Temperature Concepts and Measurement

- Temp. is a measure of kinetic energy
  - Avg. energy of motion of molecules

- Heat is the transfer/flow of energy

- Three standard scales of measurement

Thermometer and Instrument Shelter

FIGURE 3.3 Instrument shelter. A well designed instrument shelter is vital to high quality data. Left: Instrument shelter at Stevens Point, Wisconsin. Temperature sensors that control the instrument door open and close to ensure that heat and cold never reach the thermometer apparatus, providing protection from direct sunlight. [Pix1: D.C. Seim; pix2: D.C. Seim]

Copyright © 2003 Pearson Education Inc.
Importance of Temperature

Temperature is a major component of climate which impacts:
- landform processes
- vegetation
- soil development
- economic development
- patterns of human activity - culture

Latitude

Determines intensity and duration of insolation.
Most important factor influencing mean annual and mean monthly temperature.

FIGURE 5.4 Latitude affects temperature. A comparison of mean (data from near the equator to near the poles). Extreme latitudes also show greater seasonal variation in temperature compared to mid-latitudes. The influence of latitude is evident in temperature data for both high and low elevations in the northern and southern hemispheres.
Altitude/Elevation

Concepcion
490 m

La Paz
4103 m

As elevation ↑, density of atm. ↓ and reduces ability to absorb or reradiate heat

Cloud Cover

Less insolation = lower daytime temp

Increased counter radiation = higher nighttime temps

Land-Water Heating Differences

Result of four (not five) major differences between physical properties of land and water:

1. evaporation
2. transparency
3. specific heat
4. circulation

Note: in the book circulation is divided into movement and ocean currents and sea surface temperatures
**L vs. W: Evaporation**

Moderates temps over water
- Much more Q used for LE during day
- Less Q for H
- Condensation releases Q at night

---

**L vs. W: Transparency**

Land is opaque
SW used to heat surface only
Rapidly reradiates LW

Water is nearly transparent
SW transmitted to depth
Greater opportunity for absorption

---

**L vs. W: Specific Heat**

Specific heat of water 4x greater than land
Water heats slower, and losses its heat energy slower
Stores a much greater quantity of heat energy

<table>
<thead>
<tr>
<th>Material</th>
<th>Specific Heat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice</td>
<td>0.50</td>
</tr>
<tr>
<td>Sugar</td>
<td>0.77</td>
</tr>
<tr>
<td>Bone</td>
<td>0.80</td>
</tr>
<tr>
<td>Copper</td>
<td>0.89</td>
</tr>
<tr>
<td>Glass</td>
<td>0.89</td>
</tr>
<tr>
<td>Alumium</td>
<td>0.90</td>
</tr>
<tr>
<td>Sodium</td>
<td>0.90</td>
</tr>
<tr>
<td>Water</td>
<td>4.18</td>
</tr>
</tbody>
</table>
**L vs. W: Circulation**

Vertical mixing redistributes heat energy and increases storage capacity.

Horizontal motion redistributes Q to higher latitudes.

---

**Land-Water Heating Differences**

**Continental vs. Marine Climates**

- Continental: Temperature conditions more extreme—land warms and cools rapidly.
- Marine: Temperature conditions more moderate—water warms and cools slowly.

Less evaporation (lower LE) in land.

Greater evaporation (higher LE) in water.

Land has a lower specific heat.

Water has a higher specific heat.

Land has no mixing between layers.

Water has mobility and mixes in vast ocean currents.

Surface is opaque in land.

Surface is transparent in water.
Global Temperature Patterns

To summarize: temperature patterns can be explained by primary temperatures controls:
1. Latitude
2. Elevation
3. Cloud Cover
4. Proximity to Water (L vs. W differences)
Bending of Continental Isotherms

January: equatorward

July: poleward

Global Mean Temperatures: July

Annual Temperature Range
Apparent Temperature

- **Wind Chill**
  - Increased cold due to wind speed
  - More discomfort with high wind and high humidity

- **Humidex**
  - Increased heat due to higher humidity
  - More discomfort with high humidity and low wind

### Wind Chill Temperature Index

![Wind Chill Temperature Index Chart]

#### Table 5.1.2 Comfort Levels and Suggested Activities for Ranges of Humidex

<table>
<thead>
<tr>
<th>Range of Humidex (°C)</th>
<th>Degree of Comfort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 29</td>
<td>No discomfort</td>
</tr>
<tr>
<td>30 to 39</td>
<td>Some discomfort; tone down or modify strenuous outdoor activity</td>
</tr>
<tr>
<td>40 to 45</td>
<td>Great discomfort; avoid exertion, curtail activity</td>
</tr>
<tr>
<td>Above 45</td>
<td>Dangerous</td>
</tr>
<tr>
<td>Above 54</td>
<td>Heat stroke is imminent</td>
</tr>
</tbody>
</table>

Atmospheric Circulation (chapter 6)

- Basic element of atmospheric circulation is wind
  - Primary Circulation = global
  - Secondary Circulation = regional
  - Tertiary Circulation = local

- Redistributes heat energy

- Causes oceanic circulation

Wind Essentials

Wind defined by:
- Speed, as measured with an anemometer
- Direction of origin, as indicated by wind vane

Driving Forces

- Force of Gravity
- Pressure Gradient Force
- Coriolis Force
- Friction Force
Gravity

- Force of gravity produces atm. pressure
- Without gravity there would be:
  - no atmospheric pressure
  - so no variations in atmospheric pressure
  - no atmospheric motion
  - and oh . . .,
  - by the way,
  - no atmosphere

Pressure Gradient Force

- (Wider spacing of isobars)
- High pressure
- Gradual pressure gradient: LIGHT WINDS
- (Closer spacing of isobars)
- Low pressure
- Strong pressure gradient: STRONG WINDS
Areas of high pressure: air descends (hence, higher pressure) and diverges at Earth's surface

Areas of low pressure: air ascends (so lower surface pressure) and is replaced by converging flow (inflow)
Pressure Gradient Force

But the red arrows on this map are not moving directly from high to low.

Something must be affecting their path?

Coriolis Force

The current edition finally has it (almost) right!

Coriolis Force

Coriolis Force

Copyright © 2013 Pearson Canada Inc.
Friction Force

Surface friction adds a countering force to Coriolis, producing winds that spiral out of high pressure areas and into low pressure areas. Surface winds cross isobars at an angle. Air flows into low pressure cyclones and turns to the left, because of deflection to the right.

Cyclones and Anticyclones

<table>
<thead>
<tr>
<th></th>
<th>High Pressure</th>
<th>Low Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern</td>
<td>Anticyclone</td>
<td>Cyclone</td>
</tr>
<tr>
<td></td>
<td>spiral outward</td>
<td>spiral inward</td>
</tr>
<tr>
<td></td>
<td>clockwise</td>
<td>counterclockwise</td>
</tr>
<tr>
<td>Southern</td>
<td>Anticyclone</td>
<td>Cyclone</td>
</tr>
<tr>
<td></td>
<td>spiral outward</td>
<td>spiral inward</td>
</tr>
<tr>
<td></td>
<td>counter-clockwise</td>
<td>clockwise direction</td>
</tr>
</tbody>
</table>
Wind Pattern Development

Primary High- & Low-Pressure Areas

Figure 6.9a
Primary High- & Low-Pressure Areas

Result of:
- differential heating & moisture characteristics
  
  OR

- dynamic forces

---

Generalized Circulation Model

Cross-section of One Hemisphere
**Equatorial Low (ITCZ)**

- Result of differential heating
  - high sun angle
  - constant daylength
- Warm, moist air, less dense, so rises
  - Converging, ascending air
- Migrates seasonally with thermal equator
- Locally calm winds

**Equatorial Low (ITCZ)**

**Trade Winds**

- Surface flow toward ITCZ results in Trades winds
- Deflection produces Northeast trade winds and southeast trade winds
- Trade winds are warm and increasingly moist lots of latent heat storage
Subtropical High-Pressure

- Divergence aloft over ITCZ results in upper atm. flow toward subtropics
- Cool air is forced to descend and warms adiabatically (due to increase in pressure)
- High pressure results from descending, diverging air
  - mid-latitude deserts

Generalized Circulation Model

- Hadley Cell Circulation

Atlantic Sub-Tropical High

- Subtropical high-pressure system in the Atlantic
- Deserts extend to the shores of Africa, which has offshore cool currents, whereas the southeastern United States is moist and humid, with offshore warm currents.
**Westerlies**
- Result of surface flow from subtropical high toward mid-latitudes
- Deflection produces prevailing westerly circulation

**Polar High and Easterlies**
- Result of cold dry air over poles
- Descending and diverging air
- Results in a dome of high pressure
- Deflection produces polar easterlies

**Subpolar Low**
- Result of uplift along polar front
- Conflict between cold dry air and warm, moist air
- Mechanical lifting at frontal boundary
- Results in cool, moist air
Local Winds

- Land-sea breezes
- Mountain-valley breezes
- Katabatic winds
- Chinooks
Monsoonal Winds

Chinook Winds
- Occur when strong prevailing winds cross a mountain range
- Air is warmed and dried descending the leeward side
- Warm, dry, windy weather with variable cloudiness

Oceanic Currents
Thermohaline Circulation - The Deep Currents

Weather and Climate (chapter 10)

Weather is:
- temperature
- precipitation
- pressure
- humidity
- and wind

at a particular place and time

Climate: variability of daily and seasonal weather characteristics averaged over a long period of time
**Components of Climate**

- **Insolation**
  - determined by duration & intensity

- **Temperature**
  - Latitude
  - Altitude
  - Cloud Cover
  - Land-Water Heating Differences:
    - Evaporation (LE)
    - Transparency
  - Specific Heat
  - Circulation

- **Atm. Circulation**
  - Primary/Secondary Winds
  - Ocean Currents
  - Semi-Permanent High and Low Pressure Areas

- **Precipitation**
  - the W&C course

---

**Climate Variability**

*Graph* showing global temperature anomaly and atmospheric CO2 concentration over time.

- MWP
- LIA

---

**Climate Variability**

*Graph* showing Holocene temperature variations over thousands of years BP.

- End of Last Glacial Period
- Climatic Optimum?
Climate influences the physical and biotic environment:
- Landforms/landscapes
- Soil conditions/fertility
- Natural vegetation
- Wildlife

and in turn is influenced by the physical and biotic environment.

Study of the spatial and temporal patterns of climate is called climatology.

Classification of Climatic Regions:
- Genetic classification
  - Based on knowledge of causes of climate
- Empirical classification
  - Based on grouping areas with similar climate data or calculated normals
**Koppen-Geiger Classification**

Criteria include measures of:
- mean monthly temperature
- mean monthly precipitation
- and mean annual precipitation

Does not consider:
- winds, temperature extremes, precipitation intensity, amount of sunshine, cloud cover, or net radiation

**General Classification Categories**

Six main climatic regions designated:
- C - Tropical
- D - Mesothermal
- E - Microthermal
- H - Polar
- B - Highland
- W - Arid

Subgroups identified by second letter indicating seasonal precipitation patterns:
- f - no dry season
- m - monsoonal
- w - winter dry
- s - summer dry
- K - semi-arid
- B - cold
Classification Subgroups

Third letter indicates temperature characteristics of subgroups

a hot summers
b warm summers
c cool summers
d very cold winters
h hot B climates
k cold B climates

Exceptions to the above are:

E climates:
ET polar tundra
EF polar frost
EM polar marine
H climates, which are not further subdivided
Brandon, MB, Canada
Climate Normals 1971-2000

Latitude: 49.56N Longitude: 099.57W Altitude: 409m

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>17</td>
<td>14</td>
<td>7</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>8</td>
<td>11</td>
<td>12</td>
<td>10</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Precipitation (mm)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>18</td>
<td>16</td>
<td>21</td>
<td>35</td>
<td>48</td>
<td>67</td>
<td>72</td>
<td>89</td>
<td>91</td>
<td>72</td>
<td>51</td>
<td>22</td>
</tr>
</tbody>
</table>

Köppen Classification Key

1. Test for B Climate: Is the warmest month’s average temperature below 10°C?
   - YES: It is a B climate, is the average temperature each month almost greater than 5°C!
   - NO: It is a BW or a BS climate, is the average temperature each month almost greater than 10°C!

2. Test for A Climate: Is the coldest month’s average temperature above 14°C?
   - YES: Compare precipitation during the driest month with mean annual precipitation to classify the climate as AC, AE, or WS.
   - NO: It is an AM climate.

3. Test for C or D Climate: Is the coldest month’s average temperature above 0°C?
   - YES: It is a C or D climate.
   - NO: It is a B climate.

4. Test for E or B Climate: Is the coldest month’s average temperature above 1°C?
   - YES: C or D Climate
   - NO: B Climate
Climagaphs

- Typically depict:
  - mean monthly precip (vertical bar)
  - mean monthly temp (line)
- May also include:
  - location
  - mean annual temp
  - mean annual precip
  - elevation
  - population
- Provide a graphic illustration of the variability and seasonality of temp and precip characteristics