A MICROCLIMATE MONITORING FRAMEWORK FOR UBC VANCOUVER

Recommendations for long-term research

Prepared by: ***Aubrey Benson****, Primary Researcher, Urban Ecology & Sustainability Lab, Department of Forest Resources Management, Faculty of Forestry;* ***Melissa R McHale****, Principal Investigator, Urban Ecology & Sustainability Lab, Department of Forest Resources Management, Faculty of Forestry*

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SEEDS Sustainability Program

PRACTITIONERS' SUMMARY

Background: The University of British Columbia (UBC) is committed to leading sustainable development on campus, with specific attention to reducing extreme heat impacts, enhancing biodiversity, and mitigating urban heat island effects. As part of this effort, microclimate monitoring is crucial to understanding how landscape elements, such as tree canopy and ground cover, influence local temperatures and human thermal comfort.

Goals/Objectives:

1. Identify existing weather and climate datasets on campus.
2. Conduct pilot data collection to explore the relationship between landscape structure and microclimate dynamics.
3. Develop recommendations for a long-term microclimate monitoring framework to inform land management and campus development.

Methods:

- Expert Interviews
- Literature review
- Stakeholder Meeting
- Pilot Study

Key Findings: The study revealed significant temperature variation across a relatively small area of 665 meters along UBC's Main Mall. *Mean radiant temperature varied by up to 55°C between areas studied,* with the hottest areas being open, unshaded spaces and the coolest areas under dense tree canopy.

Conclusions: Preliminary data from this project highlight the significant role of trees in reducing temperatures across campus and creating variation in temperature across a landscape. To better understand these temperature variations and manage land accordingly, a long-term microclimate monitoring system is essential. Additionally, expanding tree canopy in heat-prone areas should be prioritized to help cool the campus and boost resilience against extreme temperatures.

EXECUTIVE SUMMARY

The University of British Columbia (UBC) is at the forefront of sustainable development, striving to reduce extreme heat impacts, enhance biodiversity, and mitigate the urban heat island effect on its Vancouver campus. This research focuses on understanding how landscape features, such as tree canopy and ground cover, influence microclimates and human thermal comfort. Microclimate monitoring is key to informing land management and development decisions aimed at improving campus sustainability.

Research Objectives

The primary objectives of this study were to:

1. Identify existing weather and climate datasets on UBC campus.
2. Conduct pilot data collection to establish proof of concept
3. Develop recommendations for a long-term microclimate monitoring framework that informs campus land management and planning.

Methodology

A mixed-methods approach was employed:

- **Expert Interviews:** Consultations with UBC experts provided insights into current climate monitoring systems on campus.
- **Literature Review:** Key factors influencing microclimates were identified, focusing on those relevant to land management.
- **Stakeholder Meeting:** A roundtable with campus planners and managers highlighted the need for more data on the relationship between microclimates and landscape structure.
- **Pilot Study:** Micrometeorology data were collected along a 665-meter transect on UBC's Main Mall to examine temperature variations between different landscape features.

Key Findings

- **Temperature Variation:** The study revealed substantial temperature variation over the 665-meter transect, with mean radiant temperature varying by up to 55°C between open, unshaded areas and densely shaded zones. Tree canopy played a critical role in reducing temperatures.

Conclusions

The observed variation in microclimates across UBC campus points to the need for a long-term microclimate monitoring framework that can capture temperature fluctuations across different landscape types and seasons. Expanding tree canopy coverage in vulnerable areas should be prioritized to reduce extreme heat, and ongoing monitoring will provide the data necessary to inform sustainable campus development.

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LIST OF ABBREVIATIONS

T_{mrt}	**Mean radiant temperature**	Weighted average of incoming shortwave and longwave radiation for a standing reference human.
T_a	**Air temperature**	Temperature of the air of a given area.
LST	**Land surface temperature**	Temperature of a given surface.

INTRODUCTION

Context: What Are Microclimates and How Do You Measure Them?

In the face of a global climate crisis, universities have the unique opportunity to lead in sustainable technology, planning, and policy. As influential centers of research and innovation, institutions like Canada's University of British Columbia (UBC) are pivotal in driving societal advancements. UBC's commitment to reducing campus emissions, maximizing biodiversity, implementing sustainable building designs, and decreasing water consumption highlights its dedication to sustainability (UBC Vancouver Campus Climate Action Plan 2030, Campus Vision 2050, UBC Green Building Action Plan, Water Action Plan UBC Vancouver Campus).

To achieve these ambitious goals, it is crucial to base efforts on cutting-edge scientific research. In response to increasing extreme summertime heat, changing plant life cycles, and decreasing animal habitat health, the micrometeorology of urban landscapes is emerging as a particular area of interest for further research. The well-known Urban Heat Island phenomenon (Howard 1883; Oke 1995) has been observed in many cities due to factors such as increased pavement, greenhouse gas emissions, and energy use. Conversely, vegetation, especially trees, can create vital local cool islands through shading and evapotranspiration (Oke 1987). The complex combination of varying urban materials and human activities across a cityscape generates unique microclimatic conditions- localized, long-term weather patterns that differ from the broader environment. Regional climate and weather are indicated by metrics such as air temperature, satellite-derived land surface temperature, precipitation, cloud coverage, and wind velocity, while microclimates are better understood using different variables that capture hyper-local conditions. While regional climate and weather are primary drivers of microclimates (Ibsen et al. 2024; Wang et al. 2022(1)), landscape elements can be manipulated to alter conditions at a finer scale, significantly impacting the thermal experience of local humans, flora, and fauna.

While it is well-established that increased canopy coverage reduces temperatures (Oke et al. 1998; Rahman et al. 2019; Rahman et al. 2020; Ziter et al. 2019), common metrics like air temperature and land surface temperature do not provide land managers with sufficient information about urban thermal processes for informed decision-making. Air temperature tends to be fairly homogeneous across a landscape, while land surface temperature is often coarse in resolution and does not reflect ground-level conditions. Mean radiant temperature (T_{mrt}) —the average incoming shortwave and longwave radiation relative to a single reference individual—is a superior metric for capturing spatial variation across landscapes and associated microclimates. Moreover, mean radiant temperature has a strong relationship with human thermal comfort and can serve as a proxy for it. Without fine-scale thermal data, understanding the intricate linkages between urban structure and thermal dynamics remains challenging, particularly across varying spatial and temporal scales.

Exploring the relationship between the built environment and thermal responses, by collecting hyper-local micrometeorology data, can guide land management toward a more sustainable future. Currently, sustainable development and community resilience at UBC are constrained by limited knowledge of how landscape structure influences campus thermal dynamics. Advancing our understanding of UBC microclimates across space and time will inform planners on prioritizing heat interventions for human and non-human health, where to protect local cool refuges for humans and other organisms, and how to pursue campus development while targeting heat resilience.

UBC Vancouver Campus

UBC Vancouver is located at the end of the Point Grey Peninsula in Vancouver, on the western coast of BC, Canada. The area is part of the Salish Sea bioregion, which is characterized by cool, wet winters; warm, dry summers; and rich biodiversity (Salish Sea Atlas). UBC campus spans more than 400 hectares, and temperature varies widely throughout the landscape (Figure 1).

Project Objectives

This project aims to establish a foundation for long-term data collection of microclimates across UBC campus by investigating the current state of knowledge, available resources, campus priorities, and carrying out preliminary data collection. Specifically, the objectives are to:

1) Identify current weather and climate datasets and monitoring efforts on campus.
2) Carry out pilot data collection of campus microclimates to:
    a) test methodologies,
    b) establish proof of concept, and
    c) prepare preliminary findings on the relationship between campus spatial heterogeneity and micrometeorology by analyzing trends in data.
3) Develop recommendations for a multi-scalar microclimate monitoring system for UBC Vancouver campus, including research objectives, appropriate measurement tools and equipment, suitable implementation locations, and responsible personnel.

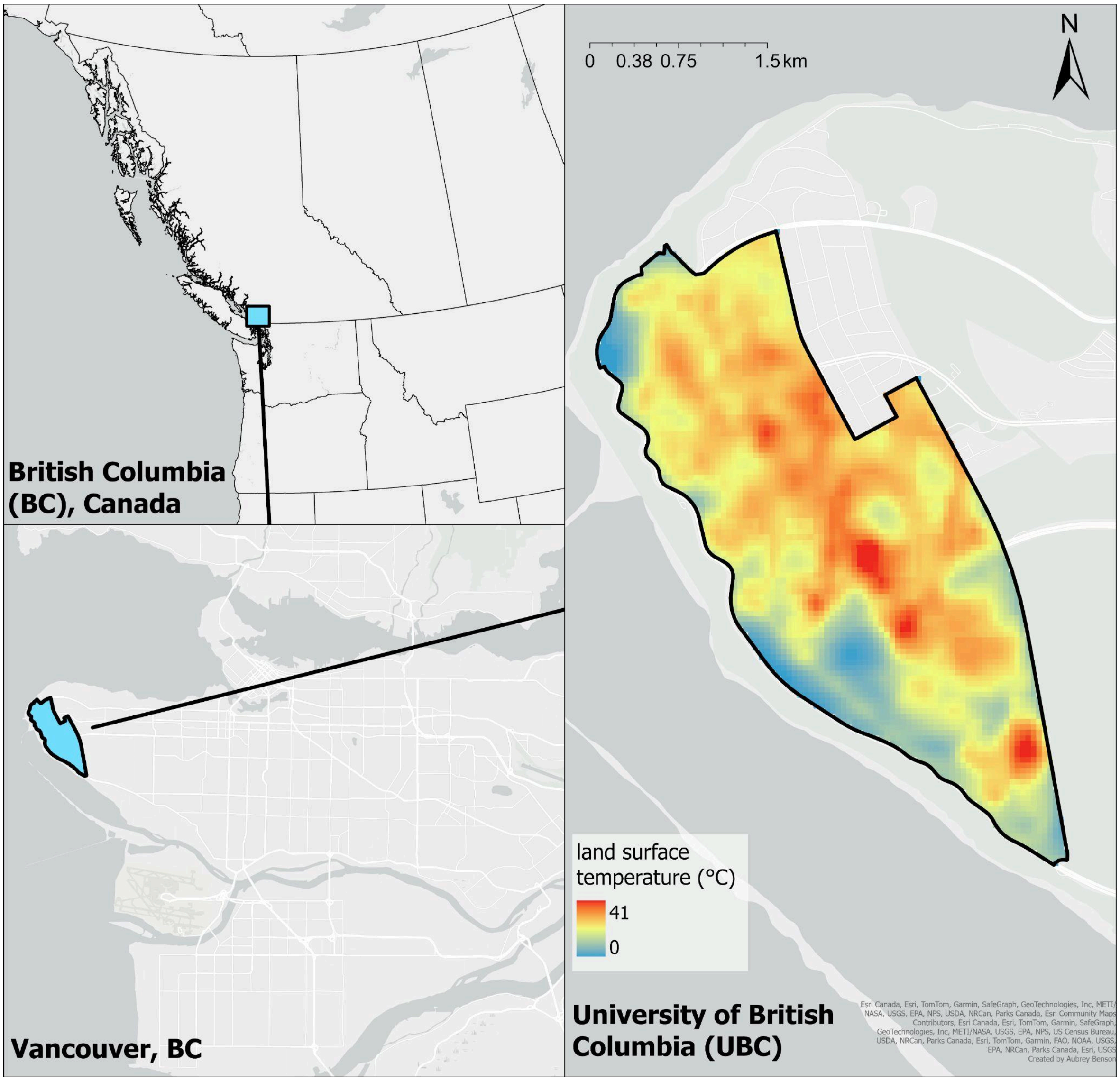

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Figure 1. University of British Columbia Vancouver (UBC) is located on the coast of the Salish Sea in Vancouver, British Columbia (BC), Canada, just north of the USA border, and experiences a wide range of temperatures across the landscape. The map on the right demonstrates the variation in land surface temperature (LST) for UBC on a hot summer day in 2023.

RESEARCH METHODOLOGIES AND METHODS

Methodologies Background

This project uses a mixed-methods approach, drawing upon expertise developed during my MSc of Forestry program. From pursuing an MSc degree in the Urban Ecology & Sustainability Lab, I have gained expertise in measuring and mapping microclimates across urban landscapes. My research up to this point has mobilized an urban ecology framework, involving 1) assessing urban ecosystem structure at a fine, ground-level scale, 2) understanding mechanisms of ecosystem functions, such as vegetation thermal processes, 3) and ultimately drawing inferences about influences on ecosystem services, such as extreme heat mitigation. In this project, I apply a similar framework to UBC Vancouver campus, where I aim to understand linkages between physical elements on the campus landscape and thermal outcomes at a human-relevant scale. This type of research can provide campus land managers and planners with valuable information about how to pursue sustainable development.

Expert Interviews

The first step in this project was to reach out to UBC experts to draw upon their knowledge of campus resources. I interviewed the directors of the Totem Field Station and the Earth Sciences Buildings (ESB) Rooftop Station, which helped me understand current weather and climate monitoring efforts on UBC Vancouver campus. I compiled information about data metrics, availability, and time periods for both stations.

Stakeholder Meeting & Literature Review

To guide land management decisions related to microclimates on campus, both literature and stakeholder input were considered. A literature review identified key factors influencing microclimates, focusing on variables relevant to land management (Table 1). In parallel, a campus stakeholder roundtable meeting highlighted a strong interest in understanding the relationships between vegetation, buildings, water, humans, and other organisms within the landscape. This feedback was crucial in assessing the relevance of identified factors to campus needs and priorities, ensuring alignment with land management goals (Table 2).

Based on these priorities, I developed a list of physical landscape variables known to influence microclimates, informed by decades of urban micrometeorology research (Oke 1989). These variables are categorized into two broad types: composition and spatial configuration. Key composition variables include ground cover type (e.g., grass lawn, concrete, asphalt) (Middel et al. 2019), green space size (Wang et al. 2022(2)), percentage of tree canopy cover (Coutts and Harris 2013; Ziter et al. 2019; Ibsen et al. 2022; Zheng et al. 2022), plant type, plant health, presence of water features, building footprint, and building materials. Configuration variables include plant abundance, building density, distance between buildings and trees, and orientation to the Sun (Simpson and McPherson 1996; McHale et al. 2007; Donovan and Butry 2009; Ko and Radke 2014; Hwang et al. 2015; Abram et al. 2022). By understanding and adjusting these variables, campus land management can mitigate extreme heat and improve thermal comfort in outdoor spaces.

Table 1. Summary of key variables impacting microclimates. These variables can be studied in relation with thermal processes of urban ecosystems to understand linkages between physical landscape elements and temperature and other biophysical outcomes.

Category	Variables/Metrics
Composition of landscape elements	*Ground cover type* *Green space size* *Percent canopy cover* *Plant growth type* *Plant species* *Plant age* *Plant health/condition* *Water features* *Building footprint* *Building material(s)*
Spatial configuration (vertical and horizontal) of landscape elements	*Plant abundance* *Building density* *Orientation to the Sun*

Table 2. Summary of priorities expressed by UBC Vancouver land managers and planners from a roundtable meeting.

Priority Areas for Microclimate Research
Design interventions and **outdoor refuges** on extreme heat days
Relationships between **land cover** and **high-resolution surface temperature**
Impact of cold and warm seasons on **tree and other vegetation health**
Impact of cold and warm seasons on **human thermal comfort**
The variation and structural drivers of **wind** across campus
Long-term neighborhood **shade mapping** and planning
Linkages between **indoor and outdoor spaces**
Linkages between **safety, pleasantness, human open space use, and thermal comfort** across campus
Thermal changes over time and impacts on **biodiversity**
Density and structure of **buildings** on different parts of campus
Shade and evapotranspiration tradeoffs - cooling effects from buildings and trees
Rooftop effects - heat across vertical space
Heat, vegetation, and soil relationships

Pilot Data Collection/Case Study

Study Area

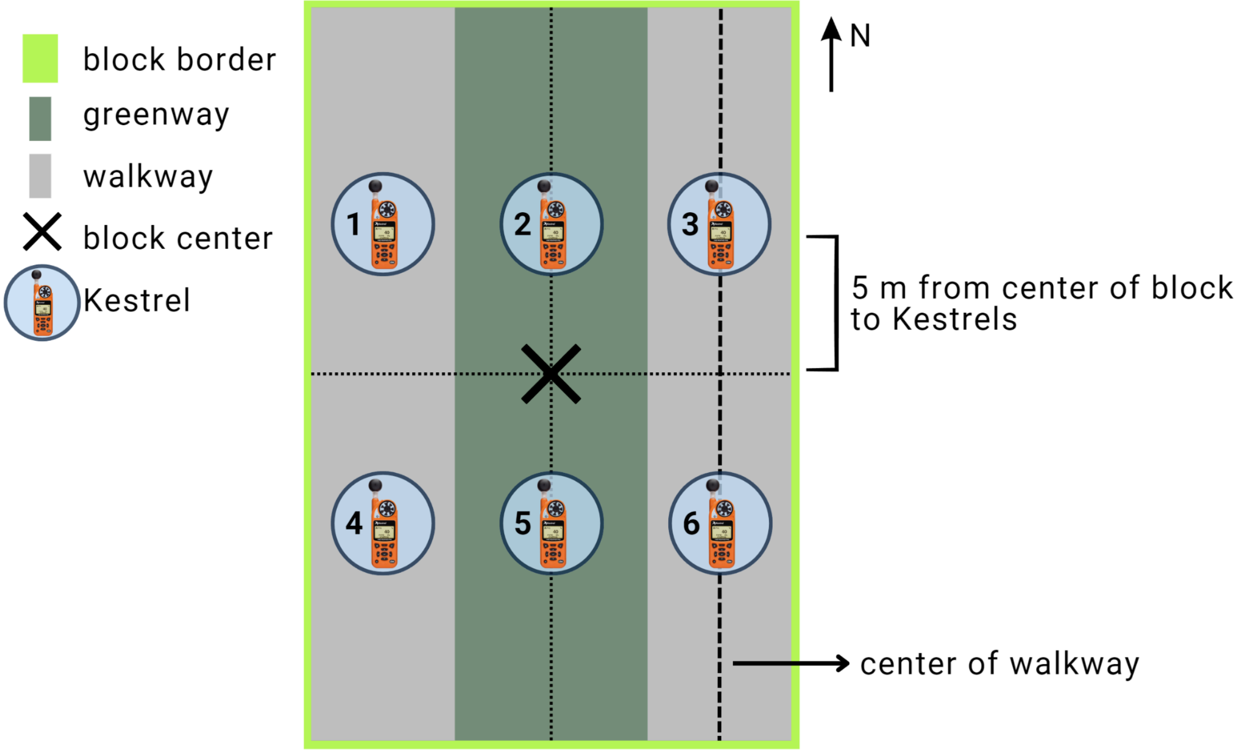
Pilot data were collected on July 8th and August 8th, 2023 to establish methods for a longer-term framework, and to develop preliminary results about the relationship between the campus landscape and thermal dynamics. A 665 m transect along Main Mall was selected for study, featuring a diversity of ground cover, shade cover, and vertical heterogeneity. The transect was segmented into six blocks, and the edges of each block were delineated by visibly distinct open space type characteristics (Figure 2). Specifically, block 1 was characterized by mature Oak trees above a mixture of turf grass and pavement walkways (Figure 3). Block 2 was characterized by younger, smaller Oak trees over the same turf grass and pavement walkway combination. The 3rd block featured a newly established pollinator garden, which was seeded in 2023 and began showing above-ground growth in 2024, in between two pavement walkways with no tree canopy cover. Block 4 featured an open turf grass field with no trees. Block 5 included a combination of tree coverage, pavement walkway, and mulch-based gardens, while block 6 included total tree coverage above a single wide pavement walkway in between mulch-based gardens.

Figure 2. Study area for pilot data collection. Data were collected from a 665 m transect along Main Mall near the center of UBC Vancouver campus (left). The transect was divided into six blocks (right), each characterized by visually distinct open space type characteristics and varying in canopy coverage and ground cover composition. Each block pictured is delineated according to GPS points collected on the ground, highlighting the edges of each open space; Blocks 5 and 6 were more narrow spaces than the other areas.

Figure 3. Pilot data were collected out on six blocks along a ~500 m transect on Main Mall. Shown are blocks 1 and 2 (top left), block 3 (top right), block 4 (middle left), block 5 (middle right), and block 6 (bottom).

Data Collection: Micrometeorology

Six Kestrel 5400s were positioned around the center of each block to collect micrometeorology data (Figure 4). Kestrels were positioned on tripods at a height of 1.1 meters, which is associated with the standard human center of gravity (Mayer and Höppe 1987), and thermal data were collected for one minute on each device. For the first round of data collection, only five Kestrels were used, due to resource limitations. Before recording thermal data, the Kestrels were positioned and left to acclimate for 10 minutes. Data collection on each block was carried out in 30 minute intervals, with data collection beginning on block 1 at 14:00, block 2 at 14:30, block 3 at 15:00, block 4 at 15:30, block 5 at 16:00, and block 6 at 16:30.



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Data Collection: Explanatory Variables

Shade type and ground cover were recorded for every Kestrel. Each point was classified as either shaded by tree or open (i.e., unshaded). No points were shaded by buildings or other artificial structures. Ground cover was recorded as either grass, pavement, or mulch/low vegetation. At the block scale, canopy cover was extracted for each block. First, GPS points were collected in the field to delineate the four corners of every block. Then, percent canopy cover was calculated for each area using 2021 LiDAR-derived tree cover data.

Data Analysis

Block scale analyses took place to examine ground level thermal dynamics across each walkway. First, all mean radiant temperature (T_{mrt}) and air temperature (T_a) values were converted to anomalies. This was achieved by subtracting T_a data from a reference weather station from our values. Then, average T_{mrt} and T_a anomalies were calculated for each block, averaging values across all points and days.

Analyses were also carried out at the individual sample point scale to quantify the impact of shading and ground cover on thermal responses. We examined differences in T_{mrt} and T_a between shade and ground cover types, regardless of location along the transect.

All analyses were conducted in R Studio (RStudio Team 2020) using the “tidyverse” package (Wickham et al. 2019).

Mean radiant temperature was calculated according to the following equation (ISO 1998; Thorsson et al. 2007; Middel et al. 2016):

$$T_{mrt} = [(T_g + 273)^4 + \frac{1.1 * 10^8 * V_a^{0.6}}{\varepsilon_g * D^{0.4}}(T_g - T_a)]^{0.25} - 273.15$$

Where T_g is globe temperature (°C), V_a is wind speed (m/s), globe thermometer $\varepsilon_g = 0.95$, globe diameter D=0.15 m (due to internal conversions the Kestrel uses when calculating T_g), and T_a is air temperature (°C). T_g and T_a were measured directly by the Kestrels. For V_a, a low, stable wind speed of 0.5 m/s was applied, as recommended by Lin and Matzarakis (2011) and Chen et al. (2014), to reduce overestimation of upper range T_{mrt} values.

Development of Microclimate Monitoring Framework

This project concludes with recommendations for a long-term microclimate monitoring framework for UBC campus, informed by findings from research objectives 1, 2, and 3. The framework emphasizes practical, achievable goals across multiple temporal and spatial scales, addressing campus development needs and priorities.

RESULTS

A Multi-tiered Microclimate Monitoring Framework for UBC Vancouver

Based on insights from this project, we have aligned the best available science with the needs of campus land managers and planners to create a list of potential recommendations for a long-term microclimate monitoring framework (Table 3). This non-exhaustive list outlines some key starting points for future research and associated methodologies. In addition to the ideas stated in the list, there is a need for more complex research that addresses the interests of multiple stakeholders. This includes examining ecosystem service tradeoffs, such as managing land for rainwater infiltration versus heat mitigation, and exploring seasonal disservices, like cold-season impacts when prioritizing extreme heat mitigation.

The continuation of this project depends on cross-departmental support, with students from various faculties mobilized to sustain its data collection efforts. The study of urban heat overlaps with the interest of the following groups on campus: Bachelor of Urban Forestry program in the Faculty of Forestry; urban planning in the School of Community and Regional Planning; Earth, Ocean and Atmospheric Sciences in the Faculty of Science; Biometeorology group in the Faculty of Land and Food Systems; Micrometeorology in the Department of Geography.

Table 3. Examples of paths forward for key future research areas examining UBC Vancouver microclimates, based on priority areas stated by campus land managers and planners and known variables influencing microclimates.

THEME	RESEARCH OBJECTIVE	METHODOLOGIES SUMMARY	DATA COLLECTION PERIOD
Open Spaces - Walkways	What is the impact of shading across campus walkways?	Assess shade cover at a large and small scale and associated temperatures; evaluate seasonal tradeoffs by examining micrometeorology conditions across seasons	Quarterly (summer, fall, winter, spring) or bi-annually (summer, winter)
Open Spaces - Courtyards	What makes some courtyards cooler/hotter than others?	Compare microclimates of courtyards across campus and identify drivers of temperature across seasons	Quarterly (summer, fall, winter, spring) or bi-annually (summer, winter)
Open Spaces - Linear Versus Circular Green Spaces	How does cooling efficacy compare between linear and circular open space?	Compare the micrometeorology of linear (i.e., walkways) versus circular (i.e., fields) to understand the cooling potential between green space types.	Annually (summertime)

Forest Health	What is the long-term impact of extreme heat on forest health?	Assess microclimatic conditions of high ecological quality forest patches and how it changes over the years; repeat DHC ecological health analysis every ~5 years	Annually (summertime)
Forest Health	What is the influence of forest health on heat mitigation?	Compare microclimates between forest patches of low and high health condition to examine the role of healthy forest patches in acting as cool refuges	Annually (summertime)
Neighborhoods	What is the variation in microclimates across campus neighborhoods?	Compare microclimates of neighborhoods to understand equity across neighborhoods; use satellite-derived land surface temperature	Remote-sensing analysis
Neighborhoods	Where are the hotspots within hot neighborhoods?	Evaluate micrometeorology within neighborhoods to understand 1) priority areas for intervention within hot neighborhoods 2) drivers of hot spots	Annually (summertime)
Buildings	What is the impact of building design and configuration on temperature?	Use an urban structure framework to evaluate the impact of various landscape structural zones on micrometeorology	Combination of remote-sensing analysis and summertime measurements

Available Campus Weather and Climate Datasets

To consolidate knowledge of available resources on campus, I examined existing weather and climate datasets specific to UBC. Two main sources for current and past weather and climate data were identified: the Earth and Sciences Building (ESB) Rooftop Station and the Totem Field Station (Table 4, Figure 5). Also identified was the SkySpark dataset, which uses data from heating, ventilation, and air conditioning (HVAC) systems to compile weather measurements around buildings on campus, but has some limitations in its uses.

Downloadable data are publicly accessible for both the ESB station and the Totem station. The ESB Station has the added benefit of being easily viewable by going to *https://wfrt.eoas.ubc.ca/*, scrolling down the page, and clicking on "UBC Rooftop Station." For information on how to download data, please contact SEEDS. SkySpark data is publicly accessible at *https://energy.ubc.ca/projects/skyspark/*. While valiant in its efforts to provide the UBC community with valuable data, the SkySpark platform remains challenging in its accessibility and reliability. Therefore, we recommend using the Totem Field and/or ESB Rooftop stations instead of SkySpark.

Table 4. Summary of weather and climate data resources on UBC Vancouver campus, including the overseeing faculty or department, date range of data, and measured variables.

Data source	Faculty/Department	Date range	Metrics
Totem Field Station	Faculty of Land Food Systems	1959 - present	Air temperature; relative humidity; air velocity; precipitation; soil temperature; global radiation
ESB Rooftop Station	Faculty of Science/ Department of Earth, Ocean, and Atmospheric Sciences	2007 - present	Air temperature; relative humidity; air velocity; precipitation; air pressure; downwelling shortwave radiation

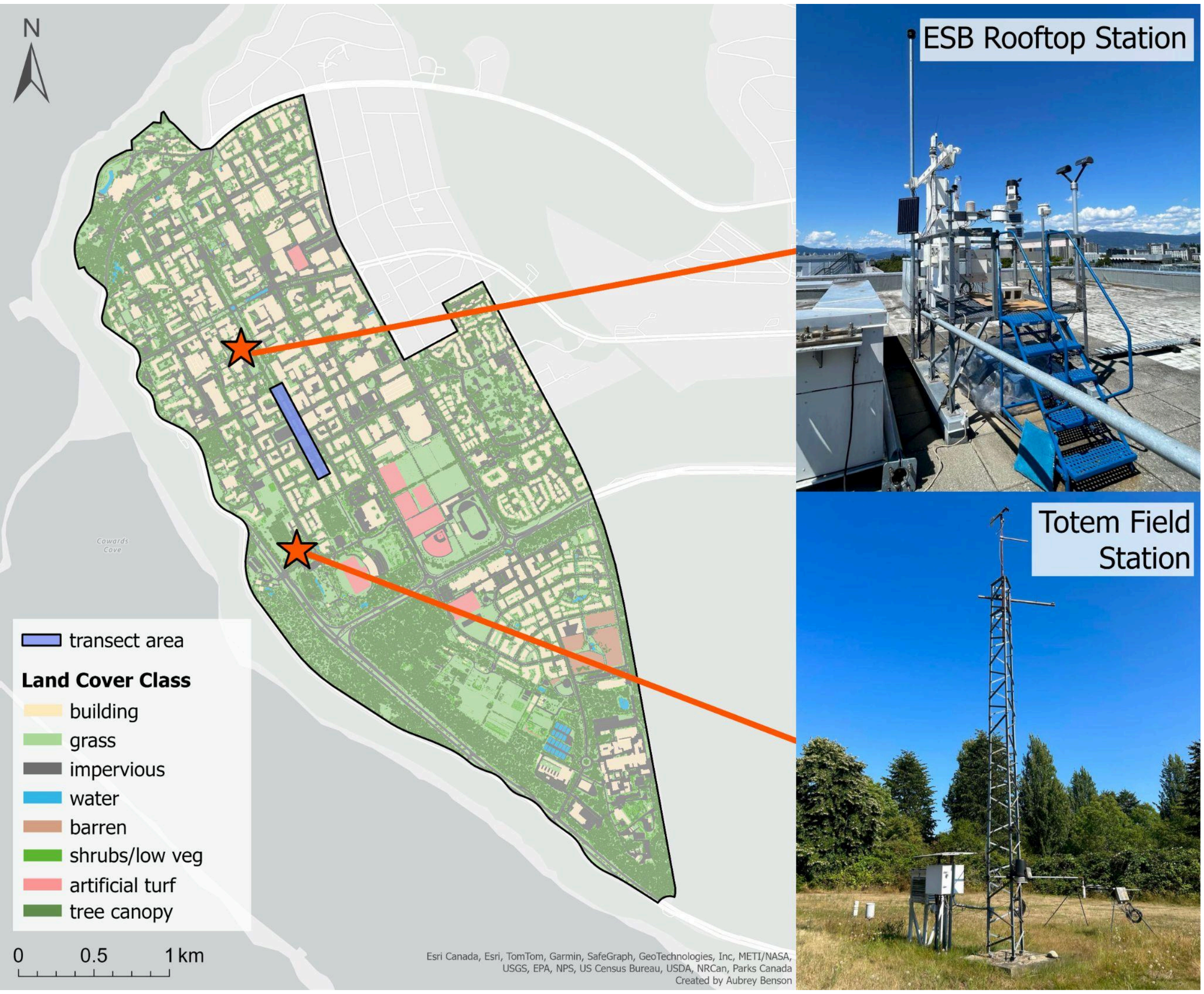

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Figure 5. Earth and Sciences Building (ESB) Rooftop Station and Totem Field Station on UBC Vancouver campus. The "transect area" indicates the study area for the transect developed for this project.

Case Study: Main Mall transect for examination of thermal dynamics of linear open spaces

Block results

To examine potential differences in microclimates between open spaces along a single transect on campus, mean radiant temperature (T_{mrt}) and air temperature (T_a) were averaged by block. Mean radiant temperature (T_{mrt}) varied greatly between blocks (Figure 6). Highest temperatures were seen in blocks 3 and 4, while lowest temperatures were seen in blocks 5 and 6. Our data showed less variation in T_a (Figure 6) and land surface temperature (LST) (Figure 7) across blocks, highlighting the importance of T_{mrt} as a metric sensitive to spatial heterogeneity.

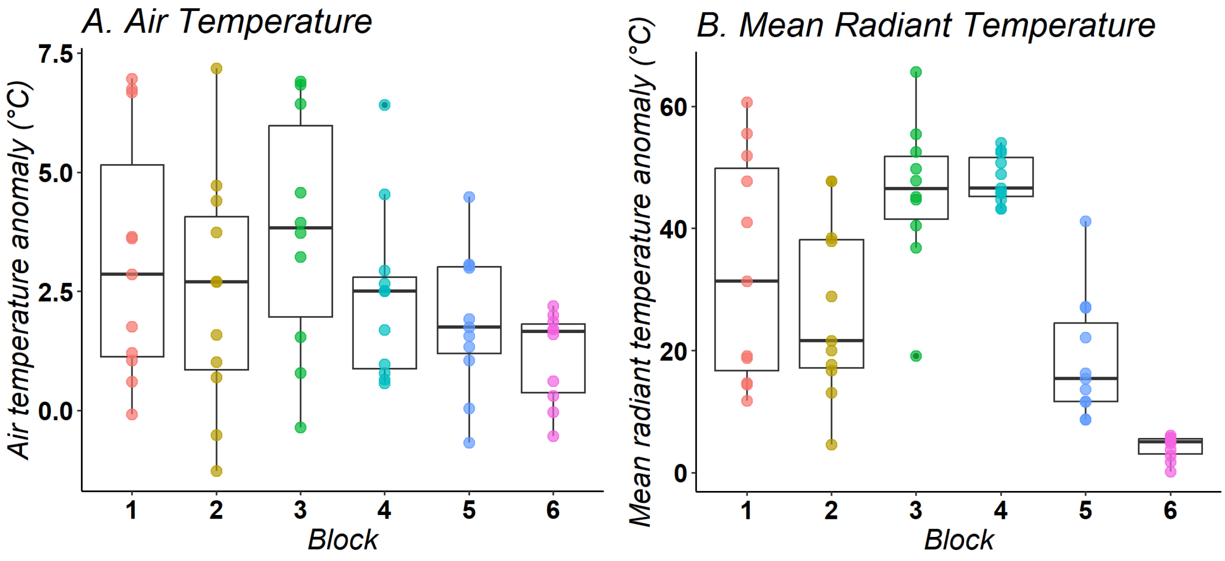

Figure 6. Air temperature (A) and mean radiant temperature (B) anomalies of the six blocks studied across a ~600 m transect on UBC Vancouver campus. Temperature per block was averaged across two afternoon measurement periods and was converted to an anomaly by comparing values to a reference station. Note the different axes scales used between panels A and B.

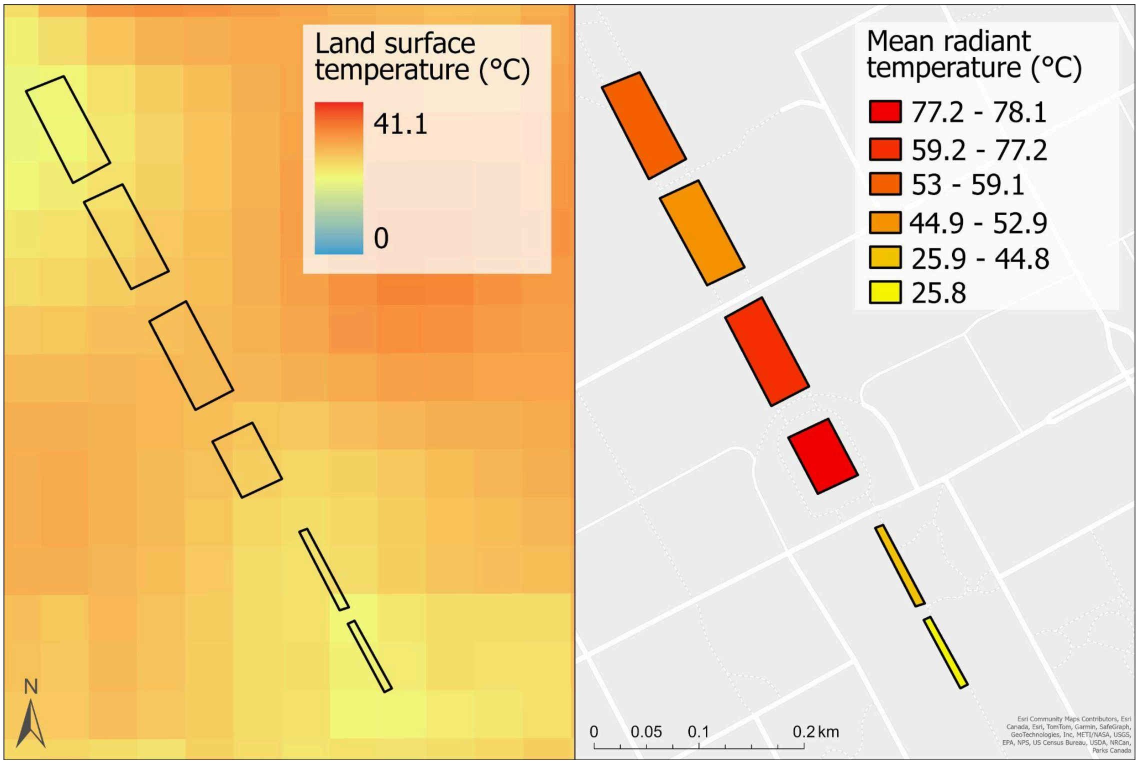

Figure 7. Satellite-derived land surface temperature (LST) from a hot day in the summer of 2023, compared to field-measured mean radiant temperature in the summer of 2024 across the study blocks. The publicly available, widely accessible LST data is coarse in resolution and does not reflect ground level conditions like mean radiant temperature does.

For each block studied, I extracted satellite-derived canopy cover to associate with temperature data. Results showed that increasing canopy cover was associated with reductions in T_a and T_{mrt} (Figure 8).

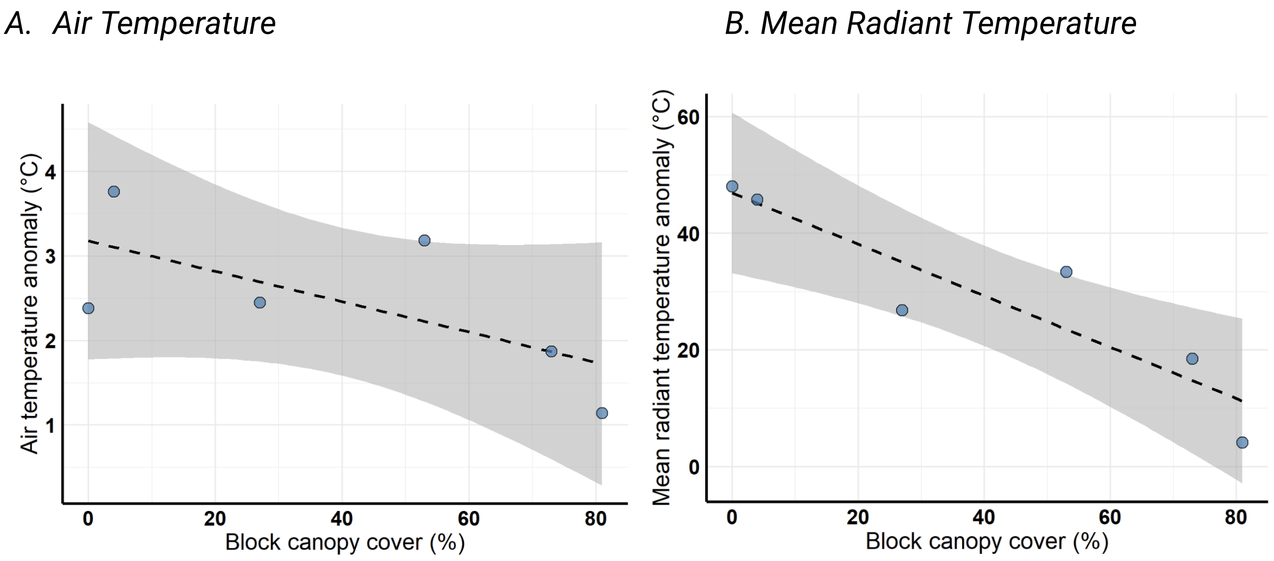

Figure 8. Percent canopy cover and temperature anomalies of the six blocks studied across a ~600 m transect on UBC Vancouver campus. Each point represents a block's satellite-derived canopy cover and either average afternoon air temperature anomaly (A) or mean radiant temperature anomaly (B). Temperature was averaged across 5-6 sample points and two afternoon measurement periods per block and was converted to an anomaly by comparing values to a reference station.

Shading and Temperature

At each sample point, shade type was recorded to indicate whether or not the Kestrel was exposed to the Sun. Results show significant differences between shaded and unshaded areas, when looking at both T_{mrt} ($p = <0.0001$) and T_a ($p = <0.0001$) (Figure 9). Analyses indicated that locations on the landscape free from shade were 41.73 C, on average, warmer in mean radiant temperature (T_{mrt}) and 1.83 C warmer in air temperature than locations under tree shade.

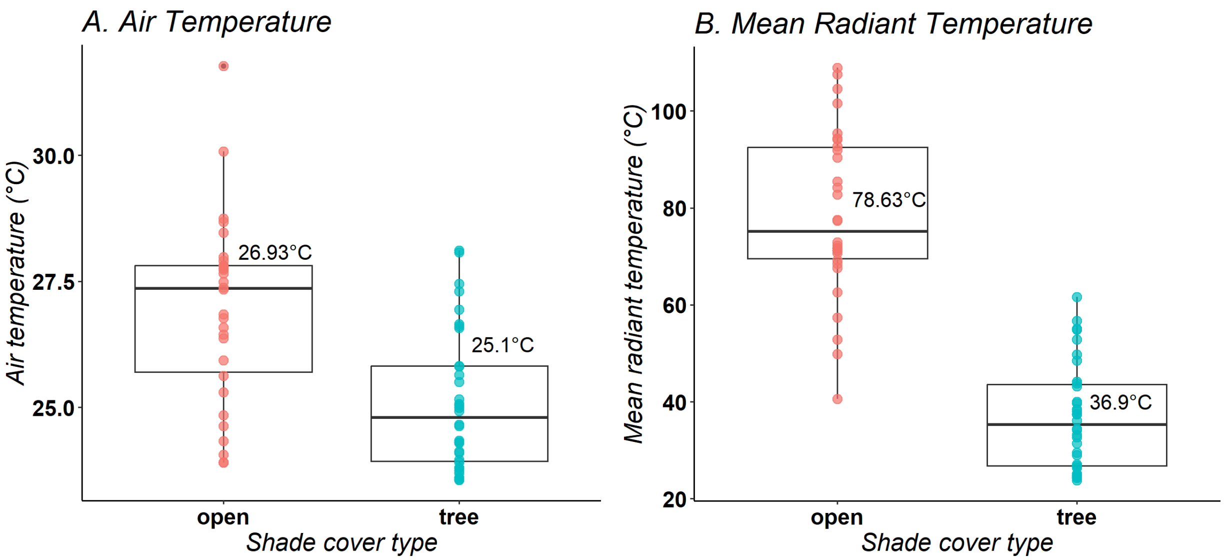

Figure 9. Panel A depicts air temperature (T_a) by shade cover type. Panel B depicts mean radiant temperature (T_{mrt}) by shade cover type. Mean values for each group are labeled. Note the different axes scales used between panels A and B.

Ground Cover and Temperature

Each data point was linked to the type of ground cover beneath the Kestrel to assess whether ground cover influenced thermal outcomes. Result showed that points above pavement were slightly cooler, on average, compared to points above grass or other vegetation (eg. forbes) (Figure 10). However, this is likely because points on pavement were more often underneath tree shade, compared to vegetated locations that tended to be in the open sun. Furthermore, differences in temperature between ground cover types were much lower compared to that of shade types- signifying the key role that tree canopy cover plays in determining thermal outcomes, compared to the less powerful effect of ground cover.

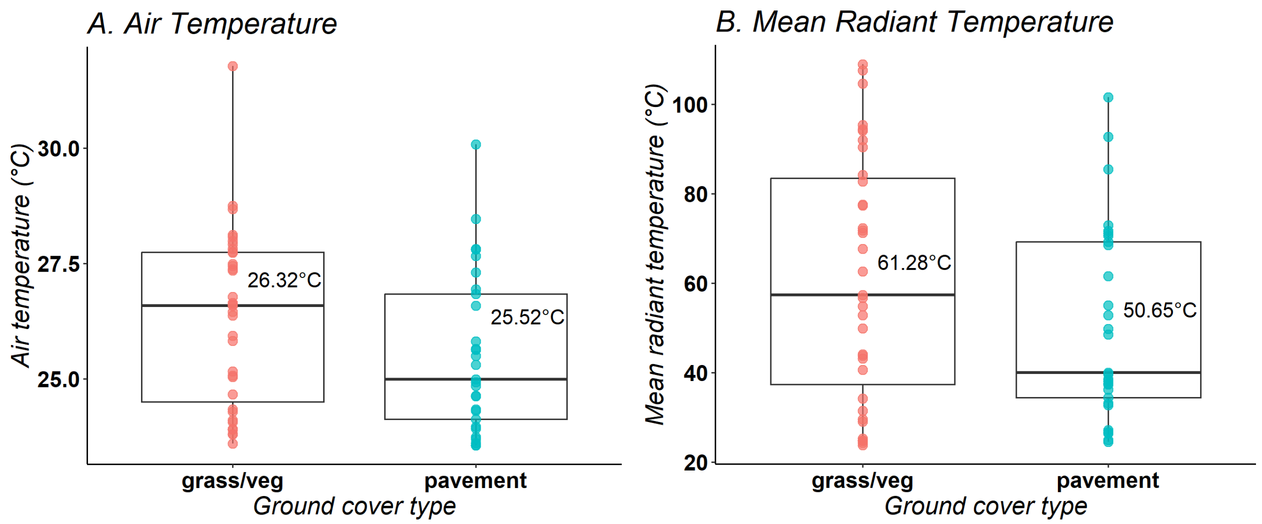

Figure 10. Panel A depicts air temperature (T_a) by ground cover type. Panel B depicts mean radiant temperature (T_{mrt}) by ground cover type. Mean values for each group are labeled. Note the different axes scales used between panels A and B.

DISCUSSION

Shading and Cooling: What Preliminary Data from the Microclimate Monitoring Framework Shows Us

Data from this project underscore the crucial role of tree canopy in mitigating extreme summer temperatures and the microclimate variations that trees create across different landscapes. Average mean radiant temperature (T_{mrt}) varied significantly between blocks, showing a clear, negative linear correlation with increasing canopy cover. This suggests that thermal experiences for humans and other organisms shift dramatically over the ~600 m walkway, with shaded areas providing cooler refuges during hot periods. Furthermore, temperature differences were much more pronounced when looking at T_{mrt}, compared to satellite-derived land surface temperature (LST) and air temperature (T_a), both of which showed minimal variation between blocks.

Ground Cover Effects, Human Thermal Comfort, Winter-term Tradeoffs, and More: Why More Data is Needed

The pilot data collected for this project offer a snapshot of microclimate conditions within a specific area of campus during a single time period, limiting broader inferences about how complex landscape features affect thermal outcomes throughout different seasons. For example, I recorded ground cover type at each sample point along the transect to assess its influence on thermal dynamics, as heat concerns are associated with paved, mulch, and rock surfaces, compared to vegetated ground (Chow and Brazel 2011; Middel et al. 2019). However, no significant temperature differences were detected between grassed/vegetated and paved areas. This was likely due to an uneven distribution of ground cover types across the transect and the overshadowing effect of canopy cover on temperature. We suspect that, because the influence of tree shading on temperature is so strong, thermal differences between ground cover types would become apparent if canopy cover were controlled for under a different study design.

Another key area for future research is incorporating human thermal comfort data, which does not always align with measured meteorology factors. While mean radiant temperature (T_{mrt}) strongly correlates with human thermal experiences, thermal comfort is also influenced by non-meteorological factors such as an individual's stress level, clothing worn, and thermal history (Chen et al. 2012; Middel et al. 2016).

These data are also limited to summertime conditions, but campus land management and planning practitioners are also interested in understanding thermal dynamics during colder periods. The study design can be easily implemented across multiple seasons, allowing for year-round data collection. Continuation into the fall, winter, and spring would reveal how the role of canopy cover shifts in determining thermal outcomes throughout the year and highlight potential winter trade-offs when residents experience cold instead of heat.

Unlocking the Future: Long-Term Microclimate Monitoring at Multiple Scales

Long-term measurement and mapping of hyper-local micrometeorology is crucial for advancing urban sciences, and UBC is well-positioned to lead this effort. Furthermore, sustainable development of UBC campus hinges on our understanding of micrometeorology across the university landscape. Understanding complex urban landscapes, like UBC campus, requires research questions and methodologies tailored to specific management needs. A multi-tiered, multi-scalar approach allows for the isolation of landscape heterogeneity and the understanding of linkages between physical elements and ecosystem service outcomes. However, this approach is novel and faces challenges due to limited precedence and technology, offering both obstacles and opportunities for testing methods and uncovering complexities in urban ecosystems. The pilot study conducted in this project provides a foundation for continued research across multiple spatial and temporal scales on campus. Elements of a larger framework can be added in a piecewise manner, incorporating more research objectives (Table 4) over time.

RECOMMENDATIONS

Resource Investment to Support a Long-Term Microclimate Monitoring Framework

Based on this research, we recommend increased resource investment into carrying out a long-term microclimate monitoring system for UBC Vancouver campus. High-quality, research-grade tools and equipment are needed to collect micrometeorology data across campus and to ensure reliable long-term data collection. The six Kestrel 5400 devices used to collect data in this project cost approximately $775 CAD each. This device is great for capturing snapshots of microclimate conditions. However, different equipment would be needed to implement continuous data collection, like what the Totem and ESB Stations record, but across multiple spaces on campus. Additionally, the Kestrel 5400 is easy to use and collects multiple micrometeorological metrics at once with high accuracy, but is limited in its ability to estimate mean radiant temperature (T_{mrt}) by its use of a globe thermometer.

A popular method for estimating T_{mrt} is by using a globe thermometer, but scientists around the world are turning to more accurate methods for measuring T_{mrt} using alternative, novel machines. These types of novel machines typically utilize six shortwave and six longwave radiometers in varying directions (upwards, downwards, north, east, south, and west) to calculate T_{mrt} with a higher level of accuracy compared to the globe thermometer method. Other researchers are developing methods using three small, metal cylinders to calculate T_{mrt}. UBC could contribute to this field and further its understanding of our own landscape by investing in the development of similar methods for calculating this hyper-sensitive thermal metric.

Other useful equipment for long-term microclimate data collection include forward-looking infrared (FLIR) cameras, radiometers, and drones. FLIR cameras capture surface temperature, with models varying in price and application. The Teledyne FLIR C5, for example, is a pocket-sized camera priced at ~$1,049 CAD. Radiometers provide direct measurements of shortwave and/or

Teledyne FLIR's Forward-looking infrared (FLIR) C5 camera. Image from flir.ca longwave radiation, offering more precise insights into mean radiant temperature compared to globe thermometers like those in Kestrel devices. Drones have many uses, including capturing high-resolution, birds-eye surface temperature measurements.

Improving Cohesion of Weather and Climate Stations Across Campus

I also recommend enhancing collaboration across disciplines and departments at UBC to support the continuation of campus weather and climate stations, as well as the implementation of the proposed microclimate monitoring system. During my research, I discovered more data than anticipated, but I also noticed challenges in accessing and sustaining these valuable datasets. As interest in heat research grows across campus, coordinated efforts are essential to implement a long-term microclimate monitoring framework. Programs like UBC SEEDS Sustainability provide a strong foundation for fostering cross-departmental communication and collaboration. Building on this, additional support—such as a cross-departmental weather station committee or a designated role—could streamline data collection efforts and enhance long-term station management. While a committee would improve communication, it may require additional time from senior faculty, whereas a dedicated position could focus specifically on managing long-term monitoring and facilitating collaboration across departments.

CONCLUSION

As extreme weather intensifies, UBC can leverage its campus as a living lab to build community resilience and lead in pioneering urban heat research. Unlike warmer cities farther south, Vancouver was not developed to withstand extreme summertime temperatures, leaving its residents vulnerable to the harmful effects of heat. Globally, urban heat is a growing concern, and municipalities and institutions will look for guidance from microclimate monitoring initiatives, like the foundation being established by this project. This project identified a wide range of priority areas for scientific research to address, ranging from human thermal comfort across the campus landscape during extreme summertime conditions, to biodiversity impacts from climate change. These varied needs highlight the pressing importance of fine scale temperature data collection across UBC campus to understand linkages between the physical landscape and thermal outcomes.

Photo from you.ubc.ca

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