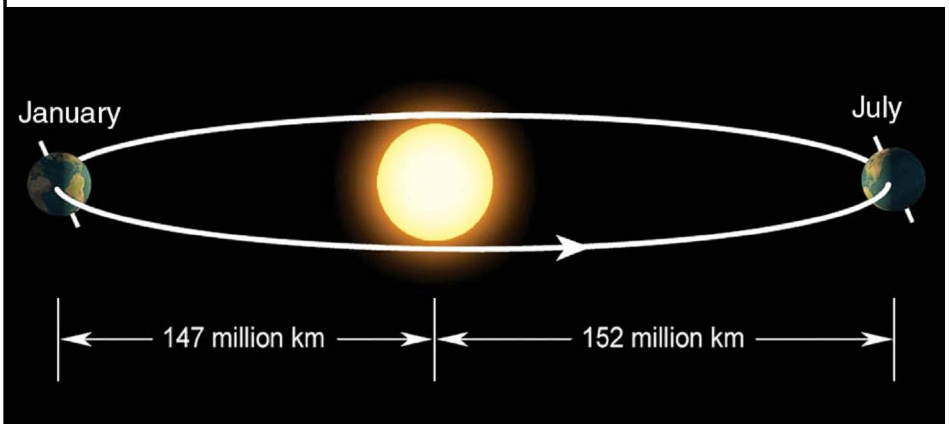
Seasonal and Daily Temperatures

Seasonal Temperature Variations

- What causes the seasons
  - What governs the seasons is the amount of solar radiation reaching the ground
- What two primary factors determine the amount of radiation reaching the ground?
  - Sun Angle
  - Time of exposure
  - These are created due to the earth's tilt and it's orbiting around the sun
  - Earth’s axis of rotation is tilted by 23.5° from the vertical axis
  - Also the amount of atmosphere the solar radiation has to pass through

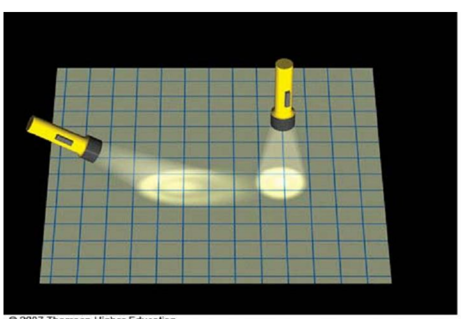
Earth's orbit around sun is elliptical

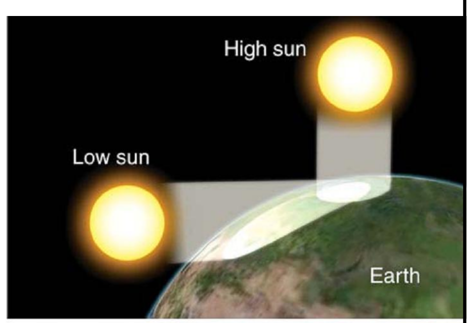


The elliptical path (highly exaggerated) of the earth about the sun brings the earth slightly closer to the sun in January than in July.

Sun Angle

Sunlight that strikes a surface at an angle is spread over a larger area than sunlight that strikes the surface directly. Oblique sun rays deliver less energy (are less intense) to a surface than direct sun rays.

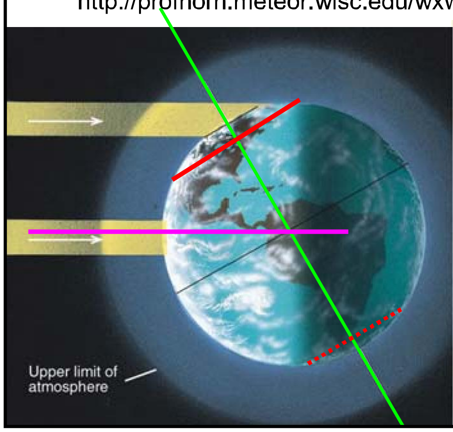


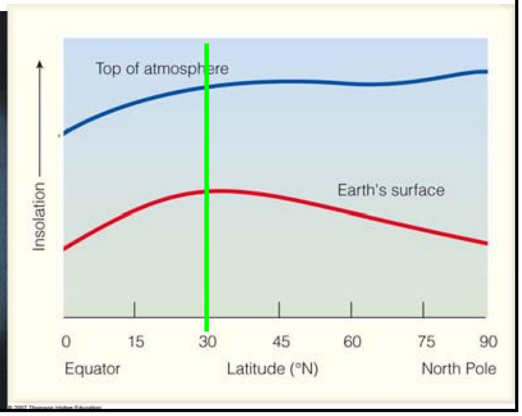


The relative amount of radiant energy received at the top of the earth's atmosphere and at the earth's surface on June 21—the summer solstice.

1. The length of day light
2. The amount energy reach the surface

Test your knowledge with this interactive tool that determines the amount of solar radiation at the top of the atmosphere anytime during the year and at any latitude
http://profhorn.meteor.wisc.edu/wxwise/radiation/sunplot6.html





Land of the Midnight Sun. A series of exposures of the sun taken before, during, and after midnight in northern Alaska during July.

How are the seasons determined?

- The astronomical definition
  - Based on the relative position between Sun and Earth: length of day
- Meteorological definition
  - Based on temperature
  - Spring -- MAM
  - Summer -- JJA
  - Fall -SON
  - Winter--DJF

Fall
begins on the *Autumnal equinox (22 September)*
12 hours of sunlight everywhere
sun angle is 90° at equator
ends on the *Winter solstice (21 December)*

Summer
begins on the *summer solstice (21 June)*
longest day of the year in NH
24 hrs of sunlight north of arctic circle
more than 12 hours of daylight in NH
sun angle is 90° at Tropic of Cancer
ends on the Autumnal equinox (September 22)

Seasons in the Northern Hemisphere –
The astronomical definition

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Winter
begins on the *Winter Solstice (21 December)*
shortest day of the year
24 hours of darkness above arctic circle
less than 12 hours of daylight everywhere in NH
sun angle is 90° at Tropic of Capricorn
ends on the *Vernal equinox* (20 March)

Spring
begins on the *Vernal Equinox (20 March)*
12 hours of sunlight everywhere
sun angle is 90° everywhere
ends on the *Summer Solstice (21 June)*

QUESTIONS FOR THOUGHT:

1. Consider two scenarios: (a) The tilt of the Earth decreased to 10°. (b) The tilt of the Earth increased to 40°. How would this change the summer and winter temperatures here at Laramie?

2. Where would you expect to experience the smallest variation in temperature from year to year and from month to month? Why?

3. At the top of the earth's atmosphere during the early summer (Northern Hemisphere), above what latitude would you expect to receive the most solar radiation in one day? During the same time of year, where would you expect to receive the most solar radiation at the surface?

Summary of the Seasons
Check out this animation showing the earth's orbit about the sun and amount of daylight for different latitudes: http://www-das.uwyo.edu/~zwang/atsc2000/Animations/44_Seasons/44.html

• TABLE 3.1

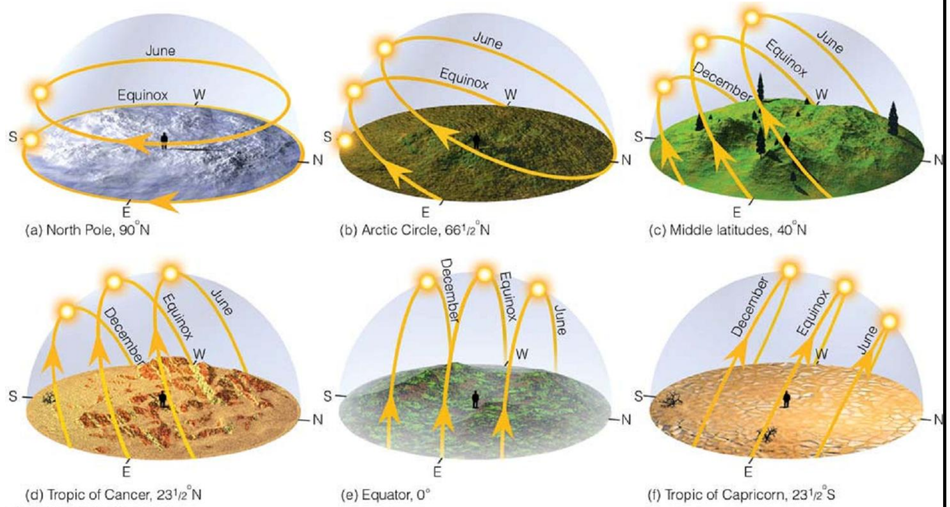
Length of Time from Sunrise to Sunset for Various Latitudes on Different Dates

	NORTHERN HEMISPHERE (READ DOWN)			
Latitude	March 20	June 21	Sept. 22	Dec. 21
0°	12 hr	12.0 hr	12 hr	12.0 hr
10°	12 hr	12.6 hr	12 hr	11.4 hr
20°	12 hr	13.2 hr	12 hr	10.8 hr
30°	12 hr	13.9 hr	12 hr	10.1 hr
40°	12 hr	14.9 hr	12 hr	9.1 hr
50°	12 hr	16.3 hr	12 hr	7.7 hr
60°	12 hr	18.4 hr	12 hr	5.6 hr
70°	12 hr	2 months	12 hr	0 hr
80°	12 hr	4 months	12 hr	0 hr
90°	12 hr	6 months	12 hr	0 hr
Latitude	Sept. 22	Dec. 21	March 20	June 21
	SOUTHERN HEMISPHERE (READ UP)			

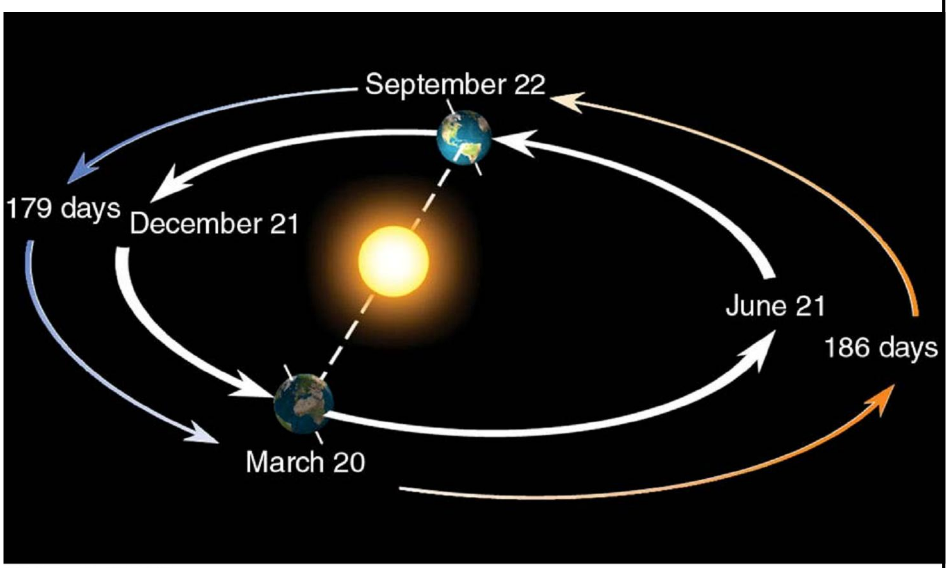
Table 3-1, p. 60

Local Season Variations

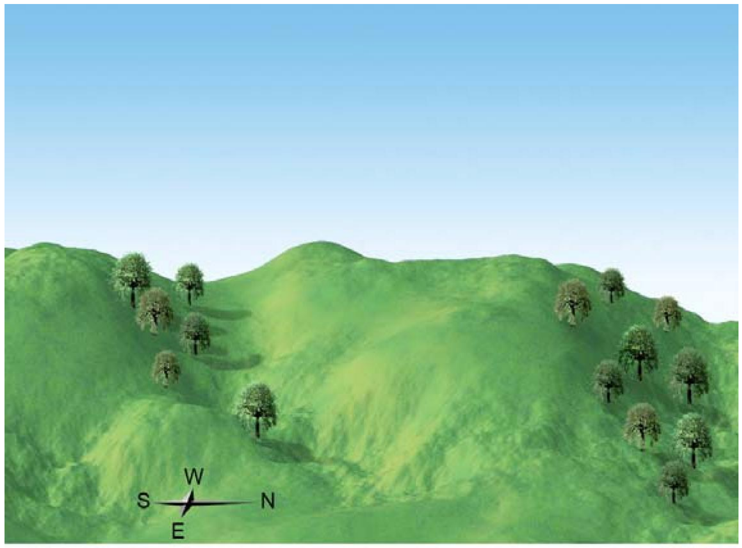
The apparent path of the sun across the sky as observed at different latitudes on the June solstice (June 21), the December solstice (December 21), and the equinox (March 20 and September 22).



Because the earth travels more slowly when it is farther from the sun, it takes the earth a little more than 7 days longer to travel from March 20 to September 22 than from September 22 to March 20

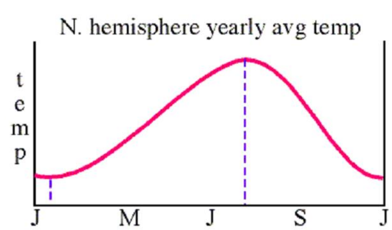


In areas where small temperature changes can cause major changes in soil moisture, sparse vegetation on the south-facing slopes will often contrast with lush vegetation on the north-facing slopes.



Yearly temperature variation in the Northern Hemisphere

- Notice that the min and max temperatures lag behind the seasons......
  - minimum in January, not the winter solstice (21 December)!
  - maximum in July/August, not the summer solstice 21 June)!
  - WHY?

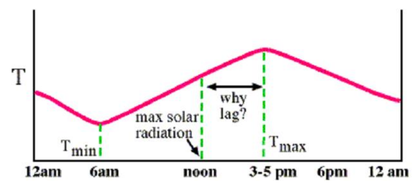


Daily Temperature Variations

Q: During a 24 hour day, when is the minimum temperature observed at a given location?

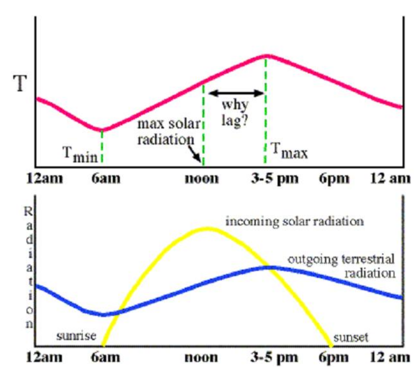
– Sun angle is greatest at local noon

Q: When is the maximum surface temperature observed?



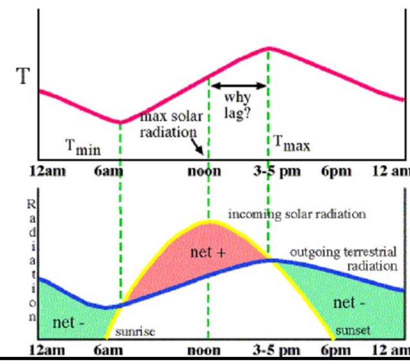
Daily Temperature Variations - Diurnal Variation of Solar and Terrestrial Radiation

- **the diurnal variation of incoming solar radiation**
  - it begins at sunrise
  - it's a max at noon
  - it shuts off at sunset
- **the diurnal variation of earth-emitted terrestrial radiation**
  - its trend is similar to the diurnal temperature trend:
  - minimum at sunrise
  - maximum at 3-5 PM



Daily Temperature Variations - Net Radiation

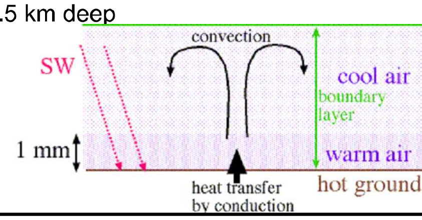
- The *net radiation* determines whether the surface temperature rises, falls, or remains the same:
- net radiation = incoming solar - outgoing IR
  - If the net radiation > 0, surface warms (6 AM - 3-5 PM)
  - if the net radiation < 0, surface cools (3-5 PM - 6 AM)
- This also explains why the warmest part of the year is in July/August, not on 21 June during the summer solstice.



Factors Affecting Daytime Warming - Fundamental Process

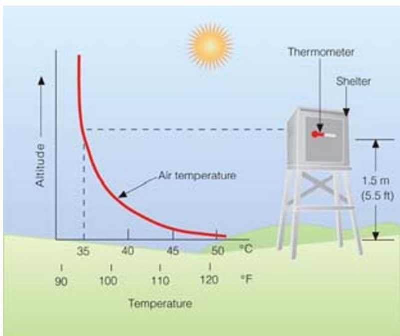
What factors affect the rate of daytime warming?

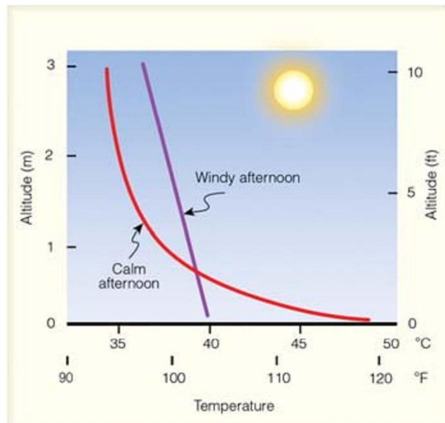
- What is the fundamental process which creates warming at the earth's surface?
  - Short wave radiation is absorbed by the earth's surface - heats up the ground
- How does the hot ground transfer this energy to the atmosphere?
  - Heat is transported from the hot surface to air molecules very near the hot surface by *conduction*
- Heat is then transported further upward by *convection* - thermals of air
- The layer of air near the earth's surface where most of the daily temperature variation occurs as a result of the heating/cooling of the ground is called the *boundary layer*
  - the boundary layer is typically 1-1.5 km deep



Factors Affecting Daytime Warming

- wind speed
  - the change in temperature near the ground on a calm day can be substantial
- land type
- humidity
- vegetation cover
- soil moisture
- cloudiness





•TABLE 1

Some Record High Temperatures Throughout the World

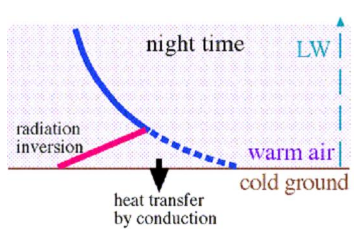
LOCATION (LATITUDE)	RECORD HIGH TEMPERATURE (°C)	(°F)	RECORD FOR:	DATE
El Azizia, Libya (32°N)	58	136	The world	September 13, 1922
Death Valley, Calif. (36°N)	57	134	Western Hemisphere	July 10, 1913
Tirat Tsvi, Israel (32°N)	54	129	Middle East	June 21, 1942
Cloncurry, Queensland (21°S)	53	128	Australia	January 16, 1889
Seville, Spain (37°N)	50	122	Europe	August 4, 1881
Rivadavia, Argentina (35°S)	49	120	South America	December 11, 1905
Midale, Saskatchewan (49°N)	45	113	Canada	July 5, 1937
Fort Yukon, Alaska (66°N)	38	100	Alaska	June 27, 1915
Pahala, Hawaii (19°N)	38	100	Hawaii	April 27, 1931
Esparanza, Antarctica (63°S)	14	58	Antarctica	October 20, 1956

Table 1, p. 66

The hottest place in North America, Death Valley, California, where the air temperature reached 57°C (134°F).

Night time cooling

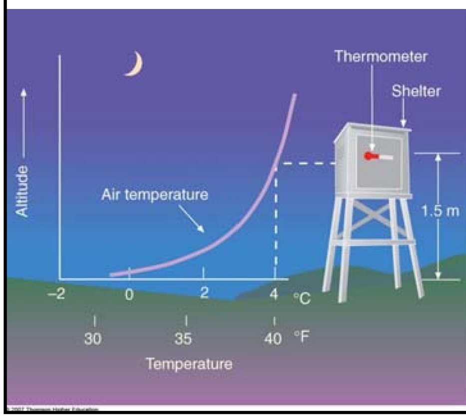
- During the night time hours, there is no SW heating the ground, so the ground cools rapidly
- hence, there is heat transfer by conduction from the warm air to the cold ground
- this heat transfer occurs in a shallow layer near the ground since air is a poor conductor
- a "*radiation inversion*" is formed: a shallow layer of air near the earth's surface where the temperature increases with height
- average radiation inversion depth is about 100m, but can vary from 10m - 1 km

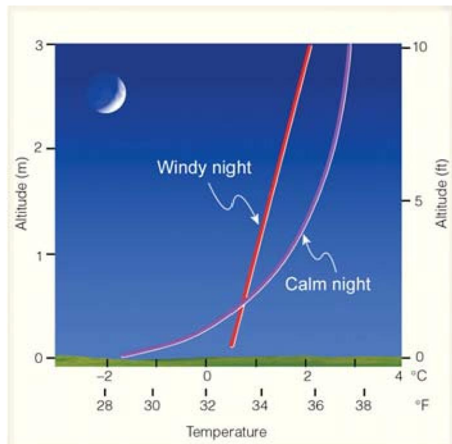


Factors promoting radiation inversion formation

- calm winds versus strong winds
- long nights versus short nights
- dry air versus humid air
- clear skies versus cloudy skies

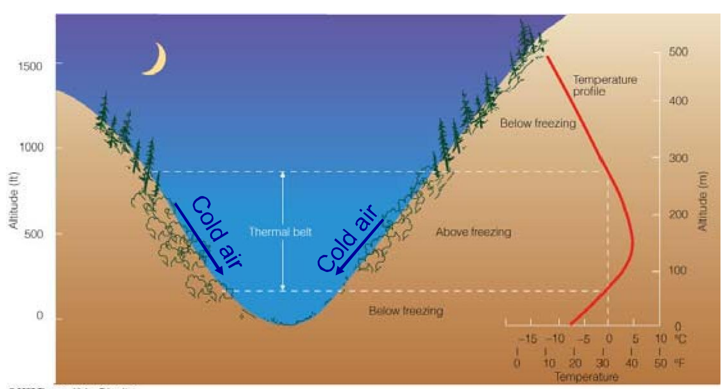
- other factors:
  - surface wetness
  - vegetation type
  - surface type (snow, sand, grass, etc...)





Drainage/Valley flows

- What happens in valleys at night?
  - heat is conducted from the near-surface air to the cold ground
  - cool air near the ground descends down the slope into the valley
- what is the result of this process?



•TABLE 2

Some Record Low Temperatures Throughout the World

LOCATION (LATITUDE)	RECORD LOW TEMPERATURE (°C)	(°F)	RECORD FOR:	DATE
Vostok, Antarctica (78°S)	–89	–129	The world	July 21, 1983
Verkhoyansk, Russia (67°N)	–68	–90	Northern Hemisphere	February 7, 1892
Northice, Greenland (72°N)	–66	–87	Greenland	January 9, 1954
Snag, Yukon (62°N)	–63	–81	North America	February 3, 1947
Prospect Creek, Alaska (66°N)	–62	–80	Alaska	January 23, 1971
Rogers Pass, Montana (47°N)	–57	–70	U.S. (excluding Alaska)	January 20, 1954
Sarmiento, Argentina (34°S)	–33	–27	South America	June 1, 1907
Ifrane, Morocco (33°N)	–24	–11	Africa	February 11, 1935
Charlotte Pass, Australia (36°S)	–22	–8	Australia	July 22, 1949
Mt. Haleakala, Hawaii (20°N)	–10	14	Hawaii	January 2, 1961

Table 2, p. 69

Protection against damaging frost

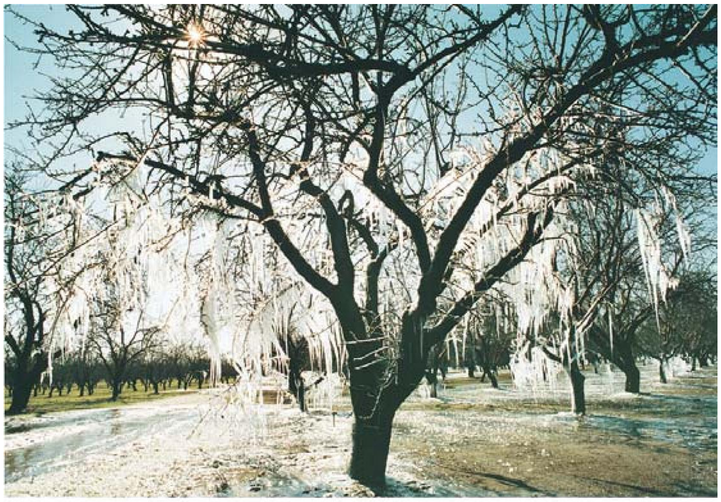
Use orchard heaters

Use wind machines

What are they trying to accomplish ?

Protection against damaging frost
Other methods

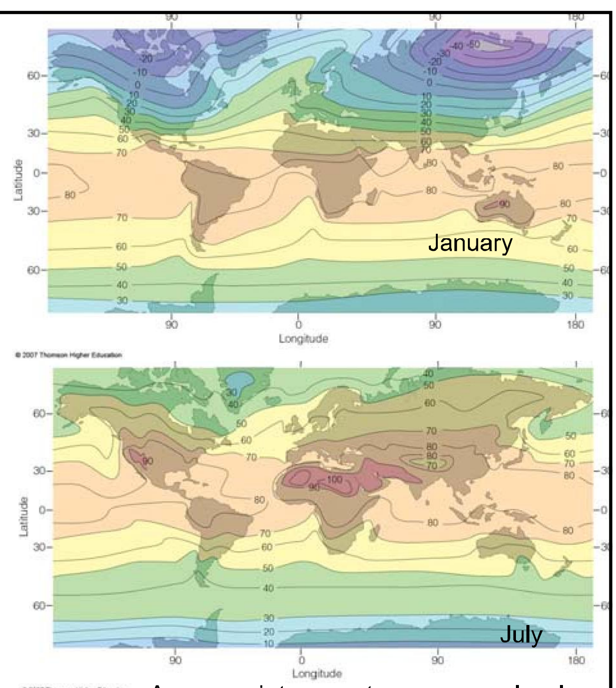
cover plants with a blanket
flooding the ground in orchard
emit fine mist of water with sprinklers



Temperature Controls

At a given location, what factors affect the location's temperature?

- Latitude
- land and water
- ocean currents
- elevation



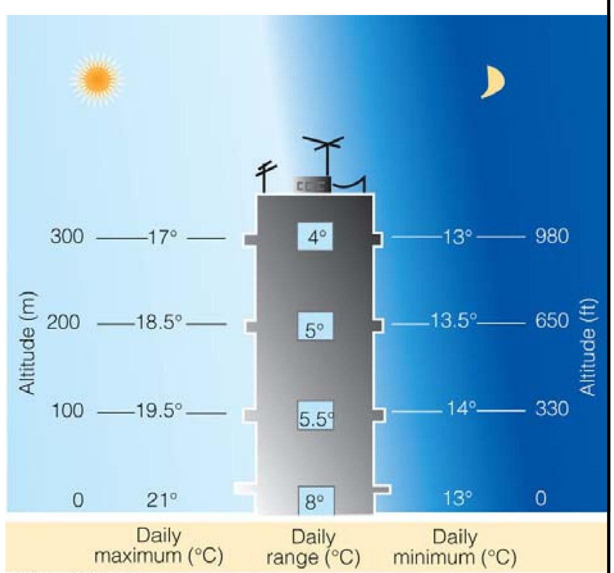
Average air temperature near sea level

Temperature Variables

- *Daily (or diurnal) range of temperature* - the difference between the daily maximum and minimum temperature.
- *Mean daily temperature* - average of the highest and lowest temperature for a 24 hour period.
- *Annual range of temperature* - the difference between the average temperature of the warmest and coldest months.
- *Mean annual temperature* - average of the twelve monthly average temperatures.

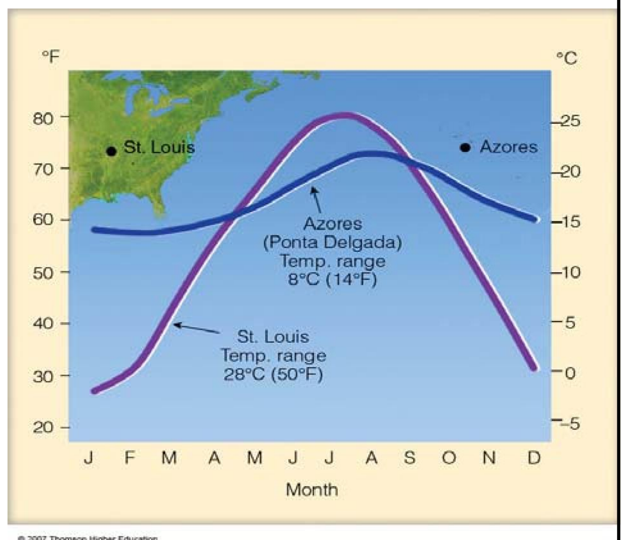
The height dependency of daily range of temperature

The daily range of temperature decreases as we climb away from the earth's surface. Hence, there is less day-to-night variation in air temperature near the top of a high-rise apartment complex than at the ground level.



Monthly temperature and annual temperature range—Location effect

Monthly temperature data and annual temperature range for St. Louis, Missouri, a city located near the middle of a continent and Ponta Delgada, a city located in the Azores in the Atlantic Ocean.

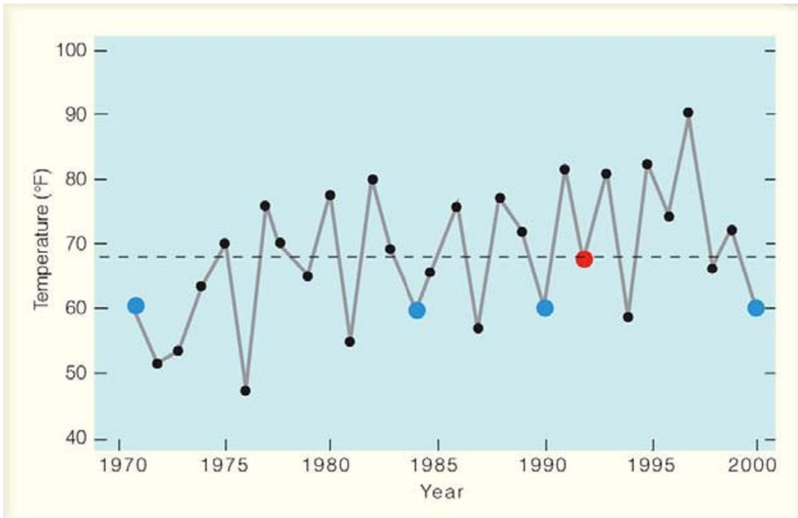


Monthly temperature and annual temperature range—Location effect

Temperature data for San Francisco, California (37°N), and Richmond, Virginia (37°N)—two cities with the same mean annual temperature.

	SAN FRANCISCO		RICHMOND	
	°C	°F	°C	°F
Mean annual temperature	14	57	14	57
Annual temperature range	6	11	22	42
Record high	39	103	41	105
Record low	–3	27	–24	–12

When it comes to Temperature, what's normal?

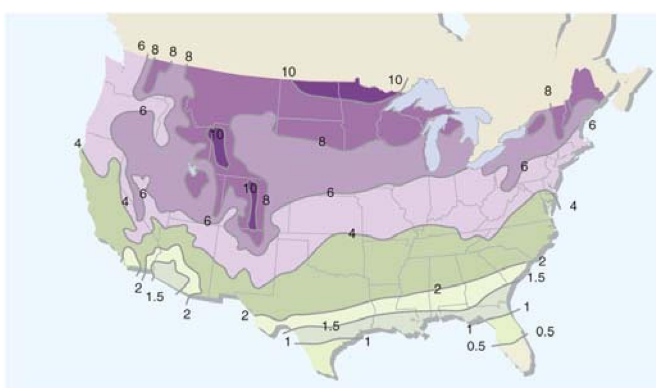


The high temperature measured (for 30 years) on March 15 in a city located in the southwestern United States. The dashed line represents the *normal* temperature for the 30-year period.

Heating Degree-days

- Application of temperature data to energy consumption:
- A *heating degree-day* is defined as:
  - 65°F – mean daily temp

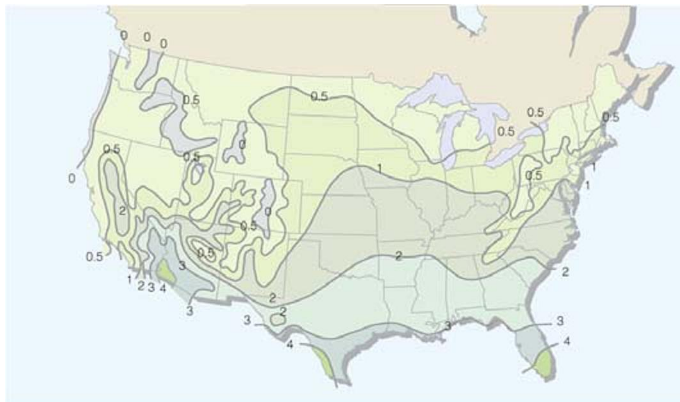
Mean annual total heating degree-days in thousands of °F, where the number 4 on the map represents 4000 (base 65°F). (Data from U.S. Department of Commerce)



Cooling Degree-days

- Application of temperature data to energy consumption:
- A *cooling degree-day* is defined as:
  - mean daily temp - 65°F

Mean annual total cooling degree-days in thousands of °F, where the number 1 on the map represents 1000 (base 65°F). (Data from U.S. Department of Commerce)



Growing Degree-days

Normally, a growing degree-day for a particular day is defined as a day on which the mean daily temperature is one degree above the ***base temperature*** (also known as ***zero temperature***) – the minimum temperature required for growth of that crop.

•TABLE 3.2

Estimated Growing Degree-Days for Certain Naturally Grown Agricultural Crops to Reach Maturity

CROP (VARIETY, LOCATION)	BASE TEMPERATURE (°F)	GROWING DEGREE-DAYS TO MATURITY
Beans (Snap/ South Carolina)	50	1200–1300
Corn (Sweet/Indiana)	50	2200–2800
Cotton (Delta Smooth Leaf/Arkansas)	60	1900–2500
Peas (Early/Indiana)	40	1100–1200
Rice (Vegold/Arkansas)	60	1700–2100
Wheat (Indiana)	40	2100–2400

Air Temperature and Human Comfort

The Wind Chill Index (WCI)

- Often on cooler days when the wind is blowing, the air temperature "feels" cooler than it actually is.
- Why?

The formula for calculating the Wind-chill equivalent temperature is:
Wind Chill Temperature (ºF) = $35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$

where T is the air temperature and V is the wind speed in *miles per hour*.

In metric units:
Wind Chill Temperature (ºC) = $13.12 + 0.6215T - 11.37(V^{0.16}) + 0.3965T(V^{0.16})$

where T is the air temperature and *V* is the wind speed in *km per hour*.

Frostbite: freezing skin
Hypothermia: the rapid, progressive metal and physical collapse that accompanies the lowering of human body temperature.

•TABLE 3.3

Wind-Chill Equivalent Temperature (°F). A 20-mi/hr Wind Combined with an Air Temperature of 20°F Produces a Wind-Chill Equivalent Temperature of 4°F.*

WIND SPEED (MI/HR)	AIR TEMPERATURE (°F)																
Calm	40	35	30	25	20	15	10	5	0	−5	−10	−15	−20	−25	−30	−35	−40
5	36	31	25	19	13	7	1	−5	−11	−16	−22	−28	−34	−40	−46	−52	−57
10	34	27	21	15	9	3	−4	−10	−16	−22	−28	−35	−41	−47	−53	−59	−66
15	32	25	19	13	6	0	−7	−13	−19	−26	−32	−39	−45	−51	−58	−64	−71
20	30	24	17	11	4	−2	−9	−15	−22	−29	−35	−42	−48	−55	−61	−68	−74
25	29	23	16	9	3	−4	−11	−17	−24	−31	−37	−44	−51	−58	−64	−71	−78
30	28	22	15	8	1	−5	−12	−19	−26	−33	−39	−46	−53	−60	−67	−73	−80
35	28	21	14	7	0	−7	−14	−21	−27	−34	−41	−48	−55	−62	−69	−76	−82
40	27	20	13	6	−1	−8	−15	−22	−29	−36	−43	−50	−57	−64	−71	−78	−84
45	26	19	12	5	−2	−9	−16	−23	−30	−37	−44	−51	−58	−65	−72	−79	−86
50	26	19	12	4	−3	−10	−17	−24	−31	−38	−45	−52	−60	−67	−74	−81	−88
55	25	18	11	4	−3	−11	−18	−25	−32	−39	−46	−54	−61	−68	−75	−82	−89
60	25	17	10	3	−4	−11	−19	−26	−33	−40	−48	−55	−62	−69	−76	−84	−91

*Dark blue shaded areas represent conditions where frostbite occurs in 30 minutes or less.

Table 3-3, p. 77

•TABLE 3.4

Wind-Chill Equivalent Temperature (°C)*

WIND SPEED (KM/HR)	AIR TEMPERATURE (°C)												
Calm	10	5	0	−5	−10	−15	−20	−25	−30	−35	−40	−45	−50
10	8.6	2.7	−3.3	−9.3	−15.3	−21.1	−27.2	−33.2	−39.2	−45.1	−51.1	−57.1	−63.0
15	7.9	1.7	−4.4	−10.6	−16.7	−22.9	−29.1	−35.2	−41.4	−47.6	−51.6	−59.9	−66.1
20	7.4	1.1	−5.2	−11.6	−17.9	−24.2	−30.5	−36.8	−43.1	−49.4	−55.7	−62.0	−68.3
25	6.9	0.5	−5.9	−12.3	−18.8	−25.2	−31.6	−38.0	−44.5	−50.9	−57.3	−63.7	−70.2
30	6.6	0.1	−6.5	−13.0	−19.5	−26.0	−32.6	−39.1	−45.6	−52.1	−58.7	−65.2	−71.7
35	6.3	−0.4	−7.0	−13.6	−20.2	−26.8	−33.4	−40.0	−46.6	−53.2	−59.8	−66.4	−73.1
40	6.0	−0.7	−7.4	−14.1	−20.8	−27.4	−34.1	−40.8	−47.5	−54.2	−60.9	−67.6	−74.2
45	5.7	−1.0	−7.8	−14.5	−21.3	−28.0	−34.8	−41.5	−48.3	−55.1	−61.8	−68.6	−75.3
50	5.5	−1.3	−8.1	−15.0	−21.8	−28.6	−35.4	−42.2	−49.0	−55.8	−62.7	−69.5	−76.3
55	5.3	−1.6	−8.5	−15.3	−22.2	−29.1	−36.0	−42.8	−49.7	−56.6	−63.4	−70.3	−77.2
60	5.1	−1.8	−8.8	−15.7	−22.6	−29.5	−36.5	−43.4	−50.3	−57.2	−64.2	−71.1	−78.0

*Dark blue shaded areas represent conditions where frostbite occurs in 30 minutes or less.

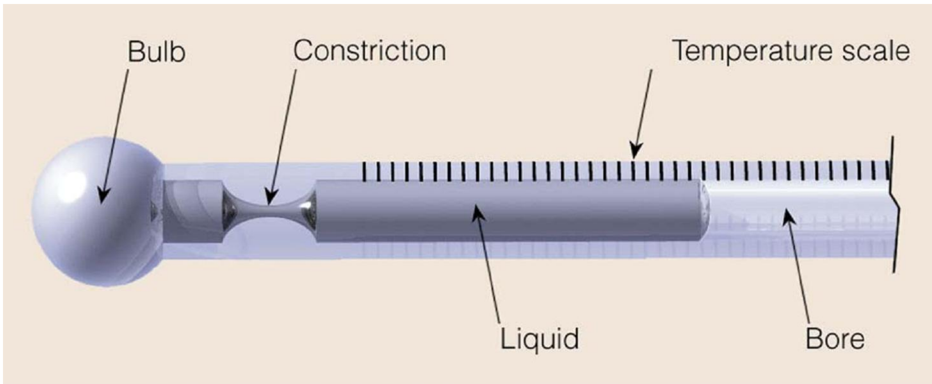
Table 3-4, p. 78

Measuring Temperature

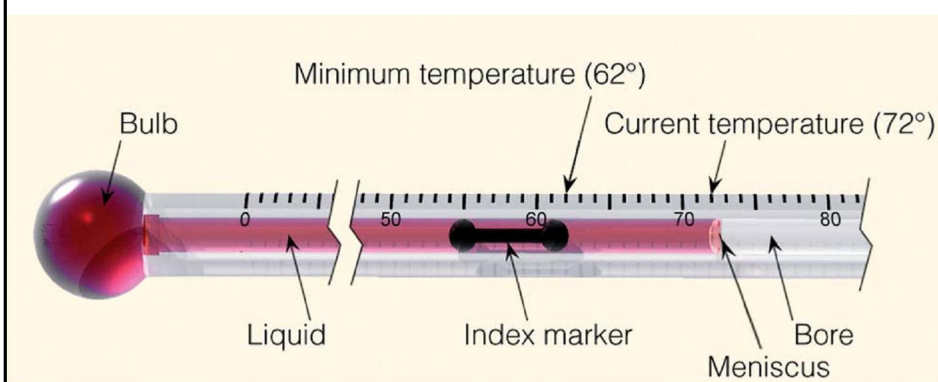
- **Types of thermometers:**
  - *Liquid-in-glass thermometer*: glass tube filled with liquid (often mercury or alcohol) that expands/contracts with air temperature
  - *Maximum thermometer*: usually are liquid-in-glass thermometers that record maximum observed temperature
  - *Minimum thermometer*: usually are liquid-in-glass thermometers (use alcohol) that record minimum observed temperatures
  - *Electrical resistance thermometers* - measure temperature by measuring resistance in a wire
  - *Radiometer* - measures radiation emitted by an object

Liquid-in-glass thermometer

A section of a maximum thermometer

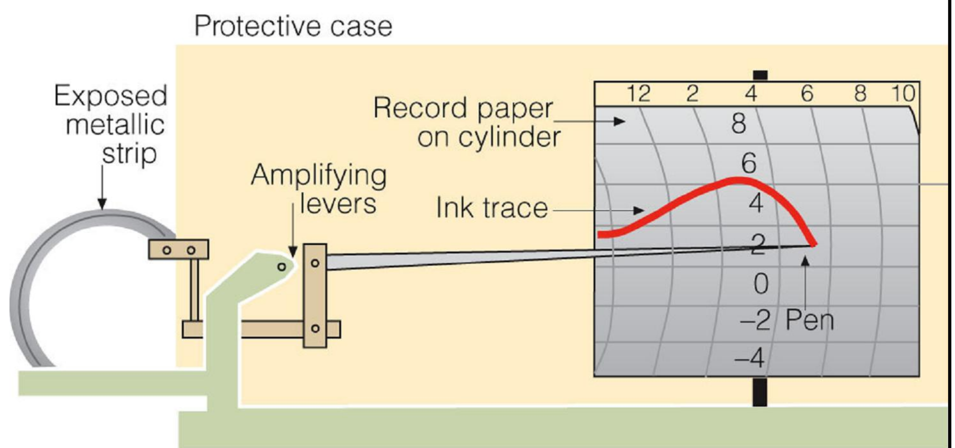


A section of a minimum thermometer showing both the current air temperature and the minimum temperature in °F.



The thermograph with a bimetallic thermometer

The two metal (usually brass and iron) expand differently as temperature change.

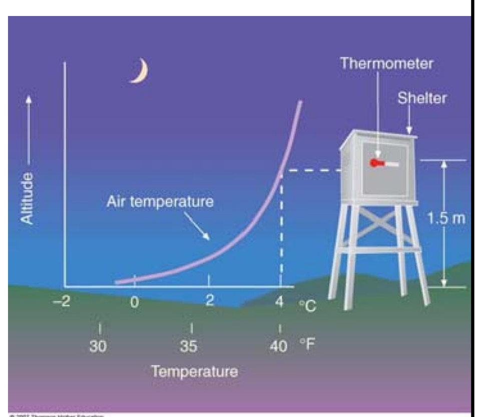


Sensor part

Recording part

Where should one measure air temperature?

- In the shade
- Not at the ground - typically 2 meters above ground level
- Most instrumentation shelters are 1.5-2 meters above the ground



The max–min instrument shelter (middle box) and other weather instruments that comprise the ASOS system.

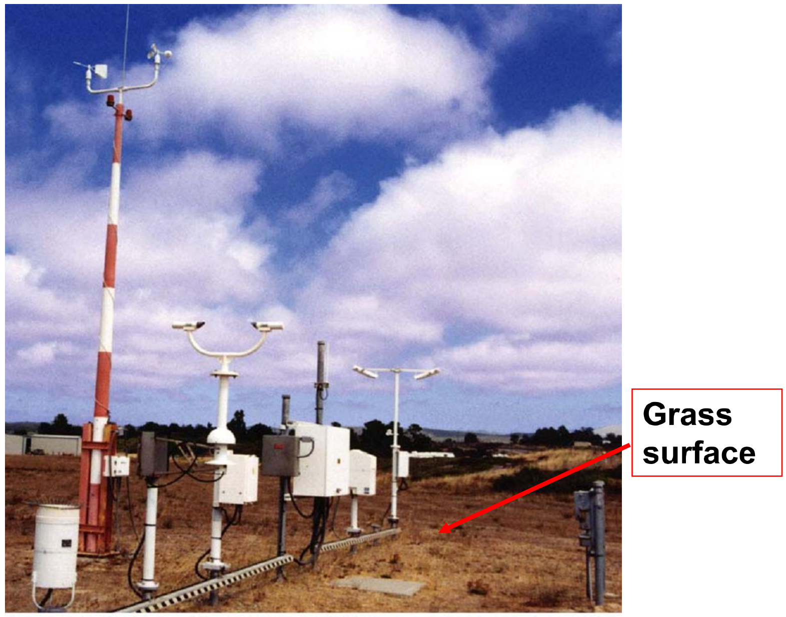


Fig. 1, p. 62