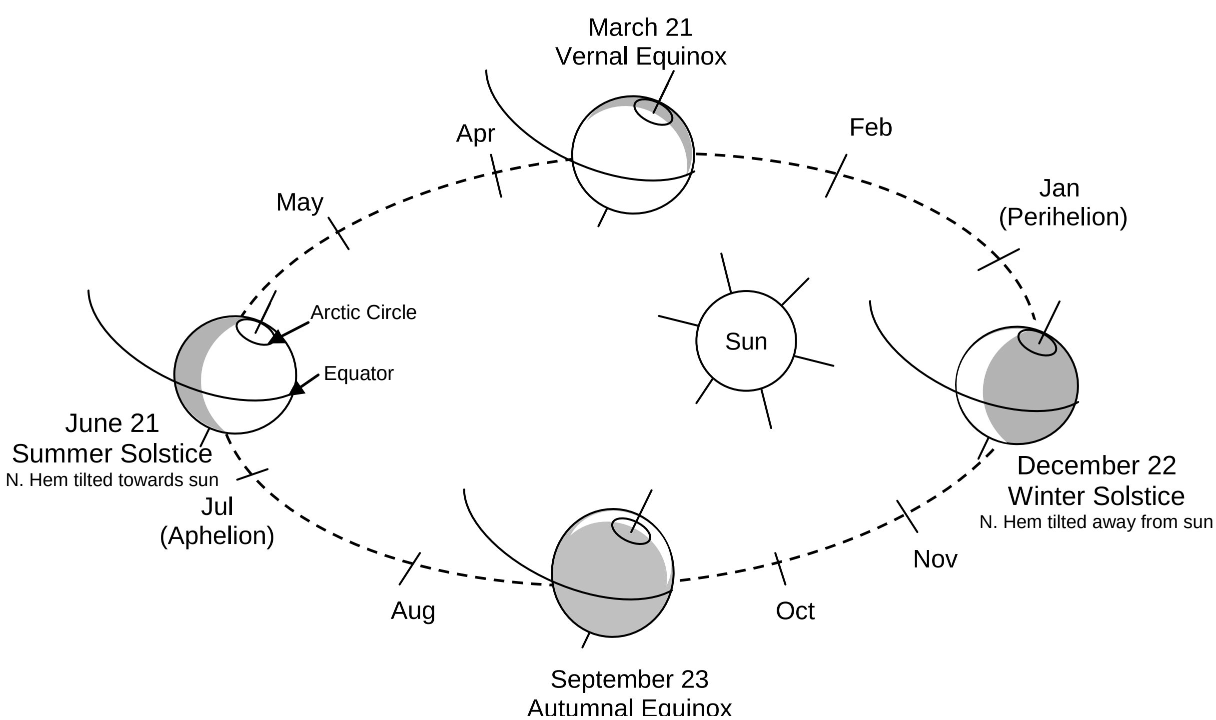
Lab 2

Earth-Sun Relationships

The purposes of this lab are to gain an understanding of the relationships between the Earth and the Sun. All weather and climate on our Earth begins with the sun. Solar radiation is the major source of energy that determines what the conditions will be on the Earth's surface, as well as in the atmosphere. This lab will also consider the variability of sunlight received annually at different latitudes.

There are two primary movements of the Earth: **rotation** and **revolution.** Rotation refers to the spinning of the Earth from west to east upon its axis once in approximately every 24 hours. Revolution refers to the movement of the Earth along an elliptical path around the Sun once every 365 ¼ days (approximately). As shown in Figure 1.3, the Earth's orbit is not an even circle, but rather an elliptical orbit with the Earth closest to the Sun in early January (91.5 million miles away), called the perihelion, and farthest away in early July (94.5 million miles away), called the aphelion.

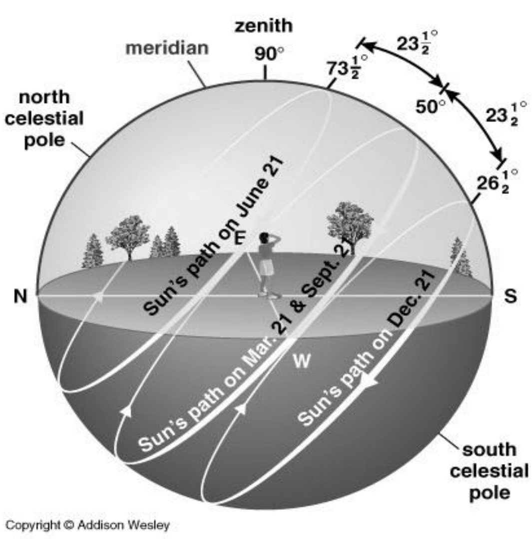
Figure 2.1 Earth's Elliptical Orbit



These movements (rotation and revolution) combined with the tilt of the Earth's axis relative to the orbital plane contribute to the daily and seasonal fluctuations in the amount of solar radiation for different locations. Figure 2.1 illustrates the annual motion of the Earth as it revolves around the sun and lists the seasons based on the northern hemisphere perspective. Only four positions of the Earth in its annual elliptical orbit are shown: December 22, the **winter solstice**; March 21, the **vernal** or **spring equinox**; June 21, the **summer solstice**; September 23, the **autumnal equinox**. The plane of the ecliptic is the imaginary plane composed of all points in the Earth's orbit, which also pass through the sun. The Earth's axis is inclined at an angle of **23 ½ °** to the vertical drawn to a plane of the ecliptic.

Note that in Figure 2.1 the Earth's axis always remains parallel to itself throughout the annual orbit, i.e. it is always tilted in the same direction. This parallelism of the axis produces the seasons. There is greater heating of the surface when the sun is directly overhead, i.e. the sun's rays are perpendicular to the surface. The latitude at which the sun is directly overhead changes continuously in an annual cycle as the Earth moves in its orbit around the sun. The sun appears to move from northern latitudes to the equator to southern latitudes and back to the equator and northern latitudes. This apparent motion of the sun (although it is the Earth that moves) may be observed in northern latitudes as the sun in our winter is low in the sky even at noon while the noon sun in our summer sky is high (Figure 2.2).

Figure 2.2 Northern Sun Path



As seen from the point of view of an observer at a northern mid-latitude, Figure 2.2 traces the path of the sun across the sky during the year.

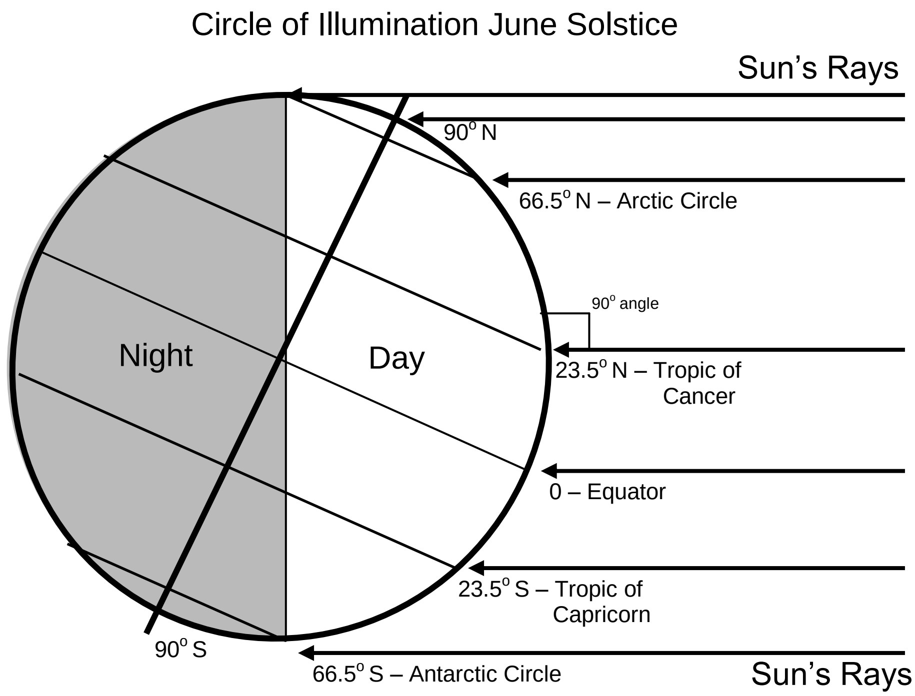
From this diagram it becomes clear that in northern latitudes in winter the days are shorter and the sun arcs south and low across the sky. Conversely, in summer the days are longer and the sun arcs high but still south. At the equinoxes the sun rises due east and sets due west (in the summer it rises and sets closer to the northeast and northwest and in winter it rises and sets closer to the southeast and southwest).

Figure 2.3 provides a more detailed view of the June 21 orbital position of the Earth. Note two important observations:

i) How the inclination of the Earth's axis influences the angle at which the sun's rays strike the surface.

ii) How the inclination of the Earth's axis and the angle at which the sun's rays strike the surface determine the relative amount of day and night.

Figure 2.3 June 21 Orbital Position



The Tropic of Cancer (23 ½ ° N) and the Tropic of Capricorn (23 ½ ° S) represent the maximum distance north and south of the equator that the sun's rays may be perpendicular to the surface of the Earth. The sun is directly overhead (the vertical noon sun) at the Tropic of Cancer on June 21 (Northern Hemisphere summer solstice). The sun is directly overhead at the Tropic of Capricorn on December 22 (northern hemisphere winter solstice). The sun is directly overhead at the Equator on March 21 (Vernal Equinox) and September 23 (Autumnal Equinox). The Arctic Circle (66 ½ ° N) and Antarctic Circle (66 ½ ° S), mark the limit of the possibility of 24 hours of darkness or light.

Internet Resources for Earth-Sun Relationships

1. US Naval Observatory: Sun and Moon information
http://aa.usno.navy.mil/data/
http://aa.usno.navy.mil/data/docs/RS_OneDay.html

2. Sandburg Center for Sky Awareness daylight calculator
http://www.wsanford.com/~wsanford/daylight/calculator.html

3. Earth-sun relationship
http://www.physicalgeography.net/fundamentals/6h.html

4. NOAA: Sunrise/Sunset Calculator
http://www.srrb.noaa.gov/highlights/sunrise/sunrise.html

5. Royal Observatory, Greenwich
http://www.rog.nmm.ac.uk/

Exercise #2 Lab Activity Name: ______________________________

Earth-Sun Relationships Lab Section: ______________________________

Please show your work. If necessary please use additional paper to show work.

✐ 1a) Consider building a house in Massachusetts. In order to gain maximum sunlight in your living room, which direction should the window face? ______________________
Why?

b. If you were building a house in Santiago Chile and wanted maximum sunlight in the living room, what direction should your window face? ______________________

Why?

✐ 2) When (what date) is the Sun directly overhead of:

a. The Tropic of Capricorn ______________________________

b. The Tropic of Cancer ______________________________

c. The Equator ______________________________

d. The Arctic Circle ______________________________

✐3) Give the latitude and the significance of:

a. The Tropic of Capricorn:

b. The Tropic of Cancer:

c. The Arctic Circle

d. The Antarctic Circle

The Arctic & Antarctic Circles

The Arctic Circle (66 ½ ° N) and Antarctic Circle (66 ½ ° S), mark the limit of the possibility of 24 hours of darkness or light. For other latitudes we can roughly establish the length of day by first determining the proportion of the parallel that is in the light zone. The same proportion of 24 hours would be daylight.

✎ 4) Notice the relative length of daylight in the northern and southern hemispheres on June 21 in Figure 2.3. On June 21 what might the daylight situation be at:

a. The Arctic Circle: ________________

b. The Equator: ________________

c. Antarctic Circle: ________________

✎ 5) Six months later on December 22 what might the daylight situation be at:

a. The Arctic Circle: ________________

b. The Equator: ________________

c. Antarctic Circle: ________________

✎ 6) Usually we think of the seasons of the year as they occur in the Northern Hemisphere. Determine when the following seasonal positions occur in the **Southern Hemisphere**. List the dates.

a. Vernal Equinox ________________________

b. Autumnal Equinox ________________________

c. Winter Solstice ________________________

d. Summer Solstice ________________________

Length of Daylight Period *based on Northern Hemisphere*

SUMMER SOLSTICE — **Map 1** June 21

Map 1	June 21
66.5N,	180
60N,	150W
50N,	128W
30N,	105W
0,	90W
30S,	75W
50S,	60W
60S,	45W
66.5S,	0
60S,	45E
50S,	60E
30S,	75E
0,	90E
30N,	105E
50N,	128E
60N,	150E
66.5N	180

WINTER SOLSTICE

Map 2	Dec 22
66.5S.	180
60S,	150W
45S,	120W
30S,	105W
0,	90W
30N,	75W
45N,	60W
60N,	45W
66.5N,	0
60N,	45E
45N,	60E
30N,	75E
0,	90E
30S,	105E
45S,	120E
60S,	150E
66.5S,	180

EQUINOXES

Map 3	Mar. 21 & Sep. 21		
90N,	90W	90N,	90E
80N,	90W	80N,	90E
70N,	90W	70N,	90E
60N,	90W	60N,	90E
50N,	90W	50N,	90E
40N,	90W	40N,	90E
30N,	90W	30N,	90E
20N,	90W	20N,	90E
10N,	90W	10N,	90E
0,	90W	0,	90E
10S,	90W	10S,	90E
20S,	90W	20S,	90E
30S,	90W	30S,	90E
40S,	90W	40S,	90E
50S,	90W	50S,	90E
60S,	90W	60S,	90E
70S,	90W	70S,	90E
80S,	90W	80S,	90E
90S,	90W	90S,	90E

We will be using three maps with the circle of illumination to determine hours of light and darkness for different places on Earth. Two maps already have the circle of illumination drawn on them. You will plot the circle of illumination on map #2 using the Winter Solstice data above.

✐ Plot the latitude and longitude locations above on Map 2 below (note how maps 1 and 3 were plotted using the data above). Carefully connect the locations with a smooth curved line to show where the circle of illumination is. This procedure should result in a smooth set of curves without irregularities. Lightly shade in the regions to the left and the right of the circle of illumination. These areas depict the nighttime.

✐ On these maps, each 15 degrees increment of longitude is equal to 1 hour of time. Thus by counting the 15 degree increments from the left side of the circle of illumination to the right side along a selected line of latitude, you can determine the duration of daylight hours for anyplace on Earth along that line of latitude, and you can do this for any line of latitude on the Earth. During the equinoxes, the number of 15 degree increments is always the same – 12. Thus, on those two days *everywhere* on Earth (except at the two Poles) will have 12 hours of daylight and 12 hours of darkness.

Example: New Orleans, LA: 30^{O} N on June 21.
✐ For the Summer Solstice, count the number of 15 degree increments from the left side of the circle of illumination to the right side along latitude 30^{O} N. There are 14, thus the duration of

sunlight is 14 hours for New Orleans. On the winter solstice, there are only 10 increments, thus 10 hours of daylight.

✏ 7. Determine the length of daylight at the following locations for the June solstice, December solstice, and equinox.

Place (approximate degrees)	**June Solstice**	**December Solstice**	**Equinox**
Barrow, AK (71° N)	____________	____________	____________
Salem, MA (43° N)	____________	____________	____________
Riyadh, SA (25° N)	____________	____________	____________
Singapore (1° N)	____________	____________	____________
Cape Town, SA (34° S)	____________	____________	____________
Vostok, Antarctica (79° S)	____________	____________	____________

✏ 8. It should become apparent that as you go northward from the equator in the summer, the daylight hours become __________ and in the winter the daylight hours become ________ as you travel northward.

✏ 9. How many hours of daylight are there at the Equator in each of the seasons?

✏ 10. Using what you know about latitude and length of daylight, describe the weather and amount of daylight you would expect to encounter:

a. In Vostok in July?

b. In Vostok in February?

c. In Barrow in July?

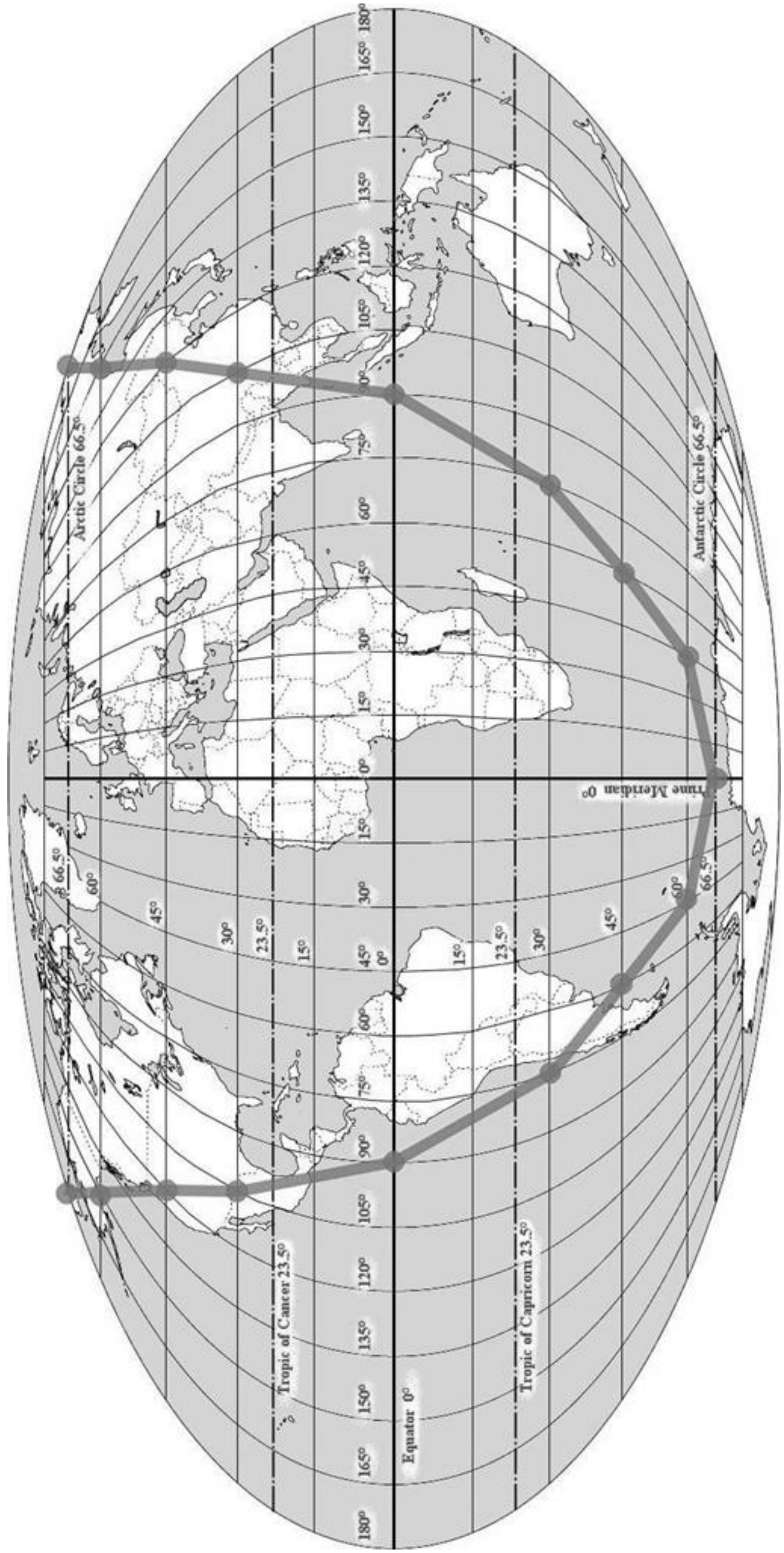
d. In Barrow in February?

e. What is the major difference in the climate at the two locations?

f. Can you think of a factor that does not involve latitude or length of daylight that might further explain the climatic differences between the two locations?

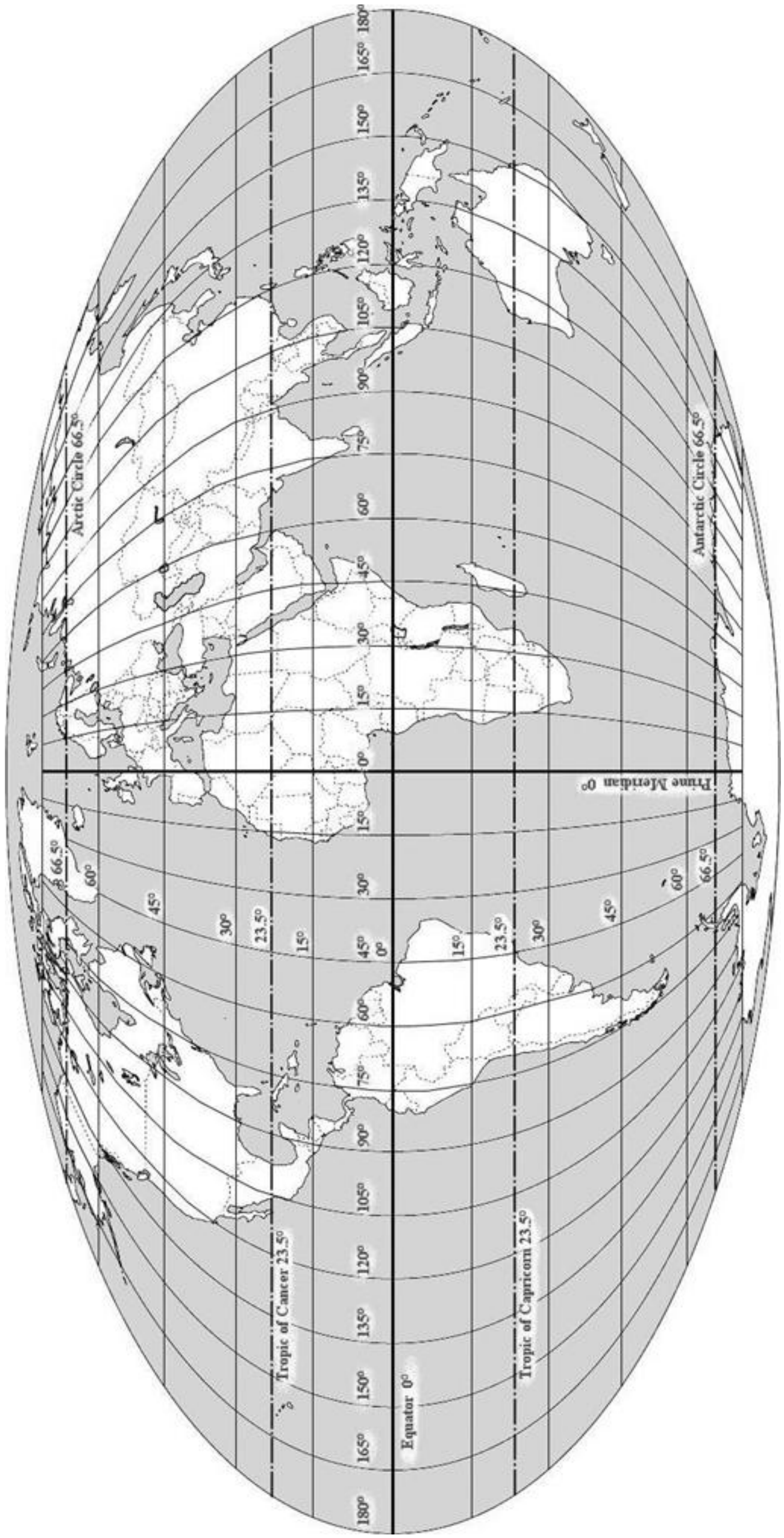
Map 1: June 21

Summer Solstice in the Northern Hemisphere / Winter Solstice in the Southern Hemisphere



✏ Map 2: December 22

Winter Solstice in Northern Hemisphere / Summer Solstice in the Southern Hemisphere



Map 3:
March 21 &
September 21

Spring and Fall Equinoxes
for both Hemispheres