Fall
16
Addendum

DEPARTMENT OF GEOGRAPHY

Salem State University

Weather & Climate Lab Manual

Acknowledgements

The laboratory manual was developed as the result of contributions from many members of the Department of Geography at Salem State University. It has been evolving over the years by the faculty and staff who have committed significant time and energy into a product which provides some hands-on experience and critical analysis of the concepts covered throughout the weather and climate lectures.

Mr. Arthur Francis deserves special recognition for the ideas and input he has provided to continually improve the manual. Specifically, certain exercises within the labs were created by Mr. Francis, and are the fundamental products of his dedication to the pedagogical pursuit of weather and climate.

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Introduction to the Weather and Climate Lab Manual

ICON KEY
Requires supplements (equipment or material) available during lab
Test your knowledge
Computer exercise
Previously introduced lab material

The exercises found in this manual are intended to complement the content presented in the lecture sections of GGR100P Weather & Climate.

The lab exercises within the Weather & Climate course structure will enhance learning of the material presented during lectures and provide hands-on activities incorporating this knowledge. Each lab begins by presenting a synopsis of the pertinent background information. A section requiring critical analysis will help students synthesize this information, followed by computation or other hands-on applications of the important concepts. Weather and climate measurement tools will be employed where feasible and in-time data from various Web sources will also be utilized. Icons are used to illustrate when the integration of outside sources is required. This manual combines selected elements from cartography, general Earth sciences, weather principles and prediction, climate differentiation, and global climate changes. These labs are appropriate for the novice geographer to provide an introduction to the concepts of weather and climate. More extensive weather and Earth science principles can be found in upper division meteorology and physical geography.

Digital Geography Laboratory (DGL) The Digital Geography Lab (DGL) was officially established in 1983 and proclaimed by the Governor of the Commonwealth of Massachusetts as a Center of Educational Excellence in 1986. It is a geo-computing facility housing a Windows NT Server, digitizing equipment, and an extensive collection of analytical and mapping software. The DGL has three main functions: education, research, and public service.

Digital Weather Station (DWS) is located on the roof of Meier Hall. The DGL collects and stores the transmitted data from the Weather Station. The weather data from this station along with the current weather conditions at Salem State College can be accessed from the Geography Departments web page:

http://www.dgl.salemstate.edu/

or directly at: http://lambert.salemstate.edu/weather/

Lab 1

The Geographic Grid

The purposes of this lab are to familiarize students with the geographic grid and how we make distance measurements on the Earth. The lab will also introduce a number of places worldwide that we will be following throughout the semester.

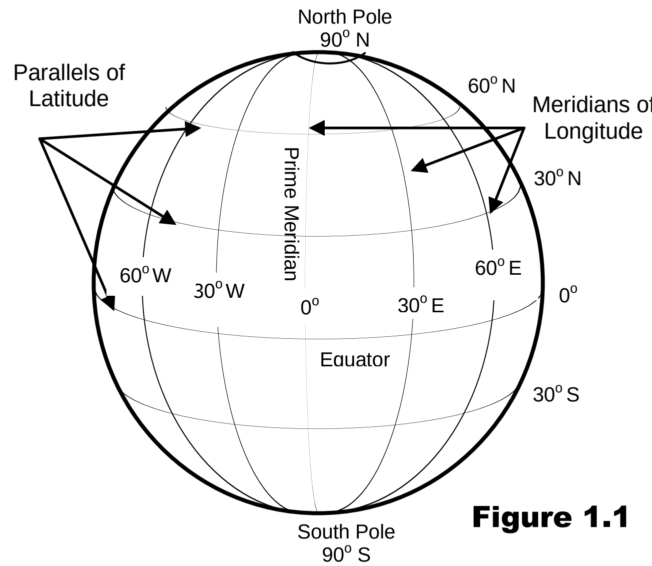


Figure 1.1

The Geographic Grid

In order to fix exact locations on the surface of the Earth a grid system has been imposed on the globe. This network of intersecting lines is comprised of **parallels of latitude**, which run East-West, and **meridians of longitude**, which run North-South (Figure 1.1).

Two lines have been chosen as 'starting points' for this grid system. The first is the **equator**, which is the mid-point between the north and south poles and which bisects the earth into the northern and southern hemispheres. The parallels of latitude are determined by measuring angles of distance north and south of the equator. Figure 1.2a illustrates the measurement of this angular distance for 30° N (note that the vertex of the 30° angle is at the center of the Earth). These parallels of latitude are used not only in locating places on earth, but also for measuring distance north and south on the globe.

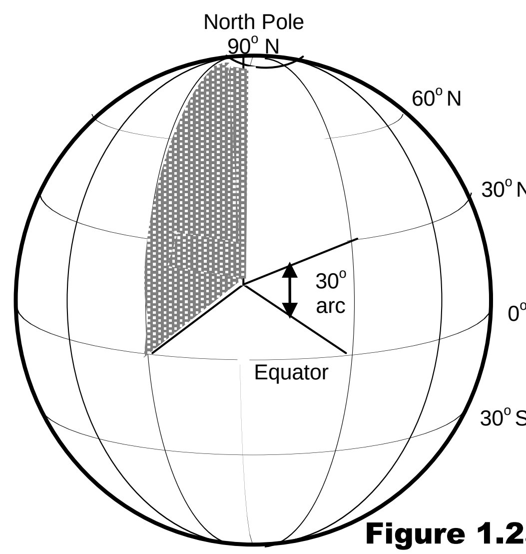


Figure 1.2a

For longitude the starting line was determined by international convention as running through Greenwich England and is known as the **Prime Meridian**. The subsequent meridians of longitude are the result of measuring angles of distance east and west of this line (meridian). Similar to the measurement of degrees of latitude, degrees longitude are also the angular distance with the vertex at the center of the Earth (Figure 1.2b). While parallels of latitude measure distance north and south, meridians of longitude measure distance east and west. All of the meridians converge at the poles and are of equal

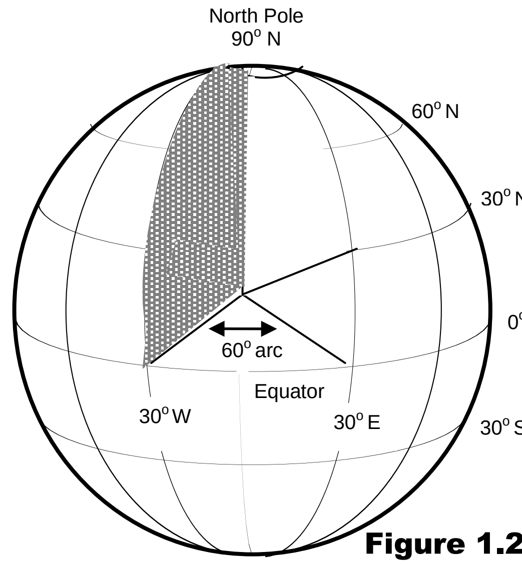


Figure 1.2b

length around the globe, whereas the parallels of latitude decrease in length as they move away from the equator towards the poles, but are equidistant.

The location of a place on the earth using the geographic grid is defined by **geographic coordinates**, i.e., latitude and longitude values. By tradition, one always states the latitude first, then the longitude. Directional labels, *north* or *south* for latitude and *east* or *west* for longitude must always be given except when the location falls upon the equator, 0 degrees latitude; Prime Meridian, 0 degrees longitude; or 180 degrees longitude—which is the same location for 180° West and 180° East.

More precise locations (angles) are measured in degrees (°), minutes ('), and seconds ("). Where 1 degree equals 60 minutes and 1 minute equals 60 seconds, 1' = 60". Below is an example of a detailed set of geographic coordinates for the road intersection in front of the Sullivan Building on the Salem State North Campus:

42° 30' 23" North Latitude; 70° 53' 28" West Longitude **or**
42.504° North Latitude; 70.888° West Longitude (using decimal form)

Measuring Distances using the Geographic Grid

When measuring distance in degrees of latitude and longitude, if the two locations are in the same hemisphere (north or south for latitude, east or west for longitude) one subtracts the smaller number from the larger number; if they are in different hemispheres, one adds them together. For example: the distance between 42° 30' N and 22° 10' N is 20° 20', while the distance between 42° 30' N and 22° 10' S is 64° 40'.

One should always measure the shortest distance between two points. Thus, one should never have a distance greater than 180° of longitude. For example, 170° W and 150° E yield 320° (which is the distance between these two points going the long way around the globe). In this case, to obtain the shortest distance subtract from 360° (360° – 320° = 40°).

The number of degrees between two locations may be converted into distance in miles (or kilometers) between the same two points by applying a conversion factor. In the case of latitude *each degree is equivalent to approximately 69 statute miles (111 km)* (the actual value varies slightly because the earth is not a perfect sphere). Therefore, for latitudinal distances (North – South) measured along a line of longitude are found by multiplying the distance in degrees by 69 miles or 111 kilometers.

The conversion of longitudinal degrees into statute miles is a bit more difficult since the number of degrees of longitude along a parallel is always the same, but the length of each parallel (circumference) becomes smaller as one moves from the equator towards the poles. *Therefore, the value of a degree of longitude varies from approximately 69 miles (111 kilometers) at the equator to 0.0 miles at either pole*. Longitudinal distances (East – West) measured along lines of latitude are determined by first finding the latitudinal location of the measurement and then using the appropriate conversion factor (i.e. 69, 53, 45, etc.) in Table 1 and multiplying it by the distance in degrees.

Statute miles may be converted into nautical miles by dividing the statute miles by 1.15. Nautical miles may be converted into statute miles by multiplying the nautical miles by 1.15.

TABLE 1 PARALLEL AND MERIDIAN ARC LENGTH DATA

Note: distances have been rounded off)

Latitudinal Location	**One Degree of Longitude** Statue Miles	Kilometers	**One Degree of Latitude** Statue Miles	Kilometers
0	69	111	69	111
10	68	110	**All North-South distances are the same**	
20	65	105		
30	60	96		
40	53	85		
50	45	72		
60	35	56		
70	24	38		
80	12	19		
90	0	0		

Note: The distance of one degree of latitude is always the same everywhere on the globe (69 miles or 111 km). For longitude, however, the distance for one degree of longitude changes depending on what degree of latitude the measurement is taken (left hand column).

Example: The distance between 20°W and 50°W at 20° N (latitude) = 50°-20°=30° difference,
at 20°N each degree of longitude = 65 miles (105 km), so 30° * 65 mi/deg = 1,950 miles.
at 50°N each degree of longitude = 45 miles (72 km), so 30° * 45 mi/deg = 1,350 miles.
at 70°N each degree of longitude = 24 miles (38km), so 30° * 24 mi/deg = 720 miles.

Internet resources for latitude – longitude

1. The Weather Underground is an excellent site to use to follow the daily weather anywhere in the world and can be used to follow any of the sites covered in this lab.
http://www.wunderground.com

2. World Atlas is an internet site explaining the basics about latitude and longitude as well as providing links to other latitude / longitude sites.
http://worldatlas.com/aatlas/imageg.htm

3. Marine Waypoints Latitude – Longitude Distance Calculator (great Circle distance calculator)
http://www.marinewaypoints.com/learn/greatcircle.shtml

4. View Above Earth – see what any point on earth looks like right now from space.
http://www.fourmilab.ch/earthview/vlatlon.html

Exercise #1 Lab Activity Name: ______________________________

Latitude / Longitude Lab Section: ______________________________

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

✎ 1) What name is given to the zero line (circle) of latitude? ________________________

✎ 2) What is the zero reference line (half circle) of longitude called? ________________________

✎ 3) Why is it necessary to include labels (North or South for latitude, East or West for longitude) when giving geographic coordinates? Explain.

✎ 4) Which lines are used to measure distance north and south? ________________________

✎ 5) Which lines are used to measure distance east and west? ________________________

✎ 6) Indicate which of the following sets of geographic coordinates are correct as shown and which are incorrect. If incorrect, circle the error in the sets of geographic coordinates and give the reason.

		correct	**incorrect**	**why incorrect**
a.	51°N, 75°W	_____	_______	______________________
b.	10°S, 182°E	_____	_______	______________________
c.	95° N, 72°W	_____	_______	______________________
d.	42°32' 38"N, 5°62' 02"E	_____	_______	______________________
e.	66°N, 74°W	_____	_______	______________________
f.	10°W, 52°E	_____	_______	______________________

✎ 7) Using a globe or atlas, determine the geographic coordinates of these cities to the nearest degree:

a. New York, NY ________________

b. Tokyo, Japan ________________

c. Sydney, Australia ________________

✎ 8) Using a globe, determine what city lies at each location given:

a. 54°N, 113°W ________________

b. 12°S, 77°W ________________

c. 62°N, 130°E ________________

Measuring Distance with the Geographic Grid

Using Figures 1.3a and 1.3b determine the distances.

✐ 9) (Figure 1.3a)

A – B = _____ degrees

B + C = _____ degrees

1° latitude = 69 statute miles

(A - B)° * 69 = ________ miles

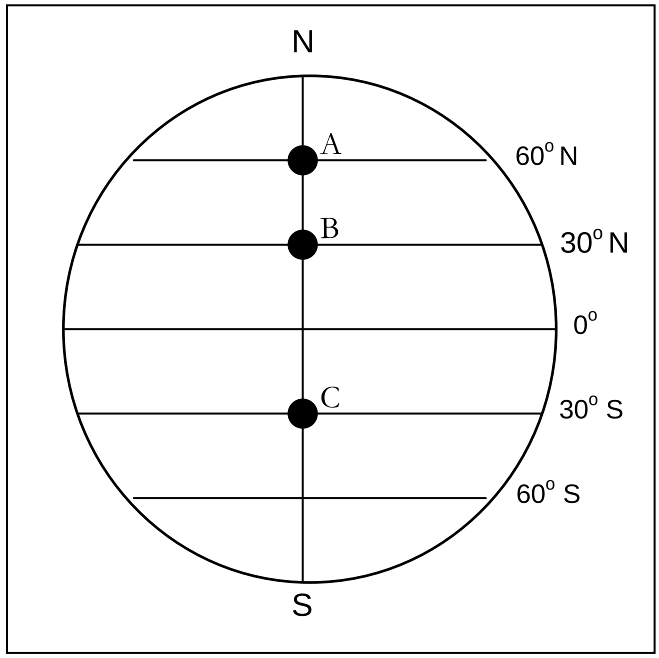
(B + C)° * 69 = ________ miles

1° latitude = 111 km.

(A - B)° * 111 = ________ km

(B + C)° * 111 = ________ km

Figure 1.3a



✐ 10) (Figure 1.3b)

D – E = _____ degrees

D + F = _____ degrees

1° longitude = 69 statute miles at 0°

(D – E)° * 69 = ________ miles

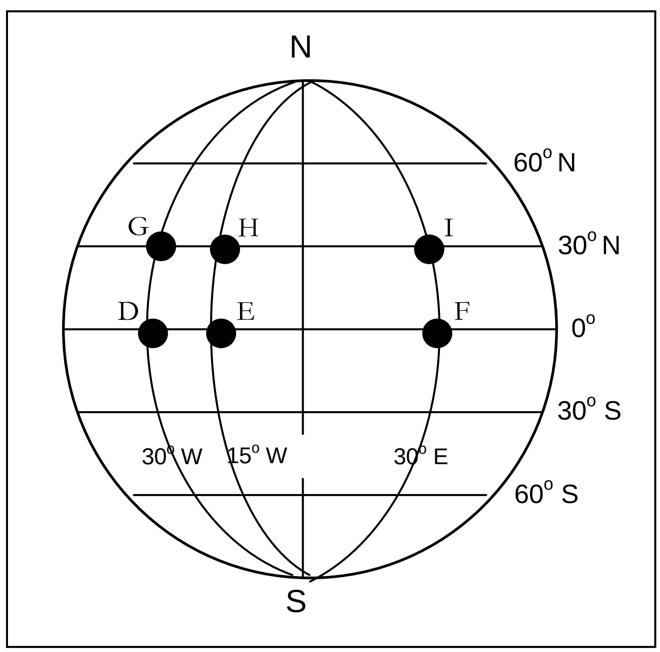
(D + F)° * 69 = ________ miles

1° longitude = 111 km at 0°

(D – E)° * 111 = ________ km

(D + F)° * 111 = ________ km

Figure 1.3b



G – H =_____ degrees

G + I = _____ degrees

1° longitude = 60 statute miles at 30°
(G – H)° * 60 = ________ miles

(G + I)° * 60 = ________ miles

1° longitude = 96 km at 30°
(G – H)° * 96 = ________ km

(G + I)° * 96 = ________ km

✐ 11) How many degrees of longitude (shortest distance) are between:

a. 90°E and 170°E ________________

b. 75°W and 105°W ________________

c. 75°W and 30°E ________________

d. 105°W and 105°E ________________ (special case involving International Date Line)

✐ 12) Find the shortest distance in statute miles and kilometers:

a. Between the Galapagos Islands (0°, 90° W) and the Howland islands (where Amelia Earhart disappeared (0°, 177° W).

Statute Miles ________________

Kilometers ________________

b. Between Seward, Alaska (60° N, 150° W) and Oslo, Norway (60° N, 12° E)

Statute Miles ________________

Kilometers ________________

c. Between Camden, NJ (40° N, 75° W) and Beijing, China (40° N, 118° E)

(special case involving International Date Line)

Statute Miles ________________

Kilometers ________________

d. Distance in Latitude: Between Albuquerque, NM (35° N, 107° W) and Boulder, CO (40° N, 107° W)

Statute Miles _______________

Kilometers _______________

Decimalization of Latitude and Longitude

The National Weather Service (NWS) uses the decimal system with degrees and tenths of degrees not degrees, minutes and seconds. For example, 42° 30' N is equal to 42.5° N. To decimalize a latitude and longitude all you need to do is to divide the minutes reading by 60 (i.e. 30'/60 = 0.5°, 45'/60 = 0.75°).

✎ 13) Decimalize the following latitude and longitude readings:

a.	25° 30' N	________________	b.	110° 15' E	________________
c.	10° 45' S	________________	d.	88° 5' N	________________
e.	5° 55' N	________________	f.	57° 47' 22" S	________________

During the semester you will become familiar with the following locations, as many of the upcoming labs will use them as examples. Please locate each of them on the globe or map in the lab room and give the country or region where each of them are located.

Place Name	**Country**	**Latitude**	**(rounded)**	**Longitude**	**(rounded)**
Barrow, Alaska	__________	71° 20' N	(71° N)	156° 00' W	(156° W)
Ulaan Baatar	__________	47° 56' N	(48° N)	107° 00' E	(107° E)
Salem, MA	__________	42° 31'N	(43° N)	70° 54' W	(71° W)
Rome	__________	41° 52' N	(42° N)	12° 37' E	(13° E)
Riyadh	__________	24° 31' N	(25° N)	46° 47' E	(47° E)
Singapore	__________	1° 18' N	(1° N)	103° 52' E	(104° E)
Dar es Salaam	__________	6° 48' S	(7° S)	39° 17' E	(39° E)
Santiago	__________	33° 28' S	(33° S)	70° 55' W	(71° W)
Cape Town	__________	33° 48' S	(34° S)	18° 28' E	(18° E)
Vostok	__________	78° 40' S	(79° S)	106° 52' E	(107° E)

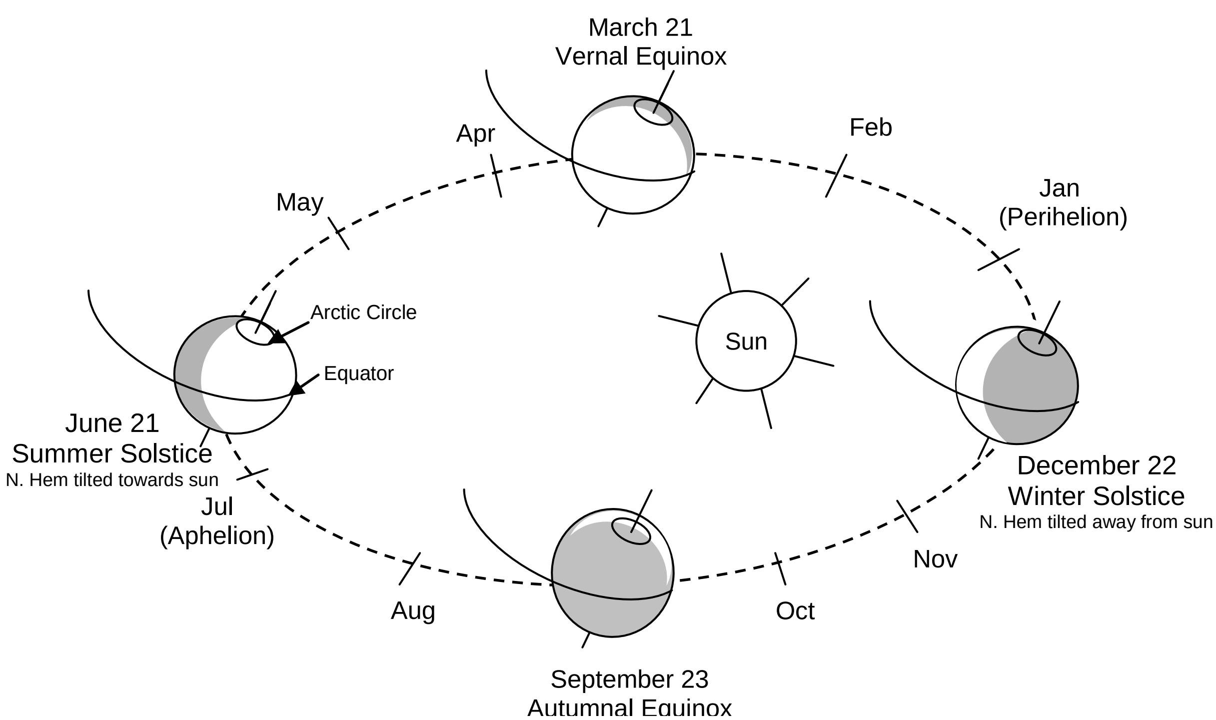
Lab 2

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.

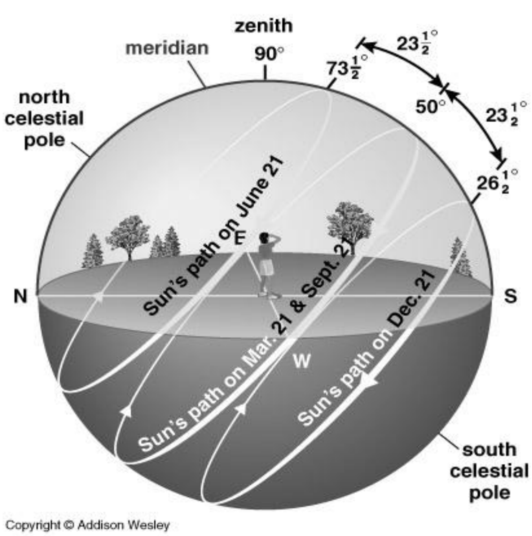
Figure 2.1 Earth's Elliptical Orbit



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.

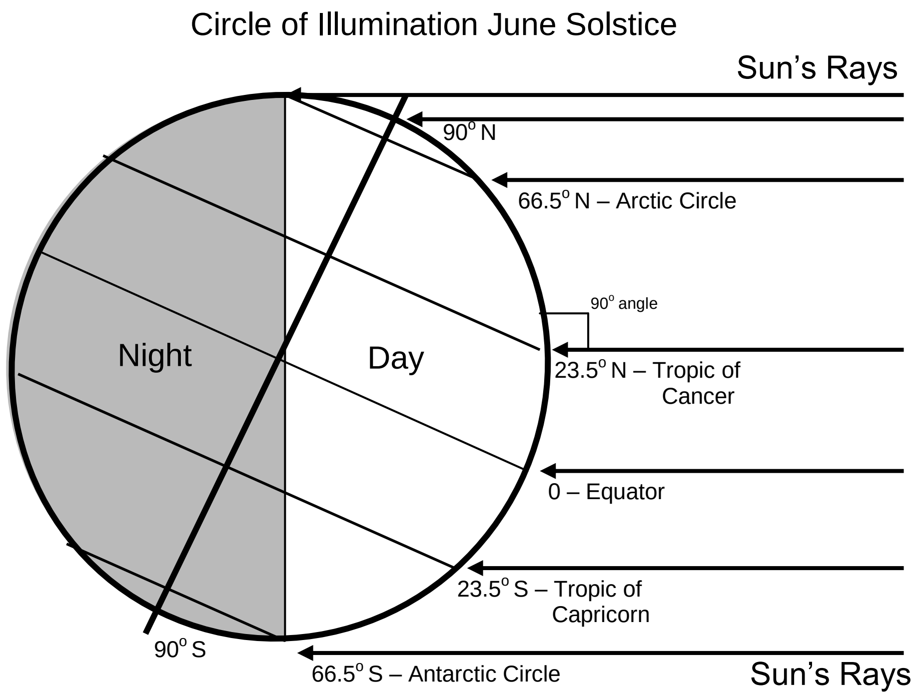
From this diagram it becomes clear that in northern latitudes in winter the days are shorter and the sun arcs south and low across the sky. Conversely, in summer the days are longer and the sun arcs high but still south. At the equinoxes the sun rises due east and sets due west (in the summer it rises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

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° 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° 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?

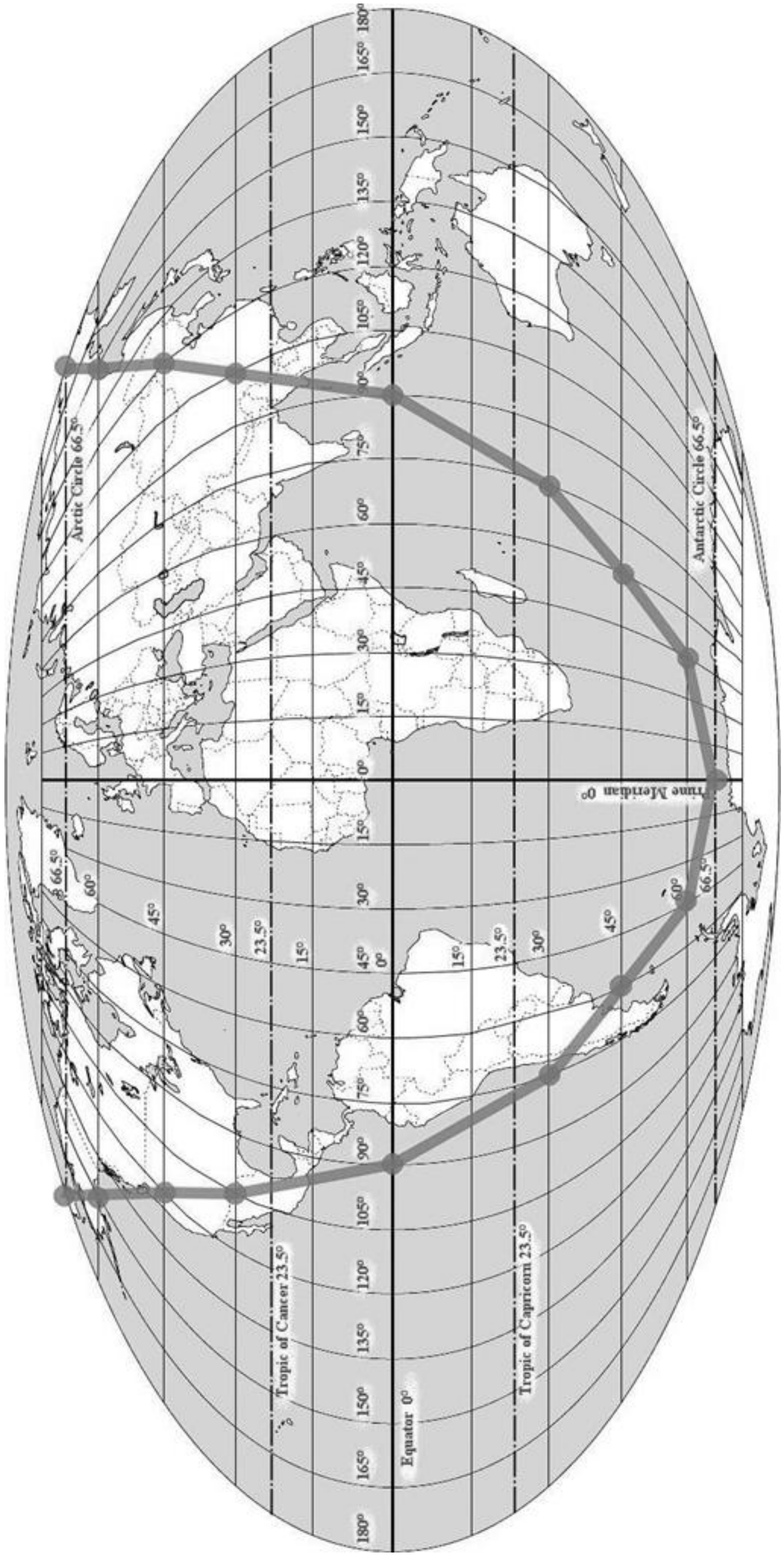
d. In Barrow in February?

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?

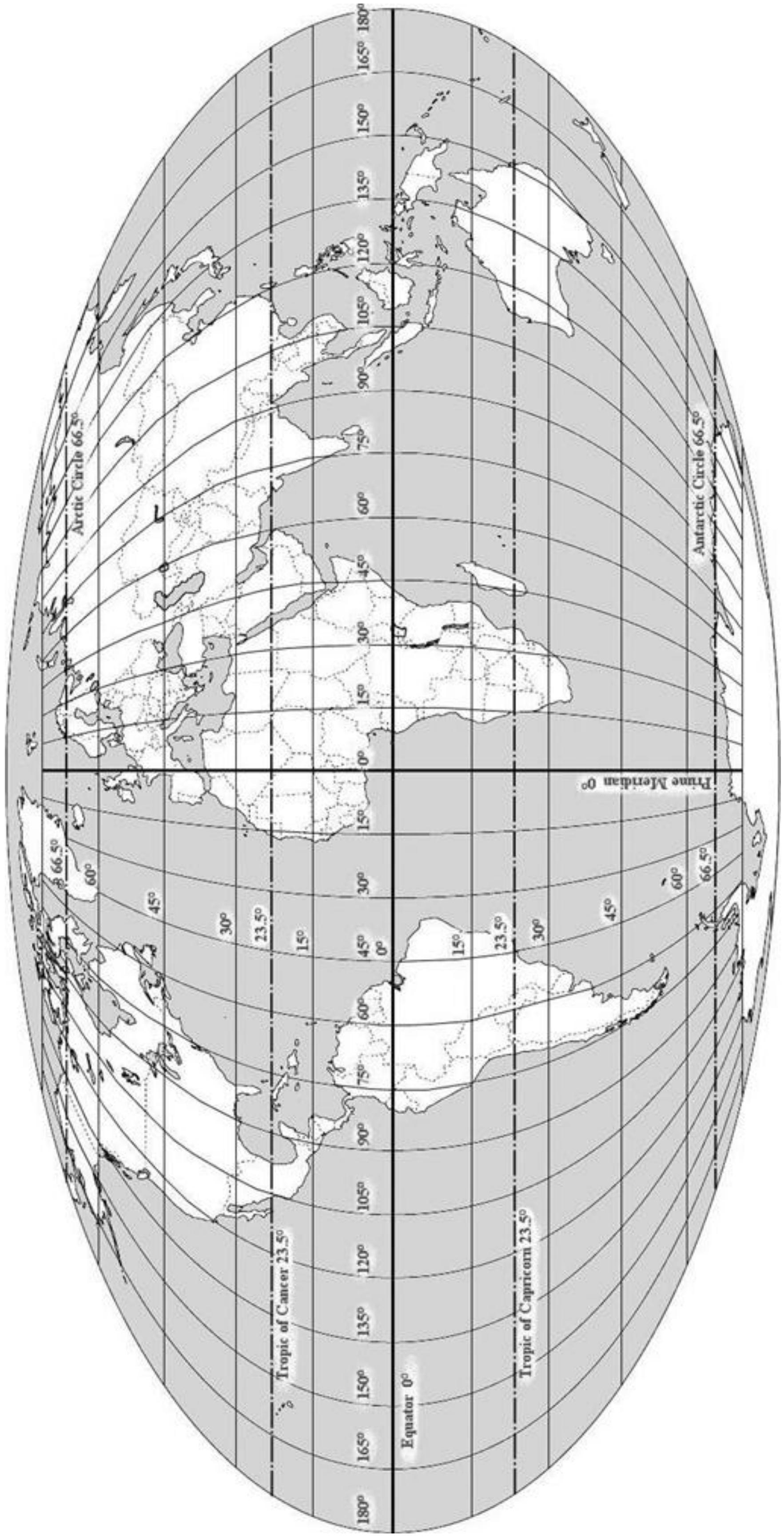
Map 1: June 21

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



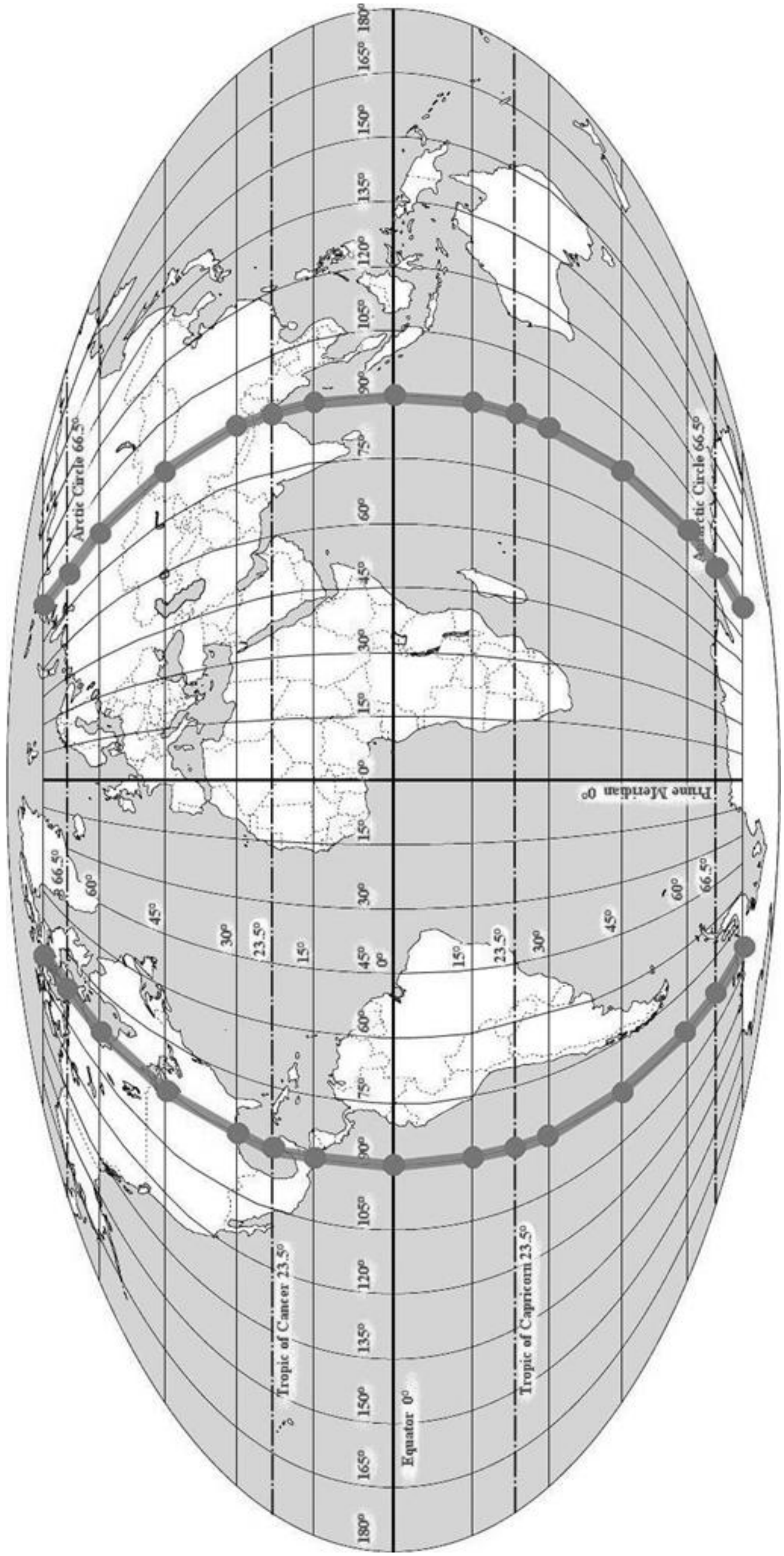
✏ Map 2:
December 22

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



Map 3:
March 21 &
September 21

Spring and Fall Equinoxes
for both Hemispheres



Lab
3

Sun Angle Calculations

The purposes of this lab are to acquaint the student with the relationships between sun angle and latitude, and to explain the method of noon sun angle calculations. The relationship between solar radiation and air temperature will also be explored.

Sun Angle and Latitude

🕮 Many concepts in this lab were introduced in Lab 2

The combination of: (a) **revolution**, (b) **inclination** of the Earth's axis, and (c) the **parallelism** of its axis, causes our seasons. These variables together result in a change in the angle of the Sun above the horizon. This is the major factor that leads to changes in our air temperatures from one season to another. The higher the Sun's angle above the horizon, the more intense the heating of the Earth's surface.

Two related Sun angle variations should be noted:

1. Sun angle varies in relation to latitude. The greater the latitudinal distance of one's location from where the Sun's rays are vertical on the Earth, the lower the angle of the Sun above the horizon is for the observer.

2. Sun angle varies during the year for all latitudes because the location of the Sun's vertical rays on the Earth is constantly changing, moving between the Tropic of Capricorn and the Tropic of Cancer throughout the year.

The Sun's noontime position in the sky (which is as high as it gets) is measured by calculating the number of degrees between the horizon and the Sun's position. This angle is referred to as the solar **altitude angle**, also known as noon sun angle (or noon solar angle).

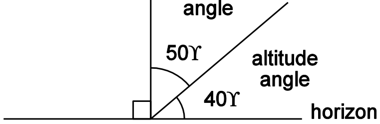


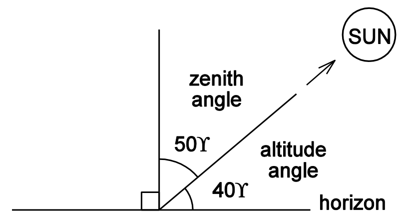
Figure 3.1

Figure 3.1 Solar Angles

The remaining angle between a point that is directly overhead and the Sun's rays is called the **zenith angle**. Therefore, the altitude angle and the zenith angle are complementary angles and always add up to 90°. In

Figure 3.1, the angle between the horizon and the Sun's rays is 40° (the altitude angle). The complement of that is 50°, which is the angle from directly overhead to the position of the Sun in the sky (the zenith angle). The zenith angle is also equal to the distance between the viewer's location and that of the vertical sun in degrees of latitude. Therefore there is a direct relationship between the altitude angle and the zenith angle where for every degree the sun is higher in the sky (altitude angle), the zenith angle decreases by one degree (one degree closer to the vertical rays of the Sun).

The above can be summarized in equation form as:



The sun angle (altitude angle) = $\angle$A

The zenith angle = $\angle$Z,

then

$\angle A + \angle Z = 90^o$, **$\angle A = 90^o - \angle Z$,** and **$\angle Z = 90^o - \angle A$.**

How to Calculate the Altitude Angle

You need to know:

1. The latitude in question (latitude of observer).
2. The latitude of the vertical Sun for the date in question (also termed the **solar declination**). This can be obtained through the use of an analemma which we provide on page 25.

You must determine:

1. The distance between the latitude in question and the latitude of the vertical Sun. This distance gives you the **zenith angle**.
2. The difference between the zenith angle and 90°. This gives you the **altitude angle** of the sun.

Example <u>Calculating the Solar Altitude Angle</u>

What is the noon sun angle at Salem, Massachusetts (43° N) on October 20?

1.	The latitude in question (of observer)	=	43° N
2.	The latitude of the vertical sun [see analemma]	=	10° S
3.	The distance between 43° N and 10° S	=	53°
4.	The zenith angle	=	53°
5.	The difference between the zenith angle and 90°	=	37° (90° – 53°)
6.	The altitude angle (at noon)	=	37°
7.	The Sun will be in	=	the Southern Horizon

Note: there are three key components:

1. latitude of the vertical sun (solar declination),
2. altitude angle, and
3. zenith angle.

If you know any two of the three you can always find the third. These calculations can be made to find the zenith angle if you are given the altitude angle, or to find the declination of the Sun (latitude of the vertical rays), or to get the latitudinal distance. The relationships are always the same.

North vs. South Horizons When Specifying Altitude Angle

An additional consideration relates to the direction in which the observer sees the Sun. When you look at the Sun at noon, you see it directly above you if you are at the latitude where the Sun is vertical. In all other situations you would view the Sun above the horizon to your North (if the vertical rays of the Sun are at a latitude north of your position), *or* you would see the Sun above the horizon to the South (if the vertical rays of the Sun are at a latitude that is south of your position). Note that this relationship is true regardless of the latitudinal label. The vertical rays of the Sun only strike between 23.5° N and 23.5° S. Therefore everywhere south of 23.5° S the Sun will always be to the north and north of 23.5° N the Sun will always be to the south. For us in Salem at 43 degrees North, the Sun is always above the southern horizon at solar noon.

Internet Resources for Sun Angle

1. This is a detailed sun angle calculator
http://www.susdesign.com/sunangle/

Here are the instructions:
http://www.susdesign.com/sunposition/instructions.html

2. This calculator is a little bit easier
http://www.geocities.com/senol_gulgonul/sun/

3. Basic calculator:
http://www.wattsun.com/resources/calculators/photovoltaic_tilt.html

Exercise #3 Lab Activity Name: ______________________

Sun Angles Lab Section: ______________________

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

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1) Calculate the altitude angle of the Sun at noon for the following problems:

	Latitude of Observer	Place	Date	Latitude of Vertical Ray	Distance from 90° Sun (∠Z)	Altitude Angle (∠A)	Horizon N/S
1.	**71° N**	**Barrow**	**March 21**	**0°**	**71°**	**19°**	**S**
2.	48° N	Ulaan Baatar	March 21	0°	________	______	_____
3.	43° N	Salem	March 21	0°	________	______	_____
4.	24° N	Riyadh	March 21	0°	________	______	_____
5.	1° N	Singapore	March 21	0°	________	______	_____
6.	7° S	Dar es Salaam	March 21	0°	________	______	_____
7.	33° S	Cape Town	March 21	0°	________	______	_____
8.	79° S	Vostok	March 21	0°	________	______	_____

	Latitude of Observer	Place	Date	Latitude of Vertical Ray	Distance from 90° Sun (∠Z)	Altitude Angle (∠A)	Horizon N/S
9.	43° N	Salem	Sept. 23	_____	________	______	_____
10.	43° N	Salem	June 21	_____	________	______	_____
11.	43° N	Salem	Dec 22	_____	________	______	_____
12.	1° N	Singapore	Sept. 23	_____	________	______	_____
13.	1° N	Singapore	June 21	_____	________	______	_____
14.	1° N	Singapore	Dec 22	_____	________	______	_____

	Latitude of Observer	Place	Date	Latitude of Vertical Ray	Distance from . 90° Sun (∠Z)	Altitude Angle (∠A)	Horizon N/S
15.	33° S	Cape Town	March 21	______	____________	________	______
16.	33° S	Cape Town	June 21	______	____________	________	______
17.	33° S	Cape Town	Dec 22	______	____________	________	______
18.	79° S	Vostok	March 21	______	____________	________	______
19.	79° S	Vostok	June 21	______	____________	________	______
20.	79° S	Vostok	Dec 22	______	____________	________	______

Note: each of the Places below are one of the ten places introduced at the end of Lab 1. Given the data below you should be able to determine the latitude of the place and then based on the latitude you should be able to name the place (see the list of places at the end of lab 1).

	Latitude of Observer	Place	Date	Latitude of Vertical Ray	Distance from 90° Sun (∠Z)	Altitude Angle (∠A)	Horizon N/S
21.	______	______	______	0°	____________	48°	S
22.	______	______	______	23.5°° S	____________	35.5°	N
23.	______	______	Nov. 22	20° S	45°	________	S
24.	______	______	______	23.5° N	____________	67.5°	N
25.	______	______	April 22	12° N	36°	________	S
26.	______	______	May 9	17° N	54°	________	S

A practical application of altitude angle

You now have an understanding of solar energy versus solar altitude angle. With this newly acquired knowledge, one can more efficiently design a new home with energy savings in mind. Depicted is a sketch of your proposed new home. On the south-facing side, you will have large picture windows that will enable you to take advantage of the delightful scenery. However, with large windows, it is important to consider energy saving ideas. **The latitude of your home is 42.5°N near Salem, MA.**

How far should you extend the roof eave for better energy savings? First, determine the altitude angles (Sun angles) at solar noon for June 21 and December 22. Then, using a protractor, plot these angles to show two sets of parallel lines (one set for each season) intersecting both the top and the bottom of the south facing picture windows. One set of line represents the sun's rays for the first day of summer, while the other will show the solar rays on the first day of winter. Each set must be drawn at the proper angle showing **only** the rays that could enter through the window. Label each set of lines by season.

Now, you can extend the roof overhang with solid lines so that the **maximum winter solar radiation** will enter the window in December and so that there will be **minimal summer solar radiation** entering the window in June.

Computations

Altitude angle December 22

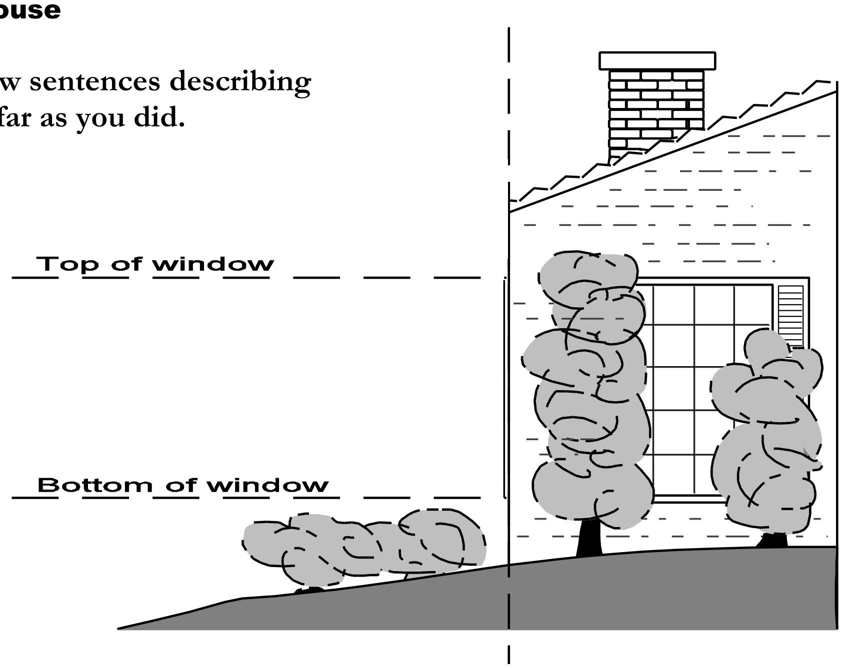
a. Lat. in question =
b. Lat. vert. sun =
c. Zenith angle (degree distance between a & b) =
d. Alt. angle (90° - the zenith angle) =

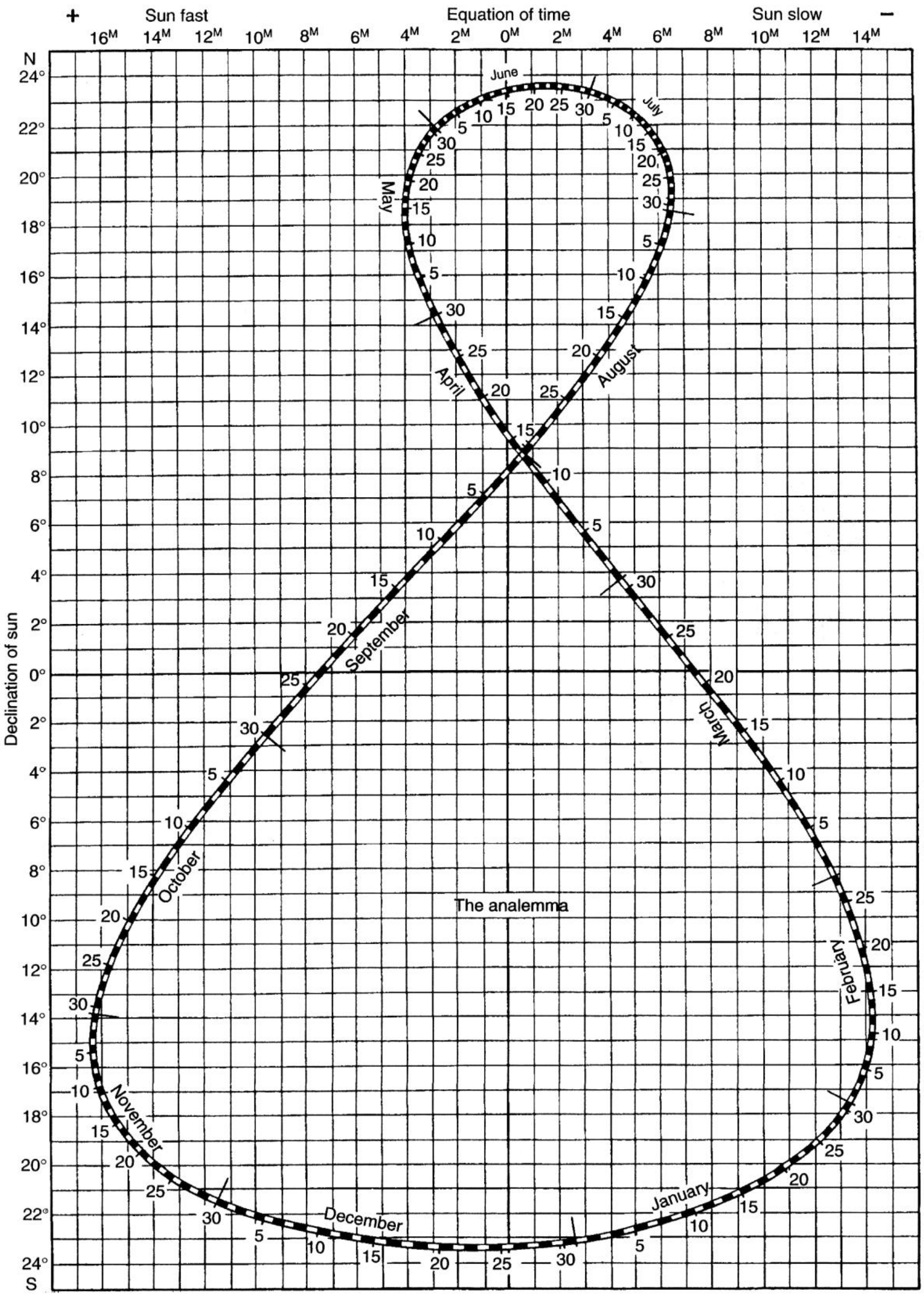
Altitude angle June 21

a. Lat. in question =
b. Lat. vert. sun =
c. Zenith angle (degree distance between a & b) =
d. Alt. angle (90° - the zenith angle) =

Figure 3.2 South side of a house

Write below your drawing a few sentences describing why you extended the roof as far as you did.





The Analemma gives the declination of the sun and the equation of time for each day in the year. From U.S. Coast & Geodetic Survey.

Figure 3.3 The Analemma

Lab
4

Solar Radiation & Temperature

The purposes of this lab are to:1) continue with the concepts of solar altitude angle and show how it has a direct relationship with air temperature; and 2) familiarize the student with reasons for different air temperatures around the world due to the Earth-Sun relationship and changing sun angles.

Insolation

Insolation (short wave radiation from the Sun) is the primary source of energy in the Earth's environment even though the Earth intercepts only a very small portion of the total energy emitted by the Sun. While the amount of insolation reaching the outer edge of the Earth's atmosphere is fairly constant, the amounts of such energy reaching the ground vary with different times and locations.

The intensity of insolation at the Earth's surface is affected by many variables, such as:

1) The sun angle above the horizon,
2) Length of period of sunlight exposure,
3) Existing atmospheric conditions, and
4) Amount of reflection, scattering, and absorption of Solar rays by the Earth's atmosphere.

Incoming short-wave energy from both the direct solar beam and indirect sky radiation are simultaneously measured with an instrument known as a **pyranometer**. The intensity of solar radiation calculated by the pyranometer is in a unit of measurement called **langleys**. A langley constitutes a unit of heat energy having one gram calorie per square centimeter. (A **calorie** is the amount of heat needed to raise the temperature of one gram of water by one degree **Celsius**.)

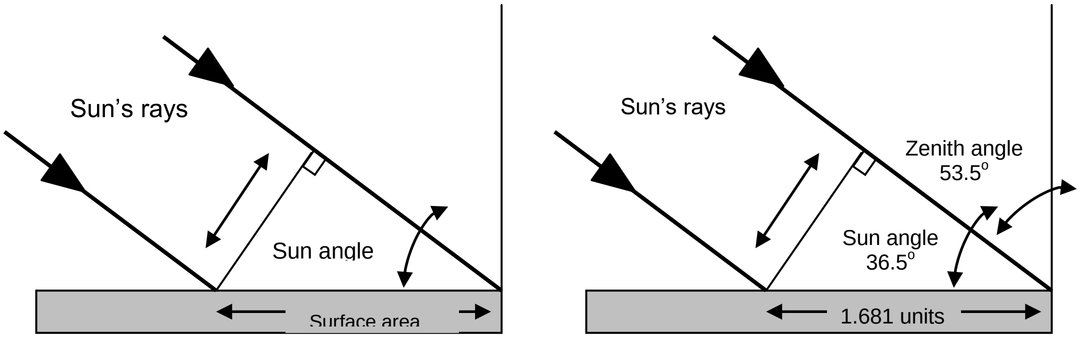
The **solar constant*** is the average intensity of vertical rays of solar energy striking a flat surface at the top of the Earth's atmosphere. Its value is approximately 2.0 langleys per minute. As solar energy passes through the atmosphere, some of it is lost due to absorption and scattering causing the intensity to drop below 2.0 langleys.

***** Also expressed as 2 gram calories per centimeter^2 per minute.

Calculating Solar Intensity

Sun angle (Altitude Angle) is very important because it affects the intensity of solar radiation reaching the ground. When altitude angles are large (i.e. closer to 90°) solar rays are more direct. As altitude angle decreases, radiation is spread over a larger surface area. When more surface area "shares" the solar energy, the intensity of the energy received is less.

Figure 4.1 Solar Angle and Surface Area



Determining the surface area of solar radiation

The surface area that the beam of solar radiation covers changes with the solar altitude angle and can be determined through trigonometry. The following equations are used to determine the surface area:

$$\sin(\text{altitude angle}) = \frac{1 \text{ unit width}}{\text{surface area}} \qquad \text{surface area} = \frac{1}{\sin(\text{altitude angle})}$$

For example, if the altitude angle = 50°.

$$\text{surface area} = \frac{1}{\sin(50°)} = \frac{1}{0.766} = 1.305$$

This means that 1 unit area of sunshine striking the earth with an altitude angle of 50° will be spread over an area of 1.305 (i.e. an area 30.5% larger). As solar radiation is spread over more of the Earth's surface, the intensity of the beam decreases according to the following equation:

Percent of beam intensity = sin(altitude angle) * 100

For example, if the altitude angle = 50°; sin(50°) = 0.766 (100 * 0.766 = 76.6) or 76.6%.

Internet Resources for Solar Radiation & Temperature

1. USA Today Temperature Conversions
http://www.usatoday.com/weather/wtempcf.htm

2. USA Today Heat Index Wind Chill
http://www.usatoday.com/weather/wheat3.htm
http://www.usatoday.com/weather/windchil.htm

4. This web site calculates average monthly sun angle of any latitude on the Earth:
http://www.wattsun.com/resources/calculators/photovoltaic_tilt.html

Exercise #4 Lab Activity

Name: ______________________________

Solar radiation & Temperature

Lab Section: ______________________________

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

Part A: Fill in the blanks below based on the formulas above.

Place	Latitude of Place	Latitude of Vertical Ray	Zenith Angle	Altitude Angle	Surface Area of Radiation	% of Beam Intensity
1. Salem, MA	**43° N**	**0°**	**43°**	**47°**	**1.367**	**73%**
2. Salem, MA	**43° N**	23.5° N	_____	_____	________	________
3. Salem, MA	**43° N**	23.5° S	_____	_____	________	________
4. Barrow	71° N	23.5° N	_____	_____	________	________
5. Barrow	71° N	0°	_____	_____	________	________
6. Barrow	71° N	23.5° S	_____	_____	________	________
7. Singapore	1° N	23.5° N	_____	_____	________	________
8. Singapore	1° N	0°	_____	_____	________	________
9. Singapore	1° N	23.5° S	_____	_____	________	________
10. Cape Town	34° S	23.5° N	_____	_____	________	________
11. Cape Town	34° S	0°	_____	_____	________	________
12. Cape Town	34° S	23.5° S	_____	_____	________	________
13. Vostok	79° S	23.5° N	_____	_____	________	________
14. Vostok	79° S	0°	_____	_____	________	________
15. Vostok	79° S	23.5° S	_____	_____	________	________

The Balance Between Insolation & Air Temperature

The following section illustrates the relationship between mean monthly insolation values and mean monthly air temperature for the Boston area.

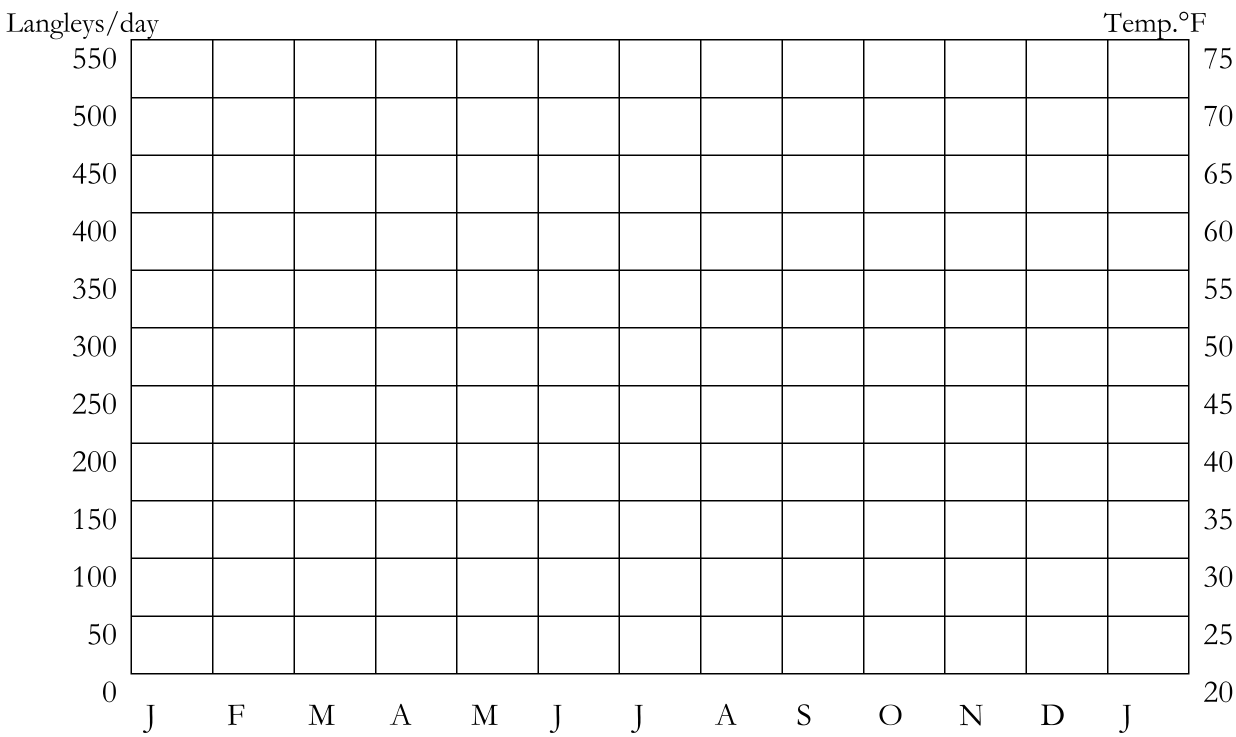
Table 4.1
MEAN MONTHLY INSOLATION – BOSTON AREA
Solar radiation in Langleys/day

Jan.	139	Apr.	364	July	496	Oct.	238
Feb.	198	May	472	Aug.	425	Nov.	145
Mar.	293	June	499	Sept.	341	Dec.	119

Table 4.2
MEAN MONTHLY AIR TEMPERATURE – BOSTON AREA
Temperature in degrees Fahrenheit

Jan.	27	Apr.	45	July	72	Oct.	52
Feb.	28	May	57	Aug.	69	Nov.	41
Mar.	35	June	68	Sept.	63	Dec.	32

Mean Monthly Solar Radiation and Temperature Graph



✐Plot the following information on the graph provided:

a. Plot the *insolation values* (solar radiation) from Table 4.1 using the left side of the graph for each month of the year. After plotting, connect all the points with a smooth, curved line.

b. Plot the *temperature values* from Table 4.2 using the right side of the graph for each month of the year. After plotting, connect these points with a smooth, dashed line.

After carefully analyzing the relationship illustrated by the lines you have graphed for Insolation and Air Temperature, answer the following:

✐16. Describe the pattern of the insolation curve in terms of *minimum* and *maximum* values during the course of the twelve months of the year.

✐17. Based on the graph and your understanding of sun angles from the prior lab, what is the relationship between insolation values and sun angles during the year?

✐18. Briefly describe the pattern of *mean air temperature values* in terms of minimum and maximum values during the year.

✐19. Compare the *insolation curve* to the *air temperature curve*. How does the *pattern* differ between the two? (Keep in mind that air temperature is ultimately a result of incoming solar radiation.)

✐20. Explain why the difference occurs between the air temperature and insolation curves. That is, why is there a lag in the temperature curve? (This is related to the *direct* source of energy heating the air.)

Specific Heat of Land and Water; Continental and Maritime Effects

The **specific heat** of a substance is the amount of heat energy required to raise the temperature of 1 gram of that substance by 1 degree Celsius. If we generalize about the surface of the earth, we might say that all water areas have a Specific Heat of 1.0 (Cal/g x °C) and all land areas exhibit a Specific Heat of 0.5 (Cal/g x °C). The significance of this fact is that land areas will heat up more quickly and cool off more quickly than water areas and that water areas will take longer to become warm and longer to cool off.

In addition, if land and water areas were recorded as having the same temperature, the water area would be holding considerably more heat since it required more heat energy to get to that temperature than for the land area. The foregoing information leads to the concepts of **continental** and **marine** (Maritime) climate effects.

Land areas in the mid-latitudes (Westerly wind belt) that are on the windward side of a large water body will experience moderation in temperatures especially during winter and summer; whereas areas that are surrounded by large expanses of land (interior of continents) will exhibit extreme conditions of temperature in winter and summer.

Using the mean monthly temperature data listed below, plot temperature curves for Denver, CO, Springfield, MO, and San Francisco, CA on the graph on the following page. Use a solid line for Denver (——), a dashed line (– – –) for Springfield, and a dash and dot line (– · – · –) for San Francisco.

Place	**Elevation**	**Latitude**	**Mean Annual Air Temperature**
DENVER, CO	5,292'	39° 32' N	50 ° F
SPRINGFIELD, MO	1,324'	37° 17' N	56 ° F
SAN FRANCISCO, CA	8'	37° 27' N	55° F

	J	F	M	A	M	J	J	A	S	O	N	D
DENVER	30	32	39	47	56	66	72	71	62	50	39	33
SPRINGFIELD	34	35	45	56	64	73	77	76	70	58	46	36
SAN FRANCISCO	49	51	53	54	56	57	57	58	60	59	56	51

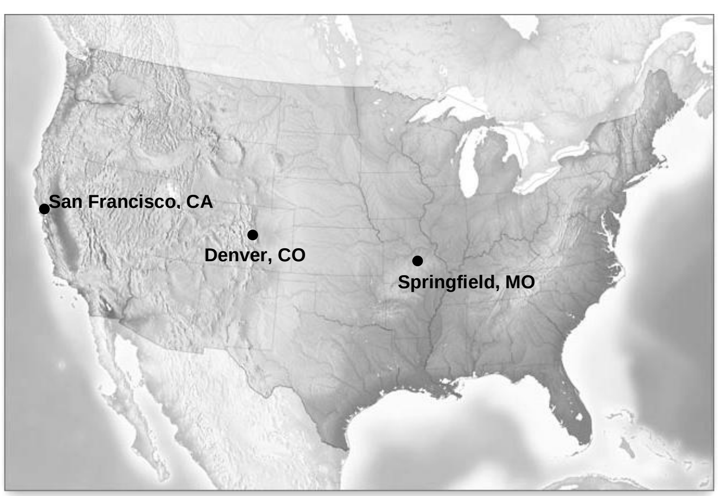
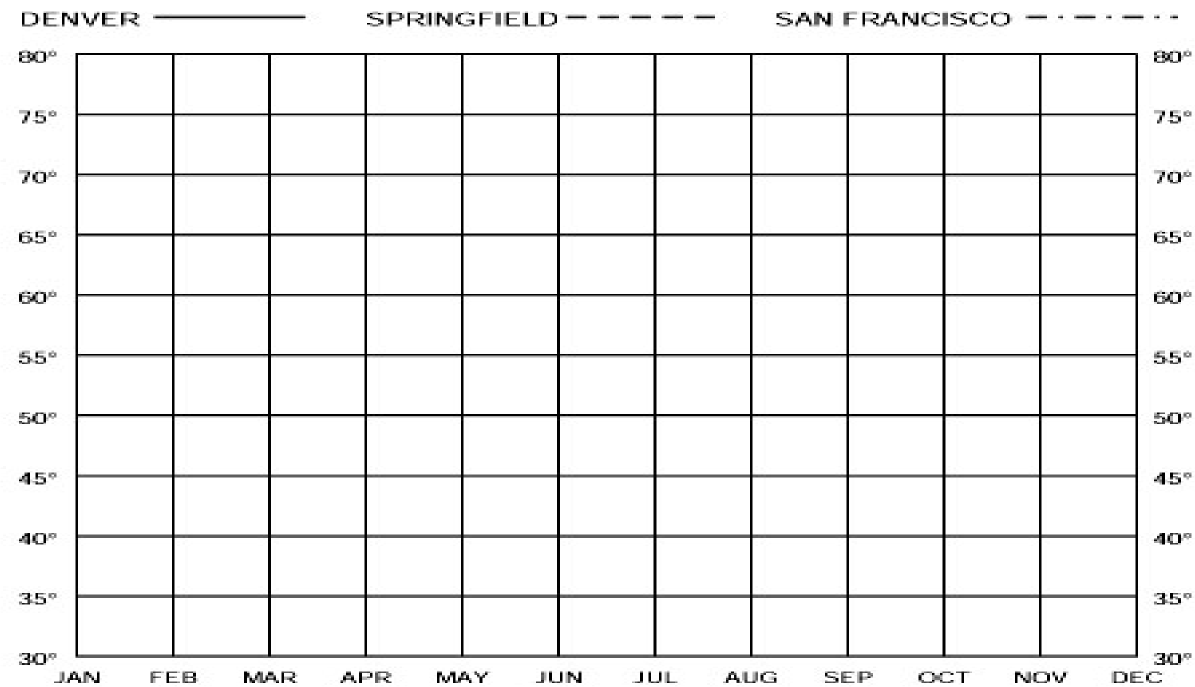


Figure 4.2
Map of city locations

TEMPERATURE CHART FOR DENVER, SPRINGFIELD, AND SAN FRANCISCO



After analyzing each temperature curve on the graph and comparing it to the information on elevation, latitude, and mean annual temperature, answer the following questions.

✐21. Which of the three cities has the greatest variation in annual range of temperature? Explain the factors accounting for this.

✐22. Compare San Francisco's temperature curve with those of Denver and Springfield. Describe the differences in the San Francisco curve.

✐23. Why is Denver always slightly cooler than Springfield?

✐24. Explain the factors that influence the San Francisco curve. (Note: next to San Francisco there is a cold ocean current, especially in summer.)

✐25. For each of the three cities, determine the month in which the maximum temperature occurs. Explain why the maximum occurs at this time in each case.

Temperature Scales and Conversions

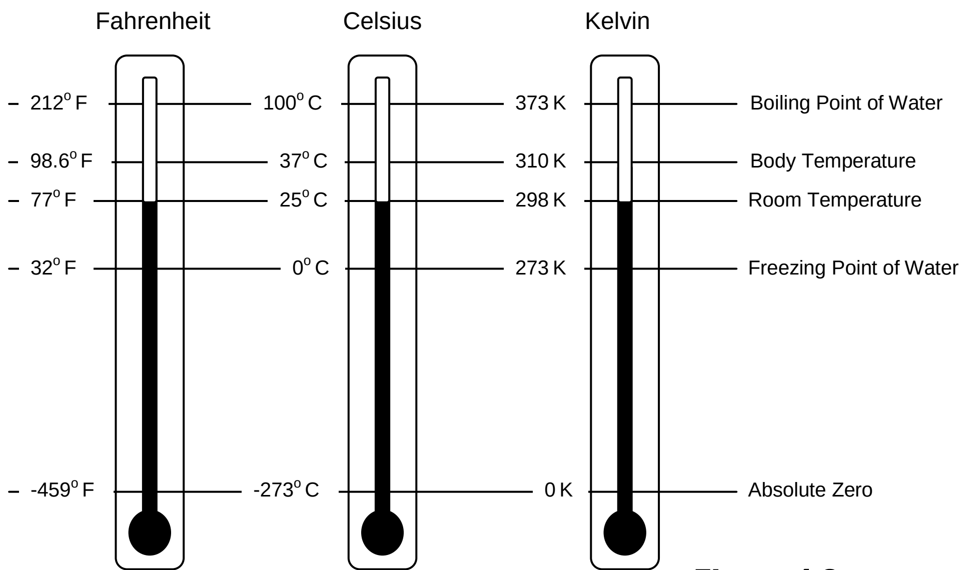


Figure 4.3

Figure 4.3 shows the most common temperature scales and shows how they relate to each other based on several important temperatures such as the freezing point of water.

To convert from one temperature scale to another, use the following:

$$°Fahrenheit = (1.8 \times °C) + 32 \qquad °Celsius = \frac{°F - 32}{1.8} \qquad °Kelvin = °C + 273$$

✐26. Convert the following Fahrenheit temperatures to Celsius.

a. 25 °F =

b. 92 °F =

✐27. Convert the following Celsius temperatures to Fahrenheit.

a. 15 °C =

b. 50 °C =

✐28. Convert 45 °F to Kelvin.

.

Lab

5

Atmospheric Moisture

Concepts about atmospheric humidity will be introduced in this lab along with the role of atmospheric moisture in the formation of clouds and precipitation.

Moisture

In terms of weather, **water vapor** is the most important of all atmospheric gases. The amount of moisture present in an air mass has a direct influence on cloud formation and possible precipitation within that air mass. The presence of this water vapor is referred to as **humidity**, and its measurement at a particular time and place may be expressed in several ways. Each of these provides different information about the amount of water present

- Vapor pressure (mb) is the pressure exerted by water vapor molecules.
- Dew point (°C or °F) is the temperature at which condensation begins as an air parcel cools (assuming no change in moisture).
- Relative humidity (%) is the moisture content relative to the saturation point.

Relative Humidity is the most common measurement of water vapor content within the air. Briefly defined, relative humidity (R.H.) is the amount of water vapor actually present in the air relative to the capacity amount it is capable of holding at a given temperature. The **capacity** (or maximum) amount of gaseous water vapor is known as the saturation amount. At **saturation**, the relative humidity is equal to 100 percent. Temperature is a critical factor in influencing the point at which saturation is reached. To determine the R.H., the actual number of water molecules present in a given amount of air is divided by the maximum number of water molecules possible in that amount of air (at the same temperature).

$$\frac{\textbf{Actual Water Vapor}}{\textbf{Capacity (maximum)}} * 100 = \textbf{Relative Humidity (\%)} \qquad \textbf{OR}$$

$$\textbf{Actual Water Vapor} = \frac{\textbf{Relative Humidity (\%) * Capacity}}{100}$$

At any given temperature, there is an upper limit on the amount of water that can exist as a gas. When that limit is reached, the atmosphere is said to be saturated; any additional water condenses to liquid. The saturation point increases with increasing temperature and decreases with decreasing temperature. When water vapor reaches the saturation point, the air temperature at which this occurs is termed the **dew point** temperature. Although dew point is a temperature, it also indicates moisture content. If dew point is low, the atmosphere is considered dry. If dew point is high, the atmosphere is moist. Dew point is always less than or equal to the current air temperature.

Water vapor molecules exert a certain amount of pressure on the surrounding atmosphere. This **water vapor pressure** varies according to the amount or concentration of water molecules in a given parcel of air. We can measure this amount of vapor pressure in **millibars** (mb) and also utilize this measure to determine saturation and relative humidity. We can substitute these terms in the previous R.H. equation:

$$\frac{\textbf{Actual Vapor Pressure (mb)}}{\textbf{Saturation Vapor Pressure (mb)}} * 100 = \textbf{Relative Humidity (\%)}$$

Therefore, the maximum possible or "upper limit" of atmospheric vapor pressure is referred to as **saturation vapor pressure**. As the temperature of a parcel of air increases, the saturation vapor pressure will increase proportionally.

Recap:

Saturation amounts may be expressed as a percentage (R.H.), or as millibars of vapor pressure or as weights of water vapor per weight of dry air. The pressure exerted by water vapor at saturation is called saturation vapor pressure. When the air is saturated with water vapor its relative humidity has reached 100% and the air temperature is the same as the dew point. The higher the dew point, the greater the amount of water vapor in the air.

A commonly used term by meteorologists to express humidity is the **mixing ratio**. The capacity amount of water vapor using the mixing ratio is known as the **saturation mixing ratio**.

Useful equations to determine R.H. are summarized below:

Water Vapor Pressure (mb)

$$\frac{\textbf{Actual water vapor pressure (mb)}}{\textbf{Saturation water vapor pressure (mb)}} * 100 = \textbf{Relative Humidity (\%)}$$

Mixing Ratio

$$\frac{\textbf{Actual mixing ratio (g/kg)}}{\textbf{Saturation mixing ratio (g/kg)}} *100 = \textbf{Relative Humidity (\%)}$$

Figure 5.1 (next page) is a graph, which shows the relationship between air temperature (x – axis) and the capacity of the air to hold water vapor (y-axis) at different temperatures. This graph shows that as air becomes warmer, its capacity to hold moisture increases, and it increases at a geometric rate.

Figure 5.1 Temperature & Water Vapor Capacity (Mixing Ratio)

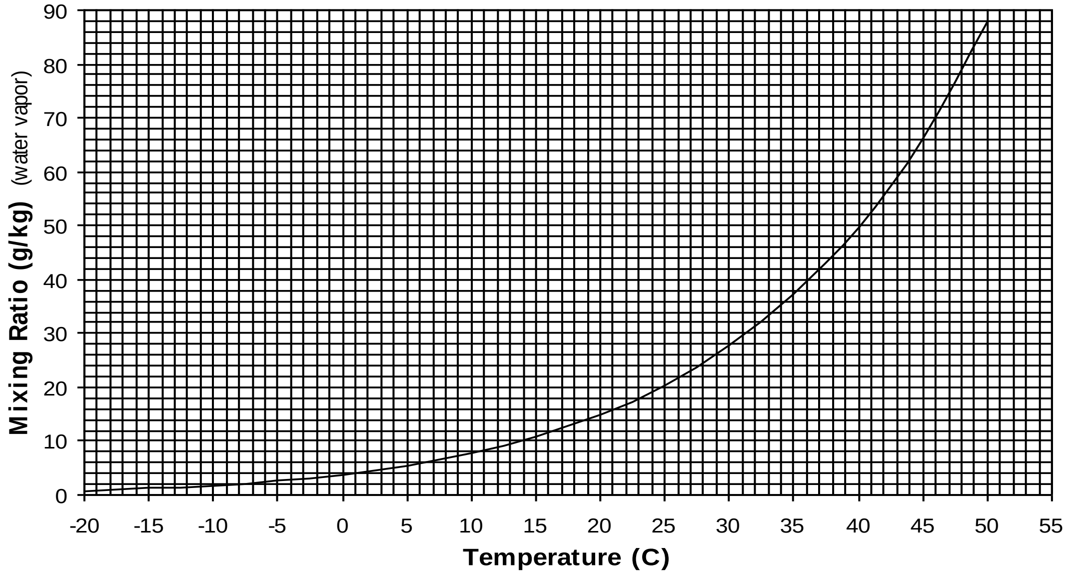


Table 5.1 (next page) provides the Saturation Mixing Ratio (or capacity of the air to hold moisture at a given temperature).

One can find the relative humidity of the air if you know the amount of water vapor in the air and the temperature of the air. For example, using Table 5.1: if the air is 15° C and there are 5 grams of moisture in the air the relative humidity will be:

$$\textbf{Relative Humidity} = \frac{\textbf{Actual Water Vapor}}{\textbf{Capacity (maximum)}} \ \frac{\textbf{(5)}}{\textbf{(10)}} = \textbf{0.5 * 100 = 50\%}$$

One can also find the actual water vapor of the air if you know the relative humidity and the temperature of the air. For example, using Table 5.1: if the air is 15° C and the relative humidity is 50%, the actual water vapor will be:

$$\textbf{Actual Water Vapor} = \frac{\textbf{Relative Humidity * Capacity}}{\textbf{100}}$$

Actual Water Vapor = (50 * 10)/100 = 500/100 = 5 grams

A Note on Temperature Scales (°F and °C):

There are three main temperature scales: Celsius (metric), Fahrenheit (English), and Kelvin (scientific). In labs we will be using both the Celsius and the Fahrenheit scales.

Conversions:

°F – (1.8 * °C) + 32 $\qquad$ $°C = \frac{°F - 32}{1.8}$ $\qquad$ °K = °C + 273

Melting Point of Ice	=	0 °C,	32 °F,	273 °K
Boiling Point of Water	=	100 °C,	212 °F,	373 °K

Exercise #5a Lab Activity Name: ____________________

Moisture Lab Section: ____________________

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

Table 5.1 Capacity Table (Saturation Mixing Ratio) (at Sea-Level Pressure)

Temperature	°C	(°F)	Capacity *(Saturation Mixing Ratio g/kg)*
	-40	(-40)	0.1
	-30	(-22)	0.3
	-20	(-4)	0.75
	-10	(14)	2
	0	(32)	3.5
	5	(41)	5
	10	(50)	7
	15	(59)	10
	20	(68)	14
	25	(77)	20
	30	(86)	26.5
	35	(95)	35
	40	(104)	47

✏ 1. Based on Table 5.1, what is the **Capacity** (Saturation Mixing Ratio) of:

a. -30 °C air mass ____________________

b. 5°C air mass ____________________

c. 40°C air mass ____________________

✏ 2. What pattern do you notice with the Capacity as air temperature rises?

✏ 3 If a parcel of air at 20°C contains 5 grams of water vapor per kilogram of air, what is its relative humidity?

✏ 4. If a parcel of air at 30°C contains 5 grams of water vapor per kilogram of air, what is its relative humidity?

✏ 5. If the same parcel of air (30°C) dropped in temperature to 5°C, how would the relative humidity change?

✐ 6. If a parcel of air at 15°C contains 10 grams of water vapor per kilogram of air, what is its relative humidity?

✐ 7. What is the actual water vapor amount in 20°C air when the relative humidity is 50%?

✐ 8. If a 25°C air mass is saturated, what is the actual water vapor amount?

✐ 9. What is the dew point of a 25°C parcel of air containing 14 grams of water vapor per kg of air?

✐ 10. On a cold day in December the relative humidity measures 20% and on a hot day in August, the relative humidity also measures 20%. Does this indicate the same water vapor presence on both days? Explain your answer.

✐ 11. During the winter months, cold air is brought into homes and heated. Explain how this process changes the relative humidity in the house. In order to compensate for this phenomenon many homes utilize an appliance to keep their surroundings comfortable; what might this be?

✐ 12. An air mass with a temperature of 5°C is saturated. If this air is brought into a house and heated up to 25°C, what is the relative humidity of this air in the house?

✐ 13. Cold, continental polar air is often described as being dry even when its relative humidity is very high. Why is this so?

Determining Relative Humidity and Dew Point Temperature based on the Sling Psychrometer

The sling psychrometer is an easy and accurate instrument for making observations of relative humidity and dew point temperature. The instrument is made up of two thermometers. One of the thermometers has a wet cloth, or "sock," over it and is known as the **wet bulb**, while the other has nothing on it and is known as the **dry bulb**. The dry bulb and the wet bulb are swung together in the air and the dry bulb records the air temperature while the resulting evaporation of water from the "sock" reduces the temperature of the wet bulb.

The temperature of the wet bulb is either the same as or less than the dry bulb. When water is evaporated from the sock, the cooling effect of evaporation reduces the temperature of the wet bulb. The greater the difference between the wet bulb and the dry bulb, the drier the air is because more water is able to evaporate and thus there is more of a cooling effect on the wet bulb. When the air is near saturation, that is, has a high relative humidity, very little water will evaporate from the wet bulb and thus the temperature of the two thermometers will be close to each other. The difference in temperature between the two bulbs equals the **wet bulb depression** (**WBD**). The wet bulb depression and the air temperature (dry bulb reading) are used with specific tables to find either the dew point temperature or the relative humidity, or both. Table 5.2 (Relative Humidity Table) and Table 5.3 (Dew Point Table) will be used in the following exercise.

Dry Bulb Temperature = Air Temperature

Dry Bulb Temperature – Wet Bulb Temperature = Wet Bulb Depression

Example: finding Relative Humidity and Dew Point Temperature using the Sling Psychrometer:

If the dry bulb temperature reading is 70° F and the wet bulb reading is 60° F, then the wet bulb depression is found as follows: 70° F - 60° F = 10° F. Now go to table 5.2 (Relative Humidity Table) and read **down** the left hand column (air temperature, which is dry bulb temperature) to 70° F and then read **across** the top of the table (wet bulb depression) to a value of 10° . You get your answer by tracing the column down from 10° (wet bulb depression) to where it meets the row from 70° F air temperature. The reading will be **55%** Relative Humidity.

Doing the same with the Dew Point Table (Table 5.3) you should get the answer **53° F** for the dew point temperature.

Exercise #5b Lab Activity Name: ______________________________

Moisture Lab Section: ______________________________

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

Using Tables 5.2 and 5.3 answer the following questions.

✐ 1. With a sling psychrometer, you measure an air temperature of 60° F (dry bulb temperature) and a wet-bulb temperature of 55°F.

a. What is the wet-bulb depression? ______________________________

b. What is the dew point temperature? ______________________________

c. What is the relative humidity of the air? ______________________________

✐ 2. An air mass has a temperature of 80°F and a depression of 13 degrees, what is:

a. The wet-bulb depression? ______________________________

b. The relative humidity of the air? ______________________________

c. The dew point temperature of the air? ______________________________

✐ 3. If the relative humidity of an air mass is 70% and the temperature of the air is 20°F,

a. what is the wet bulb temperature? ______________________________

b. what is the dew point temperature of the air? ______________________________

✐ 4. If the amount of water vapor in the air decreases and the temperature of the air stays constant, will the dew point temperature increase, decrease, or stay the same and why?

✐ 5. If the amount of water vapor in the air stays constant and the temperature of the air decreases, will the RH increase, decrease, or stay the same and why?

Table 5.2 Relative Humidity Chart

Relative Humidity (in percent)

Air Temperature °F	Depression of Wet-Bulb Thermometer (°F)																																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
0	67	33	1																																
5	73	46	20																																
10	78	56	34	13	15																														
15	82	64	46	29	11																														
20	85	70	55	40	26	12																													
25	87	74	62	49	37	25	13	1																											
30	89	78	67	56	46	36	26	16	6																										
35	91	81	72	63	54	45	36	27	19	10	2																								
40	92	83	75	68	60	52	45	37	29	22	15	7																							
45	93	86	78	71	64	57	51	44	38	31	25	18	12	6																					
50	93	87	74	67	61	55	49	43	38	32	27	21	16	10	5																				
55	94	88	82	76	70	65	59	54	49	43	38	33	28	23	19	11	9	5																	
60	94	89	83	78	73	68	63	58	53	48	43	39	34	30	26	21	17	13	9	5	1														
65	95	90	85	80	75	70	66	61	56	52	48	44	39	35	31	27	24	20	16	12	9	5	2												
70	95	90	86	81	77	72	68	64	59	55	51	48	44	40	36	33	29	25	22	19	15	12	9	6	3										
75	96	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34	30	27	24	21	18	15	12	9	7	4	1							
80	96	91	87	83	79	75	72	68	64	61	57	54	50	47	44	41	38	35	32	29	26	23	20	18	15	12	10	7	5	3					
85	96	92	88	84	81	77	73	70	66	63	59	57	53	50	47	44	41	38	36	33	30	27	25	22	20	17	15	13	10	8	6	4	2		
90	96	92	89	85	81	78	74	71	68	65	61	58	55	52	49	47	44	41	39	36	34	31	29	26	24	22	19	17	15	13	11	9	7	5	3
95	96	93	89	86	82	79	76	73	69	66	63	61	58	55	52	50	47	44	42	39	37	34	32	30	28	25	23	21	19	17	15	13	11	10	8
100	96	93	89	86	83	80	77	73	70	68	65	62	59	56	54	51	49	46	44	41	39	37	35	33	30	28	26	24	22	21	19	17	15	13	12
105	97	93	90	87	84	81	78	75	72	69	66	64	61	58	56	53	51	49	46	44	42	40	38	36	34	32	30	28	26	24	22	21	19	17	15
110	97	93	90	87	84	81	78	75	73	70	67	65	62	60	57	55	52	50	48	46	44	42	40	38	36	34	32	30	28	26	25	23	21	20	18
115	97	94	91	88	85	82	79	76	74	71	69	66	64	61	59	57	54	52	50	48	46	44	42	40	38	36	34	33	31	29	28	26	25	23	21
120	97	94	91	88	85	82	80	77	74	72	69	67	65	62	60	58	55	53	51	49	47	45	43	41	40	38	36	34	33	31	29	28	26	25	23
125	97	94	91	88	86	83	80	78	75	73	70	68	66	64	61	59	57	55	53	51	49	47	45	44	42	40	38	37	35	33	32	30	29	27	26
130	97	94	91	89	86	83	81	78	76	73	71	69	67	64	62	60	58	56	54	52	50	48	47	45	43	41	40	38	37	35	33	32	30	29	28

Table 5.3 Dew Point Chart

Temperature of Dew Point (Fahrenheit)

Air Temperature (°F)	Vapor Pressure (in.)	Depression of Wet-Bulb Thermometer (°F)															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0	0.0383	− 7	−20														
5	0.0491	− 1	−9	−24													
10	0.0631	5	− 2	−10	−27												
15	0.0810	11	6	0	− 9	−26											
20	0.103	16	12	8	2	− 7	−21										
25	0.130	22	19	15	10	5	− 3	−15	−51								
30	0.164	27	25	21	18	14	8	2	− 7	−25							
35	0.203	33	30	28	25	21	17	13	7	0	−11	−41					
40	0.247	38	35	33	30	28	25	21	18	13	7	− 1	−14				
45	0.298	43	41	38	36	34	31	28	25	22	18	13	7	− 1	−14		
50	0.360	48	46	44	42	40	37	34	32	29	26	22	18	13	8	0	-13
55	0.432	53	51	50	48	45	43	41	38	36	33	30	27	24	20	15	9
60	0.517	58	57	55	53	51	49	47	45	43	40	38	35	32	29	25	21
65	0.616	63	62	60	59	57	55	53	51	49	47	45	42	40	37	34	31
70	0.732	69	67	65	64	62	61	59	57	55	53	51	49	47	44	42	39
75	0.866	74	72	71	69	68	66	64	63	61	59	57	55	54	51	49	47
80	1.022	79	77	76	74	73	72	70	68	67	65	63	62	60	58	56	54
85	1.201	84	82	81	80	78	77	75	74	72	71	69	68	66	64	62	61
90	1.408	89	87	86	85	83	82	81	79	78	76	75	73	72	70	69	67
95	1.645	94	93	91	90	89	87	86	85	83	82	80	79	78	76	74	73
100	1.916	99	98	96	95	94	93	91	90	89	87	86	85	83	82	80	79
105	2.225	104	103	101	100	99	98	96	95	94	93	91	90	89	87	86	84
110	2.576	109	108	106	105	104	103	102	100	99	98	97	95	94	93	91	90
115	2.975	114	113	112	110	109	108	107	106	104	103	102	101	99	98	97	96
120	2.425	119	118	117	115	114	113	112	111	110	108	107	106	105	104	102	101
125	3.933	124	123	122	121	119	118	117	116	115	114	112	111	110	109	108	106
130	4.504	129	128	127	126	124	123	122	121	120	119	118	116	115	114	113	112

Exercise #5c Lab Activity

Name: ______________________

ATMOSPHERIC MOISTURE - ICE STORM Lab Section: ______________________

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

In January 1998, there was an unprecedented ice storm that ravaged and devastated northern New England and Quebec, Canada. The precipitation was of long duration and fell as continuous heavy rain. However, the ground temperatures were very cold - cold enough to cause the rain to instantly freeze on impact with everything on the surface. This resulted in a serious ice buildup (up to four inches) on trees, telephone lines, and roofs of buildings. Strong steel electric transmission towers and high-tension power lines were crumpled. Of course, vehicular and pedestrian traffic came to an abrupt standstill.

The spectacular ice storm event described above demonstrates that dangerous ice storms will result when the right atmospheric temperatures and moisture content come together to produce *freezing rain.* Freezing rain differs from ordinary rain. When cold raindrops strike a very cold surface (temperatures significantly below 32°F), the water freezes immediately. Gradually, coatings of clear solid ice build up and add considerable weight in the process. This results in the extremely hazardous conditions, which occurred in New England and Canada.

This special case utilizes atmospheric data that was obtained using a simplified Albany, NY radiosonde observation on a cold February morning and includes the readings of temperature and dew point (the temperature at which saturation occurs). Saturation is one of the conditions necessary for a cloud to exist. When further condensation occurs, the more dense clouds needed for precipitation develop.

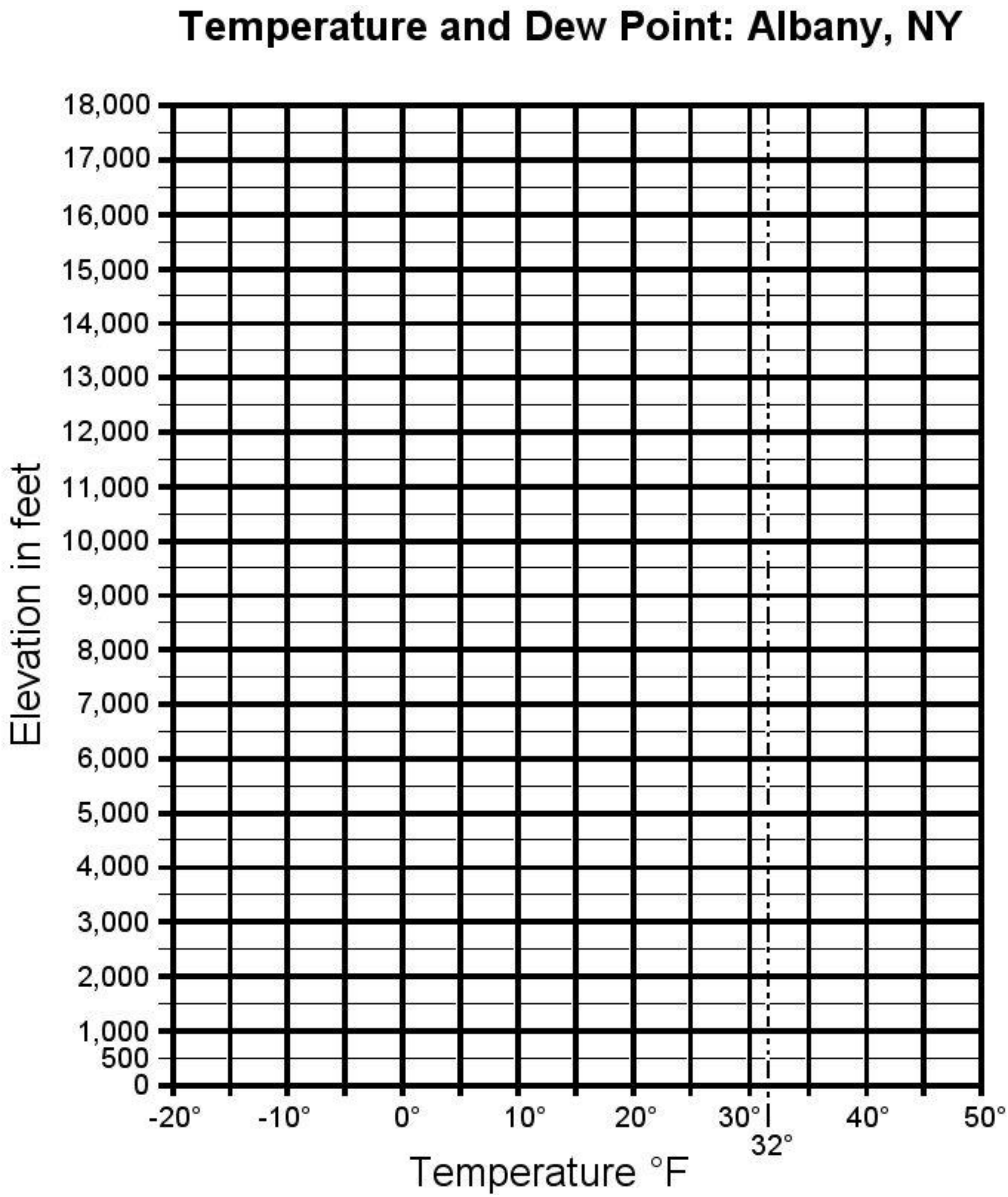
This exercise will show you: (You will need a straight edge and a pencil)
1. How to describe the conditions that can result in freezing rain.
2. The life history of the precipitation as it falls through the clouds to the ground.

The Albany NY Radiosonde Data

Altitude	Temp (°F)	Dew Point (°F)
Surface	+25	+23
500 ft.	+32	+32
1000 ft.	+32	+32
2000 ft.	+40	+40
3000 ft.	+45	+45
4000 ft.	+40	+40
5000 ft.	+35	+35
6000 ft.	+32	+32
10000 ft.	+20	+20
14000 ft.	+10	0
18000 ft	-10	-20

Plot the temperatures on the temperature-altitude diagram (next page) with a dot and a circle (O). Connect these points with straight lines. Plot the dew points with a dot and a triangle (Δ). *Note: plot the dew points only for the surface, 14,000 feet and 18,000 feet only, since the temperatures and the dew points are the same from 500 feet to 10,000 feet.* Carefully draw the dew point lines from the surface to 500 feet and from 10,000 to 18,000 feet using straight dashed lines.

Figure 5.4 The Albany NY Radiosonde Data



ANALYSIS OF THE SOUNDING

✐ 1. After completing the graph, determine the portion of the sounding where saturation was occurring (temperature and dew point the same). The air was saturated from ________ feet to _________ feet. Do you think that there were clouds over Albany at this time? _____ At what height was the cloud base? ________ feet. The cloud tops were at _____________ feet.

✐ 2. Draw pronounced horizontal lines across the graph at the cloud base and cloud top. Precipitation typically falls from relatively thick layers of clouds that are at least a few thousand feet thick. Do you think the clouds over Albany were thick enough to produce precipitation? YES or NO… Why?

✐ 3. Notice the 32°F line from the cloud tops to the cloud base. Lightly shade in the area enclosed by the sounding and this line. This highlights the layer where the temperature is above 32°F . Label this area *WARM*.

✐ 4. Assume precipitation was falling at Albany and it originated as snow in the upper parts of the clouds where the temperature was below freezing. As the snow continues to fall earthward, it reaches the warm layer and changes to __________ .

The precipitation keeps falling and reaches the layer closer to the ground where the temperature is at or below freezing. The precipitation continues to fall as *LIQUID RAIN* through the relatively shallow layer immediately above the earth's surface.

✐ 5. This lower layer *below* freezing is __________ feet thick. Since the temperature at the surface is very cold (25°F), the cool rain immediately changes to _______ upon contact with all surface objects, including trees and utility lines. The resulting surface weather is *FREEZING RAIN* - one of the most hazardous of our winter weather conditions.

✐ 6. There are two inversions depicted on the sounding. An inversion is where the temperature INCREASES as you rise in the troposphere, instead of decreasing as is normally expected. One starts at the surface and ends at __________ feet. The second starts at __________ feet and ends at ____________ feet. A shallow isothermal layer (where the temperature stays the same as you go aloft) extends from _______ feet to ________ feet.

Internet Resources for Atmospheric Moisture

Dew Point Calculator
http://www.decatur.de/javascript/dew/
http://simplythebest.net/scripts/DHTML_scripts/javascripts/javascript_74.html

Weather Related Calculators
http://www.csgnetwork.com/weatherconverters.html

Humidity Comfort Calculator
http://www.csgnetwork.com/canhumidexcalc.html

Weather Calculators http://www.srh.noaa.gov/elp/wxcalc/wxcalc.shtml

Lab 7

Introduction to Isoline Map Analysis

Mapping atmospheric phenomena and the ability to read weather maps is essential for an understanding of weather and climate. This lab focuses on providing students with an understanding of the most common weather and climate mapping technique, isoline mapping.

Weather information depicted through maps provides an easy way to understand atmospheric conditions. The spatial information about our weather is most easily understood when viewing a weather map. Imagine trying to figure out the weather for the day by looking at tables and graphs. The spatial patterns of specific variables, such as air temperature, pressure, wind, and humidity, provide the basis of our understanding the day's weather as well as providing the basis for weather analysis. Plotting discrete weather data on maps, however, can be confusing to the casual viewer as well as to the weather analyst. Geographers are always looking for patterns in the environment to help analyze what is happening in the environment. In the case of weather maps, we use isolines (also known as isopleths) to show patterns out of the discrete weather data on the maps. **Isolines** are lines of constant (or equal) value. An isoline is a line that joins points of equal value. Each type of isoline is named to reflect the variable being mapped: ***isotherms*** are lines of constant temperature, ***isobars*** are lines of constant barometric pressure, and ***isohyets*** are lines of constant precipitation. Many people are familiar with contour maps, which are a type of isoline map that depicts patterns of elevation above mean sea level. Today meteorologists often use computers to draw isolines, but in this exercise you will learn how to draw and interpret isolines manually.

Isoline Map Conventions

There are some conventions meteorologists use in the construction of isolines that we need to follow in order to correctly draw isolines.

1. Because isolines are lines of constant value, they **do not** cross.
2. Isolines should be relatively smooth and therefore they do not have sharp turns.
3. Isolines should be drawn at fixed intervals. For example, an isobar map might use a 4-mb interval where you would have isolines of: 992 mb, 996 mb, 1000 mb, 1004, mb, etc.
4. Isolines should only pass through points of equal value (that is, the value of the isoline).
5. Isolines should be labeled near the edge of the maps. When they form a circle on the map the value of the isoline should be labeled at small breaks in the lines.

Figure 11.1 Station Model Example

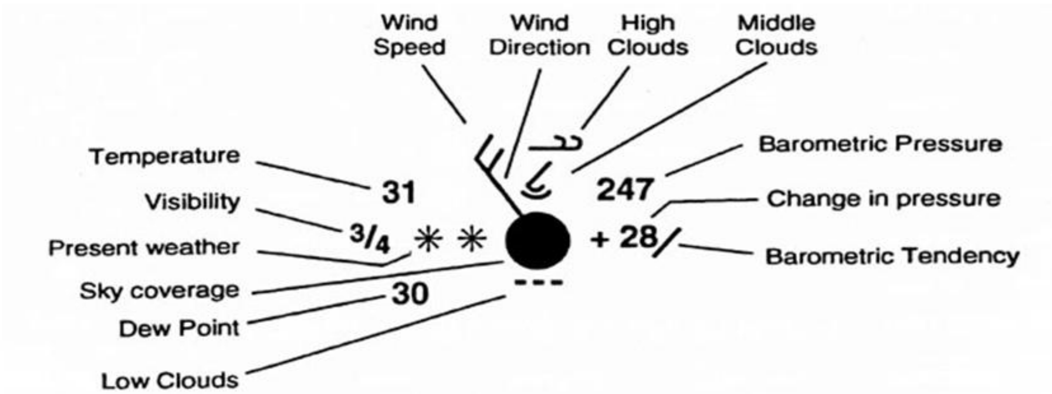
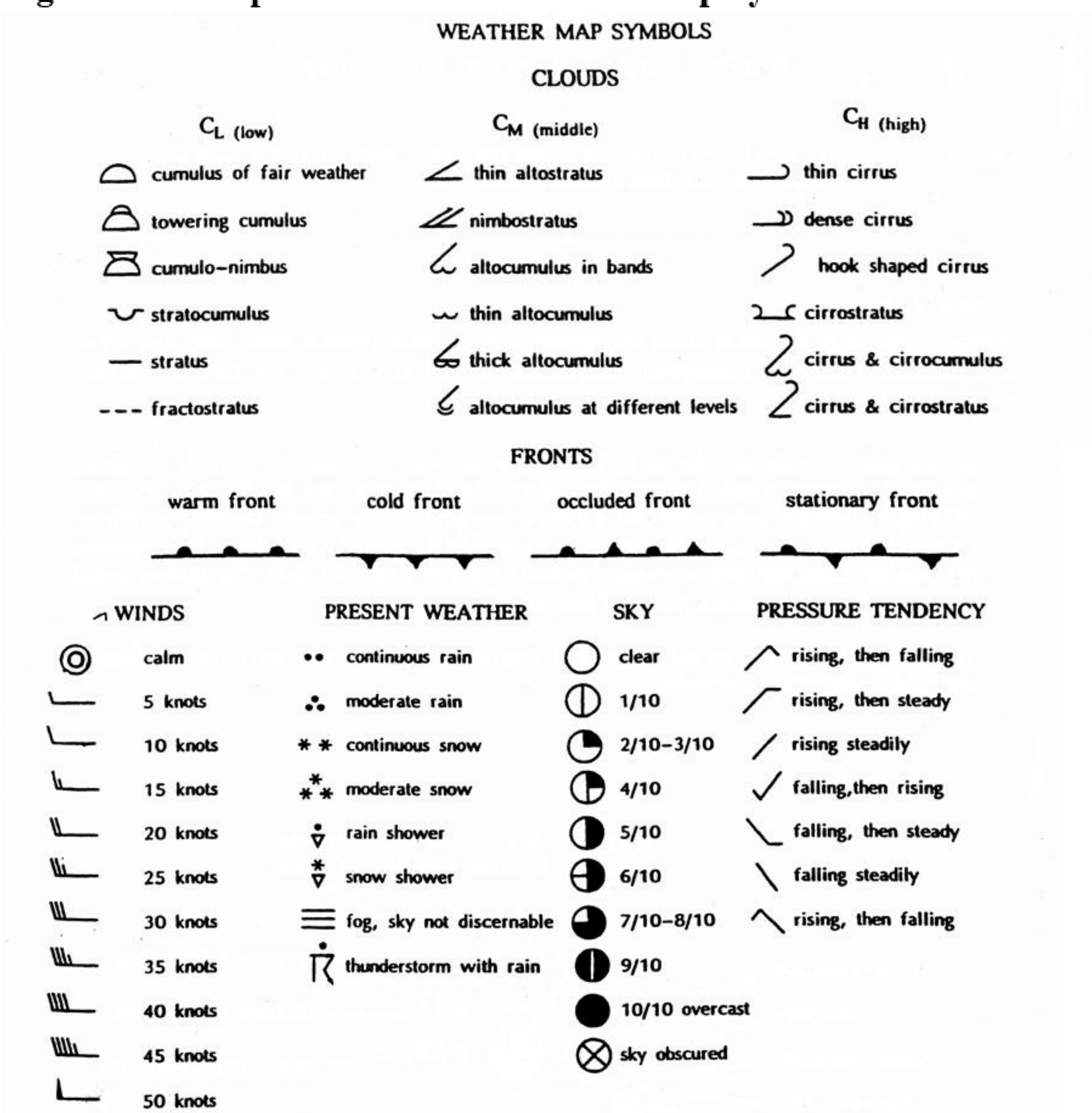


Figure 11.2 Simplified Chart of Weather Map Symbols



Exercise #7 Lab Activity Name: ____________________________

Isoline Mapping Lab Section: ____________________________

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

Example of Surface Observations

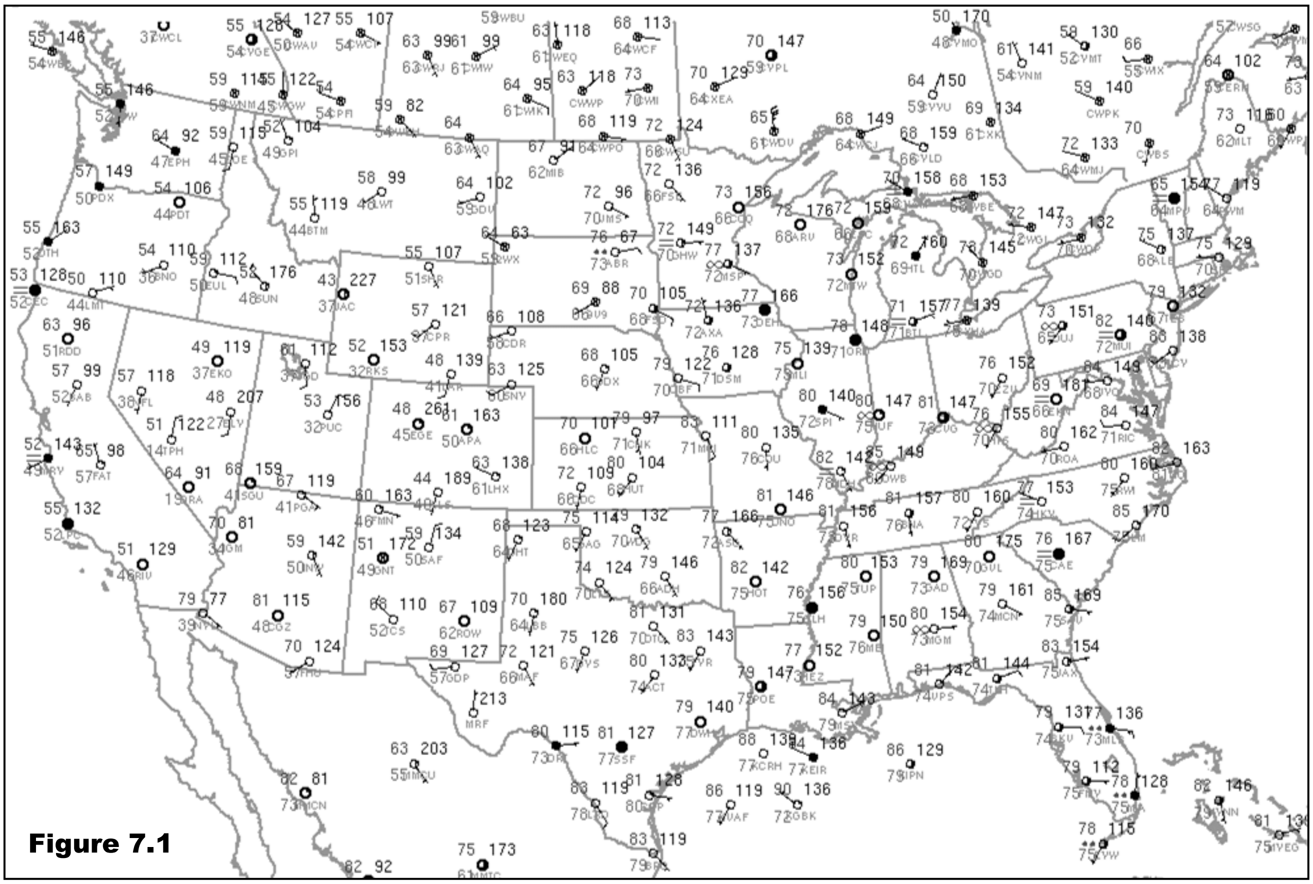


Figure 7.1

Figure 7.1 depicts surface observations (temperature, dew point, pressure, etc.) from weather stations across the United States from August 10, 2010 at 9 am EST. While this map contains a great deal of information, it is not very easy to find, for example, areas of high and low pressure. Performing an isoline analysis for sea-level atmospheric pressure yields Figure 7.2 (next page).

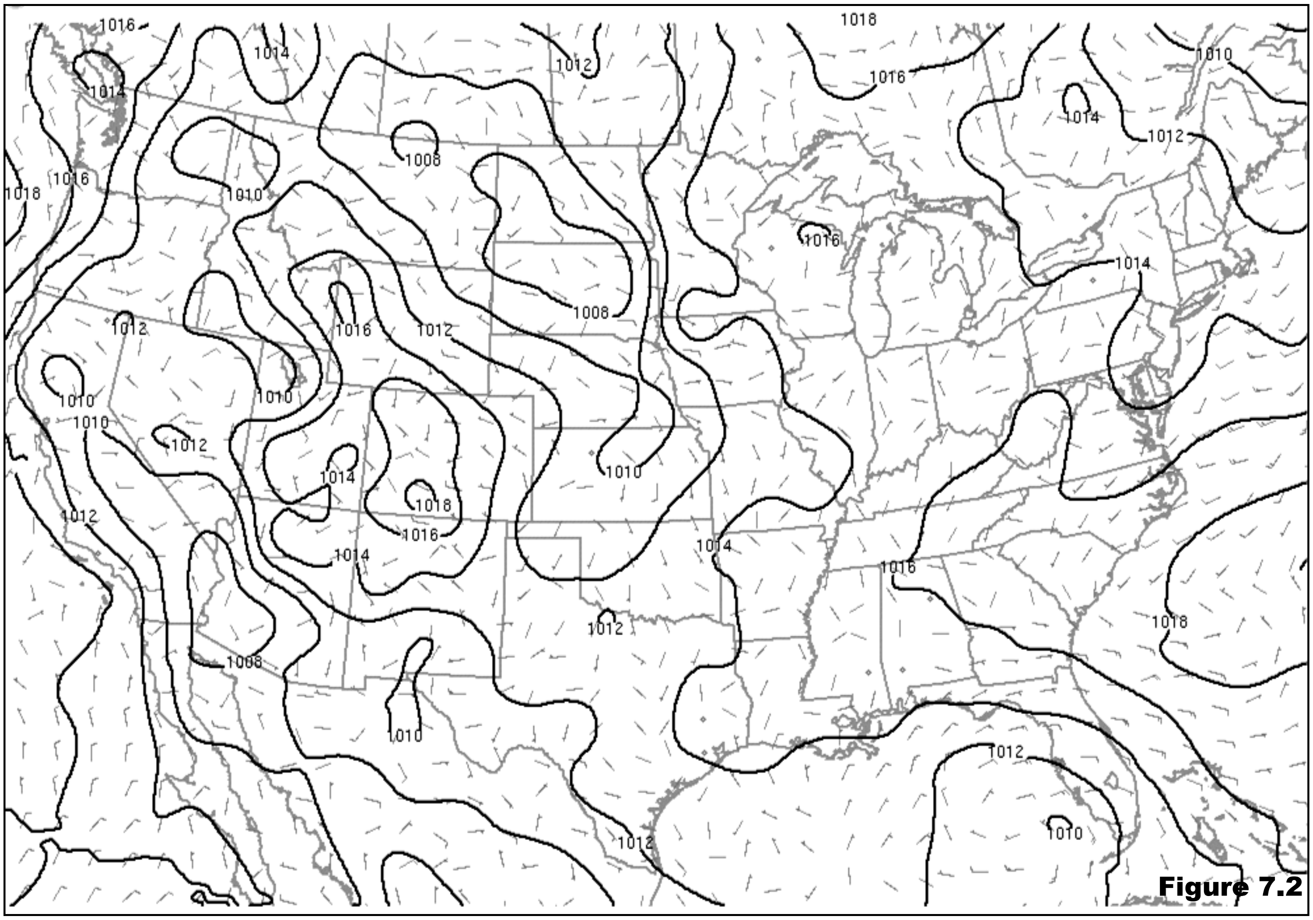
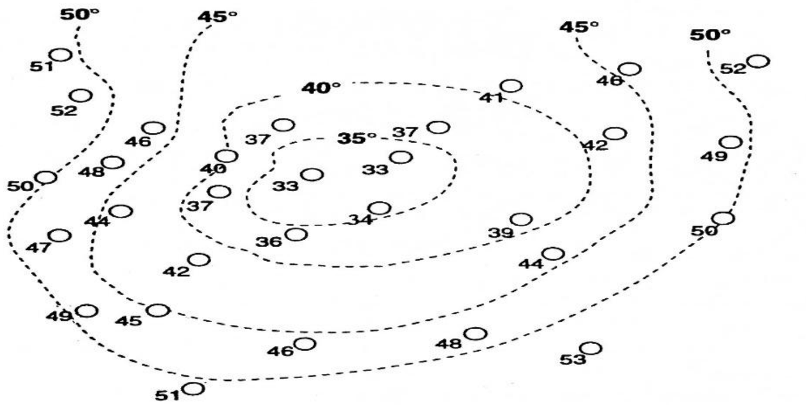


Figure 7.2

1. (a) Locate areas of high and low pressure on Figure 7.2 above. For areas of high pressure, write an 'H' on the map; for areas of low pressure, write an 'L'.

(b) Based on part (a), over which locations would a meteorologist be likely to predict precipitation? Why?

Figure 7.3 Isoline Map



Drawing Isopleths

The diagram above provides an example of an isoline map. The diagram below gives you the opportunity to draw isopleths.

In the diagram below, you will see many 1's, 2's, 3's, 4's, 5's, 6's, 7's, 8's, and 9's. After examining the chart, draw isopleths for the values 2, 4, 6, and 8. After connecting the numbers, you will see a definite pattern displayed.

Figure 7.4 Practice Isopleth map.

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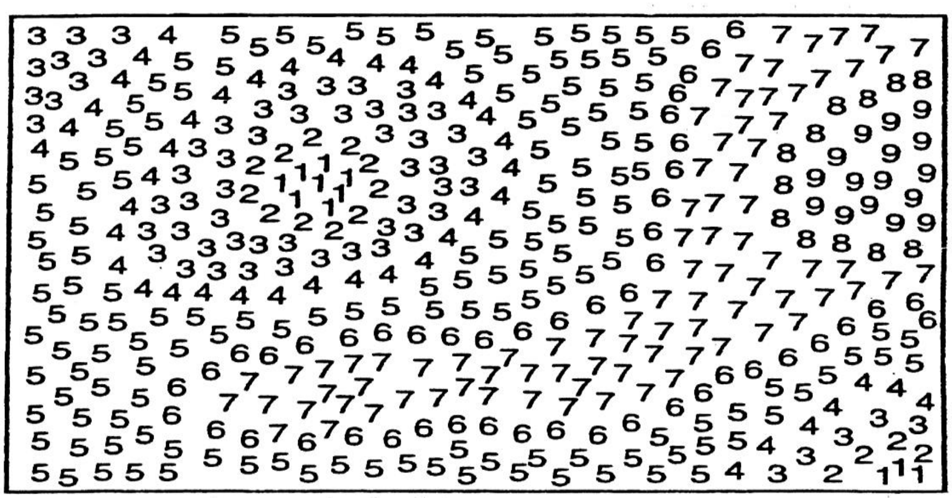
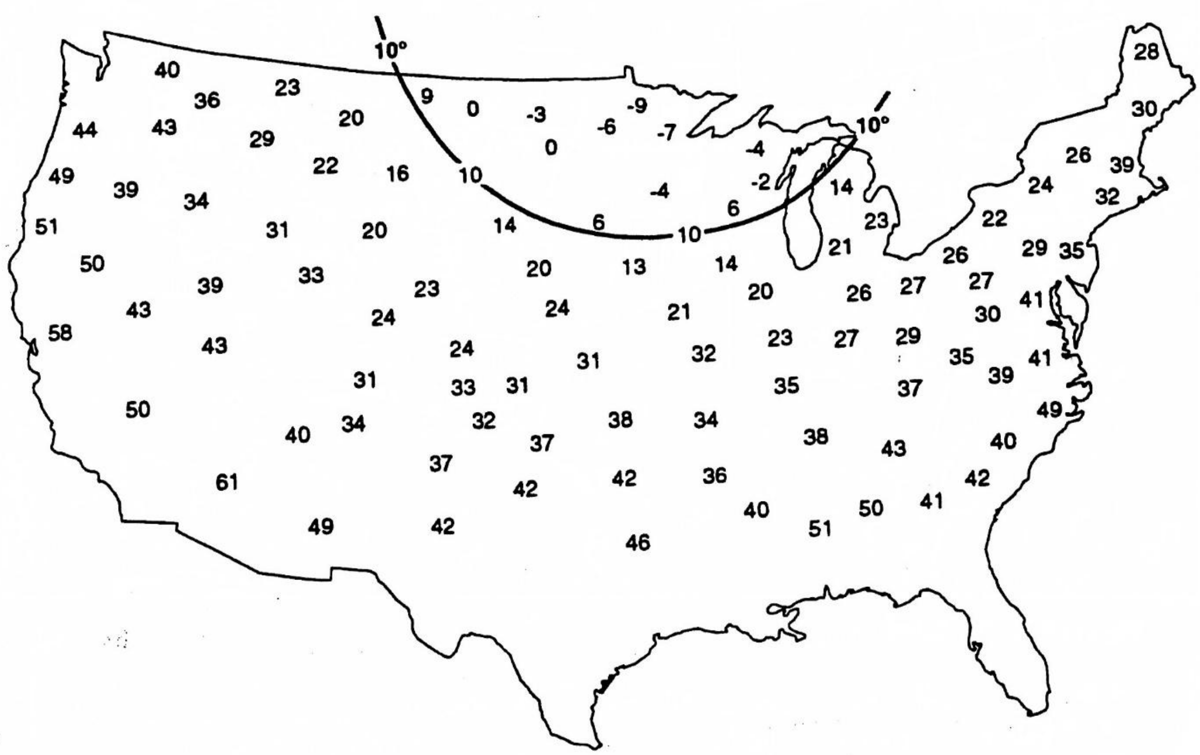


Horizontal Distribution of Temperature – Isotherms

A map comprised of isotherms can best show the distribution of air temperature over large areas. Isotherms are lines connecting points of equal air temperature. The construction of isotherms is very similar to that of drawing contours on a topographic map or lines of equal amounts of rainfall (isohyets) and so learning this technique will be useful in a number of instances. The accompanying map of the coterminous United States shows mean air temperatures for the month of February. The 10-degree isotherm has already been plotted to illustrate isotherm construction. You should now draw in the location (plot) of the isotherms with values of 0, 20, 30, 40 and 50 degrees. Note that it is possible for you to show the location of an isotherm, e.g., 30 degrees, without ANY 30 values being on the map. All you need are values above and below that amount to see where the line should go. Drawing in the isoline for 30 degrees will require the practice of *interpolation*, a common practice in cartography. Interpolation involves drawing the isoline between higher and lower data points. When interpolating an isoline between data points, the line should be drawn proportionally to the intervening value, that is, drawn closer to the nearer value (see figure 7-1 above to see how the isoline was interpolated between values).

Figure 7.5 Isotherm Map – February



✏ 2. Describe the pattern you see in the isotherm map for February.

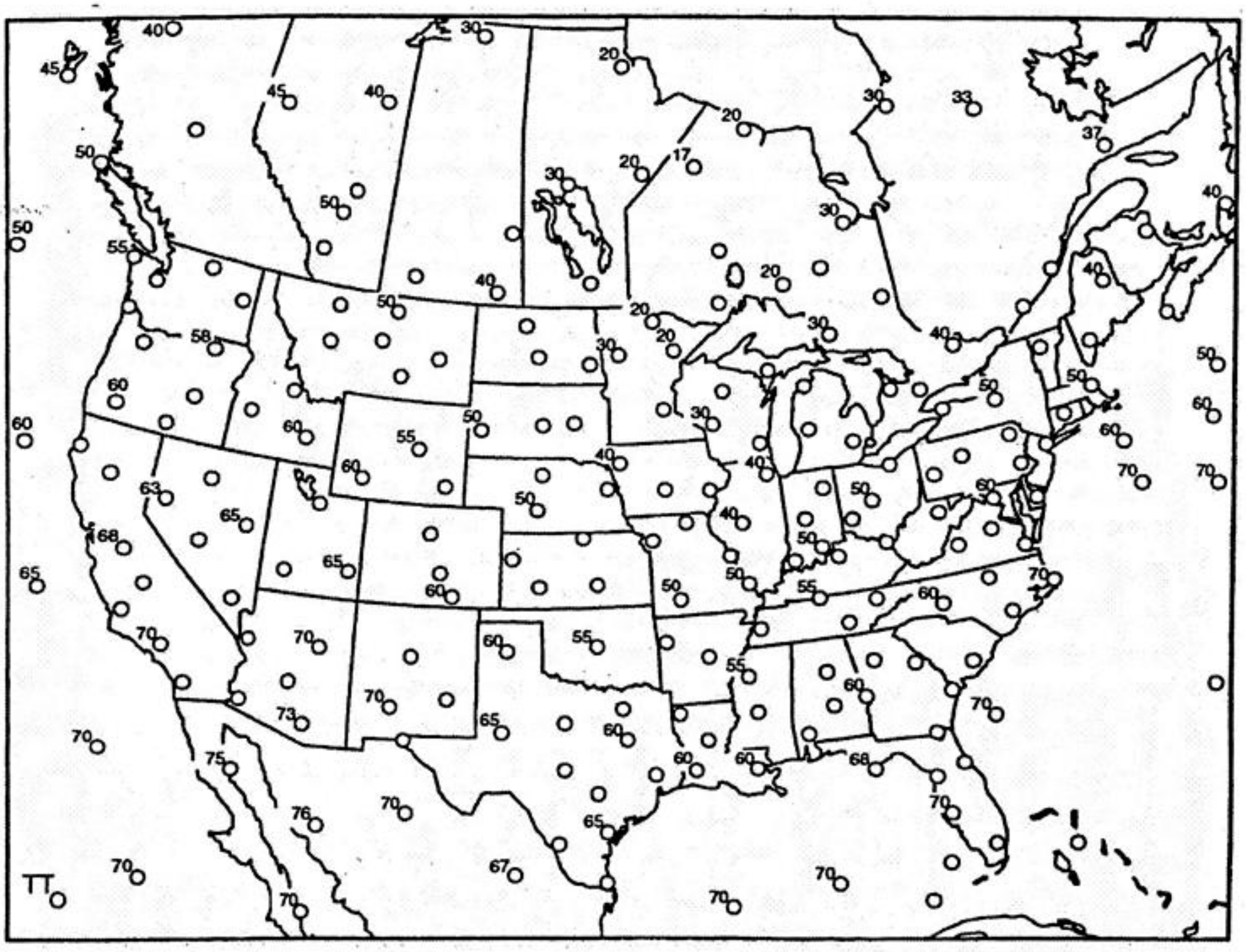
✏ 3. Which portion of the country is:
a. coldest

b. warmest

Drawing Isotherms

Look at the map below (Figure 7.6) Each circle shows a location where a temperature observation has been made at 7AM. The temperatures have been plotted to the upper left of each station circle. When you draw your isotherms, they should be drawn through the appropriate station circles, not through the temperature numbers. Use a pencil to start and when you are confident that you have drawn them correctly, use a felt-tip pen to make the lines. Use different colored pencils to shade between isolines to indicate regions of temperature. The isolines should have a constant interval of 10-degerees and should run in a sequence from 20° F, 30° F, etc.

Figure 7.6 Isothermic Map



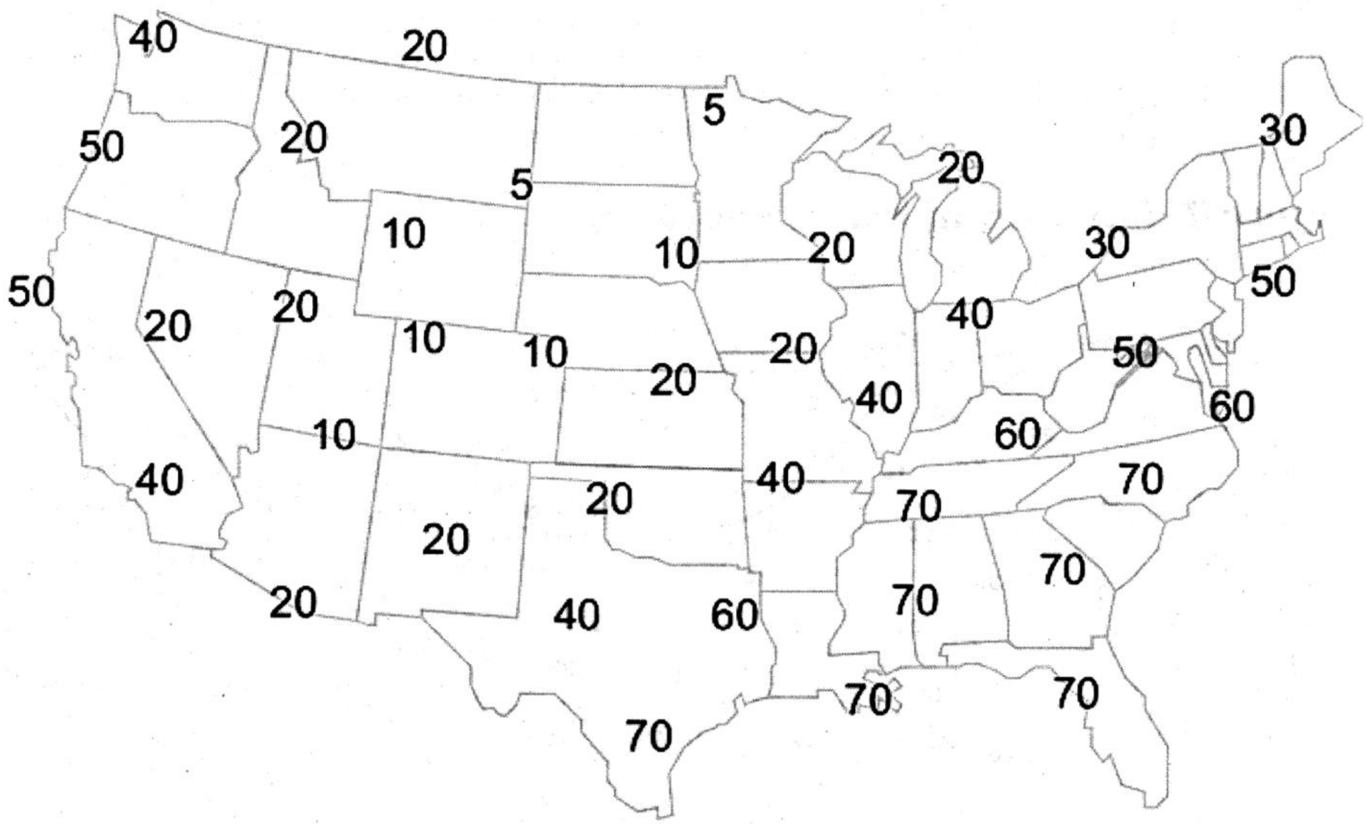
3. The coldest temperatures on this map are located over: ______________. The lowest temperature on the map is: ____________. Weather generally moves from west to east in the midlatitudes; what do you think the coming temperatures will be in New England? ____________.

4. The warmest temperatures on the map are located over ____________. The highest temperature is ____________. When the warm air moves eastward it will heat up which state _______ and to what temperatures? __________.

Drawing Isodrosotherms (Moisture)

Look at the map below (Figure 7.7) The numbers indicate dew point temperature observations in °F. Isodrosotherms are lines of equal dew point temperatures which indicate the amount of moisture present in the air. Use a pencil to start and when you are confident that you have drawn them correctly, use a felt-tip pen to make the lines. Use different colored pencils to shade between isolines to indicate regions of moisture. The isolines should have a constant interval of 10-degrees and should run in a sequence from 20° F, 30° F, etc.

Figure 7.7 Isodrosothermic Map



4. The driest areas on this map are located over: _______________. The lowest dew point on the map is: _____________. Weather generally moves from west to east in the midlatitudes; what do you think the coming dew points will be in New England? _____________.

5. The areas with the most moisture on the map are located over ______________. The highest dew point is _____________. Suppose air temperatures in Florida and California were both 90° F. Where would the heat index be highest?__________ Why?

Internet Resources for Isoline Mapping

Internet Resources for Isoline Mapping

1. NOAA – learning to read a weather map
http://www.srh.weather.gov/srh/jetstream/synoptic/ll_analyze.htm

2. How to create an isoline map
http://www.indiana.edu/~geog109/labs/lab6.htm

3. Isoline map analysis tutorial

Lab
9

Mid-latitude Cyclones & Air Masses

This lab will introduce students to the patterns of surface winds around the center of a midlatitude cyclone of low pressure. The types of weather associated with low-pressure systems will be examined as well as the differences and similarities among warm and cold fronts. In addition, this lab will discuss the air masses that influence the weather and climate of North America.

Air Masses and Fronts

An **air mass** can be defined as a large body of air which exhibits like characteristics. The two main characteristics that are found to be relatively uniform within air masses are **temperature** and **humidity**. Because air masses remain stationary for extended periods of time, they take on the temperature and moisture characteristics of the land or water surfaces below them. This is true for both the surface and upper air characteristics: they become a homogenous mass. The moisture characteristics are classified as maritime (humid) or continental (dry) depending if they were formed over water or land. The temperatures are classified as equatorial (very hot), tropical (hot), polar (cold) or arctic (very Cold), depending on the geographic region over which the body of air stagnated.

The following types of air masses result:

maritime equatorial (mE)	**continental tropical (cT)**
maritime tropical (mT)	**continental polar (cP)**
maritime polar (mP)	**continental arctic (cA)**

**Maritime arctic and continental equatorial air masses rarely occur and therefore are not listed.

Air Masses

What is an Air Mass?

- **An extensive body of air that has relatively uniform temperature and humidity derived from a <u>SOURCE REGION</u>**

Source Region

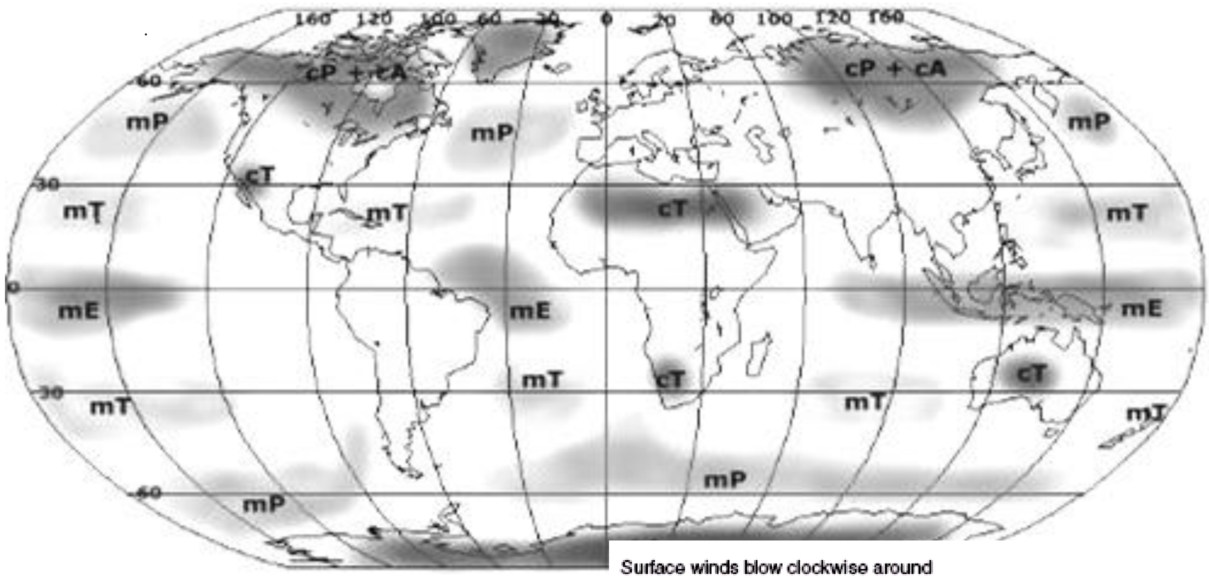
- **The place where an air mass "gets" its temperature and humidity characteristics**
- **Air needs to "sit" over this area to "get" humidity & temperature (air stagnates over this area and acquires characteristics)**

Example:

mT

Maritime
Tropical
(*Humid & Warm*)

- **Source Regions**
  - **Humidity**: Large uniform areas
    - Land = Continental = Dry
    - Water = Maritime = Humid
  - **Temperature**: Latitude
    - Arctic = Very Cold
    - Polar = Cold
    - Tropical = Warm
    - Equatorial = Hot
  - **Moisture:**
    - **m = Maritime (Humid)**
    - **c = Continental (Dry)**
  - **Temperature**
    - **A = Arctic (Very Cold)**
    - **P = Polar (Cold)**
    - **T = Tropical (Warm)**
    - **E = Equatorial (Hot)**



Air pressure at the surface is either **High** or **Low pressure.**

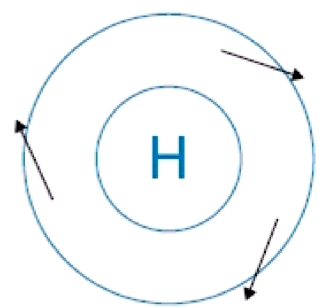
High pressure has air sinking from above and moving out from the center in a clockwise manner (**Cyclone)**

Low pressure has air rising and spinning into the low in a counter-clockwise manner **(Anti-Cyclone)**

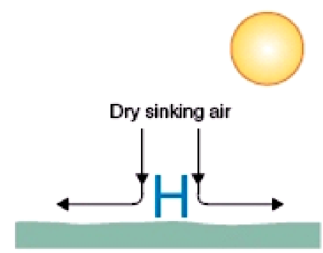
This is why we get clear skies from high pressure (the air is sinking and warming, thus it can homd more water vapor, thus no clouds).

We expect to often see cloudy and rainy skies in low pressure because the air is rising and thus cooling and reaching saturation… then condensation begins forming clouds which often lead to precipitation.

Surface winds blow clockwise around a high pressure and diverge.

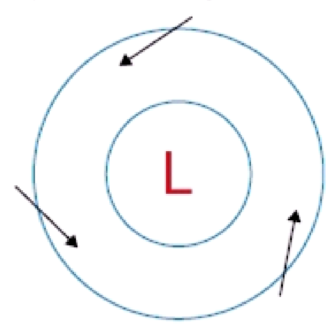


View from above

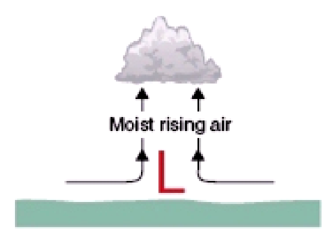


View from side

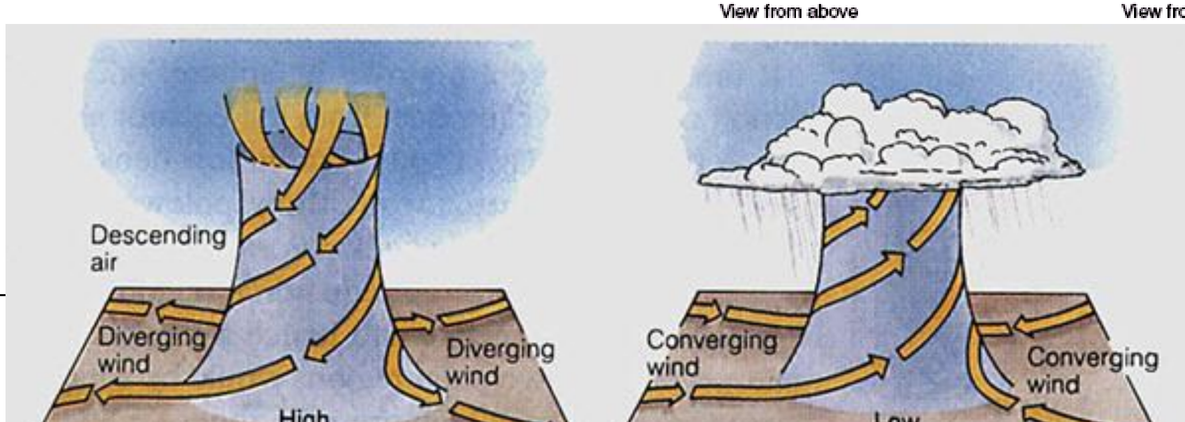
Surface winds blow counterclockwise around a low pressure and converge.



View from above



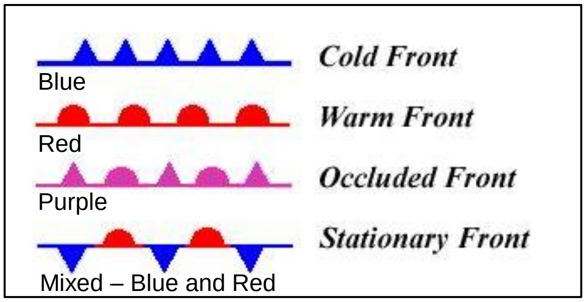
View from side



Also… Just a bit about FRONTS.

Fronts are named for the side that is overtaking the other. In a Cold Front, cold air is over taking warm air.

Front Symbols



Exercise #9 Lab Activity Name: ______________________________

Air Masses Lab Section: ______________________________

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

Air Masses

✐ 1. Fill in each numbered circle indicating which source regions are producing each type of air mass influencing North America (mP, mT, cT, cP, cA).

(1)

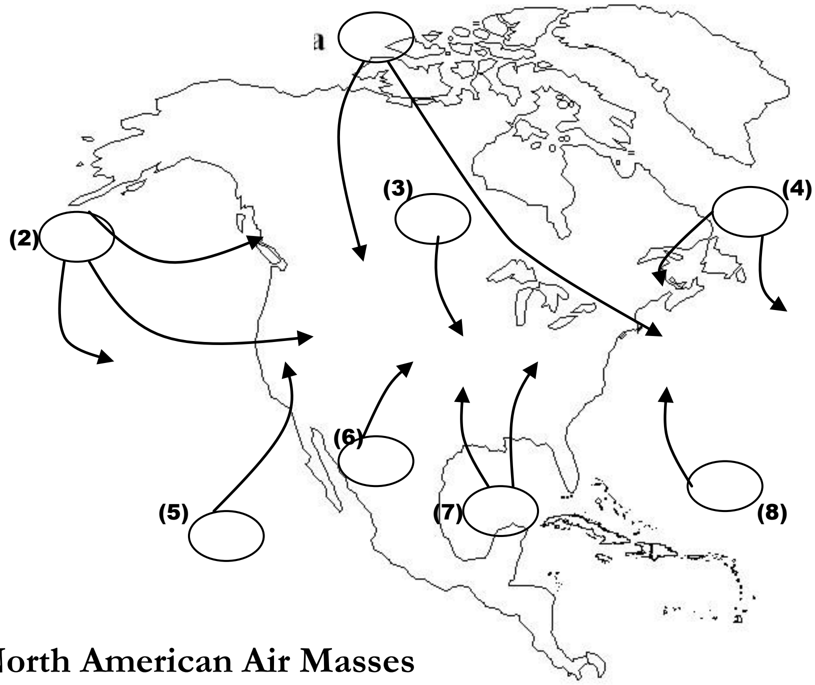
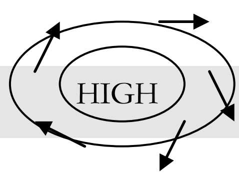


Figure 9.1 North American Air Masses

When two contrasting air masses come in contact with each other, a boundary is formed – we call this boundary a front. The fronts are found not only at the surface, but they extend aloft as well.

A cold dry cP air mass (with its source in Canada), has a high pressure area and is a clockwise out flowing wind circulation pattern.

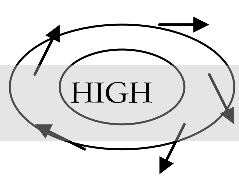
Cold & Dry



It moves SE towards the eastern US

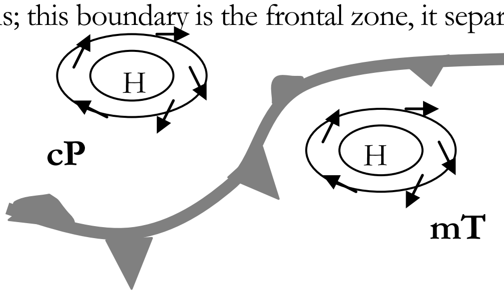
A warm, moist mT air mass lies over the SE U.S. and the SW Atlantic Ocean of the Northern Hemisphere. This subtropical high pressure area has the same flow pattern as the Canadian high pressure region.

Warm & Moist



It remains nearly stationary over its source.

When the cold high arrives in the vicinity of the sub-tropical high, a boundary forms between the two highs; this boundary is the frontal zone, it separates the cold, dry air from the warm, moist air.



If there is little movement involved, the boundary remains stationary and we have a stationary front. The air near the ground drifts across the surface isobars towards lower pressure. This air is warm and light – therefore, it rises. Convergence and lifting results in adiabatic cooling, condensation, clouds and eventually precipitation. Since the cold air almost always wins out in forward movement, a cold front develops, and in advance of it, a warm front. Along the frontal boundary, a low pressure area is spawned.

✐Using the air masses identified in Figure 9.1 answer the following questions:

✐2. In the winter, what kind of weather do you think will develop over New England if air masses **3)**, **4)** & **8)** all collide over the eastern United States and why?

✐ 3. In the late fall and winter, when air mass **1)** or **3)** moves along past the Great Lakes and towards the eastern US, what kind of weather would you expect in this region to the lee (east side) of the lakes?

✐ Explain why this phenomenon occurs.

✐ 4. When air mass **2)** arrives at the west coast of the US during late fall and winter it causes heavy ____________ at the lower elevations of the mountains and tremendous amounts of ___________ at the higher elevations.

✐ 5. Would you expect the same kind of weather in question 4 above to take place over the leeward (opposite the windward) side of the mountains? ____________ Explain your answer utilizing your knowledge of the adiabatic process.

✐ 6. Southern California often experiences very severe rainstorms during the winter. Which air mass contributes most to this occurrence?

✐ 7. The very warm air masses of the US, along with high moisture content are the ____________ air masses.

✐ 8. The hottest air mass of the US forms over the desert southwest. It is known as the ________________ air mass. It develops due to very intense surface _________________ from the sun.

✐ 9. Which air mass brings New England pleasant cool days with very low humidity during the summer?

✐ 10. While on vacation you observe some high thin cirrus clouds. Later you notice that there is a halo around the sun. Gradually the clouds lower and thicken to altostratus, then nimbostratus accompanied by steady rain. Finally you observe low stratus clouds and fog. What kind of front was approaching?

✐ 11. In the front above (question 10), warm moist air overruns the ______________ air beneath it. The warm air rises slowly and is _____________________. ____________________ takes place and stratified ___________________ form.

12. A rather cold, dry high pressure system from Canada (associated with a cP air mass) moved southeastward towards the east coast of the US and came in contact with a warm, moist high pressure region (associated with a tropical maritime air mass) just off the east coast. The front that developed between them was a(n): **Draw the map symbol for that front.**

a) cold front
b) warm front
c) occluded front
d) stationary front

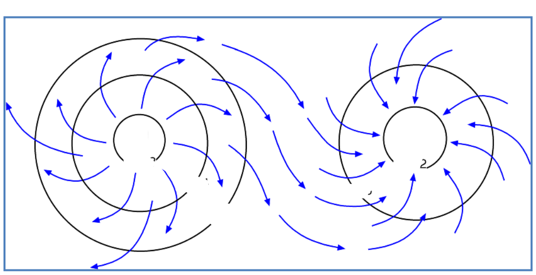
13. When a ______________ front catches up to a ______________________ front and lifts all of the warm air aloft, what kind of a front results? **Draw the map symbol for that front.**

a) cold front
b) warm front
c) occluded front
d) stationary front

14. The west coast experienced some very severe early winter-like weather. Heavy rains, driven by gale force winds prevailed along the west coast. The Sierras and Cascades had blizzard conditions with up to four feet of snow. What types of air mass gave them that kind of weather?

15. Often New England receives nor'easters with considerable rainfall. The air masses that have supplied the needed moisture for these storms are ____________ and ______________ air masses.

16. Circle correct answer: Looking down on a Northern hemisphere low-pressure system (cyclone), surface winds blow **[(counterclockwise and inward) (clockwise and outward)].**



Lab 11

Weather Maps & Forecasting

This lab will explain the structure of weather maps and explore how we forecast coming weather conditions.

Station Models

Weather maps show the state of the atmosphere at a particular point in time. They also serve as a historical record of atmospheric conditions, as well as a source for making weather forecasts.

The U.S. National Weather Service is responsible for the analysis of these maps. The maps contain daily weather data for the entire world at six hour intervals at 1a.m., 7a.m., 1p.m., and 7p.m. (eastern standard time). The information is transmitted by fax and computer utilizing a numerical code rather than a verbal description of the present weather conditions. On the weather map, these observations are entered in the station model form to conserve space. This provides the weather forecaster with a graphic method of summarizing the data.

The observations below are called **synoptic observations** because they are taken at the exact same time everywhere worldwide.

Figure 11.1 Station Model Example

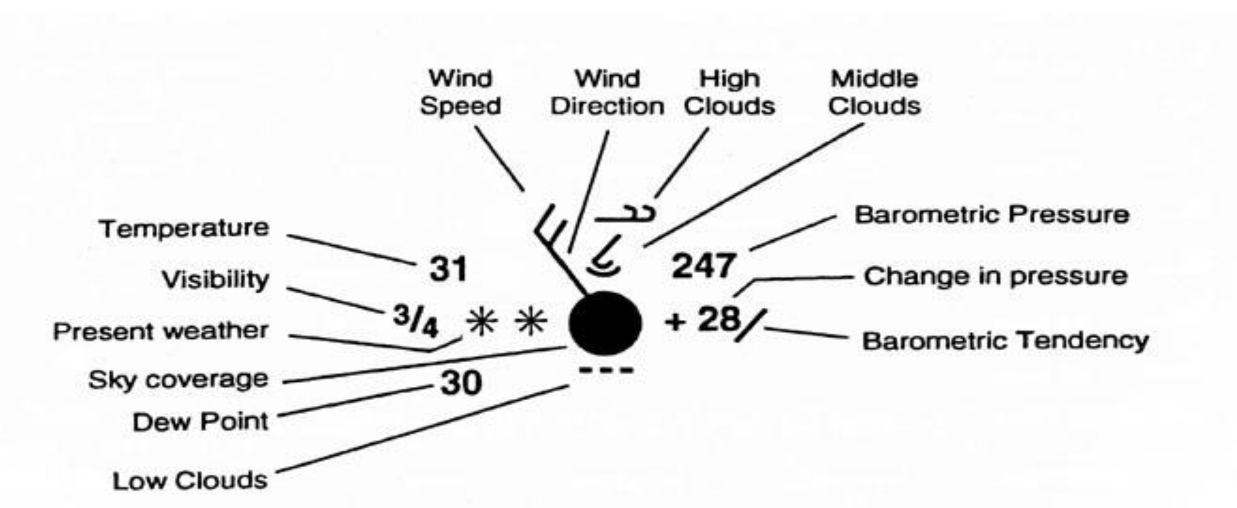
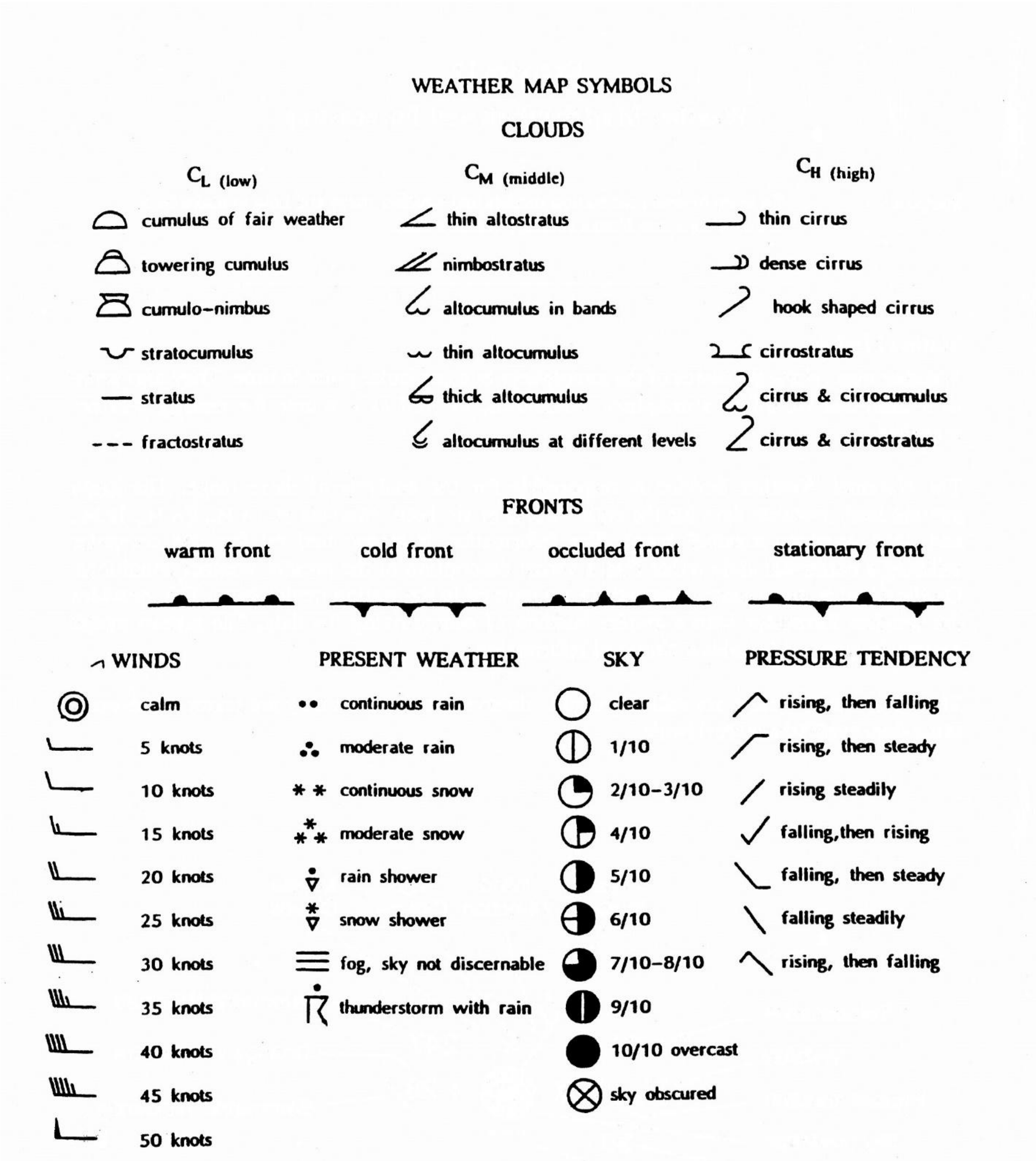


Figure 11.2 Simplified Chart of Weather Map Symbols



Barometric Pressure Labeling

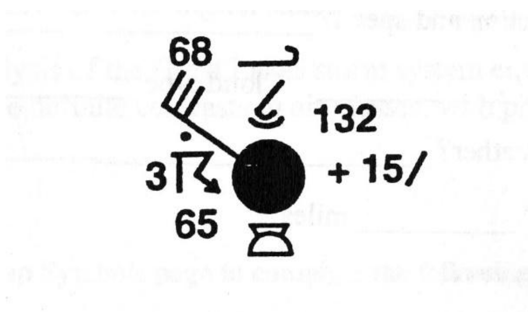
To conserve space the Barometric Pressure numbers have been condensed. The initial 9 or 10 as well as the decimal point are omitted on station models. A pressure of 1023.7 mb is abbreviated as 237. 998.6 mb is abbreviated as 986.

Exercise #11 Lab Activity Name: ____________________________

Weather Maps Lab Section: ____________________________

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

Refer to the Weather Map Symbols on the previous page for the following questions.



✐1. Using the station model above, fill in the weather observations in the spaces provided.

Wind Direction ______ Wind Speed _____knots Temperature ____ °F Dew Point ____ °F

Pressure _____mbs. Pressure tendency & change ______ mbs. Sky cover (tenths) _____

Clouds Low ____________ Middle ________________ High ________________

Present Weather __________________________ Visibility ________________ miles

✐2. Using the station model above, fill in the weather observations in the spaces provided.

Wind Direction ______ Wind Speed _____knots Temperature ____ °F Dew Point ____ °F

Pressure _____mbs. Pressure tendency & change ______ mbs. Sky cover (tenths) _____

Clouds Low ____________ Middle ________________ High ________________

Present Weather __________________________ Visibility ________________ miles

✐3. Construct a station model above showing the following information:

Sky – Obscured Wind Direction & Speed - Northeast 10 knots Temperature - 55°F

Dew Point - 55°F Pressure - 1024.1 mbs. Pressure tendency & change - falling, 1.5 mbs.

Clouds - None Visible Present Weather - Fog, sky not discernible Visibility - 1/8 mile

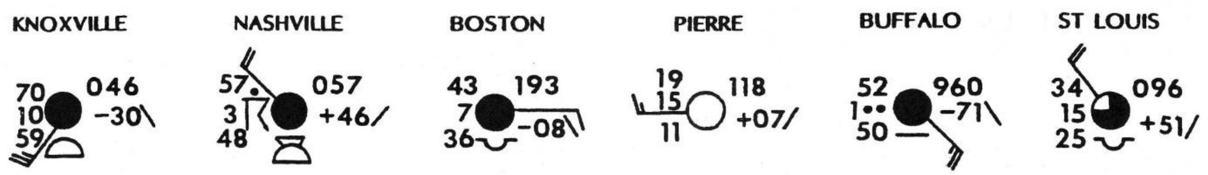
✐4. Construct a station model above showing the following information:

Sky – 6/10 Wind Direction & Speed - East 15 knots Temperature - 50°F

Dew Point - 45°F Pressure - 1019.5 mbs. Pressure tendency & change - falling, 1.0 mbs.

Low Clouds – towering cumulus Middle Clouds – altocumulus at different levels

High Clouds – dense cirrus Present Weather – rain shower Visibility - 5 miles



For low clouds use the abbreviations such as Cu (cumulus), Cb (cumulo-nimbus), St (stratus), Sc (strato-cumulus) because of space limitations. Use the abbreviation TSTM for thunderstorm with rain. Note: for pressure tendency R is for rising pressure and F is for falling pressure. Amount refers to how many millibars the pressure is rising or falling. "St. L." stands for St. Louis.

For the next set of questions please refer to the station models above. **Note** – write out the full pressure in millibars, not the abbreviations in the station models.

	Knoxville,	**Nashville**	**Boston**	**Pierre**	**Buffalo**	**St. L.**
State location (abbreviation)						
temp (F)						
dew point (F)						
pressure (mb)						
pressure tendency (R or F)						
amount (mb)						
wind direction						
wind speed						
sky cover						
low cloud						
visibility						
present weather						

Weather Forecasting

The map on the following page (Figure 11.3) gives more detail about the weather occurring when the information in the station models (below) was gathered. The weather at these places is being affected by the general eastward movement of a storm system across North America. Based on the information in this map and at the stations, we will now make a 12 hour forecast for two of these locations.

The locations of the 12 hour frontal positions are depicted on the map (figure 11.3) by means of heavy dashed lines. Remember, the entire storm system is moving eastward. Since the low pressure area is moving east-northeast, the weather currently at Knoxville (K) will move east-northeast and will be replaced by the weather to the west, similar to that of St. Louis (S). Therefore you will base your forecast on the present weather at St. Louis. Using the same logic, you will base your Boston forecast on the present weather in Buffalo. Note: the station model data is from 1 AM Eastern Standard Time. You will be forecasting for 1 PM and thus your temperatures will be influenced not only by the moving air masses, but by the "Daily March of Temperature" as well.

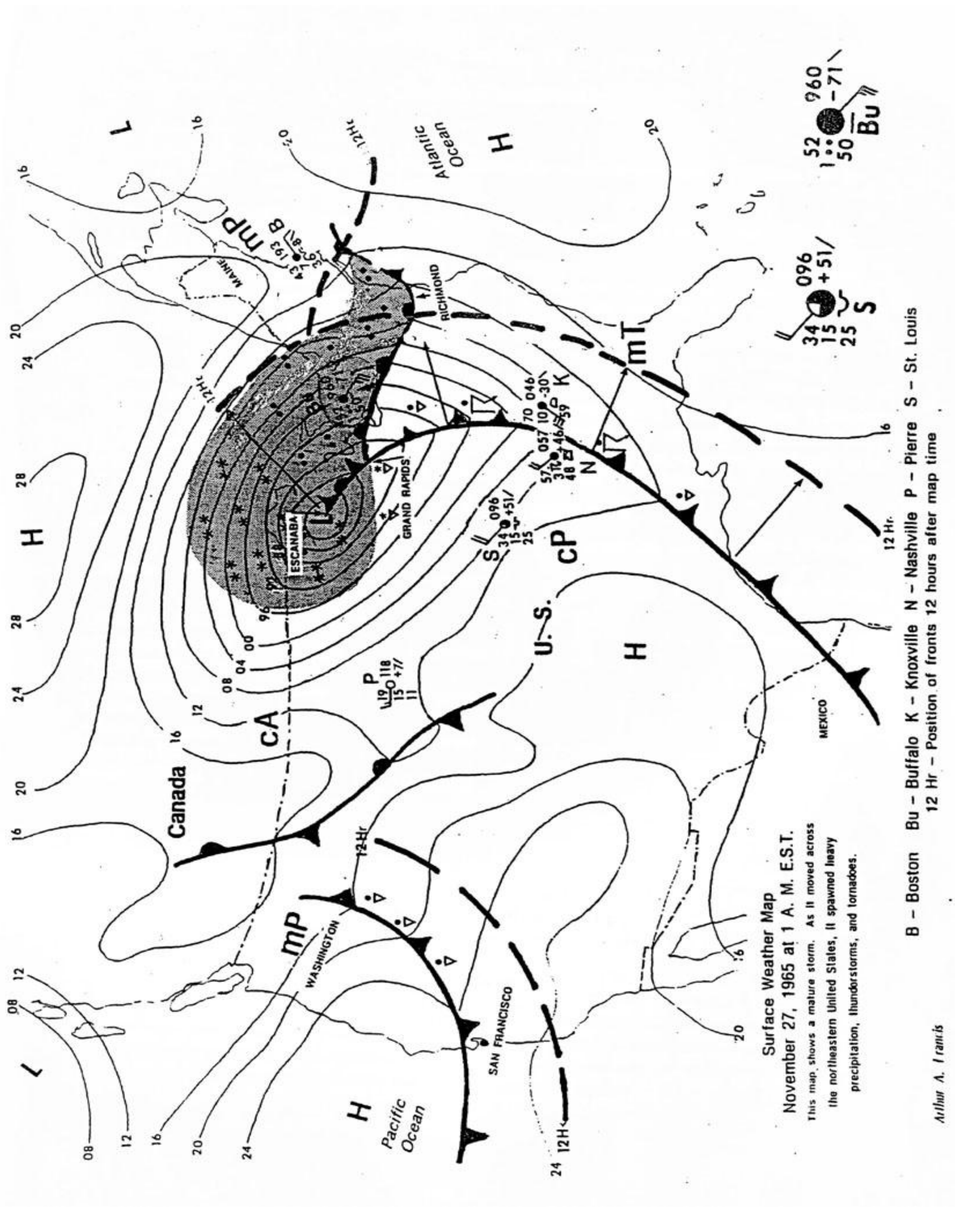
	Knoxville (in 12 hours)	**Boston** (in 12 hours)
Temperature (F)	________________	________________
Dew Point (F)	________________	________________
Pressure (mb)	________________	________________
Wind Direction	________________	________________
Wind Speed	________________	________________
Sky Condition	________________	________________
Precipitation	________________	________________
Visibility (miles)	________________	________________

Brief verbal description of weather in 12 hours for:

Knoxville:

Boston:

Figure 11.3 Weather Map



Lab

13

Climate Classification

Climate is a generalization of atmospheric conditions over a long period of time. It is more than an average, for extremes must always be considered in any climatic description along with the prevailing "normal" or mean conditions. This lab will assist students in understanding the worldwide distribution of climates and the resulting impact upon people.

The global patterns of air temperature and other weather elements that occur based upon the Earth's tilt, rotation and land/sea distribution are responsible for the Earth's many climates. Climates are the general weather conditions usually found in a particular place. While the weather varies from day-to-day at any particular location, over the years, the same type of weather will reoccur. This recurring weather pattern for each location is known as the climate for that location.

The first widely used climate classification was devised by Dr. Wladimir Köppen (1846-1940) in 1918, revised most recently by him in 1931, and modified many times by others since then. This system is based upon annual and monthly means of temperature and precipitation, but many of his boundaries were created with specific types of vegetation limits in mind. Köppen, a German climatologist and amateur botanist, divided the world's climates into several major categories based upon general temperature profiles related to latitude. Köppen's classification divides the world into four (4) major types of climate groups (A, C, D, E) based upon temperature values alone. A fifth group (B) for dry climates is determined by both temperature and precipitation values (so that evaporation, transpiration, and the availability of water for plant growth can be considered).

- **A** - tropical humid
- **B** - dry (arid) climates based on relationship between temperature and evapotranspiration
- **C** - warm temperate humid/cool winter
- **D** - cool temperate humid/cold winter
- **E** - polar
- **H** - highland (not used in Köppen's classification)

These groups are further subdivided on the basis of seasonality of precipitation, and once again on the basis of extremes of temperature.

The following diagram (Figure 13.1) illustrates some of the factors that are responsible for the creation of weather and climate.

Figure 13.1 Köppen's classification system basis

Climatic Controls	→ *act upon* →	**Climatic Elements**	→ *to produce* →	**Types and Varieties of Weather and Climate**
Latitude or Sun Angle				A – Tropical
Land–water Distribution		Insolation		
Winds and Air Masses				B – Dry
Semi-permanent Highs & Lows		Temperature		
Storms				C – Mesothermal
Altitude (elevation)		Pressure		
Mountain Barriers				D – Microthermal
Ocean Currents		Moisture		
				E – Polar

In addition to the five main classification letters described above, by adding additional letter symbols, based on additional climatic criteria, we derive 16 major *climate types*.

Af	-	Tropical Rainforest
Am	-	Tropical Monsoon
Aw	-	Tropical Savanna
BSh	-	Low Latitude Steppe
BWh	-	Low Latitude Desert
BSk	-	Middle Latitude Steppe
BWk	-	Middle Latitude Desert
Csa/Csb	-	Mediterranean (Dry Summer subtropical)
Cfb/Cfc	-	Marine West Coast
Cfa	-	Humid Subtropical
Cwa/Cwb	-	Subtropical Monsoon
Dfa/Dwa	-	Humid Continental – Long Summer
Dfb/Dwb	-	Humid Continental – Short Summer
Dfc/Dwc	-	Subarctic
Dfd/Dwd	-	Subarctic
ET	-	Tundra
EF	-	Ice Cap

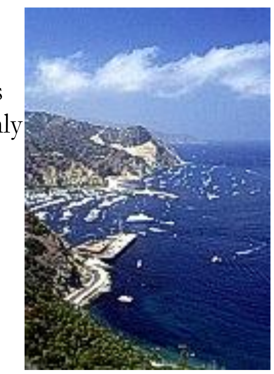
In more detail, Figure 13.2 also provides some further classification characteristics.

Figure 13.2 Köppen's classification system detailed

Tropical Climates
(Classification **A**)
Tropical moist climates extend north and south from the equator to about 15° to 25° latitude. In these climates all months have average temperatures greater than 18° C (64°F) and annual precipitation greater than 150 cm (59").

Dry Climates
(Classification B)
The most obvious climatic feature of this climate is that potential evaporation and transpiration exceed precipitation. These climates extend from 20°-35° North and South of the equator and in large continental regions of the mid-latitudes often surrounded by mountains.

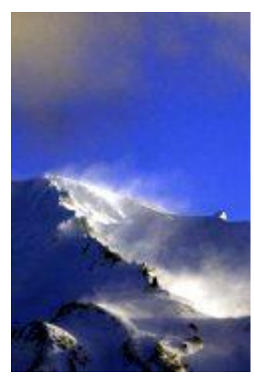
Moist Subtropical Mid-Latitude Climates
(Classification **C**)
This climate generally has warm and humid summers with mild winters. Its extends from 30° to 50° latitude mainly on the eastern and western borders of most continents. During the winter, the main weather feature is the mid-latitude cyclone. Convective thunderstorms dominate summer months.



Moist Continental Mid-latitude Climates
(Classification **D**)
Moist continental mid-latitude climates have warm to cool summers and cold winters. The location of these climates is poleward of the **C** climates. The average temperature of the warmest month is greater than 10°C (50°F), while the coldest month is less than 0°C. Winters are severe with snowstorms, strong winds, and bitter cold from Continental Polar or Arctic air masses.

Polar Climates
(Classification **E**)
Polar climates have year-round cold temperatures with the warmest month less than 10°C (50°F). Polar climates are found on the northern coastal areas of North America, Europe, Asia, and on the landmasses of Greenland and Antarctica.

Highlands
(Classification **H**)
These are unique climates based on their elevation. Highland climates occur in mountainous terrain where rapid elevation changes cause climatic changes over short distances.



Identification of Climate Types Using Köppen's Classification

It is not necessary to check climate types in a specific order as the categories are mutually exclusive. However, since dry climates tend to be more difficult to deal with, you might want to check for dry climates first and then proceed through the other major climatic types.

Whenever a climate station receives less than 750 mm (30") of precipitation, it is possible that it may be a "B" type (dry) climate. As more moisture is lost to evaporation and transpiration in warmer climates, you must consider temperature data as well. To check as to whether a climate is Dry, use the "Sector Graphs for Climates" (Figure 13.5). Each graph helps you to determine whether the climate you are examining is "BW" (desert), "BS" (steppe) or is some type of humid climate (A, C, or D). The distribution of precipitation during the year determines which of the three graphs you should use.
Even regime (precipitation well distributed throughout the year) = moderate evaporation loss,
Summer regime (April - September in the Northern Hemisphere / October to March in the Southern Hemisphere) = high loss of moisture, and
Winter regime (October to March in Northern Hemisphere / April - September in the Southern Hemisphere) = low loss of moisture through evaporation and transpiration.

Climate data for Boston, MA

Month	**Temperature**		**Precipitation**	
	°F	°C	Inches	Millimeters
January	28.8	-1.8	3.6	91.9
February	30.4	-0.9	3.6	91.9
March	38.5	3.6	3.7	93.7
April	48.0	8.9	3.6	91.4
May	58.1	14.5	3.2	82.5
June	67.6	19.8	3.1	78.4
July	73.4	23.0	2.8	72.1
August	71.8	22.1	3.2	82.2
September	64.8	18.2	3.1	77.7
October	54.7	12.6	3.3	83.8
November	45.1	12.6	4.2	107.1
December	33.4	0.8	4.0	101.8
Annual	51.3	10.7	41.5	1054.3

(Annual temperature is average while precipitation is total or sum)

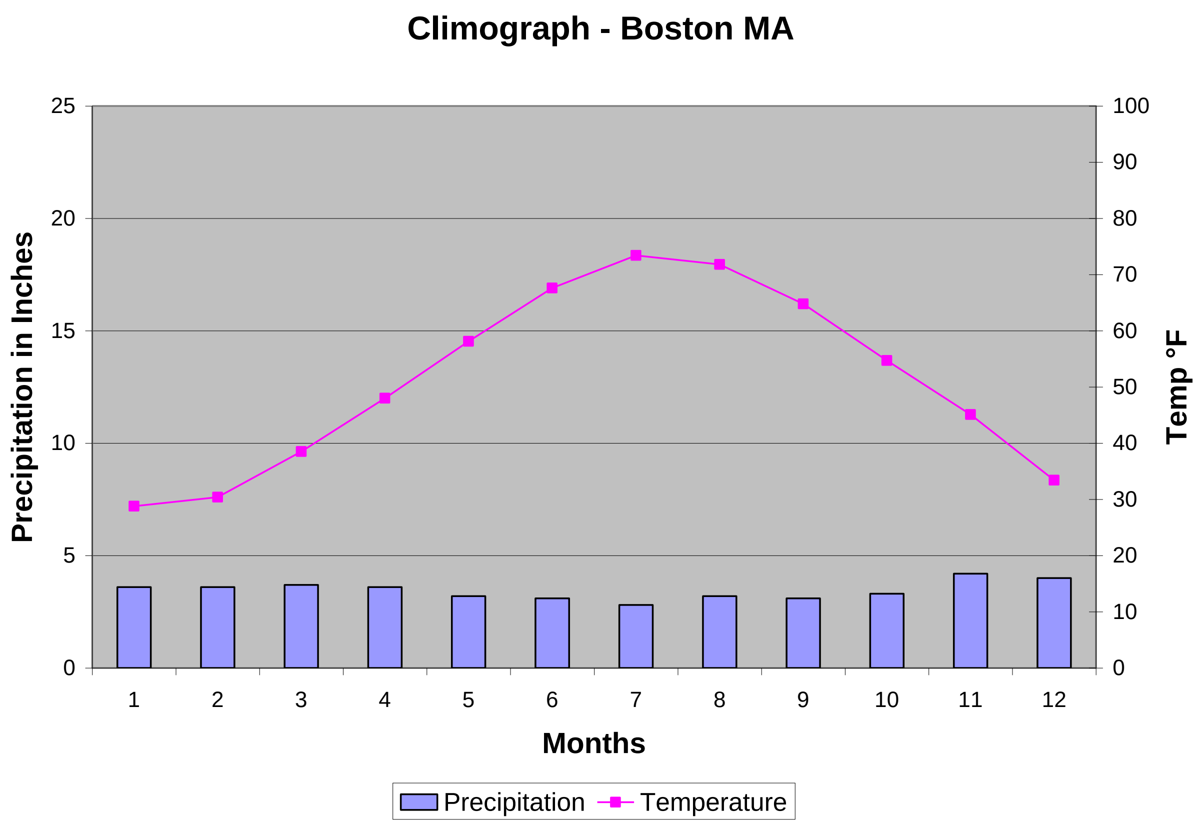
Köppen Classification _____

Winter:	cold, humid	Temp. max.:	73.4°F	23.0 °C
Summer:	warm, humid	Temp. min.:	28.8°F	-1.8 °C
Precip. total:	41.5" 1054.3 mm	Temp. range:	44.6°F	24.8 °C

Climographs

Basic climatic characteristics may be visualized by plotting the temperature and precipitation data for a station. This is referred to as a Climograph, or Temperature-Precipitation Graph.

Figure 13.3 Climograph – Boston, Massachusetts



Internet Resources for Climate

World Cimates (data source for this chapter)
http://www.worldclimate.com/

Figure13.4 – Simplified Koppen Classification of Climates

FIRST LETTER		SECOND LETTER		THIRD LETTER		
E	Warmest month less than 10°C (50°F) ICE CLIMATES	T	Warmest month between 10°C (50°F) and 0°C (32°F)		NO THIRD LETTER (with ice climates) SUMMERLESS	ET
		F	Warmest month below 0°C (32°F)			EF
B	Arid or Semiarid Climates If annual precipitation less than 750 mm (~30 in) use sector graphs (Figure 13.5) ARID CLIMATES: BS – Steppe BW – Desert	S	Semiarid Climate (see sector graphs, Fig. 13.5)	h	Mean annual temperature is greater than 18°C (64.4°F)	BSh BSk
		W	Arid Climate (see sector graphs, Fig. 13.5)	k	Mean annual temperature is less than 18°C (64.4°F)	BWh BWk
A	Coolest month is greater than 18°C (64.4°F) TROPICAL CLIMATES: Am – Tropical Monsoon Aw – Tropical Savanna Af – Tropical Rain Forest	f	Driest month has at least 60 mm (2.4 in)		NO THIRD LETTER (with Tropical Climates) WINTERLESS	Af Am Aw
		m	Seasonally, excessively moist (see Fig 13.4.1)			
		w	Dry winter, wet summer (see Fig 13.4.1)			
C	Coolest month is between 18°C (64.4°F) and 0°C (32°F) and at least one month over 10°C (50°F) WARM TEMPERATE CLIMATES	s	DRY SUMMER: Driest month in the summer half of the year with less than 30 mm (1.2 in) of precip. and less than $^1/_3$ of the wettest winter month.	a	Warmest month above 22°C (71.6°F)	Csa Csb Cwa Cwb Cfa Cfb Dwa Dwb Dwc Dfa Dfb Dfc
				b	Warmest month below 22°C (71.6°F), with at least 4 months above 10°C (50°F)	
		w	DRY WINTER: Driest month in the winter half of the year, with less than $^1/_{10}$ of the precip of the wettest summer month	c	Warmest month below 22°C (71.6°F), with 1 to 3 months above 10°C (50°F)	
D	Coldest month less than 0°C (32°F) and at least one month over 10°C (50°F) SNOW CLIMATES	f	ALWAYS MOIST: Does not meet conditions for s or w above.	d	Same as c, but coldest month is below -38°C (-36.4°F)	Dfd Dwd
H	HIGHLAND CLIMATES		NO SECOND LETTER CHARACTERIZED BY VERTICAL ZONATION		NO THIRD LETTER OF CLIMATES GIVEN ABOVE	H

Figure 13.4.1 – Use to determine moisture classification (m or w) for A climate

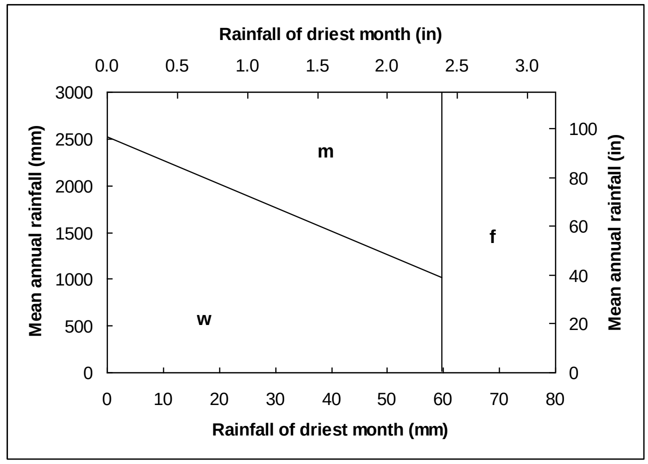
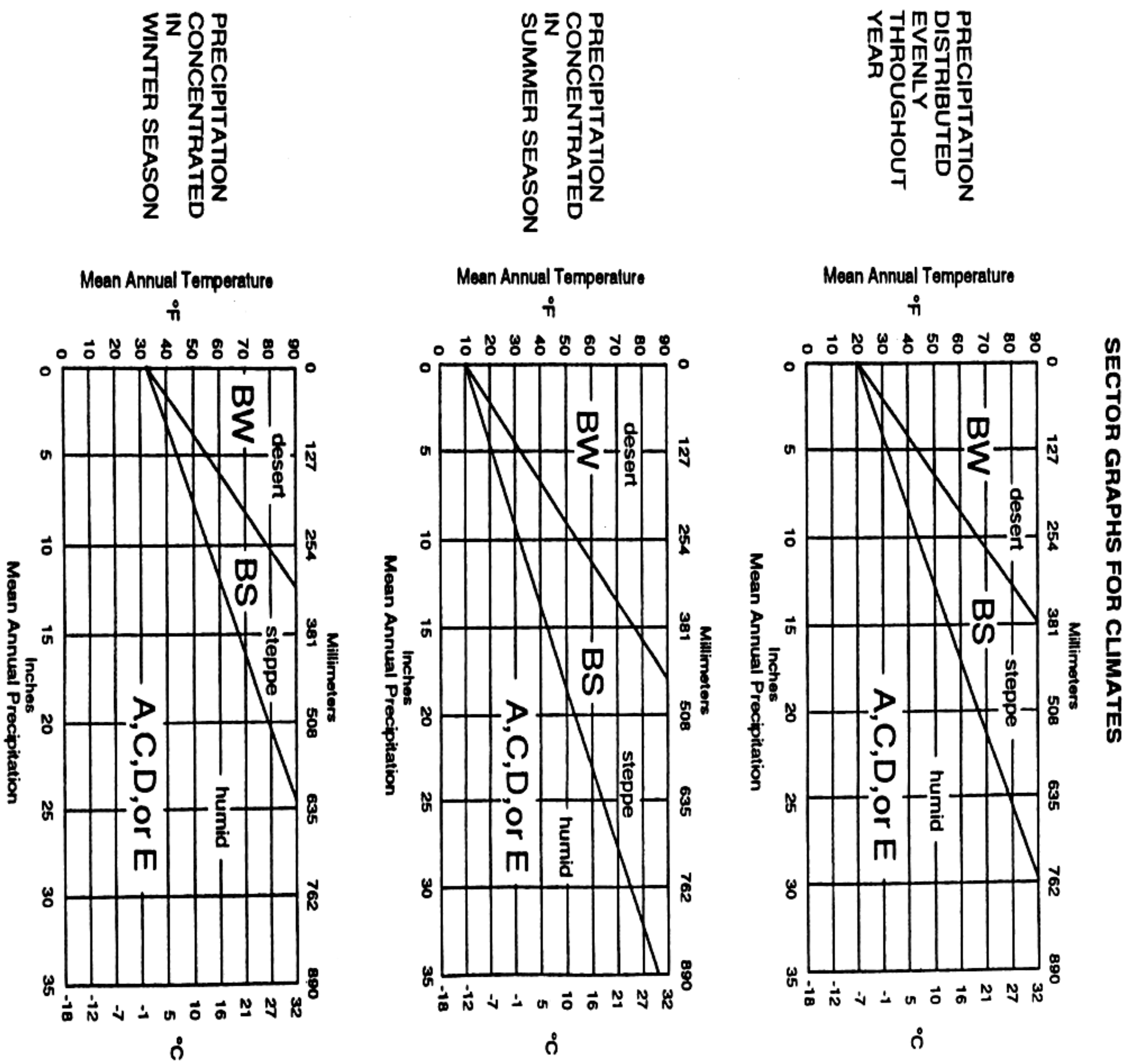


Figure 13.5 – If the total annual precipitation of a location is < 750 mm (~30 in), use the graphs to determine if the location is a 'B' (arid/semi-arid) climate.



Exercise #13 Lab Activity

Name: ______________________________

Climate

Lab Section: ______________________________

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

Classify the following climatic stations using the Köppen system. Listing the temperature maximums and minimums, temperature range, and precipitation amounts will aid the classification process. You will need to determine whether the stations are in the northern or southern hemispheres. **Note:** the station data for precipitation is in millimeters (mm) and some charts are in millimeters and some are in centimeters (cm). To convert: 1 cm = 10 mm / 1 mm = 0.1 cm.

After classifying all ten stations, match the stations with the following cities:

Barrow, Alaska	Salem, MA
Ulaan Baatar, Mongolia	Singapore
Riyadh, Saudi Arabia	Santiago, Chile
Rome, Italy	Dar es Salaam, Tanzania
Cape Town, South Africa	Vostok, Antarctica

	#1		#2		#3		#4	
	Temp (°C)	Precip (mm)	Temp	Precip	Temp	Precip	Temp	Precip
JAN	-26.2	4.5	14.3	13.8	-2.2	94.0	-20.5	1.5
FEB	-27.5	3.8	16.2	10.4	-2.2	88.9	-18.0	1.7
MAR	-26.1	3.6	20.8	29.8	1.7	104.1	-9.6	3.7
APR	-18.3	4.4	25.0	29.7	7.2	96.5	-0.4	9.3
MAY	-7.1	3.7	30.8	13.1	13.9	94.0	8.0	14.0
JUN	1.1	8.2	33.6	0.0	20	78.7	13.7	51.9
JUL	4.1	21.5	34.6	0.0	22.8	88.9	15.6	75.9
AUG	3.3	24.5	34.4	0.0	20.7	106.7	13.7	66.6
SEP	-0.8	15.6	31.4	0.0	17.2	86.4	7.3	30.0
OCT	-9.1	12.3	26.3	0.7	11.1	94.0	-1.2	5.9
NOV	-18.2	6.2	20.6	4.5	5.0	104.1	-11.0	4.0
DEC	-24.2	4.1	15.4	11.3	0.0	96.5	-18.4	2.4
ANNUAL	-12.3	113.4	25.2	112.7	9.5	1132.8	-1.7	268.0

	#1	#2	#3	#4
Temp. Max.	________	________	________	________
Temp. Min.	________	________	________	________
Temp. Range	________	________	________	________
Precip Max.	________	________	________	________
Precip Min.	________	________	________	________
Classification	________	________	________	________
City	________	________	________	________

	#5		#6		#7		#8	
	Temp (°C)	Precip (mm)	Temp	Precip	Temp	Precip	Temp	Precip
JAN	7.2	80.0	21.7	15.9	-32.1	0.1	26.2	238.5
FEB	8.3	70.9	21.8	15.2	-44.3	0.0	26.9	165.1
MAR	10.5	68.6	20.8	21.6	-57.9	0.7	27.3	173.6
APR	13.7	66.8	18.6	49.5	-64.7	0.5	27.7	166.4
MAY	17.8	51.5	15.8	91.7	-65.6	0.4	27.7	170.7
JUN	21.7	34.1	13.9	105.4	-65.2	0.5	27.5	163.1
JUL	24.4	16.3	13.3	91.2	-66.9	0.6	27.2	149.8
AUG	24.1	24.4	13.7	82.6	-67.6	0.7	27.1	171.3
SEP	20.9	69.2	15.2	54.3	-66.0	0.3	27.1	163.5
OCT	16.6	113.3	17.1	39.6	-57.1	0.2	27.2	191.0
NOV	11.7	110.7	19.2	24.2	-43.3	0.1	26.8	250.1
DEC	8.4	97.1	20.5	19.3	-32.1	0.0	26.3	268.7
ANNUAL	15.4	802.9	17.6	612.5	-55.1	4.5	27.1	2272.2

	#5	#6	#7	#8
Temp. Max.	______	______	______	______
Temp. Min.	______	______	______	______
Temp. Range	______	______	______	______
Precip Max.	______	______	______	______
Precip Min.	______	______	______	______
Classification	______	______	______	______
City	______	______	______	______

	#9		#10	
	Temp (°C)	Precip (mm)	Temp	Precip
JAN	27.5	71.1	20	0.0
FEB	27.6	63.2	19.4	2.5
MAR	27.2	128.1	17.2	5.1
APR	26.2	270.3	13.9	15.3
MAY	25.1	182.7	11.1	58.4
JUN	23.9	33.5	8.9	81.3
JUL	23.3	27.4	8.3	86.4
AUG	23.5	25.9	8.9	61.0
SEP	24.0	28.3	12.8	30.5
OCT	25.1	49.1	13.3	15.3
NOV	26.2	84.2	16.1	5.1
DEC	27.3	90.4	18.3	5.1
ANNUAL	25.6	1056.4	13.3	365.8

	#9	#10
Temp. Max.	______	______
Temp. Min.	______	______
Temp. Range	______	______
Precip Max.	______	______
Precip Min.	______	______
Classification	______	______
City	______	______

Lab

14

Climate Regions

Combining knowledge of the global patterns behind the major climatic controls, this lab will allow students to explore patterns of climate distribution employing both climate graphs and Köppen's climate classification system.

Combining Climate Graphs and Köppen's Classification

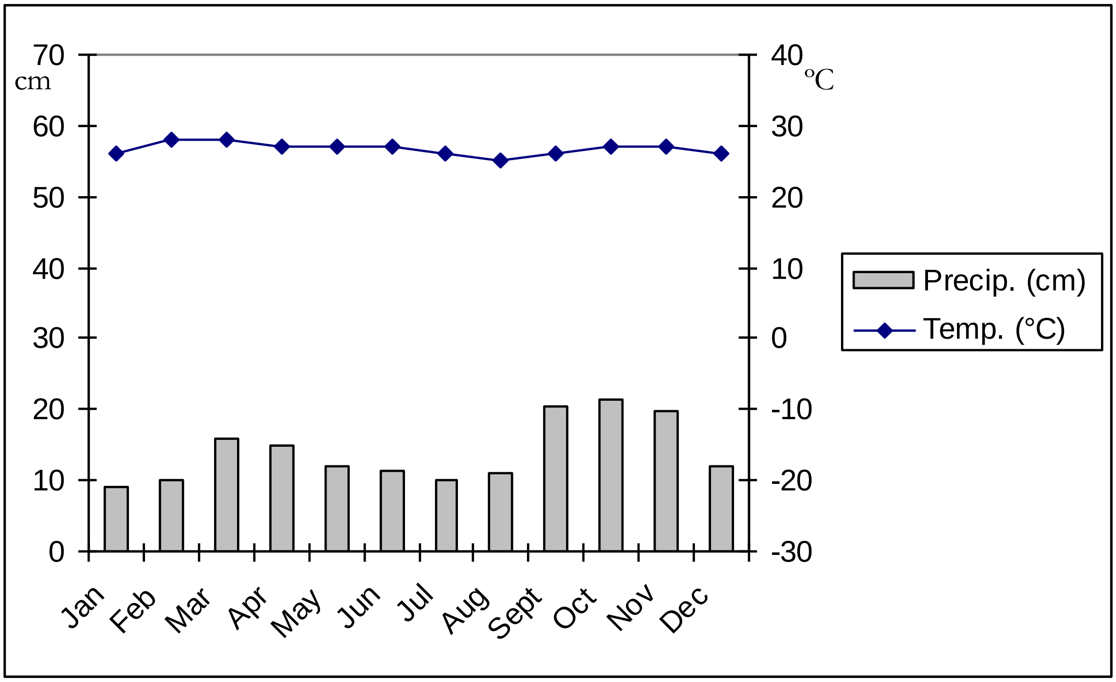
Climographs

A number of basic climatic characteristics may be visualized by plotting the temperature and precipitation data for a station. This is referred to as a Climograph, or Temperature-Precipitation Graph. The following exercise will use Climographs but will also require the use of a world map and knowledge of Köppen's classification system, and your accumulated understanding of weather and climate from this semester's course. You might want to refer back to the Köppen classification information in the last lab (#13) as well as from your text book.

Starting on the next page there will be a climograph followed by a set of questions to be answered based on the associated climographs. Each climograph provides the name of the station, its latitude and longitude, elevation, as well as monthly total precipitation and monthly average temperature.

Figure 14.1 Mbandaka, Congo (Zaire)

0°01' N, 18°17' E **Elev. 21m**



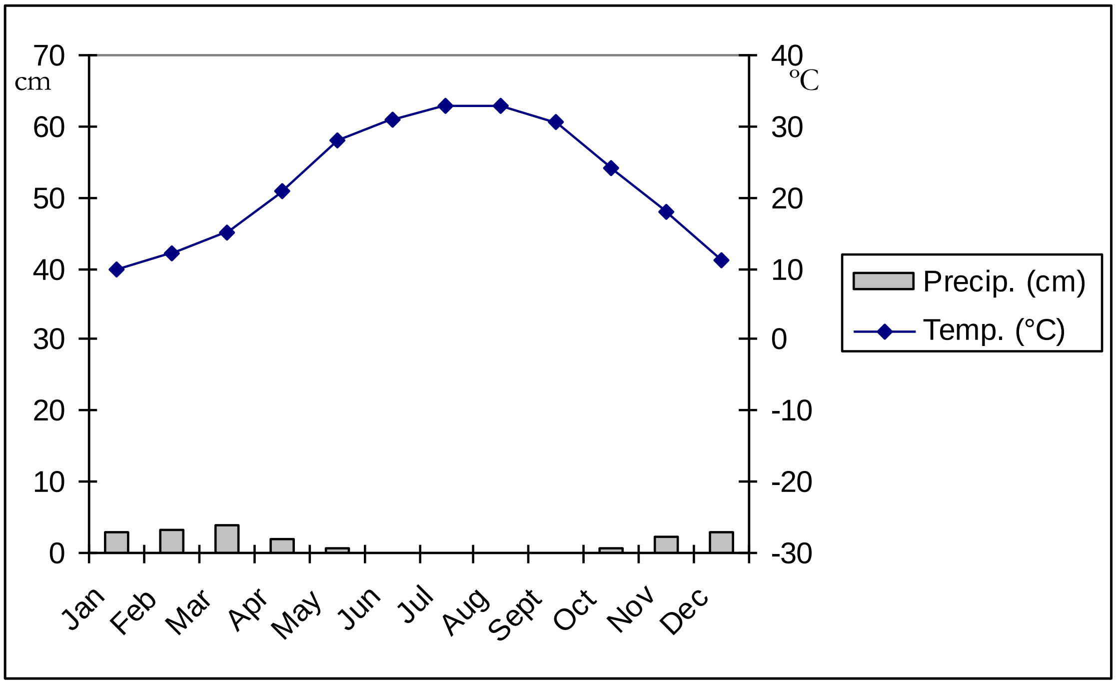
1. What wind and pressure pattern account for the double precipitation peak in Mbandaka (March/April and September/October/November)?

2. How does the latitude of Mbandaka relate to its small annual temperature range?

3. Using the Köppen-based classification system, identify the climate type of Mbandaka.

Figure 14.2 Baghdad, Iraq

33°14' N, 44°22' E **Elev. 34m**



✐ 4. Explain the relationship between Baghdad's latitude and its annual temperature range.

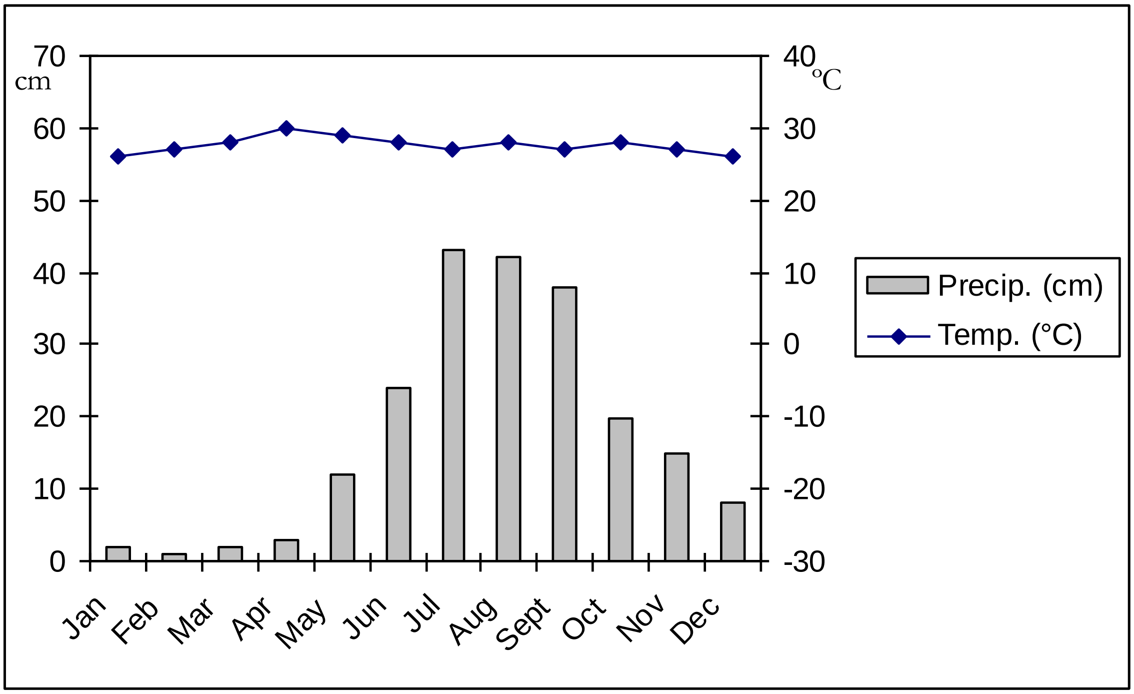
✐ 5. What is the main pressure system affecting Baghdad's annual precipitation?

✐ 6. Is Baghdad a mid-latitude or subtropical desert?

✐🗁 7. Using the Köppen-based classification system, identify the climate type of Baghdad.

Figure 14.3 Manila, Philippines

14°37' N, 121°00' E **Elev.14m**



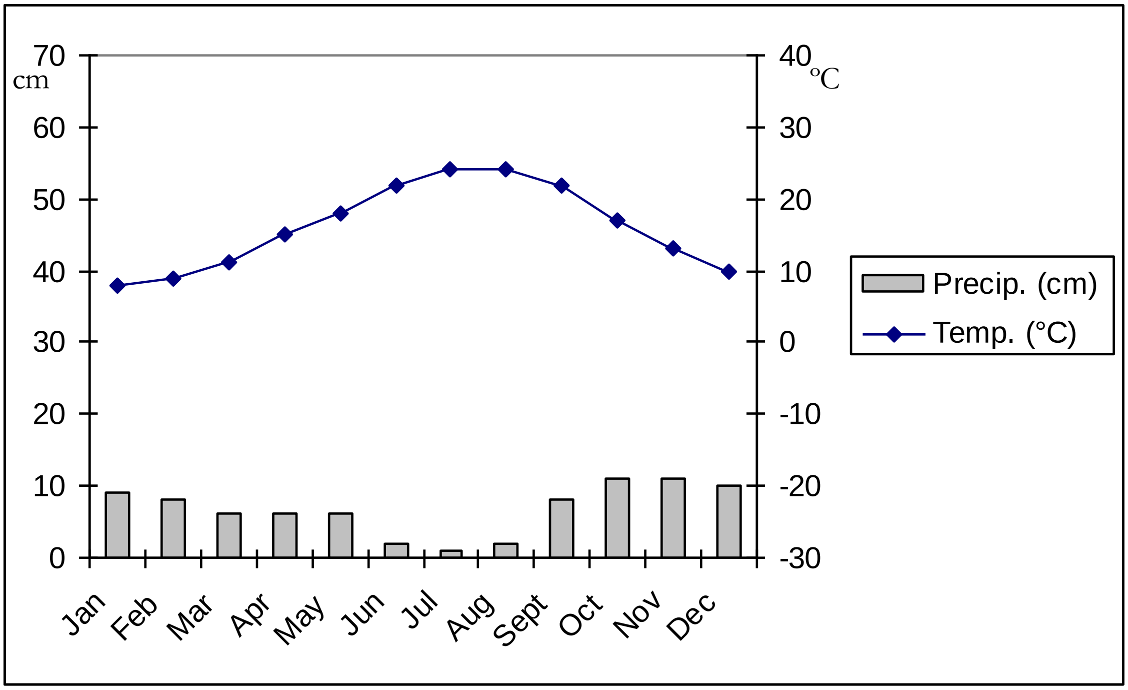
✐ 8. Account for why April is the warmest month in Manila.

✐ 9. In terms of pressure and wind systems, discuss the seasonal precipitation patterns and identify the causes of summer rains and winter dry seasons.

✐🗀 10. Using the Köppen-based classification system, identify the climate type of Manila.

Figure 14.4 Rome, Italy

41°52' N, 12°37' E **Elev. 3m**



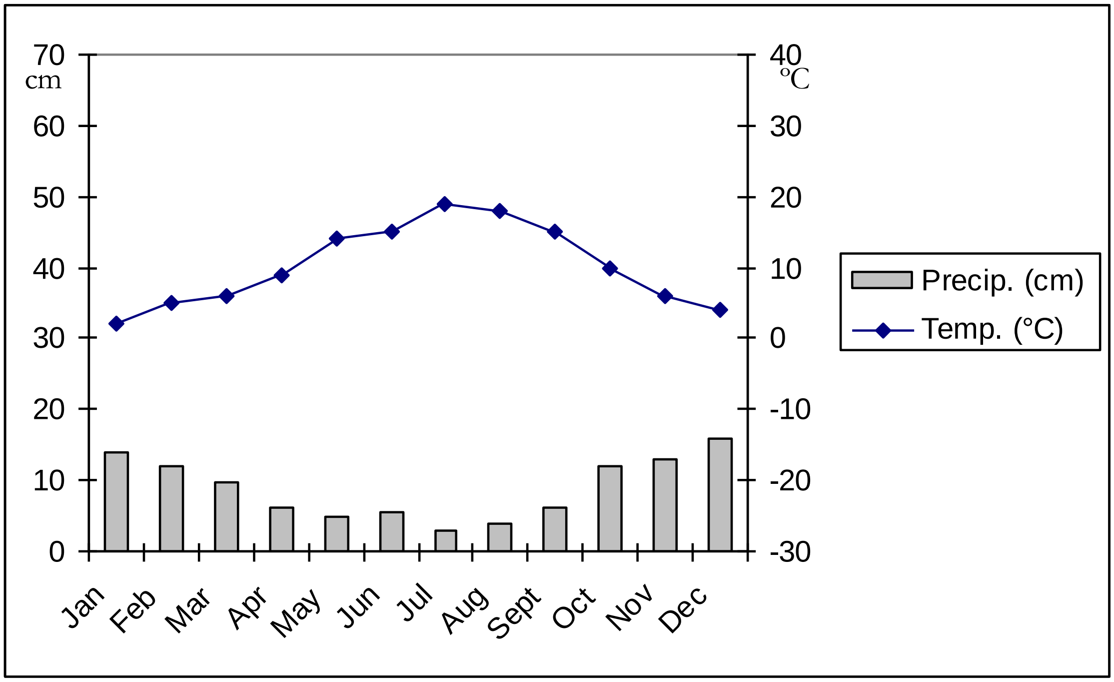
✐ 11. What wind systems and pressure patterns combine to reduce precipitation during summer months in Rome?

✐ 12. The winter months see an increase in precipitation due to what wind systems and pressure patterns?

✐🗁 13. Using the Köppen-based classification system, identify the climate type of Rome.

Figure 14.5 Vancouver, Canada

49°11' N, 123°06' W **Elev. 0m**



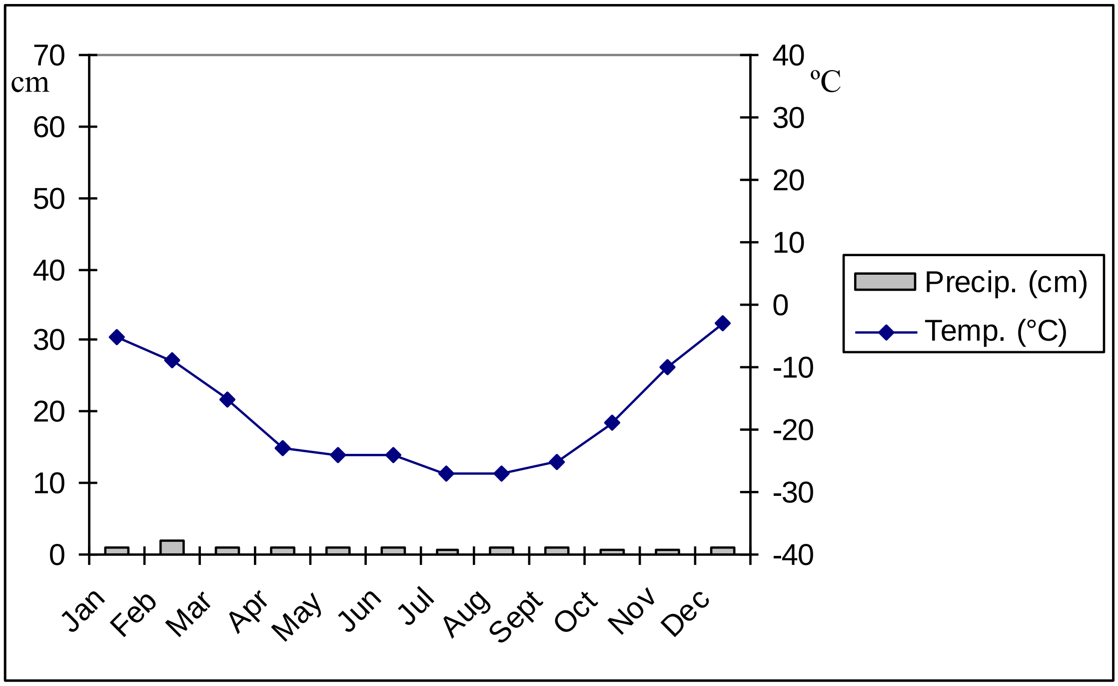
✎ 14. How does Vancouver's annual temperature range differ from most other locations at similar latitudes?

✎ 15. Precipitation is reduced during the summer months in Vancouver due to which seasonal movement of wind and pressure systems?

✎🗁 16. Using the Köppen-based classification system, identify what climate type Vancouver would have.

Figure 14.6 McMurdo Station, Antarctica

77°53' S, 167°00' E **Elev. 2m**



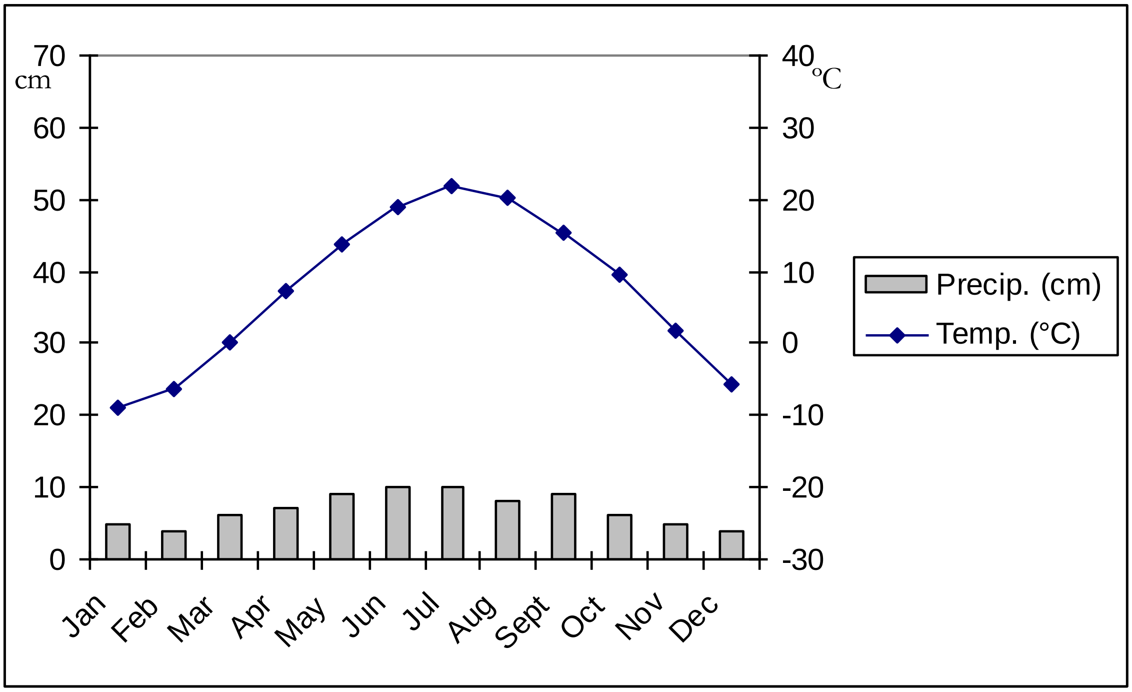
✐ 17. Because the McMurdo Station is south of the Antarctic Circle, it receives sunlight for 24-hours a day for part of the Southern Hemisphere's summer. Yet this region remains covered in ice. What sun angle issues and surface conditions contribute to ensuring that temperatures remain cold?

✐ 18. Why does this station receive such little precipitation over the course of the year?

✐🗁 19. Using the Köppen-based classification system, identify what climate type McMurdo Station would have.

Figure 14.7 Madison, Wisconsin

43°05' N, 89°24' W	Elev.264m



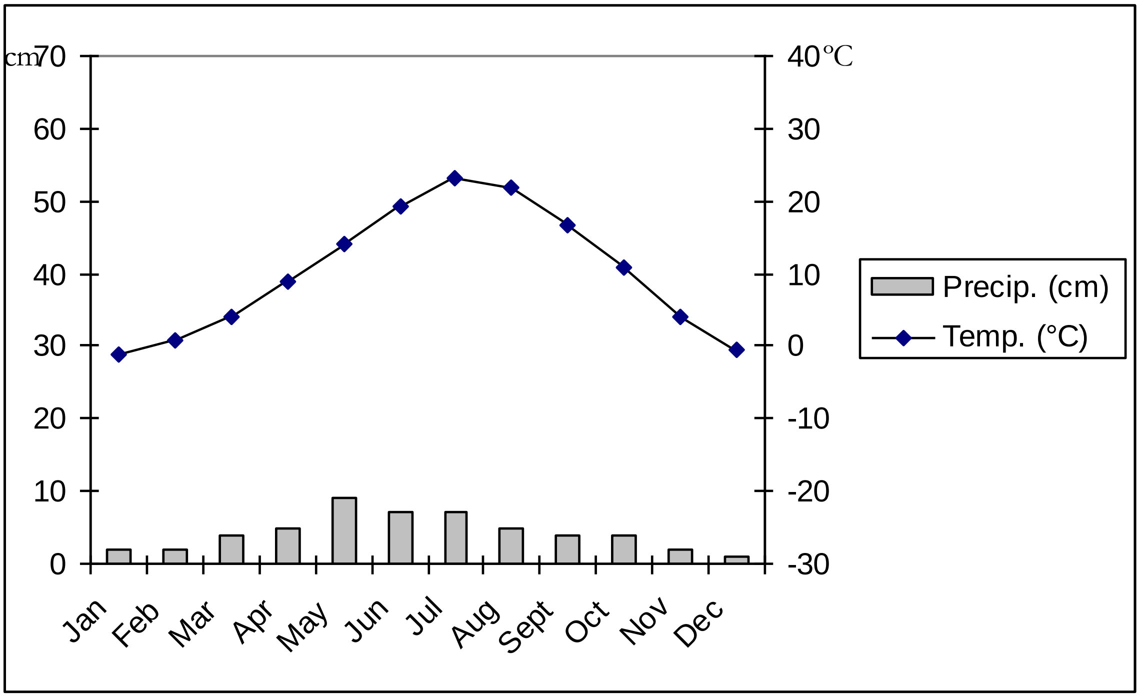
✐ 20. Identify the wind patterns that create the summer rain maximums in Madison and throughout most of the central United States.

✐ 21. What is the source of atmospheric moisture for Madison, as well as most central United States locations?

✐🗁 22. Using the Köppen-based classification system, identify the climate type of Madison.

Figure 14.8 Denver, Colorado

39°44' N, 105°00' W **Elev.1600m**

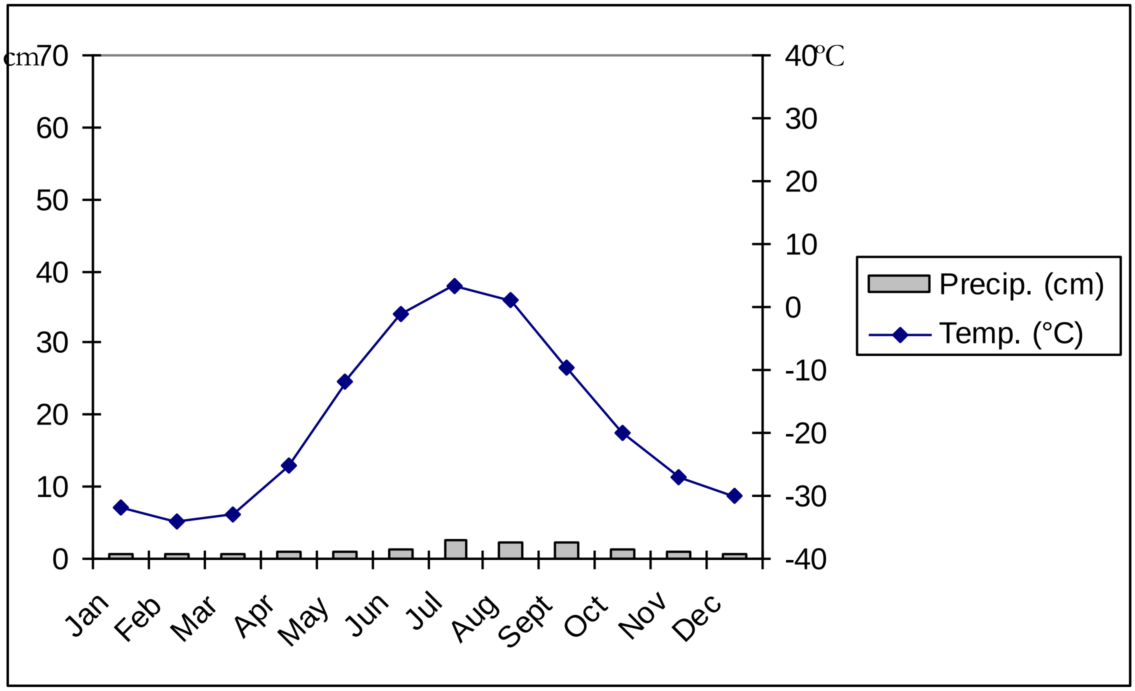


✐ 23. The relatively dry climate of Denver can be attributed to which geographical factors?

✐🗁 24. Using the Köppen-based classification system, identify the climate type of Denver.

Figure 14.9 Alert, Nunavut (Canada)

82°28' N, 62°30' W	Elev.100m



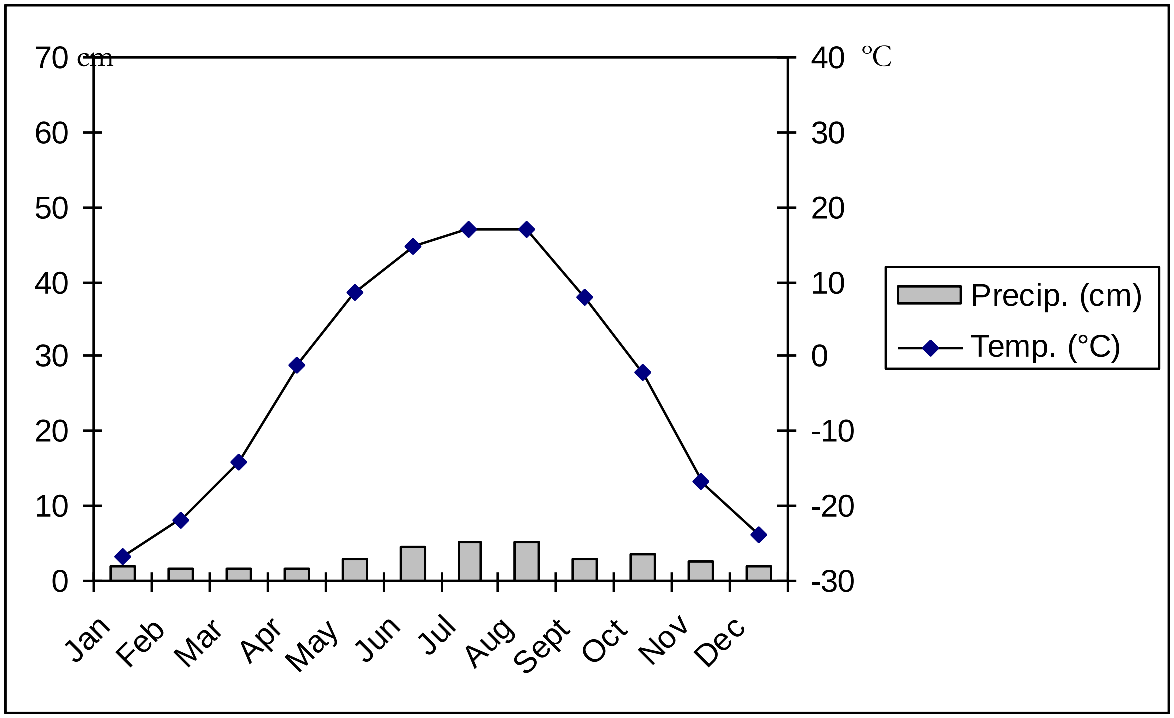
✐ 25. What air mass affects Alert's precipitation during the summer months?

✐ 26. From the perspective of vegetation, what is the significance of mean temperatures that exceed 0°C during a month or more?

✐🗀 27 Using the Köppen-based classification system, identify the climate type of Alert.

Figure 14.10 Inuvik, Canada

68°18' N, 133°29' W **Elev.168m**

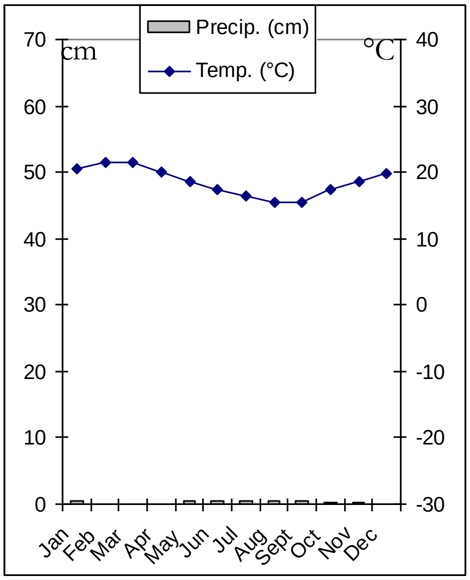


28. How do latitude and continental position cause such a large range of temperatures in Inuvik?

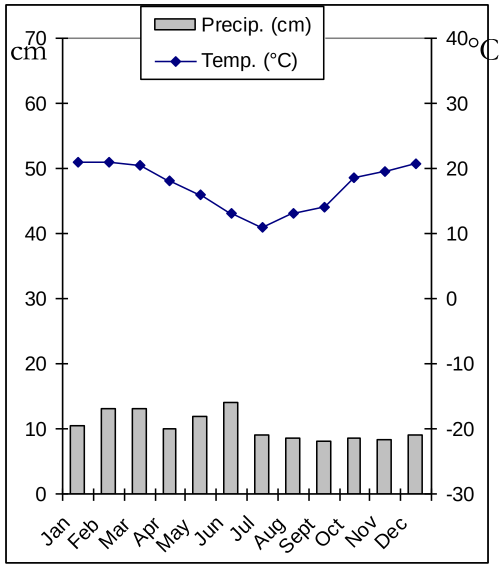
29. Using the Köppen-based classification system, identify what climate type Inuvik would have.

✐ 30. Match the following cities to the climographs below:

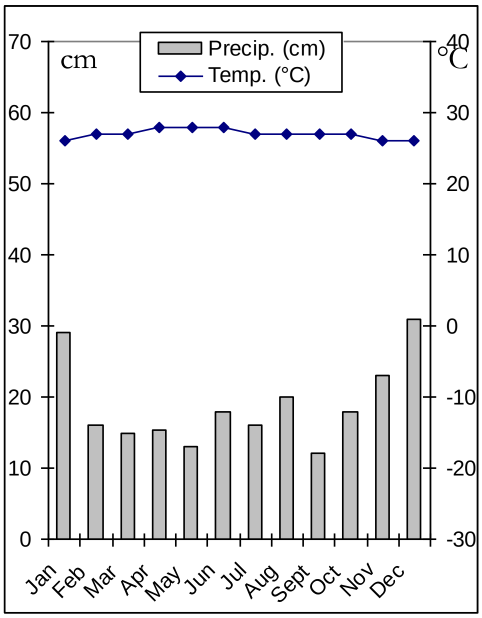
Perth, Australia	31°50'S, 116°10'E	Elev. 60 m
Singapore	1°22'N, 103°52'E	Elev. 6 m
Lima, Peru	12°06'S, 76°55'W	Elev. 120 m
Sydney, Australia	33°52'S, 151°17'E	Elev. 42 m



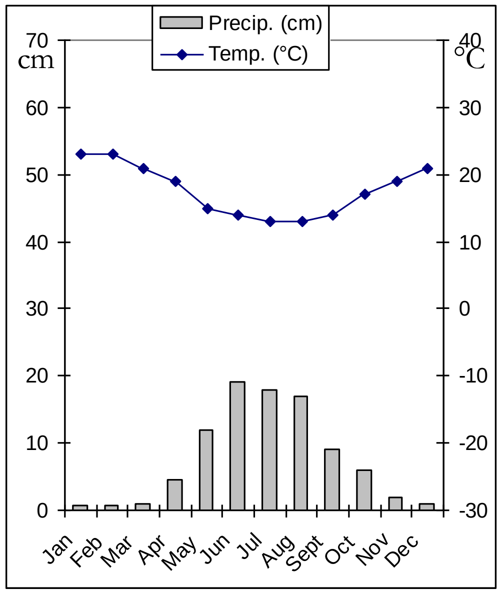
City ____________________
Climate type ____________________



City ____________________
Climate type ____________________



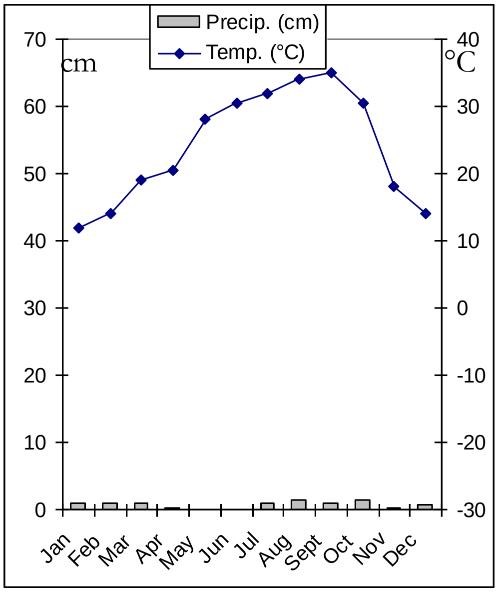
City ____________________
Climate type ____________________



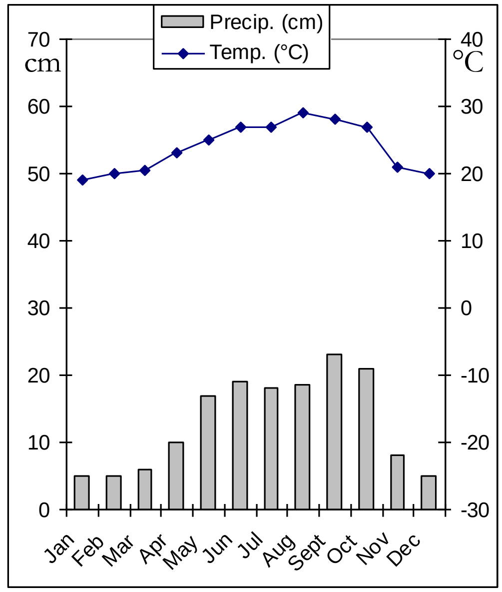
City ____________________
Climate type ____________________

✐ 31. Match the following cities to the climographs below:

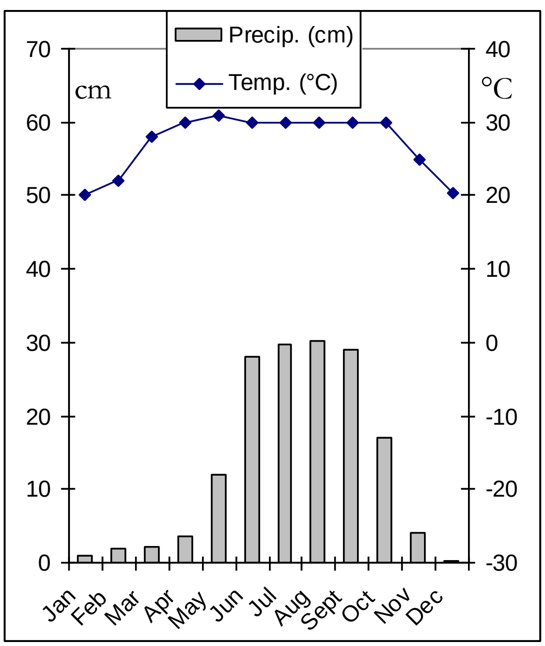
Iquitos, Peru	3°39'S, 73°18'W	Elev. 115 m
Miami, USA	25°45'N, 80°11'W	Elev. 2 m
Yuma, USA	32°40'N, 114°40'W	Elev. 62 m
Calcutta, India	22°32'N, 88°11'E	Elev. 6 m



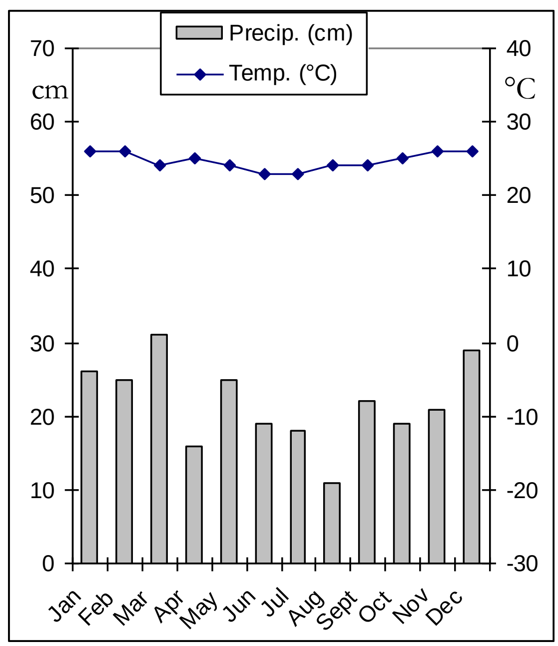
City ____________________
Climate type ____________________



City ____________________
Climate type ____________________



City ____________________
Climate type ____________________



City ____________________
Climate type ____________________

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Global Climate Patterns

💻 The Internet Web site visited in this part of the lab is produced by the Agrometeorology Group of the United Nations Food and Agriculture Organization's Sustainable Development Department.

While on line select (click on) the following address:

http://www.fao.org/waicent/faoinfo/sustdev/EIdirect/CLIMATE/EIsp0002.htm

✏🖱 1. Under Tour Guide menu on the left, scroll down to "2. Raw data maps". Under the "Rainfall" section, click on ***Animation of monthly rainfall*** total for a map which automatically cycles through the months of the year, depicting how precipitation ebbs and flows around the world. If you wish to view the monthly rainfall totals under ***Average monthly rainfall total***, you may select (click on) January. Then select each month, in turn, to display the maps of "Average Monthly Rainfall Total" (in millimeters).

✏2. In California (and much of the West Coast of the United States) the driest season occurs in [(***June-July-August***) (***December-January-February***)]. The lack of rainfall in this season is due to California's location on the east side of a center of semi permanent subtropical high pressure (which exists over the Pacific Ocean near Hawaii, mainly in the summer) and the presence of a cold ocean current off the coast. This pattern of extreme seasonal dryness [(***is***) (***is not***)] replicated in the southeastern U.S. which is located on the western side of a high pressure zone (centered near Bermuda) and near a warm ocean current.

✏ 3. Descending air, on the eastern sides of semi permanent high pressure zones, compresses and warms, reducing the possibility of precipitation. These zones of high pressure, centered about 30 degrees latitude, shift north and south with the seasons. The seasonal variation can be easily seen in the pattern of dryness which sweeps southward from the Sahara desert in northern Africa during the winter months. The dry area is displaced when the high pressure zone is replaced by a northward shift of a belt of thundershowers associated with the Intertropical Convergence Zone (ITCZ), a belt of low pressure, which is usually aligned along the equator. This shift ushers in the summer rains. The center of the Sahara Desert is always under the influence of this vast zone of high pressure despite the seasonal shifts. Similarly, some part of equatorial Africa is always under the rainy band despite seasonal shifts. This shifting pattern of alternating wetness and dryness [(***is***) (***is not***)] replicated in the part of Africa south of the equator.

✏ 4. Look at India and Southeast Asia on the same map series. This is an area affected by the monsoon. In summer, a shift northward of the band of thundershowers and low pressure (the ITCZ) and a switch in wind direction toward the continent from the surrounding warm tropical seas results in very large amounts of rainfall. In the winter, the ITCZ shifts southward and the winds blow off the land, creating dry conditions. Looking at the maps, India's driest months occur in [(***Dec and Jan***) (***Sep and Oct***)] and the wettest months occur in [(***July-Aug-Sept***) (***March-April-May***)].

✏ 5. From the Rainfall section select (click on) the map of Annual average rainfall total (in millimeters). The annual average masks the seasonal variability and reveals how wet or dry a particular region is. Some of the driest places in the world (<75 mm, appearing white and light gray on the map) occur in the interior of large continents which get little or no rainfall year round, due to distance from water sources, the effect of mountain ranges, and perhaps other factors. The center of the Sahara Desert in Africa and the Gobi Desert in the interior of Asia likely [(***do***) (***do not***)] fall into this category.

✏ 6. Other places are dry primarily due to the effect of mountain ranges which tends to "wring out" moisture orographically from air. As the air travels up the windward slope it expands, cools, and the moisture condenses to form clouds and precipitation. On the leeward side the air descends, compresses and warms, lowering relative humidity, and inhibiting cloud formation and rain. The location of the desert in these situations depends on the orientation of the mountain range and the direction of the prevailing wind. One of the driest deserts in the world is the Atacama, midway up the west coast of South America. Here, persistent winds from the east create a narrow, dry "rainshadow" on the western slopes of the Andes Mountains down to the Pacific Ocean. The dryness is enhanced by a cold ocean current which discourages the uplift of air. Further south, at a higher latitude, in a zone where the prevailing winds come from the west the coastal zone is moist and the rainshadow desert is found to the east of the Andes Mountains. In North America, the driest areas occur just east of the north-south oriented western mountains. This would suggest that at these latitudes the prevailing wind is coming from the [(***west***) (***east***)].

✏ 7. Still in Section 2. Raw Data Maps, go to the section titled "Temperature". Select Animation of monthly average temperature for a map which automatically cycles through the months of the year depicting how temperature changes through the months across the continents. Or you may select (click on) Average monthly temperature: January. Then select each month, in turn. Based on the maps, average monthly temperatures vary more during the year near the [(***poles***) (***equator***)]. The land areas on the maps indicate the [(***Northern***) (***Southern***)] Hemisphere has the greatest range in temperature throughout the year. This is due to the presence of large land masses in the midlatitudes in the Northern Hemisphere. Temperature averages tend to be lowest in the middle and higher latitudes of the Northern Hemisphere during the months of [(***Dec-Jan-Feb***) (***June-July-Aug***)]. This is primarily due to the shorter days and lower position of the sun in the daytime sky which decrease the amount of solar energy received at these latitudes.

✏ 8. It is also possible to utilize the monthly mean temperature and annual precipitation averages to classify a climate in a particular area. When the classification is mapped it is easy to see what places in the world have a similar climate and how variation in climate occurs spatially. Go to Section 3. "Derived products" and click on Köppen Climate Classification map. This is a color-coded map of climate regions that uses a Köppen-based classification similar to those found in Lab 11. The descriptive names of the color-coded climates on this map can be viewed along the bottom of the map.

✏ 9. Climates classified as "A" (Tropical) occur as expected near the [(***equator***) (***midlatitudes***)]. "D" and "E" represent climates of the [(***midlatitudes and polar regions***) (***Tropics***)]. The "B" (Dry) climates generally occur in [(***the same***) (***different***)] parts of the world that had low annual amounts of precipitation. (Note, parts of the color coding for classifications "A," "C," and "D" overlap into regions which under most classifications would be considered "B" (Dry) climates because they are mapped on the temperature criterion alone.)