Development of a Handheld Thermal Sensor for Urban Land Surface Temperature Calibration

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MOTIVATION

Satellite land surface temperature (LST) calibration is currently unavailable for cities, hence the application of satellite derived data for urban weather and climate modeling is severely limited. This project aims to develop a sensor that provides ground-truth temperature validation of the Geostationary Operational Environmental Satellite, GOES-16, and its LST data product using an Arduino-based, GPS-enabled, and non-contact passive infrared temperature camera. The sensor was lab and field tested in New York City and the data were compared to LST derived from GOES-16. Comparing the satellite data to the data collected by the sensor, an algorithm can be built to correctly calibrate the land surface temperature, thus advancing urban weather forecasts and enabling the sensor to accurately function in non-rural areas. Additionally the sensor will also help us understand the spatial variability in the emissivity of urban materials.

METHODOLOGY

Land surface temperature is measured using an infrared sensor while a thermocouple provides a reference temperature for calculating surface emissivity of various materials. A swath of temperatures is captured using the IR sensor and respective material emissivities. This allows for more in-depth comparison of true surface temperature and satellite-derived LST, which can be quantified using the following tools:

- An **Arduino board** for real-time processing
- An **Infrared (IR) sensor** to calculate LST
- A **Thermocouple** for calibrating the IR sensor
- A **GPS Module** for geolocating data points
- An **SD Card** for logging the data for post-processing analysis
- **GIS software** for visualizing geographic data points

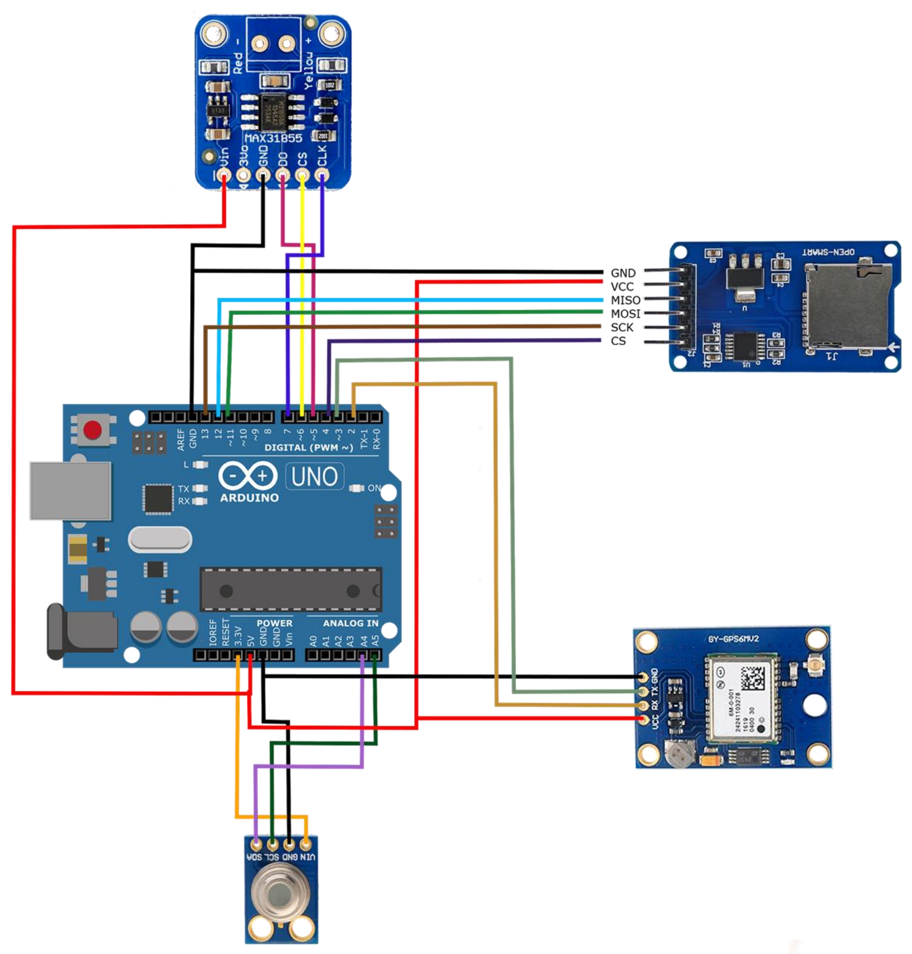

Figure 1: Wiring diagram of infrared sensor, thermocouple, gps module, and SD card module to Arduino Uno board.

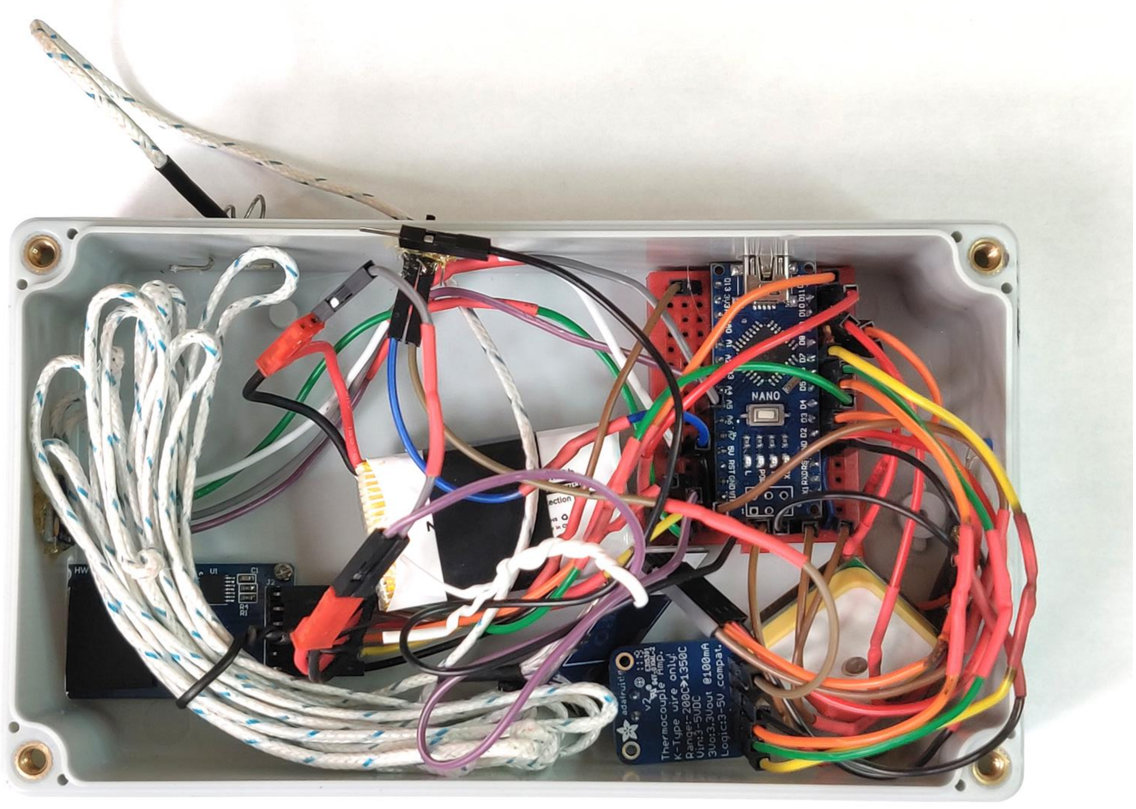

Figure 2: Wiring diagram of infrared sensor, thermocouple, gps module, and SD card module to Arduino Uno board.

RESULTS

Once the different modules and tools were connected, the sensor finally became operational and the final product was tested in several locations in New York. Communicating with at least five satellites in orbit, the sensor was able to accurately record different surface temperatures taken from asphalt, concrete, brick, and metal. Once the data was taken, it was mapped in QGIS, (Figure 3A), along with the different temperature recordings that the sensor found. The LST data captured from the GOES-16 satellite was then brought up against it in order to compare the two maps (Figure 3B).

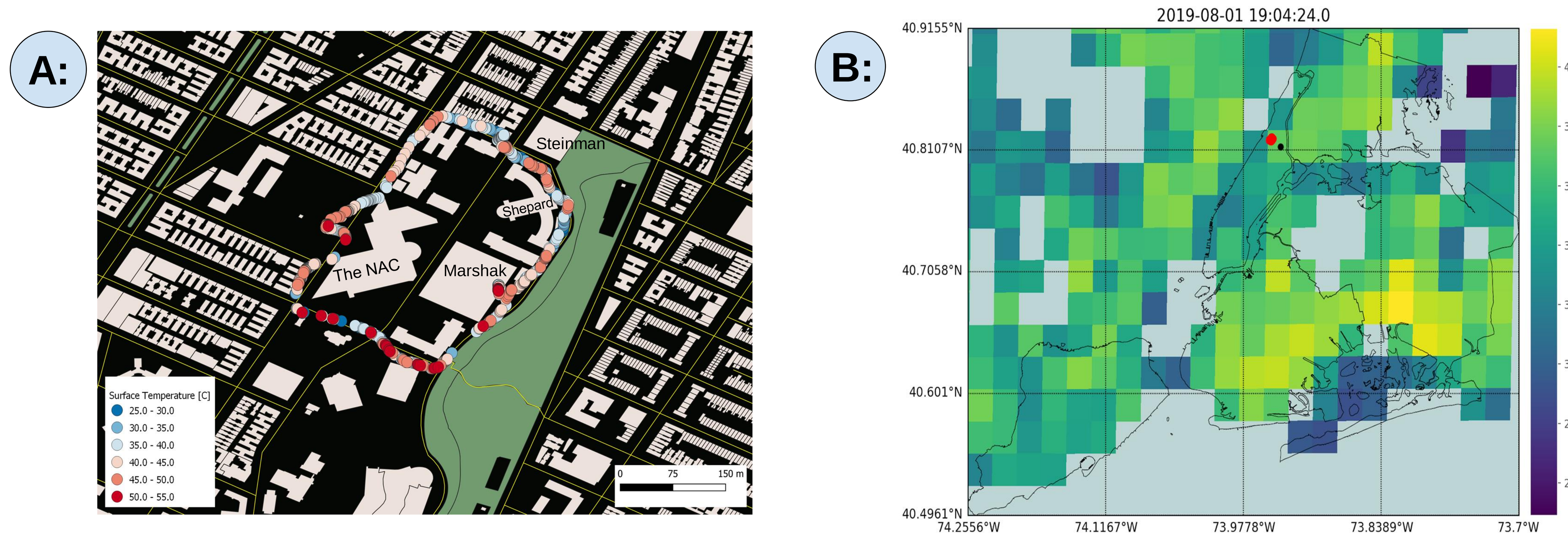

Figure 3 (A): GPS trail of first successful trial with sensor along with surface temperatures recorded. **(B)**: GOES-16 map recorded surface temperature at exact time and location trial run took place.

- Different colors in first map = different materials observed along the route.
- Built materials such as concrete, asphalt and bare soil have different thermal properties which impact their temperature.
- The series of dark red dots in the bottom indicate the temperature of asphalt. In comparison, around Shepard Hall where there is a cluster of blue dots, the temperature of concrete was lower because it has a lower emissivity and lower thermal conductivity.
- In the second map, satellite data taken from NOAA, it exhibits the surface temperature with a color range from purple to yellow

CONCLUSION AND FUTURE WORK

Ultimately, the sensor is still just a prototype and requires work to make it more efficient and reliable. Thus, this project will continue on for several months until the model is advanced enough that algorithms could start being developed in order to correct any errors in satellite. Once those algorithms are completed, the sensor can be mass-produced and sent around any major cities, thus providing millions of people with much more dependable weather forecasts.

ACKNOWLEDGEMENT

This study is partially supported and monitored by The National Oceanic and Atmospheric Administration – Cooperative Science Center for Earth System Sciences and Remote Sensing Technologies under the Cooperative Agreement Grant #: NA16SEC4810008. The author(s) would like to thank The City College of New York and NOAA Office of Education, Educational Partnership Program with Minority Serving Institutions (EPP/MSI) for support for Joshua Hrisko. The statements contained within the poster are not the opinions of the funding agency or the U.S. government, but reflect the author's opinions.The authors also thank the Pinkerton Foundation and the American Museum of Natural History for funding and supporting Fabian Firu and Michelle Tejada through the High School Initiative in Remote Sensing of the Earth Systems Science & Engineering (HIRES) program.