Objective: Students will measure schoolyard surface temperatures following the GLOBE protocol. The data collected over time will be used to evaluate whether the schoolyard acts as a "surface urban heat island" as per the US EPA definition.

Curriculum Standards:

- NGSS ESS3.C Human Impacts on Earths Systems
- MD E-Lit Standard 1 Topic A: Environmental Issue Investigation
    - Indicator 4: Design and conduct research

Students will track temperatures of surfaces following The GLOBE Program Surface Temperature Protocol. The GLOBE protocol utilizes a hand-held Infrared Thermometer (IRT) to collect temperatures and includes an assessment of sky conditions, cloud cover and snow measurement, as necessary.

Students will measure the temperature of surfaces identified during the Schoolyard Inventory (Introductory Lesson #3) which will be used for comparisons of the results between land use surfaces and/or the reference site.

Materials needed:

- Handheld Infra-red thermometers
- Schoolyard Surface Inventory from Program Intro Lesson 3.
- GLOBE Protocol: Surface Temperature Protocol

GLOBE Surface Temperature Protocol Summary

- Must choose to either use an oven mitt over the IRT or allow IRT to sit outside for 30 minutes to equilibrate to outdoor temperature.
- Requires 9 different site IRT readings, preferably 90 m x 90 m homogenous area.
- Sites need to be away from trees and buildings that create shadows on the land.
- Concrete/asphalt parking lots cannot have cars parked in them.
- Consider marking the site locations so students can return the sites to collect subsequent temperature readings.

Background

The increase in temperature in developed and urban areas as compared to rural areas is known as the Urban Heat Island (UHI). Urban Heat Islands occur due to the surface properties of construction materials and impervious surface as well as the condensed activities from large number of human population in the area. UHIs can be measured with **surface temperatures** or **atmospheric temperatures**. This lesson focuses on surface temperatures.

Surface heat islands develop from urban surfaces (e.g., roadways, buildings, sidewalks) heating at different rates than rural vegetated and shaded areas. Surface heat islands are present both day and night, but are strongest during the day when sun is shining and weather is clear.

On average, the difference in daytime surface temperatures between developed and rural areas is 18 to 27°F (10 to 15°C); the difference in nighttime surface temperatures is typically smaller, at 9 to 18°F (5 to 10°C). The magnitude of surface urban heat islands varies with seasons, due to changes in the sun's intensity as well as ground cover and weather. As a result of such variation, surface urban heat islands are typically largest in the summer.[1]

Table 1: Basic Characteristics of Surface and Atmospheric Urban Heat Islands. [1]

Feature	Surface UHI	Atmospheric UHI
Temporal Development	• Present at all times of the day and night • Most intense during the day and in the summer	• May be small or non-existent during the day • Most intense at night or predawn and in the winter
Peak Intensity (Most intense UHI conditions)	• More spatial and temporal variation: ▪ Day: 18 to 27°F (10 to 15°C) ▪ Night: 9 to 18°F (5 to 10°C)	• Less variation: ▪ Day: -1.8 to 5.4°F (-1 to 3°C) ▪ Night: 12.6 to 21.6°F (7 to 12°C)
Typical Identification Method	• Indirect measurement: ▪ Remote sensing	• Direct measurement: ▪ Fixed weather stations ▪ Mobile traverses
Typical Depiction	• Thermal image	• Isotherm map • Temperature graph

Directions:

1. **Select a time range to collect temperature measurements.** Students should collected temperatures at the same locations over several days/weeks, for example, once per week for 6 weeks.
2. **Select a site you will use as your "rural" reference.** Hood-CCWS will maintain a reference site for select locations. This reference data will be uploaded to ccwsscience.org at select intervals. Alternatively, you may choose

A **reference site** is preferably a location that has no influence of development, meaning little to no impervious surface. The reference site could represent the type of land cover the property had prior to the school being built.

Reference site surface temperatures are available on the Hood-CCWS Urban Heat Program website (ccwsscience.org). The location is dependent on your school district.

[1] USPEA Urban Heat Island Compendium – Chapter 1 Urban Heat Island Basics. October 2008. https://www.epa.gov/heat-islands/heat-island-compendium

to measure surface temperatures of a difference site, such as a wooded area adjacent to the school. See inset box.

3. **Review surface temperature measurement locations (options: use locations identified in Intro Lesson #3 OR create and select locations along a transect across the schoolyard)**

   Students have identified locations of various land use cover around the schoolyard in the Introductory Lesson #3 (Inventory Schoolyard) to repeatedly and consistently measure surface temperatures throughout the semester.

   Option: Student will select locations along a map transect across the schoolyard property (preferred method if completing the surface heat profile activity (below)). Use hard copy maps, Google Maps. Fieldscope or other online tools to provide students an aerial image of the entire schoolyard property. Draw a line (a transect) across the map, ideally crossing several types of land uses (e.g., grassy area, paved areas, wooded). Select nine locations across this transect that students can access (& have permission) to measure the surface temperature. Students in different groups could do different transects across the school property.

4. **On your class data sheet or using the table provided, include a short description of each sampling location during the FIRST collection day.** It is a good idea to mark the sample spot so students will return to the sample site each subsequent sampling day. You can also collect GPS locations, if desired. List the sampling site and a brief description to include what the land use is at each site (e.g., ball field, parking lot).

5. **On each measurement day, record temperatures of the same locations on class data sheets.** Measure the surface temperatures at each sampling site and include a measurement of the air temperature from your weather station.

At the end of the collection period, students will calculate temperature differences between surface temperatures between developed areas (school grounds) to undeveloped areas (park, wooded, or, if available, a rural reference site).

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Background:

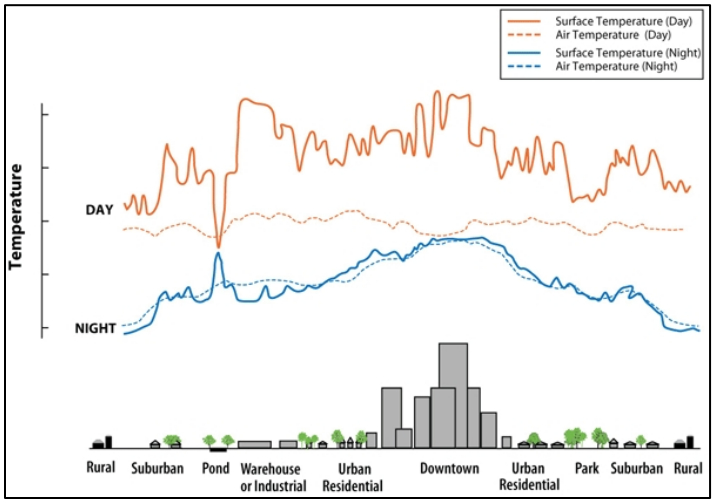

Figure 1 U.S. EPA Image of Surface & Air UHI temperatures, 2008

The term "**urban heat island**" (UHI) describes built up areas that are hotter than nearby rural areas. Urban heat is generated from human activities such as development with impervious surfaces, removal of trees, and using heat generating materials such as building heat/AC and automobiles. Recall that surface materials can reflect and emit energy depending on its albedo (Table 1) and emissivity.

Heat Islands are evaluated by comparing both the surface and air temperatures to undeveloped or rural areas. The surface temperatures in an UHI are generally warmer than a rural site by 5-10 degrees Celsius during night hours, 10-15 degree Celsius during the daytime, and are more intense in the summer.

Table 1: Typical Surface Albedo values

Surface	Typical Albedo
Conifer Forest (summer)	0.09-0.15
Deciduous Trees	0.15-0.18
Fresh Asphalt	0.04
Black Brick	0.08
Worn Asphalt	0.12
Bare Soil	0.17
Green grass	0.25
Red brick	0.36
Desert Sand	0.40
Ocean Ice	0.5-0.7
New Concrete	0.55
White brick	0.72
Fresh Snow	0.80-0.90

Terms to Know

>Albedo: *a measure of how much light that hits a surface is reflected without being absorbed. A white object with high albedo, reflects most light that hits it and a dark object of low albedo absorbs most of the light that hits it.*

>Emissivity*: the measure of an object's ability to emit infrared energy. Emitted energy indicates the temperature of the object. Emissivity can have a value from 0 (shiny mirror) to 1.0 (blackbody).*

Table 2 describes the basic characteristics between a surface and atmospheric UHI.

Table 2: Basic Characteristics of Surface and Atmospheric Urban Heat Islands. [1]

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Throughout the semester you will collect surface temperatures at several locations around the schoolyard, focusing on a variety of different land use types (e.g., parking lot asphalt, grassy fields). Temperatures will be recorded and averages calculated.

Note: This activity assumes that schoolyard surface temperatures are only collected at daytime hours.

Materials:

- Infrared Thermometer
- List of various land use locations provided by your teacher
- Classroom Surface Temperature Data Sheet or the following worksheet.

Method:

Review then land cover locations on your schoolyard previously identified during the schoolyard inventory. Your teacher will guide you in identifying where to collect temperature measurements. Remember you do not want your land surface to be shaded by other objects such as buildings.

- The FIRST time you collect temperatures around your school you need to document their exact location with a mark, on a map, or using GPS Coordinates. Use these same sites each time you collect surface temperatures. It is a good idea to mark each site with a flag or stake to identify the same location each time.
- Record temperatures on the data sheet and compile data with your class.

Measure surface temperatures throughout the semester using your IR Thermometer following GLOBE protocol.

Date:_____ Time:_____EST/EDT Student/Group:_____

RECORD: Temperature Data (°Celsius)

Site#	Describe location &/or Land Cover	Is the site shaded by trees, building or other cover? Yes / No	Color/ Estimated Albedo	Date: Time: Air Temp: Weather: Clouds: Yes/No/Part	Date: Time: Air Temp: Weather: Clouds: Yes/No/Part	Date: Time: Air Temp: Weather: Clouds: Yes/No/Part	Date: Time: Air Temp: Weather: Clouds: Yes/No/Part	Date: Time: Air Temp: Weather: Clouds: Yes/No/Part	Date: Time: Air Temp: Weather: Clouds: Yes/No/Part	Average Temperature (°C)
1				°C						
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