# Current Temperature

### Purpose

To measure the current air temperature when an instrument shelter is not available.

### Overview

Current air temperature is measured using a thermometer held in the open air but in the shade for at least 3 minutes.

### Student Outcomes

*Science Concepts*

*Atmospheric Science*

- Weather can be described by quantitative measurements.
- Weather changes over different time and spatial scales.
- Weather changes over seasons.

*Physical Science*

- Properties can be measured by tools.

*Geography*

- Temperature variations affect the characteristics of Earth's physical geographic system.

*Scientific Inquiry Abilities*

Use a thermometer to measure temperature.

### Time

5 minutes

### Level

All

### Frequency

As needed in support of other GLOBE measurements

Calibration every three months

### Materials and Tools

- Alcohol-filled thermometer (calibration thermometer or sling psychrometer)
- A clock or watch
- Rubber band and a piece of string (if calibration thermometer is used)
- *Data sheets*

### Preparation

Find a shady spot for your air temperature measurement.

### Prerequisites

None

## Teacher Support

This method should be used only when an instrument shelter is not available and a current temperature measurement is required in support of another GLOBE measurement. Remember to define the appropriate site for your measurements (i.e., if other atmosphere measurements are taken this is would be an Atmosphere Study Site, if soil temperature measurements are taken, this is a Soil Temperature Study Site, etc.).

### Calibration and Quality Control

This measurement takes only a few minutes to complete. The main concern is to allow sufficient time for the thermometer to equilibrate to the temperature of the air, perhaps three to five minutes. In addition, the shady spot you use should not be adjacent to a building or other large structure, such as a tree. Try to maintain a distance at least 4 meters away from any such object, and take the measurement over a natural surface, such as vegetation, rather than concrete or paved walkways.

Your organic liquid-filled thermometer should be calibrated at least every three months as well as before its first use. Calibrate it following the instructions in the *Maximum, Minimum, and Current Temperatures Protocol*. The thermometers on your sling psychrometer should also be calibrated at least once every three months and before first use following the instructions in the *Relative Humidity Protocol*.

# Current Air Temperature Protocol

## Field Guide

### *Task*

To measure current air temperature in support of other GLOBE measurements

### *What You Need*

- ❑ String and rubber band and calibration thermometer OR Sling psychrometer
- ❑ *Integrated 1-Day Data Sheet*
- ❑ Clock or watch
- ❑ Pen or pencil

### *In the Field*

1. Tie one end of a piece of string securely to the end of the calibration thermometer and the other end to a rubber band.
2. Slip the rubber band around the wrist so that the thermometer is not broken if it is accidentally dropped on the ground.

   OR

   Use the dry bulb thermometer on your sling psychrometer.
3. Hold the thermometer at chest height, in the shade, and away from your body for three minutes.
4. At the end of three minutes, record the temperature reading in your science log
5. Hold the thermometer the same way for another minute.
6. At the end of the minute, record the temperature once again. If the temperature is within 0.5˚ C of the previous reading, record the reading on your *Data Sheet*.
7. If the two temperature readings differ by more than 0.5˚ C, repeat steps 5 and 6 again.
8. If two consecutive temperature readings are not within 0.5˚ C of one another after 7 minutes, record the last measurement on the Data Sheet and report your other four measurements in the comments section along with a note that your reading wasn't stable after 7 minutes.

# Maximum, Minimum, and Current Temperature Protocol

***Purpose***

To measure air (and optionally soil) temperature within one hour of solar noon and the maximum and minimum air temperatures for the previous 24 hours

***Overview***

Students read the current, maximum, and minimum temperatures from a thermometer and then reset the maximum and minimum indicators to start a new 24-hour measurement period.

***Student Outcomes***

Students will learn to read minimum, maximum, and current temperatures using a digital thermometer, understand diurnal and annual temperature variations, and recognize factors that influence atmospheric temperatures.

*Science Concepts*

*Earth and Space Science*

Weather can be described by quantitative measurements.
Weather changes from day to day and over the seasons.
Weather varies on local, regional, and global spatial scales.

*Geography*

The temperature variability of a location affects the characteristics of Earth's physical geographic system.

*Scientific Inquiry Abilities*

Use a thermometer to measure 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***

5 minutes

***Level***

All

***Frequency***

Daily within one hour of local solar noon

***Materials and Tools***

Instrument shelter
Installed maximum/minimum thermometer
Calibration thermometer
*Integrated 1-Day Data Sheet*

***Preparation***

Set up the instrument shelter.

Calibrate and install the maximum/minimum thermometer.

Review how to read the maximum/minimum thermometer.

***Prerequisites***

None

# Maximum, Minimum, and Current Temperature Protocol – Introduction

### *Temperature and Weather*

Have you noticed that the daily weather forecasts are not always correct? This is partly because scientists are still trying to learn more about how our atmosphere works. Measurements of air temperature, and particularly how air temperature changes as storms pass by, are important to help scientists better understand our atmosphere from day to day. This understanding will enable meteorologists to accurately predict the weather for the next day, or even for the next week.

Measurements of air temperature are also important in understanding precipitation. Whether precipitation falls as rain, sleet, snow, or freezing rain depends on the air temperature. Air temperature also affects the amount of moisture that will evaporate and the relative humidity of the atmosphere. Moisture evaporated from land and water bodies into the atmosphere helps to fuel storms and greatly affects our weather.

### *Temperature and Climate*

Is this an unusually warm year? Is Earth getting warmer as some scientists have predicted? Is the average temperature at your school changing because of local changes in land cover? To answer these and other questions about Earth's climate measurements are needed of daily maximum and minimum air and soil temperatures, month by month, year after year.

Generally, cities are warmer than the land areas surrounding them. As cities grow, temperatures may get warmer due to the expansion of paved areas and concrete buildings. An understanding of local variations in warming and cooling helps scientists to determine if there is a global change in average surface air temperature. Data from observations in many different environments, from the country to the inner city, are needed to study these changes in Earth's climate.

Scientists studying Earth's climate are looking for patterns of temperature change at different latitudes and longitudes. That is, are all places on Earth getting warmer or colder at the same rate? Computer models predict that if Earth's climate is changing due to the effect of greenhouse gases on air temperature, more warming will take place in the polar regions than in the tropics (although the polar regions will remain colder than the tropics). Models also predict that average nighttime temperatures will increase more than average daytime temperature and that an increase in temperatures will be more apparent in the winter than in the summer.

Evaluating model predictions of Earth's changing climate requires an enormous amount of data taken in many places on Earth over long periods of time. Measurements of daily atmosphere maximum and minimum temperature by GLOBE schools all over the world can help all of us improve our understanding of climate.

### *Temperature and Atmospheric Composition*

Many of the chemical reactions that take place between trace gases in the atmosphere are affected by temperature. In some cases such as several of the reactions involved in the formation of ozone, the rate of the reaction depends on temperature. The presence of water vapor, water droplets, and ice crystals also plays a role in the chemistry of the atmosphere.

To understand weather, climate, and atmospheric composition, measurements of surface and air temperature are required. GLOBE measurements of air temperature near the ground are particularly useful because these data are hard to obtain except by reading carefully placed thermometers.

# Teacher Support

## *Maximum/Minimum Thermometer*

The instrument available to take daily measurements of maximum and minimum temperature is a digital thermometer. The digital thermometer is also available with a soil probe that can be buried in the ground so that soil temperatures can also be measured. The use of this instrument is described in this protocol. There is also another type of max/min thermometer, called a digital multi-day max/min thermometer, which logs temperatures for six days, and is described in the *Digital Multi-Day Max/Min/Current Air and Soil Temperatures Protocol*.

The digital thermometer records and displays temperatures in 0.1˚ C increments. The sensor for reading air temperature is located inside the housing of the instrument. The thermometer is also available with an optional second sensor attached to a three meter long cord. This second sensor can be buried in the ground to measure soil temperature. If you are going to be taking both air and soil measurements it is important that you correctly label the sections of the display screen that apply to each sensor. This can be done by sticking two pieces of tape, labeled 'AIR' and SOIL', on the plastic casing of the thermometer to the right side of the display screen.

## *Instrument Maintenance*

The instrument shelter should be kept clean both inside and outside. Dust, debris, and spider webs should be removed from the inside of the shelter with a clean, dry cloth. The outside of the shelter may be lightly washed with water to remove debris, but try to avoid getting too much water inside the shelter. If the outside of the shelter becomes very dirty, it should be repainted white.

## *Thermometer Calibration*

It is important that you calibrate your digital thermometer using a calibration thermometer. This calibration is done by comparing readings from the two thermometers and calculating the offsets that account for the difference between the digital thermometer readings and the true temperature. When the instrument is first set up both the air and soil sensors are calibrated following the *Digital Single-Day Max/Min Thermometer Sensor Calibration Field Guide*. Then every six months a check is made to see if the soil sensor is operating acceptably by comparing the temperatures that it is reporting to temperatures measured with a soil probe thermometer following the *Digital Single-Day Max/Min Thermometer Soil Sensor Error Check Field Guide*. If the difference between the digital soil sensor readings and the soil probe thermometer readings is greater than 2˚ C in magnitude than the digital soil sensor is dug out and both the air and soil sensors are recalibrated. If the difference is 2˚ C or more, the soil probe can be left buried and just the air sensor recalibrated.

## *Questions for Further Investigation*

When does temperature change the most from day to day?

What are the latitudes and elevations of other GLOBE schools with atmosphere temperature data similar to yours?

How does vegetation in your area respond to changing temperature?

Is your local environment affected more by average temperature or temperature extremes?

## *Frequently Asked Questions*

**1. If we missed reading the maximum/ minimum thermometer for a day or more (over the weekend, holiday, vacation, etc.), can we still report the temperature for today?**

You can and should report the current temperature. You may not report the maximum and minimum temperatures as they are the maximum and minimum temperatures for more than one day. Reset the thermometer and tomorrow you can report the maximum, minimum, and current temperatures.

**2. What should we do if our maximum/ minimum thermometer does not agree with the calibration thermometer?**

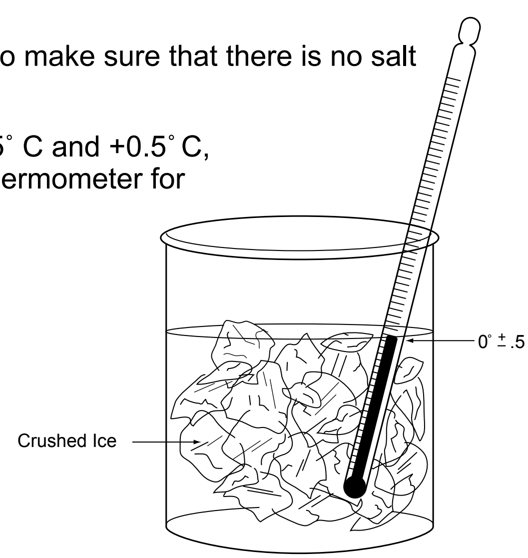
This is rare, but there are some maximum/ minimum thermometers that cannot be calibrated successfully. In this case, contact the supplier or manufacturer, explain that the calibration of the thermometer is off, and request a new thermometer.

# Thermometer Calibration
Lab Guide

### *Task*
Check the calibration of the calibration thermometer.

### *What You Need*
- ❑ Calibration thermometer
- ❑ Clean container at least 250 mL in volume
- ❑ Crushed ice
- ❑ Water (distilled is ideal, but the key is that the water is not salty)

### *In the Lab*
1. Prepare a mixture of fresh water and crushed ice with more ice than water in your container.
2. Put the calibration thermometer into the ice-water bath. The bulb of the thermometer must be in the water.
3. Allow the ice-water bath and thermometer to sit for 10 to 15 minutes.
4. Gently move the thermometer around in the ice-water bath so that it will be thoroughly cooled.
5. Read the thermometer. If it reads between -0.5˚ C and +0.5˚ C, the thermometer is fine.
6. If the thermometer reads greater than +0.5˚ C, check to make sure that there is more ice than water in your ice-water bath.
7. If the thermometer reads less than -0.5˚ C, check to make sure that there is no salt in your ice-water bath.
8. If the thermometer still does not read between -0.5˚ C and +0.5˚ C, replace the thermometer. If you have used this thermometer for measurements report this to GLOBE.



# Digital Single-Day Max/Min Thermometer Sensor Calibration

Field Guide

### *Task*

Calculate the air and soils sensor correction offset used to adjust for instrument accuracy errors.

### *What You Need*

❑ Calibration thermometer that has been checked following the instructions in the *Thermometer Calibration Lab Guide*

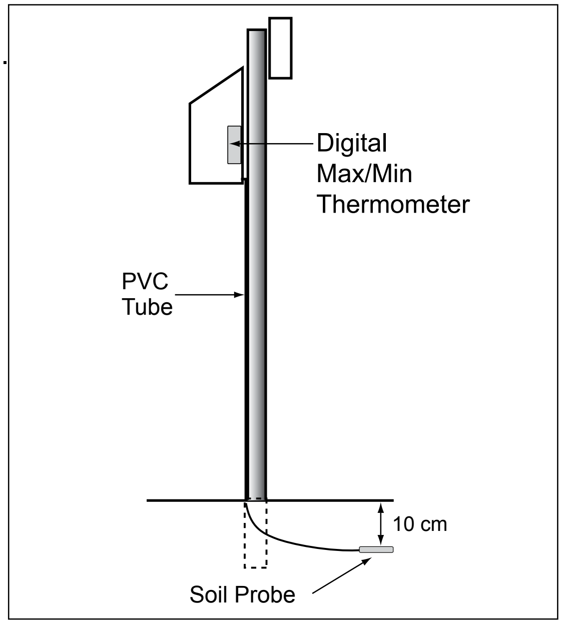
**Note:** If you plan on performing only air temperature measurements, or are only recalibrating the air sensor, skip the portions of this field guide that pertain to the soil sensor.

### *In the Field*

1. Open the door to the instrument shelter and hang the calibration thermometer, the digital thermometer, and the soil sensor in the instrument shelter so that they have air flow all around them and do not contact the sides of the shelter.
2. Close the door to the instrument shelter.
3. Wait at least an hour and then open the door to the instrument shelter. Make sure that your digital thermometer is displaying the current temperature(s) (Neither 'MAX' or 'MIN' symbols should be displayed on the screen. If they are, press the MAX/MIN button until they disappear).
4. Read the temperatures reported by the air sensor and the soil sensor of the digital thermometer and record them on a sheet of paper.
5. Close the door of the instrument shelter.
6. Repeat steps 2 to 5 four more times, waiting at least one hour between each set of readings. Try to space out the five sets of readings over as much of a day as possible.

# Digital Max/Min Thermometer Installation

Field Guide




### *Task*

Install the digital thermometer at your Atmosphere Study Site.

### *What You Need*

- ❑ GLOBE instrument shelter (specifications are given in the *GLOBE Instrument List* in the *Toolkit* section)
- ❑ Drill with 12 mm spade bit (if doing soil measurements)
- ❑ String or wire ties
- ❑ 120 cm X 2.5 cm PVC pipe (optional)
- ❑ Digging tools (if doing soil measurements)

### *In the Field*

1. Mount the digital thermometer housing to the rear wall of your instrument shelter. The housing should be placed so that the digital display may be easily read.
2. If you are not going to be taking soil temperature measurements, store the soil sensor (if your thermometer has one) and it's cable neatly in a corner of the shelter where it will be out of the way and skip the following steps. Otherwise, proceed to step 3.
3. If necessary, drill a 12 mm hole, using a drill with a spade bit, in the bottom of the instrument shelter, near the back. Feed the soil sensor probe through the hole, leaving as much cable as possible inside the shelter. You may wish to feed the sensor and wire through a thin PVC pipe that will serve to protect the wire.
4. Choose a site to place the soil temperature probe nearby on the equatorward side (sunny-side) of the mounting post for the instrument shelter. Data collected from soil in unshaded locations are preferred. Comments in your site definition should include the amount of shade that the soil surface above the probe will experience during a year.
5. Dig a hole to a depth of a little over 10 cm in depth at the chosen location.
6. Push the probe horizontally into the side of the hole at a depth of 10 cm. Use a nail or steel pin, with a slightly smaller diameter than the probe, to pilot an opening for the probe if needed.
7. Refill the hole with the soil that you removed.
8. Neatly secure all extra cable for the soil sensor using string or wire ties. Keep as much of the excess cable as possible within the shelter.

# Digital Single-Day Maximum and Minimum Temperature Protocol

Field Guide

### *Task*

Measure the current, maximum, and minimum air temperatures from the digital single-day thermometer.

Measure the current, maximum, and minimum soil temperatures from the digital single-day thermometer (optional).

Reset the digital thermometer to start the next 24-hour measurement.

### *What You Need*

- ❑ A properly sited instrument shelter
- ❑ A properly calibrated and installed digital single-day max/min thermometer
- ❑ An accurate watch or other device that tells time
- ❑ An appropriate *Data Sheet*
- ❑ Pen or pencil

**Note:** Make sure that the digital thermometer is reading in Celsius units. If it is not, press the ˚C/˚F button to switch to Celsius units.

### *In the Field*

1. Within an hour of local solar noon, open the instrument shelter being careful not to breathe on the thermometer.
2. Record the time and date on your Data Sheet in both local and UT time. Note: GLOBE Website entry should be UT time.
3. Make sure that your thermometer is displaying the current temperature(s) (Neither 'MAX' or 'MIN' symbols should be displayed on the screen. If they are, press the *MAX/MIN* button until they disappear).
4. Record the current air temperature on your *Data Sheet*. If you are taking soil readings, also record the soil temperature.
5. Press the *MAX/MIN* button once.
6. Maximum temperature reading(s) will now be displayed along with the 'MAX' symbol on the display screen.
7. Record the maximum air temperature on your *Data Sheet*. If you are taking soil readings, also record the maximum soil temperature.
8. Press the *MAX/MIN* button a second time.
9. Minimum temperature reading(s) will now be displayed along with the 'MIN' symbol on the display screen.
10. Record the minimum air temperature on your data sheet. If you are taking soil readings, also record the minimum soil temperature.
11. Press and hold the *MAX/MIN* button for one second. This will reset your thermometer.
12. Close the instrument shelter.

# Digital Single-Day Max/Min Thermometer Soil Sensor Error Check

Field Guide

### Task

Check the accuracy of the soil sensor to see whether or not it needs to be dug out and recalibrated.

### What You Need

❑ Soil probe thermometer from *Soil Temperature Protocol*.

### In the Field

1. Calibrate a soil probe thermometer following the *Calibrating the Soil Thermometer Lab Guide* of the *Soil Temperature Protocol*.
2. Open the door to the instrument shelter.
3. Select a place about 15 cm from the location of the soil temperature probe.
4. Measure the soil temperature at a depth of 10 cm at this spot following the *Soil Temperature Protocol*.
5. Record this temperature on a sheet of paper
6. Make sure that your digital thermometer is displaying the current temperature(s) (Neither 'MAX' or 'MIN' symbols should be displayed on the screen. If they are, press the *MAX/MIN* button until they disappear).
7. Read the temperature reported by the soil sensor of the digital thermometer and record it on a sheet of paper.
8. Close the door of the instrument shelter.
9. Repeat steps 2 to 8 four more times, waiting one hour between measurements.
10. Calculate the average of the soil thermometer readings.
11. Calculate the average of the digital soil sensor readings.
12. Calculate the soil sensor error by subtracting the average of the five digital soil sensor readings (from step 10) from the average of the five soil sensor readings (from step 11)
13. If the absolute value of the soil sensor error is greater than or equal to two 2˚ C, then dig-out this sensor and recalibrate both the air and soil sensors following the *Digital Single-Day Max/Min Thermometer Sensor Calibration*. Otherwise leave the digital soil sensor in the ground and recalibrate only the air sensor.

# Maximum, Minimum, and Current Air Temperature – Looking At the Data

### *Are the data reasonable?*

Air temperature varies throughout a 24-hour period. In some places there may be large daily changes in temperature, while in others this variation may be quite small. Figure AT-MM-2 shows a graph of air temperature over the course of a day with measurements taken every 15 minutes. You can see on this graph the current ($T_{current}$), maximum ($T_{max}$), and minimum ($T_{min}$) temperatures for this day.

By definition $T_{max}$ must be the highest temperature for this time period and $T_{min}$ must be the lowest.

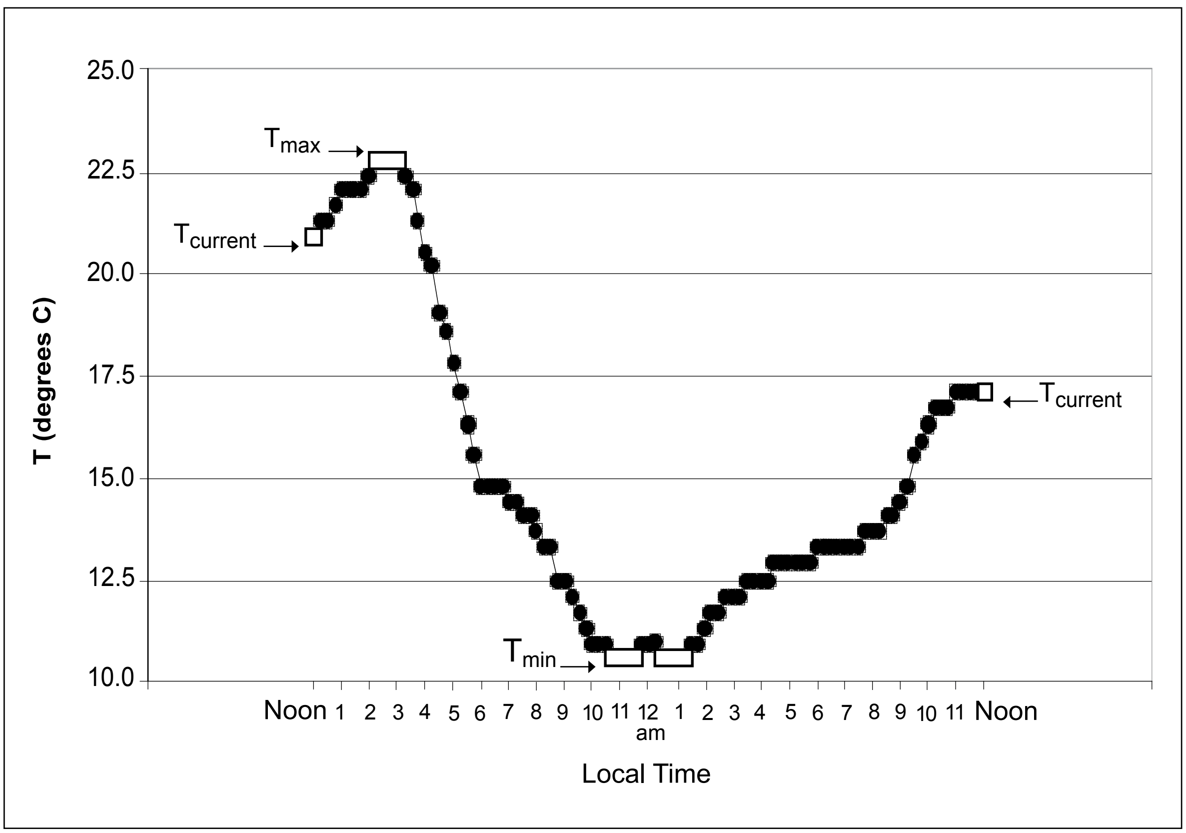
Therefore,

$$T_{max} \geq T_{current} \quad \text{and} \quad T_{min} \leq T_{current}$$

for $T_{current}$ at both the beginning and the end of the 24-hour period. If these inequalities are not true, then something is wrong with the $T_{max}$ or the $T_{min}$ for this day.

Looking at a graph of these data, such as Figure AT-MM-3, makes it easy to check them visually.

*Figure AT-MM-2: Temperature Variation Over a 24-hour Period*



Another check on the reasonableness of data from a single day is to compare them with data from near-by GLOBE schools or other sources of temperature data. Figure AT-MM-4 shows the data from a single day for 12 schools that are reasonably close to one another. Table AT-MM-1 gives the air temperature data for the schools shown in this figure. All the schools shown are in reasonable agreement.

### *What do people look for in these data?*

In climate studies, scientists are interested in the average temperature over various time periods and in the extreme values. On most days, air temperature varies with the diurnal (daily) cycle of sunlight, and this variation is often larger than the change from day to day.

In many places, air temperature varies significantly as weather systems move across the region in a succession of cold fronts and warm fronts. The exact timing of these weather systems varies from year to year so comparing temperatures from the same day in different years is not a good indication of climate variation. To really be able to compare year-to-year changes, you must average over multiple weather systems. A month is long enough to average out the effects of individual storms, but not so long that seasonal variations are averaged out.

The average temperature for a day can be estimated by averaging the maximum and minimum temperatures for that day. Research has shown that this estimate is generally within 0.1˚ C of the actual average value. For the school we are considering on April 15, 1998:

The monthly average temperature can also be calculated by averaging the maximum and minimum temperatures for every day in the

$T_{max} = 10.0^\circ C$

$T_{min} = 2.0^\circ C$

$$T_{average} = \frac{T_{max} + T_{min}}{2} = \frac{10.0^\circ C + 2.0^\circ C}{2} = 6.0^\circ C$$

*Table AT-MM-1: Data for the Schools Shown in Figure AT-MM-4 for April 15, 1998*

| MxTmp | MnTmp | CrTmp | Hour | Lat | Lon | Elev | Location of School |
|---|---|---|---|---|---|---|---|
| 14.0 | 0.0 | 12.0 | 11 | 50.0477 | 14.4393 | 272 | Praha 4, CZ |
| 13.0 | -1.0 | 12.0 | 12 | 49.7667 | 16.9167 | 273 | Mohelnice, CZ |
| 12.0 | -1.0 | 8.0 | 10 | 50.1328 | 14.4035 | 322 | Praha 8, CZ |
| 12.0 | 3.0 | 12.0 | 11 | 50.0630 | 14.4340 | 272 | Praha 4, CZ |
| 11.2 | 0.9 | 11.0 | 9 | 50.4387 | 15.3523 | 868 | Jicin,CZ |
| 11.0 | -4.0 | 10.0 | 11 | 48.9737 | 14.5027 | 395 | Ceske Budejovice, CZ |
| 11.0 | 2.0 | 9.0 | 10 | 49.9078 | 16.4218 | 460 | Ceska Trebova, CZ |
| 10.5 | -1.2 | 10.2 | 11 | 49.9042 | 16.4432 | 350 | Ceska Trebova, CZ |
| 10.0 | 2.0 | 9.0 | 11 | 49.5420 | 15.3537 | 518 | Humpolec, CZ |
| 10.0 | 5.0 | 8.0 | 12 | 49.2080 | 16.6833 | 265 | BRNO, CZ |
| 10.0 | 0.0 | 8.0 | 11 | 49.5190 | 16.2600 | 570 | Bystrice Nad Perstejnem, CZ |
| 9.0 | -2.0 | 9.0 | 11 | 49.3167 | 16.3417 | 485 | Deblin, CZ |

*Figure AT-MM-3: Air Temperature Data for One Month from a GLOBE School*

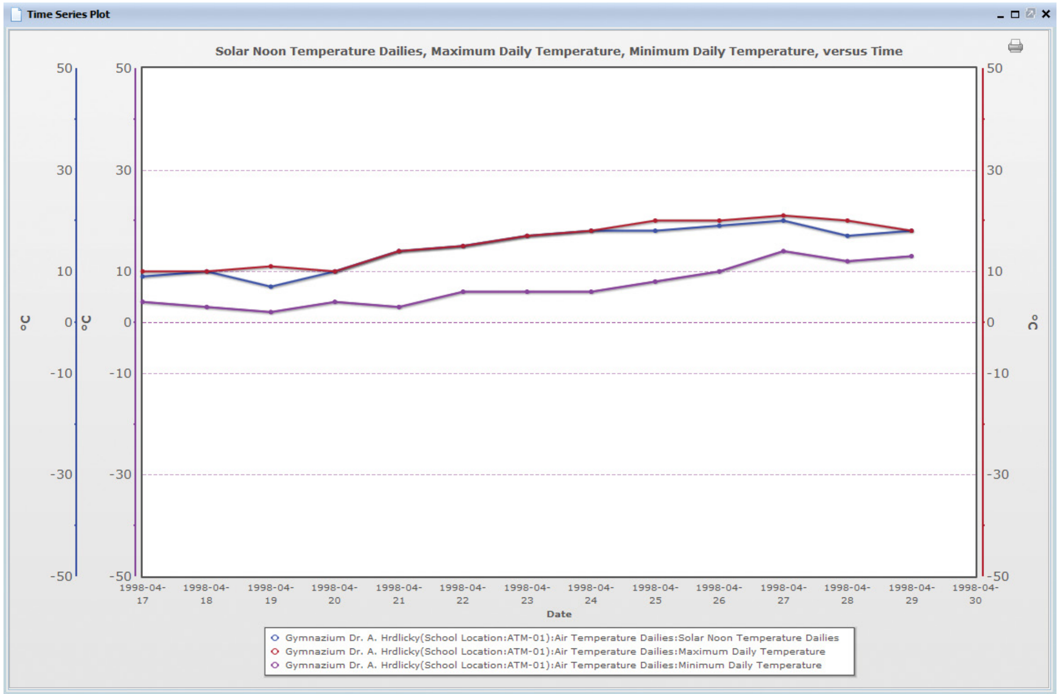
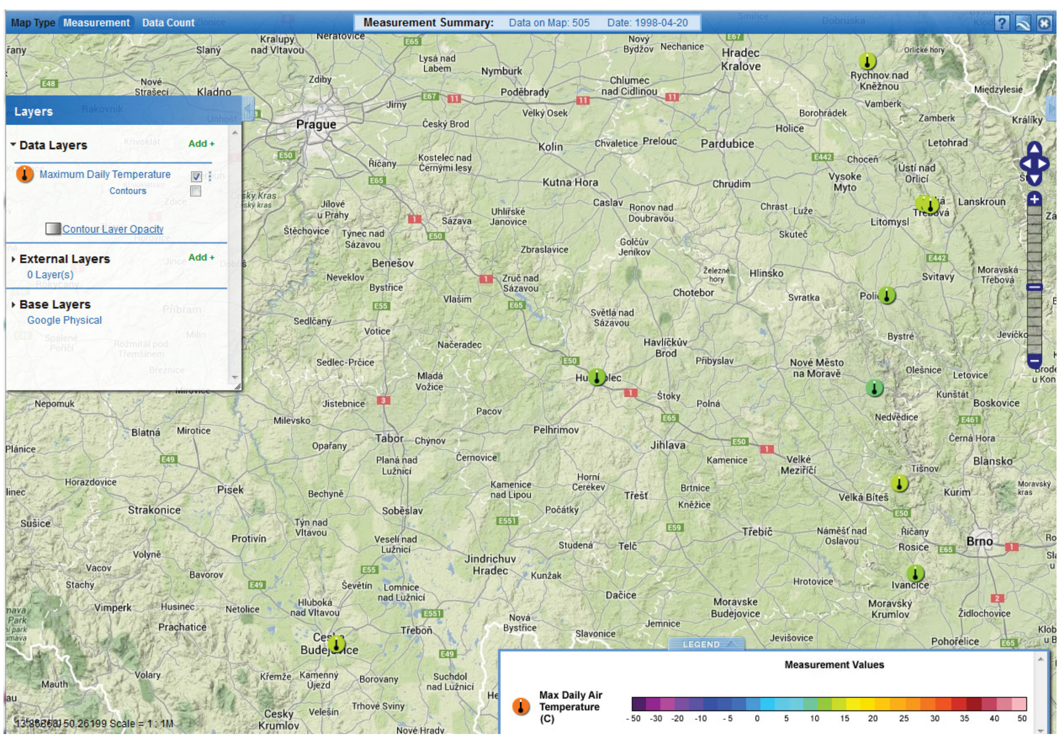



*Figure AT-MM-4: GLOBE School Data for Maximum Temperature for a Single Day*



month. From the values in Table AT-MM-2, for Gymnazium Dr. A. Hrdlicky the monthly average air temperature for April 1998 is:

$T_{average}$ (April 1998) = 10.4˚ C.

Most living things are sensitive to the extremes in temperature. This is particularly true when temperatures go below the freezing point of water (0.0˚ C). Looking at the minimum temperature curve in Figure AT-MM-3, it is easy to see that the temperature for this whole month never dipped below freezing. The lowest temperature measured was 1˚ C. The maximum temperature for the month was 21˚ C.

As student researchers, you should consider comparing temperatures, average temperatures, and temperature extremes between different schools or locations. You can compare monthly average temperatures from one year to another and look at the pattern of monthly average temperatures over the year. It is also interesting to look for the first and last days of the cold season when the minimum temperature is below freezing. A number of other sections in this Guide describe useful correlations of air temperature with other phenomena.

In comparing schools, remember that the atmosphere gets colder as elevation increases. Also, most large cities are warmer than the surrounding country side. This is called the urban heat island effect. Praha (Prague) is a large city. From the data in Table AT-MM-1 it is clear that the schools in Praha are at lower elevations as well as being in a city, and on this day they have the warmest maximum temperatures.

## *An Example of a Student Research Investigation*

### *Forming a Hypothesis*

A student at a school in Humpolec, CZ looks at the visualizations of maximum temperature for several days in April 1998. She notices that the values for the schools in Praha are warmer than those for her school for a number of days. She asks if this could be true on average. As a simple starting point for her research she hypothesizes that: *Monthly average temperatures in Praha are warmer than in Humpolec.*

*Table AT-MM-2: Temperature Data for April 1998*

| Date | Temperatures | | |
|---|---|---|---|
| (yyyymmdd) | Current | Maximum | Minimum |
| 19980430 | 15.0 | 18.0 | 11.0 |
| 19980429 | 18.0 | 18.0 | 13.0 |
| 19980428 | 17.0 | 20.0 | 12.0 |
| 19980427 | 20.0 | 21.0 | 14.0 |
| 19980426 | 19.0 | 20.0 | 10.0 |
| 19980425 | 18.0 | 20.0 | 8.0 |
| 19980424 | 18.0 | 18.0 | 6.0 |
| 19980423 | 17.0 | 17.0 | 6.0 |
| 19980422 | 15.0 | 15.0 | 6.0 |
| 19980421 | 14.0 | 14.0 | 3.0 |
| 19980420 | 10.0 | 10.0 | 4.0 |
| 19980419 | 7.0 | 11.0 | 2.0 |
| 19980418 | 10.0 | 10.0 | 3.0 |
| 19980417 | 9.0 | 10.0 | 4.0 |
| 19980416 | 8.0 | 9.0 | 6.0 |
| 19980415 | 9.0 | 10.0 | 2.0 |
| 19980414 | 8.0 | 10.0 | 1.0 |
| 19980413 | 10.0 | 11.0 | 5.0 |
| 19980412 | 11.0 | 13.0 | 5.0 |
| 19980411 | 12.0 | 12.0 | 6.0 |
| 19980410 | 11.0 | 13.0 | 5.0 |
| 19980409 | 13.0 | 13.0 | 3.0 |
| 19980408 | 10.0 | 13.0 | 6.0 |
| 19980407 | 13.0 | 13.0 | 2.0 |
| 19980406 | 11.0 | 16.0 | 6.0 |
| 19980405 | 16.0 | 18.0 | 6.0 |
| 19980404 | 17.0 | 17.0 | 5.0 |
| 19980403 | 14.0 | 15.0 | 6.0 |
| 19980402 | 13.0 | 20.0 | 10.0 |
| 19980401 | 18.0 | 18.0 | 6.0 |
| Total | | 443.0 | 182.0 |

*From Gymnasium Dr. A. Hrdlicky*

### *Collecting Data*

Data have been collected by GLOBE schools in Praha for April 1998, so she decides to test her hypothesis using this month as her sample. She starts by identifying the GLOBE schools in Praha which have reported data for this time period. She finds five schools. Then she graphs the maximum, minimum, and current temperatures from each school and looks at the graphs to be sure that the data are of good quality. She decides that they are good enough for her project as she will be combining the data from all five schools.

*Analyzing Data*

As a first step in getting the data from these schools, she generates a plot of the maximum temperature data for April 1998 from her school and the schools in Praha. She then creates a data table with all the values for this graph. She saves this information either by printing the table from the computer, cutting and pasting the table into a spreadsheet, or copying down the values by hand. She does the same thing for the minimum temperatures. Now she calculates the average of all the maximum and minimum temperatures reported by the schools in Praha for this month. She gets a value of 12.6˚ C. Since this is greater than the value for her school of 10.4˚ C, her hypothesis is supported.

She wonders if averaging all the temperatures is correct, since on some days all five Praha schools provided data but on other days only one school reported. She decides to calculate the monthly average for each individual school and then average these five values. Her results for the five schools are 11.6˚ C, 12.1˚ C, 12.5˚ C, 13.0˚ C, and 14.4˚ C and the average of these values is 12.7˚ C which is in good agreement with the original average she calculated for Praha of 12.6˚ C.

She then proceeds to write-up her hypothesis, her procedure, and her conclusions and includes calculations she has done and graphs she has used or made. As a final note, she discusses additional tests of her hypothesis that she would like to investigate in the future including doing the comparison for April of another year or even doing the comparison for all months of the year 1998.

*Further Data Analysis*

If the student doing this project has been taught about square roots and some elementary statistics, she could go a bit further and examine the statistical errors in her calculations of monthly average temperatures. All of the schools involved in this example reported temperature to the nearest degree Celsius instead of to the nearest 0.5˚ C. How can she tell? Well she notices that all of the values reported have 0 in the tenths place. If readings were taken to the nearest half degree, there should be some values with 5 in the tenths place. So, given the accuracy of GLOBE instruments and the readings by the students, the error in the individual measurements is ± 1.0˚ C. The error in the average depends on the number of independent measurements included, so for each school the statistical error in the average is:

if N = number of measurements

$$\text{Error} = \pm\ 1^\circ \text{ C} * \frac{\sqrt{N}}{N}$$

$$\text{Error} = \pm\ 1^\circ \text{ C} * \frac{1}{\sqrt{N}}$$

For the schools with data for 22 or fewer days (and therefore 2 x 22 = 44 or fewer measurements), the error is approximately ± 0.2˚ C while for schools with more measurements the error is about ± 0.1˚ C. Given these statistical errors, the student concludes that the differences among the schools' monthly averages are larger than the errors and therefore statistically significant. This is true even among the schools in Praha. This strengthens her confidence that the hypothesis has been supported by the data because the monthly average temperature in Humpolec in April 1998 is lower than for any of the schools in Praha as well as being lower than the average of all data from Praha.

*Advanced Data Analysis*

A more advanced student would not calculate the statistical error using all the measurements from the five schools taken together because these data are not independent of one another. On a given day in Praha, the data from the five schools should be correlated because they are experiencing approximately the same weather. Realizing this, an advanced student decides to make two more checks on her conclusion.

First, she decides to calculate the average temperature for each day of April in Praha. For each day she sums the maximum and minimum temperatures from all schools which have data for that day and divides by the number of measurements reported. The results of this are given in the right-hand column of Table AT-MM-3. This process gives her average temperatures for 28 days in April and she averages these to get the monthly average temperature for Praha. The result is 11.9˚ C with a statistical error of ± 0.1˚ C, and

*Table AT-MM-3: Maximum and Minimum Temperature Data for Five Schools in Praha for April 1998*

| School: | Zakladni Skola, n.Inter. | | Masarykova stredni skola chemicka | | Zakladni Skola | | Zakladni Skola Horackova | | Gymnazium | | Daily |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | $T_{max}$ °C | $T_{min}$ °C | $T_{max}$ °C | $T_{min}$ °C | $T_{max}$ °C | $T_{min}$ °C | $T_{max}$ °C | $T_{min}$ °C | $T_{max}$ °C | $T_{min}$ °C | $T_{avg}$ °C |
| 4/1/1998 | 21 | 5 | 22 | 8 | 20 | 12 | — | — | — | — | 14.7 |
| 4/2/1998 | 17 | 12 | 20 | 11 | 19 | 9 | — | — | — | — | 14.7 |
| 4/3/1998 | 17 | 9 | 20 | 10 | 18 | 9 | — | — | — | — | 13.8 |
| 4/4/1998 | 19 | 11 | — | — | 18 | 7 | — | — | — | — | 13.8 |
| 4/5/1998 | 14 | 5 | — | — | 15 | 8 | — | — | — | — | 10.5 |
| 4/6/1998 | 14 | 4 | — | — | 18 | 8 | — | — | — | — | 11.0 |
| 4/7/1998 | 15 | 3 | 18 | 8 | 19 | 8 | — | — | 26 | 5 | 12.8 |
| 4/8/1998 | 14 | 4 | — | — | 17 | 9 | — | — | — | — | 11.0 |
| 4/9/1998 | 16 | -1 | — | — | 16 | 8 | — | — | — | — | 9.8 |
| 4/10/1998 | 14 | 2 | — | — | 10 | 8 | — | — | — | — | 8.5 |
| 4/11/1998 | 14 | 2 | — | — | 14 | 7 | — | — | — | — | 9.3 |
| 4/12/1998 | 14 | 2 | — | — | 15 | 1 | — | — | — | — | 8.0 |
| 4/13/1998 | — | — | — | — | 15 | 4 | — | — | — | — | 9.5 |
| 4/14/1998 | — | — | — | — | 15 | -8 | — | — | — | — | 3.5 |
| 4/15/1998 | — | — | — | — | 12 | -1 | 14 | 0 | 12 | 3 | 6.7 |
| 4/16/1998 | — | — | 15 | 4 | 13 | 5 | 14 | 3 | 14 | 5 | 9.1 |
| 4/17/1998 | — | — | 15 | 5 | 17 | 7 | 13 | 1 | 14 | 2 | 9.3 |
| 4/18/1998 | — | — | — | — | — | — | 15 | 4 | — | — | 9.5 |
| 4/19/1998 | — | — | — | — | — | — | — | — | — | — | |
| 4/20/1998 | — | — | — | — | — | — | — | — | — | — | |
| 4/21/1998 | 17 | 8 | 21 | 5 | — | — | 16 | 4 | 16 | 2 | 11.1 |
| 4/22/1998 | 16 | 4 | 16 | 6 | — | — | 16 | 5 | 17 | 3 | 10.4 |
| 4/23/1998 | 17 | 4 | 21 | 9 | — | — | 20 | 5 | 21 | 3 | 12.5 |
| 4/24/1998 | 18 | 8 | 23 | 9 | — | — | — | — | 25 | 4 | 14.5 |
| 4/25/1998 | 20 | 7 | — | — | 19 | 8 | — | — | — | — | 13.5 |
| 4/26/1998 | 24 | 10 | — | — | 24 | 11 | — | — | — | — | 17.3 |
| 4/27/1998 | 24 | 10 | — | — | 25 | 12 | — | — | 26 | 10 | 17.8 |
| 4/28/1998 | 24 | 10 | 24 | 12 | 25 | 13 | 23 | 12 | 25 | 13 | 18.1 |
| 4/29/1998 | 25 | 9 | 22 | 15 | 20 | 13 | 22 | 12 | 21 | 12 | 17.1 |
| 4/30/1998 | 22 | 8 | 22 | 13 | 23 | 10 | 20 | 12 | 23 | 9 | 16.2 |
| Total | 396 | 136 | 259 | 115 | 407 | 168 | 173 | 58 | 240 | 71 | 333.7 |
| Number of days | 22 | 22 | 13 | 13 | 23 | 23 | 10 | 10 | 12 | 12 | 28 |
| Average Max or Min | 18.0 | 6.2 | 19.9 | 8.8 | 17.7 | 7.3 | 17.3 | 5.8 | 20.0 | 5.9 | |
| Monthly $T_{avg}$ °C | 12.1 | | 14.4 | | 12.5 | | 11.6 | | 13.0 | | 11.9 |
| Statistical error (°C) | 0.2 | | 0.3 | | 0.2 | | 0.3 | | 0.3 | | 0.2 |

this value is significantly lower than the other results. However, this monthly average is still significantly higher than that for Humpolec and the hypothesis is still confirmed.

Second, she notices that for two days, April 19 and 20, there is no data from any of the Praha schools. Were these abnormally cold or warm days which might bias the monthly average? Generally, Humpolec is close enough to Praha so that they experience similar periods of cold or warm weather as weather systems move through the Czech Republic. The student looks at the data from her school for these two days to get an indication of whether these were unusual days relative to the monthly average for April. The average temperatures for these two days were 7.0˚ C and 6.5˚ C, respectively. Both were significantly colder than the monthly average. Missing data for these two days could bias the monthly average for Praha, but by how much? To estimate this, the student decides to calculate the monthly average for Humpolec omitting these two days. The monthly average which one would obtain if data were missing for these two days is 10.7˚ C, 0.3˚ C higher than the actual average calculated. This is a significant effect, but it is not large enough to change the conclusion that average monthly temperature in Praha is higher than in Humpolec for the month of April 1998.

*Explaining and Communicating Results*

Knowing that average temperatures in Praha are higher than in Humpolec does not explain why this is the case. Pursuing this question is more challenging, but should be more rewarding. Two common effects could explain the systematic temperature differences observed – urban heat island effects and differences in elevation. A student might hypothesize that the warmer conditions in Praha compared to Humpolec are due to the difference in elevation. To test this hypothesis, the student would need to assemble data from schools in the Czech Republic at different elevations. For instance, Mohelnice and Jicin are both relatively small towns with Mohelnice at about the same elevation as Praha and Jicin at an elevation 350 meters higher than Humpolec. See Table AT-MM-2. If average temperatures in Mohelnice are about the same as those in Praha while the variation in average temperatures between Mohelnice, Humpolec, and Jincin are proportional to altitude, the hypothesis would be supported. Differences in latitude also affect average temperature. With an increase of 2˚ to 2.5˚ of latitude roughly equivalent to a 150 meter increase in elevation, the latitude effects should be significantly smaller than the elevation effects for these cities. Addressing questions such as this one is easier where there are many GLOBE schools consistently reporting data.