ASSESSING VARIATIONS IN URBAN HEAT ISLAND EFFECTS WITHIN ROANOKE, VIRGINIA

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ABSTRACT

Within urban areas, variations within the built environment create unique microclimates because of diversity in thermal properties of surface materials and alterations of the hydrologic cycle. Resolving intra-urban microclimate variability presents an opportunity to evaluate spatial dimensions of urban heat island effects, including daily air temperature fluctuations and local variations in start and end of growing seasons. Observations from National Weather Service (NWS) stations are often used to characterize regional conditions, yet such data are widely spaced and can only indicate conditions specific to that site. To effectively represent the fabric of temperature variations within an urban area, a finer network of data collection points is required.

We report on a weather data collection campaign within Roanoke, Virginia using mobile weather units and weather stations newly installed at local public schools. We describe these data collection programs, outline methods developed for our collection pattern, and our preliminary analyses. We discuss our results and how they relate to the variation in Roanoke's built environment.

This research forms the first phase of dissertation research evaluating urban social and environmental patterns to facilitate optimal placement of urban agriculture. It provides the basis for understanding the spatial context for urban agriculture, and for ameliorating social and environmental difficulties inherent to modern urban systems. It fills a gap in current strategies, which largely have lacked spatial perspectives, and uses the power of geospatial technologies to identify relationships between the environmental and social dimensions of urban systems, and the spatial nature of their synergies.

KEY WORDS: urban heat island effect, mobile mesonet units, fixed weather stations, infrared thermometers, urban microclimates

INTRODUCTION

Urban areas are inherently warmer than their rural surroundings. A plethora of studies document the urban heat island (UHI) effect and its origins in landcover/landuse changes (Hedquist and Brazel 2006, Weng 2012). More specifically, areas with higher amounts of impervious surfaces and lower vegetative cover tend to be warmer. Within an urban area, variations in the built environment create unique microclimates generated by alterations in thermal properties of surface materials, by absence of vegetative cover, and by alteration of the hydrologic cycle (Arnfield 2003, Geiger, Aron et al. 2003). Understanding microclimates requires evaluation of the spatial variability of air temperatures in the context of precipitation and humidity, across an urban area (Oke 2006).

Urban remote sensing analyses documenting microclimatic variations of the UHI are numerous but use differing resolutions (i.e. Landsat vs. SPOT) and differing techniques (Voogt and Oke 2003). Some studies have attempted to identify specific temperature values using various equations, and then to validate the temperature in the field at a limited number of sites (Weng 2012). Such observations are typically obtained either from widely-spaced

National Weather Service (NWS) stations, local news stations, or from mobile mesonets driven across specified transects (Arnfield 2003).

Other researchers have used mobile units to document differences between urban and rural temperatures. Although mobile units do provide data across many locations, they are limited to a specific time frame, usually either one day or a series of days across specified transects (e.g. Hedquist and Brazel 2006, Stabler, et al 2005). Fixed weather stations can provide a continuous stream of weather data and many studies on UHI use a network of fixed stations across an urban area (e.g. Graffin et al 2008, Bourbia 2010, Yahia 2013). However these data only reflect lower atmospheric conditions specific to site characteristics of each station (Arnfield 2003). To effectively evaluate the differing precipitation, humidity, and air temperature across an urban area, finer network of data collection points are clearly required (Geiger, Aron et al. 2003; Oke 2006; Gaffin, Rosenzweig et al. 2008).

STUDY AREA

The City of Roanoke, Virginia is located in a valley at between the Blue Ridge Mountains and the Alleghany Highlands (Figure 1). Roanoke, the largest metropolitan region in southwestern Virginia, is characterized by a variety of urban land uses. The city's history is largely based upon its role as a regional transportation hub for rail and road traffic with services and industries supporting the rail system, as well as finance, distribution, trade, manufacturing, and health care businesses.

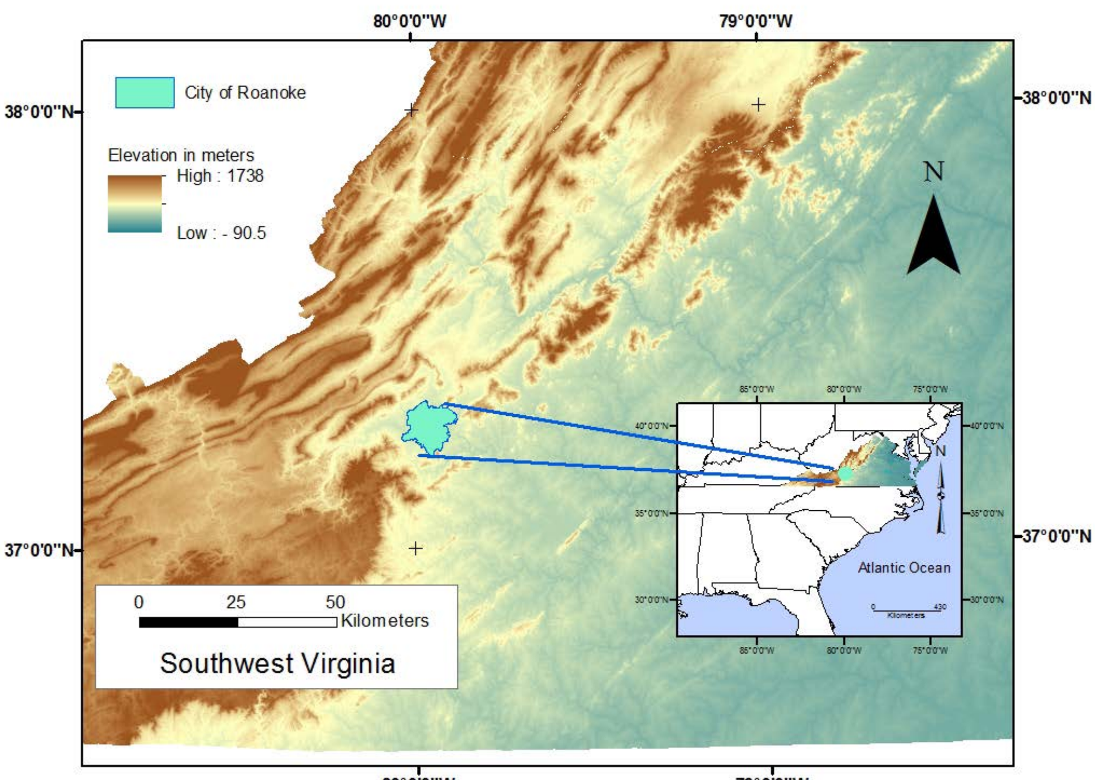

Figure 1. Roanoke, Virginia Reference Map

Over recent decades, Roanoke has formed a focus for substantial urbanization, economic stress, and landuse change. In addition, although it is a small urban area (110 km^2), Roanoke is intensely urbanized – both population density (880 persons per square kilometer) and land extent. These changes have resulted in many environmental issues, e.g. CO_2 emissions were estimated at 2.3 million tons in 2009 (Roanoke 2011). Roanoke also has substantial drainage problems and experiences frequent flooding due to its proximity to the Roanoke River, the river's tributaries, and urban stormwater runoff from impervious surfaces. Roanoke's impervious surfaces range from

13.3% to 89.5% of total area by census tract (Parece and Campbell, 2013). Many segments of the Roanoke River system within the city are on the Virginia Department of Environmental Quality's impaired waters list, due to contaminants such as *Escherichia coli*, high water temperatures, and heavy metals (Virginia 2010). For our analysis, Roanoke offers the advantage of a compact urban region with a range of land uses and urban settings that permit evaluation of urban microclimates.

METHODS

Our data collection period extended from April through November of 2013, the extent of the 2013 growing season in the City of Roanoke. At the beginning of our research, weather stations existed at four K-12 schools, the airport (National Weather Service location), Virginia Western Community College, a few private residences, and the two local TV stations. Many of these locations are WeatherBug® sites (Virginia Western Community College, Virginia Heights Elementary School, Roanoke Valley Governor's School, Roanoke Catholic School, WDBJ CBS TV). The private residences' weather stations were identified as either Davis Vantage Vue® Pros or with a MADIS Identification Number. The additional weather stations described here were purchased with grant monies, faculty research funds, scholarship monies, and by the Roanoke City Public Schools.

We purchased Davis Vantage Vue® Wireless Weather Stations (Model No. 6250), and Davis WeatherLink Dataloggers and Software to add additional locations to the network of fixed weather stations in Roanoke. This model has an Integrated Sensor Suite (ISS) to collect outside weather data every 2.5 seconds, and it transmits data wirelessly to an indoor console via FCC-certified radio transmitter. The stations are equipped with a rain collector, temperature/humidity sensor (mounted within a passive solar radiation shield), anemometer, and wind vane. The transmission limit from outdoor unit to indoor console is 1000 feet (Davis 2012).

These eleven new weather stations were installed at public schools by Roanoke City Public Schools (RCPS) facilities personnel and located in regions of the city without weather stations. RCPS personnel mounted the outdoor equipment on school roofs in locations not easily accessible by unauthorized people. Virginia Tech meteorology students installed indoor equipment and computer software. All weather stations were set up to transmit on-line to WeatherUnderground (www.wunderground.com). As part of this internet set up process, the latitude, longitude, and elevation were obtained for each outdoor unit. During the summer of 2013, while we were installing the new weather stations, three of the prior existing weather stations went off-line. In early November, near the end of our of our study period, two additional private residents acquired weather stations – one a Davis Vantage Vue® Wireless Weather Station and the other a Davis Vantage Vue® Pro2.

Virginia Tech's Geography Department's fleet of mobile mesonet units were used to collect additional temperature data across the study site, providing local snapshots of temperatures for specific times and dates. Table 1 provides the mesonet collection dates, times, the number of mesonet units that were used on that particular date, and number of readings that were collected during a specific time period.

Table 1. Date, times, number of mesonet units, and infrared thermometers readings per collection campaign

Date	Times in Roanoke	Number of Mesonet Units	Number of Mesonet Readings	Number of IR Readings
April 21, 2013	9:32 a.m. – 10:50 a.m.	3	5,843	18
	3:36 p.m. – 4:52 p.m.	3	5,099	16
April 22, 2013	9:37 a.m. – 10:56 a.m.	3	5,801	19
	2:54 p.m. – 3:50 p.m.	3	5,335	18
April 23, 2013	9:21 a.m. – 10:15 a.m.	3	4,758	18
	2:46 p.m. – 4:00 p.m.	3	5,774	19
July 23, 2013	9:10 a.m. – 12:06 p.m.	2	6,766	33
	2:30 p.m. – 3:48 p.m.	2	4,497	32
August 5, 2013	6:57 a.m. – 9:10 .am.	1	3830	27
	11:17 a.m. – 11:48 a.m.	1	803	0
	1:28 p.m. – 1:59 p.m.	1	932	0
	3:39 p.m. – 5:36 p.m.	1	3808	30
August 14, 2013	9:00 a.m. – 11:30 a.m.	3	9,868	55

	1:28 p.m. – 4:23 p.m.	3	6,610	33
September 6, 2013	10:20 a.m. – 1:10 p.m.	3	3,688	0
	2:03 pm. – 4:14 p.m.	3	3,033	0
October 26, 2013	1:04 a.m. – 2:56 a.m.	1	6,983	0
	4:00 a.m. – 4:56 a.m.	1	1.704	0
November 4, 2013	3:08 a.m. - 6:12 a.m.	1	5,533	0
November 8, 2013	10:27 p.m. – 12:30 a.m.	1	3,716	0
November 9, 2013	1:01 a.m. – 2:11 a.m.	1	2,118	0
November 25, 2013	6:39 a.m. - 8:29 a.m.	1	3,291	0
	11:07 a.m.- 12:24 p.m.	1	2,104	0
	1:22 p.m. – 2:39 p.m.	1	2,300	0
November 28, 2013	11:20 a.m. – 12:07 p.m.	1	1,430	0

These units were mounted on Chevrolet Cobalts and driven into Roanoke during each data collection run (Figure 2). While we did not drive the exact same vehicles on each date, we did use the same make and model. The meteorological equipment is Campbell Scientific mobile metrological units: RM Young wind monitor, CSL Temperature/RH probe, Sentra 278 Barometer, Garmin GPS receiver, CR800-ST-SW-NC Measurement & Control Datalogger. The temperature and humidity sensor is shielded and aspirated, all sensors are programmable for different sampling rates, and the unit registers latitude and longitude in WGS1984.

Figure 2. Two of the mobile mesonet units, mounted on Chevrolet Cobalts, driving off I-81 into Roanoke, Virginia on April 21, 2013

We set the sensors to record the climate data every two seconds, registering temperature in degrees Fahrenheit. After each run, we downloaded the data file and then created a point shapefile for use in GIS. Each shapefile contained the latitude and longitude, barometric pressure, temperature, relative humidity, windspeed and direction, and time of collection for each point.

During daytime data collection with the mobile mesonet units, each vehicle periodically stopped and obtained surface temperature using infrared thermometers (Figure 3). The infrared thermometers used in this portion of our data collection were: Fluke 574 Precision Infrared Thermometers, temperature range of -25 to +900 degrees Fahrenheit, digitally adjustable emissivity, distance to spot size (close) 50:1, and spectral range 8 – 14µm. For each surface temperature reading, we noted the date, time and location. Table 1 summarizes infrared thermometer readings obtained during each mesonet run. Readings were not obtained during every single mesonet collection date, but all readings were obtained from asphalt surfaces.

Figure 3. Using an infrared thermometer to capture the surface temperature of asphalt

In addition to temperature data collected with the mesonet units, fixed weather stations and infrared thermometers, we downloaded the digital elevation model (DEM), 10 x 10 meter resolution, from the U.S.G.S. Seamless Server (http://nationalmap.gov/viewer.html) and the National Land Cover Database 2006 Percent Developed Imperviousness (NLCD IS), 30 x 30 meter resolution, file from the Multi-Resolution Land Characteristics Consortium (http://www.mrlc.gov/nlcd06_data.php). We utilized a Tree Canopy Cover (TCC)[1], a 1 x 1 meter resolution binary raster dataset, for the City of Roanoke that was provided by Virginia Tech's Geospatial Extension Specialist. Using ArcGIS®, we derived aspect and percent slope raster files from the DEM, and we aggregated the TCC raster file to 30 x 30 meter resolution and calculated percent TCC cover for each grid cell.

We created a point-shapefile for each fixed weather station using latitudes and longitudes from WeatherUnderground and schools shapefile downloaded from the City of Roanoke GIS Portal (ftp://ftp.roanokeva.gov/GIS/). We obtained the exact location of the National Weather Station unit from the National Weather Service in Blacksburg, Virginia. WDBJ and Virginia Western Community College personnel provided us with temperature readings for the dates of our mesonet runs. Temperature data from other fixed weather station data was downloaded from WeatherUnderground as.csv files, separately for each station, and corresponding to each mesonet run. We created separate fixed weather station shapefiles for each date and time, also corresponding to each mesonet run and joined the .csv file.

We created a point-shapefile for the infrared temperature collection, a separate shapefile for each mesonet run. We also aggregated the shapefiles into one file for locations where we obtained both morning and afternoon temperature readings.

We analyzed the temperature data in the following ways:

1. In GIS, we compared and contrasted temperature data collected by the mesonet units to each fixed weather station temperature data collected at the equivalent time, to verify the accuracy of the readings;
2. In GIS, we extracted values from the Percent TCC, DEM, NLCD IS, aspect, and percent slope raster and shapefiles for each data point collected by the mesonet units, for each fixed weather station, and for each IR temperature location to determine the specific characteristics of the adjacent landscape;
3. We performed a backwards stepwise regression analysis on fixed stations to identify which landscape characteristics influenced temperatures;
4. In GIS, we extracted the mesonet data that corresponded to the infrared temperature data, and compared and contrasted it with the infrared temperature data - calculating the differences between the air temperature and surface temperature, the changes in surface temperature due to time change, and performed a stepwise regression to determine what characteristics of the landscape influenced surface temperature; and
5. We performed a stepwise regression analysis separately for each mobile unit for each run, and also jointly for all probes on each run to determine which characteristic of that specific site was related to temperature.

[1] City of Roanoke Tree Canopy Cover was completed using 1 x 1 meter resolution National Agriculture Imagery Program (NAIP) 2008 imagery, with a resultant overall accuracy of 93% (Pugh 2010).

We employ these methods to take a first look at our data, and are now, with little guidance offered in the literature, experimenting to define strategies to analyze these data. Our goals are to define simple relationships between our observed temperature and the proximate landscape variables, as a basis for estimating temperatures within a zone of about thirty meters from the points of observation.

RESULTS

We compared each mobile mesonet data to each fixed station data for every date and time of our mesonet campaign. We determined that fixed stations were registering temperature data when the mobile unit was near the station 96 times. In most cases, the mobile unit was on the street driving by the fixed station at that specific time. Seventeen (17) of these 96 times, the mesonet was between 200 and 500 meters of the fixed stations. Many other fixed stations were registering temperatures during the mobile collection dates and times but they were at least 1 kilometer or more from the mobile unit. Differences in readings between fixed stations and the mobile units (N = 96) varied from 0 and 10.1 degrees Fahrenheit, with a mean difference in temperature of +0.20 degrees. The fixed station that was furthest distance (500 meters) from the mobile unit registered the greatest difference at 10.1 degrees. Table 2 provides the distribution of the differences in temperature (N = 96).

Table 2. Distribution of temperature difference between mobile and fixed stations

Absolute value of temperature difference, °F	Number of readings
0 – 0.5	20
0.6 – 1.0	14
1.1 – 1.5	16
1.6 – 2.0	13
2.1 – 3.0	18
3.1 and above	15

We then plotted the two readings to compare mobile mesonet temperature on x-axis and fixed station temperature on y-axis, and the correlation between the two readings (Figure 4). The readings are highly correlated at the 99% level.

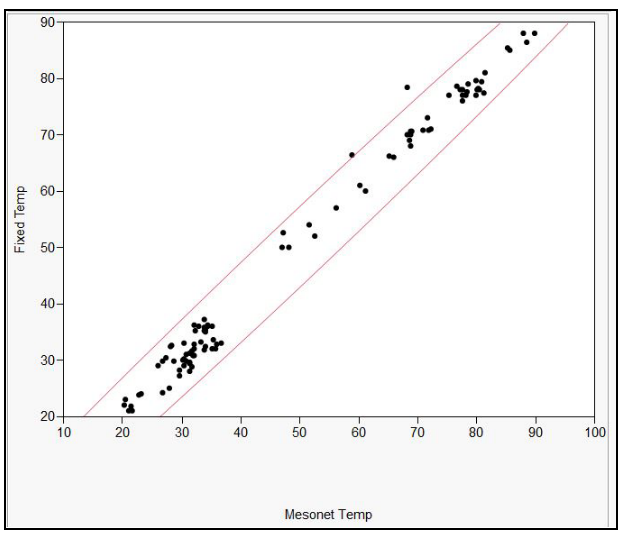

Figure 4. Correlation between mobile mesonet temperature reading and nearby fixed weather stations on same date and time (N = 96, ellipse @ 99.0% level).

From our larger collection of records, we chose five different times to complete a regression analysis to determine which landscape characteristics neighboring the fixed weather stations influenced temperatures. We choose times for which the greatest number of fixed stations were recording data – 5:00 p.m. on August 14, 5:00 p.m. on September 6, and 6 a.m., Noon, and 5:00 p.m. on October 10. Table 3 shows the results of this analysis.

Elevation and slope had no influence on our temperatures. Aspect had the greatest influence in most cases, however, when removing either percent tree canopy cover or percent impervious, our R^2 decreased 20+ points every analysis.

Table 3. Fixed station regression results for identification of landscape characteristics influencing air temperature

Date and Time	N	R^2	Landscape characteristics influencing temperature
August 14, 5:00 p.m.	18	0.97	Aspect, percent tree canopy cover
September 6, 5:00 p.m.	17	0.96	Aspect, percent impervious, percent tree canopy cover
October 10, 6:00 a.m.	16	0.83	Aspect, percent tree canopy cover
October 10, Noon	10	0.54	Aspect, percent tree canopy cover, percent impervious
October 10, 5:00 p.m.	10	0.67	Aspect, percent tree canopy cover, percent impervious

As noted from Table 1, we obtained 315 infrared temperature readings. However in some instances, readings were either not taken in the same location or readings were missed, different drivers in the afternoon did not follow the routes taken by the morning drivers, or the data was misplaced. So we only used 218 readings for this portion of the analysis (109 locations with morning and afternoon readings). We calculated differences between morning and afternoon infrared temperature readings. We then performed a backwards stepwise regression with the difference between morning and afternoon surface temperatures as our dependent variable, and change in air temperature, percent slope, aspect, percent tree canopy cover, percent impervious, and elevation as our independent variables.

Table 4 shows the results of this process. For the six dates, our R^2 ranged from 0.30 to 0.79. The landscape characteristics that influenced the surface temperature varied. Aspect, for all dates, was the most significant of variables influencing the difference between the morning and afternoon surface temperatures. For the April dates, the next characteristic of most significance was percent impervious. Slope and elevation had no influence on any of the dates. Percent tree canopy cover had no influence on the April dates, not surprising as in 2013, Roanoke and southwestern Virginia experienced a late start of growing season, thus trees had not yet fully leafed out. As we progressed to a warmer time of year, the summer months -- July and August -- change in air temperature between morning and afternoon did have a significant influence on change in surface temperature, but it was less influential than aspect, percent tree canopy cover and percent impervious.

Table 4. R^2 values and significant landscape characteristics influencing change in asphalt surface temperature from morning to afternoon for 109 locations in Roanoke

Date	N	R^2	Factors in order of significance
April 21, 2013	10	0.74	aspect, percent impervious
April 22, 2013	14	0.62	aspect, percent impervious
April 23, 2013	6	0.40	aspect, percent impervious
July 23, 2013	23	0.30	aspect, percent tree canopy cover, percent impervious, change in air temperature from morning to afternoon
August 5, 2013	25	0.79	aspect, percent tree canopy cover, change in air temperature from morning to afternoon
August 14, 2013	31	0.30	aspect, percent tree canopy cover, percent impervious, change in air temperature from morning to afternoon

The results of the backwards stepwise regression for the mobile mesonet units was extremely variable with both the R^2 and the landscape characteristics impacting temperature**.** The R^2 was the lowest for two runs – midday on November 25 and afternoon of July 23 (0.08 for both), and the highest at 0.54 on August 5 early morning. The August 5 early morning was the only R^2 that exceeded 0.40. Table 5 shows the range of R^2 values and the number of mesonet runs that fall within that range. Additionally, no one specific landscape characteristic affected all R^2; aspect and elevation were contributing factors in 22 of 25 runs, percent impervious in 18 of 25 runs, percent tree canopy cover only 7 out of 25, and percent slope was never a contributing factor (Table 6).

Table 5. Range of R^2 and the number of mesonet runs within that range

R^2 Range	Number of Mesonet Runs
0.08 – 0.10	3
0.11 – 0.20	7

0.21 – 0.30	7
0.30 – 0.54	8

Table 6. Role of landscape characteristics in R^2

Landscape characteristic	Frequency of occurrence out of 25 mesonet data collection campaigns
Aspect	22
Percent Impervious	18
Percent Tree Canopy Cover	7
Elevation	22
Slope	0

Since aspect is a landscape characteristic that we know has an effect on temperature (south facing slopes are warmer and drier than north facing slopes), we performed the backwards stepwise regression again, this time with aspect as a blocking factor. Since slope was not a contributor in any of our prior regressions, we eliminated that characteristic from any further analysis. We chose four dates from the previous regression, the two with the highest and the two with the lowest R^2, to perform this step.

Again, our results were variable. For the lowest R^2, blocking only made a slight difference and only changing the results for some of the north facing slopes. For November 25 for north facing slopes, it increased by 16 points. For July 23, north facing slopes increased by 26 points, northeast facing slopes by 18 points, and northwest increased by 14 points. For our highest R^2 – August 5 early morning - blocking decreased most results, with the exception of the north facing slopes which increased to 0.75. For the August 5 midday run (our second highest R^2 from the prior regression), we had 5 out of 8 increase. Again, our contributing landscape characteristics were variable; elevation and percent impervious were the most frequent contributing characteristic (Table 7).

Table 7. Regression analysis results for selected dates with aspect as the block, mobile units

Date Time Original R^2 Characteristics impacting R^2	August 5 6:57 – 9:10 a.m. R^2 = 0.54 Percent Impervious Elevation	August 5 1:28 – 1:59 p.m. R^2 = 0.38 Elevation Aspect	November 25 11:07 a.m. – 12:24 p.m. R^2 = 0.08 Aspect Percent Impervious	July 23 9:10 a.m. – 12:06 p.m. R^2 = 0.08 Percent Impervious Elevation
Blocking Factor	R^2 (N) Landscape characteristics, in order of impact on R^2			
East	0.59 (N=415) Elevation Percent impervious	0.56 (N=65) Elevation Percent impervious	0.05 (N=199) Percent impervious, Percent tree canopy cover	0.09 (N=672) Elevation Percent impervious,
Flat	0.24 (N=17) Percent impervious Percent tree canopy cover	No points (N=0)	No points (N=0)	0.06 (N=19) Percent impervious
North	0.75 (N=536) Elevation	0.40 (N=173) Elevation, Percent impervious, Percent tree canopy cover	0.21 (N=294) Percent impervious, Percent tree canopy cover	0.34 (N=372) Elevation, Percent impervious
Northeast	0.49 (N=646) Elevation Percent impervious	0.84 (N=136) Elevation, Percent tree canopy cover, Percent impervious	0.07 (N=249) Percent Impervious	0.26 (N=979) Elevation, Percent tree canopy cover, Percent impervious
Northwest	0.52 (N=134) Elevation Percent tree canopy cover	0.17 (N=111) Elevation, Percent impervious, Percent tree canopy cover	0.19 (N=215) Elevation, Percent impervious	0.22 (N=1086) Percent impervious, Percent tree canopy cover, Elevation
South	0.31 (N=571)	0.04 (N=181)	0.00 (N=596)	0.05 (N=1174)

	Elevation, Percent tree canopy cover	Percent impervious, Percent tree canopy cover	None	Percent impervious
Southeast	0.53 (N=496) Elevation	0.79 (N=84) Elevation, Percent tree canopy cover	0.08 (N=341) Percent tree canopy cover, Percent impervious, Elevation	0.06 (N=890) Percent impervious, Elevation
Southwest	0.38 (N=769) Elevation	0.12 (N=49) Percent impervious, Percent tree canopy cover	0.02 (N=82) Percent tree canopy cover, Percent impervious, Elevation	0.04 (N=1063) Elevation, Percent tree canopy cover
West	0.47 (N=246) Percent tree canopy cover, Elevation	0.54 (N=133) Elevation, Percent tree canopy cover, Percent impervious	0.09 (N=128) Elevation Percent impervious	0.05 (N=511) Elevation

CONCLUSIONS

Despite our low R^2 when evaluating the influence different landscape characteristics had on temperature, clearly percent impervious, and to a lesser extent, percent tree canopy cover, did have an impact. We anticipated percent tree canopy cover would have a larger impact. Upon reflection, when driving mobile mesonet units, we are mostly in areas of impervious surfaces and less tree canopy cover, so these results are reasonable. In addition, southwestern Virginia experienced a milder summer than in most past years, as such we feel that our results would be different had the air temperatures been higher.

We are also in the process of completing an impervious surface layer, hand delineated from high resolution aerial photos. This file will provide us with a greater accuracy and precision for the extent and locations of impervious surfaces. As we continue to analyze the data we have thus far collected, this new data layer will assist us in identifying the temperature variations within Roanoke, and can further guide us as to the most appropriate locations to compare temperature differences due to landscape characteristics.

We will slightly change our methods for any future data collection campaigns. When traveling near the fixed stations, we will drive around the station multiple times, gradually increasing our distance outward, so as to determine at what distance the air temperature actually changes relative to the data recorded by the fixed stations. We need to assure that the same routes are followed if our intentions are to compare morning to afternoon changes, and that surface temperature readings are taken in the same locations, even if our drivers vary. In many instances when we stopped to obtain the surface temperature reading, the mesonet was only stopped for a few seconds, we should let the mesonet stay immobile for a length of about to see if the air temperature rises more quickly over the asphalt surfaces. We suspect that this is the case as we were traveling to the RCPS schools, we observed distinct differences in the mesonet readings from when we drove into the school parking lot to when we left the school parking lot.

For most mobile mesonet dates, we timed our data collection with the Landsat overpass schedule because we intended to overlay our mobile mesonet data on Landsat imagery for analysis. However, no scenes with sufficiently low cloud cover, matched to, or close to, our collection dates during the time of our surveys. As a general statement, we note that our numerous meteorological and logistical constraints limited our ability to match our collection efforts to dates of Landsat overpasses for our area.

We also invite suggestions and critique to guide our future investigations.

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