Water Temperature Protocol

Purpose

To measure the temperature of a water sample

Overview

Students use an alcohol-filled thermometer or probe to measure the temperature of water.

Student Outcomes

Students will learn,

- how to use a thermometer;
- examine reasons for changes in the temperature of a water body;
- communicate project results with other GLOBE schools;
- collaborate with other GLOBE schools (within your country or other countries); and
- share observations by submitting data to the GLOBE archive.

Science Concepts

Earth and Space Sciences

Earth materials are solid rocks, soils, water and the atmosphere.

Physical Sciences

Objects have observable properties.

Life Science

Organisms can only survive in environments where their needs are met.

Earth has many different environments that support different combinations of organisms.

Humans can change natural environments.

All organisms must be able to obtain and use resources while living in a constantly changing environment.

Scientific Inquiry Abilities

Use a thermometer to measure water temperature.

Identify answerable questions.

Design and conduct scientific investigations.

Use appropriate mathematics to analyze data.

Develop descriptions and explanations using evidence.

Recognize and analyze alternative explanations.

Communicate procedures and explanations.

Time

10 minutes; Calibration: 5 minutes

Level

All

Frequency

Weekly

Calibration every 3 months

Materials and Tools

Hydrology Investigation Data Sheet

Water Temperature Protocol Field Guide

Alcohol-filled thermometer or temperature probe

Latex gloves

Clock or watch

Enough string to lower the thermometer into the water

Rubber band

For Calibration:

- *Calibrating the Hydrology Thermometer Lab Guide*
- Thermometer
- 400 mL ice
- Distilled water
- 500 mL beaker

Preparation

None

Prerequisites

None

Water Temperature Protocol – Introduction

Temperature is an easy measurement to make. It is, however, very important because it allows scientists to better understand other hydrology measurements such as dissolved oxygen, pH and conductivity.

Temperature influences the amount and diversity of aquatic life. Lakes that are cold and have little plant life in winter, bloom in spring and summer when water temperatures rise and the nutrient-rich bottom waters mix with the upper waters. Because of this mixing and the warmer water temperatures, the spring overturn is followed by a period of rapid growth of microscopic aquatic plants and animals. Many fish and other aquatic animals also spawn at this time of year when the temperatures rise and food is abundant. Shallow lakes are an exception to this cycle, as they mix throughout the year.

Water temperature is also important because warm water can be fatal for sensitive species, such as trout or salmon, which require cold, oxygen-rich conditions. Warmer water tends to have lower levels of dissolved oxygen.

Finally, water temperature is important for understanding local and global weather patterns. Water temperatures change differently than air temperatures because water has a higher heat capacity than air. Water also helps to change air temperature through the processes of evaporation and condensation.

Teacher Support

Advance Preparation

Use the *Practicing Your Protocols: Water Temperature Learning Activity* to help students explore sources of error in their temperature collection procedure.

Make sure that the alcohol-filled thermometer has been calibrated within 3 months.

Temperature probes must be calibrated before each use.

Supporting Protocols

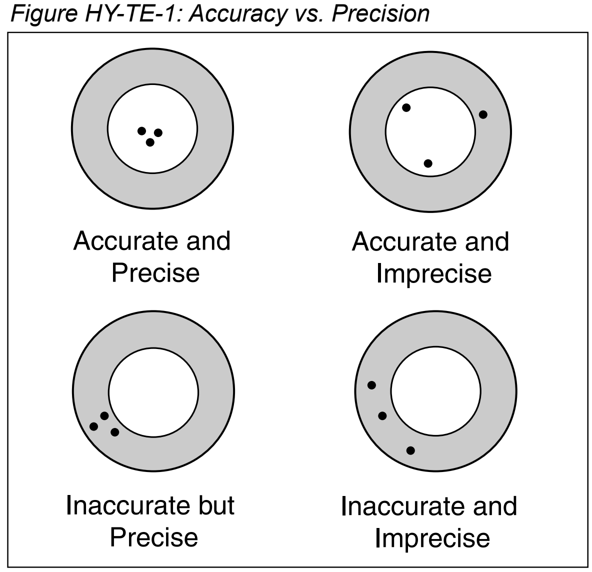
Air and *Soil Temperature Protocols*: Integration of the water temperature with atmosphere and soil temperatures provides an excellent example of how different substances transfer and retain heat differently, resulting in a better understanding of how energy is transferred and stored in the Earth's system.

Supporting Activities

The measurement of water temperature provides a good opportunity for teachers to introduce basic concepts of data accuracy and precision.

Data are accurate when the sample average (average of student observations) is equal to the true average. Data are precise when the student observations fall within a narrow range. Results may be accurate, though imprecise, when students have a wide scatter in their observations.

Figure HY-TE-1: Accuracy vs. Precision



Results may be precise, though inaccurate, when student measurements are within a narrow range, but when the mean does not equal the true mean.

The GLOBE Hydrology *Temperature Protocol* is designed so that the data students' report are both accurate and precise. Students are required to take at least three measurements and then calculate the mean. If any of the observations fall more than 1.0˚ C away from the mean, the measurement is done again to improve the precision of the data.

Measurement Procedures

Because water temperature is an easy measurement to take, students sometimes become careless about following the protocol. Sources of error include not leaving the instrument in the water long enough to stabilize, removing the thermometer from the water so that the measurement changes before it can be read, and not reading the thermometer at eye level.

Except for transparency, water temperature is taken before the other water measurements. Take the water temperature measurement as soon as possible after the water sample is taken because temperature tends to change very rapidly after a sample is collected.

Read the temperature value on the thermometer or meter while the bulb of the thermometer or probe is in the water. The temperature reading can change quickly once the thermometer is out of the water, especially if the air temperature is very different from the water temperature or if it is windy. Wind can cause evaporation to occur rapidly, lowering the temperature

It is important that the water temperature be taken at the same place every week. There may be several degrees of difference in water temperature over a small area in your water body: sunny areas vs. shady areas, or shallow and deeper areas.

When using temperature probes, you will hear references to either temperature probes or meters. For clarification, probes are the instruments that measure voltage or resistance in a water sample. Meters are instruments that convert voltage or resistance measurements to concentrations. In order to measure temperature (or other types of measurements), both a probe and meter are required. Sometimes the probe and meter are within one instrument and cannot be taken apart. Other instruments have probes that are separate from the meters and need to be connected to the meters in order to take the water measurements.

If you are using an alcohol-filled thermometer, attach a string long enough to reach the water to the top of the thermometer. Tie a rubber band to the other end of the string. Have students slip the rubber band over their wrist when taking the temperature to avoid dropping or losing the instrument.

The alcohol column in the thermometer may become separated, especially if the thermometer is not stored in an upright position. Students are asked to examine their instrument and report this problem to the teacher. The column may be rejoined by holding tightly to the top of the thermometer and shaking it down or swinging it.

Quality Control Procedure

Alcohol-Filled Thermometers

Use an ice-water bath to calibrate the thermometer every 3 months.

Temperature Probes with Meters

Temperature meters must be calibrated before use. Check with your meter manufacturer to be sure it stores the most recent calibration. If it does, the temperature meter should be calibrated in the classroom or lab before going to the Hydrology Site. If your meter does not keep the most recent calibration, you will need to calibrate it just before you take your measurements taking care not to turn the meter or any associated software off.

Safety Precautions

Students should wear gloves when handling water that may contain potentially harmful substances such as bacteria or industrial waste.

Instrument Maintenance

Alcohol-filled Thermometers

1. Make sure that the string and rubber band attached to the thermometer are not frayed before each use.
2. Store the thermometer upright in a beaker or other holder. Storing the thermometer on its end prevents the alcohol column from separating.
3. Make sure that the alcohol column is continuous and has not become separated.

Temperature Probes

1. The probe should be stored with the cap on.
2. The probe should be well rinsed with distilled water after use to avoid mineral deposit accumulation.
3. The probe should periodically be cleaned with alcohol.

Helpful Hints

Calibrating the Hydrology Alcohol-Filled Thermometer

Use the *Calibrating the Hydrology Thermometer Lab Guide* to check the accuracy of a new thermometer. If the new thermometer is not reading correctly, contact the manufacturer.

Questions for Further Investigation

How does a sudden change in air temperature affect water temperature?

Is the range of air temperature different in areas next to large water bodies as compared to areas away from water bodies?

How do water temperatures compare to air temperatures in the winter? In the summer?

Calibrating the Hydrology Thermometer

Lab Guide

Task

Calibrate the alcohol-filled thermometer or temperature probe.

What You Need

- ❑ Alcohol-filled thermometer or temperature probe
- ❑ 500 mL beaker
- ❑ 100-mL distilled water
- ❑ 400-mL crushed ice

What to Do

1. Stir together 100 mL of water and 400 mL of crushed ice in the beaker to make an ice-water bath.
2. Let the ice-water bath sit for 10 to 15 minutes so that it reaches its lowest temperature.
3. Put the bulb of the thermometer into the bath. Gently move the thermometer around in the ice-water bath.
4. Leave the thermometer in the water for three minutes.
5. Read the temperature without removing the bulb of the thermometer from the water.
6. Let the thermometer stay in the water sample for one more minute.
7. Read the temperature again. If the temperature has not changed, go to Step 8. If the temperature has changed since the last reading, repeat Step 6 until the temperature stays the same.
8. The thermometer should read between -0.5˚ and 0.5˚ C.
9. If the alcohol-filled thermometer or meter with probe does not read the proper temperature, notify your teacher. Alcohol-filled thermometers do not have an adjustment and must be replaced if they do not read temperature with the expected accuracy (± 0.5° C). Some temperature meters and probes may have adjustments for calibration. Follow the instructions that came with your probe to calibrate. If your probe cannot be calibrated, it must be replaced.

Water Temperature Protocol for Thermometer Probes
Field Guide

Task

Measure the temperature of your water using a calibrated meter and thermometer probe.

What You Need

- ❏ *Hydrology Investigation Data Sheet*
- ❏ Calibrated meter and probe
- ❏ Pen or pencil
- ❏ Clock or watch
- ❏ Latex gloves

In the Field

1. Make sure that your temperature probe and meter have been calibrated within the last 24 hours (see *Calibrating the Hydrology Thermometer Lab Guide*)
2. Fill out the top portion of your *Hydrology Investigation Data Sheet.*
3. Put the probe or the into the sample water to a depth of 10 cm.
4. Leave the probe in the water for three minutes.
5. Read the temperature on the meter without removing the probe from the water.
6. Let the thermometer probe stay in the water sample for one more minute.
7. Read the temperature again. If the temperature has not changed, go to Step 8. If the temperature has changed since the last reading, repeat Step 6 until the temperature stays the same.
8. Record the temperature on the *Hydrology Investigation Data Sheet.*
9. Have two other students repeat the measurement with new water samples.
10. Calculate the average of the three measurements.
11. All temperatures should be within 1.0° C of the average. If they are not, repeat the measurement.

Water Temperature Protocol for Thermometers

Field Guide

Task

Measure the temperature of your water using an alcohol-filled thermometer.

What You Need

- ❑ *Hydrology Investigation Data Sheet*
- ❑ Clock or watch
- ❑ Pen or pencil
- ❑ Alcohol-filled thermometer (with string and rubber band attached)
- ❑ Latex gloves

In the Field

1. Fill out the top portion of your *Hydrology Investigation Data Sheet*.
2. Put on the gloves.
3. Slip the rubber band around your wrist so that the thermometer is not accidentally lost or dropped into the water.
4. Check the alcohol column on your thermometer to make sure there are no air bubbles trapped in the liquid. If the liquid line is separated, notify your teacher.
5. Put the bulb end of the thermometer into the sample water to a depth of 10 cm.
6. Leave the thermometer in the water for three minutes.
7. Read the temperature without removing the bulb of the thermometer from the water.
8. Let the thermometer stay in the water sample for one more minute.
9. Read the temperature again. If the temperature has not changed, go to Step 10. If the temperature has changed since the last reading, repeat Step 8 until the temperature stays the same.
10. Record the temperature on the *Hydrology Investigation Data Sheet*.
11. Have two other students repeat the measurement with new water samples.
12. Calculate the average of the three measurements.
13. All temperatures should be within 1.0˚ C of the average. If they are not, repeat the measurement.

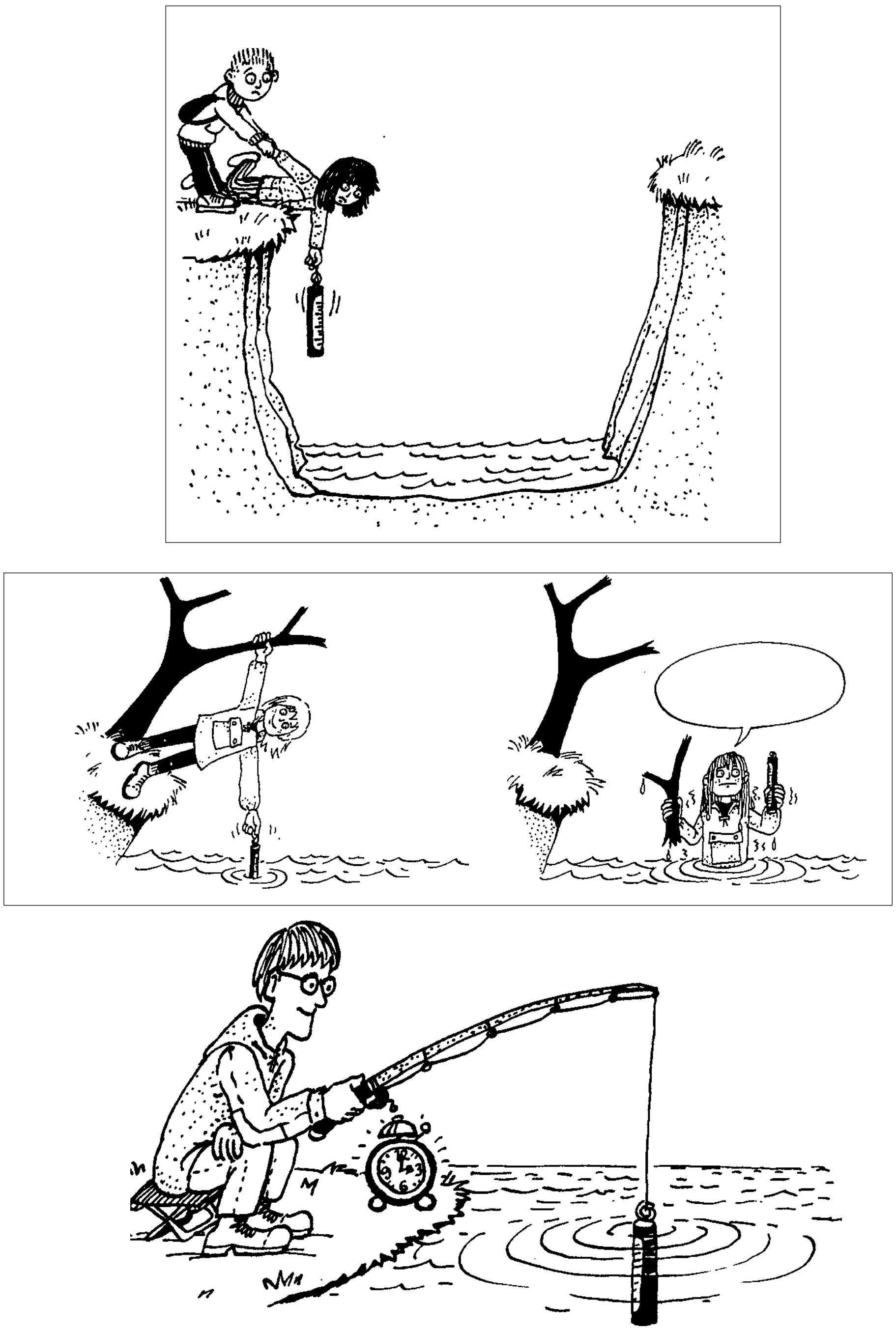
Frequently Asked Questions

1. I noticed on the GLOBE Web site that some schools were reporting water temperatures below 0.0˚ C. Is this possible?

Yes. Distilled water will freeze at 0.0˚ C, but adding dissolved particles in the water may lower the freezing point.

2. Why is the water temperature sometimes colder and sometimes warmer than the air temperature?

Water has a higher *specific heat* than air. This means it takes water longer to heat up and longer to cool down than it does air. As a result, air responds much more quickly than water to changes in temperature.



Source: Jan Smolik, 1996, TEREZA, Association for Environmental Education, Czech Republic

Water Temperature Protocol – Looking at the Data

Are the data reasonable?

Water temperature generally shows strong seasonal patterns. Graph the water temperature over time to create a picture of these patterns. Extreme outliers should be easy to recognize. An outlier is a measurement that has a value very different from the values of other data taken on days shortly before or after the extreme value. Also, graph the water temperature with the air temperature. Since water temperature generally changes more slowly than air temperature, there will be a delay (days to weeks) in changes of water temperature compared to air temperature. The range of water temperatures will also be narrower.

Can the water temperature be below zero? Many students believe they have found an error if the water temperature is a negative number. However, 0.0° C is the freezing point for distilled water. Water that has dissolved salts has a lower freezing point.

What do scientists look for in these data?

Water temperature is sometimes called a master variable because almost all properties of water, as well as chemical reactions taking place in it, are affected by it. Dissolved oxygen is strongly correlated with temperature. A graph of the water temperature and dissolved oxygen shows that oxygen solubility increases for colder temperatures.

Sudden increases or decreases of water temperature are unusual. Water has a higher heat capacity (specific heat) than air, thus it heats and cools more slowly. Unusual swings in water temperature of the expected seasonal patterns should be investigated. Identify the watershed for your site. Possible sources of sudden temperature changes might be due to release of water from upstream dams, factories, or snowmelt.

Example of a Student Research Project

Project 1

Forming a Hypothesis

Students in Czech Republic are examining plots of water temperature. They are plotting the average monthly water temperatures for several surface water sites in Czech Republic. They notice an interesting trend in the data for SWS-01, collected by Zakladni Skola Bystrice Nad Perstejnem. Site metadata indicates that this water body is the Bystrice River. According to their plot (Figure HY-TE-2), average monthly water temperature in the summer months (June, July, August) seems to be increasing each year from 1997 through 2001.

The students hypothesize that: *increases in water temperature are a result of increase in air temperature.*

Collecting and Analyzing Data

The students create a plot combining monthly mean air temperature and surface water temperature on the same plot (Figure HY-TE-3). Air temperature is clearly increasing in the summers over this same time period, except in July 2000, when air temperature and water temperature are *both* lower. Therefore, the students conclude the rising summer air temperature is responsible for the rising stream temperature. Their hypothesis is correct.

Note: In Figure HY-TE-3, the scale for the water temperature is on the left side of the graph, and the scale for the water temperature is on the right side of the graph. The scales are not the same. Downloading and plotting the data on the same scale – see Figure HY-TE-4, for an example – can also be useful, and allow you to more easily compare the actual values, and not just the trends.

Communicating Results

The students present this result to their class and use it as the starting point for a discussion. Next ask the question: Is this trend seen at all nearby sites?

Project 2

Forming a Hypothesis

The students who worked on the previous project are interested in continuing their research. They now want to know if the trends they observed for the surface water in the Bystrice River appears in other areas nearby. In other words, is this local occurrence or is it fairly widespread?

They hypothesize that: *other sites nearby should show the same increase in water temperature and air temperature.*

Collecting and Analyzing Data

They look at the surface water data for their country on the GLOBE server and see that the four schools with the most surface water data are: Zakladni Skola - Ekolog. Praktikum in Jicin; Zakladni Skola, Bystrice Nad Perstejnem in Bystrice; Zakladni Skola Banov in Banov; and Zakladni Skola, Postoloprty in Postoloprty.

They have already looked at the data for the Brystrice River. The other three surface water sites are the Cidlina River in Jicin, the Ordejov Reservoir in Banov, and the Ohre River in Postoloprty. (**Note:** To see the names and descriptions of some of the water bodies, it is useful to check the site information/metadata on the sites!)

First they make combined plots of the water temperature at all the schools and plot them. The three new sites are shown in Figures HY-TE-5 through Figure HY-TE-7.

At two of the schools, Zakladni Skola Banov and Zakladni Skola Jicin, the site number changed from SWS-01 School Location to a new site number with the proper name of the water body (Cidlini River and Ordejov Reservoir), which is why data from more than one surface water site is plotted.

The students do not see any apparent trends in summer stream temperature on the Cidlini River or the Ohre River). There appears to be a slight increase in summer air temperature at Banov, but it is not as large as the increase at Bystrice Nad Perstejnem. A water temperature change is not as obvious either. There are no water temperature data from summer 1999, so trends in water temperature across the five-year period are hard to judge.

The students conclude that the increase in air and water temperature that occurred at Bystrice Nad Perstejnem did not occur in at least two of the other three sites. They conclude that their hypothesis is not valid.

Communicating Results

The students combine the result of this project with the previous project and write a report for their class. They submit their report to the GLOBE site under *Student Investigations*.

Future Research Questions

What happens to water temperature at these for sites after 2001?

Do any other sites show increasing (or decreasing) trends in temperature?

How much can water temperature increase before dissolved oxygen levels begin to get dangerously low? Are any of these water bodies at risk?

Figure HY-TE-2

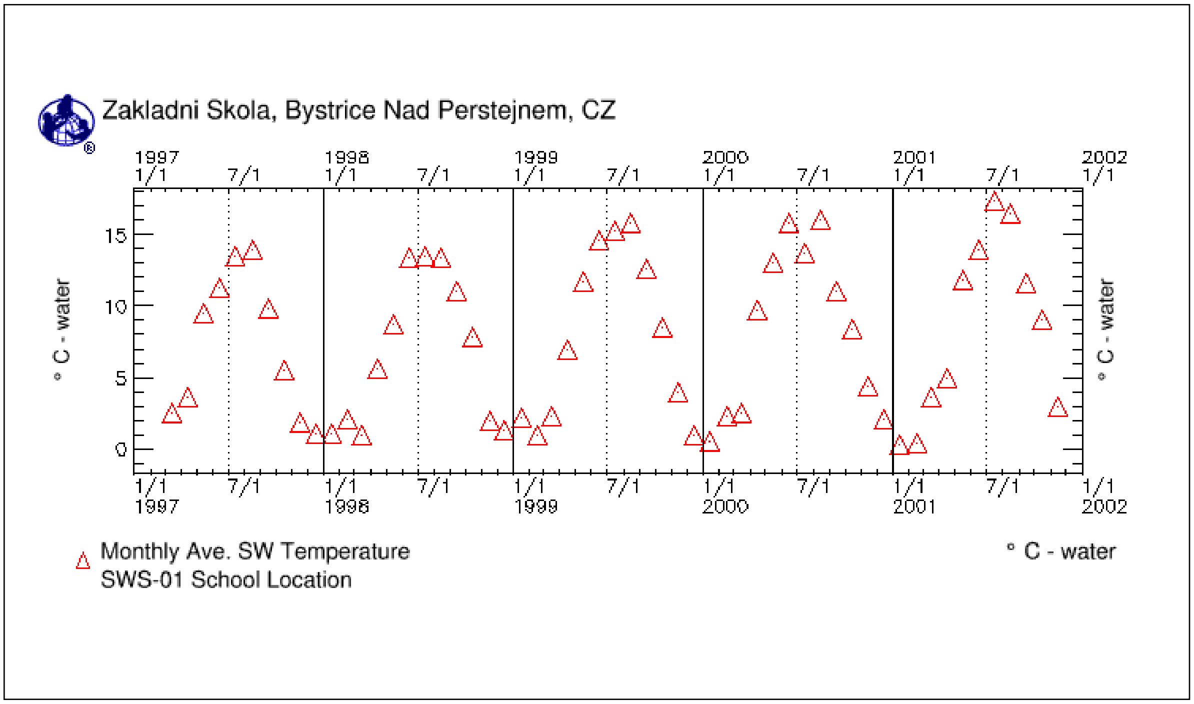


Figure HY-TE-3

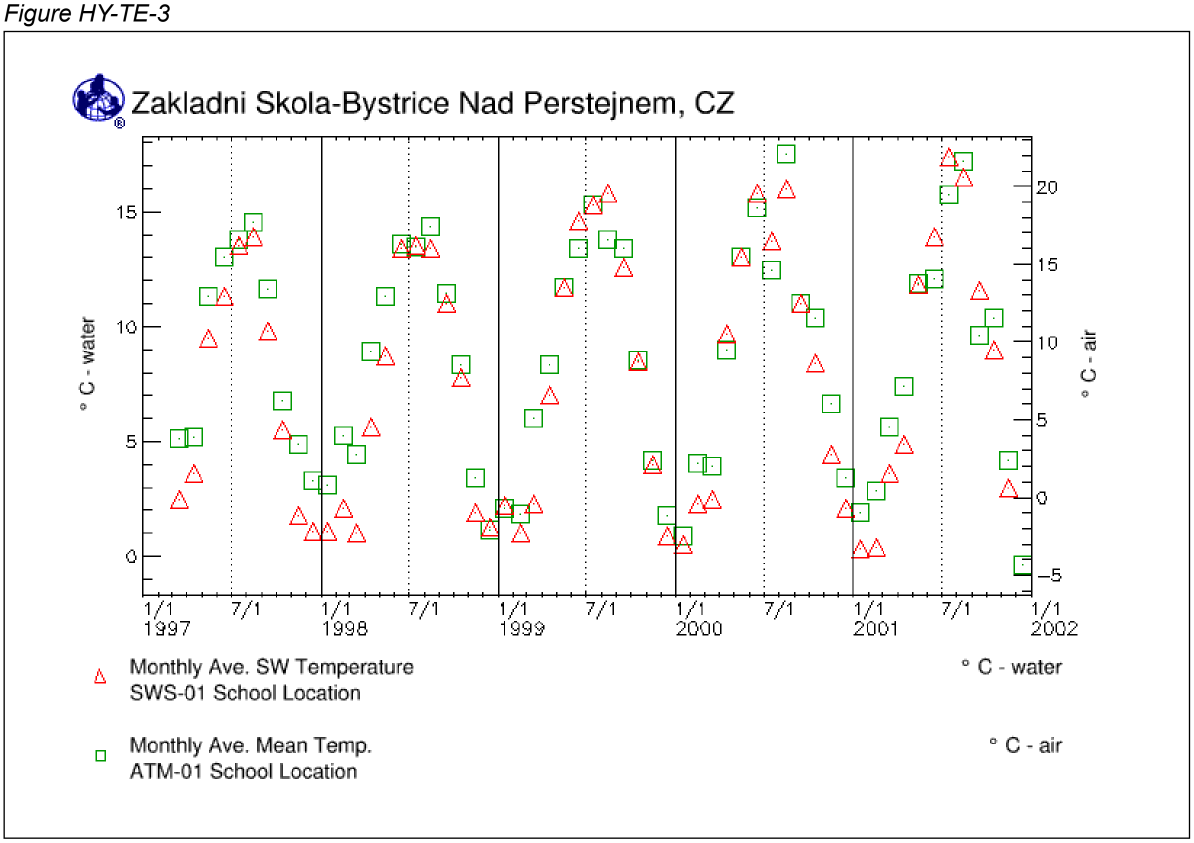


Figure HY-TE-4

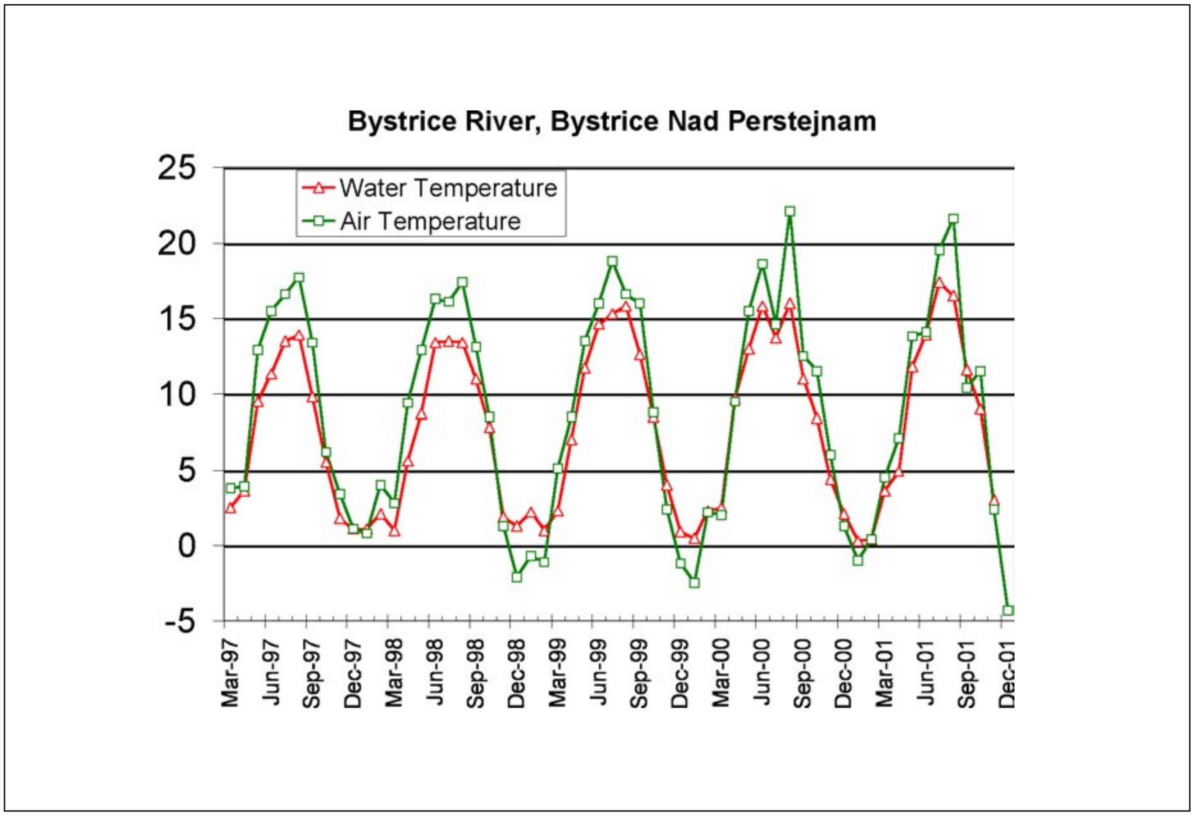


Figure HY-TE-5

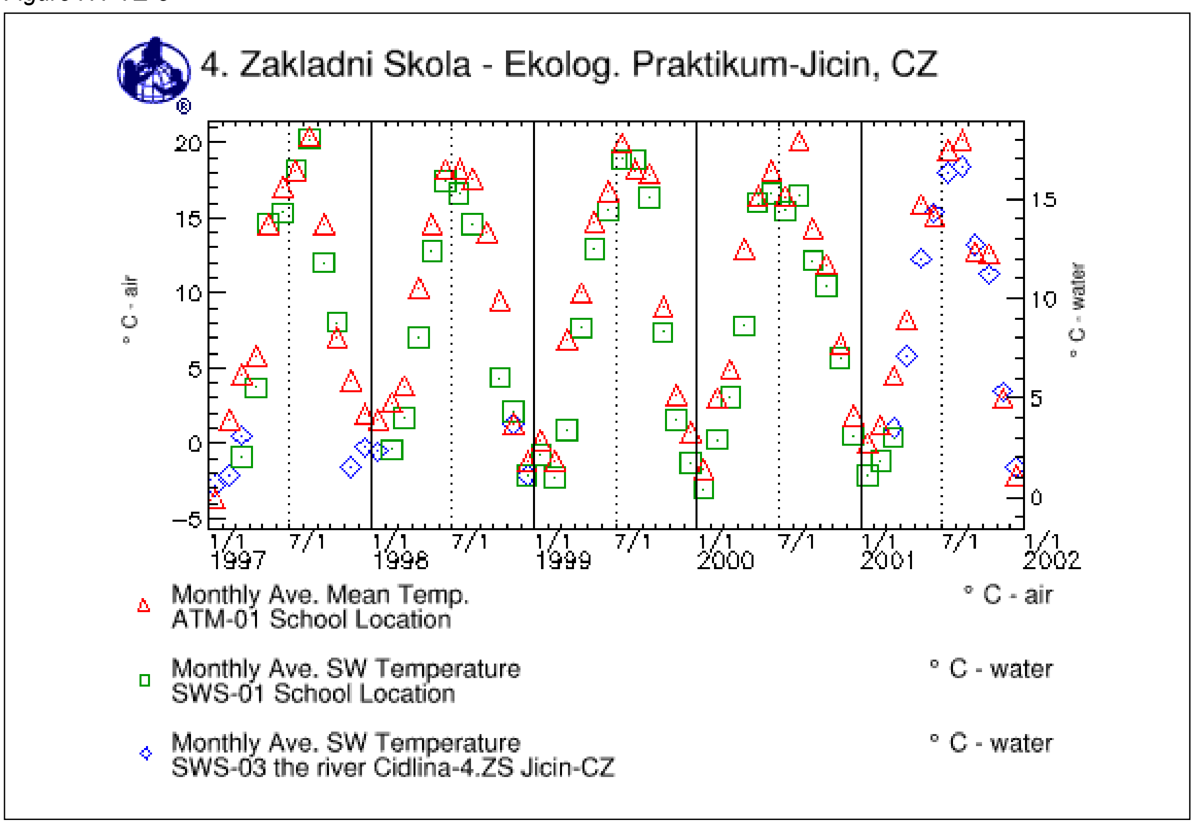


Figure HY-TE-6

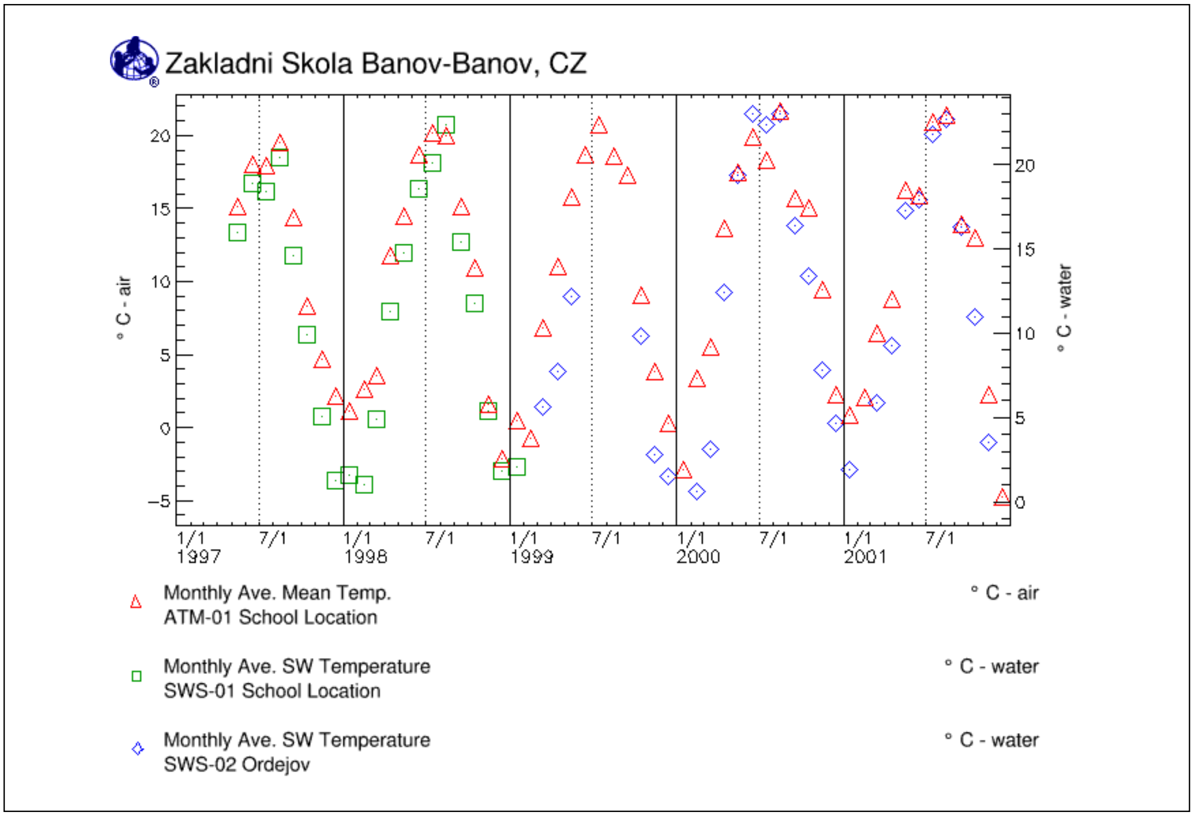


Figure HY-TE-7