Urban Heat Island Project Report

BSC 4861L

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Introduction

Recent scientific studies have found that, although developed areas account for only .5% of earth's total land area, roughly 50% of Earth's population now lives in areas that can be considered urban (Schneider 2009). As these densely populated communities are permanent elements of modern society it is essential that any efforts to increase global ecological sustainability address the negative environmental impacts of urban areas. One negative effect that developed areas have on the environment is a form of local climate change known as the "urban heat island effect." The purpose of this project is to examine exactly how the infrastructure of an urban area contributes to significant temperature increases, to describe the impacts this effect has on these areas, and to determine solutions for this widespread problem. We will begin with a discussion of the processes and structures that cause this phenomenon.

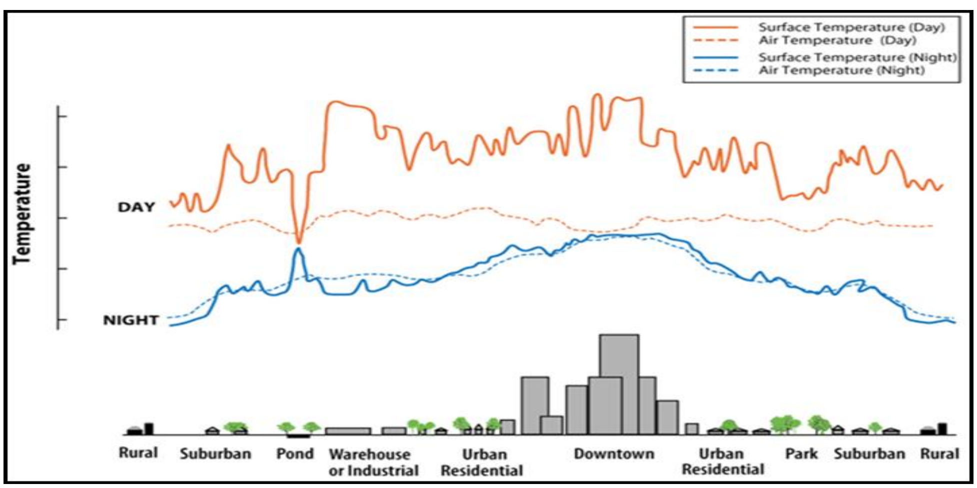

Figure 1- The more urban infrastructure an area has the more severe its temperature fluctuations are.

An Urban Heat Island (UHI) is defined as an urban area containing hotter surface and atmospheric temperatures than nearby rural areas (see Figure 1). The two types of urban heat islands are surface urban heat islands and atmospheric urban heat islands. The temperature fluctuations observed on urban surfaces are larger than those observed in the air above them. During the day the average surface temperatures of developed regions, which often contain surfaces such as asphalt and cement, are 18-27°F warmer than those of rural areas. The intensity of surface UHI's varies due to the weather and other factors. When the sun warms these dry urban surfaces the surfaces tend to absorb large amounts of thermal heat, and retain this heat for hours, before slowly releasing it as **sensible heat** (heat transferred through the air) into the atmosphere. There are two types of atmospheric UHI's: the canopy layer is from the ground up to roof tops and tree tops; the boundary layer starts above the canopy layer and extends upward one mile from the surface. Canopy layer is the type we will refer to here when mentioning atmospheric UHI's, and these generally do not become significant until the night time, because it takes so long for the heat to be released from urban surfaces (EPA 2010). A city with one million inhabitants can have an average air temperature that is 1.8-5.4°F warmer than the air of nearby areas. The combined effects of UHI's involving both surfaces and the surrounding air cause urban areas to be, on average, about 10°F warmer than surrounding natural areas (EPA 2010).

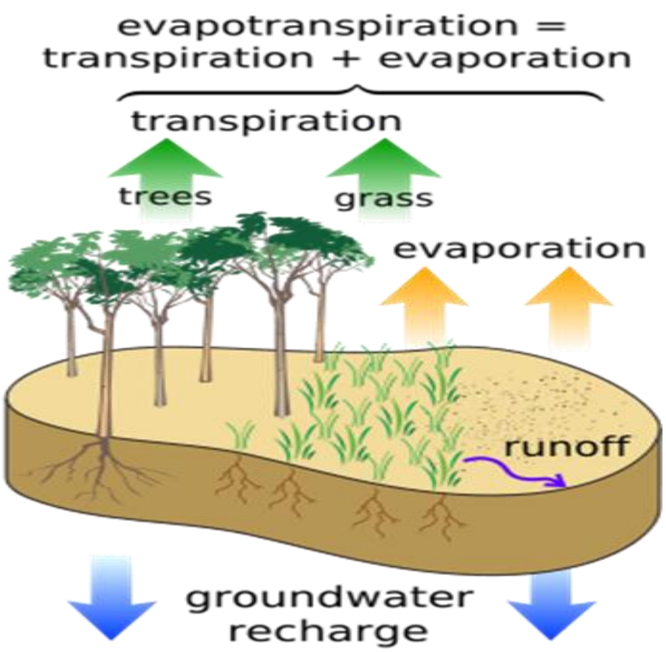

Figure 2- Transpiring plants and permeable soils help maintain the natural water cycle in an area.

UHI's are primarily caused by the removal of natural plant species and increase in urbanization, which is necessary for the development of the urban infrastructure, such as buildings, roads, and sidewalks. For this reason trees and vegetation, or the lack thereof, are the main focus of this project. In addition to providing temperature-decreasing shade, plants carry out numerous biological processes that serve to regulate their local climate within their ecosystem. One especially important process plants carry out, in regards to temperature regulation, is known as evapotranspiration. Evapotranspiration is the transport of water from surfaces such as soil, vegetation, and tree canopies to the atmosphere (see Figure 2). This is relevant in a discussion of heat islands because when plants absorb the sun's heat rays for photosynthesis they direct this energy into water which is then evaporated, releasing **latent heat** (heat transferred through a change in the state of matter, such as evaporating water) from the plant's surface into the air (Burba 2010). Evapotranspiration has a natural cooling effect, which is central to the UHI phenomenon. Urban infrastructures are made of dry, impermeable surfaces. Therefore, the "latent heat flux," or the effects of natural vegetative cooling, is dramatically decreased in cities. Furthermore, the process of photosynthesis involves plants sequestering CO2 from the air in order to build biomass. So, when vegetation is replaced with urban areas CO2-removing organisms are replaced by CO2-emitting infrastructure and technologies (such as cars and factories). The absence of vegetation causes the high levels of heat to become trapped within the atmosphere surrounding the area. CO2 retains heat, and is the primary heat-trapping agent that is causing climate change on a global scale. Finally, evapotranspiration also accounts for around 10% of the moisture in the earth's atmosphere ("The Water Cycle"). A significant lack of this hydrological process can reduce rates of precipitation, further worsening the problem of dry, heated urban infrastructure (Cain, et al 2009). Water quality also decreases where no plants exist to complete the naturally-cleansing water cycle (EPA 2010). Cyclic CO2 patterns and atmospheric moisture are aspects of UHI's that will require careful study and measurement if any solutions to this warming effect are to be found.

Also important in our discussion of UHI's is albedo: the capacity of a land surface to reflect solar radiation (Cain, et al 2009). Albedo reflectivity is generally evaluated on a scale from 0 to 1; 0 means the surface absorbs all incoming solar heat, and 1 means that it reflects all of it (EPA 2010). Since 43% of solar energy exists within the visible wavelengths, the color of a surface primarily determines its reflectivity. Darker colors absorb more heat from the sun and lighter colors reflect more of it (see Figure 3). In general the surfaces of city infrastructures tend to have reflectivity's closer to "0 albedo" than the light greens of most natural plant life. Another factor that lowers albedo is urban geometry. Tall buildings tend to cause very thorough absorption of sunlight, both by absorbing thermal energy themselves and reflecting it onto other surfaces. Also, at night tall buildings tend to trap the sensible heat being released from urban surfaces into the air, and prevent it from entering the atmosphere (EPA 2010). Figure 3 shows the albedos of both man-made and natural surfaces.

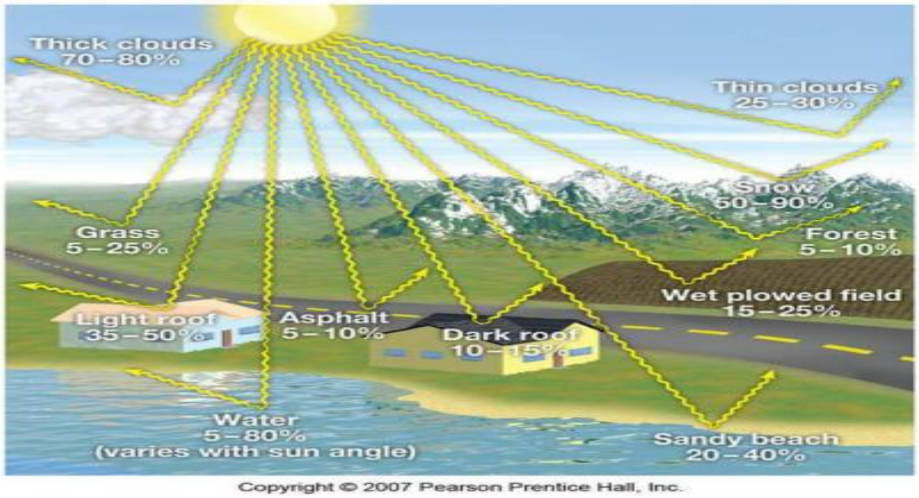

Figure 3- Albedo reflective percentages.

Lastly, anthropogenic heat is yet another contributor to UHI's. This is heat generated from manmade sources such as cars and factories, which are also primarily responsible for CO2 emissions. Related to the idea of this man-made heat is the fact that the heat created by UHI's forces increases in the use of cooling technologies, such as air conditioning systems in buildings. These increases in energy consumption required to cool these large areas of infrastructure then cause larger amounts of CO2 to be emitted into the atmosphere, and it was discussed above how CO2 intensifies this localized global warming. UHI's create a destructive cycle of excessive heating, energy consumption, and pollution that threatens the health of everyone living within these urban environments (EPA 2010).

UHI's are an issue that has only begun to be addressed by governments and businesses, yet there are techniques for overcoming their effects that are now rapidly being optimized. One especially promising potential solution is the use of a structure known as a "green roof." A green roof is created by placing living vegetation, often native species, on top of a roof within an urbanized area. There are two types of green roofs: intensive and extensive, with intensive ones requiring far more maintenance. An intensive green roof holds more soil, allowing it to support plants with larger root systems, such as trees. An extensive green roof generally supports plants like grasses and shrubs, with smaller root systems (see Figure 4). On these roofs the natural carbon sequestration and evapotranspiration processes discussed above are allowed to occur in an elevated position, providing numerous benefits, including a decrease in the effects of both surface and atmospheric UHI's. Utilizing the cooling effects of plants, as well as their increased reflectivity, green roofs reduce UHI's by lowering roof temperatures by up to 45-50°F (UCF LNR 2010).

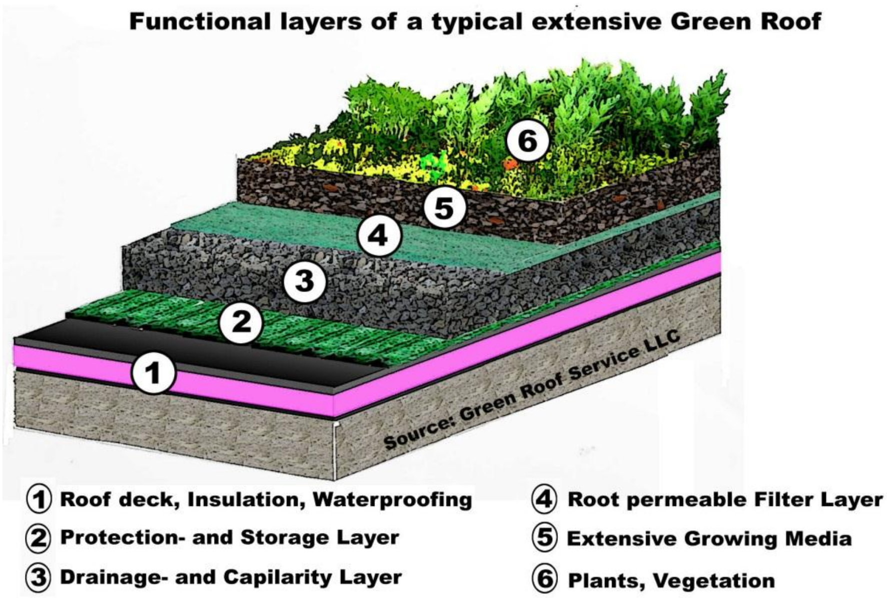

Figure 4- Green roofs have plants that provide natural cooling, and reduce the effects of UHI's.

Another increasingly popular way to address UHI's is through the use of "cool roof" technology (see Figure 5). This technique uses roofing materials with a high level of solar reflectance, meaning they direct sunlight and heat away from the building. The materials comprising a cool roof also have high thermal emittance, meaning they readily release absorbed heat, which causes significant temperature reduction in hot, sunny climates. During peak summer weather cool roofs can stay up to 50-60°F cooler than roofs made from conventional materials. Leading cool roof brands boast an albedo of .65 or higher (1 being complete solar reflectance) for low-slope roofs, and .25 for

Figure 5- This is an example of a "cool roof," which is made from materials that force solar heat away from the building.

sloped roofs. There are also many techniques of minimizing UHI's that do not involve roofs, including planting more native vegetation in urban areas and using alternative paving materials. Urban heat islands are a complex problem that will require large-scale transitions in the development of urban infrastructure and technology if they are to be thoroughly managed (EPA 2010).

Now that we have considered the causes of this phenomenon, and current techniques for minimizing it, we will examine the direct impacts that UHI's have on both the urban communities themselves and the world around them. We will consider these ramifications within the context of the main aspects of a sustainable, modern society, and what is called the "triple bottom line": social, economic, and environmental implications. This will lead into our explanation of how we plan to conduct an experiment analyzing UHI's on the main campus of the University of Central Florida.

Triple Bottom Line:

Economic

Florida's per capita energy consumption is extremely sensitive to higher temperatures, and this is shown by increases in residential consumption of 5.3%, 11.6%, and 18.8% when temperatures increased by 1 degrees, 2 degrees, and 3 degrees respectively (EPA 2010). In cities it is estimated that UHI's have caused increases in the use of air-conditioning that have elevated peak electricity demands by 5-10% (Akbari 2010). Therefore, from an economic perspective it is becoming increasingly beneficial to invest in a green roof, or cool roof, design for cooling the tops of buildings. Different UHI-reducing techniques can cut down on energy costs in different ways, and buildings of any size can use them to lower their bills. While they have an installation cost of roughly $10-25 per square foot it is estimated that green roofs can save a building between 7-10% of its total energy costs, with reductions as much as 25-50% for the energy consumed by the floor directly below the roof (EnergyStar 2007). Similar benefits exist for the use of cool roofs or homes using roofs that meet Energy Star qualifications (.65 albedo or higher for a flatter roof), which can save an average of $200-400 annually (EnergyStar 2007). So, roof-treatment methods such as planting vegetation that will carry out evapotranspiration, or building roofs with more reflective materials, can reduce the costs of the energy consumption necessary to maintain comfortable temperatures within a building. Another option for dealing with excess sunlight above urban buildings is the installation of solar panels. Installing solar panels on the roofs of buildings converts the heat that would otherwise be absorbed by the roof into electricity. This not only reduces the surface UHI effect it also produces a portion of the tremendous amount of energy needed to power a building on a daily basis. With recent investments in urban infrastructure, including those funded by the American Recovery and Reinvestment Act (ARRA), the government has increased tax breaks associated with solar energy usage. The current tax credit for solar panels installed on a home are up to 30% of the cost of the unit and $500 per .5 kW of power capacity (EnergyStar 2007). This can add up to tremendous savings over time, and as these technologies evolve consumers will begin to see returns on their investments in a shorter amount of time. With the large financial and government incentives involved in installing temperature-reducing species, equipment, and energy technology on urban roofs the solutions to UHI's will have a huge impact on urban economies in the future. Also, these new methods will create new jobs, such as horticulture specialists needed for long-term green roof maintenance, adding to the economic benefits caused by addressing the urban heat island effect (EPA 2010).

Social

The heat increases associated with UHI's have many negative social implications for those living within these areas, and most of these are far more harmful than a simple lack of comfortable temperatures. Most social issues caused by UHI's are related to elevated urban temperatures, and among these is a rise in the frequency of heat stress. People experiencing heat-related symptoms such as fatigue, heat stroke, and dehydration has become a more common occurrence due to temperature increases in urban areas. According to the Center for Disease Control, there were more fatalities between 1979 and 1999 collectively that were due to excessive heat exposure than due to hurricanes, lightning, tornadoes, floods, and earthquakes combined (EPA 2010). In addition to directly heat-related symptoms elevated temperatures also have very serious indirect repercussions in regards to health. UHI's cause the people living within them to become more susceptible to pathogens because bacteria thrive more in warmer temperatures. This is also true for disease-carrying pests such as mosquitoes, and allergen producers like molds, mildews and pollens (Yow 297). At the same time, understanding UHI's, and not simply staying inside and turning up the air conditioning, can provide opportunities for positive social change. Efforts to reduce the urban heat island effect are a chance to cause social and cultural transitions towards understanding, and appreciating, natural ecology. By developing sustainable ways to cool urban areas, educating people on the importance of plants, and encouraging the use of natural areas the solutions to this phenomenon can provide a convincing reason to increase environmental awareness in our society.

Environmental

The urban heat island effect has severe negative implications for the environment. When plants are removed and replaced with urban infrastructure CO_2 sequestration is greatly reduced, and it is completely nonexistent without the presence of plants. Increased CO_2 levels caused by a lack of sequestration, as well as increased emissions from urban areas, accelerate global warming: a huge threat to the environment all over the planet. In addition to affecting carbon in the atmosphere, a lack of vegetation also affects the water cycle. Water is one aspect of nature that is directly linked to the survival of all species. The replacing of plants with impermeable surfaces does not allow water to filter into the ground, which inhibits the replenishing of underground water sources. In these cases rain water must run off of roads, or evaporate, instead of being stored in the soil where it can be useful to vegetation. Water running off of urban surfaces leads to increased water temperature as well as elevated levels of pollutants in the water (EPA 2010). The grime that is left behind from cars, bikes, people and their pets are all washed into the drainage system with the rain water. This water often drains indirectly into natural bodies of water. Precipitation that was once naturally cleaned by plants is now inundated with harmful chemicals, and is also heated by the urban surfaces. These increases in temperature and chemicals can be harmful to natural habitats, and the species that live within them. Another negative environmental impact that the urban heat island effect has on the water cycle is reduced rates of precipitation, which is caused by a lack of evapotranspiration. Also, local levels of biodiversity, which are obviously extremely low in urban areas already, can also decrease as a result of rising temperatures. However, many of these negative impacts found in urban areas can be reduced by increasing the cities' vegetation density, and the biological processes that this can provide. Due to the abilities of plants to provide habitats that increase local biodiversity, carry out the heat-reducing water cycle, and sequester CO_2 the strategic use of vegetation in urban areas (such as planting native species and installing green roofs) has massive potential for reversing the negative environmental impacts of the urban heat island effect.

Overview

The purpose of developing this thorough understanding of the urban heat island effect is to allow the optimum design of an experiment which will study exactly how this phenomenon affects the areas within the main campus of the University of Central Florida. The diverse landscape comprising UCF's 1,415 acre campus makes it an excellent environment in which to test the effects that both developed and natural areas have on UHI's. With 72 acres of lakes and ponds, 191 acres of conservation easements, and 246 acres of wetlands and riparian habitat protection zones virtually every biological process relevant to UHI's is present. Also abundant on campus are the urban surfaces needed for the study, as there is over 6,032,365 square feet of urban infrastructure from buildings alone (Town and Gown). UCF is already making focused, large-scale efforts to both study, and reduce, the effects of UHI's around the campus. The University's Department of Landscape and Natural Resources has created an extensive green roof on top of the campuses' Physical Sciences Building (see Figure 6), which is accompanied by a Weather Station which monitors a great deal of the UHI-related patterns present on the roof (UCF LNR 2010). Furthermore, through methods such as systematic urban forestry management, this department is working to place plant species around the campus that will both beautify different areas and promote the planting of native vegetation. Clearly, UCF is a place that would be receptive to ideas regarding additional changes to its urban infrastructure in the future.

We have conducted an experiment that measures UHI-related variables across the entire range of urban development from completely vegetated areas to completely developed regions and every degree of development in between. Our study monitored temperature fluctuations and changes in humidity in locations across this entire range. Comparing data from areas representing different degrees of urban development and biological activity allowed us to draw meaningful conclusions about the

Figure 6- This picture shows the green roof on top of the Physical Sciences Building at UCF.

connection between the features of a given urban area and their impact on localized climate alterations. By obtaining results that have improved our understanding of exactly how UHI's are impacting the campus, we can help develop viable and sustainable solutions that will benefit UCF in the future.

Our UCF contact for this project is the UCF Landscape and Natural Resources Assistant Director and Land Manager, Alaina Bernard-Kitchings, who has provided us with information and the necessary tools to run our experiment.

Methodology

Purpose: To study how areas with differing amounts of vegetation and urban surfaces influence the Urban Heat Island effect on the main campus of the University of Central Florida. We will do this by recording temperature and humidity fluctuations at different locations with differing degrees of vegetation density.

Hypothesis: The more urban surfaces there are in a location, the higher the temperatures in that location will be.

Materials: 15 Hobo Pro V2 Data loggers (capable of continuously measuring, and recording, relative humidity and temperature at each location), Hobo Shuttle (data extraction device), laptops, GPS, solar radiation shields, metal ties, plastic zip ties, measuring tape, six foot ladder, 4 meter transect.

Procedure: We first conducted a survey to decide the locations at which we would record the data. We set out to place the 15 data loggers in 15 different locations based on the percent ratio of vegetation to urban surfaces within a 4 meter diameter around the HOBO units. The ratio of ground vegetation-to-urban infrastructure at the 15 locations where the data loggers were installed during the 14 day recording period are shown as the Installation Location Percentages (See Table 1). We also measured the Canopy Percentage at all 15 locations, because canopy cover greatly affects the amount of vegetative cooling happening at a location.

Location	Ground Cover Percentage	Canopy Cover Percentage	Location Type	Description
1- Psychology Building	100%	75%	Vegetative	Buildings and sidewalks present as well as a large amount of landscaping, including memory mall which contains an abundance of grass.
2- Between Health and Public Affairs I and II	25%	75%	Hybrid	Placed in a tree inside of a plot of vegetation in a court yard. It is surrounded by buildings and sidewalks, as well as trees and bushes.
3- Student Union	5%	> 75%	Hybrid	Placed just outside of the Student Union tethered to a cypress tree in the cypress dome surrounding the Union boardwalk.
4- Faculty Parking Lot C	0%	0%	Urban	Attached to a light post in the middle of a parking lot, above a concrete sidewalk and surrounded by asphalt.
5- CREOL Building	50%	0%	Urban	Tethered to a tree in a largely urban area. This is above a grassy plot, next to a sidewalk, and surrounded by buildings.
6- Arboretum Tree	75%	50%	Hybrid	Attached to a pine tree near the arboretum trailer in close proximity with a sidewalk and the Harris Engineering building.
7- Honors College Tree	25%	>75%	Hybrid	Placed in an oak tree in the Honors College garden. This area is covered with paver stones but has an abundance of planted vegetation.
8- Burnett Honors College Tree	50%	25%	Hybrid	Attached to a tree in front of the Honors College near Visual Arts. Above a concrete sidewalk, near a parking lot, and next to a grassy plot.
9- Light post near Computer Center II	25%	0%	Urban	This logger was next to a loading dock that is completely covered in concrete and surrounded by buildings. The logger was attached to a light post, and above some landscaped bushes.
10- Behind Recreation Building at Lake Claire	75%	0%	Hybrid	The logger was attached to a light post and was directly behind the recreation building. There was a wooded area on the backside and some small buildings and a sidewalk on the front side.
11-Trails behind Lake Claire	100%	100%	Vegetative	Secured to a tree and surrounded completely by vegetation.
12- Towers (light post)	0%	0%	Urban	Attached to a light post above a sidewalk surrounded by buildings. Even the grass around this location was replaced with Astroturf.
13- Oak Hammock	>75%	>75%	Vegetative	Placed in an oak tree and surrounded completely by vegetation.
14- CREOL Pond	75%	100%	Vegetative	Attached to a pine tree and surrounded completely by vegetation.
15- In front of Teaching Academy	75%	0%	Hybrid	Above a grassy area containing placed trees, and next to a sidewalk lined with light posts. A parking lot is nearby.

Table 1: The Location Type was determined by averaging together each location's percentages for ground cover and canopy cover.

Installation: The sensor of each logger was placed in a solar radiation shield so that differing albedos would not affect our readings. Each data logger was installed ten feet off the ground, below the canopy, in order to account for temperature fluctuations resulting from changes in elevation, as well as heat being released from the ground's surface. Metal and plastic zip ties were used to secure the loggers to light posts and trees (see Figure 7). Since we used the radiation shields, and tied the loggers directly to poles and trees at the locations, the installations were quick and simple.

Figure 7- Sensor installed at location

Data recording and analysis: We used a shuttle that was compatible with the HOBOware software to offload the data from the loggers onto the laptops. The data recorded included temperature and relative humidity and these readings were taken at 15 minute intervals for 14 days. We analyzed the data using HOBOware, and then exported the data into a Microsoft Excel spreadsheet in order to further manipulate and organize the data. From the data we determined how the varying degrees of vegetation density influenced the temperature at each location. If there were any variables that may have affected our recordings, we took note of them and included them in our report.

We averaged the temperatures from each data logger at noon and midnight for all 14 days, in order to analyze the temperatures during both the day and night. We then put this data into graphs and tables for analysis.

Results

Overall our data supports our hypothesis (see fig.8). The areas with more urban infrastructure experienced higher temperatures than those with large amounts of vegetation. With an average temperature in the urban areas of 71.67 degrees Fahrenheit and an average temperature in the vegetated areas of 70.08 degrees, indicating a difference of 1.59 degrees between these two location types, we fail to reject our hypothesis. The average temperature for the hybrid areas of 71.18 degrees shows that our data favors the warmer side of our temperature range. This also suggests that the ratio of urban surfaces to vegetation has a significant and quantifiable effect on the temperatures in a given area.

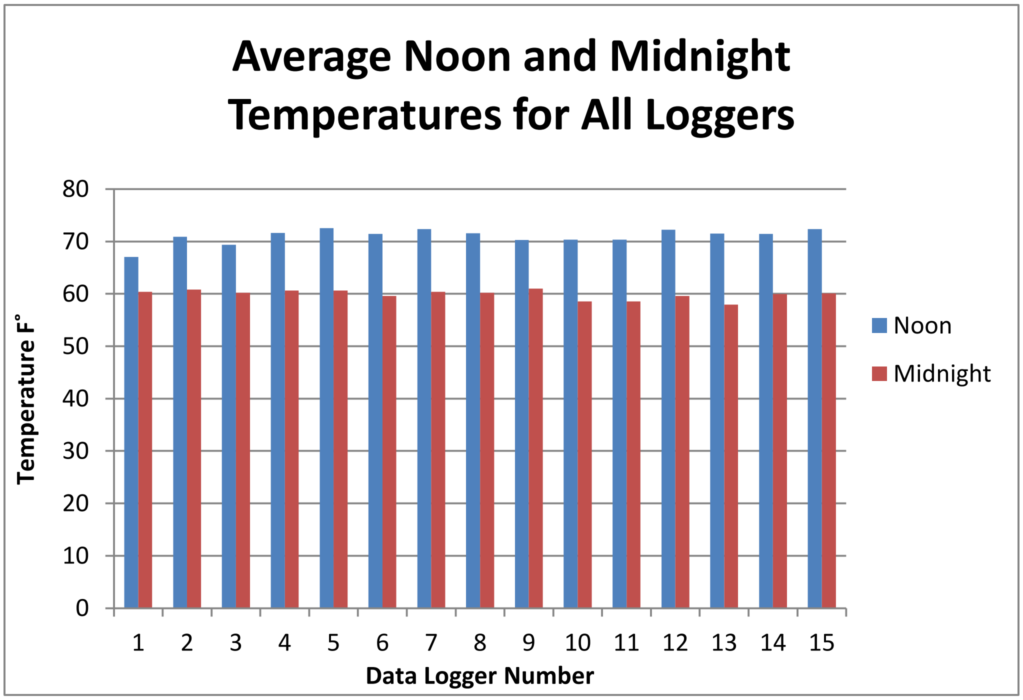

Figure 8- Comparison of all loggers' average temperatures at 12:00:00 and 24:00:00.

Figure 9 shows that our results are congruent with our hypothesis. The urban areas had warmer temperatures during both day and night time in comparison to the vegetative areas. Logger 9 recorded the highest nightly temperatures and the lowest daily temperatures. This logger was placed in a shaded area and was not exposed to direct sunlight. This accounts for the lower day time temperatures. The high nightly temperatures make sense because this logger was next to an area that is 100% urban. The urban surfaces surrounding Logger 9 absorbed the heat from the sun during the day and then released the heat at night keeping the surrounding area warmer than the other locations. Vegetative Logger 13 recorded the lowest night time temperatures overall and recorded lower temperatures than all of the loggers placed in urban locations. Although this location experienced average temperatures during the sunlight hours, the vegetation kept the area very cool at night. During the day logger 1, which was in a vegetated area, recorded the lowest temperature and logger 5, which was in an urban area, recorded the highest.

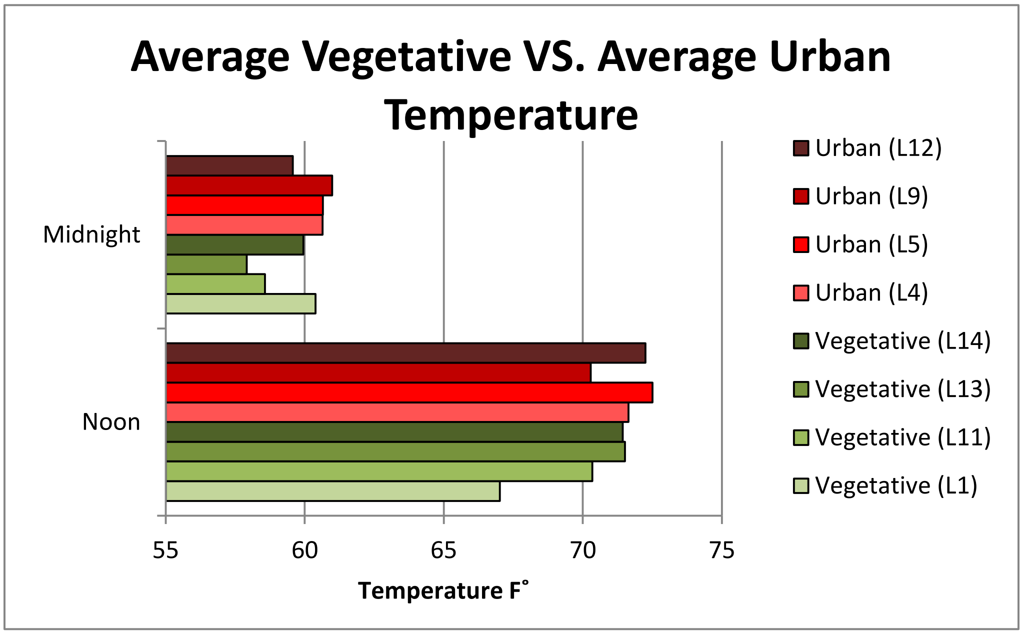

Figure 9-Comparison of the urban and vegetative locations temperature averages

Table 2 shows that the average temperatures at the 15 locations can vary by as much as 5 degrees during the day time and 3 degrees during the night time. Evapotranspiration causes there to be larger temperature fluctuations in vegetated areas than there are in urban areas during the day. At night urban surfaces release their heat, and this does not allow for as much cooling as evapotranspiration.

Comparing the temperatures in Table 2 shows the differences between the vegetative and urban location temperatures. Vegetative loggers 1, 11, 13, and 14 all show lower nightly temperatures than the urban loggers 4, 5, and 9 but not urban logger 12. Urban logger 12 may have lower nightly temperatures due to the ice rink that UCF is currently operating in the area. The vegetated areas are also cooler during the day than the urban areas, with the exception of logger 9, which is in the shade. The temperatures of the hybrid areas lie in between the high temperatures of the urban areas and the low temperatures of the vegetated areas for both the day time and night time.

Location	Ground Cover Percentage	Canopy Cover Percentage	Location Type	Average Temperature 12:00	Average Temperature 24:00
1- Psychology Building	100%	75%	Vegetative	67.01	60.38
2- Between Health and Public Affairs I and II	25%	75%	Hybrid	70.9	60.82
3- Student Union	5%	> 75%	Hybrid	69.38	60.2
4- Faculty Parking Lot C	0%	0%	Urban	71.64	60.64
5- CREOL Building	50%	0%	Urban	72.51	60.66
6- Arboretum Tree	75%	50%	Hybrid	71.43	59.58
7- Honors College Tree	25%	>75%	Hybrid	72.35	60.38
8- Burnett Honors College Tree	50%	25%	Hybrid	71.57	60.22
9- Light post near Computer Center II	25%	0%	Urban	70.28	60.98
10- Behind Recreation Building at Lake Claire	75%	0%	Hybrid	70.32	58.55
11-Trails behind Lake Claire	100%	100%	Vegetative	70.34	58.57
12- Towers (light post)	0%	0%	Urban	72.25	59.57
13- Oak Hammock	>75%	>75%	Vegetative	71.52	57.92
14- CREOL Pond	75%	100%	Vegetative	71.44	59.95
15- In front of Teaching Academy	75%	0%	Hybrid	72.33	60.08

Table 2: Average temperatures for 12:00:00 and 24:00:00 at each logger location.

According to table 3 the difference in the average temperatures at mid-day between the vegetative areas and urban areas is greater than the difference in the average temperatures at midnight. During the day, sunlight allows plants to carry out natural evaporative cooling which lowers the day time temperature in the area. In urban areas the sunlight is absorbed by the urban surfaces, and is retained until the night time. This explains why urban areas have higher temperatures during the day. During the night both urban and vegetative surfaces are releasing heat, as opposed to the day time when only vegetative surfaces are releasing heat. This explains why the difference in the average temperature between the two types of locations is greater during the day than during the night.

Vegetative vs. Urban Overall Average		
	Mid-day	Midnight
Vegetative	70.08	59.21
Urban	71.67	60.46
Difference	1.59	1.25

Table 3: Comparison of the average mid-day and midnight temperatures for all of the urban and all of the vegetative loggers.

We observed latent heat fluxes in the vegetative locations and sensible heat fluxes in the urban locations. These can be seen in Figures 10 and 11. The latent heat fluxes demonstrate a more erratic fluctuation at night, because the plants are performing their natural processes and releasing heat during random periods of evapotranspiration. The sensible heat fluxes contain quick jumps early in the night but then become steadier later in the night. There is less fluctuation in the urban locations because the urban surfaces are constantly giving off the heat they stored up all day, having one or two noticeable jumps in temperature early in the night. The vegetative locations experience more sporadic heat releases, because variables such as the weather affect rates of evaporation during the night.

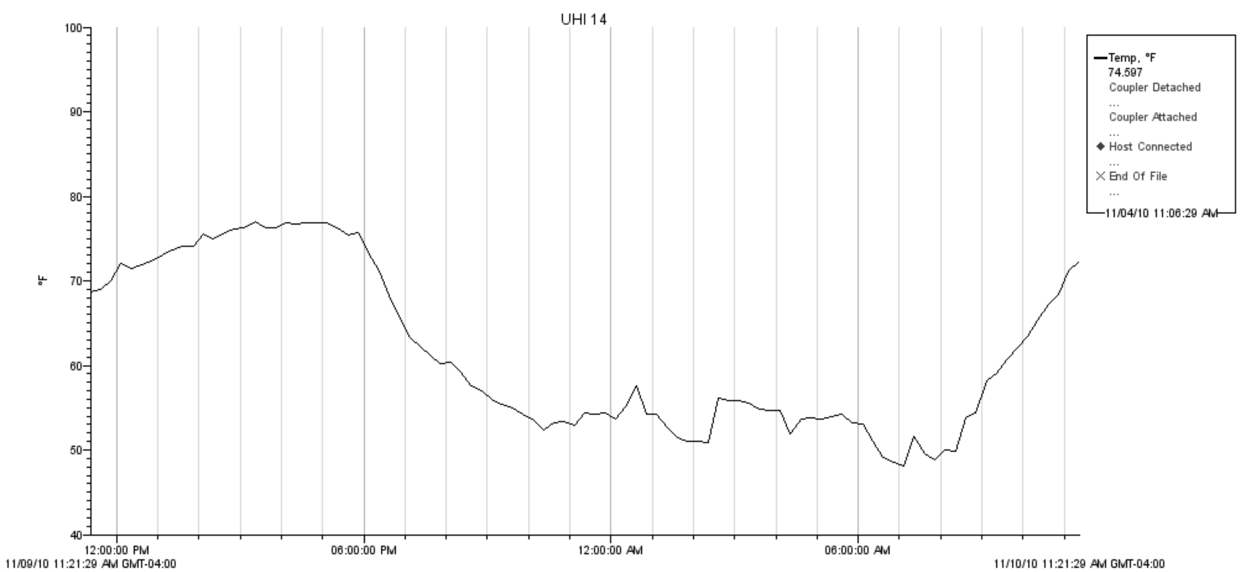

Figure 10: Logger 14 vegetative latent heat fluxes from 12:00 PM on 11/9/10 to 12:00 PM on 11/10/10

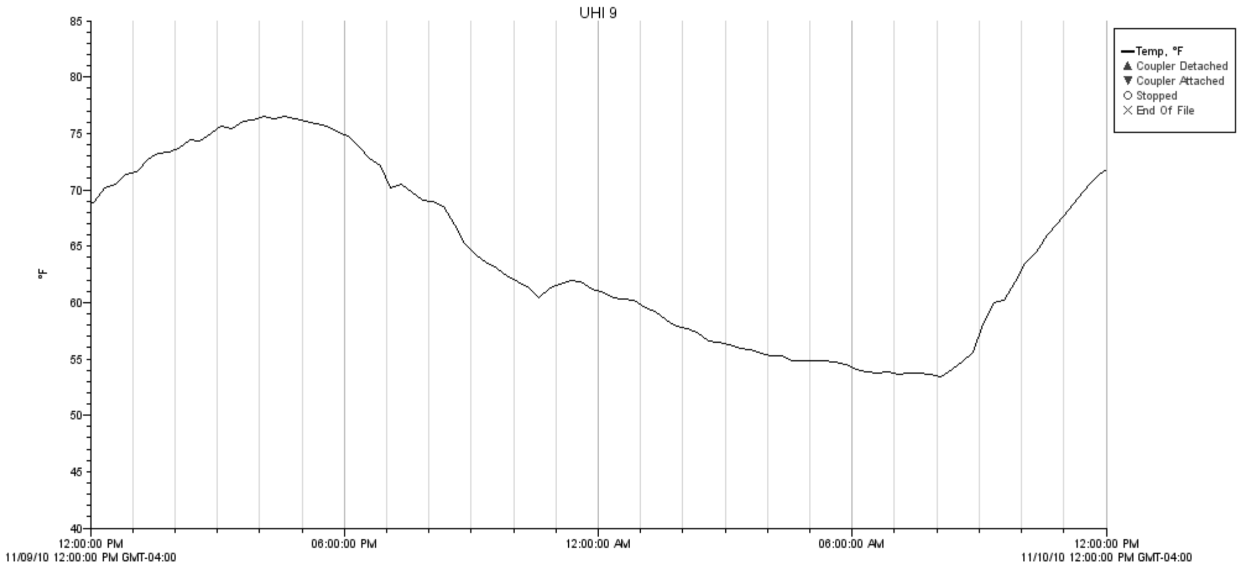

Figure 11: Logger 9 urban sensible heat fluxes from 12:00 PM on 11/9/10 to 12:00 PM on 11/10/10

Barriers

When writing our proposal and designing our experiment we decided that there would be 5 different percentage categories for our data loggers to be placed in, being 100%, 75%, 50%, 25% and 0% vegetation. We plotted these points on a map of the campus trying to find areas that we thought would be suitable to these percentage categories. When it came time to put the loggers out to record data at these locations, we had a mechanism to record the canopy cover and we also recorded the vegetative ground cover at each location. We soon realized that our percentages were not very accurate leaving our data more difficult to analyze and organize. We had to find another way to qualify our data so we came up with the average percentage approach, averaging the ground cover and canopy cover percentages together to get a single percentage. We then qualified each location as urban, vegetative, or hybrid according to its percentage.

Our data was skewed by certain weather events that occurred during the recording period. On November 3rd it rained, lowering the temperatures at each location. On November 5th a cold front came through and caused our data to be shifted towards lower temperatures at each location for the rest of the two week recording period. On November 13th day light savings time caused the clocks on the loggers to move back an hour. At times it was a struggle to offload the data from the logger onto the computer using the shuttle. We overcame this by persistently improving our extraction technique.

Improvements:

There are several ways in which this experiment could be improved upon. One improvement would be to analyze the differences in relative humidity between urban and vegetated areas, and to determine how humidity impacts temperature fluctuations in the different areas. Another improvement would be to have more precise classifications for the quantification of ground cover at each location. Also, we only recorded for a two week period. A thorough study of the Urban Heat Island effect on UCF's main campus would require a recording period of much longer than two weeks, in order to account for changes in climate, weather, etc. More time during the semester to examine our data would have allowed for the most thorough analysis of the data possible. This would have allowed for more precise calculations in our results, and a smaller standard deviation of error for our data.

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