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

Red-sky phenomenon

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

**Albedo**

- Reflectivity of the surface of an object

- As albedo increases,
  - Absorption decreases
  - Temperature decreases
Albedo
— Reflectivity of the surface of an object

<table>
<thead>
<tr>
<th>Material</th>
<th>Reflectivity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snow, ice</td>
<td>75–95%</td>
</tr>
<tr>
<td>Clouds</td>
<td>30–90%</td>
</tr>
<tr>
<td>Sand</td>
<td>15–45%</td>
</tr>
<tr>
<td>Earth/atmos. average</td>
<td>30%</td>
</tr>
<tr>
<td>Dry soil</td>
<td>5–20%</td>
</tr>
<tr>
<td>Forests</td>
<td>3–10%</td>
</tr>
<tr>
<td>Ocean</td>
<td>5–40%</td>
</tr>
</tbody>
</table>

Incoming Solar Radiation

30% overall albedo
100 units incoming solar radiation

45 units absorbed by surface (as visible light)

Emission vs. Absorption

Radiation absorbed ⇒ object warms
Radiation emitted ⇒ object cools

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

- Difference between absorbed and emitted radiation

energy balance model

Sensible Heat 8

Latent Heat 21

Infrared radiation emitted by atmosphere 104

Infrared radiation emitted by surface 88

Infrared radiation absorbed by atmosphere 25

Solar radiation 66

21

8

45

66

4

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**Sensible and Latent Heat**

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

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

  - Ice → **Water** (Melting)
  - **Water** → **Vapor** (Evaporation)
  - **Vapor** → **Water** (Condensation)
  - Water → Ice (Freezing)

**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

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

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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

  \[ s_{\text{land}} < s_{\text{water}} \]

  \[ \Delta T_{\text{land}} > \Delta T_{\text{water}} \]

  Smaller day-night temperature differences near bodies of water

Soil 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**
- Max temperature achieved
- Min temperature achieved
- Temperature increases
- Temperature decreases
- In > Out
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
Maximum Thermometer
Bimetallic thermometer element
Thermistor
Maximum Thermometer
Minimum Thermometer

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