EP-002

OHSU-E-90-001 C3

The effect of Lake Erie on climate

James D. Meinke, Beth A. Kennedy** and Victor J. Mayer****

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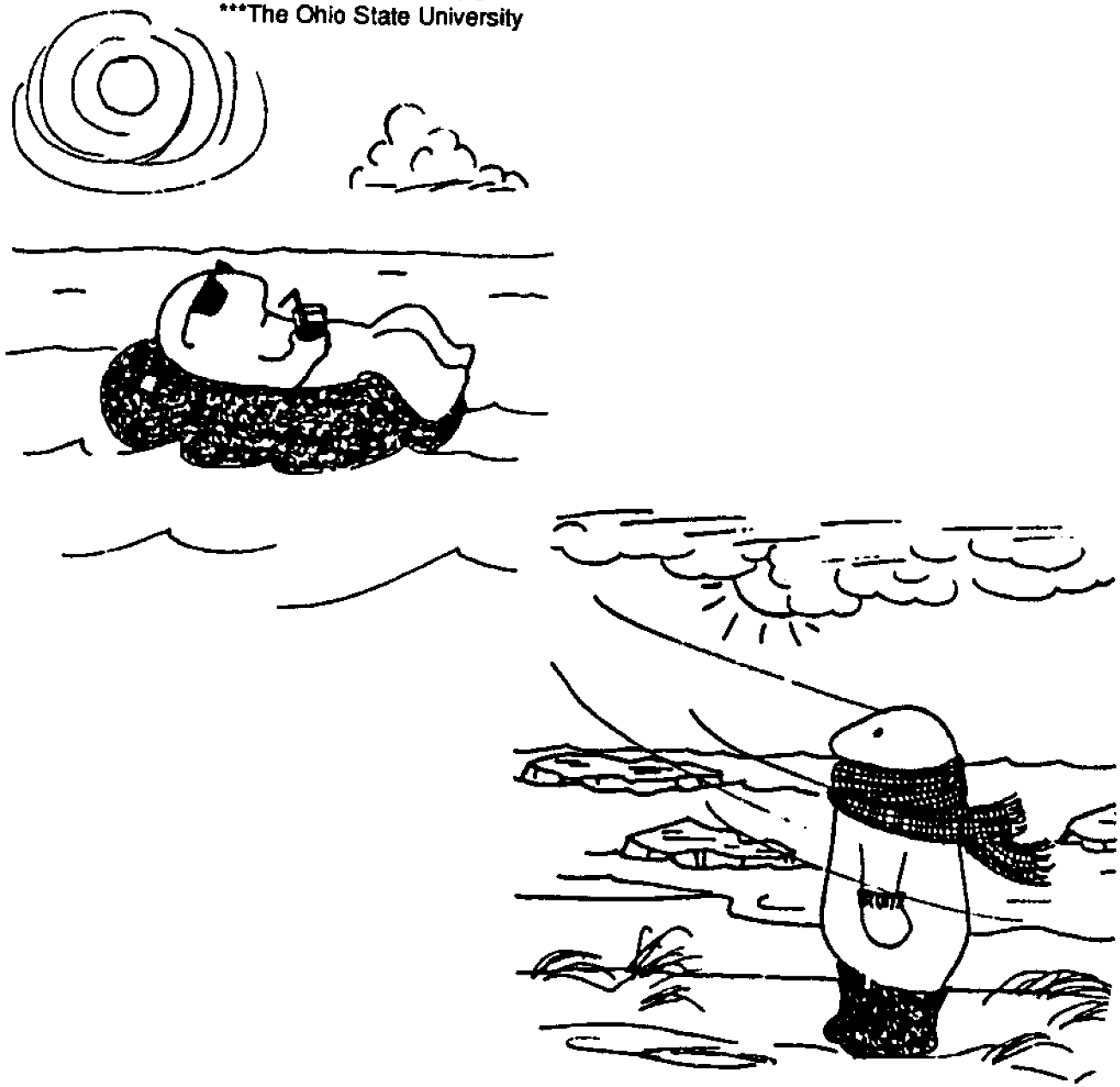

OEAGLS
OCEANIC EDUCATION ACTIVITIES FOR GREAT LAKES SCHOOLS

TEACHER GUIDE

Ohio Sea Grant Education
The Ohio State University
059 Ramseyer Hall
29 West Woodruf
Columbus, OH 43210
614/292-1078

The Ohio Sea Grant College Program is part of the Lake Erie Programs at The Ohio State University. The Center for Lake Erie Area Research (CLEAR) and Franz Theodore Stone Laboratory: Ohio's freshwater field biology station, are also part of the Lake Erie Programs.

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COMPLETED APRIL 1979
REVISED JULY 1980 AND JULY 1990

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

Rosanne W. Fortner, *Education Program Director*
Victor J. Mayer, *Research Coordinator*
Lorien Marshall, *Layout Editor*

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THE EFFECT OF THE GREAT LAKES ON CLIMATE

By
James D. Meinke, Lakewood Public Schools
Beth A. Kennedy, Newark Public Schools, and
Victor J. Mayer, The Ohio State University

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 A and B to make a general prediction about the climate of Vermilion, Ohio. Equivalent information should be available for each Great Lake state and Ontario.

OBJECTIVES

When 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 the 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.

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. Each of the activities, A and B/C, will take about one 45-minute class period to complete.

PREREQUISITE STUDENT BACKGROUND

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

Section 2-13 of ESCP (Investigating the Earth, 1988) 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 the Great Lakes on Ohio's Temperature.

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, medicine droppers, two plastic pill bottle caps, four thermometers, water, graph paper (five 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.

THE EFFECT OF THE GREAT LAKES ON CLIMATE

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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.

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, medicine droppers, two plastic pill bottle caps, four thermometers, water.

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 above both water and soil.

2. Use one dropper to put 3-5 ml of hydrochloric acid into one of the pill caps.

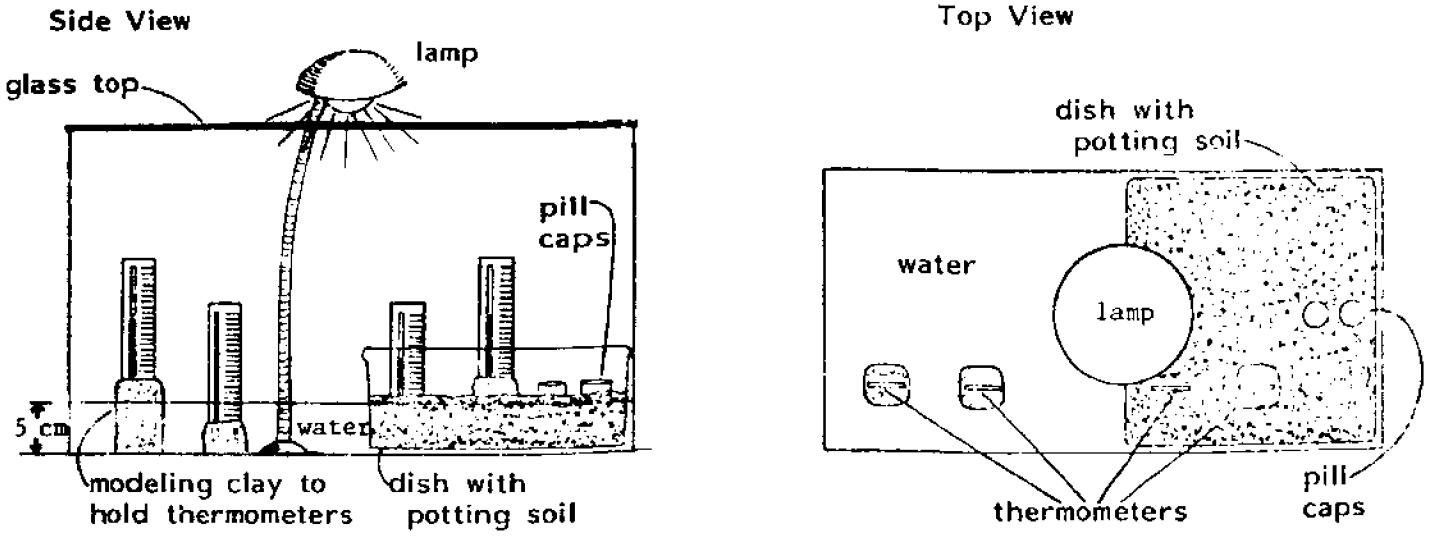


Figure TG-1: Side and Top views of Teacher's Demonstration

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. Questions and answers are as follows:

   (1) Observe the four thermometers in the container. Where is it hottest? Where is it coolest? How do you think air inside the tank might be moving?

T1. The hottest area is over "land," the 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) Can you see the air around you move? List some ways you could observe the air's motion.

T2. Moving air isn't visible, but its effects are. We can see trees swaying, and clouds and smoke being carried by the wind.

   (3) What could we do to actually see how the air is moving inside the tank?

T3. 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) Where would the denser air be located in the tank? The less dense air? Why?

T4. 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) Why does the air move in the way it does?

T5. The denser air would be located over the cooler water. The less dense air would be located over the hotter land.

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

T6. The wind will more 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 DO THE GREAT LAKES INFLUENCE THE CLIMATE OF NEARBY LAND AREAS?

MATERIALS

Graph paper and pencil

PROCEDURE

In this part of the activity students will construct a graph showing the relationship between precipitation, temperature, and distance from the shore of Lake Erie in an area of northwestern Ohio.

1. The students are to prepare a graph from information shown in columns two and three below. They are then asked what happens to the average monthly range in temperature as the distance from the lake increases, and how this relates to what was observed in Activity A.

T1. The graph is shown on the next page. 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 fall and winter. Therefore, the temperature does not vary as much (have as great a range) near the lake.

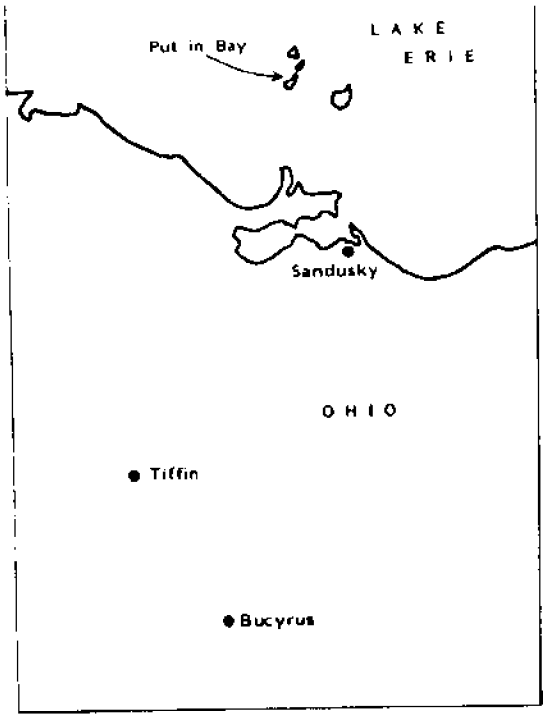


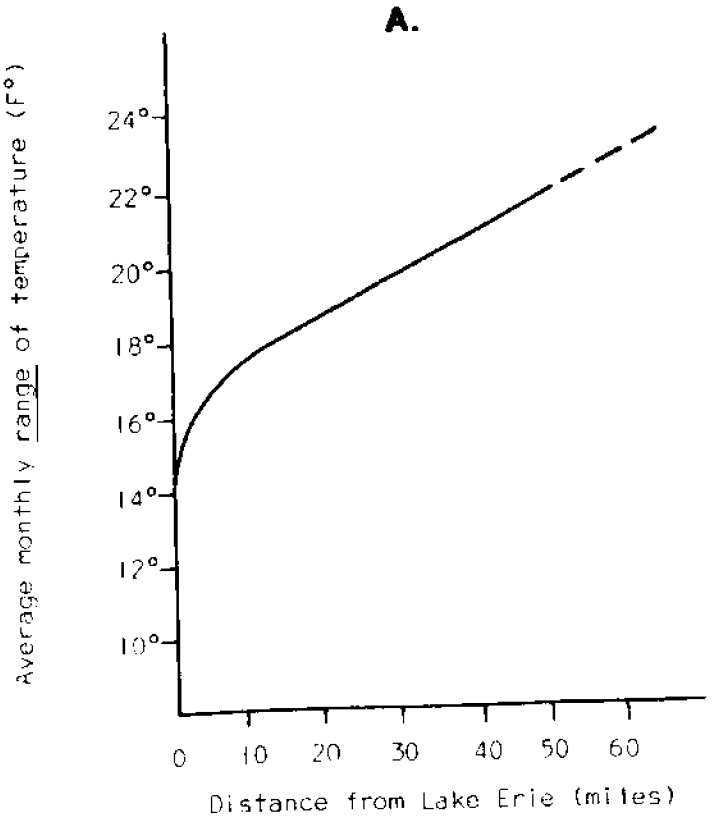
Figure 2. Map of the Lake Erie shore nea Sandusky, Ohio

Locations	Distance from Lake Erie	Average Monthly Range of Temperature (oF)	Number of Frost-Free Days
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. The students are to prepare a graph from information given on the previous page. They are then asked what happens to the number of frost-free days as the distance from the lake increases. They are also asked how the lake causes the change in the number of frost-free days.

T2. The graph is shown below. The number of frost-free days decreases as you move farther 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. The Lake Erie islands, such as the one where Put-in-Bay is located, seem especially well-adapted for growing grapes. This is primarily because of the climate. Based on what you know about Put-in-Bay from this activity, what temperature conditions are important for good viniculture (grape growing)?

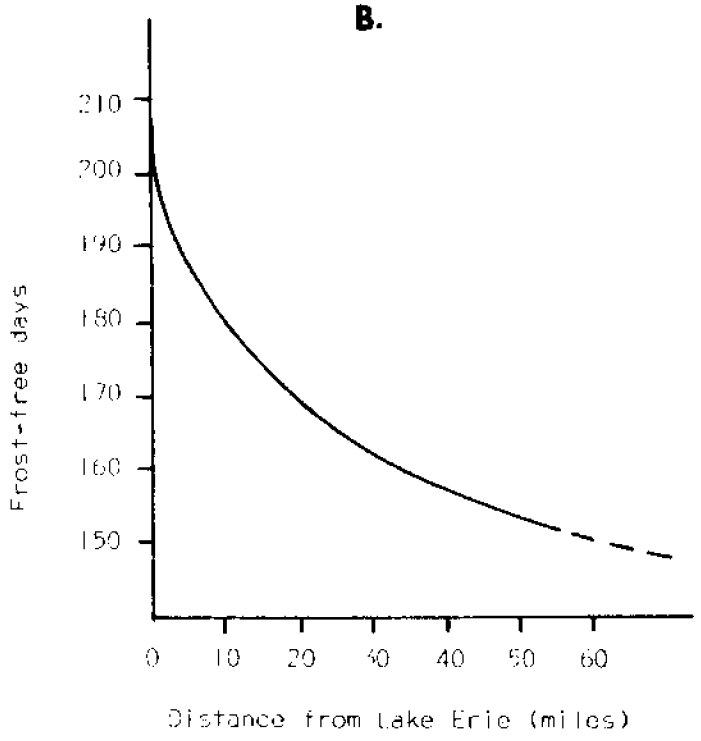
T3. Viniculture requires a long growing season (more frost- free days) and moderate temperatures (warm, with no severe changes.

4. The students are to prepare a graph from information given below. They are then asked what happens to the amount of precipitation as the distance from the lake increases.

T4. The graph is also shown below. In general, the precipitation increases as you move inland from the lake.

Locations	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
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 in Inches



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

T5. 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. Where do you think most of the water comes from that falls on Buffalo either in the form of rain or snow?

T6. The water that falls on Buffalo as rain and snow comes primarily from Lake Erie.

7. How does this water get into the air?

T7. 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 right next to the lake as is Buffalo. Why do you think Sandusky gets so much less moisture?

T8. 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. 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 most of its rainfall that month?

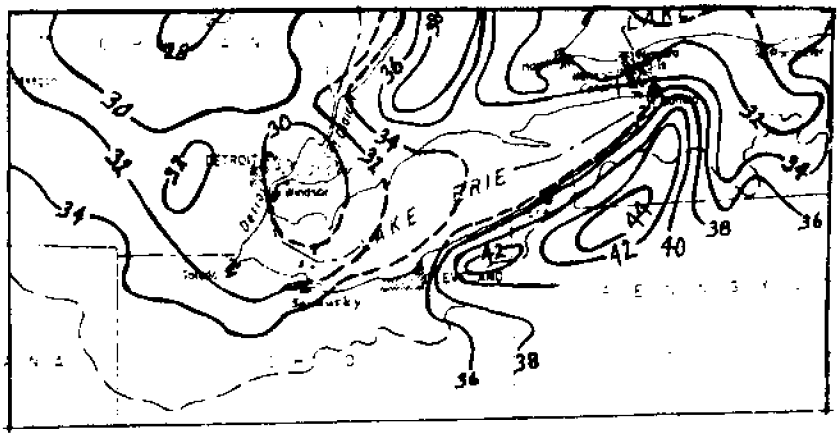


Figure 6. Total Annual Precipitation in Lake Erie Region in inches

T9. 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.

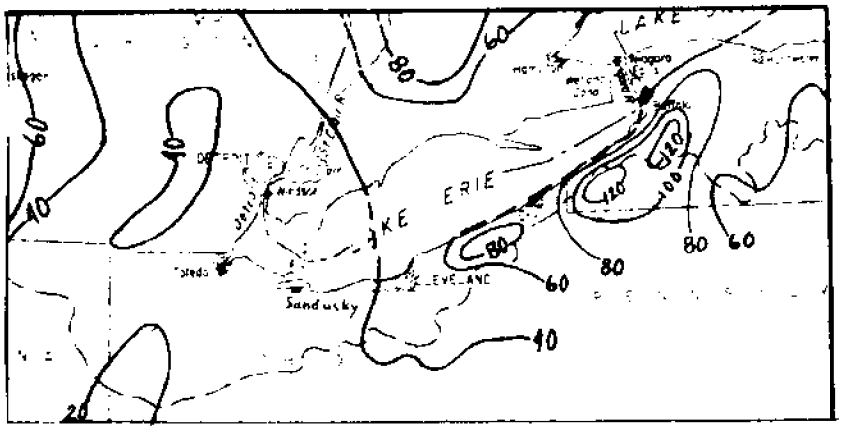


Figure 7. Annual Snowfall in Lake Erie Region in inches

ACTIVITY C: CAN YOU MAKE A GENERAL CLIMATE PREDICTION?

MATERIALS

A road map of Ohio.

PROCEDURE

The students are to locate Vermilion, Ohio, on the map. Keeping in mind the results of Activities A and B, they are to answer the following questions:

1. Compared to the cities whose weather you have examined, 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

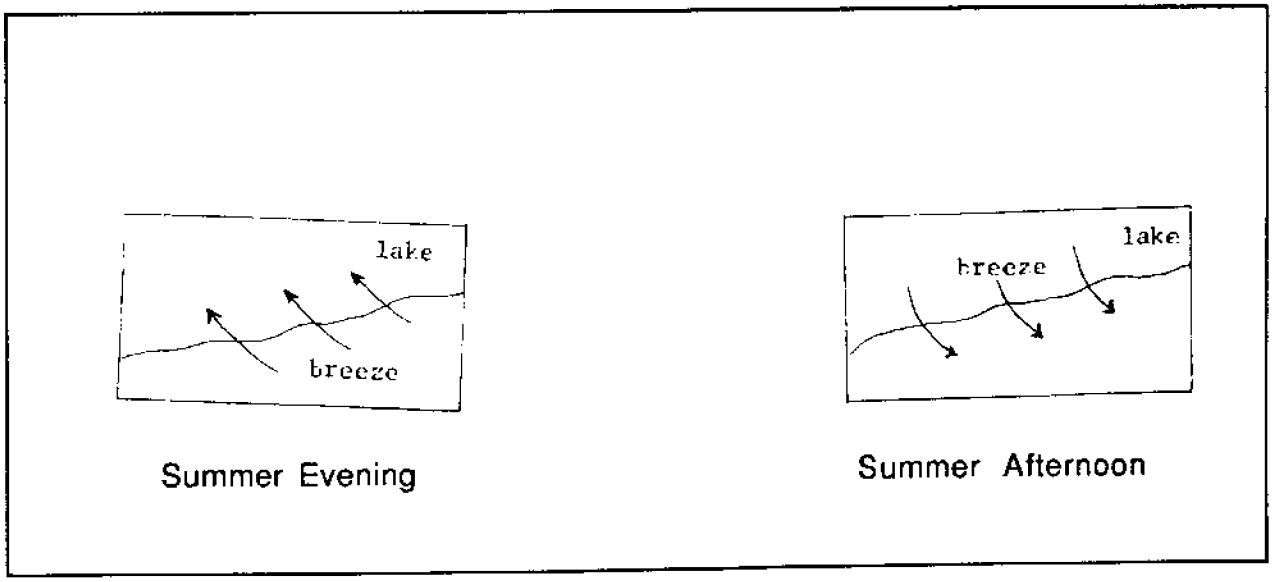
   c. precipitation

   d. frost-free days (growing season)

T1. 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. 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.

T2. The diagrams are shown below.



Summer Evening

Summer Afternoon

REVIEW QUESTIONS

1. How do winds near a shoreline circulate during the day? At night?

T1. 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.**

2. How does the circulation pattern affect the amount of precipitation and therefore the climate of an area?

T2. 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.

3. How is the agricultural economy of this area related to air circulation patterns?

T3. 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.

4. Why is there more precipitation in Buffalo, New York, than in Sandusky, Ohio?

T4. There is more precipitation in 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 land and have not had a chance to pick up much moisture.

References

ESCP, Investigating the Earth, Houghton-Mifflin Co., 1988. Lab 2-6: Investigating Convection, pgs. 54-55. Lab 2-13: Investigating Cumulus Cloud Formation, pgs. 61-62.

Phillips, D. W. and McCullock, 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:

   a. rise.
   b. sink.
   c. neither rise nor sink.
   d. sink, then rise.

2. Over a very small geographic area, winds blow:

   a. from areas of warm air to areas of cooler air.
   b. from areas of cool air to areas of warmer air.
   c. only vertically in areas of warm air.
   d. along the prevailing wind direction at all times.

3. Which heats up faster when the sun is shining?

   a. water covered by ice
   b. land and water heat up at the same rate
   c. water (lakes)
   d. land

4. In the summer, the temperature of air

   a. over water and the nearby land is the same, night or day.
   b. always follows the prevailing wind direction.
   c. over water is warmer at night than over the nearby land.
   d. over water is warmer during the day than air over nearby land.

5. As you go along Lake Erie from Sandusky, Ohio, to Erie, Pennsylvania, the average yearly precipitation

   a. increases.
   b. decreases.
   c. remains the same.

6. Normally, the air mass originating over water will

   a. have the same amount of water in it as an air mass over land.
   b. have less water in it than an air mass over land.
   c. have more water in it than an air mass over land.
   d. gain or lose water only in the daytime, when the sun is shining.

7. Cities downwind from a large water body will get

   a. more precipitation in the winter after the lade surface is covered with ice.
   b. the same amount of precipitation as cities downwind from land.
   c. less precipitation that cities downwind from land.
   d. more precipitation than cities downwind from land.

8. Compared to inland cities, cities near large bodies of water will be

   a. warmer in the winter and warmer in the summer.
   b. warmer in the winter and cooler in the summer.

c. cooler in the winter and warmer in the summer.
d. 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

a. increases.
b. decreases.
c. stays the same.
d. 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

a. electrical power generation.
b. raising grapes.
c. producing steel.
d. shipping.

Other titles of Oceanic Education Activities for Great Lakes Schools

for middle schools:

The Effect of the Great Lakes on Temperature
The Effect of the Great Lakes on Climate
Ancient Lake Shores
How to Protect a River
Changing Lake Levels on the Great Lakes
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Coastal Processes and Erosion
Pollution on Lake Erie: An Introduction
Yellow Perch in Lake Erie
Evidence of Ancient Seas in Ohio
To Harvest a Walleye
Oil Spill!
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The Estuary: A Special Place
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Knowing the Ropes
Getting to know Your Local Fish
Shipping: The World Connection
We Have Met the Enemy
It's Everyone's Sea: Or Is It?
PCB's in Fish: A Problem?
A Great Lake Vacation
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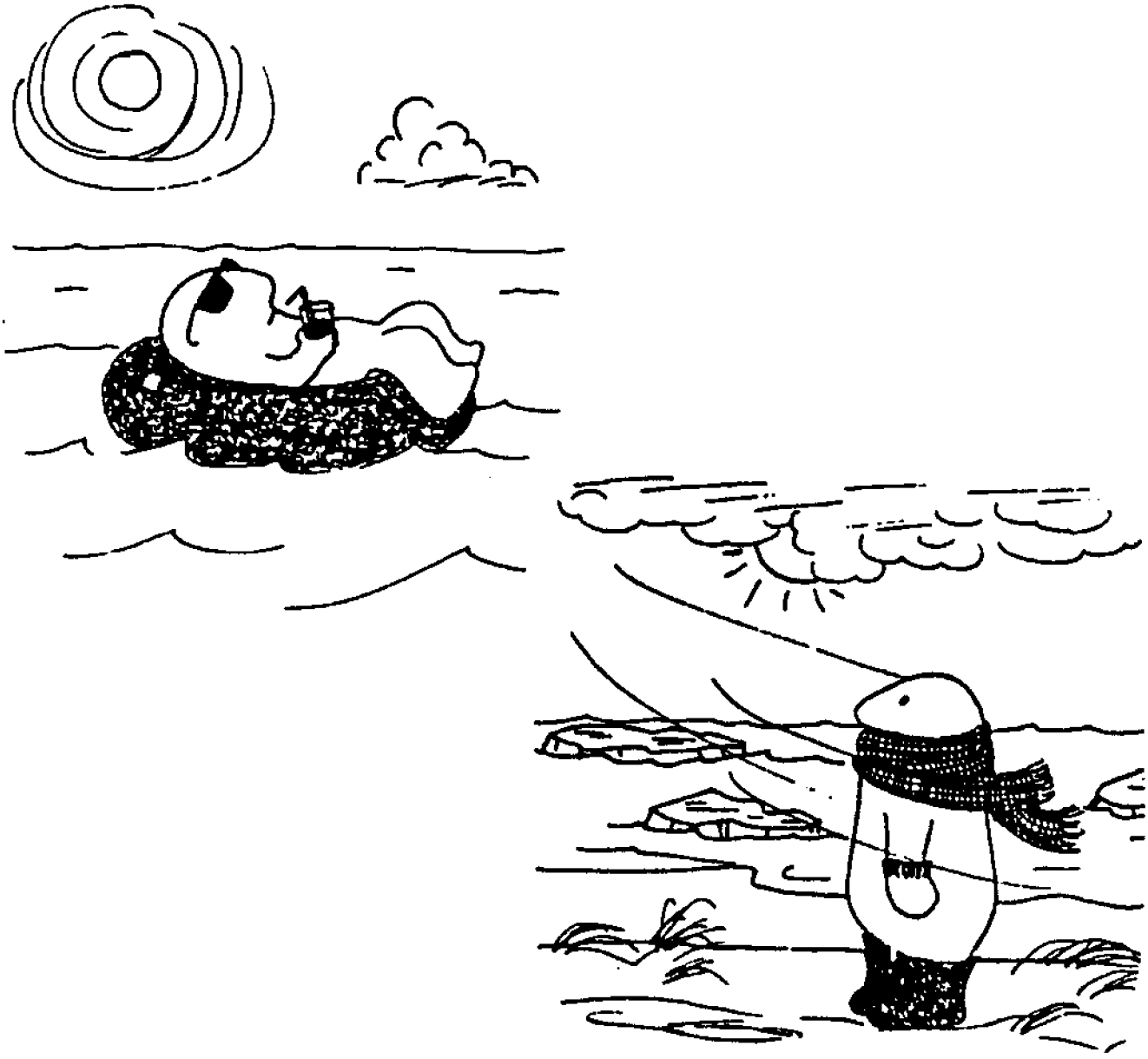

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INTRODUCTION

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, a small town on South Bass Island, and Sandusky, are two of the driest spots in Ohio. Put-in-Bay has about 2/3 of the precipitation of cities in central or southern Ohio. The one thing in common among the cities named above 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?

Large bodies of water such as Lake Erie do have an effect on precipitation and 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 the 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.

ACTIVITY A: WHAT CAUSES THE LAND-SEA BREEZE?

Perhaps you've seen a fire at home in the 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 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 rises.

PROCEDURE

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

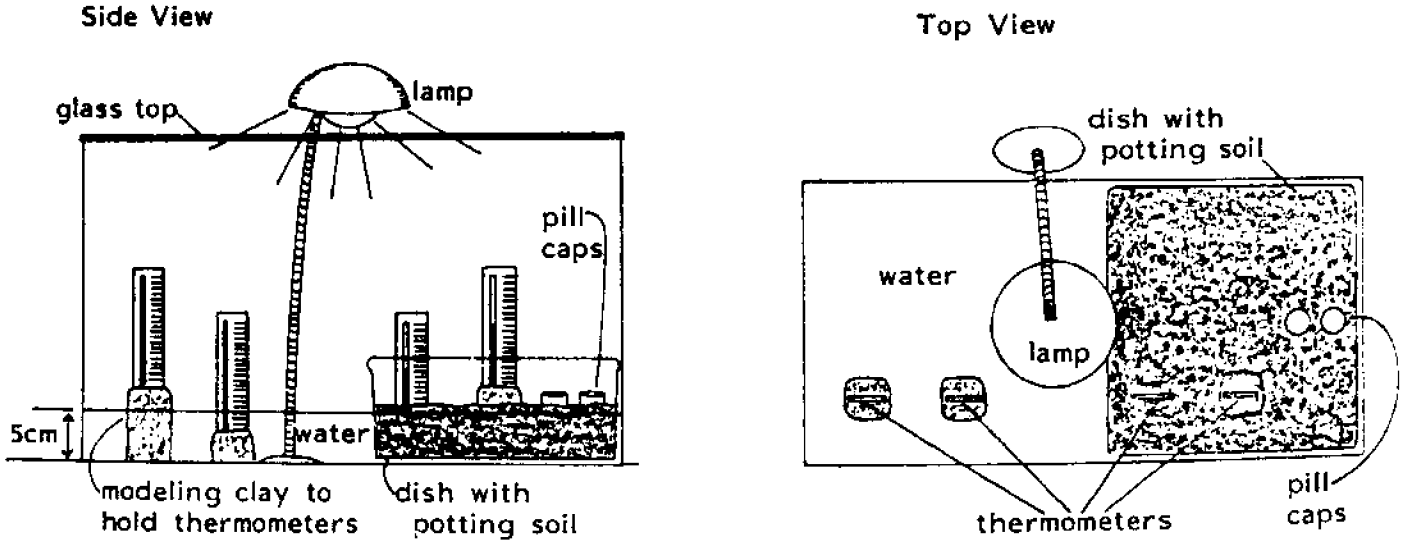
1. Observe the four thermometers in the container. Where is it hottest?

   Where is it coolest?

   How do you think the air inside the tank might be moving?

2. Can you see the air around you move?

   List some ways you could observe the air's motion.



Side and Top Views of Teacher's Demonstration

3. What could we do to actually see how the air is moving 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** in miniature. The land quickly reacts to changes in the amount of heat from the sun (the lamp), whereas the water is slow to react to such changes. Water has a high **specific heat**. It stores heat much 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 DO THE GREAT LAKES 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 Lake Erie in an area of northwestern Ohio (Figure 2).

1. 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?

   How is this related to what you observed in Activity A?

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 as the vertical axis. What happens to the number of frost-free days as the distance from the lake increases?

   How does the lake cause this? (Refer to your answer to Question 1)

3. The Lake Erie islands, such as the one where Put-in-Bay is located, seem especially well adapted for growing grapes. This is primarily because of the climate. Based on what you know about Put-in-Bay from this activity, what temperature conditions are important for good viniculture (grape growing)?

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

A moderate climate is one which does not have extreme temperature conditions, like extremely hot or extremely cold periods. We have now seen that Lake Erie has a moderating effect on the temperature of regions in and around the lake. Does the lake effect precipitation?

4. Prepare a graph from the data in Figure 4 (next page). 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?

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

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?

Locations	Distance from Lake Erie	Average Monthly Range of Temperature (oF)	Number of Frost-Free Days
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

Locations	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
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 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?

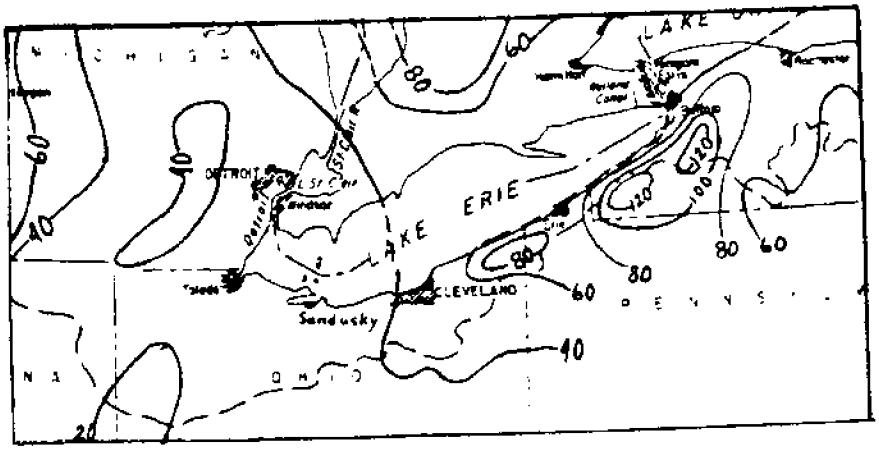


Figure 5. Annual Snowfall in Lake Erie Region in Inches

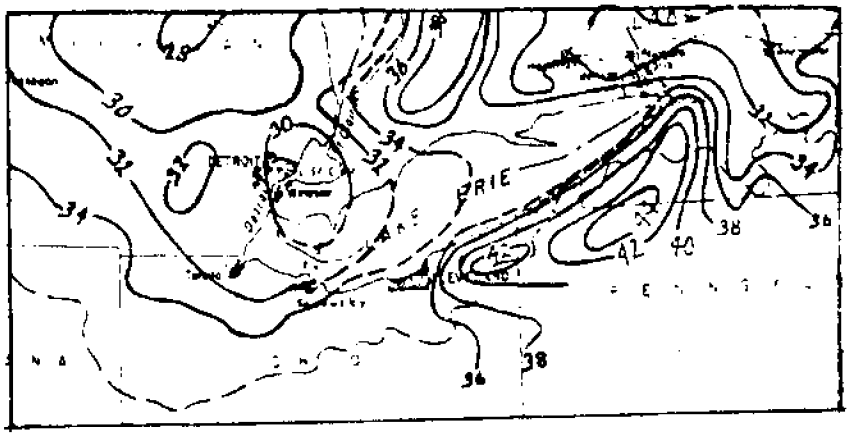


Figure 6. Total Annual Precipitation in Lake Erie Region in Inches

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 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 why Put-in-Bay is the driest part of Ohio.

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 most of its rainfall in that month?

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. Compared to the cities whose weather you have examined, 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.

REVIEW QUESTIONS

1. How do winds near a shoreline circulate during the day?

   At night?

2. How does the circulation patter 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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