MONDAY: energy in and energy out on a global scale

## Seasons & Days

- Why do we have seasons?
- Why aren't seasonal temperatures highest at the summer solstice (June 21)?
- Why aren't daily temperatures highest at Noon?

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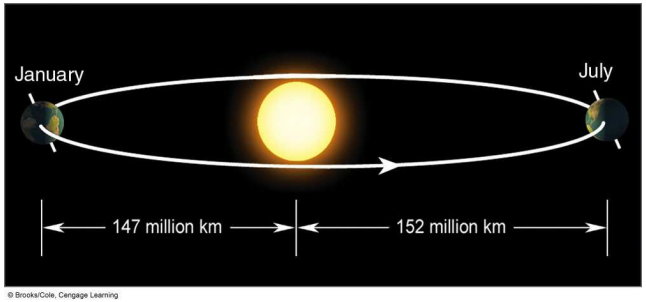
## Earth's orbit around the Sun is slightly elliptical (not circular)




Earth is somewhat closer to Sun in January than in July ...

**Is this why we have seasons?**

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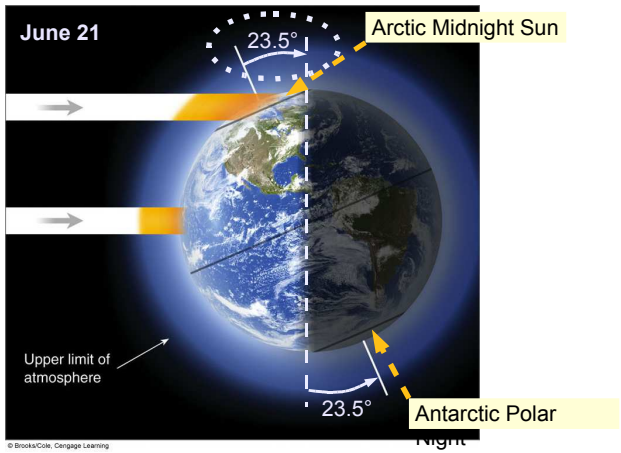
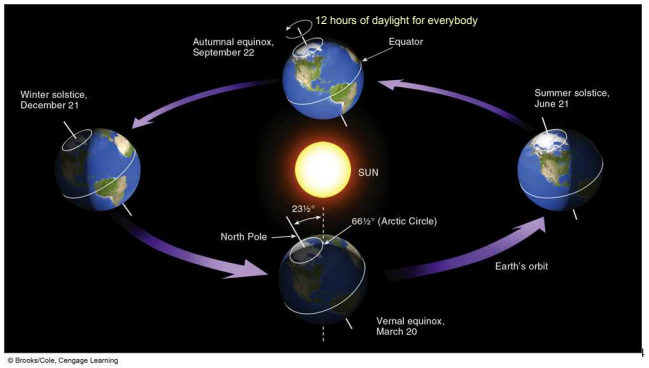
## Earth is tilted (oblique) on its Axis!




Seasonally varying distance to Sun has only minor effect on seasonal temperatures; instead it is the tilt of earth's axis combined with earth's orbit around the sun that leads to seasons!



## Seasons

- Seasons are regulated by the amount of solar energy received at Earth's surface
- The solar energy received at the *top of the atmosphere* depends on:
  - angle at which sunlight locally strikes Earth's surface
  - hours of daylight
- Seasons are NOT due to elliptical nature of earth's orbit around the sun!

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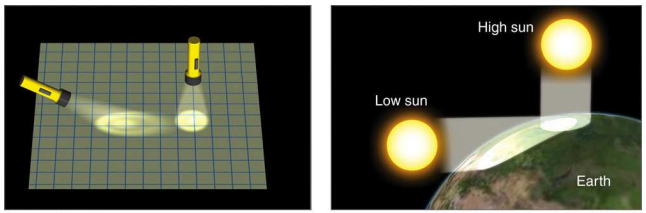
## Sun's rays that strike a surface at an angle are less intense per unit area than those from directly above

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- Smaller angle of incoming solar radiation means the same amount of energy is spread over a larger area
- High Sun (summer) = more heating
- Low Sun (winter) = less heating

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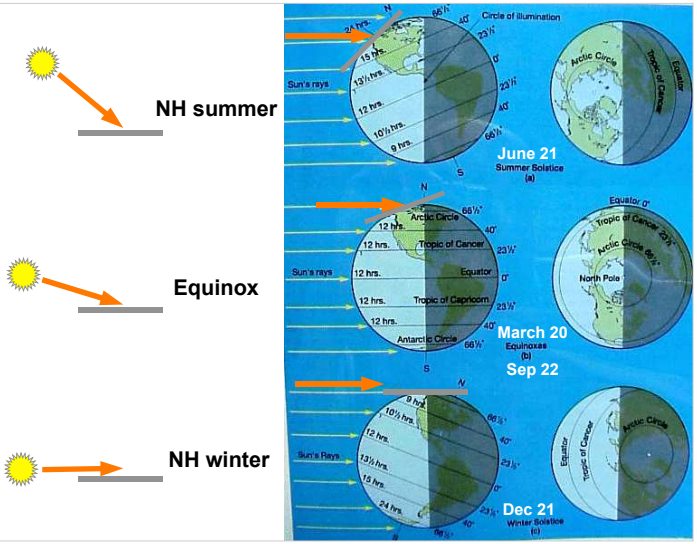


## Midnight Sun

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The region north of the arctic circle experiences 24 hours of sunlight in summer (Earth's surface does not rotate out of solar exposure).

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## Controls of Temperature

- Air temperature as you move around the globe varies regionally as a function of:
  - Latitude
  - Land and Water Distribution
  - Ocean Currents (e.g. gulf stream)
  - Elevation
  - Mountain Ranges (e.g. Rockies)

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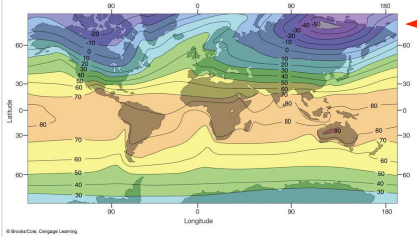
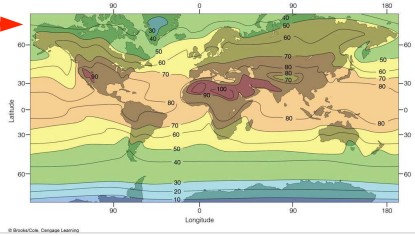
## Sea-Level Temperatures



January

Tropics are warmer than polar regions, but land and water, ocean currents, and elevation create additional variations.

July



Southern hemisphere has fewer land masses and an ocean current that encircles the globe, creating more regular temperatures than in the northern hemisphere.

## Land versus Water / Ocean

- Water has a very large heat capacity (4 times as large as land): to heat one kilogram of water by one degree Kelvin/Celcius an energy of 1000 calories is required (4186 Joules)
- Therefore, oceans (and large lakes) are able to store a large amount of heat, changing their temperature is much more difficult than land
- Some heating of oceans goes into evaporation
- Water is a fluid, so heat in the oceans is mixed efficiently; Land primarily moves heat by conduction
- Sunlight can penetrate into the ocean

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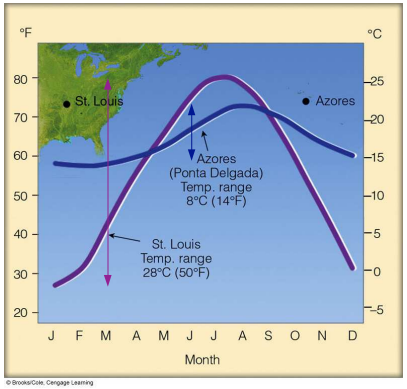
## Land versus Water / Ocean: Seasonal Cycles

- Large heat capacity of oceans make them much more resistant to changes in heat input than land
- Hence, annual temperature range is much smaller over oceans than land

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## Regional Seasonal Cycles

- Regional differences in the seasonal cycle of temperature are influenced by geography, such as latitude, altitude, and nearby water and ocean currents, as well as heat generated in urban areas
- San Francisco, CA is downwind of the Pacific Ocean
- Richmond, VA is downwind of North America!


| | SAN FRANCISCO | | RICHMOND | |
|---|---|---|---|---|
| | °C | °F | °C | °F |
| Mean annual temperature | 14 | 57 | 14 | 57 |
| Annual temperature range | 6 | 11 | 22 | 42 |
| Record high | 39 | 103 | 41 | 105 |
| Record low | -3 | 27 | -24 | -12 |

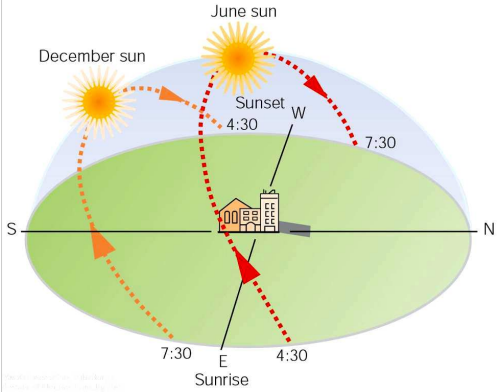


## Daily (Diurnal) Temperature Variations

- Each day is like a mini seasonal cycle:
  - Sun rays are most intense around noon
  - As is the case with seasons, the maximum temperatures lag the peak incoming solar radiation
- Heat transfer mechanisms (heating & cooling) in the atmosphere are at the heart of understanding the diurnal cycle:
  - Radiation
  - Convection
  - Conduction



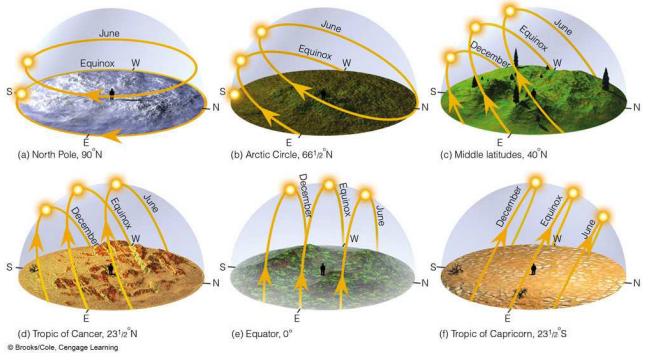
## Local Solar Changes




- Northern hemisphere sunrises are in the southeast during winter, but in the northeast during summer
- Summer noon time sun is also higher above the horizon than the winter sun

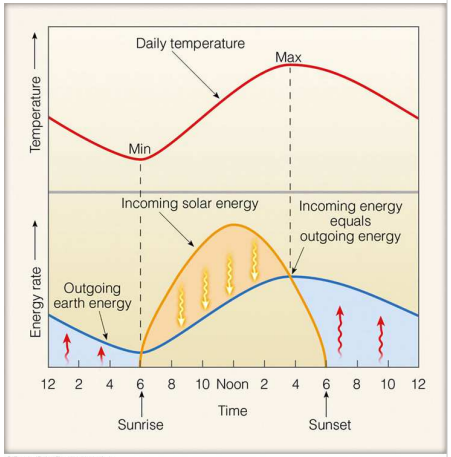


## Local Solar Changes by Latitude



## Temperature Lags Radiation

- The Earth's surface temperature is a balance between incoming solar radiation and outgoing terrestrial (longwave) radiation
- Peak temperature lags after peak insolation because surface continues to warm until infrared radiation exceeds insolation




## What Controls Daily High Temperatures?

- Daily $T_{max}$ depends on:
  - Radiation (e.g. Cloud Cover)
  - Surface Type
    - Absorption Characteristics (strong absorbers enhance instantaneous surface heating)
    - Vegetation / Moisture (available energy partially used to evaporate water)
  - Wind
    - Strong wind generates mixing of heated air near the ground to higher altitudes

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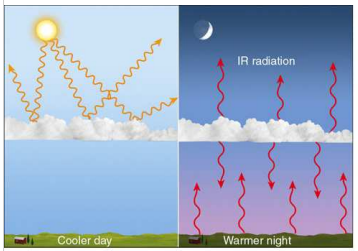
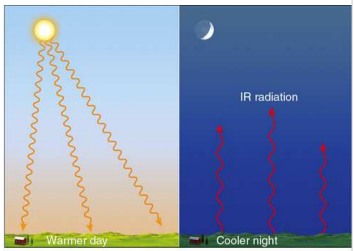
Clouds reflect solar (shortwave) radiation but absorb and re-emit terrestrial (longwave/infrared) radiation




(a) Small daily temperature range




(b) Large daily temperature range

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