Temperature

What is temperature?

Heat – form of energy that flows from one system or object to another b/c they have different temperatures

Temperature – a measure of the average kinetic energy of individual molecules

- We feel the effect of temperature as sensible heat transfer from warmer to cooler objects

Temperature and Heat are related b/c changes in temperature occur by absorption or emission (gain/loss) of heat energy

Surface Temperature

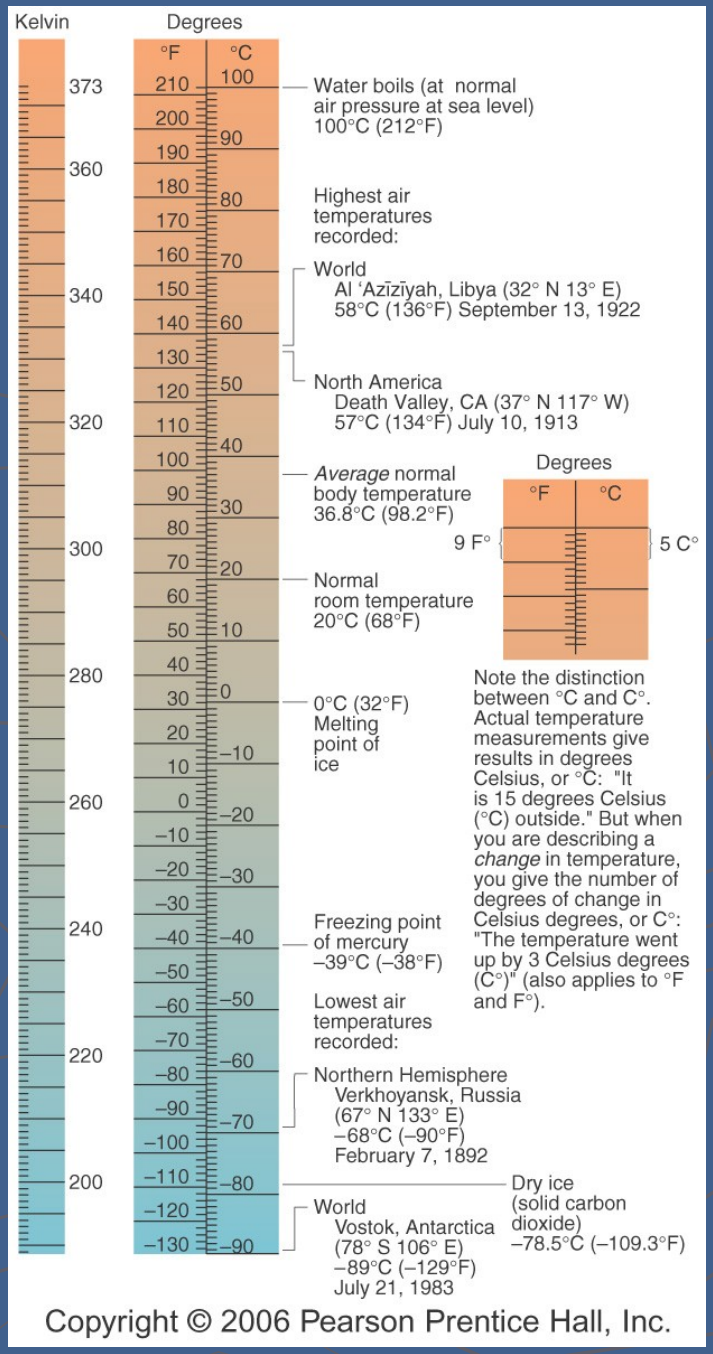
- During the day, SW inputs usually exceeds LW outputs and heating of the surface occurs
- Latent and sensible heat are also important in determining surface temperature (e.g. desert vs. oasis)

Temperature Scales

Kelvin (K) = absolute temperature scale, -273.15 degrees Celsius or 0 degree K

Celsius (C) = international standard

Fahrenheit (F) = used in the US



Measuring Temperature

Thermometer – an instrument used to measure temperature

- Alcohol thermometer: alcohol has a freezing point -112 C so it is used for cold weather measurements
- Mercury thermometer – mercury has a freezing point of -39 C so it is better suited for less extreme environments

Thermometers measure temp based on the thermal properties of the liquids above:

- Fluids expand when heated, contract when cooled
- The rise and fall of the fluid is measured using calibrations marked on the tube

Measuring Temperature

Standard Temperature Measurement:

- Taken outdoors
- Thermometer is placed within a thermometer shelter
  - A white (for albedo) box with vents (for air flow) that shades the thermometer from direct sunlight
- Temperatures taken at a standard height of 1.2m above the ground

Different Temperature Measurements:

- Max temperature – highest temp reading
- Min temperature – lowest temp reading
- Daily mean temperature – average of the max and min daily temp

- Monthly mean temperature – average of daily mean temps
- Annual temperature range – difference between the lowest and highest monthly mean temperatures for a year

Air vs Surface Temperature

- Air temperature is measured a short distance (usually 1.2m or 4ft) above the surface
- Air temperature can be quite different than surface temperature
- However, air temperature tends to mirror surface temperature

Earth's temperature patterns influenced by four physical properties:

1) Latitude
2) Elevation
3) Cloud Cover
4) Land vs. ocean

What factors control temperature?

1) Latitude

Latitude

- Latitude controls:

1) Daylength
2) Angle of incidence

Insolation is the single most important influence on temperature variations

- Why don't world temperature patterns follow latitudinal bands?

Latitude and air temperature

- Seasonal range in air temperature is strongly dependent on latitude – increases as you get closer to the poles
  - More direct rays of sunlight during summer
  - Longer daylength in summer; shorter in winter
- Equatorial locations may actually be warmer during an equinox than during a solstice!
- Generally, air temperature lags behind solar radiation by one month over land and by two months over water

2) Altitude/Elevation

What is the impact of elevation on temperature?

Elevation: temperature decreases with increasing elevation within the troposphere

- At similar latitudes, mountainous areas experience lower air temperatures than locations near sea level

- Remember that density also decreases with increasing altitude:
  - As the atmos thins, the no. of air molecules decrease
  - Fewer molecules in the air means less energy absorption
  - Less SW radiation is reflected and scattered into space
  - Surface gains and looses energy more rapidly under lower atmospheric pressure

3) Cloud Cover

Cloud Cover- clouds are the most variable factor influencing the Earth's EB

- Cover approximately 50% of the earth and their effect on temperature depends on their type, height and density
- Moderate temperature → decreasing daytime temps and increasing nighttime temps

- Clouds absorb and reflect SW energy during the day → cooling effect
- Clouds absorb and reradiate LW energy at night → warming effect

4) Land vs. Ocean

Land and Water Contrasts

- Land has different thermal properties than water resulting in differences in temperature
- Land and water absorb and store energy differently b/c of the physical nature of land and water

Four main differences:

5) Evaporation
6) Transparency
7) Specific Heat
8) Movement

Land-Water Contrasts

1) evaporation:

- More energy at the ocean surface goes into evaporation than on land
- 84% of all evaporation on earth occurs over the ocean
- Evaporation is a cooling process
- Results in lower temperatures over oceans than on land

2) transparency:

- Light can be transmitted through water but not through land
- Light striking land does not penetrate but is absorbed → heat surface
- Energy transmits through water to a depth of approx. 60m
- Energy has a greater distribution within water than on land

Land-Water Contrasts

3) Specific heat:

- Heat capacity of a substance
- When equal volumes of land and water are compared, water requires more energy to increase its temperature than land
- Water can hold more heat than soil (specific heat is x4)
- Land heats and cools quick, water heats and cools slow

4) movement:

- Land is solid and does not move whereas water is fluid and capable of movement
- Mixing between warm and cold layers is possible within water and not possible within land
- Mixing spreads available energy over and even greater volume

What is the impact on daily temperatures?

LESS DIURNAL TEMPERATURE CHANGE!

- Marine locations have cooler days and warmer nights than comparable inland locations

Marine effect (maritime) – locations that exhibit the moderating influences of the ocean. Smaller range between max and min daily and annual temps.

Continental Effect (continentality) – areas that are less affected by the sea. Greater range between max and min daily and annual temp.

Diurnal (Daily) Cycle of Air Temperature

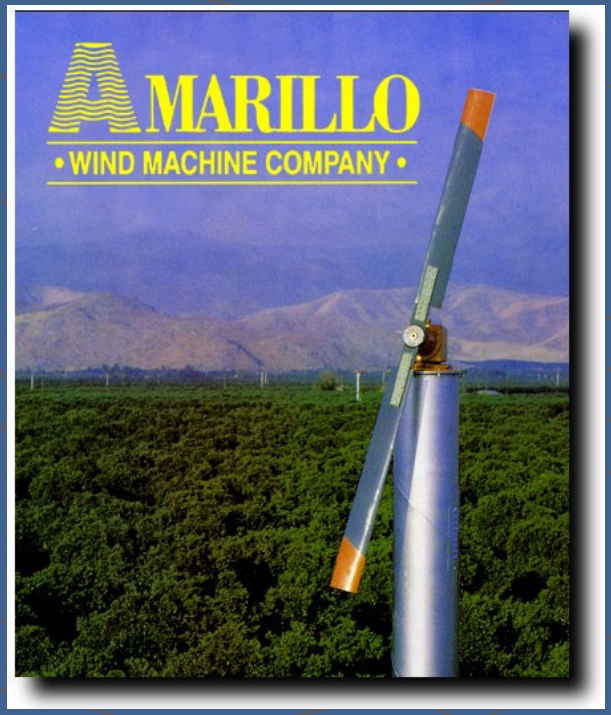
- Generally follows the sun; however, it lags due to the delay in heating the atmosphere
- Coldest air temperature usually occurs just after sunrise – no solar radiation during night
- Warmest air temperature occurs about 3pm when turbulent mixing begins (warm bubbles of air rise and are replaced by colder air from aloft)

End of material contained in the Midterm!

Diurnal (Daily) Cycle of Air Temperature

- An inversion may occur in the morning hours since the earth's surface cools rapidly when the sun sets


Warm Air
Cold Air


AMARILLO
• WIND MACHINE COMPANY •

Global temperature patterns

Temperature patterns result from:

- Latitude
- Elevation above sea level
- Cloud cover
- Land-ocean heating differences

Maximum monthly mean temperature occurs in July (N. Hem)

- Lag after summer solstice b/c inputs are still larger than outputs shortly after max insolation
- Similar to lag in daily air temperature

Minimum monthly mean temperature occurs in January (N. Hem)

- Lag after winter solstice b/c inputs are still smaller than outputs shortly after min insolation
- Similar to lag in daily air temperature

Horizontal Temperature Pattern:

Isotherms – lines of equal temperature

- Trend east and west
- Deviate from trends due to mountains and land-ocean contrasts

Thermal Equator – isotherm connecting points of highest temperature

- Hovers around latitudinal equator
- Shifts north in summer (according to location of max insolation)
- Shifts south in winter

January temperature patterns:

- Temp decreases north and south of the thermal equator
- Isotherms bend south over land
  - Cooler temps are found south over land than over water
  - Land looses heat more quickly than water
- Lowest temp over Siberia (continental location)
- Isotherms move further south over mountainous regions (elevation effect)

July temperature patterns:

- Temperature still decreases north and south of thermal equator
- Lower temperature is S. Hem than at equivalent latitudes in N. Hem
  - Max insolation in N. Hem
  - Shift is not as dramatic in S. Hem b/c S. Hem has more oceans and less land area
  - Milder winter temps due to surrounding oceans (moderating effect)
- Isotherms bend north over land and mountains

Annual temperature range:

- Identifies areas of moderate or extreme annual temp variations
- Most extreme variation over Siberia
  - Continental location
  - Extreme north latitude
- Moderate along the equator
  - Little variation in insolation during the year
  - Little temperature variations annually
- Moderate over the S. Hem
  - Moderating effect of large oceans and little land
  - Most extremes occur over desert areas (low cloud cover)

Problem Set #3

Wind Chill and Heat Index

Air temperature and the Human Body:

The human body responds not only to the air temperature but also to wind speed and humidity (amount of water vapour in the air).

- Body tries to maintain temperature of 36.8 C
- Wind and humidity can exacerbate the effect of air temperature on the human body

→Wind Chill Factor

Wind Chill Factor:

Cold weather is greatest cause of weather related death in US.

- Wind enhances the rate at which the body loses heat to the atmosphere
- Makes it feel colder than the air temperature actually is
- The "wind chill index" was developed to describe the relative discomfort/danger resulting from the combination of wind and temp

Wind Chill Index:

- Since 2000, WCI calculated using the wind speed at average height (5 feet) of the human body's face
- Incorporate modern heat transfer theory
- Use a consistent standard for skin tissue resistance
- Assumes the worst case scenario for solar radiation (clear night sky)
- Adjustments for solar radiation (i.e. the impact of sun) for a variety of sky conditions (sunny, partly sunny and cloudy)

To calculate wind chill:

$$WC\ (F) = 35.74 + 0.6215 * T - 35.75 * (V^{0.16}) + 0.4275 * T * (V^{0.16})$$

Example:

Newark → Wednesday January 17th 2007

High Temperature 35 F Wind speed = 13 mph

$$WC\ (F) = 35.74 + 0.6215 * 35 - 35.75 * (13^{0.16}) + 0.4275 * 35 * (13^{0.16})$$

$$WC = 18.55\ F$$

Wind chill warning → wind chill temperature is forecast to be minus 25 degrees F or lower

Wind chill advisory → wind chill temperature is forecast to be between minus 10 to minus 24 degrees F

Wind chill does not affect your car's antifreeze protection or freezing pipes. It's an indicator of how to dress properly for winter weather:

- Entrapped insulating air warmed by body heat
- Loose-fitting, lightweight, warm clothing in several layers
- Tightly-woven, water-repellant, hooded outer garments with mittens

Only cold winter temperatures take a greater weather-related death toll than the summer's heat and humidity.

Heat Index:

- Is an accurate measure of how hot is really feels when the affect of humidity are added to high temperature
- Human body contains several mechanisms to maintain its internal operating temperature 98.6 F
- When threatened with above "normal" temperatures, the body will try to dissipate excess heat:
  - Varying circulation of blood
  - Losing water through the skin and sweat glands
  - panting

Heat Index:

- Higher humidity reduces the body's ability to evaporate perspiration
- This lessens the body's ability to regulate temperature by cooling
  - Conditions can exceed the body's ability to cope; sunstroke, heat cramps, heat exhaustion

The HI chart shows actual air temperature and relative humidity

- This chart is based on shady, light wind conditions
- Exposure to direct sunlight can increase the HI by up to 15 F

Example:

At 90% relative humidity and 90 F → HI = 120 F (cat 2 risk)

To actually calculate the HI:

HI =16.923+((1.85212*10^-1)*T)+(5.37941*RH)-((1.00254*10^-1)*T*RH)
+((9.41695*10^-3)*T^2)+((7.28898*10^-3)*RH^2)+((3.45372*10^-4)*T^2*RH)-((8.14971*10^-4)*T*RH^2)+((1.02102*10^-5)*T^2*RH^2)-((3.8646*10^-5)*T^3)+((2.91583*10^-5)*RH^3)+((1.42721*10^-6)*T^3*RH)+((1.97483*10^-7)*T*RH^3)-((2.18429*10^-8)*T^3*RH^2)+((8.43296*10^-10)*T^2*RH^3)-((4.81975*10^-11)*T^3*RH^3)