The Urban Heat Island Effect in a Small Town

Jacob Fleming

St. Francis Xavier Catholic School

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Abstract

This experiment focused on the question, how will the Urban Heat Island Effect be shown when taking surface temperature measurements in Gettysburg, PA and at St. Francis? The hypothesis states that if surface temperature measurements are taken in an urban environment, then the surface temperature reading will be higher because there is more asphalt, tall buildings, and dark surfaces in cities which will absorb more heat, increasing surface temperature. The independent variable is the location that surface temperature testings are being taken. These locations are in downtown Gettysburg and on the rural campus of St. Francis Xavier School. The dependent variable is the surface temperature taken in Celsius. The controlled variables are the GLOBE Surface Temperature Protocol, the instruments used, and the surfaces the surface temperature is being taken on. This experiment was conducted by taking surface temperature with an infrared thermometer according to GLOBE protocols in Gettysburg downtown and near school. Grass, concrete, and asphalt were tested at both locations. Testings were being taken after school on Mondays and Fridays. The data supported the hypothesis because the in town averages were normally above the school averages. If this project was continued more data would be taken in more places.

Keywords: surface temperature, urban heat island, asphalt, dark surfaces

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Research Questions and Hypothesis

This experiment focused on the question how will the Urban Heat Island Effect be shown when taking surface temperature measurements in Gettysburg, PA and at St. Francis. The hypothesis states that if the surface temperature measurement is taken in an urban environment, then the surface temperature reading will be higher because there is more asphalt, tall buildings, and dark surfaces in cities which will absorb more heat, thereby increasing surface temperature.

Introduction

Surface Temperature is the radiating temperature of all ground surfaces and is measurable in infrared. The time of the day and year, along with the amount of surface vegetation, direct sunlight, and moisture, affect surface temperature (GLOBE, 2014). Cloud cover also affects temperatures by covering or not covering the surface, allowing or preventing the sun's energy from heating up the surface (Barry, 2010).

Heat is the amount of thermal energy. Heat transfers to objects in different ways. The rate of transfer depends on the properties of the item, such as color, ratio of mass to surface area, and material (GLOBE, 2014).

Radiation is the transfer of the sun's heat to the ground. Conduction is heat transferring from the ground to the air. Convection is the movement of heat through fluids (Barry, 2010). These are all part of the transfer of heat energy cycle. The energy cycle, otherwise known as the transfer of heat energy, begins with solar radiation with the amount depending on cloud cover reflectivity of Earth's surface. At the surface, some energy heats the earth and the rest causes water to evaporate (GLOBE, 2014). This energy cycle is important because it shows how the earth and its surface temperature is heated.

An Urban Heat Island Effect is the changing of surface temperatures caused by the changing of the surface coverage from vegetation to buildings and asphalt. The city center can be 5-10 ^{o}C warmer than the country outside of the city. Transpiration from plants in the country cools the surface and the air. Less transpiration and more heat absorbing surfaces in cities means that it is generally warmer in the cities than the surrounding country, which is how the name Urban Heat Island came into use (GLOBE, 2014). Other causes of the Urban Heat Island Effect are the insulation caused by buildings being built together and waste heat, which is the energy burned off of people and their machines, escaping into the atmosphere (National Geographic, 2012). Tall buildings decrease wind speed which can warm cities as they do not have cooling wind (UCAR, 2011).

The sun's energy is used for evaporation when there is vegetation, not for heat, so more vegetated areas will be cooler. The sun's energy can only heat the surface when there is less vegetation, because the vegetation absorbs the sunlight, so less vegetated areas will be warmer (GLOBE, 2014).

Water also plays an important role in the Urban Heat Island Effect. Water moves more than land and therefore cools more slowly because heat can more easily be retained in mobile things. Water absorbs more heat because it is transparent and mobile. Land is harder for heat to penetrate because it does not move. Land does not absorb heat as much because of its opaqueness. This is because heat can penetrate more translucent surfaces (Lutgens and Tarbuck, 1998). However, when land does absorbs heat it is held longer because of the aforementioned opaqueness.

Although Gettysburg is not necessarily urban it was the closest to the school site so it was used due to time and travel constraints.

Materials and Methods

- Infrared Thermometer - Sper Scientific 800103
- Cloud Cover Chart
- Ruler
- Pencil
- Pen
- Logbook
- Printer
- Chromebook
- GLOBE Protocol Data Papers
- 1 Oven Mitt 100% Terry to make Thermal Glove
- Scissors
- Sturdy rubber band for Thermal Glove
- Tacky Glue to make Thermal Glove

The measurements will be taken at St. Francis Xavier Catholic School (465 Table Rock Rd, Gettysburg, PA 17325) immediately after school. Another person will drive into Gettysburg and take measurements there. Temperatures were taken at the same time.

All Protocols below are taken from GLOBE

Directions On How to Construct a Thermal Glove

1. Purchase 1 ‘oven mitt’ made of 100% terry cloth.
2. Lay the ‘oven mitt’ on the actual-size pattern shown on the following page and mark the areas on the ‘oven mitt’ where it is needed to cut the 2 holes.
3. Very pointy, sharp, and sturdy scissors are needed 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 the IRT is put into the ‘oven mitt’ then holes can be increased in size 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 the thermal glove is used 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’.

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 the 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 a finger on the recording button and squeezing.

Surface Temperature Protocol

1. When necessary, either wrap the IRT in a Thermal Glove before going to the 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 the Surface Temperature Data Sheet (fill out the Supplemental Site Definition Data section if Surface Temperature Measurements are being taken 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 the Site, then check either “Wet” or “Dry” for the Site’s Overall Surface Condition field on the 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 the 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 readings are taken at the 9 individual Observation Spots within seconds of each other.)

7. Go to one of the nine Observation Spots and stand so that a shadow is not casted on the Spot.
8. Record the Current Time and its corresponding Universal Time (UT) on the Surface Temperature Data Sheet.
9. Hold the infrared thermometer (IRT) (wrapped in a Thermal Glove when necessary) with an 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. [The recording button MUST be released for the instrument to register and hold the 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.

Cloud and Contrail Cover

1. Complete the top section of the Data Sheet.

2. Look at the sky in every direction (above 14 degrees).
3. Estimate how much of the sky is covered by clouds and contrails.
4. Record the cloud/contrail cover for the overall sky, as well as each level.
5. If the sky is Obscured, record what is blocking the view of the sky. Report as many of the following as observed.

Sky Color and Sky Visibility

1. Complete the top section of the Data Sheet.
2. Look at the sky in every direction (above 14 degrees).
3. Look Up to observe sky color, reporting the shade that most closely matches the sky.
    a. Turn away from the Sun.
    b. Observe the bluest part of the sky, which is usually around 45 degrees above the horizon.
4. Look Across to observe sky visibility.
    a. Look at a landmark in the distance and estimate how visible it is under current sky conditions.
    b. Try to use the same landmark every time.
5. Record sky color and sky visibility for the overall sky. This observation will not be taken on each level.

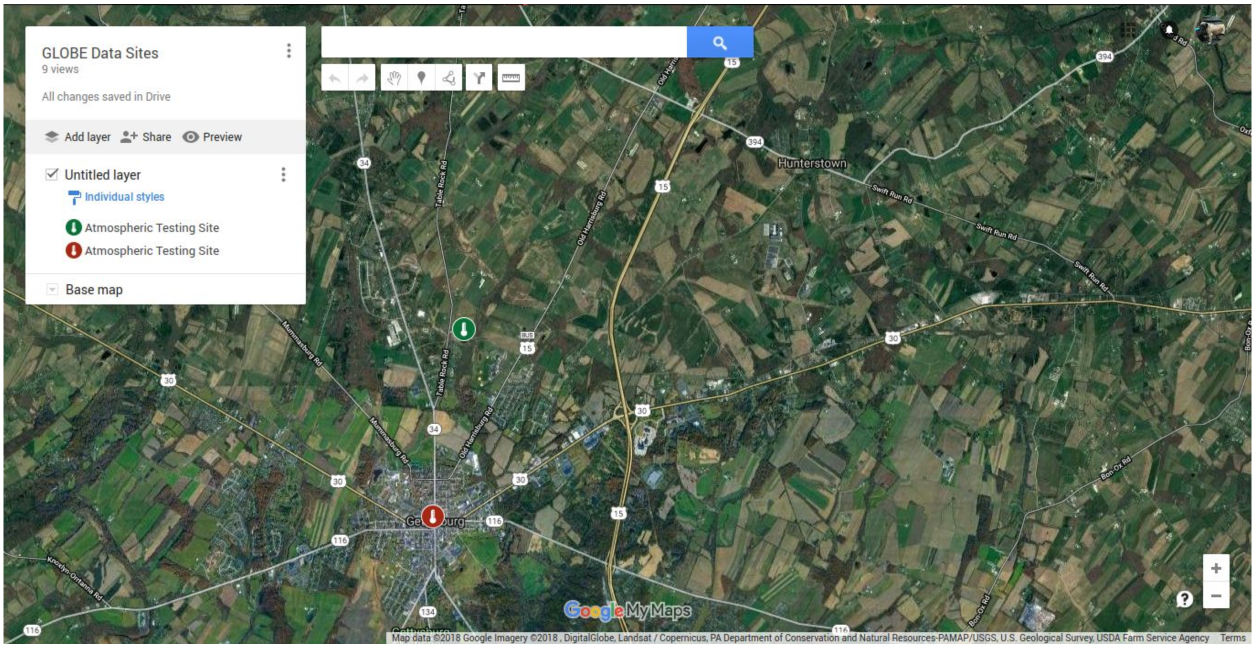
Cloud and Contrail Type

1. Look at all the clouds in the sky, in all directions.

2. Identify the types of clouds that are seen using the GLOBE Cloud Chart and the definitions found in Observing Cloud Type (shape and height).
3. Check the box on the Data Sheet for each and every cloud type seen on each level (low, mid, and high).
4. There are three types of contrails. Record the number of each type seen.

Cloud and Contrail Visual Opacity

1. Estimate how much light the cloud is letting through to the Earth's surface.
2. Classify visual opacity for clouds on each level (low, mid, and high).
    a. Reference a shadow for help:
        i. Transparent clouds in front of the Sun - crisp shadow with clear edge
        ii. Translucent clouds in front of the Sun - less crisp shadow with edges starting to become fuzzy
        iii. Opaque clouds in front of the Sun - very fuzzy and difficult or impossible to see shadow
3. Record which opacity classification best matches what is observed on each level.



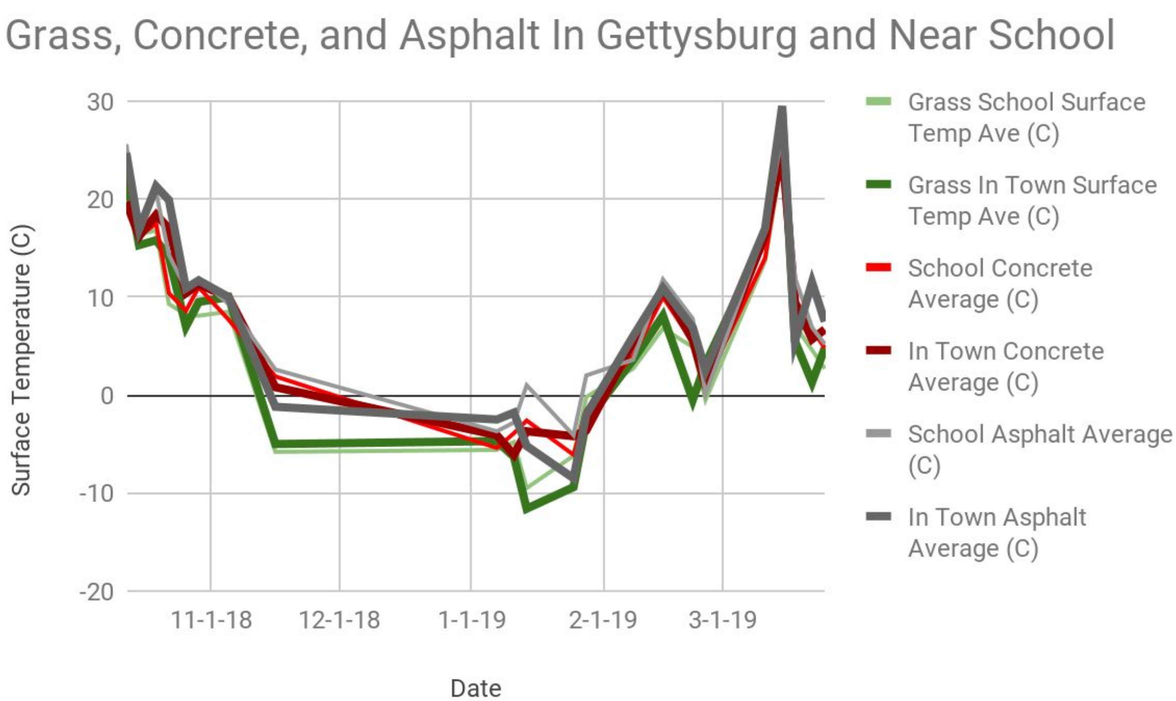
Map 1: This map shows the locations of testing.

Data Summary

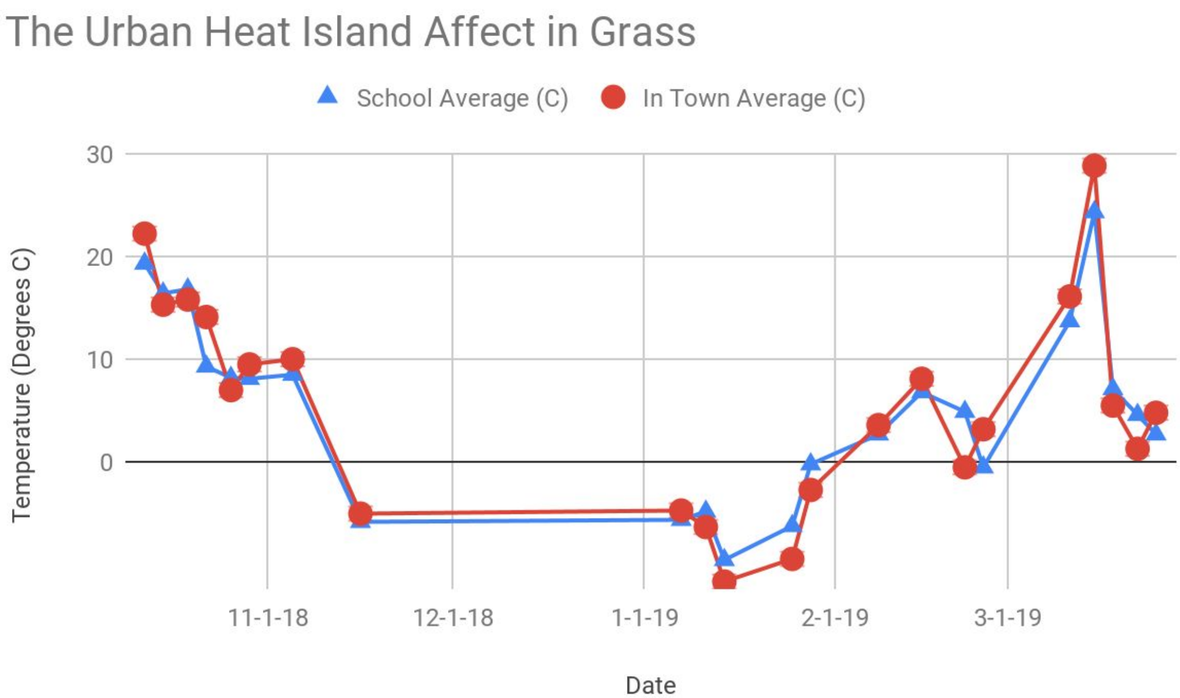
Date	**Grass School Surface Temp Ave (C)**	**Grass In Town Surface Temp Ave (C)**	**School Concrete Average (C)**	**In Town Concrete Average (C)**	**School Asphalt Average (C)**	**In Town Asphalt Average (C)**
10-12-18	19.3	22.2	23.3	19.7	25.6	24.7
10-15-18	16.4	15.3	16.2	16.2	16.6	16.9
10-19-18	16.8	15.8	17.5	18.4	20.7	21.3
10-22-18	9.3	14.1	10.4	17	14.3	19.9

10-26-18	8.2	7	8.6	10.4	10.8	10.9
10-29-18	8.1	9.5	11	11.3	11.9	11.7
11-5-18	8.5	10	7.7	10	9.3	10
11-16-18	-5.8	-5	1.9	0.8	2.6	-1.2
1-7-19	-5.6	-4.7	-5.4	-4.1	-3.7	-2.5
1-11-19	-4.8	-6.3	-3.9	-6.1	-2.8	-1.8
1-14-19	-9.5	-11.6	-2.6	-3.7	1	-5.2
1-25-19	-6.2	-9.4	-6.1	-4.2	-4.1	-8.5
1-28-19	-0.2	-2.7	-1.5	-3.6	2	-2
2-8-19	2.7	3.6	4	5.4	3.6	6
2-15-19	6.8	8.1	10	10.9	11.8	10.9
2-22-19	4.9	-0.5	5.4	5.6	7.8	6.9
2-25-19	-0.5	3.2	1.1	1	0.1	2.5
3-11-19	13.7	16.1	14	16.3	16.8	17
3-15-19	24.3	28.8	24.8	25	26.6	29.5
3-18-19	7.1	5.5	8.8	9.5	12	5.5
3-22-19	4.6	1.3	6.7	5.7	6.9	11.5
3-25-19	2.7	4.8	4.8	6.7	5.2	7.5

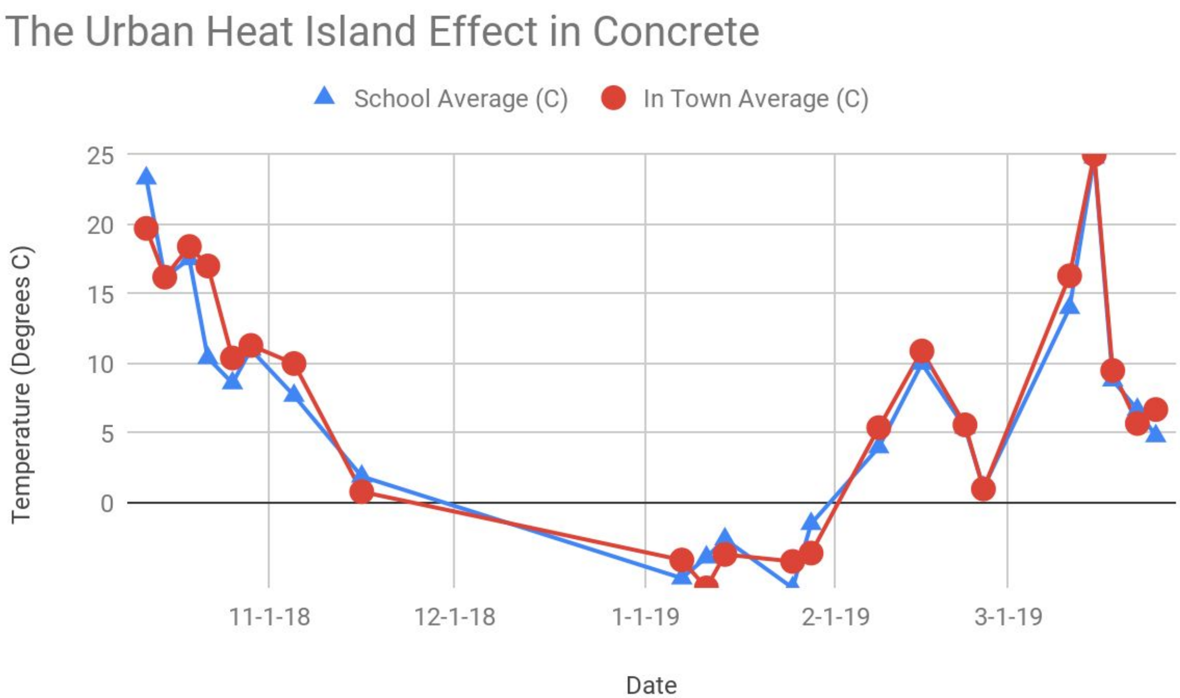
Table 1: This table shows all of the grass, concrete, and asphalt data in Gettysburg and near school.



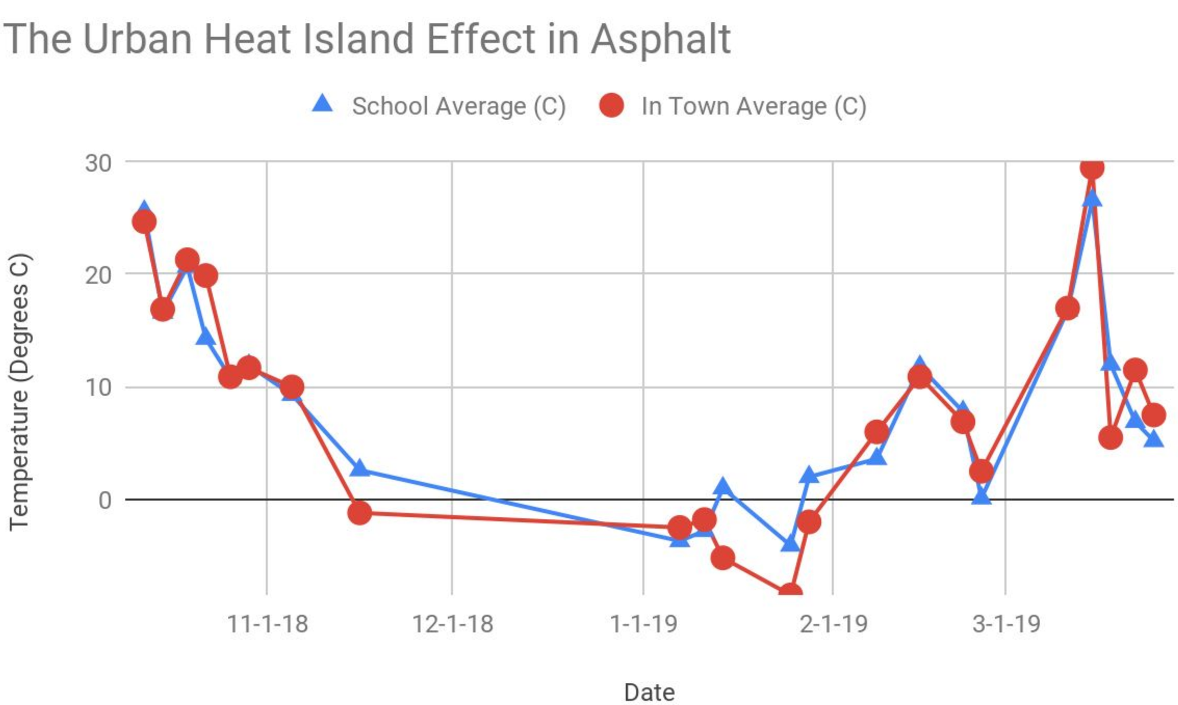
Graph 1: In this graph, which shows all data averages in one chart, there is a noticeable dip in temperature. This is most likely caused by changing seasons.



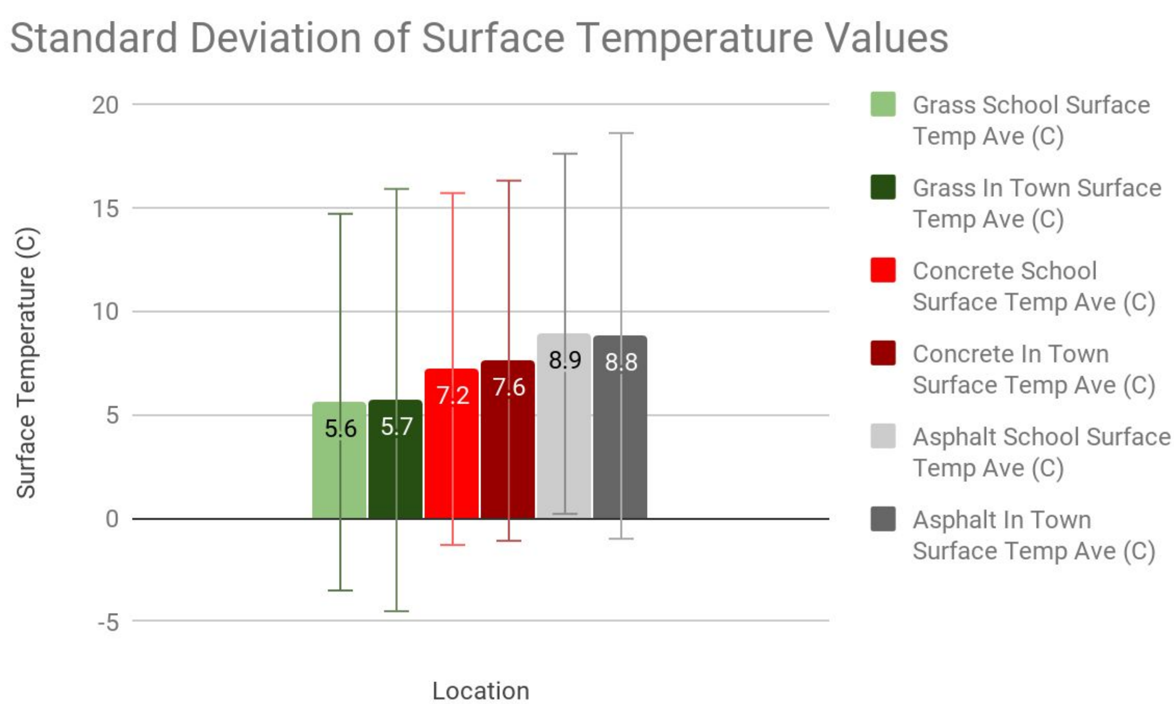
Graph 2: In this graph, which shows all of the grass data averages, the data in town and at school follow a similar pattern. This was most likely caused by the fact that the air temperatures are similar in the two places.



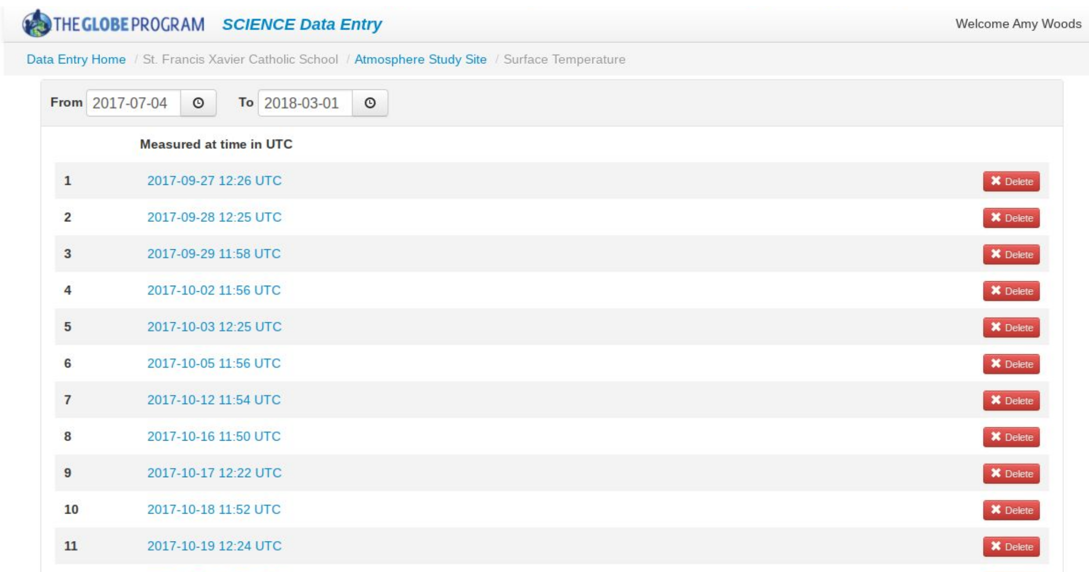
Graph 3: In this graph, which shows all of the concrete data averages, there is an increase in the in town temperatures towards the end of the data testing during mid-February heat wave followed the snow and cold fronts moving in.



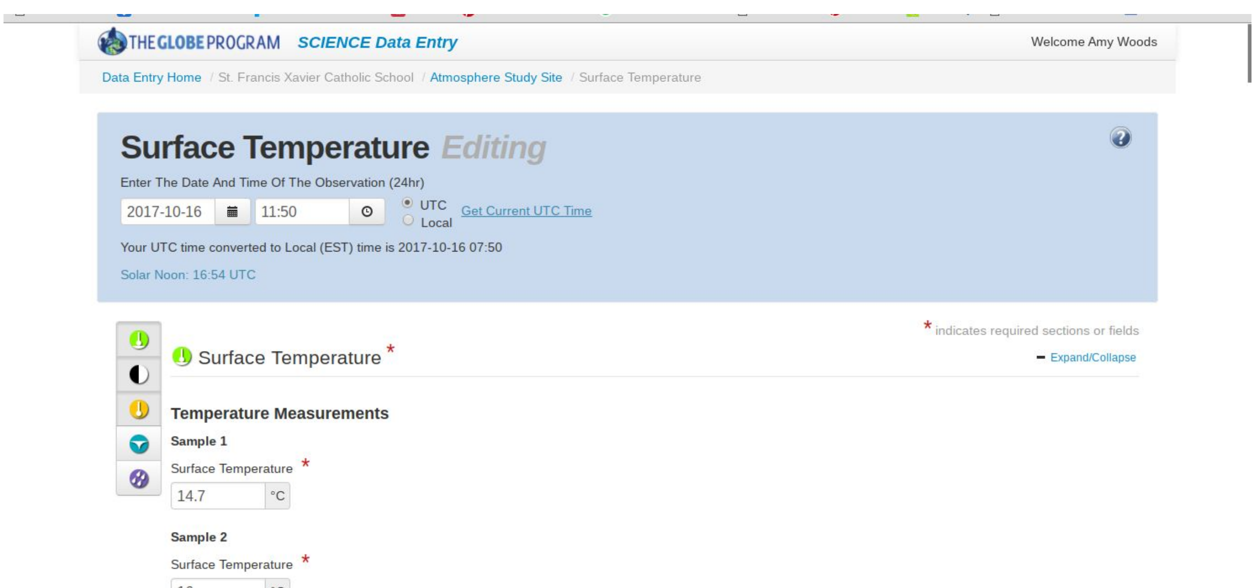
Graph 4: In this graph, which shows all of the asphalt data averages, there is a larger difference between in town and at school with the school temperatures higher than the in town temperatures. This is possibly caused by the asphalt at school being able to take in more energy because it is not blocked by buildings.



Graph 5: In this graph, showing the average temperatures for each site, the error bars are large. This is most likely due to the fact that the standard deviation, using the raw data, factors in temperatures from a very warm October and a very cold January.



Picture 1: This picture shows data previously entered into GLOBE.



Picture 2: This picture shows data being entered into GLOBE.

Analysis and Results

In the graphs the temperatures mostly follow a similar pattern. There are no major exceptions in the graphs. All of the data from in town Gettysburg is usually higher than its corresponding surface temperature near school. The surface temperature of asphalt tends to be higher than both grass and concrete.

It is possible that the surface temperature of asphalt tends to be higher than both grass and concrete is because of the different properties of the different surfaces tested. The grass is not as dense as concrete or asphalt so it will absorb heat faster but also release it more quickly. The concrete is more dense than asphalt and grass so it takes the longest to heat up but will take longest to cool back down. The asphalt is the darkest of the surfaces so it absorbs heat easily and is also dense, so it will retain heat for longer. It is clear that the temperatures taken Gettysburg are higher than those near school.

The outliers originally found in some of the school averages were thought to have been caused by incorrect use of the thermal glove in protecting the Infrared Thermometer from thermal shock. However, it was discovered were caused by a miss type, which was fixed. If the glove even shifts slightly, the glove’s temperature is recorded not the surface’s temperature and it takes some getting used to. Another possibility causing the outliers is the weather changing, sometimes drastically.

Discussion

This experiment focused on the question; how will the Urban Heat Island Effect be shown when taking surface temperature measurements in Gettysburg, PA and at St. Francis? The hypothesis states that if surface temperature measurements are taken in an urban environment, then the surface temperature reading will be higher because there is more asphalt, tall buildings, and dark surfaces in cities which will absorb more heat, thereby increasing surface temperature.

The school average tends to be below the intown average. However, there are times that the school average rises above the intown averages, but not very much.

Conclusion

The data partially supports the hypothesis because there is an occasional instance of the school average being above the intown average. In the concrete and asphalt, it was shown that there was an instance of the city being 5-10ºC as mentioned.

Some problems encountered during the experiment were finding where and when to test because of timing so that data was taken at the same time and if meetings could be arranged. There was an attempt to retrieve data from GLOBE from schools in Philadelphia and Pittsburgh, although it was not found. It was decided that testings would be taken at school and in Gettysburg after school on Mondays and Fridays. Another issue was getting used to the thermal glove. As this project is continued, data from a true urban and rural areas will hopefully be found to compare to understand the Urban Heat Island effect better. Cloud cover will also be analyzed. This project applies to the real world because the Urban Heat Island Effect is a problem in many areas and scientists are hoping to understand it better and its relationship to climate change because it seems to have an impact on the earth's energy transfer cycle.

Acknowledgements

I would like to thank Mrs. Woods who has gone into town every Monday and Friday to test surface temperature for me, Dr. Kevin Czajkowski who helped me design my project, and my mother who came out to test with me. Thank you to Mr. Todd Toth who provided the IRT

used in my project. Thank you also to the sixth grade who are taking measurements for me so that I can compare them for future competitions.

Badge Selections

Make an Impact

Understanding temperature is important to everyone in all communities because people need to know how to prepare themselves for the day and the days to come. Temperature affects how people dress, what outdoor activities can be done, how precipitation is formed, and the availability of flight at certain times. The Urban Heat Island is a major problem in many cities and has a major impact to many people. Even if it is a small increase in small towns, this contribution is important to take note of in relation to better understanding climate change.

STEM Professional

The researcher worked with two STEM Professionals. Dr. Kevin Czajkowski helped the researcher design the project and Mr. Todd Toth provided the IRT used in the project. Mr. Toth also provided data for the project, although it was decided that that the data could not be used because of how far away the data was taken from the other data that was used.

References

Allaby, M. (1999). How the weather works. London: Dorling Kindersley.

Baker, S. (2010). Climate change in the Antarctic. New York: Marshall Cavendish Benchmark.

Barry, R. G., & Chorley, R. J. (2010). Atmosphere, weather, and climate. London: Routledge.

Carson, M. K., Mackay, L., & Mackay, L. (2014). What makes a tornado twist?: And other questions about... weather. New York: Sterling Children's Books.

Cherry, L., & Braasch, G. (2018). How we know what we know about our changing climate: Scientists and kids explore global warming. Nevada City: Dawn.

Climate Central. (2019). Hot and Getting Hotter: Heat Islands Cooking U.S. Cities. Retrieved August 20, 2018, from http://www.climatecentral.org/news/urban-heat-islands-threaten-us-health-17919.

EPA. (2018, December 10). Heat Island Effect. Retrieved September 27, 2018, from www.epa.gov/heat-islands.

GLOBE. (2014). Surface Temp Protocol. Retrieved November, 2018, from https://www.globe.gov/documents/348614/7537c1bd-ce82-4279-8cc6-4dbe1f2cc5b5

GLOBE. (2017). Clouds Protocol. Retrieved November, 2018, from https://www.globe.gov/documents/348614/7b79ee82-ebd6-4382-9283-181a412f063f

Lutgens, F. K., & Tarbuck, E. J. (1998). The Atmosphere (Seventh ed.). Prentice-Hall.

National Geographic Society. (2012, October 09). Urban heat island. Retrieved 2018, from http://www.nationalgeographic.org/encyclopedia/urban-heat-island/.

Sears, K. (2017). Weather 101: From Doppler radar and long-range forecasts to the polar vortex and climate change, everything you need to know about the study of weather. New York: Adams Media.

UCAR. (2011). Urban Heat Islands. Retrieved 2018, from https://scied.ucar.edu/longcontent/urban-heat-islands