

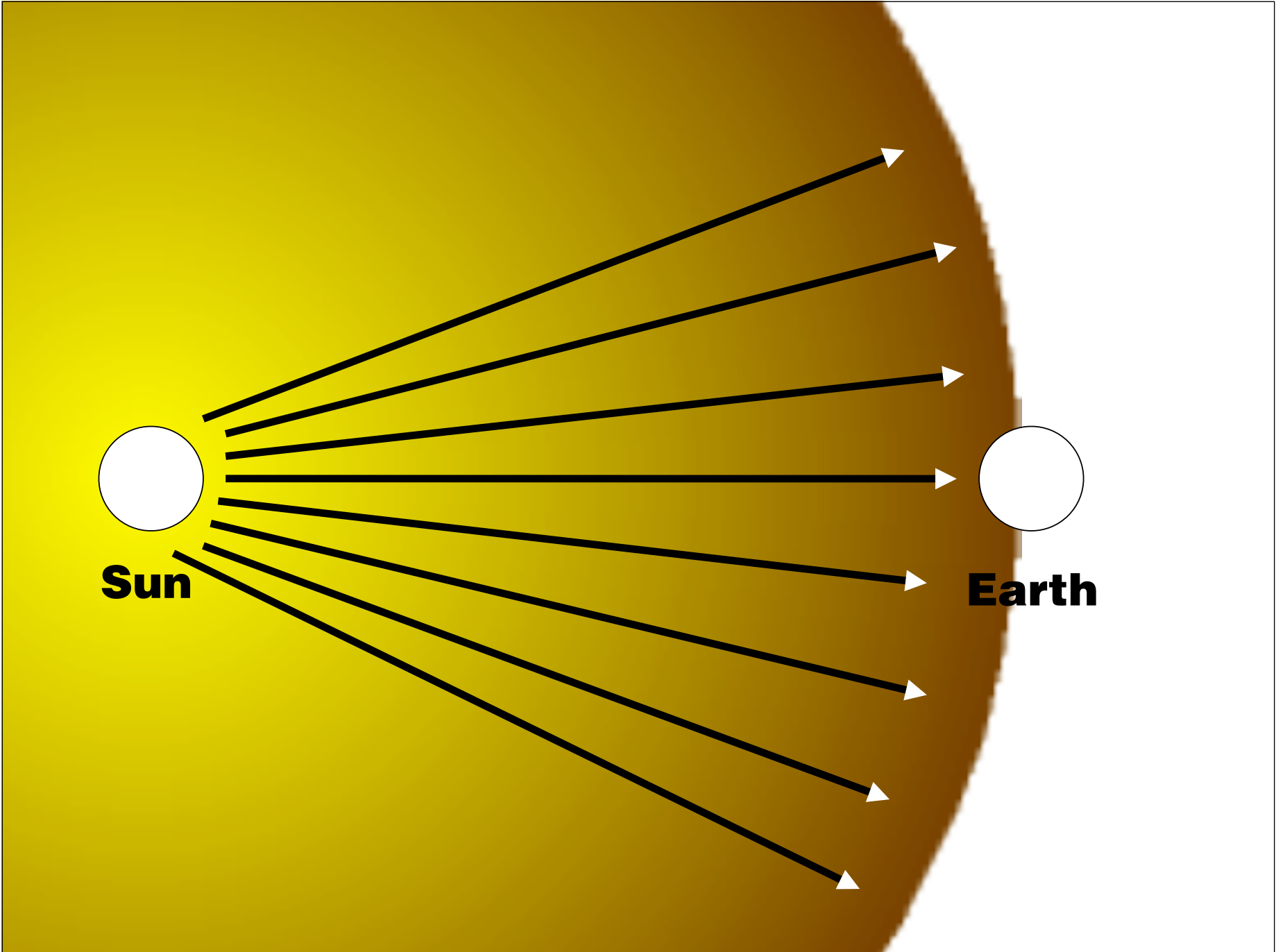
# **Energy Balance and Temperature**

# **Ch. 3: Energy Balance**

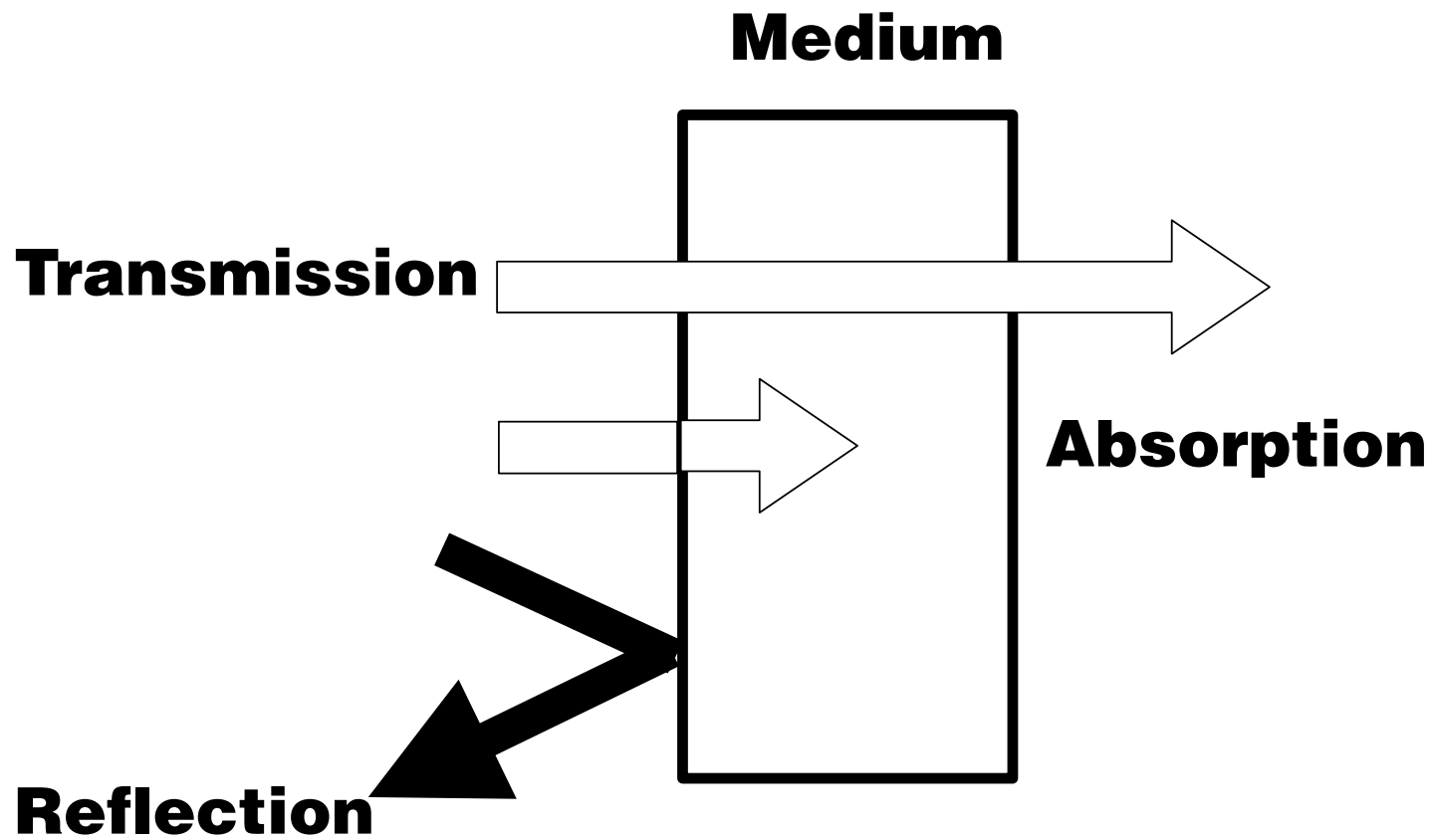
- **Propagation of Radiation**
  - **Transmission, Absorption, Reflection, Scattering**
- **Incoming Sunlight**
- **Outgoing Terrestrial Radiation and Energy Balance**
  - **Net Radiation**
  - **Sensible/Latent Heat Transfer**
  - **Greenhouse Effect**
  - **Latitudinal Energy Balance**

# **Ch. 3: Temperature**

- **Controls of Temperature**
  - **Latitude**
  - **Altitude**
  - **Circulation Patterns**
  - **Specific Heat of Surfaces**
- **Daytime vs. Nighttime Variation**
- **Measurement**
- **Windchill**

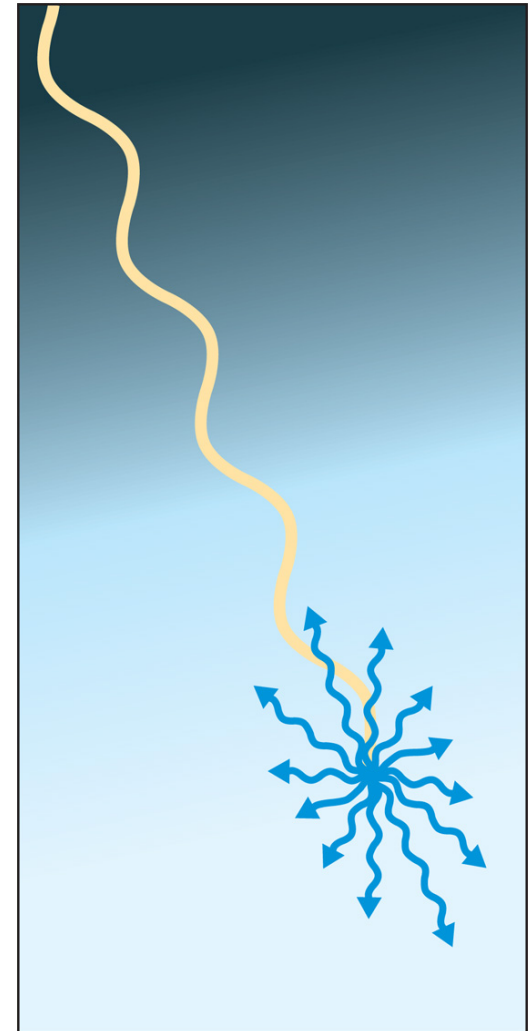


# Radiation Propagation



# Scattering

- **Resembles a combination of transmission and reflection**
  - **Random re-direction of radiation**
  - **Diffuses incident beam; reduced intensity**

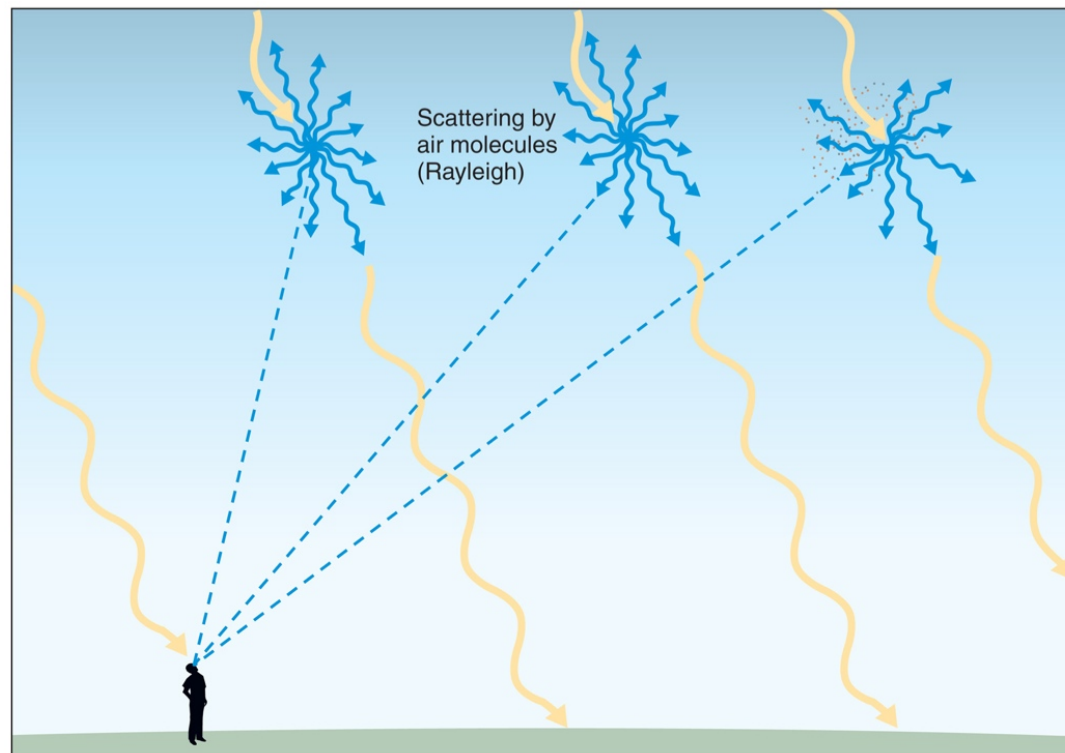


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- **Rayleigh Scattering**

- **Preferential scattering of bluish light by very small particulates and gas molecules**

- **Blue-sky phenomenon**

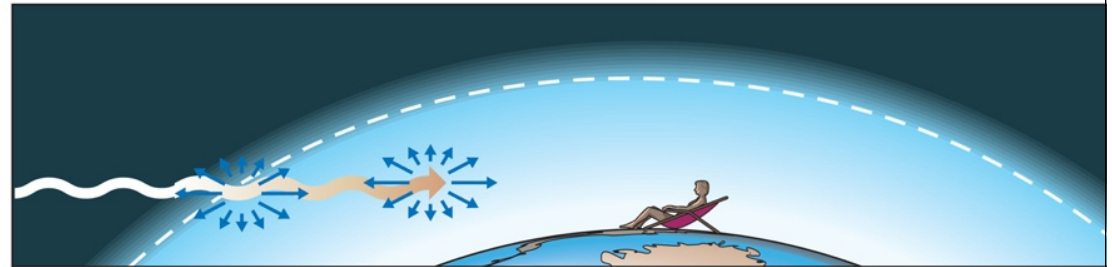


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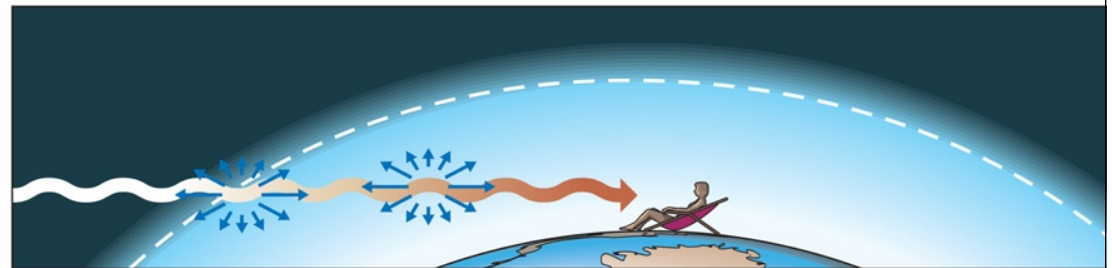
# → Red-sky phenomenon



(a)



(b)



(c)

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# **Earth-Atmosphere Energy Balance**

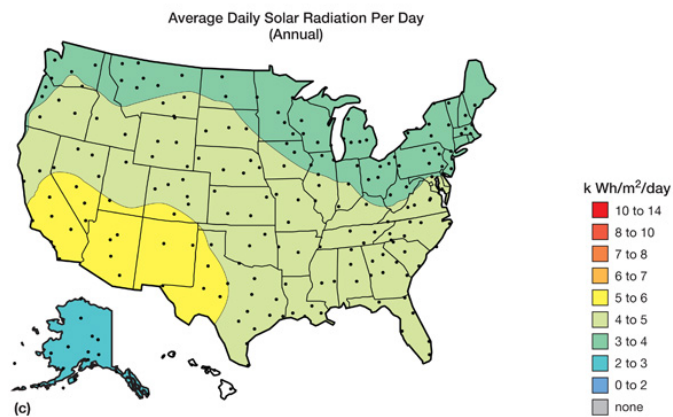
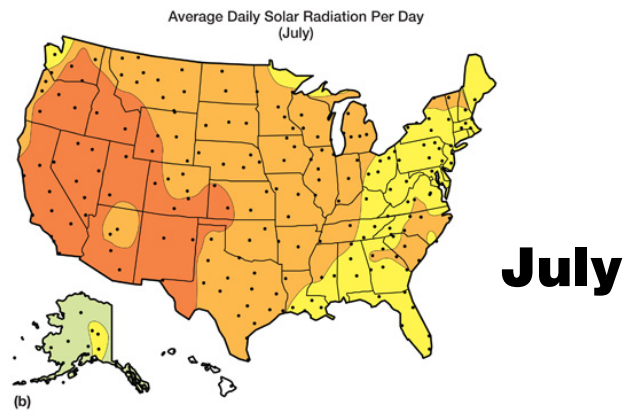
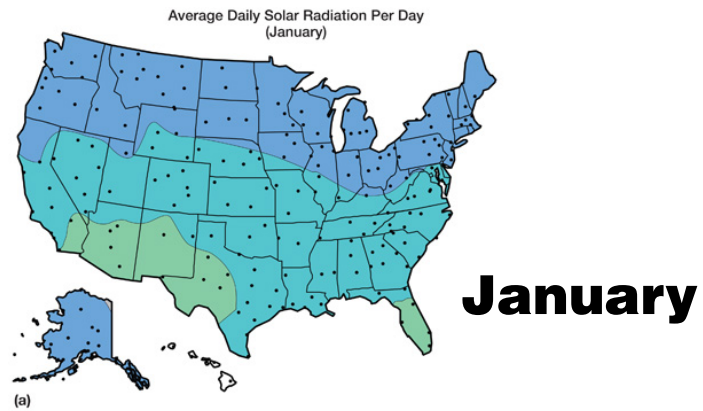
- **Balancing energy flows between:**
  - **Incoming sunlight**
  - **Reflected sunlight (due to albedo)**
  - **Terrestrial emission/absorption of IR**
  - **Atmospheric emission/absorption of IR**
  - **Cloud radiation (IR absorbed/emitted, sunlight reflected)**
  - **Conduction/convection between Earth and atmosphere**
  - **Latent heat absorbed/released at the Earth's surface and within the atmosphere**

# **Incoming Solar Radiation**

- **Source of energy for atmosphere**
- **Intensity at Earth's surface depends on:**
  - **Intensity of sunlight at top of atmosphere**
  - **Amount of scattering and reflection by atmosphere and clouds**
  - **Amount of absorption by atmosphere**

# Average daily solar radiation varies by:

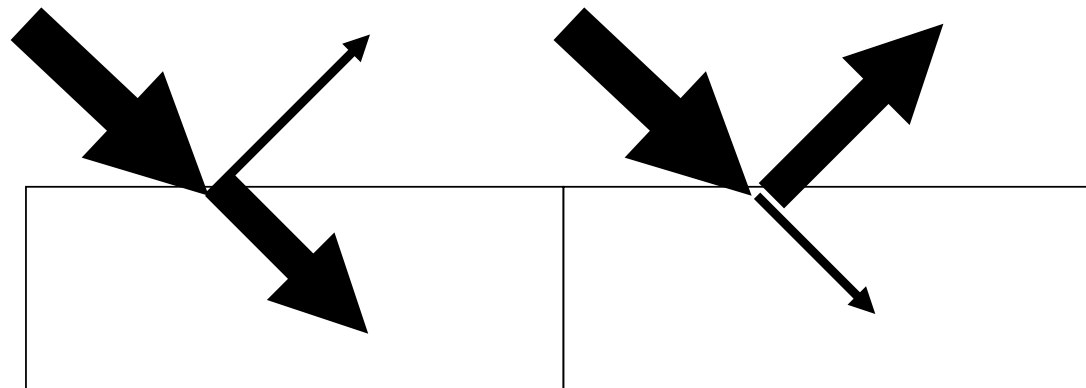
- Season
- Latitude



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# Albedo

— **Reflectivity of the surface of an object**



- **As albedo increases,**
  - ➔ **Absorption decreases**
  - ➔ **Temperature decreases**

# Albedo

— **Reflectivity of the surface of an object**

<b>Snow, ice</b>	<b>75–95%</b>
<b>Clouds</b>	<b>30–90%</b>
<b>Sand</b>	<b>15–45%</b>
<b>Earth/atmos. average</b>	<b>30%</b>
<b>Dry soil</b>	<b>5–20%</b>
<b>Forests</b>	<b>3–10%</b>
<b>Ocean</b>	<b>5–40%</b>

# Incoming Solar Radiation

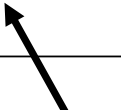
30% overall albedo

100 units incoming solar radiation

19

6

5



Scattered by atmosphere

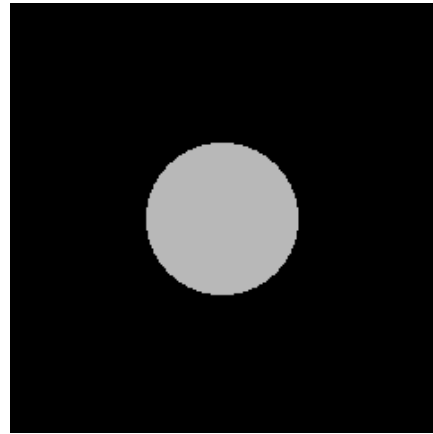
Scattered by clouds

Reflected by surface

25 absorbed by atmosphere and clouds (UV, IR)

45 units absorbed by surface (as visible light)

# Emission vs. Absorption



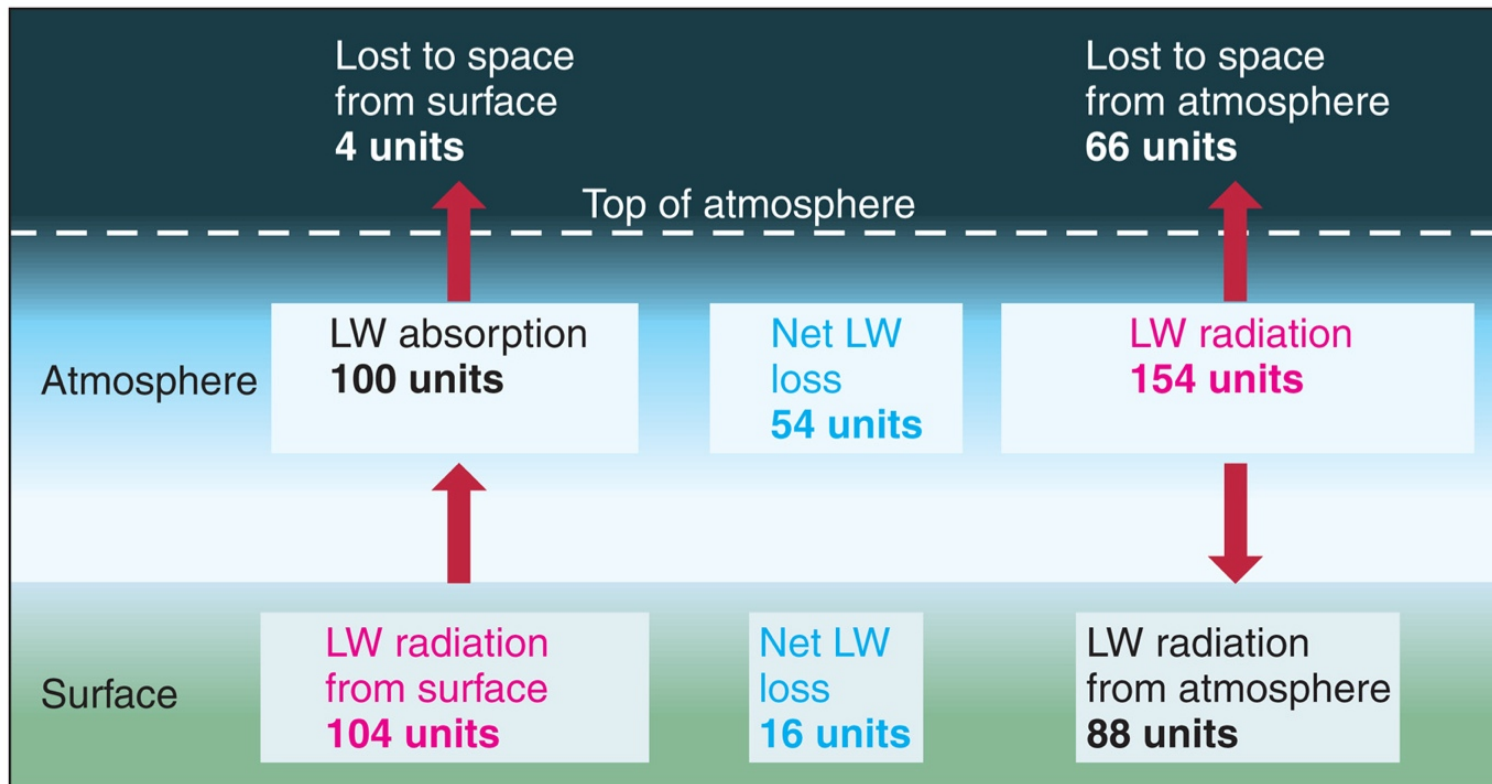
**Radiation absorbed  $\Rightarrow$  object warms**

**Radiation emitted  $\Rightarrow$  object cools**

**Amount of radiation emitted = amount  
of radiation absorbed: radiative equilibrium**

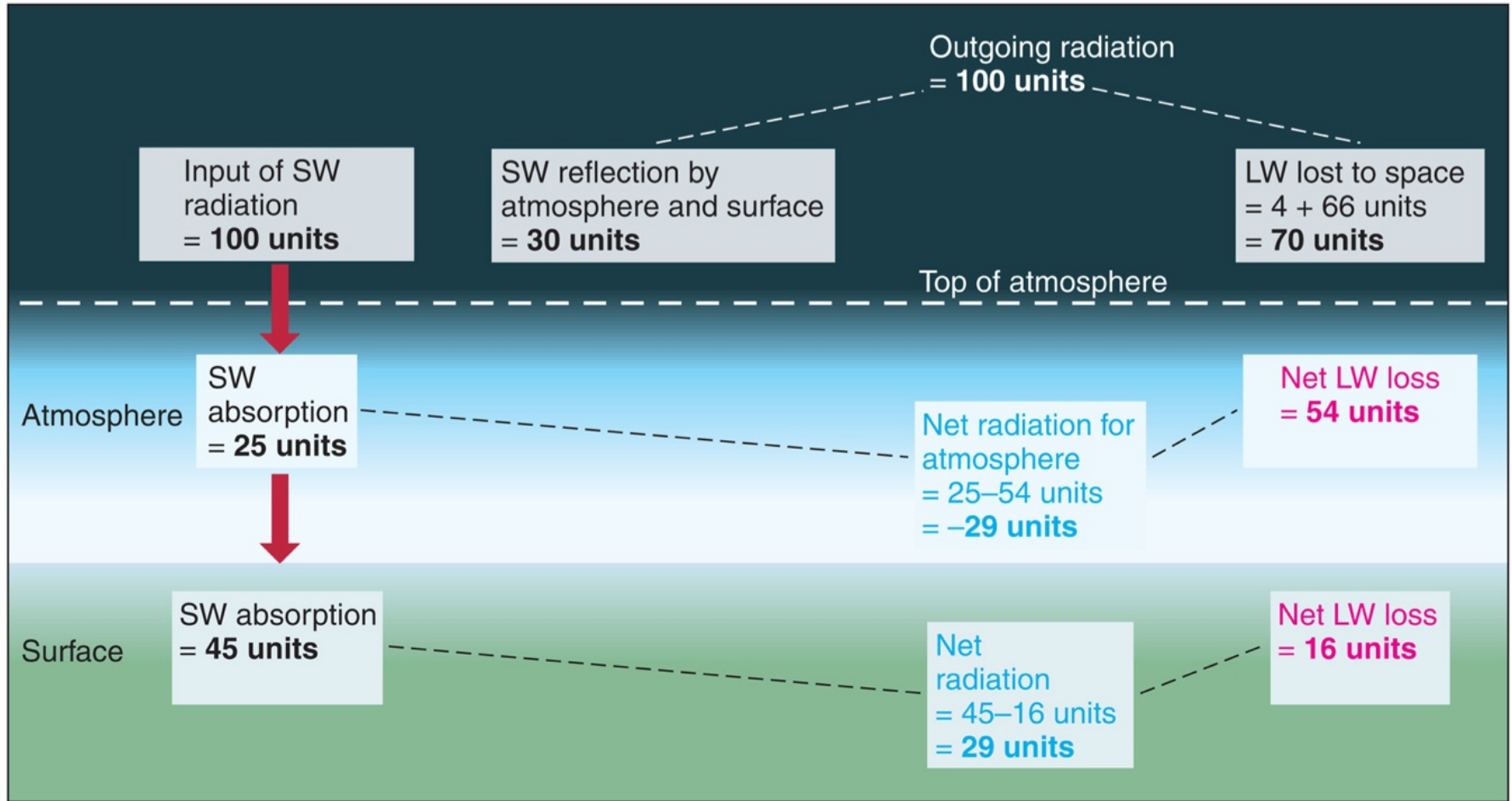
# Net Radiation

- **Difference between absorbed and emitted radiation**



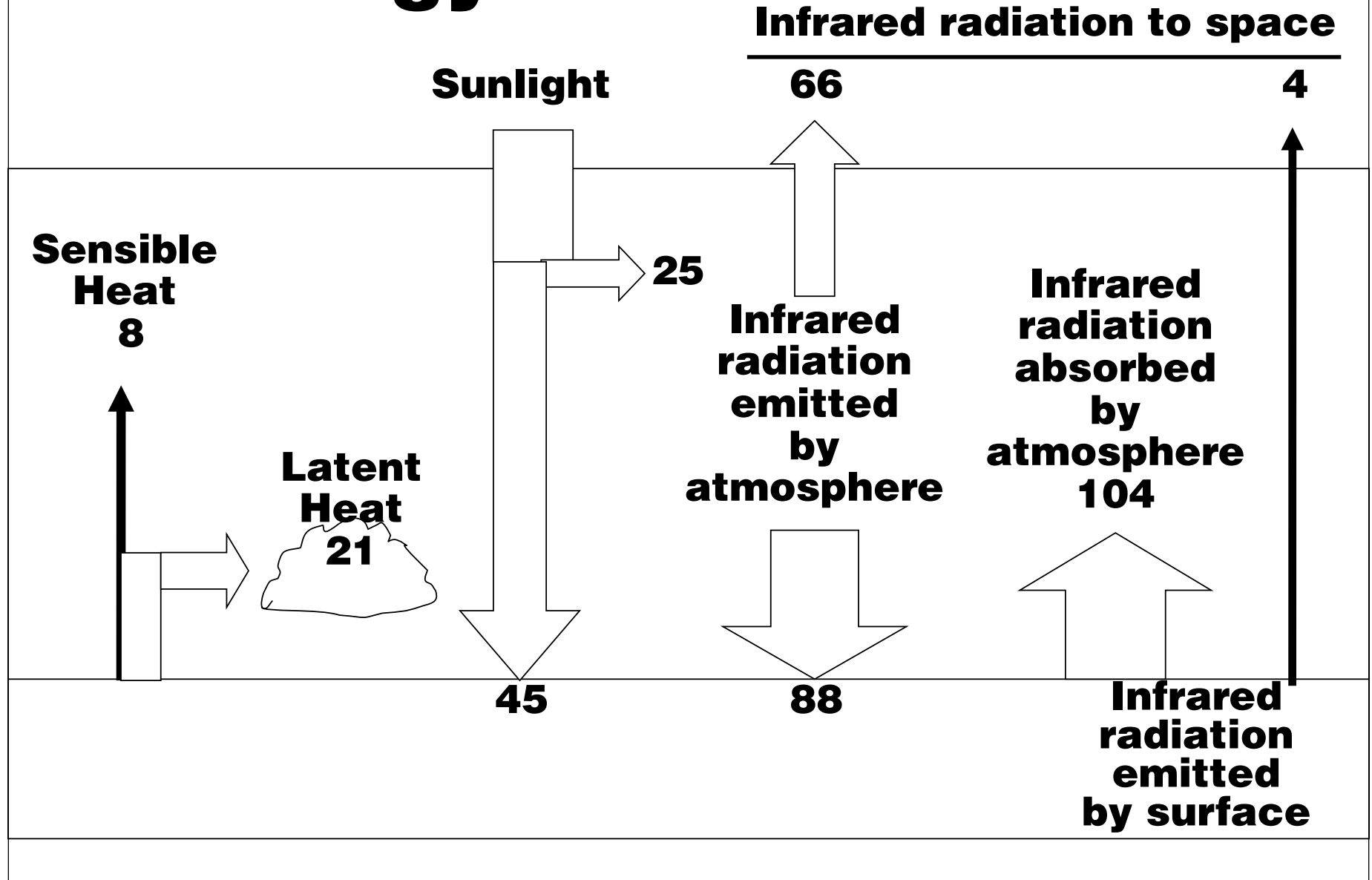
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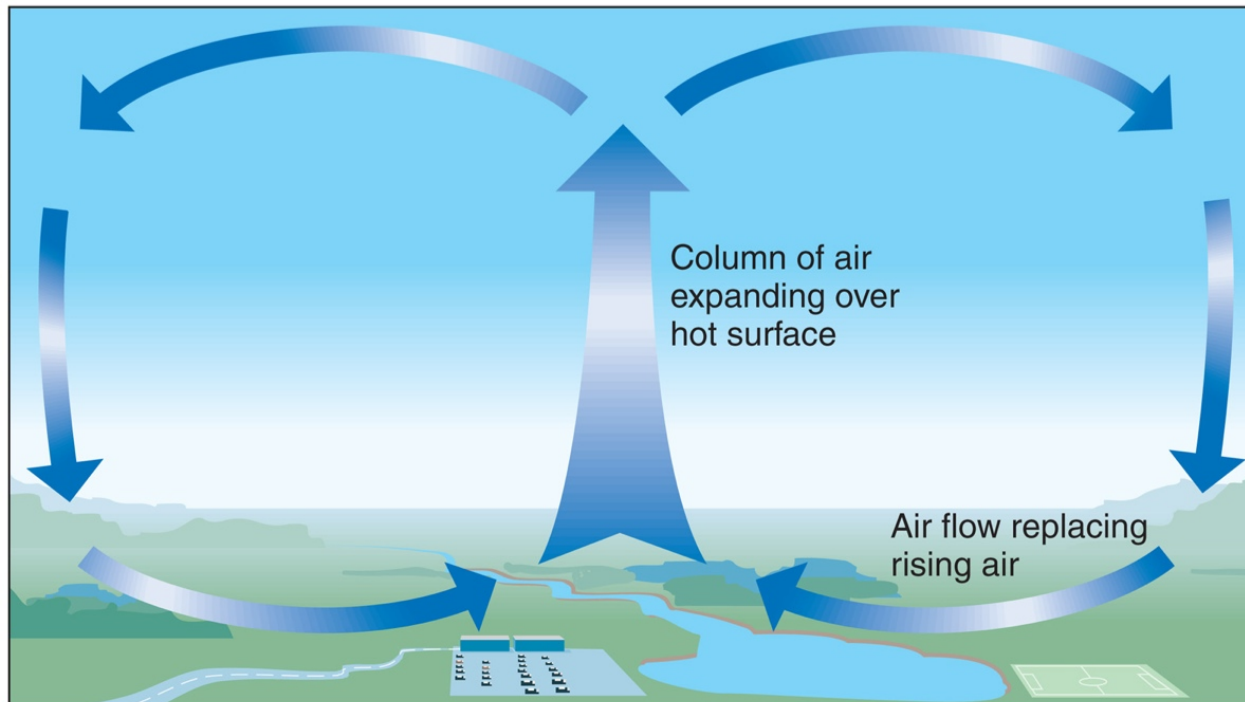
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# Energy Balance Model



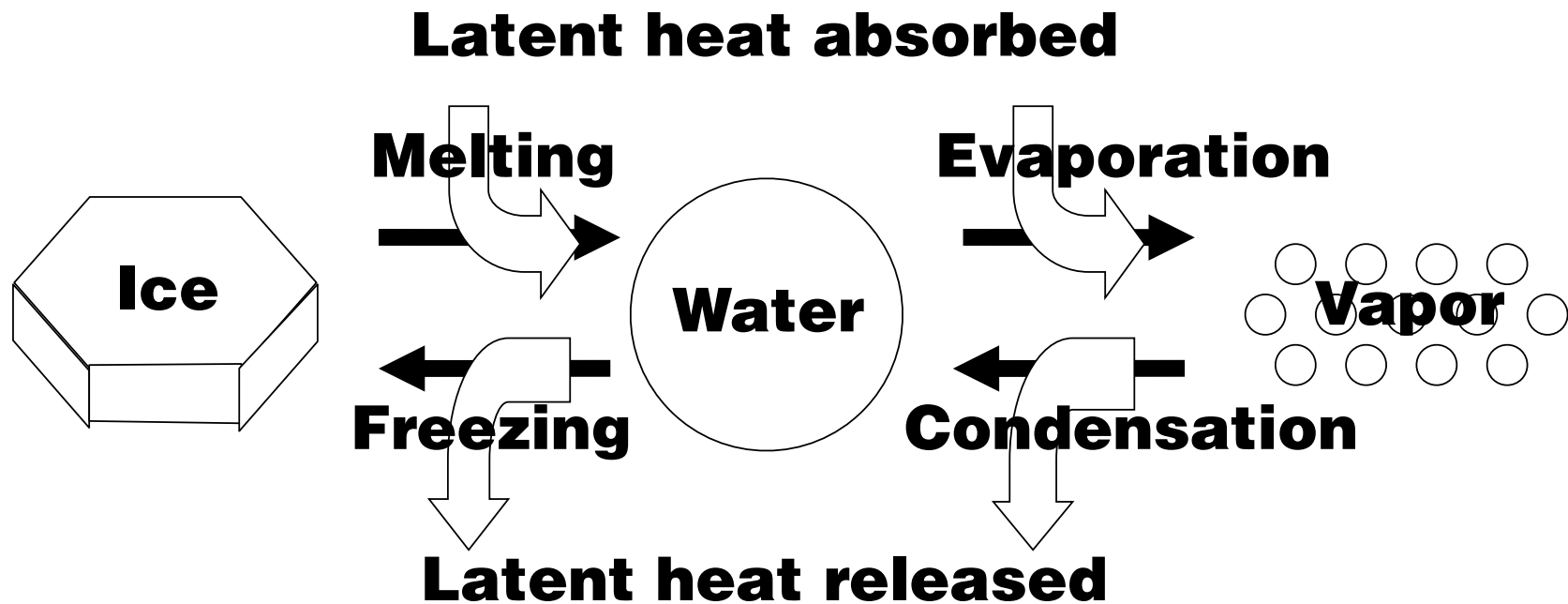
# Sensible and Latent Heat

- **Sensible heat: conduction and convection transfer heat from surface to atmosphere, increasing atmospheric temperature**



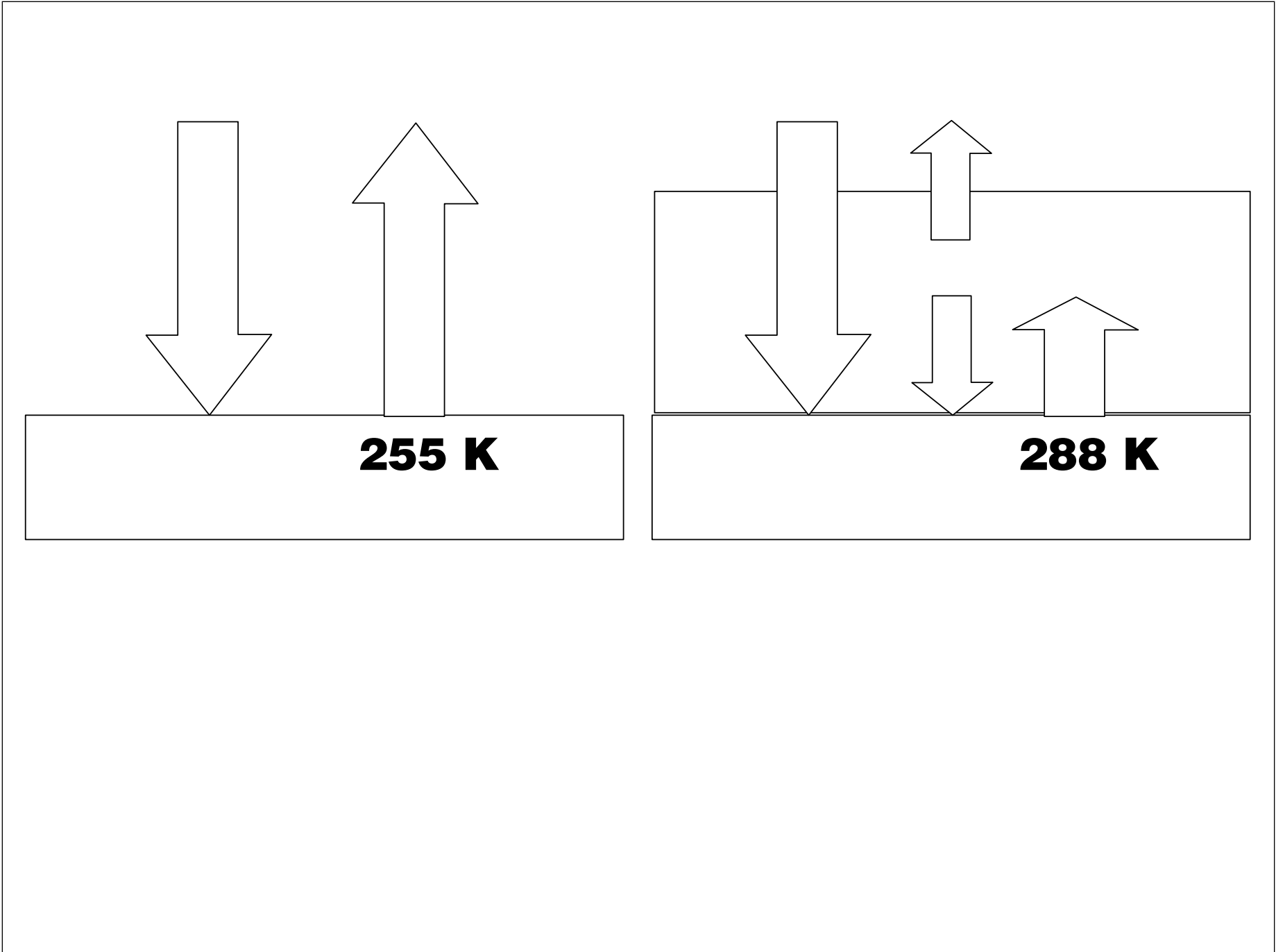
(a)

- **Latent heat: phase change of water substance absorbs or releases heat without changing the temperature of the water**

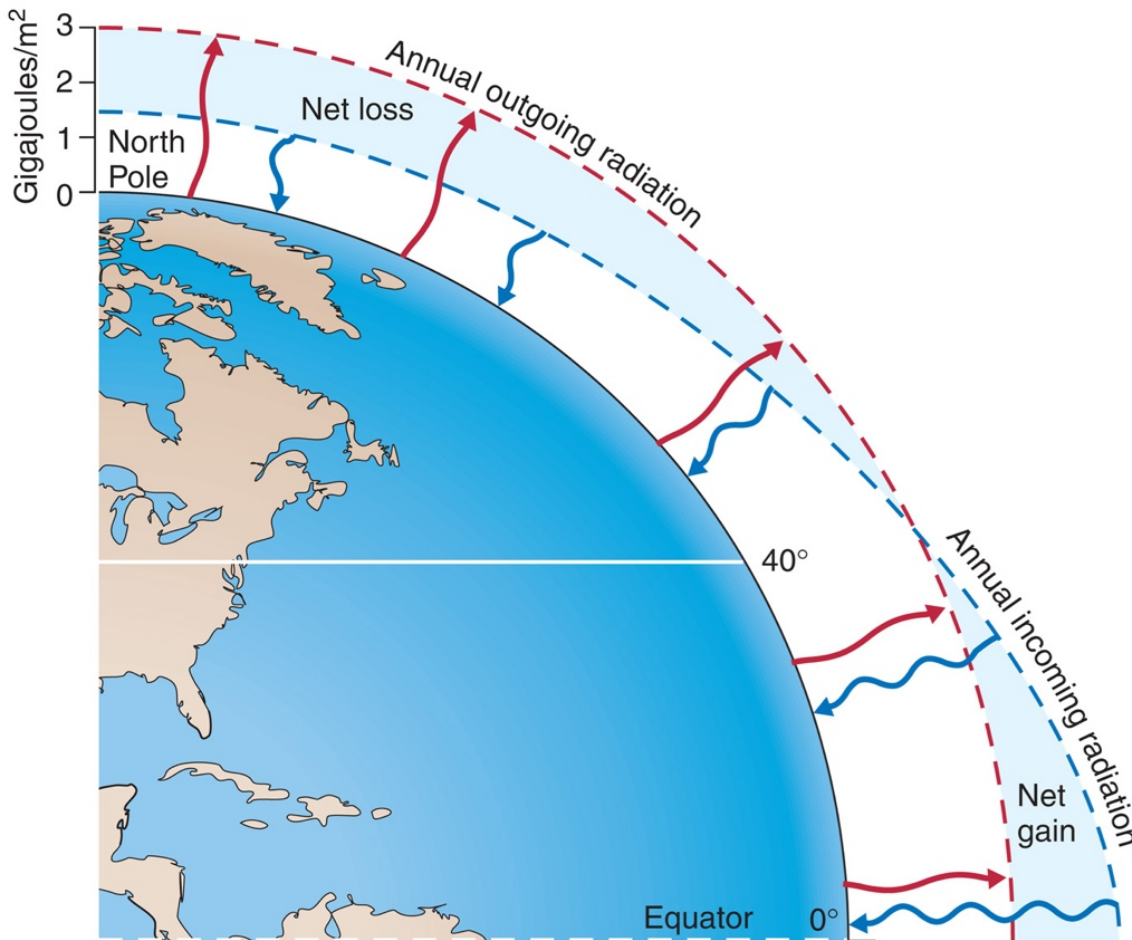


# **Atmospheric Greenhouse Effect**

- **Greenhouse gases in atmosphere preferentially absorb infrared radiation and transmit visible light**
  - **Emission of infrared by atmosphere to the ground warms the ground in addition to sunlight**
  - **Net increase in temperature at surface**

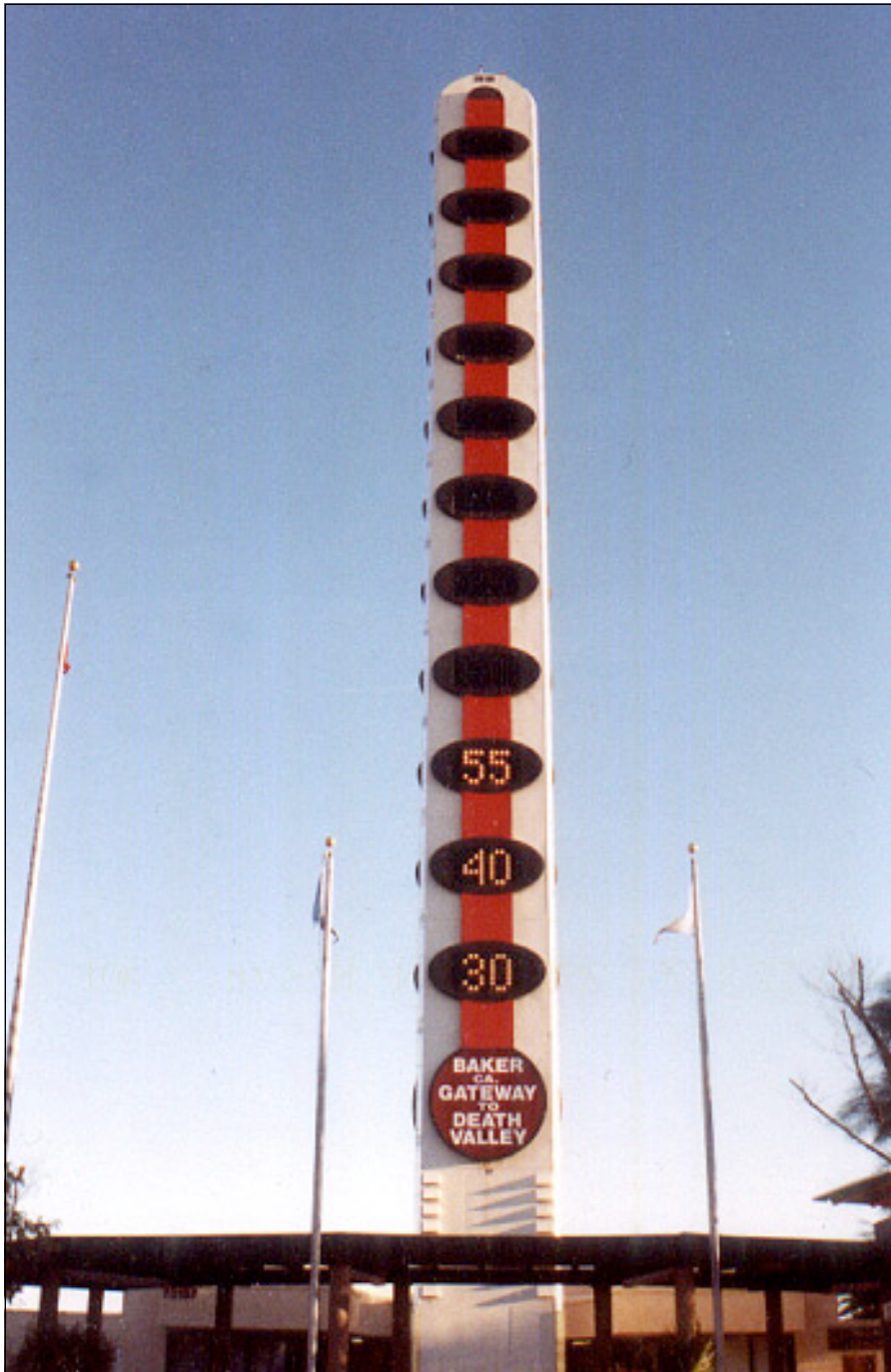


# Latitudinal Energy Balance



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**Sensible and latent heat transport by the atmosphere and sensible heat transport by ocean circulation toward the poles eliminates this energy imbalance**



# Temperature Variations



# **Controls of Temperature**

- **Latitude**

- **Temperature decreases as latitude increases**

- **Altitude**

- **Temperature decreases as altitude increases**

- **Circulation**

- **Atmospheric: cold and warm advection; cloud cover**

- **Oceanic: Gulf Stream along eastern US coast; cool California Current along western coast**



**Fig. 3-21**

- **Composition of the Surface**

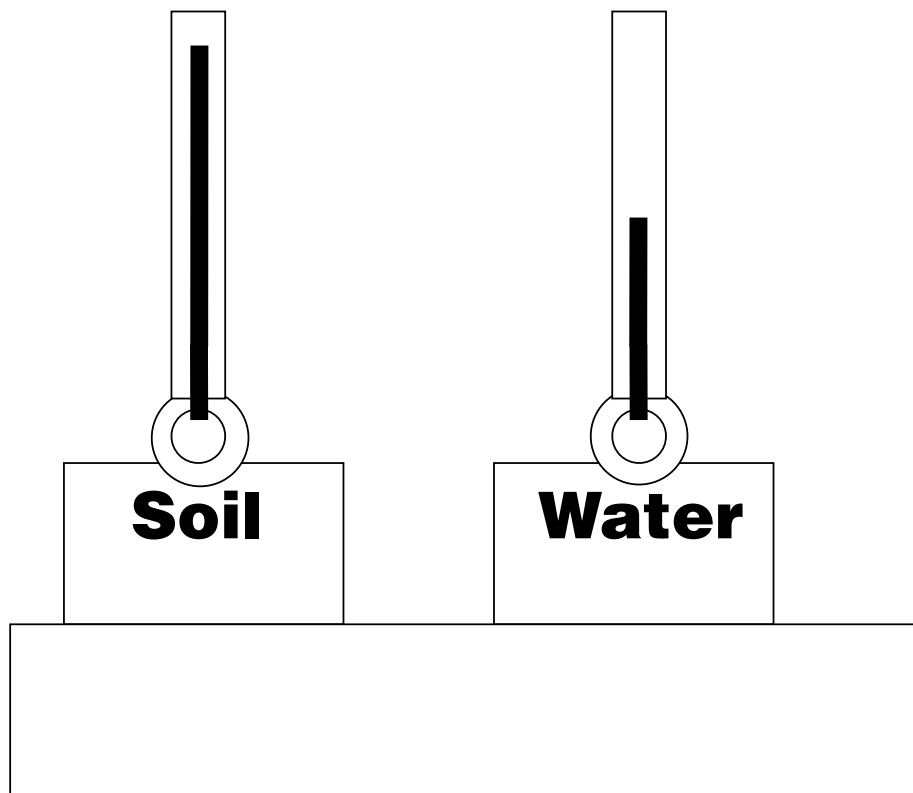
→ **Specific Heat: amount of heat required to raise the temperature of a gram of a substance by 1°C**

$$S_{\text{land}} < S_{\text{water}}$$

$$\Delta T_{\text{land}} > \Delta T_{\text{water}}$$



**Smaller day-night temperature differences near bodies of water**



# Daytime Temperatures

- **Sun rises**
- **Ground heats up**
- **Air warms up**

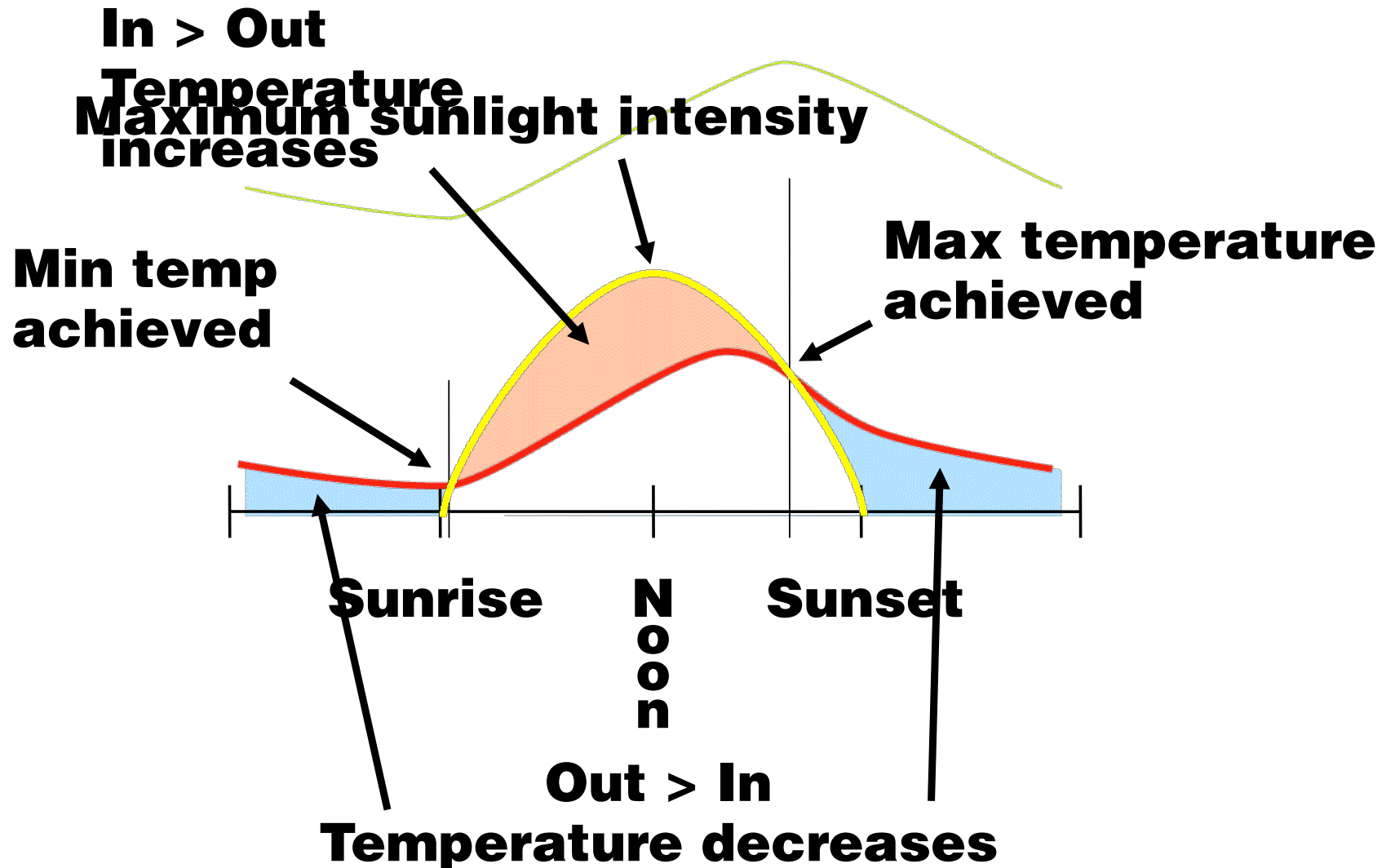


# Nighttime Temperatures

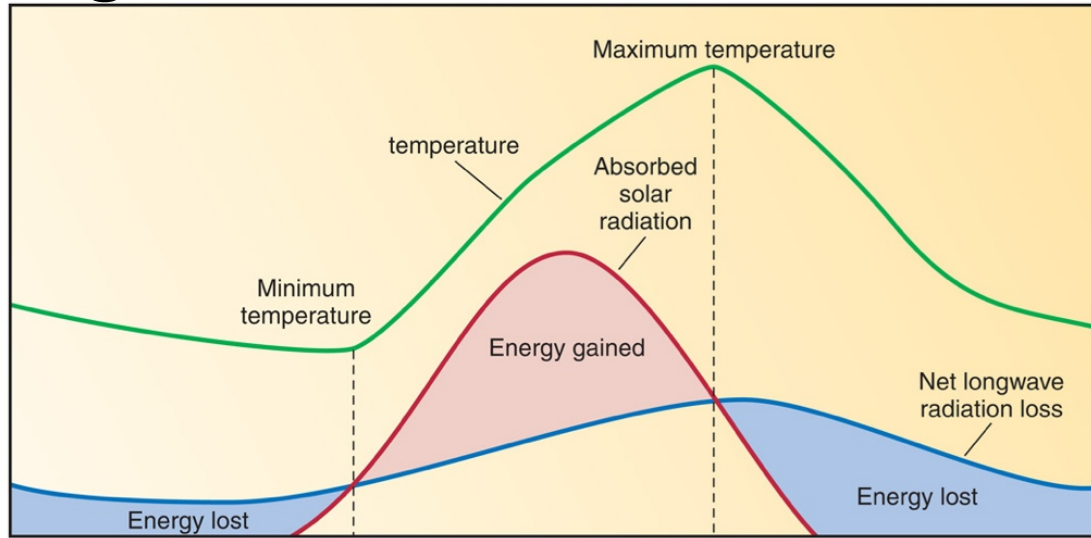
- **Sun sets**
- **Ground cools off**
- **Air temperature decreases**



# Daily Max/Min Temperature

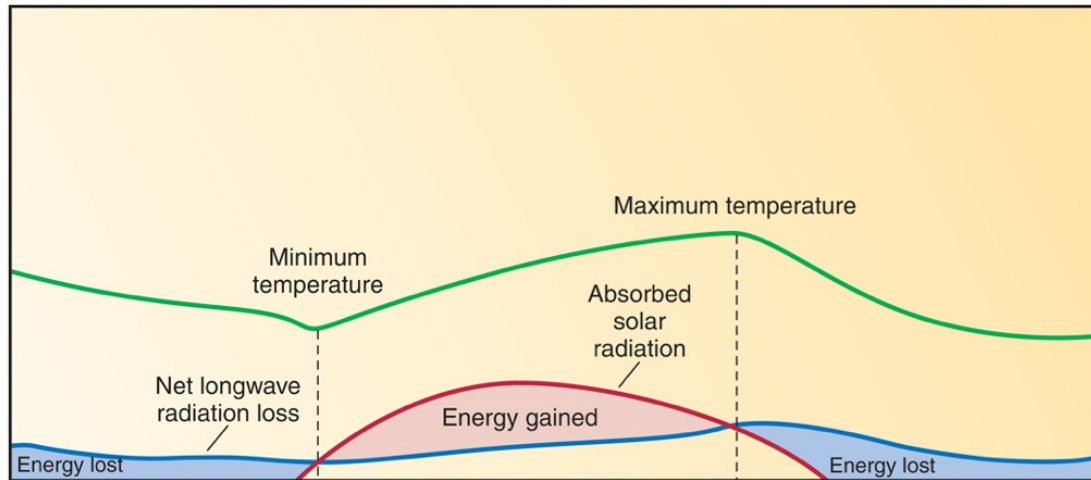


**Fig. 3-23**



(a)

**Clear sky**

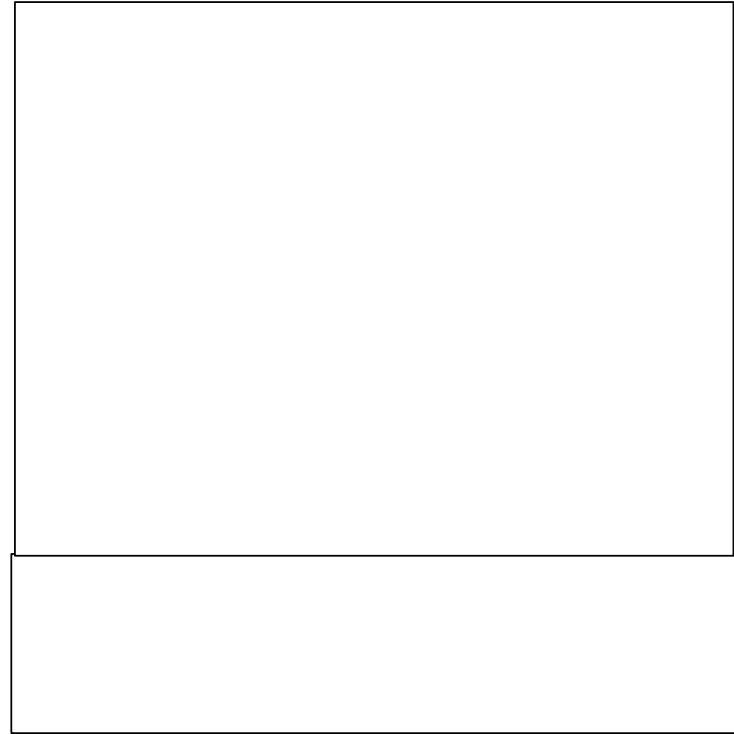
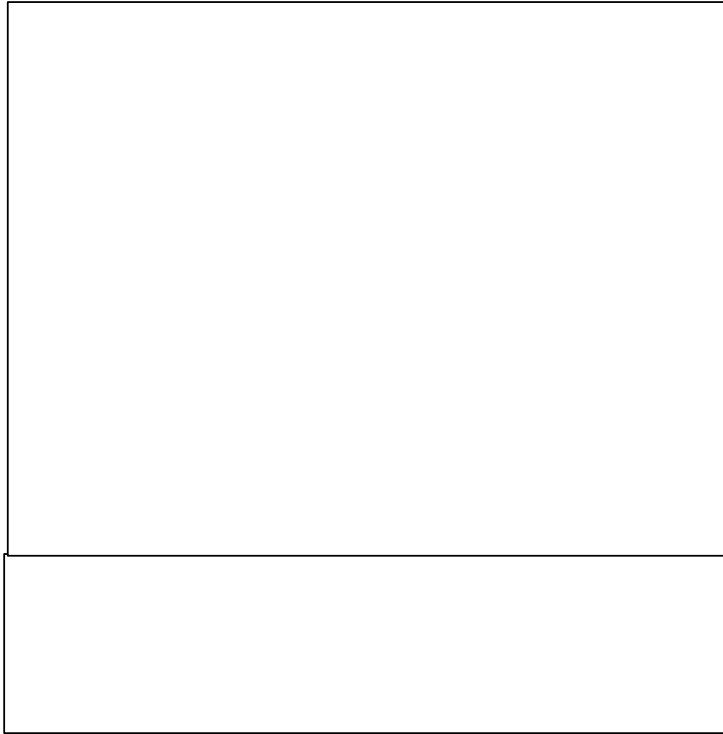


(b)

**Cloudy sky**

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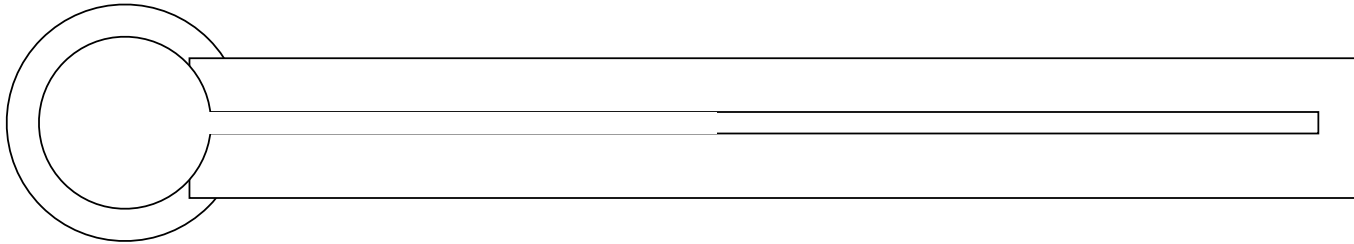
# **Windy conditions also reduce the daily range of temperature**



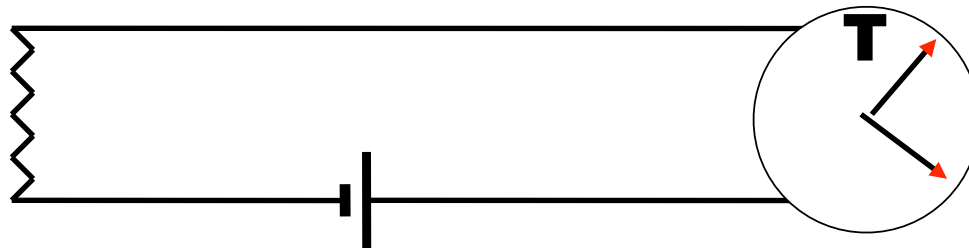


# Thermometry

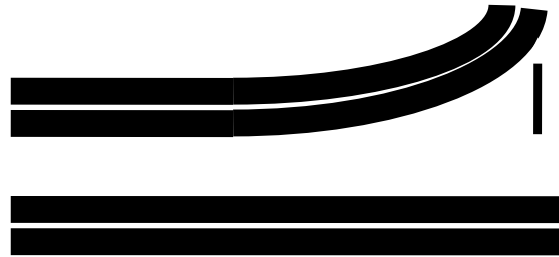
**Basic Principle 1: Materials expand as temperature increases**



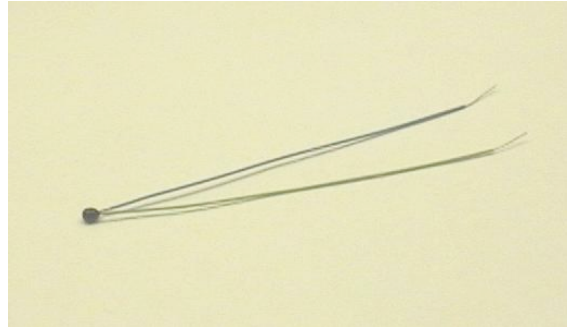
**Basic Principle 2: Resistance to current flow increases as temperature increases**



**Bimetallic  
thermometer  
element**



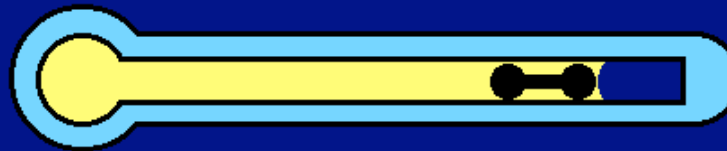
**Thermistor**



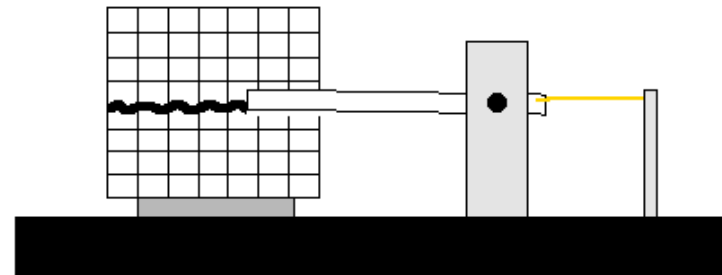
**Maximum  
Thermometer**



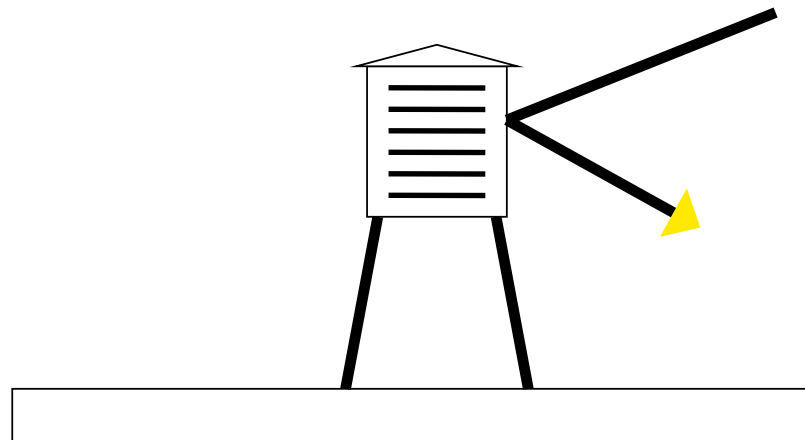
**Minimum  
Thermometer**



# Thermograph

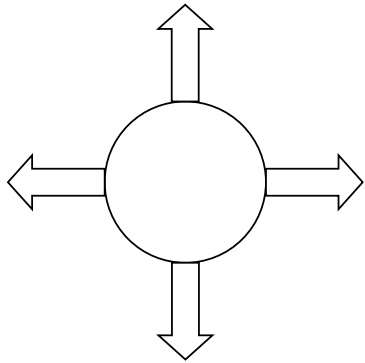


# Thermometer Shelter



# **Perceived Temperature: Wind chill**

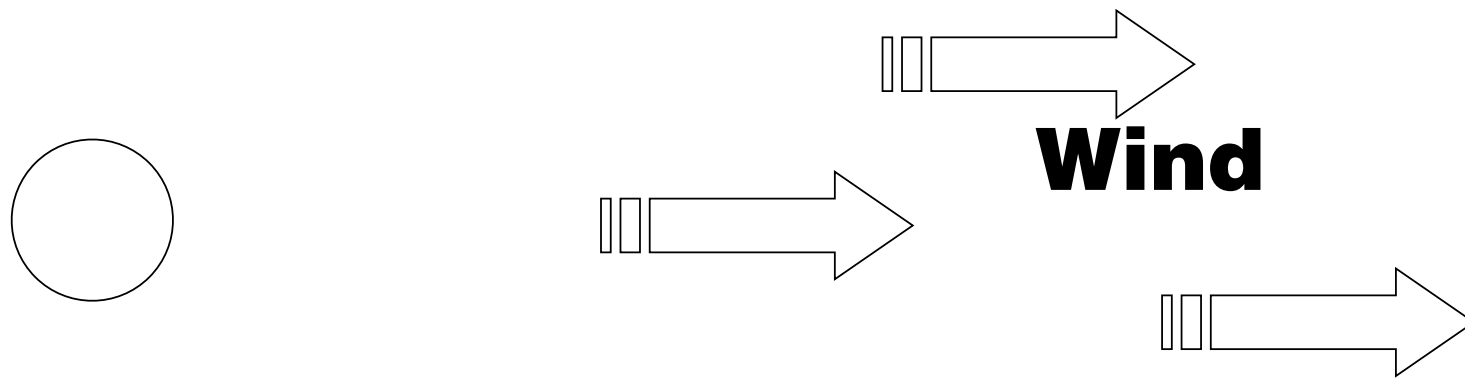
**Heat is conducted away slowly (because air is a poor conductor)**



**You sense temperature by how quickly you lose body heat (by all heat transfer processes)**

# Perceived Temperature: Wind chill

**Heat is convected away by the wind**



**Greater rate of heat loss →  
sensed as lower temperature**

**Wind Chill Temperature decreases as  
wind speed increases**



# Wind Chill Chart

