Chapter 3- Energy Balance and Temperature

*Understanding Weather and Climate*
Aguado and Burt

Influences on Insolation

- Absorption
- Reflection/Scattering
- Transmission
Absorption

- An absorber gains energy and temperature
- Gases in the atmosphere are not equivalent in their ability to absorb solar radiation
- Solar radiation has a range of wavelengths

Reflection and Scattering

- Reflection – redirected with no absorption
- All substances reflect light, but with vastly differing effectiveness.
  - Albedo – the percentage of solar radiation reflected by an object
- Specular reflection – reflected back as beam of equal intensity
- Diffuse reflection or scattering – reflected back as a number of weaker rays traveling in different directions
Scattering

- Rayleigh Scattering – performed by gas molecules, more effective at shorter wavelengths, scatters both forward and backward
- Mie Scattering – performed by aerosol particles, not biased, scatters predominately forward
- Nonselective Scattering – performed by water droplets (clouds), aggregate effect equal among wavelengths
The Fate of Solar Radiation

• 100 Units Available
  – 25 are absorbed by the atmosphere
  – 19 are reflected by cloud cover into space
  – 6 are reflected by the atmospheric gases and aerosols into space
  – 5 are backscattered into space by the ground

Surface/Atmosphere Radiation Exchange

• The Earth and atmosphere emit almost completely longwave radiation (thermal infrared)
• This radiation emitted by the Earth is largely absorbed by the atmosphere (carbon dioxide and water vapor)
Surface/Atmosphere Radiation Exchange

Shaded area is what the atmosphere absorbs.

Outline is the earth's emissions.
The Total Picture?

Surface/Atmosphere Convective and Conductive Exchange

- Conduction – a temperature gradient appears near the surface and energy is transferred upward.
  - Energy is also transferred downward below the Earth’s surface.
Surface/Atmosphere Convective and Conductive Exchange

• Convection – Heat transferred through bodily movement of the liquid or gas.
  – Free Convection – convection related to buoyancy
  – Forced Convection – turbulence, formation of eddies as the large-scale flow breaks down
Sensible Heat

- Sensible – heat which we physically sense
- The magnitude of temperature is related to two factors:
  - Specific heat
  - Mass

Latent Heat

- Latent – energy exchange required to change a phase of a substance
  - Latent heat of fusion (solid to liquid) - melting
  - Latent heat of evaporation (liquid to gas) – vaporization
  - Latent heat of sublimation (solid to gas)
  - Latent heat of freezing (liquid to solid)
  - Latent heat of condensation (gas to liquid)
  - Latent heat of deposition (gas to solid)
### A True Balance!

<table>
<thead>
<tr>
<th>Top of atmosphere</th>
<th>Atmosphere</th>
<th>Surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>SW radiation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>absorbed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 units</td>
<td></td>
<td></td>
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<tr>
<td>Net LW radiation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-54 units</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensible heat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>by convection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 units</td>
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</tr>
<tr>
<td>Latent heat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>by convection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21 units</td>
<td></td>
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</tbody>
</table>

\[
\text{Net radiation} = -29 \text{ units} = 29 \text{ units} \\
\text{Convective heat gain} = 29 \text{ units} \\
\text{Net radiation} = 29 \text{ units} = 29 \text{ units} \\
\text{Convective heat loss} = 29 \text{ units} \\
\]

### Latitudinal Variations

The image illustrates latitudinal variations with a focus on net radiation and heat exchange processes at different latitudes. The diagram shows the distribution of net radiation, outgoing radiation, and net heat gain or loss across various latitudes, including the equator and higher latitudes (such as the North Pole). The variations are depicted to highlight how changes in latitude affect the balance of incoming and outgoing radiation and the resulting heat fluxes.
Latitudinal Variations

- The tropics would continually become warmer and the polar regions would continually become if temperatures only depended on incoming radiation.
- Advection – horizontal movement of air accomplished mainly through global wind systems and oceanic currents help distribute the heat.

Global Temperature Variations

- Temperatures tend to decrease poleward in both hemispheres.
- Stronger temperature gradients occur in the winter hemisphere.
- Isotherms shift poleward over land during the summer and equatorward overland during the winter.
- The Northern Hemisphere has a steep gradient compared to the Southern Hemisphere.
Other Influences on Temperature

Altitude

Other Influences on Temperature

Land vs. Water

• Bodies of water are more conservative than land masses with regards to temperature:
  – Specific heat of water is greater
  – Radiation received by water can penetrate several meters.
  – Evaporation
  – Easy mixing (advection and convection)
Other Influences on Temperature

- Local Conditions
  - Slope of terrain
- Ocean Currents
  - Gulf Stream
- Atmospheric Circulations

Radiation and Temperature
Annual Variations in Temperature

Measuring Temperature

- Thermometers
  - Based on expansion and contraction of liquid
- Thermistors
  - Based on changes in resistance of electrical current proportional to the temperature
Temperature Scales

- Boiling point of water: 373.16 K (212 °F)
- Melting point of ice: 273.16 K (0 °C)
- Absolute zero: 0 K (−459.6 °F)

Temperature Shelters

- Temperature is always measured in the shade, therefore a shelter is used.
  - Painted white to increase albedo
  - Paneled with slats to allow airflow
  - Door mounted on north
  - Standardized 5 ft. height
Temperature Means and Ranges

• Daily mean – The average of the maximum and minimum temperature for that day
• Daily temperature range – subtraction of maximum temperature from minimum
• Monthly mean – average of daily means
• Annual mean – average of monthly means