SCIENCE
Earth and Space Science
Grade 8
Water Cycle, Weather, and Climate

Overview

Your students will most likely have heard about climate change and the implications it may have on the future. They probably have been exposed to the water cycle as well. However, they may not understand what climate is or how the water cycle works. Almost certainly, they do not know about climate classification or how to use a standard technique to classify climate based on temperature and precipitation data. Neither are they likely to understand the connection between climate and the water cycle.

In this unit, students investigate the water cycle and its processes as they investigate climate. They also examine temperature and precipitation data from around the world to classify the climate at ten cities. Finally, they are challenged to do additional work that will allow them to create a climate map of the world. This unit also builds science inquiry skills through the use and manipulation of data to support explanations.

Benchmarks

ESS-M-A10 explaining (illustrating) how water circulates—on and through the crust, in the oceans, and in the atmosphere—in the water cycle

ESS-M-A11 understanding that the atmosphere interacts with the hydrosphere to affect weather and climate conditions

SI-M-A4 developing descriptions, explanations, and graphs using data

Teacher Preparation

The term "humidity" is used frequently when people mean "relative humidity." In fact, humidity is the generic term used to refer to water vapor in the atmosphere. Relative humidity is a specific measure of humidity and is defined as the ratio, expressed as a percentage, of the pressure exerted by the water vapor in the air to the pressure water vapor would exert if the air were saturated. Since the amount of water vapor needed to saturate air increases with increasing temperature, it is possible to have a great deal of water vapor in the air (and thus a great deal of humidity) but still to have a low relative humidity. This fact is used in the first activity to create a discrepant event that introduces the unit.

From there, the unit uses pictures of two very different places to focus the students' attention onto the idea of climate and its relationship to the water cycle. It introduces the concept of the water cycle by having the students model the journey of a water molecule over time as the cycle's processes move it about. The misconception of this being a cycle in the traditional sense of returning objects to their original state also is discussed.

The relationship between the water cycle and climate is established as students learn about the Köppen climate classification system and apply it to real data from cities around the world. The system may seem complicated to invoke at first but is rather straightforward after a little experience. They then are challenged to do some research of their own in order to develop a map of world climate zones.

Materials/Equipment

- "Where is there more water vapor?" activity
- paper
- access to the Internet
- dice
- Water Cycle Game station cards
- Water Cycle Game Scorecards
- pencils
- markers
- newsprint
- climate Data Worksheet
- climate classification definitions
- calculators
- world map

Day 1
(45 minutes)

Materials/Equipment

- "Where is there more water vapor?" activity
- paper
- pencils
- access to the Internet

Set or Opener

In this activity, students are presented with a discrepant event to interest them in water vapor and to serve as a lead into the study of climate and the interaction between the atmosphere and the hydrosphere.

1. Distribute the "Where is there more water vapor?" activity and ask the students to work through it.

2. The activity first shows pictures of the Sahara Desert and the town of Sitka, Alaska, and asks the students to predict in which of the two locations would more water vapor be found if one looked from the ground to the top of the atmosphere. The picture of Sitka shows water, clouds, and snow in the mountains while the picture of the Sahara shows sand dunes, sparse vegetation, and clear skies. Based on this information, most people would predict incorrectly that Sitka would have more water vapor. Because warm air requires more water vapor for a relative humidity of 100% than does cold air, the atmosphere above the Sahara actually contains the greater amount of water vapor.

3. This fact is verified in the second portion of the activity when the students examine a map of the world showing average total water vapor content (expressed as the depth of water that would be produced by condensing all of the vapor in a column of air extending from the surface to the top of the atmosphere) for 1992. From the map, they should see that there was 16 to 20 mm of water vapor over the Sahara and 8 to 12 mm of water vapor over Sitka.

Body

1. After approximately 15 or 20 minutes with the first page, have the students form teams of two or three and discuss their predictions. Then have one of the group members report their conclusions. During this time, try to draw out the explanations for their predictions, emphasizing how the water vapor got into the atmosphere.

2. Then distribute the second sheet of the activity and allow the groups to interpret the map.

3. Discuss their findings and reasoning for the greater vapor concentration over the desert.

Closure

1. Using a whole-group discussion, ask them what they think the temperature is like during the year in these two places. The should respond with the desert being hot and Alaska being cold, but they may not realize how cold the desert can become in winter and at night.

2. Tell the students that they are to search the Internet for information about average temperatures and precipitation month-by-month through the year for two cities: one in the Sahara Desert and the other in Alaska. A good place for them to find this information is at the World Climate web site located at http://www.worldclimate.com.

3. They should report their information at the class meeting after next.

Day 2
(45 minutes)

Materials/Equipment

- dice
- Water Cycle Game station cards
- Water Cycle Game Scorecards
- pencils
- markers
- newsprint

Set or Opener

In this activity, the students will examine the water cycle and then link their understanding with the knowledge they gained from the previous activity about water vapor content.

1. Before class, construct signs for the nine stations in the Water Cycle Game (ocean, atmosphere, plant, lake, animal, soil, groundwater, glacier, and river) and post them on the walls around the classroom or in the hallway. Each sign should have the name of the stations and the list of actions to be taken. (See the resource sheet for stations names and actions to be taken to move from between stations.)

2. Divide the students into groups of three and assign roles as follows: die roller (responsible for generating a random number between 1 and 6 at each station by rolling a die), recorder (records on the scorecard the station name at which the group is present, the action to move the group to the next station, and the name of the next station), and scout (finds the location of the group's next station and guides them to it.

3. Distribute the game's Scorecards and dice, with one Scorecard and one die going to each group.

4. Tell them that each group represents a water molecule that will be followed for a brief period of time and that they should record where the molecule is, what happens to it, and where it goes next during this game.

5. Show the stations to the students and randomly distribute the groups to their initial stations.

6. Explain to them that they should record their current station on the Scorecard and should move to ten more stations over the next 10 minutes, with their movement determined by the number produced from rolling their die and the action corresponding to this number that is posted at their station. For example,

if a group is at the lake station and rolls a 4, their molecule is heated and evaporates into the atmosphere. They should then go to the atmosphere station and roll their die again to determine their next step.

7. After they have completed the ten stops, have them depict their molecule's journey in some way. For example, they may draw a picture, tell a story, or act out a skit. Allow them 10 minutes for preparation, then have each group make its presentation.

Body

1. Discuss the processes that take water molecules from one place to another in their journey.

    a. Evaporation: the process that accomplishes the phase change from liquid to vapor or gas. The input of heat, generally provided by the Sun, is required to evaporate a liquid.
    b. Condensation: the process that accomplishes the phase change from vapor to liquid. This process gives off heat that may then be used to alter other matter. For example, it may warm the atmosphere and help clouds develop.
    c. Precipitation: the process that delivers liquid and/or solid water from the atmosphere to the surface. The various forms of precipitation are rain, snow, hail, sleet, and freezing rain.
    d. Transpiration: the process by which plants convert liquid water to water vapor. Transpiration increases the amount of water vapor in the atmosphere.
    e. Infiltration: the process by which liquid water is moved from the surface into the soil.
    f. Runoff: the process that moves water across the surface or underground as a result of the force of gravity.
    g. Sublimation: the process that accomplishes the phase change from solid directly to vapor. The input of heat, generally provided by the Sun, is required to sublimate a solid.

2. Although the movement of water by these processes is referred to as the water (or hydrologic) cycle, it is in fact not a cycle in the sense that a molecule may complete its journey in a different location from where it began. Most illustrations in textbooks tend to depict the water cycle with arrows (indicating the various processes listed above) forming a circle, perpetuating this misconception. If the textbook you are using does this, have your students compare it to their version of the water cycle. Then discuss the differences and the possible misconception that the textbook may perpetuate.

Closure

1. Based on your students' understanding of these processes, have them return to considering the pictures of the Sahara Desert and Alaska that they examined in the previous activity and have them draw pictures of the hydrologic cycle as it may be occurring (invisible to their eyes) in those pictures. Have them label the processes that they depict in the drawing so that you can assess their understanding of this material.

Days 3 and 4
(45 minutes each)

Materials

- climate Data Worksheet
- climate classification definitions
- calculators
- pencils
- access to the Internet
- world map
- markers

Set or opener

1. Complete the first activity in this unit by having the students report the information they found about the month-by-month temperature and rainfall for Alaska and the Sahara Desert.

2. Discuss their findings, relating the data to the pictures and to the water cycle. For example, they will find that temperatures in the desert get very warm in the summer but not much rain falls. Thus, there is plenty of heat to cause evaporation, but so little precipitation that vegetation is sparse. Transpiration, therefore, must be limited. (The reason for the small amount of rainfall is that the region is located in an area of high pressure almost the entire year. Sinking air in the high-pressure region limits cloud formation and prevents precipitation from developing.) In Alaska, temperatures are cooler, but precipitation is more plentiful. Since there is less heating occurring, evaporation will be less but transpiration may increase since there are more plants around. Additionally, since snow is on the ground in the mountains, it may be possible for sublimation and/or runoff to occur.

3. Ask the students what kind of clothes they would take if they were moving to one of these places, having them justify their responses. They should select light-colored clothing for the desert and heavier clothes for Alaska. Guide their justifications to a statement that it is warm and dry every year in the Sahara and cool and wet every year in Alaska.

Body

1. Once the students have stated that temperature and precipitation patterns extend over long periods of time, you can introduce the idea of climate. Climate is the accumulated effects of the day-to-day weather that any location experiences. Generally, people speak of warm or cold, hot or dry climates.

2. Ask the students to identify the factors that they believe determine the climate of a location. The primary influences on climate are the following.

Factor	Influence
• Latitude	Determines average temperatures by the directness of sunlight and number of hours of daylight; temperature decreases as latitude increases. Also influential in determining precipitation. Uneven heating of Earth's surface causes air to rise near the equator and sink near the poles. The spin of Earth on its axis, coupled with this heating, produces sinking air near 30° and rising air near 60°. When air rises, precipitation often forms.
• Elevation	Temperature generally decreases with height in the lower atmosphere since heating from the ground warms the air.
• Proximity to large bodies of water	Water is slow to warm because it has a high specific heat. It cools slowly too because energy stored in it can reach greater depths than in soil. Locations near large bodies of water are typically warmer in winter and cooler in summer than locations further inland.

3. Tell them that scientists have devised a method to classify climates so that they can study them more effectively. One such system is called the Köppen climate system. Provide the students with the Köppen Climate System Guide and review the various climate types and the example that describes the manner in which they can determine the climate type based on temperature and precipitation data.

4. Then have them work on the World Climate Information Worksheet to classify the climates of a few cities from around the world.

City	Climate Type	City	Climate Type
Alice Springs	BW	Moscow	Df
Barrow	ET	New Orleans	Cf
Darwin	Aw	Riyadh	BW
Jakarta	Af	Tombouctou	BW
Madrid	Cf	Ustica	Cs

5. Ask the students to comment on which water cycle processes may be important in each of the locations. Possible answers follow.

City	Possible important processes
Alice Springs	Evaporation, infiltration
Barrow	Sublimation, evaporation, precipitation, runoff
Darwin	Evaporation, condensation, precipitation, runoff, transpiration, infiltration
Jarkarta	Evaporation, condensation, precipitation, runoff, infiltration, transpiration
Madrid	Evaporation, condensation, precipitation, runoff, transpiration, infiltration
Moscow	Evaporation, condensation, precipitation, runoff, transpiration, infiltration, sublimation
New Orleans	Evaporation, condensation, precipitation, runoff, transpiration, infiltration
Riyadh	Evaporation, infiltration
Tombouctou	Evaporation, infiltration
Ustica	Evaporation, infiltration, condensation, precipitation, runoff, transpiration

Closure

1. Assign each student five cities from different points in the world and have them find the monthly temperature and precipitation data at Worldclimate.com.

2. Have them then determine the Köppen climate classification for each city and plot the information on a world map.

3. Have the students then see if they can find patterns in the data. Are there large contiguous areas in the world where the climate is uniform? (Yes. You can find the general patterns in most climatology books, atlases, or on the Internet.) Do they notice a progression in climates with latitude? (Generally A climates are located near the equator, followed by B, C, D, and E climates as one moves poleward. This pattern primarily reflects the effects of the Sun in heating Earth.)

Resources

(activities, data sheets, lab sheets)

Where is there more water?

The atmosphere is a mixture of gases, one of which is water vapor. This particular gas is quite important because all of the rain we receive is produced from it. Use what you already know and the pictures below to consider this situation.

If we took a column of air that started at the ground and continued to the top of the atmosphere and could magically change all of the water vapor in the column into liquid water, which of the two places would have more water? Explain your answer.

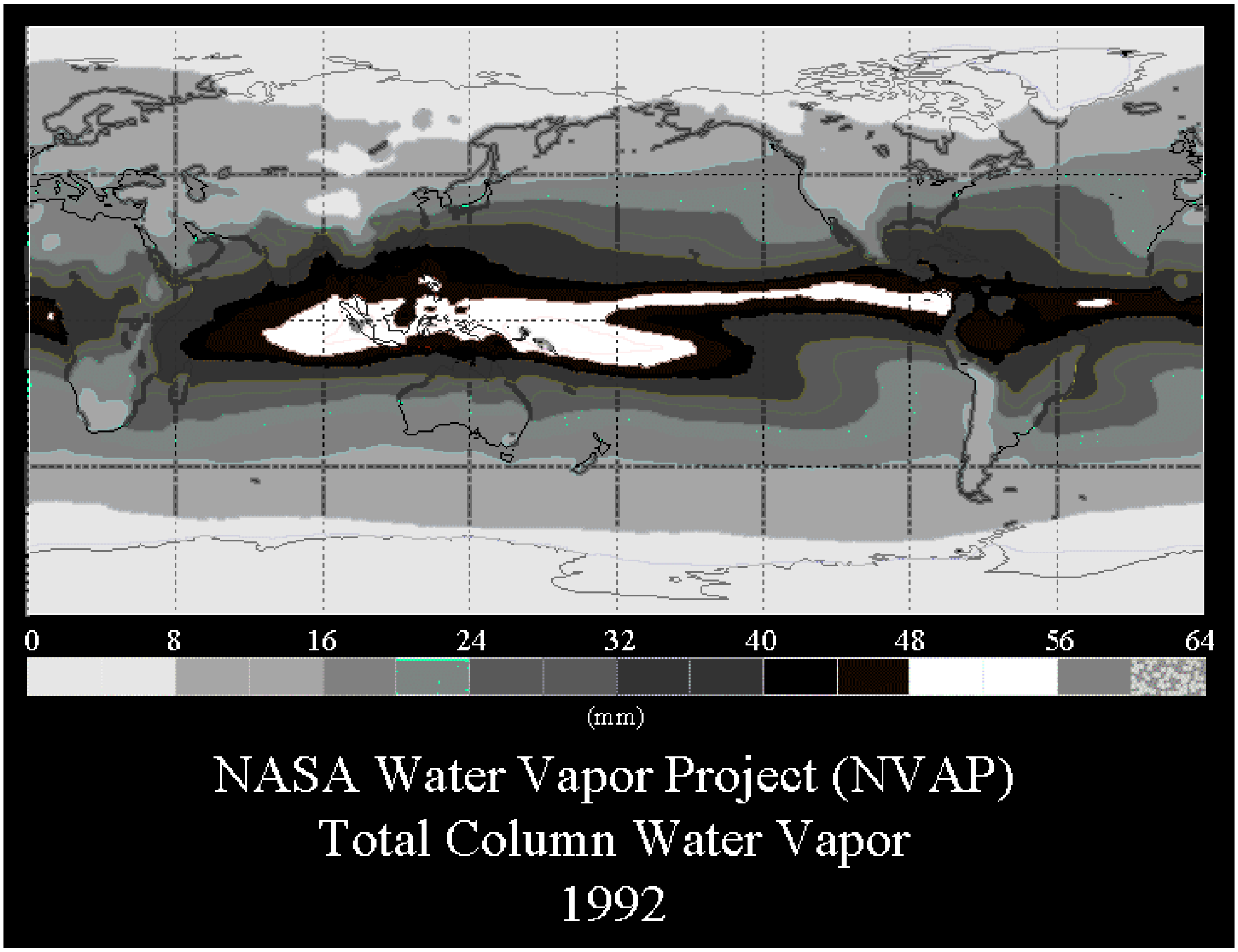
This is a picture of the Sahara Desert. It is located at 25° N latitude and 10° E longitude.

This is a picture of Sitka, Alaska. It is located at 57° 3' N latitude and 135°20' W longitude.

Write your answer and explanation here:

Do not go on to the next page until instructed to do so by your teacher.

Below is a map of the world that shows the average depth of water that would be produced if we could take all of the water vapor in a column of air and convert it to liquid water. The map is based on measurements taken in 1992.



Using this information, what was the total depth of water from the column of air over the Sahara Desert?

Using this information, what was the total depth of water from the column of air over Sitka, Alaska?

Was your earlier prediction verified? If not, what might cause this difference?

Water Cycle Game Stations and Actions

OCEAN		
WHAT YOU ROLL	WHAT HAPPENS TO YOU	WHERE YOU GO
1 or 2	Heat is added to the water so the water evaporates	Atmosphere
3, 4, 5, or 6	Water remains in the ocean	Ocean (roll again)
ATMOSPHERE		
WHAT YOU ROLL	WHAT HAPPENS TO YOU	WHERE YOU GO
1	Water condenses and falls to soil	Soil
2	Water condenses and falls as snow on a glacier	Glacier
3	Water condenses and falls on a lake	Lake
4 or 5	Water condenses and falls on an ocean	Ocean
6	Water remains as vapor in the atmosphere	Atmosphere (roll again)
PLANT		
WHAT YOU ROLL	WHAT HAPPENS TO YOU	WHERE YOU GO
1, 2, 3, or 4	Water leaves plant through the process of transpiration	Atmosphere
5 or 6	Water is used by plant and stays in cells	Plant (roll again)
LAKE		
WHAT YOU ROLL	WHAT HAPPENS TO YOU	WHERE YOU GO
1	Water is pulled by gravity and filters into the soil	Soil
2	An animal drinks water	Animal
3	Water flows into a river	River
4	Heat is added to the water, causing it to evaporate	Atmosphere
5 or 6	Water remains within a lake or estuary	Lake (roll again)
ANIMAL		
WHAT YOU ROLL	WHAT HAPPENS TO YOU	WHERE YOU GO
1 or 2	Water is excreted through feces and urine	Soil
3, 4, or 5	Water is respired or evaporated from the body	Atmosphere
6	Water is incorporated into the body	Animal (roll again)
SOIL		
WHAT YOU ROLL	WHAT HAPPENS TO YOU	WHERE YOU GO
1	Water is absorbed by plant roots	Plant
2	Soil is saturated so water runs into a river	River
3	Water is pulled by gravity and filters into the soil	Groundwater
4 or 5	Heat is added to the water, causing it to evaporate	Atmosphere
6	Water remains on the surface (in a puddle or adhering to a soil particle)	Soil (roll again)
GROUNDWATER		
WHAT YOU ROLL	WHAT HAPPENS TO YOU	WHERE YOU GO
1	Water filters into a river	River
2 or 3	Water filters into a lake	Lake
4, 5, or 6	Water stays underground in an aquifer	Groundwater (roll again)
GLACIER		
WHAT YOU ROLL	WHAT HAPPENS TO YOU	WHERE YOU GO
1	Ice melts and water filters into the ground	Groundwater
2	Ice sublimates and water vapor goes into the atmosphere	Atmosphere
3	Ice melts and water flows into a river	River
4	Ice melts and water flows into the ocean	Ocean
5 or 6	Ice stays frozen in the glacier	Glacier (roll again)
RIVER		
WHAT YOU ROLL	WHAT HAPPENS TO YOU	WHERE YOU GO
1	Water flows into a lake	Lake
2	Water is pulled by gravity and filters into the soil	Groundwater
3	Water flows into the ocean	Ocean
4	An animal drinks water	Animal
5	Heat added to the water causes evaporation	Atmosphere
6	Water remains as current in the river	River (roll again)

Water Cycle Game Scorecard

Fill in the information below for each stop you make. Be sure to record the station at which you are presently located, the action that moves you to the next station, and the name of the station to which you are going. To determine where to go next, have the designated person from your group roll the die to generate a random number between 1 and 6. Look at the actions posted at your present station. The station you should go to and the action that moves your molecule of water to that station are listed next to this number.

Present Station	Action that moves you to the next station	Station to go to
Example: Lake	Evaporation	Atmosphere
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

Köppen Climate System Guide

There are six primary climate regions identified in the Köppen Climate Classification scheme.

Designation	Name	Definition
A	Tropical	Average temperature of coldest month greater than 18°C
B	Dry	Evaporation potential exceeds precipitation (r is less than 142 + 20t where r is the annual precipitation in mm and t is the annual temperature in °C)
C	Subtropical Mid-latitude	Average temperature of coldest month greater than 0°C but less than 18°C; average temperature of warmest month greater than 10°C
D	Continental Mid-latitude	Average temperature of coldest month less than 0°C; average temperature of warmest month greater than 10°C
E	Polar	Average temperature of warmest month less than 10°C
H	Highlands	Insufficient data

Subtypes are defined as follows.

Designation	Definition
s	Dry season is summer (at least three times as much precipitation in the wettest winter month compared to the driest summer month)
w	Dry season in winter (at least ten times as much precipitation in the wettest summer month compared to the driest winter month)
f	Constant moisture throughout the year (for A, rainfall in driest month is at least 60 mm; for C and D, conditions for s and w not satisfied)
S	Semiarid, used only in B regions (r is greater than 71 + 10t, where r is the annual precipitation in mm and t is the annual temperature in °C)
W	Desert, used only in B regions (r is less than 71 + 10t, where r is the annual precipitation in mm and t is the annual temperature in °C)
T	Tundra, used only in E regions (average temperature of warmest month greater than 0°C)
F	Ice cap, used only in E regions (average temperature of warmest month less than 0°C)

Climate types	Name
Af	Tropical rainforest
Aw	Tropical savanna
BS	Steppe
BW	Desert
Cs	Mediterranean
Cf	Humid subtropical
Df	Humid continental
ET	Tundra
EF	Ice cap

Using the Köppen Climate System Guide with basic data, you can classify the climate at any location.

Example: Austin, TX (30.28°N, 97.70°W; 178 m elevation)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
t (C)	9.3	11.5	16.3	20.8	24.2	27.3	29.1	29.3	26.7	21.7	16.0	10.8	
r (mm)	49	61	49	77	118	84	47	54	81	90	55	58	

1. Calculate the average annual temperature by adding together the average temperature of each month and dividing by 12.

   t = (9.3+11.5+16.3+20.8+24.2+27.3+29.1+29.3+26.7+21.7+16.0+10.8)/12 = 20.2°C

2. Calculate the average annual precipitation by adding together the average precipitation for each month.

   r = 49+61+49+77+118+84+47+54+81+90+55+58 = 823 mm

3. Calculate 142 + 20t and determine if r is less than this value. If it is, then evaluate as a B climate; otherwise, evaluate as A, C, D, or E.

   142 + 20t = 142 + 20(20.2) = 546 mm Since r = 823 mm is greater than 546 mm, this is not a B climate.

4. If the climate region is not B, then, starting with A, examine the temperature of the coldest month compared to the standards.

   The coldest month is January (9.3°C). This value is greater than 0°C but less than 18°C so the climate region is C.

5. Evaluate the rainfall distribution for the second letter. Summer is assumed to be April through September in the Northern Hemisphere and October through March in the Southern Hemisphere.

   The driest month is in summer (July with 47.1 mm) and the wettest winter month is October (90.1 mm). Since 90.1 is less than 3 time 47.1, this is not an “s” region.

   The wettest summer month (May with 118 mm) is less than 10 times the driest winter month (March with 49 mm), so this is not a “w” region.

   Since it is not w or s, it must be f.

6. The climate classification for Austin, TX is Cf.

World Climate Information Worksheet

Use the following data to classify the climate at each of the following cities.

Station: Alice Springs, Australia (23.8°S, 133.9°E; 537 m elevation)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
t (C)	28.5	27.7	24.8	20.0	15.5	12.3	11.5	14.3	18.3	22.7	25.7	27.7
r (mm)	41	42	35	17	17	17	12	10	9	20	25	37

Station: Barrow, Alaska (71.3°N, 156.8°W; 9 m elevation)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
t (C)	-25.2	-27.6	-26.1	-19.0	-7.0	1.1	4.0	3.2	-0.8	-10.2	-18.7	-24.0
r (mm)	5	4	4	4	4	8	22	25	16	12	6	4

Station: Darwin, Australia (12.4°S, 130.8°E; 31 m elevation)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
t (C)	28.5	28.2	28.4	28.6	27.3	25.6	24.9	26.0	27.9	29.2	29.5	29.2
r (mm)	396	331	282	97	18	3	1	4	15	60	130	239

Station: Jakarta, Indonesia (6.2°S, 106.8°E)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
t (C)	25.8	25.9	26.3	26.8	26.9	26.6	26.3	26.5	26.9	26.9	26.6	26.2
r (mm)	342	302	210	135	108	90	59	48	69	106	139	208

Station: Madrid, Spain (40.5°N, 3.5°W; 609 m elevation)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
t (C)	5.3	6.7	9.7	12.0	16.1	20.8	24.6	23.9	20.5	14.7	9.3	6.0
r (mm)	45	43	37	45	40	25	9	10	29	46	64	47

Station: Moscow, Russia (55.8°N, 37.5°E)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
t (C)	-10.2	-8.9	-4.0	4.5	12.2	16.3	18.5	16.6	10.9	4.3	-2.0	-7.5
r (mm)	34	29	33	38	51	66	82	72	58	50	44	42

Station: New Orleans, Louisiana (30.0°N, 90.3°W; 1 m elevation)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
t (C)	10.7	12.3	16.4	20.2	23.7	26.6	27.7	27.5	25.6	20.6	16.1	12.5
r (mm)	136	147	124	119	135	147	167	157	138	76	101	132

Station: Riyadh, Saudi Arabia (24.7°N, 46.7°E; 635 m elevation)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
t (C)	14.3	16.2	20.8	25.0	30.8	33.6	34.6	34.4	31.4	26.3	20.6	15.4
r (mm)	14	10	30	30	13	0	0	0	0	1	5	11

Station: Tombouctou, Mali (16.7°N, 3.0°W; 263 m elevation)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
t (C)	20.2	22.8	26.2	30.2	32.9	33.3	32.1	29.7	30.2	29.4	24.5	20.6
r (mm)	0	0	0	1	4	19	62	79	33	3	0	0

Station: Ustica, Italy (38.7°N, 13.1°E; 250 m elevation)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
t (C)	10.7	10.6	11.4	13.8	17.2	20.9	24.4	24.8	22.6	19.3	15.5	12.3
r (mm)	44	35	30	29	14	9	2	8	28	59	66	68

Assessment

1. A water molecule is located in the ocean at one time. Some time later, it is observed in a lake. With what process(es) could the molecule have been involved between the two times it was observed?
    a. condensation
    b. infiltration
    c. runoff
    d. sublimation
    e. all of the above

2. Two cities are located at approximately the same latitude. One city (A) exists on the coast of a large land mass while the other one (B) is located well away from any water. Which of the following statements is likely to be true?
    a. City A will have warmer summers than city B.
    b. City B will have colder winters than City A.
    c. The two cities will likely have similar winter temperatures.
    d. The two cities will likely have similar summer temperatures.

3. Many scientists believe that the world's average temperature is increasing over time. What may happen to the distribution of climate zones across the globe if they are correct? Explain your answer.

Answers:

1. (e) Any of the processes could have been involved in the molecule's journey from the ocean to the lake. For example, evaporation may have transferred the molecule from the ocean to the atmosphere before condensation caused a cloud to form. Snow from the cloud may have fallen on a mountain and then sublimated water vapor back into the atmosphere. Condensation could have then produced another cloud that precipitated rain that infiltrated into the ground before running off below the surface and into the lake.

2. (b) Since City A is near the coast, the moderating effects of the nearby water will tend to keep winter temperatures higher there than at City B.

3. If temperatures increase worldwide, the climate zones are likely to move poleward, with the A climate region expanding and the E climate region shrinking or disappearing. The reason for this is that, all things being equal, the pattern of climate zones from A to E is determined largely by temperature. Increasing temperatures will expand the A region and shift the other regions toward the poles. The E region may vanish if there is sufficient warming so that nowhere in the world is the warmest month cooler than 10°C.

Score	Answer
5	The correct answer is given. The correct explanation is given.
4	The correct answer is given. A partially correct explanation is given.
3	A correct answer is given. No explanation is provided or an incorrect explanation is given.
2	A partially correct answer is given. A partially correct explanation is given.
1	A partially correct answer is given. No explanation is given or an incorrect explanation is provided.
0	No answer and no explanation are given or an incorrect answer and an incorrect explanation are given.

Reference links

A very good link to information about climate and its classification is found at http://members.aol.com/pakerlda/crmod.html, the Climate Regions Learning Module.

For climate data from around the world, try Worldclimate.com at the following URL:
http://www.worldclimate.com