Topic 6: Insolation and the Seasons

Topic 6 Section 1

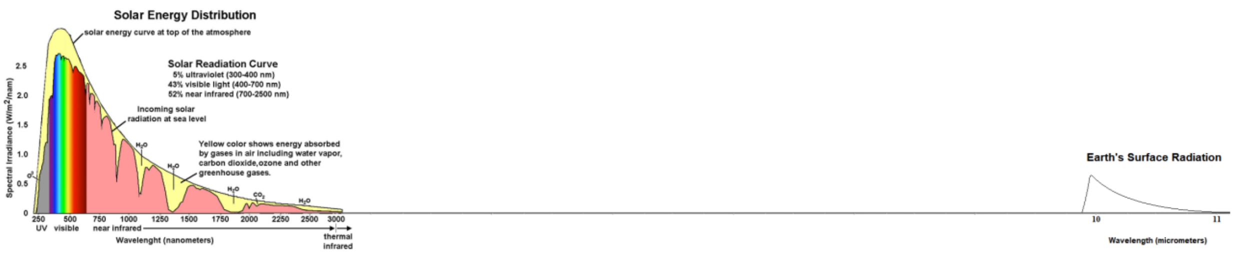
Overview: energy from the Sun drives global winds, ocean currents, the water cycle, and photosynthesis of plants. Without the Sun, there would be no food, no animals, no gases or liquids, and no light. There would be no rock cycle as it is now known because erosion would be minimal.

Solar radiation and insolation

All matter above absolute zero will radiate or emit electromagnetic energy

More energy will be radiated at some wavelengths more than at other wavelengths depending on the temperature of the object

The diagram below shows wavelengths radiated by the Sun and the Earth



Notice that:

- the hotter an object is, the more shortwave radiation is emitted
- the point of maximum output (λ_{max}) for our Sun is at visible wavelengths
- Earth's λ_{max} is in the far infrared (heat)
- about 48% of Earth's insolation is infrared
- our atmosphere absorbs or filters out much of the *in*coming *sol*ar radi*ation* (*insolation*)

Insolation – the amount of solar radiation received by Earth at its outermost atmosphere

The insolation reaching Earth's surface is different that the insolation that reaches Earth's uppermost atmosphere because much of the energy is reflected, absorbed, or scattered before it reaches Earth's surface

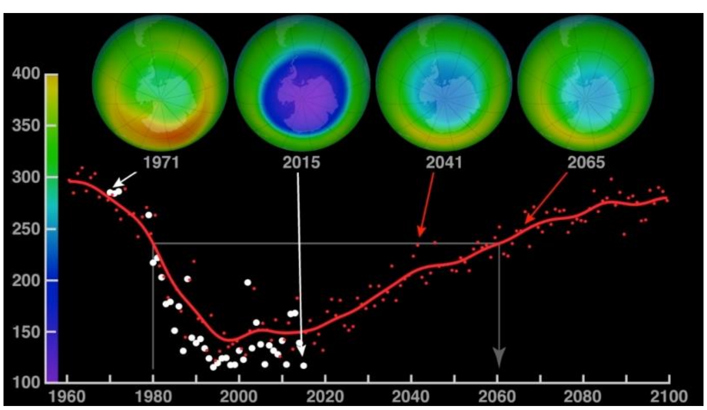
Most of the ultraviolet wavelengths from the Sun are filtered by Earth's atmosphere

Ozone, O_3, a form of oxygen, is responsible for absorbing most of the UV energy

UV radiation is harmful to life and known to cause skin cancer in humans

Human activity, freon refrigerants and propellants, destroyed much of the ozone at the polar regions, ozone holes formed at the poles, mostly at the South Pole

Since the Montreal Protocol, ozone has been recovering



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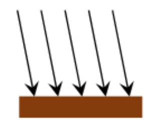
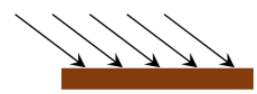
Several gases in the atmosphere absorb longwave infrared radiation
Water (H_2O), carbon dioxide, (CO_2), and methane, (CH_4)

Reflection and scattering
Clouds reflect most of the insolation back into space
Some insolation (including visible light) is reflected to the atmosphere and Earth's surface
Aerosols are responsible for scattering insolation
Aerosols include dust, bacteria, meteor fragments, volcanic ash, and various pollutants

Energy balance between insolation and Earth's surface radiation
About half the insolation that strikes Earth's outer atmosphere reaches the surface
Some of this energy heats Earth's surface raising the temperature
As temperature increases, the amount of longwave infrared Earth radiates also increases
The net effect is that Earth radiates as much energy as reaches the surface ant the temperature remains constant

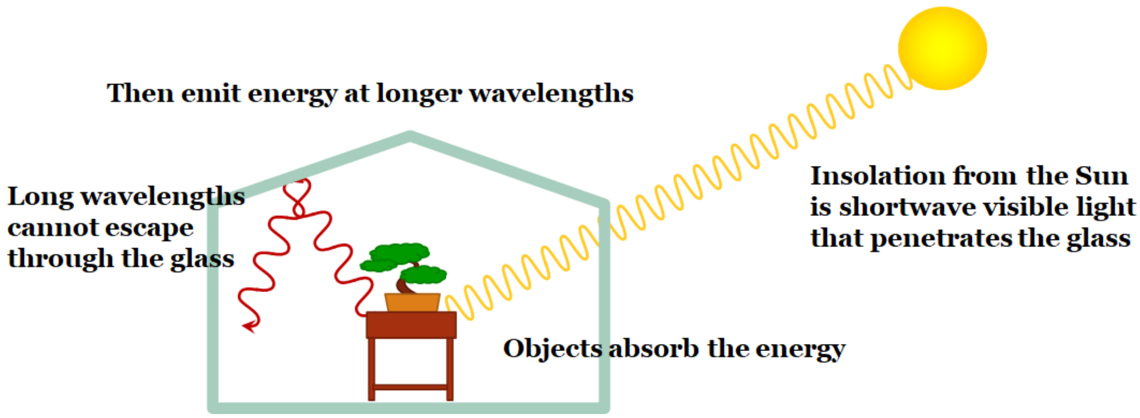

Heating a small surface


Heating a large surface

Factors that affect reflection and absorption of insolation:

- Angle of incidence
  high angles of incidence have increased absorption
  energy is also concentrated into a smaller surface area
  low angles of incidence increase reflection
  energy is also spread out over a larger surface area
- Surface characteristics
  color:
  dark surfaces absorb more insolation
  light surfaces reflect more insolation
  texture
  rough surfaces absorb more insolation
  smooth surfaces reflect more insolation
- Change of state and transpiration
  water that melts or evaporates uses energy that cannot be used to increase temperature
  energy used by plants for photosynthesis cannot be used to increase temperature
  plant transpiration releases gaseous water – energy that can not increase temperature
- Differences in land and water heating
  water has a higher specific heat than rocks so water increases temperature more slowly
  insolation penetrates deep into water but only a short distance into rocks so the large volume of water heats more slowly than the shallow surface of the rocks
  water if a fluid and can distribute energy in a large volume by convection currents while rocks must rely on slow conduction
  insolation that strikes water can cause evaporation and we have learned that change of state leaves less energy to increase temperature

The greenhouse effect



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Topic 6 Section 2

Variation of insolation

Intensity – the rate at which solar energy hits a unit area per unit time (measured in *lux*)

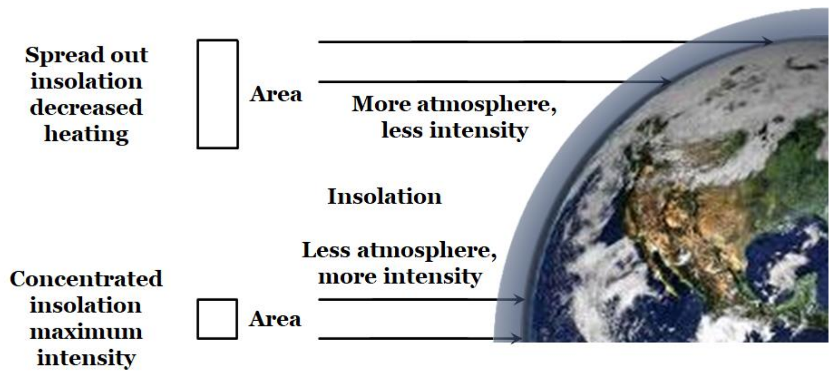
The angle of incidence will determine the *area* over which the energy is spread

- high angle of incidence (straight down) yields high intensity
- low angle of incidence (Sun low) yields low intensity

Variation in intensity and angle of insolation

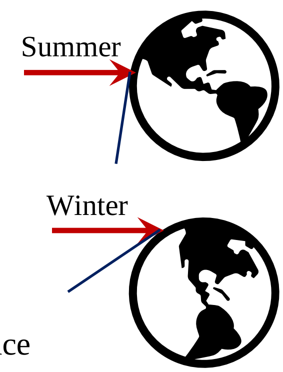
The effect of Earth's shape and thickness of the atmosphere

- high angle of incidence light travels through less atmosphere
- low angle of incidence light travels through more atmosphere



The effect of latitude – latitude sums up the effects of angle of incidence and Earth's shape and atmosphere

- latitudes between the equator and Tropic of Cancer (23½° N) or Tropic of Capricorn (23½° S) have high intensity
- the higher the latitude, the lower the intensity; the poles are very cold



The effect of seasonal changes

- latitudes greater than 23½°: greatest angle of incidence occurs on summer solstice
- latitudes greater than 23½°: lowest angle of incidence occurs on winter solstice

The effect of time of day

- at noon, insolation is at the highest angle of incidence
- morning and evening, isolation is at the lowest angle of incidence

Altitude of Sun	Length of light path	Relative Intensity
90°	1.00	0.78
60°	1.15	0.65
30°	2.00	0.31
0°	45.00	0.00

Variation in duration of insolation

Duration of insolation is the length of time each day that the Earth receives insolation

Duration of insolation is affected by latitude and season

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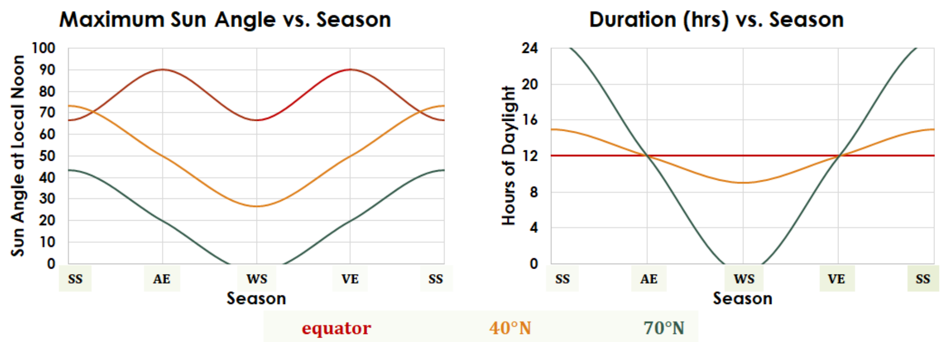
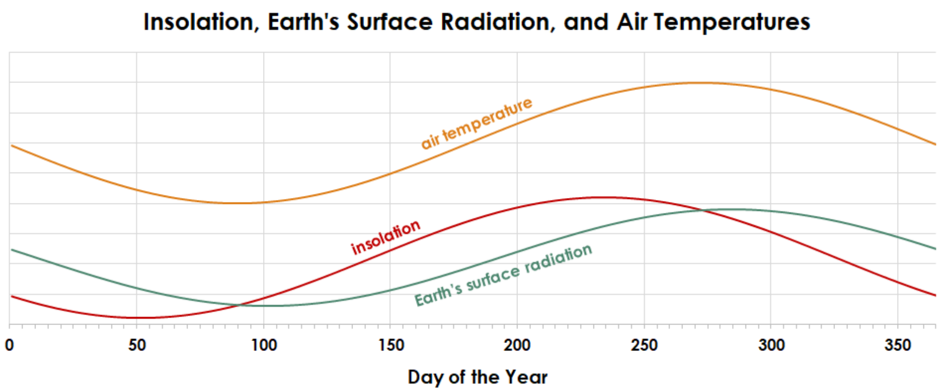
Earth's surface temperature varies:

- over the course of a day
- over the course of a year
- rises when energy gains from insolation are greater than loses from radiation
- falls when energy losses from radiation are greater than gain from insolation
- maximum and minimum temperatures occur a little past maximum and minimum insolation

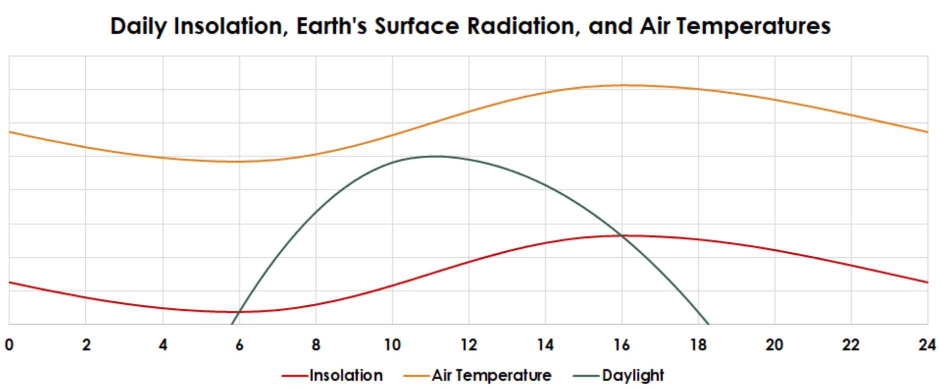
Effects of sun angle and duration due to latitude



Times of yearly maximum and minimum temperatures



Times of yearly maximum and minimum temperatures



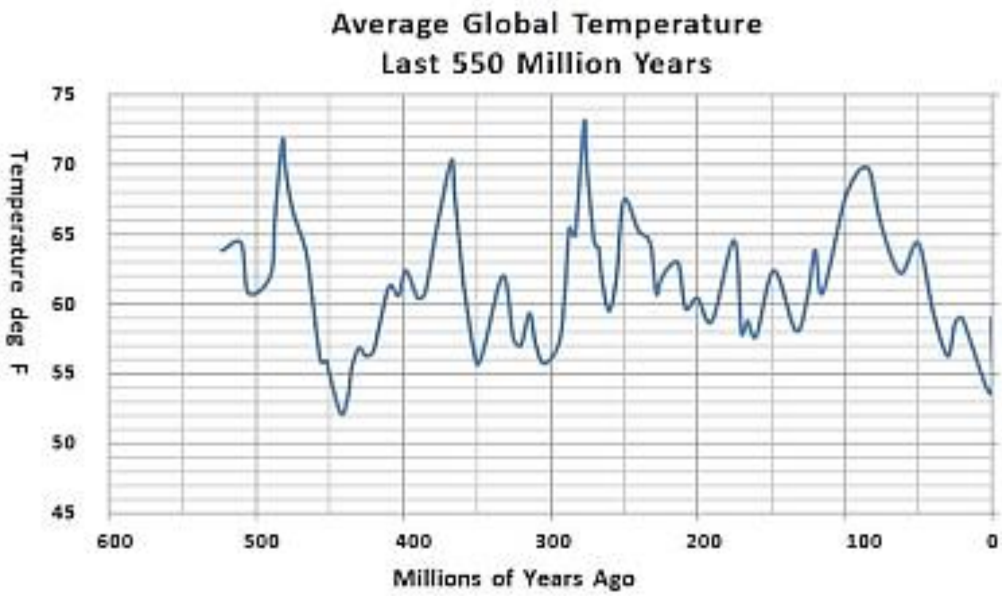
Topic 6 Section 3

Heat budget and climate change

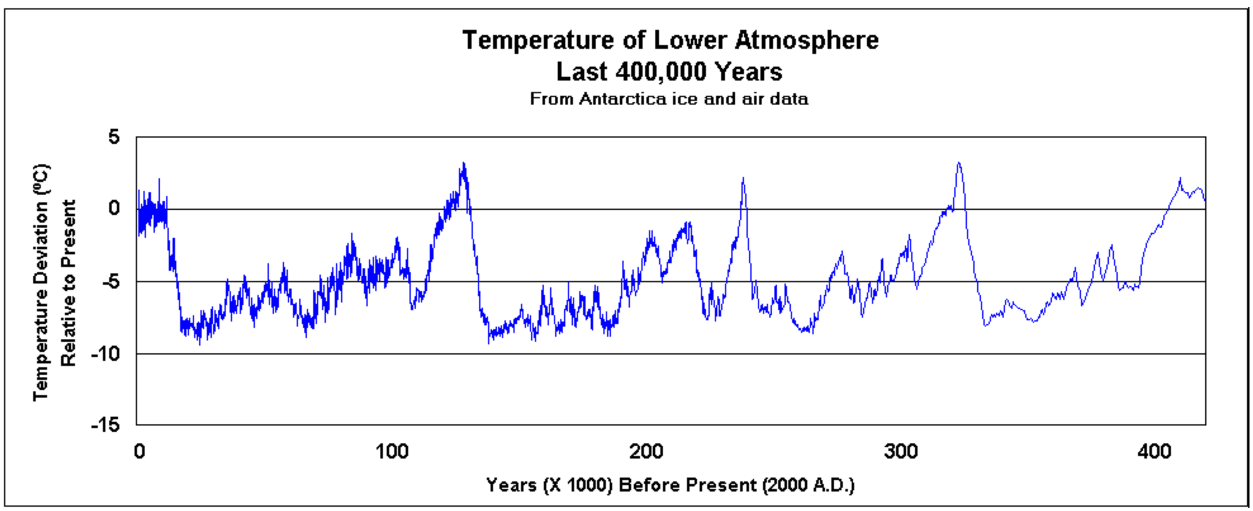
Heat budget is the balance between energy received (from Sun and Earth's interior) and energy lost (from Earth's radiation)

Examples of climate change

Past 500 million years



Past 400 000 years



Notice that in the past 400 000 years, there has been a 10 000 year interglacial period followed by another ice age every 100 000 years

From the top graph (Last 550 million years), notice that the Earth has been much warmer than it is today many times in the very distant past

El Niño and La Niña events

El Niño – every 2 to 10 years, the normally cold waters of the eastern Pacific Ocean off the coast of South America are replaced by warm water causing major climate changes around the world

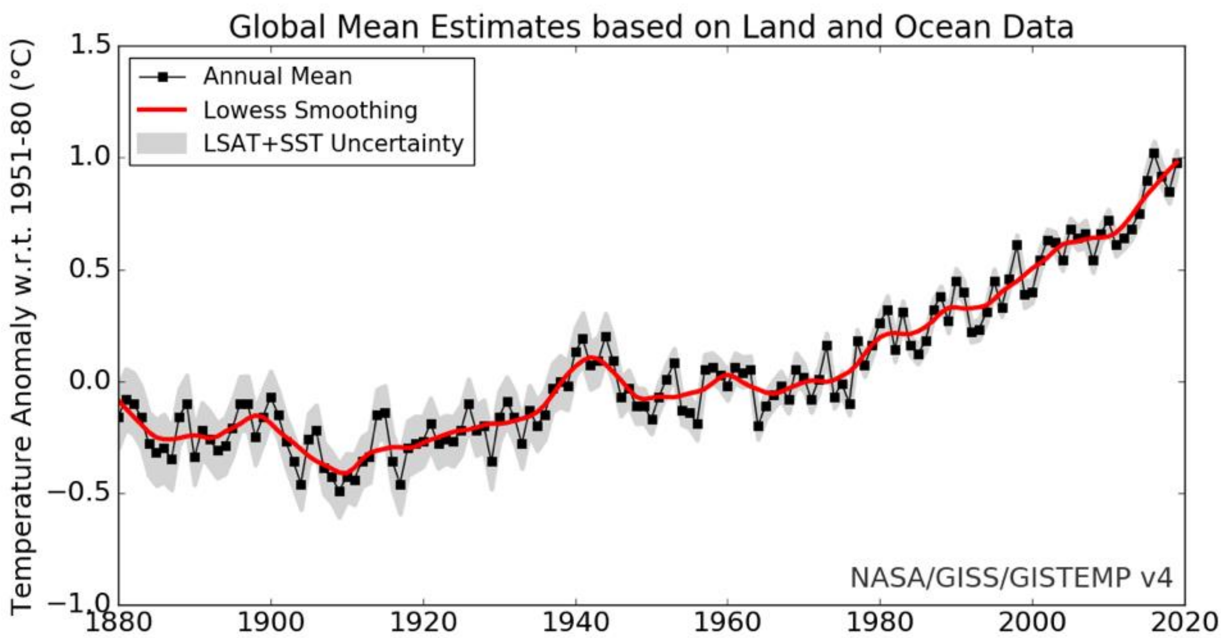
- flooding
- droughts
- heat waves

Wet and cool weather occurs in the southern US and warmer weather occurs in southern Alaska, Canada and northwestern US, and in New England

La Niña – more recently, very cold water appears in the same region of the Pacific Ocean and also causes climate changes around the world

Global warming and heat waves

Since about 1980 (and from the graph below, since about 1910), there has been a trend of rising temperatures known as global warming



Many scientists believe that some of the consequences of this recent global warming include events like increased numbers of violent storms, hurricanes, tornadoes, and increased numbers of heat waves (more than two days of unusually hot and humid weather)

Heat waves can result in hyperthermia and death

Avoid the danger of heat waves by:

- drinking plenty of water
- avoiding too much exercise
- stay in shady areas
- stay indoors in air conditioning

Wet and cool weather occurs in the southern US and warmer weather occurs in southern Alaska, Canada and northwestern US, and in New England

Causes of heat budget shifts
- The Sun's energy changes, especially during sunspot maxima
- Changes in Earth's orbit and axial tilt
- Volcanic eruptions – dust cools the Earth
- Human causes
  - Desertification (expansion of deserts) caused by overgrazing
  - Deforestation of, especially, tropical rain forests
  - Urbanization (increase in number and size of cities)
  - Increased amount of CO_2 due to burning of fossil fuels

Topic 6: Insolation and the Seasons

Topic 6 Section 4

- Seasons
  - Direct causes of the seasons
    - Cyclic and yearly changes in insolation due to:
      - angle of incidence
      - intensity
      - duration
  - Astronomical or indirect causes of the seasons
    - Tilt of Earth's axis by 23 ½° relative to the ecliptic
      - Determines that direct rays will fall between the Tropic of Cancer and the Tropic of Capricorn
    - Parallelism of Earth's axis
      - Earth's North Pole always points toward Polaris, the North Star
    - Revolution of Earth about the Sun
      - The combination of parallelism and revolution cause the angle of incidence, intensity, and duration of the Sun's rays to change with each season
    - Small seasonal effect of Earth's elliptical orbit
      - Earth is closer to the Sun during winter in the northern hemisphere (making winter milder in the northern hemisphere) and farther from the Sun during summer (making summer milder in the northern hemisphere)