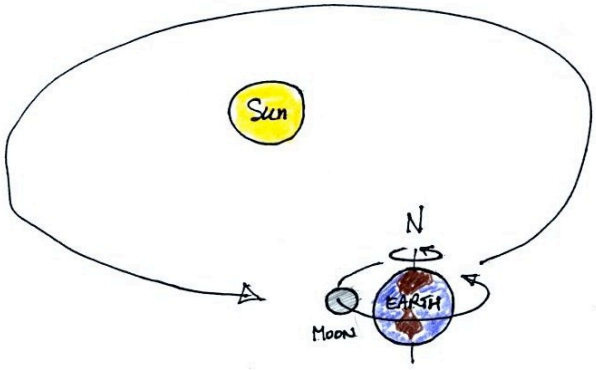
Module 6 - Lecture 17

We will begin with a review of some very basic information concerning the orbiting earth and the moon. Students are asked to fill in the three blanks below in the classroom version of this course.

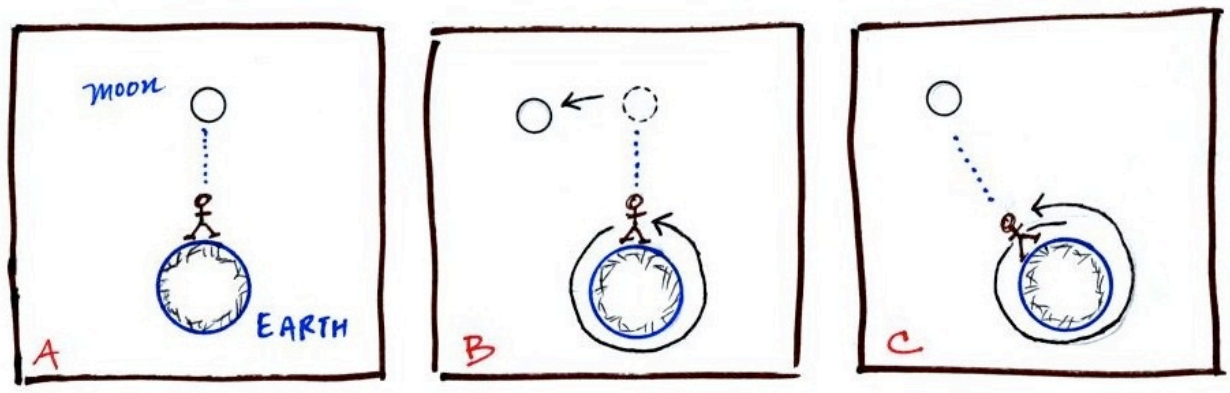


earth orbits Sun once a year

earth rotates on its axis once a day

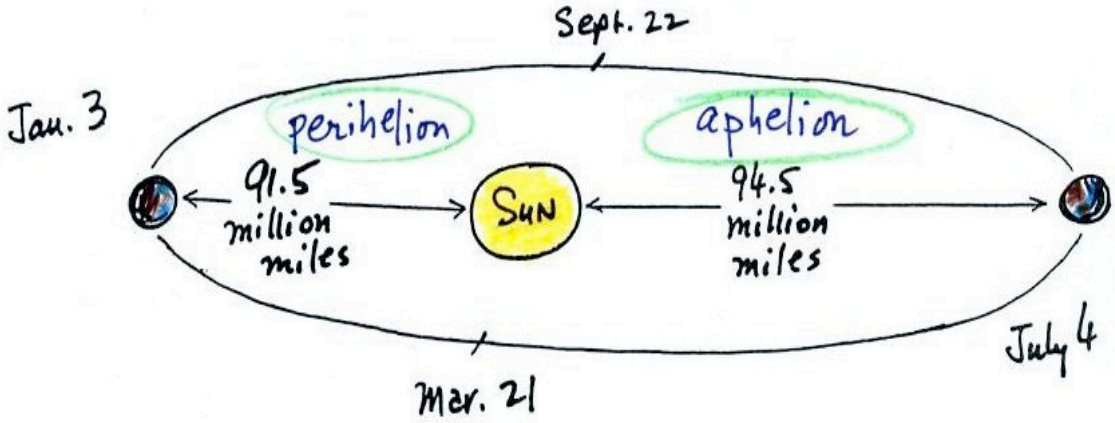
moon completes an orbit about once a month.

Some people have missed the third question and say that the moon orbits around the earth in about a day, because they see it in about the same position in the sky every night. The following figure explains what is really occurring. On the first night in Figure A, the person looks up and sees the moon. One day later on night B, the earth has completed one rotation on its axis and the person is looking up at the same point in the night sky. The person does not see the moon in exactly the same position as the night before; the moon has moved a little bit in its orbit. We see the moon again in the night sky mainly because the earth has spun around is again looking in the same direction as it did the previous night. The moon is in a slightly different position because it has moved a little bit in its orbit around the earth. In Figure C, a little more than 24 hours after Fig. A, the person again sees the moon overhead. If you were to make a note of the time the moon rises you would notice it rises a little later each successive night.



Many people know that the earth's orbit around the sun is not circular and that the distance between the earth and sun changes during the year. Many people think this is the main cause of the seasons. The earth is closer to the sun (perihelion) in January than in July. If this were the main cause of the seasons, summer in Tucson would be in January and winter would be in July. The changing distance between the earth and the sun has an effect but is not the main cause of seasonal changes.

The earth's orbit around the sun is not circular, it's elliptical.



If the seasons were due to changing earth-sun distance,

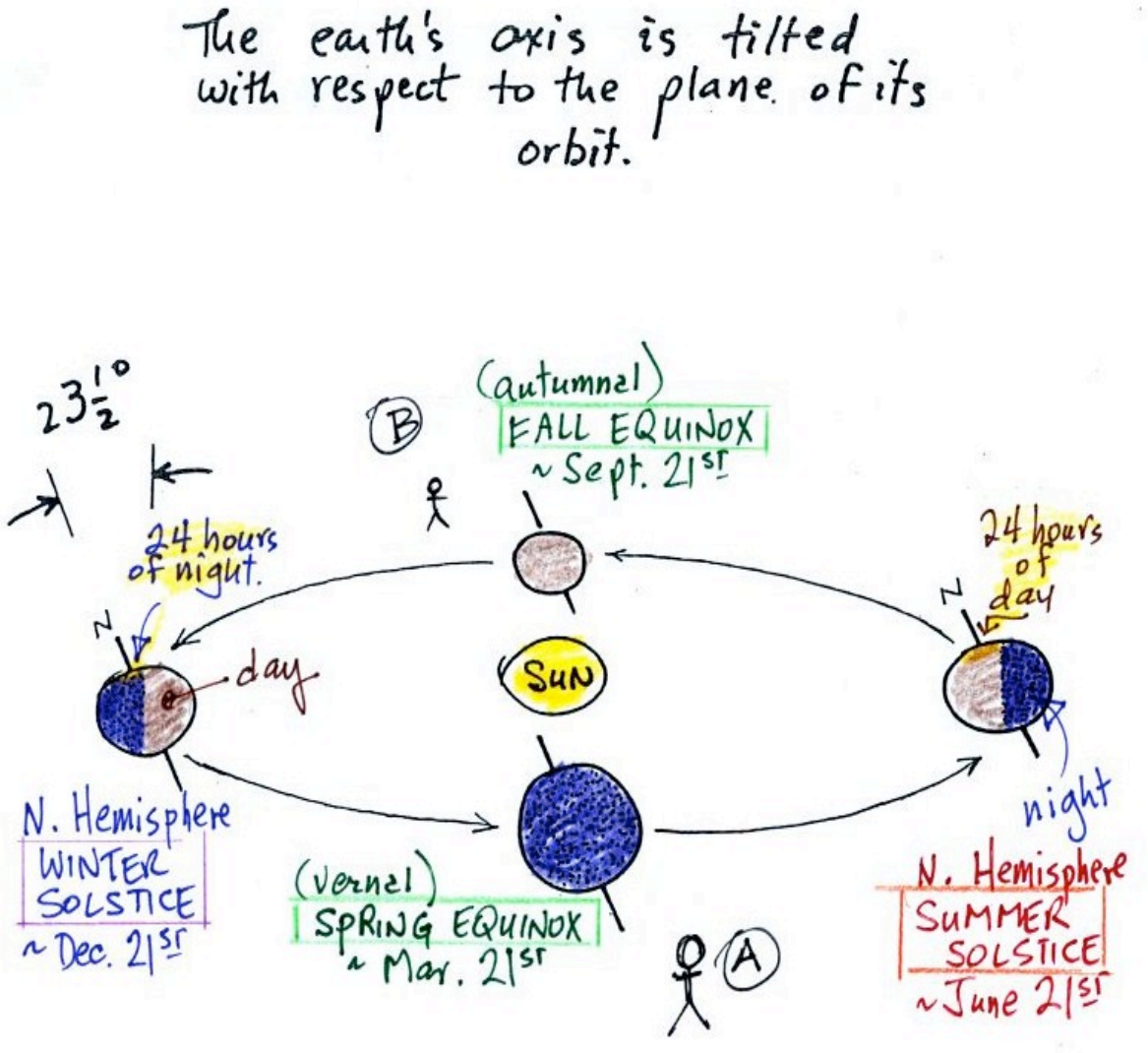
neither is true

(i) ~~X~~ Summer in Tucson would be in January.

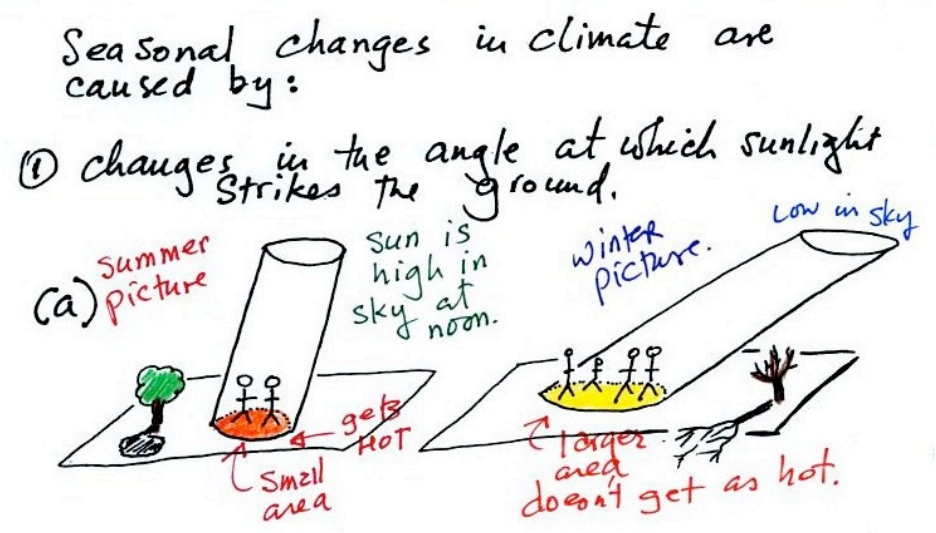
(ii) ~~X~~ Summer would occur at the same time in both the N. & S. Hemisphere.

The fact that the earth is tilted on its axis with respect to its orbit around the sun is the main cause of the seasons. This is shown in the next figure, which shows the tilted earth at four locations in its orbit around the sun. Note how the North Pole tilts away from the sun on December 21 and how there are 24 hours of night north of the Arctic Circle on that date. This is the winter solstice in the Northern Hemisphere. The North Pole is tilted toward the sun on June 21 and there are 24 hours of daylight north of 66.5 latitude. June 21 is the summer solstice in the Northern Hemisphere. Try to imagine what this picture would look like if, instead of standing at Point A, you moved to the other side of the scene and looked back toward the sun from Point B.

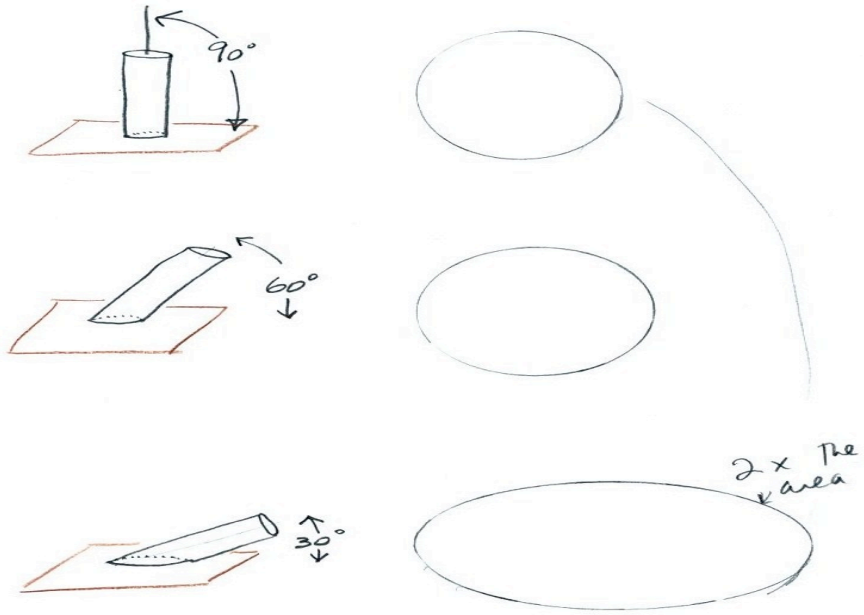
In most locations, the sun is in the sky longer in the summer than in the winter. In Tucson the days (daylight hours) are around 14 hours long near the time of the summer solstice. In the winter the sun only shines for 10 hours on the winter solstice. Days are 12 hours long on the equinoxes.



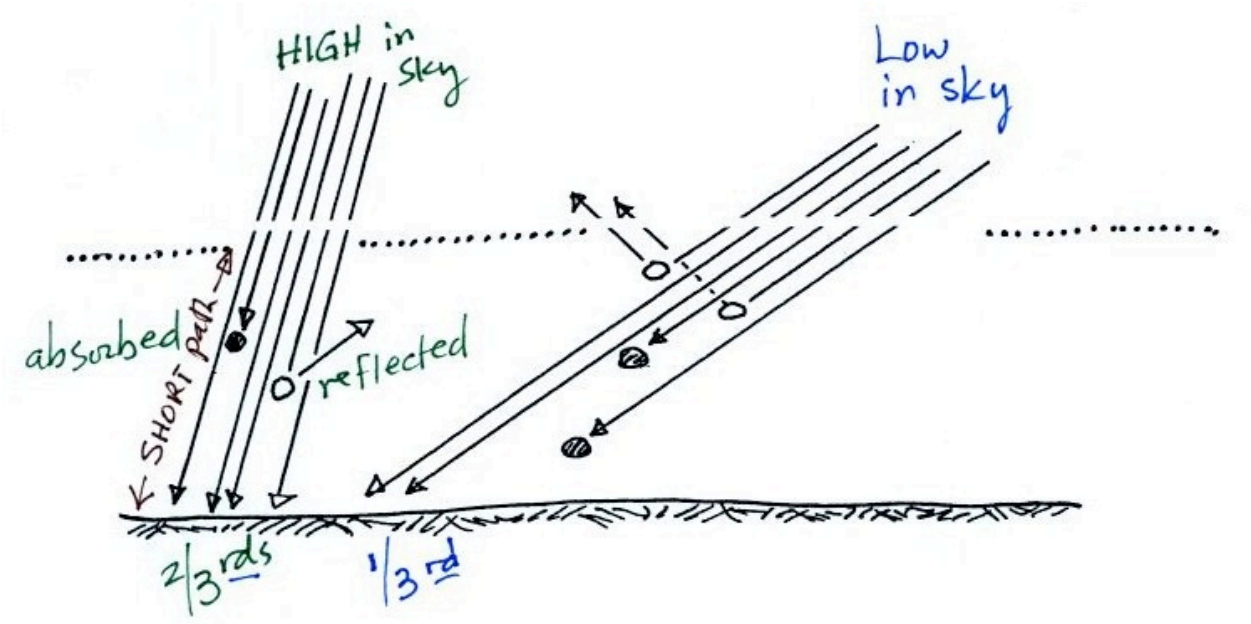
Seasons on the earth are caused by the changing orientation of the earth relative to the sun, which is further illustrated in the figure below. In the summer when the sun reaches a high elevation angle above the horizon, an incoming beam of sunlight will shine on a relatively small area of ground. The ground will get hot and the two people sharing the shaft of summer sunlight will get a sun burn. In the winter the sun is lower in the sky. The same beam of sunlight gets spread out over a larger area. The energy is being used to try heat a larger amount of ground. The result is the ground will not get as hot. Now four people are able to share the winter sunlight and will not get burned as quickly.



These area differences can be illustrated using three pieces of PVC pipe. The end of one piece is cut perpendicularly. The ends of the 2nd and 3rd pieces are cut at 30^o and 60^o angles. The end of the 30^o pipe covers twice the area of the 90^o pipe. The end of the 60^o pipe is a little larger but not a lot larger than area of the end of the 90^o pipe.



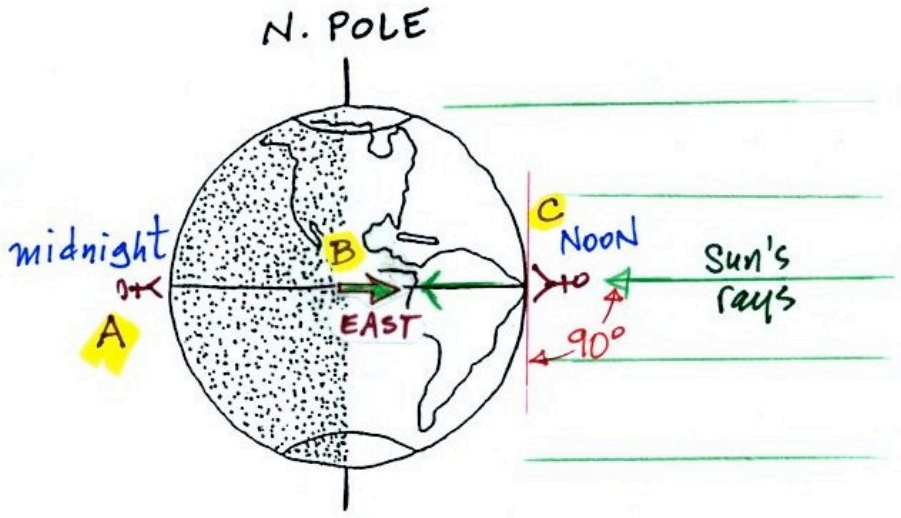
As sunlight passes through the atmosphere it can be absorbed or reflected. On average (over the globe) only about 50% of the sunlight arriving at the top of the atmosphere actually makes it to the ground. A beam of sunlight traveling through the atmosphere at a low angle (right picture below) is less intense than beam that passes through the atmosphere more directly (left picture).



Sun path diagrams are a way of showing the path that you would see the sun follow during the day. We will look at how the sun's path changes during the course of the year at Tucson, and we'll also see how the sun's path is different at different locations on the globe. We will start with the equinoxes because it is the simplest.

EQUINOXES

(2) SUN RISES IN EAST, SETS IN WEST
(1) DAYS ARE 12 HRS. LONG EVERYWHERE*
(3a) Sun is overhead at noon at equator

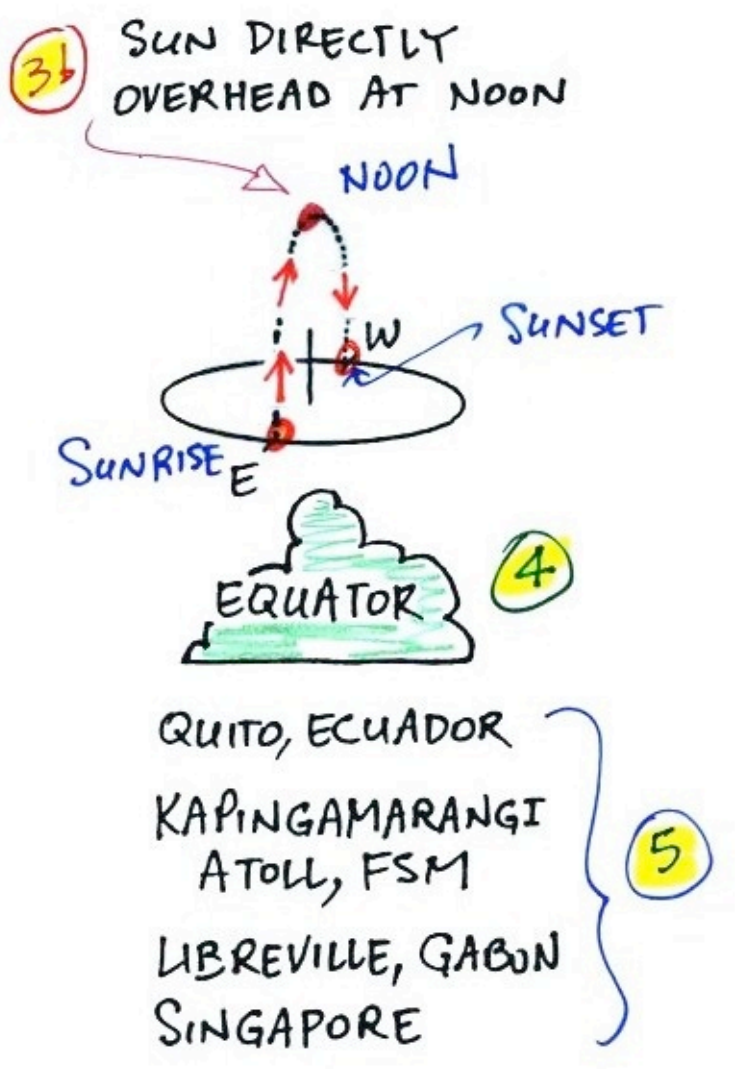


1. The line separating day from night passes through the north and south poles, which is characteristic of the equinoxes and not of the summer or winter solstice. As the earth spins on its axis, a person standing anywhere on the globe will spend exactly half the day on the nighttime side of the picture and half the day on the daytime side of the picture. Thus the day and night are both 12 hours long. This is true everywhere except at the poles. We will see what happens at the poles later.

2. Imagine standing at the equator. At point A you are positioned in the middle of the nighttime side of the globe; it is midnight at Point A. 6 hours later you will be standing at Point B where you will move from night to day; this is sunrise. To see the sun you must look exactly back along one of the rays of light coming from the sun. You must turn and look straight east to do this. Only on the equinoxes does the sun will rise exactly in the east (not just somewhere in the east but exactly due east). The rest of the year the sun will rise south or north of east.

3. Six hours later you arrive at Point C; it is noon. Now to see the sun you must tilt your head and look straight overhead. The sun passes directly overhead at noon at the equator on the equinoxes.

The previous picture shows the earth viewed from outer space. We will next look at the sun's path in the sky viewed from the ground, where most of us will spend our entire lives.

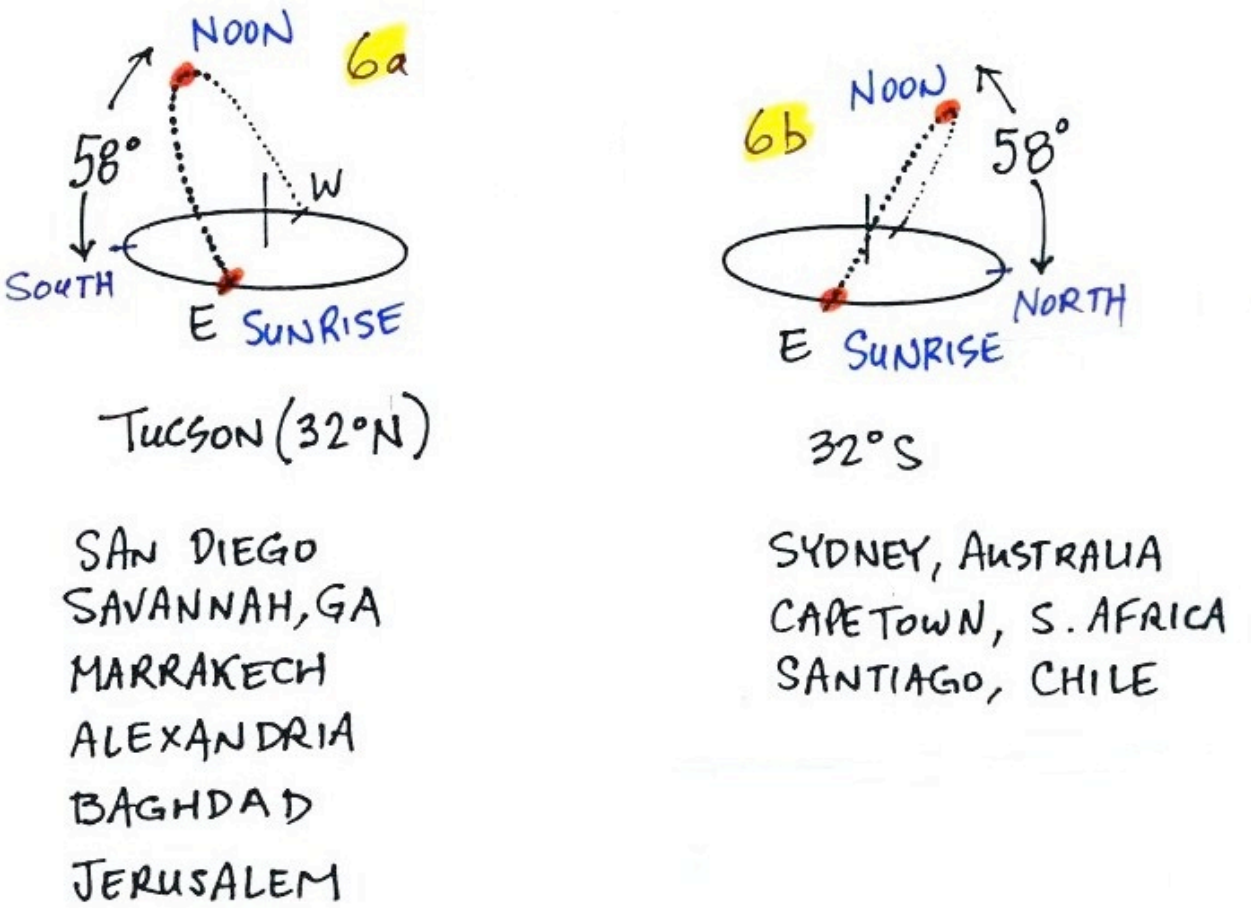


3b. This shows the path of the sun at the equator. The sun rises in the east at 6 am, passes directly overhead at noon, and sets in the west at 6 pm.

4. The cloud shown next to Point 4 above refers to a band of clouds that circles the globe at the latitude where the sun passes overhead at noon. This marks the position of the inter-tropical convergence zone (ITCZ). You can usually make out this band of clouds on a global satellite picture.

5. Here is a list of a few cities that are located on or very close to the equator.

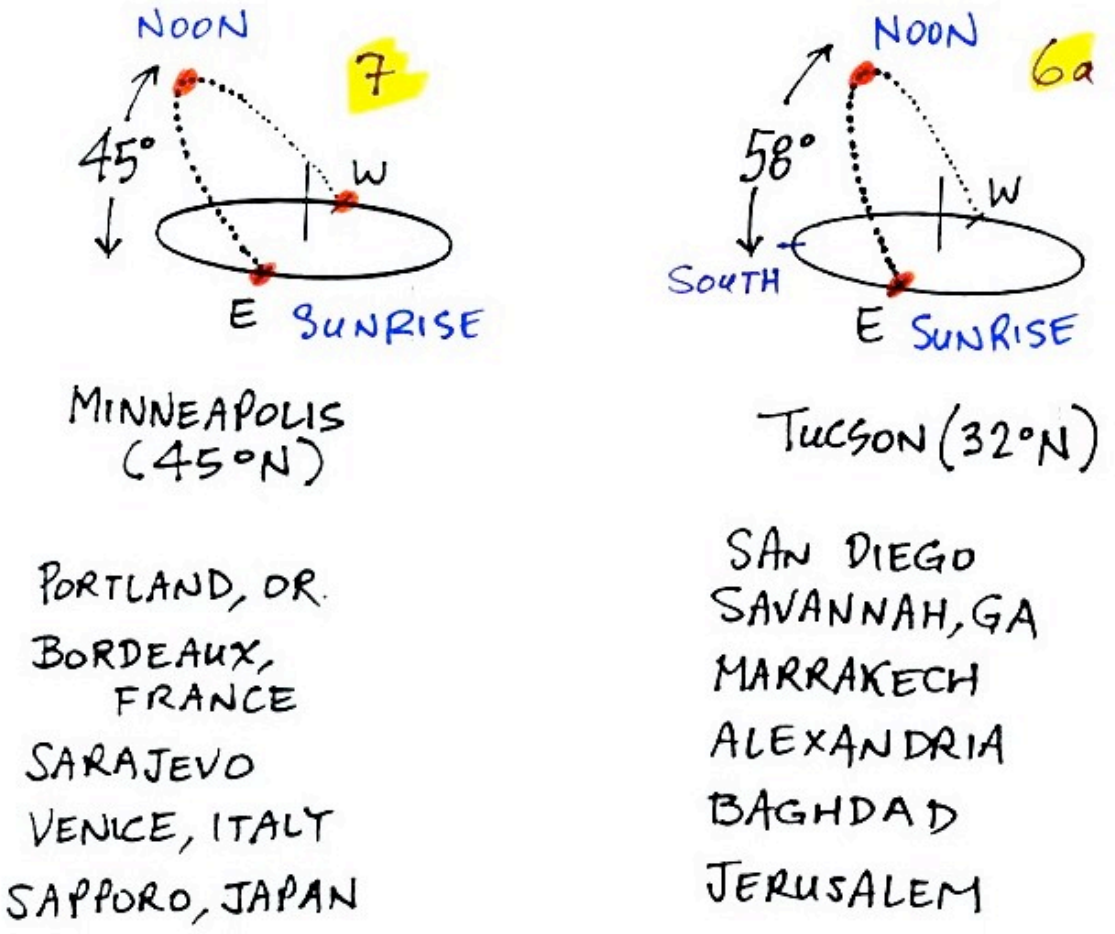
The following figure illustrates the sun path at 32 latitude north (6a) and 32 latitude south (6b).



6a. In Tucson on the equinox, the sun rises in the east at around 6:30 local time (the precise time depends on your location within a time zone), reaches its highest point in the sky (58^{o} above the southern horizon) just after noon and sets in the west at about 6:30 pm.

6b. Sydney Australia is located at 32^{o} S latitude. In the southern hemisphere the sun rises in the east, travels into the northern sky and then sets in the west.

This sun path diagram compares Tucson with cities further north on the equinoxes.

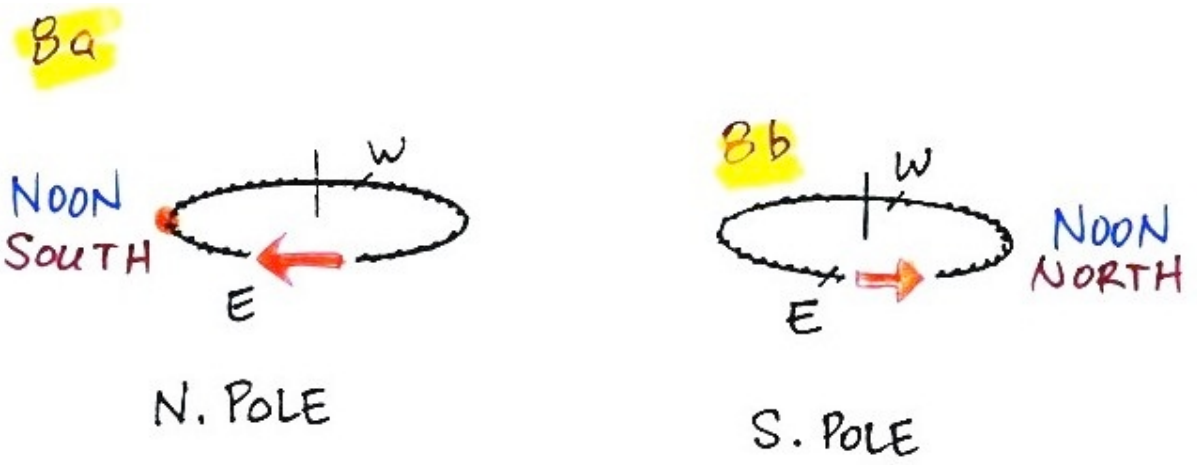


6a. In Tucson on the equinox, the sun rises in the east at around 6:30 local time (the precise time depends on your location within a time zone), reaches its highest point in the sky (58^{o} above the southern horizon) just after noon and sets in the west at about 6:30 pm.

7. At Minneapolis the sun rises in the east, does not get quite as high in the sky at noon (only 45^{o} above the southern horizon) and sets in the west. Even though the sun shines for the same amount of time in Minneapolis as it does in Tucson (12 hours), Minneapolis will receive less energy during the day because of the lower elevation angle. Remember that when the sun is low in the sky the sun's rays must pass through a longer path of atmosphere. A larger percentage of the sunlight is absorbed and reflected. Once this attenuated sunlight reaches the ground it illuminates a larger area on the ground.

8a. At the North Pole the sun really does not rise or set. At 6 am you would find the sun right on the horizon in the east. At noon it would be positioned in the south. The sun would be visible at midnight in the north.

8b. The sun also circles the sky at the horizon at the South Pole, but travels in the opposite direction than at the North Pole.



Because the sun rises in the east and sets in the west, crossing an east-west oriented street near sunrise or sunrise can be dangerous on or near the equinoxes. In this case the car driver had the sun shining directly in his eyes and is probably telling the truth that he did not see the pedestrian.

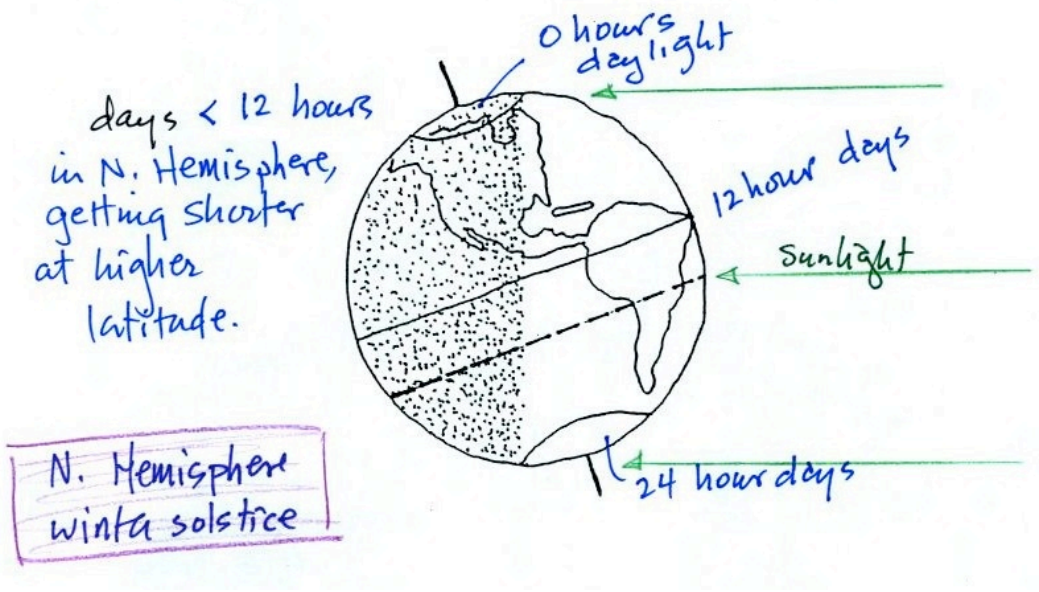
Car strikes man in crosswalk

A 28-year-old man was in guarded condition last night after being struck by a car near the University of Arizona. The accident occurred at 6:30 p.m. on East Sixth Street, just east of Park Avenue next to Arizona Stadium.

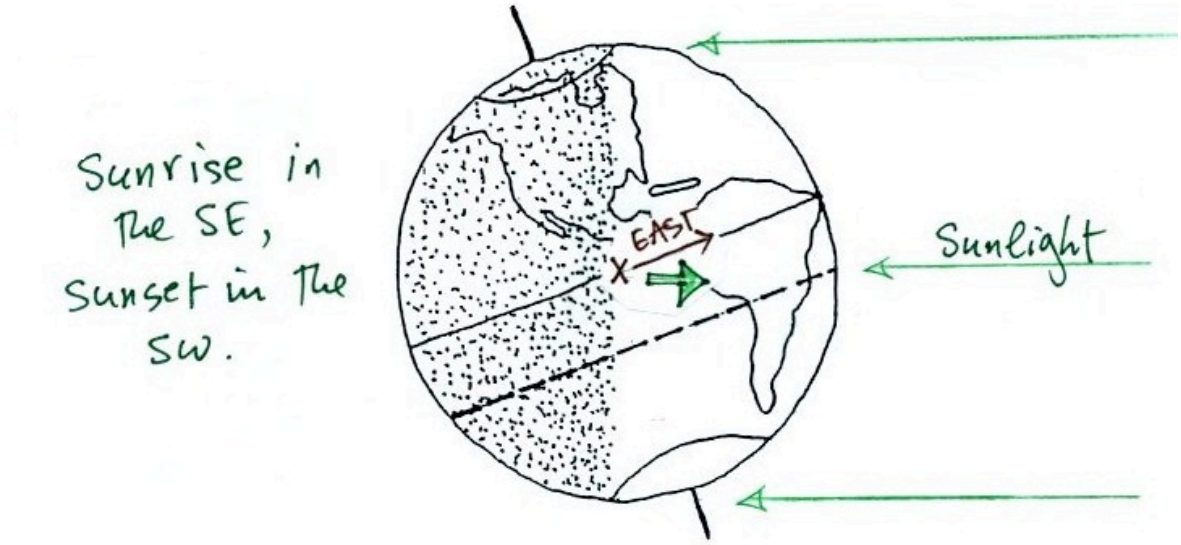
The man was walking south in a crosswalk when he was hit by a westbound car, said Chris Ilderton, a Tucson police traffic detective.

The injured man was taken to University Medical Center. No citations were issued last night. The driver told police he did not see the victim until after he had been struck.

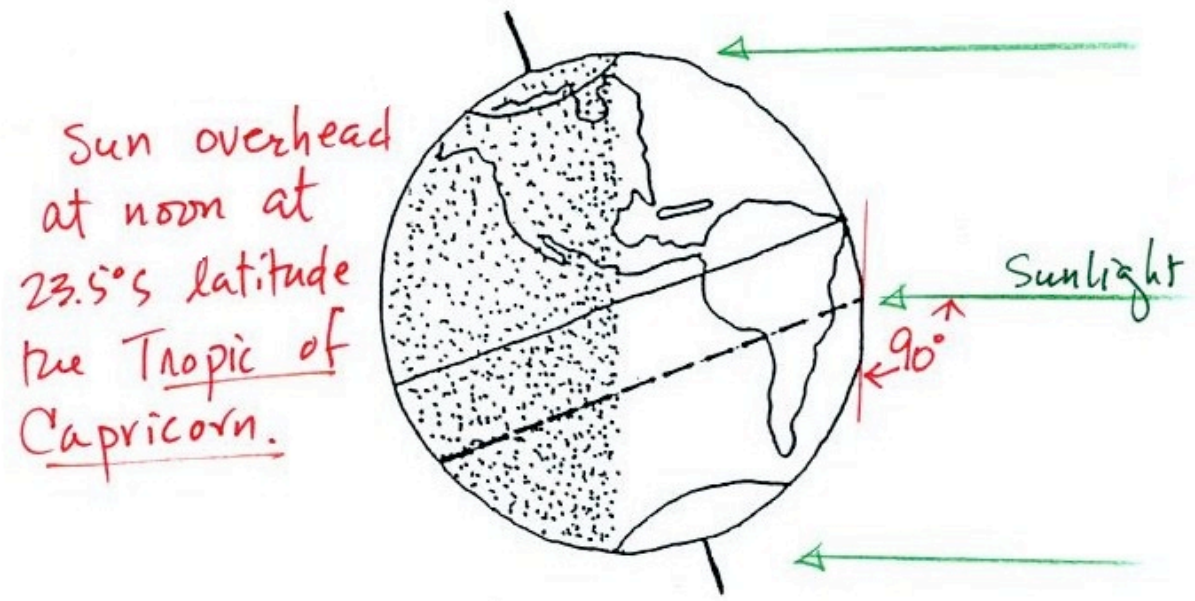
Next we will look at the situation during the Northern Hemisphere winter solstice. The North Pole is tilted away from the sun. There are no hours of daylight and 24 hours of night everywhere north of 66.5 N latitude (the Arctic Circle). There are 24 hours of daylight south 66.5 S latitude (the Antarctic Circle). The equator is halfway between the poles and the days are 12 hours long at the equator. Days are less than 12 hours long in the Northern Hemisphere, becoming shorter and shorter as you move from the equator to the Arctic Circle.



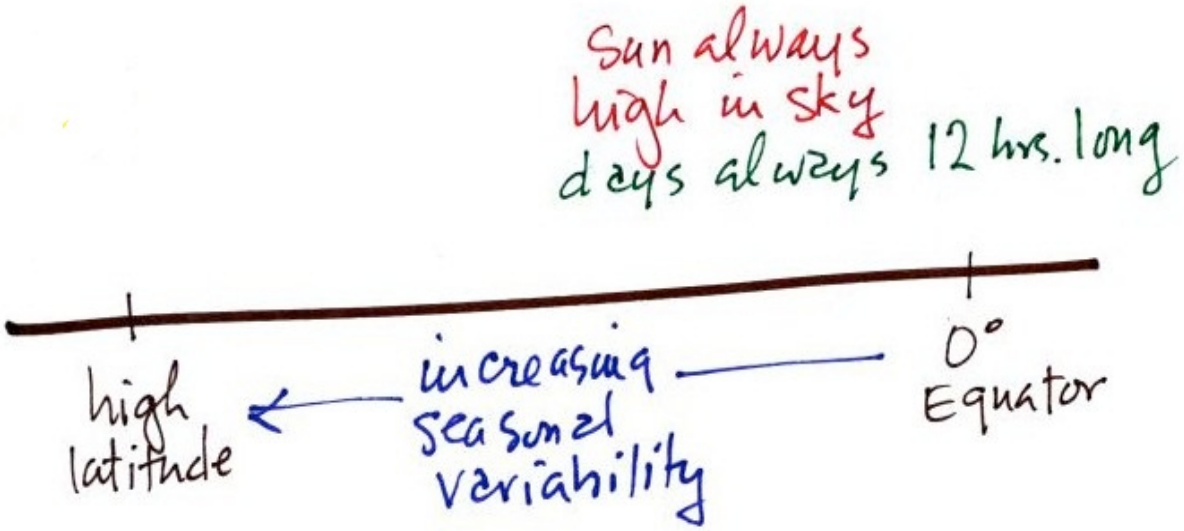
On the winter solstice you need to turn to the southeast to see the sun rise. The sun sets in the southwest.



On the winter solstice, the sun will pass overhead at noon at 23.5 S latitude, at the Tropic of Capricorn.

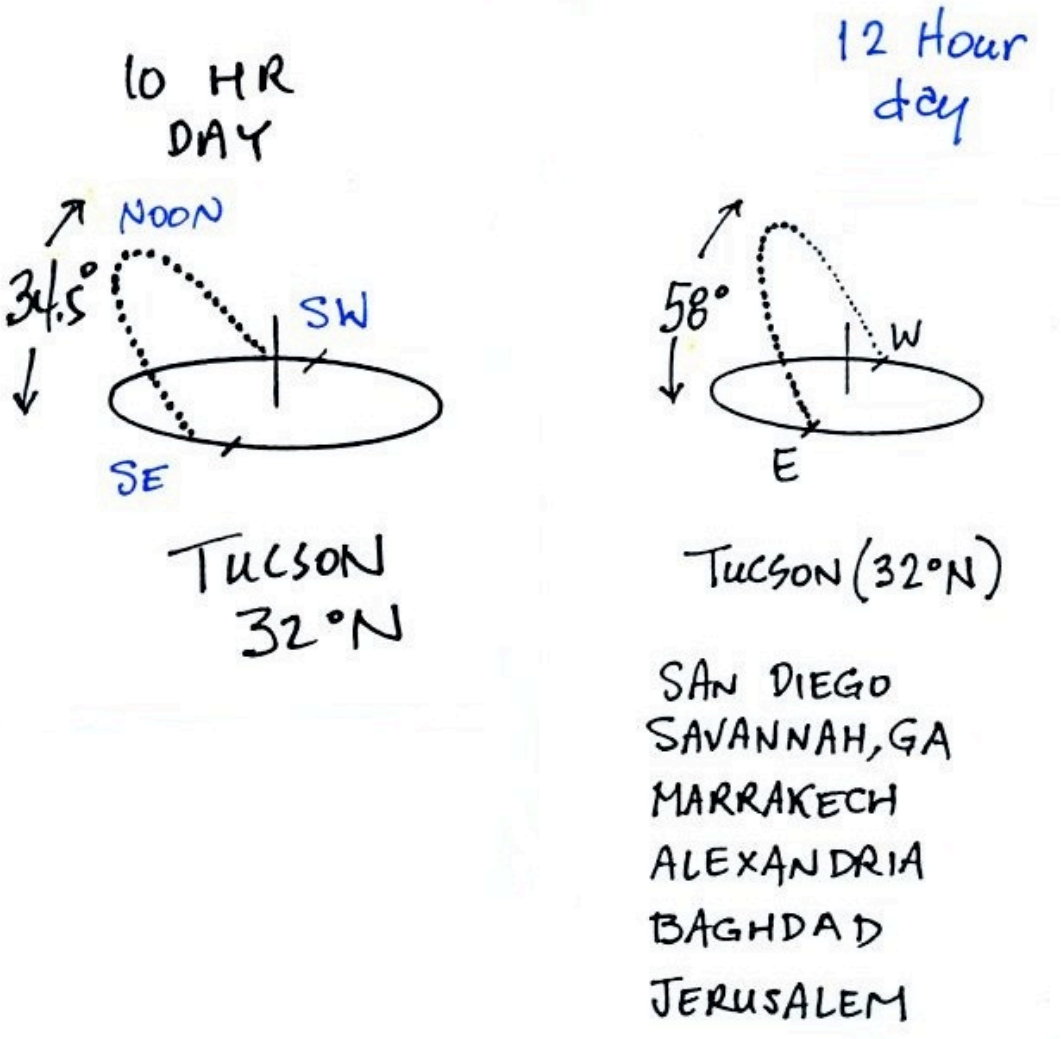


This brings up another important point. The sun is always pretty high in the sky (at noon) at the equator; not always overhead but always pretty high (66 degrees or more). That coupled with the fact that days are 12 hours long throughout the year means that there is very little seasonal change in the amount of sunlight energy arriving at the equator. Seasonal variability increases as you move away from the equator toward higher latitude.

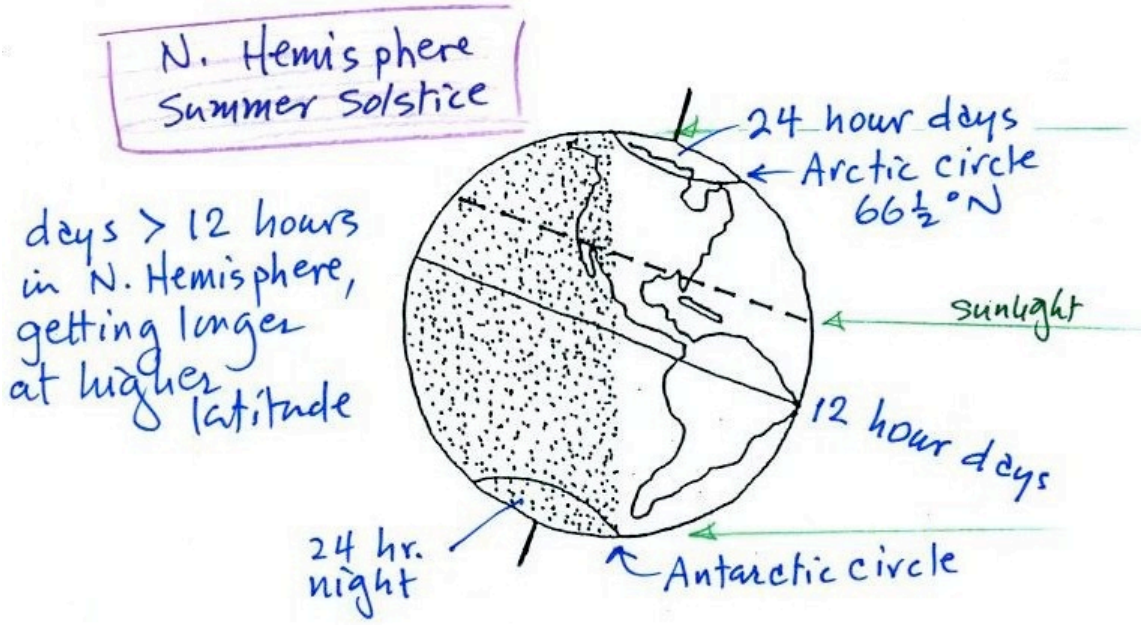


Next we will compare the sun's path in the sky in Tucson on the Winter Solstice (left figure below) and the Equinox (right figure). On the equinoxes, the days are 12 hours long and the sun rises to about 60 degrees above the southern horizon at noon. On the winter solstice the days are shorter, 10 hours long, and the sun only manages to get about 35 degrees above the horizon at noon.

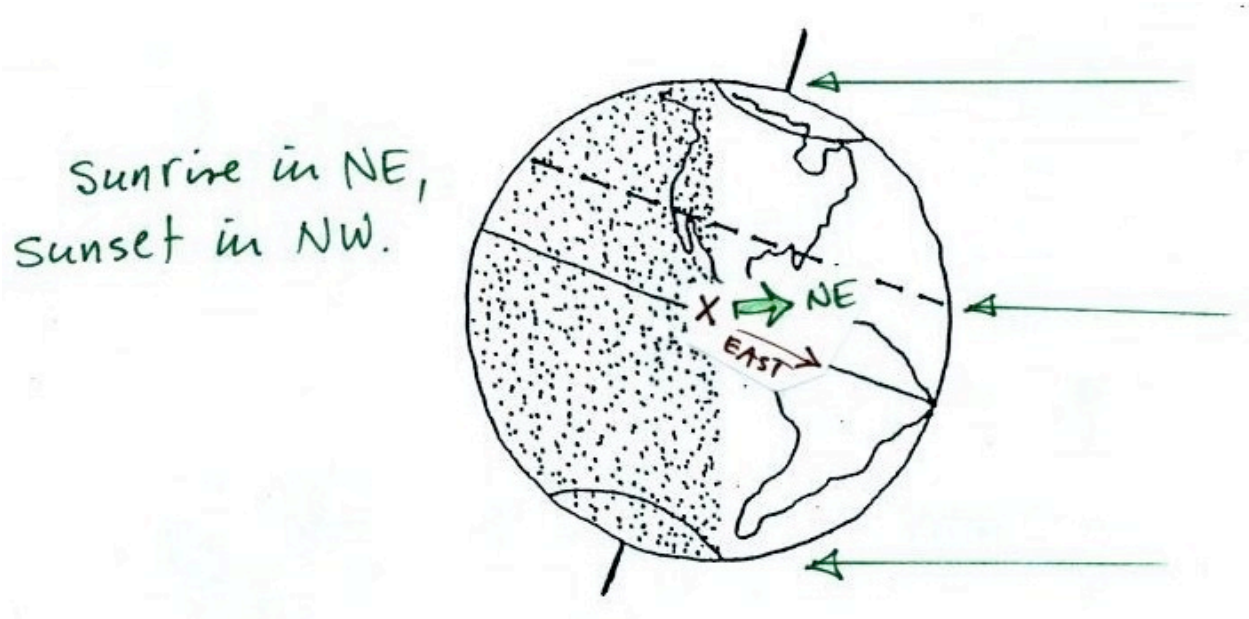
The two main factors that control the amount of sunlight energy reaching the ground are the angle of the sun and number of daylight hours. In the winter, less solar energy reaches the ground in both Tucson and Minneapolis. The situation on Dec. 21 in Minneapolis is even "worse". The days are only 8 hours long and the sun only gets just over 20 degrees above the horizon at noon. Consequently winters are severe in Minneapolis.



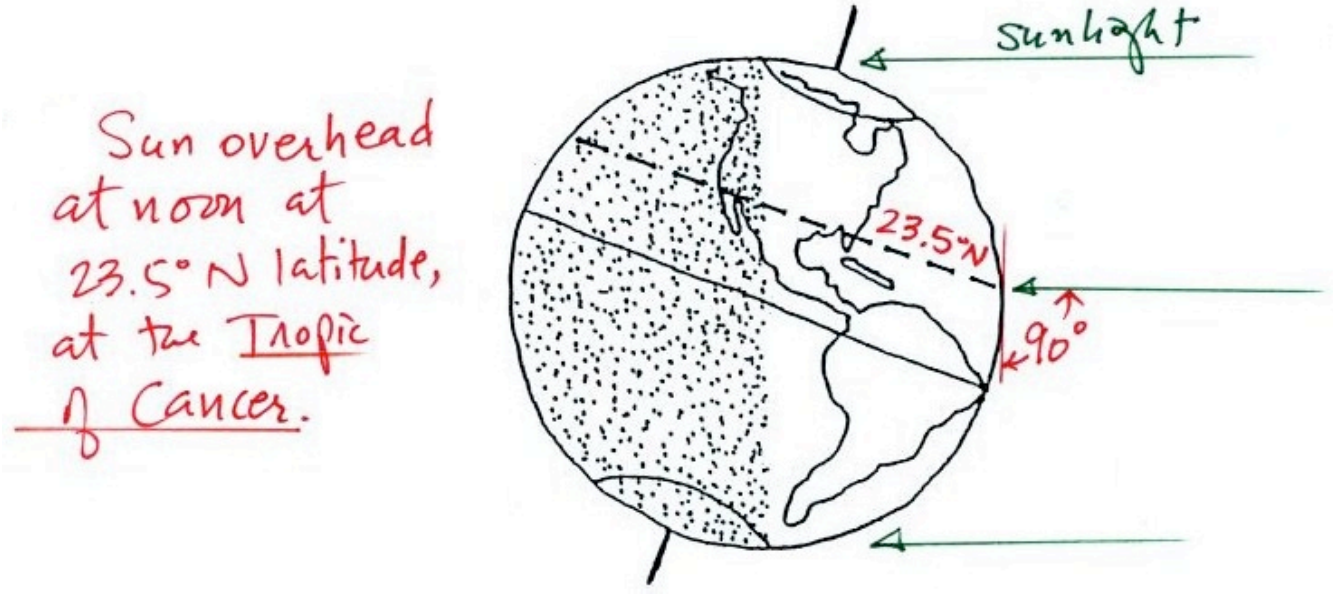
We will finish with the summer solstice. The North Pole is tilted toward the sun. There are 24 hours of daylight north of the Arctic Circle and zero hours of daylight (24 hours of night) south of the Antarctic Circle. At the equator the days are always 12 hours long.



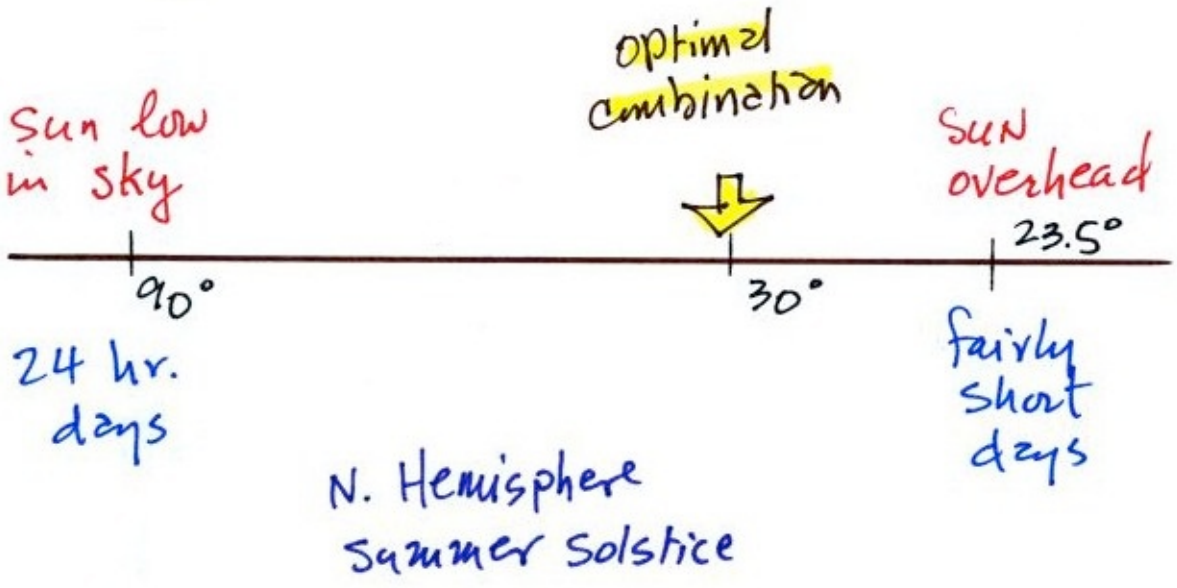
If you look east from position X in the figure below, you will not see the sun because you are not looking back along the ray of light coming from the sun. You must turn to the north. The sun rises in the NE on the summer solstice and sets in the NW.



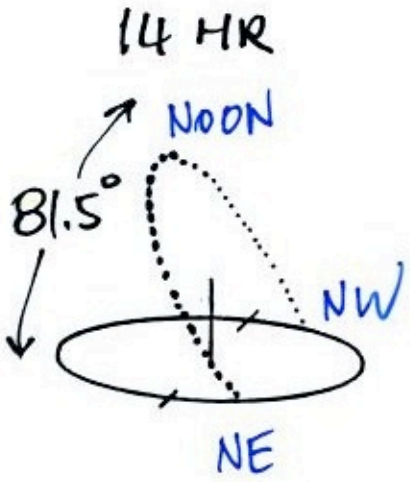
The sun is directly overhead at 23.5 N latitude, the Tropic of Cancer, at noon on the summer solstice.



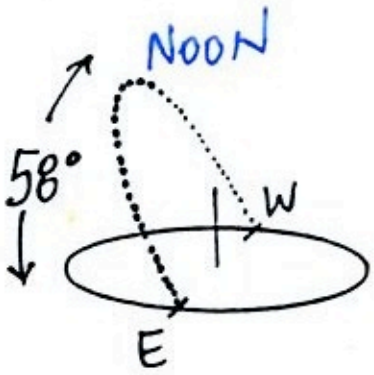
At high latitude the days are long but the sun is low in the sky. At low latitude (23.5 degrees) the sun is overhead but the days are shorter (just a little over 12 hours long). At some point in between these two extremes there must be an optimal combination of sun angle and number of daylight hours, a combination that will result in the maximum amount of sunlight energy arriving at the ground. This "optimum" location is near 30 degrees latitude. The hottest locations on earth are found near 30 degrees latitude or right here in Tucson. This is why the skin cancer incidence is so high here.



Now the situation in Tucson on the summer solstice is compared to the equinoxes. If you move from Tucson to Minneapolis, the days become longer but the sun is lower in the sky. The overall result is less energy reaching the ground in Minneapolis in a day than in Tucson.



TUCSON
32° N



TUCSON (32°N)

SAN DIEGO
SAVANNAH, GA
MARRAKECH
ALEXANDRIA
BAGHDAD
JERUSALEM