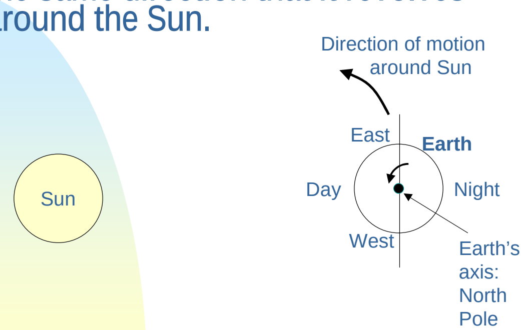
Chapter 3
Seasonal and Daily Temperature

- Why the Earth has seasons
- Local seasonal variations
- Daily Temperature variations
- Controls of temperature
- Air temperature data
  - Daily, month, and yearly temperatures
  - Use of temperature data
- Air temperature and human comfort
- Measuring air temperature

Chapter 3 requires 3-D thinking

- **Some students have trouble with chapter 3. You must think three dimensionally to understand relationships between the Sun and Earth.**
- **If you have trouble with the Earth-Sun relationships, make drawings from different perspectives and/or use a ball to represent the Earth.**

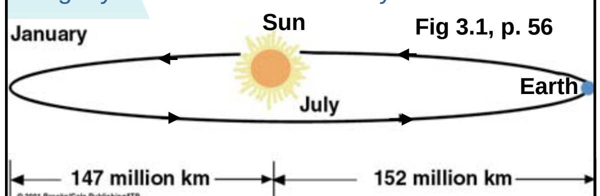
The Earth rotates around its axis in the same direction that it revolves around the Sun.



The Sun rises in the east, sets in the west.

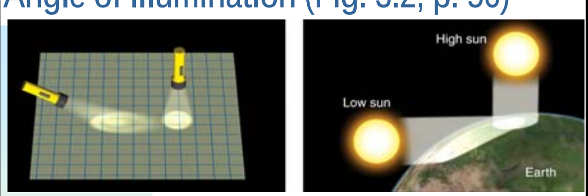
Earth's orbit around Sun: nearly circular

- Earth's orbit is almost a circle around the Sun, so orbit is not responsible for seasons.
- Earth is slightly closer to Sun in January, slightly farther from Sun in July.



Avg distance to Sun is 150 million km = 93 million miles, varying only 2% during year

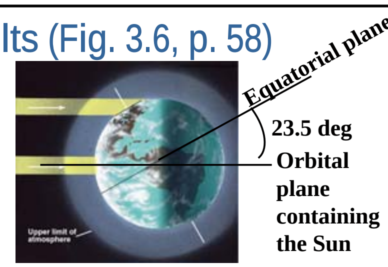
Angle of Illumination (Fig. 3.2, p. 56)



- When a light beam is perpendicular to a surface, it illuminates a smaller area, so there is more heating in that area.
- When a light beam is not perpendicular to a surface, it illuminates a larger area, so there is less heating over the larger area.
- Sun: most concentrated heating at noon, less at dawn & dusk.

The Earth tilts (Fig. 3.6, p. 58)

The Earth tilts 23.5 degrees relative to its orbital plane



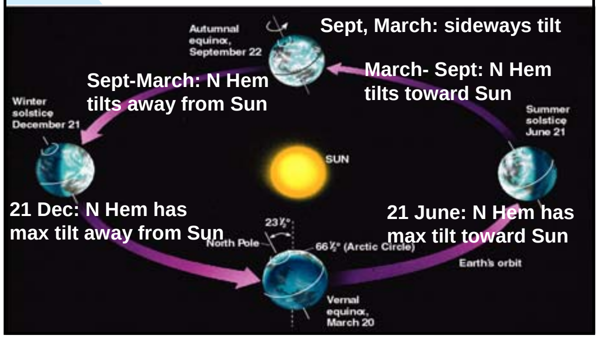
Because of the Earth's tilt:

- Hours of daylight vary with latitude. Always 12 hrs at equator. Approaches 24 hrs/day as you go toward the pole in the summer hemisphere. Approaches 0 hrs/day as you go toward the pole in the winter hemisphere.
- More/less intense sunlight in summer/winter hemisphere

Use the drawing above to visualize these 2 facts.

Solstice and Equinox (fig. 3.3, p. 57)

Earth's axis always points in same direction toward North Star.
Because of orbit around Sun, tilt relative to Sun varies during year.



Solstice and Equinox (cont.)

- Solstices: 21 December, 21 June
- Equinoxes: 20 March, 22 September
- For simplicity, think of 21st of month for all of them. Learn these dates!
- Winter solstice: minimum solar energy input to winter hemisphere
- Summer solstice: maximum solar energy input to summer hemisphere

When do seasons start? Is December 21 (the winter solstice) really the 1st day of winter? (p. 62)

- Cut the year into four equally long periods
- Center summer on the warmest 91 days, winter on the coldest 91 days.
- By that definition, summer starts around 1 June, and winter starts around 1 December for inland areas. Winter and summer start later in the month for coastal areas.
- Also, inland areas cool off faster than coastal areas in fall and warm up faster in spring

Solstice and Equinox (cont.)

Equinox (equal night and day):
- 12 hrs of daylight and night at all latitudes
- Sun overhead at noon on equator
- Tilt of Earth's axis not toward/away from Sun but to side

On all dates other than equinox:
- 12 hrs of daylight at equator but not elsewhere
- More than 12 hrs daylight in summer hemisphere, less than 12 hrs daylight in winter hemisphere
- Sun overhead at noon at some latitude in summer hem.
- Some tilt toward/away from sun in summer/winter hem.

Solstice:
- 24 hrs daylight/dark poleward of (ant)arctic circle in summer/winter hemisphere
- Sun overhead at noon at 23.5 deg lat in summer hem.
- Max tilt toward sun in summer hemisphere

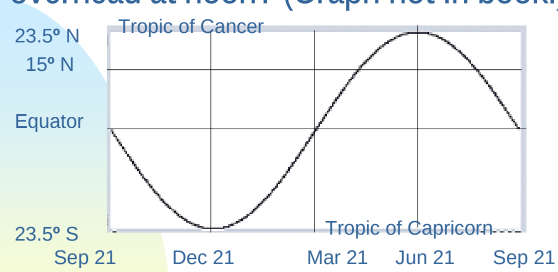
Solstice and Equinox: Hrs of daylight

FOR NORTHERN HEMISPHERE (opposite for Southern Hem)
21 December: Minimum hours of daylight
21 December to 21 June: No. of hours of daylight increasing from day to day
21 June: Maximum hours of daylight
21 June to 21 December: No. of hours of daylight decreasing from day to day

21 March: 12 hours of daylight
21 March to 21 September: 12 or more hours of daylight
21 September: 12 hours of daylight
21 September to 21 March : 12 or less hours of daylight

Examples:
On 15 January, < 12 hrs of daylight, & days getting longer.
On 4 July, > 12 hours of daylight, & days getting shorter.

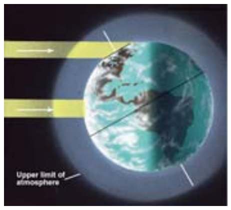
At what latitude is the sun directly overhead at noon? (Graph not in book.)



- **Sun never overhead outside of 23.5° N to 23.5° S**
- **Overhead once per year at 23.5° N or 23.5° S**
- **Overhead twice per year between 23.5° N and 23.5° S**
Example: At 15° N, overhead twice during Mar 21 to Sep 21

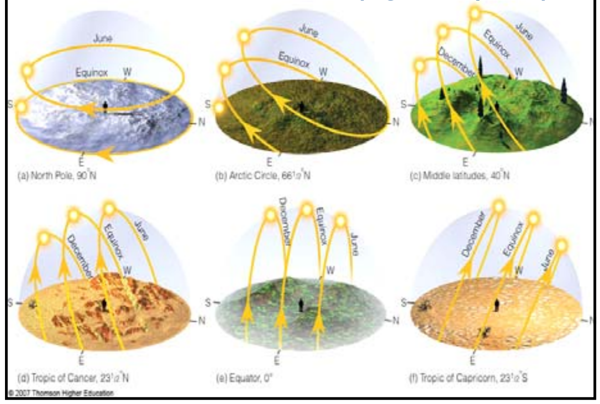
Where is the Sun at noon at other latitudes? (fig. 3.6, p. 58)

- Take N Hem latitudes as positive, S Hem as negative.
- If Sun is overhead at noon at latitude L_{Sun}, then at noon at latitude L, sun is L_{Sun}-L degrees down from vertical, toward N if positive, toward S if negative.

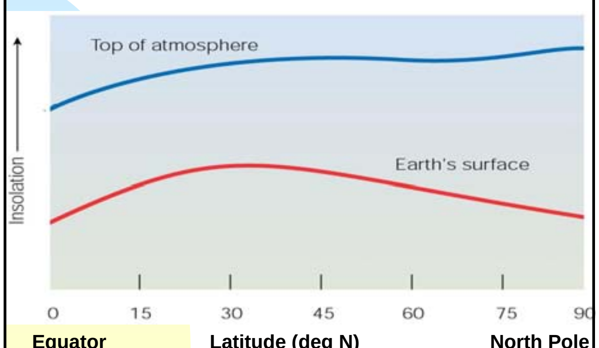


Examples: At noon on June solstice, the Sun is overhead at L_{Sun} = 23.5°N. (Use the figure above to visualize.) Therefore:
•At equator, the sun is 23.5 – 0 = +23.5° = 23.5° north of vertical
•At 47°N, the sun is 23.5 – 47 = -23.5° = 23.5° south of vertical
•At 90°N, the sun is 23.5 –90 = -66.5° = 66.5° south of vertical

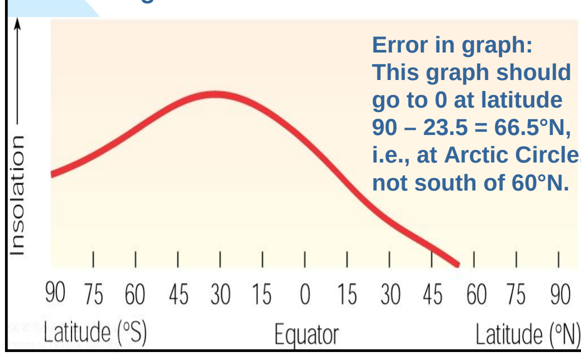
Sun at various latitudes (fig. 3.8, p. 61)



Energy received on 21 June (fig. 3.5, p. 58): Almost constant across Northern Hemisphere



Energy received on 21 Dec (from 7th ed.): Roughly constant in Southern Hemisphere. Decreasing to 0 in Northern Hem latitudes.



Error in graph: This graph should go to 0 at latitude 90 – 23.5 = 66.5°N, i.e., at Arctic Circle, not south of 60°N.

Heating Difference between Summer and Winter

- **Temperature difference between equator and pole small in summer, large in winter.**

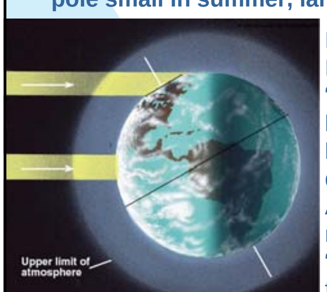
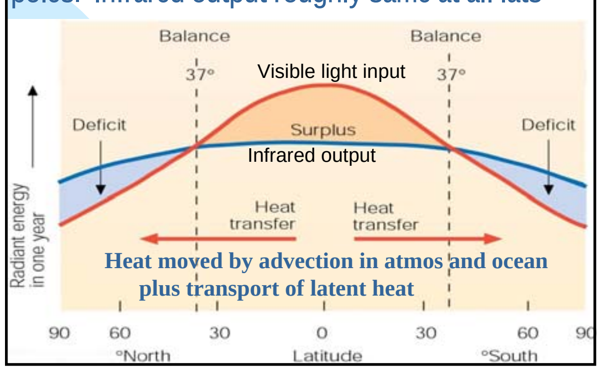


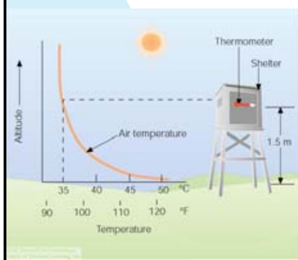
Fig. 3.6, p.58.
Radiation is more "spread out" at northerly latitudes, but more hours of daylight compensate.
Approaching S Pole, radiation is more "spread out" and fewer hours of daylight

Annual average energy input vs. energy output (7th ed.): Visible light input max in tropics, min at poles. Infrared output roughly same at all lats

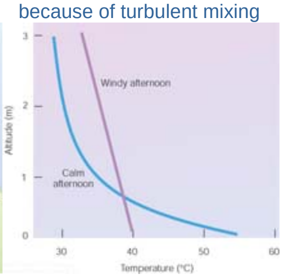


Temperature near surface in daytime (figs. 3.11 & 3.12, p. 65)

Max daytime temp at surface

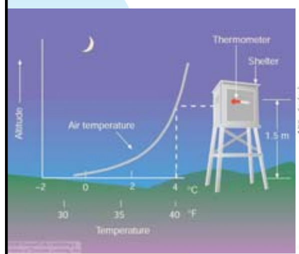


Temperature change with height reduced if windy because of turbulent mixing

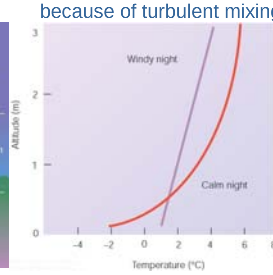


Temperature near surface at night (figs. 3.14 & 3.15, p. 67)

Minimum nighttime temperature at surface



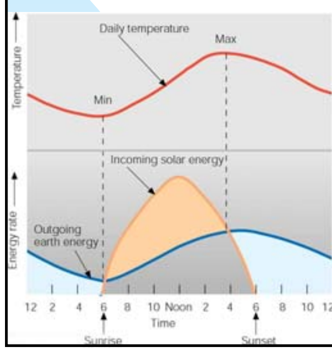
Temperature change with height reduced if windy because of turbulent mixing



Summary of last two slides

- Biggest variation in temperature between day and night occurs at surface due to surface heating by visible radiation during day and cooling by infrared emission at night.
- Temperature at surface can be several degrees different than at eye level where temperatures are read officially.
- Wind will mix the air, reducing the difference in temperature at different heights
- Application: Cold temperature near surface on a calm night is due to radiational cooling with little mixing. Many frosts occur at night under calm conditions. Cold temperature near surface on a windy night is due to advection (bringing in) of cold air. If wind stops during night, temperature will probably drop even further due to continued radiational cooling and lack of vertical mixing that would mix in warmer air.

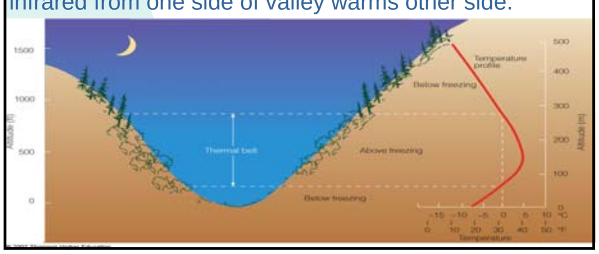
Temperature throughout the day (fig. 3.13, p. 65)



Temperature increases when incoming energy exceeds outgoing energy. Temp increases fastest when difference between visible input & infrared output is maxi-mum around noon. Coldest at sunrise & warmest in mid to late afternoon because these are the times when incoming energy equals outgoing energy. Net cooling before sunrise, net warming in afternoon.

Temperature on hillside (fig. 3.16, p. 68)

Infrared radiates from hilltop, making it cold.
Cold air drains downhill into valley. It warms by compressional heating as it sinks, but it continues to cool in the valley by upward emission of infrared.
The hillside is more moderate ("thermal belt") because infrared from one side of valley warms other side.



Controls of Temperature (p. 71-76)

- Read pp. 71-76 on your own.

Then explain to yourself why the author (Donald Ahrens) lists each of the following as a control of temperature on p. 71:

- Latitude
- Land and water distribution
- Ocean currents
- Elevation

Wind Chill Temperature (pp. 77-78)

- Wind chill temperature (or wind chill index) = temperature under calm conditions at which your face would cool at the current rate of cooling given the existing temperature and wind speed.
- A thermometer, even if exposed to the wind, measures regular temperature, not wind chill temperature.
- Wind chill temperature is computed using a formula. (See footnote, p. 77.) Results are presented as a table for simplicity, because formula complicated.
- If air temperature is higher than skin temperature, wind would not cool; rather "heat blast." Evaporation important for cooling at high temperatures: heat index (chap 4, pp. 99-100).

Wind Chill (table 3.3, p. 77)

Example: if T=20°F & wind=20mph ➔ WC = 4°F

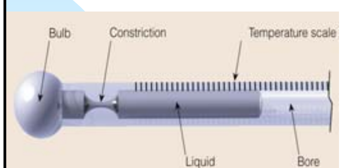
Green region: frostbite in 30 minutes

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

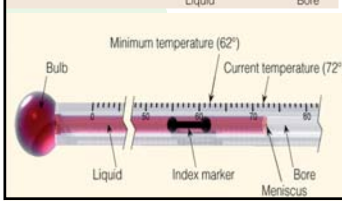
Focus: Thermometers should be read in the shade (p. 81)

- Thermometer actually measures the temperature of thermometer
- To measure air temperature, thermometer must be at air temperature.
- Air is clear, absorbing little sunlight, so thermometer should not be allowed to absorb sunlight either. Hence, it must be in shade.

Max & min temperature thermometers (figs. 3.27 & 3.28, pp. 79-80)



Max thermometer like old fever thermometer: constriction prevents mercury from returning to bulb when temperature cools.



Min thermometer has slider ("index marker") that is pushed back by alcohol as temperature cools, stays put when temperature rises.

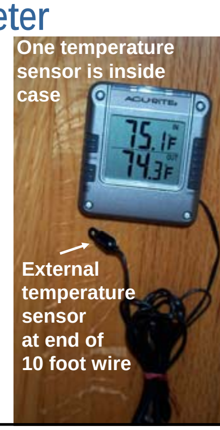
Min & max thermometers locally

- Thermometers are in white ventilated instrument shelter to minimize solar heating.
- Inside the shelter, the min thermometer is the (upper) thermometer containing red alcohol. The max thermometer is the other unit. Both are roughly horizontal, although the max thermometer is turned upright to let mercury settle for reading.
- Observations from shelters like these in backyards around the city are read to determine warm/cold parts of Tallahassee

Shelter: 18" wide 15" tall, 12" deep 5' above ground

Electronic thermometer

- Some components like resistors and capacitors can be made so that their properties change with temperature. This variable response can be calibrated to give temperature.
- Unit in picture is from WalMart and costs under $20. Every few seconds, it senses temperature in the case (75.1°F IN) and in the external sensor at the end of 10 ft wire (74.3°F OUT). Also stores min & max temp for both temperature sensors.
- Black color for wire and for external sensor not good choice.



Bimetallic thermometer: thermostat

Two different kinds of metal can be welded together to make a strip with one kind of metal on one side and the other kind of metal on the other side. The strip is then bent into a spiral. Because the two metals are different, they expand and contract differently as temperature changes, causing the coil to wind or unwind somewhat as temperature changes. At the end of coil, you can attach a pointer to indicate temperature or a glass vial with mercury that will rock one way or another, connecting or disconnecting two electrical contacts inside the vial, turning heating or air conditioning on or off.

Automated Surface Observing System (ASOS) (fig. 3.30, p. 81)

- ASOS: effort by National Weather Service (NWS), FAA, & Dept of Defense to automate weather observations to reduce number of employees and increase number of observations
- Begun in 1980's
- Sensors in photo:

Tipping Bucket Rain Gauge
Hygrothermometer (Temperature/Dewpoint)
Present Weather Identifier (LEDWI)
Wind Speed and Direction Sensors
Data Collection Package (DCP)
Ceilometer (Cloud Height Indicator)
Freezing Rain Sensor
Thunderstorm Sensor
Visibility Sensor

See http://www.nws.noaa.gov/asos