Brighton & Hove City Council ARUP

# Brighton & Hove Urban Heat Island Assessment

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## Presentation of results – Draft

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20/09/2023

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# 1. Background

# Background to the assessment

## 1. Introduction

For this project, Brighton & Hove's urban heat island (UHI) was analysed using Arup's UHEAT service. The model is run across a 300m hex grid covering the full area of interest (AOI) for Brighton & Hove. This is then aggregated to LSOA (Lower Layer Super Output Area) level to provide a visual representation of urban heat variation across neighbourhoods.

Brighton & Hove is not expected to have a significant UHI, as large coverage of the AOI is classified as rural, and it is a coastal city with higher windspeeds, mitigating UHI effect.

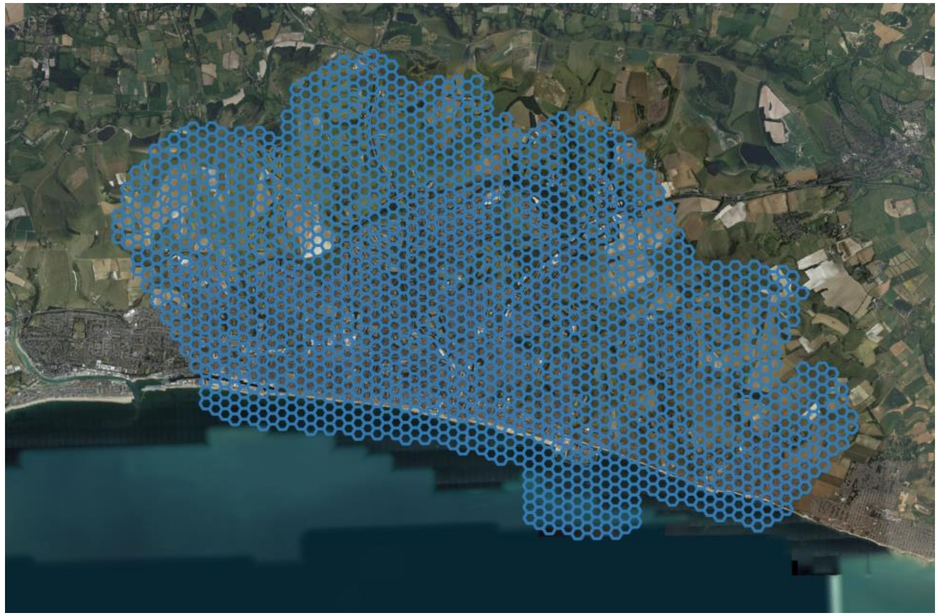

Figure 1: *Brighton AOI, showing the 300m hex grid across which UHI is analysed.*

Figure 2: *Brighton AOI, showing the LSOA areas across which UHI is aggregated.*

# Modelling

## 1. Introduction

UHeat is a digital tool that allows rapid complex modelling of the urban climate and provides the air temperatures of cities, which is much closer to what people actually feel (compared to more commonly recorded surface temperatures).

UHeat uses the Surface Urban Energy and Water Balance Scheme (SUEWS) [1]. Arup has integrated the model into UHeat to provide rapid analysis that can be used to understand the impact of design on urban heat. It accounts for several factors including building heights, surface albedos (reflectiveness), the amount of green and blue infrastructure, impervious surfaces, population density and the urban climate. Further details on the model can be found in Appendix A.

The tool comprises of three core units as shown in Figure 3:

- **Data Processing**: Processing of remote sensing data to define the urban landscapes and surface characteristics
- **Calculate UHI**: Modelling of the urban climate using the SUEWS model
- **Output**: Postprocessing and visualisation of the city-scale climate data.

The outputs of UHeat are a set of maps of the urban climate conditions across different neighbourhoods of the city, showing the average air temperature, surface temperature and urban heat island intensity (UHII). For this project, only surface and air temperatures were outputted. These maps are provided as a geopackage alongside this report.

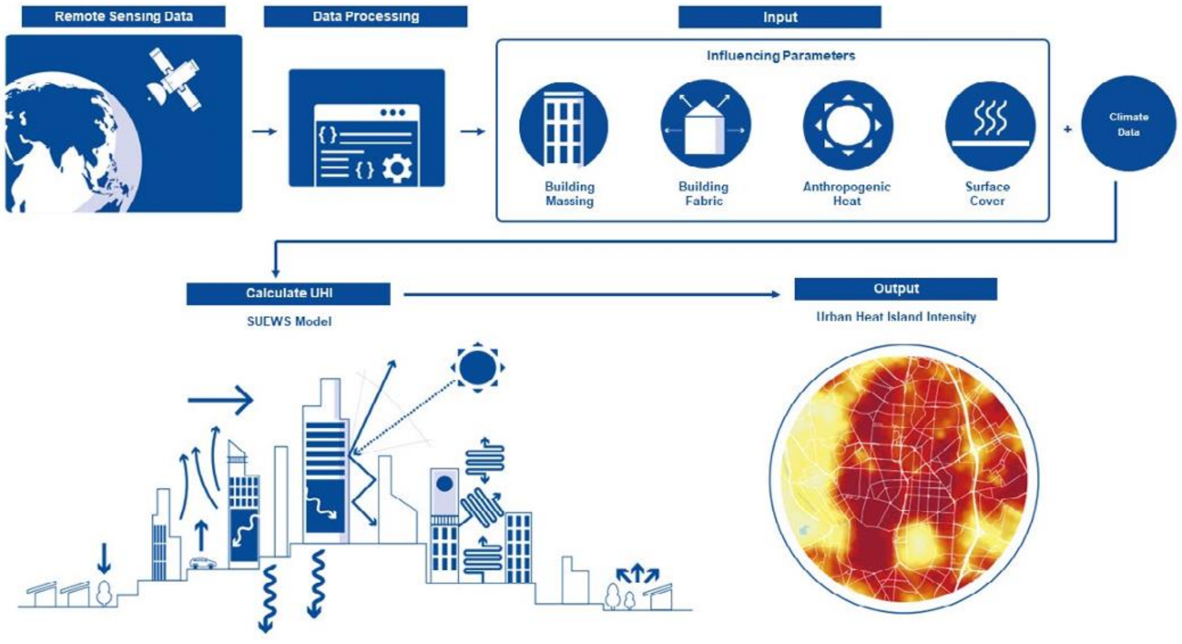


Figure 3: *UHeat methodology workflow*

[1] Model developed by Professor Sue Grimmond's team at the University of Reading.

# Data

## 1. Introduction

As shown in Figure 3, UHEAT uses climate and spatial/remote sensing data as an input to the model. The spatial/remote sensing data is processed to define the urban environment at each hex grid cell, see Figure 4.

The input climate data is historical data obtained for the whole summer period of 2022 for Brighton (see Figure 5). A severe heatwave occurred in the summer of 2022 with record-breaking temperatures of 40.3C experienced in England on 19th July.

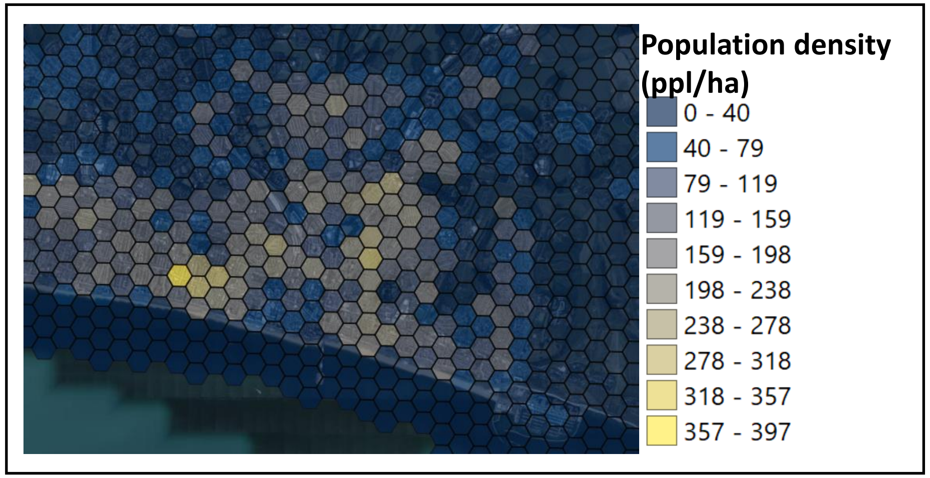


Figure 4: *Urban information, in this image population density, is collected and processed to the 300m hex grid across the full area of interest.*

### Urban 'site' data

A variety of datasets are used to obtain information on the urban landscape, these are listed in Table 1 below.

Table 1: *Data sources used to generate urban grid information*.

| Urban category | Variable | Data Source | Processing |
|---|---|---|---|
| Surface Cover | Buildings | ESA WorldCover [1] | AWS SageMaker |
| | Paved | ESA WorldCover | AWS SageMaker |
| | Trees | ESA WorldCover | AWS SageMaker |
| | Grass | ESA WorldCover | AWS SageMaker |
| | Bare Soil | ESA WorldCover | AWS SageMaker |
| | Water | ESA WorldCover | AWS SageMaker |
| Surface typology | Albedo | Sentinel 2 [2] | AWS SageMaker |
| Anthropogenic emissions | Population Density | Global Human Settlement Layer (GHS-POP) [3] | AWS SageMaker |
| Surface topology | Building heights | Global Human Settlement Layer (GHS-BUILT-H) [4] | AWS SageMaker |

[1]© *ESA WorldCover project 2021 / Contains modified Copernicus Sentinel data (2021) processed by ESA WorldCover consortium*
[2]*Copernicus Sentinel-2 (processed by ESA), 2021, MSI Level-2A BOA Reflectance Product. Collection 1. European Space Agency.* https://doi.org/10.5270/S2_-znk9xsj
[3]Schiavina M., Freire S., Carioli A., MacManus K. (2023): GHS-POP R2023A - GHS population grid multitemporal (1975-2030).European Commission, Joint Research Centre (JRC) PID: http://data.europa.eu/89h/2ff68a52-5b5b-4a22-8f40-c41da8332cfe, doi:10.2905/2FF68A52-5B5B-4A22-8F40-C41DA8332CFE
[4]*Pesaresi, M.; Politis, P. (2023)*: GHS-BUILT-H R2023A - GHS building height, derived from AW3D30, SRTM30, and Sentinel2 composite (2018).European Commission, Joint Research Centre (JRC) PID: http://data.europa.eu/89h/85005901-3a49-48dd-9d19-6261354f56fe, doi:10.2905/85005901-3A49-48DD-9D19-6261354F56FE

# Data – identifying heatwaves and extremes using climate data

## 1. Introduction

Figure 5 presents temperatures in Brighton & Hove in summer 2022. This enabled identification of the peak day, for which UHII results are presented in Figure 8.

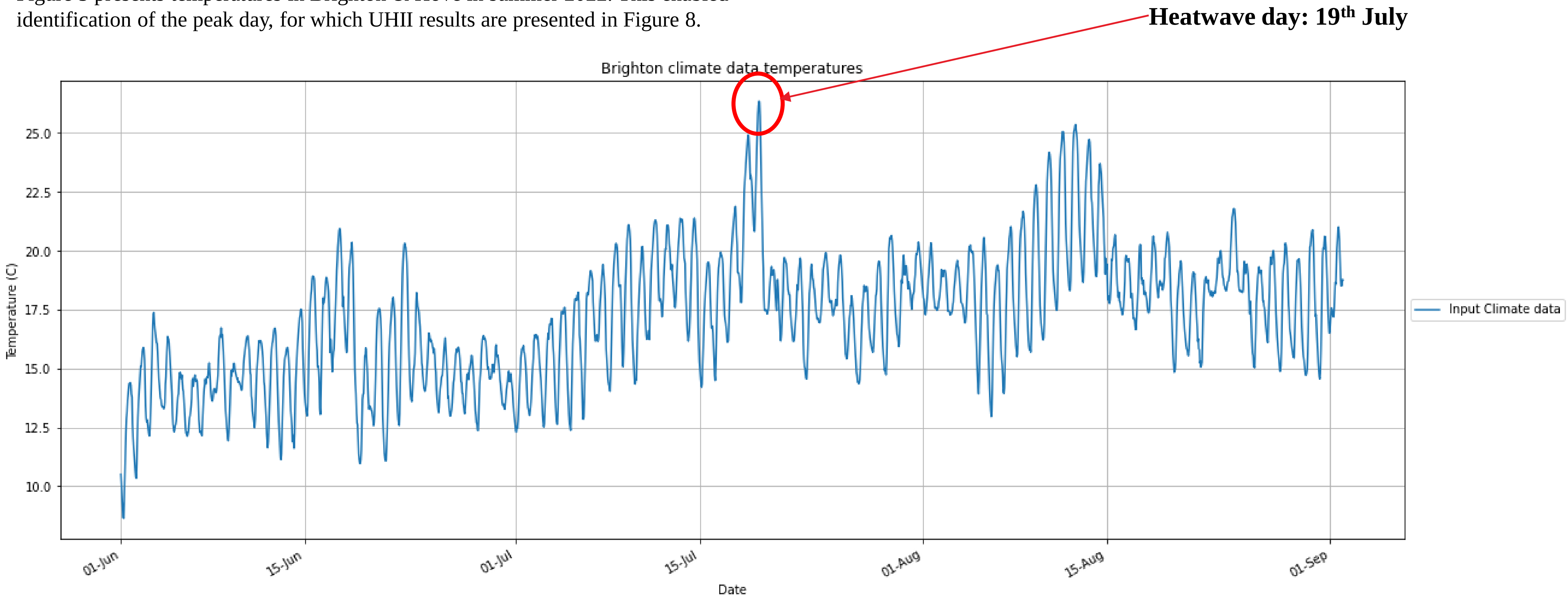


Figure 5: *Temperatures in Brighton & Hove during summer 2022. This analysis enabled identification of the peak day, for which UHII results are presented.*

# 2. Summary of results

# Modelling Outputs and Assumptions

## 2. Results

Daytime urban heat island was found to be insignificant with a very small variation in temperatures across the AOI. This is due to higher windspeeds causing (relatively) higher temperatures in forested areas which have higher resistance to wind flow than urban areas (thus there is less cooling effect from breeze felt in these areas). Therefore, only nighttime air temperature UHI is presented (for the hour of maximum UHI). In addition, surface temperatures have also been provided to give some indication of temperature variation across the city at other times of day.

The model was run for the 2022 summer period. Periods of interest were selected based on the historic temperature data (Figure 5) across the summer. Surface temperature maps were produced for:

1. Average summer period
2. Average of the peak heatwave day (19th July)
3. Peak UHII hour (from air temperature) of the peak heatwave day (which occurs at 01:00)
4. Hottest hour of the peak heatwave day (13:00)

Additionally, an air temperature map was produced for the peak UHII hour of the peak heatwave day. This hour was selected as it exhibited the greatest air temperature UHII of all hours across the hottest day.

The limitations of the modelling primarily arise due to the assumptions and data sources used:

- The accuracy of the model is dependent on the accuracy and resolution of the input data on variables such as land surface classification, land surface cover etc. There may be small features and updates that may not be captured in the model.
- Data on anthropogenic heat emissions i.e., heat from buildings, transport and people, was not readily available. Population density was used in the model to make predictions for these variables.
- SUEWS is a surface model and limited to the resolution of the data available. It does not account for detailed 3D features.
- SUEWS is not a computational fluid dynamics model and does not account for advection across the city. In reality, this would have an impact on the urban heat island but would require more complex modelling to be carried out which is outside the scope of this work.
- Other climate variables such as solar radiation and humidity will have an impact on thermal comfort and heat stress. These are not accounted for in the temperature maps. These are microclimate features and should be considered when surveying areas in more detail.

# Understanding the results

## 2. Results

**Surface vs Air Temperature UHI**

When understanding surface temperatures compared to air temperatures for UHI it is important to note:

- Air temperatures differ from surface temperatures due to surfaces absorbing and emitting radiation.
- Although the surface UHI is distinct from the air temperature UHI, they are highly correlated, particularly when solar radiation dominates the temperature (at the hottest hours of the day).
- Additionally, surface temperature still has an impact on the radiant field. As such it will influence thermal comfort. A person standing next to a hot surface will feel the radiant heat, increasing their "feel" temperature.
- Surface temperatures are predominantly dominated by impervious surface cover and albedo, while air temperature has dependency on vegetative cooling, wind speed and shading.
- Potential mitigations to reduce the surface UHI target these factors and include implementing cool roofs or green roofs and reducing impervious/paved surface area.

**Mitigation of UHI**

- Cool roofs: These are reflective roofs (high albedo) which reflect more solar radiation than traditional roofs (which have low albedo) and thus don't reach such high surface temperatures. This is also a low-cost mitigation option that usually involves painting flat roofs with reflective paint. This mitigation has the additional benefit of reducing internal building temperatures.
- Green roofs: These roofs are vegetated and experience lower surface temperatures due to a combination of shading effects, higher albedo and evapotranspirative cooling. Like cool roofs, this mitigation has the additional benefit of reducing internal building temperatures, however it is more complex/costly to implement.
- Urban greening: increasing vegetation reduces surface temperatures and air temperatures through increased shading and evapotranspiration.
- Reducing impervious surfaces: By reducing paved surfaces we reduce the amount of surface area that is available to absorb high amounts of solar radiation and reach high temperatures. Impervious surfaces can also retain more moisture leading to cooler temperatures.
- Shading structures: These will reduce incident radiation on surfaces occupied by pedestrians and thus surface temperature.
- All the above methods that reduce surface UHII will also benefit air temperatures

# Whole summer average surface temperature

## 2. Results

Figure 6 presents surface temperatures aggregated for the summer period in 2022 (for all hours). Surface UHI is highest in the city centre.

The average summer surface temperature uplift; or surface urban heat island intensity (SUHII), is 7.7°C at the worst-impacted LSOA. This follows the expected patterns of urban heat where the city centre, which has a higher proportion of dark paved/building surfaces gets much hotter than rural areas where greenery and lighter surfaces reflect more solar radiation and maintain lower temperatures.




Figure 6: Surface temperatures across Brighton aggregated over summer 2022 period presented at LSOA.

# Hottest day average surface temperature

## 2. Results

The hottest day of 2022 occurred on 19th July, which experienced record breaking temperatures for England of 40.3C. From the surface temperature map for the day, we can still see that the UHI is highest in the city centre.

Average surface temperatures across the hottest day of 32.6C are seen for the hottest neighbourhoods at the centre of Brighton. As with the average summer results, the LSOAs on the outskirts have lower temperatures.

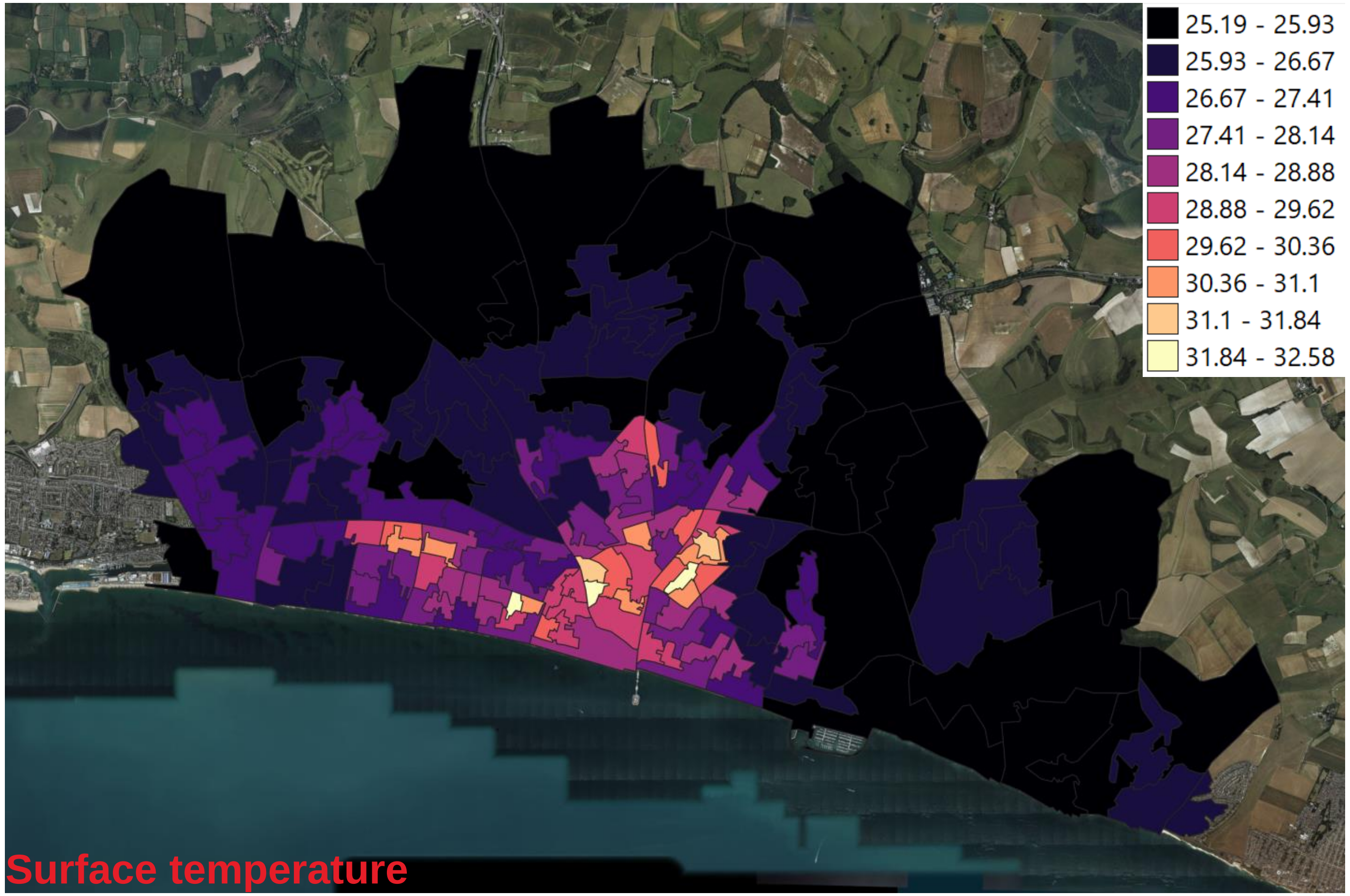


Figure 7: Average surface temperatures across Brighton on the peak temperature day presented at LSOA.

# Peak UHII hour (01:00) air temperature

## 2. Results

The air temperature UHII is presented for the hottest day of 2022. The (air temperature) UHI is strongest at nighttime during a heat wave.

The UHII is highest across Brighton & Hove during the night (at 01:00) on a hot day (the hottest day of 2022 in this case). This is due to Brighton & Hove's temperate climate and urban characteristics. Dark urban surfaces such as buildings and paving absorb solar radiation during the day and release the stored heat during the night. Furthermore, human activities (such as transportation, heating etc.) release heat in the night in more populated areas. The city centre also has a relatively lower proportion of greening (green surface and trees) further increasing temperatures.

The hottest LSOAs experience air temperatures at this time of 22.6C while rural LSOAs experience temperatures as low as 21.4C. This provides an air temperature range of 1.2C across Brighton & Hove.

The coastal area is slightly cooler due to proximity to the sea (which will be cooler) and higher wind speeds in these areas.

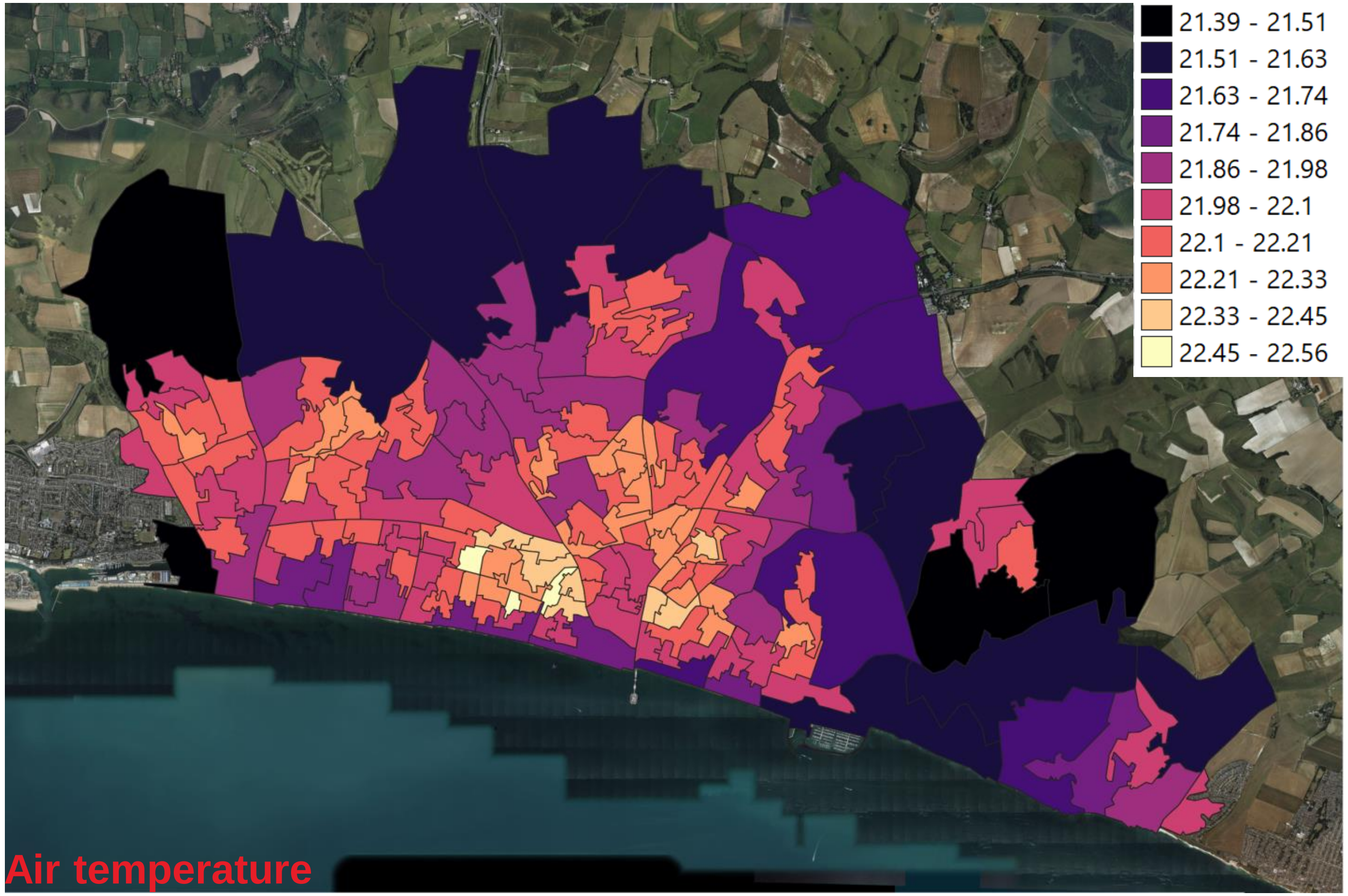


Figure 8: Air temperatures across Brighton on the peak temperature day at 01:00 presented at LSOA.

# Peak UHII hour (01:00) surface temperature

## 2. Results

Surface temperatures across the peak UHII hour of 25.3C are seen for the hottest neighbourhoods at the centre of Brighton & Hove.

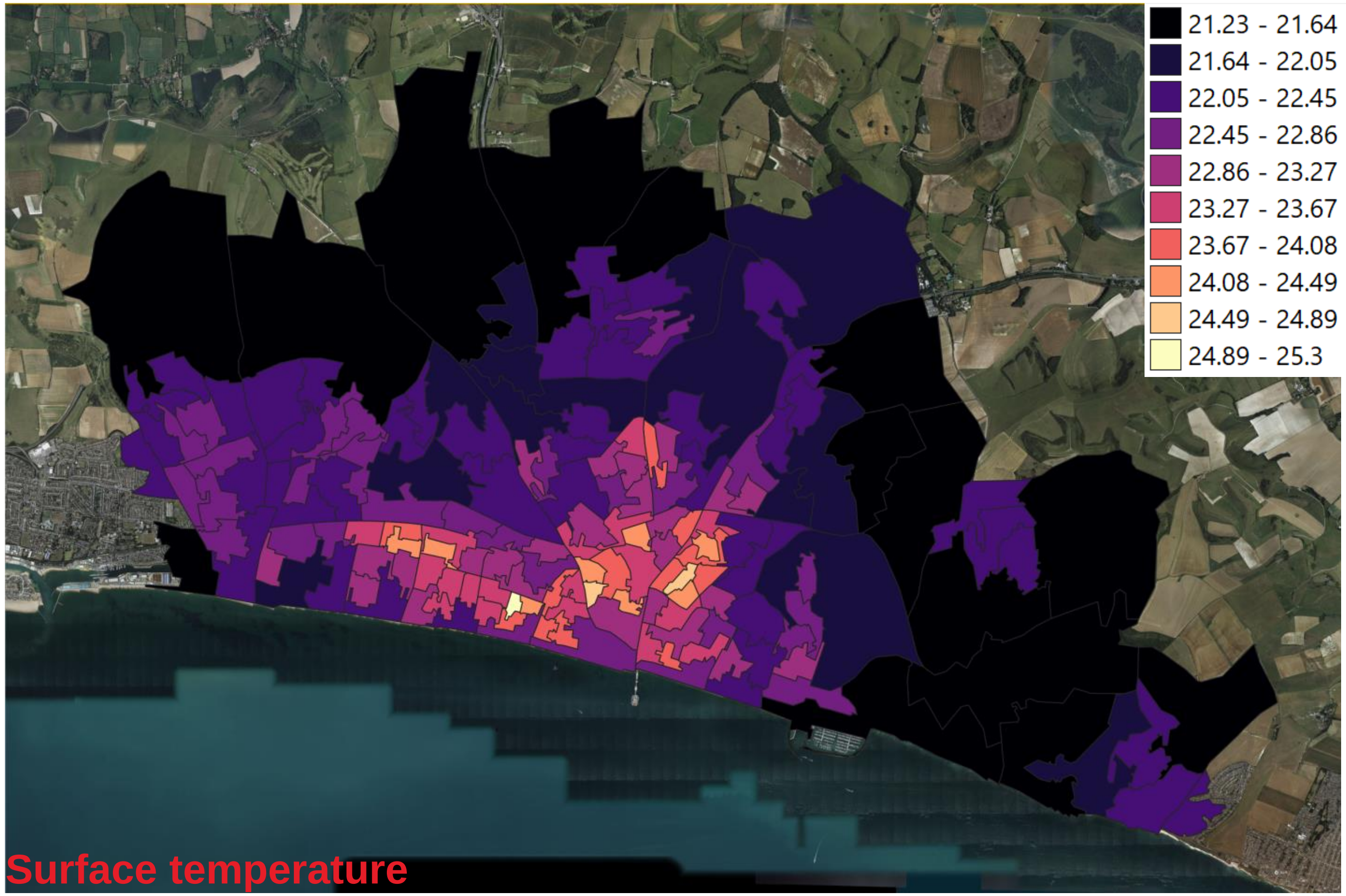


Figure 9: Air temperatures across Brighton on the peak temperature day at 01:00 presented at LSOA.

# Appendices

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# Appendix A: Modelling Methodology

The *'Surface Urban Energy and Water Balance Scheme' (SUEWS)* is an open-source model that simulates the variation of urban climate with the site characteristics and meteorological conditions. The model accounts for different surface types including paved surfaces, buildings, greenery, soil and water.

The surface properties, including albedo (reflectiveness) of the solid surfaces and transpiration of green elements, are taken from the remote sensing data and included in the model to estimate the heating effects of solar radiation on the surfaces, as well as the cooling of spaces due to evapotranspiration.

The cooling/breeze effect of the wind on the urban climate is accounted for in the SUEWS model using a combination of the wind information included in the climate data and an equivalent surface roughness across the city derived from the building and tree properties. Detailed information on the wind direction and building orientation are not considered in the SUEWS model.

Historic climate data from ERA5 reanalysis is used as the climate input for the model. ERA5 is a global reanalysis dataset of a wide variety of climate variables from various data sources, produced by ECMWF (European Centre for Medium-Range Weather Forecasts) and accessible via CDS (Climate data store).

It is available on a 30km grid covering the whole globe.

It is widely used in academia and has been validated for use in macroscale meteorological models such as WRF.