# Keep Bristol Cool Framework – Technical Appendix

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# Introduction

This document provides further technical detail on the methods uses to develop the evidence base of Bristol's climate projections and the Heat Vulnerability Index.

# Bristol's warming climate and extreme heat trends

This section provides additional information on the methods used to generate Bristol's climate data, guidance on how the results should be interpreted as well as a summary of their limitations. Met Office data can be used under the terms of the Non-Commercial Government Licence [1].

## Climate data

UK climate projections: Bristol's climate data is based on high-resolution UK Climate Projections (called UKCP Local) which have been generated using the Met Office's new climate model at a spatial resolution on par with operational weather forecast models. These projections are at a resolution or scale of 2.2 km. The Met Office climate model (a Convection Permitting Model) can better simulate small-scale behaviour seen in the real atmosphere, including the influence of urban areas, than traditional coarser resolution climate models. It also includes a more sophisticated representation of the urban land surface than in most other climate models, which better simulates effects such as the Urban Heat Island.

High emissions scenario: The UKCP Local projections use a high emission scenario known as Representative Concentration Pathway 8.5 (RCP 8.5). This represents a future where global greenhouse gas emissions grow beyond projected under current policy commitments, leading to greater levels of global warming sooner rather than later. Different RCPs are used in climate modelling to explore a range of climate futures based on different levels of greenhouse gas emissions.

[1] Non-Commercial Government License

Further details on UKCP Local projections can be found in the UKCP Local factsheet [2]and science report[3].

Climate simulations: The model used to produce UKCP Local provides an 'ensemble' of 12 climate projections. An ensemble is a group of climate simulations with each simulation slightly different to the others due to changing the model parameters. By producing more than one simulation, UKCP Local projections account for uncertainty in the model set-up. By running more than one simulation to produce the climate projections, climate data can be presented for different probability levels over a range of 10% to 90% with the 'central estimate' or 50% frequently quoted. This 50% mid-point (or median) is where the bulk of the model simulations are in agreement with one another, whereas the 10% and 90% probability levels represent the upper and lower end of projections where there is less agreement between different model simulations.

Climate data adjustments: When carrying out climate impact studies such as analysing how often climate thresholds are crossed, it is common practice to 'bias-adjust' the climate model data to account for differences between model results and observations[4]. UKCP Local projections for Bristol have been bias-adjusted using a method called scaled distribution mapping[5].

## Summary of methods

### Threshold & heatwave data

Time periods: UKCP Local provides information for three time periods, one in the recent past 1981-2000, one for the near term 2021-2040 and one for longer term 2061-2080, based on the RCP8.5 emissions scenario. A technique known as 'time averaging' is performed for each of the three UKCP Local time periods on full years of data, where an average is

[2] ukcp18_local_update_report_2021.pdf (metoffice.gov.uk)

[3] Met Office (2019) UKCP Convection-permitting mode projections: Science report

[4] Met Office (2018) UKCP18 Guidance: Bias Correction

[5] See Switanek et al (2017) for further information on this approach and its limitations (available from: https://doi.org/10.5194/hess-21-2649-2017)

calculated for the whole city. What this means is that some events will appear to be very infrequent, for example temperatures exceeding 35°C less than half a day over the 19-year period from 2021 to 2039. In reality, this means only a small part of the city has reached the temperature threshold but since an average across the whole city has been taken, this equates to a value less than 1 day.

Data ranges: The main value shown in the main report is for the 50th percentile or mid-point of the 12 ensemble members that make up the UKCP Local climate projections. The table also shows the range for the climate projections from the lower end or 10th percentile where most simulations agree that the result is higher than this value to the upper end or 90th percentile where most simulations agree that the result is lower than this value.

Global warming levels: Global warming levels (GWLs) have been calculated for each of the three periods. These GWLs have been produced using the Met Office's UKCP Global climate projections for the same 12 ensemble members that drive the UKCP Local simulations. An average of annual mean temperature change was calculated for the 20-year time periods available for UKCP Local and compared to the pre-industrial period (1850-1900).

Although there is 20 years of data available for UKCP Local it needs to use full years' worth of data. So when looking at the baseline period at the end of the last century it runs from December 1980 to November 2000. So UKCP Local uses a time slice of 19 years, compared to the 20 years used for GWLs.

UKCP Local data was not available for the full century when the Keep Bristol Cool evidence base was being developed to explicitly calculate results for a range of GWLs e.g. 2°C and 4°C as referred to in the UK's Climate Change Risk Assessment. However the results provide a useful comparison of impacts that could be expected at 2°C and a more precautionary 4.5°C.

## Keep Bristol Cool online maps

Localised data: The results displayed in the online maps follow a similar methodology to that used for thresholds and heatwave data described above. However, rather than averaging the data across the city, the results show how thresholds vary across the city.

Converting data to MSOAs: The UKCP Local projections have been re-gridded from the model's 2.2km grid to Middle Layer Super Output Areas (MSOA). This has been done by taking a weighted average of the proportion of each model grid box intersecting a MSOA to calculate the average number of days exceeding a threshold for each MSOA. MSOAs are similar in size to city wards. The average number of grid boxes used for averaging is 3, with a range of between 1-7 grid boxes, depending on the size of the MSOA. The results have been visually checked to ensure there are no spatial inconsistencies where an MSOA relies on less than, 3 grid boxes.

## Limitations

Data is an approximation: Bristol's climate data presented in this document and the online tool should be interpreted as an approximation. There will be many factors influencing these results i.e. projected number of days exceeding specific temperature thresholds and the heatwave data. These include natural variability within the climate and the fact that the climate model can't represent some small-scale local climate processes.

Met Office Hadley Centre Global Climate model: UKCP Local is driven by the Met Office's Hadley Centre Global Climate model. This means that the projections explore a narrower range of future outcomes as they only consider results from the Met Office climate model. This model also has a higher climate sensitivity to greenhouse gases compared to other models and therefore tends to be on the warmer end of the climate response. This means that it will reach a given temperature threshold such as 2°C or 4°C of warming earlier than in a model with a lower climate sensitivity[6].

Further information on the caveats and limitations of UKCP18 can be found in this Met Office guidance document[7].

## Heat Vulnerability Index

This section provides additional information on the methods used to create Bristol's Heat Vulnerability Index, guidance on how the results should be interpreted as well as a summary of their limitations.

The HVI brings together spatial information on Bristol's population, people's homes, and their local environment with a focus on heat-health risks. This library of maps is made up of three different tiers of information, each giving slightly different insights into the heat-health impacts of urban heat:

1. Top Tier - the overall HVI - identifies the most vulnerable locations in the city
2. Middle Tier - the four underlying Vulnerability Layers - identifies the most vulnerable locations in the city for specific vulnerabilities - Age, Deprivation, Indoor Exposure, and Outdoor Exposure.
3. Bottom Tier – maps for all 34 Factors used to build the vulnerability layers and overall index – shows you how these factors vary across the city of Bristol.

The method for developing the Bristol Heat Vulnerability Index was:

1. Select risk factors, data and spatial units. This was based on literature review and end user workshops.
2. Production of risk factors including pre-processing and spatial averaging. This took raw data for the factors and processed then to create one averaged value per spatial unit (either LSOA or ward). At this stage the values were in different unit, such as %, metres, °C etc.

[6] Met Office (2019) UKCP18 Science Overview Report

[7] Met Office (2018) UKCP18 Guidance: Caveats and limitations

3. Construction of vulnerability layers and overall HVI index. This involved the following:
    a. Normalisation/standardisation of values from previous stage to create values in a 0 to 1 range.
    b. Application of weighting to the factor to reflect influence on heat vulnerability.
    c. For vulnerability layers, addition or subtraction of weighted values, generating +/-1 score for each LSOA/ward.
    d. Ranking of layers and re-ranking to create overall index.
    e. Review and feedback from University of Bristol, Bristol Advisory Committee on Climate Change, end users and relevant Bristol City Council cabinet members was used to inform the stage of development.
4. Bristol City Council GIS team construction of Keep Bristol Cool mapping tool