Weather vs. Climate

"Weather tells you what to wear each day, but the climate helps you figure out what should be in your closet."

Units, Conversions, and Equations

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Symbol</th>
<th>Value</th>
<th>Exponent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peta</td>
<td>P</td>
<td>1,000,000,000,000,000</td>
<td>10^{15}</td>
</tr>
<tr>
<td>Tera</td>
<td>T</td>
<td>1,000,000,000,000</td>
<td>10^{12}</td>
</tr>
<tr>
<td>Giga</td>
<td>G</td>
<td>1,000,000,000</td>
<td>10^{9}</td>
</tr>
<tr>
<td>Mega</td>
<td>M</td>
<td>1,000,000</td>
<td>10^{6}</td>
</tr>
<tr>
<td>Kilo</td>
<td>k</td>
<td>1,000</td>
<td>10^{3}</td>
</tr>
<tr>
<td>Hecto</td>
<td>h</td>
<td>100</td>
<td>10^{2}</td>
</tr>
<tr>
<td>Deca</td>
<td>da</td>
<td>10</td>
<td>10^{1}</td>
</tr>
<tr>
<td>No Prefix</td>
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<td>1</td>
<td>10^{0}</td>
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<tr>
<td>Deci</td>
<td>d</td>
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<td>10^{-1}</td>
</tr>
<tr>
<td>Centi</td>
<td>c</td>
<td>0.01</td>
<td>10^{-2}</td>
</tr>
<tr>
<td>Milli</td>
<td>m</td>
<td>0.001</td>
<td>10^{-3}</td>
</tr>
<tr>
<td>Micro</td>
<td>µ</td>
<td>0.00001</td>
<td>10^{-6}</td>
</tr>
<tr>
<td>Nano</td>
<td>n</td>
<td>0.00000001</td>
<td>10^{-9}</td>
</tr>
<tr>
<td>Pico</td>
<td>p</td>
<td>0.00000000001</td>
<td>10^{-12}</td>
</tr>
<tr>
<td>Femto</td>
<td>f</td>
<td>0.00000000000001</td>
<td>10^{-15}</td>
</tr>
</tbody>
</table>

ATS 351
Introduction to Weather and Climate – Lab
Spring 2010
Units, Conversions, and Equations

<table>
<thead>
<tr>
<th>Physical Quantity</th>
<th>Name of SI Unit</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>Meter</td>
<td>m</td>
</tr>
<tr>
<td>Mass</td>
<td>Kilogram</td>
<td>kg</td>
</tr>
<tr>
<td>Time</td>
<td>Seconds</td>
<td>s</td>
</tr>
<tr>
<td>Temperature</td>
<td>Kelvin</td>
<td>K</td>
</tr>
<tr>
<td>Amount of substance</td>
<td>Mole</td>
<td>mol</td>
</tr>
<tr>
<td>Electric current</td>
<td>Ampere</td>
<td>A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Quantity Name</th>
<th>Derived Unit (MKS)</th>
<th>Derived Unit (SI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force</td>
<td>Newton (N)</td>
<td>kg m s⁻²</td>
</tr>
<tr>
<td>Pressure</td>
<td>Pascal (Pa)</td>
<td>N m⁻²</td>
</tr>
<tr>
<td>Energy</td>
<td>Joule (J)</td>
<td>J</td>
</tr>
<tr>
<td>Power</td>
<td>Watt (W)</td>
<td>W</td>
</tr>
</tbody>
</table>

• Meteorology often uses non standard units for both temperature and pressure.

• Conversions for temperature:
  \[(\frac{9}{5} \times °C) + 32 = °F\]
  \[(°F - 32) \times \frac{5}{9} = °C\]
  \[K = °C + 273.15\]

• Conversions for pressure:
  100 Pa = 1 hPa = 1 millibar (mb) = .75 mm Hg
  1 standard atm = 1013.25 mb = 1013.25 hPa = 760 mm Hg

Local Time

• All the US time zones are earlier than UTC (Coordinated Universal Time), since we are west of England
• Our 4 main time zones (Eastern, Central, Mountain, and Pacific) are 5, 6, 7, and 8 hours behind UTC
• UTC does not observe daylight savings time
• Currently, Fort Collins is in MST (UTC minus 7 hours)
• During the summer, we are in MDT (UTC minus 6 hours)
Atmospheric Structure and Composition
& Energy

Chemical (Gas) Composition

<table>
<thead>
<tr>
<th>Permanent Gases</th>
<th>Variable Gases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>Symbol</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>N2</td>
</tr>
<tr>
<td>Oxygen</td>
<td>O2</td>
</tr>
<tr>
<td>Argon</td>
<td>Ar</td>
</tr>
<tr>
<td>Neon</td>
<td>Ne</td>
</tr>
<tr>
<td>Helium</td>
<td>He</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>H2</td>
</tr>
<tr>
<td>Xenon</td>
<td>Xe</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gas</th>
<th>Symbol</th>
<th>(by Volume)</th>
<th>(by Weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water vapor</td>
<td>H2O</td>
<td>3 to 4%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>CO2</td>
<td>0.03%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Methane</td>
<td>CH4</td>
<td>0.0017%</td>
<td>1.7%</td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td>N2O</td>
<td>0.00003%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Ozone</td>
<td>O3</td>
<td>0.00004%</td>
<td>0.4%</td>
</tr>
<tr>
<td>Particles</td>
<td></td>
<td></td>
<td>0.01-0.15%</td>
</tr>
</tbody>
</table>

Table 1.1: Composition of the atmosphere near the earth's surface.
Chemical (Gas) Composition

- Each constituent has a
  - Source: Production
  - Sink: Destruction
  (e.g. Plant photosynthesis, decay – See Ahrens)

Gas Characteristics

- Expand or compress due to pressure, containers, etc
- Easily mixed
- Individual molecules far apart
- Individual molecules have distinct mass
- Most common measurements:
  - temperature, pressure, and volume

Atmospheric Pressure

- pressure = force/area
- Measure of the weight of air above you
- Force = push or pull, especially on other air molecules
- Compressible
  - More air (mass) above means more compression
  - Air closer to the surface more dense, because compressed by the “weight” of the air above it
- Pressure decreases with height exponentially
Hydrostatic Balance

- We tend to make the assumption that the atmosphere is in Hydrostatic Balance.
- Hydrostatic Balance is when the net upward force on a slab of air equals the net downward force.

\[ \frac{dP}{dz} = -\rho g \]

Temperature and Density

- Temp is the measure of the kinetic energy of molecules (speed) \[ KE = \frac{1}{2} mv^2 \]
- Warmer air is less dense
  - Consider the ideal gas law: \[ P = \frac{RT}{V} \]
  - If we consider constant pressure, then:\[ \frac{P}{R} = \rho T \]
  - Or:\[ \text{Constant} = \rho T \]
  - We can see then, if the temperature increases, density must decrease
- It follows: Colder air is more dense
Atmospheric Temperature

- Complicated vertical profile
- Can depend on
  - atmospheric composition
  - current conditions
- lapse rate: the rate at which the air temperature decreases with height

Layers of the Atmosphere
Layers of the Atmosphere

- Defined by changes in temperature with height
- Troposphere
  - Sun warms surface, surface radiates
- Stratosphere
  - Ozone absorbs solar radiation, warming results
- Mesosphere
  - No ozone, molecules lose more energy than they absorb
- Thermosphere
  - $O_2$ absorbs solar radiation

Energy

- Conduction: Energy transfer by molecular collisions
  - Ex: The sun warms the ground, and this heats a thin layer of air above the surface
  - In general, air is a poor conductor
- Convection: energy transfer by the motion of matter from one location to another
  - Ex: parcel of air rising
  - Important in our atmosphere
- Radiation: transfer of energy not requiring contact between bodies or a fluid between them
  - Ex: the sun warms the surface of the earth

Surface Analysis

- Variables of interest
  - Temperature
  - Pressure
  - Dew point
  - Cloud Cover
  - Wind direction and speed
  - Weather occurring
Wind

- Wind direction is named for where the wind is coming from.
- Expressed in either cardinal directions (N, S, E, W, NW, SE, etc.) or degrees from north

Mathematical

Meteorological

Station Plot

- Temperature (°F)
- Visibility (miles)
- Current Weather
- Dewpoint (°F)
- Station ID
- Sky Cover
- Station Pressure
- Wind speed, direction, and peak gust
- 3 hour pressure change
- 3 hour precipitation
- Sea-level pressure is plotted in tenths of millibars (mb), with the leading 10 or 9 omitted. For reference, 1013 mb is equivalent to 29.92 inches of mercury. Below are some sample conversions between plotted and complete sea-level pressure values:
  - 410: 1041.0 mb
  - 103: 1010.3 mb
  - 987: 998.7 mb
  - 872: 987.2 mb
Deciphering Station Plot

Station Plots – Wind Barbs
Surface Analysis

- One of the earliest maps produced from measurements
- Each point contains data taken from specific surface station
- Designed to relay maximum data

Example Station Data