# Luke Howard's *Climate of London*: The Work of an Observational Genius

Structure

1. Introduction: Citizen scientist
2. The Urban Heat Island (UHI)
3. Cities and climate change: heatwaves and the UHI.
4. Developing an urban climate awareness.
5. Conclusions

Gerald Mills, Geography (UCD, Dublin Ireland)

26th April 2023

IAUC
INTERNATIONAL ASSOCIATION FOR URBAN CLIMATE

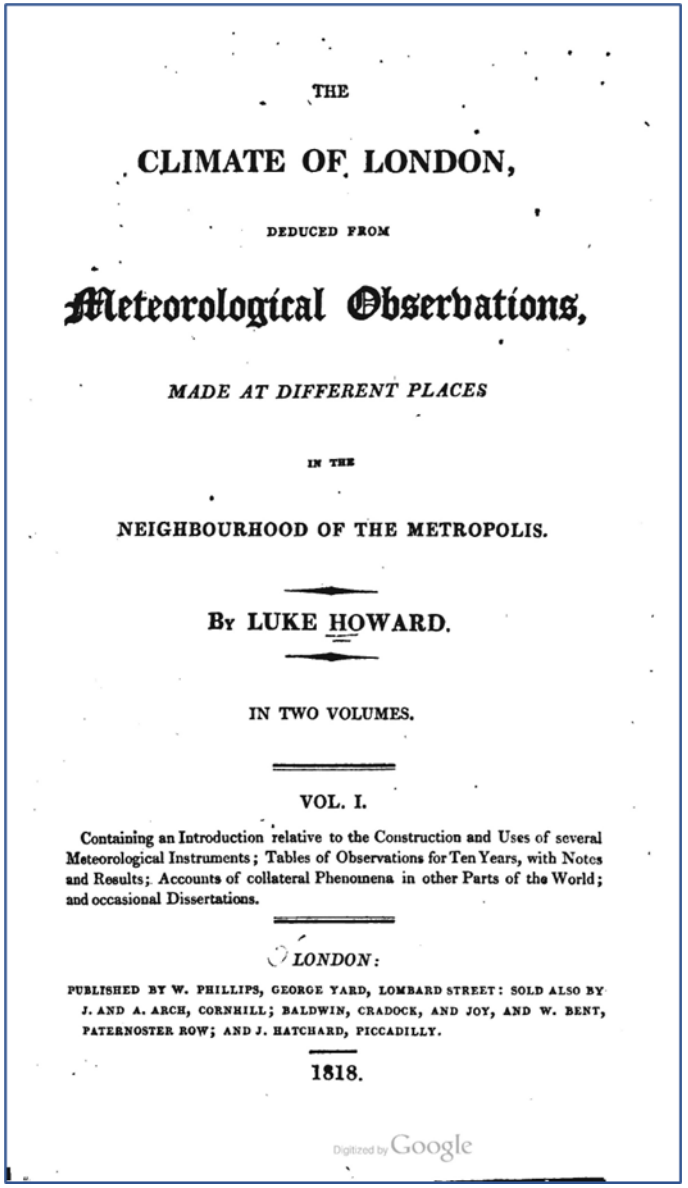
BRUCE CASTLE MUSEUM &ARCHIVE

UCD DUBLIN

## 1. Howard: Citizen Scientist

*Now, in no one department of Natural knowledge is the field less trodden, or the opportunity for a successful exertion of the judgment in establishing general principles greater, than in Meteorology, in its present state. There is no subject on which the learned and the unlearned are more ready to converse, and to hazard an opinion, than on the Weather — and none on which they are more frequently mistaken!*

*This, alone, may serve to show that we are in want of more data, of a greater store of facts, on which to found a Theory that might guide us to more certain conclusions; and facts will certainly multiply together with observers…. So, to become qualified to reason on the variations of our own Climate, we should begin by making ourselves familiar with their extent and progress, as marked by the common instruments, and the common natural indications: for which purpose such a model as the present Volume may be found very serviceable.*



THE

CLIMATE OF LONDON,

DEDUCED FROM

Meteorological Observations,

*MADE AT DIFFERENT PLACES*

IN THE

NEIGHBOURHOOD OF THE METROPOLIS.

By LUKE HOWARD.

IN TWO VOLUMES.

VOL. I.

Containing an Introduction relative to the Construction and Uses of several Meteorological Instruments; Tables of Observations for Ten Years, with Notes and Results; Accounts of collateral Phenomena in other Parts of the World; and occasional Dissertations.

*LONDON:*

PUBLISHED BY W. PHILLIPS, GEORGE YARD, LOMBARD STREET: SOLD ALSO BY J. AND A. ARCH, CORNHILL; BALDWIN, CRADOCK, AND JOY, AND W. BENT, PATERNOSTER ROW; AND J. HATCHARD, PICCADILLY.

1818.

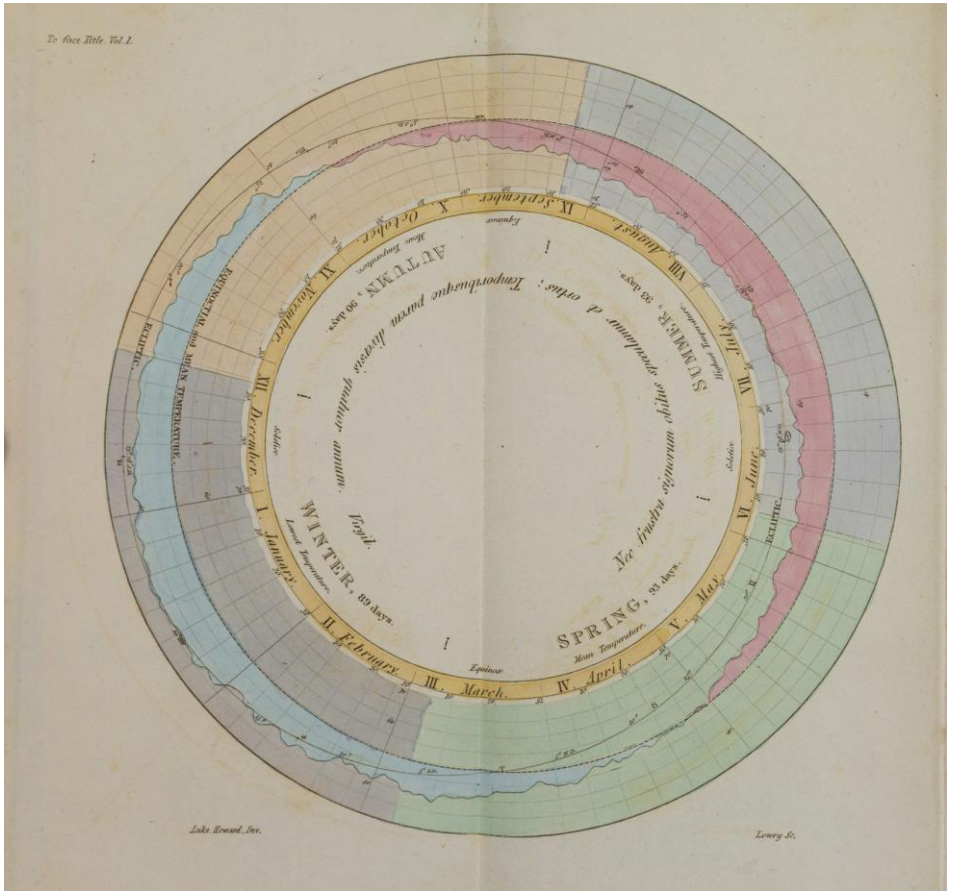
# The Climate of London

Howard's study was designed to establish the climate where London was located. Over a period of 25+ years he made daily observations of:

- Pressure
- Air temperature
- Humidity
- Wind direction
- Cloud types

In addition, he collated notes and correspondence on weather events from around the world.

This circular diagram summarises daily temperature through the year as warmer (red) or colder (blue) than the average.




The new exhibition 'Weather Notes' of historical items chosen from Senate House Library's collections offers a glimpse into different perceptions, recordings, and observations regarding the weather over the past 500 years

| 1820. | | Wind. | By Clock. Max. | By Clock. Min. | Temp. Max. | Temp. Min. | T. No. 2. Max. | T. No. 2. Min. | Evap | Hygr. at 9 a. m. | Rain, &c. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 mo. April | 1 | SW | 30·03 | 29·90 | 62° | 45° | | | — | 87 | |
| | 2 | NW | 30·17 | 30·00 | 66 | 49 | | | — | 74 | |
| | 3 | N | 30·15 | 29·80 | 64 | 36 | | | — | 79 | |
| | 4 | SE | 29·80 | 29·63 | 65 | 31 | | | — | 73 | |
| | 5 | Var. | 29·63 | 29·30 | 72 | 45 | | | 57 | 68 | 21 |
| | 6 | SW | 29·41 | 29·30 | 56 | 32 | | | — | 89 | 11 |
| | 7 | SW | 29·42 | 29·15 | 52 | 31 | | | — | 75 | |
| | 8 | SW | 29·30 | 29·10 | 54 | 44 | | | — | 76 | — |
| | 9 | NW | 29·43 | 29·30 | 52 | 28 | | | — | 86 | 10 |
| | 10 | SE | 29·50 | 29·25 | 52 | 46 | | | — | 88 | 14 |
| | 11 | SW | 29·70 | 29·50 | 59 | 45 | | | 45 | 89 | 17 |
| New M. | 12 | SE | 29·85 | 29·80 | 59 | 44 | | | — | 81 | — |
| | 13 | NE | 29·80 | 29·50 | 53 | 45 | | | — | 93 | 32 |
| | 14 | NE | 29·80 | 29·52 | 55 | 39 | | | — | 96 | 25 |
| | 15 | NW | 30·05 | 29·80 | 59 | 30 | | | 20 | 83 | |
| | 16 | SW | 30·20 | 30·05 | 63 | 43 | | | — | 73 | |
| | 17 | NW | 30·20 | 30·10 | 68 | 39 | | | — | 82 | |
| | 18 | SE | 30·14 | 30·05 | 69 | 37 | | | 30 | 83 | |
| | 19 | NW | 30·18 | 30·04 | 72 | 44 | | | — | 80 | |
| | 20 | NW | 30·27 | 30·19 | 65 | 35 | | | — | 72 | |
| | 21 | NW | 30·37 | 30·15 | 68 | 32 | | | — | 74 | |
| | 22 | E | 30·48 | 30·37 | 65 | 34 | | | 47 | 72 | |
| | 23 | E | 30·50 | 30·45 | 65 | 35 | | | — | 69 | |
| | 24 | NE | 30·47 | 30·25 | 66 | 36 | | | — | 71 | |
| | 25 | NE | 30·25 | 29·65 | 63 | 29 | | | 50 | 72 | |
| | 26 | W | 29·85 | 29·55 | 69 | 40 | | | — | 68 | 28 |
| | 27 | NE | 30·00 | 29·85 | 46 | 36 | | | — | 74 | |
| | 28 | N | 30·07 | 30·00 | 52 | 34 | | | — | 67 | |
| | 29 | SW | 30·20 | 30·07 | 60 | 37 | | | — | 68 | |
| | 30 | NW | 30·30 | 30·21 | 63 | 28 | | | 46 | 75 | — |
| | | | 30·50 | 29·10 | 72 | 28 | | | 2·95 | | 1·58 |

NOTES.—Fourth Mo. 1. Cloudy: windy. 2. Cloudy. 3. Calm: close: overcast. 4. *Cirrus: Cirrocumulus:* clear. 5. *Cirrus: Cirrocumulus.* 6. Cloudy: showers. [At Tottenham, a very bright double rainbow about half-past 6, p. m. Several *Nimbi.* Two swallows seen.] 7. Hoar-frost: some gentle showers during the day: a few flakes of snow, p. m. 8. Hoar frost: cloudy: showers. 9. Showery: fine. 10. Windy morning: heavy squalls, with showers, most of the day: some thunder-clouds and a rainbow, p. m. 11. Showery. 12. Overcast. 13, 14. Rainy. 15. Fine: *Cirrus: Cirrocumulus*





16—24. Fine, with *Cirrus* at intervals. [21. At Tottenham, hoar-frost on the ground, a. m.] 25, 26. Cloudy. 27. [At Tottenham, very windy, and wet in the night.] Some gentle rain this morning: the wind strong and cold from NE. The swallows made their appearance about five this morning in great numbers. 28, 29. Fine. 30. A gentle shower about 9, a. m.

## RESULTS.

Winds: N, 2; NE, 5; E, 2; SE, 4; SW, 7; W, 1; NW, 8; Var. 1.

| | | |
|---|---|---|
| Barometer: | Greatest height | 30·50 in. |
| | Least | 29·10 in. |
| | Mean | 29·889 in. |
| Thermometer: | Greatest height | 72° |
| | Least | 28° |
| | Mean | 49·38° |
| | At Tottenham | 49·98° |
| | For 30 days, the sun in Aries | 48·88° |
| Hygrometer: | Dry extreme | 67° |
| | Moist | 96° |
| | Mean | 78° |
| Evaporation | | 2·95 in. |
| Rain | | 1·58 in. |
| —— | at Tottenham | 1·88 in. |

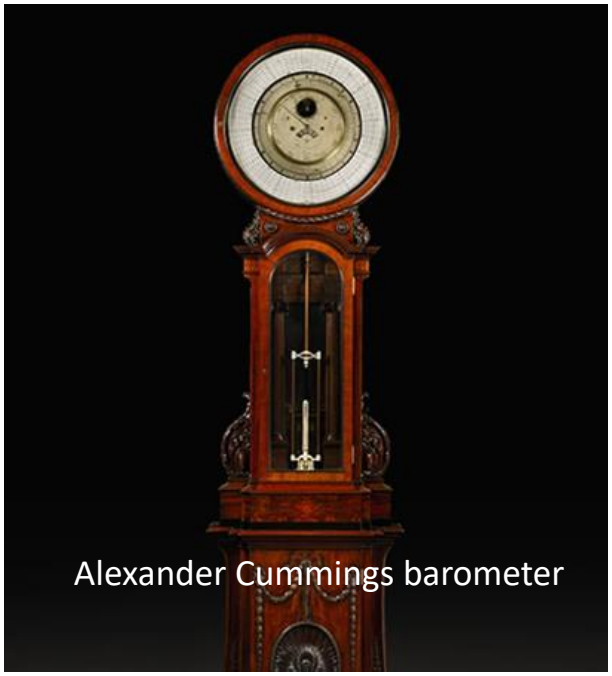
A letter received from a friend in *Philadelphia,* says, under date *Fourth Month,* 3d: "After some days of fine spring weather, we yesterday had a snow-storm of ten hours' continuance, which covered the ground about five inches deep; but the weather is again mild, and the snow has nearly disappeared.

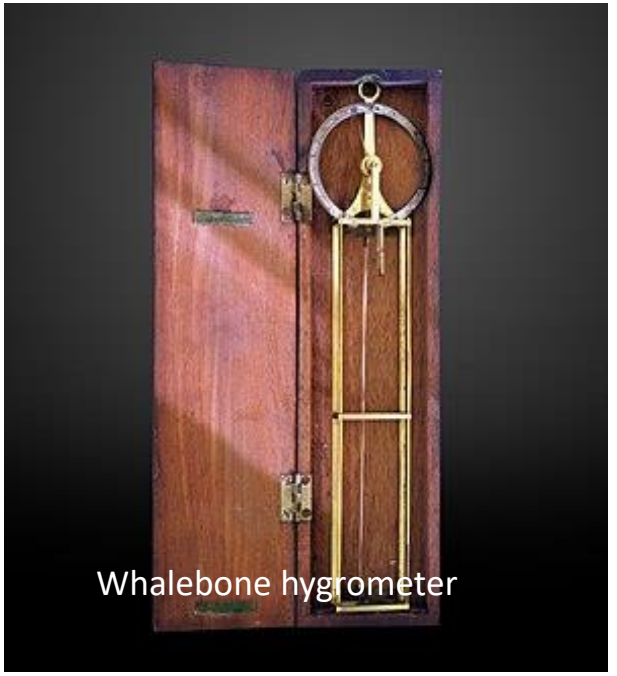
The reader is desired to compare with this account the changes from warmth to cold experienced *with us* in the early part of this month; and, in particular, the depression of the temperature by night (or minimum) between the 2d and 3d; and that by day, between the 5th and 6th of the month, which was continued through several days following.

*From an American paper.*

*Wilmington, (Delaware,) March* 29.—There was a fall of snow in the lower part of this state on Tuesday evening last, [21st,] since which the weather has been very fine. The past winter has been unusually stormy and disagreeable, though not attended by continued and severe cold. An observing friend has favoured us with a memorandum, from which we gather, that since the 25th of October last, snow has fallen twenty-two times, averaging once in seven days nearly. *The aggregate depth of all the snow that has fallen is five feet on a level.*

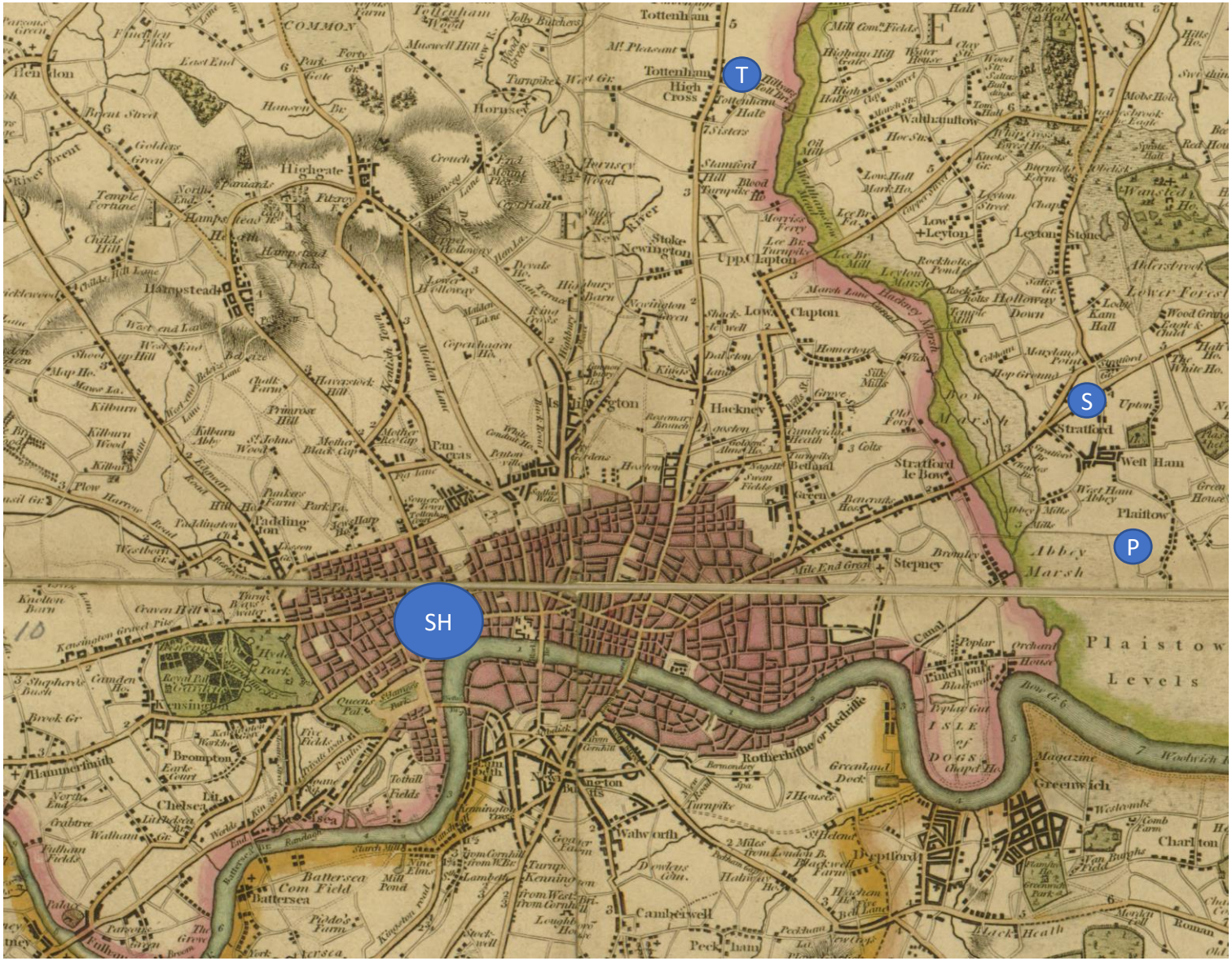

James Six Thermometer


Alexander Cummings barometer


Whalebone hygrometer


Wind vane


Rain gauge


T
S
P
SH
Tottenham
Tottenham High Cross
Stamford Hill
Stoke Newington
Upp. Clapton
Low Clapton
Hackney
Stratford
Stratford le Bow
West Ham
Plaistow
Stepney
Abbey Marsh
Highgate
Hampstead
Kensington
Brompton
Hammersmith
Chelsea
Battersea
Walworth
Rotherhithe or Redriffe
Greenwich
Deptford
Camberwell
Peckham
Plaistow Levels
ISLE of DOGS

## Concern for observational precision

Howard evaluates his weather record by comparing his findings with those made at Somerset House, home of the Royal Society, the pre-eminent scientific organisation of the day. In his analysis of Rain, he finds that the values recorded at the Royal Society are deficient and are of little scientific value:

*The average Annual rain of the ten years (from 1820 to 1830, omitting 1826) is 17.615 in. which corrected for the elevation of the gauge gives 23.277 —* ***a quantity falling below the real average of the district by more than two inches****. It may be said that probably other causes than such as have been stated, and those peculiar to a great city, contribute to this deficiency. It would be very satisfactory to be able to appreciate the action of such causes, and their annual share of effect — but until an Instrument, which is understood to be that of so respectable a Scientific corporation, and the indications of which they have so long been in the habit of publishing, shall be deemed worthy of* ***daily use*** *when Rain is falling, we shall in vain expect from this quarter the* ***data*** *needful even for the construction of the problem.*

# WMO Guidelines

*In order to achieve representative results when comparing thermometer readings at different places and at different times, a standardized exposure of the screen and, hence, of the thermometer itself is also indispensable. For general meteorological work, the observed air temperature should be representative of the free air conditions surrounding the station over as large an area as possible, at a height of between 1.25 and 2 m above ground level. For reasons of comparability the measurement should be taken over natural ground, preferably over grass.*

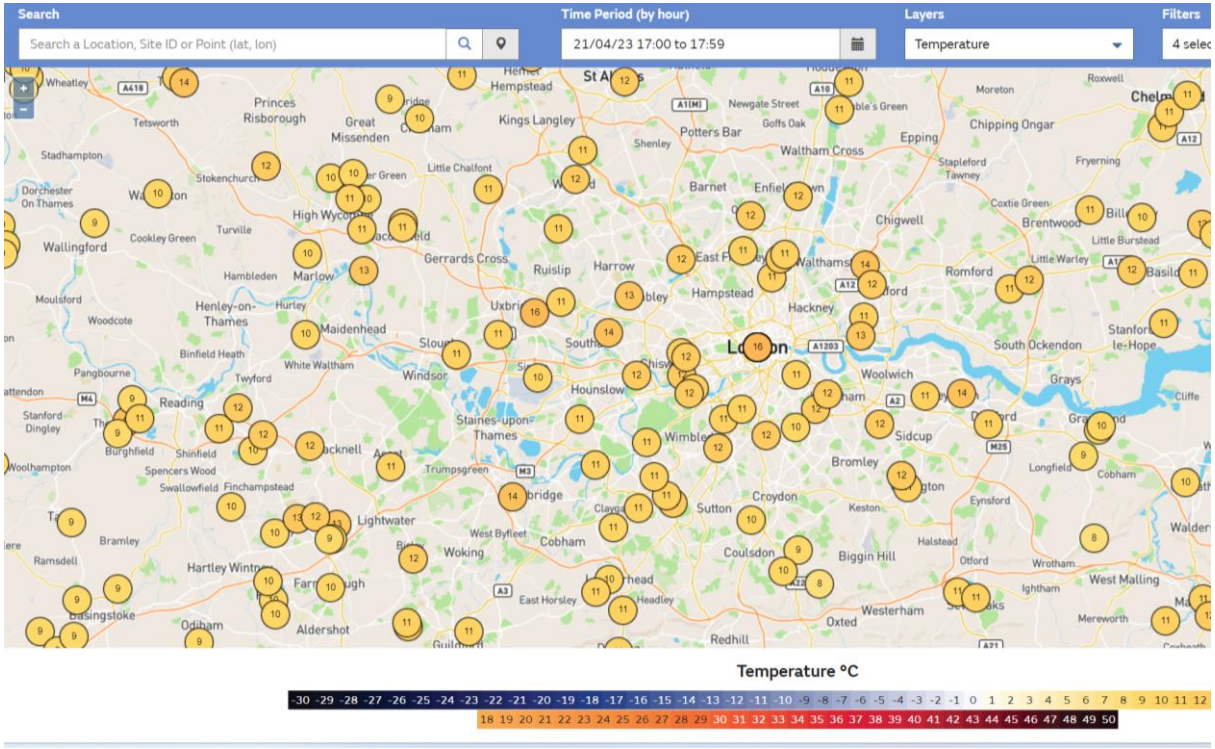
*The height above ground level is specified because large vertical temperature gradients may exist in the lowest layers of the atmosphere that can influence the temperature measurement.*

*The most appropriate site for the measurements is, therefore, over level ground, freely exposed to sunshine and wind and not shielded by, or close to, trees, buildings and other obstructions.*

**Guide to Instruments and Methods of Observation Volume I – Measurement of Meteorological Variables. 2021 edition**

David Hawgood / Weather station in Kew Gardens / CC BY-SA 2.0

# Modern citizen science



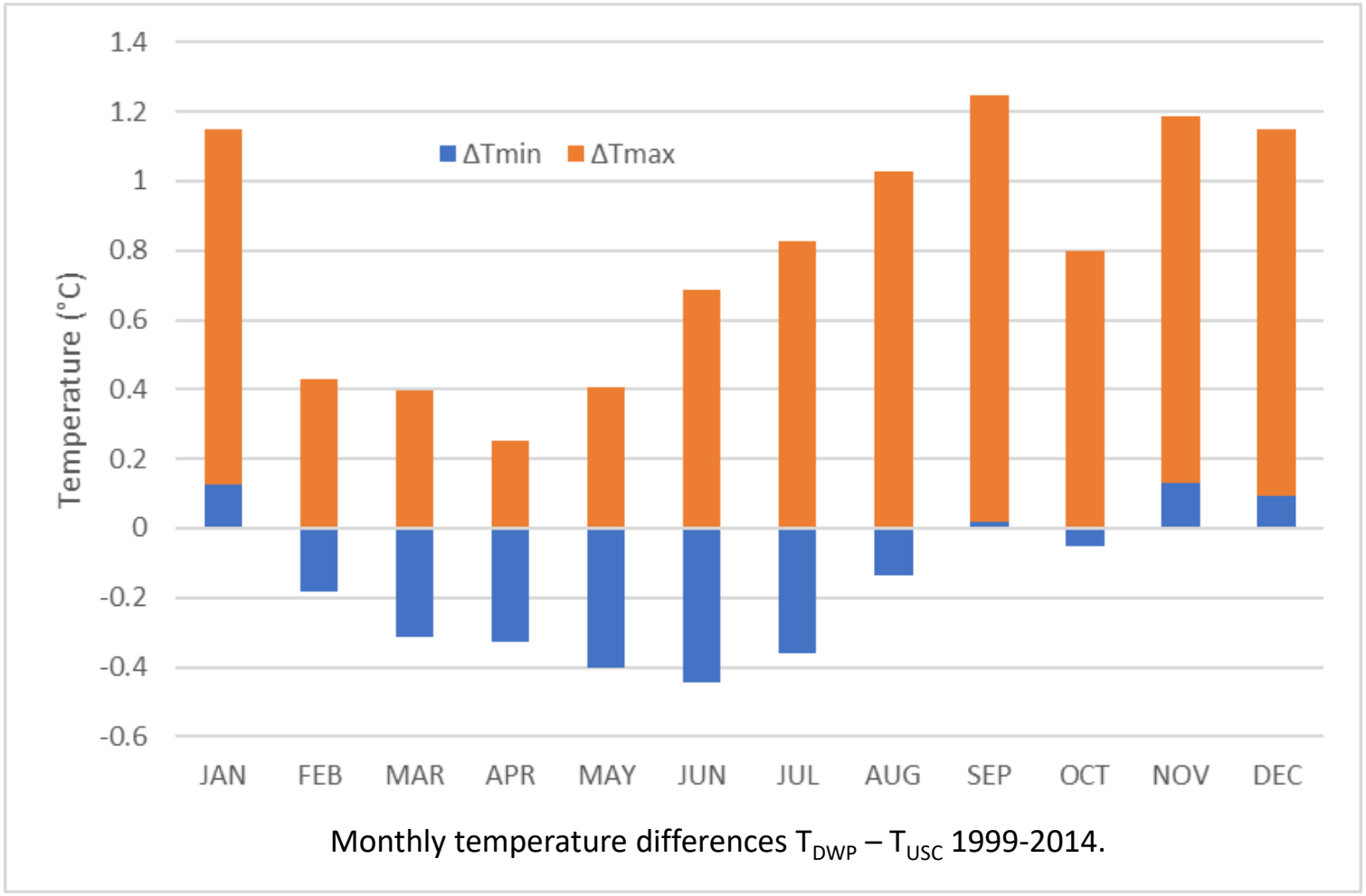

A complete Davis weather station that records atmospheric properties electronically at short intervals and uploads these to the internet. The map shows the WOW network (https://wow.metoffice.gov.uk/) which uses these volunteered weather data.

# Moving a station in Los Angeles


In August 1999, the official downtown Los Angeles weather station moved to the University of Southern California campus, 3.78 miles (almost 6 km) to the southwest of its previous location near the city center at the Department of Water & Power (DWP). This move resulted in a discontinuity in the weather records.


Because of the abundance of trees and grass, the USC station tends to be cooler during the day than the urbanized Department of Water and Power site. At night, the trees can block outgoing radiation, and the moisture in the lawns tends to absorb more heat than the drier, open Department of Water and Power site.

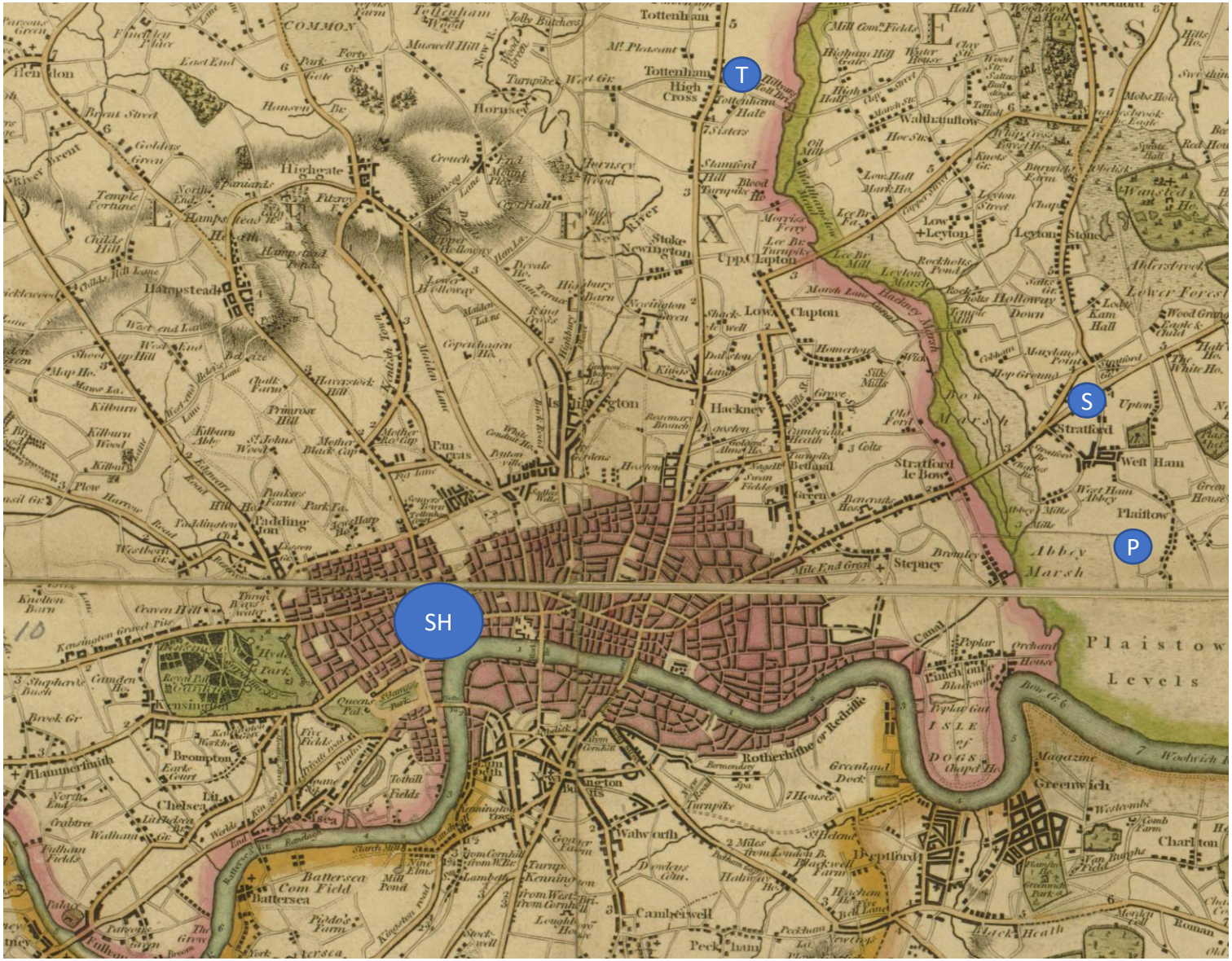
https://www.nasa.gov/vision/earth/lookingatearth/weather-20070117.html

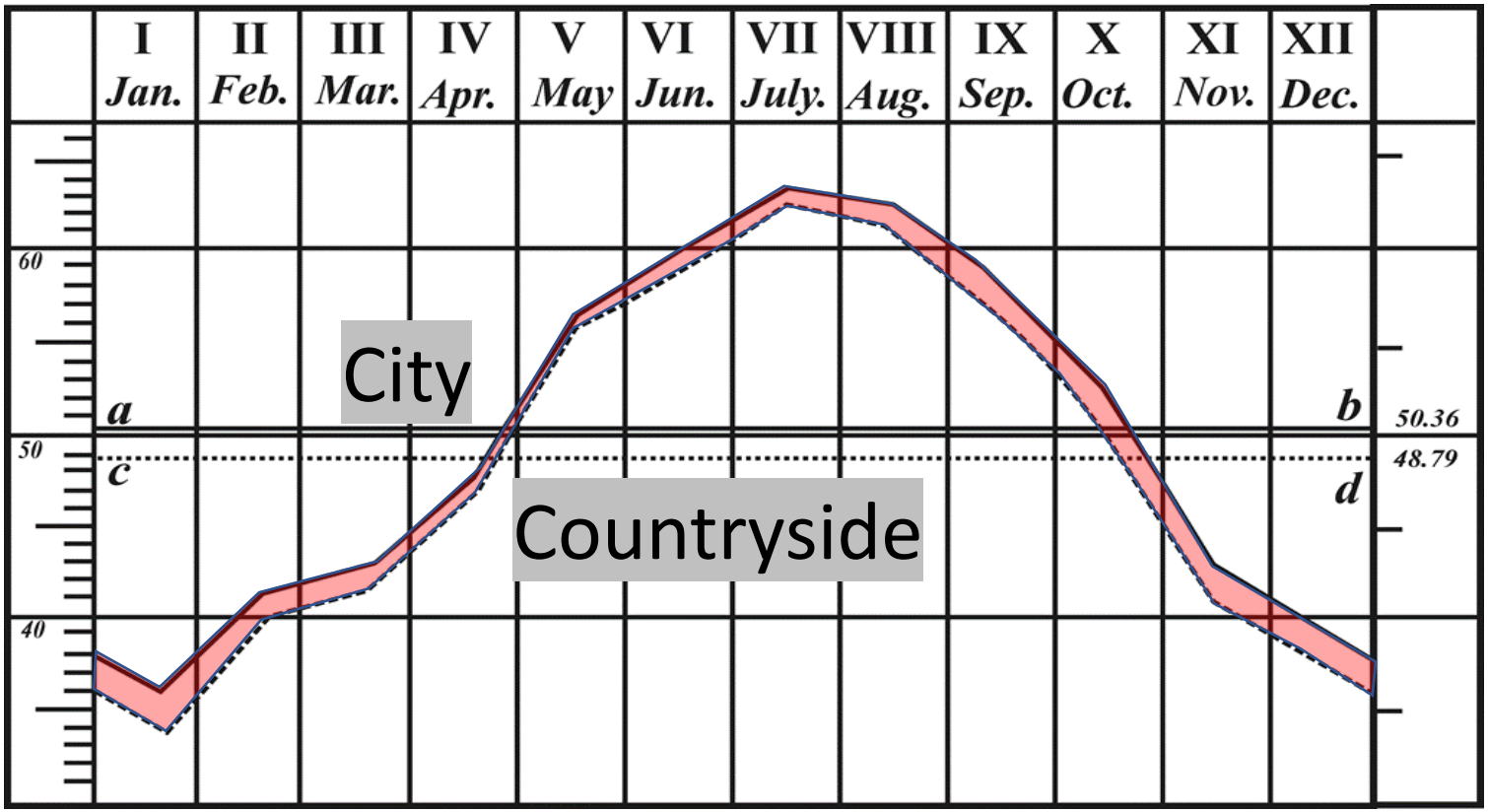



Monthly temperature differences $T_{DWP} - T_{USC}$ 1999-2014.

*A comparative study of daily temperatures and precipitation recorded at USC and DWP from 1999 to 2014 clearly shows that the move resulted in cooler, drier, and less extreme conditions. Maximum temperatures averaged 1.3°C higher at DWP, but minimum temperatures were nearly the same. Precipitation at USC for the study period averages about 19.6 mm less than the DWP location. Extreme record temperatures and precipitation are also less frequent at the USC site.*

Patzert W, LaDochy S, Ramirez P, Willis J. Los Angeles Weather Station's relocation impacts climate and weather records. The California Geographer, vol. 55; 2016.


T
S
P
SH
Tottenham
Tottenham High Cross
Stamford Hill
Stoke Newington
Upp. Clapton
Low Clapton
Hackney
Stratford
Stratford le Bow
West Ham
Plaistow
Stepney
Abbey Marsh
Highgate
Hampstead
Kensington
Brompton
Hammersmith
Chelsea
Battersea
Walworth
Rotherhithe or Redriffe
Greenwich
Deptford
Camberwell
Peckham
Plaistow Levels
ISLE of DOGS

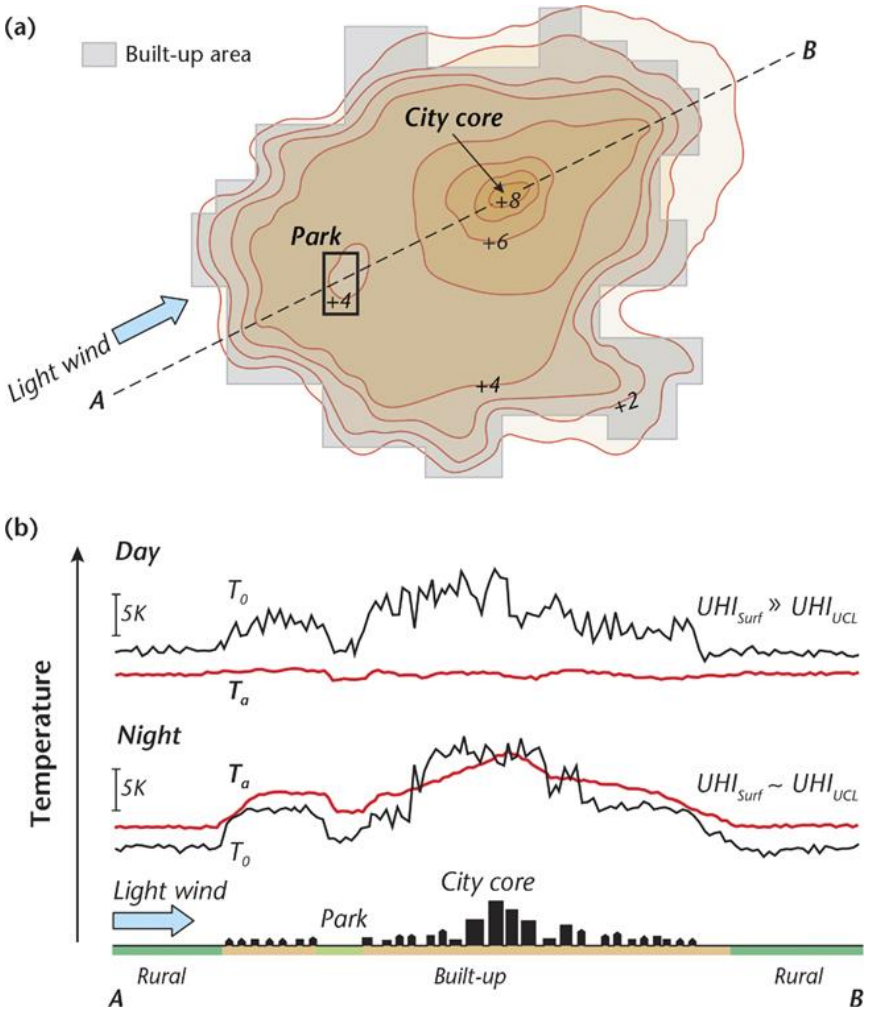



*The **Mean Temperature of the Climate** … is strictly about 48.50° Fahr.: but in the denser parts of the metropolis, the heat is raised, by the effect of the population and fires, to 50.50°; and it must be proportionately affected in the suburban parts. The excess of the Temperature of the city varies through the year, being least in spring, and greatest in winter; and it belongs, in strictness, to the **nights**; which average three degrees and seven-tenths warmer than in the country; while the heat of the day, …. falls, on a mean of years, about a third of a degree short of that in the open plain.*

# 2. The Urban Heat Island (UHI)

The UHI refers to the fact that the surface and near-surface air temperatures are usually higher in cities that outside. This temperature difference increases from the edge of the city and is usually greatest toward the city centre. As a result, the city appears as an 'island' of warm air when compared with the surroundings.

The air temperature UHI is greatest at night under clear skies and in calm conditions. In other words, the urban landscape cools more slowly than the surrounding area.



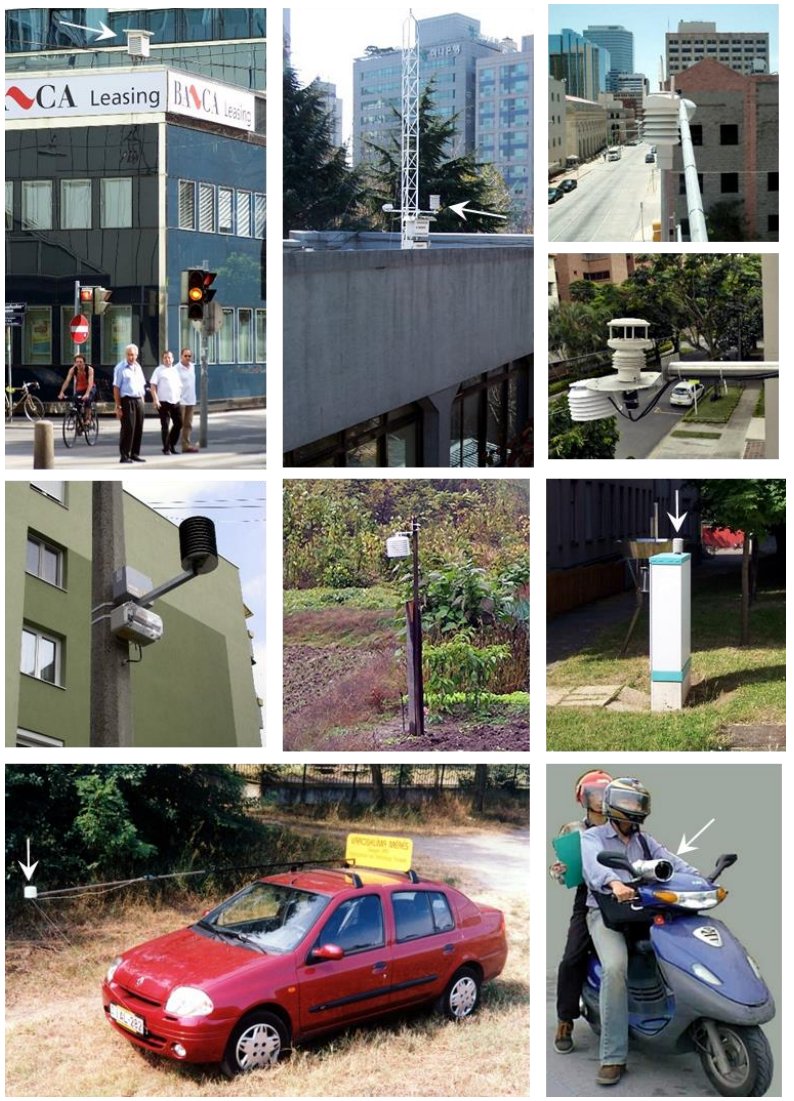

Oke, T.R., Mills, G., Christen, A. and Voogt, J.A., 2017. *Urban climates*. Cambridge University Press.

## Observing the UHI

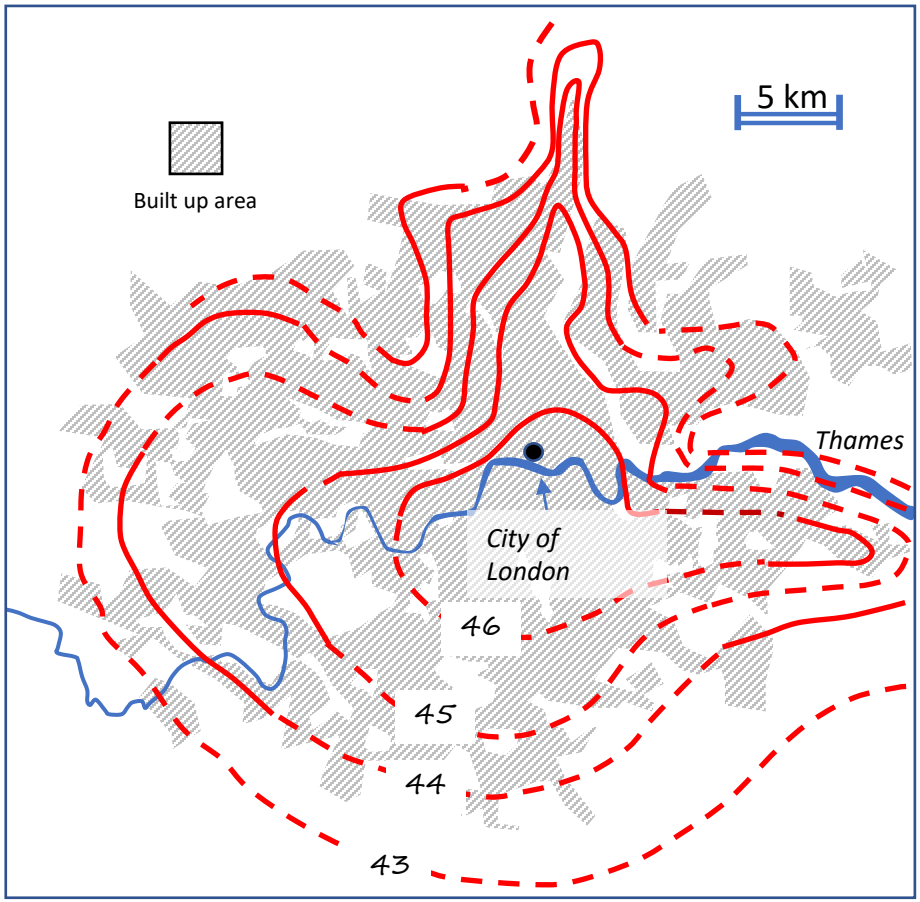
Since Howard's study there have been thousands of studies of the air temperature UHI.

These studies use fixed and/or mobile sensors to explore the temporal and spatial patterns that emerge.

The key to these studies is to ensure that the thermometer is properly exposed to the near-surface air.

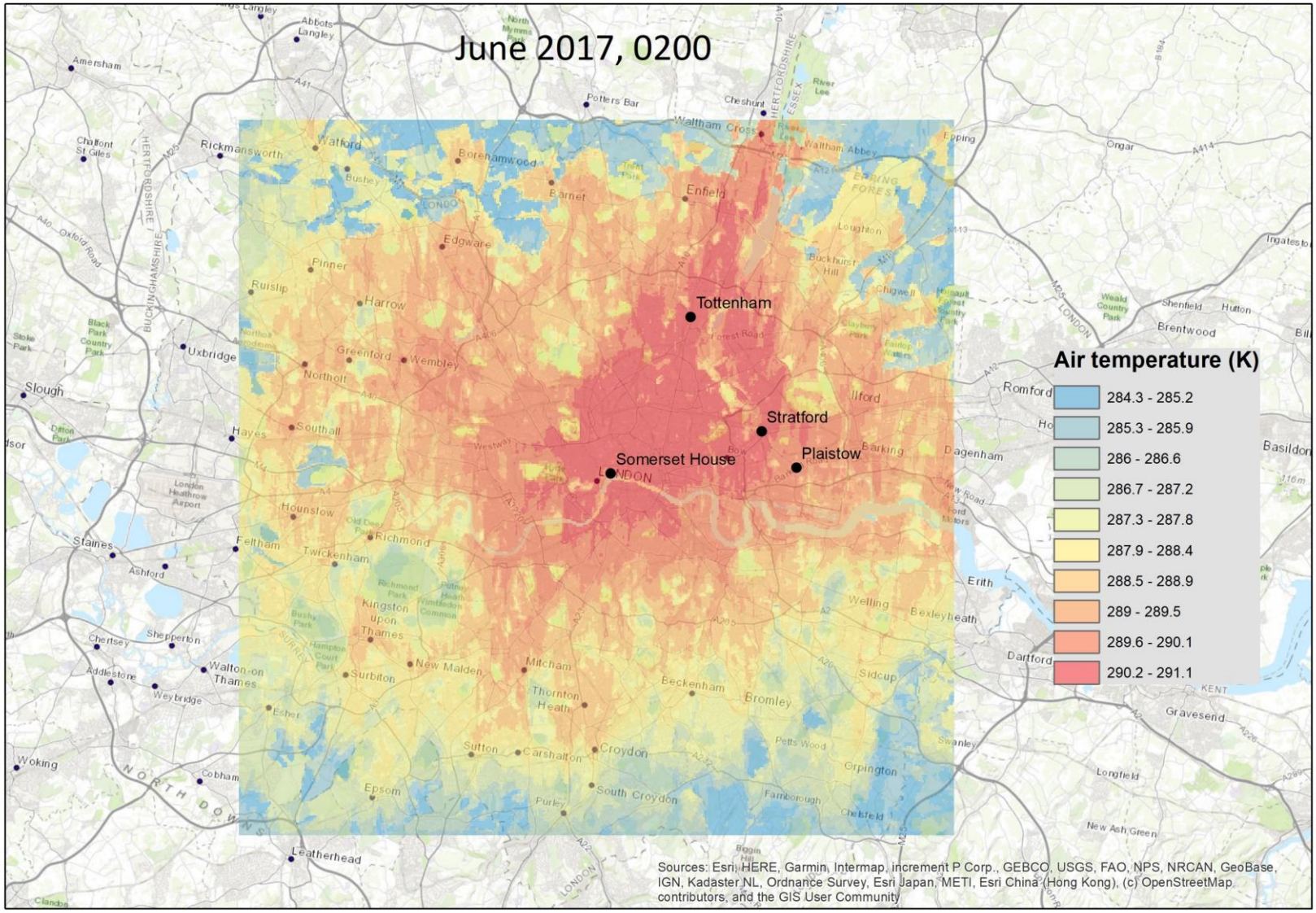



Stewart, I.D. and Mills, G., 2021. The Urban Heat Island. Elsevier.




*Londoners live in a profoundly man-modified climate. A few of the changes wrought by the widespread substitution of houses and factories for fields and woods, and surfaced roads for cart-track, might be considered favourable. Such are the higher autumn, winter and spring night-time temperatures which reduce heating costs and lengthen the frost-free period, but these advantages must surely be outweighed by increased pollution and decreased sunshine.*

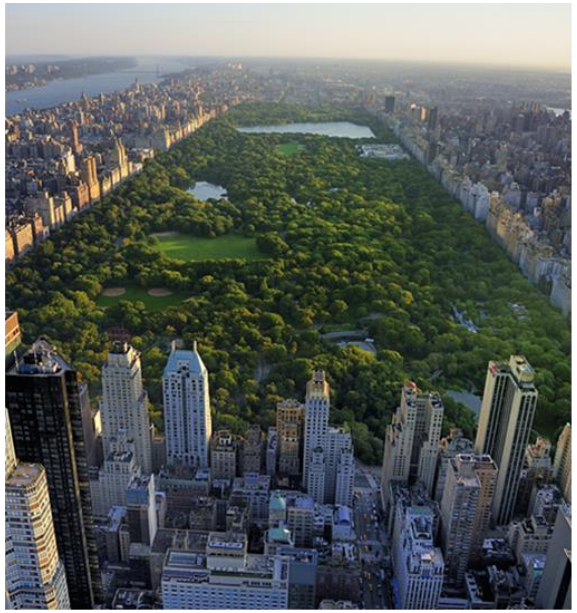
Chandler, T.J., 1965. The climate of London. Hutchinson.




Simulated UHI over London during a heatwave event in June 2017
(Source:https://cds.climate.copernicus.eu/cdsapp#!/dataset/sis-urban-climate-cities)

Causes of the near surface (canopy) UHI

| Urban driver | Climate effect |
|---|---|
| Impervious land cover | Less natural energy is used to evaporate water at the surface and more is used to heat the air. |
| Construction fabric | Urban materials tend to be dark (asphalt), dense and impermeable. This makes them good stores of natural energy. |
| 3D geometry | • The city is aerodynamically rough – air near the ground is slower but gustier.<br>• Buildings generate shadows which blocks solar energy from some surfaces, but this is compensated for by multiple reflections.<br>• Buildings block access to sky such that energy emitted by the walls and street is captured by other surfaces – this is measured by the sky view factor. |
| Anthropogenic heat | Waste heat generated by buildings, transport and industry. Also, a small amount is added by the population itself. |

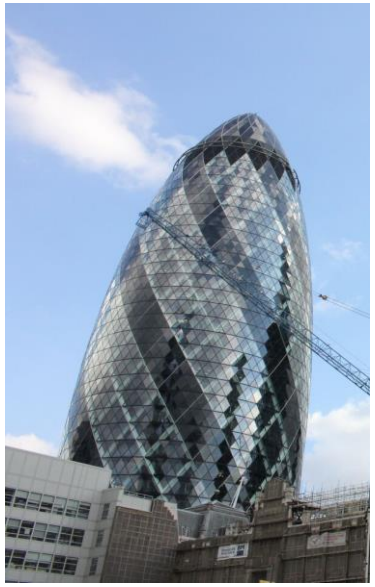


Surface cover – vegetated/built

Fabric – glass, asphalt, concrete

Geometry – street canyons

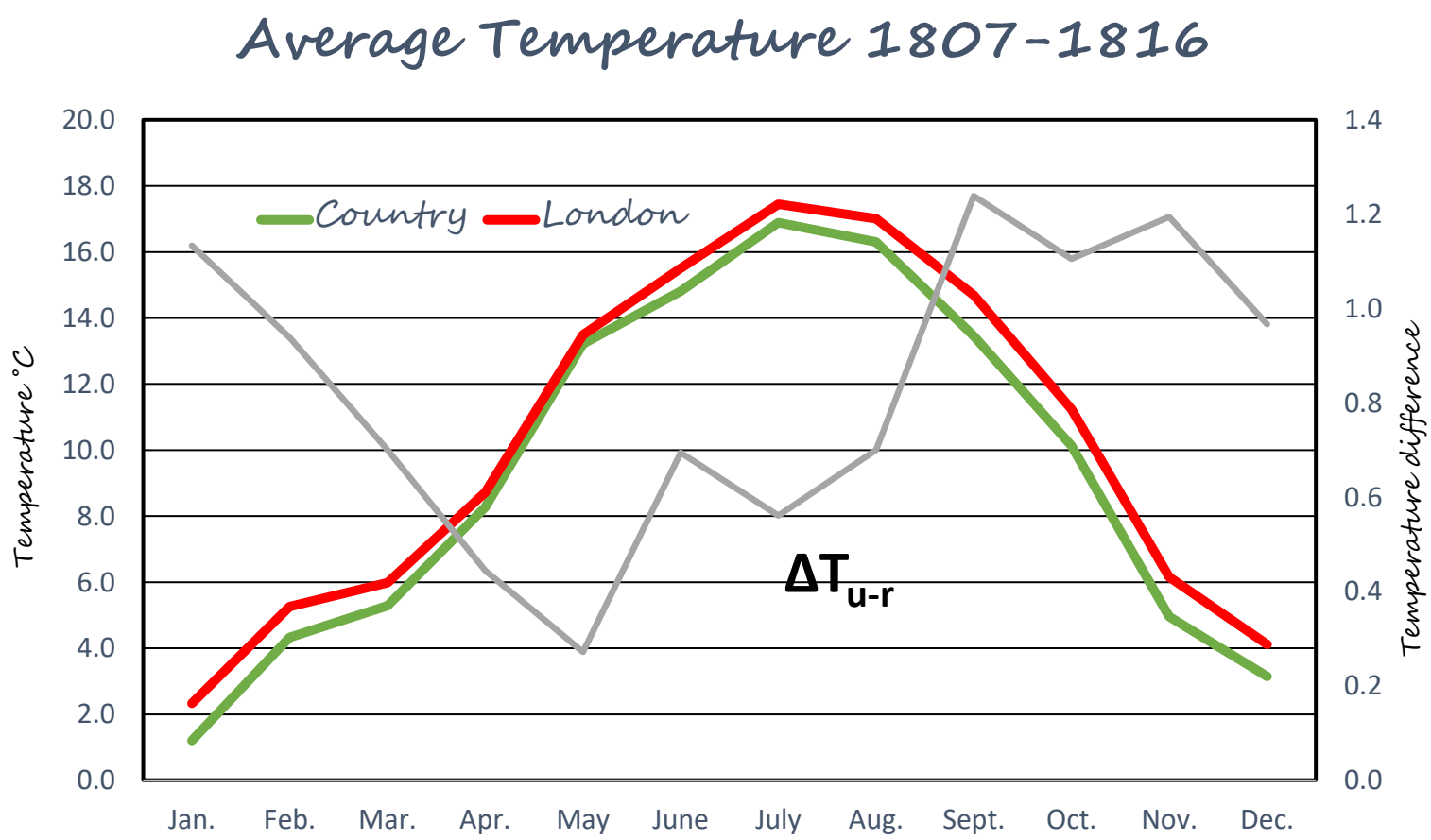
Traffic



Buildings

Industry

# Howard's UHI analysis



# Howard's analysis: Anthropogenic heat (1)

*That the superior temperature of the bodies of men and animals is capable of elevating, in a small proportion, the Mean heat of a city or populous tract of country in a temperate latitude, is a proposition which will scarcely be disputed. Whoever has passed his hand over the surface of a glass hive, whether in summer or winter, will have perceived, perhaps with surprise, how much the little bodies of the collected multitude of Bees are capable of heating the place that contains them: hence, in warm weather, we see them ventilating the hive with their wings, and occasionally preferring, while unemployed, to lodge, like our citizens, about the entrance.*

# Howard's analysis: Anthropogenic heat (2)

*But the proportion of warmth which is induced in a city by the Population, must be far less considerable than that which emanates from the fires: the greater part of which are kept up for the very purpose of preventing the sensation attending the escape of heat from our bodies. A temperature equal to that of Spring is hence maintained, in the depth of Winter, in the included part of the atmosphere, which, as it escapes from the houses, is continually renewed: another and more considerable portion of heated air is continually poured into the common mass from the chimnies; to which, lastly, we have to add the heat diffused in all directions, from founderies, breweries, steam engines, and other manufacturing and culinary fires. The real matter of surprise, when we contemplate so many sources of heat in a city is, that the effect on the Thermometer is not more considerable.*

# Howard's analysis: Urban Form

*It appears that London does not wholly lose its superiority of temperature, by the extinction of most of the fires in Spring: on the contrary, it is resumed in a large proportion in the Sixth month, and continues through the warm season. It is probable, therefore, that the Sun in summer actually warms the air of the city more than it does that of the country around. Several causes may be supposed to contribute to this:*

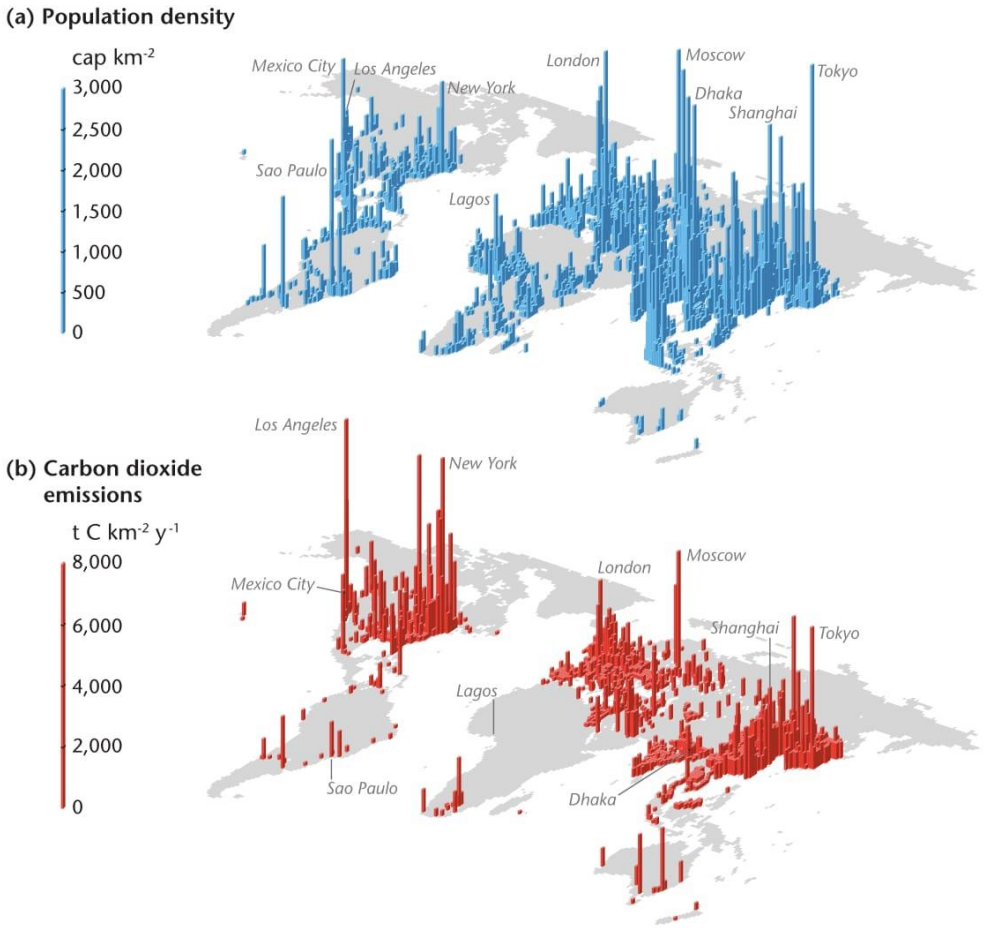
1. *the country presents for the most part a plain surface, which radiates freely to the sky, — the city, in great part, a collection of vertical surfaces, which reflect on each other the heat they respectively acquire:*
2. *the country is freely swept by the light winds of summer, — the city, from its construction, greatly impedes their passage, except at a certain height above the buildings:*
3. *the country has an almost inexhaustible store of moisture to supply its evaporation — that of the city is very speedily exhausted, even after heavy rain.*

*When we consider that radiation to the sky, the contact of fresh breezes, and evaporation, are the three principal impediments to the daily accumulation of heat at the surface, we shall perceive that a city like London ought to be more heated by the summer sun than the country around it.*

# Howard's analysis: Urban Form
# Diurnal patterns

*But this effect is not produced suddenly. For while, in the forenoon, a proportion of the walls are exposed to the sun, the remainder are in shade, and casting a shadow on the intervening ground. These are receiving, however, in the wider streets, the reflected rays from the walls opposed to them; which they return to the former, when visited in their turn by the sun. Hence in the narrow streets, especially those that run East and West, it is generally cooler than in the larger ones, and in the squares. Hence too, in the morning of a hot day, it is sensibly cooler in London than in the country; and in the evening sensibly warmer. For the hottest time in a city, relatively to the hour of the day, must be that, when the second set of vertical surfaces having become heated by the Western sun, the passenger is placed between two skreens, the one reflecting the heat it is receiving, the other radiating that which it has received. Many of my readers must recollect having felt the heat of a Western wall, in passing under it long after sunset.*

# 3. Climate change and cities




Cities are point sources of pollution at a global scale. They are responsible for 70+% of CO2 emissions.

Source: Oke et al. (2017) Urban Climates. CUP

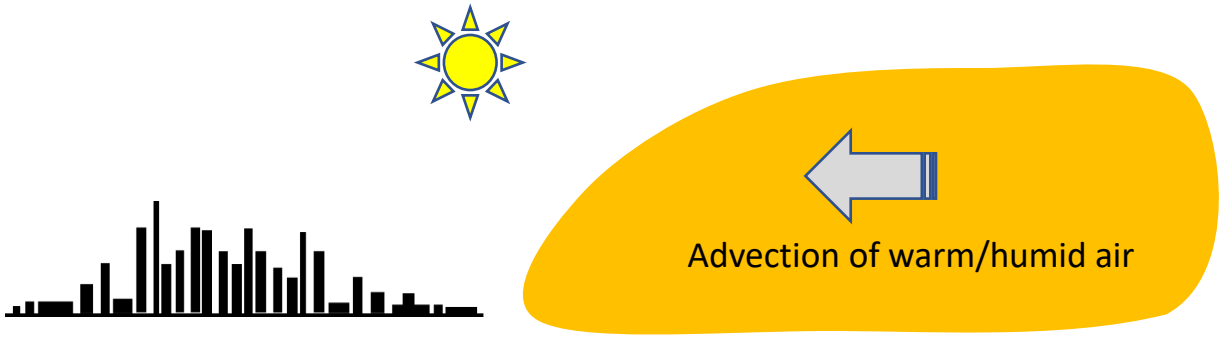
| Phenomenon[a] and direction of trend | Impact on cities |
|---|---|
| Warmer and/or fewer cold days and nights over most land areas. Warmer and/or more frequent hot days and nights over most land areas | Reduced energy demand for heating; increased demand for cooling; declining air quality; reduced disruption to transport due to snow, ice; effects on winter tourism |
| Warm spells/heat waves. Frequency and/or duration increases over most land areas. | Reduction in quality of life for people in warm areas without appropriate housing; impacts on the elderly, very young and poor. |
| Heavy precipitation events. Increase in the frequency, intensity and/or amount of heavy precipitation | Disruption of settlements, commerce, transport and societies due to flooding: pressures on urban infrastructure; loss of property |
| Increases in intensity and/or duration of drought. | Water shortage for settlements, industry and societies; reduced hydropower generation potentials; potential for population migration |
| Intense tropical cyclone activity increases. | Disruption of urban infrastructure by flood and high winds; withdrawal of risk coverage in vulnerable areas by private insurers; potential for population migrations; loss of property |
| Increased incidence and/or magnitude of extreme high sea level. | Costs of coastal protection versus costs of land-use relocation; potential for movement of settlements and infrastructure; also see tropical cyclones above |

Potential impacts on cities from projected climate changes

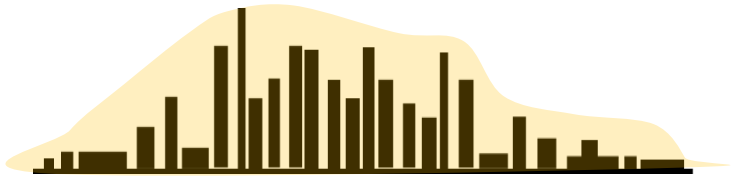
# Urban heat hazard

**Background**

Climate context
Global warming

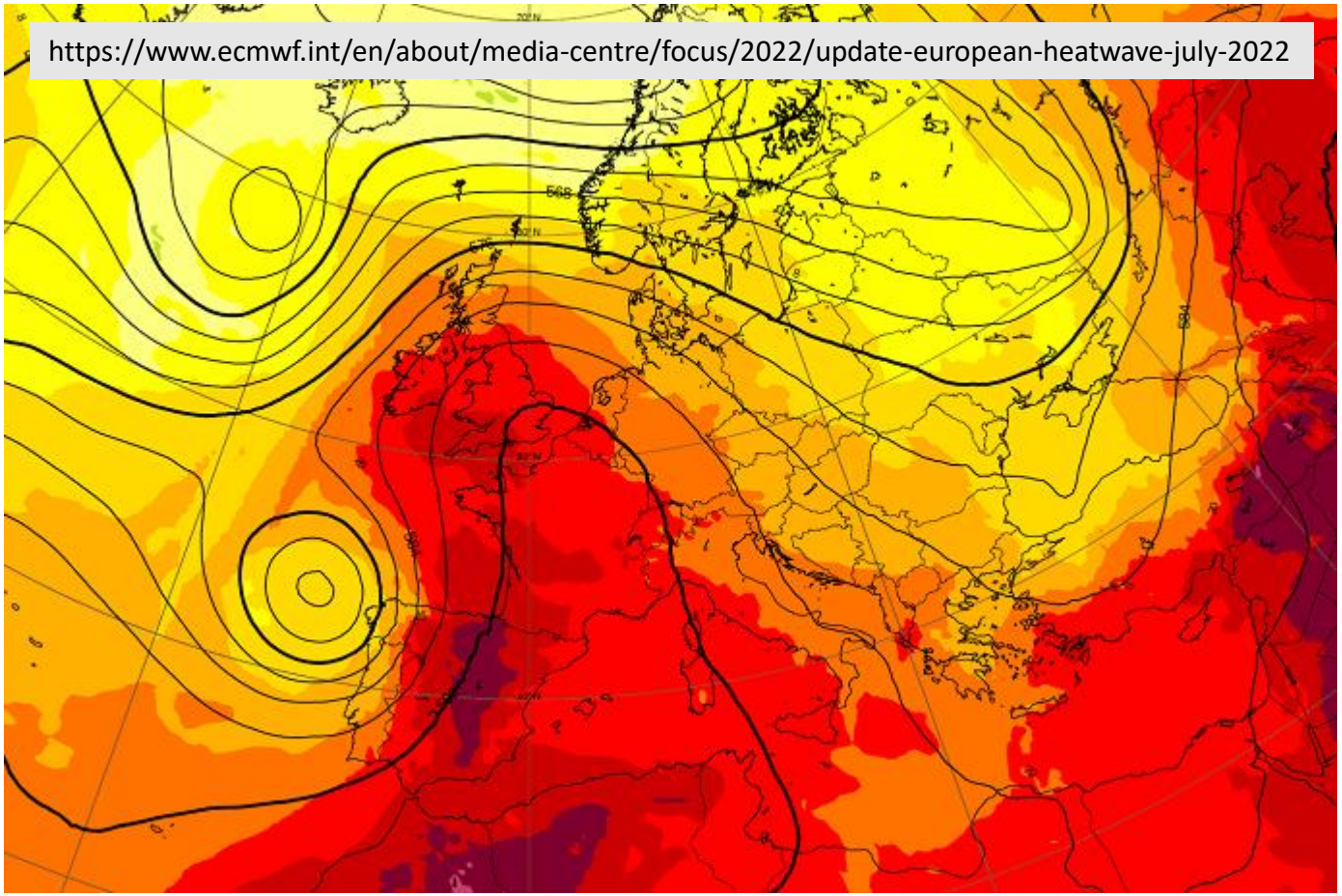



Heatwaves are associated with clear skies and warm/humid air that has advected from warmer parts of the world. Heatwaves can be associated with poor air quality linked to forest fires. These regional scale event can be predicted in advance.



**Urban contribution**

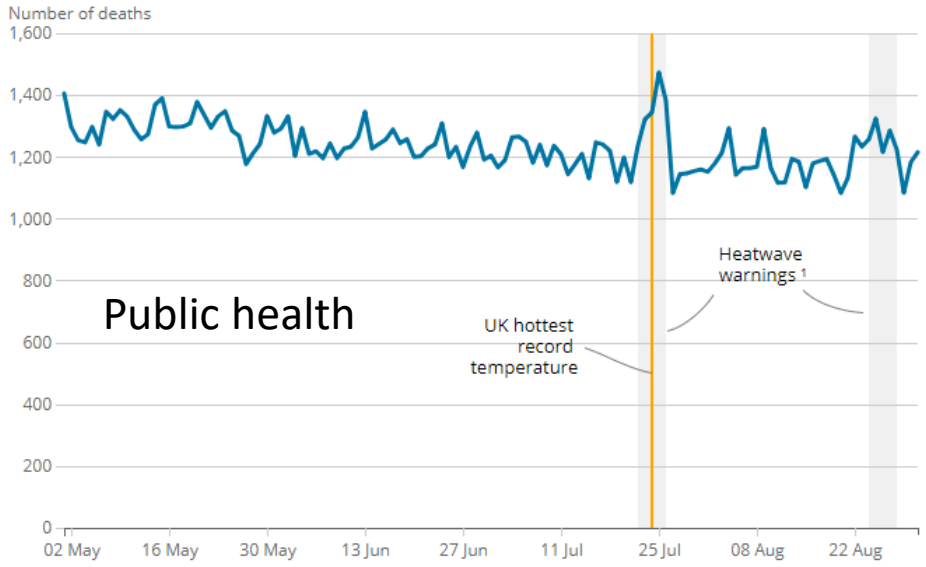
Urban heat island
Impervious surface cover
Reduced ventilation
Pollution emissions




A heatwave is currently hitting much of Europe with different but very high intensity levels. National meteorological services of each of the affected countries are responsible for the dissemination of information and warnings. A slow-moving high-pressure area has been and is still transporting hot air from North Africa over western and parts of central Europe. The hot air is moving northwards…. It is expected that local/regional temperature records will be broken this week. In combination with low precipitation rates over the last few weeks over most of these areas, this situation has been and is leading to a high risk of wildfire as currently observed on the Iberian Peninsula and France. The event is also associated with very high ozone levels.

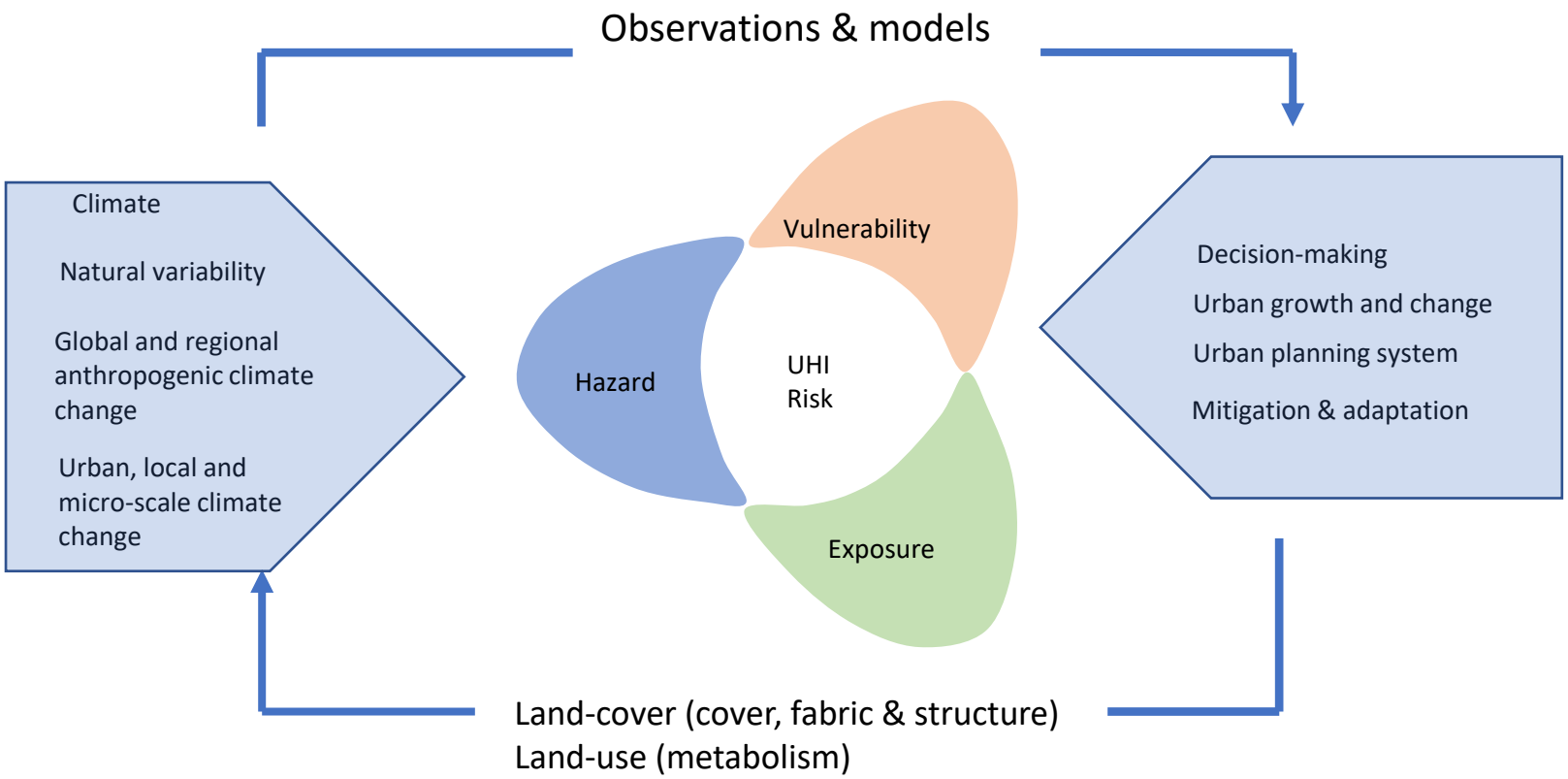
**The event was forecast at least three weeks in advance, but until last week, there was significant uncertainty about the extent and severity of the heatwave.**


Hammersmith Bridge wrapped in foil during heatwave.




**Source: Deaths registered weekly in England and Wales, Office for National Statistics**

The number of deaths increased around the same time as the hottest day on record.




Stewart, I.D. and Mills, G., 2021. The Urban Heat Island. Elsevier.

## What is the issue with heat?

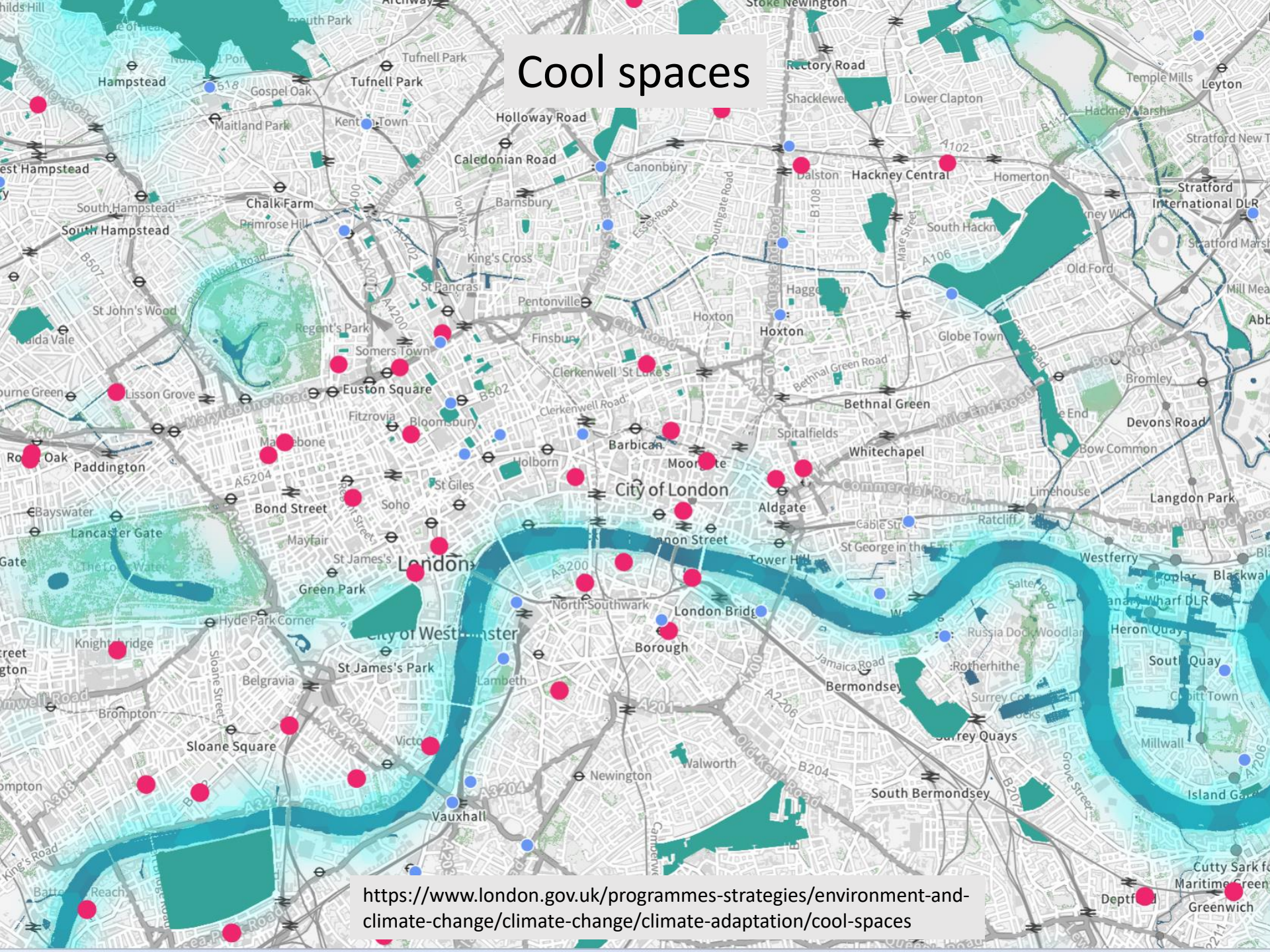
London is experiencing hotter and drier summers that are further impacted by the Urban Heat Island effect (UHI). The UHI can cause London to be up to 10'C warmer than neighbouring rural areas. This is because the sun's rays are absorbed by hard surfaces rather than by vegetation such as trees, plants and grass. Radiation from our hard surfaces is released into the air as heat. The UHI reduces the ability for cities to cool and impacts on our own capacity to regulate temperature.

We expect London's population to be 11 million by 2050 and need to build more homes to accommodate our growing population. We must ensure that managing heat risk is considered at all stages of planning and development.

Heat is impacting us all particularly those vulnerable to extreme heat.

https://www.london.gov.uk/programmes-and-strategies/environment-and-climate-change/climate-change/climate-adaptation/

# Cool spaces




https://www.london.gov.uk/programmes-strategies/environment-and-climate-change/climate-change/climate-adaptation/cool-spaces


# 4. Developing an urban climate awareness: The London Climate Walk.

# *You are a weather station!*

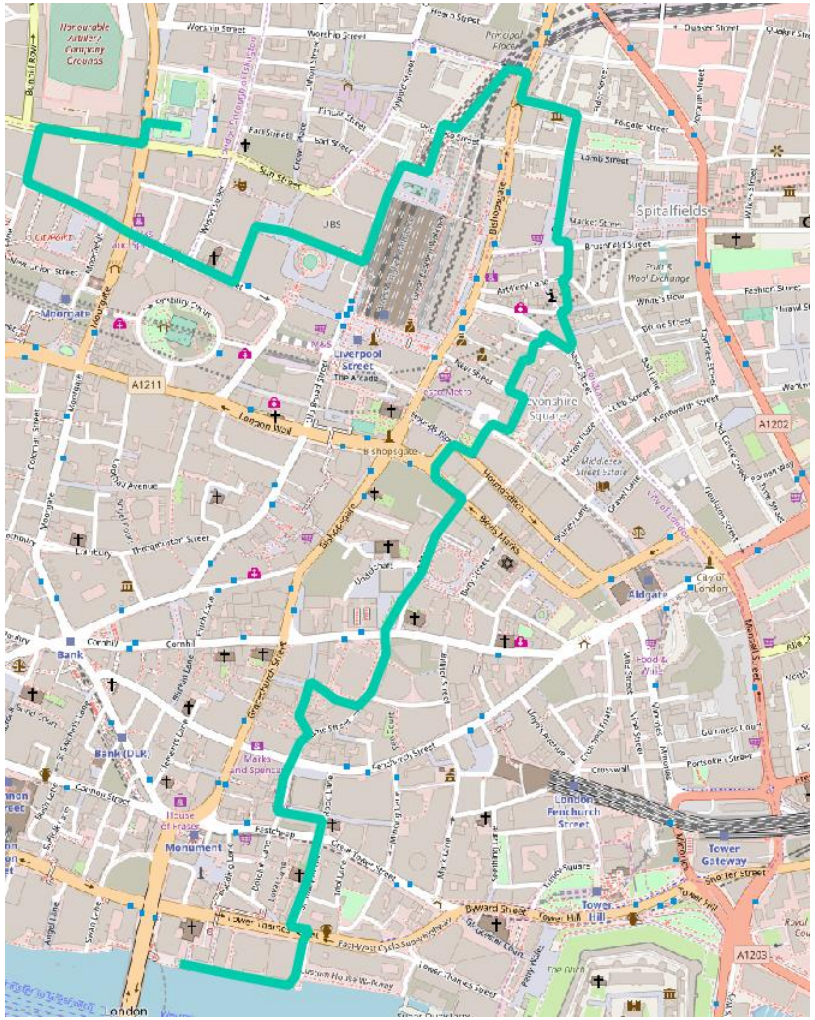
**The London Climate Walk**

Julie Futcher

The purpose of the urban climate walk is to select a route so that the participant is exposed to a variety of microclimates.

For this reason, the walk is designed through a heterogenous urban environment characterised by variations in:

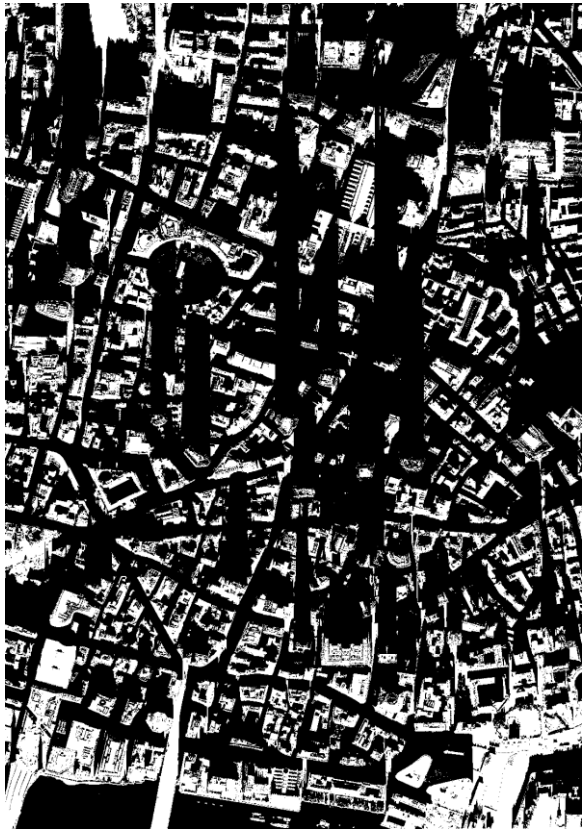
1. Street widths, building heights and orientation,
2. Traffic flows including vehicles and pedestrians,
3. Building dimensions, fabrics and uses and,
4. Green surface cover and street plantings.



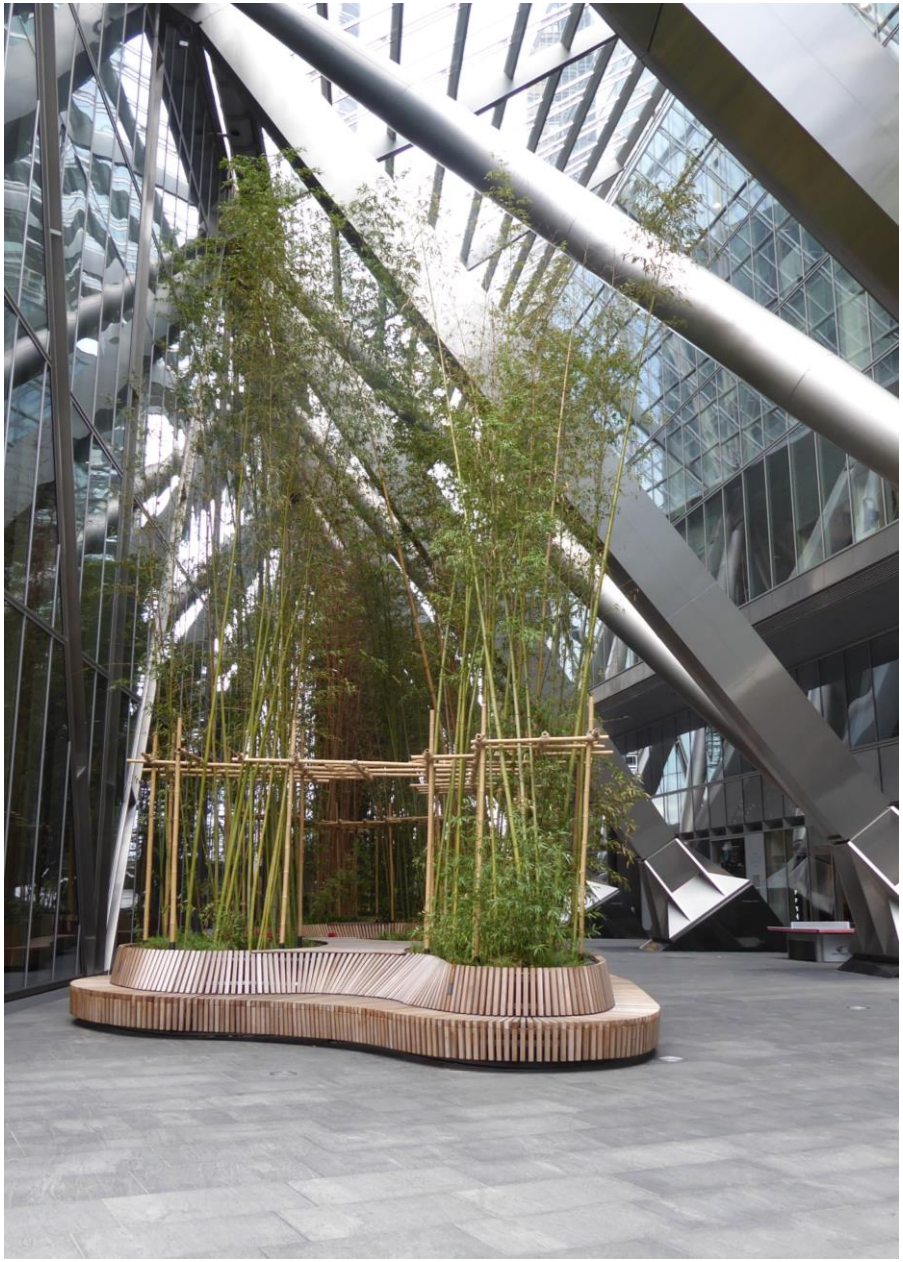
June 21

Sept 21

Dec 21



Sunshine access at 1m intervals along the London walk.



# 5. Conclusions

- Howard is the first to measure the UHI and to correctly identify most of the causes.
- His approach, comparing air temperatures measured in the city (urban) and the countryside (rural), is still followed.
- Mitigating the UHI in the context of global climate change and heatwaves has become a global imperative.

Howards' genius stems from his attention to detail, to his remarkable observational skills and his commitment to understanding natural phenomena and communicating science.

*But the principal objection to English, or any other local terms, remains to be stated. They take away from the Nomenclature its present advantage of constituting, as far as it goes, an universal Language, by means of which the intelligent of every country may convey to each other their ideas, without the necessity of translation. And the more this facility of communication can be increased, by our adopting: by consent uniform Modes, Terms, and Measures for our observations, the sooner we shall arrive at a knowledge of the phenomena of the atmosphere in all parts of the globe, and carry the science to some degree of perfection.*