

ClimateReadyClyde



MAPPING FUTURE SCOTTISH HEATWAVE EXTREMES: REPORT FOR CLIMATE READY CLYDE

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BRIEFING

SEPTEMBER 2019

Disclaimer

This report has been undertaken by University of Edinburgh in support of the work of Sniffer in their role as Secretariat to Climate Ready Clyde. The results are derived from the UK Climate Projections 2018, produced by the Met Office. While every effort is made to ensure the information in this report is accurate, no legal responsibility is accepted for any errors, omissions or misleading statements. The views expressed represent those of the author(s), and do not necessarily represent those of the host institutions or funders.

Report Citation

This report should be cited as: O'Neill, S and Tett, S. (2019) Mapping Future Scottish Heatwave Extremes: Report for Climate Ready Clyde.

The University of Edinburgh and Climate Ready Clyde are grateful to ClimateXChange for the funds used to carry out this research.

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EXECUTIVE SUMMARY

The UK, Europe and Scotland have all had unprecedented high temperature events in the last few years. Climate change as a result of human activity has been identified as the main driver in increasing the probability of such events.

The second UK Climate Change Risk Assessment suggests that certain parts of the UK are already vulnerable to increases in average temperature rises and extreme heat. Analysis of previous extreme heat events in both the UK and abroad show the potential impacts on both morbidity and mortality.

Such changes could lead to large populations being seriously impacted by extreme temperatures, resulting in many heat-health related issues, especially for more vulnerable groups, e.g., the elderly or young people. Extreme heat will also impact infrastructure, and the built and natural environment.

Previous climate projections from the MET Office (UKCP09) suggested that extreme temperatures in Scotland were unlikely to reach damaging levels, however the new UKCP18 simulations project greater warming than the previous data.

With these new projections and their impacts in mind, Climate Ready Clyde was keen to better understand the likely changes in Scotland and the wider UK, to better consider the extent to which heatwave and temperatures should factor in the development of Glasgow City Region's first Adaptation Strategy and Action Plan.

This preliminary study examines future heatwave days and extreme temperatures projected for Glasgow City Region for 2046-2055 (2050s) and 2066-2075 (2070s) using data from UKCP18.

Key findings

The maximum summer day-time and night-time temperatures associated with heatwave events that have a 1, 10 or 20% chance of occurring in any year are also projected to increase in the 2050s and 2070s. In Glasgow City Region the temperature of the one-in-ten-year hottest summer day increases from about

28°C (1980-2010) to **32°C** (2050s). By the 2070s they reach **34°C**. Glasgow City Region is also likely to experience an increasing number of heatwave days in the 2050s and 2070s.

The work shows Glasgow City Region is projected to see an increase in the number of heatwave days per decade from baseline period (1981-2010) values of **0 heatwave days per decade** to **5 to 10 heatwave days per decade** in the 2050s and **10 to 50 heatwave days per decade** in the 2070s. Heatwave days are defined as periods of three or more days where maximum temperatures exceed 28°C and minimum temperatures are above 15 °C.

In addition to this work, the report explored data on all hot day and hot night cases. Summer nights in the Glasgow City Region are predicted to warm considerably, with minimum temperatures increasing more than maximums, and more frequently. These long-lasting periods of extreme night-time summer temperatures are predicted to increase in the 2050s and 2070s. More concerning is the increase in days that meet the heatwave threshold temperatures, but do not necessarily last for three consecutive days, as they may still be significant enough to create impacts.

There is also significant difference in frequency and severity of heatwave days between the north and south of the UK, suggesting that whilst there are significant impacts in Scotland, they will not be as pronounced as other parts of the UK.

As they are raw model projections, the findings presented in this study should be taken as an indication of what may occur in the future, not as a basis for immediate action without further research. Based on the findings, Climate Ready Clyde members should consider how these issues relate to specific risks identified in the Glasgow City Region Climate Risk and Opportunity Assessment (e.g. in infrastructure or healthcare provision). They should also consider what further action will be necessary to inform the development of timely, effective adaptation options and actions, as well as broader organisational adaptation strategies.

INTRODUCTION

Extreme heat and heatwave events can have large impacts on the health of local populations, infrastructure, economic sectors, environment, and many more aspects of society. Initial work carried out by ClimateXChange (CXC) and the University of Edinburgh in November 2018 suggests that the frequency of Scottish heatwaves and warm nights will increase in the future.

The initial findings showed that the projected frequency of both heatwave days, and those with sustained warm-night periods were likely to increase in Central Scotland through to the end of the century at a much greater rate than in the previous set of UK climate projections (UKCP09).

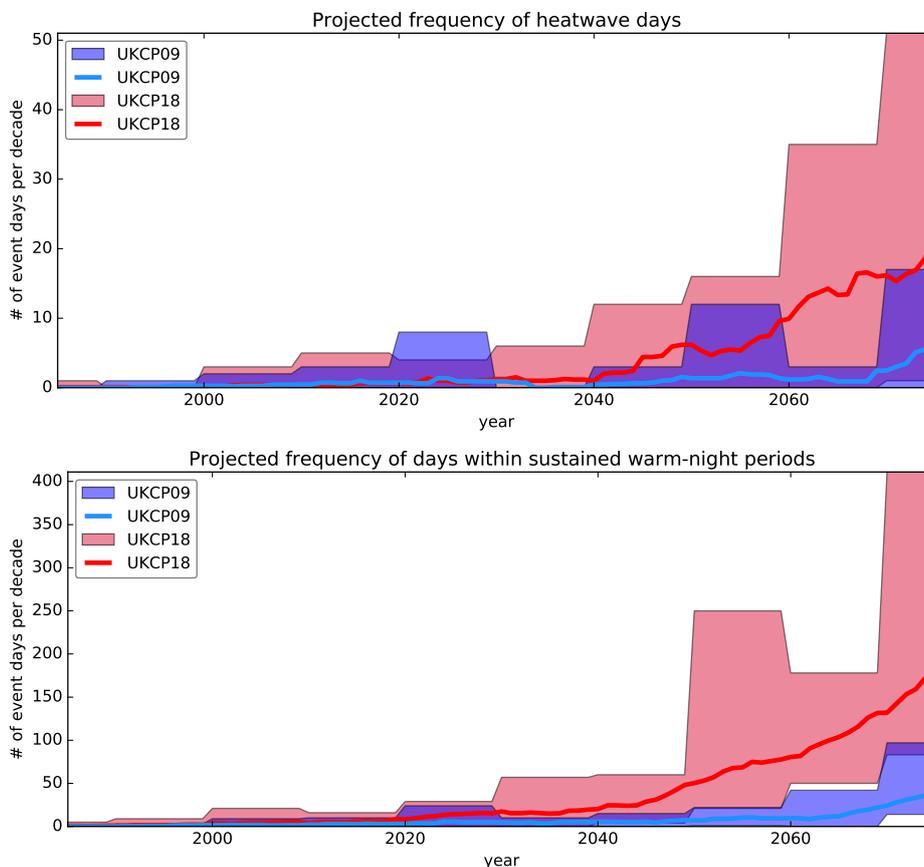
Building on these initial findings, this study aims to carry out a more detailed analysis using the recently available UKCP18 model projections for the UK.

The main objectives for this study were to:

- (i) use extreme value theory to obtain extreme temperature return values
- (ii) determine the frequency of heatwave days

for the periods 2046-2055 (2050s) and 2066-2075 (2070s) in Scotland, as well for the baseline period defined as 1981-2010. Although our primary focus was on the Central Belt/ Glasgow City Region, analysis was carried out for the whole of the UK using the 12km regional UKCP18 model data. The reason for this spatial mapping was to establish whether there was any significant variation on how future heat extremes would be experienced across Glasgow City Region.

The findings presented in this study will help to determine whether further research into extreme heat in Scotland is needed. It will also support local governments and their partners to develop a suitable framework for adaptation to more extreme temperatures and heatwave days.



Source: Undorf, S. (2019) Large increase in projected heatwave frequency for Scotland under new UK climate projections (Available from: <https://www.climatechange.org.uk/blog/large-increase-in-projected-heatwave-frequency-for-scotland-under-new-uk-climate-projections/>)

DATA, OBSERVATIONS AND MODELS

UKCP18 model data was used in the analysis in this study. A multi-ensemble dataset of daily maximum and minimum temperatures for the whole of the UK was extracted from 12 ensemble members using the 12km regional model. Only data from June, July and August was used in the analysis. The model is driven by the Representative Concentration Pathway

(RCP) 8.5 scenario for the time period 1981-2080, the highest greenhouse gas emission pathway.

Daily observational data, for both maximum and minimum temperature, was also obtained from the UKCP18 project, making use of the 12km regional observational data.



METHODS

Our analysis had four steps:

1. Bias-correct the climate model data
2. Fit a Generalized Extreme Value (GEV) distribution
3. Calculate return values for specified periods (1-year, 5-year, 10-year and 100-year)
4. Determine the frequency of heatwave days

1. Bias-correction

Bias-correction of climate model output is often carried out to account for the inaccuracy found in the climate projections. Due to parametrisation in climate models, the output will never represent the true state of the climate, therefore, inconsistencies exist. Finding the difference between observations and the climate model output allows us to correct for the assumed consistent discrepancy in the model.

In this study a simple linear bias-correction was applied to the UKCP18 output, described by the equation:

$$X(t) = (O_{base}(avg) - X_{base}(avg)) + X_{future}(t) \quad (1)$$

$X(t)$ = the bias-corrected model output, $O_{base}(avg)$ = the average over the baseline period from the observational data, $X_{base}(avg)$ = the average over the baseline period from the model data and $X_{future}(t)$ = the uncorrected model data for the period of interest.

For the fitting of the GEV distribution and subsequent calculation of the return values, summer maximum and minimum temperatures were computed from the uncorrected model data and then corrected for bias. For heatwave day frequency analysis, the simulated maximum and minimum daily temperatures were bias corrected using the summer mean maximum and minimum temperatures (June, July and August).

2. Generalized Extreme Value (GEV) distribution fitting

Extreme Value Theory is statistical analysis which makes use of extreme deviations from the median of probability distributions. A number of probability distributions could have been used, such as the Gumbel distribution, however, the GEV distribution has been shown to fit extreme temperature data best. A GEV distribution is described by three parameters:

- (i) Location parameter (μ): describes the centre of the distribution,
- (ii) Shape parameter (ξ): describes the shape of the tail, i.e. how 'fat' the tail is, and
- (iii) Scale parameter (δ): describes the spread of the distribution.

The shape parameter allows for an initial understanding of whether or not the distribution accounts for more extreme temperature values (shape parameter is greater than 0) or if it is skewed towards weaker extreme temperature values (shape parameter is less than 0).

In fitting the GEV distribution, we took the annual maximum summer temperature at each grid-point for:

- (i) the period 1981-2010 (the baseline period),
- (ii) the period 2046-2055 (the 2050s), and
- (iii) the period 2066-2075 (the 2070s).

By taking the block maxima from the 12 ensemble members for each year, a good fit should be achieved with the sufficient amount of data. A GEV distribution was fitted to the data using Maximum Likelihood Estimation (MLE) to get the best estimation of the parameters. A Kolmogorov-Smirnov test was then carried out to determine how well the GEV distribution fitted the data, whereby a good fit would be signalled by a P-value greater than **0.05**. The GEV distribution was also fitted to annual maximum night-time summer temperatures, i.e., annual maximum minimum summer temperatures, following the same steps.

3. Return values

Using the parameters of the GEV distribution at each location in our dataset, we were able to obtain estimates of return values. In particular we looked at the return periods:

- (i) Annual,
- (ii) 5-years,
- (iii) 10-years and
- (iv) 100-years.

The return value is defined as a value of extreme temperature that is expected to be reached or exceeded at least once every interval of time, i.e. once every year, 5-years, 10-years, 100-years, etc. The probability associated with this value being reached or exceeded is equal to $1/T$ where T is the time interval in units of block length.

In our case, we fitted the GEV distribution using annual maximum summer temperatures, therefore the probability was simply equal to:

$$1 / (\text{Return Period (in years)}) \quad (2)$$

and represented in table 1 for each return period.

Table 1: Probabilities associated with each return period of interest for each decade.

Return Period	Probability
Annual	0.5 (the mean) = 50% chance of the return value occurring in any summer
5-year	0.2 = 20% chance of the return value occurring in any summer
10-year	0.1 = 10% chance of the return value occurring in any summer
100-year	0.01 = 1% chance of the return value occurring in any summer

From this probability, we can allow $1 - \text{equation (2)}$ to equal to the equation of the cumulative distribution function (CDF) of the GEV distribution:

$$F(x;\mu,\delta,\xi) = \exp \{ -[1+\xi(x-\mu)/\delta](-1/\xi) \} \quad (3)$$

where x is the return value, μ is the location parameter, ξ is the shape parameter and δ is the scale parameter.

The annual return value cannot be calculated in this fashion, as the CDF simply goes to infinity. Therefore, the annual return value will be calculated as the mean maximum annual summer temperature expected for each period. Return values for each return period were calculated for (i) the baseline period, (ii) the 2050s and (iii) the 2070s.

4. Assessing heatwave frequency

The definition of a heatwave and the threshold criteria varies not just around the world, but also within countries. As outlined by the Met Office, a “UK heatwave threshold is met when a location records a period of at least three consecutive days with daily maximum temperatures meeting or exceeding the heatwave temperature threshold”, with the threshold varying by UK county. In this project we followed the criteria for triggering Public Health England’s heat-health warning service as outlined by the Met Office National Severe Weather Warning Service and NHS England for North-East England: three consecutive days in which both the daily maximum temperature was above 28 °C and the daily minimum temperature was above 15 °C. This was to allow an evaluation of whether similar types of responses and planning may need to be implemented in Scotland in the future. Note that the analysis in this study applies this criterion to the whole of the UK, neglecting the variation in threshold criteria between UK regions.

Focusing on the three periods of interest, (i) the baseline period, (ii) the 2050s and (iii) the 2070s, we analysed the UKCP18 data, after bias correction, for both maximum and minimum temperature to determine the frequency of heatwave days during the summer period for each decade.

RESULTS AND DISCUSSION

Return values

The average maximum summer temperature from the UKCP18 multi-ensemble model output, which we defined as the annual return value, is shown in figure 1. Figure 1 highlights the shift to significantly higher annual return values in the summers of the 2050s and 2070s across most of the UK, portraying a distinct transition in the UK summer climate as we progress through the 21st century.

Annual return values predicted for the Central Belt/Glasgow City Region increase from values of **22 to 26 °C** in the baseline period to values of **26 to 28 °C** in the 2050s and values of **30 to 32 °C** in the 2070s.

The return values calculated using the GEV distribution are shown for the whole of the UK and the Central Belt/Greater Glasgow region in figure 2 and 3, respectively.

The continued impact of our changing summer climate is clear when comparing the return values from each time period. An interesting highlight is the 10-year replacing the 5-year return values and the 100-year replacing the 10-year return values progressing from one time period to the next. Both the 2050s and 2070s experience a distinct and serious increase in the expected return values for each return period, which can be explained as the result of a rapidly warming climate.

The return values for the Central Belt/ Glasgow City Region in figure 3 show a stark transition in the region's summer climate from the baseline period to the 2050s and 2070s. The regional variation in predicted return values is relatively uniform, with only a slight variation between north and south, i.e., lower return values are predicted in the north compared to the south. A clear variation is obvious when considering the return values across the whole of the UK (figure 2), with far higher return values predicted for England and the South-East of the UK.

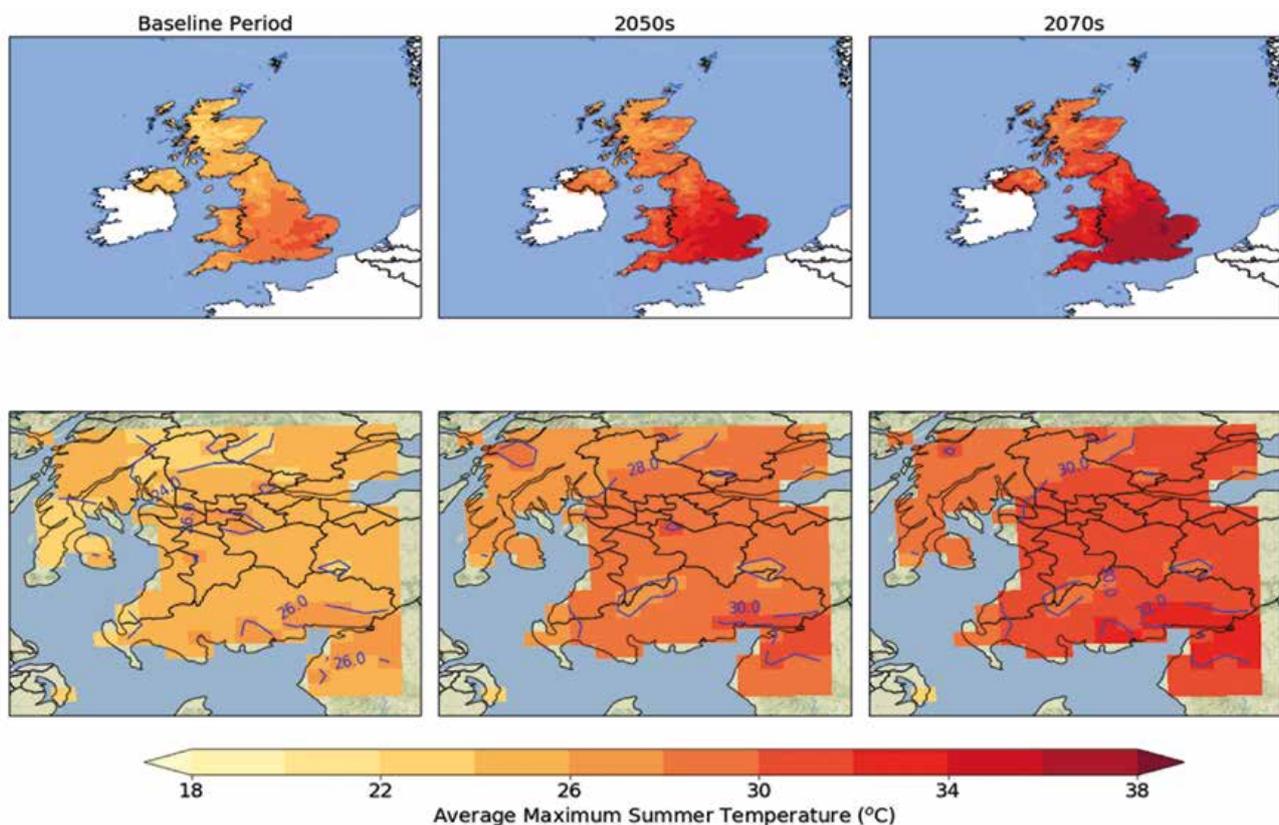


Figure 1: Average maximum day-time summer temperature for (a) the whole of the UK and (b) the Central Belt/Glasgow City Region for the three time periods of interest.

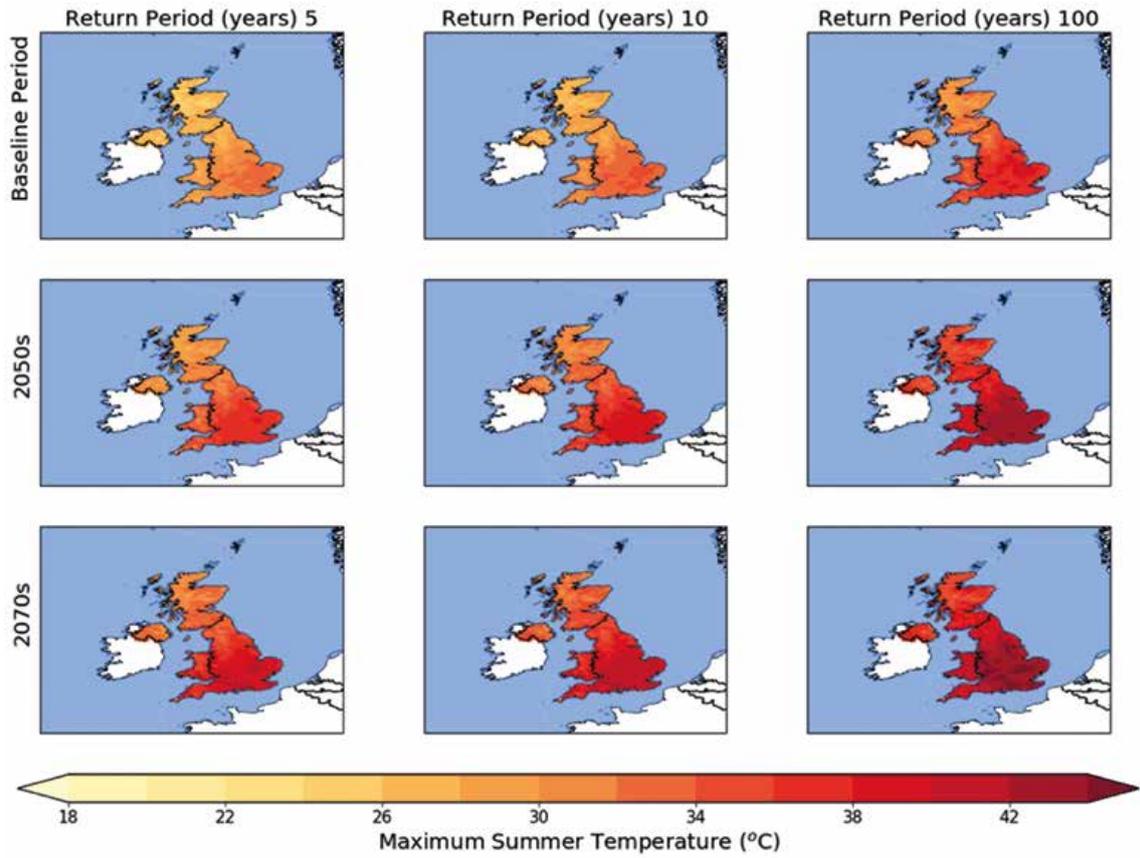


Figure 2: Maximum summer day-time temperature return values for: (i) 5-year, (ii) 10-year and (iii) 100-year return period for the whole of the UK.

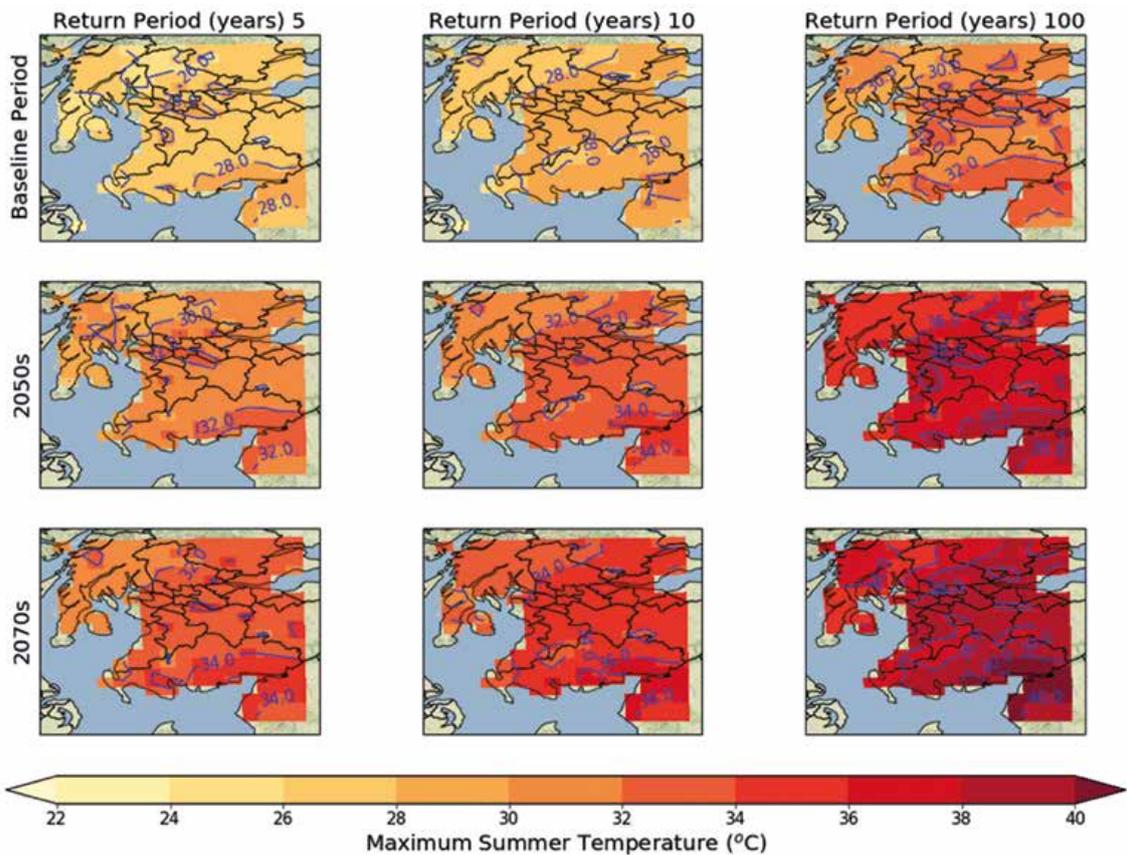


Figure 3: Maximum summer day-time temperature return values for: (i) 5-year, (ii) 10-year and (iii) 100-year return periods for the Central Belt/Glasgow City Region.

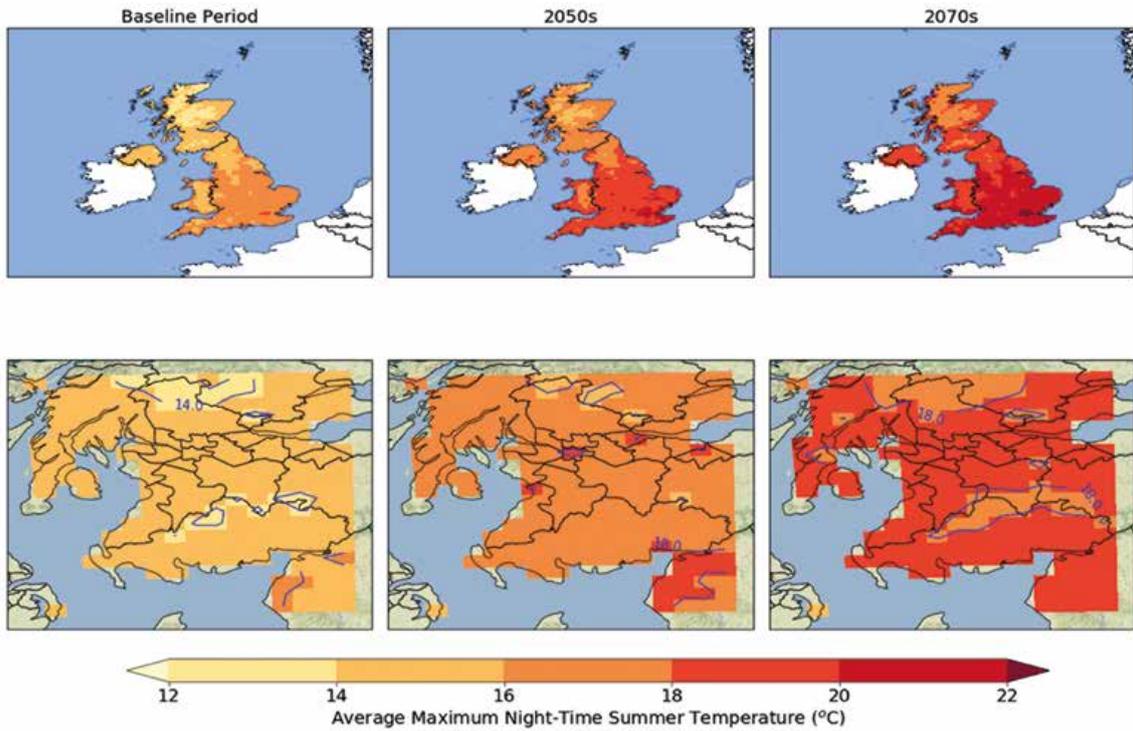


Figure 4: Average maximum night-time summer temperature for (a) the whole of the UK and (b) the Central Belt/Glasgow City Region for the three time periods of interest.

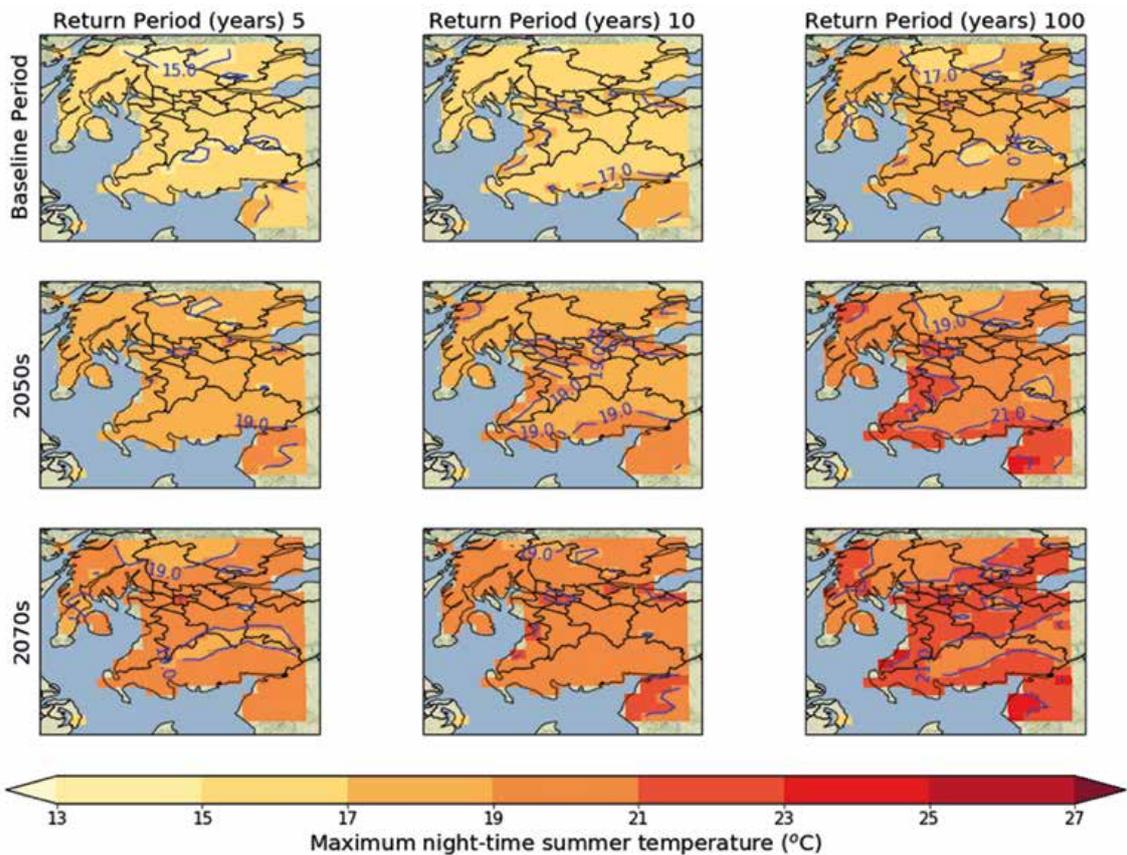


Figure 5: Maximum summer night-time temperature return values for: (i) 5-year, (ii) 10-year and (iii) 100-year return periods for the Central Belt/Greater Glasgow region.

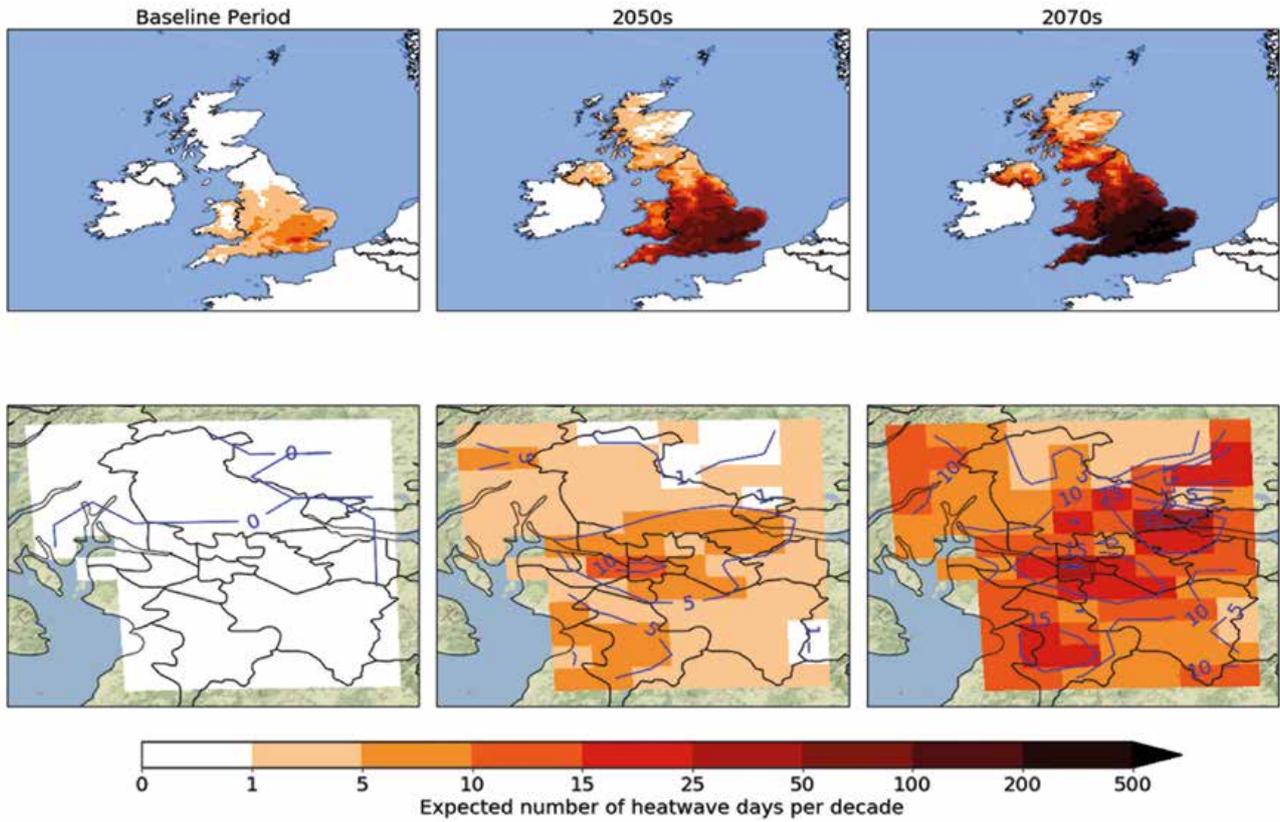


Figure 6: Number of heatwave days predicted per decade for (a) the whole of the UK and (b) the Glasgow City Region. Plot uses a log scale.

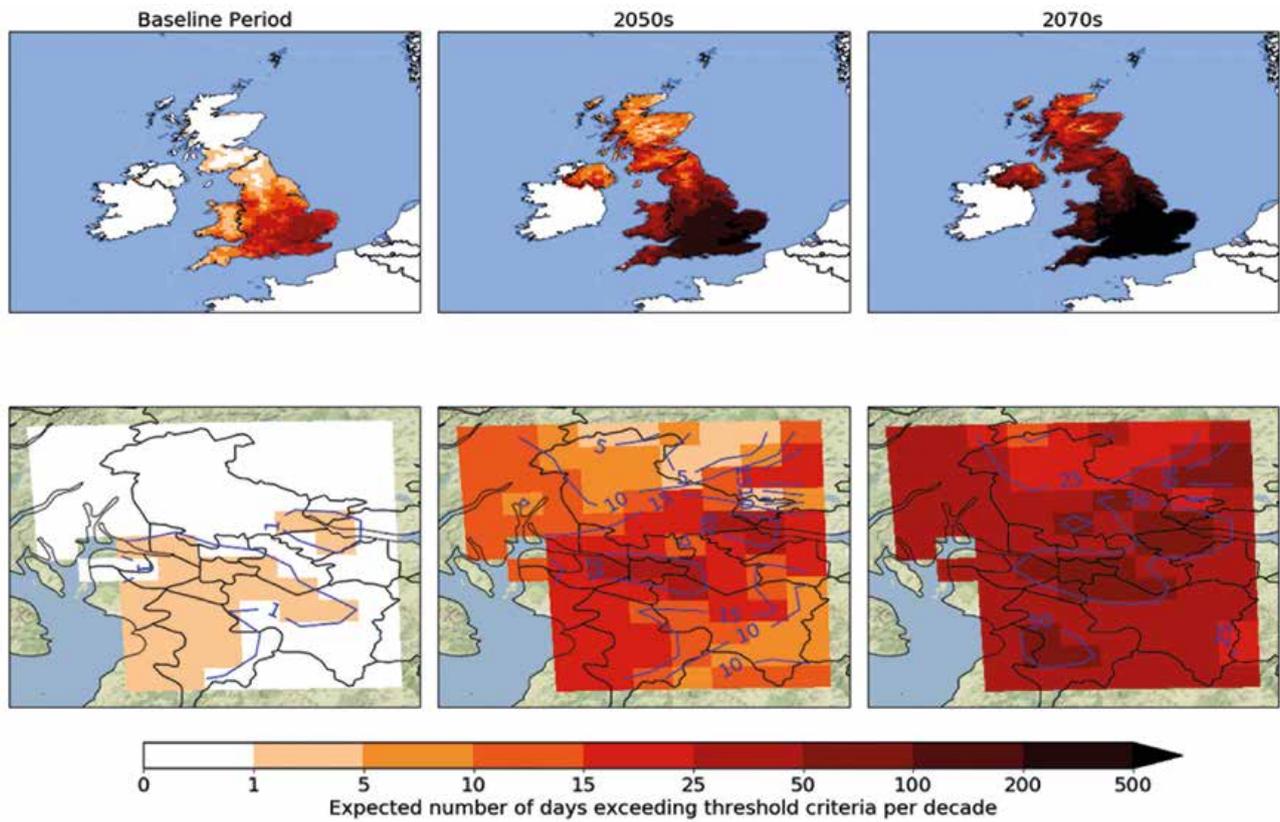


Figure 7: Number of days in which the maximum and minimum temperature thresholds are met, i.e. maximum temperature $\geq 28^\circ\text{C}$ and minimum temperature $\geq 15^\circ\text{C}$, for (a) the whole of the UK and (b) the Greater Glasgow region per decade. Plot uses a log scale.

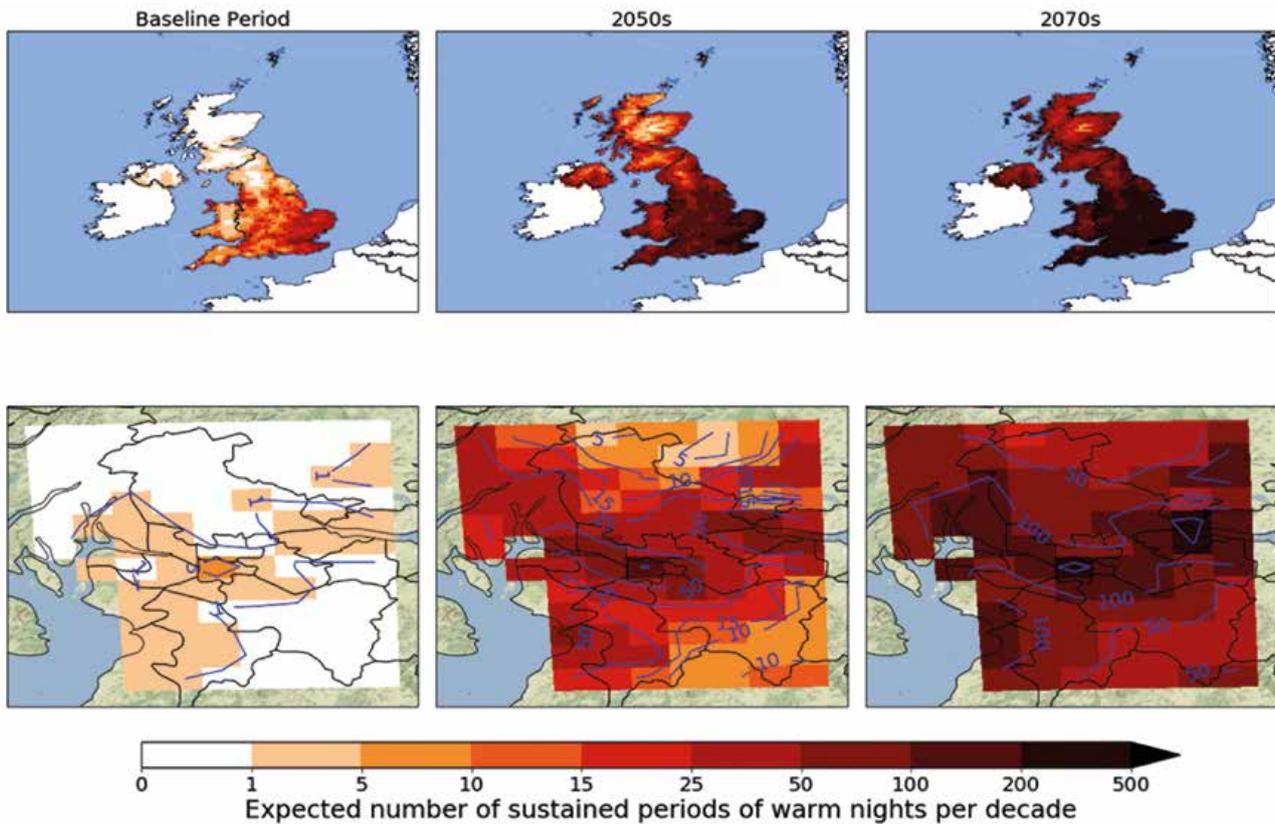


Figure 8: Number of nights in which the minimum temperature threshold is met, i.e., minimum temperature $\geq 15^{\circ}\text{C}$ for three consecutive nights, for (a) the whole of the UK and (b) the Glasgow City Region per decade. Plot uses a log scale.

These increases in daytime maximum summer return values over the Central Belt/ Glasgow City Region is mirrored in the projected maximum night-time return values seen in figure 4 and 5. Again, in figure 4, we defined the average maximum night-time summer temperature as the annual return value. One can see, looking at figure 5 as well, that the increase in return values between return periods in the same time period, as well as between the different time periods, is not as large as seen in the maximum day-time summer return values.

A lower increase in return values between each time period is seen for the maximum night-time summer temperatures compared with that of day-time. This, however, is not a result to ignore as high night-time summer temperatures could potentially have a more far-reaching impact on the region.

Heatwave day frequency

From the predicted return values for the 2050s/2070s one would expect an increase in the probability and frequency of current heatwave thresholds being met in both the UK and the Glasgow City Region. Figure 6

proves this relationship to be true. For both the whole of the UK and the Glasgow City Region, we see an increase in heatwave days as we progress from the baseline period to the 2050s and 2070s.

During the baseline period no heatwave days exist, which agrees with the annual return value result of 22 to 28°C , i.e., the chance of the maximum temperature threshold of 28°C to be reached over three consecutive days is very small. For the 2050s and 2070s, a transition to higher annual return values is complimented by an increase of heatwave days due to the threshold being met more regularly. We see the expected number of heatwave days during the 2050s **reach 5 to 10 heatwave days/decade** widely, while this number further increases to **10 to 50 heatwave days/decade** in the 2070s (figure 6).

Due to the fact we are using criteria designed for triggering heat-health warnings in North-east England, figure 7 shows the number of days expected to exceed the threshold for maximum and minimum temperature, neglecting the three consecutive day criteria. Once again, a clear transition from baseline period to the 2050s and 2070s is evident. Only a small area of the Glasgow City Region has **1 to 5 days/decade** exceeding

the temperature criteria during the baseline period, with a more widespread and large increase of **10 to 50 days/decade** in the 2050s and **25 to 100 days/decade** in the 2070s. This is more worrying and indicative of the steps needing to take place in preparation for, perhaps, isolated yet extreme weather events in the Glasgow City Region, especially as we enter the 2070s.

The frequency of sustained periods of warm summer nights per decade is shown in figure 8, with the same stark transition found as we go from the baseline period into the 2050s and 2070s.

Sustained periods of warm summer nights between each decade increase in frequency from in **1 to 10 periods/decade** during the baseline period, over a small area of the Glasgow City Region, to **15 to 100 periods/decade** in the 2050s and even further increasing to **50 to 200 periods/decade** in the 2070s. The periods of warm nights are also far more extensive, covering most of the Glasgow City Region during the 2050s and 2070s.



CONCLUSIONS

Serious consideration should be given to the impacts that could arise as a result of the increasing return values and heatwave days for the Glasgow City Region, especially as we transition from the 2050s into the 2070s.

More concerning is the increase in days that meet the heatwave threshold temperatures, but do not necessarily last for three consecutive days. Days where maximum temperatures exceeding 28 °C and minimum temperatures not falling below 15 °C are predicted to become more frequent in the 2050s and 2070s in Glasgow City Region. This could lead to large populations being seriously impacted by extreme temperatures, resulting in many heat-health related issues, especially for more vulnerable groups of people, e.g., OAPs and young children. Not just healthcare, but all sectors of society, such as infrastructure and environment, could also be greatly impacted.

Another feature as we progress through the 21st century is the increase in frequency of sustained periods of warm summer nights over the Glasgow City Region. The summer nights are predicted to warm considerably, albeit not to the same scale as maximum summer day-time temperatures, with long-lasting periods of extreme night-time summer temperatures predicted to increase in the 2050s and 2070s.

There is also a distinct and very serious difference in the predicted return values and heatwave day frequency between the north and south of the UK. The more extreme heat predicted for England may not have a direct effect on Scotland, but it could have indirect effects which need to be explored.

The data used for this study comes from a set of simulations carried out for UKCP18. These simulations have not been analysed to determine the main drivers of these changes nor have the models been rigorously tested to verify that they generate extreme temperatures for the correct reasons. Therefore, the findings presented in this study should be taken as an indication of what may occur in the future, not as a basis for immediate action by local governments or stakeholders without further research.

Based on the findings, Climate Ready Clyde members should consider how these issues relate to specific risks identified in the Glasgow City Region Climate Risk and Opportunity Assessment (e.g. in infrastructure or healthcare provision). They should also consider what further action will be necessary to inform the development of timely, effective adaptation options and actions, as well as broader organisational adaptation strategies.

APPENDIX A

Maximum night-time temperatures for the UK

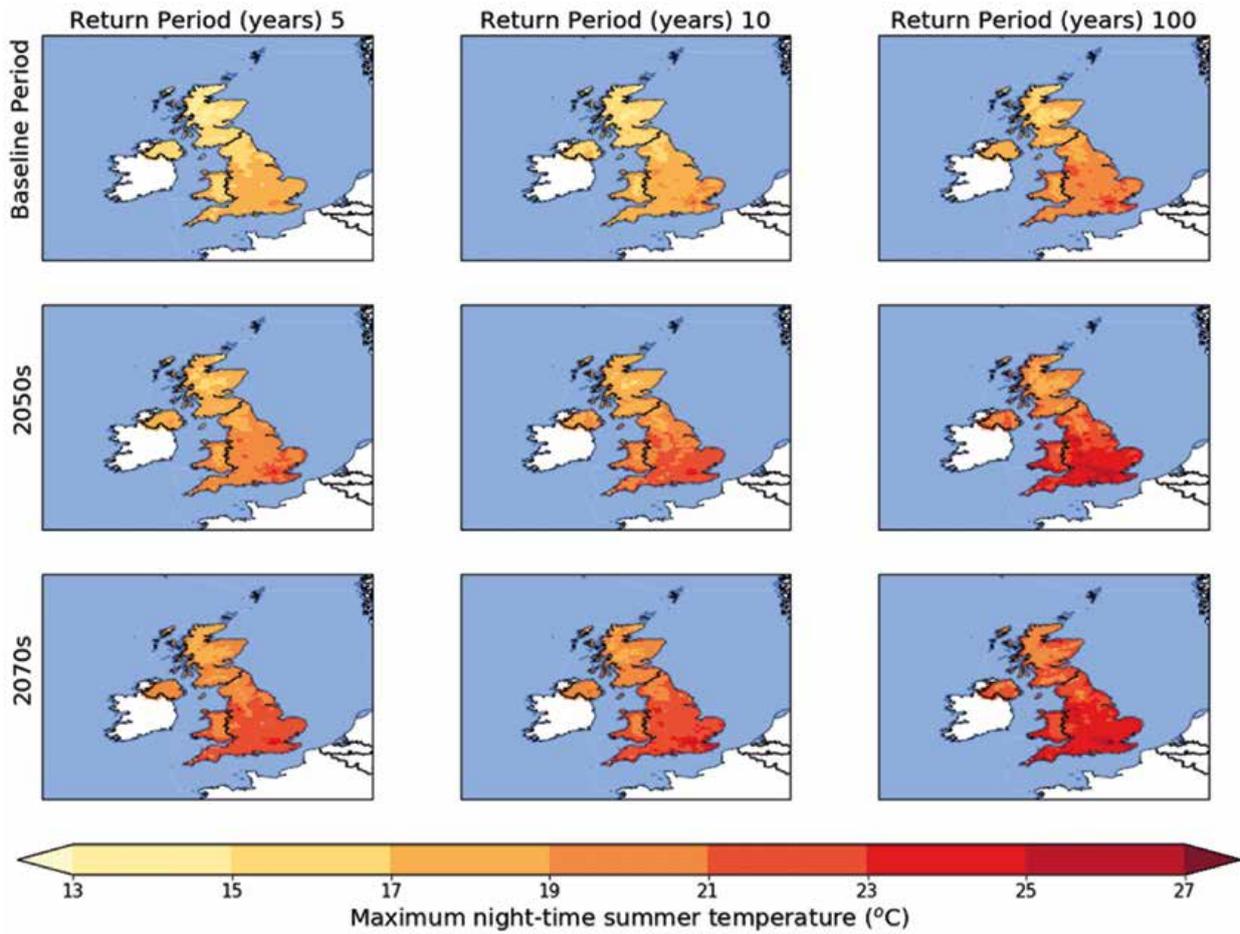


Figure 9: Maximum summer night-time temperature return values for: (i) 5-year, (ii) 10-year and (iii) 100-year return period for the whole of the UK.

APPENDIX B

Single warm nights for UK and Glasgow City Region (ignoring the three consecutive day and maximum temperature threshold criteria).

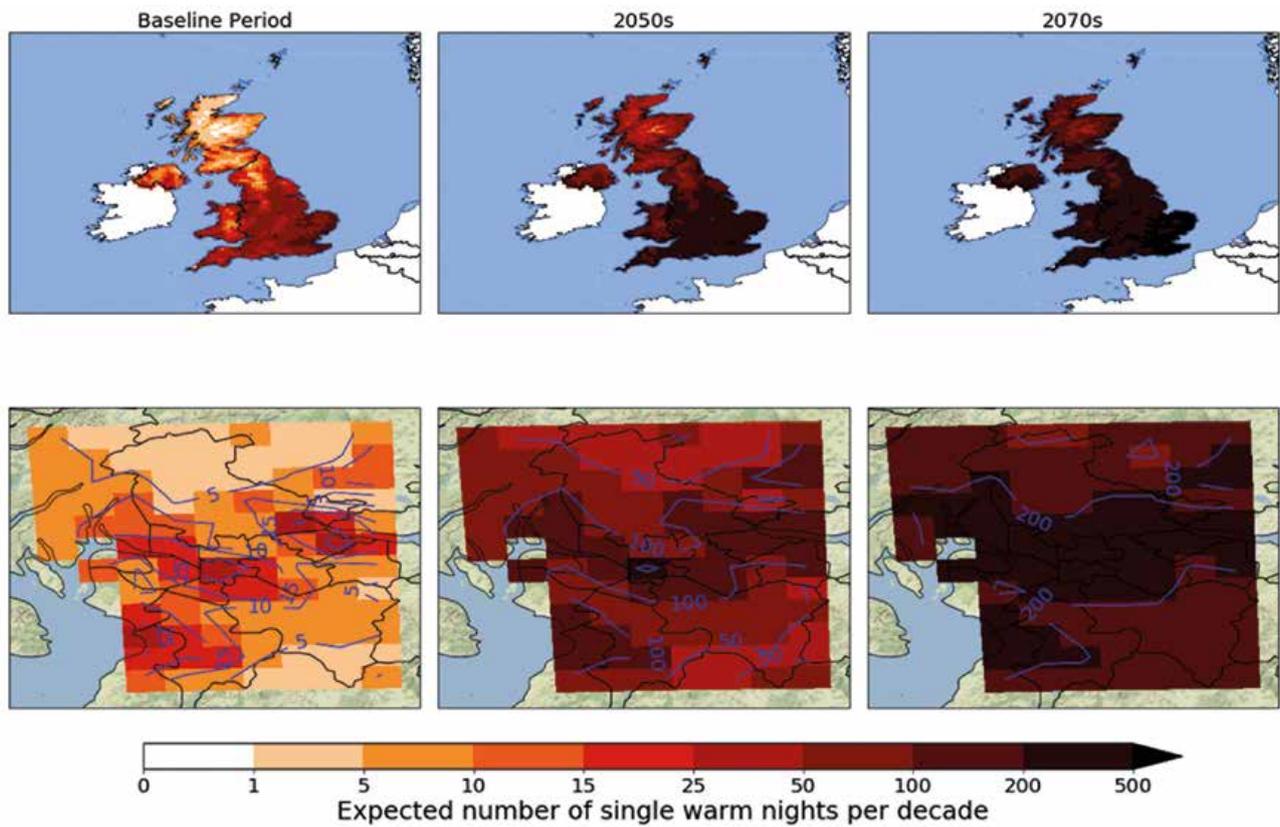


Figure 10: Number of nights during which the minimum temperature threshold is met, i.e. minimum temperature ≥ 15 °C, for (a) the whole of the UK and (b) Glasgow City Region per decade. Plot uses a log scale.

APPENDIX C

GEV Fit

This section looks in more detail as to how the parameters of the GEV fit are changing between the three time periods. It largely finds that the main reason for the change is general warming rather than changing characteristics of extreme temperatures.

The shift in distribution, signalling more extreme maximum summer temperatures, is highlighted in figure 11. Figure 11 shows the change in parameter values for the GEV distribution fit between each time period.

The centre of the distribution, i.e. the location, is the driving parameter behind the distribution change due to the widespread increase in average maximum summer temperatures. There is a positive increase in location between the time periods, for both the UK and the Western Scottish region, reflecting the widespread warming summer climate in the UK.

A negative shape parameter typically indicates weak extremes, whereas a positive shape parameter signals strong extremes. A negative shape parameter difference exists between the 2050s and today for both the majority of the UK and the Western Scottish region. This may signal a move towards lesser extreme values experienced in the 2050s than experienced today, however, the difference is very close to zero and may not be significant. The change in shape parameter between the 2070s and today is largely positive across the UK, especially positive in the south-west of the UK and particularly close to zero for Western Scotland.

The changing shape parameter may be an indication of where extreme values are most likely to develop, as

the tail of the distribution gets 'fatter' with a positive shape parameter, taking more extreme values into the distribution. It appears as if the Western Scottish region may not experience as extreme values of maximum summer temperatures than in regions such as southern UK.

The scale parameter also re-affirms the move towards more extreme values. With a positive scale parameter difference, the distribution gets wider, i.e., it is incorporating more extreme values at either end of the distribution.

The uncertainty in the GEV distribution parameters has not been explored in this study. For that reason, the change in parameters should be taken as an indication that there is an overall shift towards more extreme values as we progress through the 21st century for the UK as a whole, rather than focusing specifically on smaller regions or particular parameter values.

The GEV distribution appears to fit the data well for the three periods of interest, represented by the wide coverage of P-values greater than 0.05 across the UK (figure 12). A P-values greater than 0.05 allows us to conclude that the GEV distribution fits the data within a 95% confidence interval.

Investigation with other distributions could be explored in an attempt to obtain a better fit to the data. Although the P-values are greater than 0.05 across much of the UK, some areas of Scotland have low P-values. This may indicate the GEV distribution does not fit the data across these regions very well.

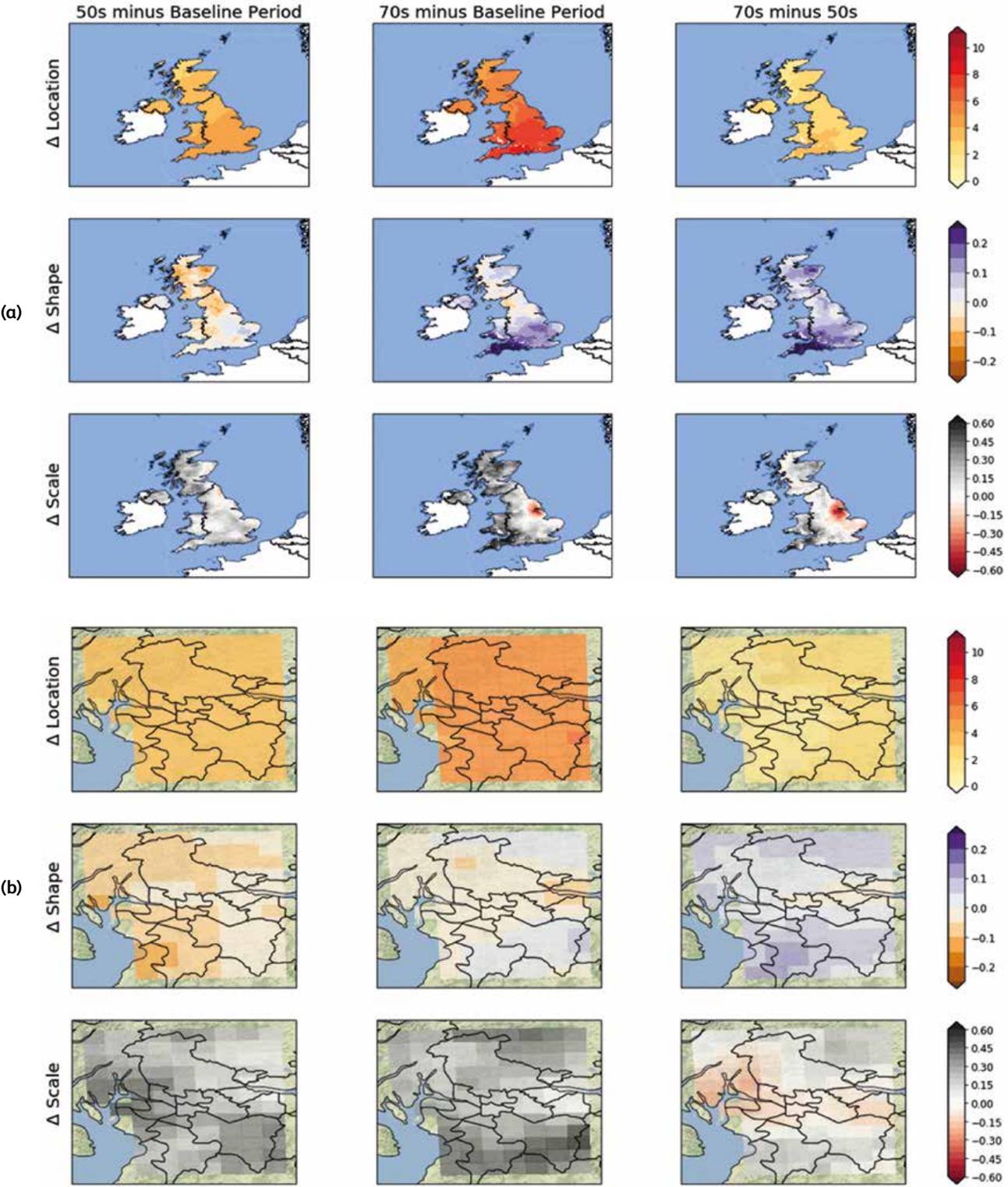


Figure 11: Change in Generalized Extreme Value (GEV) distribution parameters for (a) the whole of the UK and (b) the Glasgow City Region.

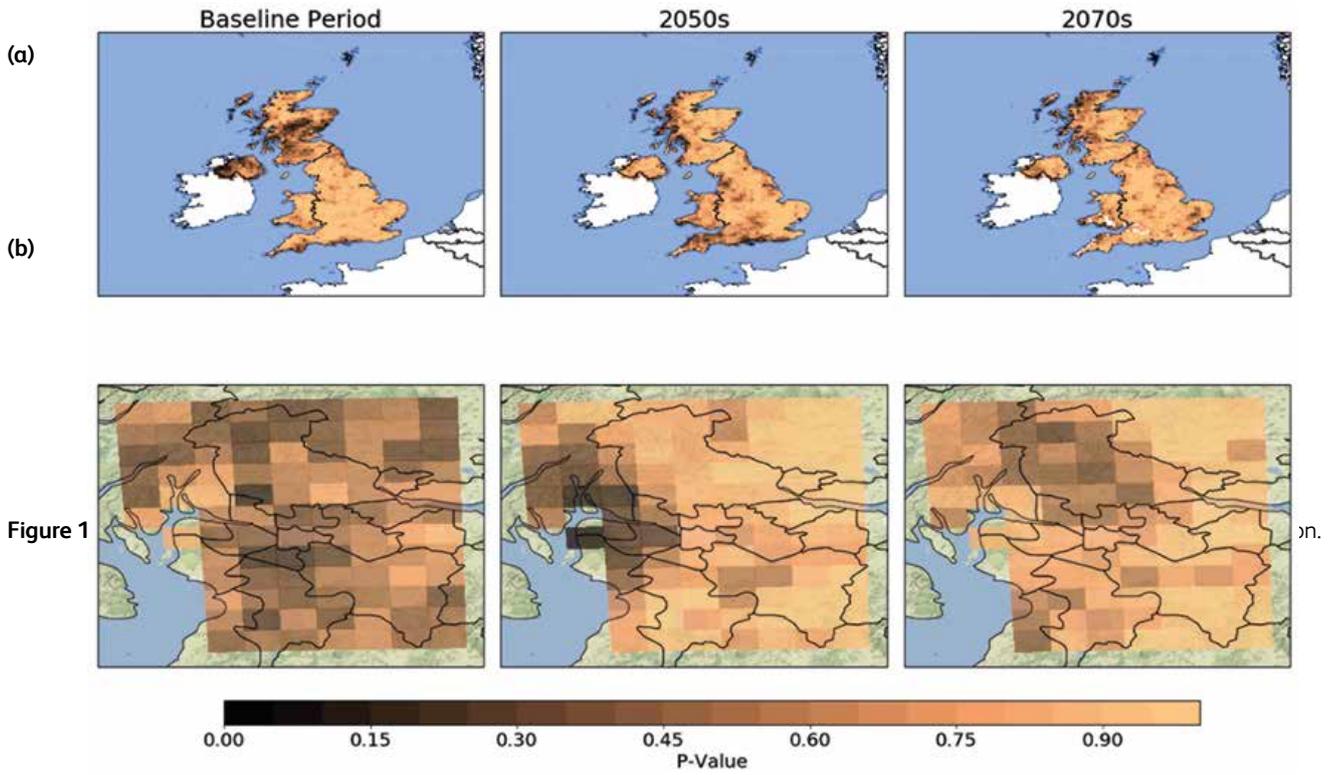


Figure 12: P-value statistic from the Kolmogorov-Smirnov test on the Generalized Extreme Value (GEV) distribution for **(a)** the whole of the UK and **(b)** Glasgow City Region.

APPENDIX D

Dataset description

Available with this report are datasets containing the results of the analysis. This is a small description as to what each data variable within each NetCDF file refers to. Bolded words with the format `_` refer to the data variables within each file.

1. Decade_baseline_period_uk.nc
2. Decade_50s_uk.nc
3. Decade_70s_uk.nc

These files contain:

- the resulting parameters of the GEV fit (**Shape**, **Location** and **Scale**) as well as the results of the KS-Test, the P-values (**P_Value_KS_Test**), for the maximum day-time summer temperatures.
- It also contains the average maximum day-time summer temperature, defined as our annual return value in this study (**Annual_return_value**), as well as the 5 year return value, the 10 year return value and the 100 year return value (**Return_value_5_year**, **Return_value_10_year**, **Return_value_100_year**).

for each time period.

4. Decade_baseline_period_minimum_temperatures_uk.nc
5. Decade_50s_minimum_temperatures_uk.nc
6. Decade_70s_minimum_temperatures_uk.nc

These files contain:

- the resulting parameters of the GEV fit (**Shape**, **Location** and **Scale**) as well as the results of the KS-Test, the P-values (**P_Value_KS_Test**), for the maximum night-time summer temperatures.

- It also contains the average maximum night-time summer temperature, defined as our annual return value in this study (**Annual_return_value**), as well as the 5 year return value, the 10 year return value and the 100 year return value (**Return_value_5_year**, **Return_value_10_year**, **Return_value_100_year**).

for each time period.

7. Heatwave_days_baseline_period_uk.nc
8. Heatwave_days_50s_uk.nc
9. Heatwave_days_70s_uk.nc

These files contain:

- the resulting number of heatwave days per decade (**Heatwave_days_1981_2010**, **Heatwave_days_50s**, **Heatwave_days_70s**),
- the resulting days where the temperature thresholds are met, but without the three consecutive day criteria being met (**Hot_days_1981_2010**, **Hot_days_50s**, **Hot_days_70s**)
- the resulting warm sustained summer nights for three consecutive nights (**Warm_sustained_nights_1981_2010**, **Warm_sustained_nights_50s**, **Warm_sustained_nights_70s**)
- the resulting warm nights without the three-day consecutive criteria being met (**Warm_single_nights_1981_2010**, **Warm_single_nights_50s**, **Warm_single_nights_70s**)

for each time period.

ABOUT CLIMATE READY CLYDE

Climate Ready Clyde is a cross-sector initiative funded by the Scottish Government and 15 member organisations to create a shared vision, strategy and action plan for an adapting Glasgow City Region.

1.8 million people live, work and play in the Glasgow City Region and a large number of businesses and organisations are based here, with £40bn of GVA – a third of Scotland’s population and wealth. Increasingly they are impacted by the effects of climate change, both directly in the city region, and from changes happening around the world.

Adaptation is a strategic issue for the city region in terms of securing inward investment and protecting the economy, as well as contributing to good place making, addressing inequality and minimising and avoiding costs arising from unplanned impacts. Climate Ready Clyde was established on the basis that adapting is cheaper, easier and more effective when done together.





The Climate Ready Clyde programme is managed and delivered by Scottish sustainability charity Sniffer

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