Using Bespoke LoRaWAN Heat Sensors to Explore Microclimate Effects within the London Urban Heat Islands– A Pilot Study in East London

Dongyi Ma*[1], Oscar Brousse[2], Martin De Jode†[1] and Andrew Hudson-Smith‡[1]

1 Bartlett Centre for Advanced Spatial Analysis (CASA), UCL

2 Bartlett Institute for Environmental Design and Engineering (IEDE), UCL

GISRUK 2024

Summary

The phenomenon of high temperature in the city relative to the suburbs is known as the urban heat island effect (UHI). This research explores the new possibilities offered by designing a lightweight, battery-powered sensor system communicating through Long Range Wide Area Networks (LoRa WAN) for studying the UHI. By coupling the sensor records to Geographic Information Systems (GIS) data, we explore the potential for informing UHI to policy makers to tailor adaptative and mitigative strategies to local environments. This paper presents evidence for applying LoRaWAN sensors to measure spatial variation of local climate, based on a sensor deployment in East London.

KEYWORDS: [Urban Heat Islands, Urban Data, Climate Mitigation Planning, Internet of Things, GIS data]

* dongyi.ma.21@ucl.ac.uk

[2] o.brousse@ucl.ac.uk

† m.dejode@ucl.ac.uk

‡ a.hudson-smith@ucl.ac.uk

1. Introduction

Cities are usually subject to hotter temperatures than the surrounding rural land, a phenomenon described as the urban heat island (UHI) effect (Oke et al., 2017). The study of the UHI at fine scale is valuable for understanding the influence of urban characteristics such as land use and land cover type (LULC) but is currently restricted by the characteristic climate data scarcity in urban areas (Brousse et al., 2022). LoRaWAN, a technology with broad coverage and low power consumption seems to be a promising technology for a long-range, wide-area urban heat island sensor network. This paper shows how LoRaWAN sensors could be deployed in large cities to cope with the existing data scarcity of air temperatures and humidity measurements and provide means of surveillance of the urban climates at fine scale. We here deployed our sensors in East London from August 2023, benefiting from the community LoRaWAN network provider "The Things Network". This project aims to establish whether affordable sensors can resolve fine scale microclimate temperature variations as a result of local variations in LULC. If successful, this will lead to larger scale deployments ultimately contributing data for urban policy and climate change mitigation planning for London.

2. Methodology

This study utilizes LoRaWAN based Internet of Things (IoT) sensor system for real-time temperature mapping in East London. A restrictive set of spatial variables identified as important for heat-related health risks helped defining suitable locations for the deployment of our sensors. In particular, deprivation level, presence/absence of other personal weather stations and ethnic minorities were considered (Brousse et al. 2023). The Hackney Wick and Fish Island neighbourhoods were selected among other candidates because of agreed collaborations with local authorities which facilitated the deployment process in these areas. They were also chosen for their proximity to the Queen Elizabeth Olympic Park which hosts a LoRa gateway atop the ArcelorMittal Orbit ensuring robust network coverage for these regions. LoRa technology, optimised for long-range (up to 10 km and greater) and low power (enabling sensor node battery life times in the range of years) stands out as a promising tool in the IoT landscape (Zourmand, A. et al., 2019), making it a pivotal tool for establishing a London-wide Microclimate Network for this project. This project starts by designing and building a low-power, lightweight and easy-to-use LoRaWAN networked sensor system for continuous UHI data (air temperature and humidity) monitoring. The sensors are then deployed in Fish Island in East London to sense real-time air temperature data at a variety of locations. This paper presents preliminary results obtained from the month of September 2023.

2.1. The Designed Sensor System

Instead of using expensive commercial weather stations this paper introduces a battery-powered LoRaWAN air temperature sensor system. This system is built around the Arduino MKR WAN 1310 microcontroller, complemented by the Texas Instruments HDC1080 air humidity/temperature sensor enclosed in affordable commercial Stevenson Screen (TFA Dostmann GmbH). The full setup, inclusive of a LiPo battery and Stevenson Screen, as shown in Figure 1, is priced at approximately £66, establishing it as potentially attractive alternative for temperature monitoring at a large scale.

Figure 1a, b and c. Illustration of the Designed Sensor System.

2.2. The Deployment

In Fish Island, sensors captured data from a variety of locations, ranging from open residential areas to closed-off sections with limited sky view, riversides, and central squares. This variety aims to assess the impact of different environmental conditions on temperature, such as the shading effects in closed areas compared to open ones, or the potential cooling influence of the canal. Figure 2-5 provides the panoramic photos of each sensor location to give the readers a sense of land classification at deployed sites. Figure 6 provides a map of the deployment.

Figure 2. Panoramic Photo of Sensor at Playground.

Figure 3. Panoramic Photo of Sensor at Courtyard.

Figure 4. Panoramic Photo of Sensor at Riverside.

Figure 5. Panoramic Photo of Sensor at Square.

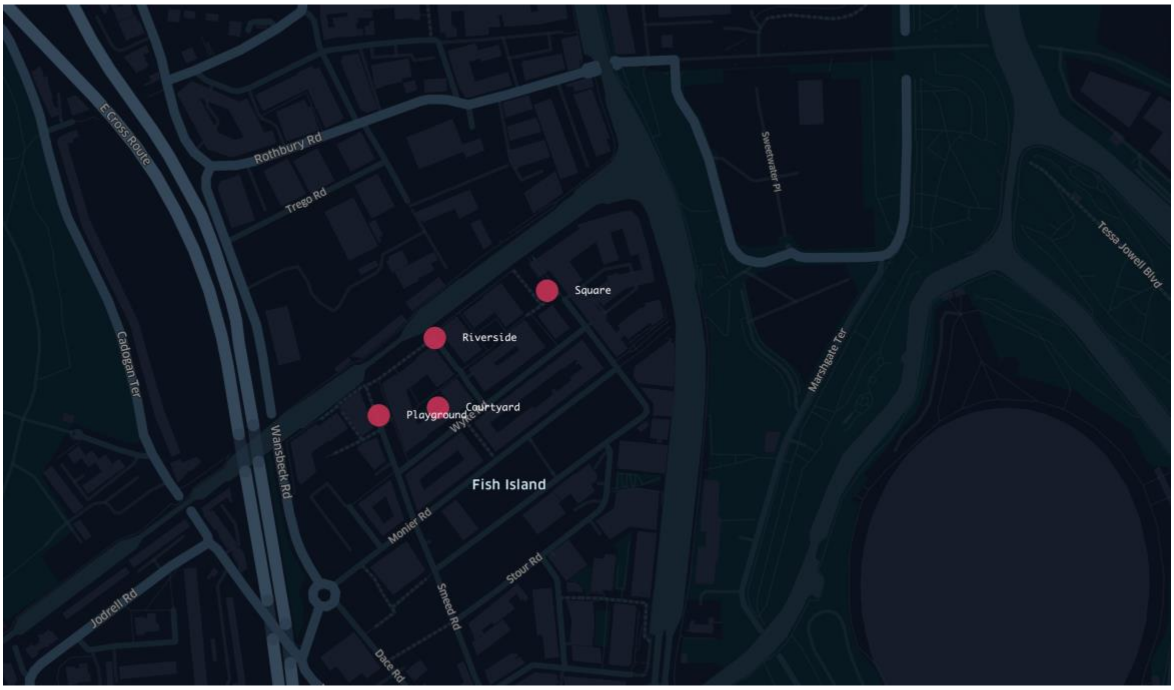

Figure 6. Deployment Map in Fish Island.

3. Preliminary Results

Based on the dataset collected from the deployment detailed in the previous section, the boxplot below is plotted based on 37189 data points, illustrating the median, the quartiles, and the range of values of collected air temperature data from the four sites in Fish Island deployment from 29th August to 29th September 2023.

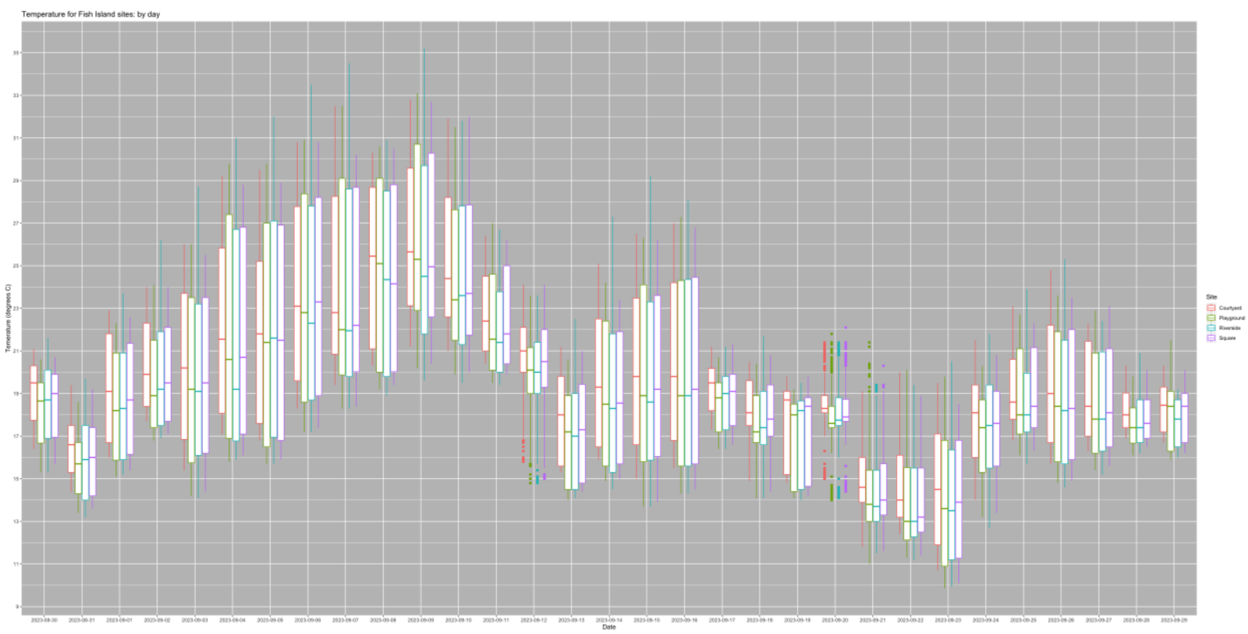

Figure 7. Data Outputs from Fish Island (overall).

Based on the analysis, there are three findings at this stage. Firstly, it is observed that the courtyard seems to have the highest temperature (day and night), while the riverside and square tend to be cooler in all weathers. The difference between temperatures observed at night by each sensor is approximately 0.5 to 1.2 degrees higher than at daytime. Lastly, Figure 8 shows that the temperature for the courtyard is obviously hotter than Met Office official weather data records (from St James Park in London) at night, likely due to the re-radiation of thermal mass from buildings. However, this study's findings are currently constrained by the dataset's limited size, which calls for larger scale and longer deployments.

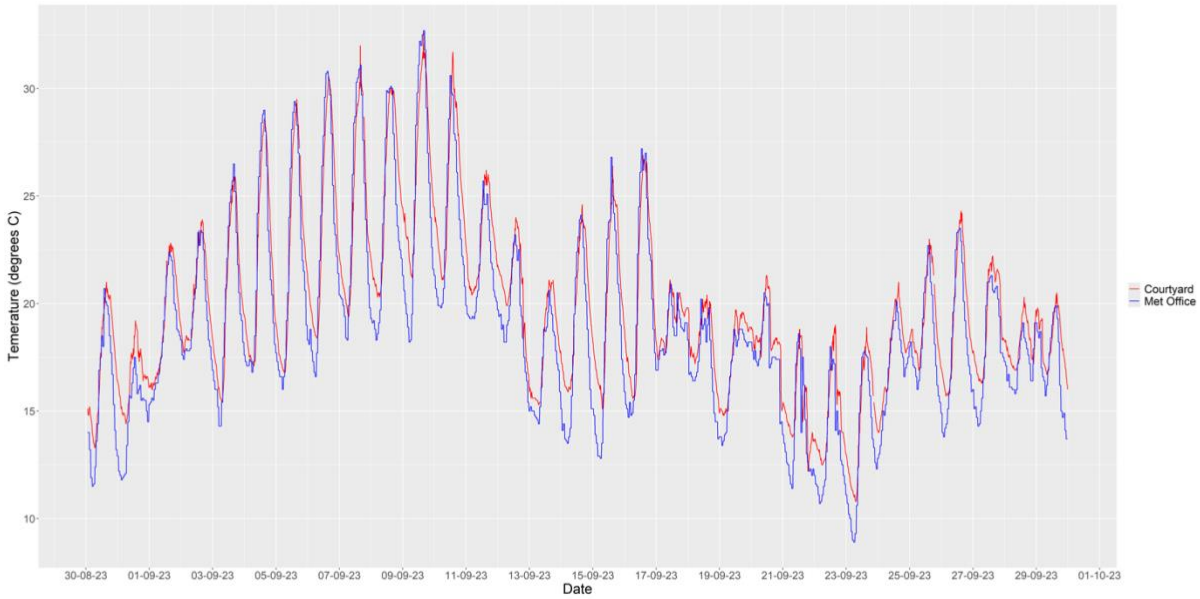

Figure 8. Timeseries temperature plot of Courtyard sensor and Met Office data.

4. Conclusion

The preliminary findings of this study indicates the future widespread deployment of designed IoT sensor systems to be a promising approach to addressing current research gaps concerning the availability of comprehensive datasets for the in-depth analysis of UHI. Overall, this study has demonstrated the utility of cost-effective temperature sensors in investigating UHI effects and the variations in local microclimates influenced by differences in LULC and provides evidence to support the rollout of a larger-scale network of sensors. The goal for future work is to deploy a London wide microclimate network via both local authorities and crowd-based methodologies. This extended monitoring will enable the investigation in real time of how environmental conditions fluctuate between geographic location, with changing seasons and the passage of time. Furthermore, the integration of sensor data with GIS opens avenues for dynamic heat mapping, thereby providing a powerful tool for policymakers and urban planners.

Acknowledgement

We are grateful to Met Office for sharing St James Park hourly temperature data.

References

Brousse, O. *et al.* (2022) 'Evidence of horizontal urban heat advection in London using six years of data from a citizen weather station network', *Environmental Research Letters*, 17(4), p. 044041. doi:10.1088/1748-9326/ac5c0f.

Brousse, O. et al. (2023) Unequal distributions of crowdsourced weather data in England and Wales [Preprint]. doi:10.21203/rs.3.rs-2715073/v1.

Oke, T.R. et al. (2017) Urban Climates. Cambridge University Press. pp 196 -200.

Zourmand, A. et al. (2019) 'Internet of Things (IoT) using LoRa technology', 2019 IEEE International Conference on Automatic Control and Intelligent Systems, I2CACIS 2019 - Proceedings, pp. 324–330.

Biographies

Dongyi Ma is a PhD student in Connected Environments started in October 2022, supervised by Prof. Andy Hudson-Smith and Dr Martin De Jode. Her research focuses on making and building IoT sensor systems to measure and communicate Urban Heat Islands and urban microclimates for input into urban policy and climate mitigation planning.

Oscar Brousse is a post-doctoral senior research fellow working at UCL's Bartlett Institute of Environmental Design and Engineering as an expert in urban climate studies and modelling. His work relates urban climates to climatic health hazards such as heat-strokes, thermal discomfort or local surges of vector borne diseases.

Martin De Jode is lecturer in Connected Environments at the Bartlett Centre for Advanced Spatial Analysis. Having originally trained as a physicist, then subsequently employed as software engineer, he now combines the two disciplines to sense the built and natural environments.

Andrew Hudson-Smith is a Professor of Digital Urban Systems at CASA, University College London. He focuses on real-time data, VR and the Internet of Things. He is an elected Fellow of the Royal Society of Arts, The Academy of Social Sciences and the Royal Geographic Society.