Energy Balance and Temperature

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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**

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Ch. 3: Temperature

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

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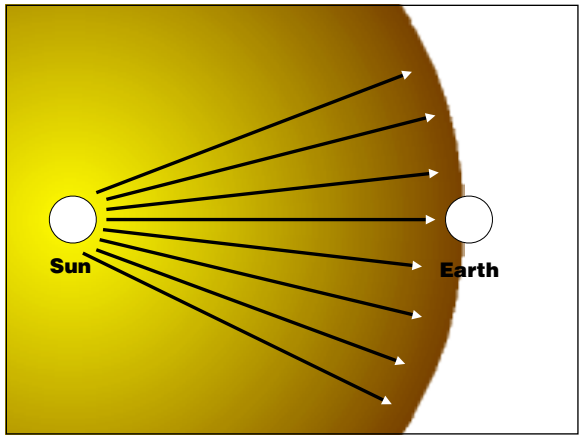

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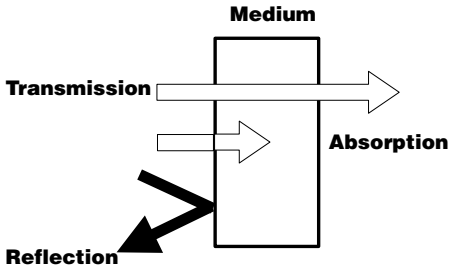
Radiation Propagation



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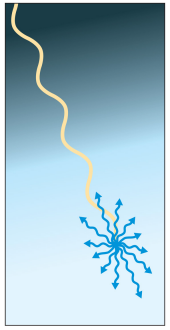
Scattering

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



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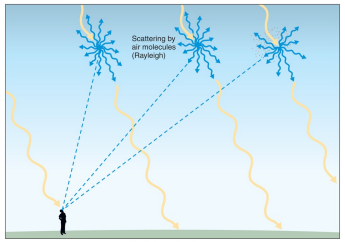
- **Rayleigh Scattering**
  - → **Preferential scattering of bluish light by very small particulates and gas molecules**
  - → **Blue-sky phenomenon**



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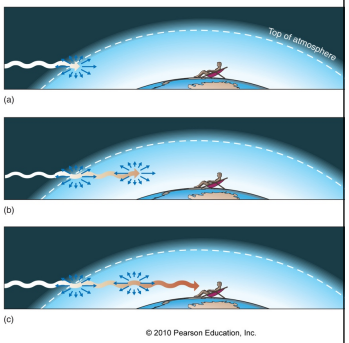
- → **Red-sky phenomenon**



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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**

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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**

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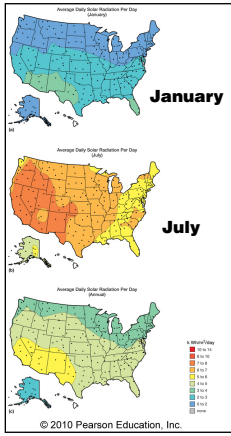

Average daily solar radiation varies by:

- **Season**
- **Latitude**

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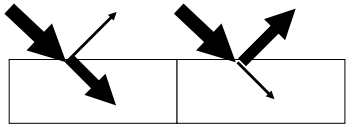
Albedo

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



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

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Albedo

— Reflectivity of the surface of an object

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

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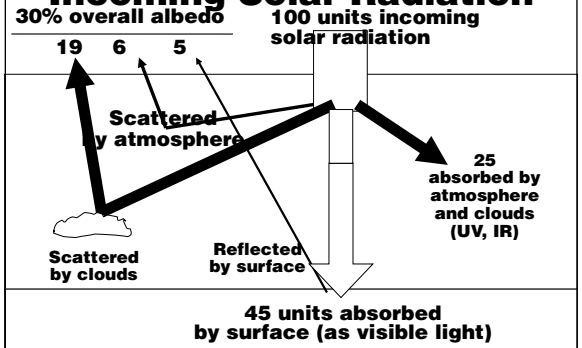
Incoming Solar Radiation



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Emission vs. Absorption

Radiation absorbed ⇒ object warms

Radiation emitted ⇒ object cools

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

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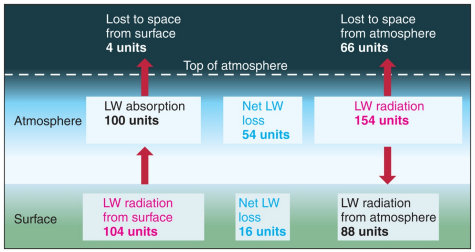
Net Radiation

- **Difference between absorbed and emitted radiation**



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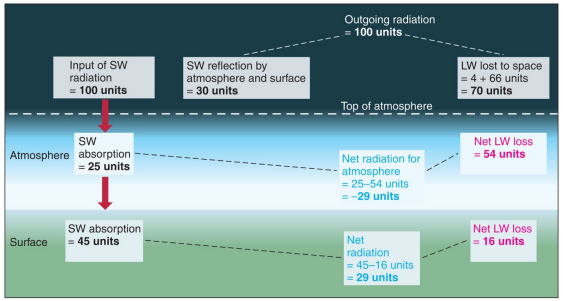

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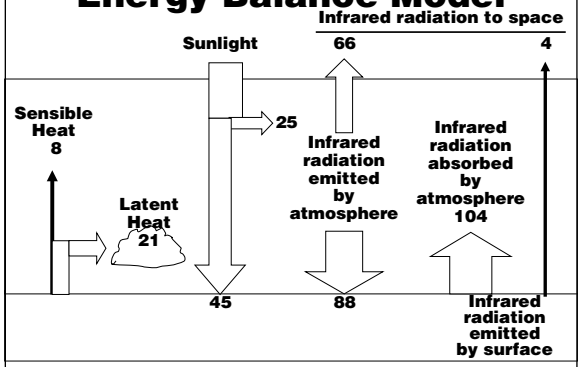
Energy Balance Model



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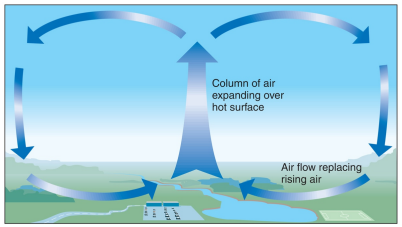
Sensible and Latent Heat

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



(a)

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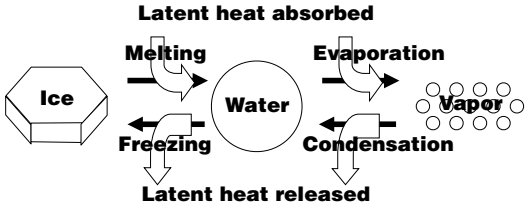
- **Latent heat: phase change of water substance absorbs or releases heat without changing the temperature of the water**



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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**

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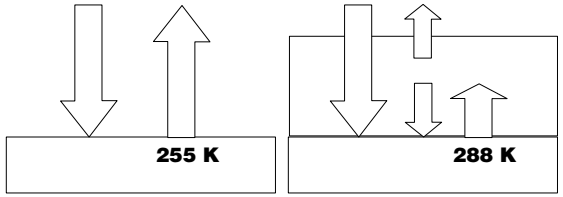

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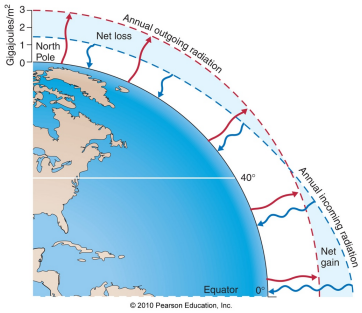
Latitudinal Energy Balance



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

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Temperature Variations

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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**

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Fig. 3–21

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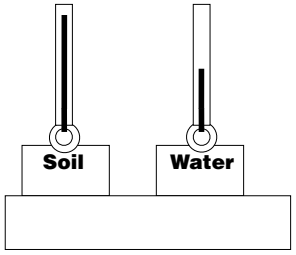
- **Composition of the Surface**
  - → **Specific Heat: amount of heat required to raise the temperature of a gram of a substance by 1°C**

$s_{land} < s_{water}$

$\Delta T_{land} > \Delta T_{water}$ → **Smaller day-night temperature differences near bodies of water**



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Daytime Temperatures

- Sun rises
- Ground heats up
- Air warms up

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Nighttime Temperatures

- Sun sets
- Ground cools off
- Air temperature decreases

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Daily Max/Min Temperature

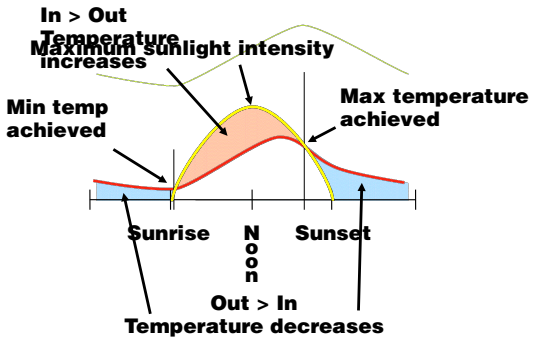

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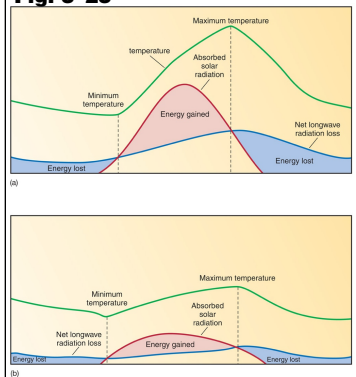
Fig. 3–23



Clear sky

Cloudy sky

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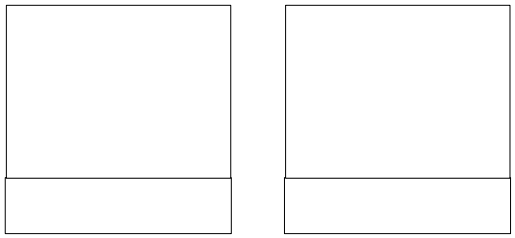
Windy conditions also reduce the daily range of temperature



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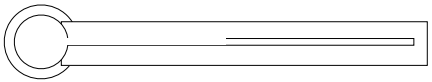
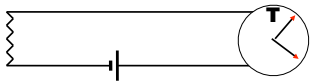
Thermometry

Basic Principle 1: Materials expand as temperature increases



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



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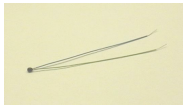
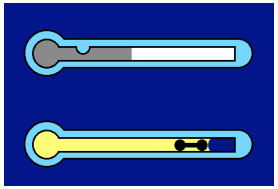
Bimetallic thermometer element

Thermistor



Maximum Thermometer

Minimum Thermometer



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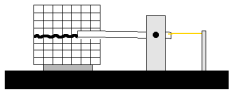
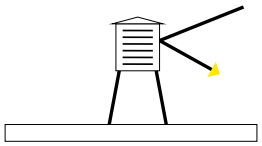
Thermograph



Thermometer Shelter



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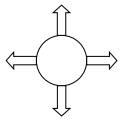
Perceived Temperature: Wind chill

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)

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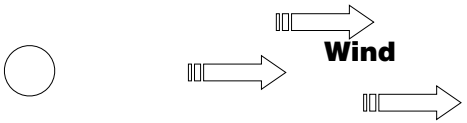
Perceived Temperature: Wind chill

Heat is convected away by the wind



Greater rate of heat loss → sensed as lower temperature

Wind Chill Temperature decreases as wind speed increases

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Wind Chill Chart

Wind (mph) \ Temperature (°F)	Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5		36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10		34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15		32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20		30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25		29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30		28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35		28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40		27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45		26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50		26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55		25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60		25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite Times — 30 minutes — 10 minutes — 5 minutes

$$\text{Wind Chill (°F)} = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$$

Where, T= Air Temperature (°F) V= Wind Speed (mph)

Effective 11/01/01

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