ACTIVITY Water Vapour Investigation

After, completing this investigation, you should be able to:

- Explain with cups of different sizes how the "capacity" of air to hold water vapour varies with temperature.
- Use the cups and styrofoam packing "peanuts" as a model to explain relationships between the "capacity" of air to hold water vapour and the actual amount of water vapour in the air.

Materials

Four 375 ml (12-ounce) clear or translucent drinking cups for every two learners, enough styrofoam "peanut" packing material (or popped popcorn) to fill one cup, scissors, permanent marking pen.

Steps to prepare the set of cups for use in this activity:

a) Fill a 375 ml (12-ounce) cup to the brim with water. Pour from that cup into another until the water levels in both are the same. Trace the water line on the outside of both cups with a permanent marking pen.

b) Empty the water from one of these and cut along the traced line to make a 187.5 ml (6-ounce) cup. Now pour the water remaining in the 375 ml (12-ounce) cup into a third cup until their water levels are the same. Trace their water levels.

c) Empty the water from the third cup and cut it down to the marked water level to make a cup that holds 93.75 ml (3-ounces).

d) You should end up with three cups - one 93.75 ml (3-ounce) cup, one 187.5 ml (6-ounce) cup that has a line marking the 93.75 ml (3-ounce) level, and one 375 ml (12-ounce) cup with lines marking 187.5 and 93.75- ml (6- and 3-ounce) levels.

e) Write a large 0 on the side of the smallest cup, 10 on the middle size, and 20 on the largest cup to indicate 0, 10, and 20 degrees Celsius. Use these cups as guides to preparing other sets.

f) The fourth and unmarked cup will hold the styrofoam packing "peanuts" (or popped corn).

Method

Cups of different sizes are used in this exercise to represent the "capacity" of air to hold water vapour at 0, 10, and 20 degrees Celsius. Styrofoam packing "peanuts" (or popped popcorn) are poured into the cups to represent the water vapour actually in the air.

Start the activity by filling the large unmarked cup approximately level with packing peanuts. Tap the cup gently to help the material settle as you fill the cup. This is the supply of packing peanuts you will use in this exercise.

This activity involves the use of four cups. The unmarked cup is used to store the packing peanuts. The largest marked cup is twice the capacity of the mid-size cup. The mid-size cup is twice as big as the small cup. The marked cups represent the capacity of air to hold water vapour at 0, 10, and 20 degrees Celsius. Each cup is labelled by the temperature related to its capacity.

1. Fill the small 0-degree cup with packing peanuts until the contents are level with the top of the container. Pour the contents into the mid-size 10-degree cup. Repeat this procedure until the 10-degree cup is level full. Now pour the filled 10-degree cup into the 20-degree cup until it is full. Assuming the cups represent the capacities of air to hold water vapour at 0, 10, and 20 degrees, complete the following statement:

   The capacity of the air to hold water vapour approximately (   ) when the temperature increases 10 Celsius degrees.

2. Starting with a filled 20-degree cup, pour its contents into the 10-degree cup until it is level full. Now pour the contents of the 10-degree cup into the 0-degree cup until filled to the brim. Now complete the following statement:

   The capacity of the air to hold water vapour approximately (   ) when the temperature lowers 10 Celsius degrees.

3. Now empty the 20-degree cup and pour the filled 0-degree cups into the large cup until it is full. Based on this, complete the following statement:

   The capacity of the air to hold water vapour increases approximately (   ) times when the temperature rises 20 Celsius degrees.

4. According to the same observations, what happens to the capacity of air to hold water vapour as the temperature falls 20 Celsius degrees?

5. When air cools its capacity to hold water vapour decreases, and any excess water vapour must condense. This can be demonstrated by attempting to pour all the packing peanuts from a filled 20-degree cup into the 10-degree cup. Level the top on the 10-degree cup. The overflow represents the water vapour that condensed out. In this example of the 10-degree cooling, how much of the water vapour condensed to 1iquid as the temperature dropped 10 degrees?

6. Air filled to its capacity with water vapour is called saturated air. If saturated air at 20 degrees is cooled 20 degrees, how much of its water vapour must condense?

7. Saturated air has a *relative humidity of* 100%. Relative humidity is a measure of the amount of water vapour actually in the air compared to the amount it would hold if saturated at the same temperature. Pour a full 0-degree cup into a 10-degree cup to determine what the relative humidity would be if air saturated at 0 degrees is warmed 10 degrees with no addition of water vapour. What is it? What would the relative humidity be if that same air were warmed another 10 degrees to 20 degrees Celsius?

8. Explain in your own words why in cold weather the relative humidity in heated buildings (without humidifiers) are quite low.

9. *Dew point* is another common humidity measure. It is the temperature to which air has to be cooled (without changing the amount of water vapour in the air) to become saturated. Whenever air is

saturated, its temperature and dew point will be the same. What is the approximate dew point of air at 20 degrees with a relative humidity of 50%? To find out, fill the 20-degree cup half full. Then, pour it into the 10-degree cup.

10. What is the dew point of air saturated at 0 degrees when the air temperature is raised to 10 degrees without the addition of water vapour? To find out, pour a filled 0-degree cup into 10-degree cup and ask yourself whether or not the dew point changed.

11. If saturated air at 20 degrees is cooled to 10 degrees, what is its final dew point? To help find your answer, attempt to pour a filled 20-degree cup into l0-degree cup while asking yourself how much water vapour the l0-degree cup is holding compared to its capacity.

12. In general, when saturated air is cooled, what happens to its capacity to hold water vapour, its dew point, and its relative humidity? Refer to your observations made above.

13. Describe, in your own words, the water vapour and temperature relationships which must exist for cloud, dew, and frost formation.

14. Look up and write out specific definitions for the following terms:

    - Relative Humidity
    - Dew Point

ACTIVITY The Atmospheric Pipeline

Upon completing this activity, you should be able to:

- calculate the approximate volume of storm precipitation.
- estimate the surface water evaporated to supply the storm.
- evaluate the amount of fresh water runoff from the storm.
- explain how topographic features affect precipitation amounts.

Introduction

Atmospheric storm systems can be a nuisance for picnics, a welcome relief to a drought, or disastrous flooding - bringing everything from joy to inconvenience to untold hardship and destruction. These storms are an integral part of the Earth's weather and climate system and the water cycle.

A strong spring storm on March 11-13, 1993 brought widespread rain and heavy snow to the Gulf of Mexico and the Eastern United States. Several US states were plagued by crippled transportation due to deep, wet snows and widespread flash flooding, both from heavy rains and subsequent snowmelt. In all, over 200 people died from this one storm.

The following activity looks at this particular storm to examine the atmosphere's ability to transport water substance. *(Note: the precipitation data is from US National Weather Service (NWS) and will be presented in its original format, i.e. inches, miles, etc).*

Liquid water is evaporated from the surface. Atmospheric circulation patterns transport this water vapour to other locations where storm systems convert the vapour back to its liquid and solid phases forming clouds and precipitation. The precipitation is returned to the surface, renewing our fresh water resources and completing the cycle. This activity will allow you to calculate the approximate amount of water that fails from a major storm system. The accompanying map shows selected total precipitation amounts (in inches) from the storm. Snowfall amounts have been converted to comparable rainfall amounts. In most areas, the ground was already saturated or still frozen, so that precipitation and melt-water became "runoff".

Procedure

1. From the displayed total precipitation amounts on the map - Spring Storm March 11-13, 1993 Total Precipitation, estimate to the nearest half inch (0.5, 1.0, 1.5, etc.), the average amount of precipitation for the entire area of each state. Ignore the states where no precipitation is given. Fill the column in the table on page 17 with the average values from each state.
2. Multiply the numbers across each row of the table to obtain products. The approximate state areas, in square miles, are given. The area times precipitation depth will be the water volume given in units of square miles-inches. Then sum the products for the states listed in the table to obtain a grand total volume.
3. The Gulf of Mexico with a surface area of approximately 600,000 square miles serves as a vapour source region for many eastern U.S. storms. If one assumes that all the water for this storm was originally

evaporated from the Gulf of Mexico, the depth of water needed may be found by dividing the grand total volume above by 600,000 (6×10^5). This is the depth equivalent of water evaporated from the entire Gulf area in inches.

Equivalent depth of evaporated water ( ) inches.

4. To determine the weight of water precipitated from this storm, first multiply the grand total volume above by 2,323,200 (2.3232×10^6) to convert the total into cubic feet. [The multiplying number is the number of square feet in a square mile divided by 12 inches per foot.] Then multiply this total by 62.4 pounds per cubic foot (density of fresh water) to obtain the total weight of water precipitated by the storm.

Total weight of storm water ( ) pounds.

5. To determine the volume of fresh water runoff from this storm, divide the total cubic feet of water found above by 1.47 x 10^{11}, the number of cubic feet in a cubic mile. This number of cubic miles of water may then be compared to the 116 cubic mile volume of fresh water in Lake Erie by taking the number of cubic miles of storm water and dividing by 116. This is the equivalent fraction of Lake Erie that would be filled, by the water running off from this one major storm.

Volume of fresh water runoff ( ) cubic miles.

Equivalent fraction of lake Erie volume ( ).

State	Area in square miles (mi^2)	Avg precip. (in.)	Product
Alabama	51,000		
Connecticut	5,000		
Delaware	2,000		
Florida	54,000		
Georgia	58,000		
Kentucky	40,000		
Louisiana	45,000		
Maine	31,000		
Maryland	10,000		
Massachusetts	8,000		
Mississippi	47,000		
New Hampshire	9,000		
New Jersey	7,000		
New York	47,000		
North Carolina	49,000		
Ohio	41,000		
Pennsylvania	45,000		
Rhode Island	1,000		
Tennessee	41,000		
Texas	262,000		
Vermont	9,000		
Virginia	40,000		
West Virginia	24,000		
		Grand total:	

Questions

1. What is the greatest amount of precipitation (at a single station) shown on the map? (   ). In what state did it occur? (   ).
   Is the heaviest precipitation concentrated in a single area or does it occur in several disconnected areas? (   ).

2. Using a topographic or relief map, can you find a general relationship between elevation and the larger precipitation amounts? (   ). What does this relation appear to be?

   ____

   ____

3. (a) How does your calculated average depth of water evaporated from the Gulf of Mexico compare to the average depths of precipitation you estimated for the states?

   ____

   How do the areas of the Gulf of Mexico and the Eastern United States compare, roughly? (   ). What does this imply about the transport of water from ocean to land locations by storms?

   ____

   ____

   (b) Is it reasonable that this transport occurs from warm tropical ocean areas to higher latitude cooler land areas? (   ). Why or why not?

   ____

   ____

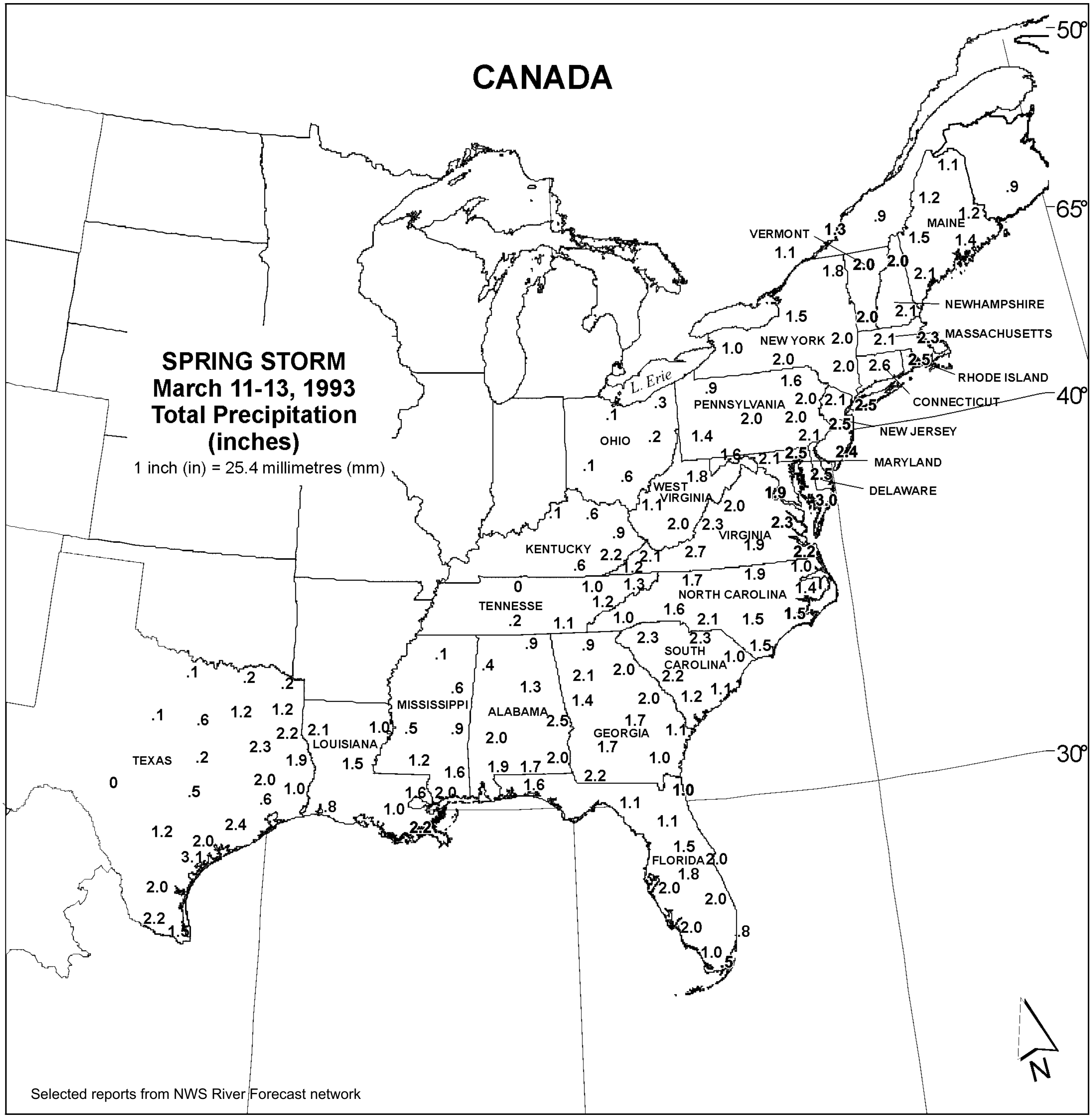
4. Atmospheric storms differ in intensity, frequency and location around the world, but assume this storm is somewhat typical in moving water substance, and was the sole disturbance occurring during this one week. How much total depth of water would be evaporated/precipitated in a year?

   ____

   How does this total compare to the world-wide average given elsewhere in this Teacher's Guide?

   ____

   ____


CANADA
SPRING STORM
March 11-13, 1993
Total Precipitation
(inches)
1 inch (in) = 25.4 millimetres (mm)
L. Erie
VERMONT
MAINE
NEWHAMPSHIRE
MASSACHUSETTS
RHODE ISLAND
CONNECTICUT
NEW YORK
PENNSYLVANIA
NEW JERSEY
MARYLAND
DELAWARE
OHIO
WEST VIRGINIA
VIRGINIA
KENTUCKY
TENNESSEE
NORTH CAROLINA
SOUTH CAROLINA
GEORGIA
ALABAMA
MISSISSIPPI
LOUISIANA
TEXAS
FLORIDA
50°
65°
40°
30°
N
Selected reports from NWS River Forecast network

ADDITIONAL ACTIVITIES

1. Obtain a metal container such as a soft drink can (with top removed) and a liquid crystal strip thermometer or other thermometer that makes good contact with the can side. Attach the thermometer to the side of the can. Fi1l the can approximately two-thirds full with water. Begin to add crushed ice to the water and stir. Continue adding ice to cool the water and the container. Carefully observe the outside of the can for the formation of dew - condensation on the sides and note the temperature when it just begins to form. This is the dew point temperature and is the temperature at which the actual amount of moisture in the surrounding air is the maximum possible for that temperature.

2. Create your own hydrologic cycle by placing soil in one end of an aquarium. Add some water in the other end to form "land" and "sea" regions. Cover the aquarium with a metal baking sheet over the land end and a plastic sheet over the sea end, sealing the top. Shine a lamp into the aquarium side to simulate the sun. Finally place some ice on the metal baking sheet. Water will be evaporating from the land and water surfaces with vapour condensing on the cool metal sheet and "precipitating" back down.

3. Use a clear cooking pan or beaker. Fill with crushed ice and water. Allow to stand until the water and ice mixture comes to the equilibrium freezing temperature of 0 degrees C, adding more ice if necessary to obtain a mixture with sufficient ice. Place the pan or beaker on a hot plate or heat source and heat slowly. Stir and continue to measure the temperature of the mixture until all the ice has melted. Does the temperature remain at (or near) the freezing temperature (0°C) during this time? Where does the heat that is being added go if the temperature does not increase? [This is *latent heat* that goes to change the phase of water from solid to liquid.]

4. Cut three one-metre square pieces of clear plastic sheeting material. Place one over a grassy surface, one over bare soil and one on an asphalt or concrete surface. After half an hour, observe the sheets of plastic to see which surface has had the most evaporation. [Evaporation from soil and transpiration from vegetation surfaces combined is called evapotranspiration.] Try this experiment at various times of the day or under various cloud cover conditions to investigate the change of solar radiation. Also try this experiment with differing humidity and wind conditions.