Surface Temperature Protocol

Purpose

To measure surface temperature.

Overview

Surface temperature is measured with a hand-held Infrared Thermometer (IRT) that, when necessary, is wrapped in a thermal glove or has been placed outdoors for at least 30 minutes prior to data collection. The instrument is pointed at the ground to take surface temperature readings. *Cloud Protocols* are performed along with the *Surface Temperature Protocol*.

Student Outcomes

Students will learn to use an infrared thermometer, and understand how different surfaces radiate energy.

Science Concepts

Earth and Space Sciences

Clouds affect weather and climate.

The diurnal and seasonal motion of the sun across the sky can be observed and described.

Materials from human societies affect the chemical cycles of Earth.

The Sun is a major source of energy for Earth surface processes.

The Sun is a major source of energy at Earth's surface.

Solar isolation drives atmospheric and ocean circulation.

Physical Sciences

Heat transfer occurs by radiation, conduction, and convection.

Light radiation interacts with matter.

The sun is a major source of energy on the Earth's surface.

Energy is transferred in many ways.

Heat moves from warmer to colder objects.

Light/ radiation interacts with matter.

The Sun is a major source of energy for changes on Earth's surface.

Energy is conserved.

Life Sciences

Sunlight is the major source of energy for ecosystems.

Energy for life derives mainly from the Sun.

General Science

Visual models help us to analyze and interpret data.

Geography

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

The nature and extent of cloud cover affects the characteristics of Earth's physical geographic system.

The nature and extent of precipitation affects the characteristics of Earth's physical geographic system.

Human activities can modify the physical environment.

Scientific Inquiry Abilities

Inquiry skills

Students will learn to use an infrared thermometer.

Use appropriate tools and techniques.

Identify answerable questions.

Design and conduct scientific investigations.

Use appropriate mathematics to analyze data.

Develop descriptions and predictions using evidence.

Recognize and analyze alternative explanations.

Communicate procedures, descriptions, and predictions.

Use a thermometer to measure temperature.

Use a cloud chart to identify cloud type.

Estimate cloud cover.

Use meter sticks to measure snow depth.

Time

60 minutes

Level

All

Frequency

Daily with other atmosphere measurements

On sunny days with few clouds for comparison with satellite observations.

When taking soil temperature measurements

When *Land Cover Sample Sites* are visited

Materials and Tools

Hand-held Infrared Thermometer (IRT)

Thermal Glove (use when the air temperature at the study site varies more than 5 degrees Celsius from the air temperature of where the IRT has been stored.)

Surface Temperature Data Sheet

GLOBE Cloud Chart

Ruler or meter stick

Watch

Pen or pencil

Preparation

Establish an Atmosphere Study Site OR

Establish a site where soil temperature is measured OR

Prepare to characterize Land Cover Sample Sites

Prerequisites

None

Surface Temperature Protocol – Introduction

As you explore your surrounding environment you will encounter objects that are at a variety of temperatures. For example, during the afternoon, areas that are exposed to direct sunlight will tend to be hotter than areas that are shaded. Within an area that is exposed to sunlight you may even notice certain objects are warmer or cooler than others. During the morning some objects, such as rocks, may take longer to warm up than their surroundings. Likewise at dusk these objects may take longer to cool.

Heat refers to the amount of thermal energy; it is transferred between objects in various ways. The rate at which energy is transferred to an object depends on its properties including the nature of its surface. The color of the object, the ratio of its mass to surface area, and the material of which it is composed all affect the transfer of energy.

The temperature of your surrounding environment is ever changing, and thermal energy is constantly being transferred among all the components of the environment. The temperature of the atmosphere will affect the temperature of Earth's surface, and likewise the temperature of Earth's surface will affect the temperature of the atmosphere.

The type of land cover present at Earth's surface will play a significant role in this relationship. What covers Earth's surface will help determine how much of the sun's energy that reaches the ground is retained by the surface or reflected back into the atmosphere. On a warm sunny day you can feel different levels of heat radiated from different types of land cover. On a warm day, where do you stand to keep cool? On a cold day, where do you go to keep warm?

Studying the transfer of heat in the environment – the energy cycle – is one key to understanding how the Earth system functions and may change in the future. The transfer of heat between the different components of the environment occurs at their boundaries. So, knowing the temperature at these boundaries is key. Surface temperature measurements provide these boundary temperatures. Therefore, measurements of surface temperature help to relate air, soil, and water temperatures and contribute critically to the study of the energy cycle. Relating land cover types to surface temperatures allows you to integrate multiple GLOBE investigation areas and truly study Earth as a system.

Your GLOBE measurements of surface temperatures will help climate studies and the understanding of the global energy cycle, both in combination with your other measurements and through comparisons with satellite data. See the *Earth As a System investigation (http://www.globe.gov/web/earth-systems/overview)* for more discussion of the energy cycle.

Surface temperature is an observation that is not normally taken by official weather agencies. There are three ways in which surface temperature is observed by scientists: 1. hand-held infrared thermometers similar to the one you use, 2. IRT instruments mounted on towers, and 3. observations from satellites. For most studies, individual scientists or groups of scientists take their own observations using the hand-held IRT instrument and tower mounted IRTs, then compare their observations with satellite imagery. In a couple of situations, organized efforts have been conducted to observe surface temperature continuously over a large area. For example, the state of Oklahoma (USA) has installed 70 IRTs on towers in its Mesonetwork of meteorological stations. These tower-mounted IRTs continuously take surface temperature observations over crop fields and rangeland. However, the total number of surface temperature observations taken around the world is relatively small. This is where GLOBE students can really help! By taking surface temperature observations, GLOBE schools have the potential to significantly add to our knowledge of Earth's surface temperature.

What is Surface Temperature?

Described scientifically, surface temperature is the radiating temperature of the ground surface including grass, bare soil, roads, sidewalks, buildings, and trees to name a few. Surface temperature can be observed using the electromagnetic spectrum. Every object emits electromagnetic energy according to its temperature. Hot objects emit shorter wavelength energy, while cooler objects emit longer wavelength energy. For example, the visible surface of the sun is approximately 5500˚ C. Its peak emission of energy is in the visible wavelengths of the spectrum, 0.4 µm to 0.7 µm. Earth's surface is much cooler and emits much longer wavelength energy. Most of its energy is emitted in the infrared, and consequently we call this part of the electromagnetic spectrum, centered around 10 µm, the thermal infrared. The Infrared Thermometer (IRT) used in this protocol measures the emitted electromagnetic energy from Earth's surface. The instrument converts this measurement into a temperature reading that is shown on the IRT's display area.

The Energy Cycle

The energy cycle describes the way in which the energy from the sun is partitioned into evapotranspiration and heating of Earth's surface. Scientifically, the energy cycle begins with incoming solar radiation. What happens to this radiation is affected by cloud cover, cloud type and by the albedo (reflectance) of Earth's surface.

At Earths surface, some of the solar energy evaporates water and some warms the surface. Heat from the surface flows into the ground and into the air if they are colder than the surface. The heat of vaporization of the water is released when and where the water condenses, often as clouds form. This is the main source of energy for storms.

At the heart of the energy cycle is surface temperature. All aspects of the energy budget contribute to or are affected by surface temperature.

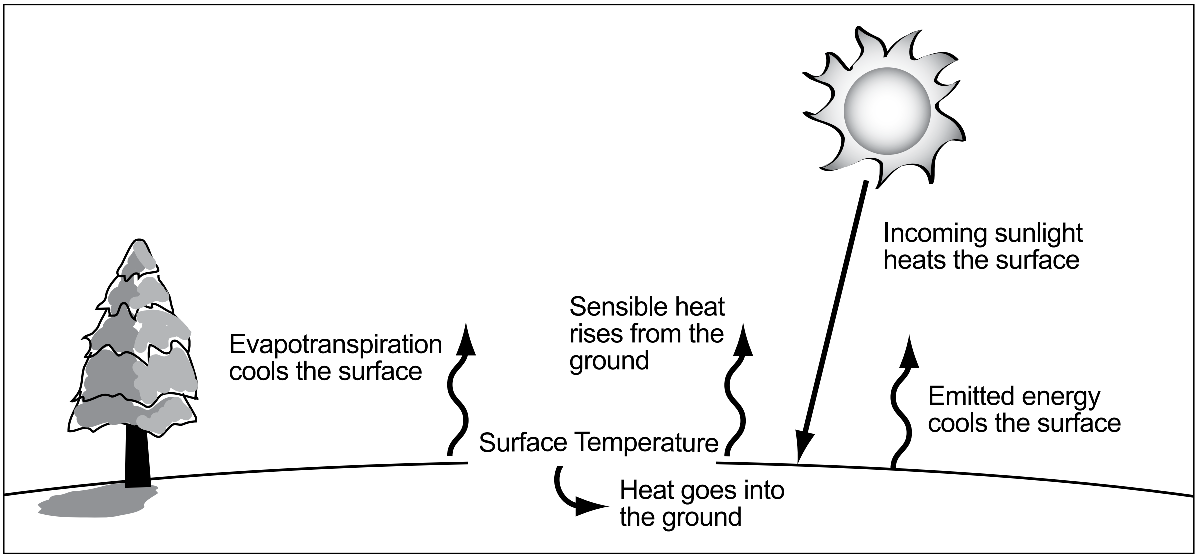
The time of day affects the surface temperature. The surface temperature increases in the morning and peaks an hour or two after local solar noon. Incoming solar radiation is also greatest during the summer and least during the winter.

The amount of vegetation and moisture available at the surface affects the surface temperature also. When moisture is not available at the surface, such as in a desert or on a paved surface, there is no evaporation to cool the surface, and the temperature of the surface increases more during daylight.

The surface temperature affects the amount of long-wave (thermal) radiation going to space. The warmer the surface, the more energy it radiates.

In order to better understand heat in the environment, scientists take temperature measurements of many different environmental components at a variety of locations. These measurements include air temperature, surface land temperatures, surface water temperatures, and soil temperatures at various depths. You, as students, can do this as well by observing the surface temperature of different cover types at several locations, while also collecting air temperature, water

Figure AT-ST-1: Partitioning of the Sun's Energy as Related to Surface Temperature



temperature, and soil temperature. Scientists also measure the temperature of the atmosphere at various heights and the temperature of the ocean at different depths using satellite sensors, balloons, rockets, and buoys. Measurements at multiple heights in the air and depths in the waters are called soundings.

For more information about the energy budget and evapotranspiration please see the *Earth as a System investigation (http://www.globe.gov/web/earth-systems/overview)*.

Teacher Support

Infrared Thermometer

An infrared thermometer (IRT) measures temperature by sensing the infrared radiation (light) coming from a surface. This instrument is sensitive to infrared radiation at wavelengths in the 8-14 µm range. It is not critical for students to understand how it works any more than they need to understand concepts about thermal expansion to use a conventional thermometer. With an the IRT (that, when necessary, is wrapped in a thermal glove or has been placed outdoors for at least 30 minutes prior to data collection), surface temperature measurements can be taken of a wide variety of surfaces including Earth's surface at GLOBE study sites.

The instrument featured in this protocol is the ST20 Infrared Thermometer (IRT) by Raytek. This model is known to meet GLOBE Instrument Specifications, as found in the *Toolkit* (http://www.globe.gov/web/atmosphere-climate/overview/toolkit). However, any IRT model instrument that meets the GLOBE Instrument Specifications can be used to take this measurement. You may need to adapt some of the instrument-specific details given in this protocol to suite your specific model instrument (be sure to consult directions provided by the manufacturer when doing so). However, the primary steps for taking Surface Temperature measurements, as outlined in the *Field Guide*, will remain the same regardless of the instrument used.

Place IRT Outdoors For At Least 60 Minutes - or use a Thermal Glove

When the air temperature at your study site varies more than 5 degrees Celsius from the air temperature of the storage location of the IRT you should do one of the following:

- Place the IRT outdoors for at least 60 minutes prior to data collection

  or
- Wrap the IRT in a Thermal Glove 'before' you go to your study site.

The purpose of placing the IRT outdoors for at least 60 minutes or using a Thermal Glove is to prevent inaccurate readings due to temporary thermal shock. Thermal shock is a phenomenon that occurs when the IRT instrument experiences a change in environmental temperature. Please note that some teachers have reported that when they leave their IRT outdoors on very cold days that their IRT was unable to provide readings. Basically, the IRT works best when it's allowed to acclimate to outdoor temperatures. Also, please select a safe outdoor location to allow your IRT to acclimate.

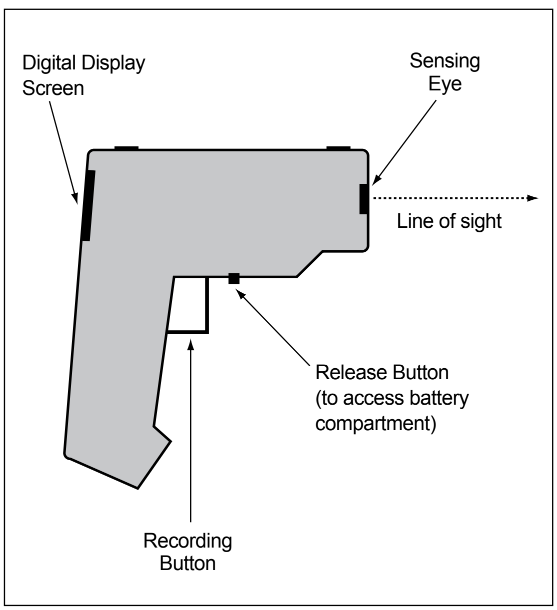
The thermal glove is the invention of a very dedicated and highly respected secondary school teacher from St. Ursula Academy in Toledo, Ohio, USA who has been involved in our student-scientist, Earth observation research projects since August 2000. Thank you, Jackie Kane, for all your inspiration and hard work! An IRT wrapped in a thermal glove has been tested to work for 30 minutes.

The thermal glove is made from a standard 'oven mitt'. An 'oven mitt' is a device that people put on their hand (like a mitten) to prevent burning when lifting hot items from an oven or a stove. An actual-size pattern of the thermal glove with hole designations for the IRT's sensing eye and digital display screen is shown on the following page.

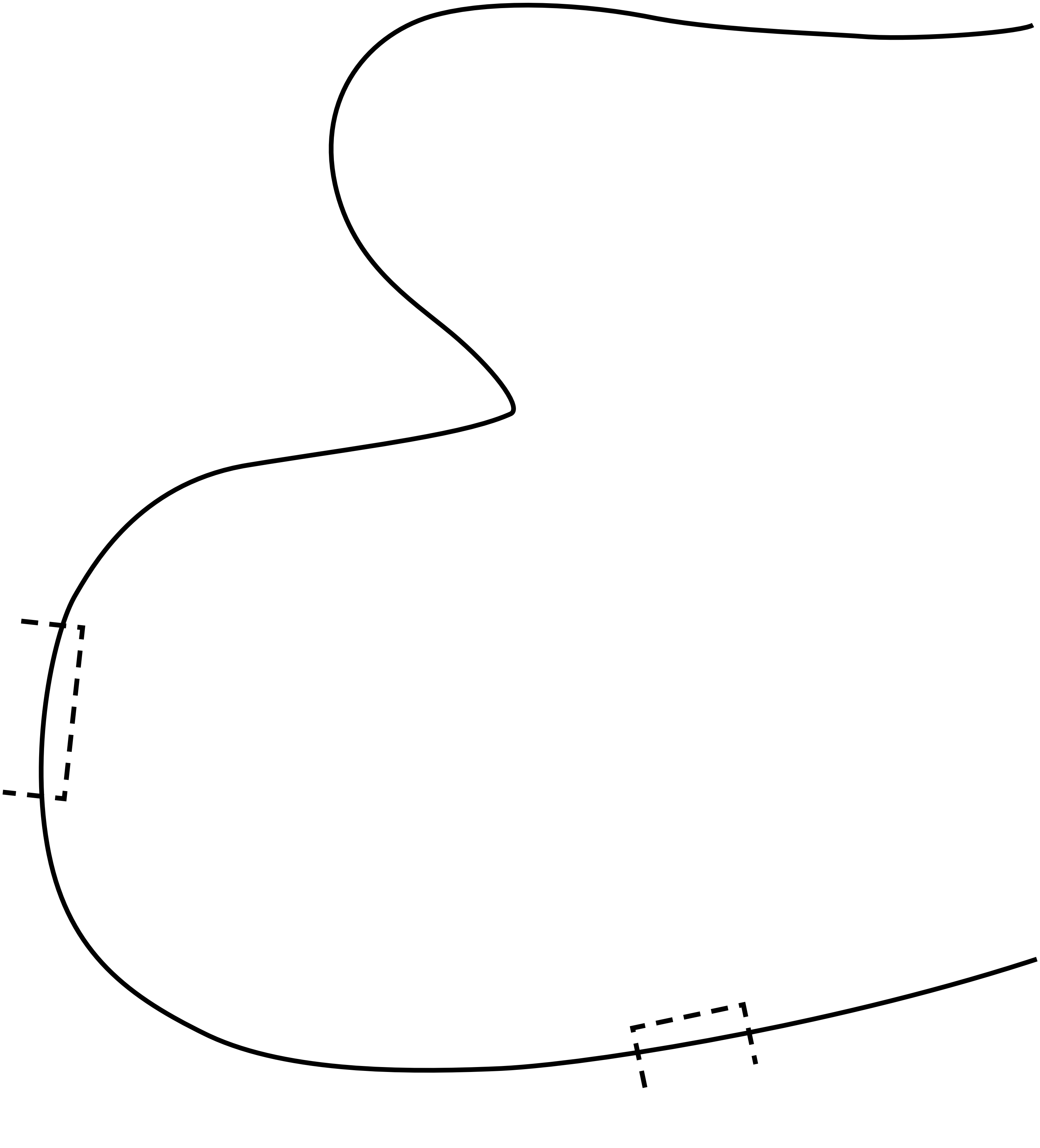
Directions On How to Construct a Thermal Glove

1. Purchase 1 'oven mitt' made of 100% terry cloth.
2. Lay your 'oven mitt' on the actual-size pattern shown on the following page and mark the areas on your 'oven mitt' where you will need to cut the 2 holes.
3. You will need very pointy, sharp, and sturdy scissors to poke through the 'oven mitt' and cut out the holes.
4. Cut out the 2 holes. These should be square shaped holes. The hole at the fingertip section should be approximately 3.5 centimeters. The other hole should be approximately 2 centimeters. It is better to error on the smaller side when cutting the holes. If a hole is cut too large it will allow airflow through the thermal glove which defeats the purpose of the thermal glove, so error on the smaller side! When you put your IRT into the 'oven mitt' then you can increase the holes if necessary.
5. Hold the 'oven mitt' so that the thumb points down.
6. Position the IRT instrument in the finger section of the 'oven mitt' with the sensing eye pointing out through the cut hole in the end of the finger section. Make sure the 'oven mitt' does not cover the sensing eye and laser areas of the IRT; however, also make sure that the IRT fits snugly against the front area of the 'oven mitt' to prevent air from flowing through the thermal glove. (Ignore the thumb section of the 'oven mitt').
7. Position the digital display screen so that it is visible from the upper cut hole (when the thumb is pointing downward.)
8. Make any cut adjustments to the 2 holes and reposition the IRT in the 'oven mitt' for hole-size verification.
9. Once the 2 holes are cut to specification, apply 'tacky glue' to all the seams that were cut. Let the glue dry overnight before you use the thermal glove in the field. The 'tacky glue' will seal the seams and stop them from unraveling.
10. Secure a sturdy rubber band around the loop located at the large bottom opening of the 'oven mitt'.
11. You now have a Thermal Glove that is ready for data collection and exploration – Have Fun!!

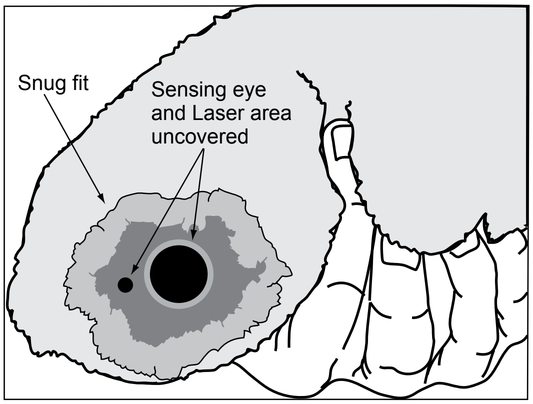
Figure AT-ST-2: Hand-held Infrared Thermometer (IRT)



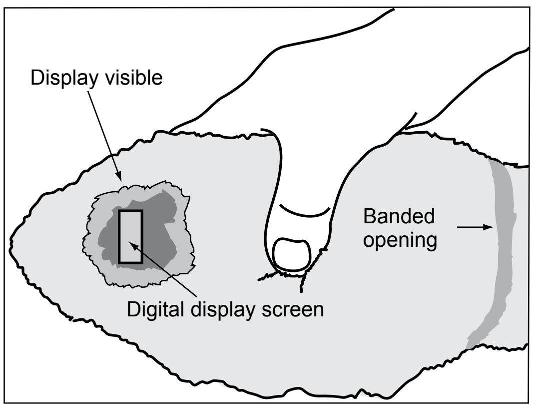
Welcome Introduction **Protocols** Learning Activities Appendix



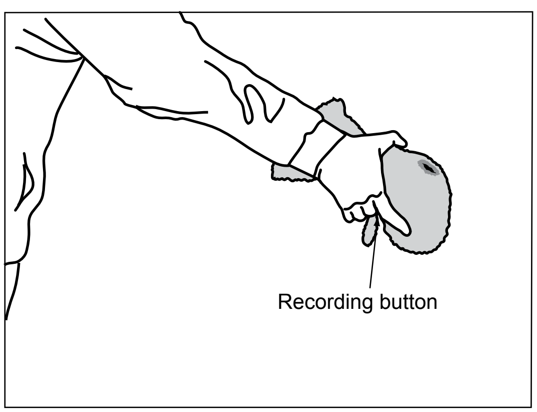
Step 2



Step 3 and 4



Step 5



Directions for Use of IRT with Thermal Glove:

1. Hold the thermal glove so the thumb points down.

2. Position the IRT in the finger section of the thermal glove with the sensing eye pointing out through the cut hole in the end of the finger section. Make sure the thermal glove does not cover the sensing eye and laser areas; however, also make sure that the IRT fits snugly against the front area of the thermal glove to prevent air from flowing through the glove. (Ignore the thumb section of the thermal glove).

3. Position the digital display screen so that it is visible in the upper cut hole (when the thumb is pointing downward.)

4. Take your hand out of the thermal glove and use a rubber band to tighten the thermal glove around the IRT handle at the large bottom opening of the thermal glove.

5. Operate the IRT from **outside** the thermal glove by placing your finger on the recording button and squeezing.

Thermal Glove Maintenance:

When needed, trim frayed edges of cut holes to avoid obstructing the sensing eye and laser area and digital display screen.

Understanding Measurements of Surface Temperature

Using other GLOBE protocols, your students can measure the air temperature and the soil temperature at several depths. With an IRT instrument (that, when necessary, is wrapped in a thermal glove or has been placed outdoors for at least 30 minutes prior to data collection) the air and soil temperature measurements can be complemented by measurements of the temperature at the surface rather than in the air or in the soil. This temperature at the surface is at the actual boundary between the atmosphere and the ground, and the resulting data are useful for understanding the transfer of heat to and from the ground. These data are also useful for comparison with satellite data, because some satellite instruments observe the ground and record surface temperature measurements in a way that is almost identical to how an IRT instrument measures surface temperature.

Instrument Maintenance

Be sure to follow all the manufacturer's instructions for proper maintenance of your Infrared Thermometer (IRT). This includes proper cleaning of the lens as accumulated particles can reduce the thermometer's accuracy by interfering with its optics. Take care not to damage the lens while cleaning it and DO NOT use solvents.

The digital readout of the IRT will display a battery icon when the battery becomes low. When you see this icon, it is time to check the battery and replace it if necessary. The battery is a 9V battery located in the handle of the instrument and can be accessed by pressing the release button (see Figure AT-ST-2) in front of the recording button and opening the handle. See the manufacturer's directions for more detailed instructions.

Make sure that your instrument is displaying temperature readings in degrees Celsius. If it is setup correctly, the temperature reading on the digital display screen will be followed by a '˚C' symbol. If instead of this '˚C ' symbol you see a '˚F' then your thermometer is displaying temperature in degrees Fahrenheit and needs to be switched to display in Celsius. The instrument has a switch that allows you to change between Celsius and Fahrenheit readings. This switch is located above the battery and is accessed in the same manner as stated above. Again, consult manufacturer's directions for further detail. Because this switch is in the battery compartment, you do not have to worry that students will accidentally change this setting.

The calibration of your Infrared Thermometer (IRT) instrument should be checked once every year. To perform a check, prepare an ice water solution in a large beaker or bowl. Point the IRT instrument directly at the water with the end of the instrument approximately 5 cm away from the water; then press the recording button. If the instrument is reading correctly, the ice water measurement will read 0˚ C. If the reading of your instrument is not within –2 to 2˚ C , then the instrument is out of calibration.

If your instrument is not reading properly, check to see if the battery is low. If that is not the problem, check to see if the lens is dirty, and clean it if it is. If you are still not able to get the instrument to read properly, contact the manufacturer.

Site Selection

Surface temperature data are valuable for comparison with satellite observations and for use in combination with air and soil temperature measurements. The sites to use are *Land Cover Sample Sites*, *Atmosphere Study Sites*, and *Soil Moisture Study Sites*.

Picking and Describing a Good Surface Temperature Measurement Site for Comparisons With Satellite Data

A large, open, homogeneous site is required to compare your surface temperature observations with satellite data (for example, the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA' s EOS TERRA and AQUA satellites with 1 km spatial resolution and the Enhanced Thematic Mapper (ETM+) sensor on Landsat 7 with a thermal instrument of 60 meter spatial resolution). Satellite overpass predictor tools are available at the following sites: ASTER (https://lpdaacaster.cr.usgs.gov/estimator/reference_info.

php); Landsat 8 (http://publiclab.org/notes/show/8960); other satellite overpass times can be predicted at the NASA Langely website (http://cloudsgate2.larc.nasa.gov/cgi-bin/predict/predict.cgi).

A *Land Cover Sample Site* where the plants are less than a meter tall is an ideal site to take surface temperature. Land cover sites are required to be homogeneous over an area that is at least 90 meters x 90 meters. When your site meets these requirements, perform the *Land Cover Sample Site Protocol*.

Sites that are open and homogeneous, but less than 90 x 90 meters are also quite useful for surface temperature measurements, but they are not suitable for the *Land Cover Sample Site Protocol*. The site needs to be away from trees and buildings that create shadows on the land area, because the shadows will reduce the amount of sunlight absorbed by the ground and may cause significant variations in the surface temperature. The site can be a grassy area (like a football field), a parking lot (concrete or asphalt), bare soil, or an area containing shrubs.

If you choose a concrete or asphalt parking lot, there cannot be cars in the lot. If there are cars in the lot, then you have the same problem with shadows as you would with trees and buildings. If a section of your parking lot is the largest open, homogeneous area available, then designate that section as your Site and use the same section of the parking lot each time you collect surface temperature data.

If your site is greater than a 30 x 30 meters open, homogeneous area (but less than 90 x 90 meters), then this is wonderful. If your site is less than a 30 x 30 meters open, homogeneous area, then choose the largest open, homogeneous area available and designate it as your Site.

Many Atmosphere and Soil Moisture Study Sites will be useful for comparison with satellite data as they will be in open areas without buildings or other sources of shade.

Mark your site's boundaries appropriately (perhaps use GLOBE marker flags) if you can, so that students can reliably return to the exact location each time they collect surface temperature data.

If the site that you choose has already been defined as a *Land Cover Sample Site*, *Atmosphere Study Site*, or *Soil Moisture Study Site*, then you are ready to begin collecting and reporting surface temperature measurements. If your site has not been defined and is over 90 m x 90 m with homogeneous land cover, define your site as a *Land Cover Sample Site* following the *Land Cover Sample Site Protocol*. If your site has not been defined, and it is less than 90 x 90 meters, then define it as either an *Atmosphere Study Site* or *Soil Moisture Study Site* depending on which will be most appropriate given the other measurements that you plan to take at the site.

When you define a new site for surface temperature, describe any unique permanent features of your site that would be likely to have an effect on Surface Temperature measurements in the *Comments* (metadata) field for the site definition. For example, *site is an asphalt parking lot that has yellow painted lines to mark the spaces and our school building as the boundary on the north side of the site*. Additional information about any temporary changes to the state of your site that relate to surface temperature readings can be recorded in the *Comments* field of your *Surface Temperature Data Sheet* when you take your measurements. For example, *site is covered with leaf litter today*.

When you report surface temperature data for the first time at a new site you will be asked to report some *Definition Data* regarding the size and ground cover type found at the site, as well as the model IRT you will be using at the site. Record this information at the top of your *Surface Temperature Data Sheet* the first time that you take measurements at the site.

You are encouraged to monitor the surface temperature at sites representing as many different land cover types as you can. The more sites that you monitor and for which you report data, the better the information will be for research. It is very exciting to monitor at least 2 sites with different land covers, so that you can observe and explore the changes in surface temperatures that occur due to the differences between these sites.

Helpful Hints

Some IRT units are equipped with a laser and backlight. You can choose whether or not to activate these. If you choose to put them on, a red laser beam will shine from the sensing eye area along the approximate line of sight of the instrument when the recording button is pressed. This will cause a red dot to appear where the surface temperature is being measured. A backlight for the digital display screen will remain lit for seven seconds after the recording button is pressed and released.

Using the laser can help you more accurately locate the point where you are measuring the surface temperature. However, it will also reduce battery life and could possibly be a distraction to students. It is imperative that the laser beam NOT be aimed directly at eyes or off surfaces where it could reflect into anyone's eyes. The laser and backlight option is controlled by a switch located above the battery in the battery compartment.

Questions for Further Investigation

How does surface temperature vary depending on whether the surface is in the sun or the shade? Does it matter whether the shade is from a tree, a shrub, or a cloud?

How does surface temperature compare with current air temperature? How does surface temperature compare with soil temperature at 5 cm and 10 cm?

How does surface temperature vary with land cover (e.g., bare soil, short grass, tall grass, concrete, asphalt, sand, forest litter)?

How does surface temperature vary with surface soil color?

How does the surface temperature of the ground, near the outside of the atmosphere shelter, compare with the current air temperature measured inside the shelter?

How does the surface temperature of the underside of a forest canopy compare with air temperature in the forest?

How does surface temperature change for different cover types (grass vs. asphalt for instance) on a cloudy day?

How does the time of year affect the surface temperature?

How does the surface temperature change for different cover types when it is wet versus when it is dry?

Surface Temperature Protocol
Field Guide

Task
Measure surface temperature.

What You Need
- ❑ *Surface Temperature Data Sheet*
- ❑ Hand-held Infrared Thermometer (IRT)
- ❑ Thermal Glove (use when the air temperature at the study site varies more than 5 degrees Celsius from the air temperature of where the IRT has been stored.)
- ❑ Ruler or Meter Stick, (if snow cover is present)
- ❑ Pencil or pen
- ❑ GLOBE Cloud Chart
- ❑ Accurate watch

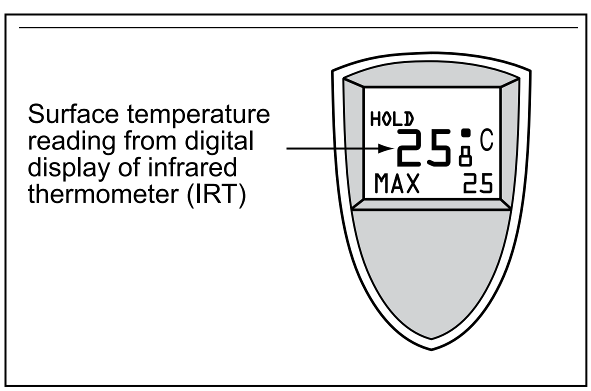
In The Field
1. When necessary, either wrap the IRT in a Thermal Glove before you go to your study site or place the IRT outdoors for at least 30 minutes prior to data collection. For more details, refer to the *Thermal Glove -or- Place IRT Outdoors For At Least 60 Minutes* section of this protocol.
2. Complete the top section of your *Surface Temperature Data Sheet* (fill out the *Supplemental Site Definition Data* section if you are taking Surface Temperature Measurements at a particular site for the first time, or if one of the values in that section has changed).
3. Take cloud observations following *GLOBE Cloud Protocols*.
4. If there is no snow on the ground anywhere in your Site, then check either "Wet" or "Dry" for the Site's Overall Surface Condition field on your *Surface Temperature Data Sheet*.
5. Check the box that corresponds to the method used to prevent the IRT from experiencing thermal shock.
6. Pick 9 Observation Spots that are in open areas within your site and are at least 5 meters apart. The Spots should also be away from trees and buildings that create a shadow on the land and in locations that have not been recently disturbed by people or animal traffic. (Note: It is best that you take readings at the 9 individual Observation Spots within seconds of each other.)
7. Go to one of the nine Observation Spots and stand so that you do not cast a shadow on the Spot.
8. Record the Current Time and its corresponding Universal Time (UT) on your *Surface Temperature Data Sheet*.
9. Hold the infrared thermometer (IRT) (wrapped in a Thermal Glove when necessary) with your arm extended straight out and point the instrument straight down at the ground.

10. Hold the IRT (wrapped in a Thermal Glove when necessary) as still as possible. Press and release the recording button. [You MUST release the recording button for the instrument to register and hold your spot's surface temperature.]
11. Read and record the surface temperature from the digital display screen located on the top of the IRT. (Note: Surface Temperature is recorded in Celsius to the nearest tenth degree, ie. 25.8)
12. Measure and record the snow depth in millimeters at the Observation Spot.
13. Repeat steps 7-12 at each of the remaining eight Observation Spots.
14. Record any other information that explains the environmental conditions of the day or site in the Comments field.

a.

b.

The above pictures show correct use of IRT, a) without a Thermal Glove and b) with Thermal Glove



Frequently Asked Questions

1. What should I do if the surface temperature reading I want to record disappears from the digital display screen before I am able to accurately read and record it?

The surface temperature reading will be displayed for seven seconds after you release the recording button of the IRT. If you are unable to read the temperature in this time, or are unsure of your reading, then retake the measurement at that Observation Spot according to the directions given in the *Field Guide*.

2. How should a dusting of snow be documented on the *Surface Temperature Data Sheet*?

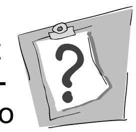
If there is snow of less than ten millimeters in depth on the ground then record the letter “T” in the snow depth section of your *Data Sheet* to indicate a dusting of snow. If there is snow of ten millimeters or more in depth then measure the depth of the snow pack in millimeters using your ruler or meter stick.

3. The *Surface Temperature Field Guide* asks for measurements of cloud cover and snow depth, for which there are also separate GLOBE measurements. Would it be helpful to take these or any other GLOBE measurements along with Surface Temperature?

Yes! Taking multiple types of measurements at the same site at the same time allows for greater insight into the state of the environment than a single measurement possibly could. Taking additional types of measurements to accompany your surface temperature readings allows you to study what factors may be affecting each individual reading. Surface temperature ties strongly to cloud cover, air temperature, soil moisture, soil characterization, and land cover type.

4. Is recording NO snow -or- NO clouds important?

Yes, reporting that there is no snow and/or no clouds is important! If there is no snow, please record a zero in all appropriate SNOW DEPTH fields. If there are no clouds in the sky, please check NO CLOUDS in the *Cloud Type* table on your *Surface Temperature Data Sheet*. The fact that there is no snow or no clouds present will directly impact your readings of surface temperature, so reporting this will help to explain your readings.



If you leave a blank in these fields, it will be confusing, because the scientists will never know if you forgot to take the data or if the measurement is zero. Also, your data for that day can not be used in research.

5. Can the Infrared Thermometer (IRT) Instrument be used for other types of temperature monitoring?

Yes. Some of its other uses are by meat packers to ensure that their refrigerators and freezers are kept at a specific temperature. Also, mechanics use this instrument to measure the temperature of a car’s oil. And a teacher has shared with us that a janitor came into her classroom to check the temperature at different places around the room that helped to determine when the classroom’s heating system was fixed.

6. The *Field Guide* says that we should take readings at 9 individual observation spots each time we go to the study site to take surface temperature measurements. Can we take fewer than 9 readings?

We strongly encourage you to take all 9 readings. The 9 points are needed by GLOBE scientists to create meaningful averages of your study site and to accurately compare your data to satellite data. The more readings that you take, the better your data is for the scientists! If your study site is less than 30 x 30 meters, we still strongly encourage you to take all 9 readings; however, we also understand that the 9 measurements may need to be closer than 5 meters apart. It is required that you take at least 3 readings to report data to GLOBE.

7. Can I use the IRT instrument to study the surface temperature of water?

Yes, the IRT instrument can be used to read the temperature of the surface of a water body. However, since it is not possible to follow the steps outlined in the *Surface Temperature Field Guide* over open water these values cannot be reported to GLOBE. However, they can be quite useful in studying the relationship between air and water temperatures, and can be included as metadata accompanying water temperature readings submitted to GLOBE.

8. When do I use the Thermal Glove?

Your Infrared Thermometer (IRT) should be wrapped in a Thermal Glove when the air temperature at your study site varies more than 5 degrees Celsius from the air temperature of where the IRT has been stored.

9. Should I round up to the nearest integer when recording the surface temperature measurement from the IRT digital display screen?

NO. The surface temperature measurement must be recorded to the nearest tenth degree, ie. 25.8.

Surface Temperature Protocol – Looking At the Data

Are the data reasonable?

There are many factors that influence the surface temperature reading including the land cover type, soil moisture content, cloudiness, and temperatures prior to your observation in addition to your location, time of day and day of year. Therefore, it will be more difficult to determine if your surface temperature data are reasonable.

As you become more familiar with your surface temperature readings at your site throughout the year, you will become familiar with what the temperature of different cover types may be. You will become trained as an observer and will be able to notice if there is an anomaly that occurs (a measurement that seems odd, compared to your other data) which will spark you to question that reading or area.

Sometimes the observations that you get may seem incorrect, but in fact, the observations may be telling you something interesting about how surfaces heat up and cool down. If asked, most people would say that an asphalt parking lot would be much warmer than a grass site. One GLOBE school in Michigan (USA) found the exact opposite temperatures on a sunny afternoon in early March. The grass was warmer than the asphalt site. In the case of these observations, the weather had been very cold all winter long. On the sunny day in question, the sun was able to warm up the grass while the asphalt parking lot retained the cold temperatures from winter for much longer. From summer through early fall on a sunny afternoon, an asphalt parking lot will be hotter than a grass site. However, during the winter through early spring on a sunny afternoon, the grass will heat up in the sun and be warmer than the parking lot.

Other times there may not be a scientific explanation for an errant surface temperature observation. For instance, you know that the ground is frozen because you can see ice; however, your IRT instrument records the ground as 40˚ C. This may lead you to ask if your IRT instrument is measuring accurately, if you made a mistake in data collection, or if something has changed within your Study Site. Scientists do this exact questioning of their observations, as well. If you think the IRT instrument may be misreading the temperature, refer to the *Instrument Maintenance* section above. The IRT may need a new battery, the lens may be dirty, or the instrument may be out of calibration.

So, get ready for some interesting and exciting learning about our planet's temperatures!

What do scientists look for in these data?

GLOBE scientists will be using student surface temperature observations in two ways. We will be using the surface temperatures recorded by GLOBE students to validate satellite algorithms that are used to record Earth's surface temperature. Satellite images give a synoptic view of the landscape that ground observations cannot. As stated above in the *Surface Temperature Protocol Introduction* section, Earth's surface emits electromagnetic energy according to its temperature. However, satellites observe Earth's emitted energy after it travels through the atmosphere. Greenhouse gases in the atmosphere, such as carbon dioxide and water vapor, absorb some of the energy emitted by Earth's surface and these gases emit energy at their own temperature which makes the satellite observation of Earth's surface temperature misleading. This atmospheric effect makes it difficult for scientists to use the surface temperature that is recorded by satellites. GLOBE students' surface temperature observations will allow us to determine if the satellite algorithms (equations) for surface temperature accurately account for the atmosphere's interference.

The second way that we will use the students' surface temperature data is to compare observations between different cover types to monitor the effect of land cover on the temperature of Earth. These observations will give us an understanding of the causes and extent of the urban heat island effect. We will compare grass sites' surface temperatures at urban vs. rural schools. The same comparison will be made with all the different land cover types between urban and rural locations.

The Urban Heat Island Effect

The urban heat island effect is a phenomenon where the change in the land from natural vegetation to parking lots and buildings can cause the temperature of the area to increase (Figure AT-ST-3). The central part of a city can be 5-10˚ C warmer than the surrounding countryside. Transpiration from vegetation including trees and grass cools the air. The energy from the sun that shines on the surface is used to evaporate water and is not available to heat up the ground. In contrast, parking lots, roads and buildings dry out under sunshine, and all of the incoming energy from the sun heats the surface warming it up more than it would otherwise. You may notice these temperature differences when you are taking your observations. (**Note:** The time of day and time of year may influence whether pavement is warmer than grass.)

Look at the image of surface temperature for Toledo, Ohio, USA, shown in Figure AT-ST-4. This image is from the Landsat 7 satellite taken on July 1, 2000 at approximately 11:00 am Local Time. Red areas are hot, and blue and purple areas are cooler. The hottest locations are sites with much pavement (concrete and asphalt), such as malls and the downtown area of Toledo. The cooler areas are the parks, that have many trees and the water in the Maumee River and Lake Erie.

An Example of a Student Research Investigation

Designing an Investigation

This is a simple investigation that can be performed using an IRT. Mikell Hedley's Research Methods class from Central Catholic High School in Toledo, Ohio, USA, investigated the properties of different land cover types that affect surface temperature. Within the boundaries of each site, they collected surface temperature readings at 4 different Observation Spots.

It was a sunny afternoon and the class decided to observe grass, asphalt, cement, and bare soil. Before going outside Mrs. Hedley asked her students to predict which areas would be warmest and coolest.

Student 1 – I know that my blacktop driveway gets really hot on a summer day. I think it's because it is black. So, asphalt will be warmest.

Teacher – Black surfaces absorb more sunlight than lighter surfaces, such as cement. We will see if you are right. What else is going on?

Student 2 – Don't plants give off water? In Biology class, we learned that plants give off water through photosynthesis. Because of this I think the grass will be coolest.

Figure AT-ST-3: Example Relationship between Land Cover and Temperature. Miller (1999)

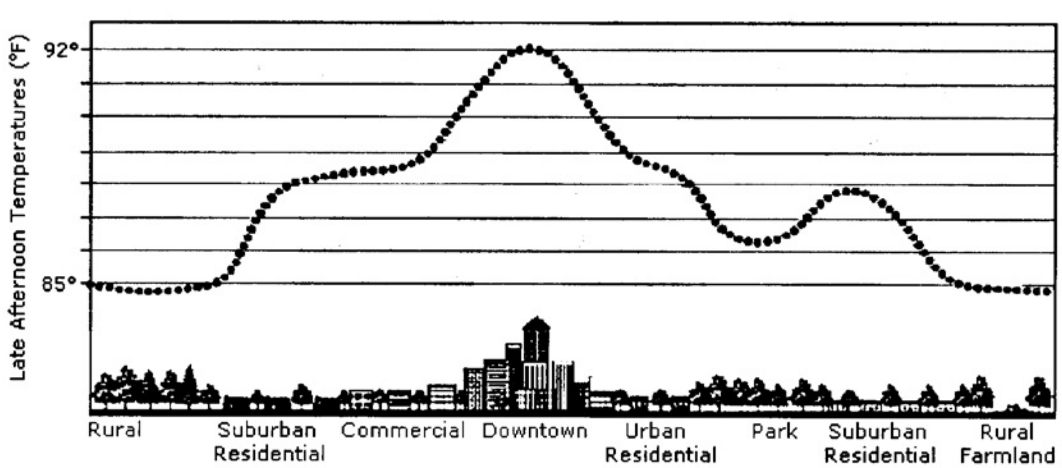
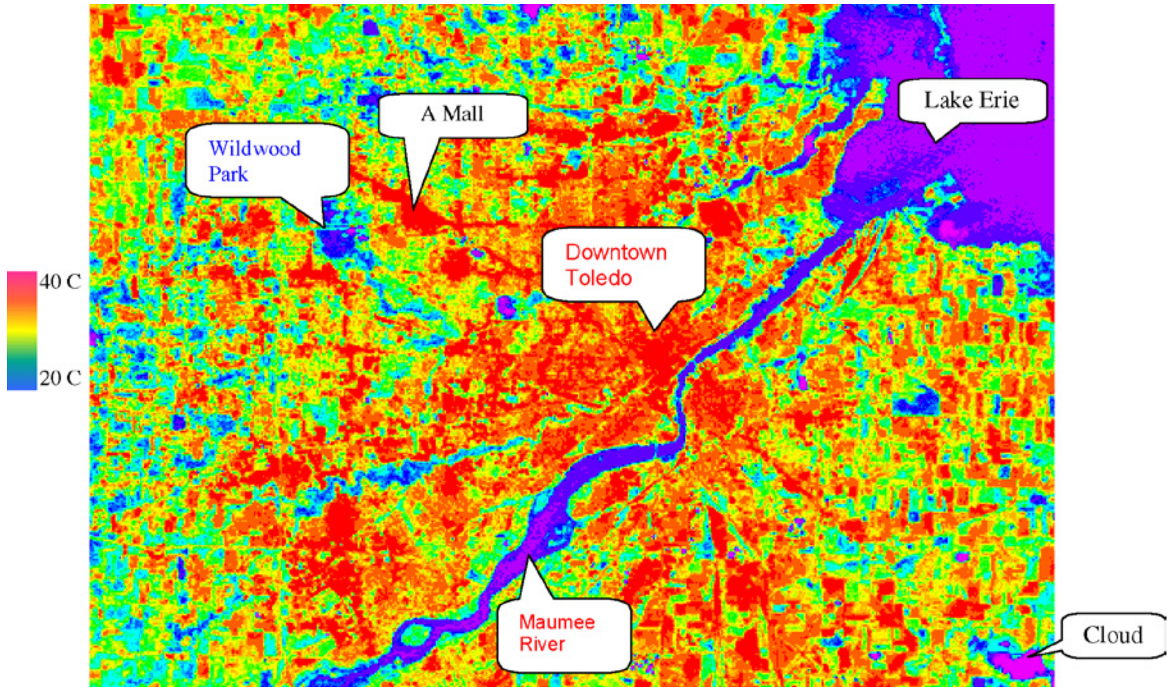


Figure AT-ST-4: Surface Temperature for Toledo, Ohio, USA



Teacher – Yes, plants are drawing water from the ground and transpiring it into the air. Evaporation cools, and, in transpiration liquid, water in the plant becomes water vapor in the air.

Student 3 – Asphalt, concrete, and bare soil are all massive and dense. I think it will take more heat to warm them up, but the grass is not so dense, so it will warm up more quickly and be the hottest.

Teacher – Let's go measure and test your predictions.

Table AT-ST-5 presents the results.

Table AT-ST-5: Surface Temperature Readings (˚C) at Areas with Different Types of Land Cover

Land Cover	Observation Spots			
	1	2	3	4
Grass	27.5	30.0	28.5	29.0
Asphalt	35.5	33.5	33.5	34.0
Cement	32.0	33.0	32.0	33.5
Bare Soil	30.0	31.0	33.0	31.5

These data show that the asphalt had the highest temperature while the grass had the lowest. So the predictions of Students 1 and 2 proved correct.