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AUTHOR Meinke, James L.; Kennedy, Beth A.
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ABSTRACT

This guidebook for teachers is accompanied by a student workbook. The investigations are intended to offer students an opportunity to study the effects of air temperature on air density and movement, the circulation of air and how it changes the amount of precipitation in the area around the Great Lakes, and the implications of the "lake effect" for the economy of northern Ohio. Illustrations, maps, data tables, and graphs accompany the written material. (Author/SA)

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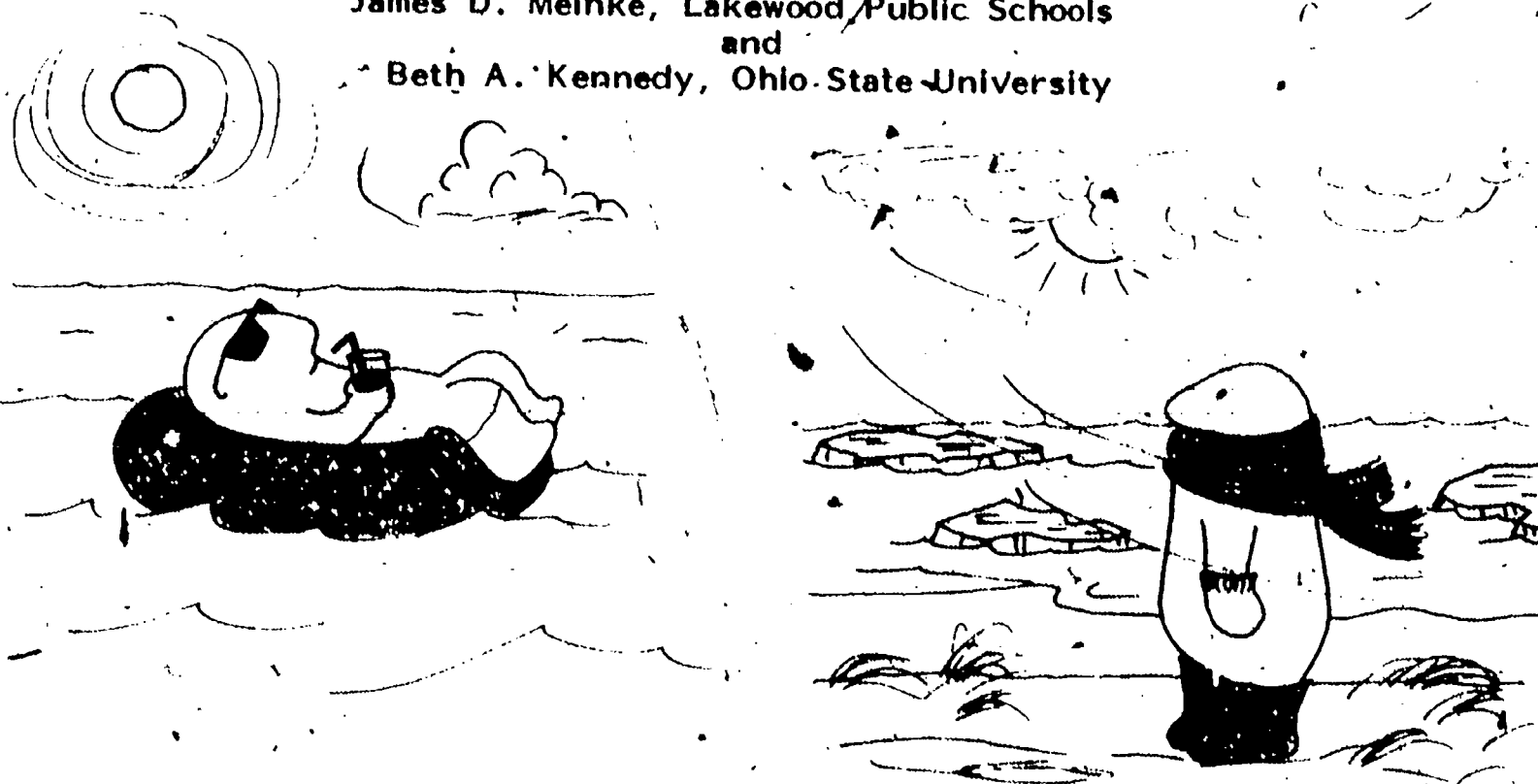
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THE EFFECT OF LAKE ERIE ON CLIMATE

by

James D. Meinke, Lakewood Public Schools
and

Beth A. Kennedy, Ohio State University



Ohio Sea Grant Program
Charles E. Herdendorf, Program Director
Victor J. Mayer, Principal Investigator

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OEAGLS INVESTIGATION 2

Completed April, 1979

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Figures 3 and 4 are from James L. Verber's "The Climates of South Bass Island, Western Lake Erie," Ecology 36(3): 388-400, 1955.

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INVESTIGATION

THE EFFECT OF LAKE ERIE ON CLIMATE

INTRODUCTION

The cities of Buffalo, New York; Erie, Pennsylvania; and Painesville, Ohio, have a common problem in winter. They have very heavy snowfall, up to 120 inches per year. They must spend millions of dollars for snow removal. On the other hand, Put-in-Bay, Ohio a small town on South Bass Island, and Sandusky, Ohio are two of the driest spots in Ohio. Put-in-Bay has about $\frac{2}{3}$ of the precipitation of cities such as Columbus. The one thing in common among all of these cities is that they are in or close to Lake Erie. Can the presence of the lake account both for high precipitation in some cities and low precipitation in other areas?

The "lake effect" not only influences summer and winter precipitation, but also the temperature. The shore of Lake Erie will often be cooler in the summer and warmer in the winter than other areas of Ohio. How does the lake affect the climate of Northern Ohio?

OBJECTIVES

When you have completed this investigation you will be able to:

1. Explain how air temperature affects air density and movement.
2. Describe how and why local winds near the shore change direction from day to night, and from winter to summer.
3. Describe how the circulation of air is affected by the land-water interface.
4. Describe how this circulation changes the amount of precipitation in the area around the Great Lakes.
5. Identify implications of the "lake effect" for the economy of northern Ohio.

ACTIVITY A WHAT CAUSES THE LAND-SEA BREEZE?

Perhaps you've seen a fire at home in a fireplace, or outside during a weiner-roast. What happened to the smoke? Normally it will rise up into the air. Why? As air heats up it becomes lighter (less dense) and it rises carrying the smoke with it. As the air rises, it leaves an "empty space" (area of low density air) in and above the fire. Something must fill in the "empty space," what? Obviously more air, but where does it come from? The air

moves in from all around the sides of the fire because it is cooler and "heavier" (more dense). This new air is then heated, becoming less dense, and it rises.

PROCEDURE

Carefully observe the demonstration (Figure 1) that your teacher has set up for you. Answer the following questions:

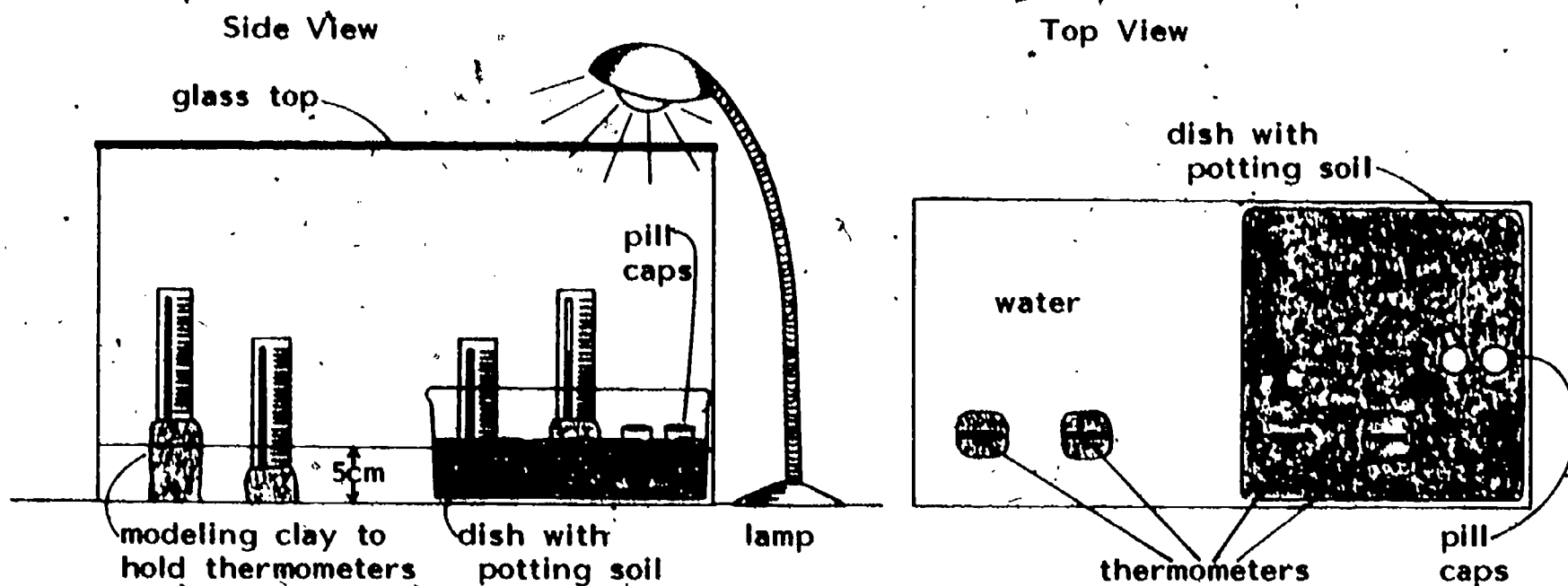


Figure 1. Side and top views of teacher demonstration

1. Observe the four thermometers in the container. Where is it hottest? _____ Where is it coolest? _____
What are your hypotheses about how the air inside the tank might be moving?

2. Can you see air around you move? _____ List some ways you could observe the air's motion.

3. What could we do to actually see the air move inside this tank? _____

4. Where would the denser air be located in the tank?

The less dense air? _____ Why? _____

5. Why does the air move in the way that it does? _____

The process you observed in the tank is the land-sea breeze effect in miniature. The land quickly reacts to changes in the amount of heat from the sun, whereas the water is slow to react to such changes. Water has a high specific heat. It stores heat more efficiently and longer than does the land.

6. During what part of the day will wind move from lake to shore? _____ Why? _____

ACTIVITY B

HOW DOES LAKE ERIE INFLUENCE THE CLIMATE OF NEARBY LAND AREAS?

MATERIALS

Graph paper and pencil.

PROCEDURE

In this part of the activity you will be constructing a graph showing the relationship between precipitation, temperature and distance from the shore of Lake Erie in an area of northwestern Ohio (Figure 2).

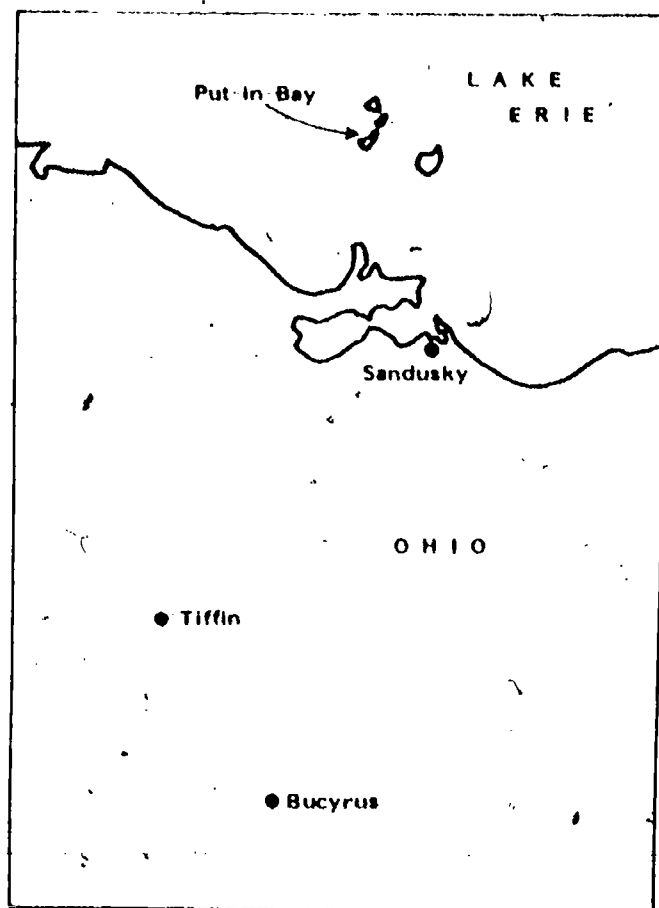


Figure 2. Map of the Lake Erie shore near Sandusky, Ohio.

Prepare a graph from the data in columns 2 and 3 of Figure 3. Plot the distance from Lake Erie on the horizontal axis and the average monthly range of temperature on the vertical axis. What happens to the average monthly range in temperature as the distance from the lake increases?

What might cause this?

<u>Locations</u>	<u>Distance from Lake Erie</u>	<u>Average Monthly Range of Temperature (°F)</u>	<u>Number of Frost-Free Days</u>
Put-in-Bay	0	13.7	205
Sandusky	1	15.9	194
Tiffin	30	19.5	162
Bucyrus	50	21.5	154

Figure 3. Distance from Lake and Temperature

2. Prepare a second graph from the data in Figure 3. Plot the distance from Lake Erie (Column 2) as the horizontal axis and the number of frost-free days (Column 4) on the vertical axis. What happens to the number of frost-free days as the distance from the lake increases? What might cause this?
3. The Lake Erie islands seem especially well adapted for growing grapes. This is primarily because of the climate. What temperature conditions do you think are important for good viniculture (grape growing)?

We have now seen that Lake Erie has a moderating effect on the temperature of regions in and around the lake. Does it affect precipitation?

4. Prepare a graph from the data in Figure 4. Use a different color to plot a line for each of the 4 locations. Plot the months on the horizontal axis and the precipitation in inches along the vertical axis. How does precipitation change from the Lake Erie islands inland to Bucyrus? Is this what you expected?

<u>Locations</u>	<u>Jan.</u>	<u>Feb.</u>	<u>Mar.</u>	<u>Apr.</u>	<u>May</u>	<u>June</u>	<u>July</u>	<u>Aug.</u>	<u>Sept.</u>	<u>Oct.</u>	<u>Nov.</u>	<u>Dec.</u>
Put-in-Bay	2.0	1.5	2.4	3.0	3.1	3.0	2.4	2.8	2.7	2.2	2.0	2.0
Sandusky	2.5	1.8	2.8	2.7	2.9	3.4	3.3	3.1	3.1	2.4	2.0	2.1
Tiffin	3.0	2.3	3.4	3.4	3.6	3.7	3.7	3.0	3.3	2.7	2.3	2.6
Bucyrus	3.2	2.3	3.4	3.3	3.6	4.1	4.1	3.2	3.2	2.9	2.6	2.6

Figure 4. Precipitation

5. Examine Figures 5 and 6. Where does the highest snowfall occur in relation to Lake Erie? _____ Is this also the area of highest annual precipitation? _____

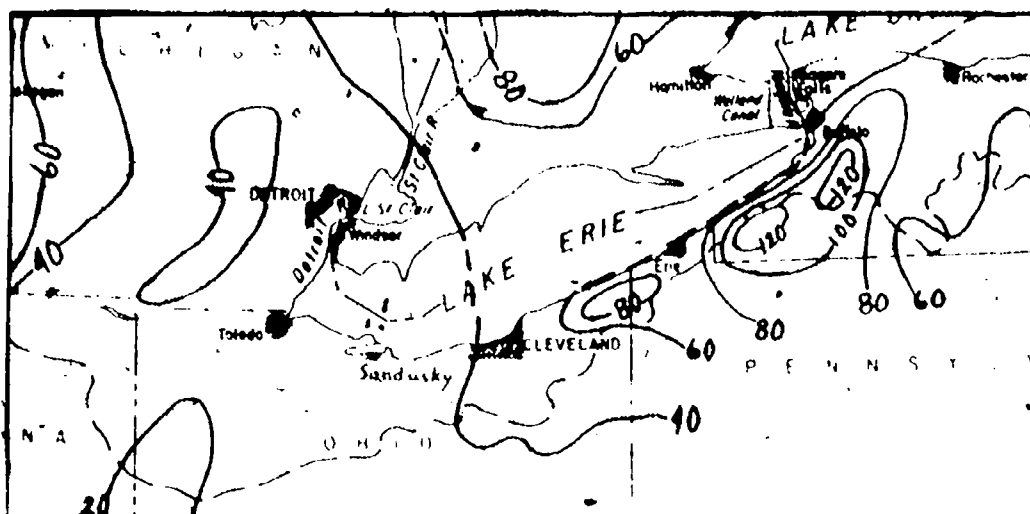


Figure 5. Annual Snowfall Lake Erie Region (in inches).

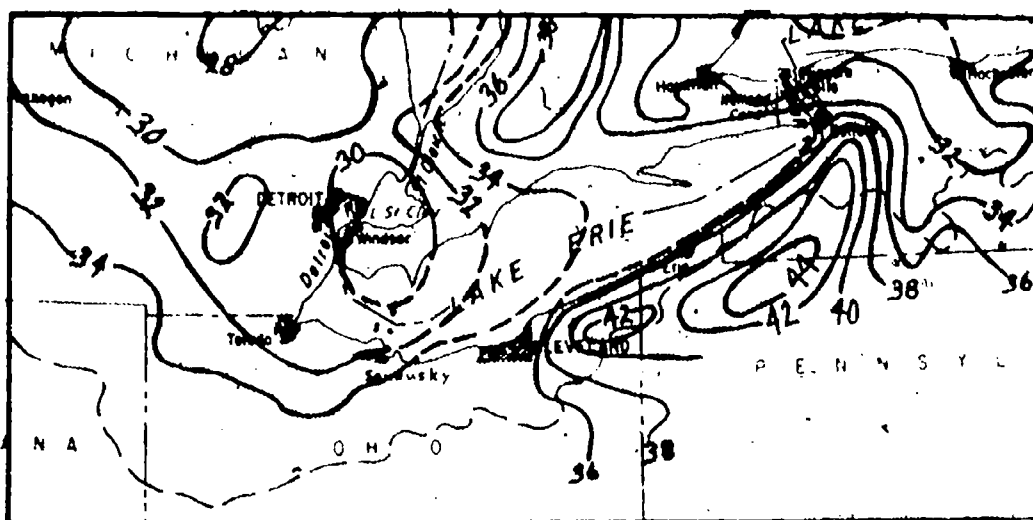


Figure 6. Total Annual Precipitation in Lake Erie Region in inches.

6. Where do you think most of the water comes from that falls on Buffalo either in the form of rain or snow? _____
7. How does this water get into the air? _____
8. Sandusky is right next to the lake as is Buffalo. Why do you think Sandusky gets so much less moisture? _____

7
The prevailing winds over Lake Erie are from the southwest and west.

9. Refer to the graph prepared in step 4. During what month do you find the greatest difference in precipitation between Bucyrus and Put-in-Bay? _____ How do you think Bucyrus gets _____ of its rainfall in that month? _____

During the summer, air over the surface of the lake is cooler than that over land (remember the demonstration in Part A). Because of this, few thunderstorms form over the lake. There simply is not enough energy (Heat) coming up from the lake surface to cause them to form. The moisture in the air, therefore, stays there until it gets over and beyond the western end of the lake. This is one of the reasons that Put-in-Bay is the driest part of Ohio.

ACTIVITY C CAN YOU MAKE A GENERAL CLIMATE PREDICTION?

MATERIALS Road map of Ohio

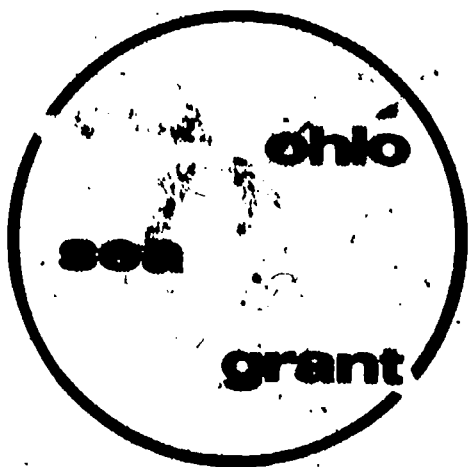
PROCEDURE Examine the Lake Erie coastline on your Ohio map. Locate a town called Vermilion. Keeping in mind the results of Activities A and B concerning temperature and precipitation differences, air density differences and air circulation, answer these questions:

1. What would you expect the weather conditions of Vermilion, Ohio, to be? Consider the following:
 - a) summer temperature near shore _____
 - b) winter temperature near shore _____
 - c) precipitation _____
 - d) frost-free days (growing season) _____
2. Draw two diagrams of the Lake Erie shoreline near Vermilion. On one diagram, indicate the wind circulation expected on a summer evening. On the other diagram, indicate the wind circulation expected in mid-afternoon in the summer.

8

REVIEW
QUESTIONS

1. How do winds near a shoreline circulate during the day?
at night?
2. How does the circulation pattern affect the amount of
precipitation and therefore the climate of an area?
3. How is the agricultural economy of this area related to
air circulation patterns?
4. Why is there more precipitation at Buffalo, New York than
in Sandusky, Ohio?



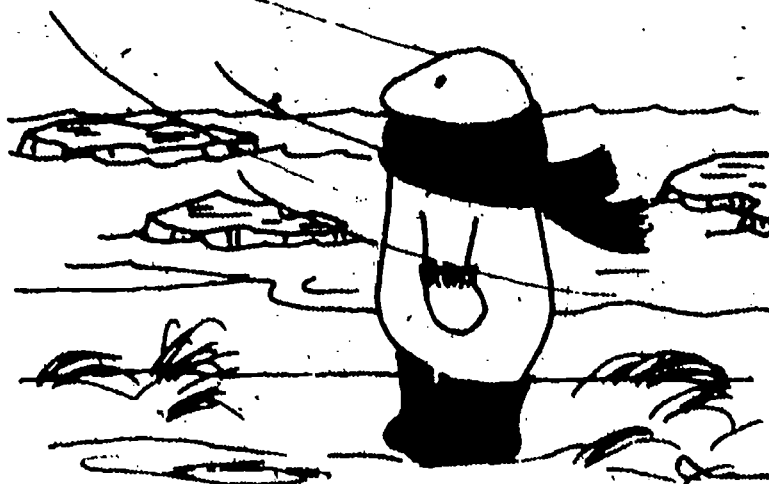
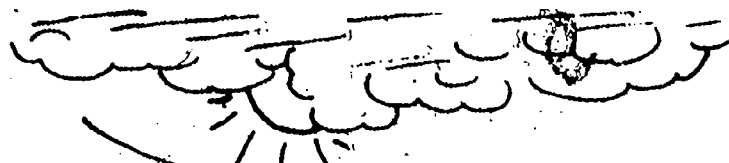
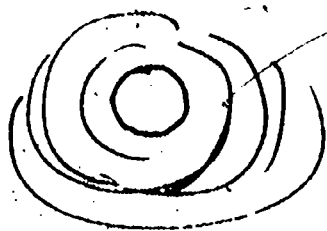
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TEACHER GUIDE

OEAGLS INVESTIGATION #2

Completed April, 1979

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OVERVIEW

Activity A is a teacher's demonstration through which the students will observe the land-sea-breeze effect in miniature and examine its causes. In Activity B, the students will compare the precipitation and number of frost free days in four Ohio cities with the distance from Lake Erie's shore. This is done to develop the idea of how Lake Erie affects the precipitation and temperature of surrounding areas. Activity C asks students to recall and use the information from B and C to make a general prediction about the climate of Vermilion, Ohio.

PREREQUISITE STUDENT BACKGROUND

Students should have some familiarity with the concepts of air density, wind or air movement patterns and their relationship to precipitation, and also specific heat.

Section 2-13 of ESCP (Investigating the Earth, 1978) deals with condensation, dew point, and clouds. It would be helpful to review this introductory material first. Ideally, this entire investigation should be preceded by OEAGLS Investigation #1: The Effect of Lake Erie on Ohio's Temperature.

OBJECTIVES

When the students have completed this investigation they should be able to:

1. Explain how air temperature affects air density and movement.
2. Describe how and why local winds near the shore change direction from day to night and from winter to summer.
3. Describe how the circulation of air is affected by the land-water interface.
4. Describe how the circulation of air changes the amount of precipitation in the area around the Great Lakes.
5. Identify implications of the "lake effect" for the economy of northern Ohio.

MATERIALS

10-20 gallon aquarium tank, 8x8 baking dish or 8-inch pie pan, 3-5 ml of concentrated hydrochloric acid and ammonium hydroxide, heat lamp, glass or plexiglass aquarium cover, modeling clay, two medicine droppers, two plastic pill bottle caps, four thermometers, water, graph paper (5 squares to one inch), pencil, and road map of Ohio.

BACKGROUND INFORMATION

Make sure you are familiar with how air temperature affects air pressure and density, and how air pressure affects the air's movement or the winds. A standard earth science textbook can provide this information.

SUGGESTED APPROACH

Activity A is a teacher's demonstration. Make sure you have tried out your set-up first.

Activities B and C could be done individually or within small lab groups.

ACTIVITY A WHAT CAUSES THE LAND-SEA BREEZE?

The introduction to this activity is meant to provide the students with clues about what to look for in the tank and why the smoke plume is moving that way.

PROCEDURE

Keywords: density, land-sea breeze effect, specific heat, convection.

Note: You should check to be sure that no thermometers are in a shadow when the lamp is turned on and also that the light does not shine directly on any thermometer bulb.

Caution: Care should be taken to prevent students from tampering with chemicals! If chemicals contact skin, wash the affected areas thoroughly at once. Clean up spills immediately. Both chemicals have a noxious odor, so keep containers sealed except when the chemicals are being used.

- 1) Set up your apparatus as shown in Figure TG-1. Be certain that the lamp is centered over both water and soil.

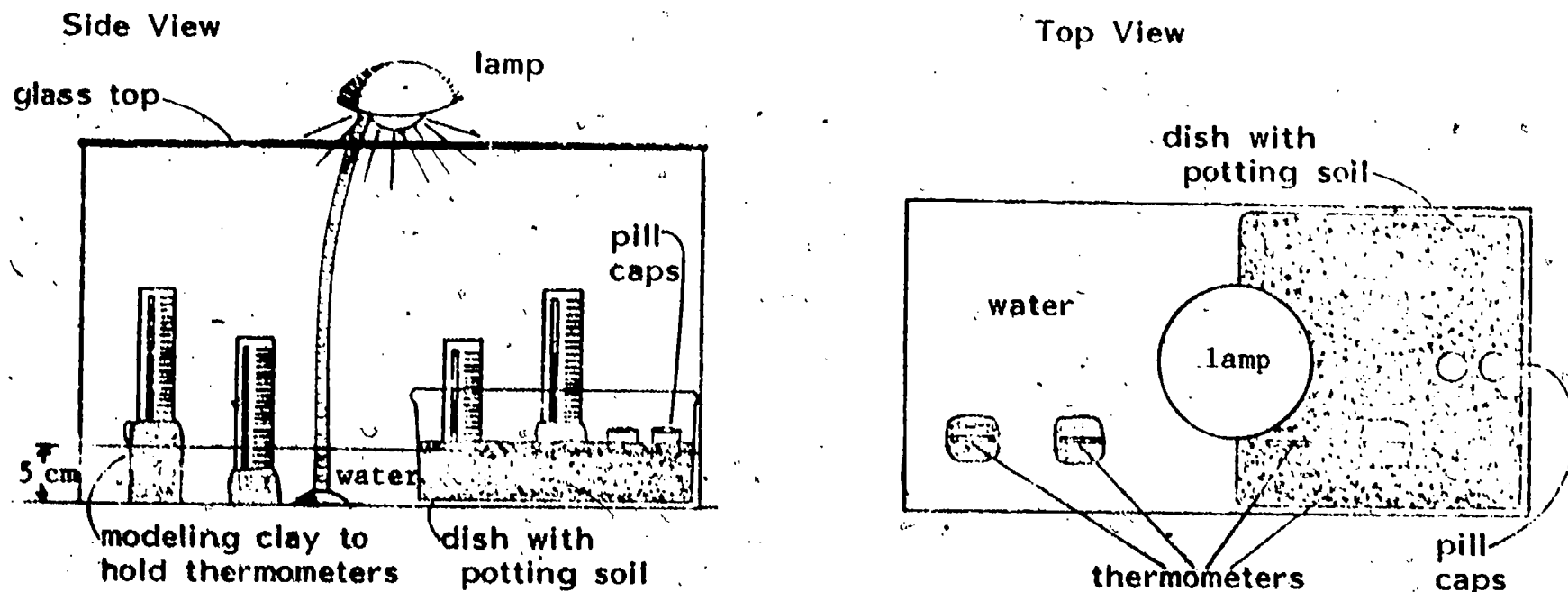


Figure TG-1: Side and Top views of Teacher's Demonstration

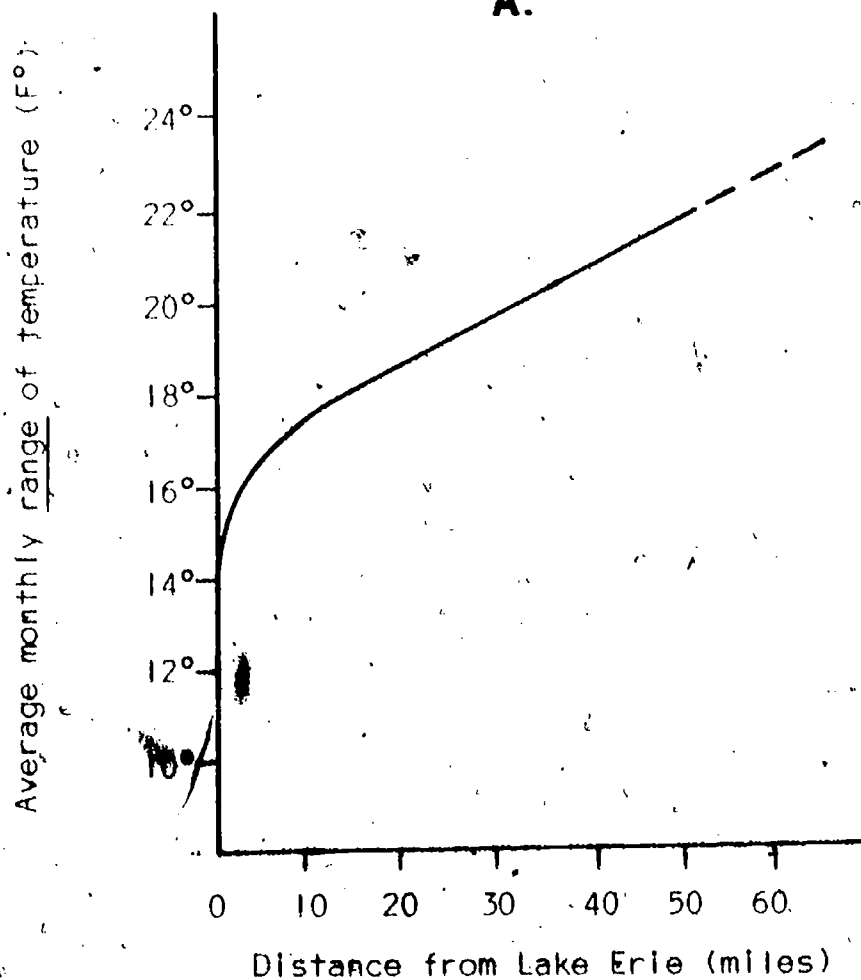
- 2) Use one dropper to put 3-5 ml of hydrochloric acid into one of the pill caps.
- 3) Cover the aquarium and turn on the heat lamp for 10-15 minutes before doing the demonstration.
- 4) While waiting for heat to build up inside the tank, discuss with students the introductory materials included in the Student Guide.
- 5) After 10 minutes, have students answer questions 1-3. Answers should be as follows:
 1. Hottest area is over "land," coolest is under water. Accept any reasonable hypothesis about how air is moving in the tank. Heated air should rise over the land and cooler air should flow in from the water to fill the "empty space" left by the rising air.
 2. Moving air isn't visible, but its effects are. We can see trees swaying and clouds and smoke being carried by the wind.
 3. Here the answers may vary. Some suggestions might work on a large scale but be impossible for use in this small tank. Accept each of the suggestions of your students, discussing them with the class.
- 6) Draw 1 ml of ammonium Hydroxide into a clean dropper.
- 7) Quickly slide the aquarium cover over a bit and carefully drop ammonium hydroxide into the empty pill cap. The vaporizing HCl and ammonium hydroxide react in the air to produce ammonium chloride, the white plume.
- 8) Remove dropper quickly and replace the aquarium cover. (A white "smoke" plume should trace out the circulation pattern within the tank).
- 9) Have students complete the answers for this activity based on their observations.
 4. The "smoke" particles are light enough to be carried by air. Therefore, they are carried by the movement of the air and outline the air currents. The less dense air over the land is rising and the denser air over the water is moving in over the land to fill in the "empty space." The lighter air has then moved over the water, cooled, dropped, and moved in over the soil to complete the convection cell.

5. The denser air would be located over the cooler water. The less dense air would be rising over the hotter land.
6. The wind will move from the lake toward the shore during the mid-day to afternoon. By this time, the sun has warmed up the land more than the lake.

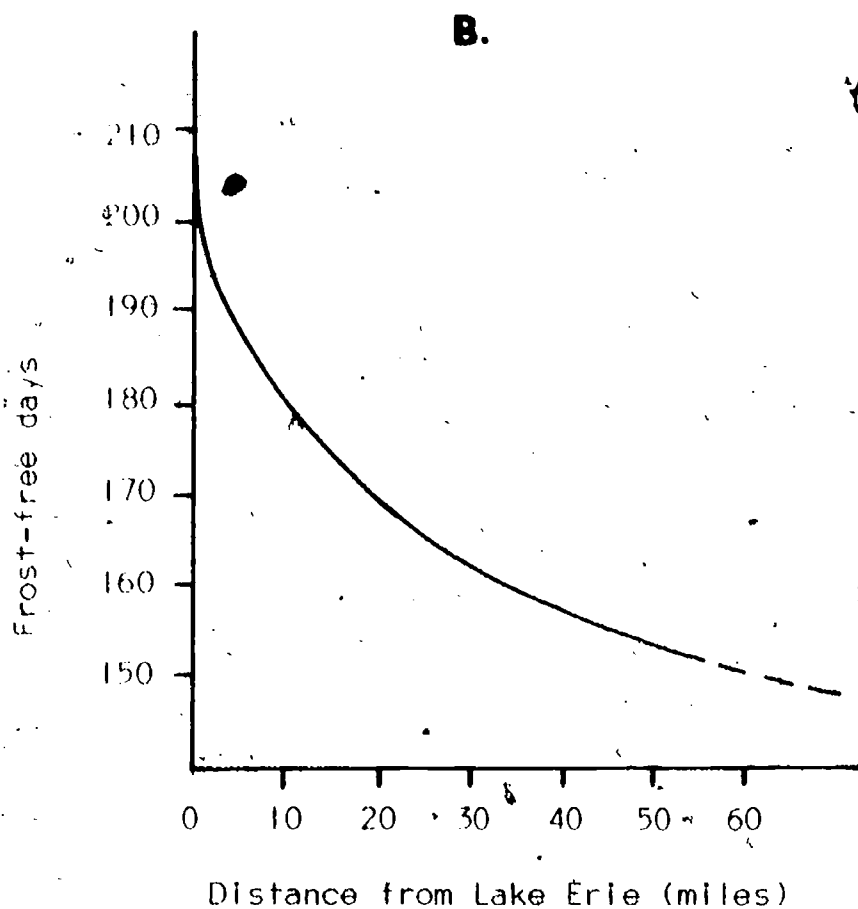
ACTIVITY B HOW DOES LAKE ERIE INFLUENCE THE CLIMATE OF NEARBY LAND AREAS?

Answers to questions in student's investigation:

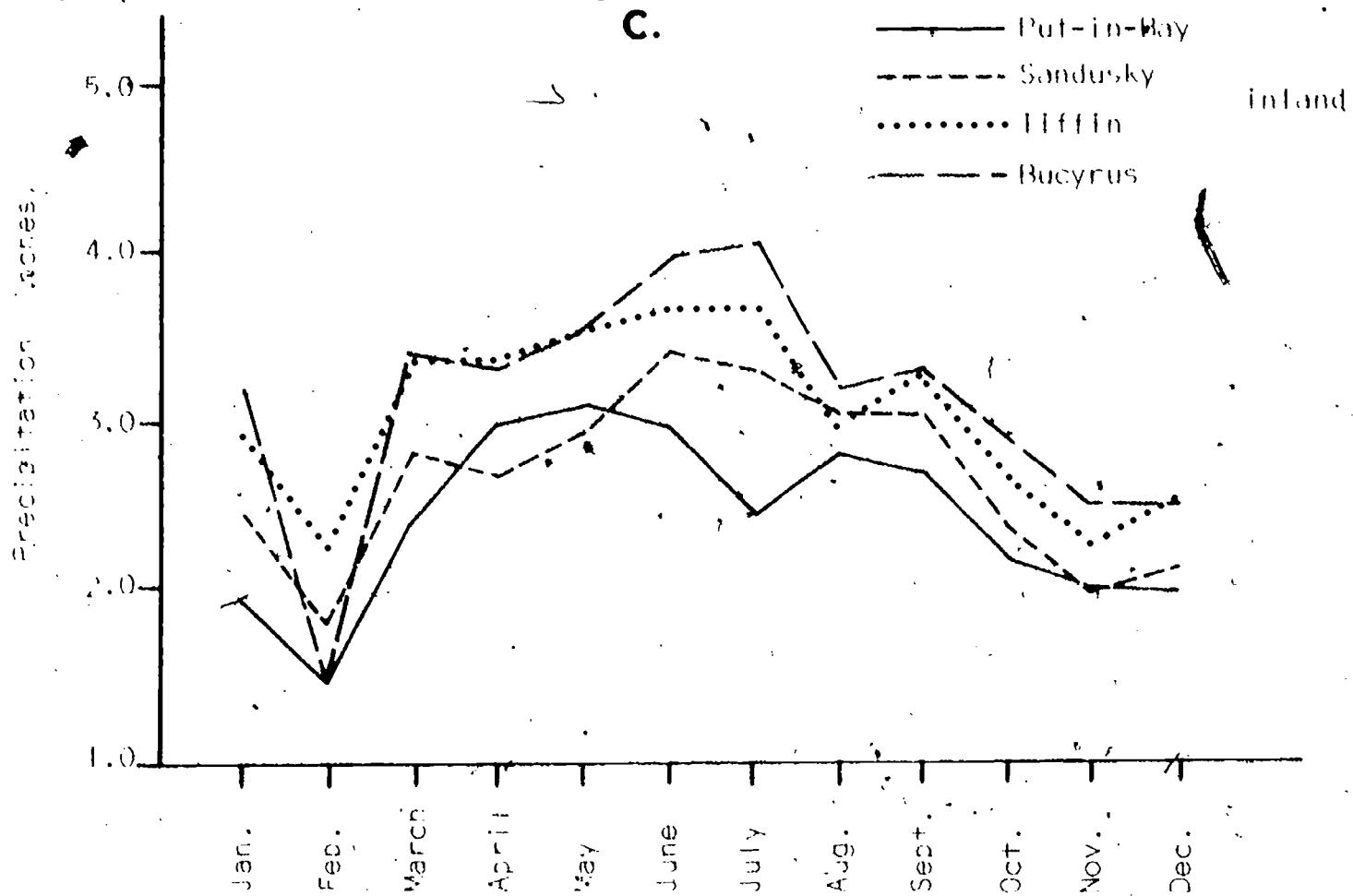
1. "A" graph. The average monthly range in temperature increases as you move farther from the lake. The range is caused by the lake's acting as a moderator for the immediate surrounding temperatures. The range is part of the "lake effect" because the lake slowly releases its stored-up energy (specific heat) to the air and keeps it warmer in the fall and winter. Therefore, the temperature does not vary as much (have as great a range) near the lake.



2. "B" graph. The number of frost-free days decreases as you move farther inland from the lake. This decrease is also part of the "lake effect." The lake slowly gives off its heat energy to the atmosphere, thereby keeping nearby land warmer and keeping the frost away longer than farther inland.



3. Viniculture requires a long growing season (more frost-free days) and moderate temperatures (warm, with no severe changes.)
4. "C" graph: In general the precipitation increases as you move inland from the lake.
5. The highest snowfall occurs not far from the Lake Erie coast between Erie, Pa., and Buffalo, N.Y. Yes, this is also the area of highest annual precipitation.



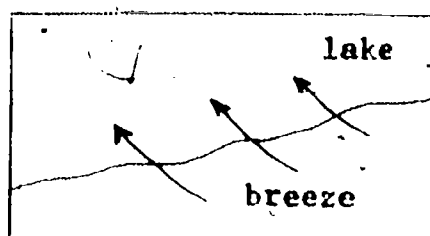
6. The water that falls on Buffalo as rain and snow comes primarily from Lake Erie.
7. The water which falls on Buffalo gets into the air by evaporation as the prevailing (southwesterly) winds blow over the lake's surface.
8. Sandusky is along the southwestern shoreline of Lake Erie. Because the prevailing winds come from the southwest, the wind has been traveling over dry land and has not yet picked up much moisture. More moisture becomes available as the wind travels over Lake Erie toward Buffalo.
9. The greatest difference in precipitation between Bucyrus and Put-in-Bay is found during the month of July. Bucyrus could be getting its rainfall from the moisture which enters the air from evaporation over streams and the land itself.

ACTIVITY C

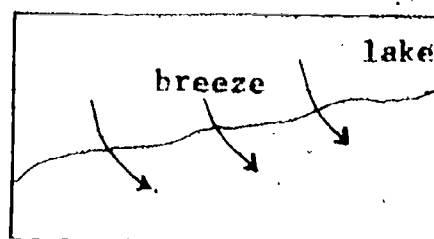
CAN YOU MAKE A GENERAL CLIMATE PREDICTION?

- Vermilion, Ohio, is situated along the Lake Erie shoreline as is Sandusky. Summer temperatures in Vermilion would warm up slower than inland cities because of proximity to the Lake, but once the water warms up, the Lake will help keep winter temperatures from dropping as low as those farther inland. Using the climate data from the cities in Activity B and the geographic position of Vermilion, students can predict that precipitation would range from about 1.5 inches in January to 3 inches in late spring. The average number of frost-free days would be about 194.

2.



Summer Evening



Summer Afternoon

REVIEW QUESTIONS

- During the day, the land heats up faster than the water. The air above the land is heated and rises because it is less dense. Cooler (more dense) air above the water blows inland to fill in the "empty space." This inland movement of air is called the on-shore breeze.

At night, just the opposite air movement occurs. The land cools off faster than the water. Thus, the air over the water becomes less dense and rises. The cooler air from over the land blows off-shore to fill in the "empty space." This is called the evening off-shore breeze.

- The circulation pattern of air does affect the precipitation of the area. The on-shore breeze brings moist air from over the lake. As it passes over the land, the air warms and rises. As warm moist air rises, rain clouds are formed and are then blown further inland where the moisture falls as rain.
- The agricultural economy of this area is very dependent upon the precipitation brought inland from the lake. The air circulation also allows more frost-free days and therefore a longer growing season.
- There is more precipitation at Buffalo, N.Y., because the prevailing winds from the west have traveled over the lake and picked up moisture. These winds move inland across Buffalo and release the moisture as rain. Sandusky, however, is on the western shoreline of the lake. The prevailing westerly winds have been traveling over the land and have not had a chance to pick up much moisture.

REFERENCES

ESCP, Investigating the Earth, Third Edition, Houghton-Mifflin Co., 1978. Lab 2-6: Investigating Convection, pages 54-55. Lab 2-13: Investigating Cumulus Cloud Formation, pages 61-62.

Phillips, D.W. and McCulloch, J.A.W., The Climate of the Great Lakes Basin. Environment Canada, Toronto, 1972.

EVALUATION ITEMS

1. Warm air, when surrounded by cooler air, will:
 - *1. rise.
 2. sink.
 3. neither rise nor sink.
 4. sink, then rise.
2. Over a very small geographical area, winds blow:
 1. from areas of warm air to areas of cooler air.
 - *2. from areas of cool air to areas of warmer air.
 3. only vertically in areas of warm air.
 4. along the prevailing wind direction at all times.
3. Which heats up faster when the sun is shining?
 1. water covered by ice
 2. land and water heat up at the same rate
 3. water (lakes)
 - *4. land
4. In the summer, the temperature of air
 1. over water and the nearby land is the same, night or day.
 2. always follows the prevailing wind direction.
 - *3. over water is warmer at night than over the nearby land.
 4. over water is warmer during the day than air over the nearby land.
5. As you go along Lake Erie from Sandusky, Ohio, to Erie, Pennsylvania, the average yearly precipitation
 - *1. increases.
 2. decreases.
 3. remains the same.
6. Normally, an air mass originating over water will
 1. have the same amount of H_2O in it as an air mass over land.
 2. have less water in it than an air mass over land.
 - *3. have more water in it than an air mass over land.
 4. gain or lose water only in the daytime, when the sun is shining.

7. Cities downwind from a large water body will get
1. more precipitation in the winter after the lake surface is covered with ice.
 2. the same amount of precipitation as cities downwind from land.
 3. less precipitation than cities downwind from land.
 - *4. more precipitation than cities downwind from land.
8. Compared to inland cities, cities near large bodies of water will be
1. warmer in the winter and warmer in the summer.
 - *2. warmer in the winter and cooler in the summer.
 3. cooler in the winter and warmer in the summer.
 4. cooler in the winter and cooler in the summer.
9. Frost-free days are days when the air temperature near the land surface does not fall below freezing. As you get closer to a large body of water, the number of frost-free days per year
- *1. increases.
 2. decreases.
 3. stays the same.
 4. increases, then decreases.
10. A major "industry" of northern Ohio and the Lake Erie Islands that results from the influence of the lake on climate is
1. electrical power generation.
 - *2. raising grapes.
 3. producing steel.
 4. shipping.