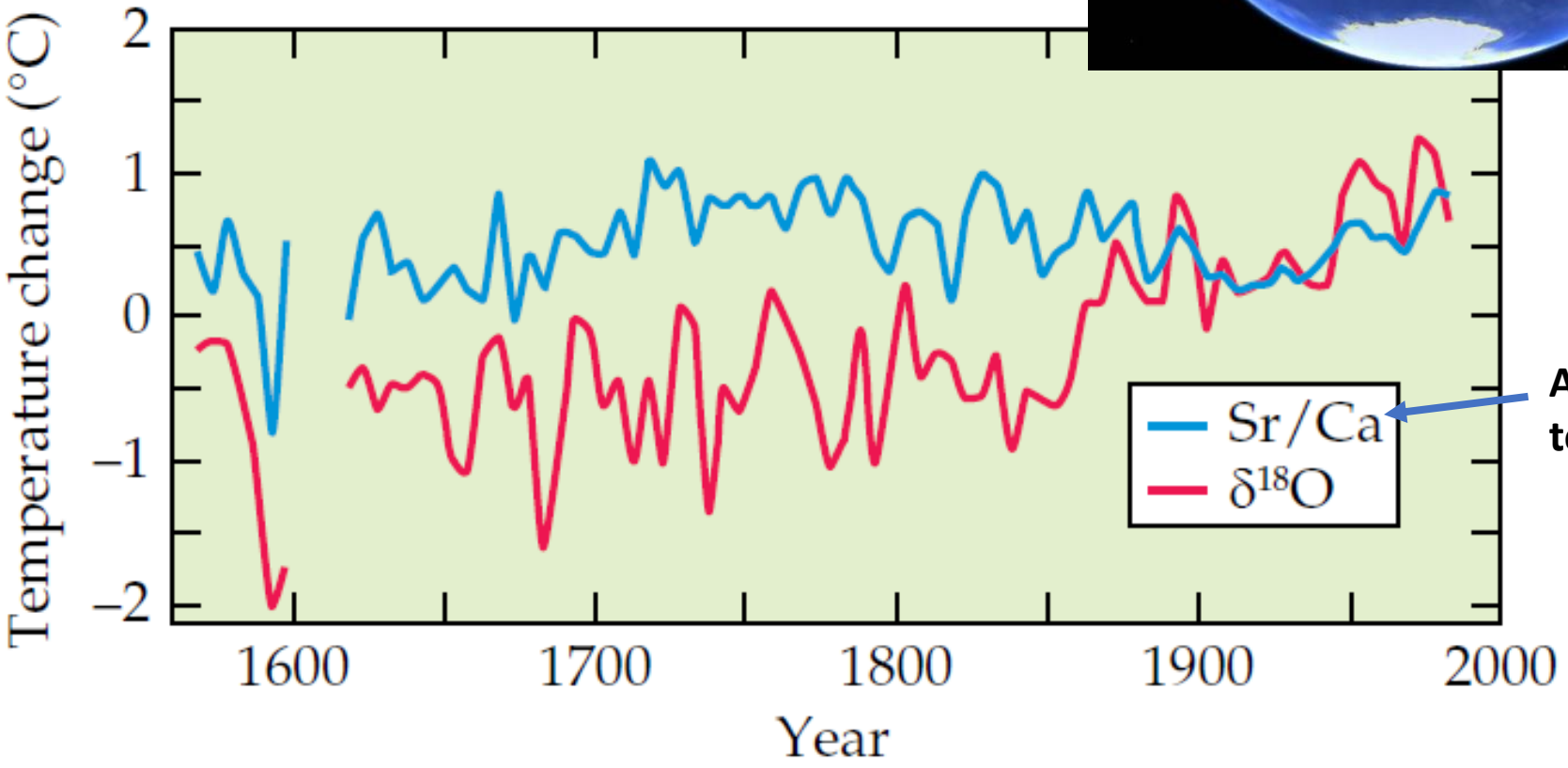
Can Tell Us About Temperature

Heavy and light oxygen gets incorporated into the exoskeleton.

- More heavy oxygen means it was a cool year (less evaporation)
- Less heavy oxygen means it was warmer (more evaporation)



Can date back as far as 1565 years



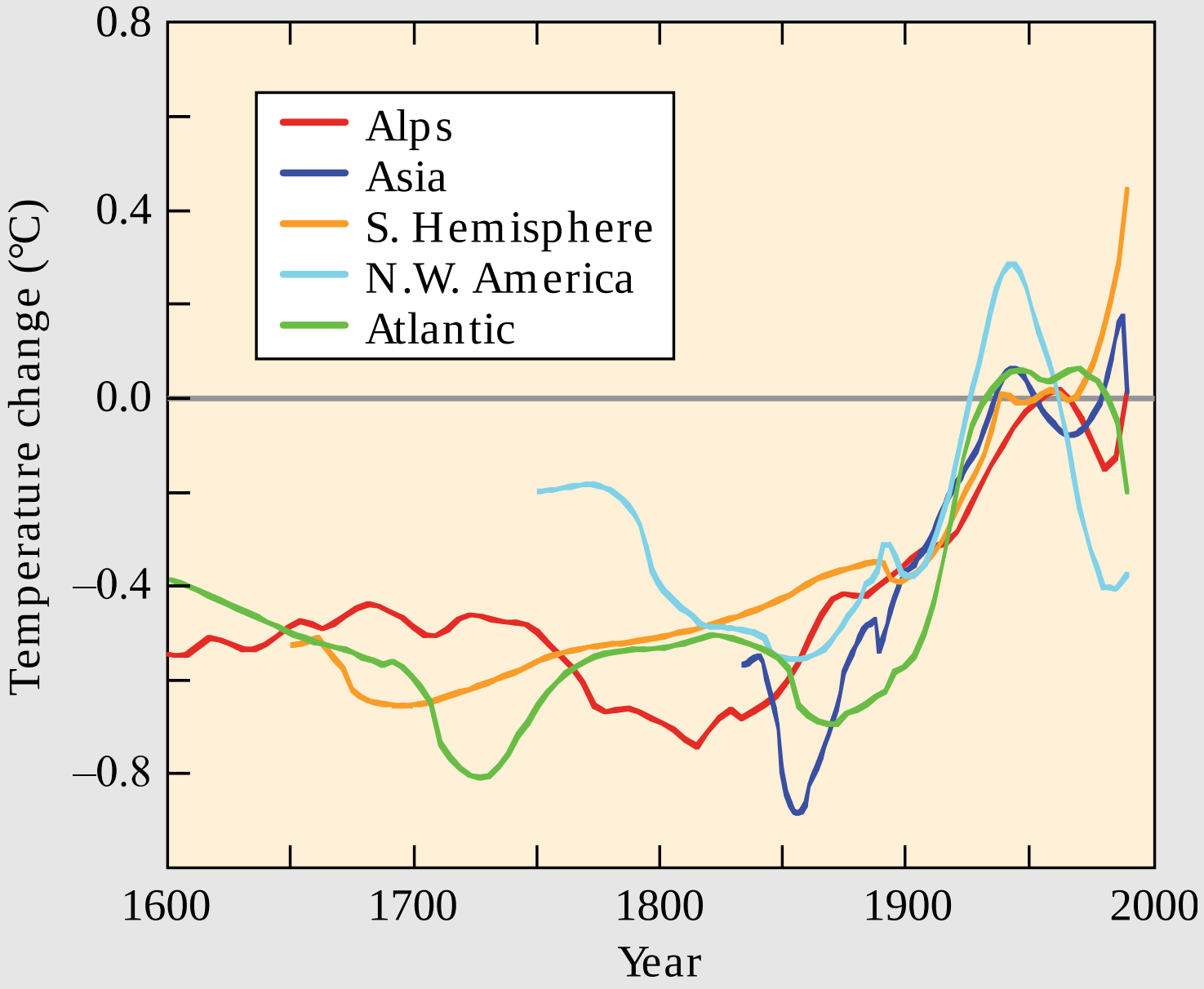
Another temp proxy

Glacial Extent

Assessment of the size of glaciers for the past 400 years

- Direct measurements
- Paintings
- Etchings
- Photographs
- Satellite images

Glacial Extent: reconstruction of temperature changes based on lengths of glaciers



Glacier National Park

Approximately 150 glaciers present in 1850, and most glaciers were still present in 1910 when the park was established. In 2010, there were only 25 glaciers larger than 25 acres remaining in GNP. Climate models predicts that some of the park's largest glaciers will vanish by 2030. However, glacier disappearance may occur even earlier, as many of the glaciers are retreating faster than their predicted rates.

Proxy Measures

Indicate Earth's average temperature has fluctuated many times

- By as much as 10°C
- Temperature changes correlate with greenhouse gas concentrations

When we look at these climate changes in concert with the fossil record, we can see that climate has deeply impacted life on earth

What other factors (non-human) influence climate?

Thank you Nydia!

Causes of Climate

Climate **forcing factors**: responsible for the climate fluctuations Earth has experienced throughout history

- External forcing factors: agents outside of Earth and in the atmosphere
- Internal forcing factors: originate on Earth

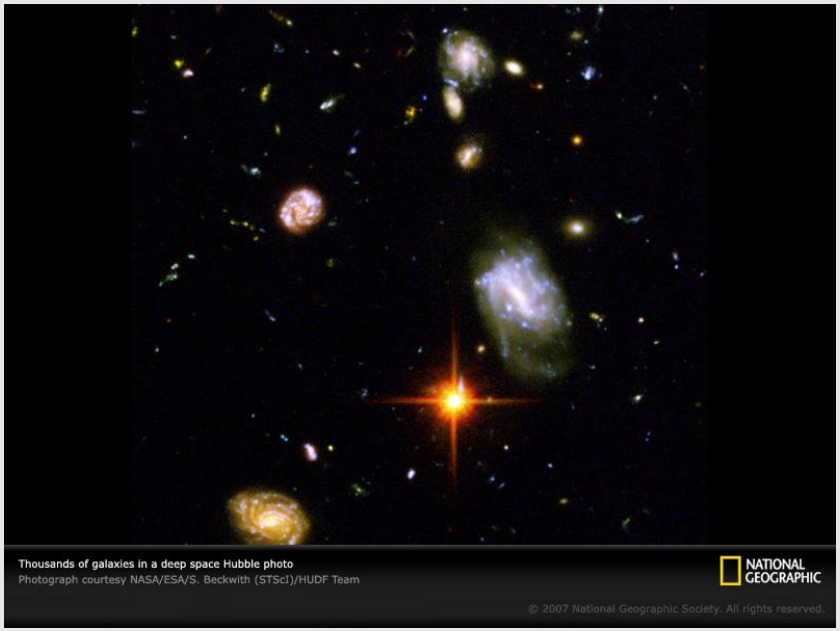
Climate Forcing Mechanisms

External

- Galactic variations
- Orbital variations
- Solar variations

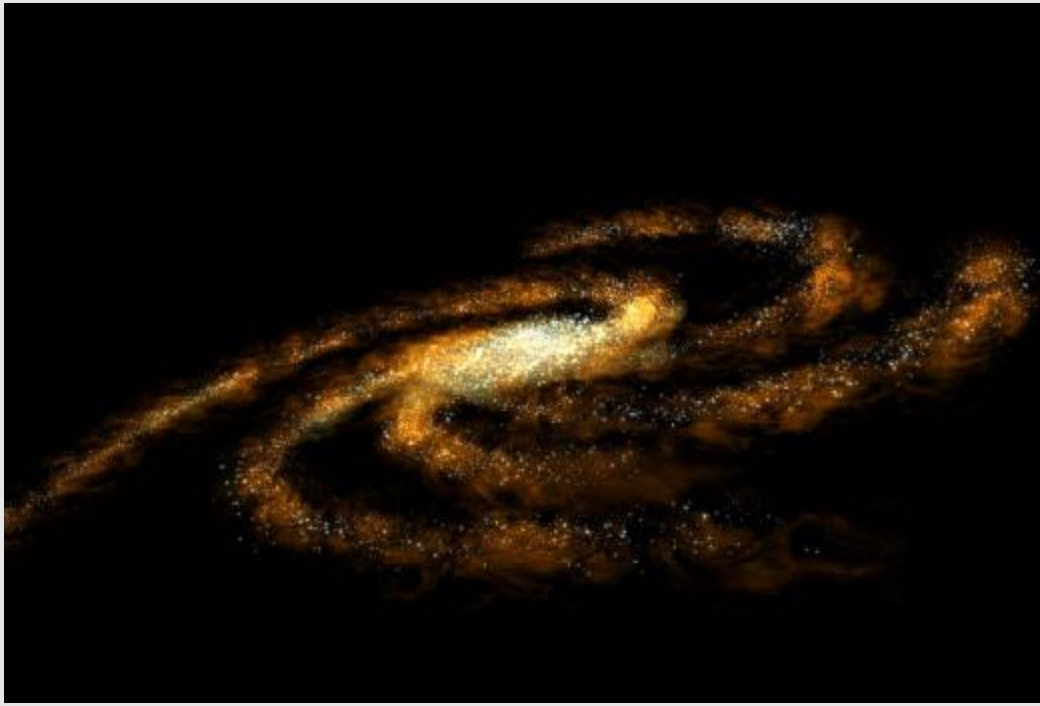
Internal

- Atmospheric composition
- Orogeny
- Epeirogeny
- Volcanic activity



Galactic Variations

Our solar system rotates around the center of the Milky Way galaxy (one galactic year = 103 million years)



Quantity and quality of energy reaching Earth from nearby star systems varies

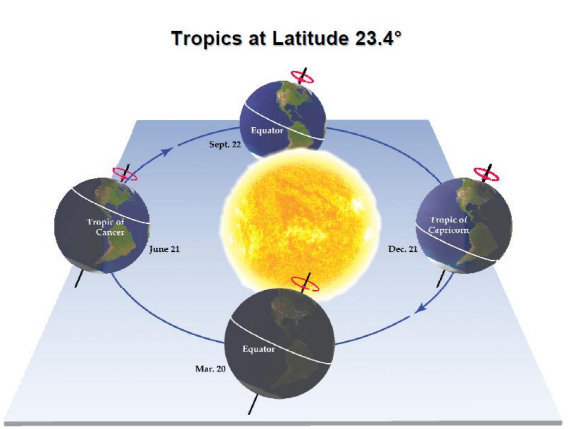
Cycle is so long, influence is uncertain

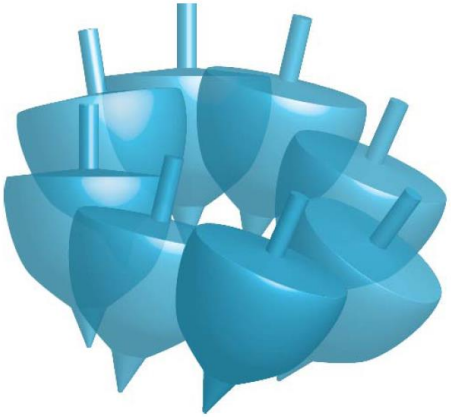
But…several major climatic events are separated by about 1 galactic year (150 million years)

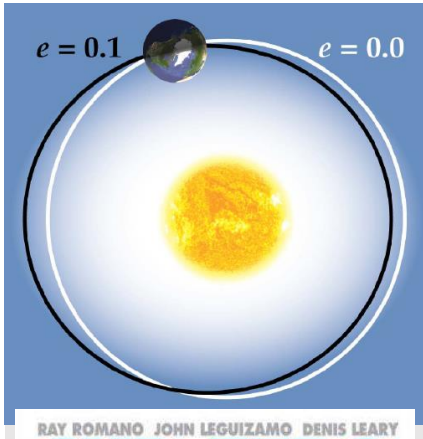
- –K-T boundary
- –Great Dying
- –Ordovician-Silurian Extinction

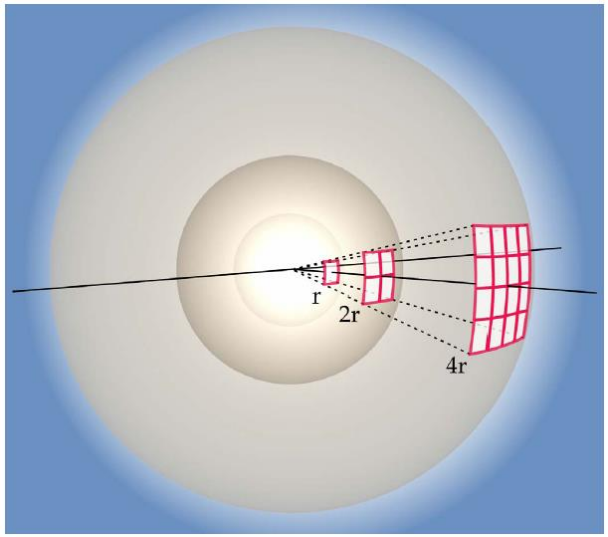
Orbital Variations

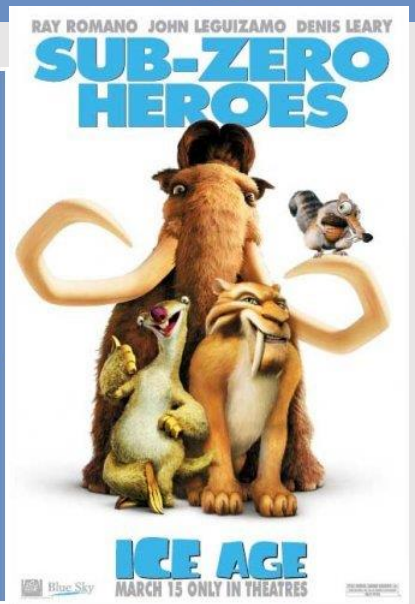
- The Cosine Law
- Inverse Square Law
- Obliquity
- Eccentricity
- Precession
- Ice ages



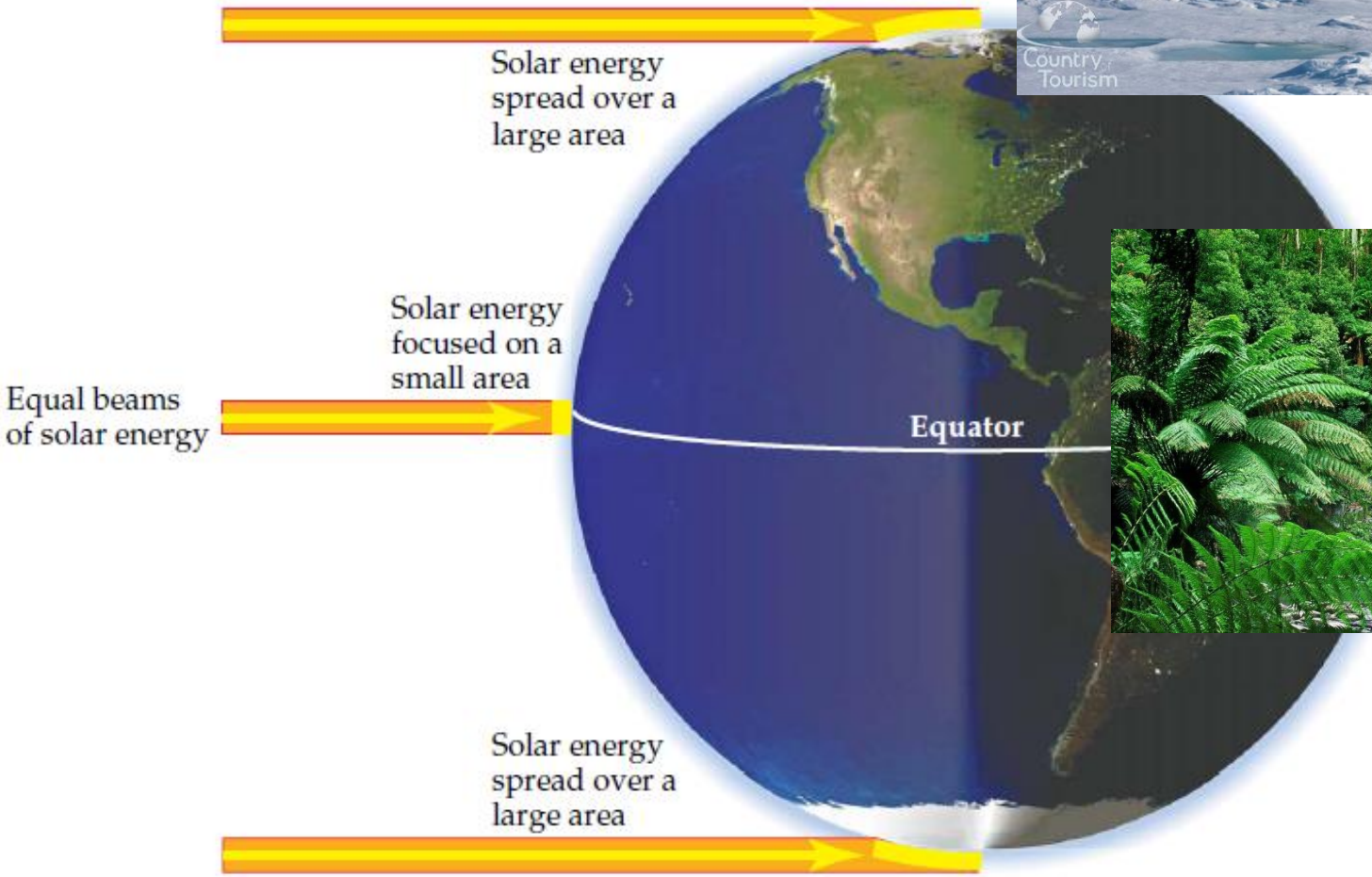








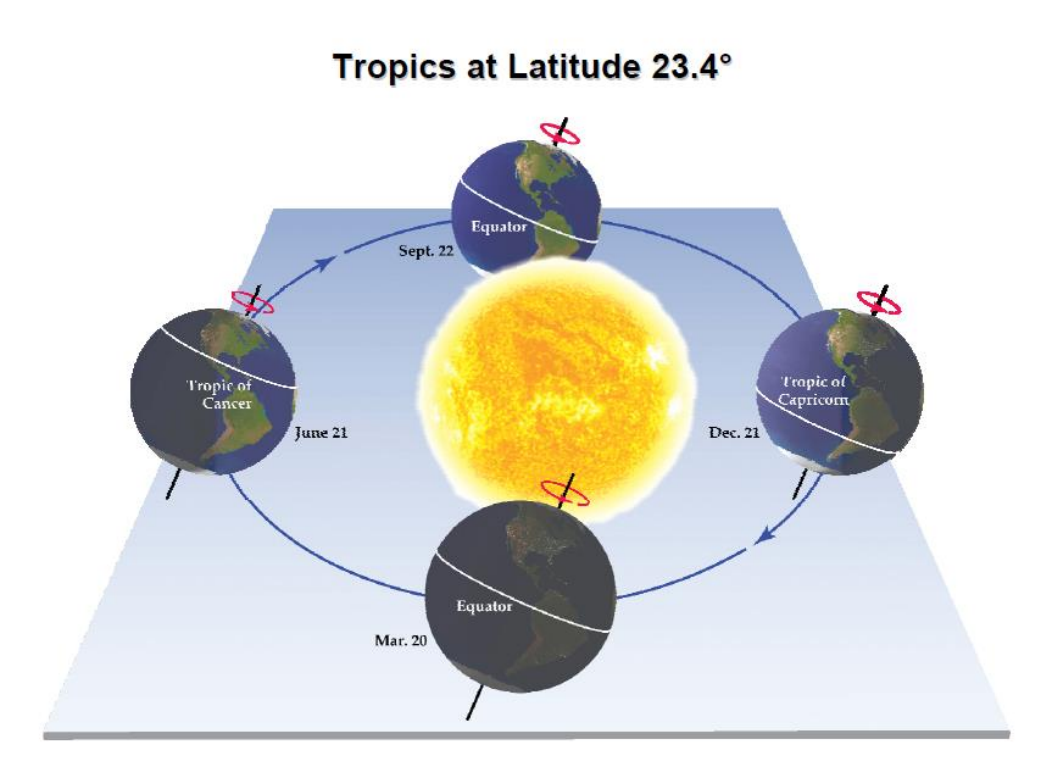
The Cosine Law



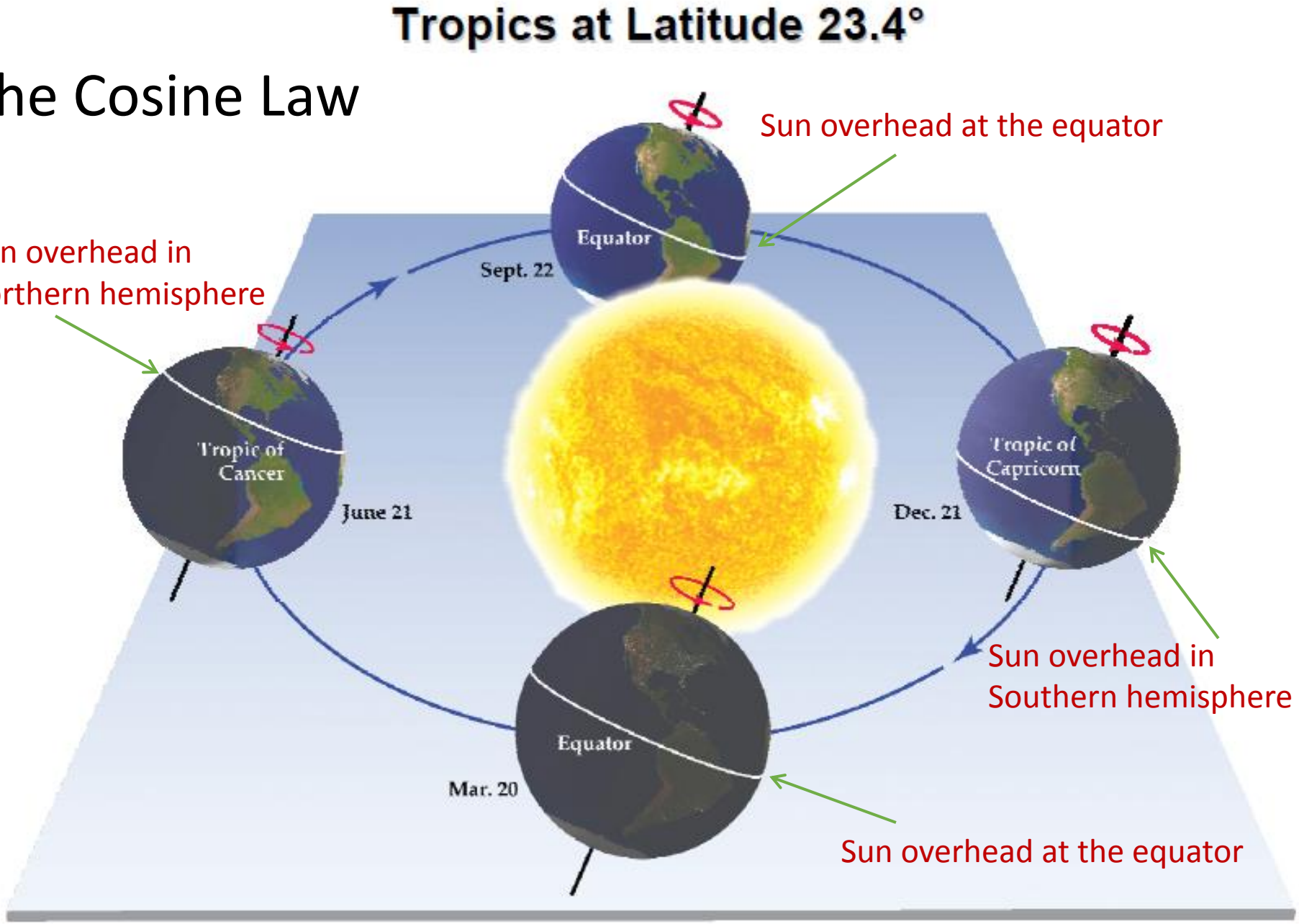
The Cosine Law

Earth is tilted on its axis of rotation

Explains differences in seasons



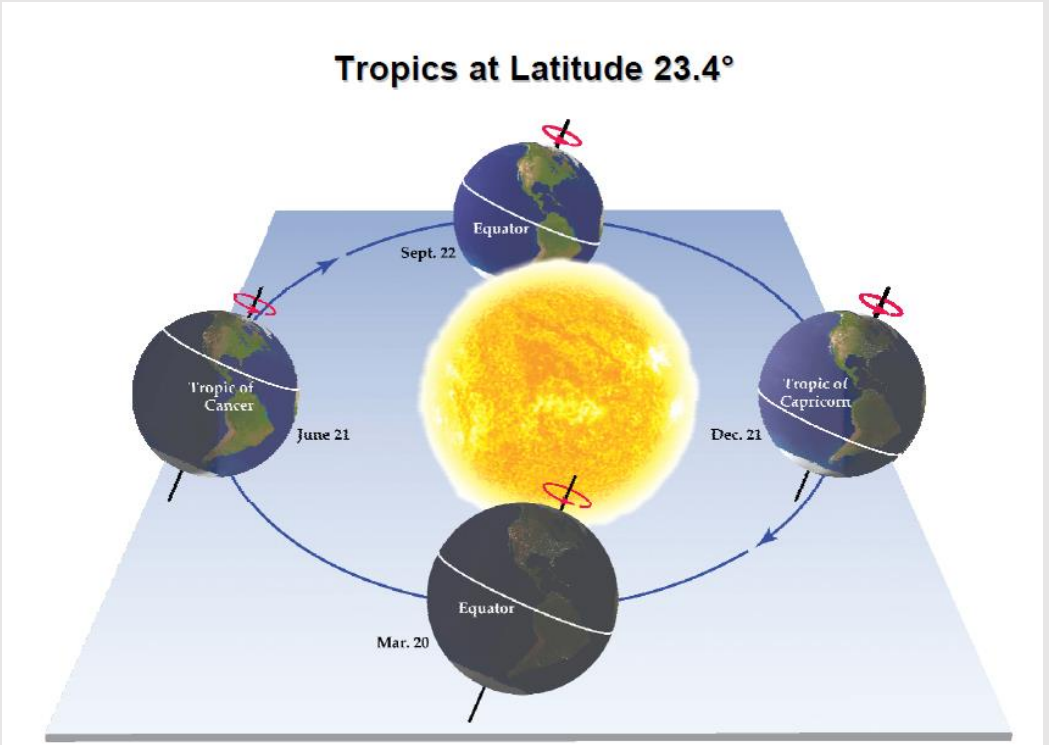
The Cosine Law



June 21: sun directly overhead in Northern Hemisphere. SUMMER

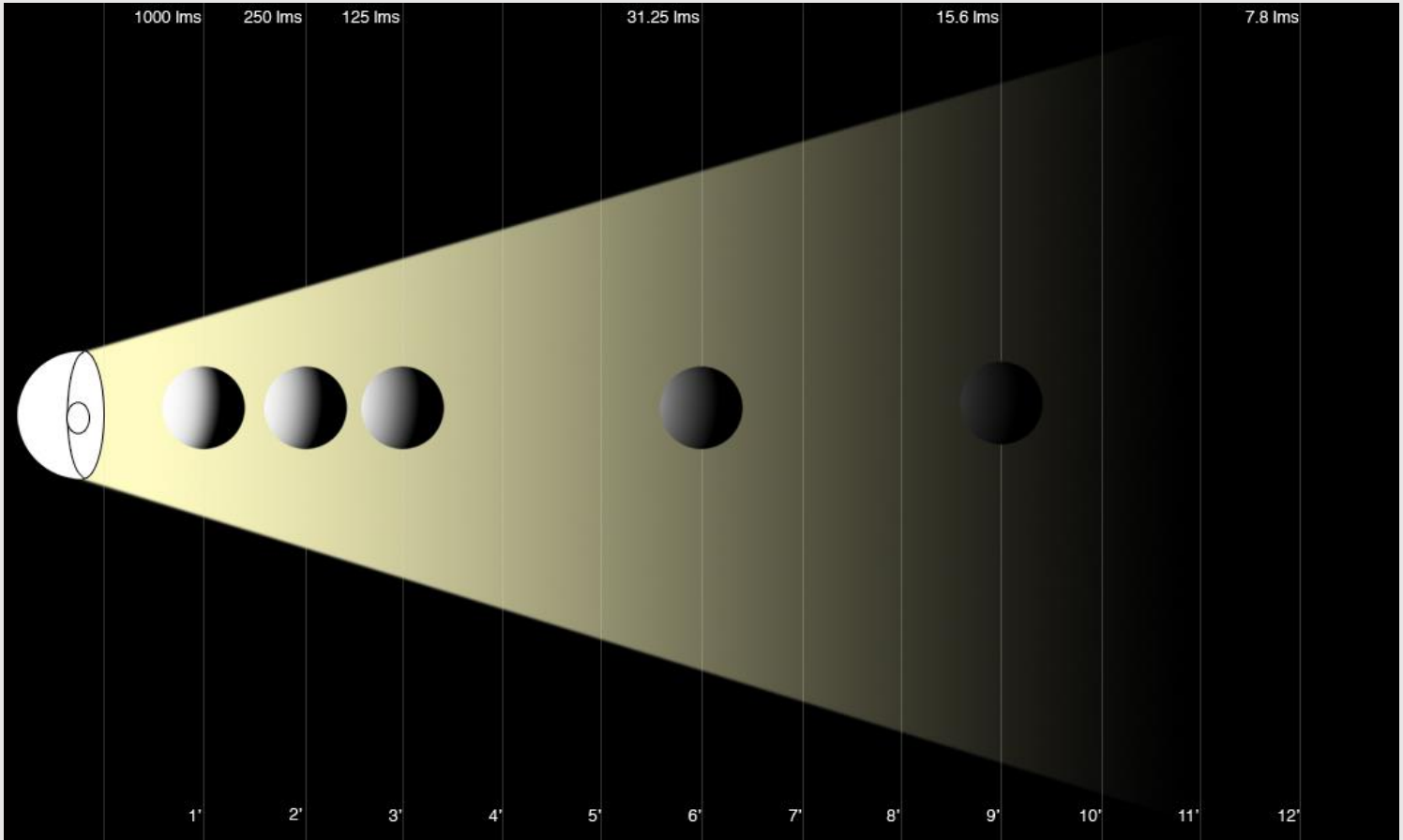
(winter in southern hemisphere)

December 21: sun is spread over largest area in N. Hemisphere. WINTER (summer in the S. Hemisphere)

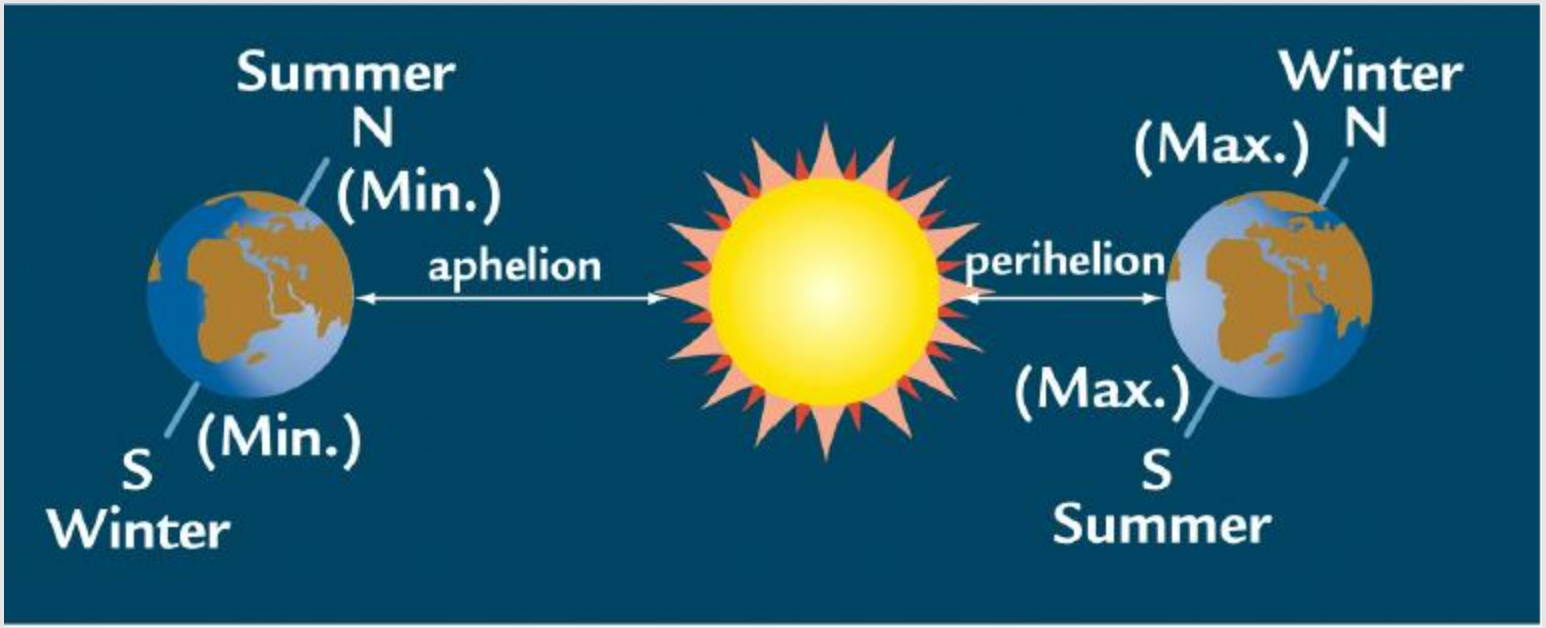


The Inverse Square Law

The amount of solar energy striking an area decreases with the square distance of the distance from the sun.



The Inverse Square Law



We are actually farther away from the sun during the summer in the N. Hemisphere

- –Energy spread over larger surface area

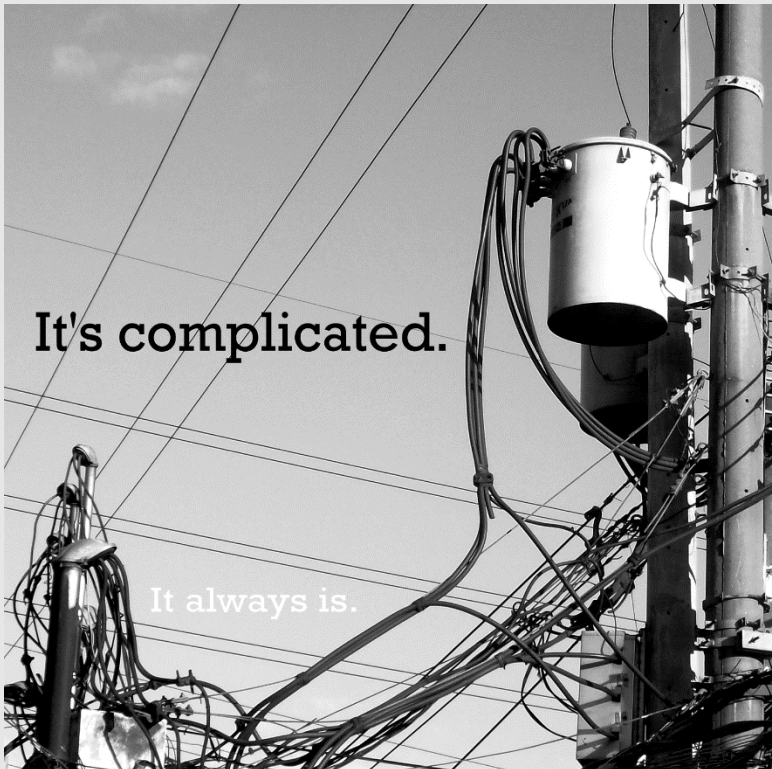
Cosine Law

The tilt of Earth on its axis effects the amount of energy we receive from the sun

Inverse Square Law

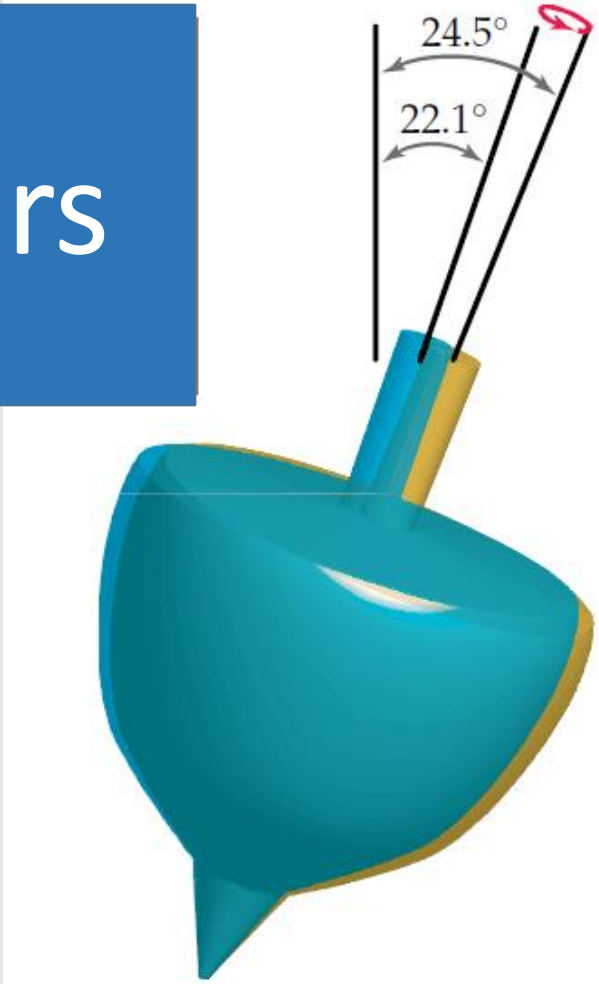
The distance of Earth from the sun effects the amount of energy we receive

The tilt and the distance both change over time

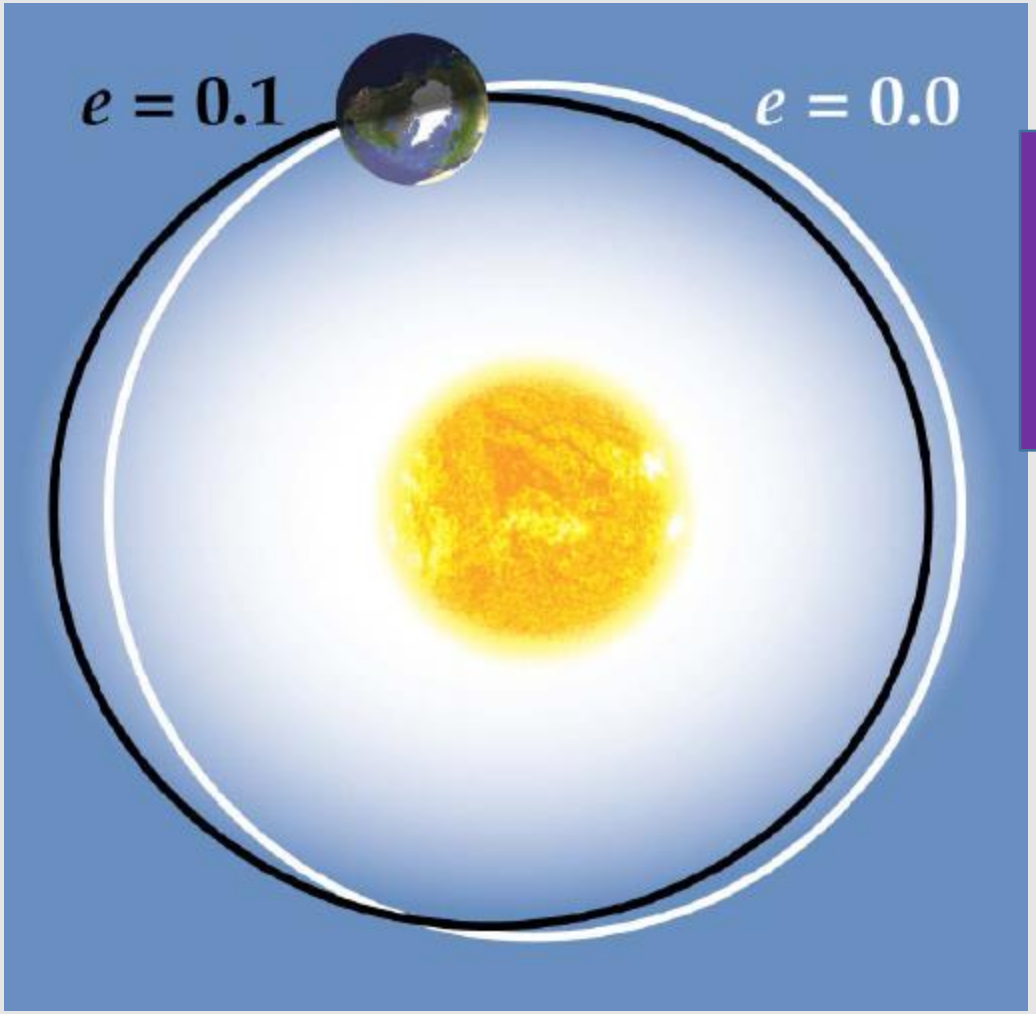


Obliquity = The Tilt of the Earth's Axis

41,000 years



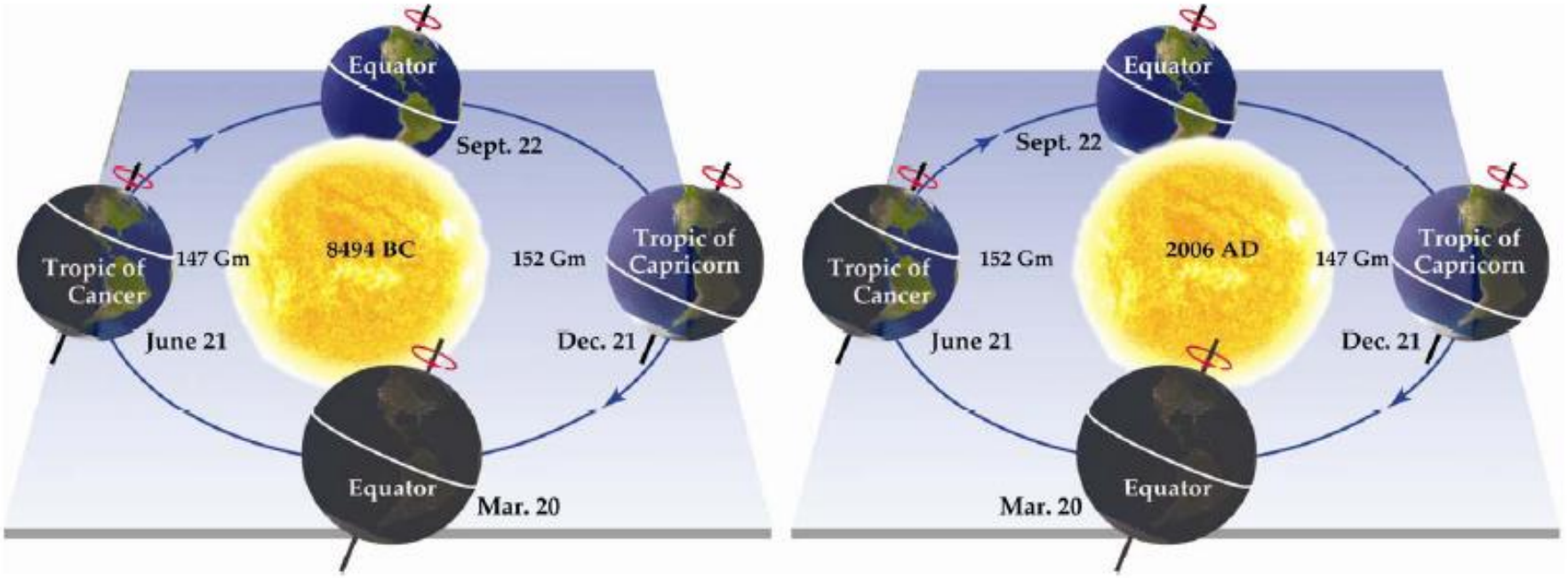
Eccentricity = a measure of deviation of an orbit from a perfect circle



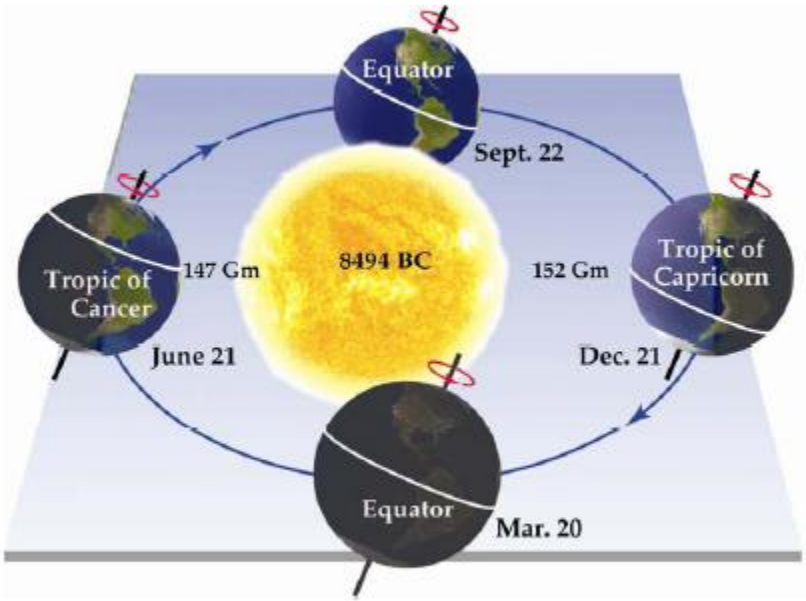
100,000 years

Precession - The Earth's orbit around the sun wobbles

21,000 years

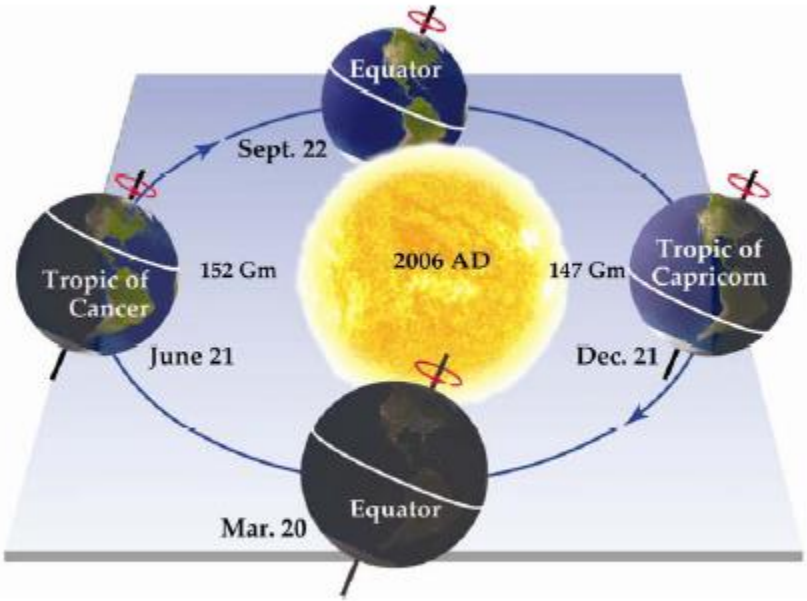


Precession



10,500 years ago

Earth was closest to the sun during June-July



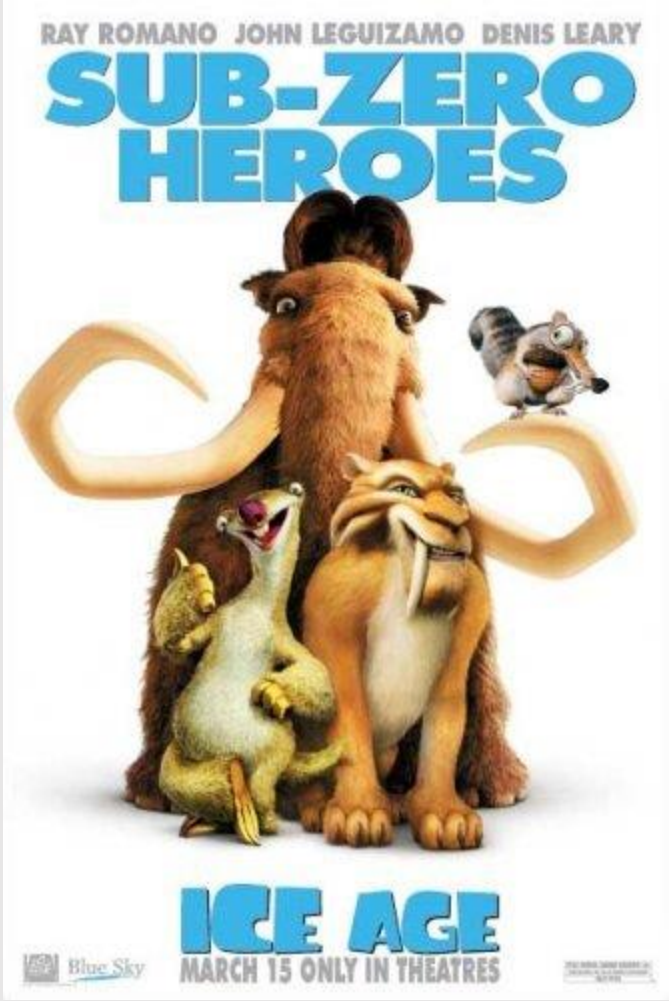
Present orbit

Earth is currently closest to the sun during December-January

Ice Ages

Milankovitch Theory

- –Serbian astrophysicist
- –Ice ages occur in the N hemisphere when:
  - Axial tilt is small (small seasonal variations)
  - Eccentricity is large (large seasonal variations)
  - Earth is closest to the sun during N. Hemisphere winter (small variations)



Are Orbital Variations Responsible for Current Climate Change?

Current combination of orbital variations lead to moderate and stable solar radiation in the N. hemisphere (Interglacial period)

If orbital variations were the sole forcing factors, Earth's climate should remain the same for the next 40,000 years.

External Climate Forcing Mechanisms

Galactic variations

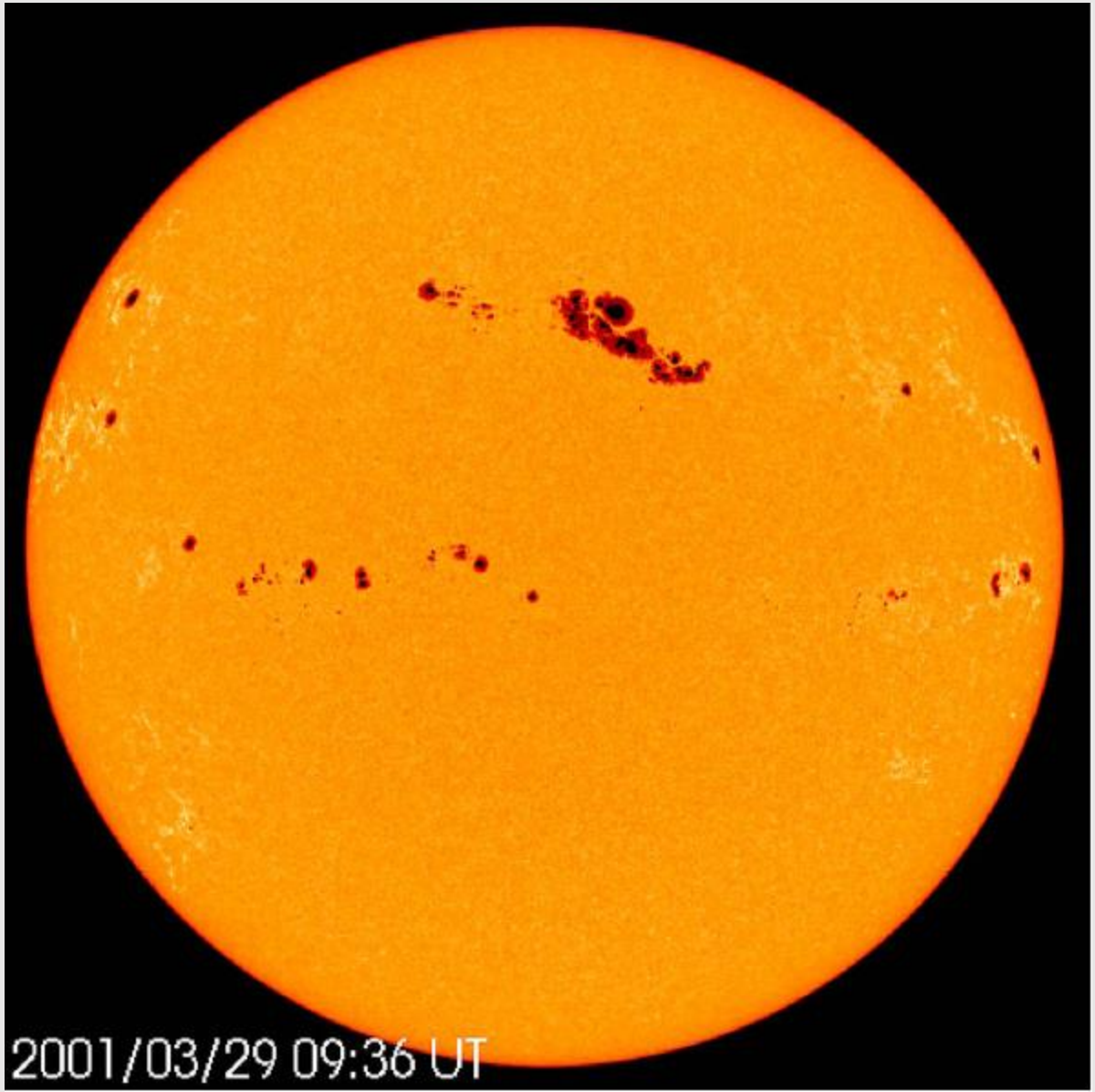
Orbital variations

- Cosine law
- Inverse square law
- Obliquity
- Eccentricity
- Precession
- Ice ages

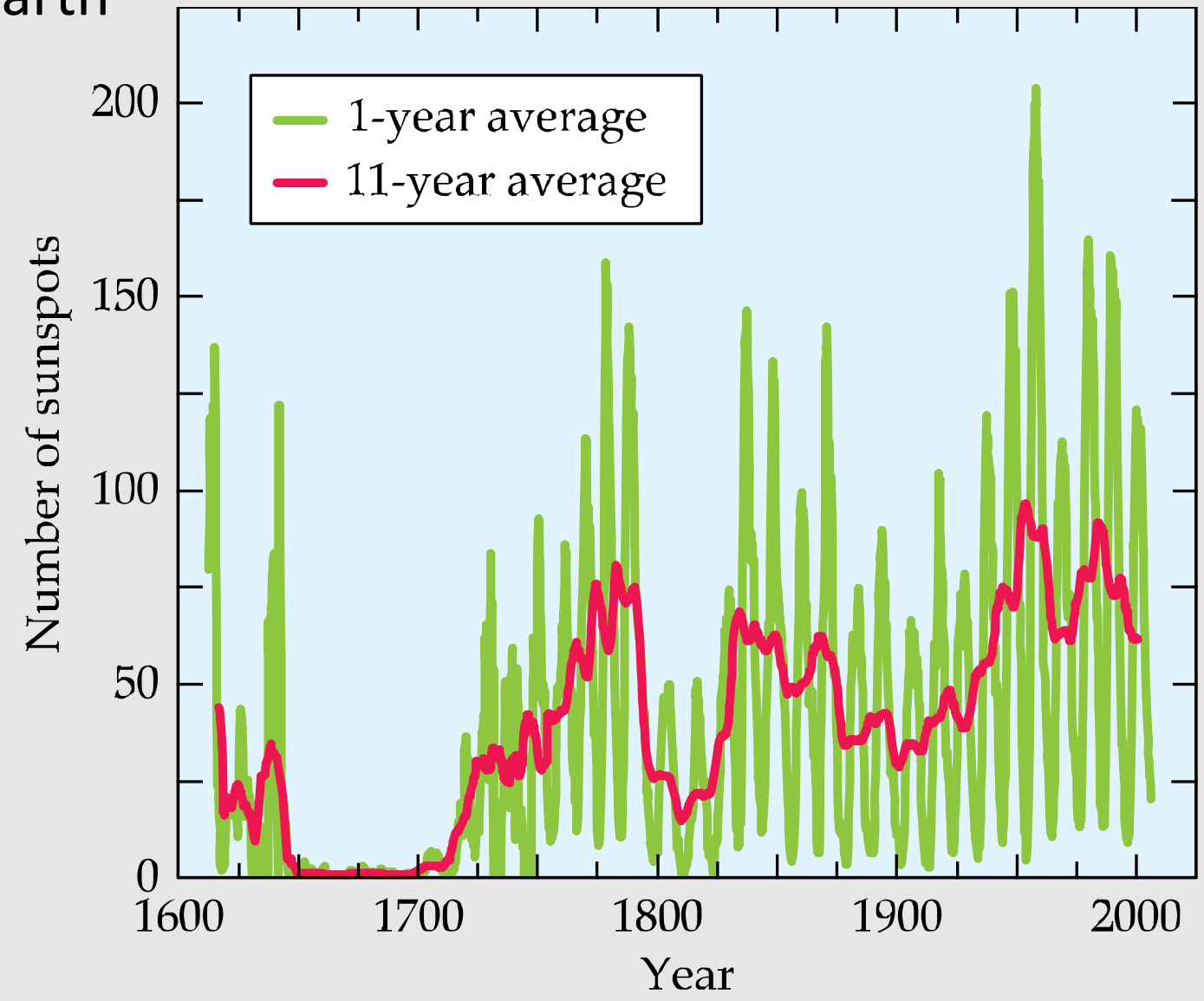
Solar variations

- **Sunspots**

Sun Spots



Number of sunspots varies over an 11 year period
When there are more sunspots, more solar energy reaches Earth



Sunspots

Variations in solar energy should account for only 0.03° C change in global temperature

But…sunspot number and mean surface temperatures in N hemisphere are positively correlated.

- 1645-1715: middle of the Little Ice Age. Very few sunspots.

Influence of sunspots is smaller than the influence of internal forcing factors.

External Climate Forcing Mechanisms

- Galactic variations
- Orbital variations
  - Cosine law
  - Inverse square law
  - Obliquity
  - Eccentricity
  - Precession
  - Ice ages
- Solar variations
  - Sunspots

Internal Climate Forcing Mechanisms

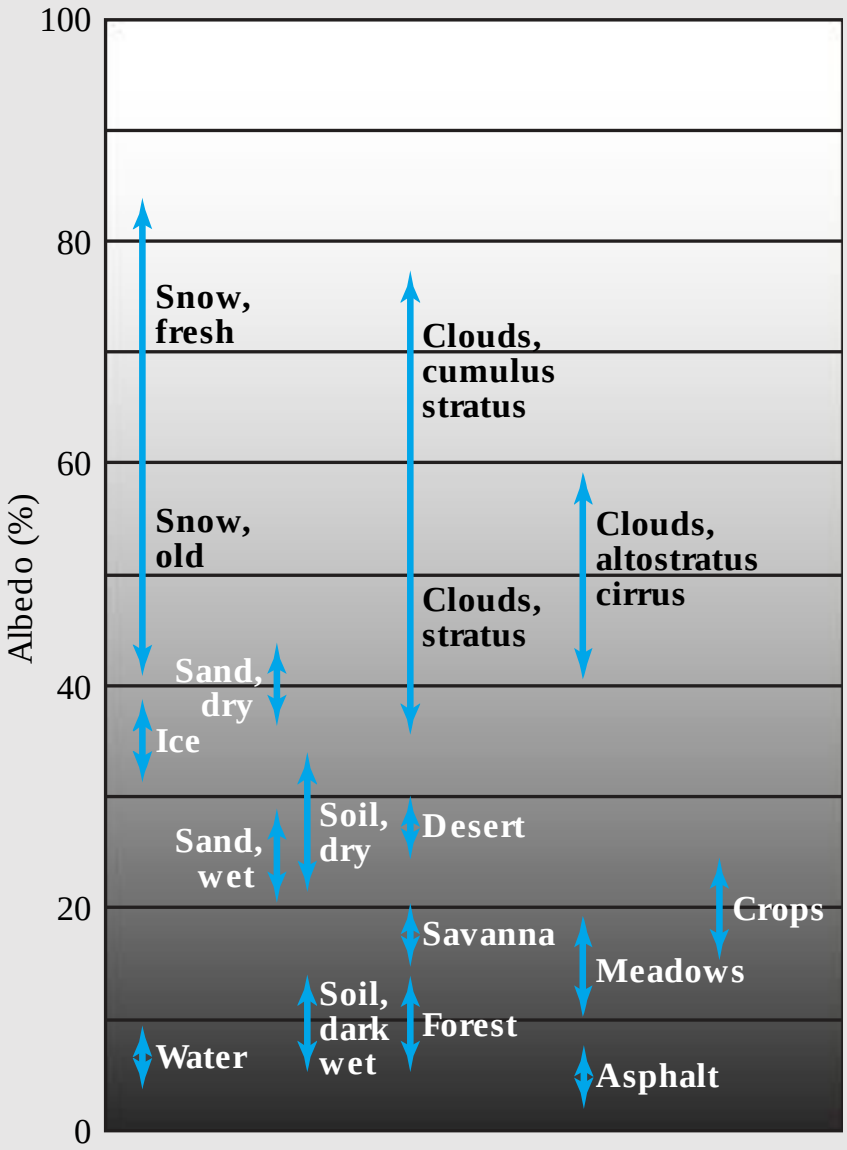
- Albedo
- Orogeny
- Epeirogeny
- Volcanism
- Atmospheric composition

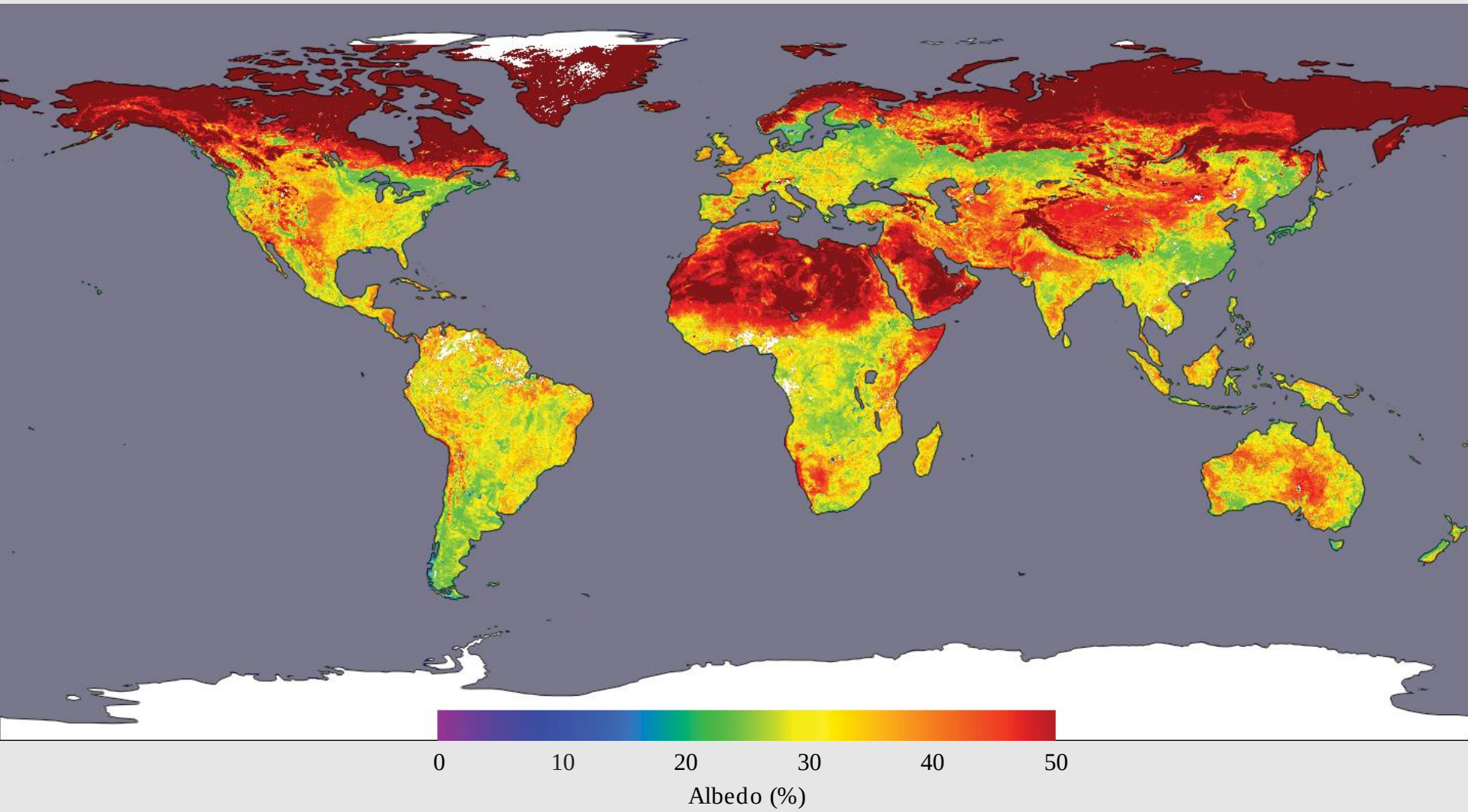
Albedo: percentage of solar energy reflected by Earth

As albedo increases, temperature decreases

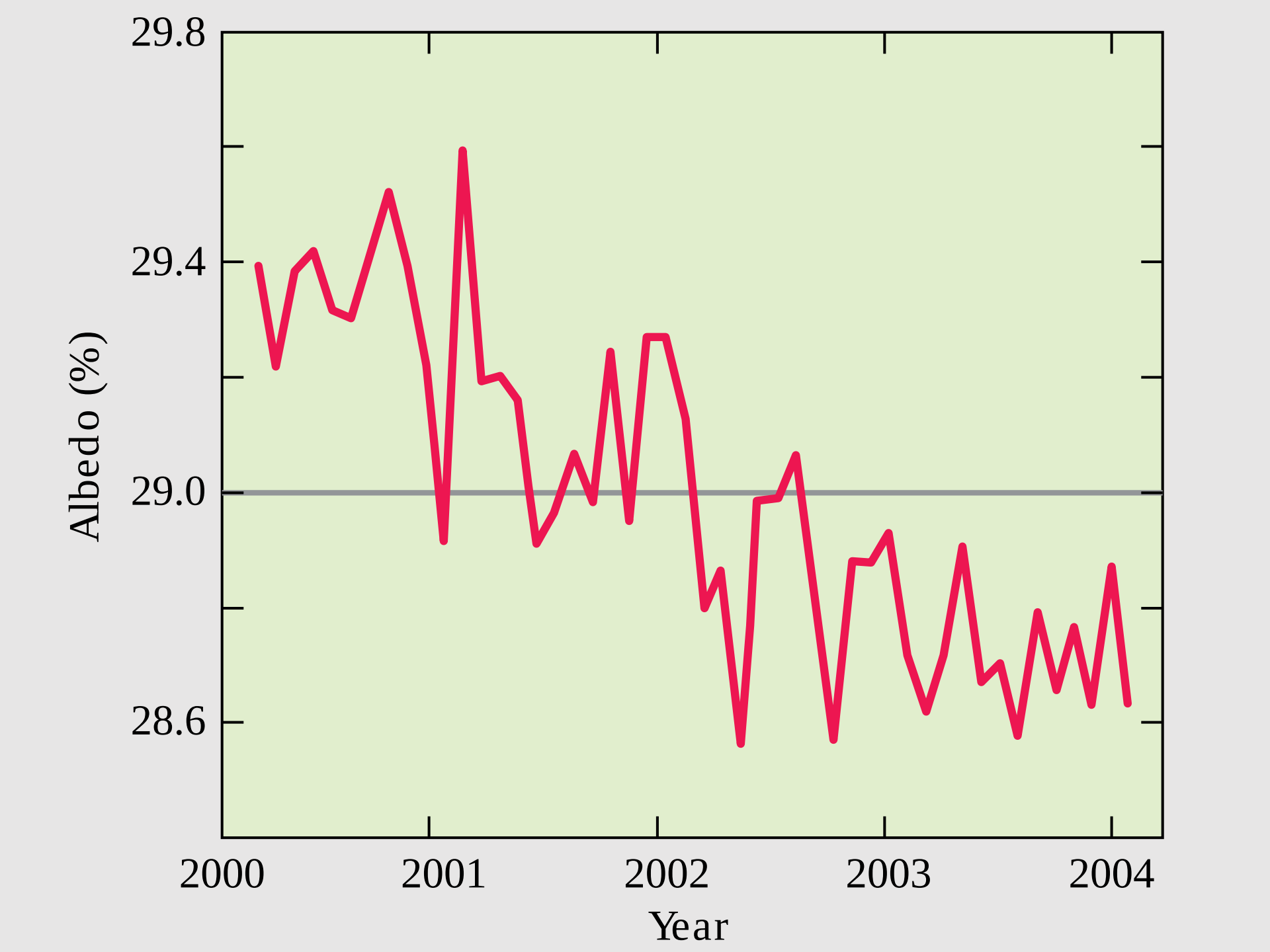
– More energy being reflected back to space means less energy warming the earth

Different materials have different albedo





Overall, albedo is decreasing


29.8
29.4
29.0
28.6
Albedo (%)
2000
2001
2002
2003
2004
Year

Orogeny: tectonic movements of Earth's crust or volcanic activities that form mountains

Uplifting of mountains changes atmospheric circulation and newly exposes rock that absorbs CO_2

Mountains are covered in snow, increases Earth's albedo (reflectivity)

When mountains rapidly uplift, leads to cooler periods.

- Uplifting of Tibetan plateau, Himalayas and Sierra Nevada may have influenced global cooling during last 40 million years

Epeirogeny: changes in global land mass distribution, driven by plate tectonics