Last time:

Fundamentals of solar and terrestrial radiation

Today:

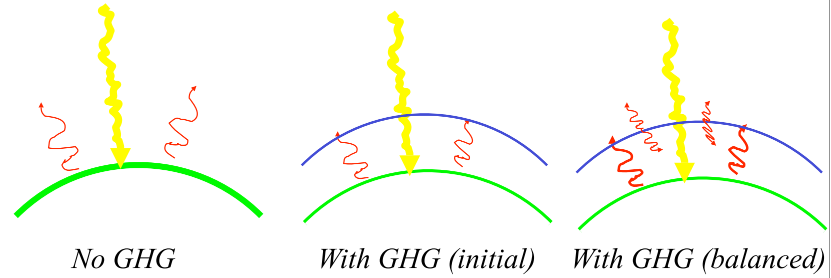
Review greenhouse effect.

Global energy balance (drives weather).

Seasonal cycle.

Daily cycle.

Imagine a hypothetical atmosphere…



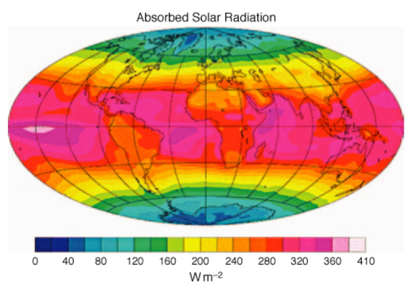
What will happen to the surface temperature of the earth if:

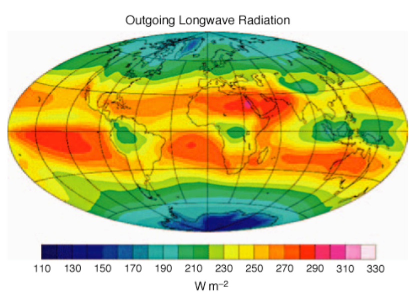
•We add a gas that preferentially absorbs LW?

•We add a gas that preferentially absorbs SW?

•We add a gas to the atmosphere that absorbs solar and terrestrial radiation equally?

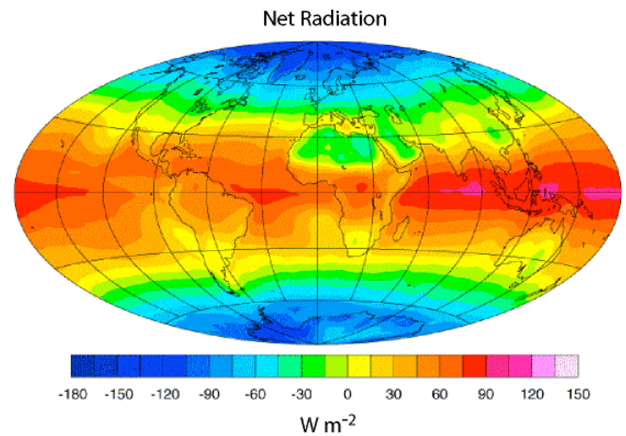
Annual-mean radiation





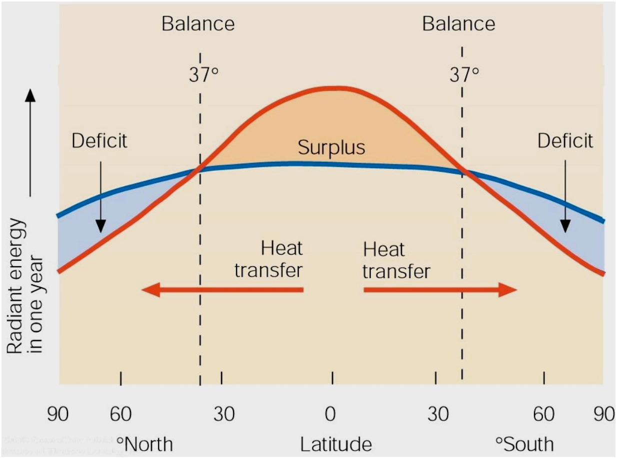
discuss what causes low olr (sfc T vs level)

Annual-mean net radiation

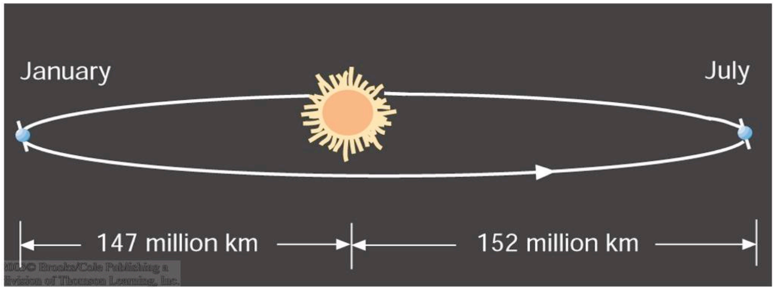


- Incoming solar minus outgoing longwave
- Must be balanced by ?

Annual-mean energy balance

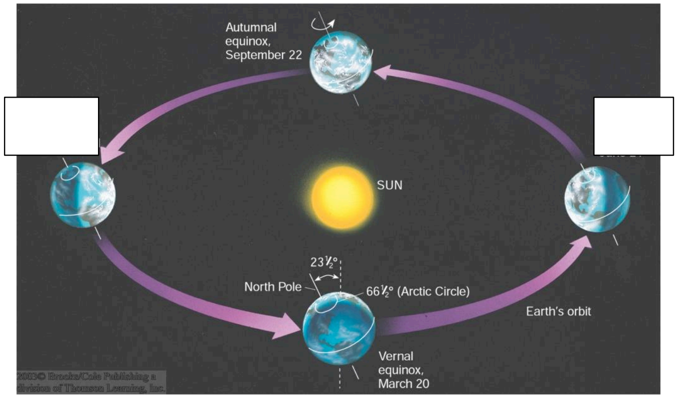


The earth's orbit around the sun is not quite circular: the earth is closer to the sun in January than it is in July



Is this why we have seasons?

The earth's orbit around the sun

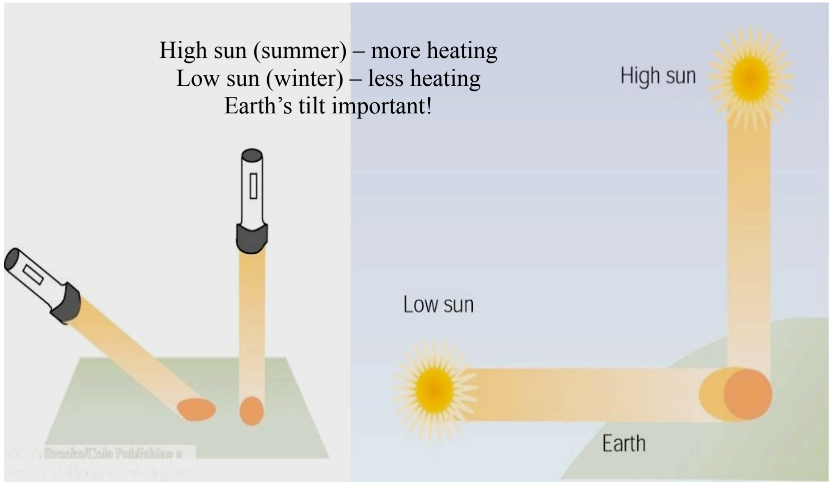


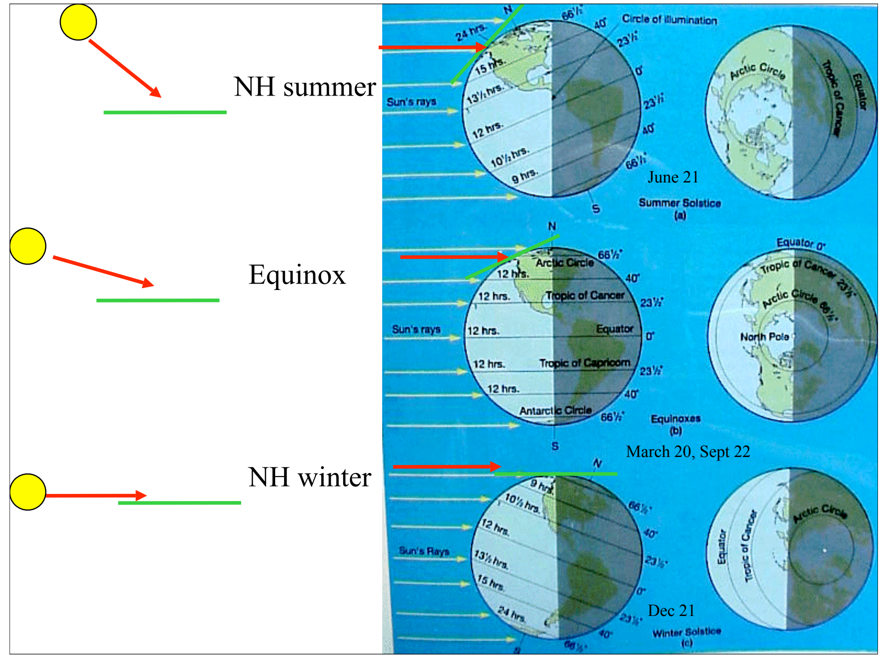
•*Seasonally varying distance to sun has only a minor effect on seasonal temperature.*
•*The earth's orbit around the sun leads to seasons because of the tilt of the Earth's axis.*

Seasons

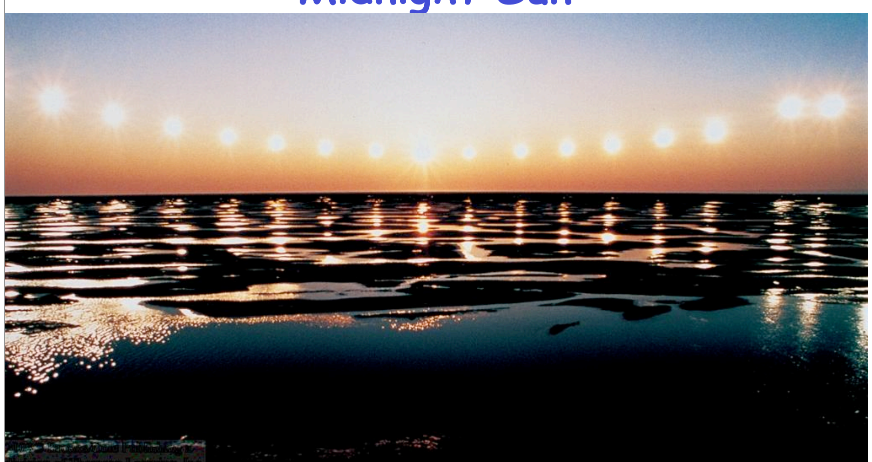
- Seasons are regulated by the amount of solar energy received at Earth's surface
- The solar energy received at the *top of the atmosphere* depends on:
  - angle at which sunlight strikes Earth's surface.
  - how long the sun shines per day.
- Seasons are NOT due to the elliptical nature of the earth's orbit.

Smaller angle of incoming solar radiation: the same amount of energy is spread over a larger area





Midnight Sun



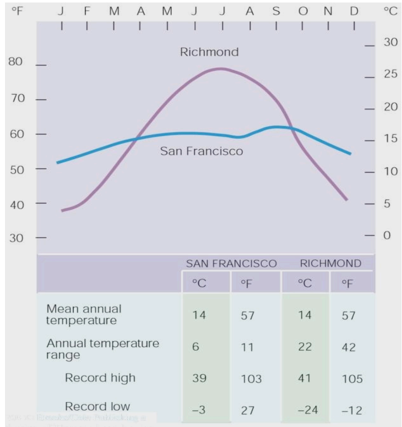
•Since polar latitudes receive the longest period of sunlight during summer, why aren't temperatures highest there?

•Why aren't temperatures highest at the summer solstice?

•What would happen if we changed the tilt of the earth?

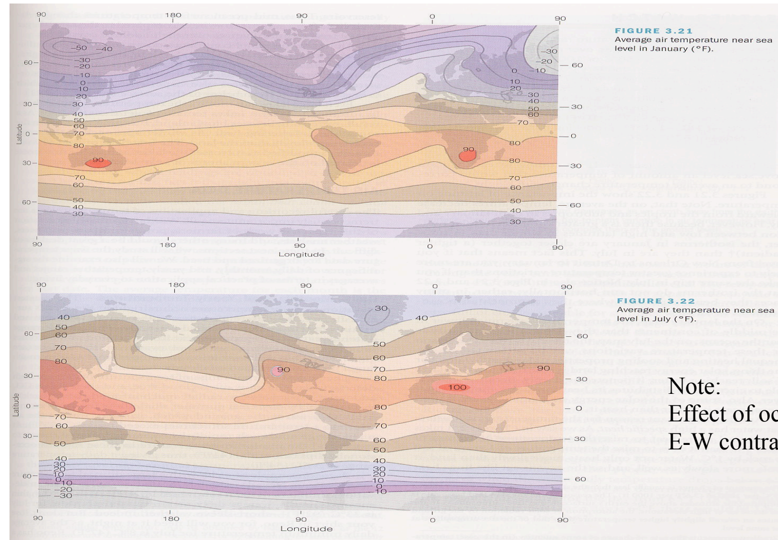
- Would we get a more/less pronounced seasonal cycle in the NH if the tilt was increased?
- What would happen if the tilt was 90 degrees? 0 degrees?

Seasons are driven by variations in solar radiation. These variations (angle of sun/amount of sunlight) are a function of latitude. So…explain the following observation:



	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

The seasonally varying temperature



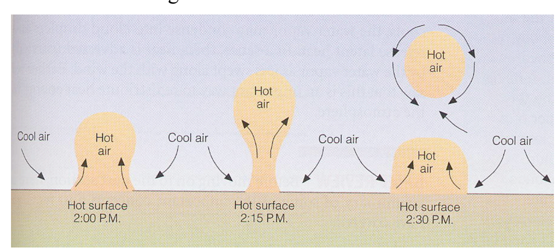
Note:
Effect of oceans
E-W contrasts

Daily temperature variations

- Each day is like a mini seasonal cycle
  - Sun rays most intense around noon
  - As is the case with the seasons, the maximum temperatures lag the peak incoming solar radiation.
- An understanding of the diurnal cycle in temperature requires an understanding of the different methods of atmospheric heating and cooling:
  - Radiation
  - Conduction
  - Convection

Atmospheric Heating

- Sunlight warms ground
- Ground warms adjacent air by conduction
  - Poor thermal conductivity of air restricts heating to a few cm
- Random motion of “hot” surface air molecules upward leads to heat transfer (diffusion)
- Hot air forms rising air “bubbles” (thermals) leading to convection
  - Mechanical mixing due to wind enhances this mode of heat transport



Vertical temperature profiles - day

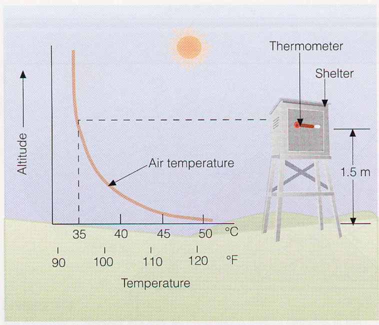


FIGURE 3.12
On a sunny, calm day, the air near the surface can be substantially warmer than the air a meter or so above the surface.

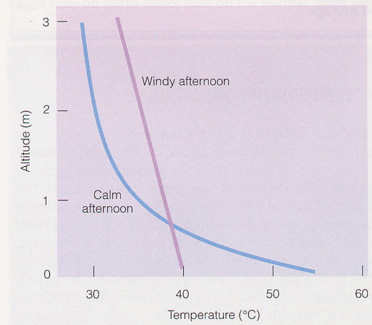
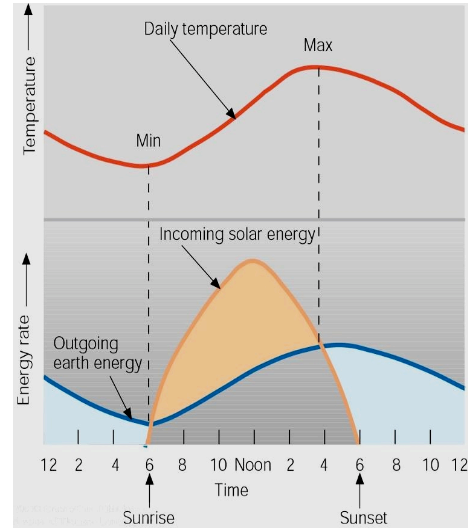


FIGURE 3.13
Vertical temperature profiles above an asphalt surface for a windy and a calm summer afternoon.

Jogger on calm, summer day may have 122 F at their feet and 90 F at their waist!

Balance of incoming/outgoing energy

- Energy accumulates in "system" as long as $E_{in} > E_{out}$
- Added energy leads to increasing T
- T_{max} occurs as E_{out} surpasses E_{in}
- T_{max} typically 3-5 PM for clear summer skies
  - What factors could change timing?



T_{max} Factors

- Tmax depends on
  - Cloud cover
  - Surface type
    - Absorption characteristics
      - Strong absorbers enhance surface heating
    - Vegetation/moisture
      - Available energy partially used to evaporate water
  - Wind
    - Strong mixing by wind will mix heated air near ground to higher altitudes

Cooling at Night

- Lower sun angle in evening means $E_{in} < E_{out}$
- During night the ground and air radiate energy to space
  - Ground is better radiator than air, so ground cools faster (Kirchoff's law).
- Ground cools adjacent air layer by conduction
  - Heat transfer from air above is slow due to poor thermal conductivity of air.
  - Why isn't convection as important at night?

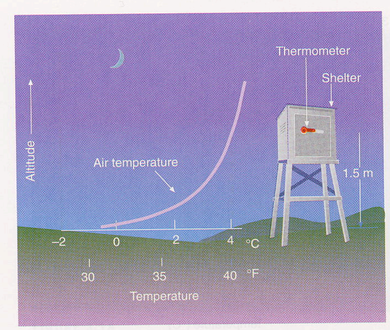


FIGURE 3.15
On a clear, calm night, the air near the surface can be much colder than the air above. The increase in air temperature with increasing height above the surface is called a radiation temperature inversion.

Radiation Inversions

- Radiation inversions
  - Feature increasing T with height above ground
  - Occur on most clear, calm nights (nocturnal inversion)
  - Are strongest when
    - Winds are calm
    - Air is dry
      - Less IR absorption
      - Less latent heat release from fog/dew formation
    - Sky is cloud free
    - Night is long

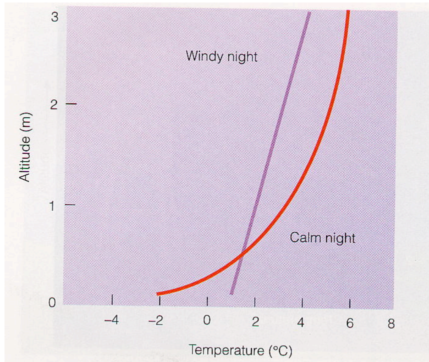
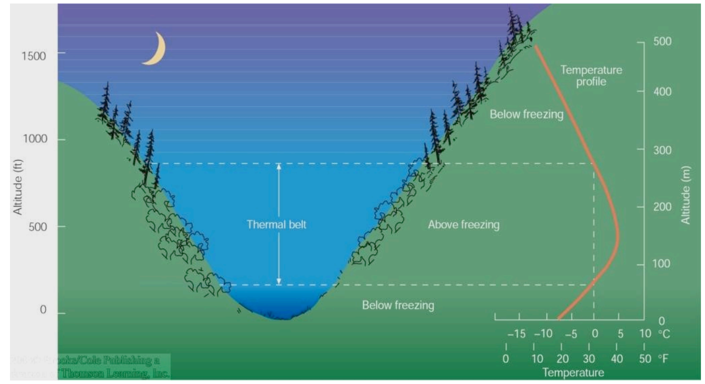


FIGURE 3.16
Vertical temperature profiles just above the ground on a windy night and on a calm night. Notice that the radiation inversion develops better on the calm night.

Cold air pooling

- As air cools, its density increases, leading to
  - Downslope flow
  - Cold air pooling in low spots/valleys



Inversions and agriculture

- Surface cooling can produce sub-freezing temperatures near ground
- Crop damage possible
  - Especially problematic for orchards in "warm" climates
- Mixing down of warmer air aloft can help limit temperature drop near surface