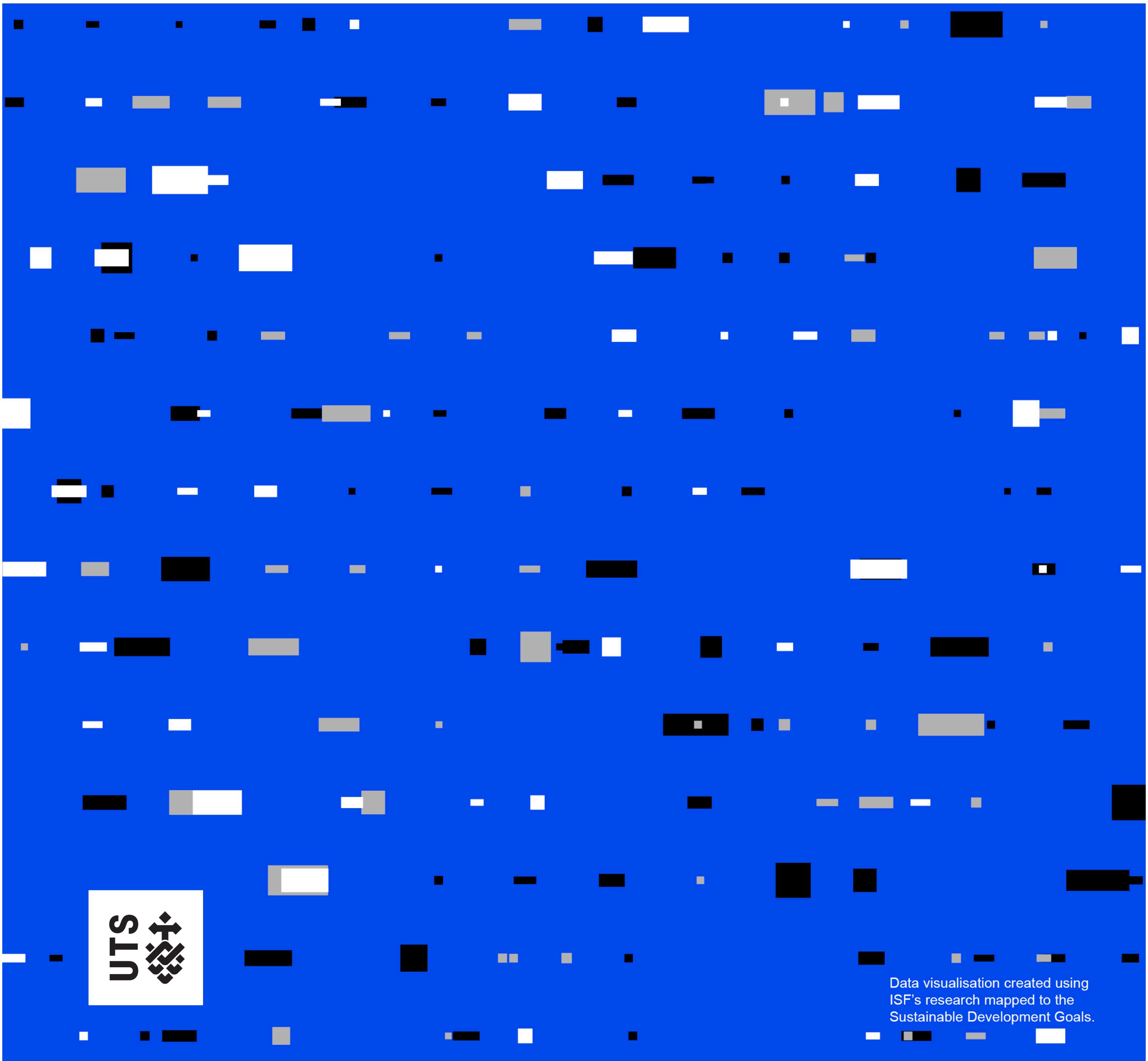

Data visualisation created using ISF's research mapped to the Sustainable Development Goals.

Institute for
Sustainable Futures

isf.uts.edu.au

Urban Heat Monitoring Trial

PREPARED FOR:
City of Sydney

About the authors

The Institute for Sustainable Futures (ISF) is an interdisciplinary research and consulting organisation at the University of Technology Sydney. ISF has been setting global benchmarks since 1997 in helping governments, organisations, businesses and communities achieve change towards sustainable futures. We utilise a unique combination of skills and perspectives to offer long term sustainable solutions that protect and enhance the environment, human wellbeing and social equity.

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Contents

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Urban heat islands in Sydney CBD

Background

Urban heat poses a serious risk to the health and wellbeing of Sydney communities and compromises the liveability of the urban regions throughout Australia. The increased hazard posed by heat is due to two distinct causes: an increase in the number and intensity of heat waves, and the urban heat island (UHI) effect.

In Australia heat waves cause more deaths than any other natural disaster (Steffen, 2015). With the number of days above 35°C projected to increase (AdaptNSW, 2015), and with projected increases in population, the number of heat wave-related deaths in Sydney is projected to grow.

Heat risks in City of Sydney are further intensified by the presence of UHIs, which can increase already extreme temperatures. The concentration of heat in urban areas is a direct consequence of vegetation clearing to make way for urban expansion. The shade and evaporation provided by trees are natural cooling processes and their removal from our urban landscapes causes heating of the land surface under exposure to solar radiation. Impervious surfaces such as roads, footpaths and buildings have replaced urban vegetation. These surfaces absorb heat and prevent rainfall from infiltrating the ground surface, which would normally contribute to evaporative cooling.

While increase in the frequency and intensity of heat waves are due to a changing climate, the UHI effect is due to landscape modification and vegetation removal, which are occurring independently of climate change.

Social groups including outdoor workers, the elderly, infants, the socially disadvantaged and the chronically ill are particularly vulnerable to the health risks associated with urban heat. For these groups, escaping the heat may be difficult due to employment requirements, financial constraints, reduced mobility, medical problems, and physical and/or psychological limitations. For such groups, monitoring of exposure and early warning of the risk is an essential part of managing extreme heat in socially diverse urban contexts.

Urban Heat Islands

Typically, urban areas show significant variation in surface temperature over relatively small areas. Figure 1 depicts the distribution of surface heat for the Leichhardt area on a day when the maximum air temperature reported by the Bureau of Meteorology was 31–33°C.

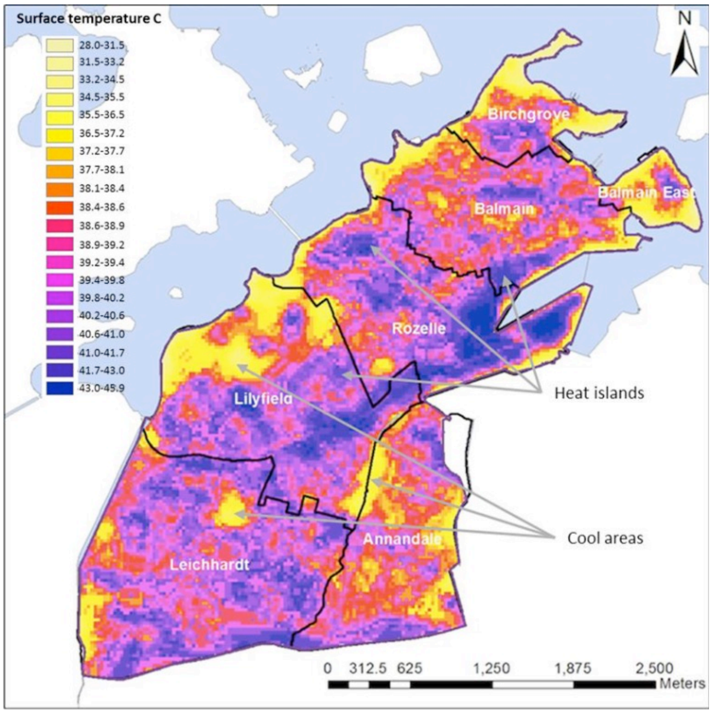

Figure 1: Map of surface temperature for Leichhardt LGA showing the spatial heterogeneity of urban heat (Jacobs and Delaney, 2015a)

Heat islands (discrete areas of high surface temperature) appear as purple shaded regions on the map; areas with cooler surface temperatures are shaded yellow and are most often associated with the presence of public parks. In general, areas close to large bodies of surface water (such as the shoreline of Sydney Harbour) have lower surface temperatures than 'landlocked' areas. Heat islands often form due to the presence of wide expanses of unshaded road surface (such as Parramatta Road and the City West Link in the inner west of Sydney).

The heat patterns across the LGA show high levels of local variation at both the neighbourhood and suburb scales. The heat signatures across the LGA form a mosaic, with a large number of microclimates that range from cool to very hot relative to ambient air temperature. Heat islands and cooler areas are often found in close proximity to each other, sometimes within a hundred metres. These temperature patterns reflect the heterogeneity of land use and variations in land surface characteristics across private, commercial and public spaces (Badcock, 1973). Such patterns typify the older established areas of Sydney's inner suburbs and are markedly different from the larger heat islands found in Western Sydney that result from more uniform land surface cover (Jacobs and Delaney, 2015b).

Reducing urban heat

Environmental conditions in urban areas are highly transient. The first step in mitigating urban heat requires monitoring of the thermal environment to identify the presence of urban heat islands, assessing their spatial and temporal dimensions, and selecting the appropriate combination of site-specific actions from the urban cooling toolkit (Figure 2).

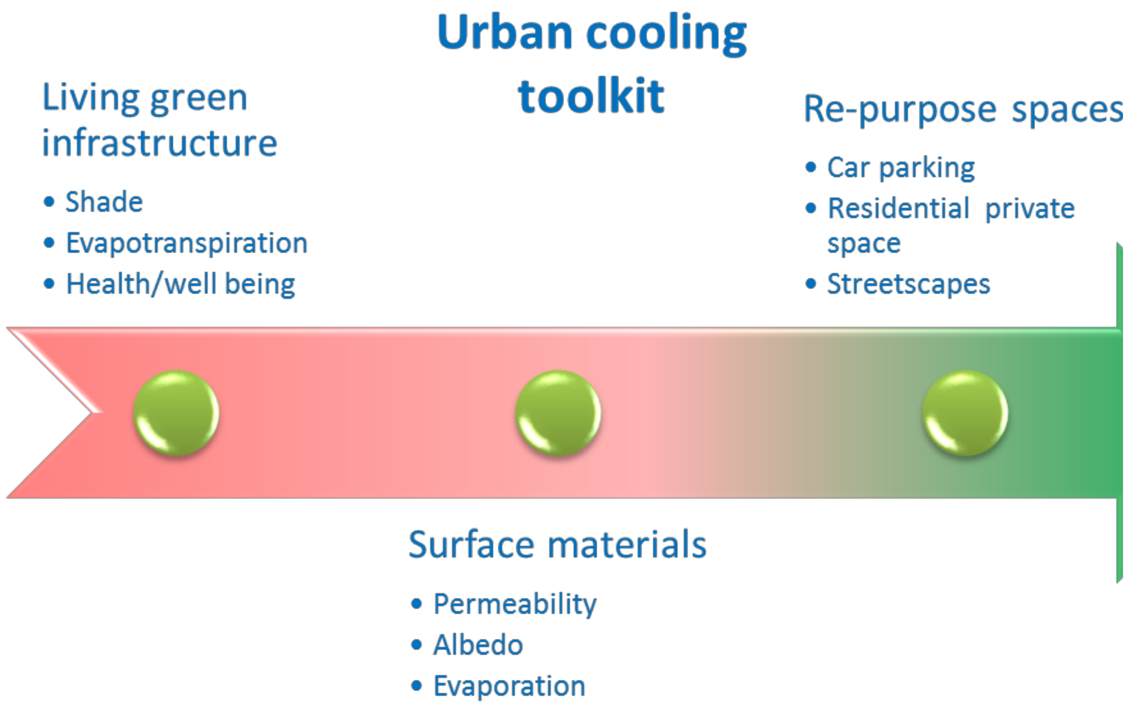

Figure 2: The toolkit of major options available to mitigate urban heat (Jacobs and Delaney, 2015a)

Project Background

The Technology for Urban Liveability Program (TULIP) is an initiative of the University of Technology Sydney (UTS), with cross-faculty support from the Institute for Sustainable Futures (ISF) and the Faculty of Engineering and IT (FEIT). In 2017, TULIP deployed LoRaWAN temperature and humidity sensors in partnership with the City of Sydney (CoS) in locations across Chippendale and Redfern, to monitor urban heat. The aim has been to trial the new technology and to establish its viability against existing temperature sensors owned by the City. The existing models (supplied by a provider called Ajenti) are large arrays mounted on custom fixed poles that were installed with relatively significant capital works. The Ajenti sensors provide real time data via 3G connectivity and are costly to maintain. Together with their bulk, this makes any upscaling to a larger sensor network impractical. TULIP is provisioning LoRaWAN sensors that cost roughly $400 per device[*], roughly one-tenth of the cost of the existing sensors. The first three of these were deployed in Chippendale and Redfern on the same poles as the existing Ajenti sensors (50cm from the existing sensors). Since this report was commissioned, another three sensors have been deployed in nearby locations such as Prince Alfred Park in Surry Hills.

The goal for this trial project was to test the performance of the new LoRaWAN sensors against the old Ajenti sensors. TULIP sees value in longitudinal monitoring and expansion of the sensor network in order to inform urban heat monitoring and strategic heat responses in the Sydney CBD. With their low cost and low maintenance fees, small size, self-contained nature (requiring no electrical wiring) and ability to quickly and easily attach them to existing poles, LoRaWAN temperature and humidity sensors have the potential to form the basis of an affordable expanding network across the city, replacing the existing Ajenti technology.

In order to explore this further, the decision was made to analyse data from both sensor types, investigating longitudinal trends from the Ajenti transmissions as well as any differences apparent in the TULIP transmission from a similar time period.

Project Objectives:

There are three major objectives associated with this work:

1) Analyse data from both sensor types to explore longitudinal trends in the Ajenti sensors and compare/contrast to the shorter-term data available from the TULIP LoRaWAN sensors, identifying any limitations in the TULIP data when compared to the Ajenti data as well as further opportunities for data-gathering and analysis.
2) Outline cost effectiveness of installing the new sensors for ongoing monitoring of urban heat.
3) Provide a case for developing a more significant urban heat monitoring strategy in the City of Sydney.

[*] *Note that sensor prices are dropping rapidly. One temperature and humidity device now costs roughly $200, including configuration, half the cost from six months ago.*

TULIP sensor technical overview

LoRaWAN network technology

Long Range Wide Area Networks (LoRaWAN) part of a raft of Low Power Wide Area Network (LPWAN) technologies that are rapidly gaining traction in the smart city space. They are a means of connecting distributed devices with a central ‘gateway’ and sit alongside better known network technologies such as Wifi, Bluetooth and 3G, though they are markedly different in their capacity. Variation amongst LPWAN technologies is clearest in terms of their dffering business models and accessiblity with some (such as Sigfox) tending towards more closed and proprietary models. While LoRaWAN is not inherently open and accessible, a majority of open LPWAN networks at this time tend to be LoRaWAN.

TULIP is not exclusively tied to the use of LoRaWAN technology however UTS does see it as perhaps the most promising available connectivity option for scalable distributed low-cost urban sensor networks at this time. The Institute for Sustainable Futures is also the owner of a LoRaWAN gateway (at 235 Jones St, Ultimo), which is enabling the urban heat monitoring trial with the City of Sydney and is positioned to support a range of other smart city pilot projects in the inner city.

Network coverage

LoRaWAN utilises shortwave radio to send small data packets from devices to a central antennae or ‘gateway’ at regular set intervals. The range of a gateway varies with topology and the built environment. With a clear line of sight, a device can connect over long distances (well in excess of 10km). In the inner city, with buildings that block the signal, connectivity tends to be strongest in a 2-3km radius of a gateway. ‘Blind spots’ do exist close to a gateway, where signal is entirely blocked, however buildngs also ‘bounce’ signals around corners so these spots are not widespread. Any new proposed location for device deployment does need to be assessed for connectivity. Initial TULIP activities relating to the UTS gateway in Ultimo have confirmed near continuous coverage across Chippendale, Redfern, Eastern Surry Hills, Ultimo and Broadway. As the number of LoRaWAN gateways in the city grows, blanket connectivity will increase.

Zero marginal cost for device connection

Unlike 3G/LTE technology, where each connected device has a direct connectivity cost, LoRaWAN allows devices to be connected to a gateway for no per-device cost. A gateway does have recurring overheads associated with maintenance and its own connectivity to the internet, however it can support thousands of devices connected to it. Adding new devices to a network has an upfront capital expenditure (the device itself) and a low installation fee. The supporting data platform (that ingests data from individual sensors) also has recurring annual costs and these are tiered by the number of devices connected, however the tiers are large – for example, the current TULIP platform costs remain level for the first 500 devices. That means, the connectivity for the first 500 devices deployed is charged at a flat rate, meaning that there is no difference in total connectivity cost for a network if there are 6 devices connected or 500 devices connected.

The devices

Self-contained power with long battery life

The power requirements of a LoRaWAN transmitter are very low, as is the computational power required to run one. Simple sensors like those for temperature and humidity also have very low power requirements. This all means that a temperature and humidity sensing device with LoRaWAN connectvity can operate on a single Lithium Ion battery for over five years.

Fast and simple device installation

LoRaWAN temperature and humidity sensors are compact and self-contained, requiring no external power or fibre connection. A device measures approximately 8cm per side and can be easily and safely strapped to a pole using stainless steel cable ties. Given that the installation height is 3 metres, a team of two people with a standard step ladder is able to complete an installation in around five minutes. Devices are very versatile in where they can be located. This is in marked contrast to the custom installation of the Ajenti sensors, which required significant civil works.

Rising HF Temperature and Humidity Sensors

The specific model of LoRaWAN temperature and humidity sensors used for the trial (referred to below as *TULIP sensors*) are made by a manufacturer called Rising HF. They measure approximately 8 x 8 x 4cm.

The Smart City industry is rapidly expanding and the range of commercially available options for hardware (and indeed, software) is rapidly evolving to meet demand. At the time of procurement for the trial, RHF devices were the best value option available. Since then, a new option has been identified from a different manufacturer that has superior ruggedness (for outdoor deployment) and is approximately half the cost. The data analysis in this report takes RHF devices as a proof point for LoRaWAN sensors more generally. As new devices are trialled in other locations, we can expect this report to be positioned as the first of a series (working with various partners) that tracks the performance of LoRaWAN temperature and humidity sensors.

Figure 3: Rising HF sensor deployed at Reconciliation Park in Redfern, as part of the trial

TULIP Data Platform

TULIP sensors transmit real-time data via an open community LoRaWAN network hosted at UTS. Data is sent to the TULIP data platform, an open modular data architecture consisting of multiple integrated layers from different industry partners. The strength of the TULIP platform is that it supports functionality and attributes vital for scaling, including:

- streamlined device onboarding and device management
- advanced device, user and locational metadata capture and management
- ingestion from multiple networks, network types and device types
- standardised data formatting and labelling to facilitate interoperability and data discovery
- instantiation of a data model to govern data storage, management, discovery, access and sharing
- heterogeneous data aggregation and management, allowing many different types of city data to be brought together and compared in one place
- designed for integration with advanced analytics and visualisation platforms (e.g. GIS)
- community/third party data production and discovery

The TULIP platform is being designed in direct partnership with another local government and a group of four core technology partners. It is growing to support all major smart city technologies on the horizon. As an open collaborative ecosystem it avoids the problem of so-called ‘vendor lock-in’, providing greater flexibility and control to cities exploring this rapidly expanding space.

Sensor deployments in this study

The first three sensors in the trial were deployed in September 2017 (Table 1, sensors 1-3) at the same sites as the Ajenti sensors. The period of September 2017 to March 2018 saw development of the TULIP data architecture. The most critical early functionality established was secure long-term storage for the data. Most existing systems (including current City of Sydney platforms) are not designed to accept and work dynamically with real time data, therefore two new technology partners were sought by UTS to provide this as a collaborative service. By March the system was running smoothly and from that point, reliable uninterrupted data sets from the first three sensors became available.

An additional three sensors (Table 1, sensors 4-6) were installed in May 2018 to provide expanded coverage.

Table 1: List of sensors deployed and locations

Map Ref	Location	Sensor Type	Parameters Measured	Sensor ID	GPS Coordinates
1	57 Buckland St, Chippendale	TULIP	Temperature, Humidity	RHF-0052	-33.88635, 151.19719
		Ajenti	Temperature, Humidity	2400	
2	Myrtle St (Chippo Hotel), Chippendale	TULIP	Temperature, Humidity	RHF-002d	-33.88735, 151.19854
		Ajenti	Temperature, Humidity, Solar Radiation	2300	
3	Wells St and George St, Redfern	TULIP	Temperature, Humidity	RHF-003a RHF-0037	-33.89186, 151.20222
		Ajenti	Temperature, Humidity	1900	
4	Prince Alfred Park Pool	TULIP	Temperature, Humidity	RHF-0034	-33.88711, 151.2062
5	Prince Alfred Park south	TULIP	Temperature, Humidity	RHF-003b	-33.88925, 151.20469
6	Reconciliation Park, James St, Redfern	TULIP	Temperature, Humidity	RHF-0026	-33.8901, 151.20336

Figure 4 displays these locations on a map of the region. An interactive map is also available.

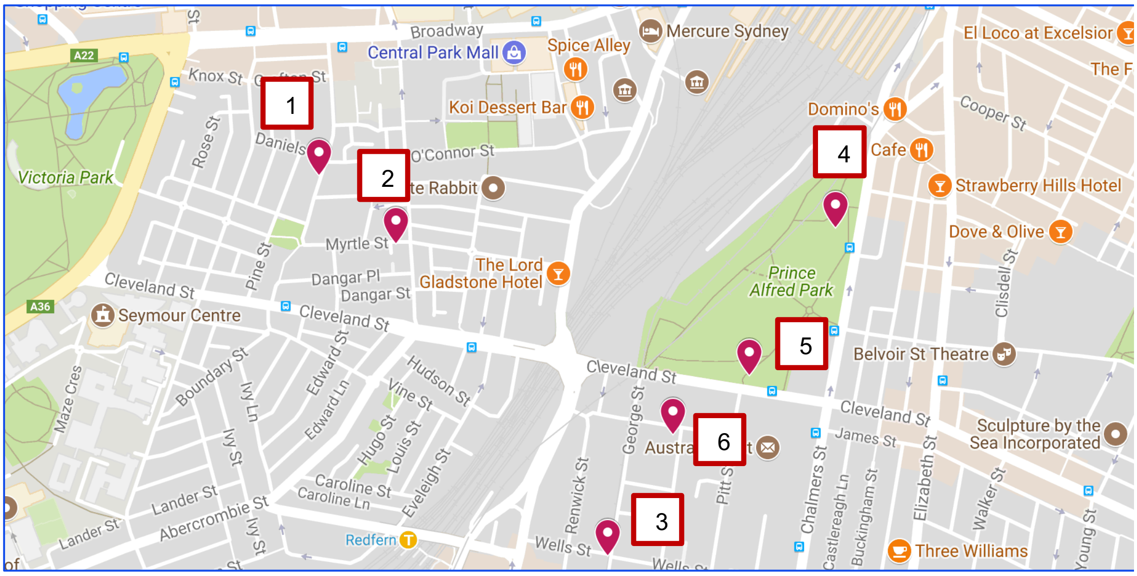

Figure 4: Map of deployment locations for Ajenti and TULIP sensors in Sydney CBD

Methods

Data acquisition and cleansing

Both Ajenti and TULIP sensor data was acquired in .csv format for analysis. A summary of the raw data library is provided in Table 1, below.

Table 2: Raw data sources

Sensor Type	Sensor/File No	Start Date	Finish Date	Parameter Measured
Ajenti	1900	9/5/17	14/5/18	temperature
Ajenti	1900	9/5/17	14/5/18	relative humidity
Ajenti	1900	1/1/17	11/5/17	relative humidity
Ajenti	2300	9/5/17	14/5/18	temperature
Ajenti	2300	9/5/17	14/5/18	global solar radiation
Ajenti	2300	9/5/17	14/5/18	relative humidity
Ajenti	2400	9/5/17	14/5/18	temperature
Ajenti	2400	9/5/17	14/5/18	relative humidity
TULIP	rhf002D-T	5/3/18	7/5/18	temperature
TULIP	rhf002D-H	5/3/18	7/5/18	relative humidity
TULIP	rhf003A-T	5/3/18	7/5/18	temperature
TULIP	rhf003A-H	6/3/18	17/4/18	relative humidity
TULIP	rhf003B-T*	5/3/18	26/3/18	temperature
TULIP	rhf003B-H*	5/3/18	26/3/18	relative humidity
TULIP	rhf0026-T	5/3/18	7/5/18	temperature
TULIP	rhf0026-H	5/3/18	17/4/18	relative humidity
TULIP	rhf0034-T	5/3/18	7/5/18	temperature
TULIP	rhf0034-H	5/3/18	7/5/18	relative humidity
TULIP	rhf0037-T	26/3/18	13/4/18	temperature
TULIP	rhf0037-H	26/3/18	13/4/18	relative humidity
TULIP	rhf0052-T	4/3/18	7/5/18	temperature

TULIP	rhf0052-H	4/3/18	7/5/18	relative humidity

*Excluded from comparative analysis

Cleansing and analysis of the data was undertaken in the open-source software program R Studio, Version 1.0.153, with small amounts of data management and analysis undertaken in Excel.

Initial data cleansing was undertaken by viewing the files and excluding any obvious outliers (such as unrealistically low temperatures) and missing fields that may affect later calculations. Only one file contained parameters relating to solar radiation, so this particular subset of data was not used in the current study. Due to one sensor (TULIP 003B) only providing a short date range, this sensor was excluded from comparative analysis between the two sensor types, however this data was reviewed on an individual basis.

The format of all the datasets included timestamps from the sensors, so these were converted into a format capable of performing calculations for exploratory data analysis.

Data analysis

Following initial data cleansing, the files were categorised into subsets according to parameters of interest. Air temperature and relative humidity were explored using boxplot functions, summary statistics, t-tests and plotting.

In order to better define the data for comparison between the two sensor types, the raw data library was reviewed to identify a date range that captured most datasets and parameters. On comparing the available data, it was decided to compare the date range between 23/03/2018 and 13/04/2018, as this range captured all but one sensor.

Due to the limited scope of this project, analytics were constrained mainly to exploratory investigations to view broad trends and visually compare summary statistics between the sensor locations and sensor types.

Results

Longitudinal analysis of Ajenti sensors

Data from the Ajenti sensors allowed for a full year of records for air temperature and relative humidity in the three locations. The temperature data from the three Ajenti sensors (Figure 5, Figure 6 and Figure 7) shows similar trends, including where outliers appear during heatwaves in the warmer months. The boxplots that follow display the minimums and maximums (dotted and capped lines), median (black line), quartiles (proportions of the coloured box above and below the median) as well as outliers (black circles). As this data is grouped by month to calculate these statistics, diurnal fluctuations may be masked, however, seasonal variation is evident across the year of monitoring. Of note are the outliers (extremes) associated with Ajenti 1900, deployed in Wells and George Sts Redfern, over the summer months. These extremes seem to extend to approximately 45°C in January 2018, whereas the Ajenti 2400, deployed in Buckland Street under tree canopy, does not appear to have recorded extremes beyond 40°C for the same period.

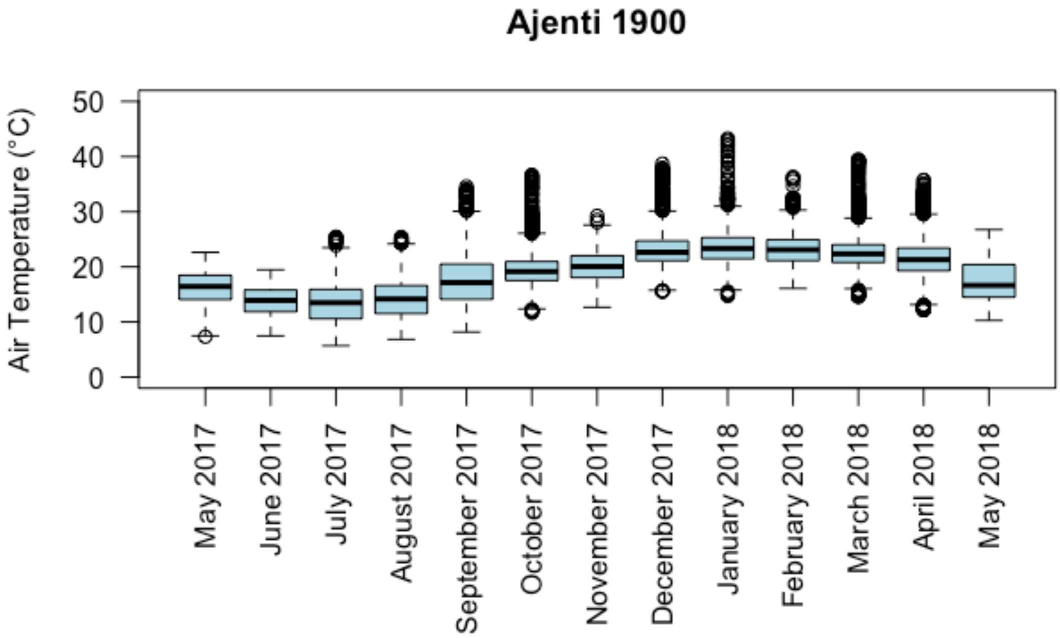

Figure 5: Ajenti 1900 sensor temperature data, summary statistics by month, May 2017-May 2018

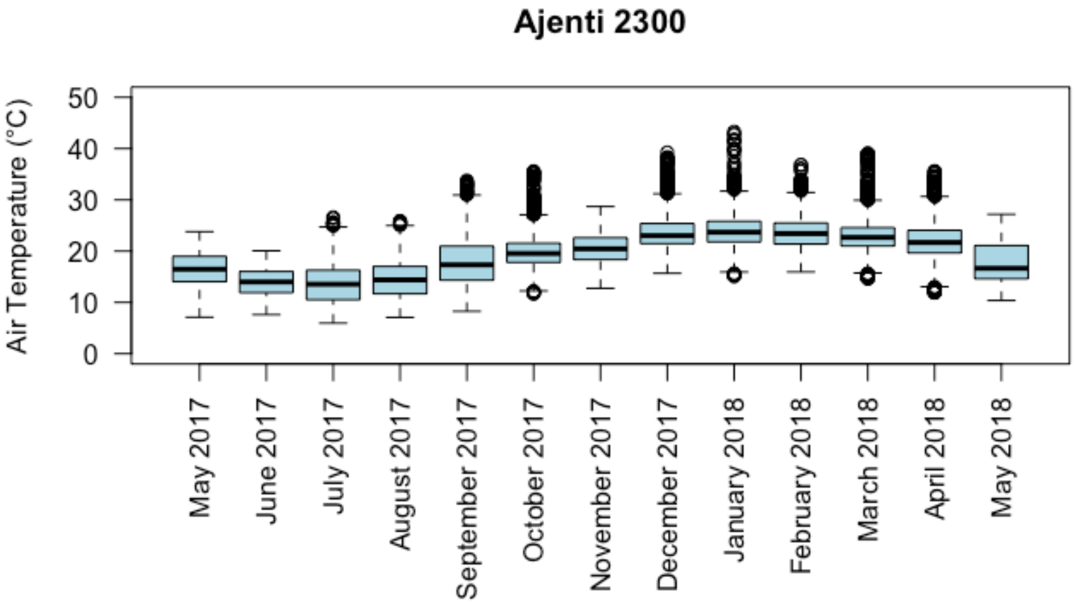

Figure 6: Ajenti 2300 sensor temperature data, summary statistics by month, May 2017-May 2018

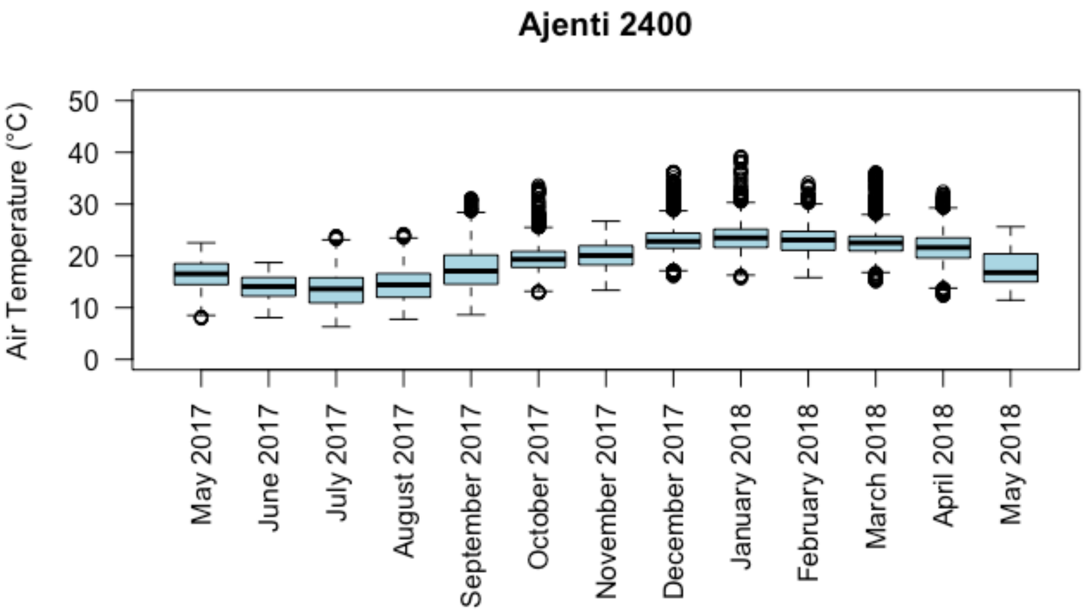

Figure 7: Ajenti 2400 sensor temperature data, summary statistics by month, May 2017-May 2018

The relative humidity patterns from the three Ajenti sensors show some variation between locations (Figure 8, Figure 9 and Figure 10). However, overall seasonal trends do not appear to dramatically differ between the three sensor locations. All three sensors show evidence of dry conditions from October 2017 – April 2018.

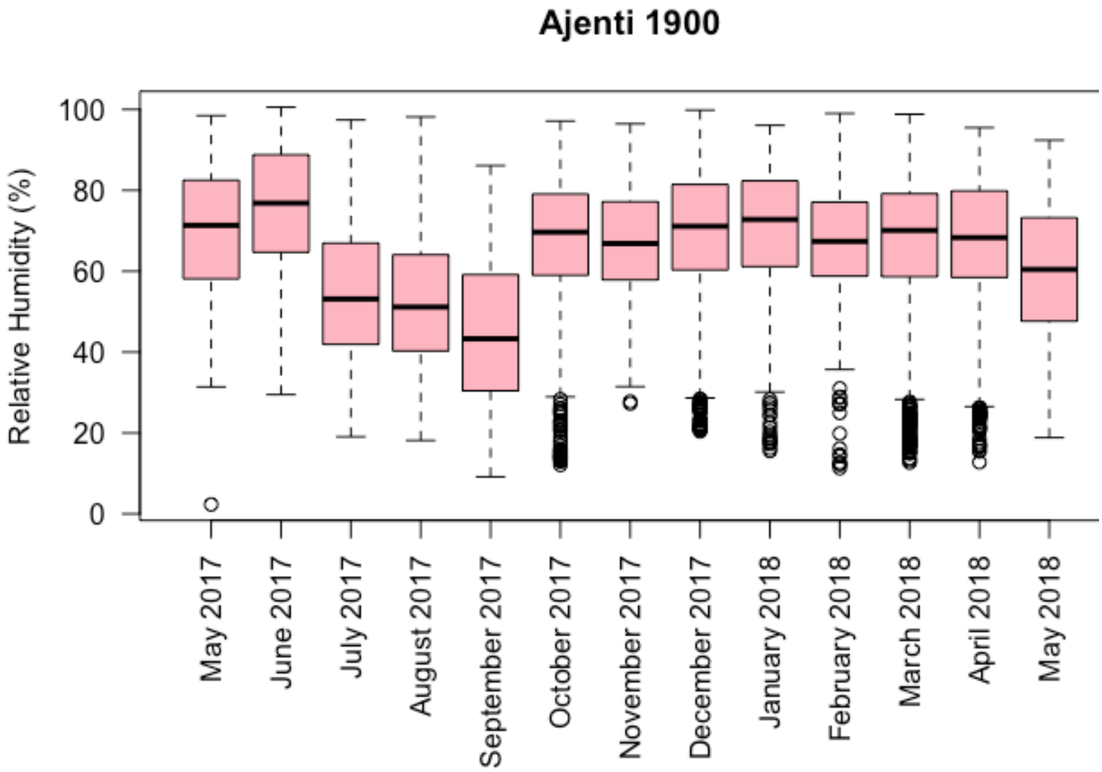

Figure 8: Ajenti 1900 sensor relative humidity data, summary statistics by month, May 2017-May 2018

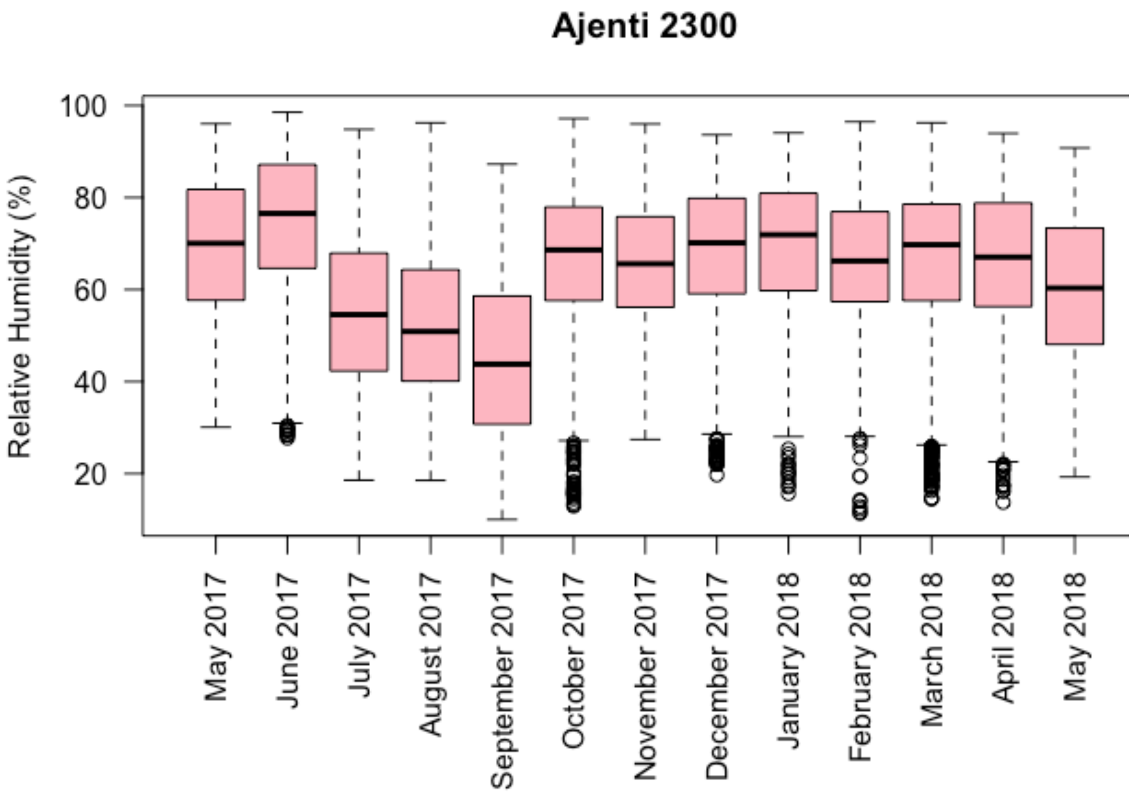

Figure 9: Ajenti 1900 sensor relative humidity data, summary statistics by month, May 2017-May 2018

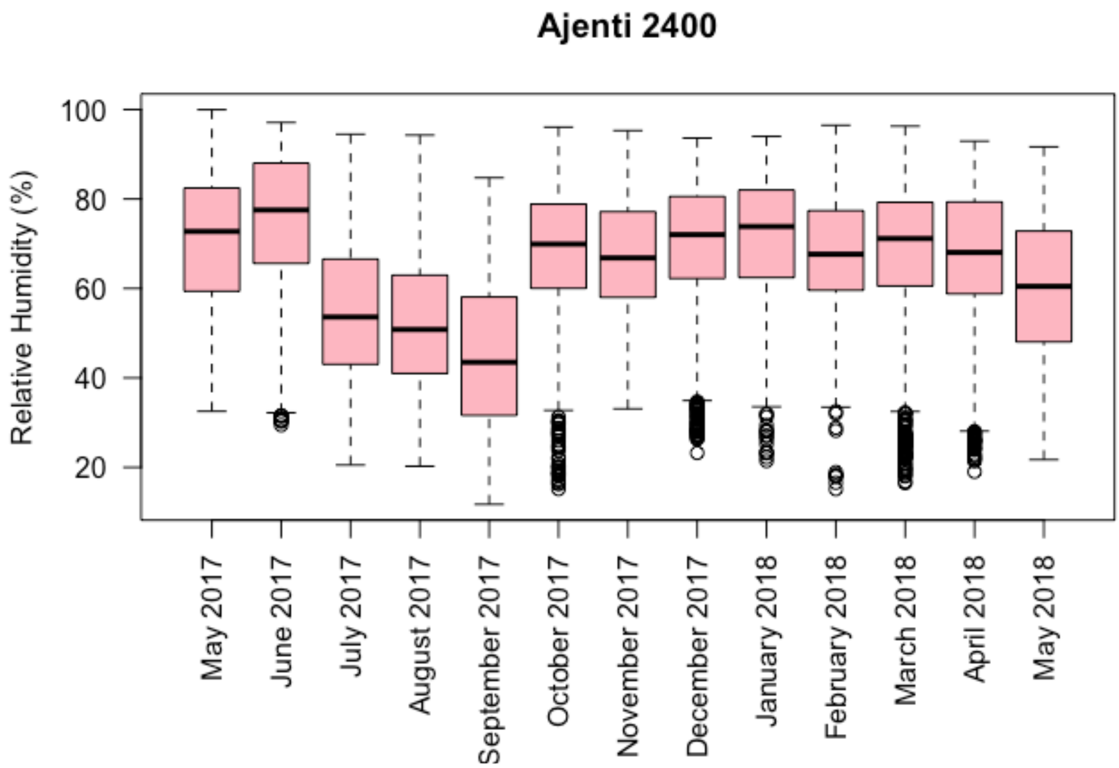

Figure 10: Ajenti 2400 sensor relative humidity data, summary statistics by month, May 2017-May2018

Sensor type comparison

The following section presents results of comparative analyses between the sensor types and individual sensors. It should be noted that two TULIP sensors were deployed at the same location due to malfunction: TULIP003a was deployed at Wells Street to replace TULIP0037.

Due to the large amounts of datapoints contained within the datasets, as well as natural variation associated with environmental data, it was not appropriate to conduct t-tests to compare means between Ajenti and TULIP parameters, as significant differences were found between all samples of the subsetted data from March/April 2018 (including between Ajenti sensors). The sample sizes between acquisition data also differed, with some datapoints representing twice as many observations for the same period. However, the summary statistics of the two sensor types (displayed in boxplots for Figure 11 and Figure 12) point to very little difference in the data medians and dispersions gathered over this period from both sensor types.

Figure 11 displays a comparison between the temperature data derived from the Ajenti and TULIP sensors for the period between 26/03/2018 and 13/04/2018. Matching colours indicate where sensors have been deployed in the same location (same pole). In this figure, it is clear that the median air temperature for this period is similar between the two sensor types and between all sensors generally, but the extremes in air temperature recorded differ somewhat. The ranges in some sensor types differ due to the different sizes of datasets (full statistics available in Table 3, in the Appendix). Interestingly, for this time period there does not appear to be any particular differences between TULIP 0034, which was deployed within Prince Alfred Park, and other sensors deployed in areas with less canopy cover. However, both sensor types deployed in Myrtle St Chippendale (Ajenti 2300 and TULIP 002D) appear to have slightly elevated median air temperature for the period as well as outliers suggesting air temperatures upwards of 37°C. Wells and George Street at Redfern (Ajenti 1900 and TULIP 003A) also appears to have recorded some extreme temperatures, with outliers of approximately 36/37°C for both sensor types. By comparison, the sensors deployed in Buckland Street (Ajenti 2400 and TULIP 0052) exhibit more moderate temperature ranges and less extreme outliers.

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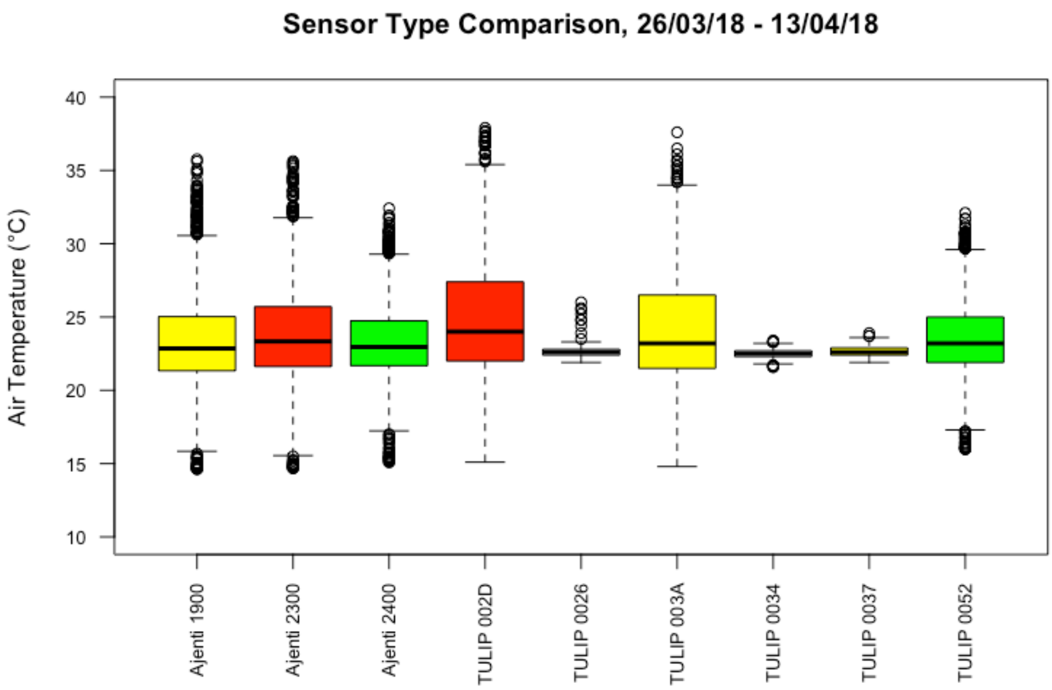

Figure 11: Ajenti and TULIP temperature data, March/April 2018.

Figure 12 displays a comparison of relative humidity data from both sensor types within the same time period of 23/03/18 to 13/04/18. Matching colours indicate where sensors are in the same location (same pole). Medians between all sensors appear similar, though it does appear that the sensors with smaller sample sizes (and therefore smaller ranges) tend to have higher median relative humidity for this period.

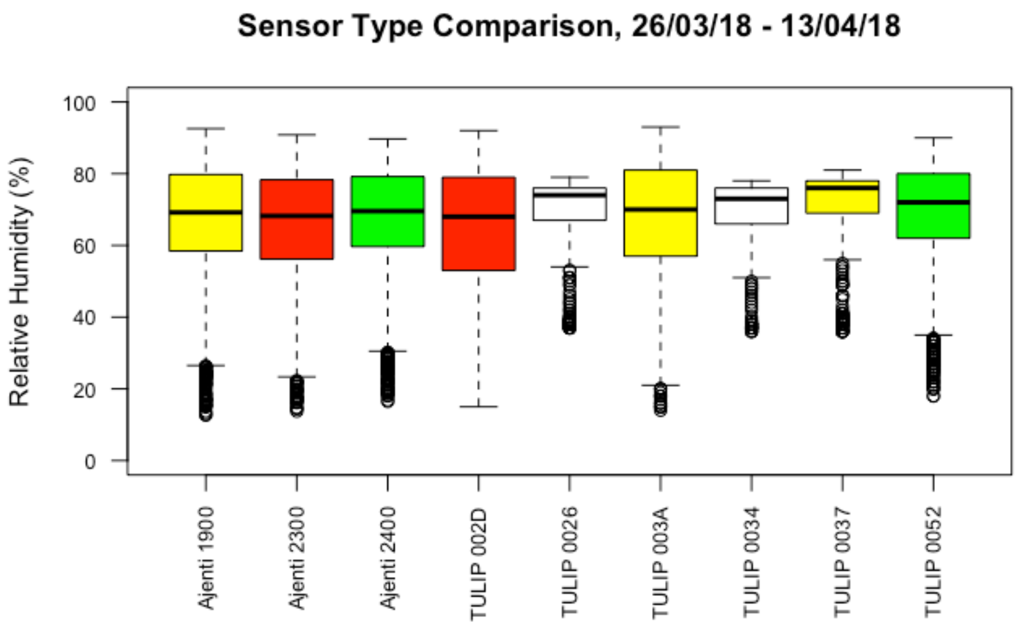

Figure 12: Ajenti and TULIP relative humidity data, March/April 2018.

Mean air temperature and mean relative humidity data, derived from the summary statistics table in the Appendix, is graphically presented in Figure 13 and Figure 14, below. It should be noted that sample sizes (n, as outlined in Appendix) vary between TULIP sensors, and would have some effect upon the statistics generated.

Figure 13 presents the mean air temperature data for each sensor, with Ajenti sensors in the hollow bars and TULIP sensors in the solid bars. Though some variation is evident, it represents only 10% difference in mean degrees Celsius for this sample.

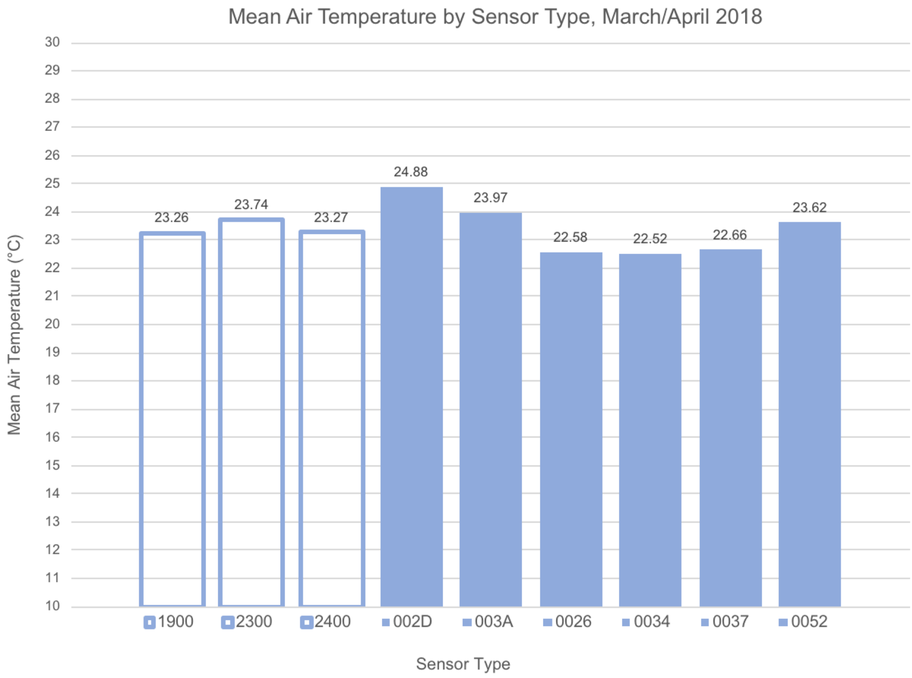

Figure 13: Ajenti and TULIP mean air temperature comparison, March/April 2018

Figure 14 presents the mean relative humidity data for the same period. Ajenti sensors are displayed in the hollow bars and TULIP sensors in the solid bars. Again, the variation evident in this sample amounts to approximately 10% variation in mean relative humidity.

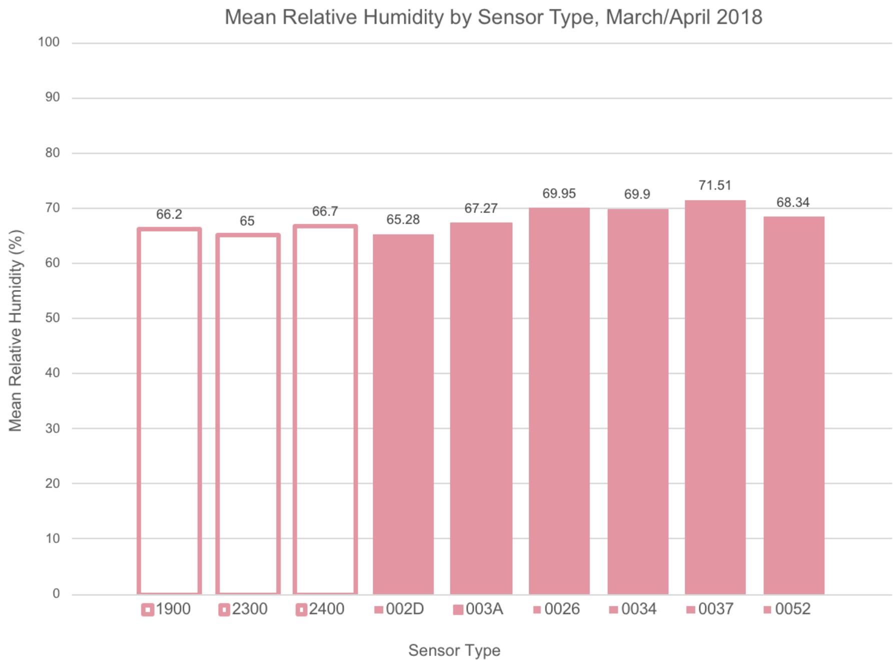

Figure 14: Ajenti and TULIP mean relative humidity comparison, March/April 2018

Discussion and recommendations

The data acquired for this study has demonstrated the value of longitudinal monitoring to assess urban heat and the factors influencing temperature extremes in the urban environment. Time series data like the data logs acquired from the Ajenti and TULIP sensors provides opportunities to assess trends over space and time, generating powerful insights into the impact of urban microclimates in mitigating extreme heat events.

In this study, we have analysed a series of sensor log datasets to investigate the usefulness of annual timestamped data as well as compare the performance of two sensor types. The Ajenti data currently proves most interesting by allowing for visualisation of annual trends in air temperature and relative humidity. These three sensors were deployed in environments with limited microclimate variation, as evidenced by the results of the analysis which show near-identical macro trends between the three sensor types. However, when the 'extremes' (outliers) in this data are assessed, some interesting patterns emerge. Of particular note in this study was the apparent effect of canopy cover in the data derived from the Buckland Street sensor (2400). A full investigation of this factor was outside the scope of the current study, but it would appear that canopy cover (and possibly other environmental factors) reduced air temperatures in this location by several degrees in January 2018.

The TULIP sensors later deployed in treed parts of the same region will likely yield opportunities for future investigations into the role of canopy cover and ground cover in urban heat considerations for the Sydney CBD. At present, the TULIP datasets are too temporally restricted to yield powerful longitudinal results. However, the comparisons carried out in this study to test the reliability of the TULIP sensors alongside their Ajenti counterparts does suggest that these sensors are comparable in their performance, provided that the TULIP data packets are transmitted and acquired in full. The obvious advantage with further deployment of TULIP sensors rather than Ajenti sensors is that a greater number of sensors can be deployed in different locations, increasing data acquisition and providing broader options for spatio-temporal analysis.

Extended monitoring duration as well as increased spatial dispersion would enhance the power of future analyses for this type of data. Further roll-outs of TULIP sensors in locations carefully chosen to assess differences in urban microclimate is recommended. Future studies could examine the impact of factors such as water bodies, building surfaces and glazing, groundcover (type/colour), and vegetation cover and type upon urban heat. The addition of air pollution monitoring alongside relative humidity and air temperature would allow for further analyses of the interaction between these parameters. These factors can be analysed through modelling, statistics, GIS, remote sensing or a combination of these approaches. Further, there is potential to create automated (online portals) and/or interactive (dashboard) analyses of this data with a view to involving the community in citizen science and encouraging education in urban ecology and the health impacts of urban heat.

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Appendix

Table 3: Summary statistics for sensor subsets

Extreme outliers are highlighted in red.

1900	**n=1824**	**n=1824**
Summary Statistic	**Air Temperature**	**Relative Humidity**
Min.	14.62	12.68
1st Qu.	21.26	58.44
Median	22.73	69.19
Mean	23.26	66.2
3rd Qu.	24.89	79.76
Max.	35.76	92.56
2300	**n=1824**	**n=1824**
Summary Statistic	**Air Temperature**	**Relative Humidity**
Min.	14.68	13.75
1st Qu.	21.52	56.16
Median	23.18	68.21
Mean	23.74	65
3rd Qu.	25.65	78.3
Max.	35.63	90.83
2400	**n=1824**	**n=1824**
Summary Statistic	**Air Temperature**	**Relative Humidity**
Min.	15.09	16.48
1st Qu.	21.63	59.66
Median	22.82	69.55
Mean	23.27	66.7
3rd Qu.	24.59	79.19
Max.	32.41	89.68
002D	**n=1663**	**n=1663**
Summary Statistic	**Air Temperature**	**Relative Humidity**
Min.	15.1	15
1st Qu.	22	53
Median	24	68
Mean	24.88	65.28
3rd Qu.	27.4	79
Max.	37.9	92

003A	n=1452	n=1453
Summary Statistic	Air Temperature	Relative Humidity
Min.	14.8	14
1st Qu.	21.5	57
Median	23.2	70
Mean	23.97	67.27
3rd Qu.	26.5	81
Max.	37.6	93
0026	n=986	n=986
Summary Statistic	Air Temperature	Relative Humidity
Min.	21.9	37
1st Qu.	22.4	67
Median	22.6	74
Mean	22.58	69.95
3rd Qu.	22.8	76
Max.	26	79
0034	n=998	n=998
Summary Statistic	Air Temperature	Relative Humidity
Min.	21.6	36
1st Qu.	22.3	66
Median	22.5	73
Mean	22.52	69.9
3rd Qu.	22.7	76
Max.	23.4	78
0037	n=1000	n=1000
Summary Statistic	Air Temperature	Relative Humidity
Min.	21.9	36
1st Qu.	22.4	69
Median	22.6	76
Mean	22.66	71.51
3rd Qu.	22.9	78
Max.	23.9	81
0052	n=1742	n=1742
Summary Statistic	Air Temperature	Relative Humidity
Min.	16	18
1st Qu.	21.9	62
Median	23.2	72

Mean	23.62	68.34
3rd Qu.	25	80
Max.	32.1	90